The Detector of the $\overline{\text{P}}$ANDA -Experiment at FAIR

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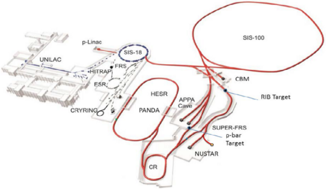
$\overline{\text{P}}$ANDA at FAIR - Facility for Antiproton and Ion Research

- Accelerator facility at Darmstadt (GSI) under construction
- Primary beams: Protons up to 30 GeV/c, heavy ion beams up to 35 GeV/c (U^{92+})
- Secondary beams: Radioactive beams, antiprotons up to 15 GeV/c

$\overline{\text{P}}$ANDA at FAIR:

- Located at slow ramping synchrotron storage ring for internal target (HESR)
- Cooled $\bar{p}$ beam

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



The $\overline{\text{P}}$ANDA -Experiment

$\bar{p}p$ annihilation, fixed hydrogen target

$\bar{p}$ momenta: 1.5 GeV/c - 15 GeV/c

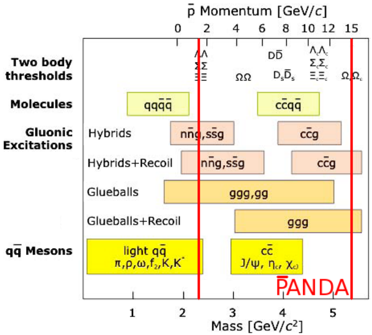
Hadron spectroscopy

- Light mesons
- Charmonium
- Open charm
- Search for exotics
- Baryons (double strange, charmed)

Proton structure

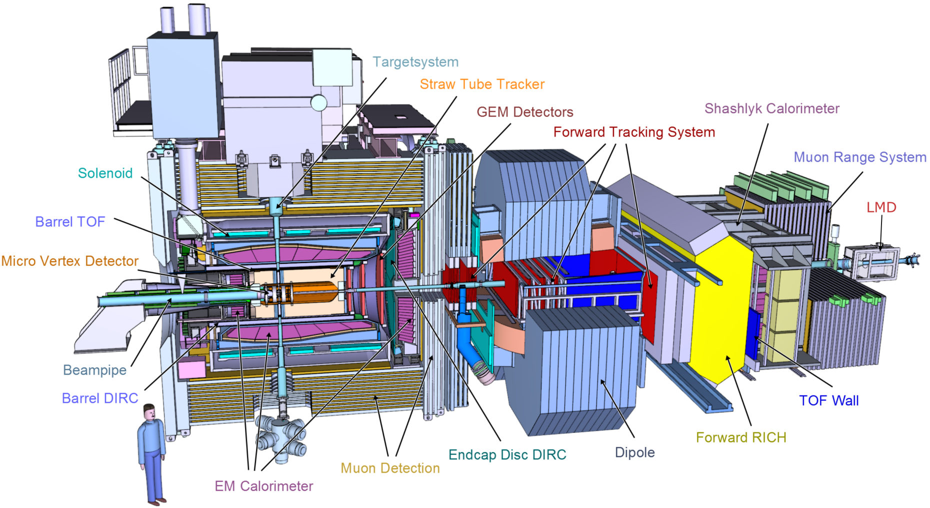
Mesons in nuclei

Hypernuclei



Exclusive studies require full reconstruction of final states

The $\overline{\text{P}}$ANDA -Detector

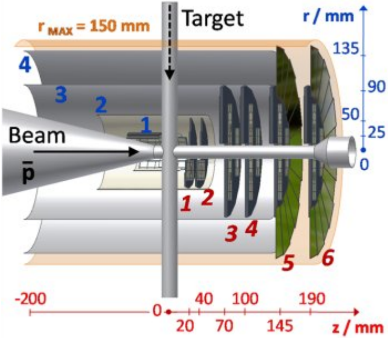


The Tracking Detectors: The Micro Vertex Detector

- Innermost detector, closest to primary interaction vertices
- Essential for precise determination of secondary decay vertices
- Barrel shell structure (4 layers), disk structure (6 pieces) in forward direction

- Double sided silicon strip detectors, pixel detectors

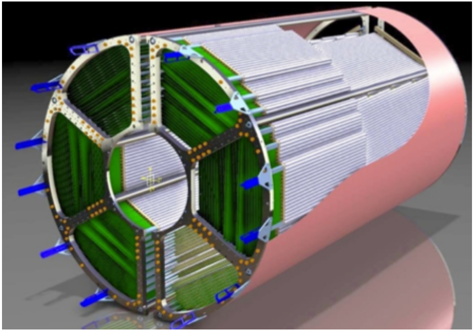
time resolution	6 ns
pixel	28 μm pos. res.
strips	14 μm pos. res.
vertex resolution	50 μm



