A_N at small negative values of x_{F} in the reaction $p + p_{\uparrow} \to \pi^0 + X$ at 70 GeV and

universal threshold in inclusive pion production.

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On behalf of the PROZA-M collaboration

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Outline

Search for single-spin asymmetry in inclusive π^0 production in the polarized target fragmentation region in $pp_{\uparrow}$-collisions at 70 GeV/c.

General behavior of pion single-spin asymmetries between 13 and 200 GeV beam energy and universal threshold.

Future measurements at PROZA-M setup.

Single-Spin Asymmetry Definition

$$A_N^H(x_f, p_t) = \frac{1}{P_{target}} \frac{1}{<cos\phi>} \cdot \frac{\sigma_\uparrow^H(x_f,p_t) - \sigma_\downarrow^H(x_f,p_t)}{\sigma_\uparrow^H(x_f,p_t) + \sigma_\downarrow^H(x_f,p_t)}$$

P_{target} – average target polarization;

ϕ – azimuthal angle;

(Due to small angles ϕ, it was considered $|\cos\phi| = 1$).

Measured asymmetry

$$A_N = \frac{D(x_f,p_t)}{P_{target}} \cdot A_N^{raw}(x_f, p_t) = \frac{D(x_f,p_t)}{P_{target}} \cdot \frac{n_\uparrow(x_f,p_t) - n_\downarrow(x_f,p_t)}{n_\uparrow(x_f,p_t) + n_\downarrow(x_f,p_t)}$$

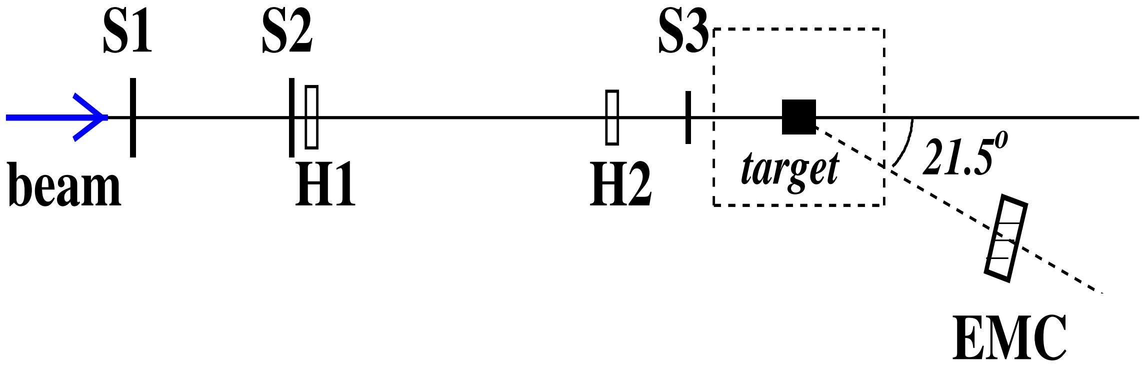
D - Dilution factor (Complex nuclei)

