Particle therapy instrumentation

UNIVERSITY OF LIVERPOOL

FONDAZIONE BRUNO KESSLER

MICRON SEMICONDUCTOR LIMITED

Rutherford Cancer Centres

Applying HEP silicon detectors to particle therapy

People

- Research staff: Gianluigi Casse, Jon Taylor, Carlos Chavez,
- Technical staff: Alan Taylor, Tony Smith, assistance from the DFF and LSDC staff as well
- Students: Fajer Alaquanti, Shaikah Moslet (2nd year), Mohammad Alsulimane (4th year) -> talks/poster in this meeting
- Industry partners: Rutherford Innovations, Micron Semiconductor Ltd, Ion Beam Applications (IBA) Ltd, FBK Trento

Rutherford Cancer Centres

Research aims / themes

- Accelerator QA - make it faster and more reliable
- High dose rates in small areas (spot scanning)
- Imaging and treatment planning / monitoring
- Secondary (unintended whole body) doses

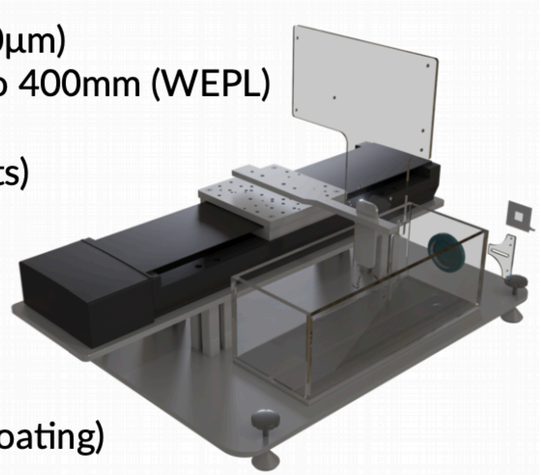
Pixelated water phantom for particle therapy

Phantom

- Compact water tank design
- Highly accurate detector positioning (better than 50µm)
- High resolution 3D dose-depth measurements up to 400mm (WEPL)

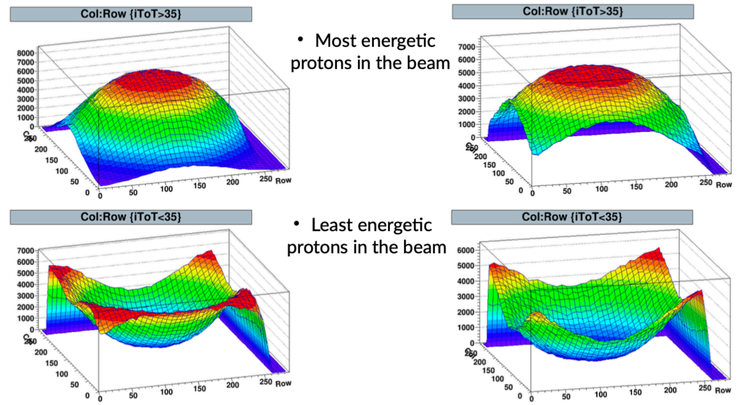
- Silicon Pixel Detectors (from CERN LHC experiments)
  - FeI4 chip (hybrid technology)
  - Timepix3 (hybrid technology)

  - Unique 2D dose-deposition
  - high resolution beam profile QA
  - Measurements directly under water (Parylene coating)
  - potential for 3D patient treatment QA

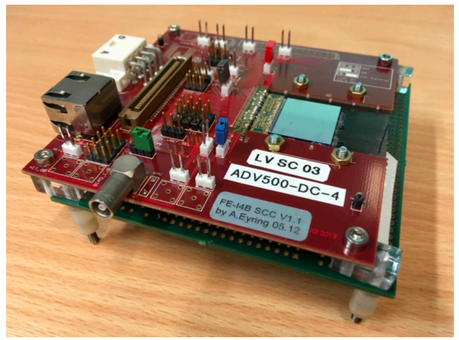


ProteusOne beam profile and Energy measurements with Timepix3 chip

- 25mm water depth
- 120 MeV Protons
- 107mm water depth



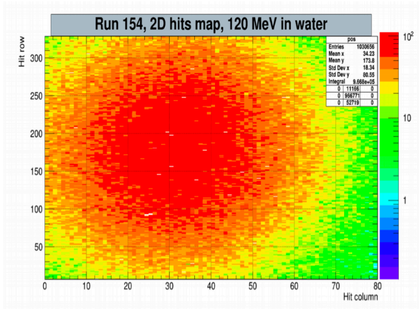
- Most energetic protons in the beam
- Least energetic protons in the beam

