AccelApp'24

Australian Government

ANSTO

Recent facility upgrades and the broad range of research and industrial applications of the heavy-ion microprobe beamlines at ANSTO

Dr Ryan Drury

Dr Stefania Peracchi, Dr Zeljko Pastuovic, Mr David Button, Mr Michael Mann, Dr David Cohen, Mr David Child

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Science. Ingenuity. Sustainability.

Overview

- Who & Where
  - ANSTO at a glance
  - CAS capabilities
- What & Why
  - Heavy ion microprobes
  - Ambient irradiation
- When & How
  - Applying for ANSTO access
- Success Stories
  - Could this be you?

Acronyms:

- ANSTO
  - Australian Nuclear Science and Technology Organisation
  - Where I'm from
- CAS
  - Centre for Accelerator Science
  - An ANSTO-based accelerator group
- HIMP
  - Heavy Ion MicroProbe
  - Electronics systems and vacuum chambers for the focussing of ion beams
- NCRIS
  - National Collaborative Research Infrastructure Strategy
  - An Australian research funding program

ANSTO

A leader in nuclear science and technology

Operating safely for over 70 years

Managing over $1.5 billion in scientific infrastructure

Over 1300 skilled employees

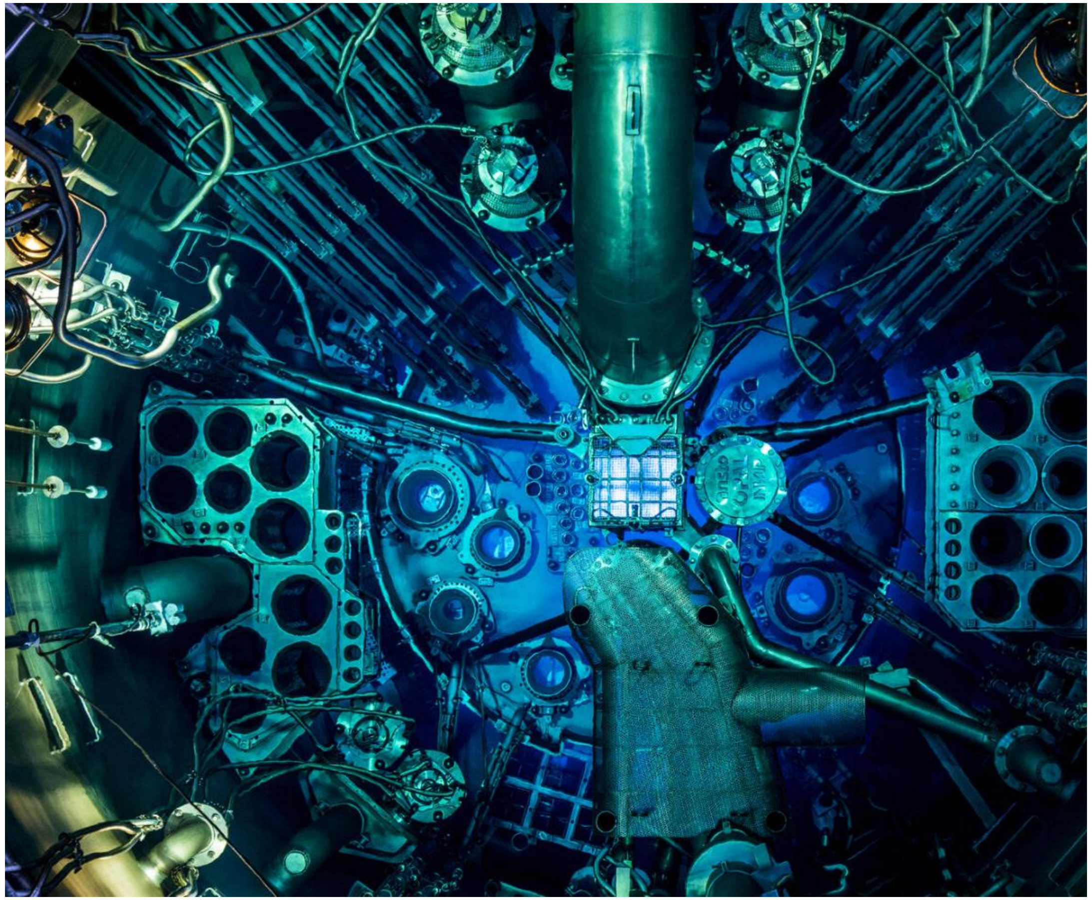
Research priorities: **Advanced manufacturing, Health,** Transport, Cyber security, Energy, Environmental Change, Food, Resources, Soil, and Water

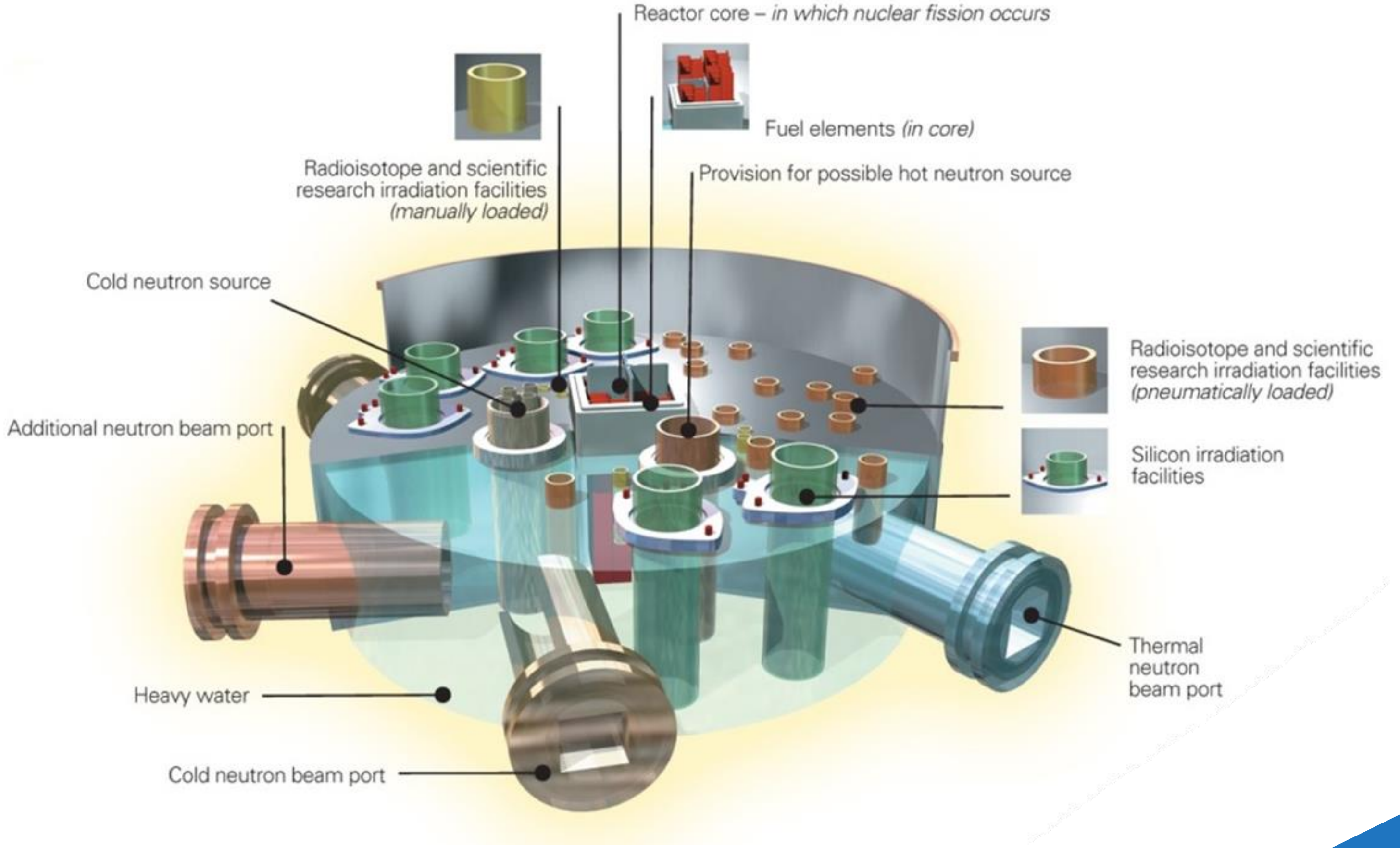
ANSTO's Lucas Heights campus.

