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Excitation Curves of $C^{12}(p,pn)C^{11}$ and $B^{11}(p,n)C^{11}$ up to 32 Mev

by

Robert Phillips and Wolfgang K. H. Panofsky

Berkeley, California

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Excitation Curves of $C^{12}(p,pn)C^{11}$ and $B^{11}(p,n)C^{11}$ up to 32 Mev

Robert Phillips and Wolfgang K. H. Panofsky

Radiation Laboratory, University of California

Department of Physics

Berkeley, California

June 21, 1948

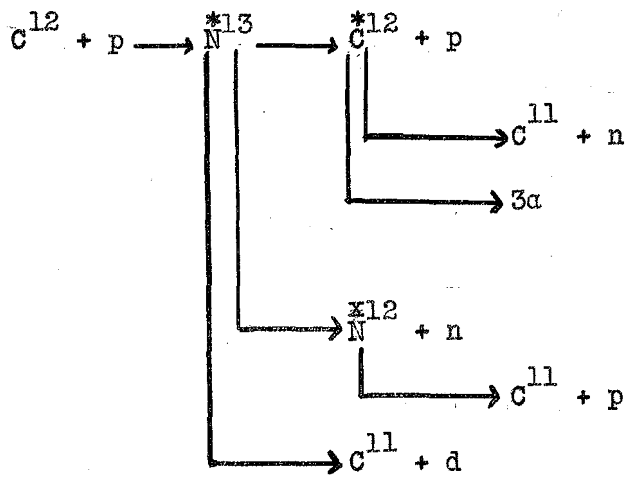
The reaction C^{12} $(p,pn)C^{11}$ which has been studied by McMillan, Chubb and Miller for energies up to 100 Mev is an example of a reaction whose high energy behavior cannot be explained by a compound nucleus process. The purpose of the study was to investigate this reaction at the high resolution possible with the Berkeley linear accelerator near the excitation threshold.

The excitation curve was obtained by stacking specially molded polystyrene (composition C_n H_n) foils of high uniformity and bombarding them in the proton beam. The resultant activity was then counted on a Geiger counter in standard geometry. The resultant curve is shown in Figure 1. An immediately evident feature is the sharp threshold of the reaction. The second derivative curve, illustrated in Figure 2, of the excitation shows an RMS width of 270 kv, the theoretical straggling width due to the foils of 170 kv, and the remaining width in accordance with the energy spread of approximately $\pm$ 100 kv half width of the linear accelerator. The data therefore are compatible with a sharp threshold for this reaction. This curve, incidentally, furnishes independent evidence as to the energy homogeneity of the linear accelerator beam.

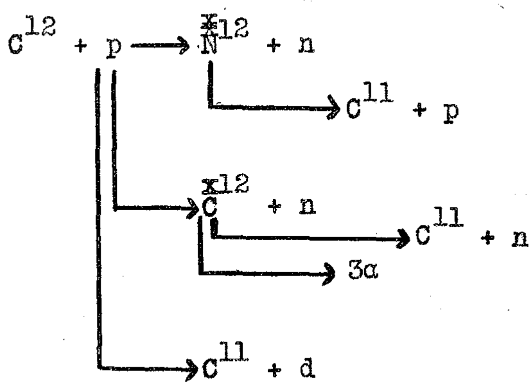
The reaction can proceed by the various mechanisms, as indicated below:

The work described in this paper was done under the auspices of the Atomic Energy Commission.

Compound Nucleus Mechanisms



Knock-out Mechanisms



The compound nucleus mechanisms will be dealt with first. The compound nucleus N^{x13} is very much more likely to lose a proton of binding energy 2 Mev than a neutron of binding energy 20 Mev. On the other hand, the resultant excited C^{x12} would disintegrate into α particles with higher probability than into C^{11} and a neutron. The cross section for the formation of C^{11} should therefore be low, and the behavior near the threshold does not agree with a two particle emission process. The only compound nucleus process which is not ruled out by the excitation curve is the emission of a deuteron from the compound nucleus. This appears to be favored also by the observed low threshold of the reaction, although the accuracy of the energy scale is at present insufficient to allow much importance to be placed on this evidence. The theoretically predicted cross section for this reaction is very much smaller than the observed cross section due to competition from the proton emitting process.

Among the knock-out processes the process resulting from inelastic scattering of protons on C^{12} would yield only a small cross section for the emission of a neutron relative to the emission of α particles. On the other hand, the process of an n-p scattering within the nucleus with the escape of the scattered nuclear neutron will necessarily lead to C^{11} since N^{12} is proton unstable. The probability of such a scattering within the nucleus can be treated by methods introduced by Serber in which the nucleus is treated as a Fermi gas in which both the incoming proton and outgoing neutron have a calculable mean free path. Such a calculation, made by Heckrotte, gives an absolute cross section and intercept behavior in excellent agreement with the measurements.

