Australian Government

ANSTO

Experiences with new Insertion devices at the Australian Synchrotron

Eugene Tan

Behalf of Engineering, Technical teams and Beamlines

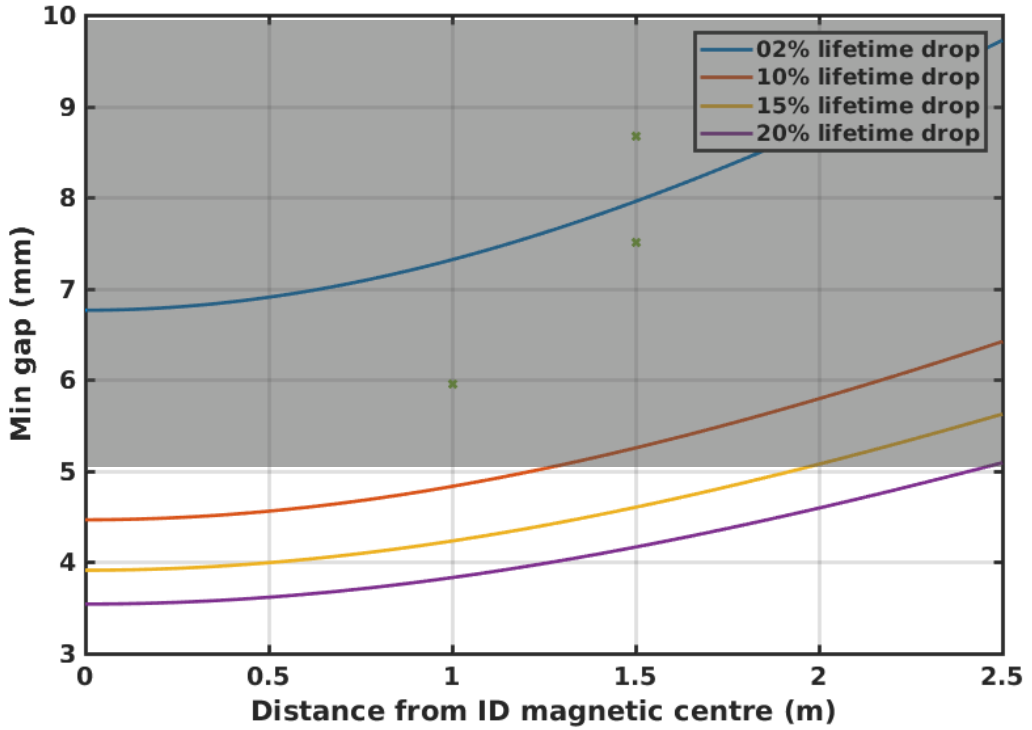
Science. Ingenuity. Sustainability.

BRIGHT

- Since commissioning in 2005 we have operated with 9 beamlines.
- In 2016 the BRIGHT project started – 6 new beamlines
  - 2 dipole beamlines (MEX and MCT)
  - BioSAX (SCU)
  - Advanced Diffraction and Scattering, ADS (4.5T SCW)
  - Protein Crystallography, MX3 (IVU)
  - Nanoprobe, NANO (CPMU)

Source Selection – Vertical Aperture

- Willing to accept reduction in lifetime 15%
  - ~22 hr → 18.7 hr
- Led to restriction of
  - 6 mm for fixed narrow gap vacuum chambers
  - 5.0 mm for IVU/CPMUs.
- Assumption chambers to be NEG coated or cryo-cooled.



ANSTO

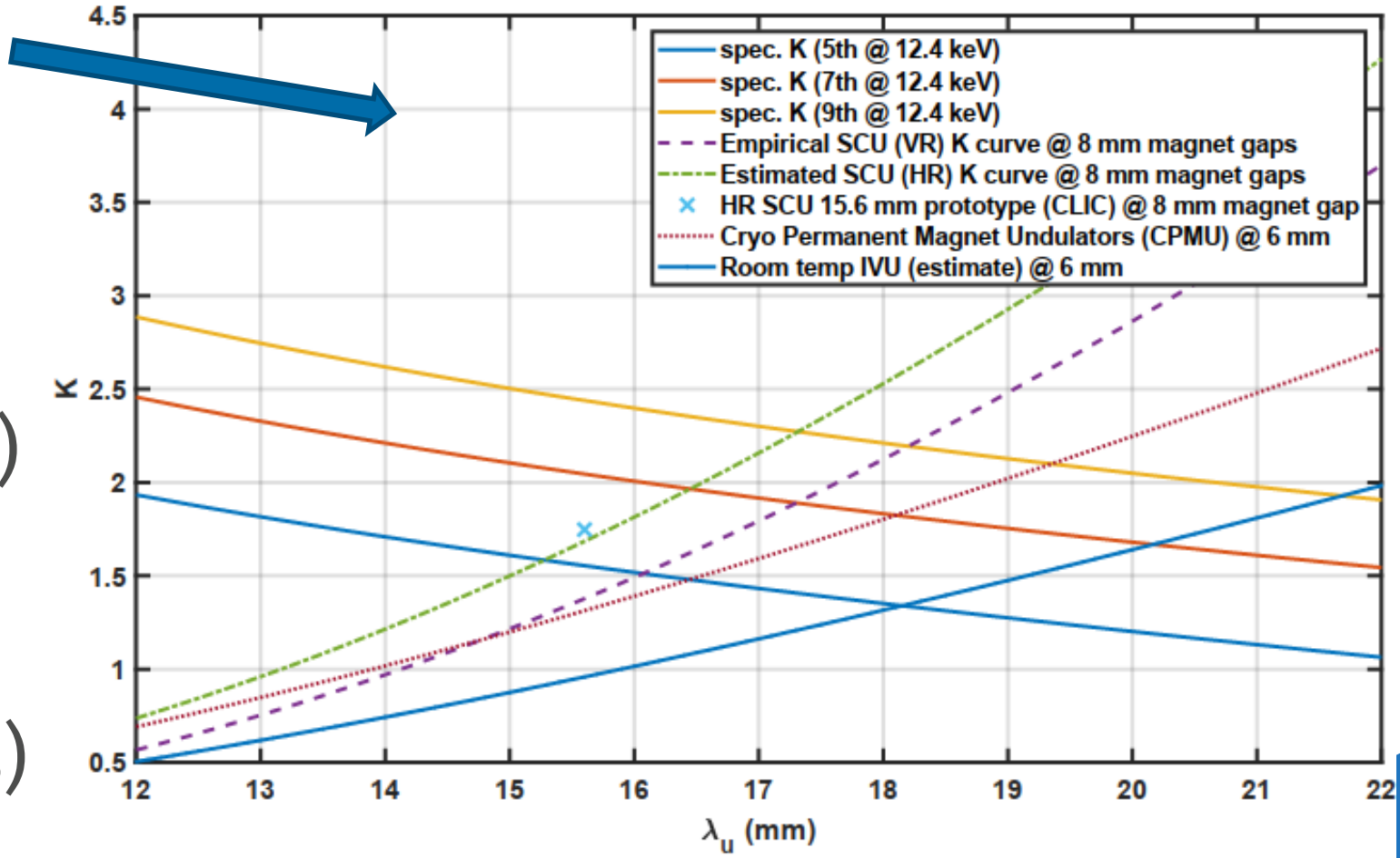
Insertion Device Source Selection

- ADS (3.5m, 150 keV)
  - Similar to JEEP Beamline at Diamond
  - SCW with the shortest period possible with decent flux at 150 keV.
  - Limited by power available from our RF system (<50 kW)
  - Arrived at 4.5T with 45 mm period at a magnetic gap of ~8 mm.

> 2024

Insertion Device Source Selection

- BioSAX (2.5m, 12.4 keV)
  - Fixed energy
- MX3 (3.5m, 13.0 keV)
  - Fixed energy
- NANO (3.5m, 5 – 25 keV)
  - Spectroscopy (K > 1.9)
- All using DMM (ΔE ~ 1%)



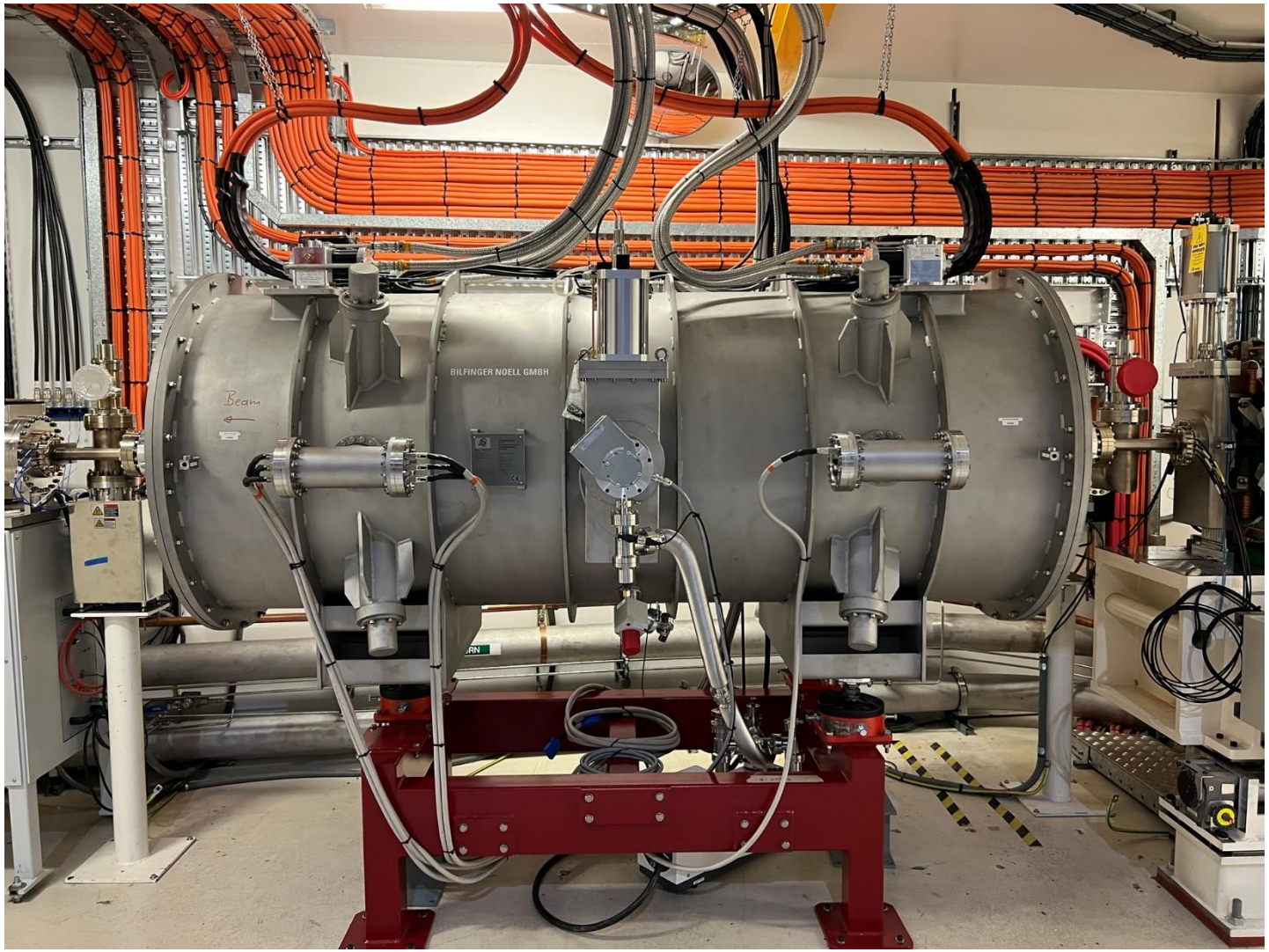
ANSTO

Insertion Device Source Selection

- BioSAX (2.5m, 12.4 keV)
  - SCU - 16 mm, 1.6 m (98), 1.084 T (K = 1.62) → AUG 2022
- MX3 (3.5m, 13.0 keV)
  - IVU – 17.2 mm, 3.0 m (172), 0.888 T (K = 1.427) → JAN 2023
- NANO (3.5m, 5 – 25 keV)
  - CPMU – 18.0 mm, 3.0 m (164), 1.23 T (K = 2.07) → ~AUG 2024
  - See talk: “Operation experiences of two CPMU at NSRRC” (Jui-Che Huang, NSRRC)

