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Detector Development Meeting

Overview of the group’s R&D and its capabilities

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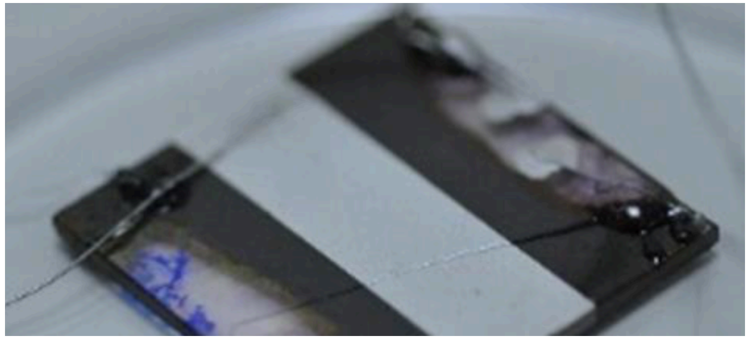
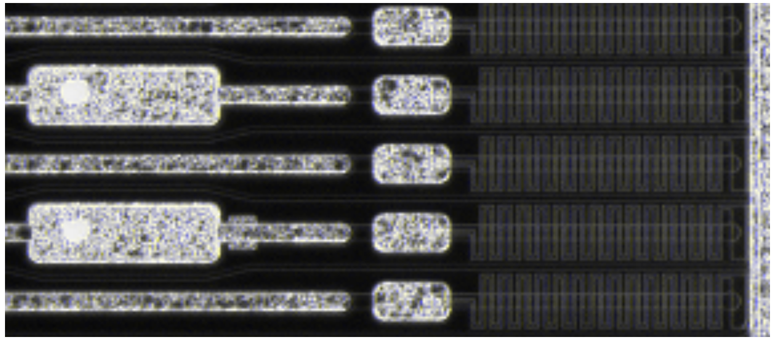
Expertise

- Chemists, Material Scientists, Physicists, Engineers, and Technicians

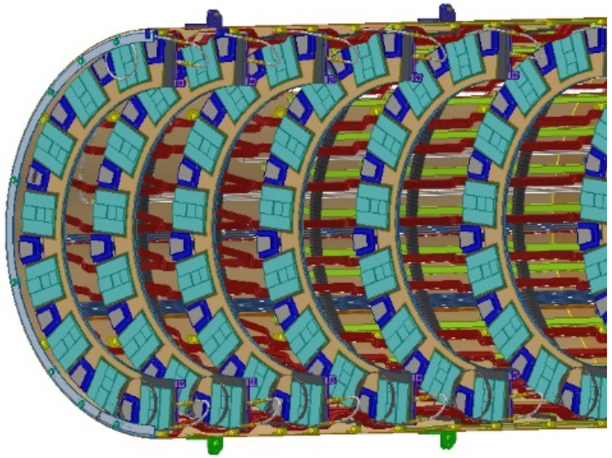
- Capabilities range from fabricating novel materials for testing, to design and constructing large scale instruments for international facilities



Organic diodes on a glass substrate



1µm resolution image capture of a silicon sensor for QC inspection made using a system developed in-house.



Engineering design for cooling system for a pixel detector destined for CERN, Switzerland

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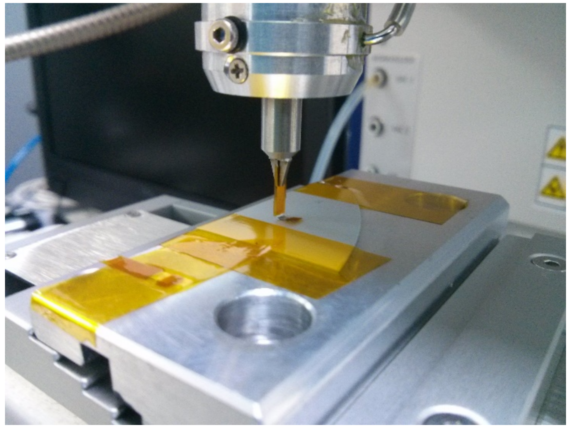
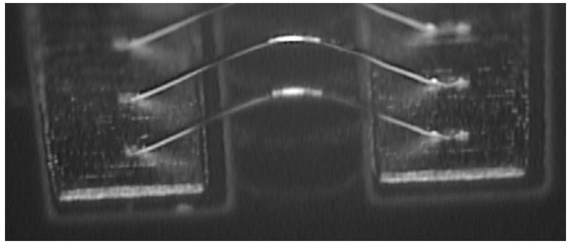
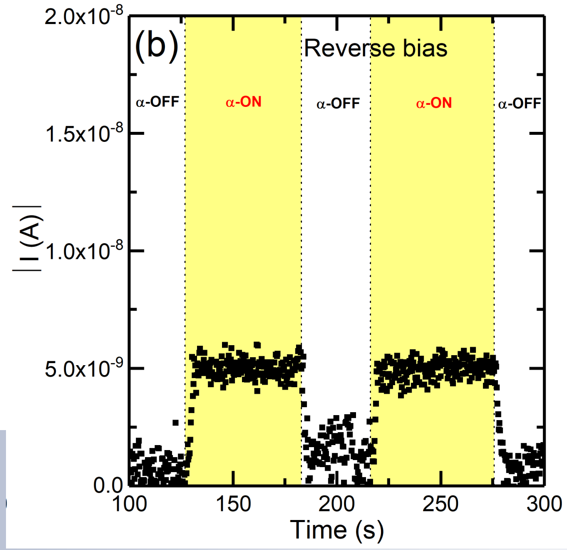
In-house facilities (i.e. dedicated labs)

- Photolithography capability
- Organic semiconductor fabrication suite
- Wire bonders, bond pullers and probe stations
- Semiconductor characterisation stations:
  - Photo-conduction (NdYAG laser)
  - IV, CV etc.
  - Irradiation tests using α, β, γ, n sources
  - Cryogenic tests of samples
- Data acquisition test facility
- Thermal imaging for large and small objects

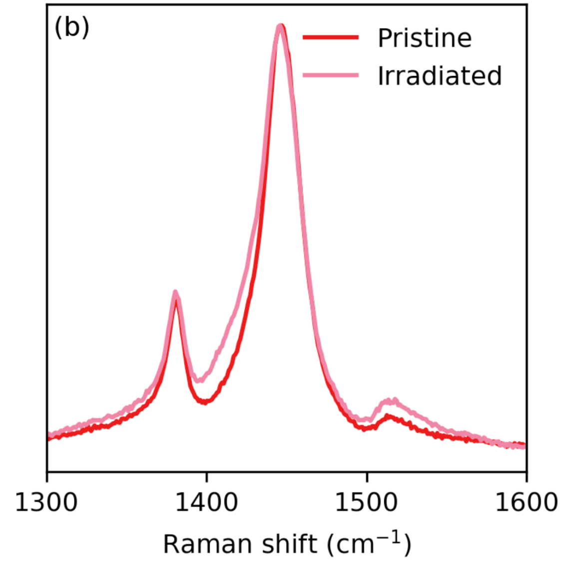






Materials Research Institute facilities (@ QMUL)

