Blinded by the Light: Past, Present and Future of Accelerators in Australia

Associate Professor Mark Boland

Australian Synchrotron

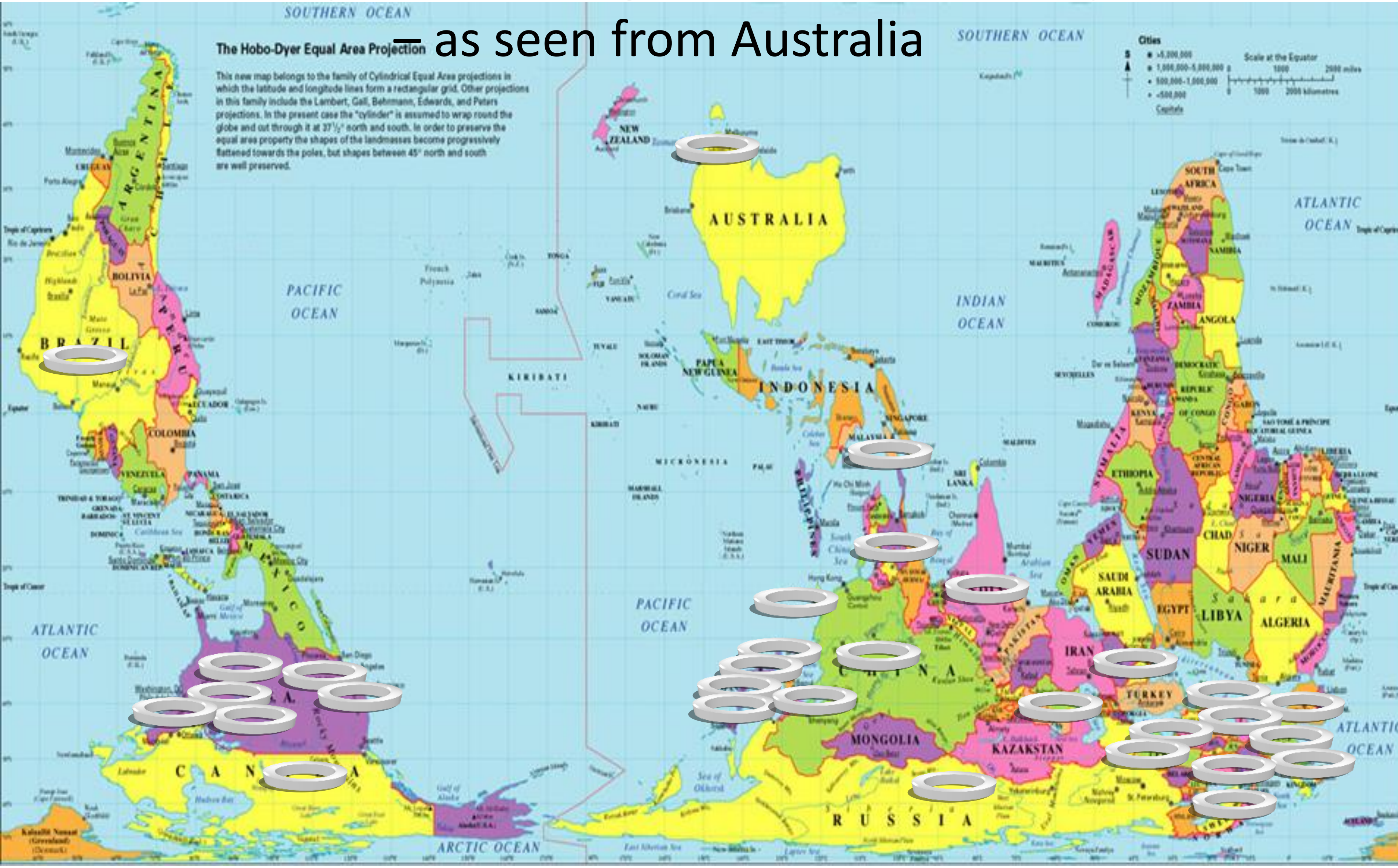
The University of Melbourne

12 years at the Australian Synchrotron

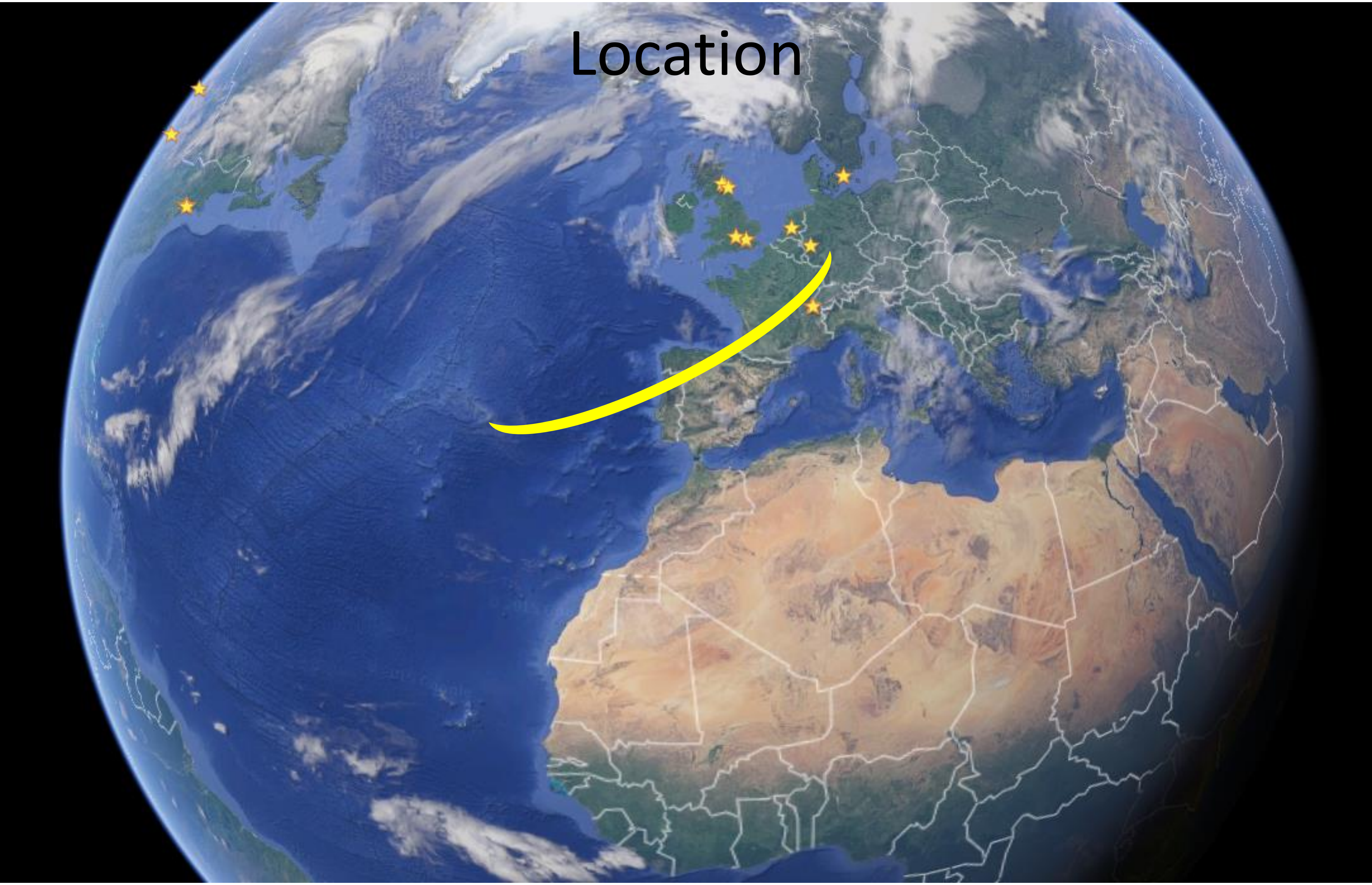
Australian Synchrotron

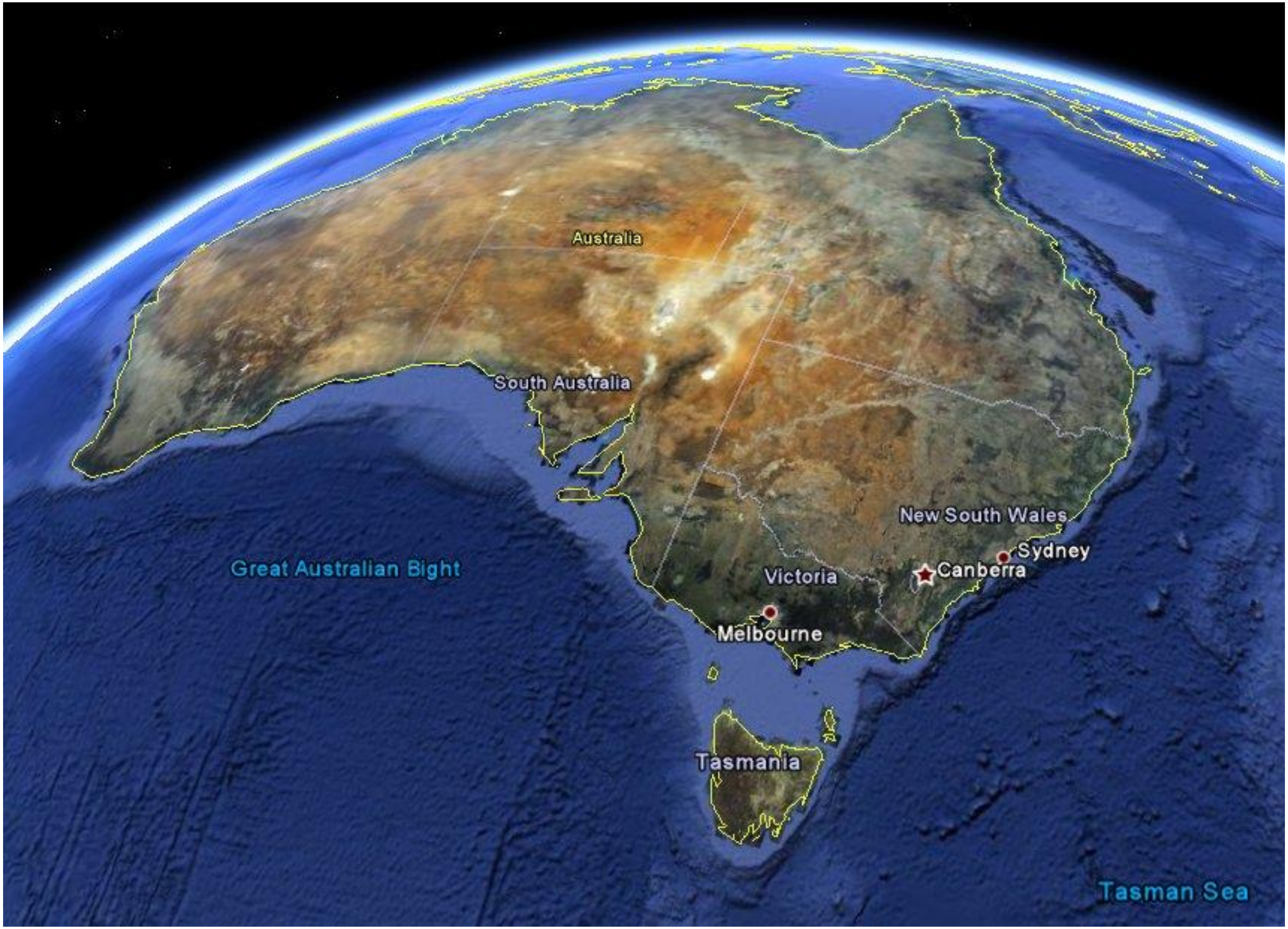
ACAS Australian Collaboration for Accelerator Science

