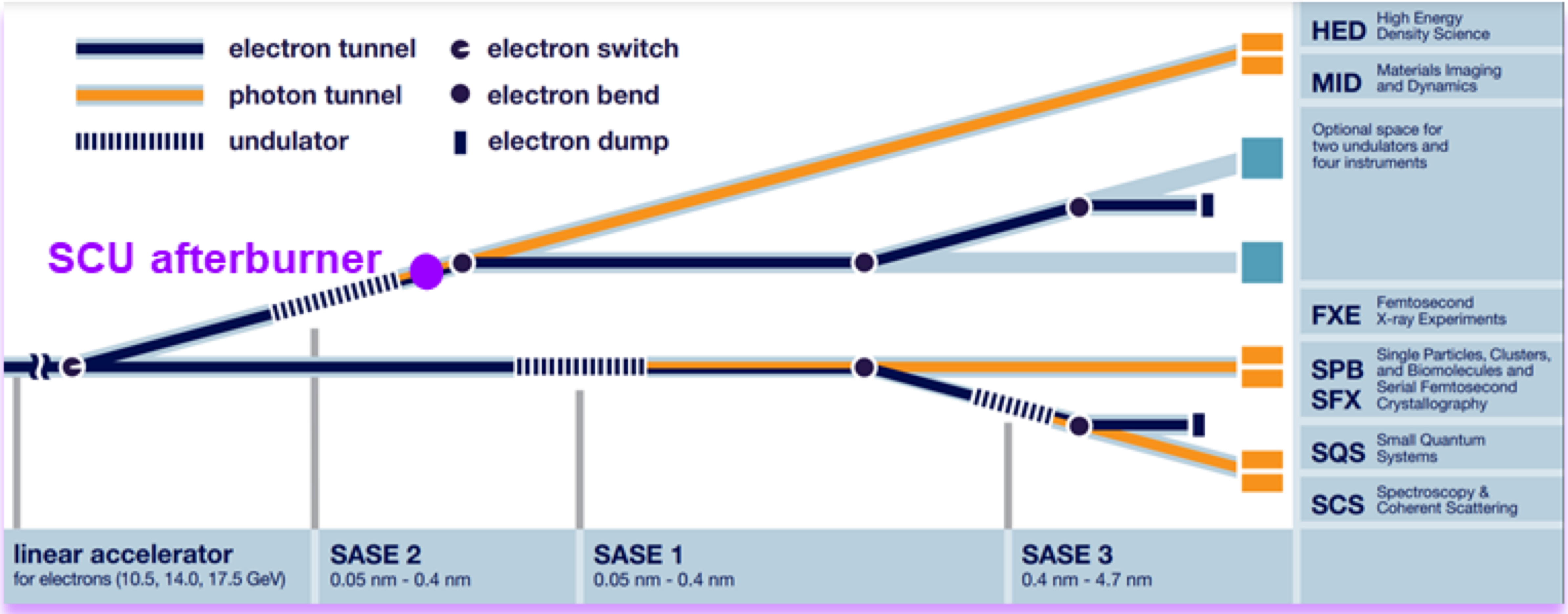
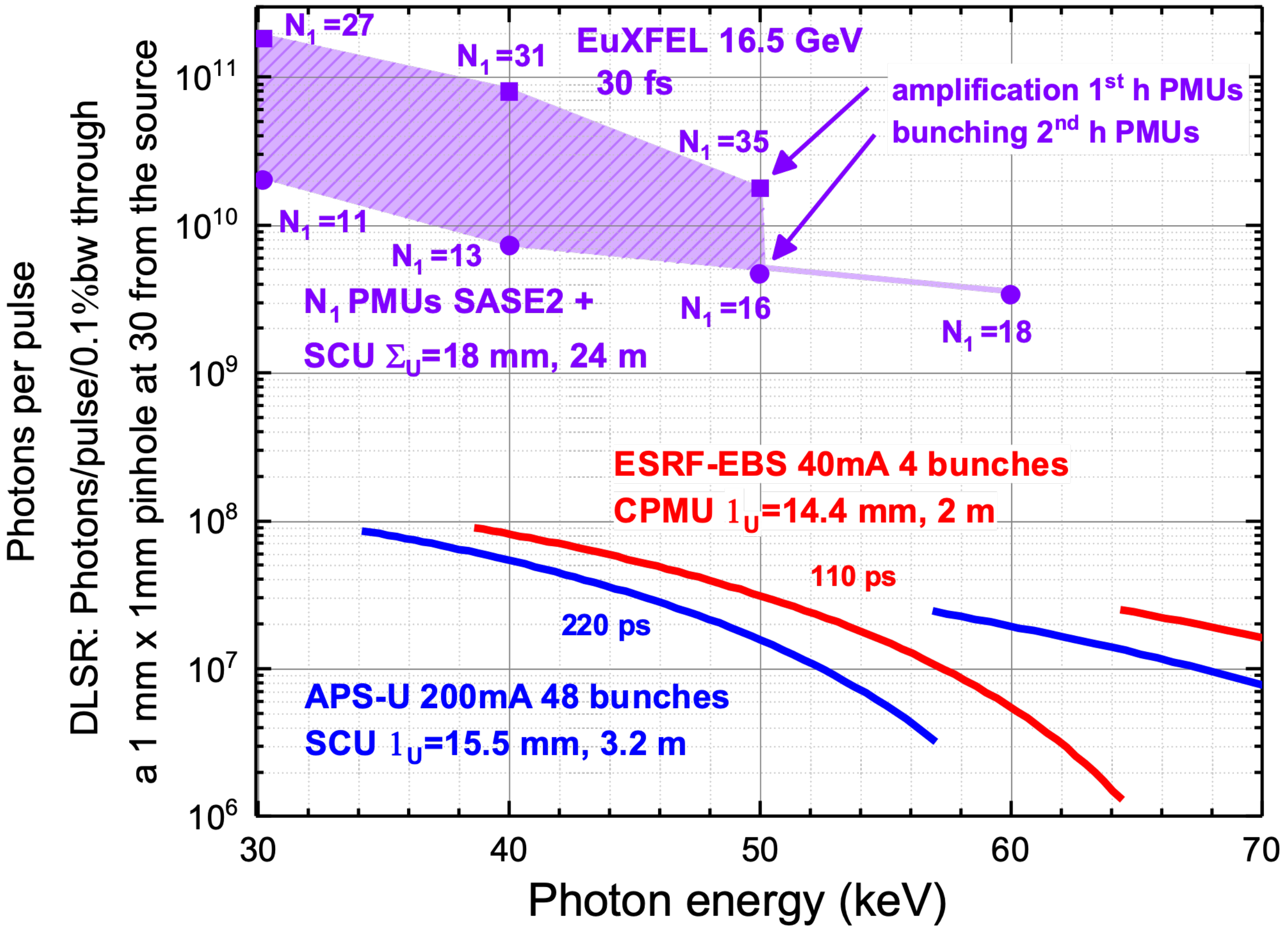
Superconducting undulator afterburner project planned at EuXFEL

Sara Casalbuoni and Mikhail Yakopov
European XFEL

26 January 2023


electron tunnel
photon tunnel
undulator
electron switch
electron bend
electron dump
SCU afterburner
HED High Energy Density Science
MID Materials Imaging and Dynamics
Optional space for two undulators and four instruments
FXE Femtosecond X-ray Experiments
SPB SFX Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography
SQS Small Quantum Systems
SCS Spectroscopy & Coherent Scattering
linear accelerator
for electrons (10.5, 14.0, 17.5 GeV)
SASE 2
0.05 nm - 0.4 nm
SASE 1
0.05 nm - 0.4 nm
SASE 3
0.4 nm - 4.7 nm

Motivation



S. Casalbuoni et al., SRI2021

- Higher peak field on axis for the same gap and period length in operation
- SCUs have 3 times larger K with respect to PMUs for the same period and vacuum gap
- Further advantage is radiation hardness widely demonstrated for NbTi magnets (i.e. HERA, Tevatron, LHC)

Comparison CPMUs and SCUs, J. Bahrdt, E. Gluskin, NIMA (2018)

- Estimated range of photons per pulse achievable by tuning the SCU afterburner on the fundamental harmonic
- Amplifying the output of the fundamental harmonic of the PMUs - 250 eV to 25 keV

Photon energy	Increase photons per pulse SCU to SASE in PMUs
30 keV	factor 2
40 keV	factor 3.3
50 keV	factor 5

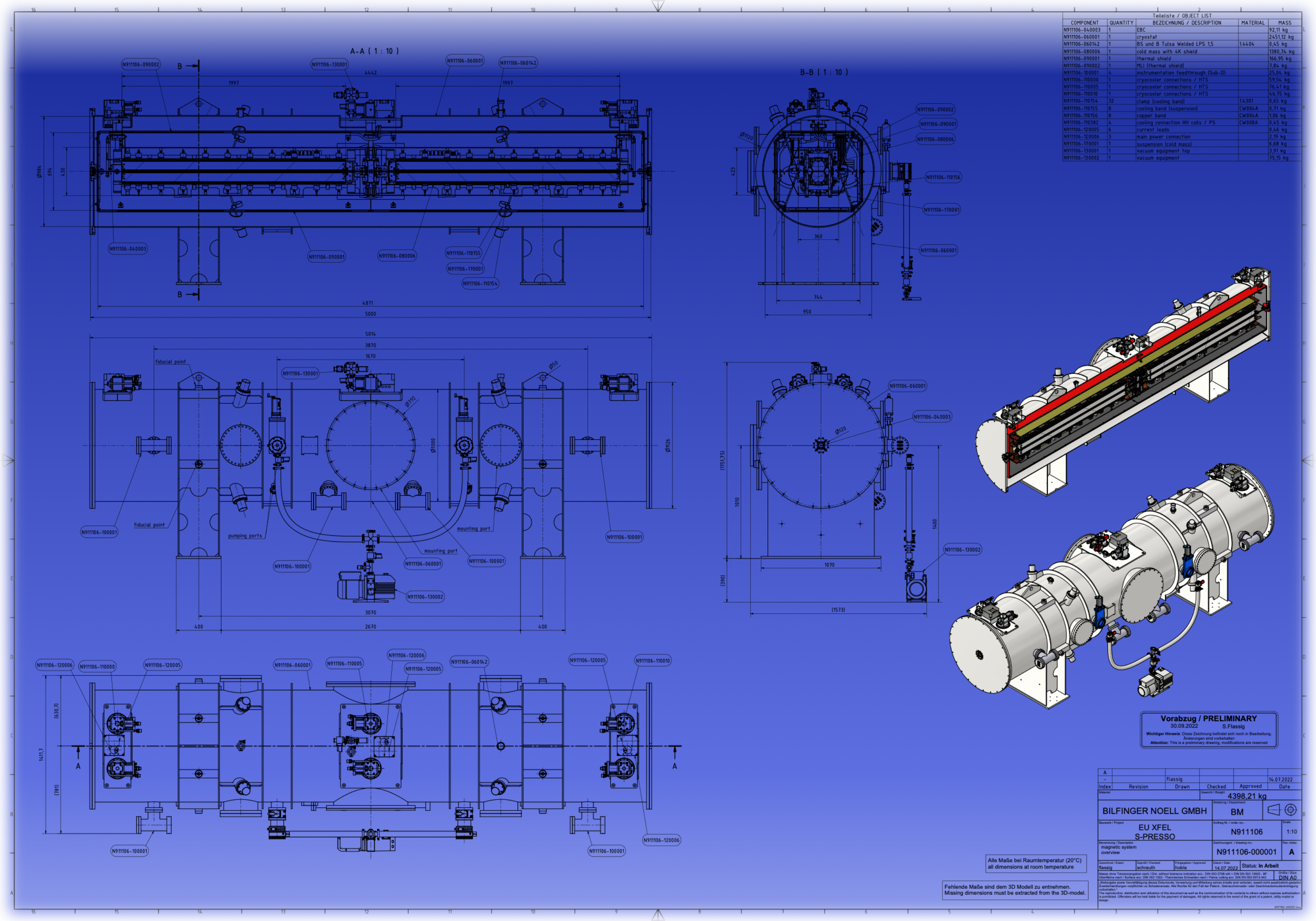
- Using the bunching of the second harmonic of the PMUs