Previous inclusive measurements at Protvino

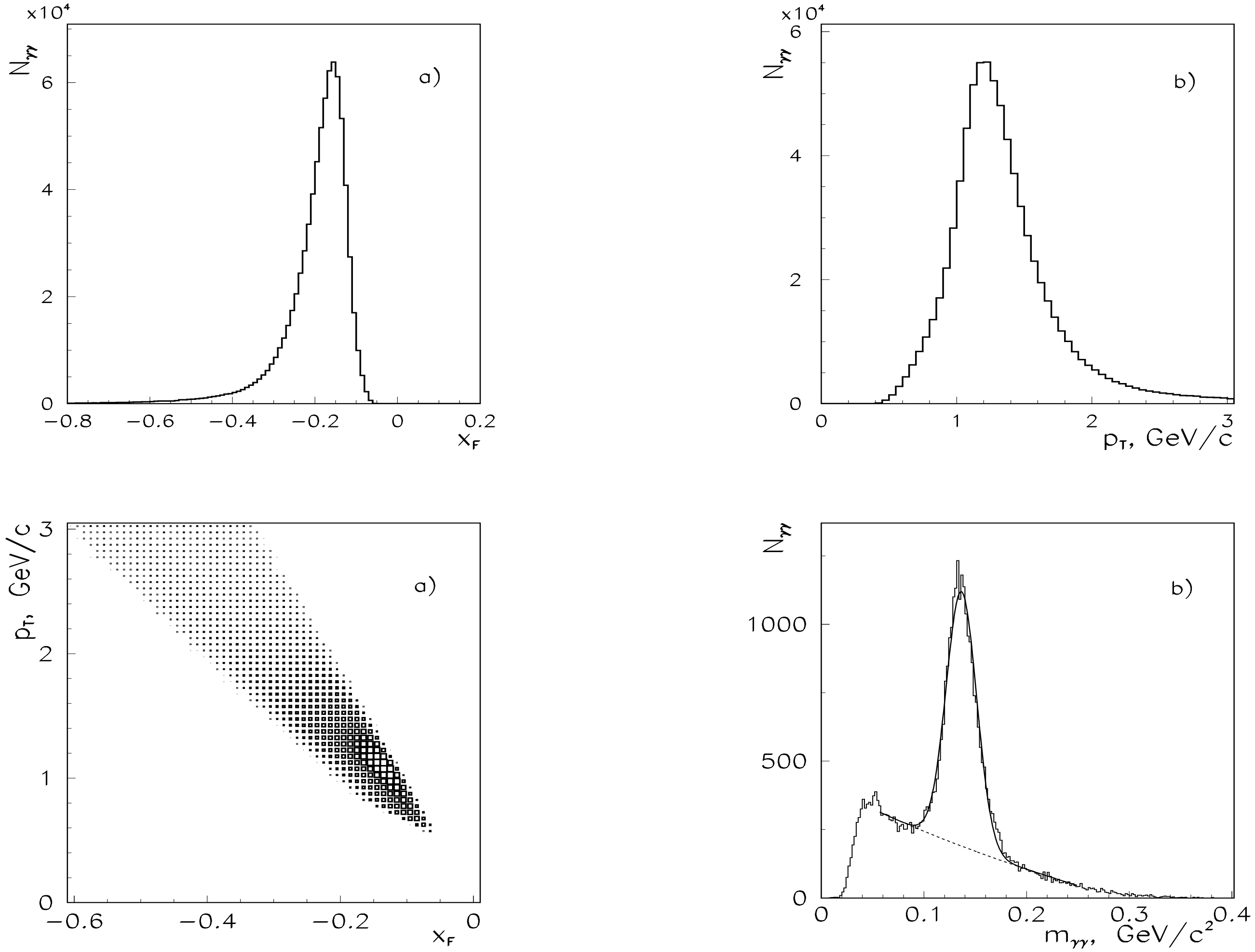
- OBSERVATION OF SIGNIFICANT SPIN EFFECTS IN HARD COLLISIONS AT 40-GEV/C
  Phys.Lett.B243:461-464,1990
- Single-spin asymmetry of inclusive π^0-meson production in 40 GeV pion interactions with a polarized target in the target fragmentation region This conference (S. Nurushev talk), IHEP Preprint 2003-21, Phys of Atomic Nuclei, Vol. 67, No. 8, p.1495, (2004)
- Searches for single-spin asymmetry in the inclusive production of neutral pion's in the central region with a proton beam energy of 70 GeV This conference (S. Nurushev talk), IHEP Preprint 2003-22, Phys of Atomic Nuclei, Vol. 67, No. 8, p.1487, (2004)