The Synchrotron Light Source World Map – as seen from Australia

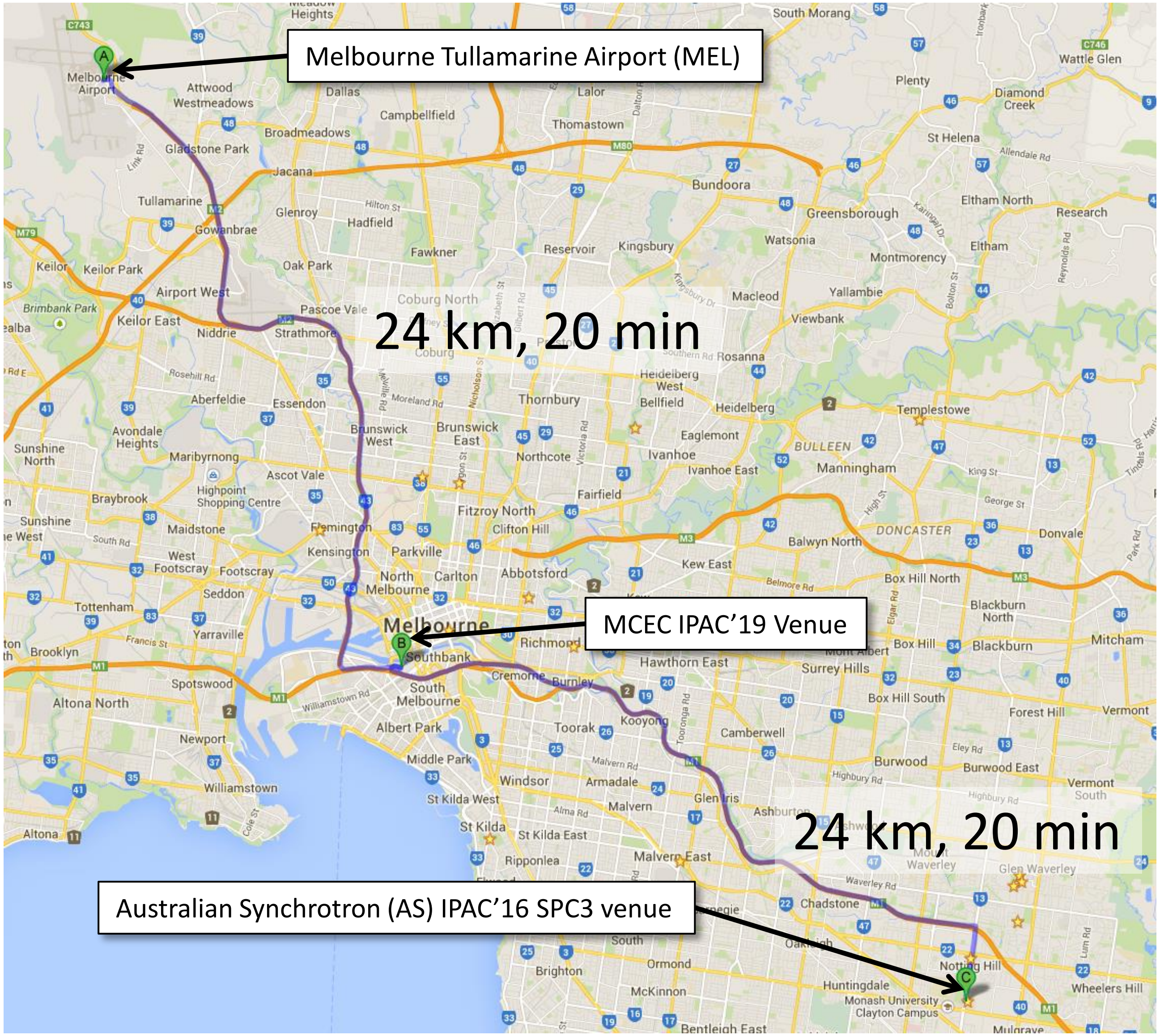


Location



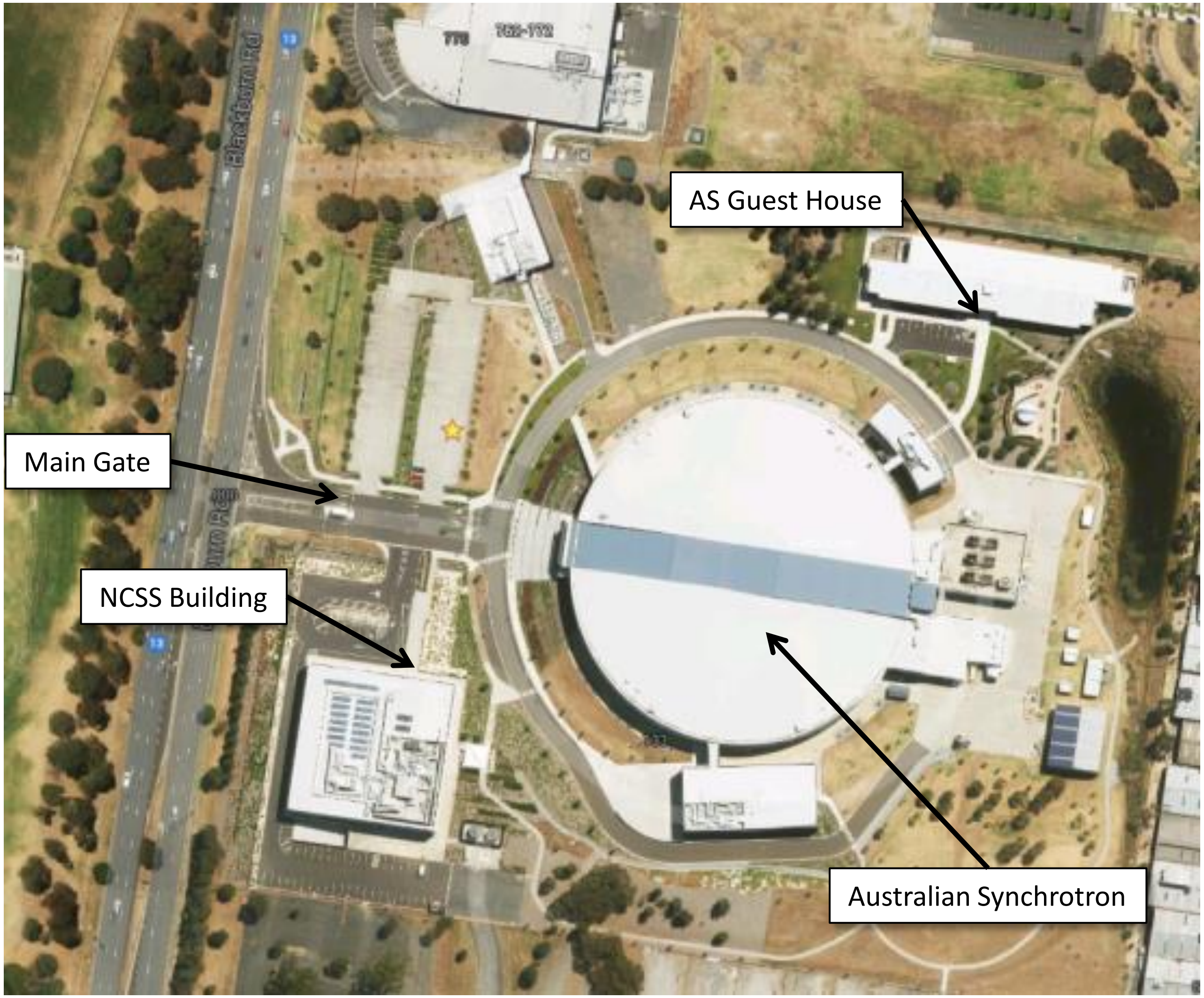


Australia
South Australia
New South Wales
Sydney
Canberra
Victoria
Great Australian Bight
Melbourne
Tasmania
Tasman Sea



Melbourne Tullamarine Airport (MEL)
24 km, 20 min
MCEC IPAC'19 Venue
24 km, 20 min
Australian Synchrotron (AS) IPAC'16 SPC3 venue

Australian Synchrotron Site Overview



$38M Building Programme

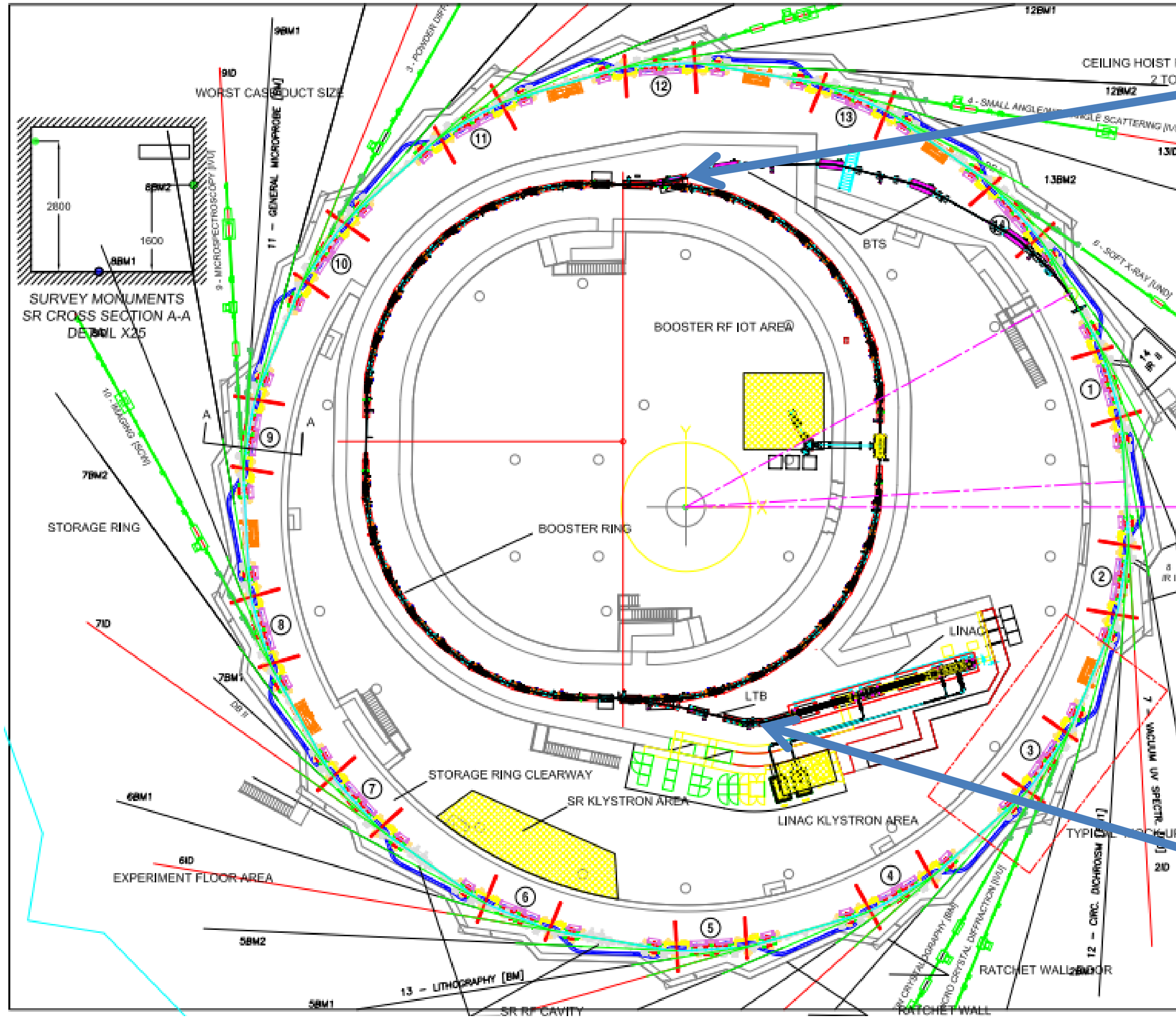
Australian Synchrotron

ACAS Australian Collaboration for Accelerator Science

2012 New National Centre for Synchrotron Science

Australian Synchrotron

Turning bright ideas into brilliant outcomes



3 GeV, 1 Hz, ~3 nC

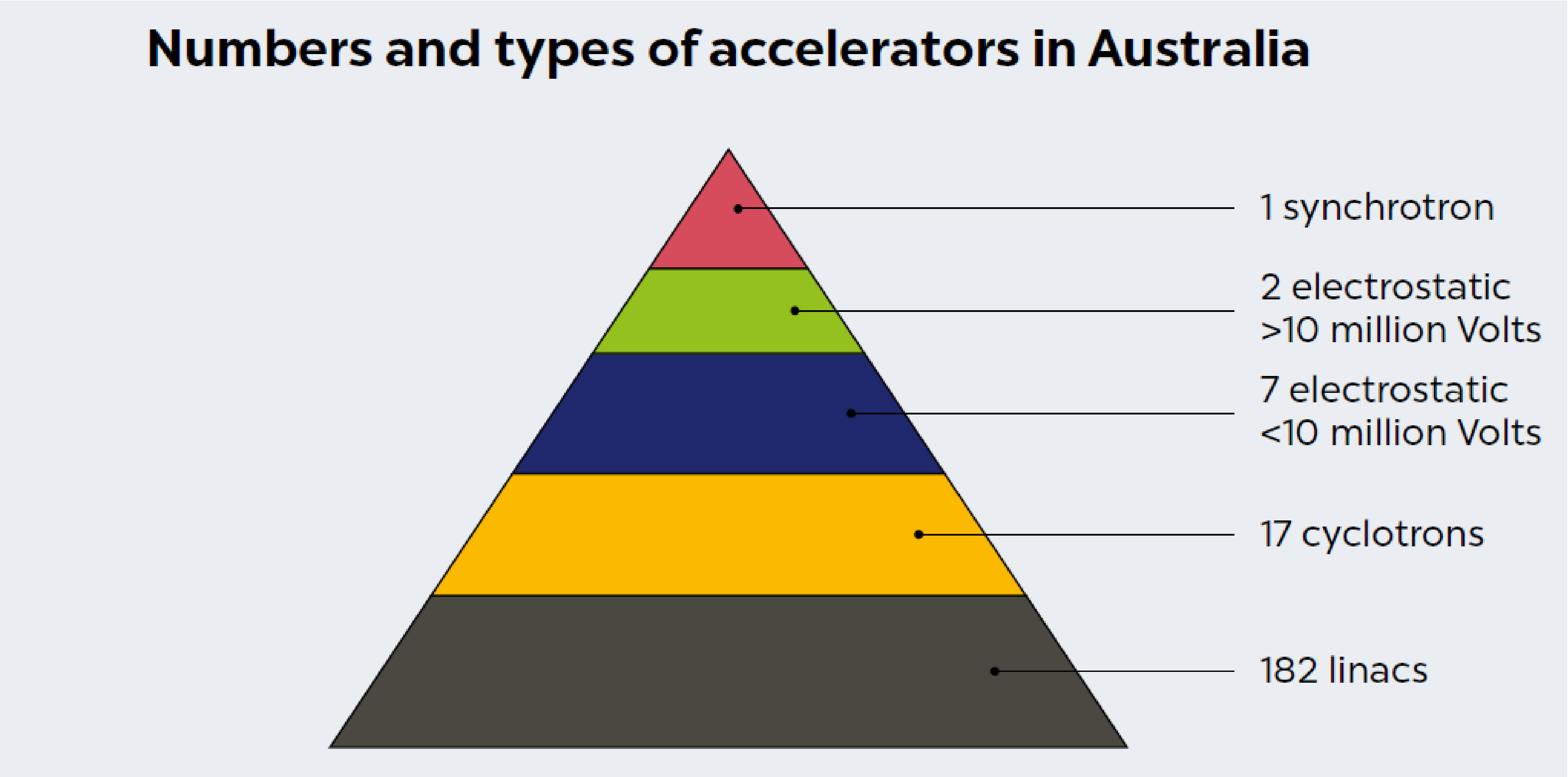
3 GeV, 1 Hz, ~5 nC

User Beam Availability 2007-2014

Australian Synchrotron | Australian Government | ansto | THE UNIVERSITY OF MELBOURNE | ANU THE AUSTRALIAN NATIONAL UNIVERSITY

- 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.)

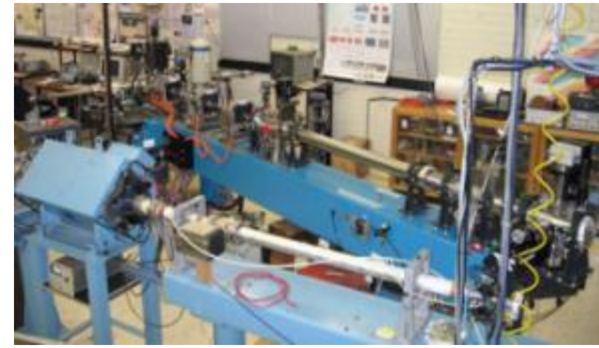
Australian Population ~22M People



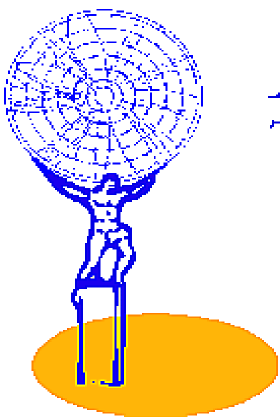
THE UNIVERSITY OF MELBOURNE

Provide Students!

Pelletron 5 MV ion accelerator

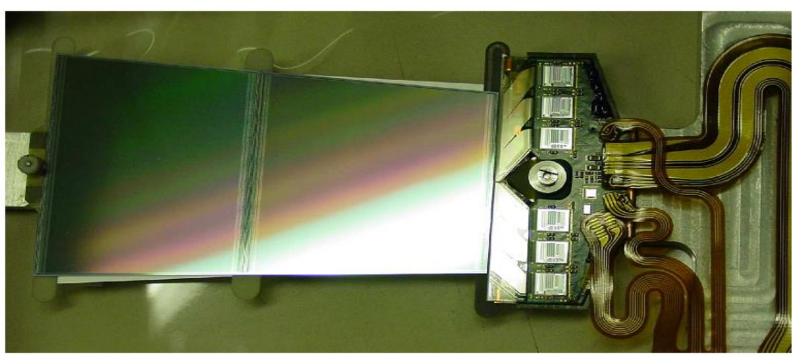


High Energy Particle Physics



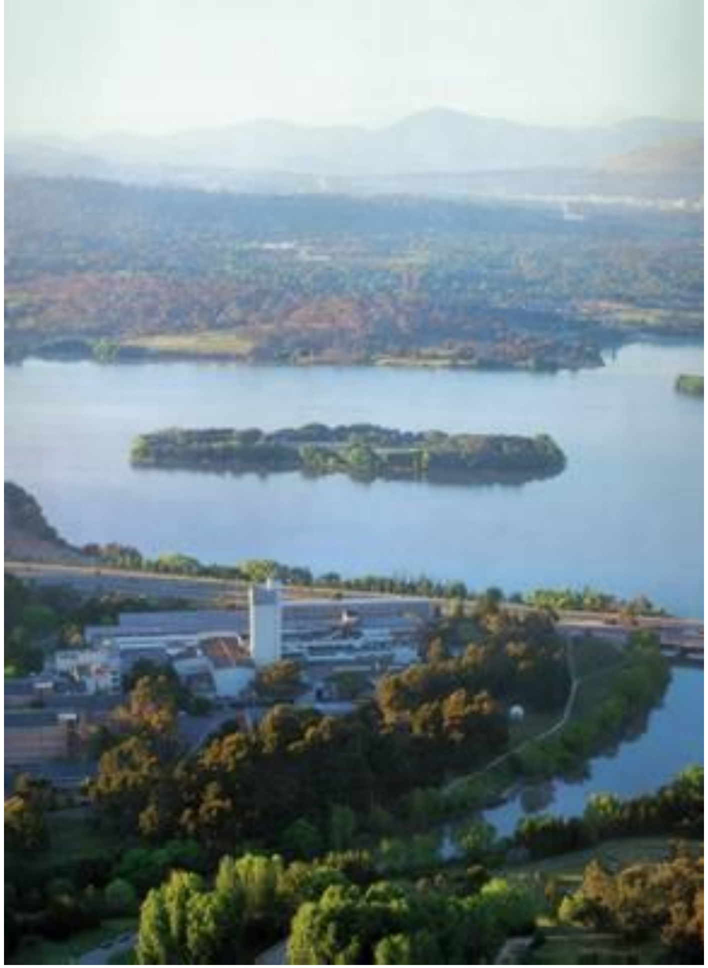
ATLAS SCT
The ATLAS Semiconductor Tracker

