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THE CROSS SECTION FOR THE $He^3(d,p)He^4$ REACTION FROM 35-100 KEV

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ABSTRACT

The 90° differential cross section for the reaction $He^3(d,p)He^4$ was measured by an absolute method using a gas target. Resulting total cross sections, assuming an isotropic angular distribution in the center of mass system, are: at 100 kev deuteron energy, $\sigma_{D\text{-}He^3}$ = 20 millibarns; at 35 kev deuteron energy, $\sigma_{D\text{-}He^3}$ = 11 millibarns. The experimental error is estimated at $\pm 5\%$ at 100 kev. The total cross sections obey, within the experimental error, a relation

$$\sigma_{D\text{-}He^3 \, \text{total (barns)}} = \frac{1.82 \times 10^4}{E} e^{-91.0\, E^{-1/2}}$$

I. INTRODUCTION

When deuterons interact with He^3 the reaction observed is:

$$He^3 + H^2 \rightarrow H^1 + He^4 + 18.4 \text{ Mev}$$

The proton has an energy of 14.7 Mev and the α particle 3.66 Mev.

Several measurements of the cross section for this reaction have been made (1-4) but at the time this experiment was performed no measurement at deuteron energies below 100 kev was known to the authors. The cross section was measured from 35-100 kev, using the apparatus which had been developed for measuring the $T(d,n)He^4$ cross section. The apparatus was readily adapted to make this measurement by changing the counter windows. The experiment used an He^3 gas target with a thin SiO window to admit the beam of deuterons to the target. The protons from the reaction were detected with proportional counters.

II. APPARATUS

The apparatus used is shown schematically in Fig. 1. This apparatus has been described in LA-1479 and only a brief description will be given here.

The analyzed deuteron beam from the Cockcroft-Walton accelerator entered the target chamber through a thin (~5 kev) SiO window after collimation by a series of apertures. The target chamber contained the target gas, He^3, at a pressure of about 1 mm Hg. The target chamber was electrically insulated and was essentially a Faraday cage which collected the beam current passing through the SiO window into the gas. The beam was measured with a current integrator. The reaction particles which came off at 90^o with respect to the direction of the incident beam were collimated and counted by two proportional counters. The collimators on the counters defined the volume of the target gas in which reactions were detected. The He^3 gas was stored in glass flasks and a sample of each target filling was analyzed by a mass spectrometer. The pressure of the gas was measured by a Consolidated Engineering Company micromanometer which was calibrated with a fluid manometer. The energy lost by the beam in passing through the window could be measured by means of a decelerator. The energy of the beam of deuterons in the target volume was then calculable from the high voltage of the accelerator, as measured by a high precision resistance stack and potentiometer, the energy lost by the beam in the SiO window, and the energy lost in the target gas in going from the window to the collimated volume. The energy loss in the target gas was measured with the decelerator(5) and is shown in Fig. 2.

The counter windows used were .035 in. aluminum. These windows transmitted the 14 Mev protons from the reaction but stopped the 3.6 Mev alpha particles. The windows were so thick that there was little possibility of confusion in the identification of the particles since only penetrating particles such as the 14 Mev protons could get through the windows. The protons lost about 90% of their energy in the windows and were then stopped in the counters, which were filled to 1 atm. It was necessary to count the protons rather than the 3.7 Mev alpha particles because any tritium contamination in the target gas would give a high yield of alpha particles indistinguishable from the He^3-D alphas.

The experimental procedure and the treatment of the data are similar to that reported in LA-1479 for the T-D cross section. In calculating the total cross sections from the measured differential cross section at 90^o, the angular distribution was assumed to be isotropic in this energy region.[2,3]

A plot of the cross section as a function of the energy of the incident deuteron is shown in Fig. 3. The lowest energy at which the cross section was measured was determined by the background, which became objectionable at low counting rates. The highest energy was determined by the maximum energy of the accelerator used.

