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MASTER

pp SPIN CORRELATIONS AT HIGH p_T

by

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Abstract

New data are presented for measurements of the spin correlation in pp reactions with longitudinally polarized beam and target. Data were obtained at 11.75 GeV/c for both elastic scattering and for π^+ - and π^--production at high p_T in pp reactions at 11.75 GeV/c. A comparison is made with recent predictions of quark-parton models.

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Introduction

A number of theoretical predictions using quark-parton models have recently been made of spin effects in pp reactions at high energy and high p_T. Inclusive π-production has been studied by Bourrely and Soffer[1], Babcock, Hidaka, Monsay and Sivers[2], Ranft and Ranft[3], Chen[4], and Cheng and Fischbach[5]. Measurable asymmetries were predicted for certain spin parameters. Elastic scattering at high p_T was investigated by Chen[6], Farrar, Gottlieb, Sivers and Thomas[7], Brodsky, Carlson and Lipkin[8], and Preparata and Soffer[9]. These predictions were inspired by the large spin correlation parameter (C_{NN}) observed by the Michigan group[10] at the ZGS for beam and target polarized perpendicular to the scattering plane, and also by the scheduled construction of polarized beam facilities at Fermilab and the AGS. Recently, Wolters[11] has also studied pp and pn elastic scattering in the quark model.

An experiment was performed by the ANL polarized target group to test some of the theoretical predictions when the beam and target are both longitudinally polarized. The beam momentum was 11.75 GeV/c and the data were collected during the final high energy running period at the ZGS. The experiment was designed to acquire elastic scattering and inclusive π^+ and π^- asymmetries at the highest possible value of p_T. The rapidly falling elastic scattering cross section will make it difficult to go far above 12 GeV/c near $\theta_{c.m.} = 90°$ with this type of measurement in the future.

The quantity measured in this experiment is

$$C_{LL} = \frac{d\sigma/dt(\rightarrow\rightarrow) - d\sigma/dt(\rightarrow\leftarrow)}{d\sigma/dt(\rightarrow\rightarrow) + d\sigma/dt(\rightarrow\leftarrow)}$$

where the arrows denote spin directions in the lab frame. Note that this is the negative of the parameter A_{LL} often calculated in theoretical papers, which is usually defined in terms of helicities in the c.m. frame.

Experimental Setup

The experimental layout is shown in Fig. 1. The beam intensity was roughly 10^7 longitudinally polarized protons per pulse with a 6 sec/pulse repetition rate and a 0.8 sec spill. The beam polarization was ~ 65%, and its direction was reversed every pulse. The relative beam intensity was monitored with a pair of scintillation counter telescopes viewing the polarized target and also a scintillation counter located in the incident beam whose current was integrated.

The longitudinally polarized proton target was 8 cm long and the target material was ethylene glycol. The target polarization averaged ~ 85% and the polarization direction was reversed every 2-3 hours.

The forward going particles were detected in a magnetic spectrometer with three x-y MWPC planes before and two planes after the magnet. A pair of 16 element scintillation counter hodoscopes were used in the trigger, one mounted upstream and the other downstream of the magnet. Finally, a large aperture, atmospheric pressure Cerenkov counter was located between the final two MWPC's for particle identification. It was filled with Freon-12 and the π threshold was roughly 3 GeV/c (the proton threshold was above 12 GeV/c). The angular acceptance of the spectrometer was θ_{lab} ~ 12-22° and $\Delta\phi \sim \pm$ 7°.

In order to insure that only high p_T particles initiated the MWPC readin, a fast matrix was used in the trigger to insure that there was an appropriate correspondence of elements firing in the two scintillation counter hodoscopes. In addition, a signal was required from the Cerenkov counter for the π^+ - and π^--production measurements. The elastic scattering triggers required a high p_T particle in the spectrometer, no signal from the Cerenkov counter, and a particle detected in one of the recoil scintillators.

