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Summary of the Research Progress Meeting

September 16, 1948

R. K. Wakerling

~~Special Review of Declassified Reports~~
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Inelastic Scattering of Protons. E. Martinelli

Experiments are being carried out in an effort to measure the energy of protons emitted by various elements when they are bombarded with protons from the linear accelerator. The object of these experiments is to discover whether or not an over-lapping of the energy levels of the nucleus exists when bombardments are carried out at these high energies (32 Mev).

A photographic technique is being employed which involves the use of eight photographic plates arranged in a holder of the form shown schematically in Figure 1. A photograph of this apparatus is shown in Figure 2. Absorbers of various thicknesses are placed between the scatterer and the plates in order to cut down the track length and thereby increase the probability of the tracks remaining entirely in the emulsion. It is possible to cover the energy range from 0 to 15 Mev with eight plates in one run. The remaining range to 32 Mev can be covered in two additional runs.

In these experiments the beam of the linear accelerator is collimated to a diameter of 1/4 in. Ilford El plates are used with an exposure time of one hour. With these plates it is possible to distinguish easily between proton and alpha particle tracks. It has been estimated that the error caused by the beam size is 1/3 per cent, while the variation of absorber thicknesses contributes an error of 1/2 per cent. No correction is needed for the thickness of the absorbers since they are specially curved to present the same thickness to beam particles scattered at all angles. Straggling in the range of the particle tracks also contributes an error of from 1 to 2 per cent, while an additional small error is introduced by the 100 kv spread in the energy of the beam. The photographic

method makes it particularly easy to eliminate the background by applying rather simple criteria for the acceptance of the tracks in the plates.

To check the apparatus a run has been made at 16.3 Mev with a carbon scatterer. One thousand tracks were tabulated with the results indicated in Figure 3. If the larger peak in the figure corresponds to a 0 threshold for the excitation of C^{12}, the smaller peak represents an energy of 4.8 Mev.

An earlier experiment with a different apparatus on the scattering of 32 Mev protons gave the curve of the type shown in Figure 4, which indicates the kind of results to be expected at higher energy; that is to say, an obliteration of definite energy peaks into a more or less continuous distribution.

Total and Absorption Cross Section Measurements. N. Knable.

To investigate the relative contribution of elastic and inelastic scattering to the total cross sections, an experiment is being carried out with a bismuth fission neutron detector. The arrangement of the apparatus is shown schematically in Figure 5. The neutron beam passes through a 1/8 in. thick aluminum window 30 in. in diameter in the tank wall and impinges upon a cone of scattering material behind which is placed the detector. A monitor chamber is placed to one side of the cone and far enough from it so that neutrons scattered by the cone do not enter it. Outside the concrete shielding is a third detector in the location shown in the figure.

With this arrangement the ratio C/A of counts from the chambers C and A determines approximately the elastic scattering cross section, defined as the difference between the total cross section and the inelastic cross section. The ratio of counters C/B determines approximately the inelastic scattering cross section, while the ratio A/B determines the total cross section.

The angle of the cone of scattering material was chosen to include all of the central peak of the elastic scattering distribution, but omits part of the contribution of the wings of the distribution at large angles. Since it is necessary to use a mean free

path of the scattering material, the choice of material was governed by its availability. Thus far measurements have been made on carbon, aluminum, copper and lead. The following table summarizes the results obtained to date.

Element	σ_T	σ_{in}	σ_{el}	$\frac{\sigma_{in}}{\sigma_T}$
C				.626 ± .026
Al				.48 ± .01
Cu	2.01 ± .02b	.865 ± .013b	1.14 ± .02b	.43 ± .006
Pb	4.46 ± .06b	1.77 ± .05b	2.68 ± .05b	.40 ± .01

As a check on the apparatus, absorption curves were also run. A similar experiment employing carbon detectors carried out by Leith and Hildebrand gave the following results for the ratio of inelastic to total scattering cross sections.

Element	$\frac{\sigma_{in}}{\sigma_T}$
C	.32 (uncorrected)
Al	.39 ± .04
Cu	.39 ± .03
Pb	.39 ± .03

In these experiments care must be taken that the cone angle is large enough to scatter all of the material into the detector (a 45° cone was used for carbon; for other materials the angle may be smaller). Also, one must be certain that no geometrical transition effects exist (this is the case since the gain in efficiency of the fission detector at large angles is offset by the loss of energies of the particles scattered at large angles). Further, one must be certain that there is not a great variation in the efficiency of detection with energy of the scattered particles. A determination of the number of inelastically scattered protons as a function of energy shows that between 15 and 20 per cent of the inelastically scattered protons are being detected by the fission chambers.