BiLFINGER

KIT Karlsruhe Institute of Technology



BioSAX

SCU16

ANSTO

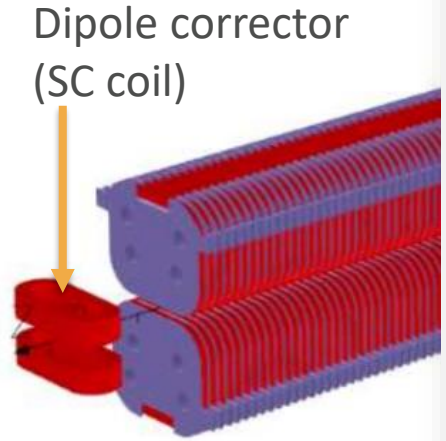
SCU16

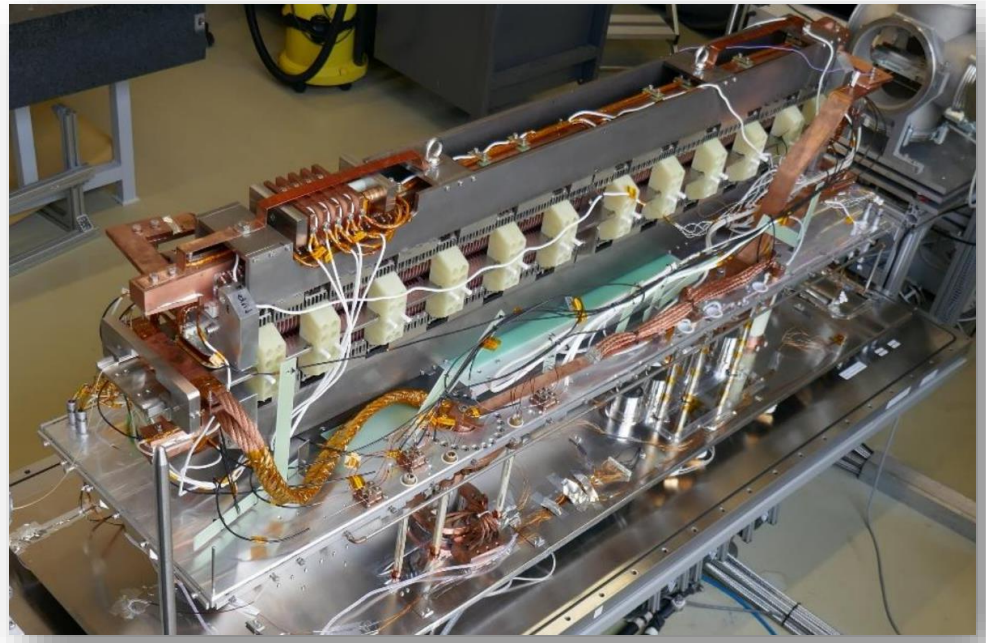
- Conduction cooled, “Cryogen-free”.
- Designed and built by BILFINGER NOELL GmbH (BNG)
- Based on SCU20 operating at KIT.
- Operating for 6 months.

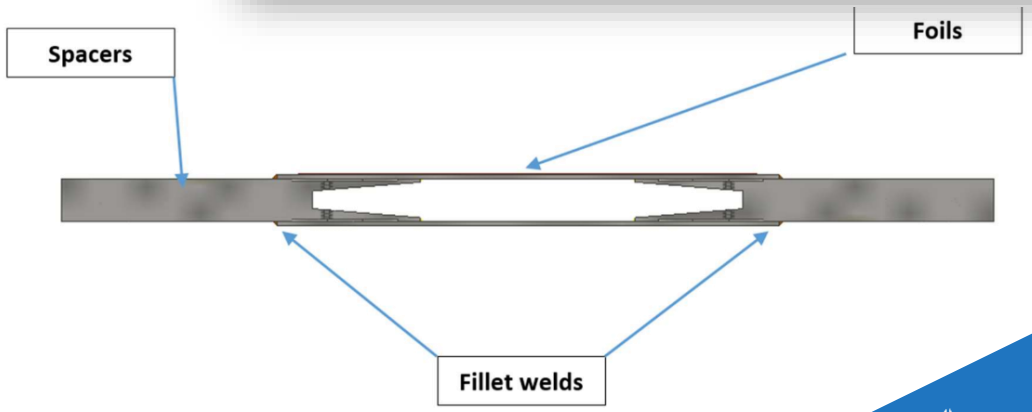
Parameter	Value
Cryostat length	2.5 m
Magnet Period	16.01 mm
Magnet Length	1.6 m
Num. Full Periods	98
Maximum Field / K	1.084 T / 1.62
Magnet Gap	8.0 mm
Vert. Vacuum Gap	5.4 mm
Horiz. Vacuum Gap	60.0 mm
Field Stability (144 hr)	< 200 ppm
Horiz. roll-off (±10 mm)	< 0.35%
Phase Error	10° - 16°

Magnet and Beam Chamber

- Vertical racetrack SCU
- When 1.08 T on axis results in 3.62 T on conductor.
- Operating current of 862A.
- Chamber
  - 316LN Stainless
  - 6 mm by 60 mm inner aperture
  - 0.6 mm 316LN foils
  - 30 um copper on inner surfaces



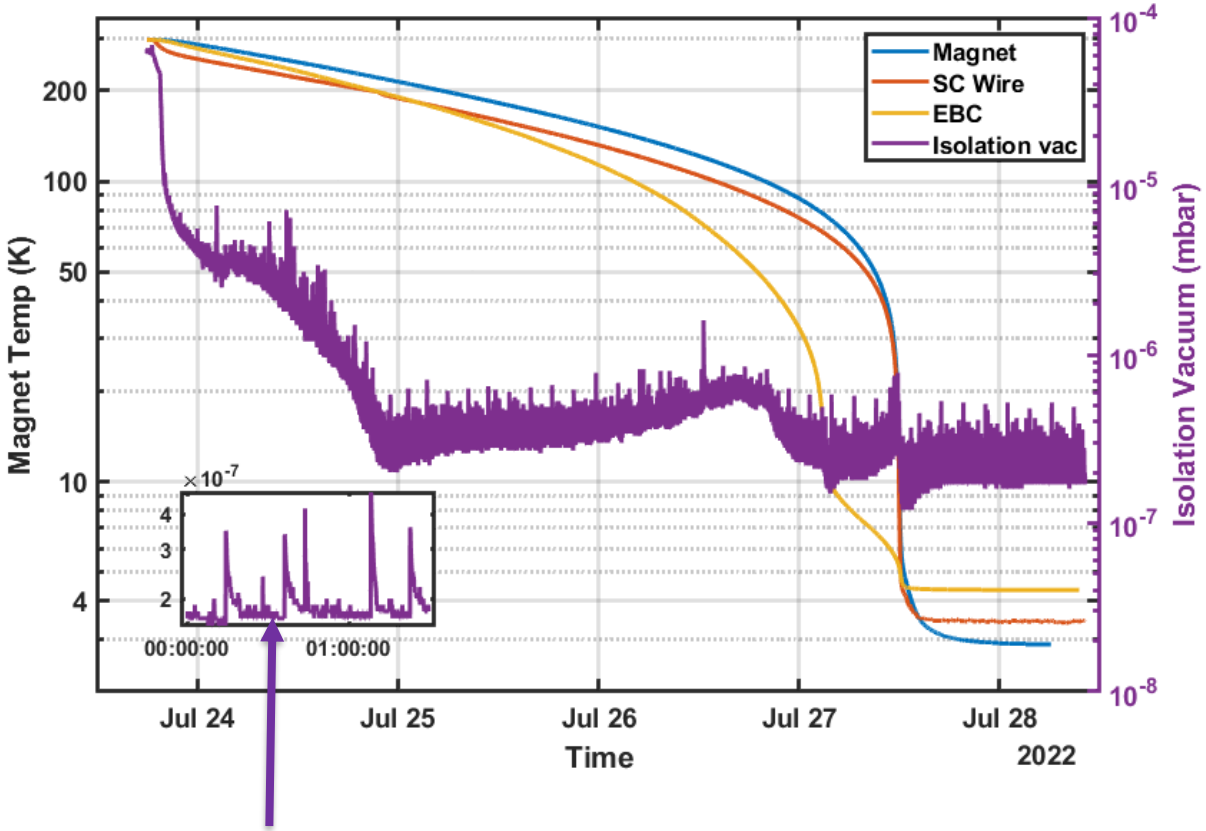




ANSTO

Cryogenics and Cooldown

- Sumitomo coldheads,
  - two RDE-412D4 (thermal shield/leads and e-beam chamber)
  - two SRDE-418D4 (thermal-shield/leads and 4K/magnet)
  - Up to 1.8W @ 4K
- Isolation vacuum pressure drop from 1e-4 down to 3e-7 mbar.
- 4 day cool down.
  - 3 day warm up with heaters.

