Single-spin asymmetry measurements in inclusive production of K^0_s and ω(782) mesons at U70 (Protvino)

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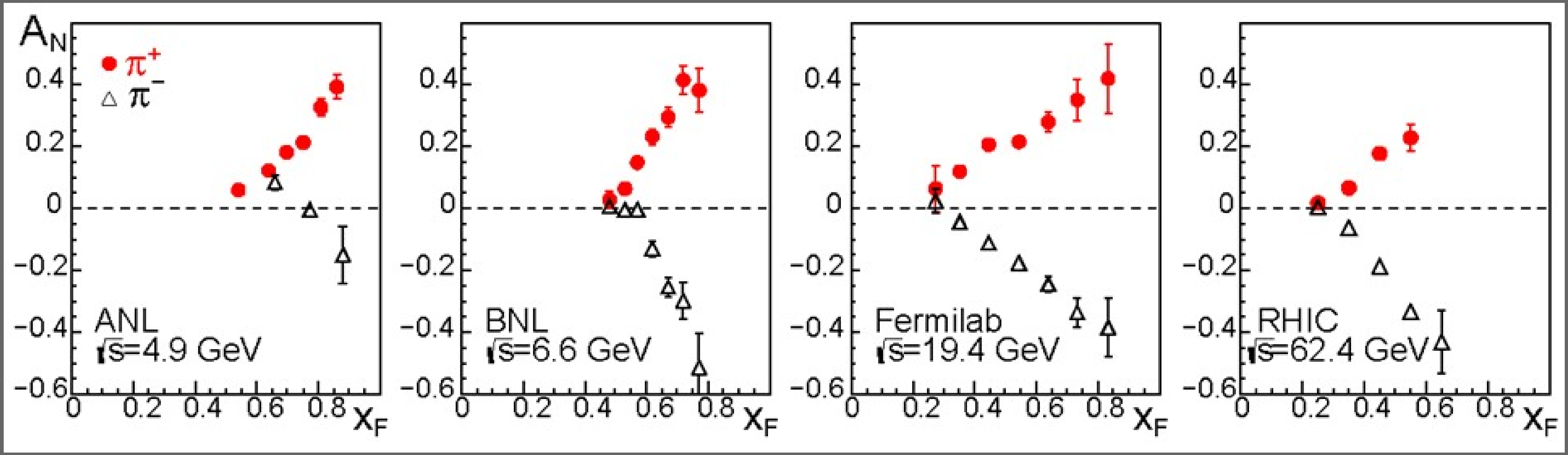
Single-spin asymmetry measurements



Single–spin asymmetries and hyperon polarization almost do not depend on beam energy – accuracy is more important

In the studies proposed at the SPASCHARM experiment, the main goal is investigation of spin effects for a lot of reactions in a wide kinematic region, including comparison of polarization effects in the interaction of particles and antiparticles with matter at the same energy and in the same kinematic region.

SPASCHARM goals

- The project is aimed at studying the spin structure of the nucleon and the spin dependence of the strong interaction at energies up to 50 GeV. The fixed target SPASCHARM experiment will systematically study polarization phenomena in exclusive and inclusive hadronic reactions.
- The universal setup allow to study dozens of reactions. In parallel with single-spin asymmetries, the polarization of hyperons and the elements of the spin density matrix of vector mesons will be measured.
- The ultimate goal of the experiment is to study spin structure of the proton, primarily the determination of the contribution of gluons to the spin of the proton through the investigation of spin effects in the formation of various charmonium states.

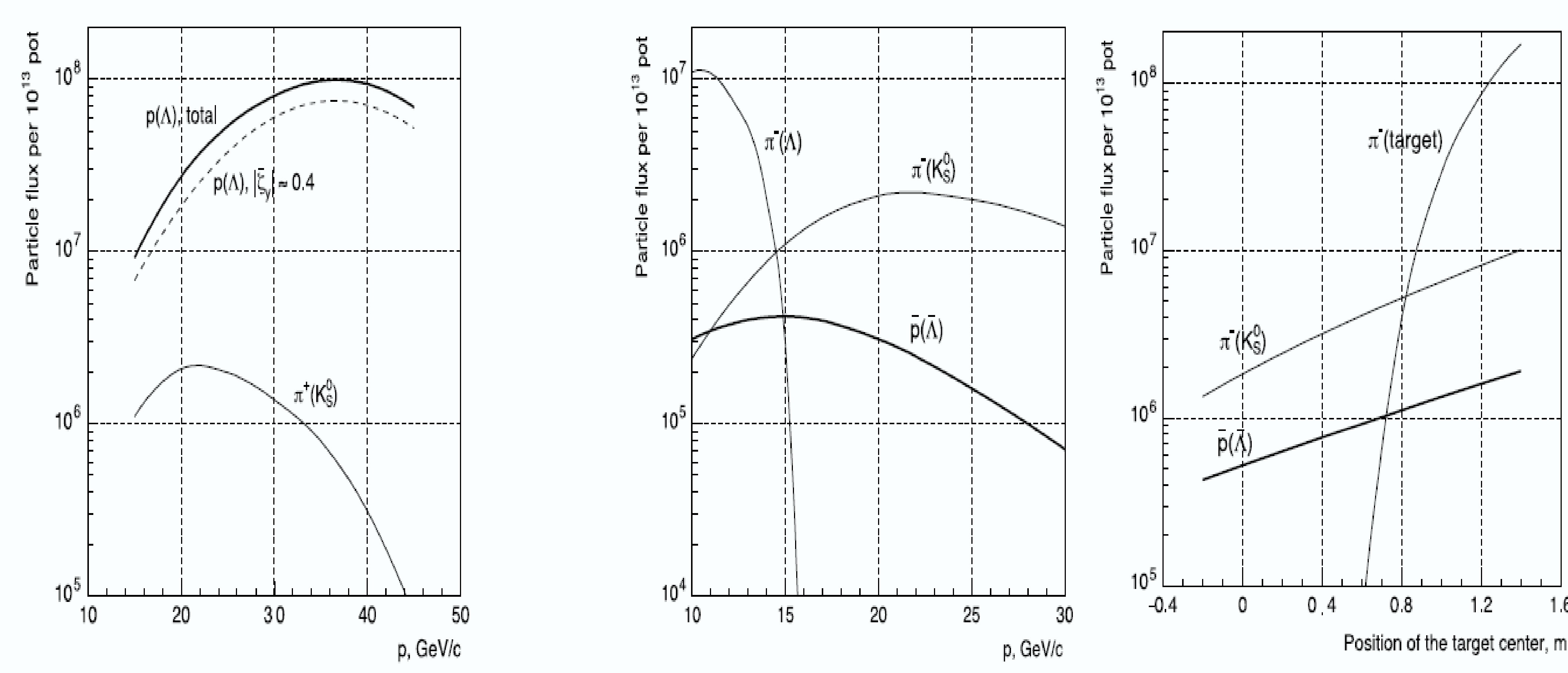
Advantages of the SPASCHARM experiment

- Extensive physical program and systematic studies of the polarization phenomenon
- Variety of beams: polarized beams of protons and antiprotons, unpolarized $\pi^{\pm}$, $K^{\pm}$, p, p̃, d, C
- Transversely and longitudinally polarized proton and nuclear targets
- Lots of studied polarization observables: A_N, P_N, A_{NN}, A_{LL}, D_{NN}, ρ_{ik}
- Full coverage of azimuthal angle to reduce systematic errors
- Identification of secondary particles, both charged and neutral

