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**A SINGLE STAGE ECR SOURCE FOR THE RADIOACTIVE ION BEAM PROJECT IN  
LOUVAIN-LA-NEUVE**

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**ABSTRACT.**

In 1987 the project RIB (Radioactive Ion Beam) was started at Louvain-La-Neuve, to produce and accelerate radioactive nuclei of C, N, O, F and Ne. Within the framework of this project, a single stage E.C.R. source will be built. The general scheme of the project and the design of the source are discussed.

En 1987 a démarré à Louvain-La-Neuve le projet RIB (Radioactive Ion Beam), dont le but est de produire et accélérer des noyaux radioactifs de C, N, O, F et Ne. Dans le cadre de ce projet, une source E.C.R. à un étage sera mise au point. Le schéma général du projet et le dessin de la source sont présentés ici.

**1. INTRODUCTION.**

In order to study the stellar burning of elements between C and Ne in the hot CNO cycle, one should study proton induced reactions on radioactive targets. Because of the short half-life of this type of target nuclei, the inverse reaction has to be studied.

Theoreticians and experimental teams of the "Katholieke Universiteit Leuven", the "Université Catholique de Louvain" and the "Université Libre de Bruxelles" started a project one year ago, to produce and accelerate radioactive nuclei and to study the reaction cross section on a proton or He target.

Within the framework of this project, we are currently developing a single stage E.C.R. source, to ionize the radioactive atoms to a low charge state.

**2. GENERAL SCHEME OF THE RADIOACTIVE ION BEAM PROJECT.**

The way the radioactive ions will be produced and accelerated is guided by the existence, at Louvain-La-Neuve, of two neighbouring cyclotrons (fig.1) : an H<sup>-</sup> machine, named

CYCLONE 30, for protons up to 30 MeV with a maximum intensity of 500  $\mu\text{A}$ , and an isochronous variable energy cyclotron, CYCLONE, with a maximum energy  $T_{\text{max}} = 120 \text{ MeV} \cdot Q^2 / A$  ( $Q = \text{charge state}$ ,  $A = \text{mass}$ ).

The 30 MeV proton beam will bombard a target situated in the wall between the two cyclotrons. The produced activity will diffuse out of the target and be injected into the E.C.R. source, where the atoms will be ionized to a low charge state. After extraction out of the source, the ions will be injected into the main cyclotron (CYCLONE). Finally, they will be accelerated to the designed energy ( $\approx 0.6 \text{ MeV} / \text{a.m.u.}$ ) and sent onto the "astrophysical" target.

The low energy beam from the E.C.R. source can also be used for other purposes, such as solid state physics studies.

Because the  $^1\text{H} (^{13}\text{N}, \gamma) ^{14}\text{O}$  reaction is one of the key reactions in the hot CNO cycle,  $^{13}\text{N}$  ( $T_{1/2} = 9.96 \text{ min}$ ) will be the first beam to be accelerated. The  $^{13}\text{N}$  activity will be produced via the  $^{13}\text{C} (p, n) ^{13}\text{N}$  or  $^{16}\text{O} (p, \alpha) ^{13}\text{N}$  reactions.

The other beams which we plan to accelerate in the future are  $^{11}\text{C}$  ( $T_{1/2} = 20.38 \text{ min}$ ),  $^{14}\text{O}$  ( $T_{1/2} = 70.59 \text{ s}$ ),  $^{15}\text{O}$  ( $T_{1/2} = 2.03 \text{ min}$ ),  $^{18}\text{F}$  ( $T_{1/2} = 109.7 \text{ min}$ ) and  $^{19}\text{Ne}$  ( $T_{1/2} = 17.22 \text{ s}$ ).

The present status of the project and the related measurements have been reported in reference /1/.

