Camera observations in the BOOSTER injection region

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LINAC 4 instrumentation review
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• Injection scheme
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• Stripping foil visual inspection
• Issues
• Budget
• $H^0$ and $H^-$ current measurement in front of the dump

All 3D drawings are courtesy of P. Faure and R. Noulibos
New injection region layout

4 pulsed dipole magnets (BS)

H0/H-

H+- Circulating beam

HO

H-

Injected

H- 160MeV

4 pulsed dipole magnets (BS)
Linac4 Instrumentation PSB Injection Region

Stripping foil mechanism
Beam profile monitor downstream of stripping foil
Stripping foil visual inspection

From recommendations found in specification papers:
- ‘measure injected beam and size’
- ‘visualize stripping foil’
- ‘a system of attenuating filters should be foreseen’
- ‘measure the H⁰ and H⁻ beam current to monitor the injection efficiency and to be able to diagnose foil for degradation and failure’

→ BTV system

Mechanics
- luminescent screen (Al₂O₃) insertion device
- lights for calibration and online visualization
- optical density filter wheel
- all support

Electronics/detector
- camera (radiation hard)
- screen, filter wheel and lights drivers
- frame grabber
- interlock system
BTV design (1)

Screen and screen mechanism

Main Issue: little space available

Design depends on the size of the screen (presently specified at 70 x 60 mm$^2$)

Screen size depends on the possibility of observing the beam after one turn

Simulation of the emittance blow up as function of screen thickness

<table>
<thead>
<tr>
<th>Thickness [mm]</th>
<th>$\varepsilon_{\text{norm}}$ [μm] (Inj.)</th>
<th>$\varepsilon_{\text{norm}}$ [μm] (1$^{\text{st}}$ turn)</th>
<th>$\varepsilon_{\text{norm}}$ ratio</th>
<th>Size ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.30</td>
<td>2.60</td>
<td>8.68</td>
<td>2.95</td>
</tr>
<tr>
<td>1</td>
<td>0.30</td>
<td>3.63</td>
<td>12.11</td>
<td>3.48</td>
</tr>
<tr>
<td>2</td>
<td>0.30</td>
<td>20.43</td>
<td>68.17</td>
<td>8.26</td>
</tr>
</tbody>
</table>

Not much use in measuring the beam size after one turn
BTV design (2)

Example of screen of the specified size at 45 degrees

Need an interlock connected to the stripping foil mechanism

*No decision has been taken yet. Still under investigation*

→ close collaboration with TE/ABT
BTV design (3)

**Camera**

Choice 1 → CERN built Radiation-hard camera based on a VIDICON tube
   This is the camera usually deployed in similar areas

Choice 2 → CIDTEC CID Radiation-Hard camera
   More sensitive and better linearity, but less resistant to radiation
   (~5 MRad for \(\gamma\))

We will need 4 or 8 cameras depending if one camera can visualize both the screen and the stripping foil or not

**Electronics**

Present BTV card can be used
   • Driver for VIDICON camera
   • Drivers for screen / filter wheel / lights
   • Frame grabber @ 1.11Hz
### BTV budget (if short term plan)

