THE ECREVIS SOURCE : A STATUS REPORT *

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Abstract.- ECREVIS is an electron cyclotron resonance source for highly stripped heavy ions presently under construction at the cyclotron laboratory in Louvain-la-Neuve (Belgium). The main design features are a large size (1,2 m between mirrors on the axis), a superconducting magnetic structure and large custom designed cryogenic pumps. Excepted for the superconducting magnetic bottle, which has been seriously delayed, the other subsystems of the source are virtually ready for initial operation. A scale model of the superconducting magnetic bottle allowing tests of a compact source, has been built in the Institute. Final tests are in progress for this small system. Extraction and beam formation tests have been done, using the plasma of the first stage of the source. Beam has been transported to the cyclotron. Those extraction tests show the dominant effect of the source fringing field crossing on the emittance of an ECR-source. Those tests also show that retarding Einzel lenses cannot be used in the fringing magnetic field. Finally some efforts have been devoted to get a better understanding of the source equilibrium. A new model has been developed and the theoretical results show good agreement with experimental data from Supermafios and Micromafios.

1. Introduction.- Ecrevis is a large superconducting E.C.R. heavy ion source, presently under construction at the Cyclotron Laboratory in Louvain-la-Neuve (Belgium). Design parameters have been described elsewhere $^{1,2)}$. The latest version is shown in fig. 1, and typical parameters are summarized in table 1.

2. Present status of the construction.- By now, (sept. 81), the first stage of the source (the cold plasma generator) has been operated, reliably for almost two years. It has been used mainly for plasma investigations, extraction and beam formation studies. The R.F. generators are installed and tested. Pumps and mechanical parts are nearly ready. The main superconducting

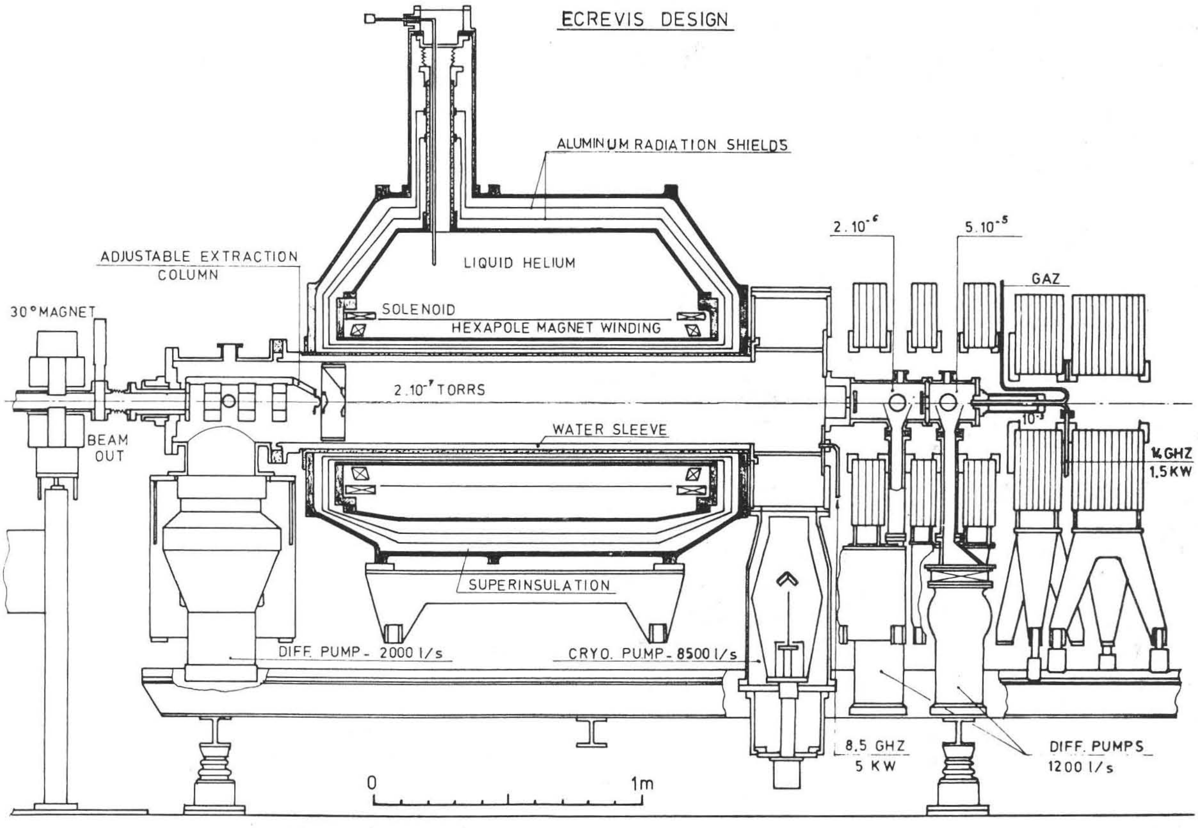
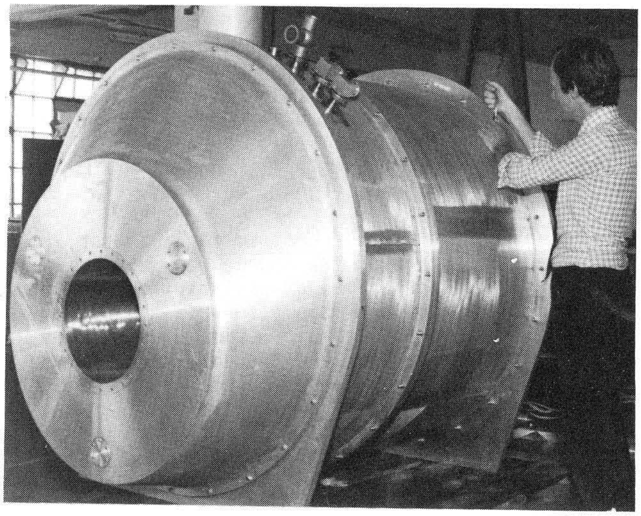


