RUHR-UNIVERSITÄT BOCHUM

The PANDA Experiment and the Electromagnetic Calorimeter

Fritz-Herbert Heinsius

RUHR-UNIVERSITÄT Bochum
FAKULTÄT FÜR PHYSIK UND ASTRONOMIE
Experimentelle Hadronenphysik

DAQFEET
DAQ/FEE/Trigger for COMPASS beyond 2020 Workshop

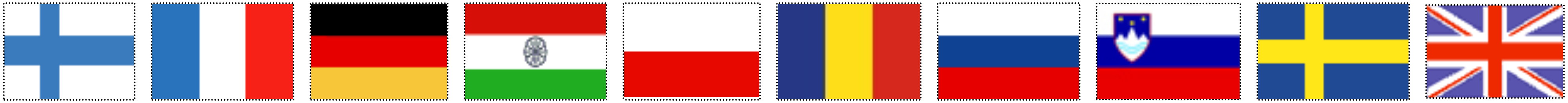
Content

- FAIR
- PANDA Physics
- PANDA Detector
- PANDA EMC
- EMC Readout
- EMC Cooling

bmb+f
Großgeräte der physikalischen Grundlagenforschung

Prague 9.-11.11.2017

The FAIR Project at Darmstadt



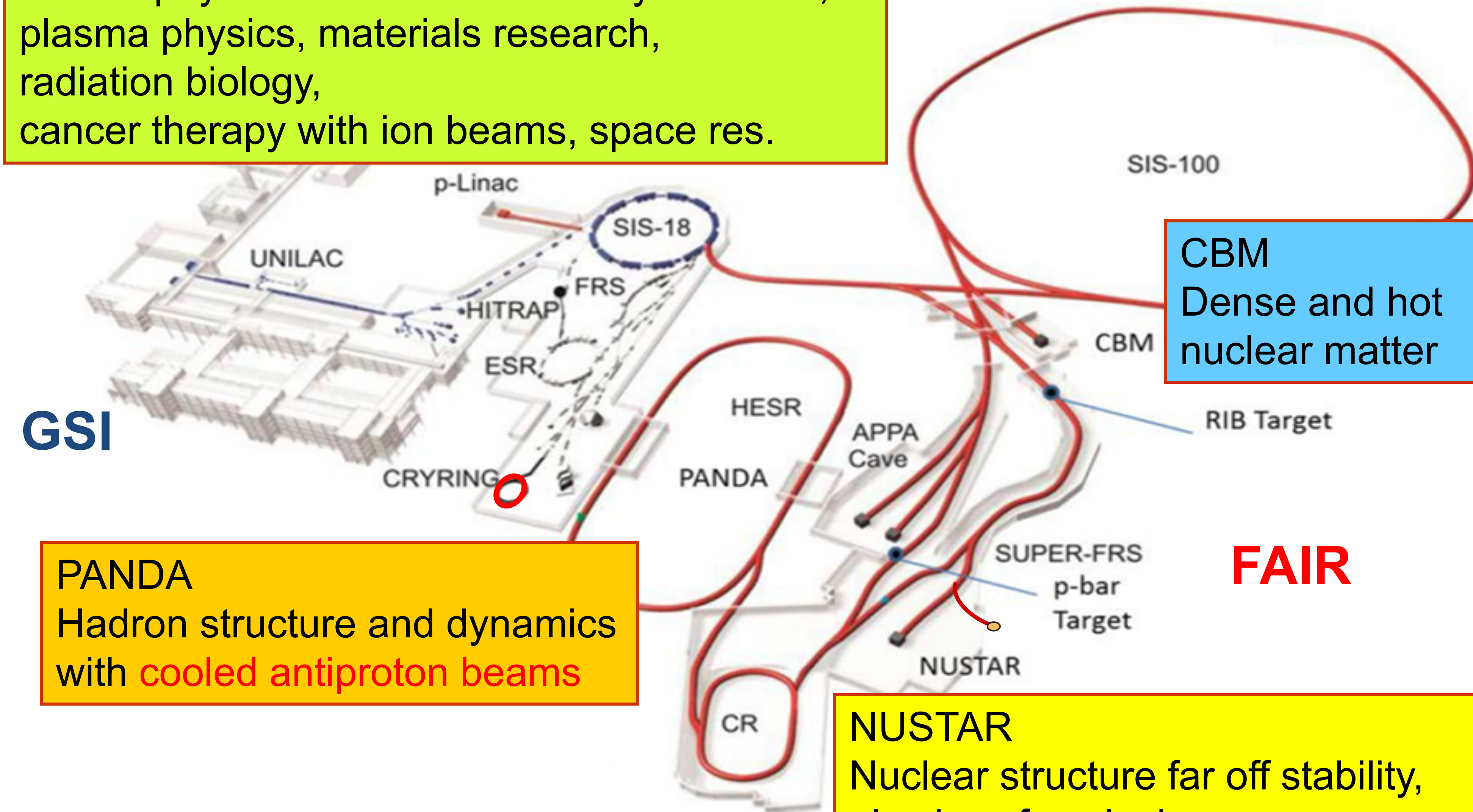
Finland France Germany India Poland Romania Russia Slovenia Sweden UK

FAIR Accelerator Complex

RUB

APPA
Atomic physics and fundamental symmetries,
plasma physics, materials research,
radiation biology,
cancer therapy with ion beams, space res.

CBM
Dense and hot
nuclear matter

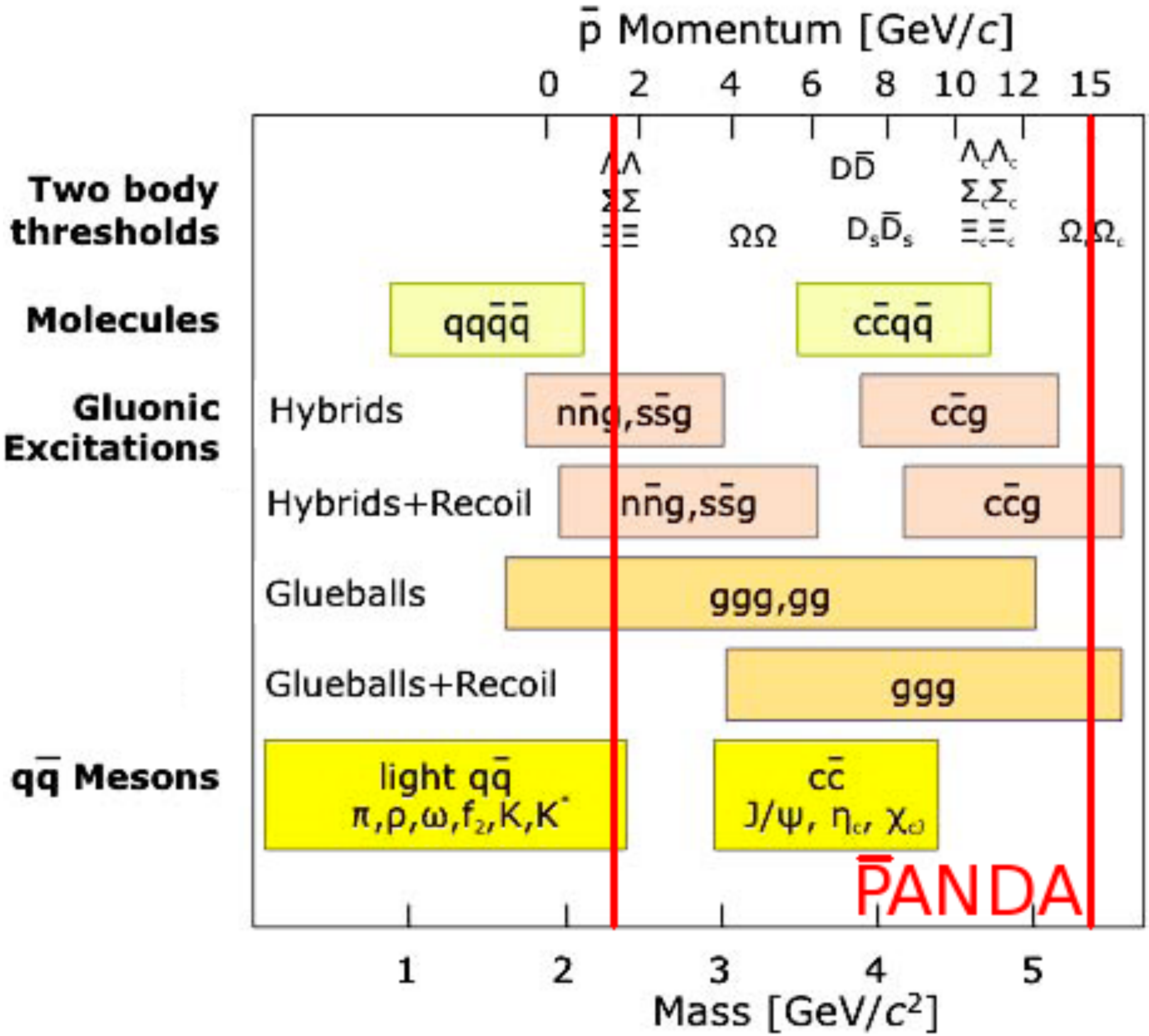


PANDA
Hadron structure and dynamics
with cooled antiproton beams

NUSTAR
Nuclear structure far off stability,
physics of explosive
nucleosynthesis (r process)

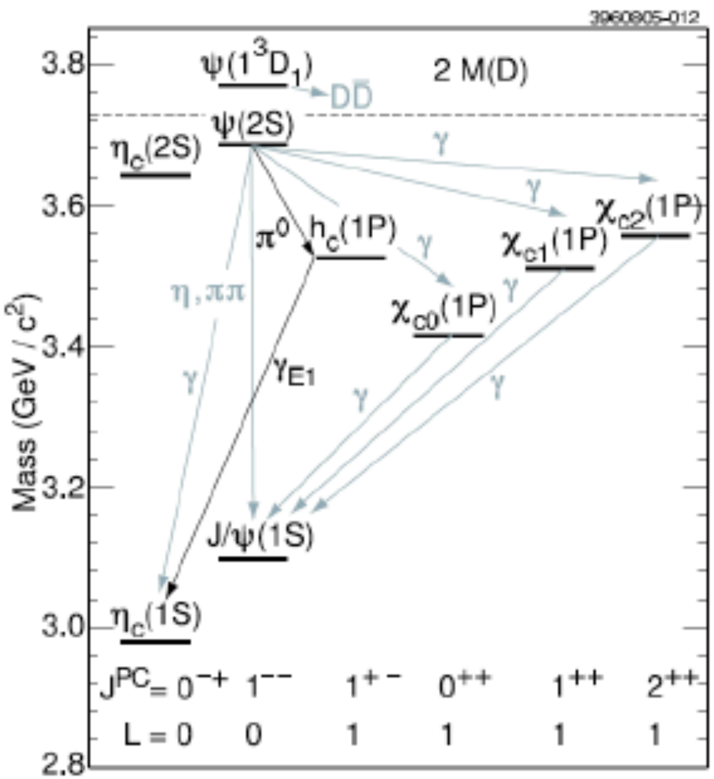
PANDA Physics Program

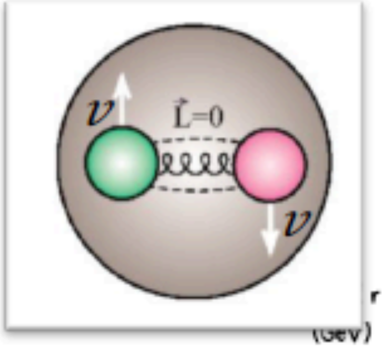
- $\bar{p}p$- and $\bar{p}A$-annihilation: beam momentum 1.5-15 GeV/c



Charmonium Spectroscopy

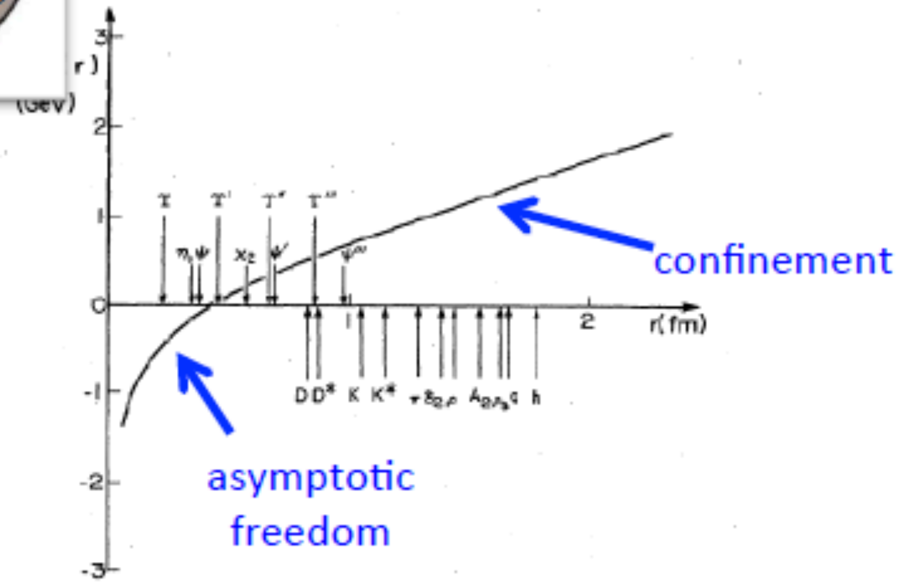
Study of charmonium states plays a crucial role in understanding QCD