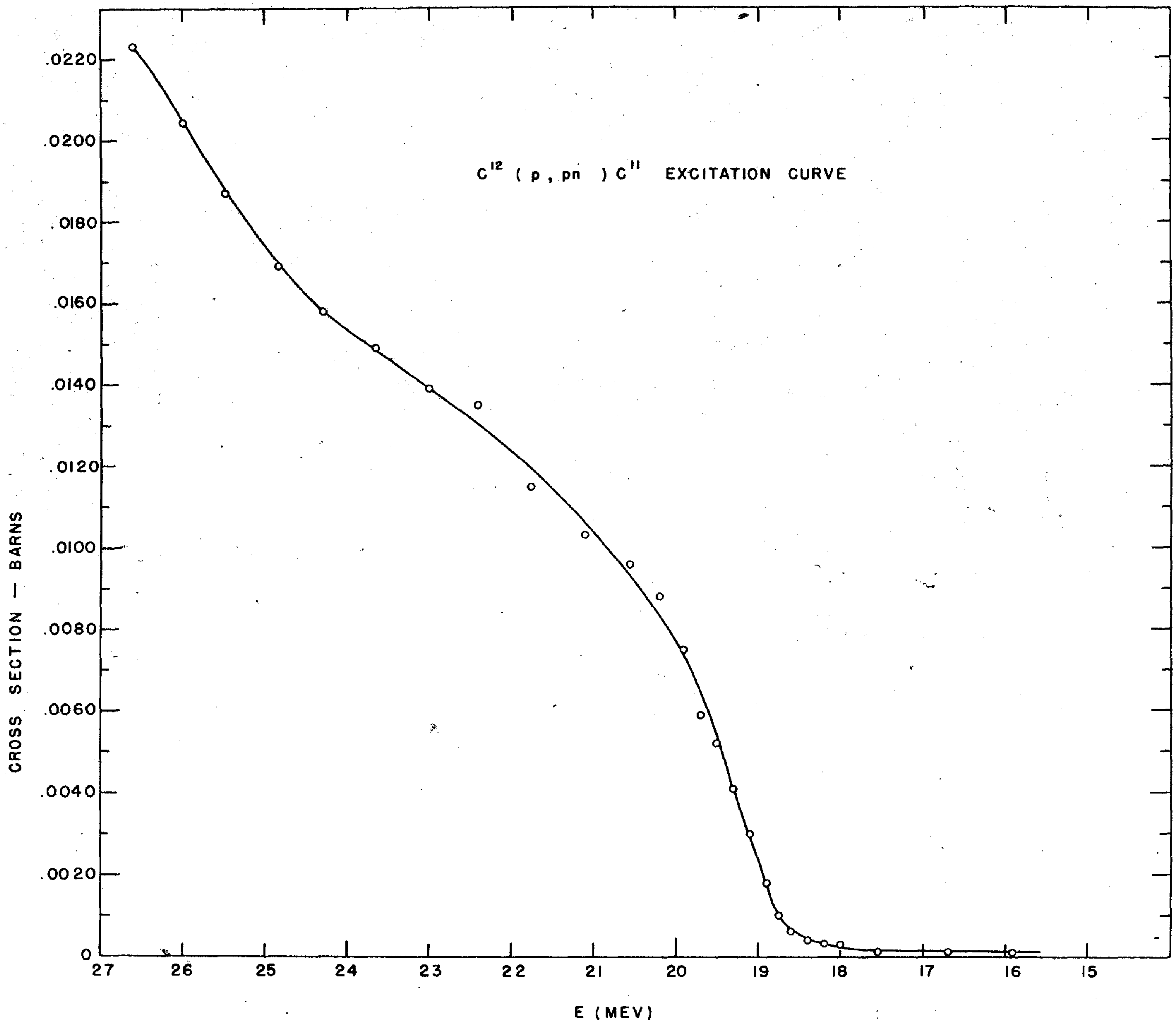
The observed excitation behavior is therefore compatible with only:

a) Deuteron emission from the compound nucleus N^{13}.

