5

GANIL

GRAND ACCELERATEUR NATIONAL D'IONS LOURDS - CAEN
LABORATOIRE COMMUN IN2P3 (CNRS) - D.S.M. (CEA)

GANIL-A-01-05

FERMILAB
DEC 27 2001
LIBRARY

Tobe published in the proceeding of the 9th International Conference on Ion Sources – Oakland, USA – September 3-7, 2001. Rew. Sci. Instr

LIMBE: A new facility for low energy beams

L. Maunoury[1], R. Leroy[2], T. Been[1], G. Gaubert[2], L. Guillaume[1], D. Leclerc[1], A. Lepoutre[1], V. Mouton[1], J.Y. Pacquet[2], J.M. Ramillon[1], R. Vicquelin[1] and the GANIL ion production group.

1. CIRIL, B.P. 5133, 14070 Caen Cedex 05, France
2. GANIL, B.P. 5027, 14076 Caen Cedex 05, France

GANIL A 01 05

Tobe published in the proceeding of the 9th International Conference on Ion Sources – Oakland, USA – September 3-7, 2001. Rew. Sci. Instr

LIMBE: A new facility for low energy beams

L. Maunoury[1], R. Leroy[2], T. Been[1], G. Gaubert[2], L. Guillaume[1], D. Leclerc[1], A. Lepoutre[1], V. Mouton[1], J.Y. Pacquet[2], J.M. Ramillon[1], R. Vicquelin[1] and the GANIL ion production group.

1. CIRIL, B.P. 5133, 14070 Caen Cedex 05, France
2. GANIL, B.P. 5027, 14076 Caen Cedex 05, France

Abstract: The goal of this paper is to present the new facility LIMBE built at GANIL. This facility is dedicated to the Ion-surface, Ion-Atom and Ion-molecule research. It is made of an ECR ion source called SUPERSHYPIE and two beam lines. We will describe the ECRIS, the beam properties and the performances of LIMBE facility.

1. Introduction

Since 1990, the ECRIS named ECR3, ECR4, ECR4M, SUPERSHYPIE and NanoganII have been used for Ion-surface, Ion-Atom and Ion-molecule research. Whether the ECRIS quality, placed at our disposal by the GANIL, has allowed to obtain many physics results leading to numerous thesis and publications, the poor beam qualities have restricted the development of new experiments. In this way, the LIMBE conception has been decided. Now, LIMBE has already been mounted, tested and the first beam has been delivered in the middle of 2000. LIMBE is composed of an ECRIS named "SUPERHYPIE"[1,2] and two beam lines.

Now, we are going to describe each part of this facility: first the ion source and second the beam lines. We will conclude with the future of this equipment.

2. The SUPERSHYPIE ion source

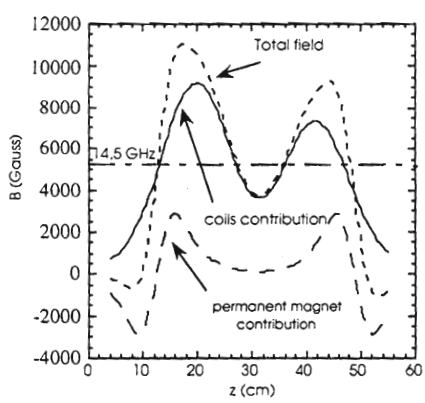

Figure 1: Axial magnetic field profile of SUPERSHYPIE

The SUPERSHYPIE ion source is an ECRIS type. It derives from the GANIL ECR4M ion source. Its axial magnetic field is an hybrid one. It is composed of two main coils and permanent magnet rings.

Figure 1 shows the piling up of the two axial magnetic field contributions . The coils contribute mainly to the configuration of the axial magnetic field whereas the permanent magnets create a modulation of the field that enhances the maxima B. The magnetic radial field is made with an hexapole (in Halbach configuration) of 0.9 T at the inner chamber. Thanks to the addition of two hexapolar rings, the plasma volume increases and the performances too.

The figure 1 shows a typical view of the axial field (dash line) used for the multicharged ion beam production. Now, the HF injection is a coaxial one. The rectangular HF guide is transformed into a circular HF guide just before HF injection. The plasma electrode is placed in 8000-9000 Gauss zone inside the magnetic bottle and allows to extract current up to 10 mA without damage.

The SUPERSHYPIE ECRIS is able to provide many highly charged ion beams as we can see on the table 1.The typical intensities were measured with a faraday cup located at the focal plane of the analyzing dipole and for an energy of about 17 keV*q (q the charge state).

Ion	Intensity (eμA)	Ion	Intensity (eμA)
He^{+}	*1500*	Ar^{8+}	*250*
He^{2+}	*1500*	Ar^{14+}	*23*
C^{4+}	*250*	Ar^{16+}	*1.9*
O^{6+}	*450*	Ar^{17+}	*0.08*
O^{7+}	140	Ar^{18+}	*4.10^{-4}*
N^{7+}	*3.5*	Kr^{16+}	*50*
Ne^{8+}	*170*	Kr^{24+}	*5.2*
Ne^{9+}	*14.5*	Xe^{23+}	*11*
Ne^{10+}	*1.2*	Xe^{27+}	*4.2*

Table 1: Intensities (eμA) of the SUPERSHYPIE ECRIS measured after the analyzing dipole.

