Particle therapy applications

FONDAZIONE BRUNO KESSLER
IRIS
INTEGRATED READOUT ASICS AND IMAGE SENSORS

UNIVERSITY OF LIVERPOOL

MICRON SEMICONDUCTOR LIMITED

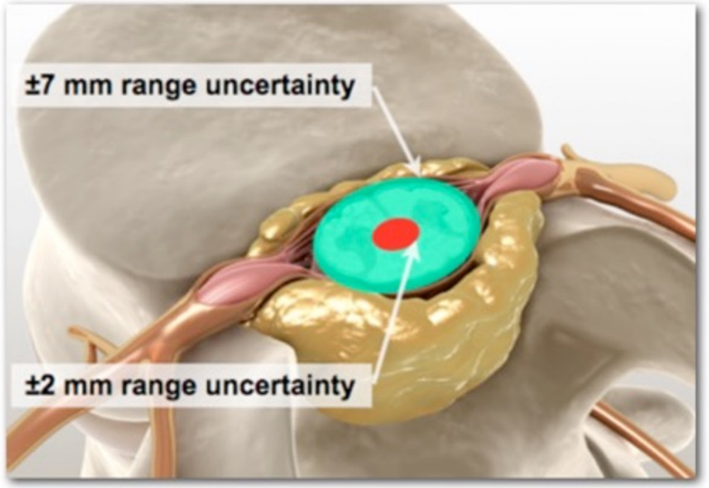
iba

People

People

- Academic / Research staff: Gianluigi Casse, Sergey Burdin, Jon Taylor, Carlos Chavez
- Technical staff: Alan Taylor, Tony Smith, assistance from the DFF and LSDC staff as well
- Students: Fajer Alqahtani, Shaikah Moslat, Mohammad Alsulimane (4th year)
- Industry partners: Micron Semiconductor Ltd, Ion Beam Applications (IBA) Ltd, FBK
- Apart from the PhD students, nobody is working >0.20 FTE on this..

Research themes and motivation

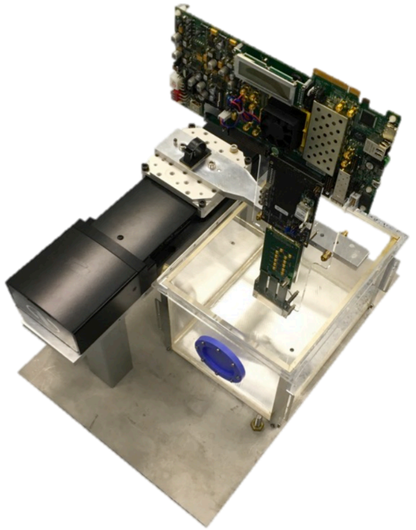


Phantom

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

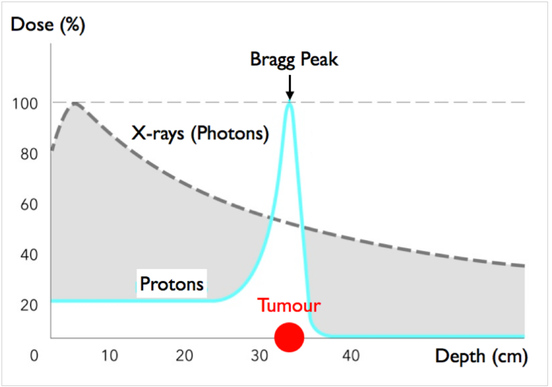
- Silicon Pixel Detectors (from CERN LHC experiments)
  - FeI4 chip (hybrid technology)
  - Timepix3 (hybrid technology)

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



Research aims / themes

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



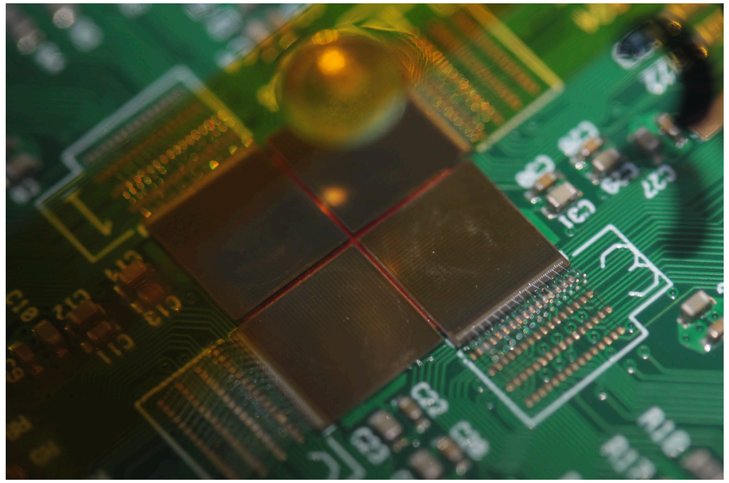
What happened this year..

