Status of P2

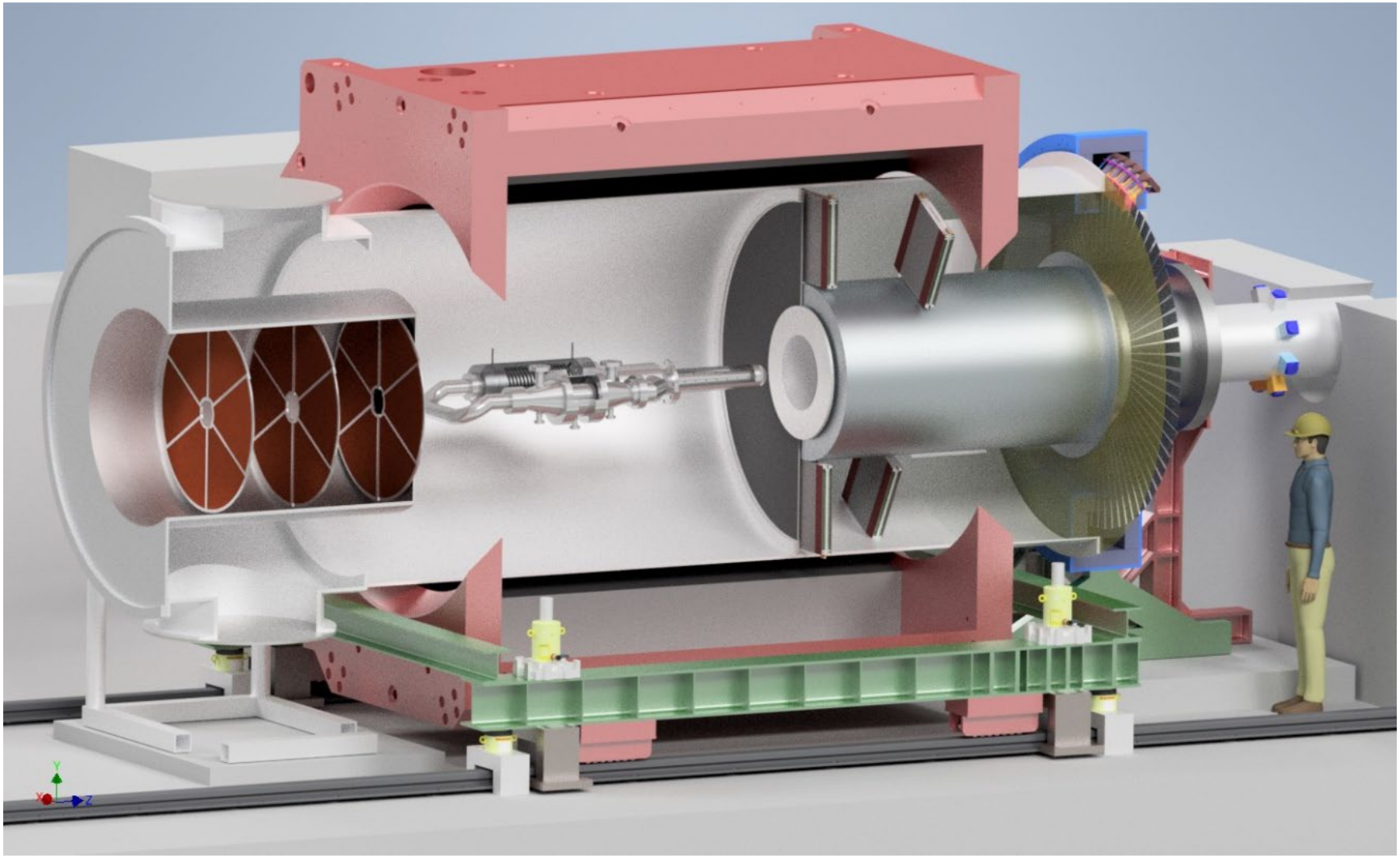
S. Baunack

2024/09/18, Mainz Meeting

Outline

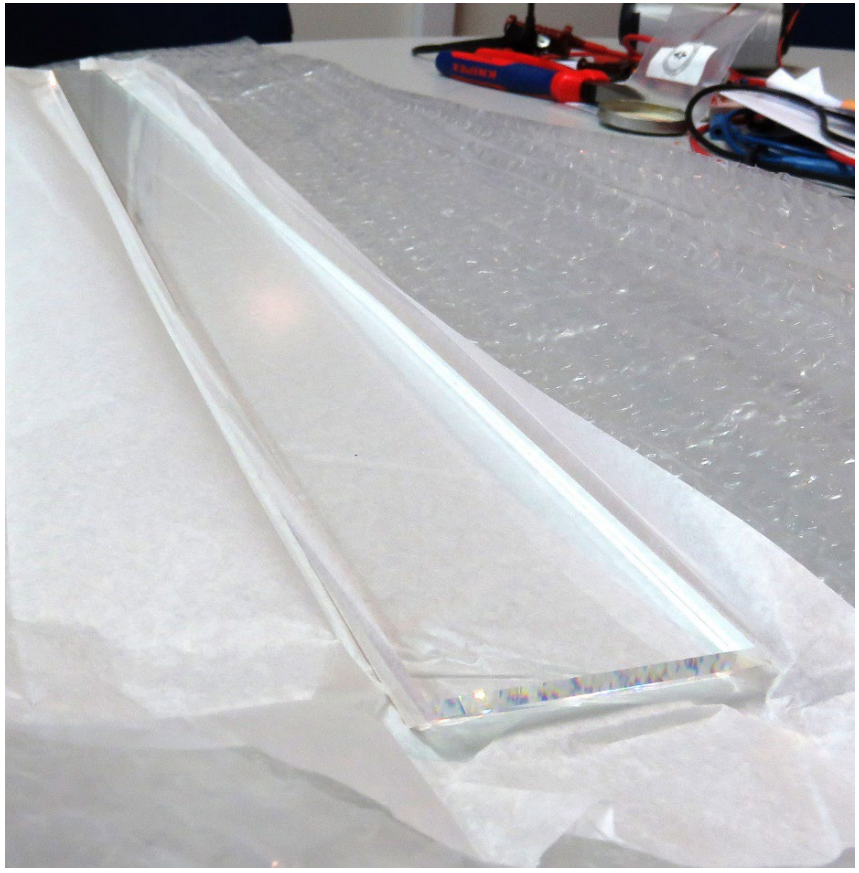
- Spectrometer detector
- Superconducting coil
- Scattering chamber
- Detector readout
- Luminosity monitors
- Computing
- Refrigerator
- Tracker

P2 experiment: Setup



Spectrometer: Fused silica bars

- Manufacturer: Heraeus Quarzglas GmbH
- Material: Spectrosil 2000



- Award of contract: 10/2020
- 100% delivered (90 pieces), most recent delivery 03/2022
- Measurement of the dimensions finished

Spectrometer: Fused silica bars

Specified dimensions:

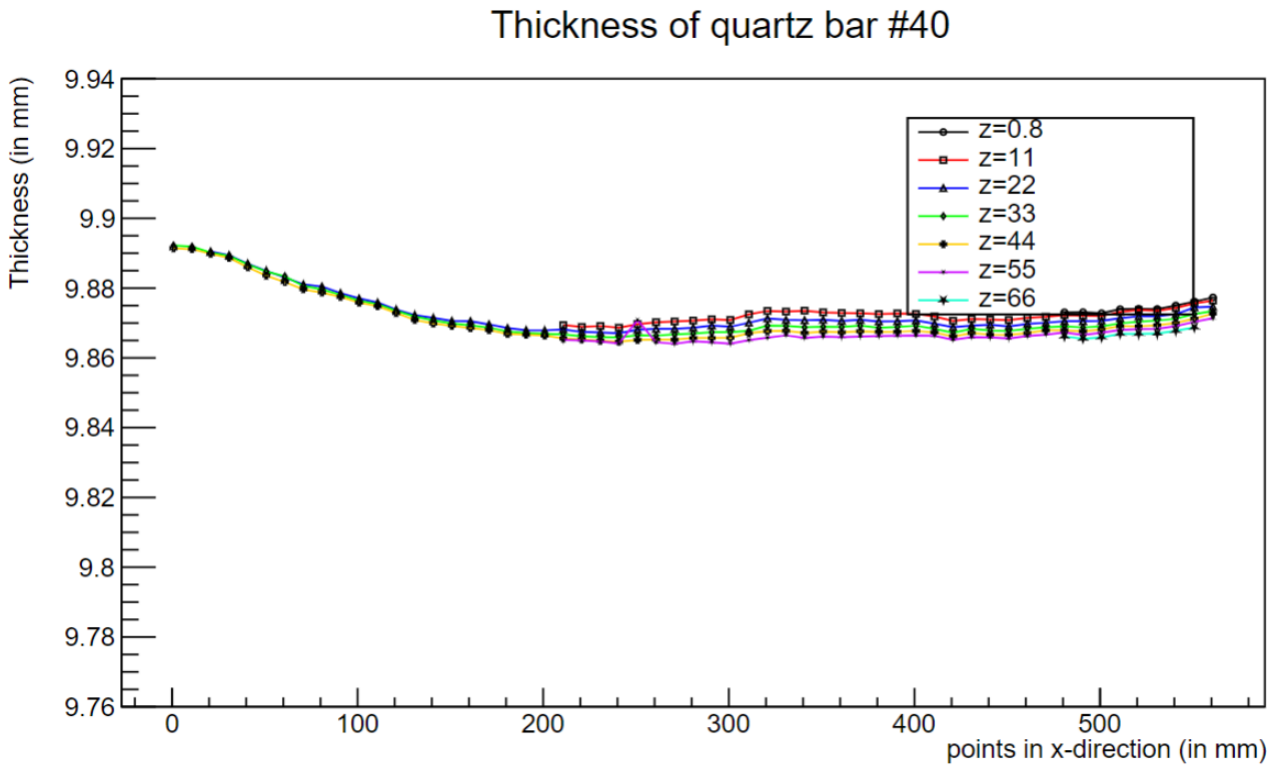
Platte, SPECTROSIL 2000, allseitig poliert

Length: 650,00 mm ± 0,50 mm

Width: 67,60 mm ± 0,50 mm

Thickness: 10,00 mm ± 0,20 mm

Typical example



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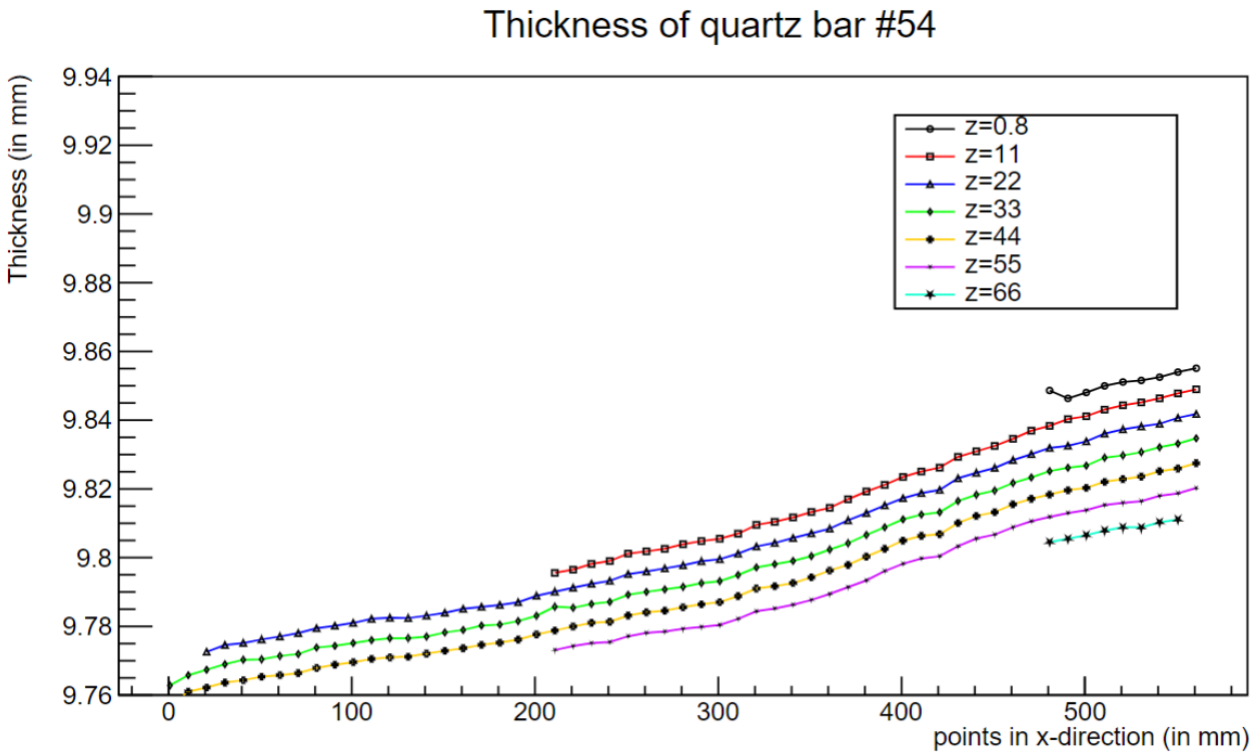
Not so typical example



