The Electromagnetic Calorimeter of the $\overline{\text{P}}$ANDA Detector at FAIR

Malte Albrecht
for the $\overline{\text{P}}$ANDA collaboration

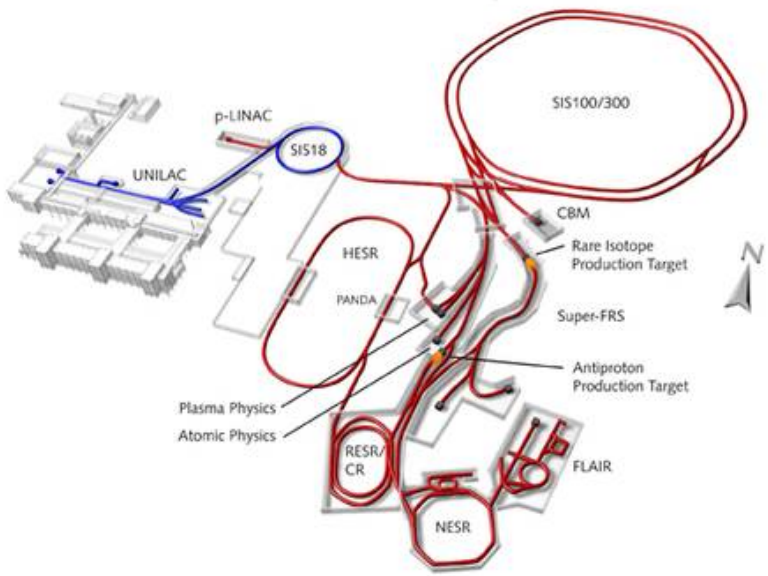
Ruhr-Universität Bochum
Institut für Experimentalphysik I

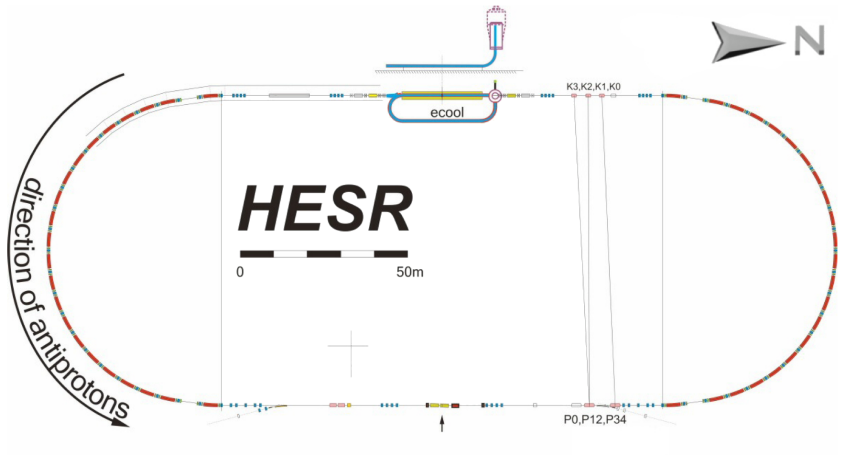
EuNPC 2015
August 31st 2015

FAIR - Facility for Antiproton and Ion Research

- Accelerator facility at Darmstadt under construction
- Primary beams: protons up to 30 GeV/c, heavy ion beams up to 35 GeV/u (U^{92+})
- Secondary beams: antiprotons up to 15 GeV/c, radioactive beams
- Antiprotons at FAIR:
  - Slow ramping synchrotron storage ring for internal target (HESR)
  - Momentum range: 1.5 – 15 GeV/c
  - Stochastic and electron cooling

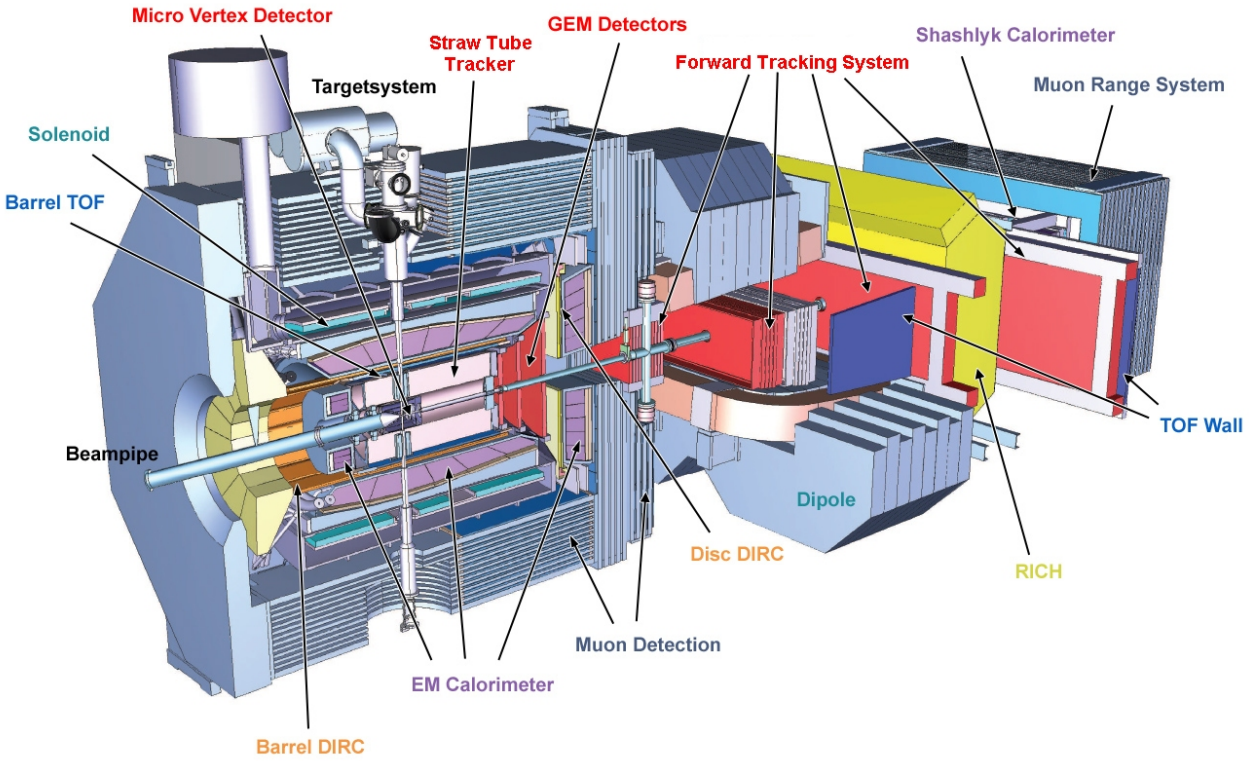
Mode	High Luminosity	High Resolution
$\Delta p/p$	$\approx 10^{-4}$	$4 \cdot 10^{-5}$
$\mathcal{L}$ [cm^{-2}s^{-1}]	10^{32}	10^{31}
Stored $\bar{p}$	10^{11}	10^{10}





