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K_S^0 reconstruction study in SPD

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The Spin Physics Detector (SPD) collaboration proposes to install a universal detector in the second interaction point of the Nuclotron-based Ion Collider fAcility (NICA) collider which is currently under construction in JINR Dubna. The collaboration will study the spin structure of the proton and deuteron and other spin-related phenomena using a unique possibility to operate with polarized proton and deuteron beams. An expected centre of mass energy will be up to 27 GeV and a luminosity up to 10^{32} cm$^{-2}s^{-1}$ in pp mode. In analysis, we presents results of K_S^0 reconstruction and of show kinematic distributions (p, θ), (x_F, p_T) and (η, p_T) phase space. The analysis of K_S^0 reconstruction efficiency was performed using SpdRoot framework.

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1. Introduction

Over the past four decades, the spin structure of the nucleon has been a highly debated subject in theoretical and experimental particle physics. Despite considerable efforts, a complete understanding of this structure remains an unresolved challenge. In order to contribute to the investigation of the proton and deuteron spin structure, as well as other spin-related phenomena, the Spin Physics Detector (SPD) at the NICA collider (JINR, Dubna) is proposed. The SPD experimental setup [1] is designed as a universal 4π detector with advanced tracking and particle identification capabilities based on modern technologies.

One aspect of the SPD physics program focuses on measuring transverse single-spin asymmetries (SSA) in hadron production, which are related to transversity TMD PDF, Sivers TMD PDF, and Collins fragmentation function. Of particular interest are the spin asymmetries observed in K-meson production, primarily because of the involvement of the s-quark in the final state which emerges from the 'sea'. The first results of SSA performed in inclusive K_S^0 production with a polarized proton beam incident on a beryllium target at beam momenta of 13.3 (18.5) GeV/c at the Brookhaven AGS are presented in [2]. The SSA for K_S^0 displayed a significant negative asymmetry of approximately 0.1 for $x_F < 0.2$, becoming more negative as x_F values increased.

To determine the feasibility of measuring SSA in inclusive K_S^0 production, the K_S^0 reconstruction efficiency should first be evaluated. The results of this study are presented in current work.

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2. Analysis

The SpdRoot framework, derived from the FairRoot software [3], was used for detector simulation and reconstruction. Proton-proton collisions were simulated at a center-of-mass energy $\sqrt{s} = 27$ GeV using the Pythia 8 generator [4] with the 'soft QCD processes' option enabled. This minimum bias dataset incorporated the inclusive K_S^0 events. The transportation of secondary particles through the material and magnetic field of the SPD setup is provided by Geant4 [5]. Track fitting was performed using the GenFit toolkit [6]. KFparticle package [7] is used to reconstruct K_s^0 meson in $\pi^+\pi^-$ hadronic decay channel (branching ratio 69.20%). The generated data sample consists of 4 million events, which will approximately correspond to 1 second of data taking of SPD.

The selection of the K_S^0 was based on a search for secondary vertices, which were made for each combination of two pion tracks with opposite charges, located downstream of the interaction. The track candidates were required to be well-fitted and to have a track fit χ^2 over the number of degrees of freedom less than 6. To suppress the combinatorial background, the tracks that could be extrapolated back to the primary vertex (track extrapolation χ^2 is less than 10) were excluded. Each pair of such tracks with opposite charges was considered a K_S^0 candidate. The fit of the two-track vertex was required to have $\chi^2 < 2$. The reconstructed K_S^0 extrapolation should be consistent with the primary vertex ($\chi^2 < 2$) and the collinearity angle, θ_{coll}, between the reconstructed K_S^0 momentum and the direction between the reconstructed primary and secondary vertices is $\theta_{coll} < 0.03$ rad. Finally, only K_S^0 candidates with decay length above 0.7 cm were accepted. The invariant mass of the K_S^0 candidates after the imposed cuts is shown in Fig. 1. The distribution was fitted within the 0.4-0.6 GeV/c^2 interval using the sum of a double Gaussian for the K_S^0 signal and a second-order polynomial for the background. In total, about 76 thousand events of K_S^0 were selected for the analysis.

