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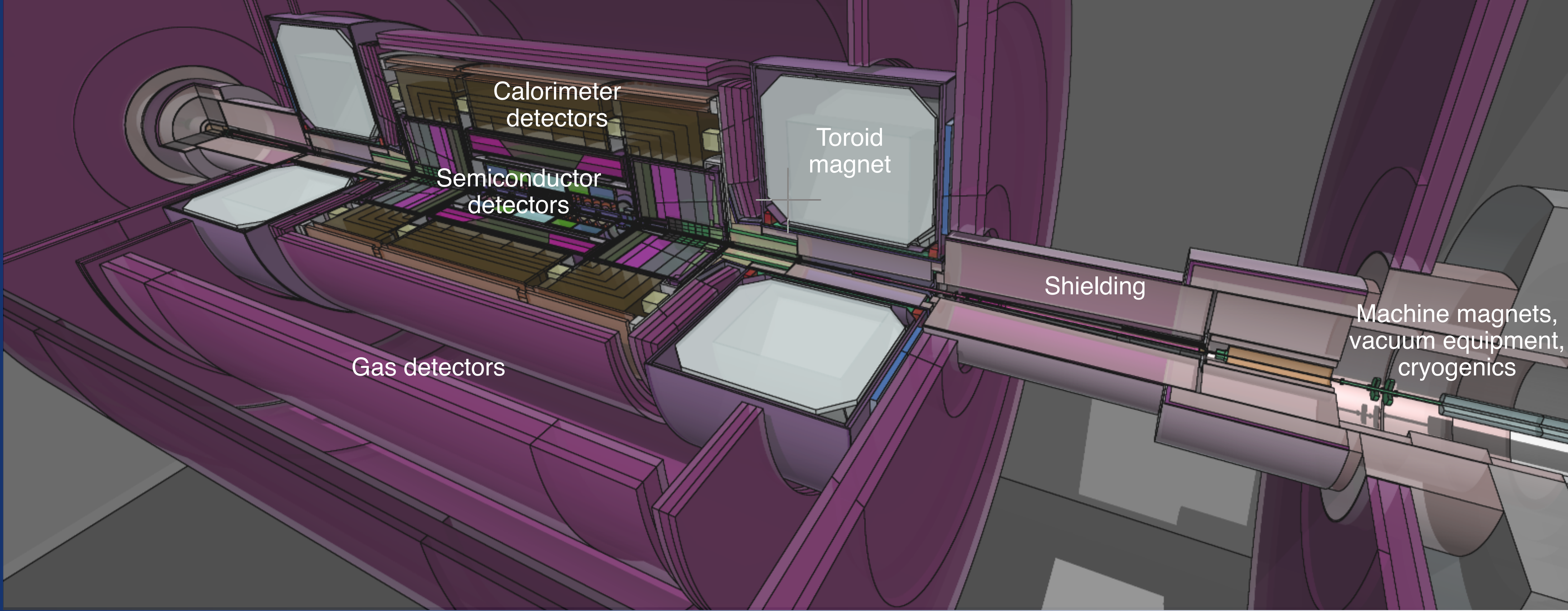
Radiation environment simulation and hardness testing

1. Radiation simulation at the Large Hadron Collider
2. Synergy with aerospace and nuclear
3. Example of recent partnerships with industry

Dr. Ian Dawson, Detector Development Group Industry Event, 26th November 2020

Responsible for simulating radiation backgrounds in the ATLAS experiment. We also coordinate the activities needed to make sure the detector systems will survive the harsh LHC radiation environments.



