The comparative study of the inclusive π^0 analyzing power in reactions $pp_{\uparrow}\rightarrow\pi^0X$ and $\pi^- p_{\uparrow}\rightarrow\pi^0X$ at 50 and 40 GeV respectively

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Abstract

- The measured analyzing powers in reactions $p+p_{\uparrow}\rightarrow\pi^0+X$ and $\pi^-+p_{\uparrow}\rightarrow\pi^0+X$ at 70 and 40 GeV respectively behave in drastically different ways in function of transverse momentum in the central region.
- At the same time in the polarized proton fragmentation region the analyzing powers of these reactions are practically coinciding. Our data are in agreement with the known experimental results at various energies.

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- Beam parameters
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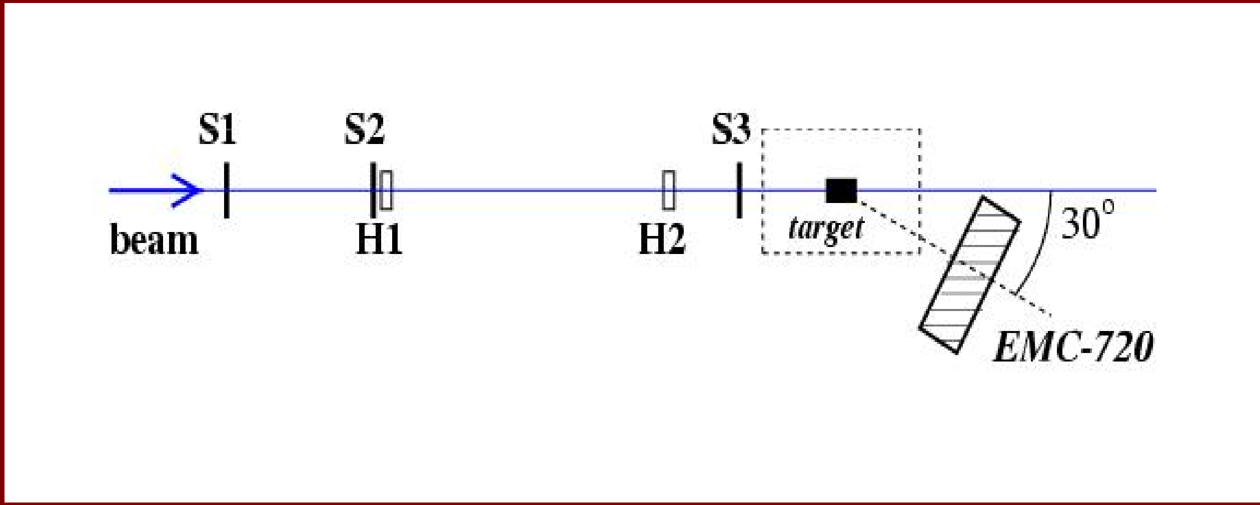
Layout of the PROZA-M set-up

Fig1. Beam comes from left side. Its parameters are presented in the Table 1.



- Beam flux measuring counters: S1 and S2 of sizes Ø=100mm, thickness t =10 mm, S3 of Ø=18mm, t=5 mm.
- Hodoscopes for beam profile measurements.

  H1 and H2 each has two planes (x,y); 16 counters with width 2 mm in each plane are installed at distances 8.7 and 3.2 m respectively in front of the polarized target (PPT).

Layout of the PROZA-M set-up

- PPT (see Table 2 below) The dashed box around the PPT – the polarizing and holding magnet (unique).
- EMC- electromagnetic calorimeter consists of 720 lead glass counters packed as 30×24 matrix. Cell size 38.1×38.1×450 mm^3 (18X_0). EMC gross size is 115×90 cm^2
- The minimum distance from the center of PPT to front end of lead glass wall is 2.16 m.
- EMC is installed at angle 30^0 to beam line.

Table 1. Beam parameters

Parameter	Negative beam	Positive beam
Momentum, GeV/c	40	50
Part. prod. method	Internal target	Bent crystal
Mom. Band $\Delta\ p/p$, %	± 2	<0.2%(estimate)
Beam compos., %	π^-(97.9): K(1.8): p (0.3)	p(>99): x^+(<1)(est.)
I, part./spill	$3 \cdot 10^6$	$(3\text{-}6) \times 10^6$
Beam size at PPT (σ), $x \times y$, mm^2	3.5×3.5	2.7×3.6
Beam angular divergence, $x' \times y'$, mr	$(\pm 2.5) \times (\pm 1.5)$	$(\pm 1.0) \times (\pm 0.5)$

Table 2. Polarized target

Parameter	Value
Target material	Propandiole, $C_3H_8O_2$
Size of the target material, diameter∗length, mm	19.6∗200
Paramagnetic mixture, Complex Cr^5 in 10^{20} spin/cm^3	$1.8^{+0.1}_{-0.2}$
B(building/holding, T	2,08/0,4
P_{max}, *P*+/*P*-, %	+(90±3)/-(94±3)
DNP, *T* (mK)/Power(mW) /rf(GHz)/ń(mol/s)	$0{,}2/90/56/3\cdot10^{-2}$
Polarization building time up to 0,8 *Pmax*, minutes	50
Spin frozen regime, *T* (K)/ń(mol/s)	$0{,}02/2\cdot10^{-3}$
Relaxation time, *P*+/*P*-,hours	1200/800

