Modification of a Classical Penning Ion Source Operating Mode for Sub-Femtoampere Beams at the U-120M Cyclotron

Tomas Matlocha
Nuclear Physics Institute of the CAS, v. v. i. Rež 130, 250 68 Řež, Czech Republic
Czech Technical University in Prague, FNSPE, Blahoňová 7, 115 19 Praha 1, Czech Republic

Cyclotron U-120M

The irradiation facility in Rez near Prague is equipped with a four-sector isochronous cyclotron U-120M [1] which allows to accelerate ions with mass to charge ratio up to m/Q=2 up to energies 10 MeV per nucleon. The cyclotron was commissioned in 1977 and is continuously upgraded. The Ion Source (IS) of the cyclotron is an internal Penning type with usual lifetime ~250 beam hours for hydrogen operation, ~60 beam hours for ³He. The maximal recorded lifetime is 700 beam hours.

Motivation

Experiments related to radiation hardness tests for newly developed semiconductor detectors need proton fluxes of very low intensities $10^{-7} – 10^{-10}$ protons s⁻¹ cm⁻². By a cooperation on radiation tests of electronic components for the upgrade of the Inner Tracking System of the ALICE experiment in CERN [2], very efficient method for lowering the beam intensity was developed.

Observations

- Ultra low beam intensities achievable by a combination of IS discharge current regulation with a shift of the IS with respect to the extraction slit on the dee
- No practical limit for the lowest IS discharge current
- Almost linear operation of the IS due a primary ionization effect in central region of the cyclotron
- Effect of the cathodes lifetime reduction due to hydrogen diffusion
  - Interesting resonance in negative Hydrogen production yield near ~ 5 µA of the discharge current
  - Continuous intensity regulation in the range $10^{-7} – 10^{-10}$ protons s⁻¹ cm⁻²
  - For intensities above $10^{-9}$ protons s⁻¹ cm⁻²: the long-term stability is better than 10%

References

1)Center of Accelerators and Nuclear Analytical Methods, Nuclear Physics Institute of the CAS http://canam.ujf.cas.cz/.
4) PTW Freiburg, Germany. http://www.ptw.de/

Beam flux monitoring & regulation

The low intensity proton beam current is monitored [3] with an ionization chamber Farmer 30010 from PTW-Freiburg connected to a UNIDOS E Universal Dose-meter. Fluxes below $10^{-7}$ protons s⁻¹ cm⁻² are monitored with a Timepix device [5].

Main beam intensity regulation techniques at U-120M:

- lowering the arc current in the ion source
- reducing the duty cycle
- shifting the horizontal position of the ion source with respect to the extraction slit
- increasing the gas pressure in the IS and worsening the accelerator vacuum
- collimating extracted beam on a vertical input slit of the beamline

Ion Source OFF

flux ~6.7 protons cm⁻² s⁻¹ for 30s.

IS discharge current 60 µA

flux ~80 protons cm⁻² s⁻¹ for 30s.

IS discharge current 200 µA

flux ~420 protons cm⁻² s⁻¹ for 30s.

Efficiency peak in H⁺ production for discharge current near 5 µA

Cathodes after ~80 beam hours

TimePIX detector

Measurement setup

Ion types and intensities at U-120M

<table>
<thead>
<tr>
<th>Ion type</th>
<th>H⁺ / H⁻</th>
<th>D⁺ / D⁻</th>
<th>He⁺⁺ / He⁺⁺</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensity of internal beam [µA]</td>
<td>~100</td>
<td>~100</td>
<td>40 / 20</td>
</tr>
<tr>
<td>Intensity of external beam [µA]</td>
<td>50 / 5</td>
<td>35 / 5</td>
<td>5 / 2</td>
</tr>
</tbody>
</table>

Nuclear Physics Institute in Rez

ICIS 2017

Czech Technical University in Prague