Insertion Device Workshop 2026

Towards Cryogen-Free Superconducting Insertion Devices

13/05/2026

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Content

Solution

1. Improved and standardized **coil production** approach
2. Compact **Beam tube**
3. **Taper / bellow system** for beam interface
4. Modular **cooling technology**: cryocooler, current leads, thermal shield, beam tube cooling

Performance

1. Field and field quality, period length, gap, length of coil, length of module
2. UHV-compliant beam tube, simple operation, allows local and integral field measurement (e.g. with KIT-equipment)
3. Geometrical adaption to beam tube, external to cryostat with easy access
4. Simple and straightforward operation: cooling and magnetic field

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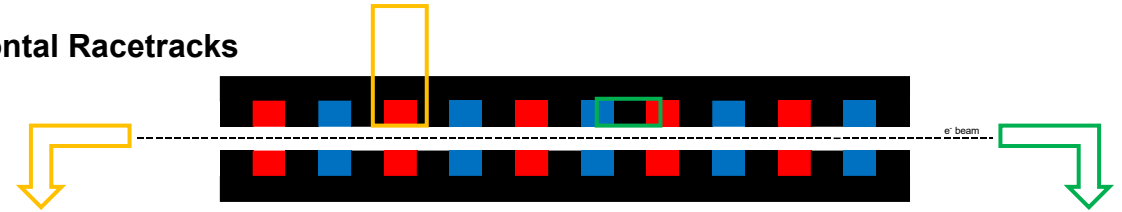
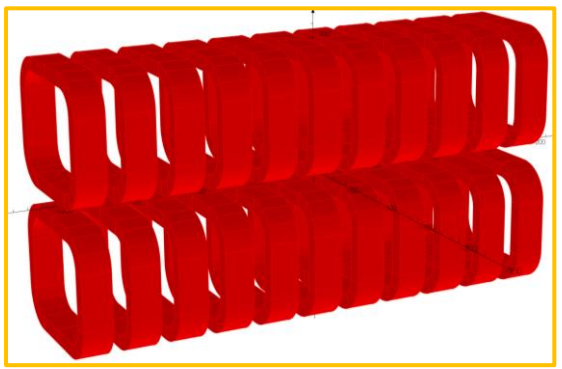
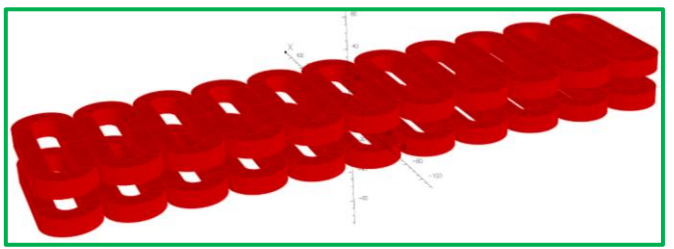
Introduction - Topology

Vertical vs. Horizontal Racetracks







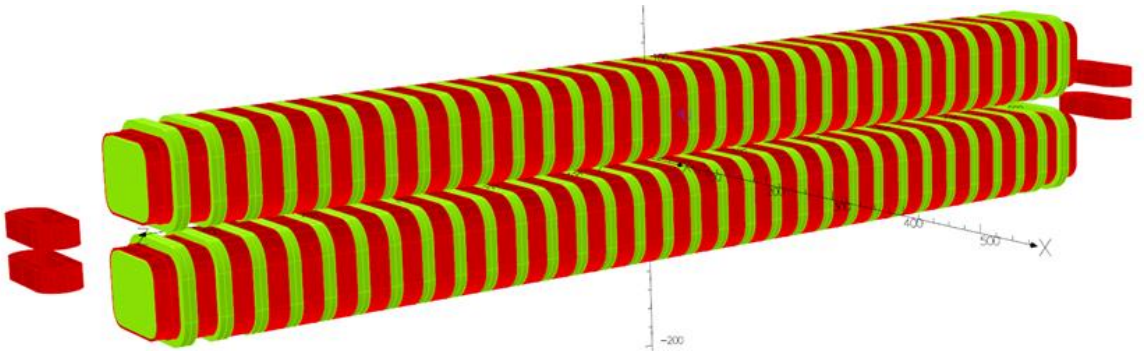
- Larger bending radius: lower peak field B_{max}
- Winding with one continuous wire – no splices
- First field integral zero for air coils

- Lower conductor amount
- Grading of coils possible

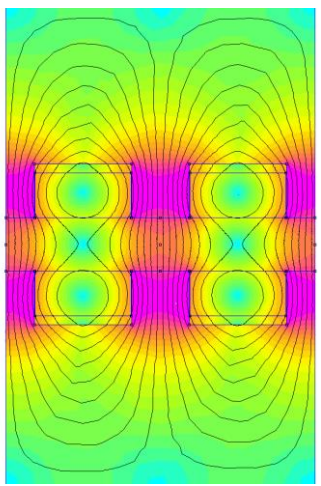
Introduction – from Specification to Design

Main Specifications (e.g. NSLS II wiggler)

- Period length: 70 mm
- Full field poles: 29 @ 4.34 T
- Electron beam aperture: 8 mm x 76 mm
- Ramping time: 30 minutes
- 1st field integral error: < 50 G*cm



2 D periodic



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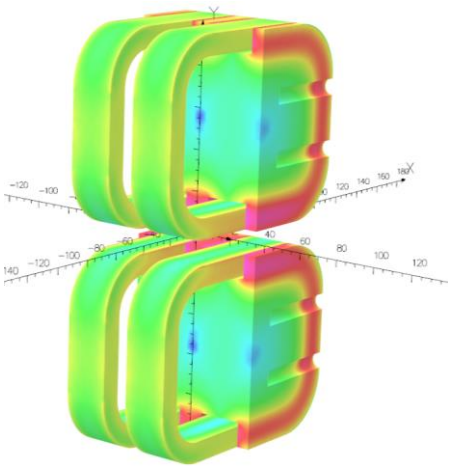


Full length

Coil Design & Manufacture: Solution

	SCU15	SCU20	HEX-SCW	ANSTO-SCU16	EuXFEL	FLUTE	DLS SCW	EuXFEL Mock-Up	ANSTO SCW	Units
Period length	15	20	70	16	18	65	48	18	48	mm
Full periods	100.5	74.5	29	98	108 * 2	20	22.5	14	40	#
Max field on axis (min. gap)	0.73	1.19	4.3	1.1	1.82	0.88	4.2	2.02	4.6	T
K-Value (approx.)	1.0	2.2	28.1	1.6	3.1	5.3	18.8	3.4	20.6	
Location	KARA, KIT	KARA, KIT	NSLS II, BNL, US	Australian Synchrotron ANSTO AUS	EuXFEL, DE	KIT DE	DLS UK	EuXFEL, DE	Australian Synchrotron ANSTO AUS	
Status	delivered 2014	delivered 2017	delivered 2022	delivered 2022	cold tested	delivered 2025	delivered 2025	cold tested	delivered 2025	
Beam Stay Clear	7 (15)	7 (15)	8	6	5	35	8	5	6	mm

