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A MEASUREMENT OF THE POLARIZATION PARAMETER FOR THE REACTION $\pi^- p \to \pi^0 n$ BETWEEN 1.03 AND 1.79 GeV/c[§]

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Measurements of the polarization parameter for the reaction $\pi^- p \to \pi^0 n$ were made at the five momenta 1.03, 1.245, 1.44, 1.59, and 1.79 GeV/c. A polarized target was used, with polarizations achieved ranging from 48% to 57%. Salient features of the experiment were the use of neutron counters for time-of-flight measurements as well as angular information and the use of optical spark chambers, seven to eight radiation lengths thick, for the detection of the γ rays from the decay of the π^0. The center-of-mass angular range covered by the 20 neutron counters was typically $-.78 < \cos\theta_{c.m.} < .87$. For each momentum there are approximately 10,000 events which fit $\pi^- p \to \pi^0 n$ with a confidence level of at least 10%.

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We report here preliminary results of measurements of the polarization parameter, $P(\theta)$, in the reaction $\pi^- p \rightarrow \pi^0 n$ at laboratory momenta of 1030, 1245, 1440, 1590 and 1790 MeV/c. Charge exchange polarization measurements have been made previously at higher energies[1], primarily to test high energy interaction mechanisms, but with the exception of one very rough measurement by Hill et al.[2] at 310 MeV, this marks the first time that detailed measurements of $P(\theta)$ have been made in a region of energy where phase shift analyses are available. At the time these measurements were started several competing phase shift solutions predicted rather different behavior for the then as yet unmeasured parameter $P(\theta)$ in charge exchange scattering. At that time we were able to show by means of computer simulation that measurements of $P(\theta)$ at about 20 angles over the full angular interval $0° < \theta_{c.m.} < 180°$, each with an uncertainty $\delta P = \pm 0.1$ should significantly reduce the number of acceptable phase shift solutions. More recent phase shift solutions[3],[4] although qualitatively similar in many respects also predict somewhat different behavior for $P(\theta)$ in the reaction $\pi^- p \rightarrow \pi^0 n$. We expect our results to provide meaningful new input to analyses of pion-nucleon scattering.

The choice of momenta, 1030, 1245, 1440, 1590, and 1790 MeV/c, was based on the existence of rather complete sets of data in the other easily accessible πN scattering parameters; i.e., σ_T for $\pi^{\pm} p$, $d\sigma/d\Omega$ for $\pi^{\pm} p \rightarrow \pi^{\pm} p$, and $\pi^- p \rightarrow \pi^0 n$, and $P(\theta)$ for $\pi^{\pm} p \rightarrow \pi^{\pm} p$. In particular, the momenta 1030, 1590, and 1790 MeV/c were chosen to conform to the recent high precision charge exchange cross section measurements of Nelson, et al.[5]

The experiment was carried out at the Bevatron. The negative pion beam was produced in a 16.5 cm long, aluminum oxide internal target and transported with a two-stage system of magnets and quadrupoles to the experimental area. The central momentum of the π^- beam was known to better than 1%. The typical momentum spread, which could be adjusted by varying the width of a slit at the first focus, was $\Delta p/p = \pm 1\%$. The duration of the beam spill was typically 1.2 seconds, and the useful intensity of the beam during most of the data-taking was limited to about 10^6/pulse by the dead time introduced by the camera used to photograph the optical spark chambers. The cross sectional area of the beam of 2×2 cm^2 was matched to the size of the target.

A 7 cm long polarized target consisting of propylene glycol doped with Cr^{+5} radical was used. The free protons constituted 12% of the target by weight. During the course of the data-taking the target polarization averaged around 50-55%. The polarization of the target was reversed every 2-3 hours. Calibration of the target polarization was made every 3 or 4 days by comparing the natural thermal equilibrium polarization of the protons with the enhanced polarization resulting from applying microwave pumping to the sample.

In Figures 1 and 2 we show a schematic representation of the detecting system. Twenty neutron counters, each subtending an angular interval of $\sim 2.5°$, at a distance of 5 m from the target, effectively spanned the whole angular interval $0° < \theta_{c.m.} < 180°$ in the center-of-mass system. Neutron time-of-flight could be measured to ± 0.5 nsec. The photons from the π^0 decay were detected in two multiplate optical spark chambers located to the right of the target. These chambers were 7-8 radiation lengths thick, and had been used previously in the experiments of Nelson et al.[5] to measure various neutral final states resulting from $\pi^- p \rightarrow$ neutrals. Surrounding the target on all sides, as well as top and bottom, was a system of scintillation counters whose function it was to veto events with charged particles. Sheets of lead, tungsten and even platinum were used in conjunction with those veto counters which were not in the incident beam nor in the path of the gamma rays going into the spark chambers. In this way all neutral final states with gamma rays leaving the target in direction other than the spark chambers had a high probability of being vetoed. It was especially important to have very high veto efficiency in the forward direction so that the large number of transmitted beam particles could be efficiently detected. To this end several counters (A1, A1', A5 and A6) were used. Using all of these veto counters we found that only 10^{-3} of all incident pions failed to be vetoed when the target was in place.

