



Commissioning of a 1.6 m long 16mm period Superconducting Undulator at the Australian Synchrotron

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ANSTO – Australian Synchrotron

Science. Ingenuity. Sustainability.

Australian Synchrotron (AS): BRIGHT

- Australian Synchrotron (AS)
 - Melbourne, Australia
 - 3GeV, 216m circumference, DBA lattice, 14 arcs.
 - Since commissioning in 2005 we have operated with 9 beamlines.
- BRIGHT project commenced in 2016 – 6 new beamlines
 - MEX and MCT (two dipole sources)
 - BioSAX (SCU)
 - Advanced Diffraction and Scattering, ADS (4.5T SCW)
 - Protein Crystallography, MX3 (IVU)
 - Nanoprobe, NANO (CPMU)

SCU16

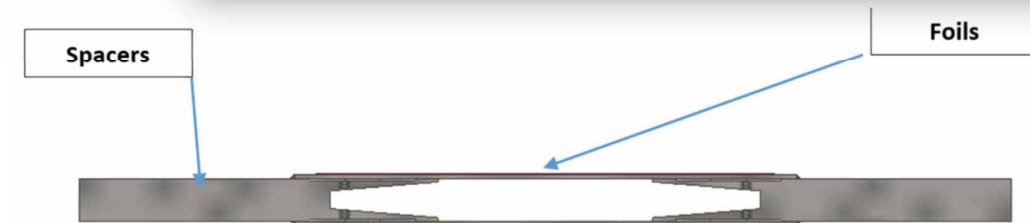
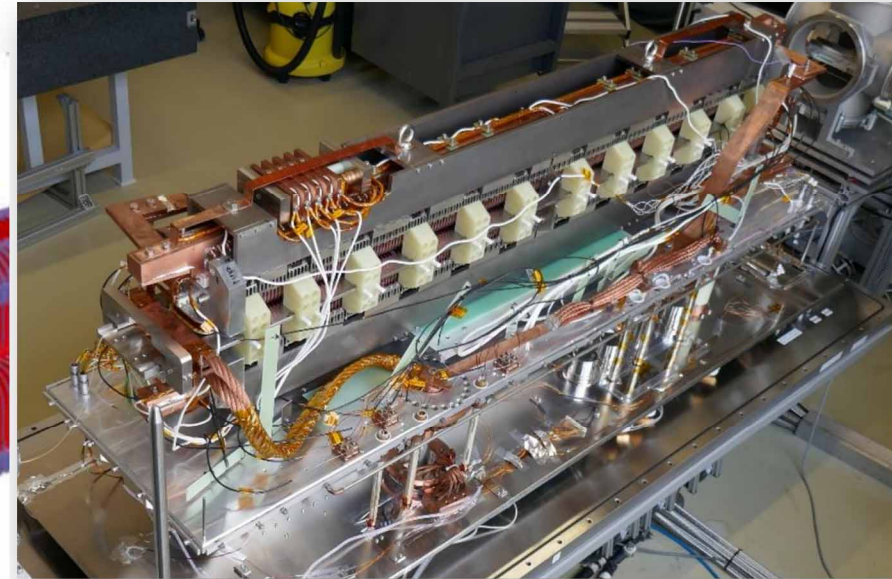
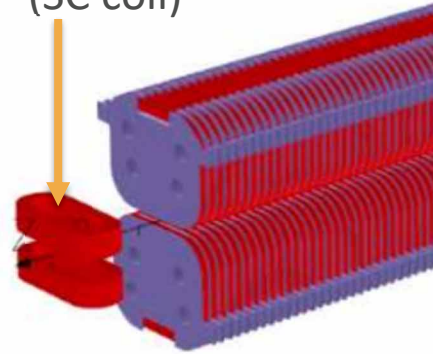
- Vertical racetrack conduction cooled SCU designed and built by BILFINGER NOELL GmbH (BNG)
- Based on SCU20 operating at KIT.
- Operating for 6 months.

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	5.6 mm (6.0 mm)
Horiz. Vacuum Gap	60.0 mm
Field Stability (144 hr)	< 200 ppm
Horiz. roll-off (± 10 mm)	< 0.35%
RMS Phase Error	$\sim 10^\circ$

Design

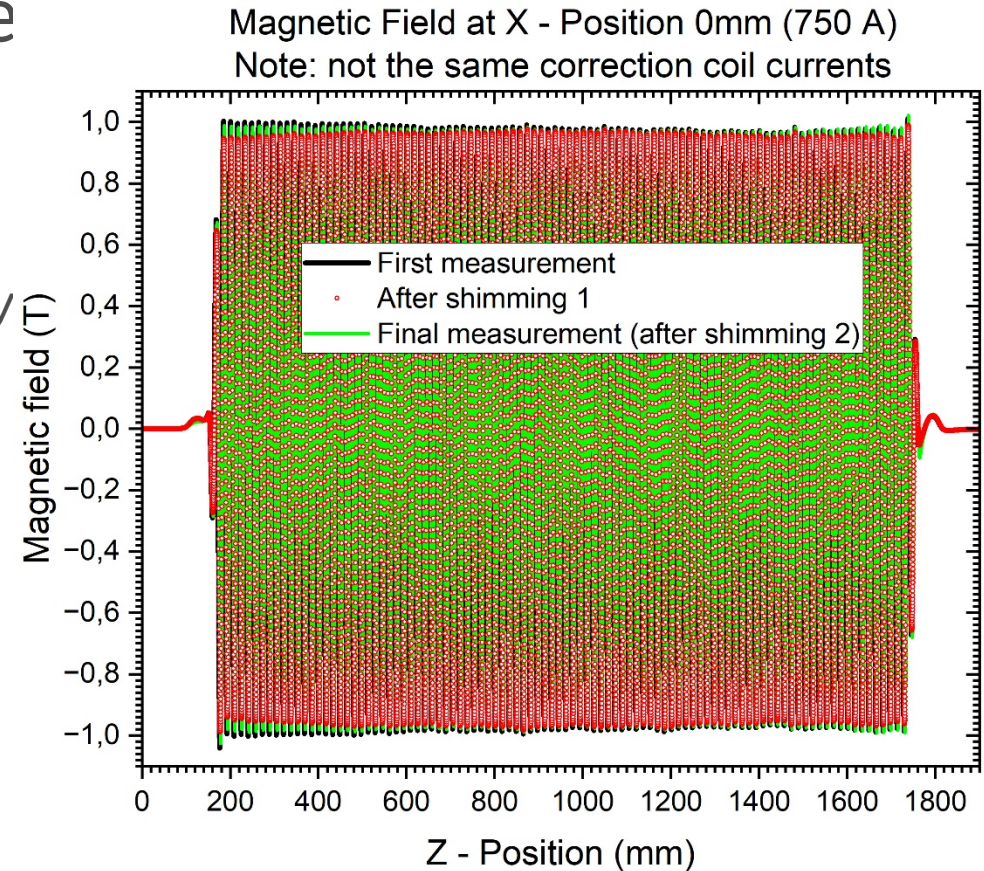
- 1.08 T (862 A) on axis \rightarrow 3.62 T on conductor.
- Electron Beam Chamber, EBC (316LN Stainless)
 - 6 mm by 60 mm inner aperture
 - 0.6 mm 316LN foils (+ 30 μ m copper on inner surfaces).
- Three Delta Elektronika SM 15-400
- Safety system:
 - Diodes
 - Danfysik 4 channel quench detector
 - 36 temperature sensors

Dipole corrector
(SC coil)



Field Measurements: Field Tuning

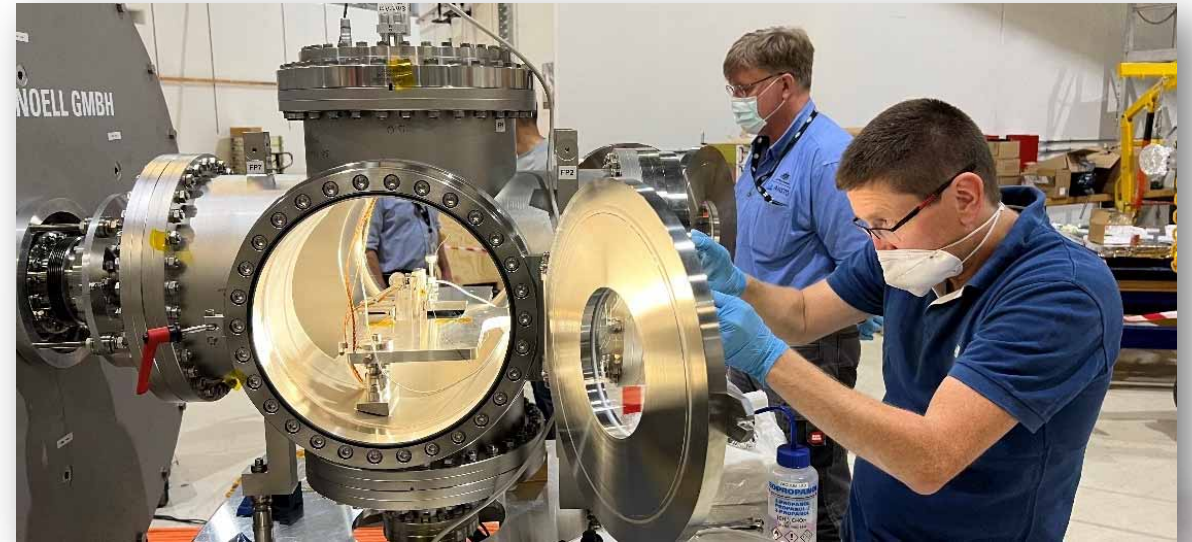
- Measurements at KIT's CASPER 2 with of the cold mass (magnet, chamber and support frame)
- Magnet gap was shimmed to symmetrise B_y longitudinally and horizontally.
 - Two adjustment were made.
 - Each iteration took ~3.5 weeks.
 - Technical issues and time constraints limited the number of iterations.
- Phase error at 1.084 T (862 A)
 - 10° (AUX coils optimised)
 - Optimisation study when beamline is ready.



