Alex Chen on behalf of the task force:
A. Shemyakin, R. Andrew, C. Baffle, R. Compos, T. Hamerla, D. Lambert, R. Kellett, T. Zuchnik, Ryan, V. Scarpine

**PII2 MEBT DPI-FV Design and 1st Test**
Outline

- Layout MEBT of Absorber to HWR(DP section)
- Function Requirement
- Design of DPI
  - Mechanical solution
  - Vacuum solution
  - Electrical solution
  - Thermal solution
- DPI-FV test setup
- 1st test results
- Summary
1) Gas($H_2$) Flux from Absorber: $1 \times 10^{-5}$ mbar.l/s

2) Uniform outgassing rate: $1 \times 10^{-10}$ starts, $1 \times 10^{-11}$ ultimate

The primary purpose of differential pumping section is to minimize the gas flux and particulates from MEBT to HWR during operation or vacuum failure in MEBT.
### DPI Requirements

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position alignment of the DPI tube with respect to beam line axis</td>
<td>( \leq 0.5 )</td>
<td>mm</td>
</tr>
<tr>
<td>Angular alignment with respect to beam line axis*¹</td>
<td>( \leq 2 )</td>
<td>mrad</td>
</tr>
<tr>
<td>Cooling</td>
<td>Natural air convection</td>
<td></td>
</tr>
<tr>
<td>Maximum average power</td>
<td>25</td>
<td>W</td>
</tr>
<tr>
<td>Maximum pulse energy deposition*²</td>
<td>0.4</td>
<td>J</td>
</tr>
<tr>
<td>Electrical isolation with respect to ground</td>
<td>300</td>
<td>V</td>
</tr>
<tr>
<td>Maximum current to report (CW/tuning)</td>
<td>20/200</td>
<td>µA</td>
</tr>
<tr>
<td>Current reading accuracy *³ (CW/tuning)</td>
<td>( \leq 1/10 )</td>
<td>µA</td>
</tr>
<tr>
<td>Accident detection: minimum trip level*⁴</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Averaged over 5 µs</td>
<td>100</td>
<td>µA</td>
</tr>
<tr>
<td>Averaged over 1/60 s =16.6 ms</td>
<td>5</td>
<td>µA</td>
</tr>
</tbody>
</table>

### Relevant Beam Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ion type</td>
<td>H-</td>
<td></td>
</tr>
<tr>
<td>Beam energy</td>
<td>2.1</td>
<td>MeV</td>
</tr>
<tr>
<td>Operation mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal beam size at DPI (6( \sigma ), X/Y)</td>
<td>8/8</td>
<td>mm</td>
</tr>
<tr>
<td>Maximum beam current, CW</td>
<td>10</td>
<td>mA</td>
</tr>
<tr>
<td>Tuning mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse repetition rate</td>
<td>Hz</td>
<td>20</td>
</tr>
<tr>
<td>Pulse length</td>
<td>µs</td>
<td>20</td>
</tr>
<tr>
<td>Maximum pulse beam current</td>
<td>10</td>
<td>mA</td>
</tr>
</tbody>
</table>

### Recommended DPI Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material of beam – exposed portion of DPI tube</td>
<td>copper</td>
<td></td>
</tr>
<tr>
<td>Minimum diameter of DPI tube</td>
<td>10</td>
<td>mm</td>
</tr>
<tr>
<td>Length of DPI tube</td>
<td>200</td>
<td>mm</td>
</tr>
<tr>
<td>Ion pump speed</td>
<td>100</td>
<td>l/s</td>
</tr>
</tbody>
</table>
Mechanical

- Insertion length with Ion Pump: 435mm
- Positioning

<table>
<thead>
<tr>
<th>Position alignment of the DPI tube with respect to beam line axis</th>
<th>≤ 0.5</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angular alignment with respect to beam line axis*¹</td>
<td>≤ 2</td>
<td>mrad</td>
</tr>
</tbody>
</table>

- DPI is supported common girder with adjustment
- Position of aperture is determined by aligning cooling disc OD
Vacuum considerations

