A Calorimeter for Proton Therapy

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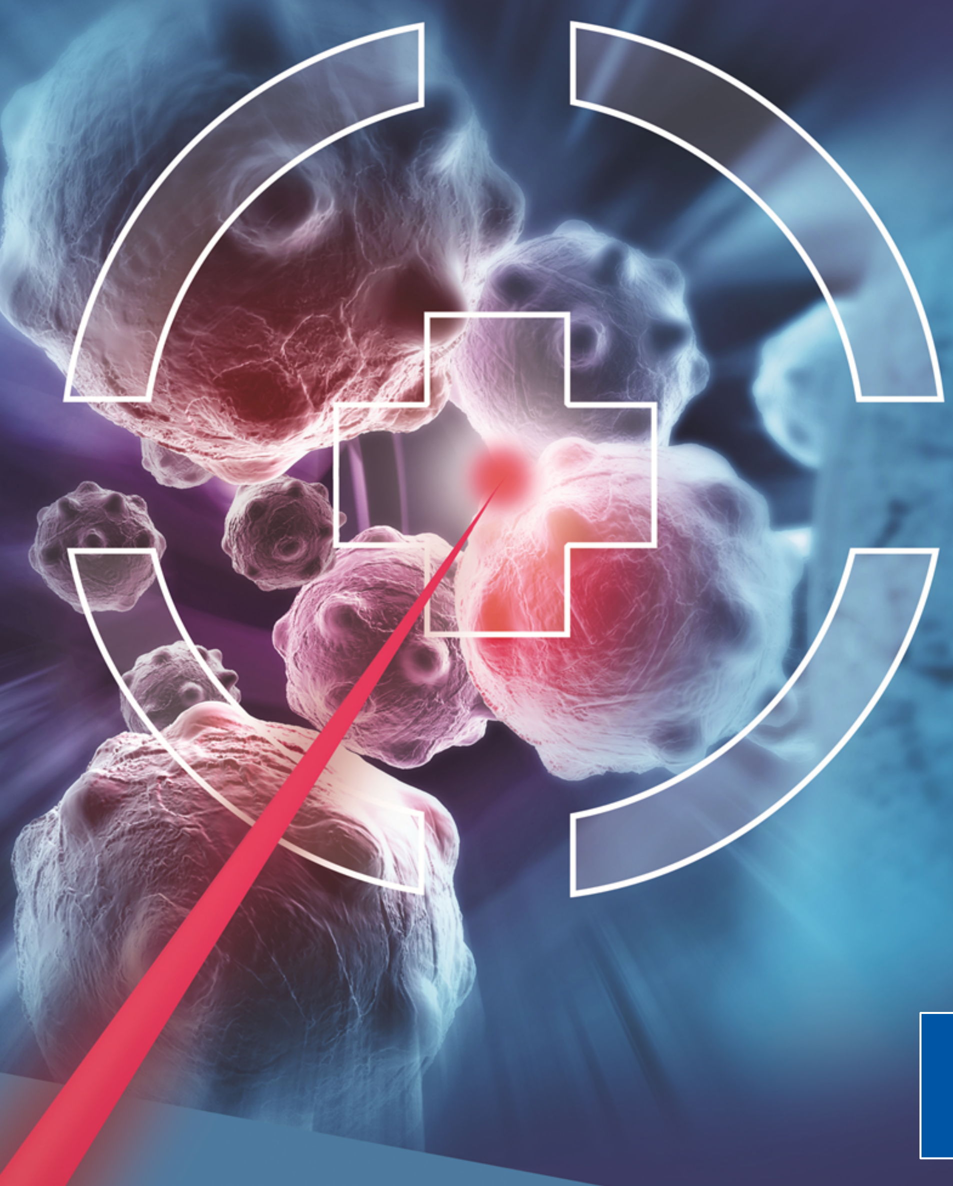
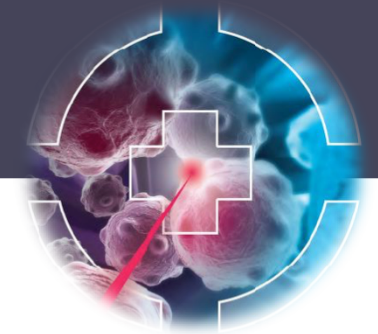