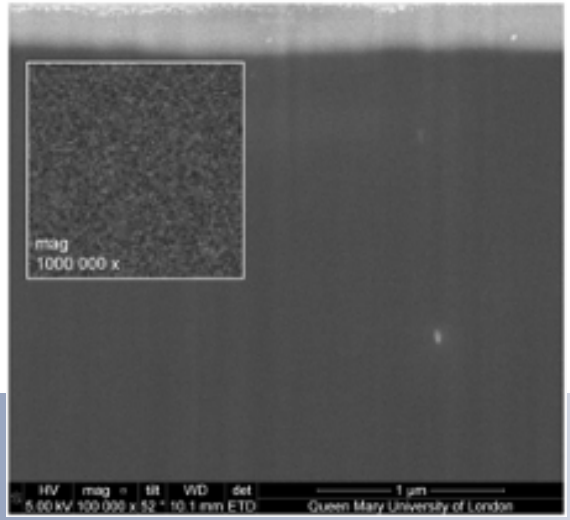
- Other relevant infrastructure that we can access at QM includes:
  - Raman scattering
  - Ultraviolet-visible spectroscopy
  - Scanning Electron Microscopy
  - Tunneling Electron Microscopy
  - X-ray diffraction
  - B-field device testing up to 7T



Raman spectroscopy: Can be used to study radiation damage.

Here we show a 300nm thick organic semiconductor sample film (P3HT); the Raman spectrum changes after exposure to 80 Gy dose from α particles.

UV-Vis and XPS are also useful tools to study the properties of these materials.



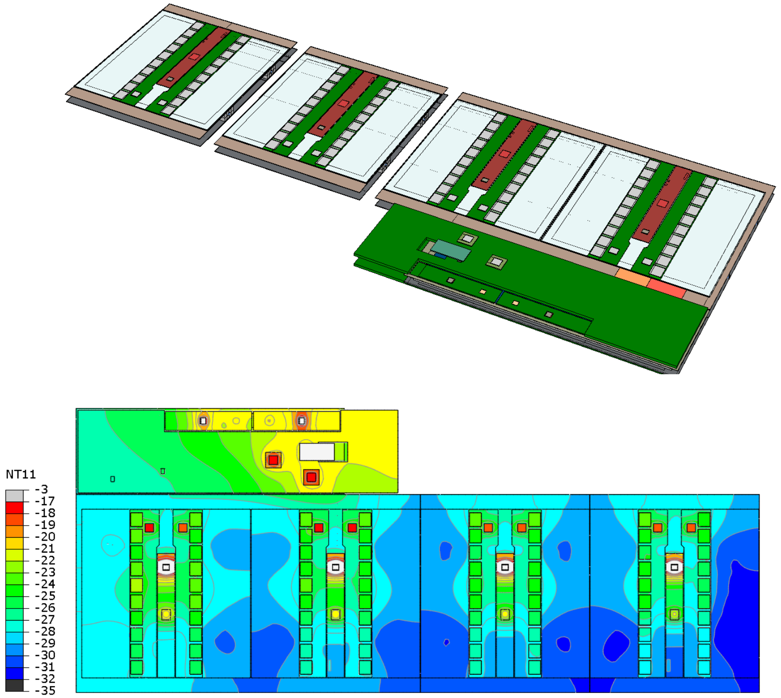
Scanning Electron Microscope: verification of homogeneous dispersion of a two-component polymer donor-acceptor system (P3HT:PC60BM) for an example radiation detector. The light coloured region at the top of the image is the glass substrate.

Phase separation of components occurs at the sub 100nm scale in this sample.

Calculations and simulation

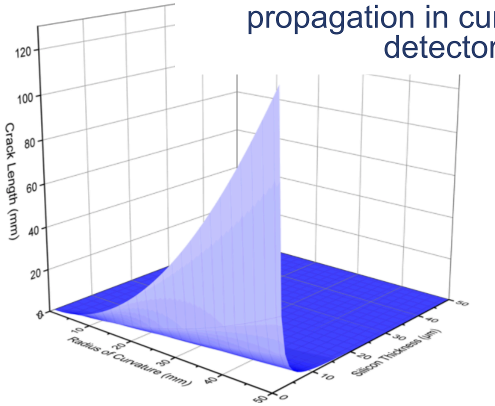
Also see Ian Dawson and Peter Hobson's talks!

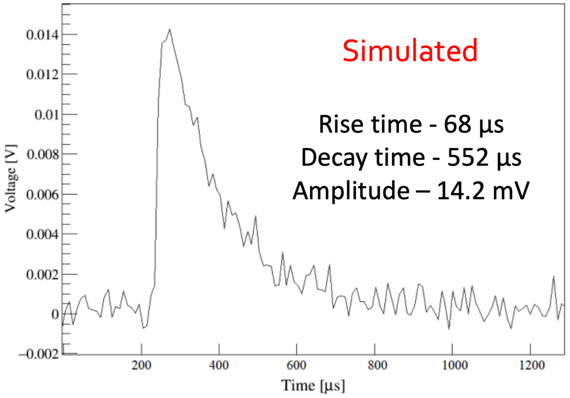
- Thermal FEA, calculation of physical properties and simulation of the interaction of radiation with material with GEANT & Fluka



