Analysis of K_S^0 production in SPD at NICA

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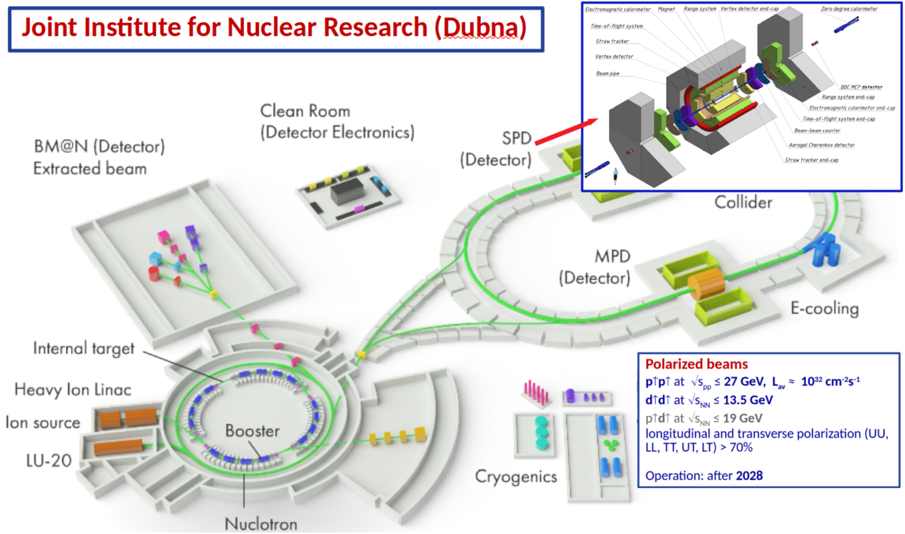
XXXI Annual International Seminar
Nonlinear Phenomena in Complex Systems

24-28 June 2024

Nuclotron-based Ion Collider fAcility (NICA)

Joint Institute for Nuclear Research (Dubna)



Polarized beams

p↑p↑ at $\sqrt{s_{pp}} \le$ **27 GeV, $L_{av} \approx 10^{32}$ cm^{-2}s^{-1}**

d↑d↑ at $\sqrt{s_{NN}} \le$ **13.5 GeV**

p↑**d**↑ at $\sqrt{s_{NN}} \le$ **19 GeV**

longitudinal and transverse polarization (UU, LL, TT, UT, LT) > 70%

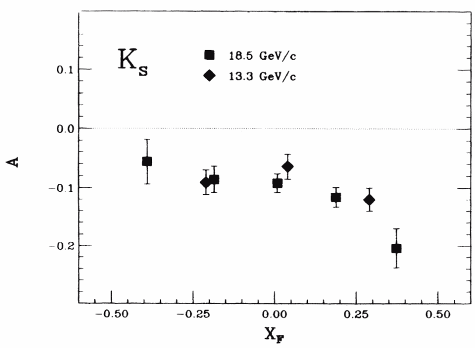
Operation: after **2028**

Motivation of study

The ultimate goal is to measure the transverse single-spin asymmetries (SSA) A_N for K_S^0 which are related to

- transversity quark TMD PDF
- Sivers quark TMD PDF
- Collins fragmentation function

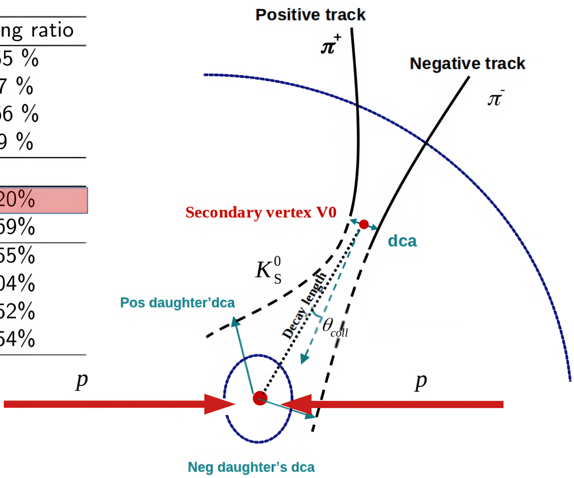
Measurement of A_N for K_S^0 could help us to study the orbital motion of strange quark inside proton.



BNL-AGS-E817
Phys.Rev.D41(1990)13-16.