- Absorber is high outgassing of Hydrogen (at level of $10^{-4}$ torr.l/s) and loose particles
- Uniform outgassing rate applied inner surfaces of SS and Copper
- Pump distribution studied
- Straight Narrow tube vs Conic Baffle studied
- Distance of DPI-IP studied
- Pressure ratio of before/after DPI calculated
- Detail Results show in ppt of Molflow+ Simulation
Design of DPI

Bellows at US&DS

Support & Adjustment to Girder
Design of DPI

- SS tube 1.5” (OD)
- Copper Tube 10mm (ID), 200mm (Length)
- Al. cooling Disc
- Ceramic Breaker (3kV)
- Ion Pump (100 l/s)
Pressure Profile (Absorber to HWR, 1E-5 mbar.l/s H2,)

PXIE Vacuum From Absorber to HWR

DP Ratio
33, 17, 21, 18, 2

Distance From DS of Absorber (m)

Pressure (mBar)
Electrical Solution

- Insulation: Ceramic breaker (3kV)
- Connection for instrumentation: clamp on OD
Thermal solution:

- Beam-Copper-SS-Alu-Air
- Worst case, 25w of heat at front face
Analyses were done on 1) material choices of inner tube, 2) heating distributions, 3) relative longitudinal positions.
Setup in final locations

S1  DPI  S2  FV  GV  
RFQ  
HWR
Setup in Current configuration

A Chen | Tuesday Technical Meeting
1. \( V_1 = 36.5 \) liters (M61VSO-FV)
2. \( V_2 = 95.1 \) liters (POST FV)
3. Permeation rate from Scanner O-Ring is about \( 6 \times 10^{-7} \) torr.l/s

Leaker Volume = 0.29 liter
1st Test on MEBT DPI-FV
Dec 21, 2017

Baseline w/ IPs off

4.5E-2 Torr w/ IPs on (1E-4 torr)

4.7E-2 Torr w/ IPs off (3.1E-4 torr)

1.1 Torr w/ IPs off (1.3E-2 torr)
Rate of Rise in the Volume (~95 liters) of downstream of FV

- Pressure rise of Baseline: $3.5 \times 10^{-9}$ torr/s
- Estimate due to permeation of O-Ring: $6.5 \times 10^{-9}$ torr/s

<table>
<thead>
<tr>
<th>Leak Size</th>
<th>before</th>
<th>after</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.7E-2</td>
<td>2.0E-9</td>
<td>2.0E-9</td>
</tr>
<tr>
<td>1.1 torr</td>
<td>6.0E-9</td>
<td>3.8E-9</td>
</tr>
</tbody>
</table>

No gas surge in V2 during or after FV closing

$\frac{dp}{dt} = 2.0 \times 10^{-9}$ torr/s

$\frac{dp}{dt} = 2.0 \times 10^{-9}$ torr/s
1st Test on MEBT DPI-FV
Dec 21, 2017

- 76 torr, IPs off (5E-1 torr)
- 760 Torr w IPs off (10 torr)
- Vented Leaker IPs off
**Time of FV closing signal to MPS**

<table>
<thead>
<tr>
<th>Leak Size</th>
<th>Time to PLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>low</td>
<td>-</td>
</tr>
<tr>
<td>medium</td>
<td>0.8s</td>
</tr>
<tr>
<td>high</td>
<td>0.9s</td>
</tr>
<tr>
<td>Very high</td>
<td>1.2s</td>
</tr>
</tbody>
</table>
Time of FV closing signal to MPS
Differential Pumping Effect

Pressure rise at US of DPI: $6.6 \times 10^{-6}$

Pressure rise DS of PDI: $7.6 \times 10^{-7}$

With current setup of DPI and IPs, $\frac{DP_{us}}{DP_{ds}} = 188$
Summary

- DPI-FV functions well at the level of current accuracy
- Meet the Requirement
- 2\textsuperscript{nd} test with leaker in upstream of DPI this week
- 3\textsuperscript{rd} test with higher accuracy by removing O-ring when possible