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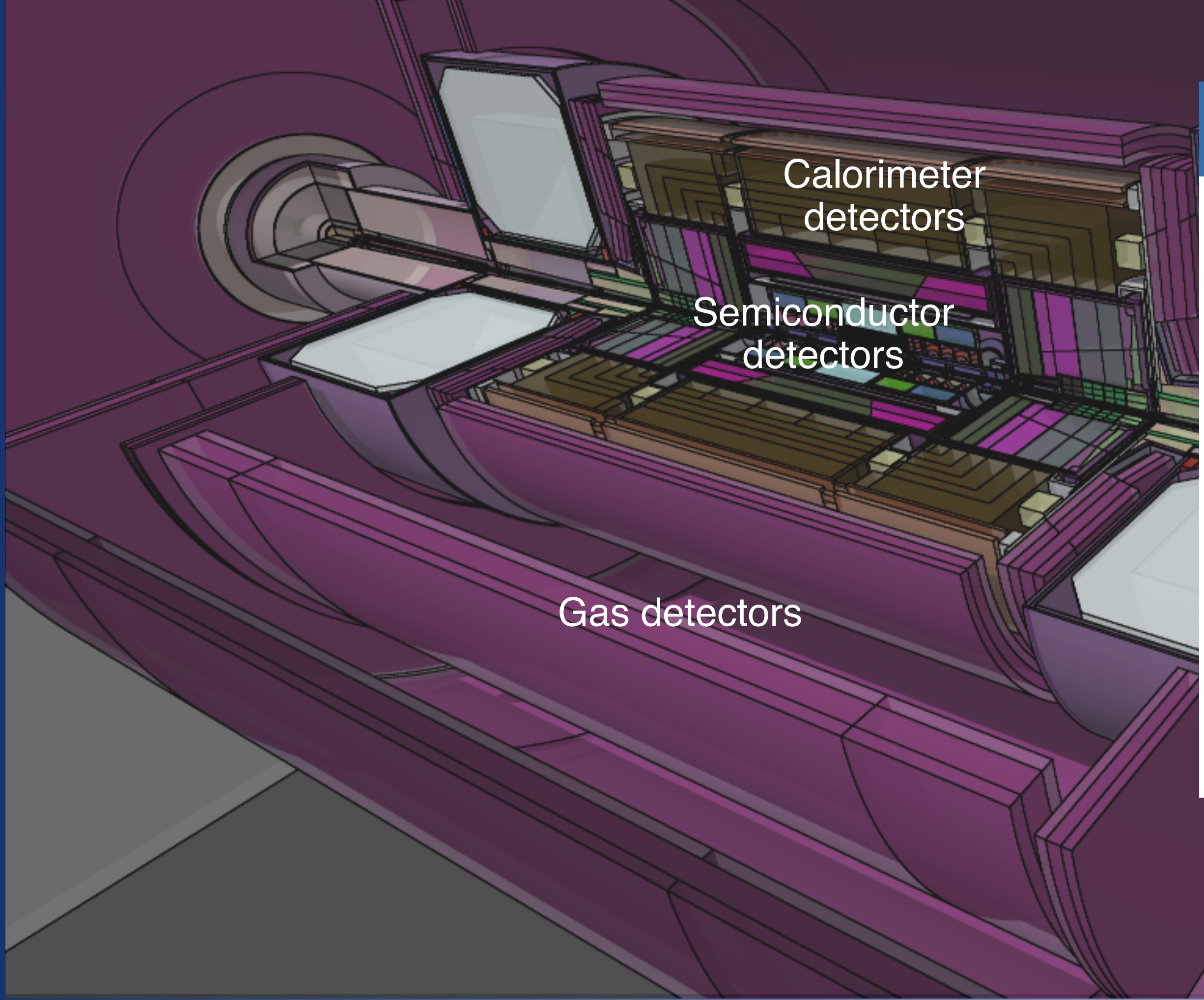
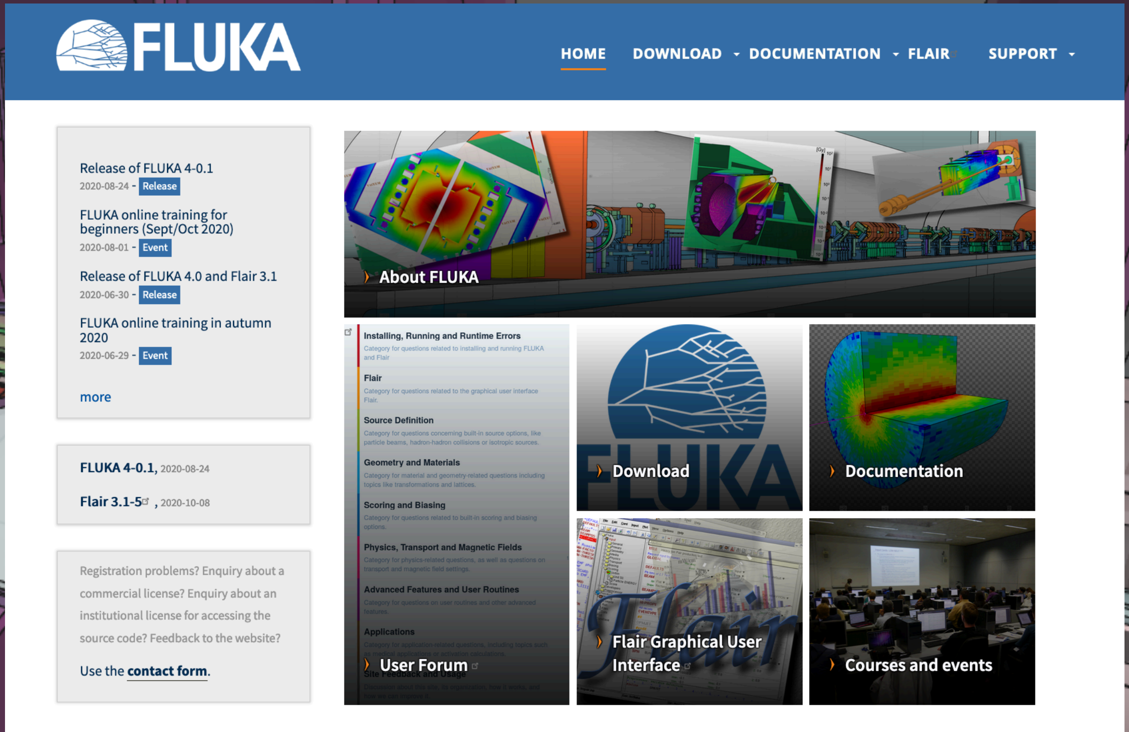