The multiplate spark chambers were fired and subsequently photographed whenever the following criteria were satisfied: (1) a charged pion went into the target and no veto counter had a pulse; (2) a neutral particle went into one of the neutron counters and was detected there. Data was acquired at a rate of about 5 to 8 events per Bevatron pulse and was usually limited by the cycling time of the camera. On each frame of the film we recorded two 90° stereographic views of each chamber along with a digitized summary of neutron counter number, neutron time-of-flight, target polarization, plus bookkeeping and fiducial information. The film was subsequently scanned for two-shower events by professional scanners and physicists. A total of about 3.3×10^5 frames was taken at each of the five momenta. Of these only about 6×10^4 satisfied our conditions for candidates for $\pi^- p \to \pi^0 n$, i.e., two showers in the spark chambers, and a neutron count within our timing window. Those events satisfying the above mentioned criteria were then measured and digitized using the SASS measuring system at LBL. The fitting program SIOUX was used to select those events consistent with elastic charge exchange scattering. There were typically about 10^4 passing events at each momentum.*

Backgrounds due to quasi-elastic charge exchange scattering (i.e., charge exchange from protons bound in carbon) and inelastic scattering were estimated in two ways: (1) A fit was made to the reaction $\pi + {}^{12}C \to \pi^0 + n + B$ and the momentum distribution of particle B was examined. In this fit the mass of particle B, m(B), was chosen to be $m({}^{12}C) - m(n)$. Elastic charge exchange events from free protons as well as quasi-elastic charge exchange from those "stationary" protons bound in the carbon nucleus should correspond to zero momentum for spectator B, whereas scattering from moving protons and inelastic scattering should correspond to a finite momentum transfer to B. Only those events with small P_B ($\lesssim$ 100 MeV/c) were candidates for elastic charge exchange scattering. These momentum distributions were then used to estimate the background. 2) At each momentum data were taken with a "dummy" target in place. This "dummy" contained no free protons but was otherwise made so as to simulate the real target as closely as possible. The dummy target data were used to estimate background effects.

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* "Passing" events having confidence level > 10%, "failing" events having confidence level < 1%.

The distribution of "failing" events from the polarized target, plotted as a function of P_B, agrees very well with the normalized distribution of "failing" events from the "dummy" target. This allows a reliable estimate of the non-elastic events in the hydrogen peak. A slight shortcoming of the "dummy" data method is that it ignores the relatively small background caused by inelastic scattering from the free protons. Typical examples of these distributions are shown in Figs. 3 and 4.

We emphasize that the results presented here are preliminary. In our more complete analysis we hope to be able to use events from the polarized target with large values of P_B to estimate the background in the region of low P_B, thus improving the reliability of the background subtraction. A few data points have been intentionally omitted because of uncertainties in the background subtraction.

We have also analyzed the raw data from the experiment using only the neutron-time-of-flight information (no spark chamber information). The latter method has the advantage of higher statistics, although at the expense of a lower signal-to-background ratio. At this stage in the analysis, we have qualitatively good agreement between the two methods.

Our results are shown in Figs. 5-9. The solid and dashed curves are the predictions of the Almehed[3] and Saclay[4] analyses respectively. The errors shown are statistical only. In addition systematic effects, resulting primarily from uncertainties in the background subtraction could at this stage of the analysis still modify these results significantly.

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FIGURE CAPTIONS

Figure 1. Experimental layout of polarized target, spark chambers and neutron detectors.

Figure 2. Arrangement of counters near polarized target. The A_i counters are used in anticoincidence, M1 and M2 define the incident beam.

Figure 3. Momentum distributions of the spectator particle B in the reaction $\pi^- + \text{polarized target} \rightarrow \pi^0 + n + B$.

Figure 4. A comparison of particle B momentum distributions for failing events from the polarized target and the dummy target.