Specific features of the reactions and detectors

This mode of experiment is unique, since difficult to realize for the following reason: The backward pion production in the c.m.s., due to the Lorentz transformation to Lab. system we deal with low energy π^0. Since the opening angle θ between two photons with energies e_1 and e_2 is defined by relation

$$\sin\left(\frac{\theta}{2}\right) = \frac{m}{2\sqrt{e_1 e_2}}$$

where *m* and *e* are the pion mass and its energy respectively;

The minimum opening angle, θ_{min}, happens at $e_1=e_2=e/2$, Since the *e* varies between 2-4 GeV. Θ_{min} occurs in the range 0.07-0.14 rad. While the geometrical solid angle subtended by EMC is 0.21 sr, the effective solid angle becomes significantly smaller.

The problem of the inclined (to the EMC surface) showers.

At such low energies the probability of finding the overlapping two showers is negligible.

Trigger and DAQ

- Trigger consists of the three parts:
  - $S=S1\times S2\times S3$
  - $H=H1X\times H1Y\times H2X\times H2Y$, where it was required ≥ 1 hits in each plane.

    The product of the two above triggers were ready after 60 ns.
  - $\Sigma = \sum e_i \geq \Sigma_0$, where E–the total deposited energy in EMC, $\Sigma_0 \approx 2$ GeV is the threshold energy. This trigger is produced in 350 ns.

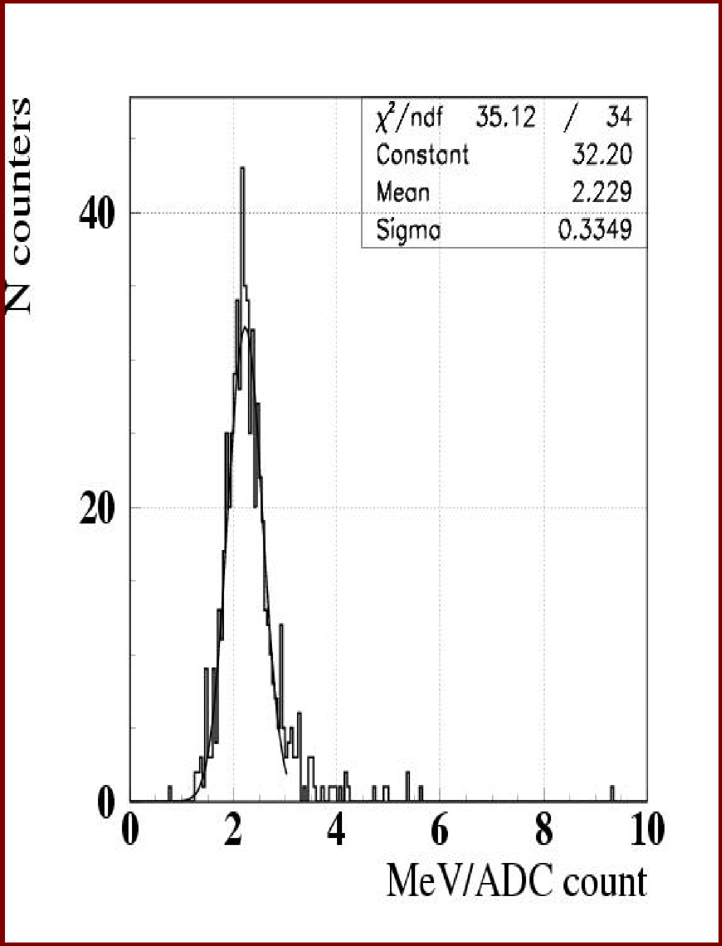
  So the final trigger: $S\times H\times E$.
- The DAQ system includes the registers for hodoscopes, 12 bits ADC for EMC, scalers, the read-out processor on the base of processor MC68030 and interface electronics.
- In average 700 events per spill were registered. During 10 hours data taking 5×10^7 events were accumulated.

Calibration

Calibration procedure:

1. Tuning H.V.on narrow e-beam for Equalizing output p.m. amplitudes
2. Calibration with the use of wide electron beam. (Sensitivity of the ADC channels is about 2.2 MeV/chan; Homogeneity of the energy calibration coefficients 15%. Fig.2. Distribution of the energy calibration coefficients)

Additional calibration was done using π° - mass during data taking (see below after describing data analysis)



Data analysis

1. Shower reconstruction: It is required that minimum 5 cells were activated (minimum $x \times y = 3 \times 3$ in each direction); energy deposit in the central counter ≥ 100 MeV. The next in amplitude pulse should appear in the neighboring counters in order to avoid the overlapping showers.
2. The average photon multiplicity is 1.6 for E>0.5 GeV (Fig.3). The bump around 2 GeV is a contribution of single gamma event and the result of the trigger energy threshold of 2 GeV.
3. For reconstruction of the π^0 the photons in the energy region 0.5-5 GeV were used. Two gamma mass spectra is shown on Fig.4. π° mass width is 16 MeV (π° mass is fitted using logarithmic Gauss function).

