Title

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Authors

Betz, F

Arens, J

Dost, H

et al.

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Ernest O. Lawrence Radiation Laboratory

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Berkeley, California

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Polarization Parameter in P-P Scattering Using a Polarized Proton Target

(presented by L. Holloway)

This is a report of the results of two experiments to measure the polarization parameter in p-p scattering.[1,2] Both experiments utilize an unpolarized proton beam incident on a polarized proton target.[3] One experiment was performed at the Berkeley 184-inch cyclotron using incident protons of 328, 614, 679, and 736 MeV kinetic energy. The other experiment was performed at the Bevatron and measurements were taken at 1.7, 2.85, 3.5, 4.0 5.05, and 6.15 GeV kinetic energy. The angular regions measured were from 20° to 100° center of mass; the square of the four-momentum transfer ranged from 0.1 to 0.8 $(GeV/c)^2$.

I. Experimental Method

The polarized proton target used in these experiments consisted of four single crystals of $La_2Mg_3(NO_3)_{12}\cdot 24H_2O$ in which approximately one percent Nd^{142} had been added. The hydrogen content was about 3°/o by weight and the hydrogen thickness was 0.15 g/cm^2. The free protons in the waters of hydration were polarized by the dynamic-nuclear-polarization technique[4], which for this experiment involved immersion of the target in a 1.2°K liquid helium bath inside a constant magnetic field of 18.75 kilo gauss. The appropriate "forbidden" transitions were excited by microwave radiation at about 71 kMc. A small variation in the microwave frequency made it possible to reverse the direction of the proton spins.

The polarization was monitored by measuring the strength of the proton nuclear magnetic resonance signal at a frequency of about 80 Mc. This signal appeared as the change in voltage across a coil surrounding the target crystals through which a constant current rf source was applied. As the rf frequency was swept across the NMR frequency the absorption of the rf power by the protons changed the Q of the coil and hence the voltage across it. Every 12 hours or so the microwaves would be turned off and the proton spins allowed to come to thermal equilibrium. The thermal equilibrium polarization, about 0.15°/o, was then measured and used as a calibration of the NMR detection apparatus. The magnitude of the target polarizations for these experiments ranged from 20°/o to 60°/o. The direction was changed every hour or so to minimize systematic errors due to beam geometry or detection efficiency changes.

Figure 1 shows the experimental arrangement. Elastic p-p scatters were detected by a coincidence in one of the 10 up-array counters and one of the 10 down-array counters. A count was stored in a coded bin of a 100-channel analyzer for each event detected, as an element of a 10x10 matrix. The dimensions of the counters and their distances were chosen to maximize the ratio of the elastic p-p scatterings to the background, consistent with the desired angular resolution and counting rate. Since quasi-elastic scatterings of protons in the beam with protons in the nuclei of the non-hydrogen elements of the target were prime contributors to the background, advantage was taken of the fact that these protons in the nuclei have an average Fermi momentum of 200 (MeV.c). The orientation of this momentum is random, and its effect is to smear out the trajectories of the scattering particles through an angle

$$\theta \approx 200\ (\mathrm{MeV}/c)\ P\ (\mathrm{MeV}/c)\ .$$

In addition background data were taken with the crystals replaced by a dummy target that contained hydrogen free elements simulating the heavy nuclei of the real crystal.

An experimental measurement of $P(\theta)$, at a given energy, consisted of storing elastic p-p events under conditions in which only the sign and magnitude of the target polarization were allowed to change. Figure 2 shows an example of elastic-to-background counting ratio at 6 GeV.

The polarization parameter $P(\theta)$ is related to the p-p differential scattering cross section by

$$\left(\frac{d\sigma}{d\Omega}\right)_{pol} = \left(\frac{d\sigma}{d\Omega}\right)_{unpol.} \left[1+P(\theta)P_T\right] \tag{1}$$

where P_T is the target polarization. The data were analyzed by means of a least squares fit to equation (1) after a proper background subtraction was made.

II. Results

The results of the measurement are shown graphically in Figs. 3 through 5. The error flags indicate statistical counting errors only. In the high energy data a relative systematic error (RSE) has been indicated which includes the error arising from the thermal equilibrium polarization measurement and a non-uniform target polarization correction. Figure 6 is a plot of the maximum polarization as a function of beam energy.

