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ANGULAR DISTRIBUTION OF n-p SCATTERING WITH 90 Mev NEUTRONS

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One of the important experiments that became feasible as soon as the 184" cyclotron started to operate was the measurement of the angular dependence of n-p scattering. As is well known, experiments of this type acquire particular significance when the de Broglie wave-length of the neutron is comparable with the range of nuclear forces.

The neutron beam[1] of the cyclotron has an angular distribution well described by Serber's[2] stripping theory. We assume that the energy distribution

(1) A. O. Helmholz, E. M. McMillan, D. Sewell, Phys. Rev. 72, 1003 (1947)
(2) R. Serber, Phys. Rev. 72, 1007 (1947)

of the neutrons is also that predicted by this theory; i.e., has a maximum at 90 Mev; the corresponding wave-length in the center of mass system is $\lambda\!\!\!^{-} = 0.95 \times 10^{-13}$ cm.

We have used these neutrons to measure the n-p cross section as a function of the angle of scattering θ, in the CM system, between 70° and 170°. Fig. 1 shows a schematic layout of the apparatus. The neutron beam produced by stripping 180 Mev deuterons on a Be target was collimated to about 2.5 cm diameter and scattered by paraffin or polyethylene targets which were larger in diameter than the neutron beam. The recoil protons used for the measurement were detected by a telescope of 3 proportional counters in coincidence pointing towards the scatterer. The primary neutron beam was monitored either by the protons scattered by an auxiliary hydrogenous target or by a bismuth fission chamber.

The telescope was made insensitive to protons below a certain energy by the absorber A. The thickness of the absorber was adjusted so that protons of energy less than $66 \cos^2 \frac{\pi-\theta}{2}$ Mev could not enter the third counter. Thus we made sure that

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if the recoil protons detected originated from elastic collisions of neutrons on hydrogen, the impinging neutron had an energy greater than 66 Mev. (We have neglected some small relativity correction.) By taking background measurements with a carbon scatterer and with no scatterer we distinguished the protons due to n-p scattering and those due to (n-p) reactions on C and air.

Table 1 gives the cross-section as a function of θ. Smaller and larger angles are being investigated but the results will not be available for some time.

From what we have said above it is apparent that our measurements give only a number proportional to $\frac{d\sigma}{d\omega}\Delta\omega$ where ω is the solid angle; however we have normalized our figures by the following method: we have hypothetically assumed that $\frac{d\sigma}{d\omega}$ is the same for θ and $\pi - \theta$ and we have made the total scattering cross-section 0.063×10^{-24} cm^2 as reported by Cook, McMillan, Peterson, and Sewell[3]. Our assumption on

(3) L. F. Cook, E. M. McMillan, J. M. Peterson, and D. C. Sewell. Phys. Rev. 72, 1003(1947)

the behavior of the cross section for $\theta < 90^\circ$ is not in disagreement with some preliminary observations at $\theta < 90^\circ$ by us and with some cloud chamber data communicated to us by Dr. W. Powell, but is by no means established. The data are also plotted in Fig. 2 with the relativistic corrections.

In order to avoid some sources of systematic error in these experiments, we have checked the following:

1. Plateau of the coincidence counting rate of the counter telescope versus voltage in the counters; bias voltage of the discriminators; duration of the opening of the coincidence gate of the counters.
2. Proportionality of the number of coincidence counts in the telescope to the intensity of the primary beam and to the thickness of the scattering target for a given primary neutron beam.
3. The influence of Rutherford scattering of the absorber A on the efficiency of the coincidence telescope.
4. Scattering by the air column traversed by the neutron beam.
5. The error introduced by the finite dimensions of the scattering target.

6. Whether the coincidence system counted only protons coming from the scatterer and all those with energy $> 66 \cos^2 \theta$.

This list is not final and there are some important controls that should still be performed, but we feel confident enough of our results to give this preliminary account.

It must be added that these experiments were performed independently with two separate sets of equipment which were similar in principle but differed in many details. This procedure helped considerably in making us aware of unsuspected causes of trouble.

The peak of protons in the forward direction is a clear indication of the existence of exchange forces between neutron and proton. A more detailed analysis that takes into account the total scattering cross section and the angular distribution indicates that there might be comparable amounts of ordinary forces.

The authors wish to express their appreciation to Drs. E. M. McMillan, W. Powell, and R. Serber for interesting discussions. This work was done under the auspices of the Atomic Energy Commission under Contract No. W-7405-eng-48.