The PANDA Detector

- Target / forward spectrometer → almost 4π coverage
- Homogeneous crystal calorimeter & sampling calorimeter (forward)
- Flexible event selection: No hardware trigger! (Talk by M.Tiemens)

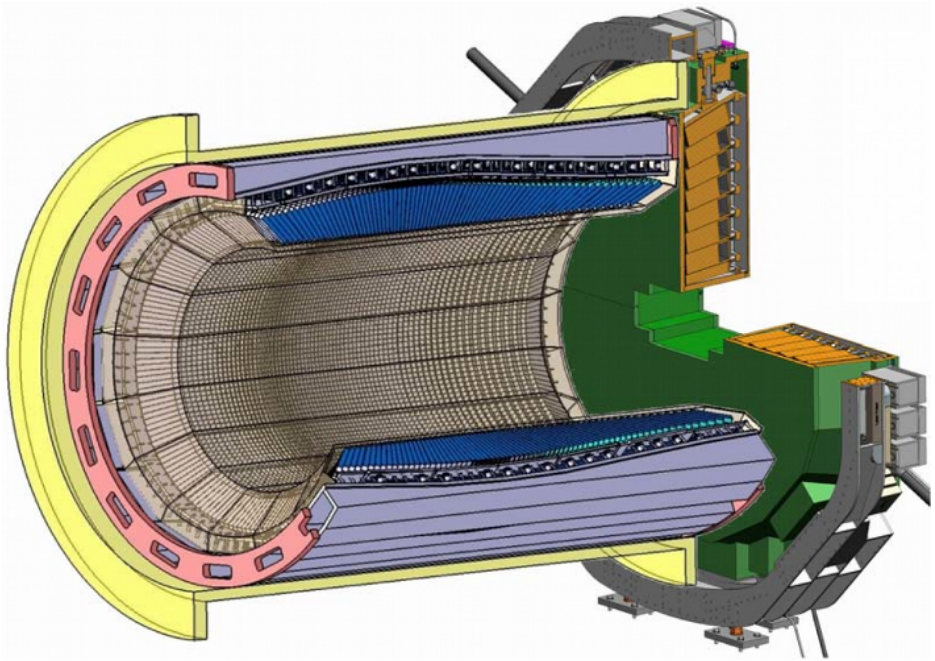


Diverse and unique ($\overline{p}$) physics program:

- Hadron spectroscopy
  - Light mesons
  - Charmonium
  - Open charm
  - Search for exotics
  - Baryons (double strange, charmed)
- Baryon anti-baryon production
- Mesons in nuclei
- Hypernuclei
- Proton structure

The $\overline{\text{P}}$ANDA EMC

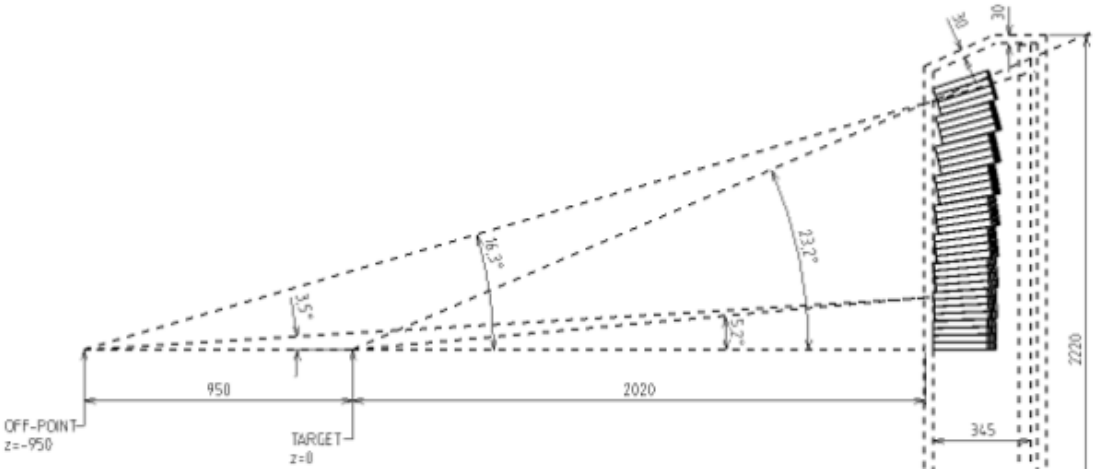
- EMC consists of barrel part and two endcaps
- Scintillation material: Lead tungstate ($PbWO_4$)
- 15552 crystals (200x25x25 mm^3; Length corresponds to $\approx 22 \cdot X_0$)
- Time resolution: $< 2\,ns$

