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MEASUREMENT OF y-DISTRIBUTIONS FOR HIGH ENERGY ANTINEUTRINO SCATTERING IN HYDROGEN-NEON

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ABSTRACT

Distributions in the scaling variable y are presented based on a study of approximately 700 antineutrino events in the energy range 10-200 GeV obtained using the Fermilab 15-ft bubble chamber filled with a light Hydrogen-Neon mixture. The distributions are inconsistent with a $(1 - y)^2$ form predicted by the simple quark parton model of the nucleon without antiquarks, but can be well fitted assuming a relative antiquark contribution of (10 ± 5)%. For small values of the Bjorken scaling variable ($x < 0.1$) the y-distribution can be well fitted assuming a relative antiquark contribution of (20 ± 5)%. For events at small x in the energy range 30-200 GeV the y-distribution is in good agreement with the results reported by the HPWF group.

I. INTRODUCTION

This letter reports on y-distributions measured in the antineutrino nucleon scattering process

$$\bar{\nu}_\mu N \rightarrow \mu^+ x \tag{1}$$

at high energy. The variable y is defined by $y = \nu/E$ where ν is the energy transfer from the lepton to the hadrons in the lab frame and E is the energy of the incoming antineutrino.

Y-distributions measured in neutrino and antineutrino scattering processes at high energy yield unique information about the constituents of the nucleon. In particular, within the framework of the quark parton model the shape of the antineutrino y-distribution is a sensitive measure of the fraction of the nucleon momentum carried by antiquarks relative to the fraction carried by the quarks. In this connection interest centers on the behavior at high y ($y \sim 1$) where in previous experiments[1-3] acceptance losses or systematic uncertainties due to the muon selection procedure have been very large. Anomalies in the antineutrino y-distribution for small values of the Bjorken scaling variable x have been reported by the HPWF group[2] and it is clearly important to search for these effects using an independent technique. (The Bjorken scaling variable x is defined by the relation $x = Q^2/2m\nu$ where Q^2 is the square of the 4-momentum transfer from the lepton to the hadrons and m is the mass of the nucleon.)

The data come from an exposure of 52,000 pictures obtained using the Fermilab 15-ft bubble chamber filled with a light hydrogen-neon mixture and using a broad-band horn focused antineutrino beam. The hydrogen-neon mixture contained 21 atomic percent of neon. The energy of the extracted proton beam was 300 GeV and the mean proton intensity on the target was $0.8\text{-}0.9 \times 10^{13}$ protons per pulse. The external muon identifier (EMI)[4] was operated in conjunction with this experiment.

The external muon identifier consists of a zinc absorber of mass 600 gms/cm^2 including the copper coils within the vacuum vessel of the bubble chamber downstream of the fiducial volume followed by an array of delay line readout multiwire proportional chambers with a total area of approximately 20 m^2 positioned outside the vacuum vessel and downstream of the absorber. The data from the proportional chambers for each picture taken is written to magnetic tape by an on-line computer which is also used to monitor the performance of the EMI throughout the exposure.

II. THE ANALYSIS

The film was scanned for all inelastic events with total momentum along the beam direction p_x more than about 1 GeV. Events which are candidates for the elastic reaction

$$\bar{\nu}_\mu p \rightarrow \mu^+ n \qquad (2)$$

with an undetected neutron and no other charged prongs visible at the primary vertex were not included in the scan. A total of about 2500 candidates were found in a fiducial volume of 21 m^3

In order to identify muons in these events all muon candidates are extrapolated to the EMI plane in attempt to match them with fitted coordinates from the proportional chambers. For this analysis muon candidates which matched in the EMI and for which the hadron confidence level[4] was less than 10% were taken as identified muons. With this criterion the fraction of hadrons hitting the EMI which are misidentified as muons is 10%.[5]

The energy of the incident antineutrino is estimated by summing the momentum of the muon and the momentum of the hadrons along the beam direction. The momentum of the hadrons has to be corrected to account for neutrals which leave the chamber undetected. The mean fraction of hadron momentum lost in undetected neutrals is estimated from Fig. 1 which shows the mean transverse momentum of the hadrons measured opposite to the transverse momentum of the muon as a function of the transverse momentum of the muon. Due to Fermi motion and to the presence of unseen nuclear fragments we do not expect to see momentum balance in individual events. However the mean transverse momentum of the hadrons measured opposite to the transverse momentum of the muon should balance the transverse momentum of the muon if there are no missing neutrals. On the basis of Fig. 1 we conclude that approximately 30% of the hadron momentum is lost[6] and therefore the hadron momentum is increased by 30% in all events to account for neutrals which leave the chamber undetected.

