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SUMMARY OF THE RESEARCH PROGRESS MEETING

February 24, 1949

H. P. Kramer

Berkeley, California

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Summary of the Research Progress Meeting

February 24, 1949

H. P. Kramer

Proton-Proton Scattering

I. Measurement by Ionization Counters. B. Cork. In the past, proton-proton scattering was investigated by Herb, Luve, and Wilson. The present research constitutes an attempt to extend this work to higher energy. Two different methods of measurement are employed at the same time by two different groups at this laboratory. One of the methods will be described in this section.

L. Alavarez has pointed out the advantage that lies in an apparatus that is capable of recording simultaneously the protons which are scattered at a number of different angles. The apparatus of Fig. 1 has been devised to this end.

Hydrogen gas is passed through a palladium tube into a chamber which lies in the path of the proton beam from the linear accelerator. Scattered protons leave through a cylindrical slit in the proton beam tube and are counted by a set of concentric terroidal ionization counters of rectangular cross section. Each ring consists of two counting volumes of about 180°. The upper and lower half-rings are wired so that a coincidence is recorded on those which are separated by 90°. In this way a number of entries may be set down in one run: upper and lower half, single counts for 10 angles and coincidence counts for 4 angles. Coincidences will arise since the two protons which are deflected in a collision move at right angles to each other.

The proton beam from the linear accelerator moves through the apparatus and is ultimately collected in a Faraday cup which is discharged through a known capacitance in order to measure the total current which has passed through the scattering volume during a run.

The main difficulties which have been encountered in this experiment have been due to background counting. The background consists of the following:

a) X-ray background from the linear accelerator. This X-radiation is produced by electrons that are accelerated between successive drift tubes and then strike a portion of the machine. X-rays account for about 7% of the total count.

b) Neutron background that arises from protons striking parts of the linear accelerator. This effect contributes about 14% to the total count.

c) Neutrons from the 184" cyclotron, which in the past furnished a considerable contribution, now only comprise 1/2-1% of the particles which are counted since the counters are pulsed with the linear accelerator.

In the past the background was counted when the cylindrical scatter slit was closed off. The number of counts obtained with this arrangement was then subtracted from the total number. However, this method of detecting background is not entirely satisfactory since the background effects are not constant during a run. In order to circumvent this difficulty a monitor chamber has been devised to record continuously during the experiment the flux of neutrons and x-rays which interfere with the measurements.

The results of the experiment are set down in a graph of $d\sigma/d\Omega$ versus θ in Fig. 3., where σ is the scattering cross section, Ω is the solid angle that an annular counter subtends at the scattering volume, and θ is the scatter angle. The smooth curves are the result of theoretical calculations. The errors in the experimental values are indicated in the customary fashion. These errors consist of about $\pm$ 1% random error computed by least squares, about $\pm$ 1% error due to uncertainty in the areas of the counters, and about $\pm$ 1% error due to slit penetration.

It is important in this experiment that all of the counters at the various angles react in the same way to protons, that is, that they are equally sensitive. In order to assure equal gas multiplication, electrons were admitted into the counters through small windows, and the gas multiplication was adjusted until the same counting rate was achieved for each counter. The counting plateau is about 300 volts. The pressure in the scattering volume is controlled by allowing the H_2 to bubble through a 1 1/2" head of oil.

The theoretical group have begun to evaluate the data and have arrived at the conclusion that neither a pure S-wave nor a mixed S-P wave explains the data. However, an S and a repulsed D wave may furnish the proper interpretation.

II. The Photographic Method. F. Fillmore. Fig. 4 shows a schematic drawing of the experiment. A monoenergetic beam of protons is obtained from the linear accelerator by deflection through 30° by an analyzer magnet. This deflected proton beam passes through a baffle of collimating slits into a chamber filled with hydrogen gas. Scattered protons are seen on a series of photographic plates which are arranged about the beam and lie slightly displaced from planes through the beam. The plate holder with photographic plates is shown in Fig. 5 and with its component parts, in Fig. 6.

The photographic plates record protons scattered between 10° and 80° from a segment of the proton beam. Thus, the protons that are counted are those emanating from a line source. With this arrangement, the total number of proton tracks N_t which emanate from a small element of solid angle in the center of mass system is,

$$N_t = N_v\, N_p \left(\frac{d\sigma}{d\omega_{c.o.m.}} \right) \frac{w\, L\, z}{y^2} \; \frac{\Delta (\omega_{c.o.m.})}{2} , \qquad (1)$$

or,

$$N_t = N_v\, N_p \left(\frac{d\sigma}{d\omega_{c.o.m.}} \right) \frac{w\, L\, z}{y^2} \; \sin\theta' d\theta' \left[1 - \frac{z^2}{y^2} \cdots \right] , \qquad (2)$$

where N_v is the number of protons contained in unit volume of the hydrogen gas,

$$N_v = \frac{2\, N_0}{22{,}414} \cdot \frac{P}{760} \cdot \frac{273}{T} .$$

$N_p = Q/e$, is the number of protons that enter by way of the beam during the time of the run. (Q is measured by means of a current integrator that collects the beam and discharges it through a capacitance.) The geometrical significance of the quantities w, L, z, y and θ is made clear in Fig. 7. Powers beyond the second of (z/y) are neglected and equation (2) is solved for $\frac{d\sigma}{d\omega_{c.o.m.}}$.

