THE COMPARATIVE STUDY OF THE INCLUSIVE $\pi^0$ ANALYZING POWER IN REACTIONS $p + p_\uparrow \rightarrow \pi^0 + X$ AND $\pi^- + p_\uparrow \rightarrow \pi^0 + X$ AT 50 AND 40 GEV/C RESPECTIVELY

V.V. Mochalov$^1$, S.B. Nurushev$^1$, A.N. Vasiliev$^1$, N.A. Bazhanov$^2$, N.S. Borisov$^2$, Y.M. Goncharenko$^1$, A.M. Davidenko$^1$, A.A. Derevschikov$^1$, V.G. Kolomiets$^2$, V.A. Kormilitsin$^1$, V.I. Kravtsov$^1$, A.B. Lazarev$^2$, Yu.A. Matuleno$^1$, Yu.M. Melnick$^1$, A.P. Meschanin$^1$, N.G. Minaev$^1$, D.A. Morozov$^1$, A.B. Neganov$^2$, L.V. Nogach$^1$, Yu.A. Plis$^2$, A.F. Prudkoglyad$^1$, A.V. Ryazantsev$^1$, P.A. Semenov$^1$, O.N. Shchevelev$^2$, L.F. Soloviev$^1$, Yu.A. Usov$^2$, A.E. Yakutin$^1$

(1) Institute for High Energy Physics, Protvino, Russia
(2) Joint Institute for Nuclear Research, Dubna, Russia
† E-mail: mochalov@ihep.ru

Abstract

Single-spin asymmetries $A_N$ in reactions $p + p_\uparrow \rightarrow \pi^0 + X$ and $\pi^- + p_\uparrow \rightarrow \pi^0 + X$ at 50 and 40 GeV/c respectively behave in drastically different ways in function of transverse momentum in the central region. At the same time $A_N$ in the polarized proton fragmentation region of these reactions are practically coinciding. Our new data on the analyzing power at 50 GeV/c in the polarized proton fragmentation region in reaction $p + p_\uparrow \rightarrow \pi^0 + X$ confirm this conclusion with better statistics and coincide with our previous data at 70 GeV/c for the same reaction.

Our previous measurements (see Fig. 1) of the single spin asymmetries in reactions $\pi^- + p_\uparrow \rightarrow \pi^0 + X(1)$ at 40 GeV/c [1] and $p + p_\uparrow \rightarrow \pi^0 + X(2)$ at 70 GeV/c [2] showed that they behave in drastically different ways in function of transverse momentum in the central region.

The analyzing power of reaction (1) is close to zero around the momentum transfer $p_T=1$ GeV/c and then increases with growth of $p_T$ up to 40% for $p_T > 2.2$ GeV/c. The

![Figure 1. Analyzing power of the reactions $\pi^- + N_\uparrow \rightarrow \pi^0 + X$ (a) and $p + p_\uparrow \rightarrow \pi^0 + X$ (b) at the central region at 40 and 70 GeV/c respectively.](image-url)
same behavior was found in reaction $\pi^- + d_\uparrow \rightarrow \pi^0 + X$ at the same kinematical region \cite{3}. At the same time $A_N$ for reaction (2) at 70 GeV/c is compatible with zero in the central region for the same domain of the transverse momentum. We may think about the following sources of the discrepancy. First one is related to the difference in the initial momentum of the incident particles, namely, 40 and 70 GeV/c. This argument does not work for the following reason. As it’s well known, one half of the incident hadron energy is carried by quarks and another one half is carried by gluons. Therefore the momentum of the interacting incident quark is 10 GeV/c in the case of pion beam and around 12 GeV/c in the case of proton beam. Assuming that the incident quark interacts with the constituent quark of the mass around 0.3 GeV we estimate the initial energy of the quark interaction in the center of mass system as 2.4 GeV for reaction (1) and 2.7 GeV for reaction (2). Such a small difference in the interaction energy should exclude the big difference in the spin effects in the reactions under discussion. As we show later our new result on $A_N$ for reaction (2) at 50 GeV/c experimentally confirms such conclusion for the beam fragmentation region. The second possibility for difference in analyzing power might be the existence of the antiquark in pion and the possible role of the annihilation process. We are not aware of any theoretical judgments about this subject.

The next discovery of the PROZA Collaboration, presented in Fig.2, is relevant to the single spin asymmetries in reactions (1) and (2) in the polarized proton fragmentation region. The asymmetry in the reaction (1) is close to zero in the interval $0 < -x_F < 0.4$, then increases with growth of the $|x_F|$ reaching the value around 30% at $|x_F|=0.7$ \cite{4}. Similar behavior is illustrated by the reaction (2) \cite{5}. So we do not see the flavor dependence of the asymmetry in contrast to the data for those reactions at the central region.