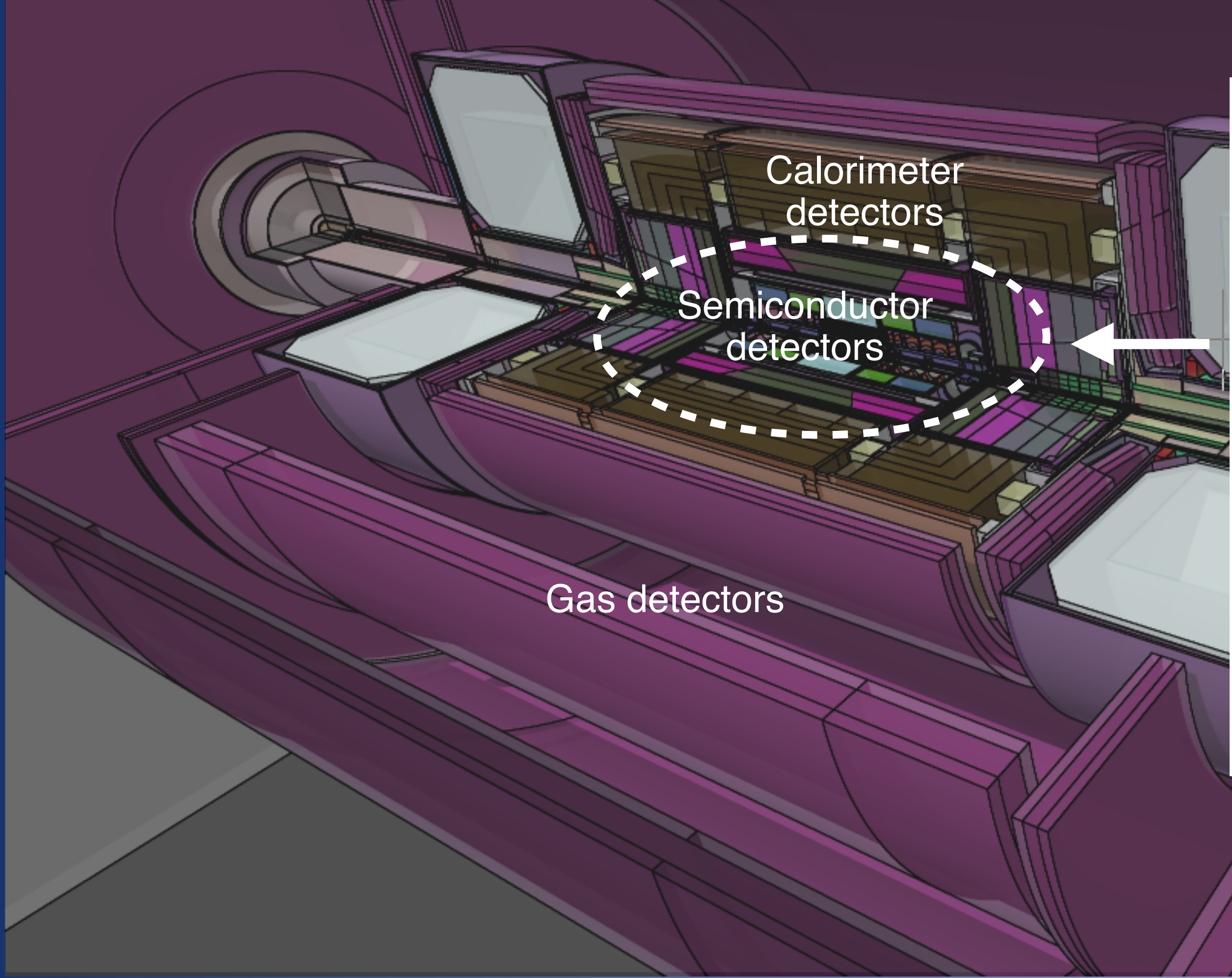
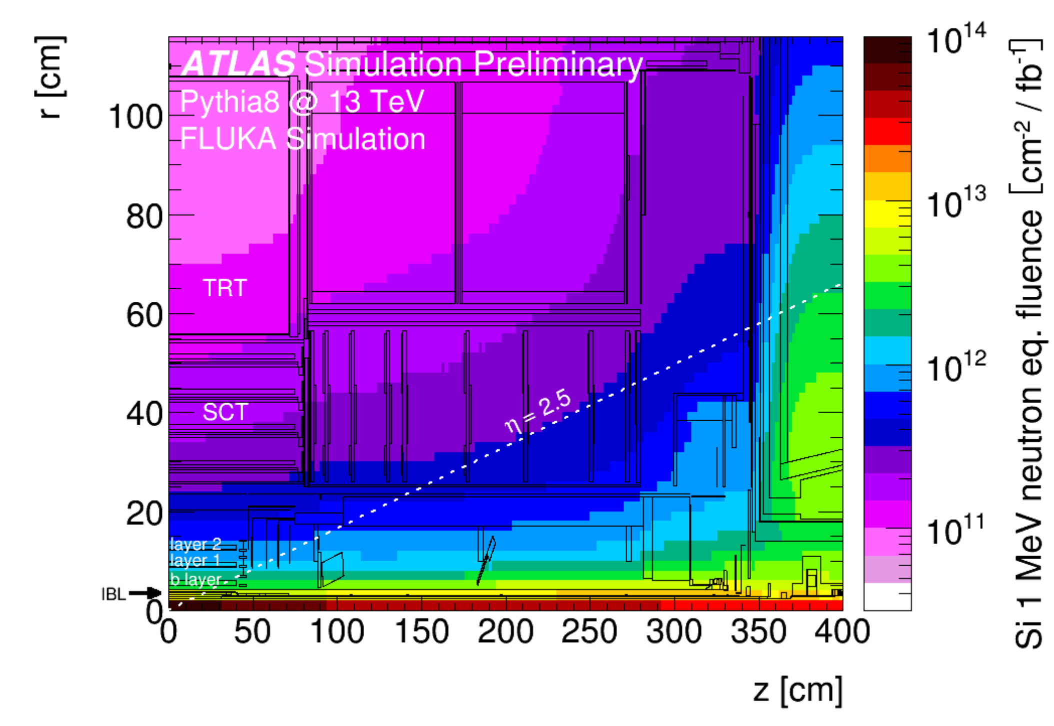
The radiation backgrounds in and around ATLAS are simulated using high fidelity Monte Carlo software, e.g. FLUKA, GEANT4, + others.