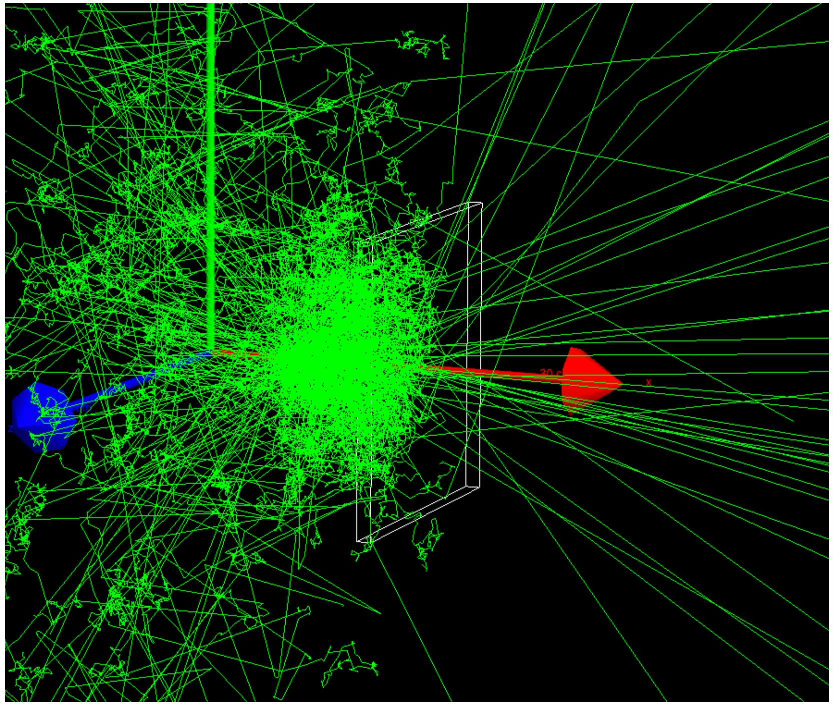
Thermal FEA Simulation: Thermal performance of a silicon detector, models power output by sensors and ASICS

Calculation: Studying crack propagation in curved silicon detectors





GEANT Simulation: Pulse reconstructed from radiation detector with shaping electronic response simulated

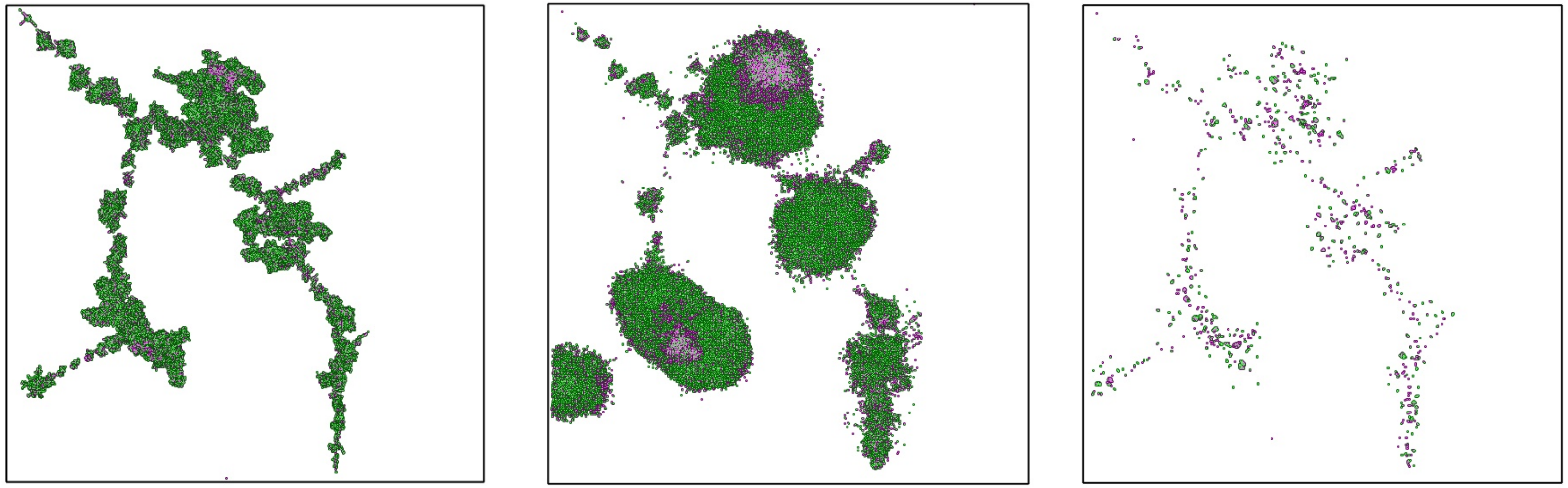


GEANT Simulation: Neutrons from a Californium source being thermalised in poly-moderator

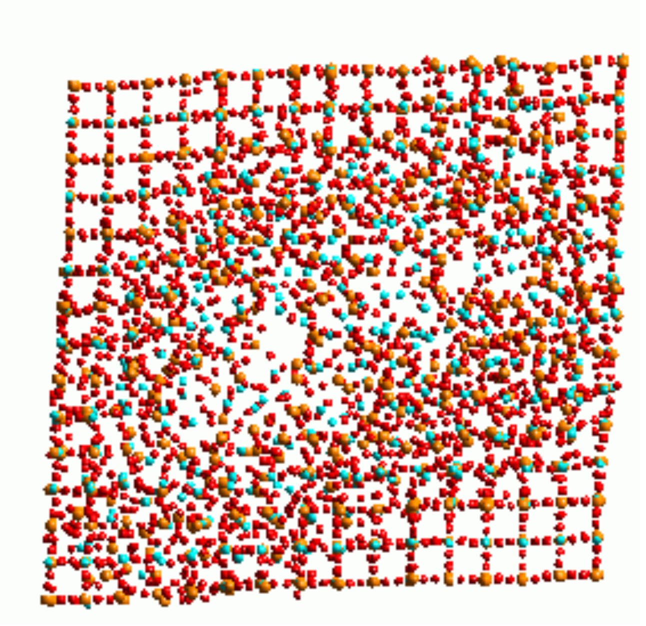
Calculations and simulation

Also see Ian Dawson and Peter Hobson's talks!

- Also have a molecular dynamics expertise



MD Simulation:
Ion damage from 14 MeV neutrons

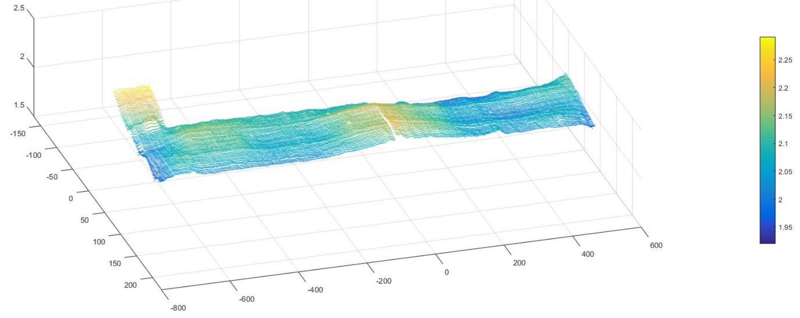


MD Simulation:
Damage in zircon due to 70 keV U recoil

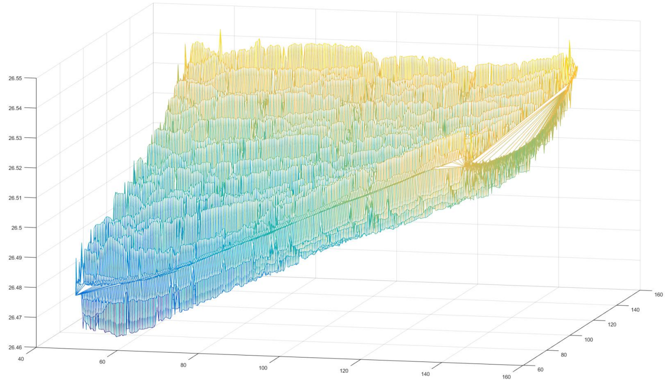
Testing

Also see Ian Dawson and Theo Kreouzis' talks!