$$\left(\frac{d}{d\omega}_{c.o.m.}\right) \simeq 8.30 \times 10^{-37} \frac{T}{Qpz} \frac{N_t}{L/y^2} \frac{1}{\sin\theta' d\theta'} \qquad (3)$$

The values of $\left(\frac{d\sigma}{d\omega}_{c.o.m.}\right)$ are plotted against scatter angle in Fig. 8. It is gratifying that the results are at least not in contradiction to those found by B. Cork.

It is planned to count 50,000 additional tracks during the period when the linear accelerator will be shut down for source change. It is thought that this amount of work is worthwhile since it will yield 2% statistics for each point.

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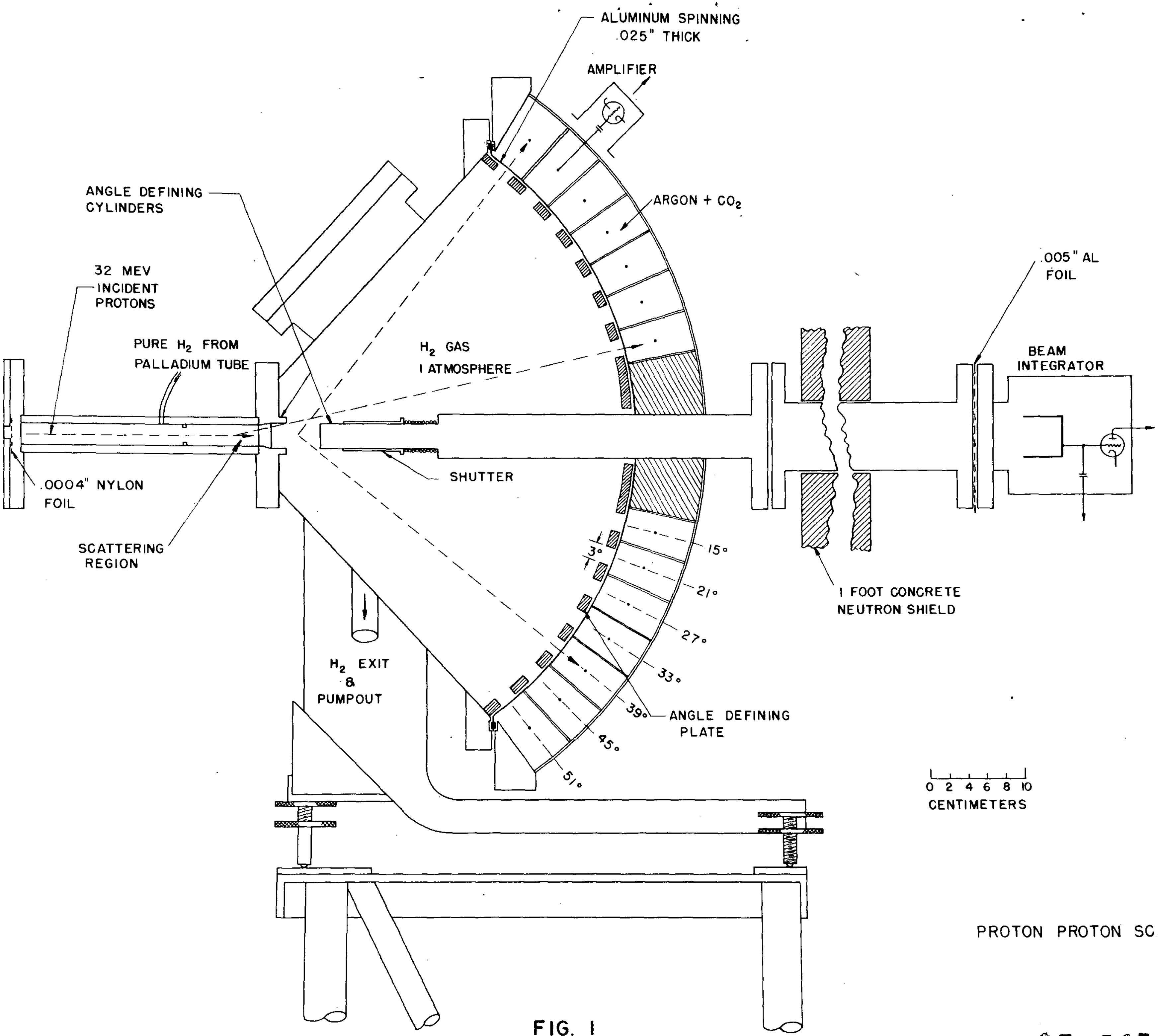


