Available online at www.sciencedirect.com

ScienceDirect

Nuclear and Particle Physics Proceedings 00 (2015) 1–4

Nuclear and Particle Physics Proceedings

An Additional Lambda Disk Detector for the PANDA Experiment *

Ajay Kumar[1], Ankhi Roy (for the PANDA collaboration)

Indian Institute of Technology Indore, INDORE-452017, INDIA

Abstract

The PANDA detector, which studies proton antiproton annhilations, 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 with a couple of cm. 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 forward region called Lambda Disk Detector. For this new detector acceptance studies have been performed using the decay channel $\bar{p}p \rightarrow \bar{\Lambda}\Lambda \rightarrow \bar{p}p\pi^{+}\pi^{-}$. Simulation 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. 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 and incident on a hydrogen or nuclear target [1]. The physics motivation of PANDA is to explore the transfer region between perturbative and non-perturbative QCD. 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). In order to increase the acceptance of hyperons, a concept was developed to include an additional Lambda Disk Detector. 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 $\bar{p}p \rightarrow \bar{\Lambda}\Lambda \rightarrow \bar{p}p\pi^{+}\pi^{-}$ channel in order to do 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 subdetectors. One of them is the Micro Vertex Detector, the innermost tracking detector. It consists of four barrel layers and six forward disks. The barrel and disk layers are made of both silicon hybrid pixel sensors and double sided microstrip sensors. The next tracking detector

*Talk given at 18th International Conference in Quantum Chromodynamics (QCD 15, 30th anniversary), 29 june - 3 july 2015, Montpellier - FR

Email addresses: ajayk@iiti.ac.in (Ajay Kumar), ankhi@iiti.ac.in (Ankhi Roy (for the PANDA collaboration))

[1]Speaker, author.

in downstream direction is the Gas Electron Multiplier (GEM) at a distance of 1.1 m. The distance between MVD and GEM would allow to place two additional Lambda disks in this region which could enhance the reconstruction probability for hyperons [2]. 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. 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.

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. EvtGen used LambdaLambdaBar model which is based on the angular distribution of Λ measured in the PS185 experiment [3]. The experiment measured the angular distribution for 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 Disk has been implemented in the PandaRoot framework [4] which is based on FairRoot [5]. 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 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. It has been observed that 99.90% of Λ and 98.70% of $\bar{\Lambda}$ decay before first layer of Lambda Disks. Similarly, 99.99% of Λ and 99.80% of $\bar{\Lambda}$ decay before second layer of Lambda Disks. Radial (R) versus longitudinal (Z) decay vertex position of Λ and the $\bar{\Lambda}$ have shown in Figure 1. 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 vary with incoming beam momentum.

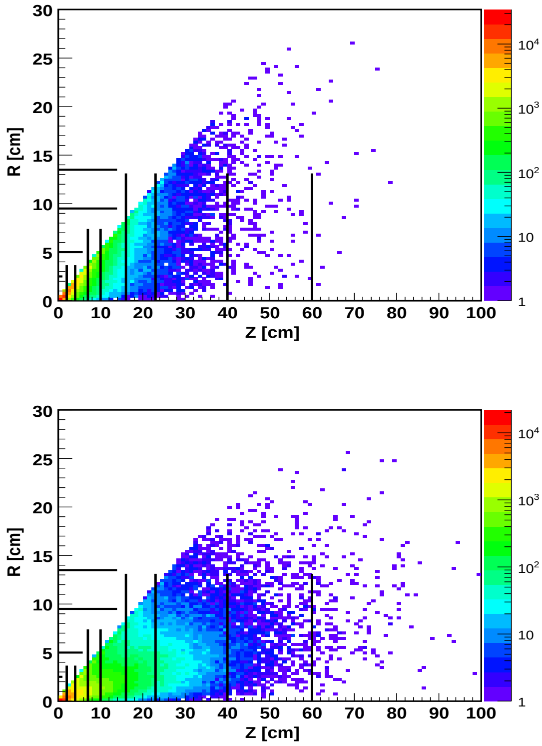

Figure 1: Radial versus longitudinal decay vertex position z of Λ (up) and $\bar{\Lambda}$ (down) at an incoming beam momentum of 1.8 GeV/c.

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 2 and for π^{+}, π^{-} in Figure 3. Protons and antiprotons create more than four hits in the angular coverage of the Lambda Disk Detector. Similarly, π^{+} and π^{-} register more than six hits with the Lambda Disk Detector.

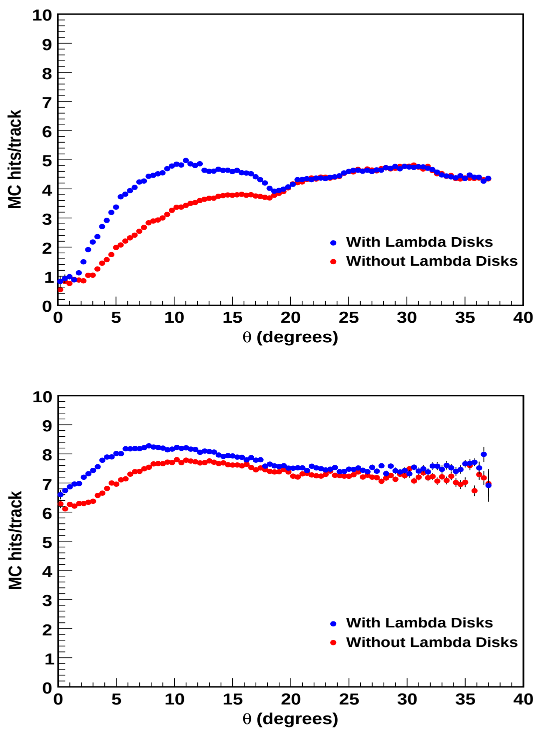

Figure 2: Number of hits per track with and without Lambda Disk Detector, p (up), $\bar{p}$ (down).

