Diagnostic, Radiation Monitoring and Interlock Systems for the X-Band RF Test Facility, X-LAB, at the University of Melbourne.

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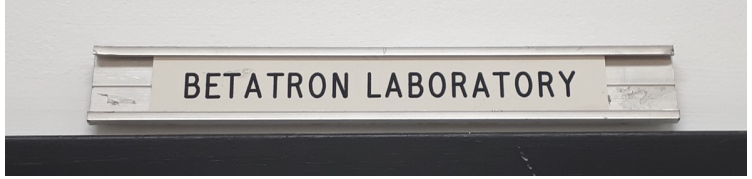
2. ANSTO, NSW Australia
3. The Australian Synchrotron - ANSTO, VIC Australia

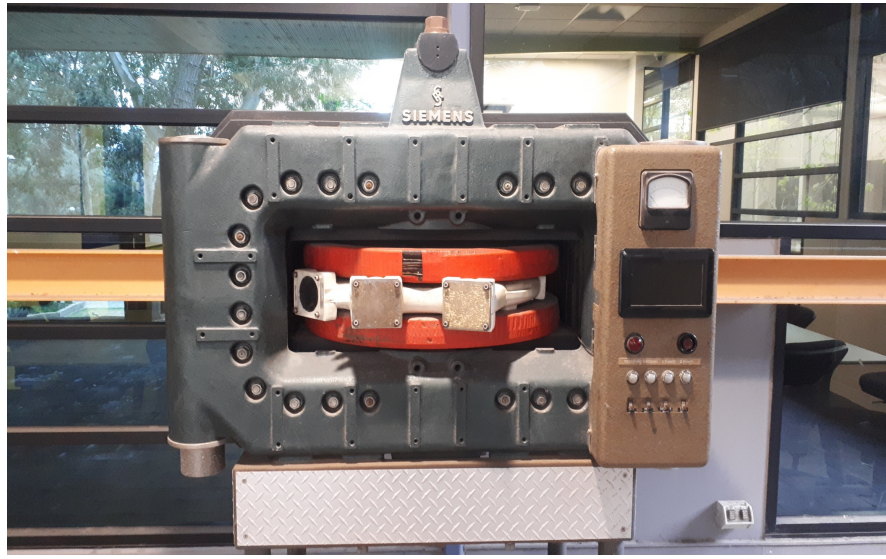
In Collaboration with the CERN XBox Team

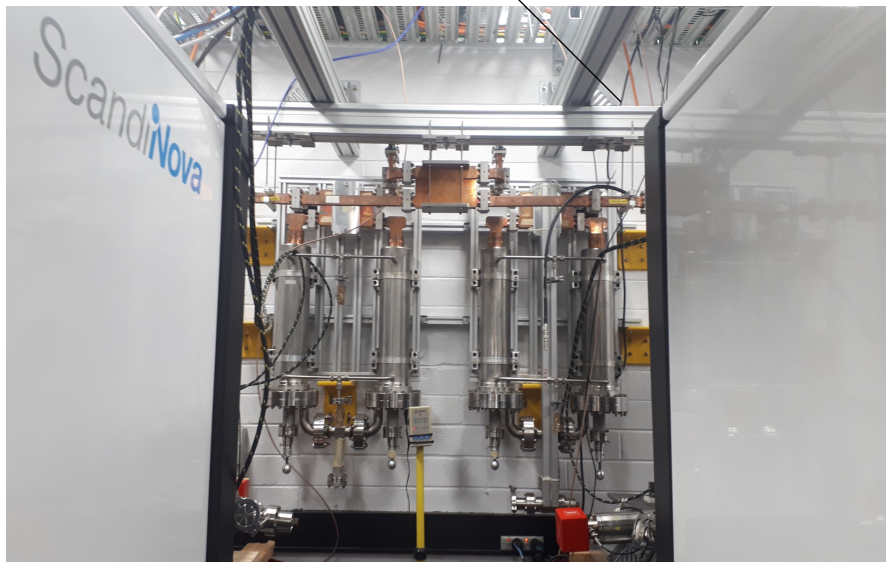
Contents

The x-Band Laboratory for Accelerators and Beams

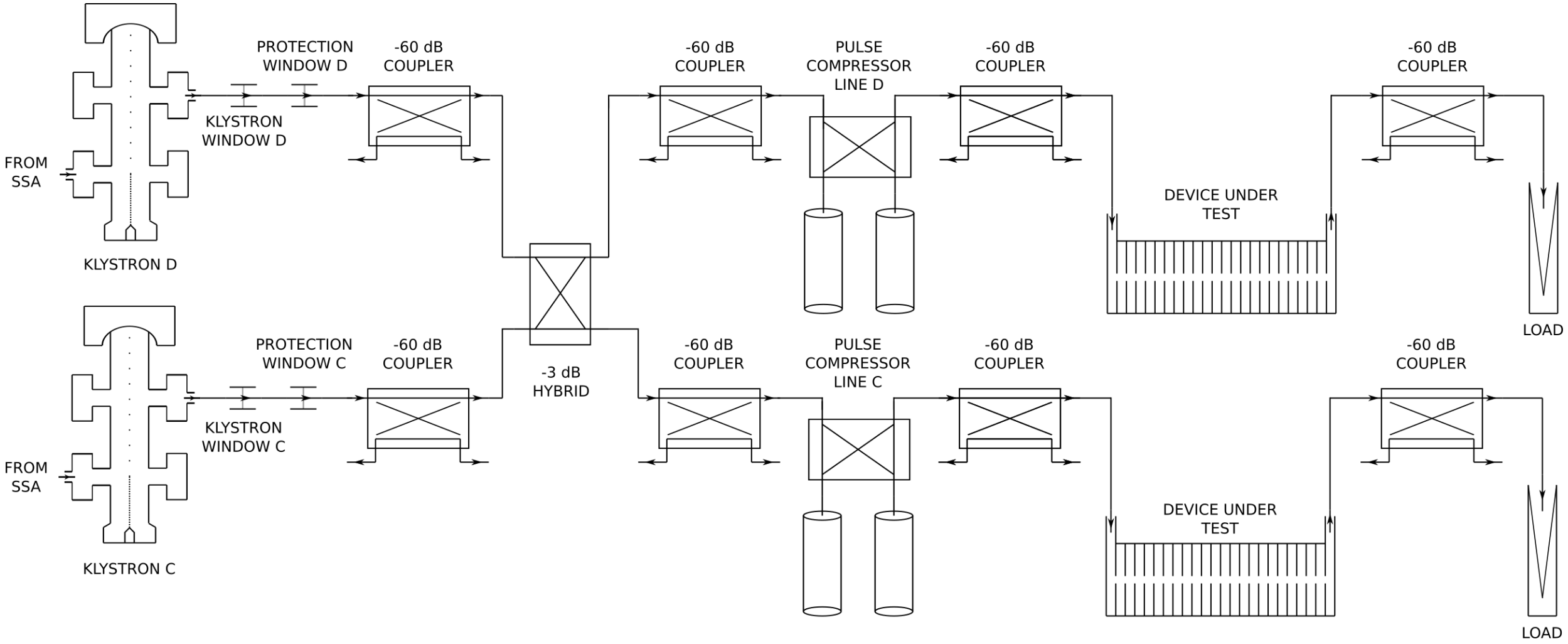
- Half of CERN Xbox-3 has been brought to Australia
- Reassembled in the old Betatron Bunker in the School of Physics at the University of Melbourne
- 2x 6 MW 12GHz Klystrons + Modulators operating in tandem to feed 2 test stands
- The two klystrons and two new RF windows have been commissioned. See Matteo Volpi's Presentation: "*Commissioning of X-band RF test stand facility at the University of Melbourne (X-LAB)* "