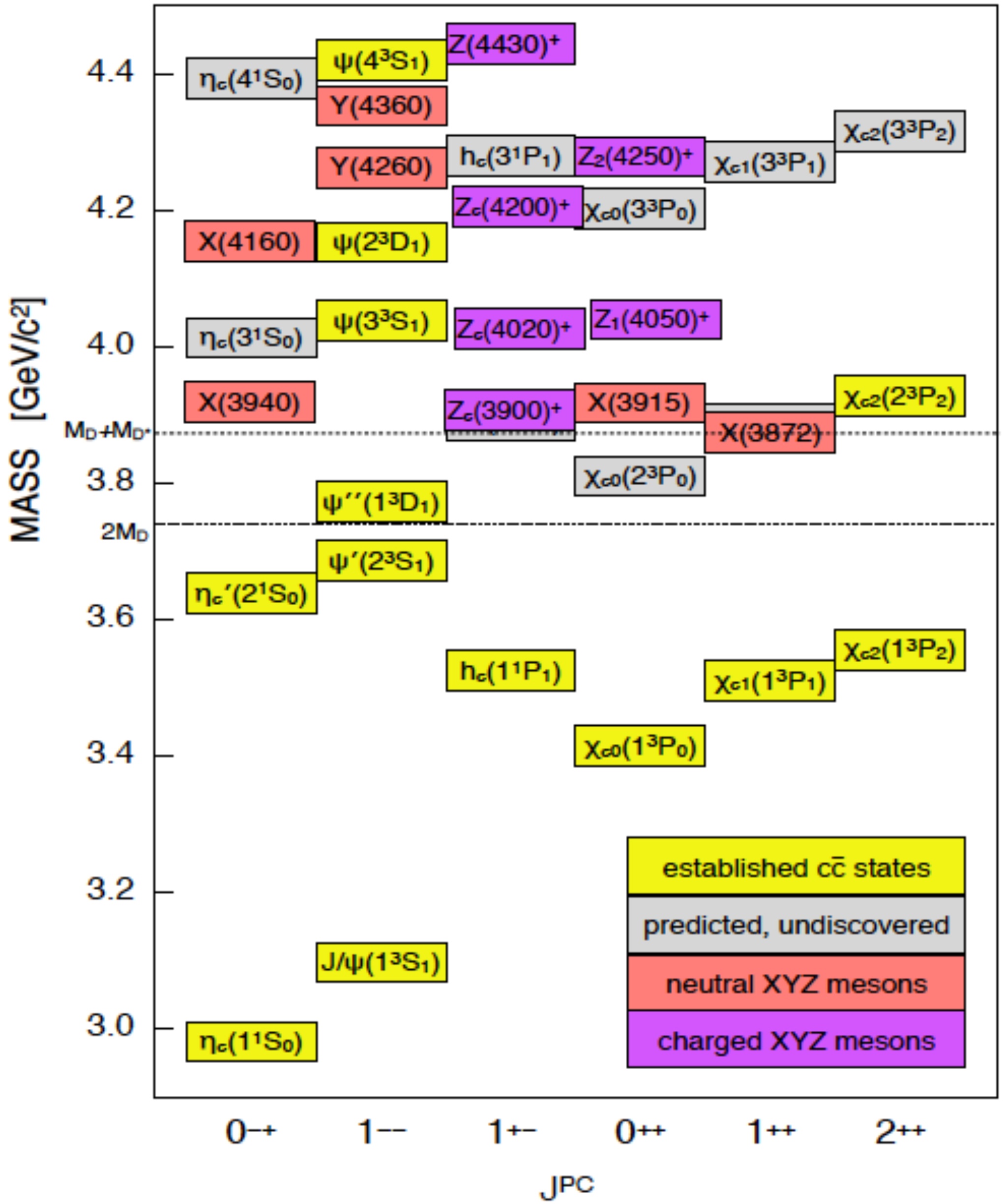
non relativistic: $v_c^2 \sim 0.3$

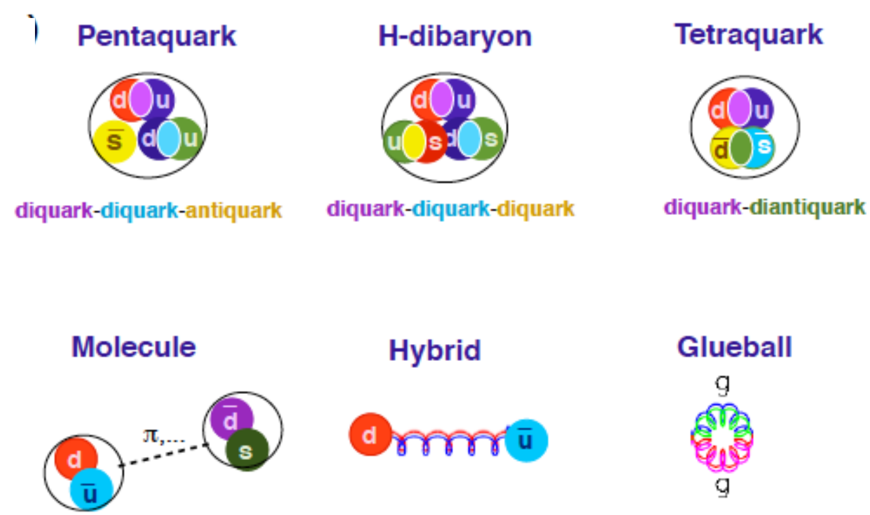
mass scale is perturbative: $m_c \sim 1.5$ GeV



Ideal probe of (de)confinement and the transition regime between perturbative and non-perturbative QCD

New States of Matter





Glueballs

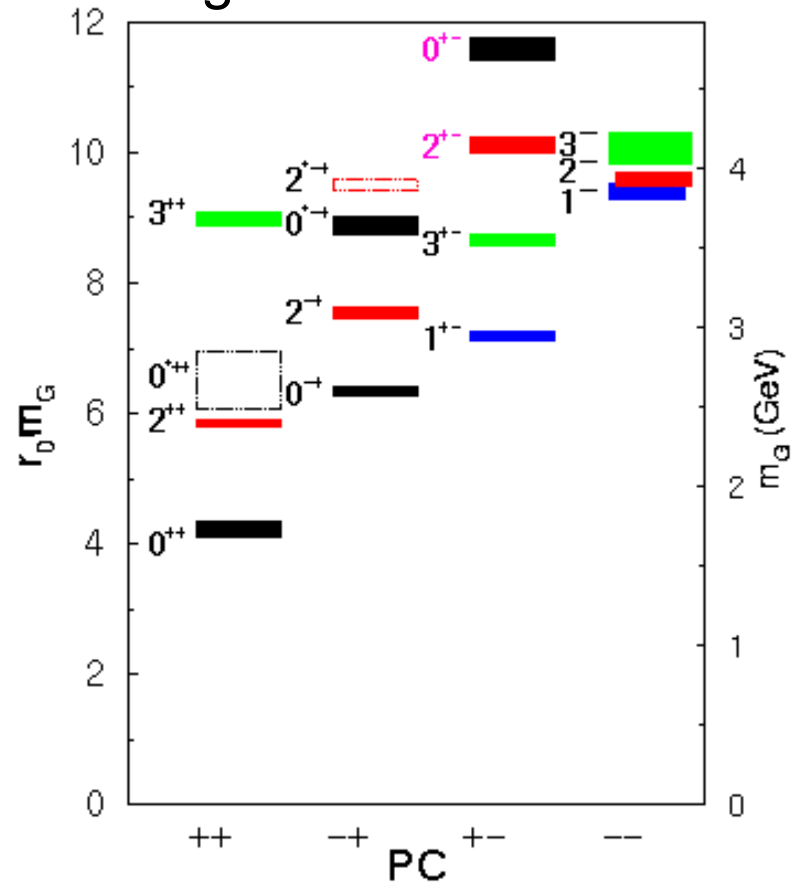
Specific predictions of mass spectrum from quenched LatticeQCD.

- Width of ground state ~ 100 MeV
- Several states predicted below 5 GeV/c^2, some with exotic quantum numbers
- Exotic heavy glueballs:
  - $m(0^{+-})$ = 4140(50)(200) MeV
  - $m(2^{+-})$ = 4740(70)(230) MeV

Some predicted decay modes:

$\phi\phi$, $\phi\eta$, $J/\psi\eta$, $J/\psi\phi$ ...

LatticeQCD prediction of glueballs

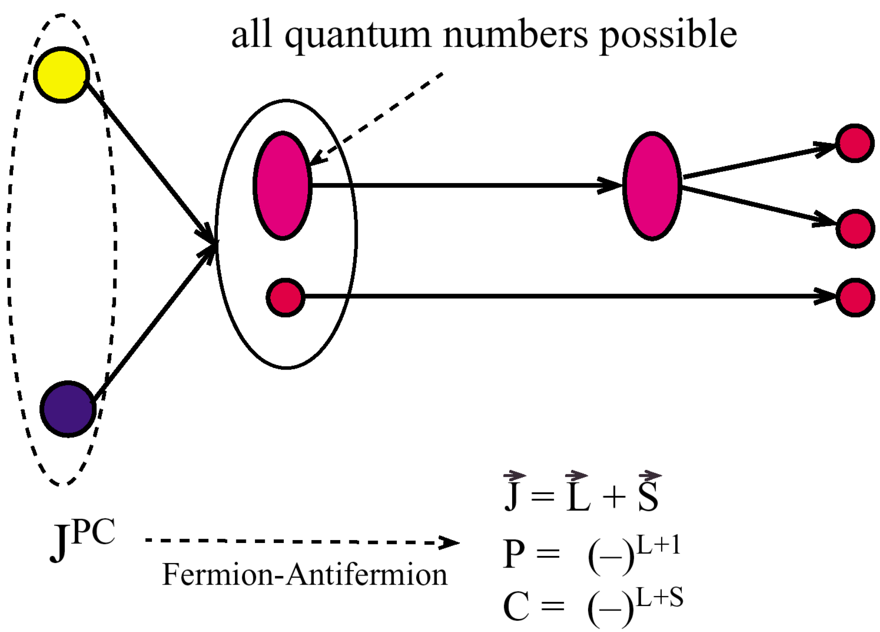


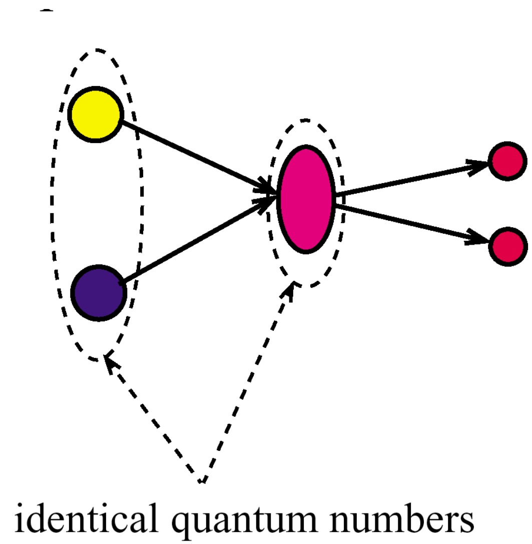
C. Morningstar and M. Peardon, Phys. Rev. D 60, 034509 (1999)

The detection of non-exotic glueballs is not trivial, as these states mix with the nearby $q\bar{q}$ states with the same quantum numbers, thus modifying the expected decay pattern.

