Radioactive ion beams at Grenoble
The PIAFE project

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Abstract

Grenoble presents the unique opportunity of having two very close laboratories : the Institut Laue-Langevin (ILL) and the Institut des Sciences Nucléaires (ISN). The PIAFE project is based on the acceleration by the two ISN cyclotrons (SARA) of neutron rich fission fragments produced in an Uranium target put inside the high thermal neutron flux of the ILL reactor. After production, the radioactive nuclei will be single-ionized in a first source and accelerated by a voltage of 15-30 kV before mass separation and transport in a 400 m long transfer line to a secondary high charge ECR source. Then, the multicharged ions will be accelerated by the SARA complex.

1. INTRODUCTION

The PIAFE [1] (Projet d'Ionisation et d'Accélération de Faisceaux Exotiques) objectives are to produce neutron rich ion beams, with masses from 80 to 150 amu. The expected intensities will be between 10^5 and 10^{12} particles per second. This project is currently studied within a large collaboration involving. Belgium, Denmark, France (IN2P3, CEA), Germany, Sweeden and Russia.

A general overview of the facility is given figure 1. We can see the following elements, described more precisely below :

- The fission source, near the reactor core at the ILL.
- An ion source, to get single charged ions of about 30 keV or less.
- A mass separator.

At this stage, the ions could be used for low energy physics. This will be the first phase of PIAFE, denoted below as PIAFE1.

A second phase, denoted as PIAFE2 will be devoted to higher energy physics (2 to 14 MeV/amu) thanks to acceleration by SARA. It will be made of :

- A 400 meter long transfer line, to transport the single charged low energy ions to SARA.
- An ECR source, needed to get highly charged ions before injection into SARA.
- The two cyclotrons of SARA, giving final energies from 2 to 14 MeV/amu.

Intensive R&D studies are currently performed both on PIAFE1 design as well as PIAFE2, in terms of feasability and cost.

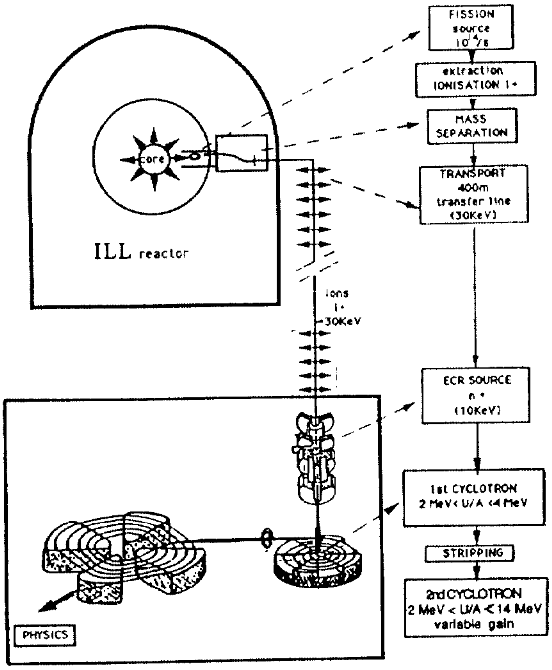

Figure 1. General schematic view of PIAFE

2. PIAFE AT ILL (PHASE 1)

2.1 Fission source

The first kind of source, identical to the Studsvik (Sweeden) source, will be made of a 1g U^{235} target put in the 10^{14} neutron/sec flux near the reactor core. The source temperature will be around 2400 °C and elements like Rb, Sr, Ce, Ba and Sm will be produced by thermoionisation. Other elements like Sn or Ga will be produced by the same source running in the plasma mode.

2.2 Beam transport inside the ILL

A schematic view is given figure 2. After the source exit, the 30 keV/1^+ ions will be transported out of the reactor by an electrostatic channel composed of 10 electrostatic Einzel lenses put on a removable girder. After a first electrostatic deflector, the ions will be separated by a magnet according to their mass and will be available for low energy physics (PIAFE1, for which 2 mass spectrometers are foreseen) or for transport to SARA.

