The PANDA Experiment

High Precision Hadron Physics at FAIR

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GSI, Darmstadt

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Outline

1. PANDA Overview
   - Introduction
   - Physics Program
2. PANDA Apparatus
   - Overview
   - Highlights
   - PANDA DAQ and Trigger

PANDA

- anti-Proton ANnihilations at DArmstadt
- New experiment at FAIR
- Storage ring HESR for antiprotons at 1.5-15 GeV/c
- **Physics topics:**
  - Charmonium spectroscopy
  - Search for exotic hadrons in the charm sector
  - Charm mesons in nuclear matter
  - Open charm physics
  - Hypernuclei

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Spectroscopy

Spectroscopy with antiprotons

- $p\bar{p}$ machine allows $\Delta E \lesssim 100$ keV vs. $\Delta E \sim 10$ MeV in e^+e^-

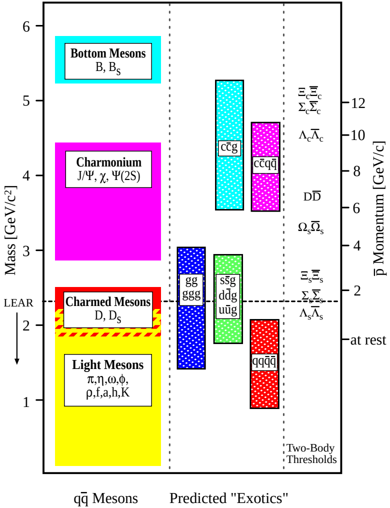
$\rightarrow$ obtain m and Γ with high precision

- e^+e^- produces only $J^{PC} = 1^{--}$ (γ)
- $p\bar{p}$ accesses all states

Charm spectroscopy

- **Charmonium system**
  - The *Positronium* of QCD
- **Charm hybrids**
  - $c\bar{c}$-states narrow, understood
  - Little interference between $c\bar{c}g$ and $c\bar{c}$-states
  - Mass 4–4.5 GeV, $c\bar{c}g$ narrow, $\sim \sigma(\bar{p}p \rightarrow c\bar{c})$
- **Charm meson spectroscopy**

Mesons and Exotics



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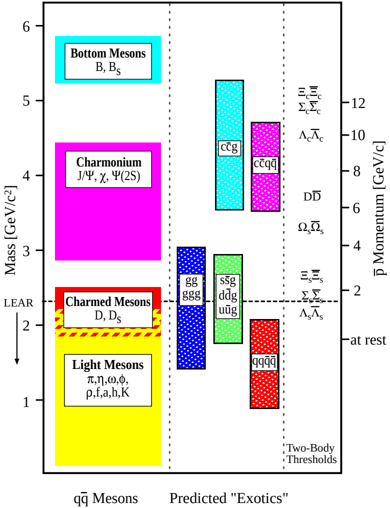


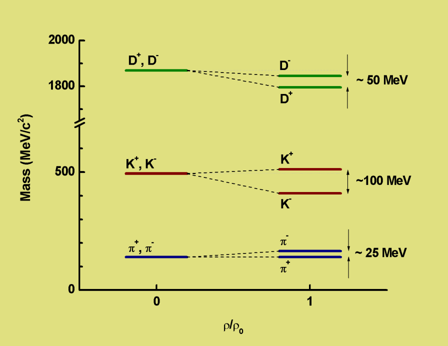
Nuclear Matter

Charm in the Medium

- **Mesons in nuclear matter**
  - Masses change in nuclei
  - D-mass lower
- Enhanced charmonium states due to lower $D\bar{D}$ threshold
- J/Ψ absorption in nuclei

Hypernuclei

- 3rd dimension in nuclear chart
- Study interactions of nucleons in the nuclear potential
- PANDA: Double Hypernuclei
  - $\Lambda\Lambda$ interaction in nucleus



