II. Physikalisches Institut

HFHF
Helmholtz Forschungsakademie Hessen für FAIR

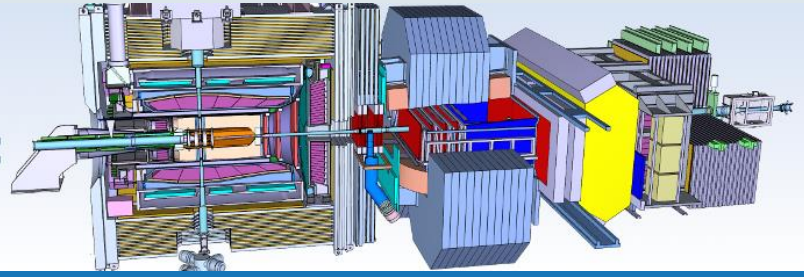
JLU
NEUE WEGE. SEIT 1607.

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

PANDA-Experiment
Hadronenphysik an FAIR

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

ErUM-FSP T08:
PANDA



Erforschung von Universum und Materie
BMBF-Forrschungsschwerpunkt

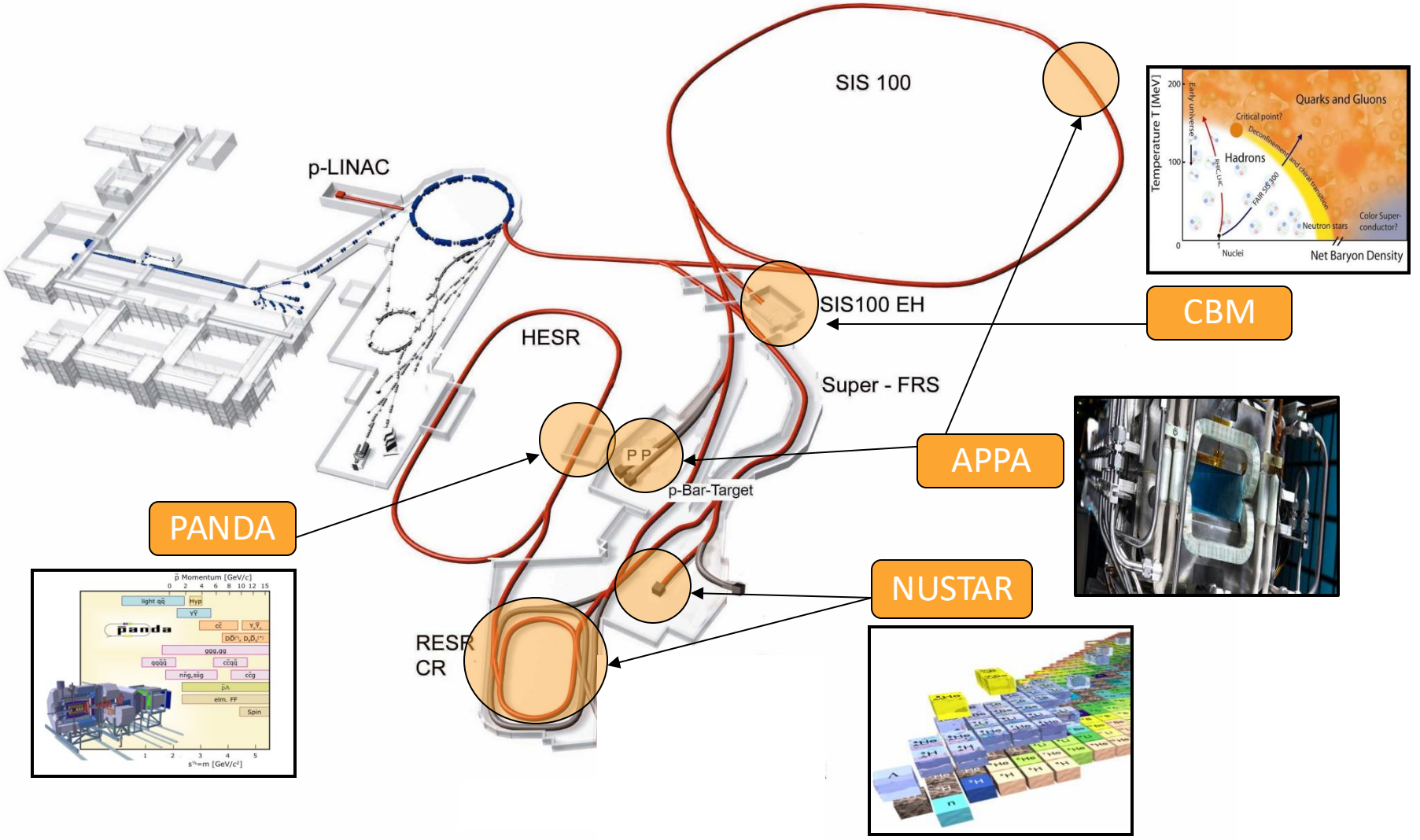
panda FAIR

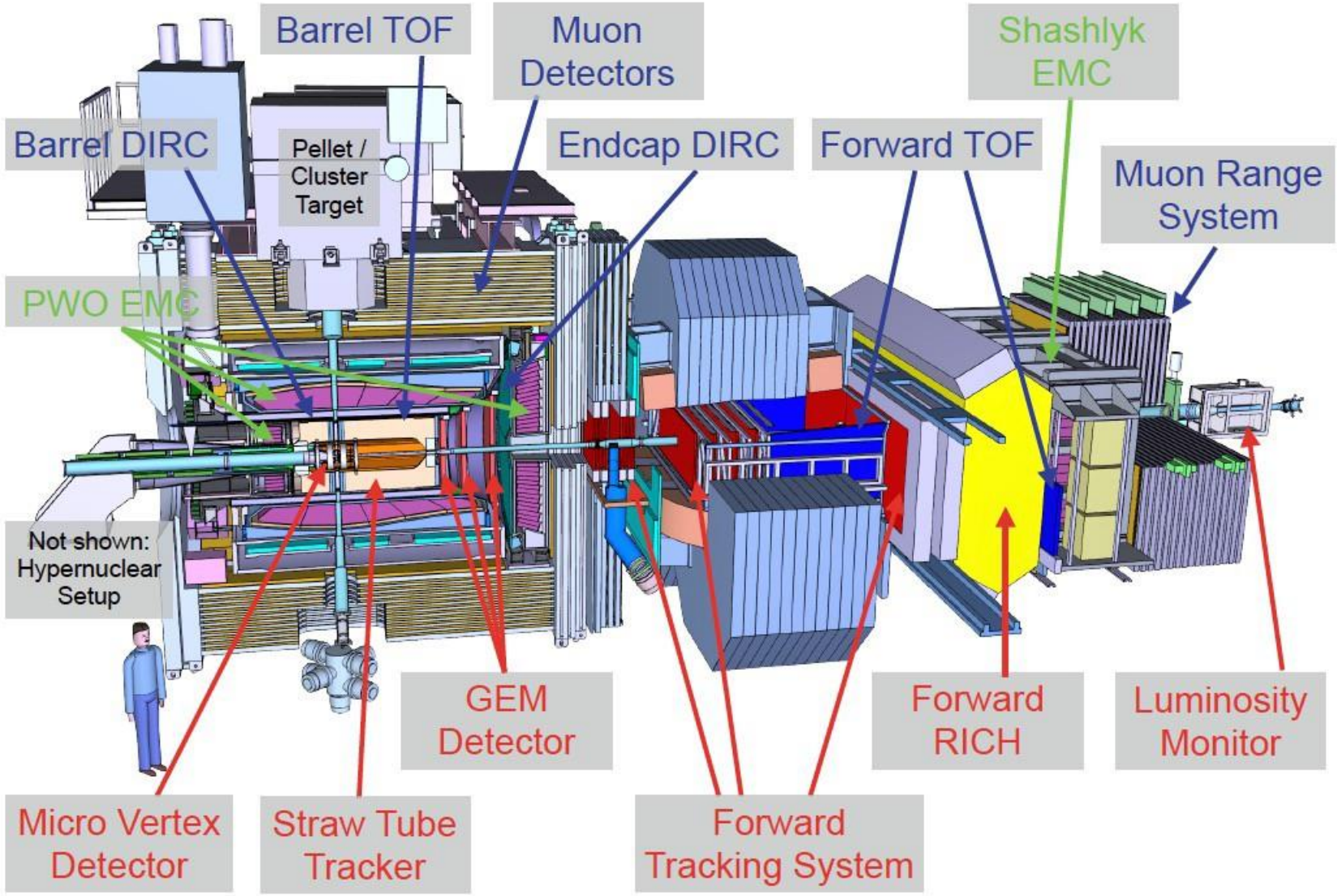
K.-Th. Brinkmann, JLU Gießen & HFHF

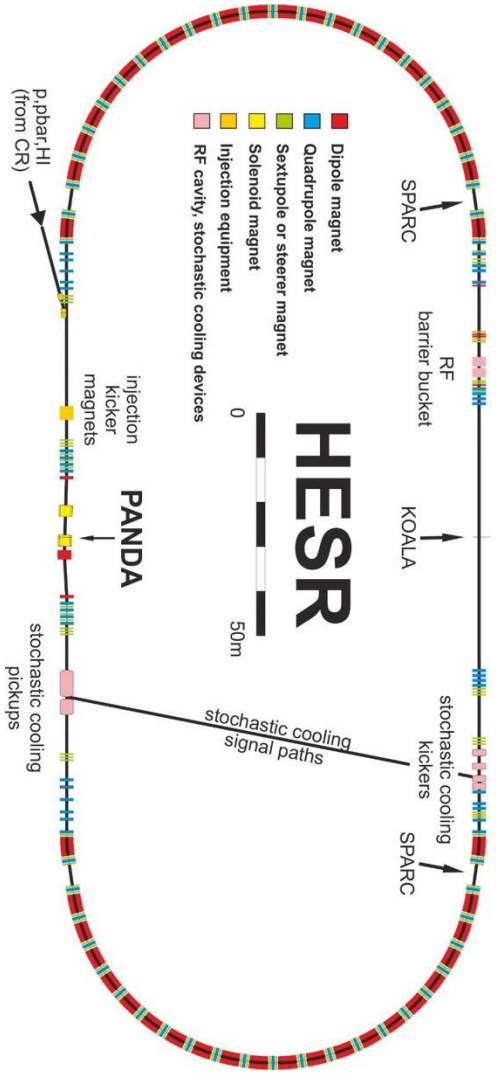
panda

bmb+f
Großgeräte der physikalischen Grundlagenforschung

Facility for Antiproton and Ion Research




Barrel TOF
Muon Detectors
Shashlyk EMC
Barrel DIRC
Pellet / Cluster Target
Endcap DIRC
Forward TOF
Muon Range System
PWO EMC
Not shown: Hypernuclear Setup
GEM Detector
Forward RICH
Luminosity Monitor
Micro Vertex Detector
Straw Tube Tracker
Forward Tracking System


p,pbar,HI (from CR)
SPARC
RF barrier bucket
injection kicker magnets
PANDA
KOALA
stochastic cooling pickups
stochastic cooling signal paths
stochastic cooling kickers
SPARC
HESR
0
50m
Dipole magnet
Quadrupole magnet
Sextupole or steerer magnet
Solenoid magnet
Injection equipment
RF cavity, stochastic cooling devices

