

ACAS Australian Collaboration for Accelerator Science



THE UNIVERSITY OF
MELBOURNE

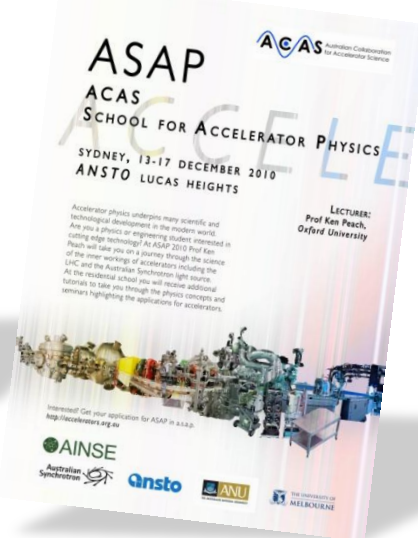


- Australian Collaboration for Accelerator Science – MoU between the four largest accelerator labs in Australia: Australian Synchrotron, ANSTO, ANU and University of Melbourne.
- Launched in 2010 by then then Science Minister Kim Carr and the present Chief Scientist Prof. Ian Chubb.
- ACAS Directors Roger Rassool (Uni. Melb.) and Mark Boland (AS and Uni. Melb.)



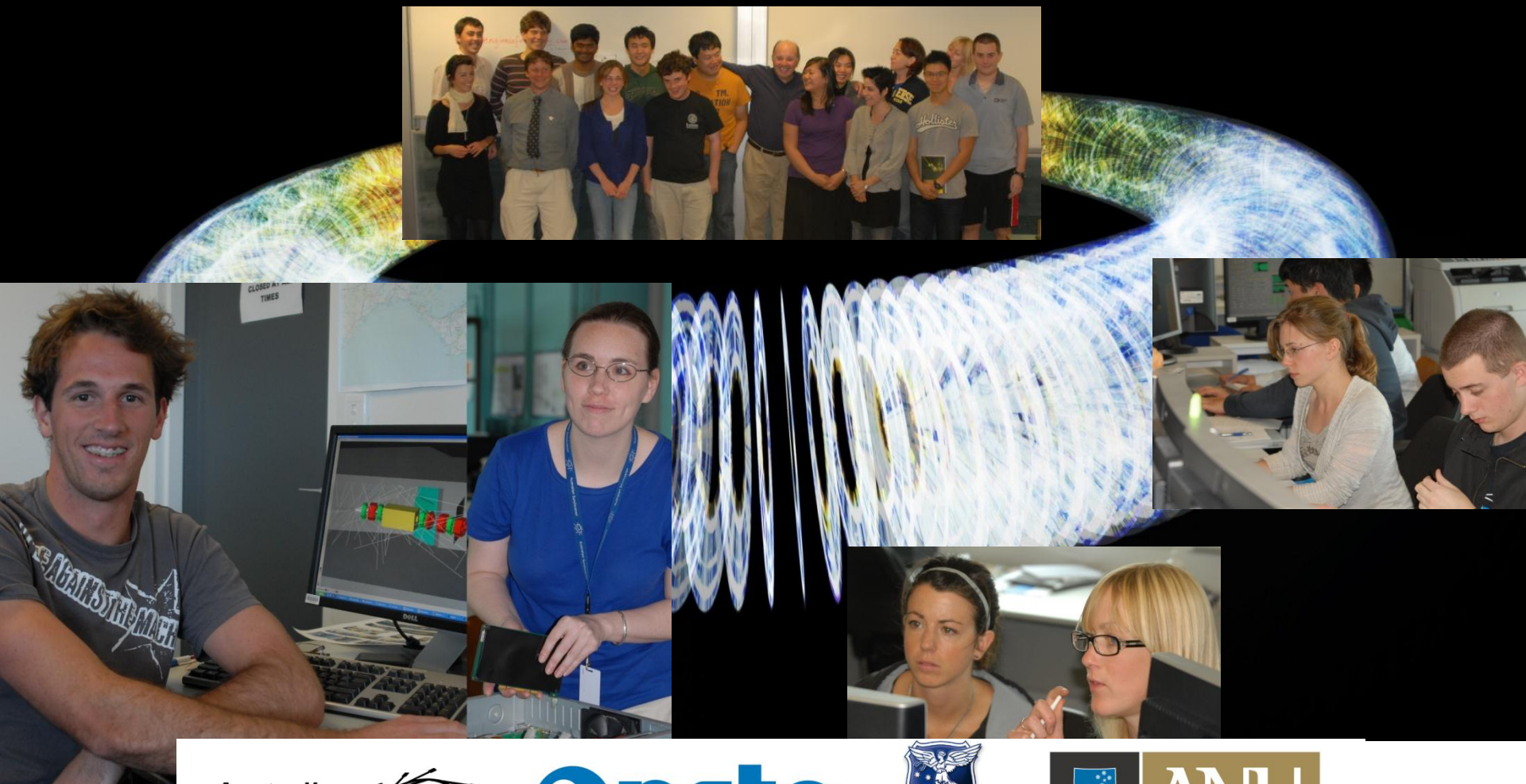
ASAP - ACAS School for Accelerator Physics

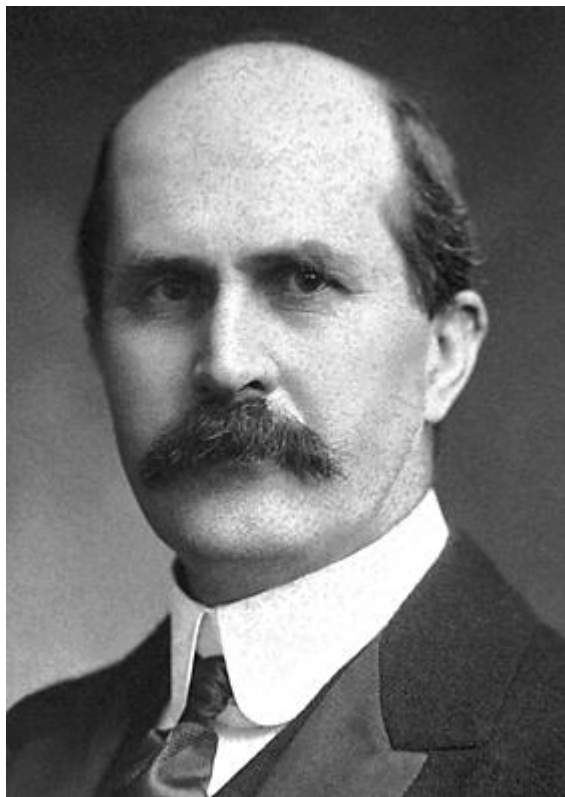
- 2008 Ted Wilson, CERN/Oxford Uni, Melbourne.
- 2010 Ken Peach, CERN/Oxford Uni, Sydney.
- 2012 Emmanuel Tsesmelis, CERN/Oxford Uni, Melbourne.
- 2014 Phil Burrows, JAI/Oxford Uni, Melbourne.
- 2016 John Fox, SLAC/Stanford Uni, Melbourne.



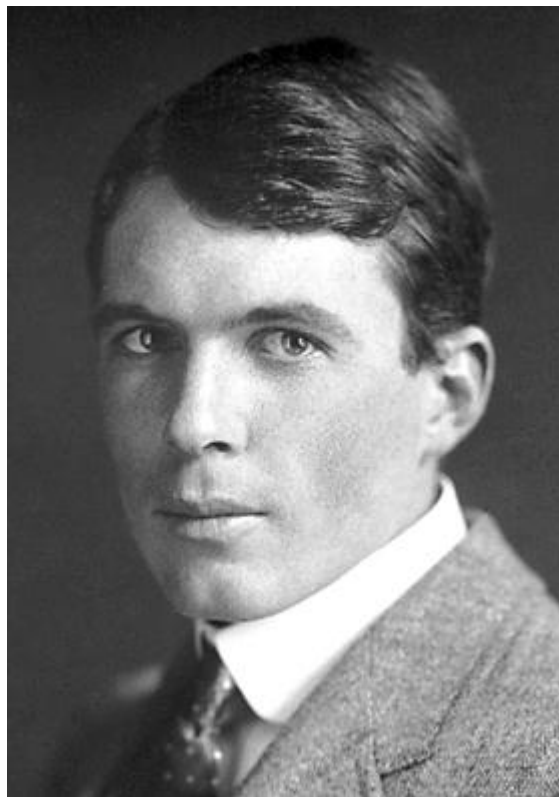
<http://accelerators.org.au>

ACAS – helping to build the future





William Bragg
Elder Professor of Physics
at the University of Adelaide
from 1886 to 1909



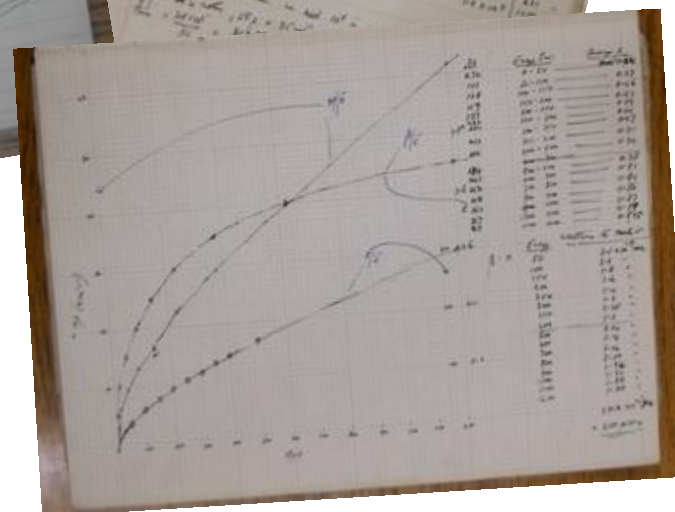
Laurence Bragg
Born 31 March 1890,
Adelaide, Australia
Educated at Adelaide University

- November 2012 marks the centenary of the founding of X-ray crystallography by Lawrence Bragg
- He and his father, William, were recognised by the award of the Nobel Prize for Physics in 1915
- Laurence was born and educated in Adelaide, Australia
- The BRAGG Symposium 6 Dec 2012, Adelaide



Synchrotron: An Australian Invention?

- Oliphant's Notebooks Adelaide University



"The New Method"

THE ACCELERATION OF PARTICLES TO VERY HIGH ENERGIES.

Introduction.

The properties of elementary particles with energies up to 10 or 20 million electron-volts (10-20 MeV.) have been investigated extensively during recent years. In the war period this work has been intensified in some directions, although it has lapsed in others. A great deal of work remains to be done, but it is probable that the main outlines of nuclear physics in this region are now clear. In any event there is ample equipment in existence in USA and elsewhere to fill in most of the gaps in our knowledge, while much will be accomplished in the government laboratories which will be set up in various countries to exploit the possibilities of nuclear fission.

The new method.

The essential feature of the proposals is that the particle should be constrained to move in a circle of constant radius, thus enabling the use of an annular ring of magnetic field of the correct form but over a total volume which is small enough to require only moderate power for its excitation. The magnetic field would be varied in such a way that the radius of curvature remains constant as the particles gain energy through successive accelerations by an alternating electric field applied between coaxial hollow electrodes, as in the cyclotron. The varying magnetic field performs the function of the guiding field in the betatron, but the acceleration is provided by an applied potential rather than by a changing flux. In this way it is possible to apply much higher accelerations per revolution. The changing magnetic field can be produced by an application of modern pulse technique as developed for radar purposes, while the accelerating potential can be provided by the same general method. Essentially, very large powers are available during the acceleration of a single burst of particles, a relatively long quiescent period between pulses reducing the average power consumed to a reasonable value.

At energies of 1000 MeV., or more, electrons and protons do not differ markedly in effective mass or velocity. Hence the greatest differences in technique required for the two particles will exist at the lower range of energies through which the particles are accelerated. These differences render it necessary to proceed in somewhat different ways in the case of ~~about~~ electrons and protons.

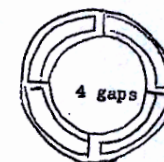
...particles should be constrained to move in a circle of constant radius thus enabling the use of an annular ring of magnetic field... which would be varied in such a way that the radius of curvature remains constant as the particles gain energy through successive accelerations by an alternating electric field applied between coaxial hollow electrodes.

Accelerating Electrodes.

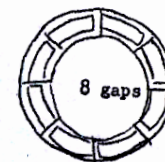
The particles may be accelerated by passage across one or more gaps between electrodes, across which an a.c. voltage is applied at the proper frequency.



(1)



(2)



(3)

The A.C. frequency is, for the Larmor frequency, $\nu_0 = 1.2 \times 10^7$.

$$\begin{array}{lcl} 1) \nu = \nu_0 = 1.2 \times 10^7 & \text{cycles/second,} & \lambda = 25 \text{ metres.} \\ 2) \nu = 2\nu_0 = 2.4 \times 10^7 & & \lambda = 12.5 \text{ metres.} \\ 3) \nu = 4\nu_0 = 4.8 \times 10^7 & & \lambda = 6.25 \text{ metres.} \\ \text{etc.} & & \end{array}$$

The gap voltages required to add an energy of 0.5 MeV per revolution are

- 1) 250,000 volts,
- 2) 125,000 "
- 3) 62,500 "

These frequencies and voltages can be obtained by coupling to an oscillator operating continuously, and their production is especially easy with pulsed operation.

M. Oliphant, The Acceleration of Particles to Very High Energies, Memo for UK Atomic Energy Directorate (1943).

Discovery of Synchrotron

The Synchrotron—A Proposed High Energy Particle Accelerator

EDWIN M. McMILLAN
University of California, Berkeley, California
September, 5, 1945

ONE of the most successful methods for accelerating charged particles to very high energies involves the repeated application of an oscillating electric field, as in the cyclotron. If a very large number of individual accelerations is required, there may be difficulty in keeping the particles in step with the electric field. In the case of the cyclotron this difficulty appears when the relativistic mass change causes an appreciable variation in the angular velocity of the particles.

The device proposed here makes use of a “phase stability” possessed by certain orbits in a cyclotron. Consider, for example, a particle whose energy is such that its angular velocity is just right to match the frequency of the electric field. This will be called the equilibrium energy. Suppose

McMillan, Phys Rev 68 p143 (1945)

Concerning Some New Methods of Acceleration of Relativistic Particles

V. VEKSLER
Lebedev Physical Institute of the Academy of Sciences, Moscow, U.S.S.R.
February 16, 1946

IN two papers^{1,2} appearing in 1944 under the above title the author of the present letter pointed out two new principles of acceleration of relativistic particles which generalize the resonance method.

New possibilities for the resonance acceleration of particles in a constant magnetic field are described in the first of these papers, and the possibility of resonance acceleration in magnetic fields which increase with time is also noted.

This latter case is specially examined in the second paper. It is shown that phase stability automatically sets in if the time variation of the field is sufficiently small; relation between the amplitude of the variable electric fields and the rate of variation of the magnetic field is established.

It is also pointed out that the radiation losses in such acceleration do not violate phasing mechanism. Finally in a detailed paper³ an accelerator of heavy particles based on a variation in frequency is analyzed.

Thus the foregoing papers cover completely the contents of the note by McMillan⁴ in which no reference is made to my investigations.

Construction of a 30-Mev accelerator with varying magnetic field is now nearing completion at the Physical Institute of the Academy of Sciences, U.S.S.R.

¹ V. Veksler, Comptes Rendus (Doklady), Acad. Sci. U.S.S.R. **43**, No. 8, 444 IX (1944) (communicated April 25, 1944).

² V. Veksler, Comptes Rendus (Doklady), Acad. Sci. U.S.S.R. **44**, No. 9, 393 (1944) (communicated July 19, 1944).

³ V. Veksler, J. Phys. (U.S.S.R.) **9**, No. 3, 153 (1945) (received March 1, 1945).

⁴ E. McMillan, Phys. Rev. **68**, 143 (1945).

Veksler, Phys Rev 69 p244 (1946)

Australian Invention?

- Mark Oliphant – invented the synchrotron in his “spare time”

Marcus Laurence Elwin Oliphant (1901–2000)

Australian physicist

Inventor of the synchrotron

Pioneered centimeter radar and the atomic bomb



Mark Oliphant was an impressive individual, tall, with thick white hair. He spoke convincingly and energetically and in later life described himself as “a belligerent pacifist.” Educated at Adelaide University, he joined Ernest Rutherford’s group at the Cavendish Laboratory, Cambridge in 1927. He and Rutherford were the first to identify tritium and helium-3 produced by bombarding light nuclei with protons and deuterons.

By 1937 he was a Professor at Birmingham and, charged with overseeing Britain’s coastal defenses, saw the clear need to use a radar wavelength much shorter than the 170 cm then current. His department set about developing a suitable power source and before long John Randall and Harry Boot from his department invented the magnetron. This was a device that made it possible for aircraft to carry their own radar and upon which the fate of the war hinged. He took this precious gift to the USA in 1941 where there were the resources to develop and mass produce it.

Andrew Sessler and Edmund Wilson, *Engines of Discovery – A Century of Particle Accelerators*, World Scientific, Singapore (2007).

OLIPHANT AUDITORIUM



A pioneering accelerator physicist, the inventor of the synchrotron particle accelerator and founding President of the Australian Academy of Science – the Australian Synchrotron is very proud to name this auditorium in honour of Sir Mark Oliphant AC, KBE, FRS.

