New polarization program at U70

A.N.Vasiliev (IHEP-Protvino)
on behalf of the SPASCHARM group

XII International workshop on high energy spin physics

(Dubna-Spin07)

September 2007

SPASCHARM – SPin ASymmetries in CHARMonium production

S.I.Alekhin, N.I.Belikov, B.V.Chujko, Y.M.Goncharenko, V.N.Grishin, A.M.Davidenko, A.A.Derevschikov, V.A.Kachanov, V.Y.Kharlov, A.S.Kozhin, D.A.Konstantinov, V.A.Kormilitsin, V.I.Kravtsov, A.K.Likhoded, A.V.Luchinsky, Y.A.Matulenko, Y.M.Melnik, A.P.Meschanin, N.G.Minaev, V.V.Mochalov, D.A.Morozov, L.V.Nogach, S.B.Nurushev, A.F.Prudkoglyad, A.V.Ryazantsev, P.A.Semenov, L.F.Soloviev, S.R.Slabospitsky, M.N.Ukhanov, A.V.Uzunian, A.N.Vasiliev, A.S.Vovenko, A.E.Yakutin

(IHEP-Protvino)

N.A.Bazhanov, N.S.Borisov, V.G.Kolomiets, A.B.Lazarev, A.B.Neganov, Y.A.Plis, O.N.Schevelev, Y.A.Usov

(JINR-Dubna)

Contents

1. Introduction
2. Physics with polarized proton beam :
   - possibility to accelerate polarized protons at U70
   - A_{LL} in charmonium production -> spin structure of the proton
3. Physics with unpolarized beams :
   - single-spin asymmetries in inclusive production of light resonances
   - single-spin asymmetries in exclusive production of light resonances
4. Conclusion

Possibility to accelerate polarized protons at U70

A possibility to accelerate high-intensive polarized proton beam up to 70 GeV at the IHEP U70 accelerator, extract it from the main ring and deliver to several experimental setups was intensively studied last time in 2005 and Spring of 2006 in Protvino. We proposed to study a wealth of single- and double-spin observables in various reactions using longitudinally and transversely polarized proton beams at U70.

Unfortunately the proposal stuck in the Ministry of Education and Science in Summer 2006. But we believe that a possibility to push the proposal still exists.

Accelerated polarized proton beam at U70

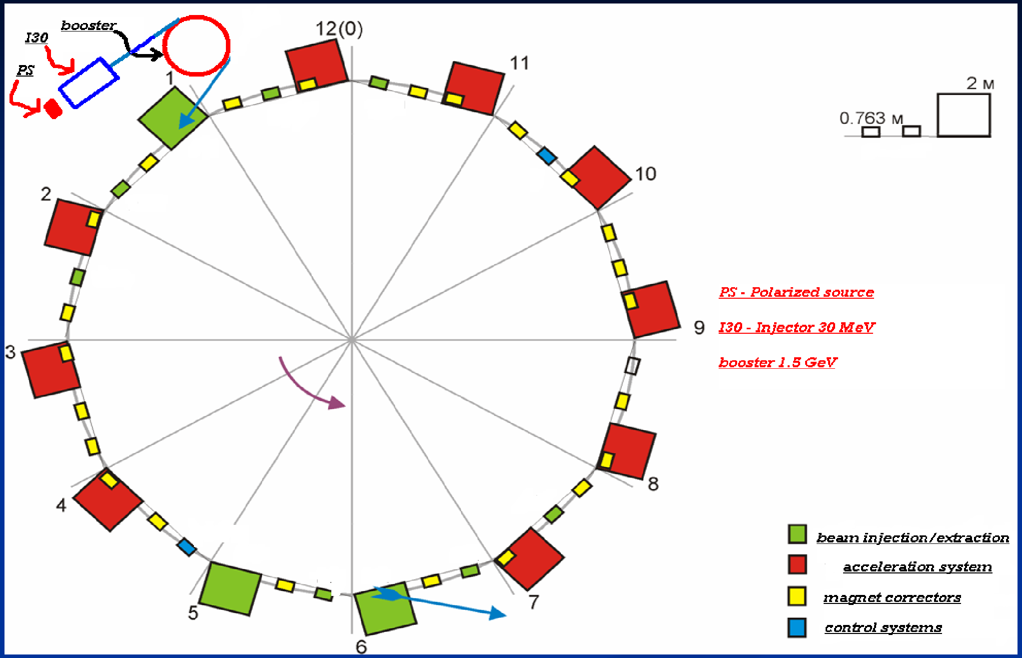
For extracted beams :

Intensity up to 5×10^{12}/spill

Energy up to 70 GeV

Polarization up to 70%

Polarized proton source up to 20 mA



Fight depolarization :

One partial snake in Booster

Three partial snakes in U70 (snake strength $W=\varphi/2\pi=0.1$-0.15)

Snakes : 12 superconducting helicoidal magnets , length 0.6-0.7m, magnetic field 5-6 Tl (straight sections in U70 are of 4.6 m in length)

Polarimetry – elastic scattering in CNI region (polarized jet target)

Collaboration of the three institutes :

Institute for High Energy Physics, Protvino

Institute of Nuclear Research, Troitsk

Budker Institute of Nuclear Physics, Novosibirsk

Physics with polarized proton beam:

1. Double-spin asymmetry A_{LL} in charmonium production ($\Delta G/G$ gluon polarization at x near 0.3 through χ_2 if gluon-gluon fusion is significant).

   In spite of many years of experiments, a detailed decomposition of the spin of the proton remains elusive – new experimental data on $\Delta g(x,Q^2)$, especially at large x are badly needed.

2. Transversity in Drell-Yan muon (electron) pairs

3. Precision measurement of single-spin asymmetry in inclusive production of miscellaneous resonances in the transverse polarized beam fragmentation region in a wide (x_F, p_T)-region.

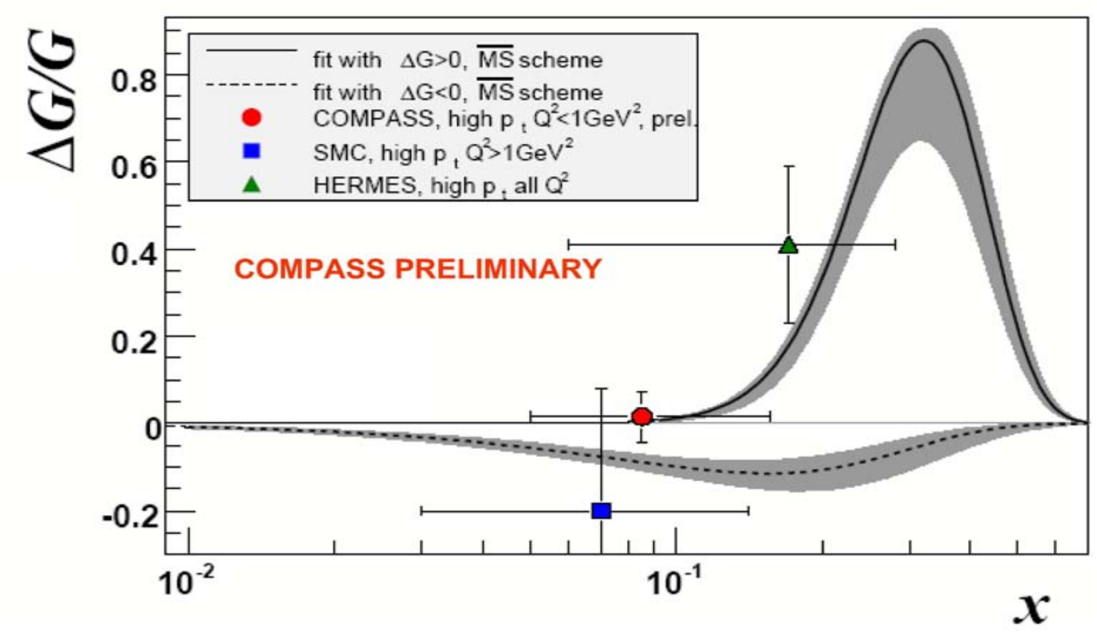
Longitudinal double-spin asymmetry in Charmonium production