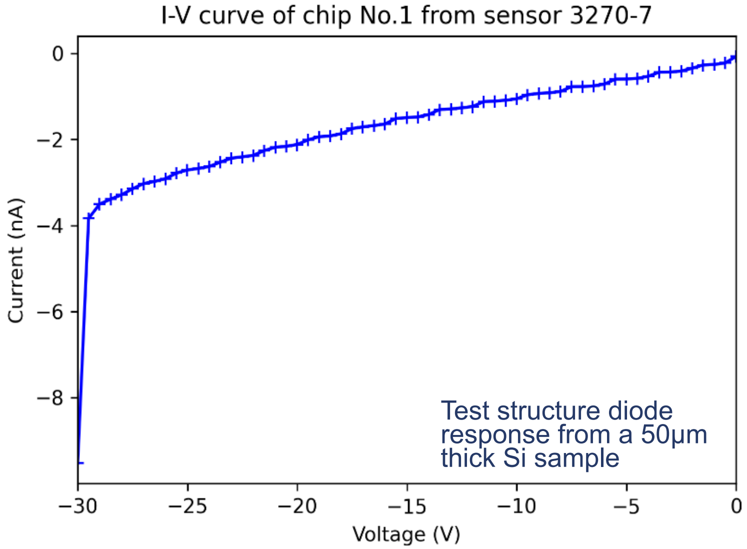
- Touch probe and non-contact metrology, precision device characterisation, production testing of semiconductor devices, thermal QC of objects, micro-material testing (bond pulling, peel strength, …)



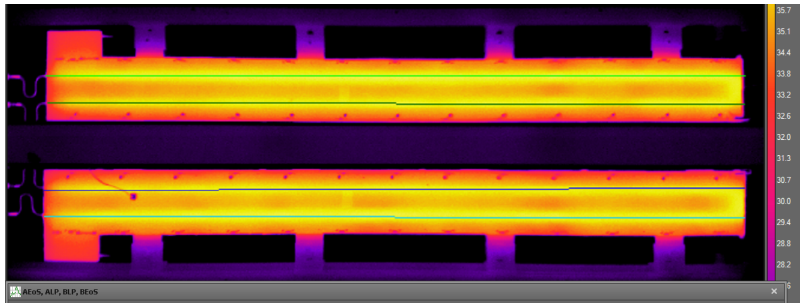
Touch-probe coordinate metrology scan of the surface of a 1.4m long support structure

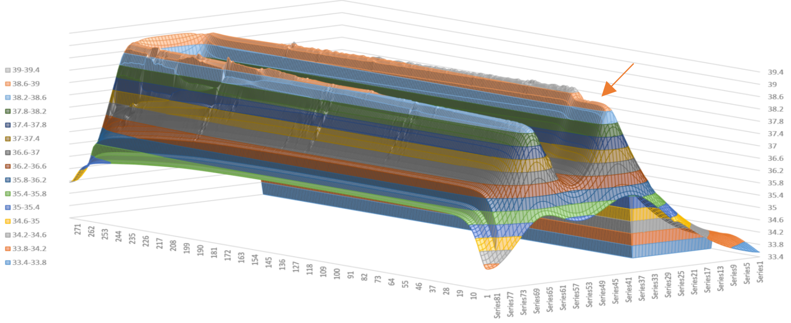


Laser metrology scan of a 10×10cm silicon sensor.



Routine semiconductor device characterisation targets O(nA) dark currents. Measure as low as O(fA) for some projects.





Thermal imaging of a 1.4m long support structure and comparison with thermal FEA simulation.

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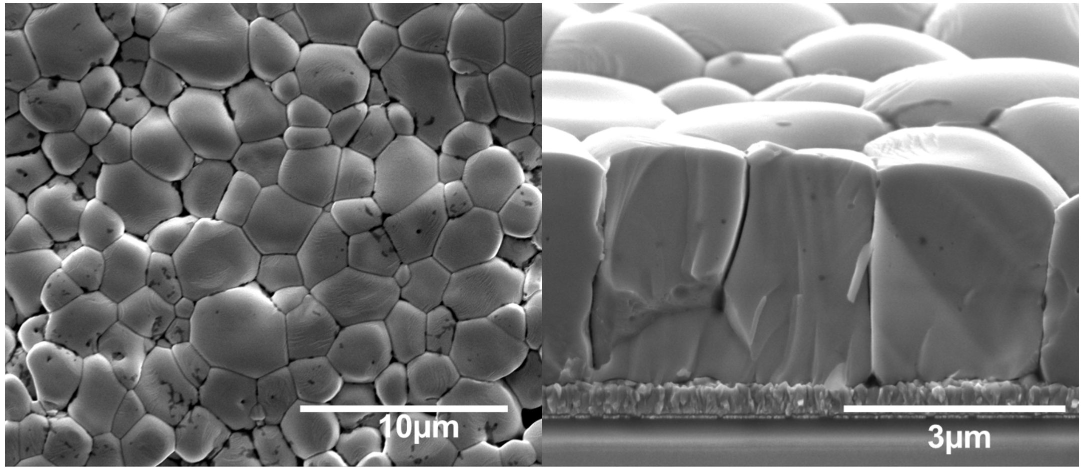
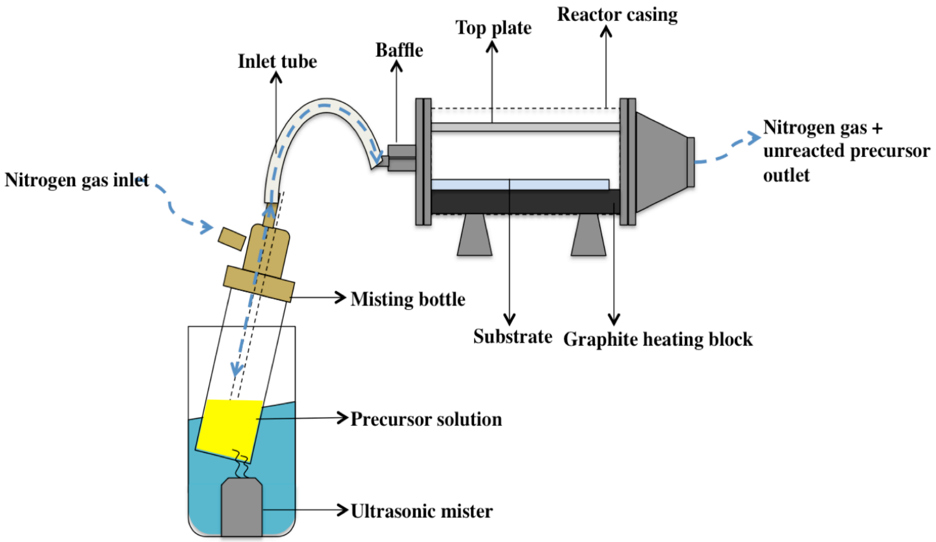
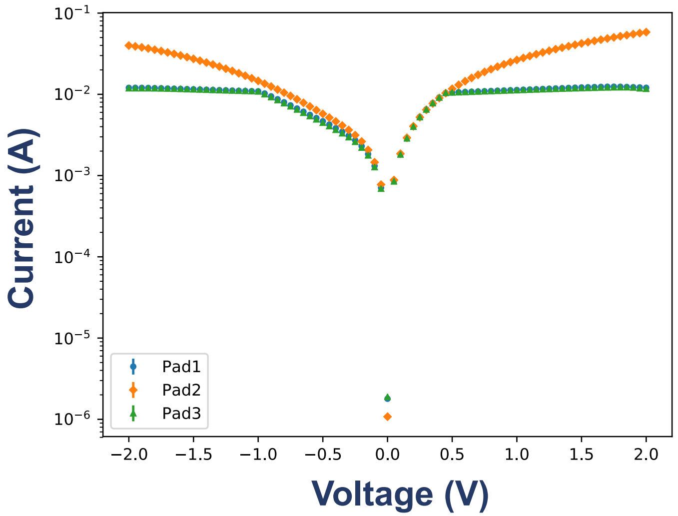
Emerging technology evaluation