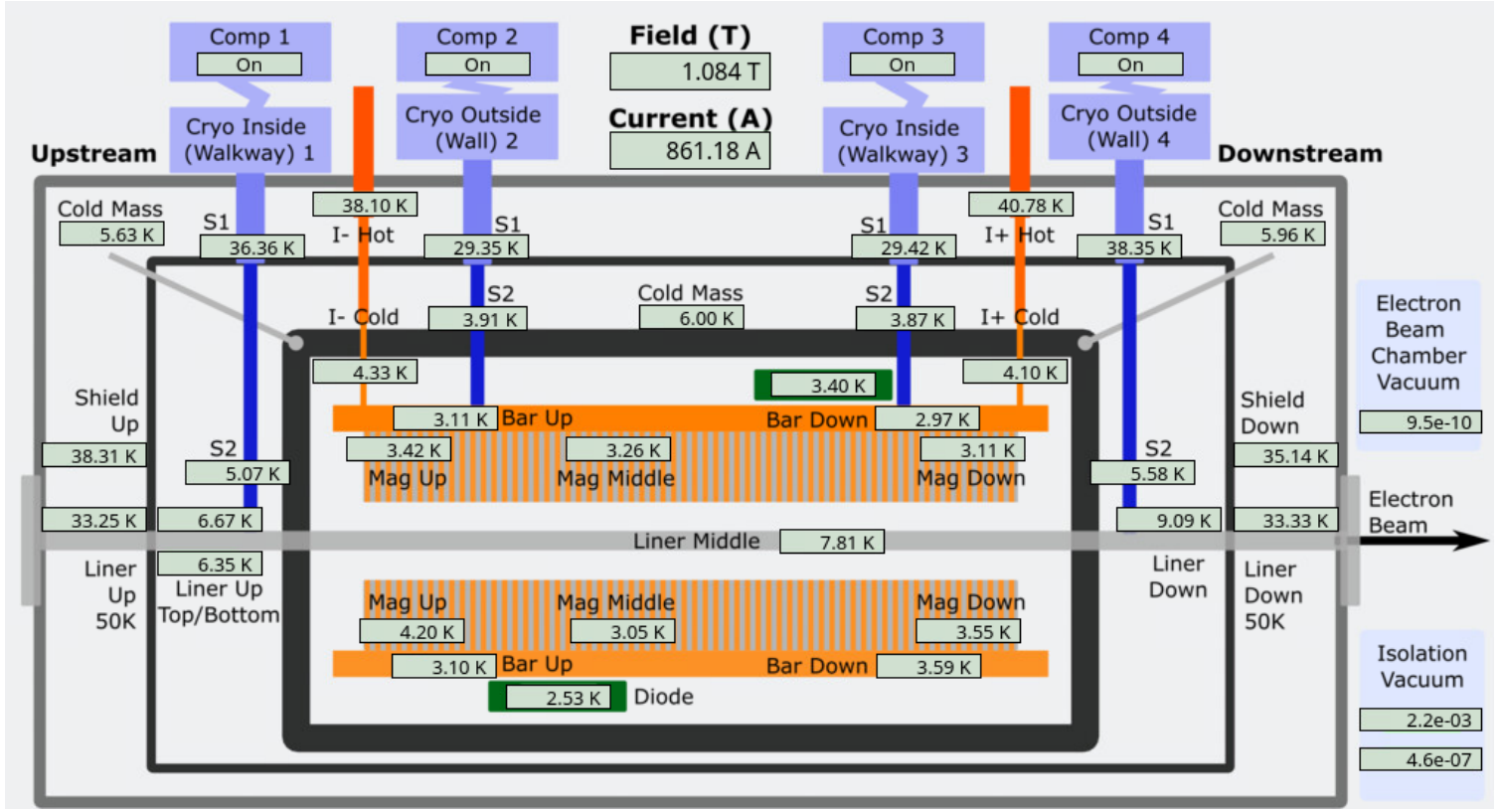


Early commissioning observed pressure spikes likely outgassing from various components like the multilayer mylar foils

ANSTO

Cryogenics and Cooldown

- Equilibrium temperatures at maximum operating field of 1.084 T (862 A) and 200 mA in the storage ring.
  - 300/360 buckets filled
  - 30 ps bunch length

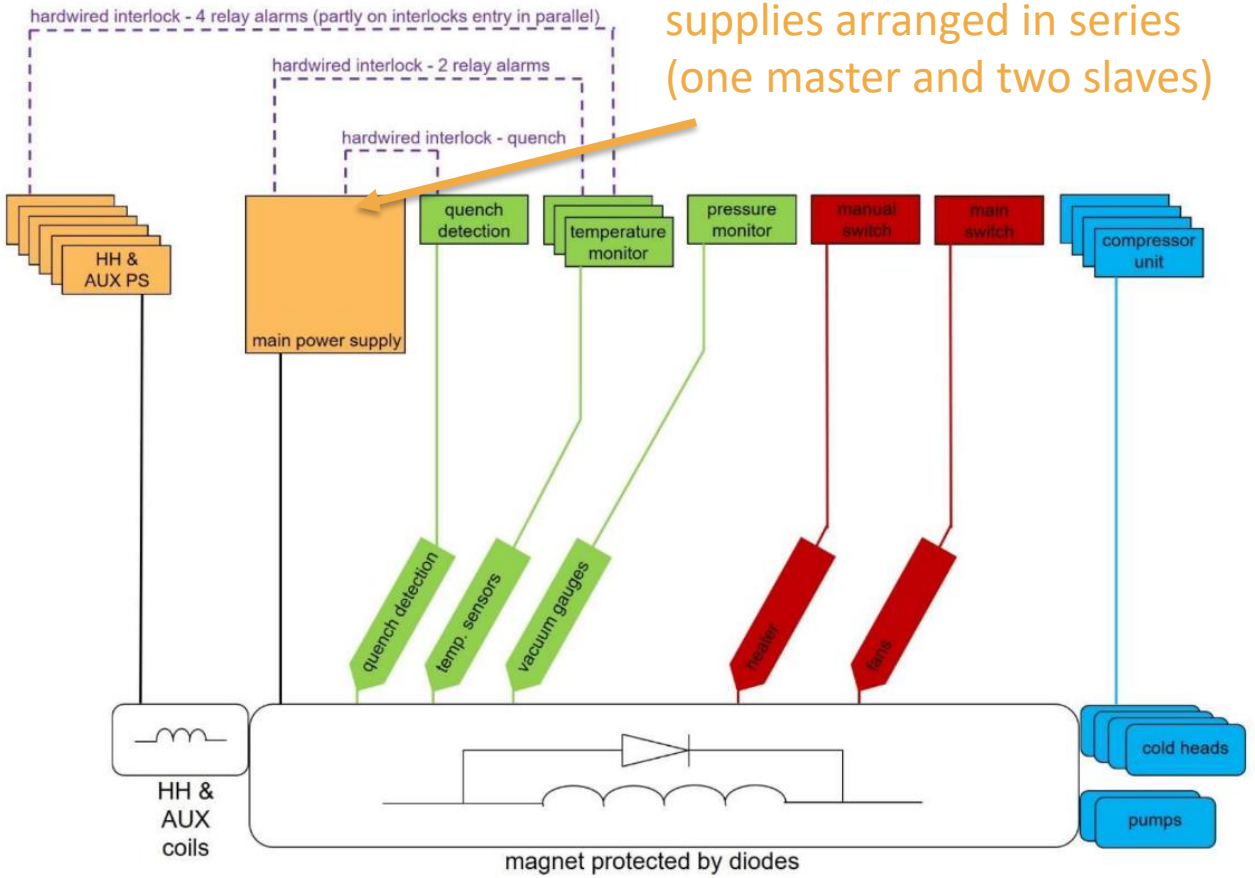


ANSTO

Power supply and Equipment Protection

- Cold diodes for passive protection
- Danfysik four channel quench detector (System 8500)
  - Interlock power supplies when voltage across SC coils exceeds 100 mV for 10 ms.
  - 200 ms from quench to zero current.
- Temperature monitoring
  - 36 sensors
  - Interlocks power supplies.

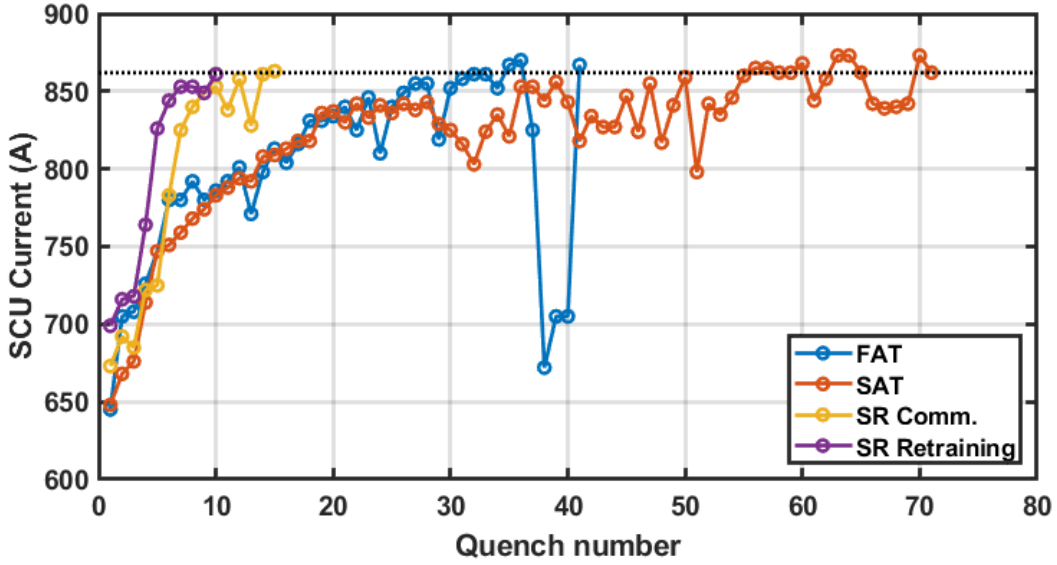
Delta Elektronika SM 15-400 (15V/400A) Three power supplies arranged in series (one master and two slaves)