PANDA antiproton physics unique advantages:

Production experiments vs. Formation experiments





Discovery potential

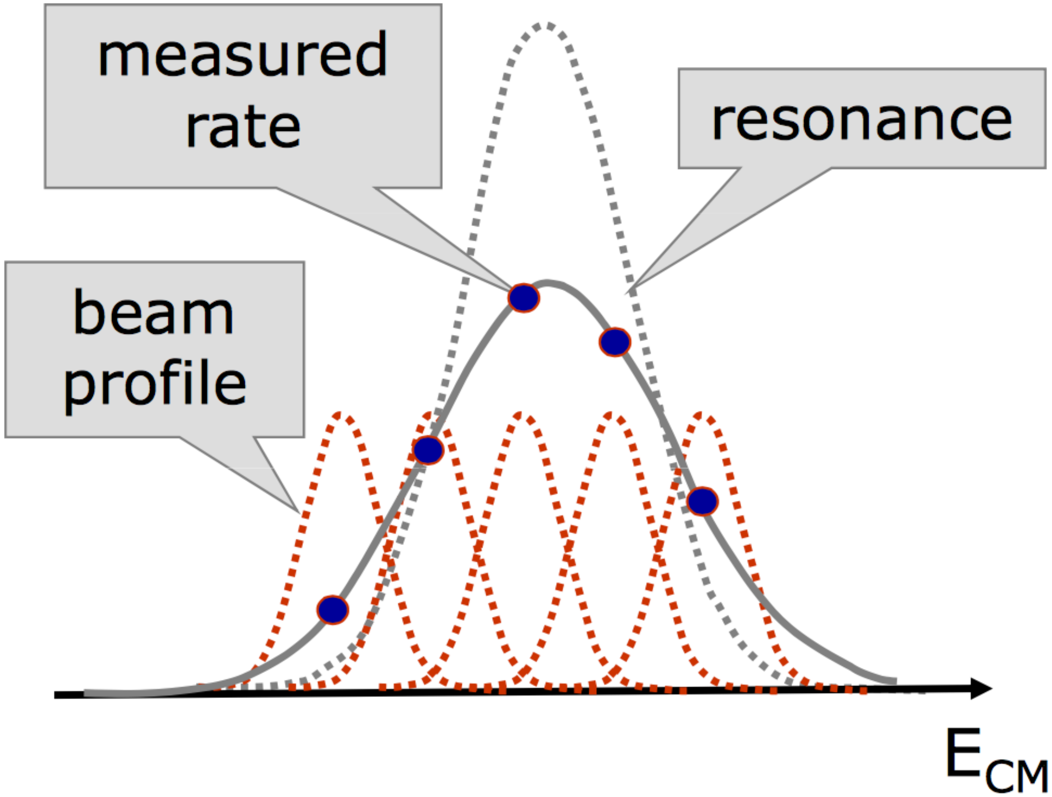
Precision physics

Resonance Scans

Cooled antiproton beam with high momentum resolution

Precise measurement of masses and width of resonances

- only dependent on beam resolution (HESR $\Delta p/p < 5 \times 10^{-5}$)



Example: χ_{c1} Resonance Scan

Production:

$$e^+e^- \rightarrow \psi' \rightarrow \gamma\chi_{1,2} \rightarrow \gamma\left(\gamma \mathrm{J}/\psi\right) \rightarrow \gamma\gamma e^+e^-$$

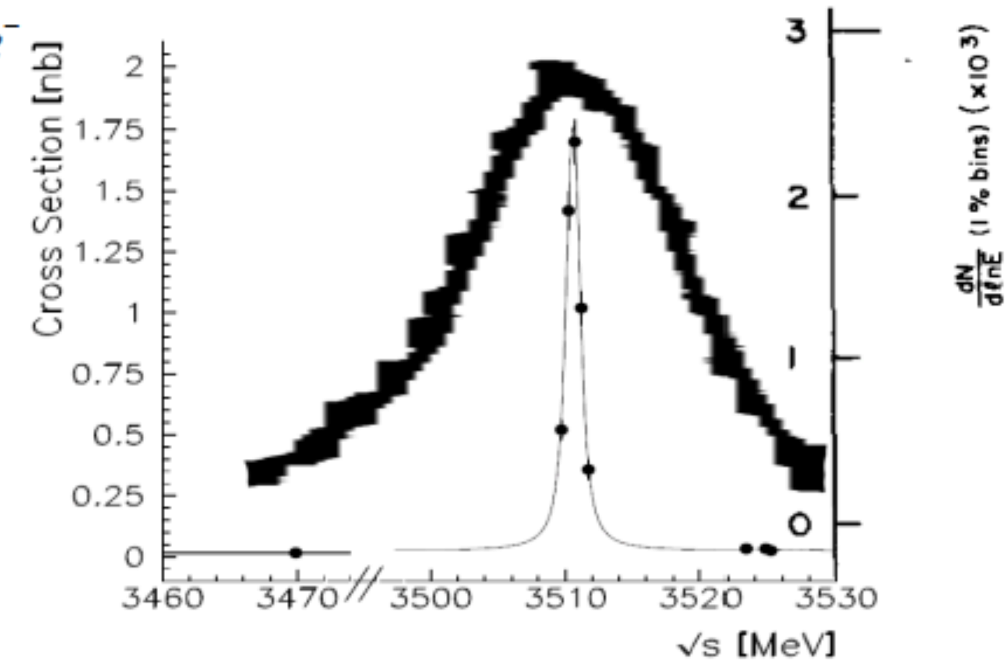
- Invariant mass reconstruction depends on the detector resolution ≈ 10 MeV

Formation:

$$\bar{p}p \rightarrow \chi_{1,2} \rightarrow \gamma \mathrm{J}/\psi \rightarrow \gamma e^+e^-$$

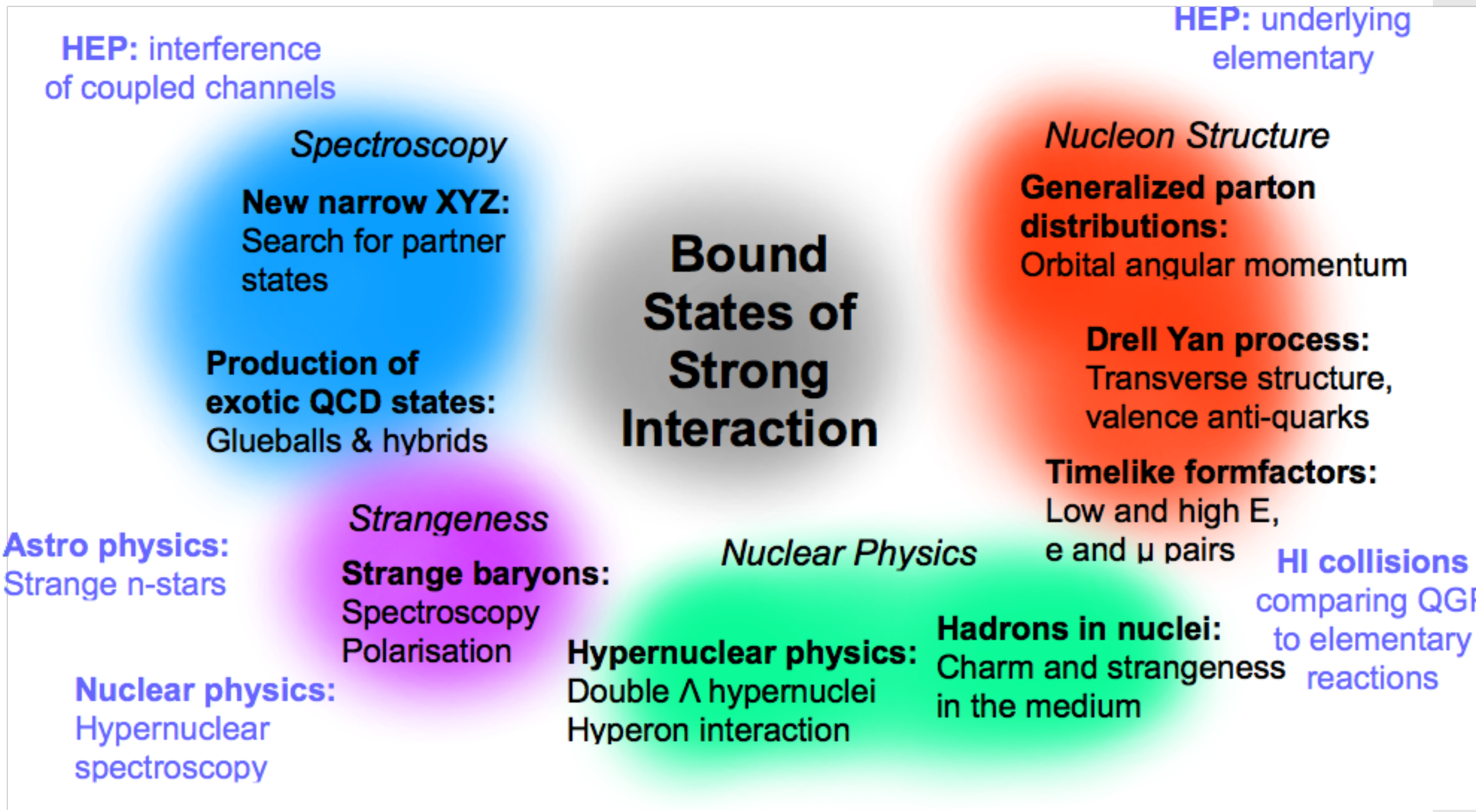
- Resonance scan:
  → mass resolution depends on the beam resolution

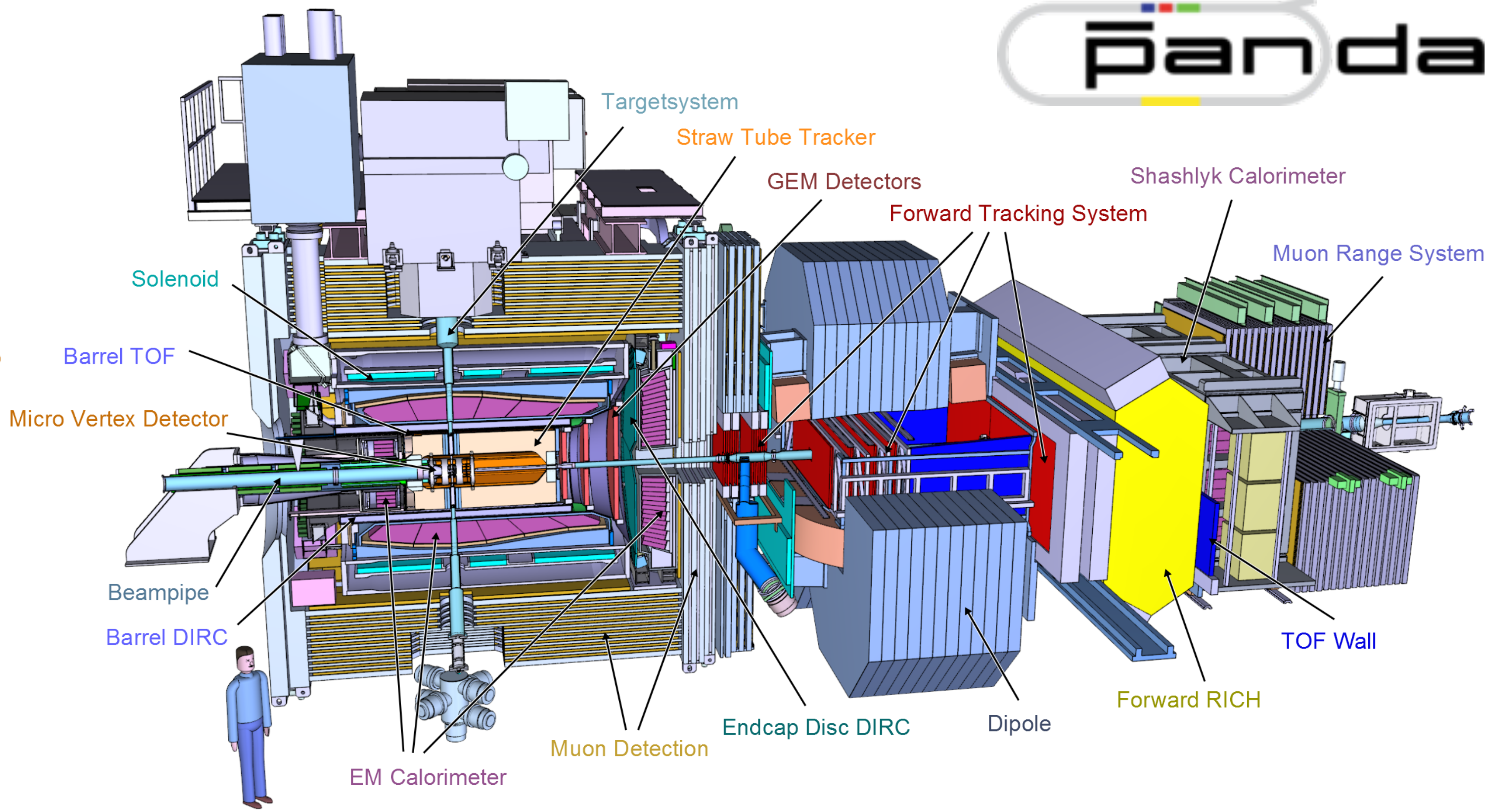
E760/835@Fermilab ≈ 240 keV
PANDA@FAIR ≈ 50 keV



Gaiser et al., Phys. Rev. D34 (1986) 711:
CrystalBall (SLAC): 3512.3 ± 4 MeV/c²
Andreotti et al., Nucl. Phys. B717 (2005) 34-47:
E835 (Fermilab): 3510.641 ± 0.074 MeV/c²

PANDA Physics Program





Exclusive measurements

- Almost 4π coverage
- Target and forward spectrometer

High event rate (10^7/s)

- Sophisticated online processing
- Detection of rare decay modes

Charged particle tracking (p<15 GeV/*c*)

- Good momentum / vertex resolution
- Good PID capabilities

Photon detection (E=0.02-15 GeV)

