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Acceptance Studies of an Additional Lambda Disk Detector for the PANDA Experiment *

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Abstract

The PANDA detector, which studies proton antiproton annihilations, will be installed at the future facility for antiproton and ion research in Darmstadt, Germany. PANDA has a wide physics program including the study of excited hyperon states. One very specific feature of most hyperon ground states are long decay lengths of several centimeters. The innermost tracking detector of PANDA, the Micro Vertex Detector, is not optimized for these long decay lengths. Therefore, an upgrade option is proposed adding two additional disks in the forward region called Lambda Disk Detector. For this new detector acceptance studies have been performed using the decay channel $\bar{p}p \to \bar{\Lambda}\Lambda \to \bar{p}p\pi^+\pi^-$. Simulations were carried out using the PandaRoot framework based on FairRoot.

Keywords: FAIR, PANDA, MVD, Lambda Disk Detector, Hyperon

1. Introduction

PANDA (AntiProton ANnihilations at DArmstadt) will be one of the major experiments of FAIR (Facility for Antiproton and Ion Research) in Darmstadt, Germany. PANDA is a fixed target experiment and will be installed at HESR (High Energy Storage Ring) at FAIR [1]. Experiments with PANDA will be performed using an intense, phase space cooled antiproton beam in the momentum range of 1.5 to 15 GeV/c incident on a hydrogen or nuclear target. The physics motivation of PANDA is to explore the transfer region between perturbative and non-perturbative QCD [2]. One part of the physics program is the study of hyperons and their excited states. Hyperons decay weakly and due to this have a long life time and a mean decay length of several centimeters. This leads to a decay of hyperons in the outer part or even outside the Micro Vertex Detector (MVD), which is the innermost tracking detector. In order to increase the acceptance for hyperons, a concept was developed to include additional tracking disk layers called Lambda Disks. Hyperons decay weakly with non-conserved parity. This opens the possibility to determine the spin observables and CP violation in the strangeness sector. Simulations have been performed for the Lambda Disk Detector with $\bar{p}p \to \bar{\Lambda}\Lambda \to \bar{p}p\pi^+\pi^-$ channel in order to perform acceptance studies. This channel has been choosen because Λ is the lightest hyperon, which is easiest to produce and all final state particles are charged.

2. Experimental Setup

The PANDA detector is divided into two parts, the Target Spectrometer (TS) with a superconducting solenoid magnet and the Forward Spectrometer (FS) based on a dipole magnet. The Target Spectrometer will surround the interaction point and consists of several sub-detectors. One of them is the Micro Vertex Detector, the innermost tracking detector [3]. It consists of

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four barrel layers and six forward disks. The barrel and disk layers are made of both silicon hybrid pixel sensors and double sided micro-strip sensors. The next tracking detector in downstream direction is the Gas Electron Multiplier (GEM) at a distance of 110 cm. The distance between MVD and GEM (87 cm) would allow to place two additional Lambda Disks in this region which could enhance the reconstruction capability for hyperons. As a starting geometry, it has been proposed that the Lambda Disks would be made out of an outer and inner ring of double-sided silicon strip sensors with the radius 13.5 cm and 5.5 cm respectively. These additional Lambda Disks cover the polar angle from 3^0 to 18^0. In this conceptual design, the outer ring has been kept similar to the outermost layers of the MVD forward disks and the inner layer has been designed using silicon strip sensors of smaller size to fit with the diameter of the beam pipe. The geometry of used trapezoidal silicon strip sensor for outer ring of Lambda Disks is shown in Figure 1. Both sides of sensor have 768 strips with a pitch of 45 μm from where every second strip is readout. Each sensor has a stereo angle of 15^0 between the two long edges and the sensor thickness is 285 μm [4].

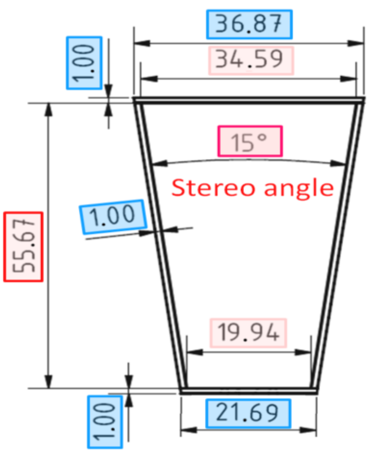

Figure 1: Trapezoidal strip sensor geometry. Dimensions are in mm.

3. Acceptance Studies for the Lambda Disk Detector

Acceptance studies have been performed for the $\bar{p}p \rightarrow \bar{\Lambda}\Lambda \rightarrow \bar{p}p\pi^+\pi^-$ channel using the Lambda Disk Detector at an incident beam momentum of 1.8 GeV/c which is just above the production threshold (1.433 GeV/c). For the simulation of the $\bar{\Lambda}\Lambda$ decay the EvtGenDirect event generator is used [5]. EvtGenDirect used the LambdaLambdaBar model which is based on the angular distribution of Λ measured in the PS185 experiment [6]. The experiment measured the angular distribution for beam momenta of 1.642 GeV/c and 1.918 GeV/c. Due to that, the model LambdaLambdaBar is limited to beam momentum just above the production threshold and less then 2.5 GeV/c. Full PANDA detector setup including the Lambda Disks has been used in the PandaRoot framework [7] which is based on FairRoot [8]. All the final state particles of Λ and $\bar{\Lambda}$ should decay before the Lambda Disk Detector to increase the acceptance of the detector. Therefore, the decay vertex positions of Λ and $\bar{\Lambda}$ hyperons have been studied. Similarly, it is important to understand the angular distributions of all the final state particles for the optimization of the detector position. Minimum of four hits are required for a good track resolution. So, hit count studies also have been performed adding Lambda Disks to the Micro Vertex Detector. Thus, decay vertex position of Λ and $\bar{\Lambda}$, angular distribution and hit count studies of each final state particle (p, $\bar{p}$, π^+, π^-) are discussed in this section.

3.1. Decay Vertex Position

The two layers of the Lambda Disk Detector are placed at 40 cm and 60 cm from the interaction point for this study. The decay vertex position of the hyperons have been reconstructed from their decay particles as it is important to verify that hyperons can be reconstructed over the detector volume. The simulations show that 99.90% of Λ and 98.70% of $\bar{\Lambda}$ decay before the first layer of Lambda Disks. Similarly, 99.99% of Λ and 99.80% of $\bar{\Lambda}$ decay before the second layer of Lambda Disks. Radial (R) versus longitudinal (Z) decay vertex position of Λ and the $\bar{\Lambda}$ are shown in Figure 2. In this study, most of the events decayed before the Lambda Disk Detector as the incoming beam momentum was 1.8 GeV/c which is close to the production threshold. However, there is a scope to optimize the position of Lambda Disk Detector as the decay vertex varies with incoming beam momentum.

3.2. Hit Count Studies

In order to achieve the required tracking performance at least four track points are needed from the combined detector setup of MVD and Lambda Disks. Hit count studies have been performed with and without the Lambda Disk Detector to see the effect of the additional disks in the angular range of 3^0 to 18^0. The acceptance for the final state particles p, $\bar{p}$ are shown in Figure 3 and for π^+, π^- in Figure 4. Protons and antiprotons create more than four hits in the angular coverage of the