Queen Mary University of London

DETECTOR DEVELOPMENT GROUP

Detector Development Group Activity Overview

Nuclear Technology Meeting, QMUL March 2023

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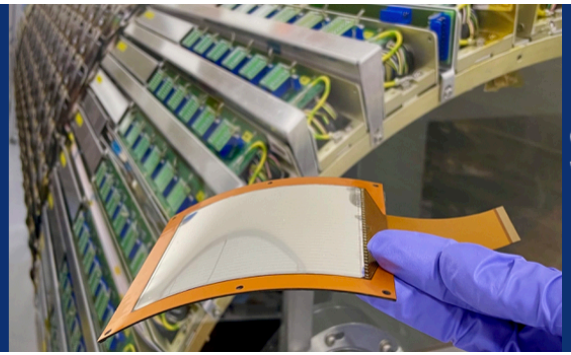
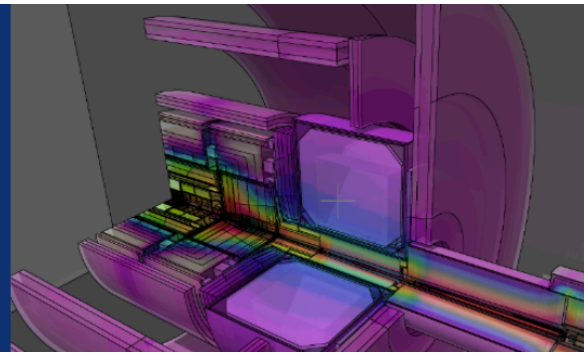
Overview

New technologies for radiation detection



- Silicon:
  - Atlas Upgrade
  - Cylindrical detectors
- Organic Semiconductors
  - Properties and X-ray response
  - α detection
  - neutron detection
- *Long range α detection
- *Diamond detectors (thermal neutrons)

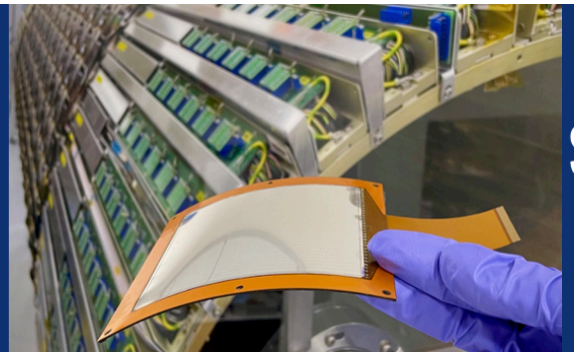
Simulation and modelling



- Non Ionising Energy Loss
- Radiation Damage
- Detector studies
- Thermal simulation of ITk structures
- Optical ray tracing

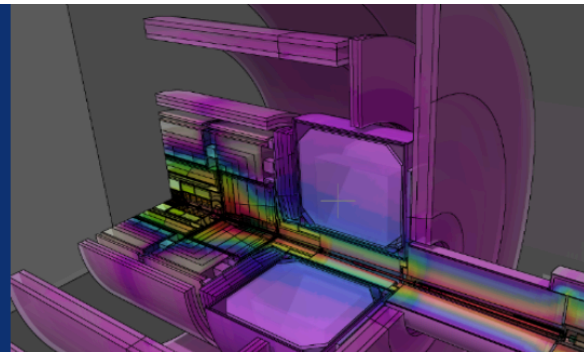
Overview

New technologies for radiation detection



- Silicon:
  - Atlas Upgrade [Seth]
  - Cylindrical detectors [Adrian]
- Organic Semiconductors [Theo]
  - Properties and X-ray response
  - α detection
  - neutron detection
- *Long range α detection
- *Diamond detectors (thermal neutrons)

Simulation and modelling [Ian, Kostya]



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Overview

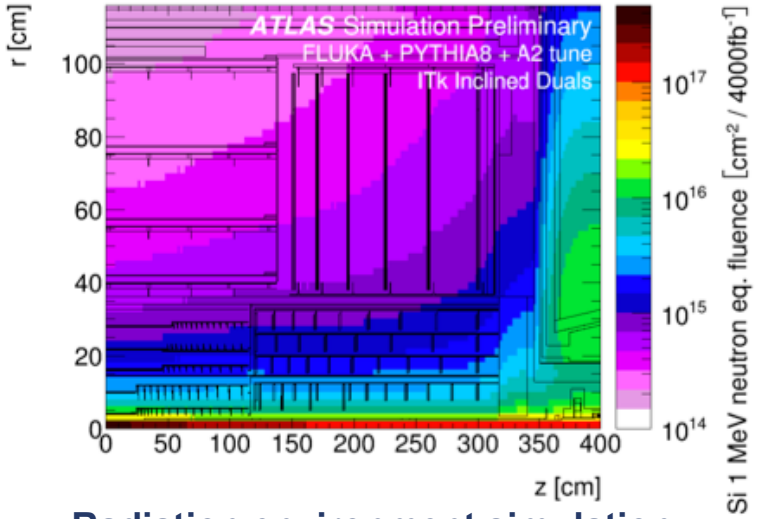
- Commercial Projects
  - Separate meetings focusing on all details including sensitive matters and IP

- Research
  - Open meetings discussing standard methods (device characterisation, etc.) found in the literature, and high level overviews

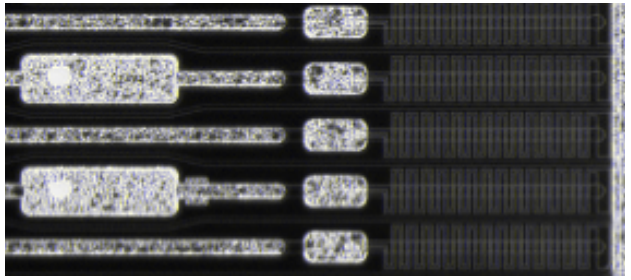
- Common lab infrastructure and training
  - Separate computing accounts for each commercial project, and one for research account to separate activities

Silicon: ATLAS upgrade

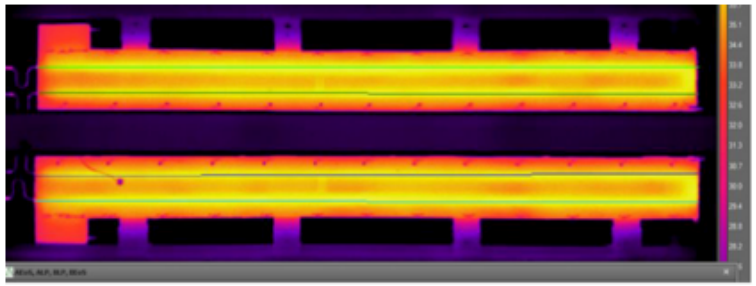
- Targeting the High Luminosity Large Hadron Collider
  - Engineering design since mid 2000's
  - Sensor Testing
  - Component quality control
  - Instrument operation expected from mid 2020's