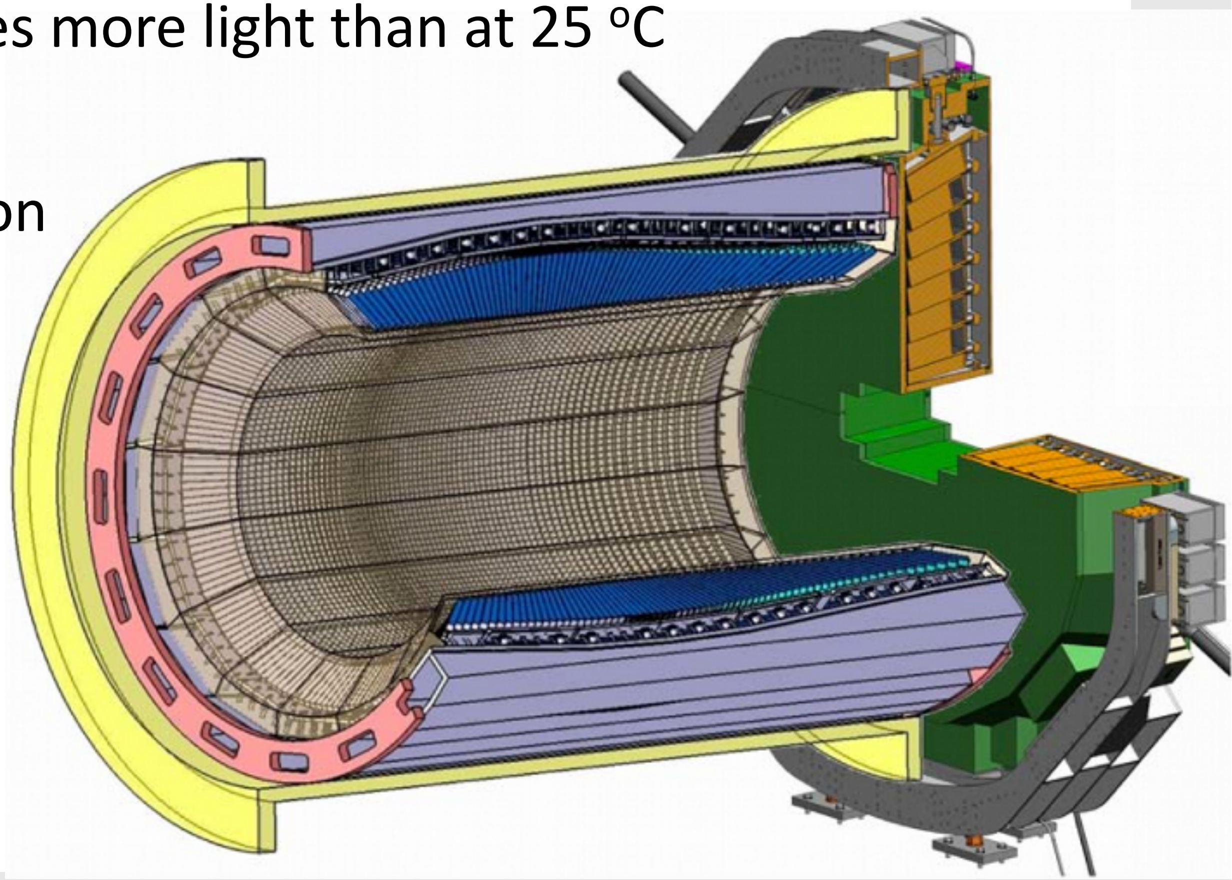
- Excellent energy / angular resolution
- Detection of low energetic photons

Electromagnetic Calorimeter (EMC)

- Sampling calorimeter in forward spectrometer
- Homogeneous crystal calorimeter in target spectrometer: Barrel and two end caps
- 15 552 $PbWO_4$ crystals (20 cm ≈ 22 X_0)
- Operating at -25 °C: 4 times more light than at 25 °C
- Time resolution < 2 ns
- Envisaged energy resolution

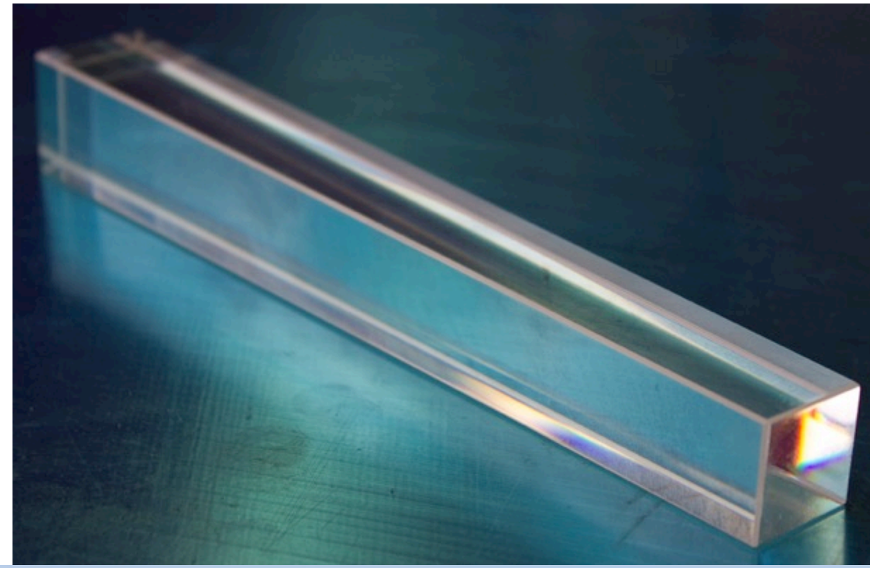
$$\leq 1\% \oplus \frac{\leq 2\%}{\sqrt{E/\mathrm{GeV}}}$$

- 99.8% of 4π
- B = 2T

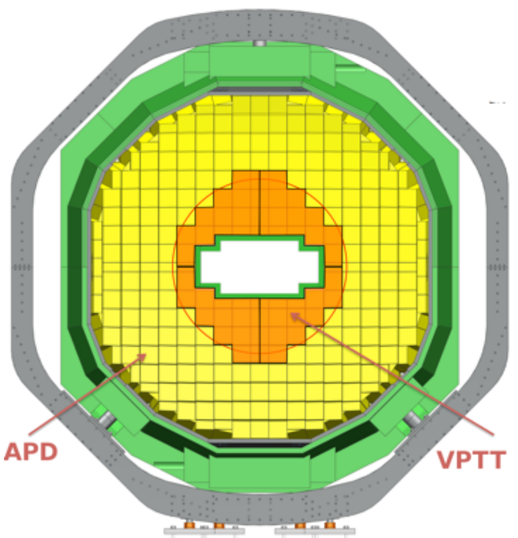


Lead tungstate (PWO) Crystals

- Partly produced at BCTP (Russia)
- Production now at Crytur (Czech Republic)

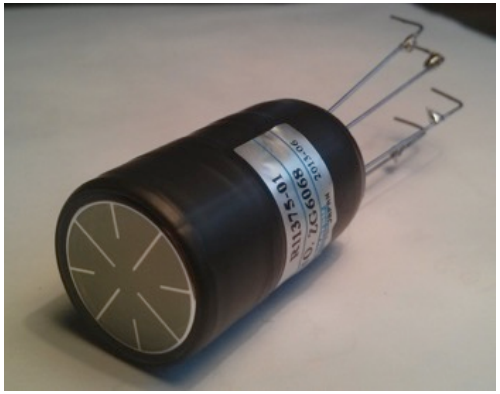


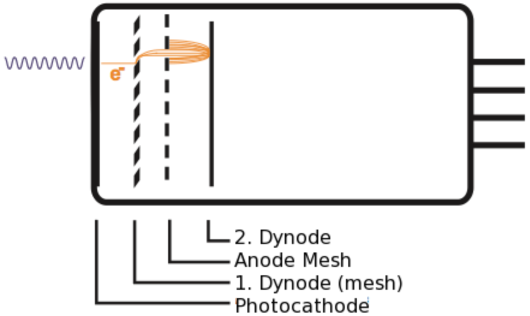
Photodetectors



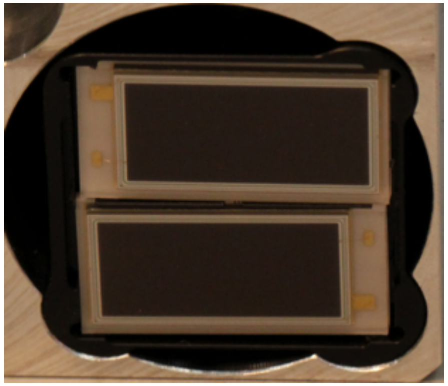
APD: 80 % fw endcap
100 % barrel
100 % bw endcap

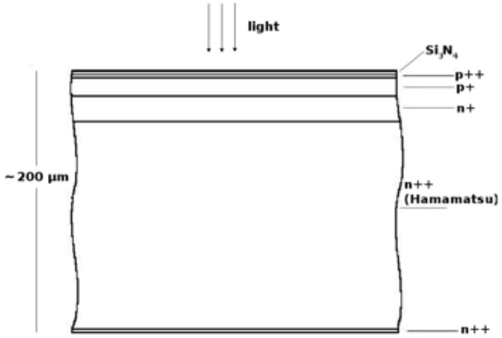
VPTT (Hamamatsu)





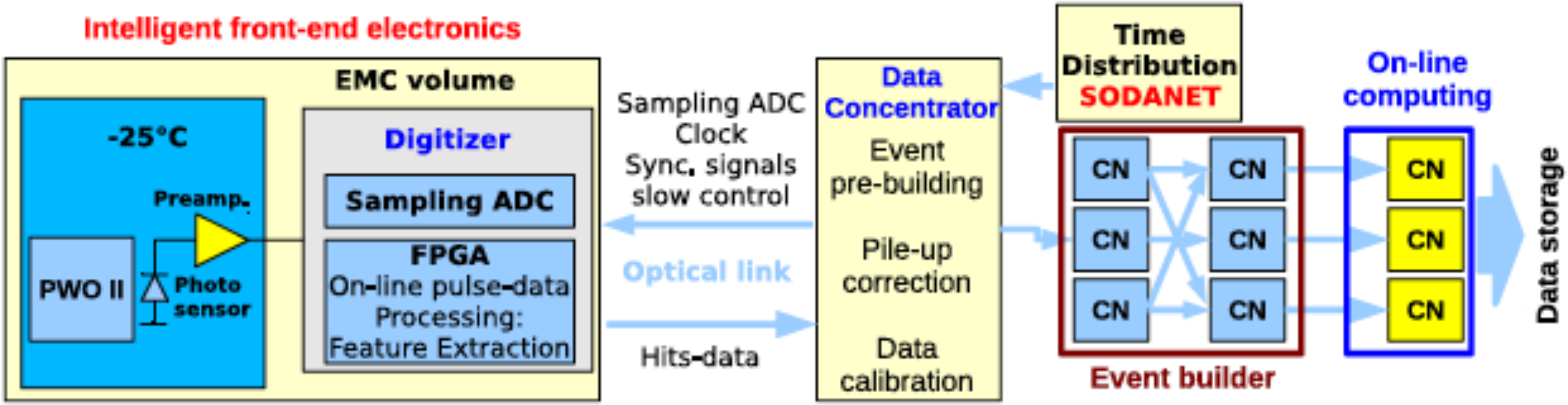
APD (Hamamatsu)





	VPTT (Hamamatsu)	APD (Hamamatsu)
Quantum eff. (typ.)	≈ 23 %	≈ 80 %
Active area	200 mm^2	6.8 x 14 = 95.2 mm^2
Gain	typ. 50	200 / 150
Dark current (Anode)	< 1 nA	1 pA – max 40 nA
Capacity	≈ 22 pF	≈ 270 pF

