Challenges in Instrumentation at the PANDA Experiment

Hadron 2013 Conference, Nara, November 8th 2013
Lars Schmitt, FAIR Darmstadt

- Antiprotons at FAIR
- PANDA Overview
- Selected Highlights
- Timeline and Conclusions
Facility for Antiproton and Ion Research

Four pillars of research at FAIR
- Applied, plasma and atomic physics, biophysics (APPA)
- Nuclear structure with RIB from Super-FRS (NUSTAR)
- Heavy ion physics at high baryon density (CBM)
- Hadron and nuclear physics with antiprotons (PANDA)

Antiprotons in FAIR
- Proton Linac 70 MeV
- Accelerate p in SIS100 to 30 GeV/c
- Produce p on Cu target
- Collect in CR, fast cooling
- Accumulate in RESR, slow cooling
- Start version: accumulate in HESR → 10x lower luminosity
- Store in HESR and use in PANDA
**HESR Parameters**

- Storage ring for internal target
- Luminosity up to $L \approx 2 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
- Initially also accumulation ($L$ 10x lower)
- Injection of $\bar{p}$ at 3.7 GeV/c
- Slow synchrotron (1.5-15 GeV/c)

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<thead>
<tr>
<th>Mode</th>
<th>High luminosity (HL)</th>
<th>High resolution (HR)</th>
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<tr>
<td>$\Delta p/p$</td>
<td>$\approx 10^{-4}$</td>
<td>$\approx 4 \times 10^{-5}$</td>
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<tr>
<td>$L \text{ (cm}^{-2}\text{s}^{-1})$</td>
<td>$2 \times 10^{32}$</td>
<td>$2 \times 10^{31}$</td>
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<tr>
<td>Stored $\bar{p}$</td>
<td>$10^{11}$</td>
<td>$10^{10}$</td>
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- Stochastic & electron cooling
- Resolution $\approx 50$ keV
- Tune $E_{\text{CM}}$ to probe resonance
- Get precise $m$ and $\Gamma$
Physics Goals of PANDA

Hadron Spectroscopy

**Experimental Goals:** mass, width & quantum numbers $J^{PC}$ of resonances

**Charm Hadrons:** charmonia, D-mesons, charm baryons
- Understand new XYZ states, $D_s (2317)$ and others

**Exotic QCD States:** glueballs, hybrids, multi-quarks

**Spectroscopy with Antiprotons:**
- Production of states of all quantum numbers
- Resonance scanning with high resolution
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Hadron Structure

Generalized Parton Distributions
- Formfactors and structure functions, $L_q$

Timelike Nucleon Formfactors
Drell-Yan Process
Physics Goals of PANDA

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Hadron Structure

**Generalized Parton Distributions**
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**Timelike Nucleon Formfactors**

**Drell-Yan Process**

Nuclear Physics

**Hypernuclei:** Production of double $\Lambda$-hypernuclei
  ➔ $\gamma$-spectroscopy of hypernuclei, YY interaction

**Hadrons in Nuclear Medium**
PANDA Spectrometer
Detector requirements:
- 4π acceptance
- High rate capability: $2 \times 10^7$ s$^{-1}$ interactions
- Efficient event selection
  - Continuous acquisition
- Momentum resolution $\sim 1\%$
- Vertex info for D, $K^0_S$, Y ($c\tau = 317$ $\mu$m for $D^\pm$)
  - Good tracking
- Good PID ($\gamma$, e, $\mu$, $\pi$, K, p)
  - Cherenkov, ToF, $dE/dx$
- $\gamma$-detection 1 MeV – 10 GeV
  - Crystal Calorimeter
PANDA Spectrometer

TARGET SPECTROMETER

FORWARD SPECTROMETER

Solenoid

Dipole

$p$-Beam
Cluster Jet Target
- H2 jets, other gases possible
- Continuous nozzle improvement
- Better alignment by tilt device
- Record $2 \times 10^{15} \text{ cm}^{-2}$ reached
- Technical design approved
Luminosity Detector
- Elastic $p$ scattering
- 4 layers of HV MAPS, pixels 80x80 $\mu$m$^2$
- sensor thickness 50 $\mu$m
- CVD diamond supports
- Retractable half planes in secondary vacuum
PANDA Spectrometer

**TARGET SPECTROMETER**

- Micro Vertex Detector
  - 4 barrel layers,
  - 6 forward disks
  - Inner layers: pixels,
  - outer layers: strips
  - Pixel ASIC 100x100 µm²
  - Low mass support
  - Thinned sensors

**FORWARD SPECTROMETER**

- Micro Vertex

Challenges at PANDA

Hadron 2013, Nov 8 2013
**PANDA Spectrometer**

**TARGET SPECTROMETER**

- **Micro Vertex**
- **Central Tracker**

**FORWARD SPECTROMETER**

- **Straw Tube Trackers**
  - Cylindrical central tracker, 27 layers
  - Planar forward tracker, 6x4 planes
  - Al mylar tubes, 27 µm walls, 1 cm Ø
  - ArCO₂ at 1 bar overpressure gives stability
  - Low mass: 0.05% $X_0$ per layer
PANDA Spectrometer