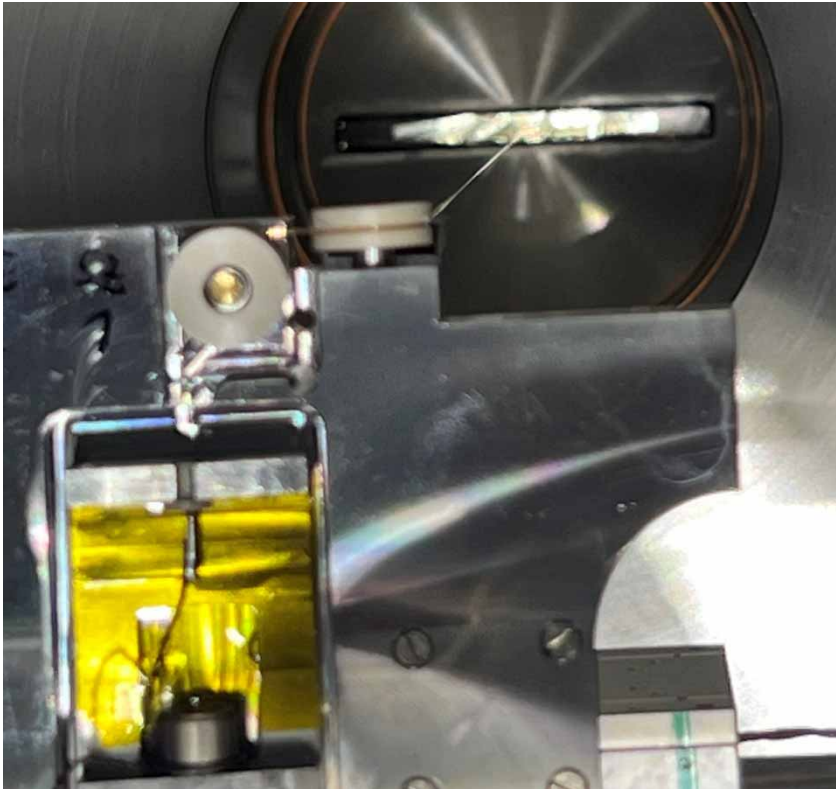
Courtesy A. Grau

Stretch Wire and Touch Test

- A portable stretched wire system was developed by KIT to measure integrals on site (Australia).
- First integrals measured
- Used “quadrupole” component at 1.084 T as the measure.
 - KL @BNG = 17.0 mT
 - KL @AS = 17.2 mT



Stretch Wire and Touch Test

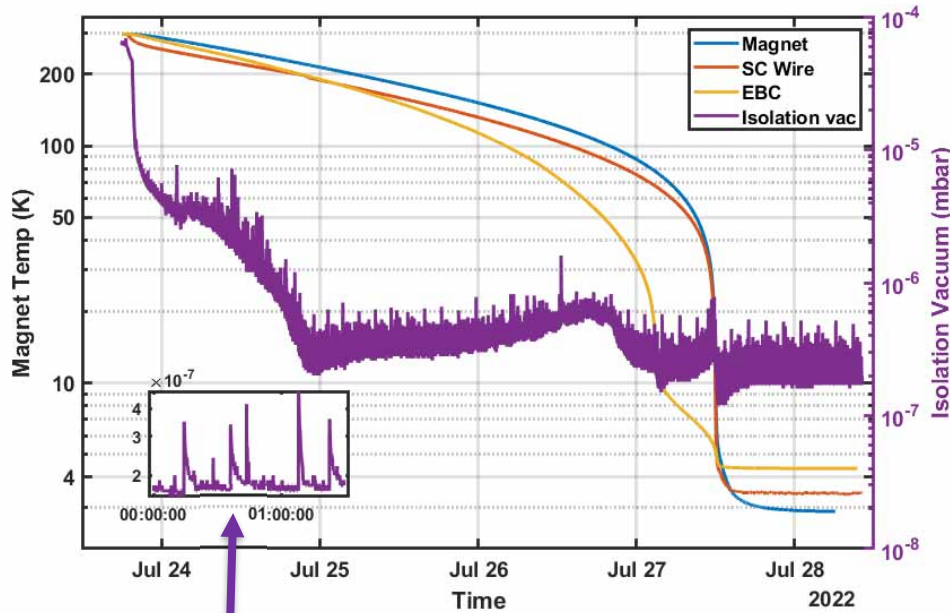


- During measurement, discovered the end flange position needed adjustment.
- Using wire to touch the surfaces to measure of the gap and position.
- Repeatability: 10 μm
- Accuracy: $\pm 50 \mu\text{m}$
- Expected/Measured gap: 5.9 mm / 5.6 mm
- Flange shifted down 400 μm / 500 μm

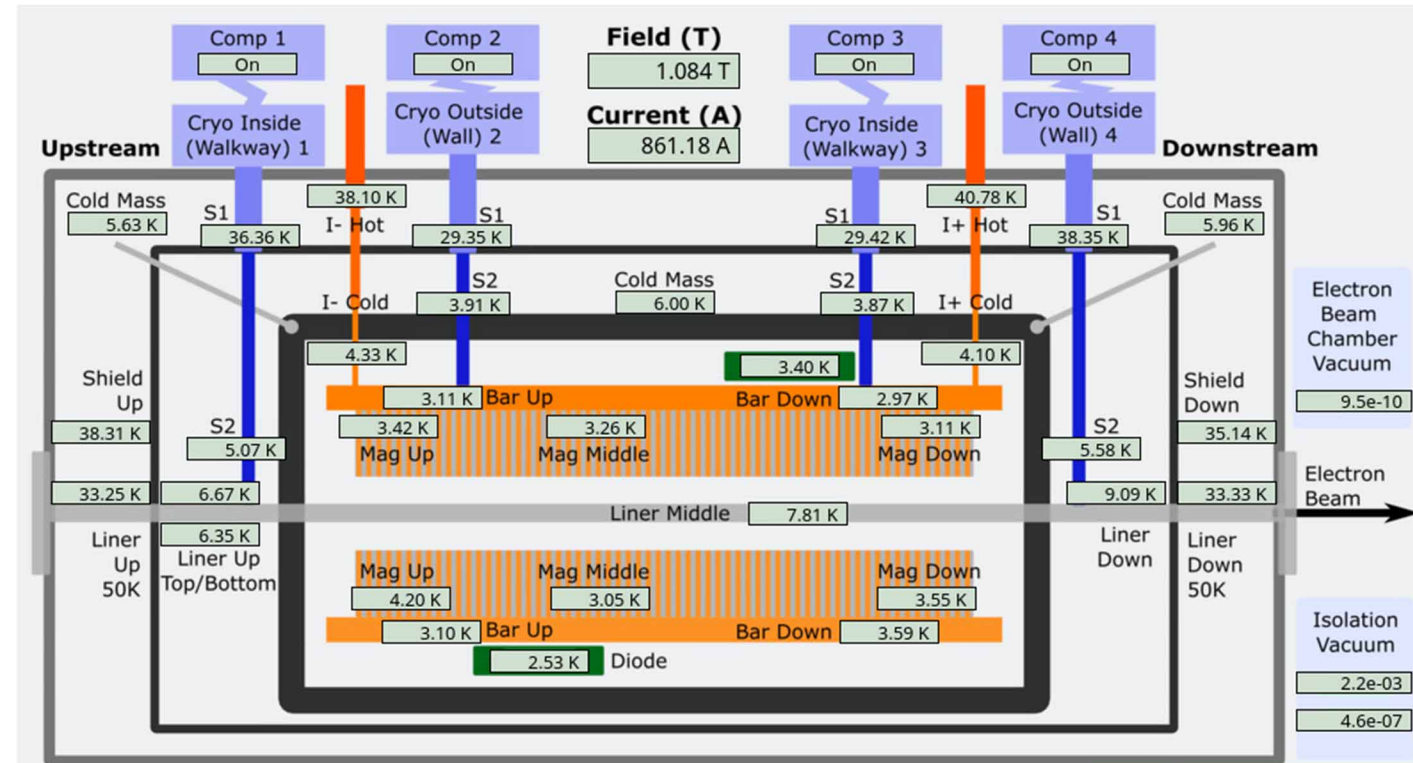
Cryogenics and Temperatures

- Sumitomo cold heads,
 - two SRDE-412D4, two SRDE-418D4
- Cool down (<4d), Warm up (3d)
- Isolation vacuum: $\sim 3e-7$ mbar.

- Equilibrium temp
 - 1.084T (862 A) , $\sigma_t = 30$ ps, 300/360 bunches, 200 mA (480 pC/bunch).

