Heavy Shutter, Bunker insert and neutronics for the test beam line

Valentina Santoro
Phil Bentley
Gabor Laszlo
ESS
Outline

• Brief overview of the test beam line and neutronics calculations

• Heavy Shutter calculations

• Bunker insert activation studies
**Test Beam Line parameters (I)**

<table>
<thead>
<tr>
<th>Nr</th>
<th>Component Name</th>
<th>Distance from TCS</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Monolith Insert</td>
<td>2.7m-5.5m (2.8m)</td>
<td>Penetration (Assymmetric! With 2mm gap around beam):</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>204.5mmx45.7mm -&gt; 108.5mmx32.7mm (Hz x V)</td>
</tr>
<tr>
<td>2.</td>
<td>Gamma Shutter Insert</td>
<td>5.5m-6.5m (0.5m)</td>
<td>ID120mm /5mm B4C attenuator inside, Argon filled</td>
</tr>
<tr>
<td>3.</td>
<td>Flight Tube 1</td>
<td>6m-7.4m (1.4m)</td>
<td>ID120mm /5mm B4C attenuator inside</td>
</tr>
<tr>
<td>4.</td>
<td>Stationary Collimator</td>
<td>7.4m-8.2m (0.8m)</td>
<td>63mmx28mm-36mmx34mm (Hz x V)/10mm larger (around) than the beam/</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>/Copper with lead shielding around</td>
</tr>
<tr>
<td>5.</td>
<td>Adjustable Collimator</td>
<td>8.3m-8.5m (0.2m)</td>
<td>310mmx260mm (Hz x V), Ø33mm 15deg cone angle</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>/Initial composition: Fe+Pb+Mirroror+Pb+Fe/</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MR304-2000-00-PE.pdf</td>
</tr>
<tr>
<td>6.</td>
<td>Pinhole</td>
<td>8.5m</td>
<td>1mm thick Cd, Ø0.5mm, Ø1mm, Ø1.5mm, Ø2mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MR304-2000-00-PE.pdf</td>
</tr>
<tr>
<td>7.</td>
<td>Double Disk Chopper</td>
<td>8.6m</td>
<td>D=500mm, 2000RPM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MR Chopper general .pdf</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MR304-3000-00-PE.pdf</td>
</tr>
<tr>
<td>8.</td>
<td>Flight Tube 2</td>
<td>8.7m-9.5m (0.8m)</td>
<td>ID120mm /5mm B4C attenuator inside</td>
</tr>
<tr>
<td>9.</td>
<td>Heavy Shutter</td>
<td>9.5m-11.3m (1.8m)</td>
<td>Attenuator: 400mmx300mmx1600mm /Pb+HDPE+B4C+Copper+Pb/</td>
</tr>
<tr>
<td>10.</td>
<td>Bunker Wall Insert</td>
<td>11.5m-15m (3.5m)</td>
<td>Steel insert. Penetration: (Assymmetric! With 2mm gap around beam):</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>108.4mmx24.2mm -&gt; 228.4mmx55.3mm (Hz x V)</td>
</tr>
<tr>
<td>11.</td>
<td>Detector</td>
<td>17m</td>
<td>Area: 300mmx300mm</td>
</tr>
<tr>
<td>12.</td>
<td>Beam Stop</td>
<td>17.5m</td>
<td></td>
</tr>
</tbody>
</table>

with ~21 cmx5cm aperture in the monolith and straight guide ....
Test Beam Line parameters (II)