TWO LOCATIONS

ANSTO

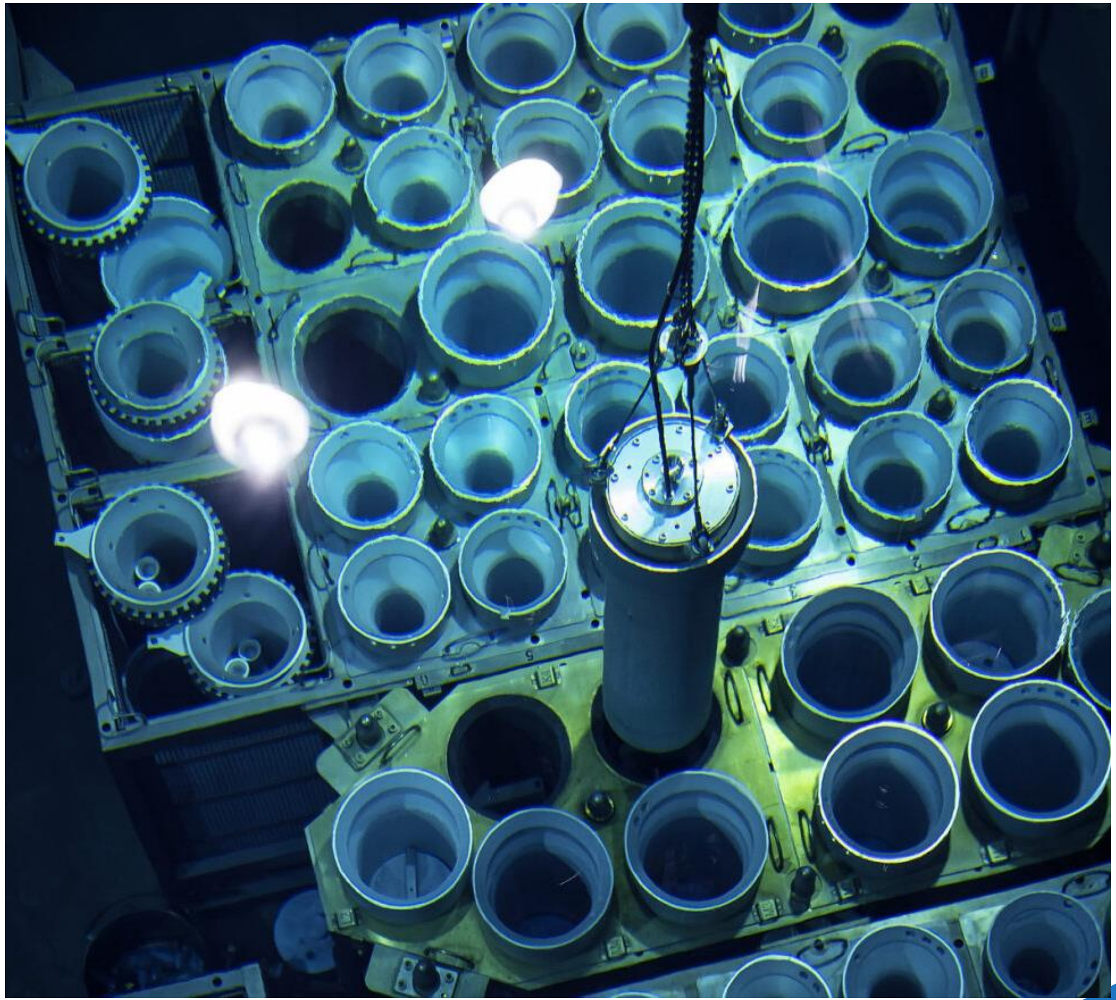
ANSTO at a glance





OPAL Research Reactor

ANSTO at a glance



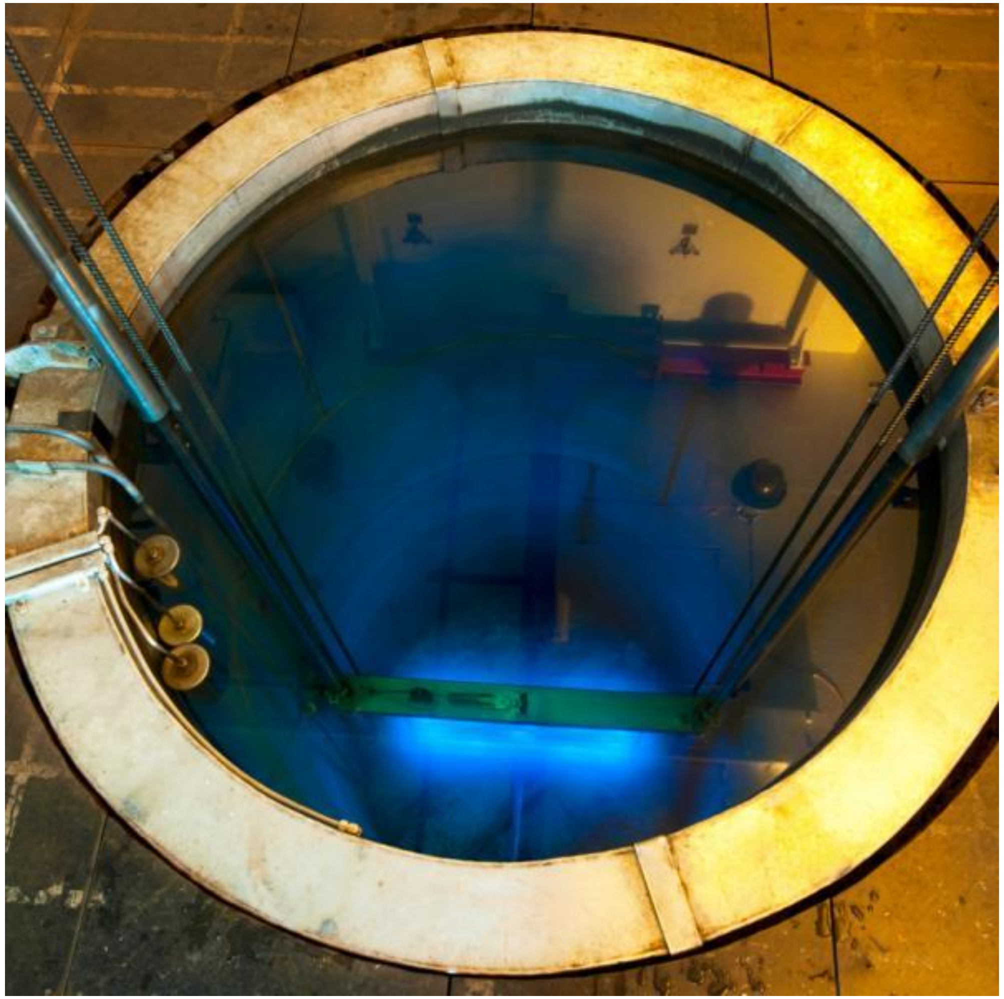
Australian Centre for Neutron Scattering

Neutron Activation Facility (silicon and radioisotope)

ANSTO

ANSTO at a glance

Australian Synchrotron

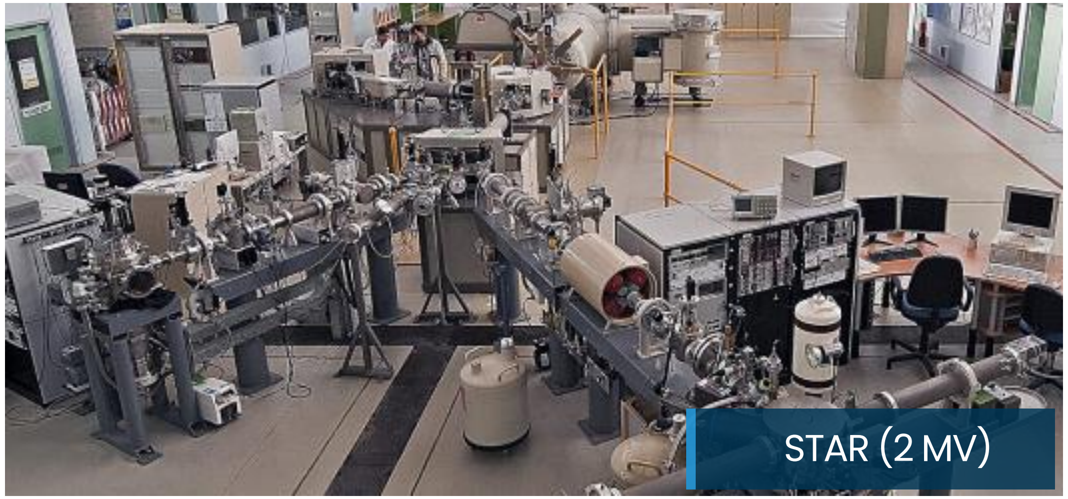


GAmma Technology
Research Irradiator

CAS Capabilities

Centre for Accelerator Science


VEGA (1 MV)


STAR (2 MV)


SIRIUS (6 MV)

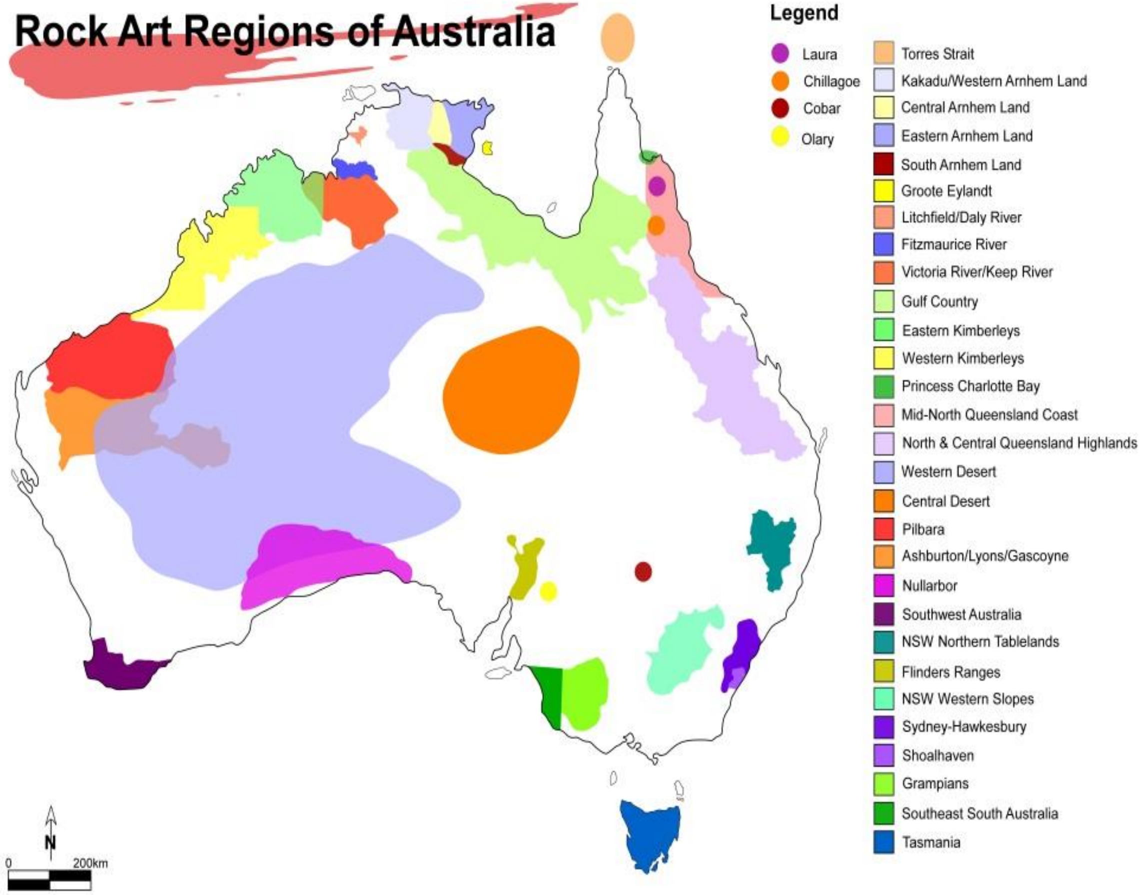

ANTARES (10 MV)

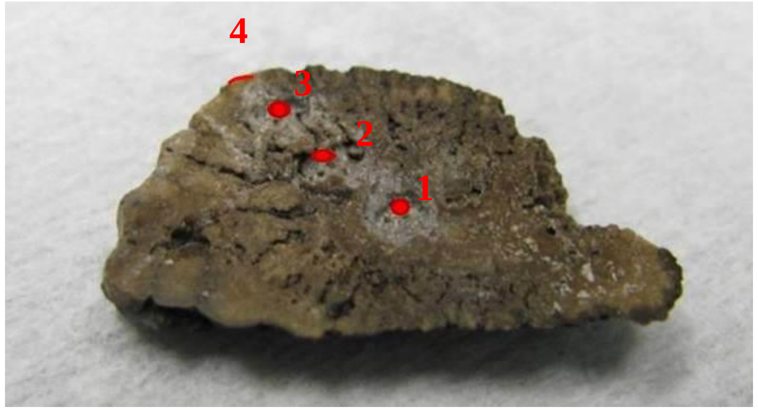
SUPPORTING
AUSTRALIA'S NATIONAL SCIENCE AND RESEARCH PRIORITIES

- Advanced manufacturing ✔
- Cyber security
- Energy ✔
- Environmental change ✔
- Food ✔
- Health ✔
- Resources ✔
- Soil and water ✔
- Transport

CAS Capabilities

Radiocarbon dating





1	Centre	1990.8 +/- 0.8 year
2	Border organic layer	1998.5 +/- 1.0 year
3	Inner part outer mineral layer	2002.5 +/- 1.0 year
4	Surface	2013.5 +/- 0.6 year

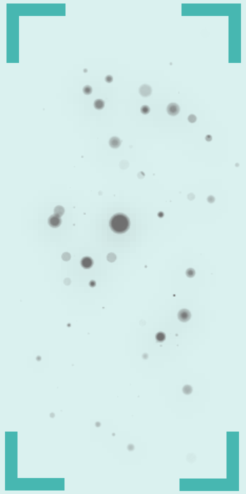
Total stone age 23 years

From: Dr Vladimir Levchenko

CAS Capabilities

Particulate Air Pollution

PM2.5



PM2.5

Standards based on mass concentration

Centre for Accelerator Science

Elements

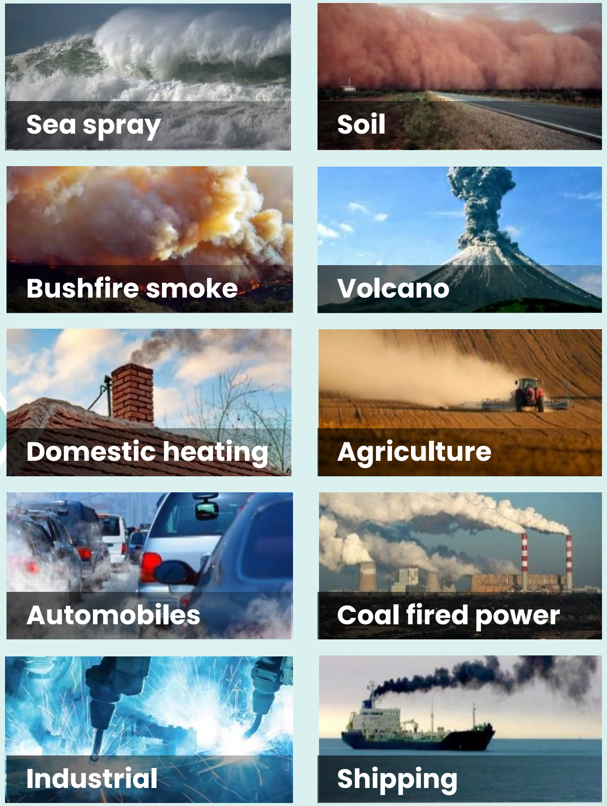
INFRASTRUCTURE

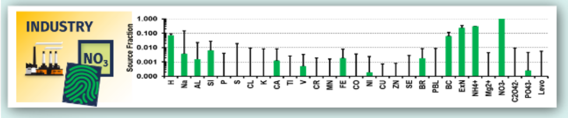
Fingerprints

SCIENTIFIC EXPERTISE

Locations

SOURCES & ORIGINS






NEWCASTLE HERALD
VOICE OF THE HUNTER
Orica to spend $39 million upgrading its Kooragang Island prill tower
8 March 2021