Simulation parameters ($h = \lambda_{1,PMU}/\lambda_{1,SCU}$)

Parameter	Value
electron beam energy	16.5 GeV
initial energy spread	3 MeV
bunch peak current	5 kA
bunch length	1 µm
normalized emittance	0.4 mm mrad
⟨β⟩	30 m
SCU operation at harmonic h	h = 1 or h = 2
undulator period of SCU	18 mm
maximum undulator K parameter of SCU	3.06
total magnetic length of SCU system	24 m

C. Lechner et al., SRI2021 and FEL2022

Superconducting undulator PRE-SerieS prototype (S-PRESSO)

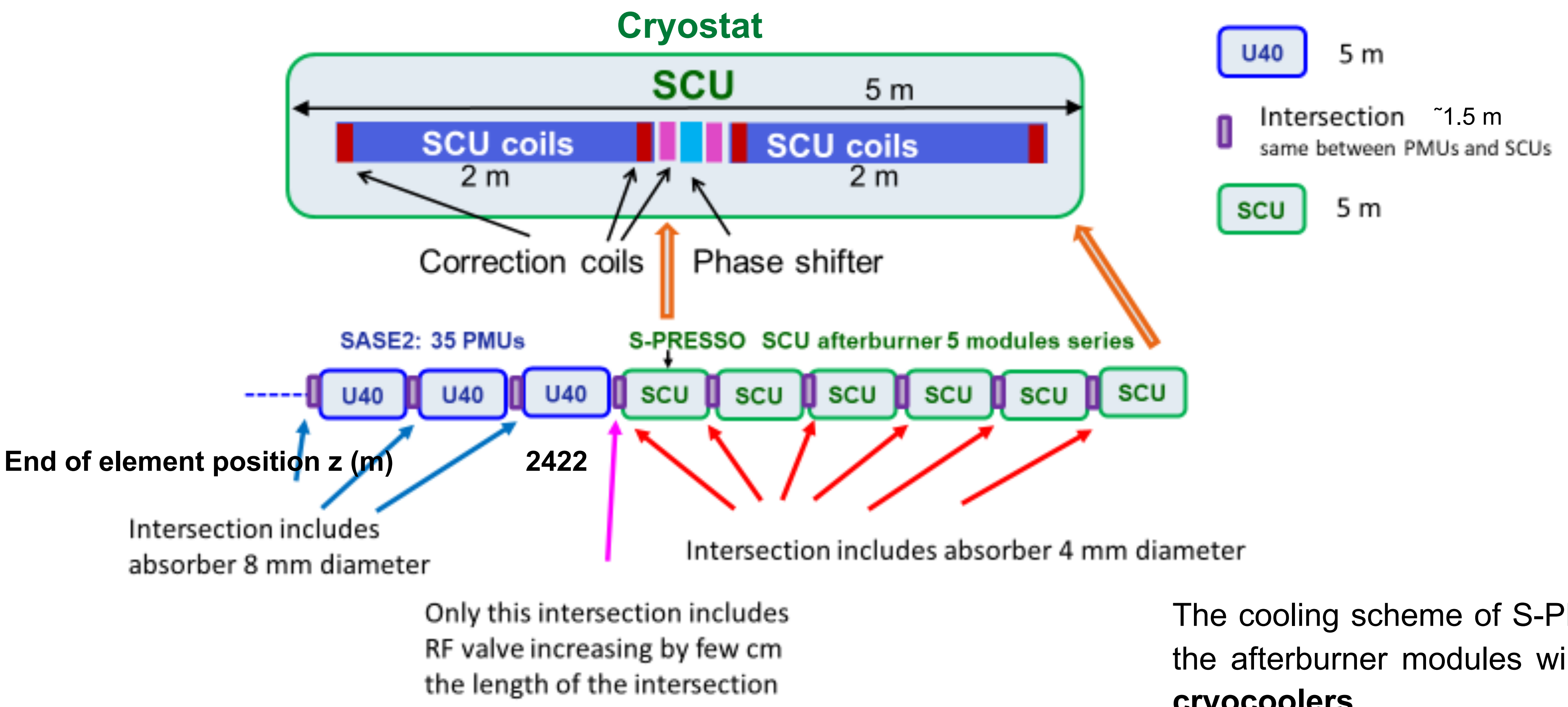


- EuXFEL plans to develop the technology of SCUs as part of its Facility Development program
- SCU afterburner for SASE2 undulator line will allow lasing at photon energies > 30 keV offering a unique source worldwide
- First module procured: installation foreseen end 2025
- Additional five modules: If positive decision by EuXFEL Council in June 2023 installation planned for 2028-29

Period length (mm)	18
Vacuum gap (mm)	5
K max.	3.06
Beam heat load (W)	10

Poster on the SCU development
high photon energy workshop 18.01.23

SCU afterburner planned at EuXFEL



The cooling scheme of S-PRESSO and of the afterburner modules will be based on **cryocoolers**

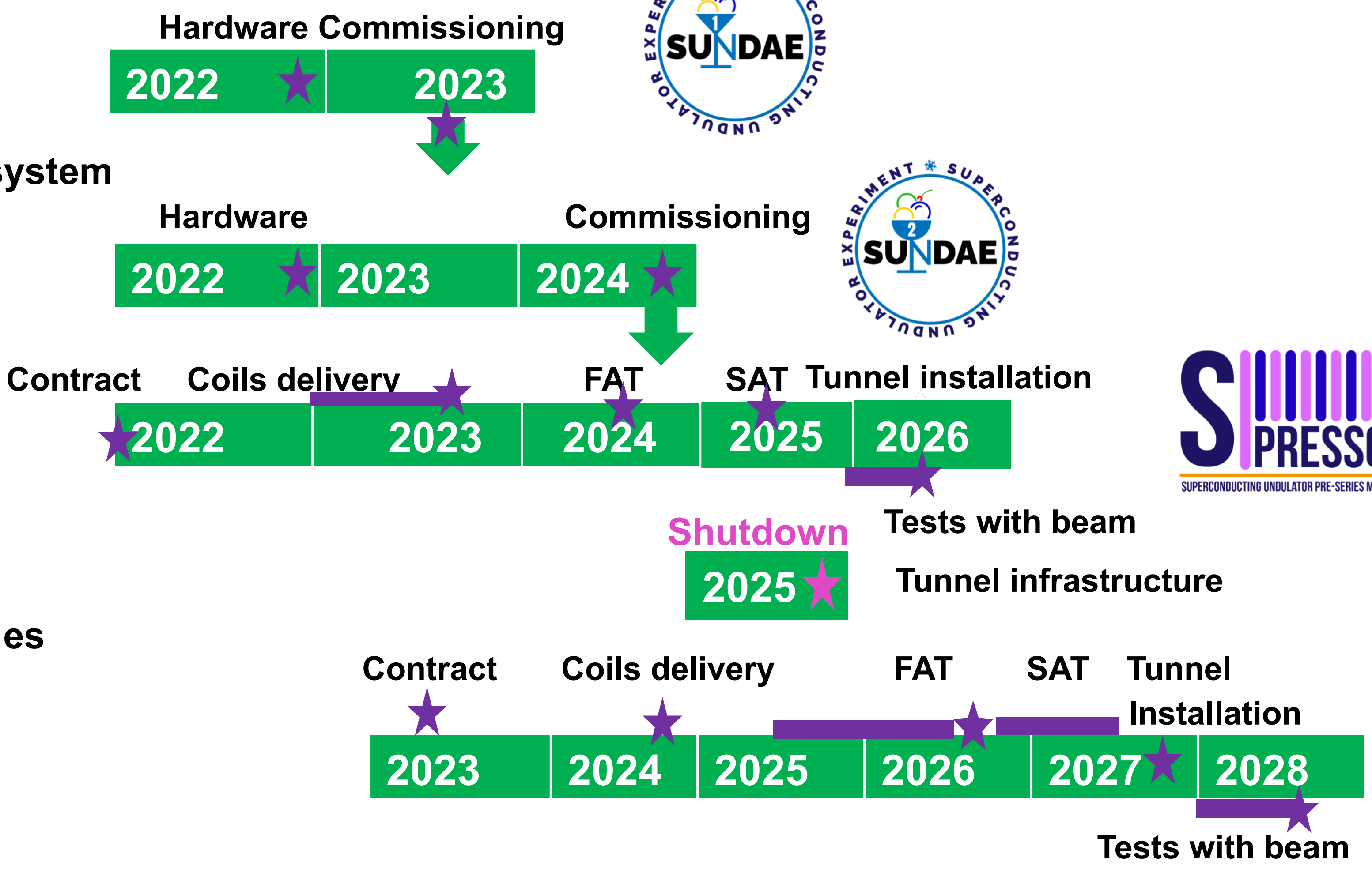
Main components for SCU project at European XFEL and Timeline