Introduction



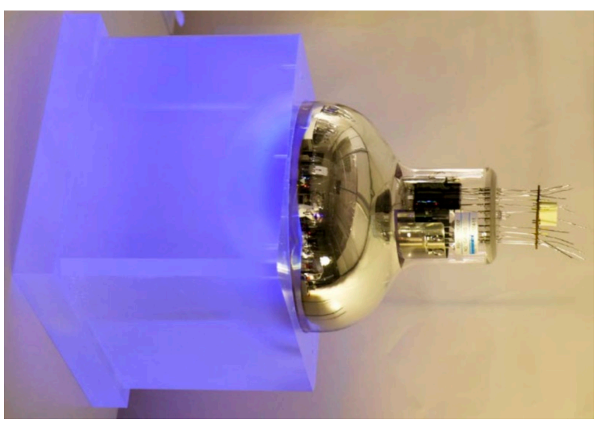
- Background:
  - M. Sc. Particle Physics (RWTH Aachen)
  - Master project at intersection of HEP an Proton Beam Therapy (PBT)
- Work within OMA:
  - Training:
    - Schools on Medical Accelerators, High-Energy Physics (HEP) and Soft Skills
    - Conferences on Acc. Physics, PBT and MC simulations
    - Participated in two beam tests in PBT Centres
  - Side project: Dose build-up in PBT
    - In collaboration with Medical Physics & Bioengineering
    - Purely simulation
  - Main focus: A calorimeter for PBT

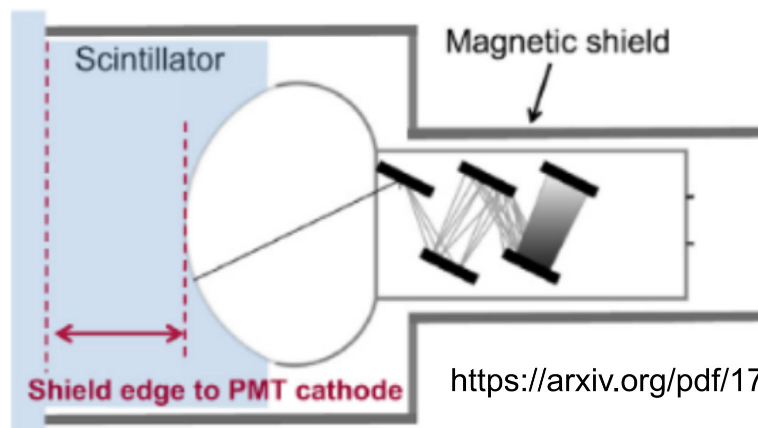
Quality Assurance (QA) in PBT

- Daily QA: Verify beam range at isocentre
- Commercial solutions (e.g. IBA Zebra) are expensive
- Manual scanning is slow (~1hr)
- Detector requirements:
  – Precise: Energy resolution < 1% σ
  – Fast: one billion protons s^{-1}
- Technology transfer from HEP?

SuperNEMO Calorimeter

- SuperNEMO aims to measure a hypothetical neutrino-less double-beta decay
- Calorimeter developed at UCL
- Plastic scintillator & photomultiplier tube
  - Energy resolution of 7% FWHM (for 1 MeV electrons)
  - Pulse length ~100 ns (maximum rate 10 million protons s^{-1})
  - Water equivalent scintillator

