Measurement of single-spin asymmetry for charged pions in the SPASCHARM experiment at U70 accelerator

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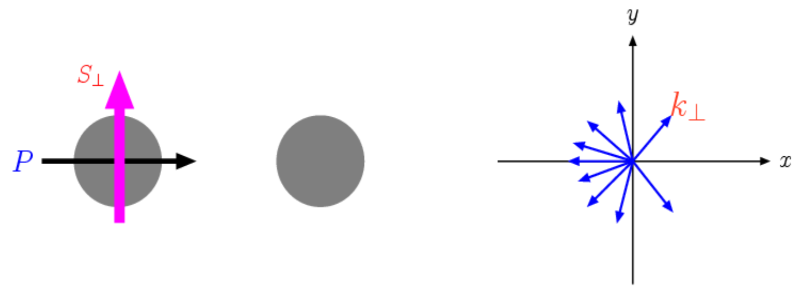
Introduction

The main physics motivation for the SPASCHARM experiment is the systematic study of spin phenomena for a wide range of inclusive and exclusive reactions in collisions of high-energy polarized hadrons in the QCD non-perturbative region.

The first stage of the SPASCHARM experiment is devoted to the study of single-spin effects. The single-spin asymmetry A_N is defined as a dependence of particle production cross-section on the direction perpendicular to the plane defined by the vectors of initial proton momentum and spin.

$$A_N = \frac{\sigma^{\uparrow}(p) - \sigma^{\downarrow}(p)}{\sigma^{\uparrow}(p) + \sigma^{\downarrow}(p)}$$



Introduction

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«КУРЧАТОВСКИЙ ИНСТИТУТ»
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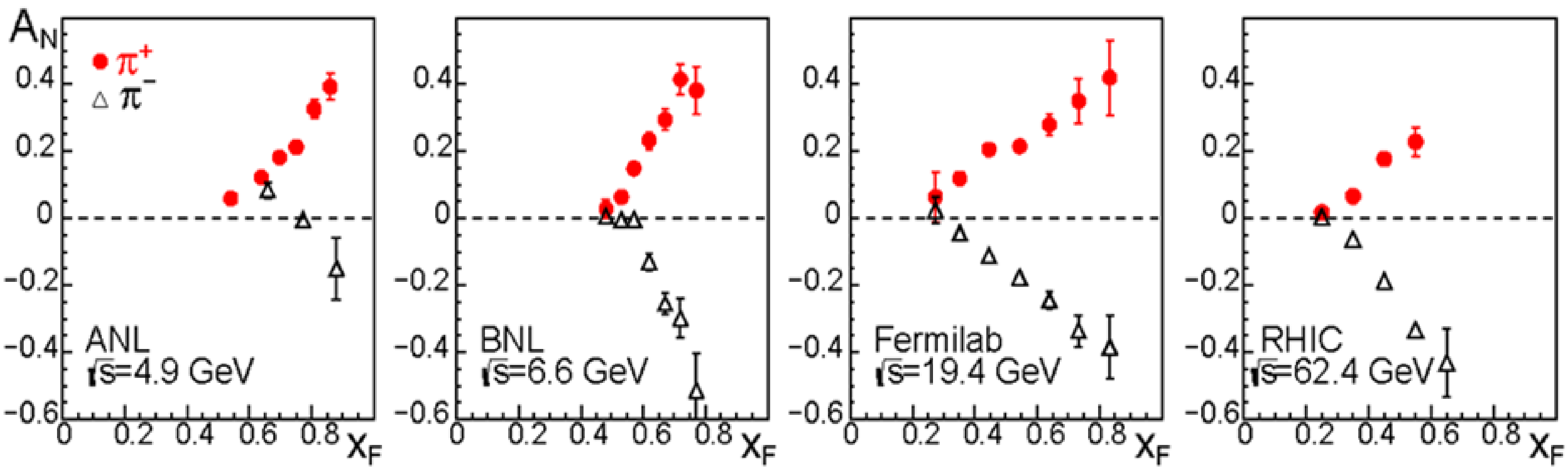
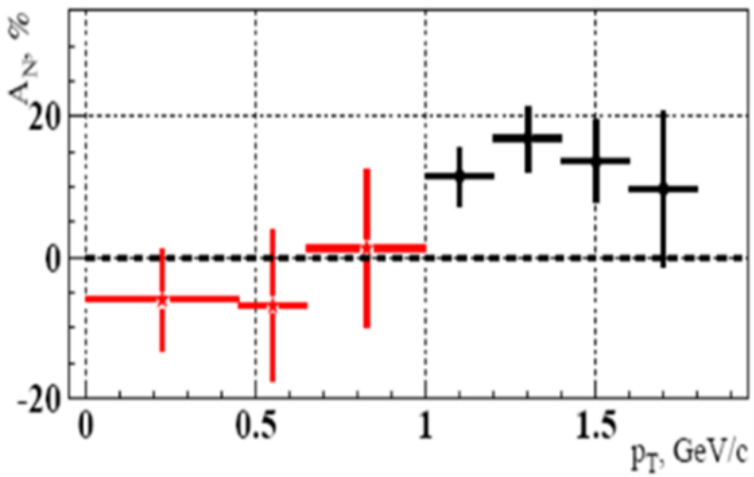
Physics motivation