SCT Module



X-ray detector development

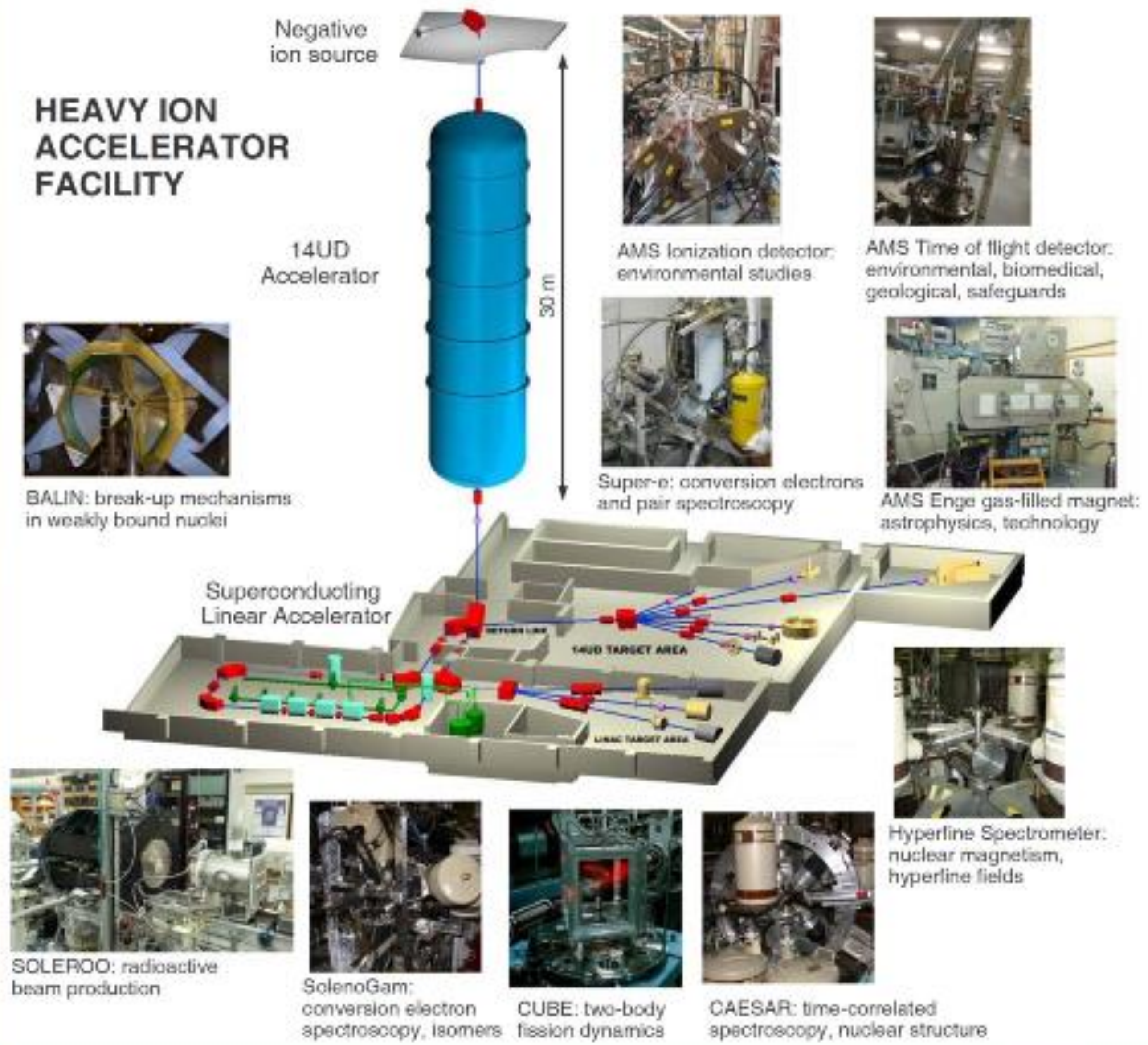
Still Going Strong: ANU 14UD



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.

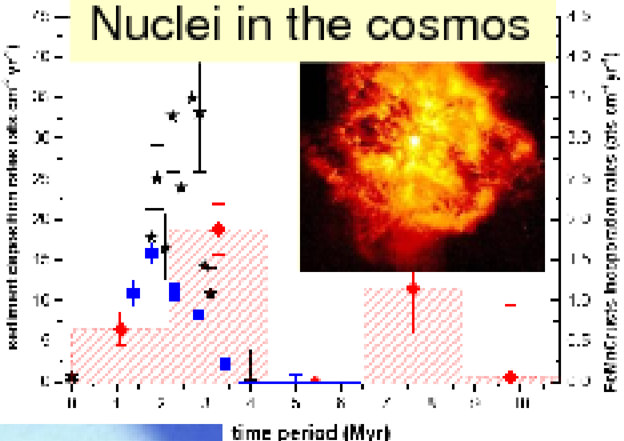
Australian National University

Heavy Ion Accelerator Facility



Research overview: some examples

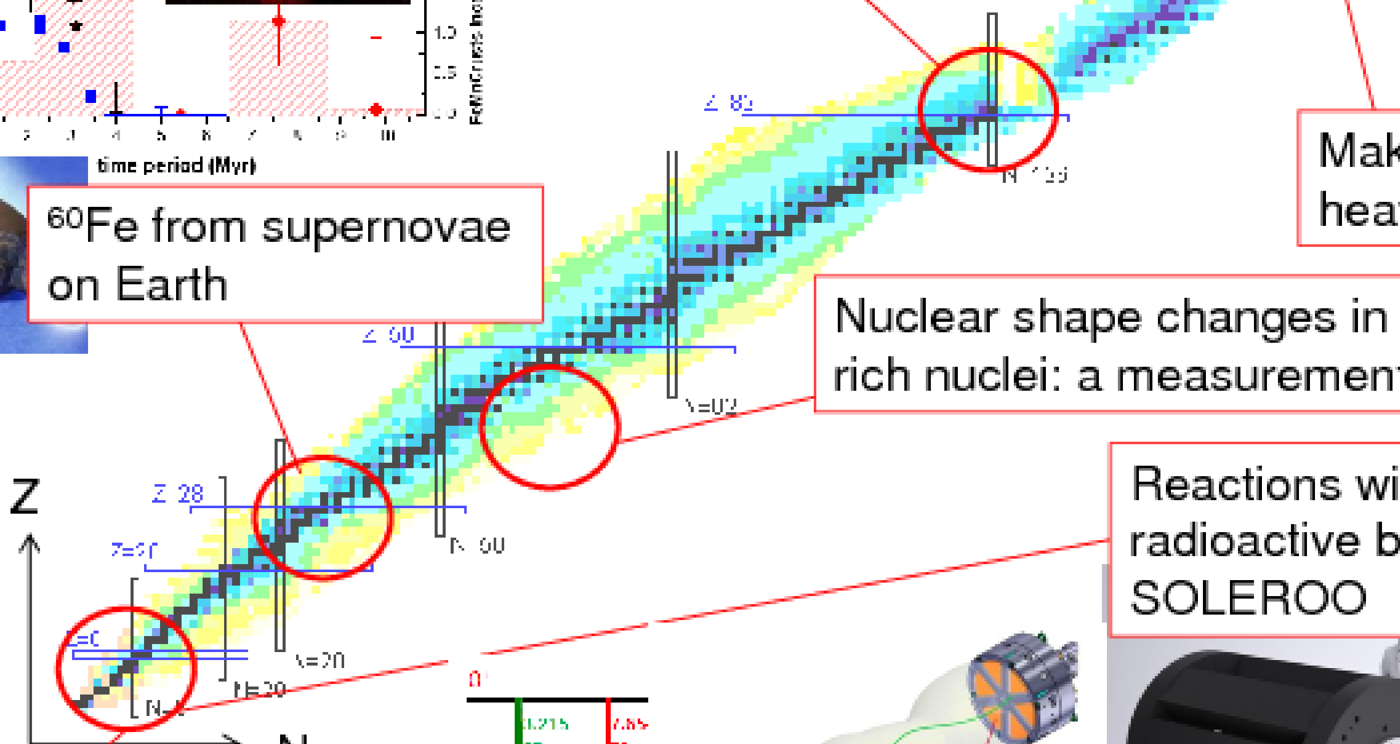
Nuclei in the cosmos

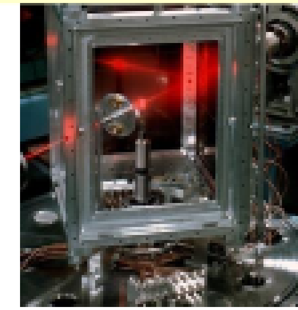


^{60}Fe from supernovae on Earth

Quantum physics with nuclei

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

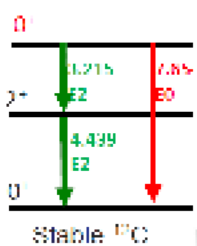


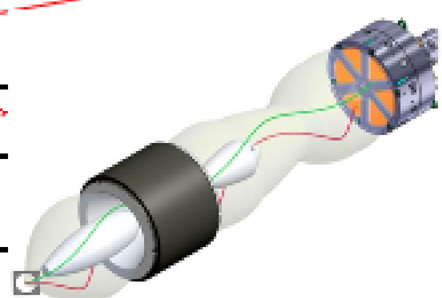


Making the heaviest elements

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

Reactions with radioactive beams – SOLEROO





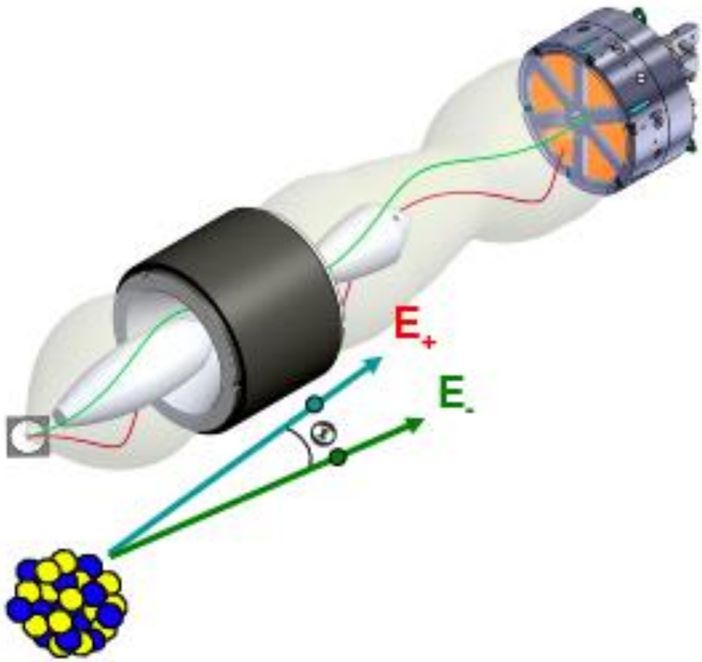
Hoyle state in ^{12}C: Making carbon in the cosmos

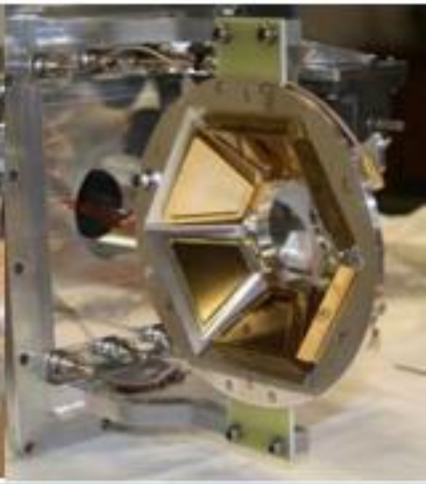
Experimental initiatives underway

Experimental and Instrumentation developments:

- DAQ multichannel (500+) capability
- CUBE – 3rd detector ↑ angular coverage
- $LaBr_3$ detectors – fast timing (MEC15)
- Pair spectrometer – Electric Monopoles
- Radioactive beams – SOLEROO
- New AMS isotopes