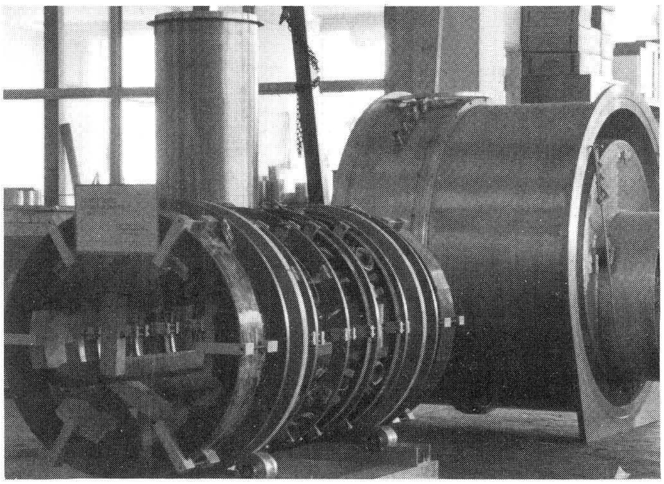
Fig. 1

Table 1 : Typical parameters

	Stage 1 (plasma injector)	Stage 2 (main confinement)
E.C.R. field	0,53 T	0,31 T
E.C.R. frequency	14,3 Ghz	8,5 Ghz
Available RF power	1,5 kW	5 kW
Neutral pressure	$\approx 10^{-3}$	$3\ 10^{-7}$ Torr
Electron density	$\approx 8\ 10^{12}$	$3\ 10^{11}\ \mathrm{cm}^{-3}$
Plasma lenght	75 cm	120 cm
Delivered ionic flux	$3\ 10^{16}\ \mathrm{s}^{-1}$	$1{,}5\ 10^{15}\ \mathrm{s}^{-1}$
Electron lifetime	$\approx 10^{-5}$	$3{,}5\ 10^{-4}$ s
Electron temperature	$\approx$ 7 eV	$\approx$ 5000 eV
Ion temperature	$\approx$ 7 eV	$\approx$ 7 eV
Mean charge state (Argon)	1,1 +	6,2 +

system has been seriously delayed but is now close to completion. The cryostat (photo 1) is completed and has been tested. The coils system has been assembled and a low level field mapping has been done at room temperature (photo 2). Final assembly and cryogenic tests are foreseen in the next weeks.