Experimental setup

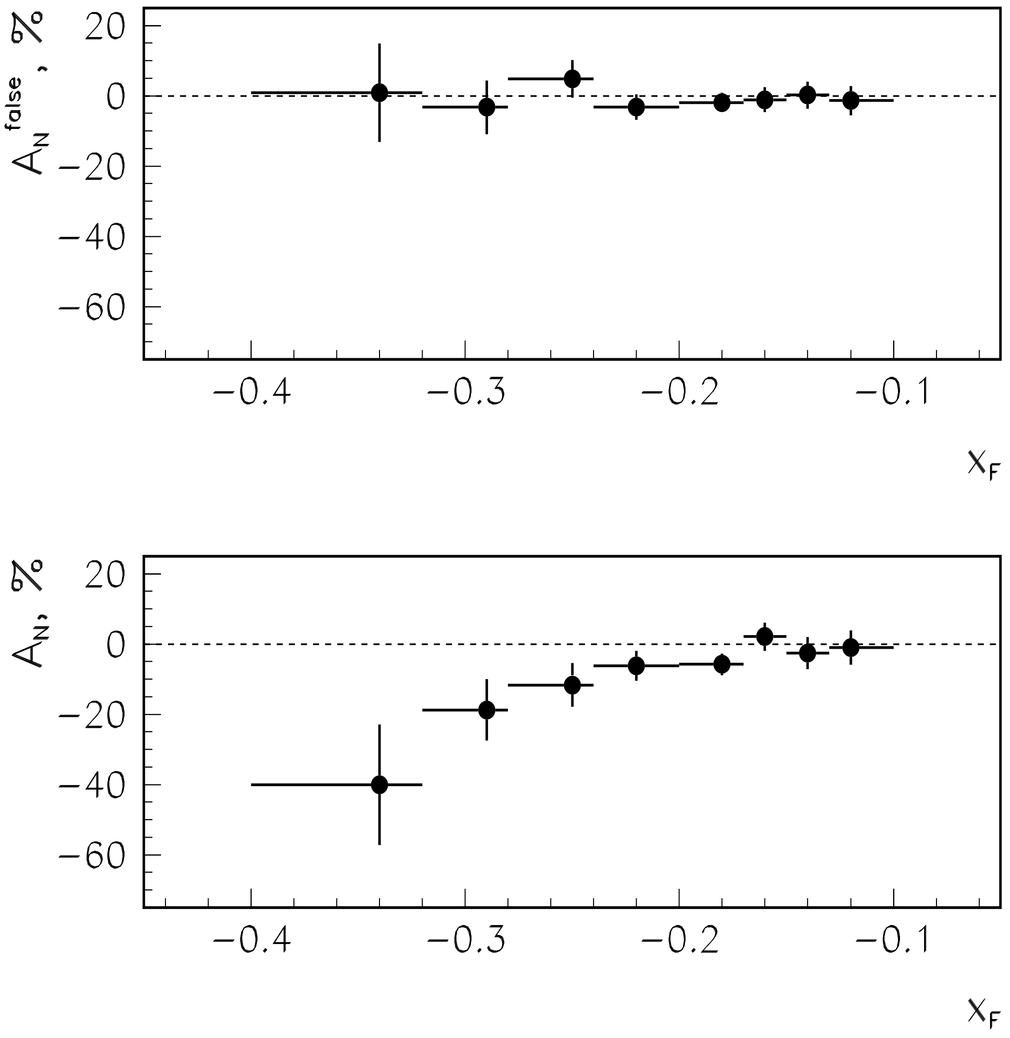
- Experiment was carried out at the U-70 accelerator in 1996.
- The proton beam was extracted using bent crystal (Intensity up to 10^7 protons/cycle)
- Polarized hydrogen target ($C_3H_8O_2$) with 80% average polarization
- γ-quanta were detected by electromagnetic calorimeter (144 lead glasses) 2.8 m downstream target)
- S1-S3: scintillation counters; H1-H2: 5-mm and 2-mm hodoscopes
- 1st level trigger on energy E