Results

The results of a preliminary analysis of the data are presented. Cuts were applied to the reconstructed target position for both inclusive and elastic scattering events. Additional cuts for coplanarity, opening angle and missing mass were made for the elastic data. Roughly 80% of the inclusive events and 35% of the elastic events have been analyzed. Corrections have not been applied for the effect of the target magnetic field on the particle trajectories. Also, a more accurate algorithm for the momentum measured in the spectrometer is being developed. The results shown here are not expected to change substantially with these improvements. The systematic error for these measurements is ± 10%, caused by uncertainties in the absolute beam and target polarization.

a) π^+ - and π^--Production Asymmetries

The asymmetries for π^+ - and π^-production are given in Fig. 2a as a function of $x = P_{||}/P_{||,max}$ in the c.m. frame for all $p_T \gtrsim 1.0$ GeV/c. The target dilution factor was taken to be 11.7, although a more accurate value will be obtained in the future (this quantity is the ratio of π-production

from all nuclei in the polarized target to the π-production from hydrogen in the target). The results seem to be independent of x and indistinguishable from 0.

The asymmetries are shown in Fig. 2b as a function of p_T after summing over x. Predictions of Babcock, Monsay and Sivers[2] and Cheng and Fischbach[5] are shown for comparison. The experimental π^- results seem consistent with the small asymmetries predicted by these models based on QCD, but the large asymmetry predicted for π^+ is not observed.

b) p + p Elastic Scattering Asymmetry

The elastic scattering results are given in Fig. 3. The Michigan C_{NN} data[10] are also plotted for comparison. It appears that striking structure may be present in both C_{LL} and C_{NN} at high p_T.

At $\theta_{c.m.} = 90°$, the following relation holds for C_{SS} (which is defined in analogy to C_{LL} with the spin direction S transverse to the beam in the plane of scattering) in terms of C_{NN} and C_{LL}:

$$C_{SS} = C_{NN} - C_{LL} - 1 \quad .$$

This relation gives $C_{SS} \approx -(0.60 \pm .12) \approx - C_{NN}$ (see Fig. 3).

Quark helicity conservation requires $C_{SS} = - C_{NN}$ at all angles[7,8]. This relation can also be tested for the angles $\theta_{c.m.} \sim 70\text{-}80°$ using the following inequality

$$1 - |C_{NN} + C_{LL}| \geq C_{SS} \geq -1 + |C_{NN} - C_{LL}| \quad .$$

In this angular range, $C_{NN} = 0.54 \pm .04$, $C_{LL} = -0.17 \pm .09$, which gives $0.63 \geq C_{SS} \geq -0.29$ with a standard deviation of ± 0.10. Therefore this measurement indicates that the assumption of quark helicity conservation, which is used in many quark-parton models, is correct within our statistical errors. The statistical errors will be considerably reduced when all the data is analyzed.

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Figure Captions

Figure 1 Experimental layout for high p_T measurements with a longitudinally polarized beam and target.

Figure 2 Spin correlation parameter $A_{LL} = - C_{LL}$ for π^+- and π^--production by pp reactions at 11.75 GeV/c. a) A_{LL} as a function of $x = P_{||}/P_{||,max}$ summing over p_T. b) A_{LL} as a function of p_T summing over x. The curves shown are from Refs. 2 (conservation distributions and 5 (QCD prediction).

Figure 3 Spin correlation parameters C_{LL} and C_{NN}[10] for pp elastic scattering at 11.75 GeV/c near $\theta_{c.m.} = 90°$. The curves shown are to guide the eye. Note the sharp rise in C_{LL} near 90°.