Spectrometer: Photomultiplier

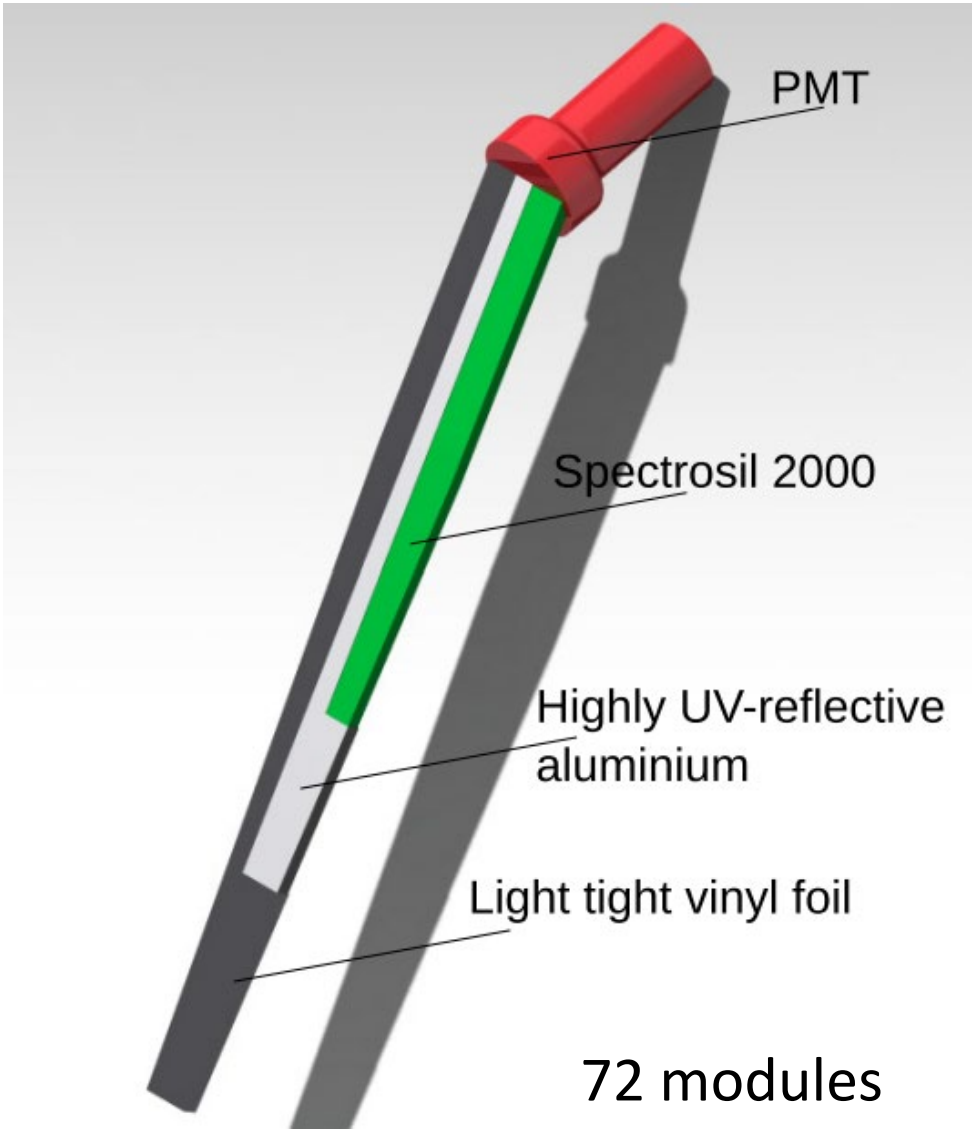
- Manufacturer: ET Enterprises
- Model: 9305QKB
- Award of contract: 11/2021

- 100% delivered (300 pieces), latest delivery 04/2023
- Testing and characterization almost completed (~90%)

High voltage supply

- Manufacturer: CAEN
- A 7030N modules
- Output voltage max. 3.5 kV
- 144 channels in total
- Order 06/2021, Delivery 03/2022

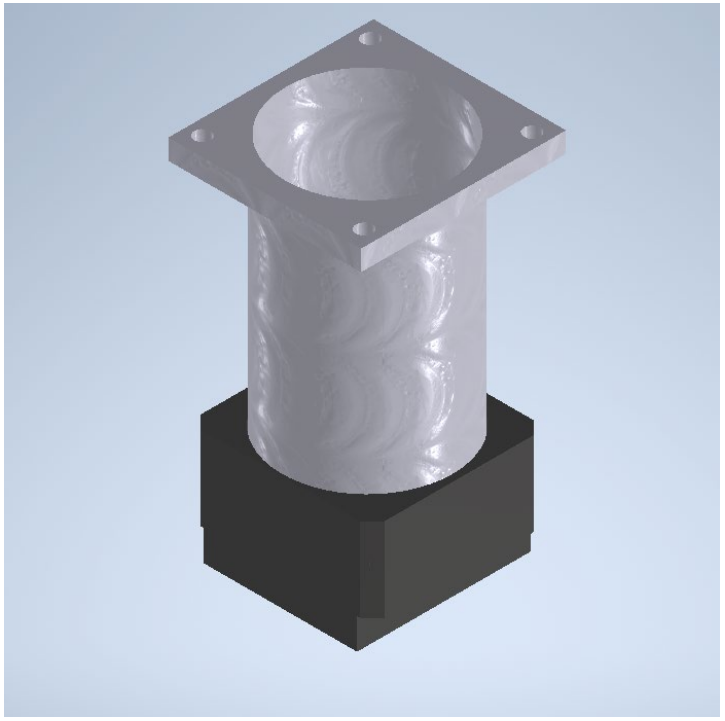
Spectrometer: Detector support

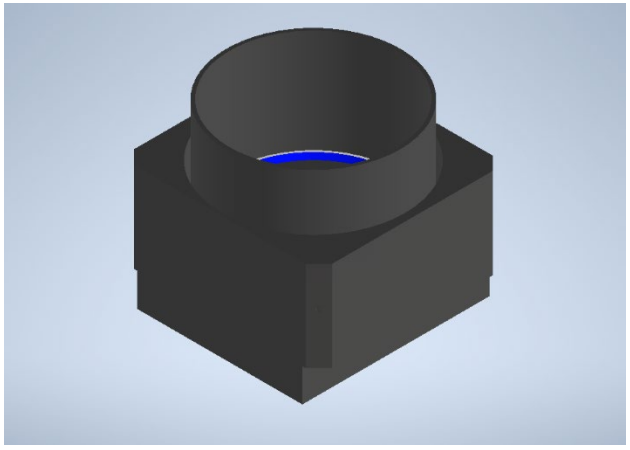


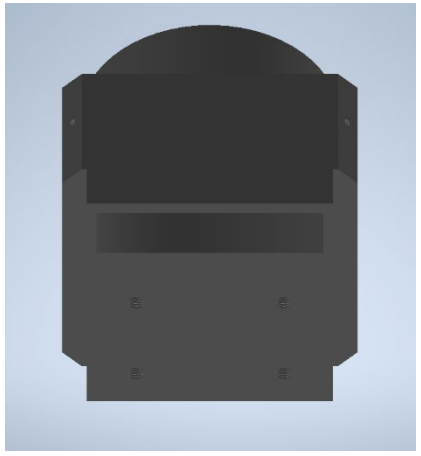
72 modules

Spectrometer: Detector support

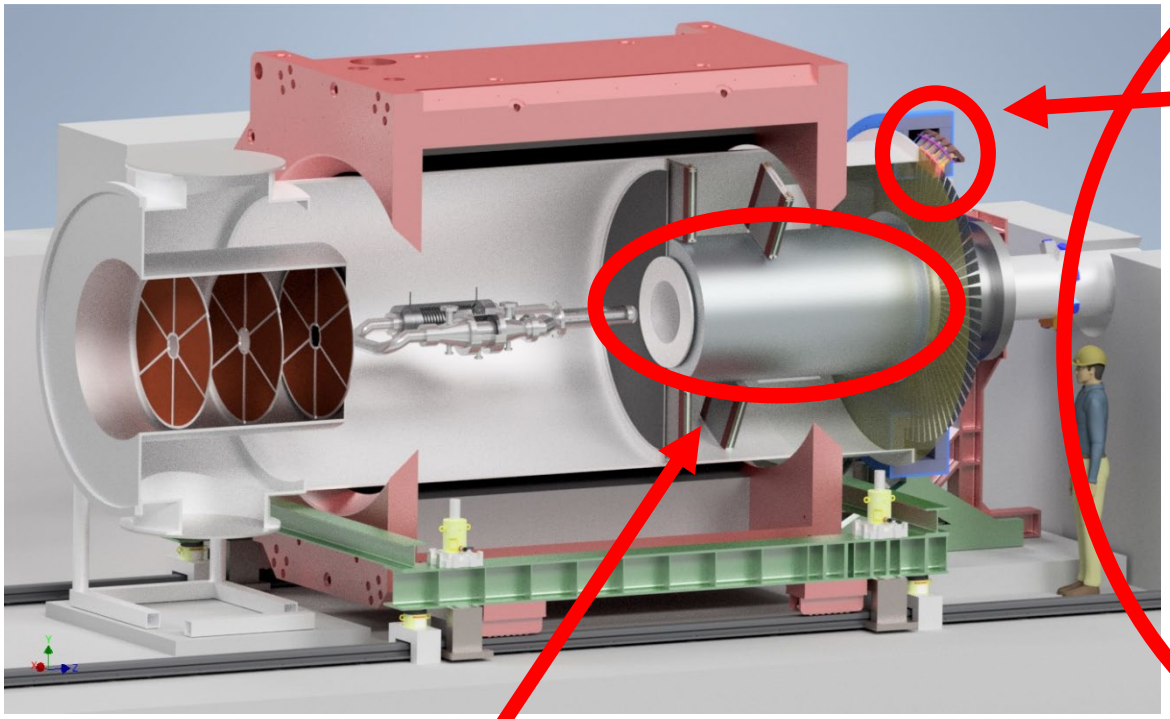
- Final design
- Can be 3D printed (Peek)
- Four test copies are currently being ordered
- 72 copies ~ 20 k€

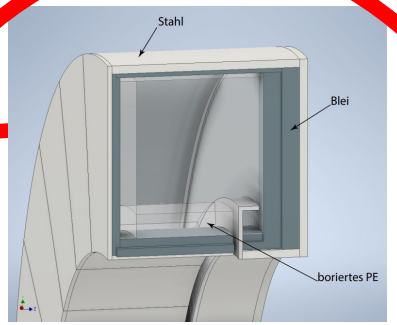




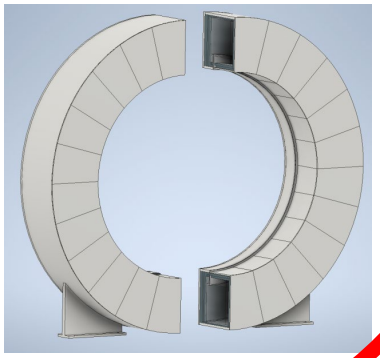


Lead shielding





- Ordering in process



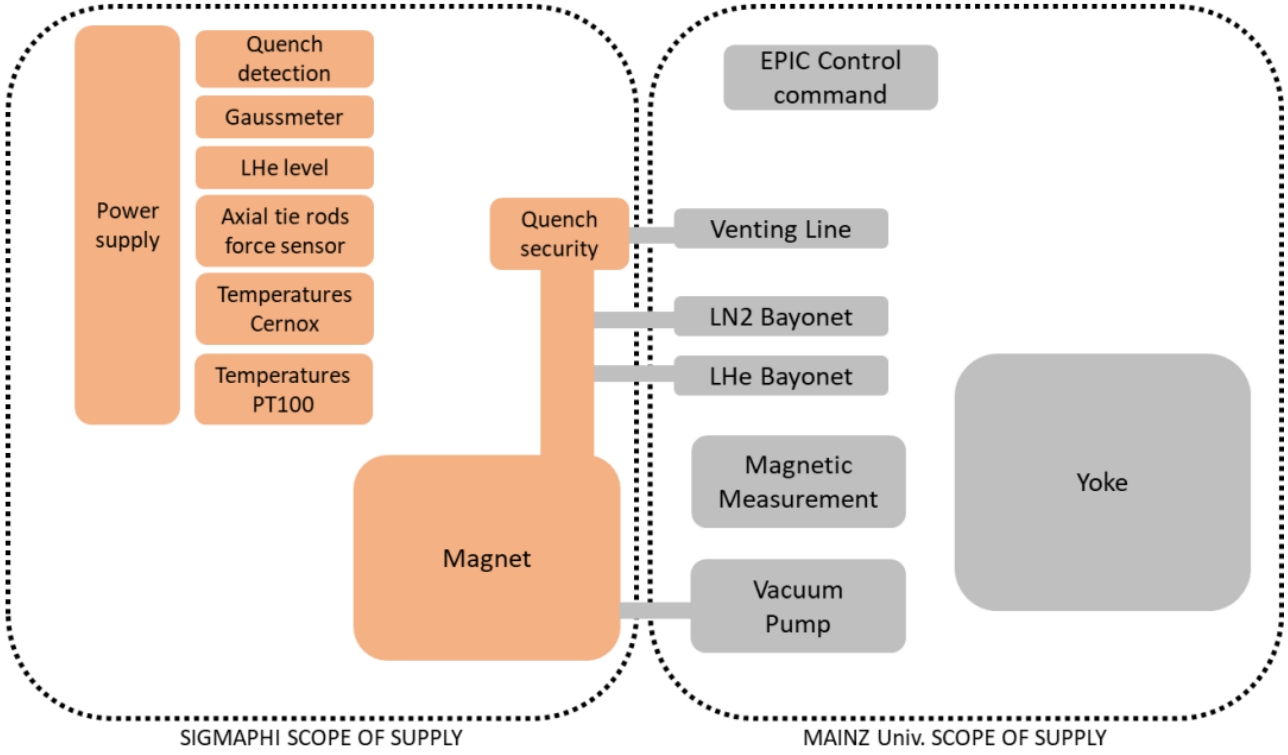
- Manufacturer: Röhr+Stolberg
- Delivered February 2024
- Approximately 9 tons

Superconducting coil

Contact and discussion with Sigmaphi Magnets since 2017
Award of contract: May 2020

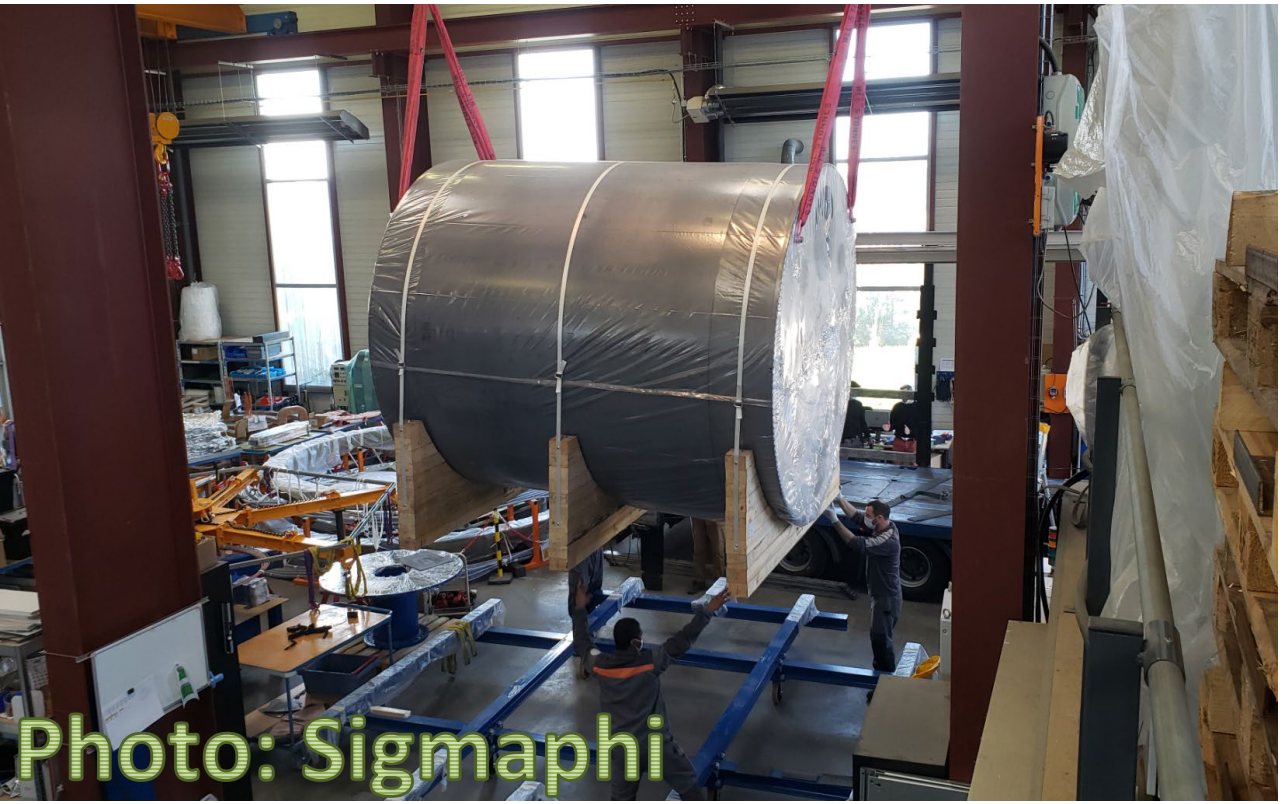
Design parameter:

- Inner diameter: 2.4 m
- Effective length: 3.4 m
- Operating current: 640 A
- Magnetic field: 0.7 T
- LHe vaporisation : 12.8 l/h
- LN2 vaporisation: 5.0 l/h



Superconducting coil

- Challenging project and Corona pandemics
- Several postponements of the delivery date

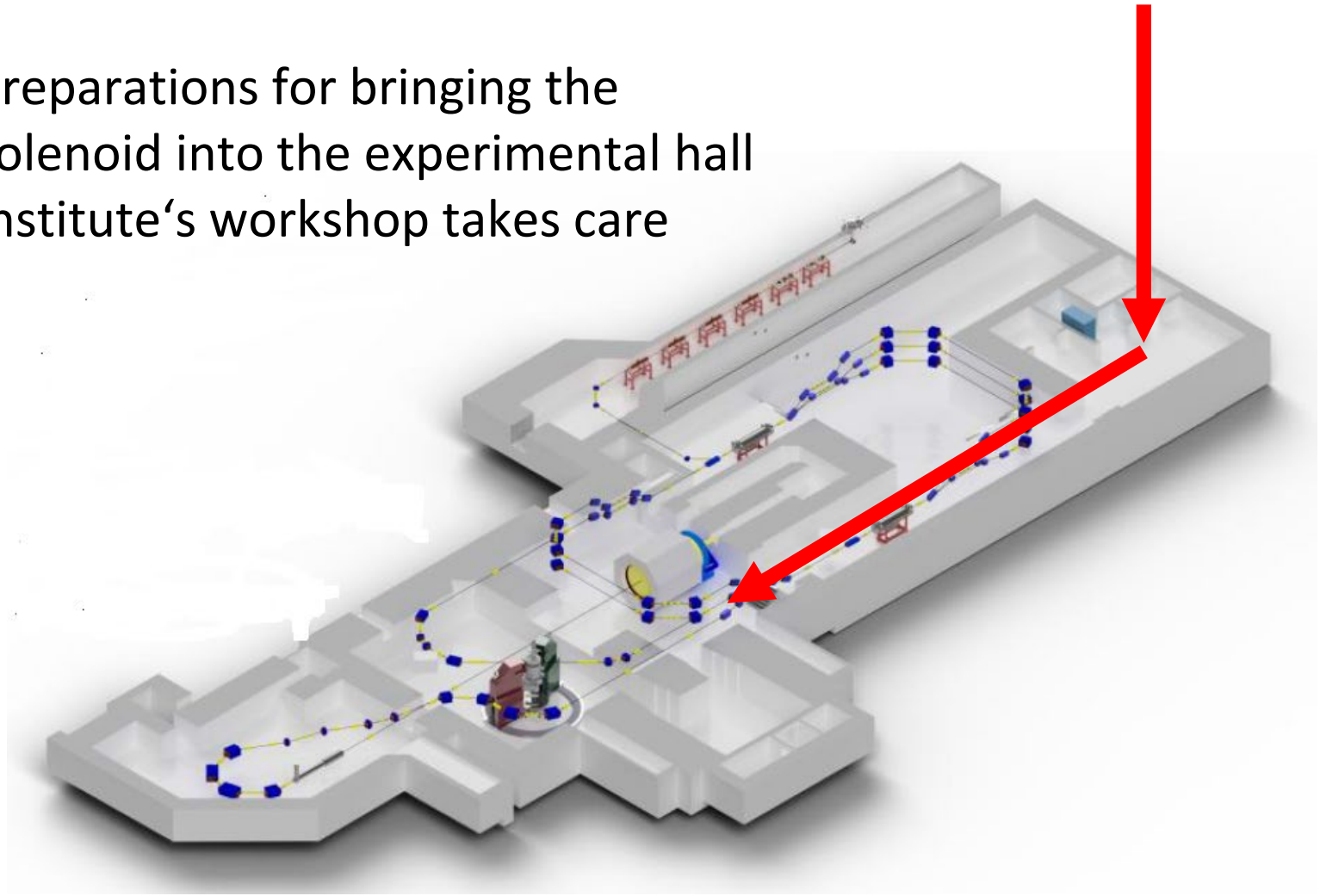


Delivery date:

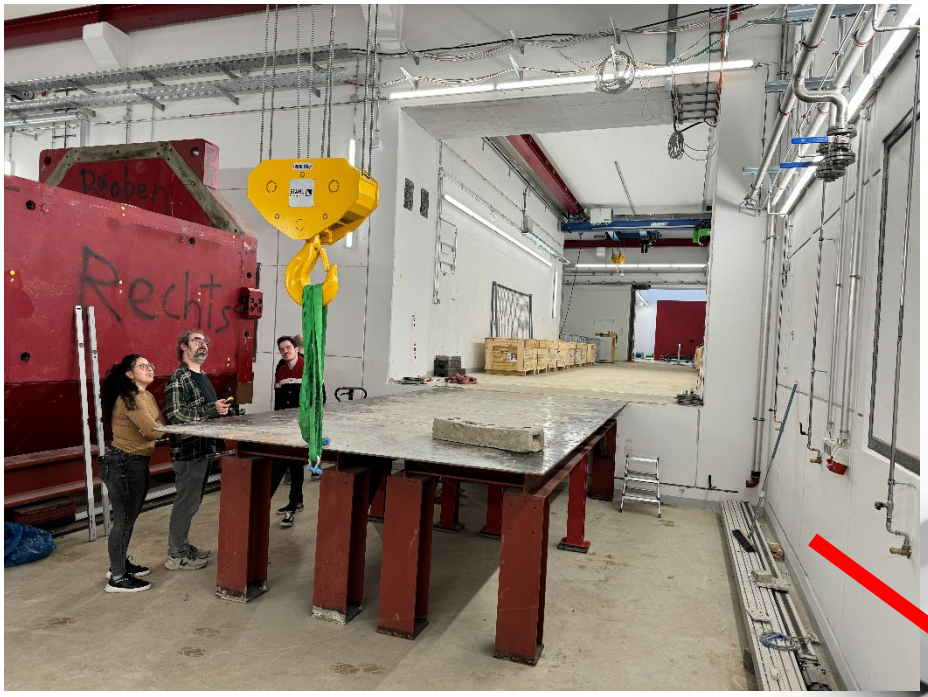
- December 2021
- December 2022
- May 2023
- November 2023
- March 2024
- September 17, 2024
- **October 31, 2024**

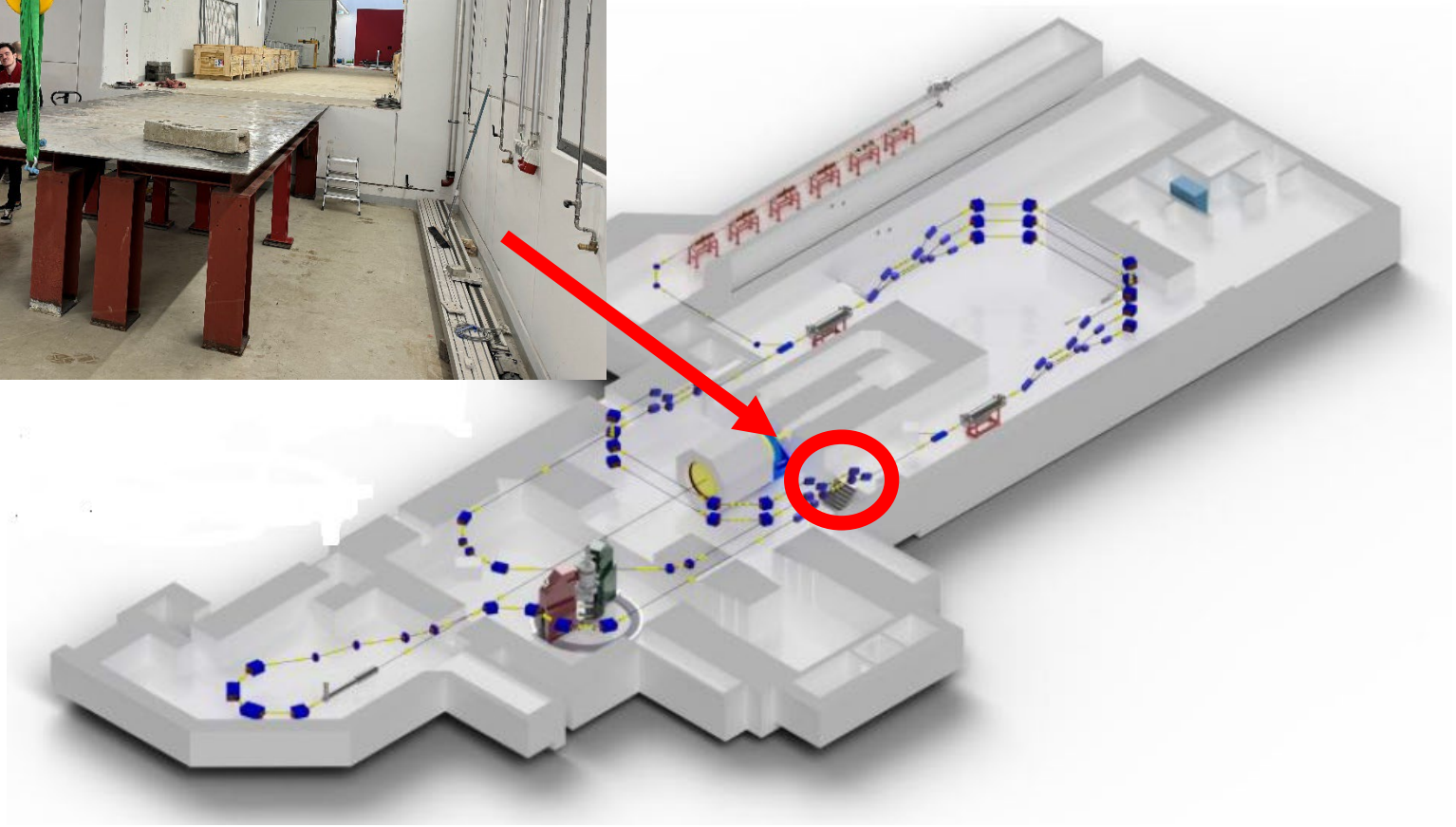
Superconducting coil

- Preparations for bringing the solenoid into the experimental hall
- Institute‘s workshop takes care