Photon energy spectra (Fig.3) and two-gamma mass spectra (Fig.4)

Fig.3. Photon Spectra

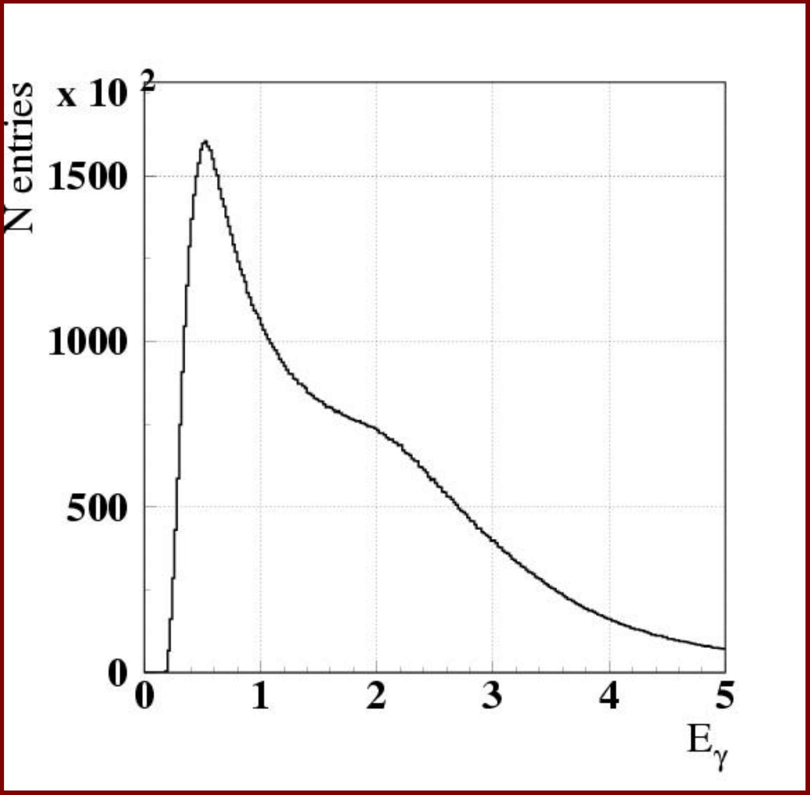
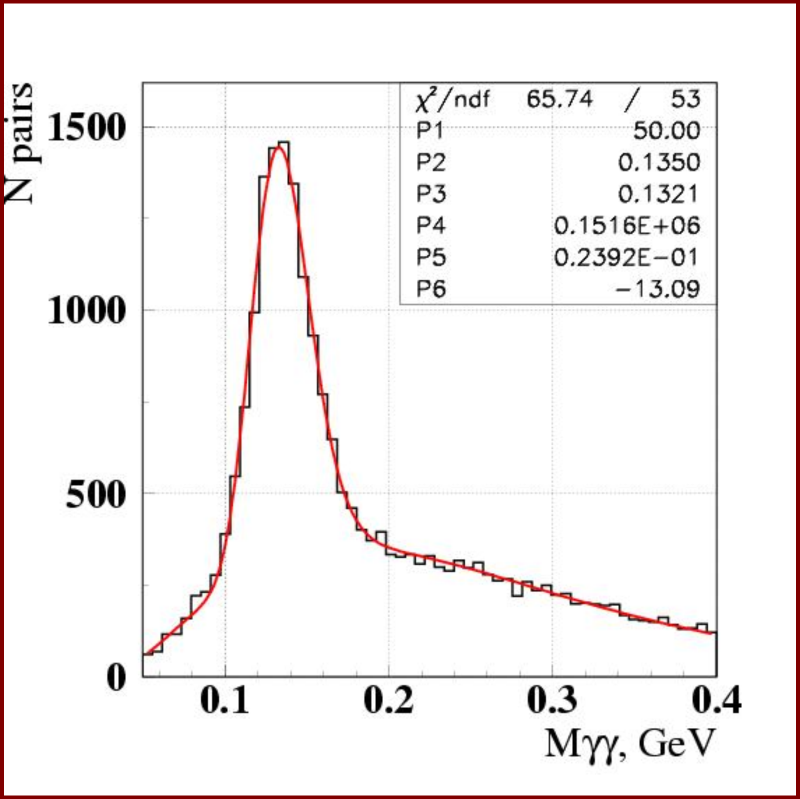