SPASCHARM experiment stages

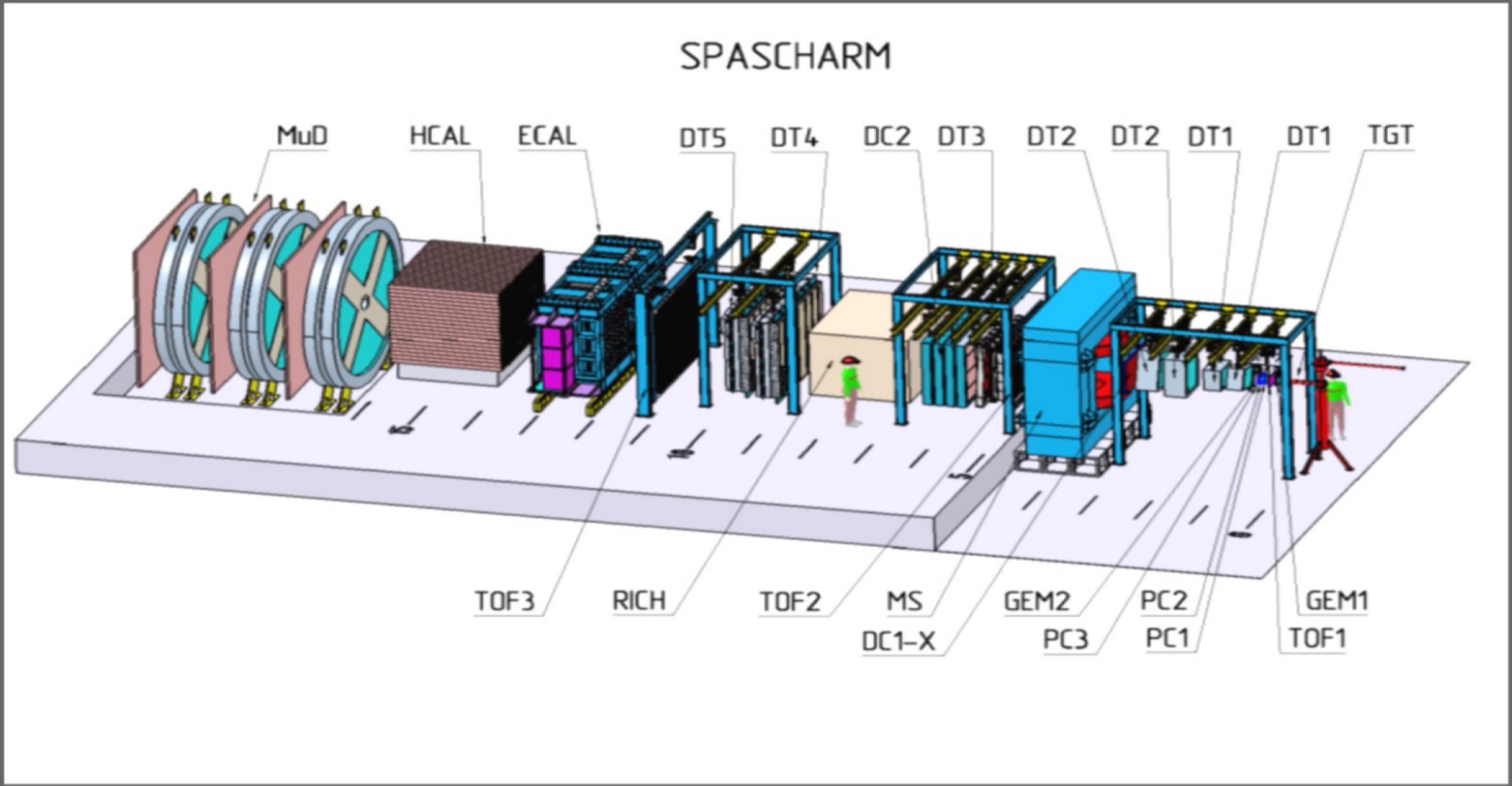
- Stage 1. Single-spin asymmetries on channel 14, including the first measurements of polarization and asymmetry
- Stage 2. Creation of a beam of polarized protons and antiprotons

Polarized beam intensity



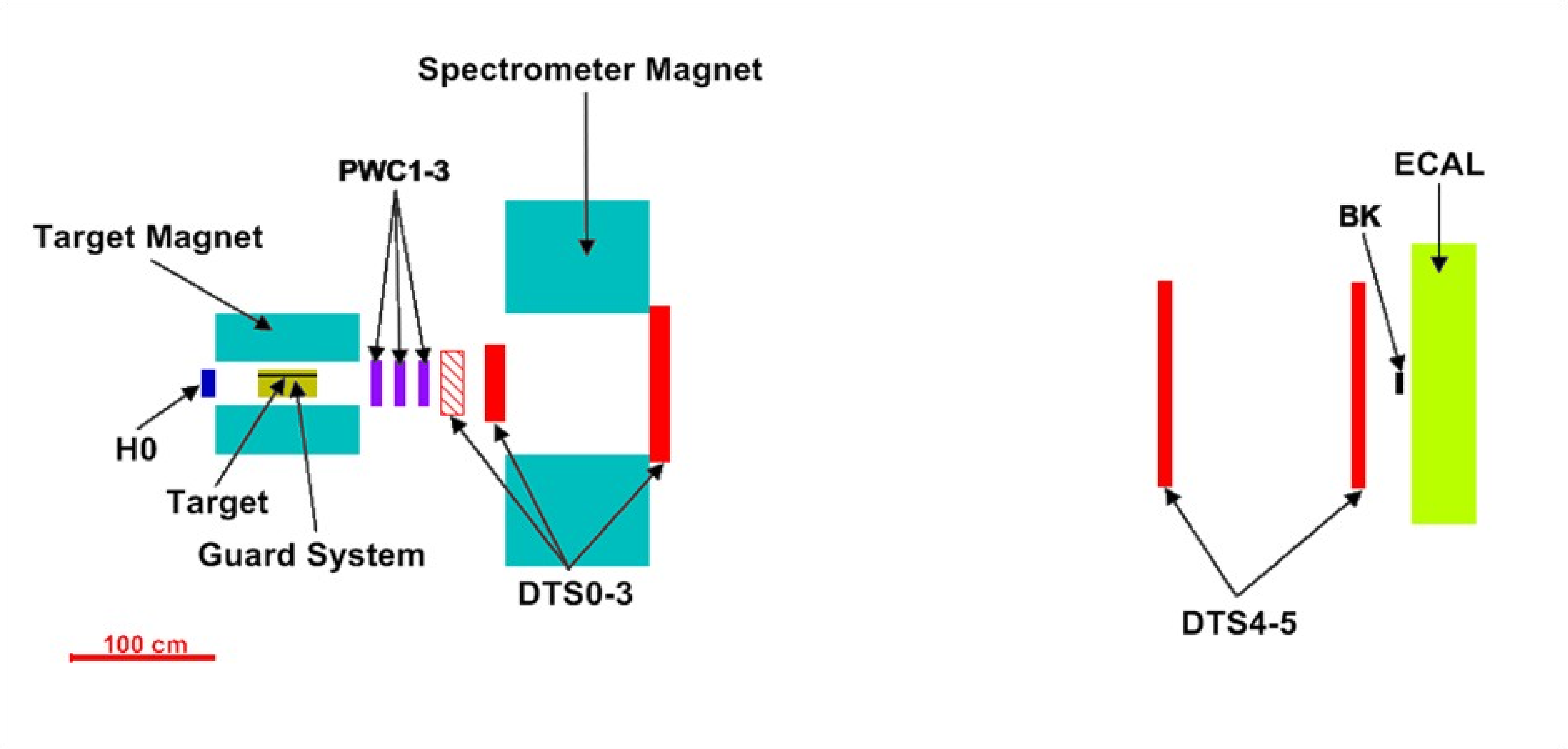
The intensity of the beam of polarized protons and background π^+(a) and antiprotons and background π^- (b,c)-mesons at the end of the channel at the maximum $\Delta p/p$, calculated for 10^{13} protons with an energy of 60 GeV on the primary target.

