Measurements of one of the S-PRESSO 2 m long coil in SUNDAE1

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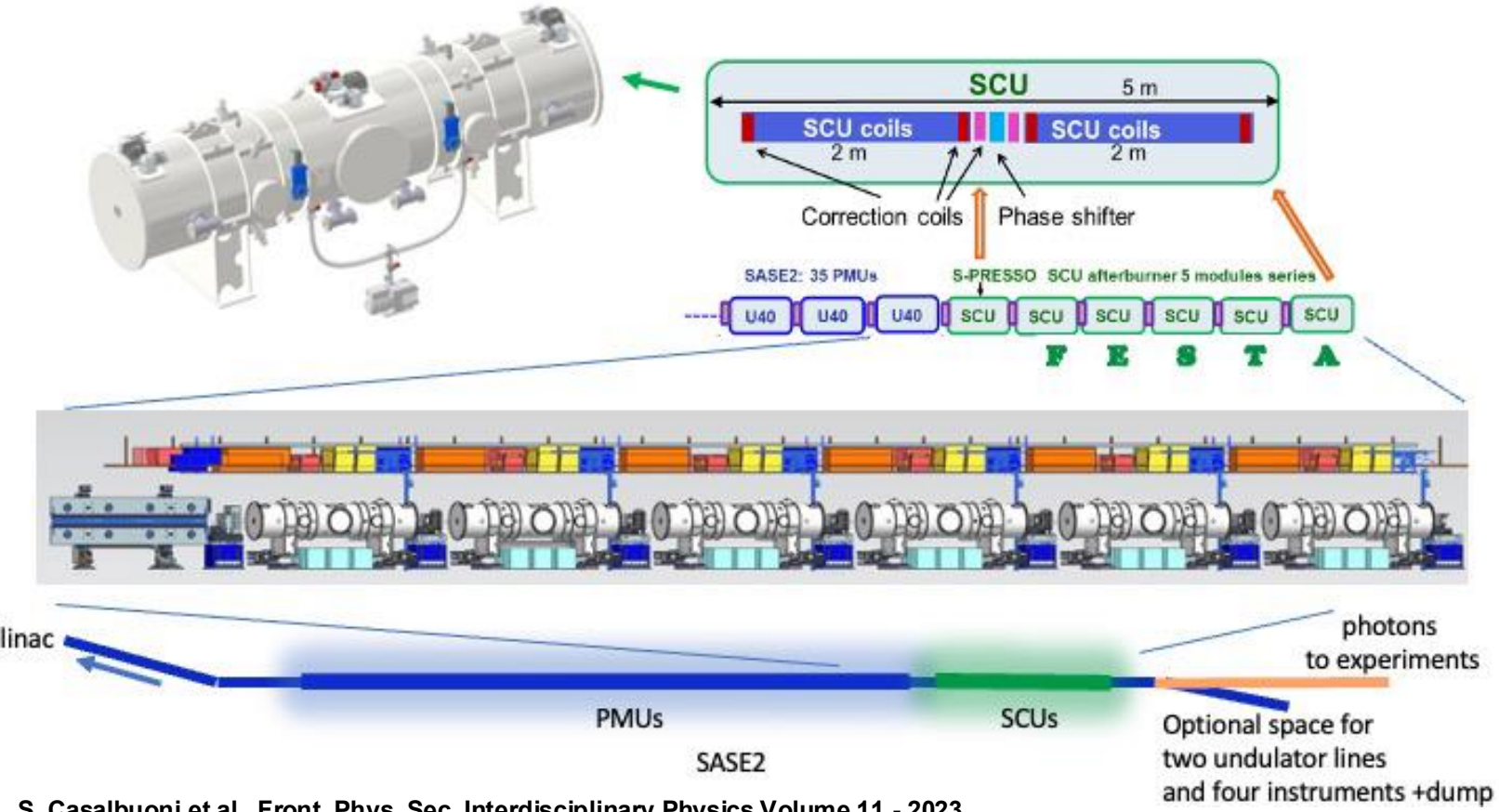
Outline

- Introduction
- Commissioning of SUNDAE1 with S-PRESSO Mockup
- Results of 2 m long S-PRESSO Magnet A
- Summary

SCU afterburner planned at EuXFEL



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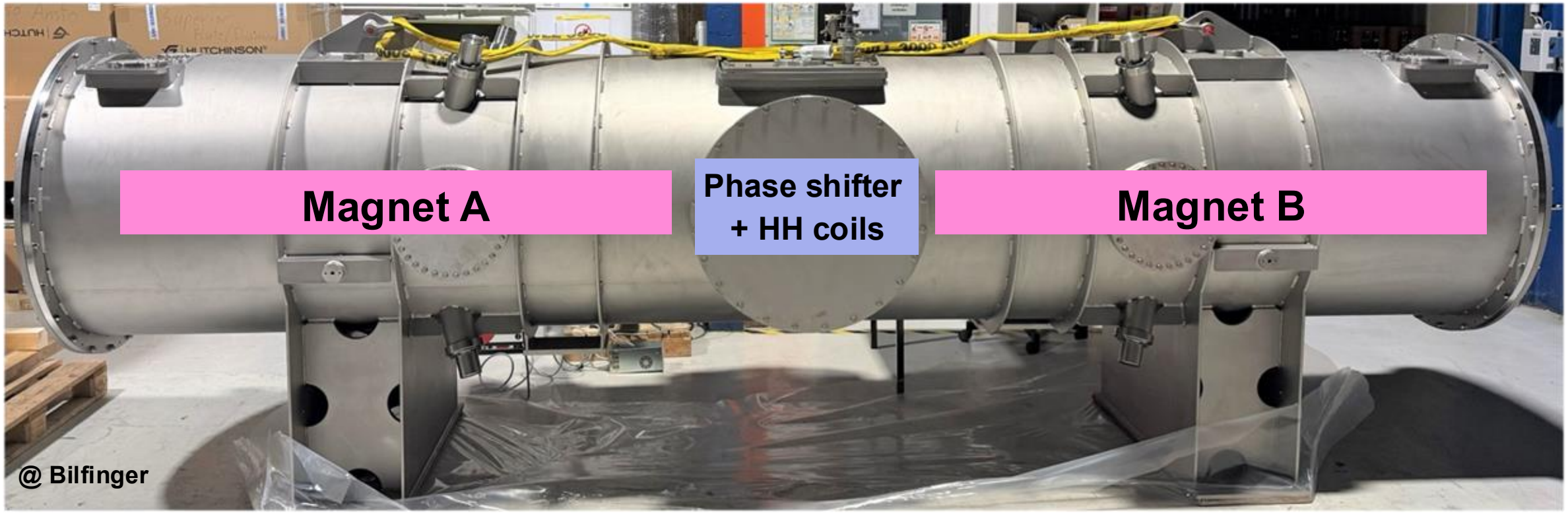
Tunnel before infrtastructure installation of SCU modules before