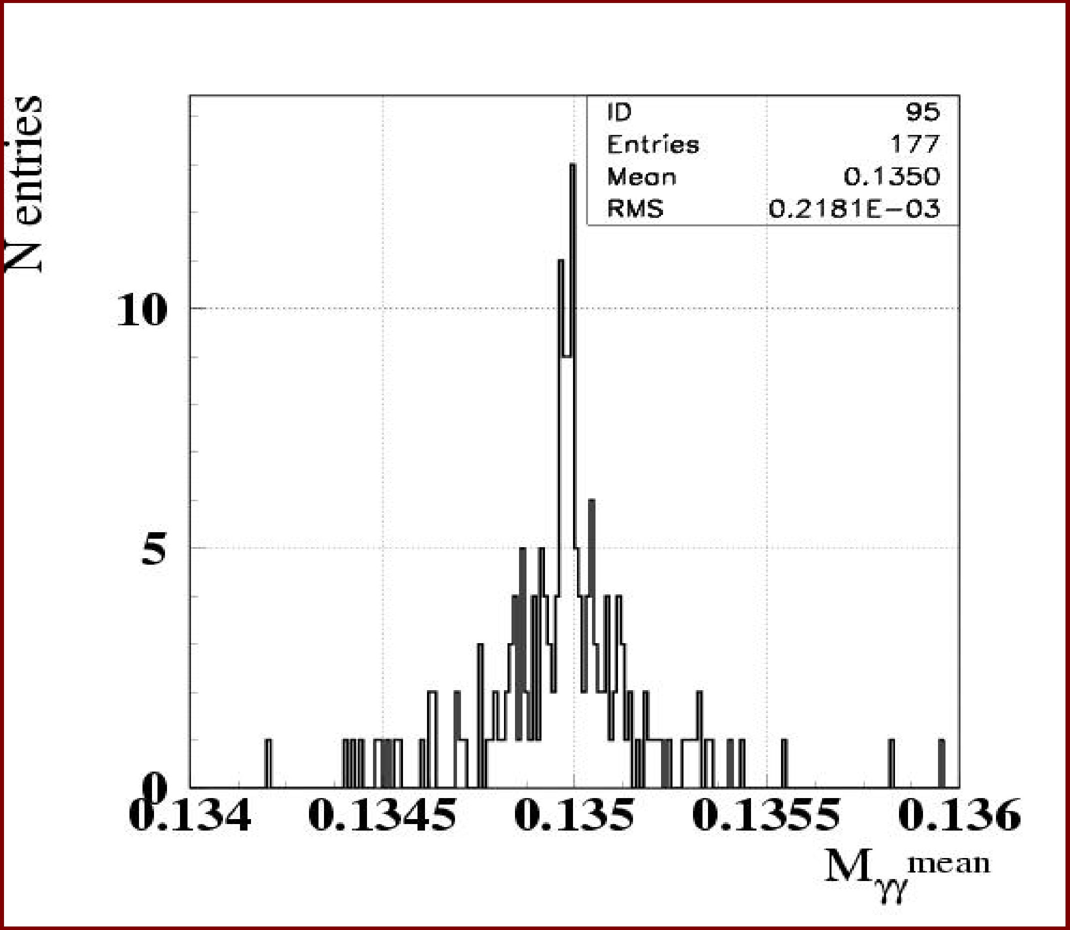
Fig. 4. γγ-mass spectra for 2 hours data taking and $-0.45<x_F<-0.15$



Additional Calibration using the Neutral pion mass

- Fig.5. Distribution of mean values of π°-mass for 2 hour intervals after first iteration

- The accuracy of each point is 0.2 MeV



Data analysis (continued)

In reconstruction of the photon parameters additional algorithms are required to take into account:

1. The dependence of the reconstructed photon energy on the real initial photon energy. This correction was of order of 10 %.
2. The dependence of the reconstructed photon energy and coordinate on its inclination angle. The energy correction was of order 5 %. Coordinate correction is 2-3 cm for 15° angle.
3. The algorithm is based on MC study. The energy resolution of EMC is estimated by the Monte Carlo method and fitted by the standard formula (Fig. 6).
4. After corrections the reconstructed π^0 mass was consistent with its Table mass within precision less than 1%. (Fig. 7)

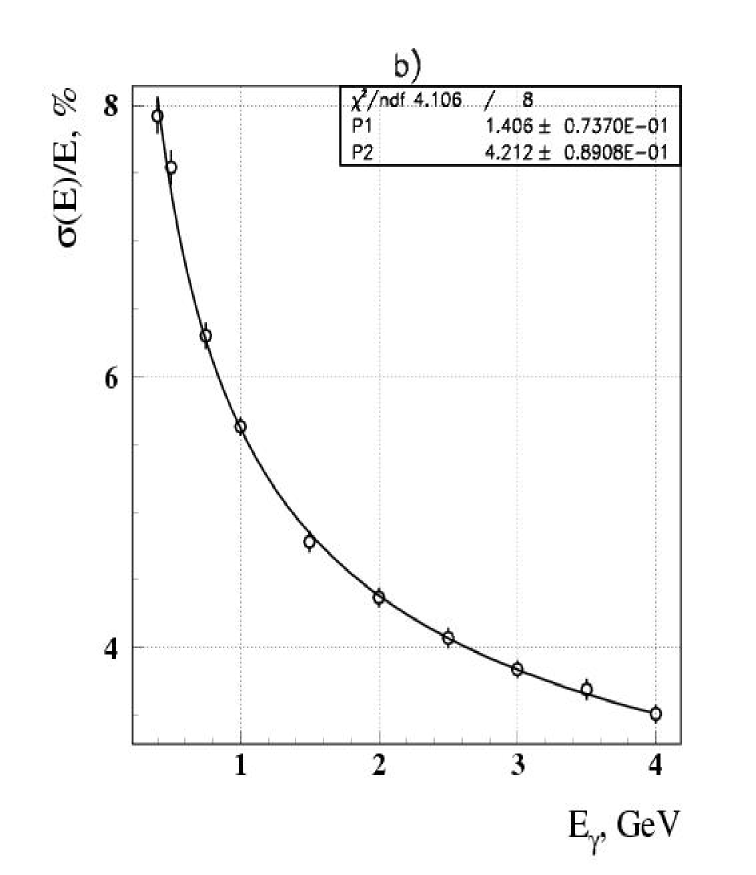
MC Energy resolution of the EMC

- Fig. 6. The energy resolution of the EMC for 90° photon incident angle was simulated by the Monte Carlo method and approximated by the analytic expression

