Simulation Studies of the Lambda Disks Detector for the $\overline{\text{P}}$ANDA Experiment

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Abstract. The $\overline{\text{P}}$ANDA experiment is one of the major experiments at the future accelerator facility FAIR which is currently under construction in Darmstadt, Germany. The $\overline{\text{P}}$ANDA is mainly to explore the non-perturbative regime of QCD and to study hadronic states. $\overline{\text{P}}$ANDA has various physics program including the study of hyperon states. Most of hyperon ground state are having long decay lengths of several centimeters and the central tracking system of $\overline{\text{P}}$ANDA is not optimized for these long decay lengths. Therefore, an upgarde option is proposed adding two additional disks forward to innermost tracking detector of $\overline{\text{P}}$ANDA, the MVD and these additional disk are called "Lambda Disks Detector". For this new detector, simulation studies are performed using decay channel $\bar{p}p \to \bar{\Lambda}\Lambda \to \bar{p}p\pi^+\pi^-$. In this paper, the reconstruction efficiency and resolution of this channel are estimated adding Lambda Disks Detector to the $\overline{\text{P}}$ANDA setup. In addition, we have also studied with $\bar{p}p \to D^{*+}D^{*-} \to D^0\pi^+\bar{D}^0\pi^-$ and $\bar{p}p \to J/\psi\pi^+\pi^-$ channels to see that how the reconstruction performance of these channels affect with and without the Lambda Disks Detector.

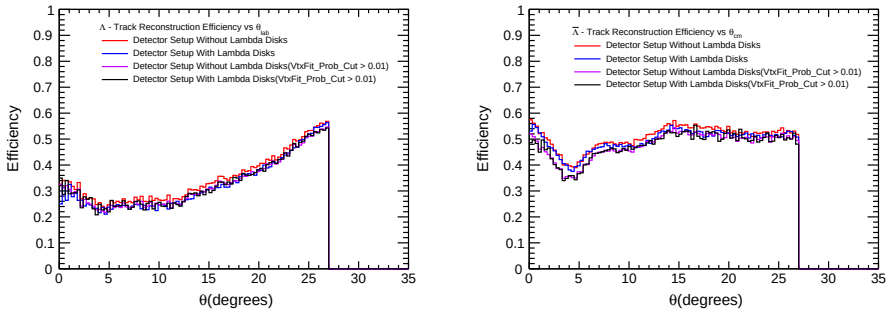
Keywords: FAIR, $\overline{\text{P}}$ANDA, MVD, LDD, Hyperon, QCD, Efficiency, Resolution

1 Introduction

$\overline{\text{P}}$ANDA (anti**P**roton **AN**nihilations at **DA**rmstadt) studies proton antiproton annihilatons at FAIR (**F**acility for **A**ntiproton and **I**on **R**esearch) facility [1]. Main physics motivation of $\overline{\text{P}}$ANDA is to shed light on the low energy regime of Quantum Chromodynamics (QCD) and to explore transfer region between perturbative and non-perturbative QCD. From this point of view, here is a possibility to include hyperon studies in the $\overline{\text{P}}$ANDA physics program. Hyperons decay weakly and hence a long decay length of several centimeters. This leads to a decay of hyperons in an inner part or even outside the Micro Vertex Detector (MVD). In order to improve the reconstruction probability of hyperons, there is a concept to include an additional Lambda Disks Detector (LDD) forward to MVD. We have introduced two layers of double sided silicon strip sensors as Lambda Disks Detector in a large detector free volume between MVD and Gas Electron Multipliers (GEM) to increase reconstruction efficiency of hyperons.

