H⁻ injection in the PSB

Bruno Balhan; Jan Borburgh; Chiara Bracco; Christian Carli; Luis Miguel Coralejo Feliciano; Brennan Goddard; Klaus Hanke; Mike Hourican; Cesare Maglioni; Remy Noulibos; Bettina Mikulec; Chiara Pasquino; Jocelyn Tan; Wim Weterings
Scope of the injection upgrade

Injection upgrade from 50 MeV protons to 160 MeV $H^-$ and increased intensity*:

1. re-build injection line for 160 MeV;

2. replace injection septum by $H^-$ injection system.

* although LIU aims at LHC-type beams, all equipment must be compatible with the highest intensities that can be expected.
Injection line for 160 MeV

- Remove obsolete BI.DIS Pb
- Modify BI.DIS for 4.3 mrad @ 160 MeV
- New BI.SMV, 4 mm thick septum and 70 mm horizontal aperture for ~165 mrad @ 160 MeV with associated new pulse generator.

- Performance increase of 1.9 in $\int B \cdot dl$ of BI.DVT30, BI.QNO30, BI.QNO40, BI.DVT40.

~0.36 Tm required from BI.BVT for ~175 mrad @ 160 MeV
Proton Distributor BI.DIS

Development on new compact UHV 12 kV feedthrough

Current Situation

New system with rapid exchange “Plug n Play” stack of fast ferrite magnets

15 Magnets currently assembled
Vertical Septum BI.SMV

Future Situation
H- injection concept

Crucial features are merging dipole (part of injection “chicane”) and stripping foil

H- is a negative ion of hydrogen
• Two electrons attached to proton: binding energies $-0.75$ and $-13.6$ eV
• Electrons are ‘easy’ to remove with a thin foil of some $\mu$m thickness (efficiency depends on energy and foil thickness).
• Typically 1% of $H^0$, $10^{-6}$ of $H^-$
**H⁻ injection concept**

Shifting the machine orbit with respect to foil (painting) fills machine aperture with beam
H⁻ injection concept

Chicane switches off to zero amplitude after injection
Intensities/emittances → number of injected turns
- From 1 to 100
PSB H⁻ injection chicane design

- BSW2 Merging Dipoles
- BSW 3 & 4 Dipoles
- BSW1 Septa
- Existing PSB Dipole Magnets
- Internal H⁰ Dump
- Vacuum manifold
- Stripping Foil System & Beam Observation
**BI.BSW Baseline magnet parameters**

For 316mm magnetic length

<table>
<thead>
<tr>
<th>Magnetic Properties</th>
<th>BSW1</th>
<th>BSW2/BSW3</th>
<th>BSW4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field in the center of the magnet [T]</td>
<td>0.399</td>
<td>0.399</td>
<td>0.399</td>
</tr>
<tr>
<td>$\int B_y dl$ at magnet centre [m.Tm]</td>
<td>126</td>
<td>126</td>
<td>126</td>
</tr>
<tr>
<td>Electric current [kA]</td>
<td>13.5</td>
<td>13.5</td>
<td>13.5</td>
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<tr>
<td>Field homogeneity [%]</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Good field region (h x v) [mm]</td>
<td>85x140</td>
<td>85x196</td>
<td>85x220</td>
</tr>
<tr>
<td>R (mΩ)</td>
<td>0.3</td>
<td>0.3</td>
<td>0.32</td>
</tr>
<tr>
<td>L (μH)</td>
<td>3.3</td>
<td>4.2</td>
<td>4.7</td>
</tr>
<tr>
<td>Number of turns</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**Mechanical properties**

| Physical length [mm]                                     | 373    | 380       | 380    |
| Septum conductor thickness [mm]                           | 7      | n.a.      | n.a.   |
| Pole face length [mm]                                     | 297.8  | 301       | 296    |
| Endplate thickness [mm]                                   | 13.6   | 15.5      | 12     |
| Yoke cross section [mm]                                   | 260x260| 390x220   | 390x220|
| Aperture [mm]                                             | 162x85 | 218x85    | 242x85 |
| Water cooling [ l/min.]                                   | 4      | 3.4       | 3.3    |
| Water cooling pressure [bar]                              | 12     | 12        | 12     |
Mechanical integration BI.BSW
Injection chicane vacuum components

- BHZ Chamber to be modified (EDMS 1146712)
- Ceramic vacuum chambers
- Racetrack bellows
- Tapered chain clamps
- Ion pumps
- DN150 Valve
- Stripping foil system (separate vacuum system)
- Shielded manifolds
- H^0/H^- dump
- Ion pumps
- Racetrack bellows
- Movement Bellows
- CERN
Stripping foil mechanism BI.STR

Foil “in beam” position

Foil “retracted” position

Valve can now close to isolate system

Change foils

Foil “retracted” position
Three loading cases:
(depending on stripping efficiency)

1) 98% (foil operational)
   Steady-state; 2% H\textsuperscript{0}, 0.8mA, \sim 14.2W

2) 90% (foil degraded)
   Steady-state; 10% H\textsuperscript{0}, 4mA, \sim 8h, \sim 71W

3) 0% (foil accident)
   Transient; \frac{1}{4} Linac4 pulse; 40mA, 100% H\textsuperscript{+}, \sim 500J (interlock after 1 pulse)

Half dump
T due to \frac{1}{4} Linac4 pulse
(bottom view, load case 3)
Mechanical integration BI.STR

Future Situation

BSWs

Existing PSB Dipole Magnets

Vacuum pumping

Stripping Foil System & Beam Observation
Summary

- The PSB injection needs to be upgraded from 50 MeV protons to 160 MeV H⁻ operation.
- The injection line components have to be modified, or newly built, for a performance increase of 1.9 in $\int B \cdot dl$.
- The current SMH septum will be replaced by a H⁻ injection system, consisting of:
  - 16 newly built BSW injection chicane magnets and powering system;
  - 4 stripping foil mechanism and motorisation system;
  - Adequate beam instrumentation: - Beam-profile measurement at the foil
    - Visual inspection of the foil
    - $H^0/H^-$ population measurement at the dump
    - Beam Loss Monitors
  - Internal $H^0/H^-$ dump with cooling system.
Conclusion

from the closing remarks of
Review on PSB 160 MeV H-Injection
9-10 November 2011

“The world’s most complex ring injection system is about to become more complex…”

“But if anyone can do it, CERN can”

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Thank You for your attention

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