various coil concepts

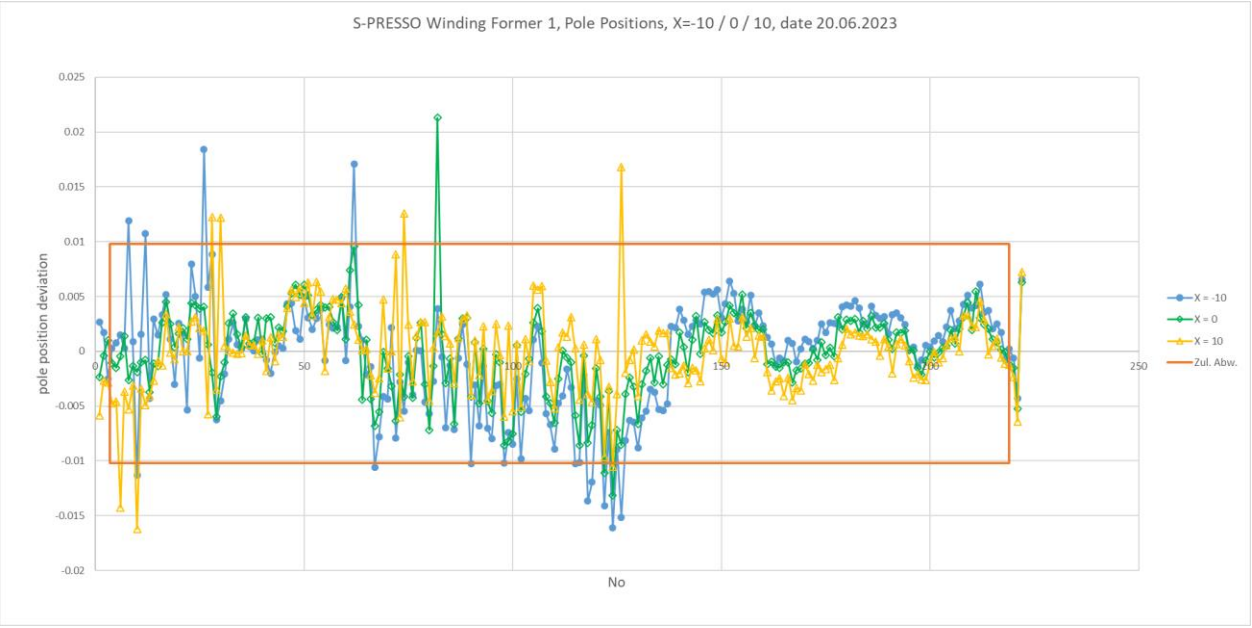
modified coil concept

- Winding former >2 m length in one piece
- Winding former machining with higher precision
- Improved impregnation process: Separation from support and mould allows easier un-molding
- Improved and stiffened coil support structure within cold mass
- Modular instrumentation: sensors mounting, thermal intercepts

Coil Design & Manufacture: Performance

S-PRESSO: Measurements on winding former before winding

- All pole, groove geometries StdDev in the order of 5 µm
- Pole position over 2 m variation StdDev in the order of 5 µm
  → no systematical position errors!

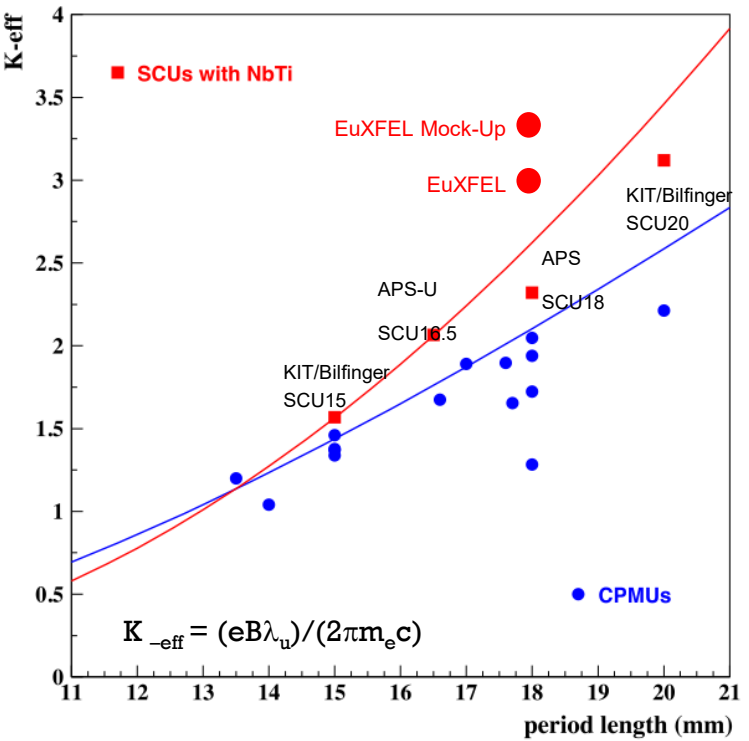


Coil Design & Manufacture: Performance

Main Specifications Magnet

- Period length: 18 mm, 2 m long SCU coils (221 winding grooves)
- Magnetic field: 1.82 T
- Electron beam aperture: 5 mm x 10 mm
- Ramping time: 1000 s
- 1st field integral error: < 4 mT*mm (~10 cm B_{earth})
- Delta K/2 / K/2: <0.0015 rms → typical tolerances of 20 µm

Exceptionally high field reached on EuXFEL Mock-Up



Source used:

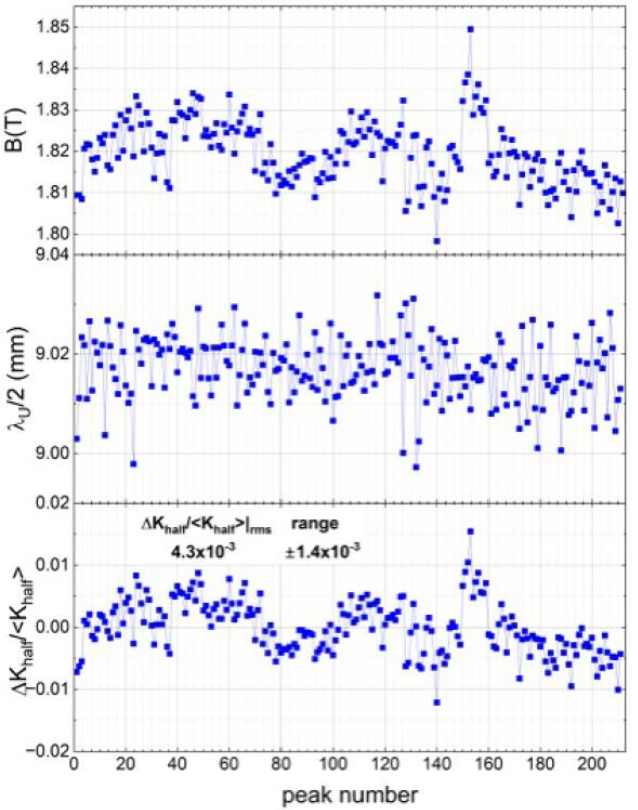
J. Bahrdt and E. Gluskin

https://doi.org/10.1016/j.nima.2018.03.069

Coil Design & Manufacture: Performance

S-PRESSO: Magnetic Measurements performed by EuXFEL

- Measurements performed on first 2 m long cold mass
- Measurements on second 2 m long cold mass under way
- Half period length variation in the order of 20 µm
- Peak field variation in the order of 0.02 T in 1.8 T
- $\Delta K/K$ about $4.5*10^{-3}$ rms at nominal current