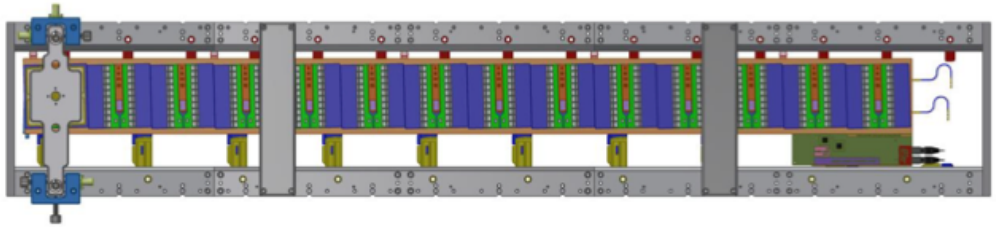
Radiation environment simulation

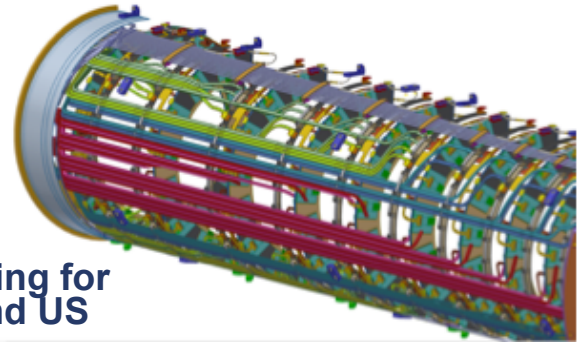


Sensor testing and quality control



Thermal imaging (and simulation)

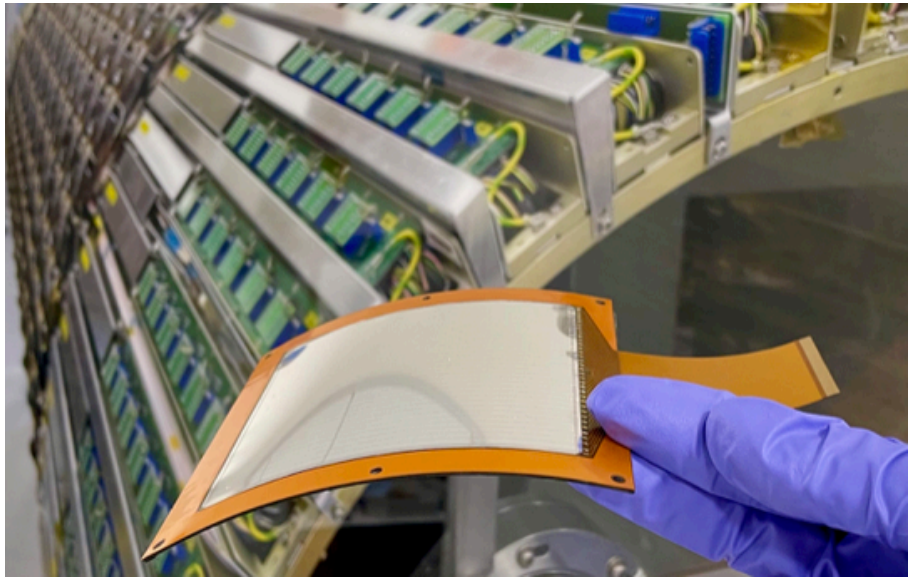


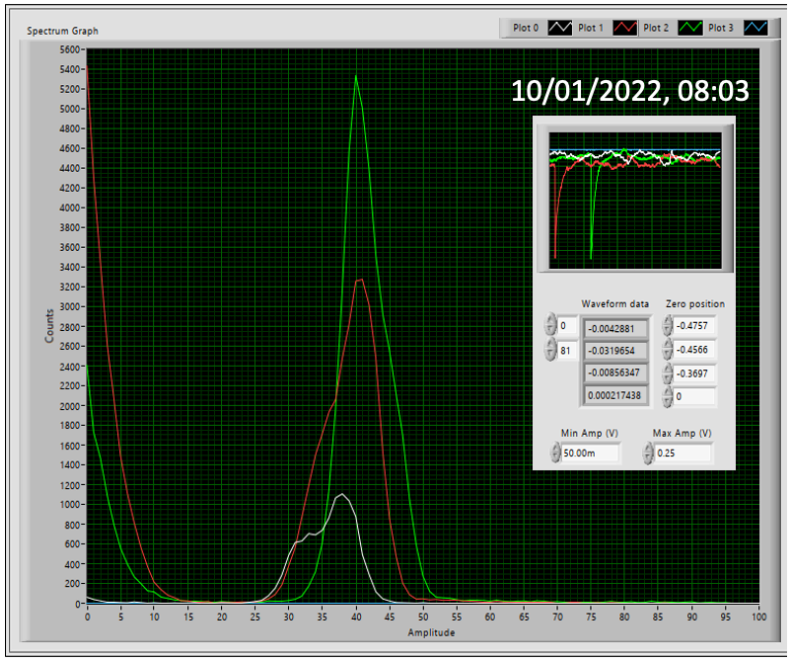


Design of structures, and precision machining for parts delivered to national labs in the UK and US