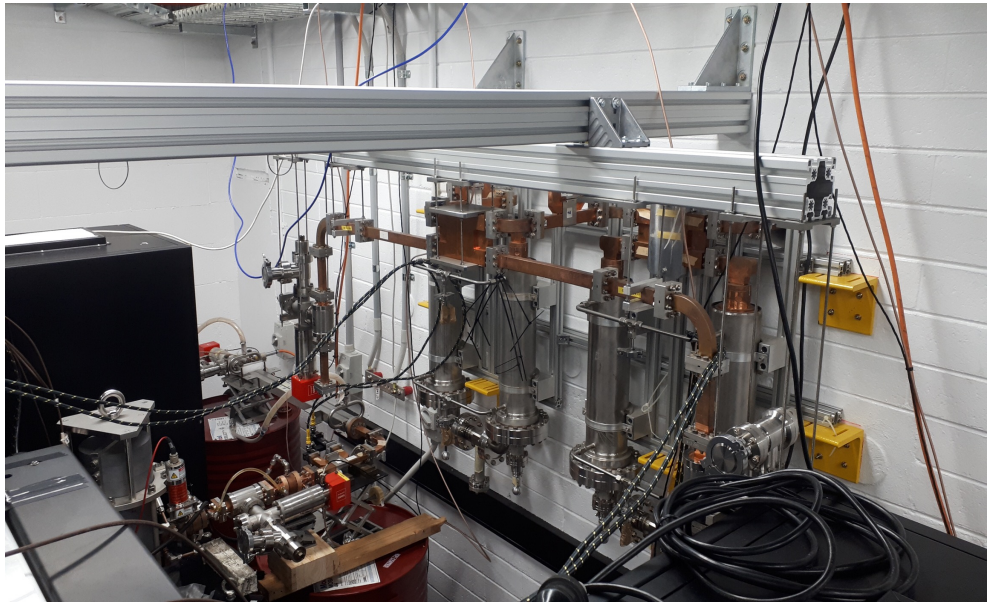


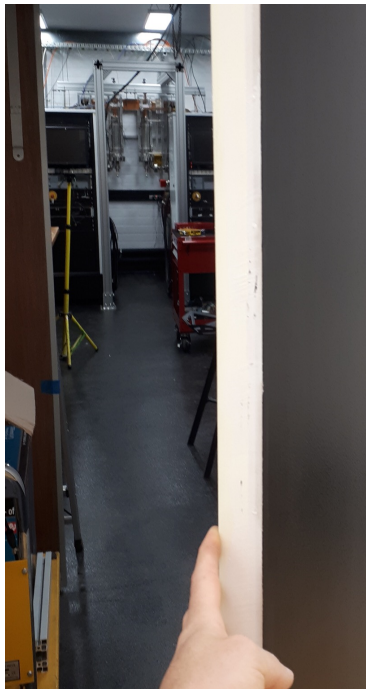
XLAB Test Stand Configuration



XLAB Progress

- Refurbishment of the lab is almost complete
- Waveguide network is almost fully installed
- Pull and calibrate cables
- Conditioning of the waveguide network to begin soon
- First structures to be installed early 2024



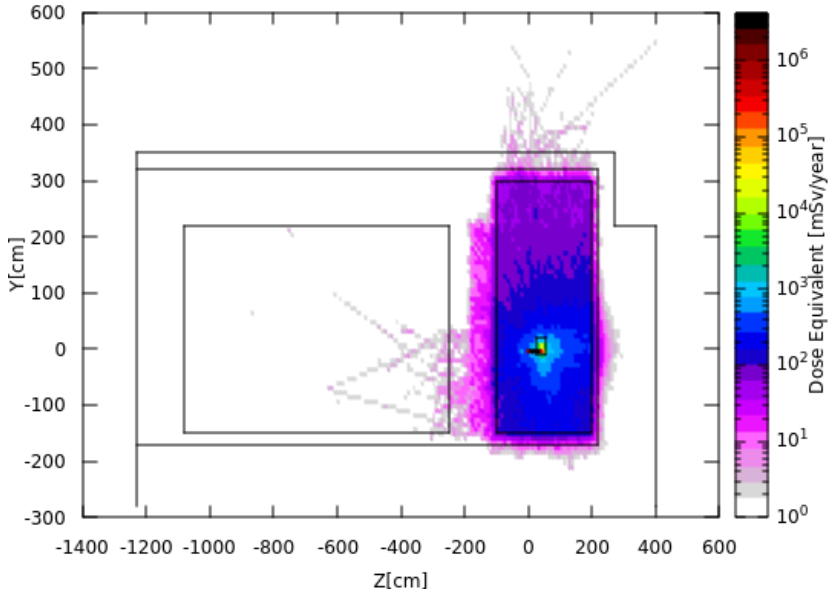


Radiation Monitoring System

- Rotem DRM-3000
- 1 main + 3 mobile Gieger Mueller tubes
- 0.1 µSv/h to 10 Sv/h (main)
- 0.1 µSv/h to 10 mSv/h (mobile)
- Out of range trigger
- Configurable threshold trigger - interlock trigger