The Tracking Detectors: The Straw Tube Tracker

- 4200 Ar/CO_2 (90/10) filled Al-mylar drift tubes
- Arranged in cylindrical volume around MVD
- Avalanche multiplication: gain $\approx$ 100

Inner radius	15 cm
Outer radius	42 cm
Tube diameter	10 mm
Tube length	150 cm
ρ/ϕ plane resolution	150 μm
z resolution	1 mm

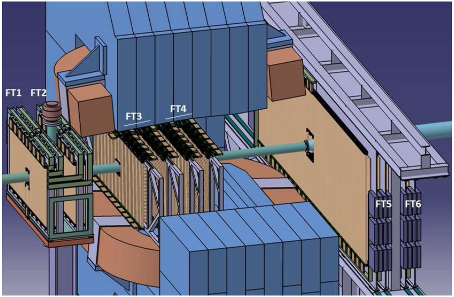


The Forward Spectrometer: Forward Tracker

Based on 10 mm diameter straw tubes as in central tracker

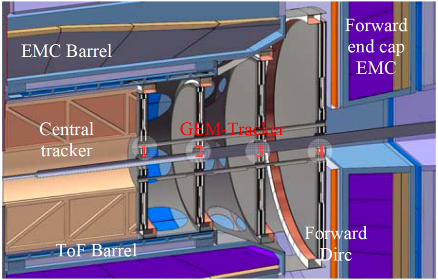
Momentum acceptance better than 0.03 $\times$ $\bar{p}_{beam}$ (B_{dipole} scaled according to $\bar{p}_{beam}$)

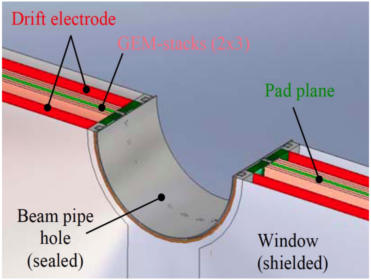
Three pairs of planer tracking stations in front, behind and inside (for low momentum particles) magnet yoke



Coverage	$\pm$ 10° horizontally $\pm$ 5° vertically
Position resolution	0.1 mm / layer
$\Delta p/p$	$<$ 1 %

The Tracking Detectors: The $\overline{\text{P}}$ANDA -GEMs





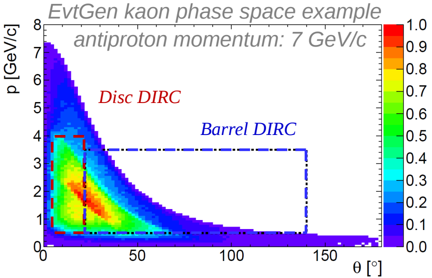
Station No.	1	2	3	4
Weight [kg]	20	20	30	40
Distance to target [cm]	81	117	153	189
Outer diameter [cm]	90	90	112	148
Resolution trajectory position		$< 100\ \mu$m		

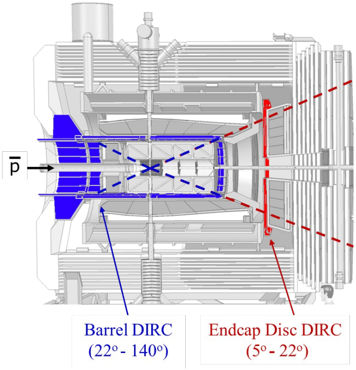
Particle Identification

Accurate PID key requirement to unveal many aspects of $\overline{\text{P}}$ANDA physics program

Various dedicated high developed PID systems able to classify particle species over whole kinematic range:

- Cherenkov detectors: DIRCs, RICH
- Time of flight systems
- Muon detection system



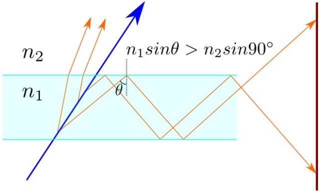


Particle Identification: The $\overline{\text{P}}$ANDA Barrel DIRC

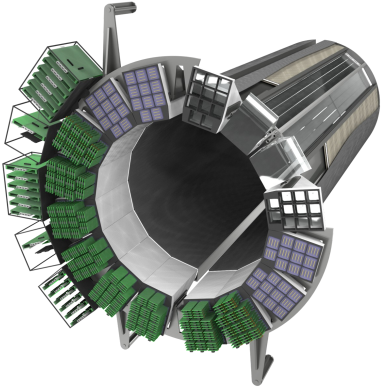
DIRC: Detection of Internally Reflected Cherenkov light

