SINGLE SPIN ASYMMETRIES IN INCLUSIVE π^0 PRODUCTION IN $P + P$ AND $\pi^- + P$ INTERACTIONS AT 40-70 GEV

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We present recent results of single-spin asymmetry A_N measurements in π^0 inclusive production. Asymmetry was measured in $\pi^- p$ and pp interactions at 40 and 70 GeV correspondingly. Significant asymmetry was observed in the polarized target fragmentation region. The results are in agreement with "universal threshold" of single-spin asymmetry.

Keywords: single-spin asymmetry; polarization; polarized target fragmentation region.

1. Introduction

Polarization experiments give us an unique opportunity to probe the nucleon internal structure. While spin averaged cross-sections can be calculated within acceptable accuracy, current theory of strong interactions can not describe single-spin asymmetries and polarization. Unexpected large values of single spin asymmetry in inclusive π-meson production are real challenge to current theory because naive perturbative Quantum Chromodynamics predicts small asymmetries decreasing with transverse momentum.

The asymmetry measurements in inclusive π^0-meson production with the use of pion and proton beams at the polarized target fragmentation region were carried out at the Protvino U-70 accelerator in the energy range between 40 and 70 GeV to investigate the dependence of A_N on a particle flavor.

2. Experimental Measurements

2.1. *Experimental Setup*

The experiment was carried out at the PROZA-M experimental set-up (See **Fig. 1**).

A 70 GeV proton beam extracted from the U-70 main ring with the use of a bent crystal had intensity $(3-6) \cdot 10^6$ protons/2 sec. spill. The full cycle time was 10 sec. A frozen polarized propane-diol ($C_3H_8O_2$) target was being operated with an average polarization of 85%. Three scintillation counters $S1$–$S3$ and two two-coordinate hodoscopes $H1$–$H2$ were used for a beam particle registration and a zero level trigger. A first level analog trigger provided the events selection with the energy deposited into the calorimeter above 2 GeV. Gamma-quanta were detected by the electromagnetic calorimeter EMC (720 lead glass blocks) placed 2.3 m downstream the target at 30° respectively to the beam direction. The EMC was adjusted to measure low energy γ-quanta, starting from 100 MeV. The sensitivity of each cell was about 2.3 MeV/ADC

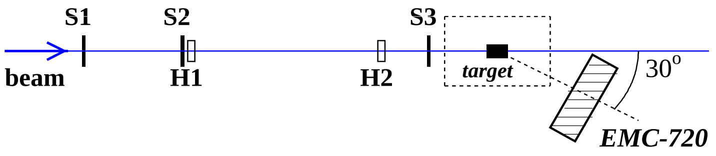

Fig. 1. Experimental Setup PROZA-M. S1-S3 – trigger scintillation counters; H1-H2 – hodoscopes; *EMC*–720 – electromagnetic calorimeter; *target* – polarized target.

count (See **Fig. 2**), the width of the distribution was less than 15%. The detailed description of the experimental setup is presented elsewhere[1].

2.2. *Asymmetry calculation*

The single spin asymmetry A_N is defined by the expression given in the eq. (1).

$$A_N(x_F, p_T) = \frac{1}{P_{targ}} \cdot \frac{1}{< cos\phi >} \times \\ \times \frac{\sigma_{\uparrow}^{H}(x_F, p_T) - \sigma_{\downarrow}^{H}(x_F, p_T)}{\sigma_{\uparrow}^{H}(x_F, p_T) + \sigma_{\downarrow}^{H}(x_F, p_T)} \quad (1)$$

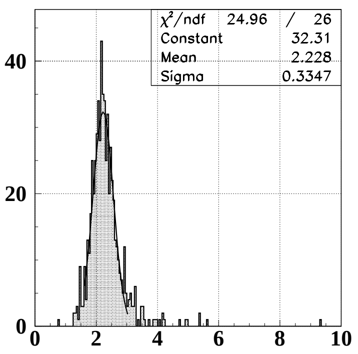

Fig. 2. Sensitivity of the EMC cells (in MeV/ADC count).