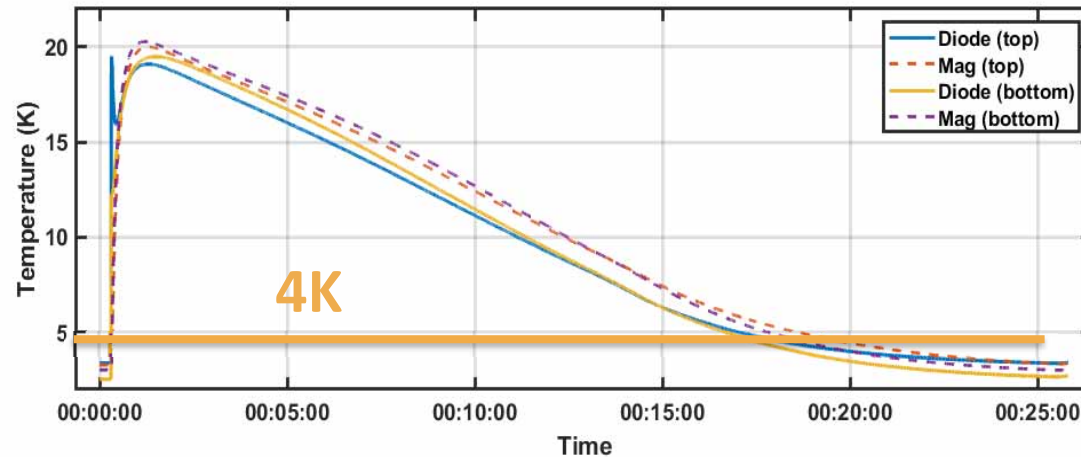
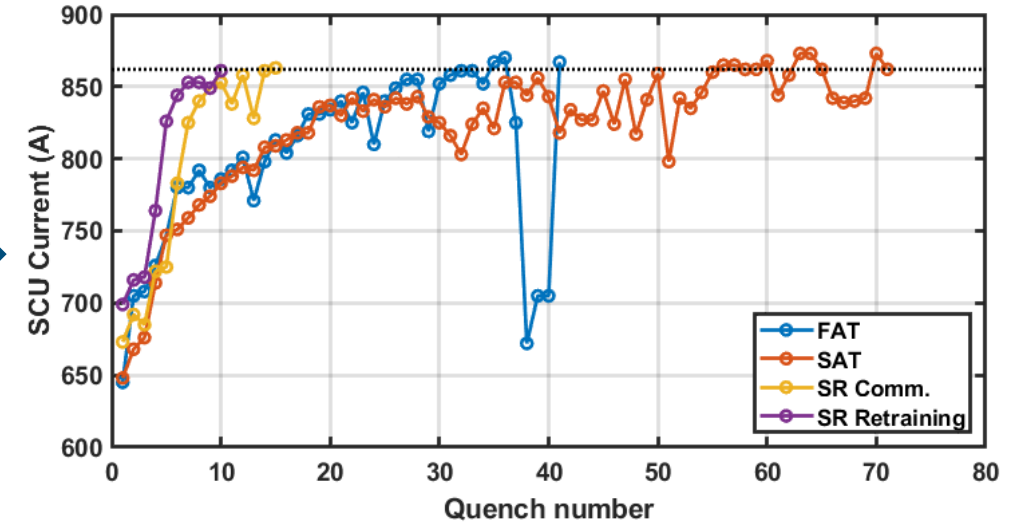


Early commissioning observed pressure spikes likely outgassing from various components.

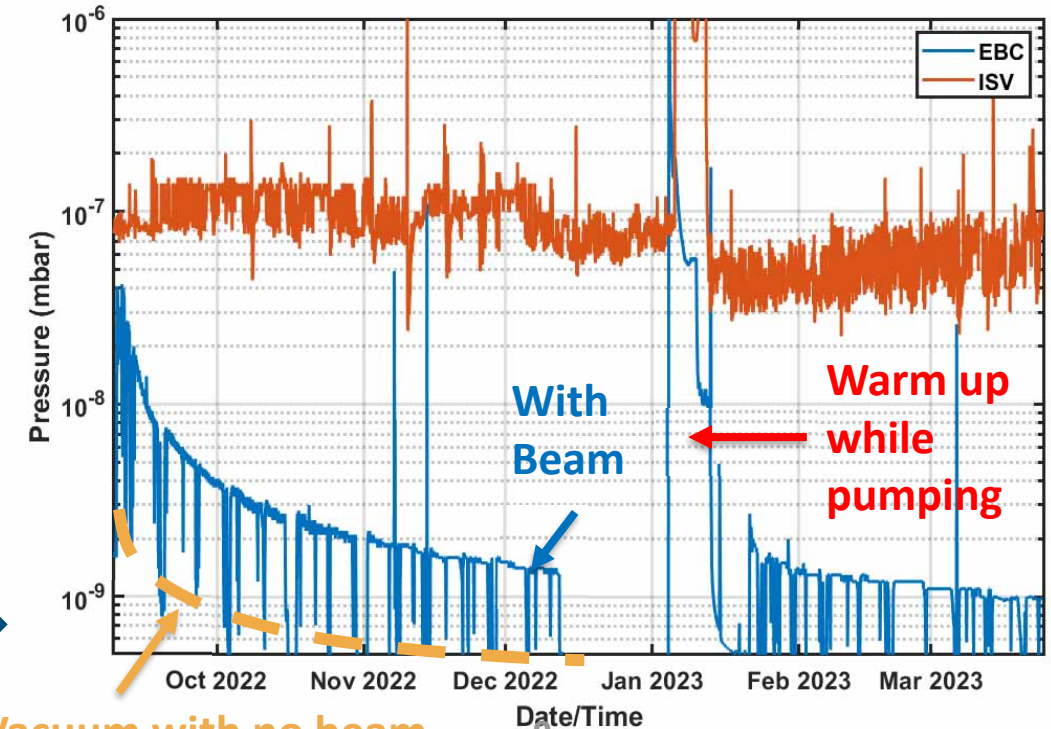


Quench Training and Vacuum

- Quench history to reach 862 A (1.084T)
 - ~20 K reached on magnets.
 - Recovery time ~25 minutes.
 - Accidental training up to 897 A (1.12 T / 1.673)



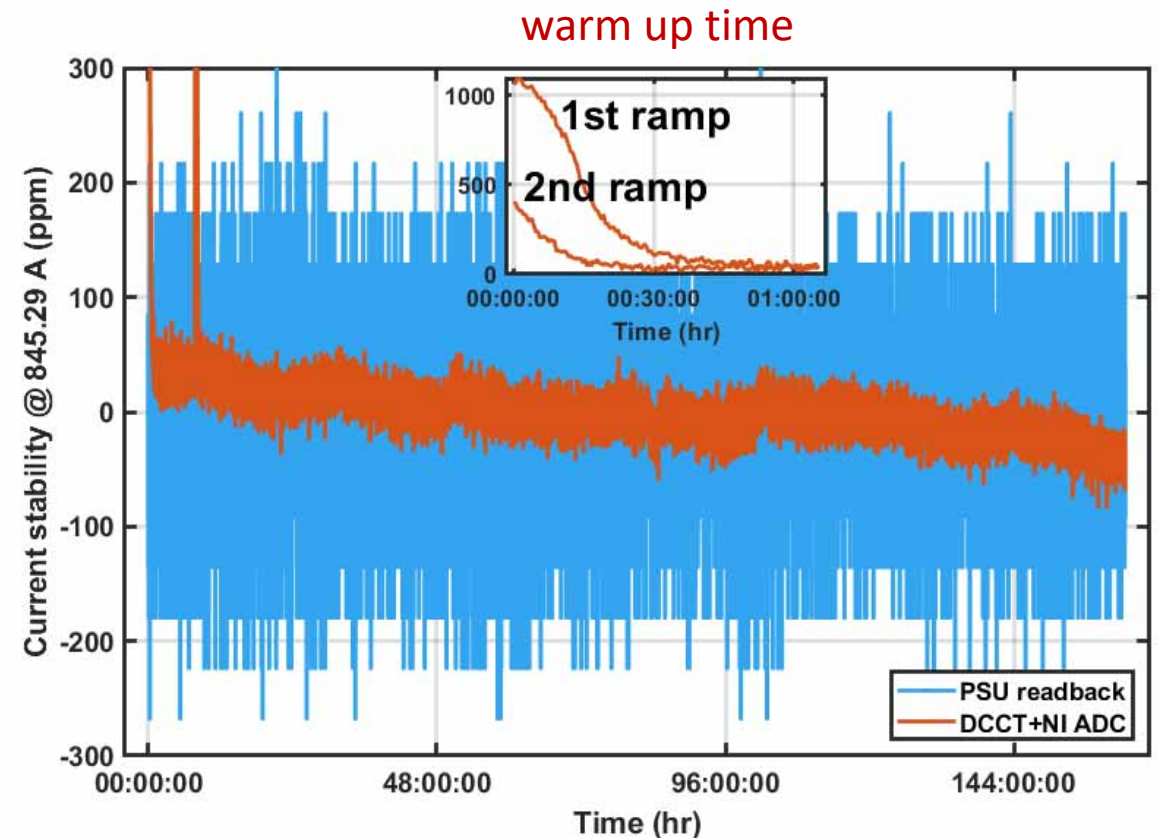
- EBC vacuum < 1e-9 mbar after 6 months.