From: Dr Armand Atanacio

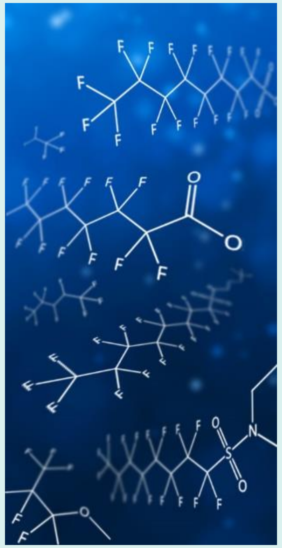
ANSTO

CAS Capabilities

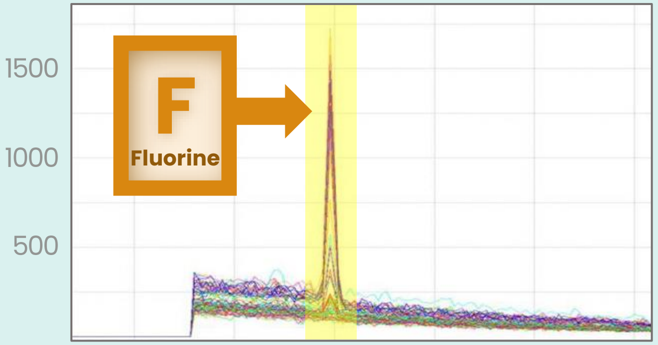
PFAS screening

PFAS

Several thousand synthetic organic compounds



Ion Beam Analysis



Advantages

Time savings

Cost savings

APCO AUSTRALIAN PACKAGING COVENANT ORGANISATION

PLANET ARK

Australian Government
Department of Agriculture, Water and the Environment

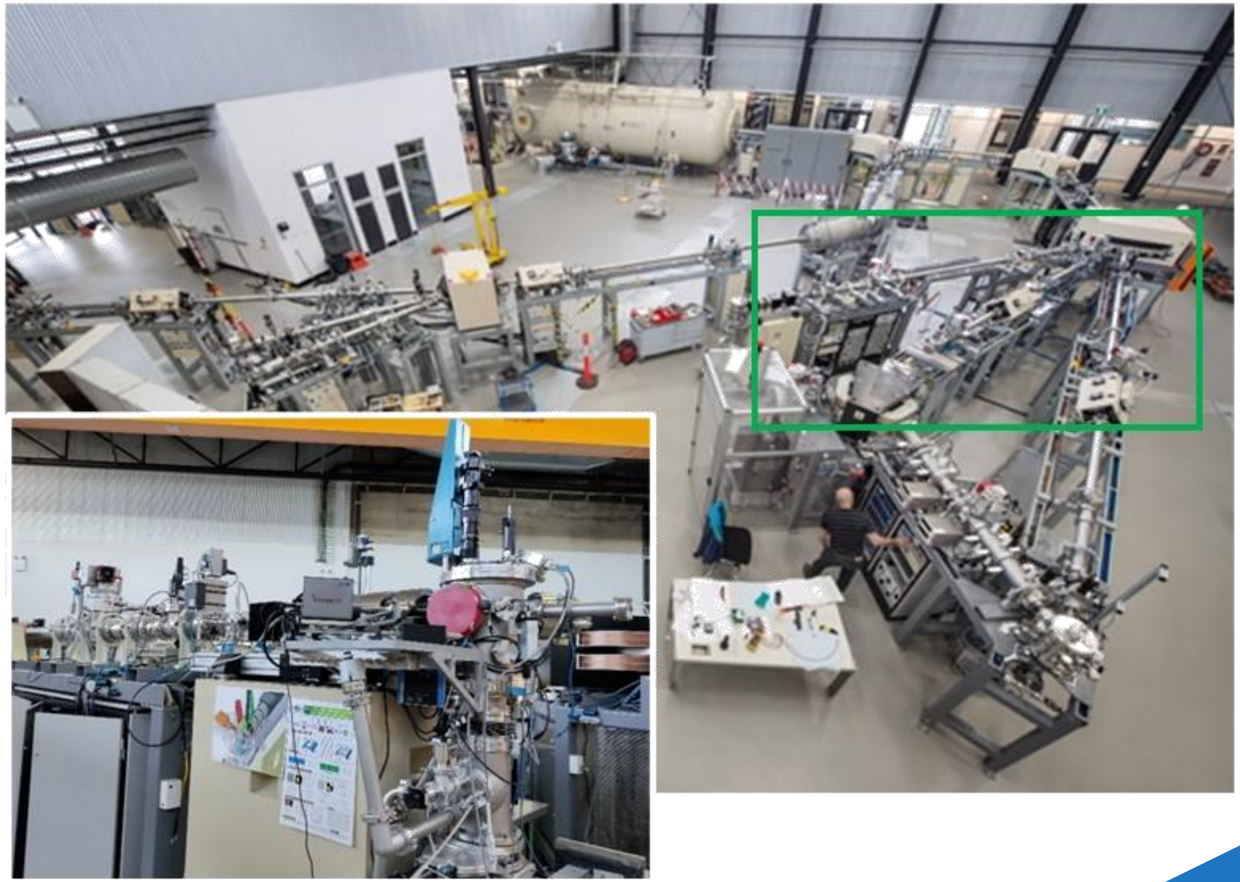
From: Dr Armand Atanacio

CAS Capabilities

Heavy Ion Microprobes

ANTARES – 10 MV VAN DE GRAFF (1990)

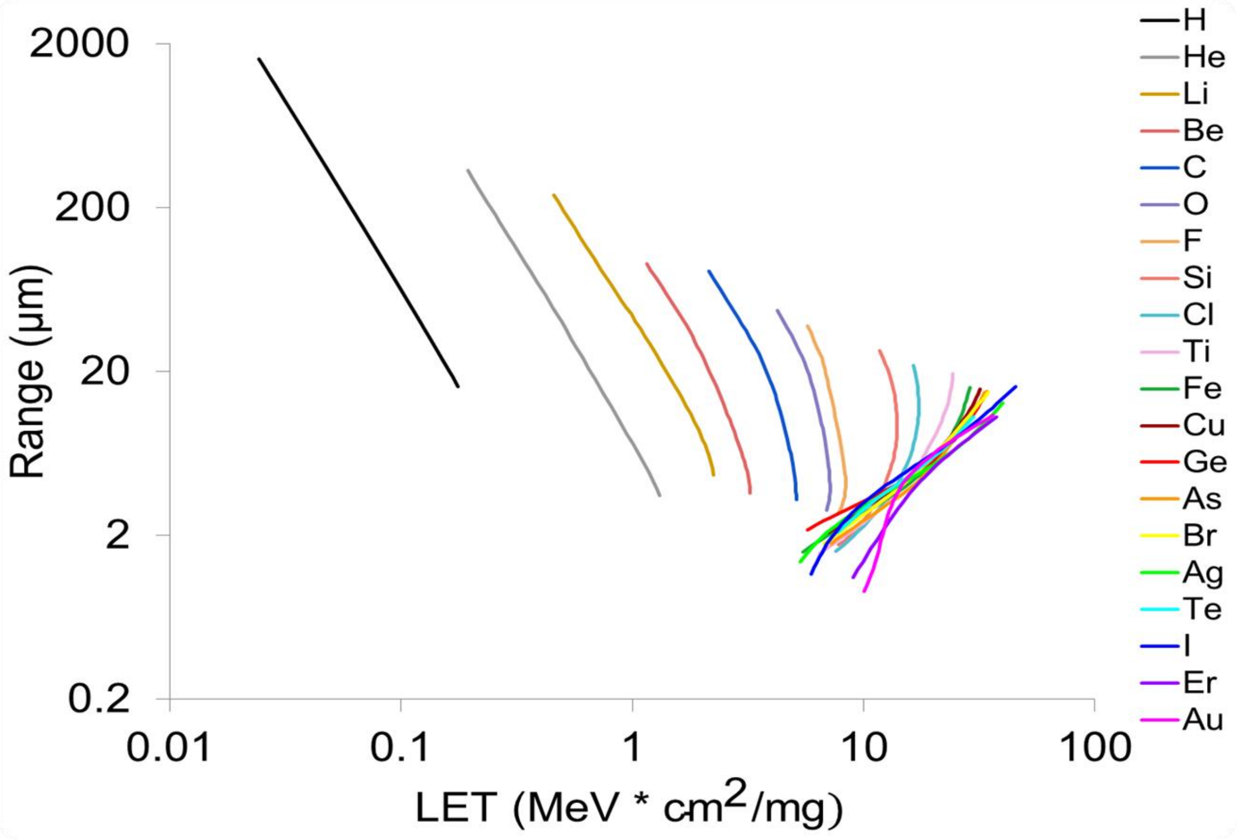
SIRIUS – 6 MV PELLETRON (2015)



Both accelerators are equipped with
Heavy Ion Beam Nuclear Microprobes

CAS Capabilities

Heavy Ion Beam Nuclear Microprobes	
Ion species	From H to Au
Energies H	Up to 15 MeV
Energies Heavy ions	Up to 120 MeV
LET(Si)	Up to 45 $MeV.cm^2/mg$
Range(Si)	1 µm – 2 mm
Beam current regime	pA to µA
Single ion regime	100 - 10000 particle/s
Flux	$10^3 - 10^9$ $particles/cm^2.s$
Fluence	$10^3 - 10^{15}$ $particles/cm^2$
Beam spot in vacuum	0.5 – 1 µm
Beam spot in air (ANTARES)	10 µm
Beam scan area	100 $µm^2$ – 12mm^2
Stage scan area (ANTARES)	Up to 50 x 50 mm^2