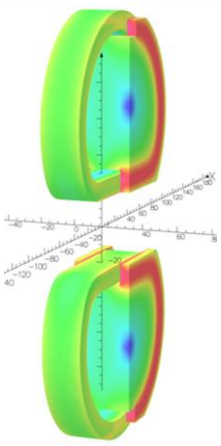


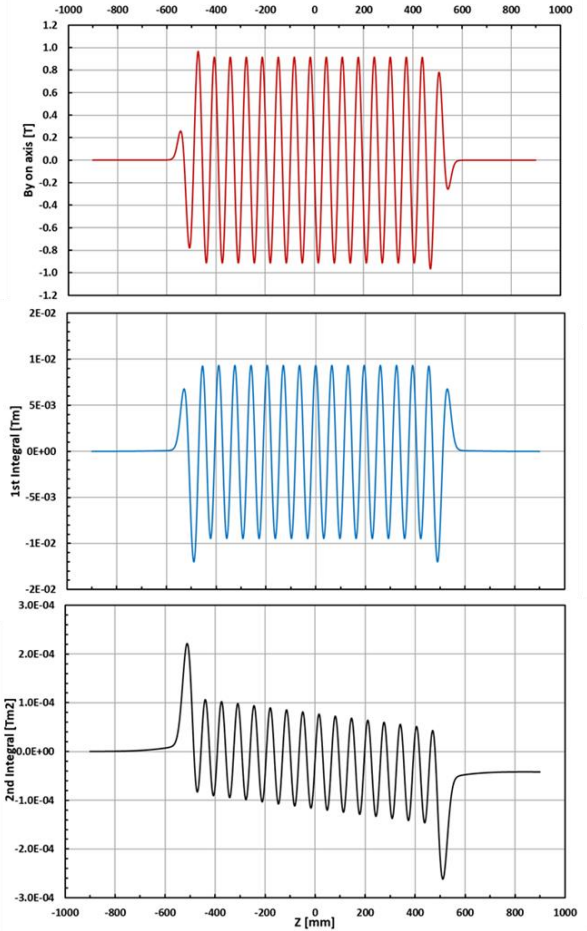
(S. Casalbuoni et al., (IPAC'26), MOP7124)

Coil Design & Manufacture: Performance

FLUTE SCU – KIT

- Magnetic field: 0.88 T on axis
- Period length: 65 mm
- 1.2 m long SCU coils (35 winding grooves)
- Large electron beam aperture: Ø 35 mm
- Phase error <2°





Computed

Magnetic Measurements @ KIT

- Local or
- Integral

- In CASPER or
- On finished device

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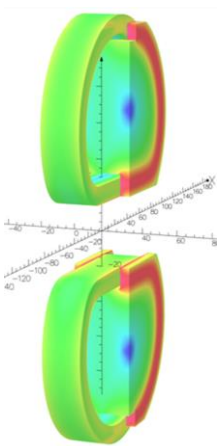

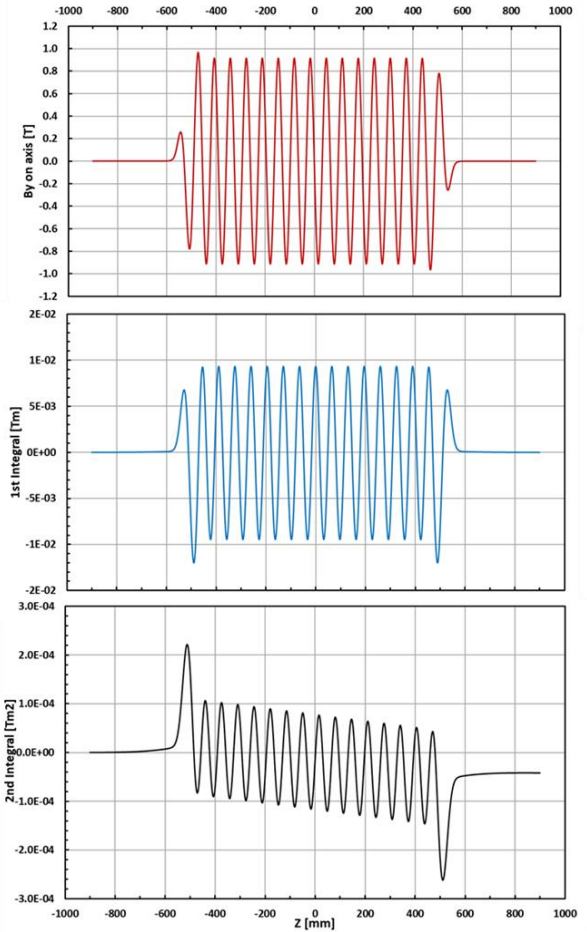

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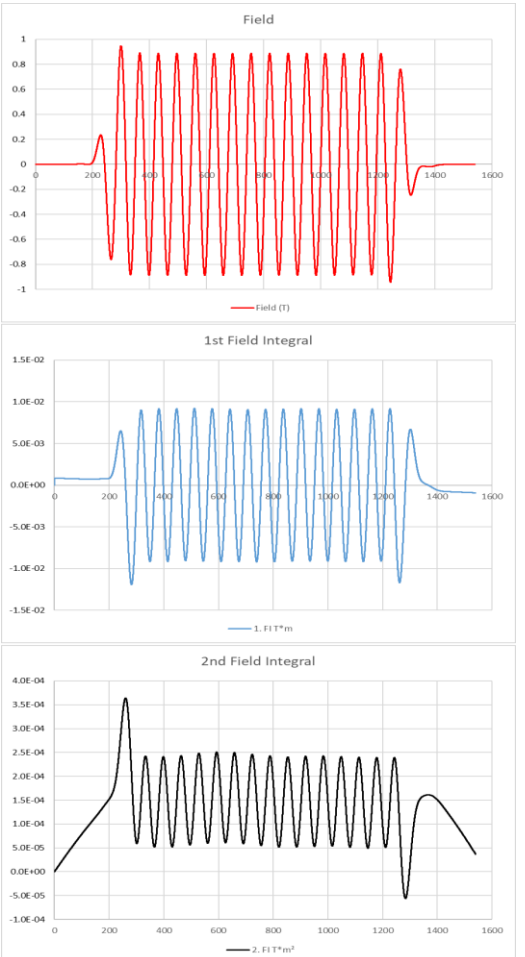

Measured by IBPT, KIT

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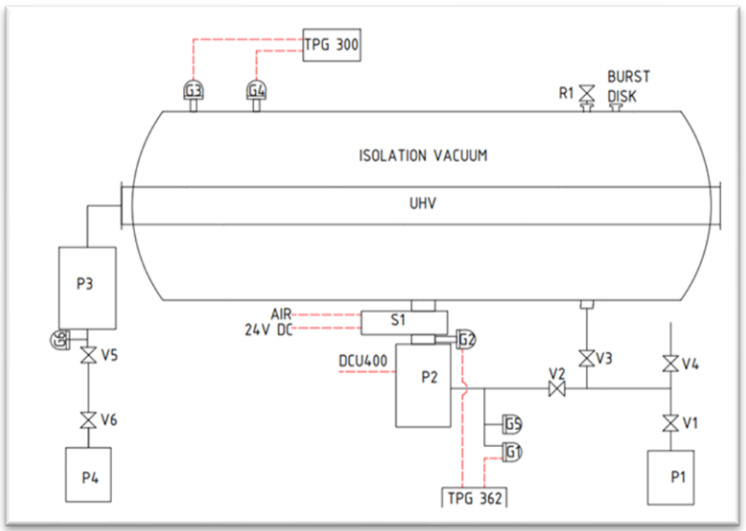
Vacuum: Solution