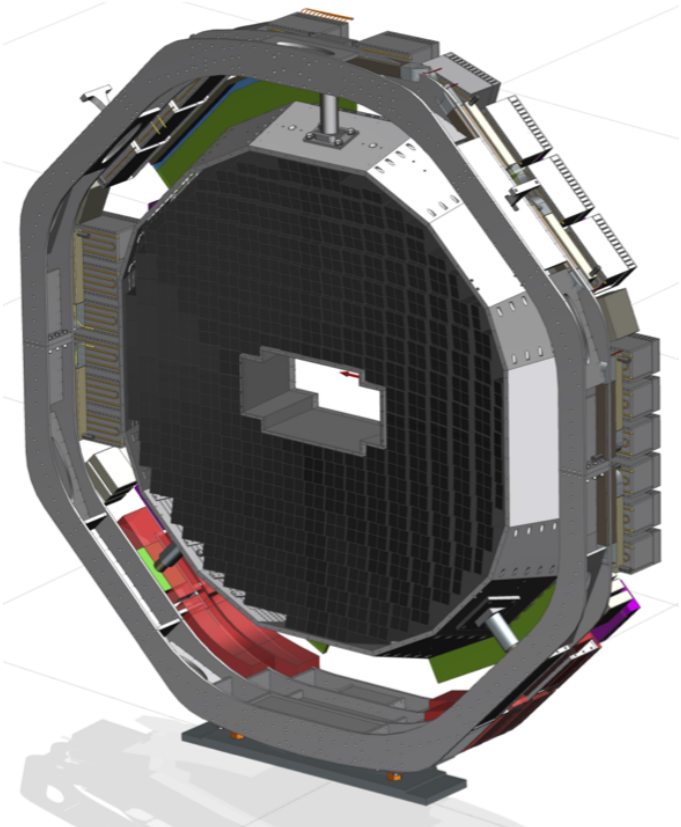


- Envisaged energy resolution: $\leq 1\% \oplus \frac{\leq 2\%}{\sqrt{E/\text{GeV}}}$
- Cluster threshold: 10 MeV
- Coverage: 98% of 4π
- Operating at -25 °C $\rightarrow$ 4 times higher light output compared to +25 °C

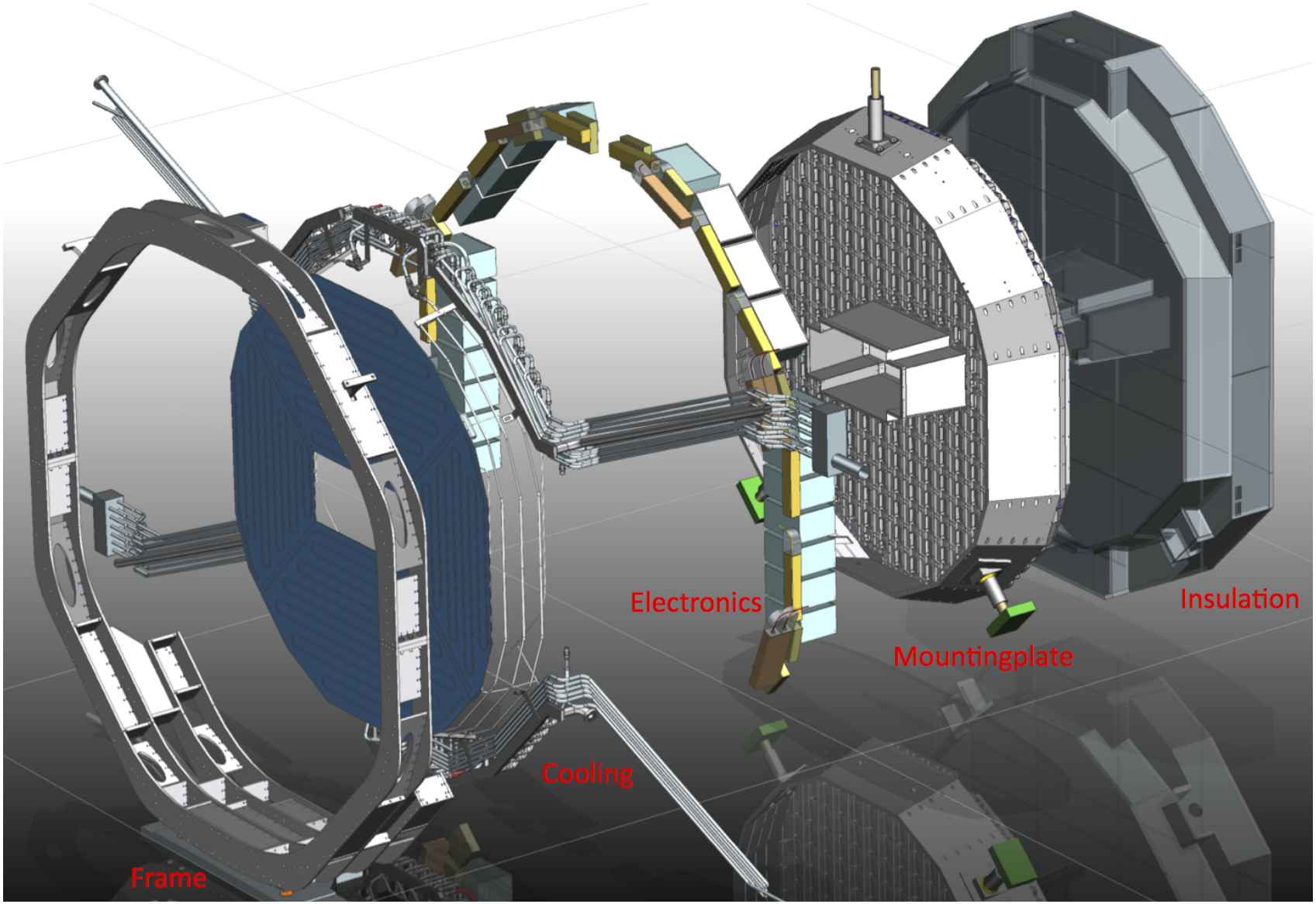
The forward endcap of the EMC

- 3856 $PbWO_4$ crystals
- Crystals are read out with Vacuum Photo Tetrodes (VPTTs) and Avalanche Photo Diodes (APDs)
- Angular coverage: $5° < \theta < 23.6°$
- Magnetic field of up to 1.2 T
- Off-pointing geometry



