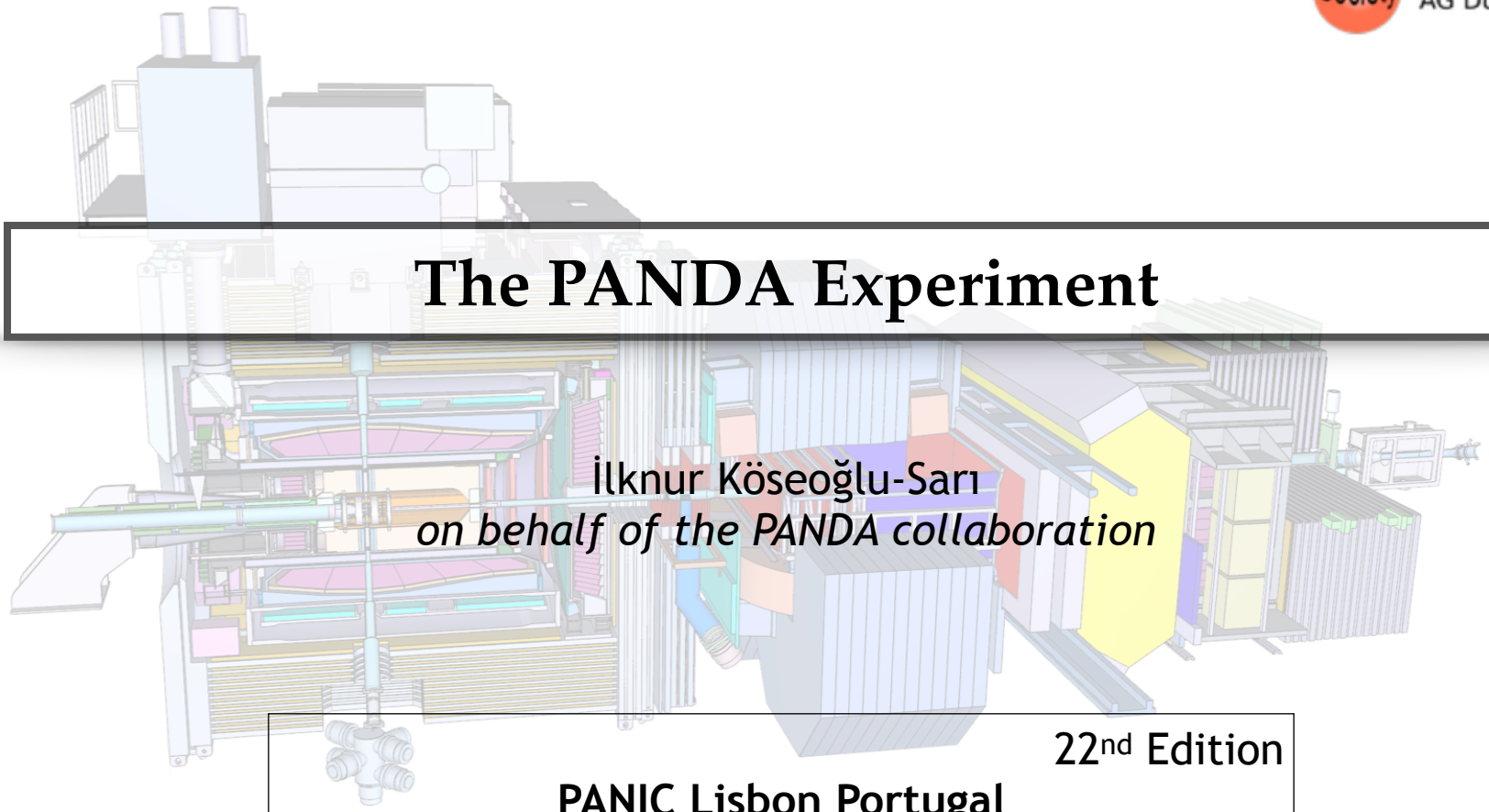
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Research Teaching Society AG Düren

The PANDA Experiment

İlknur Köseoğlu-Sarı
on behalf of the PANDA collaboration



22nd Edition
PANIC Lisbon Portugal
Particles and Nuclei International Conference 2021

2021/09/08

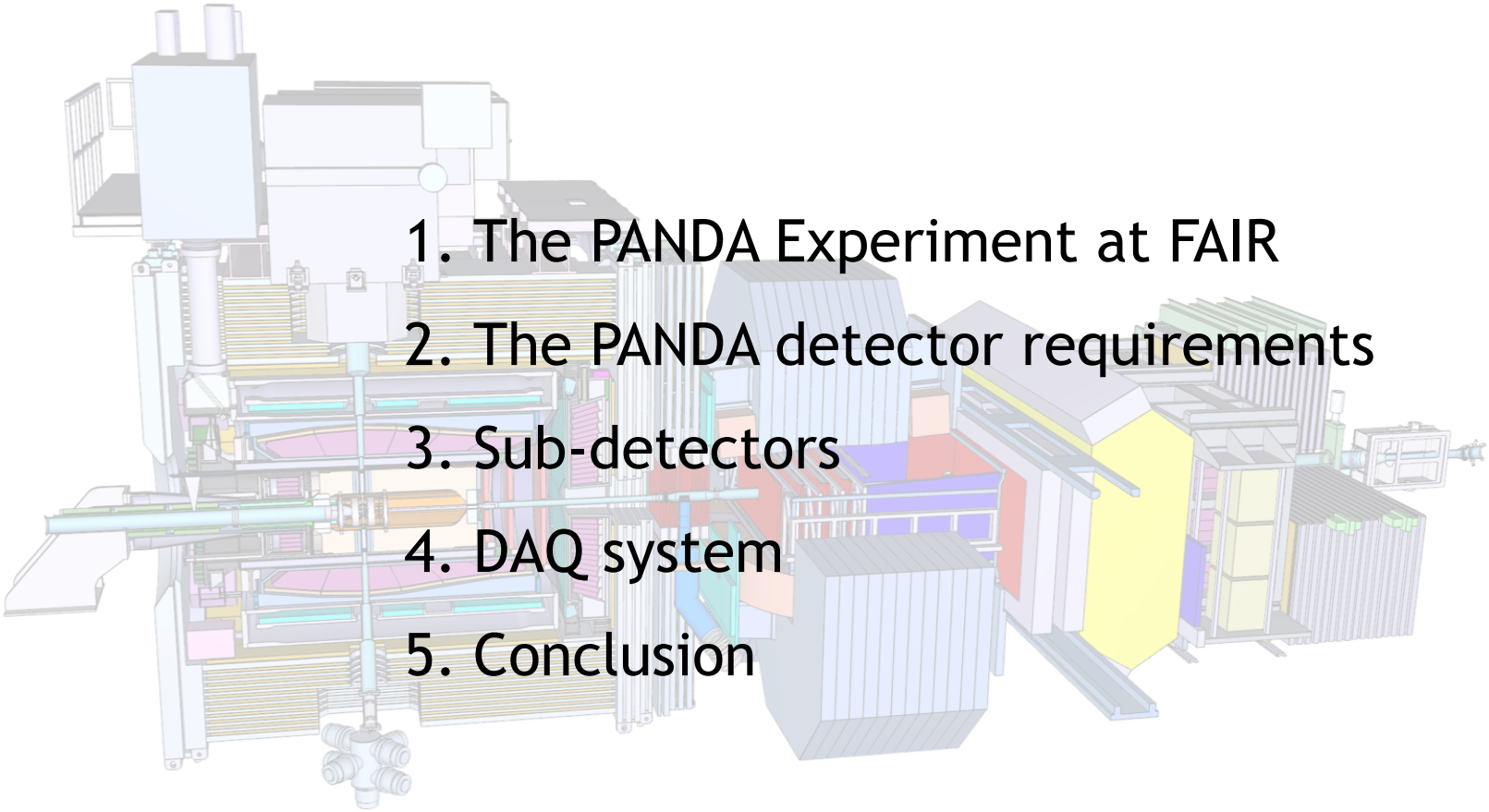
Bundesministerium für Bildung und Forschung

HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

GSI Helmholtzzentrum für Schwerionenforschung GmbH

HIC for FAIR
Helmholtz International Center

Outline



1. The PANDA Experiment at FAIR
2. The PANDA detector requirements
3. Sub-detectors
4. DAQ system
5. Conclusion

The PANDA Experiment at FAIR

p-Linac:
Proton 70 MeV

SIS100: Accelerates p up to 29 GeV

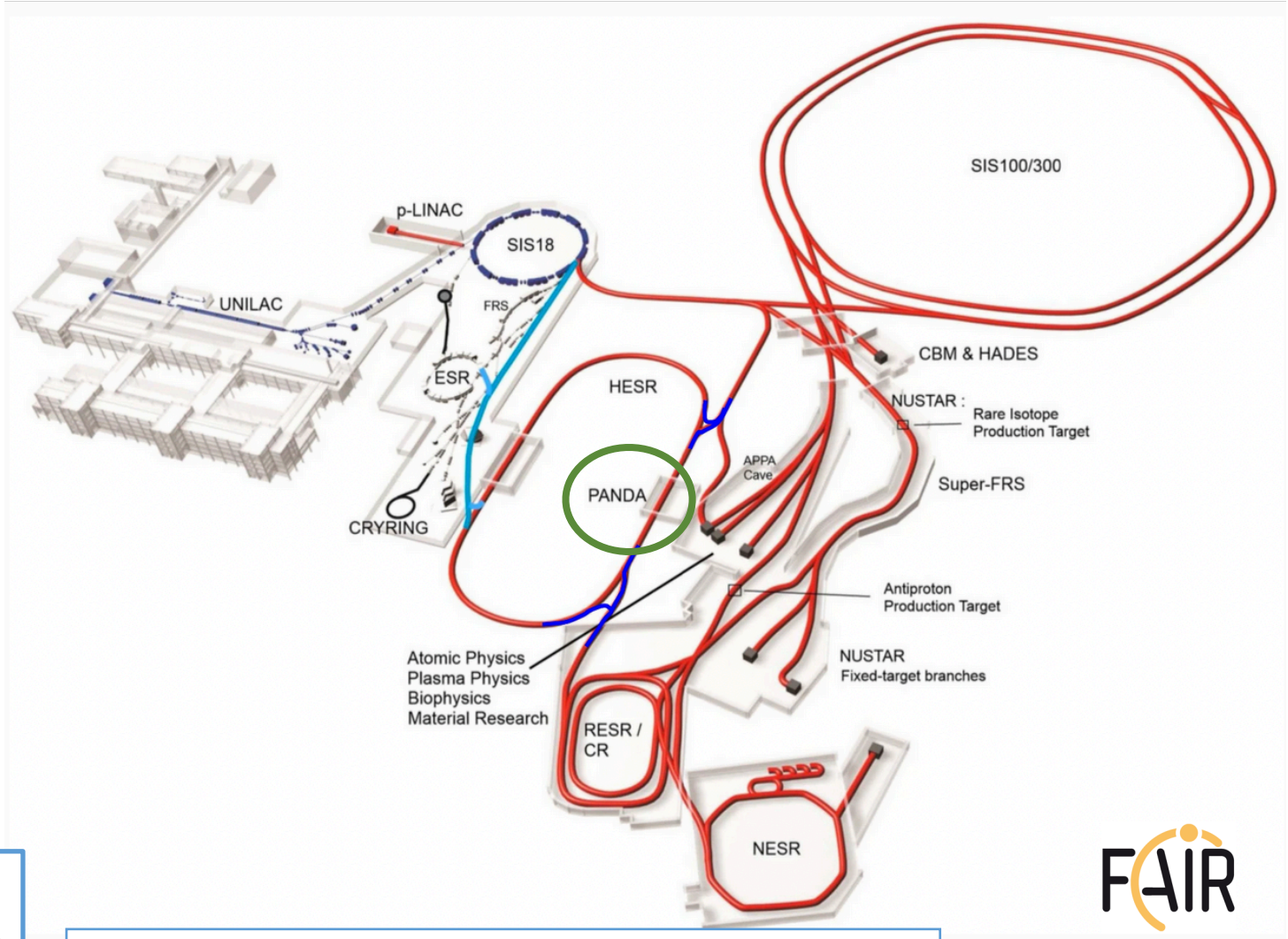
Production of $\bar{p}$ with Ni target

CR:
Fast cooling of $\bar{p}$ beam

HESR:
Accumulation of $\bar{p}$

$\bar{p}$: 1.5-15 GeV/c
L = $2 \times 10^{31} cm^{-2} s^{-1}$ (HR)
L = $2 \times 10^{32} cm^{-2} s^{-1}$ (HL)

Facility for Antiproton and Ion Research at GSI, Darmstadt, Germany



PANDA: Antiproton Annihilation at Darmstadt

PANDA project phases

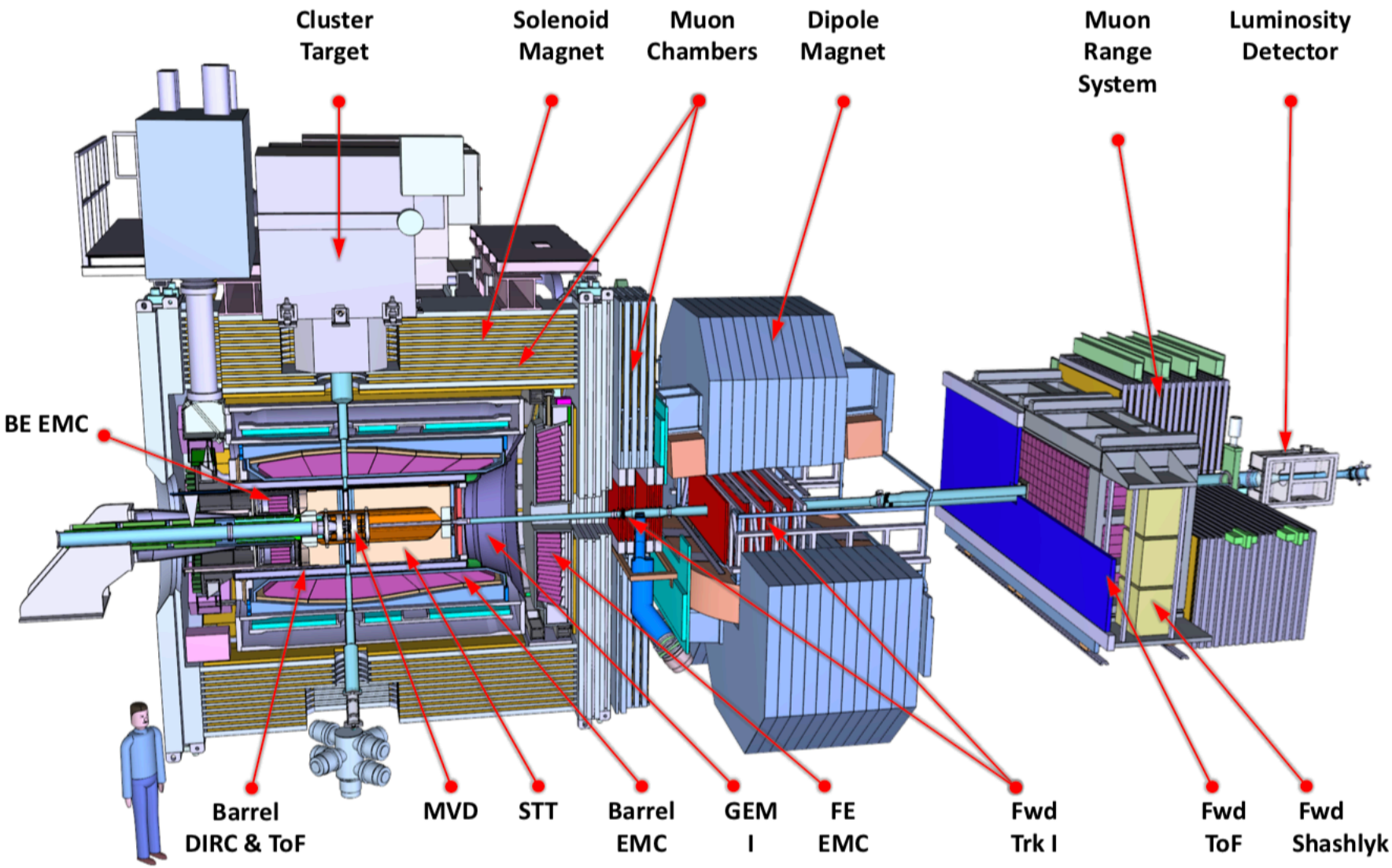
Phase-0: Sub-detectors are under construction and they are tested in the available experimental halls

Phase-1: The first physics experiments with proton will be started as an initial setup.

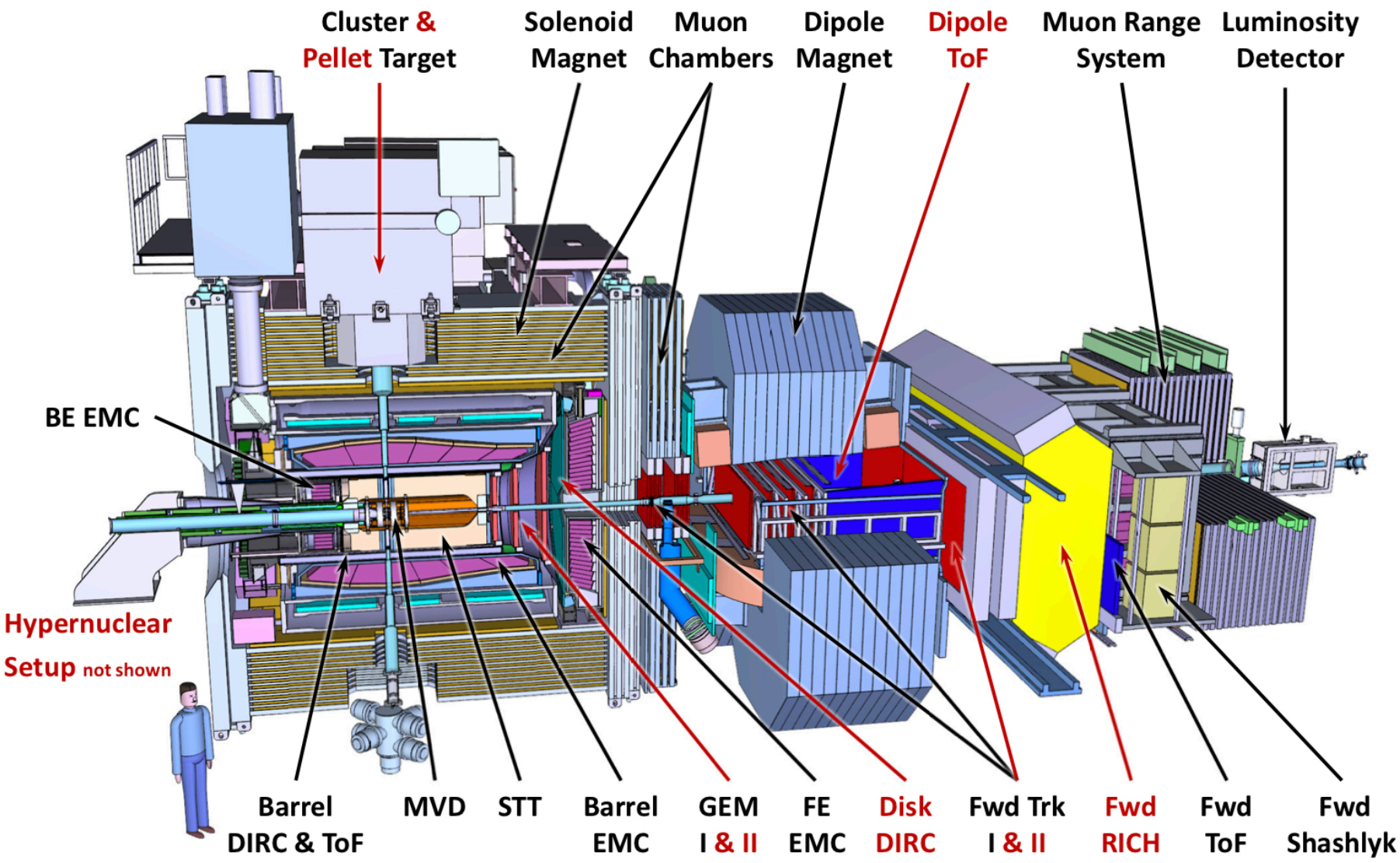
Phase-2: Remaining detectors will be installed, full setup will be available.

Phase-3: RESR will be available for high luminosity experiments.