On figures 2 up to figure 5 are shown four typical spectra dedicated to furnish highly charged ion beams requested by the physicists.

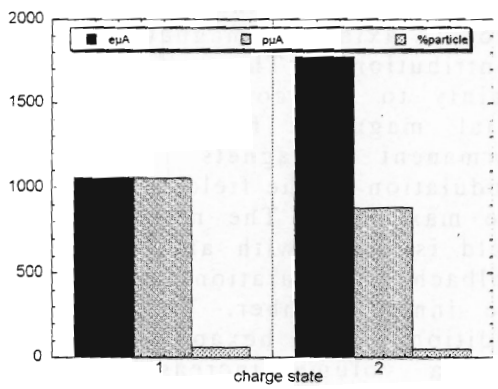

Figure 2: He charge state distribution for the optimization of $^{3}He^{2+}$ (PHF = 600W)

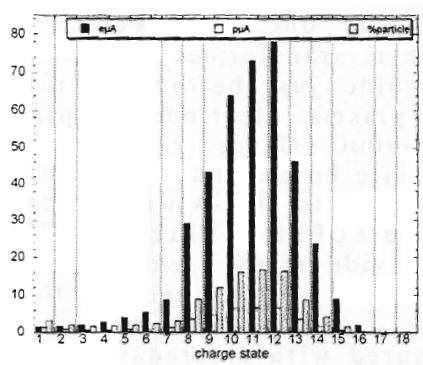

Figure 3: Ar charge state distribution for the optimization of $^{36}Ar^{17+}$(PHF = 1000W)

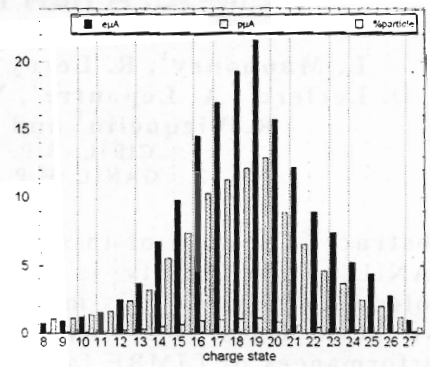

Figure 4: Kr charge state distribution for the optimization of $^{84}Kr^{22+}$(PHF = 1000W

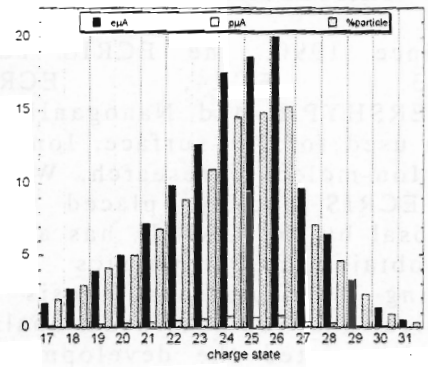

Figure 5: Xe charge state distribution for the optimization of $^{129}Xe^{27+}$(PHF = 800W)

Each spectrum shows the charge state distribution in eμA and eμp and each spectrum was measured as to optimize the highly charge state. For He, there is as much as He^{1+} and He^{2+}. The maximum particle number for a q charge state is 11/12 for Ar, 19 for Kr and 26 for Xe.

3. The beam lines

The figure 6 represents a schematic drawing of the LIMBE facility.

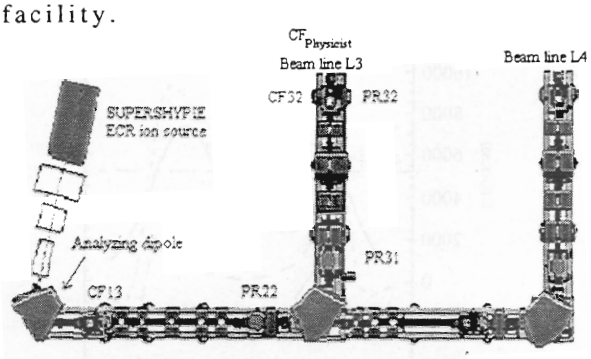

Figure 6: Artistic view of the LIMBE facility

The maximum magnetic rigidity of the system, at this time, is 0.05 T.m. It is limited by the analyzing dipole. The ECRIS is mounted on a high voltage platform able to provide a beam with an energy range between 1.5 and 25 keV*q. The two beam lines can be alternatively used. They are dedicated to transport high current intensities with very high emittance up to 150 π.mm.mrad. The operational vacuum inside the beam lines are around 10^{-9} mbar and limit greatly the charge exchange with residual gas. The pumping units are made of three cryopumps and three turbomolecular pumps.