3. The ecrevette system.- It has been decided to build, in parallel, a one third scall model of the second superconducting stage of the source. Goals are multiple : to have the possibility to verify scaling laws on quasi-identical devices, to have a small, flexible system to test modifications easily and, last but not least, to get some experience, in our laboratory, of superconducting coils construction.

The small superconducting system has been completed (photo 3) and, recently tested. No quench has been observed at all, up to a current value well above the design goal, and persistent mode operation achieved. Due to the smaller stored energy, the decay time constant is shorter than with the large system, and has been measured to be ± 1500 hours.

4. Extraction and beam formation tests.- The first stage of ECREVIS has been used to test beam formation and extraction from an E.C.R. plasma. One reason was to try to understand the apparently large emittance value found on Geller prototypes 3, 4, 5, 6).

Our tests seem to indicate that the fundamental ion temperature may not be the dominant term in the observed emittances and that some "side effects" may seriously worsen the original beam emittance.

First of all, the extraction geometry must be carefully matched to the plasma conditions. If the perveance of the extraction system does not match the plasma production, overfocusing or underfocusing occurs in the extraction gap, giving a very divergent beam, which then undergoes non linear effects in the subsequent lenses. As the perveance is mainly determined by the diameter-to-gap ratio, an ajustable gap seems a desirable feature.

If the intensity of the beam is rapidly fluctuating (plasma instabilities), the divergence will also fluctuate, an this will appear, when averaged, as a larger emittance.

A second problem, well known, is the crossing of the fringing solenoïdal field. The radial component of the field, combined with the axial speed of a particle, gives an azimutal speed component. One shows easily that the azimutal momentum is :

$$p_r = \frac{a}{2r_0} \ ;$$

where a is the extraction radius and r_0 is the radius of curvature of the accelerated particle in a field equal to the extraction axial field.

Here again, the projection of those azimutal speeds in the refèrence planes may look like an apparent emittance increase.

Finally, some technological problems are connected to the use of electrostatic Einzel lenses in the fringing field. A retarding Einzel lens in an axisymetric field make a perfect Penning jauge geometry. A plasma is trapped inside the lens, deformating the equipotential planes, and making the lens unusable.

To avoid this Penning geometry, an Einzel lens with ferromagnetic electrodes has been tested. The field lines are captured by the iron, destroying partially the Penning jauge geometry. The improvement is sensible, but due to incomplete cancellation of the field in the lens, a stable plasma still exist at the center.

On the other hand, accelerating Einzel lenses require excessively high voltages to reach short focal lenghts.

Therefore, an iron free magnetic lens seems the best choice to refocus the beam in the extraction of an E.C.R. source.

The beam from the first stage has also been used to test the injection beam line, and the axial injection system. Beam has been transported to the center of the cyclotron, with efficiences of 80 ... 90% for the axial injection system alone, and from 40% to 15% for the injection beam line, the best efficiencies beeing associated to the most rigid particles. This poor but very preliminary result indicates unsatisfactory magnetic shielding of the line.

5. A theoretical model of an E.C.R. source [9,10].- Together with those technological developpements some efforts have been devoted to get a better understanding of the source equilibrium. Starting from the work of Chan-Tung[7,8], a new model has been developped to compute the charge state distribution in the extracted beam of a source. Theoretical results show good agreement with experimental data from Micromafios and Supermafios (fig. 2). The model has been used to make some prediction on the possible C.S.D. in the ECREVIS source, presently under construction (fig. 3).

