Single-Spin Asymmetry in Inclusive π^0 Production Measured at the Protvino 70 GeV Accelerator.

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Single Spin Asymmetries (SSA) A_N measured in the two reactions at the Protvino 70 GeV accelerator are presented. A_N in the reaction $p + p_\uparrow \to \pi^0 + X$ in the central region is close to zero within the error bars. SSA in the reaction $\pi^- + p_\uparrow \to \pi^0 + X$ in the polarized target fragmentation region is equal to $(-15 \pm 4)\%$ at $|x_F| > 0.4$. There is an indication that the asymmetry arises at the same pion energy in the center of mass system.

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Introduction

Large polarization effects were found during last few decades. SSA was observed to be of order 20–40%, while Perturbative Quantum Chromodynamics (pQCD) makes a qualitative prediction that the single-spin transverse effects should be very small due to the helicity conservation [1]. Here we present new SSA measurements carried out at the 70 GeV Protvino accelerator in the reaction $p+p_\uparrow \to \pi^0 + X$ at 70 GeV in the central region ($x_F \approx 0$) and in the reaction $\pi^- + p_\uparrow \to \pi^0 + X$ at 40 GeV in the polarized target fragmentation region.

1 Asymmetry in the reaction $p + p_\uparrow \to \pi^0 + X$ at 70 GeV.

A_N in the reaction $p + p_\uparrow \to \pi^0 + X$ was measured using 70 GeV protons extracted by a bent crystal from the accelerator vacuum chamber. The experimental setup is shown in Fig. 1.

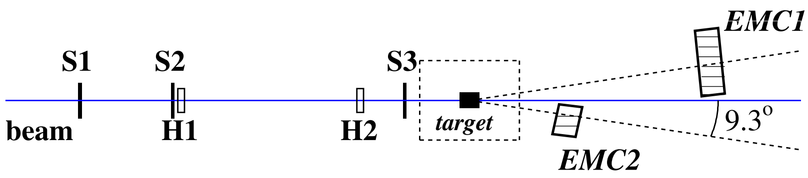

Fig. 1. Experimental setup PROZA-M: S1–S3 – trigger scintillation counters; H1–H2 – hodoscopes; EMC1 and EMC2 – electromagnetic calorimeters; *target* – polarized target.

Three scintillation counters S1–S3 were used for a zero level trigger with a coincidence from two hodoscopes H1–H2 (each consisted of two planes). γ-quanta were detected by two electromagnetic lead-glass calorimeters EMC1 and EMC2 (arrays of 480 and 144 cells correspondingly) placed 7 and 2.8 m downstream the frozen polarized target with 80% average polarization. First level trigger on transverse energy worked independently for the both detectors. Angle 9.3° in the laboratory frame corresponds to 90° in the center of mass system (c.m.s.) for 70 GeV proton beam. We were able to detect π^0-s till $p_T \approx 3.0$ GeV/c using specially developed algorithm for the overlapping showers reconstruction [2]. π^0 mass resolution was 10 MeV/c^2 for EMC1 and from 12 to 16 MeV/c^2 for EMC2.

Two dimensional distribution (x_F, p_T) was symmetrical on x_F (Fig. 2a). The slope of relative π^0-cross-section presented in Fig. 2b is in good agreement with the previous measurements of charged pion invariant cross-section. In this experiment an exponential constant $\alpha = -5.89 \pm 0.08$, while FODS experiment (Protvino) found $\alpha = -5.68 \pm 0.02$ for $\pi+$ and $\alpha = -5.88 \pm 0.02$ for π^- [3].

The asymmetry A_N with a detector to the right of the beam line is defined as

$$A_N = \frac{D}{P_{target}} \cdot A_N^{raw} = \frac{D}{P_{target}} \cdot \frac{n_\downarrow - n_\uparrow}{n_\downarrow + n_\uparrow}, \tag{1}$$

where D — target dilution factor, $n_\downarrow$ and $n_\uparrow$ — normalized number of π^0-mesons for opposite target polarizations. False asymmetry was investigated by dividing statistics with the same target polarization on two data samples and calculating the asymmetry for them. False asymmetry is close to zero. We compared the asymmetry for the two detectors and did not find any difference (see Fig. 3, left).