Silicon: thin curved silicon

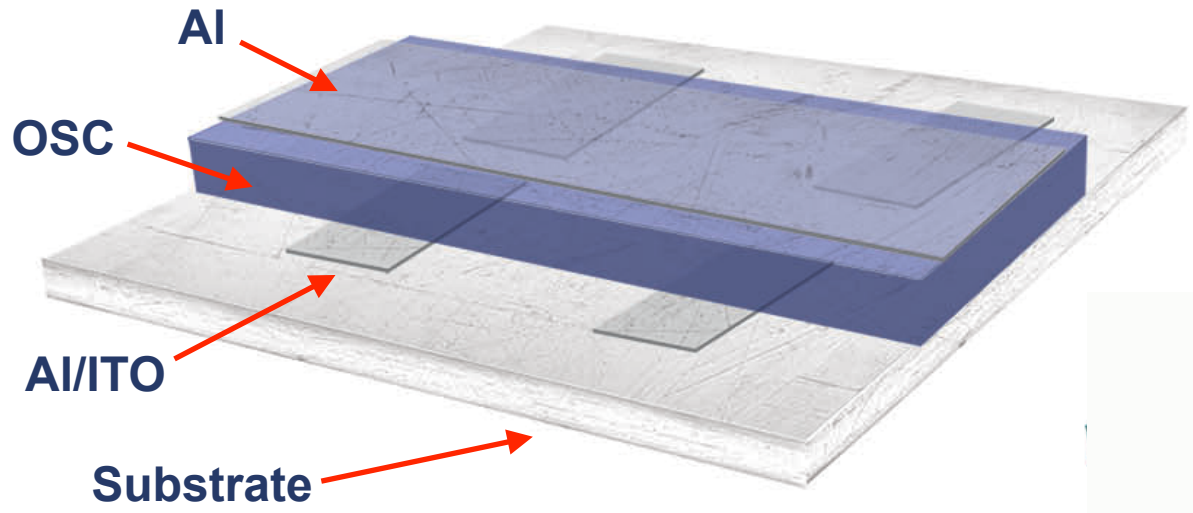
- Ultra thin silicon curved sensor modules
  - Low mass
  - Ideal for vertex systems in particle physics
  - Internal pipe inspection tooling for nuclear applications
- large S/N for α detection
- Piezo resistance effect enhances dark current when silicon curved
- Paper(s) in preparation and work ongoing to get a deeper understanding and push technology



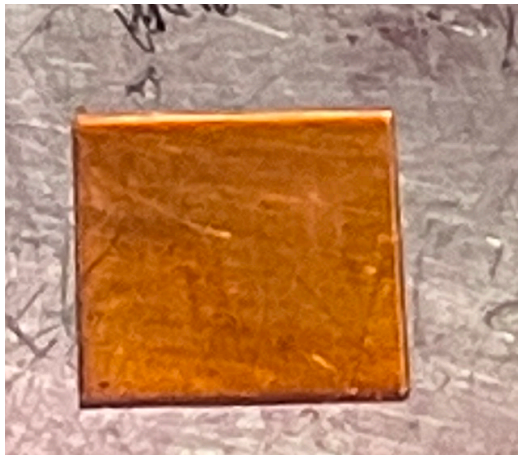


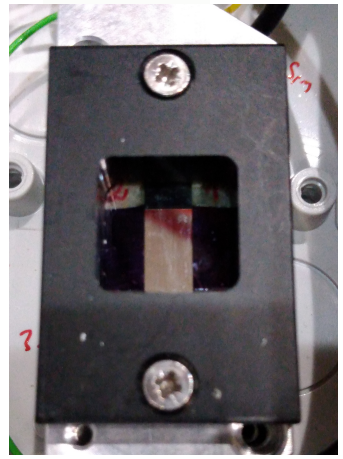
Organic Semiconductor Radiation Detectors

- Plastic electronics:
  - Low density
  - Configurable
  - Cheap
  - Scalable



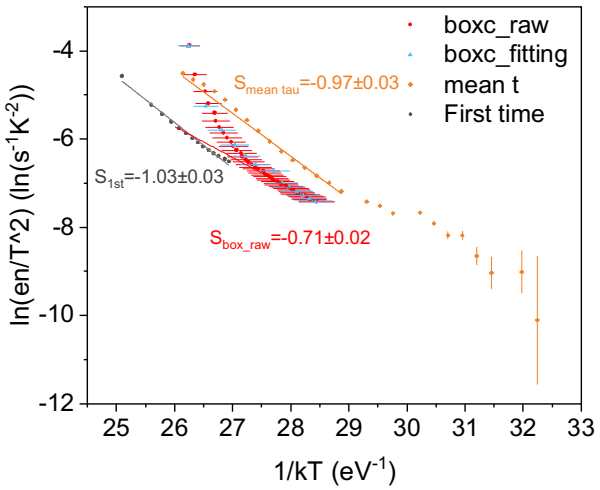
- Industry sponsors AWE and NuSec
  - Project students and interns contribute to R&D
  - NNL interested α detectors
  - Possible medical and photovoltaic applications



