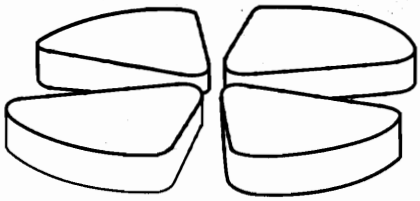
FERMILAB
JAN 3 2001
LIBRARY

4

GANIL

GANIL-P-00-49



Fermilab Library
0 1160 0089234 3

RNB production at SPIRAL/GANIL

A.C.C. Villari[1], F. Landré Pellemoine[1], C. Barué[1], G. Gaubert[1], S. Gibouin[1], Y. Huguet[1], P. Jardin[1], S. Kandri Rody[1], N. Lecesne[1], R. Leroy[1], M. Lewitowicz[1], C. Marry[1], L. Maunoury[1], J.Y. Pacquet[1], J.P. Rataud[1], M.G. Saint Laurent[1], C. Stodel[1], O. Bajeat[2], J.C. Angélique[3], N.A. Orr[3]

[1]GANIL, B.P. 5027 14076 Caen Cedex 5, France
[2]IPN, B.P. 1, 91406, Orsay Cedex, France
[3]LPC-ISMRa, Bld. Marechal Juin, 14050 Caen

FERMILAB
JAN 2 2001
LIBRARY

"Contribution présentée à CAARI-2000, Octobre 2000, Denton, TX, USA"

NAME	T.D. No.	M.S.

GANIL P 00 49

RNB production at SPIRAL/GANIL

A.C.C. Villari[1], F. Landré Pellemoine[1], C. Barué[1], G. Gaubert[1], S. Gibouin[1], Y. Huguet[1], P. Jardin[1], S. Kandri Rody[1], N. Lecesne[1], R. Leroy[1], M. Lewitowicz[1], C. Marry[1], L. Maunoury[1], J.Y. Pacquet[1], J.P. Rataud[1], M.G. Saint Laurent[1], C. Stodel[1], O. Bajeat[2], J.C. Angélique[3], N.A. Orr[3]

[1]GANIL, B.P. 5027 14076 Caen Cedex 5, France
[2]IPN, B.P. 1, 91406, Orsay Cedex, France
[3]LPC-ISMRa, Bld. Marechal Juin, 14050 Caen

Abstract. We present the on-line production system and tests for the Phase-I of SPIRAL/GANIL (Radioactive Ion Production System with Acceleration on-Line) where exotic multicharged noble gas ion beams have been obtained with the ECRIS (Electron Cyclotron Resonance Ion Source) NANOGAN-III. A new ECRIS (MONO1000) for monocharged radioactive ions is also presented, together with the diffusion properties of different graphite targets for He and Ar isotopes.

The SPIRAL facility (1) is based on the ISOL (Isotopic Separator On Line) technique for production and separation of Radioactive Ion Beams (RIB). The primary heavy-ion beam accelerated by the GANIL facility bombards a production target located inside a well shielded cave. The radioactive atoms produced by nuclear reactions diffuse out of the target, which is at high temperature ($\sim$ 2300K) and pass though a transfer tube to reach a permanent magnet ECRIS (Electron Cyclotron Resonance Ion Source) NANOGAN-III. The low-energy RIB is selected by a relatively low resolution separator (R=250) and accelerated by the compact cyclotron CIME. The energy range of the RIB varies from 1.7A to 25A MeV. Concerning the production of Radioactive Nuclear Beam, different systems have been developped (2) by GANIL for rare gaz and helium beams (NANOGAN-III), for alkali (MONOLITHE) and for the 1+/n+ project (MONO1000).

The NANOGAN-III (3) (Figure 1) is a compact permanent magnet ECRIS developed for the first phase of the SPIRAL project. The magnetic circuit consists in a sextupolar magnetic structure for radial confinement superposed by two axially and one radially magnetised permanent magnet rings. This ion source has been designed for operation with a 10GHz transmitter. Its power consumption is of 200W when tuned for the best charge state distribution performance. NANOGAN-III is an evolution of the preceeding model NANOGAN-II which worked at 14.5GHz. The new version, even working at lower frequency, has several advantages. In order to lower the magnetic field in the center of the plasma chamber, one of the permanent magnet rings has been removed. This decreased the cost and the weight of the ECRIS to 4/5 of the preceeding one. The transmission of the beam through the separator has been improved, which could mean that the emittance of NANOGAN-III is smaller than the preceding version. The ion source is linked to a carbon target by a cold and short transfer tube. This allows efficient production of noble gas elements with reasonable suppression of condensable contaminants.

The ionisation efficiency - all charge states - of Ar ions has been measured to be better than 95% when NANOGAN-III is tuned in order to maximise the 8+ charge state. (see Figure 1). In this same figure, we compare the charge state distribution of ^{40}Ar leak with and without beam on the target. The comparison between the off and on-line distributions attests that the ion source is almost insensitive to the heating and to the presence of the beam on the target.