Tunnel prepared for installation of SCU modules

Photos courtesy of M. Yakopov

S-PRESSO



Courtesy of A. Hobl

S-PRESSO

Period	18 mm
Peak field	1.82 T
K	3.06
Vacuum gap	5 mm
Beam heat load	≤ 10 W

Phase shifter and correction coils

Vacuum chamber prototype
10 mm x 5 mm

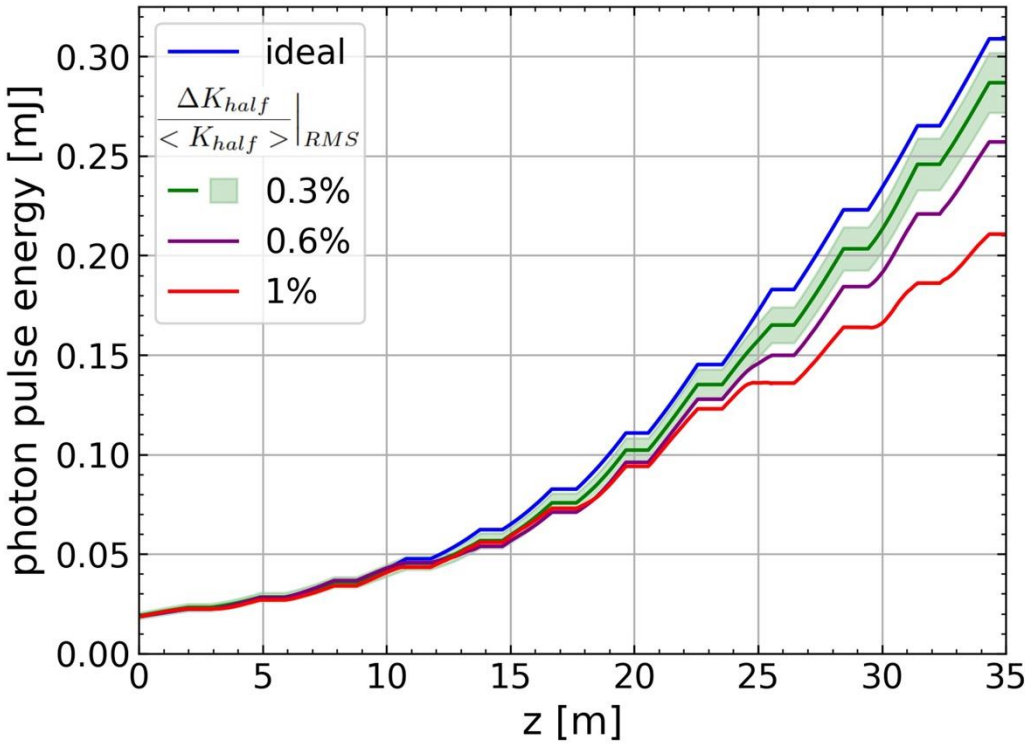
Vacuum chamber prototype

One SCU coil of Magnet A

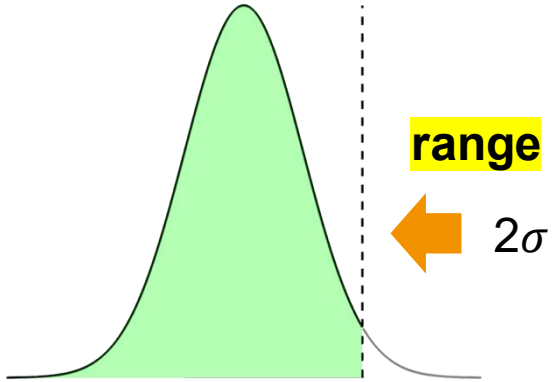
Courtesy of A. Hobl

Requirements on field quality

- Third harmonic lasing at 60 keV
- Simulations are performed with Genesis1.3 v4*
- Effect of different field error $\left.\frac{\Delta K_{half}}{<K_{half}>}\right|_{RMS}$ for 60 keV



- Normal Gaussian distribution $\left.\frac{\Delta K_{half}}{<K_{half}>}\right|_{RMS}$
  - Maximum of $\left.\frac{\Delta K_{half}}{<K_{half}>}\right|_{RMS}$ < 2σ



- Drop in energy pulse:
  - 5% for $\left.\frac{\Delta K_{half}}{<K_{half}>}\right|_{RMS}$ = 0.3%
  - 18% for $\left.\frac{\Delta K_{half}}{<K_{half}>}\right|_{RMS}$ = 0.6%
  - 31% for $\left.\frac{\Delta K_{half}}{<K_{half}>}\right|_{RMS}$ = 1%

<20% reduction of the total photon pulse energy

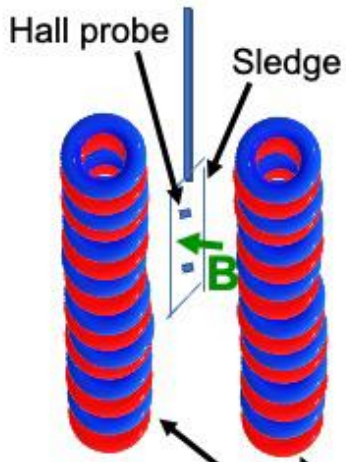
*S. Reiche and C. Lechner, IPAC'24

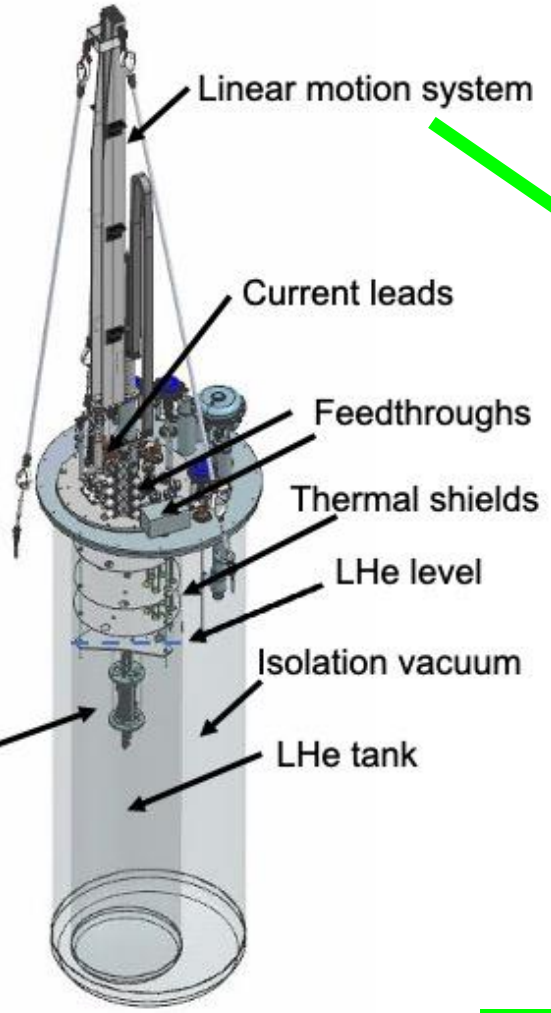
Courtesy of G. Perosa

SUNDAE1 is used to train the SC coils and to measure the magnetic field profile on axis with Hall probes from which the trajectory straightness (I_2) can be calculated