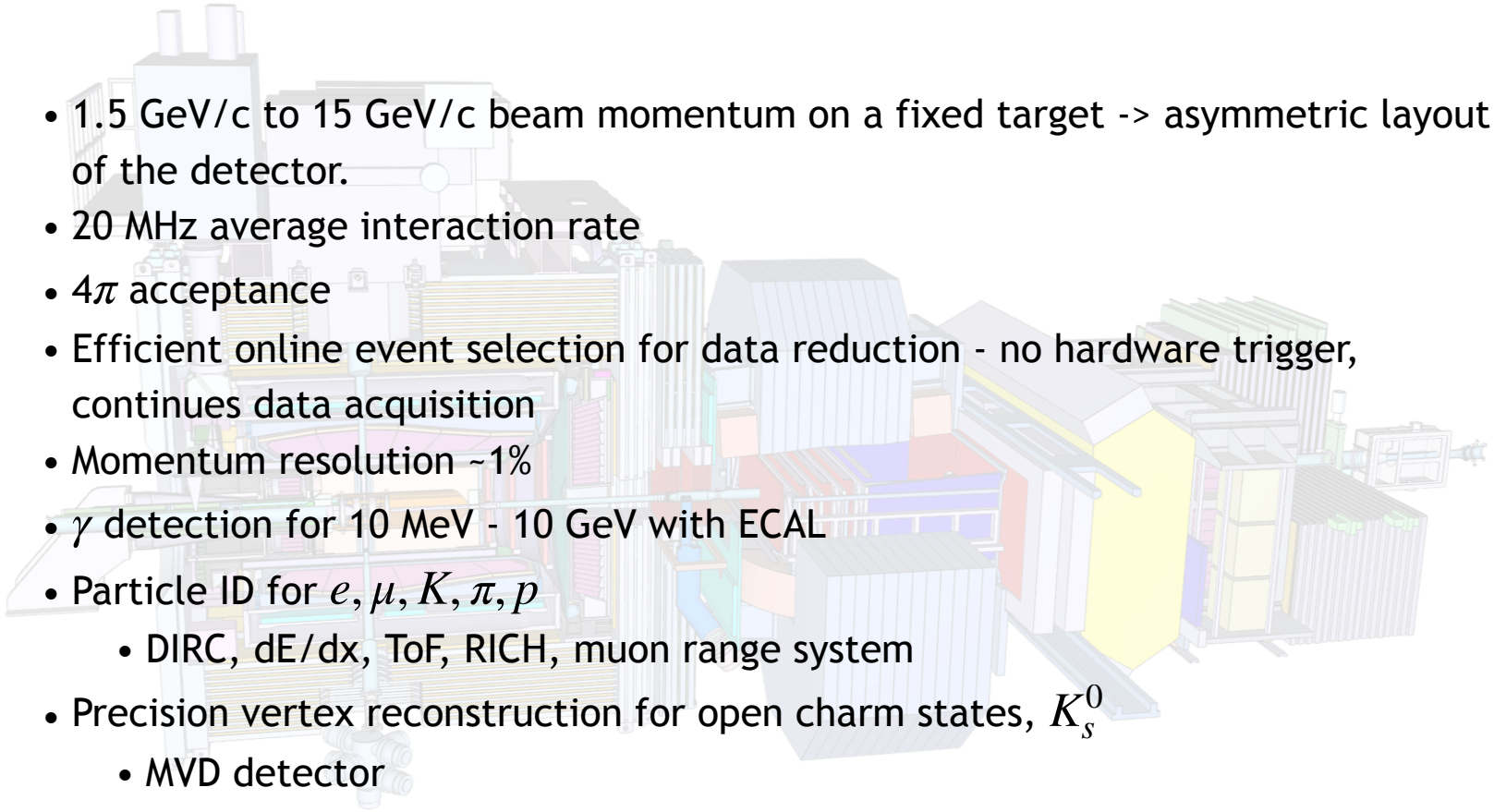
Phase-1 start setup



The PANDA Experiment at FAIR



Detector requirements



- 1.5 GeV/c to 15 GeV/c beam momentum on a fixed target -> asymmetric layout of the detector.
- 20 MHz average interaction rate
- 4π acceptance
- Efficient online event selection for data reduction - no hardware trigger, continues data acquisition
- Momentum resolution ~1%
- γ detection for 10 MeV - 10 GeV with ECAL
- Particle ID for e, μ, K, π, p
  - DIRC, dE/dx, ToF, RICH, muon range system
- Precision vertex reconstruction for open charm states, K_s^0
  - MVD detector

PANDA magnets

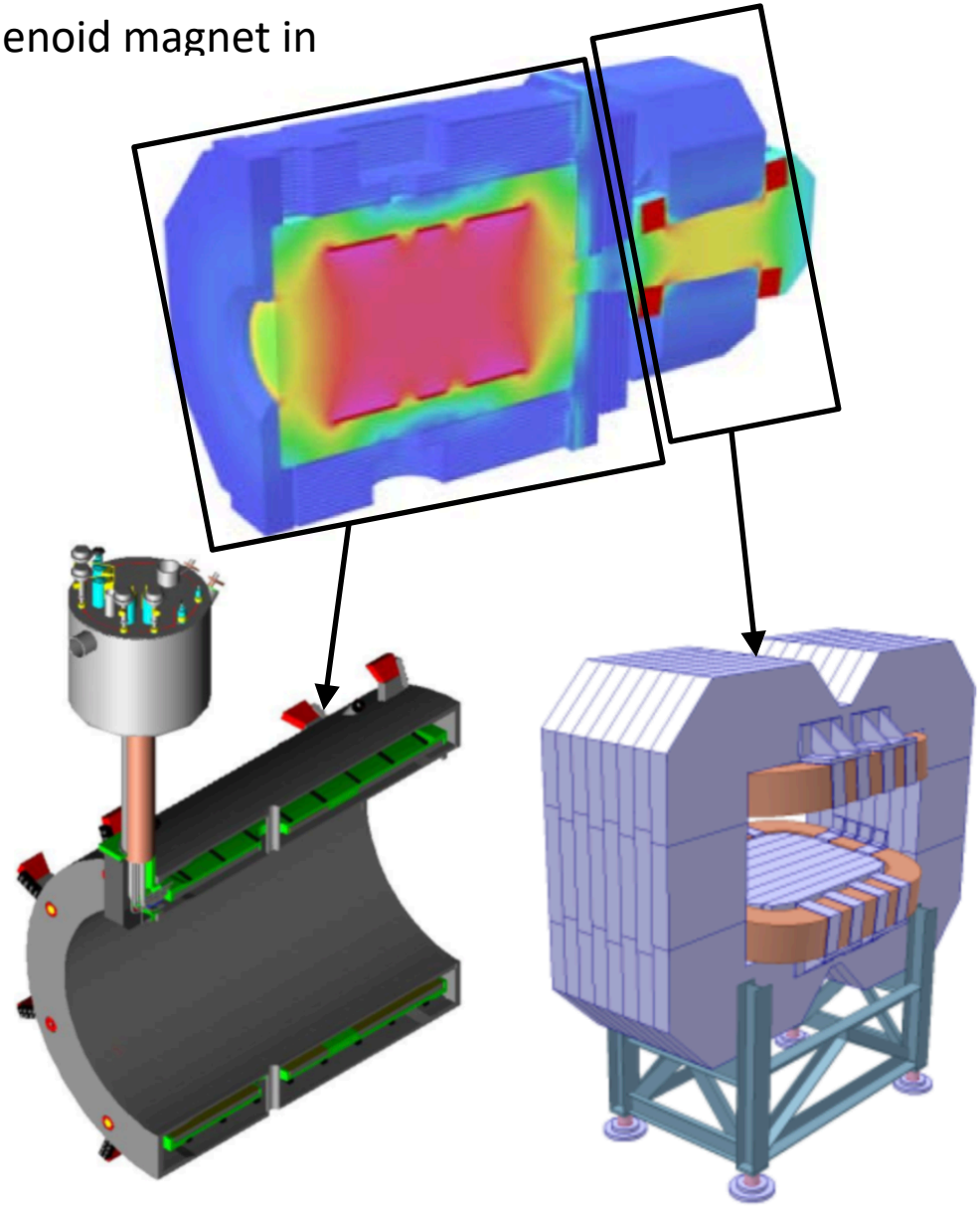
Combination of solenoid and dipole field, solenoid magnet in the TS and Dipole magnet in FS.

Solenoid magnet:

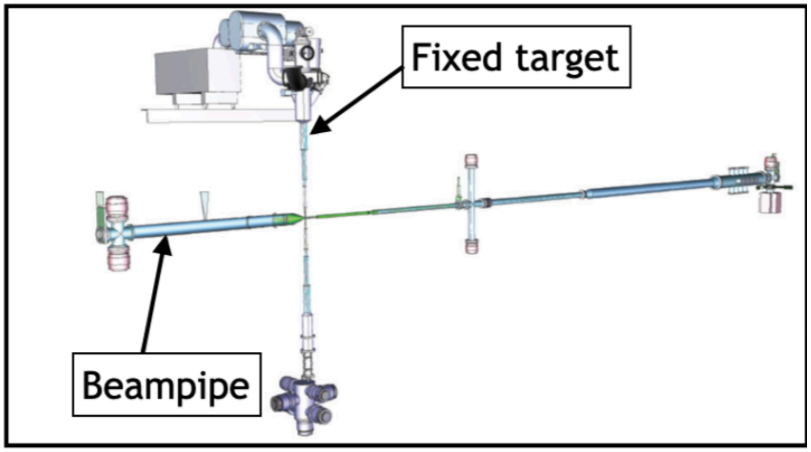
- Superconducting coil, 2T magnetic field
- Inner bore: $1.9\,m$/ L = $2.7\,m$
- Outer yoke: $2.3\,m$/ L = $4.9\,m$
- Total weight = 300t
- Iron yoke is instrumented with muon chambers.

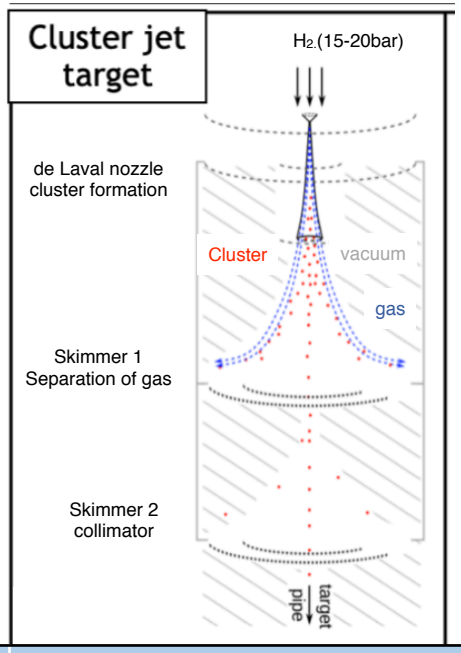
Dipole magnet:

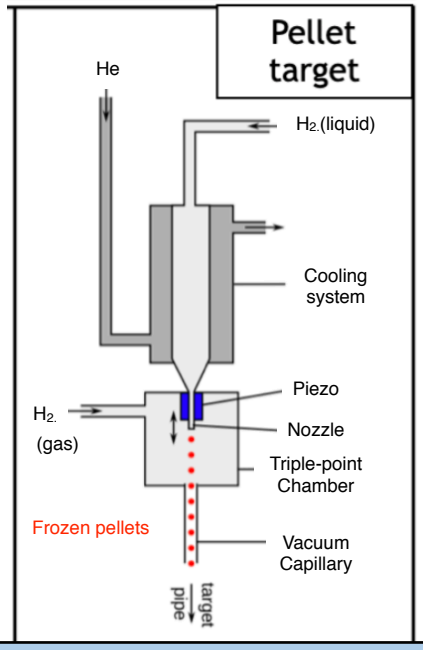
- Vertical acceptance $\pm 5^{\circ}$
- Horizontal acceptance $\pm 10^{\circ}$
- Total weight 200t
- Field 1T



