THE PROGRESS OF THE EXCYT FACILITY AT INFN-LNS

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Abstract

The EXCYT facility at the INFN-LNS is based on a K-800 Superconducting Cyclotron, as a driver for stable heavy ion beams (up to 80 MeV/amu, 1 pμA), and on a 15 MV Tandem for post-accelerating the radioactive ion beams. Since December 1999 the project has significantly progressed: the Superconducting Cyclotron operates in a stand-alone mode by means of the new axial injection beam line; the magnets of the primary beam line have been aligned and most of the components of the mass separator are ready. Low intensity beam diagnostics is also ready and reliability tests are under way.

1 ECR ION SOURCES AND SUPERCONDUCTING CYCLOTRON

In 1998 the superconducting ECR (electron cyclotron resonance) ion source SERSE [1] was commissioned and upgraded to 18 GHz, thus improving its performance. In May 1999 the conventional ECR source CAESAR [2] was also been installed. Both sources can produce intense beams of fully stripped C, N, O: SERSE provides about 7 pμA of fully stripped oxygen, for instance, whereas production rates for CAESAR are three to five times less intense.

The Superconducting Cyclotron [3], previously acting as a booster for the Tandem, has been working in the axial injection mode since the end of 1999. Radial injection, accomplished by means of a stripper placed at 10-20 cm from the centre, has been transformed into axial injection by replacing the stripper with an inflector and a central region for the acceleration of the first orbits [4] . In the new mode, the intensity of all the beams will be increased, giving the Cyclotron a major role as the primary accelerator for EXCYT and leaving the Tandem available for secondary beams acceleration.

In order to perform a fine phase selection out of the central region, a slit system consisting of three ”wedges” has been installed inside the Cyclotron. This system should increase the extraction efficiency by stopping in advance ions that would be intercepted by the deflectors, thus limiting the thermal load and the activation of the deflectors, and permitting to increase the current which can be extracted from the cyclotron.

In January 2000 a $^{58}Ni^{16+}$ beam, produced by SERSE was successfully transported through the axial beam line, the inflector and the central region, finally reaching the extraction radius with an energy of 30 MeV/amu. The operating parameters were very close to their calculated values. Since then different beams have been developed and delivered to experiments.

Injection efficiency cannot be exactly evaluated, a figure of 5-8% has been estimated, the maximum being not larger than 10%, since the central region selects approximately 35° RF. Beam tests with light ions will soon be accomplished to evaluate the maximum beam current available at the extraction radius. This result is the first step towards the goal required by a high intensity target, namely to deliver 1 pμA of a light ion beam at 80 MeV/amu. At present the beam energy is limited by the electrostatic deflector which does not reach the maximum expected voltage.

The EXCYT primary beam line will transport the high-energy beam from the cyclotron to the target. It consists of four sector magnets (two 13° bending magnets, a big 90° dipole magnet for the vertical illumination of the target and a small 5° horizontal bending magnet), three quadrupole doublets and a wobble magnet to irradiate the target with a rotating beam.

The beam line is fully assembled and will be commissioned next summer.

2 TARGET-ION SOURCE ASSEMBLY

Several innovative high-power target geometries have been developed, the designs being based on the concept of redistributing the primary beam intensity over larger transverse and longitudinal target dimensions.

At operating temperatures above ~2000 °C radiative cooling is the dominant heat transfer process: therefore geometrical target configurations which allow maximum viewing of cool surfaces will radiate most efficiently. The surface is increased by tilting the target of an angle α chosen to reach the desired level of temperature [5]. By wiggling or defocusing the beam, its spot size on the target should be increased up to ~30 mm, thus effectively reducing the beam power density. The combined effect of increasing both the beam size and the target dimensions will increase the effective radiating surface area of the latter, thus resulting in a stable target operation with increased total beam intensities. Computer simulations by ANSYS finite-element code validated this concept which will be also used for the HRIBF at ORNL. A special type of graphite (XYCARB UTR 146) has been selected among the many commercially available ones because of its properties which should allow a good release of the products: high thermal conductivity, high open porosity (19%), low closed porosity (0%) and small grain size.

Experiments carried out at CERN in collaboration with ISOLDE led to the conclusion that this kind of graphite has by far a better performance, as compared to other materials, for the release of fluorine [6].

The target will be coupled to different ion sources according to the ion species to be produced. A microwave discharge ion source (MIDAS) has been tested [7] and three ISOLDE-type ion sources (negative surface, positive surface, hot plasma) are currently under test.

3 REMOTE HANDLING SYSTEMS AND CONTAMINATED WASTE TREATMENT

The temporary deposit for activated sources has been tested, and the mobile bridge for the access to the platform has been installed.

The robot for manipulation of the RIB source together with its control system has been designed, realised and is now under test. The overall control system (hardware and software) for the EXCYT sources remote manipulation has been developed. The air treatment and pressurisation system, where a high level of contamination or radiation could be present, has been designed.

The gas and liquid waste storage device and the radiation level control system of the vacuum pumps in the exotic beam line, particularly the vacuum pumps in the two platforms have been designed.