In order to insure good EMI acceptance and to reduce backgrounds due to interactions of neutrons and incoming charged tracks and due to neutrino and antineutrino induced neutral current interactions, events with $E < 10$ GeV are removed from the sample. Out of 1000 events with $E > 10$ GeV, 600 have a μ^+ identified by the EMI and are retained in the final antineutrino charged current sample.

The geometrical acceptance of the EMI for positive muons generated within the bubble chamber fiducial volume has been computed as a function of x and y at fixed neutrino energy and the distributions shown have been corrected accordingly. Note that very low momentum muons which come to rest in the absorber do not reach the proportional chambers and are never identified as muons by the EMI. As a result, at the lowest energies, there are regions of the x,y plane ('blind regions') where the acceptance of the EMI is very small or zero, and it is not possible to correct for the lost events in a model independent way. Losses which result from proportional chamber inefficiencies and EMI software inefficiencies together with losses due to the muon selection algorithm used are expected to be only weakly dependent on y and no attempt has been made to correct for these effects at the present time.

III. RESULTS AND CONCLUSIONS

Figure 2a) shows the y-distribution for all events in the energy range 10-200 GeV. The point for $y = 0.9-1.0$ may be

biased due to the effect of the 'blind region' and has not been plotted. The distribution is inconsistent with the $(1 - y)^2$ form (solid curve) predicted by the simple quark parton model without antiquarks. Assuming the validity of the Callan-Gross relation,[7] the distribution has been fitted by the form

$$dN/dy \propto |(1 - y + y^2/2) - B\, y(1 - y/2)| \qquad (3)$$

with the result (broken curve): $B = 0.80 \pm 0.05$.
This result is consistent with measurements made in previous high energy experiments[1-3] and is also in good agreement with the low energy data.[8] In the quark parton model of the nucleon the parameter B is related to the relative antiquark contribution by the relation

$$\frac{\bar{Q}}{Q + \bar{Q}} = \frac{1 - B}{2} \qquad (4)$$

where Q and $\bar{Q}$ represent the fractions of momentum of the nucleon carried by quarks and antiquarks respectively. In terms of the relative antiquark contribution the above result for B gives $\frac{\bar{Q}}{Q + \bar{Q}} = 0.10 \pm 0.05$.

Figure 2b) shows the y-distribution for all events in the energy range 10-30 GeV and Fig. 2c) shows the same thing for events in the energy range 30-200 GeV. At the higher energies the effect of the 'blind region' is expected to be relatively unimportant and

has been neglected. There is no significant energy dependence.

Figure 3a) shows the y-distribution for events in the whole energy range 10-200 GeV with x = 0-0.1. The distribution can be fitted by the form (3) with B = 0.6 ± 0.1 (broken curve). In terms of the relative antiquark contribution this result for B gives $\frac{\bar{Q}}{Q + \bar{Q}} = 0.20 \pm 0.05$. Some increase in the antiquark contribution at small x is suggested by the low energy data.

Figure 3b) shows the y-distribution for events in the energy range 10-30 GeV with x = 0-0.1. The distribution is consistent with the form (3) with B = 0.6. Figure 3c) shows the same thing for events in the energy range 30-200 GeV. Also shown in Fig. 3c) is the y-distribution from the HPWF group for the same energy interval and for the same x-region. The distribution from the HPWF group is consistent with being flat corresponding to a negative value for B of order unity. When compared to the corresponding distribution for neutrinos from the same group this result is incompatable with charge symmetry invariance. There is good agreement between the two experiments. However with the present statistics it is not possible to rule out a distribution of the form (3) with B = 0.6 based on the data from this experiment alone.