SUNDAE1

- Test coils up to 2 m long
- 2 power supplies +/-1500 A
- 6 power supplies 20 A
- 4 current leads: 1000 A
- 4 current leads: 500 A
- Fixed He level
- Operation temperature: ~ 2 K or ~ 4 K





- Training
- Magnetic field profile measurements with Hall probes

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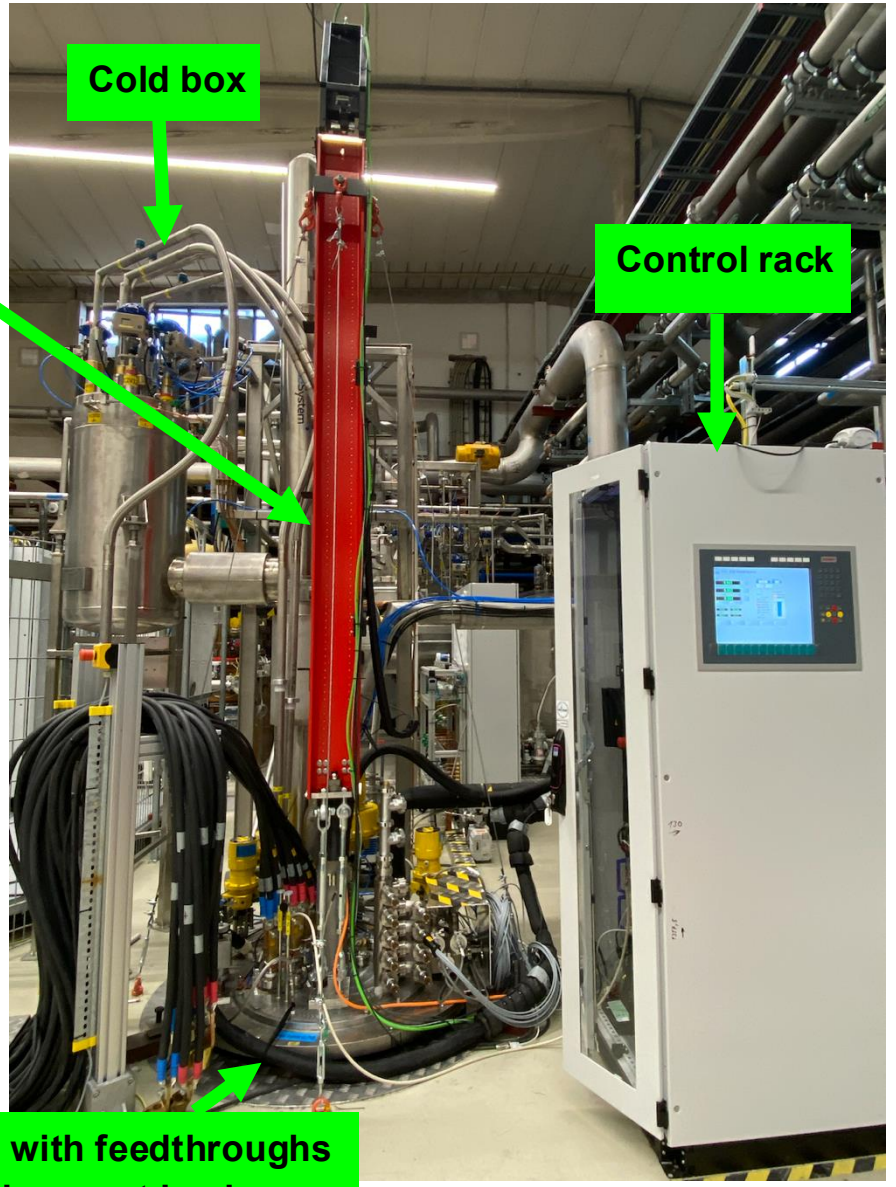