FLUKA Simulations

Side



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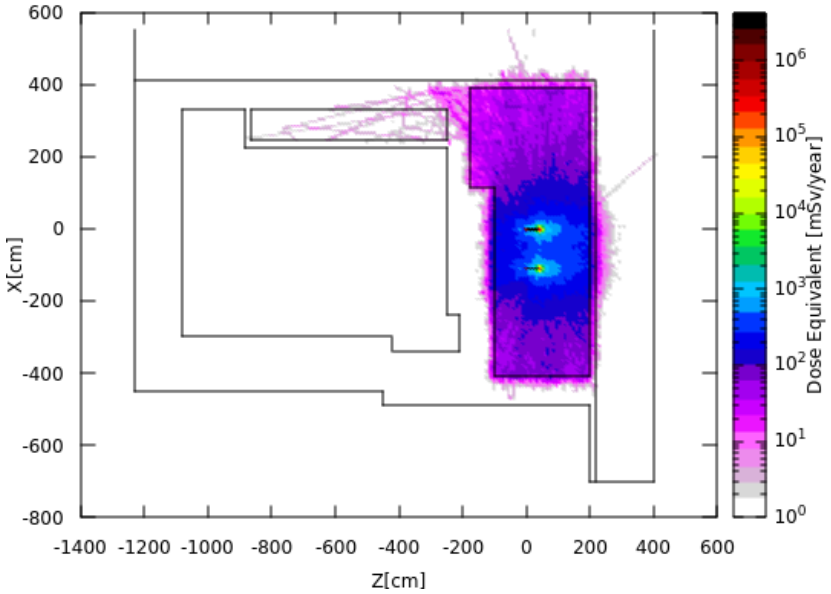
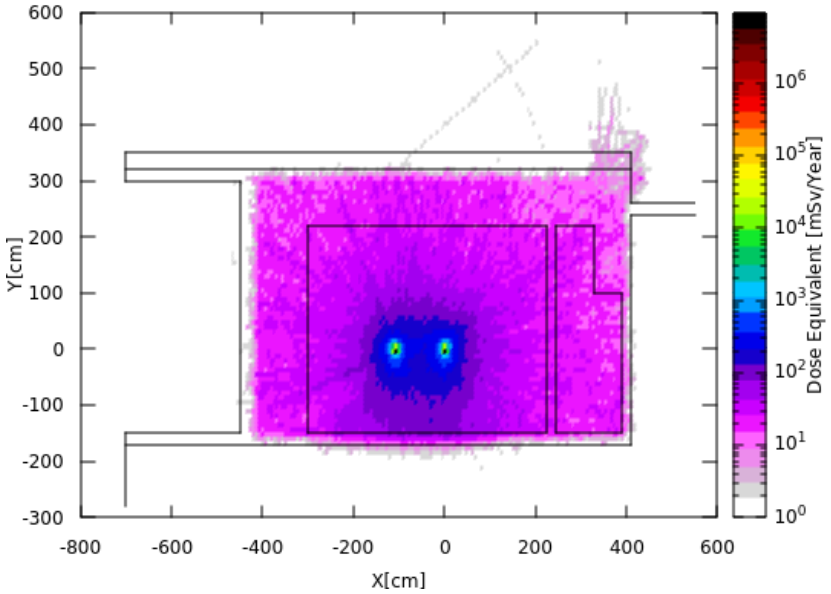
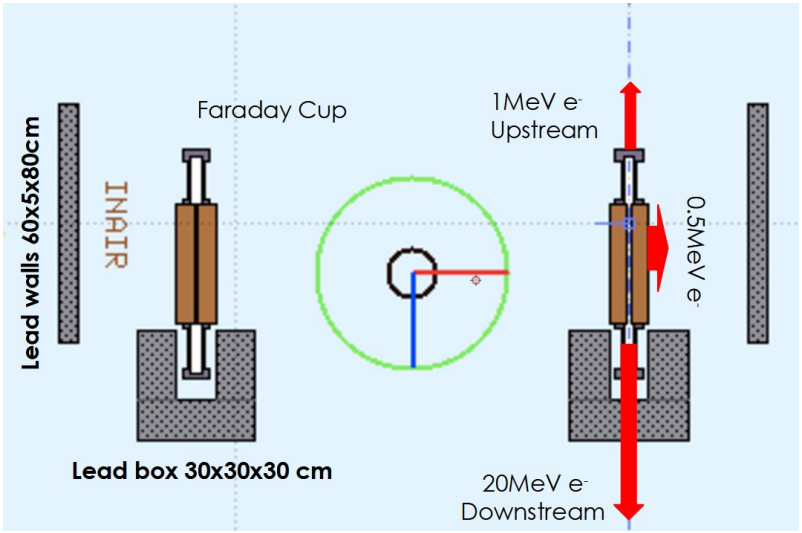


Front



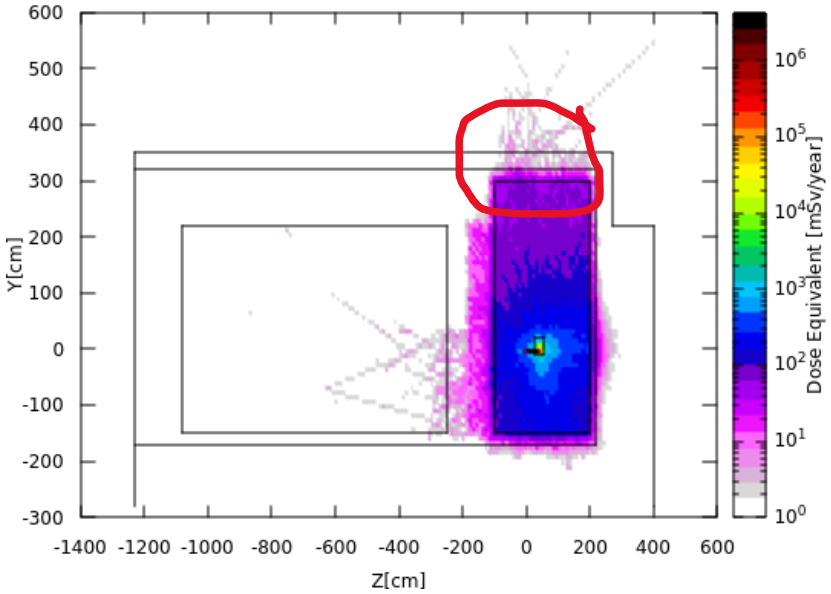


- Scenario simulated is that which would produce the most radiation
  - Worst case
  - Extremely unlikely

- Two structures
  - 200 Hz rep. rate at maximum power
  - 20 MeV maximum e^- energy
  - 100 ns flat top pulse
  - 0.5 mA / pulse dark current

FLUKA Simulations

Side



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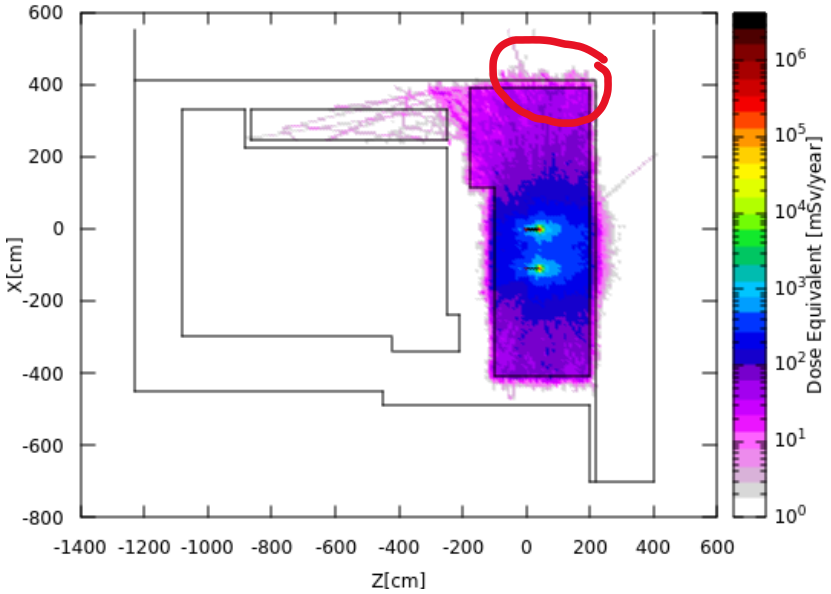