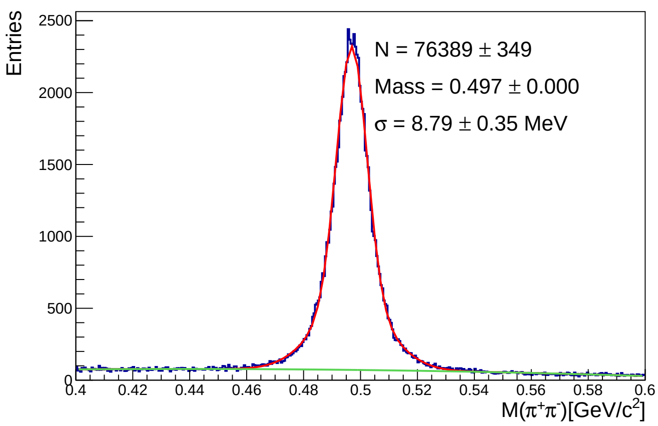

Figure 1: Invariant mass distribution of $K_S^0 \to \pi^+\pi^-$ after applying selection cuts for the full analysis sample.

Kinematic distributions of momentum versus polar angle (p, θ), Feynman-x variable versus transverse momentum (x_F, p_T) and pseudorapidity versus transverse momentum (η, p_T) of K_S^0 at the generator and reconstruction levels are shown in Fig. 2. On the reconstruction data, there are regions (selected by red ellipses) in which the influence of the beam pipe at small or large θ angles for a high momentum is observed. Impact of this effect can also be observed on x_F and η distributions.

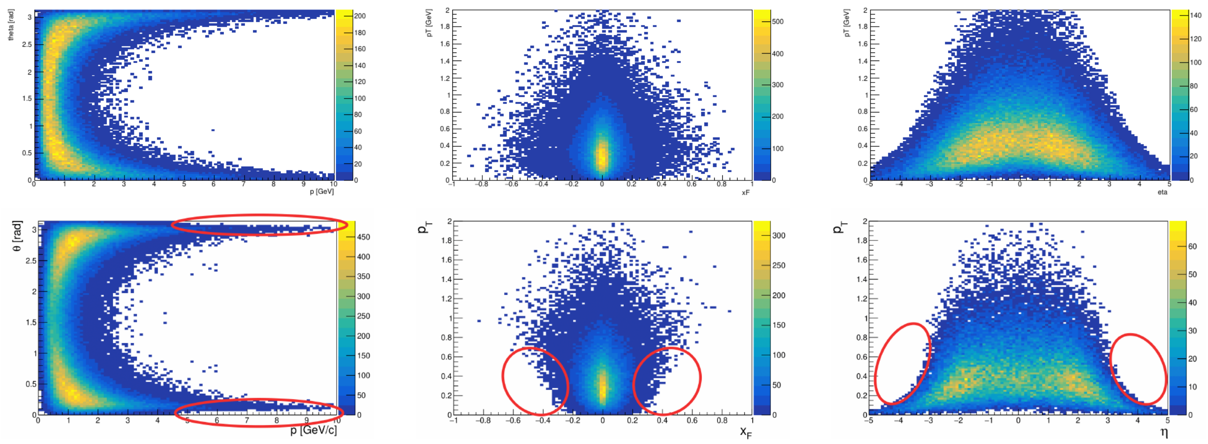

Figure 2: Kinematic distributions (p, θ), (x_F, p_T) and (η, p_T) of K^0_S phase space at the generator (top row) and reconstruction (bottom row) levels.

