The $\overline{\mathrm{P}}$ANDA Experiment

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Abstract. The PANDA (anti-Proton ANnihiliation at DArmstadt) experiment will be a multi-purpose apparatus at the future Facility for Antiproton and Ion Research (FAIR) at Darmstadt. Anti-proton induced reactions with 1.5 to 15 GeV/c beam momentum at high luminosities of up to $2{\cdot}10^{32}/(\mathrm{s}{\cdot}\mathrm{cm}^2)$ will be investigated. Exclusive detection of whole events with almost 4π acceptance and high precision are needed for the broad physics program. The focus lies on studying the strong interaction in the charm region, by charmonium, open-charm and baryon spectroscopy, and includes the search for glueballs, hybrids and other exotics, hypernuclear physics, nucleon structure studies as well as in-medium modifications of hadrons.

1. PANDA Physics

$\overline{\mathrm{P}}$ANDA is an experiment with precise antiproton beams at the Facility for Antiproton and Ion Research, FAIR [1], which is being built at the Helmholtz-Center for Heavy Ion Research [2] in Darmstadt, Germany. It is focussed on hadron physics in the charm region, addressing a broad physics program [4]. Its key aspects are:

- Hadron Spectroscopy
- Nucleon Structure
- Hadrons in Nuclear Medium
- Hypernuclear Physics

Hadron Spectroscopy The main focus of the hadron spectroscopy program lies on the spectra of charmonium ($c\bar{c}$) states, open charm mesons carrying one charm quark as well as heavy baryons containing charm and strange quarks. Furthermore the search for exotic states, such as gluonic excitations, glueballs, hybrids, etc. is of interest because such states are predicted but not identified, yet. Figure 1 illustrates how the beam energies cover the region of interest, up to the creation of Ω_c pairs. Due to the nature of antiproton-proton reactions the initial state is not limited to the photon quantum numbers as in the case of electron-positron collisions. This opens the opportunity to measure states in the whole spectrum directly.

One special feature at $\overline{\mathrm{P}}$ANDA is the beam energy scan technique. The measured reaction rates at several energies around the resonance reveal the line shape with great precision. This technique has proven its value at other experiments, e.g. for the measurement of the χ_1 resonance at E835/Fermilab [3]. Besides resonance masses and widths, also certain threshold behaviours are of particular interest.

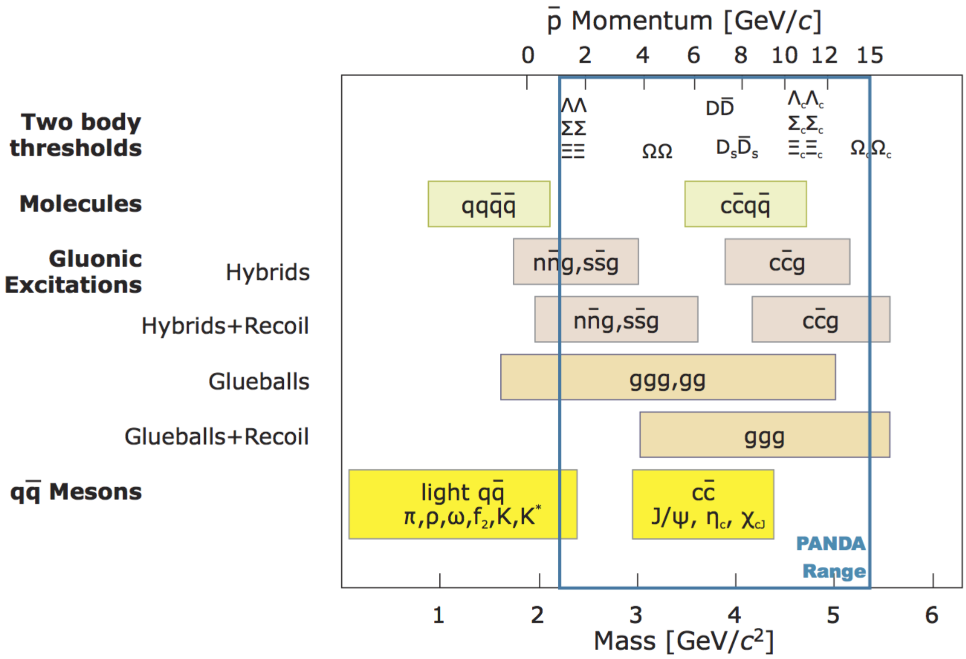

Figure 1: Range of the available energy at the storage ring HESR.