- First PhD thesis in this application submitted (Mohammad Alsulimane, viva due Summer 2023)
- Progress on understanding mixed radiation fields outside the patient volume ‘phantom’
- Pixel detector upgrade: Timepix3 -> HVTrack (Firmware developed with FBK via department IAA fund)
- Large area strip detector now available for imaging and ‘gamma camera’ experiments
- Potential for new collaboration explored with Sapienza (Rome) particularly around use of high intensity electron beams (Flash effect)

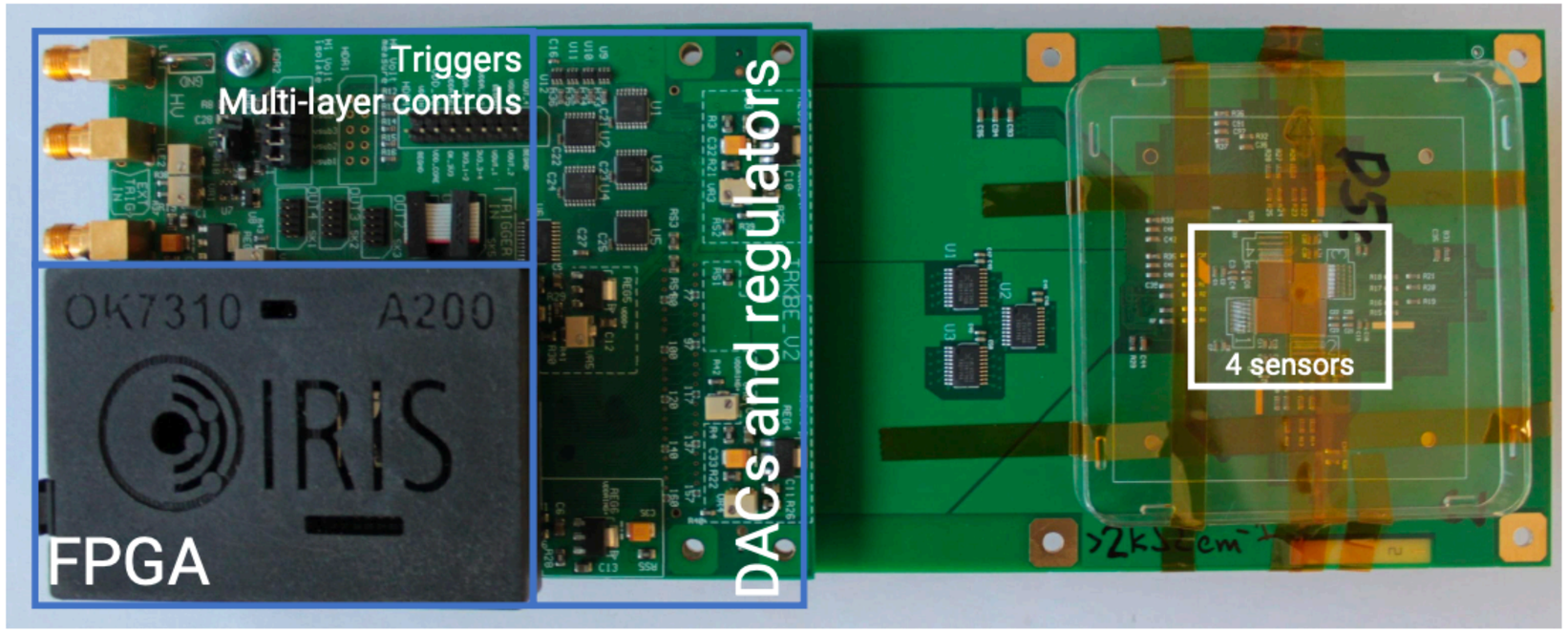
HVTrack testing and FW development

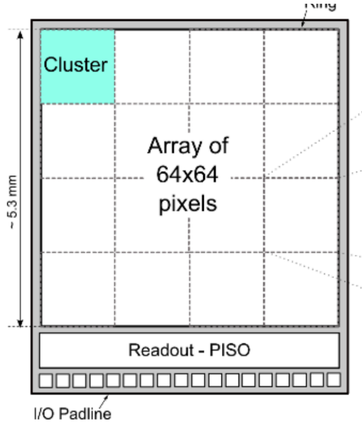
- 4 chips per layer
- (At least) 2 layers for trajectory reconstruction
- FPGA controls the 4 chips in each layer
- Synchronisation is performed at FPGA level with a primary FPGA controlling the other layers.
- The two boards can be separated and connected with a cable to ensure an adequate distance between the FPGA and the beam
- DACs ensure correct working window for each chip
- Timing is fully adjustable live on software side

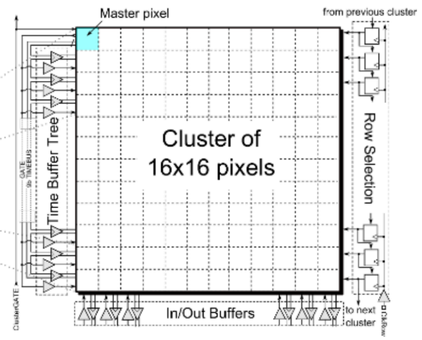
