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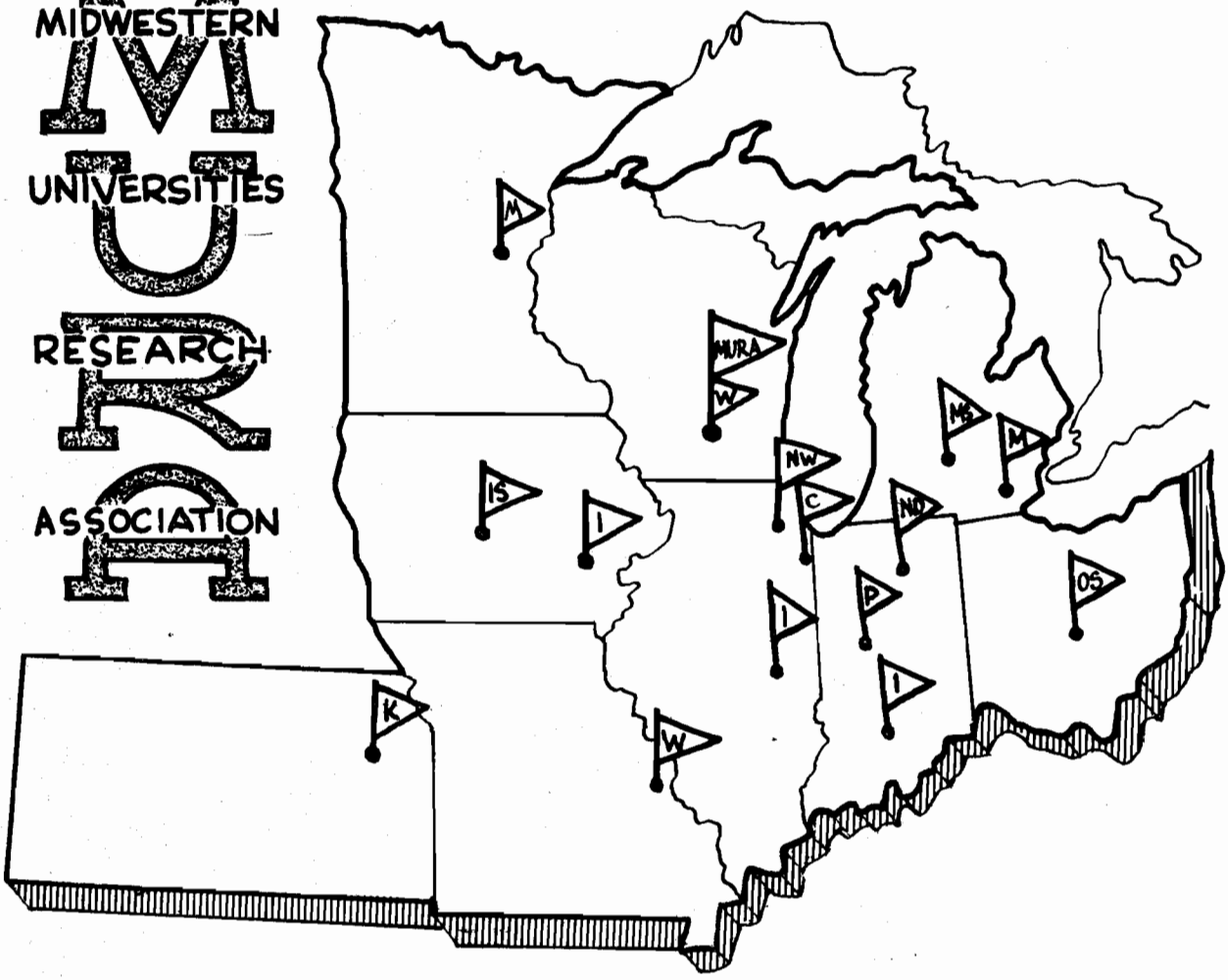

PROPOSED ELECTRON-ELECTRON SCATTERING EXPERIMENT

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REPORT **NUMBER** 486

MURA-486
Internal

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PROPOSED ELECTRON-ELECTRON SCATTERING EXPERIMENT

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July 7, 1959

ABSTRACT

An experimental arrangement is suggested for observing electron-electron scattering using the MURA 40 Mev colliding beam model. The background conditions are analyzed using empirical data from current electron synchrotron experiments and found to be negligible.

