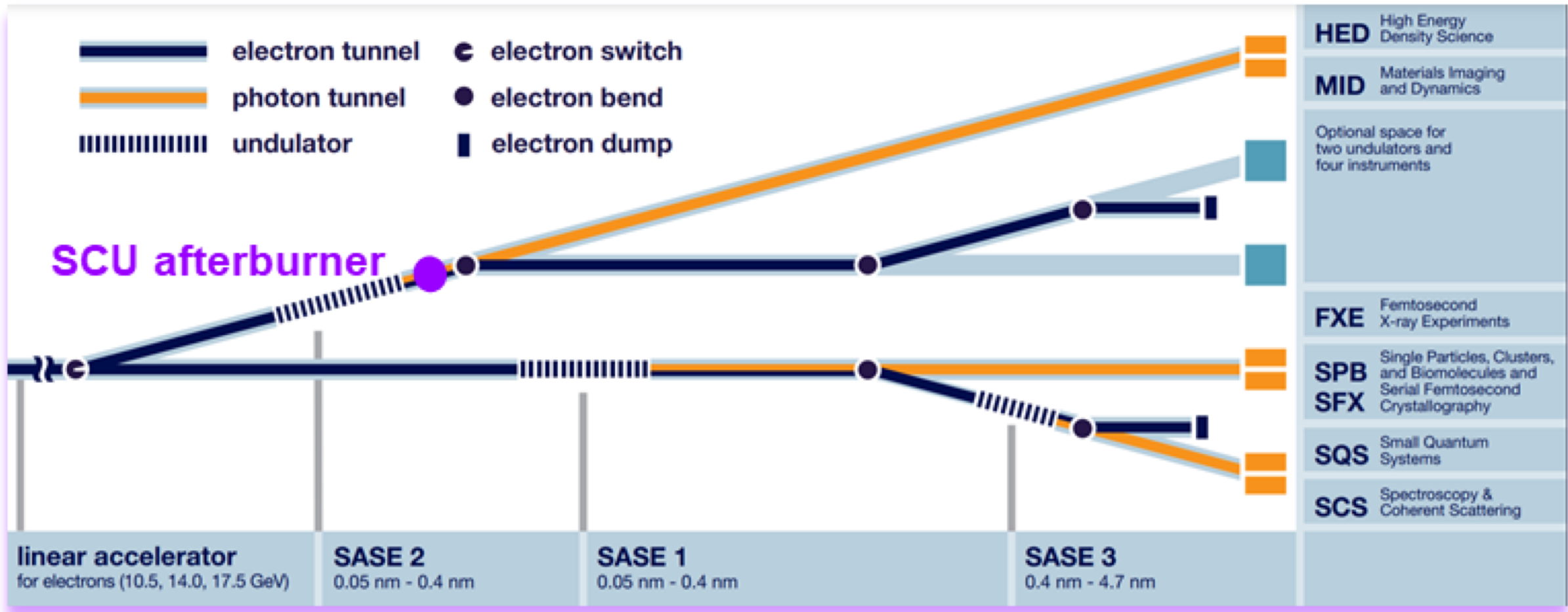


# Superconducting undulator afterburner project planned at EuXFEL

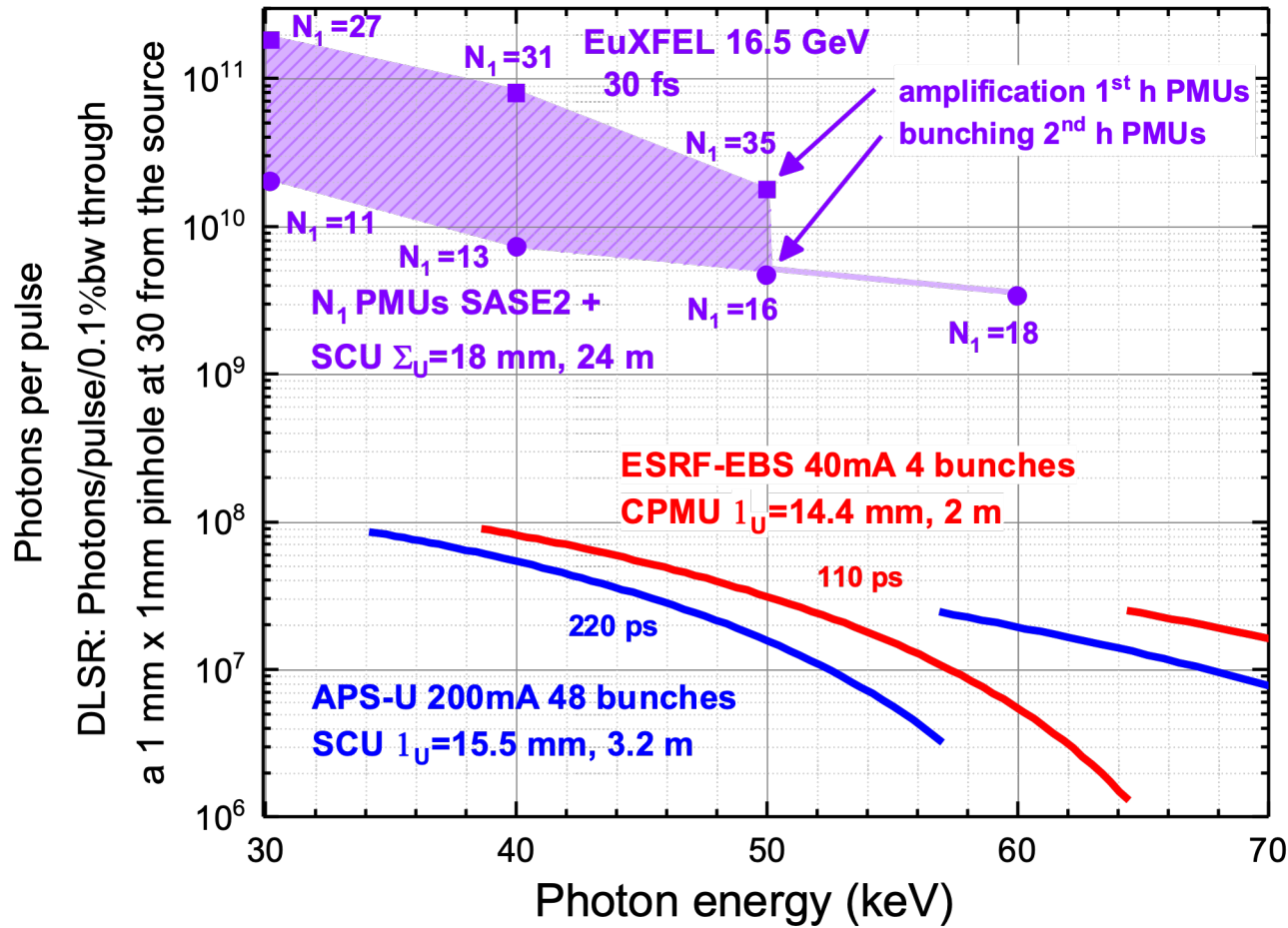
Sara Casalbuoni and Mikhail Yakopov  
European XFEL

26 January 2023





# Motivation



- 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. Bahrtdt, E. Gluskin, NIMA (2018)