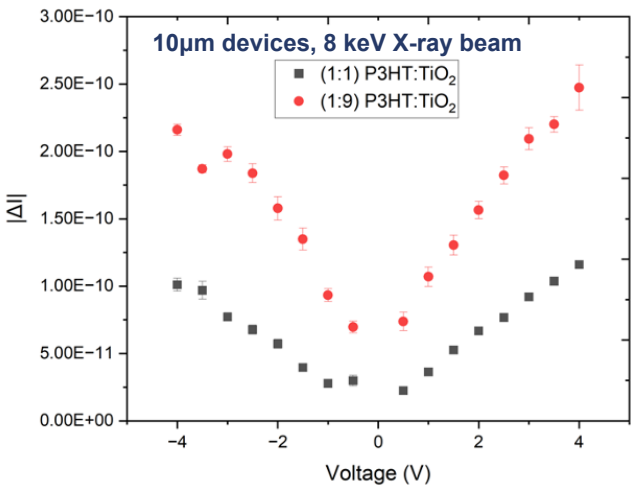


Organic Semiconductor Radiation Detectors

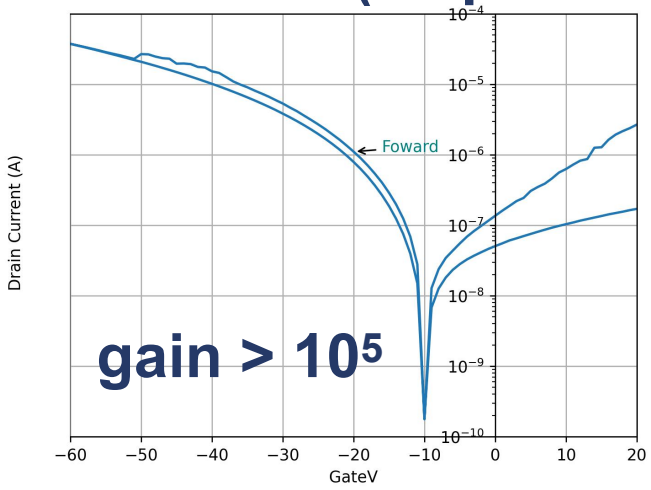
Studying trap states



X-ray detectors

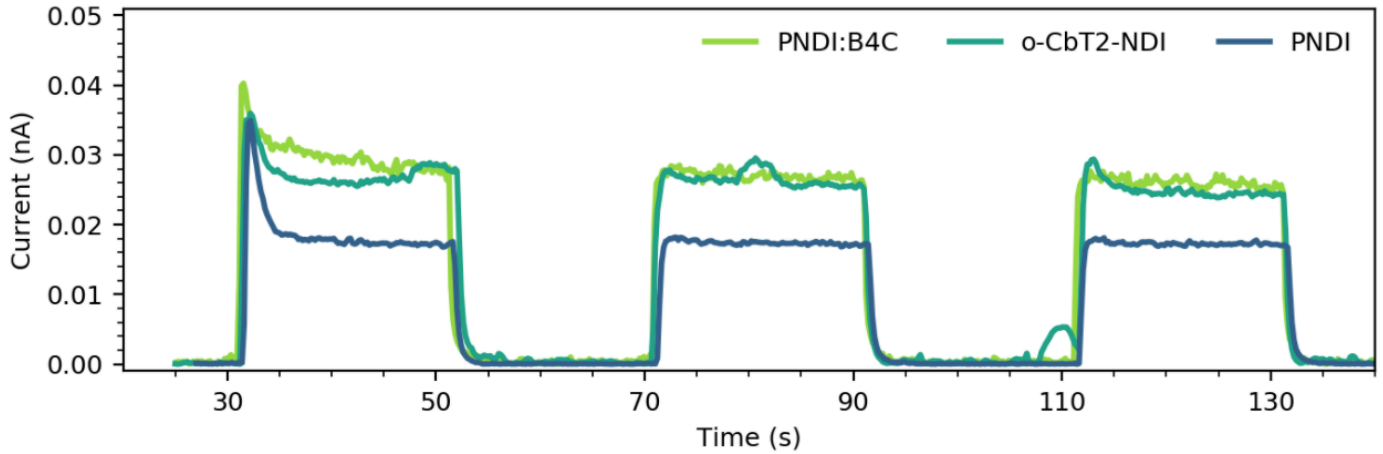


Transistors (amplifiers)



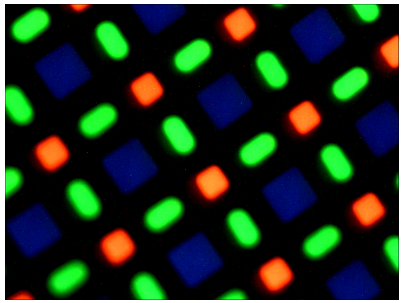
Field tests @ National labs

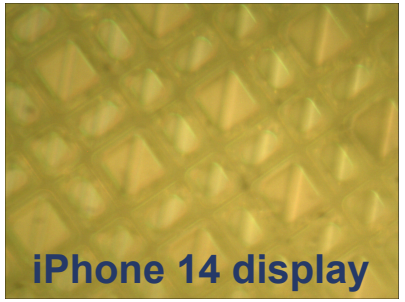
Diodes for α and n detection



Organic Semiconductors: Other ideas

- NuFor 2022 gave us some ideas about nuclear forensics testing:
  - Exploring non-destructive test methods for smartphones
  - Aim - identify terrorists handling radioactive material
  - STFC Impact Accelerator funding a pilot study:
    - ^{137}Cs exposure of an iPhone





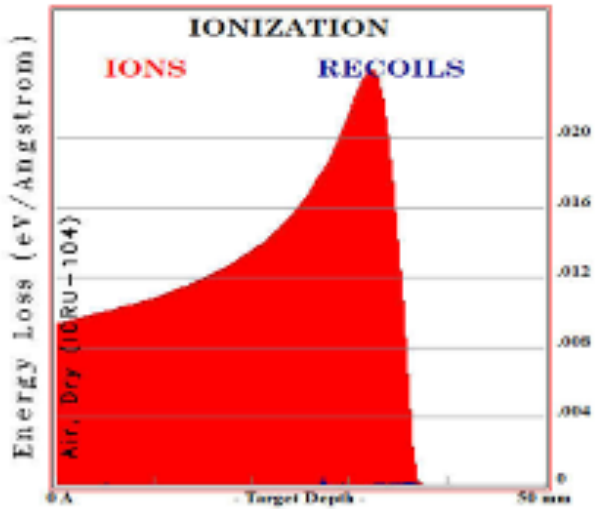
iPhone 14 display

- If pilot study successful then it may have wider implications:
  - e.g. new types of dosimeter for CBRN applications
  - e.g. low mass dosimeters for space missions

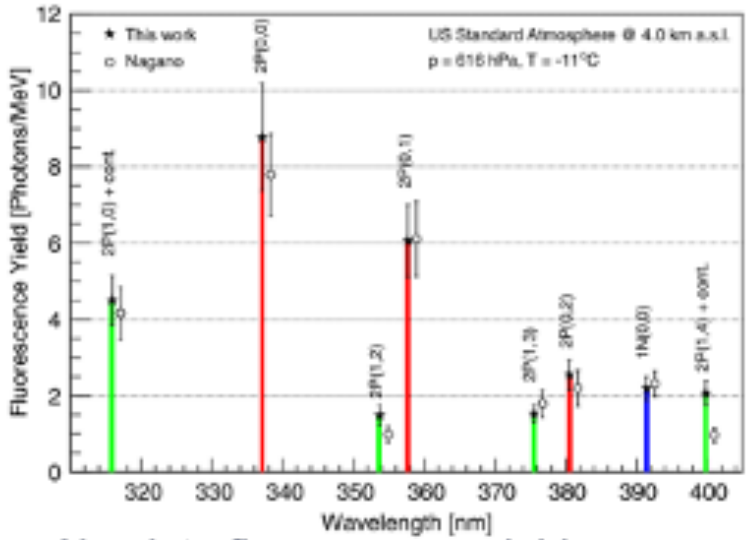
- Understanding risks and priorities will help focus efforts

Long range detection of α particles

- **Aim:**
  - **Detect α particles with a stand off distance of ~ 1 m.**
- **Motivation:**
  - **Identify contamination and minimising exposure to human operators**
- **Project:**
  - **STFC iCASE funded in collaboration with NNL**
  - **Studying possibility of using UV photons from the excitation/ionisation of N_2 molecules near alpha sources.**