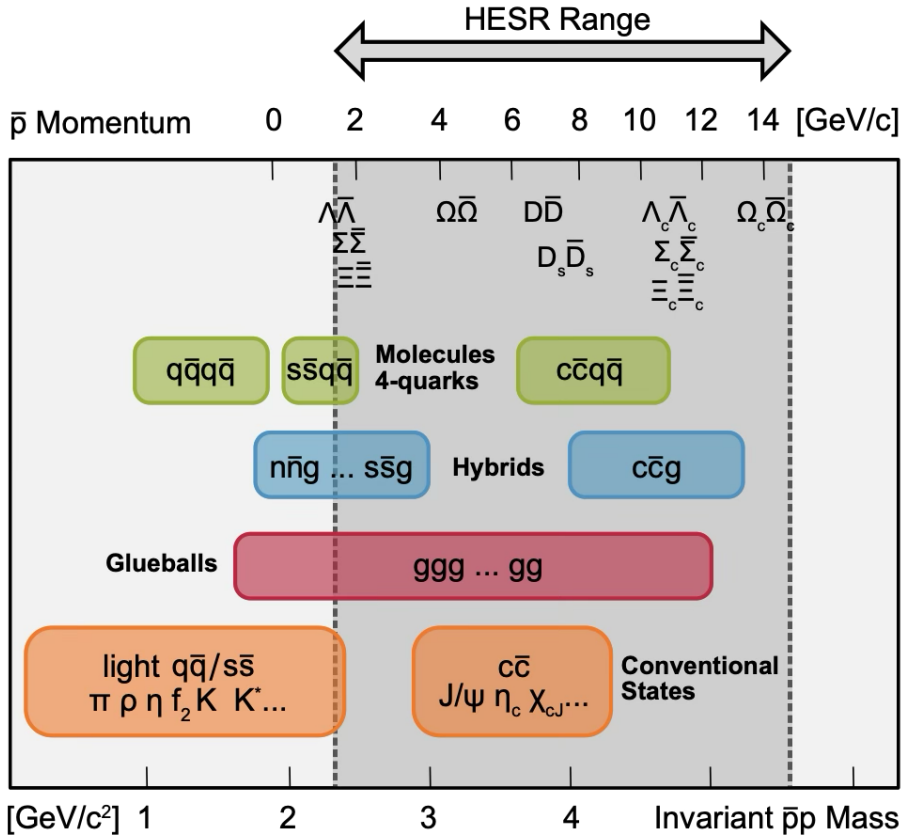
Hadron Spectroscopy

- Light mesons
- Exotic matter (Glueballs, Hybrids etc.)
- Charmonia (including XYZ states)
- Open Charm Physics
- Baryons and Hyperons

Nucleon Structure

- Generalised Parton Distributions (GPD)
- Transition Distribution Amplitudes (TDA)
- Time-like proton form factor
- Transverse Parton Distribution

Physics of Hypernuclei



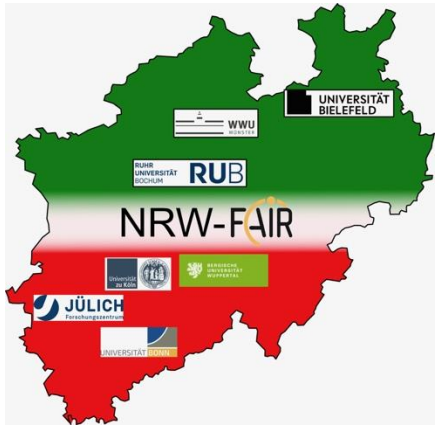
Very broad physics program

P̄ANDA will contribute to various fields!

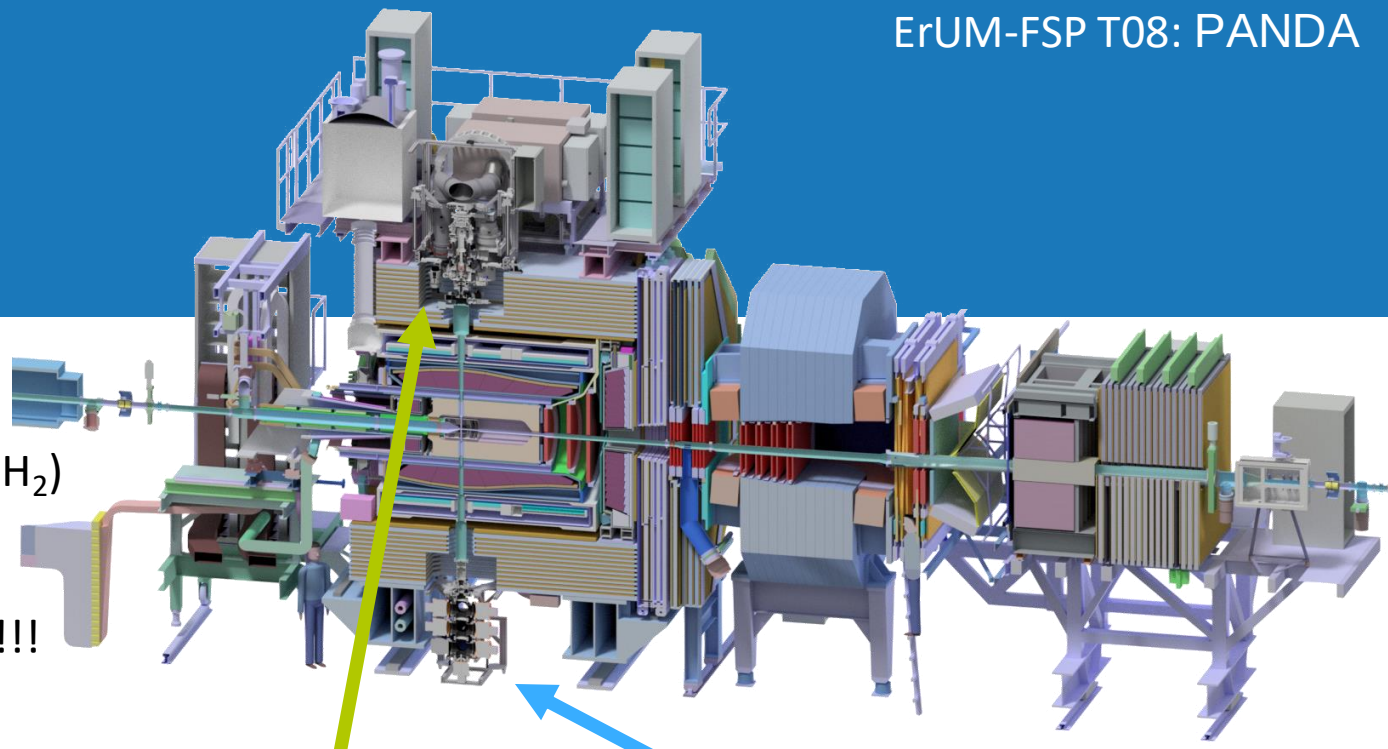
- International collaboration of about 500 scientists
- FAIR review 2022: physics reach and experimental program unique and world-class
- Yet, severe impact of FAIR delay and cost hike, world politics etc.
- Detector construction progressing well until 2022 (large Russian contribution lost)
- Large German university involvement

RU Bochum
RFWU Bonn
FAU Erlangen
GU Frankfurt
JLU Gießen
JGU Mainz (+HIM)
U Münster
FAIR/GSI

HFHF
Helmholtz Forschungsakademie Hessen für FAIR



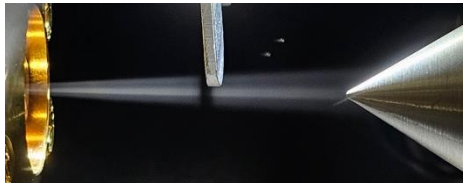
Cluster Jet Target (MS)

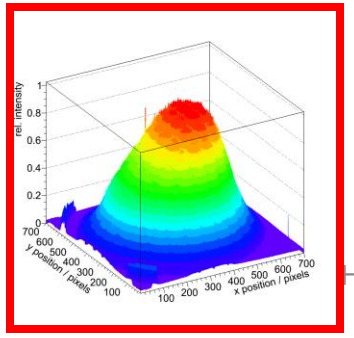


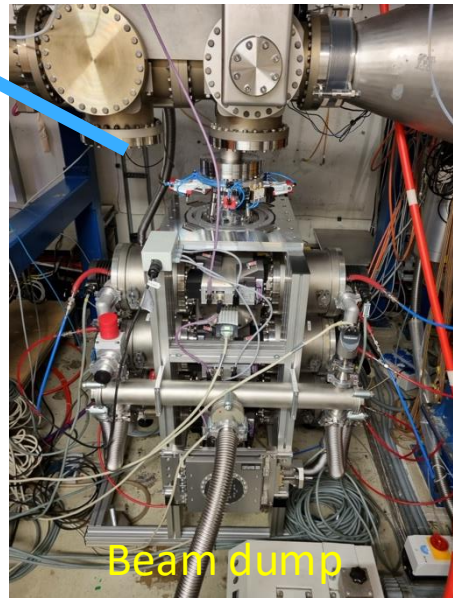
- From 2018 routinely in operation at COSY
- Target thickness achieved: **$2 \cdot 10^{15}$ atoms/cm^2** (H_2) for luminosities of up to **$L = 2 \cdot 10^{32}$ cm^{-2}s^{-1}**
- Interaction point: **> 2 m behind the jet nozzle** !!!

Very recently:

- New beam dump with new diagnostic tools in operation
- New jet nozzles produced for even higher target thicknesses



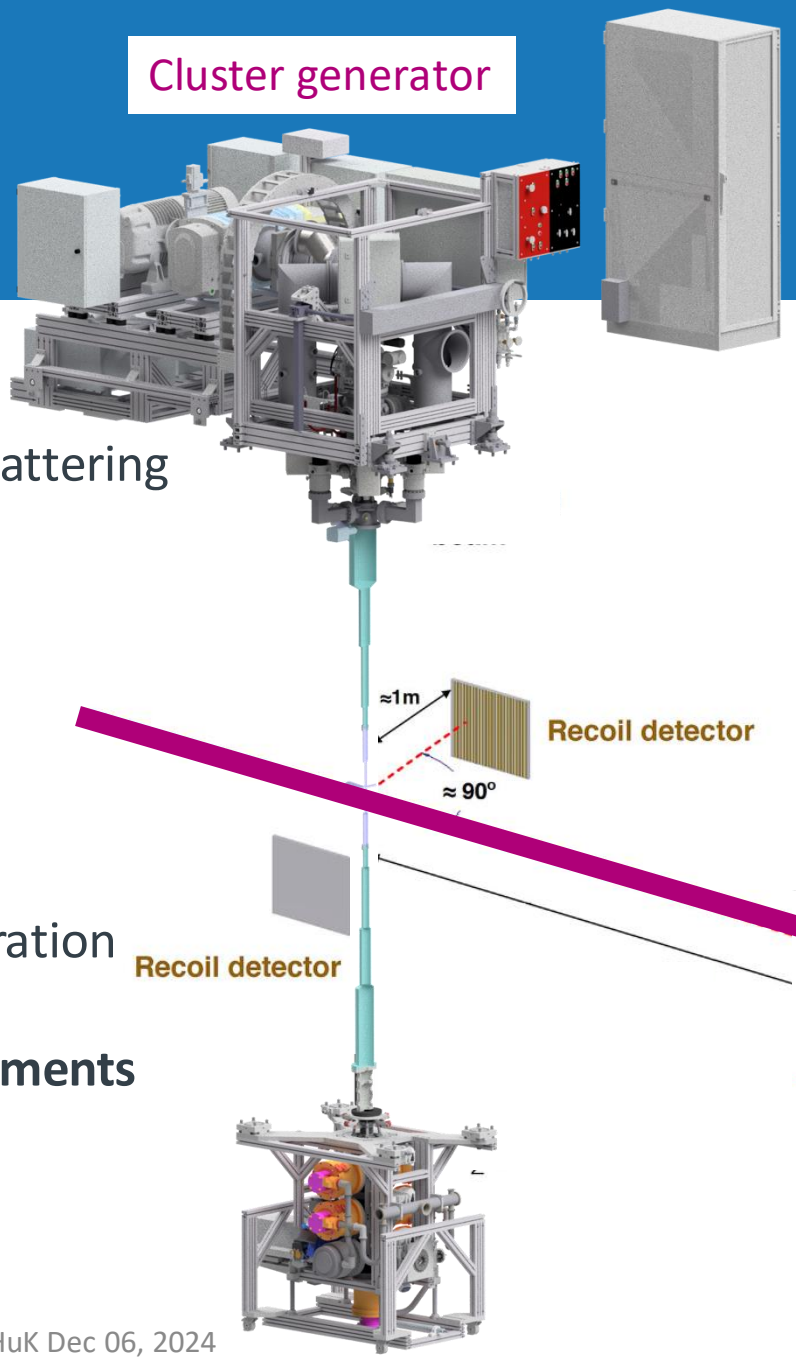




Cluster Jet Target

KOALA: From COSY to CaveC/GSI

- Preparatory measurements on $p\bar{p}$ elastic scattering at GSI-CaveC starting in 2026 using
  - **Final PANDA Cluster-Jet Target**
  - **Final PANDA Luminosity Detector**
  - **4 GeV SIS18 proton beam**
  - **90° recoil detector**
- Studies on ion beam induced cluster evaporation using protons and heavy ion beams with relevance for **PANDA** and **other FAIR experiments** (e.g. jet target experiments at Cryring)