SPASCHARM setup



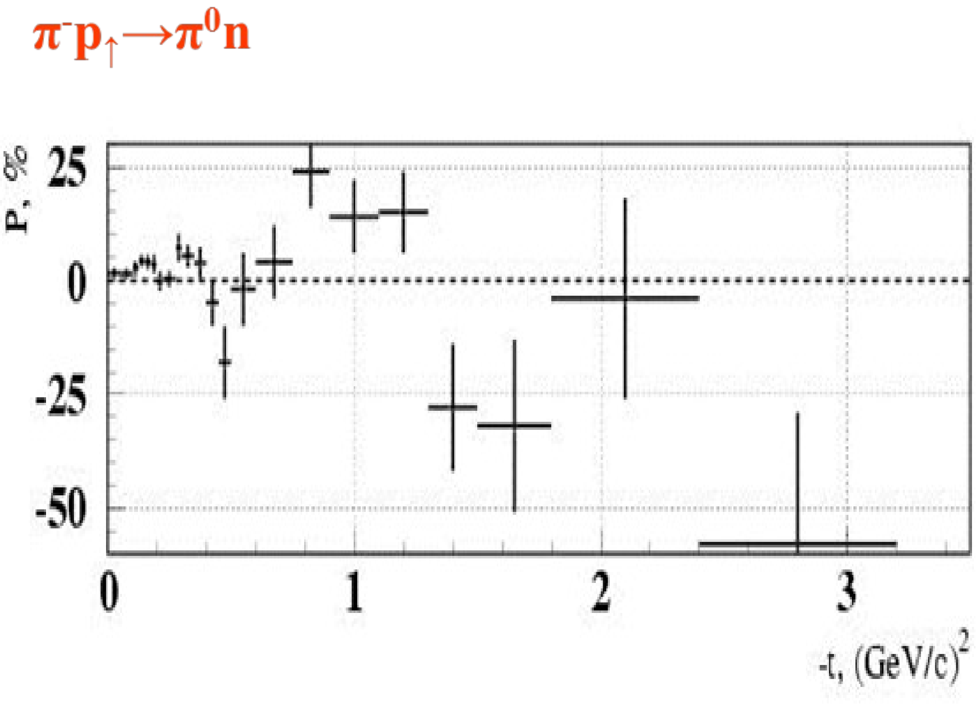
Concept of SPASCHARM experiment

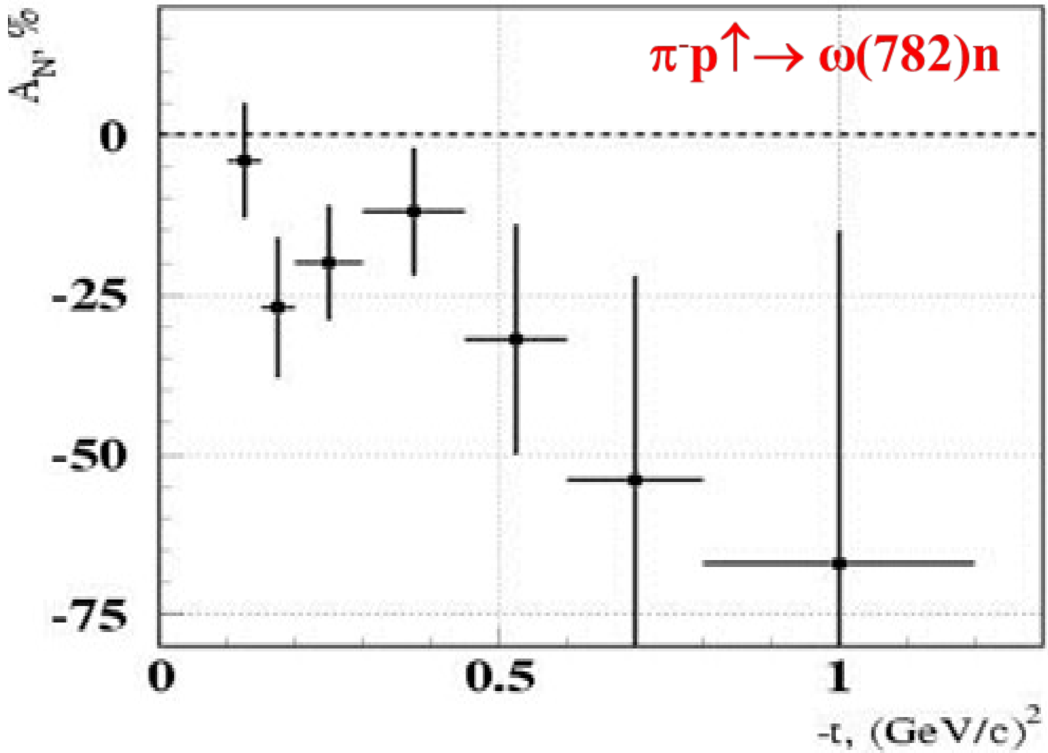
Existing (pilot) version of SPASCHARM setup



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.

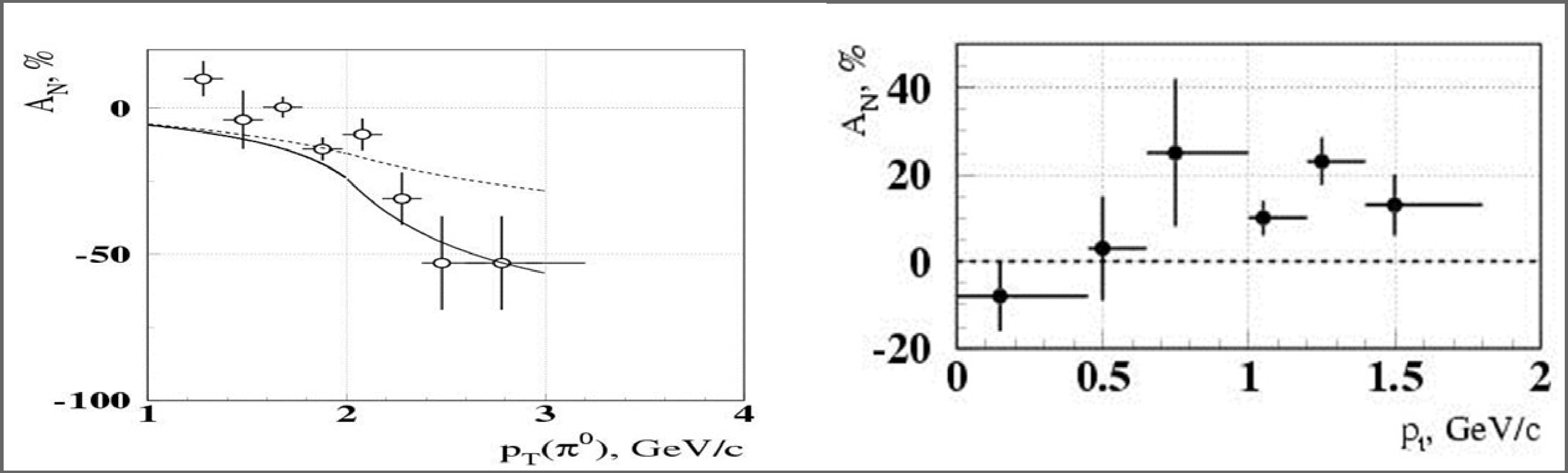
Previous PROZA results





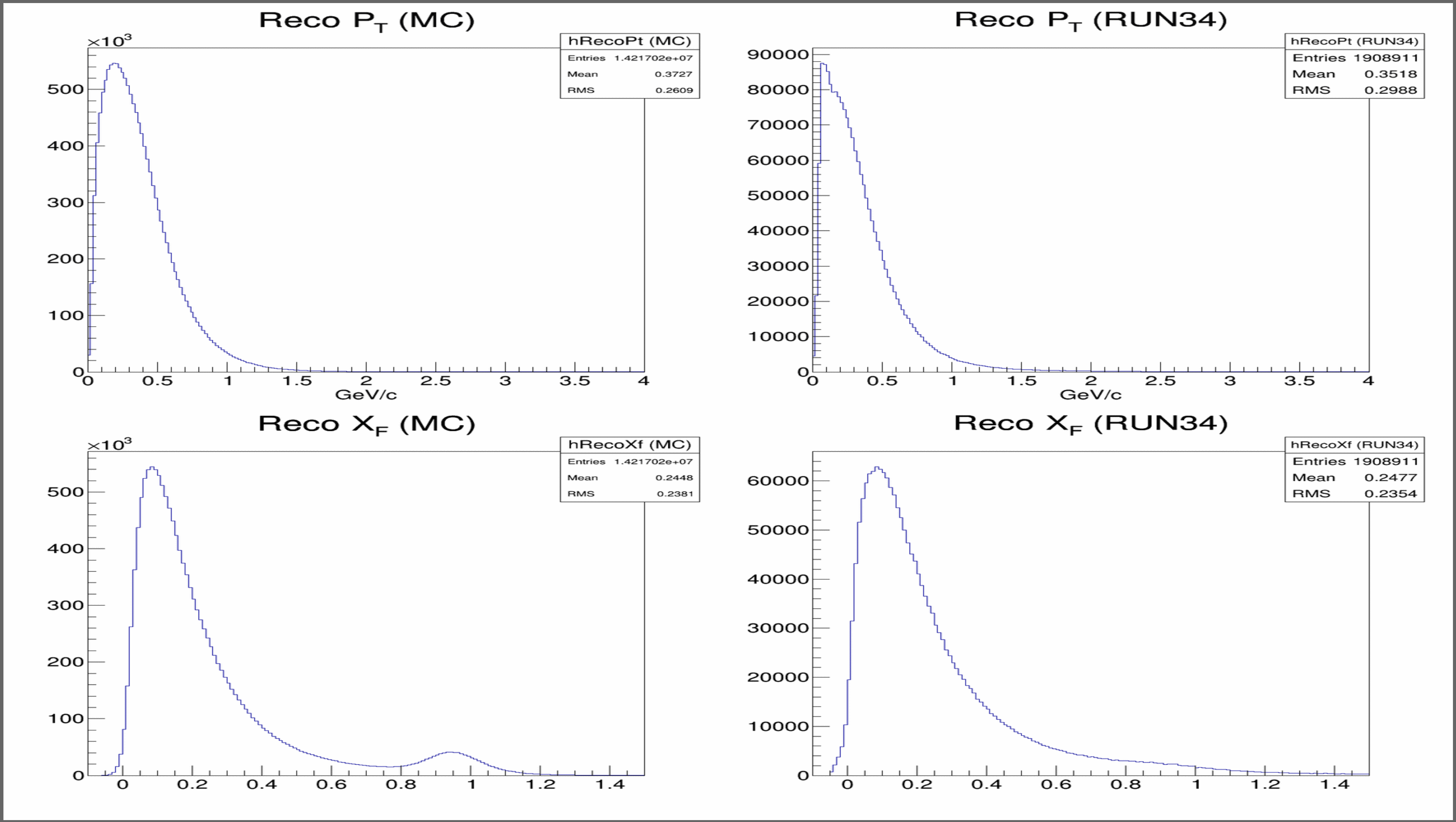
Asymmetry of π^0 (a) and ω(782) (b) in exclusive reactions

Previous PROZA-M results



Asymmetry of π^0 central region ($x_f \approx 0$) (a) and in the unpolarized beam fragmentation region ($x_f > 0.7$) (b).

First DATA analysis



The distribution shapes for MC and experimental data are approximately the same.