- Digital Data Acquisition
- SiPM & detector development

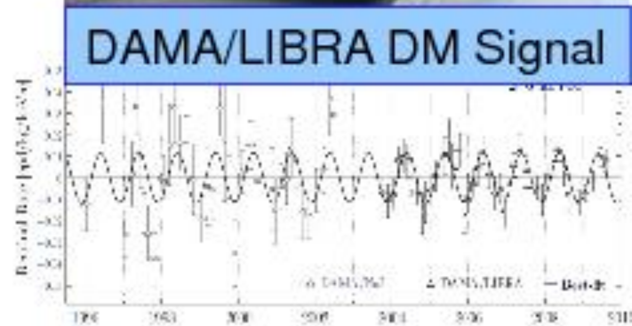


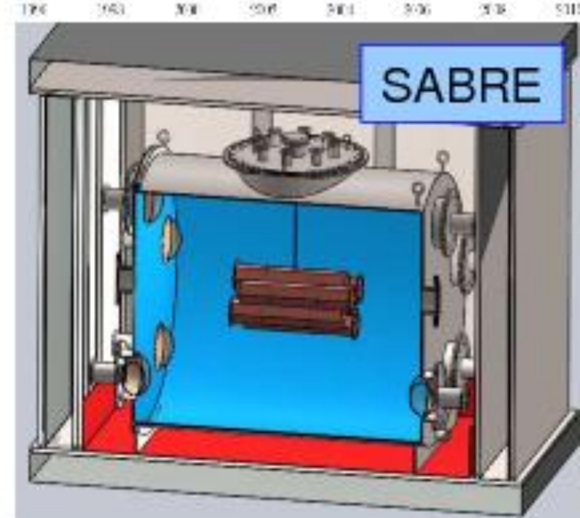


New initiative: Low background Lab - SUPL

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**





Australian Synchrotron

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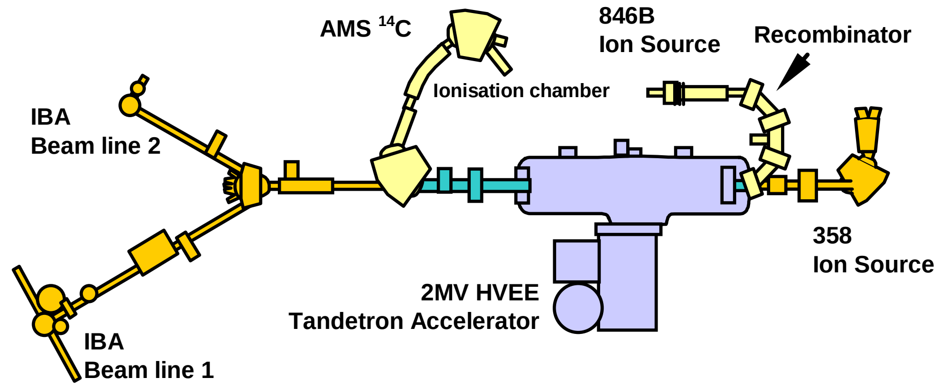
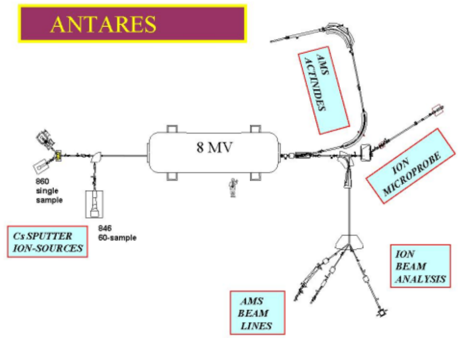
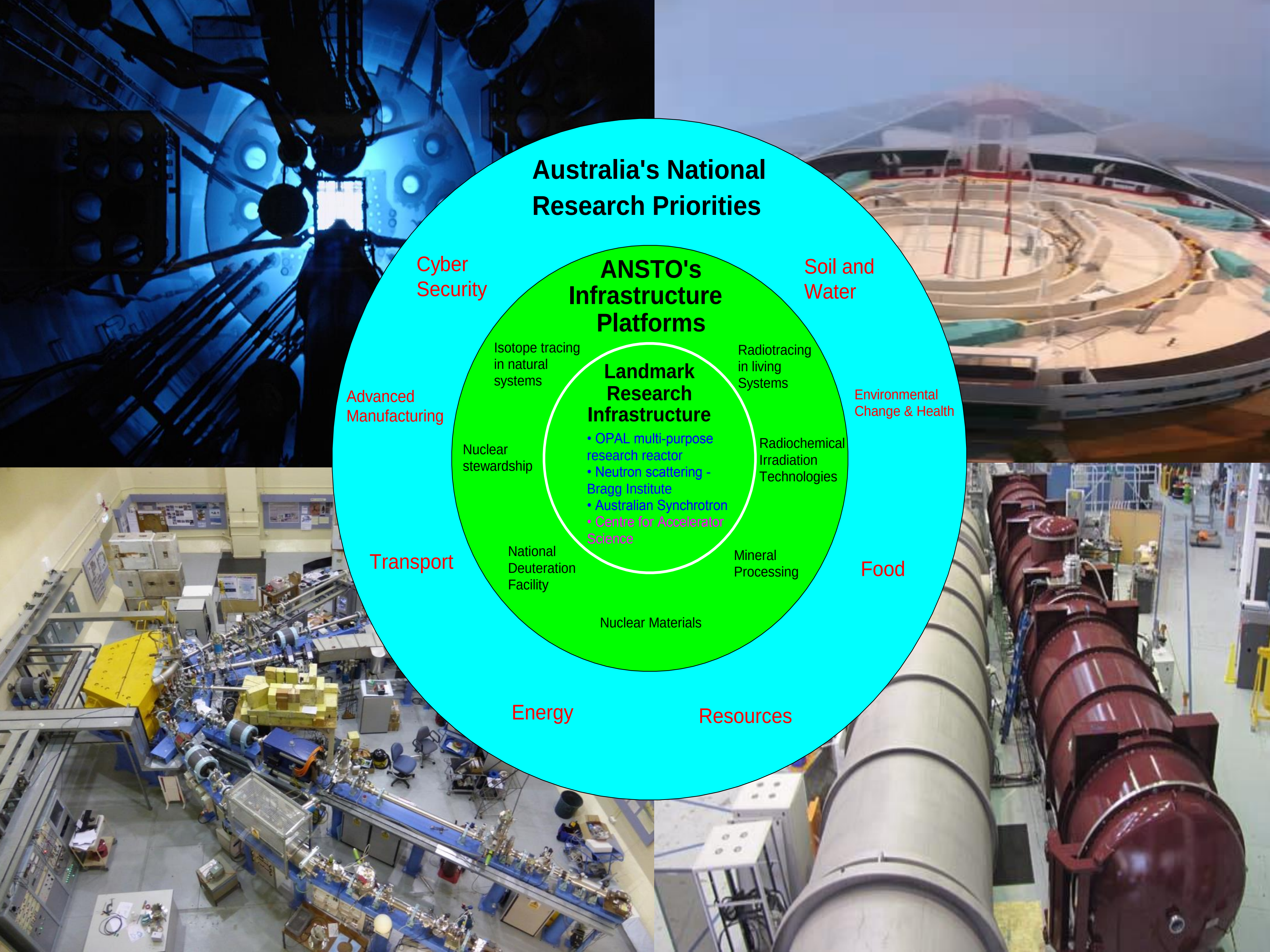
ansto

STAR - 2 MV Tandetron ion accelerator



ANTARES - 10 MV Tandem ion accelerator




Australia's National Research Priorities
Cyber Security
Soil and Water
Advanced Manufacturing
Environmental Change & Health
Transport
Food
Energy
Resources
ANSTO's Infrastructure Platforms
Isotope tracing in natural systems
Radiotracing in living Systems
Nuclear stewardship
Radiochemical Irradiation Technologies
National Deuteration Facility
Mineral Processing
Nuclear Materials
Landmark Research Infrastructure
• OPAL multi-purpose research reactor
• Neutron scattering - Bragg Institute
• Australian Synchrotron
• Centre for Accelerator Science

- 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; $^{239, 240}Pu$
  - 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

Isotopic ultra-tracing, nuclear forensics, bomb pulse, actinides,
bio uptake, diet, toxicology

Micro-spectroscopy, 2D mapping, Bio-imaging, Micro-implantation

Ion source enhancement, ECR ion source development, IRMS++

Environmental tracing, Hyper-accumulating plants systems, salinity, erosion, environmental sensors

Fundamental physics, nuclear reactions, X-ray cross sections, Subshell fluorescence yields, Heavy ion stopping, neutron cross sections, mono-energetic neutrons,
Transmutation doping

CAS Platform

Facilities - 4 accelerators: 1MV, 2MV, 6MV & 10MV
- AMS Sample Preparation Lab
- Low Energy Ion implanters

Capabilities - Accelerator Mass Spectrometry (AMS)
- Ion Beam Analysis (IBA)
- Technical Group: maintenance & development

Fine particle air pollution

Radiation dosimetry, Micro-dosimetry, Micro-detectors, IBIC mechanisms

Archaeology Geology

Earth sciences, Geomorphology, landscape change, Climate change, Water management

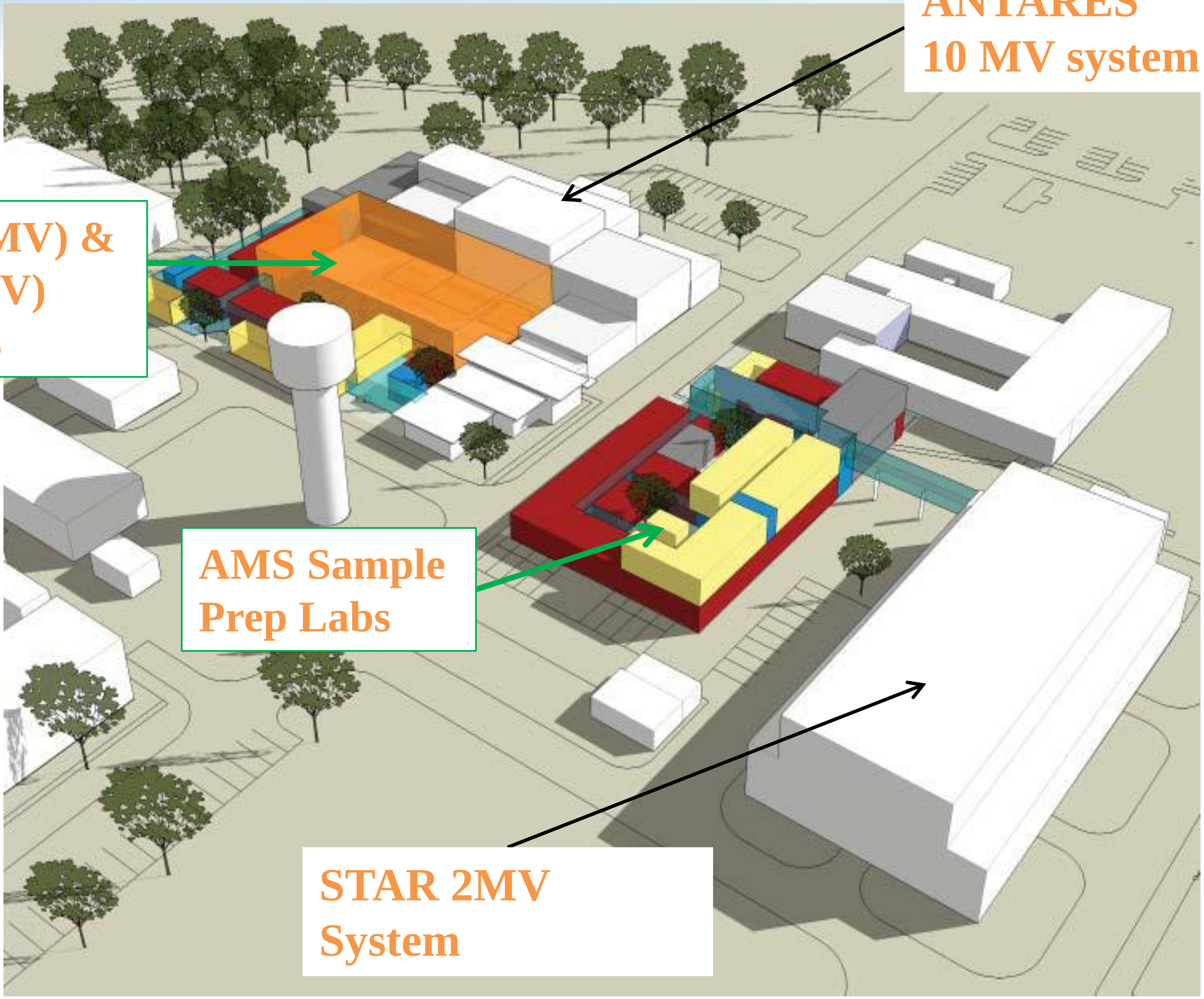
Materials research (modification & characterisation)
Structural and Functional Interface engineering, Ion beam deposition, Thin films & coatings,
Ion implantation, Ion damage, Structural Nuclear Materials

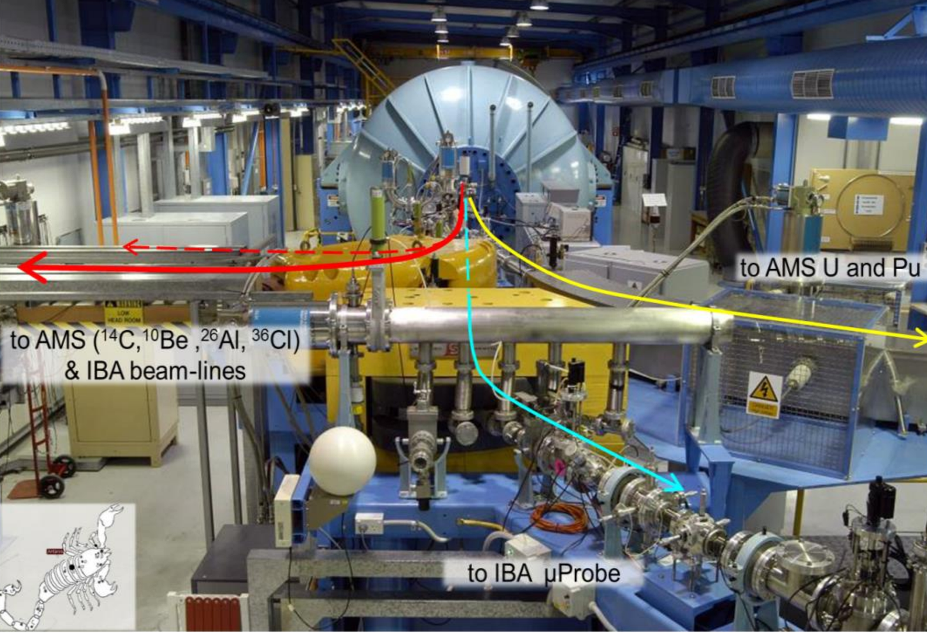
Users: universities (37), AINSE, CSIRO, IAEA, international collaborators, commercial, training

ansto

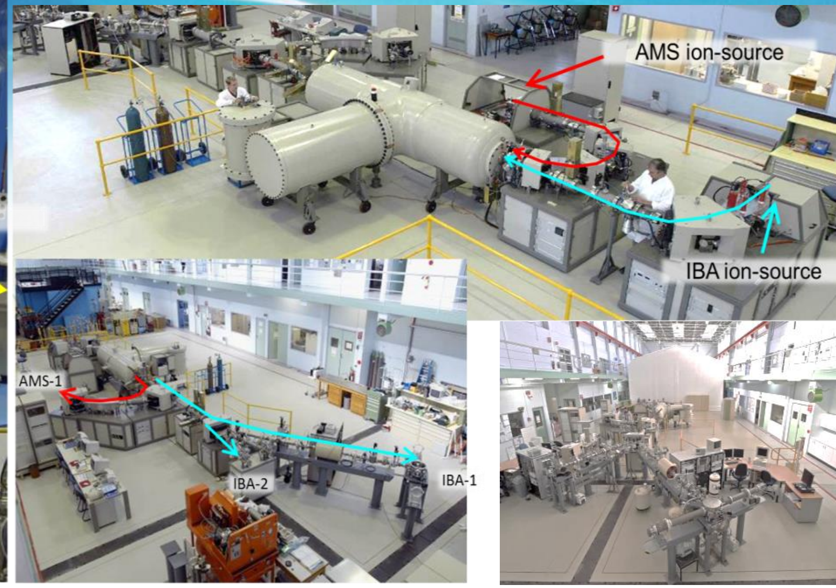
Australian Government

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

ELSEVIER
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 tandetron	1981–present	
2.8 MV	CSIRO, North Ryde	General Ionex tandetron	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[a]

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	

[a] Excluding hospital radiation treatment facilities.

Single-ended Van de Graaffs

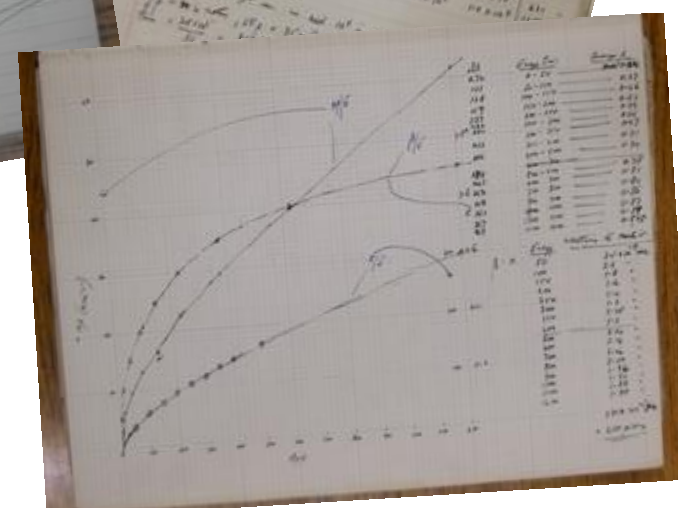
1 MV	University of Melbourne	University of Melbourne (Martin, Hirst and Dunbar)	1948–60	Air-insulated. Construction started April 1946.
0.8 MV	University of Melbourne	University of Melbourne (?)	1952–73	Air-insulated. Designated the Statitron.
1.3 MV	AAEC, Lucas Heights	HVEC Burlington, MA	1962–present	Installation 1961/2. DC electron beams of ~35 μA or 3 μs 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 Mediphysics, Japan. Shipped May 1980.
10 MeV (Protons)	Austin Hospital, Melbourne	Ion Beam Corp Cyclone 10/5	1992–present	Used for radio-isotope production. (^{11}C, ^{13}N, ^{15}O and ^{18}F)
30 MeV (Protons)	Royal Prince Alfred Hospital, Sydney		1991–present	Used for radio-isotope production.