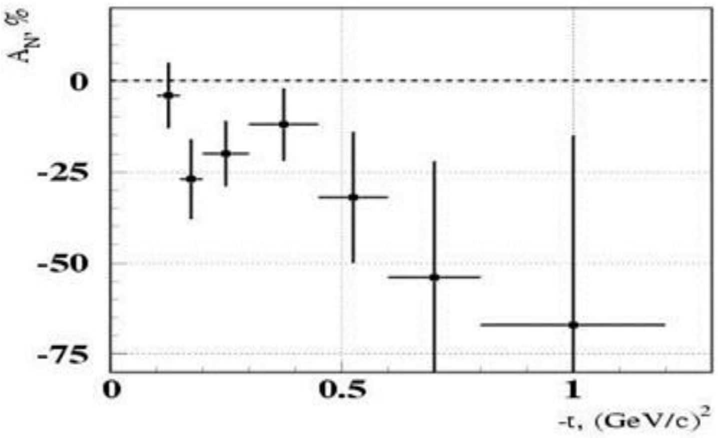


Experimental studies at various accelerators have shown that the ***A_N in inclusive pion production in the fragmentation region of a polarized proton ($p^{\uparrow}p \rightarrow \pi^{\pm}X$) almost doesn't depend on energy***. Most of the currently popular models predict the decrease of A_N as the transverse momentum of secondary particles increases.

It can be concluded that statistical and systematic accuracy of the A_N results is more important than energy.

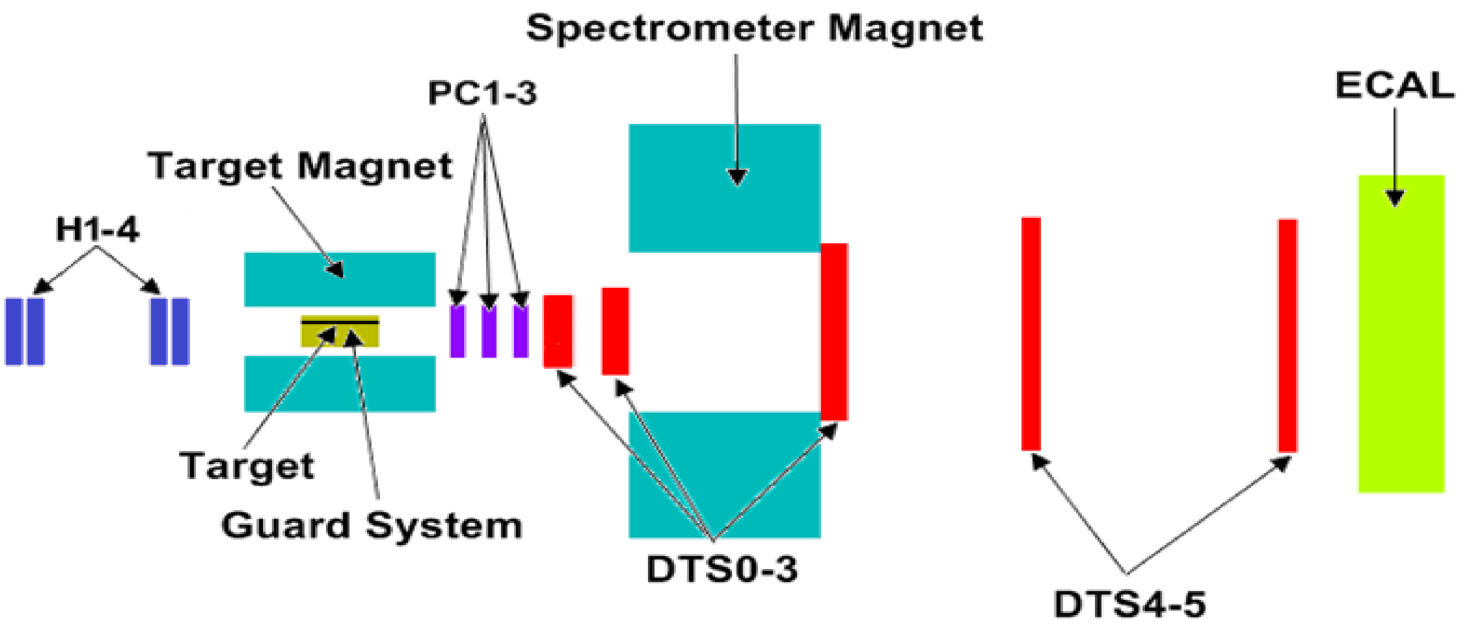
Physics motivation





Earlier, a non-zero asymmetries in non-polarized beam fragmentation region have been observed, for instance, in inclusive $\pi^0(\gamma\gamma)$ production (left) and exclusive ω $(\pi^0\gamma)$ production (right) at 40 GeV.