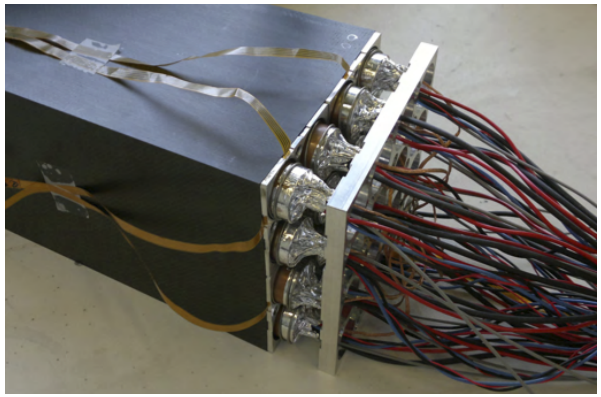


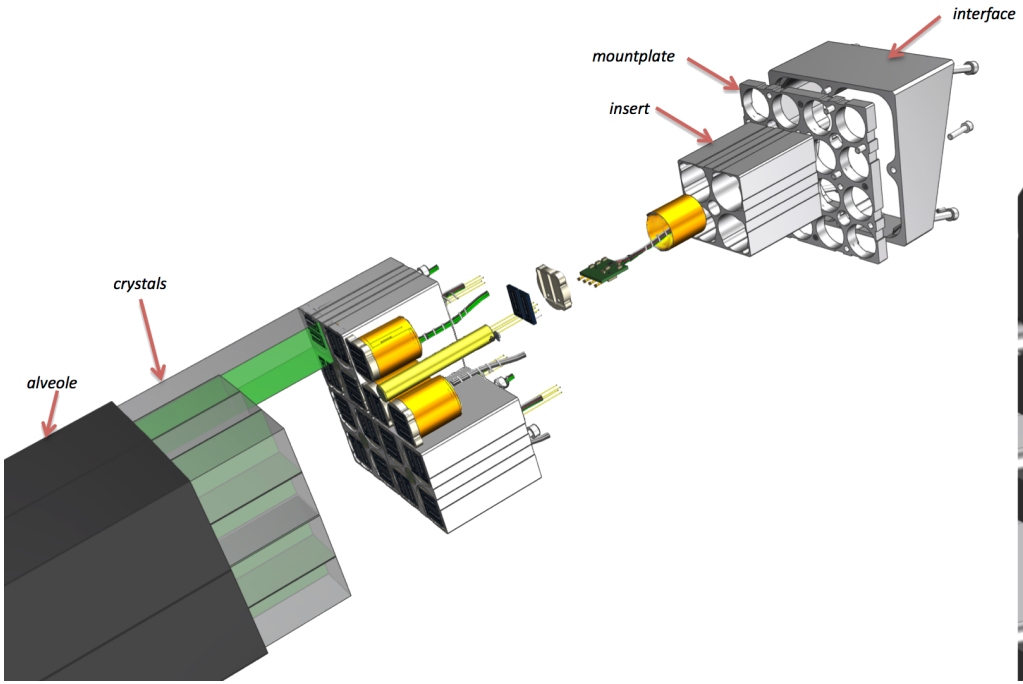
Construction of the Forward Endcap

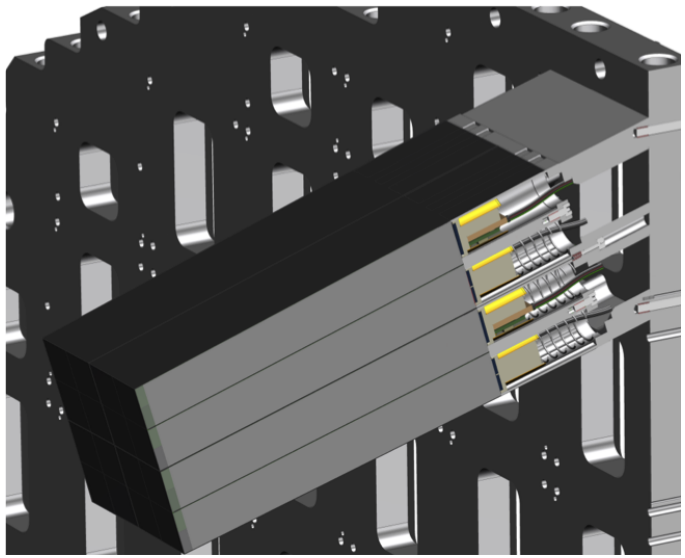


Crystal Subunits

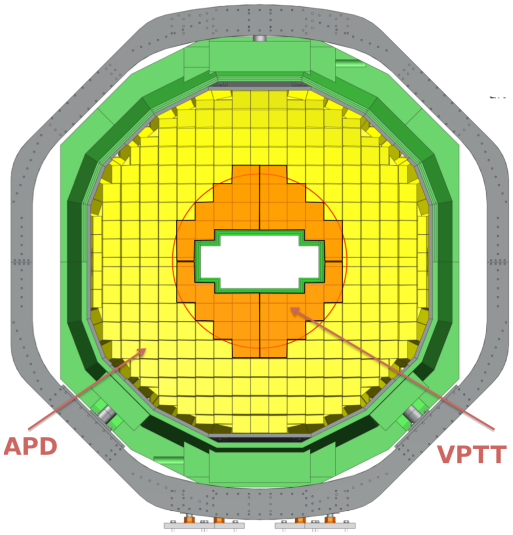
- 16 crystals are grouped into one subunit
- Each crystal is wrapped in DF2000MA reflective foil (3M)
- Ultrathin temperature sensors ($d \leq 150\,\mu m$) are placed in between the crystals
- Mechanical support structure: Carbon fibre alveole and aluminium parts



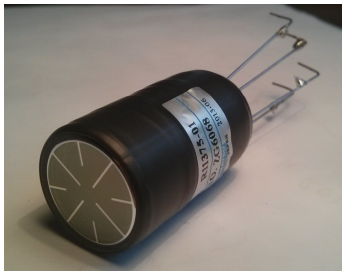


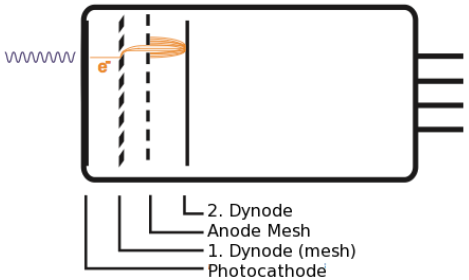


Photodetectors

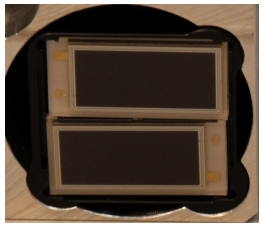


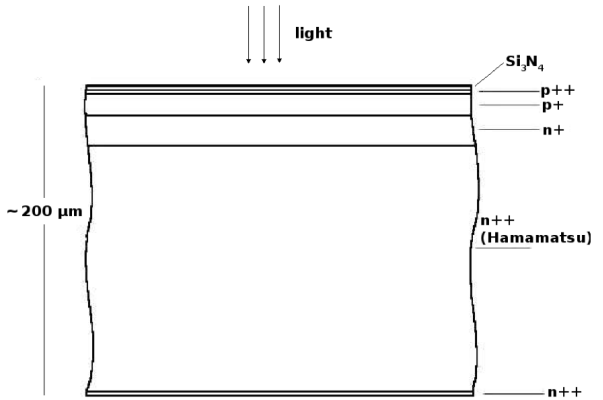
VPTT (Hamamatsu)