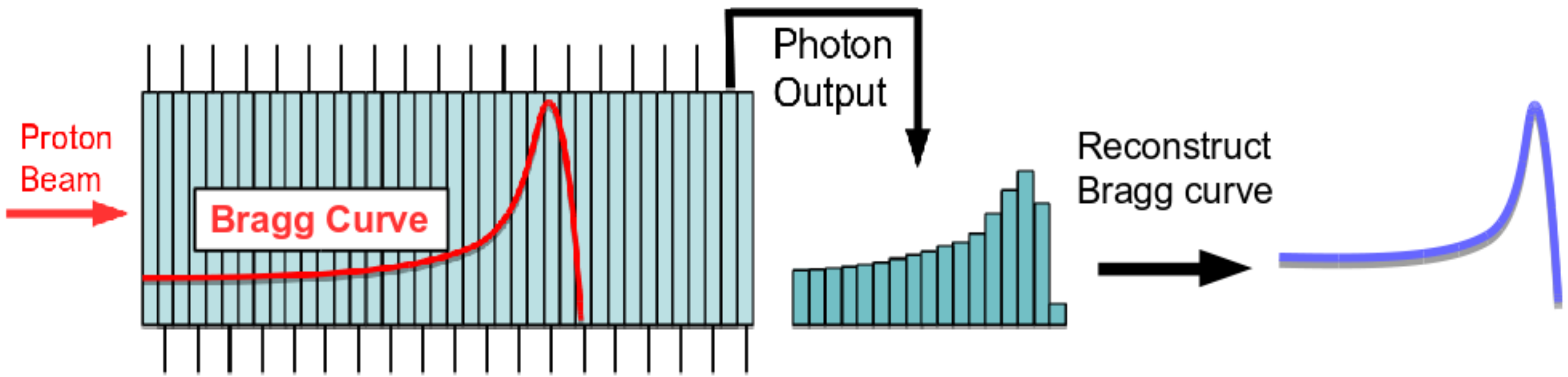




https://arxiv.org/pdf/1707.06823.pdf

Range Telescope

- Cut scintillator in segments (sheets)
- Read out each sheet individually
- Integrate signal from many protons
- Reconstruct Bragg curve from photon output
- Measure range instead of energy



Proton Range Reconstruction

- Quenching: scintillation light production not linear to energy deposition
- Developed model of a “quenched Bragg curve”
- Three parameters: range, range straggling and intensity