N. Massari, L. Parmesan, T.Smith



HVTrack system with two PCBs, on the left the controlling board and sensing PCB on the right







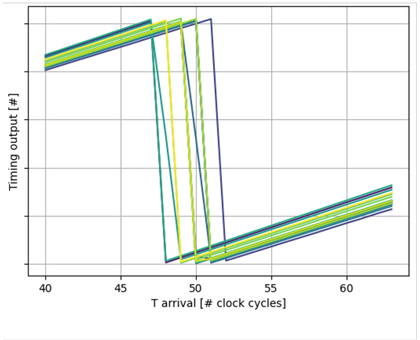
HVTrack testing and FW development

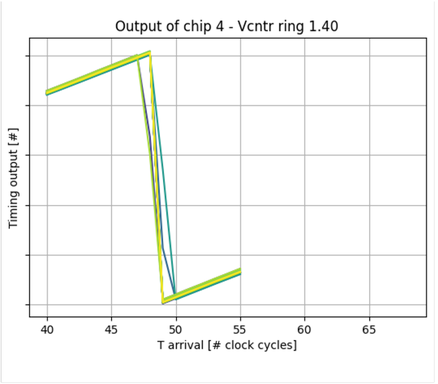
- The two general purpose memories can be used for various measurement
  - Two consecutive energy measurements
  - Two consecutive timing measurements
  - Timing and energy of the same event
- **Energy measurement**
  - The event peak is sampled in the pixel when it exceeds the threshold in a given time window
  - Then the analogue value is converted to digital value in each pixel and stored in memory
- **Timing measurement**
  - The master pixel produce the reference time for every sensing pixel in the cluster
  - The time is sampled when an event reaches the threshold
  - The event time is limited to a gated window
- **Event counting measurement**
  - With large time windows
  - Every event that exceeds the threshold it increases the counter of each pixel.
- **Combined Energy and Timing**