Nucleon Structure Through the electromagnetic annihilation of antiprotons and protons into a lepton pair, $\overline{\text{P}}$ANDA will contribute to the measurement of the time-like electromagnetic form factors with high precision. The nucleon structure can be accessed as well with the means of Transition Distribution Amplitudes, transverse momentum dependent Parton Distribution Functions or Generalised Distribution amplitudes, which can be accessed in electromagnetic channels.

Hadrons in Nuclear Medium By employing a heavy nuclear target, it is possible to study mesons (e.g. charmed mesons) inside the nuclear medium. Mass shifts and width changes are predicted for hadrons in matter. Depending on the applied model not only the mass shift magnitude but sometimes even its direction differs.

Hypernuclear Physics Double strange hyperons, produced by the antiproton beam on a nuclear target are captured in a secondary target, replacing two nucleons with single strange baryons. Gamma spectroscopy will be performed with a dedicated detector upgrade.

2. Experimental Setup

The $\overline{\text{P}}$ANDA apparatus is composed of two parts (see Figure 2), a target spectrometer surrounding the interaction region in a barrel shape and a forward spectrometer up to smaller polar angles. A superconducting solenoid and a dipole magnet provide 2T and 1T, respectively [5] for the momentum measurement of charged particles. Antiprotons of 1.5 to 15 GeV/c interact with a hydrogen or nuclear target in the interaction region. Charged particles are detected in the tracking systems, a Micro Vertex Detector (MVD), a Straw Tube Tracker (STT), Gas Electron Multiplier (GEM) disks as well as Forward Straw Tube Stations (FTS). Electrons and photons are detected by the Electromagnetic Calorimeter (EMC) and particle identification is performed by Detection of Internally Reflected Cherenkov light (DIRC) detectors as well as a time of flight system and muon counters.