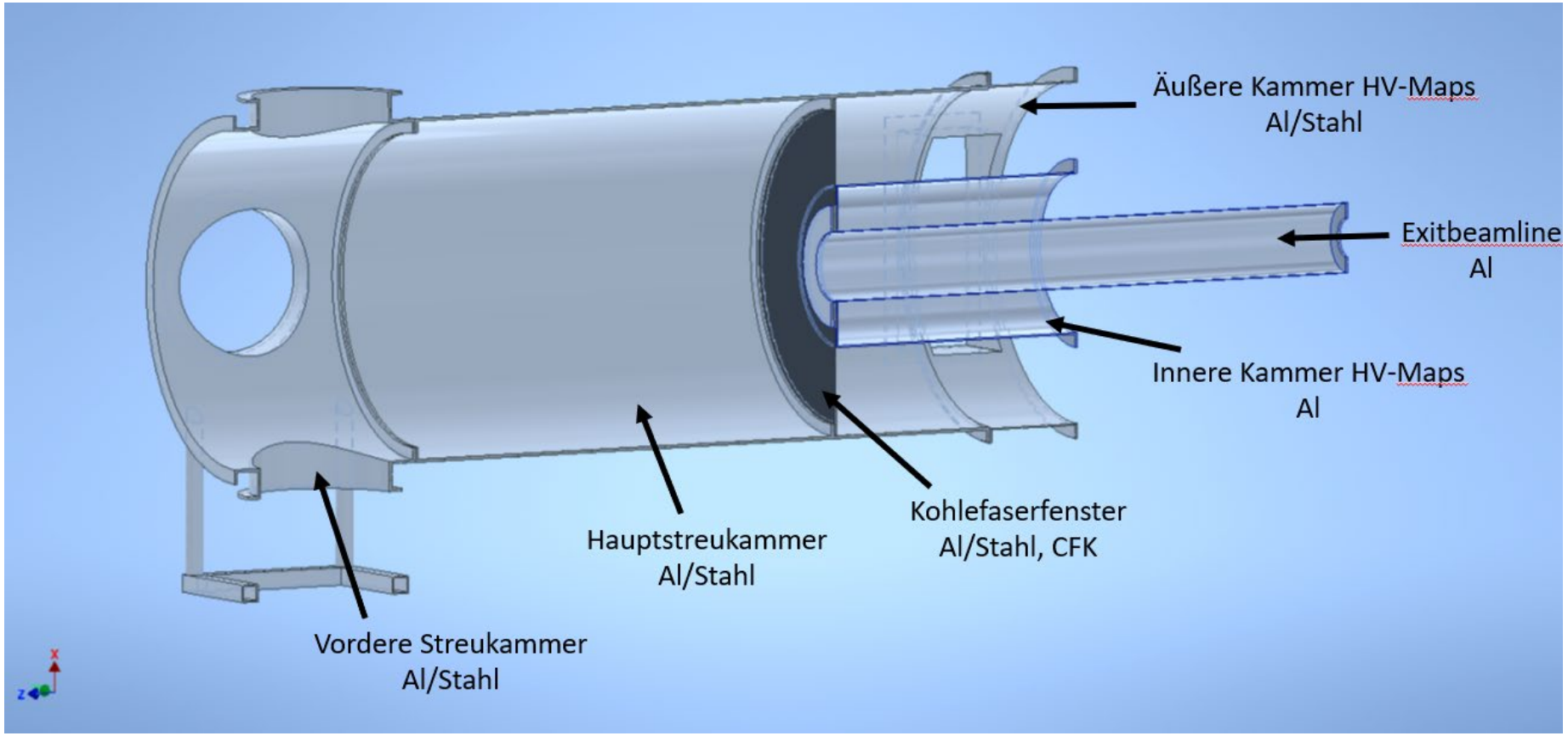
Superconducting coil





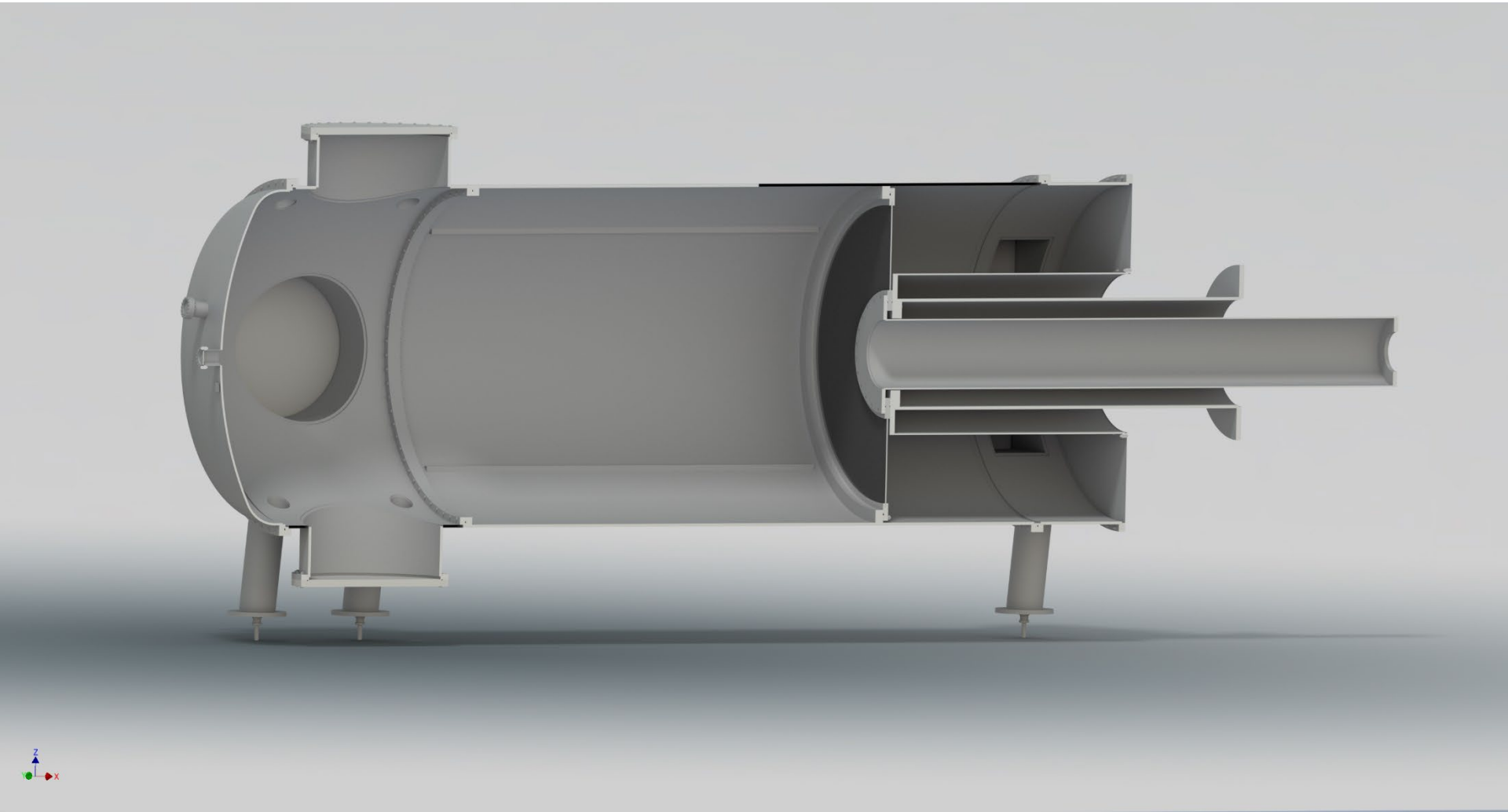
Scattering chamber

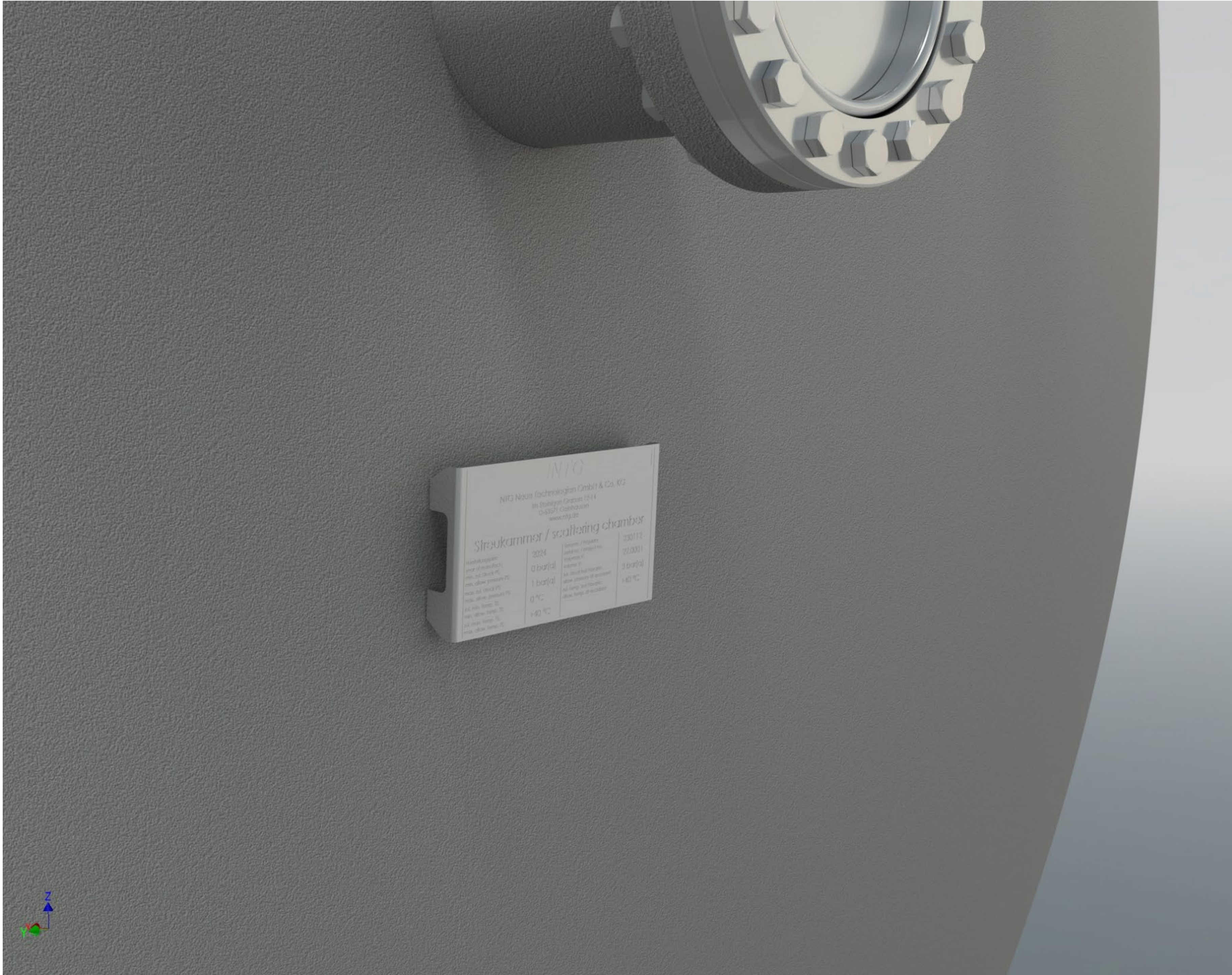
- Tender in July 2023 was succesful
- Manufacturer: NTG (Gelnhausen)
- Delivery November 2024



Scattering chamber

- Up-to-date CAD drawing from NTG



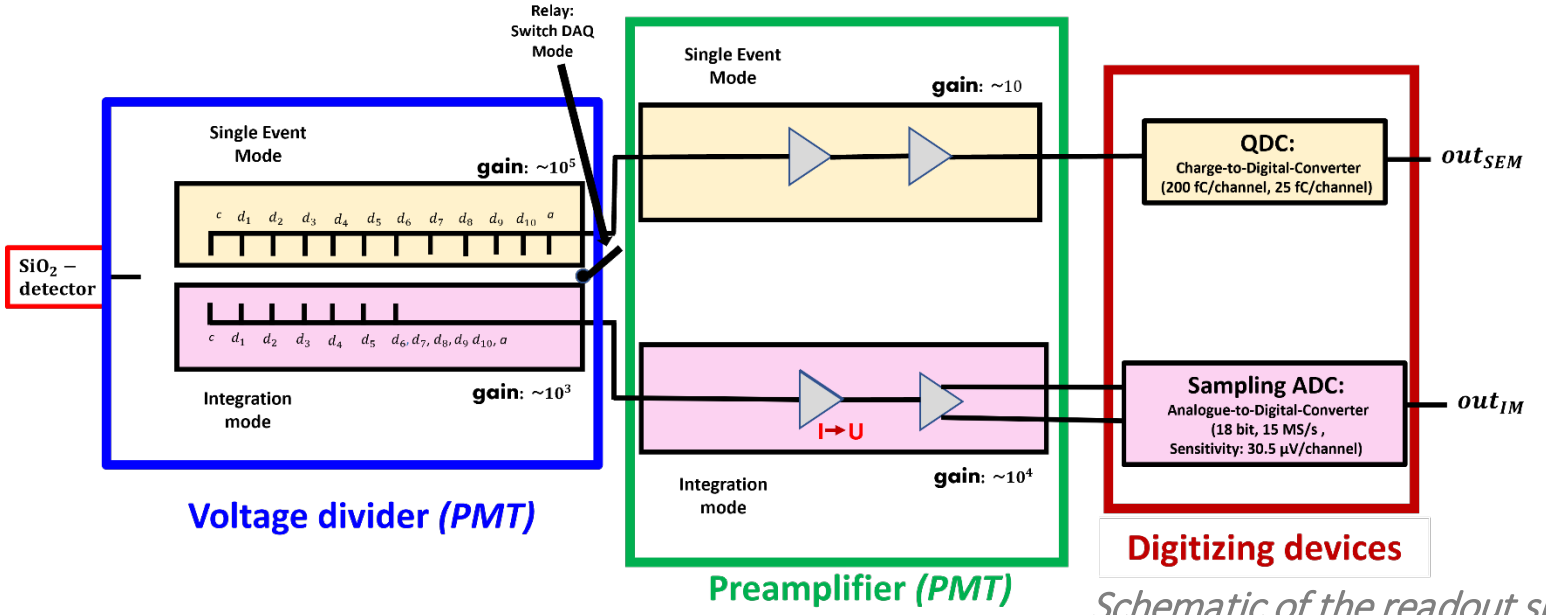

Streukammer / scattering chamber
2024
0 bar(a)
1 bar(a)
0 °C
+40 °C
3 bar(a)
+40 °C

Vacuum system

Delivered January 2024:

- 3 turbomolecular pumps (*HiPace 700 H from Pfeiffer Vacuum*)
- 3 scroll pumps (*HiScroll 18 DN from Pfeiffer Vacuum)*
- *Additional equipment*

Detector readout



Schematic of the readout signal path for the Fused Silica Cherenkov Detector

P2 DivA board

- 10 dynodes of the PMT in **SEM**
- 5 dynodes of the PMT in **IM**
- Fixed test current at the input of preamplifier

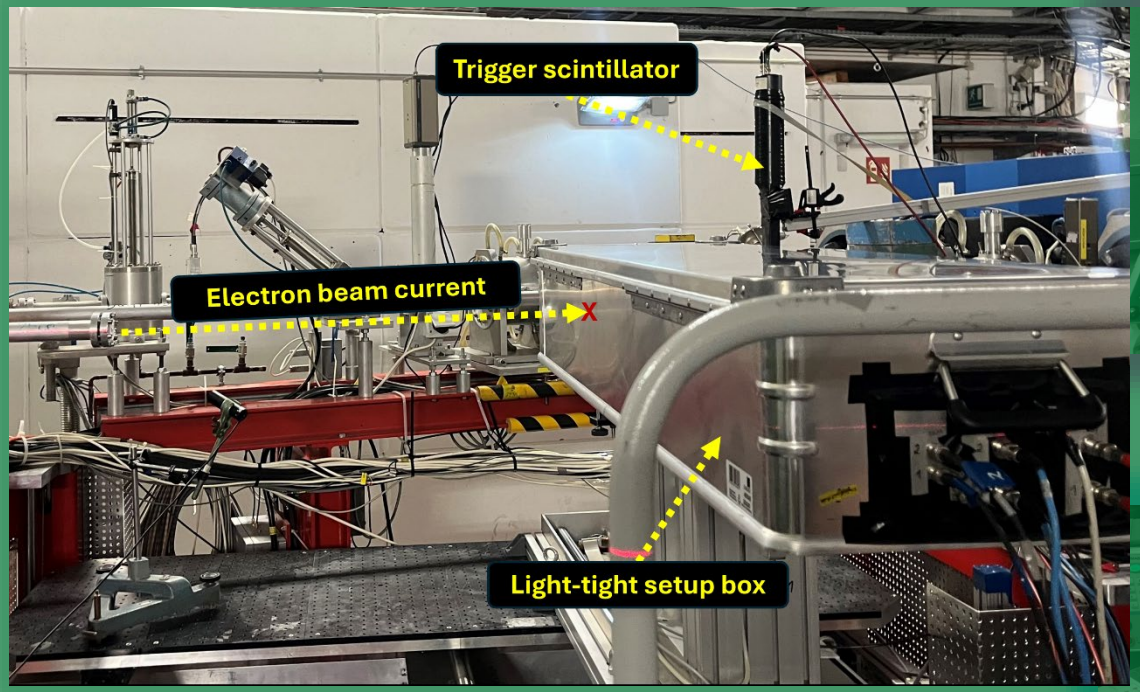
SEM: QDC basic parameters

- QDC CAEN V965
- 12 bit resolution
- 25 fC LSB and 200 LSB

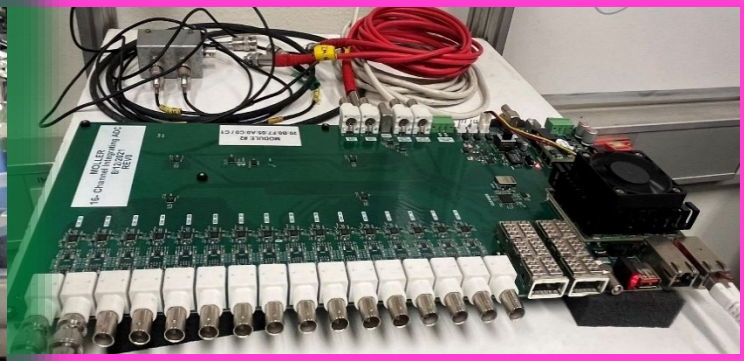
IM: Sampling ADC basic parameters

- FPGA based; Dynamic range of +/- 4.096 V
- 18-bit resolution, (Sensitivity: $\frac{8V}{2^{18}} = 30{,}5\ \mu V$)
- 15 MSps

