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POLARIZED LITHIUM-6 BEAM AT SATURNE

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Abstract: The SATURNE synchrotron facility is now equipped with a polarized Lithium-6 ion source for nuclear physics experiments. The source is an arrangement of a conventional polarized atomic beam and a ionizer injecting the Li^{1+} ions into the Saturne EBIS, DIONÉ. The Li^{1+} ions are trapped and ionized inside the EBIS electron beam. After acceleration through the RFQ, Li^{3+} ions are injected into MIMAS.

Polarized atomic beam.

The atomic beam emerges from an oven and the polarization is obtained by means of a conventional Stern-Gerlach magnet followed by three RF transitions. The device is similar to the Heidelberg source¹⁾ and some parts (oven, sextupole magnet and RF cavities) are spare elements from Heidelberg Laboratory. All these parts have been assembled and adapted to the technical requirements of an EBIS environment.

Li^{1+} beam ionizer.

The polarized atomic beam is ionized on a hot oxidized tungsten strip . The oxygen partial pressure is about 10^{-6} torr. The tungsten surface is inclined at 90° to the atomic and ionic beam axis. The ions are extracted by an uniform electrical field and the extracting voltage is 10 kV. A 460 gauss uniform magnetic field, parallel to the electrical field, defines the polarization direction during the surface ionization.

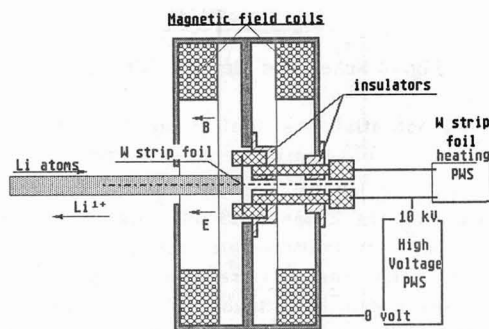


Fig. 1 **Lithium ionizer** The tungsten strip foil is directly heated and biased at 10 kV.

The emittance of the ions beam is a very important parameter for the injection in DIONÉ and has two main origins :

- the transverse energy due to the thermal energy of ions at the strip temperature (above 1000°C) . The emittance is given by :

$$E_x = \frac{\pi F}{c} (kT/m)^{1/2} ,$$

and, using ionizer parameters, one comes to $1.5 \cdot 10^{-7}$ m.rad (normalized).

- the magnetic field . In order to define the polarization, this field is uniform. The emittance is given by the flux variation inside the beam at the ionizer exit :

$$E_x = \frac{\eta B \pi r^2}{2 c} \epsilon \text{ and, using the ionizer parameters,}$$

it results on 10^{-7} m. rad. (normalized).

Therefore, the total expected emittance is 2 or 3 10^{-7} m.rad (normalized) , suitable value for injecting into DIONÉ.

Ionization process inside DIONÉ

For a few μA Li^{1+} beam intensity a conventional ionizer would have delivered a few nA of Li^{3+} in DC mode .

DIONÉ, an EBIS ion source, is usually used to produce highly charged heavy ions (Kr^{30+} , for instance). The ionization process involved has been described in detail previously²⁾. In brief, an electron gun emits a stream of electrons wich are focused and conducted through a series of cryogenically cooled drift tubes by the strong magnetic field (STs) of a superconducting solenoid.

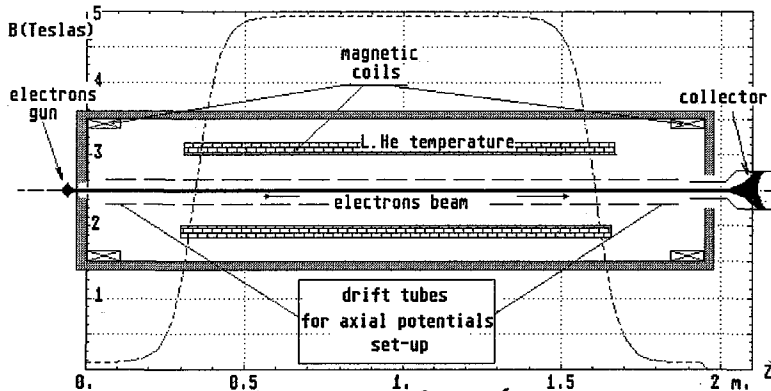


Fig. 2 Schematic view of DIONÉ

Different set of axial potentials are applied on the drift tubes according to the phase of the process : monocharged ions injection, confinement, extraction.

The Li^{1+} ions injected into DIONÉ, through the electron collector, are trapped by the electron beam and accumulated during the $200\mu\text{s}$ EBIS injection time. The next phase (confinement time necessary to ionize Li^{1+} into Li^{3+} by multiple electron collisions) is very short : according to the calculations, 3ms are sufficient. Then the ions are expelled, producing a short pulse of charges.

Therefore many pulses could be acumulated in MIMAS during the 150 ms electron beam pulse duration . In fact the limitation comes from the DIONÉ ejected pulse duration ($50\mu\text{s}$ total width) too long for the MIMAS injection system and 8 pulses represent a maximum.