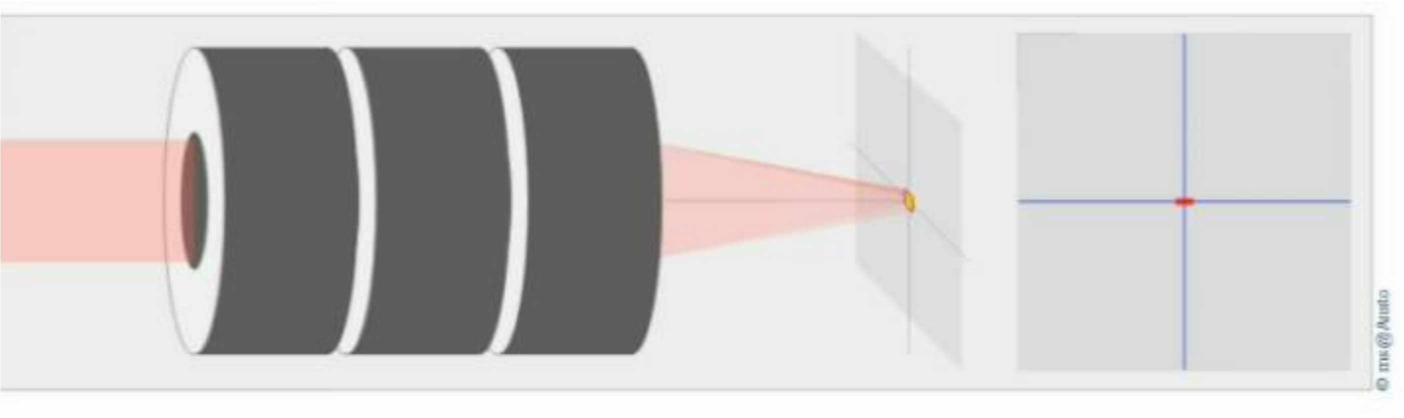


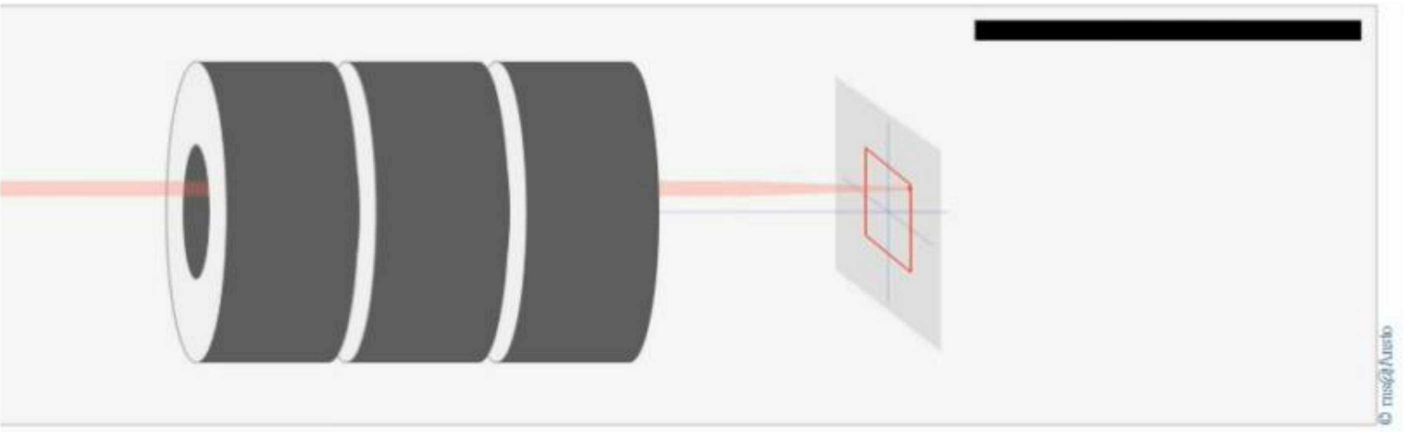
NOTE: energies are selected based on current max terminal voltage 8.7MV , max ion rigidity of 120, and beam yield above 10 %.