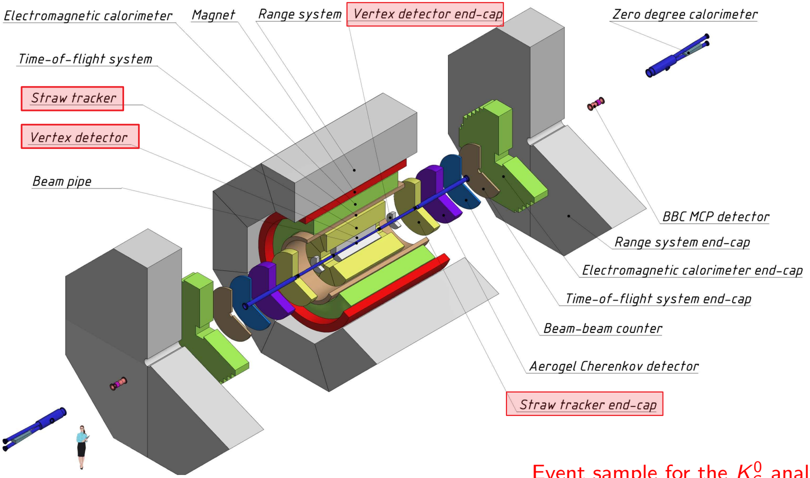
K meson

	Decay products	Branching ratio
K^+	$\mu^+\ \nu_\mu$	63.55 %
	$\pi^0\ e^+\ \nu_e$	5.07 %
	$\pi^+\pi^0$	20.66 %
	$\pi^+\pi^+\pi^-$	5.59 %
K^0	50% K_S^0, 50% K_L^0	
K_S^0	$\pi^+\pi^-$	69.20%
	$\pi^0\pi^0$	30.69%
K_L^0	$\pi^\pm e^\mp\ \nu_e$	40.55%
	$\pi^\pm\mu^\mp\nu_\mu$	27.04%
	$3\pi^0$	19.52%
	$\pi^+\pi^-\pi^0$	12.54%



Schematic view of the SPD and event sample

Secondary vertex (V^0) are reconstructed in the detectors: Vertex detector and Straw tracker.



Event sample for the K_S^0 analysis

Generation: Pythia 8, (p+p) at $\sqrt{S}$=27 GeV, SoftQCD(MB).

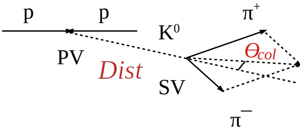
4 000 000 events (1 sec of data taking).

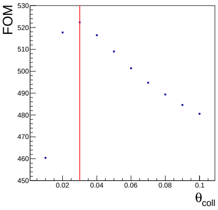
Selection criteria

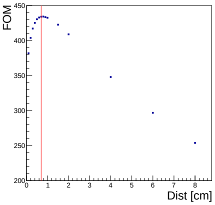
- The cuts on the quality of the tracks;
- Kinematical cuts:

  1) $\theta_{coll} < 0.03$ rad. for K_S^0.
  This cut selects V^0 events the momentum looking at the PV.

  2) $Dist > 0.7$ cm for K_S^0
  $Dist = \sqrt{(x_{SV} - x_{PV})^2 + (y_{SV} - y_{PV})^2 + (z_{SV} - z_{PV})^2}$.
  This cut selects V^0 which decay close to PV.



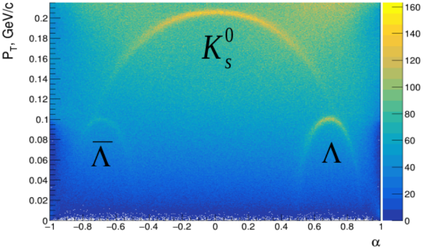




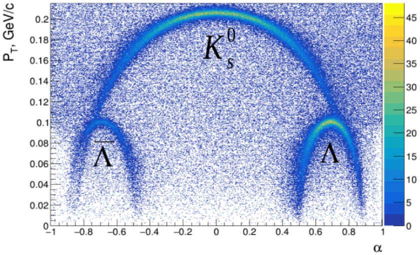
$$FOM = \frac{N_{sig}}{\sqrt{N_{sig} + N_{bg}}}$$

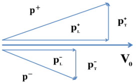
Distributions of the V^0 candidates in the Podolanski-Armenteros

Before selection criteria



After selection criteria





$$\alpha = \frac{p_L^+ - p_L^-}{p_L^+ + p_L^-}$$

p_L^+ and p_L^- are the longitudinal momenta of the positive and negative decay particle respectively