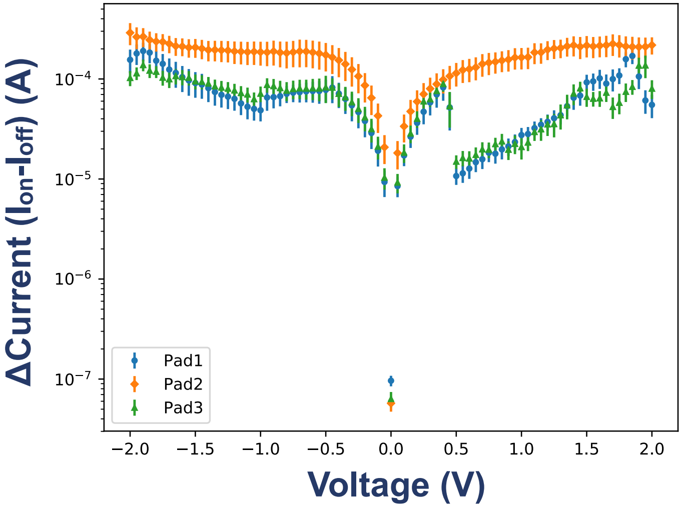
Also see Theo Kreouzis' talk!

- Control fabrication pipeline for many novel detector materials
  - e.g. aerosol-assisted chemical vapour deposition (AACVD) of hybrid lead halide perovskites
  - Ultra thick film perovskites:
  - 5-10μm thick
  - 10×thicker than conventional methods
  - α particle detection capability established



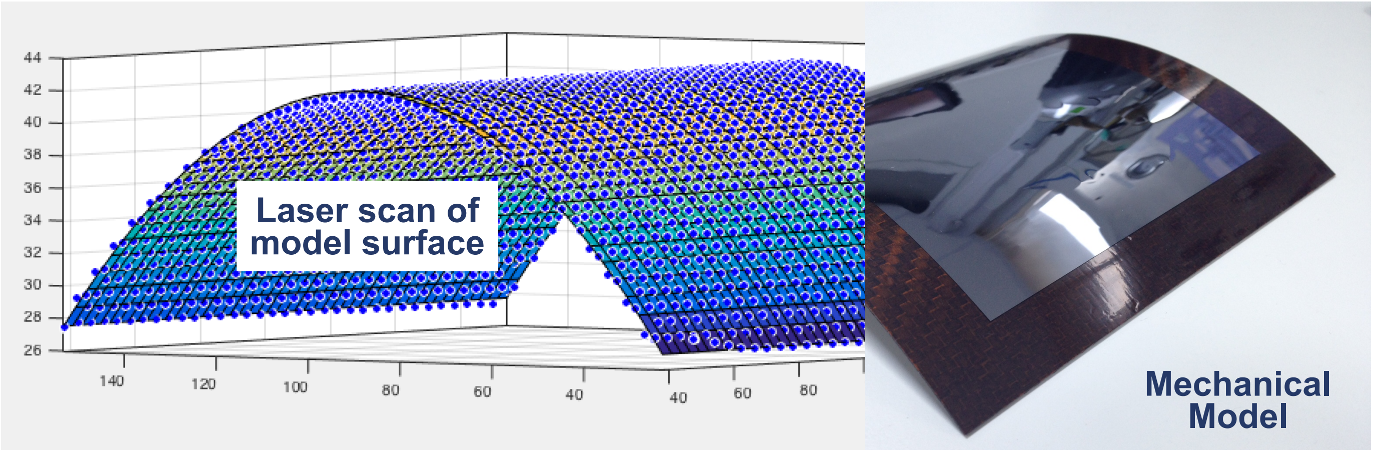






Novel uses of established technology

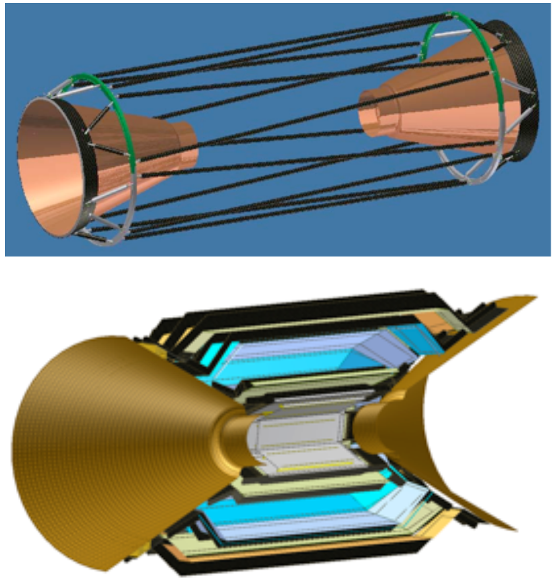
- Curved ultra-thin (low mass) silicon detector modules
- Self supporting low mass structures for improved tracking and vertexting detectors for nuclear and particle physics, using thin film properties
- Commercial application for cameras, telescope, and other instruments
- Understanding this relies on thin film theory, and developing precision assembly tooling