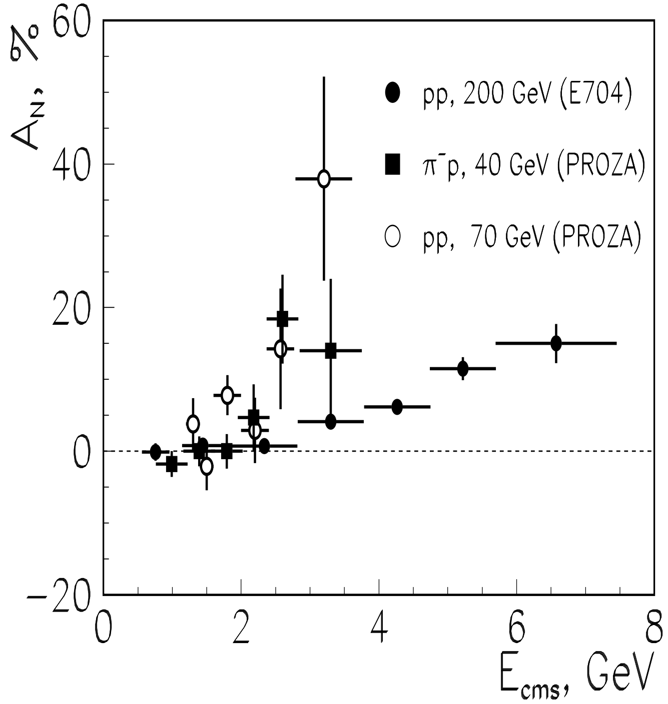
Kinematics


×10⁴
$N_{\gamma\gamma}$
a)
6
4
2
0
−0.8
−0.6
−0.4
−0.2
0
0.2
x_F
×10⁴
b)
p_T, GeV/c
1
2
3
p_T, GeV/c
−0.6
−0.4
−0.2
1000
500
$m_{\gamma\gamma}$, GeV/c²
0.1
0.2
0.3
0.4

Measured Asymmetry



Comparison with other experiments



Experiment	$\|A_N\|$, %
E704, FNAL	12.4 ± 1.4
STAR, BNL	14 ± 4
PROZA-M,π^-	13.8 ± 3.8
This experiment	11 ± 3

Conclusion from 70 GeV data

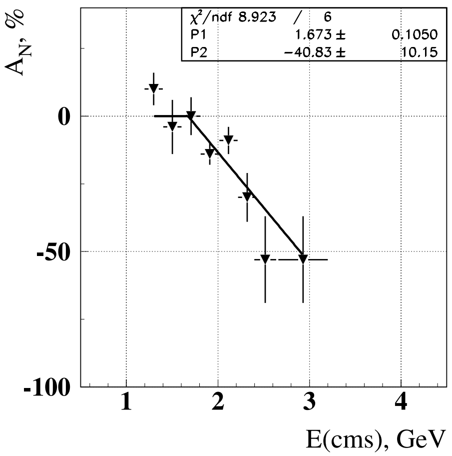
Single-spin asymmetry in the reaction $p + p_{\uparrow} \to \pi^0 + X$ at 70 GeV in the kinematic region $-0.4 < x_F < -0.1$ and $0.9 < p_T < 2.5$ GeV/c was measured.

The asymmetry is close to zero in the range $-0.2 < x_F < -0.1$ which is in agreement with previous measurements in the central region.

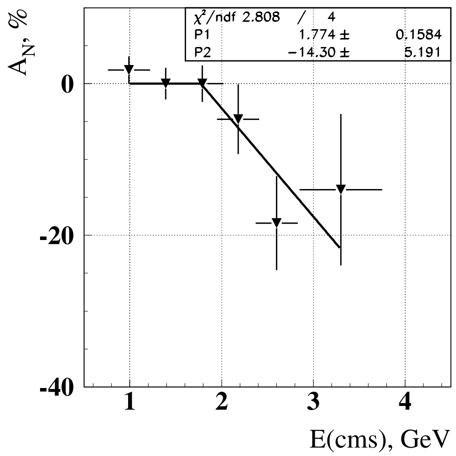
The asymmetry grows up in absolute magnitude with x_F decreasing and is equal to $(-11 \pm 3)\%$ at $-0.4 < x_F < -0.2$.

The result is published in IHEP Preprint 2004-32 and is submitted to Phys of Atomic Nuclei.

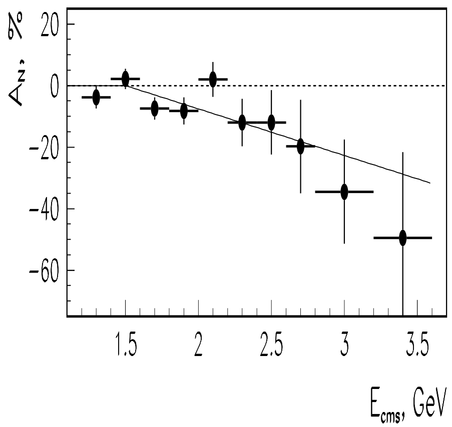
Investigation of universal threshold



Centr (π^- beam)



Fragm (π^- beam)