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

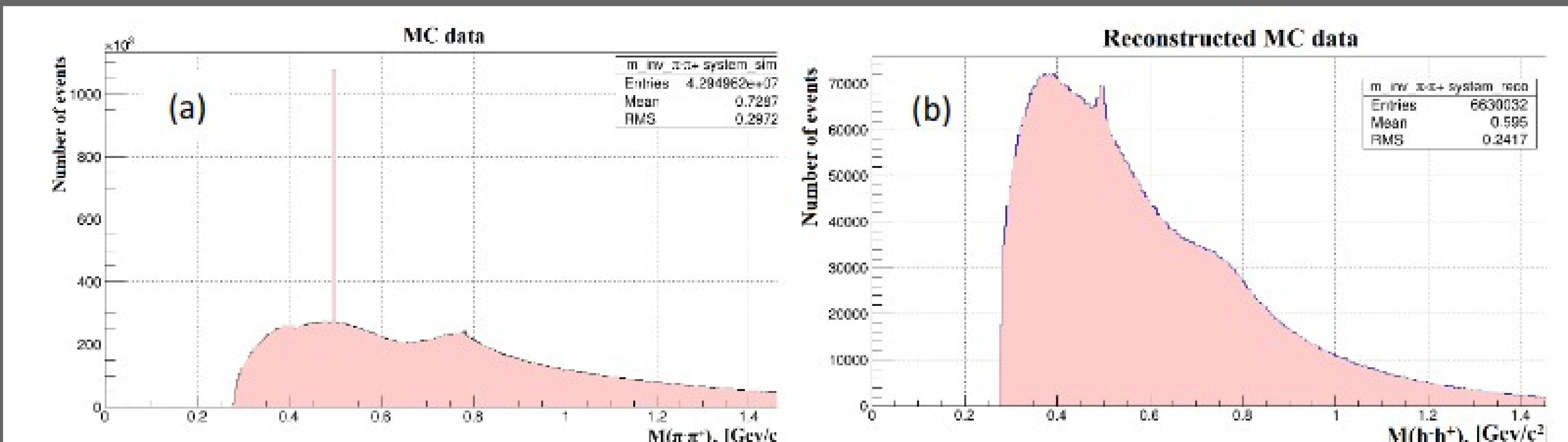
$\delta A_N(\pi^-)$	$0.0<X_F<0.1$	$0.1<X_F<0.2$	$0.2<X_F<0.3$	$0.3<X_F<0.4$	$0.4<X_F<0.5$	$0.5<X_F<0.6$	$0.6<X_F<0.7$	$0.7<X_F<1.0$
$0.0<P_T<0.5$	**0.004**	**0.004**	**0.006**	**0.008**	**0.010**	**0.013**	**0.016**	**0.013**
$0.5<P_T<4.0$	**0.078**	**0.013**	**0.009**	**0.009**	**0.011**	**0.013**	**0.015**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

On average expected statistical accuracy is about 1%

Interest in K^0 and ω(782)

- The spin asymmetries in the production of K-meson have special interest because final state contains an s-quark, which, unlike u- and d-quarks, comes from the 'sea'.
- K^0 registration is simple, even without PID.
- Significant spin effect (asymmetry) was observed in exclusive production of ω(782).
- Branching ratio of $\omega(782) \to \pi^+\pi^-\pi^0$ is $(89.2\pm0.7)\%$

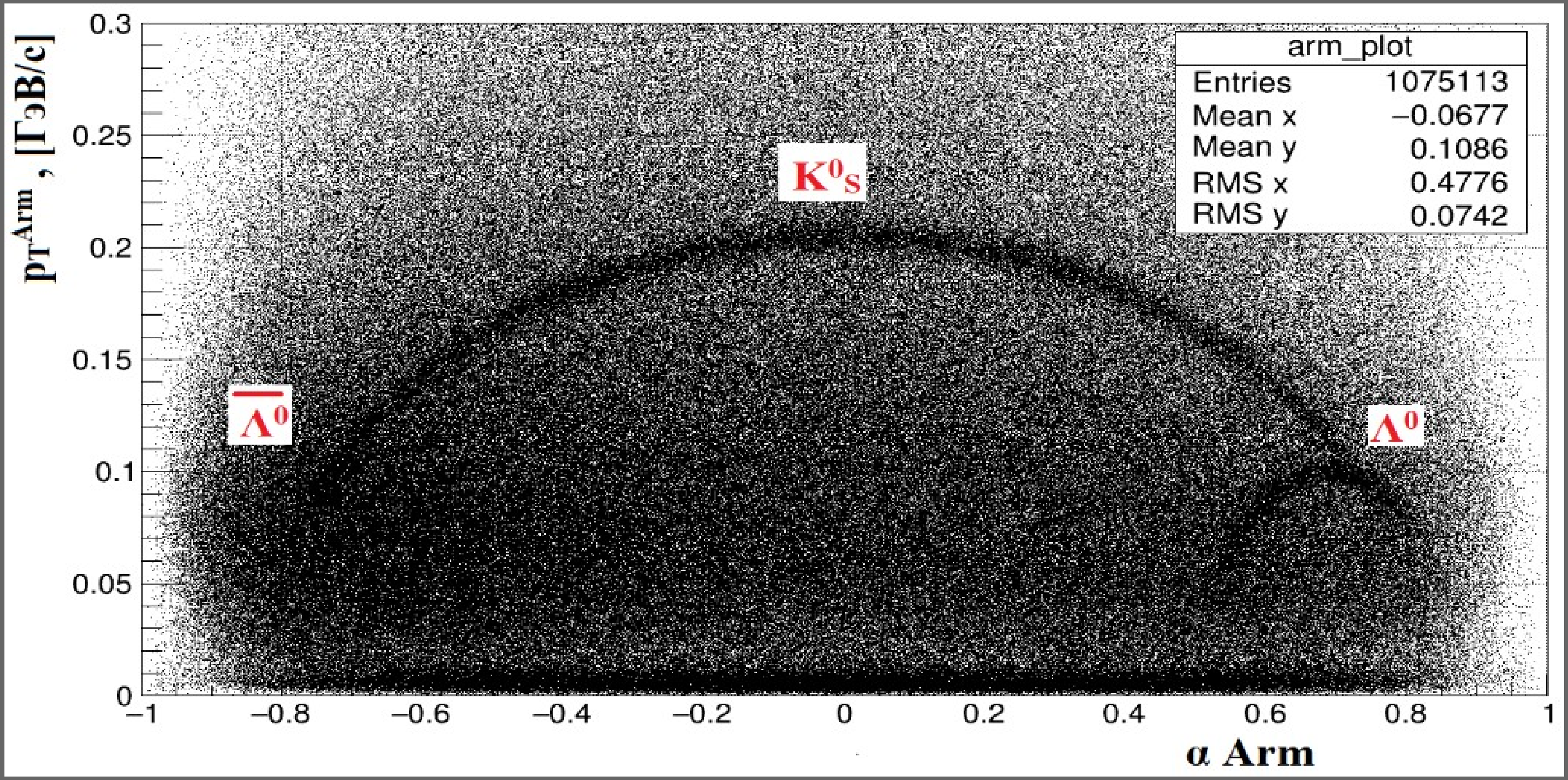
h^+h^- mass spectrum



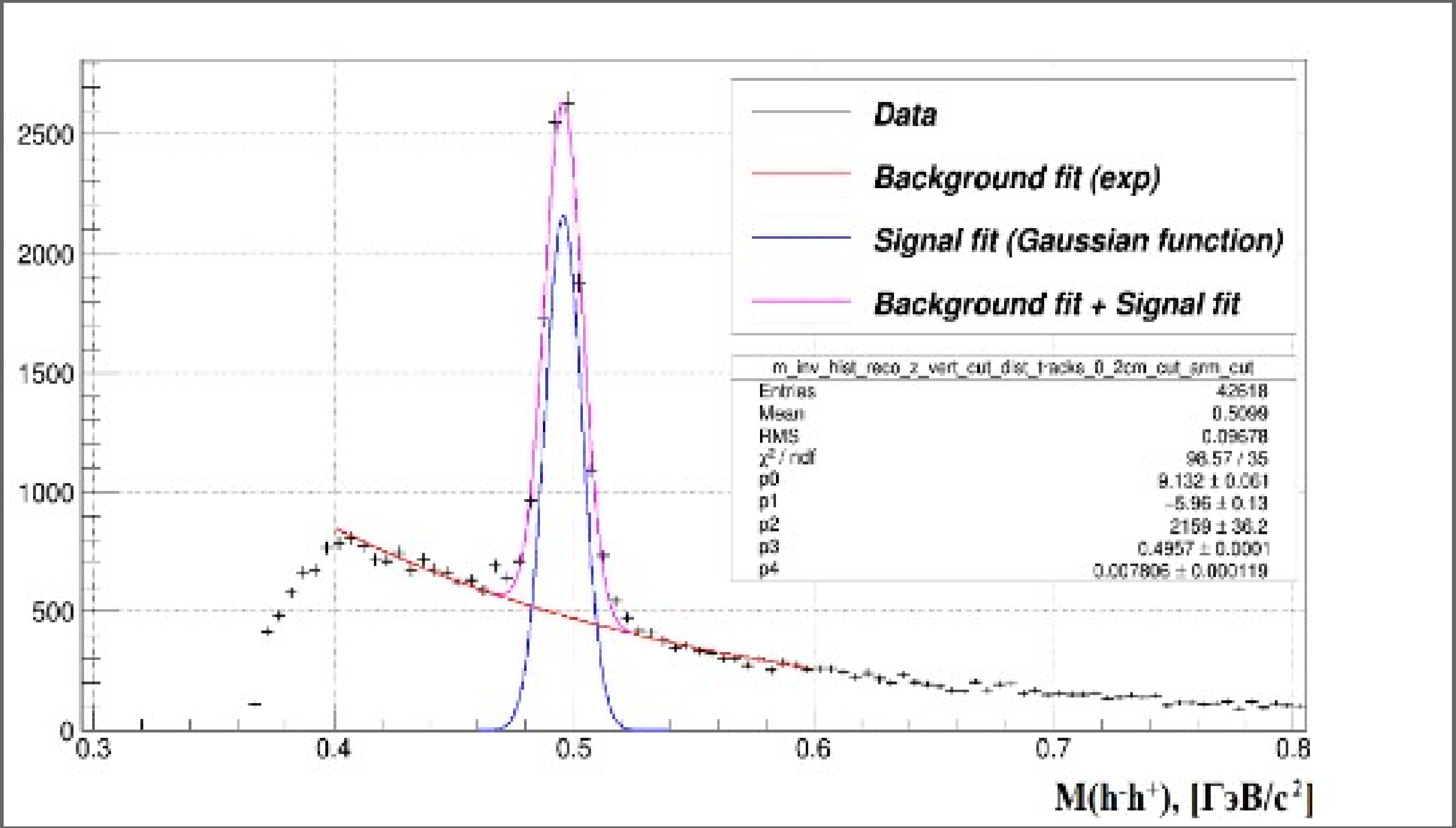
Reconstructed mass M for $\pi^+\pi^-$ pairs for True MC tracks (a) and for reconstructed MC h^+h^- tracks (b)

K^0 reconstruction cut criteria

- The Z-coordinate of the secondary vertex >8 cm from the primary vertex
- Distance between h^+ and h^- tracks <0.6 cm
- The criterion of Armenteros-Podolyansky



Invariant mass spectrum for min-bias events after all kinematics cuts



K^0 width is about 8 MeV/c^2

Expected efficiency and statistics

Table 1. Detection efficiency of the K^0_S production for SPASCHARM setup.