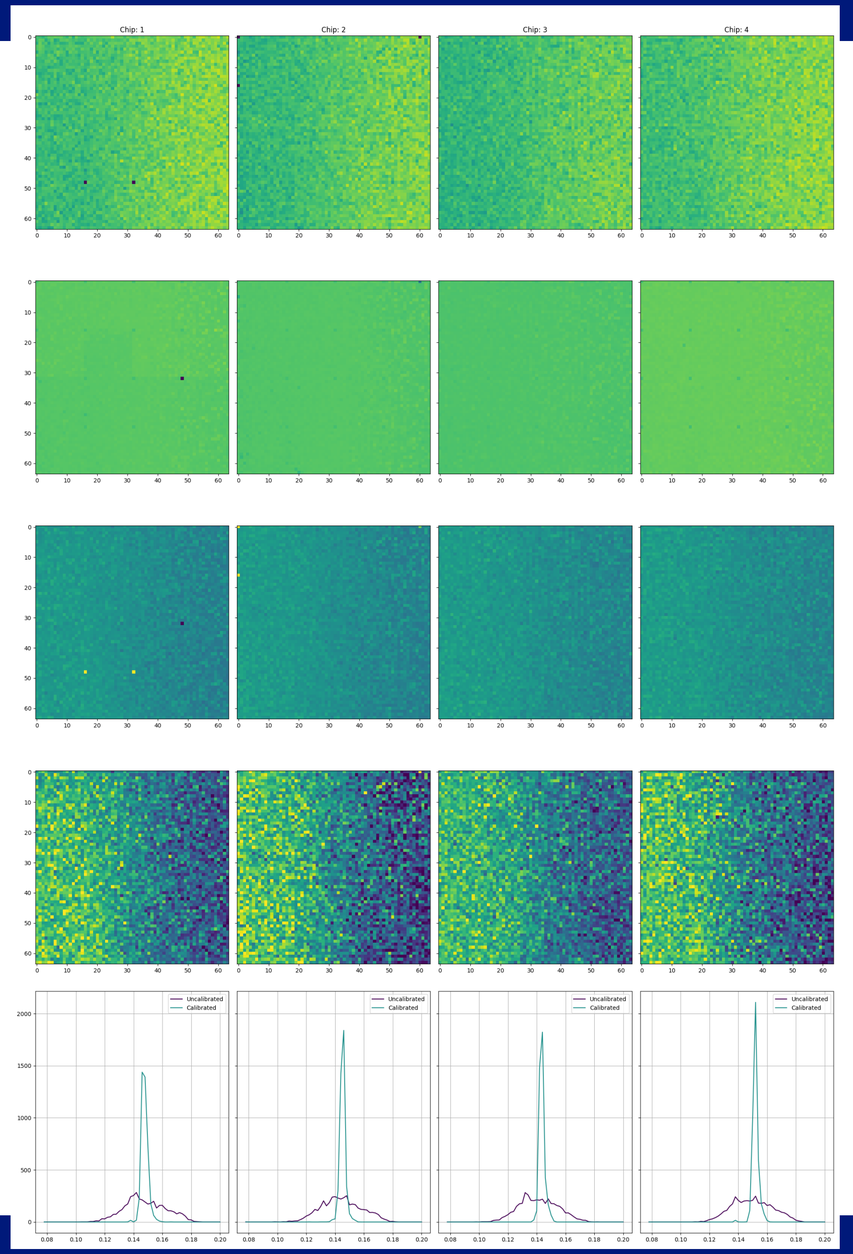
N. Massari, L. Parmesan

HVTrack testing and FW development

- FW routines and python scripts now under test at FBK
- Calibration of the thresholds and TDCs for four chips on the Liverpool PCB now tested
- 2 more modules for multi layer tests and an additional test setup in the LSDC are planned to be assembled next week