$$\frac{\sigma(E)}{E} = a + \frac{b}{\sqrt{E}}$$

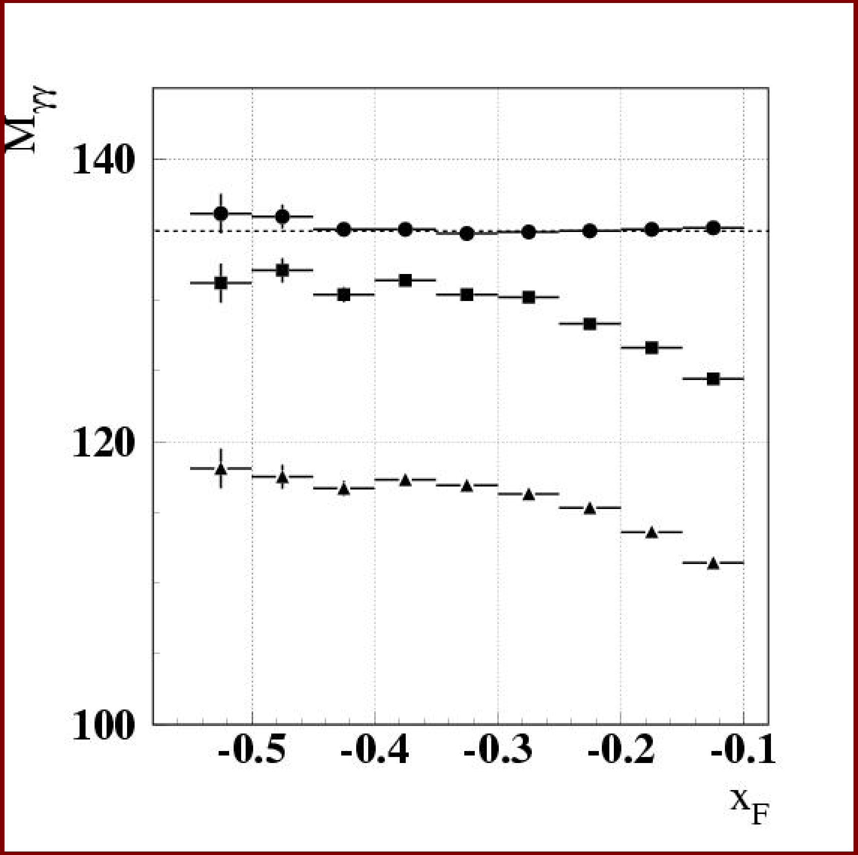
(a=(1.41±0.07)%, b=(4.21±0.09)%)

- This resolution varied from approximately 8% at 0.5 GeV to 2% at 4 GeV and is in agreement with experimental data

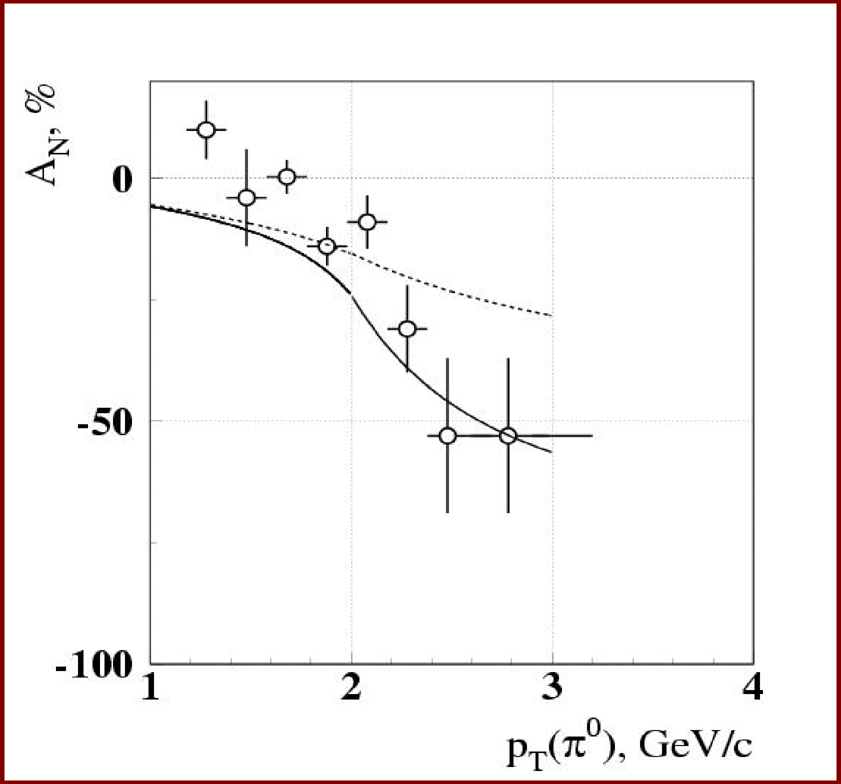


π^0 mass after corrections

- Fig.7. π°-mass dependence on x_F using special algorithm (upper points)
- Middle points - π°-mass with energy (not angular) dependence correction
- Lower points – none of the algorithms is used