III. Discussion

A Regge pole model of elastic p-p scattering predicts that in the limit of high energy the polarization parameter is given by

$$P \sim S^{(\alpha_n-\alpha_p)} \quad .$$

Here S is the total energy squared and the expression is to be evaluated at a fixed value of the four-momentum transfer t . α_p and α_n are the positions of the Pomeranchon and its nearest neighbor at low momentum transfer. Figure 7 shows a fit to the slopes $\frac{d(\log P)}{d(\log S)}$. While the fits are not too good they certainly do not disagree with the Regge hypothesis. If we assume the leading pole is on the Pomeranchuk trajectory then the interfering trajectory seems to have a value at t=0 of about 0.25 ± 0.35.

It should be pointed out that we are certainly not in the "asymptotic" energy region and should not expect perfect agreement.

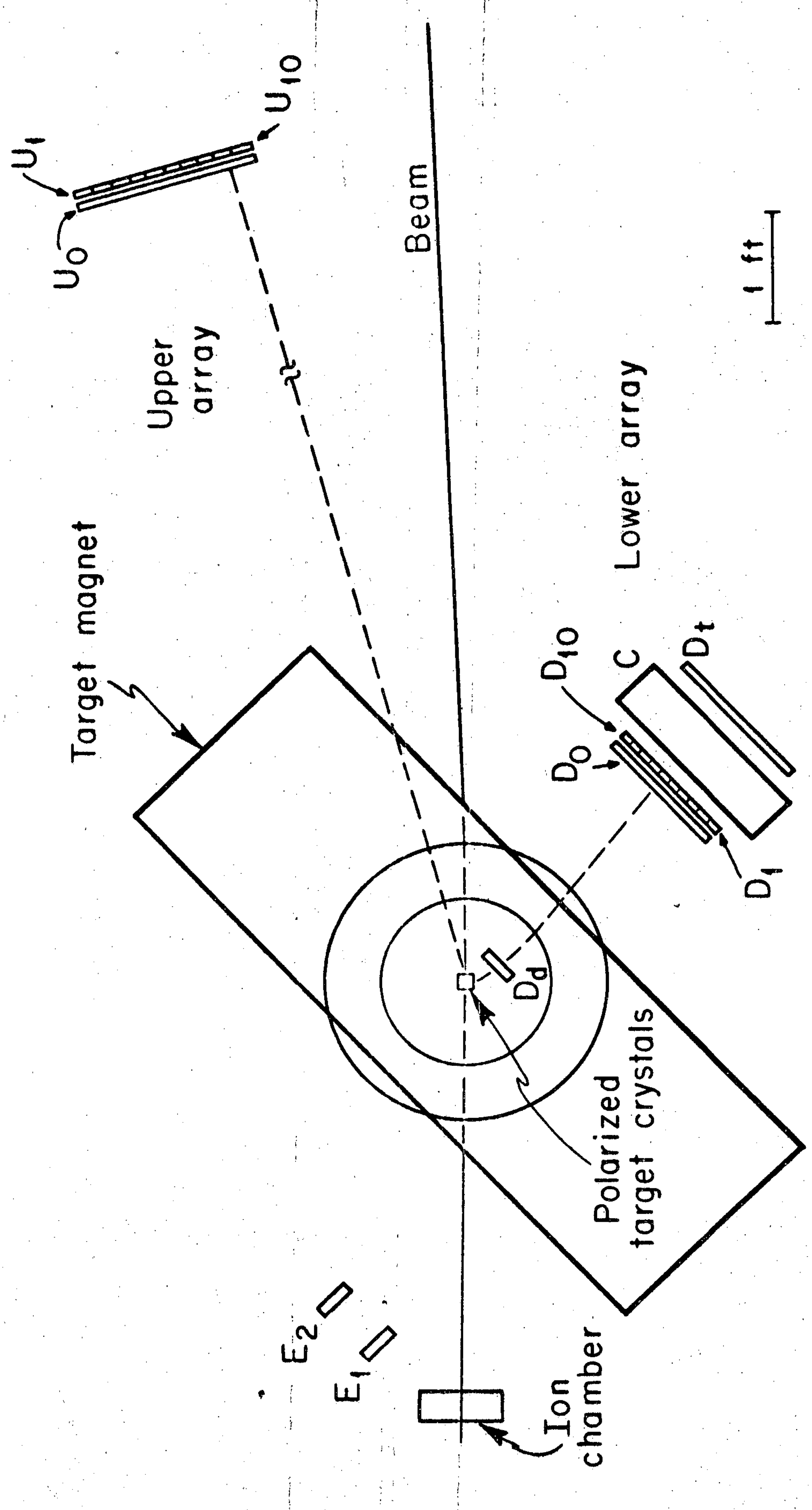
References

1. Polarization Parameter in p-p Scattering from 328 to 736 MeV.
F. Betz, J. Arens, O. Chamberlain, H. Dost, P. Grannis, M. Hansroul, L. Holloway, C. Schultz, and G. Shapiro
UCRL 16749 (to be published in Physical Review).

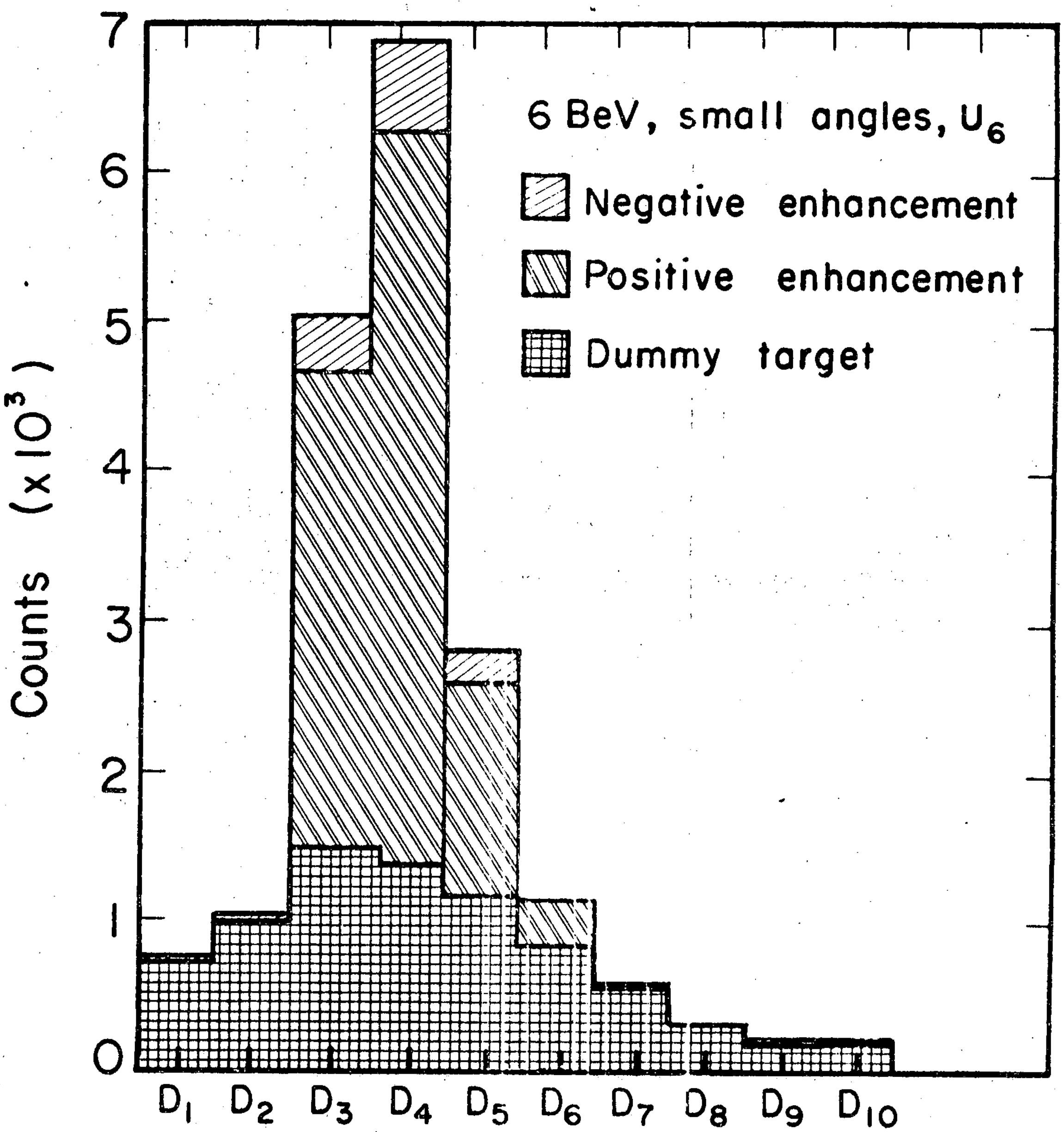
2. Polarization Parameter in p-p Scattering from 1.7 to 6.1 BeV
P. Grannis, J. Arens, O. Chamberlain, B. Dieterle, C. Schultz, G. Shapiro, H. Steiner, L. Van Rossum, and D. Weldon
UCRL 16750 (to be published in Physical Review).