B. Marchetti *et al* 2022 *J. Phys.: Conf. Ser.* 2380 012027

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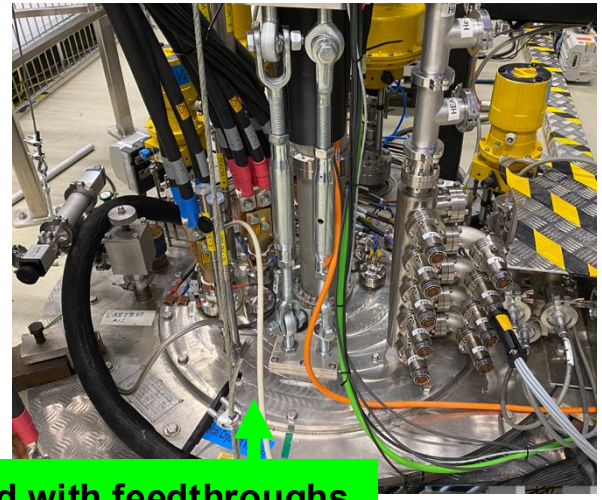
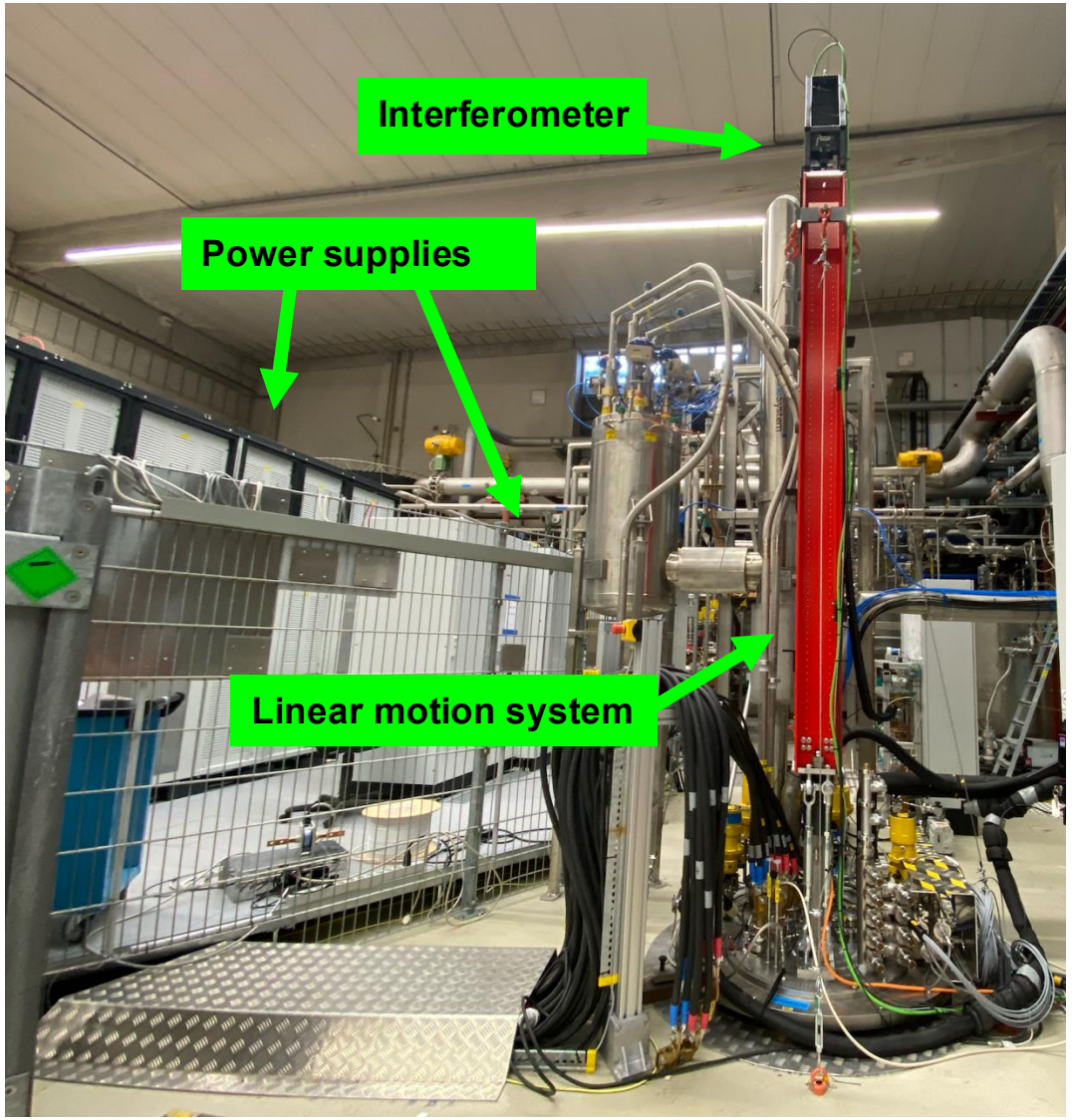