Vacuum with no beam

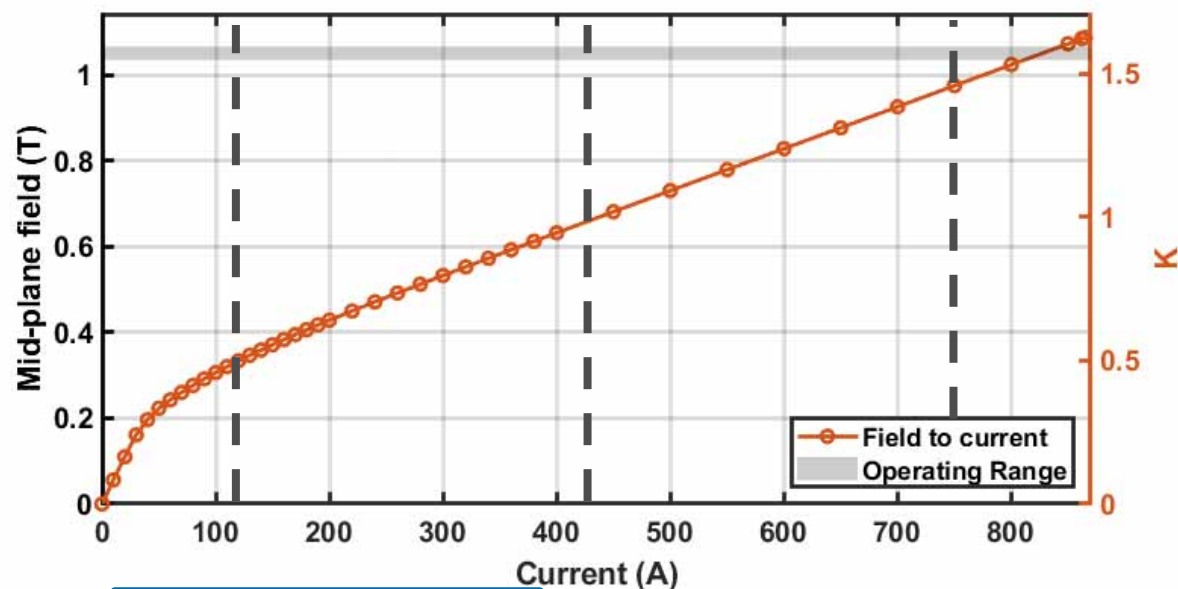
Field Stability

- DCCT + ADC used to monitor stability.
- Short 45 minute warm up time required
 - Software slow feedback to be implemented if needed.
- RMS: < 200 ppm over 6 days.
 - Within PSU specification.



Closed Orbit and Tunes

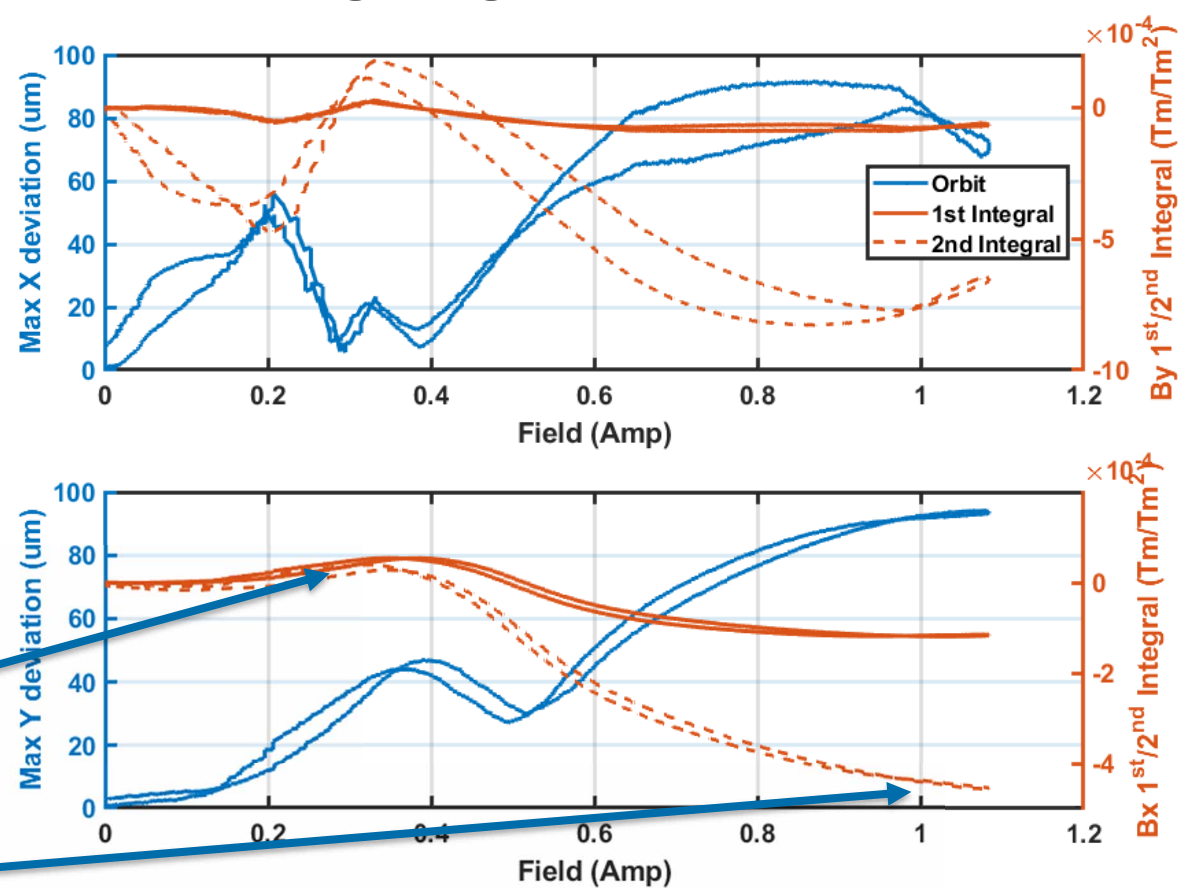
CASPER2 (KIT) Measurements



Field (T)	B_y I1 ($\times 10^{-6}$ Tm)	B_y I2 ($\times 10^{-6}$ Tm ²)	B_x I1 ($\times 10^{-6}$ Tm)	B_x I2 ($\times 10^{-6}$ Tm ²)	k (mT)	k_s (mT)
0.325	21.80	-64.89	-102.80	-146.59	2	0.2
0.650	-7.48	30.17	-3.92	20.12	8	0.7
0.975	0.890	11.82	24.00	55.70	14	2.0
1.084	-0.32	-12.95	10.99	57.02	17	1.9

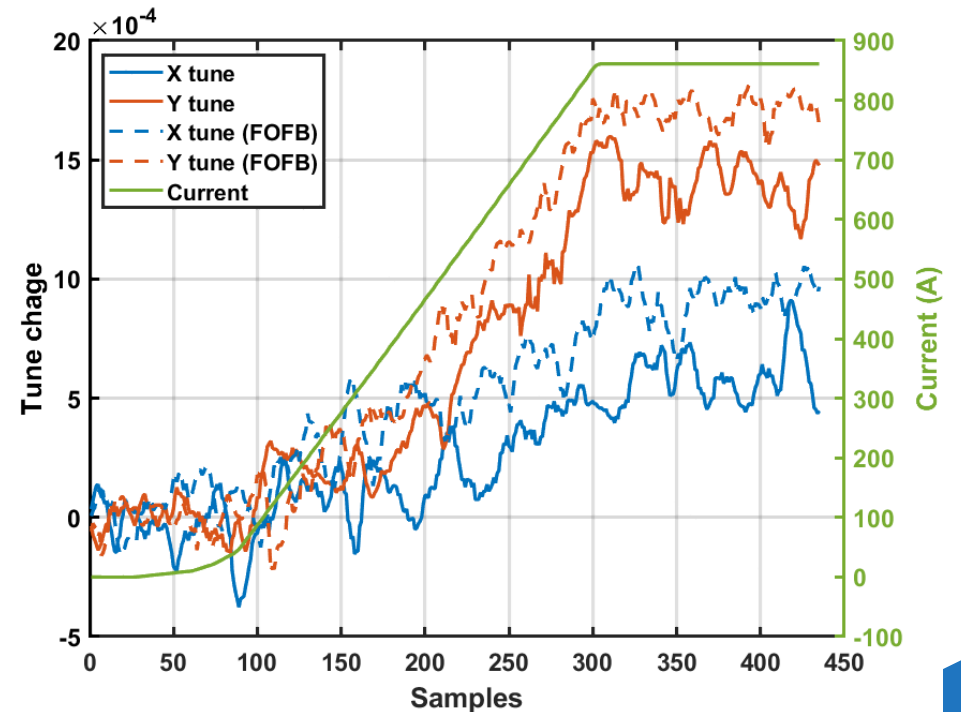
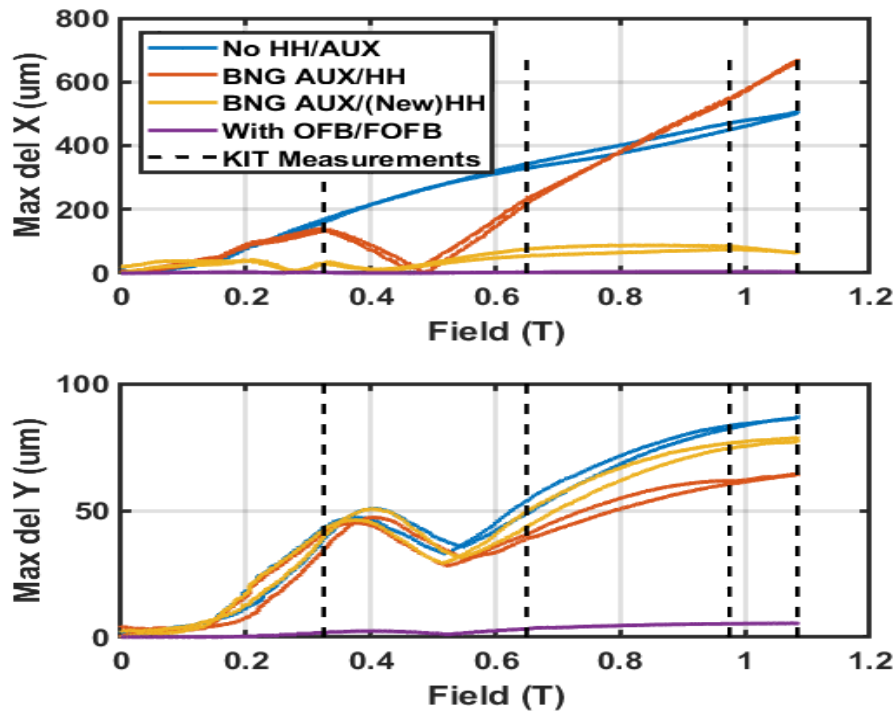
Corrected with B_y corrector coils