ANSTO

Heavy Ion Microprobes

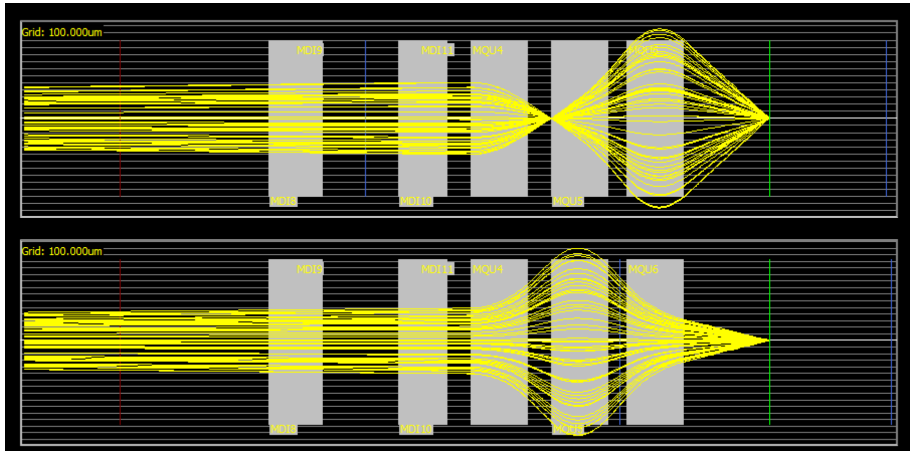
Focusing and scanning





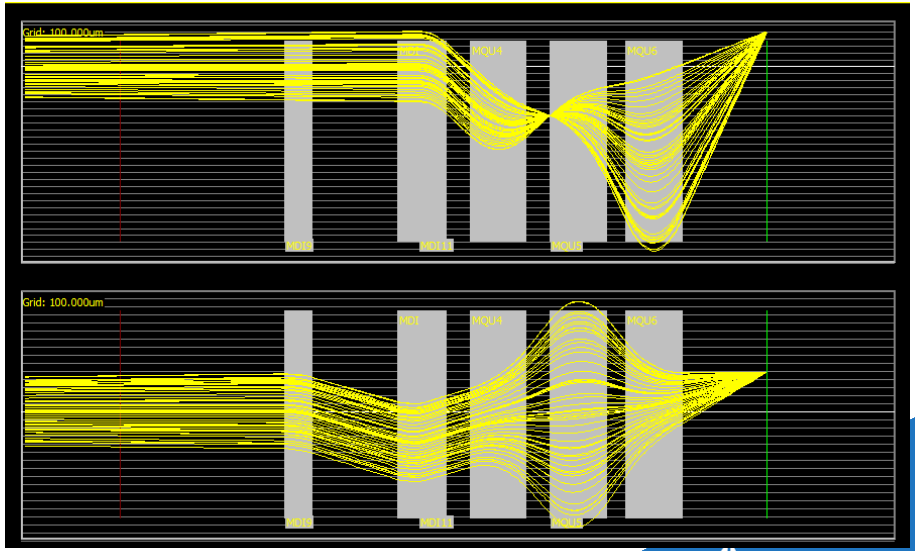
X

Y



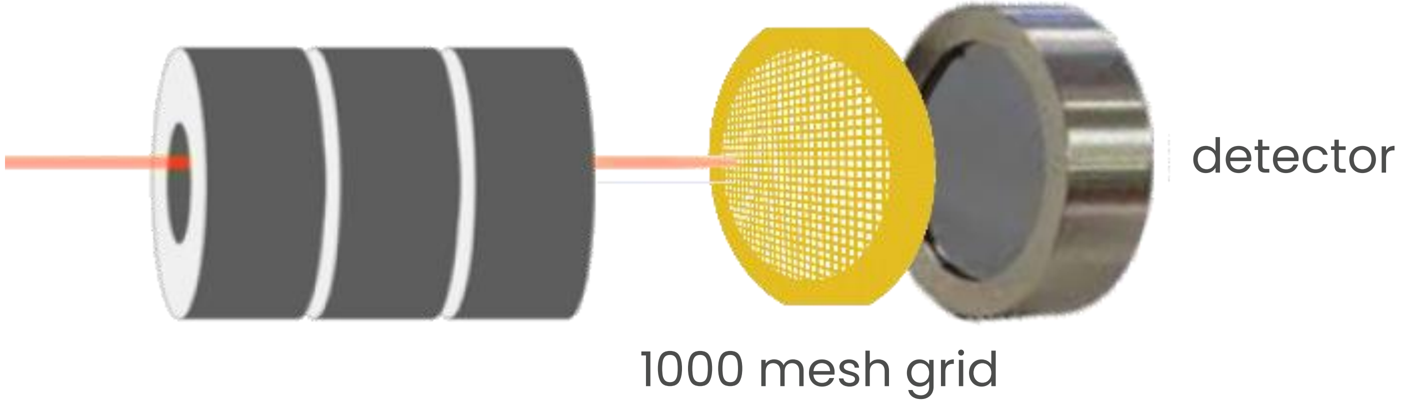
X

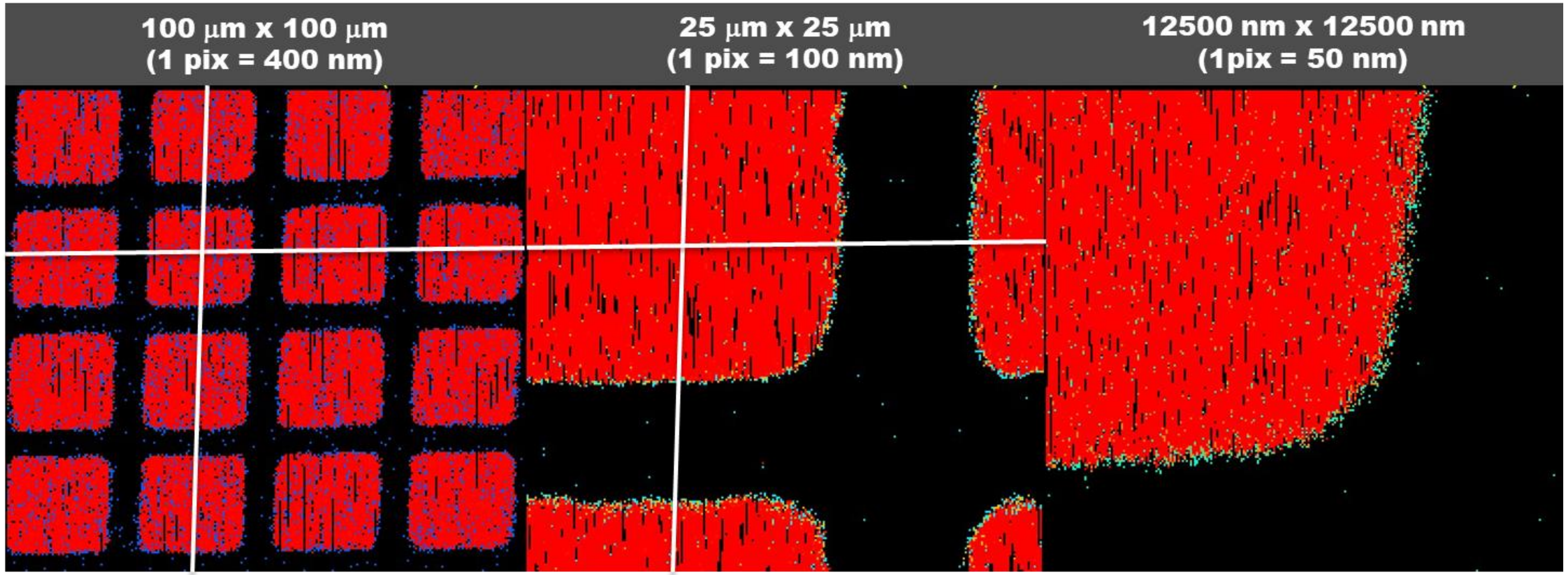
Y



Heavy Ion Microprobes

Microbeam Resolution



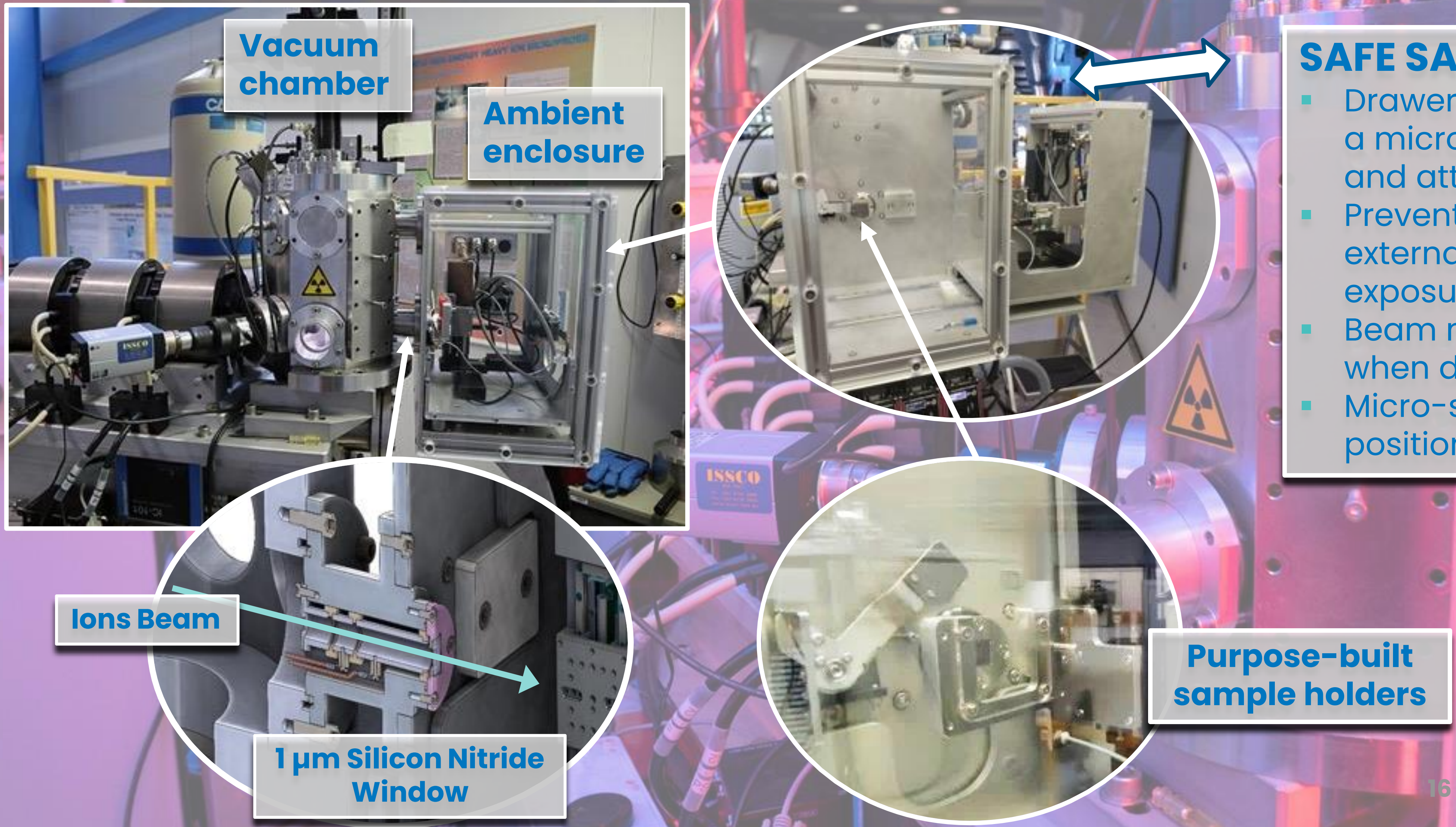


- Customisable to user needs
  - Scan area
  - Aspect ratio
  - Beam footprint
  - Pixel size/count
  - Dwell time
  - Scan pattern
  - Particle rate
  - Flux/fluence

Intermission

Cats of CAS

Australia's First Ion Microbeam Facility in air



SAFE SAMPLE HANDLING:

- Drawer on precision rails with a micromanipulator stage and attached sample holder.
- Prevents direct access to the external beam and potential exposure.
- Beam mechanic shutter when drawer out.
- Micro-switch for sample positioning

Ambient Irradiation

Irradiation of 2D/3D cell cultures

Performed with a wide range of ion species, LET, and dose rates from mGy/s to kGy/s.

Sample positioning and alignment

Via dual rear & front cameras with telecentric lenses (pixel res. 0.86 µm/pixel), motorised micro-manipulator on XYZ, and laser sensor with 2 µm repeatability for Z positioning.

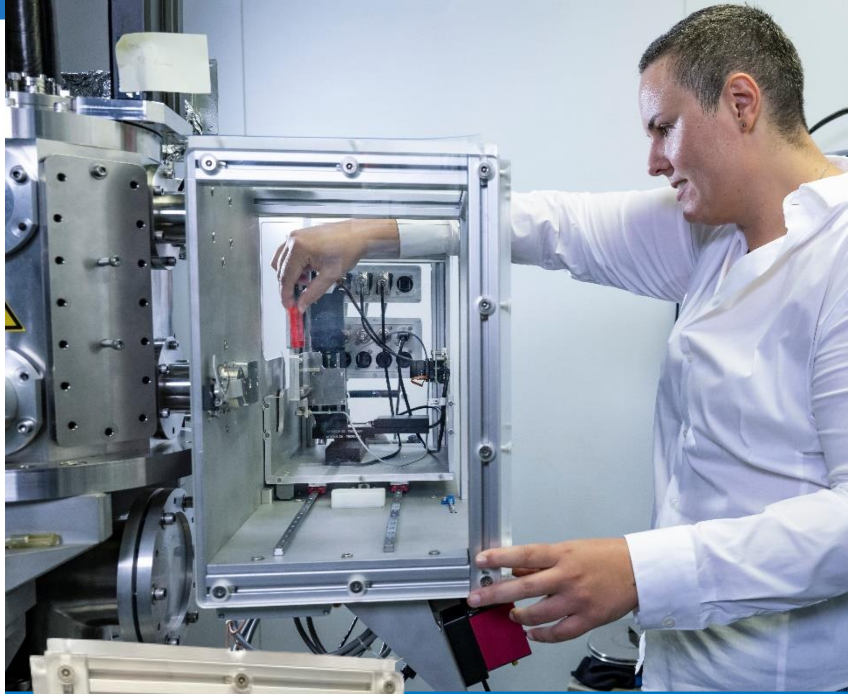
Dosimetry and imaging

Beam spot dimension, the beam trace, and the dose uniformity are measured using crystal scintillators and radiochromic films.

Scanning capabilities include

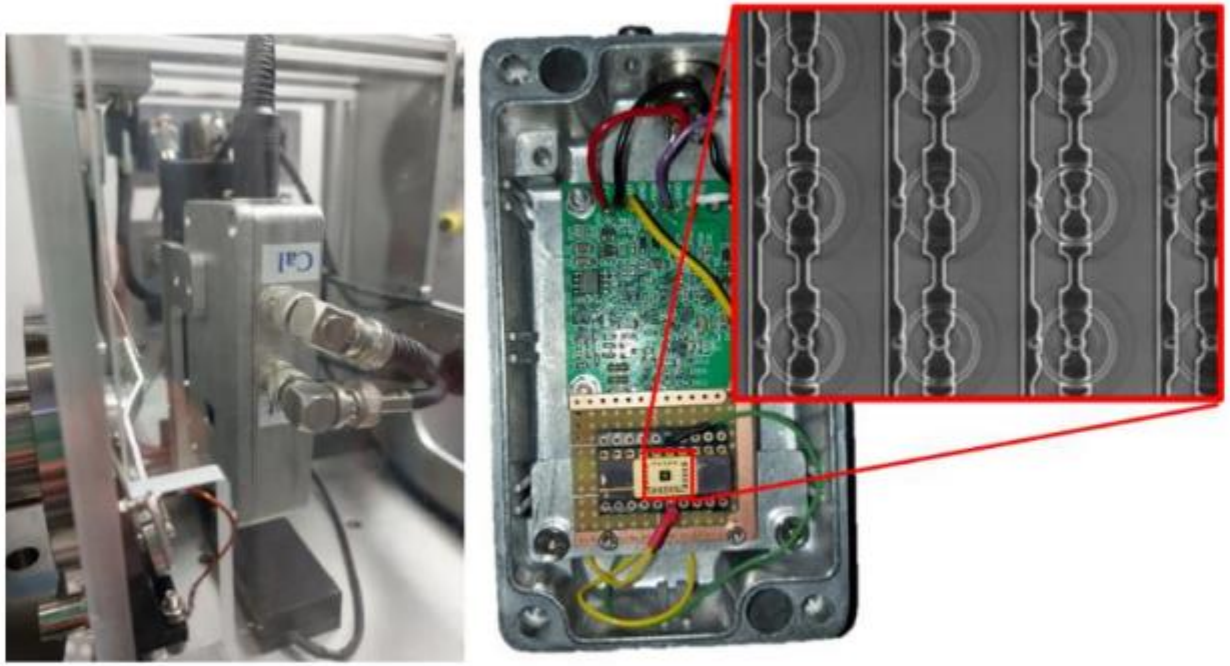
- continuous raster scanning of the microbeam across μm^2 and mm^2 areas
- scanning of the sample via motorised XY stage across cm^2 areas
- hybrid scanning (simultaneous scan of the microbeam and translation of the sample) across areas of max 50 x 50 mm^2. The hybrid scanning allows for more complex scan patterns, achieving high uniformity, and/or sparing specific areas, with micro-resolution.

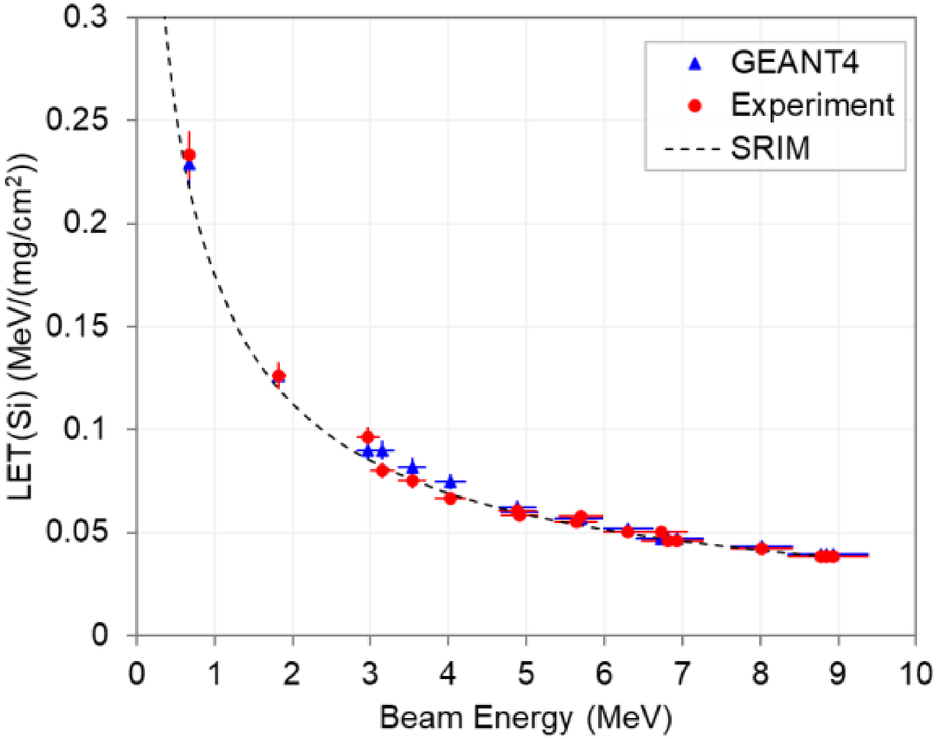
S. Peracchi et al., “Australia’s External Ion Microbeam Irradiation Facility For Space Radiation Effects Testing”, RADECS Proceeding 2022, Venice, Italy, DOI: 10.1109/RADECS55911.2022.10412528



Ambient Irradiation

Beam characterization
Linear Energy Transfer (LET)





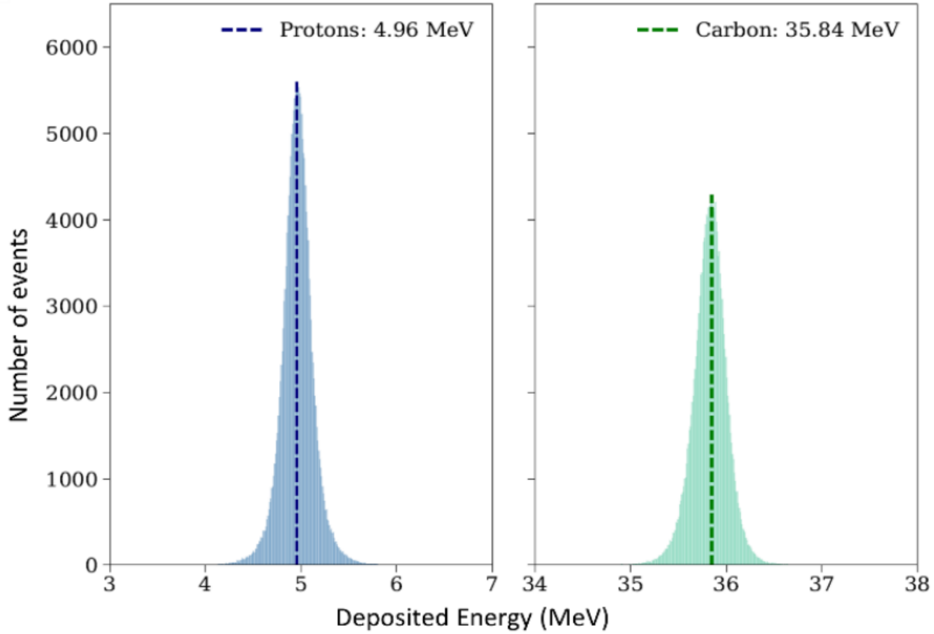
- LET measurement by using 10 μm thick SOI “mushroom” microdosimeter.