Experimental setup SPASCHARM



The SPASCHARM setup has the full 2π coverage in azimuth, this is an important advantage for minimizing the systematic errors in the measurement of spin observables.

The setup contains a polarized frozen proton Target with an average polarization of 65%.

The tracking system includes 3 proportional chamber stations (PC1-3) and 5 drift tube stations (DTS0-5). The field integral of Spectrometer Magnet is about 0.6 T•m, the field is directed upward.

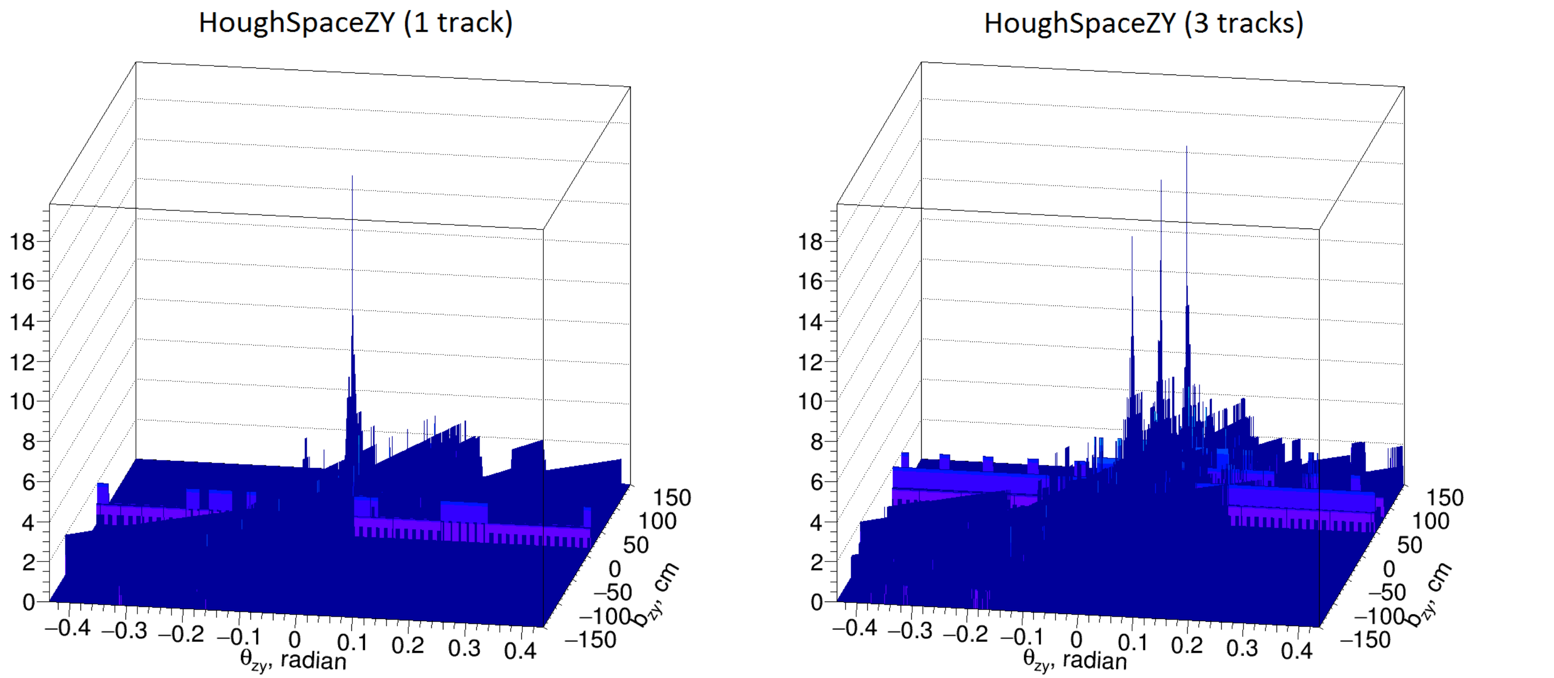
Data taking

In the beam run of Spring 2018, the negative particle (mainly π^-) beam of the energy of 28 GeV was produced at the internal target of the U-70 accelerator and the extracted to the SPASCHARM polarized pentanol target. The statistics has been accumulated in four measurement cycles: two with the target proton polarization up and two with the polarization down. The average polarization of the target protons was about 68% at the beginning of a measurement cycle and decreased down to 57% at the end. About 1 billion triggers were accumulated.