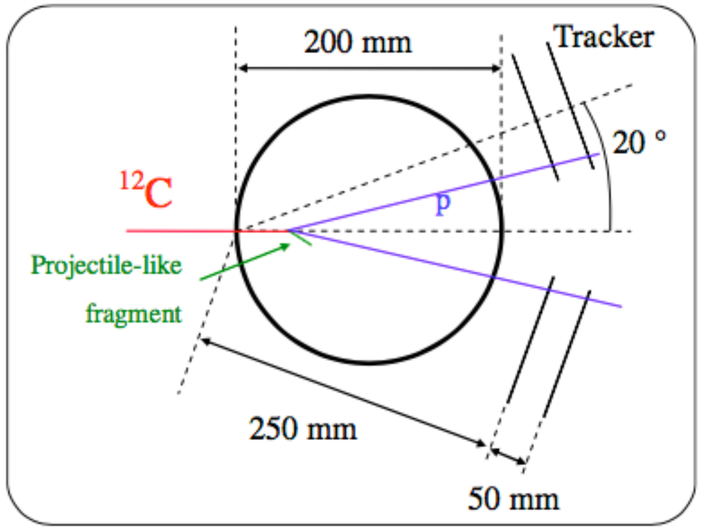




N. Massari, L. Parmesan

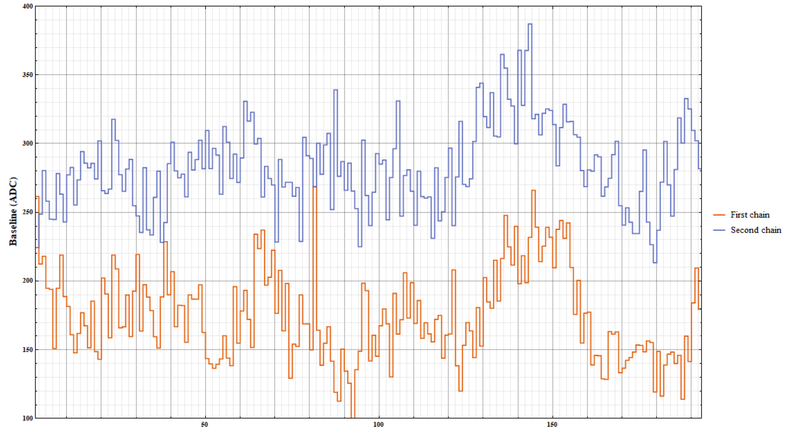
DAMPE large area strip detector

- Strip detector modules developed for the Dark Matter Particle Explorer experiment
- 242um pitch strips, 300um thick silicon, hybrid designed in Liverpool by Ashley
- Modules available for testing in proton and carbon ion beams
- First analysis on existing data beginning and further tests with a sensor later this month
- Potential to use a converter layer for detection of neutrons



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

~10x10cm DAMPE sensor with VIKING ASIC

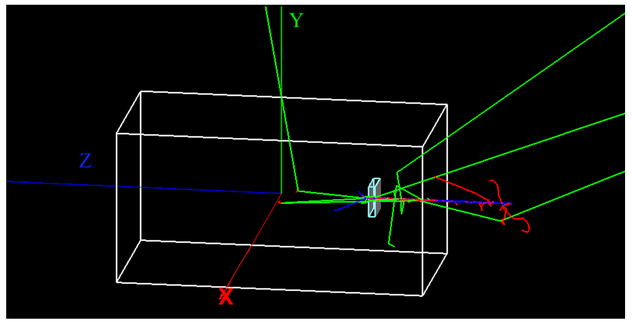


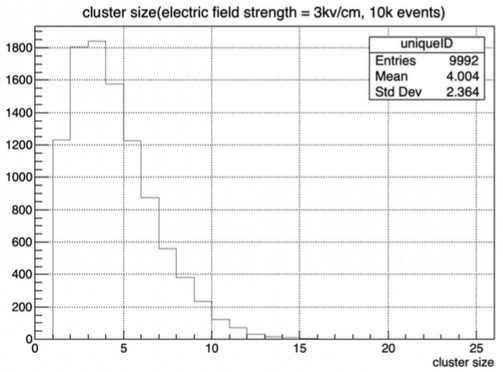
Noise distributions on bare hybrid populated with ASICs