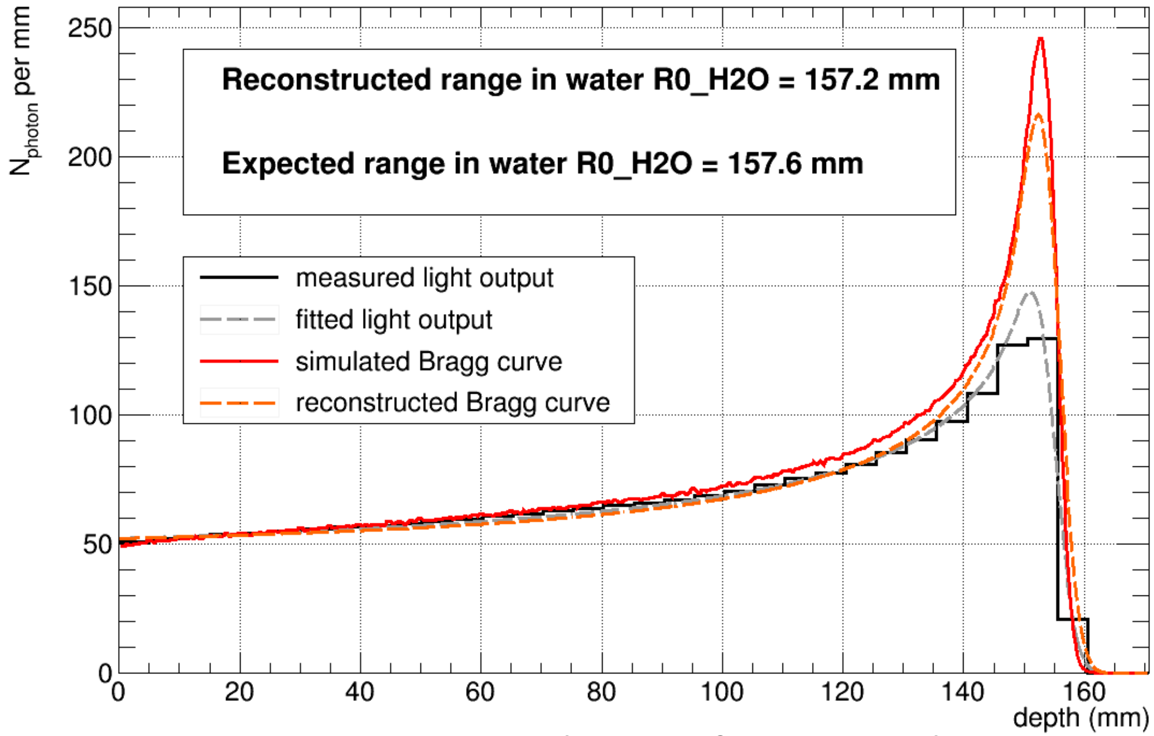
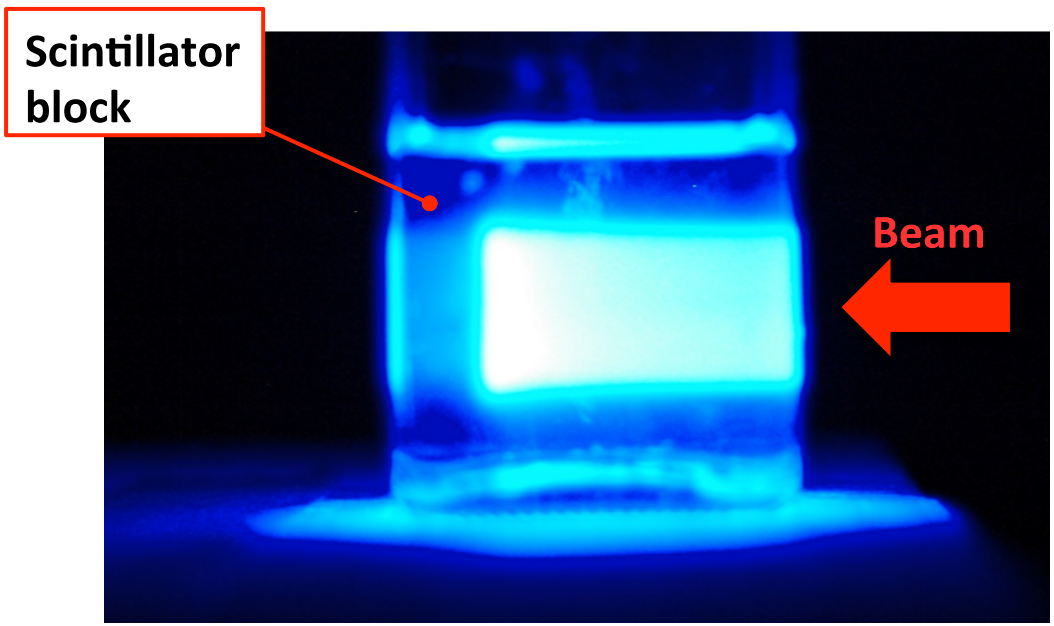
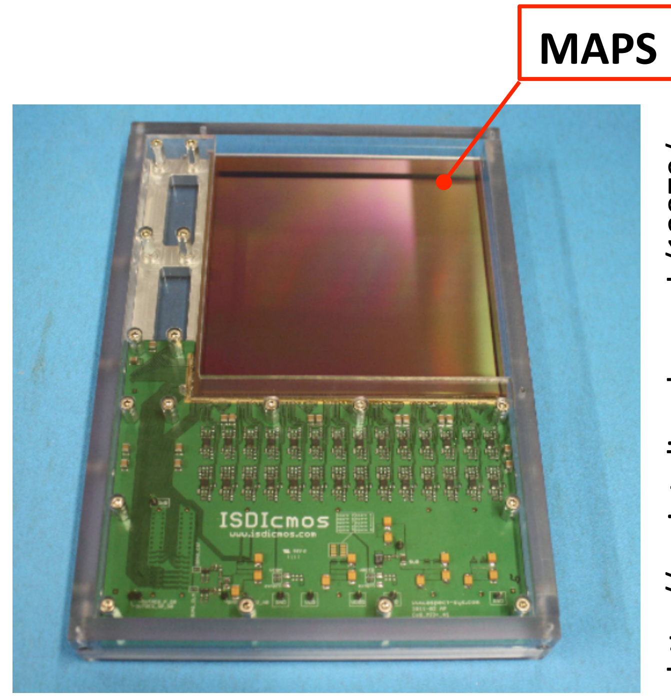