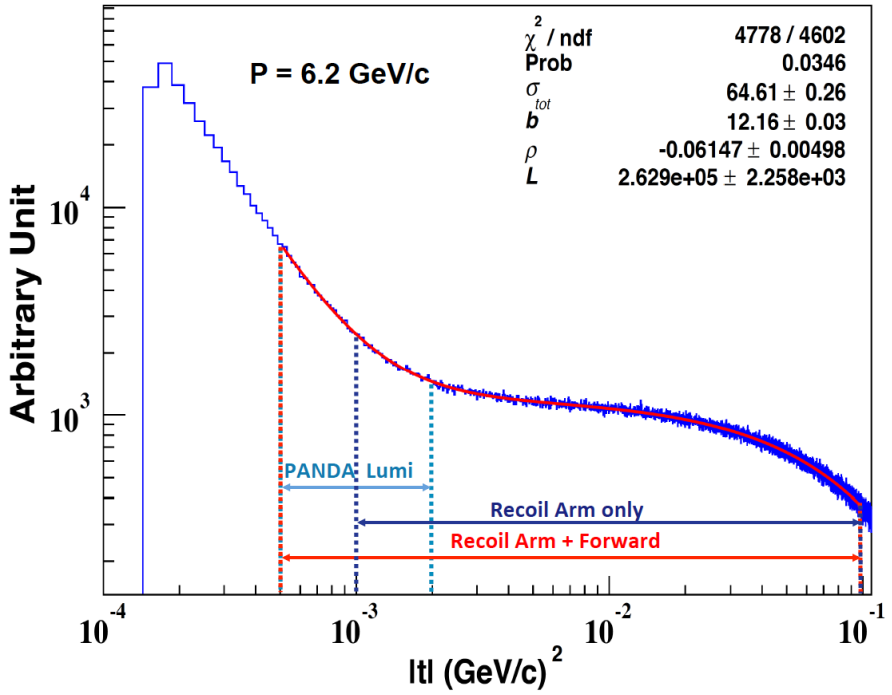


Participants:

RU Bochum, JGU Mainz, U Münster

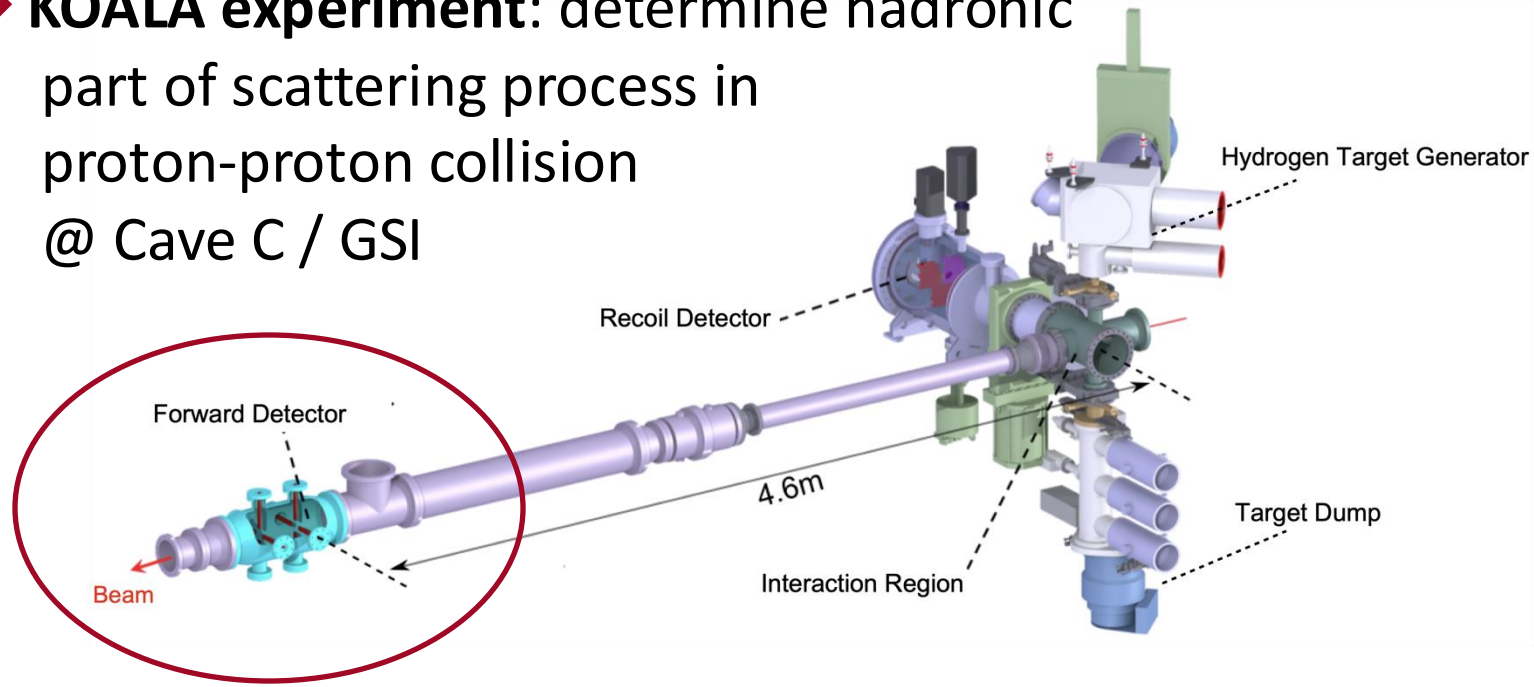
Luminosity Detector for KOALA@GSI

Knowledge of luminosity (<3%) of key importance for PANDA



- Elastic anti-proton - proton scattering process for luminosity measurment
- At small scattering angles QED part dominant
- At higher beam energies limitation from hadronic contribution

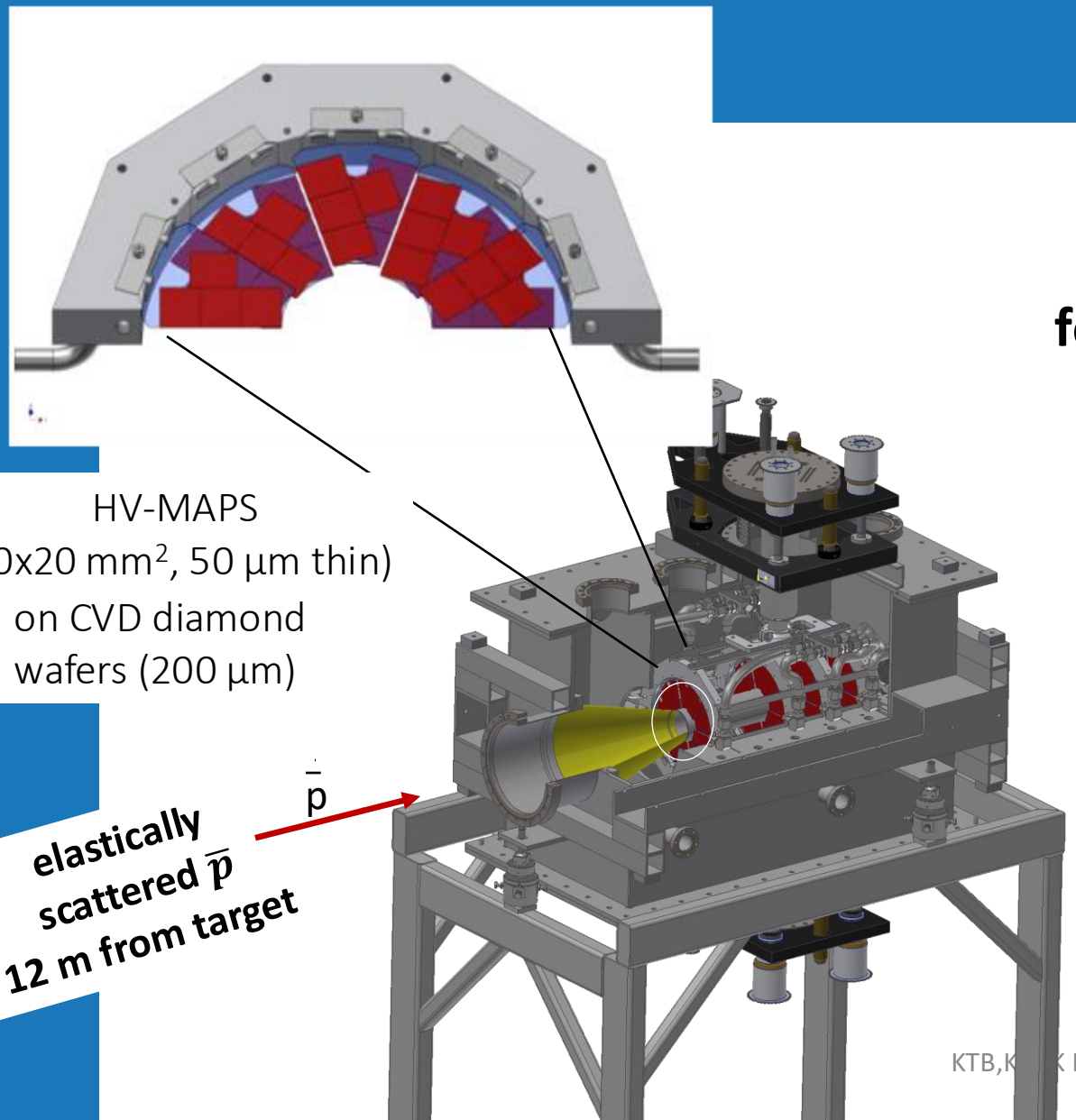
→ **KOALA experiment**: determine hadronic part of scattering process in proton-proton collision @ Cave C / GSI



BMBF

Cooperation between HIM and RU Bochum and U Münster
use PANDA luminosity detector as forward tracker

Luminosity Detector

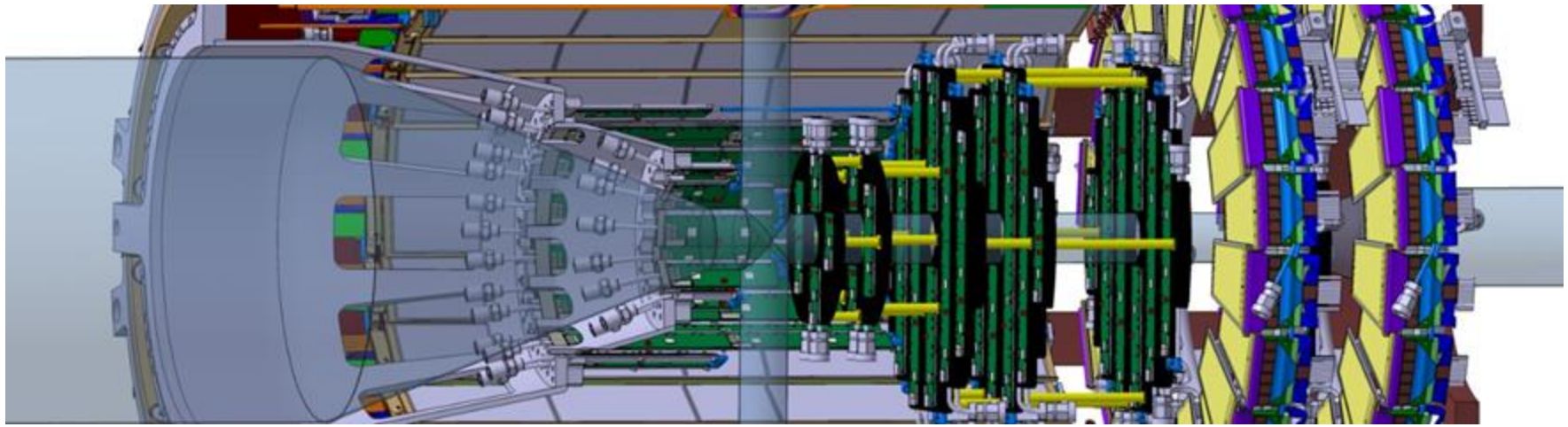


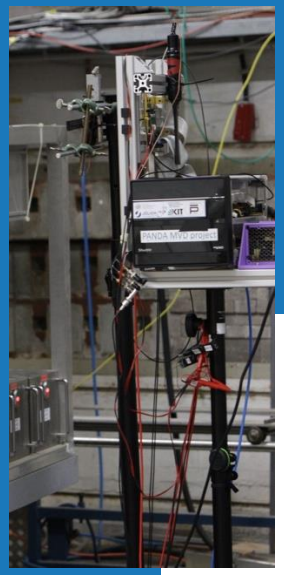
Pixel Tracking Detector
(HV-MAPS, 4 planes) located in vacuum
for elastically scattered antiprotons 3 – 8 mrad