APD (Hamamatsu)





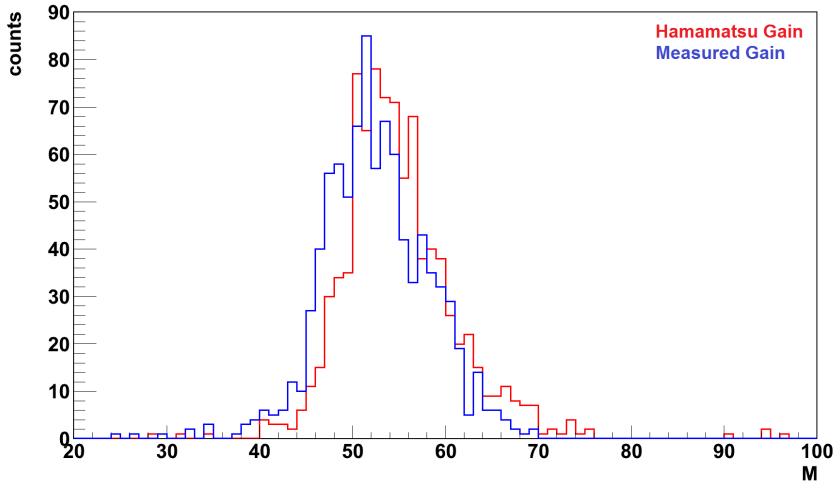
	VPTT (Hamamatsu)	APD (Hamamatsu)
Quantum eff.	$\approx 23\%$	$\approx 80\%$
Active area	$200\,\mathrm{mm}^2$	$6.8 \times 14 = 95.2\,\mathrm{mm}^2$
Gain	typ. 50	200
Dark current (Anode)	$\leq 1\,\mathrm{nA}$	$1\,\mathrm{pA}$ – max. $20\,\mathrm{nA}$
Capacity	$\approx 22\,\mathrm{pF}$	$\approx 270\,\mathrm{pF}$

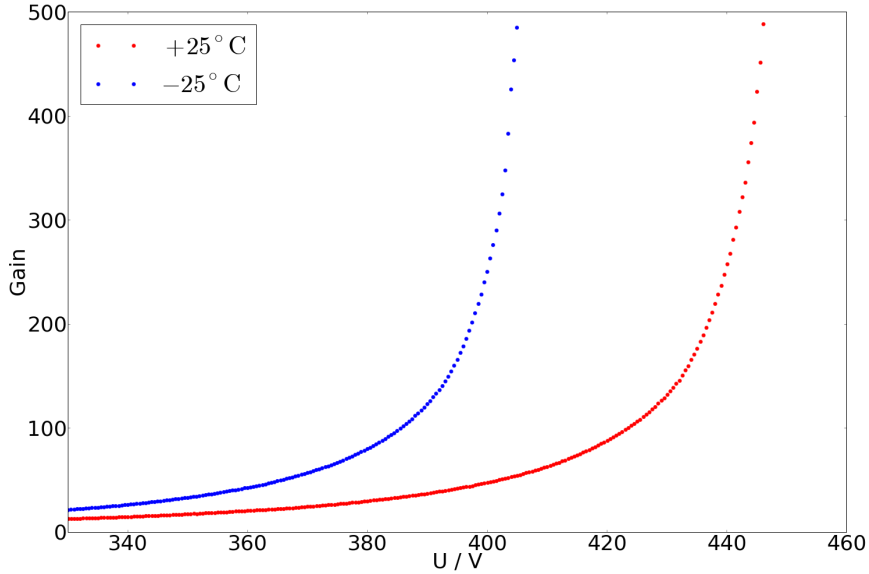
Photodetectors

- VPTTs:
  - Anode and cathode current for illumination with DC-light is measured, to verify gain given by Hamamatsu

  → **All 900 VPTTs are delivered and screened!**
  (Mean gain: $\overline{M} \approx 53$@750 V)
- APDs:
  - Gain of APDs is strongly temperature dependent
  - Matching of APDs necessary to use common high voltage

  → Measure response curve of APDs at different temperatures
  - Slope of the response curve at Gain=200, -25 °C:
  Gain changes by 15 per Volt!