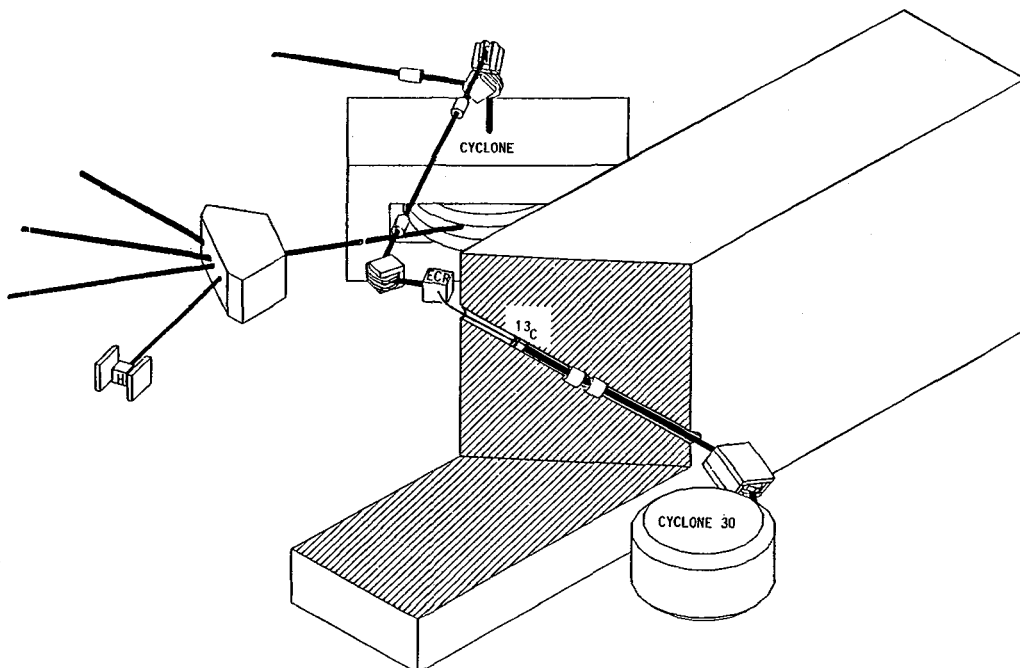


Fig. 1: Schematic layout of the Radioactive Ion Beam facility

### 3. THE SOURCE.

#### 3.1 Introduction.

It is a well known fact that elements like Carbon, Nitrogen, Oxygen and Fluorine are very difficult to ionize in a hot plasma source because they are either very refractory in their atomic form, or either very reactive. Even a noble gas like Neon seems to be difficult to be ionized in an efficient way /2/.

However, measurements with a single stage E.C.R. source show high ionization efficiencies for C, N, O and Ne /3/.

We started the development of an E.C.R. source especially designed for these elements.

#### 3.2 Layout of the source.

Fig.2 shows the conceptual layout of the source. The source will be a single stage source working at a microwave frequency of 6.4 GHz. The axial coupling of the microwaves with the plasma, and the fact that no radial pumping is necessary, made it possible to design a compact hexapolar magnetic configuration (see further). The multimode cavity consists out of a cooled Cu cylinder ( $\varnothing_{in} = 100$  mm,  $l = 300$  mm) containing the permanent magnetic bars. This cavity will also contain the plasma. The distance between the extraction electrode and the exit hole will be variable from 10 to 15 mm. The extracted ion beam will be sent directly to the double focusing deflection magnet without any focusing electromagnetic element in between.

#### 3.3. The magnetic field configuration.

The magnetic bottle will consist out of a radial hexapolar field and an axial solenoidal field. Calculations were performed using the Poisson Group codes /4/. We made sure that the BECR surface ( $B_{ECR} = 0.229$  Tesla) lies well within the physical boundaries of the chamber and of the plasma boundaries.

##### 3.3.1. The solenoidal field.

Two water-cooled solenoidal coils ( $\varnothing_{in} = 210$  mm,  $\varnothing_{out} = 411$  mm) will produce an axial field with a mirror - to - mirror length of 300 mm and a mirror ratio of 1.4. The mirror ratio can be changed by varying the distance between the solenoids. Using an iron yoke to enforce the field in the source, a value of 0.254 Tesla will be obtained at the exit hole with a current of 255 A.