Storage Ring Measurements



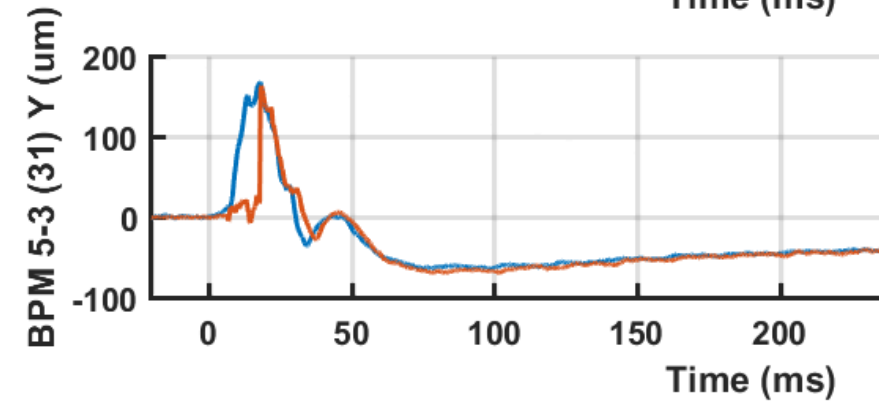
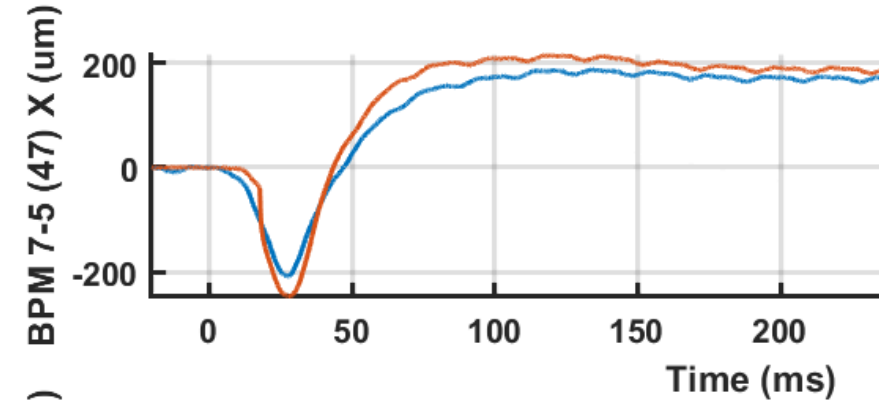
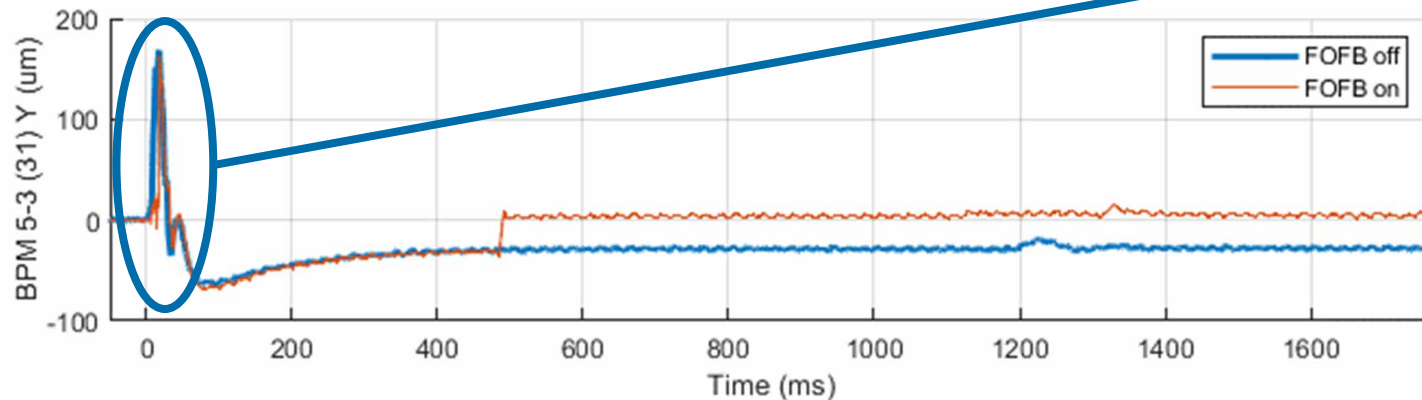
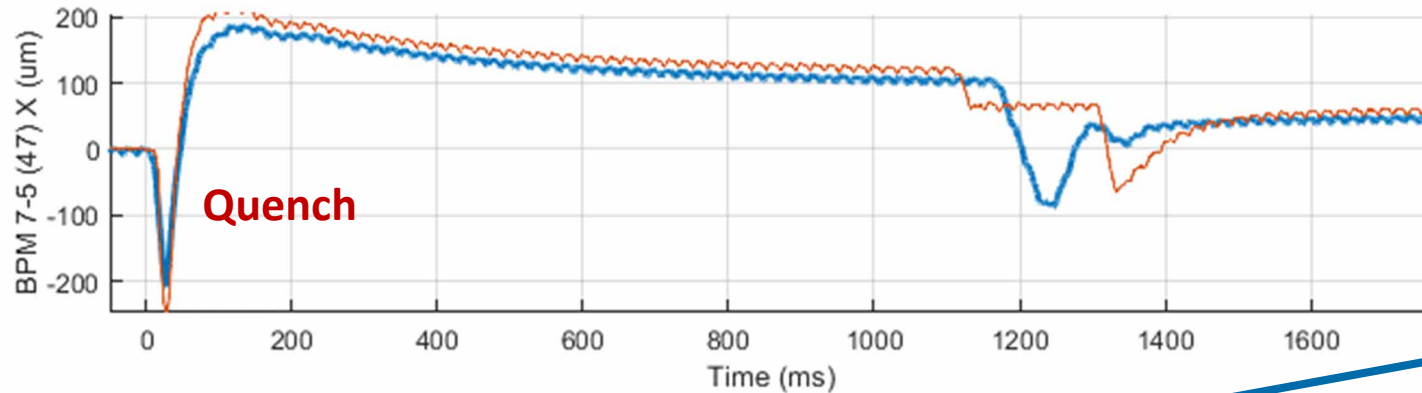
Closed Orbit and Tunes

- With the orbit feedback system $\Delta x/\Delta y < 6 \mu\text{m}$.
 - Transparent to beamlines
- Tune shift similar to other IVUs
 - Measured: +0.0010/+0.0018
 - Simulations: +0.0000 / +0.0019



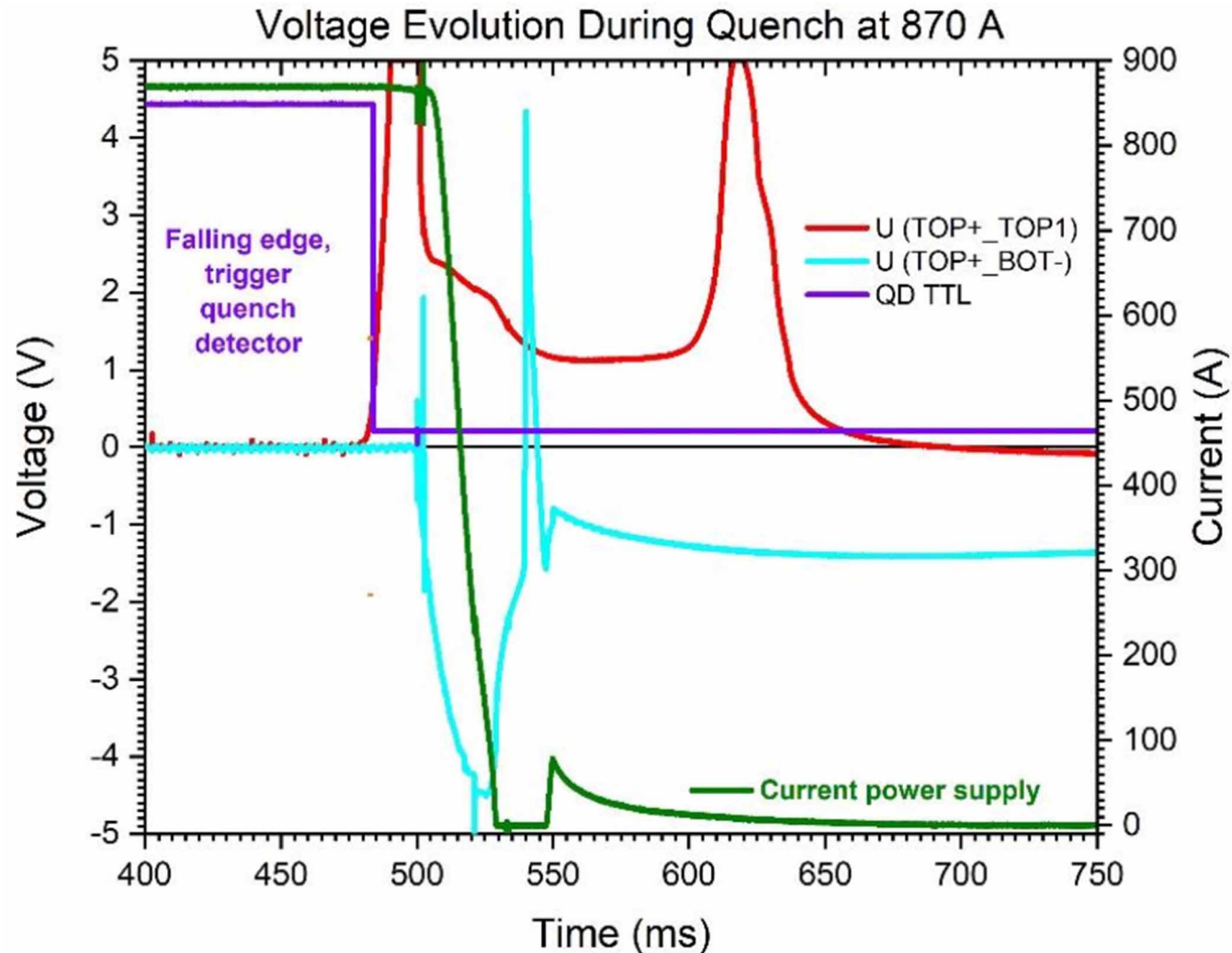
Quench and Impact on Closed Orbit

- Quenched once out of 18 beam dumps.