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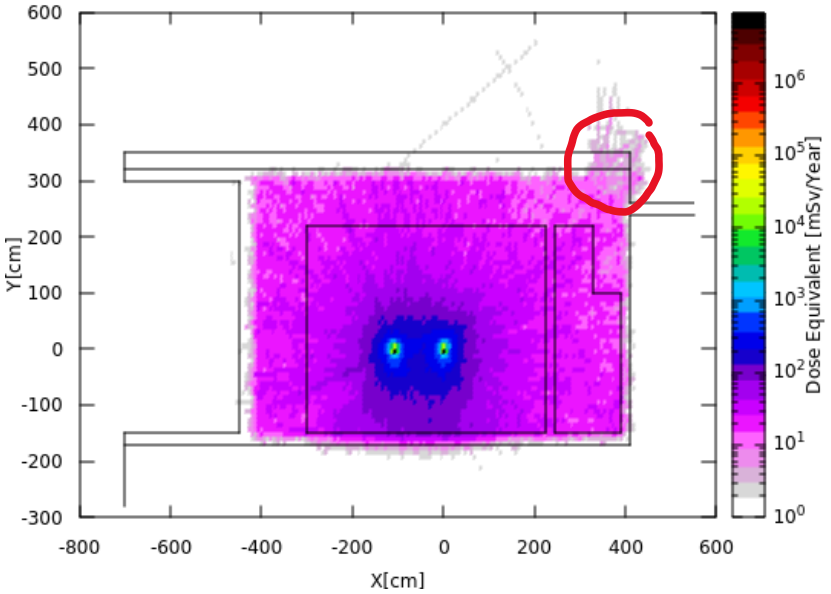
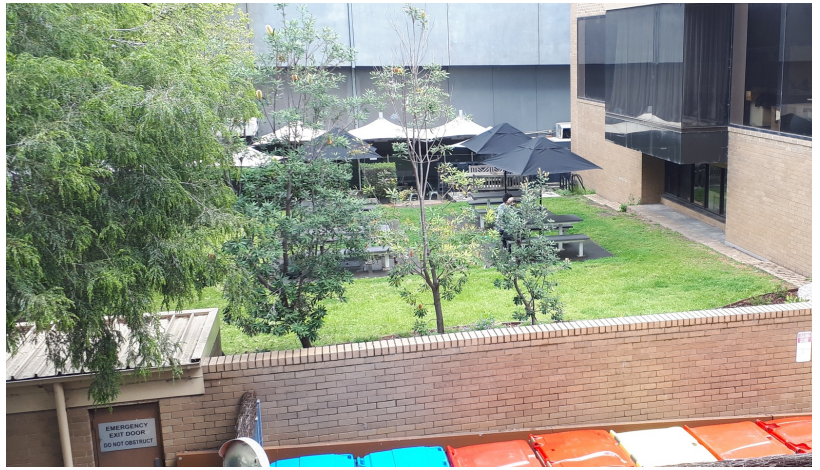
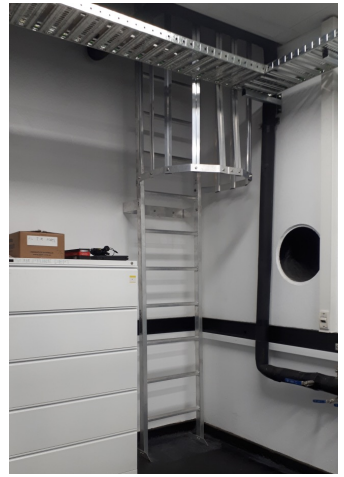
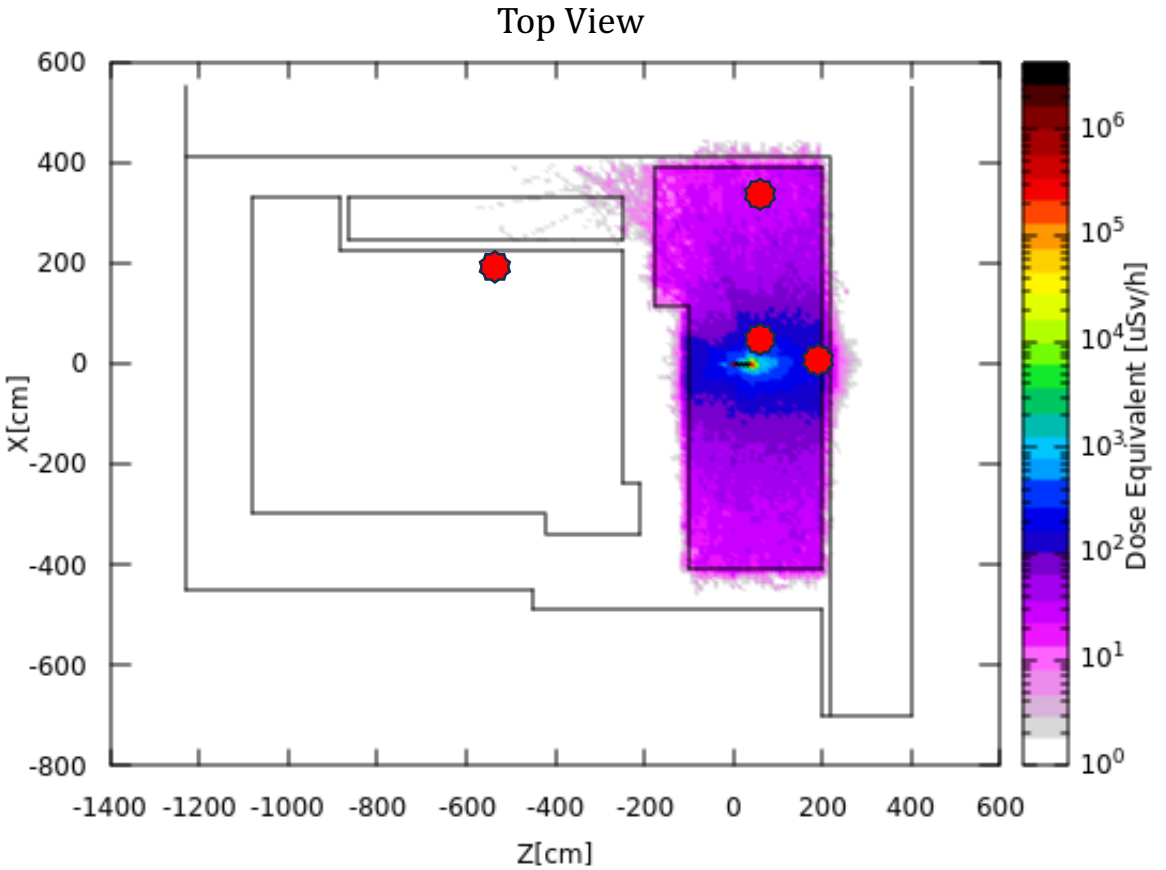


- Weak points:
  - Emergency exit ladder
  - Café
  - Thin shielding wall



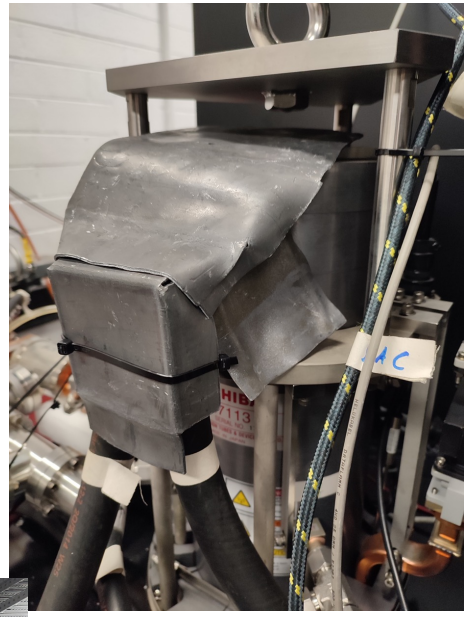


Radiation Monitors - Installation and Testing



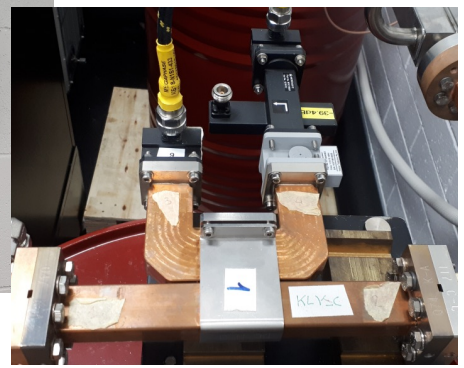
- Main hub placed outside the tunnels
- 3x mobile GM tubes placed inside the tunnels
- 2x in fixed locations
- 1x mobile close to device under test
- Interlocked