PANDA proton targets





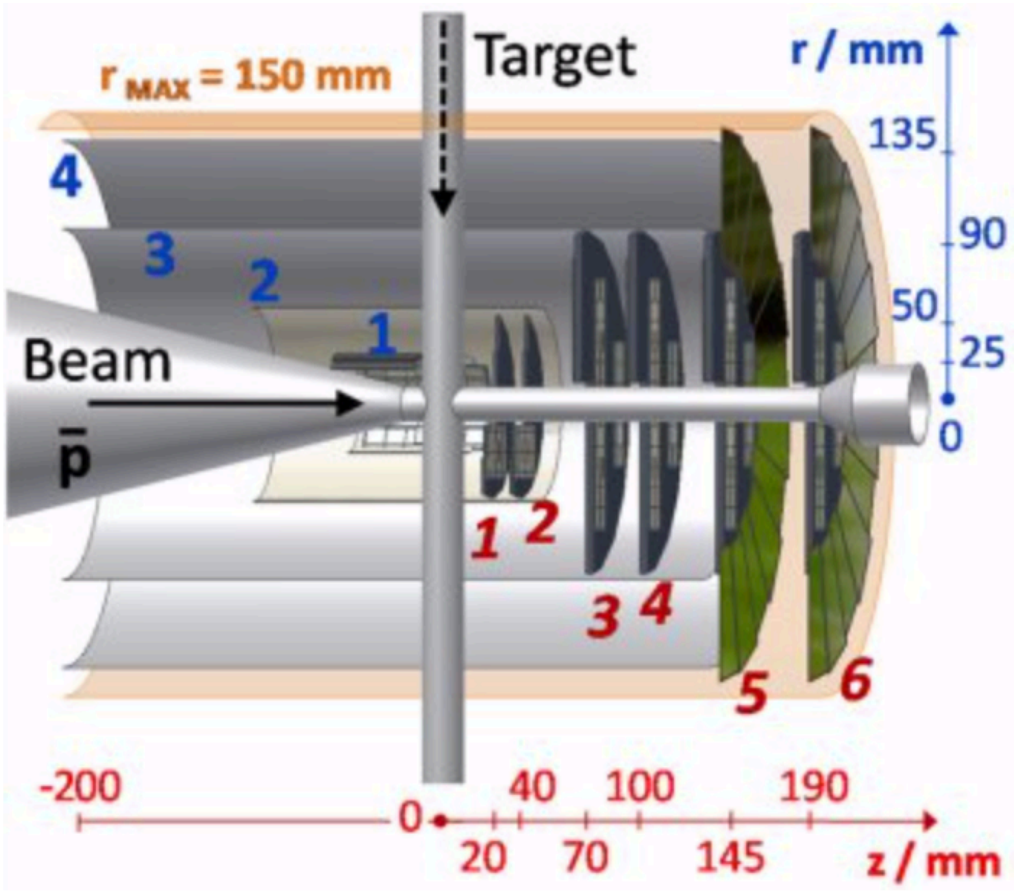


	Cluster Jet target	Pellet target
Effective target thickness	10^{15} atoms/ cm^2	5.10^{15} atoms/ cm^2
Volume density distribution	homogenous	Granular (Primary Vertex)
Size transversal to beam	2-3 mm	< 3 mm
Size longitudinal to beam	15 mm	< 3 mm
Target particle size	nm scale	20 um

- Pellet tracking system allows to detect the position of individual pellet drop.
- Further target is possible

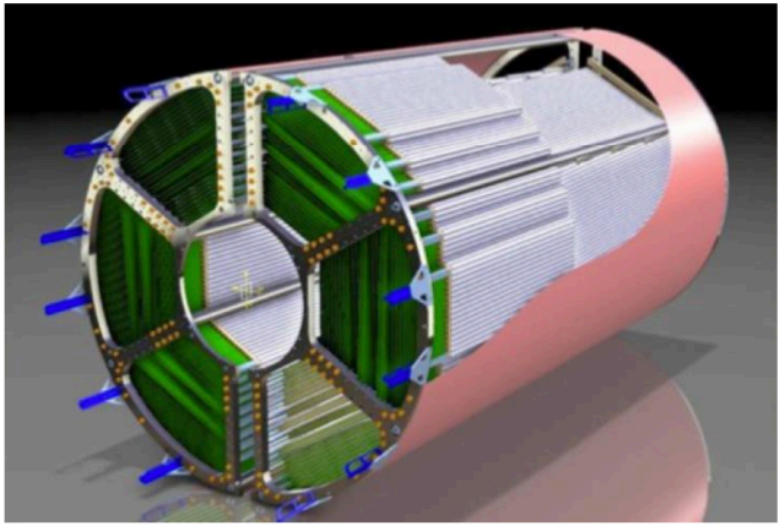
Tracking - Micro Vertex detector

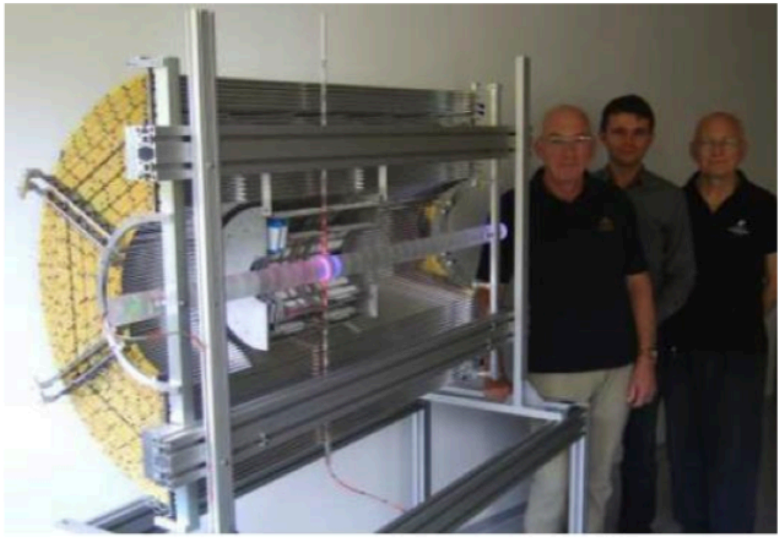
- Closest detector to the IP
- 4-barrels 6 disks
- Innermost layers are hybrid pixel detectors, outermost layers are double-sided silicon strip detector.
- Hybrid pixel detector: combination of semiconductor sensor and CMOS chip
  - $100 \times 100\,\mu m^2$
  - ToPix ASIC + 0.13 μm CMOS tech
- DSSD: Rectangles and trapezoids
  - ToASt ASIC 110 nm CMOS
- Time resolution: 6 ns
- Pixel resolution: 28 µm
- Strip resolution: 14 µm
- Vertex resolution: 50 µm (important for D mesons)
- Project Status
  - TDR approved arXiv:1207.6581
  - ASIC prototypes tests & adaptation



Tracking - Straw Tube Tracker

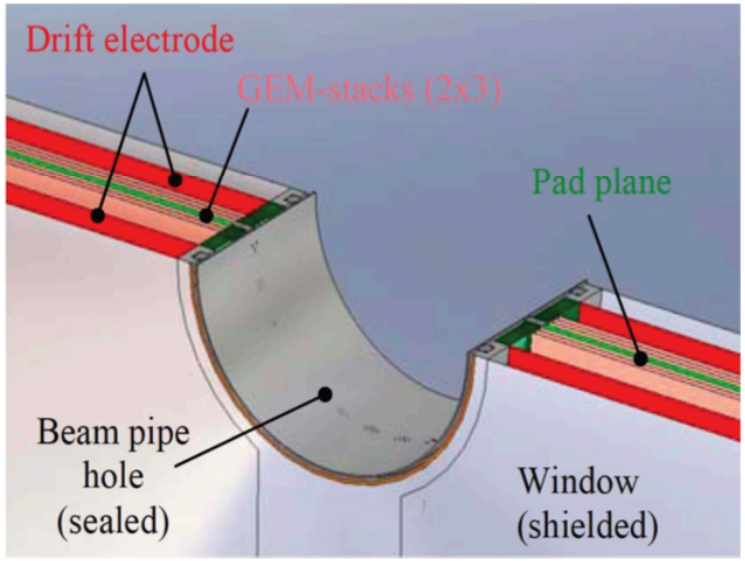
- Cylindrical shape around MVD
- Layers of 4200 drift tubes with the dimensions Rin = 150 mm, Rout = 420 mm, L = 1500 mm
- Tubes made of Al-Mylar are self supporting ~1 bar overpressure (Ar/CO2)
- Resolution $\phi \sim 150\,\mu m$, z ~ 1 mm
- Readout ASIC (PASTREC) & TDC FPGA with 0.35μm CMOS
- Project Status
  - TDR Approved arXiv:1205.5441
  - Readout prototypes & beam tests
  - Ageing tests: up to 1.2 C/cm^2
  - Straw series production finished
  - Module production starting

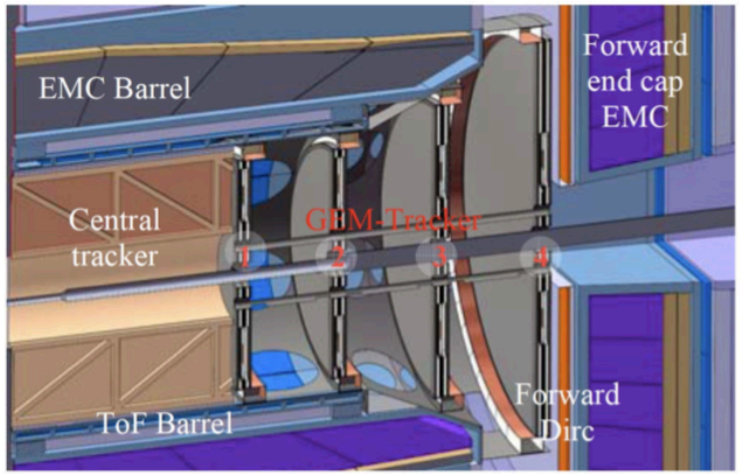




Tracking - GEM

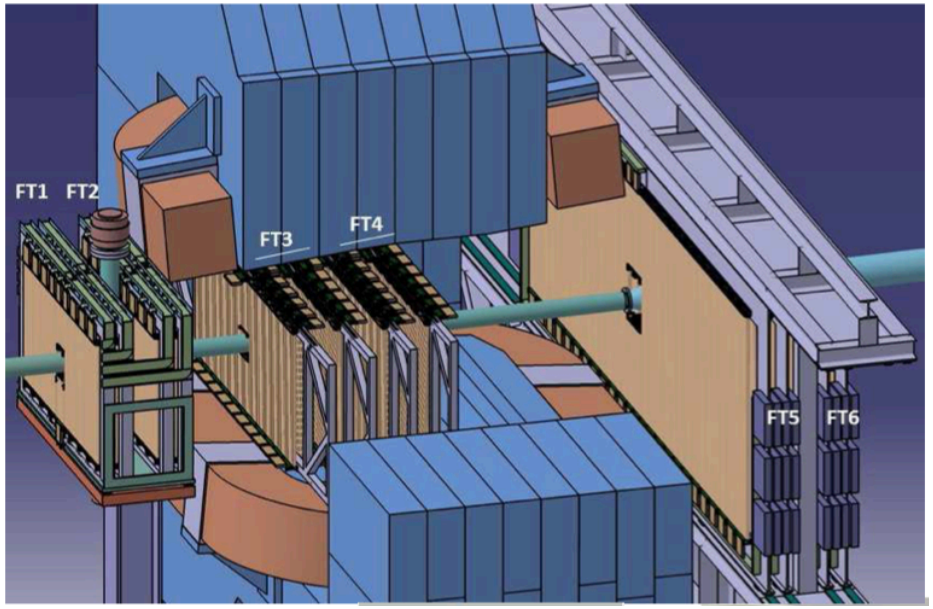
- Forward tracking inside solenoid
- Three GEM stations are available
  - Several layers filled with gas in-between.
- Polar angle range 5° to 22°
- Four projections in radial, concentric, x, y,
- Large area GEM foils from CERN, 50 μm Kapton foil, 2-5 μm copper coating.
- ADC readout for 35,000 channels
- Project status
  - TDR accepted
  - Advanced mechanical concept
  - Readout electronics tests