Helicity angle for selestions K_S^0

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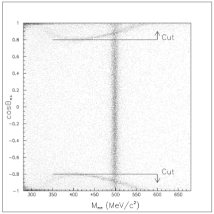
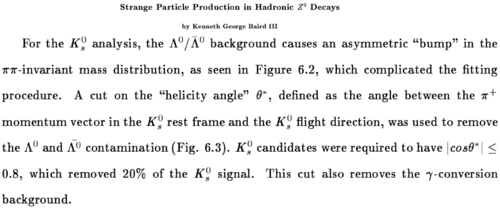


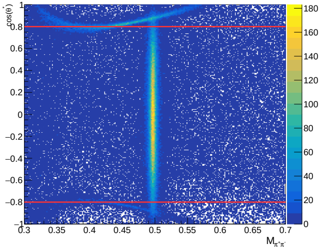


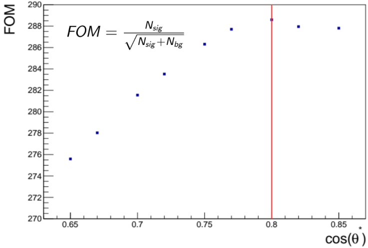
Strange Particle Production in Hadronic Z^0 Decays

by Kenneth George Baird III

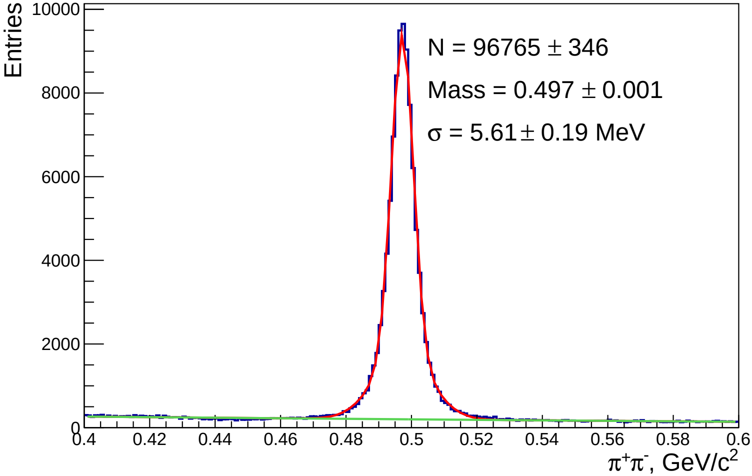
For the K_s^0 analysis, the $\Lambda^0/\bar{\Lambda}^0$ background causes an asymmetric "bump" in the $\pi\pi$-invariant mass distribution, as seen in Figure 6.2, which complicated the fitting procedure. A cut on the "helicity angle" θ^*, defined as the angle between the π^+ momentum vector in the K_s^0 rest frame and the K_s^0 flight direction, was used to remove the Λ^0 and $\bar{\Lambda^0}$ contamination (Fig. 6.3). K_s^0 candidates were required to have $|cos\theta^*| \leq 0.8$, which removed 20% of the K_s^0 signal. This cut also removes the γ-conversion background.

3) Helicity angle ($|cos\theta^*| \leqslant 0.8$) for K_S^0 at SPD.





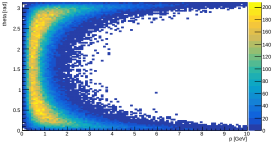
Invariant mass of K_S^0 after all cuts

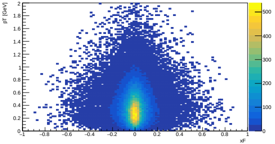


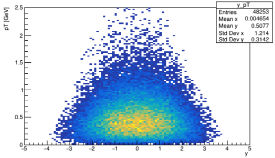
The shape of the K_S^0 signal was parametrized by double Gaussian and background was parametrized by the second order polynomial.