3. C. H. Schultz, Ph.D. thesis (University of California), UCRL 11149 (unpublished).

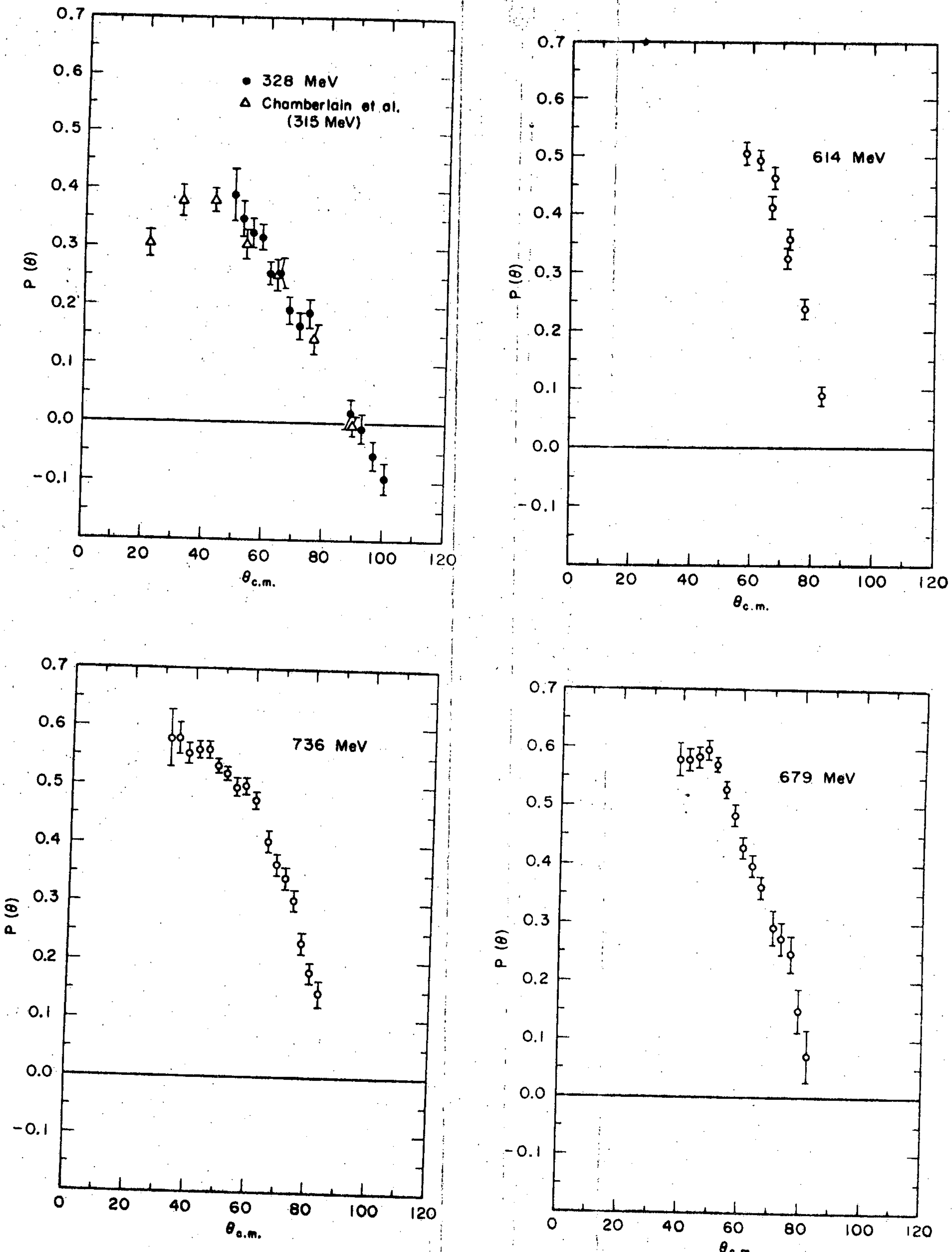
4. C. D. Jeffries, Dynamic Nuclear Orientation, Interscience, New York, 1963.

