Plenary Talks

PT - 1 – An Overview of Relativistic Heavy Ion Measurements Over a Large Region of Phase Space

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It is very important to measure data over a wide region of rapidity and transverse momentum in order to gain insight into the reaction mechanisms and initial conditions of relativistic heavy ion collisions. The BRAHMS spectrometer at RHIC was designed for the purpose of making measurements over the widest possible region of phase space. An overview of results obtained from measurements during the first four runs at RHIC with BRAHMS will be presented. Identified particle yield distributions from mid to forward rapidity will be presented for Au + Au, d + Au and p + p for $\sqrt{s_{NN}} = 200$ GeV and Au + Au for $\sqrt{s_{NN}} = 63$ GeV will be shown. The evolution of many different quantities with beam species, $\sqrt{s_{NN}}$, rapidity, and particle composition will be obtained from these yield distributions and discussed in relation to reaction mechanisms at these energies, matter formed and initial conditions for the formation of this matter.

PT - 2 – Fusion and breakup of weakly bound nuclei

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The effect of the break-up of weakly bound nuclei on the fusion cross section is a subject of major interest, since beams of unstable nuclei with such characteristics, especially halo nuclei, have become available. The understanding of this effect is important for the production of nuclei near the neutron drip line and super-heavy nuclei. However, although there has been many experimental and theoretical works in this field, at the present it is still far from being understood. A full understanding of the fusion and break-up processes induced by stable weakly bound projectiles is an essential step for the study of the fusion induced by radioactive beams. For instance, the coupling between the relative motion and intrinsic degrees of freedom of such interacting nuclei may enhance the fusion cross section relative to one-dimensional potential predictions, or the break-up of the weakly bound nucleus before reaching the fusion barrier may inhibit it by the absorption of flux that would otherwise go to fusion. In order to have a comprehensive picture of this problem, one has to study different energy regimes, from the sub-barrier to above barrier energies and also one has to span different nuclear masses, in order to investigate the effect, on the fusion, of nuclear and Coulomb break-ups. The suitable stable nuclei for this kind of study are 9Be, 6Li and 7Li , due to their small separation energies that should favor the break-up process. In this talk I will give an overall picture of our present understanding of the field, based mostly on recent experiments performed by our group and collaborators, on many different systems involving 9Be, 6,7Li, 6He and targets ranging from 27Al to 209Bi, and other systems involving tightly bound projectiles on the same targets and/or leading to the same compound nuclei. Fusion-evaporation and fusion-fission channels are measured. Special emphasis will be given to very recent and still unpublished data on complete and incomplete fusion of 9Be + 144Sm, measured at Buenos Aires by the detection of delayed KX-rays.

PT - 3 – Present Status of Hadrontherapy

Mazal, D. A.,[1] Ferrand, R.,[1] Meyroneinc, S.,[1] Habrand, J. L,[1] Mazeron, J. J.,[1] Noel, G.,[1] Fevret, L.,[1] Desjardins, L.,[1] Dendale, R.,[1] Mammar, H.,[1] Alapetite, C.,[1] Bey, P.,[1] Delacroix, S,[1] Nauraye, C.,[1] Gaboriaud, G,[1] Rosenwald, J.C.,[1] Kooy, H.,[1] Flanz, J,[1] and Kreiner, A.J.[2]

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Hadrontherapy is one of the state-of-the-art applications of nuclear physics in medicine and biology for the well being of society, and it shows a wide spread vitality all over the world. The concept comprises the use of beams of neutrons, protons and ions (like carbon) as tools for external radiation therapy (conventionally based on the use of photons and electrons), to treat clinical targets, mainly in the field of oncology. Neutron beams have radiobiological properties related to their high relative biological effectiveness (RBE). A research field is active on epithermal neutron beams combined with the selective uptake of boron compounds into tumors to use the boron neutron capture process (BNCT for Boron Neutron Capture Therapy), particularly focusing on accelerator-based neutron sources sited in hospitals. Proton facilities are based only on the ballistic selectivity of charged particles: they have a low ionization at the entrance of tissues and a "Bragg" peak just before the end of the range, with no significant dose after the peak, preserving critical organs and tissues behind the target volume. As they have low scattering, they can also minimize the dose to organs placed laterally to the beam path. First clinical trials were performed since 1950. A limited number of facilities based on nuclear physics laboratories developed the clinical experience over 40 years before hospital-based centers begun to be built as turn-key facilities offered by industry. About 15 centers are in operation and a similar number of modern facilities are being installed for the near future. Clinical applications of protons include ophtalmic tumors like choroidal melanomas, base of the skull chordomas and chondrosarcomas, head & neck, radiosurgery of intracranial targets including large arteriovenous malformations and most of the pediatric tumors, based on the rational of a reduction of the integral dose delivered to healthy tissues. More than 40000 patients have been treated. The use of any high precision technique for radiation therapy is associated to a complex logistics including for example imaging, treatment planning, dosimetry and patient positioning with radiological, ultrasound or video systems and robotic approaches, all concepts shared in synergy and competition with developments like the intensity modulation of photon beams (IMRT), something which can also be performed with protons and ions. Heavier ion beams (particularly carbon) associate the selectivity of protons and the advantage of a high RBE. In addition, their dose deposition can be verified using PET imaging on-line. After a preliminary experience in Berkeley starting 1957, three centers are treating today with carbon ions. The association of different ions is under study. New facilities are being built, mainly in Japan and Europe. They need to develop a wide program of clinical and biological research to know the real effect on different types of tissues. Several clinical protocols are already in use reducing the number of fractions up to a single one, like in some lung and hepatic tumors. Most of the facilities are concentrated in the Northern Hemisphere (US, Europe, Japan) and a single facility operates in the Southern Hemisphere (South Africa). In spite of the economic and social situation in Latin America, it is probably time to think about a cooperative program (multinational and multipurpose research and clinical) to install a proton facility with the help of the international community and with the condition that this will not affect any priority in national or regional health programs to cover basic needs of the population or to improve conventional approaches as applied today for cancer treatments. Acknowledgments: Canceropole Ile de France, Ligue National du Cancer Comité de Paris.

PT - 4 – Nucleosynthesis at the extremes of temperature and density - from thermonuclear to pycnonuclear reactions

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Accreting neutron star systems provide a perfect laboratory for probing nuclear reaction processes at extreme temperature and density conditions. Depending on the accretion rate a thermonuclear runaway is triggered through the hot CNO cycles and the rp-process in the outer atmosphere of an accreting neutron star. Such events are observed as X-ray bursts. The reaction flow and time scale of the runaway is determined by the nuclear structure of rp-process nuclei. Electron capture reactions in the subsequent cooling phase of the burst transforms the rp-process ashes into very neutron rich nuclei at the increasing densities of the neutron star crust. At near nuclear matter densities pycnonuclear reactions can occur which provide a new and as yet not fully understood energy source in the deep layers of the neutron star crust. The talk will address the conditions within the various environments. It will identify the open questions with regards to critical reaction processes at these conditions as well as the experimental and theoretical challenges required for providing reliable input for modeling the associated nucleosynthesis scenarios.

PT - 5 – Progress on the accelerator based SPES-BNCT project at INFN Legnaro

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An accelerator-based thermal neutron source, aimed at the BNCT of extended skin melanoma experimental treatment, is foreseen to be installed in the next years at the INFN Laboratori Nazionali di Legnaro (LNL) in the framework of SPES (Study and Production of Exotic nuclear Species) project. The SPES-BNCT project will exploit the intense beam delivered by the 5 MeV, 30 mA (i.e. 150 kW) Radio-Frequency Quadrupole (RFQ) proton driver, presently under construction. After extensive neutronic as well as technological feasibility studies lasted two years, an original, beryllium-based, target concept has thus been designed, in collaboration with the STC Sintez of Efremov Institute in S. Petersburg, as the best neutron converter solution consistent with the SPES design specifications The first, full-scale prototype, constructed at the end of 2004, has been undergoing a series of both operative and critical e-beam power test conditions. The Accelerator-Based Beam Shaping Assembly (AB-BSA) modeling, currently underway, will exploit the useful experience gained in the last years at the LNL CN Van de Graaff driven, low power, demonstration facility. A combined boron neutron capture plus photodynamic (BNCT+PDT) therapy approach will be investigated, due to the promising photosensitizers uptake selectivity in tumour tissues. New, boron loaded phthalocyanine compounds (B-Pc), have been recently synthesized by Molteni Pharmaceuticals (Florence, Italy) and a wide radiobiological investigation *in vitro* and *in vivo* has already started, in order to investigate this possibility. Moreover special microdosimetric detectors have been designed and constructed at LNL in order to provide an on-line therapeutic neutron beam monitor and to properly take into account all the BNCT dose components and their qualities. Both microdosimetric and radiobiological measurements are being performed at the purpose-designed HYTHOR new thermal column, installed at the ENEA-Casaccia TAPIRO reactor. The LNL-BNCT project will therefore mean to represent a challenge to provide an intense thermal neutron beam facility and a fundamental test bench for an operative, accelerator-based BNCT facility concept instead of the more complex, even low power, dedicated reactor-based systems.

PT - 6 – Characterization of Phase Transitions in Small Systems

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We consider the comparison of phase transitions in infinite and finite systems. The qualitative new feature appearing in small systems is the surface. It has been known for a long time that the liquid drop-vapor coexistence is affected in a simple way by the surface of the liquid drop which can be incorporated into the standard thermodynamics in a straightforward way. We show that the signals advocated for phase transitions in small systems such as negative specific heat and bimodality descend directly from the presence of the surface and depend significantly on the boundary conditions.

A most effective way to study the liquid-vapor phase transition is Fisher's model. This model can be generalized to describe the coexistence of a drop of liquid with its vapor and the cluster composition of the vapor. We have identified a procedure which we call "complement" that accounts in detail for the free energy change when a cluster is removed from the liquid drop and placed into the vapor. The complement is a very general method, we have tested it on the finite Ising model and we have applied it to extract the infinite nuclear matter phase diagram from intermediate mass fragments emitted in nuclear reactions. Corrections for Coulomb effects, which are very troublesome in describing phase transitions of any kind, can be introduced unambiguously within the framework of the "complement."

PT - 7 – Baryon properties in a chiral quark model

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We give an overview of previous applications of the perturbative chiral quark model (PCQM) in the analysis of the structure of the nucleon. The PCQM is based on an effective Lagrangian, where baryons are described by relativistic valence quarks and a perturbative cloud of Goldstone bosons as required by chiral symmetry. We discuss for example applications to to σ-term physics, to πN scattering including radiative corrections, to the strange form factors and to the electromagnetic polarizabilities of the nucleon. Furthermore, we present recent efforts to formulate and apply a manifestly Lorentz covariant chiral quark model, which is consistent with the latest developments in the baryon sector of Chiral Perturbation Theory.

PT - 8 – Charged particles as a probe to understand the behaviour of a dosemeter: Studies of LiF:Ti,Mg irradiated with intermediate-energy ions

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The material LiF:Ti,Mg, known commercially as TLD-100, is the most used personnel radiation dosemeter. Its thermoluminescent (TL) response (the emission of light when heated after exposure to ionizing radiation) permits to evaluate the dose received by an exposed individual. Our group has studied over the last 10 years the properties of TLD-100 to fluences of ions, with the aim of better understanding the processes that lead to the TL response under conditions of highly inhomogeneous energy deposition around the charged particle trajectory. A recent study of TLD-100 glow curve and efficiency induced by ions up to 40 MeV/A has shown interesting correlations among light emission at different temperatures as a function of the ion linear energy tranfer LET (similar to stopping power). These allow, in principle, to deduce from the glow curve not only the dose, but also the ion's identity. Also, the efficiency data reflect the presence in the dosemeter material of localized structures which are preferentially excited when the ion LET matches the trap size.

PT - 9 – GRETINA

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Gamma-ray spectroscopy has played a major role in the study of the atomic nucleus. As in almost any branch of physics, development of new detectors and techniques have always lead to discoveries of new and unexpected phenomena. For a gamma-ray detector system, the main ingredients that define its resolving power are the efficiency, the peak-to-total ratio and the effective resolution. The realization that multi-segmented HPGe detectors can provide information on the position of the interactions of a gamma-ray lead to the concept of gamma-ray tracking. This position information is derived from the pulse shapes of the main and induced signals, with a resolution of ∼2mm. The improved position resolution translates directly in a better energy resolution for most of the in-beam work, as a Doppler reconstruction can be done with better precision. With a 4πpi coverage of Ge material a large gain in efficiency is achieved and if such an array could be built, the expected resolving power is of some orders of magnitude better than current systems like Gammasphere or Euroball. GRETINA, will be one of the first implementations of a tracking array, covering 1π of solid angle. GRETINA is a major equipment initiative supported by the US-DOE Nuclear Physics Office and is being constructed at LBNL with active participation from other national laboratories and universities. In this talk we will describe the design of the array and its expected performance, discuss some of the physics potential and present results obtained with the triple-cluster prototype, including an in-beam test. Finally we will review the schedule and current status of the project.

PT - 10 – Chiral Nuclear Effective Field Theory

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Strong-interaction processes involving momenta Q much smaller than the typical QCD scale $M_{QCD} \sim$ 1 GeV can be described by effective field theories (EFTs). An EFT consists of all interactions among low-lying hadrons subject to the symmetries of QCD, and it allows the systematic expansion of observables in powers of Q/M_{QCD}. Systems of two or more nucleons are particularly interesting as they require a selective, controlled resummation of certain interactions. This resummation makes it difficult to respect renormalization-group invariance in chiral nuclear EFT —the generalization of chiral perturbation theory to multi-nucleon systems. I will review our current understanding of the non-perturbative renormalization of pion exchange and describe a new power counting that seems to remove the remaining obstacles to the implementation of EFT for $Q \sim m_\pi$, the pion mass.

PT - 11 – Experiments in Nuclear Astrophysics

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Recent astronomical observations from ground and spaced-based telescopes covering the full wave length spectrum have lead to a renewed interest in the nuclear reactions that power stars and produce the elements in the universe. Specifically, reactions involving short-lived nuclei play a crucial role in explosive astrophysical scenarios such as novae, supernovae, or X-ray bursts. A few of these reactions have been studied during the last decade using radioactive ion beams produced at the first-generation radioactive beam facilities. I will discuss some recent studies that are important for neutrino experiments, for the production of carbon and oxygen in massive stars, and for reactions occurring on the surfaces of neutron stars. This work was supported by the US Department of Energy, Nuclear Physics Division, under contract No. W-31-109-ENG and by the NSF Grant No. PHY-02-16783 (Joint Institute for Nuclear Astrophysics).

PT - 12 – On the Role of the g9/2 intruder level for the upper fp-shell nuclei Ni, Cu, Zn, Ge, Se

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Shell-model calculations for isotopes of Ge and Se are reported where valence nucleons beyond the N=28=Z core are considered to fill levels of the normal parity upper fp shell and the unique parity g9/2 intruder configuration. Results are for realistic interactions of the Kuo-Brown-3 type with various model space truncations that key on the number of nucleon pairs allowed to occupy the intruder level. Electromagnetic (E2 & M1) rates as well as decay probabilities are calculated, some of which are key in a determination of the structure "waiting point" nuclei that tend to regulate nucleo-astrosynthesis processes. The role of the intruder level, which is treated on an equal basis with the normal parity orbitals, is shown to be important for reproducing structural details. The levels of the upper fp shell are handled within the framework of a normal jj-coupled basis as well as its pseudo-SU(3) counterpart where one sees the effect of deformation on the results.

PT - 13 – Microcanonical Thermodynamics is the statistical fundament of Thermodynamics, heat can flow from cold to hot, and nuclear multifragmentation.

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Equilibrium statistics of finite Hamiltonian systems is fundamentally described by the microcanonical ensemble (ME) [1]. Canonical, or grand-canonical partition functions are deduced from this by Laplace transform. Only in the thermodynamic limit are they equivalent to ME for homogeneous systems. Therefore ME is the only ensemble for non-extensive/inhomogeneous systems like nuclei or stars where the $\lim_{N\to\infty,\rho=N/V=const}$ does not exist. Conventional canonical thermo-statistic is inapplicable for non-extensive systems. This has far reaching fundamental and quite counter-intuitive consequences for thermo-statistics in general: Phase transitions of first order are signaled by convexities of $S(E, N, Z, \cdots)$ [1]. Here the specific heat is *negative*. In these cases heat can flow from cold to hot! The original task of thermodynamics, the description of heat engines is finally solved. Consequences of this basic peculiarity for nuclear statistics as well for the fundamental understanding of Statistical Mechanics in general are discussed. Experiments on hot nuclei show all these novel phenomena in a rich variety. The close similarity to inhomogeneous astro physical systems will be pointed out.

[1] D.H.E. Gross. *Microcanonical thermodynamics: Phase transitions in "Small" systems*, volume 66 of *Lecture Notes in Physics*. World Scientific, Singapore, 2001.

PT - 14 – First Data from the Pierre Auger Project

Etchegoyen, A. for the Pierre Auger Collaboration[1]

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The Pierre Auger Project (www.auger.org.ar) is building in the Department of Malargüe, Province of Mendoza, an ultra high energy cosmic ray Observatory. The Observatory consists in a hybrid detection system emcompassing both surface detectors and optical telescopes. An outlook will be given on the surface, telescope and hybrid systems performance.

Emphasis will be laid on the first Auger experimental results: cosmic ray spectrum above 3 EeV, a description on a few ultra high energy cosmic rays, inclined airshowers, and anisotropy studies. A reference will be made on Auger future prospective.

PT - 15 – Superheavy Elements: a Phantastic Story

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The extension of the periodic system into various new areas is investigated. Experiments for the synthesis of superheavy elements and the predictions of magic numbers with modern meson field theories are reviewed. Furtheron, different channels of nuclear decay are discussed including cluster radioactivity, cold fission and cold multifragmentation. A perspective for future research is given. We also study the possibility of producing a new kind of nuclear system that in addition to ordinary nucleons contains a few antibaryons. The properties of such systems are described within the relativistic mean-field model by employing G-parity transformed interactions for antibaryons. Calculations are first done for infinite systems and then for finite nuclei from ^{4}He to ^{208}Pb. It is demonstrated that the presence of a real antibaryon leads to a strong rearrangement of a target nucleus, resulting in a significant increase of its binding energy and local compression. Noticeable effects remain even after the antibaryon coupling constants are reduced by a factor of 3-4 compared to G-parity motivated values. We have performed detailed calculations of the antibaryon annihilation rates in the nuclear environment by applying a kinetic approach. It is shown that owing to significant reduction of the reaction Q values, the in-medium annihilation rates should be strongly suppressed, leading to relatively long-lived antibaryon-nucleus systems. Multinucleon annihilation channels are analyzed too. We have also estimated formation probabilities of bound antibaryon-nucleus systems in antiproton-nucleus reactions and have found that their observation will be feasible at the future GSI antiproton facility. Several observable signatures are proposed. The possibility of producing cold multi-quark-antiquark clusters is discussed. This opens the possibility for cold compression of nuclear matter in contrast to the creation of hot and dense nuclear matter in nuclear shock waves created in high energy nucleus-nucleus collision.

Parallel Sessions

Nuclear Structure

NS - 1 – AGATA an HPGe segmented tracking array

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On behalf of the AGATA collaboration

The Radioactive Beam Facilities which will be ready in the near future will provide access, for the first time, to an incredibly large number of isotopes in the proximity of both the proton and neutron drip lines. The expected experimental conditions, however, will be extremely different from those typical for stable beams. Projectiles will be at relativistic energy, a high degree of background is expected and the intensities of such radioactive beams are foreseen to be much smaller than stable one. The next generation detector arrays consequently require unprecedented levels of efficiency and sensitivity which cannot be reached with the conventional techniques.

In the past few years a new technique has been developed based on electrically segmented HPGe detectors and digital electronics in order to identify the positions of the single energy depositions of the gamma-ray within the crystal. Starting from the gamma-ray interaction points the reconstruction of the gamma ray track (tracking) is done by software. Monte Carlo simulations suggest that an HPGe array based on such technique will have quite a high photopeak efficiency over a broad energy range (larger than 35 % for single 1 MeV photons and larger than 20 % for a cascade of 30 photons of the same 1 MeV energy), combined with an excellent peak-to-total ratio (of the order of 55 %).

The reconstruction of the gamma track, besides, will provide major advantage for such an array with respect to the present generation arrays not only in terms efficiency but also in terms of background subtraction and Doppler correction, which is critical in case of relativistic beams.

In this contribution some of the techniques of pulse shape analysis and gamma-ray tracking are introduced and the present status of the AGATA project is reviewed.

NS - 2 – Advanced Time Delayed $\beta\gamma\gamma(t)$ measurements in the N∼20 island of inversion

Fraile, L.M. for the IS414 Collaboration.[1,2]

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Nuclei in the island of inversion around N=20 have recently been subject of extensive experimental and theoretical studies in an attempt to understand the disappearance of the neutron shell closure and the dominance of intruder configurations [1]. The Mg isotopes are at the border of the island of inversion, and ^{30}Mg and ^{31}Mg in particular are expected to show the coexistence of the spherical *sd* and intruder *pf* configurations. In spite of the experimental efforts to tackle these exotic nuclei, the unambiguous identification of the excited states as members of either configuration has not been achieved yet. In a recent experiment performed at ISOLDE-CERN we have used the Advanced Time Delayed $\beta\gamma\gamma(t)$ Method [2] to study ^{30,31,32}Mg populated in the beta decay of ^{30,31,32}Na. This study is part of an extensive experimental program at ISOLDE aimed at the investigation of the structure of exotic Mg nuclei, which also includes Coulex measurements at REX-ISOLDE and hyperfine interaction studies.

The data analysis of our fast timing experiment has yielded several interesting results. New states have been identified in ^{30}Mg and ^{31}Mg, and level lifetimes have been measured for the first time in these nuclei. A new candidate for the lowest-lying 0^+ state arises from the long lifetime measured for the 1789 keV gamma transition. Furthermore, our coincidence study of the decay scheme of ^{30}Mg from the β-decay of ^{30}Na allows to establish a new placement of the 1789 and 1820 keV transitions. In the case of the odd nucleus ^{31}Mg, the newly-measured lifetimes strongly constraint the spin-parity assignments for the observed states. Our experimental results confirm the model interpretation of this nucleus based on recent data [3]. In the light of the new results the intruder configurations in ^{30}Mg and the characterization of the excited states in ^{31}Mg will be discussed. For ^{32}Mg, there exist strong indications of the vanishing of the N=20 shell closure and the domination of the intruder configurations. The measurement of the $B(E2; 0^+_{g.s.} \rightarrow 2^+_1)$ gives key information on the collectivity of the E2 transition. The ATD $\beta\gamma\gamma(t)$ method provides a direct and model-independent way to determine this transition probability by the measurement of the half-life of the first excited 2^+ state. The B(E2) rate found in our experiment will be discussed in comparison with the values obtained in studies using Coulomb excitations at intermediate energies.

[1] E. Caurier et al., Nucl. Phys. A693, 374 (2001)

[2] H. Mach et al., Nucl. Phys. A523, 197 (1991) and references therein

[3] G. Neyens, M. Kowalska et al., Phys. Rev. Lett. 94 (2005) 22501.

NS - 3 – The ALTO project at IPN Orsay

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The availability of intense neutron-rich nuclei opens new opportunities for nuclear-structure studies. Several laboratories are focusing in studies aimed at producing high enough intensities to warrant a new generation of experiments. Facilities are planned to provide these radioactive beams e.g. the SPIRAL 2 project. The program PARRNe (Production d'Atomes Radioactifs Riches en Neutrons) is aimed at studying the parameters to optimize the production of radioactive beams produced by fission. After the photo-fission experiment success at CERN, it has been decided to start a conceptual project for the installation at IPN-Orsay of 50 MeV electron accelerator : The ALTO project (Accélérateur Linéaire auprès du Tandem d´Orsay). The accelerator will be installed in the experimental area of the Tandem, to deliver beams mainly to PARRNe-2 device. The linac is composed of thermionic gun, a bunching system and a matching section to the linac. The expected intensities for the 30 keV mass separated beams at ALTO will give the opportunity for nuclear spectroscopy of very neutron-rich nuclei in various region of interest. The new project, ALTO, for the production of fission fragments using photo-fission at IPN Orsay, will be presented.