Mainz responsibilities:

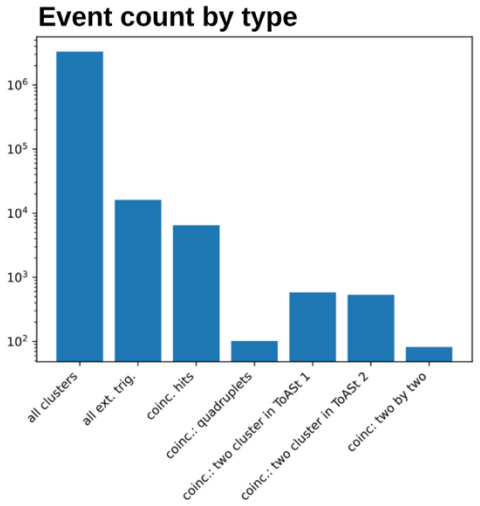
- mechanical construction
- cooling
- vacuum
- alignment
- integration
- electronics readout

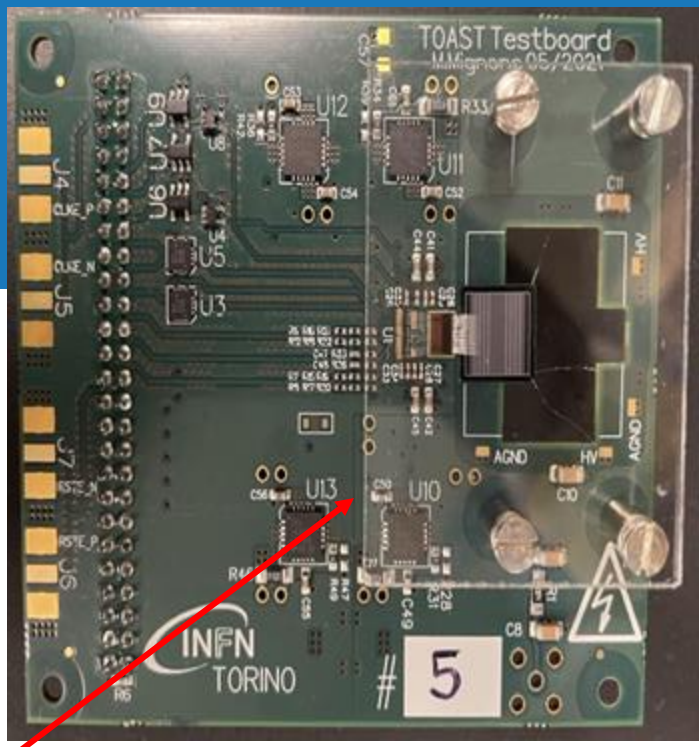
Challenges:
- cooling of HV-MAPS sensors
- operation in vacuum
- ultra-thin cables to reduce multiple scattering

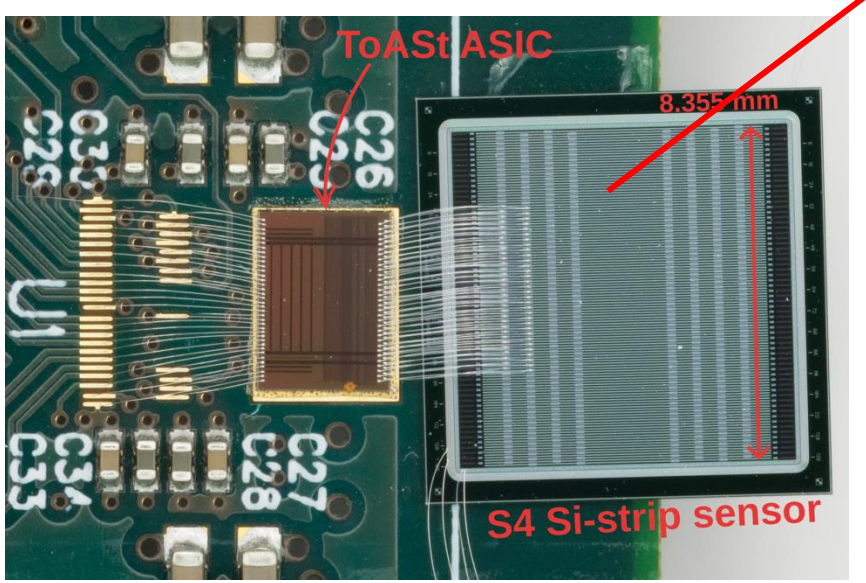


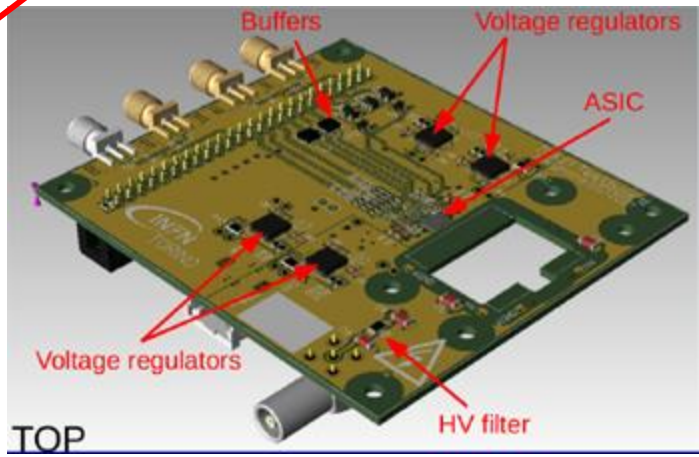


- PANDA (CiS) strip sensors connected toToASt front-end (Torino)
- Wire bonding (17 um Al, biasing, read-out, DAQ (KIT)
- Beam tests COSY, MAMI: DAQ, two-sensor coincidences



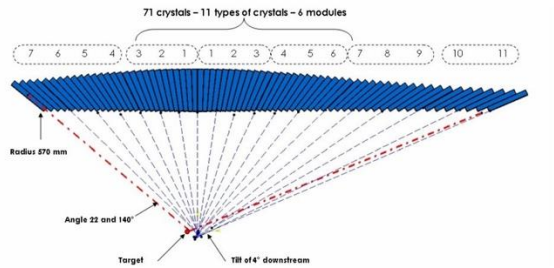


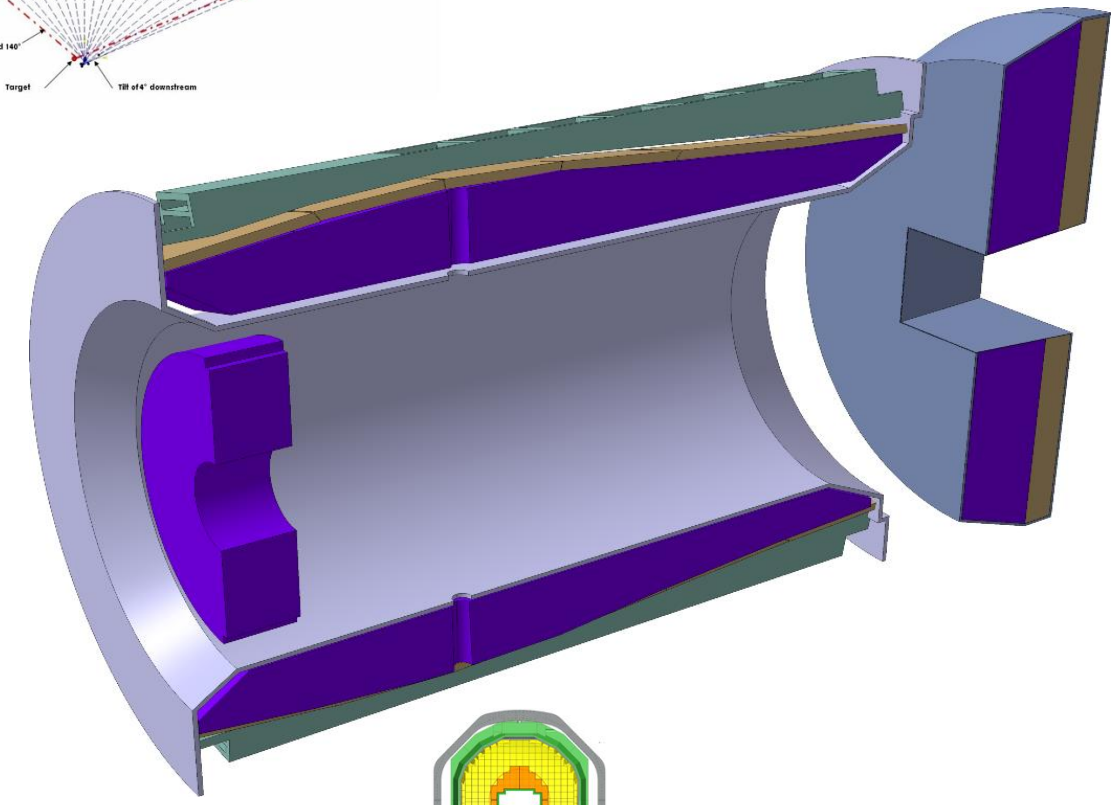


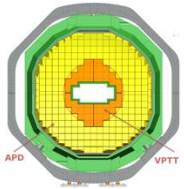


Electromagnetic Calorimeter

(BO, BN, GI, MZ, GSI, HIM,
Prague, Uppsala, Groningen ...)