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.

...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.

The new method.

The essential feature of the proposals is that the particles 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 electrons and protons.

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, $\nu_0 = 1.2 \times 10^7$.

1) $\nu = \nu_0 = 1.2 \times 10^7$ cycles/second, $\lambda = 25$ metres.
2) $\nu = 2\nu_0 = 2.4 \times 10^7$ " , $\lambda = 12.5$ metres.
3) $\nu = 4\nu_0 = 4.8 \times 10^7$ " , $\lambda = 6.25$ metres.
etc.

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).

Synchrotron publication record

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.

First Publications: 1945-46

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

Radiation from a Group of Electrons Moving in a Circular Orbit

EDWIN M. MCMILLAN
University of California, Berkeley, California
September 9, 1945

A SINGLE electron of total energy E (rest energy $=E_r$) moving in a circle of radius R, radiates energy at the rate L (electron volts per turn), given by:

$$L = 400\pi(e/R)(E/E_r)^4, \quad (1)$$

where e is the electronic charge in e.s.u., and $E >> E_r$. In the synchrotron one has the case of a rather concentrated group of electrons moving in the orbit, and the total amount of radiation depends on the coherence between the waves emitted by the individual electrons. For example, if there were complete coherence, the radiation per electron would be N times that given by (1), where N is the number of electrons in the group.

It is apparent from the above that an answer to the coherence problem is very important for any device in which groups of electrons are made to move in a circle with high velocity. This answer is given by a formula due to J. Schwinger (communicated to the author by I. I. Rabi). Schwinger's formula gives the radiation in each

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 paper[3] 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 McMillan[4] 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).

- Oliphant's Unpublished Memo: 1944

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.

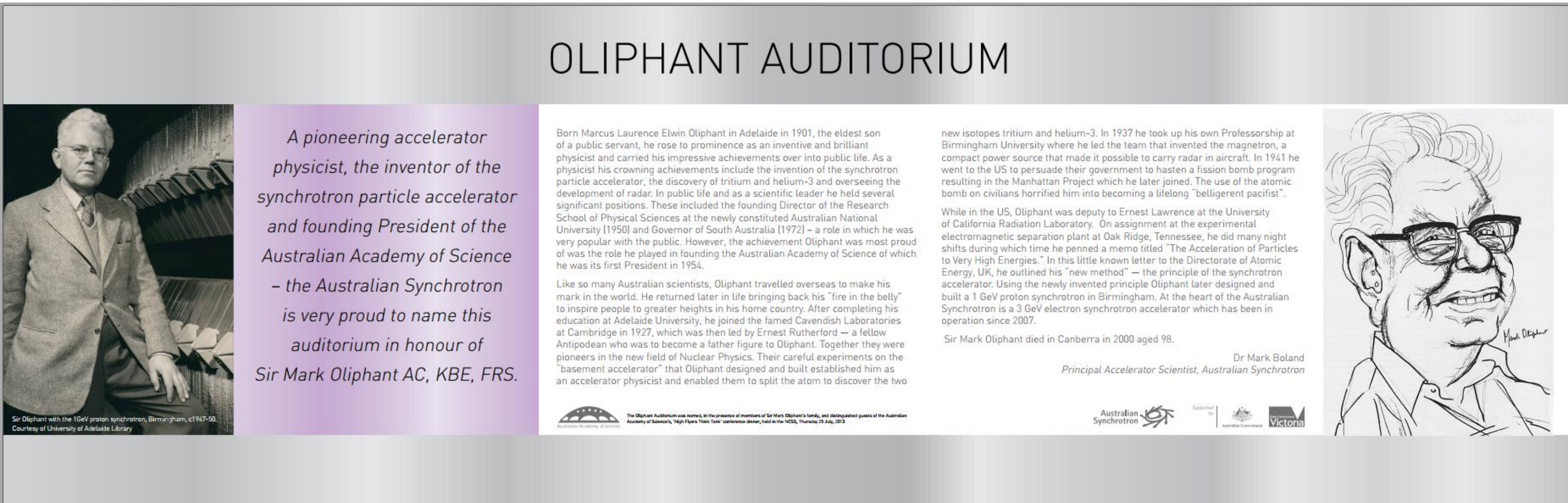
The greatest hope for an increase in fundamental understanding lies in experiments at energies above 1000 MeV. Cosmic radiation offers a source of particles with energies in this region, or higher, but, due to the low intensity and the uncertainties about the nature of any individual particle, there are difficulties in the proper interpretation of experimental results. Investigators in this field of physics have shown remarkable ingenuity and patience and very striking results have been obtained. However, the rate of progress could be greatl accelerated and obscure points could be much more easily settled, if there were available a method for accelerating particles of known kind to known energies in this region. It is certain that new and important phenomena would be discovered because of the greater intensity and ~~xxxxxxxxx~~ the freedom from obscurity as to the kind and energy of the bombarding particles, while knowledge of the fundamental properties of these primary particles would reflect on the whole of nuclear physics.

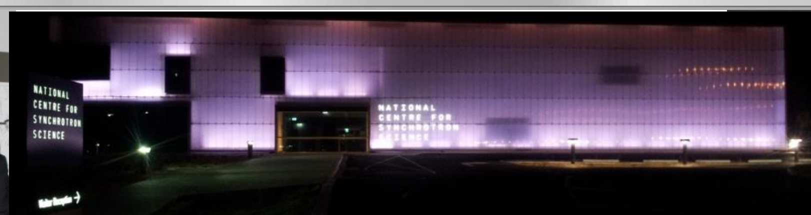
The new method.

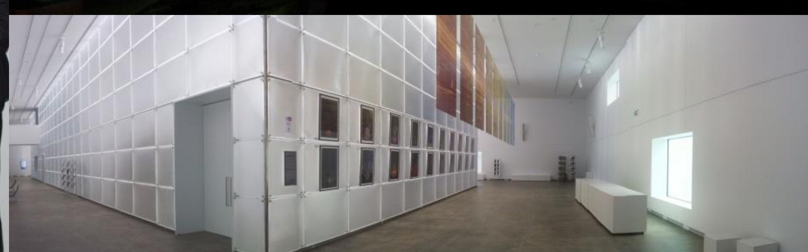
The essential feature of the proposals is that the particle should be constrained to move in a circle of constant radius, thus enabling the use of an annular ring of magnetic field of the correct form but over a total volume which is small enough to require only moderate power for its excitation. The 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 tha 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 provide 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 ~~xxxxx~~ electrons and protons.

Honouring Oliphant





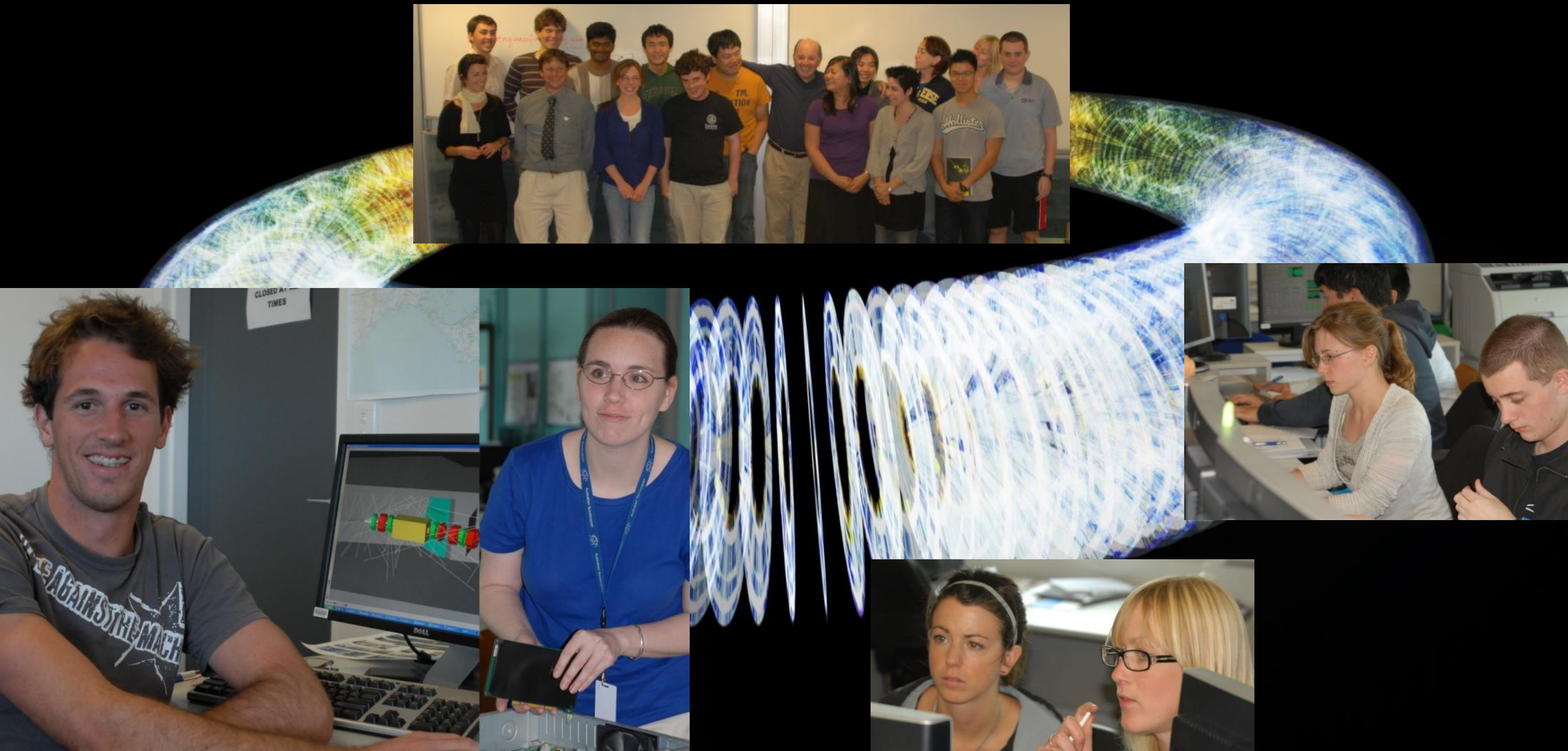


Asian Committee for Future Accelerators (ACFA) this week created a new IPAC Asia prize for PhD students in accelerator physics named in honour of Mark Oliphant. First prize to be presented at IPAC’16 in Korea.

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

ACAS – helping to build the future



Australian Synchrotron

ansto

POSTERA CRESCAM LAUDE
THE UNIVERSITY OF MELBOURNE

ANU
THE AUSTRALIAN NATIONAL UNIVERSITY

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

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

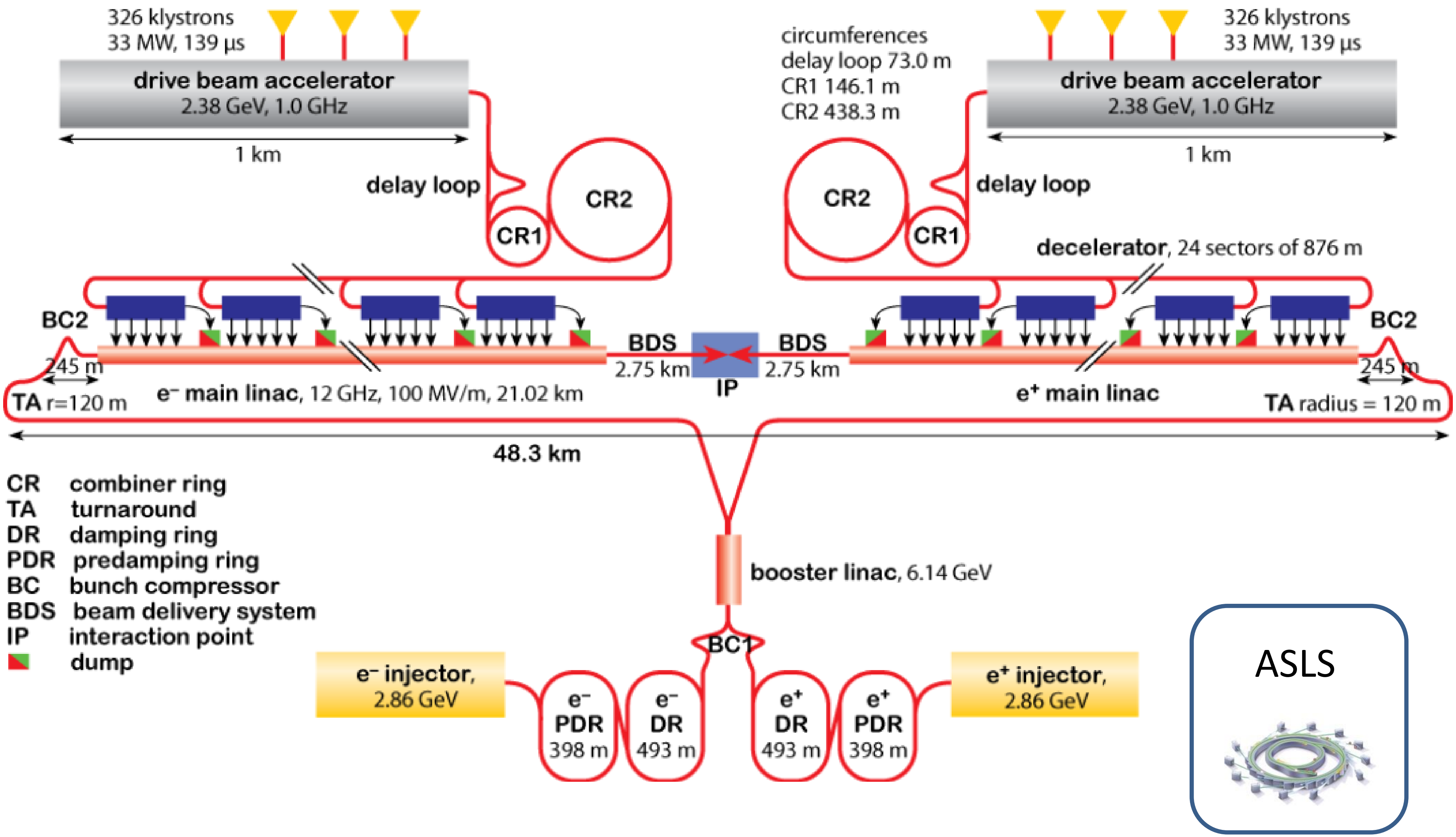

SLAC-R-985
KEK Report 2012-1
PSI-12-01
JAI-2012-001
CERN-2012-007
12 October 2012

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

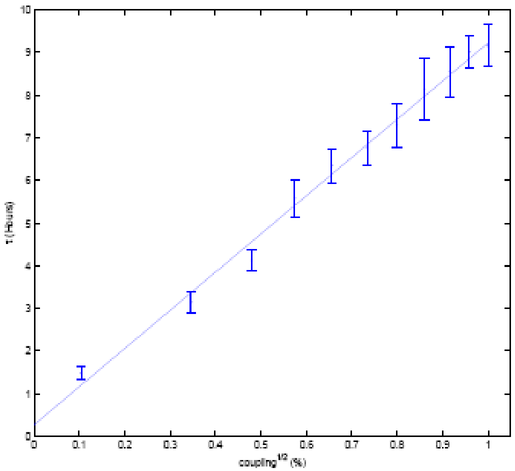
A MULTI-TEV LINEAR COLLIDER BASED ON CLIC TECHNOLOGY
CLIC CONCEPTUAL DESIGN REPORT