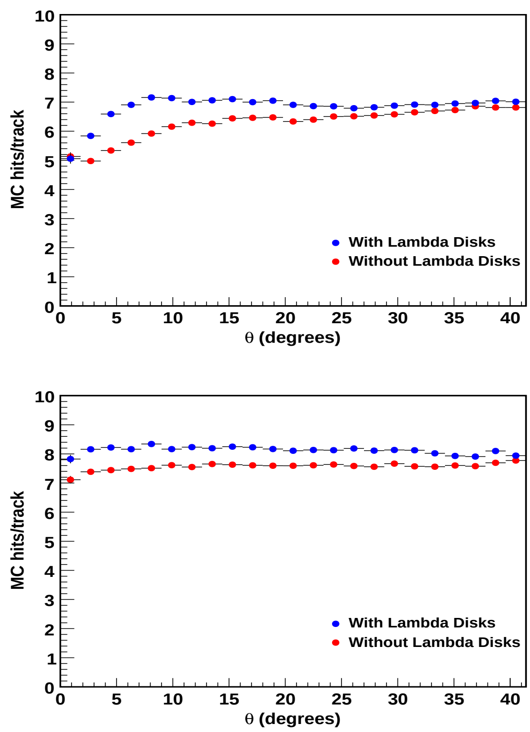

Figure 3: Number of hits per track with and without Lambda Disk Detector, π^- (up) , π^+ (down).

Above a polar angle of 20^0, the effect of the Micro Vertex Detector forward disk can be observed. Acceptance for all particles increases adding the Lambda Disks to the PANDA detector setup. Most important is the effect for protons below 20^0 where, due to the Lambda Disks, the number of hit points per track rises above four which allows individual tracking for these particles.

3.3. Angular Distribution

It is important to study the angular distribution of all final state particles to optimize the detector coverage. It has been observed that p and $\bar{p}$ have a maximum decay angle up to 38^0. However, pions (π^+, π^-) are distributed from 0^0 to 180^0. The angular disributions for all final state particles (p , $\bar{p}$, π^+, π^-) are shown in Figure 4. As we have made hit count studies for all final state particles with and without additional disks and observed that each creates more than four hits except the proton without adding Lambda disks. Protons (p) create less than four hits without these additional disks in the angular coverage from 0^0 to 20^0 (Figure 2) as they travel up to 38^0 (Figure 4).

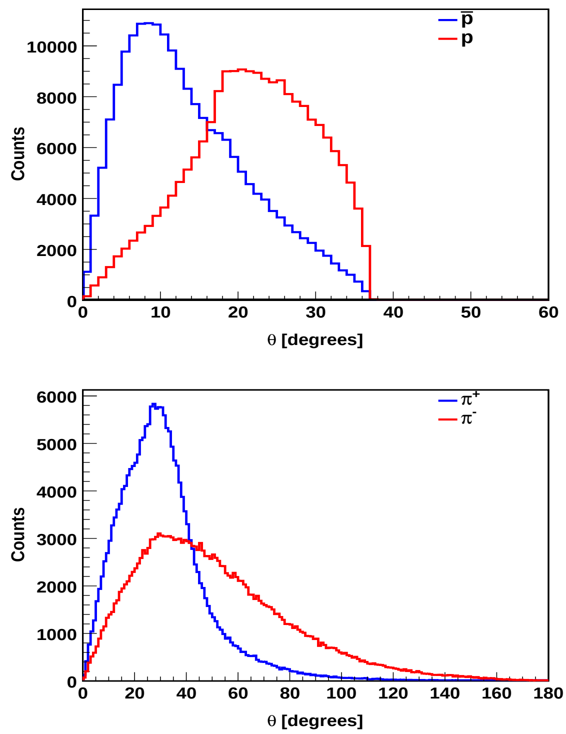

Figure 4: Polar angular distribution of p, $\bar{p}$ (up), π^+, π^- (down) at beam momentum of 1.8 GeV/c.

However, after adding the Lambda Disks number of hits of proton increased in the angular coverage of 5^0 to 20^0. Therefore, one can conclude that the present layout of Lambda Disks is helpful in the reconstruction of protons.

4. Summary

The simulation of the $\bar{p}p \to \bar{\Lambda}\Lambda \to \bar{p}p\pi^+\pi^-$ channel at an antiproton momentum of 1.8 GeV/c has been used to test the acceptance of the Lambda Disk Detector. The decay vertex position of Λ and $\bar{\Lambda}$ have been simulated and concluded that $\bar{\Lambda}$ is strongly forward boosted in comparison to Λ. Most of the $\Lambda\bar{\Lambda}$ events are decaying before the Lambda Disk Detector. The angular distribution of final state particles has been simulated. The number of hit points per track increase with the Lambda Disk Detector which is most important for the proton below 20^0.

5. Acknowledgement

We would like to thank PANDA MVD group at IKP, Juelich. This work is performed with the help and kind support of them.

References

[1] PANDA Collaboration, Physics Performance Report for: PANDA-Strong Interaction Studies with Antiprotons, [http://arxiv.org/abs/arxiv:0903.3905].
[2] PANDA Collaboration, Technical Design Report for the PANDA Micro Vertex Detector, [http://arxiv.org/abs/1207.6581v2].
[3] P. D. Barnes et al., Phys. Rev. C 54, 1877 , Oct 1996.
[4] S Spataro 2008 J. Phys.: Conf. Ser. 119 032035 .
[5] [https://fairroot.gsi.de].