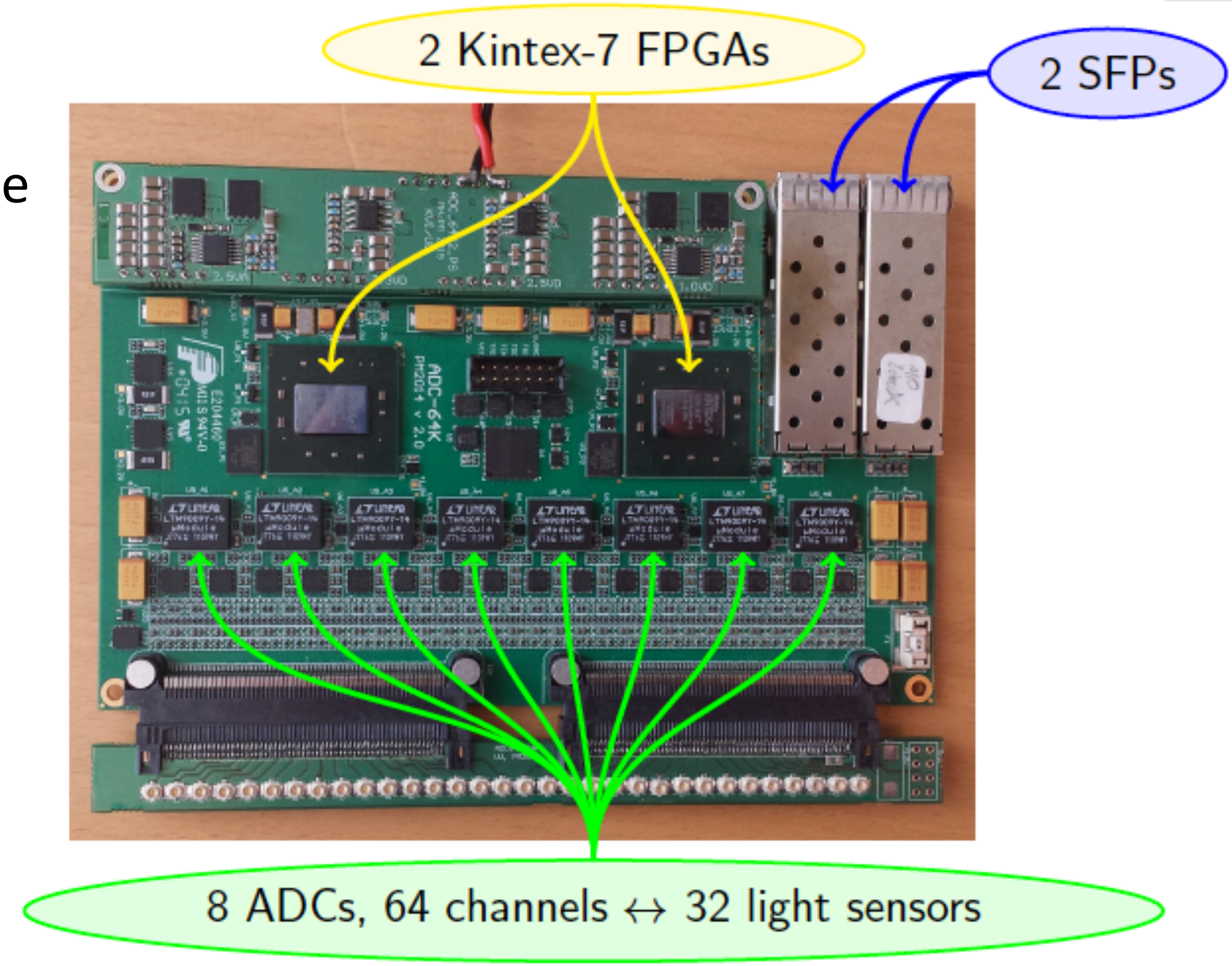
Electronics and Readout System

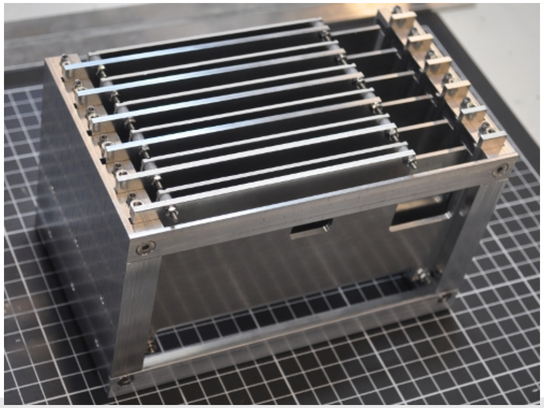


- APFEL-ASIC / Basel low noise preamplifier
- Intelligent front-end: SADC
- Time-distribution system: SODANET
- Triggerless DAQ
- Data concentrators
- Burst-building network
- On-line computing

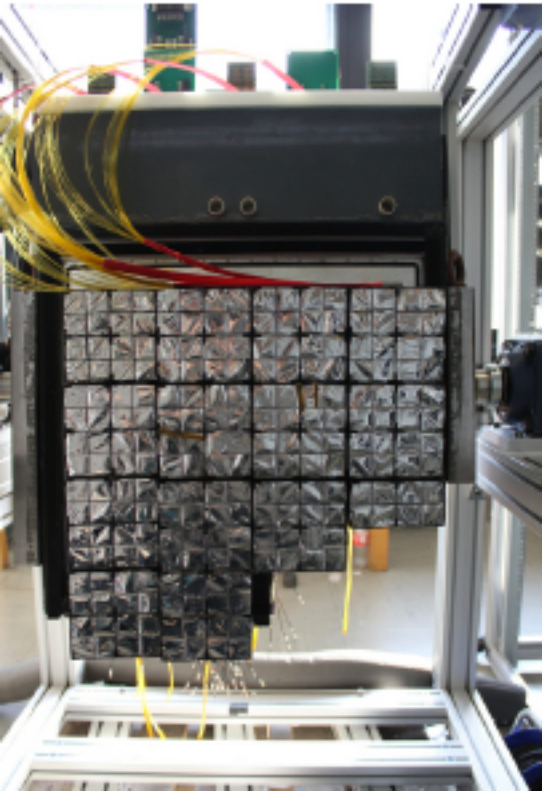
Sampling ADC

- 64 ADC channels (32 dual gain)
- 14 bit resolution
- 80 MHz sampling rate
- Feature extraction
- Two versions:
  - APFEL ASIC
  - Basel preamplifier
- Irradiated, lab and beam tests