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*AEC Research and Development Report. Research supported by the Atomic Energy Commission, Contract No. AEC AT(11-1)-384.

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INTRODUCTION

The purpose of this report is to outline crudely an experimental set-up for observing the electrons scattered in an electron-electron collision in the 40 Mev two-way model and then on this basis, analyze the background conditions using the knowledge obtained from experiments with similar experimental arrangements.

It is realized that the somewhat optimum conditions for observation of the scattered electrons described in this report may be contrary to the optimum conditions for the design and construction of the model at present, but the spirit in which this is written is that after the model has demonstrated its capabilities as an accelerator, then the necessary alterations can be made to perform the experiment. However, the initial detection of the scattered electrons, in order to demonstrate that the beams are colliding, can be made with the same experimental arrangement without alteration of the model.

DESIGN OF THE EXPERIMENT

The purpose for this experiment is to see whether there is a finite charge distribution for the electron, perhaps inside of which interactions other than Coulomb can take place. From existing measurements such as of the Lamb shift, one might expect such effects, if they exist, to occur at distances less than 0.5×10^{-13}cm. Since the De Broglie wave length of the colliding beams in the MURA model is approximately 13×10^{-13}cm, one can just begin to observe discrepancies from the Møller scattering cross section. It is estimated that the percentage accuracy, P, with which the electron-electron scattering cross section must be measured in order to see such effects is $P = 14 r_c^2$; where r_c is (See Appendix)

the critical cut off radius in 10^{-13} cm for electrons of 40 Mev incident energy. Thus the accuracy of the measurements must be at least of the order of 5%. This accuracy essentially limits one to the measurement of relative cross-sections. In particular, since the energy dependence of the cross section is so slowly varying in the energy range of this experiment, one is limited to a measurement of the angular distribution of the scattered electrons. From symmetry considerations one would expect the maximum departure from Møller scattering to be in the plane which is perpendicular to and which bisects the electron beams. The ratio of the electrons scattered into some angle in this plane to the electrons scattered at some geometrically convenient angle close to the forward direction of either beam will produce the maximum measurable effect. In the interest of performing a precision experiment, a complete angular distribution between these angles would be desirable. This would require an alteration of the model to the extent of extending one or two of the magnet legs.

Since the radiation from the accelerator, which will have a circulating current in each beam of approximately 10^{13} particles, is expected to be large especially in the plane of the orbits, the counters will have to be placed well above and below the orbit plane. To accomplish this purpose and still retain a large solid angle, magnetic analysis and focusing are essential. Two counting systems should be employed, oriented at the proper angles so that both electrons can be detected in fast coincidence. Since the electron beams will intersect at an angle of 130°, these scattering angles can be chosen so that one electron has an energy greater than the energy of each beam while the other electron has an energy less than the energy of each beam. Magnetic analysis will then sharply discriminate between electron-electron events and electron-nuclear events. Examples of the proper orientation

for the counting systems in the plane perpendicular to and bisecting the incident beams is shown in Table I. The angles θ_1 and θ_2 are measured in this plane from the direction of the center-of-mass motion. Furthermore, detection of the events in this plane can be carried out without alteration of the model. To help discriminate against the γ-ray background, directional Cerenkov counters can be used to detect the electrons that have been magnetically analyzed. A block diagram of the required experimental apparatus is shown in Fig. 1.

Table I.

Particle 1		Particle 2	
θ_1	Energy Mev	θ_2	Energy Mev
0	56.9	180°	23.1
65°	40.0	-65°	40.0
68°	39.0	-62°	41.0
90°	32.9	$-44^\circ 12'$	47.1

BACKGROUND ANALYSIS

To obtain a realistic estimate of the background conditions that will prevail in the vicinity of the model, a knowledge of the background encountered in the use of other electron accelerators can be used. In particular, two experiments, one performed using the Iowa State University Synchrotron[1] and the other using the University of Michigan Synchrotron,[2] are used. In both experiments approximately 1-1/2 ft. of lead is between the counters and the accelerator and magnetic analysis and focusing is used to remove the particles from the median plane for better detection conditions. Except for scaling factors, the background from these accelerators is essentially the same as for the model. In the model, electrons