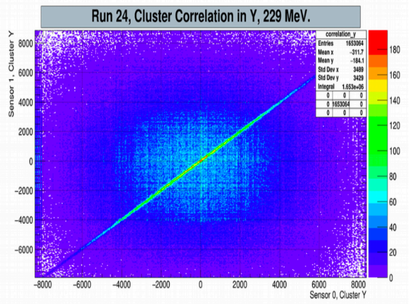


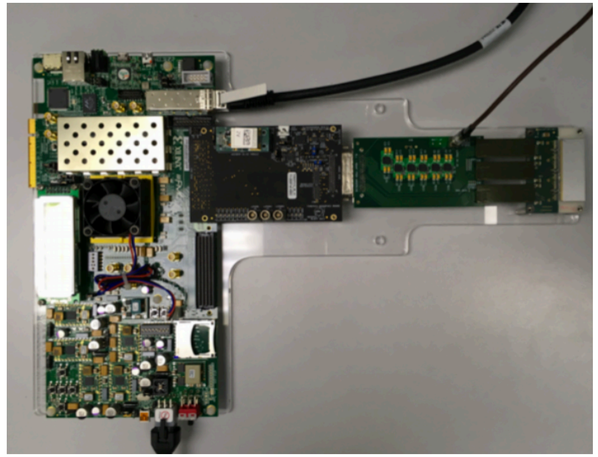
FE-I4

ProteusOne beam profile and tracking measurements with FEI4 chip

- 2D hit map in water
- Proton tracking correlations between two FEI4 detectors



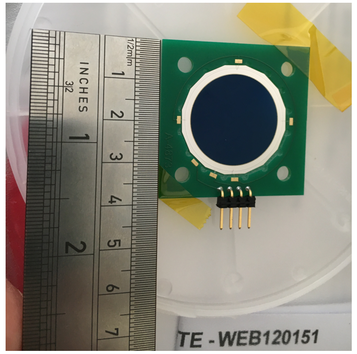


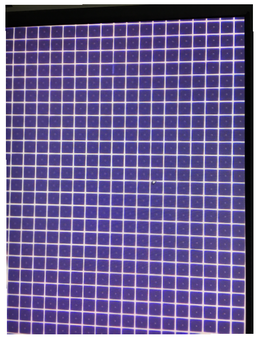


Timepix3

Highlights from current PhD students

New detector technology from Micron with 10um trenches in surface

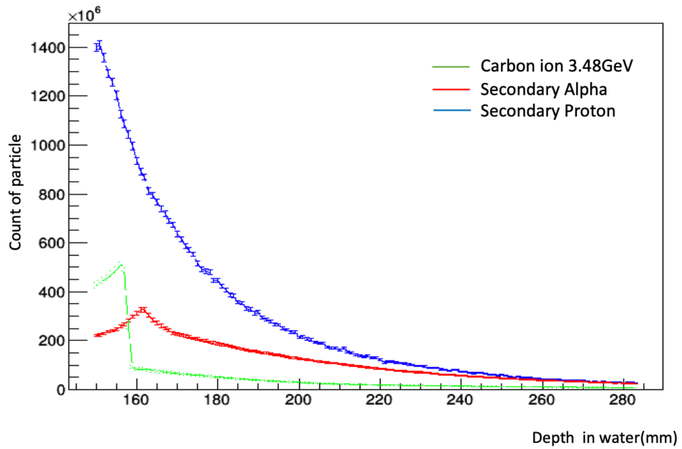




$$^{6}_{3}Li + {}^{1}_{0}n \rightarrow {}^{3}_{1}H\ (2.73\ MeV) + {}^{4}_{2}\alpha\ (2.05\ MeV)$$