We wish to thank the Berkeley and Hawaii groups[4] for technical assistance in running the EMI and for making available to us their analysis programs. We also wish to thank the members of the Neutrino Laboratory at Fermilab and the scanning and measuring staff in our respective laboratories for their contribution to this experiment.

REFERENCES

[1]B. C. Barish et al., Phys. Rev. Letters.

[2]B. Aubert et al., Phys. Rev. Letters. See also D. Cline, Palermo Conference.

[3]S. J. Barish et al., Phys. Rev. Letters.

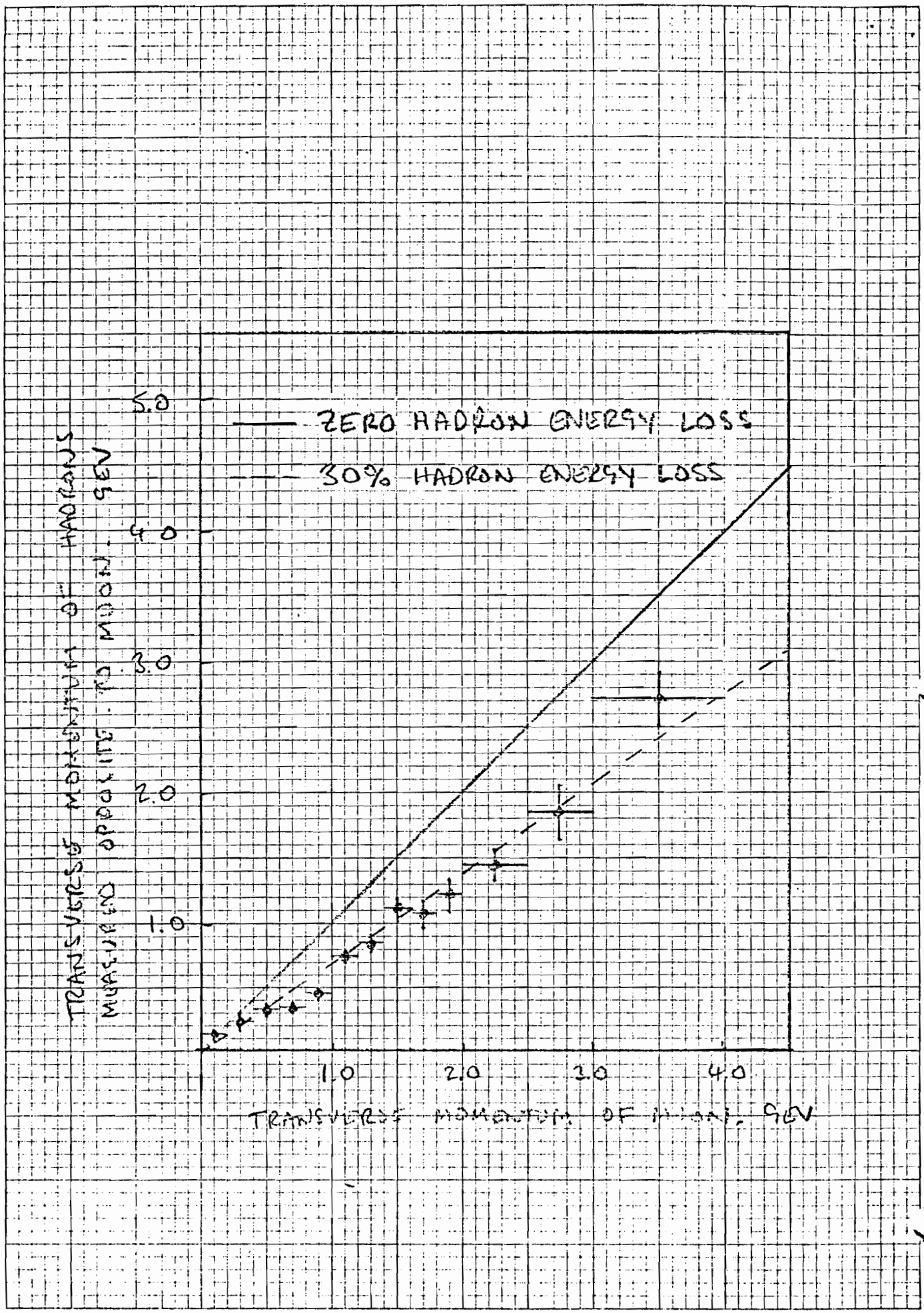
[4]Fermilab Proposal 155, R. J. Cence et al.