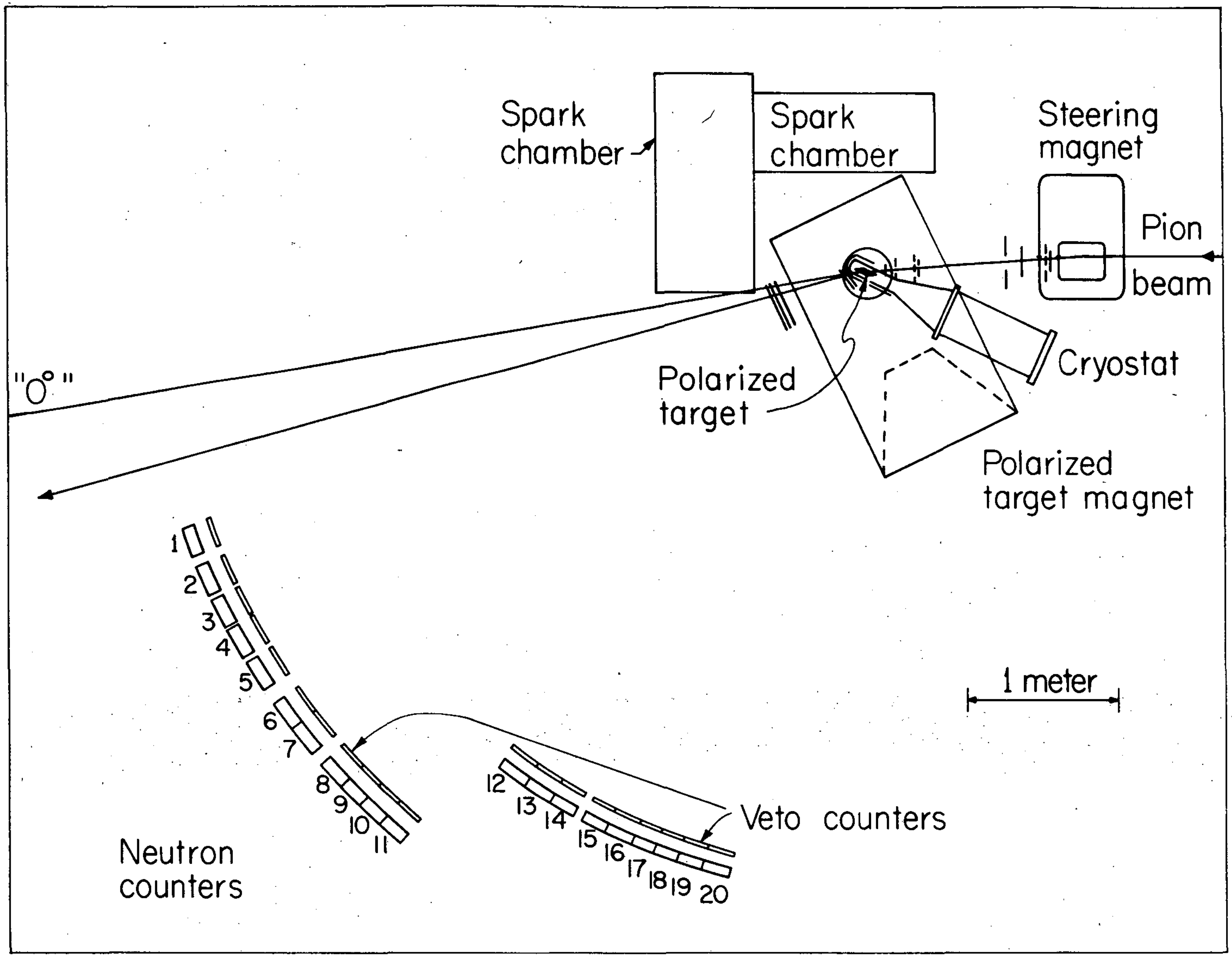
Figure 5. Polarization parameter, $P(\theta)$, for the reaction $\pi^- p \rightarrow \pi^0 n$ vs cos *. $p_\pi = 1.030$ GeV/c. The dashed curve gives the phase shift predictions of Almehed and Lovelace[3]. The dotted curve is the prediction of the Saclay group.[4]

Figure 6. $P(\theta)$ vs $\cos\theta^*$ for $p_\pi = 1.245$ GeV/c. The phase shift prediction of Saclay is at 1.282 GeV/c.

Figure 7. $P(\theta)$ vs $\cos\theta^*$ for $p_\pi = 1.440$ GeV/c. The phase shift prediction of Lovelace is at 1.441 GeV/c, that of Saclay is at 1.438 GeV/c.

Figure 8. $P(\theta)$ vs $\cos\theta^*$ for $p_\pi = 1.590$ GeV/c. The phase shift prediction of Lovelace is at 1.579 GeV/c, that of Saclay is at 1.578 GeV/c.