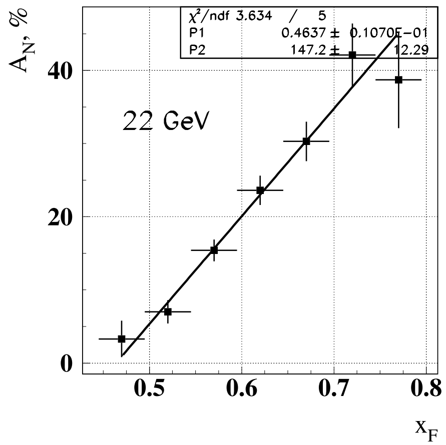


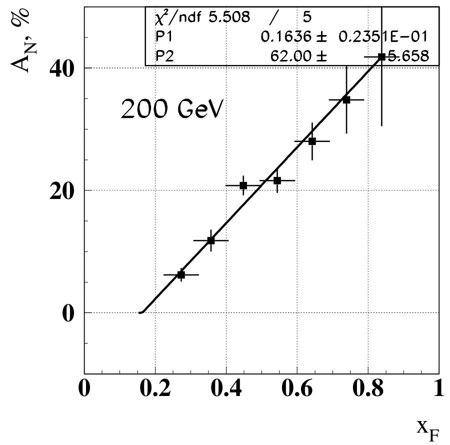
Current exp

The same threshold if fitting by function

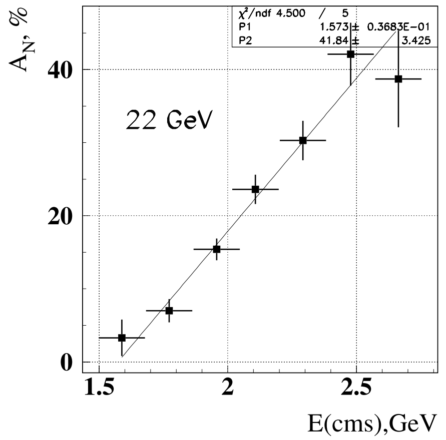
$$A_N = \begin{cases} 0 & , \text{ if } E < E_0 \\ k \cdot (E - E_0) & , \text{ if } E \geq E_0 \end{cases}$$

