Romanian Reports in Physics, Volume 55, Number 4, P. 349-352 , 2003

Thirty years of physics at the Bucharest tandem accelerator

S. Dobrescu, L. Marinescu, G.Dumitru, Gh. Cata-Danil
National Institute for Physics and Nuclear Engineering, Bucharest

(Received July 28, 2003)

Abstract. The main parameters of the Bucharest tandem accelerator, as well as the main milestones of its history since March 1973 when it was commissioned are shortly presented. A general presentation of the main basic and applied physics research so far undertaken at the tandem is given, ending with some ideas related with the future perspectives of the tandem.

1. The Bucharest tandem accelerator

The FN-model Tandem Accelerator in Bucharest was commissioned thirty years ago and in this lapse of time nuclear and atomic physics researches, basic and applied, were undertaken by scientists of our institute as well as from other institutes of Romania and of other countries. The main milestones of the Bucharest tandem accelerator history are:

1973 : commissioning of the Tandem (7.5 MV maximum terminal voltage; negative ion injector based on a duoplasmatron ion source followed by an electron adding channel; accelerated particles: protons, deutons, C, N, O, F, S) and beginning of the researches.

1977 : a strong earthquake (7.2 Richter scale) provoked the collapse of the tandem column. The rebuilding of the column was completed in 1979 [1].

1979 : upgrade (mainly by installing new accelerator tubes, substituting the old resistive terminal voltage divider with a new one and addition of SF_6 to the isolating gas in the accelerator tank) that allowed to raise the maximum terminal voltage at 9 MV.

1983 : development and installation of a new negative heavy ion injector [2] based on a sputter negative ion source (model HICONEX 834) that allowed to produce and accelerate more than 30 ion species, extending from protons to Au.

1986 : a strong earthquake (6.9 Richter scale) damaged again the tandem column that could be repaired only in 1990 due to the high costs involved.

1989 - 1990 : an original earthquake protection system of the tandem accelerator tank was developed in IFIN-HH and installed [3]; a new original terminal voltage resistive divider was constructed and installed on the tandem column [4].

1996 - 2001 : the construction and installation of a third negative ion injector based on a spherical sputter ion source aimed for converting the tandem in an accelerator mass spectrometer (AMS).

Excepting the long periods (1977-1979 and 1986-1990) of interruption due to the column damage by the earthquakes, the tandem delivered each year 3000 - 4000 hours of beam on target for physics experiments and applications. In normal operation the terminal voltage is ranging actually from 1.5 MV to 8.5 MV, value that is not exceeded in order to protect the system.

In the table 1 is given a list of the negative ion beams currently produced and accelerated at the Bucharest tandem accelerator.

Table 1

Ion species	Injected beam current from ion source [μA]		Range of accelerated ion energy (MeV)
	Duoplasmatron	Sputter source	
$_{1}$H	5	0.5	3-17
$_{2}$H	5	0,5	3-17
$_{7}$Li	-	0.2	3-25
$_{9}$Be	-	0.05	5-34
$_{10}$B	-	0.1	5-42
$_{11}$B	-	0.2	5-42
$_{12}$C	1.7	5	5-50
$_{14}$N	2.5	-	5-60
$_{16}$O	2.2	4	5-68
$_{19}$F	6	8	5-68
$_{24}$Mg	-	0.2	8-76
$_{27}$Al	-	0.07	8-76
$_{28}$Si	-	3	8-76
$_{32}$S	2.5	8	8-85
$_{35}$Cl	2	1.8	8-85
$_{40}$Ca	-	0.15	10-85
$_{48}$Ti	-	0.05	10-85
$_{52}$Cr	-	0.03	10-85
$_{55}$Mn	-	0.08	10-85
$_{56}$Fe	-	0.15	10-93
$_{58}$Ni	-	0.6	10-93
$_{59}$Co	-	0.35	10-93
$_{63}$Cu	-	0.5	10-93
$_{64}$Zn	-	0.05	10-93
$_{79}$Br	-	2	10-102
$_{127}$I	-	1.2	10-102
$_{198}$Au	-	0.6	10-102

2. The Research Program at the Bucharest tandem accelerator

The excellent quality of the tandem accelerator ion beam (good energy definition and resolution, continuously variable energy easy to be changed and low beam emittance) stimulated along the years numerous investigations both in basic and applied research.

Up to the years ninety several studies on heavy ion reactions mechanisms have been pursued by measuring the reaction products both with commercially silicon and with gas ionization home made detectors. In nuclear structure investigations there was along the years and there is still nowadays an active research program. Experimental investigations in nuclear structure physics include a wide range of experiments addressing studies of collective excitations in nuclei by gamma ray spectroscopy (angular distributions, excitation functions, single and coincident spectra), lifetime measurements by electronic and Doppler shift techniques in the "in-beam" measurements. Several nuclear moments measurements have been completed along the years. Recently, "off-beam" experiments became also available by the commissioning of an electric beam-chopper installed on the low energy side of the accelerator. The enhancement of the weak reaction channels is usually done by measuring gamma rays in coincidence with neutrons and/or charged particles.