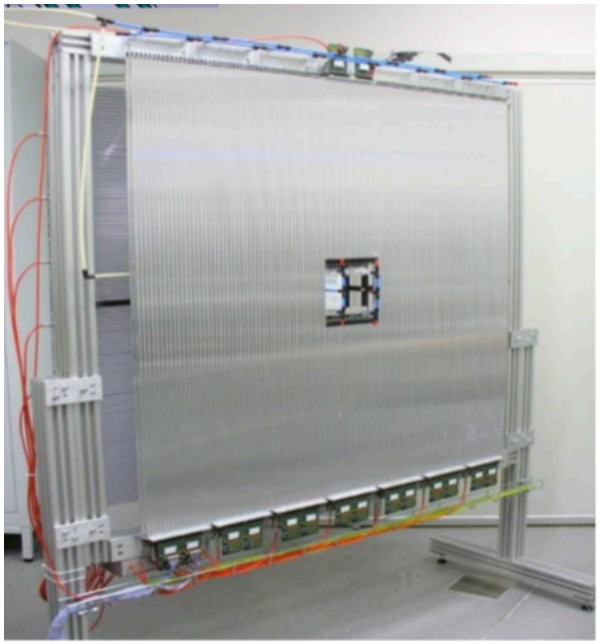




Tracking - Forward Tracker

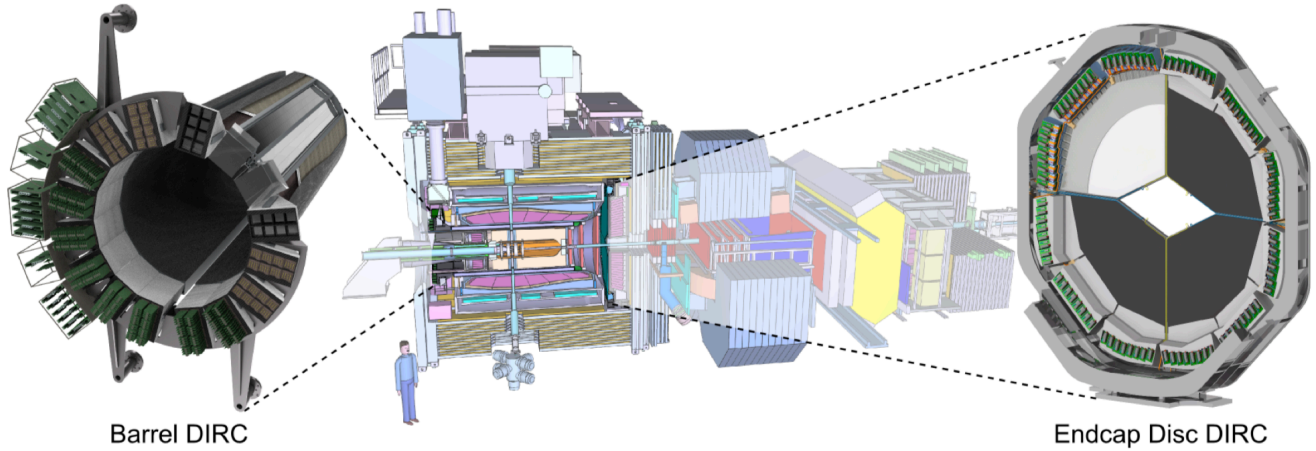
- Tracking in forward spectrometer
- Six stations are available
  - FT1-2: Between solenoid and dipole magnet
  - FT3-4: In dipole gap
  - FT5-6: Large chambers behind dipole
- Straw-tubes are similar to used in central tracker
- Readout ASIC (PASTREC) & TDC FPGA with 0.35μm CMOS
- Coverage
  - $\pm 10^{\circ}$ in horizontal direction
  - $\pm 5^{\circ}$ in vertical direction
  - Position resolution 0.1mm/layer
  - Momentum resolution ≤ 1%
- Project status
  - TDR accepted
  - Ageing tests: up to 1 C/cm^2
  - Readout electronics tests



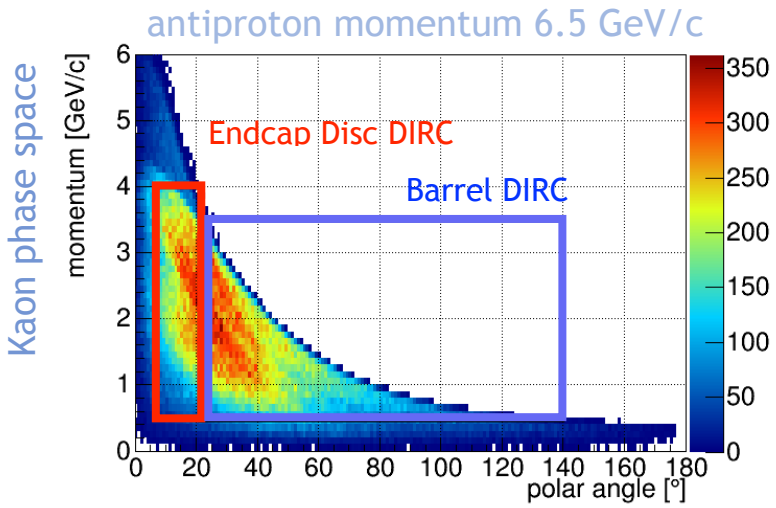


Particle identification - Target Spectrometer

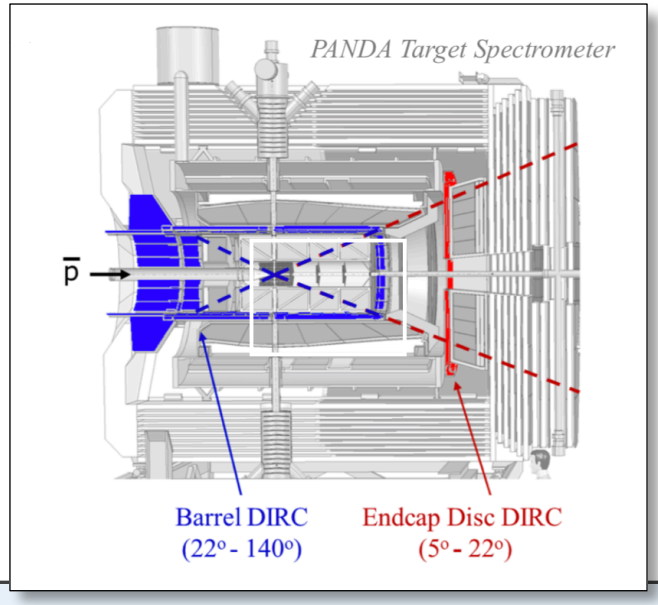
Detection of Internally Reflected Cherenkov light



- Barrel DIRC Goal:
  3. s.d. π/K separation up to 3.5 GeV/c



- Endcap Disc DIRC Goal:
  3 s.d. π/K separation up to 4 GeV/c



Full Coverage: Combination of Barrel and Disc DIRC

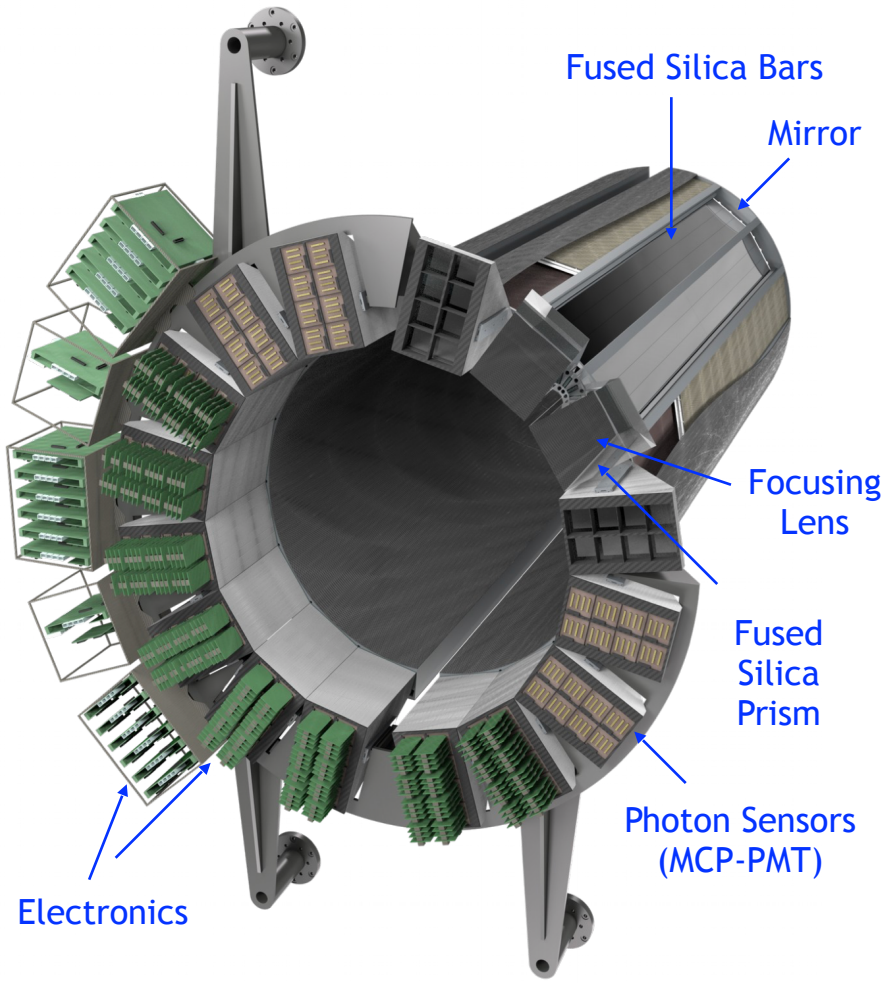
PID - Barrel DIRC

- 48 radiator bars (16 sectors), synthetic fused silica 17 mm (T) x 53 mm (W) x 2400 mm (L)
- Mirror attached to one bar end to reflect photon back through to readout end.
- Focusing optics: 3-layer spherical lens
- Compact expansion volume:

  30cm deep solid fused silica prisms,

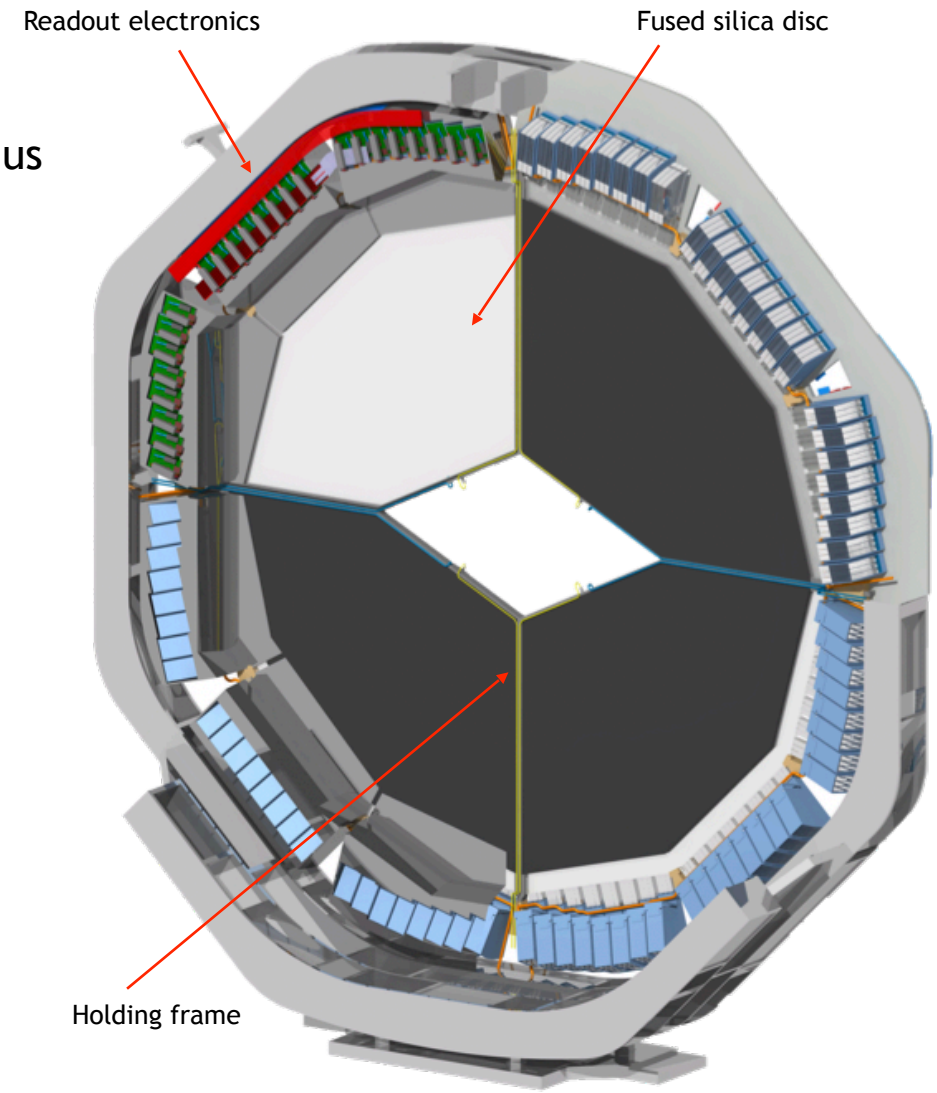
  ~8200 channels of lifetime-enhanced MCP-PMTs (Microchannel Plate Photomultiplier Tubes)
- Fast FPGA-based readout electronics

  ~100ps per photon timing resolution
- Expected performance (simulation and particle beams)
  better than 3 s.d. π/K separation for entire acceptance
- Project Status
  - TDR published [arXiv:1710.00684]



PID - Endcap Disc DIRC (EDD)

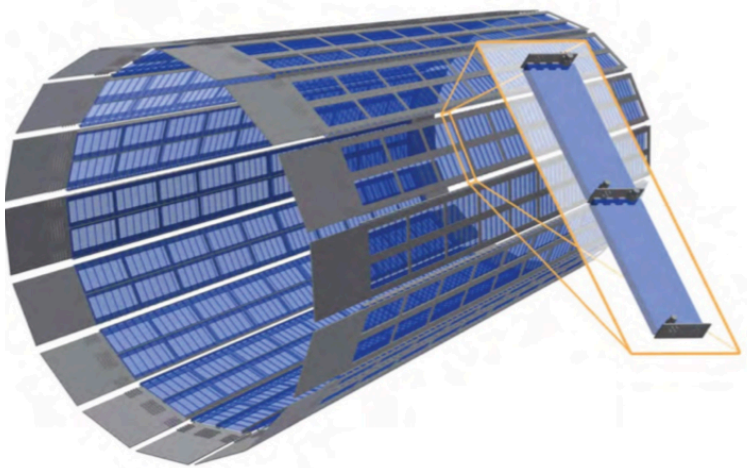
- 4 independent quadrants
- high polished fused silica (Quartz), 20 mm thickness in z direction, 1056 mm outer radius
- Focusing elements convert angle to position information, fused silica bars and expansion volume
- Sensors: 96 MCP-PMT sensors with highly segmented anode
- TofPET2 ASIC readout:
  - 24 (ROM)s per quadrant , ~28,800 pixel
- Project Status:
  - TDR approved [arXiv:1912.12638]
  - Prototype device is tested in Giessen Cosmic Stations by using cosmic muons.



PID - Barrel TOF

- PID of low momentum particles <1 GeV/c
- Scintillator Tile hodoscope

  $87 \times 29.4 \times 5\ mm^3$
- Readout based on Hamamatsu SiPM
- Time resolution is better than 100 ps
- Frontend electronics PETsys TOFPET ASICs

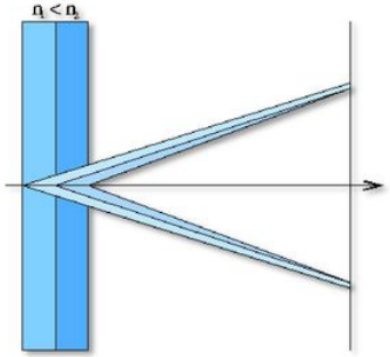


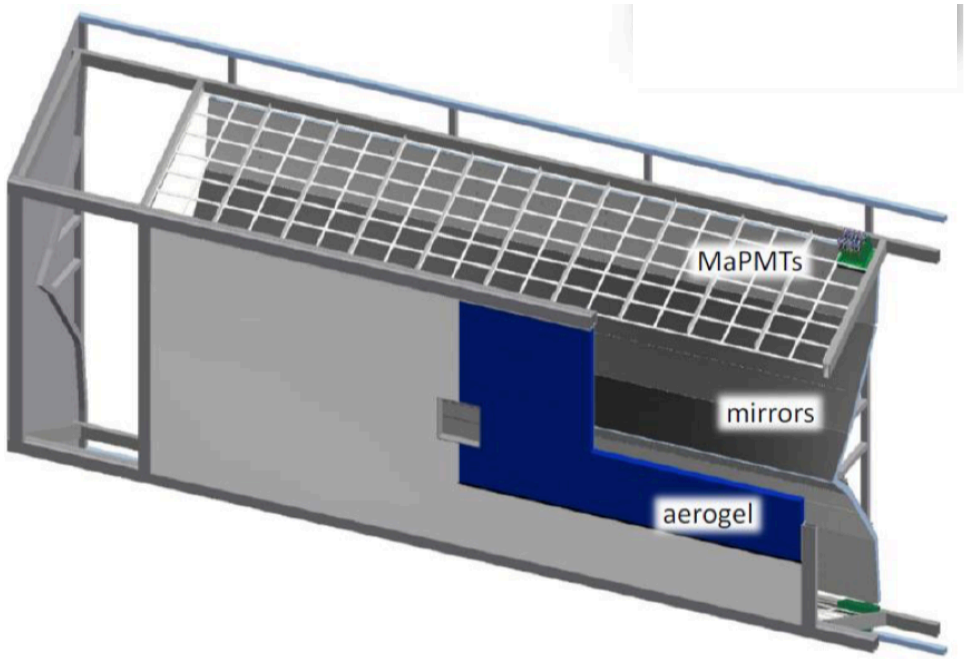
Project status

- TDR approved
- Study of scintillator thickness (3-6 mm)
- SiPM radiation hardness studies planned