The meaningful results on the A_N measurements are expected in the kinematic region of Feynman variable $X_F > 0.5$ and transverse momentum $P_T > 0.5$ GeV/c in the reaction – $\pi^- p^{\uparrow} \rightarrow \pi^{\pm} X$ and in the future data taking run – in the reactions:

- $\pi^- p^{\uparrow} \rightarrow K_s(\pi^+\pi^-)X$ (see also talk by N. K. Kalugin)
- $\pi^- p^{\uparrow} \rightarrow \omega(\pi^+\pi^-\pi^0)X$
- and others.

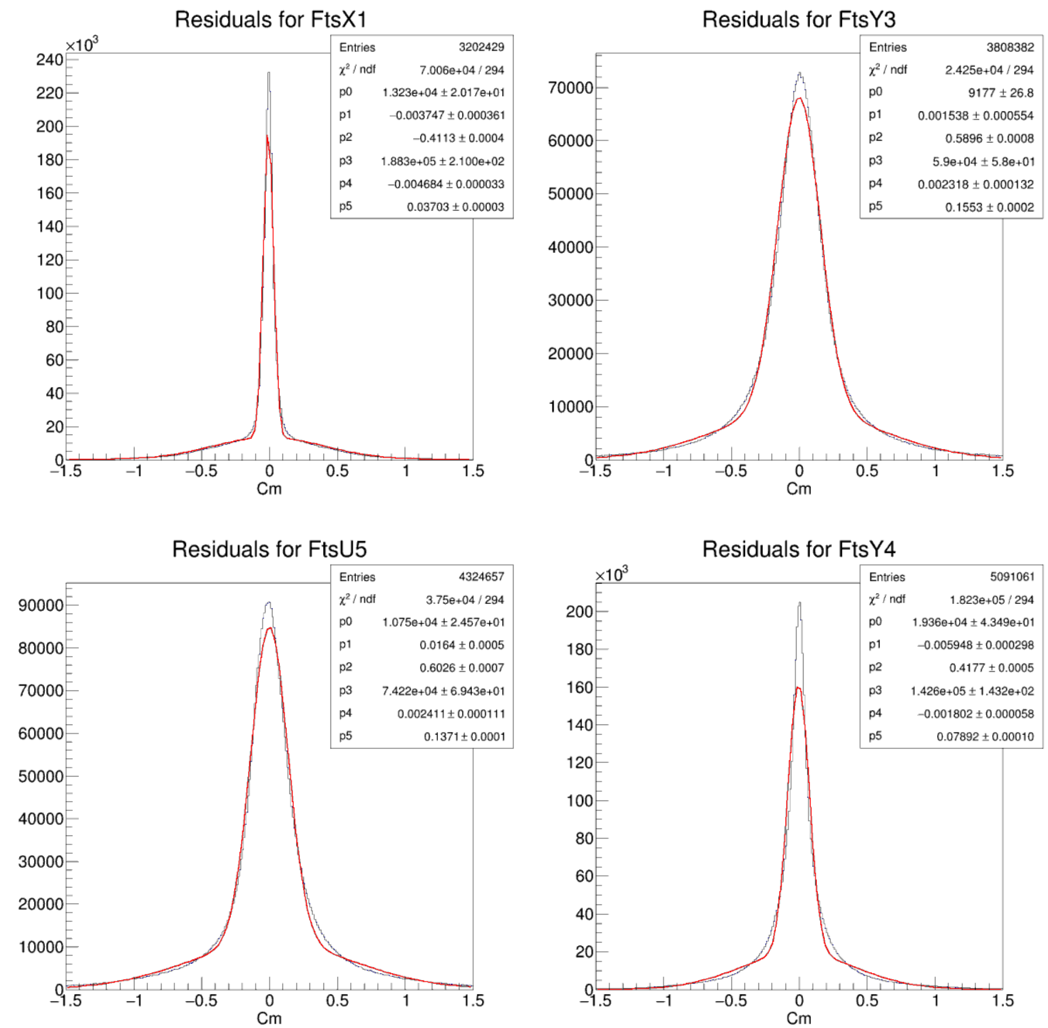
The Hough transform



The Hough transform is used to find track candidates. Figures above presents examples of the obtained Hough spaces in the ZY plane for MC simulation with one and three muons per event.