- Agreement between experimental, SRIM and GEANT4 results within 5%.
- Energy peak spread in air 10%.

S. Peracchi et al., “LET calibration of ion microbeams and their SEE cross-section characterisation”, IEEE Trans. Nucl. Sci, 2024, DOI: 10.1109/TNS.2024.3372135

Ambient Irradiation

Beam characterization
Energy and flux



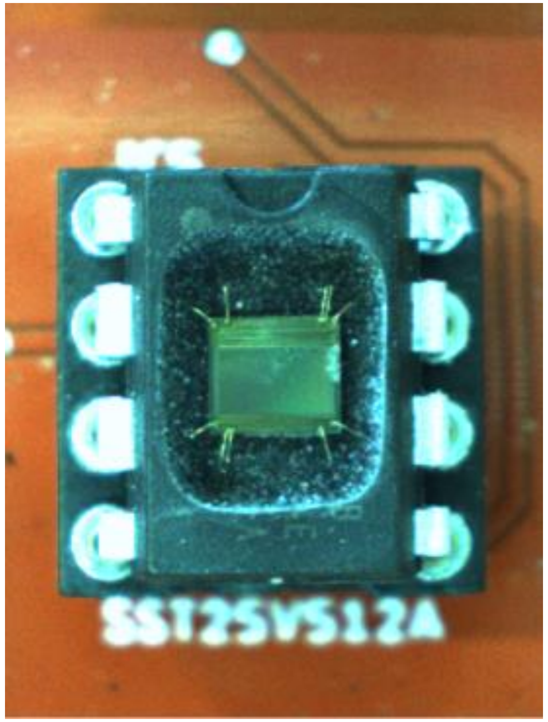
- PIPS silicon detector for the direct measurement of energy spectrum and flux.
- Well characterised radiation-sensitive chip for correlation with international facilities.

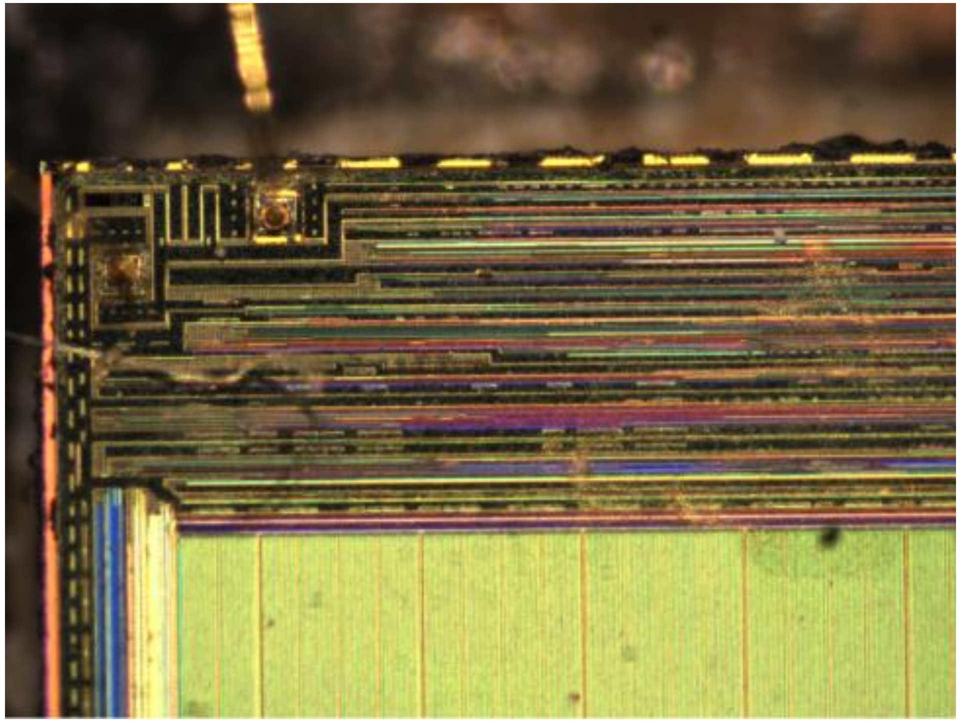
- Energy deposition within 1% nominal energy.
- Flux variability 5%.
- Multiplicity: 1 in 99% cases
- Flux variability from European facilities = 1%
- Cross-section variability from European facilities < 4%

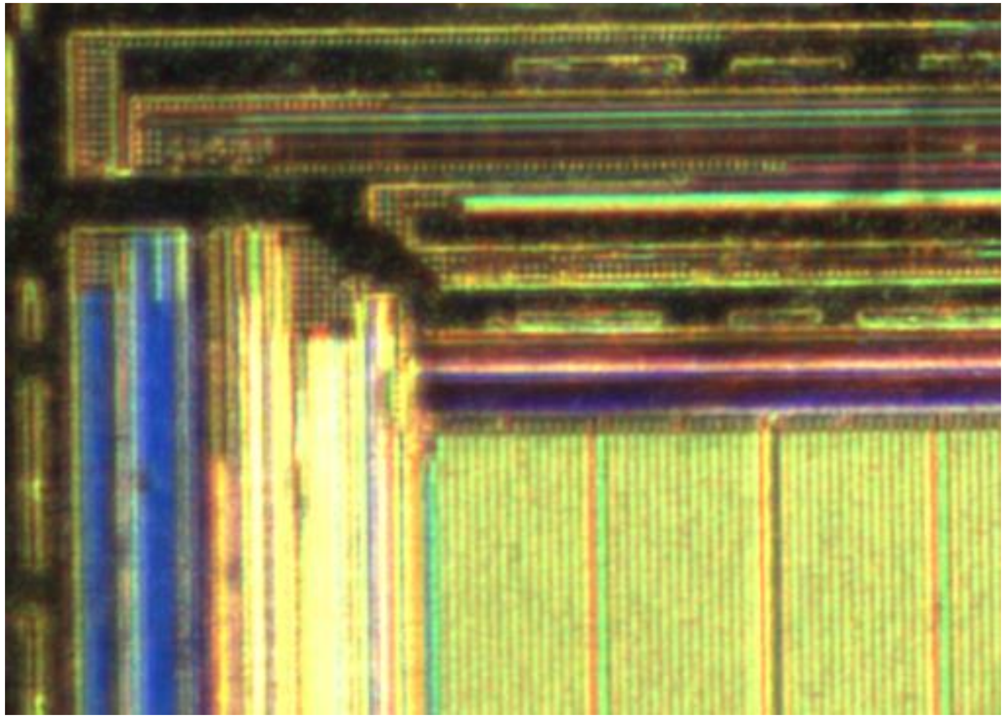
S. Peracchi et al., "LET calibration of ion microbeams and their SEE cross-section characterisation", IEEE Trans. Nucl. Sci, 2024, DOI: 10.1109/TNS.2024.3372135

Ambient Irradiation

Precision sample positioning







Package size
6.6 mm by 9.6 mm

Die size
3.0 mm by 2.7 mm

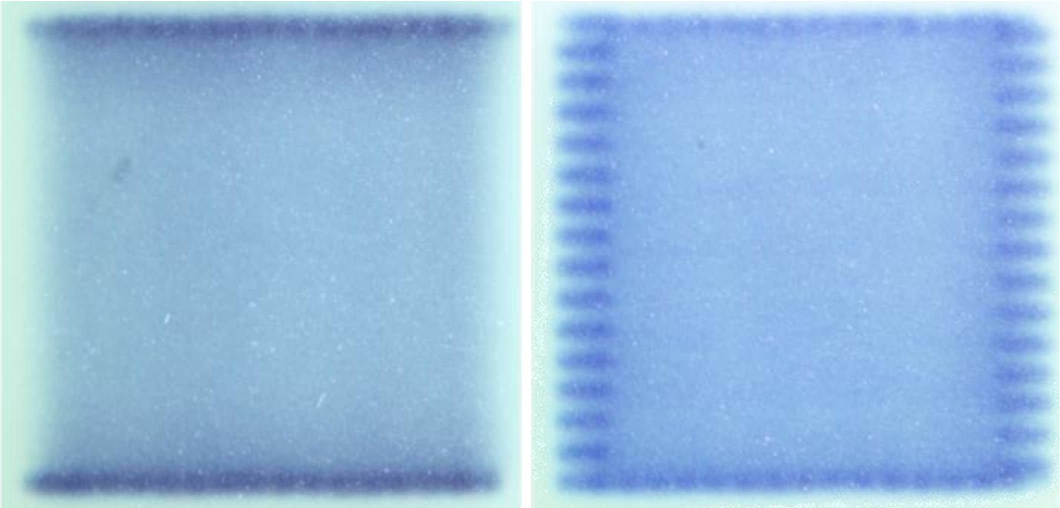
Field of view
1.76 mm by 1.33 mm

Lens distortion
<0.2%

Pixel resolution
0.86 µm/px

Ambient Irradiation

Scanning methods
EM coil and motorised stage



Electromagnetic Scanning

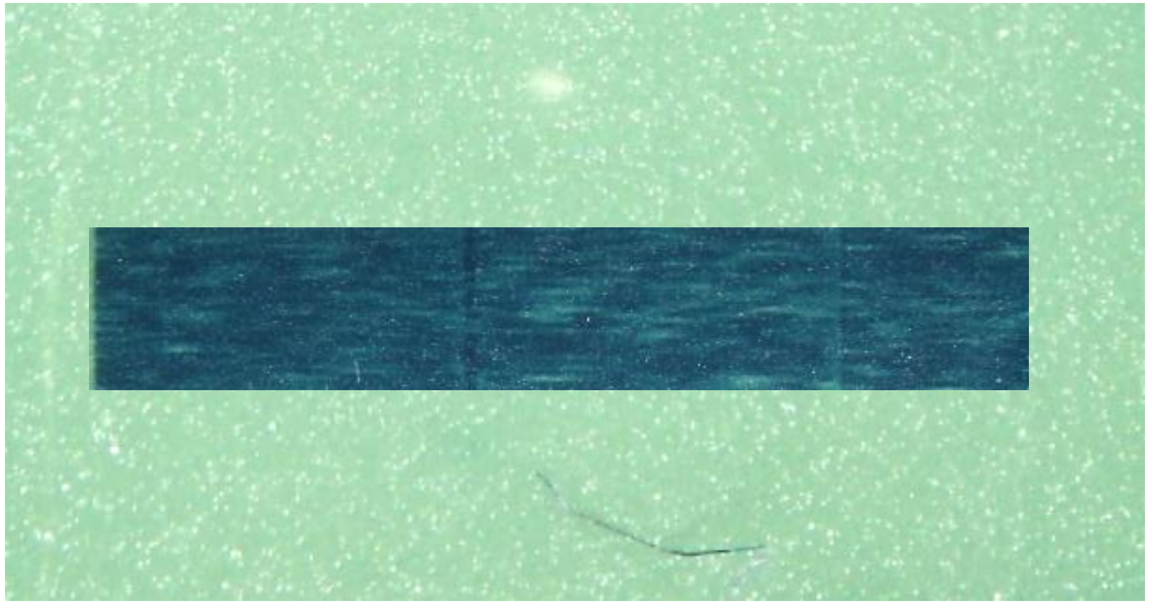
- Area (XY): from 50 x 50 μm to 4 x 3 mm
- Resolution: 64 – 1024 pixel scanning in both XY
- Pixel dwell time: 100 μs – 1s
- Speed: dependent on pixel resolution and dwell time