Compact fused silica (quartz) bars, spherical lenses, prisms

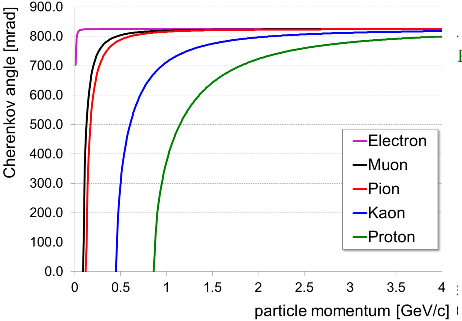
MCP-PMT read out: excellent timing, B-field performance

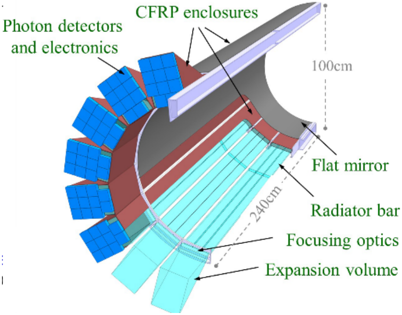


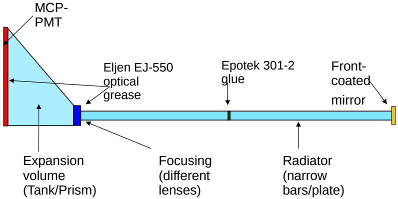
$\beta > 1/n$	$\cos\Theta_C = 1/\beta\ n(\lambda)$
n radiator	1.47
π/K separation	3 σ (up tp 3.5 GeV/c)
γ time res.	100 ps
PMT channels	10000



Particle Identification: The $\overline{\text{P}}$ANDA Barrel DIRC





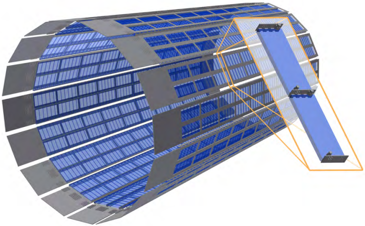


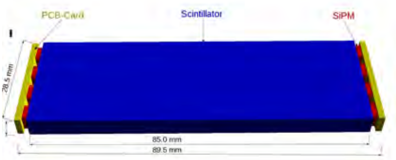
Radiator bar dimensions:
17 mm × 53 mm × 2400 mm

48 radiator bars in 16 sectors

Particle Identification: The $\overline{\text{P}}$ANDA Barrel TOF system

- Low momentum particle PID (< 1 GeV/c)
- Excellent time resolution of ≈ 100 ps
- System of scintillator tiles read out by SiPMs (two sides)
- Light weight construction



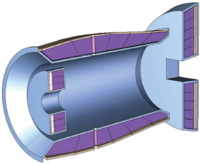


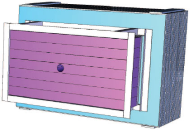
Scintillator	plastic (EJ-228 or EJ-232)
Read out	SiPM (Hamamatsu)
FEE	TOF PET ASIC (PETsys electronics)

Electromagnetic Calorimetry

- $\overline{\text{P}}$ANDA physics: Complete reconstruction of multi-photon and lepton-pair channels of utmost importance
- Good energy and spatial resolution for photons up to 15 GeV
- High yield and background rejection
- Target spectrometer: Homogenius barrel part plus two endcaps
- Forward spectrometer: Sampling calorimeter

Energy threshold	10 MeV
Spacial coverage	99 % of 4π
Single crystal rate	up to 1 MHz





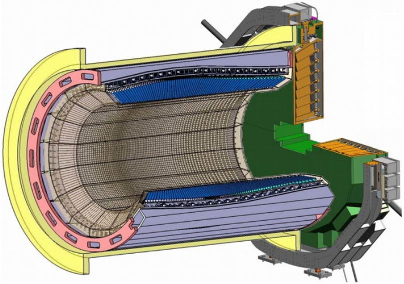
Electromagnetic Calorimetry: The Target Calorimeter

2nd generation $PbWO_4$ (PWO-II), improved light yield, radiation hardness, 15744 crystals

Operating at -25 °C ($\times$ 4 light yield)

Read out: Large area APDs (2 per crystal), vacuum photo tetrodes (inner forward endcap)

Radiation length	0.9 cm
Molière radius	2.1 cm
Crystal dimensions	$20 \times 2.5 \times 2.5$ cm^3
Time resolution	≤ 1 ns (> 100 MeV)
Energy res. $\frac{\sigma_E}{E}$	$1\% \oplus \frac{2\%}{\sqrt{E[GeV]}}$
Spacial resolution	≤ 1.5 mm