4 THE HIGH-RESOLUTION MASS SEPARATOR

The EXCYT mass separator is designed as a two-stage separator, which will be operated at different potentials [8]. This design not only provides a good purification of the ion beam of interest but also allows to achieve an energy achromatic mass separation [9,10]. Moreover, the system will be preceded by a preseparator, and a beam transport system will finally deliver the separated beam to the tandem postaccelerator. The preseparator consists of an electrostatic quadrupole quadruplet and a 18° dipole magnet located on a 250 kV high-voltage platform. It should have a mass resolving power $(\Delta M/M)_{Pre}$ of ≈ 180, which will already eliminate the bulk of undesired ions from the beam of desired ions, so that no heavy radioactive shielding after the preseparator is required.

Two electrostatic quadrupole triplets will guide the ion beam through a 1 m thick shielding wall and focus it into a charge-exchange-cell. Thus is followed by the 1st stage separator, consisting of an electrostatic quadrupole quadruplet and two 77° and 90° dipole magnets which should provide a mass resolving power $(\Delta M/M)_{1st}$ of ≈ 2000. All these elements will be placed on a second 250kV high-voltage platform which was just installed last month.

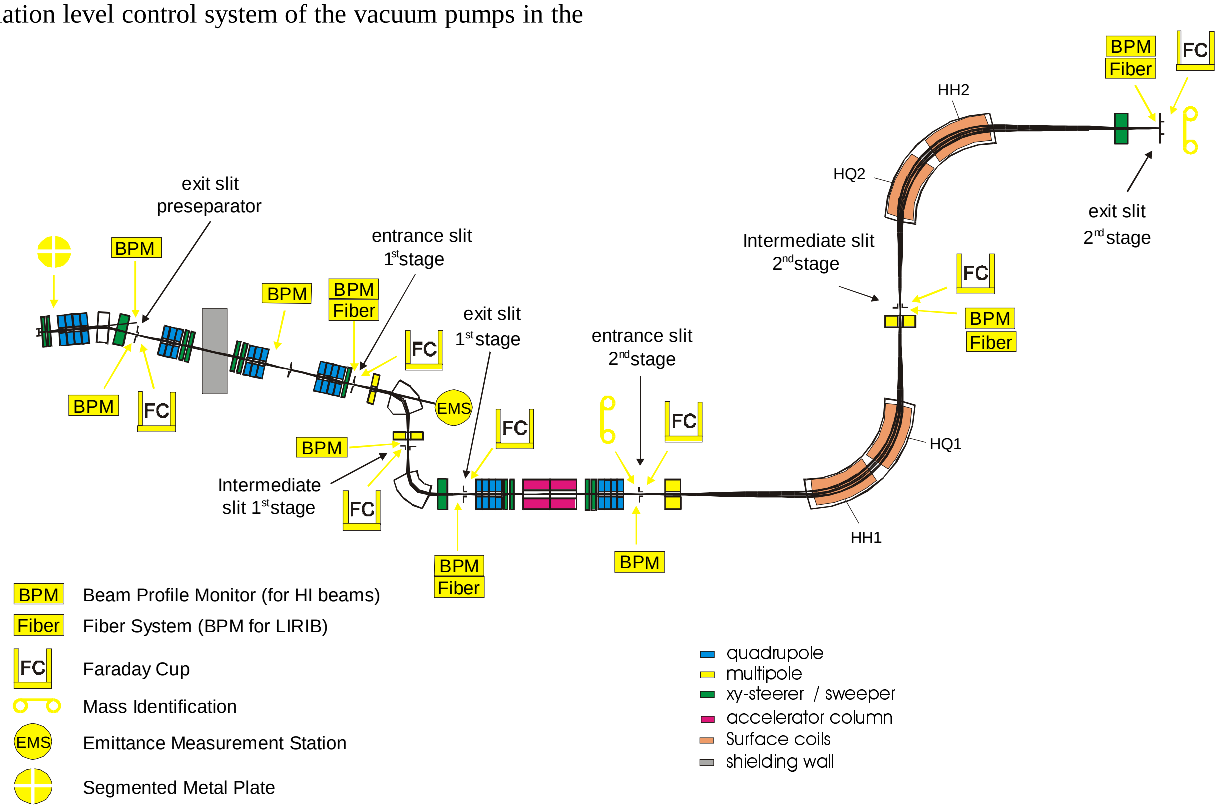

Figure 1: Layout of the EXCYT mass separator. Indicated are also diagnostic elements

The overall mass separation is achieved in the second-stage mass separator, which is placed on ground potential. Again this separator stage consists of an electrostatic quadrupole quadruplet and two large 90° dipole magnets, which should finally allow to achieve a mass resolving power $(\Delta M/M)_{2nd}$ of ≈ 20000.

Commissioning of the separator with a stable ion beam is expected for the end of this year.

5 CONTROLS AND BEAM DIAGNOSTICS

The most important components have already been installed and tested: the remote console, a dedicated LAN based on the Fast Ethernet architecture and some local stations. At present, the remote control of the axial injection line is complete and in operation, now we are working to integrate the controls of the primary beam line and some components of the cyclotron.