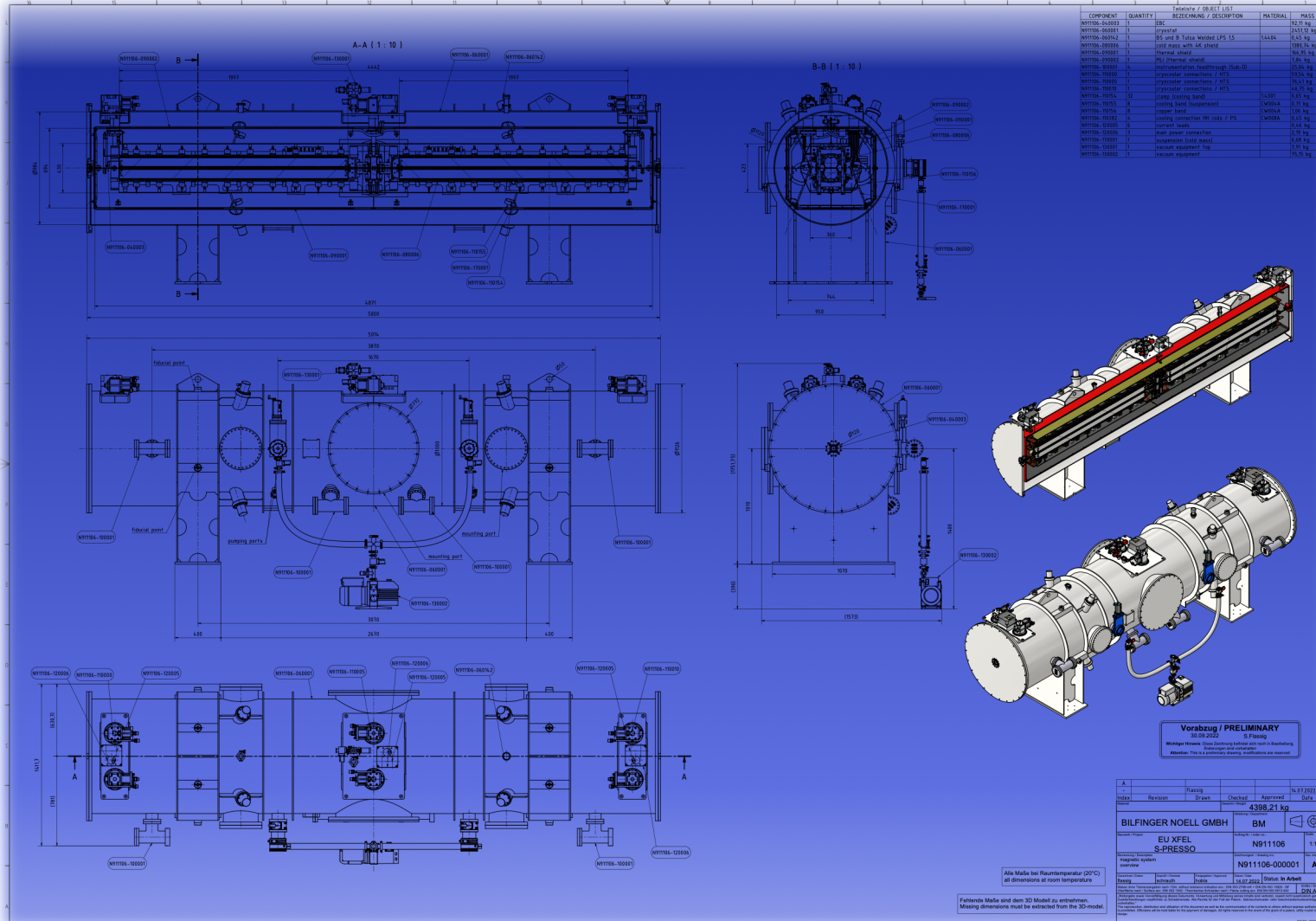
- Estimated range of photons per pulse achievable by tuning the SCU afterburner on the fundamental harmonic
- Amplifying the output of the fundamental harmonic of the PMUs - 250 eV to 25 keV
 

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 $\mu$ m
normalized emittance ( $\beta$ )	0.4 mm mrad
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

# 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

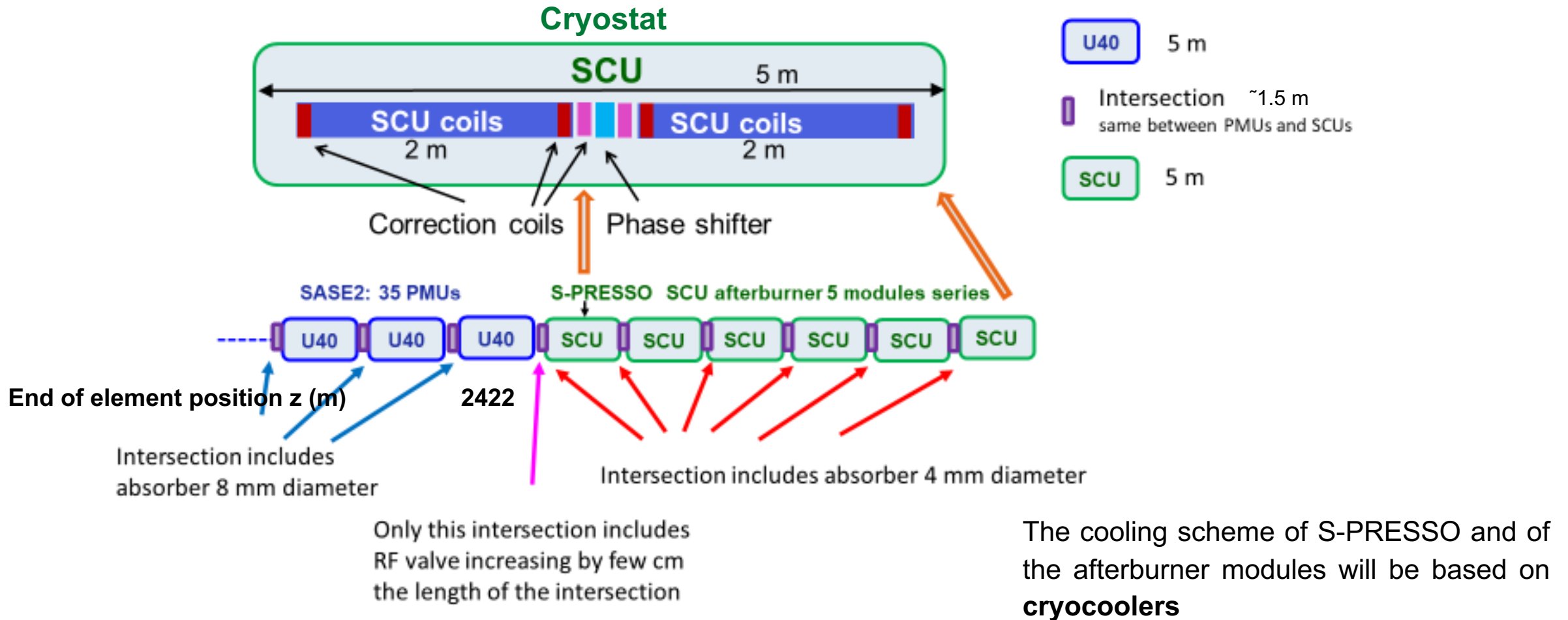
First module procured: installation foreseen end 2025

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



# Main components for SCU project at European XFEL and Timeline

**Vertical cryostat**  
Ongoing



**Horizontal measurement system**  
Ongoing



**S-PRESSO**  
Contract signed with Noell



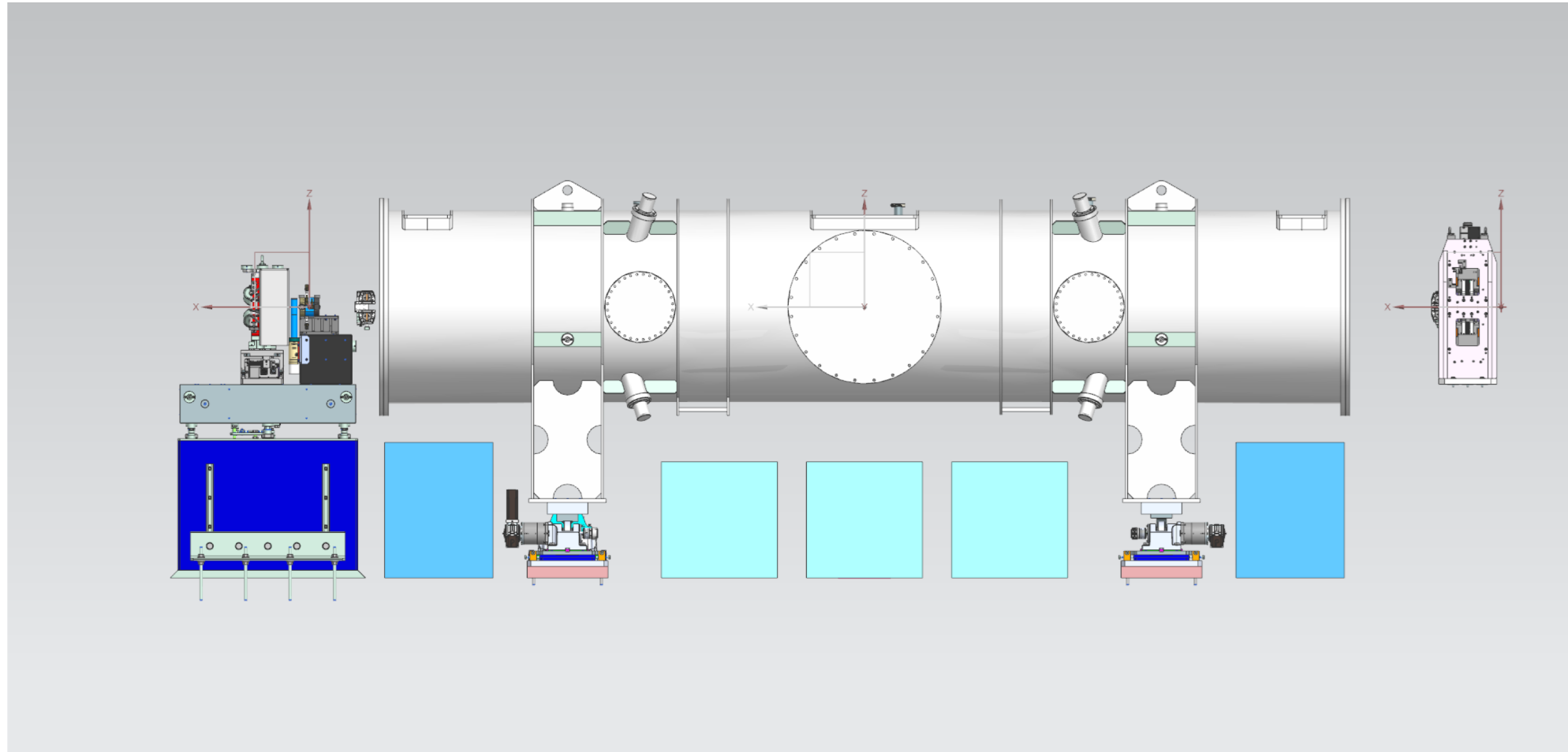
Shutdown  
2025 ★  
Tests with beam  
Tunnel infrastructure