- *We propose to simultaneously measure the double-spin asymmetry A_{LL} for inclusive χ_2, χ_1 and J/Ψ by utilizing the 70 GeV/c longitudinally polarized-proton beam on a longitudinally polarized target.*

- *Our goal is to obtain besides the quark-spin information also the gluon-spin information from these three processes in order to determine what portion of the proton spin is carried by gluons. Better understanding of charmonium production at U-70 energies is needed – for this pion and proton beams will be used to produce charmonium.*

- **Gluon contribution into the proton spin as well as strange quarks and orbital momentum contributions - worldwide studies at HERMES, COMPASS, RHIC, JLAB and SLAC.** ***We propose a new experiment in this field – should be complimentary to the existing experiments. Will give new data at large x for Global analysis – see the next slide.***

ΔG/G



✓ **Gluon polarisation Δ*G/G***

- **Unpolarised *G*(*x*) from MRST**
- **Bands correspond to statistical errors of Δ*G***

H. Santos (helena@lip.pt)

Requirements on beam intensity

Information about gluon polarization might be obtained through simultaneous measurements of A_{LL} in inclusive production of χ_2 and J/Ψ . This experiment was proposed at Fermilab (P838) at 200 GeV as a continuation of E704. The Fermilab's PAC pointed out that physics is extremely interesting , but an intensity of the polarized proton beam from Λ-hyperon decays was small – the statistics would not be enough. The experiment was not approved.

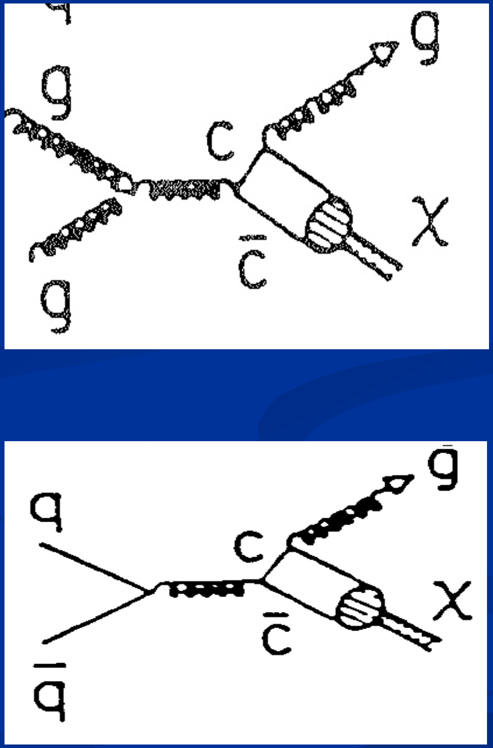
In our new proposal for U70 we expect to have up to $4 \cdot 10^8$ /min instead of $2.7*10^7$/min (P838) (factor 15!).

Charmonium production mechanisms in hadronic interactions

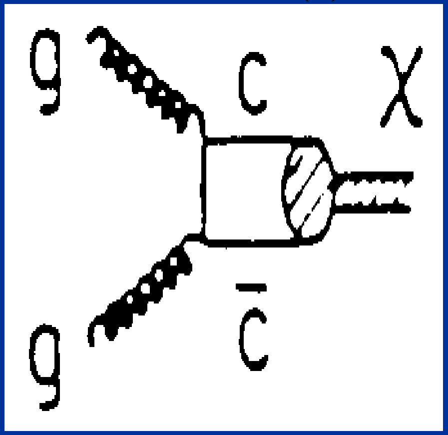
The hadronic production of the χ states involves three parton fusion diagrams :

- gluon fusion (a);
- light quark annihilation (b);
- color evaporation (c).

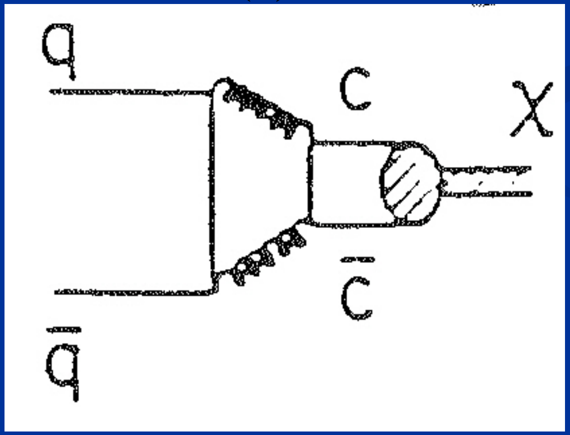
(c)



(a)



(b)

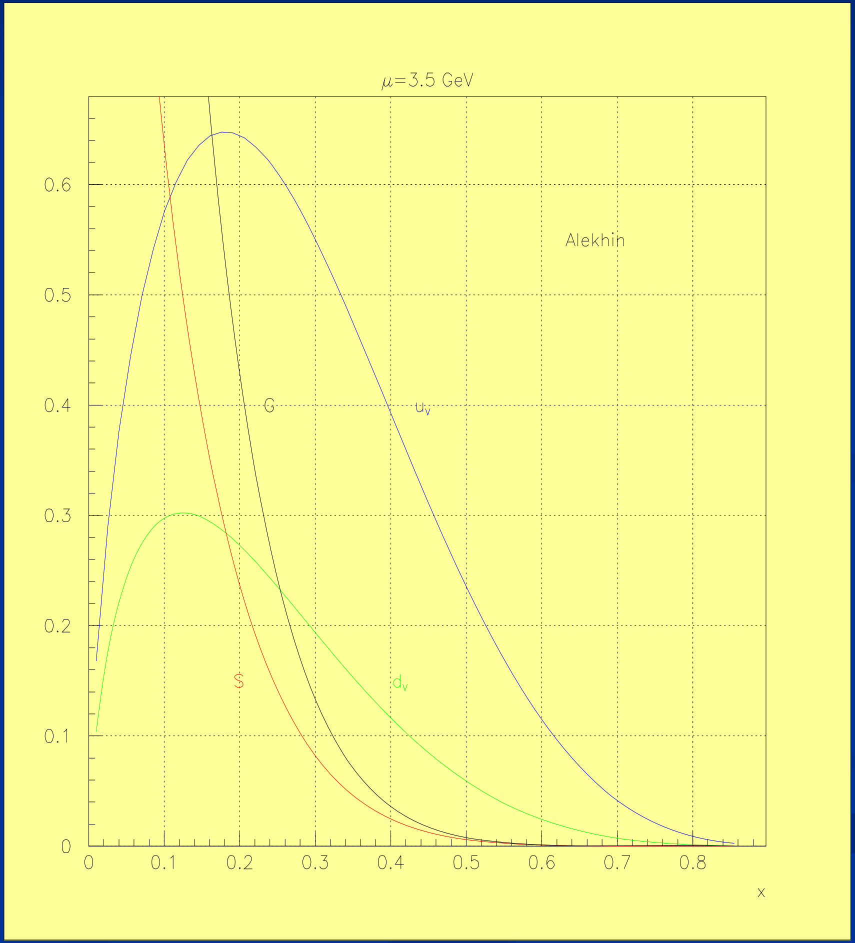


Parton distributions in proton

Parton distributions (at μ=3.5 GeV, close to the masses of χ-states) in the 70 GeV proton → see Figure (Alekhin-2005)