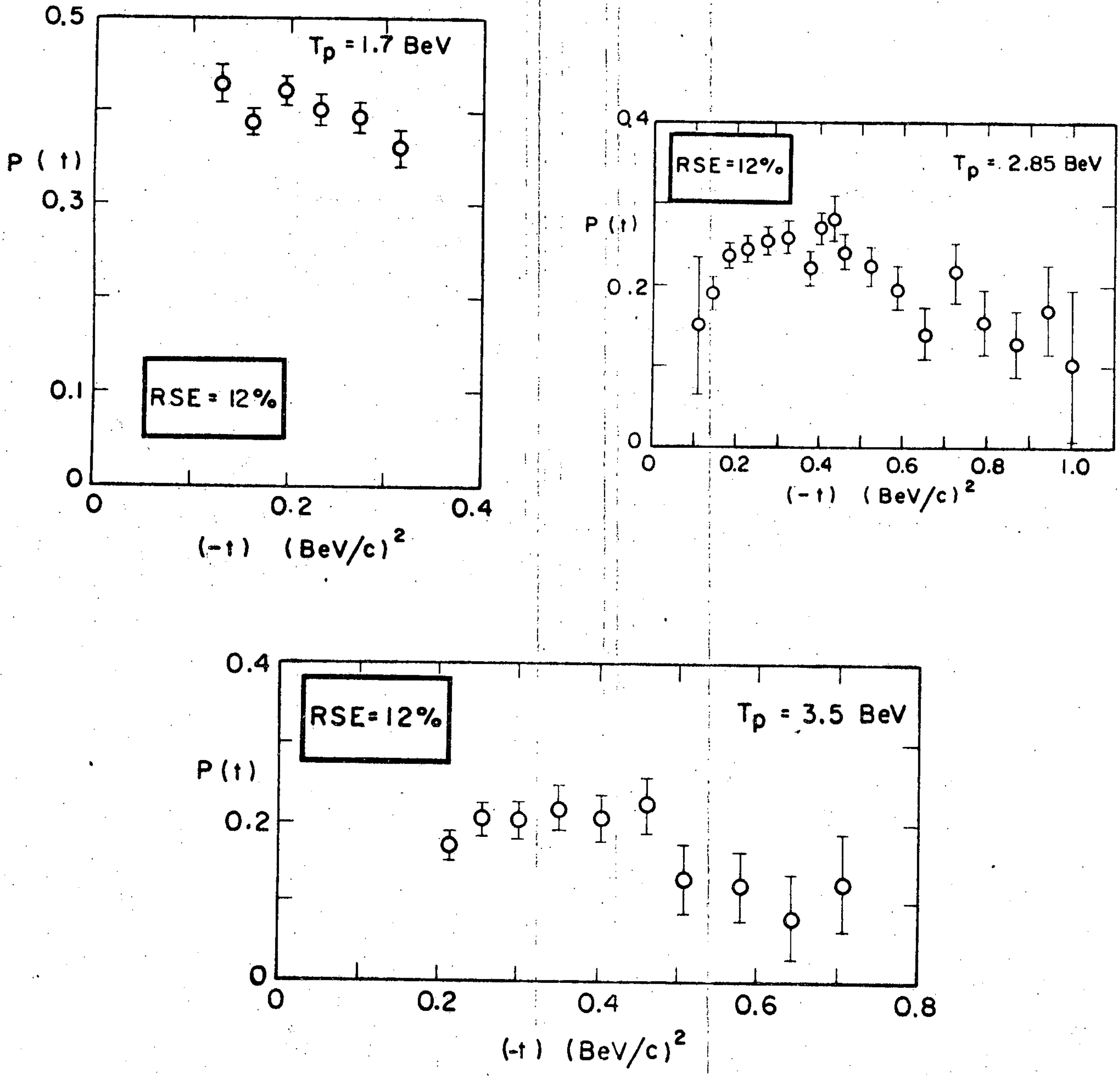

Target magnet
Upper array
Lower array
Beam
U_0
U_1
U_{10}
D_0
D_1
D_{10}
C
D_t
D_d
Polarized target crystals
E_2
E_1
Ion chamber
1 ft

MU-35856

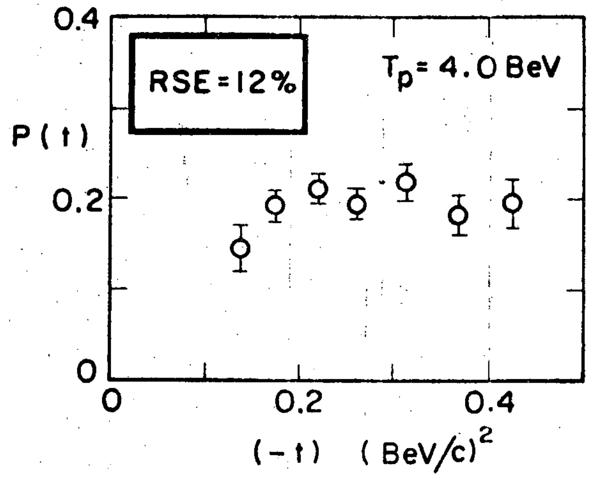

6 BeV, small angles, U6
Negative enhancement
Positive enhancement
Dummy target
Counts (x10³)
0
1
2
3
4
5
6
7
D1 D2 D3 D4 D5 D6 D7 D8 D9 D10