Typical Vacuum System (insulation vacuum and UHV beam vacuum)

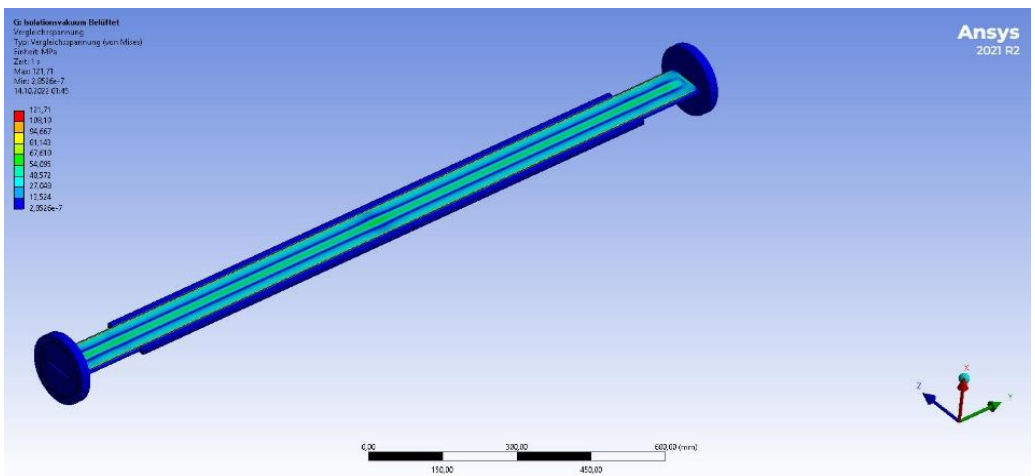
- >100 l/s TMP on insulation vacuum: off at cold
- EBC vacuum dominated by cryopumping
- Mechanical analysis on EBC, stresses, deformation under operation and failure scenarios



Aperture 65 mm x 6.5 mm

for magnetic gap 8.5 mm

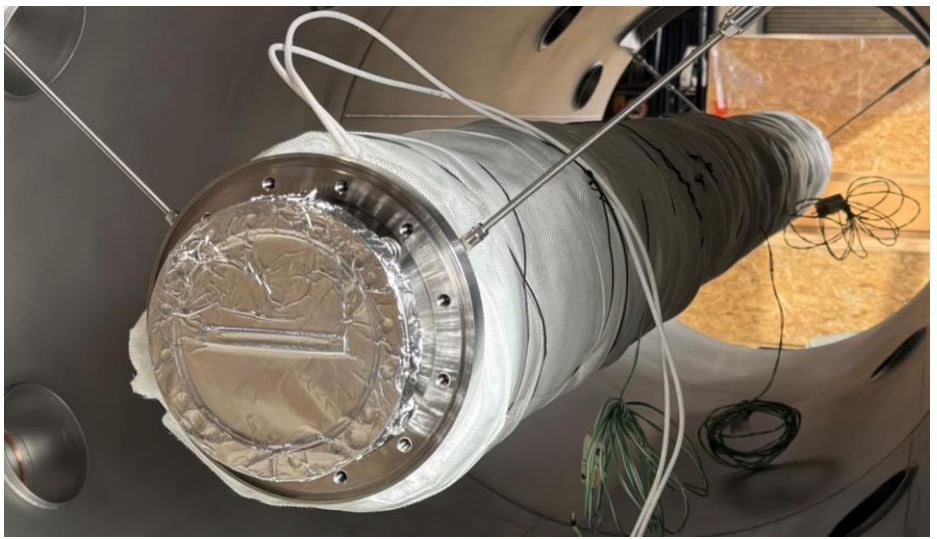
Length 2500 mm

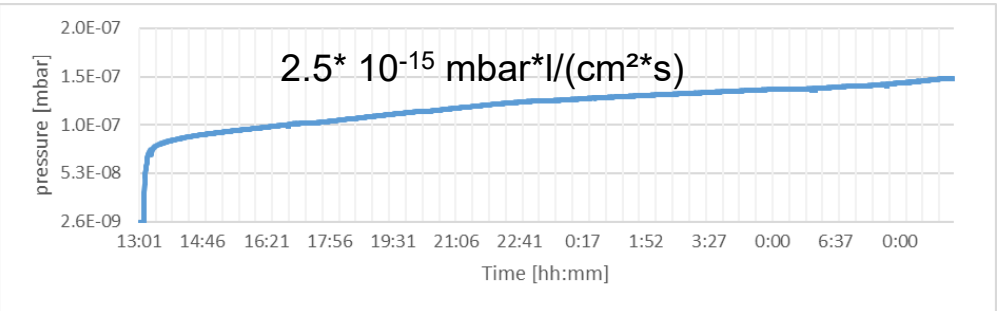


Vacuum: Performance

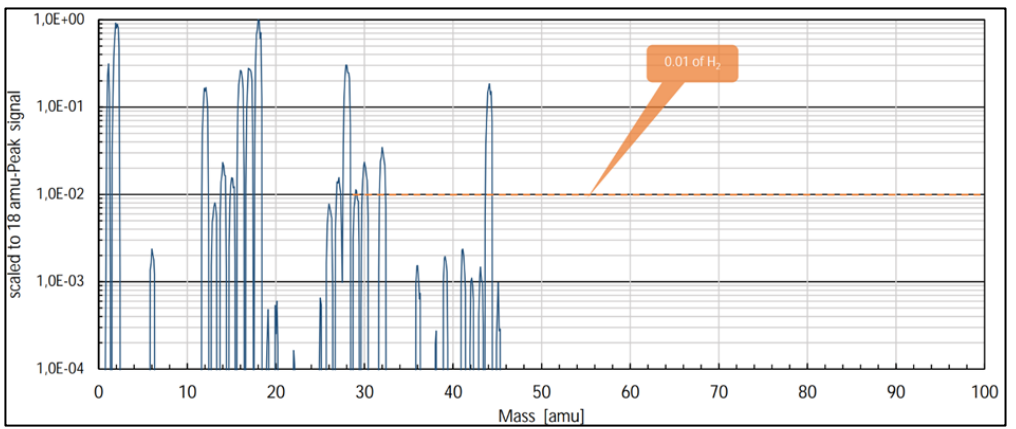
UHV component: EBC

- Manufacturing
- Copper plating inside and outside
- Pressure & leak testing
- UHV conditioning