5 MeV α in dry air, range = 36 mm



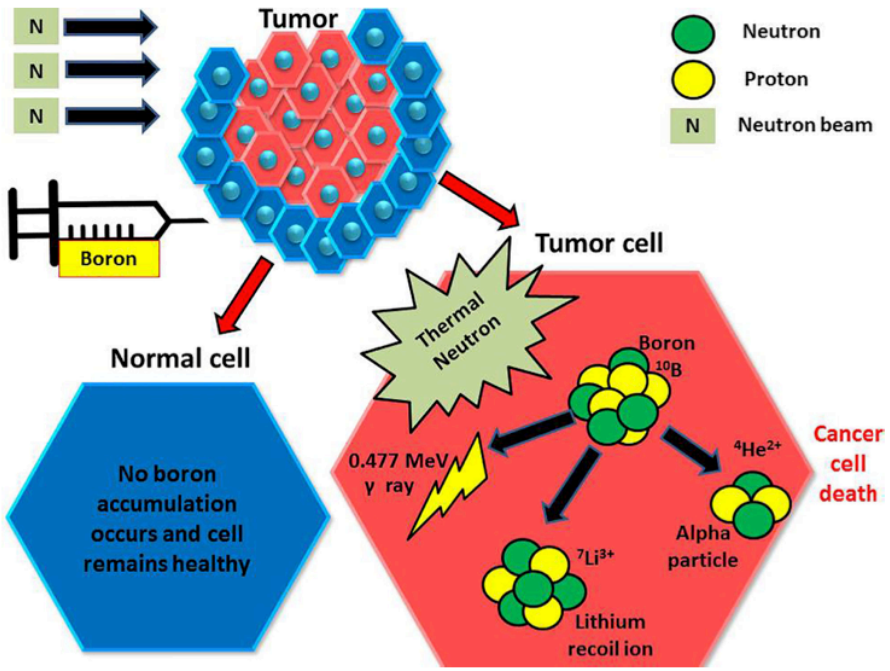
Absolute fluorescence yield
Astroparticle Physics 29 (2008) 205–222

Diamond Detectors

- Aim:
  - Develop room temperature processed converter layer for CVD diamond targeting a thermal neutron detector for Boron Neutron Capture Therapy

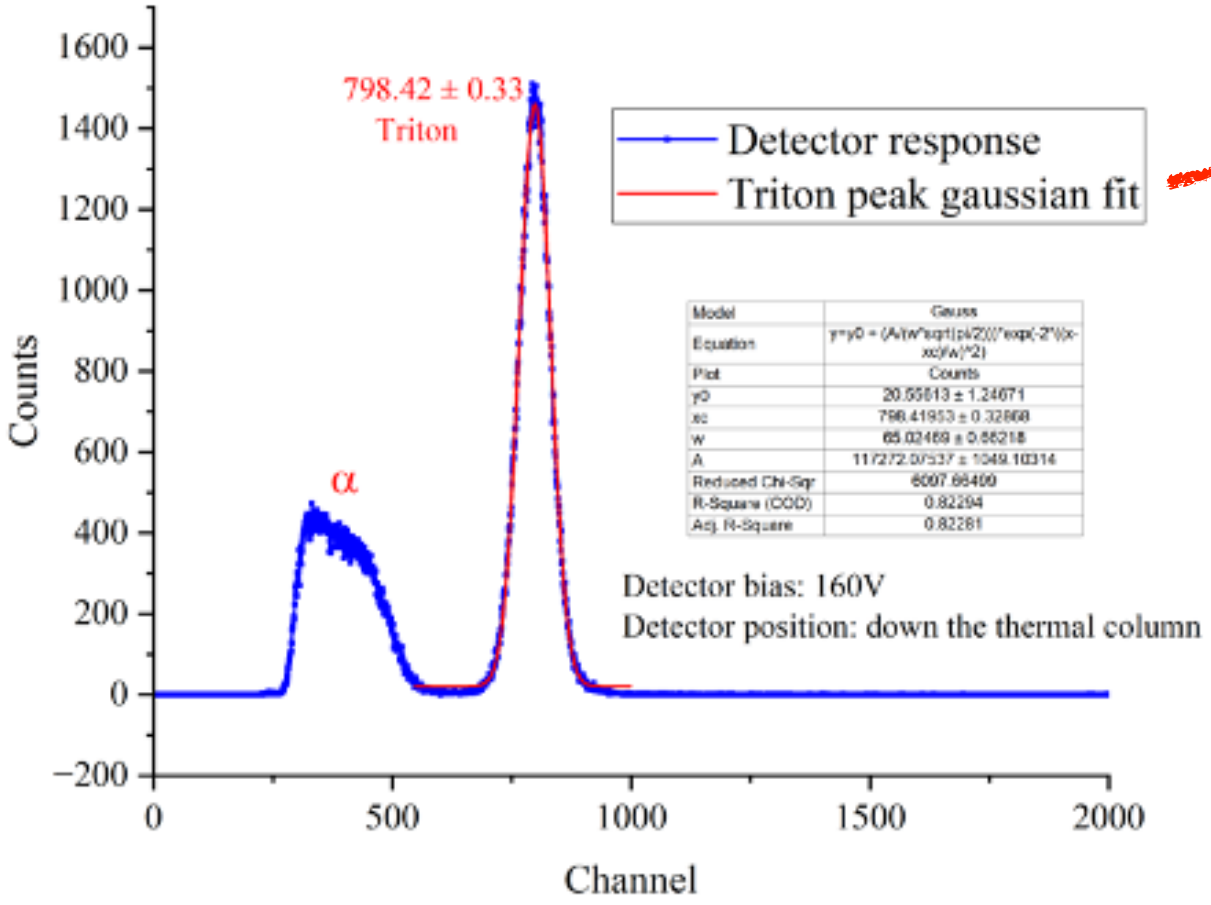
- Clinicians design drugs for delivery to tumour
  - Label drugs with ^{10}B