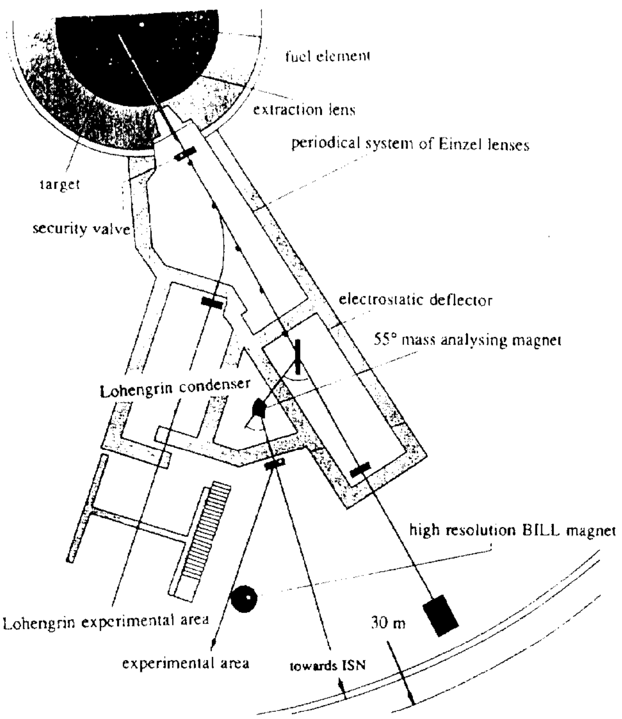

Figure 2. View of PIAFE phase 1 in the ILL reactor hall

3. PIAFE AT SARA (PHASE 2)

3.1 Beam transport from ILL to ISN

The transport between the two institutes will be done at low energy. It must be noticed that this part will be an important component of the facility in terms of transmission, cost and reliability. For these purposes, an experimental 18 m long line has been built.

The *focusing* will be done by a magnetic FODO lattice (see figure 3) rather than an electrostatic one in order to use a maximum aperture as well as to get an easier access; maintenance will be possible without safety problems of opening the vacuum chamber in a radioactive environment. The quadrupoles will be no-iron elements made of four 0.7 m long copper conductors where a 1500 A current will provide a 0.25 T/m gradient. This solution is cheap and simple. The distance between quadrupoles will be 0.8 m. The quadrupoles will be installed by set of 4 on a granite girder put on 3 LEP-kind jacks. The precision of quadrupole relative positionning is 0.3 mm RMS. As their center is mechanically known, no fiducialization is needed, and they are set directly on the girder.

The *alignment* of girders will be done by using well proven CERN-like techniques as streched wire (for horizontal position) and optical level (for altimetry), used both for first alignement as well as for correction of ground motion [2].

Such a beam is sensitive to low *parasitic magnetic fields*. It has been shown that the most important one is the Earth magnetic field, leading to a several mm oscillation of the central trajectory. This field is constant and a compensation can be foreseen if necessary. It has been shown that other magnetic fields due to, for exemple, trucks, are well below and are negligible.

Interaction with *residual gas* will increase the beam emittance and reduce the transmission by charge exchange. Analytical estimates and first experiments have shown that a 90 % transmission needs about 10^{-8} mbar. This can be done by using only a 45 l/sec ionic pump every 18 meters (pumping for diagnostics excluded).

The *control and correction* of the central trajectory requires one beam position monitor and (at least) one steerer every 18 meters. All these considerations leads to the conclusion that a 18 m long section can be considered as one module of the line in terms of pumping, diagnostics and corrections.

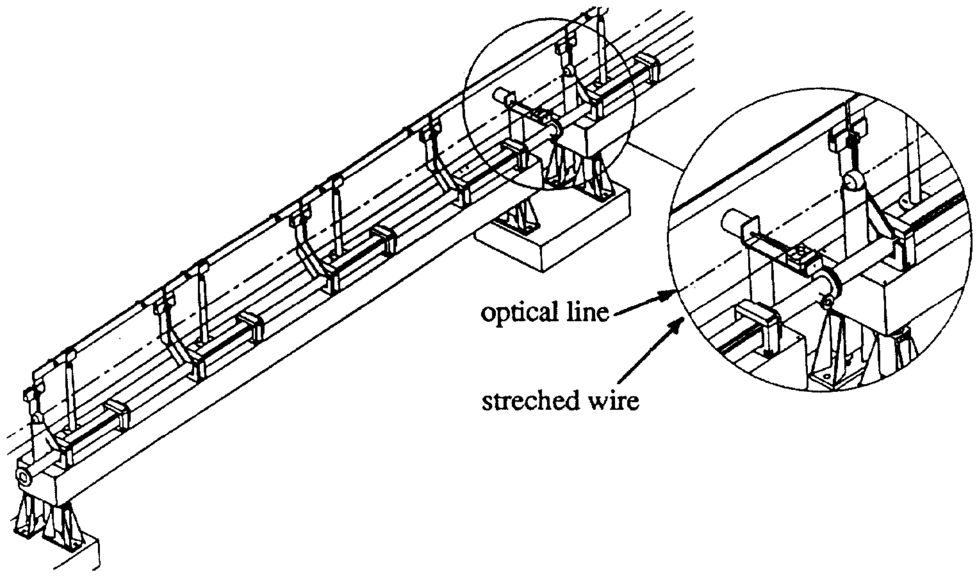

Figure 3. View of the future 400 m transfer line, made of no-iron quadrupoles put on granite girders. A (schematic) ecartomer is used for transverse alignment. A Taylor Hobson sphere is put at the other extremity of the girder, for vertical alignment.