[5]Since not all of the hadrons produced will hit the EMI the actual fraction of hadrons misidentified as muons will be very much less. Note that for E > 10 GeV the number of events in which two or more muon candidates are identified as muons by the EMI is less than 2% of the total. For events in this category the highest momentum identified muon candidate is taken as the muon.

[6]The fraction of hadron momentum lost in missing gamma rays is estimated to be in the region 15-20% based on a study of detected gamma rays. The remaining 10-15% is presumably lost in the form of neutrons, which even if they are detected usually deposit only a small fraction of their energy in the chamber.

[7]C. G. Callan and D. J. Gross, Phys. Rev. Letters 22, 156 (1969).

[8]Deden et al., Phys. Letters (1975).



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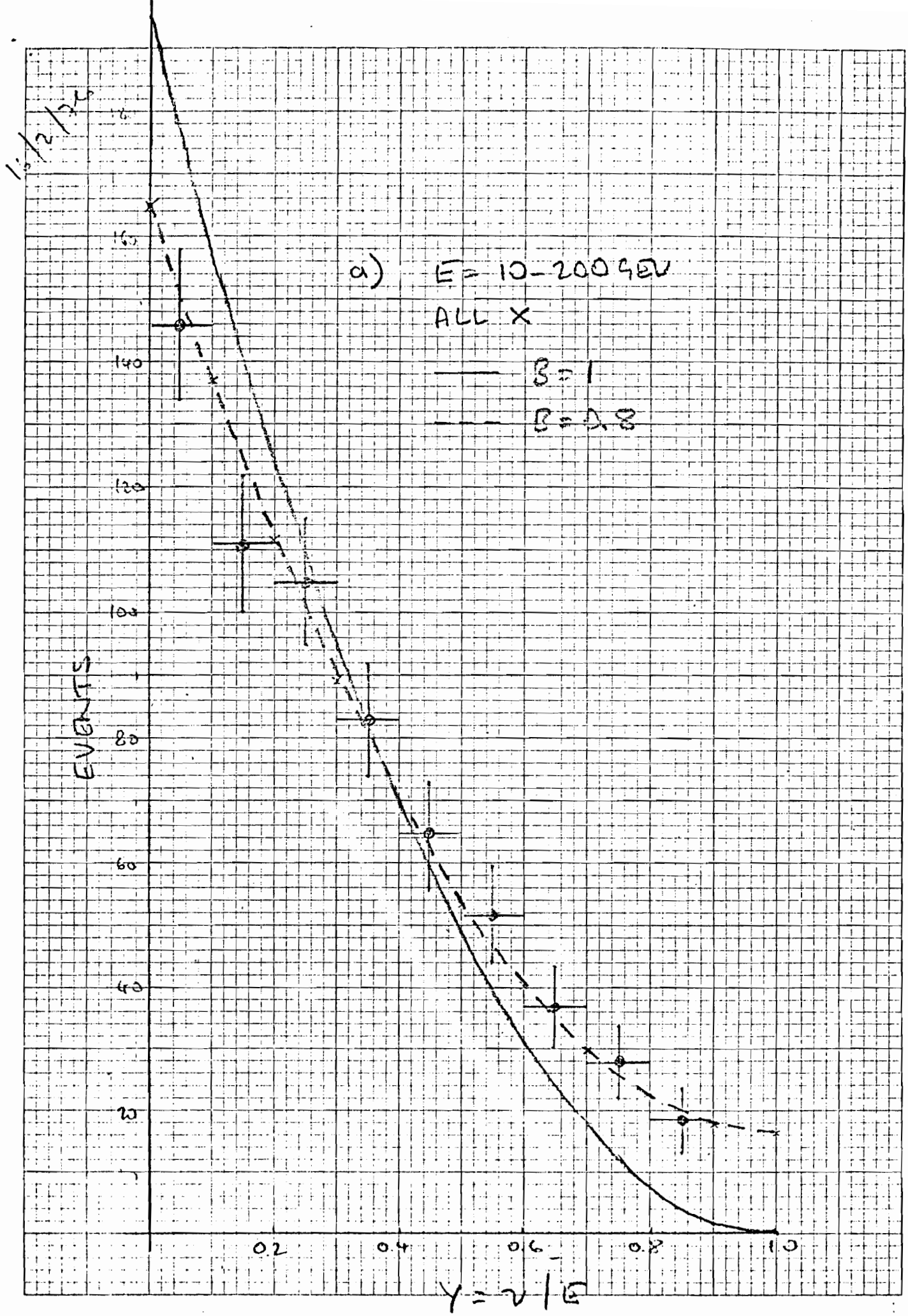