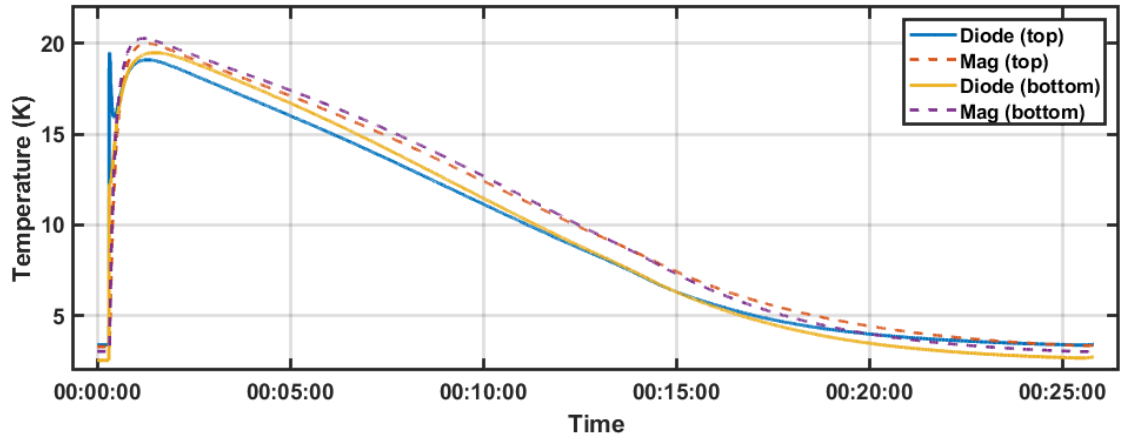


ANSTO

Quench Training and Recovery

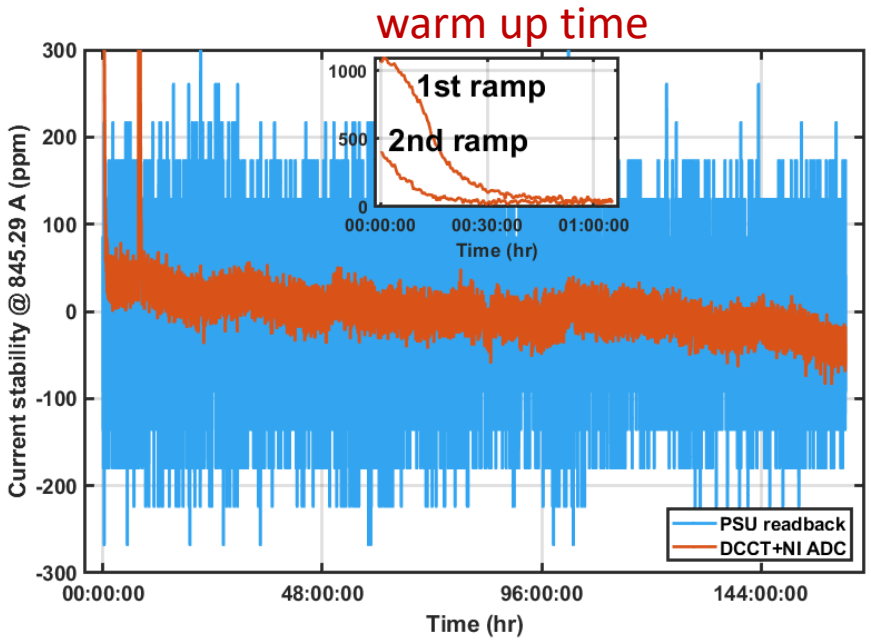
- Quench training history to reach 862 A (1.084T)
- Accidental training up to 897 A (1.12 T / 1.673)
  - Power supply mis-configuration resulted in output being 1.333 more than setpoint and readback.
- Recovery time ~25 minutes.

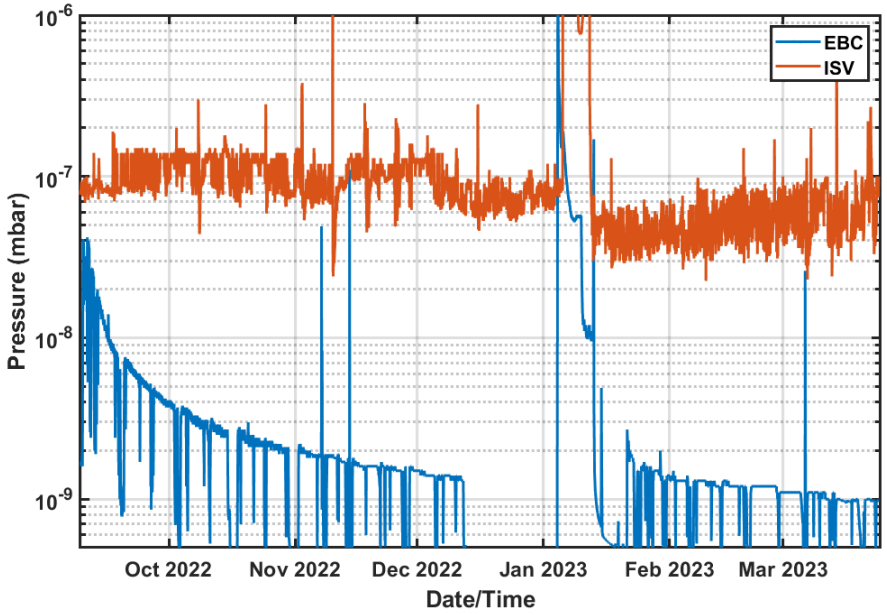




Operational Experience

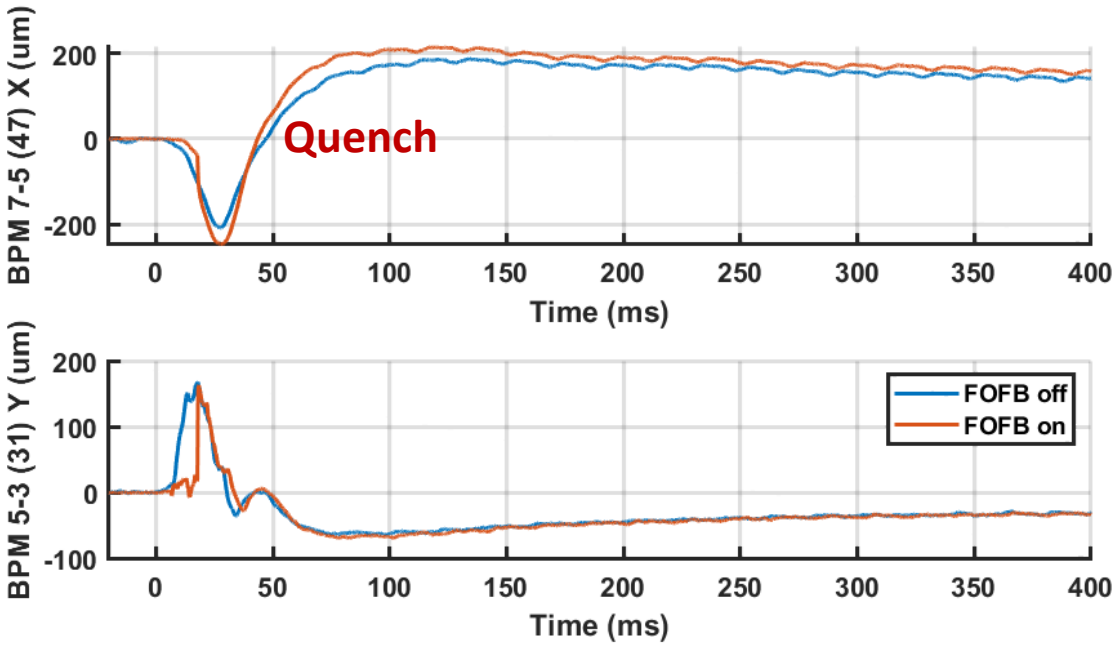
- Field/PSU stability is good
  - < 200 ppm over 6 days
  - Short 45 minute warm up time required
  - Vacuum conditioning with 200 mA is good.
- Narrow gap impact on lifetime is hard to determine.
  - Estimates: 2% to 10%.
  - No impact on injection efficiencies.

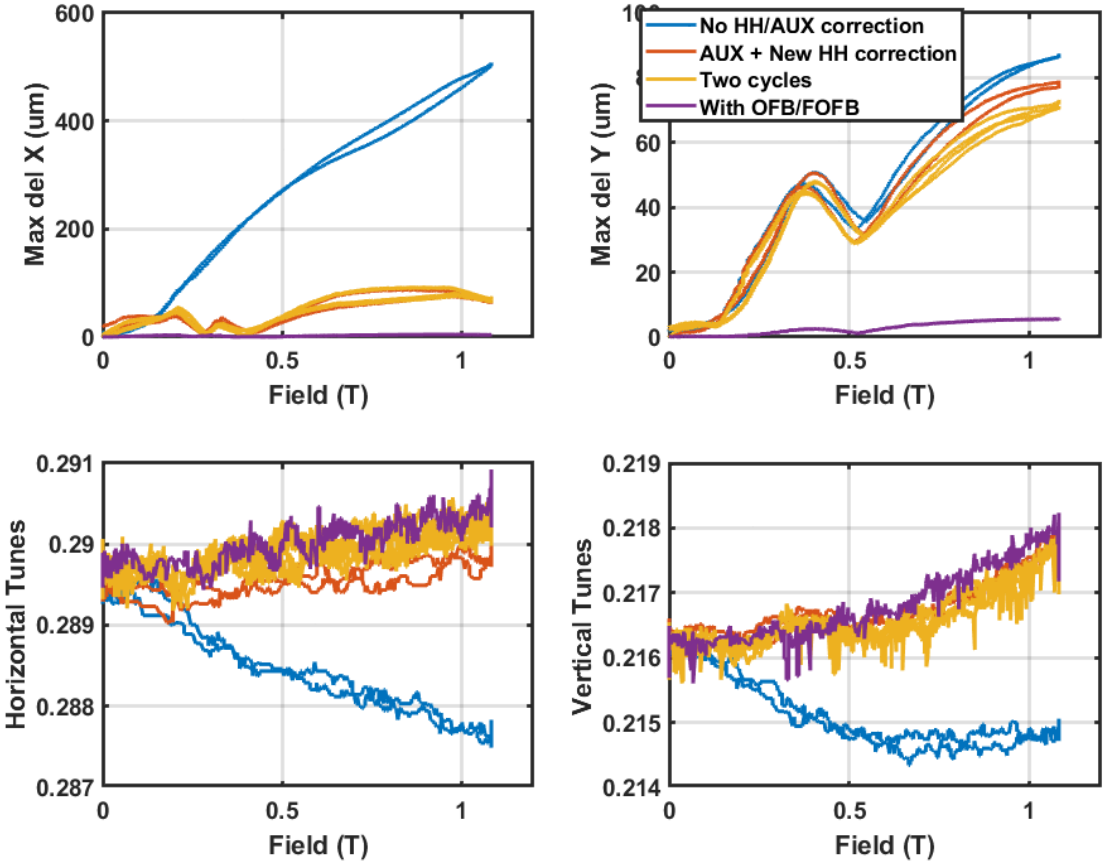




Operational Experience

- Quench does not dump beam.
- With Fast Orbit Feedback, SCU can be operated with no disturbance to users