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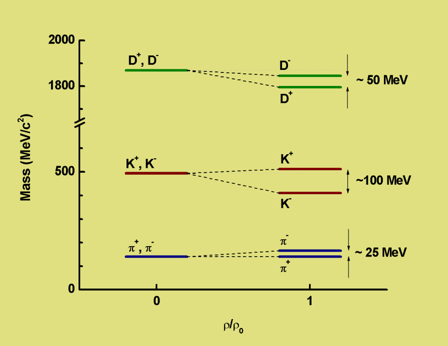
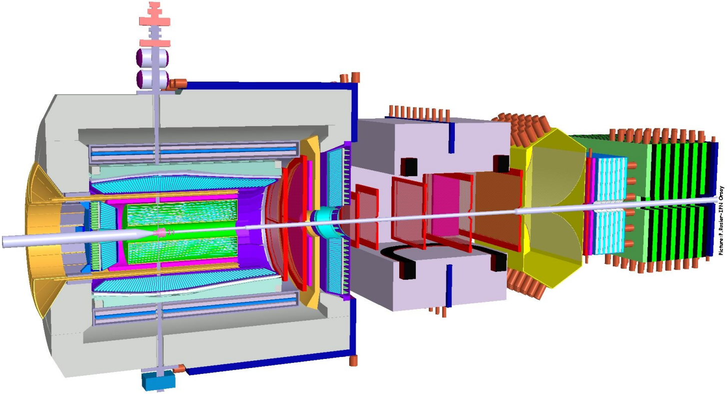


Overview

Antiproton Beam

- Momentum 1.5 – 15 GeV/c
- Cooled $\bar{p}$: $\delta p/p \sim 10^{-4} - 10^{-5}$
- 2×10^7/s production, $\sim 10^{11}$ stored



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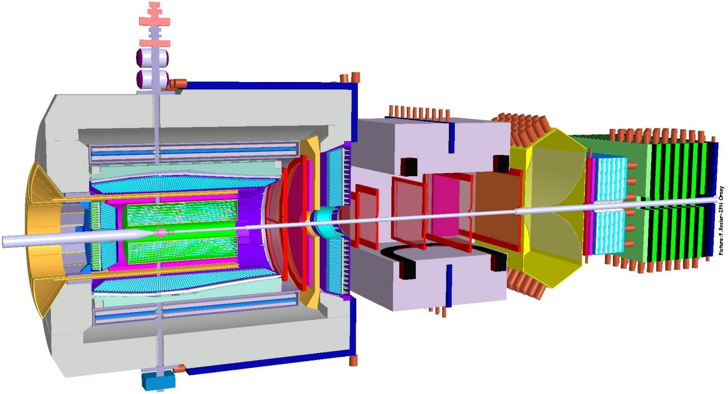
Internal Targets

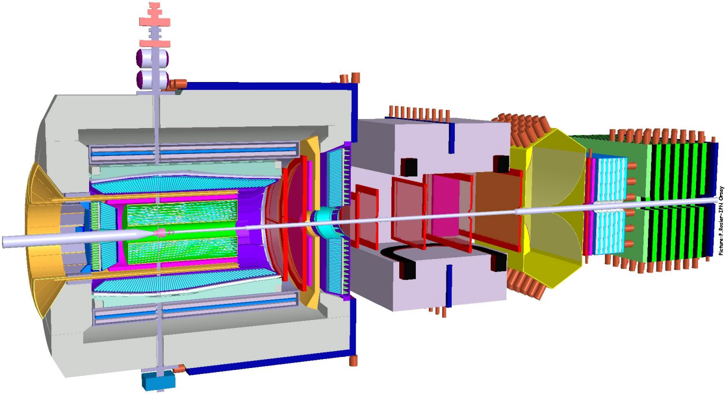
- Luminosity $10^{31} - 2 \times 10^{32}$ cm^{-2}s^{-1}
- Proton targets: pellets, cluster jet
- Nuclear targets: wires, foils