PROZA Results (A_N) in the central region



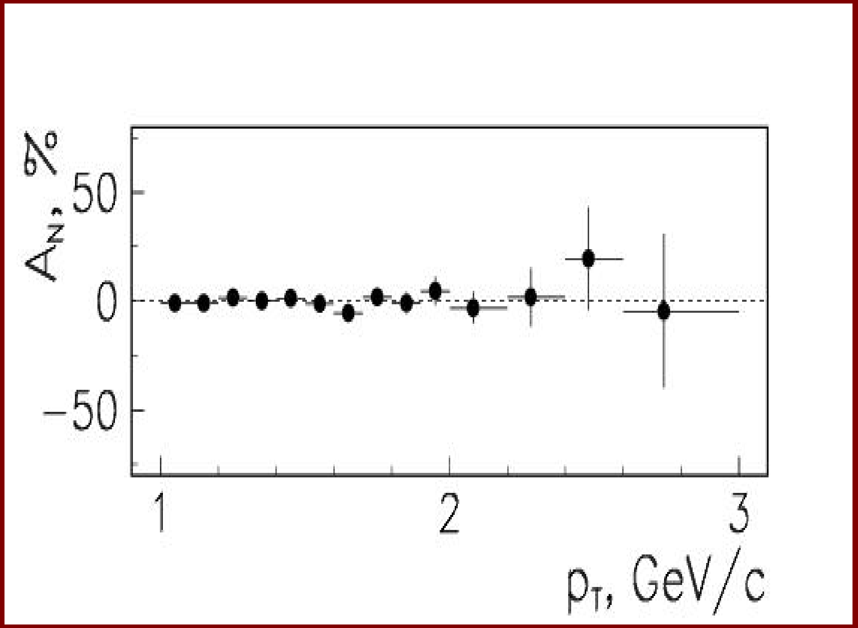


Fig.8. $\pi^- p_\uparrow(d_\uparrow) \rightarrow \pi^0 X$, 40 GeV **Fig.9. $pp_\uparrow \rightarrow \pi^0 X$, 70 GeV**