The selected V^0 candidates are plated in (p,θ), (x_F, p_T) and (y, p_T) phase space

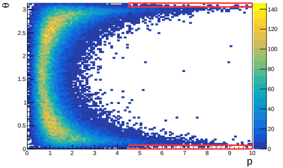
Pure Pythia 8 (true), K^0_S:



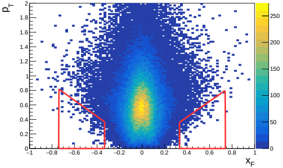




Reconstruction data (RD):

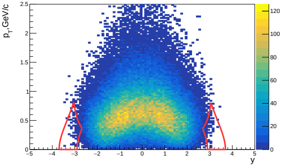


θ - polar angle
p - total momentum



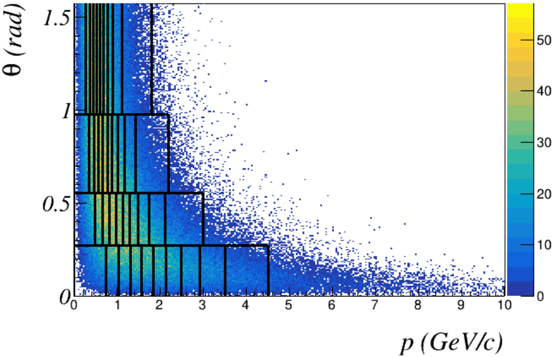
p_T - transverse momentum
x_F - Feynman variable

$$x_F = \frac{2p_L}{\sqrt{S}}$$



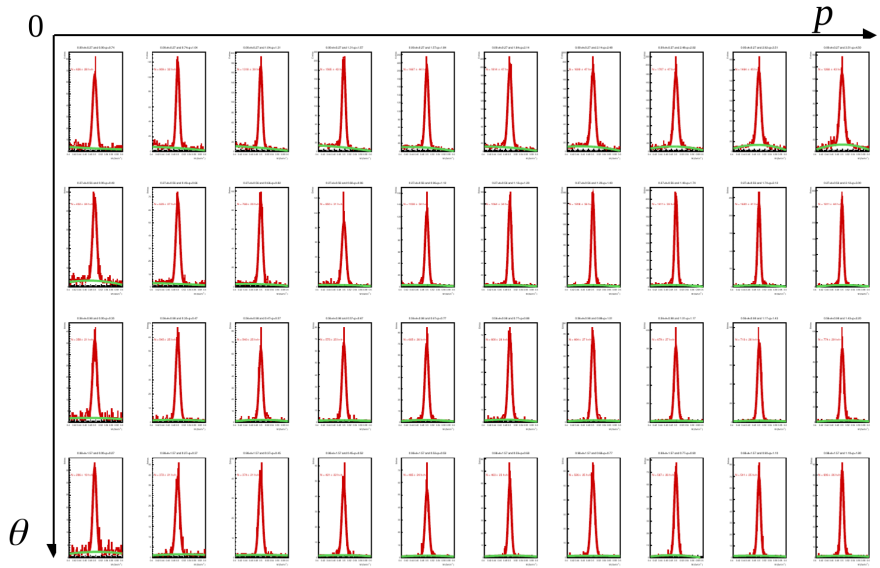
p_T - transverse momentum
y - rapidity

$$y = \frac{1}{2}\ln\frac{\sqrt{p^2+m^2}+pcos\theta}{\sqrt{p^2+m^2}-pcos\theta}$$



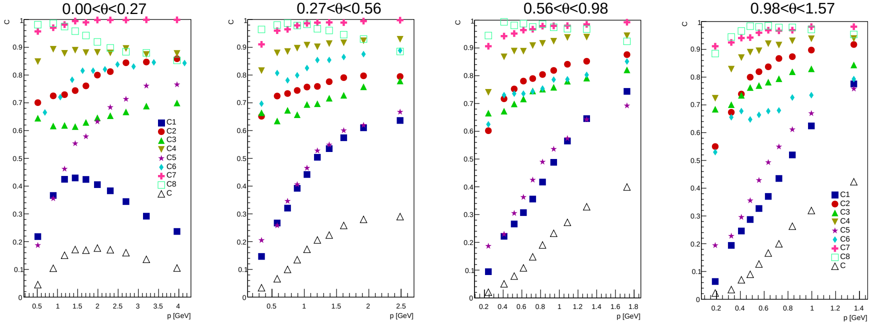
The choice of the binning scheme is obtained from distribution of K^0 simulated in Pythia 8. It was done to have the similar number of K_S^0 in bins ($n_{bin}^{\theta} = 4, n_{bin}^{p} = 10$).