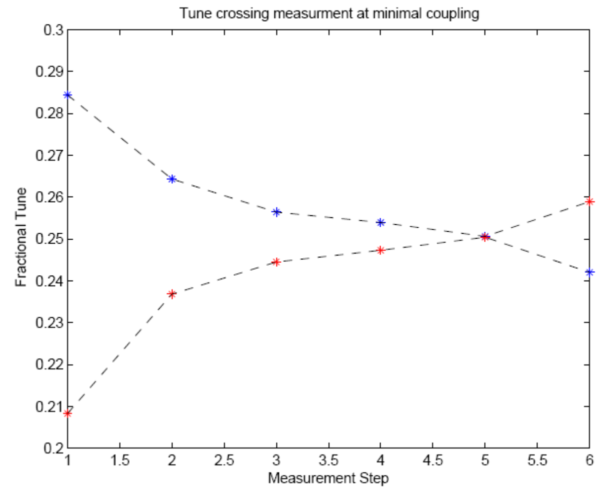
GENEVA
2012

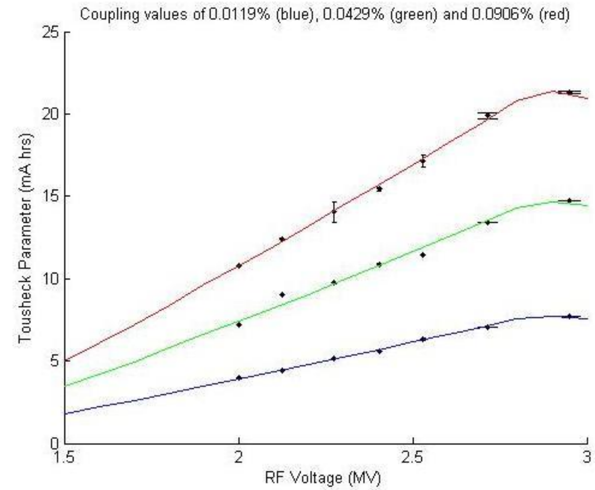
CLIC Damping Rings Kent Wootton (PhD UoM)

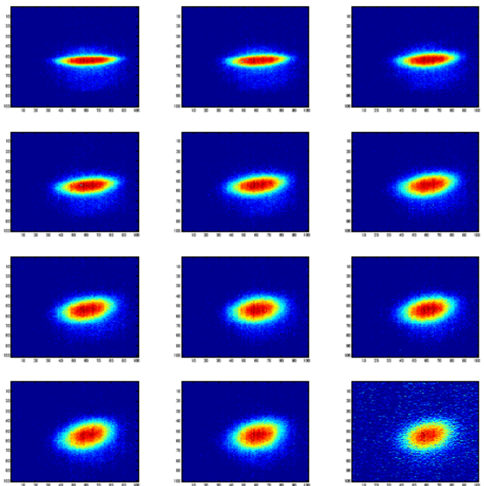


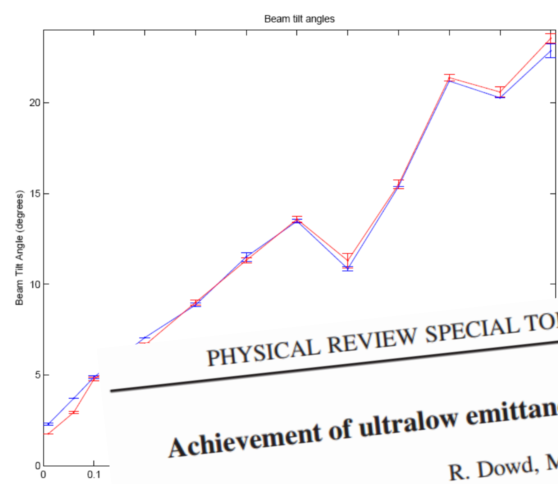
Body of evidence for world low emittance





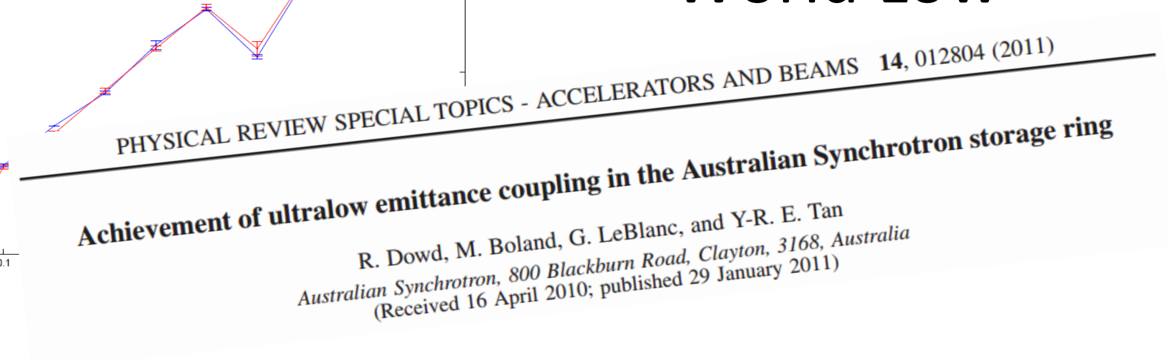






$\varepsilon_y = 1.24 \pm 0.4$ pm

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)

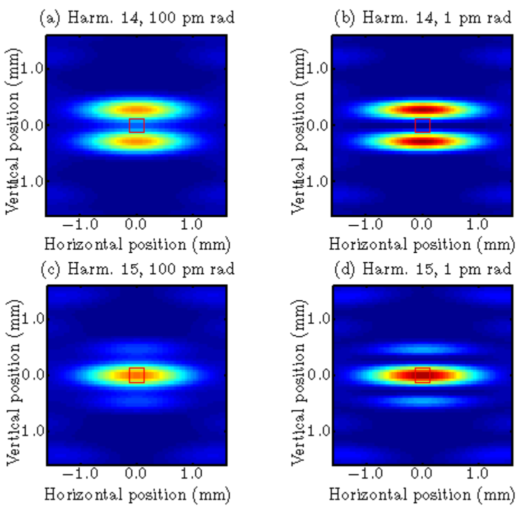
Improved Vertical Undulator Measurements

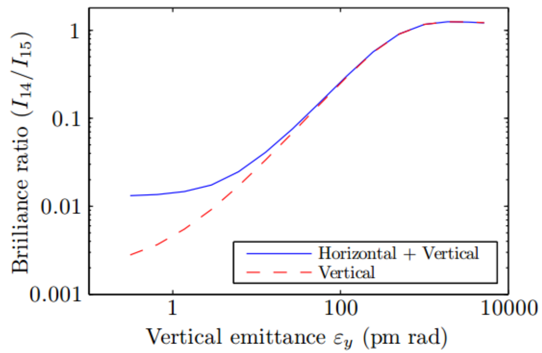
PRL 109, 194801 (2012) PHYSICAL REVIEW LETTERS week ending 9 NOVEMBER 2012

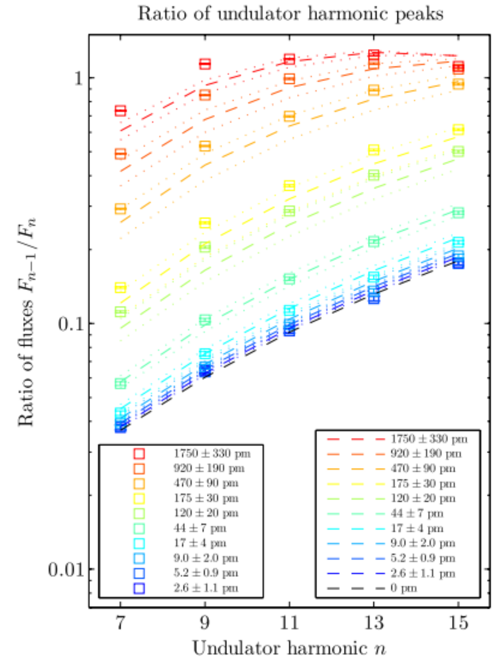
Observation of Picometer Vertical Emittance with a Vertical Undulator

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. Rassool[1]

[1]*School of Physics, The University of Melbourne, Melbourne VIC 3010, Australia*
[2]*Australian Synchrotron, 800 Blackburn Road, Clayton VIC 3168, Australia*
[3]*European Organization for Nuclear Research (CERN), BE Department, 1211 Geneva 23, Switzerland*
(Received 11 July 2012; published 8 November 2012)





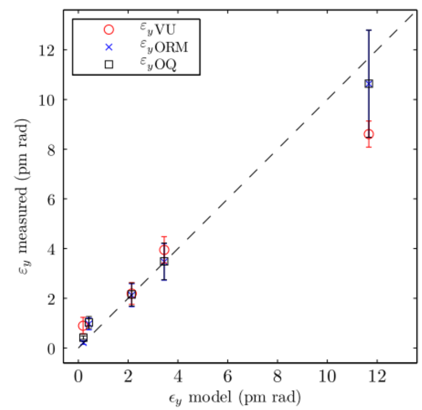


PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 17, 112802 (2014)

Measurement of ultralow vertical emittance using a calibrated vertical undulator

K. P. Wootton,[1,*] M. J. Boland,[1,2] and R. P. Rassool[1]

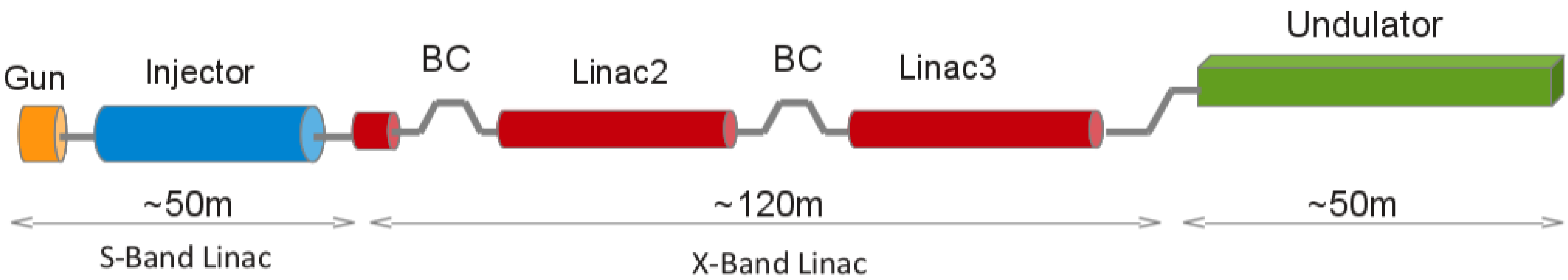
[1]*School of Physics, The University of Melbourne, Parkville, VIC 3010, Australia*
[2]*Australian Synchrotron, 800 Blackburn Rd, Clayton, VIC 3168, Australia*
(Received 7 July 2014; published 14 November 2014)



FEL Overview

A. Aksoy

Slide from D. Schulte, CERN



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=5.8GeV Q=200pC σ_z=7µm ε≈200nm-500nm

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

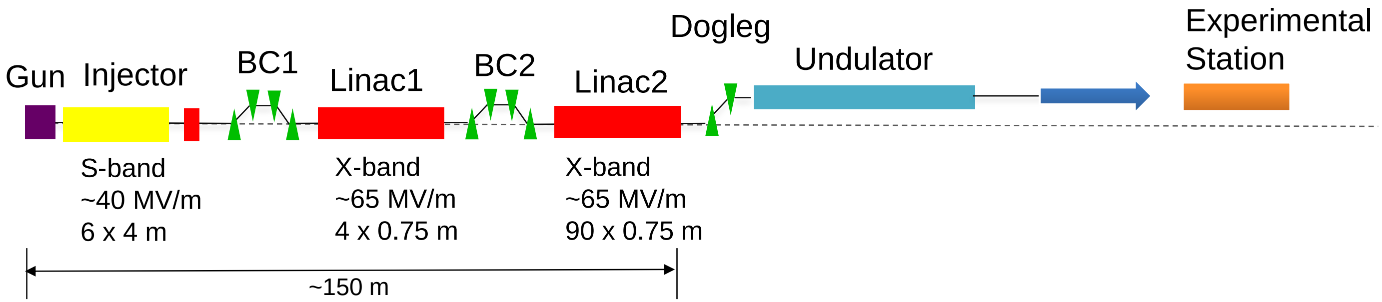
E=6GeV Q=250pC σ_z=8µm ε≈400nm-500nm

As example we did chose Q=250pC, E=6GeV and will go for similar bunch lengths

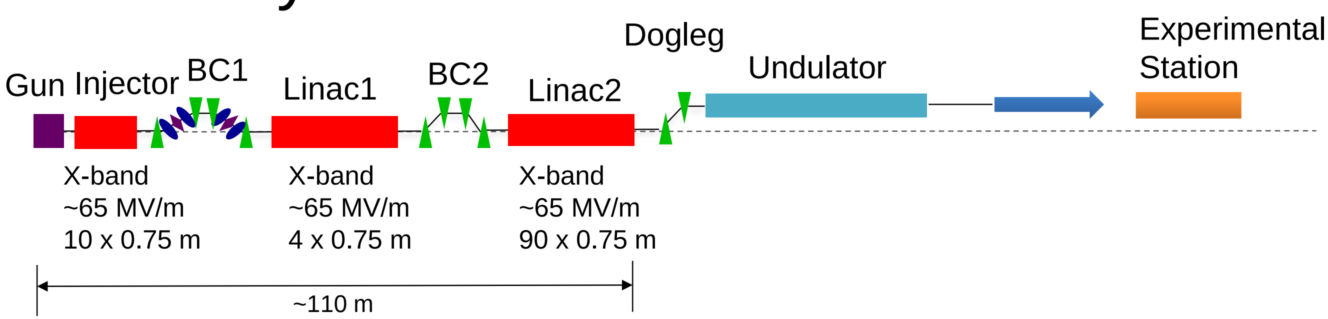
Do not study injector (use the one from PSI for now) or undulator

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

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



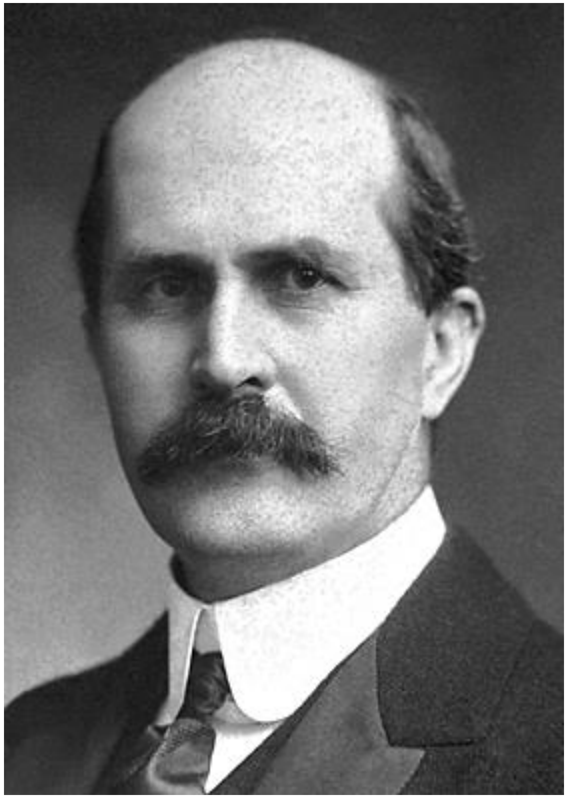
2. Alternative design being considered: X-band the whole way



