Tests (a) and (b) require high-resolution beta-ray spectrometer techniques. A coincidence spectrometer having an electron-line resolution of 1% or better might possibly provide an answer to (c). (An attempt to do this was made with the intermediate-image spectrometer without success.) The problem is difficult because the 1014.2-kev transition is bracketed between the 987.8- and 1043.7-kev transitions both of which have K-conversion lines $\sim$5 times as strong as the K-1014.2 line and which are separated from the K-1014.2 line by $\sim$2% in momentum. If the approach is to look for the absence of coincidences between the K-1014.2 line and the K x rays due to electron capture, one must bear in mind that K-conversion lines are always in coincidence with their own corresponding K x rays. In the coincidence spectrum of K-conversion lines with K x rays the intensity ratio of the K-1014.2 line to the K-1043.7 line should be measurably smaller than the ratio in the singles electron spectrum if the 1014.2-kev transition is delayed. The reduction of the ratio K-987.8/K-1043.7 may be taken as a measure of what to expect since the 987.8-kev transition is known to be delayed. It might be more profitable to look for the complete absence of coincidences between K x rays and the L-1014.2 line. An experiment to see if the K-1014.2 line is in delayed coincidence with K x rays would probably be very difficult.

Under the assumptions discussed above, a partial half-life value of 0.6 sec for the 1014.2-kev transition would be a lower limit. Any contribution to its K line by the K line of the above-mentioned cascade transition from the 2566.5-kev state would lower the $M4$ branch relative to the 26-kev transition and would thereby increase the derived partial half-life of the $M4$ transition in the direction of the value suggested by the systematics. On the other hand if the 1013.8-kev level proves to be a 13/2+ state at least 1/3 of the K-1014.2 line intensity would have to correspond to the $M4$ transition in order for the partial half-life to agree with the systematics.

ACKNOWLEDGMENTS

The author is indebted to Mrs. Mea Lindner for carrying out the chemical separation of the Bi^{205} activity and to Dr. S. H. Vegors for communicating results of work on Bi^{205} in advance of publication. The cyclotron bombardment was carried out under the direction of Dr. J. L. Need of Oak Ridge National Laboratory.

PHYSICAL REVIEW VOLUME 118, NUMBER 4 MAY 15, 1960

Proton-Proton Scattering at 25 Mev*

T. H. Jeong, L. H. Johnston, and D. E. Young†
University of Minnesota, Minneapolis, Minnesota

AND

C. N. Waddell
University of Southern California, Los Angeles, California

(Received December 28, 1959)

The differential cross section for proton-proton scattering has been measured for 23 center-of-mass angles from 10° to 90°, with ±0.8% absolute probable error at angles greater than 14°. The incident proton energy was 25.63-Mev lab. The 90° cross section is 18.59 millibarns, and the interference minimum of 17.09 mb occurs at 24° c.m. A set of phase shifts which fit the data are: $^1S_0$, 49.5°; $^3P_0$, 8.2°; $^3P_1$, −4.2°; $^3P_2$, 2.0°; $^1D_2$, 0.62°.

METHOD

The scattering chamber and electronics and most of the experimental techniques used in this experiment were similar to those reported in a 40-Mev proton-proton scattering paper[1] from this laboratory.

The proton beam was obtained from the second accelerating cavity of the Minnesota linear accelerator. Since the desired energy was intermediate between the terminal energies of the cavity (10 and 40 Mev), a sheet copper diaphragm was placed in the cavity between two drift tubes at such a position that the electric field was cut off in the "later" part of the cavity. This gave a beam of normal intensity, angular divergence, and energy spread (±0.5%). The mean energy and energy spread were measured by a magnetic spectrometer.[1]

The target material was hydrogen gas at $\frac{1}{2}$ atmosphere pressure, obtained from a palladium filter. To avoid substantial contamination of the gas by foreign gases from the chamber walls, fresh gas was added continuously at the rate of about one chamberful per hour, while the old gas was bled out through a pressure-regulating valve, as described in a recent publication.[2]

* Supported in part by the U. S. Atomic Energy Commission.
† Now at Midwestern Universities Research Association, Madison, Wisconsin.
[1] L. H. Johnston and D. A. Swenson, Phys. Rev. **111**, 212 (1958).
[2] L. H. Johnston and D. E. Young, Phys. Rev. **116**, 989 (1959).