Figure 9. $P(\theta)$ vs $\cos\theta^*$ for $p_\pi = 1.790$ GeV/c. The phase shift prediction of Lovelace is at 1.801 GeV/c.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Spark chamber
Steering magnet
Pion beam
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Cryostat
Polarized target
Polarized target magnet
1 meter
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2
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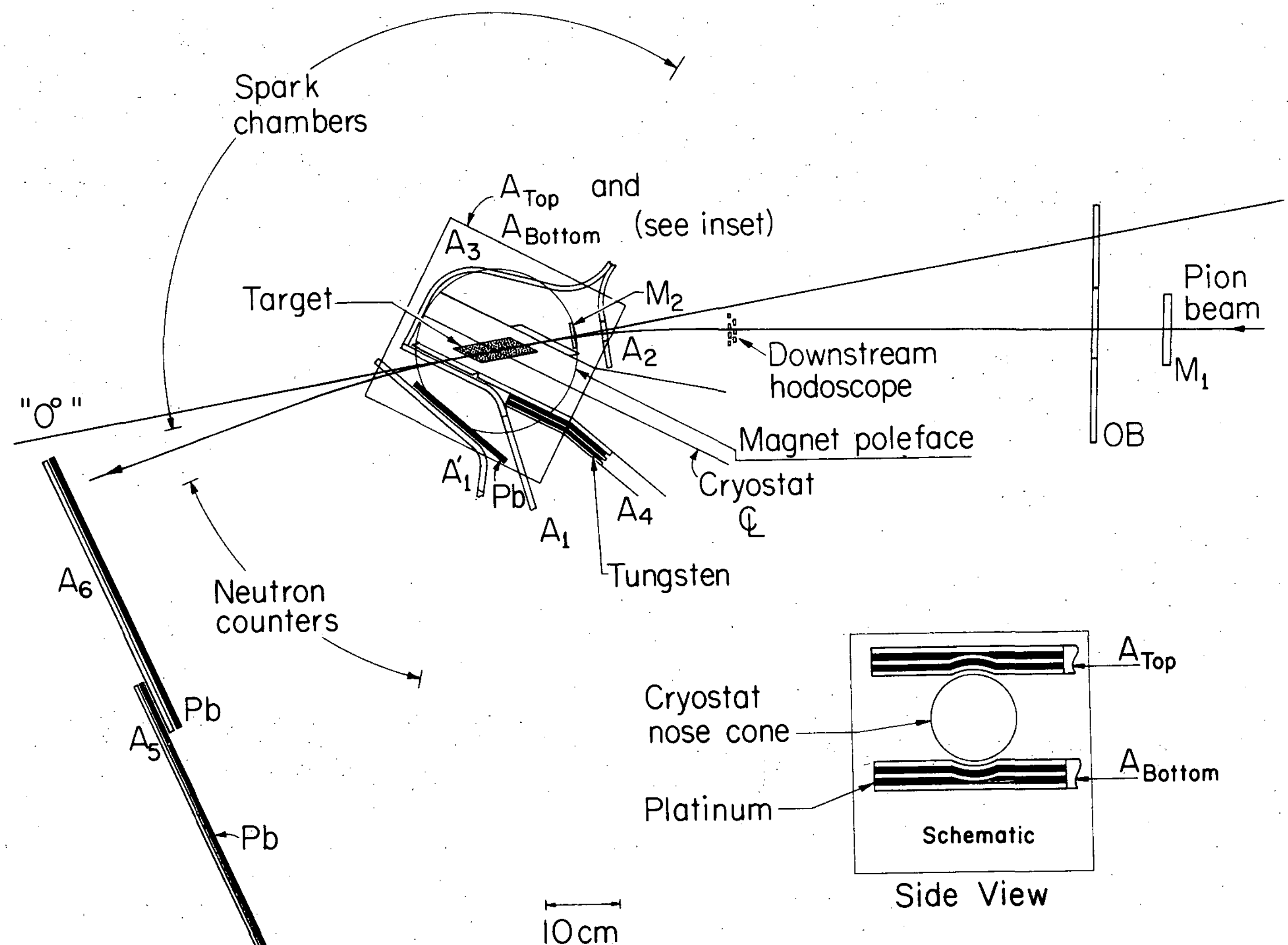
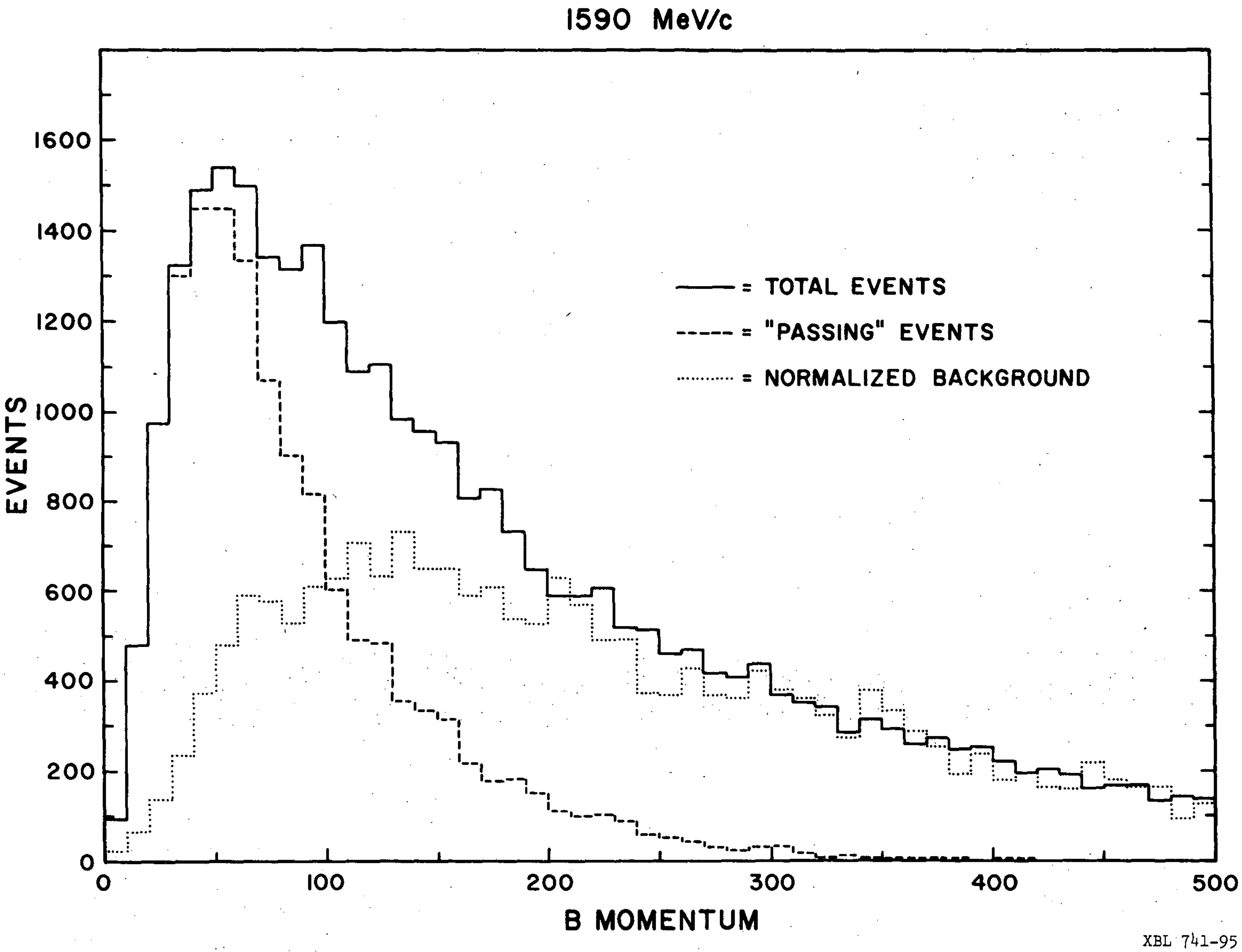
Veto counters
Neutron counters
XBL 738-3698