At GANIL, the development of ECRIS for monocharged production is intrinsically related to the 1+/n+ project, i.e. the reinjection of the beam into another ion source for charge multiplication before the injection into the accelerator. This important condition fixes not only the required efficiency but also the characteristics of the beam provided by the 1+ ECRIS which its cost is cheaper than a multicharged ion source. If one consider that the life time of the production system is limited, a smaller and cheaper ion source is needed inside the production cave - very close to the irradiation point.The MONO1000 ECRIS (4) (Figure 2) has been designed in order to have a large magnetised chamber

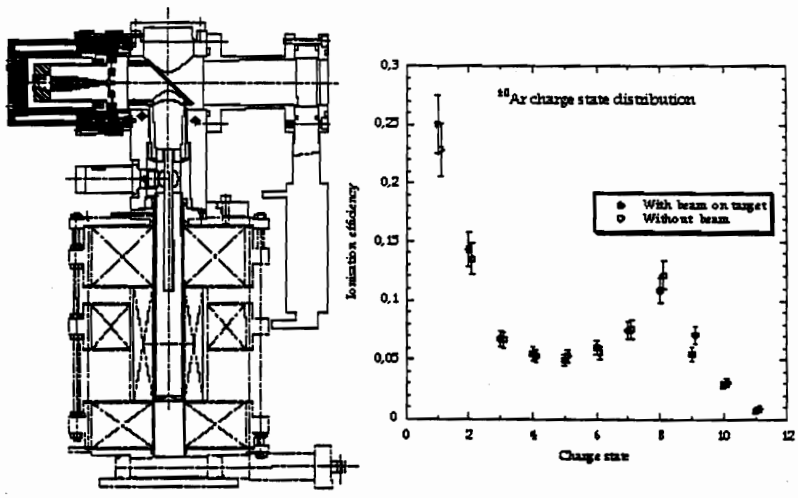


FIGURE 1. NANOGAN-III system and charge state distribution of ^{40}Ar with and without beam in target

of approximately 1 liter of volume, allowing one to place a target and/or a heating internal wall system with external cooling. The magnetic structure is made with two permanent magnets rings (total weight of 22.2 kg), which allows to create a closed 2000 Gauss surface at the wall of the plasma chamber. The plasma electrode is located in a 1800 Gauss magnetic field. It has to be pointed out that no specific radial structure is used - the magnetic field is on revolution symmetry - and that the magnetic field in the extraction area presents a cylindrical geometry. During the first commissioning tests, the 2.45 Ghz microwave was injected into the large diameter (90 mm) cylindrical plasma chamber through a coaxial transition ended by an antenna.

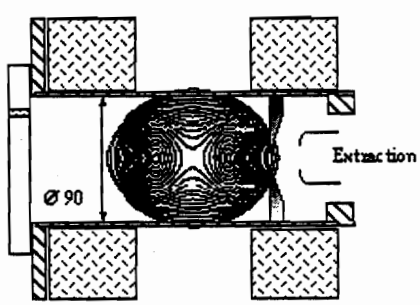


FIGURE 2. The MONO1000 ion source

The first tests of this ion source have been made with Argon through a calibrated leak and Helium as support gas. The measured ionisation efficiencies for ^{40}Ar at 1+ and 2+ states were respectively 90% and 9%, inside a root mean squared emmitance of 27 π mm mrad at $E = 14keV$. Moreover, ^{32}S beam production has been also studied injecting a calibrated quantity of the gaseous molecule of SO_2 in the source. This test revealed an overall efficiency of ionisation for the compounds of ^{32}S of around 95% It is clear that several different molecules are still present on the spectrum of the extracted ions. The ratio between the yield of this molecules and the ^{32}S (1+) beam varies strongly with the microwave power.Presently we are limited to around 20W due to our microwave coupling. A new coupling is being developed which could allow one to deliver one order of magnitude more power in the ion source.

The efficient production of radioactive nuclear beams by ISOL method is intrinsically related to the efficiency of the ion source and to the release delay time of the target. The carbon target has been chosen due to its excellent release properties, low atomic number and high sublimation temperature. A special conical design has been choosen to distribute uniformly the power density of the beam (due to the Bragg peak) (5). We present in figure 4 the diffusion-effusion efficiency of carbon targets with different grain microstructure, i.e. 1μm, 4μm and 15μm.

The results (6) show an important enhancement of the diffusion effusion efficiency for the 1μm microstructure. We also observed an enhancement of a factor 2 for the production for ^{35}Ar and a factor 10 for ^{32}Ar. The diffusion effusion efficiency of ^{6}He in the 1μm microstructure target has been also mesured as a function of the target temperature. The obtained efficiencies are presented in figure 4.The most important observation is the fact that the ^{6}He diffusion effusion efficiency reaches 100% at reasonably low temperatures, around 1600K.