Vertical cryostat
Ongoing

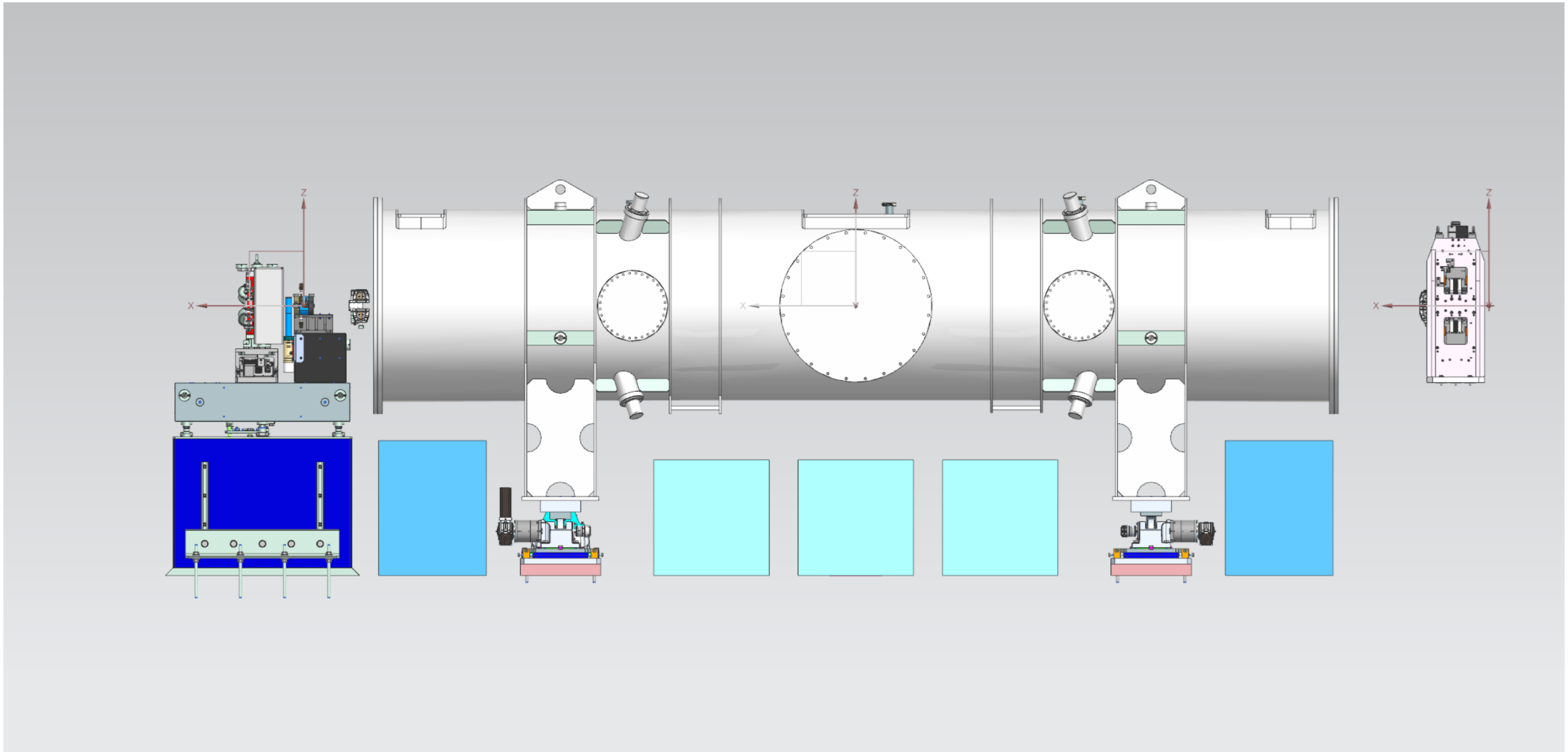
Horizontal measurement system
Ongoing

S-PRESSO
Contract signed with Noell

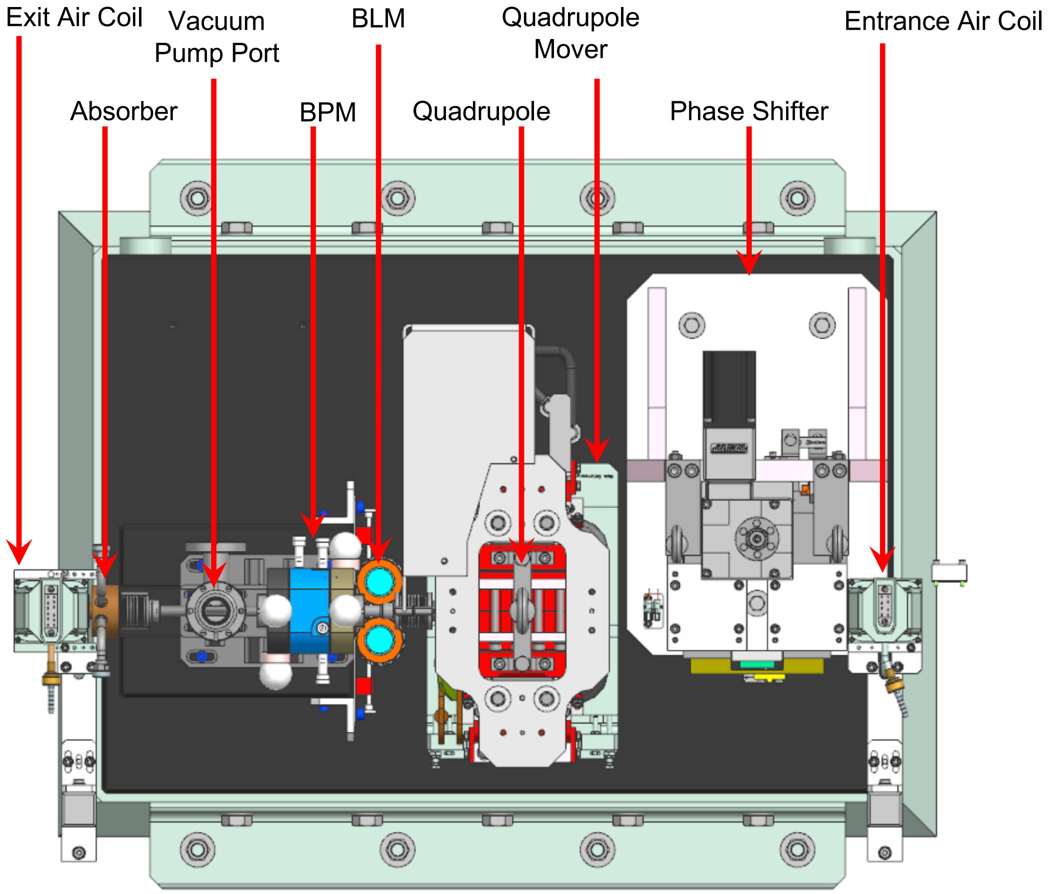
SCU Afterburner: 5 modules
Council decision needed