Fig. 1.



XBL738-3697

Fig. 2.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1000
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1400
1600
0
100
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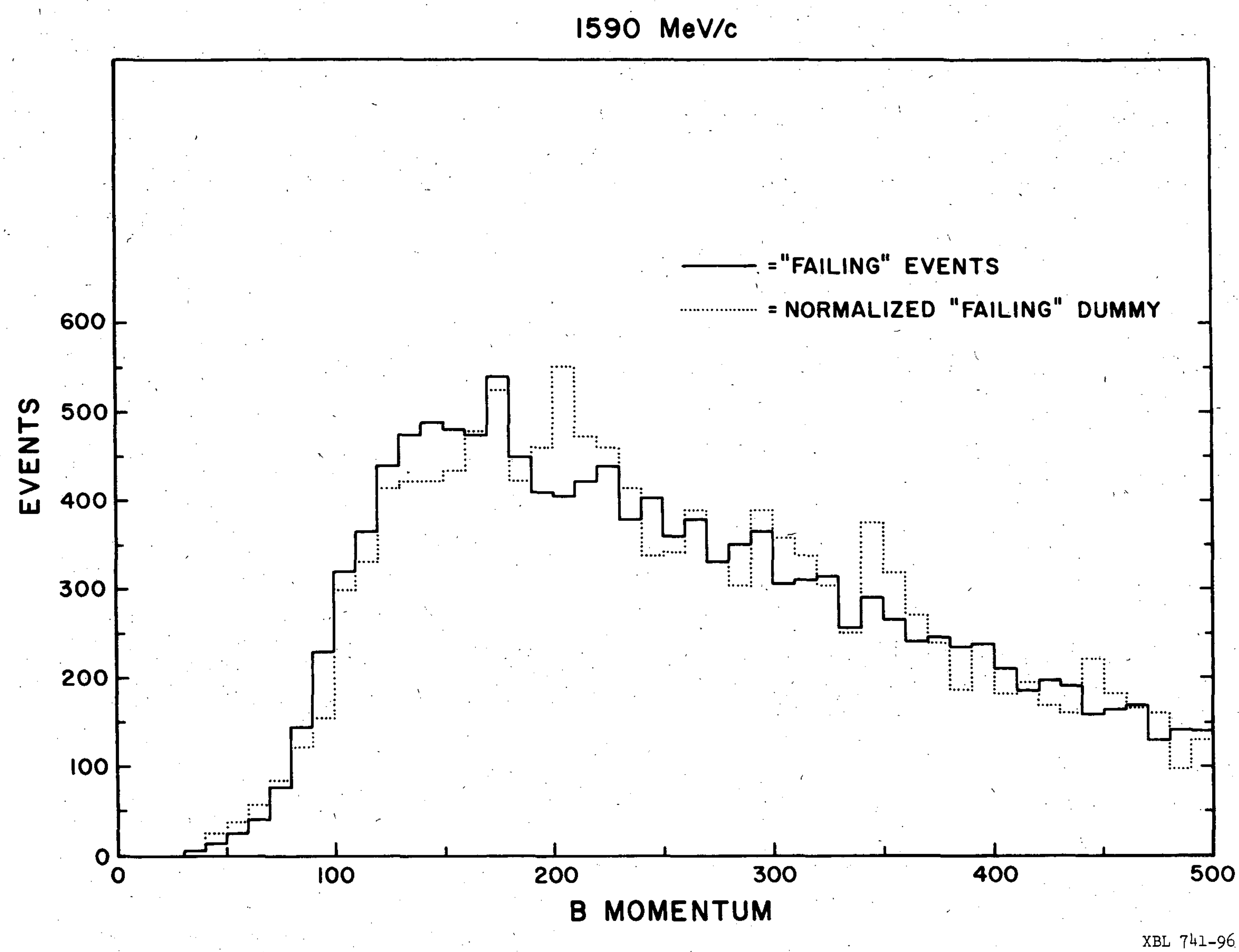
300
400
500
XBL 741-95

Fig. 3.


1590 MeV/c
= "FAILING" EVENTS
= NORMALIZED "FAILING" DUMMY
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500
B MOMENTUM
XBL 741-96

Fig. 4.

