EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EF/80-88
4.6.1980

SPIN DEPENDENCE OF THE INCLUSIVE REACTION

$p + p$ (POLARIZED) $\rightarrow \pi^0 + X$ at 24 GeV/c FOR HIGH p_T
 π^0 PRODUCED IN THE CENTRAL REGION

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ABSTRACT

The spin dependence of π^0 inclusive production by 24 GeV/c protons has been measured using a polarized target for Feynman x near 0 in the transverse momentum range $1.0 < p_T < 2.5$ GeV/c. The results indicate a negative up-down asymmetry growing strongly with p_T and greater than 50% in absolute value for p_T greater than 2 GeV/c.

Submitted to Physics Letters B

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† Also supported by the Swiss National Science Foundation

Strong spin effects have been observed in inclusive reactions for particles with high transverse momenta^{1),2)}. The most striking result was the large polarization of Λ^0 's produced in inclusive p-p collisions from 24 to 2000 GeV/c²⁾. It was, therefore, of some interest to study spin effects at high transverse momenta for other inclusive reactions. The experiment described below studied the asymmetry in the production of π^0 's produced in $p + p \rightarrow \pi^0 + X$ for the central region, using a polarized target at an incident proton momentum of 24 GeV/c and for transverse momenta > 1 GeV/c. A preliminary result has been presented earlier³⁾. It was obtained using an independent method of analysis on a different set of data.

At 24 GeV/c an extracted proton beam from the CERN PS was focused onto a polarized proton target (propanediol). The beam and target were monitored with the use of a) a thin plate ionization chamber, b) two 3-counter telescopes directed at the target and in the plane of the polarization and c) a magnetic spectrometer to detect 300 MeV/c protons scattered backwards from unpolarized nucleons in the target. Details concerning beam, target and monitors were discussed in a previous paper⁴⁾, however, for stability purposes, the beam intensity was reduced to $2 \cdot 10^8$ ppp.

π^0 's are detected by four contiguous γ detectors placed at 16 degrees in the laboratory, which corresponds to 90 degrees in the centre-of-mass system. Each γ detector consisted of a veto counter V_i to reject charged particles, a converter (one radiation length of lead), a dE/dx counter N_i , an x-y scintillator hodoscope and a lead-glass^{*} shower counter G_i of 15 radiation lengths (Fig. 1). The trigger was defined by a majority coincidence between at least two of four V_i - N_i - G_i with threshold at twice the minimum ionization in N and G counters. Areas of all N and G counters and latches of hodoscopes were recorded for each event. The lead-glass calibration was determined from well-chosen data samples by requiring the effective mass of γ pairs to peak at the known π^0 mass. An independent check was provided by observing the pulse height from minimum ionizing particles traversing the counters (equivalent to 350 MeV photons). A simulation program using EGS⁵⁾ reproduces the observed γ energy and γ - γ mass spectra rather well. The resolution of the π^0 mass, for example, is 40 MeV (FWHM). The main source of background is due to uncorrelated photons from the decay of two π^0 's. The acceptance of the detector is a factor of ~ 6 greater for two γ 's originating from different pions than for two γ 's coming from a parent pion. Unfortunately, the cross-section for production of two pions at 24 GeV/c is unknown. The simulation program shows that the events from uncorrelated γ 's contribute mainly to low effective

^{*}) Type PEMG 4 (Chara), similar to SF5 (Schott) extensively studied⁶⁾.

masses and also low energy. By normalizing the observed spectrum in the region where the acceptance for a single π^0 is zero, one can make an estimate of the background resulting from the uncorrelated photons. In this way one can reproduce the shape of the $\gamma\text{-}\gamma$ mass spectrum resulting from π^0 's by a suitable subtraction. Details concerning the analysis can be found in Ref. 7).

The raw asymmetry is defined as

$$A_r = (1/PT) \cdot (N_+ - N_-)/(N_+ + N_-)$$

where PT is the target polarization and N_+ and N_- are the normalized number of observed π^0 's with the direction of target polarization positive (spin up) and negative (spin down). Drifts in the asymmetry were controlled by reversing the sign of the target polarization every two hours. The data from carbon targets (unpolarized) were also used for the same purpose. The internal stability of the monitors was such that ratios between different monitors were equal for runs of opposite signs with a precision of 0.002. The number of π^0 's was sorted in x and p_T bins. Systematic errors were monitored by observing the transverse momenta spectra of the π^0 's for both directions of the target polarization. A final check was made on drifts by using a time-dependent analysis⁸⁾ developed for inclusive spin measurements of this type⁹⁾.