Born Marcus Laurence Elwin Oliphant in Adelaide in 1901, the eldest son of a public servant, he rose to prominence as an inventive and brilliant physicist and carried his impressive achievements over into public life. As a physicist his crowning achievements include the invention of the synchrotron particle accelerator, the discovery of tritium and helium-3 and overseeing the development of radar. In public life and as a scientific leader he held several significant positions. These included the founding Director of the Research School of Physical Sciences at the newly constituted Australian National University (1950) and Governor of South Australia (1972) – a role in which he was very popular with the public. However, the achievement Oliphant was most proud of was the role he played in founding the Australian Academy of Science of which he was its first President in 1954.

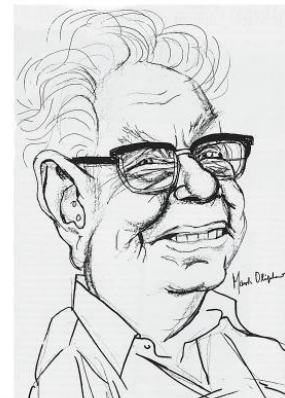
Like so many Australian scientists, Oliphant travelled overseas to make his mark in the world. He returned later in life bringing back his "fire in the belly" to inspire people to greater heights in his home country. After completing his education at Adelaide University, he joined the famed Cavendish Laboratories at Cambridge in 1927, which was then led by Ernest Rutherford – a fellow Antipodean who was to become a father figure to Oliphant. Together they were pioneers in the new field of Nuclear Physics. Their careful experiments on the "basement accelerator" that Oliphant designed and built established him as an accelerator physicist and enabled them to split the atom to discover the two

new isotopes tritium and helium-3. In 1937 he took up his own Professorship at Birmingham University where he led the team that invented the magnetron, a compact power source that made it possible to carry radar in aircraft. In 1941 he went to the US to persuade their government to hasten a fission bomb program resulting in the Manhattan Project which he later joined. The use of the atomic bomb on civilians horrified him into becoming a lifelong "belligerent pacifist".

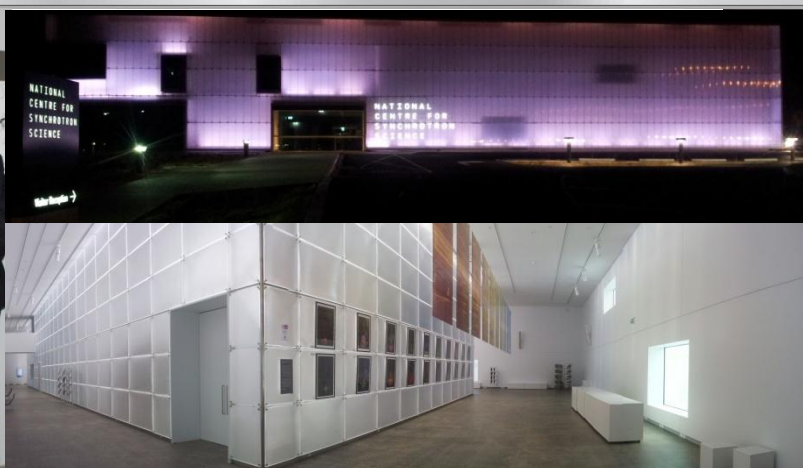
While in the US, Oliphant was deputy to Ernest Lawrence at the University of California Radiation Laboratory. On assignment at the experimental electromagnetic separation plant at Oak Ridge, Tennessee, he did many night shifts during which time he penned a memo titled "The Acceleration of Atomic Energy, UK, he outlined his "new method" – the principle of the synchrotron accelerator. Using the newly invented principle Oliphant later designed and built a 1 GeV proton synchrotron in Birmingham. At the heart of the Australian Synchrotron is a 3 GeV electron synchrotron accelerator which has been in operation since 2007.

Sir Mark Oliphant died in Canberra in 2000 aged 98.

Dr Mark Boland
Principal Accelerator Scientist, Australian Synchrotron



The Oliphant Auditorium was named, in the presence of members of Sir Mark Oliphant's family, and distinguished guests of the Australian Academy of Science, 100 Years Since 1916, Melbourne dinner, held at the ACSS, Thursday 20 July 2016



Asian Committee for Future Accelerators (ACFA) this week created a new IPAC Asia prize for PhD students in accelerator physics named in honour of Mark Oliphant. First prize to be presented at IPAC'16 in Korea.



Nuclear Instruments and Methods in Physics Research A 382 (1996) 20–31

**NUCLEAR
INSTRUMENTS
& METHODS
IN PHYSICS
RESEARCH**
Section A

A history of accelerators in Australia

T.R. Ophel*

*Department of Nuclear Physics, Research School of Physical Sciences and Engineering, Australian National University,
Canberra 0200, Australia*

Abstract

Over a period of almost sixty years, a surprisingly diverse range of accelerator activity has occurred.

The earliest involved the electrostatic machines constructed at the University of Melbourne between 1938 and 1950. The most ambitious project undertaken, a 10.6 GeV proton synchrotron at Canberra, was never completed.

These and other developments in laboratories through the country will be reviewed.

History of Accelerators in Australia

T.R. Ophel, *A history of accelerators in Australia*, Nuclear Instruments and Methods in Physics Research Section **A382**, 20-31 (1996)

Cockcroft-Walton accelerators

| Rated voltage | Location | Maker | Period of use | Comments |
|---------------|-------------------------|---|---------------|---|
| 200 kV | University of Melbourne | University of Melbourne (Martin & Hill) | 1938–51 | d–d neutron generator |
| 200 kV | University of Melbourne | University of Melbourne (Darby & Swan) | 1946–51 | d–d neutron generator. Higher current intensity than original. |
| 1.2 MV | ANU, Canberra | Philips, Eindhoven | 1951–67 | Current of 1 mA protons achieved. Sold to University of NSW 1967. |
| 0.6 MV | ANU, Canberra | Philips and ANU (Inall) | 1954–60 | Destroyed by fire, July 1960. |

Tandem accelerators

| Nominal rated voltage | Location | Maker | Period of use | Comments |
|-----------------------|--|--------------------------|--|---|
| 5 MV | ANU, Canberra (Nuclear Physics) | HVEC model EN (EN5) | 1961–78 (Canberra) 1985–present (New Zealand) | Highest voltage achieved 7 MV. Sold to DSIR, New Zealand. Shipped from Canberra in 1981. Now operating as AMS facility at Wellington, NZ. |
| 14 MV | ANU, Canberra (Nuclear Physics) | NEC Model 14UD | 1974–present | Has compressed geometry tube. Resistors have replaced corona point voltage distribution system. Now rated at 16 MV. A booster (ex-Oxford/Daresbury) is being added. |
| 1 MV | RMIT, Melbourne | General Ionex tandemtron | 1981–present | |
| 2.8 MV | CSIRO, North Ryde | General Ionex tandemtron | 1983–present | |
| 1.7 MV | ANU, Canberra (Electronic Materials Engineering) | NEC | 1990–present | SNICS source. Beam intensities of several hundred microamps available. |
| 7.5 MV | ANSTO, Lucas Heights | HVEC Model FN (FN1) | 1964–89 (Rutgers) 1991–present (ANSTO) | Obtained from Rutgers University, New Jersey. Mainly used for AMS measurements. |

Electron Accelerators*

| Energy | Location | Maker | Period of use | Comments |
|---------|---------------------------------|------------------------------------|---------------|---|
| 2.8 MeV | University of Melbourne | University of Melbourne (Lasich) | 1946–49 | Betatron. |
| 18 MeV | University of Melbourne | University of Melbourne (Muirhead) | 1949–62 | The original betatron was upgraded to a synchrotron. In two stages, the energy was increased to 14 MeV and then 18 MeV. |
| 33 MeV | ANU, Canberra (Nuclear Physics) | Metropolitan-Vickers (ex Harwell) | 1955–61 | A gift of the UK Government. Given to the University of Western Australia in 1962. It operated there for a number of years. |
| 30 MeV | University of Melbourne | Siemens | 1962–86 | |

* Excluding hospital radiation treatment facilities.

Single-ended Van de Graaffs

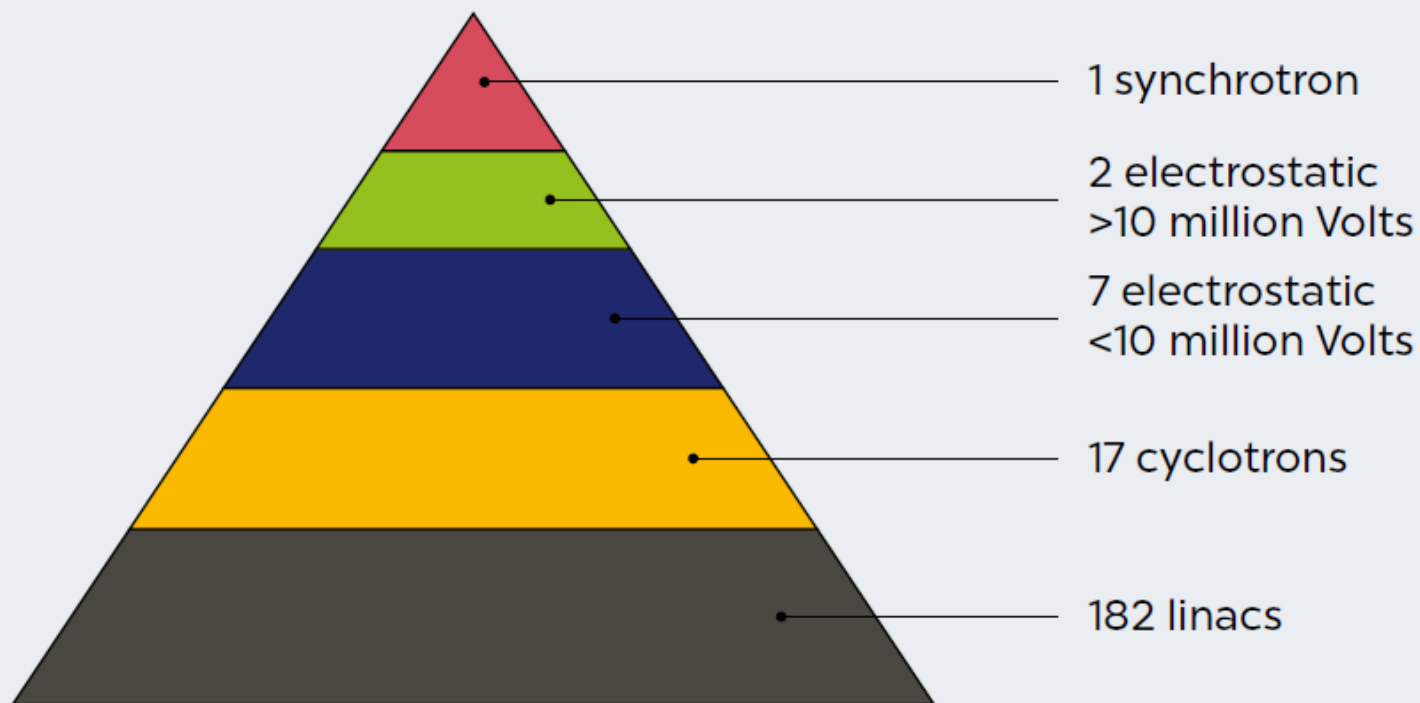
| Energy | Location | Maker | Period of use | Comments |
|--------|--|--|---------------|--|
| 1 MV | University of Melbourne | University of Melbourne (Martin, Hirst and Dunbar) | 1948–60 | Air-insulated. Construction started April 1946. |
| 0.8 MV | University of Melbourne | University of Melbourne (?) | 1952–73 | Air-insulated. Designated the Statitron. |
| 1.3 MV | AAEC, Lucas Heights | HVEC Burlington, MA | 1962–present | Installation 1961/2. DC electron beams of ~35 μ A or 3 μ s pulsed. |
| 2 MV | ANU, Canberra (Nuclear Physics) | HVEC Model AK | 1962–present | Original helium injector. Now used for RBS by Department of Electronic Materials Engineering. |
| 3 MV | AAEC, Lucas Heights | HVEC Model KN | 1964–present | Installation 1962–4. |
| 1 MV | ANU, Canberra (Nuclear Physics) | HVEC Model JN | 1967–73 | Used as helium injector. Superseded by lithex source. Sold to Queensland Institute of Technology 1973. |
| 2 MV | Western Australia Institute of Technology | HVEC | 1971–present | Now at University of NSW. Acquired by Chemical Physics, CSIRO in 1986 but remained in storage. |
| 0.4 MV | ANU, Canberra (Department of Physics, Faculties) | HVEC Model LC400 | 1971–present | The so-called teaching laboratory. Used for undergraduate training. |
| 5 MV | University of Melbourne | NEC Madison, WI Model 5U | 1975–present | Used to develop state of the art micro-probe beams. |

Cyclotrons

| Energy | Location | Maker | Period of use | Comments |
|--------------------|--------------------------------------|---|---------------|---|
| 10.6 GeV (Protons) | ANU, Canberra (Particle Physics) | ANU (Oliphant, Blamey, Hibbard & Smith) | – | Not completed 1950–60. The homopolar generator that was to power the air-cored magnet was used for plasma research |
| 7.7 MeV (Protons) | ANU, Canberra (Particle Physics) | ANU (Smith & Morton) | 1957–58 | 30 in. magnet originally used for proto-type homopolar generator. Built as injector for proton synchrotron. (Used for ρ , γ) |
| 12 MeV (Protons) | University of Melbourne | University of Melbourne (Caro & Rouse) | 1959–74 | A pioneering variable energy cyclotron. |
| 26 MeV (Protons) | ANU, Canberra (Nuclear Physics) | The Cyclotron Corporation Berkeley, CA | 1972–79 | Used as injector for EN tandem to provide 26–38 MeV protons or 14–26 MeV deuterons. Sold to Nihon Mediphsysics, Japan. Shipped May 1980. |
| 10 MeV (Protons) | Austin Hospital, Melbourne | Ion Beam Corp | 1992–present | Used for radio-isotope production. (^{11}C , ^{13}N , ^{18}O and ^{18}F) |
| 30 MeV (Protons) | Royal Prince Alfred Hospital, Sydney | Cyclone 10/5 | 1991–present | Used for radio-isotope production. |

Australian Population ~22M People

Numbers and types of accelerators in Australia



Future Accelerators

- Report published by the Australian Academy of Science
- Led by the User community
- Will be used in a call for future infrastructure requests



Australian Accelerator Science: Past, Present and Future

Associate Professor Mark Boland

Australian Synchrotron

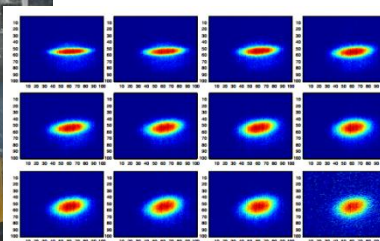
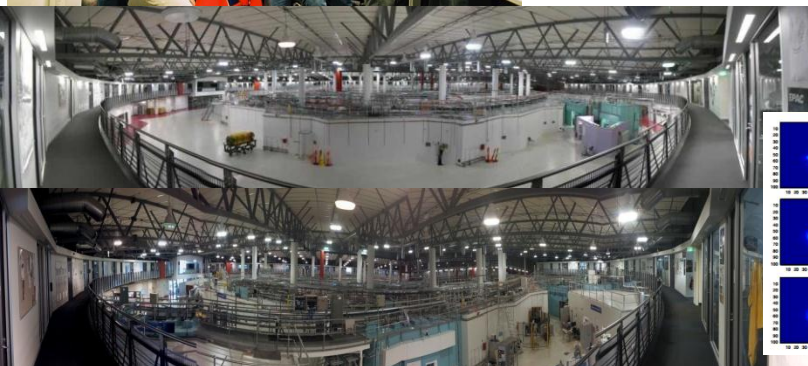
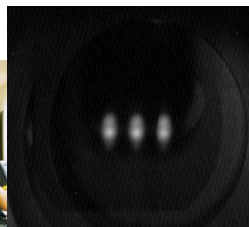
The University of Melbourne