A Gamow plot of the data (Fig. 4) is linear with a slope 91.0 $\log_e$ barns-kev/kev$^{-1/2}$. The simple penetrability

$$\exp\left(\frac{2\pi z_1 z_2 e^2}{\hbar}\sqrt{\frac{m}{2E}}\right)$$

where E is in ergs and m is the deuteron mass, gives a numerical constant 88.80, within 2.5% of the experimental value.

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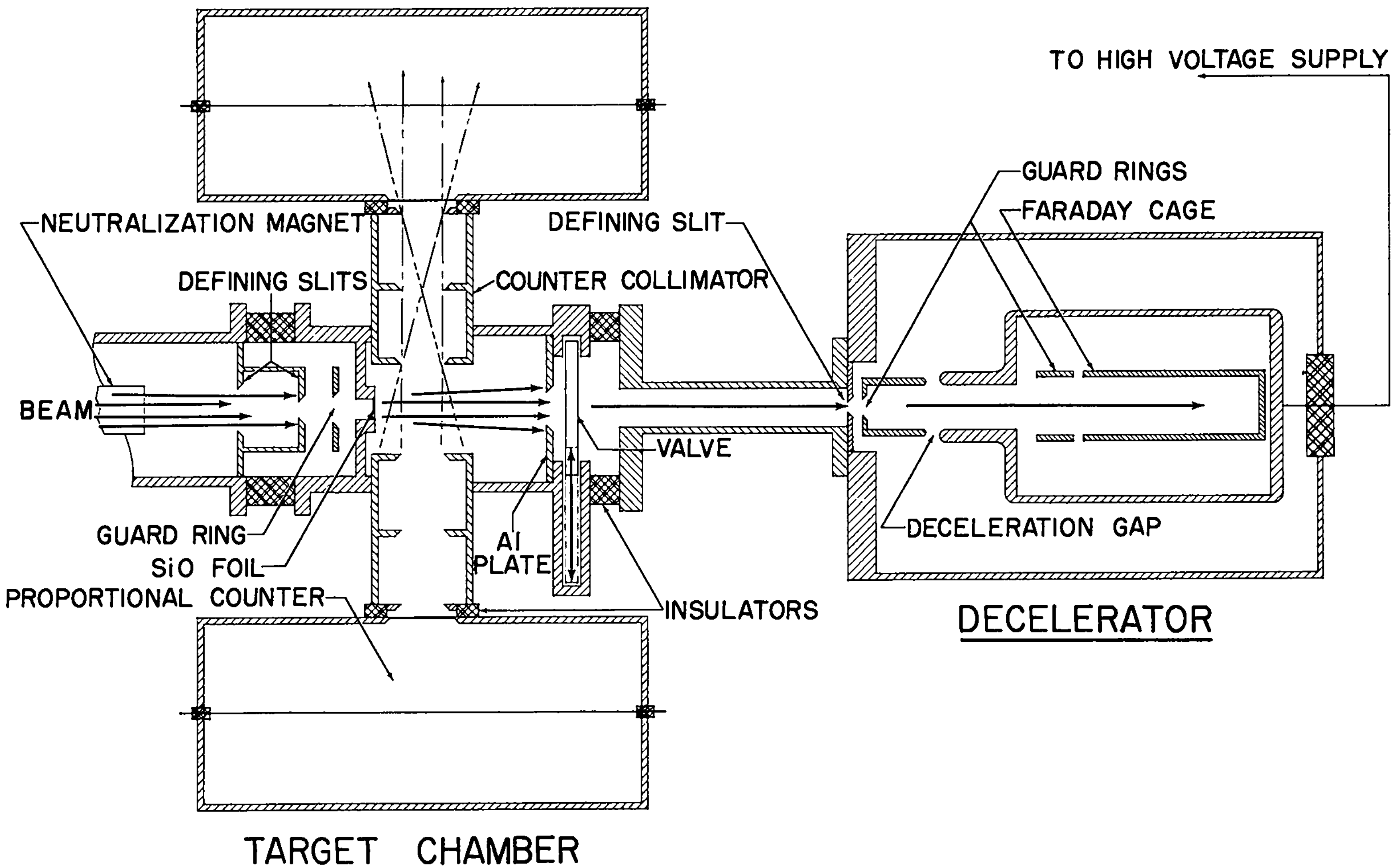