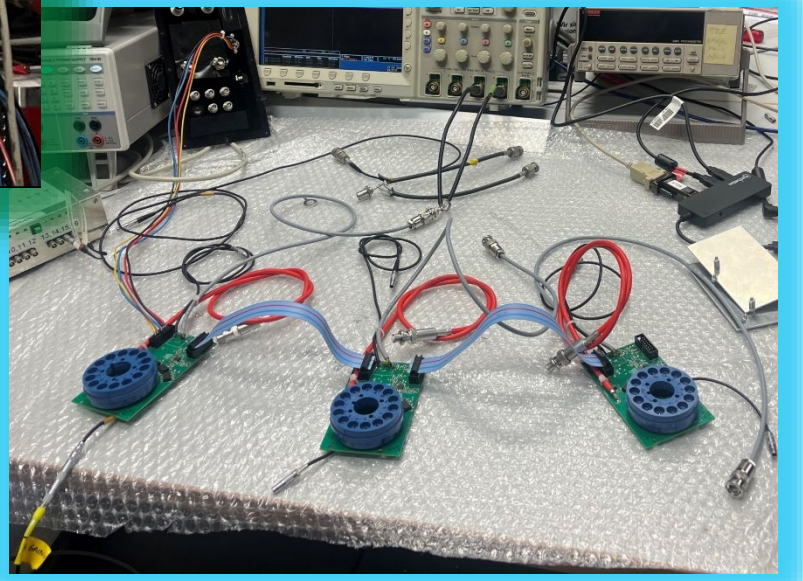
Detector readout



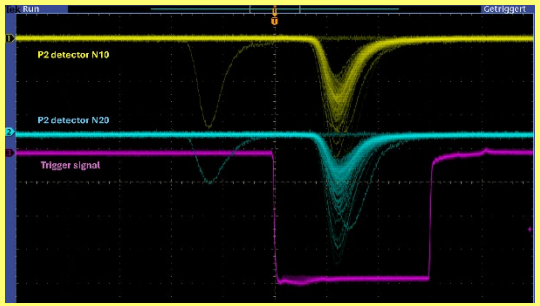
Setup for detector and electronics tests at MAMI



Sampling ADC board



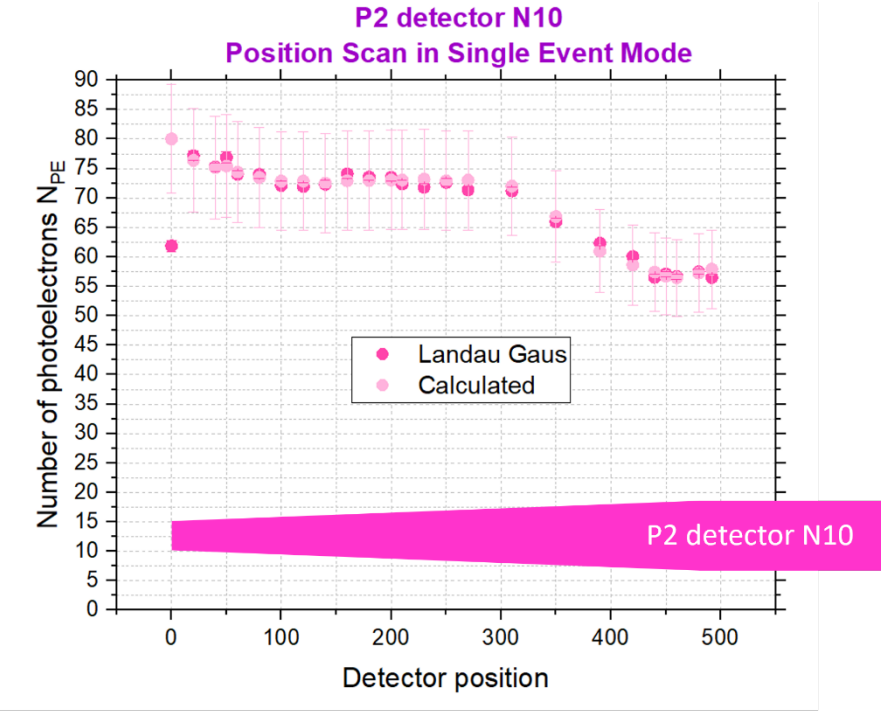
3 DivA boards powered via daisy chain



P2 detector pulses on oscilloscope

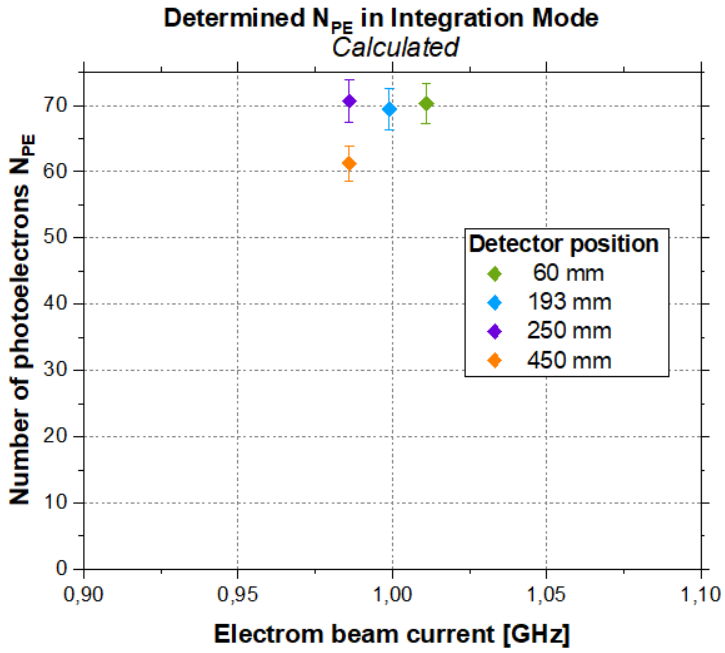
Detector readout

DAQ MODE: SEM



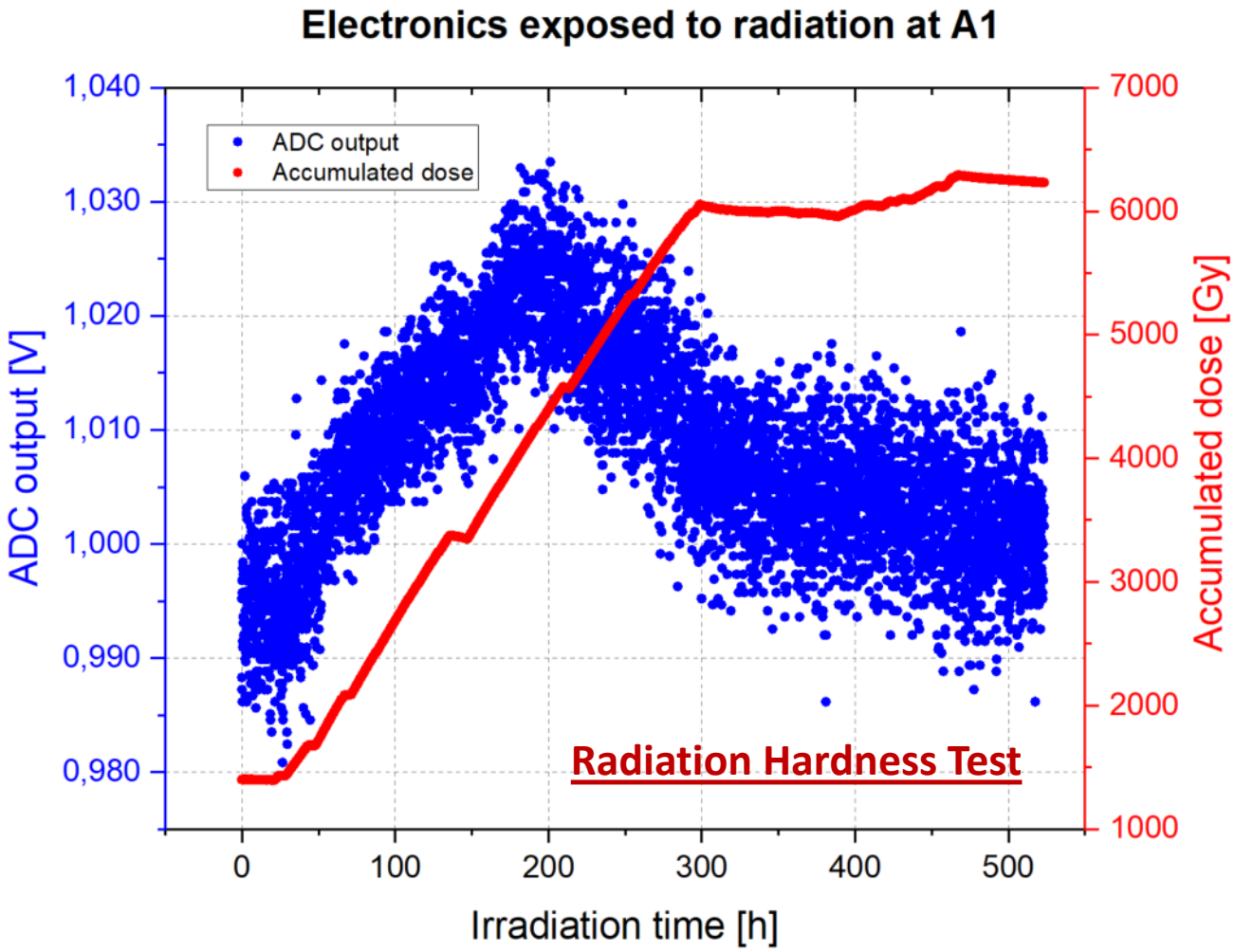
ET923 + P2 detector (N10)
SiO2 detector voltage = 790 V (nom. voltage)
DAQ Trigger: Trigger scintillator
Electron beam rate = 4 kHz @ scaler

DAQ MODE: IM



Comparable determined number of photoelectrons in SEM (@4 kHz) and IM (@1 GHz)

Detector readout



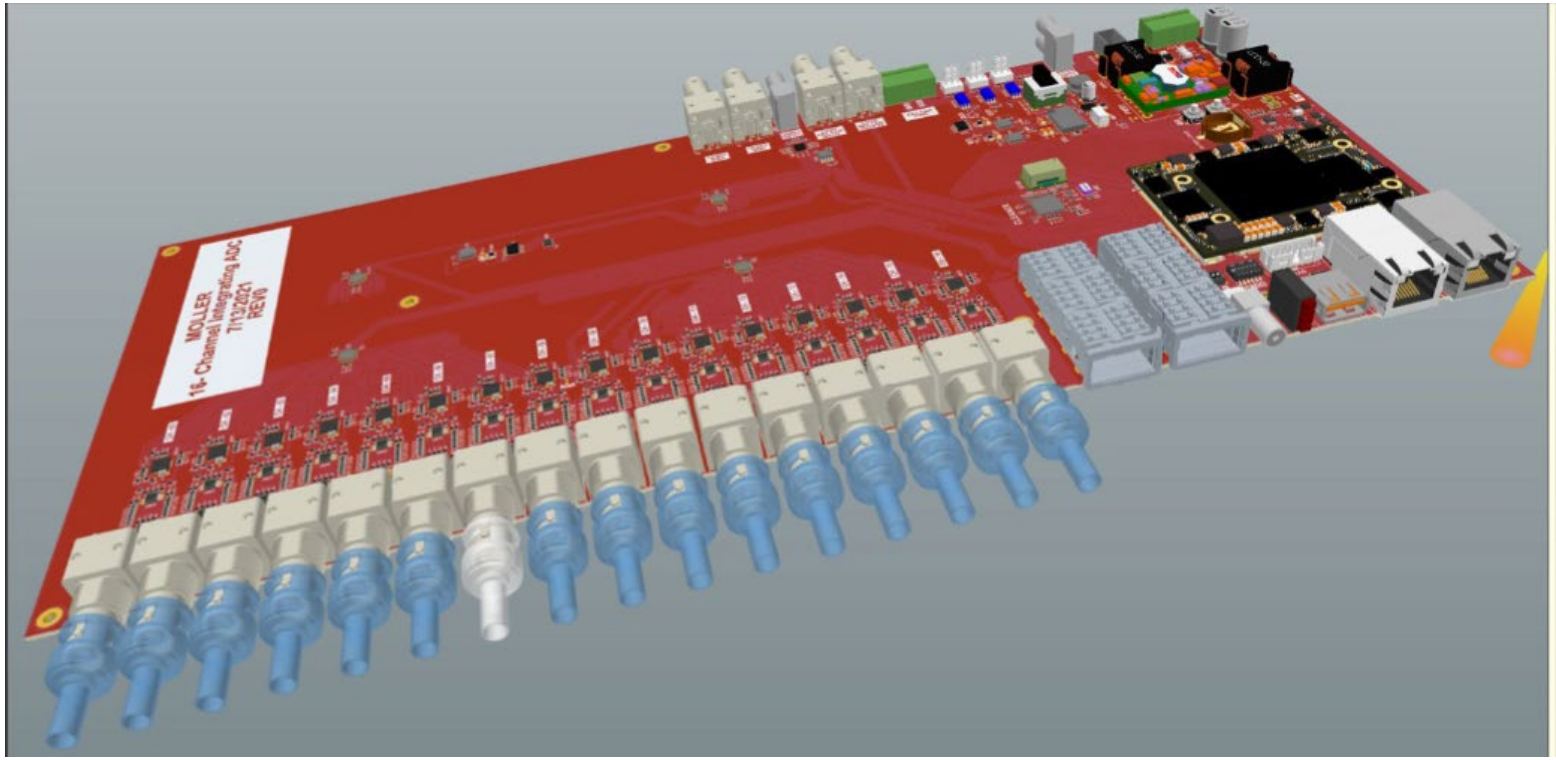
Different voltage regulators are tested of radiation hardness
→ results are coming soon

Single event mode: QDC

- QDC CAEN V965, 5 pieces delivered in September 2023, together with VME crate and CPU
- 80 readout channels in total
- First beam tests in August 2024