The final result for the both detectors is presented in Fig. 3 (right). The asymmetry is zero within the error bars. Our result is in agreement with the FNAL data at 200 GeV [4] and contradicts to the previous CERN measurements at 24 GeV [5]. Comparing the presented data with the π^0 asymmetry $A_N \approx -40\%$ at 40 GeV [6], we may conclude that the asymmetry depends on quark flavour. Otherwise we have

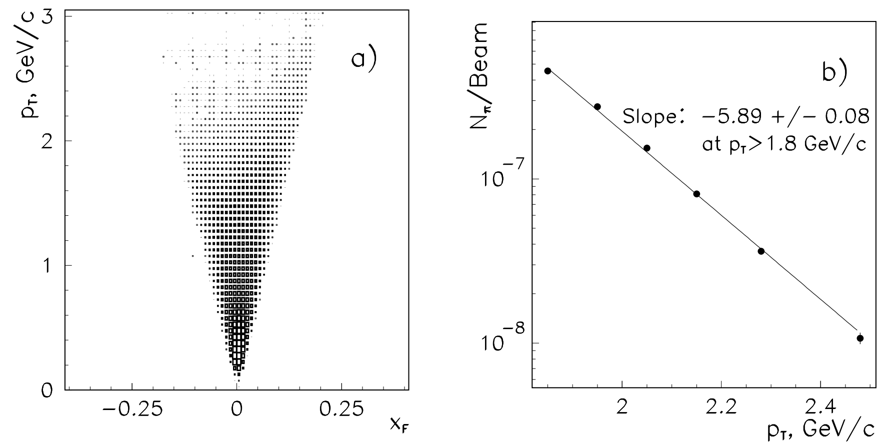

Fig. 2. Two-dimensional π^0 distribution on p_T and x_F (a) and relative π^0 cross-section ($N_{pions}/Beam$) (b).

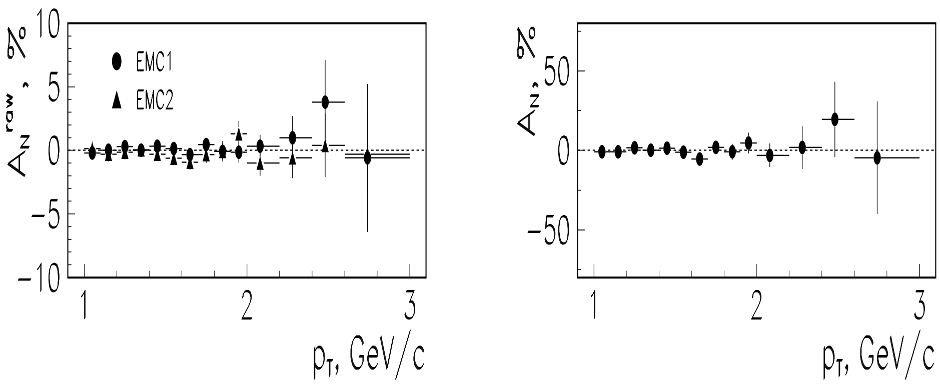

Fig. 3. Raw asymmetries for the two detectors separately (left) and summed A_N (right).

to suppose significant changes in interaction dynamics in the energy range between 40 and 70 GeV.

2 A_N in the reaction $\pi^- + p_\uparrow \rightarrow \pi^0 + X$ at 40 GeV.

The measurements in the reaction $\pi^- + p_\uparrow \rightarrow \pi^0 + X$ at 40 GeV were done in 2000 with the modified experimental setup PROZA-M. The electromagnetic calorimeter of 720 cells was placed at 2.3 m downstream the target at the angle of 40° in the laboratory frame to measure the asymmetry in the polarized target fragmentation region. A mass spectrum and the detector kinematic region are presented in Fig. 4.

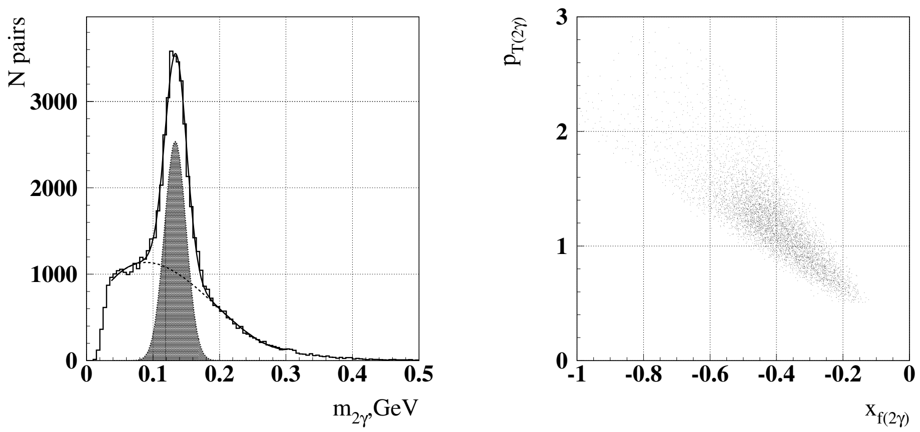

Fig. 4. Mass spectrum (left) and two-dimensional distribution on kinematic variables for the reaction $\pi^- + p_\uparrow \rightarrow \pi^0 + X$ at 40 GeV.

