Nuclear Spectroscopy

The activities of the group include two sets of different problems. Both subjects utilize in general similar nuclear spectroscopy techniques and the same heavy ion beams produced by the TANDAR accelerator. The first set of problems corresponds to applied research (from the point of view of nuclear physics but not necessarily of the other disciplines) and tries to contribute in other areas generating interdisciplinary and partly technological activities. Applications to biomedical and environmental problems are being pursued. On this sector, we can distinguish two main lines:

a) Trace element analysis and research with a heavy ion microbeam; b) Feasibility studies on novel accelerator-based cancer therapy modalities.

The second set of problems is in the field of basic research on nuclear structure.

Trace Element Analysis and Research with a Heavy-Ion Microbeam

The most frequently employed techniques are PIXE and PIGE (Particle Induced X-ray (Gamma)

Emission). The first one is a high-sensitivity multielement analysis technique based on the heavy ion excitation and detection of characteristic X-rays of the elements present in samples of diverse origin. In biomedicine, problems studied have been, among others, metabolic alterations in living species related to presence of Cu and Cd and multielement determination in cancer tissue samples.

As far as environmental problems are concerned the PIXE technique has been applied to the determination of lead concentration and other polluting agents in atmospheric aerosols of Buenos Aires city and surroundings. Since our last survey, Pb concentration in Buenos Aires diminished by a factor of about 20 after the introduction of unleaded gasoline in Argentina, a behavior similar to that observed in other large cities around the world. A systematic study of X-ray production cross sections using ^{12}C ions has been performed, for PIXE applications. The heavy ion microbeam is now fully operational and research has started on this new facility. Multielementary maps with micrometric spatial resolution have been obtained for several samples using the microPIXE technique. In particular we have started to study microdistributions of a new drug of potential interest for cancer research in tissue sections of injected and non-injected control hamsters. This microbeam in conjunction with nuclear and atomic techniques of excitation and detection like PIXE, PIGE, HIRBS (Heavy Ion Rutherford Backscattering), STIM (Scanning Transmission Ion Microscopy), etc., allows the quantitative determination of the multielement composition, the modification of properties and structural characterization of different systems with a spatial resolution of the order of one micrometer.

Feasibility Studies related to novel accelerator-based Cancertherapy modalities

• Protontherapy

The charged particle beams have definite advantages compared to other types of radiation (like gamma rays) for tumor treatment. In some cases, like eye melanoma, spectacular success has been achieved. This technique is known as protontherapy. There is interest to stimulate activity which may eventually lead to the introduction of this modality in our country. In this context external proton, alpha and Li beams have been produced at the TANDAR accelerator and a program to irradiate small animals and cell cultures was started in collaboration with radiobiology personnel. Relative Biological Effectiveness (RBE) associated with p, alpha and Li beams of different energies was determined for different tumor cell lines. In particular the Li and alpha beams aim at simulating the effects of the Li fragment being emitted in the BNCT reaction (see below).

• Boron Neutron Capture Therapy (BNCT)

With the proton or deuteron beams available at the TANDAR accelerator it is possible to generate a

neutron flux that can be used to carry out feasibility studies related to a possible therapy which utilizes boron neutron capture, BNCT, based on the very high cross section of the capture reaction $^{10}B(n,alpha)7Li$. The idea is to load selectively a tumor with boron and irradiate it with neutrons. The microexplosion associated to each reaction has a high lethality for cancer cells affecting only the immediate surrounding tissue. In the past BNCT has been based exclusively on nuclear reactors for research and treatment. There is however currently a strong tendency and important progress towards the development of accelerator-based neutron sources. There is a generalized perception that if BNCT is to become an option for cancer treatment it would be necessary to have accelerator-based neutron sources, not only due to their much lower cost and complexity but also because the installation of a nuclear reactor in a hospital would not be acceptable given the public perception in relation with this type of facility. We have started to explore the neutron production via protons of relatively low energy (some MeV) on a lithium target. A LiF neutron production target has been built and neutron flux determinations have been performed both trough the activation method and through the detection of the 478 keV gamma ray following the BNCT reaction. The latter method will serve to monitor on-line the dose delivered to a tumor. Extensive numerical work has been performed to design an optimal production and beam shaping assembly and work has started to mount a prototype. We have also started to explore the possibility of developing a low-energy (2 MeV), high-current (20 mA) proton accelerator for BNCT.

Basic research on nuclear structure

This program includes several high-spin nuclear structure topics of current interest. One is the study of coupling schemes of valence nucleons in doubly odd species of deformed nuclei. In particular the problem of signature inversion in the heavy rare earth region has been one the subjects under investigation. Finally, we mention the study of the octupole instability in the actinide region. The aim has been here to map out the reflection asimmetry degree of freedom to reach the predicted maximum in this deformation and to establish the limits for performance of in-beam spectroscopic studies in the presence of a very severe fission competition. Work on Rn, Fr and Ac isotopes is in progress.