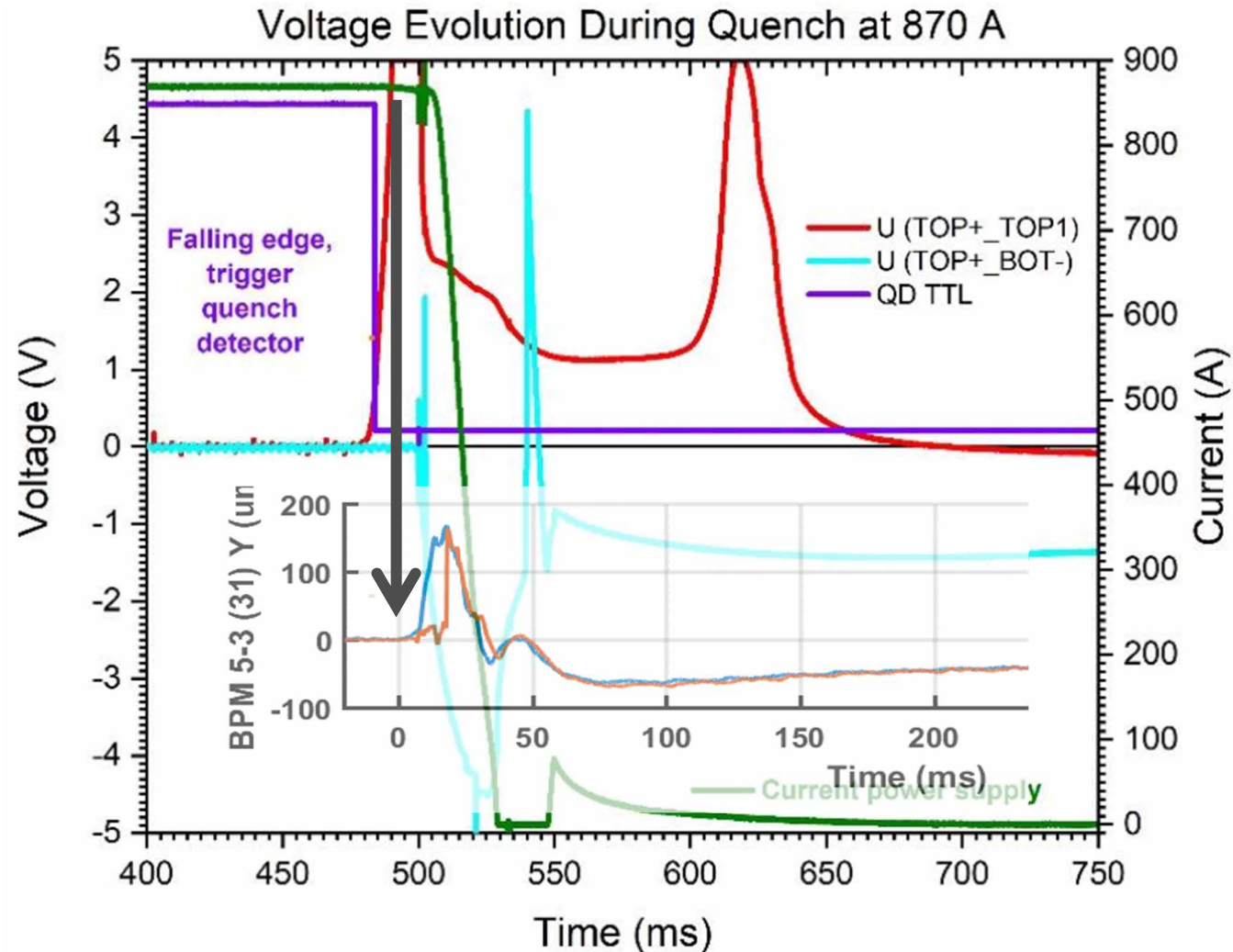
Implementing a controlled beam dump by kicking the beam and losing electrons in a non-SC straight.

Quench and Impact on Closed Orbit



Measurements at
CASPER 2
A. Grau

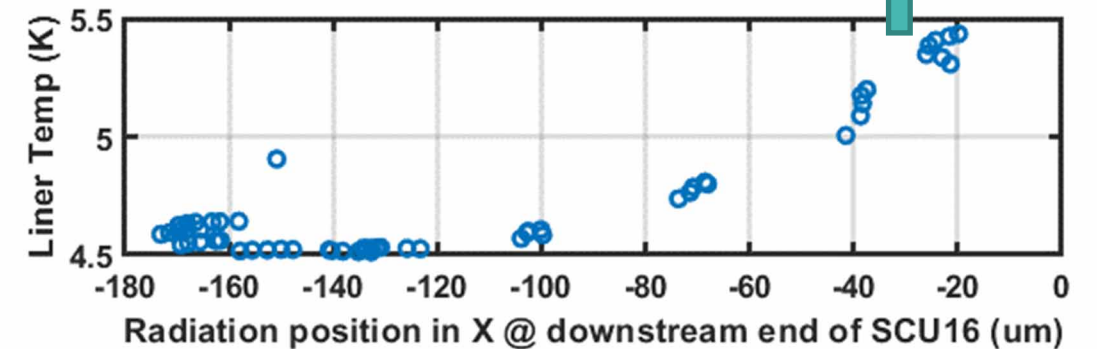
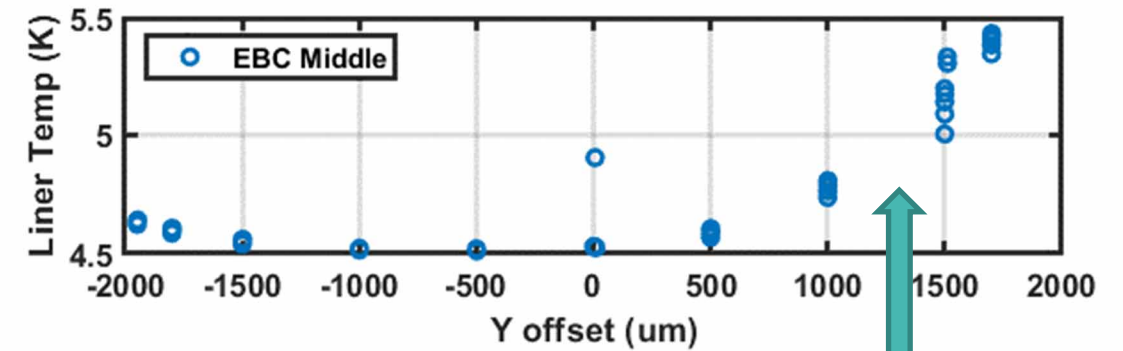
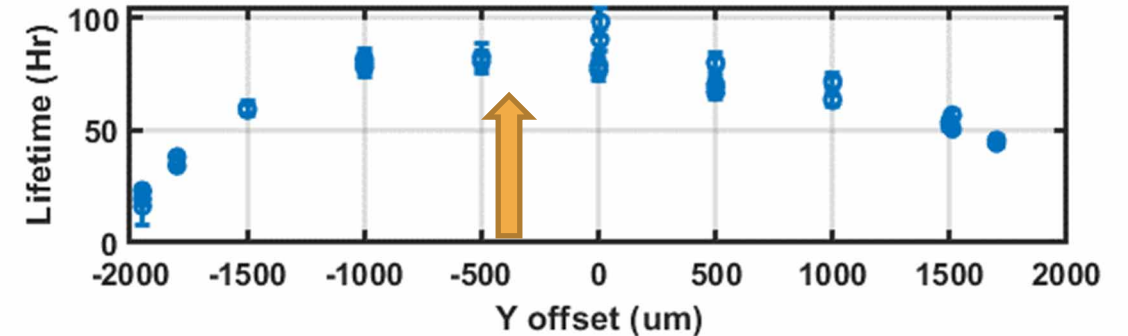
Quench and Impact on Closed Orbit



Measurements at
CASPER 2
A. Grau

SCU Vertical Centre

- Beamline was not ready.
- Vertical parallel bumps of the electron beam while measuring the lifetime.
 - Measured with sum signal from ~98 BPMs.
 - 2.5 mA single bunch.
 - Walls should be at ± 2.8 mm
- Upstream dipole radiation clipping edge of vacuum chamber.
- SCU vertical centre may be 400 μm too low.