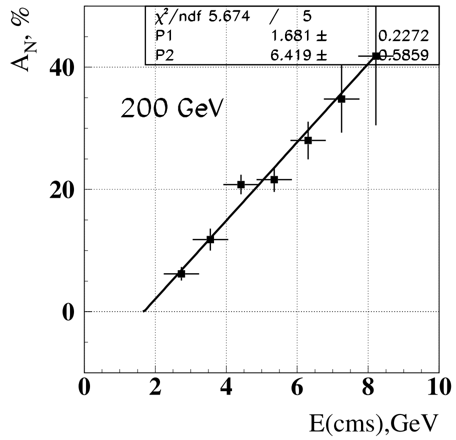
A_N in inclusive π^+production





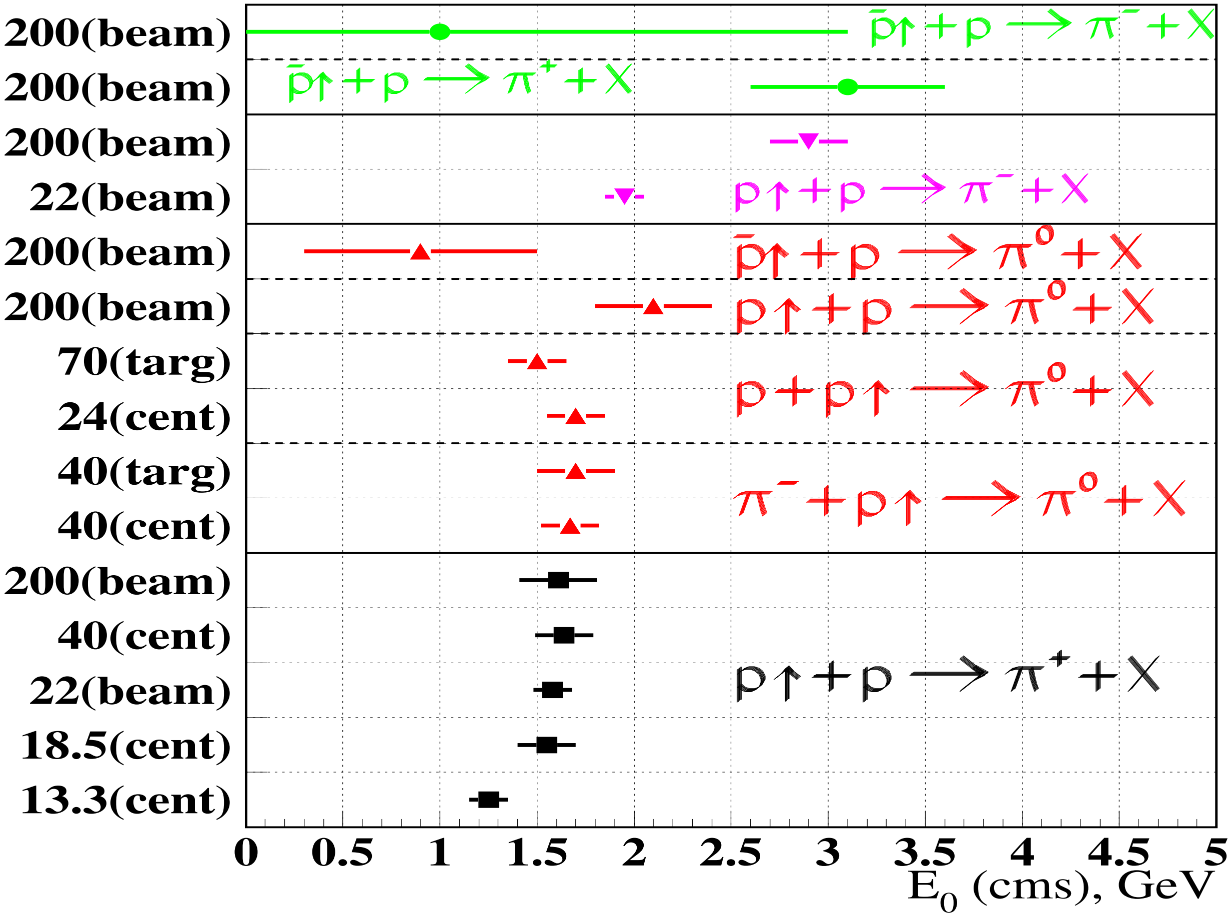
The asymmetry begins to grow at different x_F values, but at the same values in terms of E in c.m.s