NS - 4 – Nuclear structure studies on moderately neutron-rich nuclei with PRISMA-CLARA

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For many decades, the theoretical modelling of nuclear structure was constructed relying on the experimental information obtained for nuclear systems near the stability line. The continuous experimental developments allows nowadays to study exotic nuclei far from stability. In particular, neutron-rich nuclei are currently of substantial interest. In the shell-model description of nuclei, the relative shell energies are expected to undergo significant changes with the increasing neutron excess, leading to the disappearance of some of the nuclear magic numbers known near stability, and to the appearance of new ones [1.2]. The production of neutron-rich nuclei is quite difficult in reactions induced by stable beams. Most of the available information on the structure of these nuclei has been obtained in β-decay studies. Fusion-evaporation reactions, that are the standard tool for the spectroscopy of yrast high-spin excited states, mainly produce nuclei near to stability and/or proton-rich systems. Multi-nucleon transfer and deep-inelastic collisions have been shown to be appropriate reaction mechanisms to populate medium and high-spin states in neutron-rich nuclei. In these types of reactions a large number of both projectile-like and target-like isotopes are produced. Consequently, a device to perform the mass and atomic number identification, as well as to detect the γ rays following the de-excitation of the nuclei produced in the reaction, is needed.

The coupling of the gamma-ray Ge clover array CLARA with the magnetic spectrometer PRISMA [3] at the Legnaro National Laboratory constitutes the appropriate instrument to obtain new in-beam spectroscopic information on medium-mass neutron-rich nuclei. Selected results on neutron-rich nuclei of mass $A \simeq 60$, that give information about important problems raised by modern nuclear structure theory will be presented. In this mass region, subshell closures, new deformation regions and shape phase transitions are observed and different theoretical nuclear models can be applied to describe these structures.

[1] T. Otsuka *et al.*, Phys. Rev. Lett. **87**, 082502 (2001).

[2] E. Caurier, F. Nowacki and A. Poves, Eur. Phys. J. **A15**, 145 (2002).

[3] A.Gadea *et al.*, Eur. Phys. J.**A20**, 193 (2004) and A.M. Stefanini *et al.*, Nucl. Phys. **A701**, 217c (2002).

NS - 5 – Resonant states in light nuclei revisited in full kinematic studies

Borge, M.J.G.,[1] Prezado, Y.,[1] Tengblad, O.,[1] Diget, C. Aa.,[2] Fynbo, H.O.U.,[2] and Riisager, K.[2]

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The study of particle spectroscopy is a powerful source to obtain information on the structure of nuclei very far from stability. The process of beta-delayed particle emission has been the subject of much study in the last few decades as it allows, if the final state is known, to uniquely determine the decay pattern from the energy of the emitted particle. As the decay pattern depends on the structure of the states involved, these studies are an important tool to investigate nuclear structure.

Beta decays followed by multi-particle emission present a special experimental challenge recently overcome by the development of detectors with high granularity and large solid angle allowing to detect most particles resulting in the break-up of a nuclear state. This multiple detection is important as the break-up mechanism involving several particles is not fully determined by the conservation laws. In three-body break-up there are three binary subsystems, where each may have resonances influencing the break-up. The decay can proceed sequentially via each of the three resonances or directly to the continuum if the width of the resonances is larger than the energy available. Although the physics is very different for the sequential and direct processes incomplete data on multi-particle break-up can allow for both interpretations.

The stability of the α-particle and the fact that ^{8}Be is unbound makes multi-particle break-up to dominate the decay of very light nuclei. In this contribution I will review the new physics results that have emerged from recent beta-decay studies made at ISOL-type facilities to determine the multi-particle break-up mechanism of resonant states in light nuclei by studying them in full kinematics. In particular the results obtained for the A=9 isobars [1] and for the states in ^{12}C beyond the 3α threshold [2] will be discussed.

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NS - 6 – Laser spectroscopy: a powerful tool for the determination of the global properties of the ground and isomeric states

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Laser spectroscopy allows the determination of the isotope shift and of the nuclear moments of the ground and isomeric states through long isotopic chains. This provides reliable information on the shape of nuclei, structure of states, location of magic numbers, effects of dynamics, pairing. The nuclear data ($\delta <r_c^2>$, μ and Q_S) are obtained by studying the interaction between the nucleus and its electronic cloud that gives rise to frequency changes of the atomic transition between the isotopes. The effect that we want to observe is about 10^{-6} what requires high resolution laser spectroscopy measurements. In order to study, not only a wide range of elements in the chart of the nuclides, but also nuclei located farther and farther fromstability, very efficient techniques are necessary. All these points will be illustrated by taking examples, especially among results obtained at ISOLDE from resonance ionization spectroscopy using COMPLIS[1,2)] (COllaboration for Measurements using a Pulsed Laser Ion Source) and RILIS[3,4)] (Resonance Ionization Laser Ion Source).

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NS - 7 – Spectroscopy of primary gamma radiation in heavy-ion fusion-evaporation reactions

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The research of the nucleus in regions where such interesting phenomena like shape phase transitions should be observable supposes the possibility of performing experimental investigation in the quasi-continuum region. A short summary of today's experimental possibilities can be found in Ref. [1] where we also report on a new method, combination of the Hk [2] and the "Energy-Ordered Spectra" [3] techniques: Information on the initial spin and energy of the gamma cascades is obtained by using the sum energy and multiplicity. Additionally, picking out the most energetic gamma rays in each cascade we obtain spectra that have very useful similarities to those of the primary gamma radiation, our essential piece of information on the states in the continuum. The M gamma-rays emitted by the nucleus in a cascade hit k detectors and as a result the original excitation energy E in the nucleus is detected as H. Performing any reliable data analysis on multiplicity and sum-energy supposes the knowledge of the array's response function to these two varibles. The development of the Hk technique provided also a method to obtain such a response function by using standard gamma sources [2]. Towards the characterization of the detector array, we instead use realistic gamma cascades provided by the Monte Carlo code GAMBLE [4] as input to an application [5] of GEANT4 [6] simulating the GASP array. We obtained $k-H$ maps when cascades of fixed multiplicity and excitation energy (M, E) interact with the 80 BGO-detectors of GASP. A first important result is that the dispersions σ_k, σ_H around the corresponding mean values are only of around 10% for multiplicities and excitation energies typical of fusion-evaporation reactions. These and other results, to be discussed, produce a very encouraging picture towards the goal of using the new proposed method to obtain an approximation of the primary radiation from states at high energy and high spin with arrays like GASP.

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NS - 8 – Isovector and Isoscalar pairing multiplets in the vecinity of the A=56 nuclei.

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We present a microscopic description of spin-isospin degrees of freedom, based on the coupling between isovector and isoscalar vibrations, and particle and hole states. The formalism is applied to describe the structure of low-lying levels of even and odd mass nuclei around the N=Z=28 double closed shell. Data on Gamow-Teller transitions are analyzed.

NS - 9 – Ground-state properties of several spherical and deformed isotopic chains in the Dirac-Hartree-Bogoliubov approximation

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With the aim of studying unstable nuclei, new experimental facilities have enabled the measurement of masses, radii and deformations in an ever wider region of the nuclear chart. Studies in this 'terra exotica' have revealed new features such as neutron halos or skins and brought new perspectives to nuclear physics. With the growing number of measurements of nuclei far from stability, a more detailed analysis of the variations in their ground-state structure is becoming possible.

Theoretically, microscopic mean field models that include pairing correlations are the most appropriate tools for a study of ground-state structure, whether non-relativistic HFB ones, using a Skyrme or Gogny interaction, or relativistic Dirac-Hartree-Bogoliubov (DHB) ones. Here we compare the masses, deformations, spin-orbit splittings, level structure, rms radii and surface diffuseness parameters obtained from DHB calculations of the O, Ca, Ne, Se, Kr, Sr, Sn and Pb isotopic chains with the available experimental data. We thus give an overview of the present capabilities of the model in predicting ground-state nuclear properties.

NS - 10 – Structure investigation of light proton-rich nuclei on the drip-line.

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The shell structure is one of the very important quantities concerning nuclear structure. Recently, magic numbers in the neutron-rich region have been extensively studied indicating interesting features like desappearance of nuclear magicity towards the neutron drip line [1]. Here, we present such discussion on the proton drip-line. We have been performing a systematic experimental investigation on the structure of isospin T=3/2 light proton-rich nuclei, where nuclear structure of 25Si [2], 21Mg [3], 17Ne [4], 11N [5] have been investigated. The structure of these nuclei have been investigated by the three-neutron pick-up reaction (3He,6He). This reaction has been shown to be very suited for spectroscopic studies of these exotic nuclei and it has even been used to probe resonances in unboud nuclei such 11N [5]. To complete this systematic, we included the new and recent analysis of proton rich nucleus 13O investigated by the 16O(3He,6He)13O reaction. The angular distributions measured for this reaction have shown a characteristic feature of a transferred angular-momentum (L) dependence, which provides spin-parity assigments for many new levels observed in 13O. The nuclear structure of the 13O is also important for evaluating the astrophysical radiative capture reaction rate, 12N(p,gamma)13O. This reaction is expecting to play a role in the hot p-p hidrogen burning in massive objects [6], and spectroscopic information on the excited state in 13O just above the proton threshold is most needed for a precise reaction network calculation.

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NS - 11 – Paring Induced Interaction in Finite Nuclei and in Neutron Stars

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The pairing interaction obtained making use of the matrix elements of the bare nucleon-nucleon force is strongly renormalized by the induced interaction produced by the exchange of collective vibrations.

We compare the effects of the induced interaction in neutron matter - where spin fluctuations prevail and the pairing gap is quenched - and in finite, open shell nuclei - where density fluctuations dominate and the pairing gap is enhanced.We then apply the previous results to the calculation of the pairing gap in the inner crust of neutron stars, in which a Coulomb lattice of finite nuclei is inbedded in a sea of free neutrons. The spatial dependence of the gap is a fundamental ingredient for a microscopic quantum calculation of vortex pinning, which has been proposed as an explanation of the glitches phenomenon.

NS - 12 – Cranking in Iso Space: a Probe to Neutron Proton Pairing and the Nuclear Symmetry Energy

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The iso-cranking model elucidates the different role played by iso-vector and iso-scalar pairing, respectively [1,2,3]. The iso-cranking model also gives a better insight into the nuclear symmetry energy. This new concept for the nuclear symmetry energy is confirmed by self consistent Skyrme Hartree Fock calculations[4] as well as relativistic mean field[5]. The importance of these findings to global mass calculations is addressed.

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NS - 13 – Spatial characteristics of borromean, tango, samba and all-bound halo nuclei

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A systematic study of the spatial characteristics of halo nuclei will be made taking into account our recent works. The halo nuclei is approached by a weakly bound three-body system compounded by two halo neutrons and a point-like core. The constituents of the halo have a high probability to be found much beyond the interaction range. Then, the concept of a short-range interaction between the particles and its implications are useful in understanding the few-body physics of the halo. The quantum description of such large and weakly bound systems are universal and can be defined by few physical scales despite the range and details of the pairwise interaction. For the case of two identical particles in the three-body system, we have considered four possibilities for the two-body subsystems: all unbound (*Borromean*); all bound (*All-bound*); one bound and two unbound (*Tango* configuration); and one unbound with two bound (we suggest a name *Samba* for this configuration). We have calculated the nn root-mean-square radii for ^{6}He, ^{11}Li and ^{14}Be. We have also calculated the respective two neutron correlation functions for the dissociation process of these light exotic nuclei and we will show that our results agree very well with recent experimental data.

NS - 14 – Coulomb Energy Differences in Isobaric Multiplets

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One of the central topics in nuclear physics is the isospin symmetry. It shows experimentally in nearly identical spectra in pairs of mirror nuclei (obtained interchanging protons and neutrons) and isobaric multiplets. Interesting results concerning isospin multiplets have been obtained in the last years in the sd and fp shells thanks to important experimental and theoretical developments (1–4). By comparing the excitation energies of analogue states (Mirror Energy Differences (MED) and Triplet Energy Differences (TED)), several remarkable properties can be studied as a function of the angular momentum up to high spin states, and in many cases, along rotational bands. Both MED and TED can be reproduced in the shell model framework. It is interesting to see how Coulomb effects can account for *nuclear structure* features such as the nucleon alignment at the backbending, the changes of the nuclear radius with increasing spin, and the different configurations of states of equal spin and parity in the same nucleus. In addition, the evidence of a nuclear non-conserving term has been recently suggested (5). A review on the latest results on what we can learn from MED and TED will be presented.

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NS - 15 – Recent achievements in the nuclear pairing problem

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The pairing states in nuclear and neutron matter are studied in the framework of the generalized BCS theory. The nucleon-nucleon pairing interaction is dressed by medium self-screening effects approximated by the whole class of ring diagrams. The dynamical medium dispersion effects are also embodied in the single particle spectrum. While the latter always result in a strong suppression of the energy gap, the screening mechanism of the background is strongly isospin dependent: The magnitude of the vertex corrections is much stronger in nuclear matter than in neutron matter for the dominant role of the neutron-proton tensor force . Implications of the new energy gaps on the superfluidity of neutron stars and pairing in nuclei are discussed.

NS - 16 – What is the Nature of the first excited K=0+ in Deformed Nuclei?

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What is the Nature of the first excited K=0+ Bands in Deformed Nuclei*

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The nature of the first excited K=0+ bands in deformed nuclei remains elusive. We have recently reported [1,2] on the observation of a large number of K=0+ bands in the deformed 158Gd nucleus below an excitation energy of 3 MeV. A microscopic description of these bands remains a challenge to nuclear models in spite of the flurry of activity within different theoretical constructs including the projected shell model, pseudo SU(3), GCM, IBM, and the Quasi-particle phonon model [3-9]. The focus of this presentation will be on the experimental evidence for the observations of K=0+ bands, their lifetimes, and transition probabilities in several deformed rare-earth nuclei. Observations and calculations will be discussed in terms of their implications to our present understanding of vibrational motion in nuclei. * This work is supported by the National Science Foundation under contract number 01-140324.

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NS - 17 – New clues for the B(E2: $0^+_1 \to 2^+_1$) behavior around ^{68}Ni : seniority and p-n interaction

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The B(E2: $0^+_1 \to 2^+_1$) (B(E2)↑) reduced transition probability of an even-even nucleus is correlated to the possibilities to perform excitations leading, from the single-particle level spectrum of the ground state, to the 2^+_1 state. Its value is then very sensitive to the (sub-)shell structure. The difference of B(E2)↑ behavior observed in ^{66,68}Ni and ^{68,70}Zn [1] is important to understand since concerning the still discussed N=40 sub-shell closure.

In recent theoretical papers [2,3] the ^{66,68}Ni B(E2)↑ decrease is discussed using different calculations performed on Ni isotopes only, and in relation with the size of the N=40 sub-shell closure. In another paper [4] the $^{62-70}$Zn B(E2)↑ values are analysed on the basis of shell-model calculations performed only in $^{62-70}$Zn. Nevertheless, the Ni and Zn B(E2)↑ curves exhibit features, also observed in heavier nuclei wih N, Z$\simeq$40, that a N=40 gap does not allow to explain.

We have analysed the experimental B(E2)↑ values as a function of N taking into account these common features and using curves obtained in an approximation of the generalized seniority which gives a very simple expression of the B(E2)↑.
Our analysis casts a new light on the evolution of the B(E2)↑ from the Ni up to the Se isotopes. The reproduction of this evolution requires a complex sub-shell structure in which the p-n interaction plays an important role [5]. It suggests a scenario locating the sub-shell closure at N=38, with a small spacing at N=40

diminishing with Z as indicated by the excited spectra in the odd-Ni and Zn isotopes. It is worth noting that the predictions ensuing our calculations have been recently confirmed by results obtained recently at Ganil on the ^{70}Ni and ^{74}Zn B(E2)↑ [6], at Isolde on $^{74-78}$Zn (preliminary) [7,8] and at Riken on the $^{78-80}$Ge [8].

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NS - 18 – The Importance of Triaxial Shapes in Odd and Even Z Nuclei from Y to Rh

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The level structures of odd Z ^{99,101}Y, ^{101,105}Nb, ^{105,107,109}Tc, and $^{110-113}$Rh and even Z ^{104,106}Mo, $^{108-112}$Ru and $^{112-116}$Pd have been significantly extended from $\gamma-\gamma-\gamma$ coincidence studies (6×10^{11} coincidences) with Gammasphere. Many new band structures are observed in all these nuclei. The bands in the Y, Nb, Tc and Rh nuclei show a smooth evolution from strong prolate deformation with very little signature splittings in ^{99,101}Y to increased signature splittings in Nb nuclei and maximum splittings and maximum triaxiality in Tc and Rh nuclei. One particle plus rotor calculations support these interpretations. The calculations find axial symmetry for ^{99,101}Y and γ values of -13^o to -19^o in $^{101-105}$Nb, -22^o for ^{107}Tc and -28^o for ^{111,113}Rh. In the even Z nuclei, we find in ^{106}Mo and ^{110}Ru two sets of energy degenerate ΔI = 1 bands with all the characteristics of sets of chiral doublet bands. Such chiral bands have been found in triaxial nuclei. Theoretical tilted axis rotor calculations support the chiral assignments. In ^{110}Ru, a second band starts at 10^+ and coexists with energies nearly degenerate with the ground band. This is the first such ground band doubling. The γ bands in these nuclei show unexpected rapid variations and oscillations with neutron number in signatuare splittings not seen in other regions.

NS - 19 – Spectroscopic Factors within an Algebraic Model

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A parameterization of the spectroscopic factor is presented which perfectly matches the ones obtained via the microscopic SU(3) model of the nucleus. A short introduction of the model is given. It is the Semimicroscopic Algebraic Cluster Model (SACM) which includes the Pauli-exclusion principle. Afterwards, the parameterization of the spectroscopic factor is explained, justified and compared, for light nuclei, to the microscopic SU(3) model. Finally, some applications are shown, like the fusion cross section of $^{12}C+^{12}C$ and the description of heavy cluster decay.

NS - 20 – Nuclear Forecasting as Pattern Recognition: Can we predict Nuclear Masses?

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We analyze different approaches to predict nuclear masses and propose a new method which interprets this question as a pattern recognition problem on the N-Z plane. We can maximize the observed patterns by examining the liquid-drop mass deviations. This technique does not attempt to minimize the measured global mass deviations or a priori restrict the calculation to be consistent with particular nuclear models. We also discuss the possibility of pattern recognition-constrained calculations which use the Garvey-Kelson relations as physical input.

NS - 21 – Ground state energy fluctuations and chaos in nuclear masses

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IIn order to gauge the possible presence of chaotic motion inside the atomic nucleus [1,2], in the present work the statistical fluctuations of the nuclear ground state energies are estimated using shell model calculations in which particles in the valence shells interact through well defined forces, and are coupled to an upper shell governed by random 2-body interactions [3] to mimic the presence of quantum chaos associated with neutron resonances at energies between 6 to 10 MeV. Diagonalizations were done for 2 protons and 2 neutrons in very large Hilbert spaces, including two major shells for protons and 2 for neutrons. A conservative scaling, based on random matrix studies in a single major shell, was employed to deduce an upper bound for the energy fluctuations at mid-shell. This estimate is consistent with the mass errors found in large shell model calculations along the N=126 line, and with local mass error estimated using the Garvey-Kelson relations [4], all being smaller than 100 keV [5]. The mass dependence was fitted, and found to be close to $A^{-4/3}$. This agrees in both size and functional form with the fluctuations deduced independently from second order perturbation theory

Being an order of magnitude smaller than the mass errors in the FRDM, associated with a chaotic component in [2], we conclude that this component cannot be related to *nuclear chaos* as defined by neutron resonances. The fact that this large chaotic component, whose existence was confirmed by a power spectrum analysis, disappears when additional 2-body forces or local mass information are employed [5], strongly suggest that it is nota physical phenomenon but rather a characteristic arising from the mean field approximation. Investigations along these lines are underway.

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NS - 22 – The gamma decay of the GDR at finite temperature

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The study of the Giant Dipole Resonance &# 61543; &# 61485;decay has given many insight for the understanding nuclear structure at finite temperature and in particular of the damping mecchanisms of this collective mode. The production of hot nuclei is made through compound nucleus formation using heavy ion fusion reactions. A difficult question remains as to determine the effective excitation energy of the equilibrated system and many discussions have been raised in the last years on this point. Clearly pre-equilibrium particle emission would decrease the available excitation energy for the compound system and the Giant Dipole vibration would then probe a system in a lower temperature regime. Measurement of particle emission together with &# 61543;-ray decay from the GDR allows to estimate the amount of pre-equilibrium emission and consequently to determine the resulting excitation energy of the compound nucleus. Giant Dipole Resonance parameters can then be extracted for a more realistic nuclear temperature and their behaviour with increasing temperature can be studied more confidently. With the advent of radioactive beams and the possibility to produce exotic nuclei with a N/Z ratio far from the typical value of the stability valley, it becomes possible to study the collective vibration involving the less bound nucleons with respect to the inner core, namely the so called pygmy resonance. Such a resonance is predicted by some theoretical models and it is expected to be stronger in neutron rich nuclei. The first measurements focusing on the &# 61543;-decay for nuclei in the medium mass region, 68Ni, have been performed.

NS - 23 – The Mutability of Nuclear Shells

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Shells lie at the very heart of nuclear structure, and in the past the nuclear shell gaps were generally considered to be stable with respect to such parameters as proton and neutron number. However, this assumption was largely based on the study of nuclei near the valley of stability, within a very limited range of proton to neutron ratios. Recent investigations of very neutron-rich nuclei have revealed significant variability in the shell gaps.

One example is the “Island of Inversion,” a region of neutron-rich nuclei with Z = 10-12 and N = 20. Instead of the spherical behavior expected for nuclei with a “magic number” of neutrons, these nuclei exhibit considerable deformation and other signs of domination of f-p intruder configurations in their ground states. This implies a much weakened N = 20 shell gap, unlike the case for N = 20 nuclei near Z = 20. A major open question has been how far the Island of Inversion persists below N = 20.

A recent investigation [1] of ^{28}Na and ^{29}Na has revealed that the transition occurs between N = 17 and 18 at Z = 11. The structure of these nuclei was investigated for the first time following the beta decay of mass separated ^{28,29}Ne produced in the fragmentation of a 140 MeV/nucleon ^{48}Ca beam. The low-lying level structure of ^{28}Na is rather well reproduced by shell model calculations restricted to the s-d shell using the standard USD interaction. In contrast, ^{29}Na differs considerably from the USD predictions, but agrees rather well with large scale Monte Carlo shell model calculations [2] which include p-f configurations as well as s-d excitations.

Effects of excitations from the lower p shell have recently been observed in ^{22}F and ^{20}O produced in the reaction of a long-lived radioactive ^{14}C beam on a radioactive ^{10}Be target [3]. Two new states below 1 MeV in ^{22}F and several between 4 and 6 MeV in ^{20}O are not accounted for by USD shell model calculations. Calculations which include intruder configurations from the p shell with the PSD interaction overpredict the energies of candidates for the new states in ^{20}O and ^{22}F. However, it was found that these and other previously known intruder states can be reproduced by systematically reducing the gap between the p and s-d shells with increasing neutron number. Such an effect has important consequences for nuclear astrophysics calculations for even more neutron rich nuclei.

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NS - 24 – Theory of decay out of superdeformed bands

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Formulas for the energy average and variance of the intraband decay intensity of a superdeformed band are presented and discussed. Formally, they are energy integrated versions of the Hauser-Feshbach and Ericson formulas for compound nucleus reactions and are expressed in terms of three dimensionless variables: $\Gamma^{\downarrow}/\Gamma_S$, Γ_N/d, and $\Gamma_N/(\Gamma_S+\Gamma^{\downarrow})$. Here $\Gamma^{\downarrow}$ is the spreading width for the mixing of a superdeformed (SD) state $|0>$ with the normally deformed (ND) states $|Q>$ whose spin is the same as $|0>$'s. The $|Q>$ have mean level spacing d and mean electromagnetic decay width Γ_N whilst $|0>$ has electromagnetic decay width Γ_S. The average decay intensity may be expressed solely in terms of the variables $\Gamma^{\downarrow}/\Gamma_S$ and Γ_N/d or, analogously to compound nucleus reaction theory, in terms of the transmission coefficients $T_0(E)$ and T_N describing transmission from the $|Q>$ to the SD band via $|0\angle$ and to lower ND states. The variance of the decay intensity, in analogy with Ericson's theory of cross section fluctuations depends on an additional variable, the correlation length $\Gamma_N/(\Gamma_S+\Gamma^{\downarrow}) = \frac{d}{2\pi}T_N/(\Gamma_S+\Gamma^{\downarrow})$. This suggests that analysis of an experimentally obtained variance could yield the mean level spacing d as does analysis of the cross section autocorrelation function in compound nucleus reactions. Comparison with other approaches is made.

Nuclear Reactions

NR - 1 – Higher order effects in the 16O(d,p)17O and 16O(d,n)17F transfer reactions.