Fulbright Visiting Scholar, Stanford University

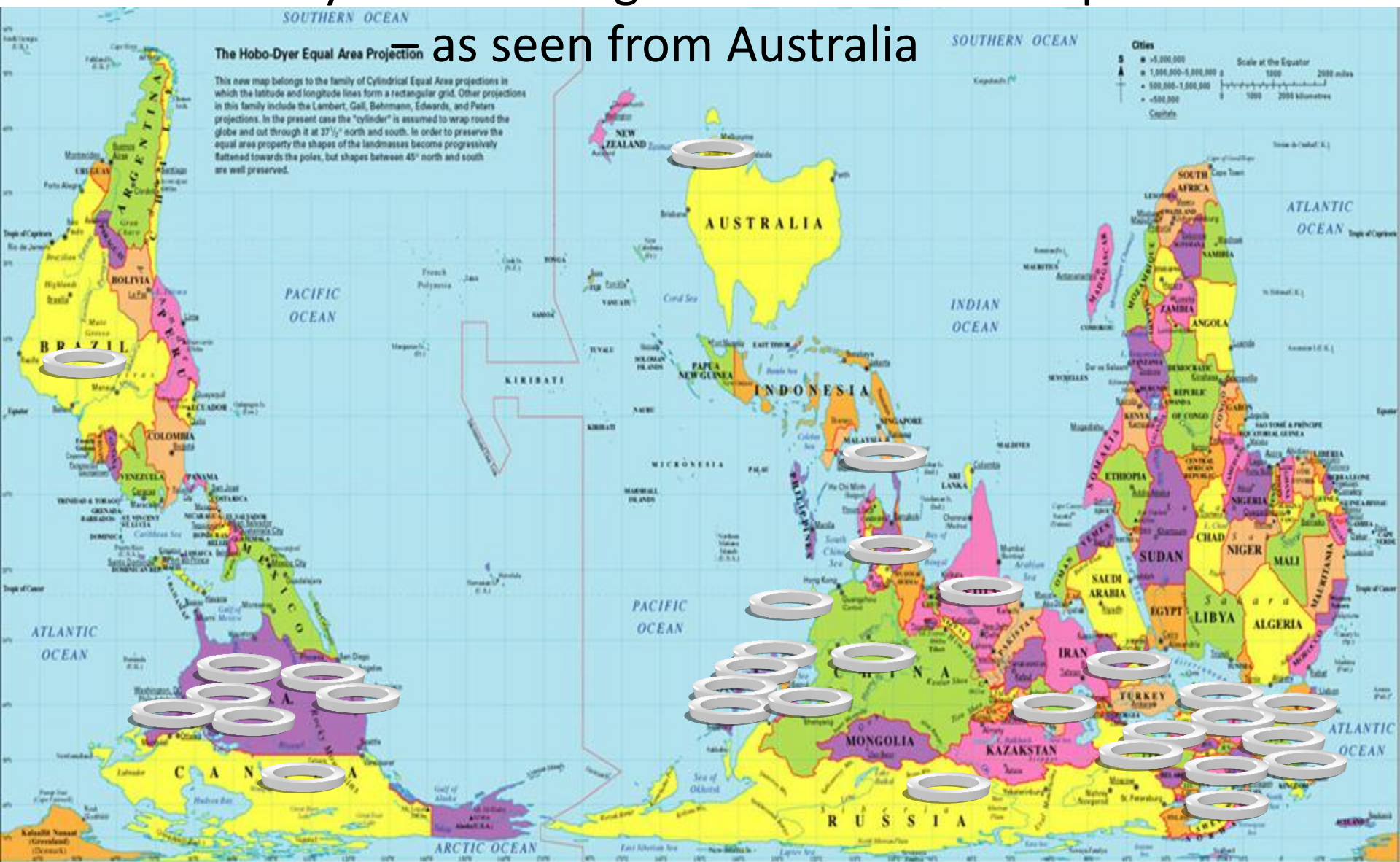


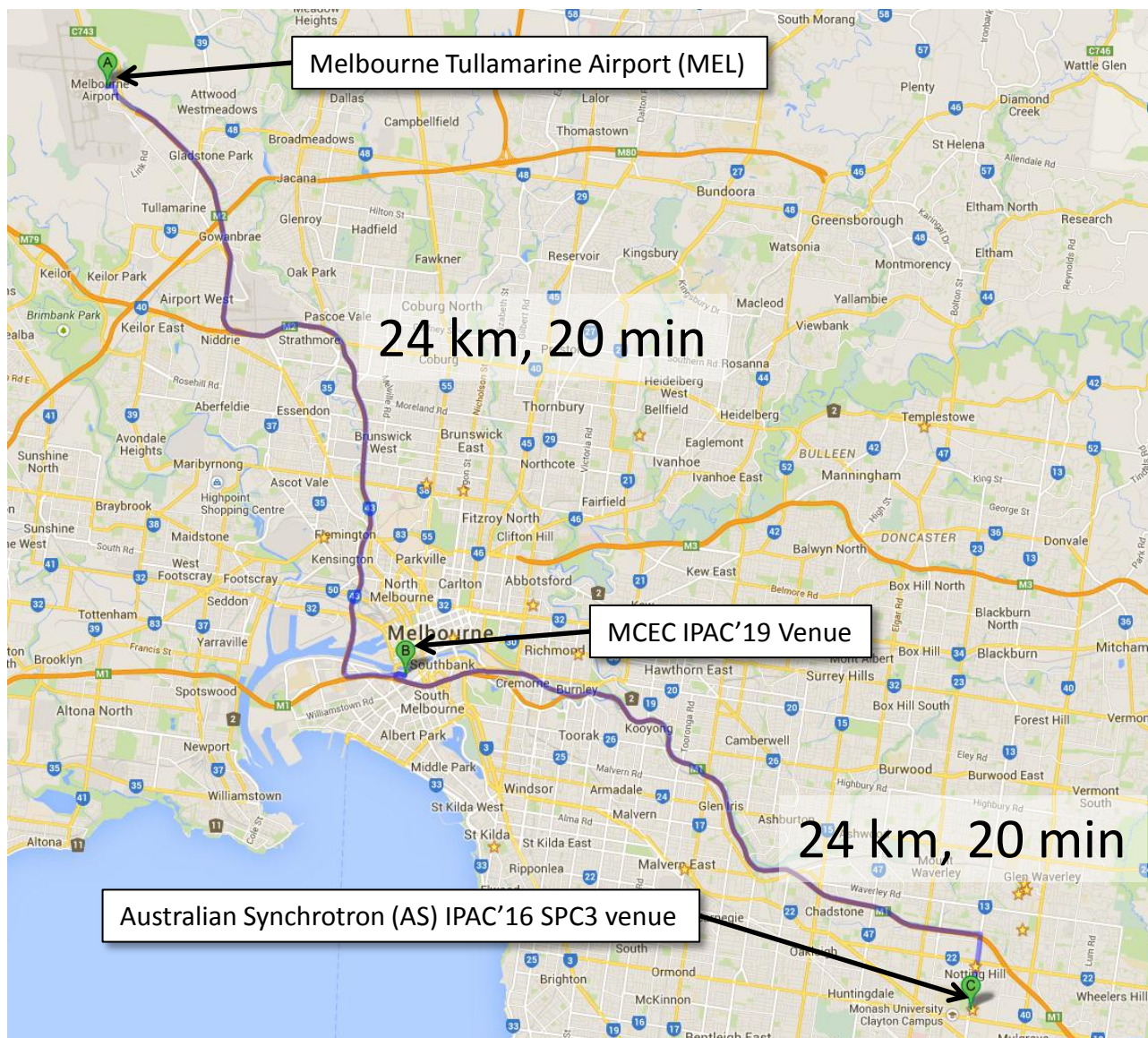
Australian Synchrotron

12 years at the Australian Synchrotron

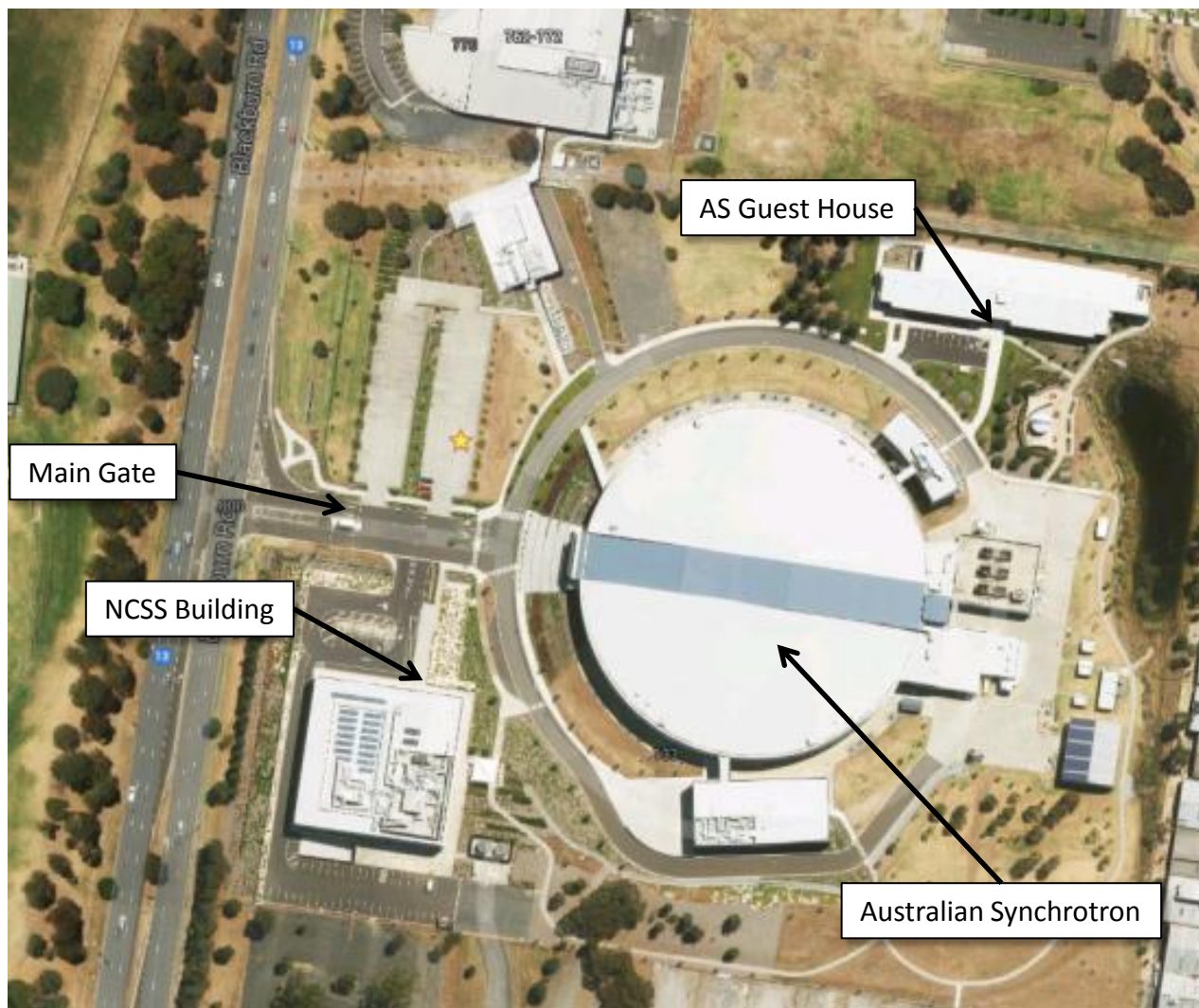


The Synchrotron Light Source World Map





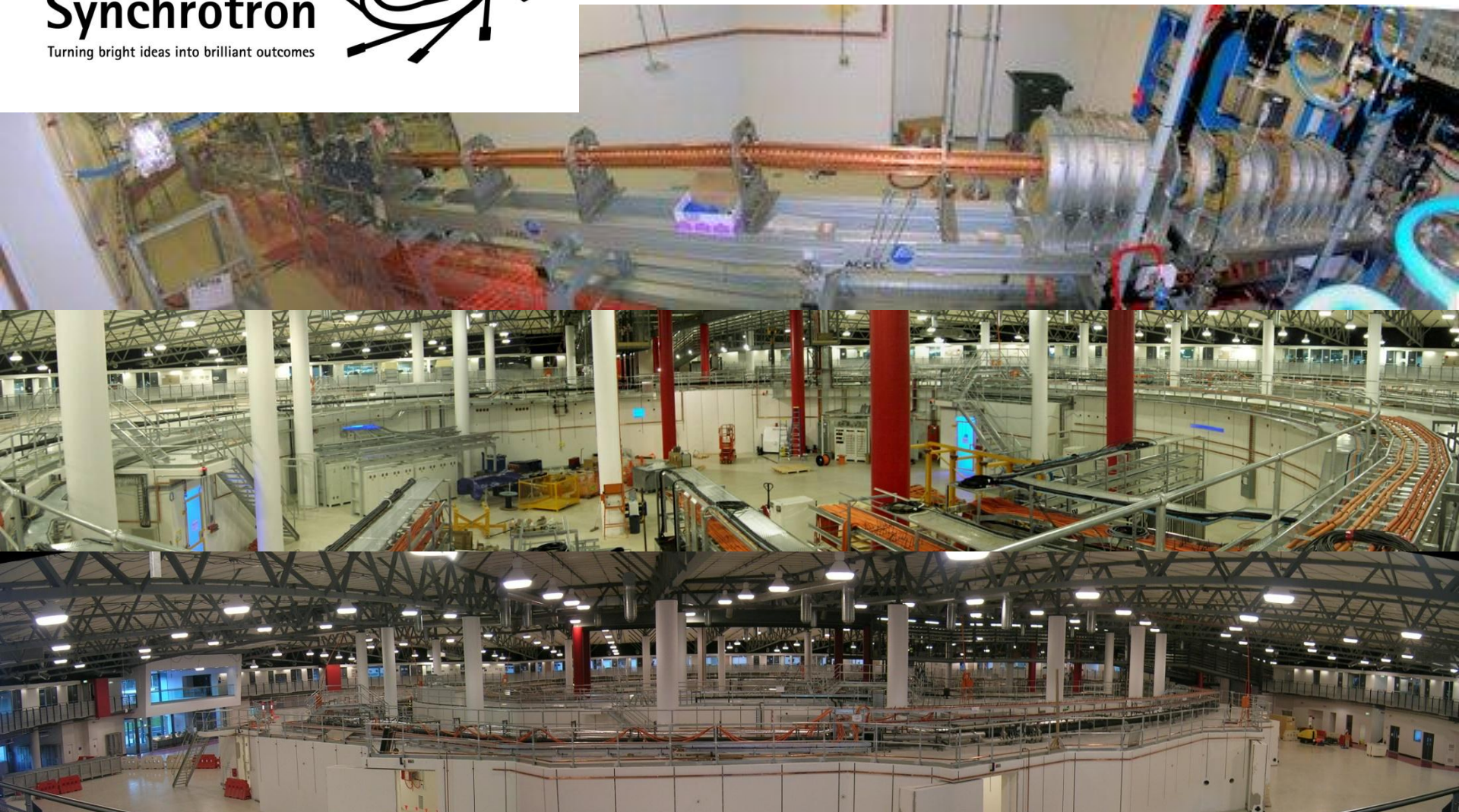
Australian Synchrotron Site Overview





2012 New National Centre for Synchrotron Science

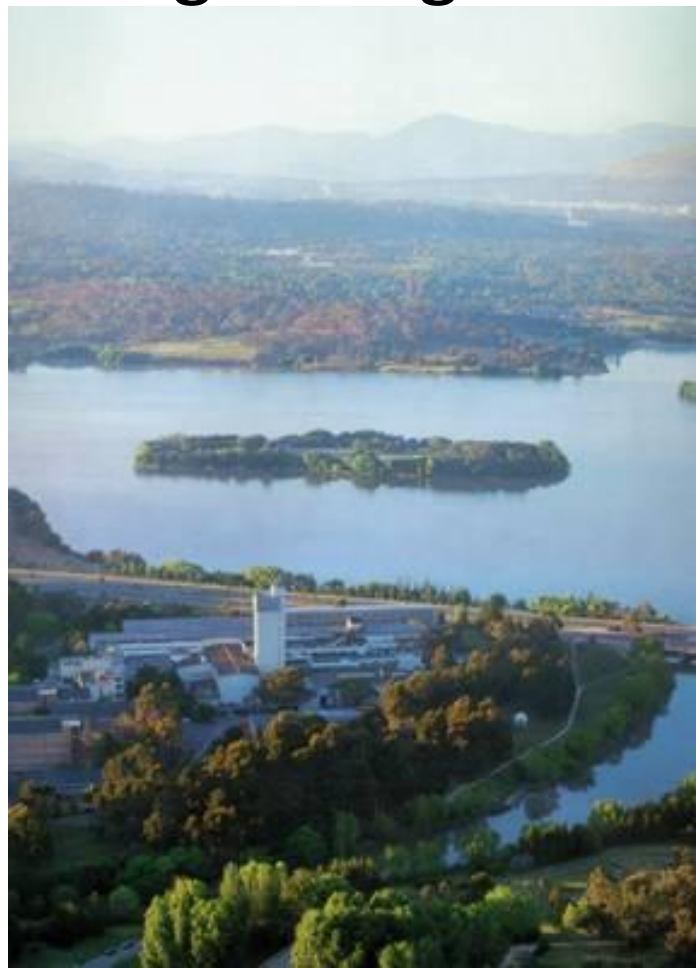




User Beam Availability 2007-2014

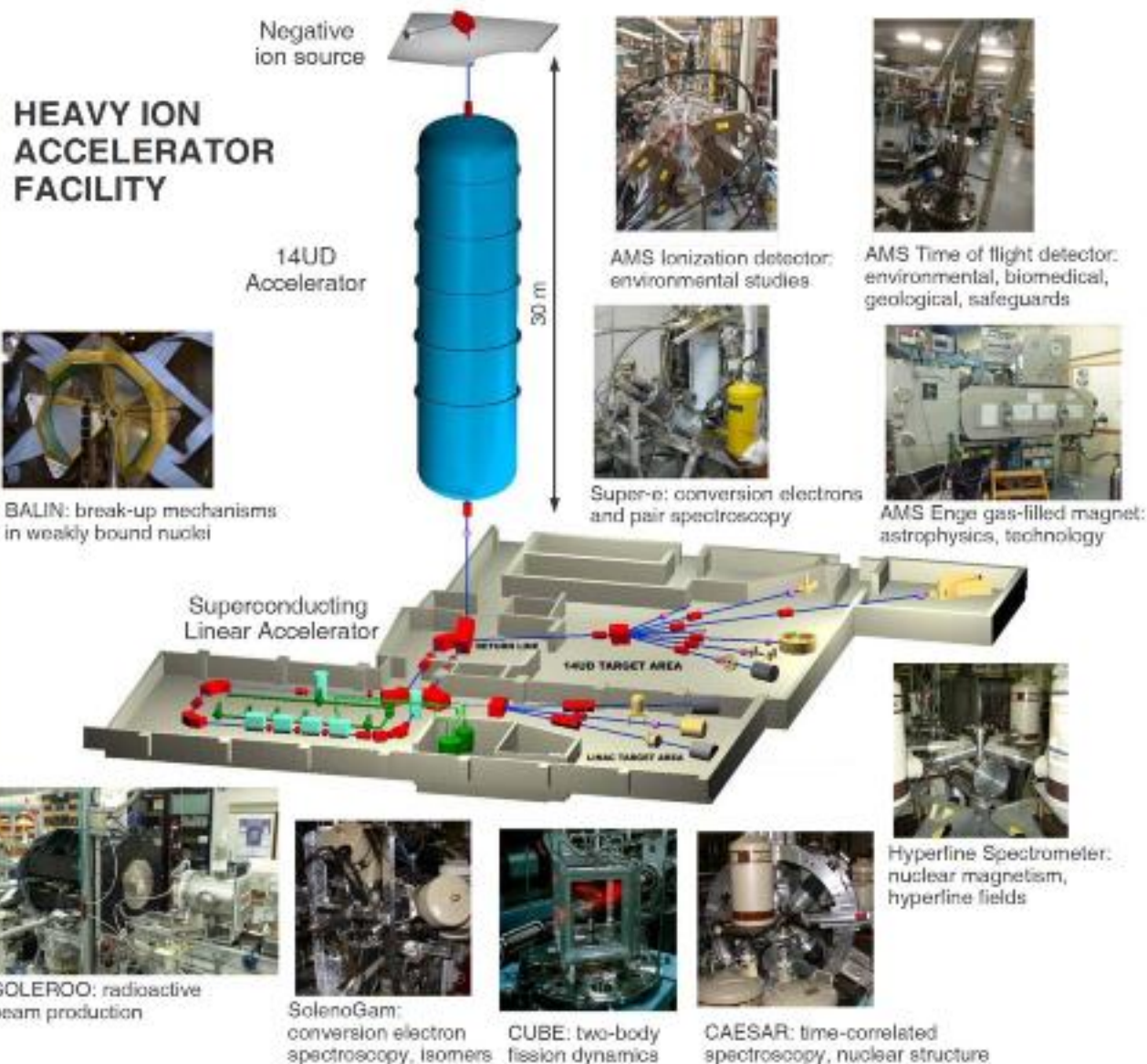


Still Going Strong: ANU 14UD



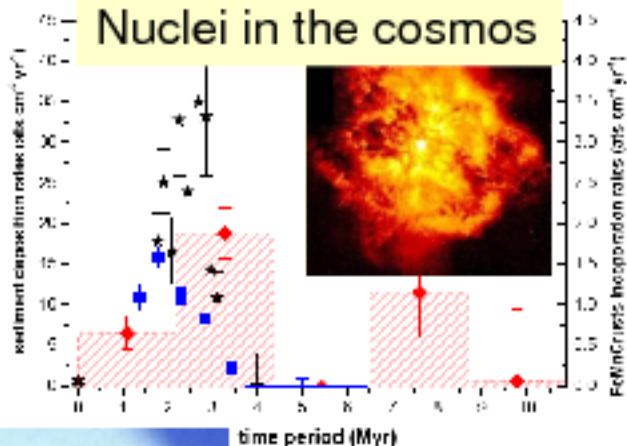
| | | | | |
|-------|------------------------------------|-------------------|--------------|---|
| 14 MV | ANU, Canberra (Nuclear Physics) | NEC Model 14UD | 1974–present | Has compressed geometry tube. Resistors have replaced corona point voltage distribution system. Now rated at 16 MV. A booster (ex-Oxford/Daresbury) is being added. |
|-------|------------------------------------|-------------------|--------------|---|

Heavy Ion Accelerator Facility



Research overview: some examples

Nuclei in the cosmos

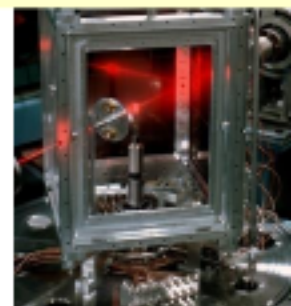


^{60}Fe from supernovae
on Earth



Isomeric decays and the
structure of many-particle
excitations near ^{208}Pb

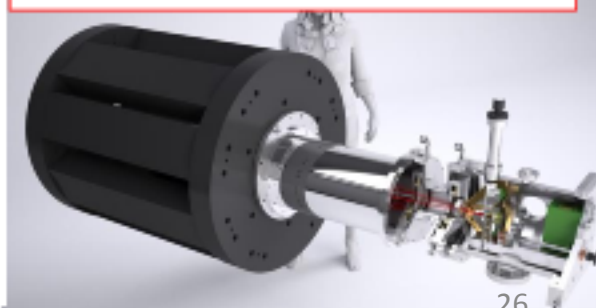
Quantum physics with nuclei



Making the
heaviest elements

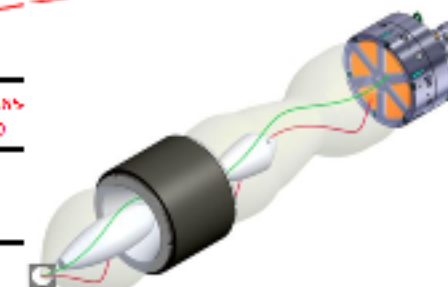
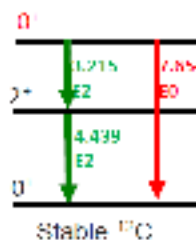
Nuclear shape changes in very neutron-
rich nuclei: a measurement at CERN.

Reactions with
radioactive beams –
SOLEROO



Hoyle state in ^{12}C : Making
carbon in the cosmos

2016-01-18