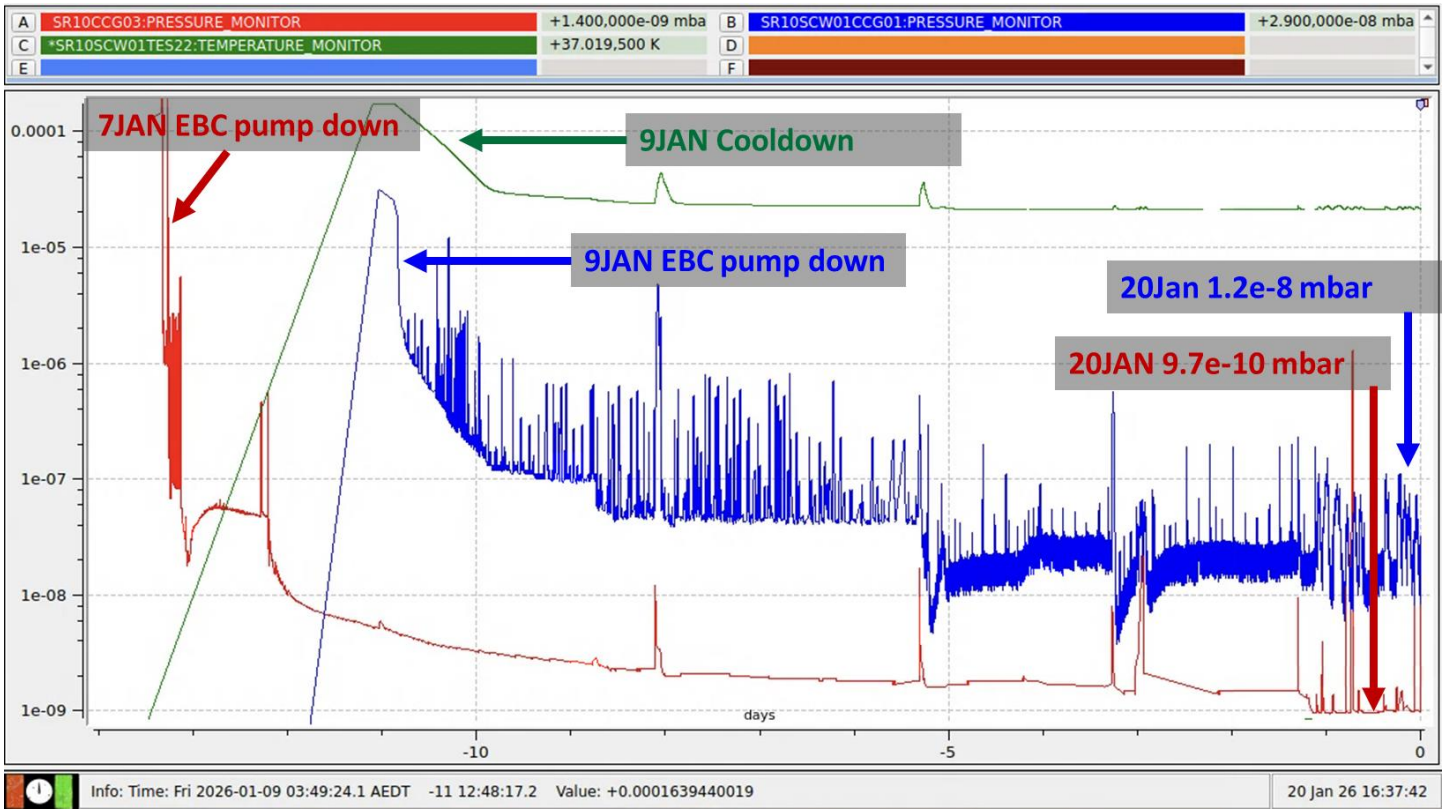
Pressure increase measurement ↑ and RGA ↓



Vacuum: Performance

Evacuation @ ANSTO

- System cool down within 6 days
- EBC vacuum <1e-9 mbar
- Cryostat vacuum <1e-7 mbar



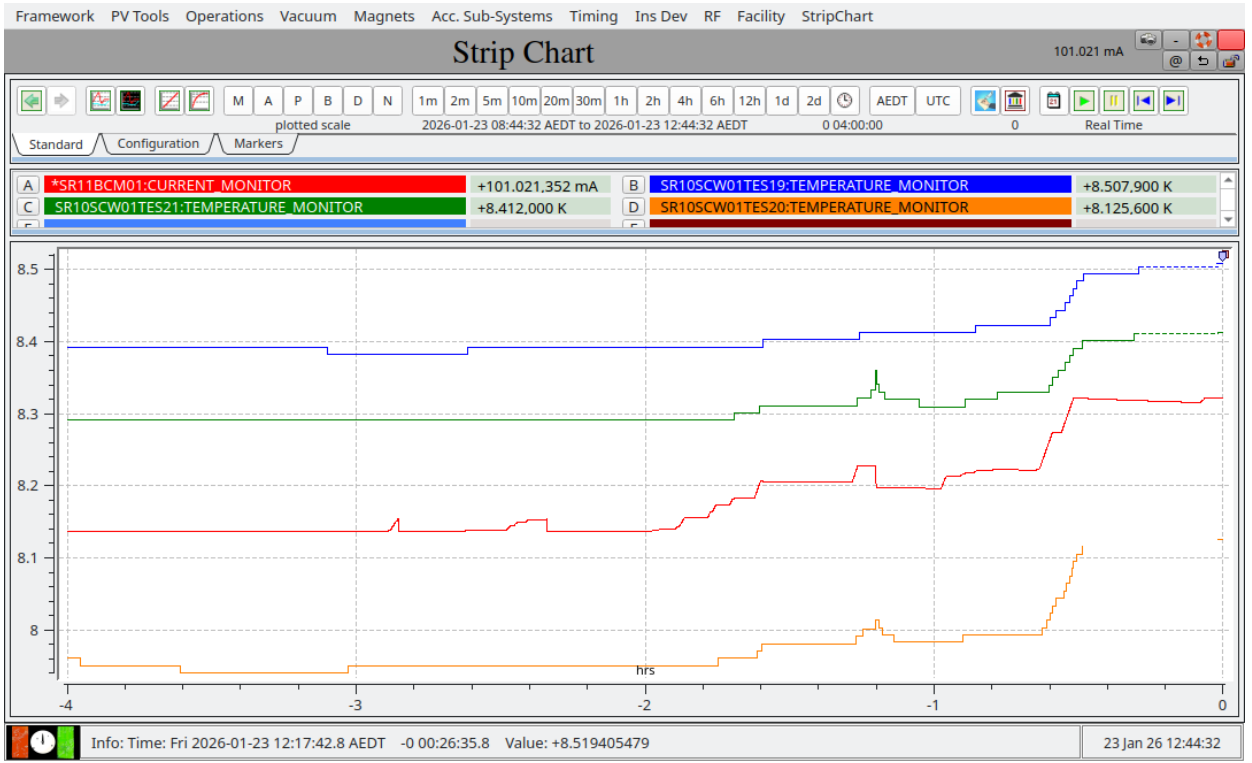
Courtesy of Eugene Tan (Australian Synchrotron)

Vacuum: Performance

Measurements @ ANSTO

- EBC temperature rises are very small
- Beam heating and synchrotron radiation are not heating the chamber