**SCU Afterburner: 5 modules**  
Council decision needed

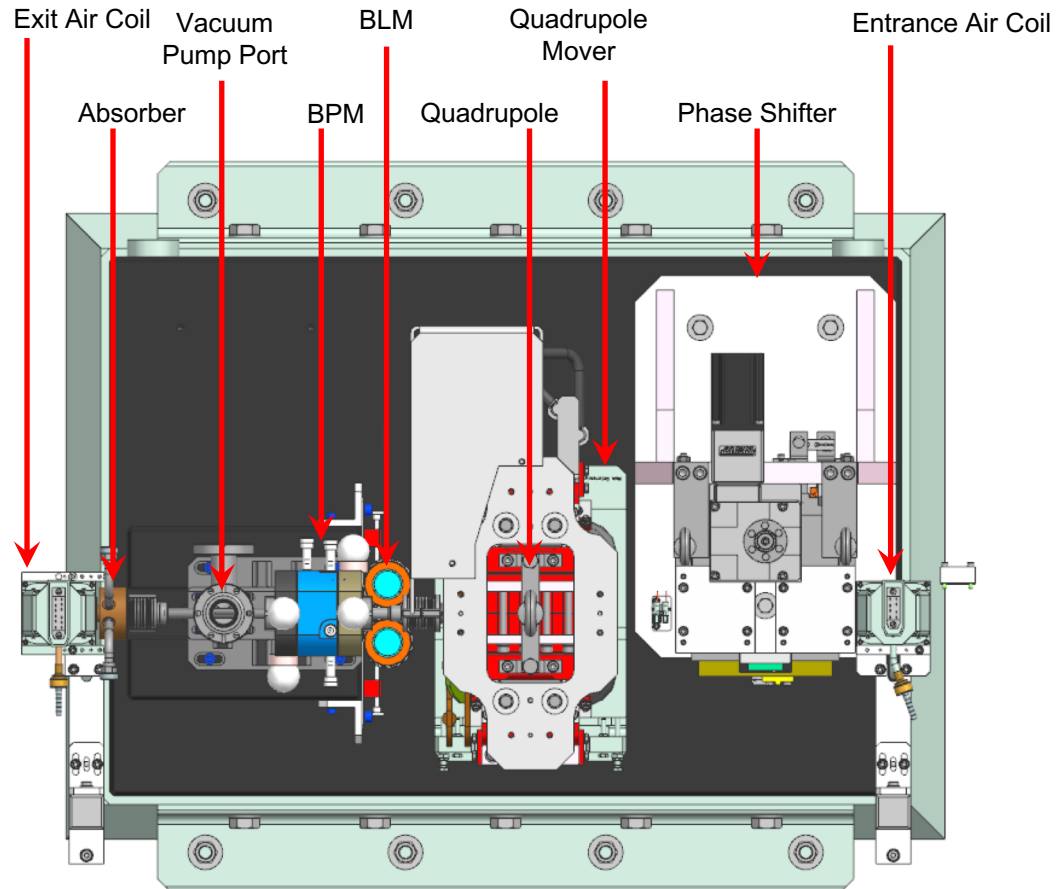


Tests with beam

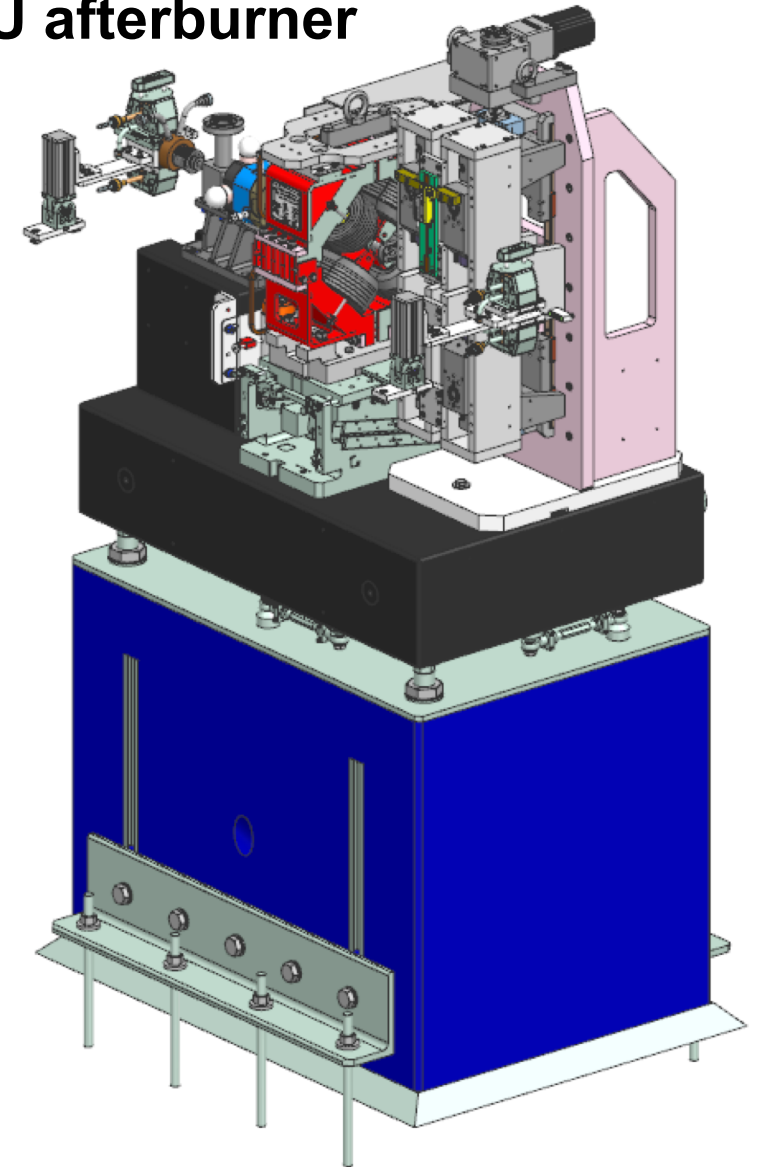
# SCU Cell



# Planar undulator intersection SASE 2 will be used for SCU afterburner



SASE 2 Intersection Top View

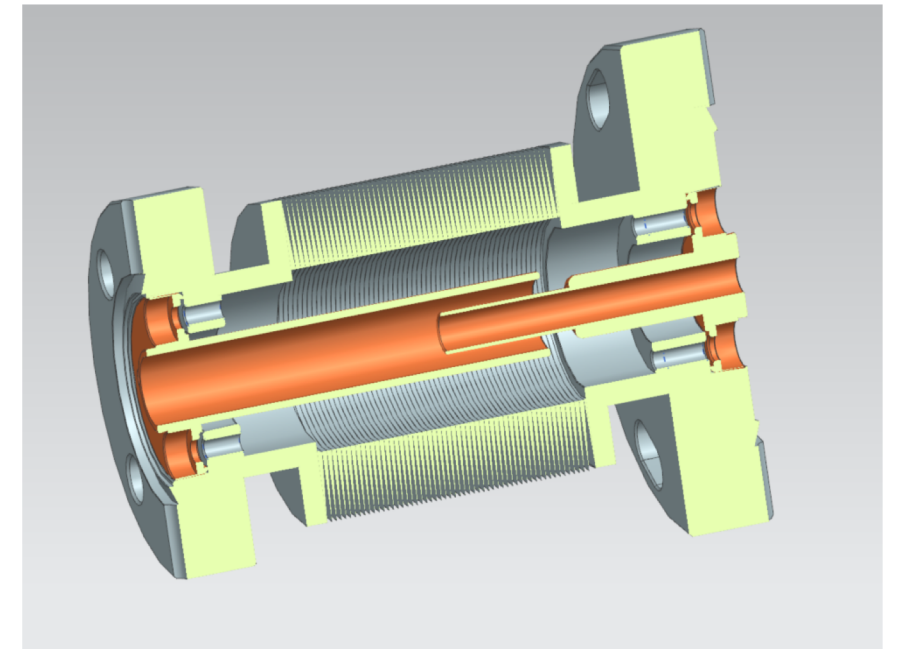
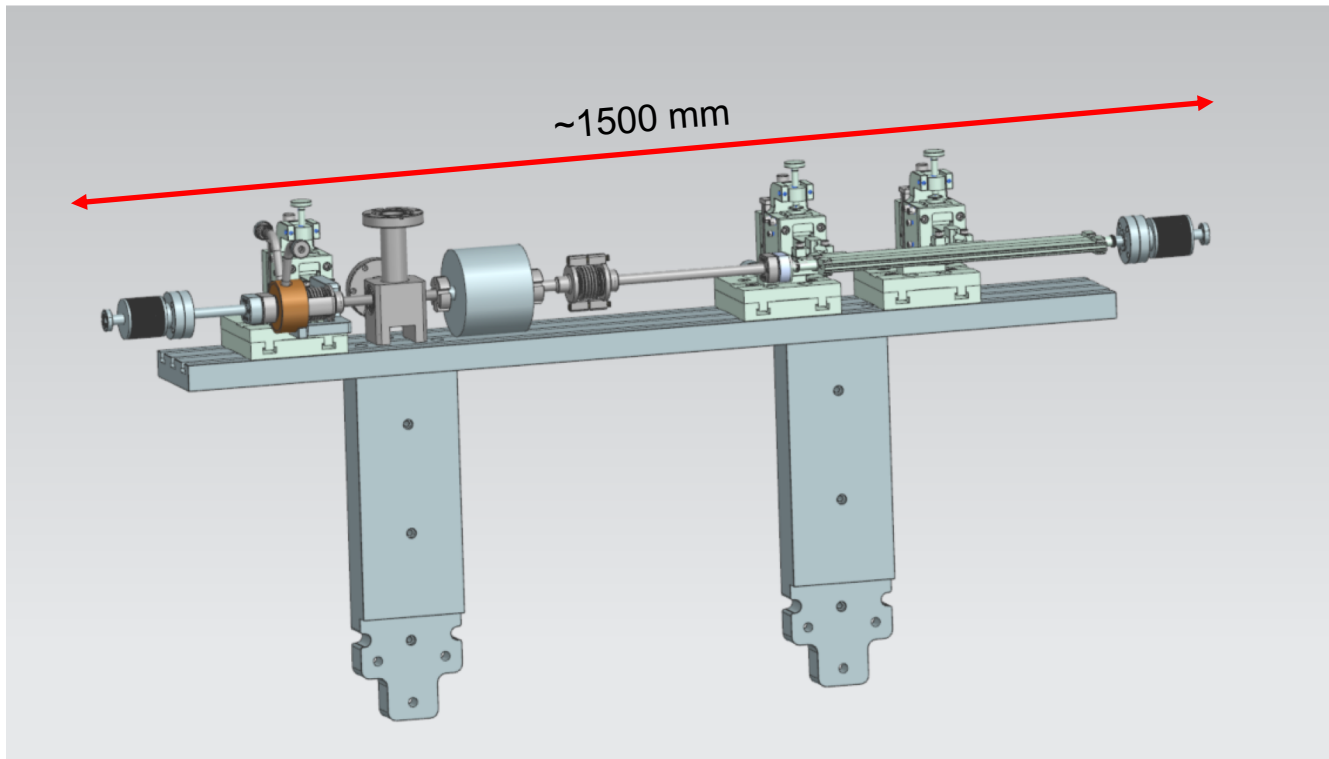


SASE 2 Intersection Isometric View



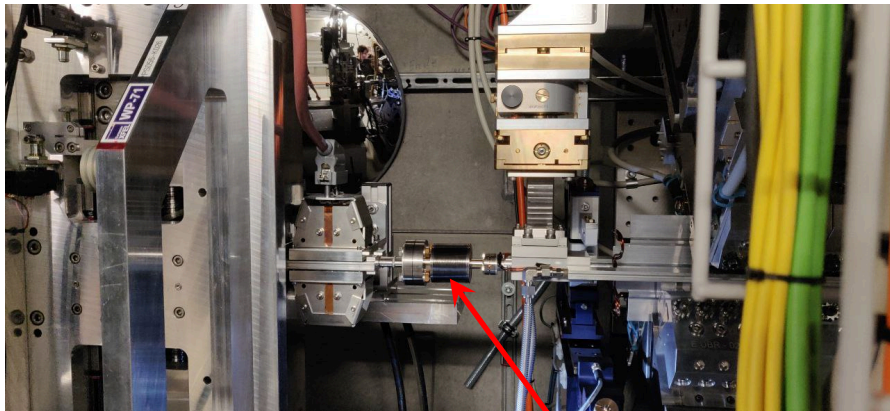
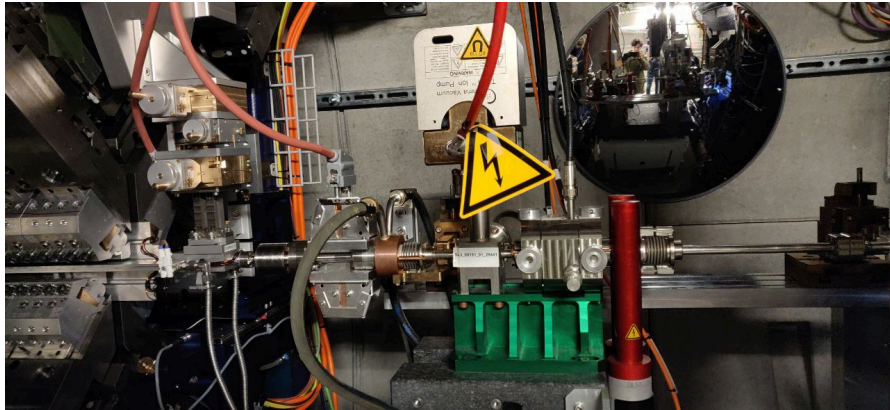