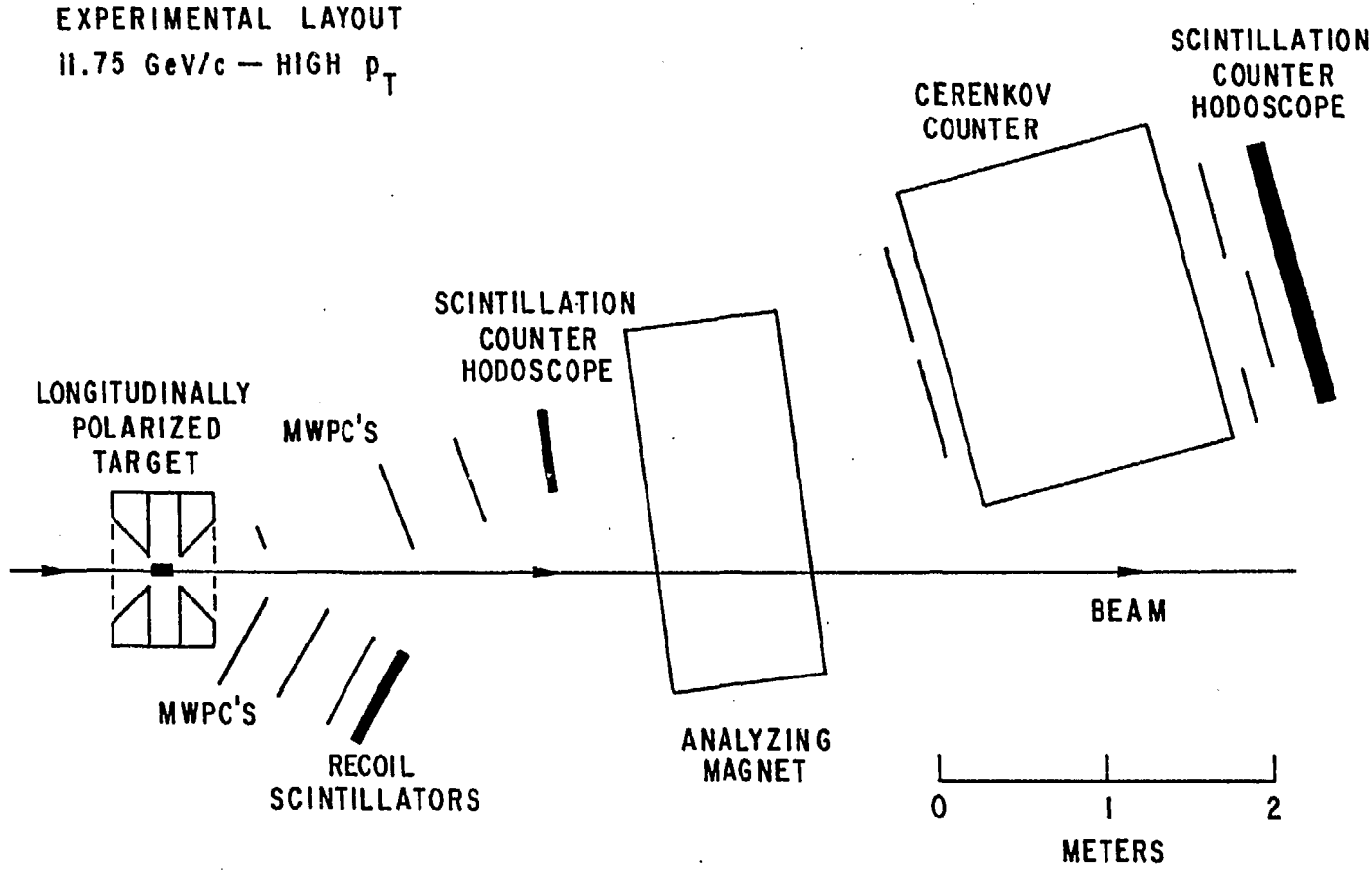
EXPERIMENTAL LAYOUT
11.75 GeV/c — HIGH p_T
SCINTILLATION COUNTER HODOSCOPE
CERENKOV COUNTER
SCINTILLATION COUNTER HODOSCOPE
LONGITUDINALLY POLARIZED TARGET
MWPC'S
BEAM
MWPC'S
RECOIL SCINTILLATORS
ANALYZING MAGNET
0
1
2
METERS