The measured asymmetry A_N (see Fig. 5) is close to zero at low values of $|x_F|$ and $A_N = (-15 \pm 4)\%$ at $-0.8 < x_F < -0.4$. The result is similar to the π^0 asymmetry in the polarized beam fragmentation experiments E704 ($(12.4 \pm 1.4)\%$, $\sqrt{s} = 20$ GeV [7]) and STAR ($(14 \pm 4)\%$, $\sqrt{s} = 200$ GeV [8]). Earlier we also measured the asymmetry in this reaction in the central region and found that A_N starts to rise up at $p_T \approx 1.6$ GeV/c [6]. We studied the asymmetry dependence on c.m.s. momentum and surprisingly found the asymmetry to begin to grow up at the same momentum $p_T^0(cms) = 1.70 \pm 0.25$ GeV/c (Fig. 6, left).

We have analysed the experimental data of other experiments and concluded that the asymmetry arises in the energy range between 1.5 and 2.0 GeV for all fixed target experiments (Fig. 6, right).

Conclusions

Finally we may summarize:

- A_N in the reaction $p + p_\uparrow \rightarrow \pi^0 + X$ at 70 GeV equals to zero in the central region for $1.0 < p_T < 3.0$ GeV/c and is in agreement with the E704 result.

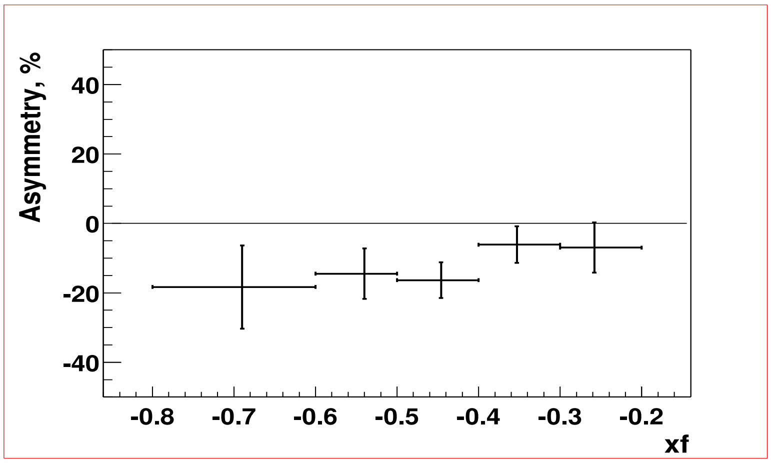

Fig. 5. Asymmetry A_N in reaction $\pi^- + p_\uparrow \to \pi^0 + X$ at 40 GeV.

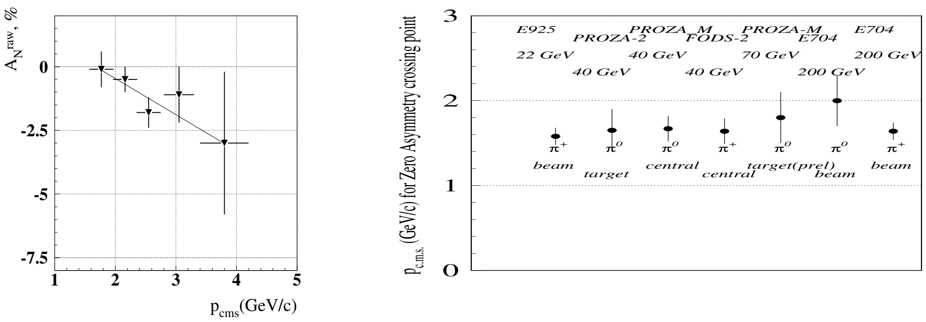

Fig. 6. The dependence of A_N on momentum in c.m.s. (left) and center of mass momentum values where the pion asymmetry starts to grow up for different experiments.

- In the reaction $\pi^- + p_\uparrow \to \pi^0 + X$ at 40 GeV in the polarized target fragmentation region $A_N = (-15 \pm 4)\%$ at $-0.8 < x_F < -0.4$ and $p_T > 0.8$ GeV/c and close to zero at small $|x_F|$ and $p_T < 1.5$ GeV/c.

- The last result is similar to the π^0 asymmetry in the polarized beam fragmentation region measured by E704 and STAR experiments. The π^0 inclusive production in the polarized proton fragmentation region can be considered as a proper reaction for polarimetry.

- The asymmetry in fixed target experiments arises at p_{cms} from 1.5 to 2.0 GeV/c independently on the beam energy and kinematic region.

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