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Full coupled channels calculations were performed for the 16O(d,n)17F and 16O(d,p)17O transfer reactions at several deuteron incident energies from Elab=2.29MeV up to 3.27MeV. A strong polarization effect between the entrance channel and the transfer channels 16O(d,n)17F (1/2+, 0.87) was observed. This polarization effects had to be taken into account in order to obtain realistic spectroscopic factors from these reactions. The radiactive capture cross sections evaluated from the present spectroscopic factors values are in agreement with the experimental data.

NR - 2 – Comparison between pre-equilibrium reactions models

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Pre-equilibrium processes are important in reactions induced by the nucleons above 10 MeV. Currently, two types of models are used to describe this process: exciton model and the hybrid model. An examination of these models reveals that the fundamental difference between them is the hypothesis concerning the mixing of the configurations state excited in successive nucleon-nucleon interactions. The interaction mixing configurations does not appear in either of the models. However, in the exciton model, in which complete mixing is assumed, it is implicit in the hypothesis of the model. The hybrid model, on the other hand, simply ignores this interaction and assumes that no mixing occurs. We have developed a microscopic model that explicitly includes the mixing of configurations that leads to equilibrium. This model permits the modelling of both the complete and no mixing cases as well as the intermediate physical one. We compare the Monte Carlo model, in form and results, with the exciton and the hybrid models, to analyze the limits of each and the validity of the equilibrium hypothesis.

NR - 3 – Fragmentation measurements with Ca and Ni isotopes

Mocko, M.,[1] Tsang, M. B.,[1] Famiano, M.,[1] Delaunay, F.,[1] Ginter, T.,[1] Goethem, M-J van,[1] Hui, H.,[1] Knaub, A.,[1] Lynch, W. G.,[1] Oostdyk, D.,[1] Steiner, M.,[1] Stolz, A.,[1] Tarasov, O.,[1] Verde, G.,[1] Wallace, M.,[1] Zalessov, A.,[1] Friedman, W. A.,[2] Andronenko, L.,[3] Andronenko, M.,[3] and Ono, A.[4]

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Projectile fragmentation is used extensively to produce rare isotopes at many radioactive isotope facilities such as the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University. Thus understanding the mechanisms behind the production of rare isotopes using neutron-rich beams is important for the operation of many current facilities such as NSCL, GSI, RIKEN, GANIL as well as future facilities like the Rare Isotope Accelerator, RIA.

We have studied the fragmentation yield dependence on the asymmetry of the primary beam and targets ^{40,48}Ca and ^{58,64}Ni beams were produced by the K500-K1200 Coupled-Cyclotron Facility at the NSCL. The fragments produced from collisions with ^{9}Be and ^{181}Ta targets were identified in the A1900 mass separator. The cross sections of about 200 isotopes have been measured for the projectile fragmentation of ^{48}Ca and ^{58,64}Ni beams. For ^{40}Ca beams, the cross-sections of about 100 isotopes were measured. The experimental cross-sections will be compared to EPAX2, a phenomenological parameterization of the fragment cross-sections used in most facilities to predict rates of secondary beams as well as more realistic models such as the abrasion-ablation models to extract excitation energy of the collision systems. Results from dynamical calculations will also be discussed.

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NR - 4 – Isomer and Ground State Partial Cross Sections in $^{90}Zr(\gamma,n)^{89}Zr$ Reactions from Threshold to 22 MeV

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The partial cross sections that populate the isomeric and ground state in $^{90}Zr(\gamma,n)^{89}Zr$ reactions has been measured from threshold (12.5 MeV) to 22 MeV. The reactions were induced by a tunable high-energy bremsstrahlung beam with an endpoint energy resolution of 250 keV. The yield of the isomer and ground state were measured using standard

gamma-ray spectroscopy techniques and the partial cross sections were de-convoluted from these yields using the method of Penfold and Leiss. We find that near threshold to 15 MeV, these partial cross sections are heavily influenced by the nuclear structure and spin distributions of the continuum states in parent and daughter nuclei. These results are in contrast with previous measurements that have not observed the strong influence of nuclear structure. Furthermore, these measured cross sections agree with detailed theoretical cross section calculations.

NR - 5 – Gamma Rays Produced by Muon Capture on Al, Si, Ca, I, Au, and Bi.

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We have extended our earlier study of gamma-rays produced in muon capture on ^{14}N [1] to a variety of other nuclei, including Al, Si, Ca, I, Au, and Bi. The new data are far superior to existing measurements. Muon capture complements the (n,p) and (d,2p) reactions. In the lighter elements the direct transitions are clearly distinguished, but in the heavier elements, only break-up reactions are identified in which one or two neutrons are emitted. We follow our recent review [2] and compare these results to other reactions, especially photoproton studies. [1]. T.J. Stocki et al., Nucl. Phys. A697, 55 (2002). [2]. D.F. Measday, Physics Reports 354, 243 (2001).

NR - 6 – Two-particle interferometry to study emission time sequence and isospin dependence in excited nuclear matter

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Two-particle interferometry with protons, neutrons and light particles, has been used for about 20 years as a probe for the space-time extent of emission sources created in heavy-ion collision. In the intermediate energy domain, particles are emitted from equilibrated nuclear systems, with long emission times, as well as in non-equilibrium processes, that proceed on much shorter timescales. Several experimental constraints (e.g. cuts in energy and momentum, impact parameter, relative direction of emission) are introduced in the correlation functions to disentangle the different origins of emission. This allows to determine the characteristics of the equilibrium sources and to get some insight on the collision dynamics.
A recent development in the interferometry technique, has been to use correlations of non-identical particles to obtain model-independent information about the time sequence of particle emission. The order of emission of different particles is sensitive to the details of the reaction mechanism, and may even be used to extract information on some aspects of the nuclear equation of state, such as the density dependence of the nuclear symmetry energy. Experimental emission time sequence of neutrons, protons, deuterons and tritons have been measured in two different reactions (E/A=45 MeV ^{58}Ni+^{27}Al and E/A=61 MeV ^{36}Ar+^{27}Al), by comparing correlation functions with selection on the particle energy.
Finally, two-particle correlation functions have turned out to be sensitive probes for the isospin dependence of the nuclear Equation of State, which is needed to study not only nuclear structure and nucleosynthesis, but also to extrapolate this knowledge to astrophysical objects, such as neutron stars. A measurement of the isospin dependence of two-particle interferometry was performed at the Argos Cyclotron (KVI, Groeningen), in the reactions E/A=61 MeV ^{36}Ar+^{112,124}Sn. The detector setup consisted of 36 liquid scintillator cells for neutron detection, 16 CsI(Tl) crystals, for light charged particles, and a forward wall of 32 phoswich modules for selection of the collision centrality.
In this talk, we will present the experimental apparatus used in recent measurements of particle interferometry, and discuss the results on the emission time sequence and on the isospin dependence of the correlation functions.

NR - 7 – Incoherent π^0 photoproduction at intermediate and high energies (∼6 GeV)

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The nuclear matter effects in meson photoproduction from nuclei are addressed in detail using a sophisticated Monte Carlo intranuclear cascade calculation[1]. The incoherent contribution, where the incident photon interacts directly with a single nucleon and brings the nucleus to an excited state, is of special theoretical interest mainly because the related amplitudes simply add and the nuclear background is precisely calculated. Moreover, the elementary photoproduction operators can be described using straightforward standard techniques, such as the Regge model analysis proposed elsewhere[2]. In this work, we report a full dynamical calculation[1], based on a time dependent multicollisional cascade framework[3−4], to describe the incoherent π^0 photoproduction near the $\Delta(1232)$ resonance and at high energies ($4.0 \leq E_\gamma \leq 6.0$) GeV and forward angles. While the former reproduces some intriguing results recently obtained by the MAMI Collaboration[5] for the π^0 angular distributions for ^{12}C and ^{208}Pb, the later propitiates a clean and powerful method to separate nuclear backgrounds in various experiments, such as the PrimEx Collaboration at the Jefferson Laboratory[6]. The transport of the mesons thru the nuclear matter takes into account the most relevant branching ratios of the total πN scattering, also including: i) appropriate momentum distributions for the nucleons, ii) the dynamics of the photoproduction vertex $\gamma N \pi^0$, iii) Pauli-blocking effects for small momentum transfers and iv) $\pi - N$ final state interactions via a state-of-the-art analysis of a time sequenced multiple scattering scenario during the cascade stage.

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NR - 8 – Fusion and breakup reactions with weakly bound nuclei

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The strong coupling of the elastic channel with continuum states leads to serious difficulties in theoretical descriptions of collisions of weakly bound nuclei. The most effective theory to deal with this problem is the Continuum Discretized Coupled Channel (CDCC) method. However, this is quite complicated and requires powerful computer resources. Therefore, the development of other approaches is desirable. In this talk we discuss the use of a semiclassical coupled-channel approximation to evaluate the breakup and the fusion cross sections in collisions of these nuclei. We show that its predictions for the breakup cross section are rather close to those of the CDCC method. Calculations of the fusion cross section are also discussed in a schematic two-channel example. We conclude that reasonable results are obtained above the Coulomb barrier but the method cannot reproduce the enhancement at sub-barrier energies, obtained in corresponding quantum-mechanical calculations. To avoid this shortcoming, analytical continuation to complex time is included, leading to a better description of the fusion process at sub-barrier energies.

NR - 9 – Elastic scattering with weakly bound projectile: the ^{7}Li + ^{27}Al system

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Possible effects of the break-up channel on the elastic scattering threshold anomaly has been investigated. We used the weakly bound ^{7}Li nucleus, which is known to undergo break-up, as a projectile in order to study the elastic scattering on a ^{27}Al target. The measurements were performed using beams of ^{7}Li between 8 and 18 MeV at the TANDAR laboratory. In this contribution we present preliminary results of these experiments, which were analyzed in terms of the optical model and compared with other elastic scattering data using weakly bound nuclei as projectile.

NR - 10 – Fusion, reaction, and break-up cross sections for the systems $^9Be +^{27} Al$, $^{6,7}Li +^{27} Al$

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We present the results of total fusion cross sections measurements for the $^9Be +^{27} Al$, $^{6,7}Li +^{27} Al$ systems at energies above and below the Coulomb barrier ($0.8V_b \leq E \leq 2.0V_b$). Reaction cross sections for these systems were derived from elastic scattering data, and the sum of the cross sections for the break-up and transfer channels was estimated from the difference between reaction and total fusion cross sections. The experimental evidence at the measured energy regime show that the total fusion cross sections of ^{7}Li, ^{9}Be with a light mass target are not affected by the break-up process. The elastic break-up cross section seems to be important at energies near and above the barrier. The results for the $^{6}Li + ^{27}Al$ system are preliminary and the data are still being analyzed.

NR - 11 – Fusion hindrance and quasi-fission in heavy-ion induced reactions: disentangling the effect of different parameters

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The dynamics of heavy-ion fusion at energies around the Coulomb barrier is an open problem in the field of low energy nuclear physics. In particular, when the compound nucleus is heavy the quasi-fission reaction channel becomes increasingly important and may lead to a large hindrance for fusion, therefore affecting the probability of producing superheavy elements. Therefore, it is important to understand which are the main parameters playing a role in the onset of quasi-fission reactions.

In this framework, fusion-evaporation and fusion-fission cross sections have been measured in a large energy range for different entrance channels leading to the same ^{192,202}Pb*, ^{210}Rn* and ^{216}Ra* compound nuclei. Light (^{12}C, ^{16}O) and relatively heavier (^{34}S, ^{40,48}Ca) projectiles were chosen to bombard both spherical and deformed targets (^{144,154}Sm, ^{168}Er, ^{176}Yb, ^{194}Pt). The comparison of reduced evaporation data for the same compound nuclei put in evidence a fusion hindrance effect in reactions induced by heavier projectiles with respect to light beams. Such fusion hindrance is consistent with a noticeable contribution coming from quasi-fission events observed in the mass-energy distribution of fission fragments. The anisostropy in angular distrtibutions of fission fragments confirmed the pre-equilibrium character of the mechanism involved.

The role of mass asymmetry, nuclear deformation and shell effects on the onset of the quasi-fission mechanism will be discussed.

NR - 12 – Prompt dipole γ-ray emission: a new cooling mechanism in fusion heavy-ion reactions

Pierroutsakou, D. on behalf of the EXOTIC and MEDEA collaborations[1]

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The prompt dipole γ-ray emission is associated with the charge equilibration process occuring in dissipative heavy-ion collisions between partners with different N/Z ratios. Therefore, it takes place in charge asymmetric collisions in addition to the statistical γ-ray emission, originating in the thermal excitation of the dipole vibration in hot compound nuclei. It was predicted in fusion reactions that the prompt dipole γ-ray emission depends on the incident energy, taking a maximum value in an appropriate energy region, situated between the low incident energies near the Coulomb barrier and the higher ones near the Fermi energy domain, where the dipole emission diminishes. As this kind of dipole emission is a cooling mechanism of the composite system in fusion reactions, becoming comparable with the statistical emission under certain conditions, the study of its dependence on incident energy could be of great aid in the formation of superheavy elements. This argument becomes more interesting, when associated with the availability of exotic beams, which allow to reach very large entrance channel charge asymmetries, maximizing thus, the prompt dipole γ-ray emission.

In the present talk, we will present an overview of the existing data (1–6) concerning this kind of dipole emission in peripheral and fusion collisions and we will focus on its evolution with incident energy. Results of new measurements will be reported, where the prompt dipole γ-ray emission is studied as a function of incident energy in fusion reactions. In these experiments, carried out at various incident energies, the same compound nucleus was formed through different charge asymmetry entrance channels. Furthermore, calculations based on a collective bremsstrahlung analysis of the reaction dynamics will be discussed and compared with the experimental findings.

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NR - 13 – The interaction of ^{12}C and ^{16}O with medium-heavy nuclei

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The results of a series of experiments on the interaction of ^{12}C and ^{16}O with medium and heavy nuclei (^{59}Co, ^{93}Nb, ^{103}Rh, ^{197}Au), in which the spectra of intermediate mass fragments and the excitation functions for production of a large number of evaporation residues have been measured up to 400 MeV incident energy, are reviewed. The scope of these experiments was to get a comprehensive information on the reactions which may occur and to develop a model which might reproduce all the measured data within a unique global calculation. This was indeed found to be possible considering the complete fusion of the two interacting ions, the binary fragmentation of the projectile followed by the fusion of one of the fragments with the target nucleus, and the projectile inelastic scattering. The main results of these investigation was that (a) ^{12}C and ^{16}O may fragment in many different ways including essentially the production of any possible charged fragment, (b) before fragmentation they may suffer a considerable energy loss, (c) in addition to fragments produced by projectile fragmentation one observes a considerable emission of low energy intermediate mass fragments produced by nucleon coalescence during nuclear thermalization, the process through which the nuclei produced in complete and incomplete fusion reach a state of thermal equilibrium. The theoretical models which allow to reproduce the data, i.e., the fragmentation model and the Boltzmann Master Equation theory which describes nuclear thermalization are briefly summarized together with the global set of parameters used.

NR - 14 – Quasi-elastic barrier distribution in light systems.

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The treatment of heavy-ion reactions as coupling between the relative movement and other degrees of freedom of the system, in a context of a coupled reaction channels, leads to the idea that a distribution of fusion barriers can be generated by those couplings.

After the elaboration of a method that permits to extract that distribution from the experimental data, the concept of barrier distribution became very useful for the understanding of the reaction mechanisms that enhance the fusion cross section of heavy systems at energies below the Coulomb barrier. The barrier distribution can be obtained by two complementary ways: from the fusion excitation function, or from the quasi-elastic excitation function measured at backward angles. Arguments of conservation of flow suggest that these two representations should carry the same information, and this is confirmed by the available experimental data. However, up to now those studies were mainly restricted to heavy systems, because it was believed that light systems would have very narrow distributions which would not evidence the couplings between the reaction channels. This work will show that the recente experimental results indicate the opposite of this. The quasi-elastic barrier distributions of systems like $^{16,17,18}O +^{58} Ni,^{63} Cu,^{64} Zn$ have very characteristic shapes, which allowed us to put in evidence the most important reaction channels in each of them. It will be also discussed the use of this method for understanding the influence of the break-up on the fusion of weakly bound systems.

NR - 15 – Production Rates of Neutron-Rich Nuclei Near the Fluorine Drip-line

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The limits to the existence of nuclei is one of the major interests in nuclear physics. Since the discovery of ^{31}F and the demonstration of nonexistence of ^{24}O through ^{28}O, there has been a renewed focus on this region of the chart of nuclides. The only method that can produce these exotic nuclei is projectile fragmentation. We performed a series of measurement of production cross sections in order to investigate the influence of the N/Z ratio of target on the production yields of these nuclei and performed a search for ^{31}F. An ^{40}Ar beam, accelerated to 140 MeV/nucleon in the coupled cyclotrons at the NSCL, was fragmented in targets of Be, Ni, and Ta. The measured cross-sections were then used to determine the best target to use with 140 MeV/nucleon ^{48}Ca to investigate the heavy Fluorine nuclei. We confirmed the existence of ^{31}F. The measured reaction yields from the four reactions will be presented and compared with theory. This work was supported by the NSF under the grant PHY-01-10523.

NR - 16 – Recent results obtained with the RIBRAS - Radioacive Ion Beam facility.

Lépine-Szily, A.,[1] Lichtenthäler, R.,[1] Guimaraes, V.,[1] Benjamim, E. A.,[1] Faria, P.N. de,[1] Gomes, P.R.S.,[2] Arazi, A.,[3] Padrón, I.,[4] Denke, R.Z.,[1] Pires, K.C.C.,[1] Mendes, D.R.,[1] Camargo Jr., O.,[1] Alcantara Nuñez, J.A.,[1] Meira, M. P.,[1] and Barioni, A.[1]

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The RIBRAS (Radioactive Ion Beam Brasil) facility, consisting of two superconducting solenoids of 6 T, was installed next to the Pelletron Accelerator of the Open Laboratory of Nuclear Physics in the Institute of Physics of the University of São Paulo. The Pelletron Accelerator provides the primary beam, which impinges on a production target, producing nuclear reactions. The transfer reactions present a forward angle focalization and can lead to radioactive ejectiles as ^{6}He, ^{7}Be, ^{8}Li, ^{8}B etc. The solenoids are used to focalize and select the radioactive secondary beams. We have already produced secondary beams of ^{6}He, ^{7}Be, ^{8}Li using ^{6,7}Li primary beams and ^{9}Be, ^{3}He production targets.
The research program includes secondary nuclear reactions induced by radioactive beams on secondary targets. The low-energy, low-mass radioactive beams have a special interest for the study of nuclear reactions of astrophysical interest. The radioactive ions with half-lives of hundreds of milliseconds do not exist on Earth, but can be continuously produced in high-temperature and high-density environments in the Universe. Their influence in the primordial nucleosynthesis following the Big Bang, or in the actual stellar nucleosynthesis depends on the reaction rates involving these nuclei.
The first experiments performed with radioactive beams are of elastic scattering of ^{6}He, ^{7}Be, ^{8}Li beams on targets of ^{27}Al, ^{51}V and ^{197}Au. Results of the experiments will be presented and discussed.

NR - 17 – Nuclei in Cosmic Rays - Results from AMS01 and Potential of AMS02

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The Alpha Magnetic Spectrometer (AMS) on the International Space Station, scheduled for a three years flight starting in 2007, will be able to identify nuclei both in the earth's radiation belt and in primary cosmic rays. Charge determination allows searching for anti-nuclei. A ten days test flight (AMS01) in 1998 on the space shuttle Discovery (STS-91) in a 51.7° orbit at altitudes between 320 and 390 km yielded a vast amount of data on the fluxes of charged particles. The major detector elements of AMS01 were a permanent magnet with an analyzing power $B*L^2$ of 0.14 Tm^2, a six layer, double sided silicon tracker, time of flight hodoscopes, an aerogel threshold Cerenkov counter and anti-coincidence counters.
A total of 2.86×10^6 helium nuclei were observed in the rigidity range 1 to 140 GeV. No antihelium nuclei were detected at any rigidity. The upper limit on the flux ratio of antihelium to helium was determined as 1.1×10^{-6}. Below the geomagnetic cutoff a second helium spectrum is observed and more than 90% of the helium was identified as ^3He. A search for charge two anomalous nuclei was conducted, and one candidate event, which corresponds to a flux of $10^{-4}m^{-2}sr^{-1}sec^{-1}$, was found. The candidate has a Z/A ratio of 0.11 and a kinetic energy of 2.1 GeV. The estimated background from ordinary nuclei is one per mille.
For the forthcoming AMS02 flight, several major upgrades have been done, the most prominent being the replacement of the permanent by a superconducting magnet, the first of its kind to be used in space. This, together with the much longer data taking period, allows to greatly extend the sensitive region of the spectrometer. The addition of a transition radiation detector, a ring imaging Cerenkov counter and an electromagnetic calorimeter enables a diversification of the physics program of AMS02.

NR - 18 – Measurements of stellar nuclear-reaction rates by means of Accelerator Mass Spectrometry

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For charged-particle induced reactions occurring in astrophysical scenarios, projectile energies are usually well below the Coulomb barrier of the reacting system. Hence, extremely small cross section reaction pose a difficult task for laboratory measurements. Most commonly, these energy-dependent cross sections are studied by detecting the emitted prompt gamma rays following the de-excitation of the produced compound nucleus. In this work we present alternative methods for the measurement of the extremely small cross sections, based on the use of the Accelerator Mass Spectrometry (AMS) technique. These methods were applied to the measurement of the ^{25}Mg(p,γ)^{26}Al resonant reaction and the ^{12}Mg(p,γ)^{13}N non-resonant reaction.

Nuclear Physics Applications

NPA - 1 – Light ion interactions of concern for hadrontherapy

Cerutti, F.,[1,2] Ballarini, F.,[3] Battistoni, G.,[2] Colleoni, P.,[1,2] Ferrari, A.,[4] Förtsch, S.V.,[5] Gadioli, E.,[1,2] Garzelli,M.V.,[1] Mairani, A.,[3] Ottolenghi, A.,[3] Pinsky, L.S.,[6] and Sala, P.R.[2]

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There is an ever growing belief of the need of information on the nuclear reactions induced by heavy ions for their relevance in interdisciplinary and applicative fields. The data to be known for these purposes are the spectra of the particles and the intermediate mass fragments (IMFs) which may be produced and the yields and the spectra of the evaporation residues.

Reactions induced by light particles (Z $\leq$ 2) are rather accurately known both experimentally and theoretically. Present knowledge in the case of heavy ion reactions is much less systematic and essential experimental information is lacking even in the case of the reactions induced by ^{12}C ions which seem particularly interesting in view of their increasing use in cancer hadrontherapy.

To the reactions between such ions and light nuclei which have mass and charge not too different from those of the constituents of the biological tissue a large variety of different mechanisms contribute even at low energies, originating both from their fusion and their fragmentation. Our recent analysis of the IMFs produced in the C+Al system at 13 MeV/n, both in direct and inverse kinematics, supplied a satisfactory reproduction of the wealth of double differential spectra which we measured, enlightening about the leading reaction mechanisms. In fact, such study is relevant to allow a more realistic prediction of the space distribution of the physical and biological dose delivered by a therapeutic carbon beam in the Spread-Out Bragg Peak region.

NPA - 2 – A Tandem-ESQ for Accelerator-Based Boron Neutron Capture Therapy.

Kreiner, A.J.,[1,2] Kwan, J.W.,[3] Burlon, A.A.,[2,1] Henestroza, E.,[3] Minsky, D.,[1,2] Valda, A.A.,[1,2] Debray, M.E.,[1,2] and Somacal, H.[1,2]

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Boron Neutron Capture Therapy (BNCT) is considered by a significant international community as a promising option for the treatment of certain types of cancer [1]. The progress of BNCT will require neutron sources suitable for installation in a hospital environment. Low-energy particle accelerators are most appropriate for this purpose and can be constructed for modest cost. We report here on a project to develop a Tandem-ElectroStatic-Quadrupole (ESQ) accelerator for accelerator-based BNCT. The project goal is a machine capable of delivering 30 mA, 2.3 MeV protons to be used in conjunction with a neutron production target based on the $^7Li(p,n)^7Be$ reaction slightly beyond its resonance at 2.25 MeV. In order to make a decision as to the most appropriate accelerator for BNCT, different options have been evaluated, comprising d-d or d-t neutron generators, RFQs and electrostatic machines of various types. The technologically simplest and cheapest solution points to an electrostatic machine. Existing electrostatic accelerators, produce only a few mA of proton beam current limited by the column design. High beam current density, as implied by a size limited 30 mA proton beam, needs strong focusing in the transverse plane. In this regard ESQs are much stronger than the aperture lens used in conventional Tandem accelerators. An ESQ column can be designed using a lower field stress than a Pierce column in multi-MeV beam energy applications [2]. Strong transverse fields will also suppress secondary electrons sideways through the electrodes hence preventing induced X-rays and electrical breakdown. In the present work a compact combination of an ESQ column with a Tandem in a folded geometry is discussed. This option would allow the ion source to be operated at ground potential and would require a voltage of 1.15 MV to reach the desired 2.3 MeV proton energy. On the other hand such a machine requires an H- ion source and the transport of a high intensity beam through a gas stripper. Furthermore, if a lower voltage solution is needed (at the expense of higher current), extensive simulations and safety considerations have shown that up to 1 MeV the d-d reaction (on a TiD_2 target)

is best and that at 1.1 MeV the $^9Be(d,n)$ reaction takes over. At somewhat higher energies still, the $^{13}C(d,n)$ comes into play. In this energy regime the accelerator could be a single-ended ESQ column operating with a multicusp positive ion source.