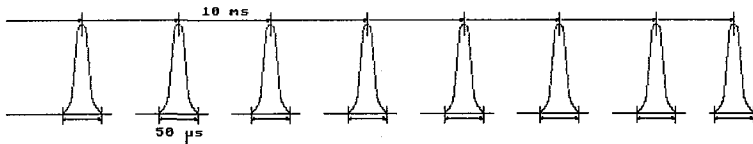


Fig. 3 Successive pulses with a separation of 10 ms

According to the expected intensity of monocharged ions, DIONÉ should be able to deliver at least $20\mu\text{A}$ peak intensity pulses.

Moreover, the magnetic field value (5 Ts) is large enough to decouple the 1S electron and nuclear spin. The magnetic field axis of the ioniser is parallel to the DIONE axis in order to avoid depolarization and a Wien filter provides the required spin direction for the accelerator.

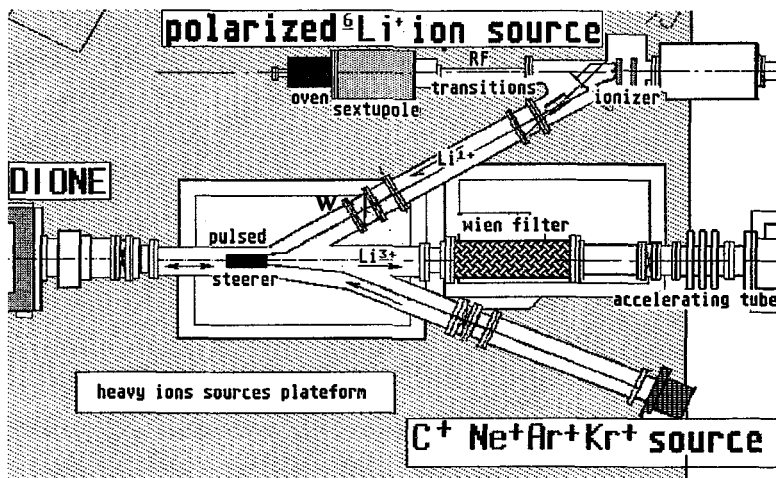
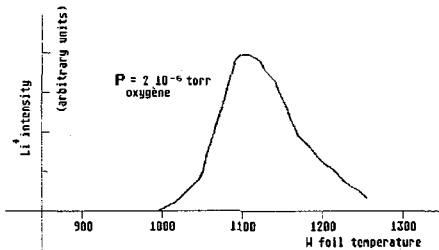


Fig. 4 Lithium platform set-up

Experimental results.

1) Atomic beam and ionizer performances.

The Lithium oven worked satisfactorily and a $35 \mu\text{A Li}^{1+}$ beam has been obtained, as expected.



The Fig 5 shows the variation of the intensity versus tungsten foil temperature.

2) Transmission to the EBIS collector.

The transmission is poor : $7 \mu\text{A}$ are injected into DIONÉ. The beam losses measurements point out that the Li^{1+} beam emittance is larger than the expected value, due to optical aberrations effect in the ionizer extracting region. The focusing system will be modified to improve the transmission.

3) MIMAS and SATURNE tuning. Polarization measurements

- 8 pulses of DIONÉ post-accelerated at 187.5 keV/A by a RFQ cavity are injected into MIMAS ring; the total injected charge is 4.10^9 c. ; the intensity accelerated in MIMAS is $2 \cdot 10^9$ charges, the efficiency of injection is 55%, the optimum value is 70%.

All the beam accelerated in MIMAS is transferred into SATURNE, giving $2 \cdot 10^9$ charges (710^8 particles) each acceleration cycle up to 750 MeV/A .

- the polarization P_{zz} amounts to about of 70%, measured at 187.5 keV/A . The tensor polarization P_{zz} was measured in the $\text{D}(\text{}^6\text{Li}, \alpha)^4\text{He}$ reaction at 0° . The analysing power $A_{yy}(\text{}^6\text{Li})$ has been taken as equal to the known tensor analysing power $A_{yy}(\text{}^6\text{Li}(d, \alpha)^4\text{He})$ of the $\text{}^6\text{Li}(d, \alpha)^4\text{He}$ reaction at the same c.m. energy ($A_{yy} = 0.444$).

These measurements are confirmed at 200 MeV/A .

- Depolarizations. Two depolarization resonances can occur :

* the first one in MIMAS : $\nu_z = 2 - \gamma_g$ ($\nu_z = 2.18$)

This line is practically set on injection tuning ($\nu = 2.19$; $\nu = 2.22$)

Taking into account the low intensity ($< 10^{10}$ charges) \times there is no space charge effect and a different vertical tuning is possible ($\nu_z = 2.2$).

* the second one in Saturne : $\gamma_g = \nu_z - 4$ occurring at 1125 MeV/A for $\nu_z = 3.607$, also avoided by a different vertical tuning.

A four days physics experimental run with an excellent reliability has been achieved.

Conclusion

These first results are very encouraging and we hope to increase the number of particles by factor 3 and reach in future 10^{10} charges accelerated in Saturne.

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