Radiation Monitors – Calibration and Klystron Emissions



- Calibrating with sources soon
- Working with our radiation safety officer to bring in a source
- Portable monitor for klystron/window conditioning
- Weak point at the klystron water pipe inlet/outlet
- Measured approx. 1 µSv/h at ~ 6 MW 100 Hz
- Install a gate and chains to restrict access around the klystron modulators
- May interlock in the future

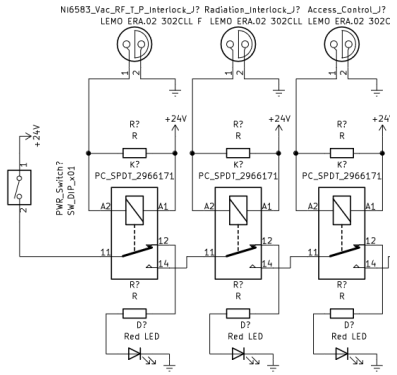
Interlock System - Triggers

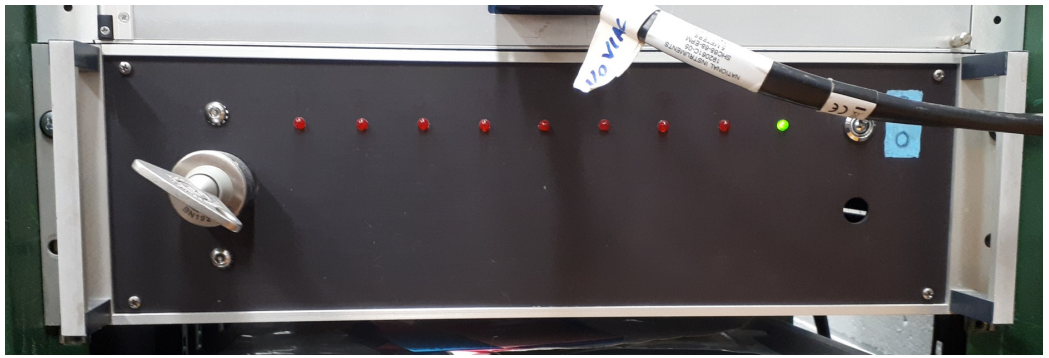


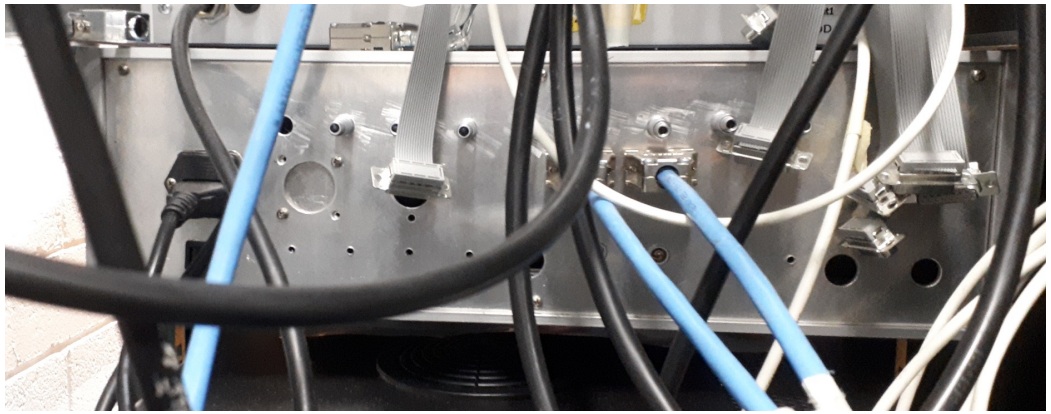
- Radiation monitors
- RF reflections
- High vacuum activity
- Open doors
- Key-based interlock the system cannot be started if the tunnels are open
- E-Stop

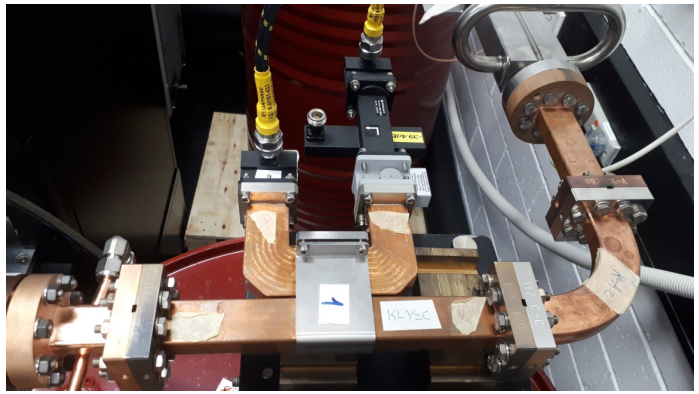
Interlock System

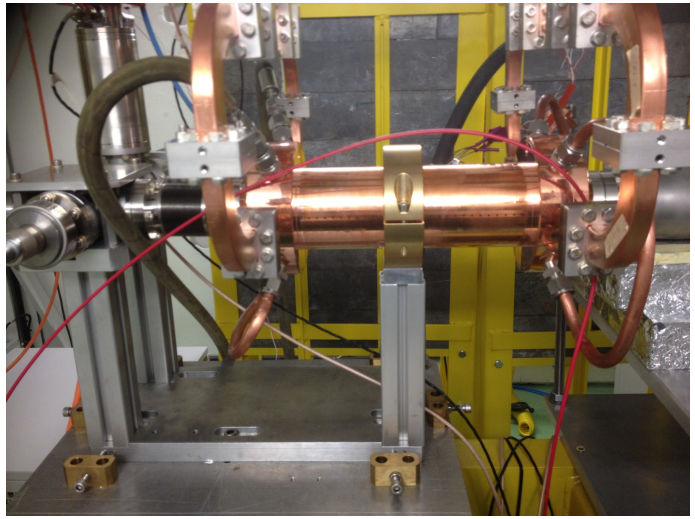
- Three levels of interlocking
- Software interlocks (National Instruments PXI)
- Hardware interlocks – Interlock crate
  - Similar to the XBOX3 design
  - Relay based
  - Interlocks the modulators
  - Developing an interlock distribution system for use as the lab grows
- E-Stop – Emergencies only
  - Hard power cut for the lab