The selected K^0_S candidates are binned in the (p, θ) phase space are shown in Fig. 3. The choice of the binning scheme is driven by the available statistics to have a similar number of kaons in every bin. We ended up with 40 bins for our analysis ($n^{\theta}_{bin} = 4$, $n^{p}_{bin} = 10$). A fit of the invariant mass distribution was performed in each of these (p, θ) bins. The K^0_S reconstruction efficiency, A, was evaluated as a ratio of the number of reconstructed K^0_S to the number of MC generated ones, $A = N^{MC}_{Rec}/N^{MC}_{Pythia}$. The reconstruction efficiency of K^0_S candidates as a function of momentum for a fixed θ interval is shown in Fig. 4. The total correction factor includes: the geometrical acceptance, track and vertex reconstructed efficiency, and feed down contributions. The latter represent the contribution from kaons created not in the primary vertex. The K^0_S reconstruction efficiency depends on p and θ and varies from 30% at low θ to 10% at high θ. In the first θ bin (small angle), we can clearly observe an influence from the beam pipe, where one of the pions from K^0_S decay is lost resulting in reduced reconstructed efficiency.

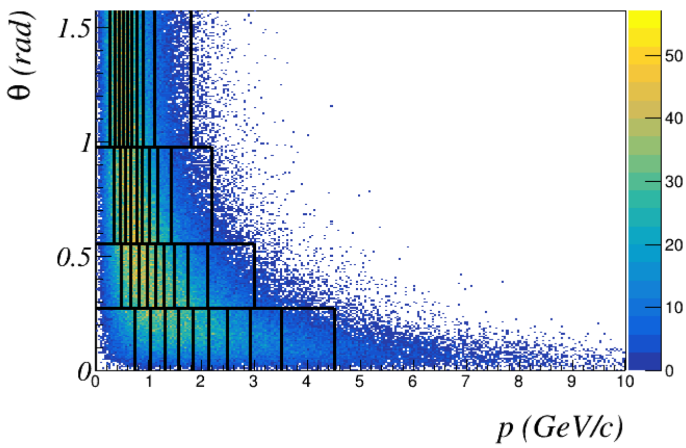

Figure 3: The (p, θ) phase space of K^0_S in SPD is shown. The binning used in the analysis is indicated by the outlined boxes.

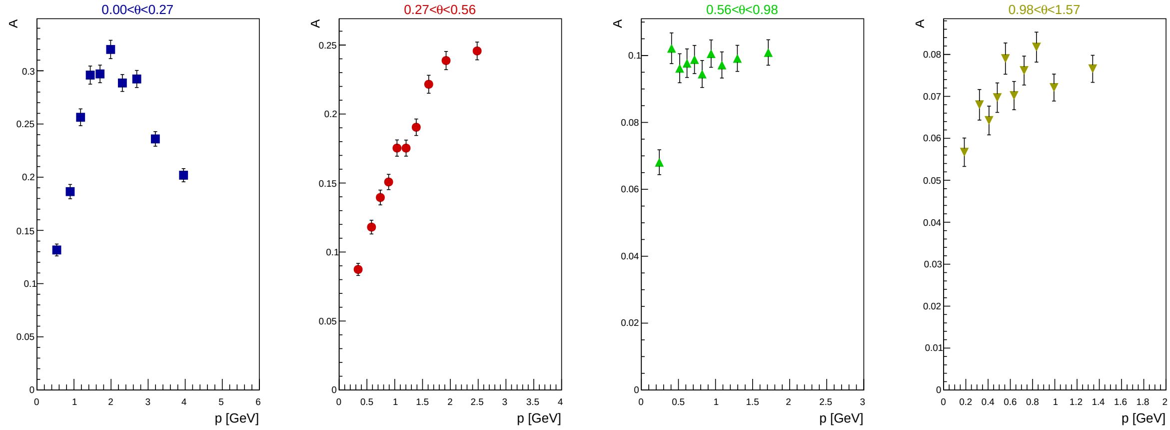

Figure 4: The overall reconstruction efficiency of K_S^0 candidates as function of the momentum for fixed θ interval.

3. Conclusion

The study of the reconstruction efficiency of K_S^0 meson has been presented. For this purpose, an analysis of proton-proton collisions at center of mass energy 27 GeV were performed at the generator level and then the full event reconstruction was done at detector level. The K_S^0 reconstruction efficiency depends on p and θ and varies from 30% at low θ to 10% at high θ.

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