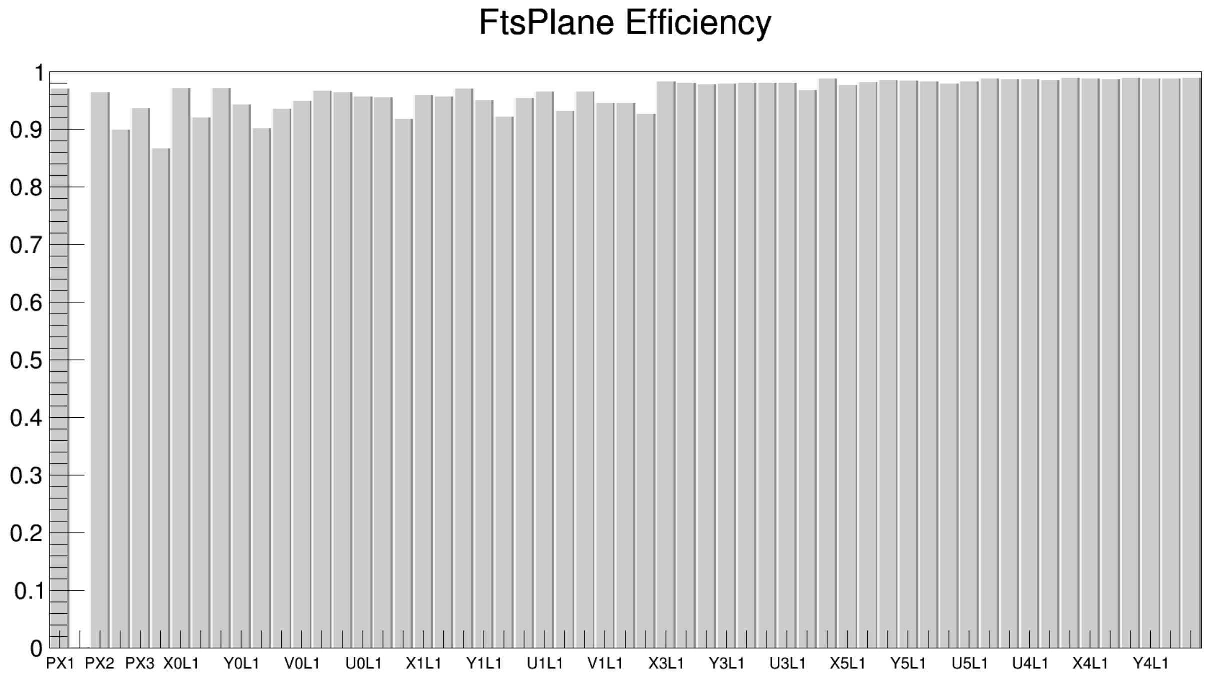
It was found that the reconstruction efficiency for one track in event is 98%, for two tracks – 93%, for three tracks – 85% and for four tracks – 77%.

Tracking system alignment



The tracking system has been aligned, using the specially developed and verified by MC simulations iterative method. This method provides an accuracy for the lateral displacements at about 100 microns.

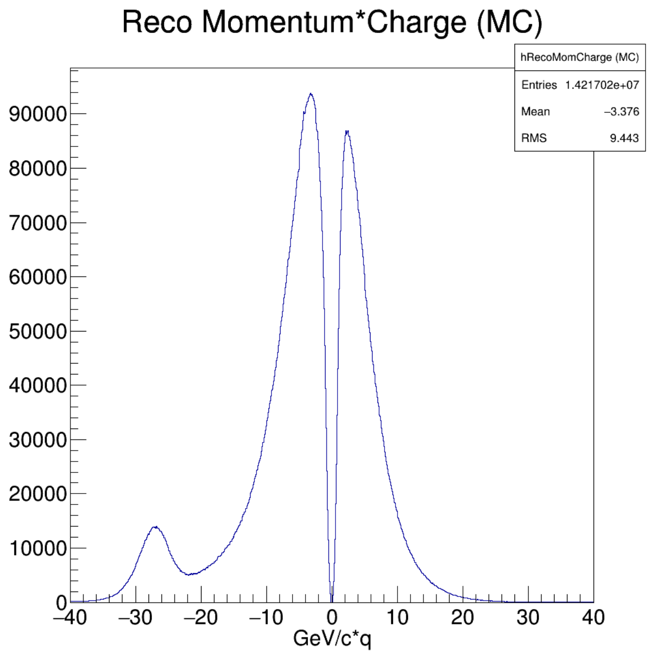
Tracking system efficiency

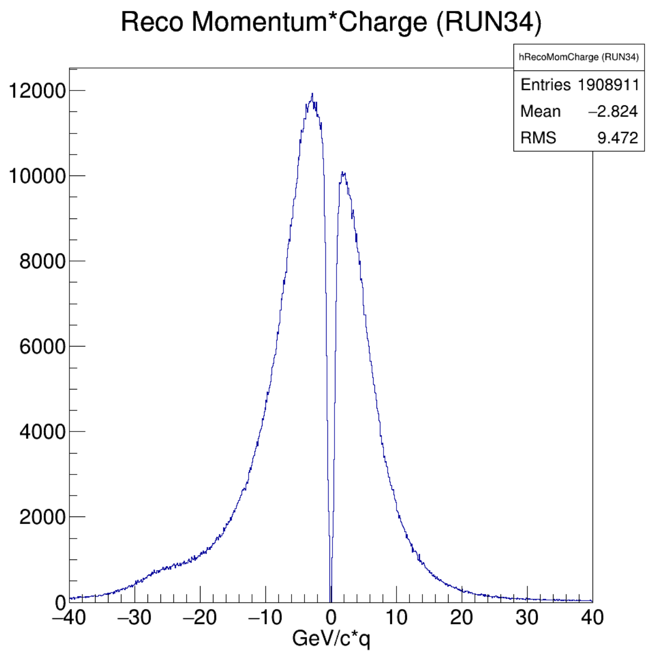


In the special test-beam run in the 2019, the tracking system has been tuned up, and the higher efficiency has been achieved for all the sub-planes of tracking detectors.

