Lawrence Berkeley National Laboratory

Recent Work

Title
PROTON-PROTON POLARIZATION AT 170 MEV

Permalink
https://escholarship.org/uc/item/0tm99412

Authors
Fischer, David.
Baldwin, John.

Publication Date
1955-06-01
Radiation Laboratory

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 5545

BERKELEY, CALIFORNIA
DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.
PROTON-PROTON POLARIZATION AT 170 Mev
David Fischer and John Baldwin
June, 1955
PROTON-PROTON POLARIZATION AT 170 Mev*

David Fischer and John Baldwin
Radiation Laboratory, Department of Physics
University of California, Berkeley, California

June, 1955

ABSTRACT

The proton-proton polarization has been measured at 170 Mev. The data have been fit to a curve of the form \( P = \sin \theta \cos \theta (\alpha + \beta \cos^2 \theta) \), yielding
\[
\alpha = 0.31 \pm 0.09, \\
\beta = 0.30 \pm 0.14.
\]

A comparison is made with results obtained at other energies.

INTRODUCTION

During the past several years the group of Segre, Chamberlain, Wiegand, and students has been studying experimentally neutron-proton and proton-proton scattering.

Recently a polarized proton beam has been obtained from the cyclotron.\(^1\) This has greatly increased the amount of information obtainable from scattering experiments.

Some of the results of experiments at about 315 Mev have been reported in the past. It is interesting to extend them to lower energies for several reasons:
(a) at lower energies fewer partial waves are involved and the analysis ought to be simpler,  
(b) data at lower energies will supplement the data at 300 Mev and help in choice of the correct set of phase shifts in case of multiple solutions.

Chamberlain and Garrison\(^2\) have investigated the angular distribution and

\(^1\) Chamberlain, Segre, Tripp, Wiegand, and Ypsilantis, Phys. Rev. 93, 1430, (1954)
\(^2\) O. Chamberlain and J. Garrison, Phys. Rev. 95, 1349, (1954)

* This work was done under the auspices of the U.S. Atomic Energy Commission.
Pettengill\textsuperscript{3} has measured the total cross section at about 170 Mev.

We now report measurements on the polarization obtained by scattering at this energy. Similar work at 130 Mev has been done by Dickson and Salter\textsuperscript{4} at Harwell.

**APPARATUS**

The beam used was rectangular in cross section, 2 inches vertical by 1/2 inch horizontal. This was monitored at low beam intensities with two thin counters, called "a" and "b", and at high beam intensities with an argon-filled ion chamber. A three-counter telescope was used to detect the scattered protons. Absorbers were placed between the telescope counters Nos. 1 and 2, and between 2 and 3. The counters were plastic scintillators viewed by 1P21 photomultiplier tubes. Counter No. 1, the nearest to the target, was defining and was 1 in. wide by 6 in. high. The target used was a 1.0-g/cm\textsuperscript{2} liquid hydrogen target.

**BEAM**

The 170-Mev polarized beam was obtained by degrading the 315-Mev polarized beam.\textsuperscript{1} The beam intensity was approximately $1.5 \times 10^4$ protons/sec. Figure 1 shows the plan view of the cyclotron and experimental area. During most of the experiment the beam was degraded by beryllium bricks placed at position A. By placing the degrader before the bending magnet we could obtain a fairly monoenergetic beam. This beam had an energy of $174 \pm 10$ Mev. Some data were taken with the beam degraded by graphite plugs at position B. This beam had an energy of $185 \pm 17$ Mev.

**EXPERIMENTAL PROCEDURE**

The position of the beam at the hydrogen target was determined by exposing x-ray film to the beam. A transit at the rear of the experimental area, located approximately on the beam line, was trained on the center of the beam spot of the developed film. The scattering table was moved to place the center of the target windows on the center of the beam.


The beam energy and energy spread were determined by taking a Bragg curve with two ion chambers. The counters were plateaued against high voltage on the photomultiplier tubes. Counting rates were measured with variable delays in each of the counters. This gave the proper delay in each line and gave a measurement of the time resolution of the equipment.