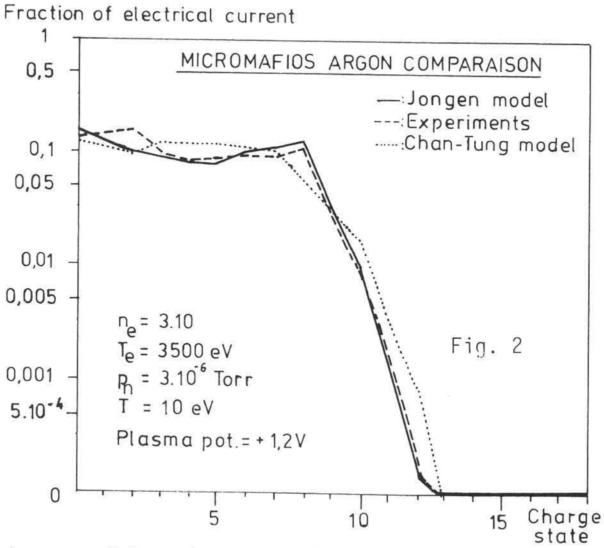
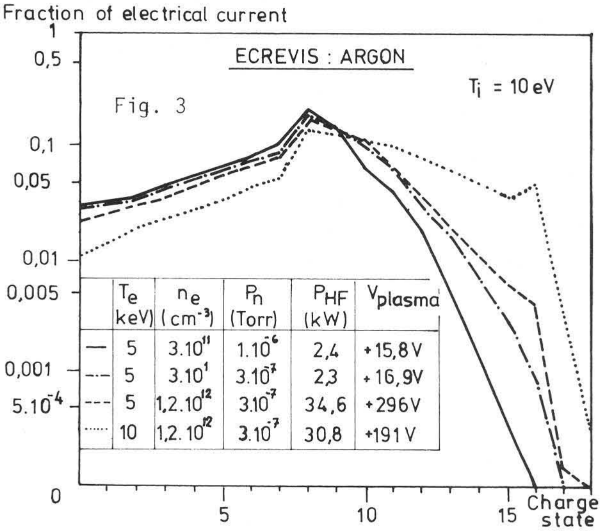


Fig. 2

Finally, a simple way has been found to reconstruct the plasma shapes in the vacuum chamber (fig. 4).



	T_e keV)	n_e (cm^{-3})	P_n (Torr)	P_{HF} (kW)	V_{plasma}
—	5	3.10^{11}	1.10^{-6}	2,4	+15,8 V
-·-	5	3.10^{1}	3.10^{-7}	2,3	+16,9V
---	5	$1,2.10^{12}$	3.10^{-7}	34,6	+296V
·····	10	$1,2.10^{12}$	3.10^{-7}	30,8	+191 V

Fig. 3

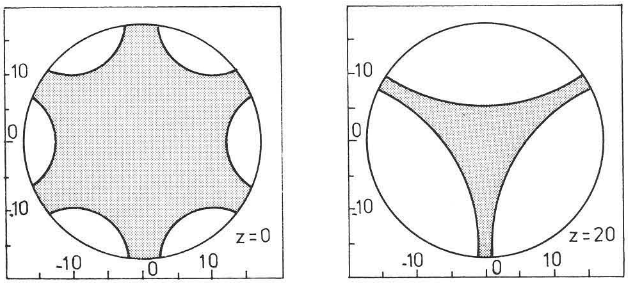


Fig.4

Computed shapes agrees well with the plasma marks found on the walls of actual sources.

Acknowledgements.- This project is the joined effort of a large team : the cyclotron crew, the institute workshop and many others. Their constant efforts, their skill and experience allow this project to come to life.

The whole project is conducted under the direction of Professor P. Macq. His enthousiasm, the frequent meetings and countless fruitful discussions are a key of success.

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