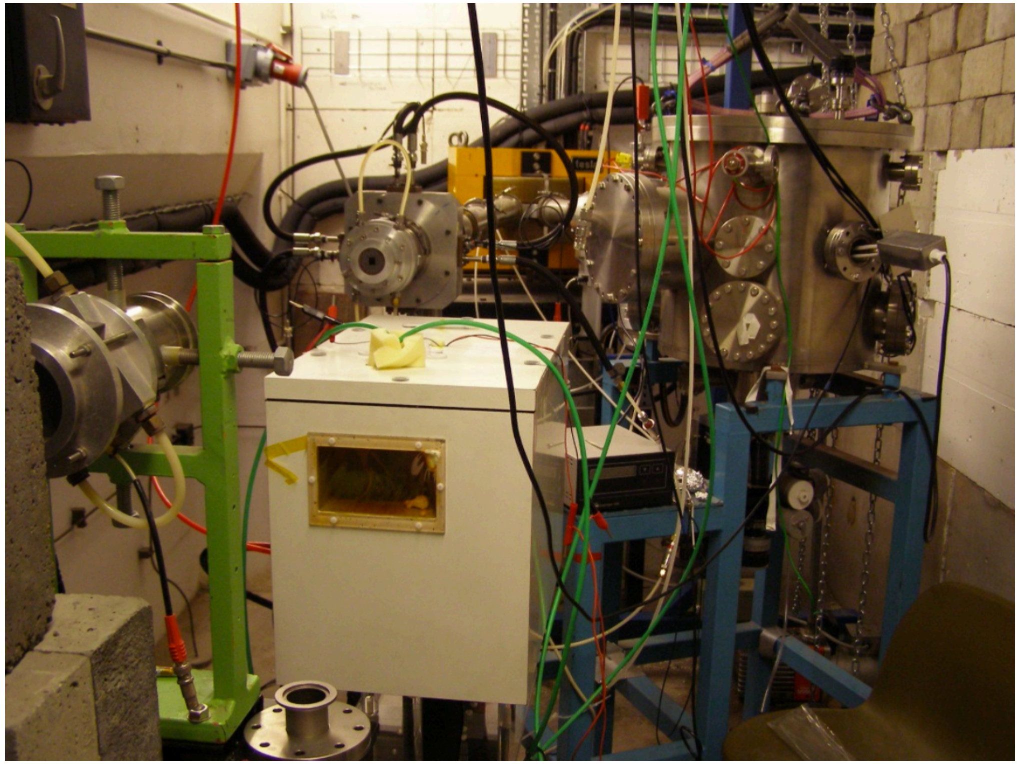


From the simulations we obtain the radiation damage quantities of interest: ionising dose; neutron fluence; SEE flux, etc..





The simulated predictions are used as input for: radiation resilient detector design; damage mitigation studies; testing at irradiation facilities. Simulations provide the link between the real life radiation environment and the test facilities.

