Chapter 146
Simulation Studies of the Lambda Disks Detector for the $\overline{\text{P}}$ANDA Experiment

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146.1 Introduction

$\overline{\text{P}}$ANDA (anti**P**roton **AN**nihilations at **DA**rmstadt) was conceived to study proton antiproton annihilations at the FAIR (**F**acility for **A**ntiproton and **I**on **R**esearch) [1]. The main physics motivation of $\overline{\text{P}}$ANDA is to shed light on the low energy regime of Quantum Chromodynamics (QCD) and to explore the energy region between perturbative and non-perturbative QCD. This presents the possibility to include hyperon studies in the $\overline{\text{P}}$ANDA physics program. Hyperons decay weakly and hence have a long decay length of several centimeters. This leads to a decay of hyperons in an outer part or even outside the Micro Vertex Detector (MVD). In order to improve the reconstruction of hyperons, it was proposed to include an additional Lambda Disks Detector (LDD) in forward direction in front of the MVD. It consists two layer of double sided silicon strip sensors located in a large free volume between the MVD and the Gas Electron Multipliers (GEM) detector.

146.2 Simulation Studies of Lambda Disks Detector

The reaction $\bar{p}p \rightarrow \bar{\Lambda}\Lambda \rightarrow p\bar{p}\pi^{+}\pi^{-}$ was simulated and reconstructed at incident beam momenta of 1.8 and 4.0 GeV/c to perform feasibility studies of the Lambda Disks Detector, using FairRoot and PandaRoot. The selected 1.8 GeV/c

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beam momentum was 4.0 GeV/c chosen near to production threshold (1.436 GeV/c) of the above reaction, while 4 GeV/c was selected to assess the performance of the detector at higher energies. The EvtGenDirect [2] event generator is used for the generation of $\Lambda\bar{\Lambda}$ events. EvtGenDirect provides two different decay models for this decay, LambdaLambdaBar and LambdaLambdaBarHE. The LambdaLambdaBar model is based on an experimental angular distribution described by 8th order Legendre polynomials, for 1.8 GeV/c beam momentum. The LambdaLambdaBarHE decay model is used for the simulation at 4 GeV/c and also based on an angular distribution parametrization with a momentum dependent exponential function.

We have estimated the reconstruction efficiency and mass resolution of Λ and $\bar{\Lambda}$ hyperons with and without the Lambda Disks Detector. A double Gaussian function is used to fit the Λ peak from invariant mass distributions, since the combinatorial background has approximately a Gaussian shape. The mean values and the σ of the fitted distributions are tabulated in Table 146.1 without and including the Lambda Disks Detector at both the tested beam momenta. The reconstruction efficiencies of Λ hyperons is shown in Fig. 146.1 and estimated values are tabulated in Table 146.1. The overall $\Lambda\bar{\Lambda}$ reconstruction efficiency is found to be 28.5 and 20% at 1.8 and 4.0 GeV/c, respectively. Simulations for $\bar{p}p \rightarrow D^{*+}D^{*-} \rightarrow D^0\pi^+\bar{D}^0\pi^-$ and $\bar{p}p \rightarrow J/\psi\pi^+\pi^-$ were performed as well to study the effect of the Lambda Disks Detector on their reconstruction efficiencies. The reconstruction performance of these two channels should not be affected by the addition of Lambda Disks to the $\overline{\text{P}}$ANDA detector setup. The mean and σ values of the fitted mass distributions from both the channels and the average reconstruction efficiency for each produced particle are tabulated in Table 146.1.

It is concluded from these simulation studies that the reconstruction efficiency and resolution of produced Λ hyperons are not affected after the addition of the LDD. However, the number of hit points per track are increasing with the addition of these two disks to the central detector system of $\overline{\text{P}}$ANDA, which is a positive sign

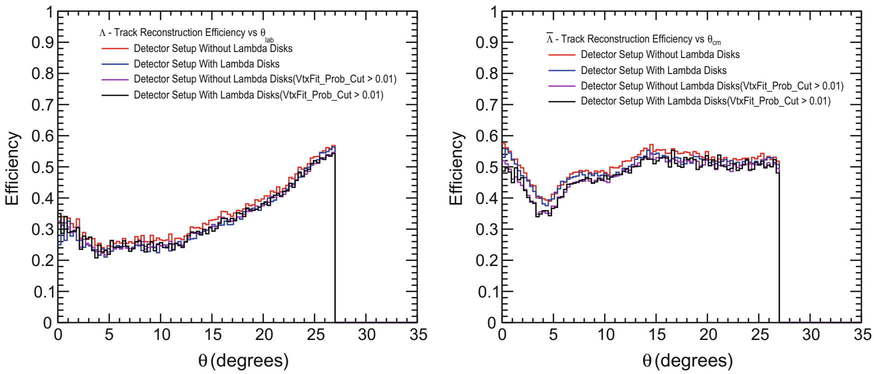

Fig. 146.1 Reconstruction efficiency of Λ (left) and $\bar{\Lambda}$ (right) at 1.8 GeV/c incident beam momentum with and without the Lambda Disks Detector

Table 146.1 Reconstructed invariant mass and efficiency without (with) the Lambda Disks Detector of Λ ($\bar{\Lambda}$) hyperons at two different beam momenta and for produced mesons from both selected channels. The statistical errors for the 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	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
w/o LDD	8.0	D^0	1.86	0.019	75
		$\bar{D}^0$	1.86	0.019	75
	8.0	D^{*+}	2.01	0.017	40
		D^{*-}	2.01	0.017	40
w/ LDD	8.0	D^0	1.86	0.019	75
		$\bar{D}^0$	1.86	0.019	75
	8.0	D^{*+}	2.01	0.017	40
		D^{*-}	2.01	0.017	40
w/o LDD	6.0	J/ψ	3.086	0.052	84
w/ LDD	6.0	J/ψ	3.085	0.053	84

towards the development of the LDD. In these feasibility studies, the LDD are kept at fixed positions from the interaction point and an ideal track finder algorithm is used to find the tracks from the secondary decay vertices, considering them decayed at origin, due to the unavailability of a secondary track finder algorithm with the present PandaRoot software. One could repeat the same study with the secondary tracking algorithm while it is implemented within PandaRoot software and by changing the locations of the LDD in order to optimize the position of the detector. Finally, if one considers the improvement in the reconstruction efficiency of hyperons with LDD, then $\overline{\text{P}}$ANDA should add the LDD. This will help to improve the hyperon studies.

References

1. PANDA Collaboration, Technical Design Report for the PANDA Micro Vertex Detector, http://arxiv.org/abs/1207.6581v2 and references therein
2. S. Spataro, [PANDA Collaboration], Simulation and event reconstruction inside the PandaRoot framework. J. Phys. Conf. Ser. **119**, 032035 (2008). and references therein