In order to accurately determine the zero of the counters were swept through the beam and the counting rate was measured for small angles. Figure 2 shows typical results for such measurements.

The counter telescope was then swung to larger angles to measure asymmetries. At each angle the following counting rates were determined:

(a) **Target**: The 1-2-3 coincidence counts per integrator volt with the target (either the 1.0-g/cm² H₂ target or the 2.18-g/cm² Be target) in the beam.

(b) **Blank**: The 1-2-3 coincidence counts per integrator volt with a blank target in the beam. The blank target for H₂ was similar to the H₂ target except that it contained no H₂, while that for the Be consisted of no target at all. For this measurement an absorber equal in stopping power to the target was added to the counter-telescope absorber.

(c) **Accidentals**: The 1-2-3 coincidence counts per integrator volt due to accidental coincidences. This was determined by adding a delay of $6 \times 10^{-8}$ sec (the time between the cyclotron rf pulses) to counter No. 1. The accidental rate was determined to be negligible at all angles measured.

At each angle the above measurements were made for scattering to the left and to the right. ("Left" and "Right" are as seen by an observer looking in the direction along which the beam is moving.)

The ratio of Blank to Target rates varied from about 0.35 at $\theta = 10^\circ$ to about 0.10 at $\theta = 35^\circ$ for the H₂ runs, and was about 0.05 for the Be runs.

With the beam degraded at position A (see Fig. 1), measurements were made on H₂ for $\theta = 10^\circ$, $15^\circ$, $22.5^\circ$, $30^\circ$, and $35^\circ$. Beryllium measurements were made at $13^\circ$. Several runs were made at each angle for H₂. A run was made on Be each day to determine whether the beam polarization changed from day to day. These Be checks were in good agreement. Finally measurements were made at $13^\circ$ with Be and the beam degraded at position B. This last measurement was made in order to determine the polarization of the beam, which was degraded at position A. The polarization of the full-energy (315-Mev) beam is known to be $0.76 \pm 0.03$. It is assumed that the polarization of the beam.

---

full energy beam is not changed appreciably in degradation. Therefore, measurements made on Be with the beam degraded at B determine the polarization of Be at 13° at the degraded energy. When the beam is degraded at position A it is not guaranteed that the same component of the internal scattered protons is steered into the 46-inch collimator as is steered in with the full-energy beam. Thus measurements made on Be with absorber at position A served to calibrate the polarization of this beam.

RESULTS

Counting rates due to the target were determined by

\[ I = (\text{Target}) - (\text{Blank}). \]

Asymmetries were determined by

\[ e = \frac{I(\Theta)_{\text{left}} - I(\Theta)_{\text{right}}}{I(\Theta)_{\text{left}} - I(\Theta)_{\text{right}}} \]

where \( I(\Theta)_{\text{left}} \) refers to the target effect for a scattering at a laboratory angle of \( \Theta \) to the left. The Be asymmetry for the position A degraded beam was 0.443 ± 0.013. The Be asymmetry for the position B degraded beam was 0.437 ± 0.014. These agree within the statistical error of the measurements. Therefore the beam which was used for the \( H \) measurements (position A) had a polarization of 0.76 ± 0.05. The results are summarized in Table I. The polarization as a function of \( \theta \) is shown in Fig. 3. The errors quoted are due to counting statistics only.