Fig. 1. Target chamber and decelerator for measurement of the T-D cross section

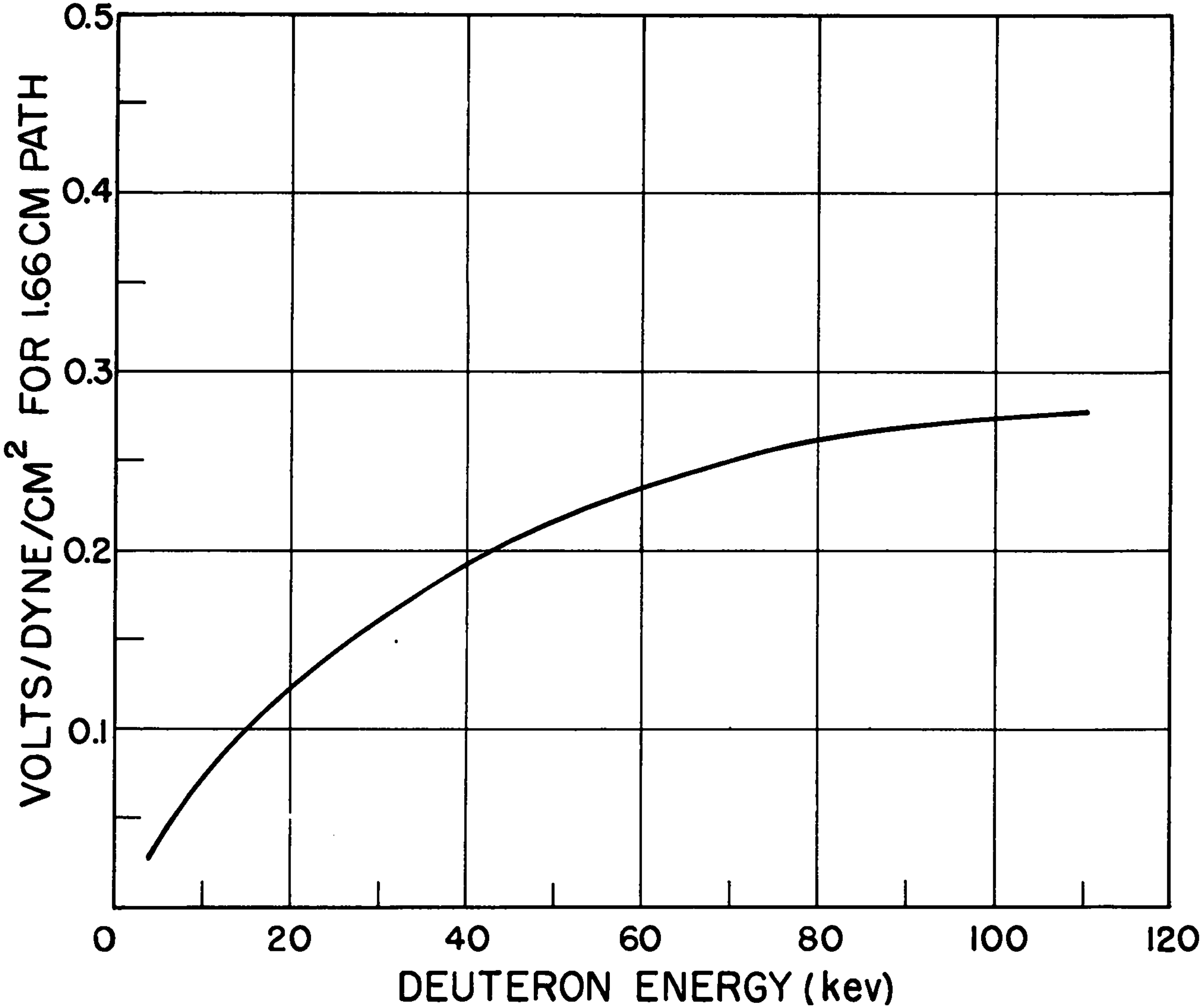

