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THE PANDA DETECTOR AT FAIR

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Abstract

The PANDA collaboration plans to study interactions of antiprotons with nucleons and nuclei using a multi-purpose internal target detector system located at the FAIR laboratory in Darmstadt to investigate the physics of strong interactions. With the planned high interaction rates using cooled antiprotons of up to 15 GeV/c the PANDA detector will allow high-precision measurements and the observation of rare reaction channels.

1 Introduction

At the international Facility for Antiproton and Ion Research (FAIR) at Darmstadt, the PANDA (anti-Proton ANnihiliation at DArmstadt) collaboration (see Ref. [1]) prepares to construct a multi-purpose internal target detector system located on the High Energy Storage Ring (HESR) to study interactions of antiprotons with nucleons and nuclei in the mass range of up to $\sqrt{s} = 5.4\mathrm{GeV/c}^2$.

The core programme of PANDA comprises charmonium spectroscopy with precision measurements of mass, width and decay branches; the investigation of more exotic configurations like multiquark states, charmed hybrids and glueballs; the search for medium modifications of charmed hadrons in nuclear matter; and the γ-ray spectroscopy of hypernuclei, in particular double λ states.

For the example of charmonium spectroscopy theoretical calculations differ significantly in particular above the $\mathrm{D\overline{D}}$ threshold and do not properly predict several recently discovered states. On the experimental side, a fair number of states and their properties at higher energy are not well established.

[1] on behalf of the PANDA collaboration

The combination of HESR with cooled antiprotons, and PANDA aims at both high reaction rates and high resolution to be able to study rare production processes and small branching ratios. With up to 10^{11} stored antiprotons for beam momenta 1.5-15 GeV/c and high density targets the experiment anticipates interaction rates of $2{\cdot}10^7\,\mathrm{s}^{-1}$. The stored antiprotons do not have a bunch structure, and with 10% allocated to a barrier bucket, the antiprotons are continuously spread over 90% of the HESR circumference.

Two complementary operating modes are foreseen, high luminosity and high resolution. The high luminosity mode with $\Delta p/p = 10^{-4}$, stochastic cooling and pellet target density of $4 \cdot 10^{15}\,\mathrm{cm}^{-2}$ will have a luminosity of $\mathrm{L}{=}10^{32}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$. For the high resolution mode $\Delta p/p = 3 \cdot 10^{-5}$ will be achieved with electron cooling for momenta up to $p = 8.9\,\mathrm{GeV/c}$ and will operate in conjunction with a cluster jet target to limit the energy broadening caused by the target, the luminosity will be $\mathrm{L}{=}10^{31}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$.

The task of the PANDA detector will be to measure $\mathrm{p\overline{p}}$ reactions comprehensively and exclusively. This requires simultaneous measurements of leptons as well as charged and neutral hadrons, with potentially high multiplicities. Benchmark channels are simulated to determine the required detector performance from physics parameters. In the example of $p\overline{p} \to Y(4260) \to J/\psi\pi^+\pi^-$ with $J/\psi \to e^+e^-$ one sees that a combined lepton plus hadron detection capability is required, and from further benchmark channels a similar case can be made for charged and neutral particles.

2 The PANDA detector setup

The PANDA detector setup (see Fig. 1) is a fixed target experiment scattering a storage ring antiproton beam off a pellet or cluster jet target. It is divided into two parts, the Target Spectrometer around a solenoid magnet, subdivided into backward endcap, barrel and endcap, and the Forward Spectrometer with an angular acceptance of ± 10 degrees horizontally and ± 5 degrees vertically.

2.1 Magnets

In the Target Spectrometer most of the detectors are housed inside the magnet return yoke, the systems of the barrel part are inside the superconducting solenoid magnet. The Forward Spectrometer starts with a dipole magnet to provide bending power with a B-field perpendicular to the forward tracks. The majority of the detector systems are downstream outside the magnet. Additionally parts of the magnet iron are laminated to allow the insertion of muon detectors into the gaps.