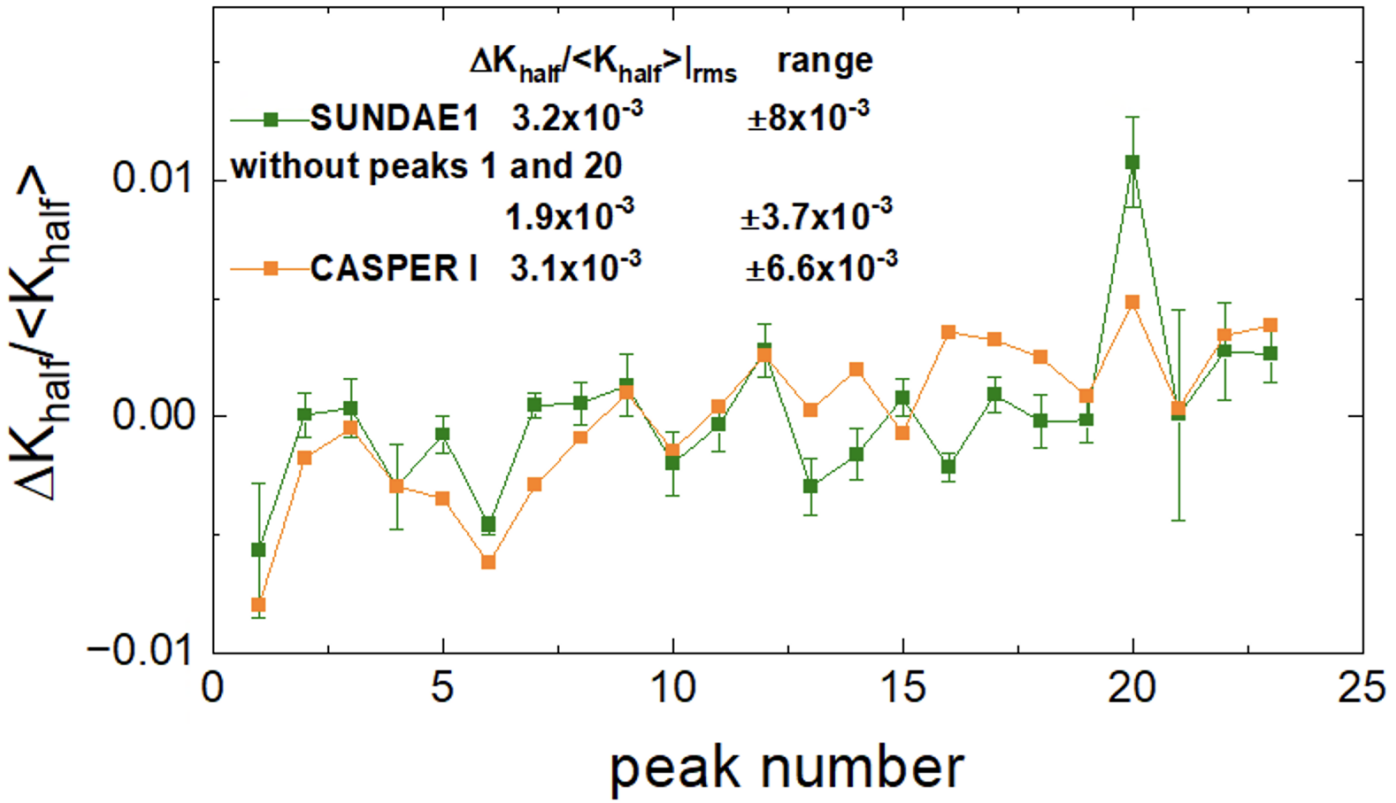
Lid with feedthroughs and current leads



Commissioning of SUNDAE1 with S-PRESSO Mockup 0.3 m long

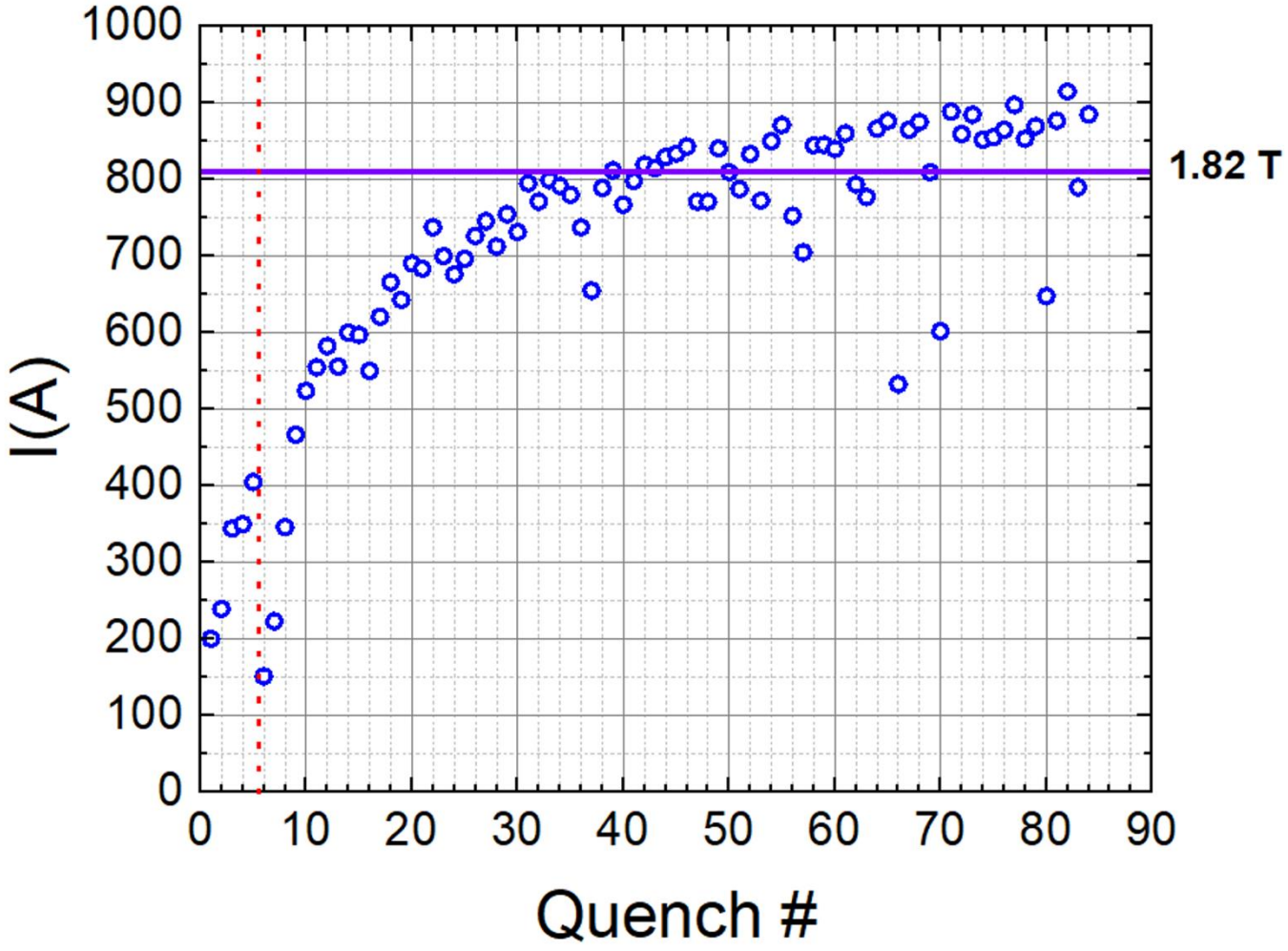
- Stability: Coil supplied with 900A for 16 hours
- Quench: Memory effect after thermal cycle confirmed in SUNDAE1
- Field quality confirmed
- Repeatability error on $\Delta K_{half}/\langle K_{half}\rangle$ ~0.1%

For more details please see A. Elghandour. Poster MO125



Measurement of Magnet A

Training of Magnet A



Specified magnetic field on axis

1.82 T at 16.5 GeV corresponds to 25 keV allowing overalp to the first harmonic of the installed permanent magnet undulators in SASE2

SASE2 demonstrated lasing up to 30 keV with 16.5 GeV (1.64T → 700A)