The value of $E_0^{cms} \approx 1.7$ GeV The same value as for π^0 data

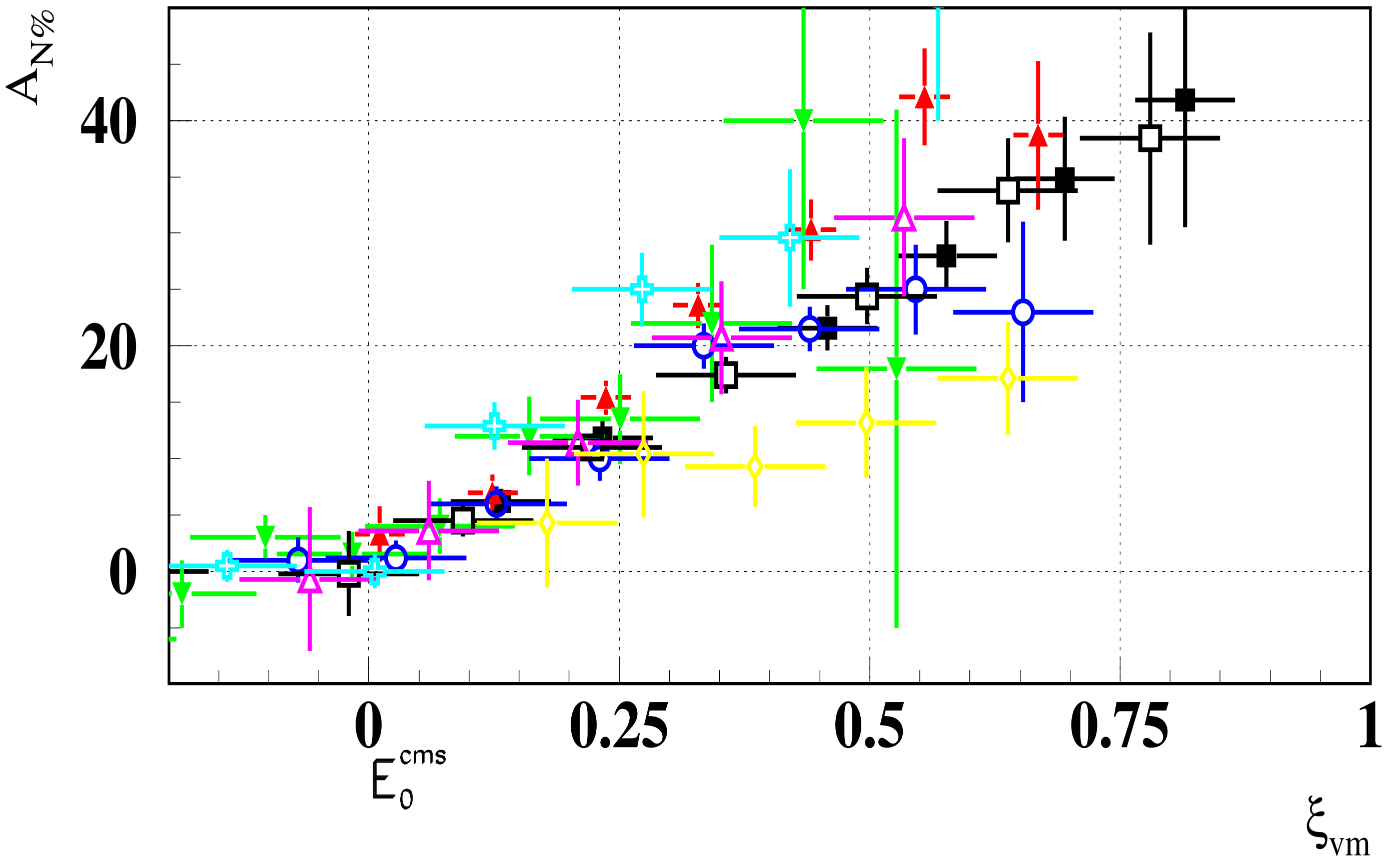
The value of threshold for all experiments



Combined result

Reaction	Energy	E_0^{cms}, GeV	χ^2/N	$k \cdot (E_{max}^{cms} - E_0^{cms})$, %
$p_\uparrow + p \to \pi^+ + X$	13.3	1.26 ± 0.1	0.9	52 ± 6
$p_\uparrow + p \to \pi^+ + X$	18.5	1.46 ± 0.15	0.85	63 ± 16
$p_\uparrow + p \to \pi^+ + X$	21.92	1.57 ± 0.1	0.9	68 ± 6
$p_\uparrow + p \to \pi^+ + X$	40	1.64 ± 0.15		
$p_\uparrow + p \to \pi^+ + X$	200	1.68 ± 0.25	1.1	52 ± 5
$\pi^- + p_\uparrow \to \pi^0 + X$	40	1.67 ± 0.15	1.5	107 ± 26
$\pi^- + p_\uparrow \to \pi^0 + X$	40	1.76 ± 0.2	0.7	36 ± 14
$p + p_\uparrow \to \pi^0 + X$	24	1.7 ± 0.15	0.6	334 ± 165
$p + p_\uparrow \to \pi^0 + X$	70	1.5 ± 0.2	0.15	50 ± 15
$p_\uparrow + p \to \pi^0 + X$	200	2.1 ± 0.3	0.5	26 ± 5
$\bar{p}_\uparrow + p \to \pi^0 + X$	200	0.9 ± 0.6	0.5	13 ± 4
$p_\uparrow + p \to \pi^- + X$	21.92	1.95 ± 0.1	0.5	-87 ± 11
$p_\uparrow + p \to \pi^- + X$	200	2.9 ± 0.2	<0.1	-51 ± 6
$\bar{p}_\uparrow + p \to \pi^+ + X$	200	3.1 ± 0.5	<0.1	-59 ± 16
$\bar{p}_\uparrow + p \to \pi^- + X$	200	1.0 ± 2.2	0.1	25 ± 15