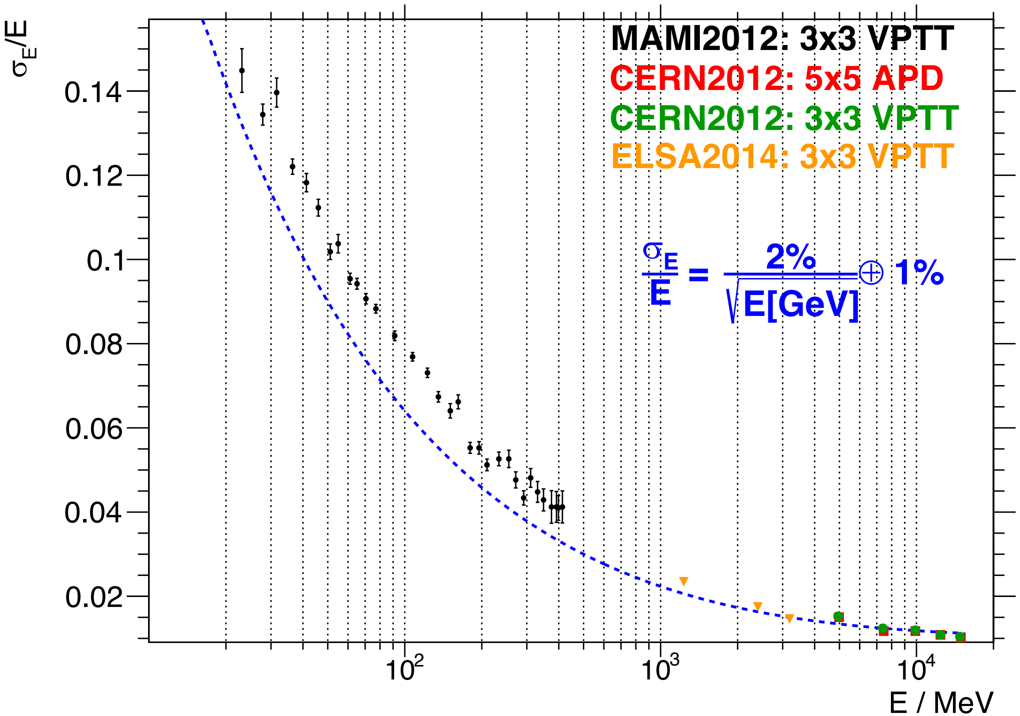




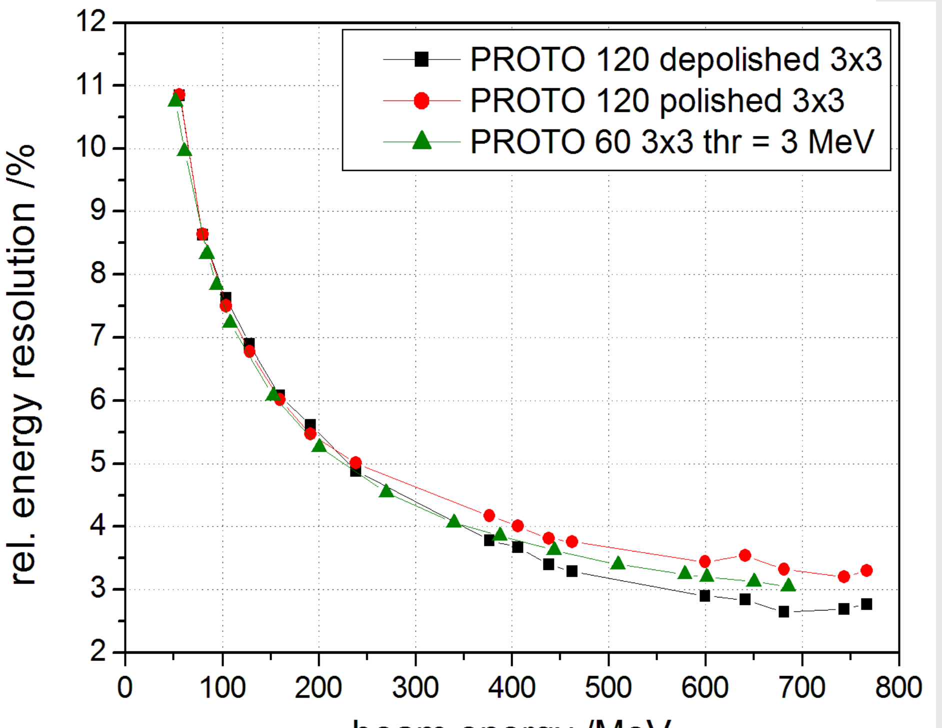
Test Beam Results

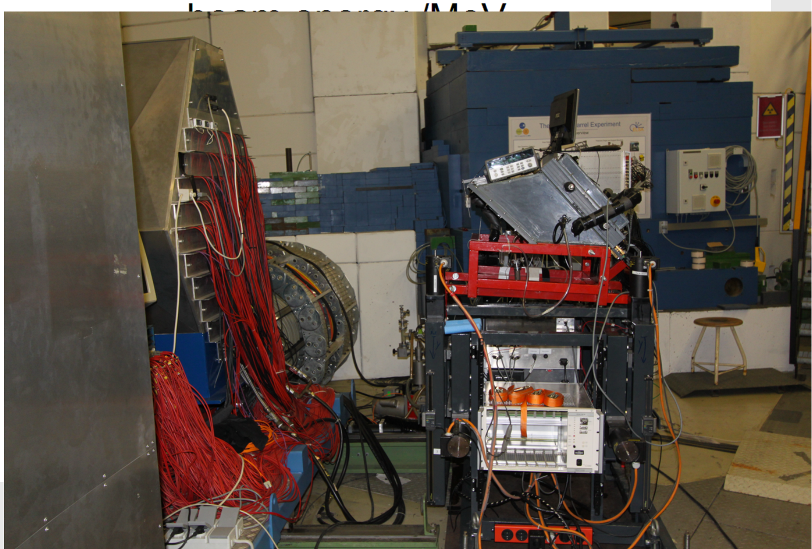


Forward endcap prototype

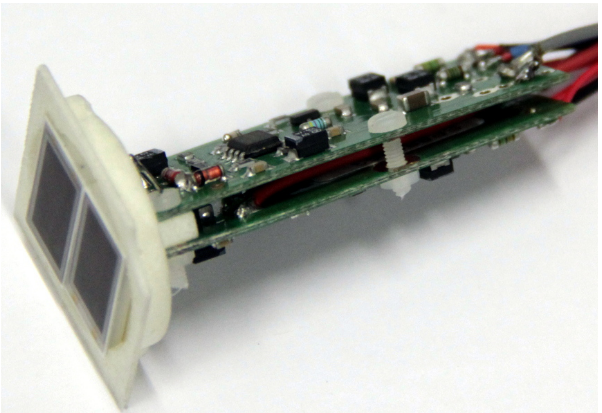


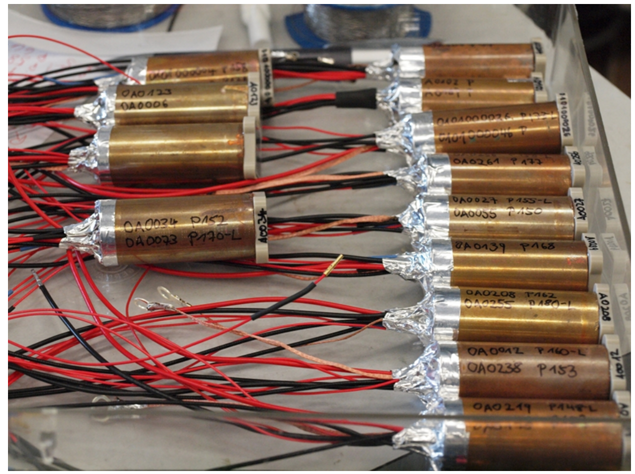
Barrel prototypes

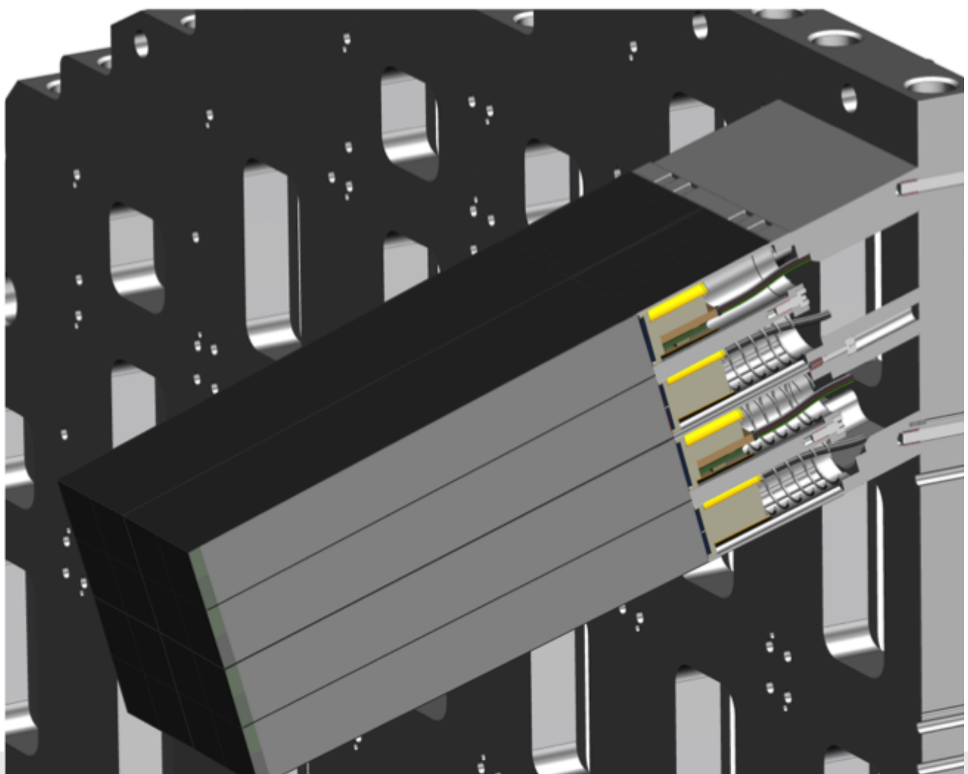


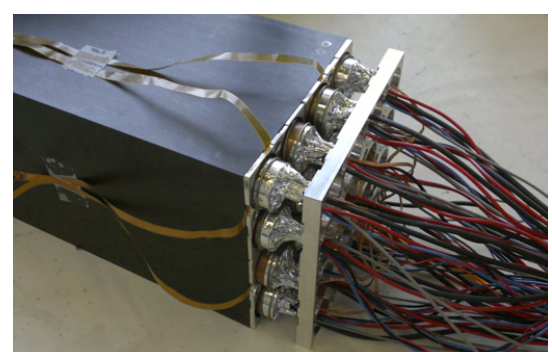


Production of Forward Endcap

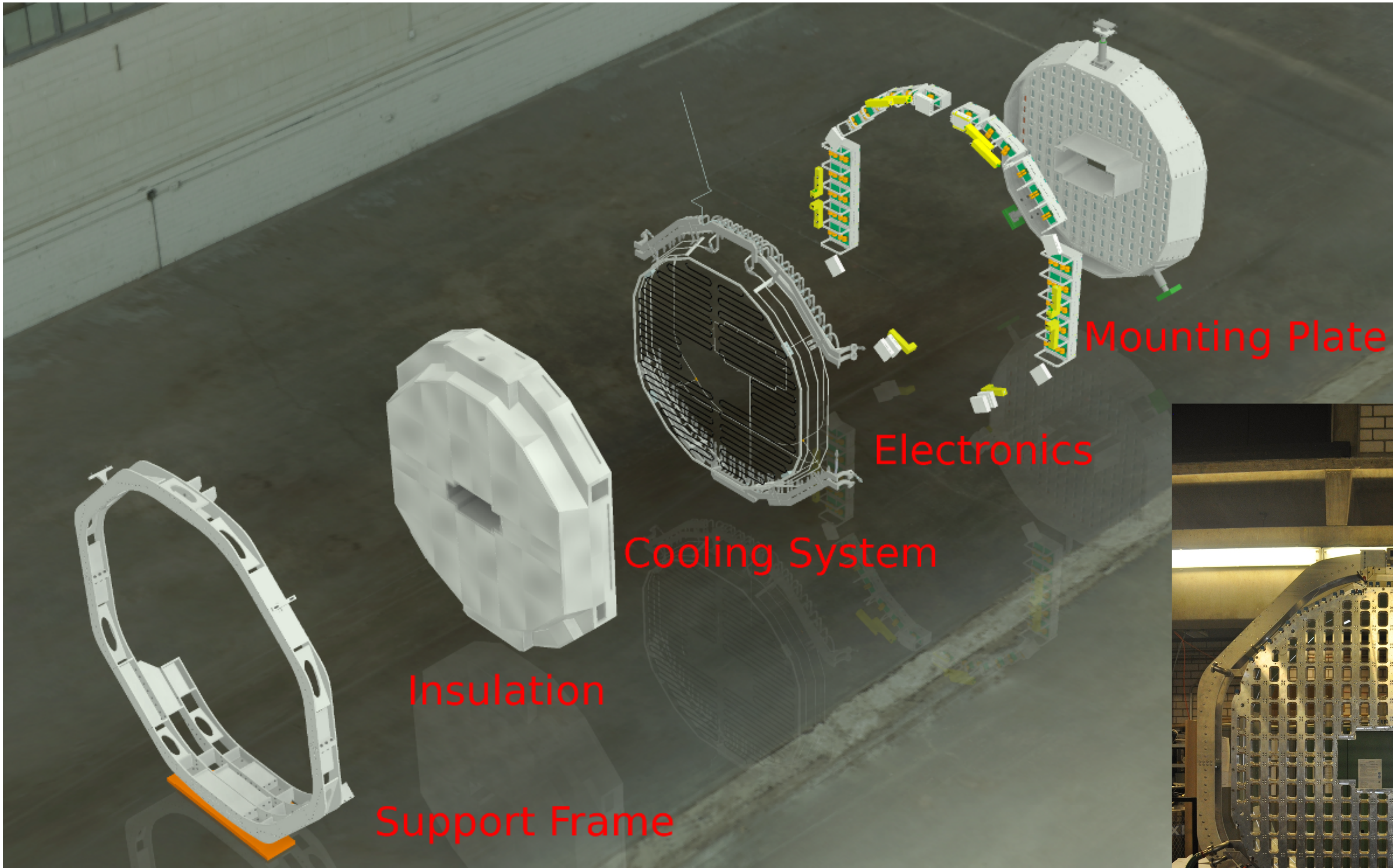


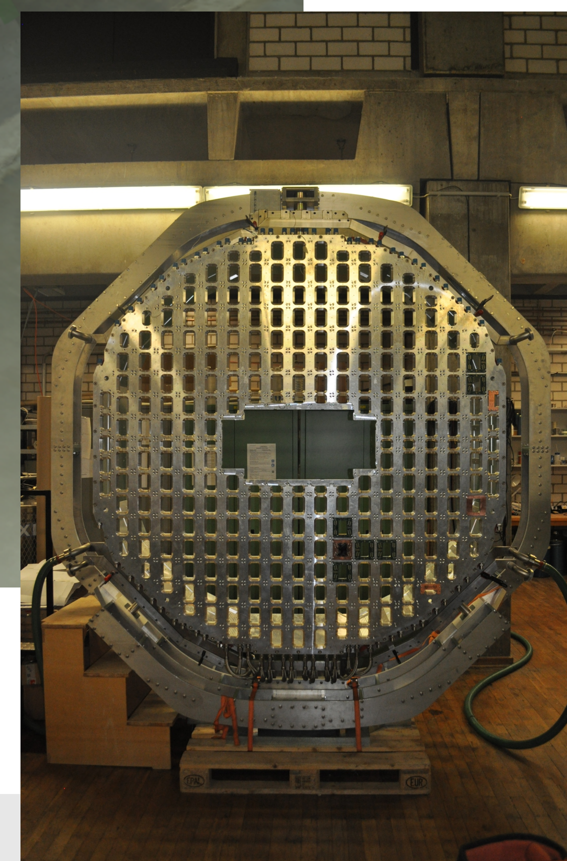




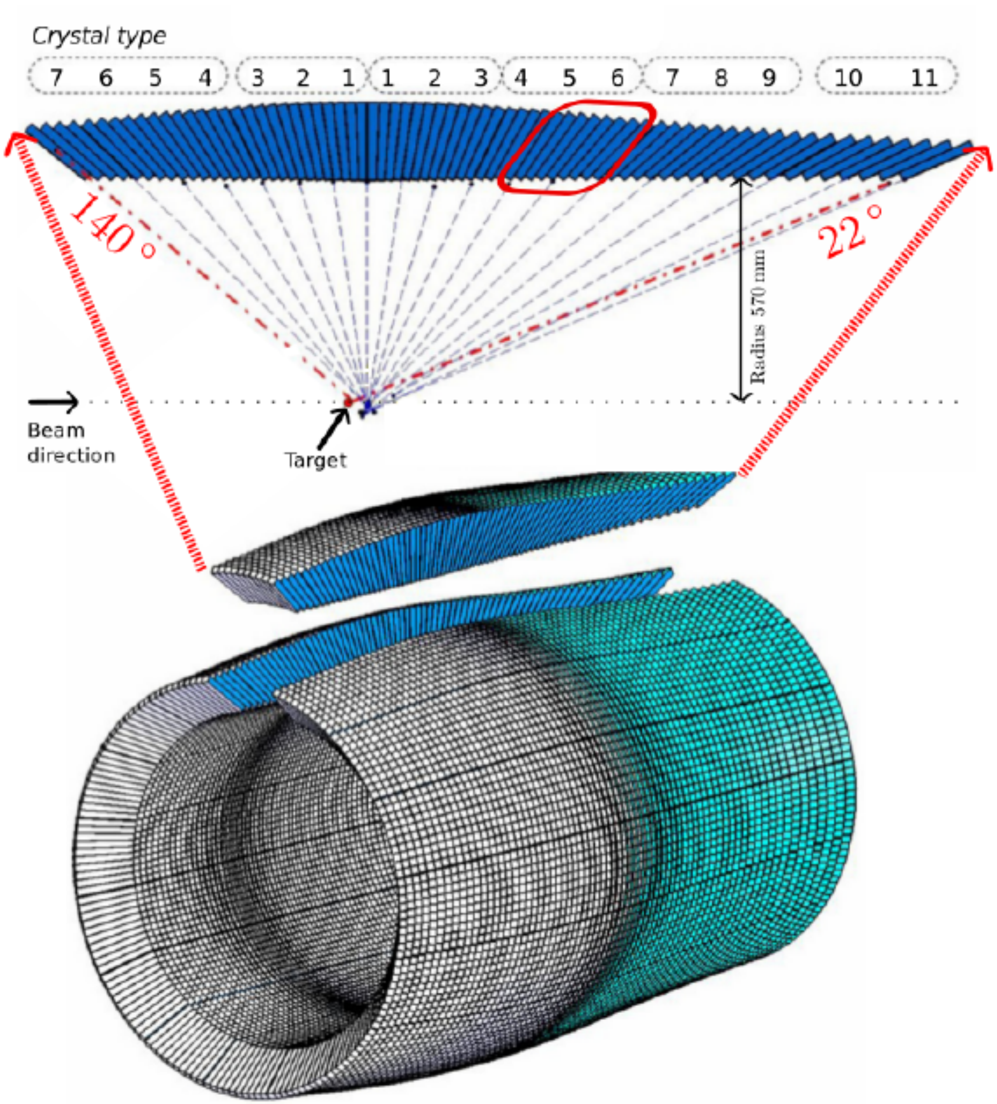


- Assembly of forward endcap EMC at Jülich
  - Beam and DAQ tests with straws, MVD etc. at COSY-TOF area