Distributions of the K_S^0 candidates with all cuts



Factorization of the MC correction (1st step)

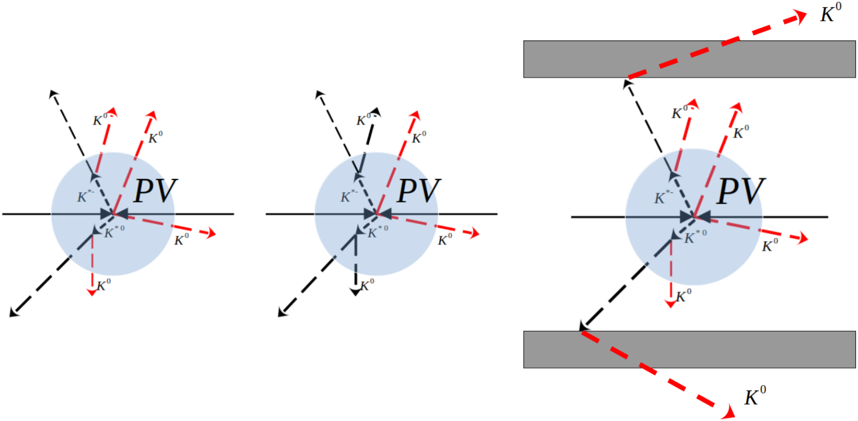
$$\mathrm{C} = \frac{N(RD)}{N(K^0_{true}(all))} = C1 * C2 * C3 * C4 * C5 * C6 * C7 * C8$$



$$C1 = \frac{N(3hits)}{N(K^0_{true}(all))} \qquad C2 = \frac{N(\chi^2/NDF_{tr1,2}<6)}{N(3hits)} \qquad C3 = \frac{N(\chi^2_{V0}<2.0)}{N(\chi^2/NDF_{tr1,2}<6)} \qquad C4 = \frac{N(\chi^2_{tr1,2}toPV>10)}{N(\chi^2_{V0}<2.0)}$$

$$C5 = \frac{N(convergency==1)}{N(\chi^2_{tr1,2}toPV>10)} \qquad C6 = \frac{N(\theta_{coll}<0.03)}{N(convergency==1)} \qquad C7 = \frac{N(Dist>0.7)}{N(\theta_{coll}<0.03)} \qquad C8 = \frac{N(|cos\theta^*|\leqslant 0.7)}{N(Dist>0.7)}$$

Feed down correction in PV and outside PV (2nd step)



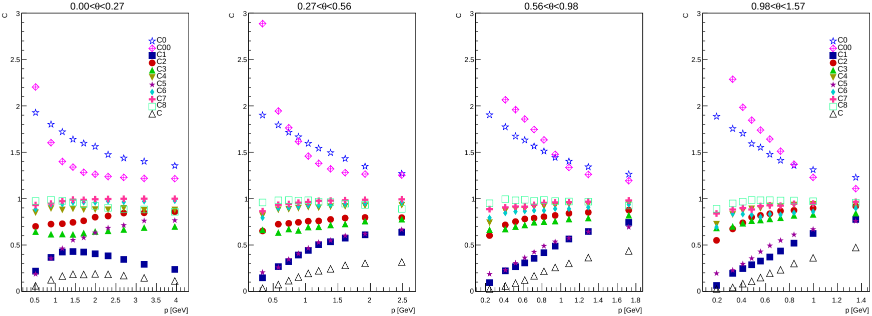
$N(K^0_{true} inPV)$ $N(K^0_{true,direct} inPV)$ $N(K^0_{true}(all))$

$$C0 = \frac{N(K^0_{true} inPV)}{N(K^0_{true,direct} inPV)} \qquad C00 = \frac{N(K^0_{true}(all))}{N(K^0_{true} inPV)}$$

Factorization of the MC correction

$$C = \frac{N(RD)}{N(K^0_{true,direct}\,inPV)} = C0 * C00 * C1 * C2 * C3 * C4 * C5 * C6 * C7 * C8$$

$C0 = \frac{N(K^0_{true}\,inPV)}{N(K^0_{true,direct}\,inPV)}$ – feed down in PV $\quad C00 = \frac{N(K^0_{true}(all))}{N(K^0_{true}\,inPV)}$ – feed down correction outside PV



$C1 = \frac{N(3hits)}{N(K^0_{true}(all))}$ ... $\quad C8 = \frac{N(|cos\theta^*| \leqslant 0.7)}{N(Dist > 0.7)}$

Extraction of A_N for selestions K_S^0

$$p^{\uparrow} + p \rightarrow K_S^0 + X$$

The cross section of production
in polarized p↑ + p collisions, is modified in azimuth.