In p-p scattering, the product of the polarization and the unpolarized differential scattering cross section, \( P\sigma \), may be expressed as

\[ P\sigma = \sin \theta \cos \theta \sum_{n=0}^{\infty} a_{2n} \cos^{2n} \theta. \]

The results of the 300-Mev experiments show that a good fit should be obtained by including in the sum only \( a_0 \) and \( a_2 \). If one assumes that the p-p unpolarized differential cross section is constant in the center-of-mass system, then he should expect \( P(\theta)/\sin \theta \cos \theta \) to be expressible in the form

\[ P(\theta)/\sin \theta \cos \theta = \alpha + \beta \cos^2 \theta. \]

Figure 4 shows \( P(\theta)/\sin \theta \cos \theta \) vs \( \cos^2 \theta \) together with the least-squares fit to the data. The least-squares values of the parameters are

\[ \alpha = 0.31 \pm 0.09, \]
\[ \beta = 0.30 \pm 0.14. \]

---

6 L. Wolfenstein, Phys. Rev. 75, 1664, (1949)
The values of $a_0$ and $a_2$ are then simply the product of $a$ and $\beta$ above times the average value of the 170-Mev differential cross section, which is taken to be 4.16 mb/sterad.

Figure 5 shows $a_0$ and $a_2$ vs energy. The data used were from Harwell at 130 Mev, Berkeley at 170 and 300 Mev, and Carnegie Tech. at 415 Mev. The errors are mean-square errors, and reflect the uncertainties in the asymmetries only, and not those in the differential cross section or beam polarization.

**CONCLUSIONS**

The existence of an appreciable $\cos^2 \theta$ term in $P/\sin \theta \cos \theta$ indicates considerable contribution to the scattering by waves of $t \geq 3$. The internal consistency of the data does not permit us to make any estimate of the $\cos^4 \theta$ term.

**ACKNOWLEDGMENTS**

This experiment was done with the close cooperation of Dr. Owen Chamberlain, Dr. Emilio Segrè, Drs. Clyde Wiegand, Bob Tripp, and Tom Ypsilantis. The authors wish to express their appreciation for this support.
**Table I**

Values of p-p polarization at mean scattering energy of 170 ± 14 Mev

<table>
<thead>
<tr>
<th>θ</th>
<th>θ</th>
<th>Δθ</th>
<th>e</th>
<th>Δe</th>
<th>P</th>
<th>ΔP</th>
</tr>
</thead>
<tbody>
<tr>
<td>10°</td>
<td>20.8°</td>
<td>1.9°</td>
<td>1.83</td>
<td>0.025</td>
<td>0.241</td>
<td>0.036</td>
</tr>
<tr>
<td>15°</td>
<td>31.3°</td>
<td>2.5°</td>
<td>0.169</td>
<td>0.015</td>
<td>0.222</td>
<td>0.024</td>
</tr>
<tr>
<td>22.5°</td>
<td>46.8°</td>
<td>3.4°</td>
<td>0.162</td>
<td>0.013</td>
<td>0.213</td>
<td>0.032</td>
</tr>
<tr>
<td>30°</td>
<td>62.2°</td>
<td>3.9°</td>
<td>0.137</td>
<td>0.024</td>
<td>0.180</td>
<td>0.034</td>
</tr>
<tr>
<td>35°</td>
<td>72.4°</td>
<td>4.7°</td>
<td>0.071</td>
<td>0.028</td>
<td>0.093</td>
<td>0.037</td>
</tr>
</tbody>
</table>

θ is the lab scattering angle,
θ is the center-of-mass scattering angle,
Δθ is the rms angular resolution,
e is the asymmetry,
Δe is the rms uncertainty in e,
P is the polarization,
ΔP is the rms uncertainty in P.
FIGURE CAPTIONS

Fig. 1 Plan view of the 184-inch cyclotron and experimental area.

Fig. 2 Typical counting rate in telescope for small angles, versus lab. angle θ.

Fig. 3 Proton-proton polarization at 170 Mev, versus center-of-mass angle θ.

Fig. 4 P(θ)/sin θ cos θ versus cos² θ. The solid line is the least-squares fit of the data to a curve of the form α + β cos² θ.

Fig. 5 Least-squares values for a₀ and a₂ in the expansion

\[ P \sigma/\sin \theta \cos \theta = a_0 + a_2 \cos^2 \theta, \] versus energy.
\[ \begin{align*}
\circ &: a_0 \\
\Delta &: a_2
\end{align*} \]