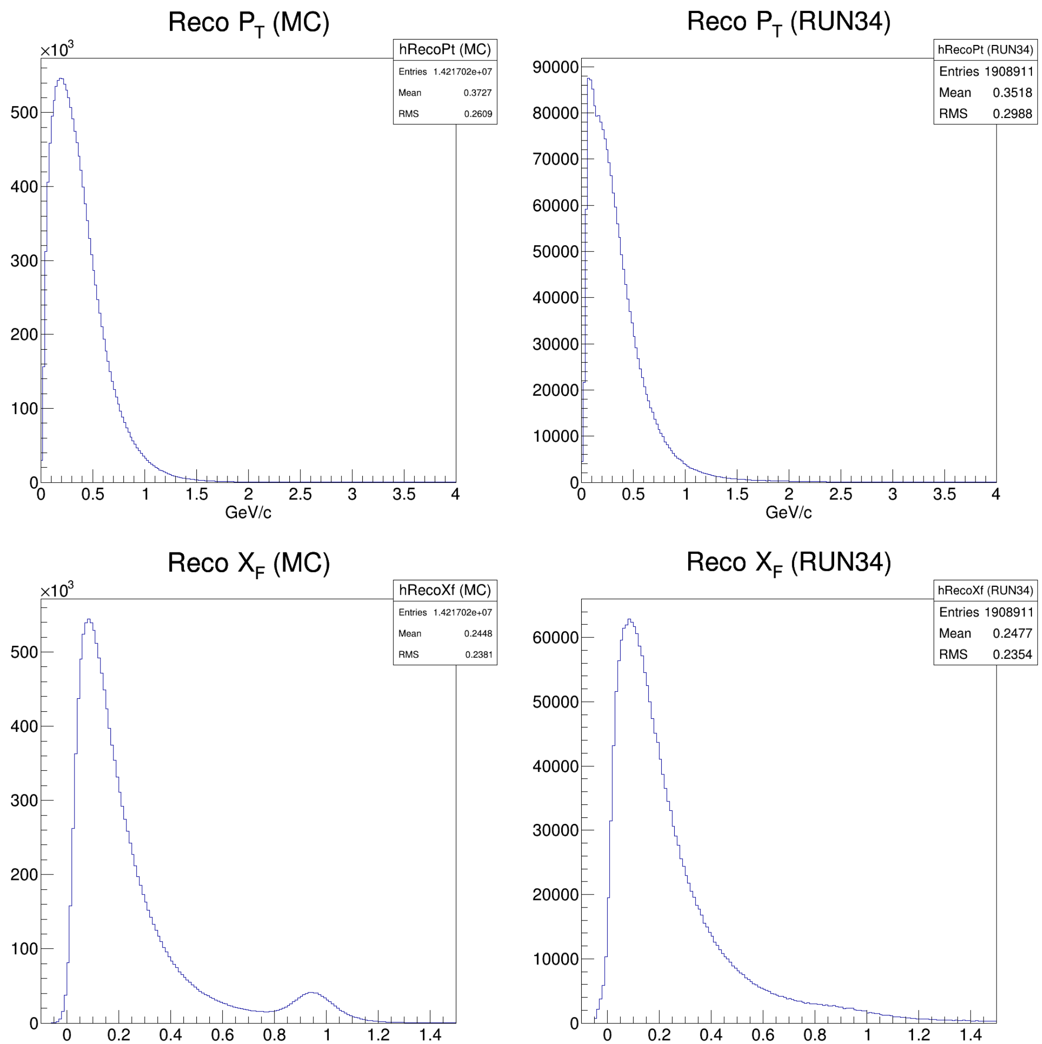
Reconstructed P•q distributions for MC and run34

The obtained results (for run34) are shown in comparison with MC simulation using the Pythia8 generator in minbias mode ($\pi^- p$) – 28 GeV/c (π^-), 10^7 events.





Reconstructed P_T and X_F distributions for MC and run34



The distribution shapes for MC and experimental data are approximately the same except of the elastic-scattering peak, which is suppressed by the trigger in the real data.

