Positron source: Target shielding studies

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DESY

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Outline

- Input conditions
  - Positron source options
  - Target area
  - FLUKA model

- Dose rates near the target without shielding

- Residual dose rate
  - Ordinary concrete shielding
  - Heavy concrete shielding

- Dose rates during source operation (prompt radiation)

- Summary
Different OMD options:

- **AMD, immersed target**: 14 cm long
- **AMD non-immersed target**: 14 cm long
- **Lithium lens**: 2 cm long, 1.4 cm in diameter
- **QWT**: 2 cm long

* OMD optimization studies and required undulator length have been done by Wanming Liu and Wei Gai (ANL)

<table>
<thead>
<tr>
<th>e+ source options</th>
<th>RDR</th>
<th>SB2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>e− Drive Beam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam energy, GeV</td>
<td>150</td>
<td>250</td>
</tr>
<tr>
<td>No. of e− per bunch</td>
<td></td>
<td>2 · 10^{10}</td>
</tr>
<tr>
<td>No. of bunches per pulse</td>
<td>2625</td>
<td>1312</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Positron Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positron Yield, e+/e−</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Helical Undulator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undulator K-value</td>
</tr>
<tr>
<td>Undulator period, cm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Undulator Length*, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD immersed target</td>
</tr>
<tr>
<td>AMD non-immersed target</td>
</tr>
<tr>
<td>QWT</td>
</tr>
<tr>
<td>Li-Lens</td>
</tr>
</tbody>
</table>

**Ti6Al4V Target, 0.4 X₀**
Provisional Target Area Sketch
provided by Norbert Collomb, Neil Bliss (Science & Technology Facilities Council)

- Photon Beam
- Beam direction
- BDS Beam, 1.5m offset from Photon Beam
- Concrete Shielding (Bounding Box)
- Collimator
- Target + Magnet
- Standing Wave Accelerators
- More detail on next slide
- Electron Dump
- Standing Wave Accelerators
- Photon Dump

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Target shielding studies
LCWA’09
Concrete Shielding Sketch
provided by Norbert Collomb, Neil Bliss (Science & Technology Facilities Council)

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Target shielding studies

BDS Beam

Target

BDS Beam 100mm from outside Shielding (1m) = 400mm from inside Shielding to Photon Beam

Concrete Shielding (Bounding Box)

Collimator

Matching Device

Standing Wave Accelerators

Beam direction

Target + Magnet

Target Rim

Simplified Support Structure

R: 2m

Target Motor + Drive Shaft

0.55m

4.55m

1.6m

400mm
FLUKA Model

FLUKA allows to calculate in one step:

- (activation of source)
- dose rate during source operation
- residual dose rate after 5000 h of source operation and different cooling times:
  - 0 second
  - 1 hour
  - 1 day
  - 1 week

Dose $\equiv$ Ambient Dose Equivalent from ICRP74 and Pelliccioni data (AMB74)

Geometry simplifications:

- **Target:**
  Ti6Al4V disk
  thickness = 1.48 cm,
  radius = 15 mm
  no rotation

- **Vacuum chamber:**
  steel hollow cylinder,
  inner radius = 65 mm,
  thickness = 4 mm

- **Shielding:**
  concrete hollow cylinder,
  inner radius = 40 cm,
  thickness = 1 m
Residual Dose Rate
after 5000 h of source operation
0 sec. cooling time
RDR. QWT

\[ D_{0s} \text{ [mSv/h]} \]

\[ r \text{ [cm]} \]

\[ D \]

\[ 2 \times 10^2 \]

\[ 3 \times 10^3 \]

\[ 4 \times 10^4 \]

\[ 5 \times 10^5 \]

\[ 6 \times 10^6 \]

\[ 7 \times 10^7 \]

RDR (231 m Undulator)
SB2009 (100 m Undulator)

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Target shielding studies
LCWA’09
Dose Rates: QWT (Target only, with Rotation)

Extrapolation from original (non-rotating) data to rotating target:

\[
\dot{D} = \frac{\dot{D}_{\text{original}}}{\left(1 + \frac{2R_{\text{target}}}{r}\right)}
\]

Dose Rate [mSv/h]

\[ r = 140 \text{ cm} \]

QWT, Rotating Target

<table>
<thead>
<tr>
<th>Decay Time</th>
<th>RDR</th>
<th>SB2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 sec.</td>
<td>258.4</td>
<td>254.2</td>
</tr>
<tr>
<td>1 hour</td>
<td>208.9</td>
<td>213.7</td>
</tr>
<tr>
<td>1 day</td>
<td>111.0</td>
<td>121.3</td>
</tr>
<tr>
<td>1 week</td>
<td>79.1</td>
<td>83.8</td>
</tr>
</tbody>
</table>
Ordinary Concrete
\((\rho = 2.3 \text{ g/cm}^3)\)

\[
\dot{D}_{0s}(r = 140 \text{ cm}) \approx 1.5 \text{ mSv/h} \gg 10\mu\text{Sv/h}
\]

