Heavy Ion Physics and Accelerator Mass Spectrometry

The scientific activities of the Heavy Ion Physics and Accelerator Mass Spectrometry group aims at two major subjects: 1) Studies to understand nuclear structure and reaction mechanisms at low energies. 2) Applications of the accelerator mass spectrometry (AMS) technique in the field of astrophysics. These two research lines are performed at the TANDAR laboratory and at external facilities with contributions of physicists of the group.

Highlights of the nuclear physics activities are:

- Search for chaotic behavior in nuclear reactions: Theoretical studies based upon coupled- channel calculations predict for elastic and inelastic-scattering that, under certain conditions, nuclear scattering might exhibit peculiar behavior associated with the quantum manifestation of chaotic phenomena. We have continued our study of the $^{16}O + ^{28}Si$ system for which a chaotic behavior in certain energy-range has been predicted. A new experiment was carried out in collaboration with the LBN Laboratory, in order to improve several experimental aspects by the use of a large efficiency heavy ion detector combined with the multidetector array Gammasphere. Obtained data are under currently evaluation. Preliminary results of the collected data i.e. the angular distributions for the 2^+ excited state in ^{28}Si (1.78 MeV) for the low energy range (40-46 MeV) in the angular region $40< \ _{cm}<120$ are available. The data for the high-energy range (71, 73 and 75 MeV) plus the angular distributions for the backward hemisphere are still under analysis.
- The influence of the break-up of stable weakly bound and radioactive nuclei on the fusion process at energies near the Coulomb barrier, is another subject with renewed interest in the last years. Recently in the frame of a collaboration with colleagues of the Universidade Fluminense of Niteroi we have performed a series of experiments to study fusion cross sections at energies around and below the Coulomb barrier for the $^{6}Li + ^{27}Al$, ^{64}Zn and $^{9}Be + ^{27}Al$, ^{64}Zn systems. These are the natural continuation of previous measurements, i.e. fusion cross-sections carried out at energies well above the Coulomb barrier for the above mentioned systems.
- Fusion barrier distributions: These studies involve two aspects, experimental (a) and theoretical (b) investigations:

  a A typical device employed to separate evaporation residues from beam-like ions is an electrostatic deflector. However, the evaporation residues have a broad range in energy and charge state and, therefore, a wide angular range. In order to reduce this angular range we have designed and constructed a system that involves two electrostatic deflectors instead of a single one. Finally, to detect the evaporation residues we have devised and built a small ionization chamber from which one can obtain four signals: energy loss, residual energy and two timing signals (start and stop). Thus, the measurements associated to the energy and the time of flight will allow us to distinguish the evaporation residues from the beam-like particles. At the present, we are testing and evaluating the double electrostatic deflector through scattering studies ($^{127}I(80MeV)+^{nat}C$ and $^{12}C(30MeV)+^{nat}Pd$) to simulate evaporation residues of intermediate mass and low energy.

  b A coupled-channel program is being developed in order to obtain simultaneously differential -for elastic, inelastic and reaction channels- and fusion cross sections. At the same time the fusion barrier distributions derived from several kinds of data (fusion, quasielastic, spin distributions, etc) are computed. Interaction potentials and form factors can be provided by the user.

- The nuclear spectroscopy line encloses research, in the mass region A ≈ 160-190, on shape coexistence phenomena, on the signature inversion phenomenon, on the influence of the residual proton-neutron interaction, and on the nature and behavior of band crossing in blocked odd systems. Deformed ^{163,4}Ho, ^{168}Tm, and ^{178}Ir have been studied through heavy ion induced reactions. Beta-decay studies were performed for ^{182}Os and ^{182}Ir.

The other research line is related to the application of accelerator mass spectrometry technique. In collaboration with the Munich Technical University and the University of Vienna we accomplished measurements of resonance strengths of the ^{25}Mg(p,γ)^{26}Al at very low energies, which are of astrophysical interest. In our method, ^{25}Mg targets are firstly proton bombarded. Then this material is chemically treated so as to eliminate original Mg and to homogenize a well-determined amount of ^{27}Al carrier. Finally, the ^{26}Al/^{27}Al ratio is determined by means of the AMS technique.

Under this same collaboration the ^{12}C(p, γ)^{13}N reaction was measured tuning ^{12}C in the low-energy side of the tandem accelerator and producing the reaction in inverse kinematics in a H_2-gas stripper. The produced ^{13}N was further accelerated in the high-energy side and its identification was accomplished by usual AMS detection techniques.

In addition, further measurements of spurious ionic charge states in the tandem accelerator were carried out. These spurious charge states, originated by multiple electron-loss reactions of accelerated ions with molecules from the residual gas, provide useful information on atomic collisions.

Finally, during 2003 we finished the first stage of a 3-year project as a group participating in the reevaluation of nuclear structure data. This activity is part of an ongoing and continual international program coordinated by the National Nuclear Data Center at Brookhaven (U.S.A.), which maintains the master data file (ENSDF). This program is supported and supervised by the International Atomic Energy Agency.

In this first installment, we performed the reevaluation of the structure data for the following isotopes of the A=193 mass chain: Hg, Tl, Pb, Bi, Po, and At. As a result, we can now include, for the first time, level schemes for ^{193}Bi, ^{193}Po and ^{193}At, which were unknown at time of the earlier evaluation. In addition, the number of known superdeformed bands in ^{193}Pb has been updated from six to nine. Other changes include the updating of all Q-alpha, Q-beta, and neutron and proton separation energies, to take into account the recent reevaluation of atomic masses (Nucl. Phys. A729, 3 (2003)).