Novel PET Imaging for Proton Therapy Applications

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Acknowledgement

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Proton therapy & beam range measurement

Mono energetic beam Therapy targeting
PET imaging for beam-range verification
Inter- and intra-treatment beam range (BR) measurement

Challenges of on-line BR measurement with PET

Count dependency of BR measurement
Major factors that influence the beam range measurement

- Energy
- Proton radiation
- Flux
- Material size
- Phantom
- Composition pattern
- Sensitivity
- Acquisition
- Counts
- Resolution
- Stability
- Data correction
- AR measurement
- Neutron radiation
- Image reconstruction
- Post-process
- VOI selection
- Axial distribution

Preliminary phantom study:
Shao, etc. PMB 59 (2014) pp. 3373-3388

Prototype PET system
(with DOI)

(without DOI)

New detector components and development

- Photon sensors
- Solid-state PM
- Scintillator and array
  - X: 0.9
  - Y: 0.9
  - Z: 0.9
- Detector module
  - DOI measurable

...
In-beam PET imaging - experiment setup

- 9 acquisitions
- 20° detector rotation/acq.
- Sensitivity (at one acq.): ~2%
- Image resolution: ~2 mm
- 5 mm collimated beam (~180 MeV)
- 800 MU (~4 fractionated dose)
Locate activity peak

16 direct-crystal planes in the axial direction

Activity peak outside FOV

Position for range acquisition

16 direct-crystal planes in the axial direction

"PET performance" and "Activity range" acquisitions
“PET performance” and “Activity range” acquisitions

Rotational detectors

PMMA

PET performance and Activity range acquisitions

Rotational detectors

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“PET performance” and “Activity range” acquisitions

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PMMA
**“PET performance monitoring” and “Activity range” acquisitions**

Data from monitoring-acquisition (Na-22 disk-source)

Images of Na-22 disk-source (before, during, and after proton radiations)
Impact of image by Neutron Irradiations

Data from range-acquisition (coincident counts)
Beam: 180 MeV (800 MU)
~50 beam spills
0.5 sec spill time
1.5 sec inter-spill time
~2 min in-beam & 5 min post-beam acquisition

Energy spectra (range-acquisition)
Full-tomographic image (MLEM)

In-beam data

Post-beam

Partial tomographic imaging with limited-angle recon

Rotational detectors

PMMA

Partial-tomographic image (MLEM)

In-beam data

Post-beam data
Comparison of measured and simulated axial profiles

Count-depth distribution (direct projection data)

Summary of measured and simulated activity-range
Impact factors to the accuracy of activity-range measurement

Reconstruction iteration numbers

Size of ROI

Data with number of spills

Range vs number of beam spills
Summary
- Preliminary study
- Specific phantom imaging setup
- Fast converging of BR measurement
- Tangible initial result
- … can be achieved in clinical?

More researches on on-line BR measurement

Count dependency of BR measurement

Impact of image smooth
5mm DOI

No DOI

PET detector and system development

Thank you!
<table>
<thead>
<tr>
<th>Post-beam Detection Time (s)</th>
<th>Activity Range (mm)</th>
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<tbody>
<tr>
<td>0 50 100 150 200 250 300</td>
<td>0 1 2 3 4 5 6 7 x 10</td>
</tr>
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Monte Carlo simulated images

Acquired images
Latest PET detector and system development