$$\frac{d\sigma}{d\phi} = \frac{d\sigma}{d\phi}\left(1 + \underbrace{P \cdot A_N \cos\phi}_{\text{Azimuthal cosine modulation}}\right)$$

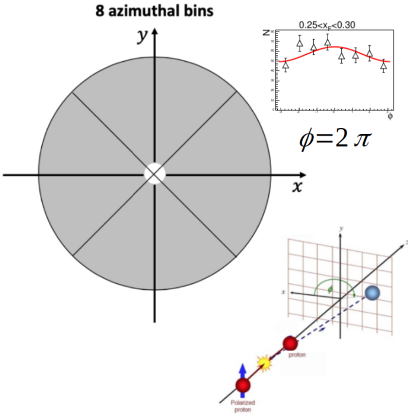
$$N_{K_S^0}(\phi) = A(1 + B\cos\phi)$$

$$\boxed{A_N = \frac{B}{P}}$$

$N_{K_S^0}(\phi)$: Yield of K_S^0

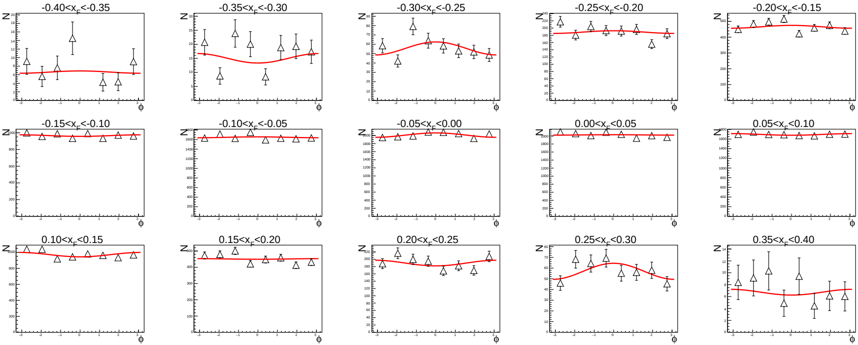
P: Beam polarization,

$P \sim 0.7$ was assumed



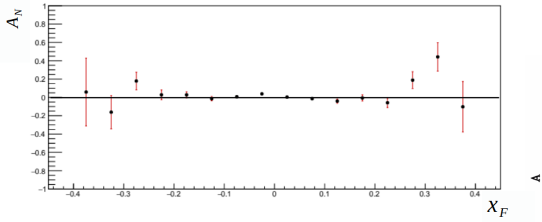
- The spin dependent K_S^0 yields for each bin are extracted from the invariant mass spectra in different x_F sub-ranges for each ϕ bin.
- The invariant mass was fitted with a second order polynomial function for the background and a normalized Gaussian distribution representing the signal peak.

Extraction of A_N for selestions K_S^0

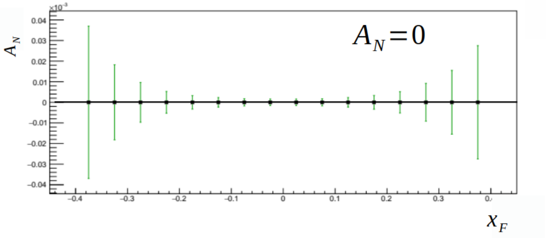


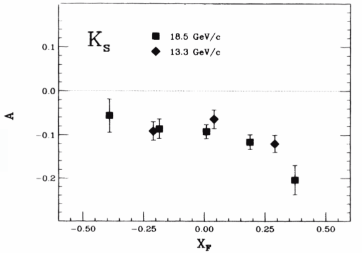
Relative A_N error in x_F intervals

A_N in x_F intervals for 1 sec



Relative A_N error in x_F intervals for 1 year





BNL-AGS-E817
Phys.Rev.D41(1990)13-16

Conclusion

- Analysis the K_S^0 reconstruction efficiency was performed. This procedure will be further applied for analysis $\Lambda(\bar{\Lambda})$.
- K_S^0 reconstruction efficiency depends on p and θ and in general is about 20%. K_S^0 reconstruction efficiency was factorized. Fraction of feed-down contribution is obtained.
- A_N for K_S^0 can be one of the first results of polarised measurements at SPD.
- Once the experimental data are collected, this decay can be used to validate event reconstruction and to probe quark TMD PDFs.