Verification of a novel calorimeter concept for studies of charmonium states
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3. The PANDA Detector

The physics program of the PANDA experiment demands a detector with challenging requirements, which are described as follows [27]:

The detector must
• cover 4\(\pi\) solid angle;
• be capable of operation with high rates (2\(\cdot\)10\(^7\) annihilations/s);
• have a good particle identification and momentum resolution for \(\gamma\), e, \(\mu\), \(\pi\), K and p;
• have a good vertex reconstruction and excellent calorimetry.

The PANDA detector consists of two parts, namely the target spectrometer and the forward spectrometer. The combination of these two spectrometers provides the full angular coverage. The target spectrometer surrounds the interaction point and will be placed inside a 2 T solenoid magnet. The forward spectrometer will host a 2 T dipole magnet for tracking of charged particles under small angles with respect to the beam direction. A three-dimensional illustration of the PANDA detector including all sub-detectors is shown in Figure 3.1.

The most important sub-detector and infrastructure systems are discussed briefly in the following sections.

3.1 Target Spectrometer

The target spectrometer is designed to detect particles with scattering angles larger than 22\(^\circ\) and is placed inside the 2 T solenoidal field of a superconducting magnet. The most important sub-detector components of the target spectrometer are [28]:

**Target System:** The target will be brought into the beam-line by a vertical pipe structure as shown in Figure 3.1. There are two options for the target system: a cluster-jet target and a pellet target. Both target systems fulfill the requirement of a target thickness of roughly 4\(\cdot\)10\(^{15}\) hydrogen atoms per cm\(^2\) in order to cope with the design luminosity of 2\(\cdot\)10\(^{32}\) \(s^{-1}\) cm\(^{-2}\). The cluster-jet target will be realized by a narrow jet of hydrogen-clusters with 10\(^3\) - 10\(^6\) hydrogen molecules per cluster. The pellet target would feature a stream of frozen hydrogen micro-spheres (“pellets”). Such type of pellet target is presently in use in the WASA experiment at the COoler SYnchrotron (COSY) accelerator at the Forschungszentrum Jülich, Germany [29].

**Solenoid Magnet:** The solenoid coil surrounds the electromagnetic calorimeter and the inner tracking detectors inside the calorimeter barrel. The solenoid produces a 2 T magnetic field in the target spectrometer. To achieve optimum tracking performance the magnetic field homogeneity is required to be better than \(\sim 1\%\) [31].
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Figure 3.1: The PANDA detector including the sub-detector systems. The beam enters from the left. The length of the whole detector system is \( \sim 12 \) m [30].

**Central Tracker and MVD:** The Micro-Vertex Detector (MVD) directly surrounds the interaction region with a radiation-hard silicon pixel and silicon-strip detector system. The current design of the MVD uses a four-layer barrel detector and eight additional layers perpendicular to the beam direction. It has a very good spatial resolution, which can improve the momentum resolution of the whole detector setup. The MVD is able to detect secondary vertices, such as D-meson decays, kaon and hyperon decays. The Central Tracker surrounds the MVD and has a good detection efficiency for secondary vertices which can occur outside the inner vertex detector [28]. The detectors foreseen for the Central Tracker of PANDA are either a Time Projection Chamber (TPC) or a Straw Tube Tracker (STT), depending on the prototype performances. The tracks of particles emitted below 22° in the forward direction will be covered by a Gas Electron Multiplier (GEM) detector layer: The high particle flux and the magnetic field forbid the employment of traditional drift chambers.

**Cherenkov Detector:** Particle identification (PID) is a very important aspect of the event reconstruction in order to obtain reliable physics information. PID requires the determination of velocity or energy loss in addition to the particle momentum. Above momenta of 1 GeV/c the PID will be provided by Cherenkov Detectors. Below the Cherenkov threshold the tracking system will provide information on the energy loss of particles. The Cherenkov detector for the target spectrometer contains a barrel and a forward endcap component.

**ElectroMagnetic Calorimeter:** The crucial part of the PANDA detector is a ElectroMagnetic Calorimeter (EMC) [7], which is placed in the magnetic field and surrounds the interaction point. The PANDA EMC of the target spectrometer consists of three parts: the Barrel, Backward and Forward Endcap EMC. The PANDA EMC employs very dense scintillation crystals with a short radiation length. Lead tungstate (PbWO₄ or PWO) crystals were already chosen for the CMS (Compact Muon Solenoid) [32] and the
ALICE (A Large Ion Collider Experiment) experiments at CERN [33]. In addition, the very fast scintillation decay time and the radiation-hardness, verified also at low temperatures [33], make the PWO crystals an excellent choice for the PANDA EMC. Recent developments of PWO-II crystals [34], as foreseen for the PANDA EMC, provide a two times higher light yield than achieved for CMS crystals [32]. The roughly 20 cm long crystals will be cooled down to a temperature of -25 °C in order to improve the light yield by a factor of four. To achieve the ultimate energy resolution, a temperature stability of 0.1 ° is required [34].

**Time Of Flight**: As already mentioned above, the Cherenkov detector will detect particles with momenta higher than 1 GeV/c. To identify the particles with lower momentum, a Time Of Flight (TOF) detector will be used providing a time resolution of about 100 ps. The TOF detector will be placed in front of the Barrel and the Forward Endcap EMC and consists of ~2×2cm² scintillation tiles coupled to silicon photomultipliers. Such a construction provides fast timing, position sensitivity, and easy handling of multiple-hit events, and allows minimizing the γ conversion in front of the EMC due to the low material budget.

**Muon detector**: Muons in the final state of interesting decay channels (e.g. J/Ψ decays, semi-leptonic decay of D mesons) and muons from background pion decays require proper tracking and separation. Therefore, the PANDA detector incorporates muon detectors, which will be installed in the outer layers of the detector setup and consist of the inner barrel and the outer barrel components.

### 3.2 Forward Spectrometer

The forward spectrometer is also equipped with a charged-particle tracking system, particle identification, calorimetry, and muon detector. Tracking of high-energy particles is done by a set of wire chambers. For the PID and the p/K and K/π separation a Cherenkov detector and a time-of-flight wall detector will be employed.

For the detection of photons and electrons with moderate energy resolution and high efficiency, the forward spectrometer will be equipped with a Shashlyk-type [7] calorimeter. The detection is based on lead-scintillator sandwiches read out with optical fibers which are coupled to photomultipliers. The last detection system of the forward spectrometer in downstream direction is a muon detector built as a multi-layer muon-range detection system.