<table>
<thead>
<tr>
<th>Electronics / Camera</th>
<th>Responsibility</th>
<th>Quantity</th>
<th>Time Design [month]</th>
<th>Price [CHF]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum tank</td>
<td>TE/ABT ?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanism (?)</td>
<td>BE/BI</td>
<td>4+1 spare</td>
<td>3</td>
<td>20000 (?)</td>
</tr>
<tr>
<td>Camera support / filter wheel / lights</td>
<td>BE/BI</td>
<td>4+1 spare</td>
<td>2</td>
<td>10000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electronics / Camera</th>
<th>Responsibility</th>
<th>Quantity</th>
<th>Time Design [month]</th>
<th>Price [CHF]</th>
</tr>
</thead>
<tbody>
<tr>
<td>VME Crate (BTV equipped)</td>
<td>BE/BI</td>
<td>1</td>
<td>0</td>
<td>15000</td>
</tr>
<tr>
<td>VME card</td>
<td>BE/BI</td>
<td>4+1 spares</td>
<td>0</td>
<td>10000</td>
</tr>
<tr>
<td>Interface module/RAD BOX</td>
<td>BE/BI</td>
<td>4+1 spares</td>
<td>1</td>
<td>5000</td>
</tr>
<tr>
<td>Cabling</td>
<td>BE/BI</td>
<td>4x2</td>
<td>0</td>
<td>10000</td>
</tr>
<tr>
<td>Camera VIDICON</td>
<td>BE/BI</td>
<td>4+2 spares</td>
<td>0</td>
<td>12000</td>
</tr>
<tr>
<td>Camera CIDTEC</td>
<td>BE/BI</td>
<td>4+2 spares</td>
<td>0</td>
<td>42000</td>
</tr>
</tbody>
</table>

**TOTAL CHF**: 82000 < TOTAL CHF < 114000 depending on camera type
H\(^0\) and H\(^-\) current measurement

*Dump*
\[\frac{H^0}{H^-}\]

2x current measurement to monitor injection efficiency and be able to diagnose foil degradation and failure

Ratio \(\frac{H^0}{H^-} = 1000\)

2 acquisition channels needed
H⁰ and H⁻ current measurement:

Two aluminum foils as Faraday cups for electrons (protons will go through). Secondary electrons exiting the foil and/or the dump could perturb the measurement.

Two polarization rings can suppress the secondary emission. Secondary electrons trajectories with \( V \text{bias} = 0 \text{V} \) and \( V \text{bias} = -1000 \text{V} \).

Not perturbation of magnetic field. Compact design (3 cm from the first ring to the dump). Monitor attached to the dump.
References

MEASUREMENT OF BEAM CURRENT AT THE PSB H⁰/H⁻ INJECTION BEAM DUMP
Brennan Goddard, Chiara Bracco, Christian Carli, Bettina Mikulec, Wim Weterings
L4-T-EP-0003 v.1.0  https://edms.cern.ch/document/1069244/1.0

H⁰/H⁻ BEAM DUMP FOR LINAC4 PS BOOSTER INJECTION
Wim Weterings, Jan Borburgh, Chiara Bracco, Brennan Goddard
L4-T-EP-0002 v.1.0  https://edms.cern.ch/document/1069240/1.0

LOADING ASSUMPTIONS FOR BEAM DUMPS OF LINAC4 PS BOOSTER INJECTION
Wim Weterings
L4-T-EP-0001 v.1.2  https://edms.cern.ch/document/963395/1.2

STRIPPING FOIL FOR LINAC4 PS BOOSTER INJECTION
Wim Weterings, Remy Noulibos
L4-T-EP-0005 v.0.2  https://edms.cern.ch/document/1108941/0.2

**Linac4-PSB Active Issues**: Instrumentation at the stripping foil

Thanks to Remy Noulibos and Wim Weterings for their active collaboration

THANKS
Radiation-hard cameras

VIDICON tube based camera

CIDTEC CID camera
SCREEN mechanism ideas
SCREEN MECHANISM IDEA 1

- $H^+$ beam observed
- Image of back of screen and back of foil
- Fixed mirror inside the chamber $\rightarrow$ single movement (screen)
- $H^-$ beam observed
- Image of front of screen and front of foil
- Fixed mirror inside the chamber $\rightarrow$ single movement (screen)
- Tricky design of supports (tilted)
SCREEN MECHANISM IDEA 3

- H\(^+\) beam seen by screen
- Image of front of screen and back of foil
- Fixed mirror outside the chamber -> double movements: screen + mirror
BTV design Issues

- Constraints: Radioactive environment
  Limited space
  Beam observation + foil observation
  Limited maintenance
  Remote controlled arm for magnet maintenance

Both optical lines should be OK for the depth of field.

Check the available space on the side of the dedicated space of the stripping foil vacuum chamber