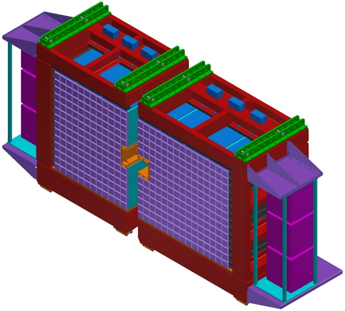


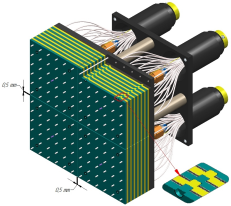
Electromagnetic Calorimetry: The Forward Calorimeter

Shashlik type sampling calorimeter

Lead absorbers, plastic scintillators, PMT readout

$5.5 \times 5.5\ \text{cm}^2$ cells



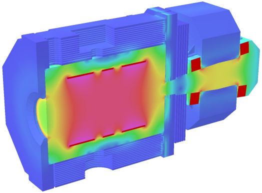


$\frac{\sigma_E}{E}$	$1\% \oplus \frac{2-3\%}{\sqrt{E[GeV]}}$
E_{thresh}	10-20 MeV
Spatial resolution	3.5 mm
Cell rate	1 MHz
Total dose	10 kGy
Number of cells	1512

The Magnets

Ideal combination of superconducting solenoid (target region) and dipole (forward spectrometer, below 5°/10°)

	Solenoid	Dipole
Field	2 T	1 T
Diameter	inner/outer 1.9/2.3 m	1 m × 3 m opening
Length	4.9 m	2.5 m
Weight	300 t	220 t



Solenoid:

- Instrumented flux return
- Field inhomogeneity ≤ 2 %

Dipole ramping operation fully synchronous with storage ring, ramp speed 1.25 %/s

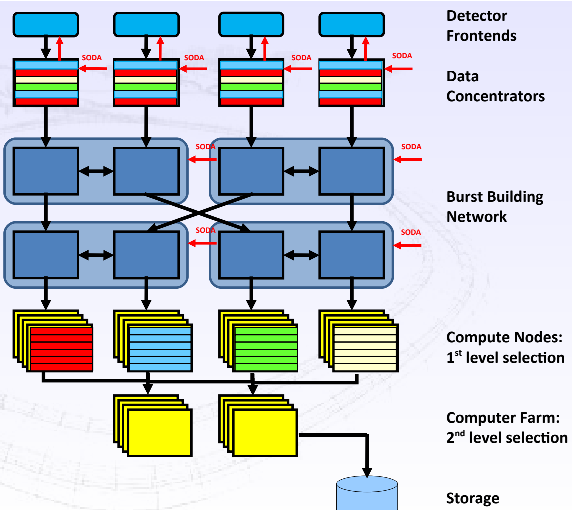
Data Aquisition

High interaction rate, wide physics objectives: triggerless DAQ

Time distribution: SODA

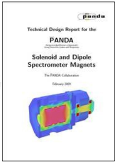
Time tag / hit

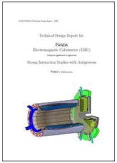
Selection after event building

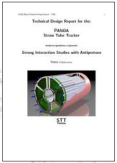


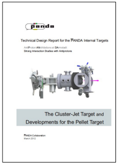
Timeline

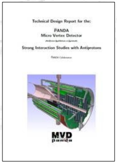
- Detector component construction started in 2014
- Most/all phase 1 TDRs completed in 2017/2018
- Mounting of the detector in $\overline{\text{P}}$ANDA hall starting 2021
- Comissioning 2024
- $\overline{\text{P}}$ANDA -experiment will be operational from 2025 on
  - Doing hadron physics from $\bar{p}p$ collisions
  - Unveil many of today's QCD puzzles

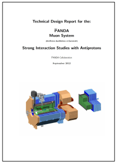

Technical Design Report for the
$\overline{\text{P}}$ANDA
Solenoid and Dipole Spectrometer Magnets
The PANDA Collaboration
February 2009


Technical Design Report for:
PANDA
Electromagnetic Calorimeter (EMC)
Strong Interaction Studies with Antiprotons


Technical Design Report for the:
PANDA
Straw Tube Tracker
Strong Interaction Studies with Antiprotons
STT


Technical Design Report for the $\overline{\text{P}}$ANDA Internal Targets
Strong Interaction Studies with Antiprotons
The Cluster-Jet Target and Developments for the Pellet Target


Technical Design Report for the:
PANDA
Micro Vertex Detector
Strong Interaction Studies with Antiprotons
MVD


Technical Design Report for the:
PANDA
Muon System
Strong Interaction Studies with Antiprotons