## APPLE X type of VC and the Air coils support structure for SCU afterburner

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  $\pm 1$  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.

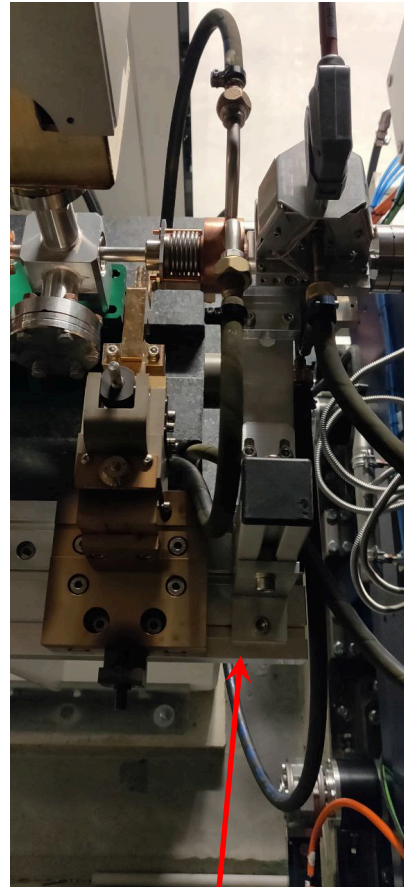


Cut through the RF-SCU Bellow for the connection on the bellow of the SCU EBC chamber. The bellow allowed to move the beam lateral  $\pm 1$  mm.

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

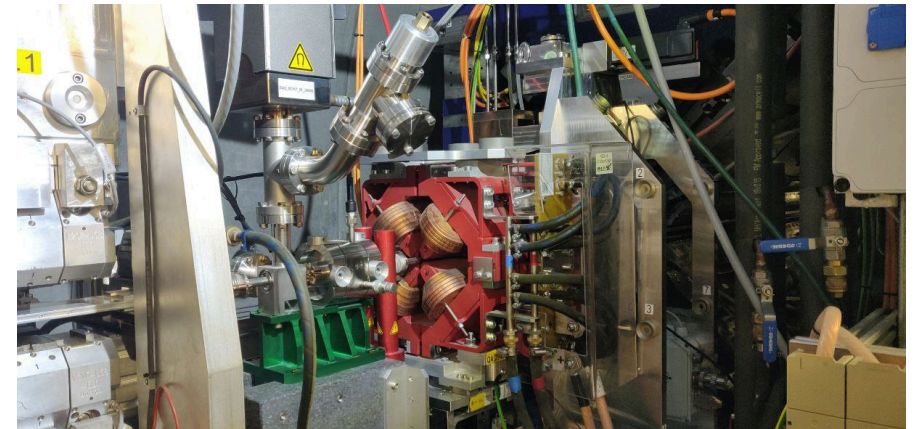
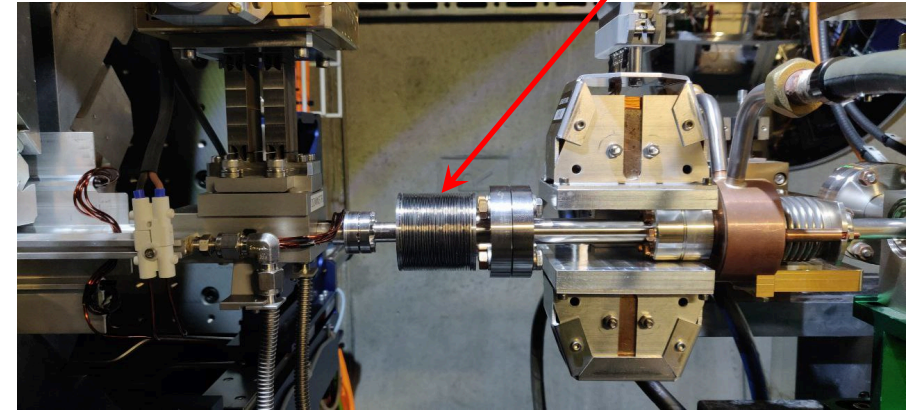