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NPA - 3 – Nuclear Physics Issues in Space Radiation Risk Assessment - The FLUKA Monte Carlo Transport Code Used for Space Radiation Measurement and Protection

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The long term human exploration goals that NASA has embraced, requires the need to understand the primary radiation and secondary particle production under a variety of environmental conditions. In order to perform accurate transport simulations for the incident particles found in the space environment, accurate nucleus-nucleus inelastic event generators are needed, and NASA is funding their development. For the first time, NASA is including the radiation problem into the design of the next manned exploration vehicle. The NASA-funded FLUER-S (FLUKA Executing Under ROOT-Space) project has several goals beyond the improvement of the internal nuclear physics simulations. These include making FLUKA more user-friendly. Several tools have been developed to simplify the use of FLUKA without compromising its accuracy or versatility. Among these tools are a general source input, ability of distributive computing, simplification of geometry input, geometry and event visualization, and standard FLUKA scoring output analysis using a ROOT GUI. In addition to describing these tools we will show how they have been used for space radiation environment data analysis in MARIE, IVCPDS, and EVCPDS. Similar analyses can be performed for future radiation measurement detectors before they are deployed in order to optimize their design. These tools can also be used in the design of nuclear-based power systems on manned exploration vehicles and planetary surfaces. In addition to these space applications, the simulations are being used to support accelerator based experiments like the cross-section measurements being performed at HIMAC and NSRL at BNL.

NPA - 4 – Development of a tomographic system for online dose measurements in BNCT (Boron Neutron Capture Therapy)

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Within our activities on accelerator-based boron neutron capture therapy (BNCT) carried out at the Tandar Laboratory (Comisión Nacional de Energía Atómica, Argentina) we present here the study and design of a tomographic imaging system for the measurement of the spatial distribution of the absorbed dose during a BNCT session.

Boron neutron capture therapy (BNCT) is a radiation therapy under development for the treatment of some cancers like melanoma and glioblastoma multiforme. It is performed in two steps: first, a stable isotope of boron (^{10}B) is administered to the patient via a carrier drug and then the patient is irradiated with an epithermal neutron beam. ^{10}B can then undergo the capture reaction ^{10}B$(n,\alpha)^{7}$Li (^{10}B capture cross section for thermal neutrons: 3840 b). The emitted charged particles (~ 1 MeV) have a high linear energy transfer (LET) and are lethal only to the cells in close proximity to the reaction point because their range is $\sim 10\mu m$. The ^{10}B$(n,\alpha)^{7}$Li boron neutron capture reaction produces a 478 keV gamma ray in 94% of the cases. In BNCT a large fraction of this radiation escapes from the patient body. Its detection is thus very attractive for a noninvasive boron concentration measurement and an online absorbed dose evaluation since the absorbed dose to the tumor cells and healthy tissues strongly depends on the boron uptake and the neutron flux. For this purpose we have proposed, a dedicated tomographic imaging system based on SPECT (Single Photon Emission Computed Tomography, a diagnostic medical imaging modality used in nuclear medicine) since standard SPECT cameras cannot be used due to the photon energy (478 keV) and the particular background gamma field in BNCT. Monte Carlo numerical simulations have been used for an implementation of a statistical algorithm for the tomographic image reconstruction.

In the present work we study by means of Monte Carlo numerical simulations the effects of the limited number of counts, i. e. the statistical noise, and the finite spatial resolution on the reconstructed image contrast of numerical phantoms. These phantoms, of simple geometry, mimic the tumor (specific) and the normal tissue (non specific) boron concentrations. The simulated projection data are reconstructed using the expectation-maximization maximum-likelihood algorithm on a 2D image size of 21 × 21 voxels of 1 cm × 1 cm.

NPA - 5 – Geant4 Simulation of a Fiber Based Scintillating Detector for Brachytherapy Treatment (GESIB)

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Uniformity of radioactive sources is vital in delivering accurate doses in brachytherapy. To determine source uniformity, a fiber based scintillating beta detector was developed at the Center for Advanced Medical Instrumentation (CAMI) at Hampton University. To understand and optimize the capabilities of the beta detector, a Geant4 Monte Carlo simulation of the detector system was developed. It consisted of 32 scintillating fibers with cross sections of 1mm2, coupled to two Hamamastsu (H6568) photomultiplier tube for photon to current conversion. The fibers consisted of a polystyrene based core and polymethylmetharcrylate (PMMA) cladding. The brachytherapy sources (90Sr/90Y and 32P) were simulated using the General Particle Source (GPS), and sandwiched between the fibers. Uniform and non-uniform sources were simulated and compared.

NPA - 6 – Space Applications of the FLUKA Monte-Carlo Code: Lunar and Planetary Exploration

Wilson, T.L.,[1] Zapp, N.,[1] Empl,A.,[2] Pinsky, L.S.,[2] Battistoni, G.,[3] Campanella, M.,[3] Cerutti, F.,[3] Gadioli, E.,[3] Garzelli,M.V.,[3] Muraro, S.,[3] Rancati, T.,[3] Sala, P.R.,[3] Ballarini,F.,[4] Ottolenghi, A.,[4] Scannicchio, D.,[4] Fasso,A.,[5] Ferrari, A.,[6] Roesler,S.,[6] Vlachoudis, V.,[6] Ranft, J.,[7] Carboni,M.,[8] and Pelliccioni, M.[8]

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The Monte Carlo transport code known as FLUKA is used in a number of fundamental research applications, varying from elementary particle physics to nuclear physics, cosmic-ray astrophysics, and radiation biology. The validity of its physical models has been benchmarked against a variety of experimental circumstances such as particle accelerator data and cosmic-ray air showers in the Earth´s atmosphere, covering a considerable range of energies. In a parallel development aimed at improving the heavy-ion collision physics in Monte Carlo simulations, NASA has recognized the need for making additional heavy-ion collision measurements at the U.S. Brookhaven National Laboratory in order to support further improvement of several transport-code models for space exploration applications. FLUKA has been identified as one of the codes that merit further enhancement in support of robotic and human planetary exploration programs that have the goal of reaching the Moon, Mars, and beyond. Our collaboration will discuss current NASA-funded developments and present some of the applications that a simulation tool such as FLUKA provides. Applications include the particle albedos produced in simulations of the primary particle radiation and secondary particle production by relativistic nuclei during heavy-ion collisions of cosmic rays with the planetary surface. The neutron albedo for nuclear-based power systems on the Moon will be given as an example.

NPA - 7 – Direct contributions of nuclear science to society: an experience in Latin America

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In the Latin-American region nuclear science played increasingly important role during the past decades in several fields. In spite of early involvement in nuclear science and several attempt to promote an industry, Venezuela never become a nuclear one although radiation application spread from oil-business to medical therapy with high energy accelerator beam. At one time more than 220 industrial and commercial firms including several research centres and universities were involved in nuclear applications. Interesting initiatives was the PET-cyclotron project that introduced a nuclear tool to improve radiation diagnosis and education. Nuclear technology certainly is one of the most fertile when application in different fields such as medicine, environmental and most recently astronautical dosimetry or fluid dynamic's parameters are sought. During the past decade several project developed in our Laboratory allowed to accumulate an important experience mainly in nuclear analytical techniques and industrial applied fields. We would resume the most significant achievements with emphasis of interesting results reached in our nuclear facility. Conclusions will be drawn to extrapolate a direct contribution of nuclear science to our society.

NPA - 8 – A novel technique to estimate the track dimensions induced by heavy ions on UHMWPE.

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When a heavy ion penetrates a polymer film it induces a dense trail of excited and ionized molecules. The large amount of energy deposited in a very short time is mainly dissipated by electrons which are emitted essentially perpendicular to the ion direction, producing a damage zone around the ion path, the so-called latent tracks. This cylindrical region can be divided in two different areas, a inner core, in which considerable part of the ion energy loss is deposited, and a outer zone called penumbra, affected by electrons (delta rays) with enough energy to leave the core. The diameter of each zone depends on the ion type and its energy. In the present work we studied the physico-chemical modifications generated by the heavy ions as a function of the ion fluence. The medical grade UHMWPE, Ultra High Molecular Weight Polyethylene, (GUR 1050) used in this study was kindly supplied by Poly Hi Solidur (Germany). The polymeric material was cut in thin foils of approximately 20-30 mm thickness and then irradiated with different ions and energies, provided by the TANDAR accelerator. The analysis of the structural changes originated by the irradiation was performed by means of Fourier transform infrared (FTIR) spectroscopy in the transmission mode. To study the relationship between the irradiation fluence and the induced changes, Monte Carlo simulations were performed. It is assumed that the observed absorbance is proportional to the penumbra area without taken into account the carbonized central core area. The algorithm implemented as a Fortran program consists on randomly distribute, on a rectangular lattice, overlapping discs of radius R1, that represents the penumbra zone, filled with a second concentric disc of radius $R2 < R1$, that denotes the core zone. For each simulated fluence the total penumbra zone area was calculated. The simulation results reproduce the behavior of the experimental data The penumbra zone area reaches a maximum for a fluence that depends on the radii of both zones and the slope of the decreasing region of the curve is determined by the core radius. Finally, from the absorbance measurement as a function of the ion fluence, it is possible to obtain both the penumbra and core radii. The general characteristic of the present new technique is discussed, as well as the comparison with other methods, such as dechanneling, forward X-ray scattering and small-angle neutron scattering.

NPA - 9 – Multielemental Composition Determination of Human Amniotic Fluid

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Nuclear elastic scattering at forward angles can be used to carry out multielemental analysis of liquid samples of scientific and technological interest. A simultaneous quantification of elements lighter than silicon is possible. Experimental conditions such as ion beam type, bombarding energy and detection angles giving the best mass separation have been established. Tests of the method have been carried out by bombarding evaporated human amniotic fluid (AF) samples with 13 MeV 6,7Li3+ beams. The dilution of the AF with distilled water reduces the AF target thickness and improves the target homogeneity. The diluted sample is deposited on a very thin formvar backing and dried naturally. First C and O concentration values in AF have been obtained recently. The content of C and O present in the backing was subtracted. Further experimental work is required in order to establish how the concentrations of different elements contained in an AF sample are affected by the dilution and drying processes. Forward elastic scattering is a potential method for light trace element analysis.

NPA - 10 – Activities on bio-medical research by nuclear microscopy at iThemba LABS, Cape Town, South Africa

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In recent years applications of PIXE in the bio-medical field have opened important areas of research with a significant sensitivity to compete with techniques such as XRF, EDXRF, EMP and/or SEM. The micro-PIXE technique is used to investigate the elemental composition of human tissues on a microscopic scale. In addition, complementary ion beam techniques such as Rutherford backscattering and proton induced gamma-ray emmision are used to provide information on the major and minor components. This paper will deal with an overview of bio-medical projects at iThemba LABS particularly in relation to the spatial distribution of trace metals in hard human tissues such as kidney stone concretions, teeth, hydroxyapatite (HAP) coatings and hair, undertaken at the Nuclear Microprobe (NMP) facility at iThemba LABS. Relevant information about ion beam techniques used for material characterization will be discussed. Mapping correlation between different trace metals to extract information related to micro-regions composition will be illustrated with several examples using proton energies of 1.5 and 3.0 MeV and applied to: 1) Teeth erosion mechanisms; 2) Human kidney stone concretions nucleation region analysis; 3) Quality assurance on the manufacturing of bioconductive coatings on Ti implants; 4) Mapping of human hair cross sections from two different population groups; and 5) Trace elements variability in the developing rat pancreas in response to a high fat diet (HFD). In adition examples of analysis of nano-materials which may be relevant to medical applications will be highlighted.

NPA - 11 – Use of neutrons for the detection of explosives in Civil Security applications

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The threat of terrorist actions against civil populations has become one of the most important issues on the political agenda of European Union [1]. In this respect, the contrast of illicit trafficking of explosive materials is one of the aspects of the problem. Currently used X-ray or gamma-ray based systems provide precision density measurements with high-resolution three-dimensional images, but only limited information on the elemental content of the inspected item. Fast neutron interrogation, on the contrary, offers the possibility of measuring the elemental density of the elements contained in explosive materials [2,3,4]. Furthermore with the use of 14 MeV neutrons tagged by using the well known associated particle technique it is possible to determine the local elemental distribution inside large volume, or to inspect a precise portion of the volume (voxel) that has been identified as suspect in previous X-ray inspection. In this case it is possible to implement the already existing X-ray scanner with an additional neutron tool that is used as verification system. During the last years, we have developed a prototype of Tagged Neutron Inspection System (TNIS) using fan beams of 14 MeV neutrons, produced by the D+T reaction [5-7]. Tests on the detection of hidden explosives with TNIS have been published recently [7]. New developments are now underway within the NATO Science for Peace program and the EURITRACK (EURopean Illicit Trafficking Countermeasures Kit) Project that has been also recently approved in the 6th Framework Program of the European Union. The TNIS system will be presented and its use in cargo container inspection at seeports discussed.

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NPA - 12 – Radiometric analysis of Quaternary coastal deposits of the Brazilian Southeast

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The formation of sedimentary strata is associated with the breakdown of source rocks, followed by the transport of the terrigenous matter, its re-disposition and sedimentation. Therefore, beach sands are weathering-resistant remainders of geological formations. Consequently, mineralogical properties of beach sand reflect the geological history of the original rock formations. The primordial radionuclides ^{40}K and the decay products of the ^{238}U and ^{232}Th series, present in the formation of igneous rocks, can be detected by γ-ray spectroscopy in sediment samples.

In the parent materials for silici-clastic sediments, most of uranium and thorium atoms are bound in accessory and dark-colored minerals, which possess higher specific weight than the rock-formation minerals. Consequently, the transport of minerals is affected by gravitational separation, and uranium and thorium are thus enriched or depleted in individual places. On the other hand, uranium tends to be highly mobile near the surface whereas thorium is relatively stable. Potassium γ-ray activity of sands having the same origin (parent rock) should be equal, regardless of their mineralogical composition. Such behaviors make it possible to use concentration of Th, U and K as well as its ratios Th/U and Th/K as markers in the study of origin and transport of sediments.

In this way, beach sands were collected in an extensive selection of places in the Brazilian coast, in order to determine its concentration of natural radionuclides. The sand samples were analyzed at the Radioecology Laboratory of Universidade Federal Fluminense, by using HPGe and NaI γ-ray spectrometers.

Radiometric analysis of Quaternary coastal deposits of the Brazilian Southeast showed that strandplains of Rio de Janeiro [RJ] and Espírito Santo [ES] States have heavy mineral deposits, each one with specific features for their heavy-mineral concentrations. For instance, Guarapari (ES) deposits have monazite enrichment above Buena (RJ), Serra (ES) or São Mateus (ES) deposits. Particularly, it was discovered the existence of a deposit in Mambucada (RJ), which source of heavy minerals is possibly on marine placers of this site. The results obtained in this work also confirm the main features of the geological mapping of Quaternary coastal deposits, showing that the γ-ray technique can be used as a tool to understanding the origin and transport of sediments. Th/U ratios showed to be useful when used as proxy for the redox conditions of the depositional environment, since values of Th/U ratios are different in surface and deep water. Thus, the low values observed in strandplain of south Rio de Janeiro State may be associated with marine condensed sequences.

NPA - 13 – Searching the Pyramid of the Sun in Teotihuacan, Using Muon Absorption

Alfaro, R.,[1] Belmont-Moreno, E.,[1] Cervantes, A.,[1] Grabski, V.,[1] Lopez-Robles, J.M.,[1] Manzanilla, L.,[1] Martinez-Davalos, A.,[1] Moreno, M.,[1] and Menchaca-Rocha, A.[1]

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The search of hidden vaults in historical sites is one of the most exiting tasks in archaeology which has lead to surprising discoveries as much in Egypt (Giza) as in Mexico (Monte Albán and Palenque). This fascinating research is complicated in sites where excavation is not allowed and the penetrability of standard techniques, such as radar, is not sufficient. To tackle this problem, 40 years ago the Nobel Price Luis Alvarez proposed the use of modern cosmic ray detection technologies to carry out radiographic style measurements in the Great Pyramid of Chefren, in Egypt, eliminating speculations about undiscovered royal chambers, arisen from the similarity of Chefrén with its neighboring Pyramid of Cheops. Of course, these transmission measurements require the unusual existence of a tunnel running under the investigated monument. However, in Teotihuacan, Mexico, a tunnel located 8 meters under the Pyramid of the Sun (Teotihuacan) reaching near the center of its base, represents an extraordinary opportunity to carry out an Alvarez type experiment. As in Chefren, there is a long standing speculation about the possible existence of a ceremonial burial in the famous Mexican pyramid When the primary cosmic rays, which are mainly high energy protons (hydrogen nuclei), interact with the atmospheric particles, unstable particles denominated pions are created which rapidly decay, ultimately producing high energy muons. These are highly penetrating leptons able to cross the atmosphere and considerable thicknesses of dense material, like soil and rocks. Because of their electric charge, these muons loose energy continuously, also suffering small deviations from the original trajectories due to multiple interactions which become more important as the muon kinetic energy is reduced. These effects induce a measurable attenuation in the atmospheric muon flow which is related to the density of the traversed mass. Hence, the Alvarez technique uses simulation and measurement to search for places where the observed and the predicted muonic flow differ. If more muons than expected are observed in a given direction, that is an indication of less density than assumed in that direction, i.e., a possible cavity. Therefore, the muon detector required by this type of experiments should identify the muon and measure its traveling direction. The presentation includes a brief discussion of the detector design and the current status of the project. Special emphasis will be given to the general limitations of the method in order to define important experimental parameters, such as the minimum detectable cavity size.

NPA - 14 – Recent studies of GFAA (Group for Applied Physics with Accelerators)

Added, N.;,[1] Rizzutto, M.A.,[1] Tabacniks, M.H.,[2] Curado, J.F.,[1] and Barbosa, M.D.L.[2]

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Different research themes are being supported by GFAA of the University of São Paulo, during the past few years, using several ion beam techniques and accelerators. We will present and discuss some of the main results to give an overview of some typical studies being accomplished. We will also show the importance of interdisciplinary work establishing the access to powerful physical analytical methods for other scientific research areas. Ion beam analytical methods are making a dramatic difference in dentistry research, like studying surface effects on teeth enamel by the use of clarifying products and processes. Ion beam methods also helped chemists and archaeologists in the investigation on the corrosion of ancient metallic statuettes or in the identification of chemical elements in inks used in antique paintings. Though important, the connection between these highly sensitive physical analytical tools and the non-physical scientists is not always easy, neither is it seamless, since the respective investigation methods and concepts and can vary immensely.

NPA - 15 – Design, Modeling and Simulations in the RACE Project: First study for the development of a transport line.

Maidana, C. O.,[1] Hunt, A. W.,[1] Beller, D.,[2] and Folkman, K.[2]

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As part of the Reactor Accelerator Coupling Experiment (RACE) different studies are being conducted for the design of a transport beam line that could bring a 25 MeV electron beam from a Linear Accelerator to a neutron-producing target for a nuclear reactor subcritical system. Because of the relatively low energy beam, the beam size and a relatively long beam line (implicating a possible divergence problem) different parameters and models must be studied before a final design could be submitted for assembly. This report shows the results obtained from different simulations for different lattices of the transport line optics and dynamics.

NPA - 16 – Measurement of neutron capture cross-sections at n_TOF (CERN), and their implications to Astrophysics and ADS

Tagliente, G. and the n_TOF Collaboration[1]

[1]Istituto Nazionale Fisica Nucleare, Sezione di Bari

New ideas and developments in Nuclear Technology have recently raised the practical need for high-accuracy neutron data. In particular, requests exist for experimentally determined capture, fission and (n,xn) cross-sections on several radioactive isotopes, mainly actinides and long-lived fission frangments, aimed specifically at the design and understanding of the behaviour of innovative Accelerator Driven Systems (ADS) for energy production and nuclear waste incineration. Furthermore, advances in laboratory measurements of neutron cross-sections are required for improving the understanding of neutron capture nucleosynthesis in evolved stars and supernova explosions. Finally, new access to fundamental information on nuclear matter can be provided by additional data on neutron-induced reactions.
An innovative neutron Time-of-Flight facility (n_TOF) operative since a few years at CERN is particularly suited for measurements relevant to Nuclear Technology, Nuclear Astrophysics, and fundamental Nuclear Physics. Neutrons in the wide energy range, 1 eV - 250 MeV, are generated by spallation of 20 GeV/c protons on a lead target. The high instantaneous neutron flux, low duty cycle, high resolution and low background make this facility unique for cross-section measurements and particularly suited for measurements of radioactive isotopes, such as those relevant to projects of nuclear waste incineration, or involved in s-process branching points.
Starting in 2002, a vast experimental program has been carried out by the n_TOF collaboration, on capture reactions. Measurements have been performed on isotopes involved in the Th-cycle (^{232}Th, ^{233,234,236}U), on long-lived fission fragments and s-process branching (^{151}Sm, ^{93}Zr) and on minor actinides that constitute the high-level nuclear waste (^{237}Np, ^{240}Pu, ^{243}Am). Finally, a large effort has been devoted to the measurement of capture cross-sections for isotopes related to structural material in ADS, and that are important as well for improving the knowledge of the galactic chemical evolution (^{90,91,92,94,96}Zr, ^{204,206,207,208}Pb, ^{209}Bi, ^{24,25,26}Mg).
In this talk, the n_TOF facility will be briefly described, together with the main features of the detectors used for capture cross-section measurements. An overview of the results will be given, with emphasis on the results of measurements on Zr, Sm and La isotopes. The implications of the results in ADS and Nuclear Astrophysics will be discussed.
This work is supported by the European Commission under the contract n. FIKW-CT-2000-00107.

NPA - 17 – Charge-state distribution and spurious ionic charge states in a tandem accelerator

Negri, A.E.,[1] Arazi, A.,[1] Capurro, O.A,[1] De Barbará, E.,[1] Fernández Niello, J.O.,[1] Figueiras, J.M.,[1] Martí, G.V,[1] Pacheco,A.J.,[1] and Testoni, J.E.[1]

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The charge-exchange processes between energetic ions and material media, such as foils or gas cells, is of great interest both for understanding the atomic properties involved in these collisions and for the design and operation of facilities like tandem accelerators in which the charge-state distribution at the stripper must be known [1-4]. In particular, the performance of beam transport systems depends on the space-charge fields which affect the focusing and commonly used AMS detection systems, such as a gas-filled magnet [5], are also based on charge-exchange processes.

In our work we measured the charge state distribution of ^{127}I ions accelerated to a 8 MV terminal voltage at the TANDAR Laboratory in Buenos Aires. Most probable charge states ($4 \leq q \leq 14$) could be measured directly with a Faraday cup. Intermediate abundant states ($11 \leq q \leq 19$) were measured in an $E-\Delta E$ detector after an elastic scattering in a gold target as an attenuation method. Finally, very rare charge states ($q \geq 19$) were examined with the $E-\Delta E$ detector at $\theta = 0°$ without any attenuation.

Apart from the tuned charge state, the obtained $E - \Delta E$ spectra show spurious (lower) charge states which are originated by multiple electron-loss collisions of accelerating ions and molecules of the residual gas in the high-energy section of the accelerator tube. Depending on the position at which the charge exchange takes place, these new charge states can achieve the necessary energy to be accepted by the analyzing magnet and to reach the detection system.

We quantitavely analyzed the ratio between spurious and tuned charge states and we compared these results with calculations which takes in account the accelerator characteristics and theoretical electron-loss cross sections. Estimates for both single and multiple electron-loss collisions [6,7] are generally based on a binary-encounter approximation for a ground-state hydrogenic electron scattered by an incident proton, and scaling laws are given for other targets and projectiles. Multiple-ionization cross sections are calculated in terms of single-electron probabilities for each atomic shell assuming independency between electrons and shells [8].

[1] J.O. Fernández Niello et al., Nucl. Instr. and Meth. B 223-224 (2004) 242.