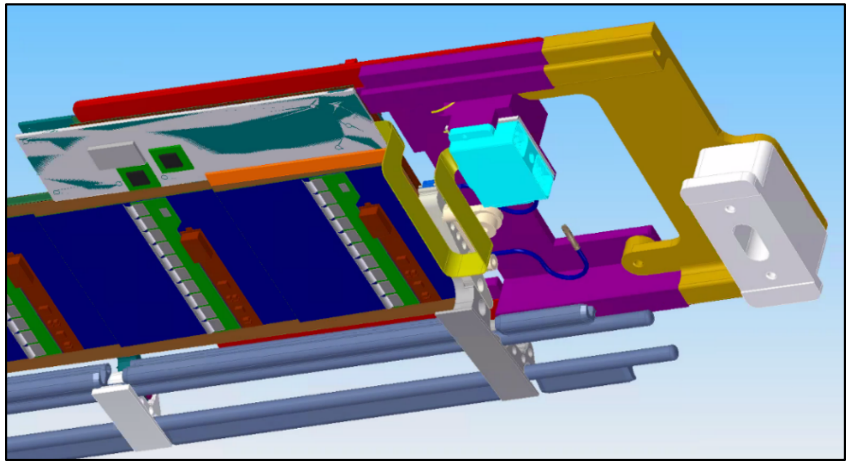
- Extensive programme of mechanical models over past decade
- Able to measure and model silicon surface accurately
- Using ultrathin TTT10 sensors from Micron Semiconductor Ltd.

Instrument design and construction

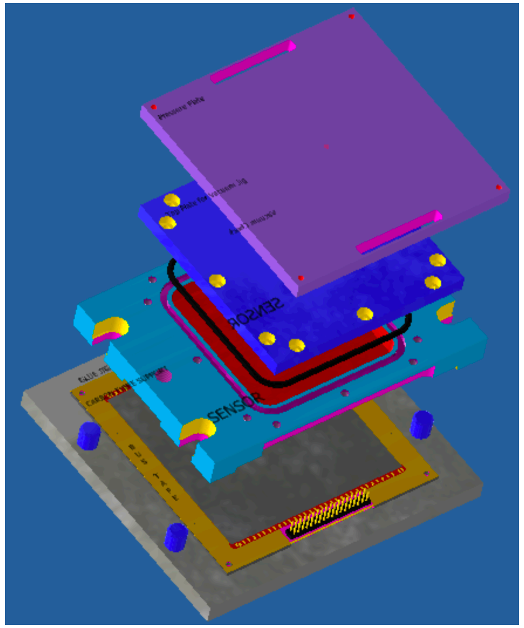
- Our design engineering team has decades of experience with precision design work providing a variety of bespoke scientific solutions
- Specialise in designs that are practical and can be easily realised



Design for silicon detector with structural support



Detector support structure insertion tooling design



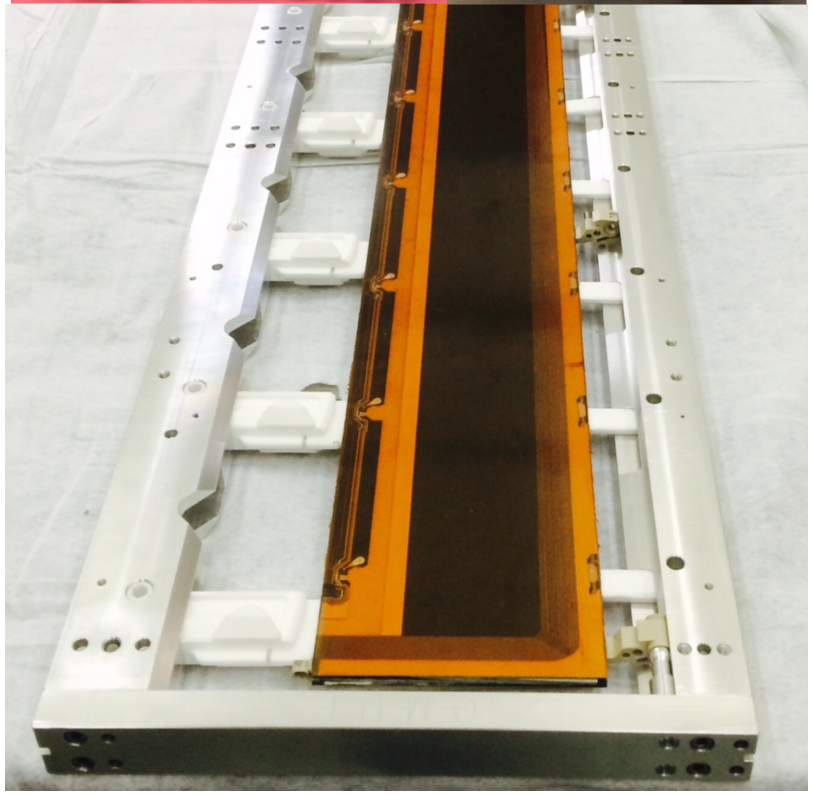
Jigs for assembling a detector module

Precision mechanics

- Well equipped world class workshop with an excellent team of dedicated technicians:
  - Test jig design and fabrication
  - Production runs
  - Capability to machine a wide variety of materials, including precision machining of plastics, metals and carbon fibre moulding materials

- Provides infrastructure for international labs:
  - CERN in Switzerland and J-Parc in Japan
- Serves national labs in the UK and US:
  - Rutherford Appleton and Brookhaven

300μm thick walls on peek supports, manifolds, vacuum jigs and chambers and other parts