- valence u-quarks (blue) ;
- valence d-quarks(green);
- sea quark/antiquarks (red) ;
- gluons (black)

Estimate shows that at 70 GeV the contributions of gluon-gluon fusion and quark-antiquark annihilation to produce charmonium with a mass of 3.5 GeV in pp-interactions **<u>are comparable.</u>**



Goals of the experiment

The goal is to measure double-spin asymmetry A_{LL} with the use of longitudinally polarized beam and target in the following processes :

$p\uparrow + p\uparrow \rightarrow \chi_2 + X$ и $p\uparrow + p\uparrow \rightarrow J/\Psi + X$

$J/\Psi + \gamma$ ↲ $\mu^+ \mu^-$ ↲

$\mu^+ \mu^-$ ↲ (e^+e^- will give a ~30% additional statistics, not much due to bremmstrahlung)

J/Ψ	(3096)	$J^{PC} = 1^{--}$
χ_1	(3510)	$J^{PC} = 1^{++}$
χ_2	(3555)	$J^{PC} = 2^{++}$

Double spin asymmetry A_{LL}

The measured experimental asymmetry is given by

A_{LL} = [1/(P_B * P_T^{eff})] * [I(++) – I(+ –)] / [I(++) + I(+ –)],

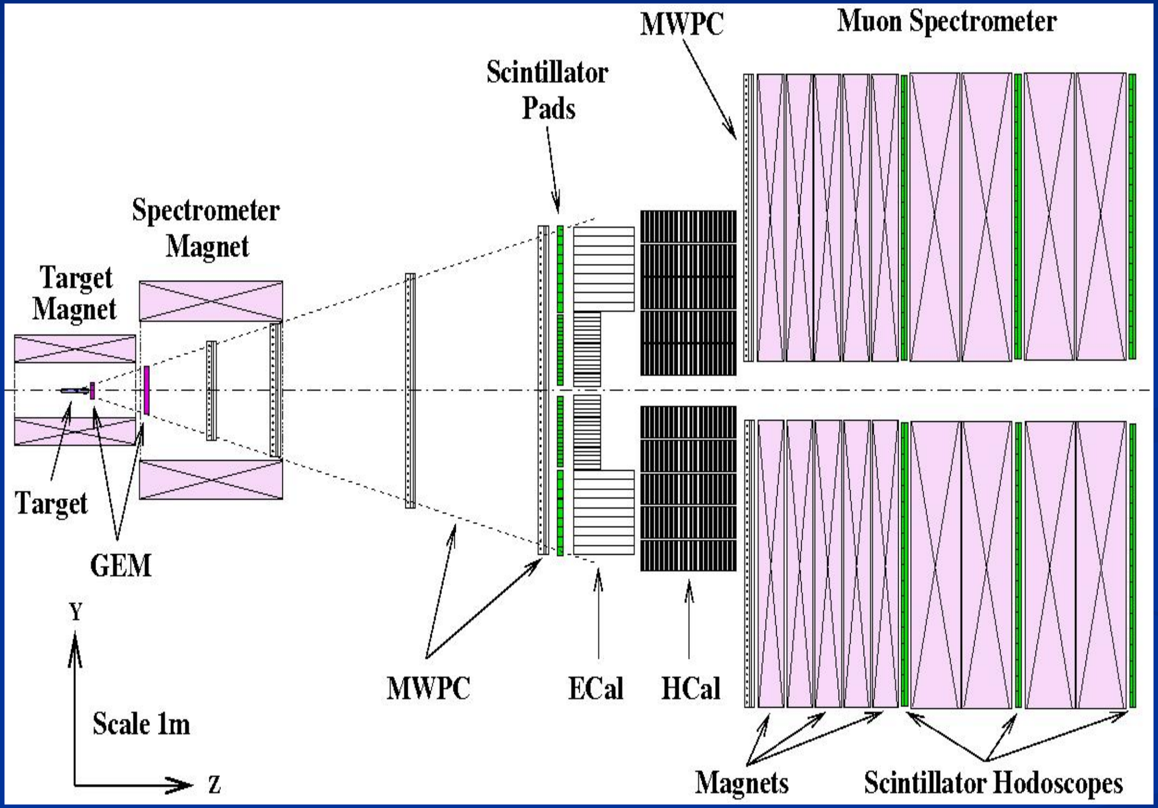
where P_B is the beam polarization,
P_T^{eff} – effective target polarization ,
I(++) ,I(+–) are the number of events normalized to the incident beam.
The helicity states (++) and (+–) correspond to ($\rightarrow\leftarrow$) and ($\rightarrow\rightarrow$) respectively , where arrows indicate the beam and target spin direction in the laboratory system.

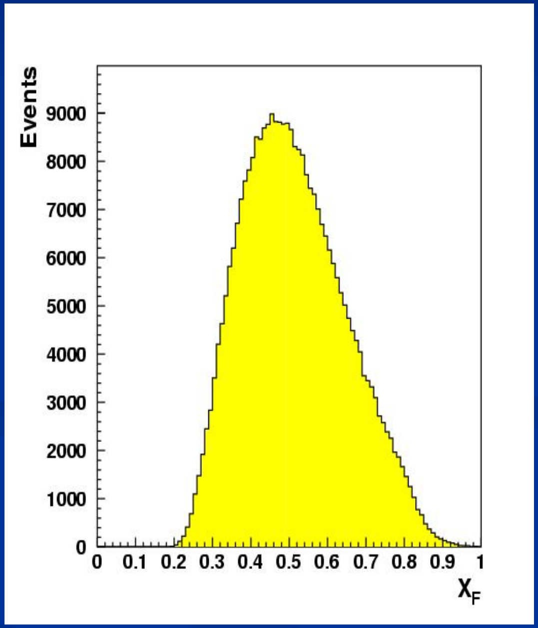
Theoretical predictions of A_{LL} mainly depend on two assumptions :

1. gluon polarization $\Delta G/G$ and
2. charmonium production mechanism which defines $\hat{A}_{LL}$ at the parton level (in parton-parton interaction)

Experimental setup SPASCHARM

Open geometry. Main parts : electromagnetic calorimeter, GEM, drift and proportional chambers, muon detector.