[2] K. Shima et al., Phys. Rev. A40, No. 7 (1989) 3557.

[3] Y. Boudinet-Robinet, Nucl. Instr. and Meth. 190 (1981) 197.

[4] M. Kiisk et al., Nucl. Instr. and Meth. A481 (2002) 1.

[5] M. Paul, Nucl. Instr. and Meth. B52 (1990) 315.

[6] J.H. McGuire, P. Richard, Phys. Rev. A8, No. 3 (1973) 1374.

NPA - 18 – On Line Release Simulator of Radioactive Beams produced by ISOL

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Radioactive ion beam facilities provide a large variety of radioactive isotopes for a multitude of applications in Nuclear Physics and related areas. There are basically two methods of production: Isotope Separator On Line (ISOL) and in Flight method. With the ISOL method very intense beams (up to several 10^{12} ions per s) of radioactive ions can be obtained. The produced isotopes are stopped in the target, which at high temperature causes the diffusion of the nuclides, effusion to the ion source and further transport to the experiment.

The improvement in the release time is the major objective in the development of target and ion source units. The release efficiency depends on the diffusion in the target, random walk effusion to the ion source and adsorption/desorption processes at each surface collision. Therefore a simulation of these three processes allows to study and to optimize the geometry and composition of the target and ion source system before its fabrication.

The Isotope RElease Simulator (IRES) is an on line configuration tool that lets us to follow the path of a created nuclide from different possible targets to a FEBIAD or to a surface ion source. A web interface provides remote access to the simulator allowing to specify the simulation parameters and its invocation. The IRES is based on a Monte Carlo code [1] that simulates track nuclides in dependence of the geometry and materials used. The code allows to simulate targets formed by powders or fibers with variable geometries stored in an ORACLE database [2]. The database also contains the diffusion parameters and adsorption enthalpies to be used for the specific choice of target material. The result of the simulation is sent to the user by e-mail and stored in the pertinent table. The IRES application provides the possibility of recovering the results of previous simulations obtained by the user himself or by other users.

[1] M.Santana, Ph.D: A Monte Carlo code to optimize ISOL targets (2005)

[2] TARGISOL database http:www.targisol.csic.es

Subnuclear Physics

SP - 1 – Recent advances in Chiral Perturbation Theory

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In this talk I will cover the recent progress in Chiral Perturbation Theory. Among the topics I will discuss isospin breaking corrections in several quantities and processes (e.g., neutral pion decay, pion decay constants, pion-nucleon couplings, etc.), and the recent efforts to extend the range of validity of Chiral Perturbation Theory by including low lying resonances explicitly.

SP - 2 – Nuclear Structure aspects of neutrinoless double beta decay

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The theoretical description of the double beta decay is strongly dependent on several assumptions concerning the nuclear structure of the participant states. The talk is devoted to the review of these approximations and it focus on the following aspects: a)possible connection between single and double beta decay processes, as a way to determine nuclear matrix elements; b)possible connection between two-neutrino and neutrinoless modes of the nuclear double beta decay; c)structure of the matrix elements of the mass sector of the decay rate for neutrinoless double beta decay. d)uncertainties in the calculations of nuclear matrix elements, for double beta decay, due to suppression mechanisms. Finally, we shall review the experimental situation concerning double beta decay systems which are currently under investigation.

SP - 3 – The structure of the nucleon

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Recent experimental data on space- and time-like electromagnetic form factors of the nucleon are analyzed in a two-component model with a quark-like intrinsic structure surrounded by a meson cloud. A good overall agreement is found for all electromagnetic form factors with exception of the magnetic form factor of the neutron for which no satisfactory description for both the space- and the time-like region has been obtained. This analysis suggests that there may be an inconsistency between the neutron space- and timelike data.

SP - 4 – Two flavor color superconductivity under compact stars conditions

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We study the properties of isospin asymmetric quark matter under compact stars constraints using a relativistic quark model with non local interactions in the mean field approximation. We consider a Gaussian regulator, and medium and large coupling ratios. We present the corresponding phase diagrams and discuss, in particular, the competition between chiral symmetry restoration and the various forms of two flavor color superconductivity.

SP - 5 – Extracting the Hadron Spectrum of QCD Using a Space-Time Lattice

Basak, S.,[1] Edwards, R.,[2] Fleming, G.T.,[3] Heller, U.M.,[4] Lichtl, A.,[5] Morningstar, C.,[5] Richards, D.,[2] Sato, I.,[1] and Wallace, S.[1]

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Advances in computing hardware and algorithms have made it feasible to evaluate increasingly complex path integrals by the use of a space-time lattice. We discuss how the lattice approach can be used to extract the hadron spectrum of QCD from operator correlation functions, and present a method of constructing quantum operators which attempts to maximize the overlaps with the low-lying states while minimizing the number of sources needed in the computation of expensive quark propagators.

SP - 6 – QCD running coupling with diquarks

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Correlated quarks in color anti-triplet states can play a role in low-energy QCD and hadron structure (R.L. Jaffe, Phys. Rept. 409 (2005)1). These diquarks structures have an enhanced stability due to the color exchange-interaction between the quarks. The explicit diquark degree of freedom has been largely explored to model the nucleon structure (see e.g. W.B.Araujo et al Phys. Lett. B478 (2000) 86) and more recently appeared in the interpretation of light scalar mesons as a antidiquark-diquark nonet (L. Maiani et al Phys. Rev. Lett. 93 (2004) 212002). Although, it has been recognized that color anti-triplet pairs of quarks in a symmetrical combination of flavor triplet and spin 1 states may also be important to hadron structure, we study a color gauge invariant effective Lagrangian containing only the scalar diquark as an elementary field, quarks and gluons, inspired by the work of Hong and collaborators (Phys. Lett. B596 (2004) 191). In this renormalizable model, we calculate the beta-function up to second order in the coupling constant and by solving the appropriate RG-equation we obtain the contribution of diquarks to the QCD running coupling constant.

SP - 7 – Effective interactions from q-deformed quark fields

Timoteo, V. S.[1] and Lima, C. L.[2]

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From the mass term for q-deformed quark fields, we obtain effective contact interactions of the NJL type for the non-deformed quark fields. We obtain, as a function of both temperature and q-deformation, the parameters that establish an equivalence between a system of free q-deformed quarks and the NJL model.

SP - 8 – The ALICE Silicon Pixel Detector

Moretto, S.,[1] Antinori, F.,[1] Dima, R.,[1] Fabris, D.,[1] Lunardon, M.,[1] Pepato, A.,[1] Scarlassara, F.,[1] Segato, G.,[1] Turrisi, R.,[1] Viesti, G.,[1] Bruno, G.E.,[2] Caselle, M.,[2] Dalessandro, A.,[2] Elia, D.,[2] Fini, R.A.,[2] Ghidini, B.,[2] Lenti, V.,[2] Manzari, V.,[2] Navach, F.,[2] Santoro, R.,[2] Cinausero, M.,[3] Fioretto, E.,[3] Prete, G.,[3] Vannucci, L.,[3] and Anelli, G.[4]

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ALICE is an experiment presently under construction at the CERN Large Hadron Collider (LHC). It is primarily designed to investigate the behavior of strongly interacting matter under the extreme conditions of heating and compression that will be reached in ultra-relativistic nucleus–nucleus collisions at the energy of the LHC. The inner region, with a radius of about 0.45 m, will be instrumented with the Inner Tracking System (ITS) which consists of six concentric layers of silicon detectors: two layers of Silicon Pixel Detectors (SPD), two layers of Silicon Drift Detectors (SDD) and two layers of Silicon Strip Detectors (SSD). The SPD barrel layers, at average radii of 39mm and 76mm respectively, are formed by 120 half-staves with 240 bump-bonded detector ladders containing in total about 10 million pixel cells with dimension 50×425. The half-staves have to be assembled on a carbon fibre support with micrometric precision. Each half-stave is equipped with a multi-chip module (MCM) and an optical fibre link for control and readout. A 5-layer aluminium/polyimide bus ensures the distribution of power and signals on each half-stave. An overview of the SPD development and the current status of the construction will be presented.

SP - 9 – Recent Results From the PHOBOS Experiment at RHIC

Garcia, Edmundo[1]

[1]University of Illinois at Chicago

The charged particle multiplicity produced at RHIC will be presented as a function of collision energy, centrality and species. The data will be discussed in terms of the measured collision geometry scaling of mid-rapidity yields, extended longitudinal scaling of the pseudorapidity density distributions, participant scaling of total charged particle multiplicities, and the extent to which all the data are found to factorize in both centrality and collision energy.

SP - 10 – Strangeness Production At the Relativistic Heavy Ion Collider

Munhoz, M. G.[1]

[1]Universidade de São Paulo

The STAR (Solenoidal Tracker At RHIC) experiment is a large acceptance detector that measures primarily hadronic observables in search for signatures of the quark-gluon plasma phase transition and to study the characteristics of the strongly interacting matter at high energy density. Operational since June 2000, RHIC has already provided Au+Au collisions at 62, 130 and 200 GeV as well as p+p and d+Au collisions at 200 GeV. The various collision energies and systems allow the systematic study of particle production in heavy ion collisions. In particular, the production of strange (anti-)particles is one of the major topics of STAR. This detector allows the measurement of a variety of particle species at mid-rapidity, like neutral Kaon, Λ, Ξ and Ω hyperons that are reconstructed via their decay topology. The strangeness measurements provide important information on various phenomenological aspects of ultra-relativistic heavy ion collisions.

SP - 11 – Recent results from RHIC

Hallman, T.[1]

[1]BNL ,USA

SP - 12 – Primary Cosmic Rays Composition: Simulations and Detector Design

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The determination of the primary cosmic rays composition is one of the most difficult and important problems in the physics of cosmic rays. It is well known that the number of air shower muons produced by the interaction of the cosmic rays with the Earth atmosphere is the best parameter to discriminate between different nuclei.

The Pierre Auger Observatory is a hybrid detector of cosmic rays. Although, the surface detectors, water Čerenkov tanks, are sensitive to the muon content in air showers they are not able to measure the number of muons directly. In this work we study, from simulations, the improvement of the mass discrimination power due to the addition of muon counters to the Pierre Auger surface detector.

One of the most important parameters used to discriminate between primaries is the number of muons at a given distance to the shower axis, then the design of the counters is made to maximize the discrimination between protons and iron nuclei considering the muon density at a given distance to the shower axis.

SP - 13 – Fluorescence Detector Upgrade for the Auger Southern Observatory

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In this work we evaluate a possible Field-Of-View (FOB) extension of an Auger South Observatory fluorescence detector in order to register cosmic rays showers of lower energies ranging between log(E/eV) = 17.0 - 18.5. Quality cuts are selected and applied, in particular on the slanted atmospheric depth at shower maximum, Xmax, which is requested to be well within the FOV. This latter requisite is not met at the proposed range of energies (especially for those showers that develop near the telescope) with the present FOV of the installed telescopes and therefore many detected events lead to very poor reconstructions. The present telescope systems cover a range of view of 180° in azimuth and 28.5° (from 1.5° to 30°) in elevation. To perform the telescope upgrade simulations we chose two possible configurations: 1) the addition to the current setup, four telescopes covering a range of 120° in azimuth, and a 30° to 58.5° range in elevation; 2) only two telescopes, rather than four, on the upper part, i.e. a 60° range in azimuth. We study the efficieny of the current telescope array and of the two proposed upgrades, by considering a full reconstructions of simulated Gaiser-Hillas shower profiles of showers impinging on a circular area situated at different distances from the telescope. We do these simulations for four different energies. Also, a comparison of simulations against Observatory data is performed.

SP - 14 – The Physics with Linearly-Polarized Photon in Hall B of Jefferson Lab

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The set of experiments forming the first phase of the g8 run took place in the summer of 2001 (6/04/01 – 8/13/01) in Hall B of Jefferson Lab. These experiments made use of a beam of linearly-polarized photons produced through coherent bremsstrahlung and represent the first time such a probe has been employed at Jefferson Lab. Among the several new and upgraded Hall-B beamline devices commissioned prior to the production running of g8a were the photon tagger, coherent bremsstrahlung facility (goniometer +an instrumented collimator), a photon profiler, and the PrimEx dipole + pair spectrometer telescopes. We essentially commissioned a new beamline for photon running in Hall B. This past summer (2005), the two-month run for the second phase of g8 took place.

The scientific purpose of g8 is to improve the understanding of the underlying symmetry of the quark degrees of freedom in the nucleon, the nature of the parity exchange between the incident photon and the target nucleon, and the mechanism of associated strangeness production in electromagnetic reactions. With the high-quality beam of the tagged and collimated linearly-polarized photons and the nearly complete angular coverage of the Hall-B spectrometer, we seek to extract the differential cross sections and polarization observables for the photoproduction of vector mesons and kaons at photon energies ranging between 1.10 and 2.25 GeV. We will present results on the photoproduction of hyperons and rho mesons from the first run and preliminary results from the the second run.

SP - 15 – Search for Modification of Vector Meson Properties in Nuclei

Djalali,C.[1]

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The properties of vector mesons, such as their mass and width, are predicted to be modified in dense medium such as a nucleus. This modification, if proven to exist, could be related to more fundamental physics such as a partial restoration of chiral symmetry at high density. The g7 (or E01-112) experiment has been designed to look for medium effects on the properties of the light vector mesons (rho, omega, and phi) in photoproduction, through their rare leptonic decay into e+e-. This decay channel has been preferred to the two-pion channel to avoid distorting the information by strong final interaction. The data for this experiment was taken in the fall of 2002 using the CLAS detector at the Jefferson Lab. A bremstrahlung photon beam was sent on a target containing a liquid deuterium cell and several nuclear targets: C, Fe, Ti, and Pb. First results will be presented.

SP - 16 – Spin Duality on the Neutron (^{3}He)

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Jefferson Lab experiment E01-012 used the polarized ^{3}He target in Hall A for a measurement of the virtual photon asymmetry $A_1^{^3\mathrm{He}}$ and the spin structure function $g_1^{^3\mathrm{He}}$ in the resonance region over a Q^2 range from 1.0 to 4.0 $(GeV/c)^2$. The same quantities are extracted for the neutron. Data from E01-012 combined with deep inelastic scattering data will provide a test of quark-hadron duality predictions. This will be one of the first test of the spin and flavor dependence of quark-hadron duality. The demonstration of duality for spin structure functions will enable us to use the resonance data to study the nucleon spin structure in the large x_{bj} region. Some details of the experiment and preliminary results will be presented.

SP - 17 – The G0 Experiment : Parity Violation in e-N Scattering

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The goal of the G^0 experiment, currently underway at the Thomas Jefferson National Accelerator Facility, is to investigate the contributions of the strange quarks to the fundamental properties of the nucleon. The experiment uses a polarized electron beam and unpolarized hydrogen and deuterium liquid targets. The experiment will measure parity-violating asymmetries, over a momentum transfer range of 0.1 - 1.0 $(GeV/c)^2$, in elastic electron scattering off hydrogen at both forward and backward angles, and quasielastic electron scattering off deuterium at backward angles. From the measurements, one can extract the vector neutral weak form factors, G_E^Z and G_M^Z, and the effective axial current of the nucleon, G_A^e. These form factors, along with the electromagnetic form factors, will yield the contribution of the strange quark to the proton's charge and magnetization distributions. The forward angle phase was completed in 2004 and the backward angle phase will begin in 2006.

SP - 18 – Hypernuclear physics with FINUDA at the DAΦNE facility.

Grion, N.[1]

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The $A(K^-_{stop}, \pi^\pm)_Y A$ reaction on ^{6,7}Li, ^{12}C, ^{27}Al, ^{28}Si and ^{51}V was investigated with the FINUDA spectrometer at the DAΦNE e^+e^-−collider (L.N.F.). Electron-positron collisions produce $\phi(1020)$−mesons at rest, whose back-to-back decay mode K^+K^- (B.R. 50%) finds an uncommon use for *incident beam.* The negative kaon initiate the reaction process while the associate positive kaon tags the process. These kaons have a kinetic energy of ∼16 MeV. They can suitably be stopped in thin targets $\sim 0.2gr/cm^2$, which reduces the energy struggling of kaons to a few hundreds of KeV. As a consequence, $_YA$−bound states can be identified with an energy resolution of about 1 MeV (FWHM) in the $(K^-_{stop}, \pi^\pm)$ excitation spectra. Finally, the spectrometer subtends a solid angle larger than 2π sr. The physics discussed comprises several topics: The formation and decay of Λ− and Σ−hypernuclei in comparison with recent results, new results on deeply-bound kaonic states (NNK) resulting from the K^-A interaction, and newly observed rare decays.

Nuclear Thermodynamics and Dynamics

NTD - 1 – Isospin Transport at Fermi Energy

Baran, V.,[1] Colonna, M.,[1] Di Toro, M.,[1] Zielińska-Pfabé, M.,[2] and Wolter, H.H.[3]

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The BUU formalism with an inclusion of fluctuations was used to study a mechanism of isospin equilibration in semiperipheral collisions of heavy ions at energies close to the Fermi energy. A low density "neck" region which is created at the interface between the interacting nuclei plays an important role in the transport of neutrons and protons between the projectile an the target. This transport of isospin is affected by an interplay between drift and difussion which are both sensitive to the density dependance of the symmetry term in the nuclear equation of state (EOS). The imbalance parameter was used as a measure of isospin equilibration. The comparison with experiment favors a more asy-stiff nuclear equation of state.

NTD - 2 – Reaction Geometry from Low-Velocity Correlations

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Exploiting final-state interactions and/or identity interference, analysis of anisotropic correlations of particles at low-relative velocity yields information on the geometry of a multiparticle final-state of a reaction. We show that the use of cartesian surface-spherical harmonics in such analysis allows for a systematic expansion of the correlations in terms of real angular-moment coefficients dependent on magnitude of the relative velocity. Those coefficients are directly related to the analogous coefficients characterizing the geometry of the final state. We illustrate the analysis with an example of correlations generated by the classical Coulomb interaction.

NTD - 3 – Multifragmentation studied with antisymmetrized molecular dynamics

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In medium energy heavy-ion collisions, many fragments are formed almost simultaneously in an expanding and excited nuclear system, which gives us an opportunity to investigate the nuclear matter properties at various temperatures and densities, such as the nuclear equation of state and the liquid-gas phase transition. However, fragments are formed in dynamically evolving system in most cases, and therefore dynamical model calculations are necessary.

Antisymmetrized molecular dynamics (AMD) model respects several quantum features in fragment formation reactions. It uses a fully antisymmetrized many-body wave function of Gaussian wave packets, which can describe the ground state properties of nuclei reasonably well. The single-particle evolution in the mean field potential is treated by the the motion of the wave packet centroids and the stochastic quantum branching process which respects the change of the shape of the phase-space distribution, keeping the advantage of the molecular dynamics that the fragments are formed with the wave packets localized in phase space. The two-nucleon collision effect is also treated as a stochastic process.

AMD can be used to generate a microcanonical ensemble by solving the time evolution of many-nucleon system with a given energy confined in a container with a given volume. The constant-pressure caloric curves obtained from these microcanonical ensembles show clear back-bending (i.e., negative heat capacity) which is an evidence of the first order liquid-gas phase transition in nuclear system with a finite number of nucleons.

The AMD simulations for heavy-ion collisions are useful not only to explain the experimental data but also to know what kind of information is reflected in the fragment formation. For example, AMD simulations show that the fragment isospin composition is basically consistent with the statistical expectations even in dynamically evolving systems. Isoscaling is satisfied by the AMD results. The width of the fragment isotope distribution can be explained by the ratio of the symmetry energy to the temperature if the symmetry energy at a reduced density is assumed to be relevant. This assumption is justified by studying the dependence on the density-dependent symmetry energy. The symmetry energy extracted from the AMD results is almost independent of the fragment size, which suggests that the fragment isospin composition is governed by the symmetry energy of low-density uniform matter rather than the symmetry energies for isolated nuclei.

The formation of light clusters such as deuterons and tritons is a quantum mechanical issue which requires an extension of AMD. It is shown that the light cluster formation has significant effects on the observables of intermediate mass fragments.

NTD - 4 – A classical mechanics study of isoscaling

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The phenomenon of nuclear isoscaling is studied using classical molecular dynamics. Isoscaling was studied with simulations of several reactions at various energies. Isoscaling at different stages of the reaction was investigated and the validity of the isoscaling power law was estimated.

NTD - 5 – Bimodality: a robust signature of the liquid-gas phase transition of nuclear matter?

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Bimodality is an expected signature of a first order phase transition when the system is at the transition temperature. This signal is clearly observed in nucleus-nucleus collisions when the deposited energy is in the range 3-6 MeV/nucleon. We will discuss the corresponding results which have been obtained with the INDRA array at GSI for semi-peripheral symmetrical collisions between 60 and 100MeV/nucleon. Bimodality signal is not cancelled by the fact that full thermal equilibrium is not reached but it is better evidenced if one selects events which are closer to full equilibrium. This result is in agreement with lattice-gas simulations showing that the bimodality signature is robust even if full thermal equilibrium is not reached. We will also show that the bimodality signal is observed together with other phase transition evidences: negative heat capacity or delta scaling. We will also show that the experimental results are coherent with the fact that the two phases (residue production and multifragmentation) correspond to similar temperatures and to different excitation energies as it is expected from theory. Altogether, this large set of data is a strong evidence for the observation of the liquid-gas phase transition of nuclear matter.

NTD - 6 – Isoscaling, Geometry and Correlations

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The property of isoscaling is studied starting with a generalized bond percolation model in d dimensions with nodes of N colors. It is shown analytically that under very general conditions the isoscaling property is obtained. When the results are expressed in terms of low dimension lattices and two colors (isospin) the standard relations used in nuclear fragmentation are recovered. Going beyond the simple percolation model, correlations are introduced by using techniques akin of the lattice gas model. It is shown that correlations alter the exponents in the isoscaling relation. Non equibrium effects are analyzed using expansions in terms of the bond lattice animals. It is, thus, concluded that isoscaling emerges from the simple assumptions of fair sampling with homogeneous probabilities and lattices at the same bond breaking probabilities.

NTD - 7 – Phase Transition in Small System: from nuclear physics to astrophysics

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Everybody knows that when a liquid is heated, its temperature increases until the moment when it starts to boil. The increase in temperature then stops, all heat being used to transform the liquid into vapor. What is the microscopic origin of such a strange behavior? Does a liquid drop containing only few molecules behave the same? Recent experimental and theoretical developments seem to indicate that at the elementary level of very small systems, this anomaly appears in an even more astonishing way: during the change of state - for example from liquid to gas - the system cools whereas it is heated, i.e. its temperature decreases while its energy increases. This paper presents a review of our understanding of the negative specific heat phenomenon. Special emphasis will be put on nuclear physics and astrophysics.

NTD - 8 – Nuclear Multifragmentation and Zipf's Law

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Experimental evidence suggests that a subset of events in nuclear fragmentation experiments is able to probe the critical point of the nuclear matter phase diagram. Fragmentation of nuclei offers the opportunity to study extreme finite-size modifications on the location of the critical point as well as the critical exponents.

Recently, a variant of Zipf's Law has been applied to nuclear fragmentation data. We show how one arrives from rather general assumptions based on scaling theories at distributions of fragment size ranks. Further, we show that Zipf's Law is not valid for all universality classes. Instead we show how one can find a wider class of Mandelbrot-Zipf distributions that can be obtained for all universality classes that one can consider for the problem of nuclear multifragmentation. We discuss finite-size modifications and their influence on the distributions, as well the modifications of the distributions for control parameter values that are close to the critical point, but not at the critical point.

Finally, we draw comparisons to other physical systems, and in particular to the distributions of gene lengths in different genomes.

NTD - 9 – Clusters in hot and dense fluids

Campi, X.[1]

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CLUSTERS IN HOT AND DENSE FLUIDS

The concept of clusters of particles plays a key role in many theoretical studies of hot and dense fluids. This talk reviews various definitions of clusters, discussing their theoretical grounds and expected domains of validity. It focuses on the applications of this concept to nuclear dynamics and thermodynamics problems, like cluster formation, thermometry, negative heat capacities and bimodality.

NTD - 10 – A quark model with excluded volume correction for hypermatter at high density.

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We study the effects of the finite size of baryons on the equation of state of homogeneous hadronic matter. The finite extension of hadrons is introduced in order to improve the performance of field theoretical models at very high densities. We simulate the in-medium averaged baryon-baryon strong repulsion at very short distances by introducing a Van der Waals like normalization of the fields. This is done in the framework of the Quark Meson Coupling model that allows to take care of the quark structure of baryons. Since within this model the confinement volume evolves with the fields configuration, the treatment is not equivalent to a simple hard-core potential. We investigate the phase transition to quark matter and the structure of neutron stars. We have found significant corrections at high densities.