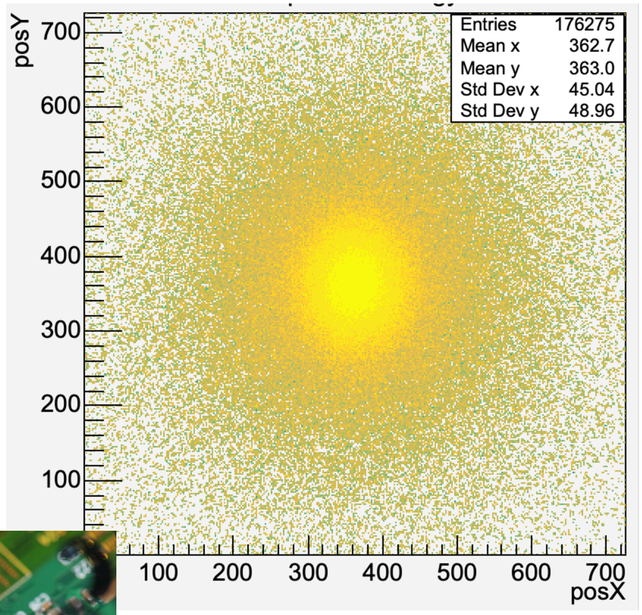
T. Jones, A. Greenhall

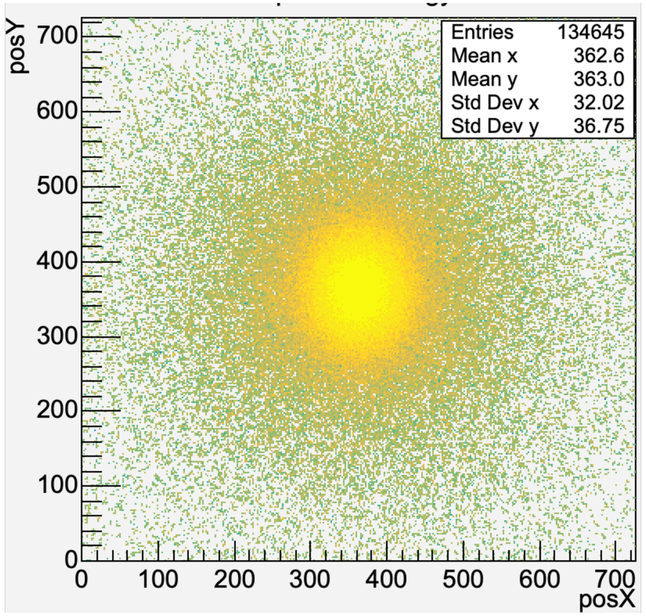
Monitoring of primary beam

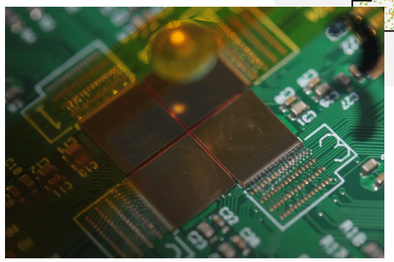
- Setup of TOol for PArticle Simulation (TOPAS) a GEANT4 wrapper with additional features for simulation of clinical beams
- Allows experiments to be simulated much more rapidly using text files rather than geometry defined in C++
- Simulation of primary beam monitoring using a water tank (phantom) and a parylene coated pixel sensor (HVTrack)