We also developed a carbon target for helium production which is devided in two parts, due to the long range of ^{8}He in C (figure 5). The first part (production target) is only heated by the ^{13}C primary beam ; the second part

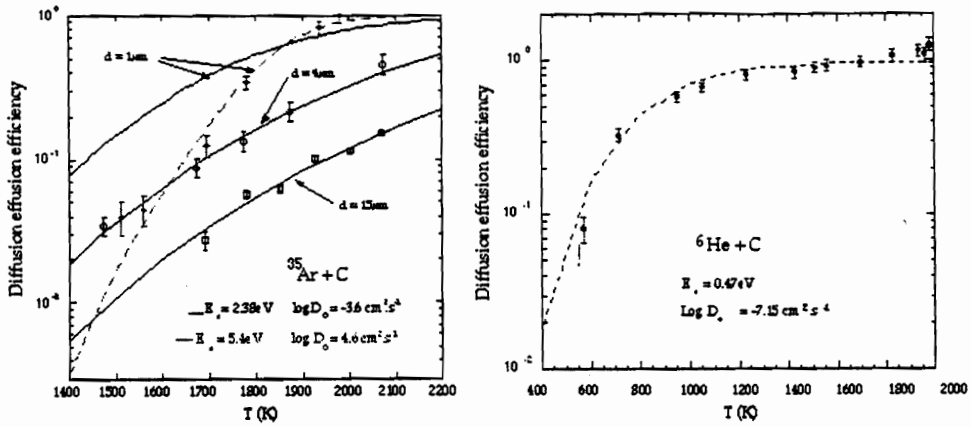


FIGURE 3. Diffusion-effusion efficiency as a function of the target temperature for ^{35}Ar and ^{6}He

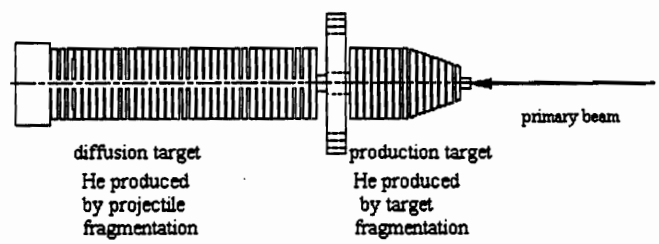


FIGURE 4. Target for helium production

(diffusion target), stops the fragmentation products, and is heated by an electric current through the axis.

Yields of different isotopes have been measured at the SIRa on-line test bench.For exemple, we obtained yields of 5.4 10^8 and 1.48 10^6 for $^6He^+$ and $^8He^+$, 2.7 10^3 and 5.4 10^8 for $^{32}Ar^{7+}$ and for $^{35}Ar^8$, 4.49 10^4 1.95 10^7 and 6.76 10^8 respectively for $^{73}Kr^{15+}$, $^{75}Kr^{15+}$ and $^{77}Kr^{15+}$ (7) normalised to 1pμA.

For the future at GANIL (8) , a new project is developped for the production of neutron-rich beams by fission of Uranium induced by neutrons or photons : SPIRAL Phase-II. To study the optimum conditions of this method, different experiments and simulations are being performed. The energy range and the angular distribution of the neutrons produced at different deuteron incident energies on different converters has been already measured. Cross sections of fast neutron induced fission and the isotopic yields of several elements diffused out of a thick target are now available. Moreover, the photofission is also investigated in order to choose between fission induced by fast neutrons and photofission. Simulations are also being made in order to be able to predict the production rate for neutron-rich nuclei.

REFERENCES

1. *The SPIRAL Radioactive Beam Facility,* GANIL Report **R-94-02** Caen(1994).
2. A.C.C. Villari, *Nucl. Instr. Meth. Phys. Res.,* **B126** (1997) 35.
3. L. Maunoury et al., *18th Int. Work. ECR Ion Sources,* Texas USA (1997).
4. A.C.C. Villari, *Ion source development for RNB production at SPIRAL/GANIL,* Proceedings of RNB 2000, to be published in Nucl. Phys. A.
5. R. Lichtenthäller and al., *A simulation of the temperature distribution in the SPIRAL target,* NIM **B 140** (1998) 415-425.
6. F. Landré-Pellemoine and al., *Recent results at SIRa test bench : Diffusion properties of Carbon graphite and Boron carbide targets,* Proceedings of RNB 2000, to be published in Nucl. Phys. A.
7. L. Maunoury, *Production de faisceau radioactifs multi-chargés pour SPIRAL : Etudes et réalisation du premier ensemble cible-source,* GANIL PhD **T-98-01** Caen (1998).
8. M.G. Saint Laurent and collaborators, *SPIRAL Phase-II contract number ERBFMGECT980100,* GANIL Report, April 2000.