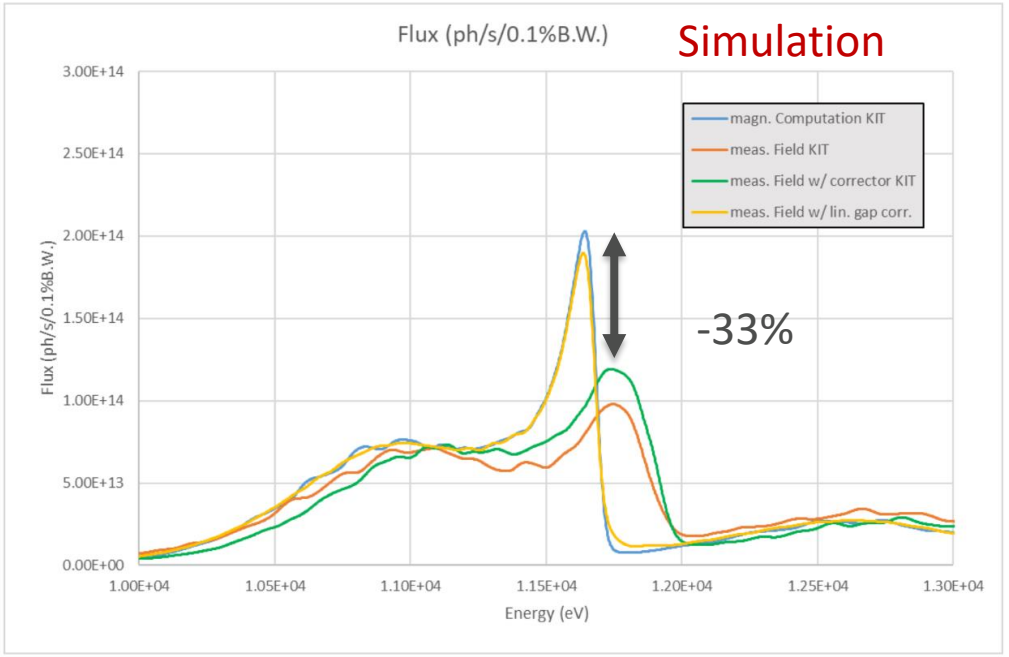


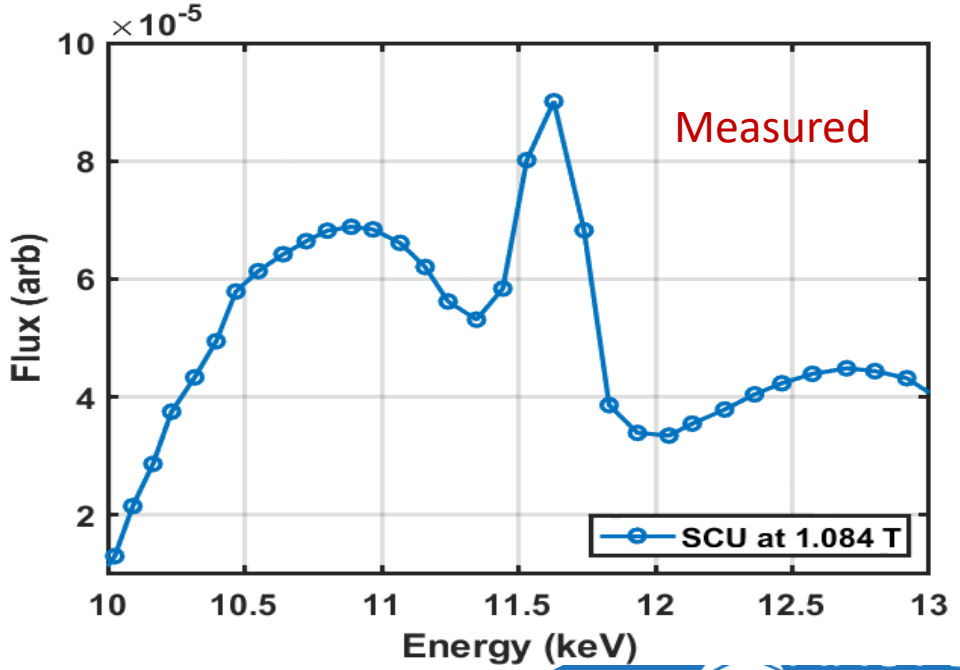


ANSTO

Operational Experience

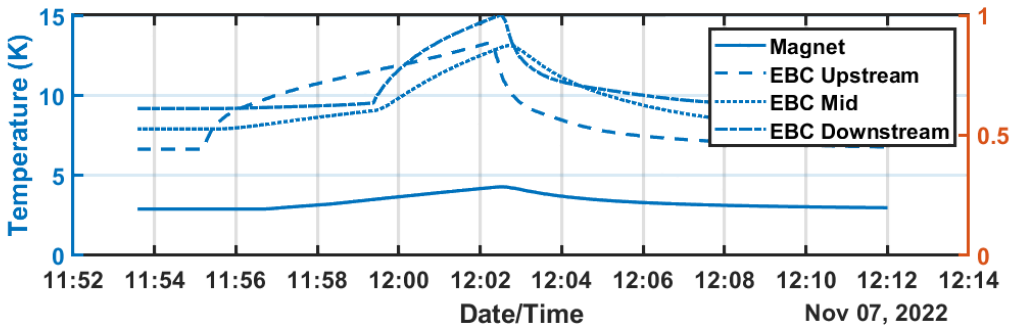
- Phase error and impact on photon flux
  - SPECTRA sim. Indicates 10% reduction in flux at 5th harmonic with 10° RMS phase error.
  - At 15.3° → 33% reduction.
  - Min integral errors ≠≠ min RMS phase errors (can be reduced to ~10°)
  - Bragg angle not calibrated so energy is not exact.
- Beamline measured ~1e14 ph/s on sample with calibrated photodiode.

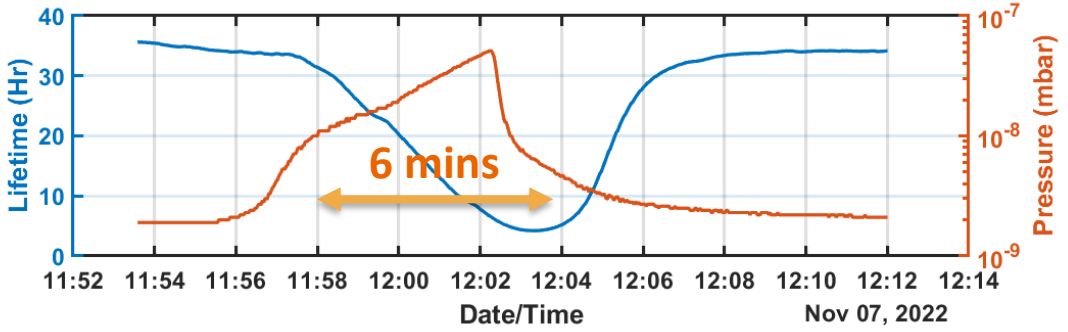


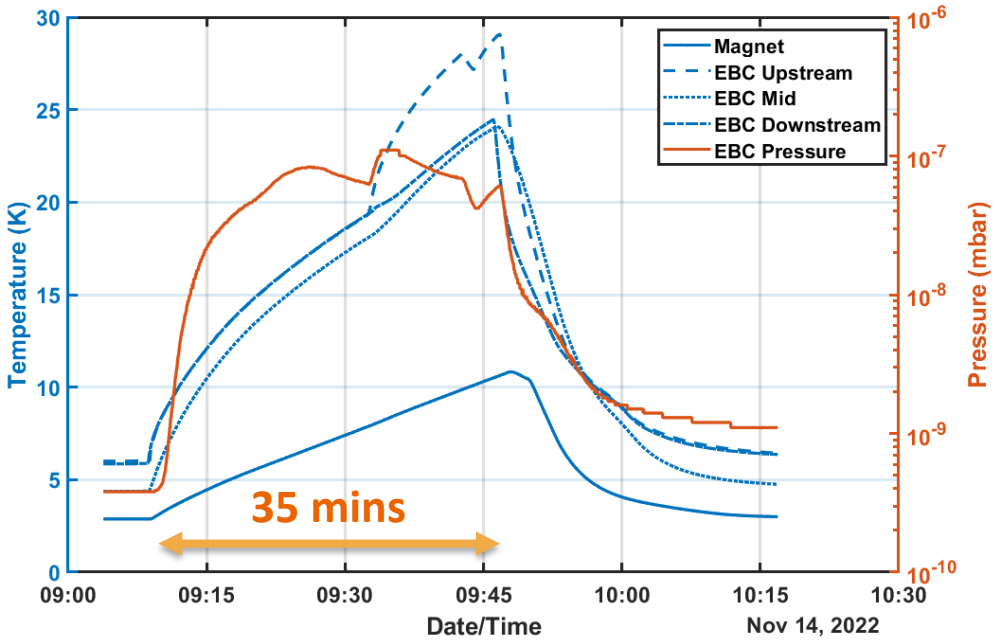


Operational Issues

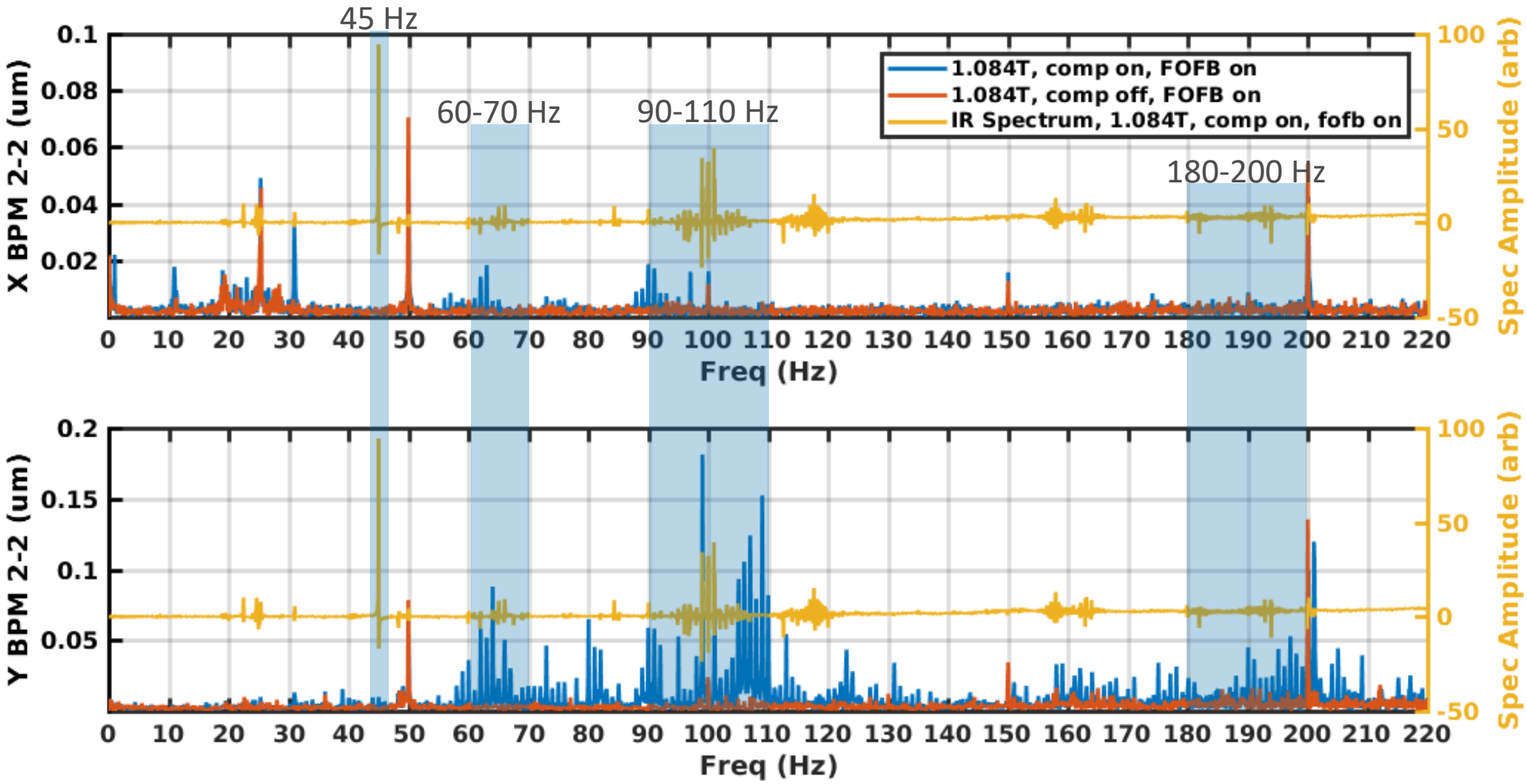
- Current Step losses (0.1 mA to 2 mA)
  - More frequent in the past 4 months.
  - Vertical beamsize blow up
  - UFO (unidentified falling objects)?
- Loss of cooling on SCU
  - Rapid increase in pressure.
  - Outgassing of cryopumped gasses
  - Lifetime plummets and beam becomes unstable.
- Question:
  - Should we warm up the chamber and pump during shutdowns?