EBC Sensor Location	\delta T @ 145 mA (K)
Upstream	0.224
Middle	0.345
Down	0.249



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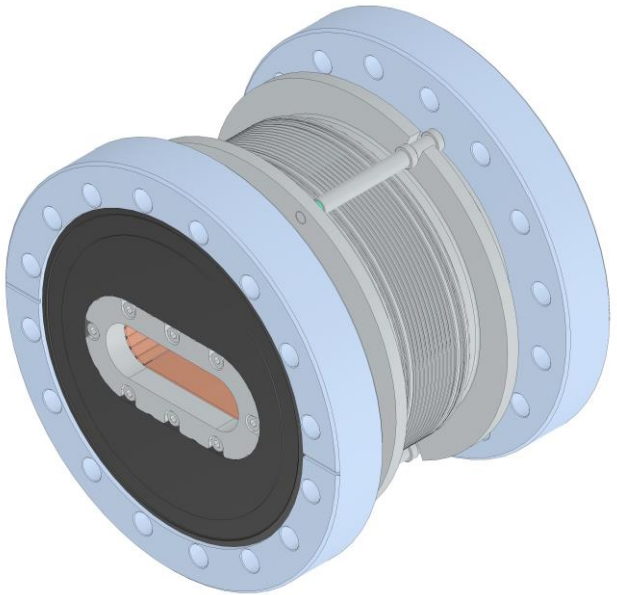
Taper / Bellow System

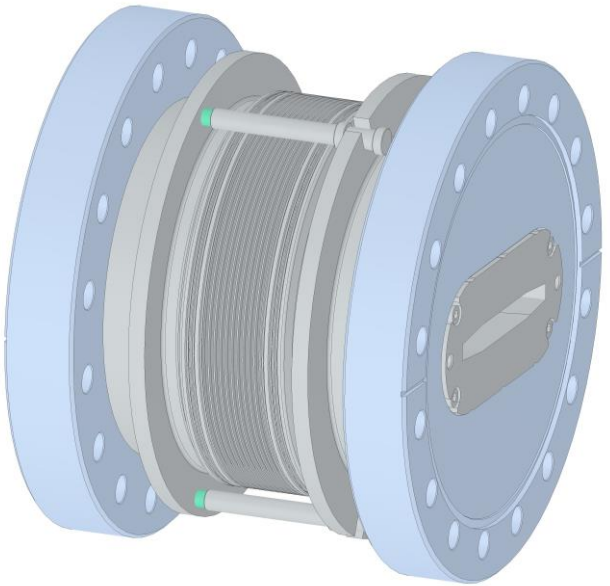
Taper / Bellow System: Solution

- Smooth geometrical transition in EBC profile
- Axial length compensation



Taper / Bellow System: Performance

- UHV compatible
- Easy access outside the cryostat
- Can be used to match the ID total length



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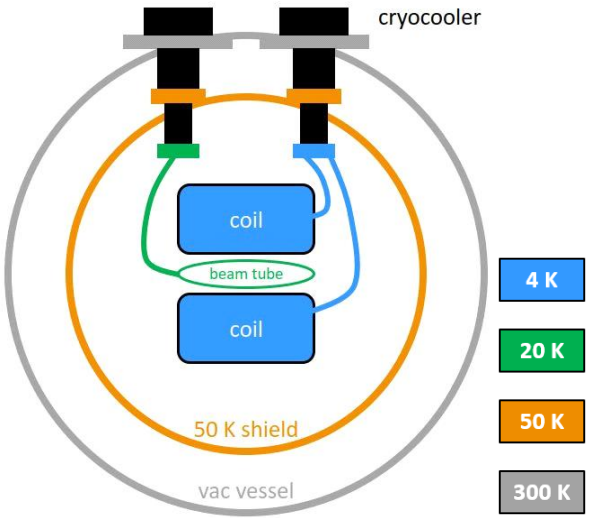
Cryogenics: Solution

Cooling system: Conduction cooling

- E.g. 2 coolers for coil and current leads
- E.g. 2 coolers for electron beam chamber
- Dry system, cooling by heat conduction
- No cryogens, no quench gas or blow off



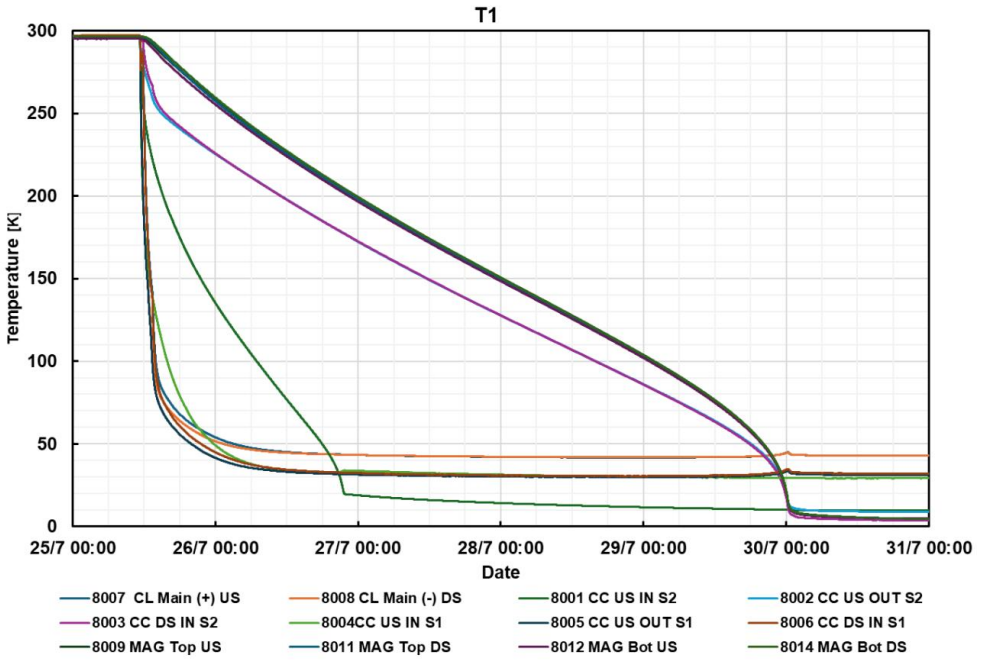
	4.2 K	20 K	50 K
Total heat load	**0.975 W**	**22 W**	**75.9 (52.4) W**
Available cooling power (60Hz)	**2 x 2.0 W** **4 W**	**2 x 20 W** **40 W**	**2 x 45 W + 2 x 50 W** **190 W**

Pulse tube coolers can offer servicing without warm-up at the cost of higher power demand (and higher price)