PROTON PROTON SCATTERING CHAMBER

FIG. 1

OZ-363

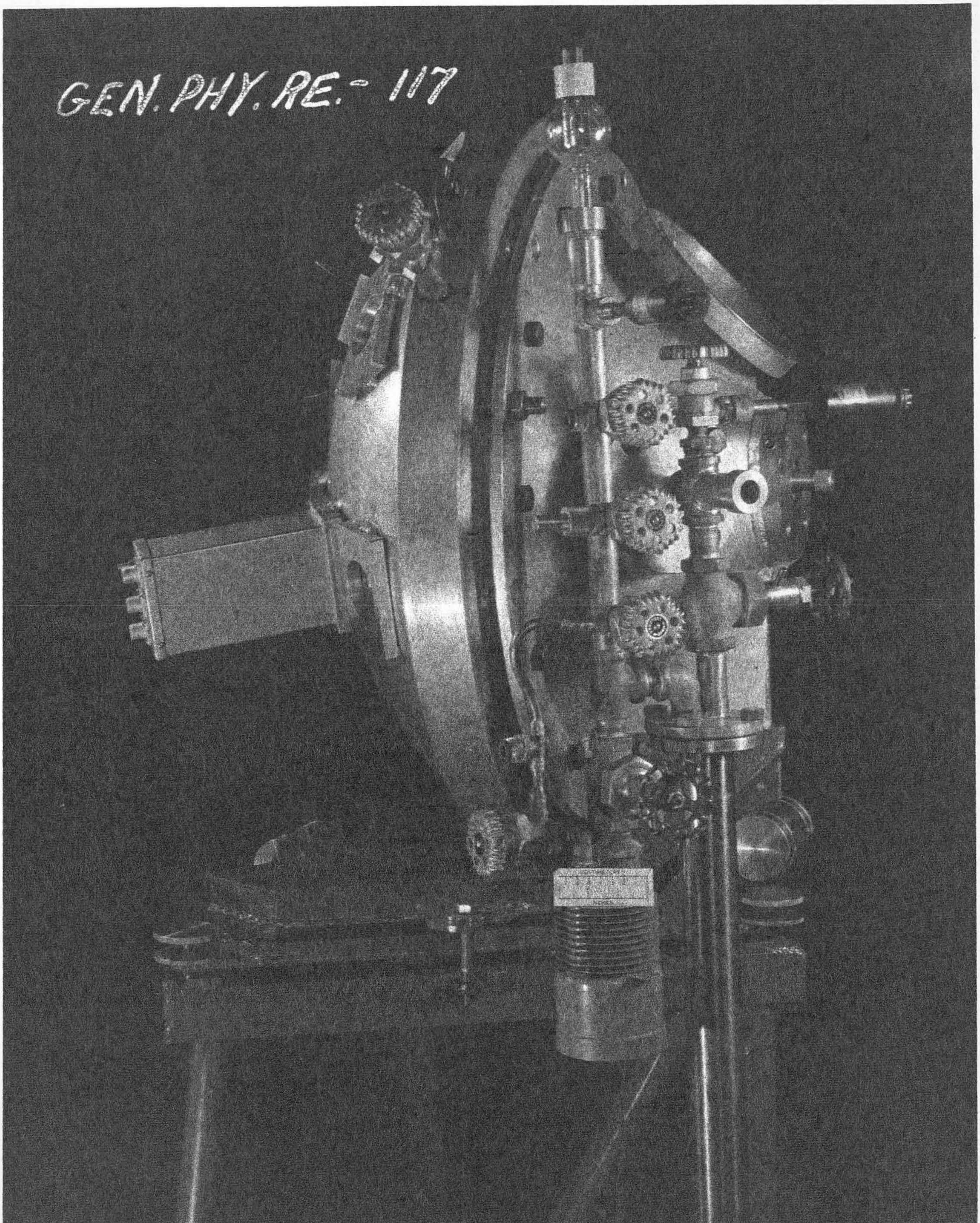
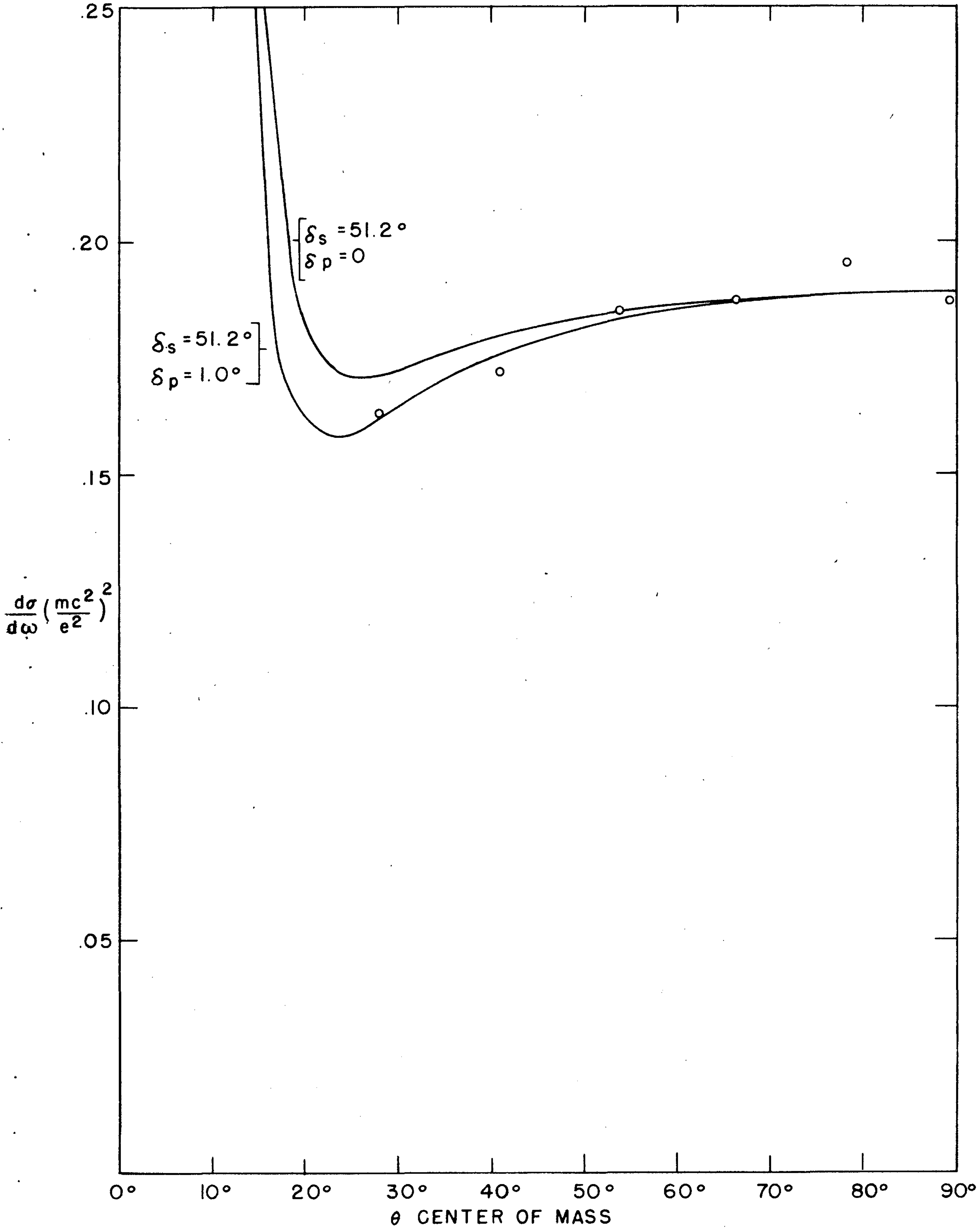