	$0 < p_Z \leq 4.0$	$4.0 < p_Z \leq 8.0$	$8.0 < p_Z \leq 12.0$	$12.0 < p_Z \leq 16.0$	$p_Z > 16.0$
$0 < p_T \leq 0.25$	0.013	0.091	0.093	0.042	0.02
$0.25 < p_T \leq 0.5$	0.004	0.077	0.096	0.069	0.041
$0.5 < p_T \leq 1.0$	-	0.03	0.093	0.084	0.065
$p_T > 1.0$	-	-	0.031	0.071	0.081

Table 2. The expected number of detected K^0_S –mesons for a 20 days long data taking run.

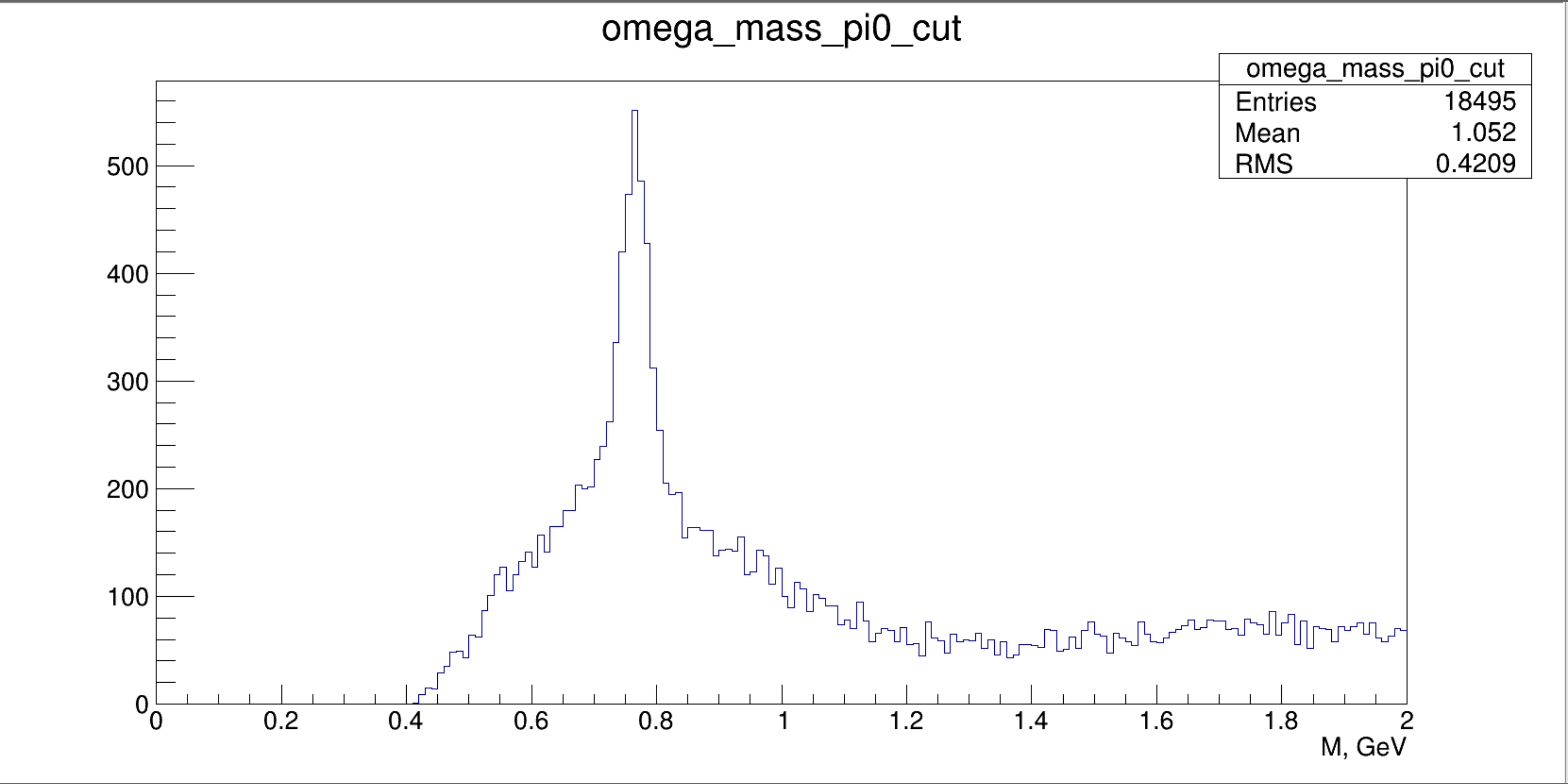
	$0 < p_Z \leq 4.0$	$4.0 < p_Z \leq 8.0$	$8.0 < p_Z \leq 12.0$	$12.0 < p_Z \leq 16.0$	$p_Z > 16.0$
$0 < p_T \leq 0.25$	$6.6 \cdot 10^5$	$1.6 \cdot 10^6$	$5.0 \cdot 10^5$	$9.3 \cdot 10^4$	$3.2 \cdot 10^4$
$0.25 < p_T \leq 0.5$	$3.0 \cdot 10^5$	$2.4 \cdot 10^6$	$1.1 \cdot 10^6$	$3.0 \cdot 10^5$	$1.1 \cdot 10^5$
$0.5 < p_T \leq 1.0$	$3.0 \cdot 10^3$	$1.0 \cdot 10^6$	$1.3 \cdot 10^6$	$4.6 \cdot 10^5$	$1.6 \cdot 10^5$
$p_T > 1.0$	-	$4.9 \cdot 10^3$	$1.1 \cdot 10^5$	$1.1 \cdot 10^5$	$5.0 \cdot 10^4$

Expected accuracy

Table 3. The estimates for statistical errors on the A_N measurements in inclusive K^0_S -production for 20 days long data taking run.

	$0 < p_Z \leq 4.0$	$4.0 < p_Z \leq 8.0$	$8.0 < p_Z \leq 12.0$	$12.0 < p_Z \leq 16.0$	$p_Z > 16.0$
$0 < p_T \leq 0.25$	0.016	0.01	0.018	0.043	0.073
$0.25 < p_T \leq 0.5$	0.024	0.008	0.012	0.024	0.039
$0.5 < p_T \leq 1.0$	0.237	0.013	0.011	0.019	0.033
$p_T > 1.0$	-	0.186	0.039	0.039	0.058

Reconstructed mass M for $\pi^+\pi^-\pi^0$ clusters with cut on π^0 mass



Expected statistics and accuracy

The expected numbers of detected ω(782) for one experimental run		
	$p_z < 12$ GeV	$p_z > 12$ GeV
$p_t < 0.5$ GeV	$0{,}6 \cdot 10^5$	$3{,}5 \cdot 10^5$
$p_t > 0.5$ GeV	$0{,}7 \cdot 10^5$	$3{,}1 \cdot 10^5$

The estimates for statistical errors on the A_N measurements in inclusive ω(782) production for one experimental run		
	$p_z < 12$ GeV	$p_z > 12$ GeV
$p_t < 0.5$ GeV	0,052	0,022
$p_t > 0.5$ GeV	0,050	0,024

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 particle beam. First results on asymmetry measurements of charged pions are expected soon.
- Single-spin asymmetry in inclusive K_0 production on the SPASCHARM setup can be measured with an accuracy of 2% in various kinematic regions for p_T and p_Z.
- Single-spin asymmetry in inclusive ω(782) production on the SPASCHARM setup can be measured with an accuracy of 2.5% at p_T>0,5 GeV and p_Z>12 GeV.
- The new data taking run at the U70 accelerator is expected in November 2021.