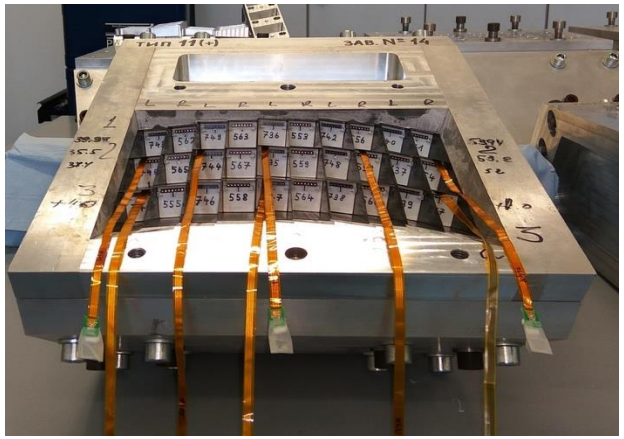






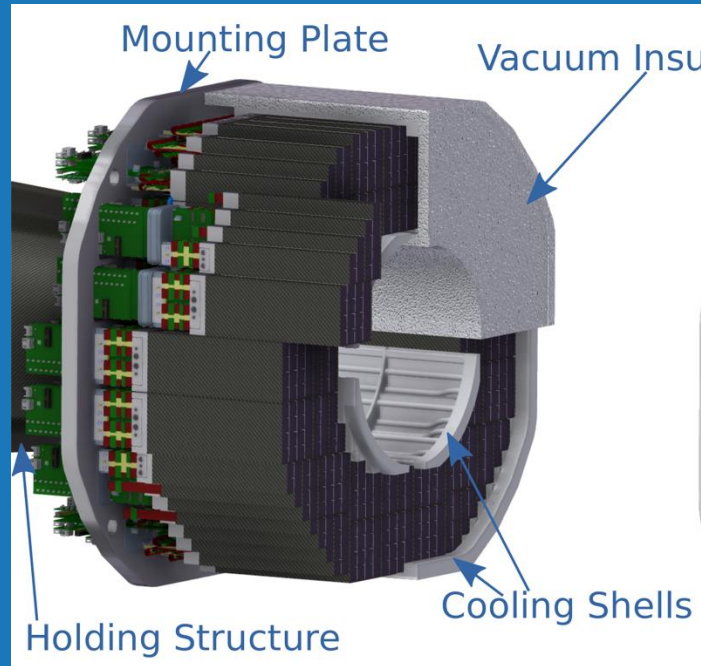
PWO-II

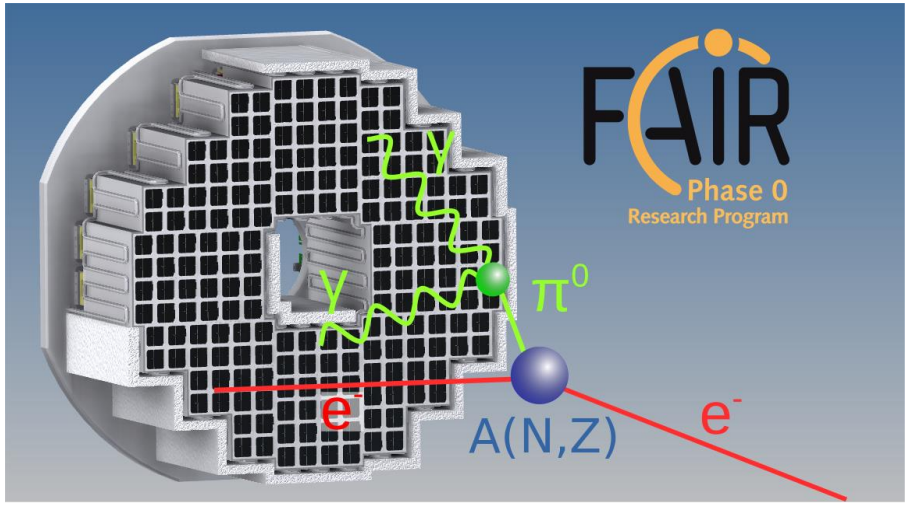
200mm (23 X_o)

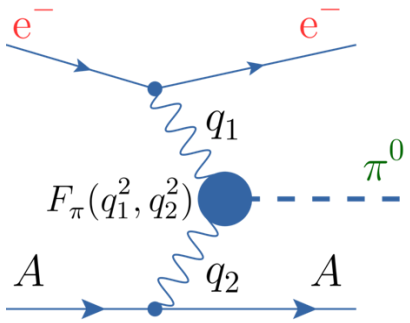


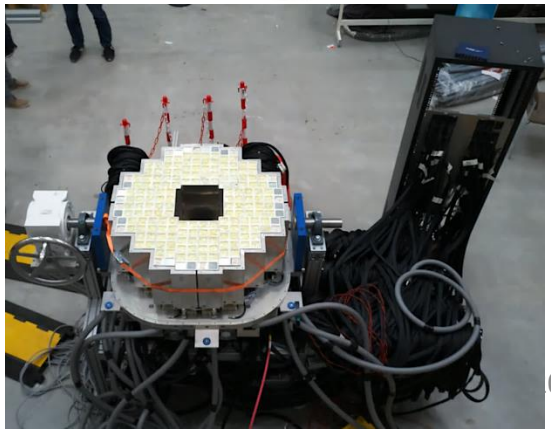
Electromagnetic Calorimeter: Backward Endcap at MAMI (MZ, HIM)

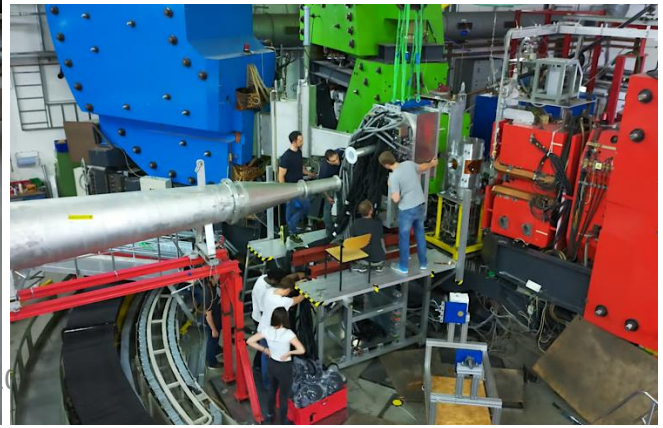
ErUM-FSP T08: PANDA

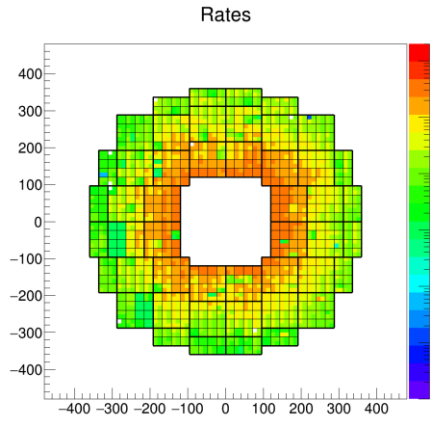




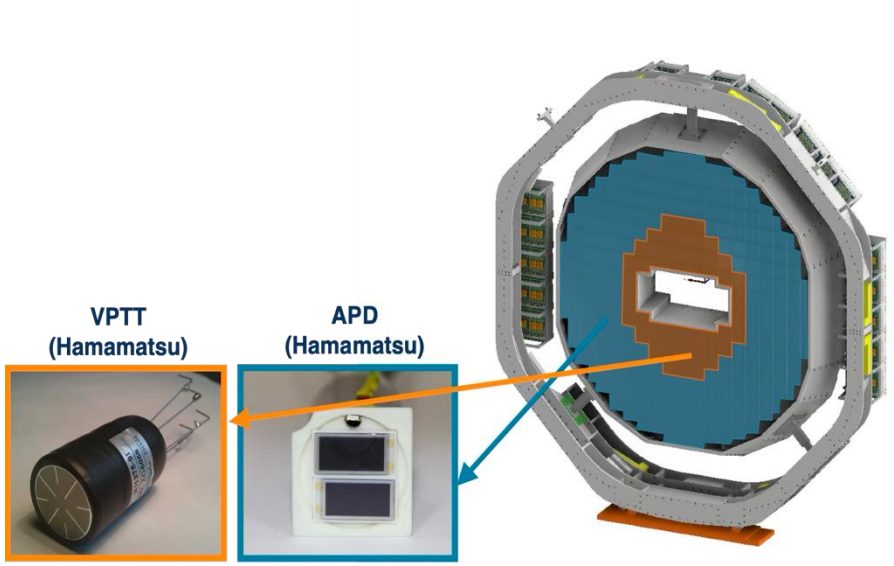


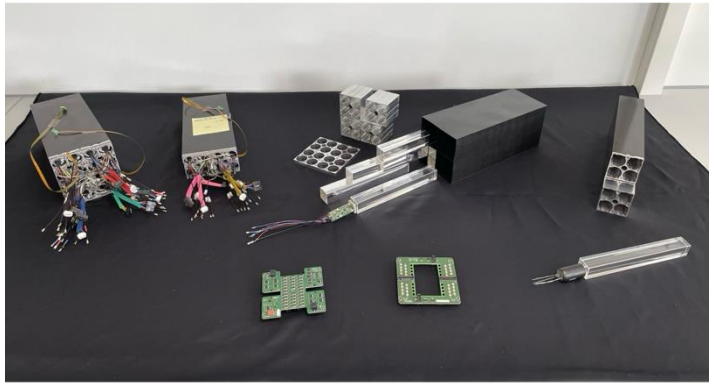


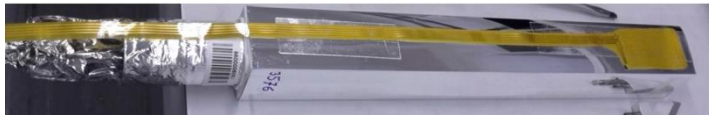




Electromagnetic Calorimeter: Forward Endcap (BO, BN, GI, GSI et al.)

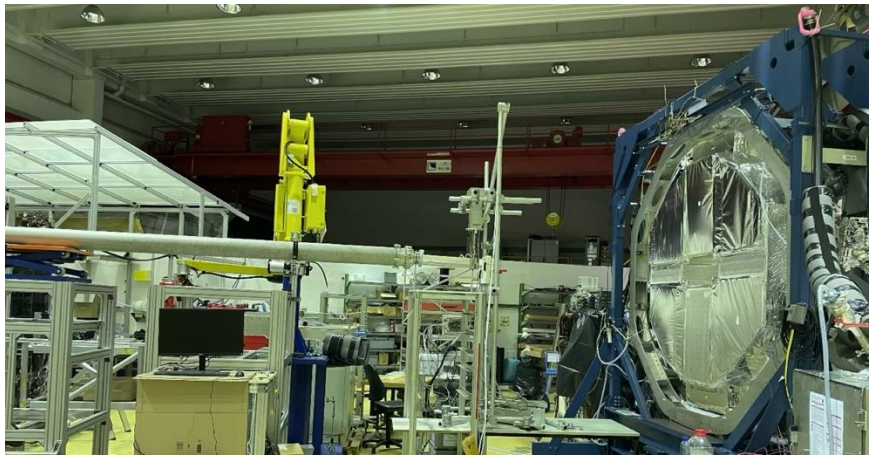






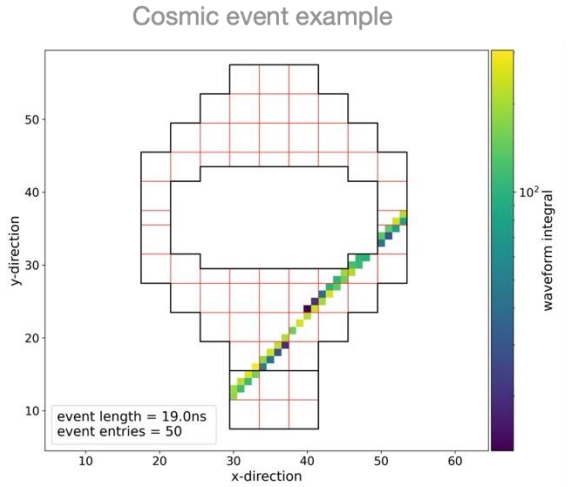
First test: COSY 2023

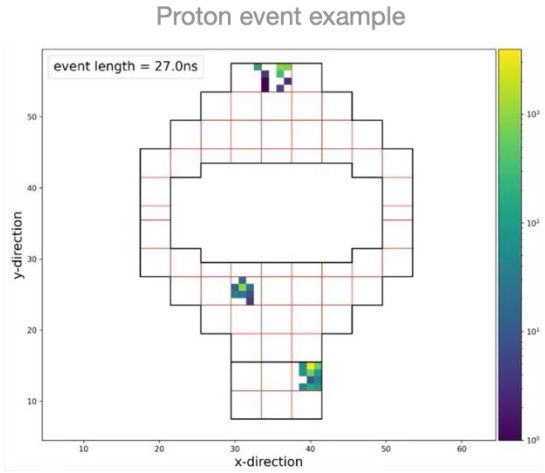
$pp \rightarrow pp\pi^0$

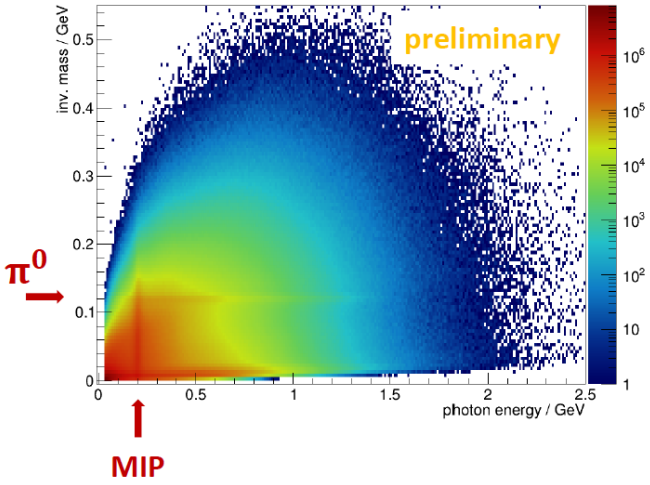


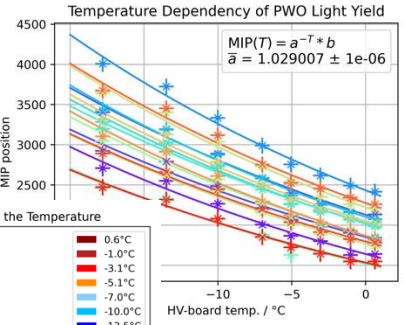
Electromagnetic Calorimeter: Forward Endcap at COSY