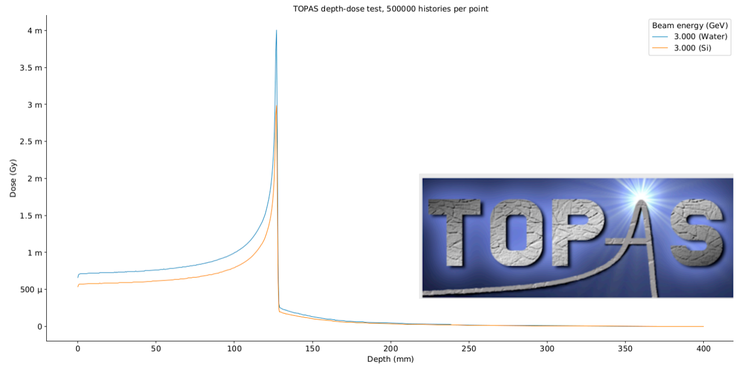
see poster by M. Alsulimane

Simulation of interaction vertex imaging with carbon ion fragmentation

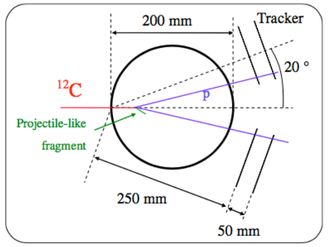


see talk by Shaikah Moslat

Commissioning of new monte carlo software for carbon and proton beams



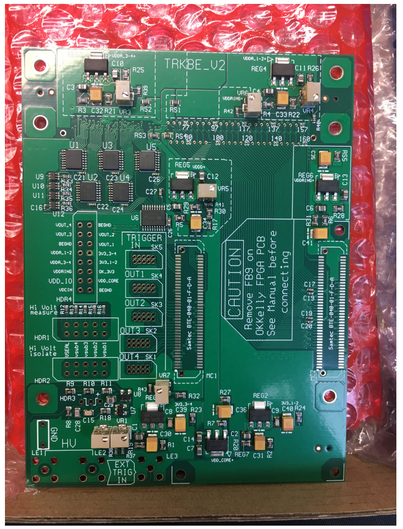
see talk by Fajer Alqahtani

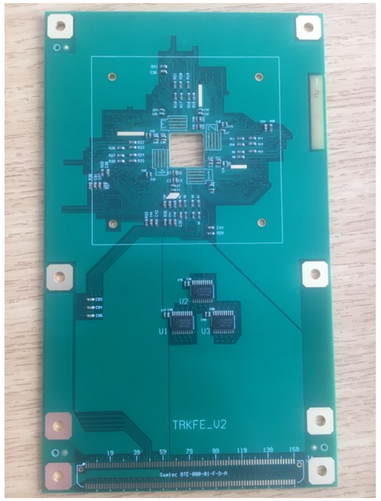


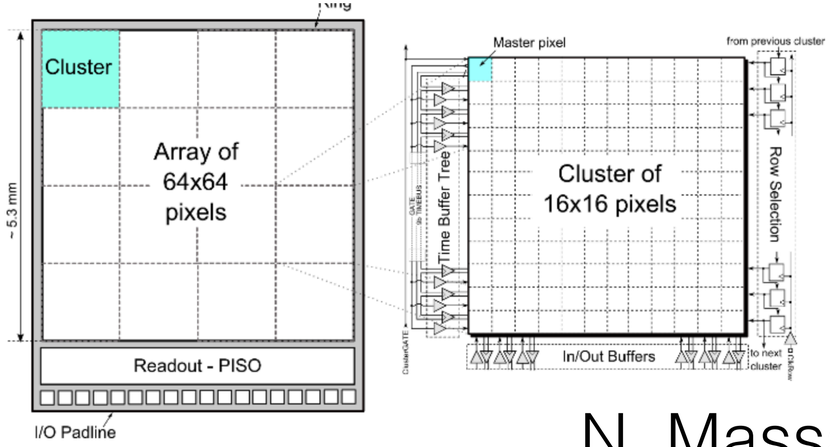
P Henriquet et al 2012 Phys. Med. Biol. **57** 4655

HVTrack - a new HV-CMOS detector for particle therapy

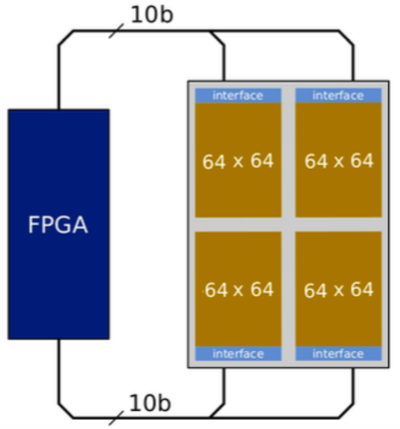
- HVTrack is new HV-CMOS pixel detector optmised for IBA ProteusOne accelerator
- MPW in 0.13um produced by LFoundry and initial testing took place at FBK
- Area of 1.06cm x1.06cm and a pixel pitch of 80µm x 80µm (>15k pixels/cm$^{2)}$
- Three modes of operation (proton counting, energy (dose), time (tracking)
- Front end and back end PCBs designed at Liverpool by Tony Smith and manufactured nd loaded by JLC have now been received - population with connectors and ASICs ongoing
- Test beams at Rutherford Cancer Centres with IBA Proteus One in late 2022