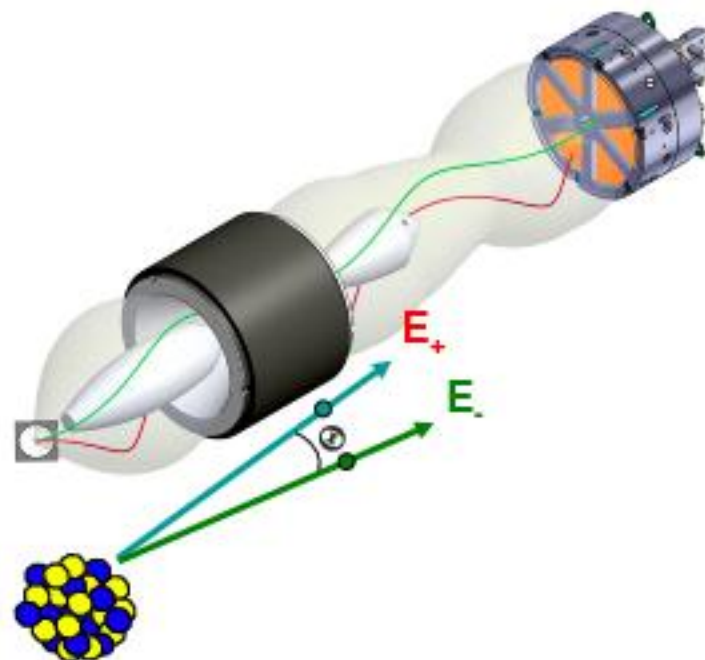
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26

13

Experimental and Instrumentation developments:

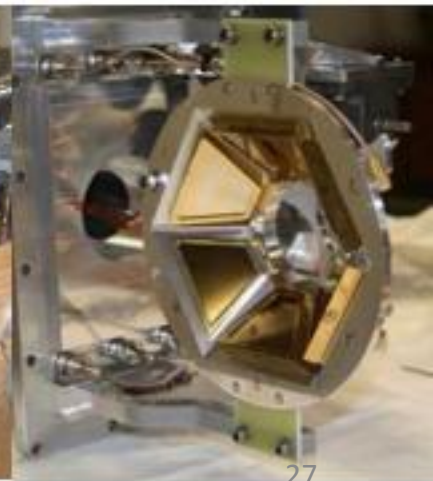
- DAQ multichannel (500+) capability
- CUBE – 3rd detector \uparrow angular coverage
- LaBr₃ detectors – fast timing (MEC15)
- Pair spectrometer – Electric Monopoles
- Radioactive beams – SOLEROO
- New AMS isotopes
- Digital Data Acquisition
- SiPM & detector development



2016-01-18



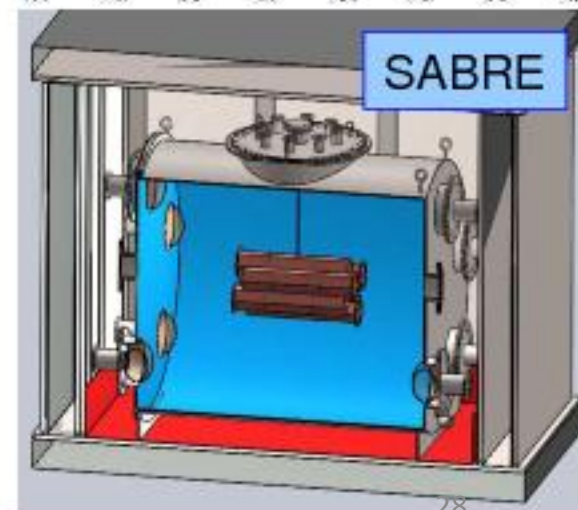
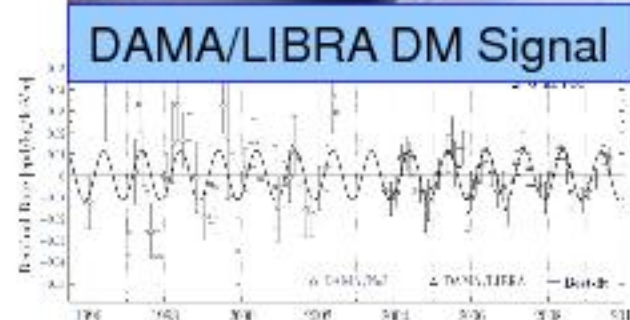
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27

Stawell Underground Physics Laboratory

- ✓ First dark matter experiment in Southern Hemisphere - Stawell Gold Mine (Victoria)
- ✓ Collaboration: Melbourne, ANU, Swinburne, Adelaide, ANSTO (ARC LIEF)
- ✓ International collaboration: USA, Italy, Australia
- ✓ Nuclear Physics expertise: Integral to detector build, DAQ
- ✓ Quenching factor measurements with 14UD
- ✓ **Decades of opportunities for low-background science**



Accelerator & Beamlines (0-3 years)

1. Consolidating EIF projects: optimization & operational experience

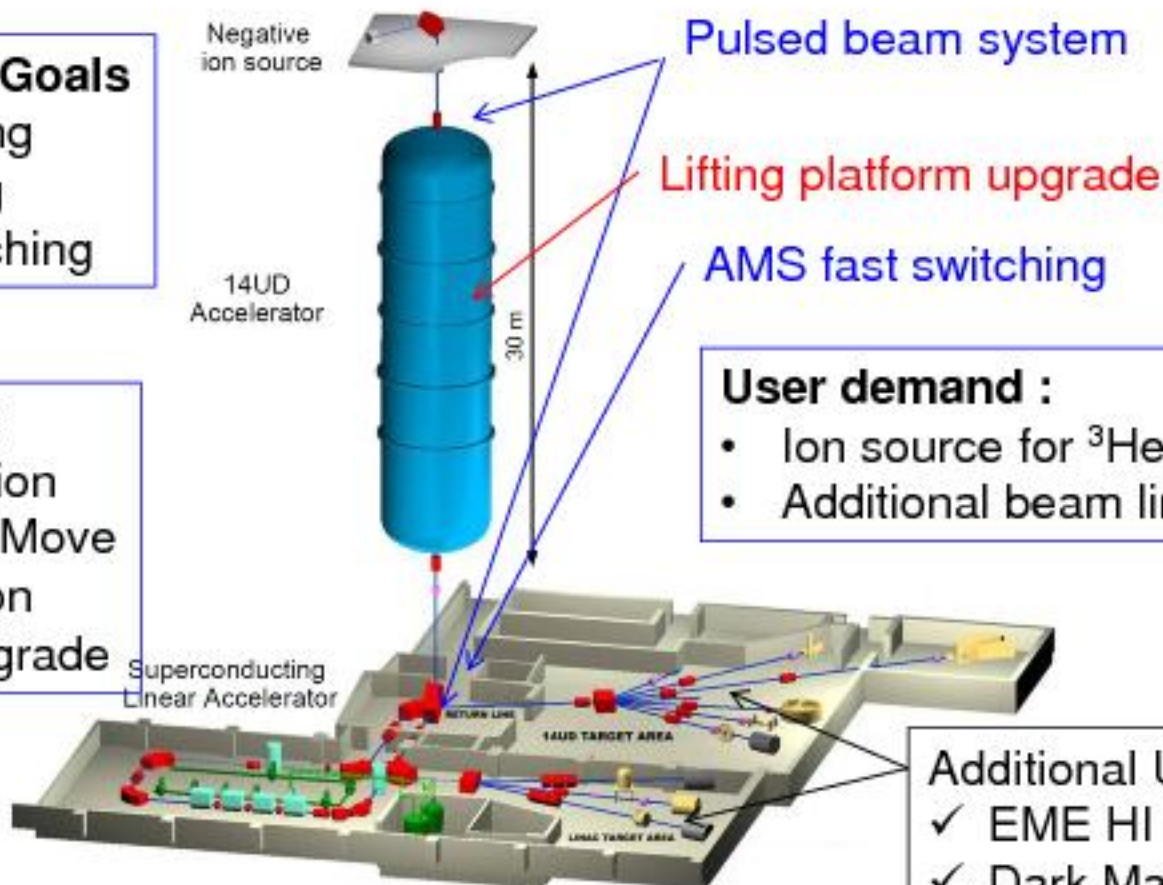
2. OHS: Lifting Platform & Electrical Safety Compliance

HIAF Capability Goals

- ✓ 3 freq. bunching
- ✓ Sub ns pulsing
- ✓ AMS fast switching

Building Project

- Active discussion
- Control Room Move
 - ✓ Preparation
 - ✓ Safety upgrade



User demand :

- Ion source for ^3He , ^4He beams
- Additional beam lines

Additional Users:

- ✓ EME HI irradiations
- ✓ Dark Matter
- ✓ Medical Physics

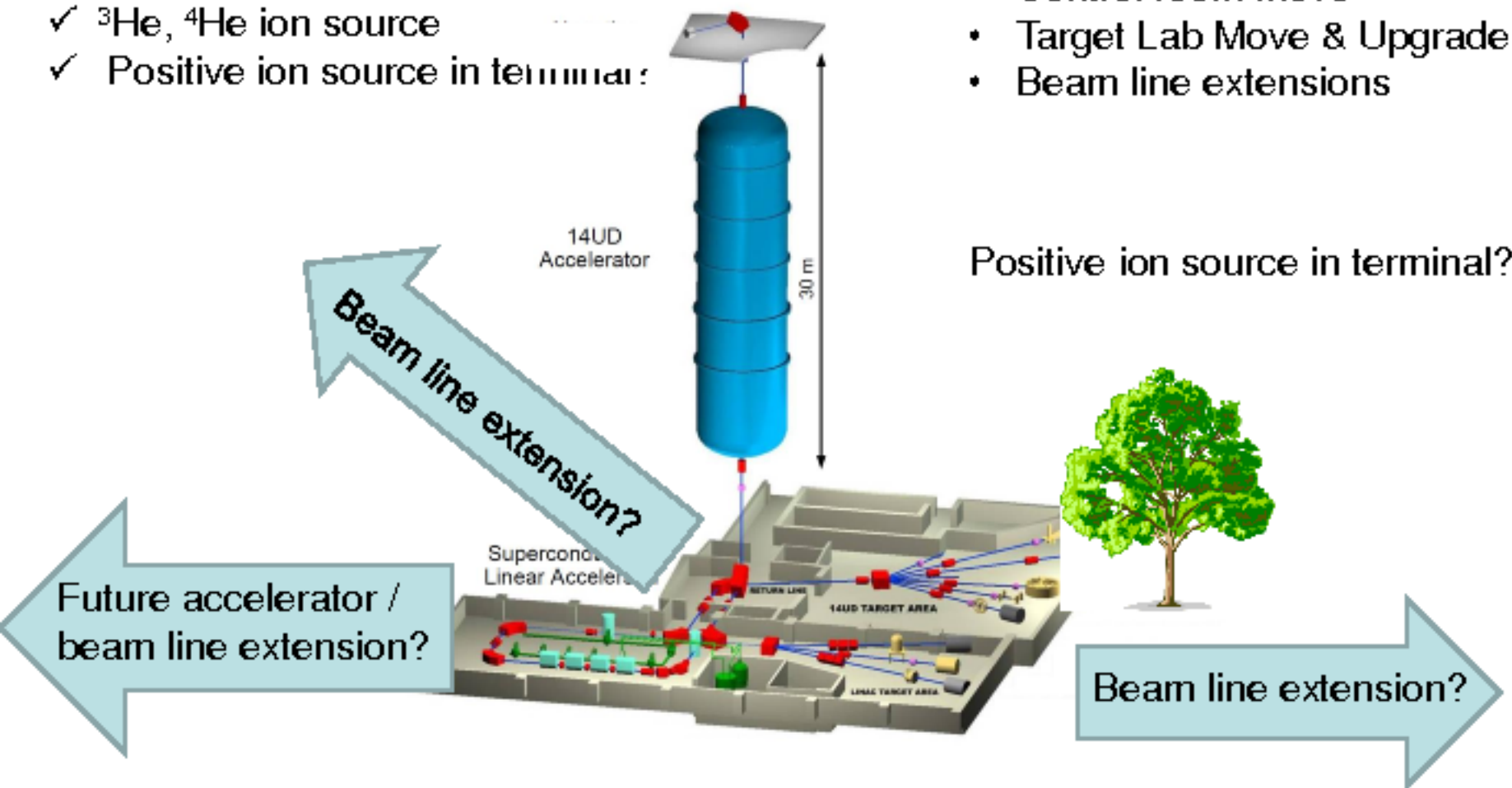
3-6 years Accelerator & Beam lines

Ion source development:

- ✓ ESA injection for AMS
- ✓ ^3He , ^4He ion source
- ✓ Positive ion source in terminal:

Building program:

- Control room move
- Target Lab Move & Upgrade
- Beam line extensions



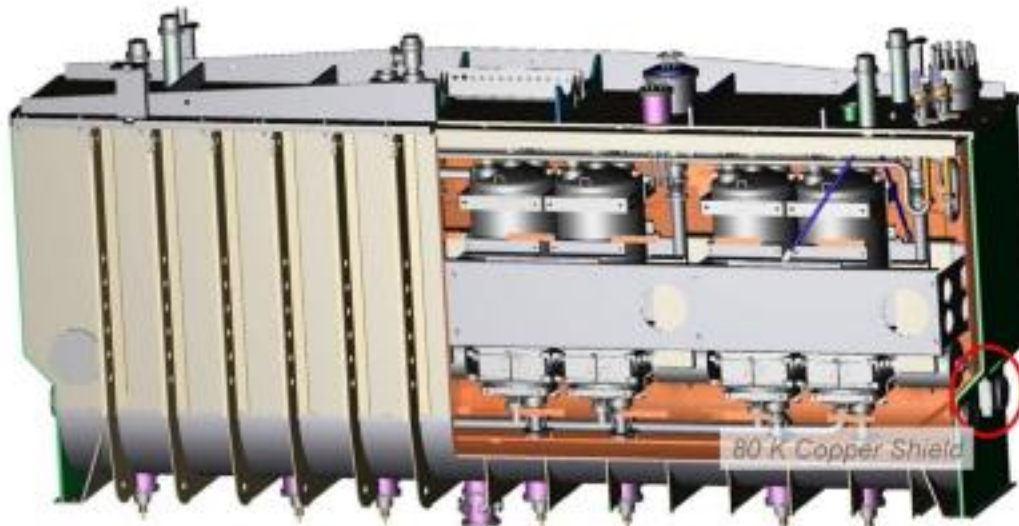
Accelerator development aspirations

Time

- New beam lines
- New Linac 4× higher field gradient
- New Linac injector
 - ✓ Parallel operation of 14UD and Linac

Cost

- Staged as funding available
- Ready for new CRIS equipment \$\$



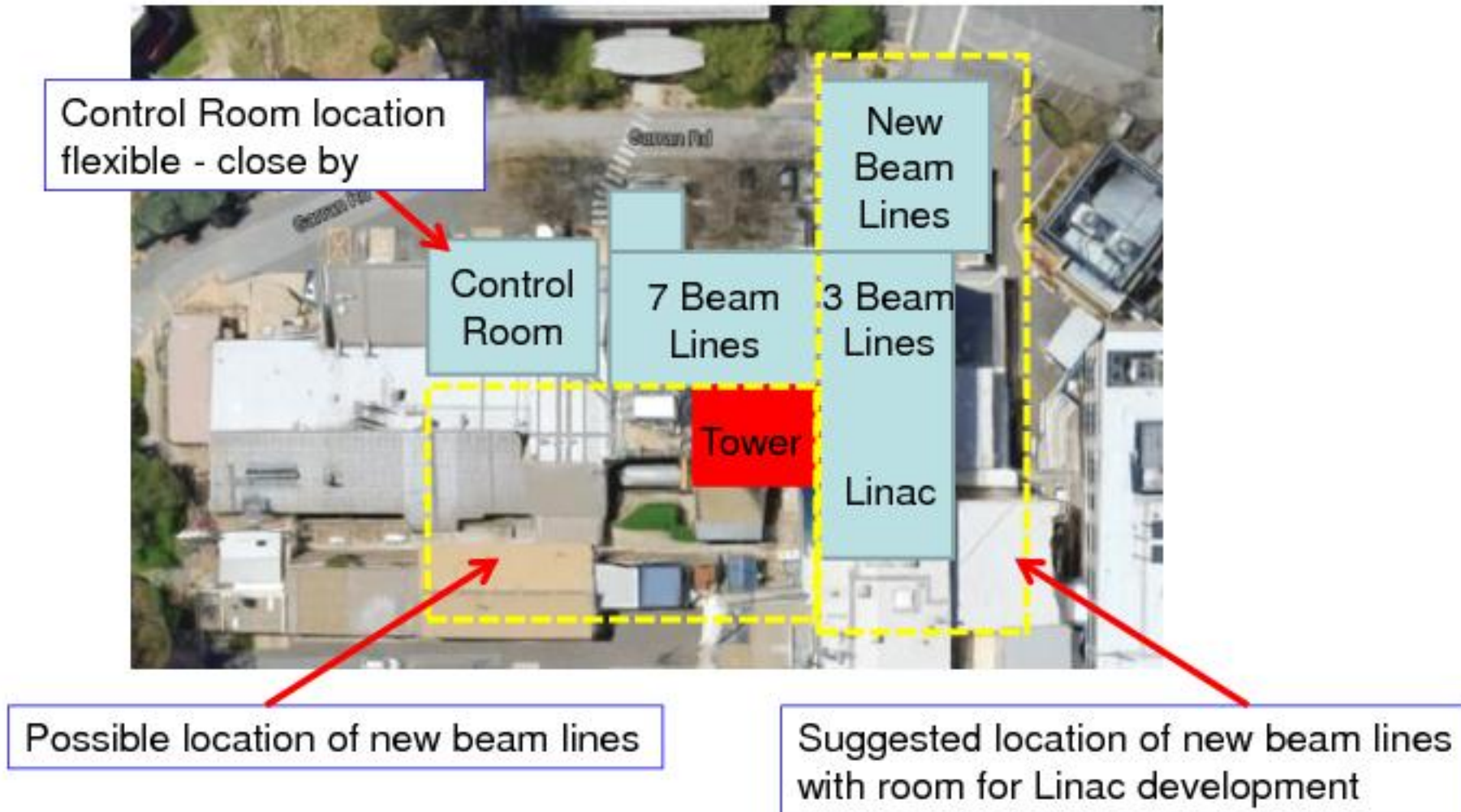
Argonne cryomodules

- ✓ 17.5 MV in 5 m
- ✓ USD \$4M each
- ✓ 2 = ANU Linac footprint

Present Lab Layout



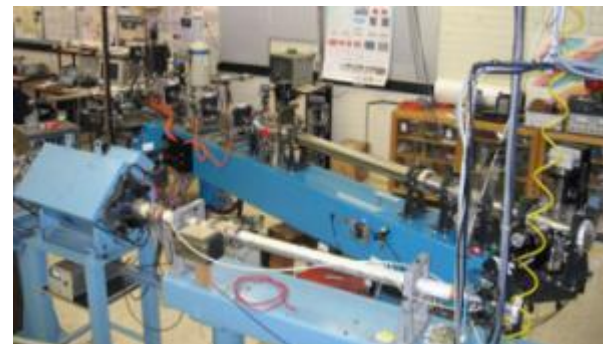
Possible future layout



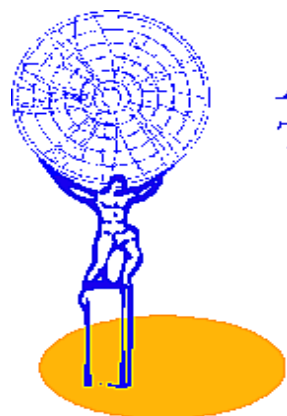


Provide Students!