Fig. 2. Energy loss of deuterons in He as a function of energy

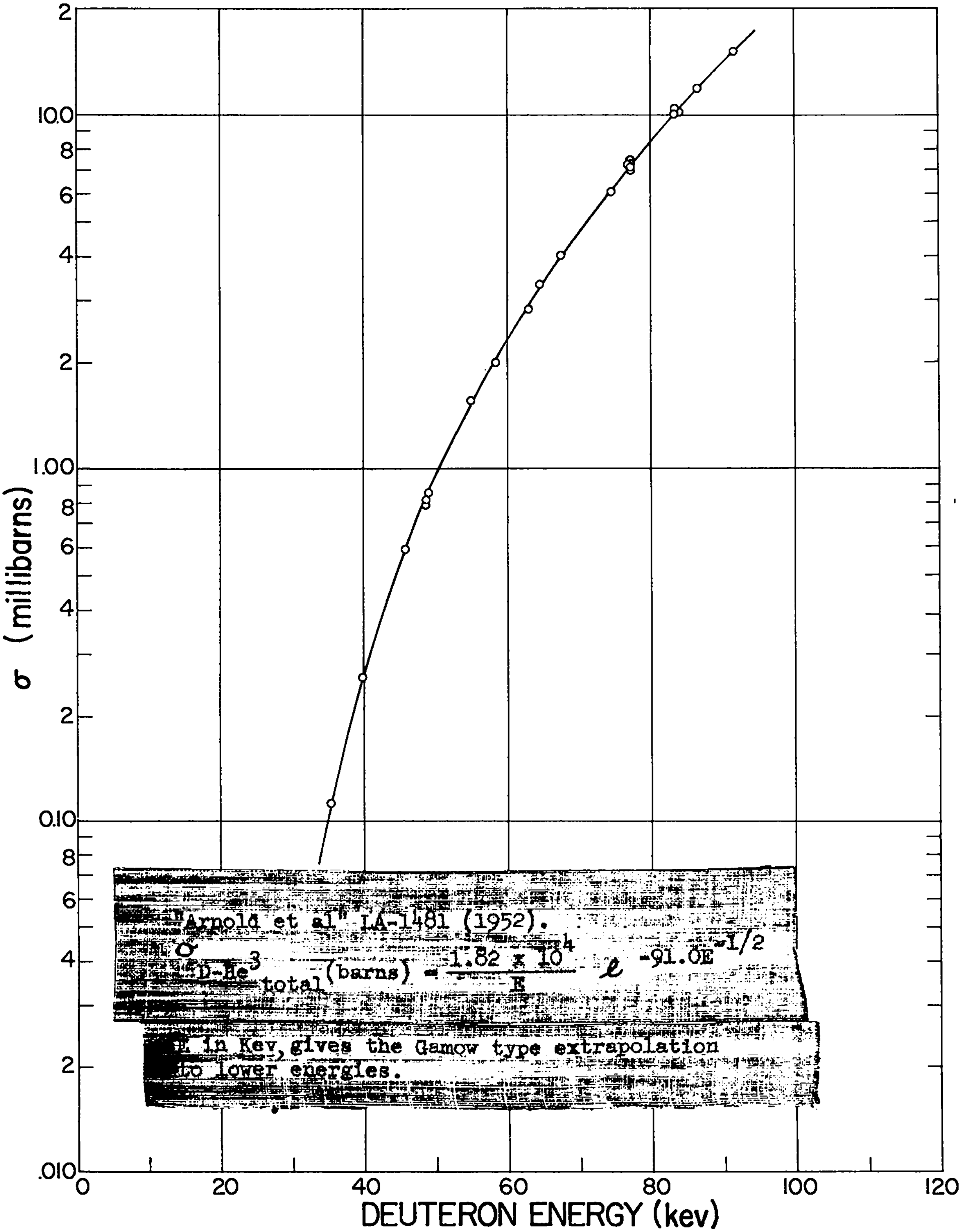