The transmission is very high: better than 80% for L3 and better than 60% for L4. These transmissions are available as long as there is no diaphragm. The transmission difference would come from a length 30% higher for L4 than for L3. For the moment, it is difficult to transport high intensity beams inside L4 beam line due to the space charge. We have to work as to find the good optic parameters. As to tune the beam, LIMBE is equipped with five beam profile monitors and three faraday cups. The beam can be cut by a set of horizontal slices placed at the focal plane of the analyzing dipole.

As an example, let us take a beam of $^{40}Ar^{11+}$ at 121 keV. The figure 7 shows the shape of this beam along the L3 beam line. The last profile, named "PR", represents the beam shape and size where the physicist mounts its experiment. For this case, the horizontal slices were fully open (24 mm). The distance between PR32 and PR was about 80 cm. At the PR profile, the beam size is around 23 mm diameter (see figure 7).

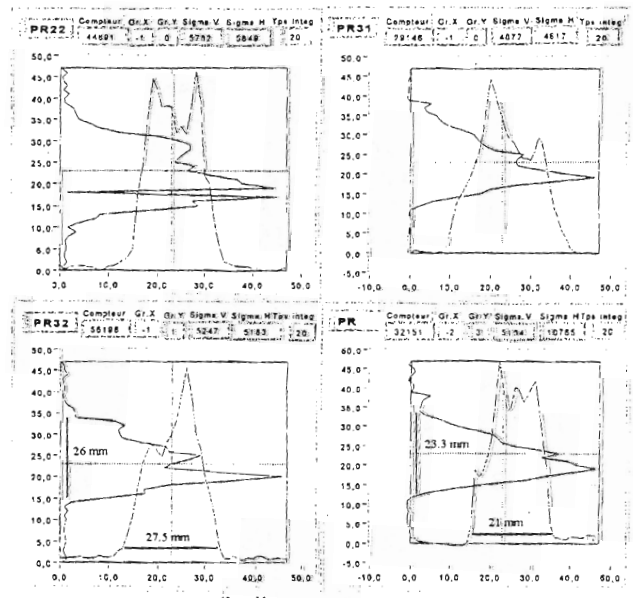

Figure 7: View of the $^{40}Ar^{11+}$ beam profiles at 121 keV on the L3 line

The divergence values are about 40 mrad and 17 mrad for the horizontal and vertical beam profile respectively. The transmission between CF32 and CF13 was 83.3% and the transmission between CF32 and $CF_{Physicist}$ was 98%.

All procedures (adjustment of dipole and quadrupole currents, beam profiling, vacuum, etc...) are supervised and visualized by computers. The control-command has been made with the Labview software.

The first experiment[3] was devoted to collisions between O^{7+} and He^{2+} with CO. Ten experiments have been accepted and about eight[4,5,6,7] have been successfully performed (mid July 2001). In particular, a double experiment requiring the use of very highly charged Xe beams with a constant velocity was able to do. One of this experiment[8] was a great technology challenge. It has been realized because the LIMBE facility was able to provide continuously a high stability Xe^{9+} beam during 30 hours.

The high performance and great stability of the SUPERSHYPIE ion source joined with the numerous tunings of beam line allow us to provide many multicharged ion beams of great quality to the physicists.

4. The future

For the future, two projects will be realized. The former will be the magnetic rigidity increase up to 0.136 T.m by the exchange of the analyzing dipole (102° switched for a 90°). The latter will be the merging of the AIM (Grenoble) facility with the LIMBE facility. At this time, H. Lebius (from Grenoble) develop an ion slackening of speed as to use eV energy beams. In the medium term, six beam lines and two ECRIS will be available for Physicists with energy from eV*q up to 25 keV*q.

But the requests of highly charged ion beams leads us to go on to get better the ion source performances. Two ways will be prospected: the double frequency which mainly improves the high charge state distribution[8] and the ion source extraction. We would like to insert an Einzel lens just behind the mass extraction electrode as to increase the beam transport which is quite low at this time (10% to 40%).

Finally, we will adapt the "MONO1000"[9] monocharged ion source to LIMBE as to furnish high intensity beams. A factor 10 for Ar and 100 for Xe with respect to the SUPERSHYPIE intensities can be reached in terms of particle number.

It is very significant that this facility must always keep its adaptability to receive easily most of the high performances ion sources.

References

[1]R. Leroy et al., *to be published in this proceedings*
[2]D. Leclerc et al., *Journées Source d'ions*, Ganil, Caen, 18-19 Mars 1999
[3]F. Frémont et al., *VII Th International Conference on the Physics of Highly Charged Ions*, Berkley, California, USA, August 2000
[4]S. Martin et al., Phys Rev A 62, 022707, 2000
[5]Z.J. Zhang and H. Naramoto, Phys. Rev. B 58(19), 12652, 1998
[6]N. Bechu, *Thesis*, University Pierre et Marie Curie, Paris, 1999
[7]F. Haranger et al., *19th International Conference on Atomic Collisions in Solids*, Paris, France, August 2001
[8]S. Gammino et al., Proceedings of the 14th International Workshop on ECR Ion Sources, CERN, Geneva, Switzerland, 3-6 May 1999
[9]N. Lecesne et al., *to be published in this proceedings*