3.2 Single to high charge ion transformation

As the 30 keV ions are transported in the 1^+ state, it is necessary to increase their charge before injection in the first cyclotron. The solution that is currently studied is to stop them by a hot catcher put inside an ECR source. They will be released as neutral atoms (rare gases) or 1^+ ions (alcalines) and then ionized by the ECR plasma. Experiments are done with a MINIMAFIOS source, several kinds of catchers and noble gases. For a carbon catcher and a non-radioactive krypton beam, about 7 % of the particles incoming on the catcher have been transformed into Kr^{9+}. Considering the theoretical distribution of ions over the whole charge spectra, we can conclude that about 100% of the incoming ions are released and ionized. A schematic view of the experimental set up is given figure 4: an ECR 1^+ source generates the ions (ex: Kr^{1+}) which are focused and sent on the catcher through the MINIMAFIOS plasma. After desorption and ionization, the multicharged ions are analysed and directed towards a Faraday cup. Rb beams will be studied further. Studies of ion implantation are also done with radioactive noble gases produced by a Californium source.

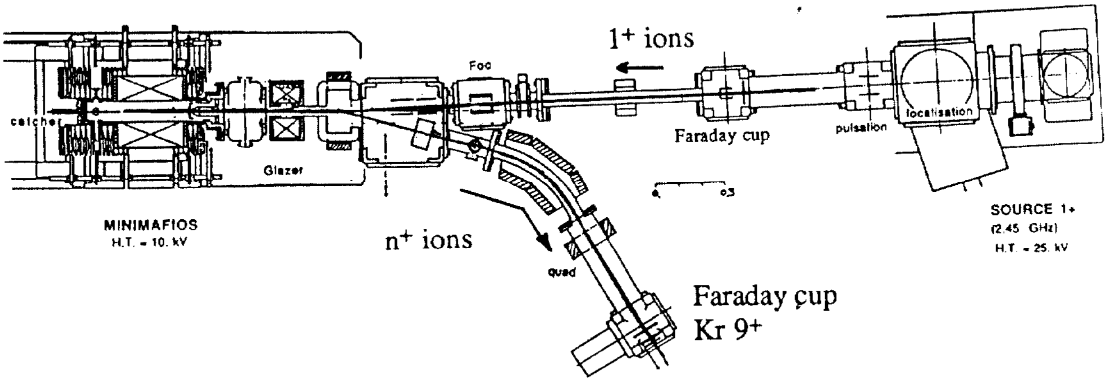

Figure 4. 1^+ to n^+ experimental setup

3.3 Acceleration

The SARA system is made of two cyclotrons. The first one is a compact, K=88MeV, cyclotron and the second one is a separated sectors machine with K=160 MeV. In the present state of SARA, the second cyclotron can be considered as an energy amplifier of gain 5.3. This leads to a lower limit of achievable energies of 10.3 MeV/amu, which is too high and not acceptable for physics as it corresponds to a hole in the range of energies between the two machines. The solution which is currently foreseen is to remove one RF resonator of the second machine and to replace it by a movable extraction septum magnet, in order to have an energy gain between 1.7 and 3.8 (figure 5).

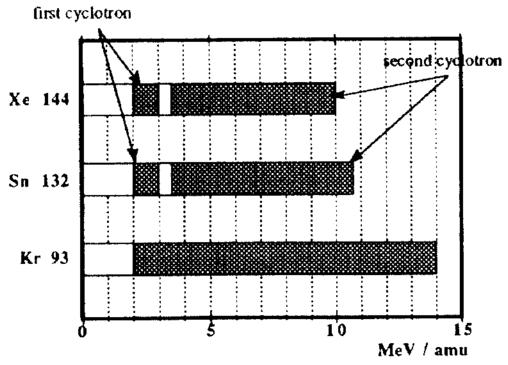

Figure 5. Achievable energies (phase 2)

A modification of the injection into the second cyclotron is also foreseen to increase the injection radius by a factor 7/6 in order to be able to inject heavy ions for which the stripping efficiency is lower.

4. PLANNING

PIAFE phase 2 will begin only after the measurement of the exotic elements production rates with PIAFE1. Considering the time needed to set up phase 1, phase 2 building is foreseen for the beginning of 1997. The first beam with SARA is foreseen for 1999.

5. CONCLUSION

PIAFE is a project interesting a large international collaboration and will be a unique facility to produce neutron rich heavy elements. Many theoretical as well as experimental studies are currently made for the two phases. The first phase is now well defined and the second one is still under R&D progress.

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