TABLE 1

DIFFERENTIAL CROSS SECTION IN 10^{-28} cm^2
(normalization hypothetical)

The errors listed are based only on statistical standard deviations.

Scattering Angle θ	(1)	(2)	(3)	(4)
70	43.7 ± 4.0	35.3 ± 2.8	39.0 ± 3.7	40.8 ± 3.1
80	42.6 ± 3.5	32.5 ± 4.9	40.4 ± 3.7	40.2 ± 2.5
90	42.0 ± 2.4	44.0 ± 4.2	45.1 ± 4.9	43.5 ± 2.4
100	47.0 ± 3.0	42.4 ± 6.1	48.0 ± 3.7	46.7 ± 2.7
110	50.2 ± 3.4	51.8 ± 6.1	53.0 ± 3.5	51.4 ± 2.5
120	59.0 ± 2.7	59.7 ± 6.3	63.2 ± 4.5	60.4 ± 2.4
130	66.8 ± 3.1	70.0 ± 7.0	61.5 ± 3.8	65.6 ± 2.7
140	79.5 ± 3.1	78.5 ± 7.8	84.7 ± 5.6	81.2 ± 2.8
150	92.5 ± 4.4	99.0 ± 7.0	94.0 ± 5.4	94.1 ± 4.1
160	105.5 ± 3.8	127.0 ± 10.6	107.5 ± 7.9	107.7 ± 3.8
170	126.0 ± 5.8	127.5 ± 14.0	123.2 ± 9.4	125.7 ± 5.0

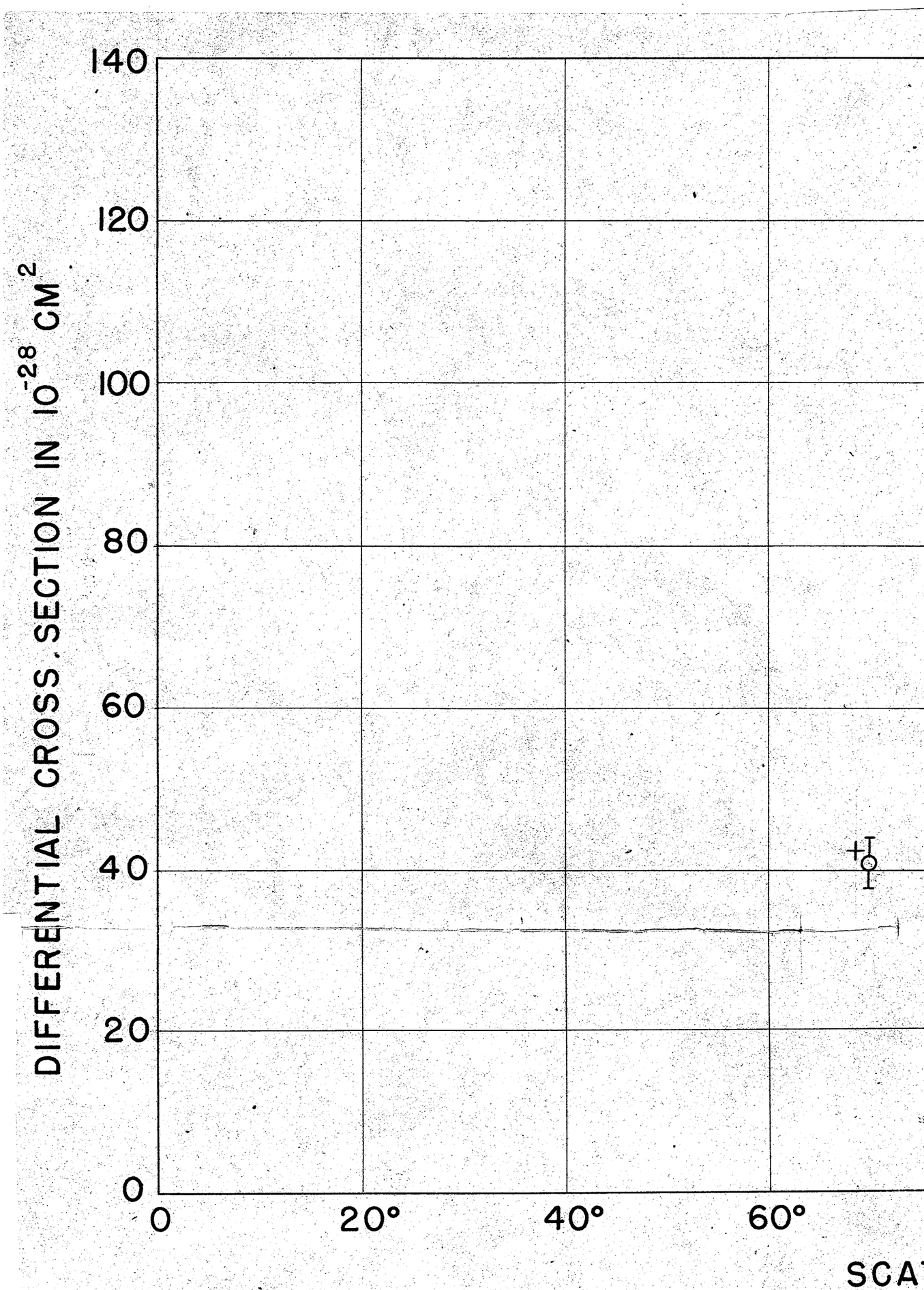
θ Neutron scattering angle in the center of mass system.