NTD - 11 – The Equation of State of Symmetric and Asymmetric Nuclear Matter

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The nuclear equation of state (binding energy as a function of matter density) is a very important ingredient in the study of properties of nuclei, neutron stars, supernova and heavy ion collisions. To extend our knowledge of the nuclear matter (NM) equation of state (EOS) beyond the saturation point, an accurate determination of the value of the NM incompressibility coefficient, K, (which is directly related to the curvature of the EOS) is needed. We will review the current status of the value of K, concentrating on the most sensitive method of analyzing the experimental data on compression modes of nuclei within microscopic realtivistic and non-relativistic theoretical models. We will consider, in particular, the recent accurate experimental data on isoscalar giant monopole resonance (ISGMR) and isoscalar giant dipole resonance (ISGDR) in nuclei. We will discuss the consequences of common violations of self-consistency in mean-field based random-phase approximation calculations of strength functions and present results of highly accurate calculations of strength functions and excitation cross sections. Explanations (resolutions) of long standing discrepancies in the value of K will be presnted.

NTD - 12 – Probing densities and shapes of emitting sources in heavy-ion collisions

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Two-particle correlation functions are used to probe the properties of emitting sources produced in heavy-ion collisions at intermediate energies. A detailed imaging study of the shape of these sources with its physical implications is presented. Similar analyses are also used to determine the density of the nuclear systems produced during Sn+Sn and Xe+Au collisions at 50 MeV/u. Imaging analyses of correlation functions also probe transport theories of nuclear reactions. In this context, a sensitivity to the density dependence of the symmetry energy in the nuclear equation of state is expected. Experimental efforts to extract such an information are discussed.

NTD - 13 – Density Dependence of the Symmetry Energy in the Equation of State of Asymmetric Nuclear Matter

Yennello, S.J., Shetty, D.V., Souliotis, G.A.[1, 1]

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The asymmetry term in the nuclear equation of state (EOS) of strongly interacting matter is important for studying the structure, chemical composition and evolution of neutron stars and the dynamics of supernova explosions. Under laboratory conditions the low density dependence of the asymmetry term of the

EOS can be investigated via heavy-ion reaction studies. The isotopic composition of fragments produced has a significant sensitivity to the density dependence of the asymmetry term. Recent data will be presented and compared with theoretical calculations.

NTD - 14 – The energetics and structure of fermionic ^{3}He droplets

Szybisz, Leszek[1]

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The energetics and structure of ^{3}He droplets are studied as a function of the number of helium atoms N. Calculations are performed within a density functional theory. The asymptotic surface tension is determined from the fit of the energy per particle to a polynomial expansion in terms of $N^{-1/3}$. A comparison with other results is presented.

Poster Sessions

Posters: Nuclear Structure

P-NS- 1 – Comparision between the Dirac-Hartree-Fock-Bogoliubov and the Bardeen-Cooper-Schriffer approximations.

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In this work we compare the Dirac-Hartree-Fock-Bogoliubov (DHFB) and the Bardeen-Cooper-Schriffer (BCS) approximations in isotopic chains of Se, Kr and Sr. After fitting the binding energies to the experimental values, we compare deformations, pairing gaps of these nuclei with the available experimental data.

P-NS- 2 – Asymmetry parameter for nonmesonic hypernuclear decay

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We derive general explicit expressions for a shell model calculation of the asymmetry parameter a_Λ in nonmesonic hypernuclear weak decay. Incontrast to the approximate formula widely used in the literature, they include the effects of three-body kinematics in the final states of the decay and correctly treat the contribution of transitions originating from single proton states beyond the s-shell. The expressions are particularized to the cases of ${}^5_\Lambda$He and ${}^{12}_\Lambda$C, and used for the corresponding numerical computations of a_Λ within several one-meson exchange-models. Besides the strictly local approximation usually adopted for the transition potential, we also consider the addition of the first-order nonlocality terms. We find values for a_Λ from -0.62 to -0.24, in qualitative agreement with other theoretical estimates but in contradiction with some recent experimental determinations.

P-NS- 3 – Nuclear matter generalized polarizabilities: symmetry energies

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Nuclear matter symmetry energies (neutron-proton (n-p), spin dependent ones) are investigated from generalized polarizabilities (which can also include a dipolar incompressibility in the scalar channel). The dependences on the nuclear densities and the asymmetries (n-p, spin up-down) temperature and exchanged energy and momentum(ω, q) are obtained. The $q-w$-dependences of the symmetry energy coefficients with Skyrme-type forces are found to depend strongly in the particular force mainly for the spin dependent channels. A brief discussion from the point of view of relativistic mean field models is done. Aspects of the corresponding spatial nucleonic distributions are discussed. Solutions for a previously derived differential equation for the simultaneous dependence of the symmetry energy on the n-p asymmetry and on the density are analysed.

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P-NS- 4 – The Relativistic BCS Approximation

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In 1974 a model in relativistic quantum field theory was introduced by Walecka and collaborators to study nuclear many-body systems. This model is referred to as quantum hadrodynamics (QHD). Proposed initially as a fully renormalizable theory, nowadays it is seen as an effective field theory, derivable, in principle, from quantum chromodynamics.

The relativistic mean field theory (RMFT), which can be thought of as a mean field (Hartree) approximation to QHD, has been applied to describe the structure of very exotic nuclei. In these calculations, the pairing interaction has been neglected or simply treated by a nonrelativistic BCS type of approximation. For nuclei on or near the stability line, the BCS approach provides a reasonably good description of pairing properties.

A more precise relativistic description of pairing correlations, a Dirac-Hartree-Fock-Bogoliubov (DHFB) approximation, was develop some time ago and, more recently, applied to nuclear matter calculations with sucess. A hybrid Hartree-Bogoliubov

(RHB) approximation based on the DHFB approximation, in which the Hartree mean field is calculated relativistically but a non-relativistic Gogny interaction is employed to describe the pairing, has been applied extensively, and quite successfully, to the calculation of the ground state properties of spherical and deformed nuclei.

Here we present a fully relativistic DHFB approximation for axially deformed nuclei. We solve the nucleon and mesons fields equations by expanding the fields as well as the wavefunctions in complete sets of eigenfunctions of harmonic oscillator potentials. Starting from this approximation we developed a relativistic BCS approximation and compare it with the Dirac-Hartree-Boboliubov one. We verify that the relativistic BCS approximation generally yields larger values of the pairing field and larger deformations.

P-NS- 5 – ALTO Project

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The installation of electron Linac at Orsay in the frame of ALTO project is dedicated to the development of fundamental research on exotic nuclei and also to other subjects of research, particularly in industrial application. In the fundamental research, the main goal of ALTO is the neutron rich beams production using the photo-fission process and the *R&D* with the aim of the optimisation of the target-ion source system for the future installation SPIRAL-2 and the Eurisol project. The production uses uranium carbide target (238UCx) irradiated by $10\mu A$ electron beam at 50 MeV. The accelerator components were recovered from decommissioned LEP injector (CERN) and NEPAL station (LAL). Presently the project is at the end of its construction phase, the commissioning is expected at the end of this year. An overview and the status of the project will be presented.

P-NS- 6 – ^{101}Ru low-energy levels calculation

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During the last years, neutron rich nuclei near $A = 100$ have been the subject of numerous studies. Experimentally, these nuclei were investigated by beta and gamma decay in the sixties and seventies and also by particle transfer [1]. Recently we done a study of ^{101}Ru by the β^- decay, producing new information about the level scheme of this nucleus [2]. Aiming to a theoretical support for the experimental study, the nuclear structure of ^{101}Ru was studied with a single particle model plus pairing residual interaction. In this model, the deformation parameters in equilibrium were obtained by minimizing the total energy calculated by the Strutinsky prescription: the macroscopic contribution to potential from the Liquid Droplet Model and the shell and paring corrections as microscopic contributions [3]. The nuclear shape was described using the Cassinian ovoids as base figures, with deformation parameters ϵ (elongation and quadrupolar momentum), α_4 (hexadecapolar momentum) and α_3 (octupolar momentum)[3]. The single particle energy spectra and wave functions for protons and neutrons were calculated in a deformed Woods-Saxon potential [4]. The parameters of the potential for protons were obtained from literature [5], and the ones for neutrons were adjusted in order to describe the main sequence of angular momentum and parity of the low energy excited levels (band heads), as well as proton binding energy of ^{101}Ru. The residual pairing interaction was considered in the BCS prescription with Lipkin-Nogami approximation [6].

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P-NS- 7 – Odd-odd nuclei around the shell closure at N=Z=28

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Nuclei close to doubly magic shell closures have been subject of extensive experimental and theoretical investigations [1-4]. The shell gap at N=Z=28 is due to the spin-orbit lowering of the high-j, $f_{7/2}$ orbital from the next major shell. The gap is relatively small so that particle-hole excitation across the gap has relatively low energies. For shell model calculations around this magic number, ^{56}Ni has often been assumed as an inert core. However, it has been shown that this core is rather soft and only a very limited description is provided by the closed-shell model for the magic number 28 [5]. The structures for N or Z =

28 nuclei were successfully described only after considering the existence of significant core-excitations in low-lying non yrast states as well as in high-spin states [4]. In this work we present the study of the odd-odd nuclei ^{54,56,58,60}Co (Z=27) described in the framework of the Large Scale Shell Model, using the Antoine code [6]. The experimental level scheme and electromagnetic properties for these odd-odd nuclei [1,7-9] are compared with the Shell Model calculations using the GXPF1 effective interaction, developed for use in the pf shell [4,10]. The calculation were performed in the full pf shell with up to 8 particle excitations from the $1f_{7/2}$ orbital to the $1p_{3/2}$, $1f_{5/2}$ and $1p_{1/2}$ orbitals. The Shell Model calculations reproduce reasonably well the experimental level schemes, specially those of the lighter odd-odd nuclei. Nevertheless, more excited particles are needed in the description of the ^{60}Co nuclei.

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P-NS- 8 – Momentum distribution of nucleons outside the equilibrium deformation.

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The momentum distribution (MD) of nucleons in a nucleus is an important issue for analysing single-particle aspects of nuclear structure, for a review see [1]. One of the still open problems is the influence of global nuclear deformation on MD. There already exist some studies on that subject, see, *e.g.* [2,3] and references therein. Nonetheless, the present knowledge about deformation effects in MD is still rather poor, especially in heavy deformed nuclei. At the same time, these effects can be essential for a correct treatment of knock-out reactions, such as $(e, e'p)$, in rare earth and actinide regions and for investigation of deep hole states in deformed nuclei (see, e.g., [4,5]).

In our work we analise momentum distributions of neutrons in odd plutonium isotopes at second minimum deformations in the framework of the phenomenological deformed Woods-Saxon potential. The shell correction and macroscopic part of the potential energy have been calculated via the Macroscopic-Microscopic formalism[6], considering as main deformation parameters ε(elongation) and α_4 (hexadecapolar momentum) in Pashkevich's nuclear shape parametrization[6,7]. The parameters for the nuclear potential in the equilibrium deformations as well as in the second minimum were taken from a previous work[7].

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P-NS- 9 – Lifetime Measurements in ^{83}Y

Pérez, D.,[1] Garzón, A.,[1] Cristancho, F.,[1] Tabor, S. L.,[2] Kaye, R. A.,[2] Solomon, G. Z.,[2] Döring, J.,[3] Johns, G. D.,[4] Devlin, M.,[5] Lerma, F.,[5] and Sarantites, D. G.[5]

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When investigating nuclear structure, one of the most important experimental quatities is the electric quadrupole moment, which is obtained via the measurement of the state lifetime. In turn, correct lifetime values rely on the proper determination or isolation of sidefeeding time effects, a very elusive quantity related to the population of discrete states from the quasi-continuum region and therefore, not directly measurable. A recent work [1] has shown that when taking properly into account side-feeding effects, the resulting sidefeeding times can be surprinsingly much longer than usually expected in the mass region $A \approx 80$.

The GAMMASPHERE [2] detector array and the charged-particle multidetector array MICROBALL [3] were used to analize the gamma decay of ^{83}Y after the heavy ion fusion-evaporation reaction ^{32}S(^{58}Ni,$3p\alpha$)^{83}Y at 134 MeV beam energy. After production in a thin ^{58}Ni foil (415 μg/cm^2), the recoil nuclei slowed down in a thick ^{181}Ta backing (Doppler Shift Attenuation Method). We report on the lifetimes in the positive parity yrast bands by means of the Gate From Above technique which switches off side-feeding effects and therefore provides a more reliable measurement of the state lifetimes. Analyzing the same transition in a Gate From Below (GFB) provides an independent measurement of the side-feeding time. Previous measurements exist in ^{83}Y [4,5], but all of them were analyzed only under the GFB condition.

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P-NS- 10 – Quantum Algebras and Many Body Problems.

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Recently, great attention has been paid to the study of different realizations of deformed algebras (q-algebras). In this talk we present and describe some applications of these mathematical objects to find the solution to specific many body problems. Particularly, we shall discuss the way in which boson degrees of freedom are replaced by a deformation parameter, when fermion-boson interactions are present in the Hamiltonian. Also, we shall show that non-standard q-deformations of the harmonic oscillator can be used to describe finite range potentials. Finally, we report on the solution of an asymmetric rotor in terms of cubic polinomial algebrae.

P-NS- 11 – Quantum entanglement in pseudospin models

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Quantum entanglement is one of the most fundamental and intriguing features of composite quantum systems, playing a fundamental role in the science of quantum information. It represents essentially the ability of these systems to exhibit correlations with no classical analogue. In this contribution we examine the entanglement of thermal states of some pseudospin models employed in nuclear physics, which deal basically with n qubits or spins fully connected through a spin-spin coupling. Entanglement is measured by evaluating the so called negativity of all possible bipartite partitions of the system and subsystems. This quantity, which is determined by the operation of partial transposition of the concomitant density matrix, always vanishes in any classically correlated state, as well as for sufficiently high temperatures, constituting a measure of quantum-like correlations. In particular, it will be shown that limit temperatures for non-zero global negativities are independent of the value of the effective magnetic field in all XXZ type models, in spite of the quantum transitions that these models may exhibit at zero temperature, while in anisotropic XYZ type models they always increase for sufficiently large fields. Results also show that these temperatures are higher than those limiting pairwise entanglement, and that their behavior may differ considerably from that of the corresponding mean field critical temperature [1].

[1] N.Canosa, R.Rossignoli, Phys. Rev. A 69, 052306 (2004); Phys. Rev. A (2005, in press).

P-NS- 12 – Spreading widths for the decay of superdeformed bands?

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Recent models of the decay out of superdeformed (SD) bands can broadly be divided into two categories. One approach is based on the similarity between the tunneling process involved in the decay and that involved in the fusion of heavy ions, and it builds on the formalism of nuclear reaction theory. The other arises from an analogy between the superdeformed decay and transport between coupled quantum dots. These models suggest conflicting values for the spreading width of the decaying superdeformed states. In this paper, the decay of superdeformed bands in the five even-even nuclei in which the SD excitation energies have been determined experimentally is considered in the framework of both approaches, and the significance of the difference in the resulting spreading widths is considered. The results of the two models are also compared to tunneling widths estimated from previous barrier height predictions and a parabolic approximation to the barrier shape.

P-NS- 13 – Halos in Four Body Systems?

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We apply the dynamic model of Ref. (7), to investigate the equation of motion (EOM) and the electromagnetic proprieties of nuclei with $A \leqslant 12$. The model is characterized by large systems of non linear equations which have been solved in terms of dynamic linearization approximations and cluster factorization coefficients (CFC). Dynamic linearization approximations are used to generate the model eigenvalue equations that are then solved self-consistently. The resulting valence-particle states are then "dressed" by the core excitation modes. Since the input to solving the dynamical eigenvalue-equations are the 4-body matrix elements, we have elaborated a cluster factorization theory (CFT) which enable us to build up all the matrix elements needed to perform calculation in a complex 4p-5p1h, 4p-6p2h configuration spaces (different-shells included). The (CFT) is exact and gives the possibility to compute the complex matrix elements of the nuclear interaction and of the different model operators (distributions, transitions, and beta-decay operators) in a strict economic regime. The presented model is particularly feasible to be applied to the study of the poorly known halo-structure of exotic nuclei. Calculation for the spectrum, matter (halos?) and charge distributions, and radii of A=8,12 nuclei are discussed. Within this calculation the validity of the alpha cluster model can be tested.

[7] M. Tomaselli, L.C. Liu *et al.*, Journal of Optics B**5**, 395 (2003); J. Phys. **G**, 999 (2004); *Key Topics In Nuclear Structures*, edited by A. Covello, 159 (2005).

P-NS- 14 – EXOTIC NEUTRON-RICH NUCLEI IN A THREE BODY MODEL

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We report studies on low-energy universal aspects of light nuclei systems, considered as two neutrons and a core. The possible existence of Efimov states is verified considering a plane defined by the ratios of the energies of the subsystems and the three-body ground-state energy. We also present results obtained recently on spatial distributions of light exotic nuclei and mean-square distances of the particles. The results are derived from a universal scaling function that depends on the mass ratio of the neutron and the core, as well as on the nature of the subsystems, bound or virtual. The model consider a minimal number of physical inputs, which are directly related to observables: the two-neutron separation energy, the neutron-neutron and neutron-core s-wave scattering lengths (or the corresponding virtual or bound energies). As the only inputs are observables that are fixed in the renormalized model, a more realistic potential will not effect the generality of the conclusions. The use of a simplified model with only s-wave can be partially justified, even in case where other partial waves are present. For example, in case of Lithium-11, it was already observed by Zinser et al. [Phys.Rev.Lett. 75, 1719 (1995)] that even an s-wave correlation produces a ground state of the halo nuclei with two or more shell-model configurations.

P-NS- 15 – Chirality in Nuclear Physics

Tonev, D.,[1] De Angelis, G.,[1] Petkov, P.,[2] Dewald, A.,[3] Gadea, A.,[1] Pejovic, P.,[1] Balabanski, D.,[4] Bazzacco, D.,[5] Lenzi, S.,[5] Lunardi, S.,[5] Menegazzo, R.,[5] Marginean, N.,[1] Napoli, D.R.,[1] Ur, C.,[5] and Zell, K. O.[3]

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In the work [1], it is pointed out that the rotation of triaxial odd-odd nuclei may attain to almost degenerate doublet bands with identical transition probabilities from the corresponding levels. The Interacting boson fermion-fermion model (IBFFM) [2] also reproduced well the level schemes of the chiral candidates, as for instance these in ^{134}Pr. In addition, crucial experimental observables for the understanding of nuclear structure and for checking the reliability of the theoretical models are the electromagnetic transition probabilities.

For the first time the lifetimes of the levels of the doublet bands in ^{134}Pr were measured by means of the recoil-distance Doppler-shift method and the Doppler-shift attenuation method using the Euroball spectrometer and the Cologne plunger device. The excited states of ^{134}Pr were populated via the reaction ^{119}Sn(^{19}F,4n)^{134}Pr at a beam energy of 87 MeV.

Nine lifetimes in the ground-state band and five in the second chiral candidate band were determined. Within the experimental uncertainties, the B(M1) values in both partner bands behave similarly, varying in an interval indicating relatively strong transition strengths. In contrast, the intraband B(E2) strengths within the two bands differ. This result is incompatible with the "static chiral picture" where the intraband B(E2) transition strengths must be equal. We have used particle-rotor + TAC and IBFF models to compare with the experimental data. In the first case, the calculation has been done using two quasi-particles plus a triaxial rotor with pairing. The moments of inertia have been calculated by means of the Cranking model. In the IBFFM case we have used a triaxial core. The calculations within the IBFFM are in a good agreement with the experimental data, while in the case of the particle-rotor + TAC model the calculations and the data differ. Such finding points to the fact that the limit of static chirality is not really reached in ^{134}Pr and the nuclear system stays in a very soft vibrational regime.

[1] S. Frauendorf and J. Meng, Nucl. Phys. A **617**, 131, (1997).
[2] S. Brant, D. Vretenar and A. Ventura, Phys. Rev. C **69**, 017304, (2004).

P-NS- 16 – Pseudo-orbital symmetries in the Pseudo-SU(4) model and its application to $2p\frac{1}{2} - 2p\frac{3}{2} - 1f\frac{5}{2}$ shell

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The Pseudo SU(4) ⊗ SU(6) symmetry model is proposed to combine the pseudo-spin, pseudo-orbits and isospin. The pseudo SU(6) symmetry was checked for the Ni-Cu-Zn isotopes with A=58,59 and 60, by analyzing the binding energy. The pseudo-orbitals symmetries was employed to analyze the spectra and the beta decay, and reasonably good results were obtained in a unified description of the nine nuclei.

P-NS- 17 – On the nature of excited bands in deformed nuclei

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It has been shown that several bands can be described with shell model in light and heavy nuclei. We discuss in this presentation the microscopic origin of excited bands in deformed nuclei.

P-NS- 18 – Angular Correlation Study of Excited Levels in ^{193}Ir

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The nucleus ^{193}Ir occupies a very interesting place in the nuclide table; whereas the ^{192}Os nucleus has been successfully described as a prolate-deformed nucleus, the ^{194}Pt nucleus shows oblate deformation; the usual approach is to describe the ^{193}Ir nucleus as a triaxial rotor, but a recent study has shown that it can be equally well described as a prolate rotor. Moreover, while the ^{193}Ir nucleus has been recently thorougly studied through many different reactions, the last full examination of the β^- decay from ^{193}Os was made in 1972, using Ge(Li) detectors with much lower detection efficiency than the presently-available HPGe detectors.

In this work, the excited states in ^{193}Ir populated by the β^- decay of ^{193}Os were investigated via γ-γ angular correlation analysis. For this purpose, 5mg samples of 99%-enriched ^{192}Os samples were irradiated for 30min in a neutron flux of about $10^{12} cm^{-2}s^{-1}$, and then analysed using a set of 4 HPGe detectors working in coincidence, using a multiparametric acquisition system. This setup allows for the simultaneous acquisition of 6 pairs of detectors, forming 4 independent angles (90^o, 120^o, 150^o and 180^o). From these results, the multipole mixing ratio (δ) of many transitions have been determined, allowing for the confirmation of the spin assignments and, in some cases, the proposition of new ones.

P-NS- 19 – DSAM side-feeding and state lifetimes in ^{75}Br

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In a previous work (see [1] and references therein), side-feeding times in the A ≈ 80 region were simulated and compared with experimental results. ^{75}Br was the only nucleus that did not fit neither into the systematics nor in the simulation results, having too short side-feeding times as compared to its neighbors. This result motivated a new measurement in order to check the latest experimental values in this nucleus [2]. We used the Tandem-LINAC facility at Florida State University and the fusion-evaporation reaction ^{48}Ti(^{30}Si,p2n)^{75}Br at 85 MeV to populate high-spin states in ^{75}Br. γ-γ coincidences were detected using an array of 16 Ge-detectors, eight of them arranged in two Clovers.

In this work, side-feeding and lifetimes of the main bands of ^{75}Br were measured up to spin 37/2, two transitions above Ref. [1]. In fact we found much longer side-feeding times, one order of magnitude longer than those in Ref. [2]. As a consequence, the state lifetimes became shorter producing an average transitional quadrupole moment $\bar{Q}_t = 3.1$ eb for the main bands, 25% larger than in the earlier publication [2], which means a significant larger deformation and therefore motivates new considerations about the collective structure of ^{75}Br.

[1] E. Galindo and F. Cristancho, Revista Colombiana de Fisica, **29**, 359 (1997).

[2] L. Lühmann *et al.*, Phys. Rev. **C**, **31**, 828 (1985).

P-NS- 20 – Calculus of CLAS Aceptance for $\vec{\gamma}p \rightarrow K\Lambda$ Using Linear Polarized Photon Beam

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This poster shows how the CLAS[1] detector aceptance for $\vec{\gamma}p \rightarrow K\Lambda$ was calculated which is study object of g8-experiments that use a Linear Polarized Photon Beam in Hall B at Thomas Jefferson Lab.

Due to solid angle covers by CLAS is less than 4pi and its subsystems have efficiency less than 1, it is necessary calculate the global detector efficiency (aceptance) for each particular reaction. This computation is relevant in order to obtain the differential and total cross sections because is a significant correction of the data.

This work implemented an Event Generator (EG) base on some theoretical models for $\vec{\gamma}p \rightarrow K\Lambda$ reaction. Outputś EG is a set of data that has the same real data format and it becomes inputś GSIM (Geant Simulation), the software that simulates the CLAS behavior. Outputś GSIM gives a set of data which are similar to the real data. This was analyzed getting how many events (from events that were produced by GE), were detected (aceptance) as a function of photon beam energy E_γ and angular distributions of final state particles.

