Conceptual Design of the Lambda Disks Detector for the $\overline{\text{P}}$ANDA Experiment

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$\overline{\text{P}}$ANDA (anti**P**roton **AN**nihilations at **DA**rmstadt) is a future experiment in the FAIR (**F**acility for **A**ntiproton and **I**on **R**esearch) facility located next to GSI, Darmstadt, Germany. The HESR (**H**igh **E**nergy **S**torage **R**ing) of the FAIR facility will provide antiproton beam of any momentum between 1.5 GeV/c and 15 GeV/c.

Main physics motivation of $\overline{\text{P}}$ANDA is to explore the low energy regime of Quantum Chromodynamics (QCD). Mainly it will focus on the following areas: charmonium spectroscopy, search for the gluonic states, hadrons in nuclear matter, hypernuclei physics and electromagnetic processes [1].

The $\overline{\text{P}}$ANDA detector setup is made up of two major parts - target spectrometer and forward spectrometer. Target spectrometer consists of tracking detectors, particle identification detectors, electromagnetic calorimeter. Micro Vertex Detector (MVD) is the innermost tracking detector of the target spectrometer. It has four barrel layers and six disks layers. After the last disk layer of MVD and first layer of Gas Electron Multipliers (GEM), there is a large detector free volume. By including the Lambda Disks Detector (LDD) into the $\overline{\text{P}}$ANDA setup, there is a possibility to extend hyperon study in the $\overline{\text{P}}$ANDA physics program. Hyperons have a large decay length of the order of a few centimeters. Therefore, they travel a large distance before decaying into other particles. The LDD will have the capability to improve the reconstruction probability of hyperons having a longer decay length.

Also present database of hyperon physics is not complete. PS185 experiment at the LEAR (**L**ow **E**nergy **A**ntiproton **R**ing) facility had measured $\Lambda\bar{\Lambda}$ cross-section from its beam production threshold momentum (1.436 GeV/c) to 2 GeV/c and Bubble Chamber experiment provides cross-section above 2 GeV/c with low statistics and there is no data available above 7 GeV/c. Not only addition of LDD will verify previous measured cross-section below 7 GeV/c, it may also provide data above 7 GeV/c with large statistics [2].

In the proposed geometry of the Lambda Disks Detector, the outer and inner ring of these disks are both made up of Double-sided Silicon Strip Sensors.

To test the capability of LDD, we have simulated and reconstructed $\bar{p}p \rightarrow \Lambda\bar{\Lambda}$ channel under the $\overline{\text{P}}$ANDA simulation framework at beam momentum 1.8 GeV/c that is near threshold beam momentum of the reaction and other at 4 GeV/c to compare the performance of the detector with increasing beam momentum. In order to perform the feasibility studies for the Lambda Disks Detector of the $\overline{\text{P}}$ANDA experiment, we have studied the angular distributions from the daughter particles of Lambda (Λ) hyperons to map the direction of the final state particles inside the target spectrometer.

We have also studied vertex and momentum resolution from $\bar{p}p \rightarrow \Lambda\bar{\Lambda}$ channel with and without the LDD. We have found that vertex resolution of Λ and $\bar{\Lambda}$ remain unchanged after the addition of LDD. However, we observed that the addition of LDD spoils the momentum resolution in the z-direction and remain unchanged in transverse direction. Hit count studies of the daughter particles from both hyperons are performed and observed that hit counts are increased after the addition of LDD to the detector set up. At low beam mo-

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mentum (1.8 GeV/c), the most significant effect is the increment in the number of hits of protons in the angular range of the Lambda Disks. The average number of hit points per track rises above four, which allows individual tracking of the particle. At a higher beam momentum (4.0 GeV/c), antiprotons are forward boosted in comparison to protons and usually have more than six hits in angular coverage of the Lambda Disks. Final state pions (π^+ and π^-) register more than six hits after the addition of LDD to the $\overline{\text{P}}$ANDA. The increment in the particle hits after adding the LDD is a positive sign towards its development. We have estimated mass resolution and reconstruction efficiency of Λ and $\bar{\Lambda}$ hyperons with and without the LDD, which are most important parameters for the feasibility studies of this detector. A double Gaussian function is fitted to the mass distribution of hyperons because the combinatorial background is also Gaussian in nature [3].

As the addition of a new detector should not affect the reconstruction of already well reconstructed channels, therefore, we have studied two mesonic channels $\bar{p}p \to D^{*+}D^{*-} \to D^0\pi^+\bar{D}^0\pi^-$ and $\bar{p}p \to J/\psi\pi^+\pi^-$ in the presence of LDD.

As a part of this thesis to gain hardware experience, we have done the characterization of trapezoidal Double-sided Silicon Strip Sensors. We have perform Quality Assurance (QA) tests which is basically I-V and C-V characterization of these sensors. Most important parameters of QA tests are leakage current and depletion voltage of the whole sensor as well as individual strips. It is essential to know these parameters before the operation.

The QA tests on the DC-DC converters are also performed which is required for constant power supply to each sensor used for the LDD. The QA tests include I-V characteristics, efficiency measurements, load regulation on the available DC-DC converter modules.

The organization of the thesis is as follows:
Chapter 1: This chapter gives a short introduction of Standard Model and QCD. We have discussed $\overline{\text{P}}$ANDA physics program in details. It elaborates how the $\overline{\text{P}}$ANDA experiment could shed light on some of the unanswered questions in hadron physics and nonperturbative regime of QCD. At the end, we have discussed the present status of hyperon physics and requirement of Lambda Disks Detector for the reconstruction of hyperons.
Chapter 2: This chapter describes the Facility of Antiproton and Ion research which will be future accelerator facility at GSI. We basically discuss the various experimental programs which use this facility. Special emphasis has been given to the $\overline{\text{P}}$ANDA experiment and its sub-detector systems.
Chapter 3: In this chapter Lambda Disks Detector layout is discussed. A description of the detector technology, material budget of the LDD is given. The efforts have been made towards the mechanical services for the Lambda Disks Detector.
Chapter 4: Simulation studies for the $\overline{\text{P}}$ANDA Lambda Disks Detector are presented in details for three physics channels in this chapter.
Chapter 5: This chapter describes the characterization of the Double-sided Silicon Strip Sensors and DC-DC converters.
Chapter 6: This chapter provides summary and conclusions drawn from this thesis work and future outlook.

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