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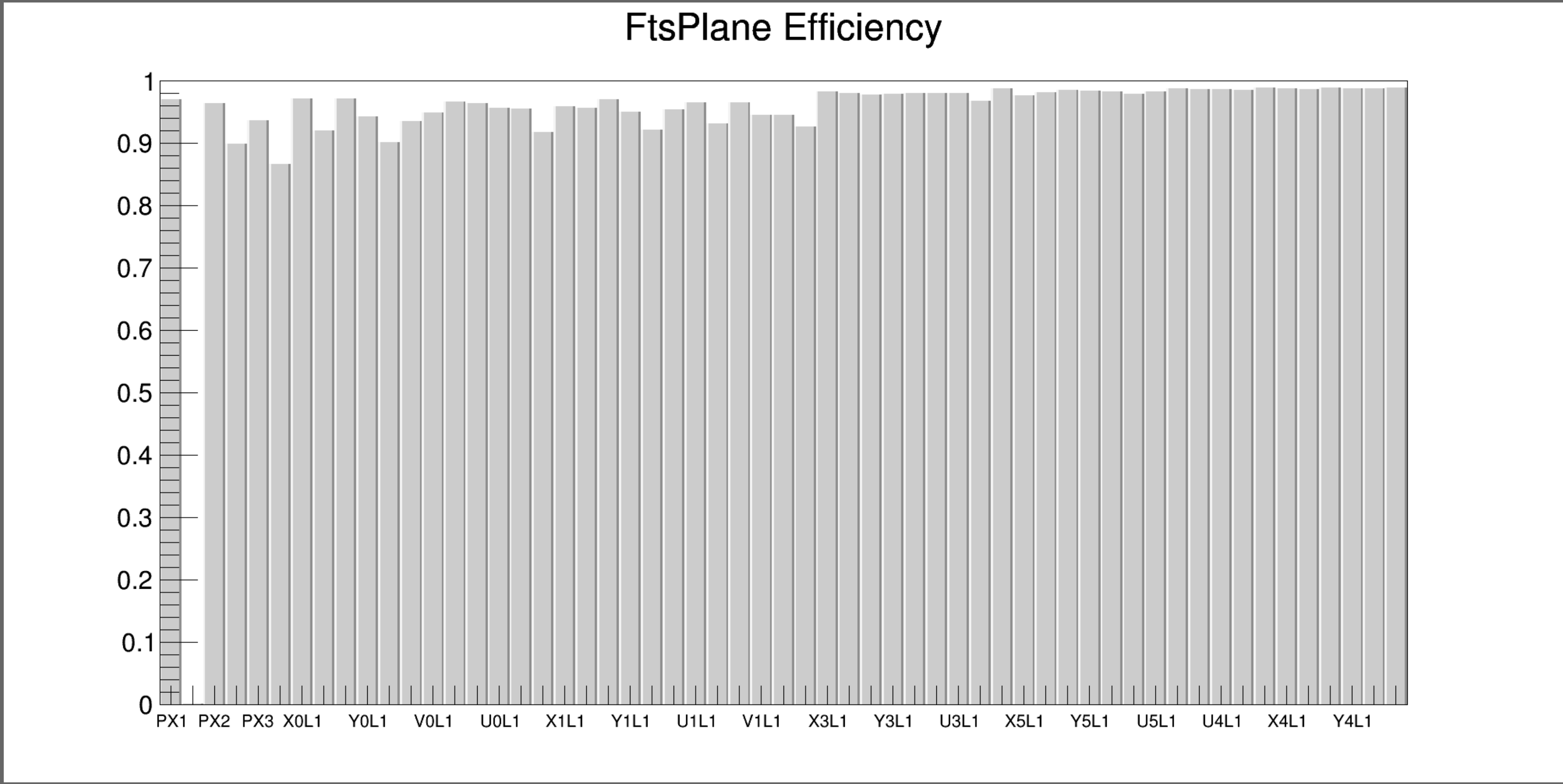
Backup Slides

Tracking system efficiencies



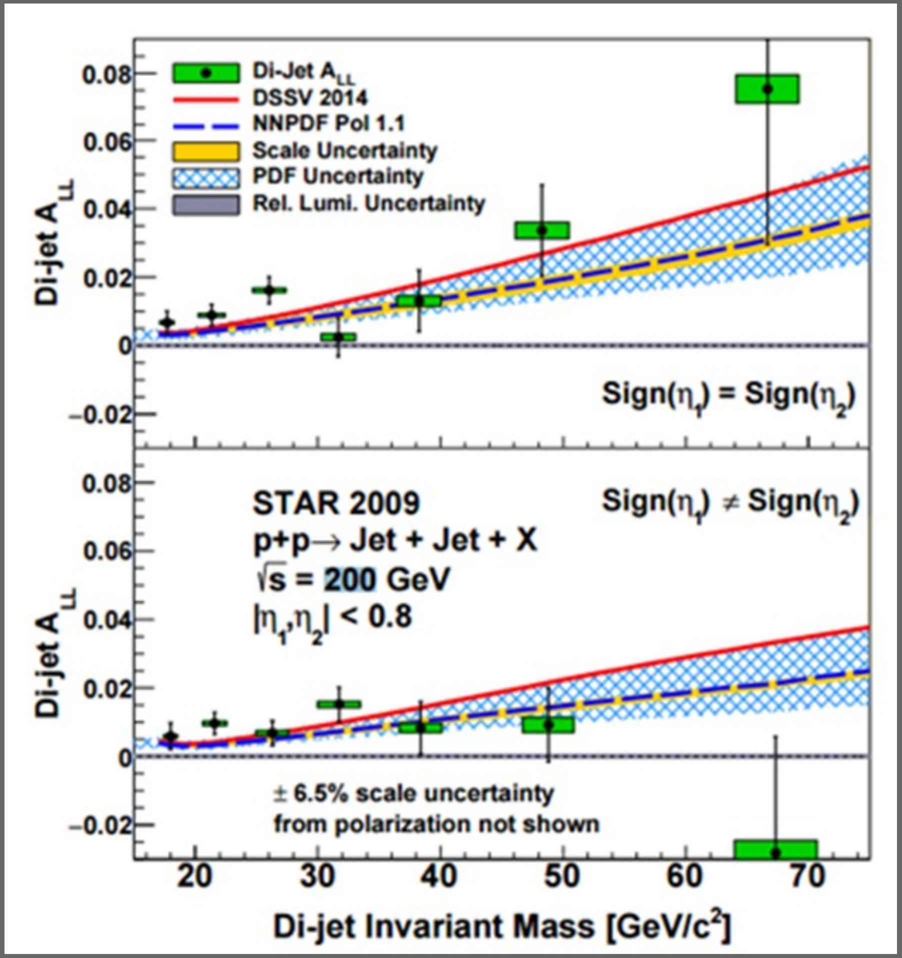
In the special test-beam run in the 2019, the tracking system has been tuned up, and the higher efficiency has been achieved for all the sub-planes of tracking detectors.

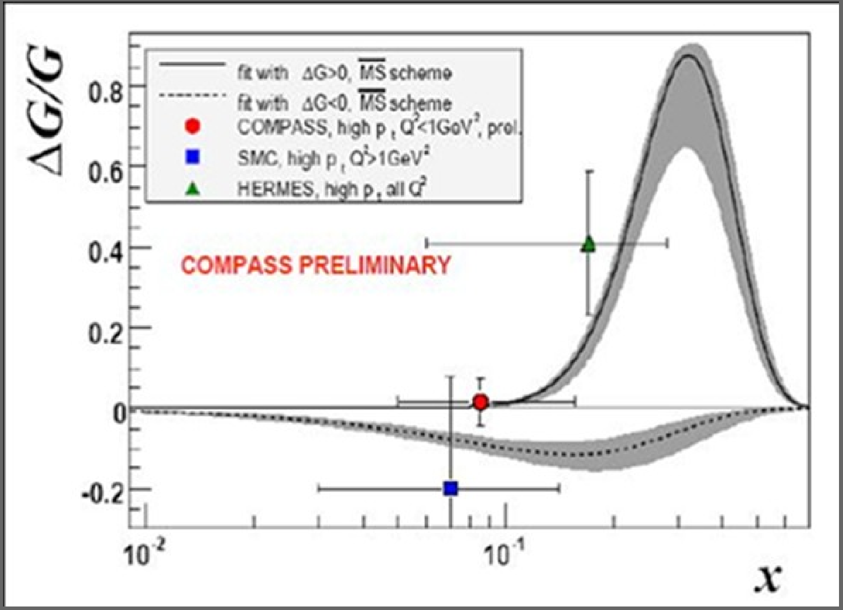
SPASCHARM tracking system

Detector name	Distance from target, [m]	Planes	Tube diameter, [mm]	Dimensions, Y[см]xX[см]	Channels
DTS0	1,00	U,V,X,Y	15	48 × 48	384
DTS1	1,67	X,Y,U,V	30	72 × 96	336
DTS3	5,29	X,Y,U	30	120 × 168	432
DTS5	8,07	X,Y,U	30	192 × 240	672
DTS4	9,77	X,Y,U	30	192 × 240	672
PC1	0,81	X,Y	1	20 × 20	400
PC2	0,85	X,Y	1	20 × 20	400
PC3	0,89	X,Y	1	20 × 20	400