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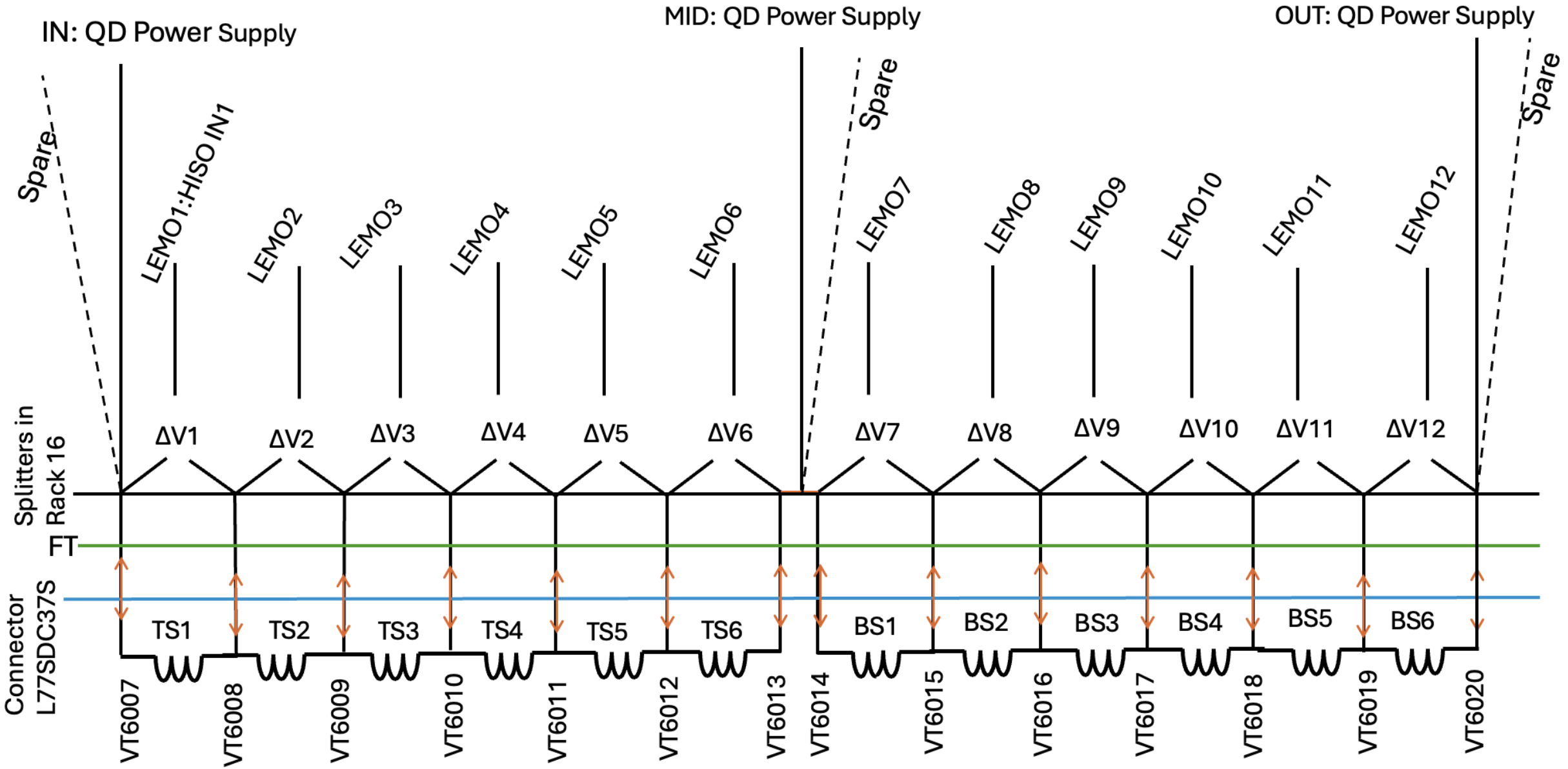
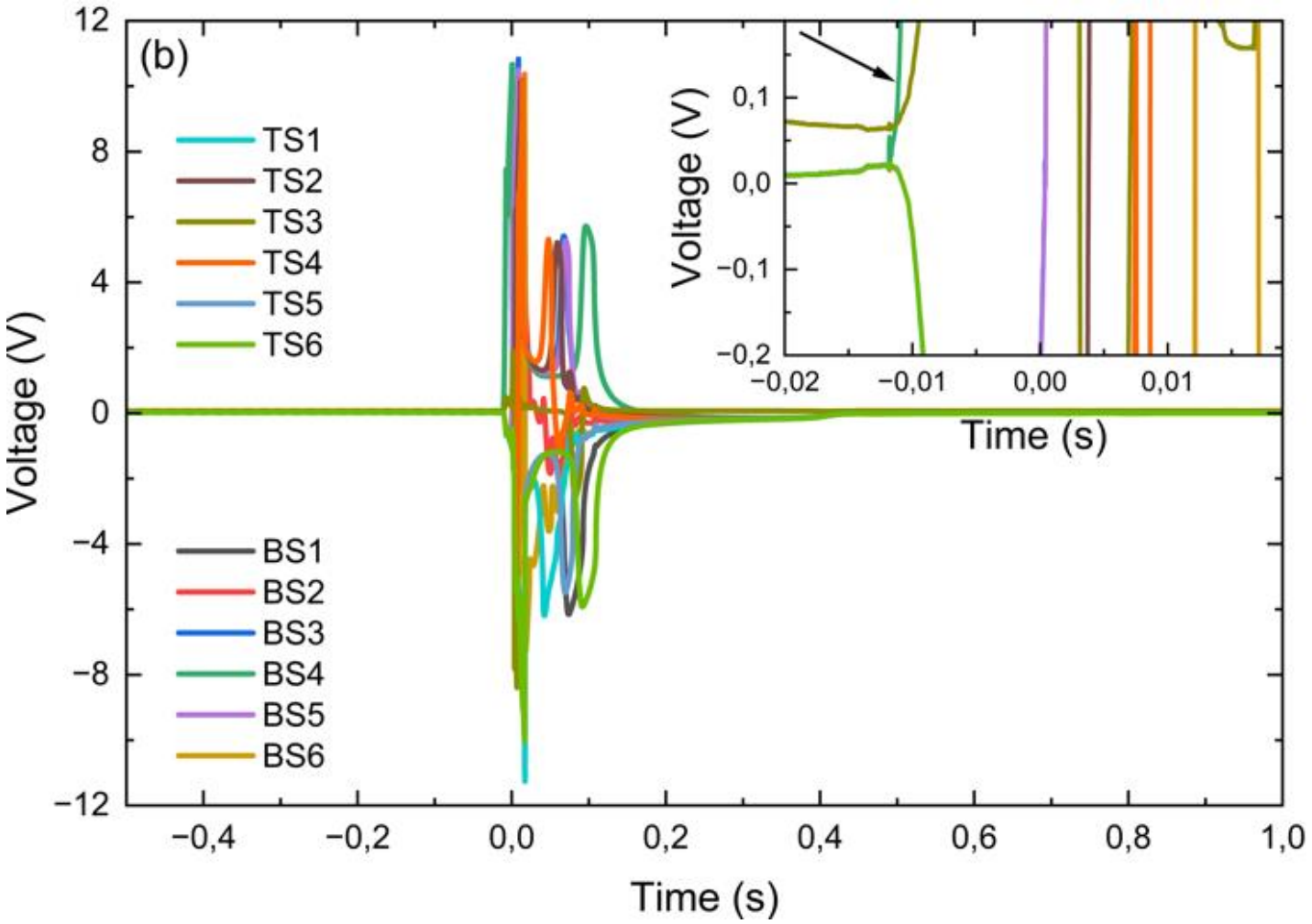
Schematic of voltage taps connection of Magnet A



TS= Top Section, BS = Bottom Section, QD = Quench Detection

Typical quench

- Voltage-tap signals during a quench at 884 A



- Settings quench

$\Delta V > 100$ mV

$\Delta t > 10$ ms

- The inset shows the onset of the event and identifies BS4 as the quench-origin section