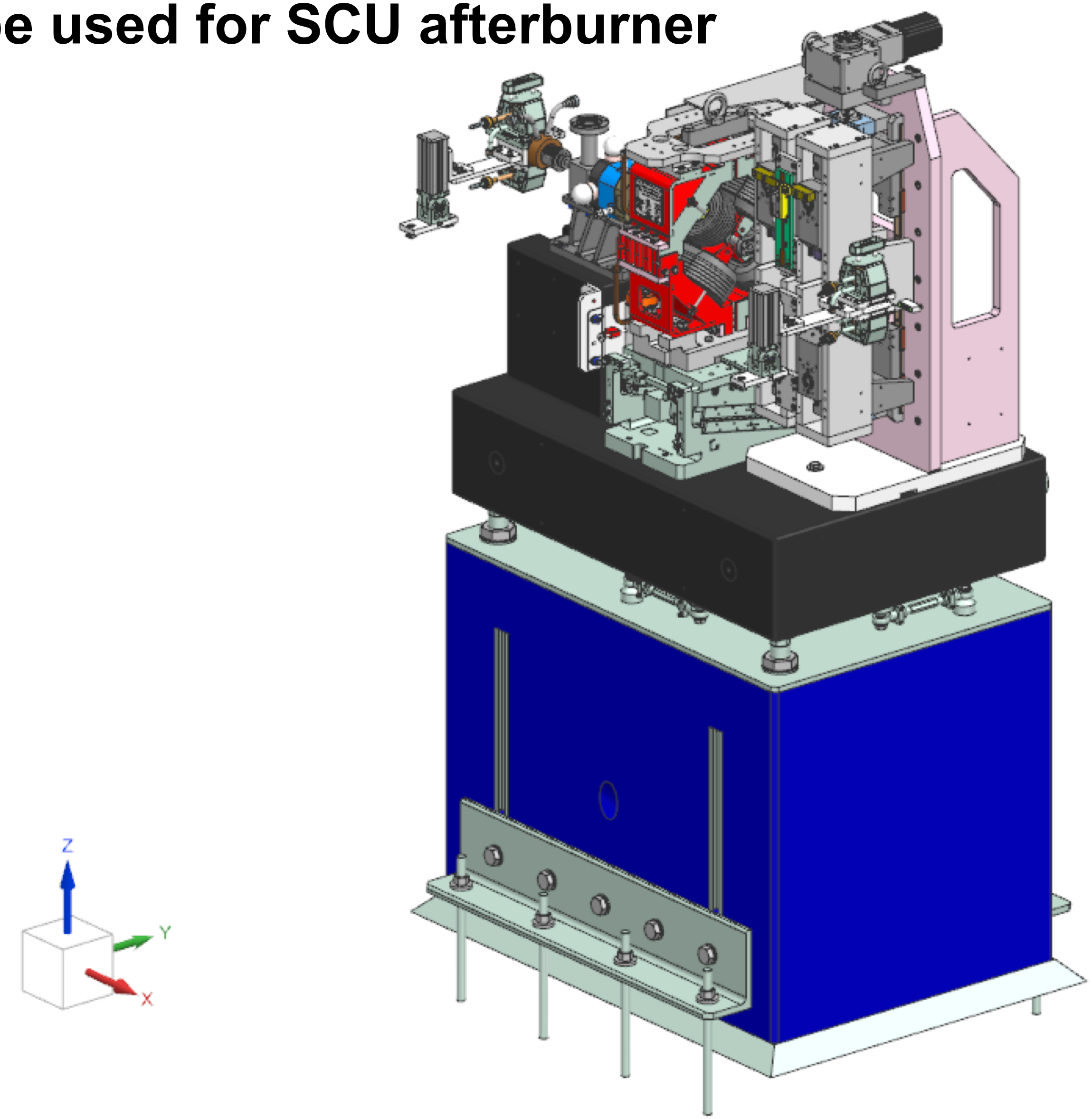
SCU Cell



Planar undulator intersection SASE 2 will be used for SCU afterburner



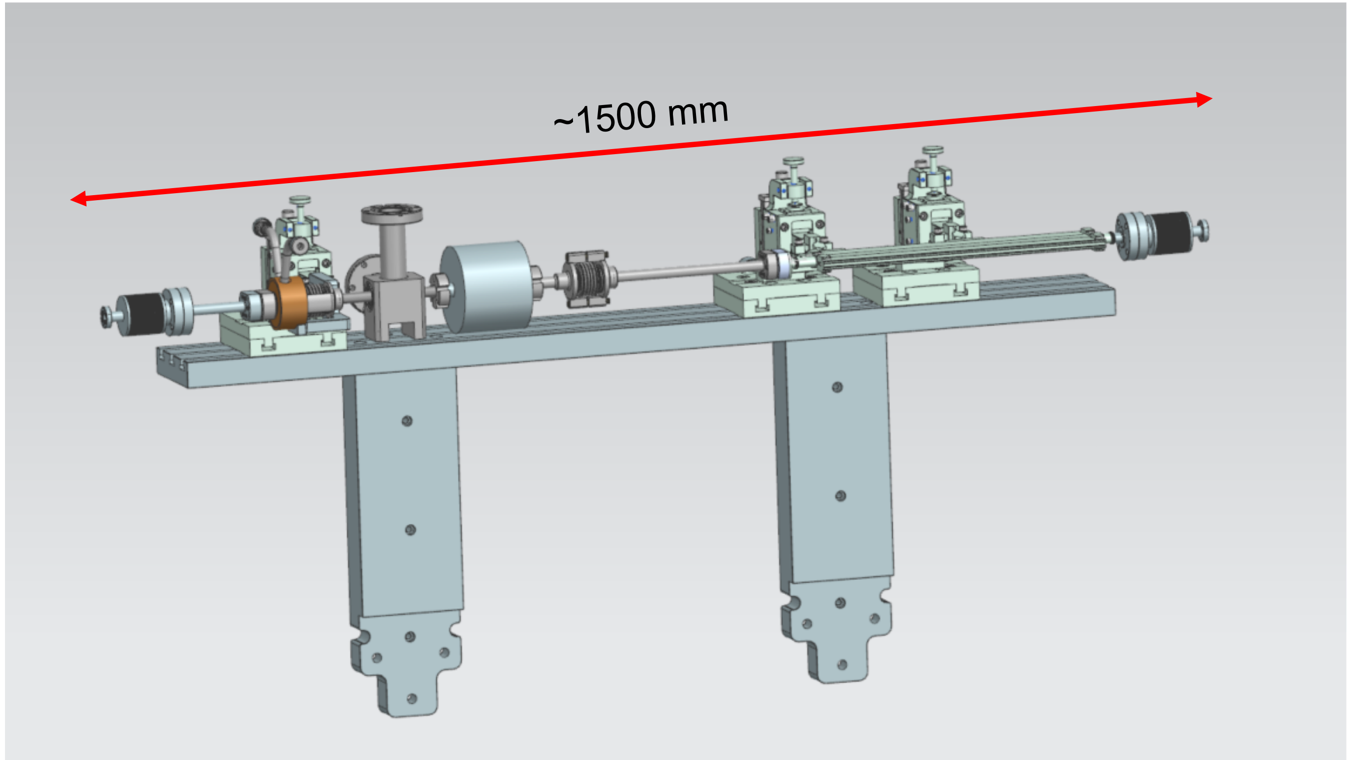
SASE 2 Intersection Top View



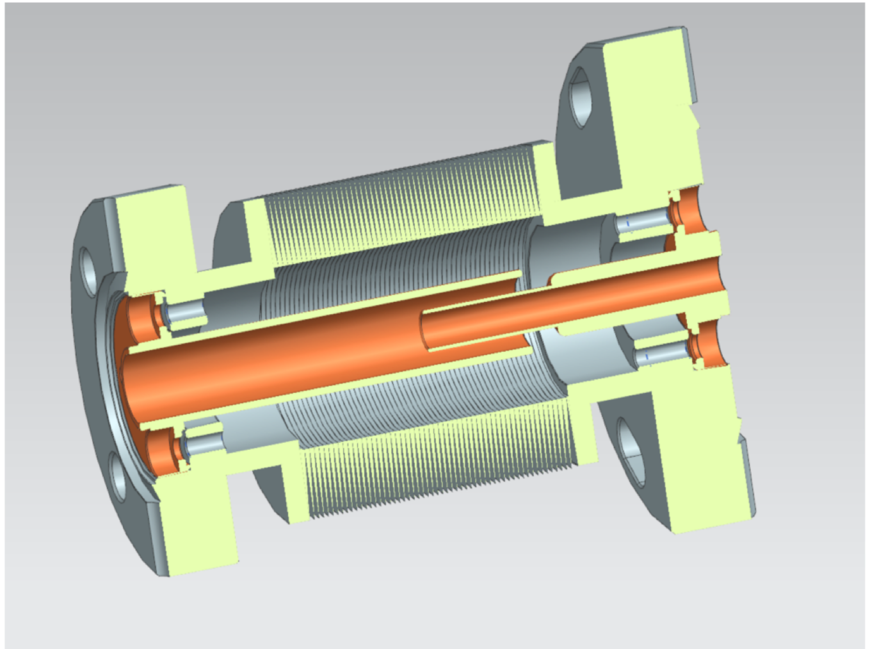
SASE 2 Intersection Isometric View

APPLE X type of VC and the Air coils support structure for SCU afterburner

The new RF bellows needs to be designed together with the respective company for the connection to be done between the S-PRESSO electron beam chamber (EBC) and the IVC. The bellows allows a relative movement of +/- 1 mm on a circle of the IVC and S-PRESSO. The wake fields need to be calculated. The length of the bellows is not yet fixed. The 40 CF flanges are foreseen to be used for both sides of the bellows. The 4 mm inner diameter absorber will be used for the SCU afterburner project.



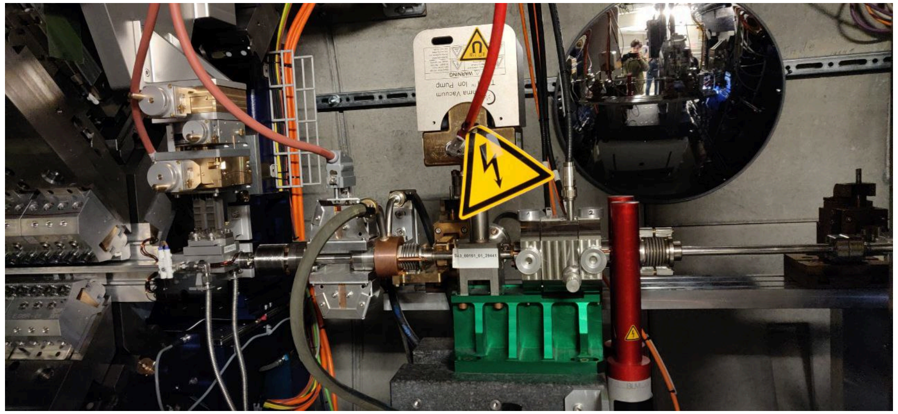
T. Wohlenberg

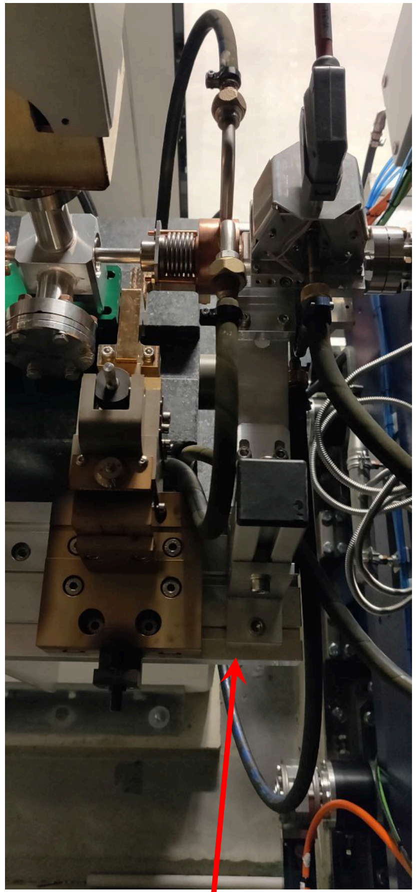


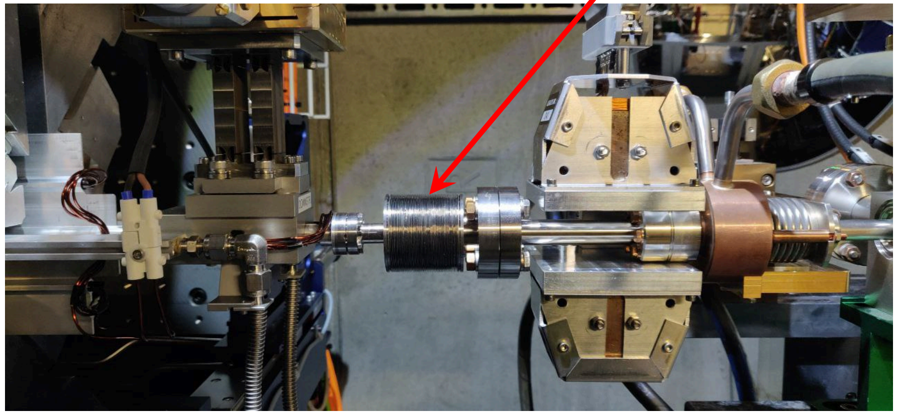
Cut through the RF-SCU Bellow for the connection on the bellow of the SCU EBC chamber. The bellow allowed to move the beam lateral +/- 1mm.

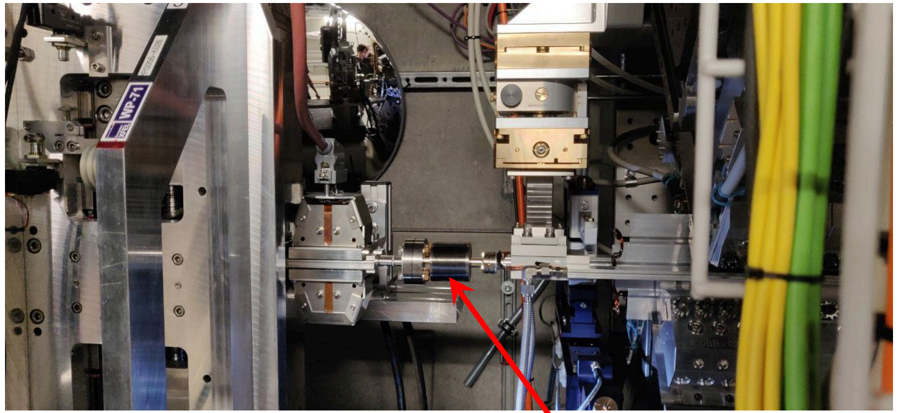
Support air coils and RF bellows similar to APPLE X type of intersection for SCU afterburner