PID - Forward RICH

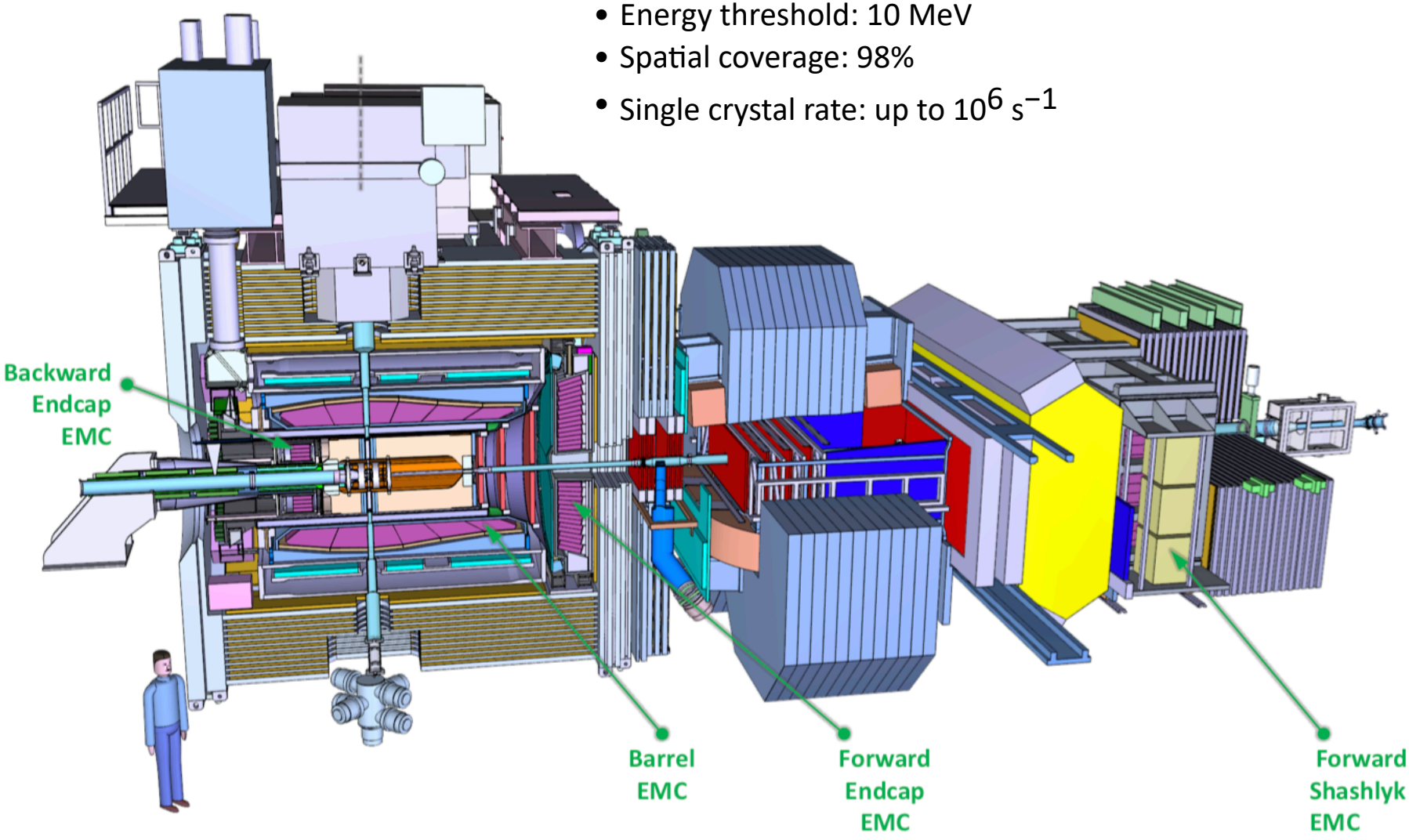
- Focusing aerogel RICH
- Two layers of aerogel with refractive index n_1 = 1.050 and n_2 = 1.047
- Flat mirrors
- π / K separation up to 10 GeV/c
- μ / K separation up to 10 GeV/c
- Coverage
  - $\pm 10^{\circ}$ in horizontal direction
  - $\pm 5^{\circ}$ in vertical direction
- Readout with Hamamatsu MaPMTs
  - 8x8 anode structure with 6 mm pixel size
  - Robust and long-life time





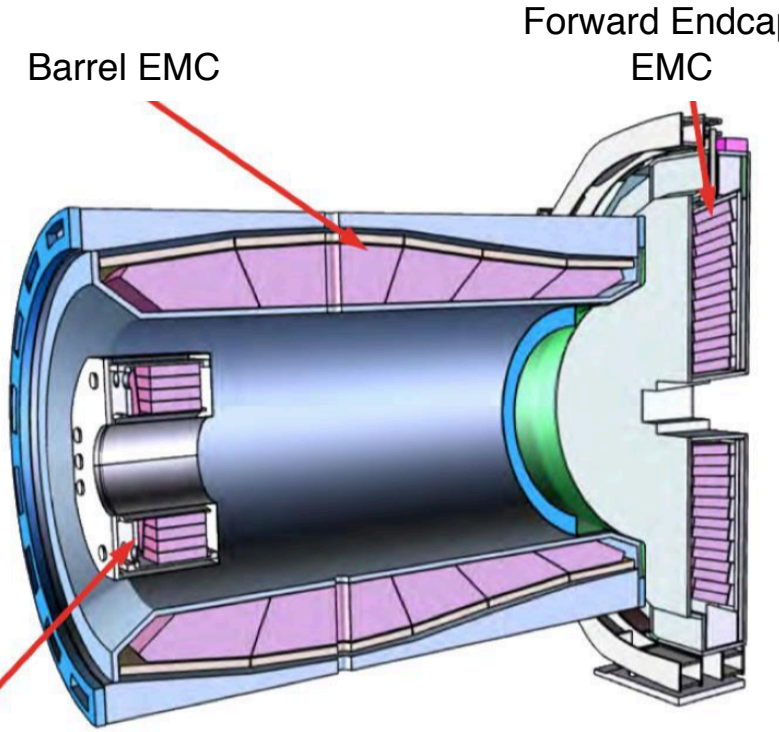
Energy measurement - ECAL

- Photons up to 15 GeV/c, good energy and spatial resolution
- Energy threshold: 10 MeV
- Spatial coverage: 98%
- Single crystal rate: up to 10^6 s^{-1}

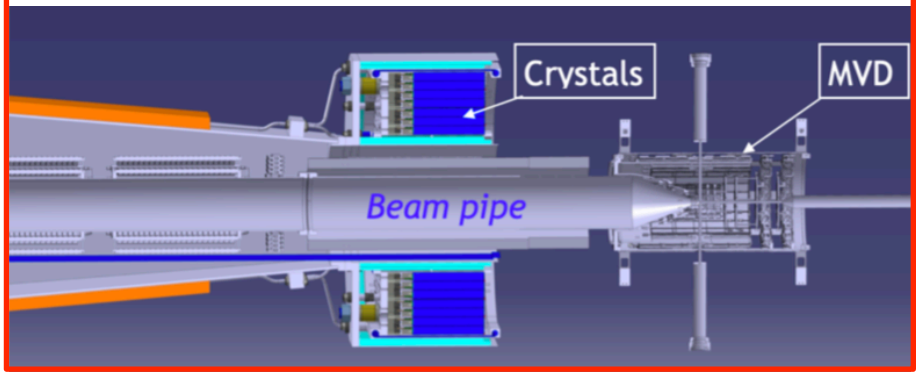


Energy measurement - ECAL

- 2^{nd} generation of $PbWO_4$ crystals (lead tunstate)
  - improved photon yield and radiation hardness
- In total 15744 crystals in target region
- Operation temperature: −25 ± 0.1 °C multiplies photon yield x4
- Radiation length: 0.9 cm
- Moliere radius: 2.1 cm
- Typical crystal dimensions: 20 cm × 2.5 cm × 2.5 cm
- Time resolution:
  ≤ 1 ns (≥ 100 MeV)
- Energy resolution: $1\% \oplus 2\,\% / \sqrt{(E/GeV)}$
- Spatial resolution ≤ 1.5 mm
- 75% of crystals in phase 1
- ASIC based readout system (ASIC for PANDA Frontend Electronics -> APFEL ASIC)
- Project Status
  - TDR approved [arXiv:0810.1216]



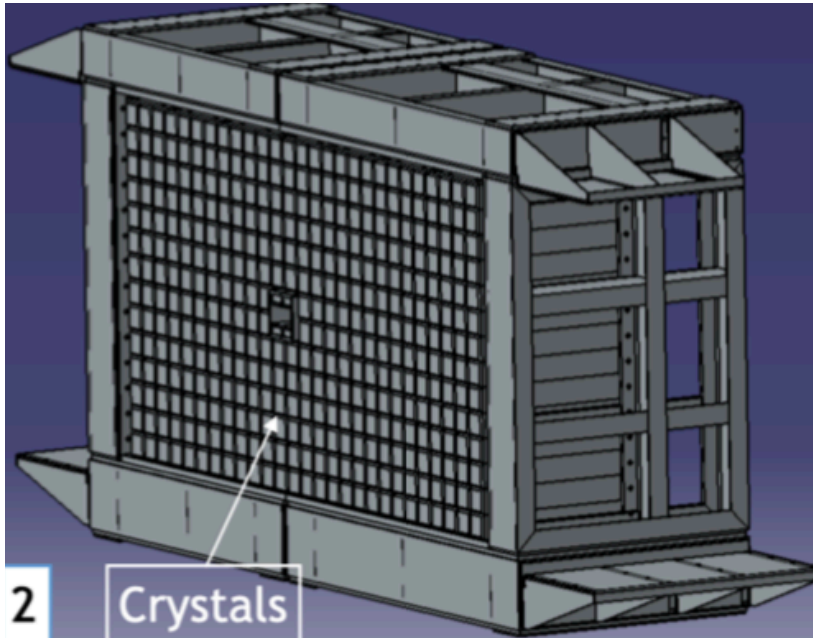
Backward endcap EMC



Energy measurement - Forward ECAL

- Shaslyk type calorimeter
- Interleaved scintillator and lead absorber
  - 380 layers of lead and scintillator
- Active area size 297x154 cm^2
- PMTs for photon readout
- FADCs for digitization
- Time resolution 100 ps
- Energy resolution where b ≈ (2..3)% and c ≈ 1%:

$$\frac{\sigma_E}{E} = \frac{b}{\sqrt{E/GeV}} \oplus c$$

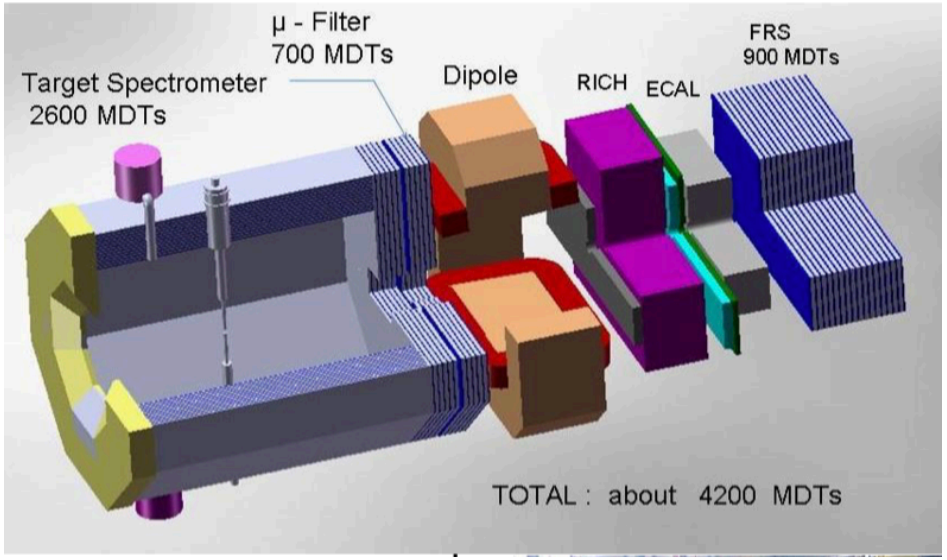


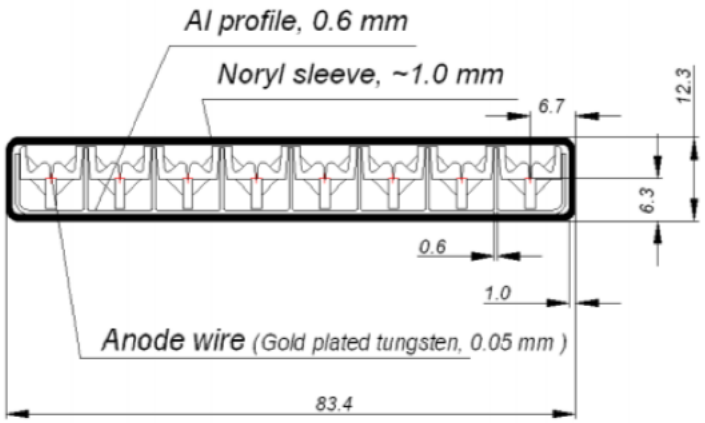
Project Status

- TDR approved [arXiv:1704.02713]
- Module design 2 x 2 cells of 5.5 x 5.5 cm^2 verified
- Tests with electrons and tagged photons

