Lateral response heterogeneity of Bragg peak ion chambers for narrow-beam photon & proton dosimetry

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Motivation

- Usage of large area ionization chambers for narrow beam dosimetry

- Scanned ion beams
  - Current recommendations based on passive scattered beams
  - Calibration in terms of number of particles

- Narrow photon beams
  - LAIC to measure output factors

→ A homogenous response over whole area is assumed

*Aim: response map and impact on scanned proton dosimetry and narrow photon beams*
Material and Methods

• Bragg Peak Chambers PTW (LAIC)
  – Chamber diameter: 81.6 mm
  – 4 Type 34070 (thick entrance window)
  – 4 Type 34080 (thin entrance window)

• Experimental Setup
  – Collimated X-ray beam (3.2 mm FWHM)
  – LAIC mounted on moving mechanism of MP3-P
Correction Maps

• 300 measurement points for response map
  – Resolution 5mm

• Corrected response at chambers’ edges

• Response as function of radius
Correction Maps

$\text{LAIC}_{\text{Thick}}$

$\text{SNo118}$  $\text{SNo124}$  $\text{SNo119}$  $\text{SNo125}$

$\text{LAIC}_{\text{Thin}}$

$\text{SNo32}$  $\text{SNo42}$  $\text{SNo33}$  $\text{SNo49}$

$\rightarrow$ LAIC have heterogenous lateral response
Practical dosimetric implications of heterogeneous response

- Proton reference dosimetry
- Proton integral depth dose curves
- Small field photon dosimetry
### Effect on proton reference dosimetry

- Correction factors for an 8 mm (FWHM) proton beam
- For equations see: Palmans and Vatnitsky (2016)
  Kuess et al (2016) - submitted to PMB

<table>
<thead>
<tr>
<th>SNo</th>
<th>Absolute dose deviation</th>
<th>Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNo118</td>
<td>3.2±0.3%</td>
<td>0.968±0.003</td>
</tr>
<tr>
<td>SNo119</td>
<td>4.1±0.5%</td>
<td>0.959±0.005</td>
</tr>
<tr>
<td>SNo124</td>
<td>2.4±0.5%</td>
<td>0.976±0.005</td>
</tr>
<tr>
<td>SNo125</td>
<td>3.2±0.4%</td>
<td>0.968±0.004</td>
</tr>
<tr>
<td>SNo32</td>
<td>-3.0±0.4%</td>
<td>1.030±0.004</td>
</tr>
<tr>
<td>SNo33</td>
<td>-0.6±0.7%</td>
<td>1.006±0.007</td>
</tr>
<tr>
<td>SNo42</td>
<td>-9.5±0.8%</td>
<td>1.095±0.009</td>
</tr>
<tr>
<td>SNo49</td>
<td>9.4±0.5%</td>
<td>0.906±0.005</td>
</tr>
</tbody>
</table>
Effect on proton reference dosimetry

- Correction factors for an 8 mm (FWHM) proton beam
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<table>
<thead>
<tr>
<th>Chamber Type</th>
<th>Number</th>
<th>Absolute dose deviation</th>
<th>Chamber Differences: predicted &amp; measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAIC&lt;sub&gt;Thick&lt;/sub&gt;</td>
<td>SNo118</td>
<td>3.2±0.3%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SNo119</td>
<td>4.1±0.5%</td>
<td>Δ=1.7% (0.9%)</td>
</tr>
<tr>
<td></td>
<td>SNo124</td>
<td>2.4±0.5%</td>
<td></td>
</tr>
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<td>3.2±0.4%</td>
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<td>-0.6±0.7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SNo42</td>
<td>-9.5±0.8%</td>
<td>Δ=18.9% (19.9%)</td>
</tr>
<tr>
<td></td>
<td>SNo49</td>
<td>9.4±0.5%</td>
<td></td>
</tr>
</tbody>
</table>
Effect on proton IDD

- Typical application of LAIC is measurement of IDD
- Change of beam size (with depth) $\rightarrow$ different sensitive area
Effect on proton IDD

- Experimental validation using two thin LAIC
- Difference in response
Effect on small field photon dosimetry (FS: 6x6 mm²)

- Thick window LAIC overestimate signal by 2.5—4.5%
- Thin window LAIC vary by 20%
Effect on small field photon dosimetry (FS: 6x6 mm²)

- Thick window LAIC overestimate signal by 2.5—4.5%
- Thin window LAIC vary by 20%
- Reduce effect by cross-calibration to intermediate FS (42x42 mm)
Conclusion

• Response of large area chambers is heterogeneous
  – Chamber depended correction maps needed
  – Effect on reference and relative dosimetry with narrow beams

• Thin window LAIC should be used carefully

• Dosimetric effects have been experimentally confirmed

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Thank you for your attention
Backup Slides
Effect on proton IDD

- Experimental validation using two thin LAIC
- Measurement for 4 energies
Influence of water pressure on LAIC
Material and Methods: Theory

\[ \text{DAP}^A_{w,Q_{\text{spot}}} (z_{\text{ref}}) = M^A_{\text{LAIC}} N^A_{\text{DAP},w,Q_0} \kappa^A_{\text{Q}_{\text{spot}},Q_0} \]

Considering non-uniform response of detector:

\[ \text{DAP}^A_{w,Q_{\text{spot}}} (z_{\text{ref}}) = M^A_{\text{LAIC}} N^A_{\text{DAP},w,Q_{\text{cross}}} \kappa^A_{\text{Q}_{\text{spot}},Q_{\text{cross}}} \times \frac{\iint_{A(\text{LAIC})} D_{wQ}(x,y)dx\,dy}{\iint_{A(\text{LAIC})} Q(x,y)D_{wQ}(x,y)dx\,dy} \]

\[ Q(x,y) = \frac{R(x,y)}{\iint_{A(\text{LAIC})} R(x,y)dx\,dy} \]

Reference Dosimetry:

\[ DAP = \frac{M \times N_{D,W} \times \Delta x \Delta y}{N} \]

Dose Area Product in a large field (18 x 18 cm²)

\[ DAP = \frac{M \times N^A_{\text{DAP},w,cross}}{\text{Counts}} \]

Dose Area Product using a single beamlet

Dose Area Product in a large field (18 x 18 cm²)