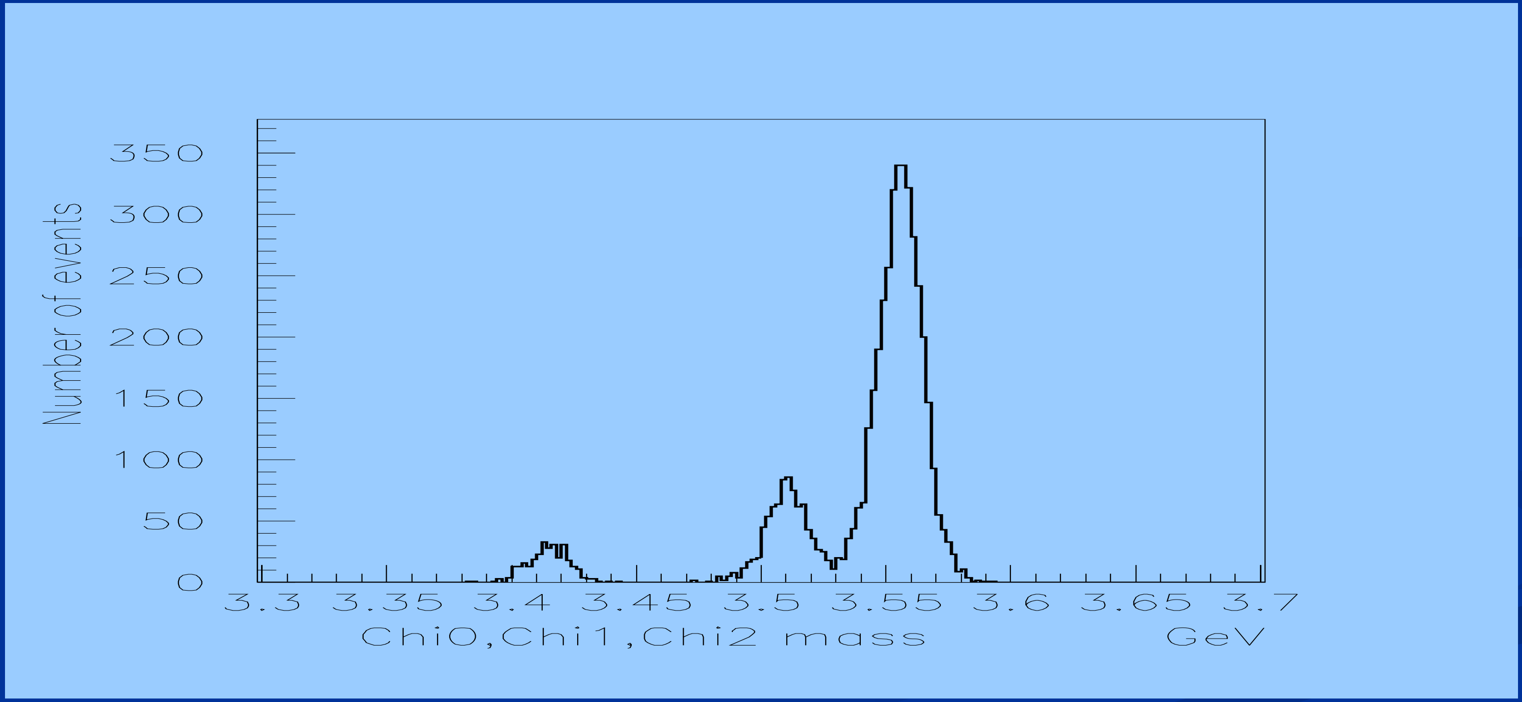




The x_F-distribution of the accepted χ_2-events.

χ_1 / χ_2 separation

Monte-Carlo for 70 GeV. Masses of χ_0(3410), χ_1(3510) and χ_2 (3555). The J/Ψ (in μμ-decay mode) 4-momentum is taken as a result of 1C-fit. For charged particles $\Delta p / p = 0,004$ at 10 GeV/c. For γ -quanta $\sigma(E)/E = 2,5\%/\sqrt{E}$.



Expected sensitivity in A_{LL} for charmonium

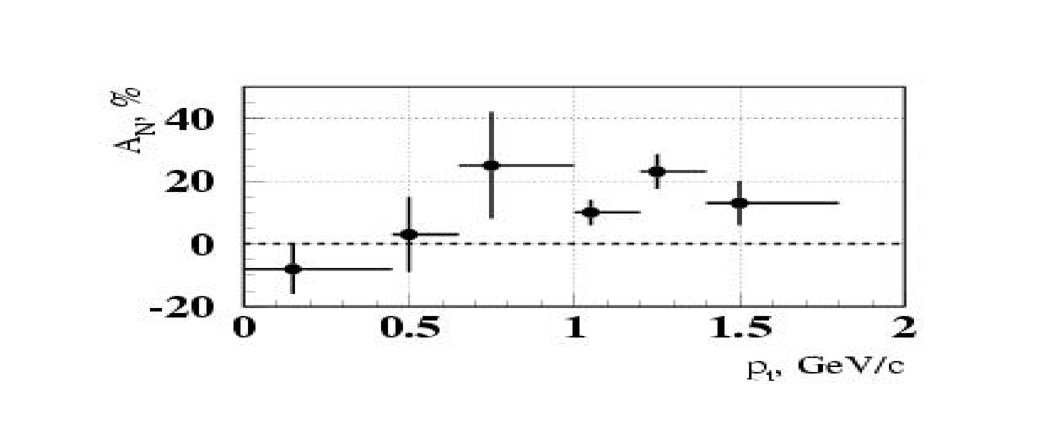
The P838 estimate was1640 χ_2/month and 9200 J/Ψ month for a beam intensity of 2,7*10^7 protons/minute.

Cross section of J/Ψ at 70 GeV pp-interaction is ~15 nb per nucleon. We expect 12 500 χ_2 and 100 000 J/Ψ over ~100 days at beam.

At x=0.3 we expect to get a precision of σ (A_{LL}) = **0.07** for χ_2 and **0.025** for J/Ψ for ~100 days of data taking.

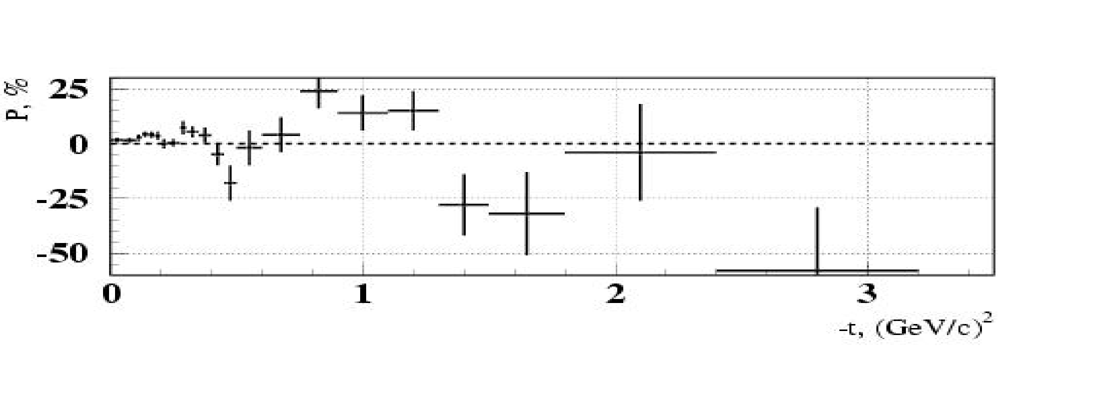
First stage of the experiment - physics with unpolarized beams

Single-spin asymmetries in inclusive production of light resonances



p_T-dependence of A_N in the reaction $\pi^- d\uparrow \rightarrow \pi^0 X$ at 40 GeV/c at $x_F > 0.7$

$A_N = (16 \pm 5)\%$ near $p_T = 1$ GeV/c.



t-dependence of A_N in the reaction $\pi^- p\uparrow \rightarrow \pi^0 n$ at 40 GeV/c

$A_N = (18 \pm 5)\%$ near $t = 1$ (GeV/c)^2

Where do we expect non-zero asymmetries ?