Similar Bellows (Entrance Side)

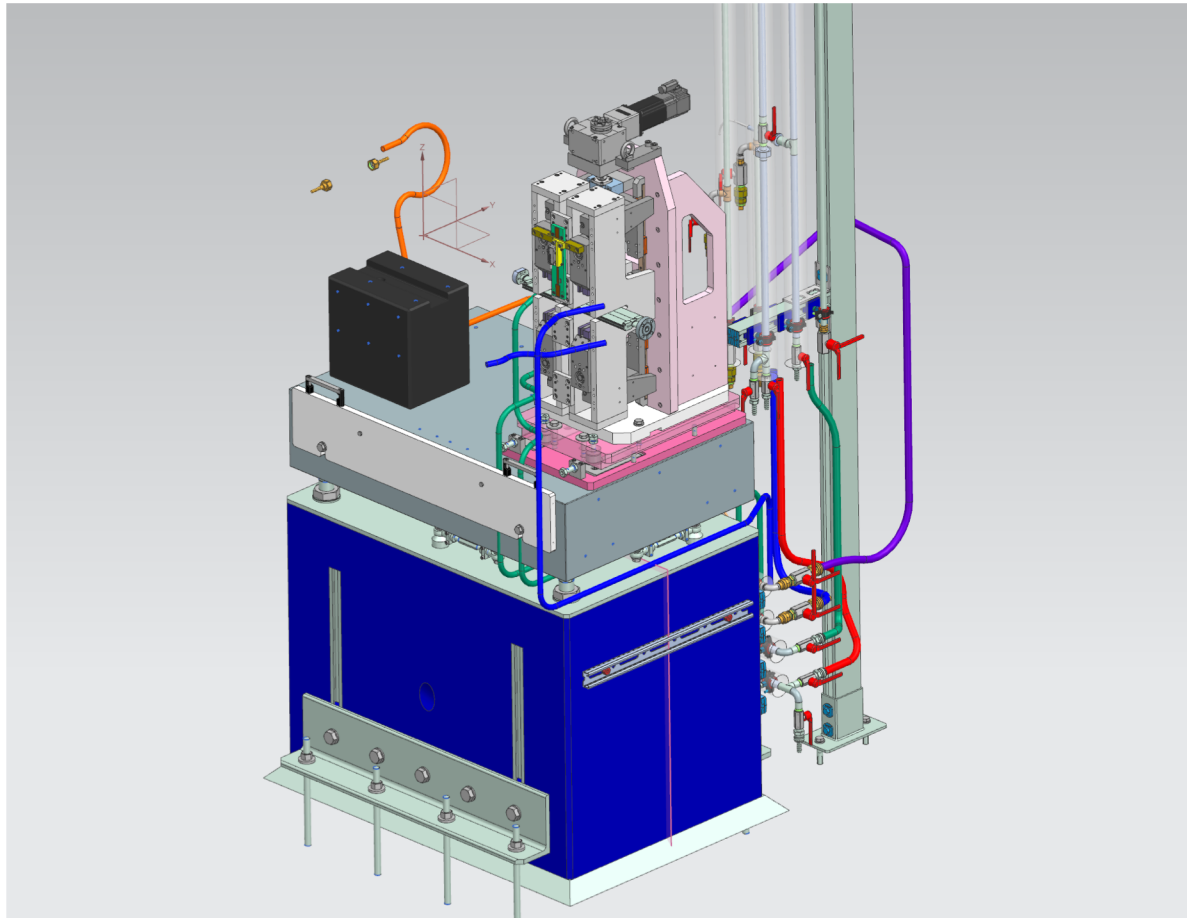


Same Intersection VC and Air Coils Support Structure

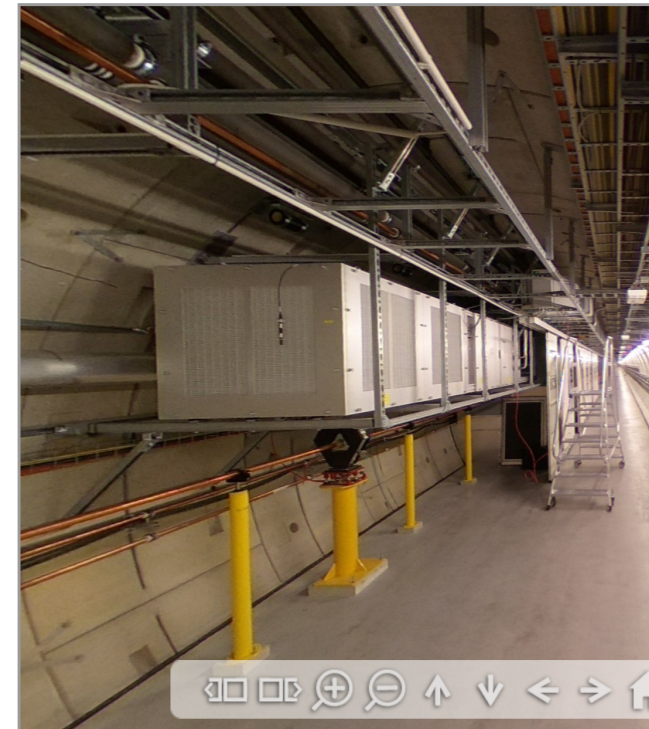
Similar Bellows (Entrance Side)



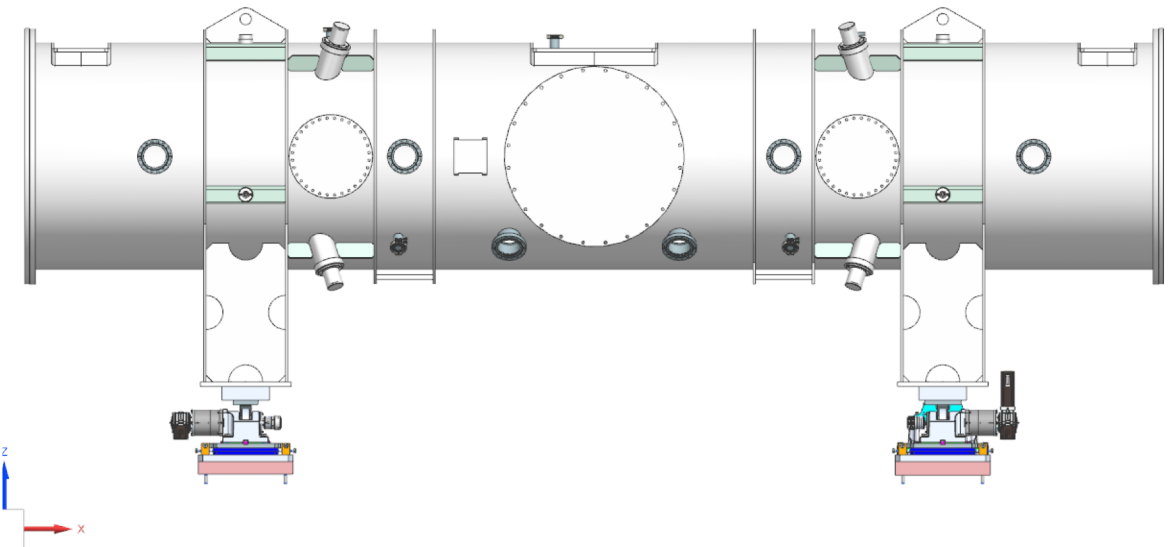
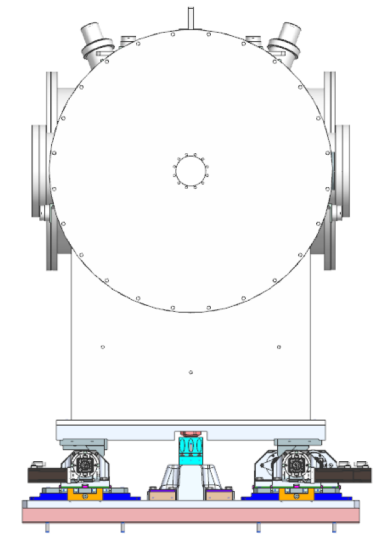
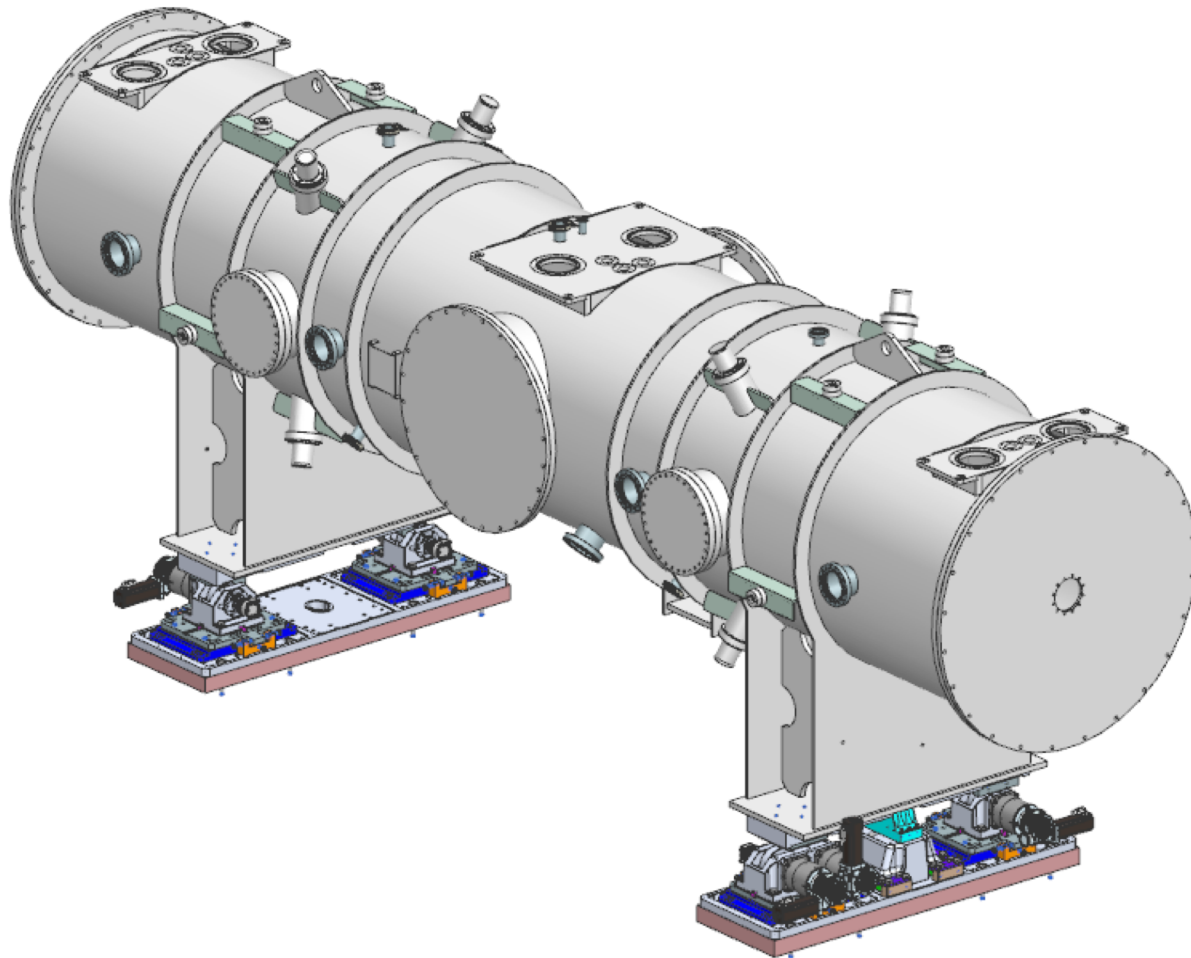
# Implementation of phase shifter alignment platform