After few months of operation the performance and reliability of the new architecture [11] have been tested. Preliminary measurements of the control system performance, considering that only 30% of the control stations are already installed, are very encouraging. The bandwidth occupation along the 100Mbit links is lower than 2%; this value was obtained with an overall update rate of 10 Hz. We forced an update rate of 100Hz in order to measure the bandwidth occupation along optical link Gigabit Ethernet corresponding to the control system running at 100% of its capabilities. The occupation increased linearly up to values lower than 20%. Using the network tools available for Windows NT 4.0 we performed several measurements of network load, protocol analysis, error statistics, communication reliability and hardware diagnostics. This has been a big advantage because it reduced strongly the time necessary to optimize the control system performance and to debug the control applications.

For the EXCYT beam diagnostics a set of devices for beam profiling and identification has been developed. It is based on scintillators (fibers and plates), semiconductor detectors and gas detectors, aimed to operate in a wide range of beam energy and intensity, before and after the Tandem acceleration [12] [13]. A Low Energy Beam Imaging and Identification (LEBI) station is able to detect the decay products from the radioactive ions implanted onto an inert tape. It is so possible to locate the beam position, to estimate the transversal size and identify the nuclear species of the beam. It operates in the preacceleration stage at 300 keV.

A quantitative and qualitative High Energy Beam Identifier (HEBI) is based on a silicon telescope, which after the acceleration detects the beam particles scattered on a thin gold target [14]. Calculations based on the test results, allow to demonstrate the excellent capability of the system to discriminate the beam of interest from the neighbor contaminants.

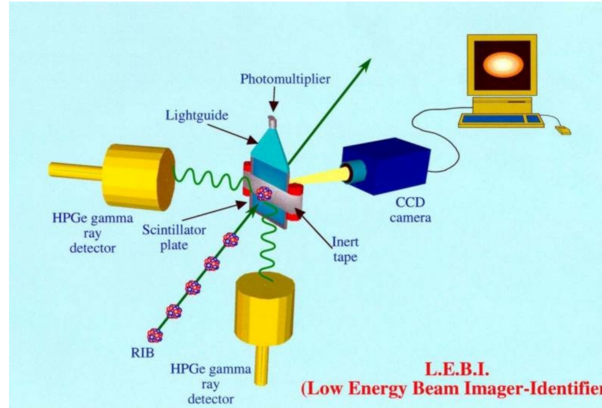

Figure 2: Sketch of the LEBI device .

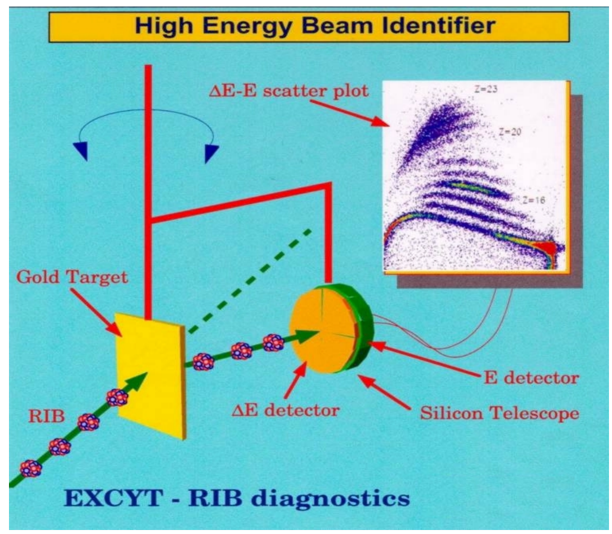

Figure 3: Sketch of the HEBI

REFERENCES

[1] S. Gammino et al., Rev. Sci. Instr. 71 (2000) 631

[2] S. Gammino et al., Proc. of 14th Int. Workshop on ECR ion sources, CERN, 1999, 139-142.

[3] D. Rifuggiato et al., Proc. XV International Conference on Cyclotrons and their Applications, Caen, France, 1998, p. 599-602.

[4] D. Rifuggiato et al., Proc. XV International Conference on Cyclotrons and their Applications, Caen, France, 1998, p. 646-649.

[5] G. Ciavola et al., Proc. of Particle accelerator Conference, New York, 1999, 2578-2580.

[6] M.Menna. et al., in preparation

[7] L. Celona et al., these proceedings

[8] G.Ciavola et al., NIM B126(1997)17.

[9] H.Wollnik, "Proc. ORNL RIB workshop", ed. J.Garrett, ORNL Conf 9210121 (1992), 213.

[10] Z.N. Quamhieh et al., NIM B70(1992), 131.

[11] A. Rovelli et al., ICALEPCS'99 Trieste, Italy, October 1999, 22-24.

[12] P.Finocchiaro et al., NIM A 419(1998), 83.

[13] P.Finocchiaro et al., NIM A 437(1999), 552.

[14] P. Finocchiaro et al., in preparation