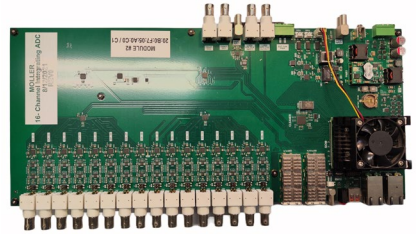
Integrating mode: Sampling ADC

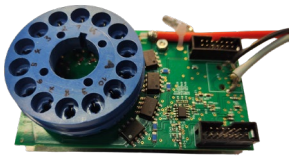
- Developped by U Manitoba/Triumf (MOLLER, P2)
- 16 channels per board
- 10 boards ordered, delivery until December 2024
- 10 FPGA (SoC Mercury+ XU1/Enclustra) already delivered

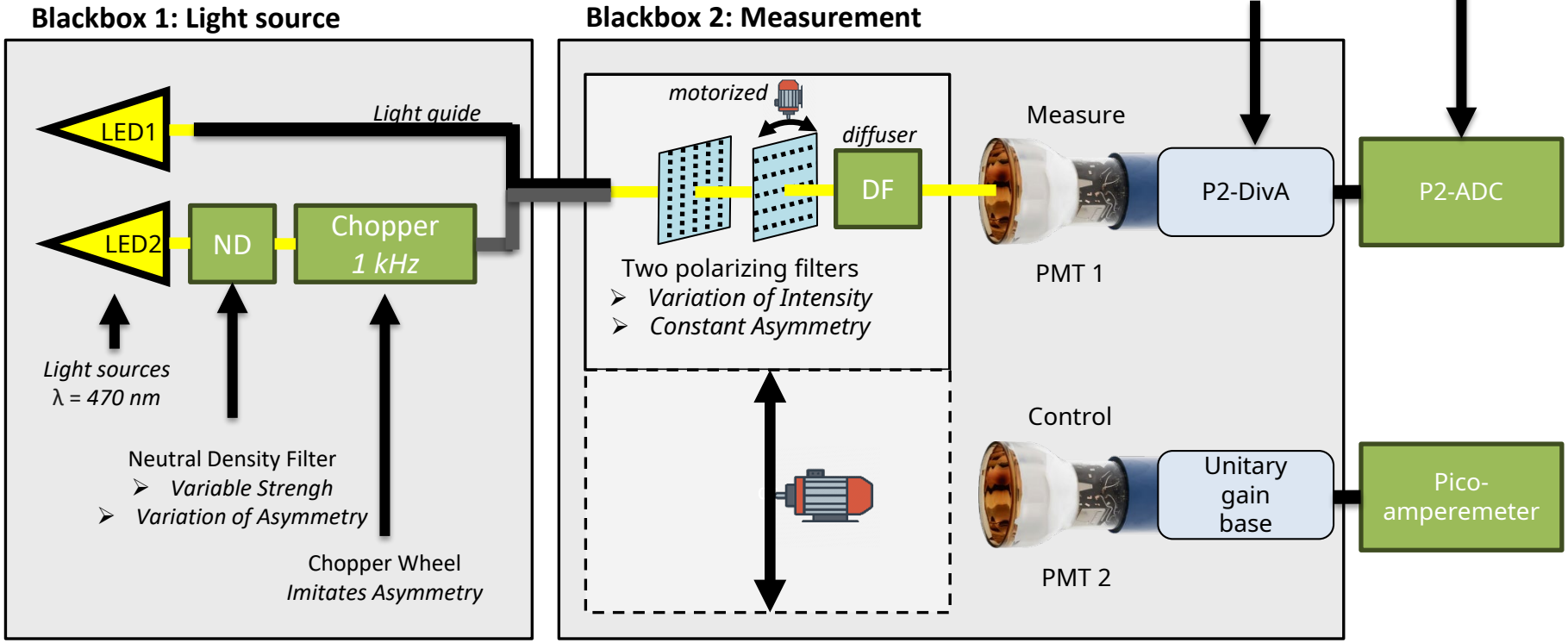


Characterization of readout electronics – Integration mode

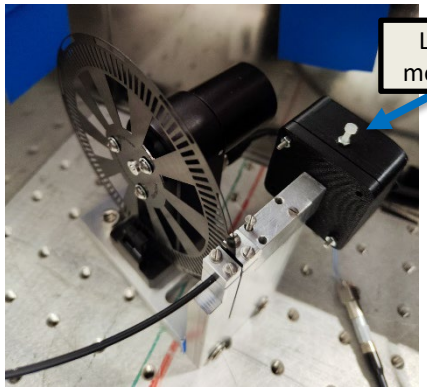
- Characterization of the **integration mode**
- Test the **P2-DivA** and the **P2 Analog-to-Digital converter (ADC)**
- LED setup produces an **asymmetric light signal**
  - **Mimic the parity violating asymmetry** of the P2 experiment
- Motorized polarizers for different light intensities
  - Keeping the asymmetry constant



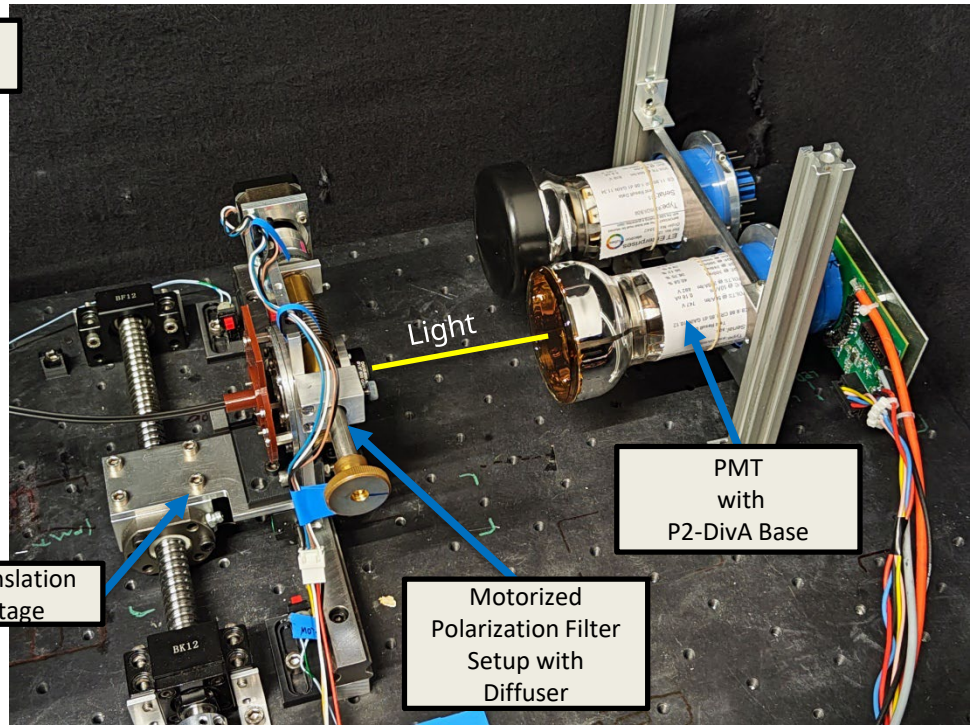




Characterization of readout electronics – Integration mode



Chopper wheel with LED mount

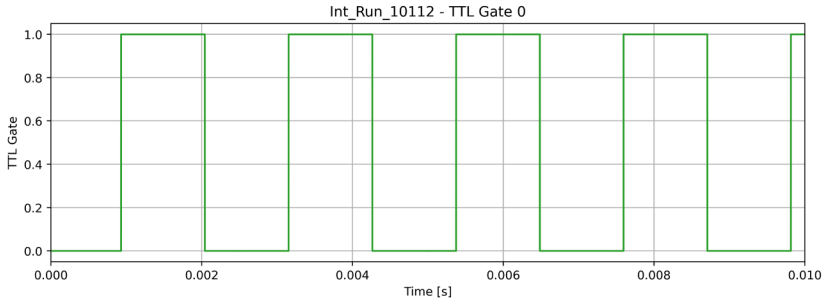


Measurement setup with a single PMT and P2-DivA Base

Goal:
Tune (reduce) asymmetry produced by chopper setup to an order comparable to the P2-experiment

Measure asymmetry with
P2-DivA and P2-ADC

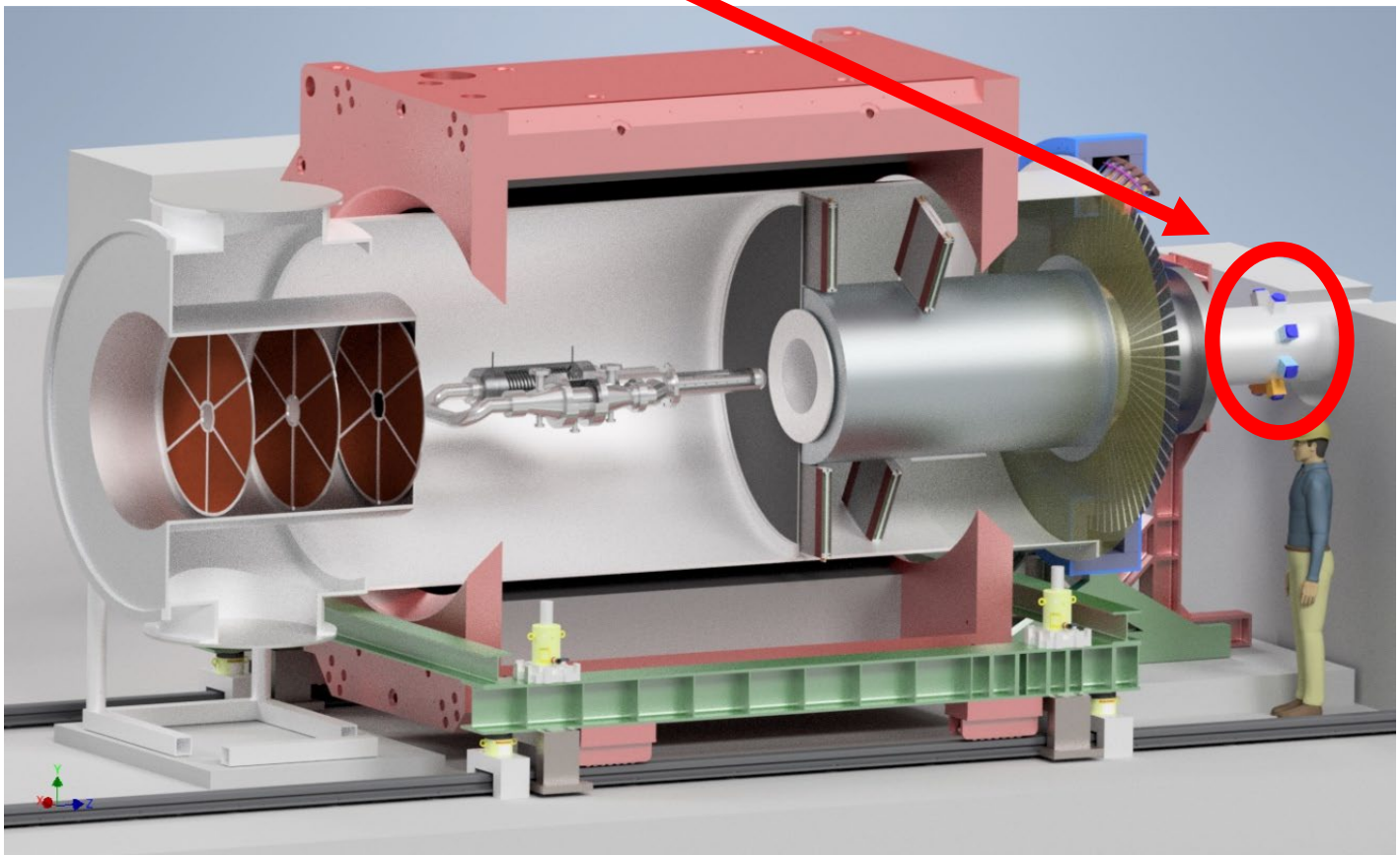
Example for an exaggerated asymmetry measured by P2-ADC



Gate given by the reference output of the Chopper wheel controller

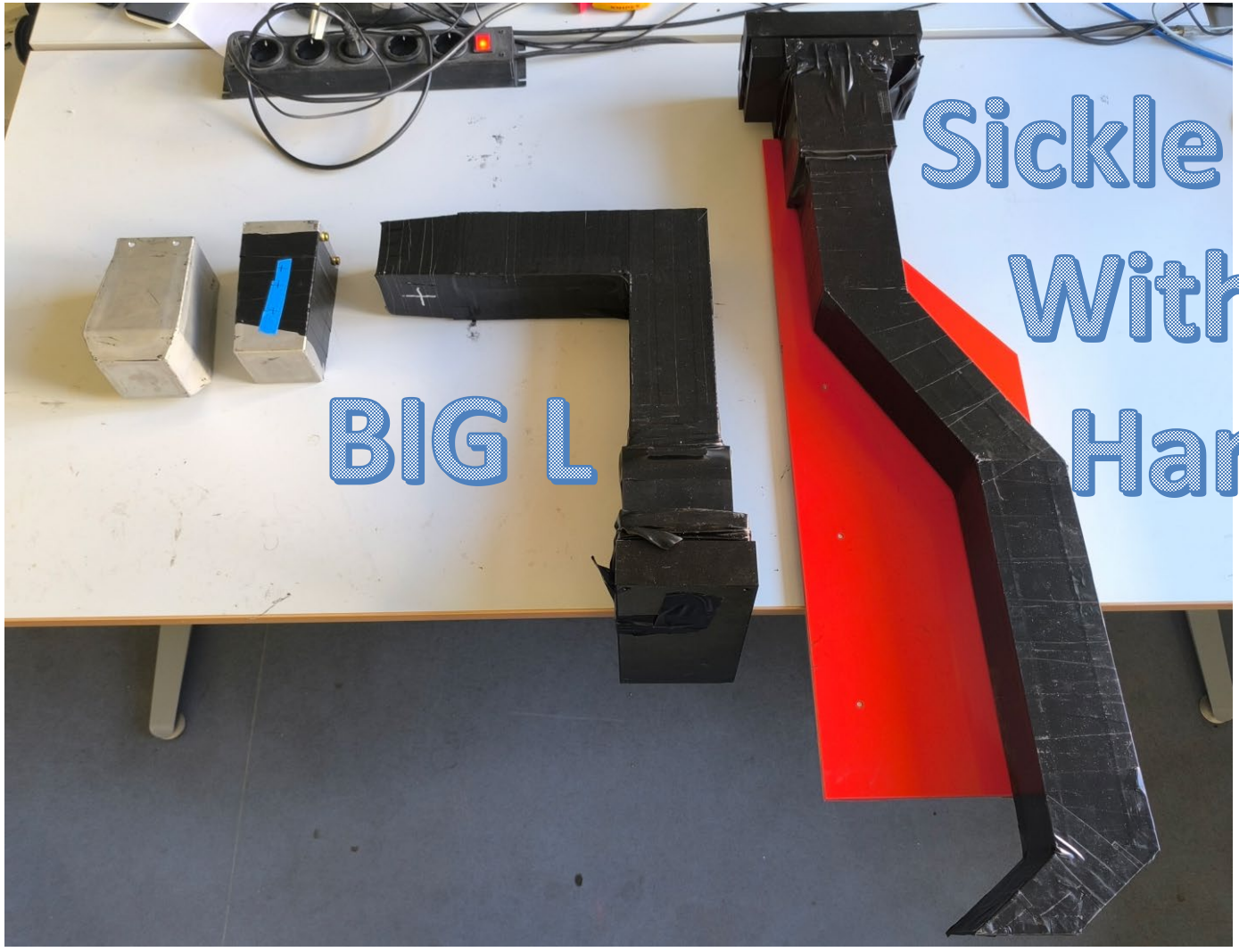
Luminosity monitors

- Air Cherenkov detectors
- Møller electrons and small angle elastic scattering
- Placed 4.9 m behind the target