where P_{targ} is the target polarization, ϕ is the azimuthal angle between the target-polarization vector and the normal to the plane spanned by the beam axis and the momentum of the outgoing neutral pion, and $d\sigma_{\uparrow}^{H}$ ($d\sigma_{\downarrow}^{H}$) are the invariant differential cross sections for a neutral-pion production on hydrogen for the opposite directions of the target-polarization vector. We detected neutral pions in the azimuthal angle range of $(180 \pm 15)^{\circ}$; therefore, we set $\cos\phi = -1$. Since the π^0's detection efficiency is identical for the two directions of the target polarization vector, we find for the detector on the right side of the beam, that

$$A_N = -\frac{D}{P_{targ}} \cdot A_N^{raw} = -\frac{D}{P_{target}} \cdot \frac{n_{\uparrow} - n_{\downarrow}}{n_{\uparrow} + n_{\downarrow}} \quad (2)$$

where A_N^{raw} is the raw asymmetry actually measured in the experiment, D is the target-dilution factor, and $n_{\uparrow}$ ($n_{\downarrow}$) are the normalized (to the monitor) numbers of detected neutral pions for the up and down directions of the target-polarization vector. The procedure used to calculate $D \approx 8.1$ was described in detail elsewhere[2]. In measuring the asymmetry A_N, there can arise an additional asymmetry caused by a trigger-electronics jitter, failures of the monitor counters, a beam drift or by some other reasons. This gives a rise to a systematic bias of the true asymmetry. A method that can be used to remove this bias and which is based on the fact that the asymmetry of photon pairs off the neutral pion mass peak is zero is described in detail in[3]. We estimated the stability of the EMC energy scale at the level of 0.1% based on the stability of π^0 -mass. The beam position instability was the main reason of systematic bias of the true asymmetry

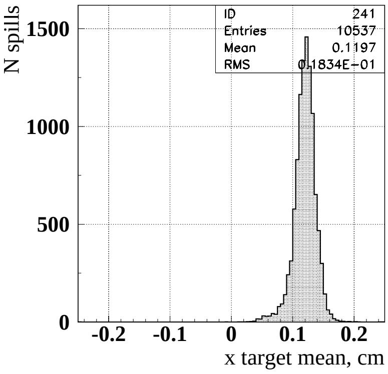

Fig. 3. Average beam position during spill.

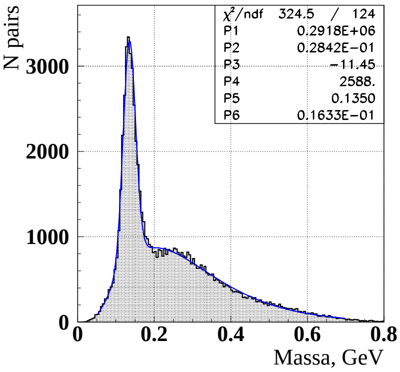

Fig. 4. Mass of the $\gamma\gamma$-pair for $-0.30 < x_{\mathrm{F}} < -0.25$ interval.

in the previous measurements. The improvement of the beam extraction technique[4] allowed us to achieve the stability of a beam position at the target at the level of 0.2 mm (See **Fig. 3**).

3. Data Analysis and Results

3.1. π^0*-reconstruction*

The events with more than two clusters were selected for a π^0-search and analysis. The clusters were considered to be good if their shower shape is comparable with the shape of the electromagnetic shower. A special procedure has being developed for compensate energy losses at low energies[3] and due to the shower leakage at large angles[5]. The mass spectrum of $\gamma\gamma$-combination after all corrections is presented in **Fig. 4**. The mass width σ is of the order of 16 MeV/c^2. The resolution is pretty good, in spite of the size of the target (about 20 cm long) is noticeable in comparison with the distance from the detector to the target (about 2.3 m).

We have the possibility to measure A_N in a wide interval of $-0.2 > x_{\mathrm{F}} > -0.8$. The kinematic parameters of the detected particles (transverse momentum p_t and x_{F}) are correlated. The two-dimensional distribution of the kinematic parameters of $\gamma\gamma$-combinations in the mass range $105 < m_{\gamma\gamma}(MeV/c^2) < 165$ for the recent data taking run are presented on **Fig. 5**. We plan to increase statistics for large negative values of x_{F} over the next exposition.

3.2. *Measured Asymmetry*

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A large asymmetry was observed previously in the reaction $\pi^- + p_\uparrow \to \pi^0 + X$ in the central region at 40 GeV[6]. A_N achieved -40% at $p_T > 2.5$ GeV/c. At the same time, the E704 experiment found zero asymmetry in the same kinematic region in the reaction $p_\uparrow + p \to \pi^0 + X$. Our recent measurements[7] in the reaction $p + p_\uparrow \to \pi^0 + X$ at 70 GeV (**Fig. 6**) are in agreement with E704 result. One may conclude that the asymmetry in the central region depends on the flavor of inter-

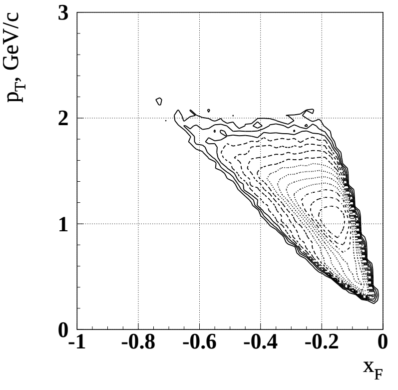

Fig. 5. Kinematic parameters of $\gamma\gamma$-pair for mass region $110 < m_{\gamma\gamma}(MeV/c^2) < 160$.