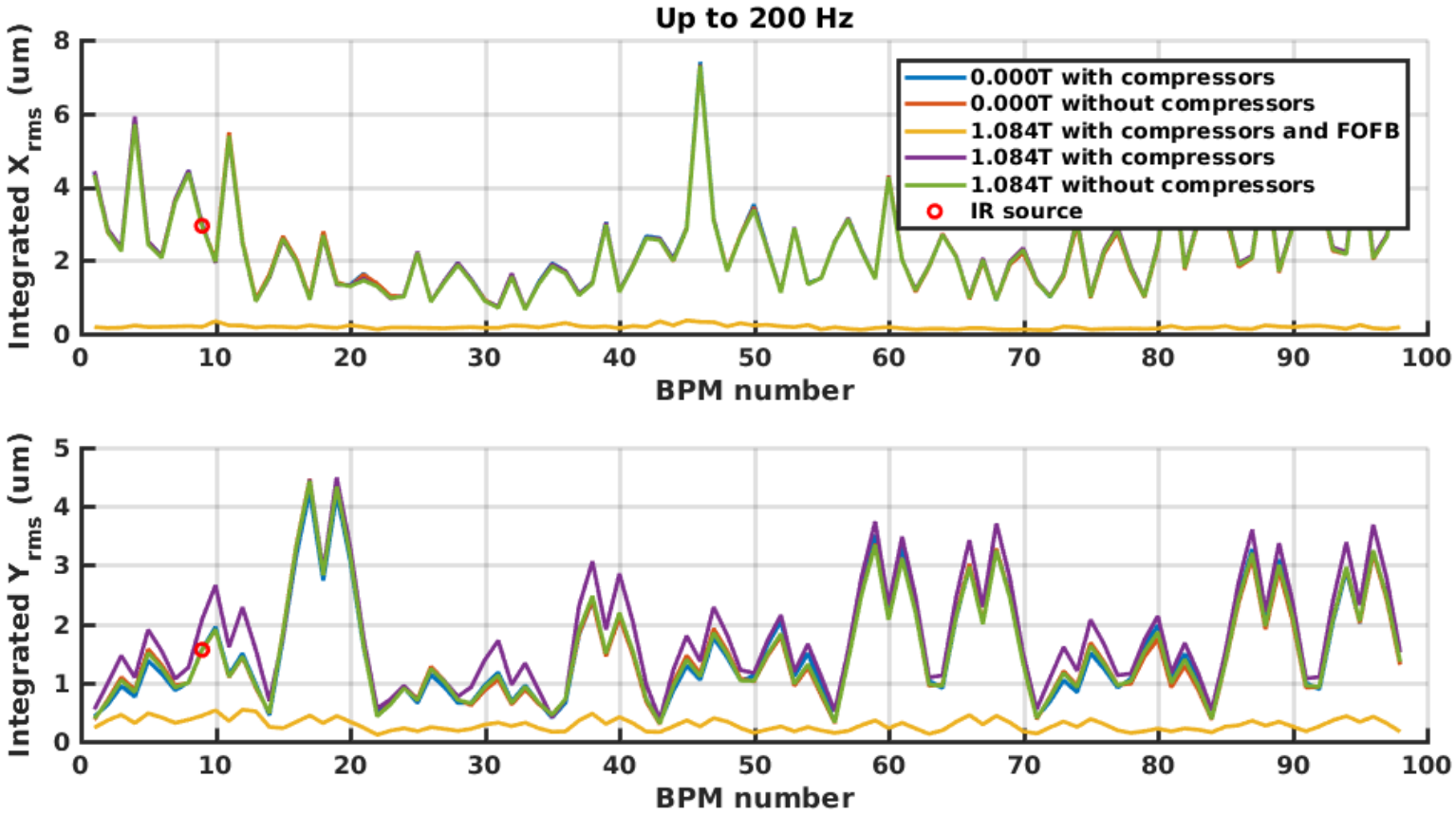


Issues – Compare IR with Beam Spectrum

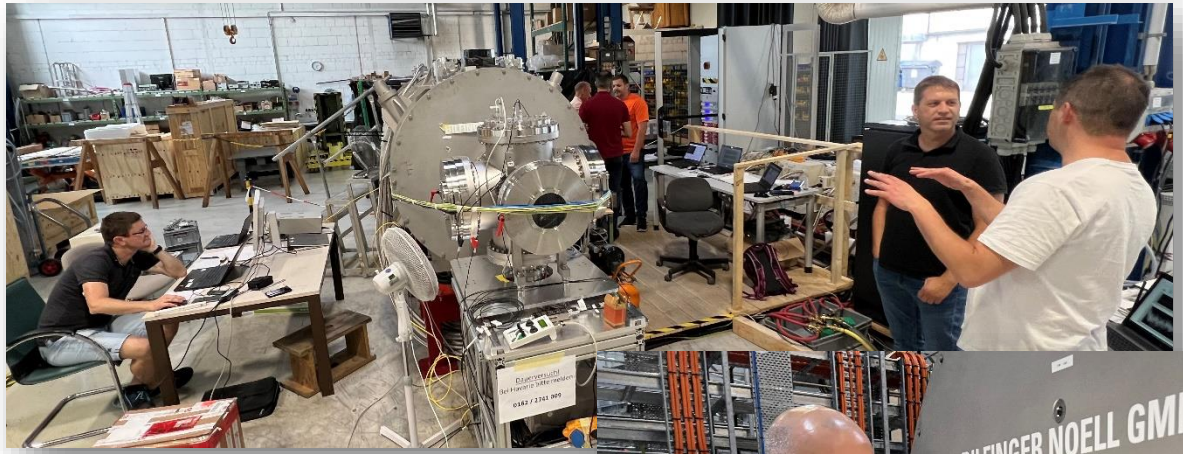


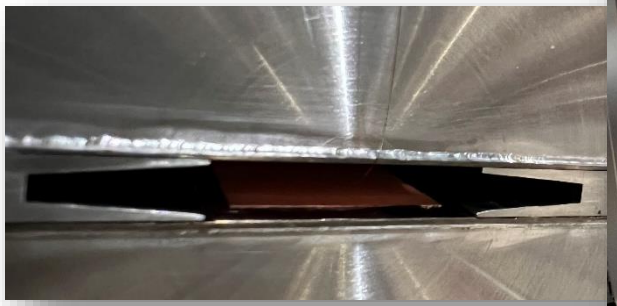
Issues – Integrated RMS to 200 Hz

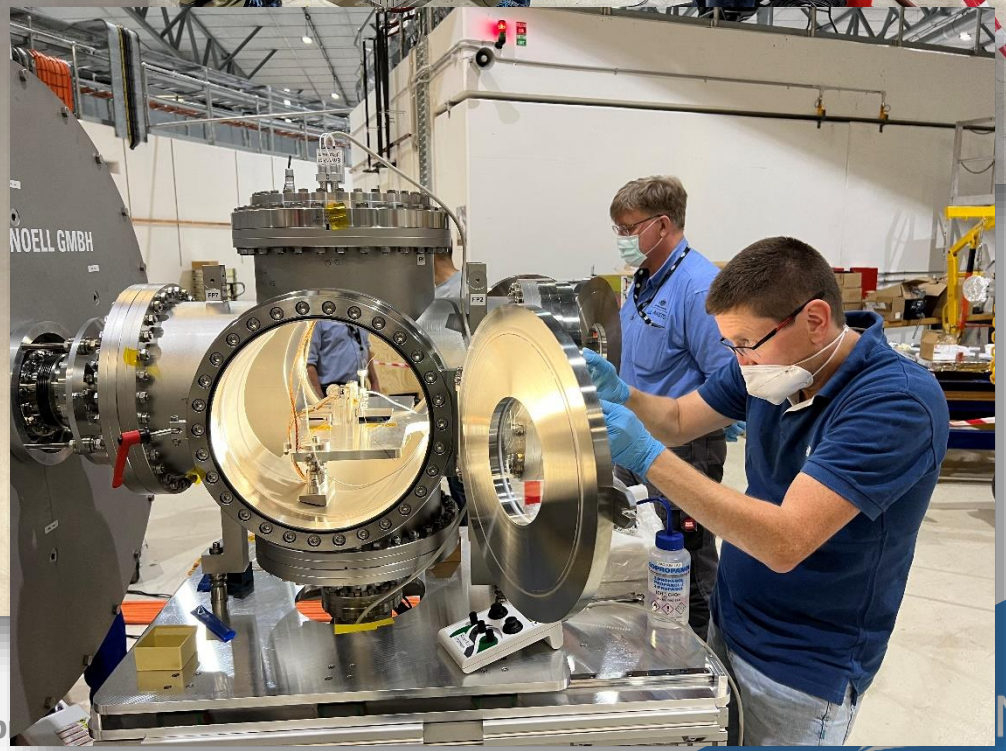
- Integrate all noise components up to a given frequency, give RMS beam motion to the given frequency.