The raw asymmetry in the region $0 < x < 0.1$ is presented as a function of p_T in Fig. 2. Statistical error bars are included.

Since the π^0 's that are produced on bound unpolarized nucleons of complex nuclei are not separable from π^0 's produced on free protons, the real asymmetry $A = A_r \cdot D$ is diluted in the measured asymmetry A_r . This dilution factor D^{*)} may vary, depending on the kinematical conditions. Using the backward monitor to measure the ratio between bound nucleons in propanediol and carbon targets, one can extract the dilution factor (the ratio of π^0 's produced on bound and free nucleons to π^0 's produced on free protons). The empirically determined dilution factor increases with p_T , but the precision is limited by low statistics. Therefore existing values of cross-sections for π^+ and π^- produced by 24 GeV/c protons on free protons¹⁰⁾ and bound nucleons¹¹⁾ are used to deduce the p_T dependence of D, assuming that the π^0 cross-section is the half-sum of π^+ and π^- cross-sections. The fact that the dilution factor increases with p_T can be understood by the Fermi motion in bound nucleons, which extends the kinematical limit in p_T .

*) It would be for propanediol ($C_3H_8O_2$) 9.5 (ratio of free protons to all nucleons) if cross-sections for production of π^0 in p + p (free), p + p (bound) and p + n (bound) were the same.

The results of the asymmetry measurement are presented in Table 1. The errors on raw asymmetry are statistical: the uncertainty in the dilution factor comes from the errors of fits used; the error on real asymmetry includes both statistical errors and errors due to the dilution factor. The last value is larger than the allowed limit: this is due to the large uncertainty of the dilution factor. The real asymmetry increases strongly with p_T , as one can see in Fig. 3.

Table 1

Measured and real asymmetries for $0 < x < 0.1$

p_T band (GeV/c)	A_r (%)	D	A (%)
1.0 - 1.2	$+0.34 \pm 0.20$	8.7 ± 4.5	$+2.9 \pm 2.3$
1.2 - 1.4	-0.34 ± 0.27	8.8 ± 4.5	-3.0 ± 2.8
1.4 - 1.6	-0.27 ± 0.40	9.4 ± 5.0	-2.6 ± 4.0
1.6 - 1.8	-1.34 ± 0.62	10.7 ± 5.4	-14 ± 10
1.8 - 2.0	-4.2 ± 1.0	13.3 ± 6.8	-56 ± 32
2.0 - 2.5	-7.0 ± 1.4	18.1 ± 9.4	-126 ± 71

The spin dependence in inclusive reactions has been studied in a number of theoretical papers. The large polarization of the Λ 's produced in inclusive p-p collisions mentioned above is not understood in Regge cuts analysis which gives a very small result¹²⁾, nor in perturbative QCD where there exist arguments to predict a negligible effect¹³⁾. A semi-classical model has also been proposed recently to explain this large polarization effect¹⁴⁾. In the case of π^0 inclusive production, the π^0 's produced at high p_T are believed to come from hard scattering collisions between the constituents of hadrons^{15),16),17)}. The consequences of these ideas in the case where one initial proton is polarized have been investigated in Ref. 18) and restrictive bounds on the asymmetry have been obtained. However, one cannot be sure that the strong spin effect seen in this experiment at 24 GeV/c is a hard scattering effect. Also, some caution should be taken in interpreting this particular result since the high p_T π^0 's are produced close to the kinematic limit at 24 GeV/c. It might be a crucial test for the spin properties of hadronic constituents to repeat this experiment at higher energies as already anticipated¹⁹⁾. Nevertheless, it is interesting to observe such a strong spin memory even at this low energy.

We acknowledge the contribution of J.B. Jeanneret who developed part of the simulation program. We wish to thank M. Borghini, T. Niinikoski and J.M. Rieubland for their polarized target. We are indebted to W. Huta, A. Kupferschmid and A. Looten for their technical assistance and to D. Dufournaud for her help on on-line software.

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Figure Captions

- Fig. 1 : Side view of the π^0 detector.
- Fig. 2 : Raw asymmetry as a function of p_T in the Feynman x range 0 - 0.1.
- Fig. 3 : Asymmetry as a function of p_T in the Feynman x range 0 - 0.1.

FIG 1

FIG 2

FIG 3