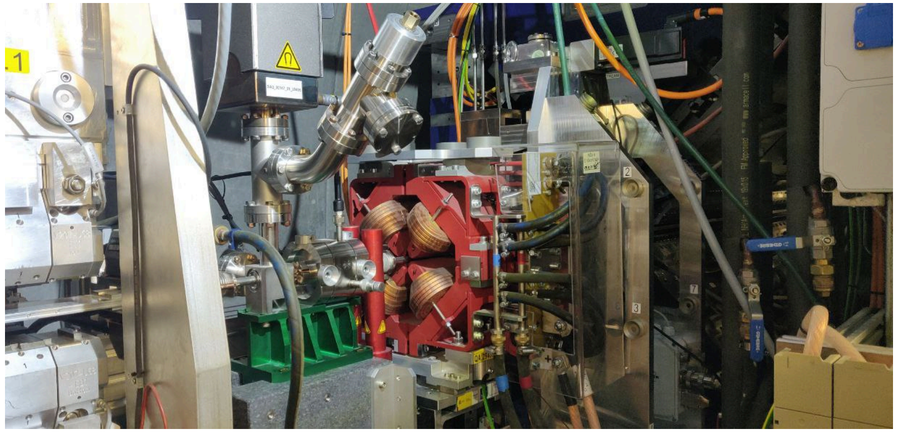
Similar Bellows (Entrance Side)









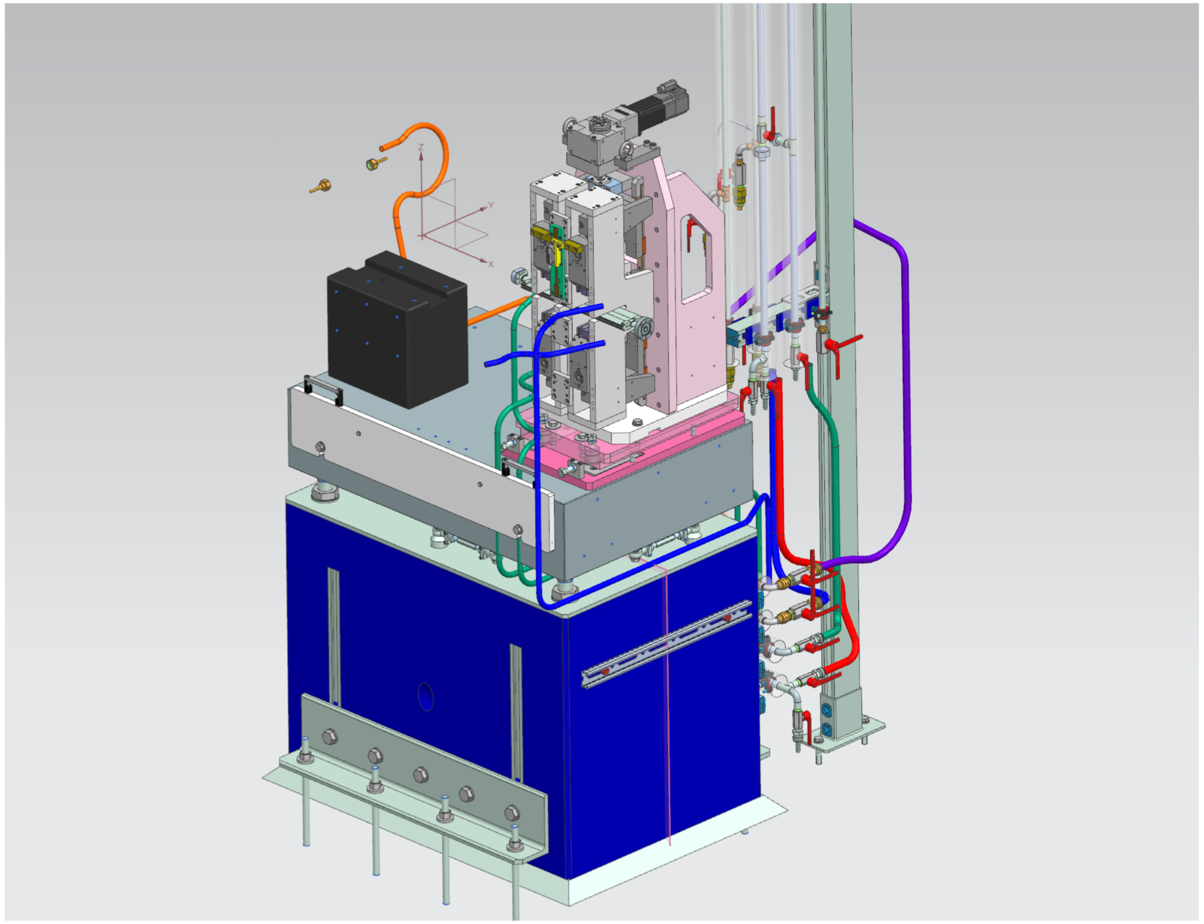


Similar Bellows (Entrance Side)

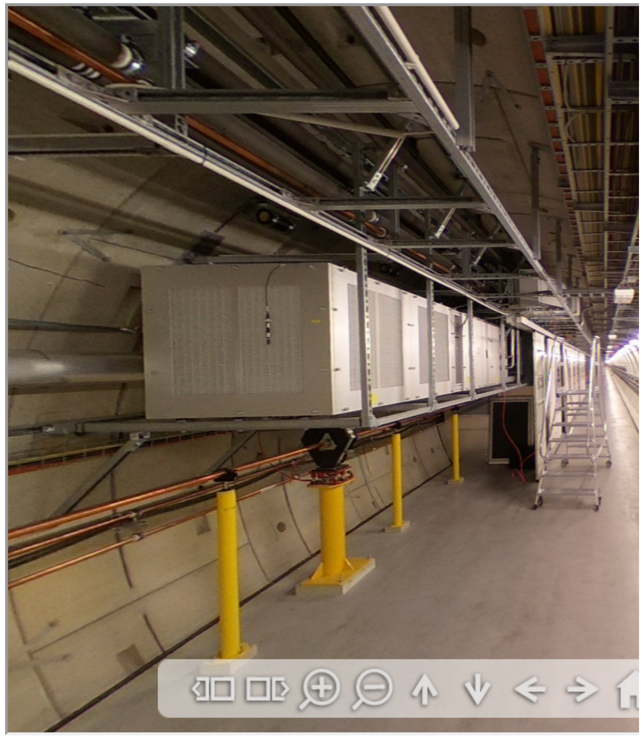
Same Intersection VC and Air Coils Support Structure

T. Wohlenberg

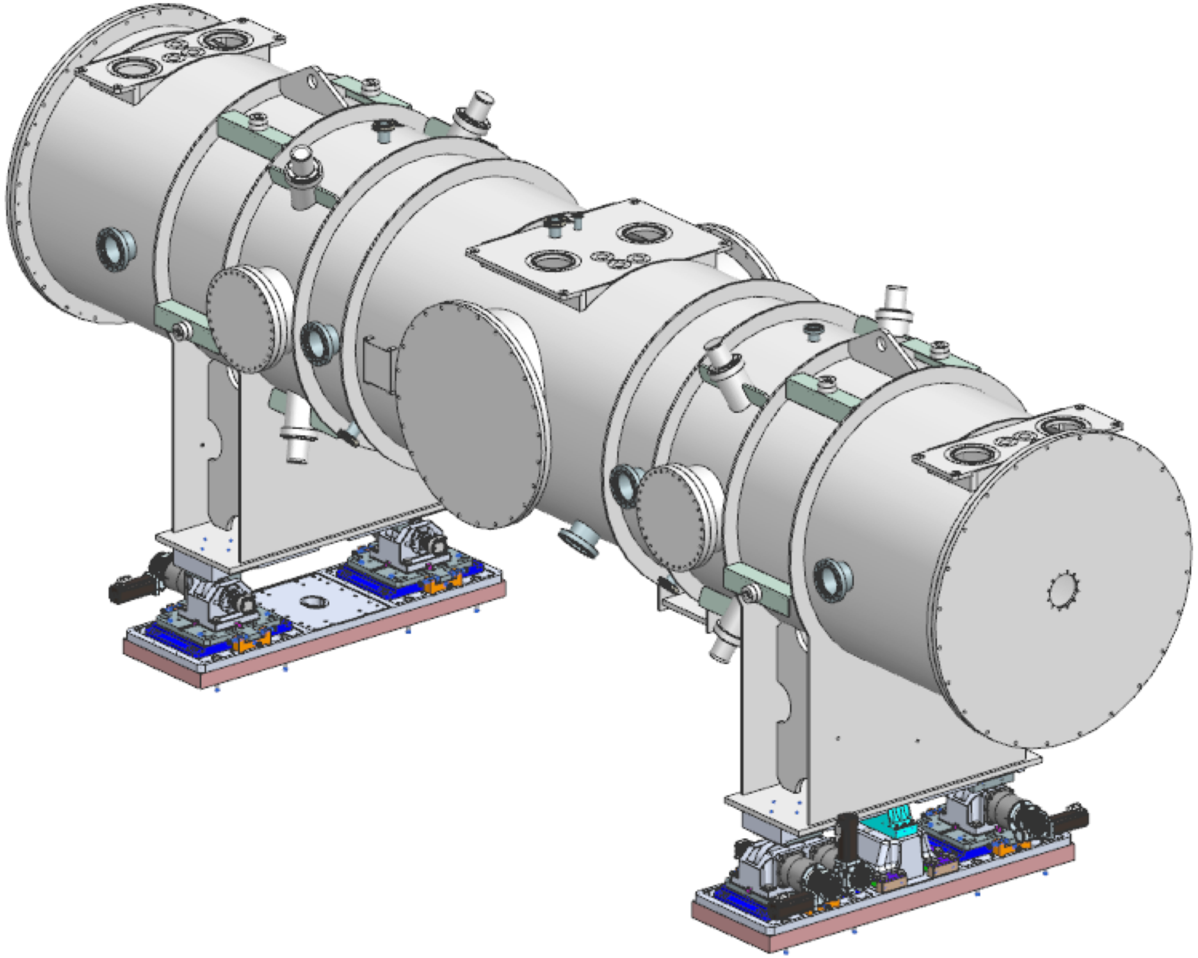
Implementation of phase shifter alignment platform