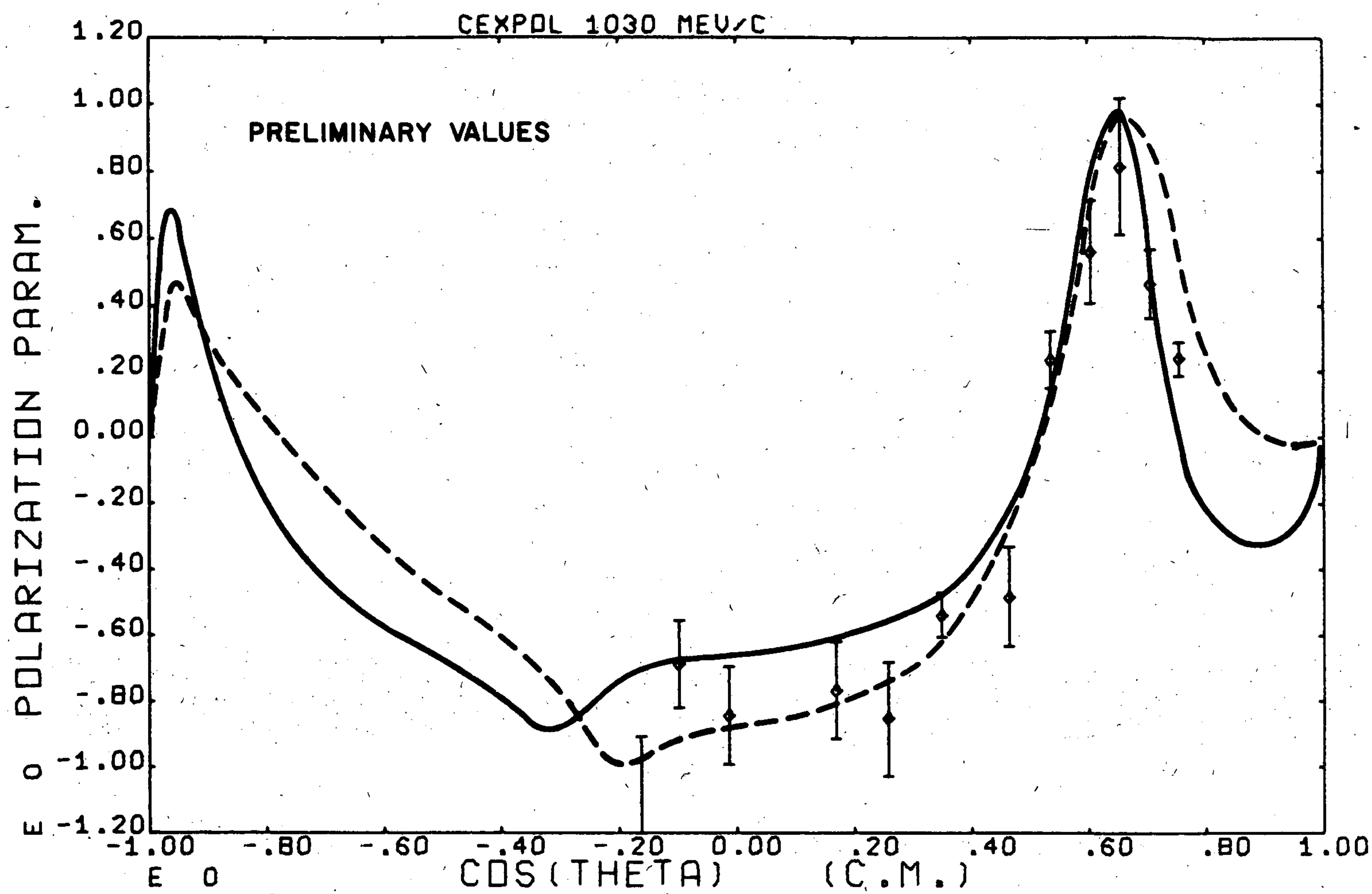

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Fig. 5.