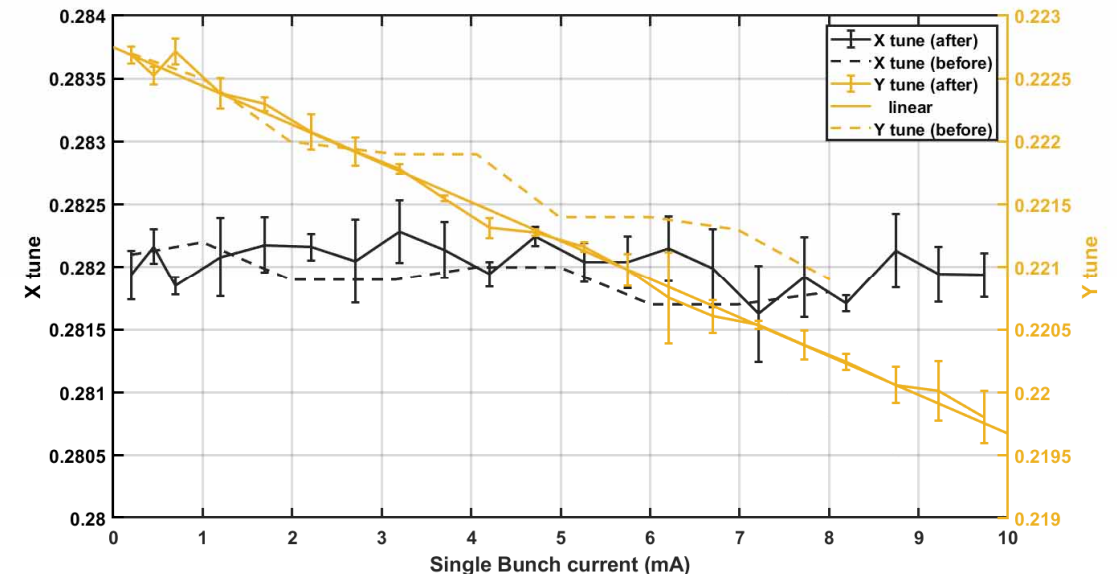
Narrow Gap Chamber

- Narrow gap impact on lifetime is hard to determine.
 - Estimates: 2% to 8%.
 - No impact on injection efficiencies.
- Transverse Impedance
 - Expect to increase vertical impedance by 5%.
 - Single bunch tune gradient
 - › Prev ν_y gradient: -0.211 A^{-1}
 - › Curr ν_y gradient: -0.308 A^{-1}
 - Growth rates: **Todo...**

Before
SCU

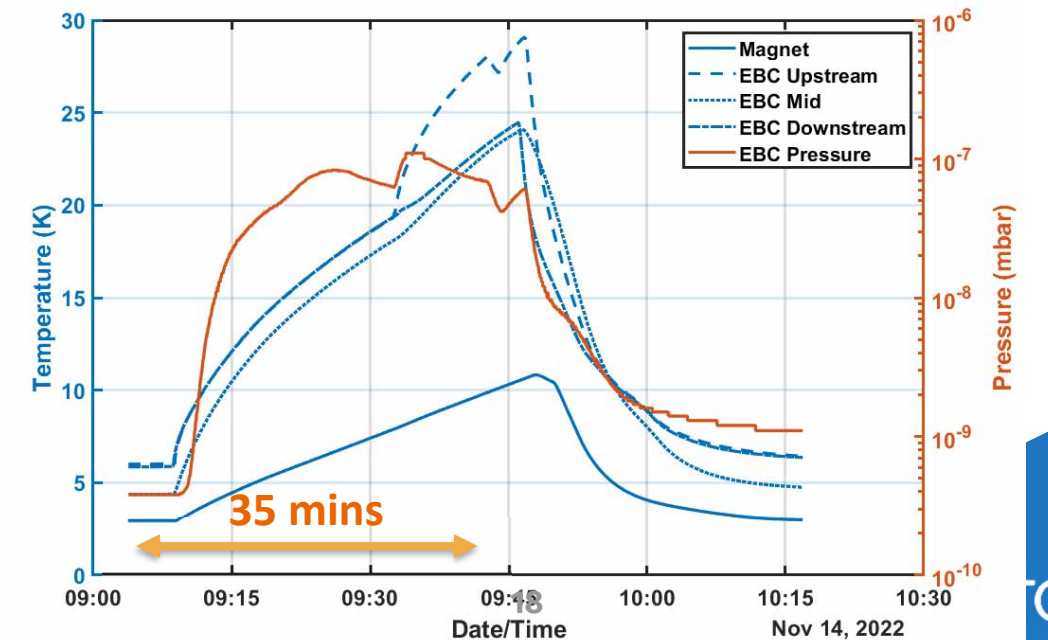
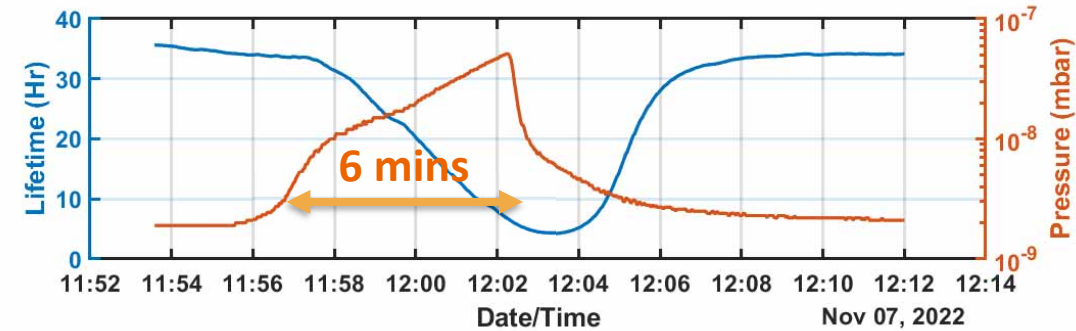
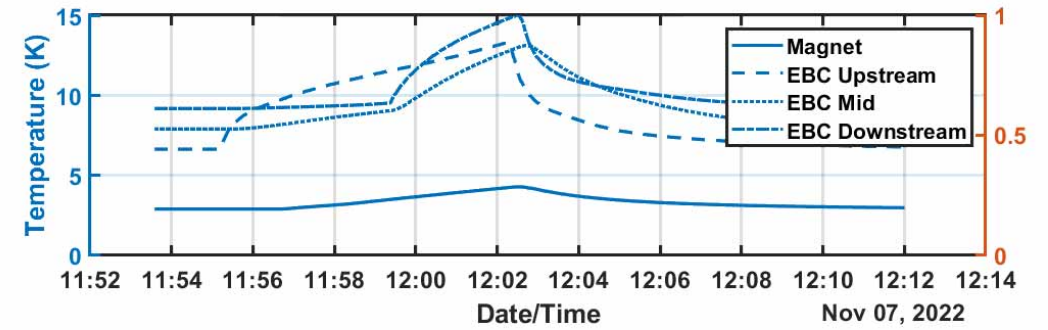


Lifetime	25.8 Hr	21.8 Hr	23.6 Hr	25.5 Hr
Current Lifetime	5.20 A Hr	4.38 A Hr	4.89 A Hr	5.01 A Hr
Lifetime ratio	100 %	84.5 %	91.5 %	98.8 %
EBC vac. (mbar)	4.5e-10	1.9e-8	4.7e-09	2.0e-09



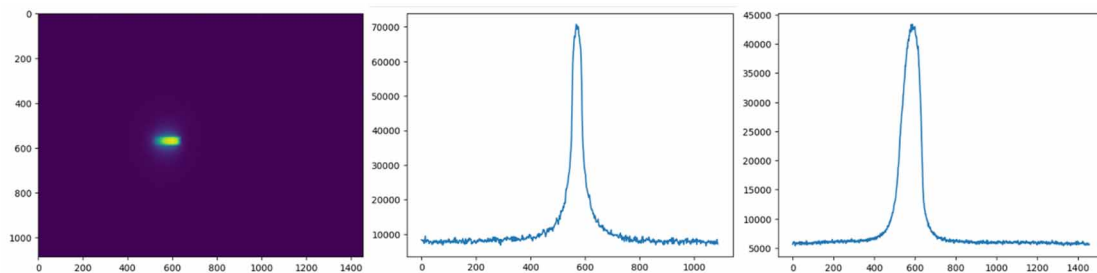
Narrow Gap Chamber

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



Photon Spectrum

- Phase error and impact on photon flux
 - SPECTRA → 10% reduction in flux at 5th harmonic with 10° RMS phase error.
 - Current measured field → 33% reduction (AUX coils likely not optimised)
- Beamline measured ~1e14 ph/s on sample with calibrated photodiode.
 - Flux after DMM with 1% BW (FWHM)