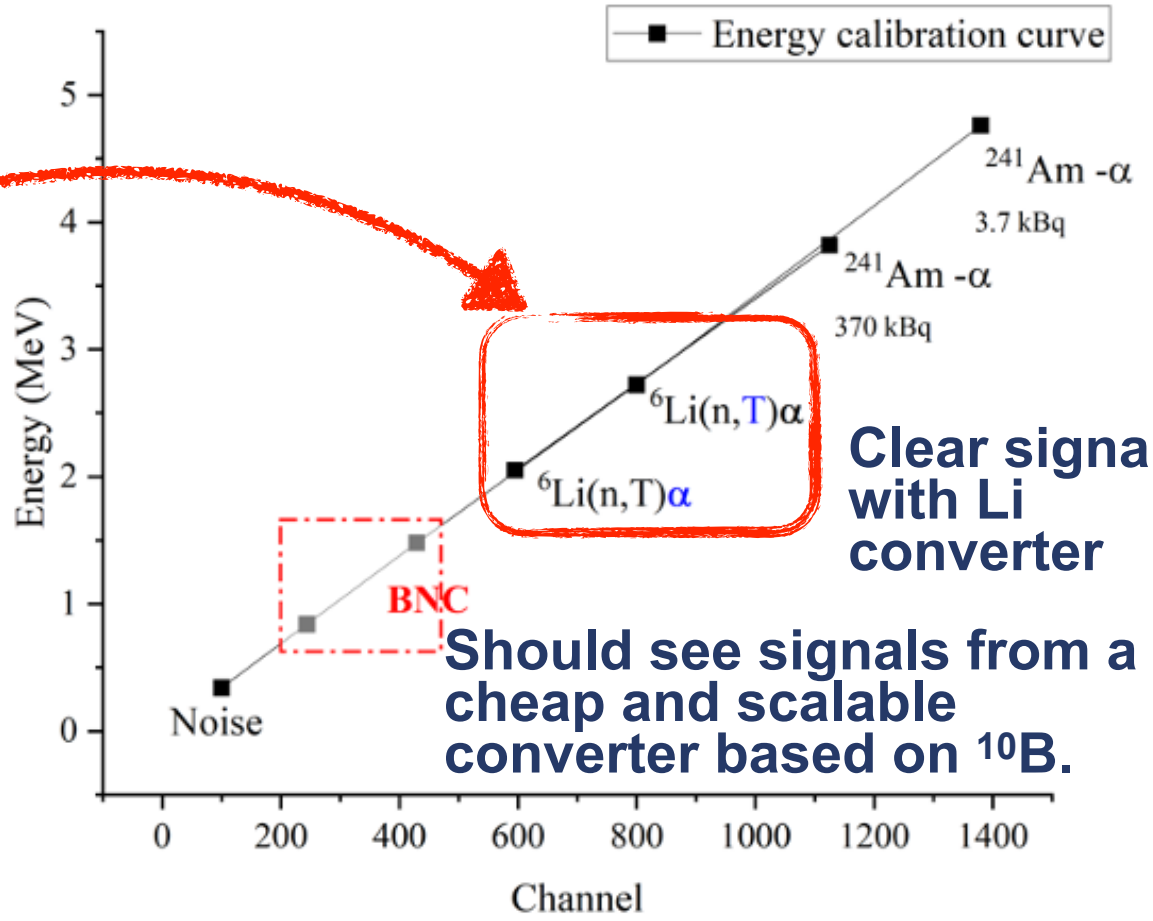
- Patients are exposed to epithermal neutrons
  - Local delivery of highly ionising dose from BNC (α, ^{7}Li)



Diamond Detectors

- Evaluation of a commercial competitor device: Cividec B6 (Li converter)



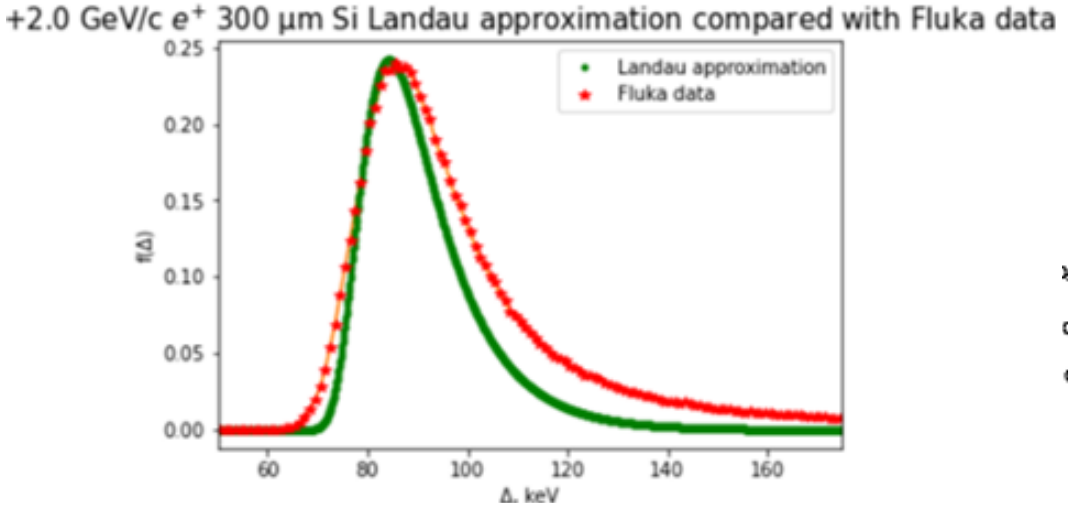


Clear signal with Li converter

Should see signals from a cheap and scalable converter based on ^{10}B.

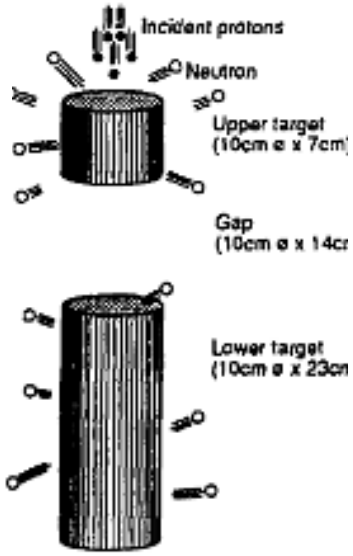
Simulation highlights

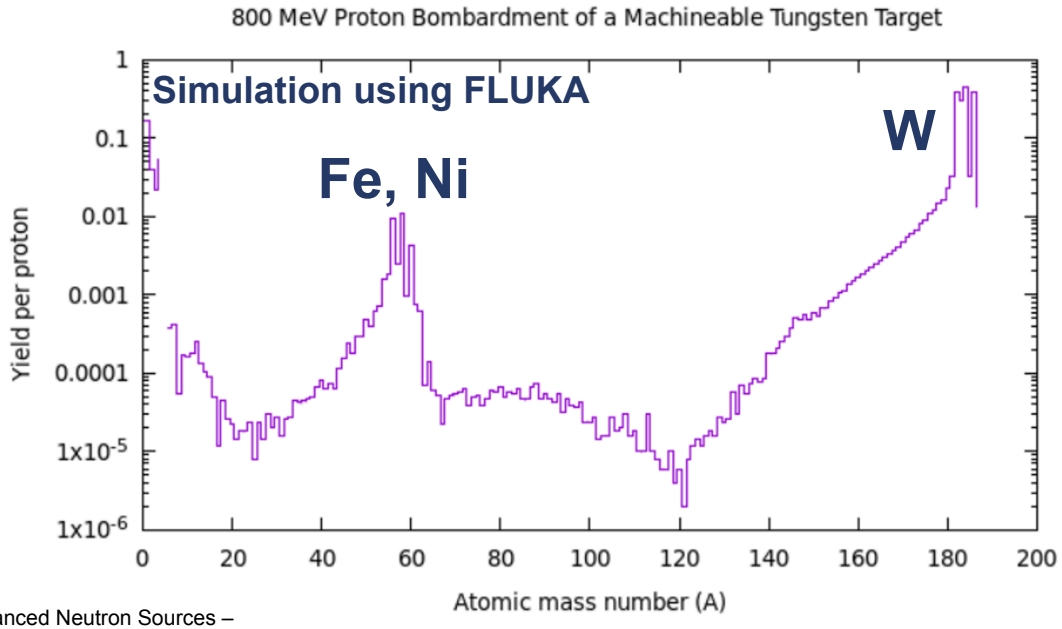
- **Simulating thin semiconductor devices and a neutron spallation target to build benchmarks to verify simulations with data in the public domain**