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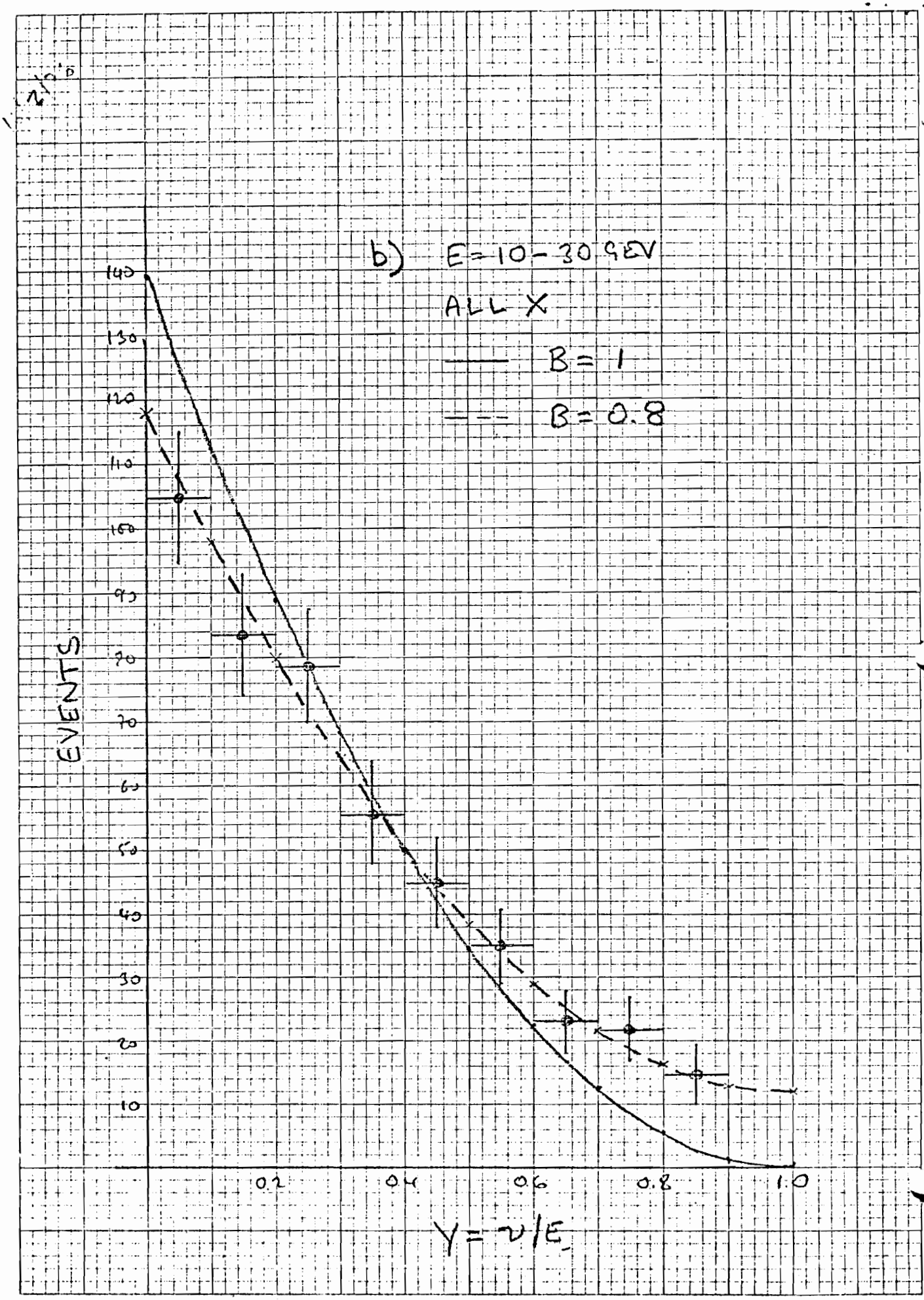