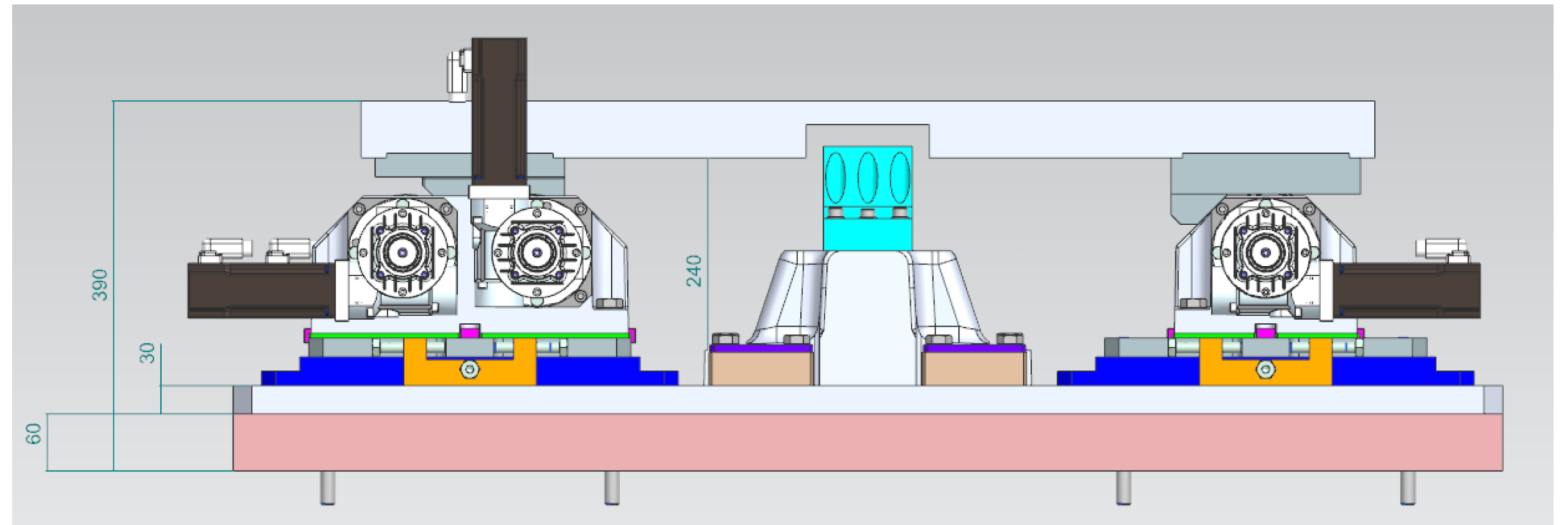
- All new 6 intersections will be longer than the present ones: from 1.1m to about 1.5 m
- The first intersection will host an RF valve to separate the vacuum of the room temperature to the cold sections and one bellows allowing the alignment of the SCU modules and compensating the thermal shrinkage
- 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

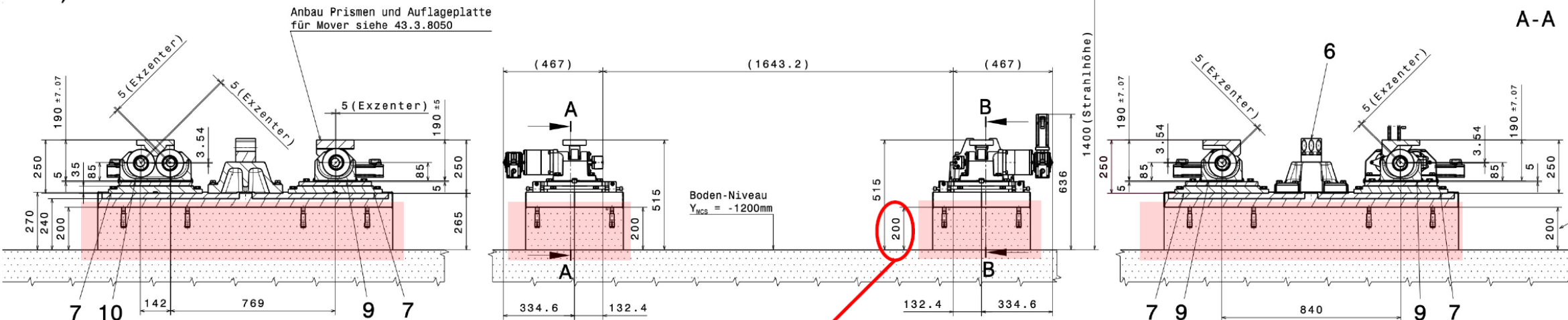


- Top plates are the interface
- Transversal width of the supports should match the plate
- Threaded holes, pins and central hole should be implemented (see next slide)
- Reference marks at “known” distance ( $\pm 0.05\text{mm}$ ) from the above mentioned pins
- Nominal height of the grouting is 60mm: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

SCU CAM movers Daniele La Civita 09.11.2022

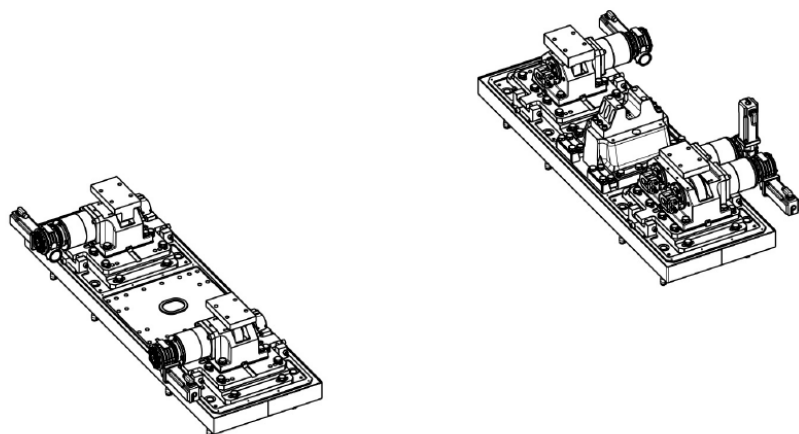
# Cam movers similar to APPLEX

1:10)