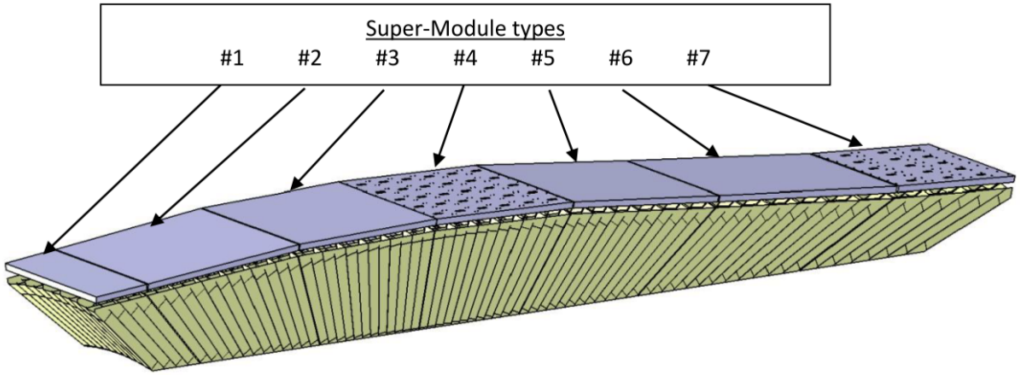


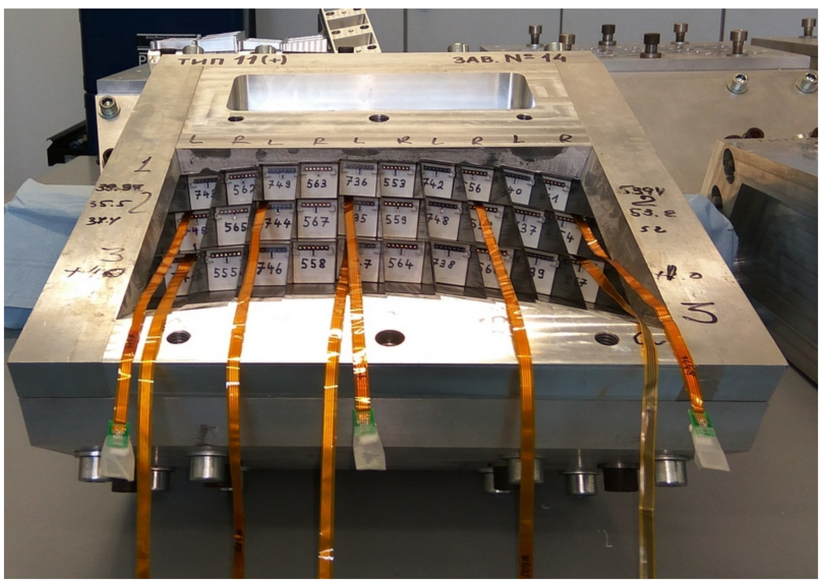


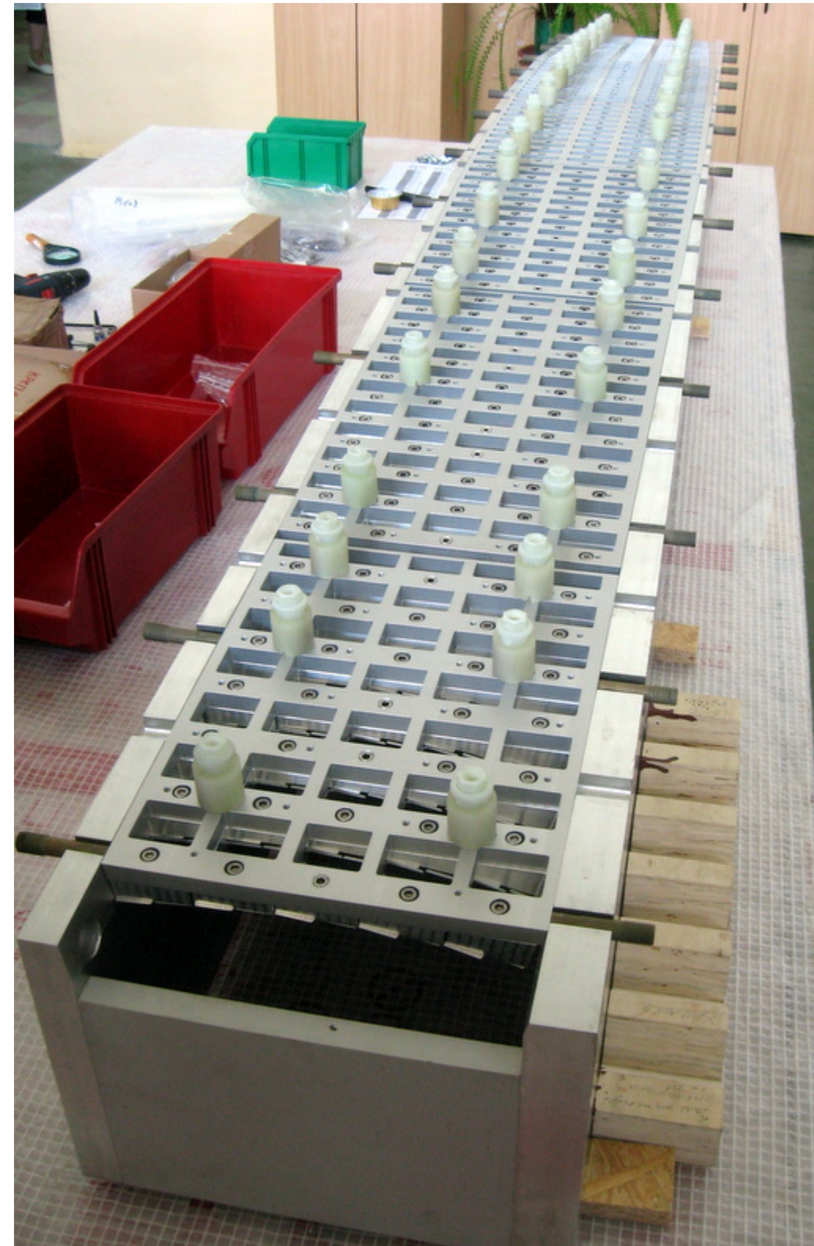
Production of Barrel Slice

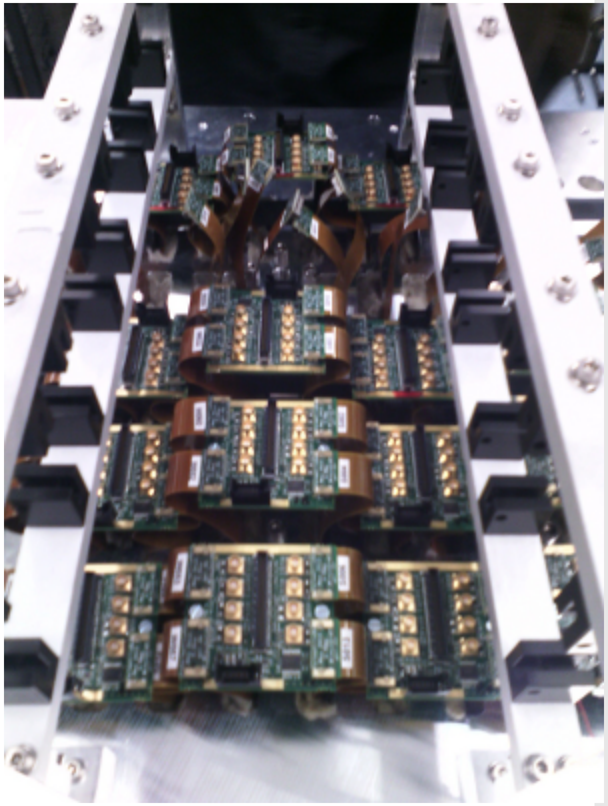


- 710 crystals in 11 different geometries
- Assembly of first slice in 2017


Super-Module types
#1
#2
#3
#4
#5
#6
#7

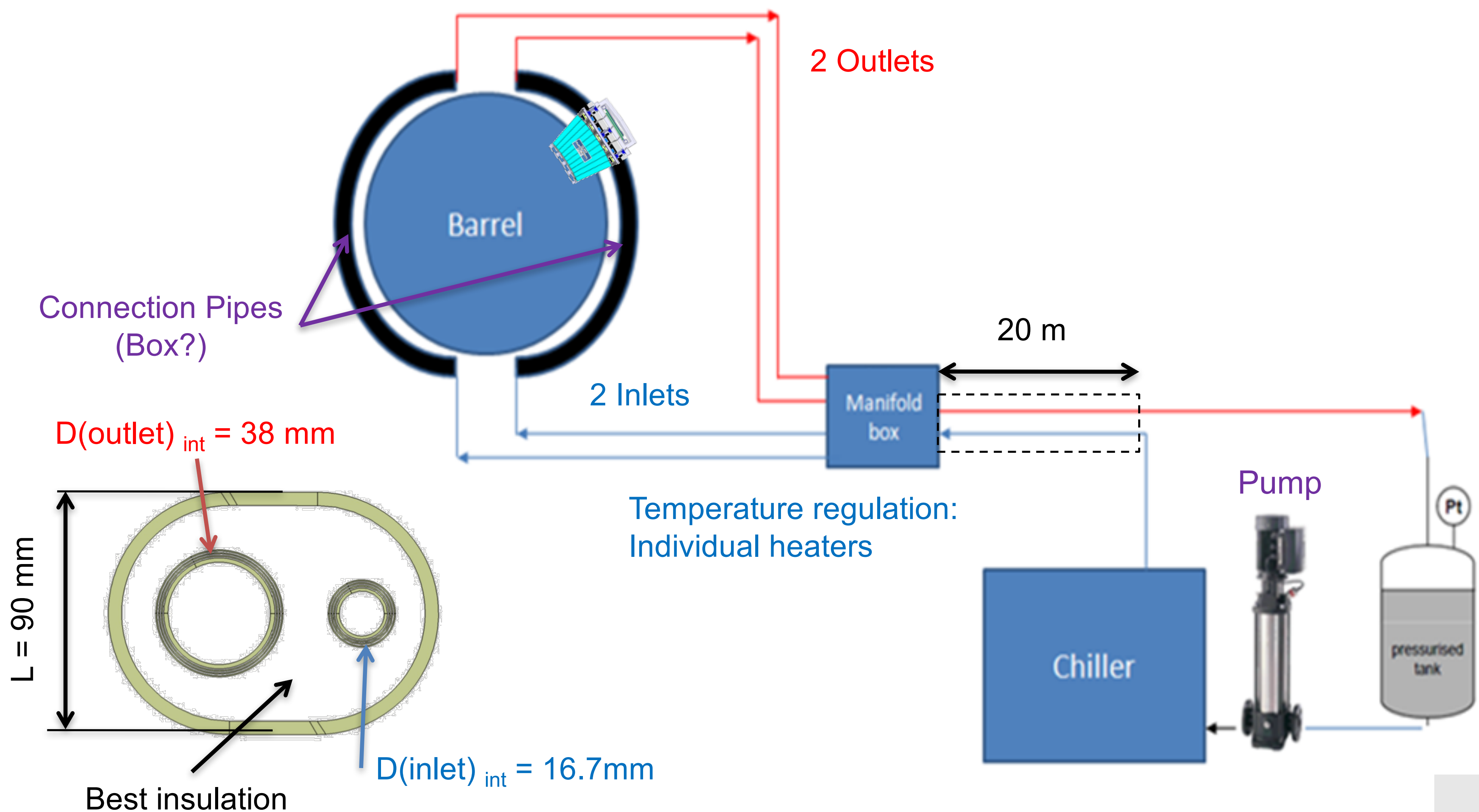




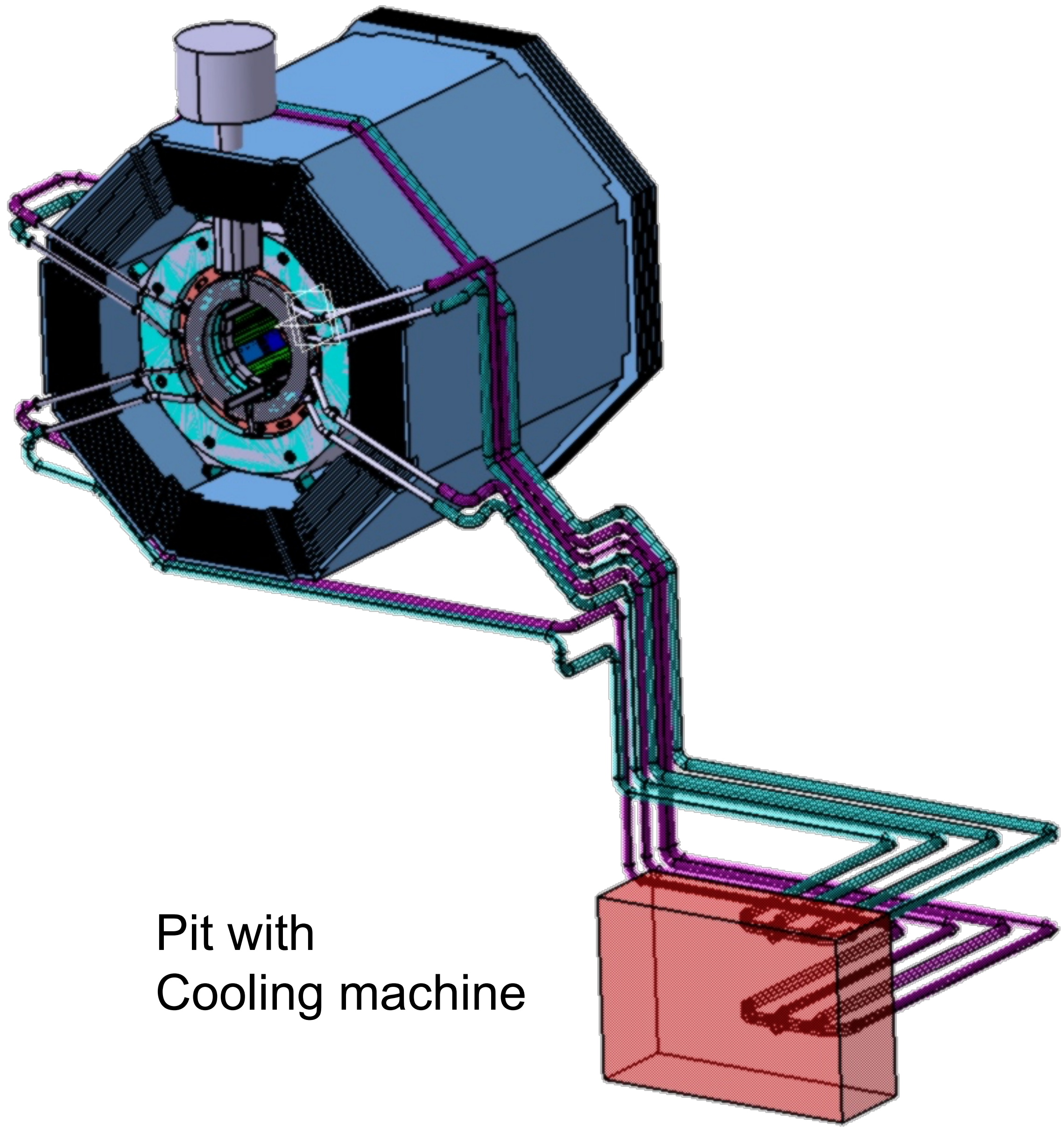



2000 kg

Cooling System



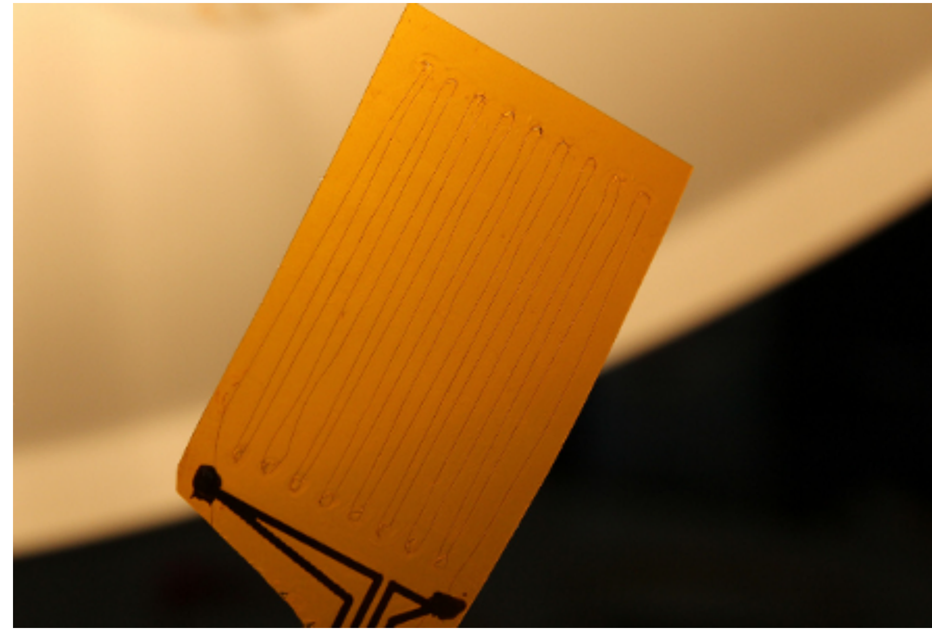
Cooling System

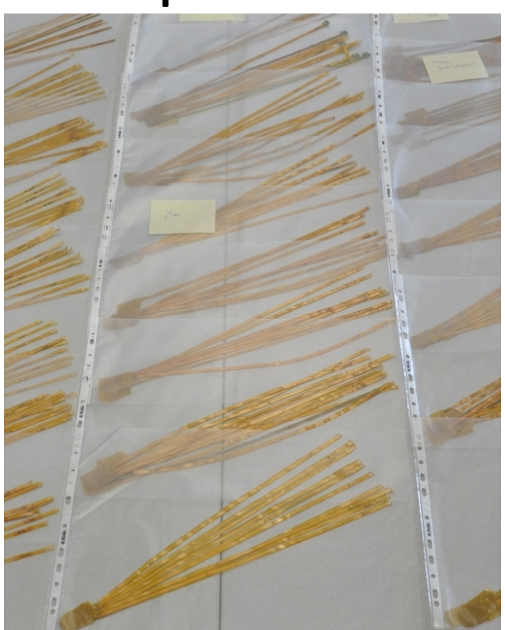


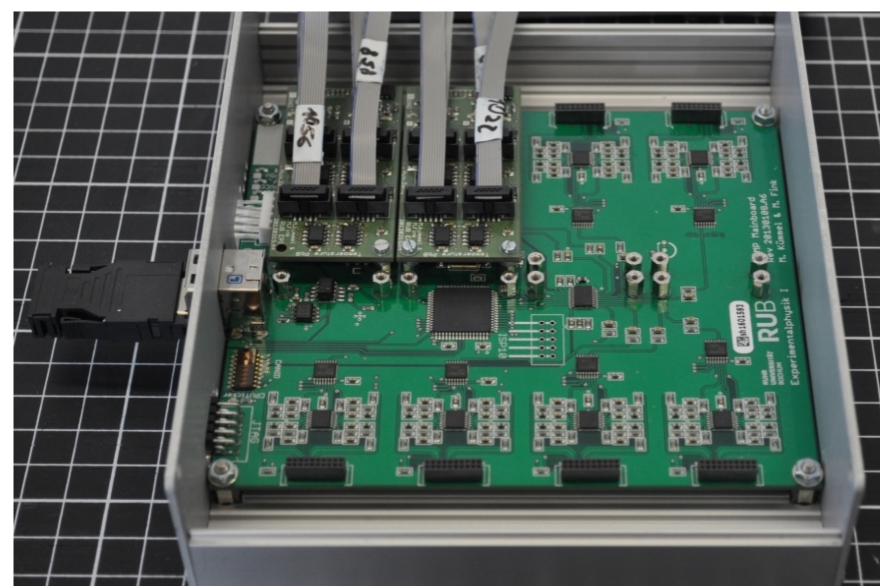
Pit with
Cooling machine

Temperature Monitoring

- Pt100
- Resolution < 0.02 °C
- Thickness < 140 µm
- Distributed between crystals
- Own production



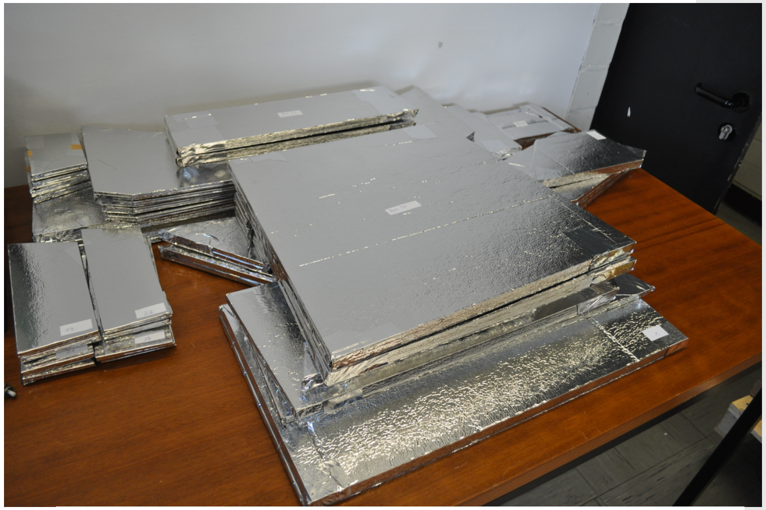


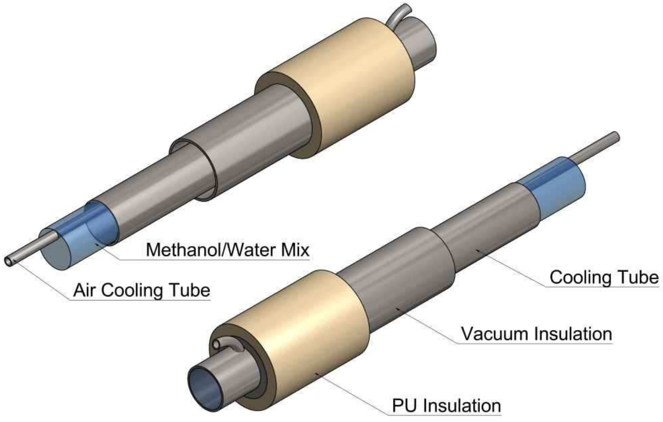