P-NS- 21 – CLAS Aceptance Computation for $gp \rightarrow kL$ Reaction Using a Linear Polarized photon Beam.

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This poster shows how the CLAS* detector aceptance for $gp \rightarrow kL$ was calculated which is study object of g8-experiments that use a Linear Polarized Photon Beam in Hall B at Thomas Jefferson Lab.

Due to solid angle covers by CLAS is less than 4pi and its subsystems have efficiency less than 1, it is necessary calculate the global detector efficiency (aceptance) for each particular reaction. This computation is relevant in order to obtain the differential and total cross sections because is a significant correction of the data.

This work implemented an Event Generator (EG) base on some theoretical models for $gp \rightarrow kL$ reaction. Output's EG is a set of data that has the same real data format and it becomes input's GSIM (Geant Simulation), the software that simulates the CLAS behavior. Output's GSIM gives a set of data which are similar to the real data. This was analyzed getting how many events (from events that were produced by GE), were detected (aceptance) as a function of photon beam energy E_g and angular distributions of final state particles.

*(CEBAF Large Aceptance Spectrometer)

P-NS- 22 – Structure Studies of Heavy Actinium Isotopes

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Since the observation of low-lying $K^\pi = 0^-$ bands in doubly even radium nuclei [1] the possibility that some nuclei have stable octupole deformation has been considered. Numerous experimental and theoretical discoveries were done in the 80's providing extra evidence of reflection asymmetric octupole deformation around A=225. An important feature of static octupole deformation in odd-A nuclei is the observation of parity doublets, i.e. rotational bands with the same intrinsic parameters and spins, but opposite parity lying close in excitation energy.

A survey of the available data for odd-A nuclei reveal that the largest octupole correlations are present in the Ac and Pa nuclei. In particular for the Actinium isotopes the low-energy spectra of ^{223,225,227}Ac display parity doublets and can be described in terms of static octupole deformation. In the case of ^{229}Ac the four $K=1/2^\pm$ and $K=3/2^\pm$ bands are interpreted either as normal Nilsson levels or by assuming a weak octupole coupling.

The study of the upper border of this octupole deformed region is of great relevance in order to understand the interplay of octupole and quadrupole collectivities and to reveal the exact mechanism by which the octupole deformation disappears in the presence of a well developed quadrupole field. Within the IS322 collaboration at CERN we have carried out a systematic investigation of the heavy Fr – Th nuclei [2]. Here we report on the structure of the next odd-Ac isotope, ^{231}Ac, and the heaviest available for spectroscopic studies, the even-even isotope ^{232}Ac.

The low-energy structure of ^{231}Ac and ^{232}Ac populated by β-deccay have been investigated by γ-γ-spectroscopy. Their β-decay schemes have been con-

[1] CEBAF Large Aceptance Spectrometer

structed for the first time and will be presented in this contribution. In the case of ^{231}Ac also conversion electrons were measured and the multipolarities of 22 transitions were established. The Advanced Time Delayed $\beta\gamma\gamma$(t) method [3] was used to measure the half-lives of several levels in ^{231}Ac. The deduced B(E1) rates are used to infer possible presence of octupole correlations. 1. F.S. Stephens, F. Asaro, I. Perlman,

Phys. Rev. 96 (1954) 1568; Phys. Rev. 100 (1955) 1543.
2. W. Kurcewicz, Hyp. Int. 129 (2000) 175.
3. H. Mach, et al., Nucl. Instr. Meth. A280 (1989) 49.

P-NS- 23 – High-spin states in odd-odd ^{168}Tm

Cardona, M. A.,[1, 2, 3] Hojman, D.,[1, 2] Bazzacco, D.,[4] Blasi, N.,[5] Davidson, J.,[1, 2] Davidson, M.,[1, 2] Debray, M. E.,[1, 3] De Poli, M.,[6] Kreiner, A. J.,[1, 2, 3] Lenzi, S. M.,[4] Levinton, G.,[1] Lo Bianco, G.,[7] Martí, G. V.,[1] Napoli, D. R.,[6] and Rossi Alvarez, C.[4]

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High-spin states in doubly odd ^{168}Tm were investigated by means of in-beam γ-ray spectroscopy techniques using the multidetector array GASP of the Laboratori Nazionali di Legnaro, Italy. Excited states of ^{168}Tm, which lies close to the stability line, were populated basically via the incomplete fusion mechanism in the ^{164}Dy(^{11}B,α3n) reaction at a beam energy of 65 MeV. A level scheme is proposed and the band structures are discussed.

P-NS- 24 – High-spin states and deformation properties in ^{187}Pt

Cardona, M. A.,[1, 2, 3] Hojman, D.,[1, 2] Aguilar, A.,[4] Cluff, W. T.,[4] Hinners, T.,[4] Hoffman, C. R.,[4] Lagergren, K.,[4] Lee, S.,[4] Perry, M.,[4] Pipidis, A.,[4] Riley, M. A.,[4] Tabor, S. L.,[4] and Tripathi, V.[4]

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High-spin states in ^{187}Pt have been populated through the ^{181}Ta(^{11}B,5n) fusion-evaporation reaction at E(^{11}B) = 71 MeV. The beam was delivered by the Tandem-LINAC superconducting accelerator at the Florida State University, USA, and γ-rays were detected with an array consisting of 3 clover and 3 single-cristal Ge detectors. Known bands have been significantly extended and new bands have been found. The band structures are discussed.

Posters: Nuclear Reactions

P-NR- 1 – The 3He + 10B reaction study at CMAM (Madrid)

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In the past decade there have been a series of experiments performed at ISOLDE (CERN) to populate by beta-decay resonances in the ^{9}B and ^{12}C nuclei. All levels in ^{9}B are unbound, whereas in ^{12}C the lowest threshold is the triple-alpha threshold at 7.275 MeV. We plan to perform low energy reaction studies to obtain complementary information on the resonant states of these nuclei.

The goal of these experiments is twofold. First, one is interested in simply mapping which resonances exist in the low energy region. This is of fundamental interest in Nuclear Physics where ab-initio calculations now are feasible with empirical nucleon-nucleon interactions up to A=12. Perhaps more important is that astrophysical reaction rates are often determined by nuclear resonances situated close to thresholds. It is therefore important to determine properties of these resonances, such as their energy, width and spin-parity. The study of the ^{3}He + ^{10}B reaction allows us to gain complementary information on both the ^{9}B and ^{12}C structure. In a previous measurement published in 1966 the p + ^{12}C* and α + ^{9}B* channels were identified [1], but the technology at that time was insufficient to fully characterize these processes. The difficulty stems from the fact that the final state in both cases consist of four particles: three alpha-particles and one proton. The technology for detecting such events is now available, and the new tandetron of 5 MV at the CMAM (Madrid) is the ideal machine for this reaction due to its excellent energy stability.

The experimental setup consisted of two DSSSD telescopes of which one had a third Si pad detector to be able to stop up to 21 MeV protons emitted when ^{12}C is created in the ground state. The DSSSD telescopes were situated symmetrically around the target at 90° with respect to the incoming ^{3}He beam covering angles in the lab-frame from 64° to 116° with respect to the incoming beam. The experiment took data during the last week of April. In this contribution the preliminary results of the experiment together with future perspectives will be presented.

1. M.A. Waggoner et al., Nucl. Phys. 88 (1966) 81.

P-NR- 2 – Continuum effects in transfer reactions induced by heavy ions

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In the usual treatment of transfer nuclear reactions the continuum states of the transferred particle are neglected. Here we perform two simplified calculations. In the first the continuum is completely disregarded. The second,although still simplified, treats the continuum in an exact way. The comparison of these two calculations indicates that the influence of the continuum states may be very important for weakly bound reactants.

P-NR- 3 – Reaction-dependent spin population and evidence of breakup in ^{18}O

Hojman, D.,[1] Cardona, M. A.,[1] Arazi, A.,[1] Capurro, O.A.,[1] Fernández Niello, J.O.,[1] Martí, G.V.,[1] Pacheco,A.J.,[1] Testoni, J. E.,[1] Bazzacco, D.,[2] Burlon, A.,[1] Davidson, J.,[1] Davidson, M.,[1] De Angelis, G.,[3] De Poli, M.,[3] Debray, M. E.,[1] Gadea, A.,[3] Kreiner, A. J.,[1] Lenzi, S. M.,[2] Lunardi, S.,[2] Medina, N.H.,[4] Napoli, D.R.,[3] Rossi Alvarez, C.,[2] and Ur, C.[3]

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Angular distributions and angular correlations have been measured for the emission of one and two-α particles in the ^{18}O + ^{207,208}Pb,^{209}Bi reactions at several beam energies above de Coulomb barrier. The results rule out fusion-evaporation as the main reaction mechanism and support the breakup of the ^{18}O projectiles into (^{14}C,α) and (^{8}Be,^{8}Be) before the fusion.

P-NR- 4 – Helicity Dependent Angular Distributions in Three-body Photodisintegration of ^{3}He

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The photodisintegration of ^{3}He in the reaction $\vec{\gamma}\,^3\mathrm{He} \rightarrow ppn$ has been studied at Jefferson Lab Hall B using a circularly polarized tagged photon beam in the energy range between 0.35 GeV and 1.55 GeV. Beam-helicity-dependent angular distributions of the final-state particles were measured. For the first time clear asymmetries have been found in the angular distributions; they are presented in this poster.

P-NR- 5 – QUASIELASTIC ELECTRON SCATTERING ON ^{65}Cu.

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In this work the method to divide an electron scattering spectrum into resonance and quasielastic (QE) parts is proposed. This method is based on the so-called "bin" technique, which has been successfully tested in the energy region where the QE process is absent [1]. The results of the investigation of giant resonances (GR) by means of the inelastic electron scattering depend strongly from the QE background, which should be extracted before analyzing the strength and multipolarity of GR's. At the same time the energy dependence of pure QE cross section is interesting in itself as an object for veri¯cation of different theoretical models of QE electron scattering. Up to now the energy dependence of QE cross section at the energy region of GR is unknown because of impossibility to separate QE part of the spectrum from the resonance part. All testing of different theoretical QE scattering models were carried out at high excitation energies where there are any resonances. The method has been applied to electroexcitation of ^{65}Cu. The experiment was carried out at the LINAC-300 of NSC KIPT. The details of experimental technique being used, methods of scattered electron spectra measuring and obtained data processing can be found in [2]. As a result the transition probability energy dependence was obtained for each multipolarity. There are any resonances at high excitation energy (more than 50 MeV) and the only energy dependence of QE reduced probability is present here. So we consider reduced probability energy dependence for each multipolarity as a sum of GR's and much more broad high-energy maximum corresponding to QE process. The Gaussian function was fitted to each experimental maximum by least square method. The obtained Gaussian shape of the high energy maximum for each multipolarity gives us energy dependence of the QE process. The momentum transfer energy dependence is given by Helm formfactor. So the QE cross section now can be represented as a sum of Helm formfactors with Gausian amplitudes. The QE peak was obtained for 11 spectra of inelastic electron scattering within the transferred momentum range from 0.5 to 1.4 fm^{-1}. The accuracy of QE curve determination in all excitation energy intervals is better than 15%.

1. V.V. Denyak, V.M. Khvastunov et al., Physics of Atomic Nuclei, 2004. V.67. P.882.
2. G.A. Savitsky, V.A. Fartushny, I.G. Evseev et al., Sov. J. Nucl. Phys. 1987. V. 46. P. 29.

Posters: Nuclear Physics Applications

P-NPA- 1 – Evolution of ion Track Profiles in SiO2

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The folding track replica method is applied to analyse the extension and shape characteristics of track profiles in SiO2- Si wafer, with beams of 118 MeV 197Au ions. The shape evolution characteristics of track profiles on the SiO2 layers, along the projectile trajectory, are analysed up to the SiO2-Si interface zone.

P-NPA- 2 – Pigments elementary chemical composition study of Gainsborough attributed painting employing a portable X-ray fluorescence system

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The investigated painting, identified with the title "The woodman", is attributed to Thomas Gainsborough (XVIII century) and is under investigation at the Laboratory of Conservation Science (LACICOR), CECOR/EBA/UFMG. The measurements were carried out with a portable X-rays fluorescence (XRF) system constituted of a X-rays tube with Ag anode, a Si PIN – diode detector, nuclear electronic chain and a special designed mechanical system for the detector and X-ray tube positioning, that enables angular and XYZ movements of the excitation-detection system. The employed voltage and current intensity were 17 kV and 3 μA, respectively. The time of acquisition for each measurement was 500s. XRF spectra were analyzed using the AXIL-WinQXAS software. Three measurements in each of the following regions of the painting were done: face, leaves, arm, sky and firewood. The carried out analysis indicated the following pigments: White (lead white and calcium sulfate, identified by the elements Pb, Ca and S), Blue (Prussian blue, identified by the key element Fe), Red (Vermilion, identified by the elements Hg and S) and Brown (mixture of Fe and Mn oxides, identified by the elements Fe and Mn). Elements belonging to modern pigments corresponding to the same colors were absent in the analyzed spectra.

P-NPA- 3 – Experimental and simulation studies of a neutron production target for boron neutron capture therapy at the Tandar accelerator.

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In this work we studied an optimized neutron production target including a beam shaping assembly to be used for thermal and epithermal Accelerator-Based Boron Neutron Capture Therapy (AB-BNCT). The neutrons were produced through the ^{7}Li(p,n) ^{7}Be reaction which has a pronounced resonance of 582 barns at 2.25 MeV. To maximize the neutron production and at the same time keep the maximum energy of the neutron spectrum at an acceptable low value it is convenient to use a proton beam of an energy slightly higher than 2.25 MeV. Since the Tandar accelerator was not designed to deliver such low energies implied in BNCT, we worked with a 6.5 MeV proton beam (3.25 MV terminal voltage). This beam was degraded to an average energy of 2.4 MeV by passing it through a 78 μm thick Ta foil and subsequently made to bombard a thick LiF target. The resulting neutrons were moderated by using an assembly consisting of slabs of Al, polytetrafluoroethylene (PTFE) (commercially known as Teflon) of 15 cm x15 cm and a total length of 34 cm including slabs of LiF as a thermal neutron shield. The target and moderator were surrounded by a reflection mantle composed mainly of lead and some graphite with the aim of collecting the largest possible number of fast neutrons produced. At the output port of the assembly we installed a simplified water-filled acrilic head phantom. The neutron flux in and around the phantom was determined by the foil activation method using different materials sensitive to different energy portions of the neutron spectrum (Au, W, In, Co, Cu). Finally the experimental results were compared to the values obtained by simulation with the Monte Carlo method (MCNP).

P-NPA- 4 – In vivo evaluation of Fe in human skin employing X- Ray Fluorescence Methodology (XRF)

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Recent technological improvements allow the method of in vivo XRF to provide useful sensibility for diagnostics or monitoring in biomedical applications. In cases of hereditary sanguine disorders as the β-Thalassemia or a genetic disorder like Haemochromatosis, there is a high concentration of elements as Fe, Zn and Cu in the skin and internal organs, due to the treatment of those abnormalities or due to the own dysfunction caused by the disease. The levels of Fe related to the patient bearers of the β-Thalassemia are determined, at the moment, measuring a protein in the sanguine current, called ferritin. The monitoring of the protein is ineffective in several situations, such as when the patient suffers any disturbance of health. Nowadays, the main forms of measuring the levels of those metals through hepatic storage are the biopsy of the liver, that is invasive and potentially dangerous, presenting a rate of mortality of 0,1%, and through magnetic susceptibilities that employs a quantum superconductor, which is highly expensive and there are only three main world centers with this equipment. This work investigates the use of a Si PIN-diode detector and a 238Pu source (13 and 17keV; 13%; 95.2mCi; 86y) for the measurement of Fe skin levels compatible with those associated to the disease β-Thalassemia. XRF spectra were analyzed using a set of AXIL-WinQXAS programs elaborated and disseminated by the IAEA The correlation coefficient of the calibration model (sensitivity curve) was 0.97. Measurements on skin phantoms containing concentrations of Fe in the range from 10 to 150 parts per million (ppm), indicate that we are able to detect Fe at levels of the order of 15ppm, using monitoring periods of 50 seconds and skin entrance dose less than 10 mSv. The literature reports skin Fe levels from 15.0 to 60.0 ppm in normal persons and from 70 to 150 ppm in thalassaemic patients. So, the employed methodology allows the measurement of the pretended skin Fe concentration.

P-NPA- 5 – Stopping Power of Gold for Titanium and Copper Ions at Low Velocities

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The energy loss of ions in materials is an important issue not only because of its direct applications for analytic techniques of materials but also for studying the basics of ion-atom interactions. Nevertheless, the Stopping Power of solids for heavy ions is still poorly known. Since ab initio calculations are unable to produce reliable quantitative estimates, most of the predictions currently in use are of a semiempirical nature. This is especially true at low velocities due to the rapid changes in the charge state of the slowing ions and to complicated dependence on the atomic numbers of the stopper medium and of the stopping ion. An accurate knowledge of the stopping power in this low velocities region is necessary in many experimental techniques like ion implantion, surface analysis, etc. Also in nuclear physics, with the Doppler Shift Attenuation Method [1], the knowledge of the stopping force as a function of the velocity of the recoiling excited nucleus is used to determine the timescale for the nucleus decaying in flight while slowing down in a heavy substrate, usually Au or Pb.

The main aim of this work is to present new experimental data for Titanium and Copper ions slowing down in an Au foil in the velocity range $0,02c - 0,04c$, where c is the light velocity. Experimental data were obtained using the elastic scattering technique [2], where a primary beam of ^{16}O and ^{28}Si, with energies from 35 to 52 MeV and 49 to 79 MeV respectively, were used to scatter Ti and Cu ions from a thin target ($\sim 100\,\mu g/cm^2$). The scattered primary beam is detected at 60° by a Si detector, producing recoiling atoms of the target in an angle given by elastic scattering kinematics. The recoiling ions in temporal coincidence with scattered primary beam will compose the secundary beam. The energy loss, in a gold foil with thickness about $520\,\mu g/cm^2$, was obtained by measuring the energy of the secundary beam with a Si detector, with and without the Au foil intercepting the recoiling ions. The detector's calibration is done by means of a Monte Carlo program where the energy lost by primary beam and recoiling ions within the thin target is taken in account following the formalism described in [3]. Our experimental data were compared with most used programs applied in this case. In general, predictions given by those programs overstimate the stopping power of gold target.

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P-NPA- 6 – Accumulation and Long Term Behavior of Radiocesium in Tropical Plants

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In recent years, there has been a growing interest in the evaluation of nutrient fluxes and radioactive contaminants in forest and agricultural ecosystems.

Several studies on forest ecosystems have been carried out, mostly in Europe, after the Chernobyl accident. Japanese forest sites and native plant species of the Marshall Islands have also been extensively investigated. These studies have been used for various purposes, including the development of models for predicting plant concentrations from soil concentration measurements or the long term of dietary contamination by radiocesium following a fallout nuclear. Cesium is an alkali metal just like potassium and its behavior in nature, as well as in the human body, is similar to that of potassium.

Uptake of ^{137}Cs from contaminated soil represents a significant pathway of human radiation exposure, either due to the direct consumption of cereals, fruits and vegetables or, indirectly, following consumption of milk and meat from animals fed on contaminated vegetable matter. The decline of ^{137}Cs levels as function of time of fruit trees is of interest given its long life in the field. Therefore, the cesium behavior is important in the design of management strategies to mitigate any negative health effects of radioactivity on the environment. It is also important to apply the current knowledge of the transport and distribution of salts derived from forest ecosystems in agricultural ecosystems, especially for tropical fruit trees. So far, in the South hemisphere there have been only a few studies on this subject, without conclusive results.

With this aim, the Laboratory of Radioecology (LARA) of the Universidade Federal Fluminense has been performing analyzes of ^{137}Cs and ^{40}K concentrations in several tropical plants (guava, mango, avocado, pomegranate, papaya, manioc and chili pepper trees) in order to determine the accumulation of these radionuclides throughout these trees and the long term behavior of radiocesium. These trees were planted at one site that was contaminated by ^{137}Cs due to a radiological accident occurred in the city of Goiânia, Brazil, in 1987. Longitudinal and radial distributions of ^{137}Cs and ^{40}K for these trees were obtained. In particular, the study of biological half-life due to ^{137}Cs translocation from the tree reservoir performed in this work indicate that its values are of the order of months, calling the attention to the importance of such information in the reclaiming of agricultural ecosystems after a nuclear fallout.

P-NPA- 7 – Energy dispersive X Ray Fluorescence from useless tires samples with a Si – PIN detector

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The concentration of Zn from discard tire samples is of environmental interest, since on its production are used S for the rubber vulcanization process, and ZnO as reaction catalyze. The useless tires are been used for asphalt pave, burn in cement industry and thermoelectric power plant and in erosion control of agriculture areas. Analyses of these samples requires frequently chemical digestion that is expensive and take a long time. Trying to eliminate these limitations, the objective of this work was use Energy Dispersive X Ray Fluorescence technique (EDXRF) with a portable system [1] as the technique is multi elementary and needs a minimum sample preparation. Five useless tires samples were grind in a knife mill and after this in a cryogenic mill, and analyzed in pellets form, using a X ray mini tube (Ag target, Mo filter, 25 kV/20 μA) for 200 s and a Si-PIN semiconductor detector coupled to a multichannel analyzer[2]. Were obtained Zn concentrations in the range of 40.6 to 44.2 μg g^{-1}, representing nearly 0.4

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P-NPA- 8 – EMPREGO DA REGIÃO DE SENSIBILIDADE NA TÉCNICA DE RADIOTRAÇADORES

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O registro de maneira eficiente e correta dos fótons incidentes e coletados por um detector submerso é de fundamental importância para o estudo de um tanque industrial de grandes dimensões. No instante em que o material radioativo é inserido no sistema em estudo, logo se forma uma nuvem radioativa que se aproxima do detector ocorrendo um aumento considerável do número de fótons incidentes, pois tanto o ângulo sólido como a concentração do traçador varia com o tempo. Para isso foi feita uma simulação utilizando uma fonte padrão plana de ^{137}Cs e um detector cintilador NaI, onde um tanque industrial foi dividido em três planos: superior, intermediário e inferior e em cada plano foram fixados 12 posições ao longo da extensão do tanque, com a posição zero definida como sendo a que o detector e fonte estão colinear. A variação da distância entre as posições foi de 7,8 cm. Os resultados do ângulo sólido usando o método numérico de Simpson foi validado por uma simulação feita pelo método de Monte Carlo, onde foram considerandos fatores como: raio da fonte, do detector e as geometrias associadas a eles. O erros associados aos dois métodos variaram entre 1,5 por cento e 5 por cento.

P-NPA- 9 – CHARACTERIZATION OF AEROSOL PARTICLES FROM BUENOS AIRES CITY AND ITS SUBWAY SYSTEM: macroPIXE, microPIXE AND SEM/EDX

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Total suspended particle (TSP) samples have been collected at two sites of Buenos Aires City (34^o 34´S, 58^o 31´W). One site placed outdoors of the TANDAR Laboratory, and the other one at an underground subway station in central Buenos Aires. A conventional PIXE (macroPIXE, Particle Induced Xray Emission) analysis was performed on aerosol samples in order to determine metal and non-metal (Cl, S, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Br, Pb) bulk levels. Individual particles were analysed by scanning microbeam PIXE (microPIXE) to gather information on the microdistribution of its elemental composition. In both cases, ^{16}O (5$^+$) projectiles at 50 MeV energy, provided by the TANDAR tandem accelerator, were used. These studies were complemented with SEM (Scanning Electron Microscopy) images and EDX (Energy Dispersive X ray) analysis. All this information, in addition to meteorological data obtained during the sampling period, was used to infer the most probable sources of aerosol particles.

P-NPA- 10 – Analysis of a Brazilian painting using PIXE

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The Laboratório de Análise de Materiais por Feixes Iônicos-LAMFI of the Institute of Physics of the University of São Paulo has been installed an external beam facility for PIXE analysis. This new setup is being used for the analysis of archeological pottery artifacts, paintings and biological tissues (teeth and bones), which are not compatible with the high vacuum of the regular PIXE target chamber. Applications of this facility will be presented in the analysis of a Brazilian painting of the beginning of the last century. The painting has 460 mm length e 185 mm width on a wood support. The PIXE analysis were done with a 2.4 MeV proton beam and an exit window made of a 7.5 μm thick Kapton foil. Due to the 10 mm air path and the Kapton exit window the final beam energy which reach the painting was approximately 2.2 MeV. Typical beam currents used to analyze the painting were about some nA to keep dead time and pile-up low and to prevent painting damage. The painting was horizontally laid over at approximately 10 mm from the exit window. An Al collimator of 0.3 mm diameter limited the analyzed area and was positioned just after the external Kapton foil. PIXE measurements were made on 12 selected points 6 - 8 mm from the boarder. The PIXE painting analysis at several points gives us an idea about the elemental composition of some colors and pigments used by the author. Several elements were identified in the painting and were correlated with the colors. Elements as Fe, Zn and Pb are frequently visible through strong peaks in PIXE energy spectra; however elements as Ca, Ti, Cr, Ba and Cu are in less intensity.