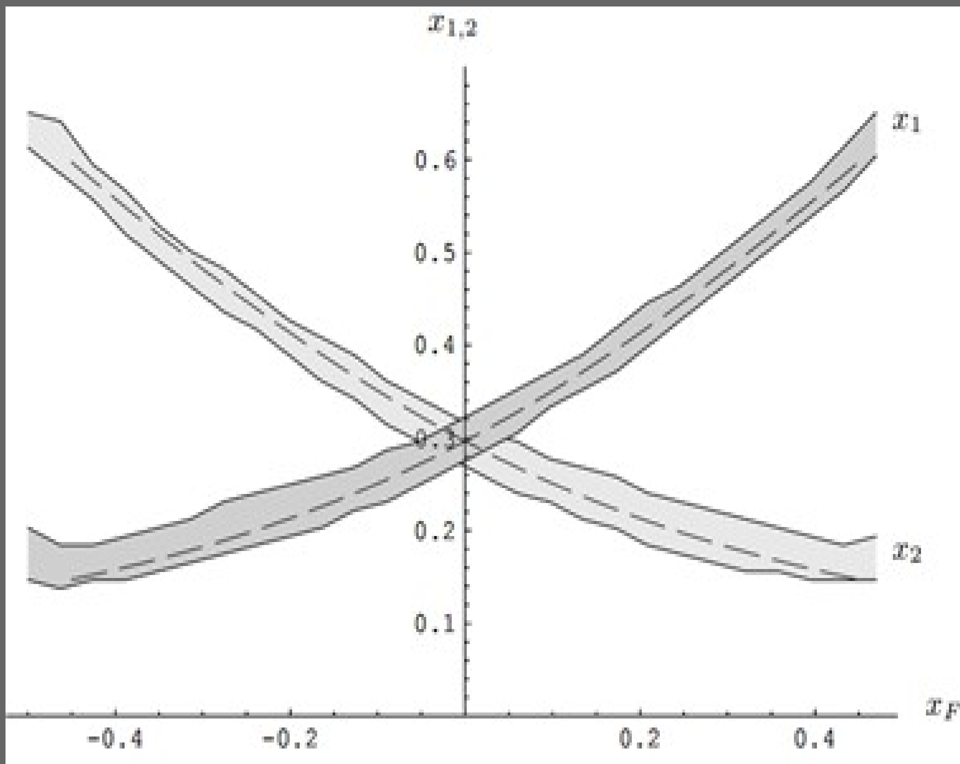
Parameters of SPASCHARM experiment’s track system

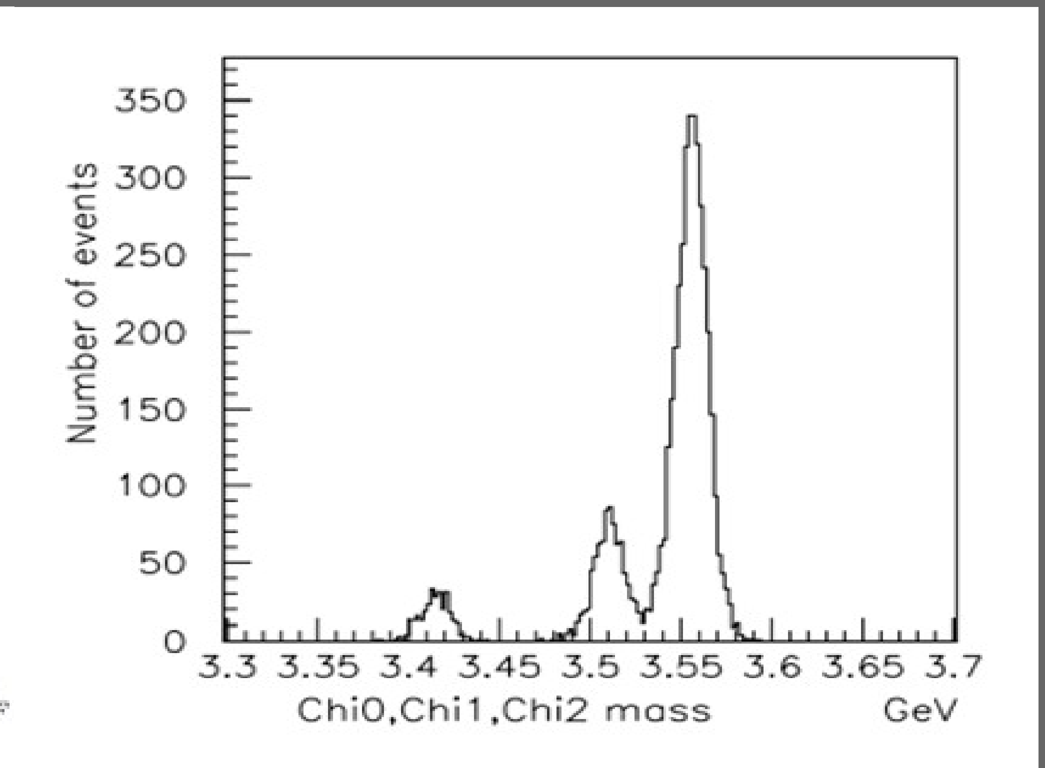
Double-spin asymmetry measurements (motivation)





SPASCHARM experiment

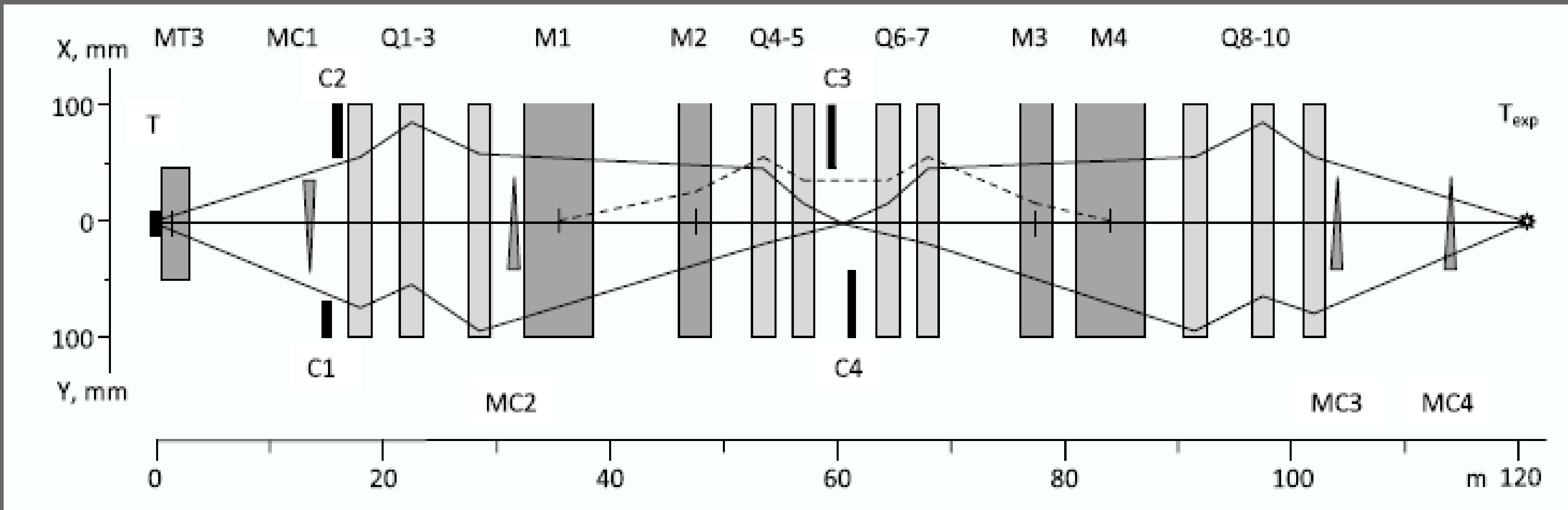




Prediction of double-spin assymetries' measurments

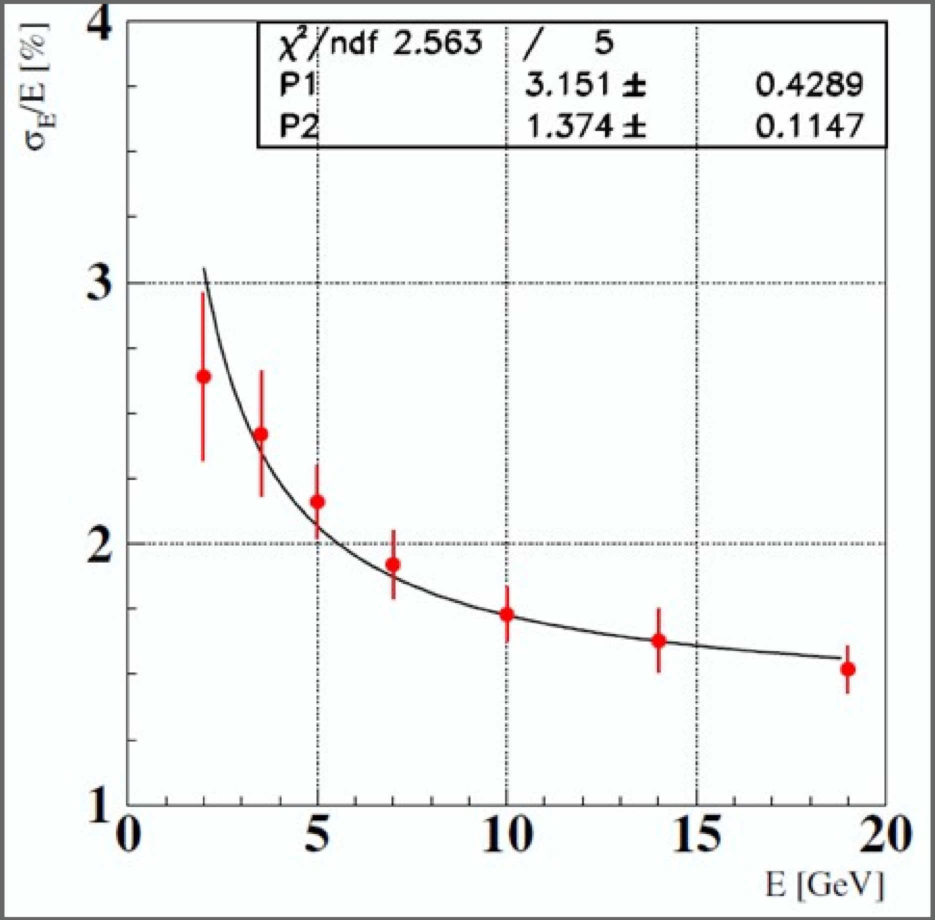
Double-spin asymmetry A_{LL} in charmonium production to study gluon polarization *ΔG/G(x)* at