Forward Endcap EMC Cooling

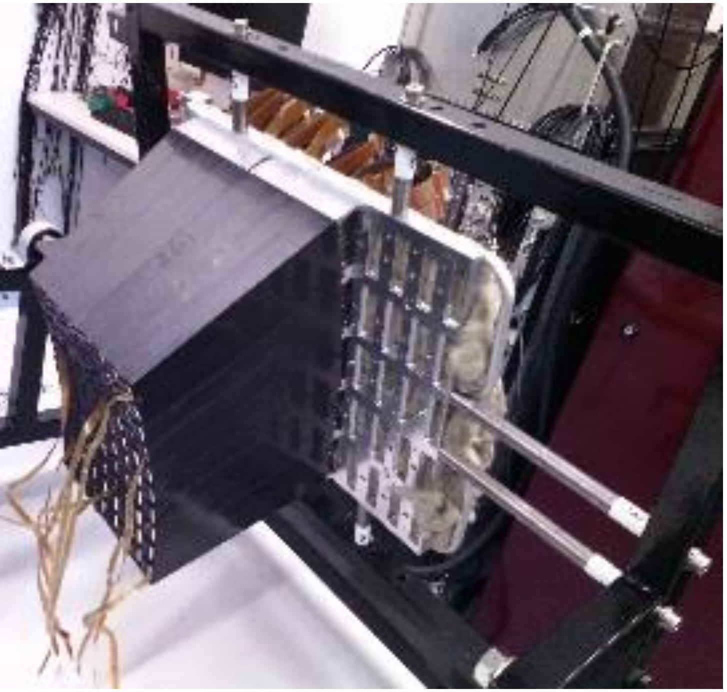
Cooling and Insulation

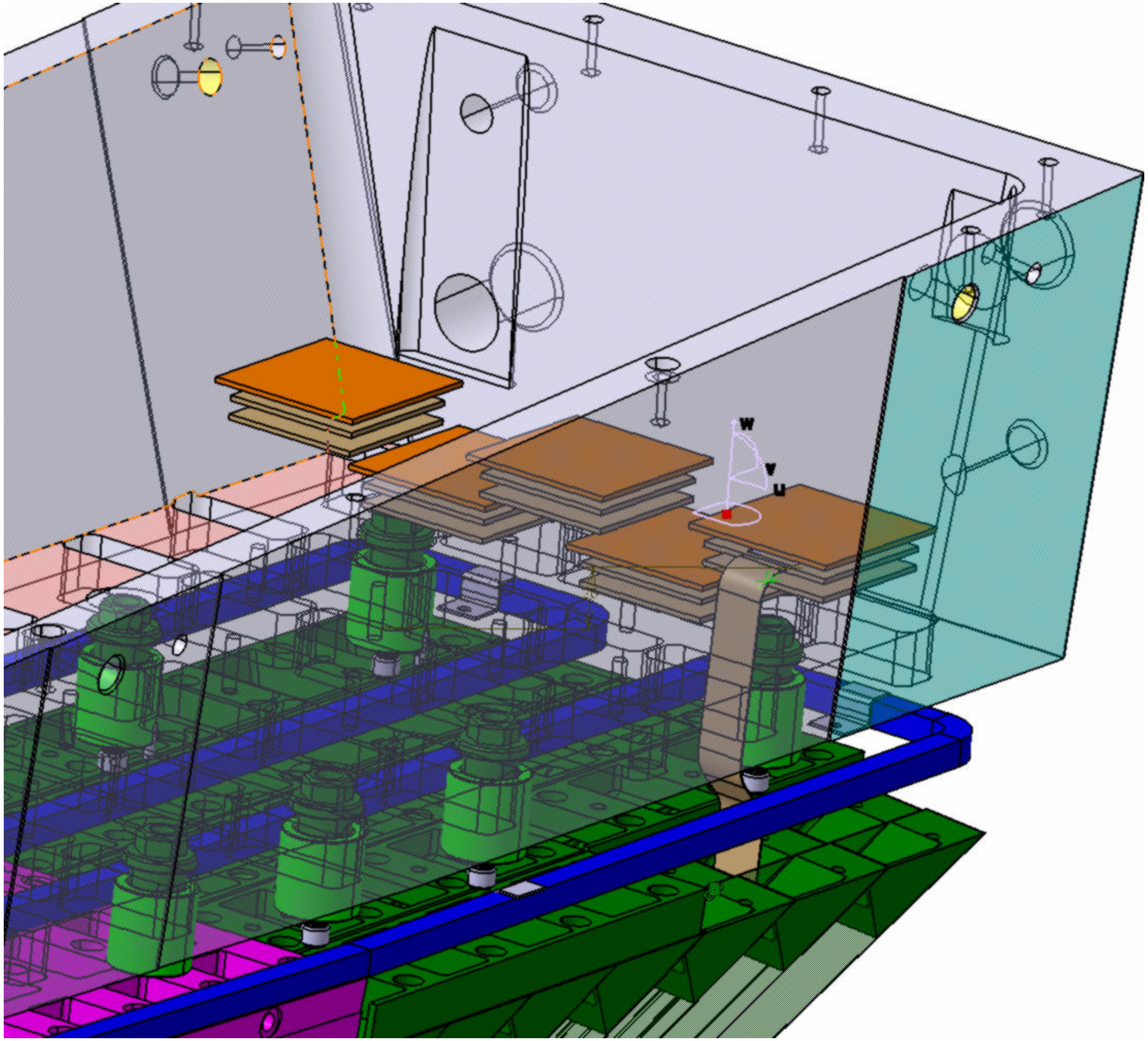
- Cooling lines through drilled holes in backplate support
- Low mass Vacuum Isolation Panels
- Vacuum insulation of cooling lines through solenoid magnet





Barrel EMC Cooling





Summary

- HESR provides an antiproton beam with 1.5 – 15 GeV/*c* momentum
- The PANDA detector covers almost 4π around a fixed target
- PANDA experimental program is covering the three pillars of hadron physics
  - Hadron spectroscopy
  - Hadron structure
  - Hadron interaction
- Lead tungstate crystals enable a compact EMC design, capable of resolving a high hit rate
- Assembly of the forward endcap calorimeter and slice
- Looking forward to produce excellent physics results at the beginning of the next decade