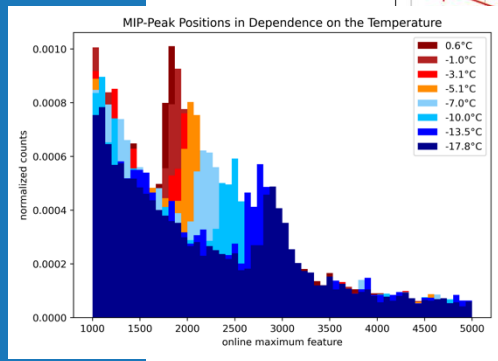
ErUM-FSP T08: PANDA

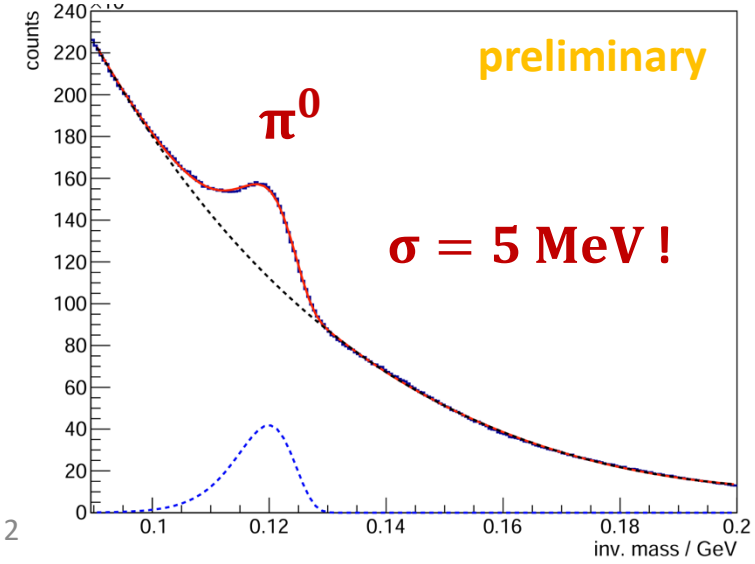












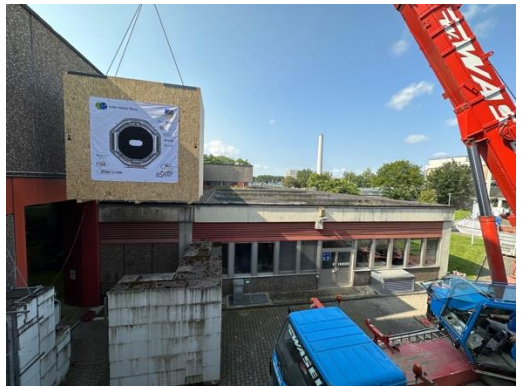
beam test, COSY:
protons, 2.74 GeV/c

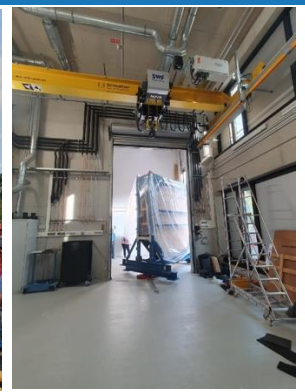
$pp \rightarrow pp\pi^0$

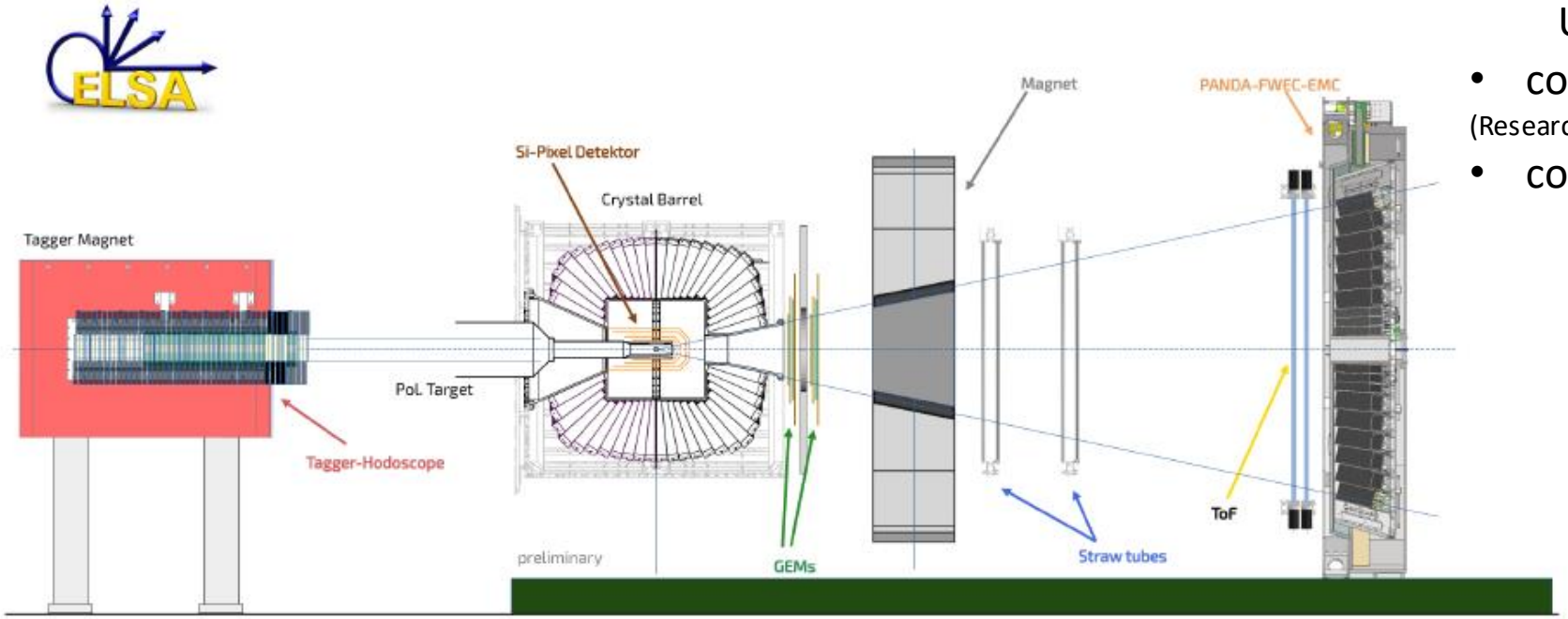
π^0 reconstructed

mass resolution
better than
$\sigma \approx 5$ MeV

Electromagnetic Calorimeter: Forward Endcap at ELSA





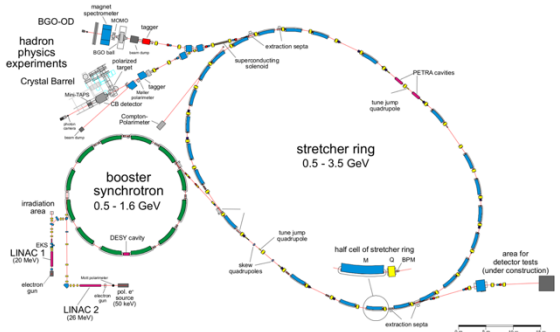


UHaul to Bonn for

- completion **at the FTD**

(Research and Technology Center for Detector Physics)

- commissioning **at ELSA**



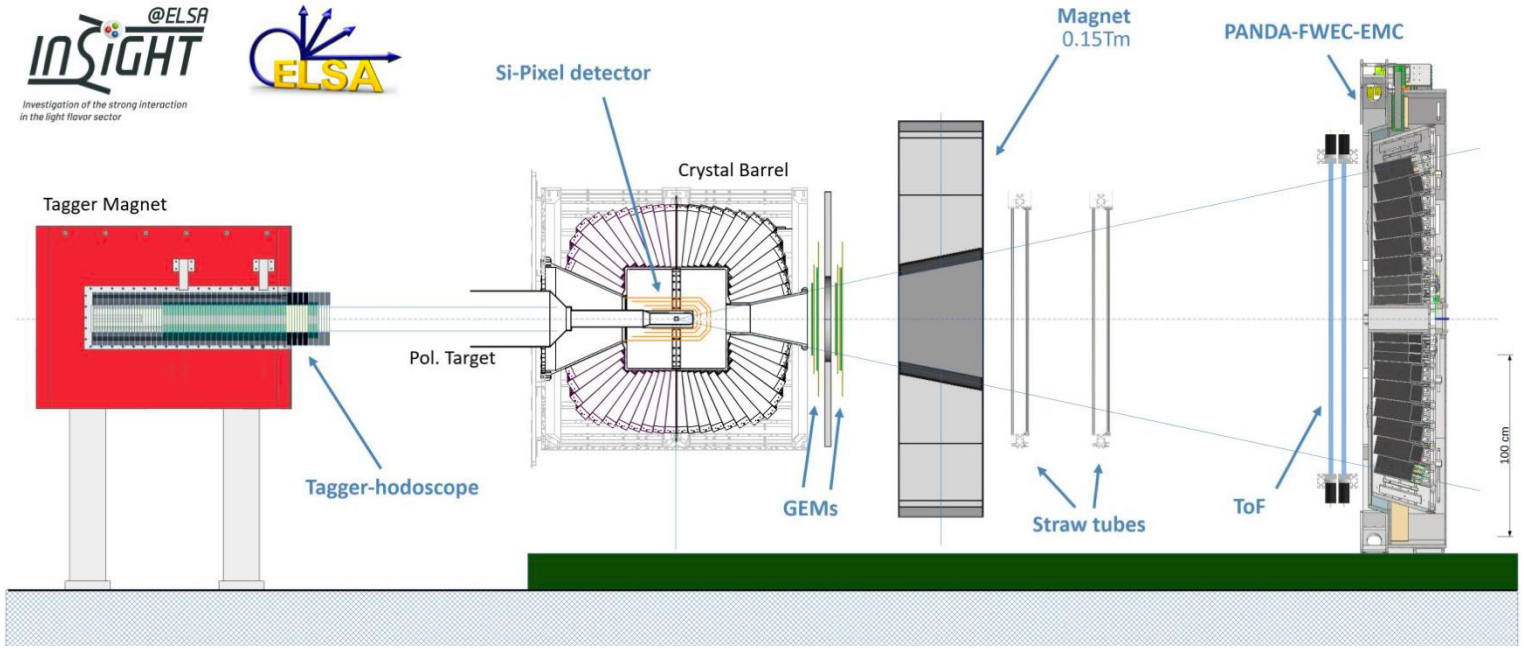
Electromagnetic Calorimeter: Forward Endcap at ELSA

ELSA: huge impact on baryon spectroscopy in the N^* and Δ sector; aspects of production, interaction and decay of strange hadrons

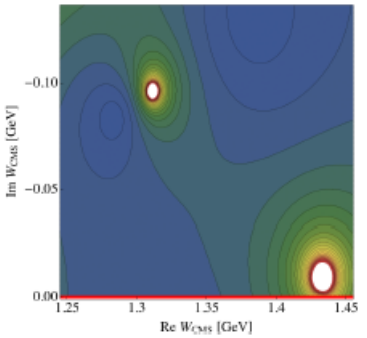
strange degrees of freedom
not yet addressed adequately!