(1) Composite of runs on apparatus 1.

(2) Run on apparatus 2, scatterer 150 mg/cm^2 $(CH_2)_n$

(3) Run on apparatus 2, scatterer 283 mg/cm^2 $(CH_2)_n$

(4) Weighted average of all runs with estimated error.


DIFFERENTIAL CROSS. SECTION IN 10^{-28} CM^2
140
120
100
80
60
40
20
0
0
20°
40°
60°
SCA

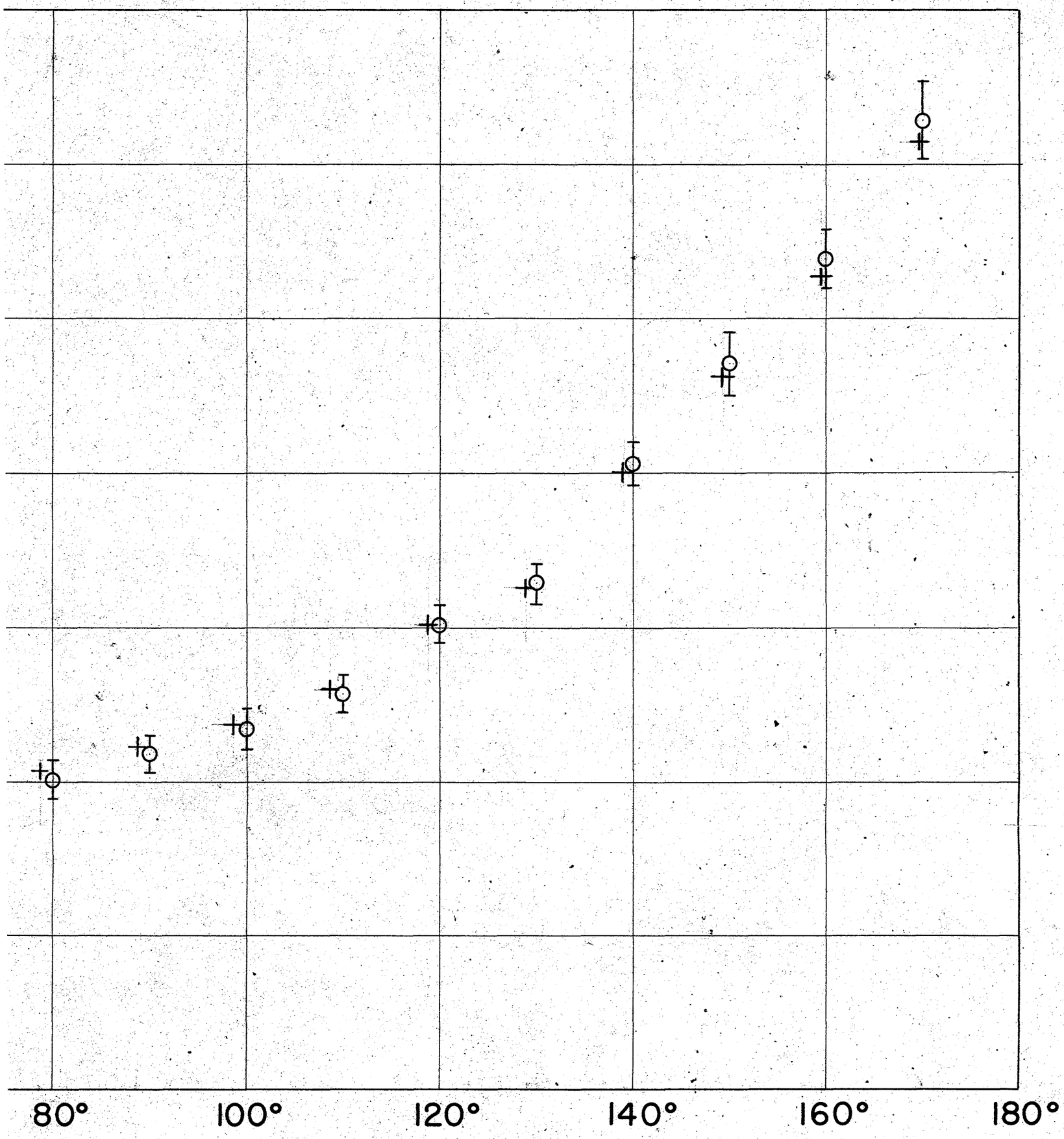
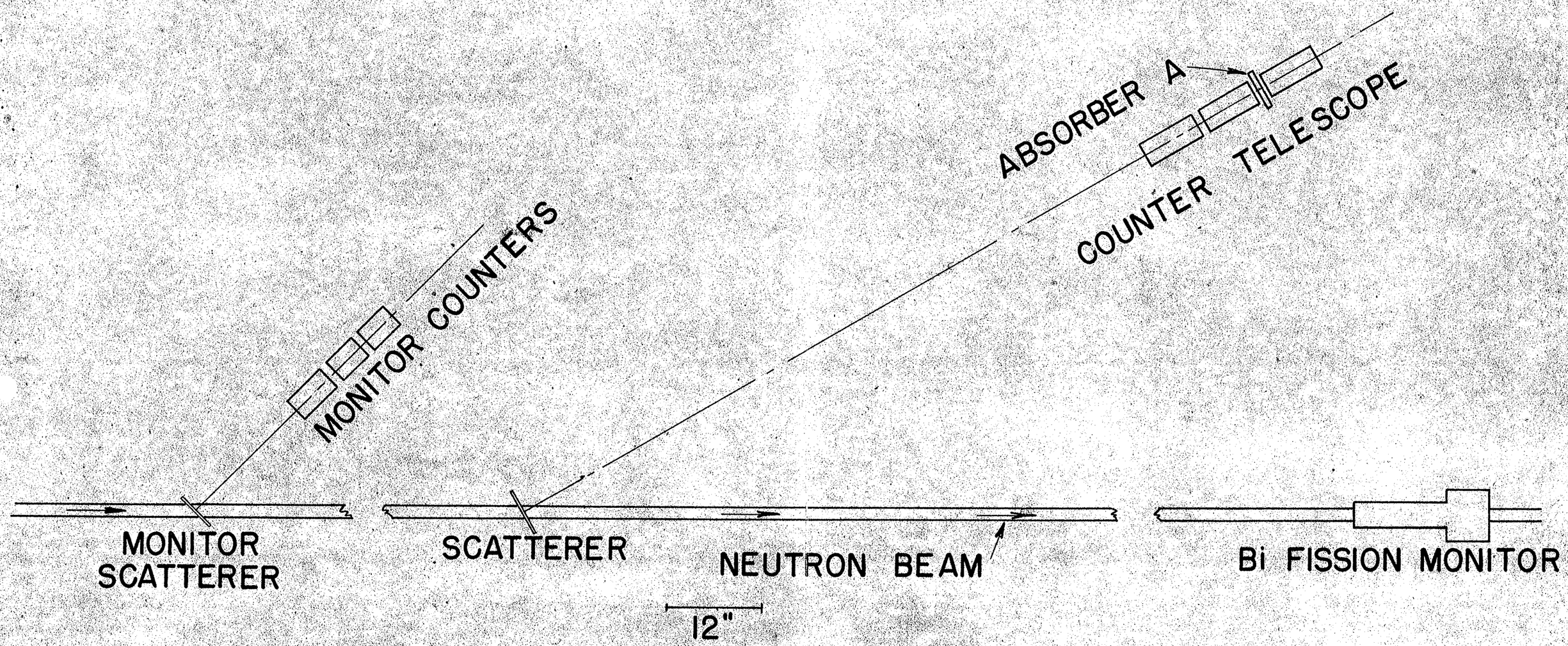


FIG. 2



PLAN VIEW OF EXPERIMENTAL ARRANGEMENT

FIG. 1

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