Optical scheme and properties



p, ГэВ/с	15		30		45	
$\sigma_{\Delta p/p}$, %	2.0	4.5	1.4	4.4	1.2	4.1
$\sigma_x \times \sigma_y$, мм	17 × 14	19 × 16	14 × 10	17 × 11	11 × 8.7	16 × 9.0
$\sigma_{x'} \times \sigma_{y'}$, мрад	1.4×1.5	1.3×1.5	1.5×1.8	1.3×1.8	1.4×1.7	1.4×1.7
I_p per 10^{13} pot	3.5×10^6	9.2×10^6	2.1×10^7	7.8×10^7	1.5×10^7	6.8×10^7

SPASCHARM experiment

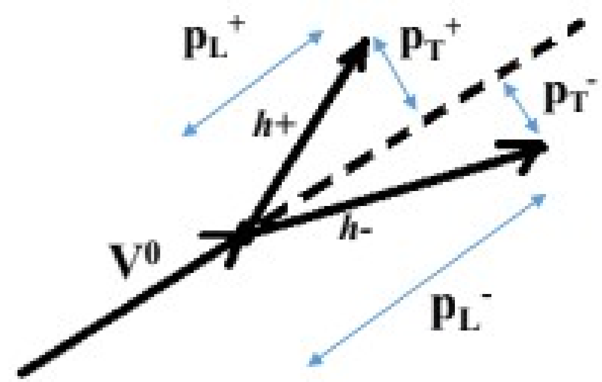


Energy resolution of SPASCHARM's electromagnetic calorimeter

$K^0_S \rightarrow \pi^- \pi^+$

$\Lambda^0 \rightarrow p \pi^-$

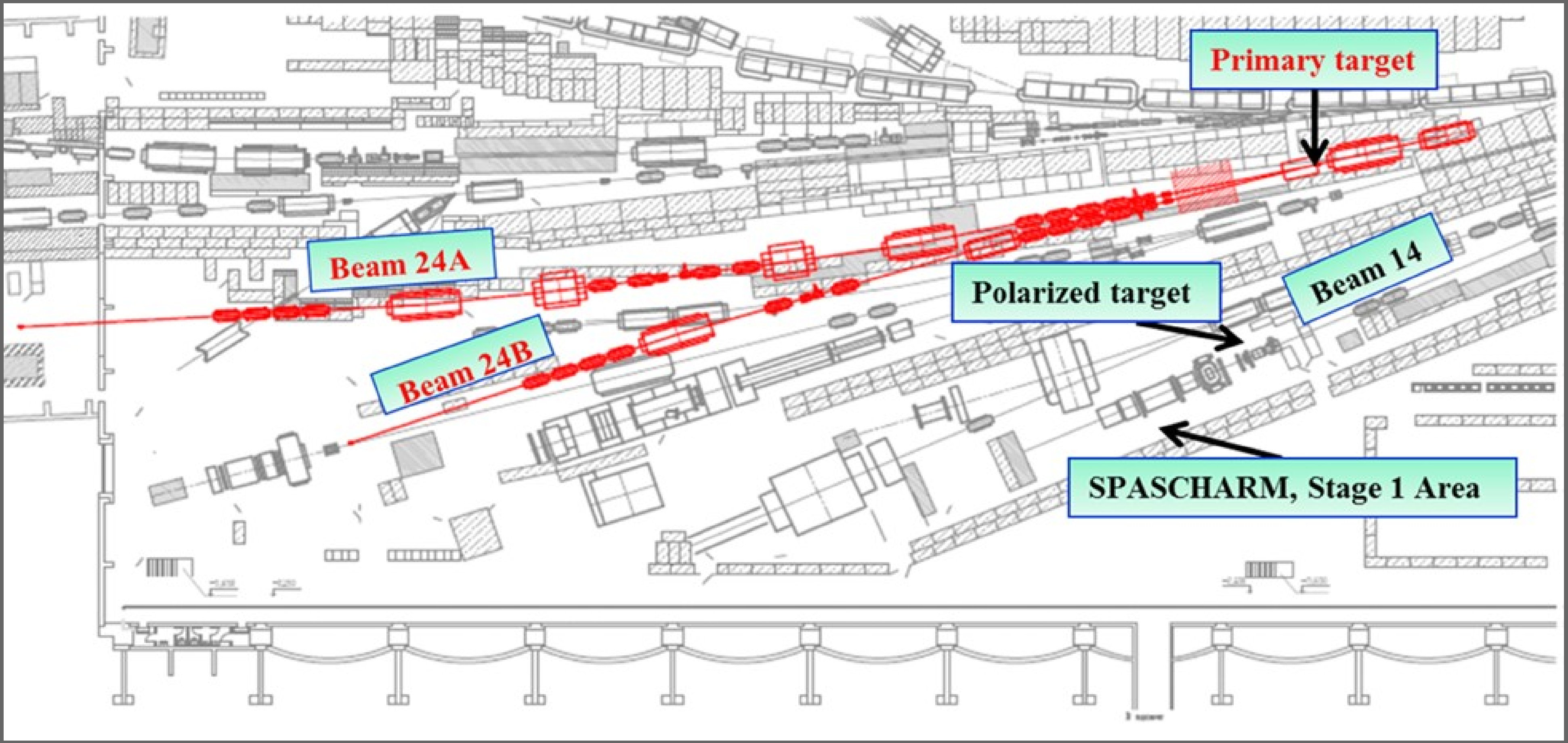
$\overline{\Lambda^0} \rightarrow \bar{p} \pi^+$



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

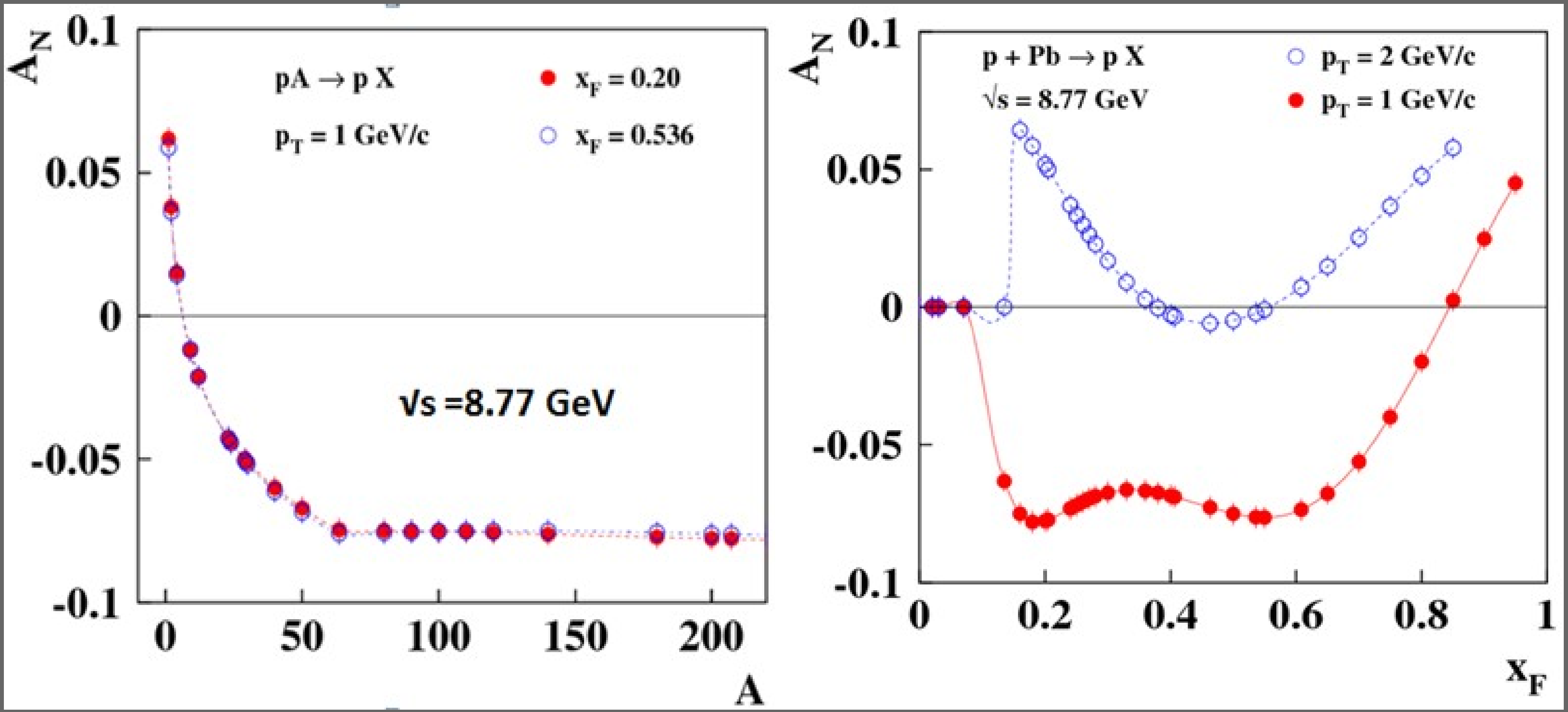
Для K^0_S : $p_T^{\pm} > 0.11$ ГэВ/с и $|\alpha| < 0.45$

Polarized beams facility



Layout of channels 24A and 24B in the experimental hall of U-70 accelerator

Some predictions



Prediction of single-spin asymmetries' measurements