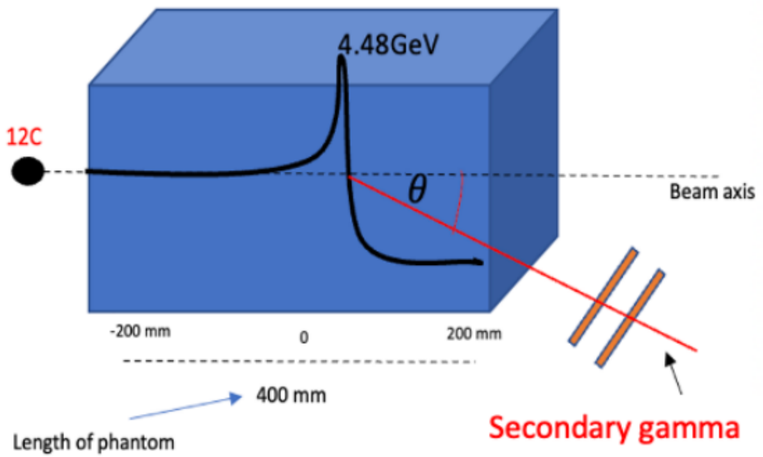


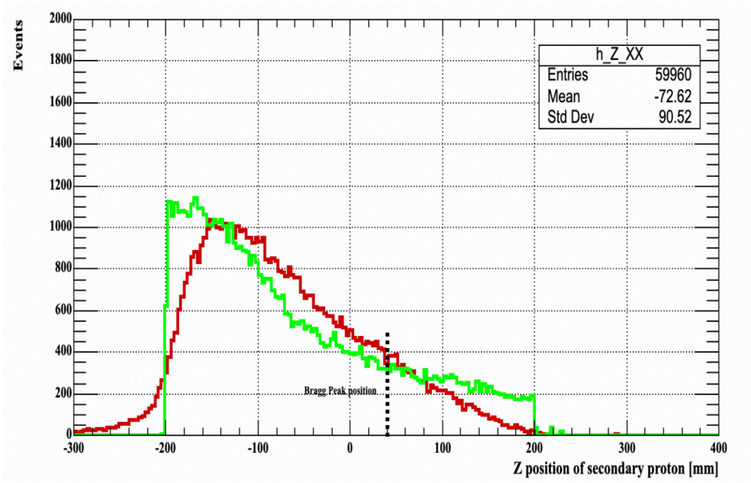


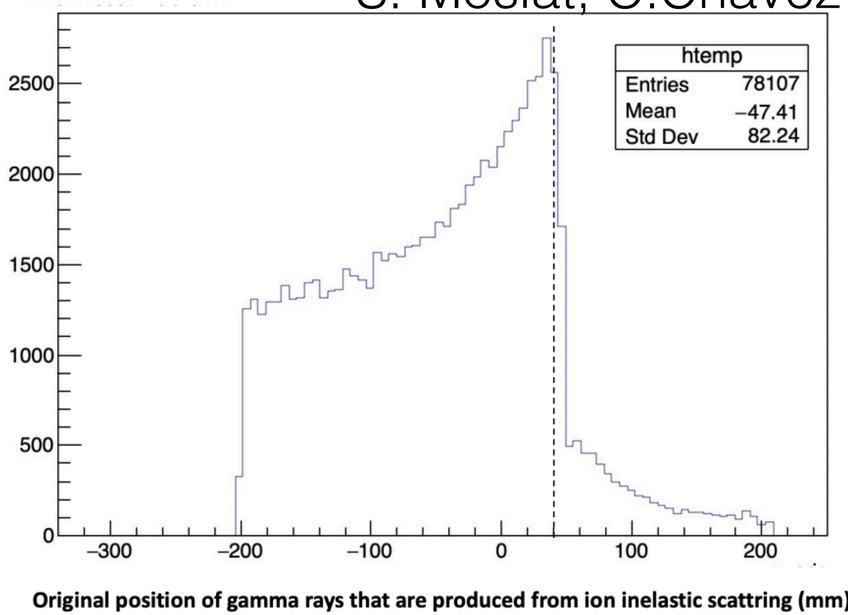
F. Alqahtani, J. Taylor

Monitoring of secondary gammas

S. Moslat, C.Chavez





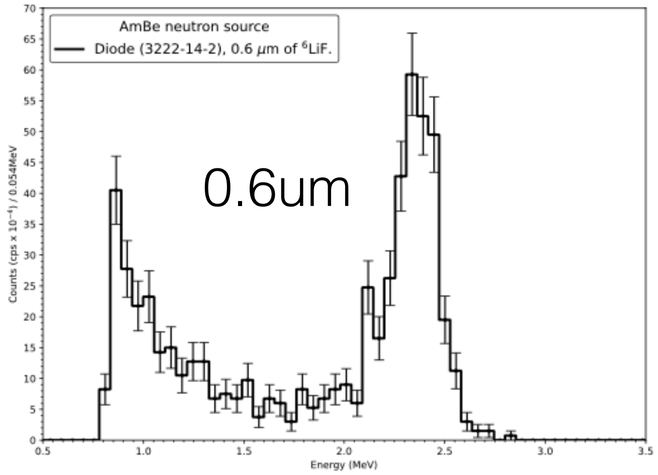


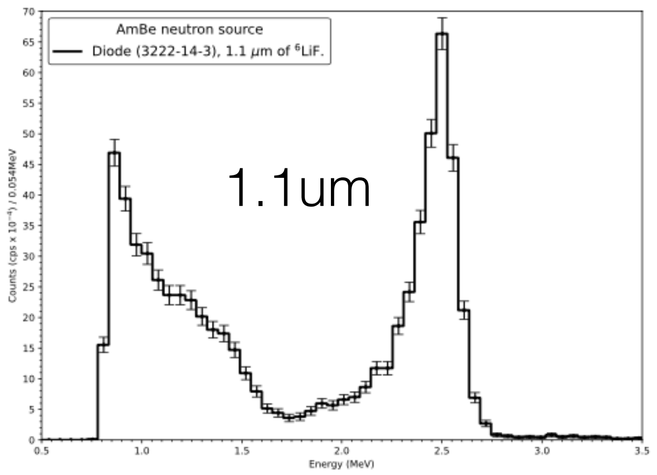
- Straggling of secondary charged particles makes vertexing difficult - almost an anti-correlation with the position of the bragg peak (see proton distribution above)
- Correlation of secondary gamma position in detectors to carbon ion beam range
- Potential to build alternative ‘compton camera’ experiment using large area strip detector that measures initial compton scatter of gamma ray in first detector and subsequently scattered electron in second detector