Test Beam Line is really the bad* guy of the ESS beamlines

* from shielding point of view
MCNP Model for target +Bunker+instrument hall +instrument cave produced with Comblayer package developed by Stuart Ansell

https://github.com/SAnsell/CombLayer
Test Beam Line @ W11

Zoom in the bunker region

First Collimator

Second Collimator

Heavy Shutter

exit of the bunker wall ~15m after the moderator

Pin-Hole
Neutron Energy Spectrum Out of the monolith

Flux per unit lethargy (n/cm²/s)

\[ 10^{10}, 10^9, 10^8 \]

\[ 10^{-12}, 10^{-11}, 10^{-10}, 10^{-9}, 10^{-8}, 10^{-7}, 10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}, 10^{-2}, 10^{-1}, 10^1, 10^2, 10^3 \]

\[ E_{\text{kin}}(\text{MeV}) \]
Neutron Energy Spectrum before the pin-hole
Neutron Energy Spectrum out the bunker wall

Iron resonance

Cadmium pin-hole

Flux per unit lethargy (n/cm²/s) vs. $E_{\text{kin}}$ (MeV)
Some numbers

5.5 m out the monolith

Φ = 2.5e+10 (n/s*cm²) Flux

Total number of neutrons in the beam
Φ x A = 3.1e+12 n/s

A is the size of the opening at the end of the monolith

Total dose = 474200 Sv/h

15 m out the bunker wall

Φ = 1.05e+07 (n/s*cm²) Flux

Total number of neutrons in the beam
Φ x A = 1.31e+09 n/s

A is the size of the opening at the end of the bunker wall

Total dose = 400 Sv/h
Spectra Out of the monolith

Test Beam Line: Big Opening Straight instrument
Loki: Bender in the monolith
Heavy Shutter Current Design

Shutter Design (width 17 cm, height 14 cm, length 152 cm)

1 cm $B_4C$
130 cm of copper
20 cm of polyethylene
1 cm of $B_4C$
Heavy Shutter Neutron Dose Rate in the bunker

μSv/h

Copper Collimator

Heavy Shutter

Bunker Wall

~ 1.2 e^7 μSv/h

~ 41000 μSv/h

IKON 13, ESS Headquarter Lund 27 September 2017
Heavy Shutter Neutron Dose rate, from the bunker wall to the end of the bunker wall

μSv/h

Heavy Shutter

Bunker Wall

<1.5 μSv/h

~ 41000 μSv/h
Heavy Shutter Photon Dose map with current Design

<<1.5 μSv/h

3.000E+05
7.388E+04
1.820E+04
4.481E+03
1.104E+03
2.718E+02
6.694E+01
1.649E+01
4.060E+00
1.000E+00
ACTIVATION OF THE HEAVY SHUTTER AND BUNKER INSERT

Irradiation conditions: 10 years of operation beam @2GeV 5MW
Heavy Shutter Activation after 24 hour of beam off

$\mu$Sv/h

≈ 500 $\mu$Sv/h

≈ 120 $\mu$Sv/h

≈ 390 $\mu$Sv/h
Heavy Shutter Activation after 3 days beam off

\[ \mu S v / h \]

- \( \sim 300 \mu S v / h \)
- \( \sim 18 \mu S v / h \)
- \( \sim 390 \mu S v / h \)

Materials:
- Copper
- B\(_4\)C
- Steel
Bunker insert Geometry

Bunker Roof

Chopper

Heavy Shutter

Bunker Wall

Bunker Insert

Shutter is open
Bunker insert activation after 1 day beam-off

μSv/h

First part of the insert

~200 μSv/h

~900 μSv/h

<1 μSv/h
Bunker insert activation after 3 days beam-off

~ 40 µSv/h
~ 900 µSv/h
First part of the insert

<1 µSv/h
Conclusions (I)

• Test Beam Line neutronics have been performed

• Shielding could have been a challenge but the use of a relatively cheap collimator can help you a lot

• Heavy Shutter calculation done

• Bunker insert activation does not seem an issue
Conclusions (II)

Even the “bad” radiation from the beam line can be fixed with some shielding simulation
BACK –UP SLIDES
Heavy Shutter simulation

μSv/h

2.2 m of steel

25 μSv/h
Absorbed Dose for the chopper sealing
View of the chopper