Luminosity monitors

Two favourite designs under investigation



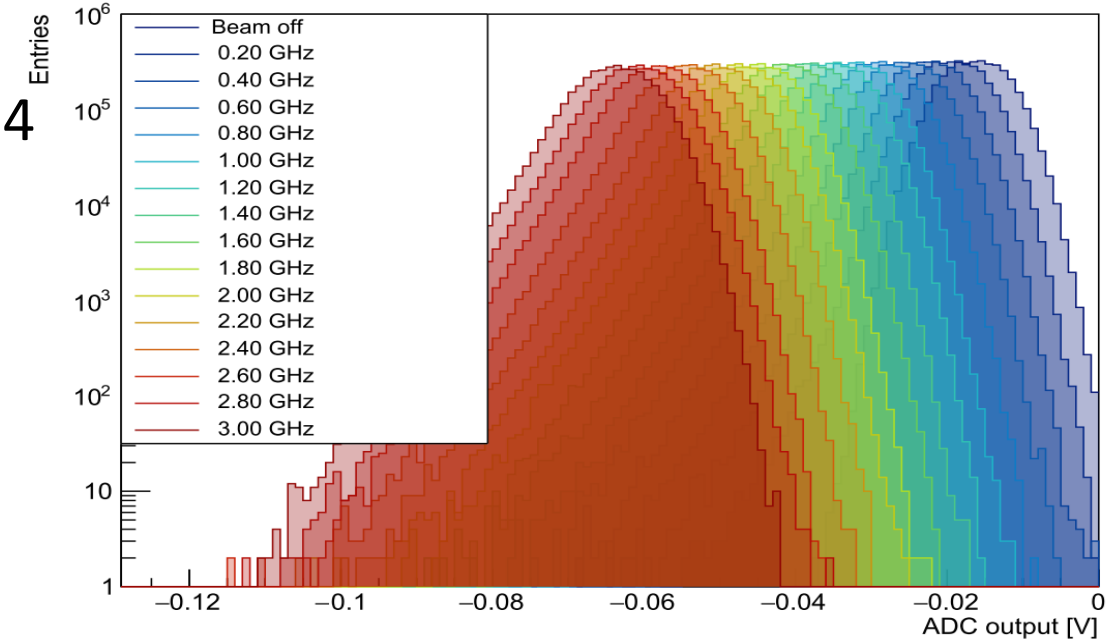
Luminosity monitors

Design goals:

- Little light yield
  (*around 1 photoelectron per incident electron*)
- Little dependence of the yield on the beam position
  (*keep helicity correlated false asymmetries small*)

Beam test in August 2024

Analysis ongoing



Computing

Delivered in November 2023:
6 servers for data processing, 1 server for data storage,
1 multicore server for analysis, 5 NUKs for the counting room

- IT equipment for the counting room
- Online analysis
- Short term storage (100 Terabyte)

Not included here:

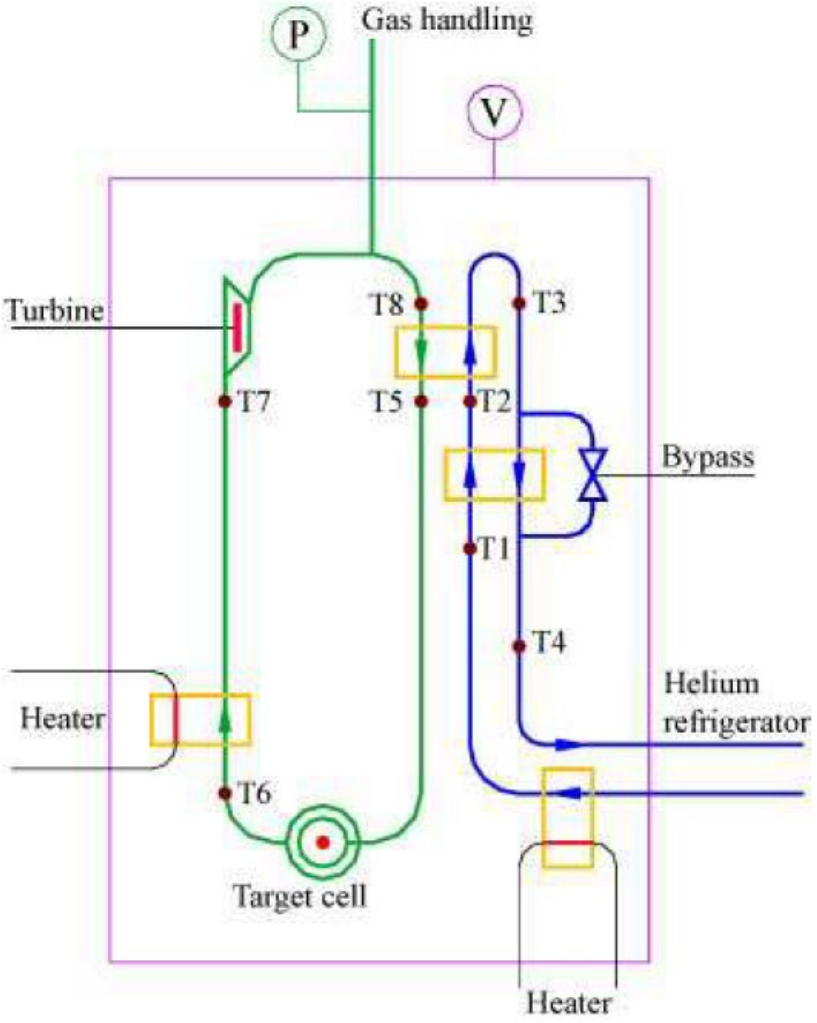
- Long term storage (1-2 Petabyte)
- Backup

Refrigerator

- Provides cold helium gas to cool the liquefied hydrogen target
- Design parameter:

Cooling power	4.2 kW
Inlet temperature	15 K
Inlet flow pressure	2.7 bar
Return temperature	19 K
Return flow pressure	1.2 bar

- Manufacturer: Linde Kryotechnik AG
- Compressors delivered: October 2023
- Cold box delivered: January 2024



Refrigerator: Installation

Refrigerator: Installation

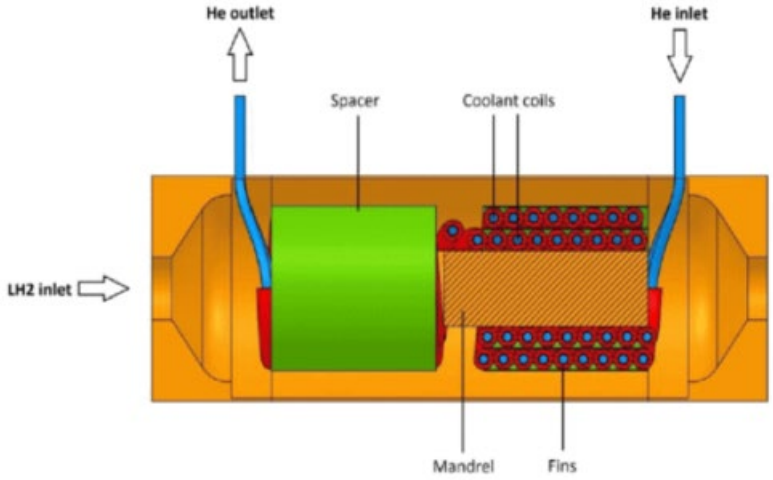
Refrigerator: Installation

Liquid hydrogen target

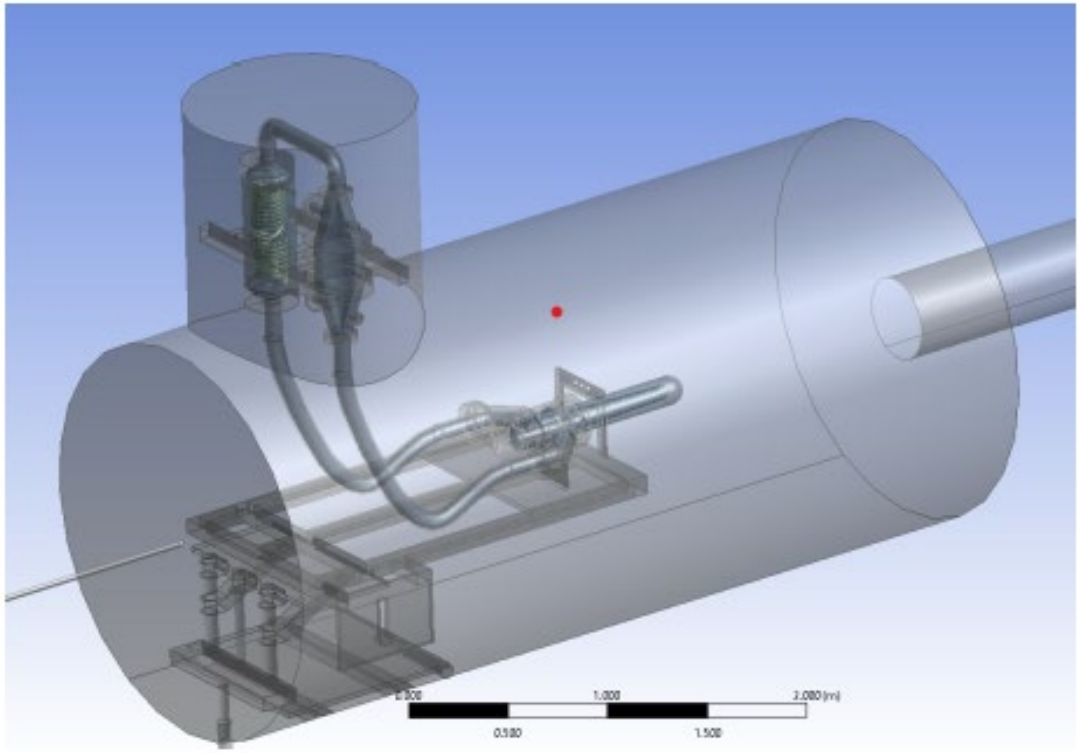
Target parameter

Pressure/Temperature	2.4 atm / 20 K
Cell Length	60 cm
$\dot{m}$ (mass flow)	< 2 kg/s
LH2 pump head	< 0.1 atm
Beam area on target	25 mm^2
HX cooling power	4 kW
Target thickness	4.3 g/cm^2
LH2 $(\Delta\rho/\rho)$	$< 2\%$
LH2 $(\delta\rho/\rho)$ at 1 kHz	< 10 ppm

Heat exchanger (HX)

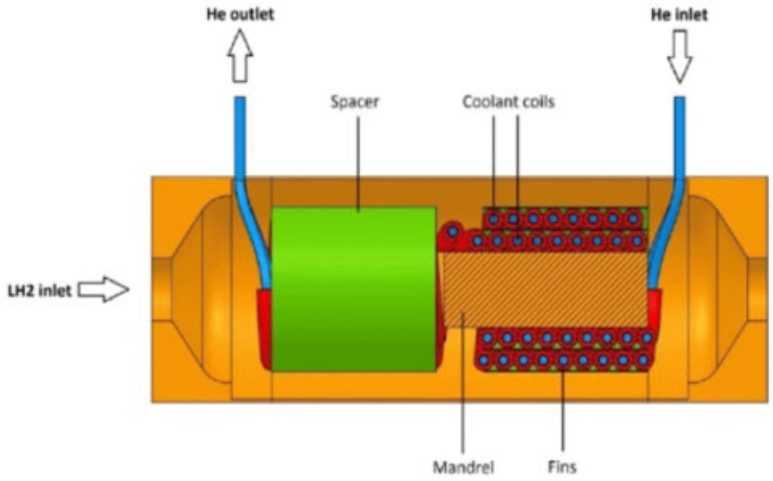


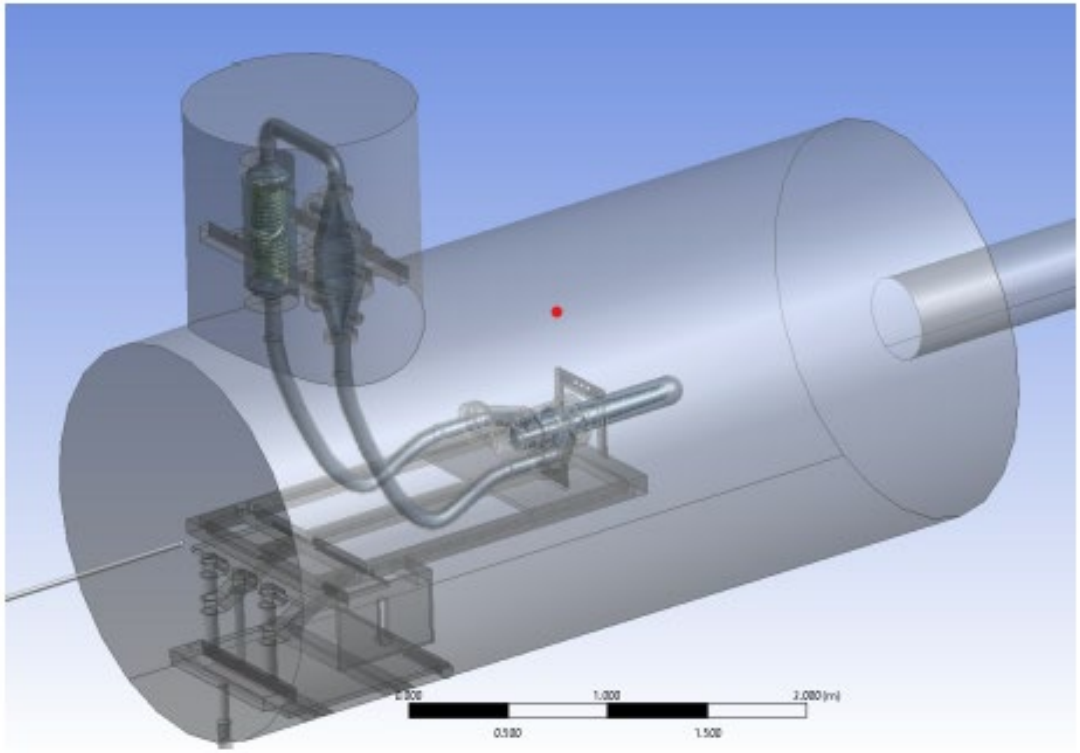
Target loop



Liquid hydrogen target

- Cooperation with Silviu Covrig (Jlab), Jim Dunne (MSU) et al.
- Calculations and design exist
- Dedicated PhD thesis