New setup using PANDA hardware:

- decays of baryons into hyperon – kaon systems
- hyperon spectrum
  e.g. the 2-pole structure of the $\Lambda(1405)$ not commensurate with the systematics of the quark model



- $\Lambda(1405)$: 2 pole structure
  chiral unitary approach
  ↔ meson-baryon interaction

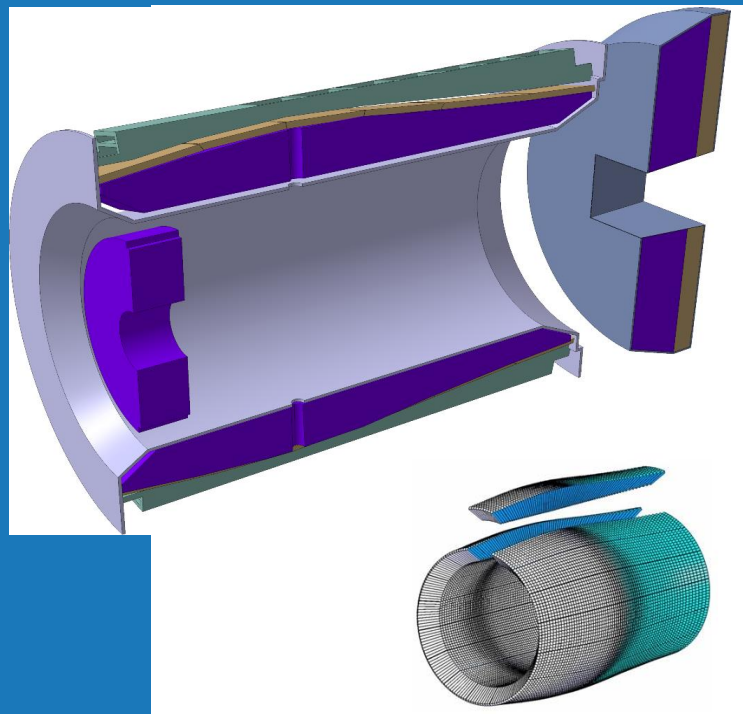


M. Mai EPJST (2021) 230:1593

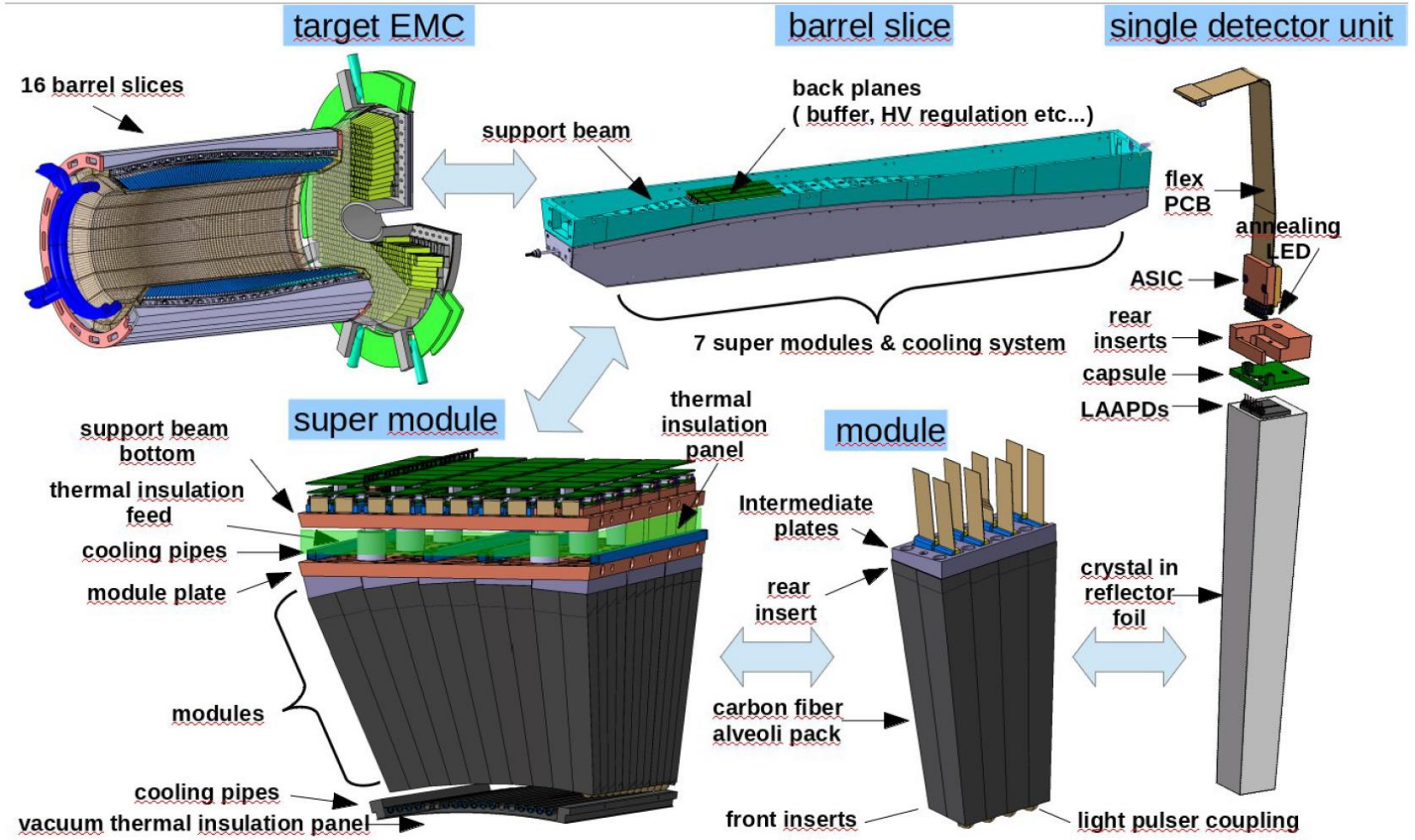
$(m,\Gamma)=(1325\pm16,\ 180^{+24}_{-36})$MeV

$(m,\Gamma)=(1429^{+8}_{-7},\ 24^{+4}_{-6})$MeV

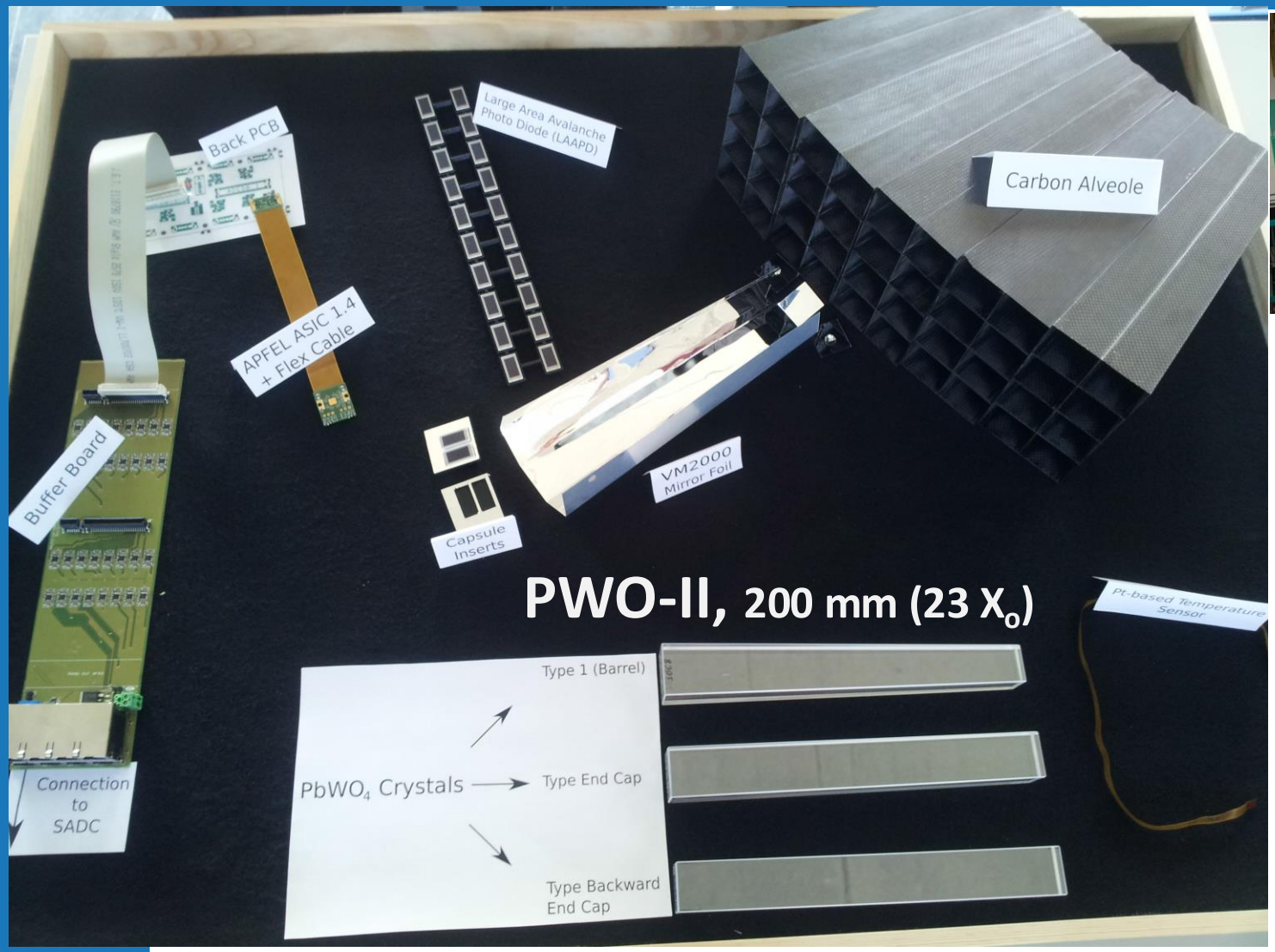
Electromagnetic Calorimeter: EMC Barrel

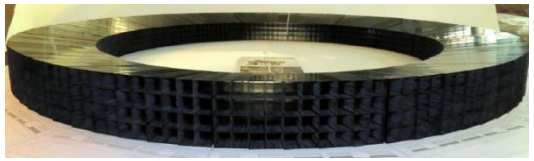


barrel (11 000 X'tals)