Fig. 1

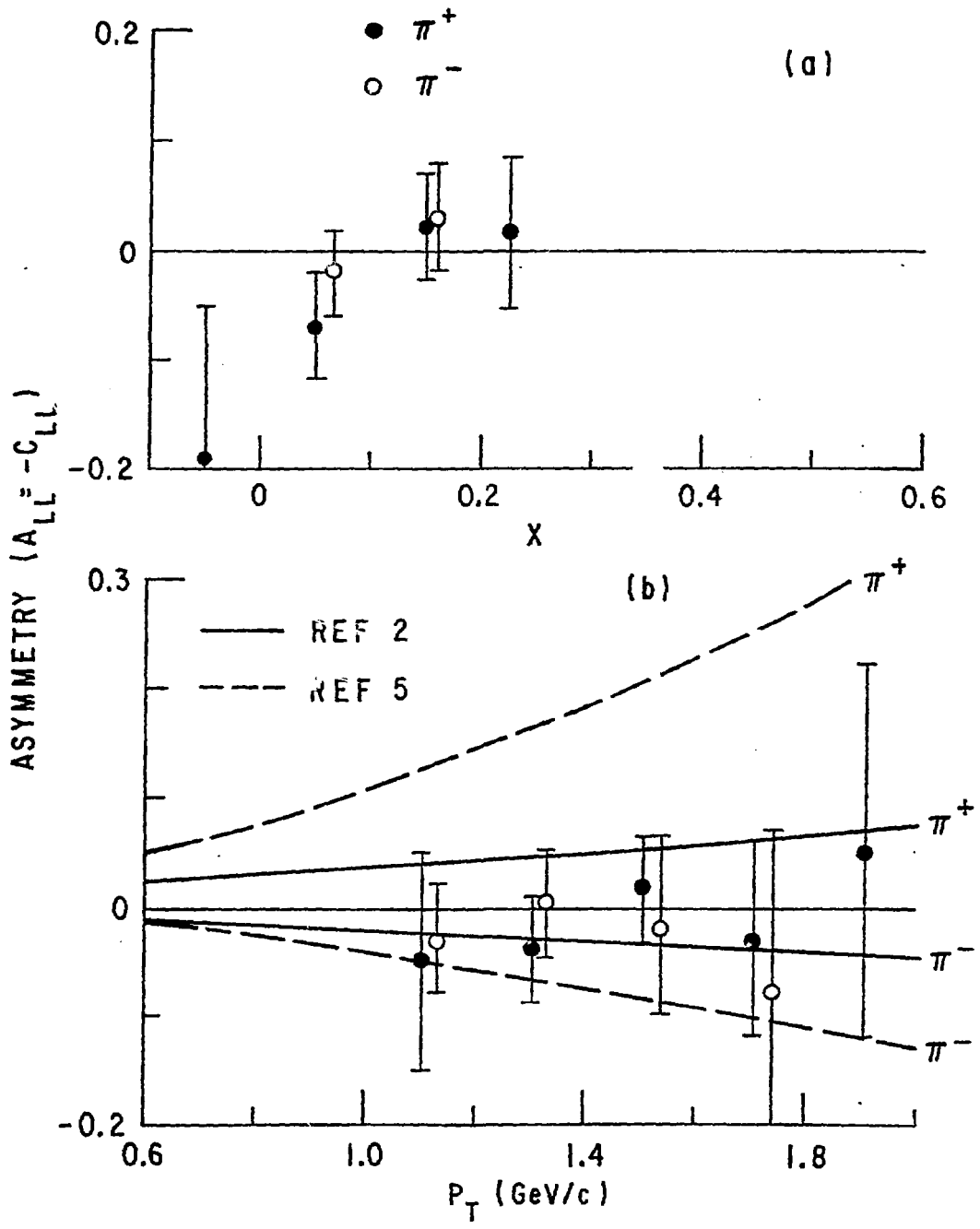
0.2
0
-0.2
π^+
π^-
(a)
0
0.2
0.4
0.6
X
ASYMMETRY ($A_{LL}^{=} - C_{LL}$)
0.3
0
-0.2
(b)
REF 2
REF 5
π^+
π^+
π^-
π^-
0.6
1.0
1.4
1.8
P_T (GeV/c)