Heavy Concrete
\((\rho = 4.68 \text{ g/cm}^3)\)

\[
\dot{D}_{0s}(r = 140 \text{ cm}) \lesssim 10^{-5} \text{ mSv/h} \ll 10\mu\text{Sv/h}
\]
<table>
<thead>
<tr>
<th></th>
<th>Ordinary</th>
<th>Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density, g/cm³</td>
<td>2.3</td>
<td>4.68</td>
</tr>
<tr>
<td>H</td>
<td>1.0</td>
<td>0.89</td>
</tr>
<tr>
<td>C</td>
<td>0.1</td>
<td>0.55</td>
</tr>
<tr>
<td>O</td>
<td>52.9</td>
<td>37.07</td>
</tr>
<tr>
<td>Na</td>
<td>1.6</td>
<td>0.14</td>
</tr>
<tr>
<td>K</td>
<td>1.3</td>
<td>0.12</td>
</tr>
<tr>
<td>Mg</td>
<td>0.2</td>
<td>0.36</td>
</tr>
<tr>
<td>Al</td>
<td>3.4</td>
<td>0.80</td>
</tr>
<tr>
<td>Si</td>
<td>33.7</td>
<td>2.45</td>
</tr>
<tr>
<td>S</td>
<td>0.0</td>
<td>0.29</td>
</tr>
<tr>
<td>Ca</td>
<td>4.4</td>
<td>9.98</td>
</tr>
<tr>
<td>Fe</td>
<td>1.4</td>
<td>47.35</td>
</tr>
</tbody>
</table>
### Dose Rate at $r = 140$ cm

<table>
<thead>
<tr>
<th>Decay Time</th>
<th>RDR $\dot{D}$, mSv/h</th>
<th>Err, %</th>
<th>SB2009 $\dot{D}$, mSv/h</th>
<th>Err, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 sec.</td>
<td>0.96</td>
<td>4.6</td>
<td>1.26</td>
<td>8.2</td>
</tr>
<tr>
<td>1 hour</td>
<td>0.75</td>
<td>5.9</td>
<td>0.94</td>
<td>9.5</td>
</tr>
<tr>
<td>1 day</td>
<td>0.26</td>
<td>6.0</td>
<td>0.32</td>
<td>9.6</td>
</tr>
<tr>
<td>1 week</td>
<td>$6.3 \cdot 10^{-4}$</td>
<td>31.5</td>
<td>$5.1 \cdot 10^{-4}$</td>
<td>24.6</td>
</tr>
</tbody>
</table>
Different OMD. Ordinary Concrete. Rotating Target
Dose date at \( r = 140 \) cm, decay time = 0 s

\[
\dot{D}_{0s}(r = 140 \text{ cm}) \text{ [mSv/h]}
\]

<table>
<thead>
<tr>
<th>OMD</th>
<th>RDR</th>
<th>SB2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD immersed target</td>
<td>0.41</td>
<td>0.63</td>
</tr>
<tr>
<td>AMD non-immersed target</td>
<td>0.57</td>
<td>0.67</td>
</tr>
<tr>
<td>QWT</td>
<td>0.96</td>
<td>1.26</td>
</tr>
<tr>
<td>Li-lens</td>
<td>0.41</td>
<td>0.5</td>
</tr>
</tbody>
</table>
QWT. Heavy Concrete
“Required” Thickness of Concrete

| Radius [cm], where $\dot{D}_{0s} = 10 \mu$Sv/h |
|-----------------|--------|-----------------|
| OMD             | RDR    | SB2009          |
| AMD imm.        | 101.4  | 117.6           |
| AMD non-imm.    | 102.7  | 117.8           |
| QWT             | 109.1  | 118.7           |
| Li-lens         | 101.4  | 117.2           |

Thickness of shielding $\lesssim 80$ cm
Dose Rates during Source Operation

RDR. QWT. Ordinary Concrete

Dose Rate along Z (R = 140 cm)
QWT. Ordinary Concrete.
RDR and SB2009

Behind the concrete shielding:
Dose rates during source operation approx. 1000 times higher than residual dose rates
Estimations of dose rates for different OMD options give similar results (the highest rate is for QWT)

Residual dose rates have been calculated for ordinary and heavy concretes:
- 1 m thick ordinary concrete shielding is not sufficient,
- heavy concrete shielding with thickness $\sim 80$ cm should be enough

Dose rate during source operation has been estimated

Future plans: Simulations of more sophisticated geometry model