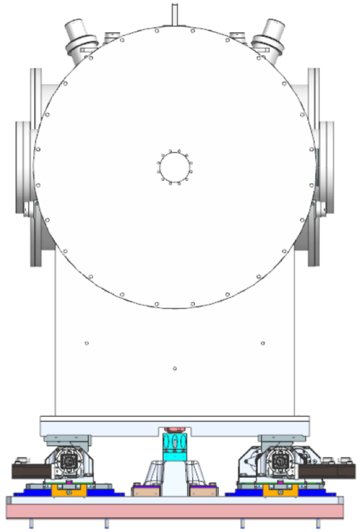


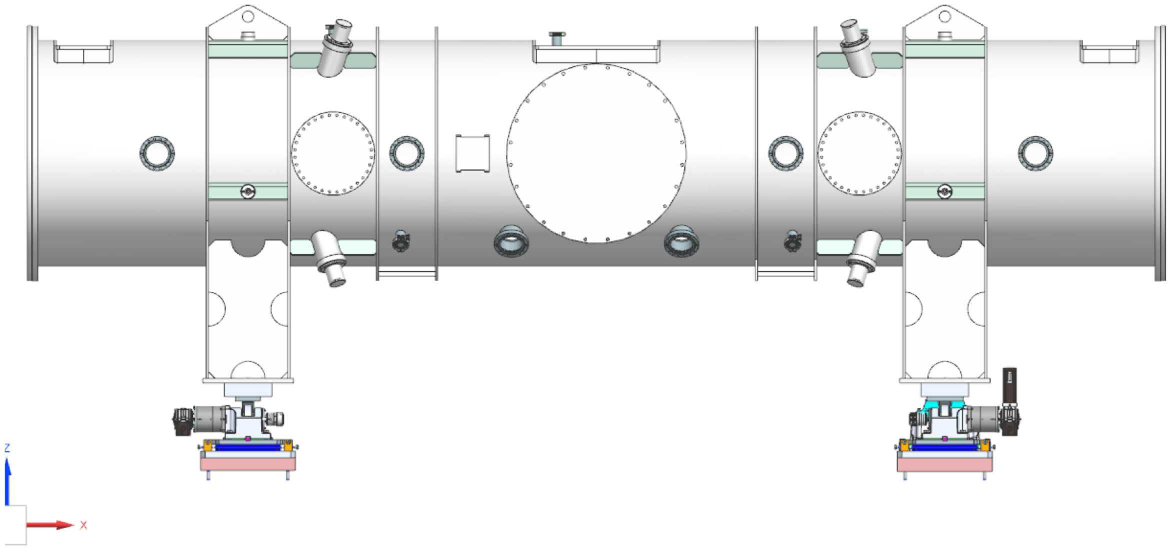
- All new 6 intersections will be longer than the present ones: from 1.1m to about 1.5 m
- The first intersection will host an RF valve to separate the vacuum of the room temperature to the cold sections and one bellows allowing the alignment of the SCU modules and compensating the thermal shrinkage
- The other five intersections will host 2 RF bellows each next to the two SCU modules.
- Additional components (one intersection without phase shifter) will be installed after the last SCU module
- The removal of the PKG to allow installation of the SCU modules right after the last permanent magnet undulator



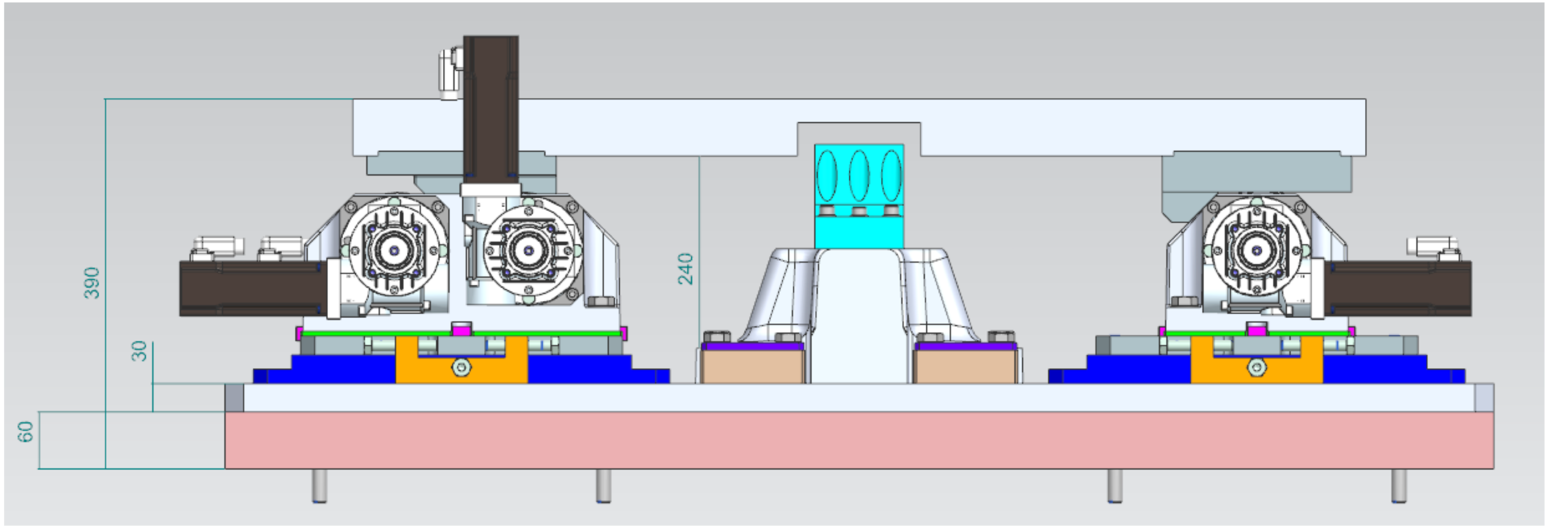
CAD model integration (Mark Wünschel and Daniel Thoden)







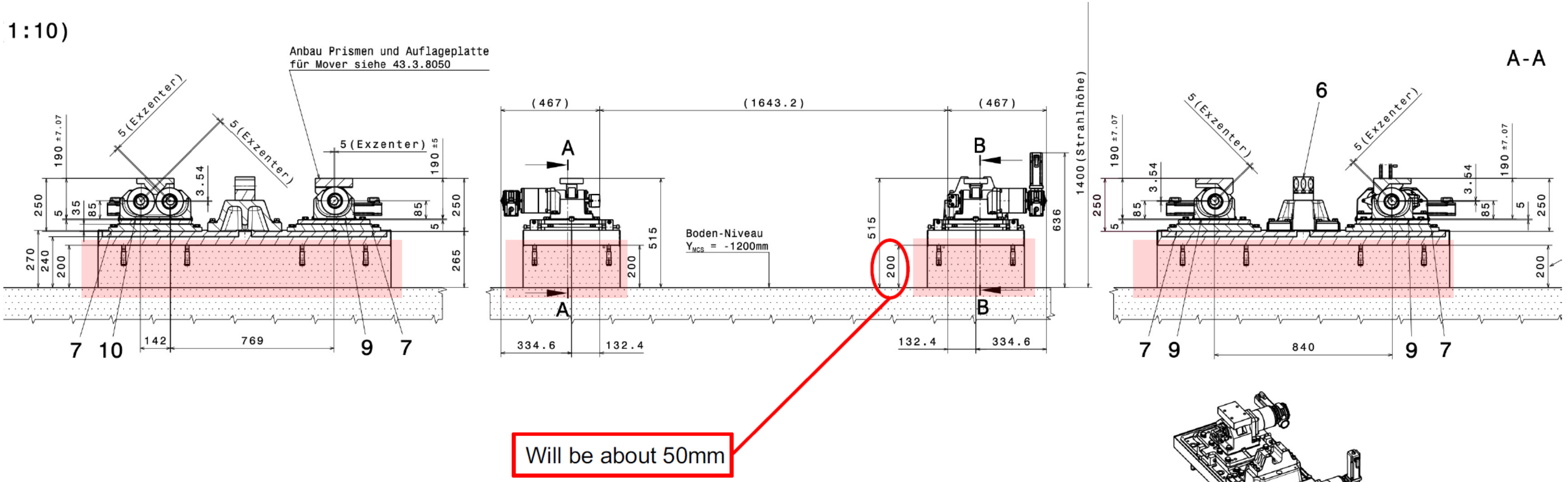
SASE2 SCU interface

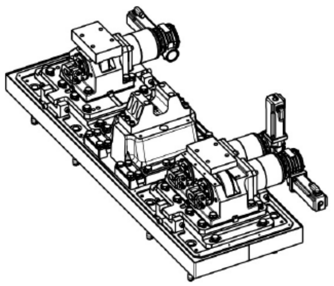


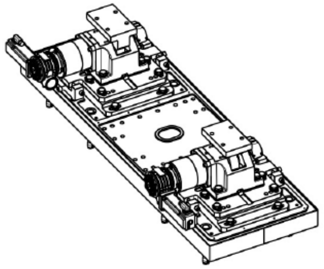
- Top plates are the interface
- Transversal width of the supports should match the plate
- Threaded holes, pins and central hole should be implemented (see next slide)
- Reference marks at “known” distance (+/-0.05mm) from the above mentioned pins
- Nominal height of the grouting is 60mm: distance from floor to interface is 390mm