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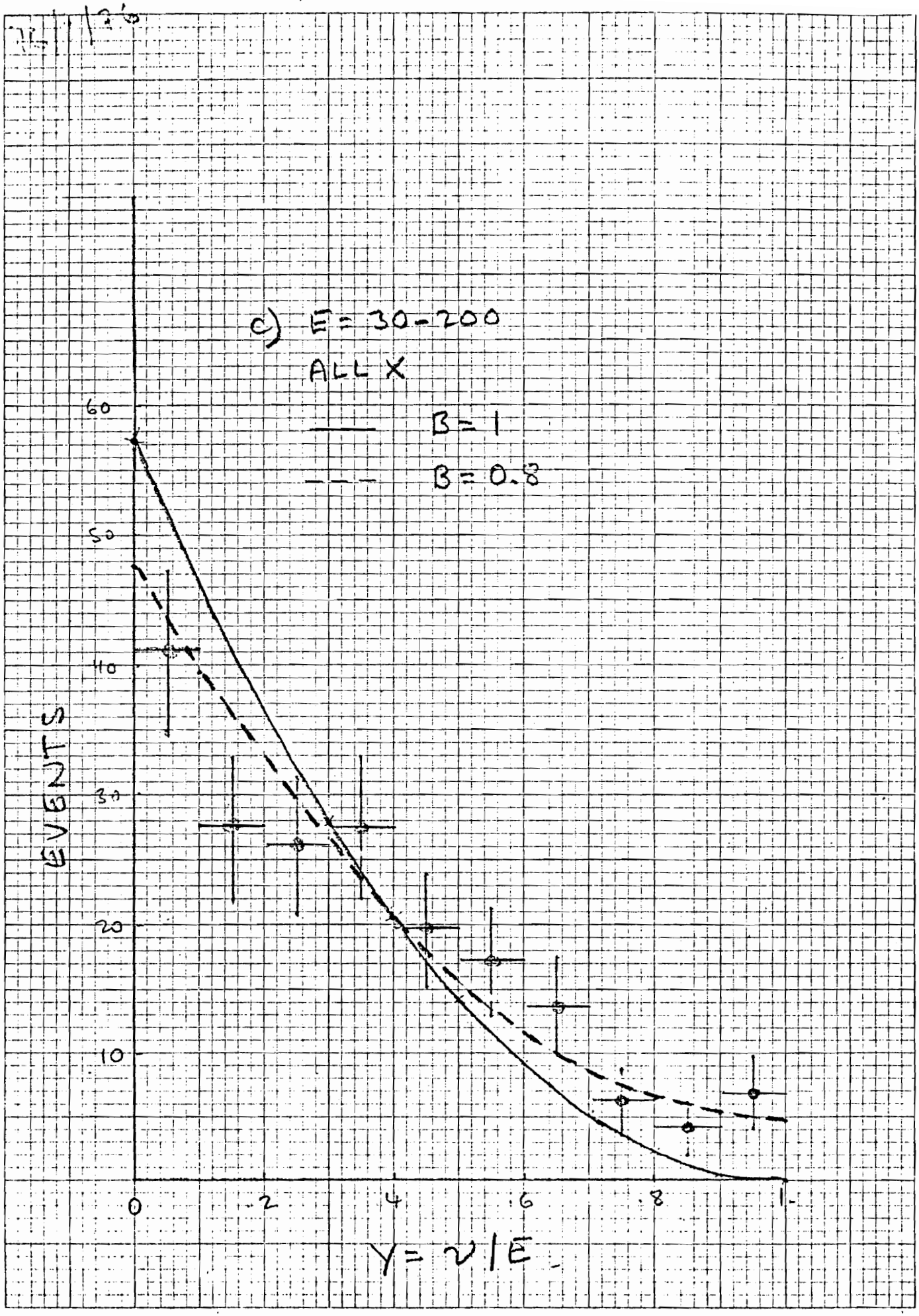