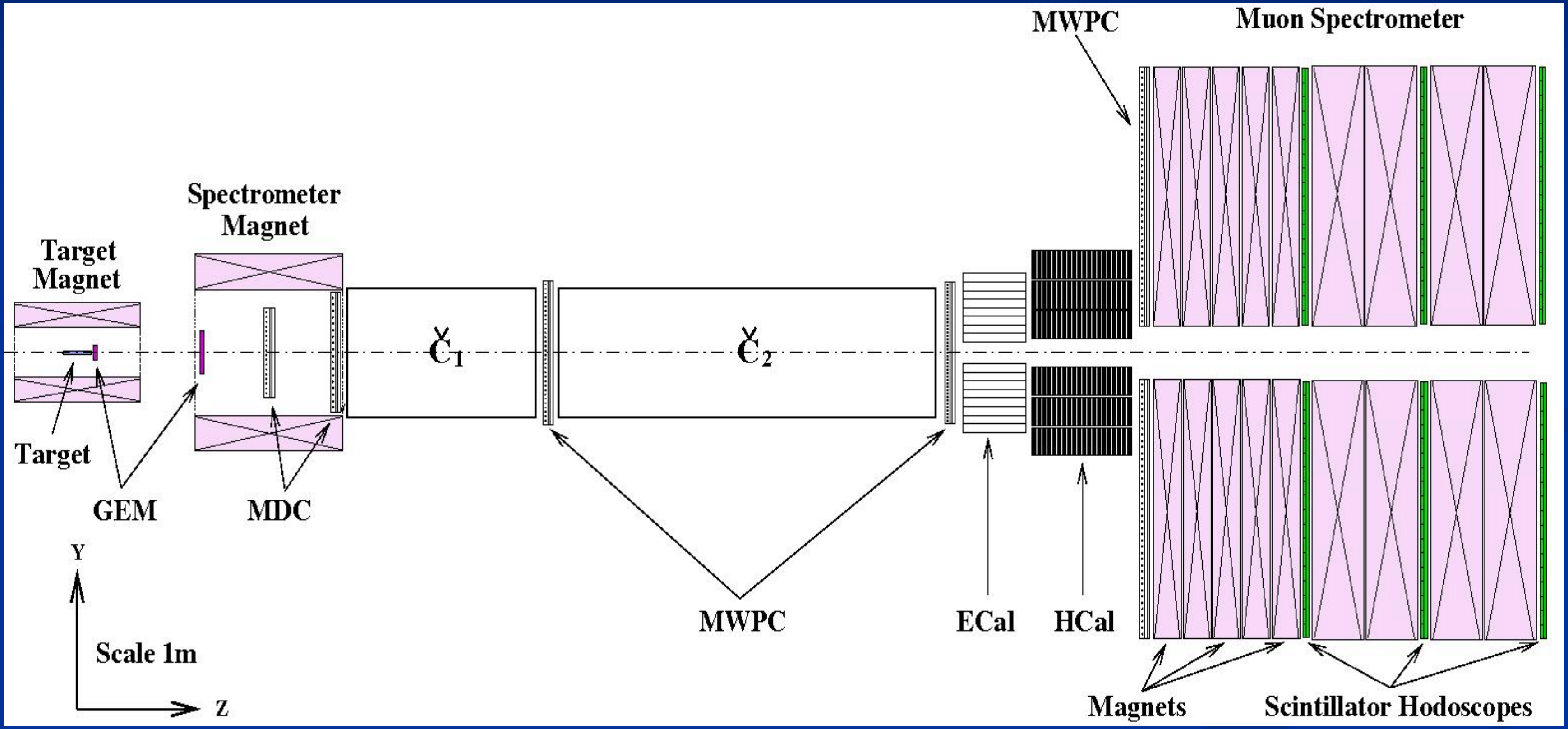
- We might expect big asymmetries in inclusive production of light resonances in the unpolarized beam fragmentation region **close to the boundary of phase space** ($x_F \to 1$, $p_T \to \sqrt{s}/2$). These asymmetries will approach the ones for the appropriate exclusive reaction. From the PROZA experiment we know that asymmetries in the reactions of

$\pi^- p\uparrow \to (\pi^0, \eta, \eta', \omega^0, f_2)\, n$ are big.

Why do we need to measure A_N in a big variety of inclusive and exclusive reactions ?

- In the Standard Model QCD at leading twist level all $A_N=0$. But the experiments show very big A_N in the confinement region.
- Therefore A_N is very sensitive to the effects outside the SM. The known theoretical approaches (Sivers and Collins effects, twist-3 effect, etc.) try to reconcile theory and experiment. To discriminate the existing theoretical approaches and to stimulate to develop the new ones, a systematic study of A_N for a big number of miscellaneous inclusive and exclusive reactions is needed, especially in the confinement region, which is the most unclear for theory . To make this systematic study is the main goal of the first stage of the SPASCHARM project.

SPACHARM-1 setup for light resonances



Two multi-channel threshold Cherenkov counters are added to distinguish between pions and kaons. However, acceptance is still significant for light resonanses. Due to DAQ inclusive and exclusive reactions will be studied simultaneously.

Trigger and Data Acquisition System

The SPASCHARM experiment plans to have 25 000 electronic channels – 7 000 ADC, 2 000 TDC and 16 000 registers.

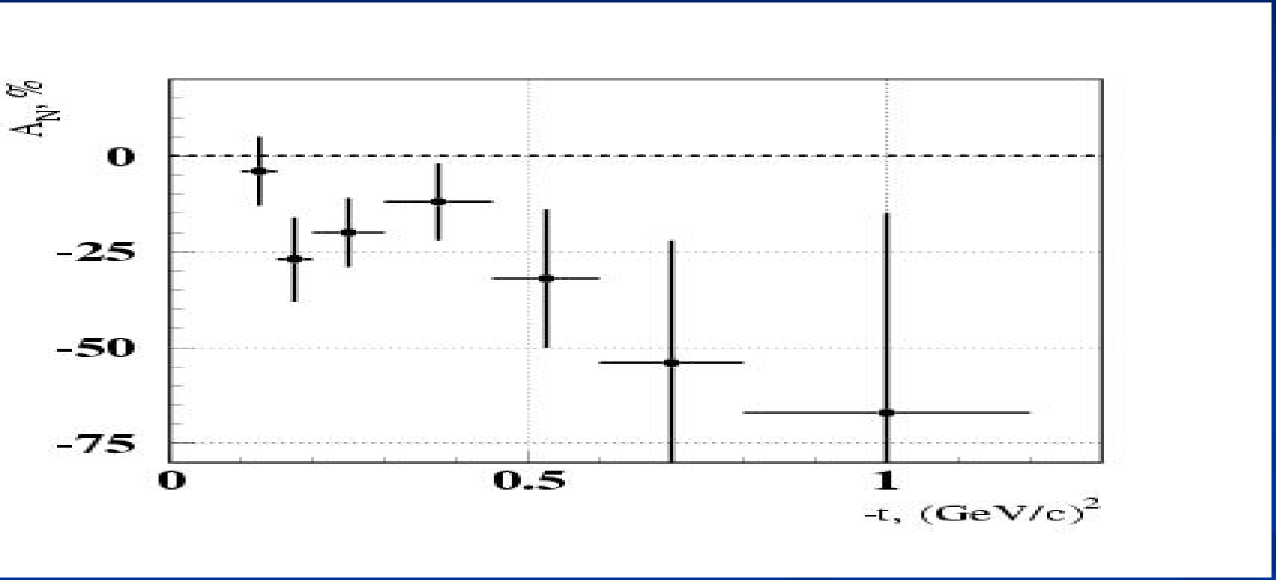
The trigger for interaction in the target will be the only hardware trigger. Information from the interaction will be digitized in each sub-detector, pre-processed and buffered for further processing. A high level trigger selection will occur in compute nodes which access the buffers via a high bandwidth network fabric.