FIG. 2

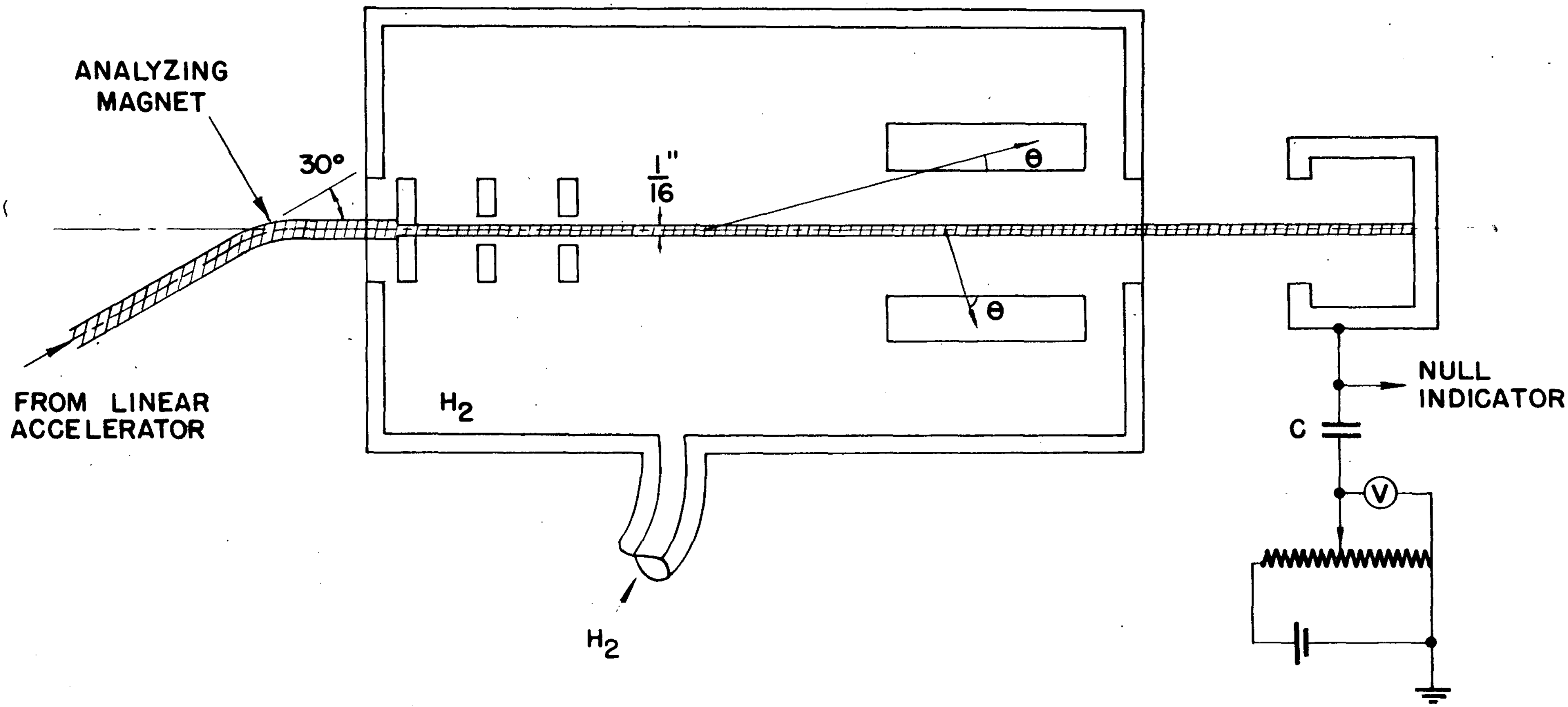
0Z-359



.25
.20
.15
.10
.05
$\frac{d\sigma}{d\omega}\left(\frac{mc^2}{e^2}\right)^2$
$\delta_s = 51.2°$
$\delta_p = 0$
$\delta_s = 51.2°$
$\delta_p = 1.0°$
0° 10° 20° 30° 40° 50° 60° 70° 80° 90°
θ CENTER OF MASS