The goal of this article is to present our new data for reaction (2) with better statistics, but at the initial proton momentum 50 GeV/c, which corresponds to the quark energy in c.m.s around 2.2 GeV.

The layout of the experiment PROZA-M is presented in Fig.3. The proton beam of momentum 50 GeV/c extracted by curved mono-crystal \cite{6} comes from the left side, passes through the scintillation counters S1-S3, hodoscopes H1, H2 and strikes the polarized proton propane-diol target (PPT). Specific features of the PPT are the fairly high target polarization (90%), the long polarization life time and sufficiently large target length which was used in the frozen spin mode. \cite{7}. The photons emitted from target are detected by

![Figure 2](image.png)

**Figure 2.** Analyzing power of the reactions $\pi^- + p_\uparrow \rightarrow \pi^0 + X$ (a) and $p + p_\uparrow \rightarrow \pi^0 + X$ (b) at the polarized target fragmentation region at 40 and 70 GeV/c respectively.
the electromagnetic calorimeter EMC-720, consisting of 720 lead glass counters packed as $30 \times 24$ matrix. Cell sizes are $38.1 \times 38.1 \times 450 \text{ mm}^3$ ($18 \times 0$). It is installed under angle $30^\circ$ to the beam direction at the distance $l = 2.16 \text{ m}$ from the center of the PPT. The dashed box around the PPT denotes the unique magnet carrying two functions: building up the target polarization and holding it during the data taking. The PROZA setup is described in detail somewhere [8].

EMC was calibrated by wide electron beam of 5 GeV/c using inverse matrix method. Sensitivity of the ADC channels is about 2.2 MeV/channel. Additional calibration using $\pi^0$-mass during data taking was used to monitor EMC energy stability in time with accuracy 0.1%.

Trigger requires the coincidence of signals from three scintillation counters, at least one hit in each plane of hodoscopes and total deposited energy in EMC $\Sigma E > 2 \text{ GeV}$. The DAQ system includes the registers for hodoscopes, 12 bits ADC for EMC, scalers, the read-out processor on the base of processor MC68030. In average 700 events per spill were registered. During 10 days data taking $5 \times 10^7$ events were accumulated.

For shower reconstruction it is required that at least 5 cells among 9 central ($3 \times 3$) were activated; energy deposit in the central counter should be at least 100 MeV. For reconstruction of the $\pi^0$ the photons in the energy region 0.5-5 GeV were used. Additional procedures were implemented to reconstruct actual photon energy and coordinate:

1. The dependence of the reconstructed photon energy on the real initial photon energy[2]. This correction was of order of 10%.
2. The dependence of the reconstructed photon energy and coordinate on its inclination

**Figure 3.** Experimental Setup PROZA-M. S1-S3 – trigger scintillation counters; H1-H2 – hodoscopes; EMC – 720 – electromagnetic calorimeter; target – polarized target.

**Figure 4a.** False raw asymmetry for different sets of data

**Figure 4b.** $A_N$ in the reactions $p + p_\uparrow \rightarrow \pi^0 + X$ at the polarized target fragmentation region at 50 GeV/c (circles) and 70 GeV/c (squares).
angle[9, 10]. The energy correction was of order 5%. The coordinate correction is 2-3 cm for 15° gamma inclination angle.

After corrections the reconstructed $\pi^0$ mass was consistent with its table mass within precision less than 1% in whole kinematical range.

The raw asymmetry was calculated by usual way normalizing the counting rate to the events outside of the $\pi^0$-mass region. In order to check that the false asymmetry is zero for the fixed target polarization the vents were divided in two groups with almost equivalent statistics. Using these two groups we calculated the false asymmetry. Such procedure was applied to both sign of the polarization target independently. The results for such false asymmetries are presented in Fig.4a.

New results for the reaction $p + p_\uparrow \rightarrow \pi^0 + X$ in the polarized target fragmentation region at 50 GeV are shown in Fig.4b. $A_N$ in the inclusive $\pi^0$ production at polarized target fragmentation region increases by magnitude with growth of $|x_F|$ and achieves $-(20.4 \pm 3.3)\%$ at $-0.45 < x_F < -0.25$. These data are consistent with our previous measurement of the analyzing power for the same reaction and at the same kinematical region at 70 GeV/c presented in the same figure. It supports our conclusion that asymmetry in quark scattering is not sensitive to the small energy difference in the initial state.

We can conclude that the analyzing power in the inclusive $\pi^0$ production at high energies appears to illustrate the following features:

- In the central region it is zero for reaction (2) [PROZA, E704, PHENIX] in the energy range $\sqrt{s} = 10 - 200$ GeV and non zero for reaction (1) [PROZA only];

- In the polarized particle fragmentation region for reactions (2) [PROZA, STAR] and (1) [PROZA] it is non zero and $A_N$ does not depend on the energy in the range $\sqrt{s} = 10 - 200$ GeV for reaction (2).

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