The SPASCHARM experiment plans to operate at interaction rates of the order of 2 MHz. With pre-processing on the detector electronics for a substantial reduction of the data volume, typical event sizes are in the range of 2 to 4 kB. This amounts to total raw data rates in the order of 3 GB/s.

Some advantages of the new experiment

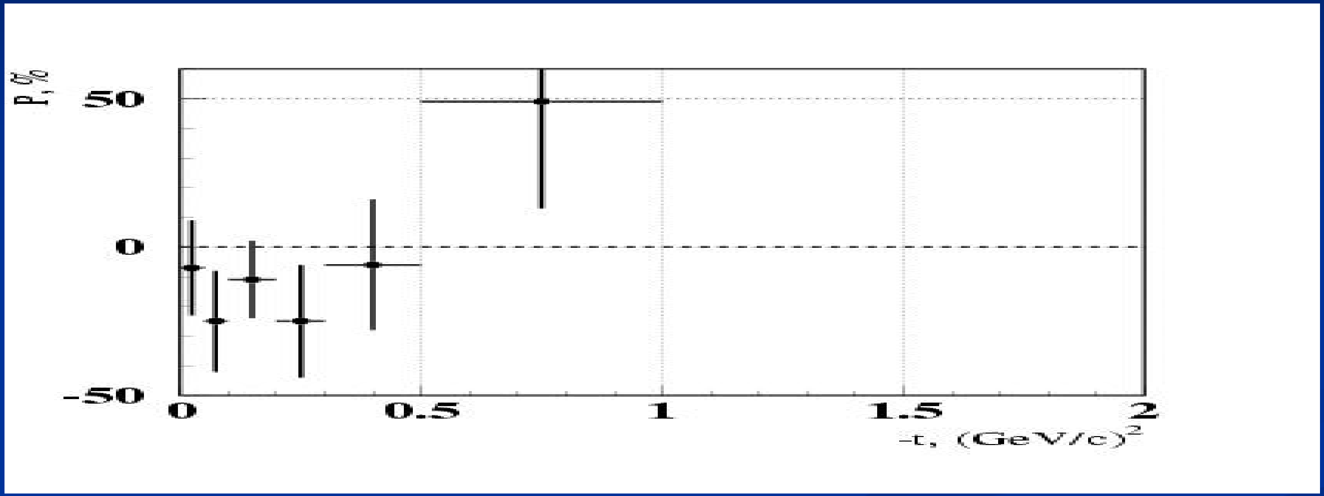
- Exclusive and inclusive reactions were studied either in neutral decay modes or in charged decay modes in the previous experiments. We propose to measure the both modes simultaneously and therefore we expect a significant increase in statistics – see the next few slides.
- Addition of new detectors (***GEM, MDC, high quality EMC*** etc.) compare to the previous experiments might bring us to discovery of "new channels" (***exotic glueballs, hybrids***…).
- Extremely high-speed DAQ will allow to detect inclusive and exclusive reactions simultaneously.
- PWA of a huge statistics on polarized target will raise a robustness of the results on rare resonanses.
- SPASCHARM has 2π-acceptance on azimuthal angle φ and therefore the systematic errors in single-spin asymmetries will be negligible.

Asymmetry in the reaction $\pi^- p\uparrow \to \omega(782)n$ at 40 GeV



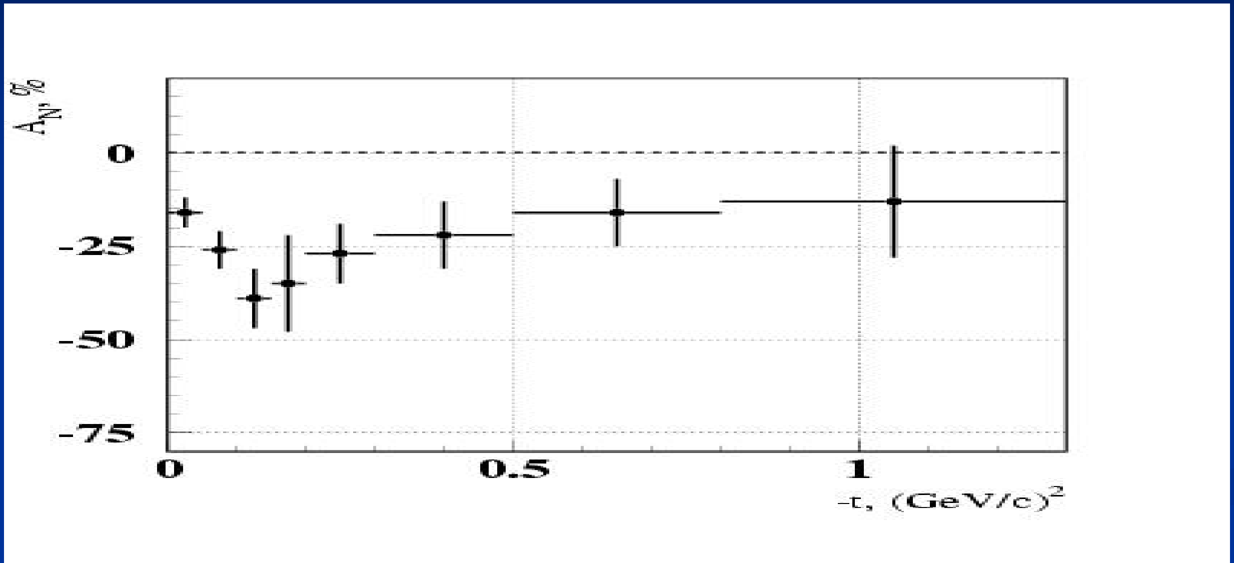
Asymmetry in $\pi^- p\uparrow \to \omega(782)n$ at 40 GeV. The $\omega(782)$ has been detected in $\pi^0\ \gamma$ decay mode with 8% branching. 33,000 events on polarized target were collected in three runs. Solid angle was twice less than in SPASCHARM-1. Bu using two decay modes ($\pi^+\pi^-\pi^0$ with 89% branching and $\pi^0\gamma$), statistics can be increased in 20 times over three accelerator runs. Errors in the first four points would be 2% rather than 10% now.

Asymmetry in the reaction $\pi^- p\uparrow \rightarrow \eta^/(958)\ n$ at 40 GeV



Asymmetry in $\pi^- p\uparrow \rightarrow \eta^/(958)n$ at 40 GeV. The $\eta^/(958)$ has been detected in $\gamma\gamma$ decay mode with 2% branching. 11,000 events on polarized target were collected in five runs. Solid angle was about the same as in SPASCHARM-1. Bu using two additional decay modes ($\pi^+\pi^-\eta$ and $\pi^+\pi^-\gamma$ with branchings of 45% and 30%), statistics can be increased in 20 times over three accelerator runs. Errors in the first three points would be 3-4% rather than 13-17% now.