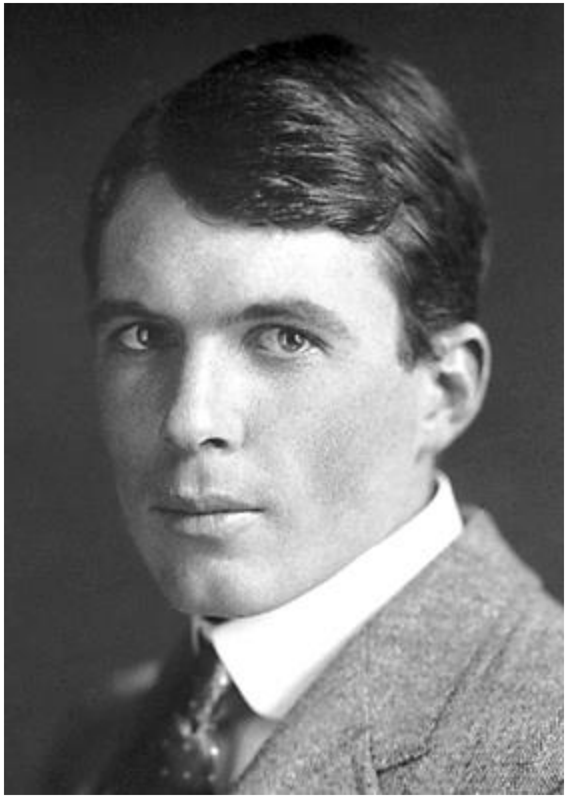
Laboratory Panorama (from my office)
2007-2015

Bragg Centenary 2012

- 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
- Lawrence was born and educated in Adelaide, Australia
- The BRAGG Symposium 6 Dec 2012, Adelaide



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

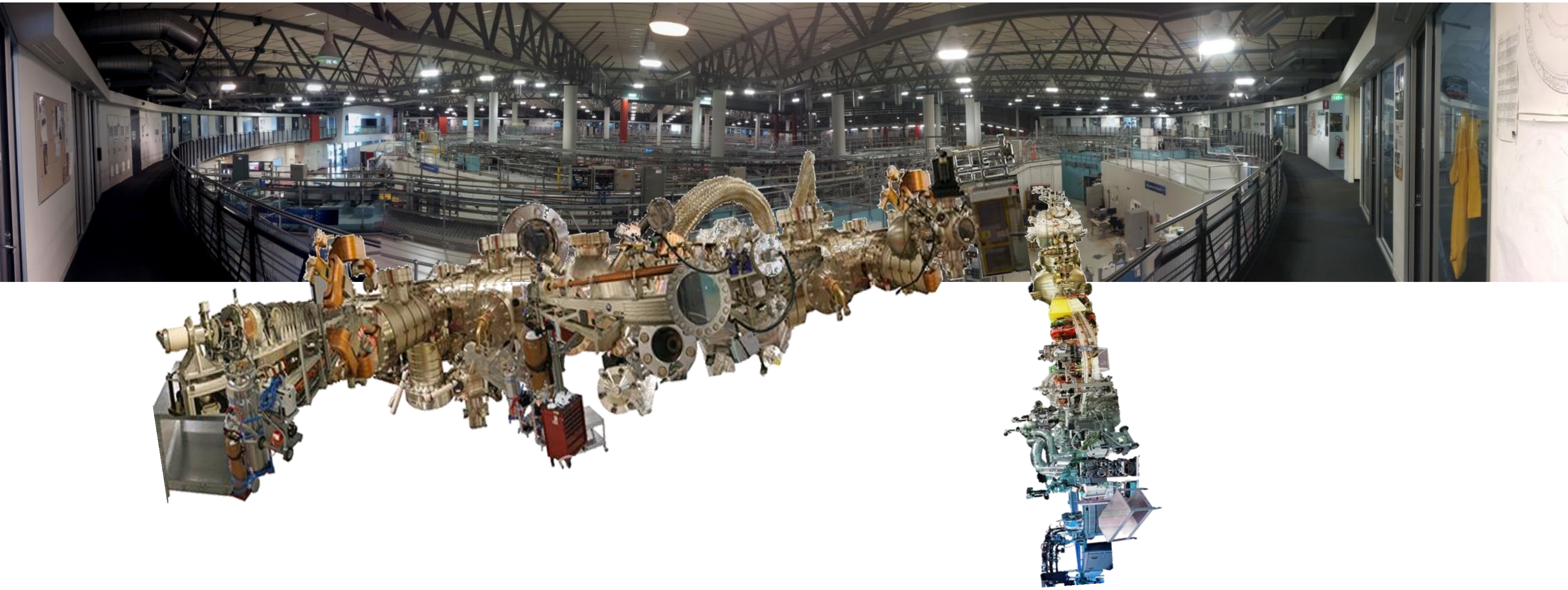


Laurence Bragg
Born 31 March 1890,
Adelaide, Australia
Educated at Adelaide University

Laboratory Panorama (from my office)

2016-2025

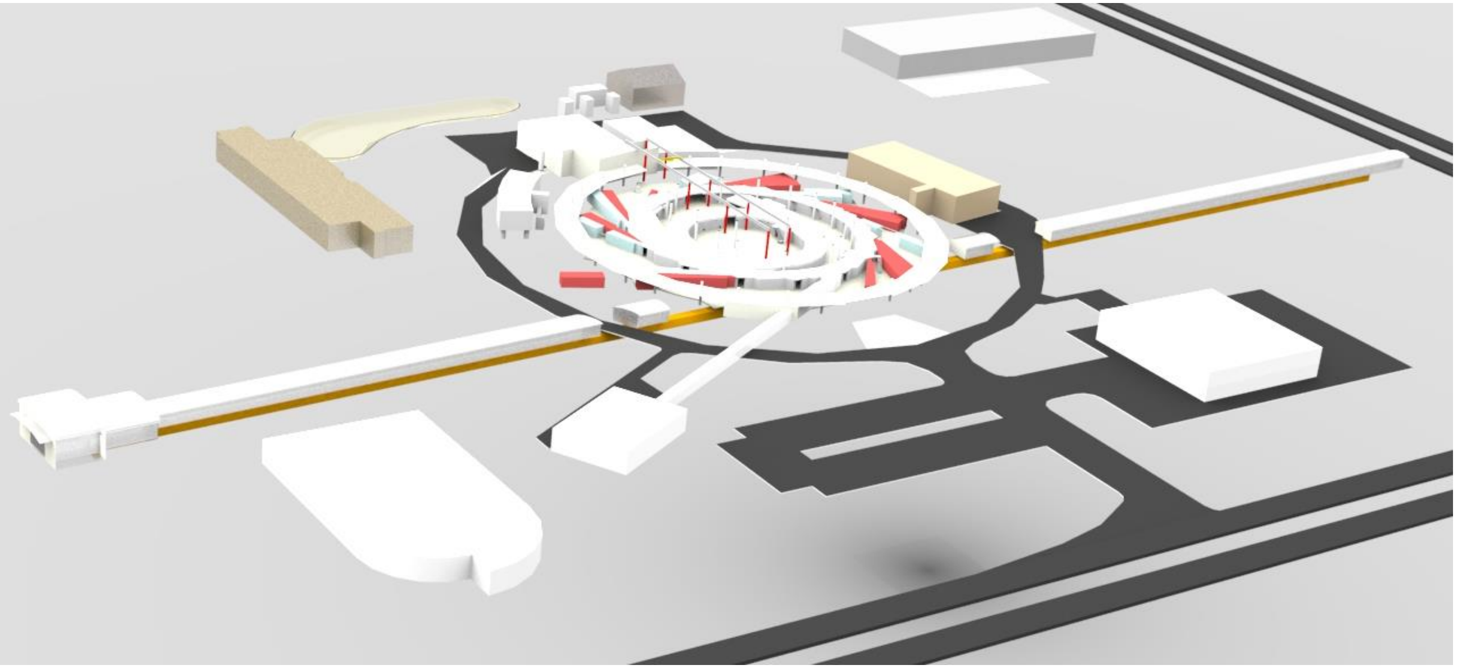
More beamlines



AXXS

AXXS – Australian X-band X-ray Source
AXXS n. /ˈæksɪs/ *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)

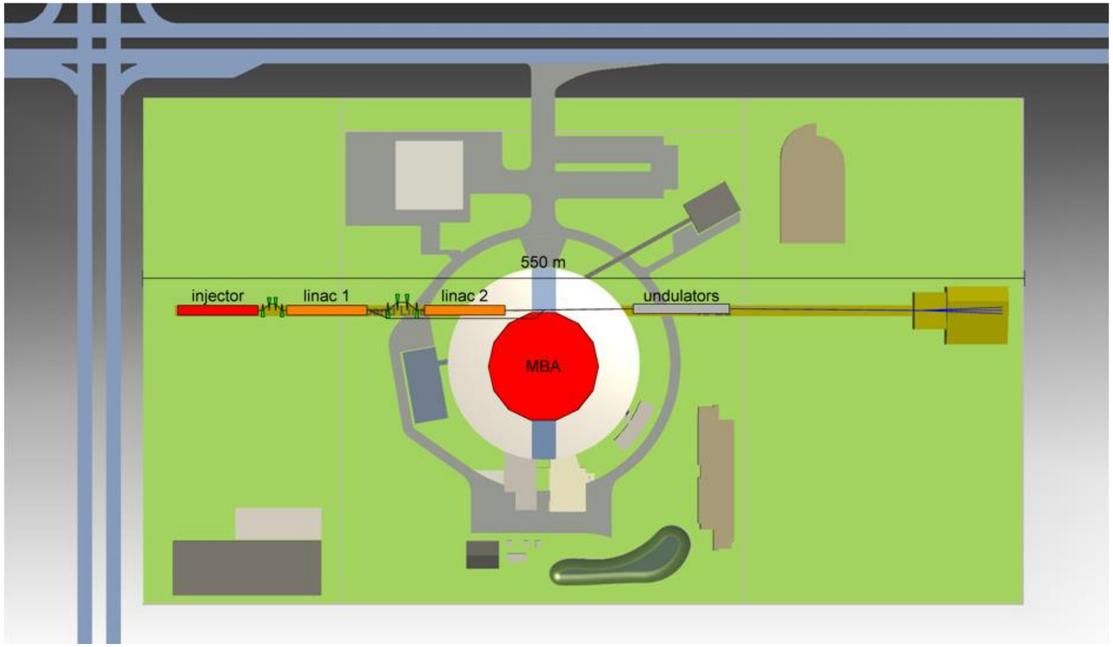


AXXS

- 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.



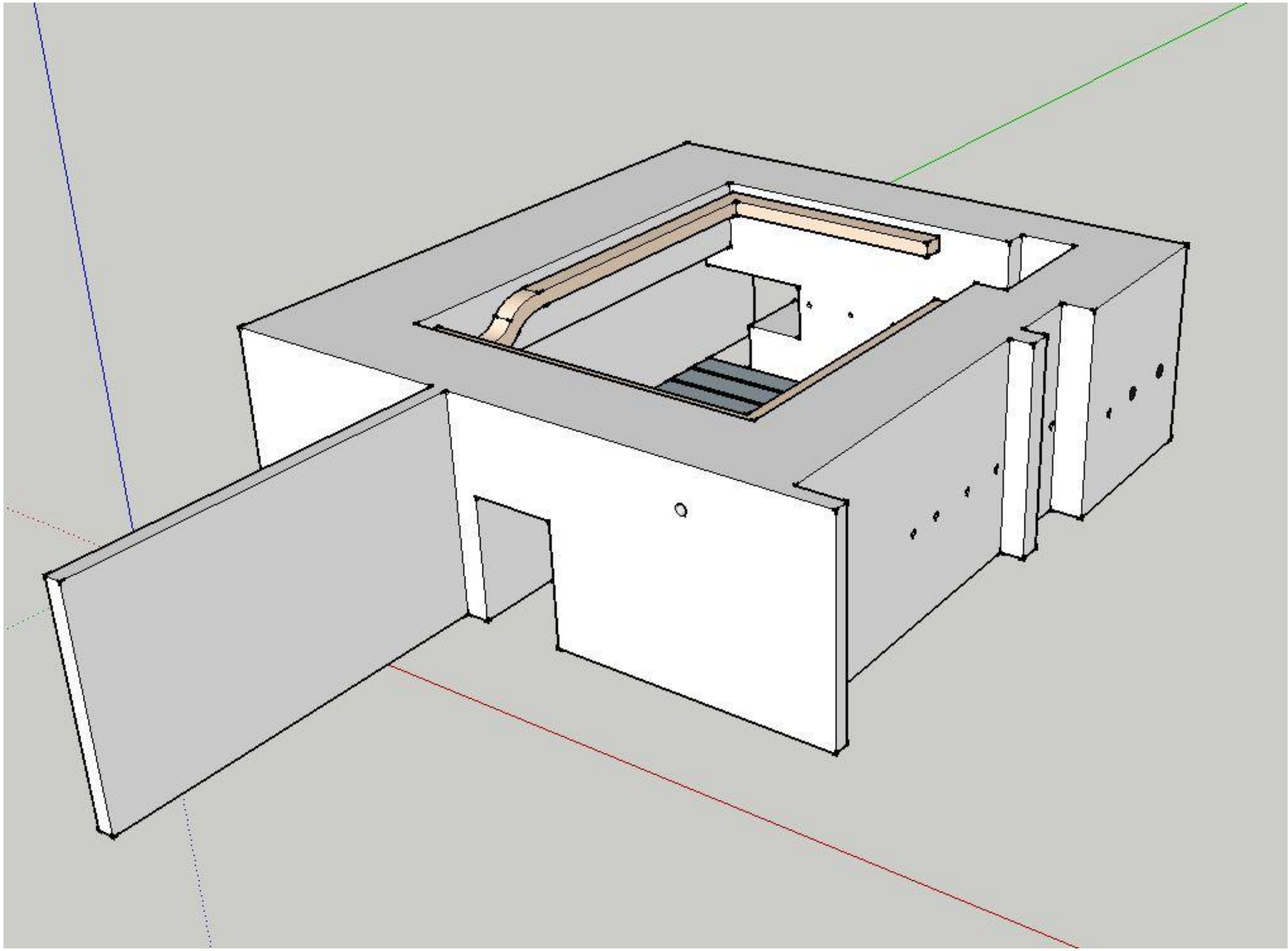
Australian Synchrotron

ACAS Australian Collaboration for Accelerator Science

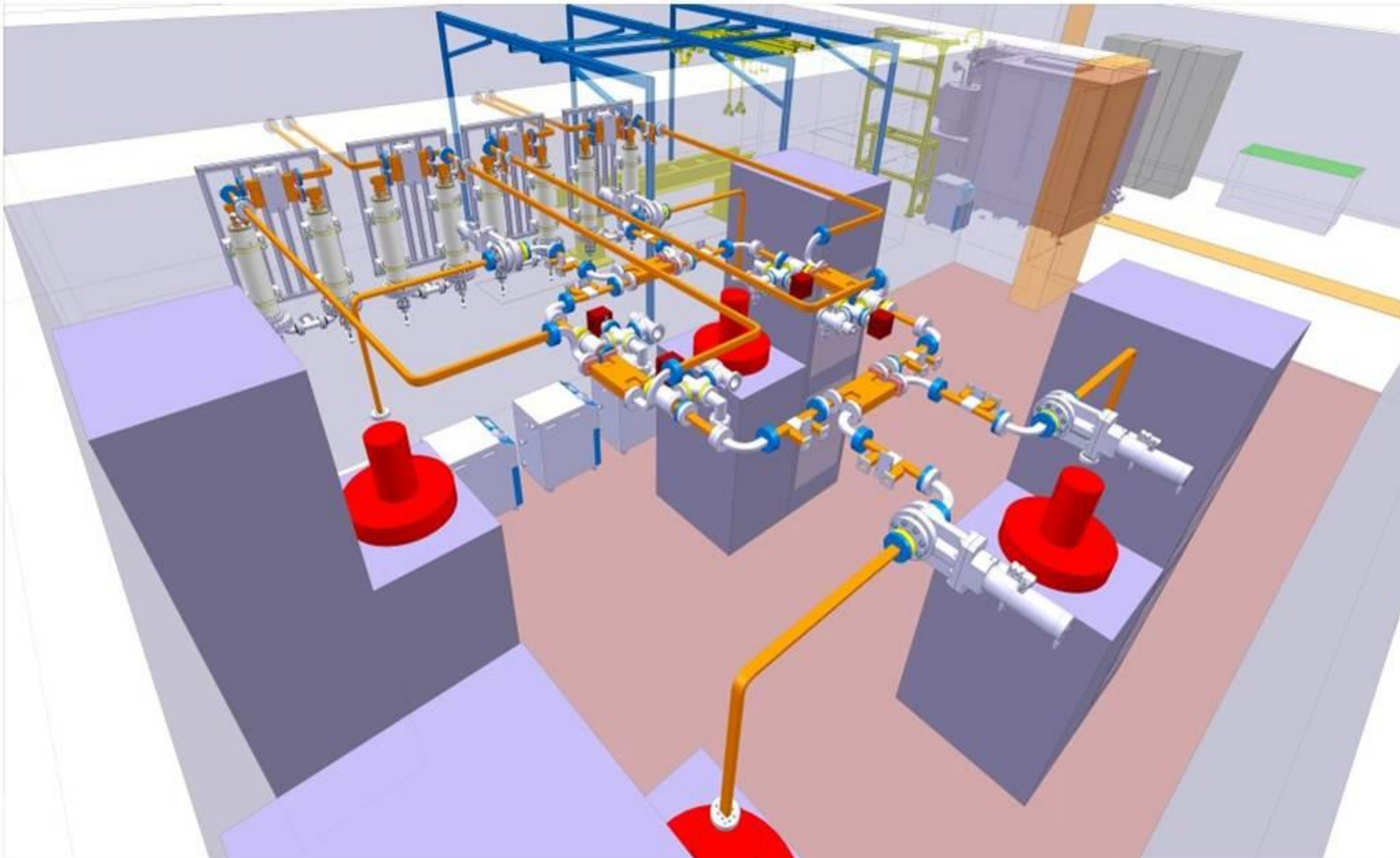
Advanced Accelerator R&D at Melbourne Uni