Cryogenics: Performance

FLUTE Undulator

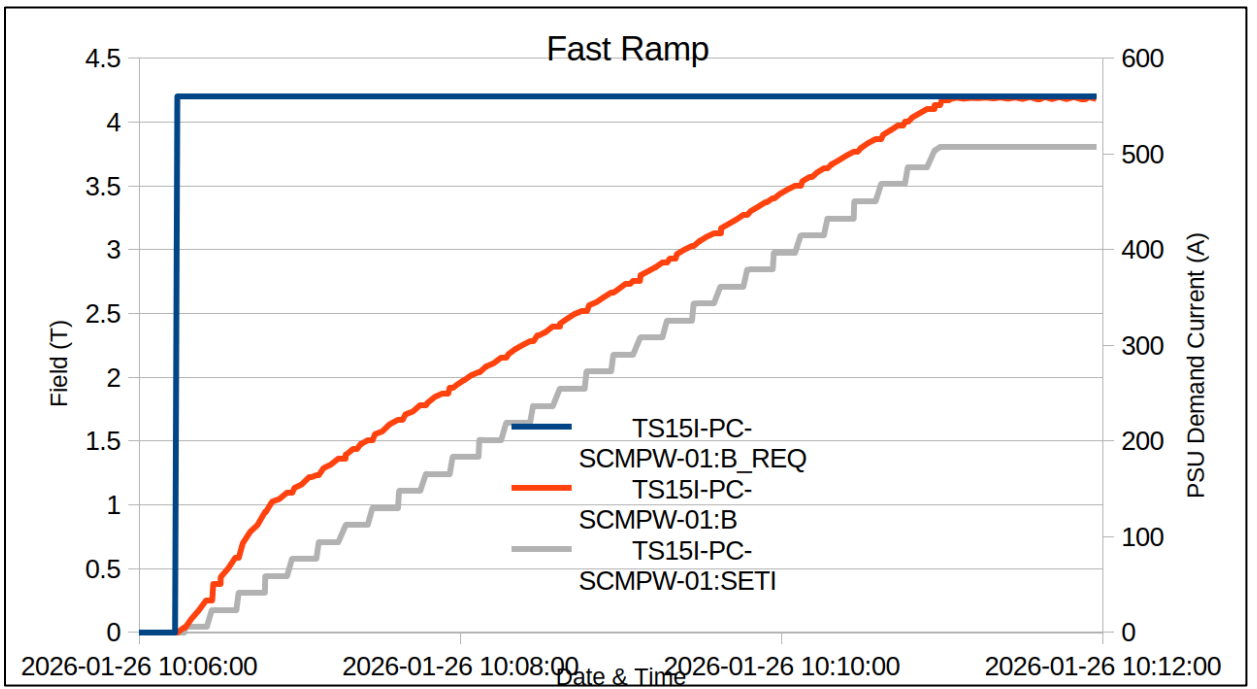
- 3 cryocoolers only
- Cool down within 5 days



System: Performance

Current Ramping Curve of Diamond SCW

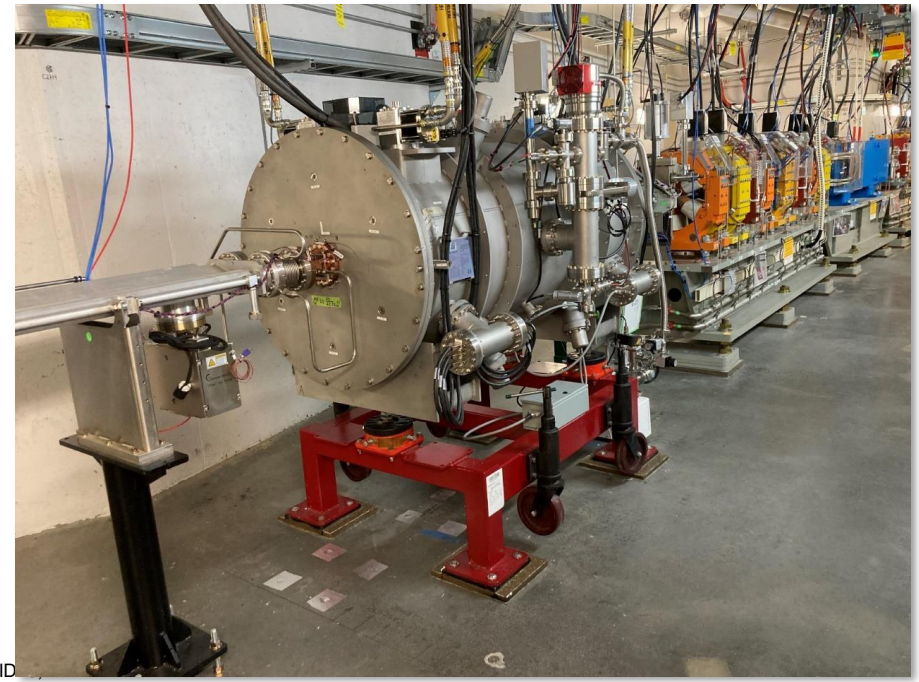
- Ramping time 5 minutes to nominal field