Muon detector system

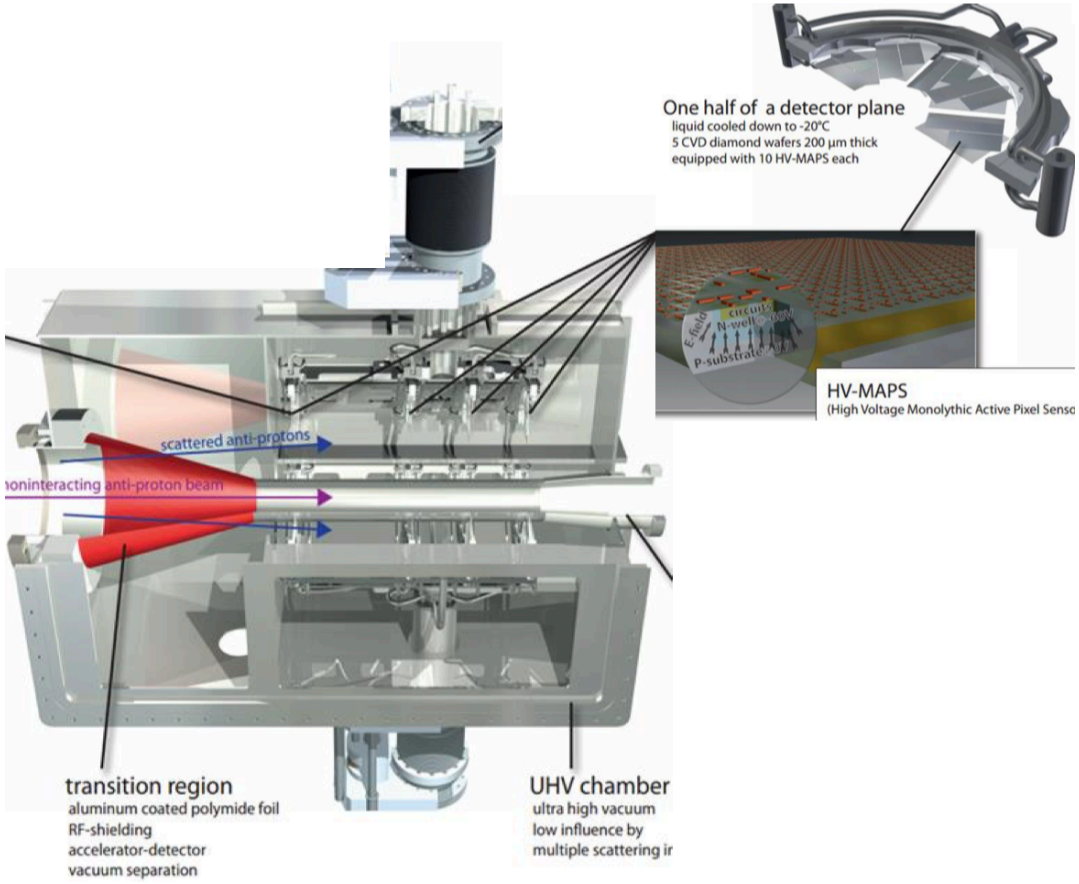
- Muon range system is required
- Barrel : 12+2 layers in yoke
- Endcap : 5+2 layers
- In forward RS: 16+2 layers
- Drift tubes with wire + cathode strip readout
- Project status
  - TDR approved
  - Testbeams at CERN, cosmics
  - Aging tests up to 3C/cm^2
  - Digital FEE (Artix-7) development





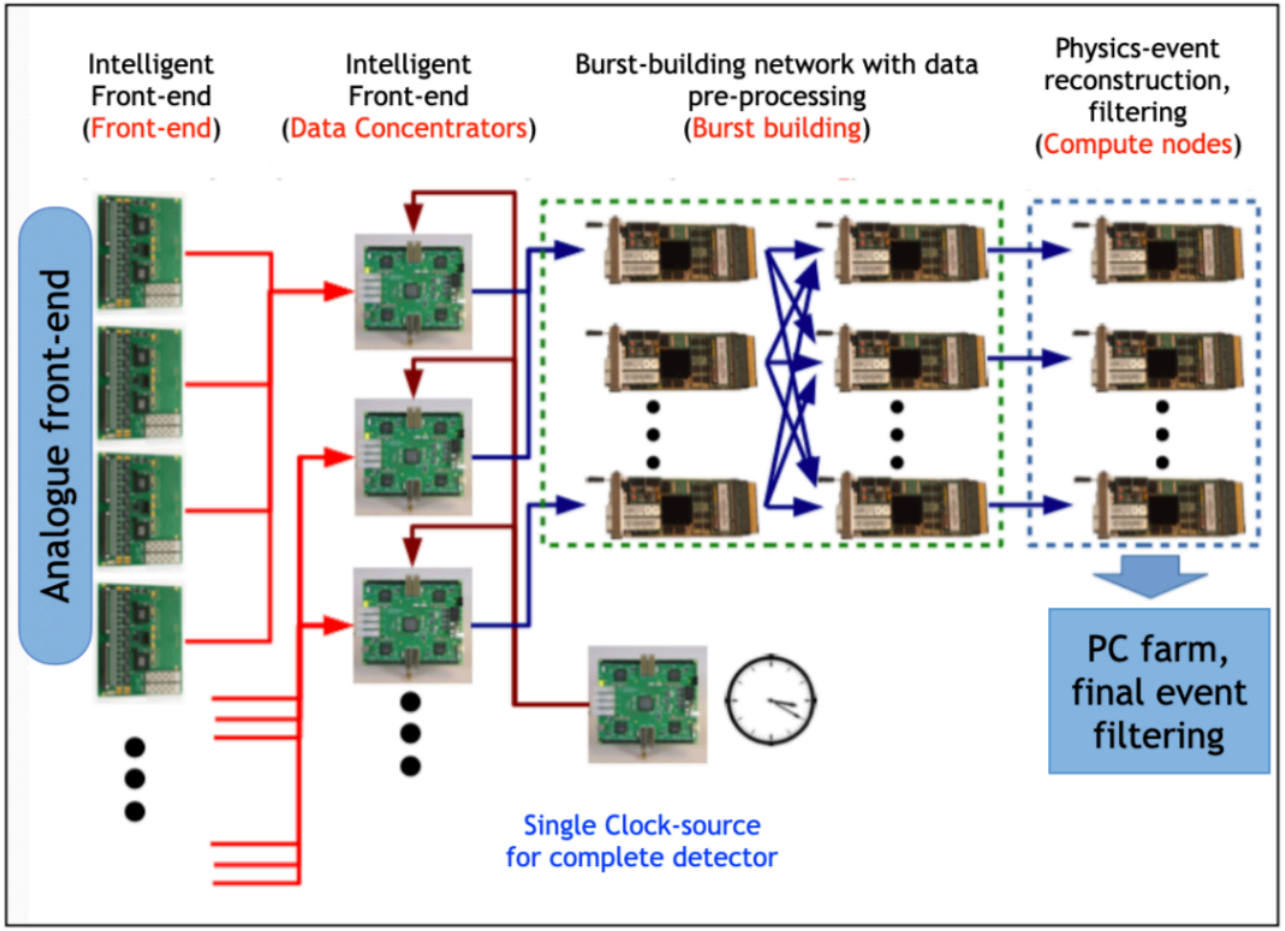
Luminosity detector

- Positioned in 11 m downstream of IP
- Goal: to measure elastically scattered antiprotons in the forward region in the range of 3 mrad to 8 mrad.
- Roman Pot system
- Silicon Pixel detector
  - 4 layers of HV-MAPS 50 μm thickness
    - Radiation hard and provide high spatial res.
  - Pixel size $80\,\mu m \times 80\,\mu m$
- Project Status
  - TDR approved
  - CVD diamond supports available
  - Mechanical vessel, vacuum, cooling ready



Data acquisition

- Self-triggered readout
- Intelligent frontends
- Powerful compute nodes
- Synchronization protocol SODANET
- High Speed network
- Project status
  - DAQ TDR is accepted



Conclusion

- Detector designs for PANDA is planned as 2 phases.
- HESR and PANDA detectors are well in time
- Development and construction ongoing
- Installation at FAIR planning 2024
- Studies of physics experiments for Day-1 and phase 1 & 2 still ongoing
- Addressing large amount of physics questions with full setup after 2026

On behalf of..

Collaboration

UniVPM Ancona
U Basel
IHEP Beijing
U Bochum
U Bonn
U Brescia
IFIN-HH Bucharest
AGH UST Cracow
IFJ PAN Cracow
JU Cracow
U Cracow
FAIR Darmstadt
GSI Darmstadt
JINR Dubna
U Edinburgh
U Erlangen
NWU Evanston
U & INFN Ferrara
FIAS Frankfurt
U Frankfurt
LNF-INFN Frascati
U & INFN Genova
U Gießen
U Glasgow
BITS Pilani KKBGC, Goa
KVI Groningen
Sadar Patel U, Gujart
Gauhati U, Guwahati
USTC Hefei
URZ Heidelberg
FH Iserlohn
FZ Jülich
IMP Lanzhou
INFN Legnaro
U Lund
HI Mainz
U Mainz
INP Minsk
ITEP Moscow
MPEI Moscow
BARC Mumbai
U Münster
Nankai U
BINP Novosibirsk
Novosibirsk State U
IPN Orsay
U Wisconsin, Oshkosh
U & INFN Pavia
Charles U, Prague
Czech TU, Prague
IHEP Protvino
Irfu Saclay
U of Sidney
PNPI St. Petersburg
West Bohemian U, Pilzen
KTH Stockholm
U Stockholm
SUT, Nakhon Ratchasima
SVNIT Surat-Gujarat
S Gujarat U, Surat-Gujarat
FSU Tallahassee
U & INFN Torino
Politecnico di Torino
U & INFN Trieste
U Uppsala
U Valencia
SMI Vienna
U Visva-Bharati
SINS Warsaw

more than 460 physicists from
from 75 institutions in 19 countries

Thank you for your attention