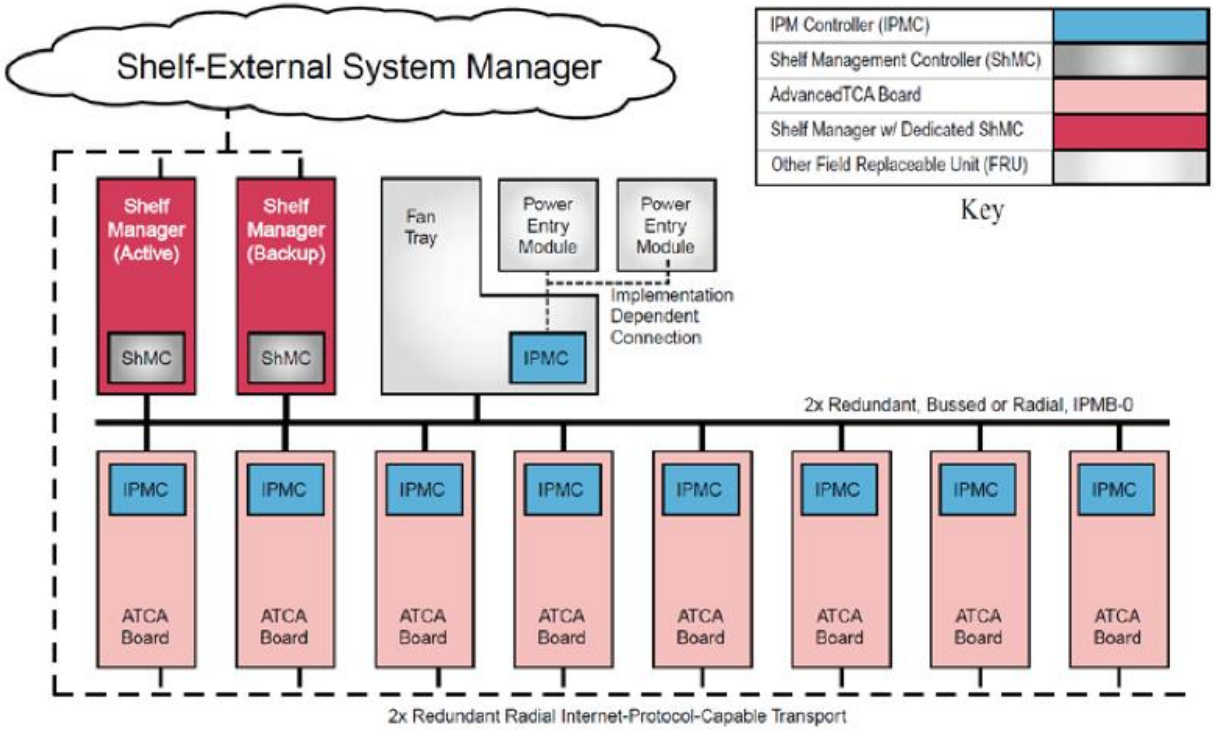


High precision assembly frame for a silicon detector

Data acquisition

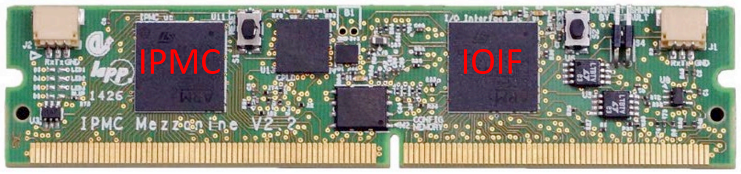
- Prototype single and multi channel readout schemes
- Target both research and proof of concept systems
- DAQ integration with both devices and data storage
- Extensive scripting capability for task automation
- Expertise on fast triggering software for the CERN Large Hadron Collider
- Firmware expertise for crate controllers for fast selection

- From commodity hardware control using LabView through to custom firmware development for bespoke systems