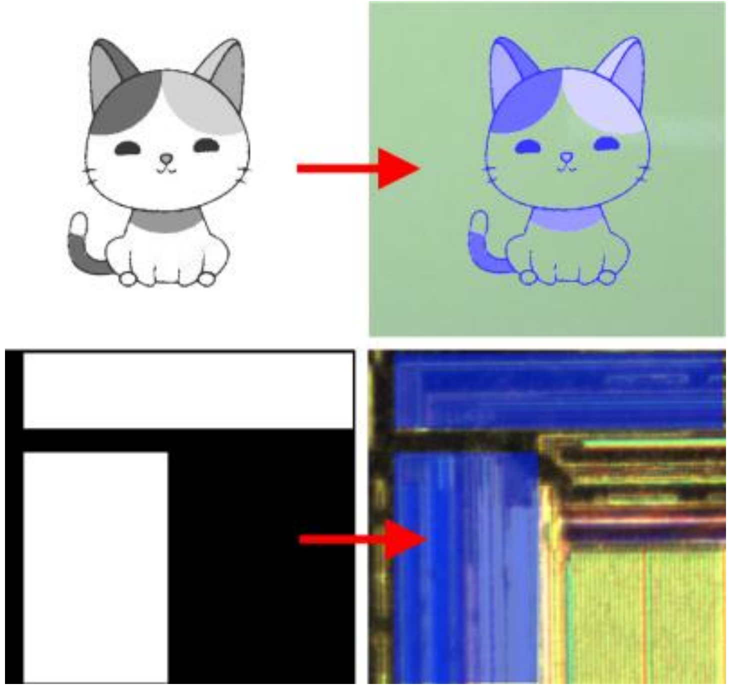
Motorised Stage Scanning

- Range (XYZ): 0 – 50mm
- Area (XY): up to 50 x 50mm, depending on sample size
- Resolution: repeatability of 0.8 μm
- Speed: up to 2.4 mm/s

Ambient Irradiation

Scanning methods
In development





Hybrid Scanning
Synchronisation between beam and stage scanning systems:

- Faster beam scanning in Y-axis
- Larger range stage scanning in the both axes

Greyscale & Arbitrary Patterns
Image or arbitrary waveform fed into the scan amplifier:

- Variable dose/flux across the target
- Can avoid or target multiple sensitive regions

AccelApp'24

Applying for ANSTO access

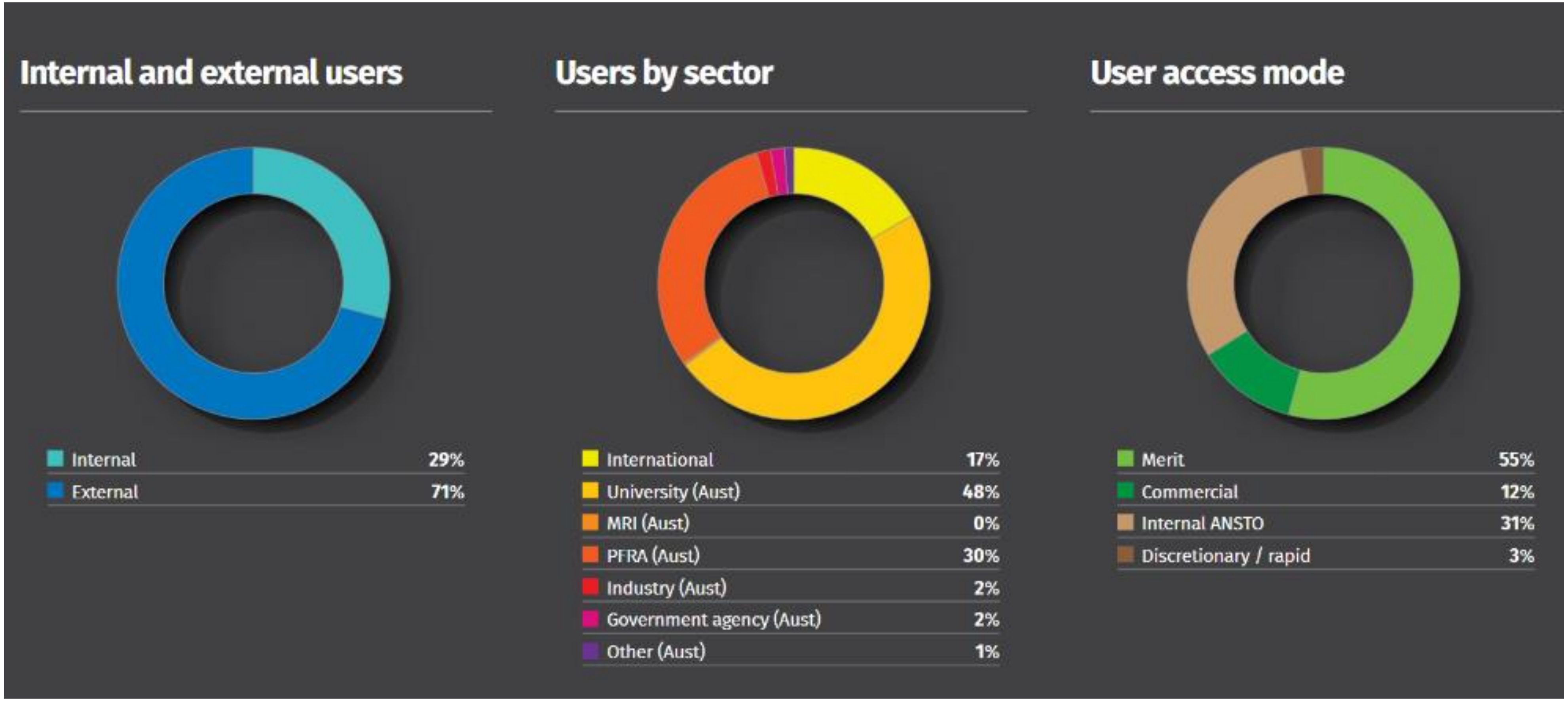
1. Merit - based	2. Commercial	3. Collaborative
Two proposal rounds every year	Commercial contract access including scientific consultancy	Longer term projects based around external grants or a memorandum of understanding (MOU).
Peer-reviewed competitive access, ranked on scientific merit, approved per capacity	Timely and rapid access, minimal waiting period	Continuously open for concept proposals and feasibility discussions
Fully funded (no charge) but an expectation to publish and share data	IP conditions that support commercial use	Charge varies but an expectation to publish

https://portal.ansto.gov.au/

ANSTO

Applying for ANSTO access

Centre for Accelerator Science



>300 individuals on approved proposals per year

>60 publications with CAS authors or featuring CAS data per year

Could this be you? This could be you.

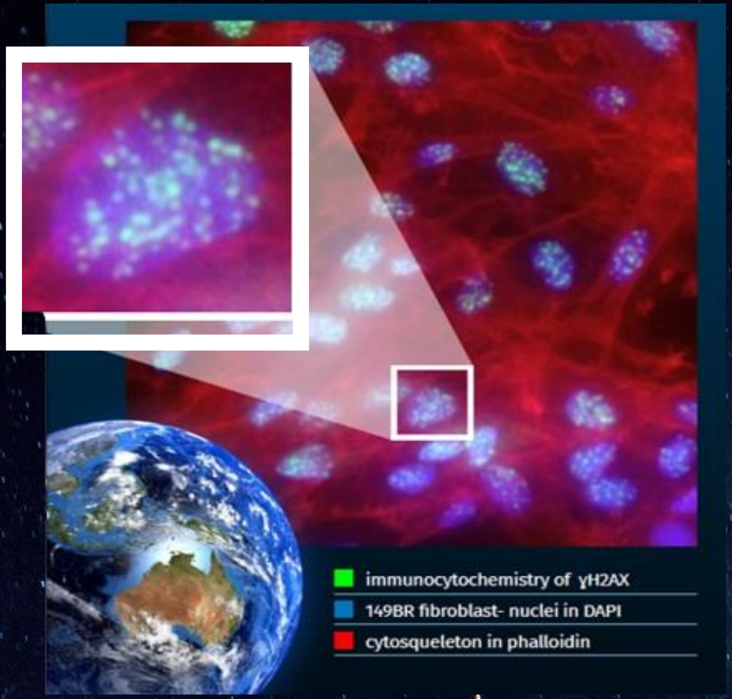
AccelApp'24
2024 International Topical Meeting on Nuclear Applications of Accelerators

CASE STUDY

Radiobiology

Scope
Study of DNA double strand breaks in humans' exposure in space, by Dr Melanie Ferlazzo (ANSTO).

Sample
Non-transformed human fibroblast cells (149BR), mono-layer adherent culture grown on 75nm silicon nitride membrane.

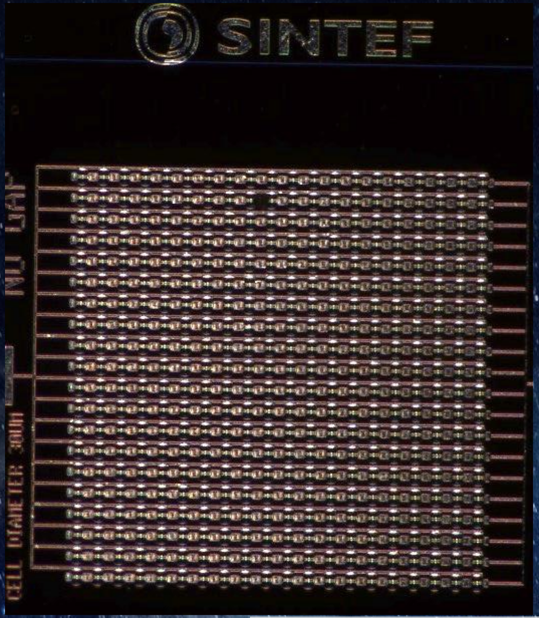


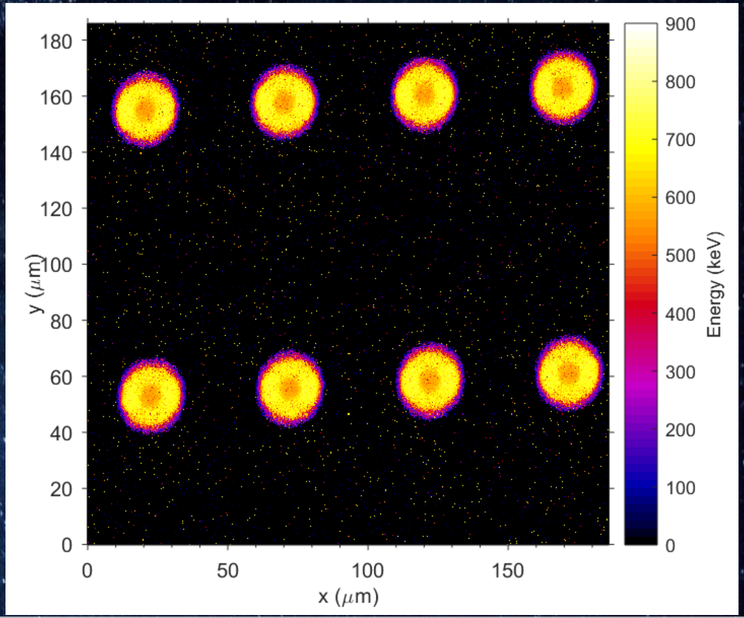
Results not yet published, studies are ongoing

Dosimetry

Scope
Development of microdosimeter for dose and dose rate monitoring of astronauts and mixed field characterisation, by D/Prof Anatoly Rosenfeld & team (UOW).