Will be about 50mm

Shorter concrete pedestals according to interface with cryostat



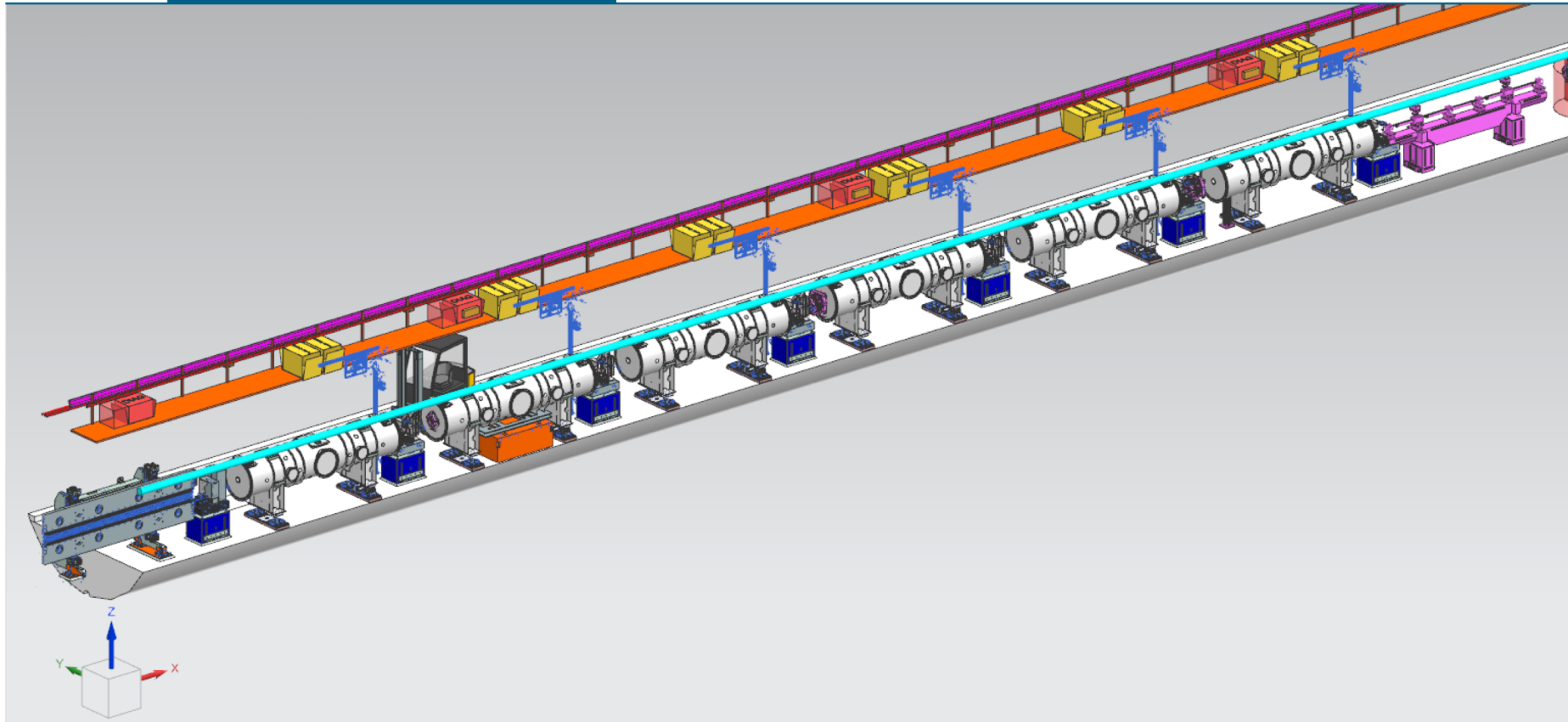
# SCU afterburner section XTD1



- 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

Discovery Center XFEL Integration S-PRESSO-D10000000761802/A001(!) 🔒 🔍





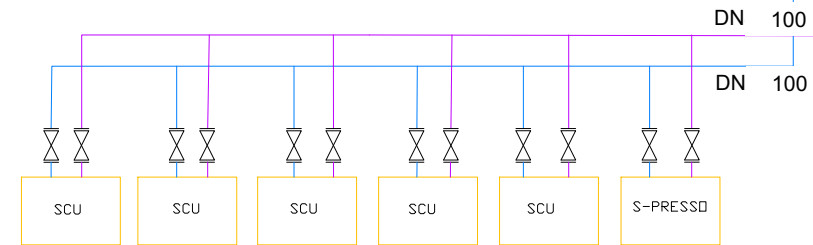
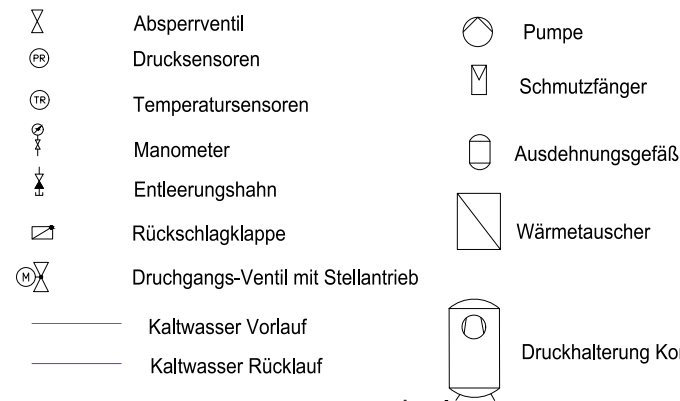
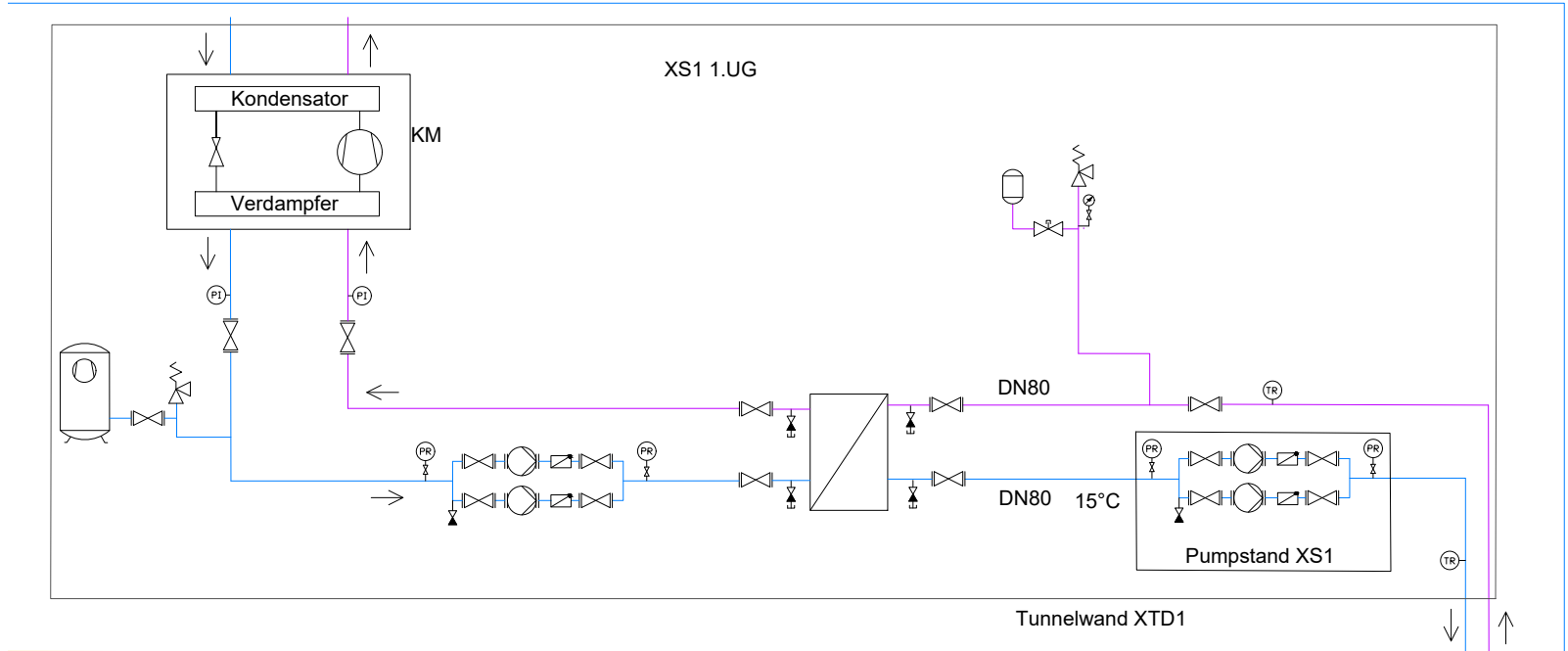
# Example of cryocooler

- 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 supplying pipe will be used to supply the SCU main power supplies with the cooling water. Aluminum heat exchanger Under discussion