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HW

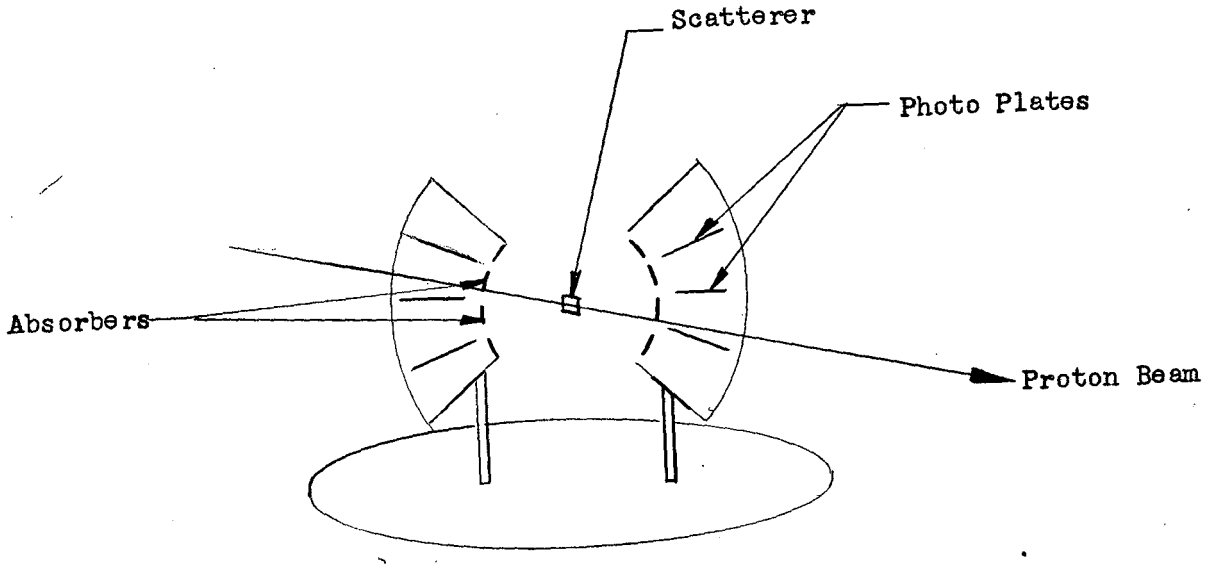

Fig. 1

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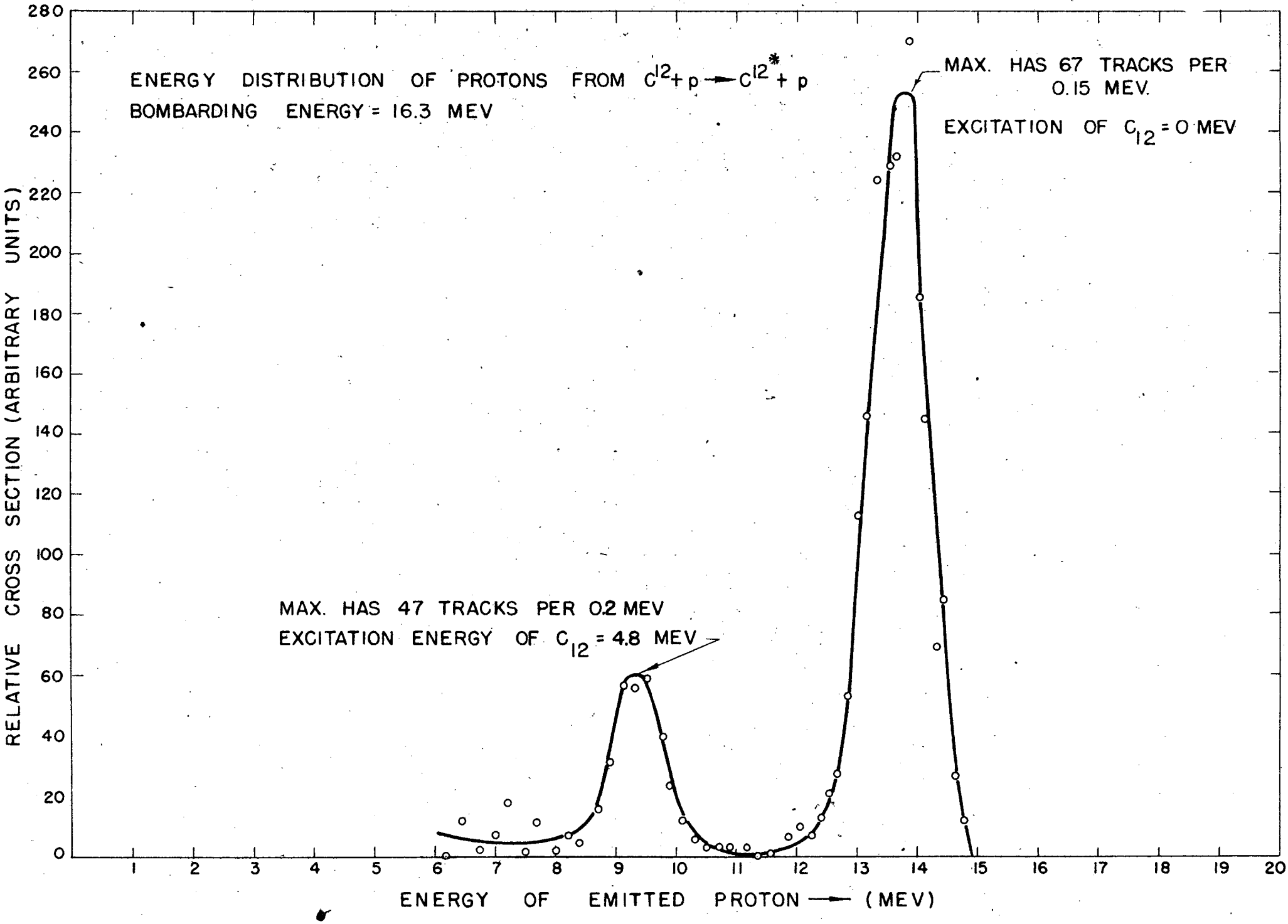
ENERGY DISTRIBUTION OF PROTONS FROM $C^{12} + p \rightarrow C^{12*} + p$
BOMBARDING ENERGY = 16.3 MEV
MAX. HAS 67 TRACKS PER 0.15 MEV.
EXCITATION OF C_{12} = 0 MEV
MAX. HAS 47 TRACKS PER 0.2 MEV
EXCITATION ENERGY OF C_{12} = 4.8 MEV
RELATIVE CROSS SECTION (ARBITRARY UNITS)
ENERGY OF EMITTED PROTON → (MEV)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