Christina
Kamma
Lorger

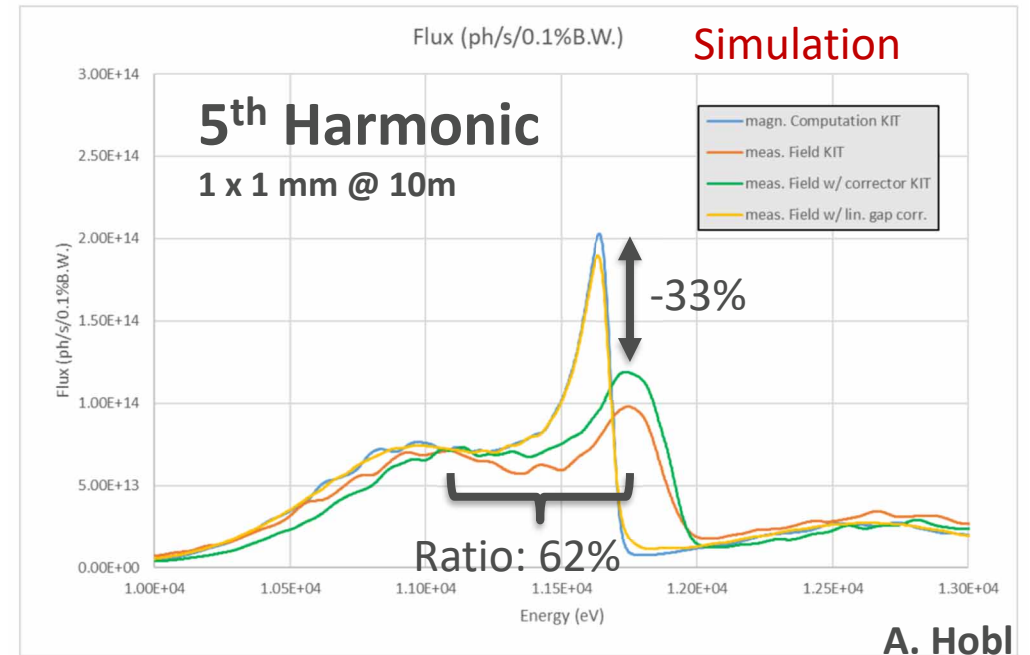
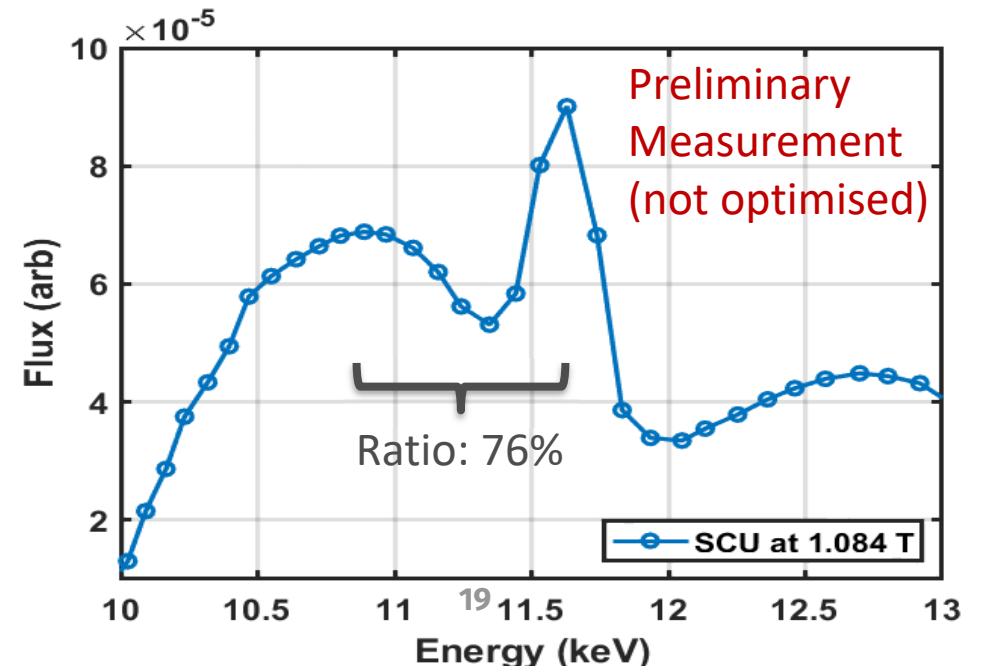
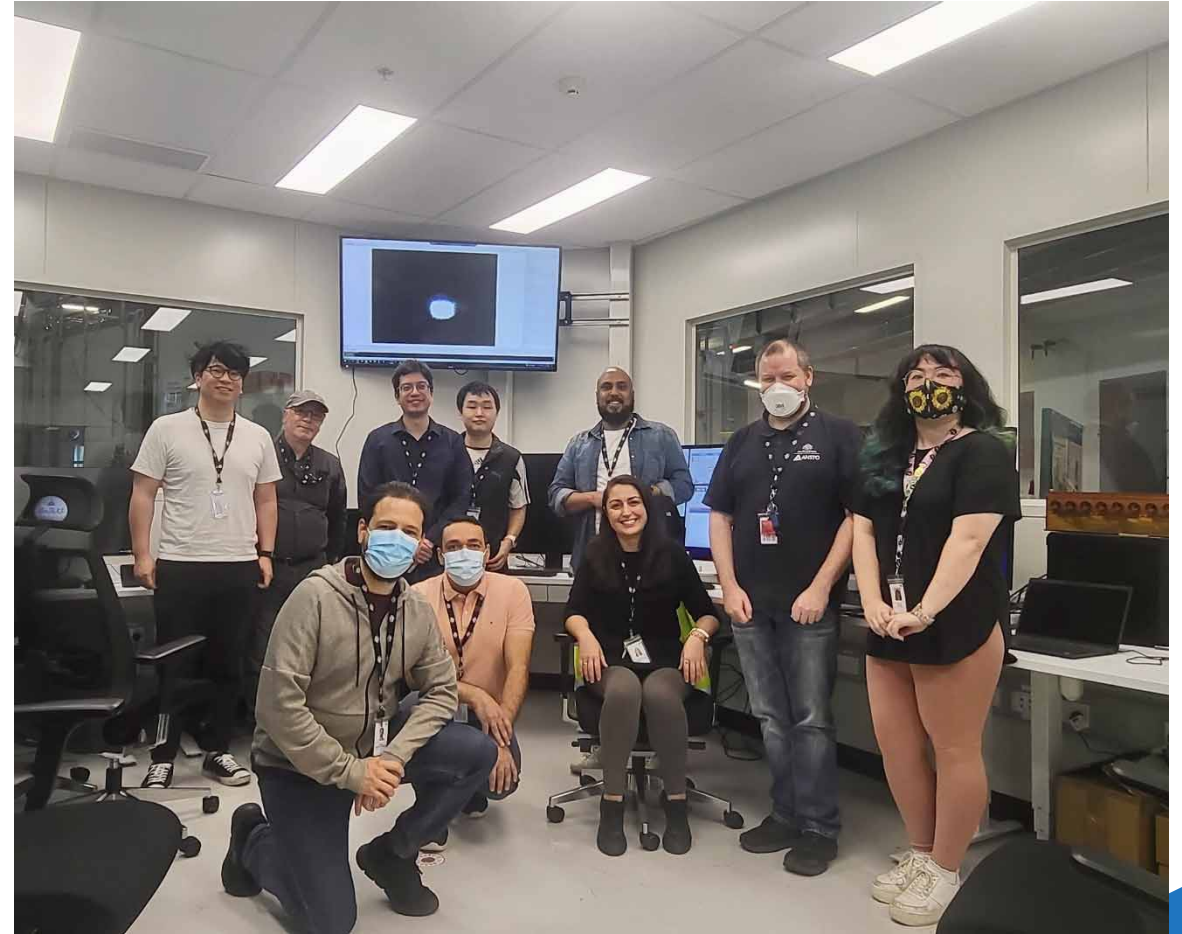
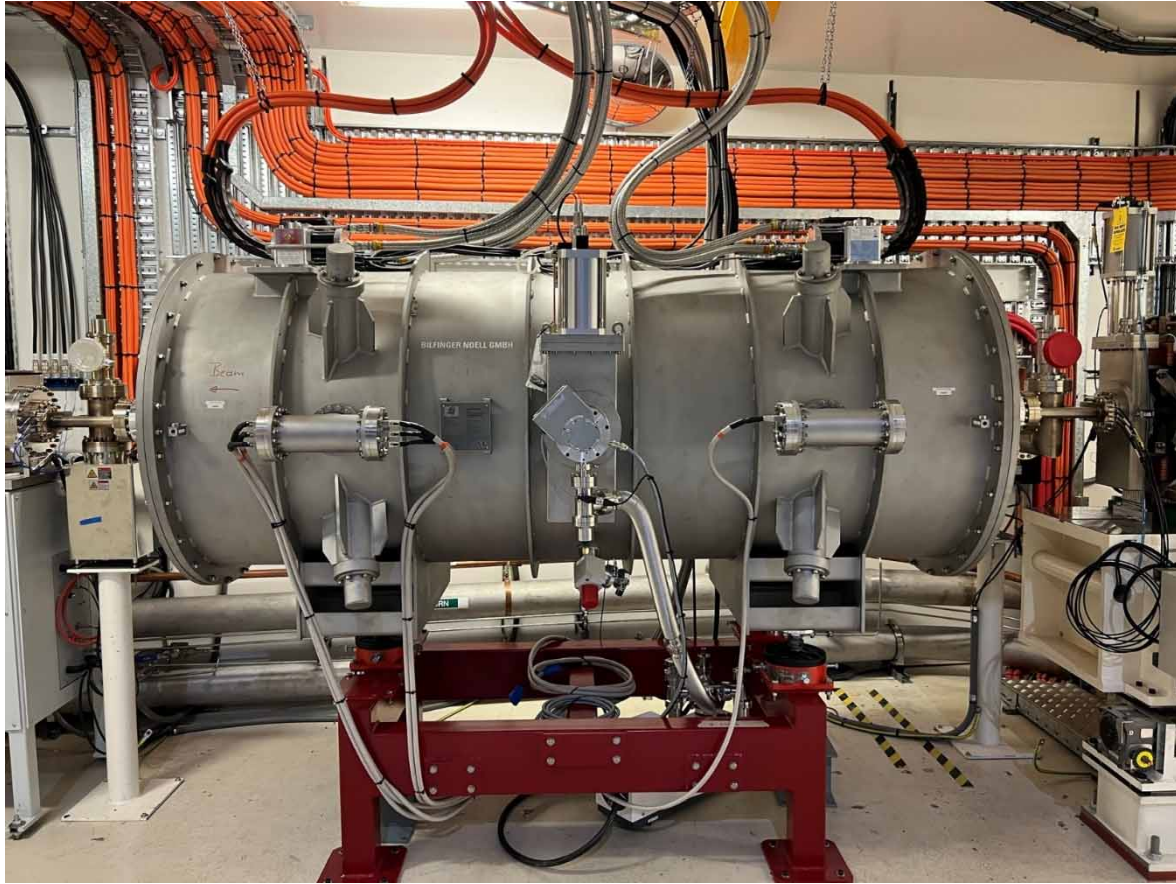


Figure 12: Photon flux computed from magnetic field (numerical and measured field), 5th harmonic.



Photos



Acknowledgements

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