SCU CAM movers Daniele La Civita 09.11.2022

Cam movers similar to APPLEX

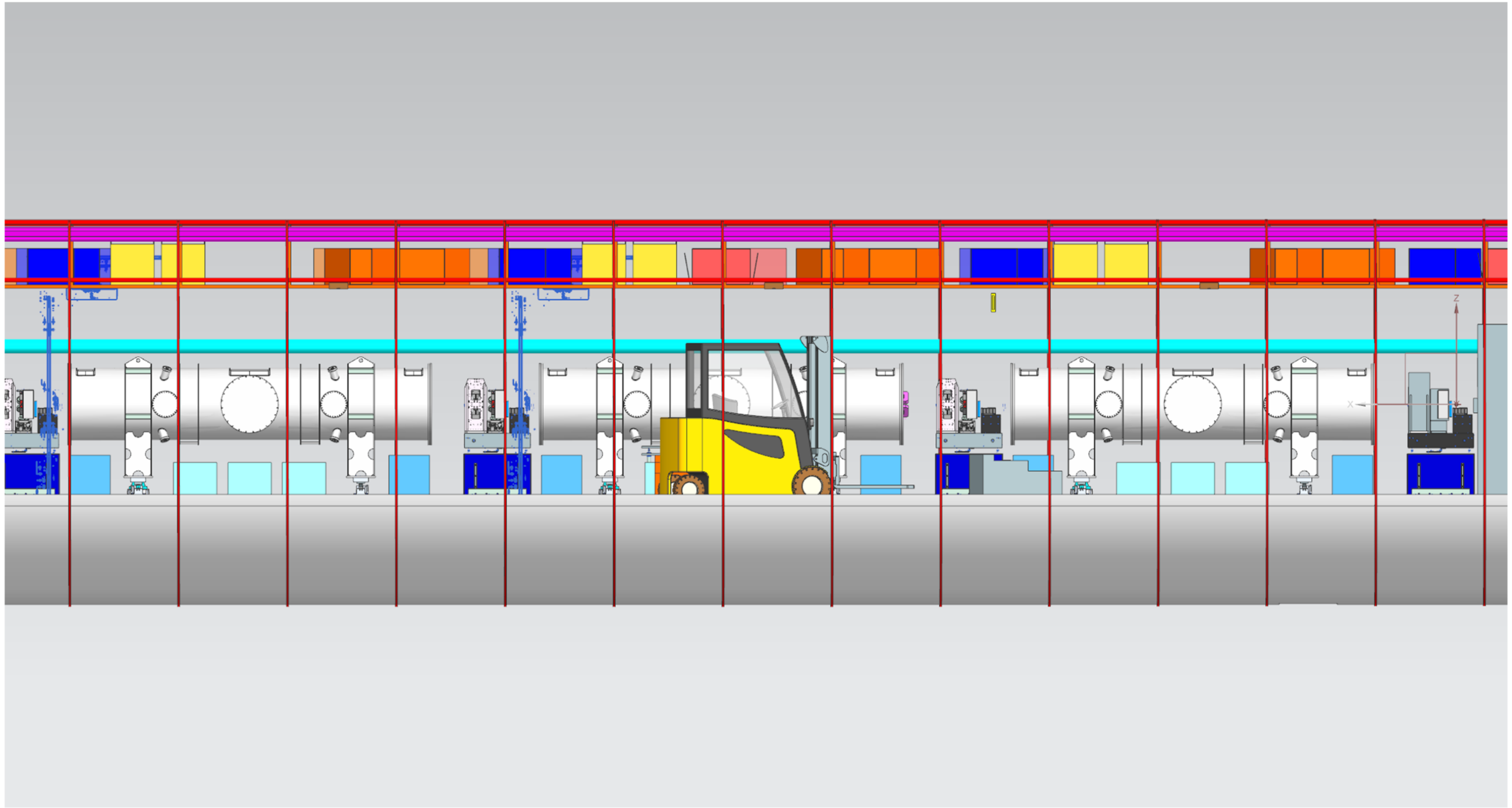






- Shorter concrete pedestals according to interface with cryostat

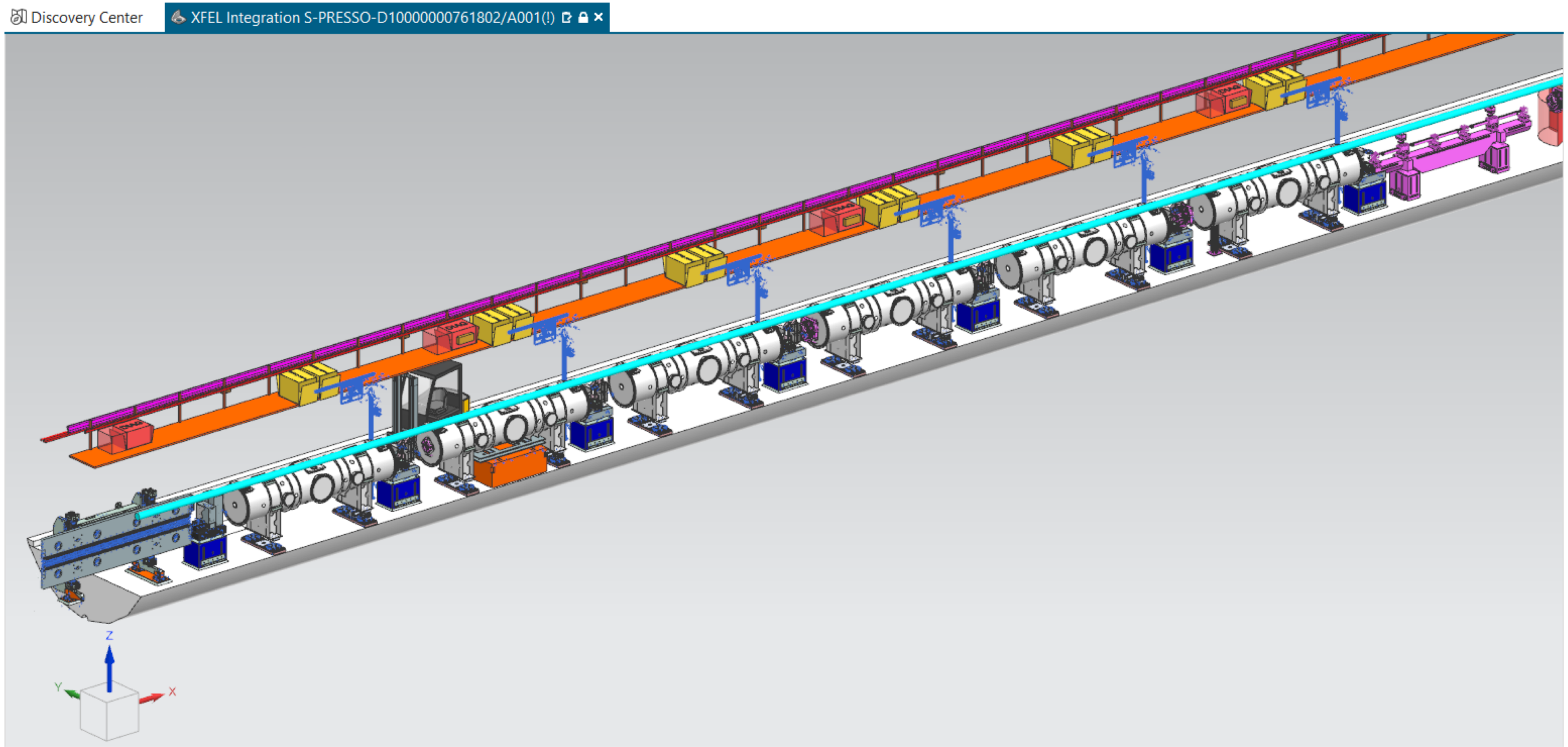
SCU afterburner section XTD1



- SCR - S-PRESSO control rack
- ICR – Intersection control rack
- SPR - S-PRESSO power supply racks
- DR - diagnostic rack
- Fire extinguishing system (not shown)

- Cryocooler compressors
- Vacuum pump carts

SCU afterburner section XTD1



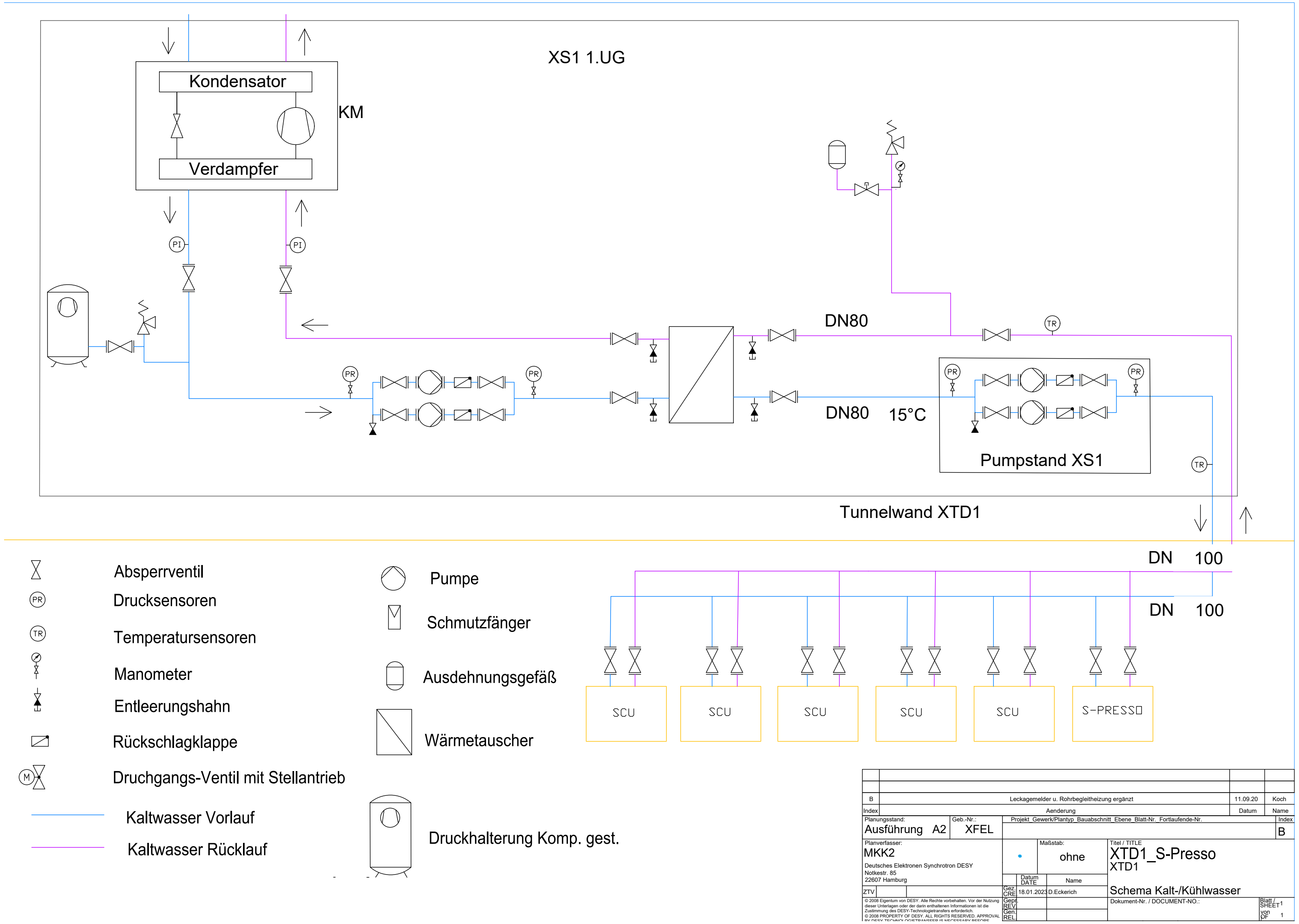
Example of cryocooler

- Sumitomo GM cryo cooler cold head: RDK-418D4 1.8/2W @4 K
- Compressor water cooled: F-50L/H
- Dimensions (HxWxD):

- Six of such compressor will be installed underneath S-PRESSO
  - F-50L/H, : 591 x 450 x 585 mm

Cooling water supply

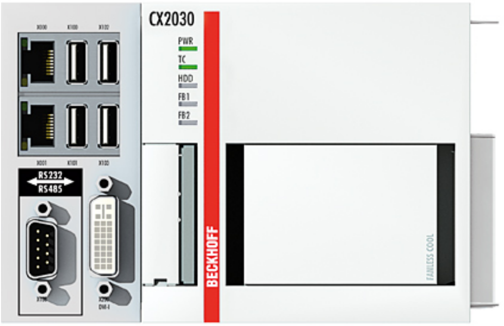
- Two new pipes DN 100 will be placed from XS1 downstream to the SCU afterburner section to supply the cryocooler’s compressors with the cooling tap water
- The cooling concept of the diagnostic racks and the intersection components will be kept the same as for the planar undulator section
- No need to have a VC temperature stabilization system→ no mixing valve→ no flowmeter→small distribution plate
- PKG water suppling pipe will be used to supply the SCU main power supplies with the cooling water. Aluminum heat exchanger Under discussion