System: Performance

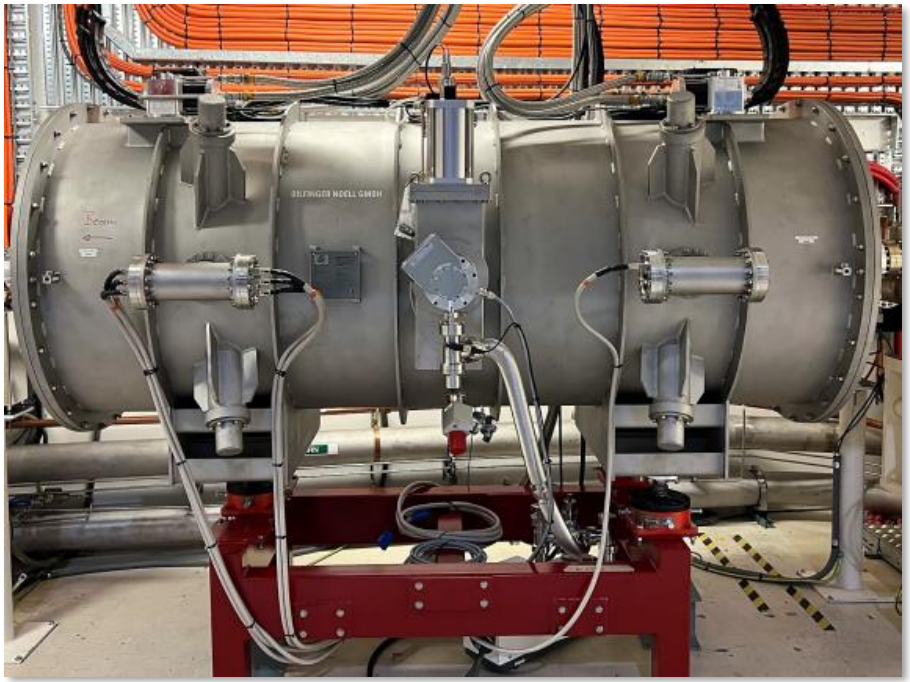
HEX-SCW @ NSLS II

70 mm, 4.34 T, 8 mm BSC



SCU 16 @ ANSTO

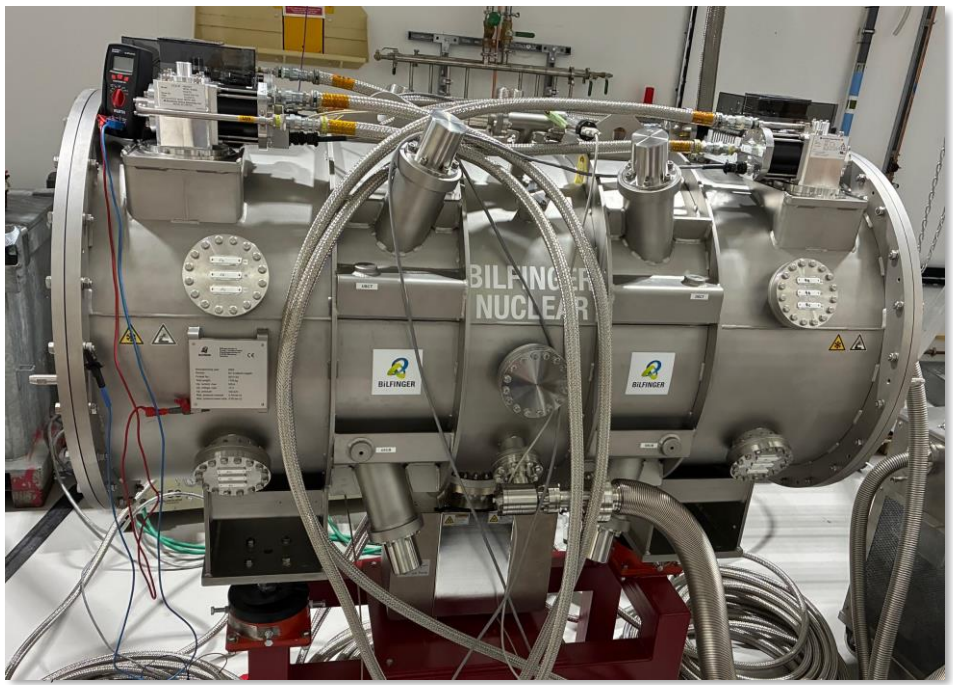
16 mm, 1.08 T, 6 mm BSC



System: Performance

SCW @ DLS

48 mm, 4.2 T, 8 mm BSC



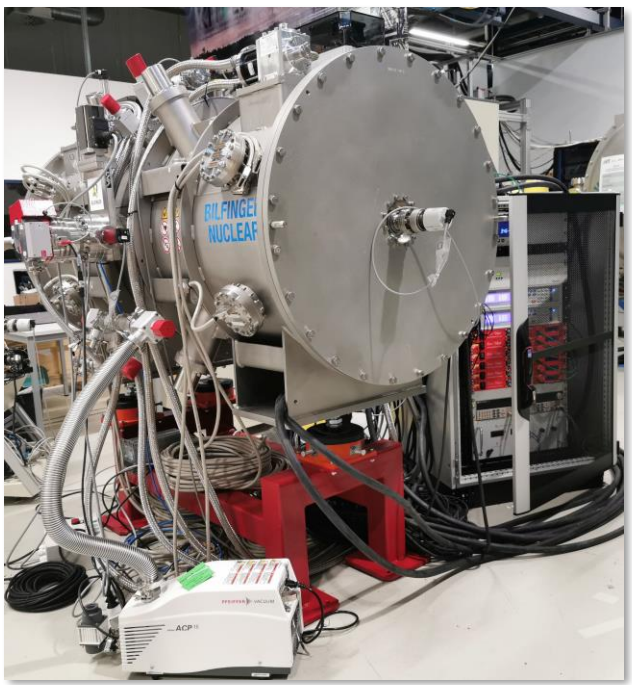
SCW @ ANSTO

48 mm, 4.6 T, 6 mm BSC

System: Performance

FLUTE @ KIT

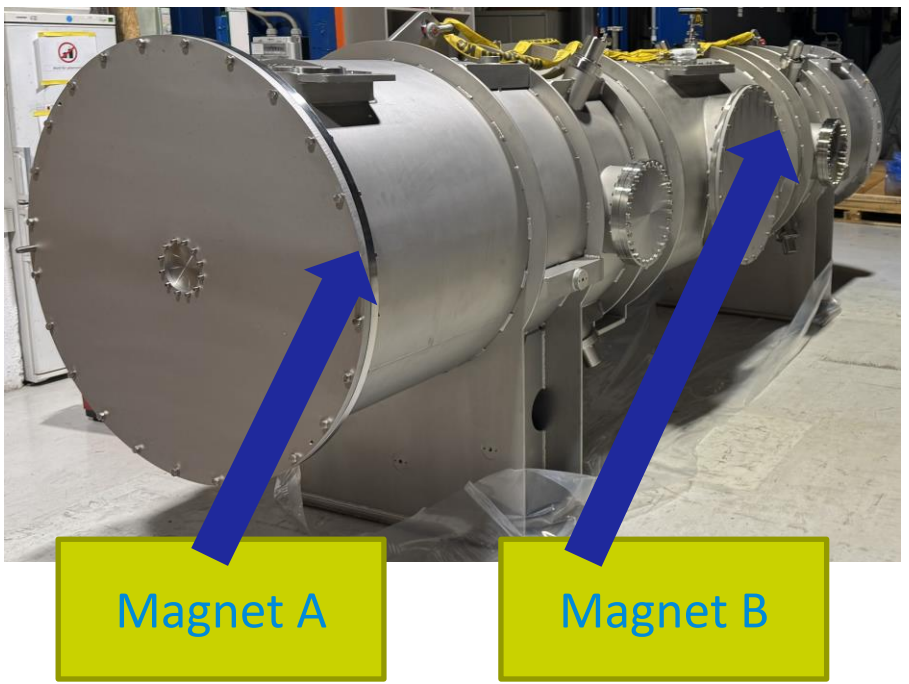
65 mm, 0.88 T, 35 mm BSC



S-PRESSO @ EuXFEL

(not yet completed)

18 mm, 1.82 T, 5 mm BSC



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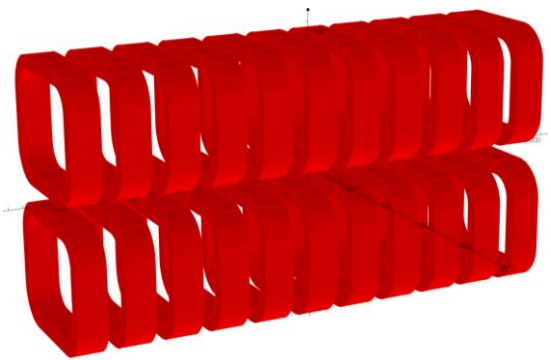
Summary & Outlook

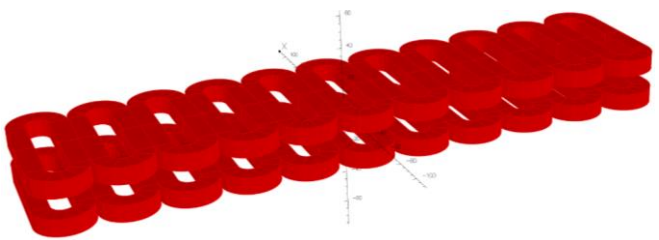
All SCID technologies used in light source magnets available and successfully demonstrated

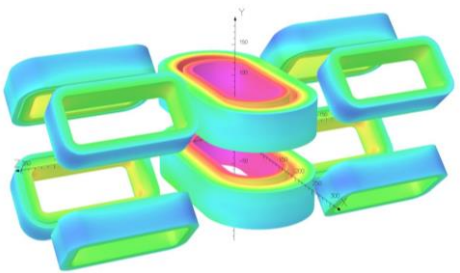
- High magnetic field
- Consistent field quality
- UHV-compatible operation for EBC and taper/bellows
- Operation is straightforward with simple “push button” control

This builds the modular platform for reliable and user-friendly

- Undulators
- Wigglers
- Wave length shifters
- Superbends
- Combined function magnets
- Phase shifters







Many thanks to colleagues and friends at KIT, EuXFEL, BNL, ANSTO, Diamond and to the Bilfinger Team