The asymmetry scaling for charged pion's



$$\xi_{vm} = (E^{cms} - E_0^{cms})/(\sqrt{s}/2 - E_0^{cms})$$

Discussion

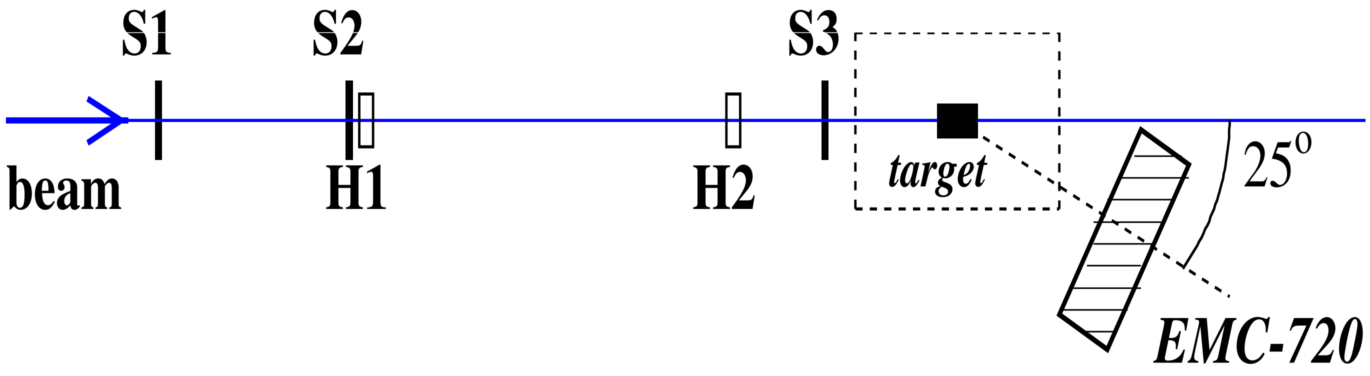
- The asymmetry starts to grow up at the same center of mass energy. (if $p_T > 0.5\mathrm{GeV/c}$).
- π^- production seems to contradict to this because of: π^--meson at small x_F can be produced not only from the valence d-quark but also from other channels. The interference of different channels is also responsible for asymmetry cancellation in π^0 and π^- production in the central region.
- The asymmetry behavior in $\bar{p}_\uparrow p$ interactions in π^+ and π^- production should be inversed in comparison with the $p_\uparrow + p \to \pi^0 + X$ in agreement with E704 data.
- In the reaction $\pi^- + p_\uparrow \to \pi^0 + X$ in the central region A_N is big in the contrary to the $p_\uparrow + p \to \pi^0 + X$ reaction. The valence u-quark from a polarized proton combining with the valence $\bar{u}$-quark from π^- gives the main contribution to π^0 production, while other channels are suppressed.

Conclusions on universal threshold

- We can conclude that the meson asymmetry produced by valence quark starts to grow up at the same universal energy E^0_{cms}.
- Also the values of the parameter $k \cdot (E^{max}_{cms} - E^0_{cms})$ are close for all eight measurements in the inclusive production of charged pion's.
- This behavior can be explained inside constituent quark model (see Phys.Rev.D69:077503,2004 or hep-ph/0310224)
- The paper is published in e-archive: hep-ex/0312007

Next measurements:

- Continue to measure asymmetry in the $p + p_{\uparrow} \rightarrow \pi^0 + X$ reaction at the target fragmentation region
- The detector of 720 cells with increased sensitivity will be placed on 30^o, allowing to cover $-0.8 < x_{\mathrm{F}} < -0.3$ region.
- Main goal - to increase accuracy and check universal threshold.
- The experiment is planning for 2005 and 2006.



Summary

- The asymmetry is close to zero in the range $-0.2 < x_F < -0.1$ which is in agreement with previous measurements in the central region.
- The asymmetry grows up in absolute magnitude with x_F decreasing and is equal to $(-11 \pm 3)\%$ at $-0.4 < x_F < -0.2$.
- Meson asymmetry produced by valence quark starts to grow up at the same universal energy $E^0_{cms} \approx 1.7$ GeV/c.
- New measurements will be carried out in next two years

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