FIG. 3

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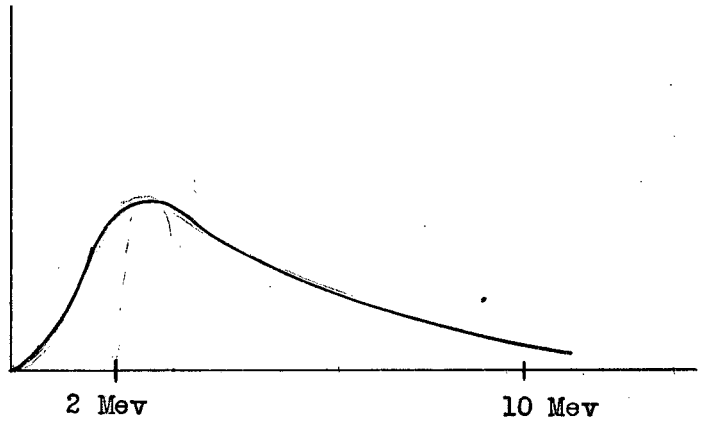

Fig. 4

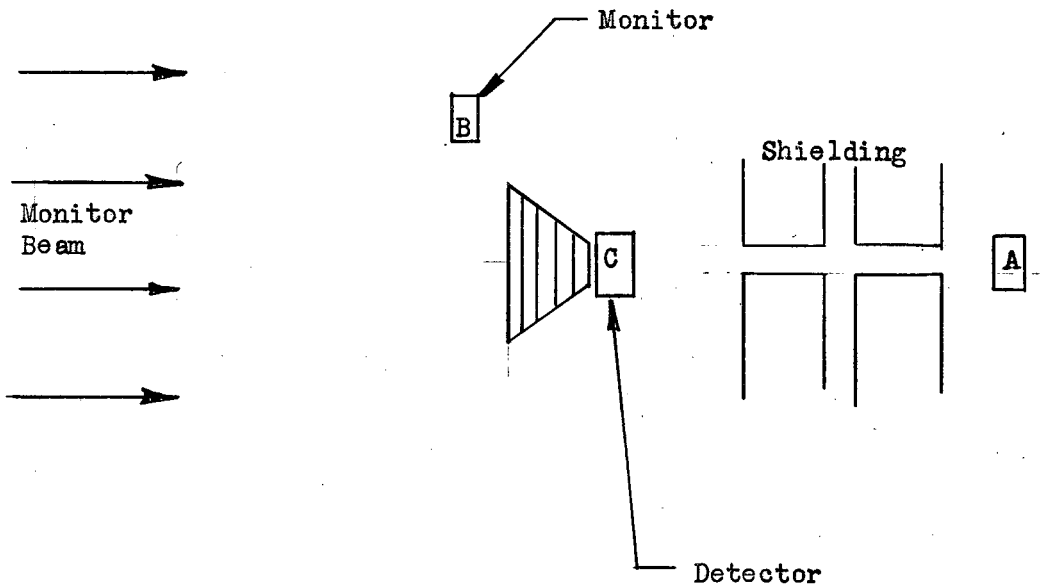

Fig. 5

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