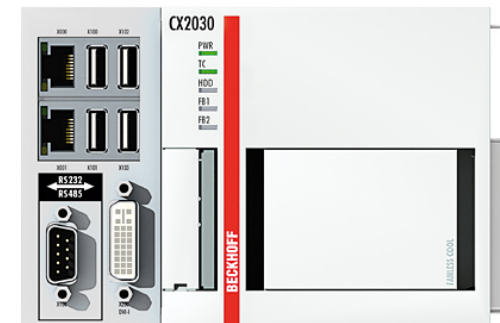
Leckagemelder u. Rohrleitungsheizung ergänzt		11.09.20	Koch
Index	Aenderung	Datum	Name
Planungsstand: Ausführung A2	Obj.-Nr.: XFEL	Projekt: Gwex/Parttyp: Bauabschnitt Ebene: Blatt-Nr.: Fortlaufende-Nr.	B
Formelzeichen: MKK2	Maßstab: ohne	Titel: XTD1_S-Presso XTD1	
Deutsches Elektronen-Synchrotron DESY Notkestr. 85 22607 Hamburg		Datum: 16.01.2022	Name: D. Eckstein
Schema Kalt-/Kühlwasser		Dokument-Nr.: DOCUMENT SIG.	Blatt 1
© 2022 Eigentum von DESY. Alle Rechte vorbehalten. Vor der Nutzung dieses Diagramms sind die geltenden Vorschriften zu berücksichtigen. Änderungen sind nur durch schriftliche Genehmigung von DESY zulässig. DESY ist nicht verantwortlich für Schäden, die aus der Nutzung dieses Diagramms resultieren.			Blatt 1 von 1

# Additional Requirements to the Superconducting undulator PRE-SeriesS 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

EPLAN\_...\_Modified for S-PRESSO

## IPC CX2030



## AX8206





# 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

Worksheet in Superconducting undulator afterburner

Code	Location	Equipment	Manufacturer	Quantity	Power	Voltage	Frequency	Notes							
XTD1	UG2	SCU Afterburner	2425 - 2467	F-50H Cryocooler Compressors	UNSYS - Mikhail Yakopov	36	CEE 400 V, 16 A	Drehstrom 400 V	1200	100%	1200	Ja	Nein	Nein	Operating Current 13A, Starting Current 75-90A
XTD1	UG2	SCU Afterburner	2425 - 2467	Main magnet power supply A, B	UNSYS - Mikhail Yakopov	12	Festanschluss ?	Wechselstrom 230 V	75000	100%	75000	?	Nein	Nein	Parameters of the power supplies can be changed once the exact model is decided.
XSS ?	?	?	?	Helmholtz coil A1, A2 power supply	MPC - Axel Haaberg	12	Festanschluss ?	Wechselstrom 230 V	300	100%	300	?	Nein	Nein	Parameters of the power supplies can be changed once the exact model is decided.
XSS ?	?	?	?	Correction coil A1, A2 power supply	MPC - Axel Haaberg	12	Festanschluss ?	Wechselstrom 230 V	300	100%	300	?	Nein	Nein	Parameters of the power supplies can be changed once the exact model is decided.
XSS ?	?	?	?	Helmholtz coil B horizontal, vertical power supply	MPC - Axel Haaberg	12	Festanschluss ?	Wechselstrom 230 V	300	100%	300	?	Nein	Nein	Parameters of the power supplies can be changed once the exact model is decided.
XSS ?	?	?	?	Correction coil B1, B2 power supply	MPC - Axel Haaberg	12	Festanschluss ?	Wechselstrom 230 V	300	100%	300	?	Nein	Nein	Parameters of the power supplies can be changed once the exact model is decided.
XSS ?	?	?	?	Phase shifter coil power supply	MPC - Axel Haaberg	6	Festanschluss ?	Wechselstrom 230 V	300	100%	300	?	Nein	Nein	Parameters of the power supplies can be changed once the exact model is decided.
XSS ?	?	?	?	Shim coil I-11 power supply	MPC - Axel Haaberg	66	Festanschluss ?	Wechselstrom 230 V	300	100%	300	?	Nein	Nein	Parameters of the power supplies can be changed once the exact model is decided.
XTD1	UG2	SCU Afterburner	2425 - 2467	Diagnostic Racks	MDI Fachgruppe 2 - Dirk Lipka	3	Festanschluss ?	Wechselstrom 230 V	0	100%	0	?	Nein	Nein	Parameters of the power supplies can be changed once the exact model is decided.
XTD1	UG2	SCU Afterburner	2425 - 2467	Undulator Control Rack (UCR) + Intersection Control Rack (ICR)	UNSYS - Mikhail Yakopov	3	CEE 400 V, 16 A	Drehstrom 400 V ?	0	100%	0	?	Nein	Nein	Parameters will be given once the design of the ICR is done.
XTD1	UG2	SCU Afterburner	2425 - 2467	Pumping stations MVS (2+1 spare) - horizontal cryostat	MVS	3	CEE 400 V, 16 A	Drehstrom 400 V ?	1800	100%	1800	Ja	Ja	Nein	
XTD1	UG2	SCU Afterburner	2425 - 2467	Pumping stations MVS D62 - horizontal cryostat	MVS	12	CEE 400 V, 16 A	Drehstrom 400 V	2000	75%	100	Ja	Ja	Nein	

Electrical Requirement	Power	Voltage	Frequency	Notes
Line Voltage (+/-10%)	AC 380, 400, 415 V / 50 Hz, 3 phase (3W+PE)	AC 400, 480 V / 60Hz, 3 phase (3W+PE) (Aground, Commercial Power Source)		
Operating Current	Max. 13 A (Both 50 and 60 Hz)			
Starting Current	75/ 80 A (50/ 60Hz)			
Min. Circuit Ampacity	17 A			
Max. Fuse or Circuit Breaker Size	30 A			
Power Requirement	Minimum 9 kVA			
Power Consumption	Recommended 12 kVA			
	Max. 8.3 kW / Steady State 7.8kW at 60Hz			
	Max. 7.2 kW / Steady State 6.9kW at 50Hz			
	See the ELECTRICAL SCHEMATIC of "APPENDIX" for detail.			

Qty	Type	Company	Name / Type	Voltage / grid	Regular operation power [kW]	Maximum power [kW]
2	main magnet power supply	ibid	ibid	200-240V, 50/60Hz	25	75
2	auxiliary heater power supply, adjustable	ibid	ibid	200-240V, 50/60Hz	0.1	0.3

Power Supply

Code	Location	Equipment	Manufacturer	Quantity	Power	Voltage	Frequency	Notes
XTD1	UG2	SCU Afterburner	2425 - 2467	F-50H Cryocooler Compressors	UNSYS - Mikhail Yakopov	36	CEE 400 V, 16 A	Drehstrom 400 V
XTD1	UG2	SCU Afterburner	2425 - 2467	Main Power Supplies	UNSYS - Mikhail Yakopov	12	Festanschluss ?	Wechselstrom 230 V
XTD1	UG2	SCU Afterburner	2425 - 2467	Diagnostic Racks	MDI Fachgruppe 2 - Dirk Lipka	3	Festanschluss ?	Wechselstrom 230 V

**For Water**

**For Antifreeze (50/50 mixture of water and ethylene glycol or propylene glycol)**  
The larger circulating pump will be required for the Antifreeze

**Simplified possible diagram of water supply for the cryocooler compressors**

Trinkwasserpumpe  
Vorlauf DN 65 VE16 Grad  
Rücklauf 20 Grad  
Kryokühler-Kompressoren  
Nächste SCU x 5

**Cooling water requirement**

Min. Flow Rate: 7 ltr/min @ 28deg C (1.85 gal/min @ 82.4 deg F)

Temperature Range: 4 to 28 deg C (39.2 to 82.4 deg F)

Quality: See the Figures 1.1 and Table 1.2

**Table 1.2 COOLING WATER SPECIFICATIONS**

CHARACTERISTICS	INLET Temperature Range [deg.C] [deg.F]	INLET Pressure Range [MPa] [psig]	Flow Rate [litter/min.] [gallon/min.]	Pressure Drop [MPa] [psig]	Heat Output [kW] [BTU/Hr]
	[4.0 - 28.0] [39.2 - 82.4]	[0.10 - 0.69] [14.5 - 100]	[4.0 - 10.0] [1.1 - 2.6]	[0.025 - 0.085] [3.55 - 12.1]	<Steady State> [ $< 6.5$ ] [ $< 22180$ ] for 50Hz [ $< 7.5$ ] [ $< 25590$ ] for 60Hz <Maximum> [ $< 7.2$ ] [ $< 24570$ ] for 50Hz [ $< 8.3$ ] [ $< 28320$ ] for 60Hz

Water Supply

## Operational packages involved in shutdown 2025

SCU	OP-330: Controls
SCU	OP-341: Vacuum
SCU	OP-345: Magnets
SCU	OP-360: Diagnostic
SCU	OP-515: Trans. & Align
SCU	XFEL Undulator Group

T. Wilksen and R. Bacher
S. Lederer and T. Wohlenberg
R. Wickmann and W. Decking
D. Lipka and Kay Wittemburg
J. Prenting and M. Schloesser
M. Yakopov and S. Casalbuoni

# Thank you for your attention !