P-NPA- 11 – Nuclear Fragmentation in Protontherapy

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The aim of conformal radiation therapy is to deliver the dose as high and as uniform as possible to diseased tissue sparing all the other parts, that is healthy and critical tissues, without causing unwanted and unnecessary side effects for the patient. Difficults to achieve this goal start with the determination of the three-dimensional volumes of interest and end up in realizing a three-dimensional uniform and maximal as possible, the dose distribution. The technique of intensity-modulated radiotherapy (IMRT) as form of conformation in radiation therapy is a real revolution. One of the newest attempts in this field, which reaches to have a great success, is the use of multi-leaf collimators (MLC). But it is not the unique new technique. In fact the use of therapeutic ions, especially carbon ions and protons is the technology of the actual future which is really the challenge in conformation of dose to targets, thanks to energy deposition characteristics of hadronic beams. Besides the atomic energy loss, the proton induces nuclear fragmentation which generates other smaller nuclei at almost zero kinetic energy plus secondary protons of 2/3 of the incident proton energy. The effect of nuclear fragmentation in the passage of 180MeV protons through the human body tissue is discussed.

P-NPA- 12 – An algebraic reconstruction algorithm applied to transmission X-ray and micro PIXE tomography with few projections

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A number of nondestructive or noninvasive studies applied to material and life sciences involve the use of tomographic reconstruction from projection images. These approaches have mainly been developed in the field of medical imaging, giving origin to several modalities such as X-ray computed tomography (CT), single photon emission tomography (SPECT), positron emission tomography (PET) and magnetic resonance imaging (MRI). On the other hand, some analytical tools for materials science based on accelerated charged particle beams such as PIXE (Particle Induced X-ray Emission) and STIM (Scanning Transmission Ion Microscopy) have been used with particle microbeams, opening the possibility to perform localized analysis at the micron scale on small samples. The information obtained from these techniques is integrated along the beam direction producing two-dimensional projection images of the sample under study. These projections can be reconstructed in order to give micro PIXE or micro STIM tomographic imaging capability. In medical or in microtomography applications, there are many cases of practical interest where it is not possible to acquire enough number of projections for applying analytical reconstruction methods. For these cases, special algebraic reconstruction algorithms have been developed, e. g. ART (Algebraic Reconstruction Technique). In this work we present a C++ implementation of an ART algorithm for application in problems with limited number of projections. Specifically we study its performance on radiological and micro PIXE data. The first one consists of phantom projections obtained with a radiological system used in medical diagnosis. Secondly micro PIXE data were acquired with the microbeam facility of the Tandar Laboratory (Comisión Nacional de Energía Atómica, Argentina).

P-NPA- 13 – NON DESTRUCTIVE NUCLEAR ANALYSIS OF ART AND ARCHEOLOGICAL OBJECTS

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The conservation and preservation of cultural heritage is becoming an important topic of research at the moment. The analysis of art and archaeological objects opens some unique opportunities for studying ancient civilizations. Some art and archaeological pieces are unique, and it can be of great value trying to understand the culture behind it. Ion beam analysis for the study of artworks and archaeological artifacts was a great push for the development of the PIXE technique in the early seventies. Non-destructive ion beam analysis was successfully improved with in air analysis for large sized or fragile art objects. Ion beam analysis of organic and volatile samples, archeological pottery artifacts and paintings are by now also possible at the external beam facility of Laboratório de Análise de Materiais por Feixes Iônicos (LAMFI-USP). Open-air PIXE analysis was applied for the study of some archaeological artifacts from the Museum of Archaeology and Etnology of the University of São Paulo (MAE-USP). The main objective was to characterize the corrosion products at some metallic objects from MAE´s collection. PIXE analysis allowed identifying major and some secondary components in the alloys and in the corrosion products on the samples. Data also allowed the identification of the corrosion mechanisms and the corrosion agents in the exhibition environment and helped setting up new standards for the conservation of the museum´s collection. The external PIXE setup is also being used for the analysis of paintings where several elements were identified and correlated with their respective colors and pigments.

P-NPA- 14 – Energy measurements in a prototype proton CT scanner

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The use of protons instead of X-rays for computed tomography (CT) studies has potential advantages, especially for medical applications in proton treatment planning. A Proton computed tomography (pCT) prototype system is under development, in order to perform treatment planning for proton therapy, instead of X-ray CT. The prototype pCT detector consists of a combination of a proton tracking system and an energy detector capable of respectively measure the position and the residual energy of individual protons with a high degree of spatial and energy resolution. In order to provide highly accurate maps of relative electron density for proton treatment planning, proton CT requires accurate measurement of the energy loss of protons passing through the object. In preparation for the development of a prototype proton CT scanner, we have studied the response of CsI(Tl) crystals to protons in the energy range from 40 MeV to 250 MeV. This scintillator material is a good candidate for use in proton calorimetry related to proton CT. The energy resolution in the energy range studied was found to be comparable or better than the energy spread due to multiple Coulomb scattering in medical imaging objects. Work supported by CNPq, CAPES and Fundação Araucaria.

P-NPA- 15 – Gamma and proton irradiation of plasmid DNA pBKS

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Ionizing radiation causes DNA damage, inducing Single and Double-Strand Breaks. The strand breaks may be generated directly by radiation in DNA or by the radicals produced by radiolysis. We studied the induction of SSB and DSB in DNA pBluescript II (pBKS) in aqueous solution under different conditions of concentration, scavenging capacity, and dose. Firstly, plasmid DNA was irradiated with gamma rays. SSB and DSB yields were quantified by agarose gel electrophoresis. The results were compared to literature values. After, others samples were irradiated with 10MeV protons. The preliminary results showed an inverse relation between the scavenging capacity and the SSB and DSB yield, these values decreasing with the increasing of scavenger concentration. These results show that secondary radiation products had an important role in DNA- ionizing radiation interaction. Variation in SSB and DSB yield in relation to DNA concentration in aqueous solution was less significant than in relation to the scavenging capacity change. This experiment will provide new informations about DNA irradiation with protons.

P-NPA- 16 – A Radiographic Technique with Heavy Ion Microbeams

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The use of particle microbeams is well established and extended throughout the world. A number of analytical techniques are being utilized in these facilities like PIXE and STIM. The first of these techniques allows the performance of multielemental analysis of samples and the second one gives densitometric information, both with about 1 micron spatial resolution. To characterize trace elements quantitatively it is necessary to combine both techniques. This is cumbersome, because it requires two independent experiments for each sample, with conflicting requirements. PIXE needs high ion currents to enhance the production of X-rays induced, and STIM low currents, to spare the silicon surface barrier detector. In this work, we introduce a new technique to perform densitometric and multielemental analysis of samples at the same time using only one detector. It consists in the simultaneous analysis of the X-rays induced in the sample and its own radiography produced by an X-ray source induced in a secondary target arranged behind it. By selecting conveniently the secondary target it is possible to distinguish the two sources. With the aim of doing this selection we have studied different configurations of secondary targets by means of computer simulations. In this report these simulations are presented and compared to recent experimental results, obtained with the heavy ion microprobe at the Tandar Accelerator of the Argentine Atomic Energy Commission.

P-NPA- 17 – Radioisotope neutron activation analysis of cryolite-alumina solutions

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A new procedure, with minimum sample preparation, has been developed for a fast, serial analysis of cryolite with varying concentrations of dissolved alumina by neutron activation analysis (NAA) making use of a radioisotope source. The analysis supplies the sodium/aluminium ratio of Hall-Herault reduction cell specimens at a rate of one analysis every 10 minutes. The compact analyzer contains a (98Cf252) radioisotope source graphite-moderated which supplies the thermal neutron flux for irradiation during a period of 3 hours of 250 g solid samples directly taken from the cell. Activated samples are measured by a BGO-scintillation-detector gamma ray spectrometer. Relative alumina concentration is obtained from a calibration curve derived with the use of standardized samples.

P-NPA- 18 – Tracks registration of cosmic ray and neutron induced nuclear reaction with CR-39 and its implication in astronautical dosimetry

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CR-39 passive track detectors are excellent technique for charged particle registration. This has found application in studies of the primary galactic cosmic rays (GCR) and secondary particles to which personnel of the International Space Station (ISS) may be exposed. Latent tracks formed during the absorbed incident particle or related to beam spallation are visualized either by atomic force microscope or after etching by a light transmission optical microscope; in both cases the damaged zone produce information on the absorbed energy, direction and mass. We present a set of tracks induced by a large variety charged particle including HZE and its interpretation with the purpose to determine the incident beam characteristics. PADC's tracks calibrations were obtained exposing CR-39 to a high-energy neutron reference field (CERF Geneva, Swiss) and high-energy proton (Loma Linda, CA, USA). A set of CR-39 were exposed inside the Service Module, Zvezda, ISS in different missions; later they were analysed by multiple track etching technique (2 to 20 h etching time) to obtain track geometrical parameters. From the data base collected, the secondary neutron dose and the LET were deduced.

P-NPA- 19 – 3-D Digital Image Reconstruction of Nuclear Tracks Induced in CR-39 Detectors

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A method for object volume reconstruction based on the image capture of only one off–axis hologram is discussed. This technique is developed to obtain quantitative information from the intensity and the phase distributions of the reconstructed image at different locations along the propagation direction. The potentialities of digital holography microscopy for 3–D image reconstruction of nuclear tracks induced in CR–39 detectors are presented. The micro-holographic method developed in this work constitutes an alternative procedure for three-dimensional analysis of nuclear tracks, which includes advantages in cost and technological simplicity. This visualization technique provides a new, non-destructive way to analyze 2D and 3D geometry of etched tracks in SSNTDs to complement existing optical microscopy methods. Digital holography is a very useful tool to study track formation and etching mechanism of tracks in detectors.

P-NPA- 20 – Planar waveguide fabrication in $NbLiO_3$ using MeV O^{2+} and O^{3+} ion implantation

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$LiNbO_3$ crystals were implanted at room temperature with MeV-range O^{2+} and O^{3+} ions at different energies (at 5 and 13 MeV respectively) and fluences (ranging from 1.0 x10^{14} to 2.0 x10^{14} O/cm2). The results show that according to the LET (Linear Energy Transfer) of the ^{16}O ion beam, the irradiated material presents two different kinds of damage: near surface damage (corresponding to the "plateau" region of the Bragg curve) related to electronic stopping power with increment of the refraction index and end-of-range damage (corresponding to the Bragg peak) related to nuclear stopping with a decrease of refraction index. After annealing at 230 ^{o}C for 40 min., the near surface damage is fully recovered. The obtained

planar waveguides were characterized by the prism-coupling method. The reflectivity calculation method (RCM) was applied to simulate the refractive index profiles in waveguides.

P-NPA- 21 – Contribution of nuclear reaction secondary particles to the absorbed dose in tissue. A Monte Carlo evaluation.

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In this work the MCNPX and FLUKA codes are used to survey the influence of proton induced nuclear reaction secondary products on the deposited dose in different biological tissue equivalent materials. Proton broad beams, as well as pencil-beams with energies ranging from 100 to 250 MeV were simulated. Depth and radial dose distribution from the beam axis were determined. A method to differentiate primary and secondary protons by means of both codes was performed. According to our results, the absorbed dose in these materials is mainly due to the incident primary protons, while the secondary protons are the major contributors between the secondaries produced by non-elastic nuclear reactions. We show that the yield of secondaries strongly depends on the beam shape and the incident energy.

P-NPA- 22 – Applications of the gamma detection technique in environmental sciences.

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Ultra-low background gamma-detection systems represent a powerful tool to measure radioisotopes commonly present in environmental samples. In this paper we discuss two different applications of this technique that are been carried out in our laboratory. In the first case, we present measurements on concentrations of ^{210}Pb and ^{137}Cs in samples collected from a river located in the argentine province of Buenos Aires in order to determine the rate of sediment accumulation of the site. The second case deals with an attempt to develop a possible way for the bioremediation of uranium contaminated effluents. We investigate the adaptation of the bacteria *Acidithiobacillus thiooxidans* to high uranium concentrations and its potential use as catalyst for the reduction/precipitation of this element. In this case, the quantitative determination of the uranium present in liquid and solid samples is done by means of the gamma-ray identification of the products stemming from the decay of ^{235,238}U.

P-NPA- 23 – Evaluation of Fe employing X-Ray Fluorescence Methodology (XRF) in mice skin during acute phase of experimental infection with *Trypanosoma cruzi*

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Recent technological improvements allow the method of in vivo XRF to provide useful sensibility for diagnostics or monitoring in biomedical applications. One potential application involves monitoring of Fe in human skin with hereditary blood disorder as β-thalassaemia and another ailments that request invasive methods for diagnostic but they are high undesirable. In addition, many systemic infections provoke a host hypoferremic response that reduces the level of Fe in the in the plasma transferring iron pool and thus limits the availability of extracellular Fe. *Trypanosoma cruzi* is protozoan parasite causing widespread human disease in Latin America, known as Chagas' disease. C57BL/6 Mice (resistant to infection) when infected with *T. cruzi* had a biphasic hypoferremic response. Treatment of those mice with exogenous Fe enhanced the mortality rate of *T. cruzi* infection, whereas depletion of iron was protective. This work investigates the use of a Si PIN-diode detector and a 238 Pu source (13 and 17KeV; 13%; 95.2mCi; 86.v) for measurement of Fe skin levels from susceptible Swiss mice infected with *Trypanosoma cruzi* (Strain Y). XRF spectra were analyzed using a set of AXIL-WinQXAS programs elaborated and disseminated by the IAEA. The correlation coefficient of the calibration model (sensitivity curve) was 0.97. Measurements on skin mice phantoms containing concentrations of Fe in the range from 10 to 150 parts per million (ppm), indicate that we are able to detect Fe at levels of the order of 8 ppm, using monitoring periods of 100 seconds and skin entrance dose less than 6 mSv. Preliminary measurements on skin from susceptible infected mice suggest that the pathogenicity

of the *T. cruzi* correlated with its growth rate and with the amount of Fe available by XRF. So, the employed methodology allows the measurement of the pretended skin Fe concentration during experimental Chagas' disease.

P-NPA- 24 – Gamma Radiation Measurements in Brazilian Commercial Granites

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Gamma radiation from radionuclides which are characterized by half-lives comparable to the age of the earth, such as ^{40}K and the radionuclides from the ^{238}U and ^{232}Th series, and their decay products, represent the main terrestrial source of irradiation to the human body. Their concentrations vary for different types of rocks, where high radiation levels are associated with igneous rocks such as granite.

Thorium, uranium and potassium concentrations of granitic rocks are intimately related to their mineral compositions and general petrologic features. Then, these features associated with effects of weathering and metamorphism produce expressive alterations in the relationship between the natural radionuclides (Th, U, K, Th/U and Th/K). Consequently, the measurements of thorium, uranium, and potassium concentrations of different granite samples result on individual differentiation sequences. From the ^{232}Th, ^{238}U and ^{40}K activity concentrations obtained for each sample, it is possible to evaluate their respective dose rates in air, when these stones are used as tiling rocks. These results are of great interest in the environmental radiological protection study, since granites are widely used as building and ornamental materials, including as indoor covering.

In this way, the Laboratory of Radioecology (LARA) of the Physics Institute of the Universidade Federal Fluminense (IF-UFF) has been performing analyzes on more than one hundred different types of the main Brazilian commercial granites in last two years. Using NaI and HPGe gamma-ray spectrometers to determine the concentration of natural radionuclides in these samples, the annual effective dose rates and the gamma activity concentration index have been evaluated and compared to the limits proposed by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and European Commission (EC). In addition, the correlations between thorium, uranium and potassium have been obtained with the aim of correlating the petrographic characteristics of commercial granites with their corresponding dose rates for natural radioactivity. Our results show, contrary to what some works have reported in international literature, that the Brazilian granites are not composed by minerals which could produce high levels of dose rates when used as covering material.

P-NPA- 25 – Preliminary Calibration of a Multi-catheter Apparatus for Brachytherapy Treatments

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Brachytherapy is an outpatient, short time, dose radiation oncology treatment procedure. In the case of prostate cancer, there exist two modalities: high dose rate (HDR), where a high activity source (12 Ci) is brought to or near the tumor for a few minutes every day for about 5 days, and low dose rate (LDR), where a low activity source, referred to as seed, (20 mCi) is implanted and left within the patient. The procedure consists primarily of transporting a radioactive source to the tumor site via a catheter.

When the catheter is inserted in the patient, the source is moved forward by a computer controlled stepping mechanism called an after-loader. The position of the source inside the patient is determined post-treatment by pre-calibration of the system. Presently, the exact position of the source within the catheter and the effective dose received by the patient during treatment is not known.

Our research has lead to the construction of an apparatus employing catheters that detect radiation coming from the source. By a suitable correlation between the detected signal and the source position, one is able to reconstruct the 3D dose distribution delivered in real time.

Our preliminary results come forth by placing a 25 mCi 90Sr source at different positions with respect to our apparatus and a definitive different signal shape has been observed for each position of the source.

Before the data was analyzed, we performed different measurements to calibrate our apparatus. The apparatus configuration, the calibration procedures and the data results will be discussed.

P-NPA- 26 – ^{222}Rn INDOOR CONCENTRATION MEASUREMENTS RELATED TO CONSTRUCTION MATERIALS

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Considering that the indoor radon inhalation by humans has been found as the main source of radiological hazard [1] and probably the second most important cause of lung cancer after smoking [2], many countries have put considerable efforts into direct estimates, measurements and monitoring of radon exposure. In this report we present the results of ^{222}Rn concentration measurements and preliminary correlation analysis of these data with used construction materials. For this purpose several dozens of Lexan track detectors were exposed in the air (indoor as well as outdoor) during two months within the central region of Curitiba and Campo Largo (PR, Brazil). This exposition time was chosen to prevent possible saturation of alpha tracks. For the purpose of track revelation [3], it was build the electrochemical cell that permits to work simultaneously with 20 polycarbonate passive alpha track detectors. Visualization, identification and counting of alpha tracks were accomplished using MATLAB programming tools. Achieved results are compared with other experimental data. This work is supported by CNPq and CAPES.

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P-NPA- 27 – Evaluation of Particle Trajectories in Proton Computer Tomography.

Denyak, V.V.,[1] Paschuk, S.A.,[1] Schelin, H.R.,[1] Setti, J.A.P.,[1] Klock, M.C.L.,[1] Pashchuk, A.,[1] Evseev, I.,[2] Yevseyeva, O.,[2] and Mesa, J.[3]

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At the present time proton computer tomography is in a growing process in contrast to the well known X-ray computer tomography. The possibility of constructing such device for medical purposes was shown twenty years ago [1, 2]. The actual interest to this subject is due to the successful development during the last decades of micro-strip detectors, which makes it possible to register with high precision the spatial position and output angle of each proton passing through the object. The quality of tomographic image depends strongly on the accuracy of the proton trajectory determination. Unfortunately the process of proton interaction with matter differs significantly from the case of photon, and there is no simple relation between proton output characteristics and its trajectory in the object. Due to Coulomb multiple scattering the last one is very complex and depends on a number of random parameters. This problem was considered on the base of the Fermi theory of particle interaction with matter [3, 4] and the formula of spatial distribution in an object for particles with output parameters is obtained. The formula has been applied to the specific case of proton tomography for medical purposes and the estimations of particle spatial distribution for various possible registration methods have been considered.

1. Computed Tomography Using Protons Energy Loss. K.M. Hanson, J.N. Bradbury, T.M. Cannon, R.L. Hutson, D.B. Laubacher, R.J. Macek, M.A. Paciotti, and C.A. Taylor, Phys. Med. Biol., 1981, Vol.26, No.6, 965-983.
Proton Computed Tomography of Human Specimens. K.M. Hanson, J.N. Bradbury, R.A. Koeppe, R.J. Macek, D.R. Machen, R. Morgado, M.A. Paciotti, S.A. Sandford, and V.W. Steward, Phys. Med. Biol., 1982, Vol.27, No.1, 25-36.
2. Proton Computed Tomography with a 250 MeV Pulsed Beam. Y. Takada, K. Kondo, T. Marume, K. Nagayoshi, I. Okada, and K. Takikawa, Nucl. Instr. Meth A 273 (1988) 410-422.
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Posters:Subnuclear Physics

P-SP- 1 – Testing QCD sum rules in a dense hadronic medium, within hadronic field models

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The compatibility of QCD sum rules and effective hadronic models are examined, for this purpose we take as input the nucleon self-energy provided by different QCD sum rules calculations. They are immersed in a theory of hadronic fields giving rise to non-linear interactions. Nuclear observables are evaluated consistently and compared with the nuclear phenomenology.

P-SP- 2 – Neutrino oscillations: Measuring theta-13 including its sign

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In neutrino phenomenology, terms in the oscillation probabilities linear in $\sin\theta_{13}$ lead naturally to the question "How can one measure θ_{13} including its sign?" Here we demonstrate analytically and with a simulation of neutrino data that $\mathcal{P}_{e\mu}$ and $\mathcal{P}_{\mu\mu}$ at $L/E = 2\pi/\Delta_{21}$ exhibit significant linear dependence on θ_{13} in the limit of vacuum oscillations. Measurements at this particular value of L/E can thus determine not only θ_{13} but also its sign, if CP violation is small.

P-SP- 3 – Strong decays of excited baryons in Large N$_c$ QCD

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We present the analysis of the strong decays widths of excited baryons in the framework of the $1/N_c$ expansion of QCD. These analysis are performed up to order $1/N_c$ and include both positive and negative parity excited baryons.

Posters:Nuclear Thermodynamics and Dynamics

P-NTD- 1 – Some theoretical considerations on the nuclear caloric curve

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We present several theoretical implications for the nuclear caloric curve in the intermediate energy. These include connections, if any , with nuclear phase transition, order of phase transition, relationship with equilibrium etc.

P-NTD- 2 – Geometrical Aspects of Isoscaling

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The property of isoscaling in nuclear fragmentation is studied using a simple bond percolation model with "isospin" added as an extra degree of freedom. It is shown analytically, first, that isoscaling is expected to exist in such a simple model with the only assumption of fair sampling with homogeneous probabilities. Second, numerical percolations of hundreds of thousands of grids of different sizes and with different N to Z ratios confirm this prediction with remarkable agreement. It is thus concluded that isoscaling emerges from the simple assumption of fair sampling with homogeneous probabilities, a requirement which, if put in the nomenclature of the minimum information theory, translates simply into the existence of equiprobable configurations in maximum entropy states.

P-NTD- 3 – Dynamical aspects of fragmentation

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The process of fragmentation of highly excited Lennard-Jones drops is studied in terms of the emission of quasi-stable fragments. We focus on the dynamics and thermodynamics of the emitting sources, and show, among other things, that this kind of process is a mixture of sequential and simultaneous events, that simultaneous events have a broad time distribution, and we show how a local equilibrium scenario comes up on top of expanding collective motion, allowing us to define and explore a local temperature, which turns out to be a strongly time-dependent quantity, signaling that we are facing an out of equilibrium process.

P-NTD- 4 – Isospin fluctuations in spinodal decomposition

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The isospin dynamics in fragment formation has been studied within the framework of an analytical model based on the spinodal decomposition scenario. The probability to obtain fragments with given charge and neutron number has been calculated, focussing on the derivation of the width of the isotopic distributions. Within our approach this is determined by the dispersion of N/Z among the leading unstable modes, due to the competition between Coulomb and symmetry energy effects, and by isovector-like fluctuations present in the matter that undergoes the spinodal decomposition. Hence the widths exhibit a clear dependence on the properties of the Equation of State (EOS). By comparing two systems with different values of the charge asymmetry we find that the isotopic distributions reproduce an isoscaling relationship. Our results essentially refer to the distributions of the fragments just after the early break–up of the system. So our approach can be considered complementary to dynamical model calculations based upon semiclassical kinetic equations for one–body phase–space density, as far as the description of the early fragmentation mechanism is concerned. The advantage here is that one can make significant predictions on observables of experimental interest on an analytical basis. This allows us to directly relate the results obtained to the EOS properties and the features of the spinodal mechanism. In our scheme the onset and the growth of the fluctuations about the mean phase–space density in unstable situations, are self–consinstently treated. The self–consistency condition is provided by the fluctuation–dissipation theorem.

Index