TARGET SPECTROMETER

FORWARD SPECTROMETER

GEM Tracker

- High occupancy close to IP forward
- Gas electron multiplier, strip r/o
- Large area GEM foils, r=90cm
PANDA Spectrometer

TARGET SPECTROMETER

Disc DIRC

Muon ID

RICH

FORWARD SPECTROMETER

Shashlyk Calorimeter

Barrel DIRC

PWO Crystal

Calorimeters

Forward ToF

Muon Range System
Modified Hypernuclear Setup
- Primary retractable wire/foil target
- Secondary active target to capture $\Xi$ and track products with Si strips
- HP Ge detector for $\gamma$-spectroscopy
- Mod. central tracker and beam pipe
PANDA DIRC Detectors

Detection of Internally Reflected Cherenkov light

SiO$_2$ Radiator
n=1.47

BaBar type Barrel DIRC

- Pin hole focusing
- Large water tank
- Readout with PMTs
  (BaBar 11000, PANDA 7000)
PANDA DIRC Detectors

Detection of Internally Reflected Cherenkov light

SiO$_2$ Radiator
n=1.47

PANDA Barrel DIRC

- Shorter radiator
- No large tank
- Faster photo sensor

Focusing with lenses

<table>
<thead>
<tr>
<th>SiO$_2$</th>
<th>NLAK33A</th>
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<tr>
<td>n=1.75</td>
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</table>
PANDA DIRC Detectors

Detection of Internally Reflected Cherenkov light

SiO₂ Radiator
n=1.47

Focusing with lenses

Shorter radiator
No large tank
Faster photo sensor

Disc shaped radiator
Readout at rim with light guides

PANDA Barrel DIRC

PANDA Disc DIRC
DIRC Challenges and Progress

Radiator production and QA
- BABAR-DIRC bars polished to 5 Å rms, PANDA needs ~15 Å rms
- Candidates for synthetic fused silica material (Heraeus, Corning)
- Laser test stand to measure transmission and reflectivity

Photosensors for DIRCs
- Single photon sensitivity, low dark count rate, high PDE, fast timing: $\sigma(TTS) \approx 100$ ps, operation in magnetic field, few mm position resolution, high rates up to 2 MHz/cm$^2$
- Long lifetime: 4-10 C/cm$^2$ per year at $10^6$ gain (Barrel: 0.5 C/cm$^2$/yr)
- For long time no sensor matched all criteria, Most promising candidate: MCP PMTs with enhanced lifetime

DIRC Prototyping
- Testbeams at GSI, CERN and DESY
- Radiator characterisation
- Electronics developments
Electromagnetic Calorimeters

PANDA PWO Crystals
- PWO is dense and fast
- Low γ threshold is a challenge
- Increase light yield:
  - improved PWO II (2xCMS)
  - operation at -25°C (4xCMS)
- Challenges:
  - temperature stable to 0.1°C
  - control radiation damage
  - low noise electronics
- Delivery of crystals started
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Large Area APDs
- CMS
- PANDA
  - 5x5 mm²
  - 10x10 mm² and 7x14 mm²

Challenges at PANDA
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Electromagnetic Calorimeters

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**Barrel Calorimeter**
- 11000 PWO Crystals
- LAAPD readout, 2x1cm²
- $\sigma(E)/E \sim 1.5%/\sqrt{E} + \text{const.}$

**Forward Endcap**
- 4000 PWO crystals
- High occupancy in center
- LA APD or VPT

**Backward Endcap** for hermeticity, 560 PWO crystals

**Large Area APDs**
- CMS
- PANDA
- 5x5 mm², 10x10 mm², and 7x14 mm²

**Forward EMC** shashlyk behind dipole
Radiation Damage in PWO

- Radiation induced absorption → reduces light yield
- At RT recovery by annealing
- At -25°C annealing is slower
- PANDA crystals: control radiation induced absorption loss $dk$

Recovery can be stimulated with light
- Fast recovery with blue light
- Slow recovery with IR light (online)

![Image of crystals under blue and red light]

![Graph showing PMT output over time at -25°C and RT]

![Histogram showing acceptance limit: < $dk > 0.82 \text{ m}^{-1}$ for 3967 crystals lot 1-7]

Courtesy R. Novotny
PANDA Data Acquisition

Self triggered readout
- Components:
  - Time distribution system
  - Intelligent frontends
  - Powerful compute nodes
  - High speed network
- Data Flow:
  - Data reduction
  - Local feature extraction
  - Data burst building
  - Event selection
  - Data logging after online reconstruction

Programmable Physics Machine
Summary

Present Status of PANDA
- Several systems head for TDR submission
- Preparation for Construction MoU
- Physics and detector topics

Timeline of PANDA
- Many TDRs to complete by end 2013
- Start of construction in 2014
- Start of preassembly at Jülich in 2016/17
- Mounting at FAIR in 2017/18

PANDA & FAIR start in hadron physics from end 2018
- Versatile physics machine with full detection capabilities
- PANDA will shed light on many of today's QCD puzzles
- Beyond PANDA further plans for spin physics at FAIR exist
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See plenary Fr 8/11, 15:30 by James Ritman
### Challenges at PANDA

**PANDA Collaboration**

More than 520 physicists from 67 institutions in 17 countries

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<th>Country</th>
<th>Institution</th>
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<td>Karnatak U, Dharwad</td>
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