Expected statistical accuracy δA_N for $\pi^{\pm}$

$\delta A_N (\pi^+)$	$0.0<X_F<0.1$	$0.1<X_F<0.2$	$0.2<X_F<0.3$	$0.3<X_F<0.4$	$0.4<X_F<0.5$	$0.5<X_F<0.6$	$0.6<X_F<0.7$	$0.7<X_F<1.0$
$0.0<P_T<0.5$	0.004	0.004	0.007	0.011	0.017	0.025	0.035	0.035
$0.5<P_T<4.0$	0.106	0.019	0.012	0.013	0.016	0.021	0.026	0.021

$\delta A_N (\pi^-)$	$0.0<X_F<0.1$	$0.1<X_F<0.2$	$0.2<X_F<0.3$	$0.3<X_F<0.4$	$0.4<X_F<0.5$	$0.5<X_F<0.6$	$0.6<X_F<0.7$	$0.7<X_F<1.0$
$0.0<P_T<0.5$	0.004	0.004	0.006	0.008	0.010	0.013	0.016	0.013
$0.5<P_T<4.0$	0.078	0.013	0.009	0.009	0.011	0.013	0.015	0.010

Summary

- The new SPASCHARM experiment at the U70 accelerator has been commissioned and begun physics data taking for measuring A_N with the polarized proton target at the 28 GeV negative beam.
- Charged tracks reconstruction algorithm is validated with the MC simulation and currently used for the data analysis.
- The data analysis of 2018 beam-run data is now in progress for extracting the first physics results on A_N in the inclusive production of charged pions. The presented here real track reconstruction algorithm is in good agreement with the MC simulations. Expected statistical accuracy δA_N is about 1%, calculation of systematic errors is under study.
- The new data taking run at the U70 accelerator is expected in the Spring 2021 with the full optimized tracking system.

Acknowledgments

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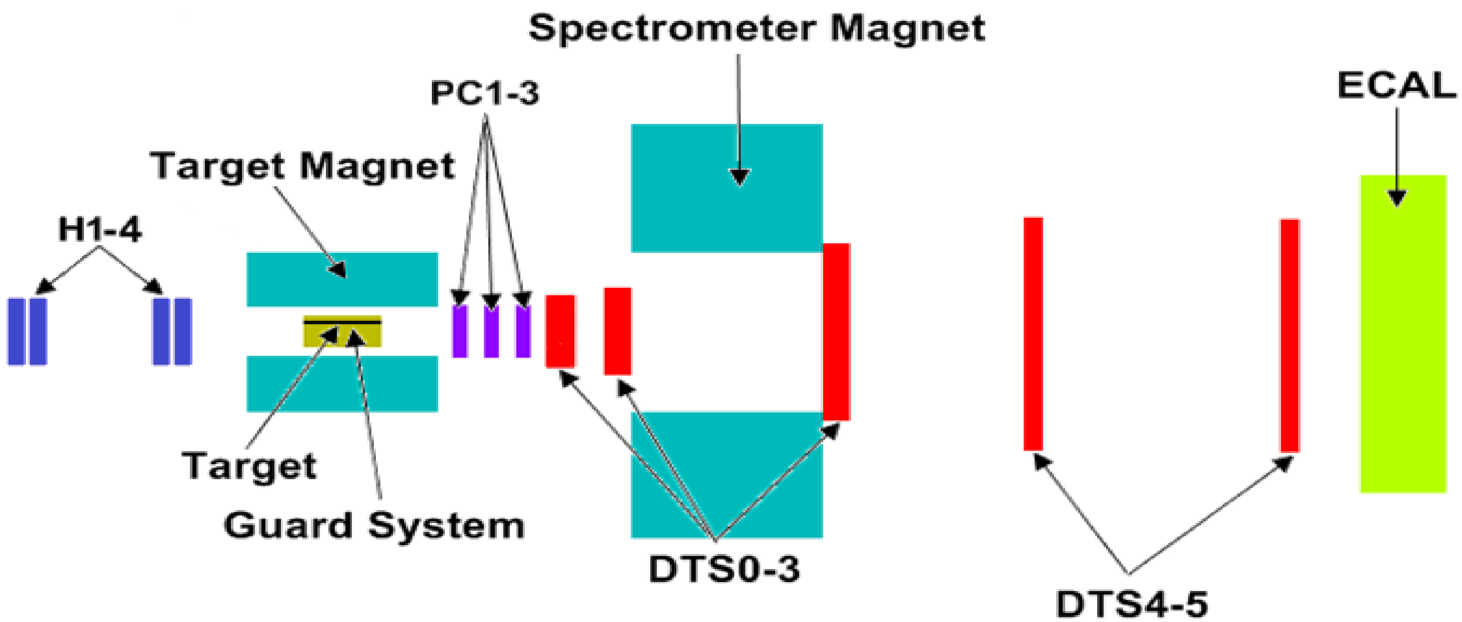
Backup

Experimental setup SPASCHARM



The SPASCHARM setup contains four beam scintillation hodoscopes (H1-4). Each hodoscope consists of two identical, mutually perpendicular arranged planes. The beam hodoscopes are used to determine the coordinates of the track on the target.