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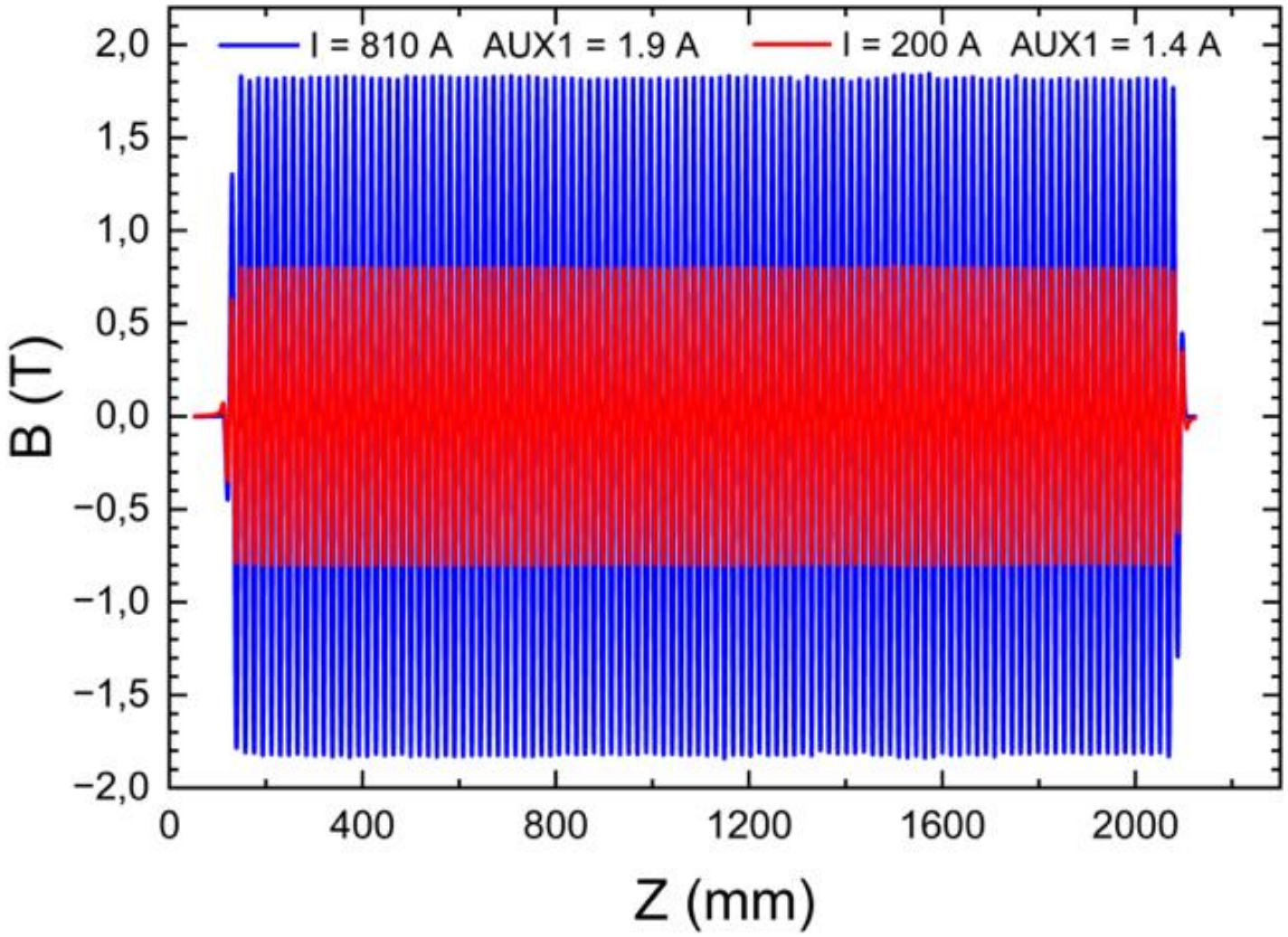
Field profile



Specified magnetic field on axis 1.82T reached at 810 A

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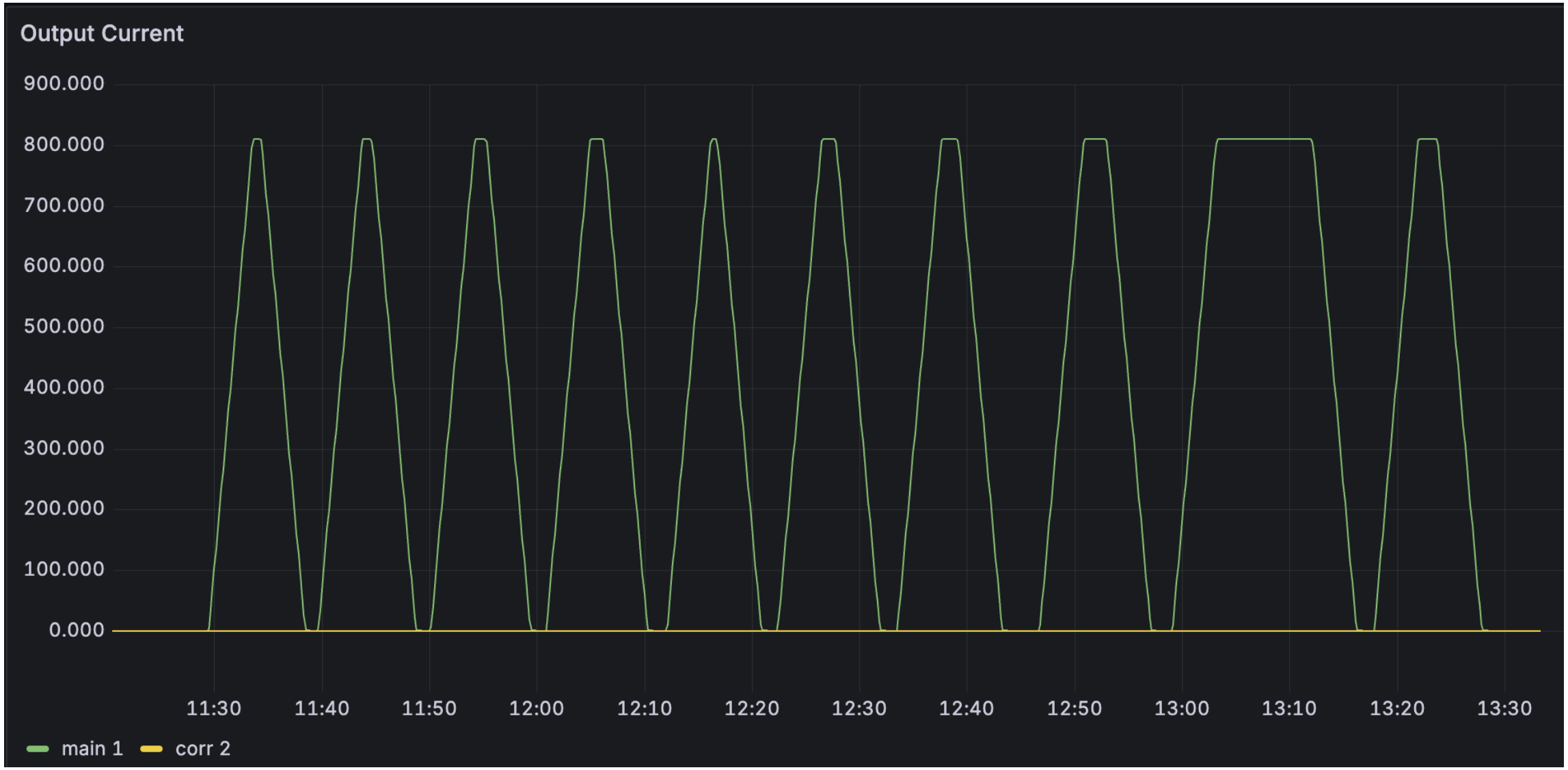
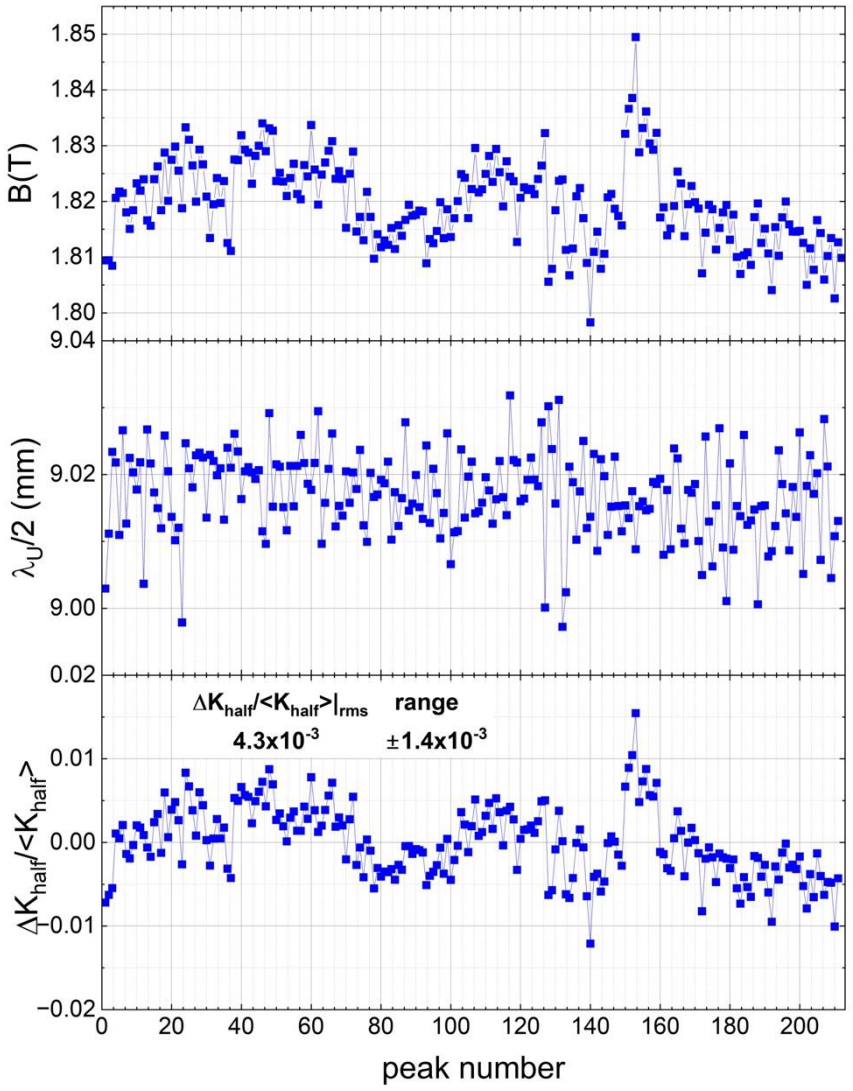
Nominal current corresponding to 1.82 T reached 10 times in a row