Sample
3D silicon-on-insulator (SOI) microdosimeters with varying active layer thicknesses



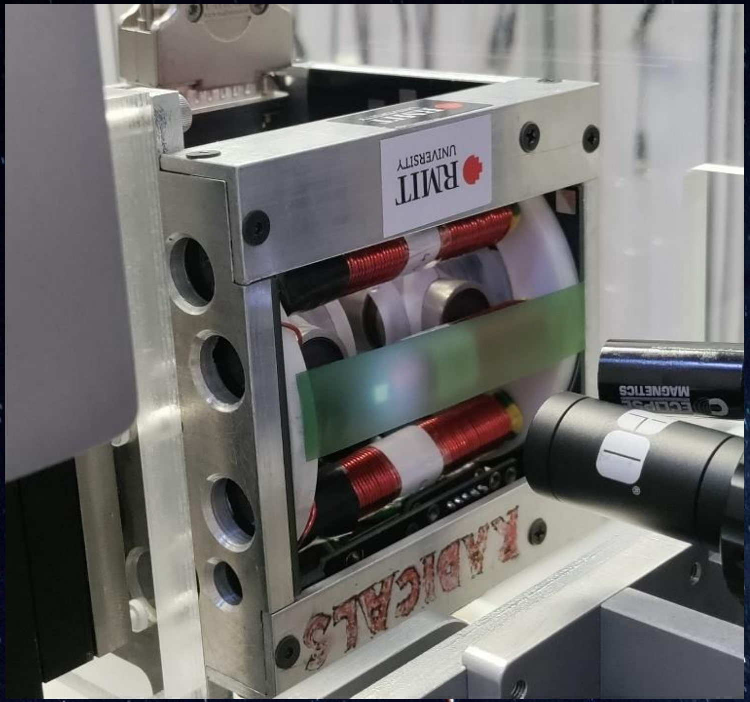


S. Peracchi et al., "LET calibration of ion microbeams and their SEE cross-section characterisation", IEEE Trans. Nucl. Sci, 2024, DOI: 10.1109/TNS.2024.3372135

Active Shielding

Scope
Performance of active magnetic shielding to deflect space radiation (i.e. protons and light ions), by Prof. Gail Iles & team (RMIT).

Sample
1U payload "RADICALS" (Radiation Deflector of Ionising Charges using a Lorentz Shield).

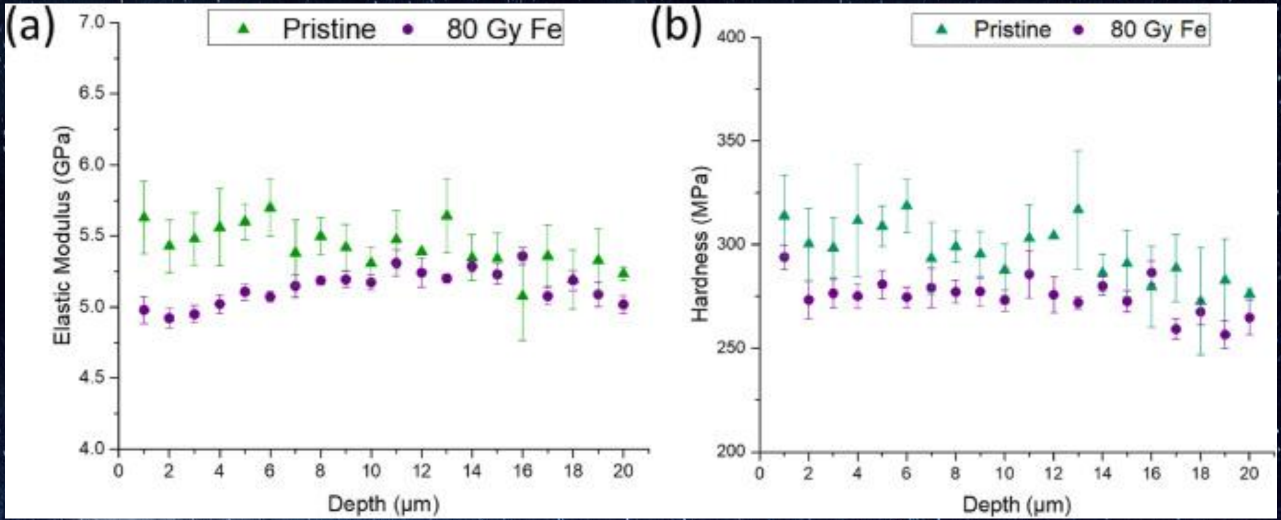


Results not yet published, studies are ongoing

Advanced Materials

Scope
Evaluating radiation effects on the material properties of additively manufactured PEKK, for future habitats on Moon and Mars, by Dr Kaifur Rashed (RMIT)

Sample
FDM printed poly ether ketone ketone (PEKK)



Kaifur Rashed, et al., "Investigation of effects induced by 57 MeV 56Fe ions and 9 MeV Protons on additively manufactured PEKK for space application", Polymer Testing, pp. 108354, 2024

CASE STUDY

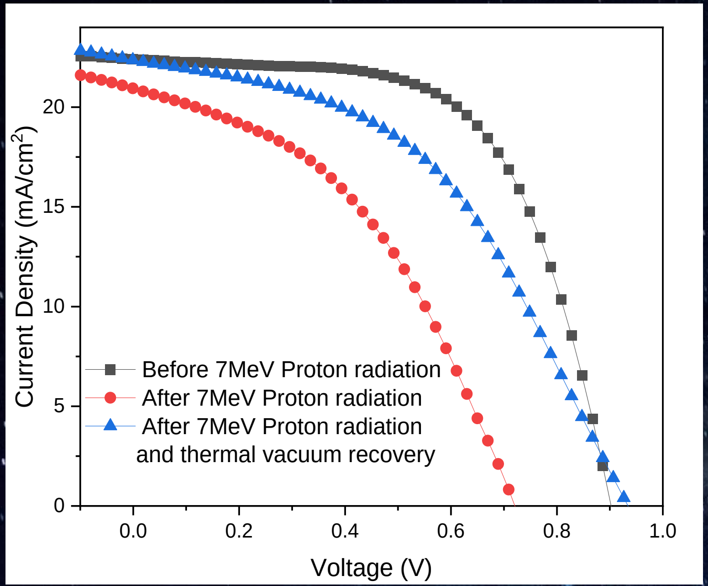
Solar Cells

Scope

Effect materials and doping on the Stability and Recoverability of Perovskite Solar Cells on Very Thin Substrates, by Prof. Anita Ho-Baillie and Dr Shi Tang (USYD)

Sample

Perovskite solar cells samples of various compositions and thicknesses.



S. Tang et. Al, “Effect of Hole Transport Materials and Their Dopants on the Stability and Recoverability of Perovskite Solar Cells on Very Thin Substrates after 7 MeV Proton Irradiation”, vol 13, no 25, 2023, DOI:10.1002/aenm.202300506

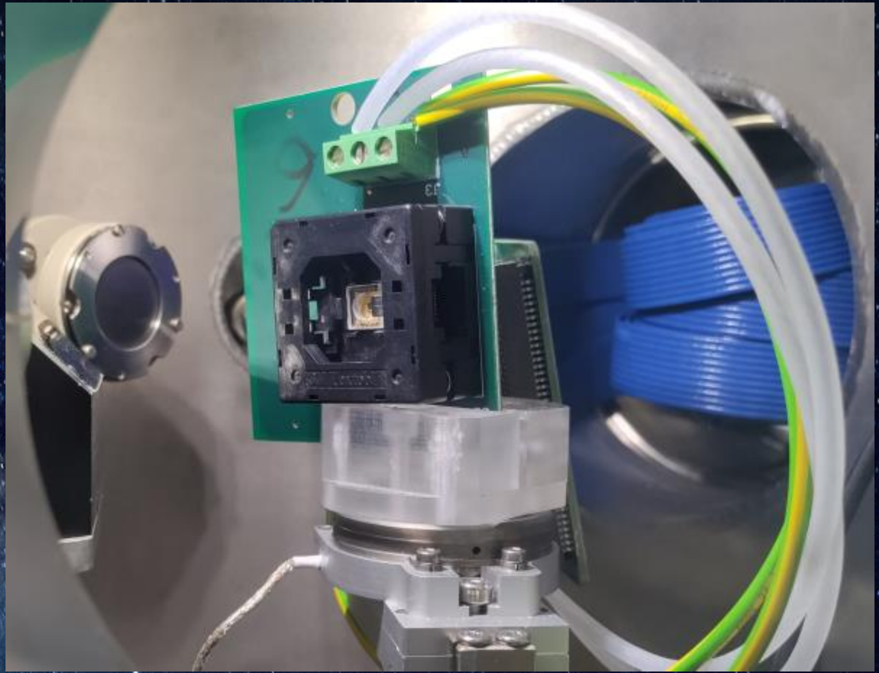
Electronics

Scope

Evaluation of a radiation hardened static RAM for high-energy physics experiments and space applications, by Dr Jafar Shojaii (Swinburne University)

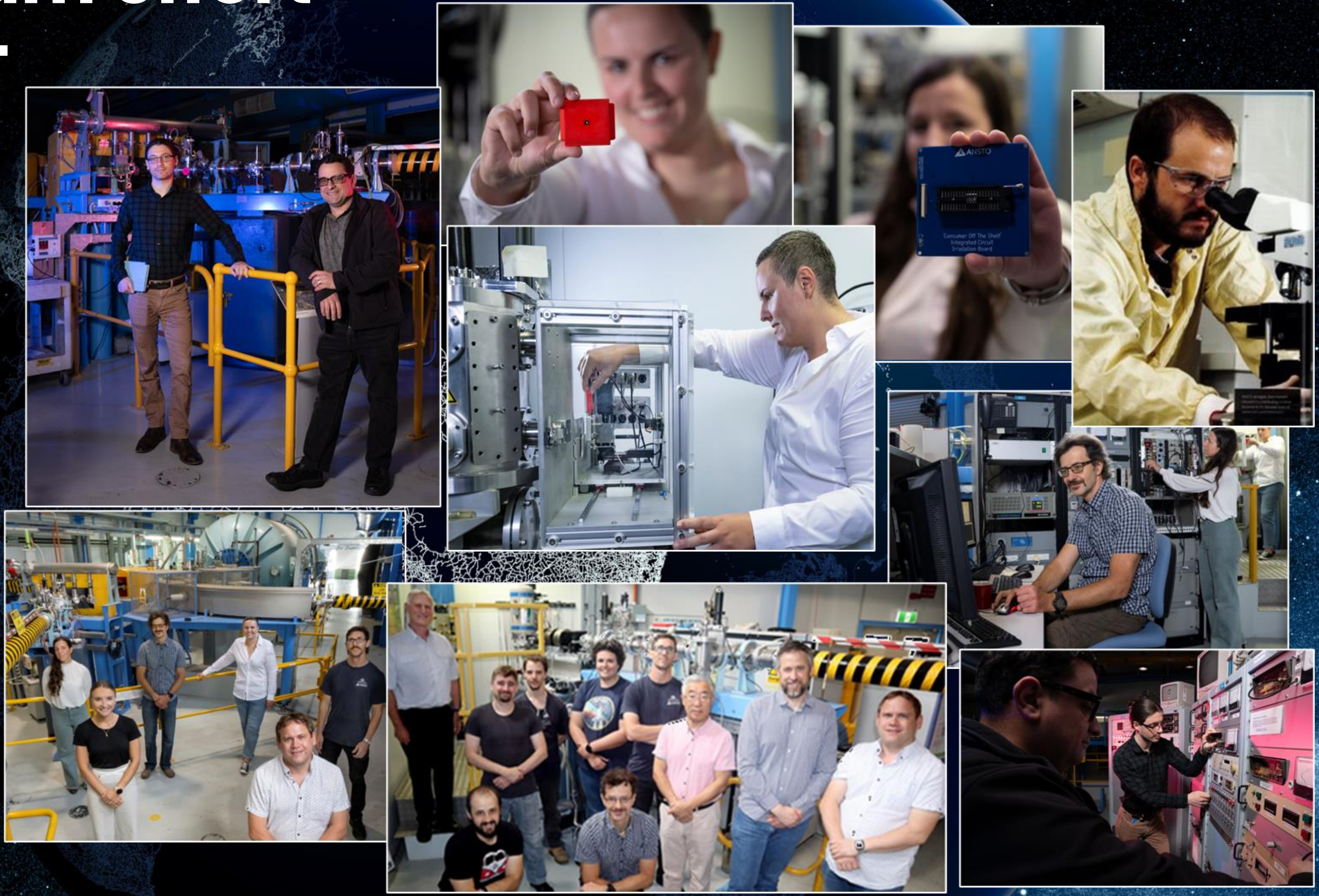
Sample

Custom designed radiation hardened 65 nm CMOS SRAM.



Results are partially IP, partially under publication consideration

Team effort



ANSTO team

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Australian Space Agency

NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

ANSTO