PROZA result for A_N in the polarized target fragmentation region

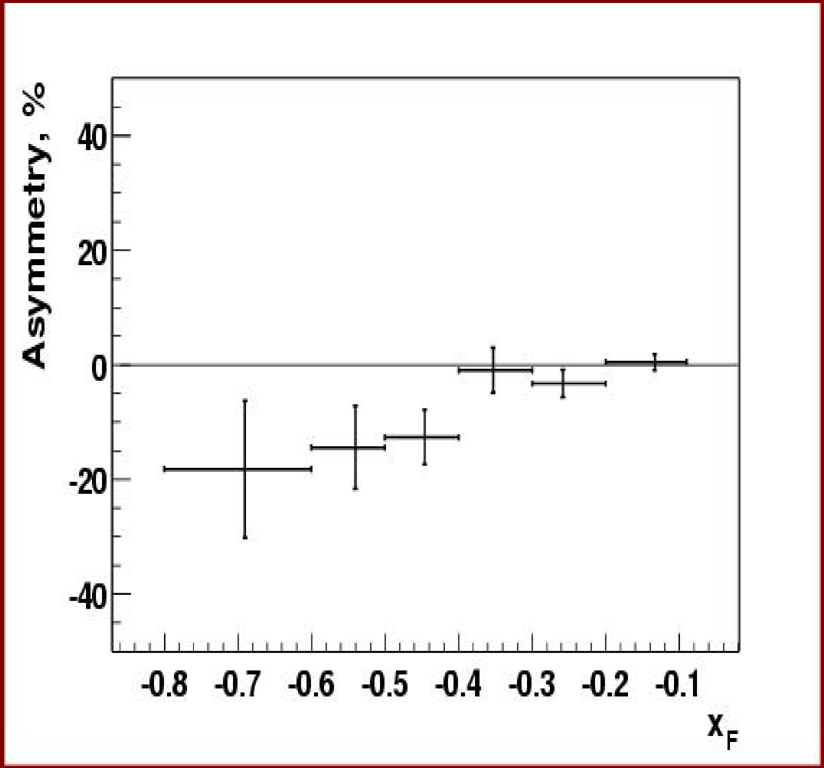


Fig.10. $\pi^- p_\uparrow \rightarrow \pi^0 X$, 40 GeV

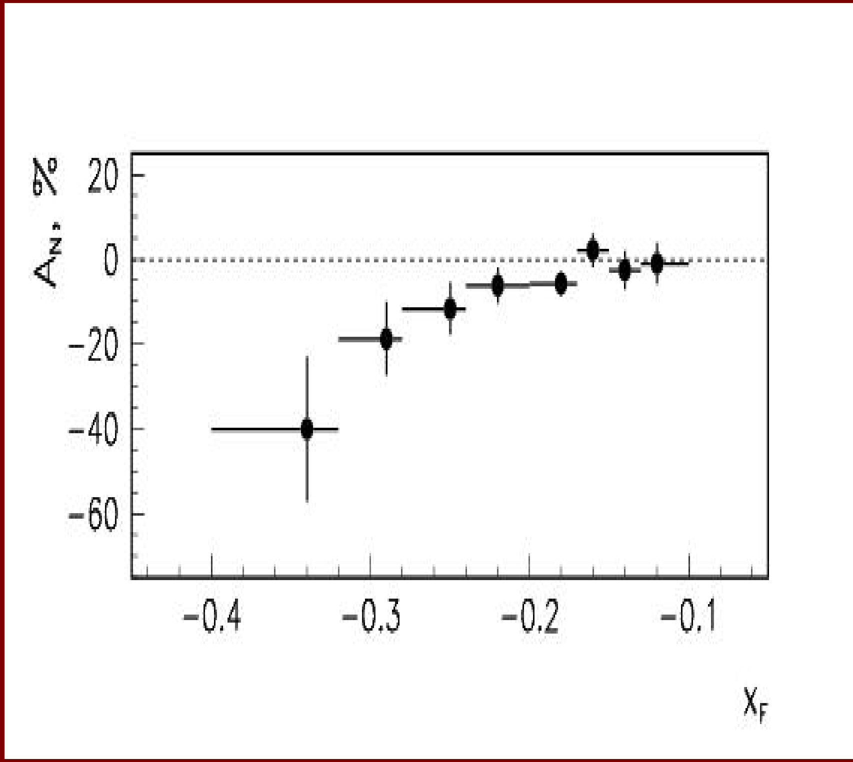
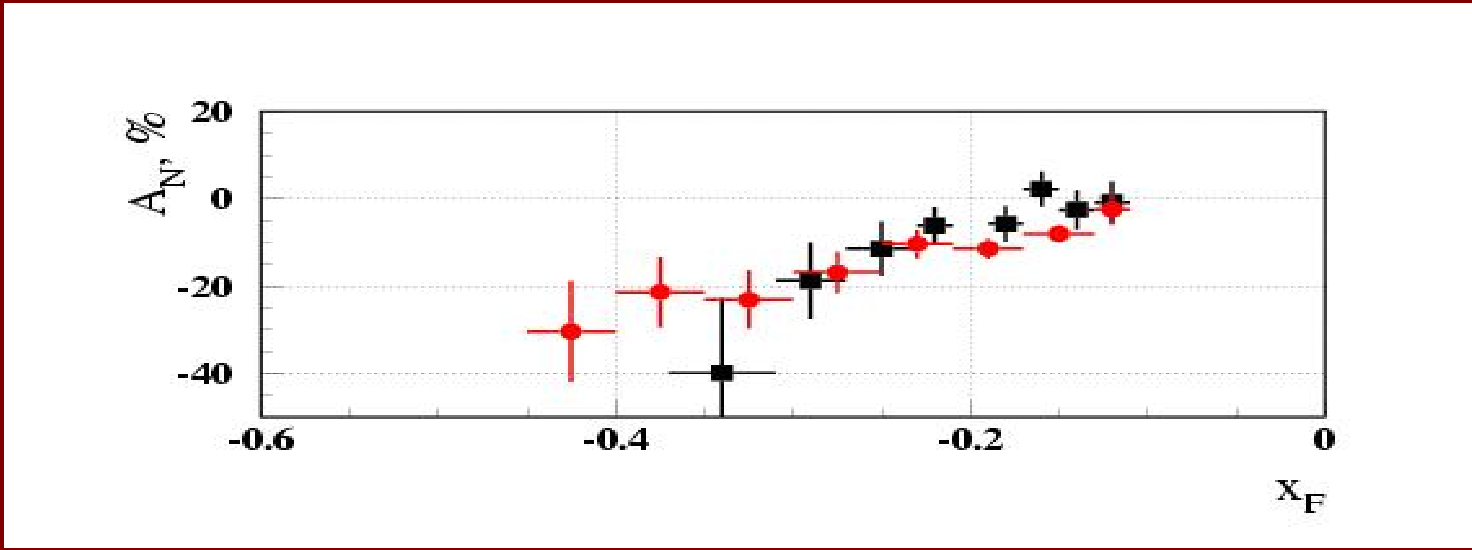


Fig.11. $pp_\uparrow \rightarrow \pi^0 X$, 70 GeV

New preliminary results (Fig.12) on A_N in the reaction $pp_{\uparrow} \rightarrow \pi^{\circ} X$ for polarized target fragmentation region at 50 GeV



- Black points: A_N at 70 GeV,
- Red points – new result (at 50 GeV)

Discussion

The analyzing power in the inclusive π^0 production at high energies appears to illustrate the following features:

1. In the central region it is zero for reaction **$pp_{\uparrow} \rightarrow \pi^0 X$** (A) [PROZA, E704, PHENIX] in the energy range $\sqrt{s}$=10-200 GeV and non zero for reaction **$\pi^- p_{\uparrow} \rightarrow \pi^0 X$** (B) [PROZA only]
2. In the polarized particle fragmentation region for both reactions (A) [PROZA, STAR] and (B) [PROZA] it is non zero and A_N does not depend on the energy in the range $\sqrt{s} \approx$10-200 GeV for (A).