Photos







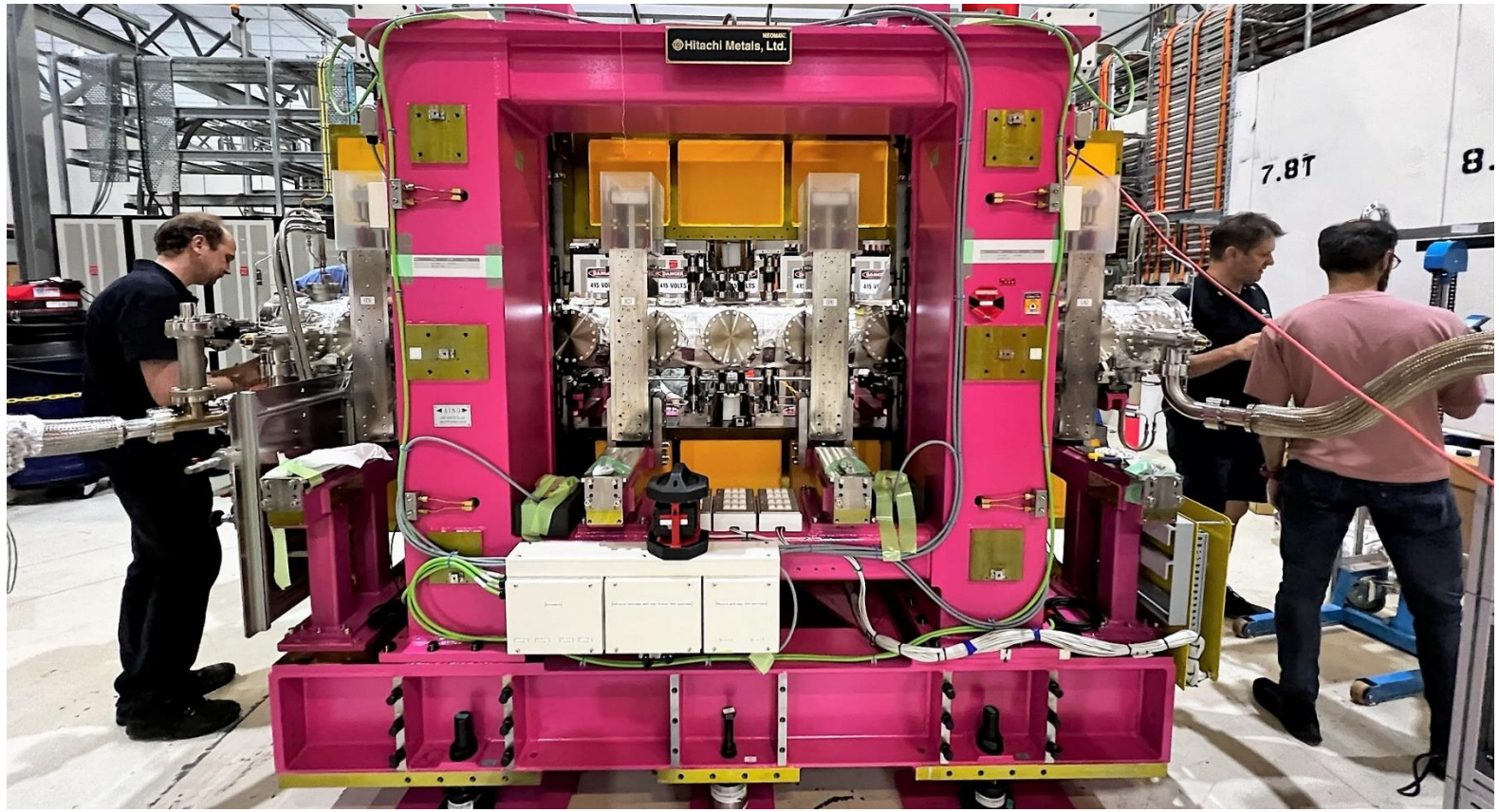
PROTERIAL

NEOMAX
NEOMAX Engineering Co., Ltd.

Materials Magic
Hitachi Metals

MX3

U17



ANSTO

U17

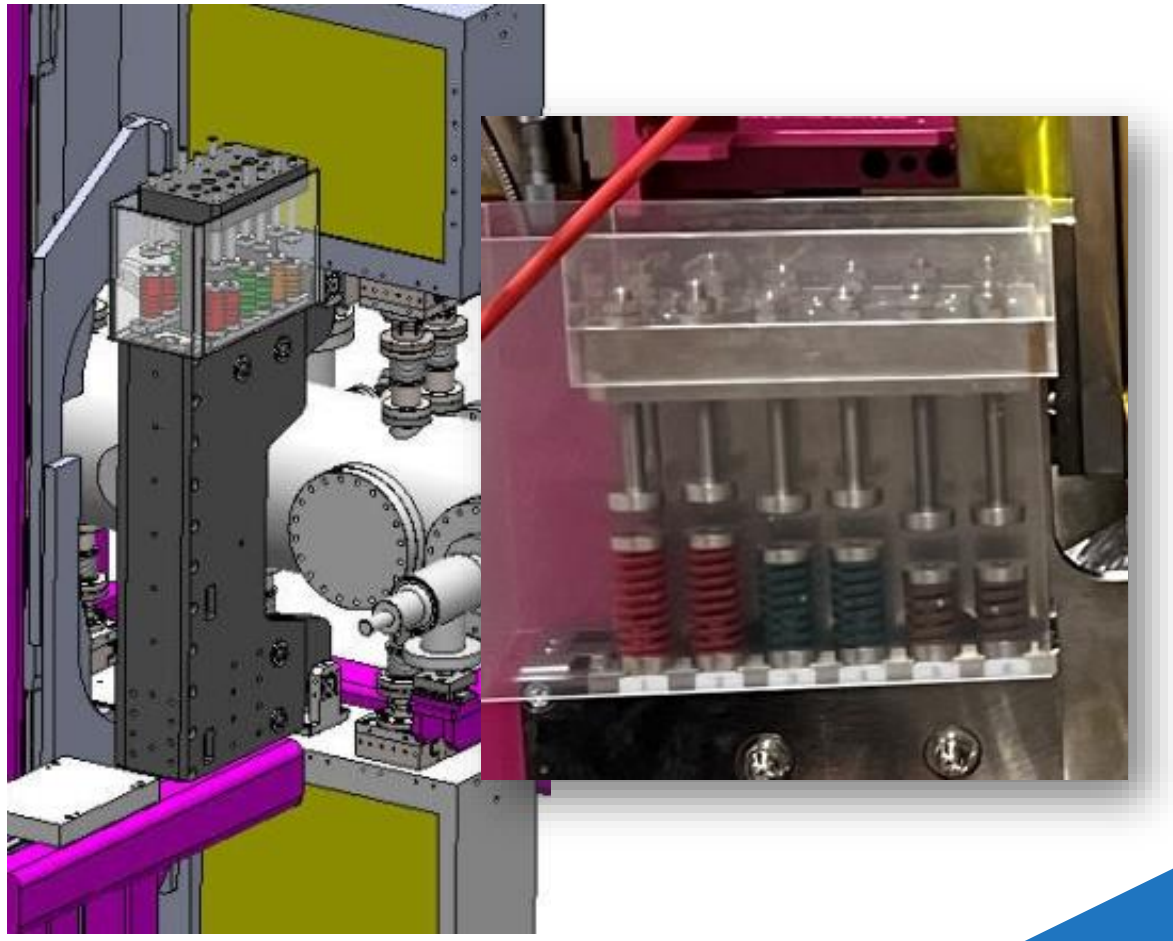
- Invacuum undulator
- Compensation springs
- Ferrites installed for trapped mode compensation.
  - Similar application of ferrites for mode damping for the CPMU
- Commissioning May 2023

Parameter	Value
Materials	NMX-S41EH / 49Co-2V-Fe
Br	1.24 T
Hcj (25°C)	>1990 kA/m
Magnet Period	17.2 mm
Magnet Length	3.0 m
Num. Full Periods	175
Maximum Field / K	0.9225 T / 1.48
Min. Magnet Gap	5.5 mm
Vert. Vacuum Gap	5.3 mm
Phase Error	< 2.53°

Compensation Spring System

- Minimises deformations to the support frame and girder.
- Improves minimum achievable phase errors.

Magnet Gap(mm)	Physical Gap(mm) (vertical clear aperture)	Phase Error(deg.)	B
5.5	5.3	2.53	
5.7	5.5	2.43	
6	5.8	2.39	
7	6.8	2.28	
8	7.8	2.10	
10	9.8	1.84	
12	11.8	2.12	
15	14.8	1.90	