Overview

Target Spectrometer: Solenoid

- Tracking: MVD, STT or TPC
- PID: DIRC, TOF, muon chambers
- EMC: PbWO crystals



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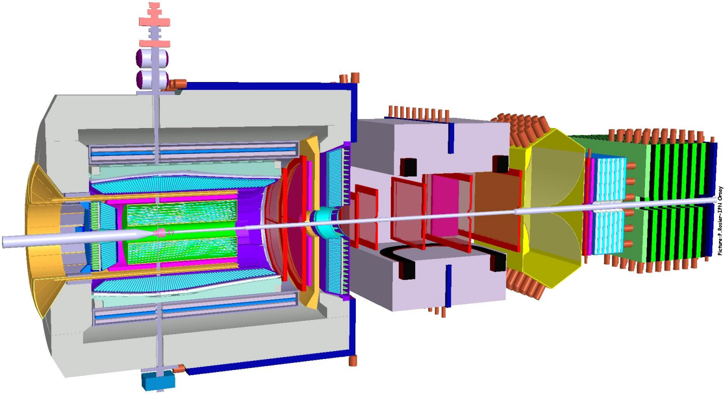
Forward Spectrometer: Dipole

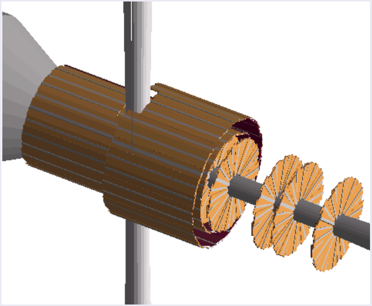
- Tracking: MDC
- Gas RICH, TOF, muon chambers
- Shashlyk calorimeter



Tracking

Micro Vertex Detector

- ATLAS/CMS type hybrid silicon pixels
- Barrel + forward disks
- 5 M pixels + 350 k strips
- 5 layers



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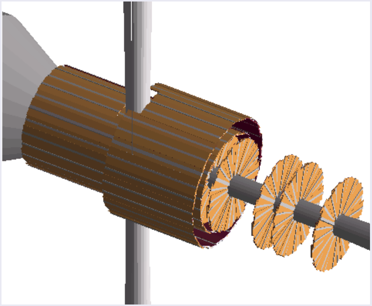
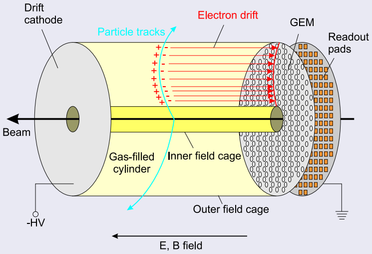


Time Projection Chamber

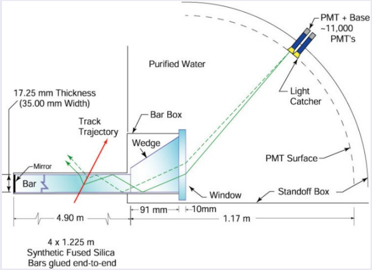
- 1.2 m length, $NeCO_2$ mixture
- Continuous readout via GEM and 100k pads (2×2 mm^2)
- PID via dE/dx



PID and Calorimetry

DIRC Detector

- Quartz radiator rods
- Internal reflection of
- 2D readout: (x, y) or (ϕ, t)



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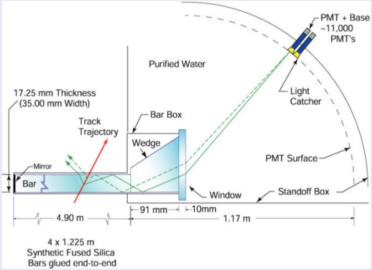
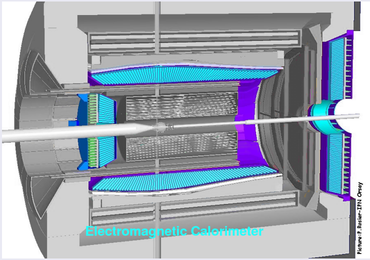


Electromagnetic Calorimeter

- 19000 PbWO crystals
- $\Delta E \sim 1.6\%/\sqrt{E}$
- Temperature $-(25 \pm 0.1)°C$



Requirements

Physics Requirements

- Rare events, tiny cross sections, small deviations
  - High precision
  - High interaction rate
  - Very high data rates

Basic Rate Requirements

- 10 MHz interaction rate
- Raw rates $\lesssim$ 200 GB/s
- Data logging $\lesssim$ 200 MB/s
- Small event size $\lesssim$ 8 kB