Pelletron 5 MV ion accelerator

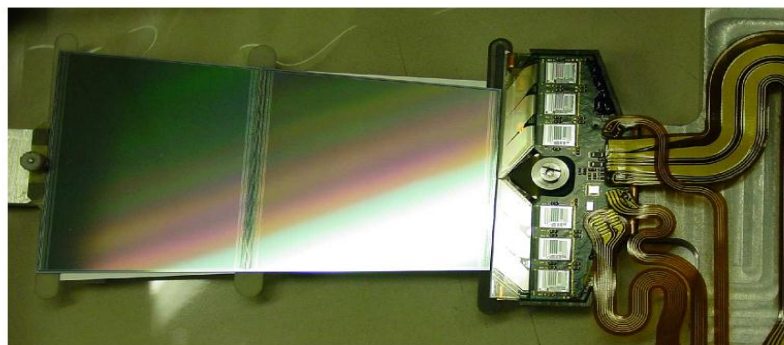


High Energy Particle Physics



ATLAS SCT
The ATLAS Semiconductor Tracker

SCT Module

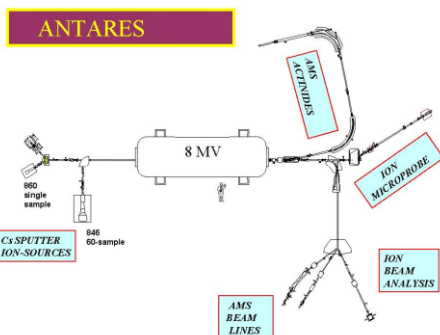


X-ray detector development

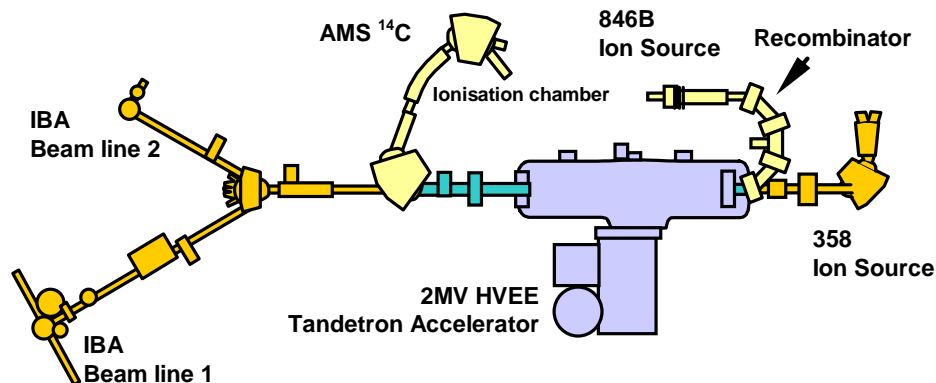


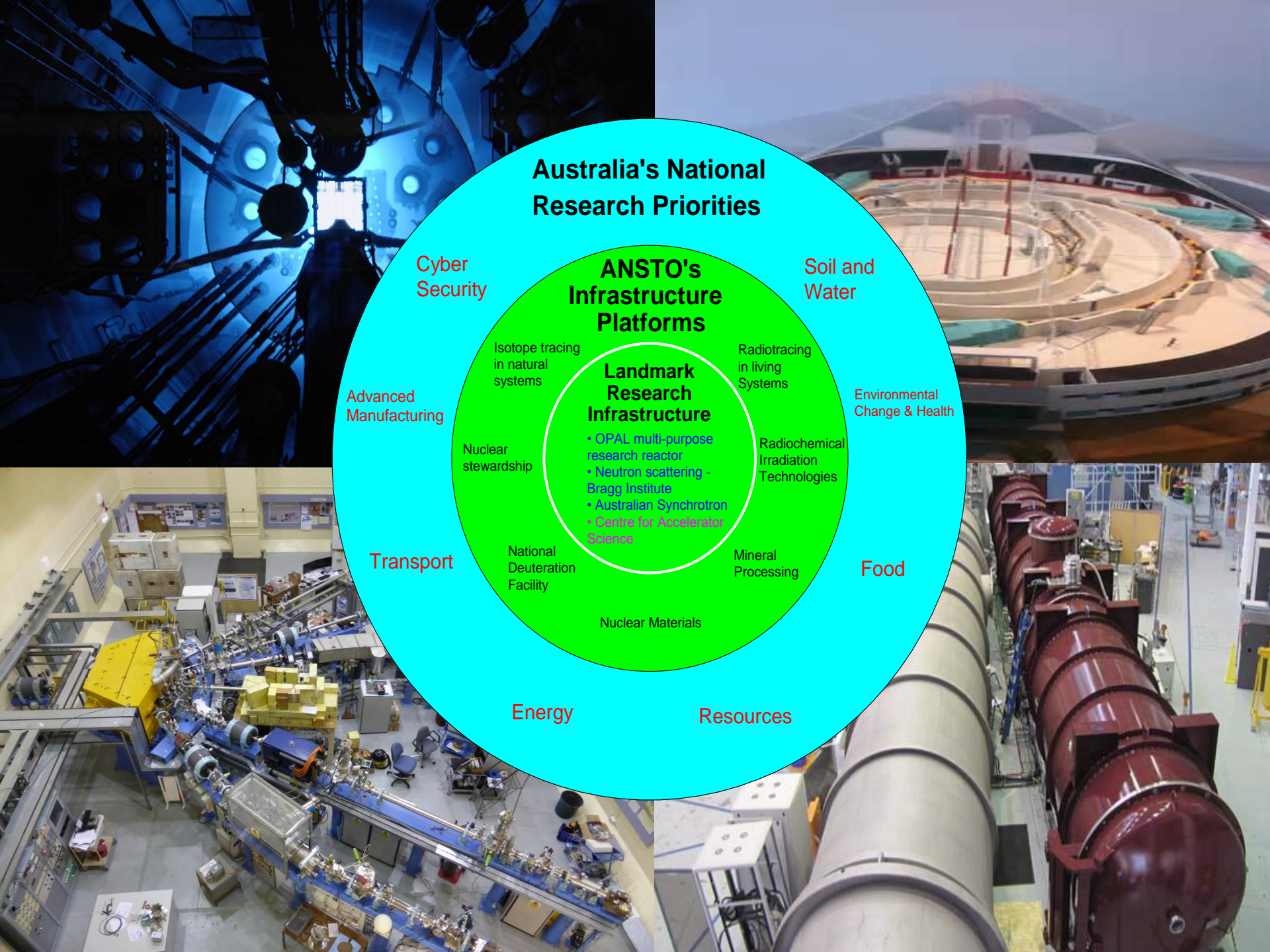


ANTARES - 10 MV Tandem ion accelerator

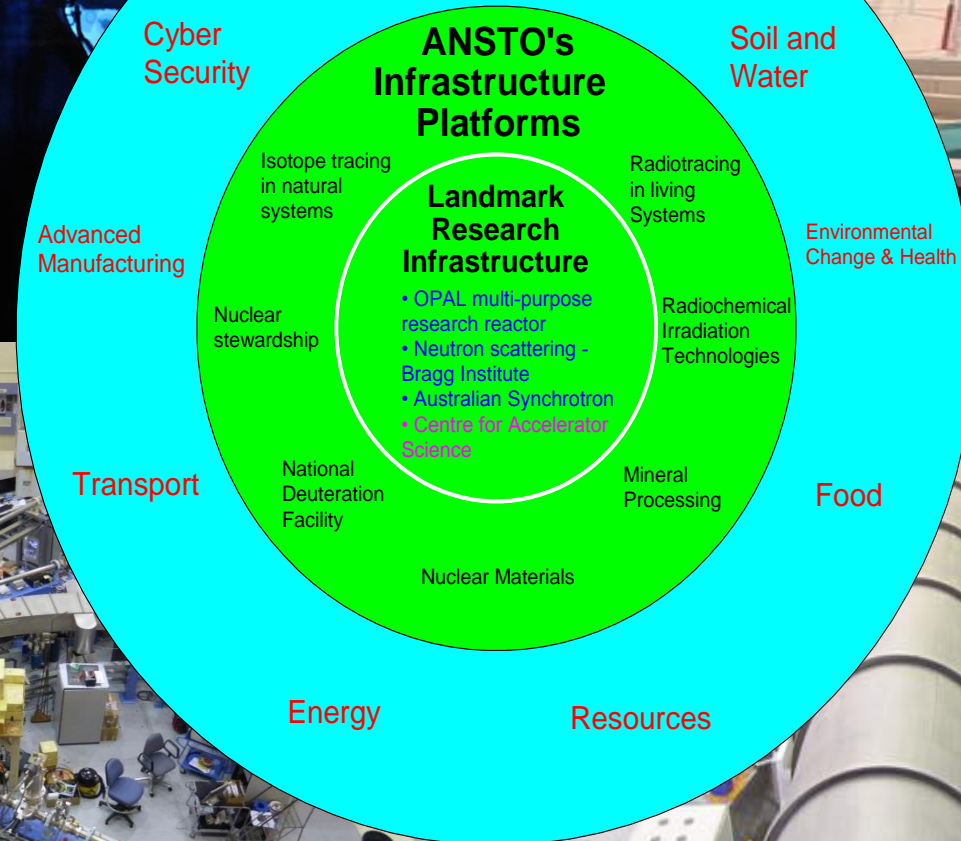


STAR - 2 MV Tandetron ion accelerator





Australia's National Research Priorities



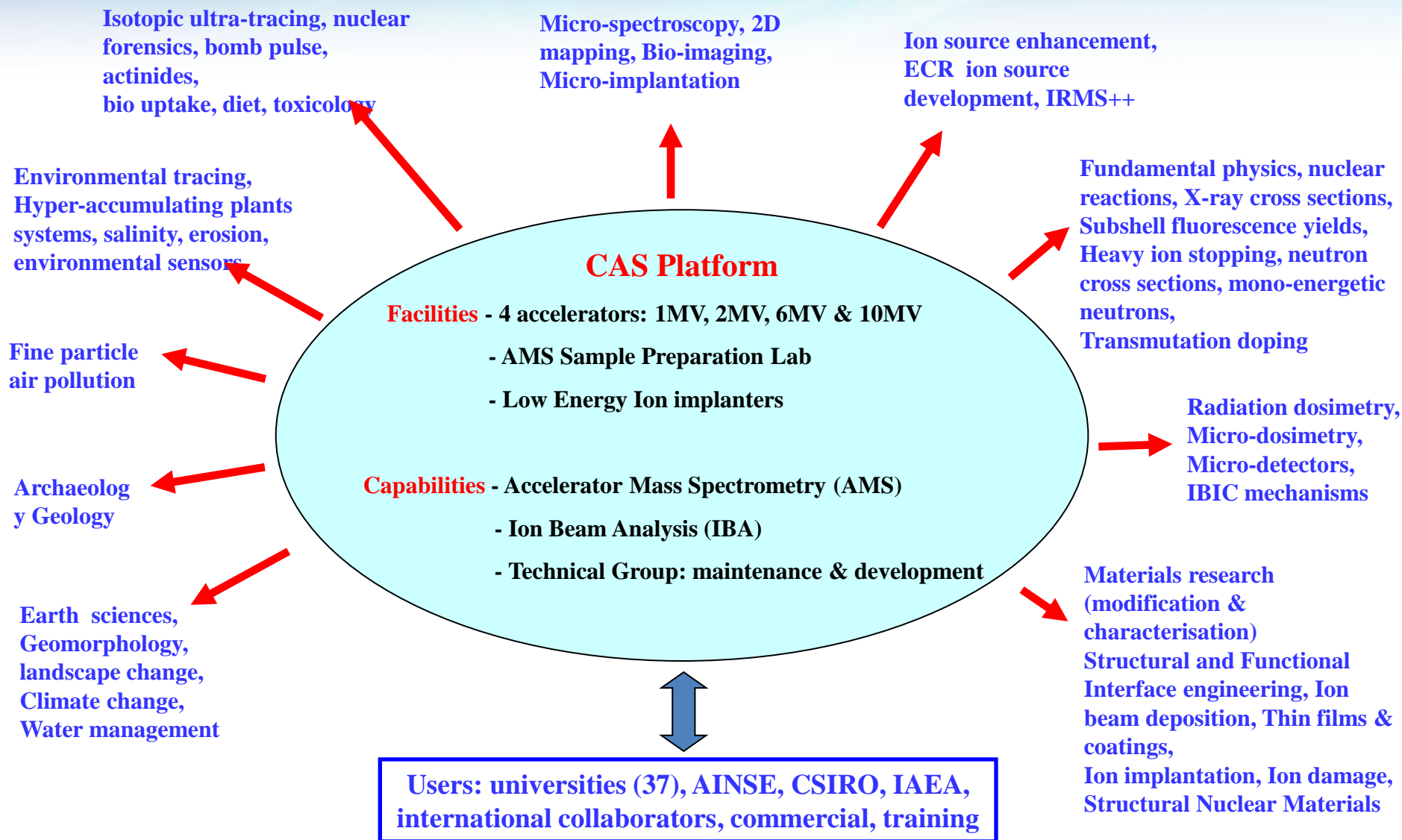


- CAS: current activities
 - Maintenance and development of ion Accelerator Systems
 - Accelerator Mass Spectrometry (AMS): ^{10}Be ; ^{14}C ; ^{26}Al ; ^{36}Cl ; ^{129}I ; ^{236}U ; $^{239, 240}\text{Pu}$
 - AMS Sample Preparation Facility
 - Ion Beam Analysis (IBA):
 - Ion Beam Irradiation (Chemistry, Defects, Damage)
 - Ion Beam Characterization: Rutherford Backscattering Spectroscopy (RBS, C-RBS); Particle Induced X-ray Emission (PIXE, μ -PIXE); Elastic Recoil Detection Analysis (ERDA); Nuclear Reaction Analysis (NRA); Heavy Ion Micro-probe (HIMP); Mono-energetic Neutron Production
 - On the drawing board:
 - Medical Therapy
 - Triple beam irradiation



Australian Government

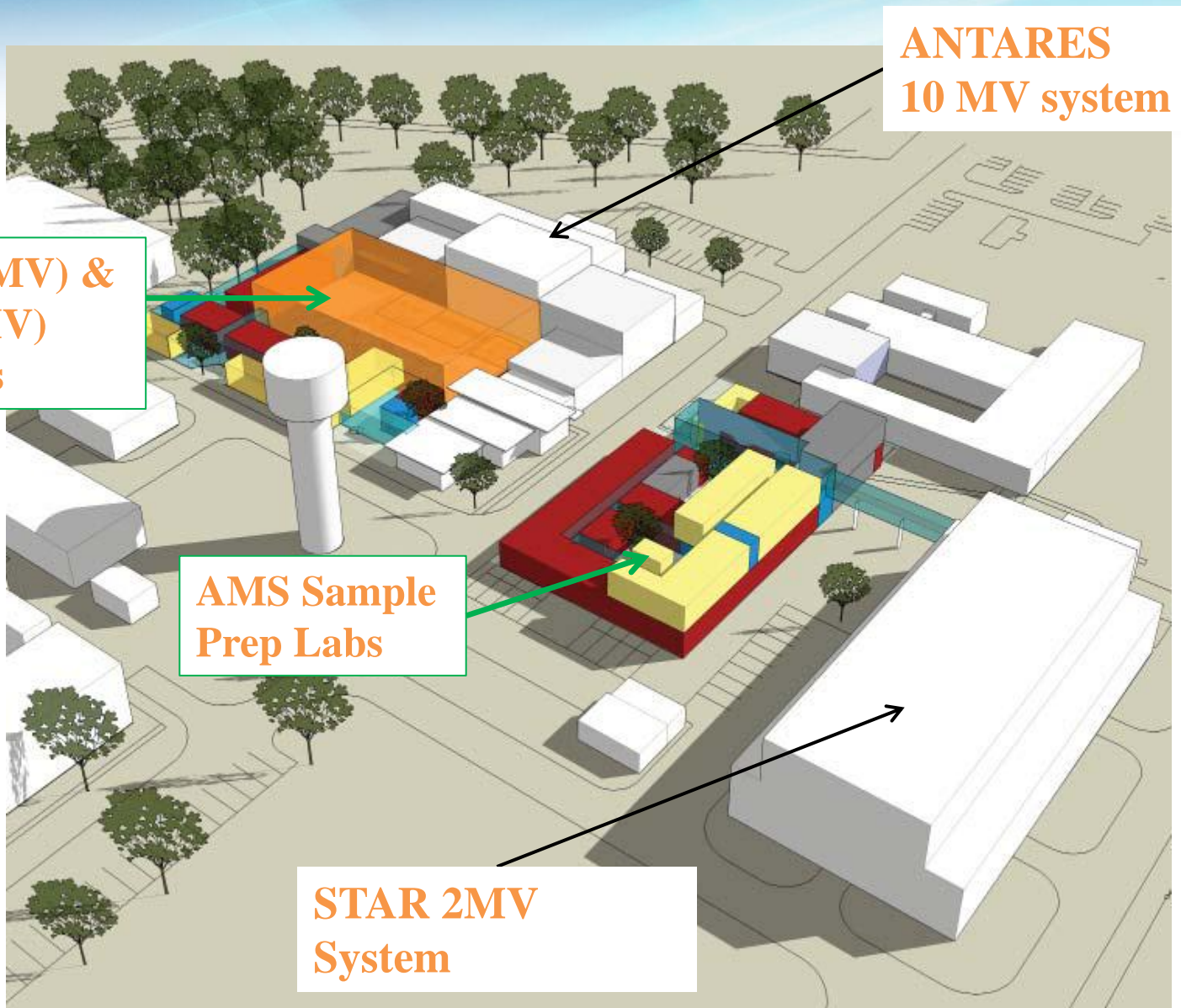
ANSTO's CAS Research and Technology Platform

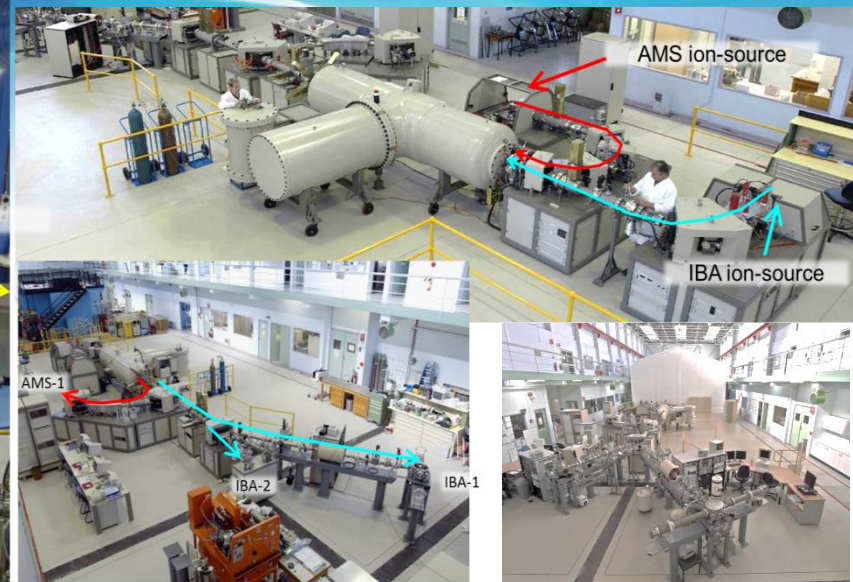
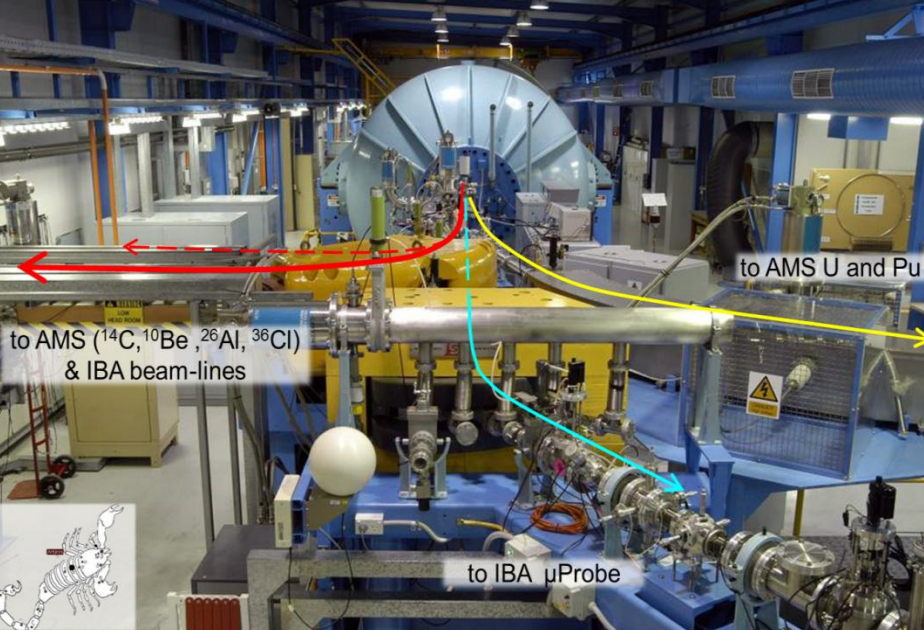




Australian Government

Ansto Accelerators





ANTARES accelerator, built USA 1960's, refurbished at ANSTO 1990's

STAR accelerator at ANSTO -2MV Installed 2003 - 5



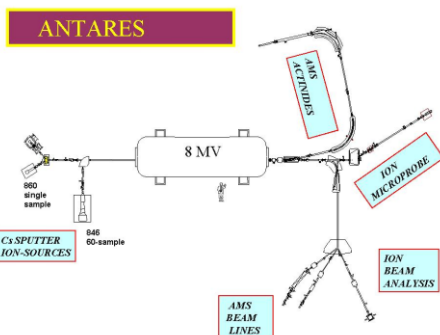
Sirius 6MV Installed 2014-2015



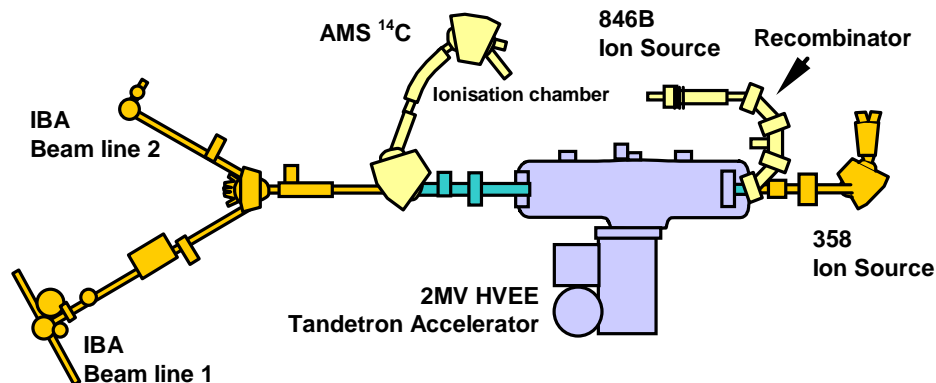
Vega 1MV Installed 2014-2015



ANTARES - 10 MV Tandem ion accelerator

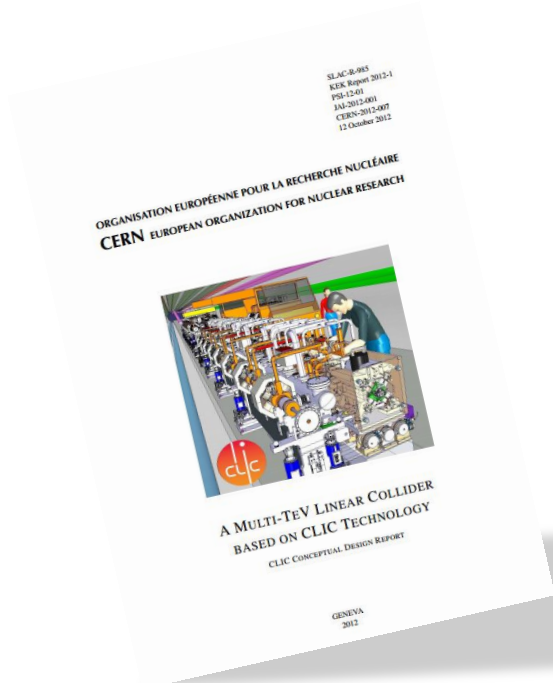


STAR - 2 MV Tandetron ion accelerator



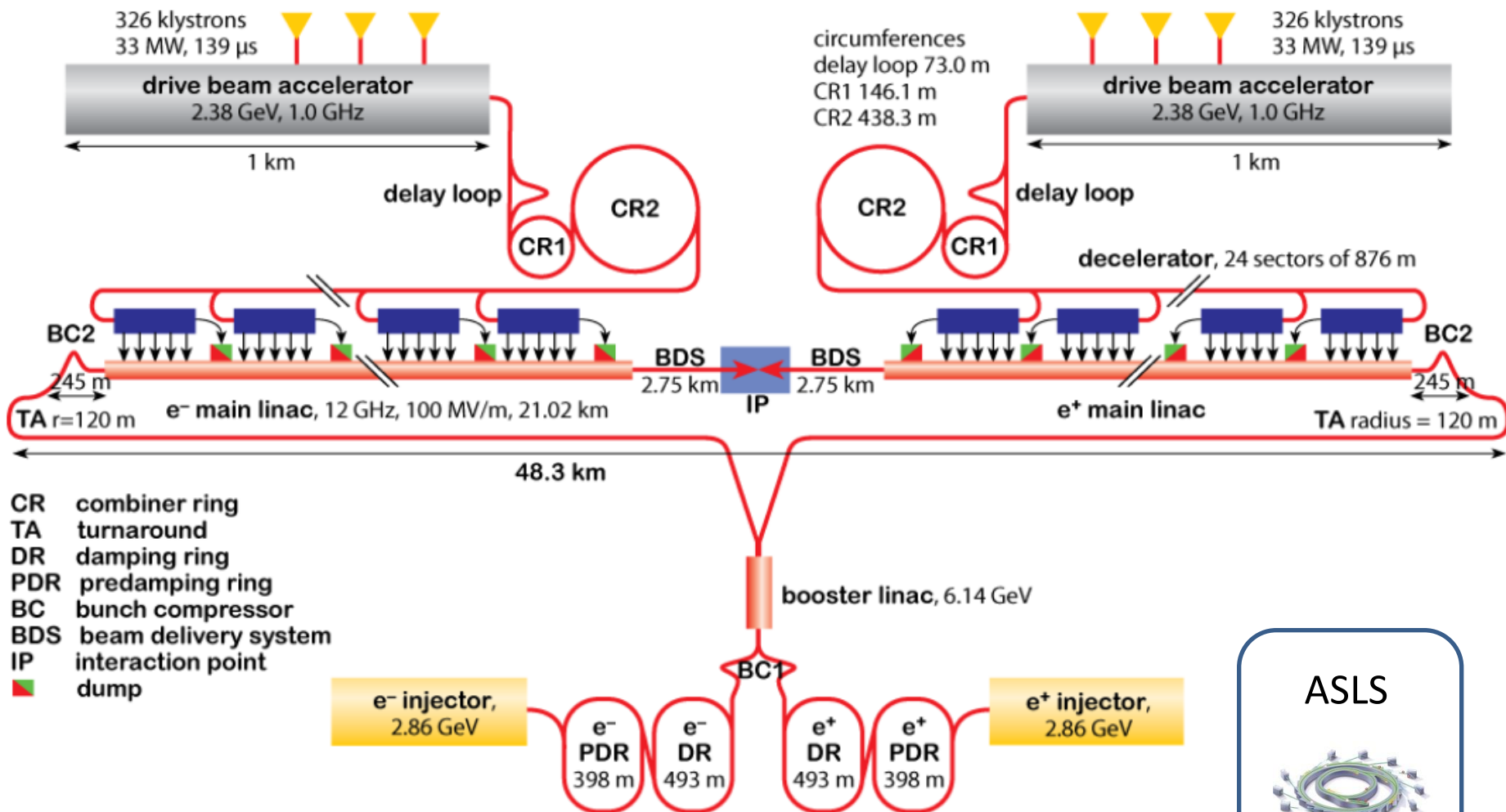
CERN CLIC Collaboration

- Started with damping rings work
- Serendipitous discussion with CLIC Project Director led to CLIC XFEL Collaboration
- Need to start planning now for XFEL in ten years
- Collaboration has high level support as CERN are interested in Australia becoming an Associate Member State