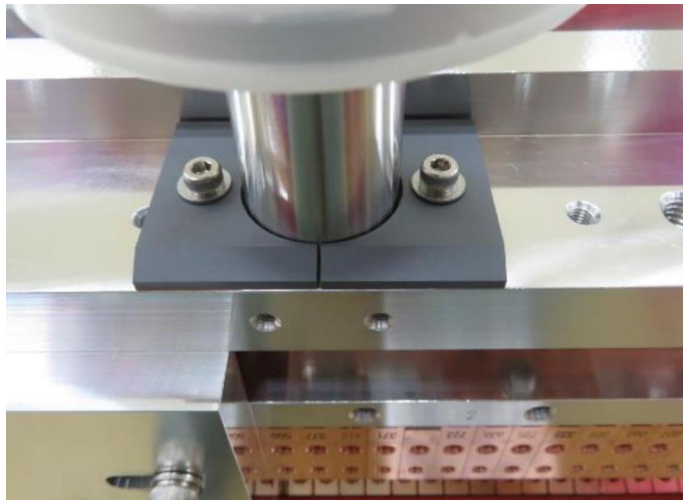


IVU Trapped Modes

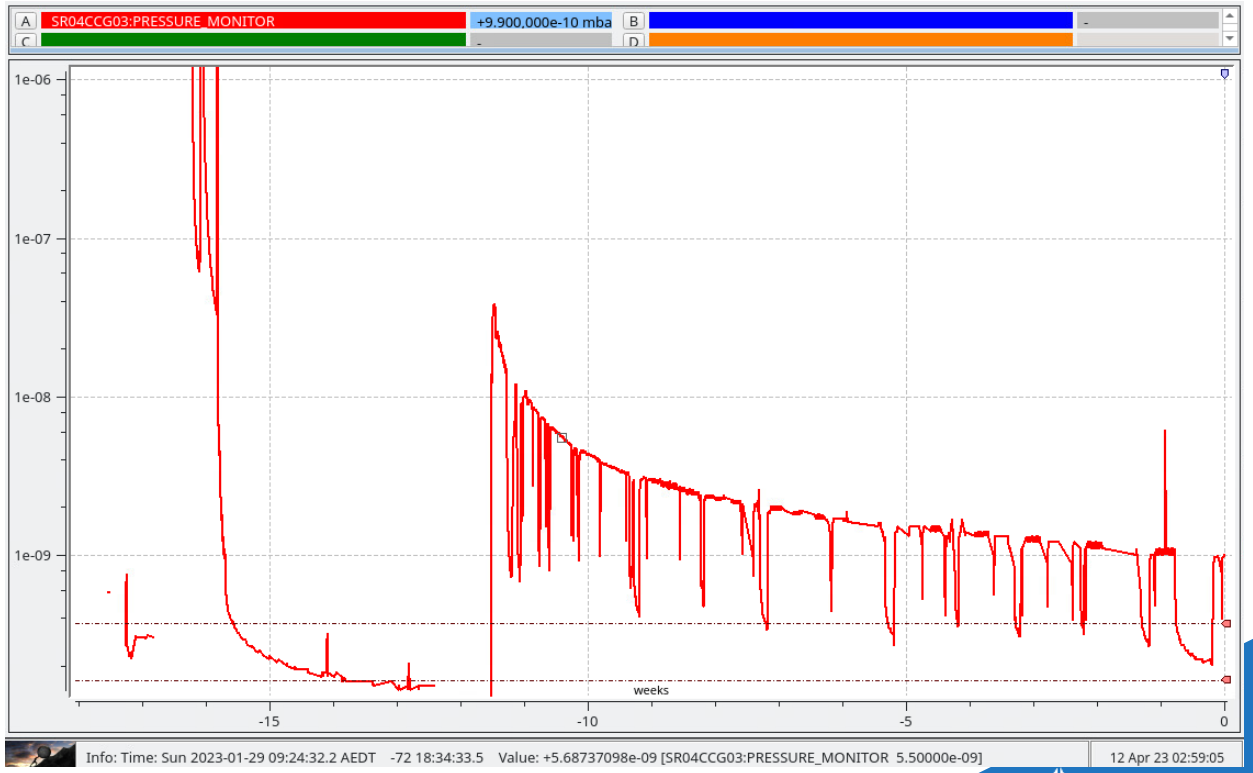
	Q				Shunt Impedance			
	None	40 pairs	20 pairs top 0 pair bottom	10 pairs top 10 pair bottom	None	40 pairs	20 pairs top 0 pair bottom	10 pairs top 10 pair bottom
Mode 1	665	4	7	12	33	0.1	0.2	0.5
Mode 2	663	5	9	15	48	0.9	1	2.1
Mode 3	628	8	13	22	157	2.4	3.8	8.8
Mode 4	618	12	19	32	150	2.8	5	11
Mode 5	631	18	27	47	110	2.7	4.6	10.5
Mode 6	672	26	17	65	79	2.3	1.5	8.7

Ferrites and Vacuum Conditioning

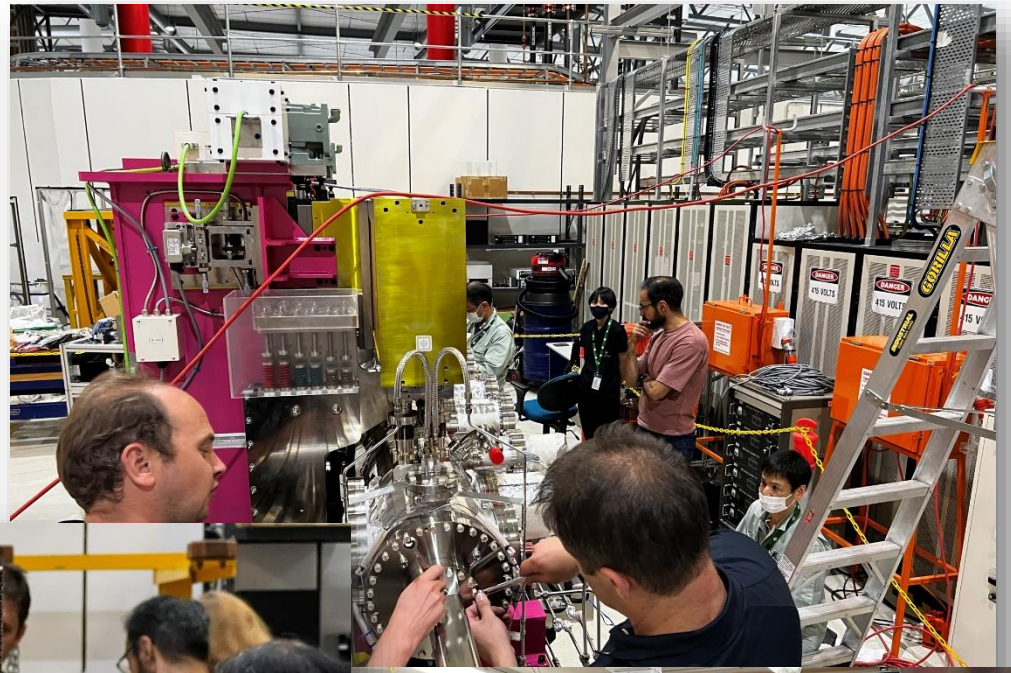
- SLAC Design that was shown to work
- Negligible heating effect expected < 2W across all ferrites.

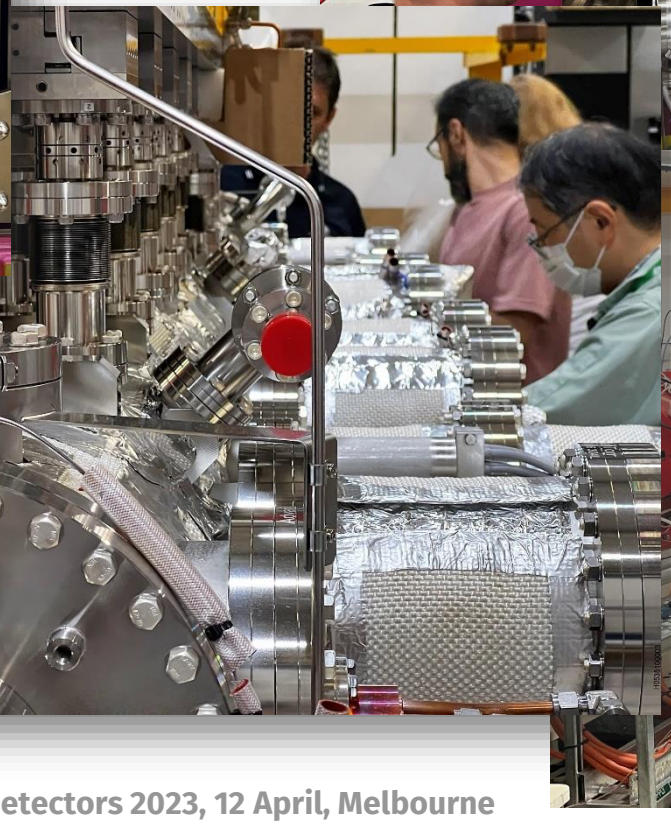


- Vacuum conditioning with open gap. 12 weeks → 1e-9 mbar.



Photos





Acknowledgements

Accelerator Physics

- Rohan Dowd
- David Zhu
- Jonathan Chi
- *Operators team*

Engineering/Technical Team

- Sina Porsa
- Jason Wirthensohn
- Luke Adamson
- Trent Smith
- Brian Jensen
- Jonathan McKinlay
- Simin Chen
- Andrew Starritt
- Rick LeGuen
- …

Kyma

- Raffaella Geometrante

Bilfinger Noell GmbH

- Wolfgang Walter
- Achim Hobl
- Martin Kirchler
- Alexander Vatagin
- …

Hitachi/Proterial

- Kitamura, Hideo, RIKEN
- Khoda, Tsutomu
- Miyazaki, Takeshi
- …

Beamlines

- Christina Kamma Lorger
- Tom Caradoc-Davies
- Justin Kimpton
- Martin De Jonge

KIT

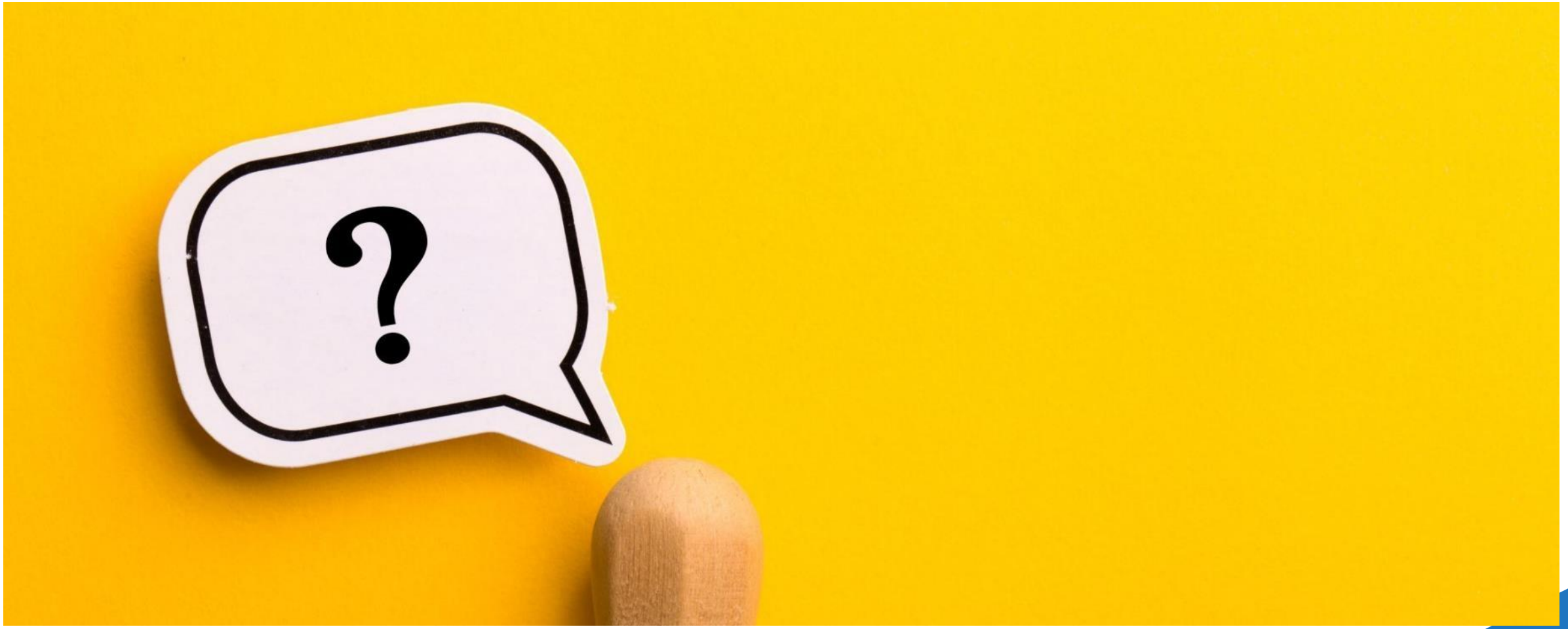
- Andreas Grau
- Nicole Glamann

Colleagues

- Jui-Che Huang, NSRRC
- Sarah Casalbuoni, KIT
- Johannes Bahrdt, HZB
- Katherine Harkay, APS
- Andrew Broadbent, BNL
- Stephen Milward, DLS

ANSTO

Questions and Feedback



Thank You

Australian Government