Fig. 2

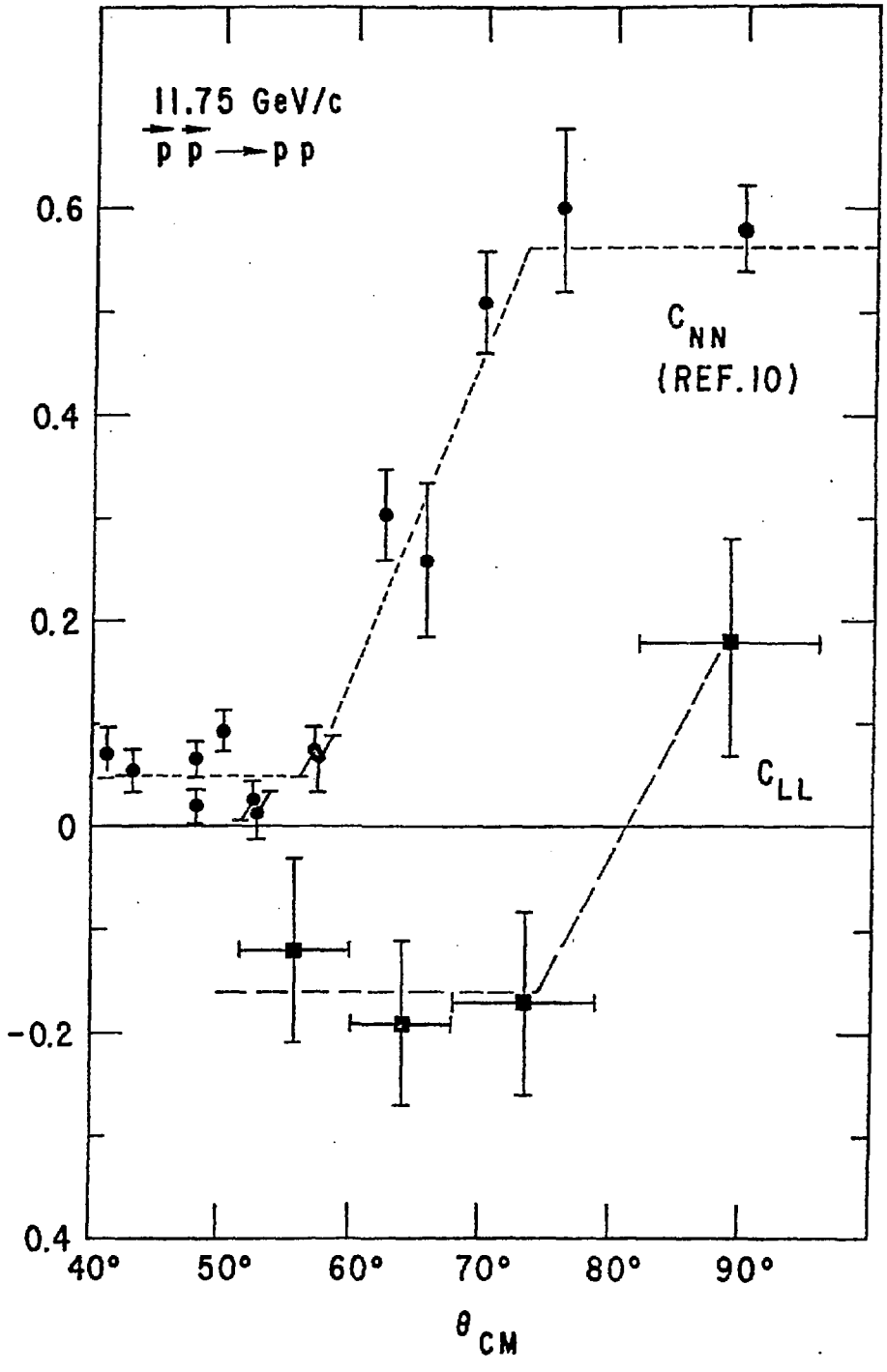

Fig. 3