##### 3.3.2. The radial hexapolar field.

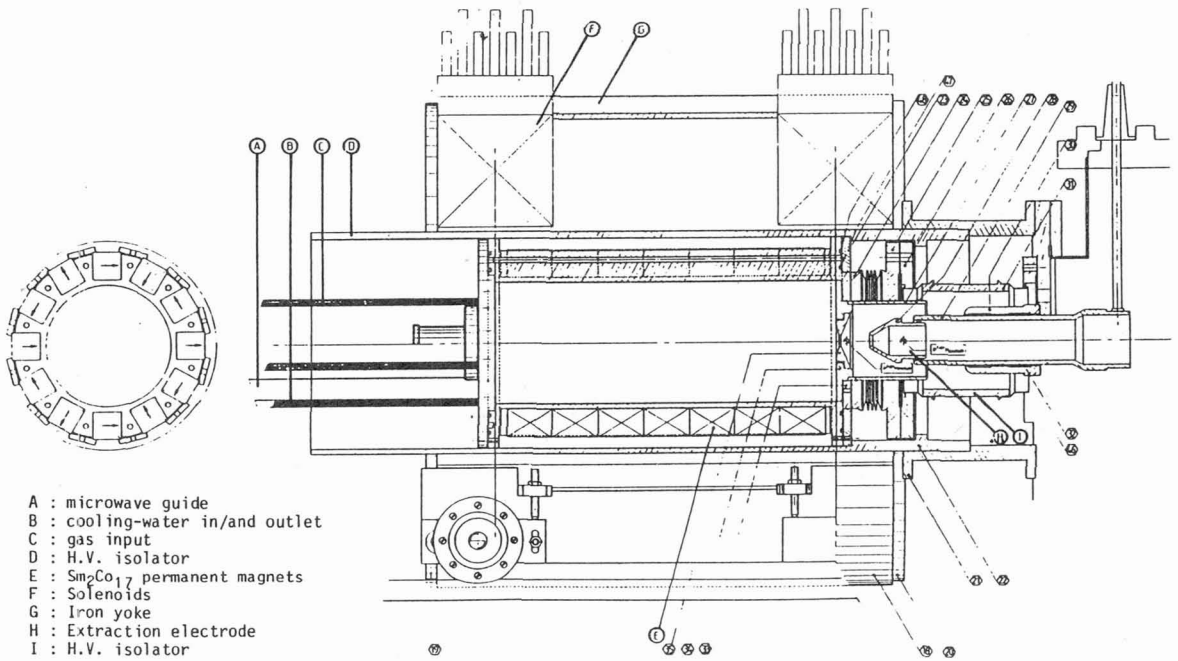
This field will be produced with 12 bars of permanent magnetic material (Sm-Co) arranged in a compact way (see fig.3). This reduces the amount of permanent magnetic material needed, and also reduces the inner diameter of the solenoids. The results of the calculations using permanent magnets with  $B_R = 0.9$  Tesla and  $H = 676$  kA/m are shown in fig.3. Although the source will be shielded from the target, the n-flux coming from the target will be large. Therefore, we will use radiation resistant Sm<sub>2</sub>Co<sub>17</sub> permanent magnetic material.

### 4. CONCLUSION.

The design of the E.C.R. source is finished. Assembling of the source and off-line tests will be performed in the fall of 1988. The beam line between the two cyclotrons, the target assembly and the source will be installed between November 1988 and February 1989.

The first radioactive beam can be expected in Spring 1989.

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- A : microwave guide
- B : cooling-water in/and outlet
- C : gas input
- D : H.V. isolator
- E :  $\text{Sm}_2\text{Co}_{17}$  permanent magnets
- F : Solenoids
- G : Iron yoke
- H : Extraction electrode
- I : H.V. isolator

Fig. 2: Layout of the E.C.P. ion source

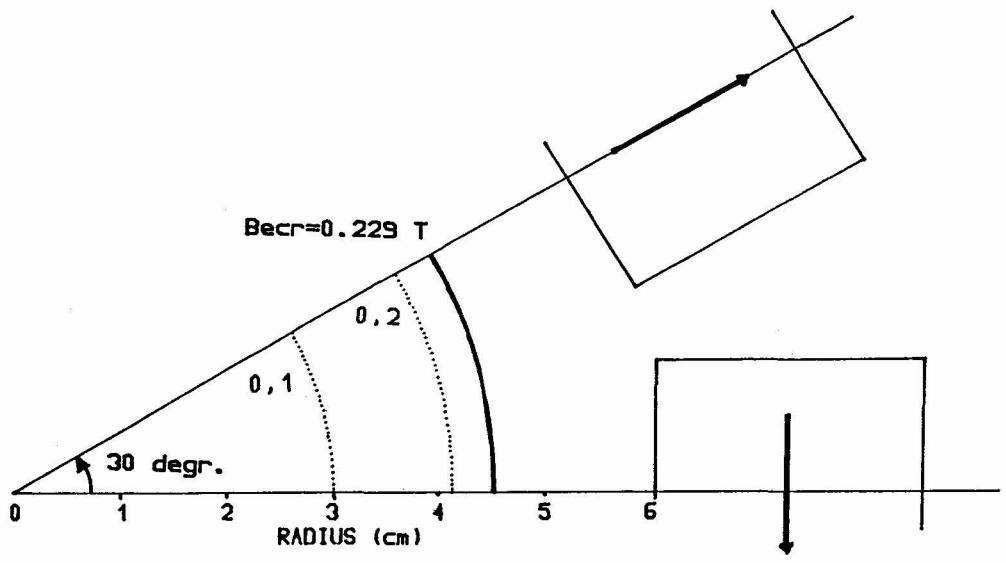


Fig. 3: The results of the calculation for the hexapolar field. The  $B_{eCr}$  surface in the absence of the axial-solenoidal field is shown as well as the equipotential lines for 0.1 and 0.2 Tesla

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