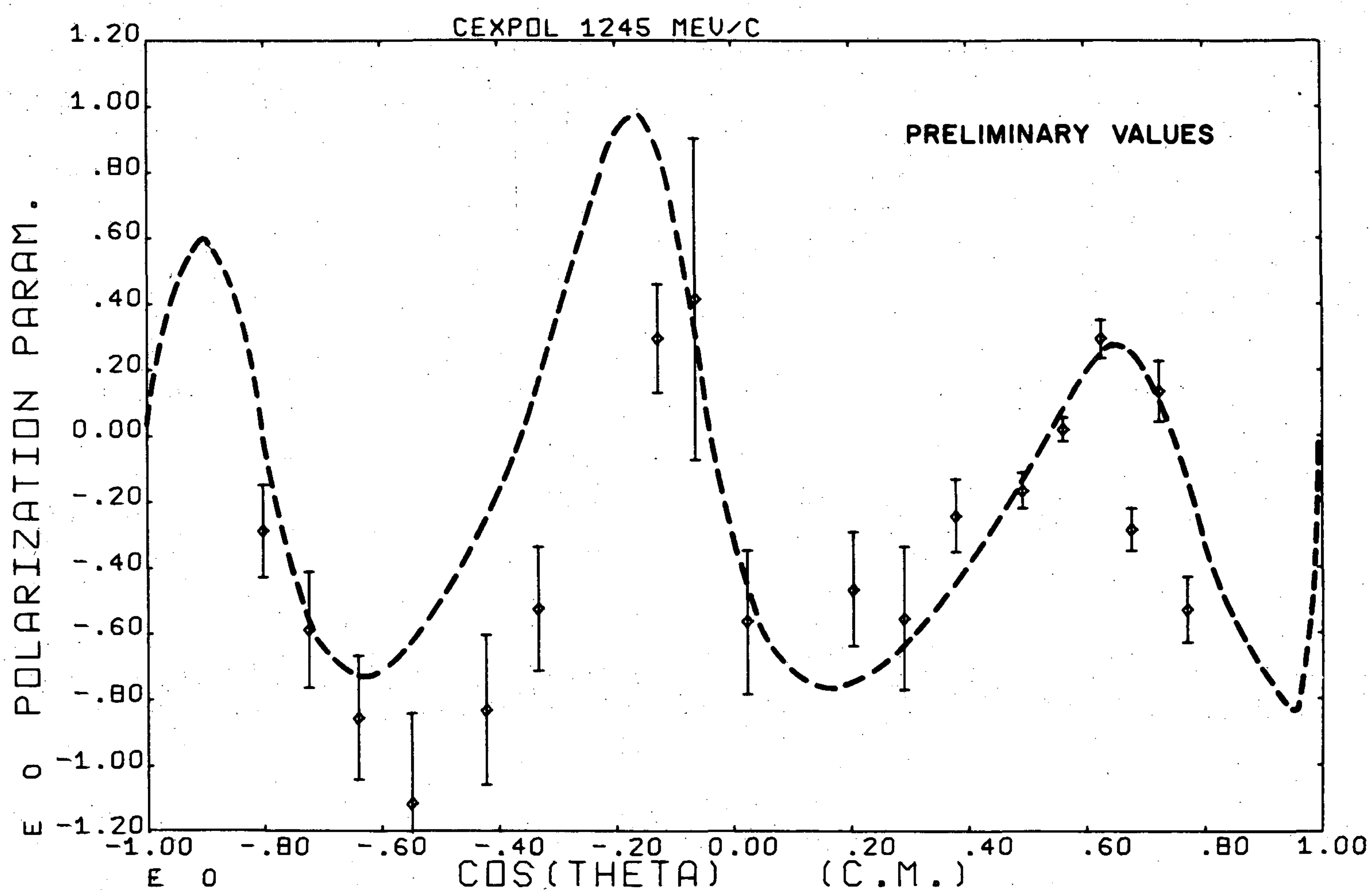

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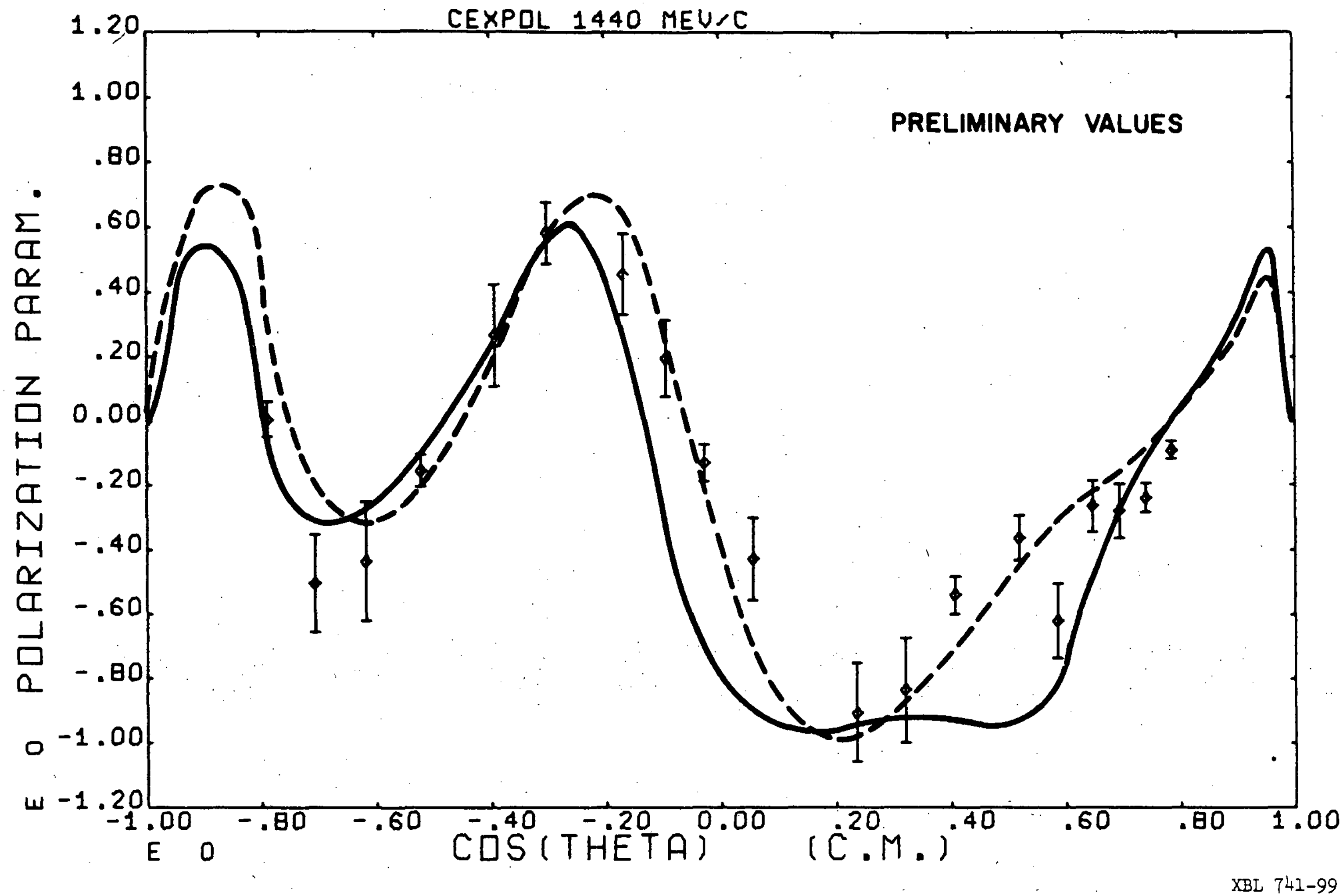
Fig. 6.