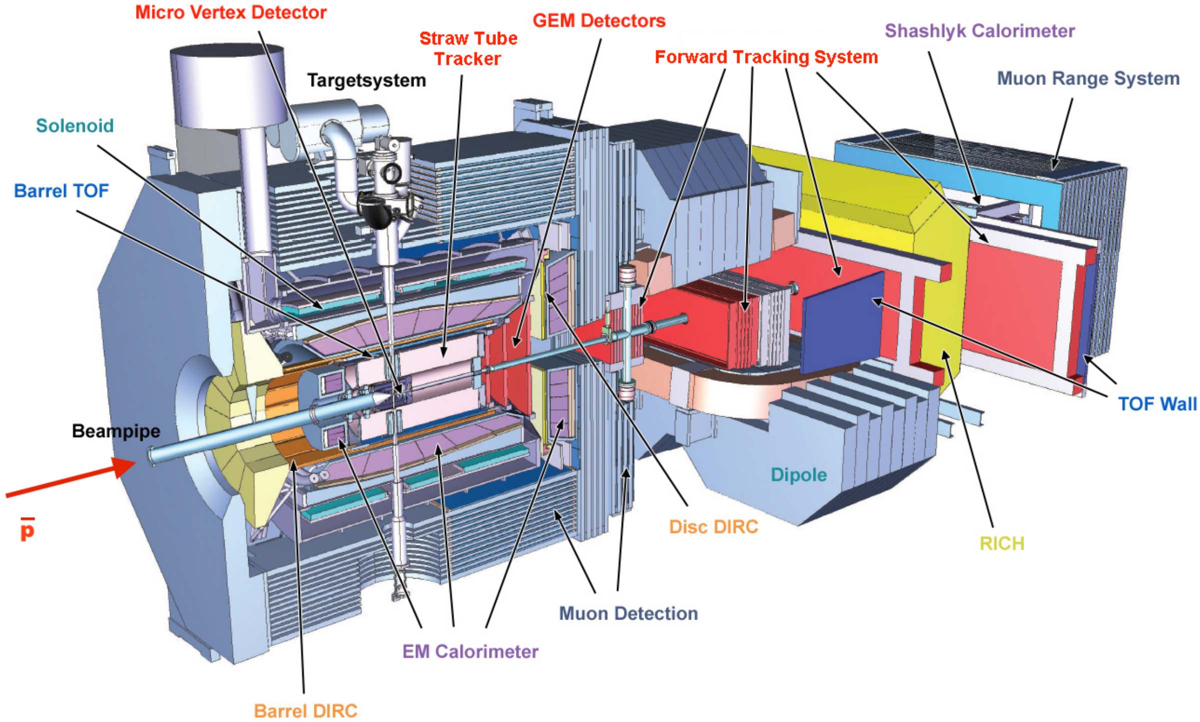

Figure 2: The $\overline{\text{P}}$ANDA detector. The beam enters from the left into the Target Spectrometer, where it reacts with the target and the produced particles with higher transverse momentum are measured.

Target Falling from the top of the detector through a pipe, the target material reacts with the beam of antiprotons. Two options are considered for the hydrogen target, a gaseous cluster jet and a stream of frozen pellets. Both options aim to provide the design luminosity of $10^{32}\text{cm}^{-2}\text{s}^{-1}$. The cluster jet will provide a rather homogeneous density distribution, whereas the advantage of pellets is a strong localisation of the interaction region.

MVD The MVD [6] consists of two barrel and four disk layers with silicon pixel detectors ($100\times100\mu\text{m}^2$ pixel size) as well as two barrel and two disk layers of double sided silicon strip detectors (130µm and 65µm strip pitch). Precise measurements as close as possible to the interaction point provide a high resolution of about 100µm for primary and secondary decay vertices. The front-end electronics will run self-triggered to measure efficiently at the high interaction rates.

STT & FTS There are two straw tube tracking systems, the barrel-shaped STT [7] and the FTS stations in the forward part. The tubes are made from an aluminum-mylar laminate with an argon/carbon dioxide gas mixture inside and a central wire. Glued together, they form self-supporting double layers which are arranged straight along the general magnetic field lines as well as tilted by an stereo angle for polar angle measurements.

EMC Photons and electrons are measured by their electromagnetic showers inside the more than 15000 PWO crystals of the EMC [8], surrounding the interaction region in a barrel shape with end-caps in both, forward and backward directions for a optimal phase space coverage.

Large Area Avalanche Photo Diodes (LAAPD) are foreseen for fast readout inside the strong magnetic field.

PID Charged particles are identified by multiple techniques in the various subsystems. The DIRC detectors, will separate pions, protons and kaons of momenta up to 3.5 GeV/c. Energy loss measurements by the tracking detectors as well as time-of-flight information will be used to improve the PID, especially at the lowest momenta. Resistive plate chambers embedded inside the iron yoke separate muons from pions while the EMC primarily identifies electrons.

DAQ Each subsystem will run in a self-triggered mode, sending data whenever there is a signal. This leads to a large amount of data that will be reconstructed online for filtering. It is expected to deal with a data rate of 200 GB/s. Typical signal signatures contain J/Ψ mesons, $D\overline{D}$ pairs, light hadrons as well as photons which have to be distinguished from the, by a factor of 10^5-10^7 dominant, background channels. Online filtering is pursued by performing a partial physics analysis with the available reconstructed data.

3. Perspectives

Basic Research and development on most components is finished and first component constructions have started. Until the civil construction on site is available, parts of the detector will be assembled at the research center in Jülich. Installation and commissioning at the accelerator is foreseen for 2018 and the start of data taking one year later.

References

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