Proportional chamber stations have a wire pitch of 0.1 cm, drift tube stations have tube diameter of 3 cm (except DTS0 - 1.5 cm). Each "drift" chamber consists of three layers of tubes.

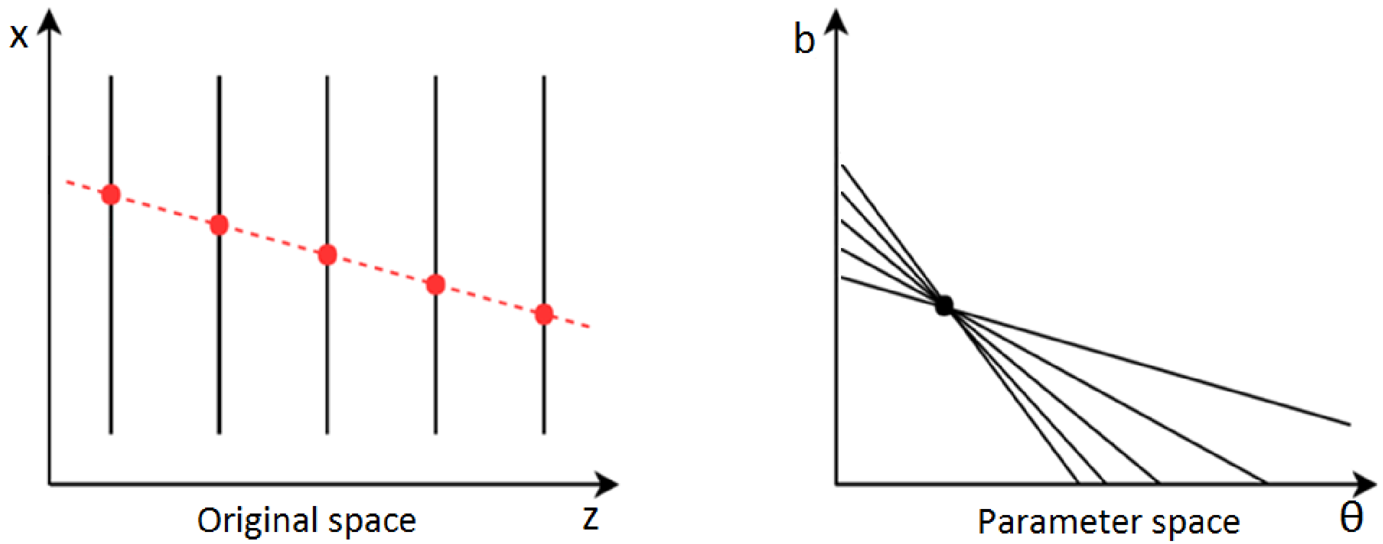
A liquid helium cooling system is used to holding the polarization and performance of the spin rotation system.

Target Magnet (the field is directed downward, the integral is about 0.4 T•m) is used for pumping and holding polarization.

A Guard System is located around the target to highlight exclusive reactions.

Neutral particles registration is carried out by electromagnetic calorimeter (ECAL) – 720 lead-glass cells.

The Hough transform



This method assumes a parametric track description. Each point in the parameter space describes a track in coordinate space. The search for track candidates is reduced to the search for local maxima in a Hough space. For each red point in the original space a straight line in the parameter space is constructed, and their intersection characterizes the track.

Reconstructed number N of $\pi^{\pm}$

$N(\pi^{+})$	$0.0<X_F<0.1$	$0.1<X_F<0.2$	$0.2<X_F<0.3$	$0.3<X_F<0.4$	$0.4<X_F<0.5$	$0.5<X_F<0.6$	$0.6<X_F<0.7$	$0.7<X_F<1.0$
$0.0<P_T<0.5$	*9463873*	*8385284*	*3524408*	*1406370*	*594184*	*274715*	*139023*	*140887*
$0.5<P_T<4.0$	*15124*	*476849*	*1201155*	*971386*	*636463*	*401469*	*255718*	*374674*

$N(\pi^{-})$	$0.0<X_F<0.1$	$0.1<X_F<0.2$	$0.2<X_F<0.3$	$0.3<X_F<0.4$	$0.4<X_F<0.5$	$0.5<X_F<0.6$	$0.6<X_F<0.7$	$0.7<X_F<1.0$
$0.0<P_T<0.5$	*11406664*	*11255134*	*5585071*	*2847597*	*1651537*	*995434*	*639596*	*993864*
$0.5<P_T<4.0$	*27662*	*966387*	*2252962*	*1908131*	*1364632*	*996727*	*773200*	*1646118*