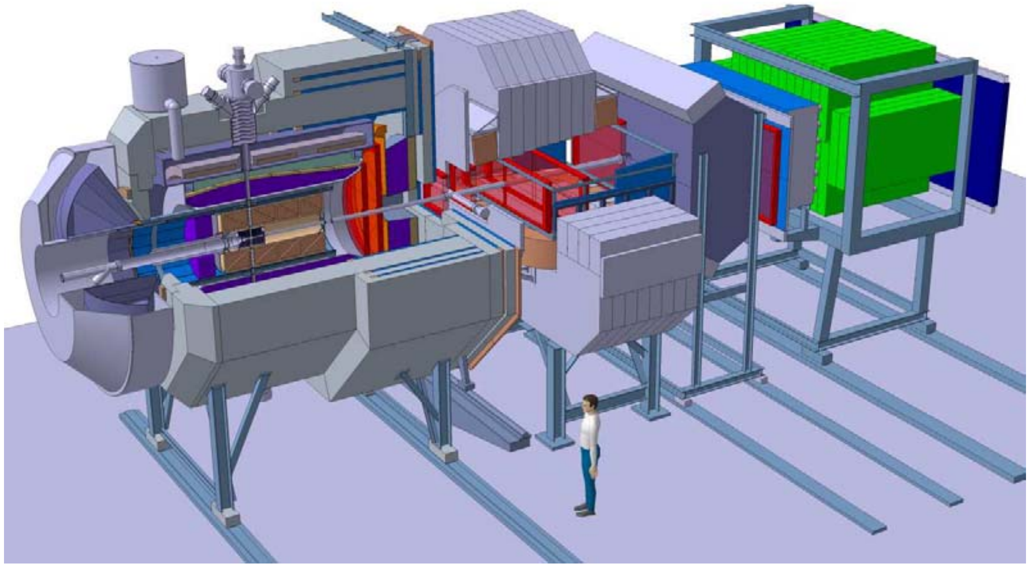

Figure 1: Visualisation of the PANDA detector, the antiproton beam coming from the left. On the left side the Target Spectrometer, on the right side the Forward Spectrometer with individual detectors downstream of the dipole magnet.

2.2 Vertex detectors

Closely surrounding the target area a silicon microvertex detector provides secondary vertex sensitivity for decays of particles with decay lengths in the order of $100\,\mu m$.

For the central tracker two technologies are being considered. The more conservative option is a straw tube tracker, a technology known to work for example in the WASA detector. A time projection chamber is the more ambitious option, it must be self-quenching as the requirement is continuous operation in high particle fluxes. Investigation of several technologies for a detector component may continue for a few more years before the choice of one and the freeze of the detector design.

There are several tracking stations in the endcap and forward detector parts. Here the candidate technologies are multiwire drift chambers and gas detectors with GEM readout.

2.3 Calorimetry

For the electromagnetic calorimeters (EMC) inside the Target Spectrometer one foresees lead tungstate (PWO) crystals read out with Avalanche Photo

Diodes (APD). As the crystal light output and the APD performance both inprove with lower temperature, the plan is to operate these detectors at T=–25°C. In the Forward Spectrometer, a Shashlyk type electromagnetic calorimeter (scintillator fibres in lead matrix) is followed by a scintillator-absorber-sandwich hadron calorimeter.

2.4 Particle identification

Charged particle identification (PID), with a focus on positive kaon identification, is the task of three imaging Cherenkov detectors. Inside the TS a DIRC similar to the BaBar covers the barrel part, in the endcap part a novel design foresees a circular fused silica plate with optical readout elements placed on the rim outside the acceptance. In the FS an aerogel mirror focussing RICH is located after the dipole magnet. Time-of-Flight measurement covers slow particles below the Cherenkov light threshold. Overall PID will also use input from tracking and calorimetry.

2.5 Detector readout

Detector readout has to be self-triggering or continually sampling into a pipeline as there is no beam bunch structure and the triggers software-implemented and configurable using intelligent frontends and powerful compute nodes. The high data rate requires several stages of data selection and reduction with the data logging after an online reconstruction.

3 Conclusions and Outlook

The PANDA detector is designed to be a versatile QCD detector. Novel techniques in detector and readout design are required and are currently being developed. Such Research and Development will continue for a few more years.

4 References

References

[1] Technical Progress Report for $\overline{\text{P}}$ANDA, GSI, January 2005.