Asymmetry in the reaction $\pi^- p\uparrow \rightarrow f_2(1270)\ n$ at 40 GeV

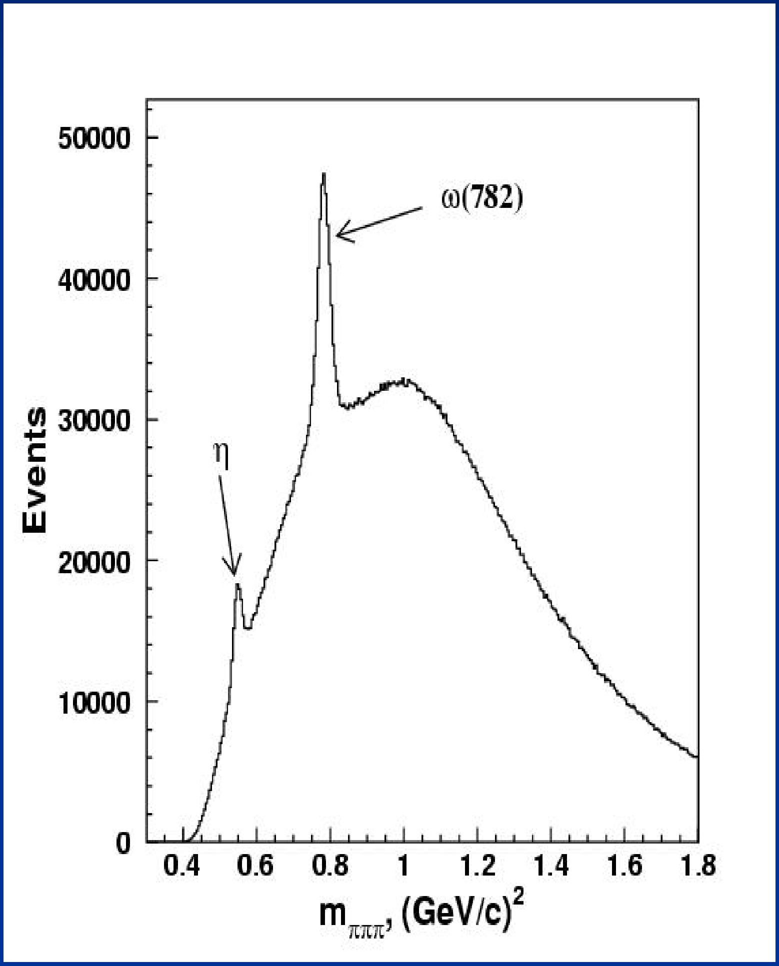


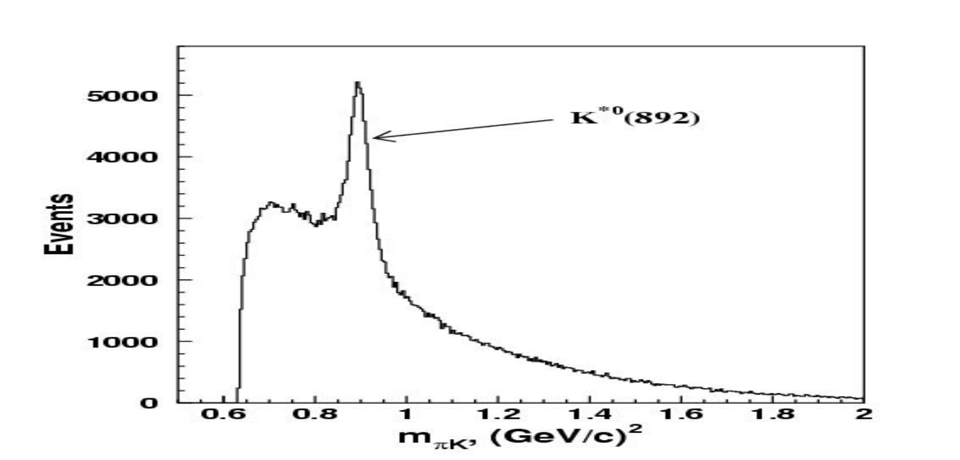
Asymmetry in $\pi^- p\uparrow \rightarrow f_2(1270)\ n$ at 40 GeV. The $f_2(1270)$ has been detected in $\pi^0\pi^0$ decay mode with 28% branching. 100,000 events on polarized target were collected in five runs. Solid angle was about the same as in SPASCHARM-1. Bu using the additional decay mode ($\pi^+\pi^-$ with 56% branching), statistics can be increased in 3 times over three accelerator runs. Errors would be about two times less than now.

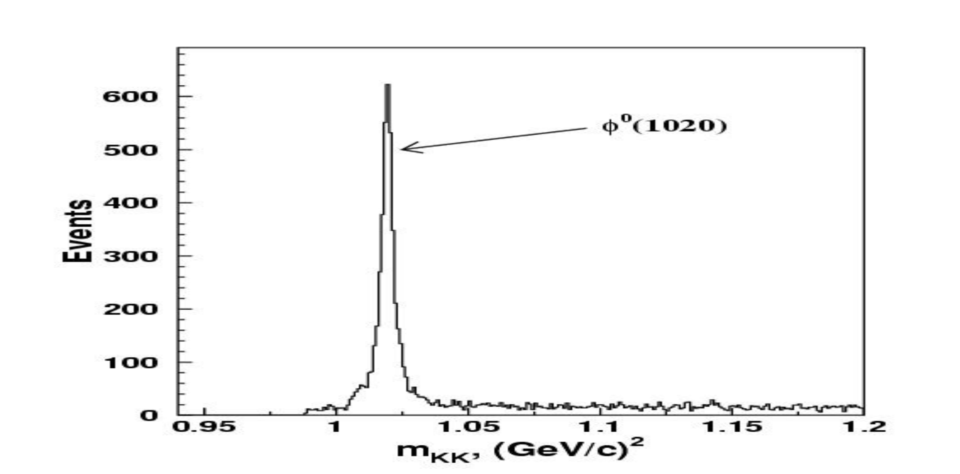
Expected asymmetry errors in inclusive reactions

- For the MC simulations, two options of the setup were considered with two distances from the center of the polarized target to the beam downstream end of the last Cherenkov counter – “7 meters” and “4 meters” – *see several next slides.*
- Variant “4 meters” has one Cherenkov counter in the setup. π-mesons will be identified in the momentum region of 3-23 GeV/c. No π/K-separation. Acceptance for “usual” (non-strange) resonances is huge (3 times bigger than for “7 m”). We request a beam time of 30 days.
- Variant “7 meters” has two Cherenkov counters in the setup and allows π/K-separation in the momentum region of 3-23 GeV/c. We request a beam time of 70 days.