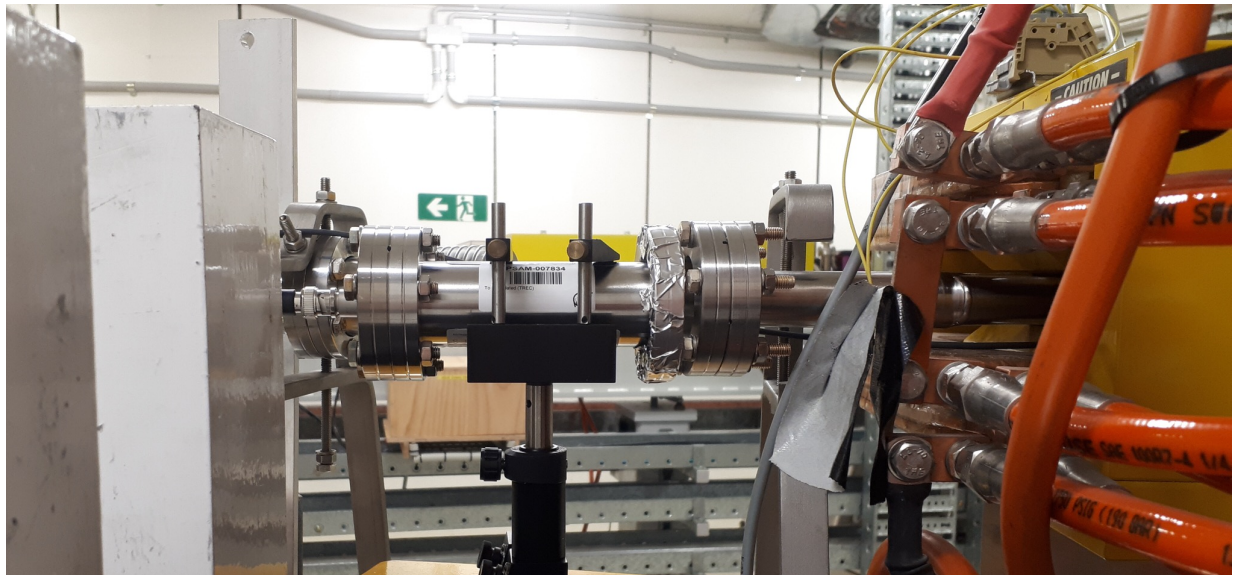


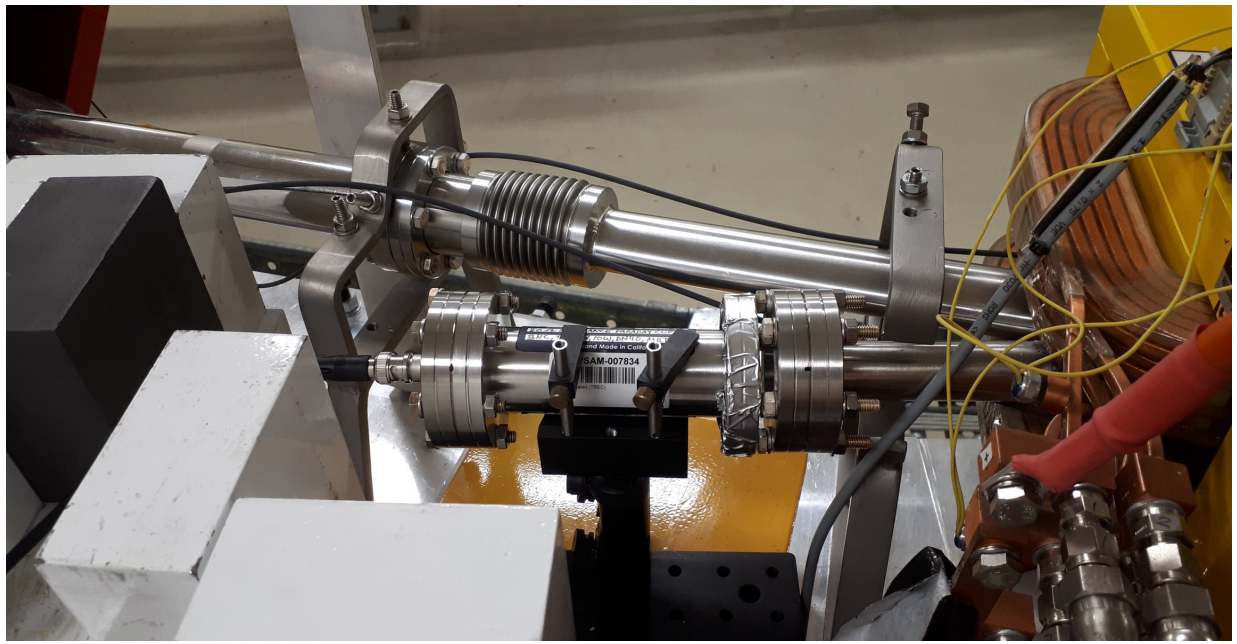
Diagnostic Systems

- Directional couplers
- Faraday cups – RadiaBeam 35 MeV
- BLMs
  - Optical fibre – 1 mm quartz fibre with Sensl/Hamamatsu SPMs
  - Scintillator Based – Libera BLM
  - PIN diodes
- Vacuum Gauges
- Very few channels remain on the NI-PXI
- Exploring options for increasing diagnostic capacity
- Likely move towards an EPICS based system

Faraday Cup Testing

- RadiaBeams 35 MeV Faraday Cup
- Australian Synchrotron ANSTO is building an electron beam test stand at the end of the 100 MeV injection system linac
- Recently installed a fork at the first dipole with a thin 125 μm titanium foil window in the forward direction when the dipole is off
- RadiaBeam Faraday cup is the first device to be tested
- In air with a nominal 100 MeV beam



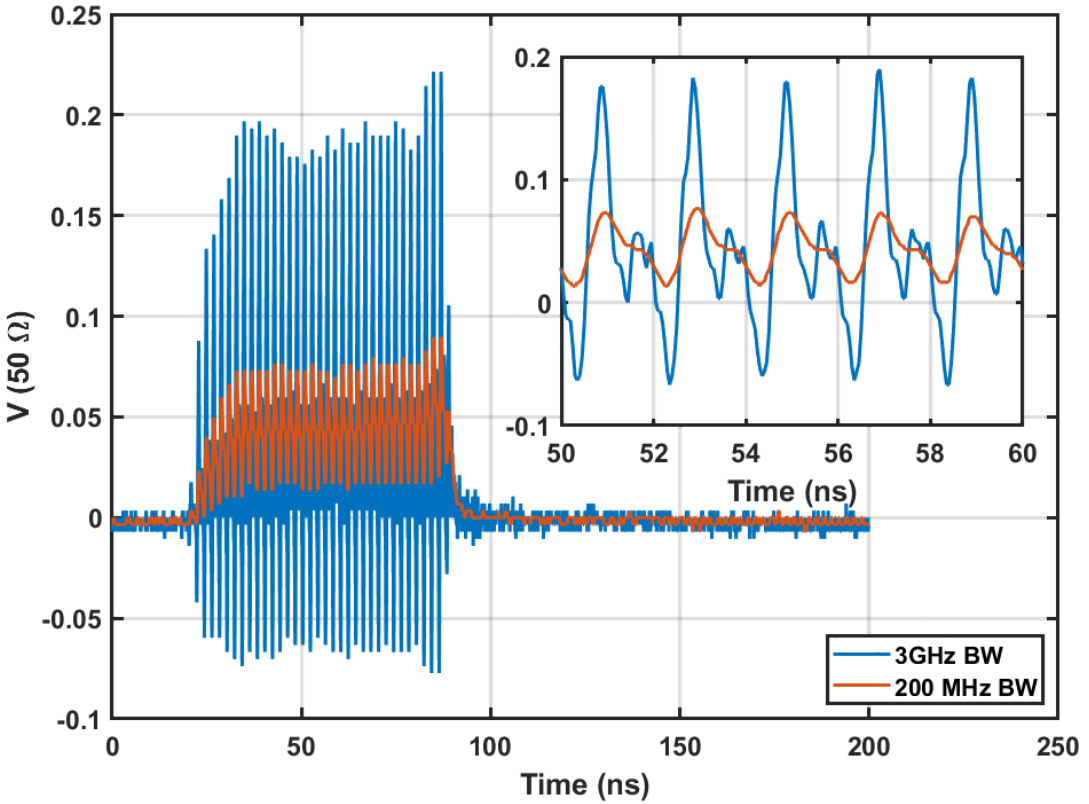


Results Courtesy of Y-R. E. Tan, The Australian Synchrotron - ANSTO

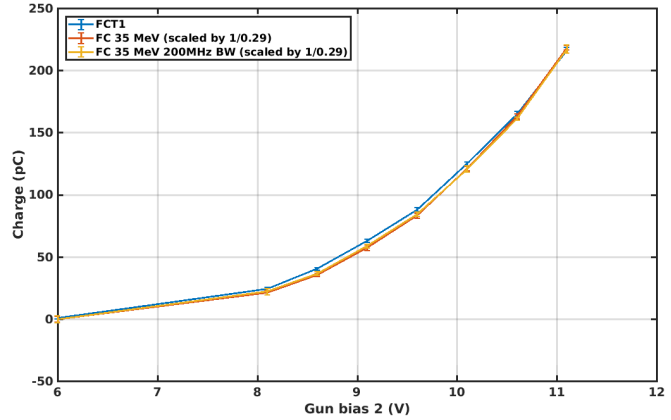
Faraday Cup Testing – Preliminary Results