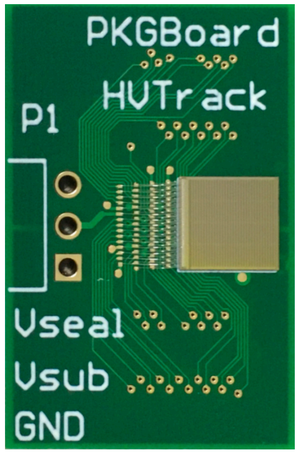




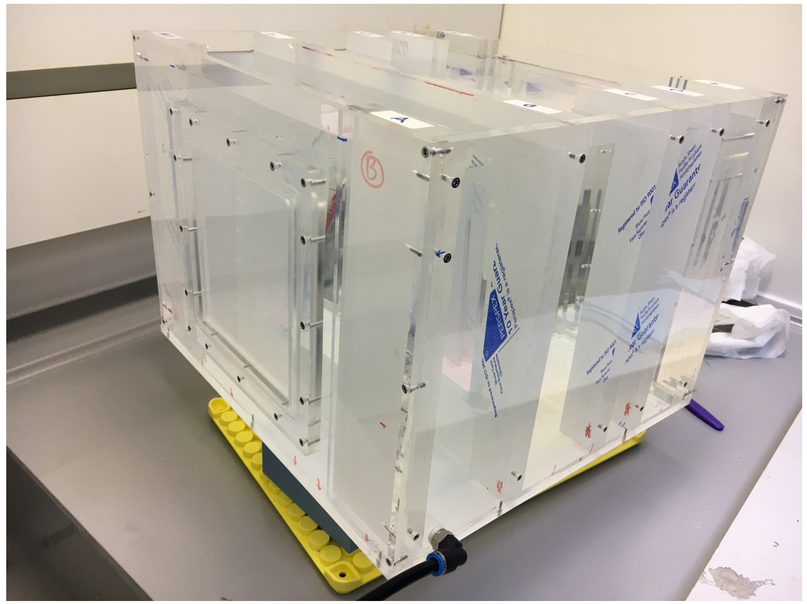


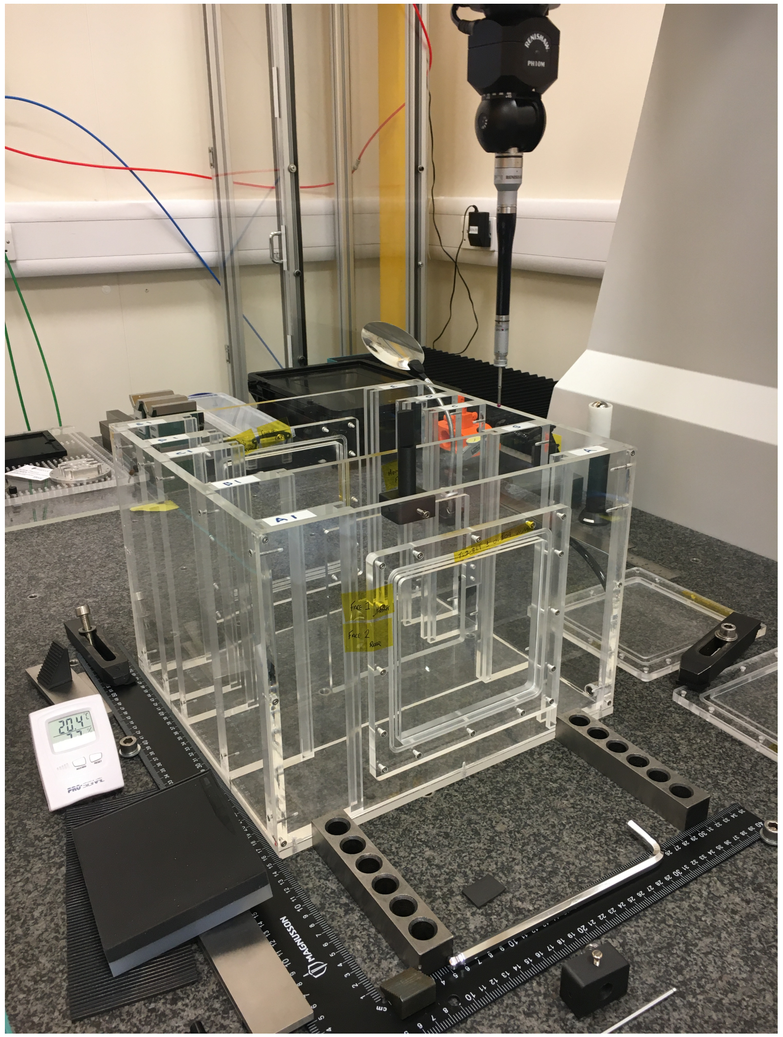
N. Massari





Water phantoms for MRLinacs



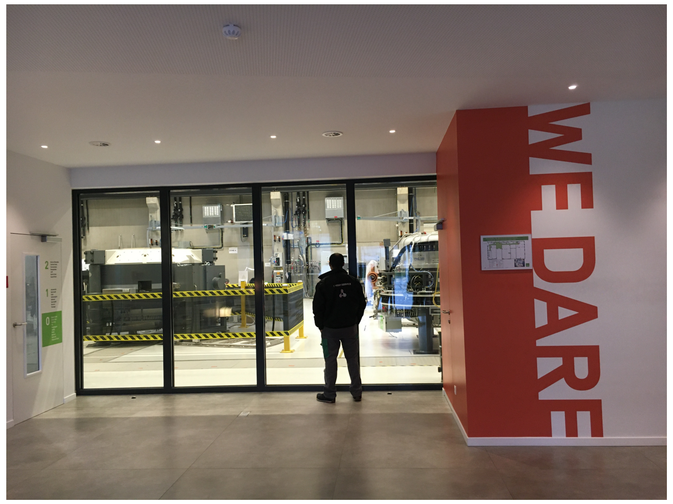


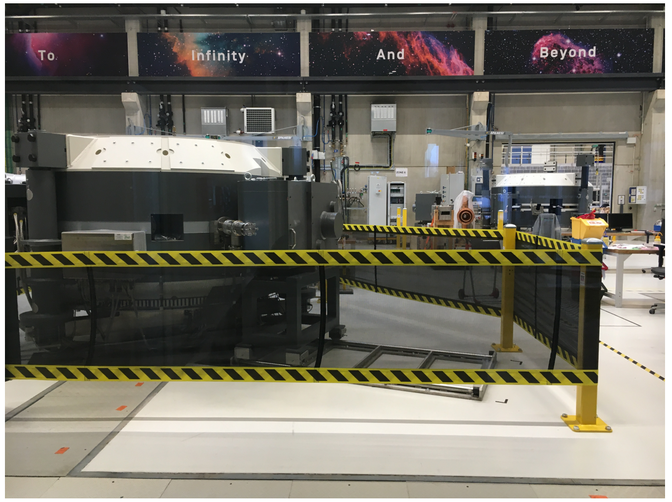
- New water phantoms with precision slots for positioning of QA/QC ionisation chambers in MR Linac at Rutherford Cancer Centre Liverpool
- Parts machined and assembled in the workshop, measured in the LSDC using the CMM
- Can be instrumented with additional detectors e.g. silicon diodes to cross calibrate dose

D.Sim, T. Lee & DFF

Ion Beam Applications

- Largest manufacturer of proton therapy accelerators in the world
- Supplier of all superconducting proteus one accelerators for Rutherford Health in the UK
- Carrying out R&D on carbon ion accelerators for future production
- Joint submission with IBA and Rutherford to Wellcome Trust for detector development (unsuccessful) meeting with IBA later this month to establish possible new funding paths





IBA's 'particle accelerator factory', Louvain-La-Neuve

Summary / Conclusions

- Several years experience adapting detectors from high energy physics for use in clinical proton therapy beams
- Lessons bring learnt with spot scanning accelerators compared with passive scattering
- Development a new HV-CMOS chip with FBK and Rutherford innovations for IBA Proteus One
- New opportunities for instrumenting ion beams such as carbon - secondary vertexing, neutron dosimetry, prompt gammas, ion CT/radiography will probably all become easier
- Pursuit of a stronger partnership with IBA and CNAO allowing use of clinical carbon ion beams