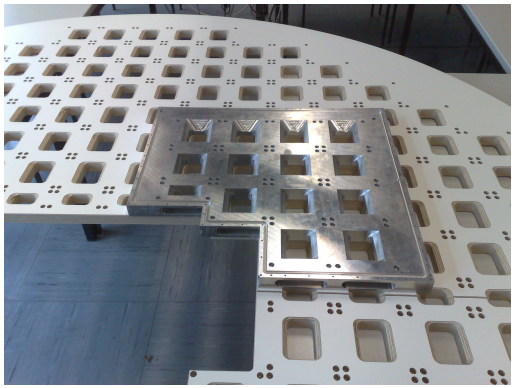


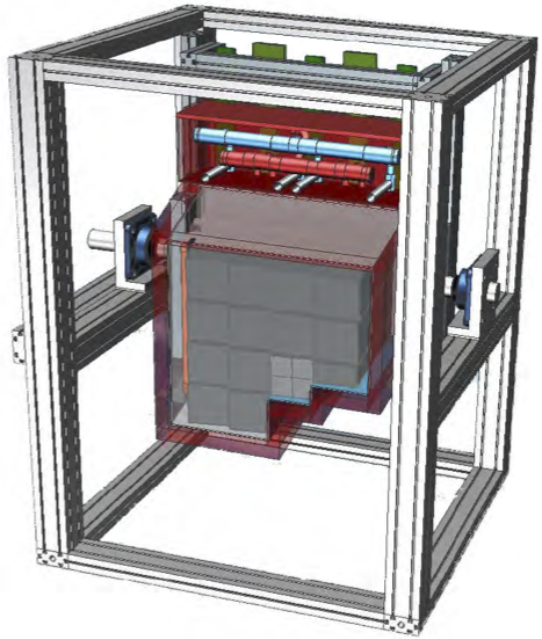
The Forward Endcap Prototype

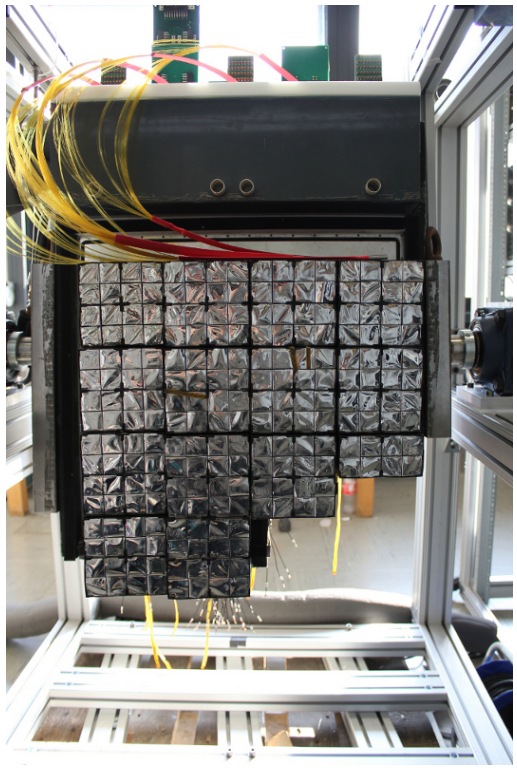
- Subsection of forward endcap comprised of 216 crystals
- Equipped with different types of photosensors

→ Tests of mechanical components, cooling, readout electronics, slow control

→ Determination of minimal energy threshold, energy resolution, spatial resolution and rate stability of photosensors

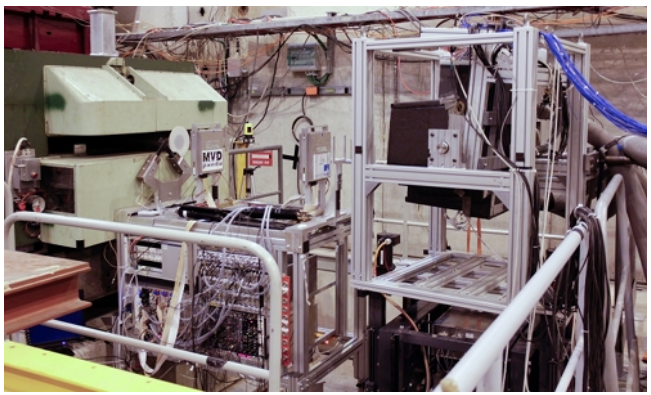


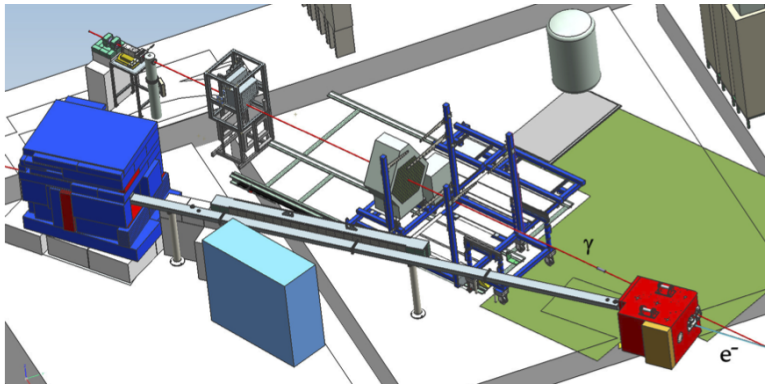




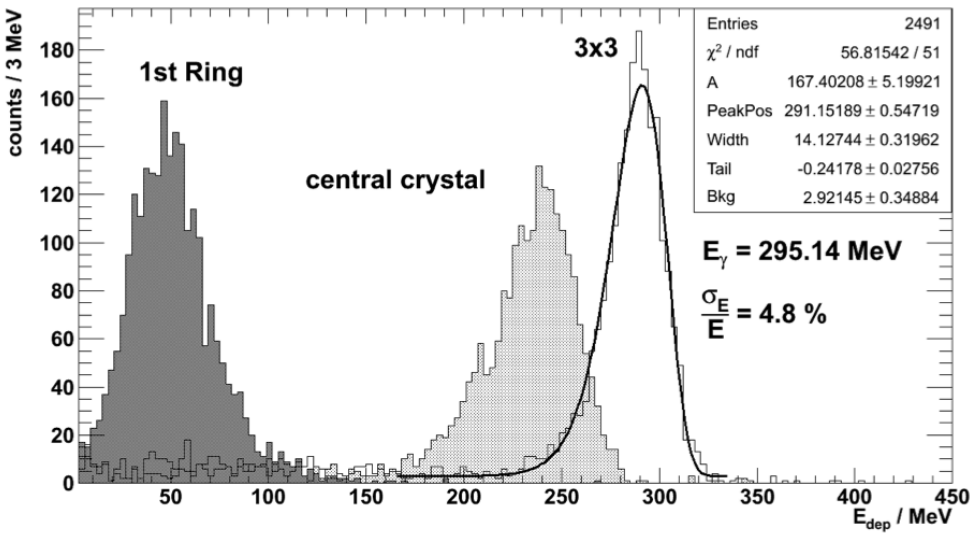
Test Beamtimes

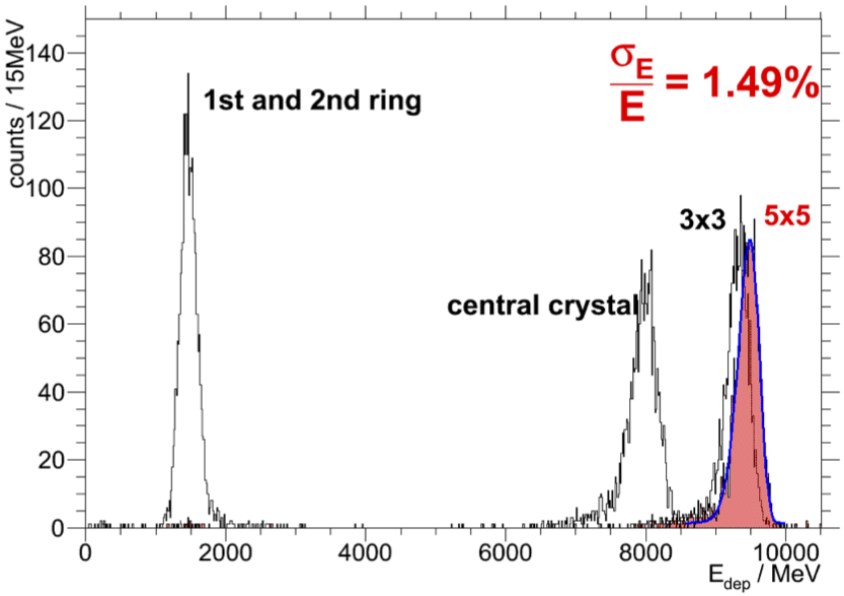
	Beam particles	E_{Beam} or p_{Beam}	Specialties
CERN/SPS	e^+ μ^+	10, 15 GeV/c 150 GeV/c	max. PANDA energy dep. energy $\approx$ 230 MeV
ELSA/Bonn	Tagged γ	1, 2.1, 3.1 GeV	Rates up to $2 \cdot 10^6\ \text{s}^{-1}$
MAMI/Mainz	Tagged γ	20 – 415 MeV	excellent beam energy resolution
CERN/SPS	e^- $\pi^+, K^+, \bar{p}$	5 – 15 GeV/c 15, 50 GeV/c	Fibre / Si-strip TrackingStation
ELSA/Bonn	e^-	1.25, 2.4, 3.2 GeV	2 final subunits tested