Figure: Geant4 simulation of a range telescope

Building a Range Telescope

- Large number of channels requires expensive read-out system
- Solution: “Monolithic Active Pixel Sensor” (MAPS)
- Take “picture” of scintillation photon depth curve





http://eprints.lincoln.ac.uk/13879/

Birmingham Beam Test

- 28 MeV proton beam: 7.8 mm range in water
- Measurement with two scintillator sheets (3 and 4 mm thick)
- Two PRaVDA Priapus MAPS (10x5 cm^2)

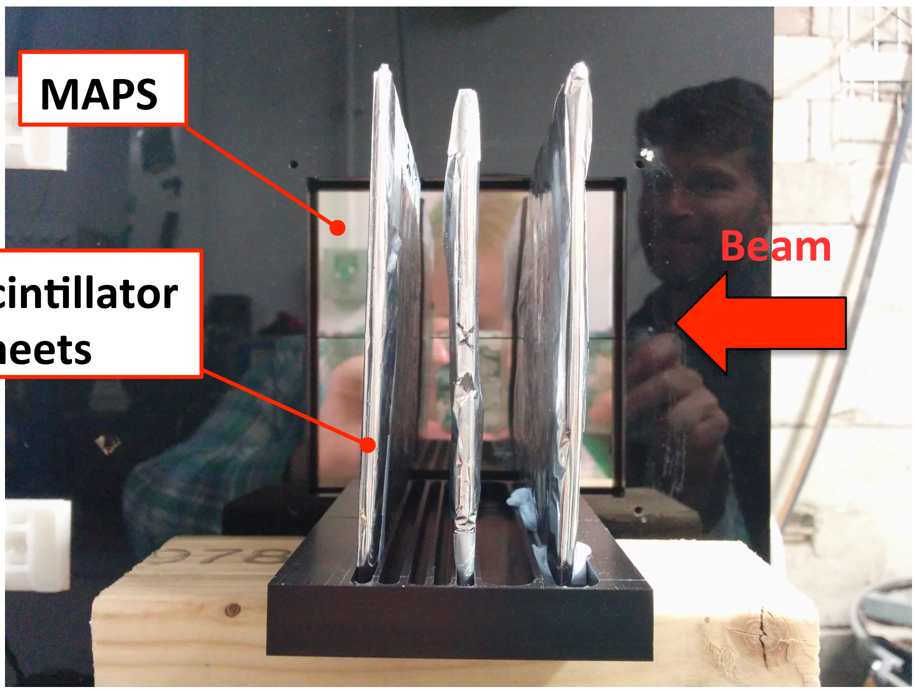
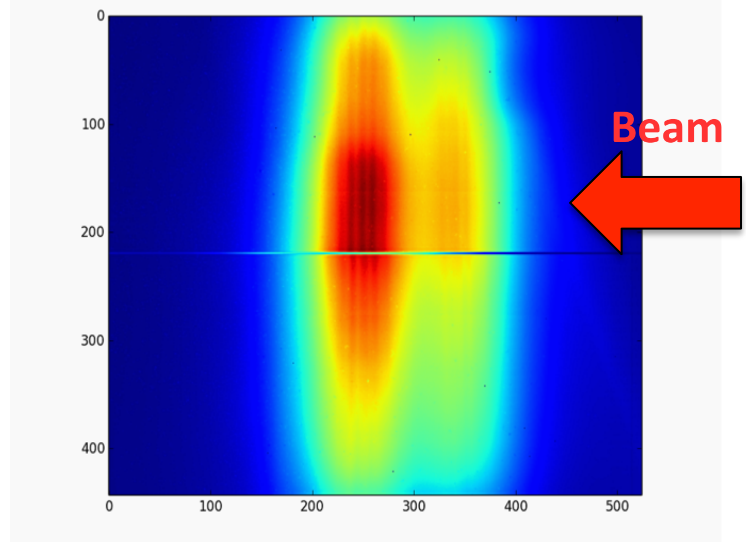