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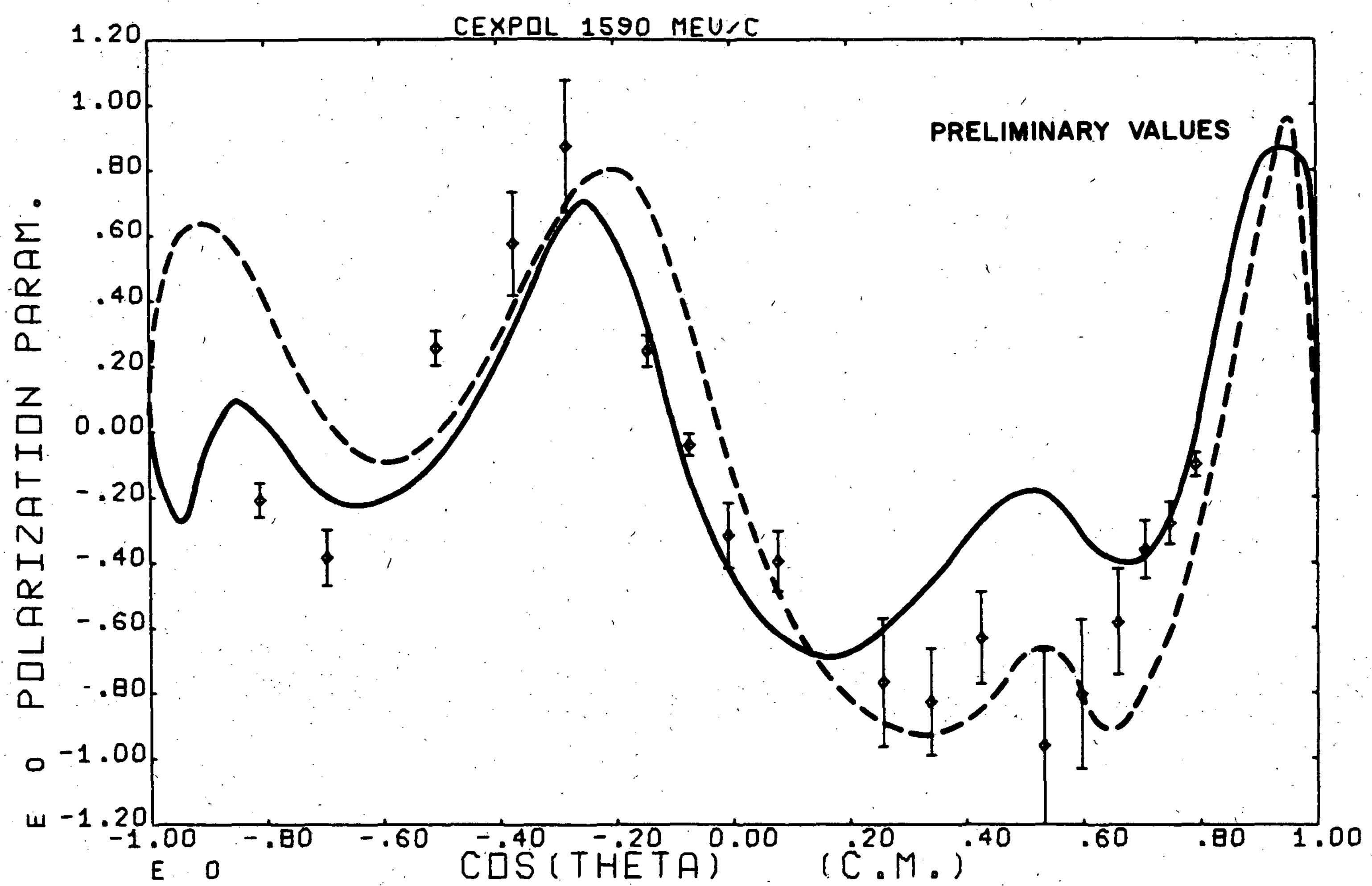
XBL 741-99

Fig. 7.



XBL 741-100

Fig. 8.

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