2 Simulation Studies of Lambda Disks Detector

The reaction $\bar{p}p \to \bar{\Lambda}\Lambda \to p\bar{p}\pi^+\pi^-$ is simulated and reconstructed at an incoming beam momentum of 1.8 GeV/c and 4.0 GeV/c to do the feasibility study of the Lambda Disks Detector using the software FairRoot and PandaRoot. We have selected 1.8 GeV/c beam momentum which is near the threshold and another one at 4 GeV/c to compare the performance of the detector with increasing beam momentum. The EvtGenDirect [2] event generator is used for the generation of $\Lambda\bar{\Lambda}$ events. EvtGenDirect provides two different decay models for this decay i.e. LambdaLambdaBar and LambdaLambdaBarHE. The LambdaLambdaBar model is used for event simulation based on experimental angular distribution which is described by 8^{th} order Legendre polynomials as suggested in Ref. [3] for the beam momentum at 1.8 GeV/c. The LambdaLambdaBarHE decay model is used which is also based on an angular distribution parametrization using a momentum dependent exponential function [4] and simulated at beam momentum of 4.0 GeV/c.



(a) Reconstruction efficiency of Λ **(b)** Reconstruction efficiency of $\bar{\Lambda}$

Fig. 1: Reconstruction efficiency of Λ and $\bar{\Lambda}$ at an incoming beam momentum of 1.8 GeV/c with and without the Lambda Disks Detector.

We have estimated reconstruction efficiency and mass resolution of Λ and $\bar{\Lambda}$ hyperons with and without Lambda Disks Detector, which are most important parameters for the feasibility study of any detector. The invariant mass of Λ hyperons is 1.115 GeV/c^2. A double Gaussian function is fitted to the mass distributions because the combinatorial background has approximately a Gaussian shape. The peak values and the σ values of the fitted distributions are tabulated in Table 1 without and with the Lambda Disks Detector at both beam momenta. The track reconstruction efficiency of Λ hyperon are shown in Figure 1 and estimated values tabulated in Table 1. Overall $\Lambda\bar{\Lambda}$ reconstruction efficiency is estimated and found to be 28.5% and 20% at beam momentum of 1.8 GeV/c and 4.0 GeV/c, respectively. Also simulations for $\bar{p}p \to D^{*+}D^{*-} \to D^0\pi^+\bar{D}^0\pi^-$ and $\bar{p}p \to J/\psi\pi^+\pi^-$ have been performed. These channels are selected to study the effect of the Lambda Disks Detector on the reconstruction of these channels. Reconstruction performance of these two channels should not be effected after

Detector Status	**P_{beam} [GeV/c]**	**Particle**	**Mean [GeV/c^2]**	**σ [GeV/c^2]**	**Avg. Reco. Effi.[%]**
w/o LDD	1.8	Λ	1.114	0.004	42
		$\bar{\Lambda}$	1.115	0.003	48
	4.0	Λ	1.116	0.003	25
		$\bar{\Lambda}$	1.116	0.002	52
w/ LDD	1.8	Λ	1.115	0.004	42
		$\bar{\Lambda}$	1.115	0.003	48
	4.0	Λ	1.116	0.003	25
		$\bar{\Lambda}$	1.116	0.002	52

Table 1: Reconstructed invariant mass and efficiency without and with the Lambda Disks Detector of Λ and $\bar{\Lambda}$ at two different beam momenta. Errors in mean and σ values are less than 1 MeV/c^2.

Detector Status	**P_{beam} [GeV/c]**	**Particle**	**Mean [GeV/c^2]**	**σ [GeV/c^2]**	**Avg. Reco. Effi.[%]**
w/o LDD	8	D^0	1.86	0.019	75
		$\bar{D^0}$	1.86	0.019	75
	8	D^{*+}	2.01	0.017	40
		D^{*-}	2.01	0.017	40
w/ LDD	8	D^0	1.86	0.019	75
		$\bar{D^0}$	1.86	0.019	75
	8	D^{*+}	2.01	0.017	40
		D^{*-}	2.01	0.017	40
w/o LDD	6	J/ψ	3.086	0.052	84
w/ LDD	6	J/ψ	3.085	0.053	84

Table 2: Reconstructed invariant mass and avg. reco. effi. without and with Lambda Disks Detector for produced mesons from both channels.

the addition of Lambda Disks to the $\overline{\text{P}}$ANDA detector setup.The peak and σ values of the fitted mass distributions from both the meson channels with average reconstruction efficiency of each particle are tabulated in Table 2.

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