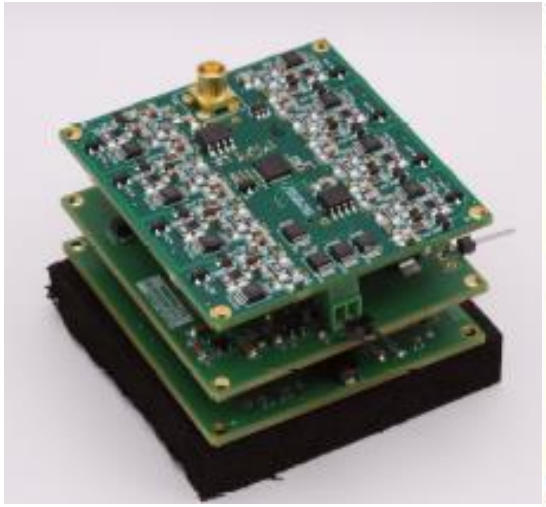


Electromagnetic Calorimeter: EMC Barrel





Electromagnetic Calorimeter: EMC Barrel

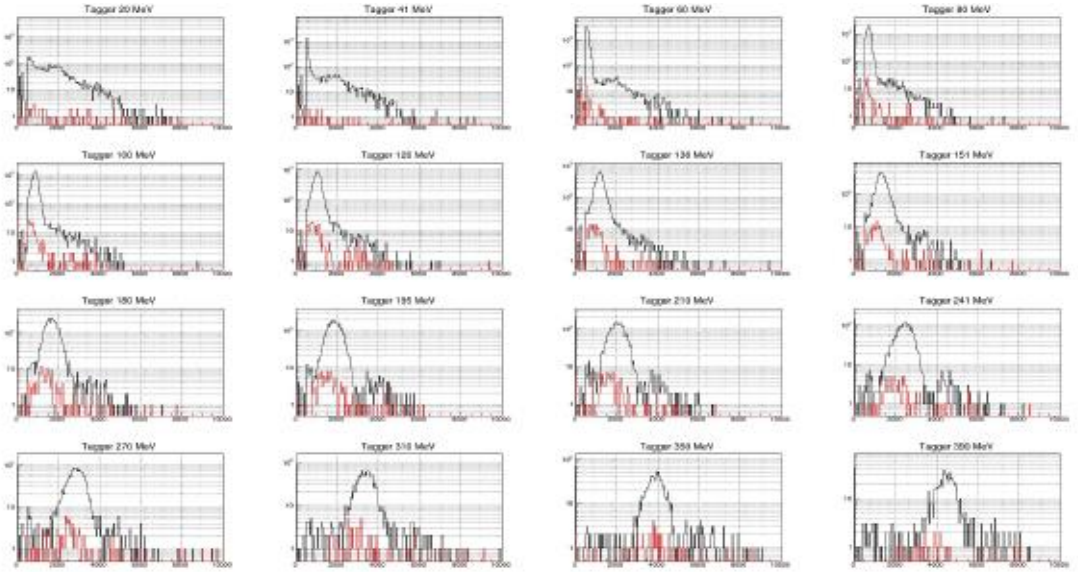


Established for slice 0:

- Cooling
- On-detector slow control
- On-detector front-ends (APFEL) / flexPCBs
- Cold-space handing

Established for 4x4 X'tals prototype (MAMI tagged photons, 20 to 360 MeV**):**

- On-detector slow control
- On-detector front-ends (APFEL) / flexPCBs
- Data acquisition
- Time resolution



cluster light output

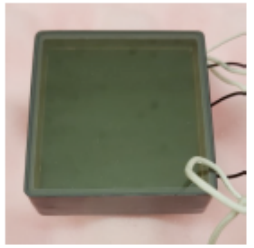
Barrel DIRC (GSI, ER, F, MZ, HIM)

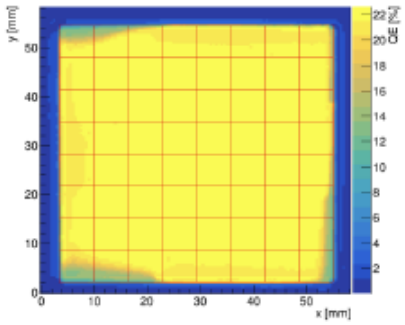
ErUM-FSP T08: PANDA

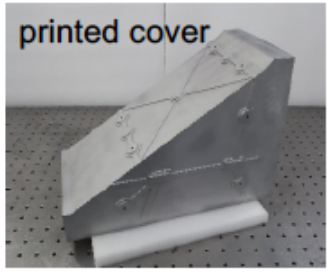
- German In-Kind contribution, 100% project construction funding via GSI
  Close cooperation between GSI, FAU Erlangen, GU Frankfurt, JGU Mainz, HI Mainz
- Key component of the PANDA PID system, innovative lens-focused design
- Series production of MCP-PMT DIRC photon sensors underway
  (Photonis Netherlands BV), QA measurements performed at FAU Erlangen
  (A. Lehmann et al., supported by BMBF and GSI)
- Produced first prototype of readout module cover - 3D-printed aluminum alloy
  → will construct "vertical slice" mock-up to validate assembly strategy
- Developing methods for reconstruction/PID with machine learning
  Process 3D Barrel DIRC images (image recognition, generative AI)
  → improve performance, reduce required computing resources

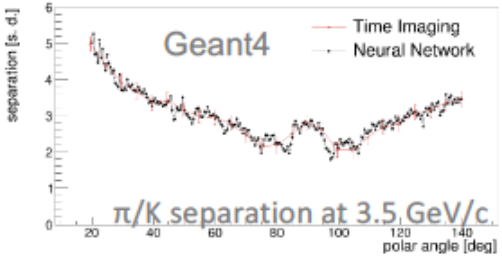
2D quantum efficiency scan at FAU Erlangen

Photonis MCP-PMT



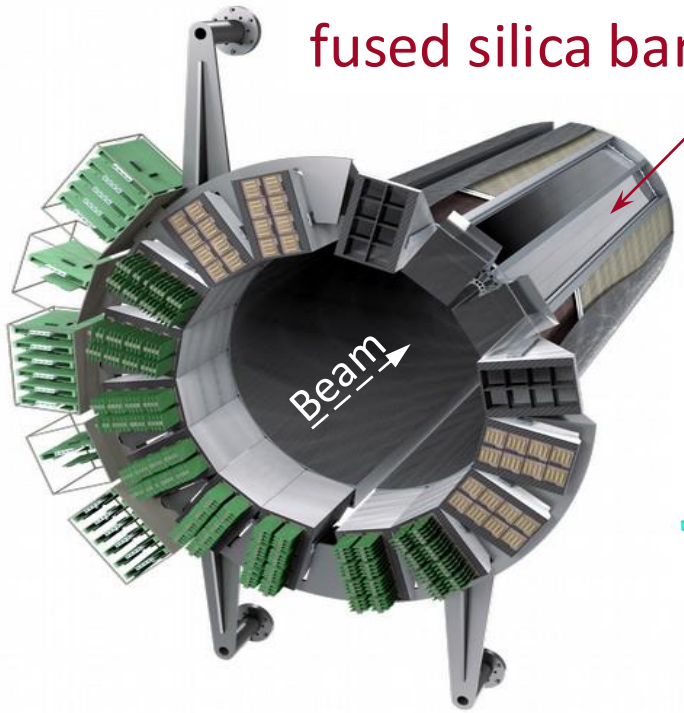


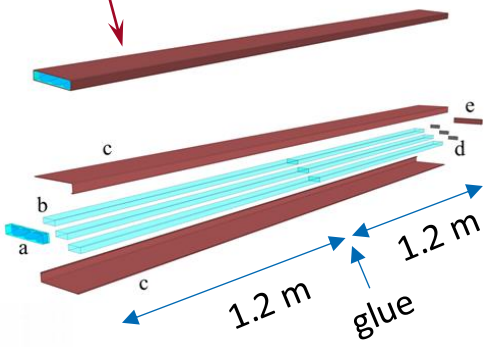


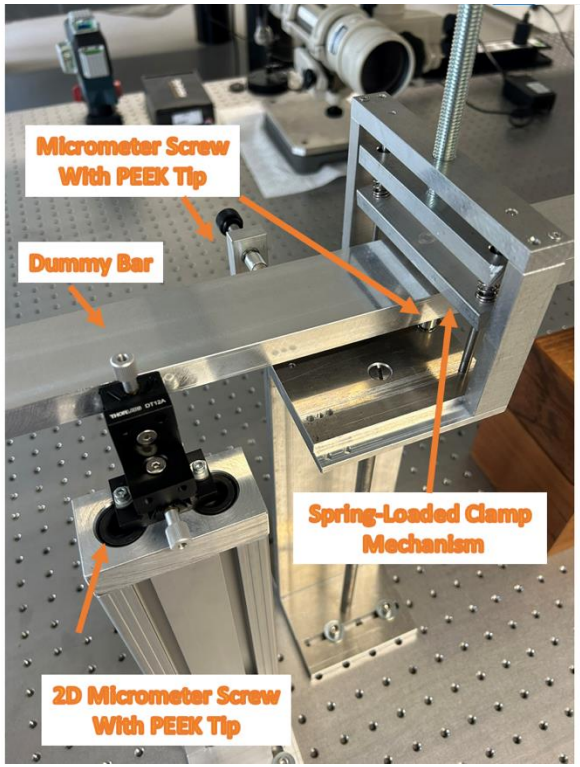


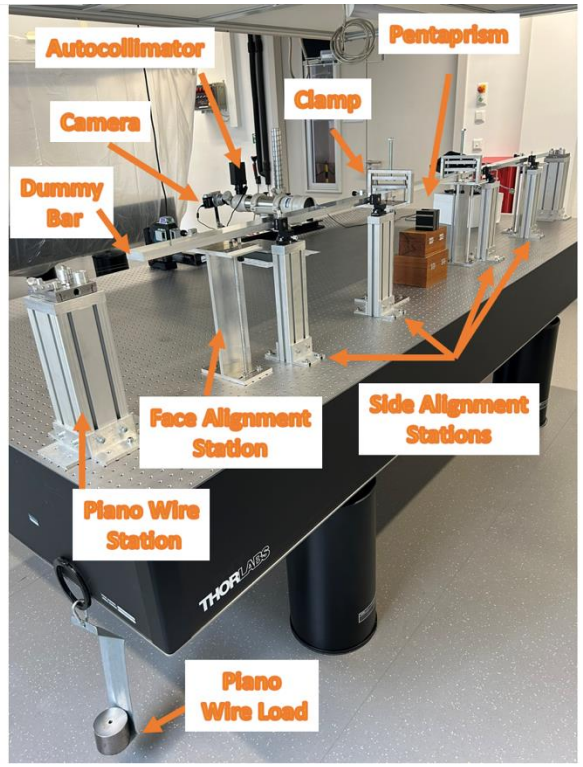
Barrel DIRC (ER, F, MZ, HIM, GSI)

fused silica bars (Bar Box)



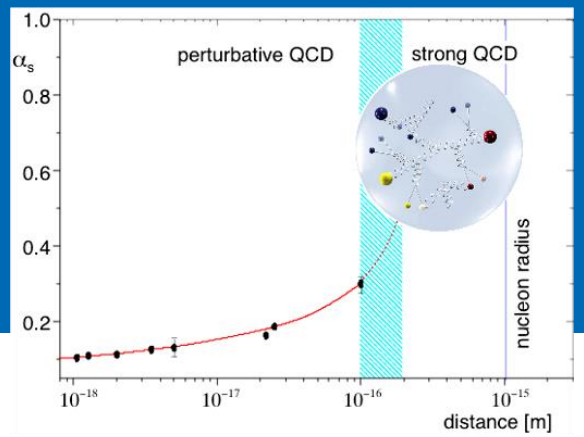




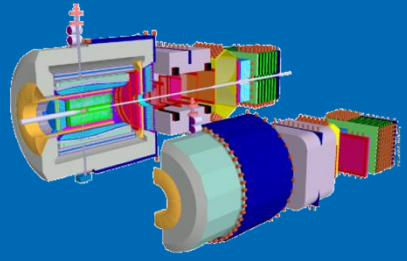


- DIRC bars to be oriented parallel before gluing
- Gap size between bars adjusted to ~50 µm
- Dedicated gluing jig constructed
- Autocollimator employed to confirm alignment before and after gluing (0.5 arcsec precision!)
- Strength of glue joint successfully tested

Design and construction of gluing support structure completed (technical note in preparation)



Summary



PANDA …

- is a unique facility featuring a broad physics program employing antiprotons.
- is therefore **unique** and c**omplementary** to running and future experiments.
- enlists modern detector technologies.
- **is in the process of putting finalized detector parts to good use in other (hadron) physics endeavors.**

The experimental program at PANDA …

- covers aspects of nuclear, hadron and particle physics across the transition from elementary nucleons to elementary quarks.
- puts precision spectroscopy alongside high discovery potential.

panda

https://www.giantpandaglobal.com/zoo/chiang-mai-zoo/santa-claus-visits-lin-ping-4/

Thank You
and
Happy Holidays

https://www.giantpandaglobal.com/zoo/chiang-mai-zoo/santa-claus-visits-lin-ping-4/