Image taken by MAPS
(10^8 protons s^{-1}, 1 s integration time)



Dose Build-up in PBT

- Goal: Quantize dose build-up (BU) in PBT using Geant4
- Distinguish between electron and proton build-up
- Express BU as dose difference normalized to entrance dose

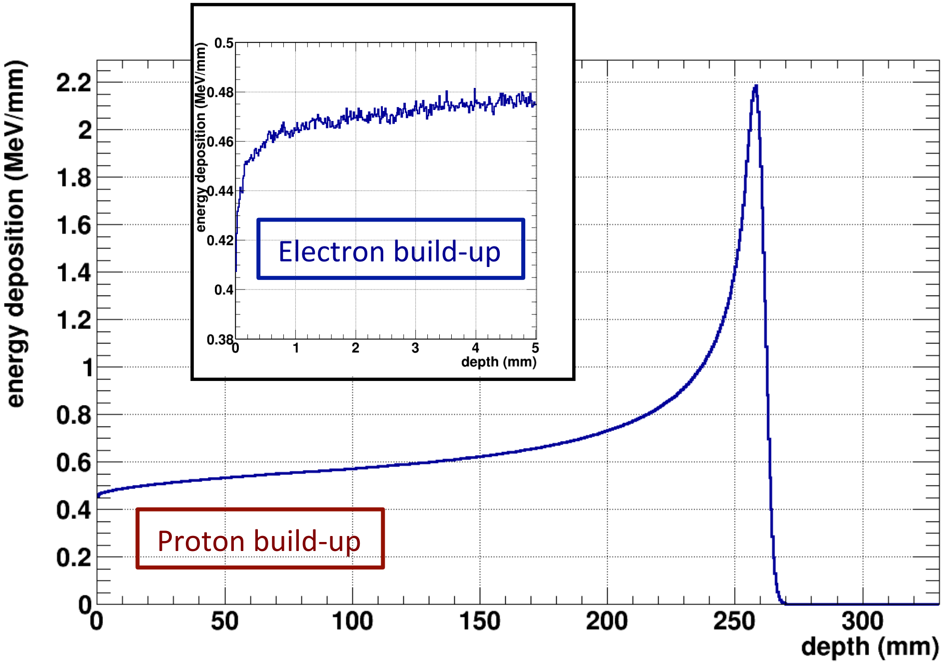


Figure 1: 200 MeV proton beam in a block of water

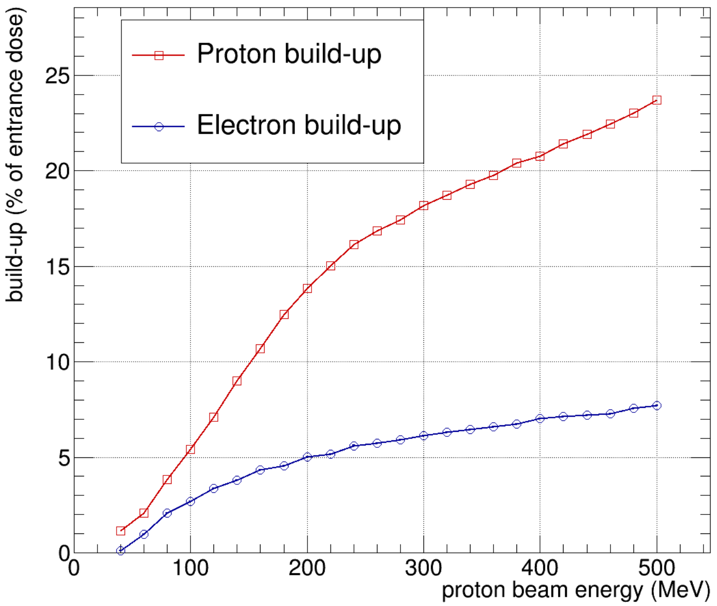
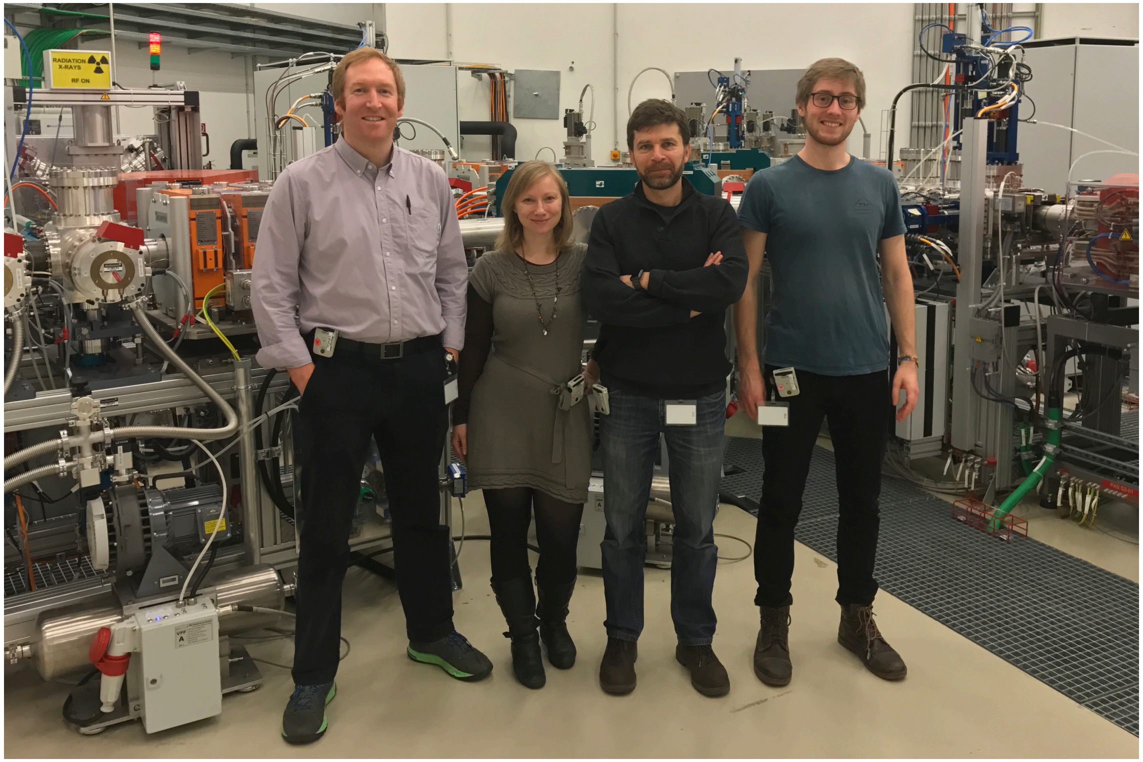


Figure 2: Dose build-up vs. beam energy

Conclusion

- Summary
  - Beam tests with single-module detector show limitations
  - Range telescope optimized in Geant4
  - Developed model for range reconstruction
  - Found solution for cheap readout of large number of channels (MAPS)
  - First beam test shows promising results
- Outlook
  - Improve software of read-out with MAPS
  - Build larger prototype
  - Make radiation hardness tests with scintillator
- Impact
  - Extensive training at intersection of HEP and PBT
  - Prospect of building a commercial device for PBT

Thank you for your attention



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