FIG. 3

13476-1



ANALYZING
MAGNET
30°
1"
16
θ
θ
NULL
INDICATOR
C
V
FROM LINEAR
ACCELERATOR
H2
H2

FIG. 4

OZ -361

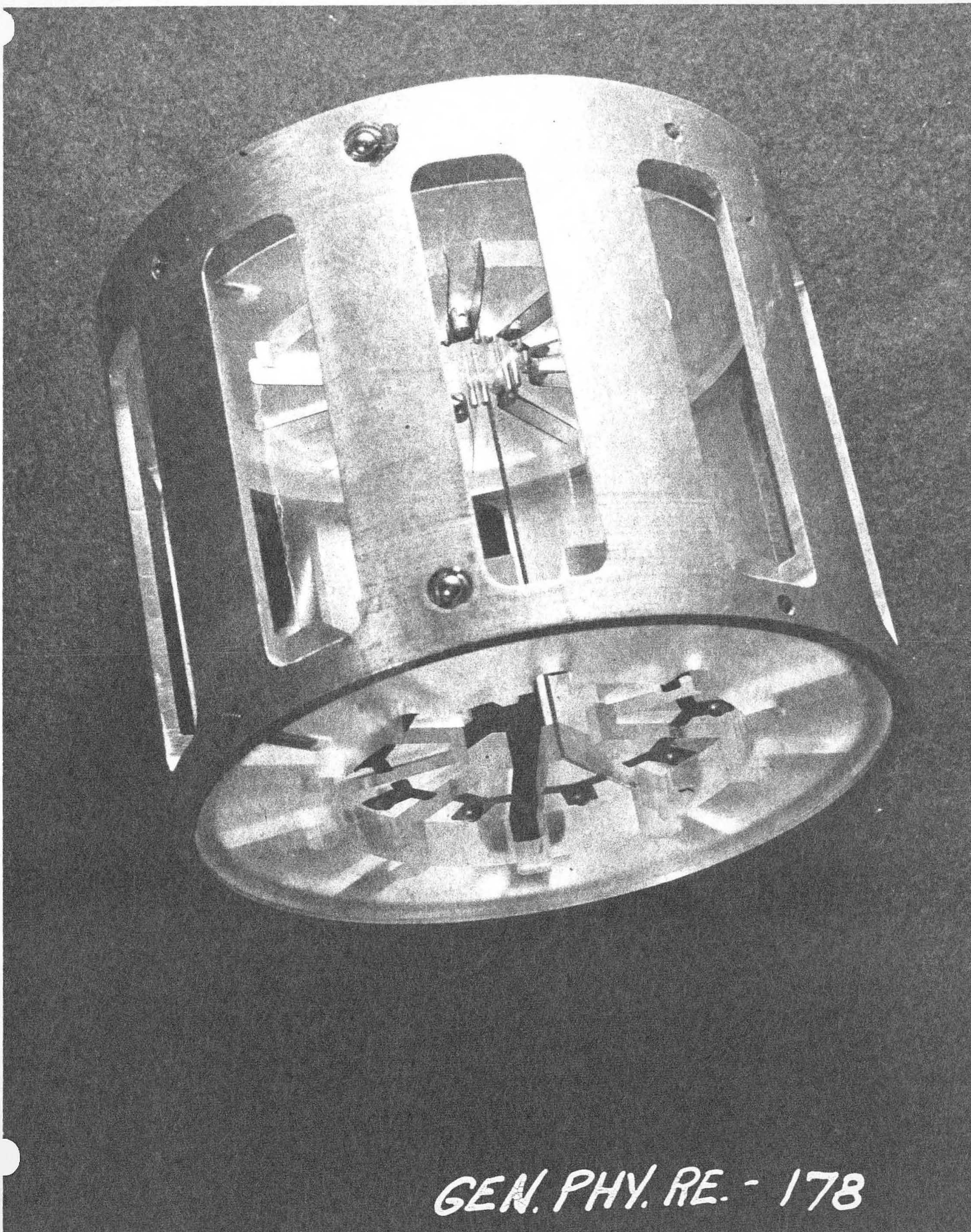


FIG. 5 OZ-360