	Charge Generated (C)		
x (µm)	π^+	p	e^+
30	4.304×10^{-16}	4.610×10^{-16}	4.401×10^{-16}
50	7.249×10^{-16}	7.762×10^{-16}	7.444×10^{-16}
100	1.469×10^{-15}	1.581×10^{-15}	1.521×10^{-15}
300	4.561×10^{-15}	4.894×10^{-15}	4.736×10^{-15}

LANSCE spallation neutron source beam target: Machinable Tungston; 800 MeV proton beam

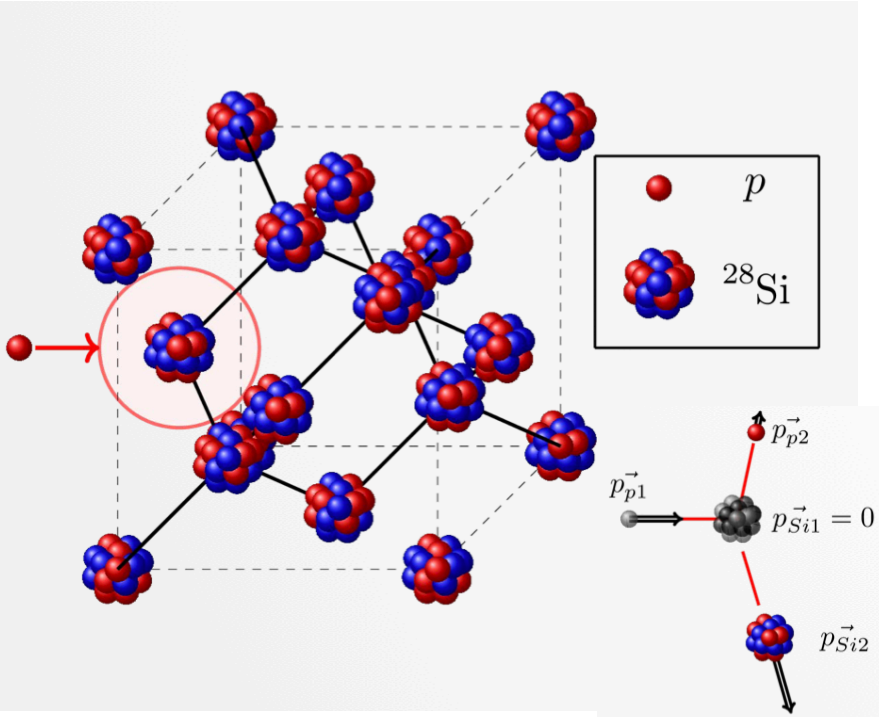


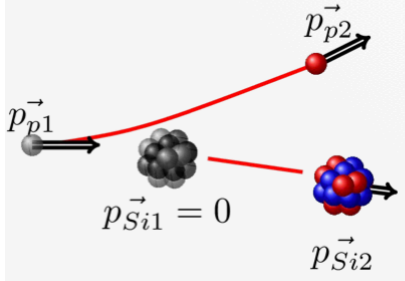


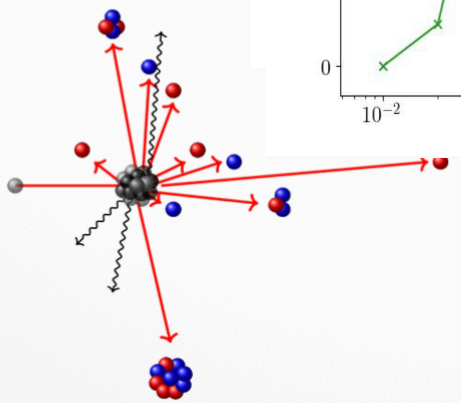
Russel, G. Collaboration on Advanced Neutron Sources – Spallation Physics – An Overview, (1990)

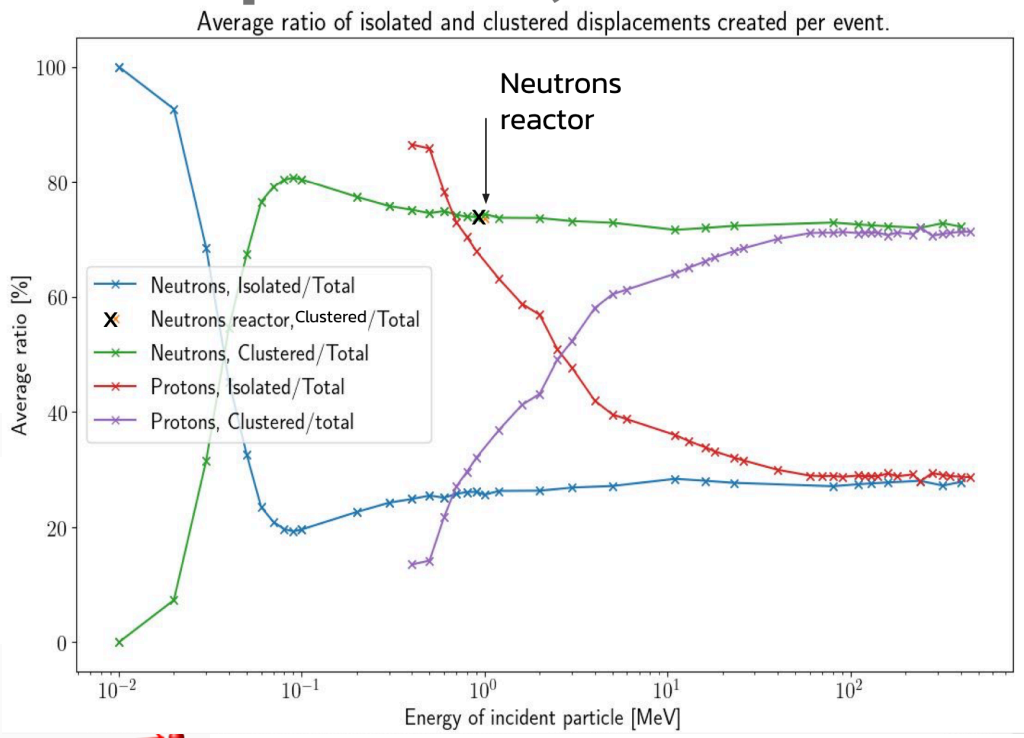
Simulation highlights

- Non ionising energy loss (work as part of the CERN RD50 project)