Typical mass spectra of light resonances in inclusive reactions at the SPASCHARM-1 setup







Expected statistical errors in the reaction $\pi^- p \rightarrow \omega X$ [$\omega(782) \rightarrow \pi^+ \pi^- \pi^0$] over ~100 days at 34 GeV pion beam

p_T, GeV/c / x_F		0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 – 1.0
0.5-1.0	4 m	0.4	0.6	0.7	1.0	3.0
	7 m	0.4	0.6	0.7	1.3	3.3
	total:	*0.3*	*0.4*	*0.5*	*0.8*	*2.2*
1.0-1.5	4 m	0.6	0.9	1.0	1.6	4.1
	7 m	0.9	1.0	1.3	2.2	4.5
	total:	*0.5*	*0.7*	*0.8*	*1.3*	*3.0*
1.5-2.0	4 m	1.1	1.5	2.6	3.8	
	7 m	2.0	2.3	3.2	4.3	
	total:	*1.0*	*1.3*	*2.0*	*2.8*	
2.0-2.5	4 m	2.5	3.2	5.0	9.8	
	7 m	---	7.1	11.5	14.6	
	total:	*2.5*	*2.9*	*4.6*	*8.0*	

Expected statistical errors in the reaction $\pi p \rightarrow \rho X$ [$\rho(770) \rightarrow \pi^{+}\pi^{-}$] over ~100 days at 34 GeV pion beam

$p_{T,}$GeV/c / x_F		0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 – 1.0
0.5-1.0	4 m	0.3	0.5	0.6	1.0	3.0
	7 m	0.3	0.4	0.6	1.1	3.3
	total :	*0.2*	*0.3*	*0.4*	*0.7*	*2.2*
1.0-1.5	4 m	0.5	0.7	0.9	1.6	4.1
	7 m	0.5	0.6	1.0	2.0	3.7
	total :	*0.4*	*0.5*	*0.7*	*1.2*	*2.7*
1.5-2.0	4 m	0.8	1.2	2.3	3.8	
	7 m	0.9	1.3	2.2	3.1	
	total :	*0.6*	*0.9*	*1.6*	*2.4*	
2.0-2.5	4 m	1.6	2.3	4.4	12.7	
	7 m	2.5	3.0	4.5	14.8	
	total :	*1.3*	*1.8*	*3.1*	*9.6*	

Expected statistical errors in the reaction $\pi^- p \to \eta' X$ [$\eta'(958) \to \rho^0(\pi^+\pi^-)\gamma$ and $\pi^+\pi^-\eta(\gamma\gamma)$] over ~100 days at 34 GeV pion beam

p_T, GeV/c / x_F		0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 – 1.0
0.5-1.0	4 m	0.4	0.7	0.7	1.0	2.5
	7 m	0.6	0.7	0.9	1.3	3.0
	total:	0.3	0.5	0.6	0.8	1.9
1.0-1.5	4 m	0.7	0.9	1.0	1.5	6.9
	7 m	1.1	1.1	1.4	2.2	7.0
	total:	0.6	0.7	0.8	1.2	4.9
1.5-2.0	4 m	1.2	1.5	2.6	4.0	
	7 m	2.1	2.6	3.6	4.4	
	total:	1.0	1.3	2.1	3.0	
2.0-2.5	4 m	2.4	3.1	5.6	11.8	
	7 m	5.4	5.7	6.8	12.1	
	total:	2.2	2.7	4.3	8.4	

Expected statistical errors in the reaction $\pi^- p \to f_2 X$ [$f_2(1270) \to \pi^+\pi^-$ and $\pi^0\pi^0$] over ~100 days at 34 GeV pion beam

p_T, ГэВ/c / x_F		0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 – 1.0
0.5-1.0	4 m 7 m total:	0.2 0.2 0.1	0.3 0.3 0.2	0.3 0.3 0.2	0.3 0.4 0.2	0.8 1.0 0.6
1.0-1.5	4 m 7 m total:	0.3 0.4 0.2	0.3 0.4 0.2	0.3 0.5 0.3	0.4 0.6 0.3	1.7 1.7 1.2
1.5-2.0	4 m 7 m total:	0.4 0.6 0.3	0.5 0.7 0.4	0.6 0.8 0.5	1.0 1.0 0.7	
2.0-2.5	4 m 7 m total:	0.7 1.4 0.6	0.8 1.3 0.7	1.1 1.7 0.9	5.1 7.0 4.1	

Expected statistical errors in the reaction $\pi p \to \varphi X$ [$\varphi(1270) \to K^+K^-$] over ~100 days at 34 GeV pion beam

p_T, ГэВ/c / x_F	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 – 1.0
0.5-1.0 7 m	3	6	11		
1.0-1.5 7 m	4	8	26		
1.5-2.0 7 m	10	26			
2.0-2.5 7 m	25				

Expected statistical errors in the reaction $\pi^- p \rightarrow K^* X$ [$K^* \rightarrow K^+ \pi^-$] over ~100 days at 34 GeV pion beam

p_T, ГэВ/с / x_F	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 – 1.0
0.5-1.0 7 m	0.6	0.9	1.7	4.3	
1.0-1.5 7 m	1.0	1.5	3.6	9.7	
1.5-2.0 7 m	2.8	4.3	12.7		
2.0-2.5 7 m	10.3	18.4			

Expected statistical errors in the reaction $\pi^- p \rightarrow K^* X$ [anti-$K^* \rightarrow K^- \pi^+$] over ~100 days at 34 GeV pion beam

p_T, ГэВ/c / x_F	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 – 1.0
0.5-1.0 7 m	0.9	1.5	2.9	10.3	
1.0-1.5 7 m	1.5	2.5	6.2	21.7	
1.5-2.0 7 m	3.8	8.0	25.4		
2.0-2.5 7 m	17.8				

Expected accuracies of A_N in inclusive reactions (*summing table*)

- **Kinematical region :** $x_F = 0.5\text{-}1.0$, $p_T = 0.5\text{-}2.5$ GeV/c :

- ***Reaction $\pi^- p_\uparrow \to \omega X$ $\to$ typical $\sigma(A_N) = 0.3\text{-}3\%$***
- ***Reaction $\pi^- p_\uparrow \to \rho X$ $\to$ typical $\sigma(A_N) = 0.2\text{-}2.5\%$***
- ***Reaction $\pi^- p_\uparrow \to \eta' X$ $\to$ typical $\sigma(A_N) = 0.3\text{-}4\%$***
- ***Reaction $\pi^- p_\uparrow \to f_2 X$ $\to$ typical $\sigma(A_N) = 0.1\text{-}1\%$***

- ***Reaction $\pi^- p_\uparrow \to \varphi X$ $\to$ typical $\sigma(A_N) = 3\text{-}10\%$***
- ***Reaction $\pi^- p_\uparrow \to K^{*0} X$ $\to$ typical $\sigma(A_N) = 0.6\text{-}10\%$***

Time schedule and cost

- First stage 2007-2010 years, ~$2 M

Start to work on π^--beam in 2010

- Second stage 2011-2014 years, ~$3M

Start to work possibly on polarized proton beam in 2014

The proposal has been submitted to the IHEP management and will be considered at IHEP this fall. However, IHEP-JINR contract on polarized target upgrade has been already approved by the two sides and is being prepared now.

Conclusions

- **The new polarization program SPASCHARM is being prepared in Protvino. The progam has two stages.**

- **The first stage (to be started in 2010) is dedicated to single-spin asymmetries in the production of miscellaneous light resonances with the use of 34 GeV π^--beam. Inclusive and exclusive reactions will be studied simultaneously. The errors in the exclusive reactions with big asymmetries are expected to be several times less than now. The brand new data for inclusive reactions will be obtained. All the new data will much better help us to understand spin dependence of strong interaction in the most difficult from the theory point of view kinematical region, namely in the quark confinement region.**

- **The second stage (to be started in 2014) is dedicated to single-spin and double-spin asymmetries in charmonium production with the use of ~70 GeV polarized proton beam which will allow us to understand charmonium hadronic production mechanism and make Δg (x) extraction at large x. The results on Δg (x) at large x will be unique and will be complementary to those which exist and might be obtained at COMPASS, HERMES, RHIC and JLAB at smaller x. The global analysis with the use of the new large x data on Δg (x) will significantly improve our knowledge of the gluon polarization integral ΔG.**