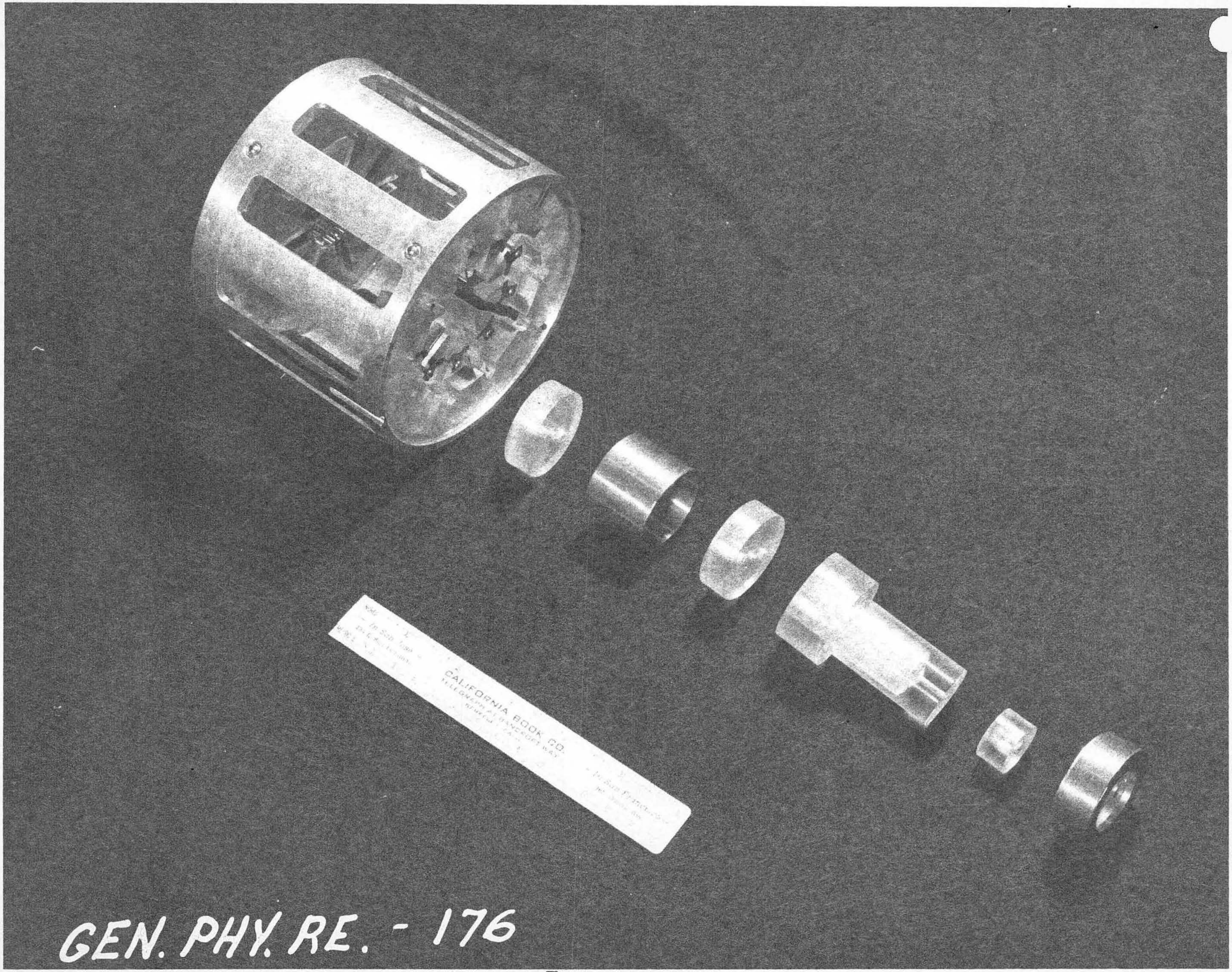


FIG. 6

OZ-237

$$\text{NUMBER OF TRACKS} = N_v\, N_p \left(\frac{d\sigma}{d\omega_{c.o.m.}}\right) \frac{wLz}{y^2} \frac{\Delta(\omega_{c.o.m})}{2\pi}$$