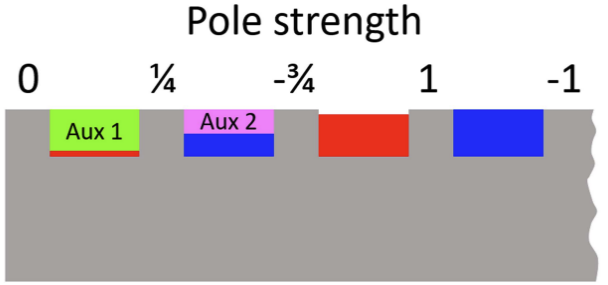
Stability at nominal current for more than 8 hours

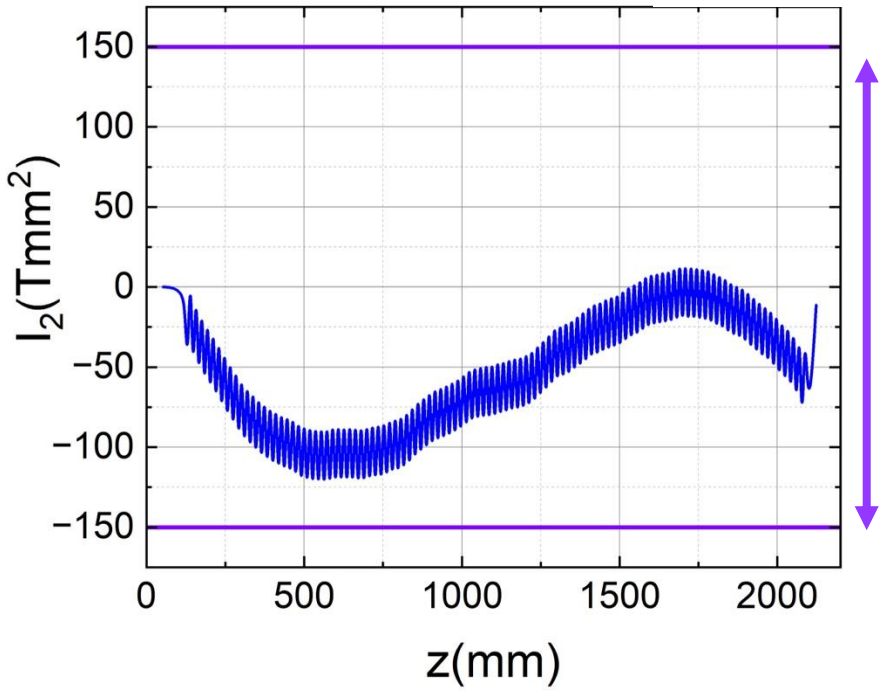
Measured field quality Magnet A



Main AUX1 AUX2
800A -0.35A 3A (entr)
-3A(exit)

End field configuration





5 µm
@16.5 GeV

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Measured field quality Magnet A

- The FEL process requires that photons emitted along the undulator overlap spatially: beam dimensions $\sigma \approx 20\ \mu m$> beam trajectory ($\propto I_2$)
- In addition, only very small variations of K_{half} are allowed so that the emitted photons stay in phase and interfere constructively.
- The measured deviations of K_{half} limit the photon pulse - energy loss to under 20% (i.e., pulse energy $\gtrsim$ 80% of ideal) at 60 keV, comfortably meeting acceptance criteria
- The robust support structure, which secures the magnet's top and bottom coils, effectively prevents long-range magnetic field errors - under cryogenic conditions and strong magnetic forces

Conclusions and Outlook

- Presented magnetic characterization of a S-PRESSO 2-m SCU magnet, to our knowledge the longest SCU coil produced and magnetically tested to date
- Characterization validates coil design and manufacturing
- Demonstrates integration of magnetic tests into the production workflow
- Represents a key step toward scaling SCU production

Thank you for your attention!