IPMC Serial Port

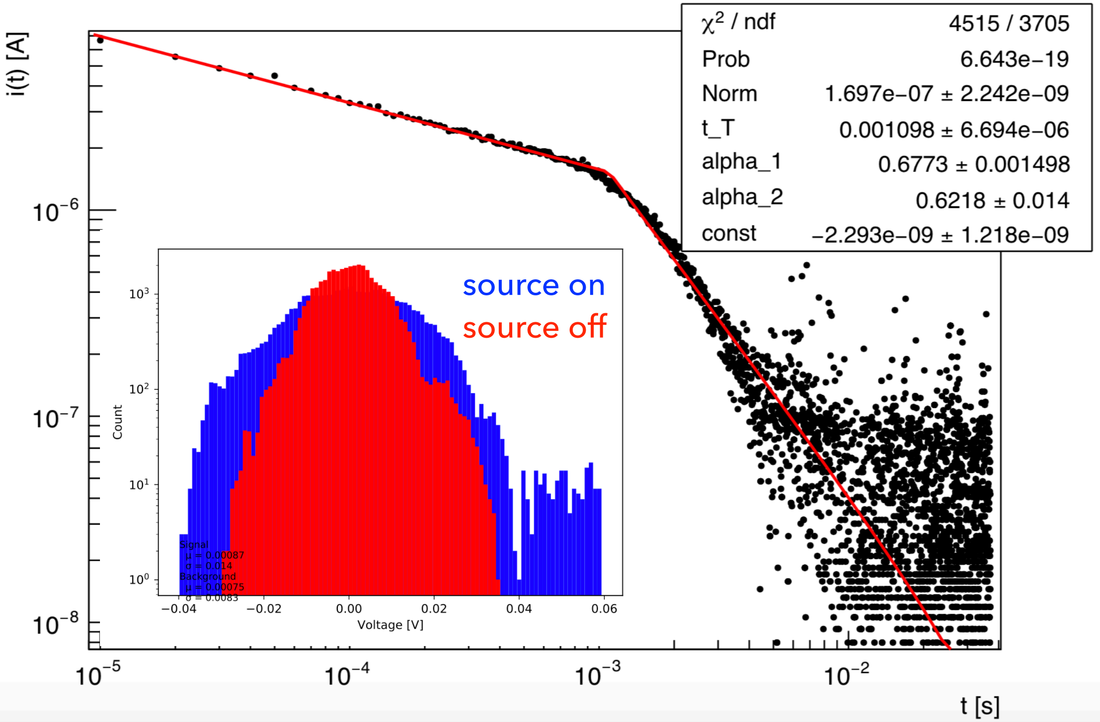
IOIF Serial Port



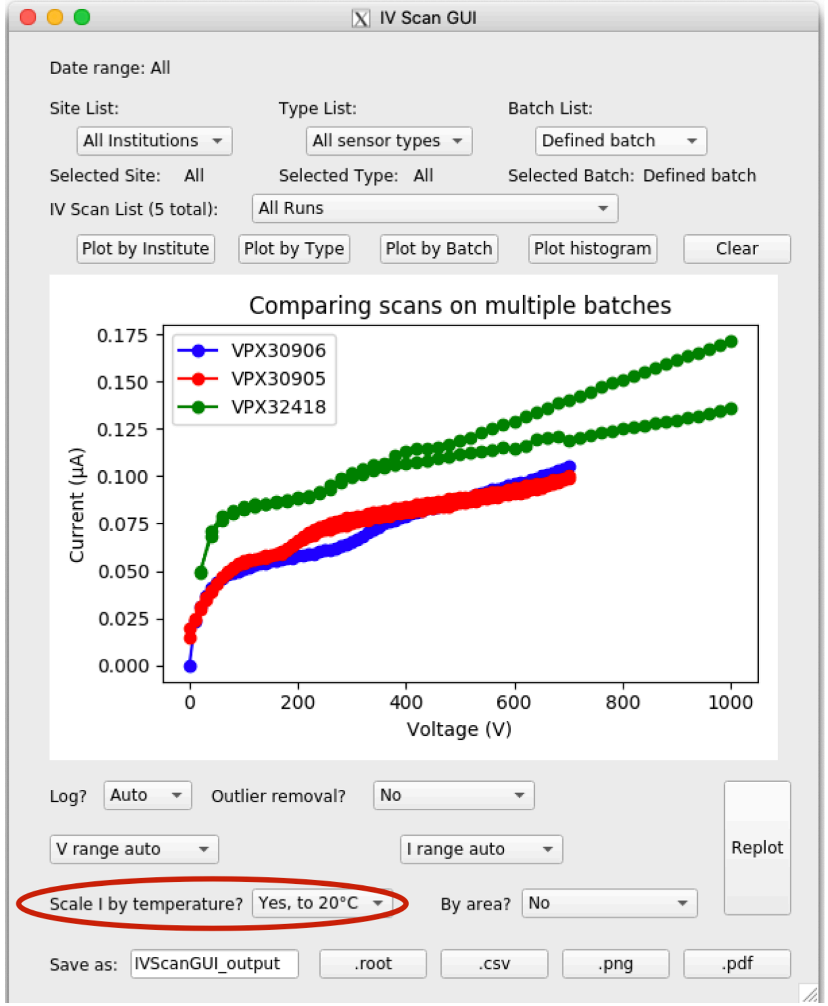
Intelligent Platform Management Controller for custom ATCA-based event selection hardware, and NI CompactRIO ADC system

Data analysis

- C++, LabView and Python expertise
- Integrate analysis tools with SQL databases
- Signal processing and data fitting



Fit photo-conduction data to study long lifetime trapping behaviour of organic devices. Inset - Python Multi-Chanel Analyser tool - sensitivity dominated by charge sensitive pre-amplifier.



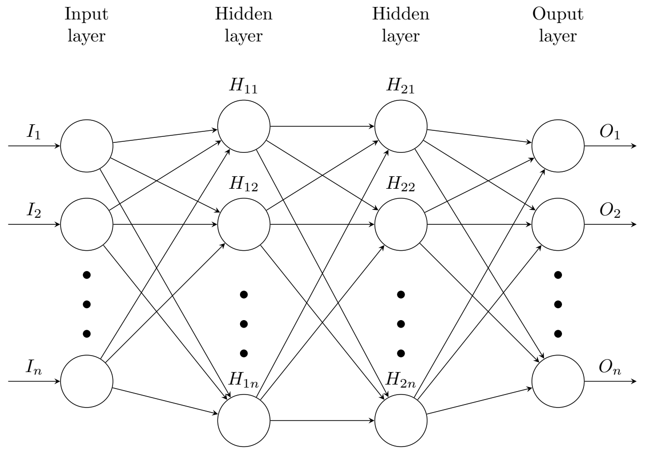
Interface to the ATLAS Tracker Database for extracting sets of parameter scans on silicon sensors.

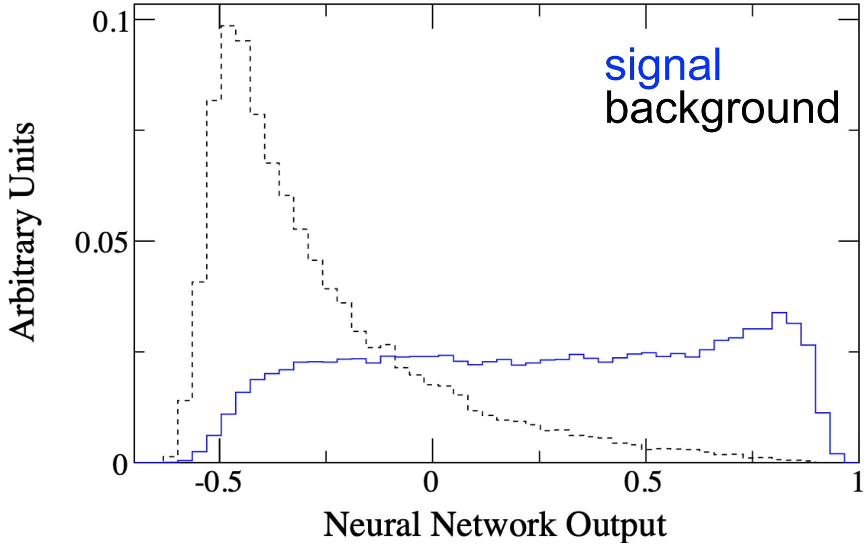
Machine Learning (ML)

- Process data streams from images to abstract data sets
- Can handle data volumes from a few kilobytes to petabytes
- Use ML make predictions and classify data
- Deep Learning expertise
- Talk with us about your Machine Learning or Data Analysis
- Bespoke training courses available

Example uses:

- Search for defects in nuclear track detectors
- Search for rare physics processes in noisy data
- Anomaly detection





Artificial Neural Networks, Boosted Decision Trees, Deep Networks including Convolutional Neural Networks, K-Nearest Neighbours, Random Forests, Support Vector Machines, Autoencoders, ….

Summary

- Multidisciplinary team of world class researchers
- Wide range for facilities for device and material fabrication, testing and prototyping
- Instrument construction capability
- Fully integrated with modern data science capability
- The remaining talks discuss three areas of expertise in more detail
- e-mail detectors@qmul.ac.uk to follow up with us on how we can help your organisation

- The slides today summarise the work of many people including:

M. Ali, A. Bevan, G. Beck, M. Bona, J. Borowiec, J. Briscoe, T. Charman, I. Dawson, D. Dunstan, P. Finn, F. Gannaway, G. Gannaway, K. Hayrapetyan, N. Hehir, P. Hobson, T. Kreouzis, J. Mistry, P. Miyagawa, S. Moss, C. Nielson, F. Noyes, K. Scott, A. Shah, J. Selvarajah, F. E. Taifakou, C. Timis, K. Trachenko, L. Vozdecky, S. Zenz, Z. Zhang