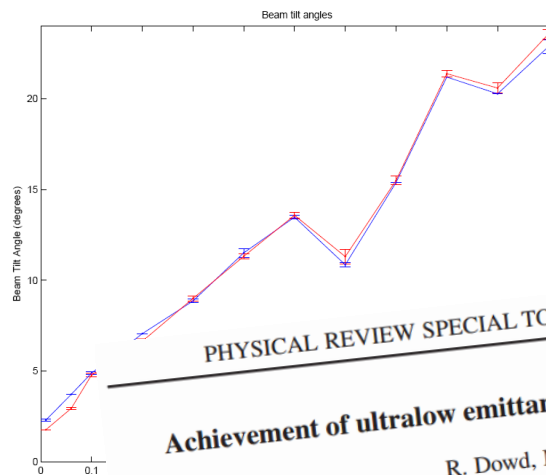
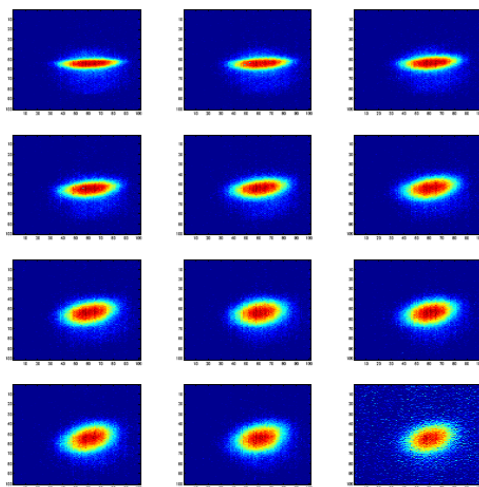
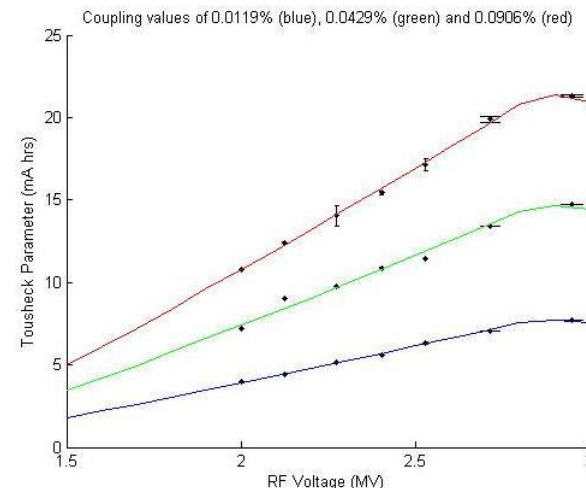
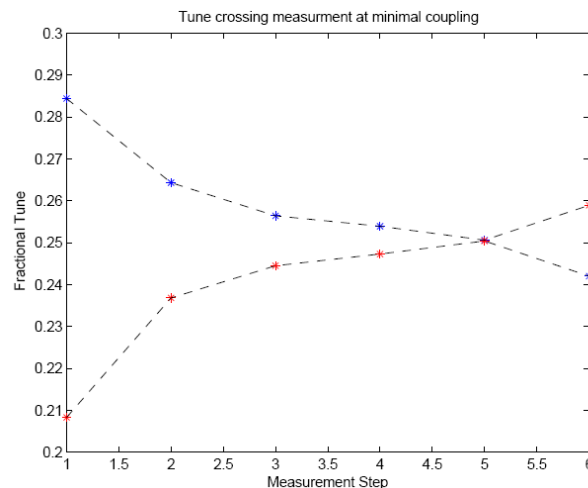
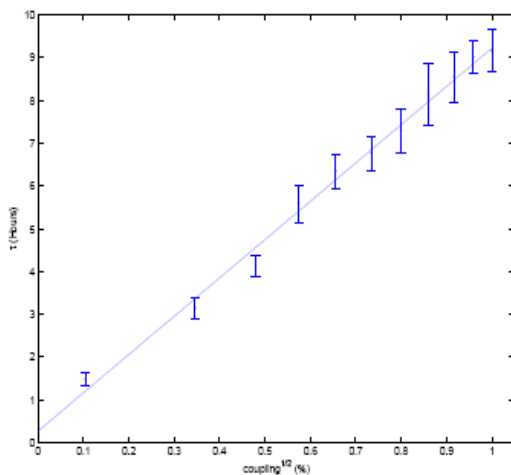


CLIC Damping Rings

Kent Wootton (PhD UoM)



Body of evidence for world low emittance



$$\epsilon_y = 1.24 \pm 0.4 \text{ pm}$$

World Low

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **14**, 012804 (2011)

Achievement of ultralow emittance coupling in the Australian Synchrotron storage ring

R. Dowd, M. Boland, G. LeBlanc, and Y-R. E. Tan
 Australian Synchrotron, 800 Blackburn Road, Clayton, 3168, Australia
 (Received 16 April 2010; published 29 January 2011)

Improved Vertical Undulator Measurements

PRL **109**, 194801 (2012)

PHYSICAL REVIEW LETTERS

week ending
9 NOVEMBER 2012

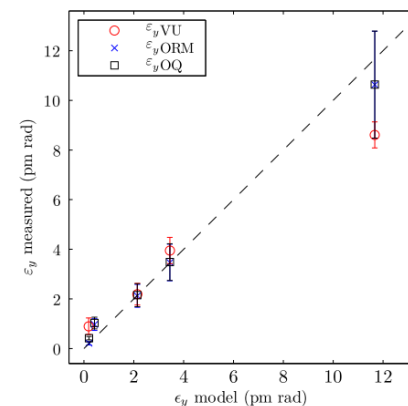
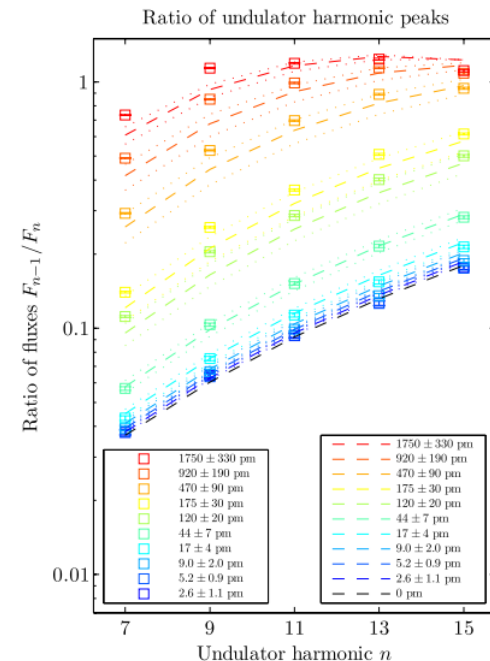
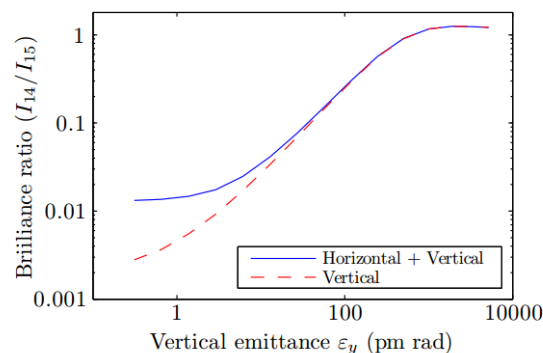
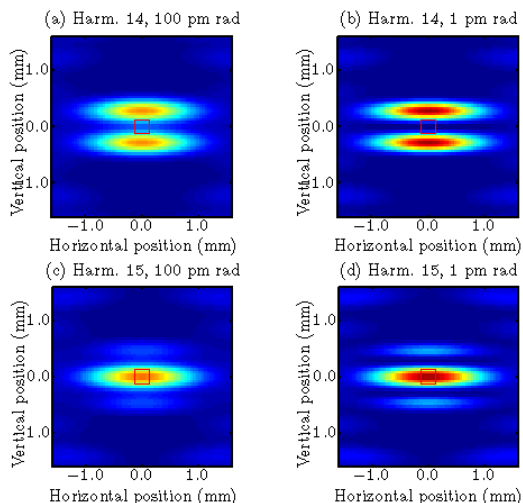
Observation of Picometer Vertical Emittance with a Vertical Undulator

K. P. Wootton,^{1,*} M. J. Boland,^{1,2} R. Dowd,² Y.-R. E. Tan,² B. C. C. Cowie,² Y. Papaphilippou,³
G. N. Taylor,¹ and R. P. Rassool¹

¹School of Physics, The University of Melbourne, Melbourne VIC 3010, Australia

²Australian Synchrotron, 800 Blackburn Road, Clayton VIC 3168, Australia

³European Organization for Nuclear Research (CERN), BE Department, 1211 Geneva 23, Switzerland
(Received 11 July 2012; published 8 November 2012)



PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **17**, 112802 (2014)



Measurement of ultralow vertical emittance using a calibrated vertical undulator

K. P. Wootton,^{1,*} M. J. Boland,^{1,2} and R. P. Rassool¹

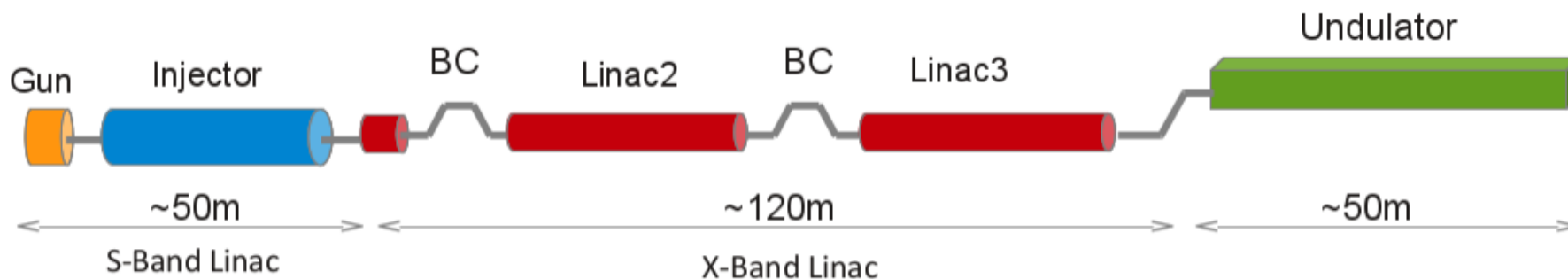
¹School of Physics, The University of Melbourne, Parkville, VIC 3010, Australia

²Australian Synchrotron, 800 Blackburn Rd, Clayton, VIC 3168, Australia

(Received 7 July 2014; published 14 November 2014)

Slide from D. Schulte, CERN

A. Aksoy



Looked a bit into a linac design for a typical Ångström FEL

We do not know the real user needs

Swiss FEL (C-band, approved):

$$E=5.8\text{GeV} \quad Q=200\text{pC} \quad \sigma_z=7\mu\text{m} \quad \varepsilon \approx 200\text{nm}-500\text{nm}$$

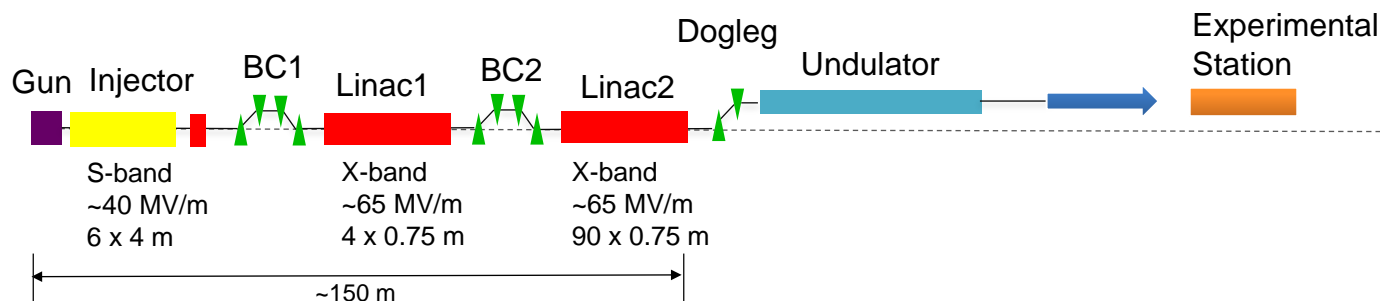
Proposal of Ch. Adolphsen et al. shows concept for X-band

$$E=6\text{GeV} \quad Q=250\text{pC} \quad \sigma_z=8\mu\text{m} \quad \varepsilon \approx 400\text{nm}-500\text{nm}$$

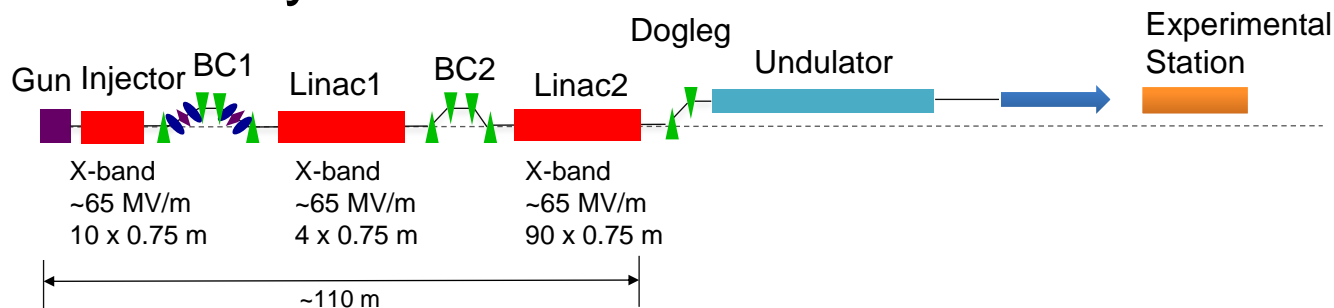
As example we did chose $Q=250\text{pC}$, $E=6\text{GeV}$ and will go for similar bunch lengths
Do not study injector (use the one from PSI for now) or undulator

AXXS (Australian X-band X-ray Source) - Two Designs

1. Base line design: S-band with X-band structure for linearizing before BC1



2. Alternative design being considered: X-band the whole way



Laboratory Panorama (from my office)