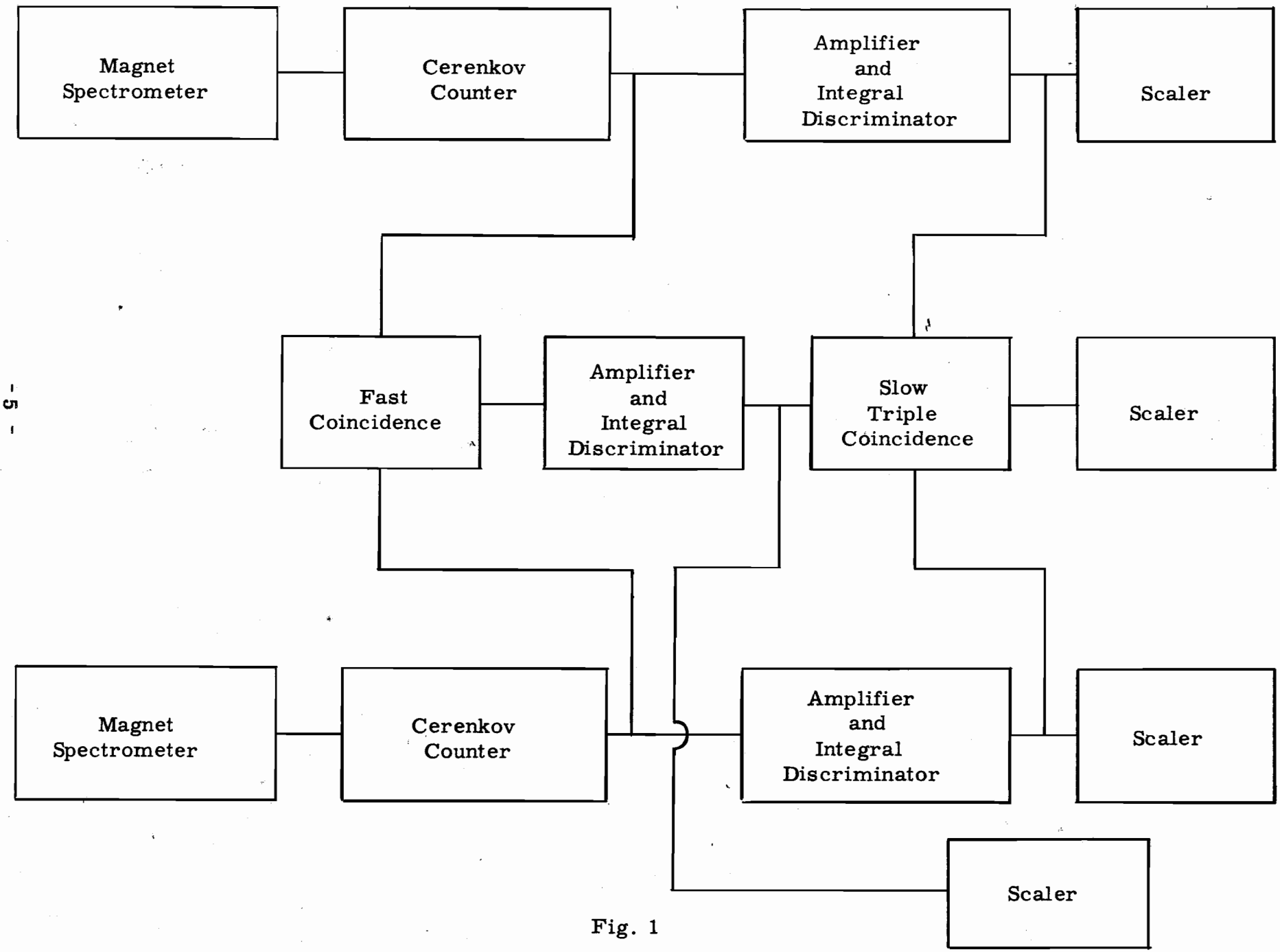
Magnet Spectrometer
Cerenkov Counter
Amplifier and Integral Discriminator
Scaler
Fast Coincidence
Amplifier and Integral Discriminator
Slow Triple Coincidence
Scaler
Magnet Spectrometer
Cerenkov Counter
Amplifier and Integral Discriminator
Scaler
Scaler