Identified need: cheap readout

- Aim to develop a proof of concept:
  - DAQ to accommodate silicon, diamond and organic technologies
  - Touchscreen display/interface

- Building on Raspberry Pi technology
  - Most PI's are made in the UK
  - Versatile technology

- More information on progress so far tomorrow

- Feasibility study in progress - prototype of a 16 channel readout system

Other capabilities

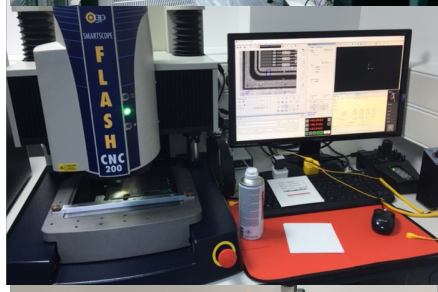
- Data science
  - Big data for the Large Hadron Collider
  - Large molecular dynamic simulations
  - Air pollution studies - Mexico City as a case study
  - AI for scientific applications

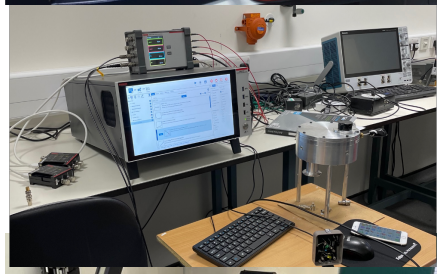
- Material studies
  - Materials research network provides a wide range of facilities to test different types of materials: AFM, Raman, SEM, UV-Vis, XRD, XPS, …

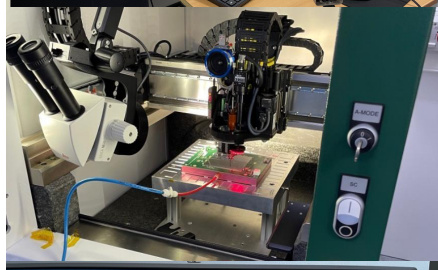
- Study explosions
  - Our department of chemistry has a experience of studying explosions for commercial partners in their “explosions lab”

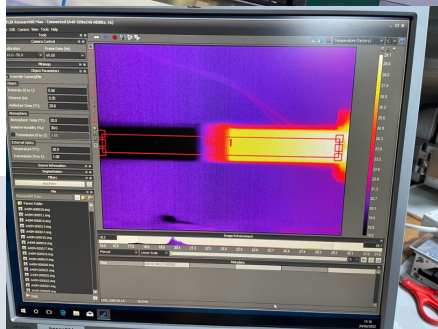
Facilities

- Est £2.1M of state of the art equipment
  - Micro electronic testing and assembly
  - Organic semiconductor fabrication and testing
  - Metrology (nano and micro precisions)
  - Precision device characterisation
  - Spectroscopy
  - Thermal studies of materials and structures
- Used for fundamental research and commercial projects
- Open for collaborative work with academic and industry partners
- Facilities available for external users



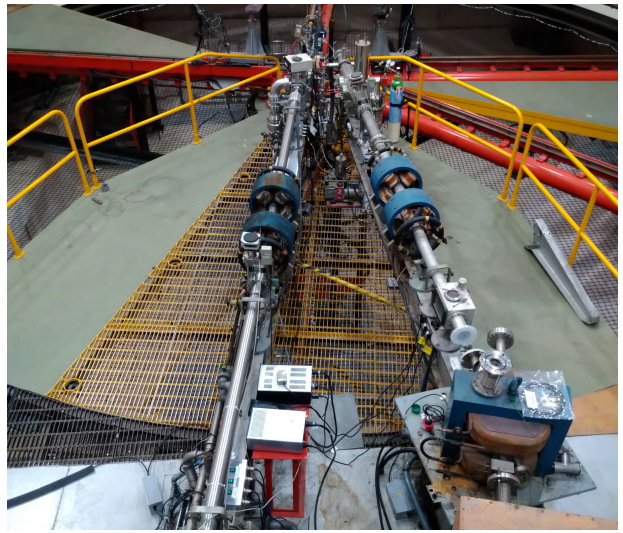


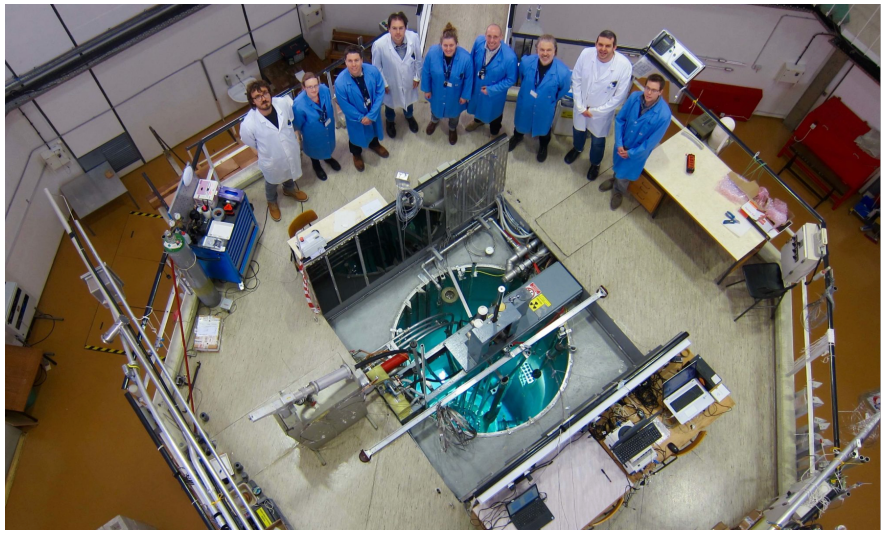




Test Facility Usage

- Experienced users of a range of test facilities including:
  - Test beams in the Europe and the US (CERN, DESY, FNAL, NPL)
  - Reactors (TRIGA reactor in Slovenia)
  - Irradiation facilities (DALTON)





Summary

- Strong detector development community @ QMUL
  - Monthly group meetings
  - Multidisciplinary teams
  - Experience with low level lab work through to large scale international infrastructure design, construction and operation
  - Familiar with a range of irradiation test facilities
- Key strengths include:
  - Semiconductor detectors
  - Design and engineering
  - Simulation
  - Data science
- Strong links to chemists and material scientists