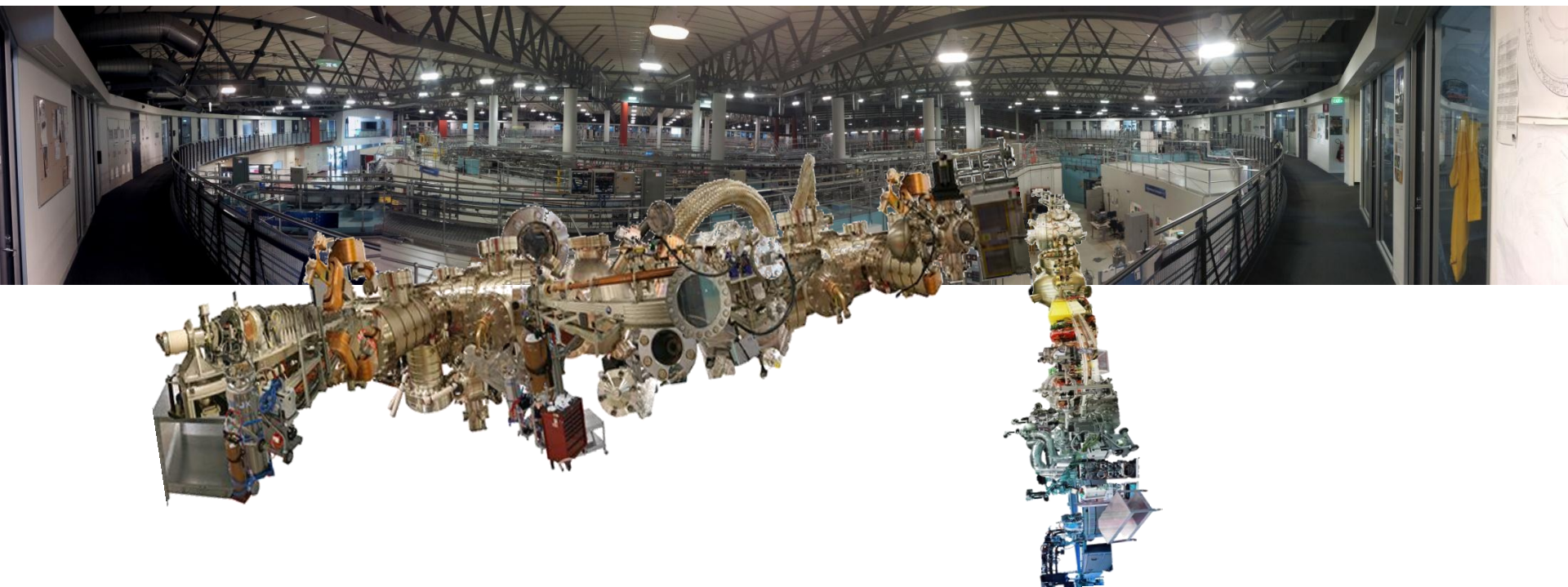
2007-2015



Laboratory Panorama (from my office)

2016-2025

More beamlines



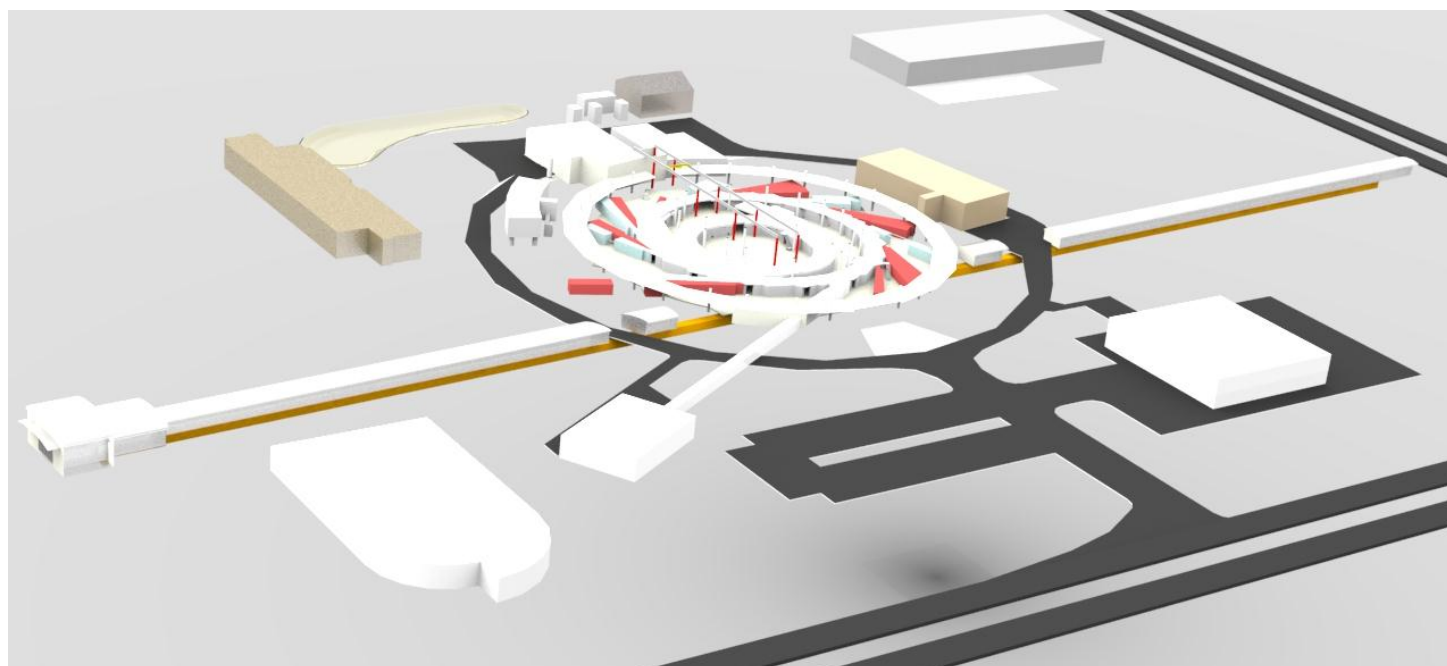
AXXS

AXXS – Australian X-band X-ray Source

AXXS n. /'æksɪs/ *fig.* A central prop, which sustains any system.

Development plan for the Australian Light Source community:

1. develop the remaining beamlines (space for an additional 6 IDs)
2. upgrade the storage ring lattice to MBA (compact MAX IV magnets)
3. upgrade the injector to a full energy x-band linac (3 GeV)
4. upgrade to additional linac for XFEL (6 GeV)

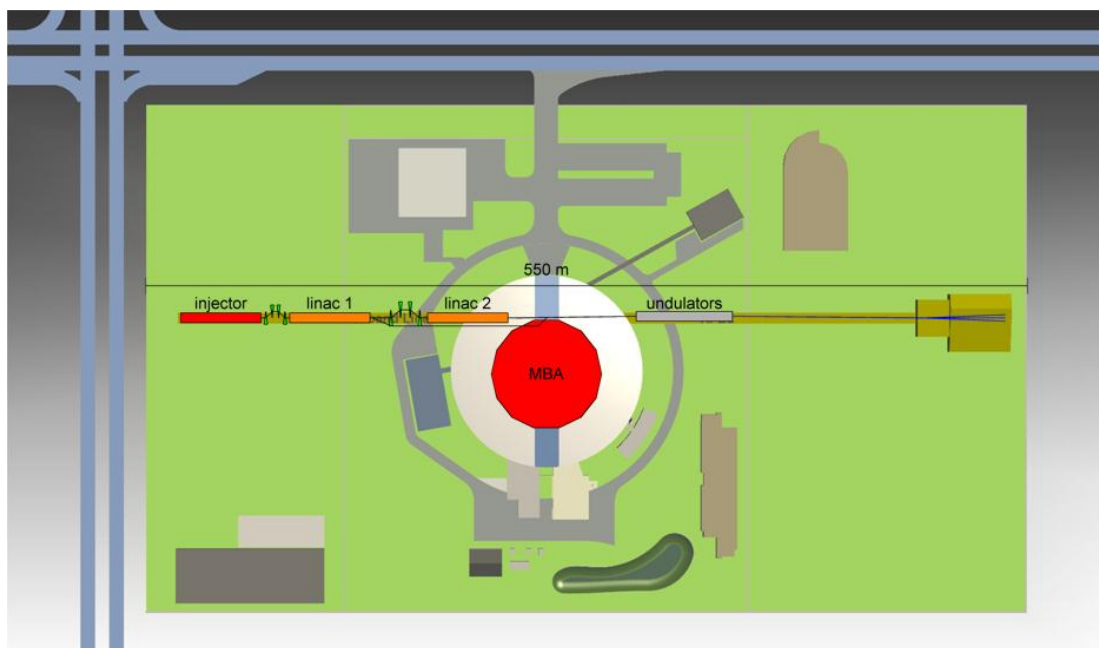


- Strong XFEL user base with regular beamtime on LCLS and members of review committees for European XFEL
- Strong government funding, especially in life sciences



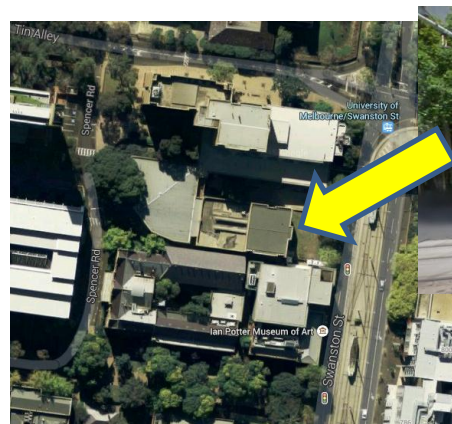
**CENTRE FOR ADVANCED
MOLECULAR IMAGING**
AN ARC CENTRE OF EXCELLENCE

- Site constraint 550 m:
- Same tunnel, energy and source points for storage ring upgrade.
- Time constraints: need to finish building out the remaining beamlines before justifying a new ring or FEL.

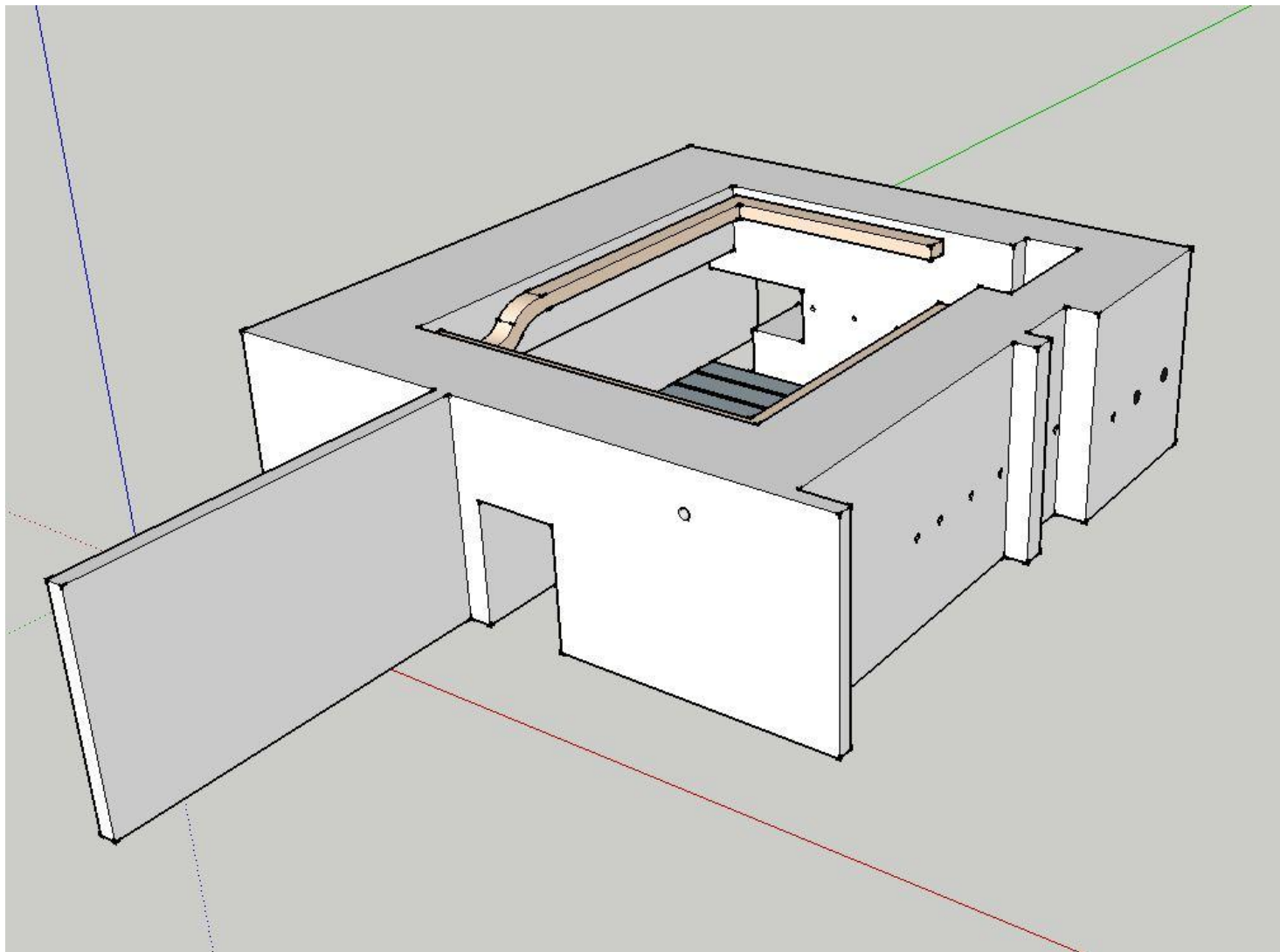


Advanced Accelerator R&D at Melbourne Uni

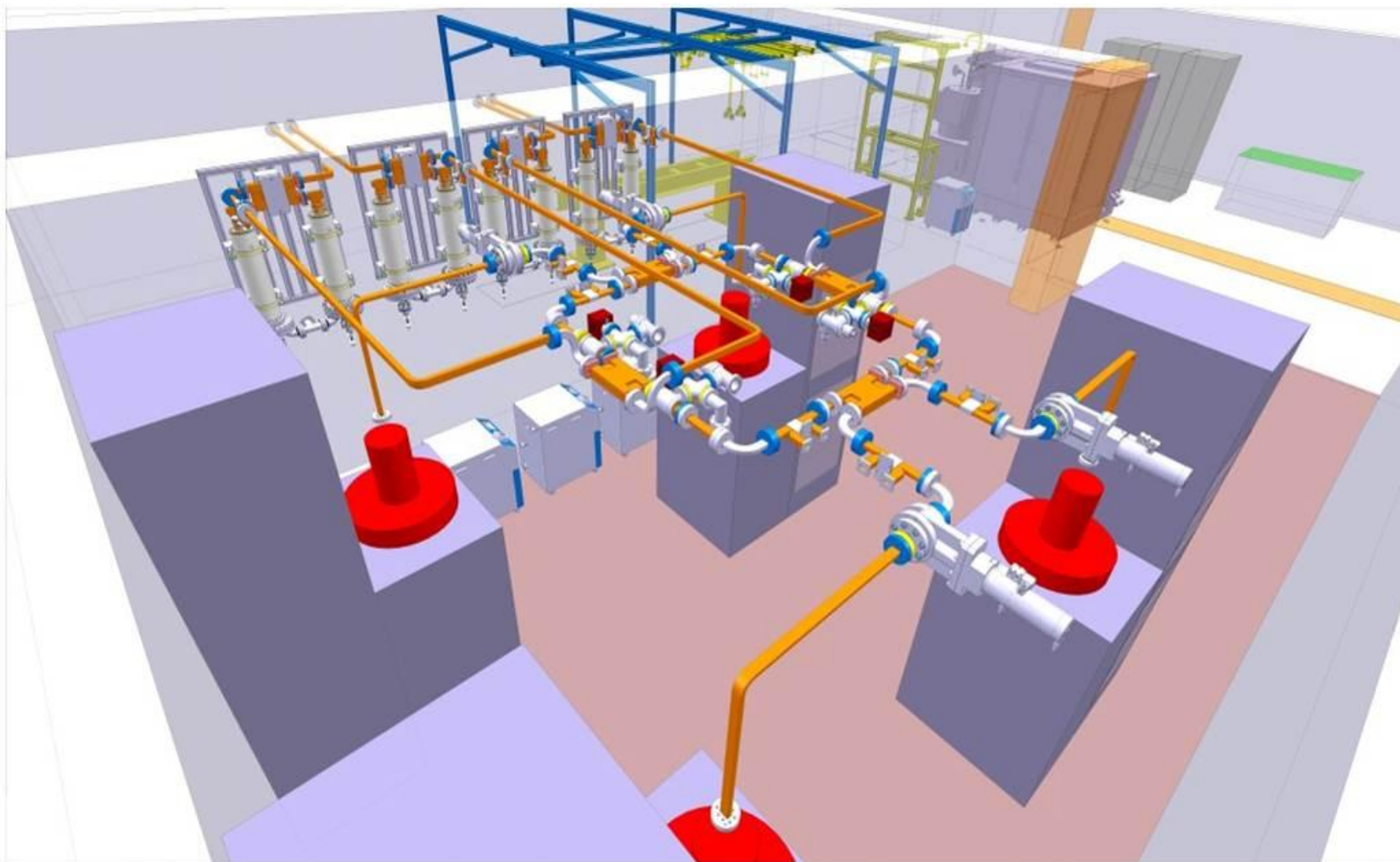
- Propose new X-band accelerator lab in the old 35 MeV betatron lab
- Future RF photocathode development



Accelerator Bunker at Melbourne University



Split XBOX3



Conferences in Melbourne, Australia

Past conferences:

- IBIC, 13-17 September 2015
- ICALEPCS, Oct 2015



Future conference:

- International Particle Accelerator Conference – IPAC'19, May 2019



Thank you for your collaboration!