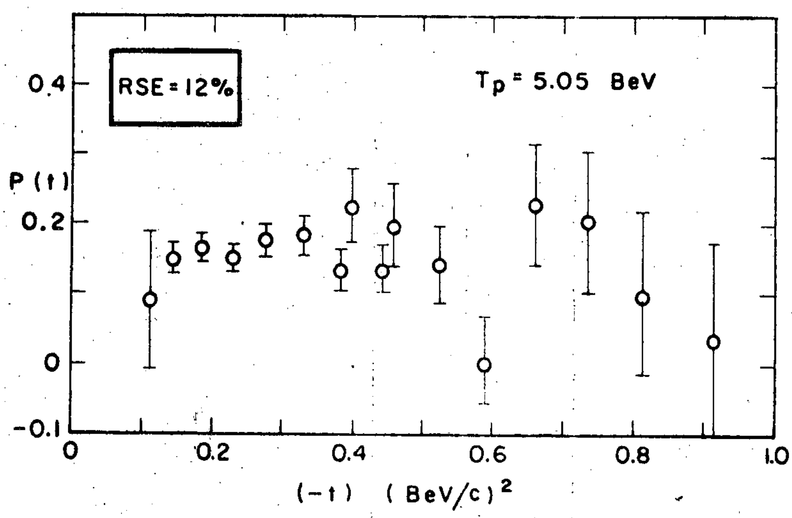
MU-33098

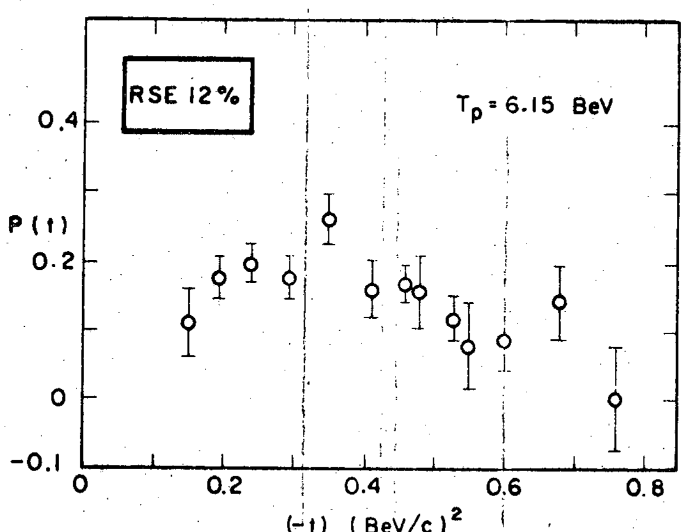

328 MeV
Chamberlain et al. (315 MeV)
614 MeV
736 MeV
679 MeV
P (θ)
θc.m.

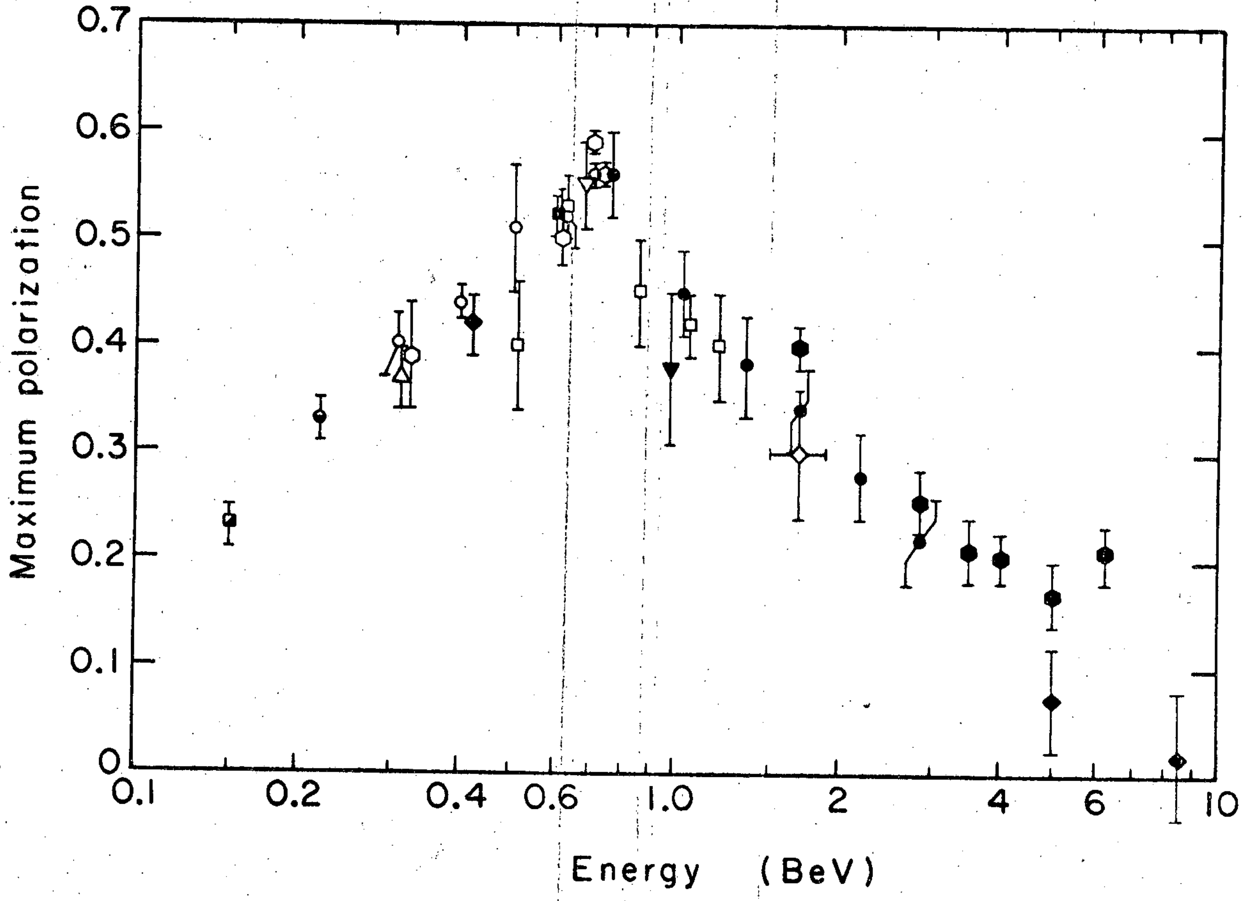


0.5
0.3
0.1
0
P (t)
Tp = 1.7 BeV
RSE = 12%
0
0.2
0.4
(-t) (BeV/c)²
0.4
0.2
0
P (t)
RSE=12%