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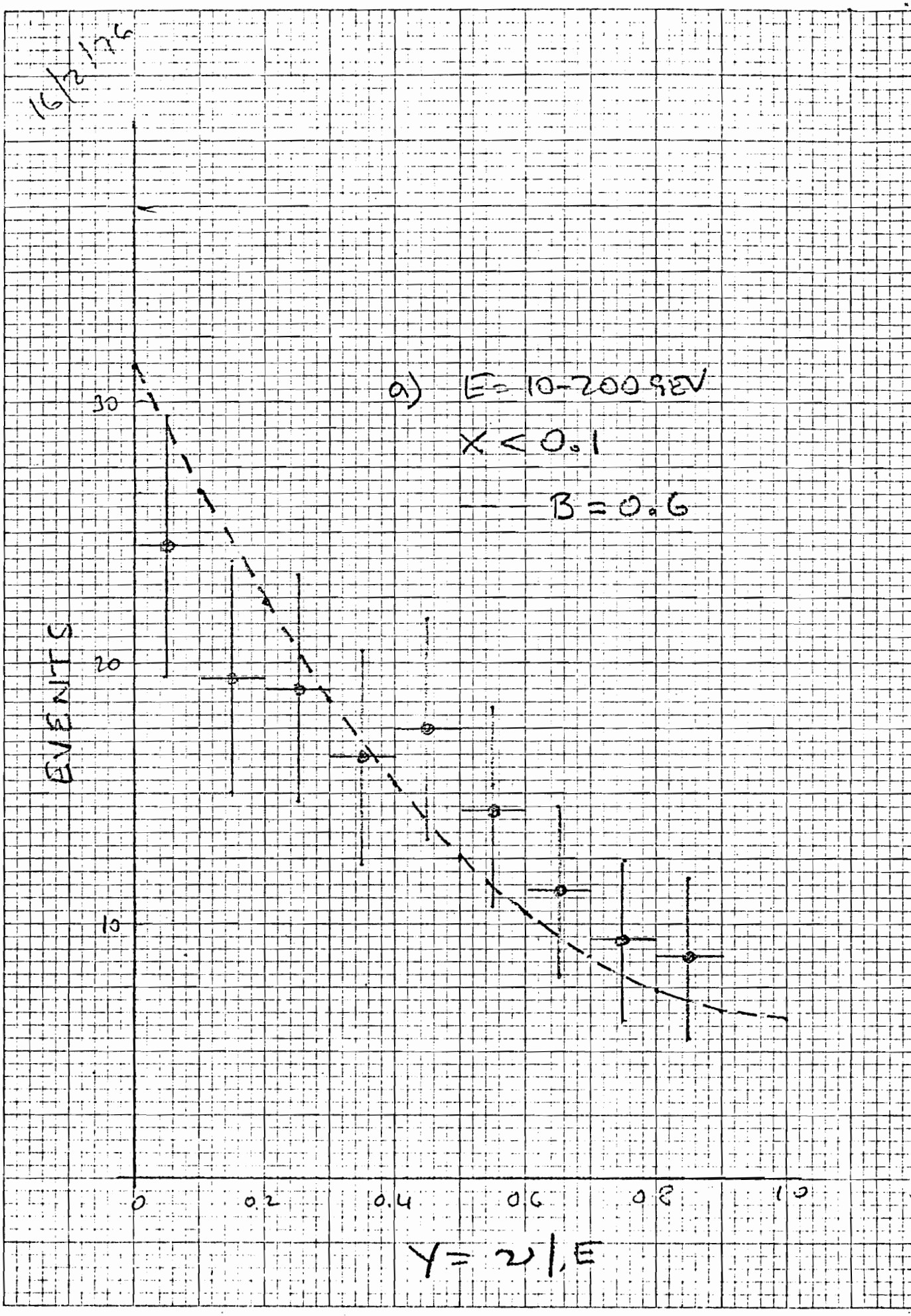