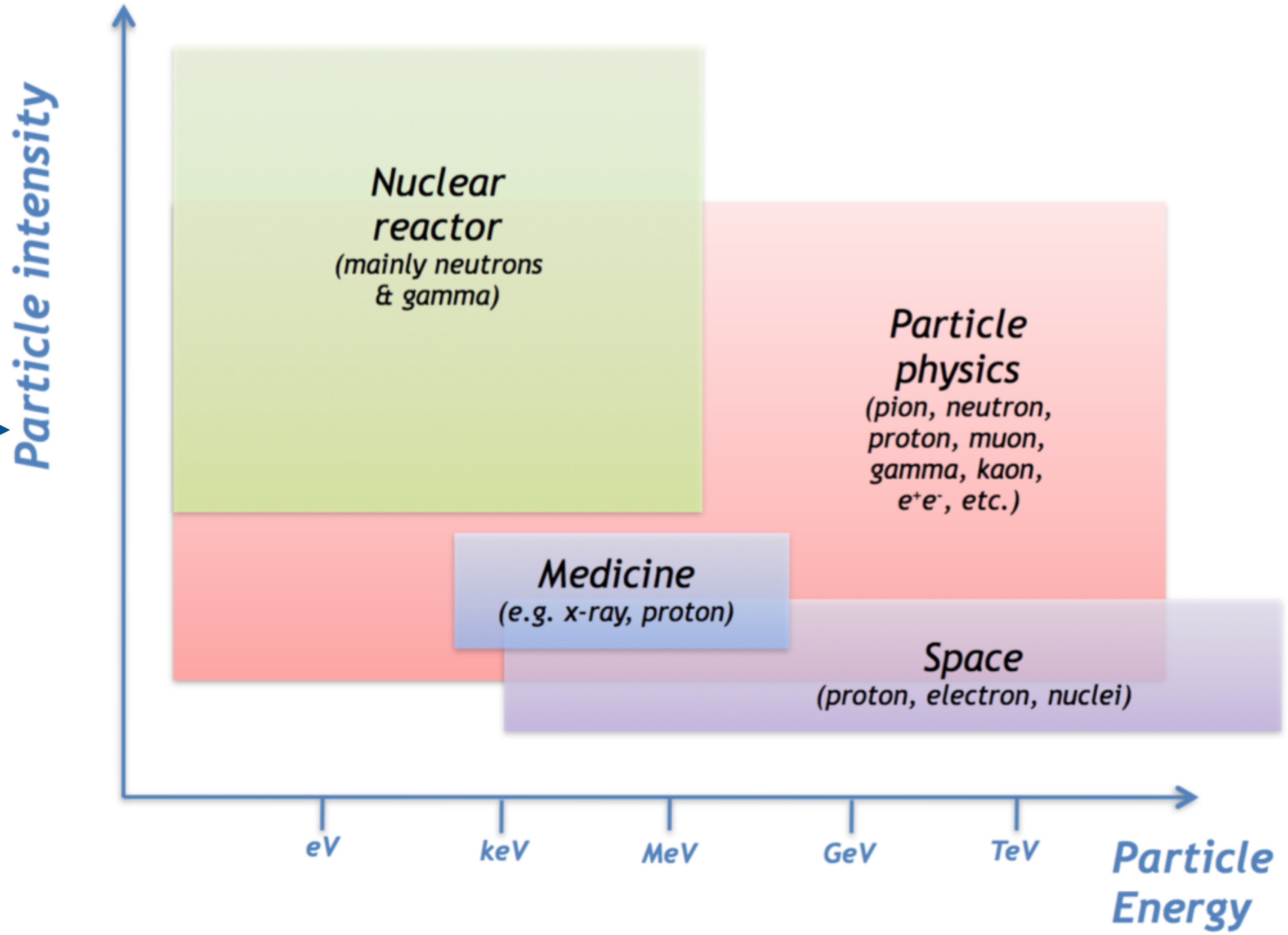


High flux 27 MeV protons for ionising dose and bulk material damage.

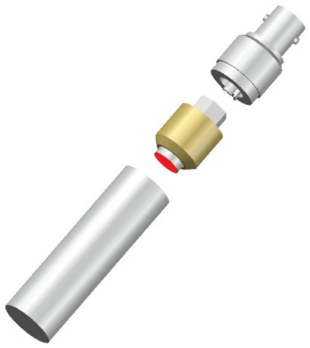
Nuclear reactor for neutron and gammas damage studies.

Synergy between industries?

- In terms of radiation simulation and testing, there is strong overlap between what we do in collider experiments and the aerospace and nuclear industries.
- For example, we've used FLUKA/ GEANT4 for simulation radiation effects in all these research fields.
- Similarly, radiation quantities such as ionising-dose, 1 MeV neutron equivalent flux, etc., are used across these sectors. Therefore the same irradiation test facilities can be used.



Example of partnerships with industry SMEs to develop radiation resilient ultrasound transducers (UT) for non destructive testing in nuclear applications.



PRECISION ACOUSTICS

Investigate piezopolymer (PVDF) ultrasound transducers for radioactive waste monitoring. Understanding gamma response crucial. PVDF sensor material of interest for high frequency/resolution imaging applications.

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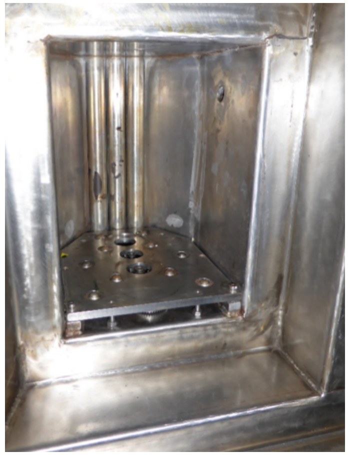
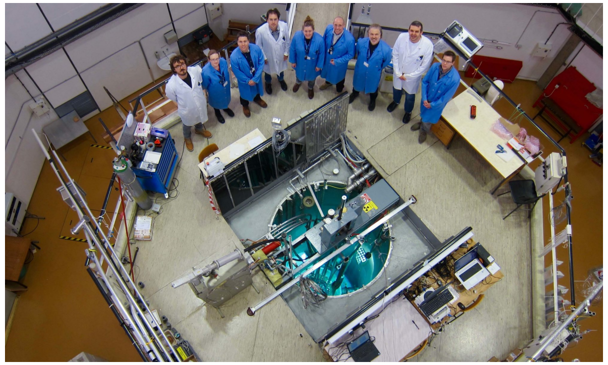
Piezoceramic based ultrasound transducers for monitoring extreme environment applications, such as inside nuclear reactors. Evaluating both neutron and gamma response crucial.

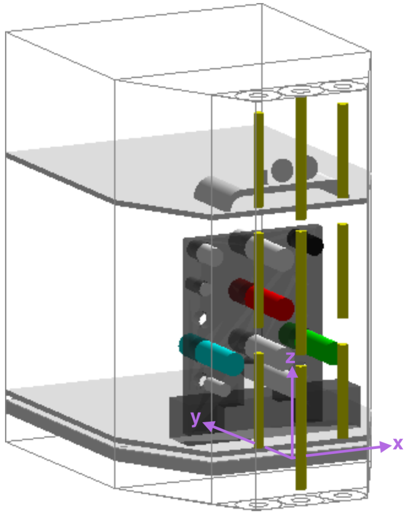
Gamma/neutron irradiations and simulations.