Energy Resolution

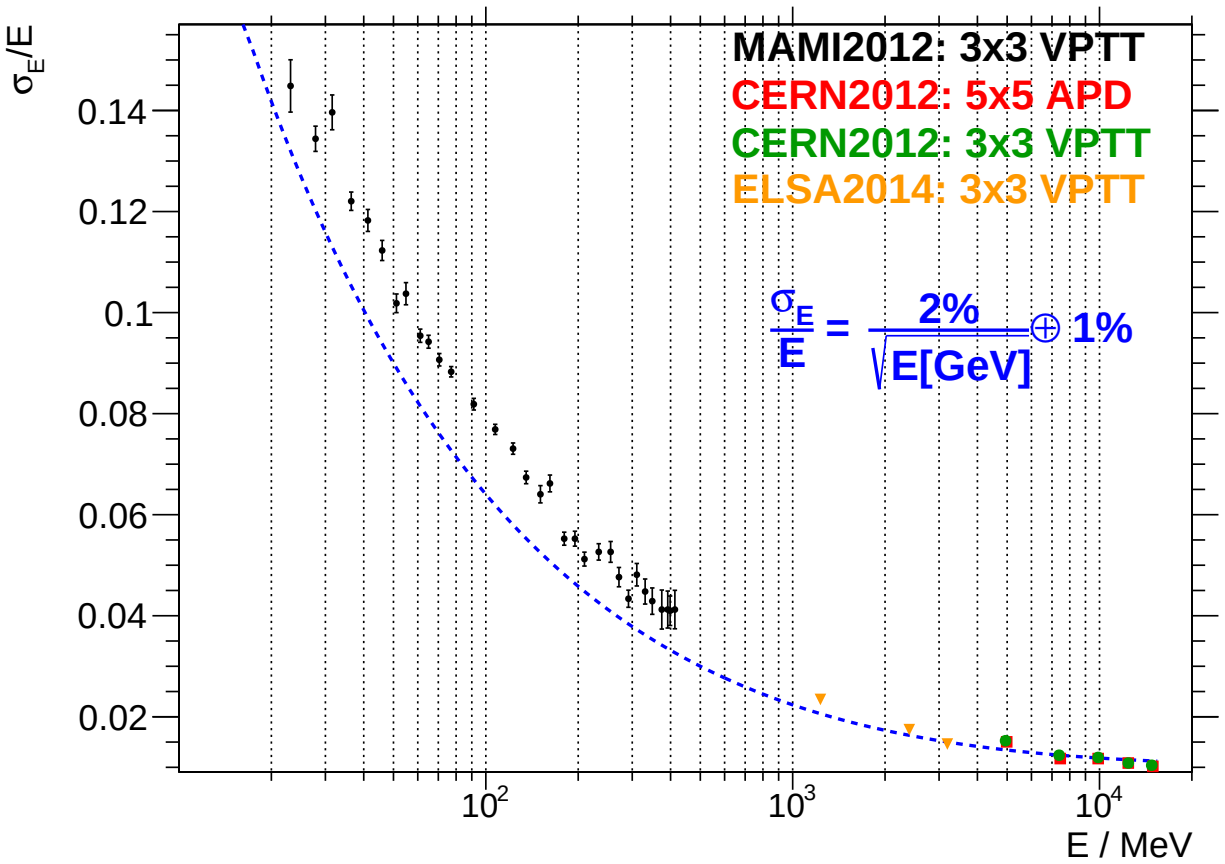




- Tagged photons (MAMI beamtime)
- $E_\gamma = 295.14\,\mathrm{MeV}$
- Data from 3×3 crystal matrix equipped with VPTTs

- 10 GeV positrons (CERN/SPS beamtime)
- Data from 5×5 crystal matrix equipped with VPTTs / VPTs

Energy Resolution - Summary



- Blue: Envisaged resolution (TDR)
- High energies: TDR values can be reached
- Low energies: small deviations → could be improved with final design of readout electronics (shaper + ADC boards)

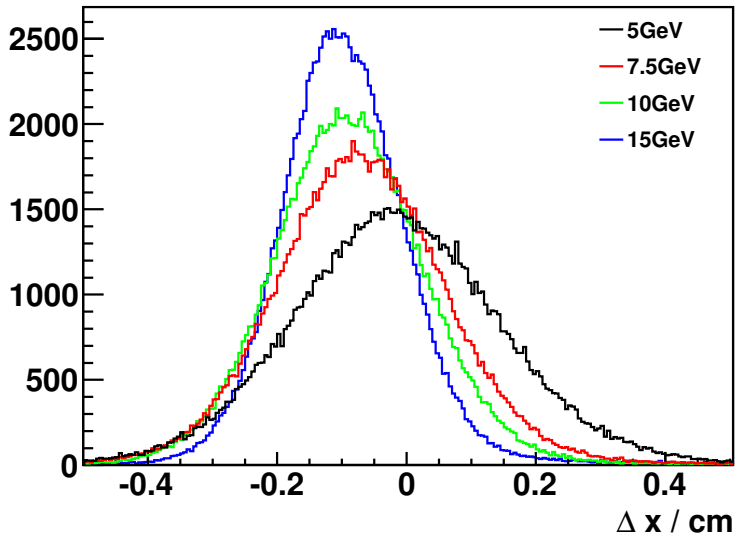
Position Resolution

- Spatial resolution: Difference between point of impact calculated from energy deposition and tracking detectors (Δx)
- Resolution has been determined for 5 – 15 GeV electrons
- Distribution is shifted with increasing energy due to non-zero angle between beam axis and crystals
- TDR requirement: ≤ 3.5 mm (for forward endcap)
  $\rightarrow$ has been achieved!