Fig. 3. $D(He^3, p)He^4$ cross section

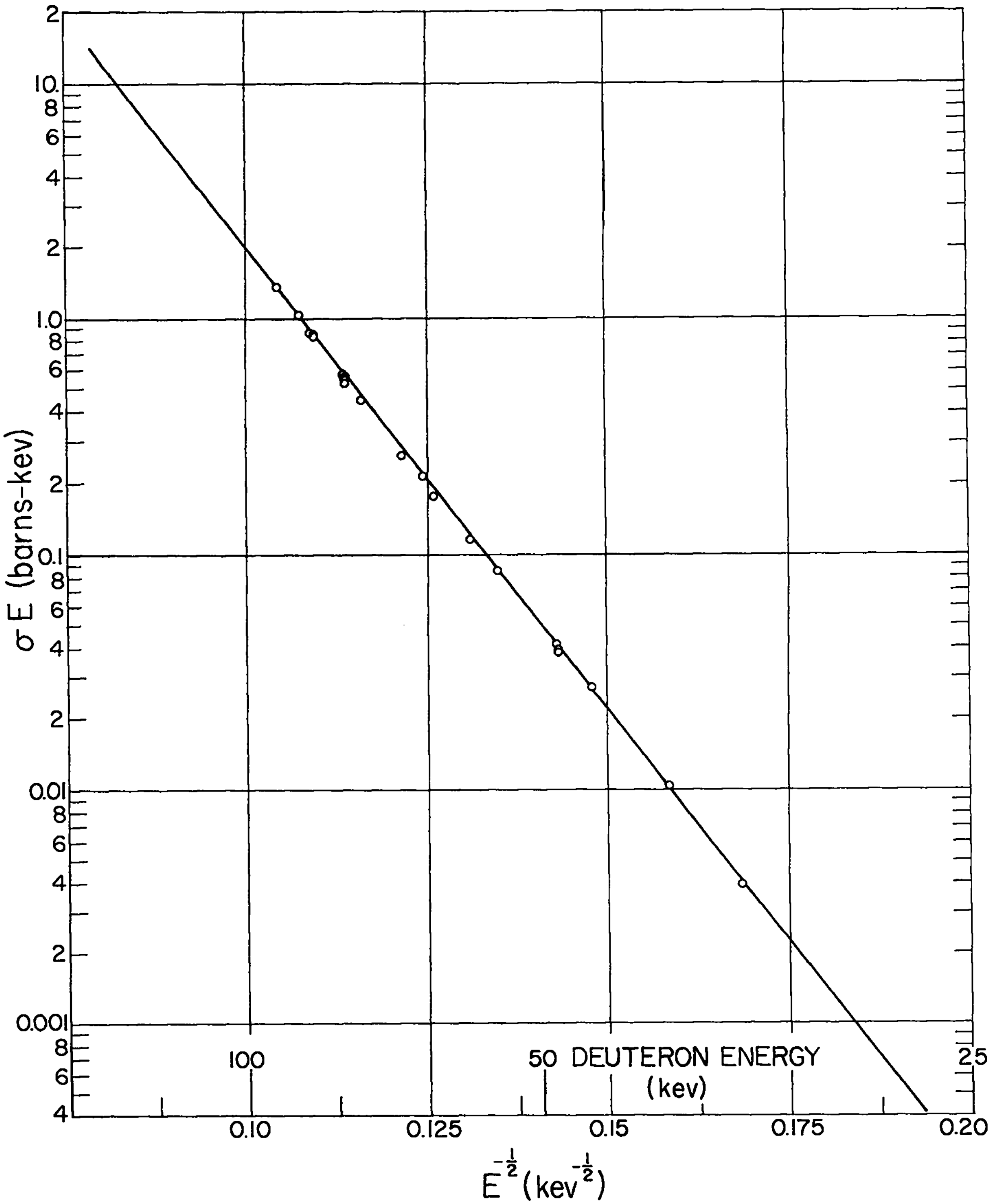

Fig. 4. Gamow plot. $D(He^3, p)He^4$ cross section