- Signals recorded with an oscilloscope
  - 3 GHz FEB
  - 40 GS/s
- The electron beam properties
  - 500 MHz bunch structure
  - 3 GHz micro bunching
  - 75 buckets filled
- High frequency structure is visible
- Capture efficiency estimated to be ~30%

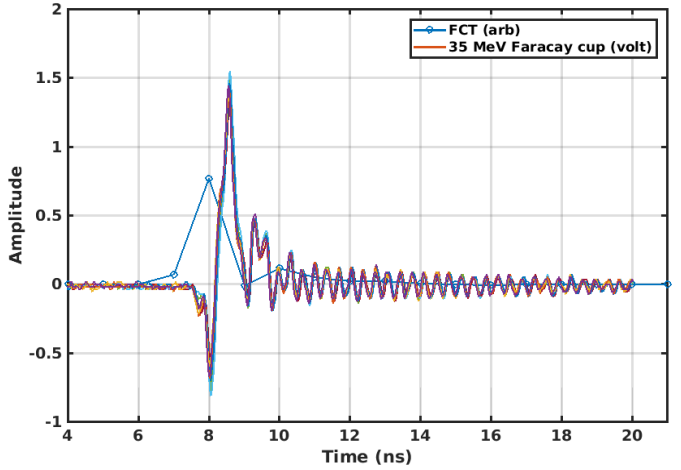
Multi-bunch Signal



Charge Collected



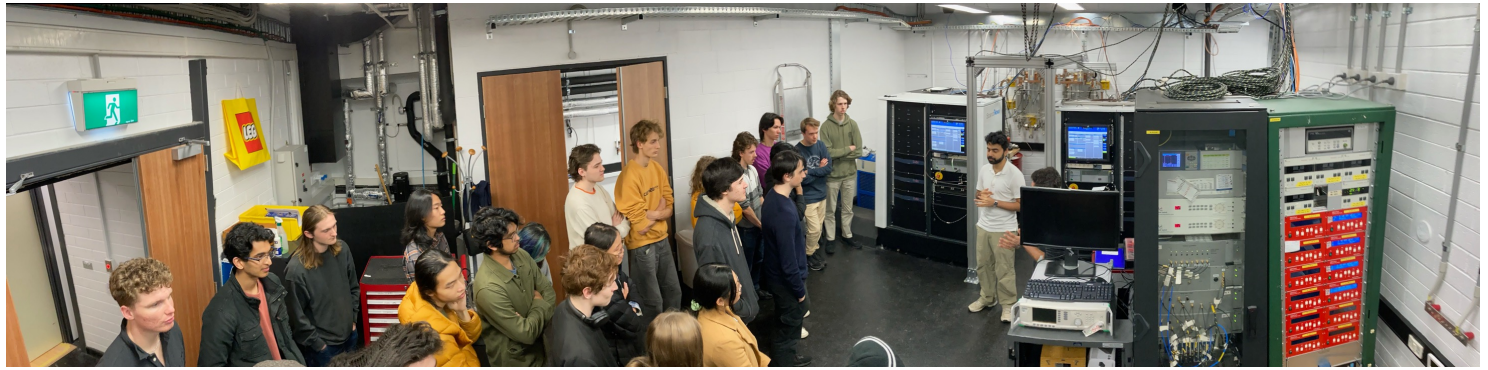
Single Bunch Signal



Results Courtesy of Y-R. E. Tan, The Australian Synchrotron - ANSTO

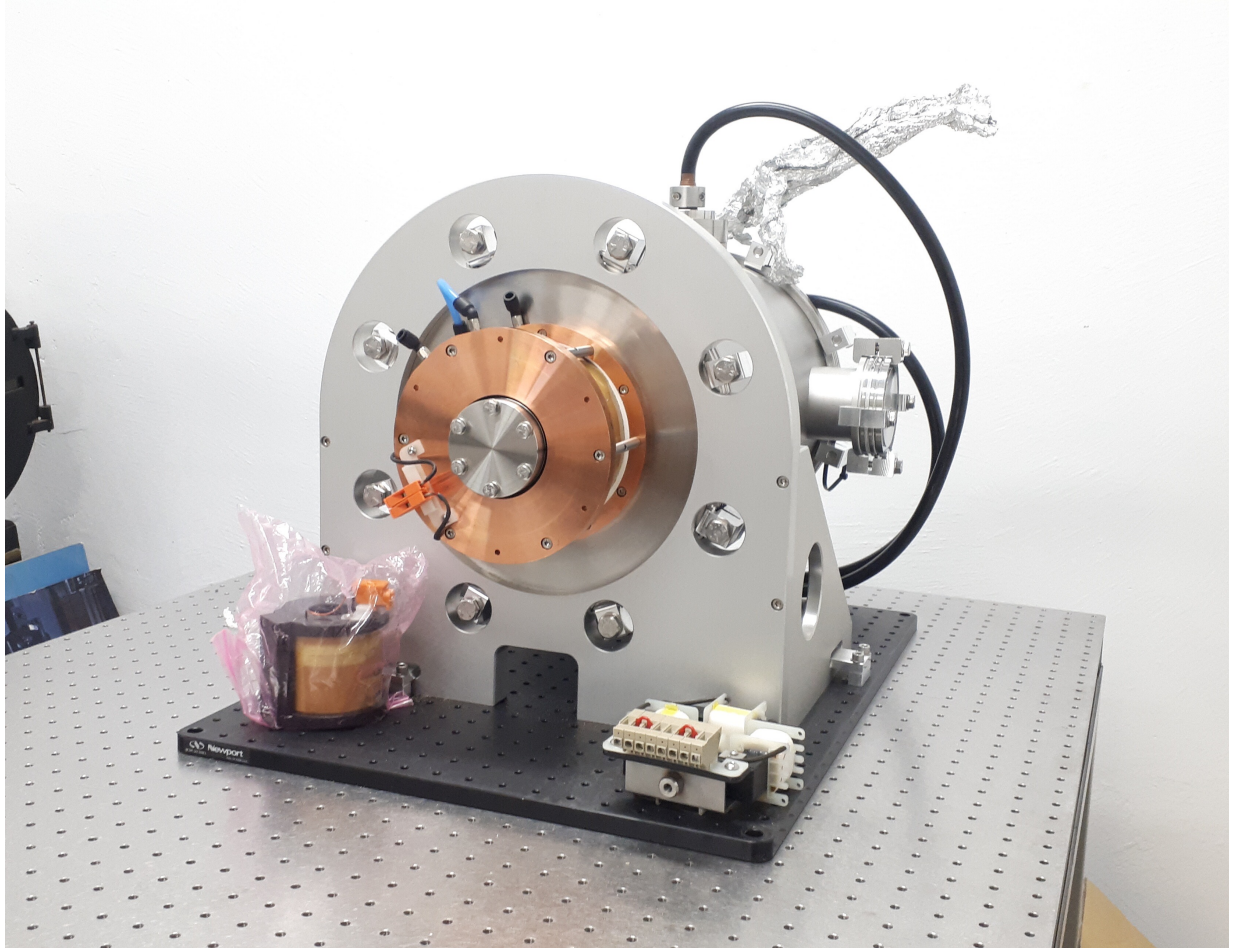
The Future of XLAB- Student Engagement

- XLAB is located on the University of Melbourne main campus
- The hope is that students will be heavily involved in the XLAB
- All levels from Undergraduate to PhD
- First PhD Student to be working in the XLAB has started
- Winter and summer internships
- Regular tours