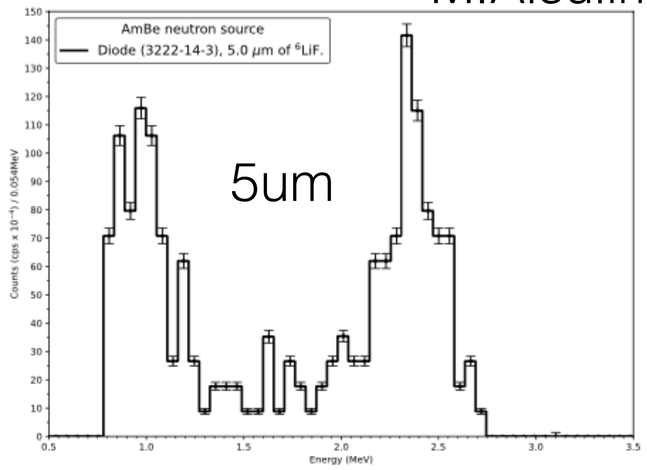
Monitoring of secondary neutrons

M.Alsulimane

Planar diodes with 6LiF

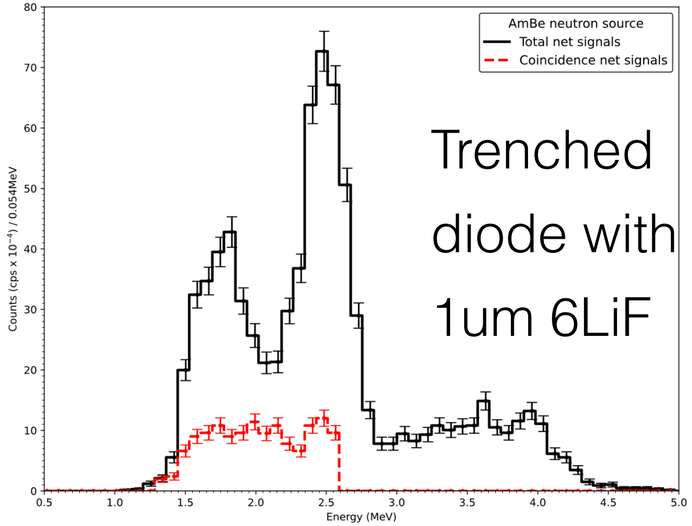


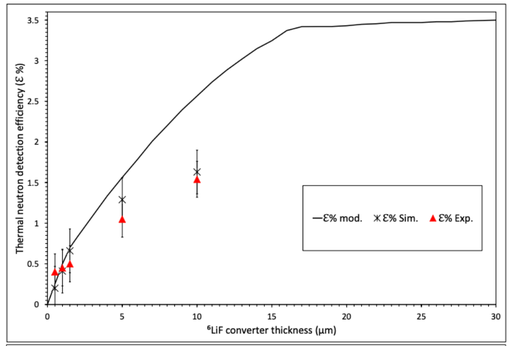


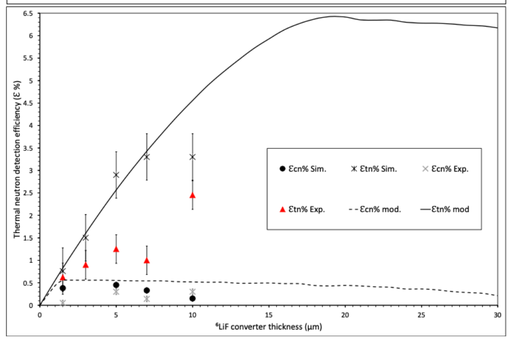


- Thesis submitted on measurements and simulation of planar and trenched diodes for thermal neutron detection
- Evolution of efficiency with converter thickness
- Coincidence measurements in a single (trenched) layer
- Ready for measurement in clinical beam

$$^6_3Li + {}^1_0n \rightarrow {}^3_1H\ (2.73\ MeV) + {}^4_2\alpha\ (2.05\ MeV)$$







Summary and Future plans

- HVTrack FW now (finally) underway and initial test show chip is alive in all 3 modes
- Current testing has demonstrated threshold and timing calibration on all 4 chips on the Liverpool PCB
- Promising results with neutron sensitive silicon using sputtered 6LiF converters and ‘trenched’ silicon sensors. Tests in a clinical beam and calibrated neutron beams would be an interesting next step
- Simulation models in TOPAS and GEANT4 now sufficiently well developed to allow rapid design of experiments for the strip and pixel detectors in a clinical environment
- Pursuit of a stronger partnerships with other partners now that Rutherford has ceased trading (CNAO for carbon ion beams, Sapienza for high energy electrons and IBA for protons)
- Submission of proposal when we have first results from the detectors (lab + clinical beam test)