Achieved resolution:

- 5 GeV/c: $\sigma_x = 1.6$ mm
- 7.5 GeV/c: $\sigma_x = 1.3$ mm
- 10 GeV/c: $\sigma_x = 1.1$ mm
- 15 GeV/c: $\sigma_x = 0.9$ mm

(Work by: C.Hammann, U Bonn)

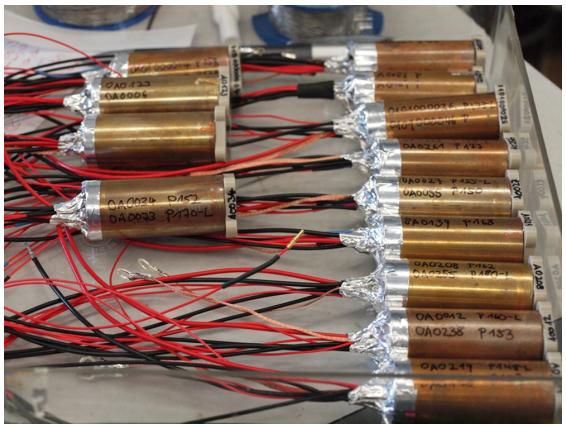


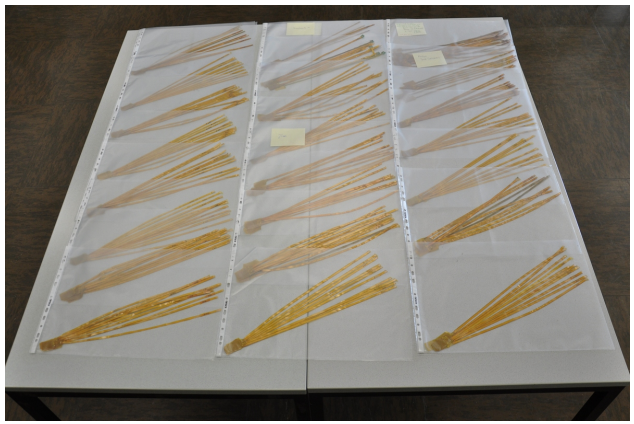
Summary

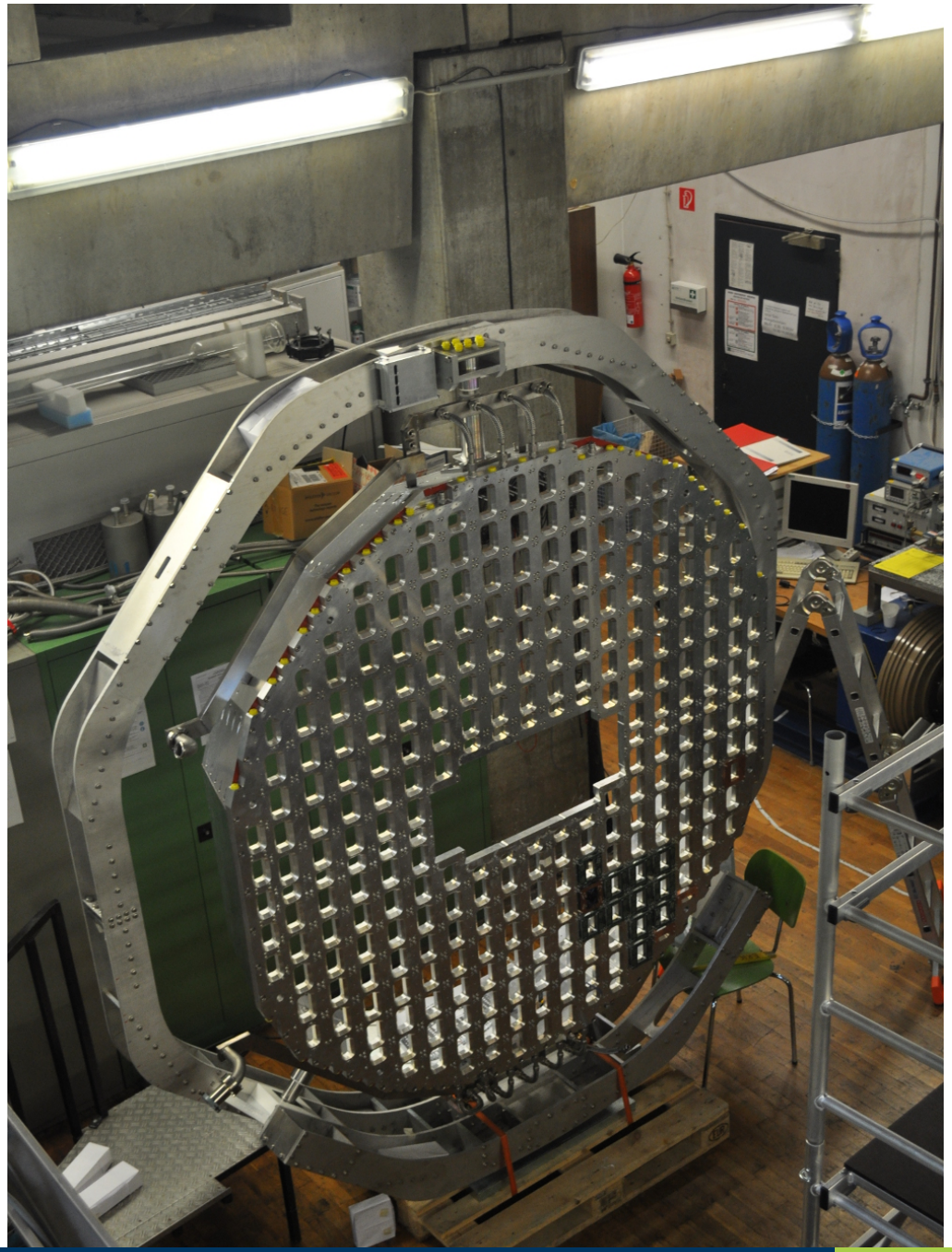
- Design of mechanical components finished, production started

→ **Backplate and support frame are delivered and assembled!**

- Delivery and screening of VPTTs finished
- Final gain matching of readout chain in progress
- Mass production of subunits will begin in the next months







Thank you for your attention!