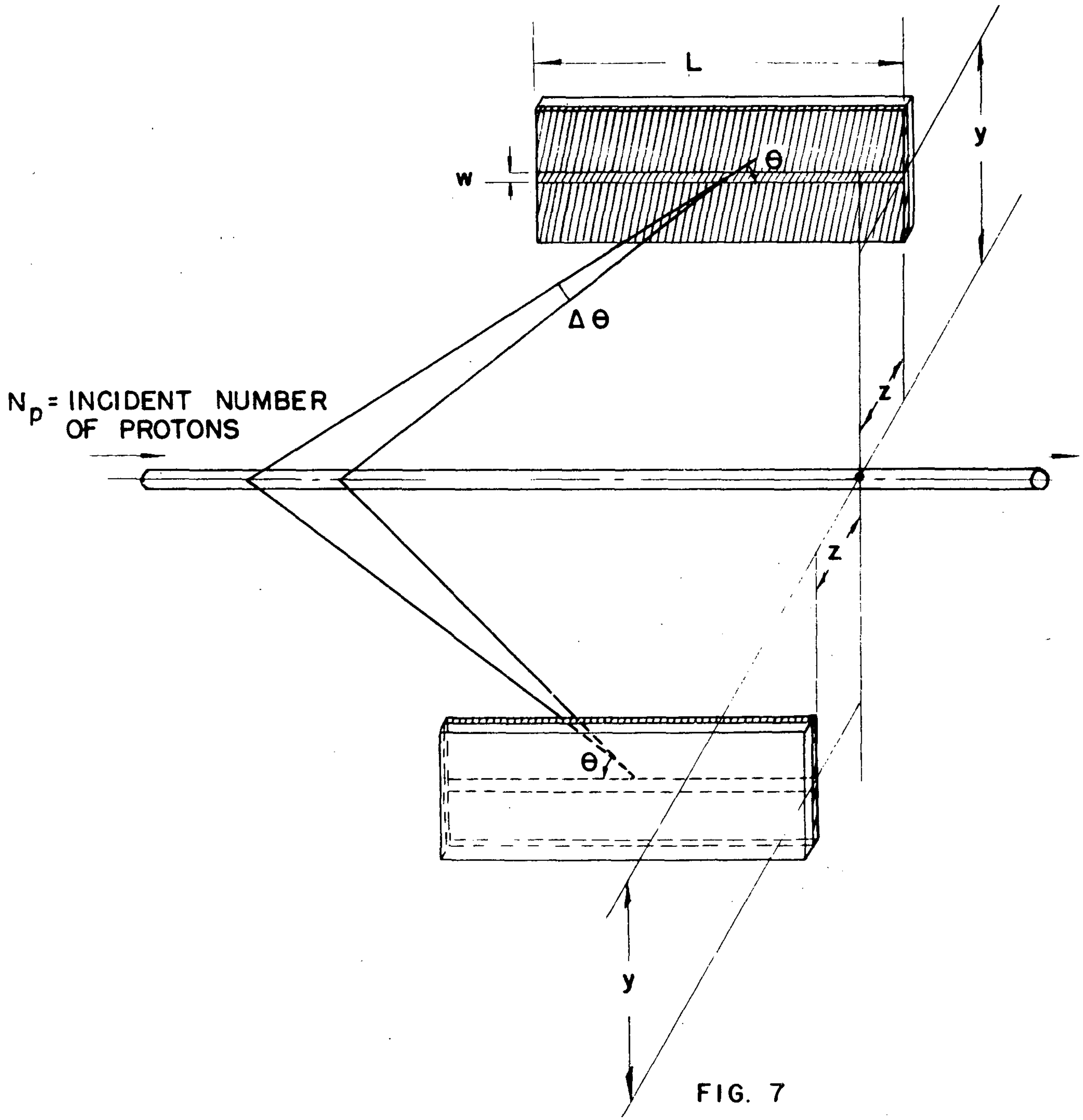


FIG. 7

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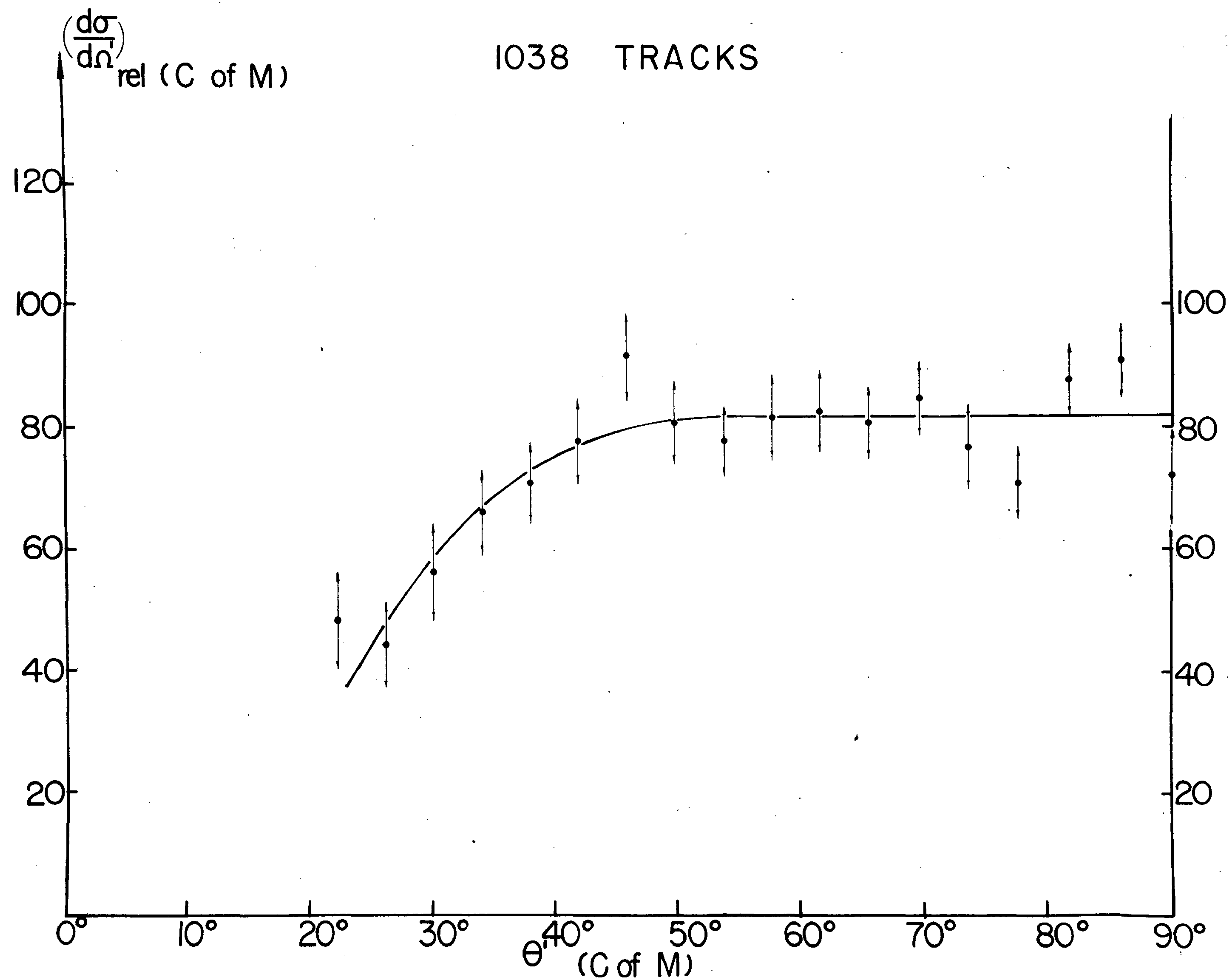

1038 TRACKS
$\left(\frac{d\sigma}{d\Omega'}\right)_{rel}$ (C of M)
120
100
80
60
40
20
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
θ' (C of M)

FIG. 8

OZ-368