Fig. 1

are multiply scattered by the residual gas uniformly at all azimuthal positions. These electrons strike the walls of the vacuum chamber, making high energy x-rays. In both the I. S. U. and the U. of M. machines the electron beams are adiabatically peeled off onto thin targets. These targets take the place of the residual gas in the model so that the electrons strike the vacuum chamber walls uniformly in azimuth in this case also. Important differences in this case are:

1. All of the electrons strike the walls in times of the order of microseconds instead the order of seconds as is the case with the MURA model.
2. The I. S. U. experiment is operated in the forward cone of the Bremsstrahlung beam made by all of the electrons striking a metal target whereas the electron-electron scattering experiment will be only in that Bremsstrahlung beam made by the stray electrons striking the vacuum chamber walls at the proper azimuth.

Both of these differences are taken into account by scaling the number of particles in the I. S. U. and U. of M. machines up according to the ratio of the times for beam destruction assuming all 10^{13} particles in the MURA accelerator meet their end in one second and by taking into account, in the I. S. U. case, the difference in the target azimuth (1 cm) compared to circumference of the accelerator (2π 30 cm.). The result of this scaling and other pertinent data are given in Table II. In calculating the expected counting rate for the electron-electron scattering a solid angle of 5×10^{-3} steradians and an interaction volume of 0.06 cm^3 (0.25 x 0.25 x 1) is used. From this table one sees that according to the I. S. U. experiment a signal to background ratio of 500:1 is expected for the electron-electron scattering experiment while from the U. of M. experiment the ratio is 50:1. It is felt that these results are conservative, firstly, because

in both of the above experiments the counters were approximately only one foot above the median plane and secondly, the circulating current in the MURA model will have a life time longer than one second.

Table 2

	I. S. U.	U. of M.	MURA Model
No. of particles	10^9	10^8	10^{13}
Time Scaling	$(10^6/40)$	$(10^6/100)$	1
Target Effect	2×10^2	1	1
Effective Number of Particles	0.5×10^{16}	10^{12}	10^{13}
Counting Rate per sec	0.5	1	0.6
Signal to Background	1:1	1000:1	
Type of Counter	gas & plastic scint. in coincidence	Cerenkov	

Only the first significant figure is retained. The number in the denominator of line 2 is the duration of the beam pulse in microseconds.

A much larger background than that described above can be expected to come from the elastic scattering of the electrons from the beam by the residual gas and the walls of the vacuum chamber into the solid angle subtended by the counting systems. Assuming the same solid angle and interaction volume given before, the singles counting rate due to this effect is expected to be

$$R_n = 2 \times 10^3 \text{ per sec.}$$

For a residual gas pressure of 10^{-7} the scattering from the gas is negligible compared to the scattering from the chamber. The effective target

thickness offered by the aluminum chamber was taken to be (1/4") and the cross-section $4 \times 10^{-27} cm^2$.[3,4] Thus, for a coincidence resolution of 20×10^{-9} sec, the accidental counting rate would be 0.16 counts/sec for a signal to background ratio of 4:1. However, if one uses the energy selection described earlier, the accidental counting rate given above will be many orders of magnitude lower.

CONCLUSIONS

It is concluded that an angular distribution for electron-electron scattering can be measured to approximately 4% providing that both energy selection and coincidence techniques are used to minimize the background.

For detection of the colliding beams, a single Cerenkov counter oriented at $\theta_1 = 0$, using magnetic energy selection could be expected to record a signal-to-background rate at least the order of 50:1.