Functional Requirements

- Wide physics range $\rightarrow$ high flexibility
- Parallel measurements
- High selectivity

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Sampling Readout

Continuous Sampling

- All channels are digitized continuously, free running, unbiased readout
  - Each detector can contribute to event selection
  - No dedicated trigger detector

Technical Implications

- Massive data reduction as early as possible
- Flexible selection by programmable nodes
- Very high bandwidth

Data Reduction: Convert digital hits to physical coordinates

- Noise reduction, zero suppression
- Signal time determination
- Clusterisation and coordinate evaluation
- Pattern recognition (rings, tracklets, ...)

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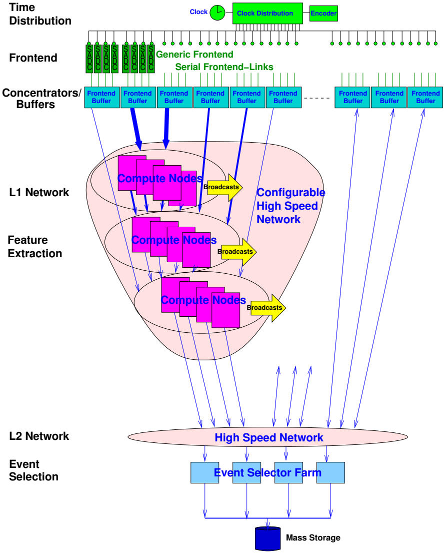
Architecture

Components

- Time distribution
- Intelligent frontends
- Powerful compute nodes
- Configurable high speed network

Data flow

- Data reduction
- First selection at high rate
- Further selections at lower rates, but with more detectors
- Data logging after online reconstruction



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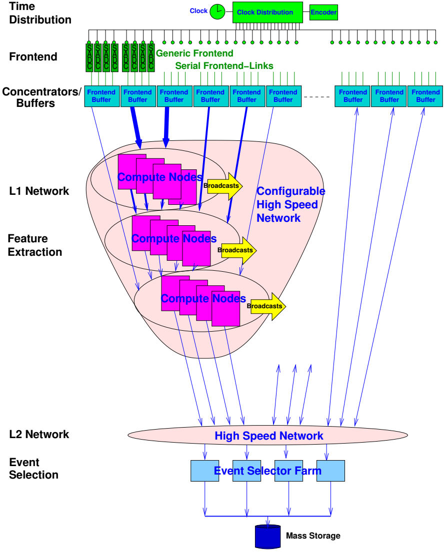
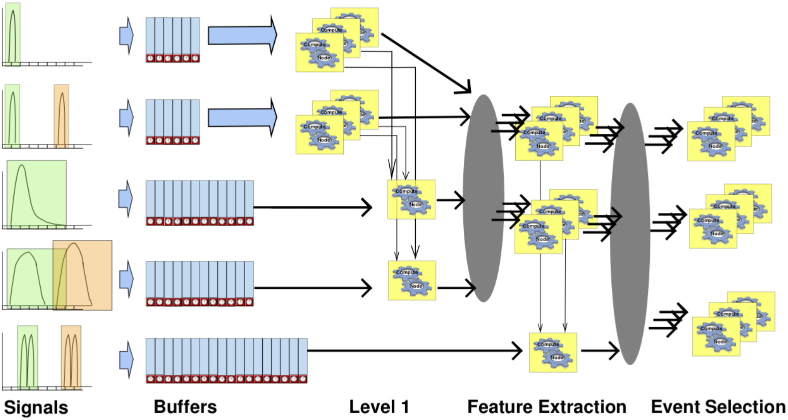


Sampling and Selection



- Reconstruct signal time and form *detector specific* time slices
- Associate time slices according to event selection scheme

Summary and Outlook

Summary

- Hot topics in hadron physics by using an anti-proton beam
- Spectrometer: hermiticity, high precision and rate capability
- DAQ & trigger: highly flexible programmable physics machine

Outlook

- Roadmap: Technical Design Report in 2008
- Data taking from 2013