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

Accelerator Bunker at Melbourne Univeristy



Split XBOX3

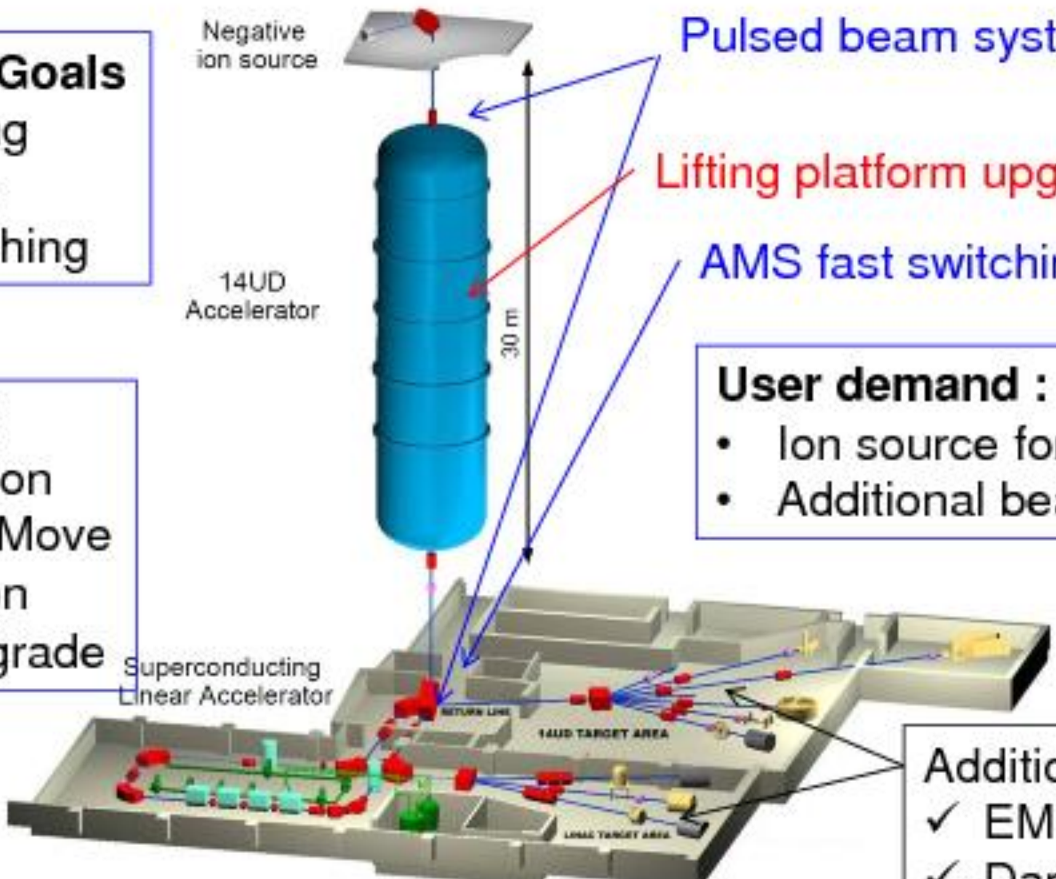


Accelerator & Beamlines (0-3 years)

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



Pulsed beam system

Lifting platform upgrade

AMS fast switching

User demand :
- Ion source for ^{3}He, ^{4}He beams
- Additional beam lines

Additional Users:
- ✓ EME HI irradiations
- ✓ Dark Matter
- ✓ Medical Physics

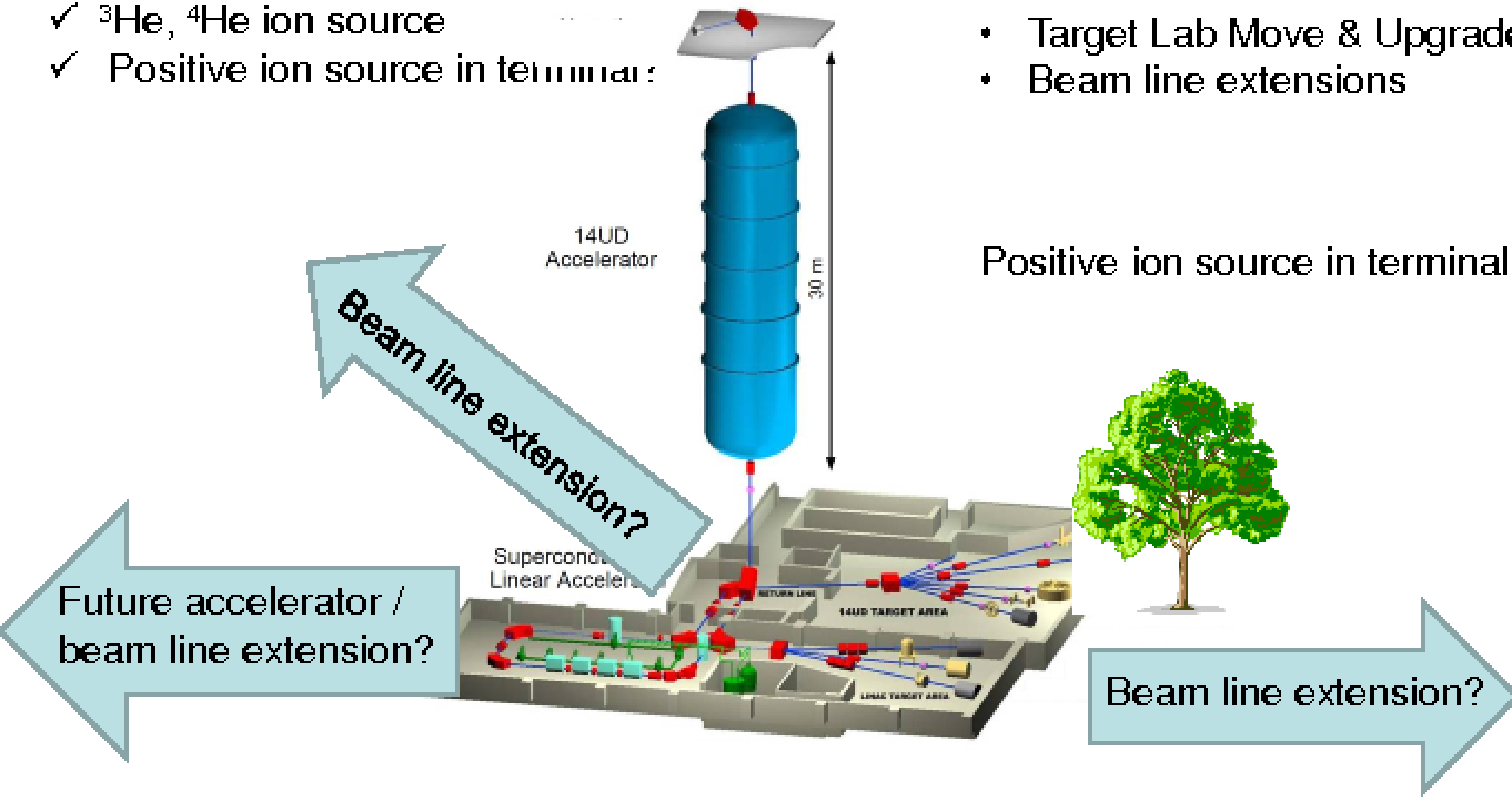
3-6 years Accelerator & Beam lines

Ion source development:

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

Building program:

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



6-9 years and beyond

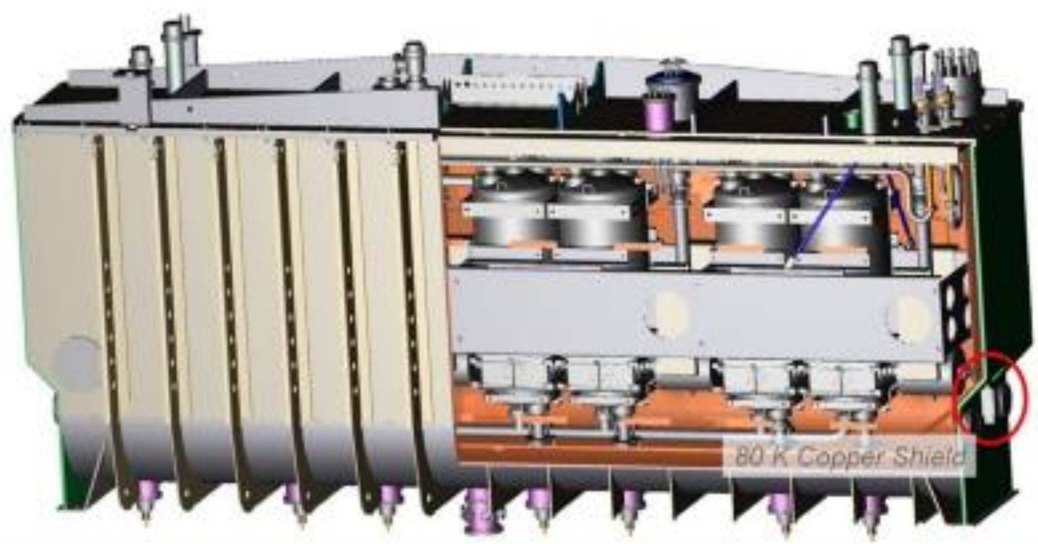
Accelerator development aspirations

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

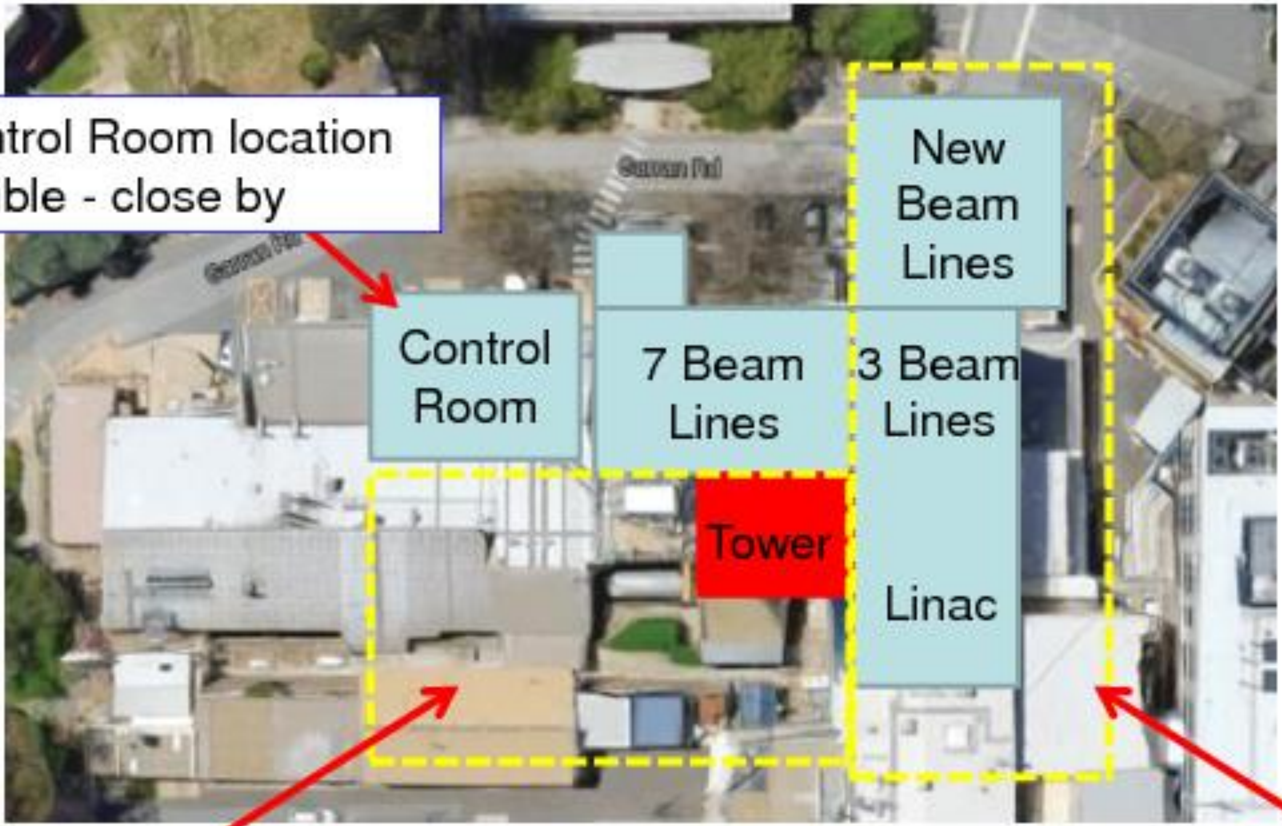
Future Accelerator & Beam lines

Present Lab Layout

Future Accelerator & Beam lines

Possible future layout

Control Room location flexible - close by



Possible location of new beam lines

Suggested location of new beam lines with room for Linac development

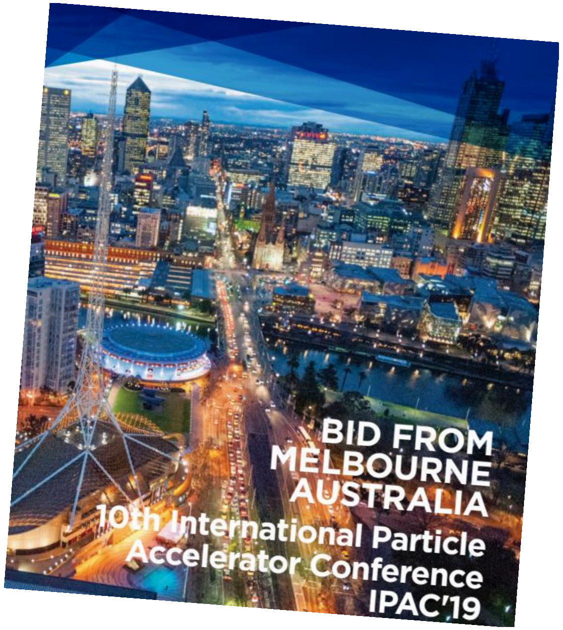
Conferences in Melbourne, Australia

Past conferences:

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

Future conference:

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



Thank you for your interest