APPENDIX

The differential cross-section for electron-electron scattering in natural units ($\hbar = m = c = 1$), in the plane wave approximation assuming a potential cut-off of the form $\frac{1 - e^{-\frac{r}{r_c}}}{r}$, is

$$d\sigma = d\sigma_m \left\{ 1 - 12 \quad r_c^2 \quad \frac{W^2 \sin^2 \theta_{10} \sin^2 X}{3 + \cos^2 X} \right\}$$

where, W = total energy of either incident electron.

$$\cos X = \frac{\sin \theta_{10} \sin \theta_1 \cos \varphi}{1 - \cos \theta_{10} \cos \theta_1}$$

$d\sigma_m$ = Møller differential scattering cross-section,

$\theta_{10} = 65^\circ$ for the MURA model, θ_1 and φ are the scattering angles shown in Fig. II.

The percentage accuracy with which an experiment must be performed is therefore given by

$$P = .12 \; r_c^2 \; W \sin \theta_{10}$$

for a scattering angle of $\theta_1 = 90^o$, $\varphi = 0$.

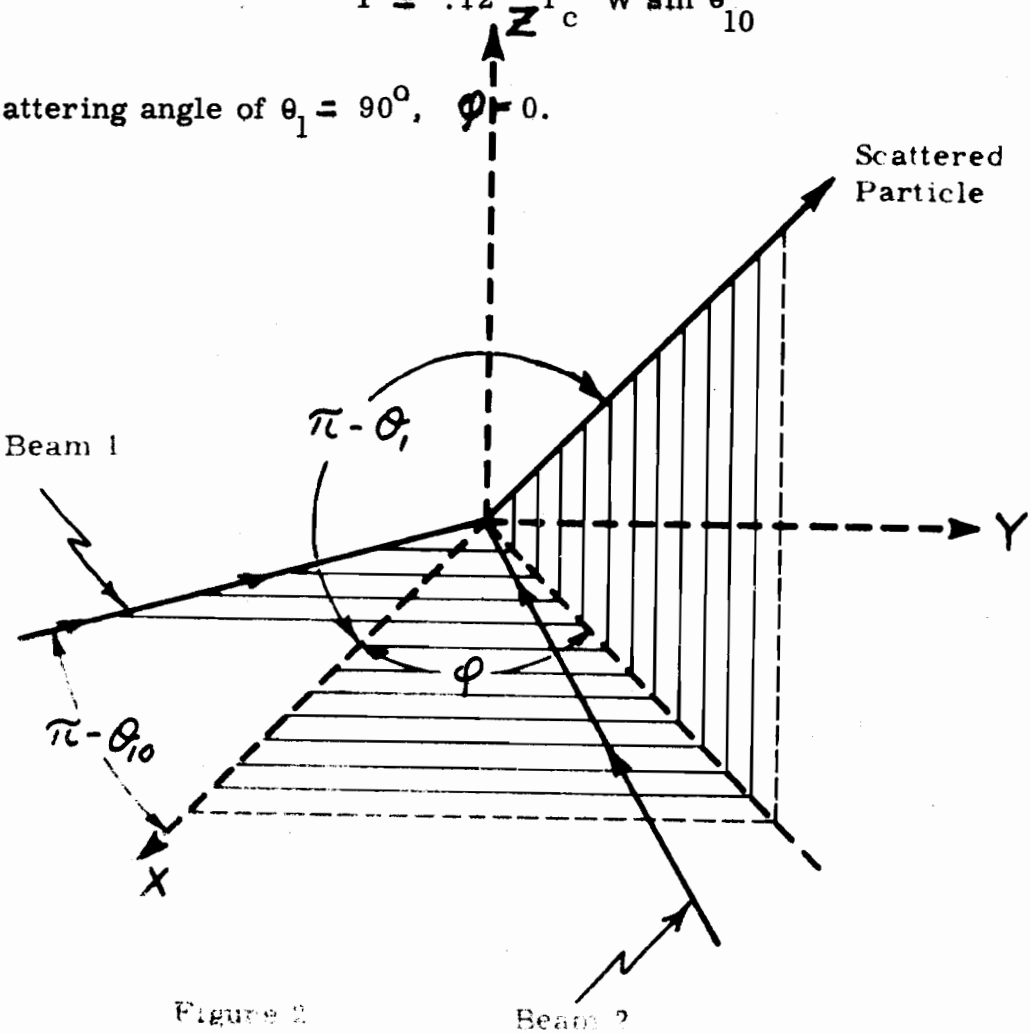

Figure 2

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