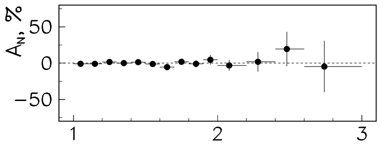

Fig. 6. A_N in the reaction $p + p_\uparrow \to \pi^0 + X$ in the central region at 70 GeV.

acting particles and does not depend on the energy.

Significant effects were observed eearlier in the polarized beam fragmentation region in the reaction $p_\uparrow + p \to \pi^0 + X$ at FNAL and BNL. We measured the asymmetry in the polarized target fragmentation region. A_N in the reaction $\pi^- + p_\uparrow \to \pi^0 + X$ at 40 GeV achieves $(-14 \pm 4)\%$ (See **Fig. 7**) at $-0.8 < x_F < -0.4$[3].

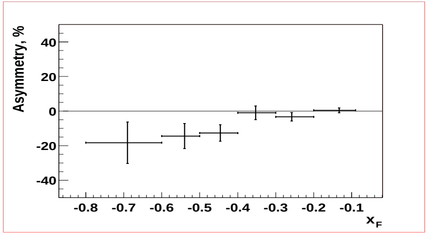

Fig. 7. A_N in the reaction $\pi^- + p_\uparrow \to \pi^0 + X$ in the target fragmentation region at 40 GeV.

The asymmetry in the reaction $p + p_\uparrow \to \pi^0 + X$ at 70 GeV equals to $(-24 \pm 8)\%$ (See **Fig. 8**) at $-0.4 < x_F < -0.28$[8]. The asymmetry in the polarized target fragmentation region does not depend on the beam particle flavor.

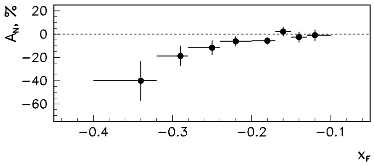

Fig. 8. A_N in the reaction $p + p_\uparrow \to \pi^0 + X$ in the target fragmentation region at 70 GeV.

4. Discussion

The asymmetries in the both reactions are in an agreement with each other. A_N in the polarized particle fragmentation region does not depend on the energy and on the particle flavor. The result is in agreement with "universal threshold" of the asymmetry[9] in the fixed target experiments (See **Fig. 9**) and may be explained with the help of the constituent quark model[10].

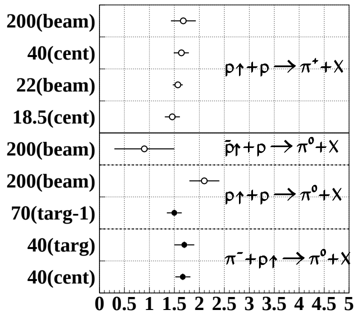

Fig. 9. Center of mass energy where asymmetry starts to grow. The energy along the Y-axis is in GeV; *cent* – corresponds to experiments in the central region, *targ* (*beam*) – the polarized target (beam) fragmentation region.

Acknowledgments

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References

1. V.D. Apokin *et al. Preprint IHEP* 97-38; *Instrum.Exp.Tech.* **41**, 464 (1998).
2. N.S. Amaglobeli *et al. Sov.J.Nucl.Phys.* **50**, 432 (1989), [*Yad.Fiz.* **50**, 695 (1989)].
3. A.N. Vasilev *et al.*, *Phys. Atom. Nucl.* **67**, 1495 (2004), [Yad. Phys.6715202004.
4. A.P. Bugorsky *et al.*, *Instrum.Exp.Tech.* **44**, 1 (2001).
5. A.N. Vasilev *et al.*, *Instrum. Exp. Tech.* **49**, 468 (2006), vol.4.
6. V.D. Apokin *et al.*, *Phys. Lett.* **B243**, 461 (1990).
7. A.N. Vasilev *et al.*, *Phys. Atom. Nucl.* **67**, 1487 (2004) [*Yad. Phys.* **67**, 1512 (2004)].
8. A.N. Vasilev *et al.*, Phys. Atom. Nucl.68, 1790 (2005) [Yad. Phys.68, 1852 (2005).
9. A.N. Vasilev and V.V. Mochalov, *Phys. Atom. Nucl.* **67**, 2169 (2004) [*Yad. Phys.* **67**, 2193 (2004).
10. V.V. Mochalov, S.M. Troshin, A.N. Vasiliev, *Phys. Rev.* **D69**, 077503 (2004).