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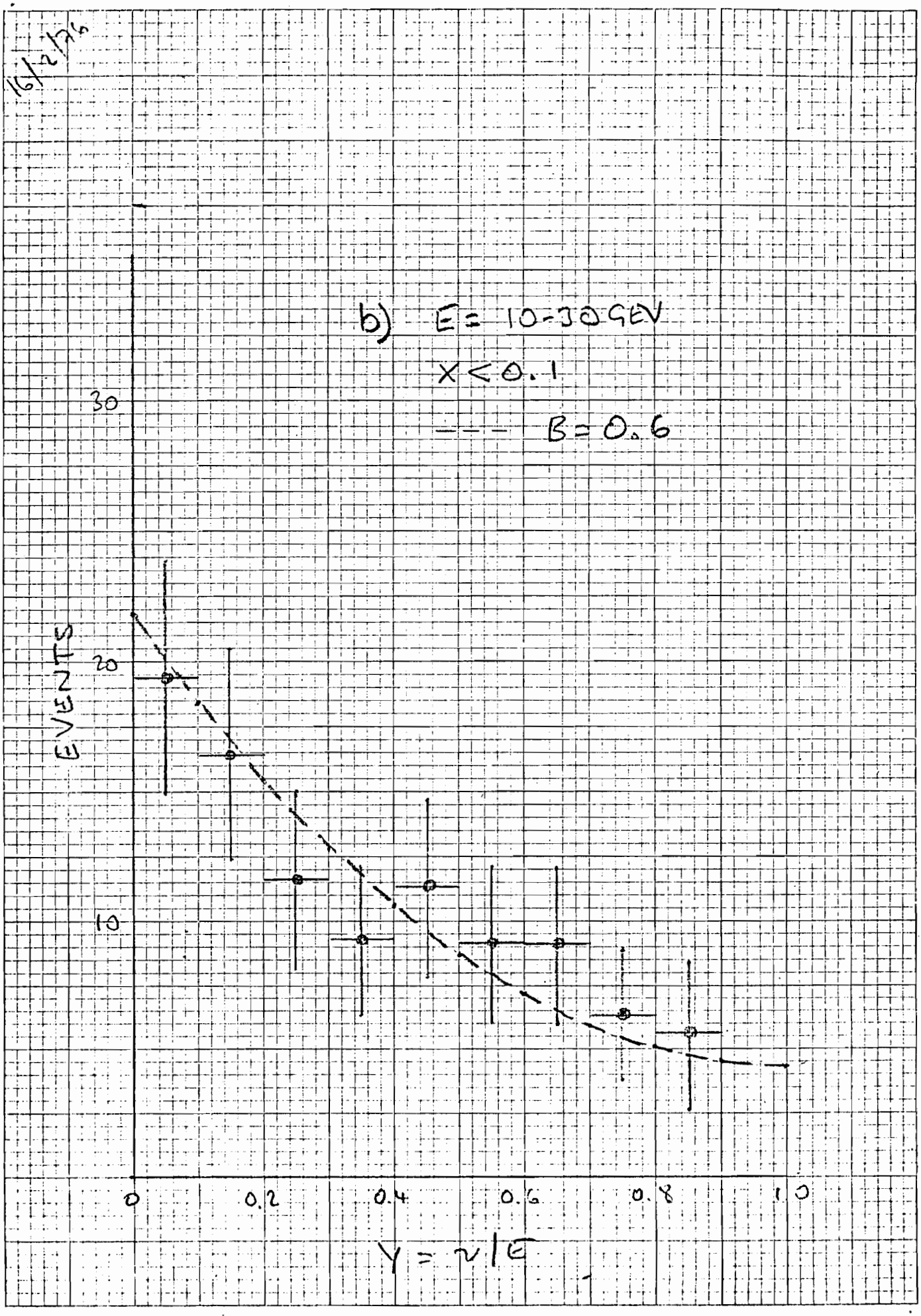

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