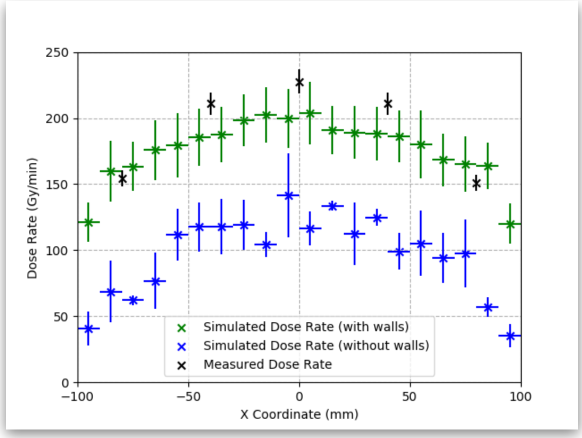
Dalton Co-60 gamma irradiation chamber.



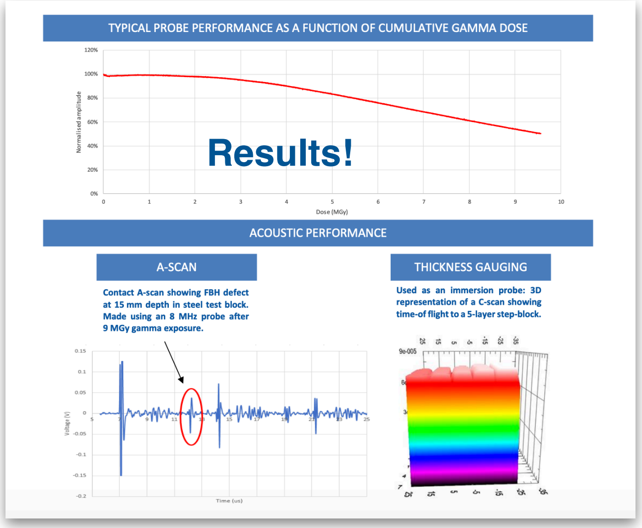
UT probes irradiated in research reactor facility (neutrons and gammas).



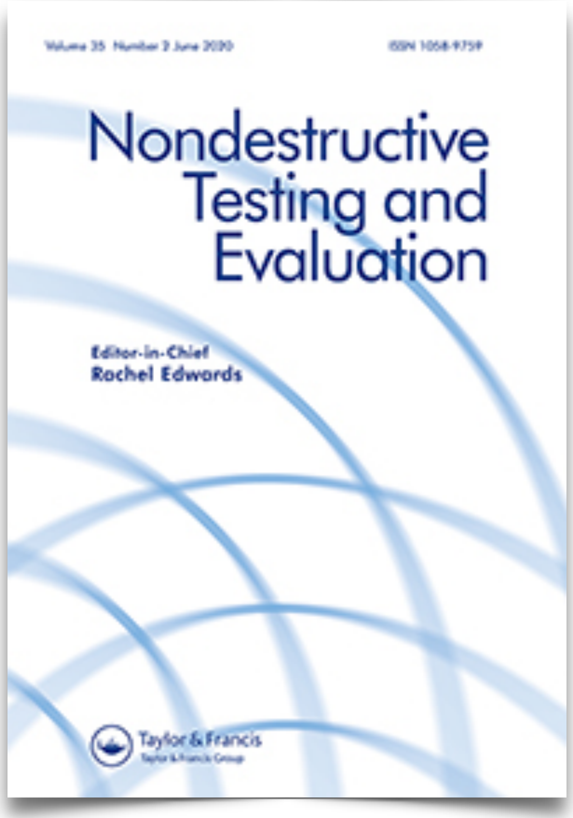
GEANT4 simulation model of Dalton irradiation chamber, Co60 rods, DUTs.



Benchmarking/calibration of simulations with data.



Outcome of project?



Publication (Vol 35, Issue 2, 2020) and presentation at Advanced GEANT4 workshop.

