A study of beam loss pattern & dose distribution around the TPS LINAC during beam commissioning

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### TLS & TPS in NSRRC

<table>
<thead>
<tr>
<th>NSRRC</th>
<th>TLS</th>
<th>TPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_e$ (GeV)</td>
<td>1.5</td>
<td>3.0</td>
</tr>
<tr>
<td>$I$ (mA)</td>
<td>360</td>
<td>400</td>
</tr>
<tr>
<td>$C$ (m)</td>
<td>120</td>
<td>518</td>
</tr>
<tr>
<td>$E_{sb}$ (J)</td>
<td>216</td>
<td>2074</td>
</tr>
<tr>
<td>DL (mSv/y)</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
TPS LINAC

1 meter thick concrete

15 meter transfer line

Q1 Q2 Q3 D1 Q4

Three - section LINAC (2.25W)

1 meter thick concrete
Radiation measurements

• A series of actions have been carried out to improve radiation safety in the area
  – Access control & beam interlock, radiation survey, local shielding

• Beam loss intensities and locations could change significantly and cause radiation safety concern

• Area monitors and survey meters used to measure radiation around the area
  – Gamma rays : VICTOREEN Model 451P
  – Neutrons : FHT 762

• Radiation survey providing useful information for beam studies
Local shielding & radiation survey

- Gamma-ray dose rates outside the downstream shielding wall could sometime reach to several mSv/h during the initial stage.
- Local shielding set up between D1 and Q4.
- Gamma-ray dose rates outside the downstream concrete wall are now mostly below a comfortable level about 10 μSv/h; other areas and roof are well-controlled below about 1 μSv/h (full power).
FLUKA simulations

- A rather detailed geometry model was built
  - Main components, bunker structure, and local shielding
- USRBIN for dose distribution
- Fluence-to-ambient dose conversion factors
- Various beam loss locations were considered from LINAC outlet, Q1, Q2, Q3, D1, Q4, and the beam dump
Dose maps for electron scotchoing pipe in opposite side
A series of beam loss scenarios with different electron loss locations along the transfer line has been systematically studied by FLUKA simulations. The calculated results show a quantitative relationship between beam loss pattern and dose distribution in the area.
Dose rate distributions for electrons lost at the LINAC outlet

γ-ray

neutron

γ-ray on wall

neutron on wall
Dose rate distributions for electrons lost near the Q4

γ-ray

neutron

γ-ray on wall

neutron on wall
Dose rate distributions for electrons lost at beam dump

γ-ray

neutron

γ-ray on wall

neutron on wall
Beam loss patterns & dose distributions

- Differences between the resultant dose distributions caused by different beam loss scenarios are evident
- These distinguishing dose response functions could be used to analyze measured results
- Beam losses near Q4 play a dominant role in the magnitude of downstream dose rates - consistent with our experience during commissioning
- Neutron and gamma-ray spectra due to electrons lost at Q4
The dose distributions of some proposed beam loss scenarios

1% loss at linac outlet, 1% loss at Q2, and 2% loss at Q4

2% loss at Q4
Calculations & measurements

<table>
<thead>
<tr>
<th>Position</th>
<th>P11</th>
<th>P12</th>
<th>P13</th>
<th>P21</th>
<th>P22</th>
<th>P23</th>
<th>P31</th>
<th>P32</th>
<th>P33</th>
</tr>
</thead>
<tbody>
<tr>
<td>1% at Q4</td>
<td>1.8±1.0%</td>
<td>2.3±3.6%</td>
<td>1.6±3.6%</td>
<td>4.1±2.0%</td>
<td>3.7±2.0%</td>
<td>2.8±2.7%</td>
<td>5.1±2.1%</td>
<td>0.3±4.6%</td>
<td>4.1±3.2%</td>
</tr>
<tr>
<td>2% at Q4</td>
<td>3.6±0.9%</td>
<td>4.5±3.7%</td>
<td>3.2±3.7%</td>
<td>8.0±2.0%</td>
<td>7.3±2.0%</td>
<td>5.5±2.8%</td>
<td>10.2±2.1%</td>
<td>0.5±5.2%</td>
<td>8.2±3.2%</td>
</tr>
<tr>
<td>3% at Q4</td>
<td>5.3±0.9%</td>
<td>6.7±3.7%</td>
<td>4.7±3.7%</td>
<td>12.0±2.0%</td>
<td>11.0±2.0%</td>
<td>8.2±2.8%</td>
<td>15.2±2.1%</td>
<td>0.7±5.4%</td>
<td>12.2±3.2%</td>
</tr>
<tr>
<td>Measured</td>
<td>2.7</td>
<td>5.3</td>
<td>4.2</td>
<td>2.7</td>
<td>8.3</td>
<td>7.3</td>
<td>11.9</td>
<td>0.3</td>
<td>8.8</td>
</tr>
</tbody>
</table>

- A measurement on Sep. 23, 2011 by model 451P
- Scenario: 2% at Q4 and 98% to Dump
Conclusions

• A series of simple point beam loss scenarios were used to calculate dose distributions around the LINAC area
  – Some resultant dose distributions are distinguishing with each other and can be regarded as response functions
• Dose distributions due to different beam loss scenarios are different and distinguishable, which could be used to identify possible beam loss locations
• This study has demonstrated that a reasonable beam loss pattern and a detailed dose distribution could be obtained through a synthetic analysis of the calculated response functions and on-site dose rate measurements
Thanks for your attention