By the 90s, CEA has undertaken to develop the production of high intensity light ion beams from plasma generated by electron cyclotron resonance (ECR). Important results were obtained with the SILHI source in pulsed or continuous mode.

To improve and test new sources, a new test bench named BETSI (Banc d’Etudes et de Tests des Sources d’Ions) is now operating for several years. Low energy beam line diagnostics consist of a Faraday cup, cameras and a species analyzer. The SILHI emittance scanner can also be installed on the beam line. On this test bench, different permanent magnet source configurations are tested.

The new test bench BETSI (Banc d’Etudes et de Tests des Sources d’Ions)

- Quick and easy connection to the beam line with movable table.
- Plasma chamber and RF windows are water cooled.
- The gas injection system is located on high voltage platform.
- The radio frequency wave injection is produced by a magnetron located at ground potential.
- An additional pumping is installed on the high voltage table.
- Pair of solenoids to reduce beam divergence and focalization.
- Pumping and diagnostic box:
  - Vertical and horizontal viewport for CCD camera diagnostics
  - Vertical movable Faraday cup.
- Classical mass analyzer magnet.
- Beam stop with magnetic electron repeller.
- Future LEBT solenoid with H+V Correctors

Pumping

Fixed accelerator column

2 LEBT solenoids

Gas injection

Water cooling

Movable source table

Iron tube shielding

B field on ECR

Map of 87.5 mT

Movable Faraday cup

Analyzer magnet

Analyzer magnet → Measurement of H+ and H2+ ions rates.

**Permanent magnet sources developments**

First experiments showed Penning discharges occurred in the extraction system with the SILHI extraction system. It came from the particular permanent magnet configuration built without shielding. To reduce the magnetic field in that accelerator column, an iron shielding was introduced as close as possible to the extraction electrodes side. Two resonant zones of 87.5 mT were respectively measured with 2 or 3 permanent magnets rings. No plasma produced

Good results

The best results were obtained with 2 permanent magnets and 2 plates (one of 15 mm thick located between the 2 magnets, and the second one of 5 mm on the extraction electrodes side). The two resonant zones of 87.5 mT were respectively located near radio frequency input and near plasma extraction electrode. A 5.1 mA total beam was extracted with 86 % of H+.

<table>
<thead>
<tr>
<th>SOURCE CHARACTERISTICS</th>
<th>BEAM CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrode F/beam</strong></td>
<td></td>
</tr>
<tr>
<td>Gas flow</td>
<td>Total current</td>
</tr>
<tr>
<td></td>
<td>5.75 mA</td>
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<tr>
<td>Pressure</td>
<td>H+ max current</td>
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<tr>
<td></td>
<td>4.97 mA</td>
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<tr>
<td>‘e’ Filter</td>
<td>H+ max current</td>
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<tr>
<td></td>
<td>0.54 mA</td>
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<tr>
<td>HTEI</td>
<td>H+ max current</td>
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<tr>
<td>HT</td>
<td>H+ /total</td>
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<td>PHF</td>
<td>H+/total</td>
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<td>9.45 %</td>
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<tr>
<td>Pulsed time</td>
<td>H2+/total</td>
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<tr>
<td></td>
<td>4.14 %</td>
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</tbody>
</table>

With the SILHI emittance scanner measurement after the solenoids normalized emittance: 0.012 mm.mrad

Proton Beam intensity: 2 mA

Extraction voltage: 20 kV

Hole diameter: 3 mm 

RF injected power : 800 W

The developments realized on BETSI test bench are focused on magnetic optimization of permanent magnet sources. In order to simplify the shielding, several magnetic simulations were realized with 2 or 3 permanent magnets rings.

**MAGNETIC OPTIMIZATION OF PERMANENT MAGNETS SOURCE**

- 1 day with 2 people to assemble all circle red part
- Water cooled at 3 bars
- Pressure in the chamber 10^-3 Pascal
- Water cooled at 3 bars
- Pressure in the chamber 10^-3 Pascal
- High voltage extraction limit 50 kV
- High voltage extraction limit 50 kV