TECHNICAL DATA SHEET

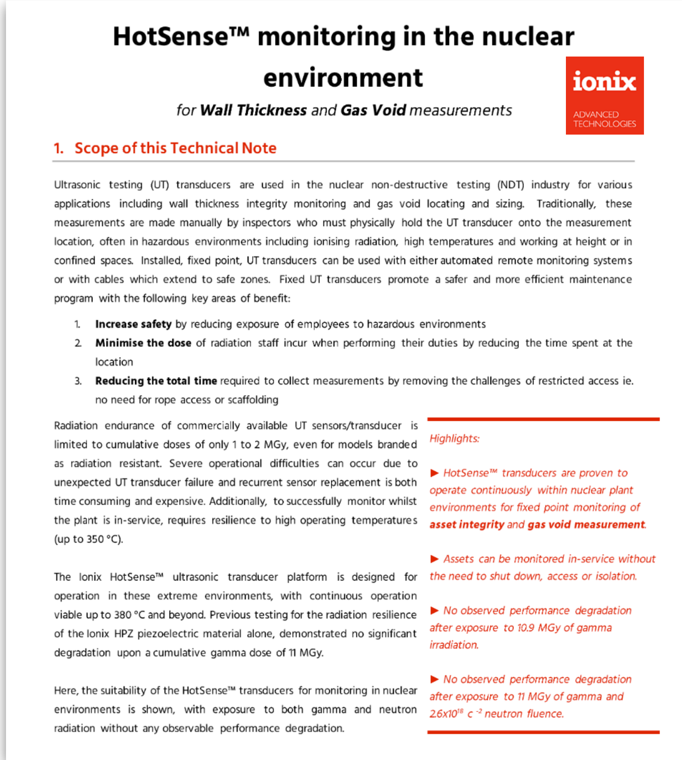
PRECISION ACOUSTICS

Innovate UK
Technology Strategy Board

Radiation resilient ultrasonic transducers

Designed for ambient temperature inspection and NDT applications in high radiation environments, Precision Acoustics' RRUS transducers have been tested up to a cumulative Gamma dose of 9.5 MGy with almost no change in performance up to doses of 2 MGy.

Transducers are available from 5-20 MHz and incorporate a 20 mm delay line as standard. Additional radiation shielding and/or delay line lengths can be supplied by request to allow greater radiation exposure or to allow probes to be fitted into existing systems with specific size requirements for sensors.



HotSense™ monitoring in the nuclear environment

for ***Wall Thickness*** *and* ***Gas Void*** *measurements*

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1. Scope of this Technical Note

Ultrasonic testing (UT) transducers are used in the nuclear non-destructive testing (NDT) industry for various applications including wall thickness integrity monitoring and gas void locating and sizing. Traditionally, these measurements are made manually by inspectors who must physically hold the UT transducer onto the measurement location, often in hazardous environments including ionising radiation, high temperatures and working at height or in confined spaces. Installed, fixed point, UT transducers can be used with either automated remote monitoring systems or with cables which extend to safe zones. Fixed UT transducers promote a safer and more efficient maintenance program with the following key areas of benefit:

1. **Increase safety** by reducing exposure of employees to hazardous environments
2. **Minimise the dose** of radiation staff incur when performing their duties by reducing the time spent at the location
3. **Reducing the total time** required to collect measurements by removing the challenges of restricted access ie. no need for rope access or scaffolding

Radiation endurance of commercially available UT sensors/transducer is limited to cumulative doses of only 1 to 2 MGy, even for models branded as radiation resistant. Severe operational difficulties can occur due to unexpected UT transducer failure and recurrent sensor replacement is both time consuming and expensive. Additionally, to successfully monitor whilst the plant is in-service, requires resilience to high operating temperatures (up to 350 °C).

The Ionix HotSense™ ultrasonic transducer platform is designed for operation in these extreme environments, with continuous operation viable up to 380 °C and beyond. Previous testing for the radiation resilience of the Ionix HPZ piezoelectric material alone, demonstrated no significant degradation upon a cumulative gamma dose of 11 MGy.

Here, the suitability of the HotSense™ transducers for monitoring in nuclear environments is shown, with exposure to both gamma and neutron radiation without any observable performance degradation.

Highlights:

- *HotSense™ transducers are proven to operate continuously within nuclear plant environments for fixed point monitoring of* ***asset integrity*** *and* ***gas void measurement****.*
- *Assets can be monitored in-service without the need to shut down, access or isolation.*
- *No observed performance degradation after exposure to 10.9 MGy of gamma irradiation.*
- *No observed performance degradation after exposure to 11 MGy of gamma and $2.6x10^{18}$ c $^{-2}$ neutron fluence.*

Companies now advertising their radiation resilient products. Any lessons learned? SMEs have much to offer the aerospace and nuclear industries, but need expert support to navigate radiation hardness assurance and test facility usage.

In summary …

- We have expertise understanding radiation damage effects in:
  - Sensors;
  - Electronics;
  - Materials.
- We can help find solutions for applications involving:
  - Space missions and space weather monitoring;
  - Nuclear decommissioning and new build simulation studies;
  - Accelerator design for medicine and particle physics.

- Our capabilities:
  - Simulating complex radiation environments using high fidelity Monte Carlo software;
  - Optimise shielding design and study radiation damage mitigation strategies;
  - Organise and supervise radiation testing at gamma and neutron irradiation facilities;
  - Radiological assessments;
  - Strong links with CERN technology groups and STFC knowledge transfer.

For further information or queries, email: detectors@qmul.ac.uk