Experiment proposal:
Energy calibration of the Bucharest FN tandem accelerator

D. Pantelica, D. Ghita, N.Scintee, G.Velisa, P.Ionescu, Cristina-Roxana Nita, S. Dobrescu, A. Enulescu

The Bucharest FN tandem accelerator was installed in 1973. The maximum terminal voltage was 7.5 MV. The accelerator was equipped with a negative ion injector based on a duoplasmatron ion source. The strong earthquake (7.2 Richter scale) in March 1977 induced a serious damage of the column and accelerator tubes, as well as a complete loss of the tank gas. The tandem repair was completed in 1979. After the tandem repair an upgrading program was started, involving the upgrade to 9 MV and the installation of a new negative heavy ion injector using a Hiconex 834 sputter source. In 1986 another strong earthquake (6.9 Richter scale) damaged again the column without damaging the accelerator tubes. In 1989-1990 an original seismic protection of the tandem accelerator tank was installed. Finally, in 2006 a program of modernization and development of the tandem was started, including the replacement of the old accelerator equipment by the new ones, installation of a pelletron system for the Van de Graaff generator, installation of new negative ion injectors and installation of a beam pulsing system in the nanosecond range. The research program at the Bucharest FN tandem is mainly concentrated on nuclear structure, atomic physics and interdisciplinary researches using IBA techniques and also AMS.

Ion Beam Analysis (IBA) denotes a suite of analytical techniques that exploit the interactions of high energy (~MeV) charged particles with matter to determine the composition and structure of the surface regions of solid samples (from ~0 to 100 µm). The basic physical processes underlying IBA are now well understood and the reliability of data interpretation is limited by knowledge of the physical data. The primary quantities required are the stopping powers and the cross sections of the interactions involved. Whilst work remains to be done on accurate stopping powers the field is largely catered for by the considerable body of work of Ziegler and coworkers, embodied the SRIM computer code. The case is quite different for cross sections for nuclear reactions and non-Rutherford elastic scattering. There exists a considerable body of published data in the nuclear physics literature, much of which has been incorporated into computer-based databases over the last decade by a small number of individuals. The two principal such databases are the SigmaBase web sites and the NRABase cross section library. Examination of this unevaluated experimental data has revealed numerous discrepancies beyond the error limits reported by the authors, and ion beam analysts are faced with the dilemma of trying to decide which (if any), amongst the divergent cross section data, they should use. At our tandem we started a program for light elements profiling using NRBS (Non-Rutherford Backscattering spectrometry) and NRA (Nuclear Reaction Analysis) techniques. We intend to use some elastic scattering and nuclear reaction cross sections and also to measure or remeasure some cross sections in cases where discrepancies exist in the literature data. Both absolute energy of the beam and and beam energy spread are important for such measurements. The accurate energy calibration of the accelerator is necessary.

The beam from the accelerator is analysed by a double focussing 90^0 magnet with radius of curvature 1000 mm. We intend to perform the energy calibration of the analyzing magnet, to measure its differential hysteresis and to measure the energy spread of the analysed beam. The most commonly used techniques for energy calibrations of the tandem Van de Graaff accelerators are based on measurements of both (p,n) thresholds and narrow (p,p) resonances. Both techniques were used many years ago to calibrate the analyzing magnet of our tandem accelerator. The last calibrations based on the measurement of the narrow resonance from $^{12}C(p,p)^{12}C$ elastic scattering at E=14.231 MeV were performed in 1980 and 1999. The result of the last calibration has evidenced a 21.5 keV shift in the energy of the resonance. So, a new and and more complete calibration of the energy analysis system is needed since the last magnet calibration was based on only one calibration point. The method adopted is based on a simple alpha-particle backscattering technique and consists of comparing the energies of alpha particles from a radioactive source with the energies of ^4He projectiles back-scattered by thin C and Au layers. The field of the 90^0 magnet will be measured with a NMR fluxmeter. The relativistic relationship between the energy E of the analysed particle and the magnetic field B is given by the expression:

$$E = K_1 B^2 \frac{Q^2}{M}\left(1+\frac{E}{2Mc^2}\right)^{-1} \quad (1)$$

Where Q is the effective charge of the particle, M is its mass and (E/Mc^2) is the ratio of its kinetic energy to rest mass energy. E is in MeV, Q in units of electronic charge and B is in Tesla. The mass M, expressed in nuclidic mass units, is obtained by subtracting the mass of the appropiate number of electrons from the atomic mass, neglecting the electron binding energies. The magnetic field B is correlated with the frequency f of the RMN in MHz by the expression:

$$B = 2.3487\times 10^{-2} f \quad (2)$$

The relationship between particle energy E and the measured NMR frequency is given by the expression:

$$E = Kf^2 \frac{Q^2}{M}\left(1+\frac{E}{2Mc^2}\right)^{-1} \quad (3)$$

The calibration of the analysing magnet consists in a precise determination of the constant K. The constant K may be a weak function of the magnetic field due to saturation and fringing field effects.

The method which will be used consists in determining the beam energy and the calibration parameters of the pulse height analysis system simultaneously. The data are the peaks from the alpha source and the peaks from the scattered beam by two elements, C and Au.

If a linear relation is assumed beween the energy E and the channel number N the following system of equations can be formed:

$E_C=K_CE=aN_C+b$

$E_{Au}=K_{Au}E=aN_{Au}+b$

K_C and K_{Au} are the kinematic factors for backscattering from C and Au, respectively. E_C, E_{Au}, N_C, N_{Au} are the energies and channel numbers for backscattering from C and Au, respectively.

For the alpha source we have:

$E_\alpha=aN_\alpha+b$

where E_α and N_α are the energy and the channel number for the alpha source peak, respectively.

E is the ^{4}He bombarding energy and a and b are the energy per channel and the energy intercept of the pulse height analysis system. The a,b and E are the unknown parameters. The energy E will be used in conjunction with the reading of the NMR fluxmeter to calculate K.

To minimize effects of differential hysteresis the magnetic field will be recycled before starting the measurements. The magnetic current will be increased smoothly from zero to the maximum and then reduced to zero. This will be done three times and then the field will be increased to the required value without overshooting. All data will be taken in the direction of the increasing energy. If it will be necessary to reduce the energy, the field will be recycled.

We also intend to measure the narrow ^{12}C(p,p)^{12}C elastic scattering at E=14.231 MeV. The exact resonance energy is (14.23075±0.00020) MeV and the width of the resonance is (1.2±0.2) keV. For the measurements the object and image slits will be set at 1.0 mm. The gain of the pulse height analysis system will be monitored with a precision pulser.

For these measurements we ask for 7 days beam time (21 shifts).