Additional Requirements to the Superconducting undulator PRE-SerieS prototype (S-PRESSO) Control System

- Connection to the ICR (Control voltage on)
- Cam Mover control - 5 Axes
- Power supplies for the correction coils (Control of four Air Coils 4 power supplies)
- C6925-0030 Accu-Pack, IPC safe shutdown system
- Switch off/reboot neighbour rack
- Fire detection system with door switches

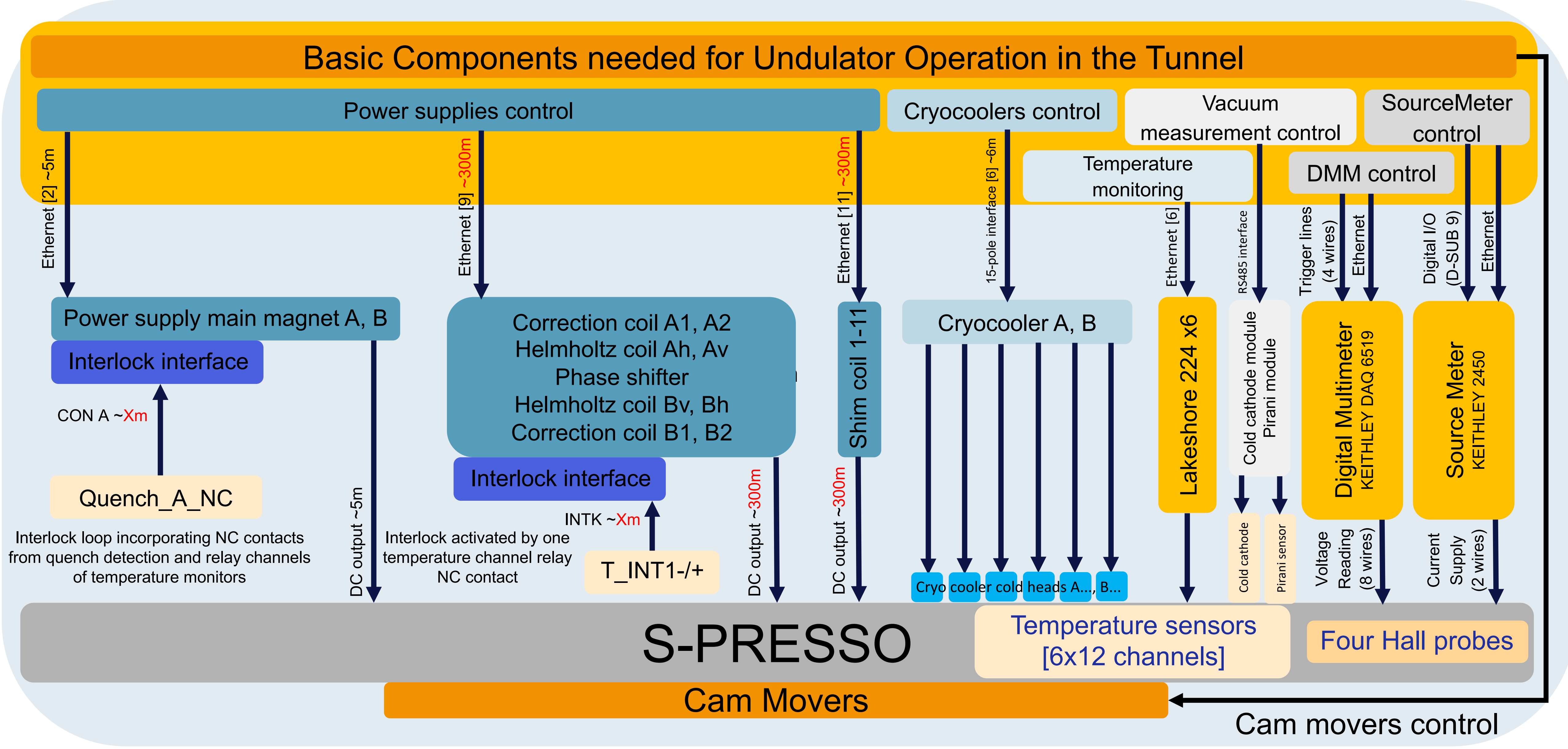
IPC CX2030



AX8206

EPLAN_..._Modified for S-PRESSO

Simplified Diagram of the S-PRESSO Local Control System in the Tunnel



Simplified diagram of the S-PRESSO Control Cabinet

Basic Components needed for Undulator Operation in the Tunnel

S-PRESSO Control I/O terminals

Model 224 Temperature Monitor

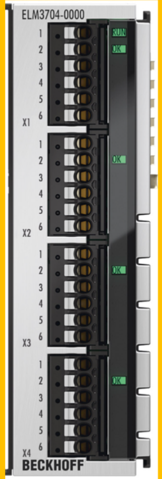
X 6 pieces

435mm x 89mm x 368mm W x H x D

Digital Multimeter (DMM)

X 1 piece

Maybe can be replaced by ELM3704 – 0000 terminal →

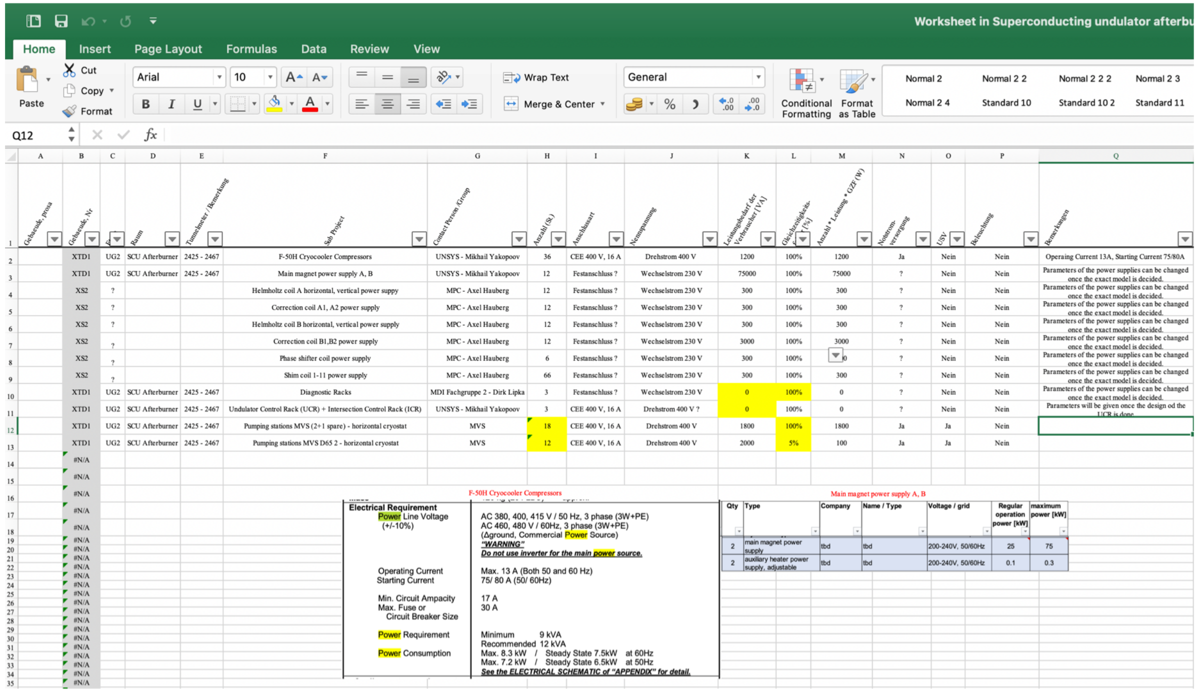


Source Meter

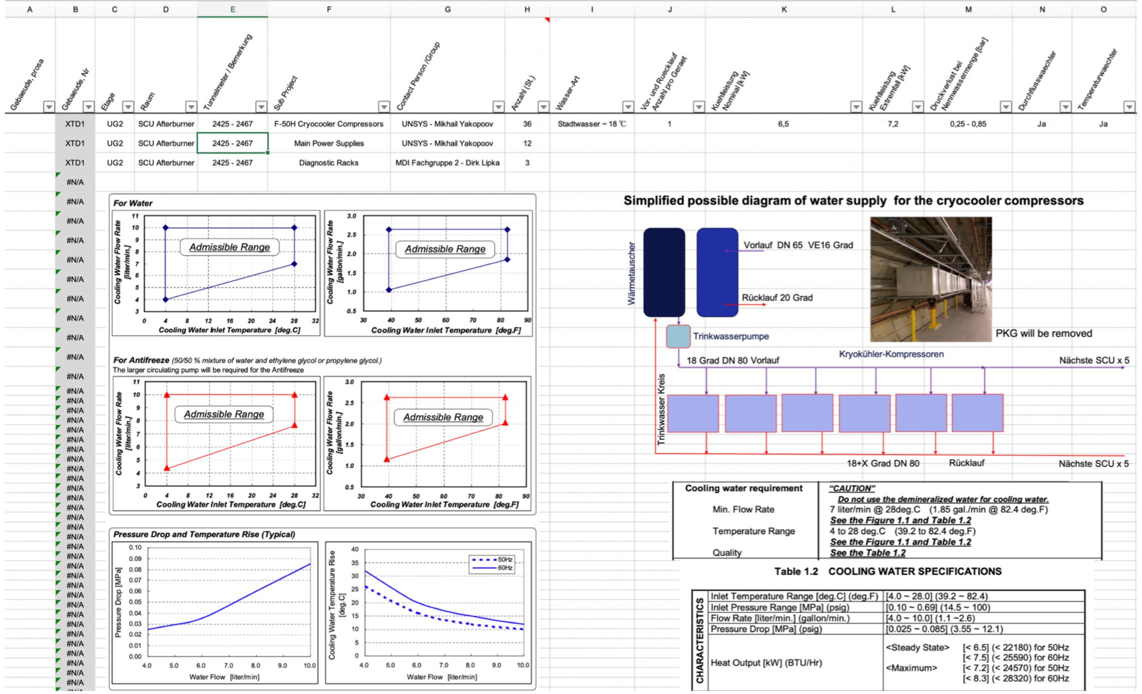
X 1 piece

Maybe can be replaced by a more compact solution

Raumbuch



Power Supply



Water Supply

Operational packages involved in shutdown 2025

SCU	OP-330: Controls	T. Wilksen and R. Bacher
SCU	OP-341: Vacuum	S. Lederer and T. Wohlenberg
SCU	OP-345: Magnets	R. Wickmann and W. Decking
SCU	OP-360: Diagnostic	D. Lipka and Kay Wittemburg
SCU	OP-515: Trans. & Align	J. Prenting and M. Schloesser
SCU	XFEL Undulator Group	M. Yakopov and S. Casalbuoni

Thank you for your attention !