By using the large variety of ion beams provided by the tandem accelerator (and by the 14 GHz ECR ion source RECRIS [5] recently put in operation) an ambitious atomic physics research program is pursued with the goal of obtaining new information on the ionization cross sections.

The detection systems for all these studies include four GeHP high resolution, high efficiency detectors, five liquid neutron scintillators, a velocity selector and several charged particles silicon telescopes. The coincidence measurements are performed with a combination of CAMMAC-NIM electronics allowing 8 channels of amplitude (ADC) and 8 channels of time (TDC) in "list mode". Home made software for data acquisition and lists writing is used in conjunction with advanced off-line data reduction software originating from famous abroad laboratories (LNL, CERN, GANIL, ORNL). Scientific works performed at Tandem have been subjects to many papers published in the most prestigious international journals (Physical Review C, Nuclear Physics A, J.Phys.G, Eur. Phys. J., etc.) and communications at international meetings.

In addition to the basic nuclear physics interests, in the last decades, the tandem laboratory fostered a rich interdisciplinary research program in applications of the accelerated ion beams in studies of new materials, environment samples, archeometry, biology and medicine. PIXE (Particle Induced X-ray Emission), RBS (Rutherford Backscattering) and ERDA (Elastic Recoil Detection Analysis) are the basic techniques used. For these studies a new beam-line has been re-constructed in order to achieve very high and clean vacuum. The research in this direction refers to elemental analysis of samples for control of pollution, for semiconductor research and industry, for new materials and nuclear waste management. The Ion Beam Analysis techniques (IBA) with heavy ion beams are nowadays widely spread in many laboratories around the world who run tandem or Van de Graaff accelerators. At the Bucharest tandem accelerator these methods are becoming more and more refined and universal.

Another innovative and sophisticated analytical technique designed for tandem accelerators is the Accelerator Mass Spectrometry (AMS). It aims to detect rare atoms at unprecedented levels of sensitivity. AMS is using in conjunction techniques of mass spectrometry, ion acceleration and nuclear particle identification that allow to attain extremely high sensitivities, less than 100 000 atoms of a specific nuclide per mg of material. At this level of sensitivity, well beyond achievable chemical purification, even the highest purity materials (including hiper-pure Ge crystals) contain traces of practically all elements of the periodic table. At the Bucharest Tandem accelerator an advanced AMS system is in commissioning stage.

3. Perspectives for the future

The Bucharest Tandem Accelerator will be used extensively in the next years as it is today for atomic and nuclear physics research and for applications. Among these the AMS will become more and more important.

The old HVEC inclined field accelerator tubes with stainless steel electrodes, that have been in service for over 40,000 hours which is very close to their life-time, will be replaced by a new set of Dowlish spiral field accelerator tubes with titanium electrodes that we have in spare. By this, the transmission of the ion beam through the accelerator is expected to increase from about 8% as is presently to about 20%.

Another very important issue we have been considering for quite a long time is the change of the present electrical charge transport system of the Van de Graaff generator, based on a rubber belt (12 m long, 0.5 m wide, no longer commercially available), by an electrostatic induction system (a Pelletron chain). This latter system has at least two important technical advantages: it allows to improve the terminal voltage short term stability from ±2.5 kV to ±0.5 kV and the accelerator tank is no longer "polluted" by belt rubber dust. To these should be added the much longer life-time of the Pelletron chain if compared with that of a rubber belt. We are now looking for a financial support of this project.

To sum up, the Bucharest tandem accelerator was along the last 30 years and is for the future as well the main infrastructure basis for the development of a sound nuclear and atomic physics program in our institute. It provides over 3000 hours/year of ion beams with a large variety of ions from protons to gold. We are optimistic about the future of the physics with the tandem ion beams, in basic, applied and interdisciplinary researches, especially if more university research groups will become users and an international support will be further attracted from the EU, NATO and in bilateral international collaborations with important research centers of the world.

REFERENCES

1. S. Dobrescu, Nucl. Instrum. and Methods, **184**, 103 (1981).
2. S.Dobrescu, L.Marinescu, Proceedings of the 6th International Symposium on the Production and Neutralization of Negative Ions and Beams, Upton NY, Nov.1992, (AIP Press, AIP Conf. Proc. No. 287, Particles and Field Series 53, Editors J.G.Alessi and A.Hershcovitch, BNL), p.474.
3. L. Marinescu, V. Zoran, S. Dobrescu, G. Pascovici, G. Semenescu, G. Marmureanu, H. Sandi and T. Sireteanu, Nucl. Instrum. and Methods, **A287**, 127 (1990).
4. L. Marinescu, M. Petrascu, R. Dima and D. Serban, Nucl. Instrum. and Methods, **382**, 82 (1996).
5. S. Dobrescu and L. Schachter, Rev. Sci. Instrum. **72**, 567 (2002).