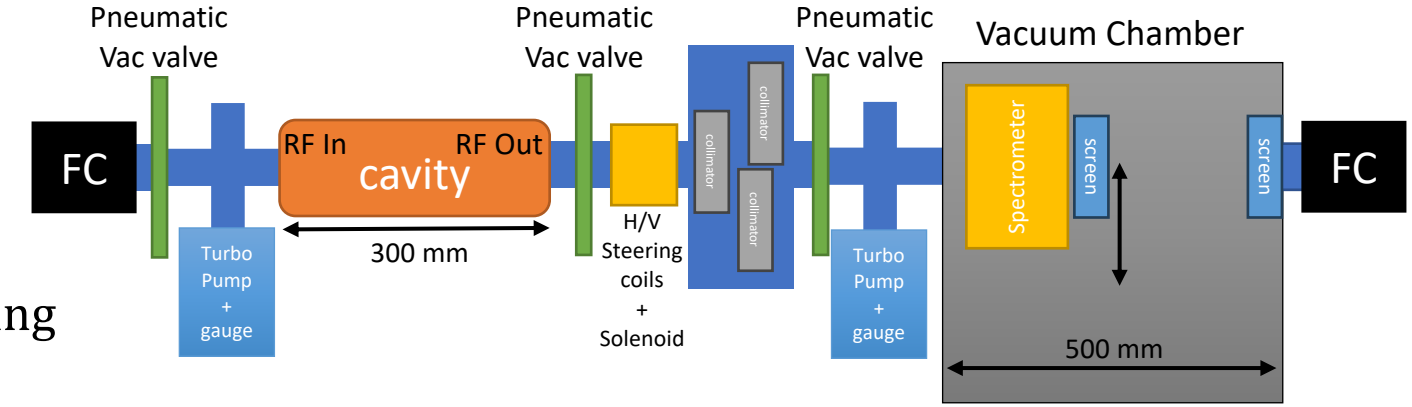
The Future of XLAB – Accelerator Physics Lab

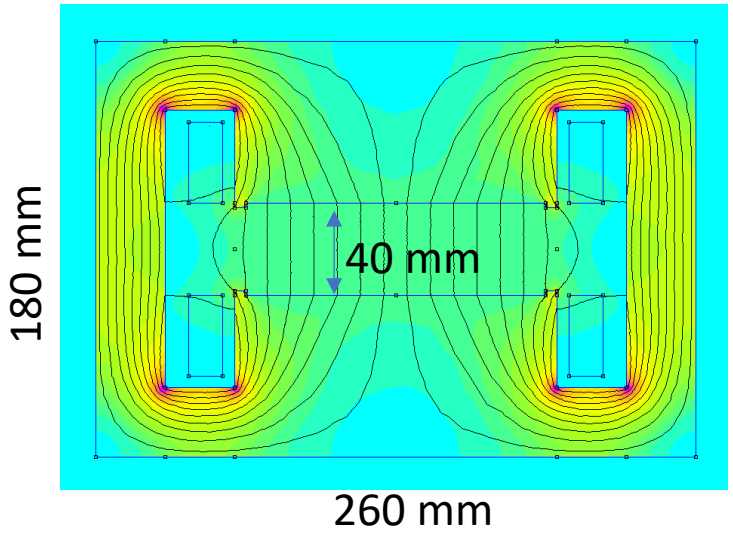
- Build on the RF test stand
- Develop hands-on skills in accelerator systems
- Electron Gun
  - DRX Works
  - 100 kV Photogun
  - 12.3 MV/m
  - Copper cathode
  - Illumination with a 1 μJ 266 nm 1fs laser pulse can produce 1 pC electron bunches
  - Looking for advice on a suitable laser



Spectrometer

- Designing a spectrometer
- Dark current energy spectrum
- H and V Collimator
- Steering dipoles and solenoid for focusing
- 15 mT Dipole with 100 mm good field region
- 200 mm wide x 40 mm high screens
  - Plastic scintillator, or
  - Rare-earth phosphor screen
- CCD camera
- Target energy resolution/range: 0.5 keV @ 1 MeV to 500 keV @ 18 MeV
- Move to a beamline configuration after completion of structure testing



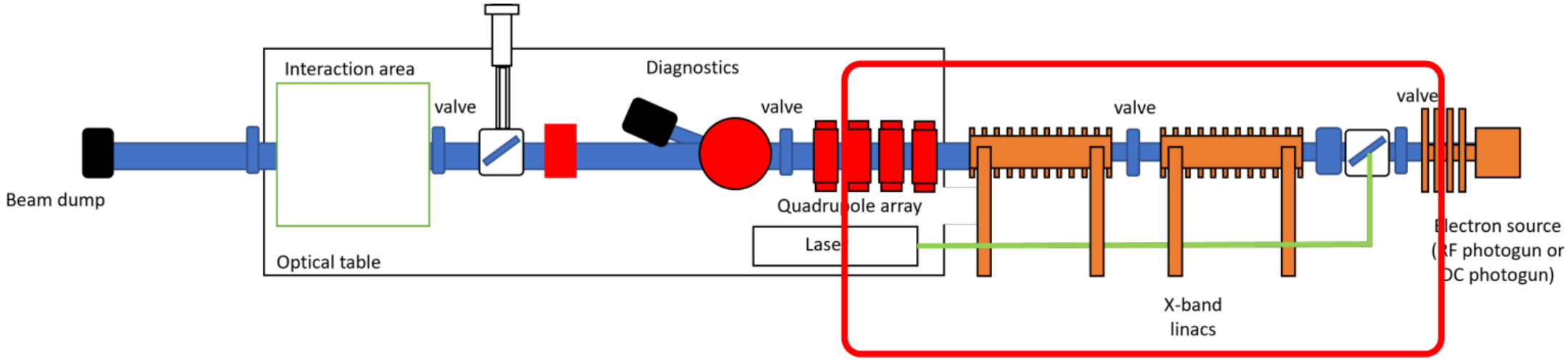


Results Courtesy of Y-R. E. Tan, The Australian Synchrotron - ANSTO

Beamline

- Build on the RF test stand
- Compact accelerator
- Design and build low beta buncher to use CLIC structures
- Multiple avenues we might pursue
- Accelerator test stand

- Small grant for beamline diagnostics
- Compact light source inverse Compton
- Electron therapy
- Dosimetry
- Instrumentation testing
- Beam studies in high gradient structures



S. Williams (2023). *Simulations of a compact beamline utilising high gradient X-band RF accelerating cavities at the University of Melbourne X-LAB* [PhD Thesis]. The University of Melbourne

Thank you for listening