TABLE I. Summary of experimental errors.

	Absolute error	Relative error
Beam current errors	±0.25%	±0.1%
Counting errors	±0.45%	±0.35%
Geometry errors[a]	±0.40%	±0.1%
Target errors	±0.2%	±0.2%
Beam energy errors	±0.4%	±0.1%
Rms error[a]	±0.8%	±0.5%

[a] The geometrical errors are larger than indicated here for angles smaller than 8° lab.

ERRORS AND RESULTS

Table I gives a summary of probable errors assigned to various causes. The nature of the errors is discussed in reference 1. The geometrical formulas used to calculate cross sections in the laboratory system are given in reference 2, and the conversion of angles and cross sections from the laboratory to the center-of-mass system of coordinates uses formulas identical to those given by Chamberlain et al.[3]

TABLE II. Values of the proton-proton differential scattering cross section for laboratory proton energy of 25.63 Mev.

θ_{lab}	$\theta_{\text{c.m.}}$	$d\sigma/d\Omega$ (c.m.) (mb/sr)	Relative probable error (±)	Absolute probable error (±)
5°	10.07°	109.6	1.8%	1.8%
6°	12.08°	56.31	1.1%	1.2%
7°	14.09°	33.20	0.6%	0.9%
8°	16.11°	23.76	0.5%	0.8%
9°	18.12°	19.90	0.5%	0.8%
9.5°	19.13°	18.70	0.5%	0.8%
10°	20.13°	17.98	0.5%	0.8%
11°	22.15°	17.33	0.5%	0.8%
12°	24.16°	17.09	0.5%	0.8%
12.5°	25.16°	17.16	0.5%	0.8%
13°	26.17°	17.17	0.5%	0.8%
14°	28.18°	17.30	0.5%	0.8%
15°	30.19°	17.43	0.5%	0.8%
16°	32.21°	17.68	0.5%	0.8%
17°	34.22°	17.80	0.5%	0.8%
18°	36.23°	17.93	0.5%	0.8%
20°	40.25°	18.20	0.5%	0.8%
22°	44.27°	18.33	0.5%	0.8%
25°	50.30°	18.52	0.5%	0.8%
30°	60.34°	18.56	0.5%	0.8%
35°	70.37°	18.65	0.5%	0.8%
40°	80.38°	18.60	0.5%	0.8%
45°	90.39°	18.59	0.5%	0.8%

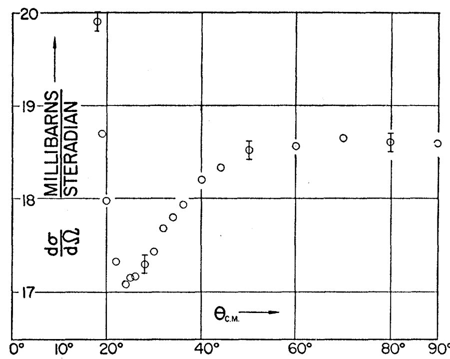

FIG. 1. Angular distribution of proton-proton differential cross sections for 25.63-Mev proton energy. Error bars represent the estimated relative probable error of ±0.5%.

Table II gives the resulting cross sections, along with their estimated relative and absolute probable errors. The probable errors at small angles increase due to uncertainty in the absolute angle calibration of the small angle detector telescope. The cross sections are plotted in Fig. 1.

A phase shift analysis of these data is currently being performed by M. H. MacGregor of the Lawrence Radiation Laboratory in Livermore. He has supplied us with two preliminary sets of phase shifts which fit the data as follows:

$^1S_0$	$^3P_0$	$^3P_1$	$^3P_2$	$^1D_2$
45.2°	−17.1°	0.8°	4.1°	0.62°
49.5°	8.2°	−4.2°	2.0°	0.62°

ACKNOWLEDGMENTS

The operation of the linear accelerator at this unusual energy was made possible by hard work on the part of the laboratory staff, under R. P. Featherstone and C. W. Ekman. We are grateful to M. H. MacGregor for permission to use preliminary phase-shift results before publication.

[3] O. Chamberlain, E. Segrè, R. D. Tripp, C. Wiegand, and T. Ypsilantis, Phys. Rev. **105**, 288 (1957).