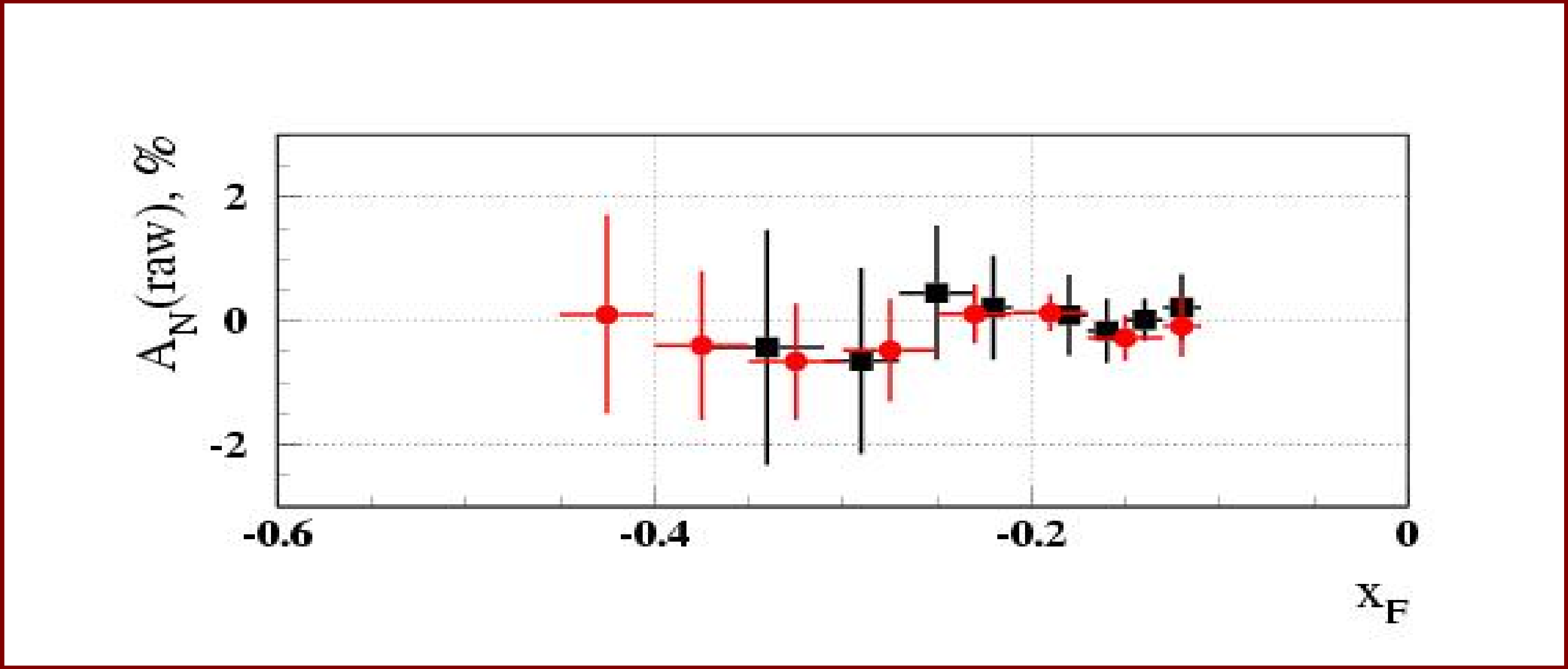
We see that asymmetry depends upon the flavor of the initial quarks and the kinematical domain of the reaction.

Summary

- A_N in the inclusive **π^0** production at polarized target fragmentation region at 50 GeV increases by magnitude with growth of $|x_F|$ and achieves $-(20.4 \pm 3.3)\%$ at $-0.45 < x_F < -0.25$.
- A_N at 70 and 50 GeV are completely coinciding at $0.4 < x_F < -0.1$
- Our results are in good agreement with data in polarized beam fragmentation region (E704, STAR)
- We are planning to measure asymmetry in the reaction **$pp_{\uparrow} \rightarrow \pi^0 X$** at 50 GeV up to $|x_F|=0.7$ this fall

Backup slides

Raw False asymmetry



Red points for positive sign of polarization

Black points for negative sign of polarization

A_N

X_F	<p_t>	Asym,%	Error bars
0.11-0.13	0.9	-2.5	3.5
0.13-0.17	1.0	-8.1	1.97
0.17-0.21	1.1	-11.5	2.35
0.21-0.25	1.2	-10.5	3.2
0.25-0.30	1.3	-17.	4.7
0.30-0.35	1.4	-23.2	6.7
0.35-0.40	1.55	-21.5	8.1
0.40-0.45	1.7	-30.5	11.6