Tp = 2.85 BeV
0
0.2
0.4
0.6
0.8
1.0
(-t) (BeV/c)²
0.4
0.2
0
P (t)
RSE=12%
Tp = 3.5 BeV
0
0.2
0.4
0.6
0.8
(-t) (BeV/c)²

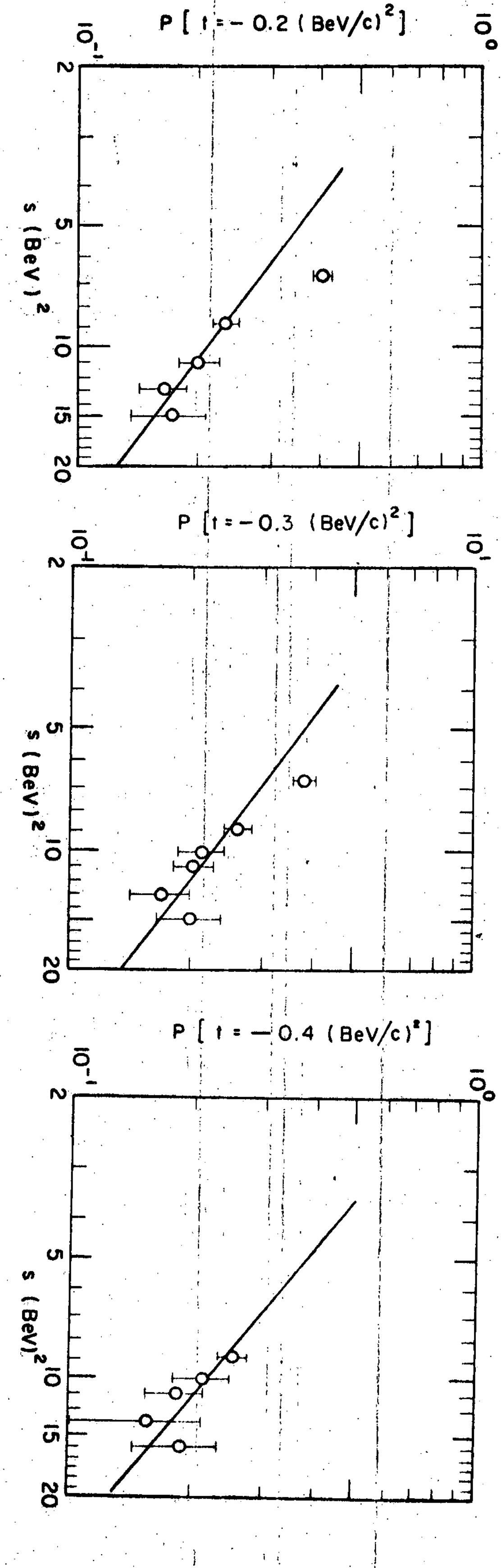

RSE=12%
T_p= 4.0 BeV
P(t)
0.4
0.2
0
0
0.2
0.4
(-t) (BeV/c)^2


RSE=12%
T_p = 5.05 BeV
P(t)
0.4
0.2
0
-0.1
0
0.2
0.4
0.6
0.8
1.0
(-t) (BeV/c)^2


RSE 12%
T_p = 6.15 BeV
P(t)
0.4
0.2
0
-0.1
0
0.2
0.4
0.6
0.8
(-t) (BeV/c)^2


0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Maximum polarization
0.1
0.2
0.4
0.6
1.0
2
4
6
10
Energy (BeV)

MUB-9685


P [t = − 0.2 (BeV/c)²]
s (BeV)²
P [t = − 0.3 (BeV/c)²]
s (BeV)²
P [t = − 0.4 (BeV/c)²]
s (BeV)²