Hydrogen buffer

- 90 m³ volume
- Pressure up to 3 bar
- Ordering in process

Status of the P2 forward tracker

Niklaus Berger

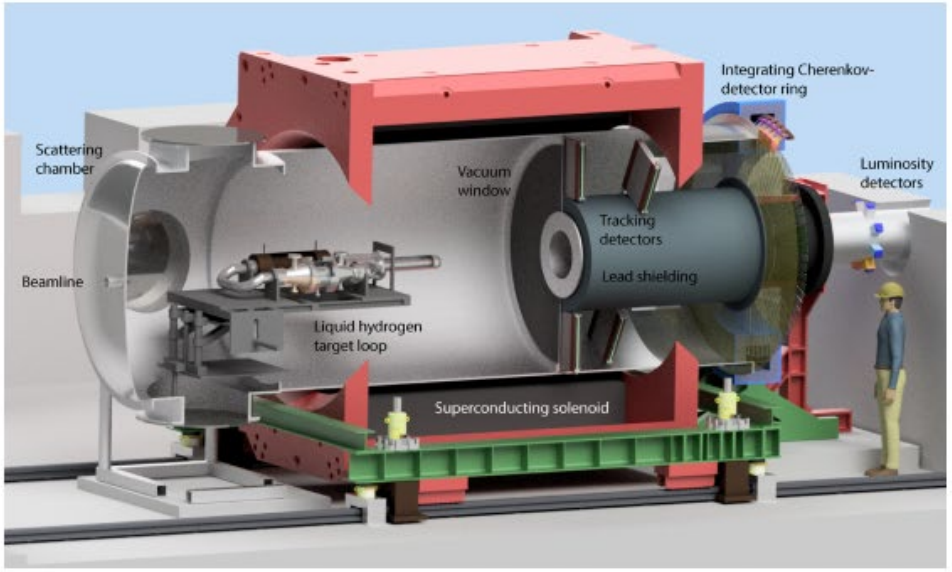
Institut für Kernphysik, Johannes-Gutenberg Universität Mainz

September 2024

JG|U

PRISMA+

The P2 Experiment



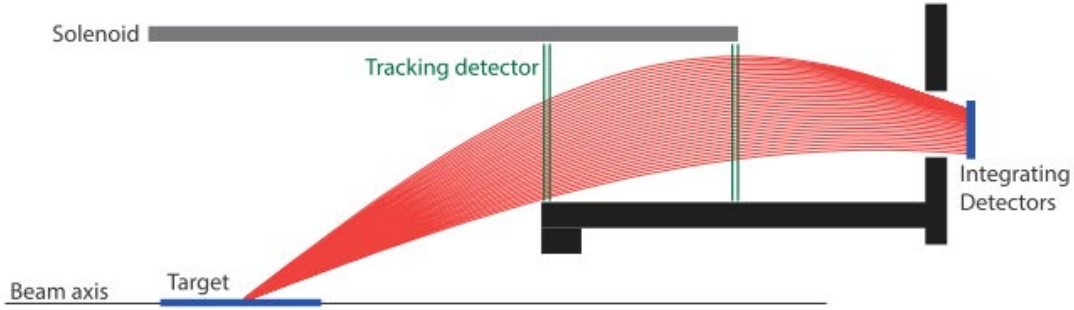
- High precision extraction of the weak mixing angle

$$A_{PV} = \frac{N_R - N_L}{N_R + N_L} = \frac{G_F Q^2}{4\sqrt{2}\pi\alpha}(Q_W - F(Q^2))$$

$$Q_W = 1 - 4\sin^2\theta_W$$

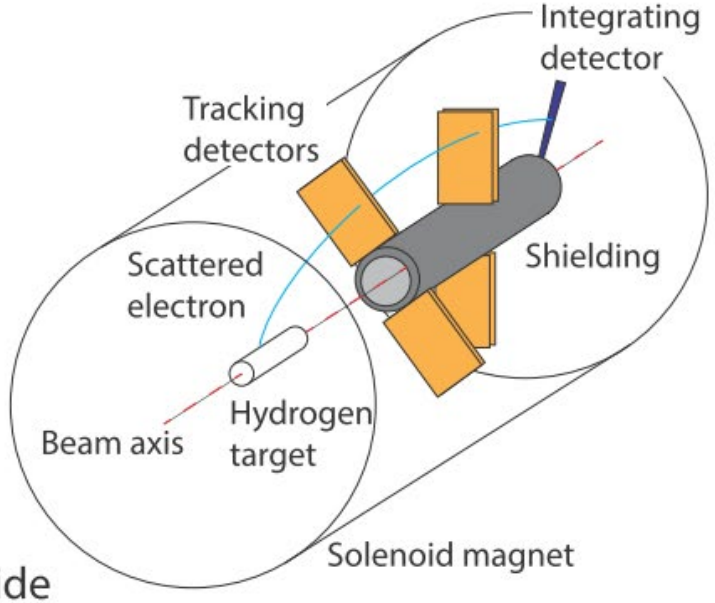
Need to know Q^2:

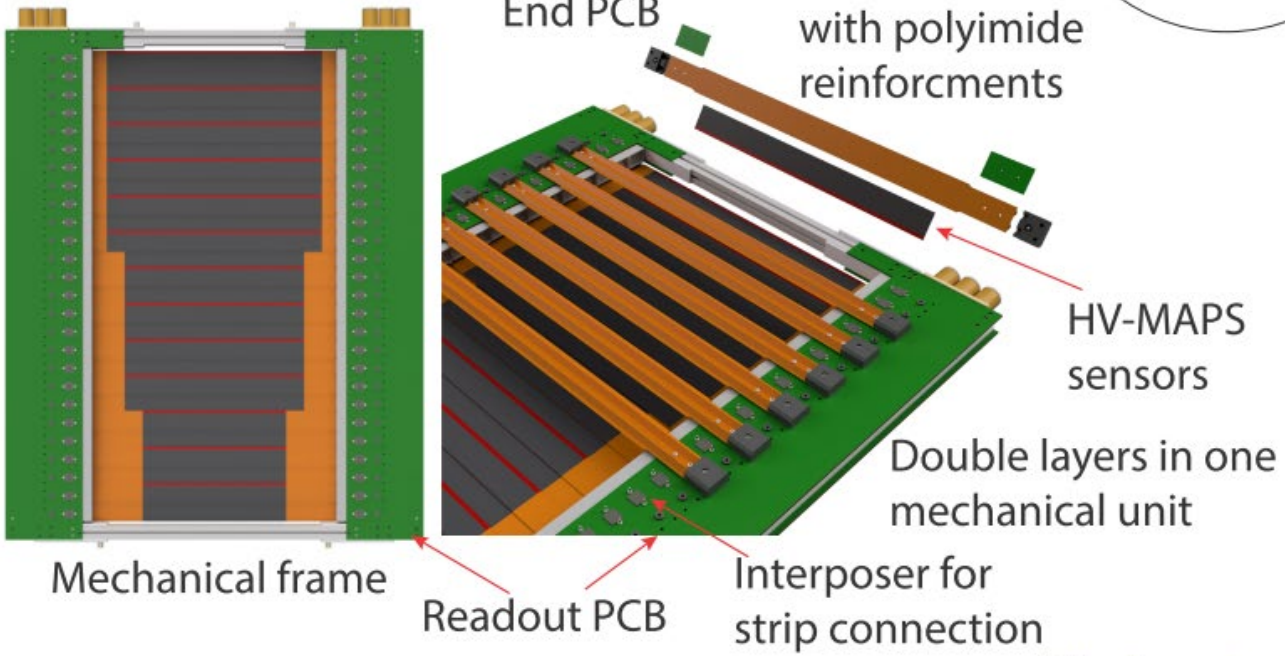
- Tracking detector in magnetic field
- Typically at lower rates
- Also important for systematics



P2 Tracking detector

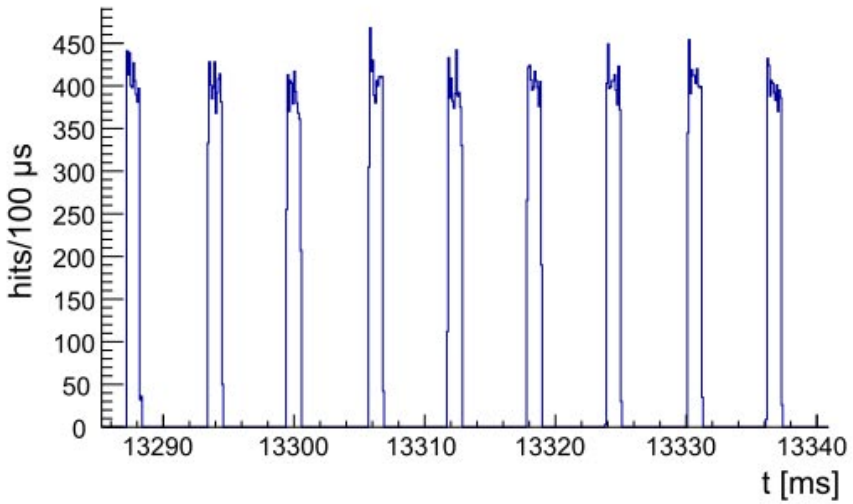
- Four double layers of HVMAPs
- Not covering the full azimuth: Two sectors in ϕ
- Built from flexprint/chip strips





HV-MAPS requirements

- ~ 2 x 2 cm, 80 µm pixels, 70 µm thin
- < 300 mW / cm^2 power consumption
- LPGbT compatible output:
  160 MHz clock input, x4 PLL, 1.28 Gbit/s DDR output, 1 link per chip
- Wire-bond to flexprint
- Gated operation: Hit detection can be suppressed outside ~ 1 ms gates without introducing extra noise
  (done successfully with two threshold mode in MuPix11, see figure)
- Surviving high instantaneous electron rate
- MuPix11 (Mu3e collaboration) does all this...



P2 production needs:

- 2700 working chips
- 155 wafers of 44 chips at 40% end-to-end yield

Chip production issue

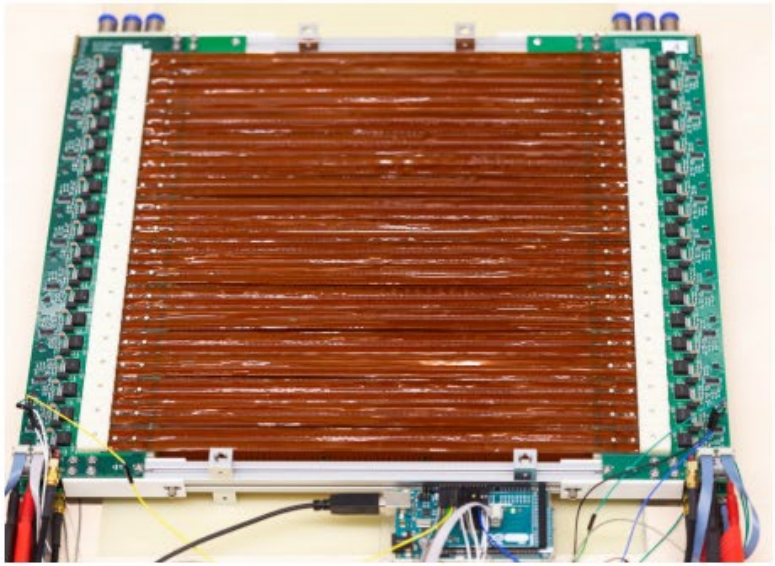
- The MuPix11 Fab (TSI) was bought by Bosch, change of production to SiC
- Barely enough MuPix chips for Mu3e...
- Moved to AMS-Osram (Austria), similar process
- Adapted chip design, included direct gate input
- Chip submitted, available ~ end of year/ early 2025
- Big interest in the community

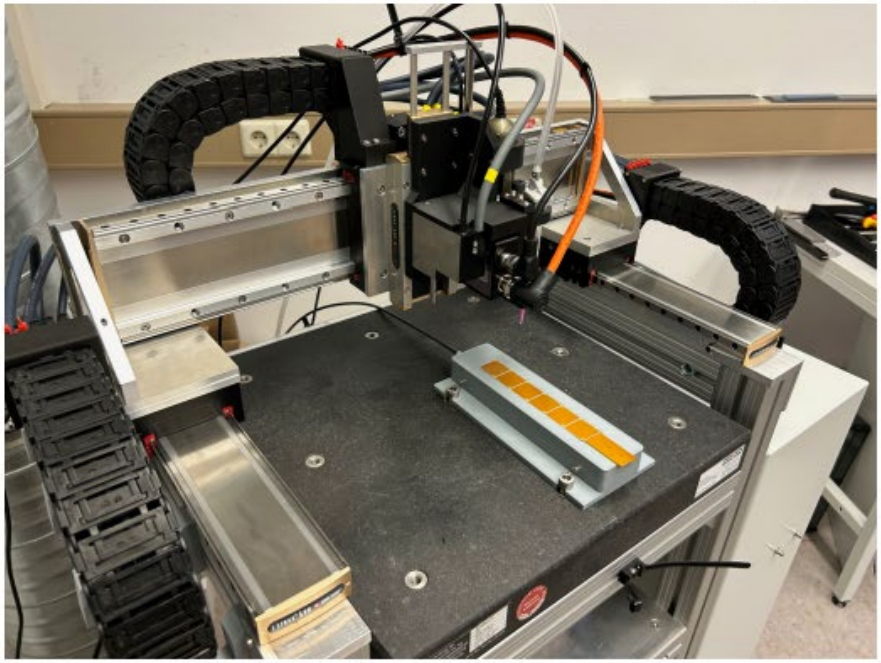
TSI SEMICONDUCTORS

amsOSRAM

Preparation for construction

- Built many mechanical and cooling prototypes
- Built a pick & place and glueing robot for automated assembly





Outlook

- Preparing for module assembly
- Chips should become available in 2025
- Bottleneck likely testing of chips

- Need to procure gaseous helium cooling system, parts of DAQ hardware
- Ideally have first modules by end 2025

Summary

- Many components already delivered
- Others ordered, waiting for delivery
- Few items: Ordering in process

- Starting setup of the experiment after magnet commissioning