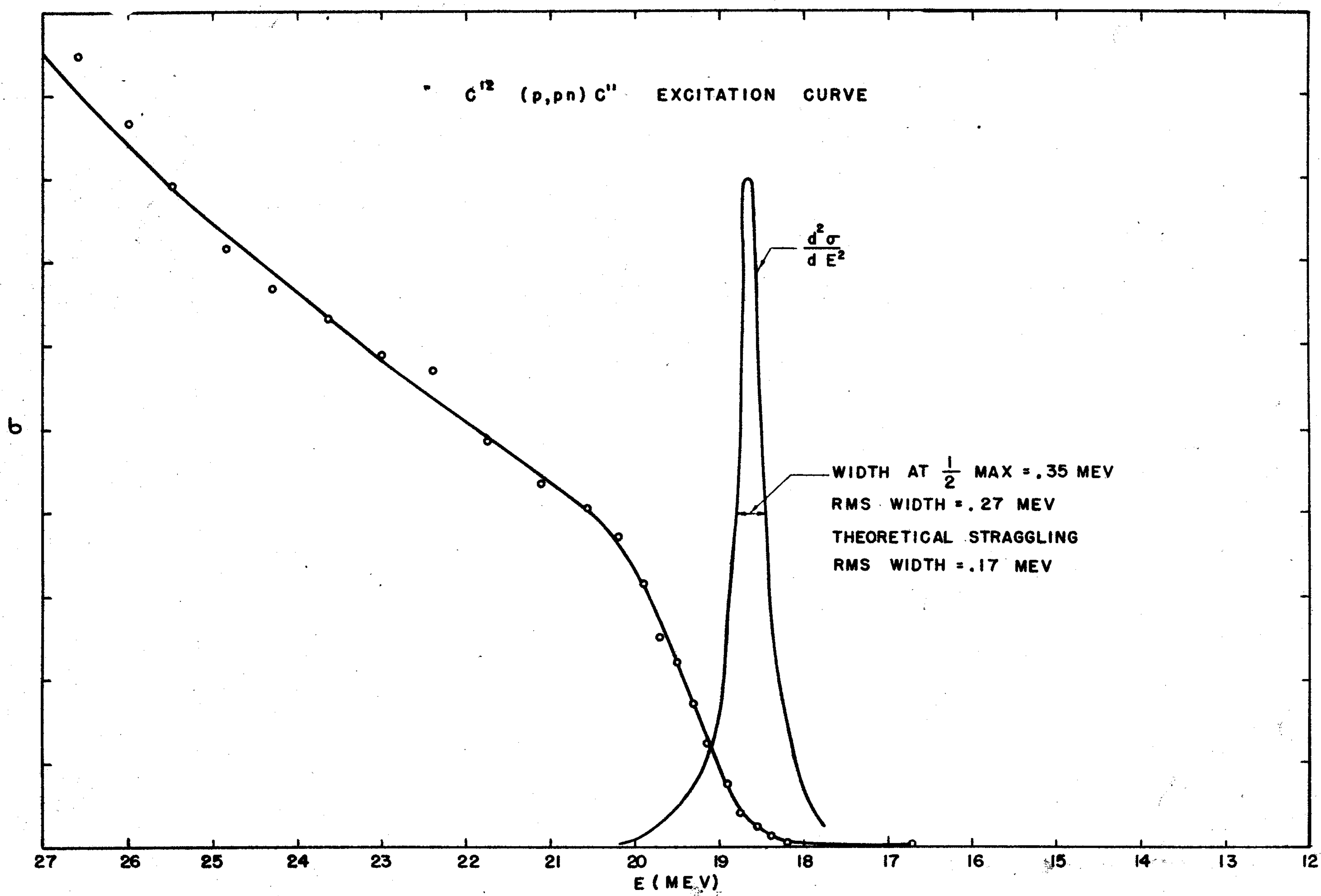
b) Intra-nuclear n-p scattering in the carbon nucleus leading to proton unstable N^{12}.

These two possibilities can be distinguished by improved accuracy on the energy scale, which is now being studied. One of the methods for establishing an improved energy scale is the comparison of the $C^{12}(p,pn)C^{11}$ threshold with the $B^{11}(p,n)C^{11}$ threshold which can be precisely calculated. This work is now in progress.

The assistance of Messrs. Heckrotte, Levinthal and Martinelli in the theoretical interpretation of these results is acknowledged.



C12 (p , pn) C11 EXCITATION CURVE
CROSS SECTION — BARNS
.0220
.0200
.0180
.0160
.0140
.0120
.0100
.0080
.0060
.0040
.0020
0
27
26
25
24
23
22
21
20
19
18
17
16
15
E (MEV)



C^{12} (p,pn) C^{11} EXCITATION CURVE
σ
$\frac{d^2\sigma}{dE^2}$
WIDTH AT $\frac{1}{2}$ MAX = .35 MEV
RMS WIDTH = .27 MEV
THEORETICAL STRAGGLING
RMS WIDTH = .17 MEV
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
E (MEV)