NOTAS DE FÍSICA

VOLUME IX

Nº 9

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CENTRO BRASILEIRO DE PESQUISAS FÍSICAS

Av. Wenceslau Braz, 71

RIO DE JANEIRO

1962

Notas de Física - Volume IX - Nº 9

THE $Li^7(p, \alpha)\alpha$ REACTION *

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(Received April 9, 1962)

ABSTRACT: The $Li^7(p,\alpha)\alpha$ reaction has been studied up to 4.8 MeV proton energy. The angular distribution has been fitted to a polynomial of the form $C(1 + A(E)\cos^2\theta + B(E)\cos^4\theta)$. The coefficients A(E) and B(E) show enormous variation above 4.0 MeV proton energy. The results are discussed in terms of levels in Be^8. The results indicate the presence of direct interaction.

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* To appear in Nuclear Physics.

** On leave of absence at the C. E. N. Saclay.

1. Introduction.

The $Li^7(p, \alpha)\alpha$ reaction has been extensively studied up to about 3.5 MeV of incident proton energy[1]. The angular distribution up to this energy has beeen fitted to a polynomial of the form $C(1 + A(E) \cos^2\theta + B(E) \cos^4\theta)$. The coefficients A(E) and B(E) are functions of incident proton energy. The coefficient A(E) shows a maximum at around 1 MeV proton energy, while B(E) is fairly constant and small over a considerable energy region. The total cross section shows a broad resonance at proton energy of 3 MeV with a total laboratory width of about 1 MeV. On the assumption two interfering levels one with $J = 2^+$ corresponding to the observed resonance in the total yield curve and another with $J = 0^+$ and a width much larger than the experimental energy range, Inglis was able to obtain a reasonable fit to the variation of A(E) and B(E) with energy. The resonance parameters in this calculation were used as arbitrary parameters whose values were determined from the data. Unfortunately the fluctuations in the experimental points do not permit one to assign unique values to these parameters.

Recently measurements using polarized protons have been performed in this energy region[3]. Though there seems to be some disagreement between the two authors, these measurements tend to indicate that the original assumptions of Inglis may not be valid and that the assumption of two $J = 2^+$ levels, as proposed by Christy[4], are needed to explain the experimental data.

The experiment was undertaken to extend the data for this reaction to higher energies in order to check the validity of the above assumptions as well as to obtain the resonance parameters of the states in question if possible. It is interesting to study this reaction near the 21.6 MeV state in Be which is very close to the $He^5 + He^3$ and $Li^5 + H^3$ thresholds. Also it would be of interest to see if at the higher energies the reaction goes partially through direct interaction.

2. Experimental Technique.

The reaction was studied up to 3.5 MeV using the Rice University Van de Graaff and up to 4.8 MeV using the machine at Saclay.

The Rice experiments were done with a natural lithium target of about 20 $\mu g/cm^2$ deposited on 50 $\mu g/cm^2$ carbon backing. The excitation curves at eight angles were obtained using solid state counters as detectors of alpha particles. The target deterioration was checked after each excitation curve and was found to be less than 5%.

The target used in the Saclay experiments was about 10 to 15 $\mu g/cm^2$ deposited on carbon foils about 10 $\mu g/cm^2$ thick. The angular distribution at each energy was studied from 90° to 170° using a solid state detector. It is not necessary to measure in the forward angles also, since for unpolarized protons the reaction is symmetric about 90°. This symmetry was checked at the lowest energy used in this experiment. A solid state detector at 90° was used as monitor.

3. Results.

The excitation curves up to 3.5 MeV for various angles used in the Rice experiments are shown in fig. 1. The angular distributions obtained in the experiments performed at Saclay normalized to unit monitor reading are shown in figs. 2 and 3. The solid curves in these figures represent least squares fitting to the polynomial $C(1 + A \cos^2\theta + B \cos^4\theta)$. The coefficients A and B as functions of energy obtained from the above data are plotted in fig. 4. In figs. 5 and 6 we compare the value of these coefficients with those obtained by earlier works. The solid lines in these figures are just smooth curves drawn through the points.

The total cross-section curve as shown in fig. 7 was obtained as follows. In the Rice experiments we integrated our angular distribution to obtain the yield curve. In the Saclay experiments we integrated the angular distribution normalized to unit monitor and multiplied this with the average monitor reading for the particular energy. Since this depends on the stability of the monitor readings, in fig. 8 we show typical curves of monitor readings taken at each energy. These curves show that the monitor was stable within the experimental errors which includes errors due to current integrator. The total error was estimated to be around 5%. It is also seen that these is no appreciable target deterioration. Since the Saclay and Rice experiments overlap in energies it was possible to normalize these two data and it was found that in the region of overlap there was very good agreement. The absolute cross section was obtained by normalizing our curves to the value obtained by Freeman et al.[5] at 1.47 MeV and that quoted by

Burcham et al.[6] at 2.02 MeV. The excitation curve is shown in fig. 7 where we have also plotted the values obtained by Heydenburg et al.[1] after normalizing it at 2.02 MeV. The errors in the total cross-section curve include also the errors quoted in the above references for the energies at which the curves were normalized.

4. Discussion.

As can be seen fron figs. 2 to 6, the absolute values of the coefficients A(E) and B(E) increase enormously above 4 MeV. Within our errors we see no resonance in this region. This result cannot be reconciled with the assumption of a 2^+ and 0^+ state in Be^8.

The $\cos^4\theta$ term seems to indicate the presence of more than one 2^+ state in this region. It is possible that there is a large contribution from direct interaction. One can see an anomaly developing in the angular distribution around 150° with increase of energy above 3.8 MeV, this anomaly increasing with increasing energy. To obtain a good fit in this region one needs a large number of terms in the polynomial in $\cos^3\theta$. In fig. 9 we compare one such angular distribution with a $\cos^6\theta$ term also added. This may be due to the presence of direct interaction. The large variation in A(E) and B(E) might hence partly be due to interference between direct and compound nuclear contributions.

At 4.82 MeV proton energy we observe a large drop in the value of these coefficients. At this particular energy, our experimental errors may be larger than those shown, which are due to statistics and charge integration only. It would be very interesting to perform the experiment at higher energies to elucidate this point.

The absence of resonance in the (p, α) reaction around the 21.6 MeV state in Be^8 is not surprizing. This state was observed in $Li^7(p,n)Be^7$ reaction[7]. It would be reasonable to assume that the alpha reduced widths of even parity, even angular momentum states with T = 0 in Be^8 are very close to the Wigner limit and that these states would predominantly decay by alpha emission. Then any nucleon emitting state may not satisfy the above criterion for parity or angular momentum or isobaric spin, an hence would not show up in the $Li^7(p,\alpha)\alpha$ reaction. This does not exclude the possibility of alpha emitting states in the same region and the complexity of the angular distribution of the $Li^7(p,\alpha)\alpha$ reaction probably indicates the presence of such states near this energy region.

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Acknowledgements

Part of the above work was done when one of the authors (G. S.M.) spent a delightful year at the Rice University, Houston, Texas. He takes this opportunity to thank Dr. T. W. Bonner and Dr. G. C. Phillips for their hospitality and kindness. He also wishes to thank Dr. Cotton for his hospitality during his stay al Saclay. The authors wish to acknowledge the help provided by the members of the Computing Section at Saclay.

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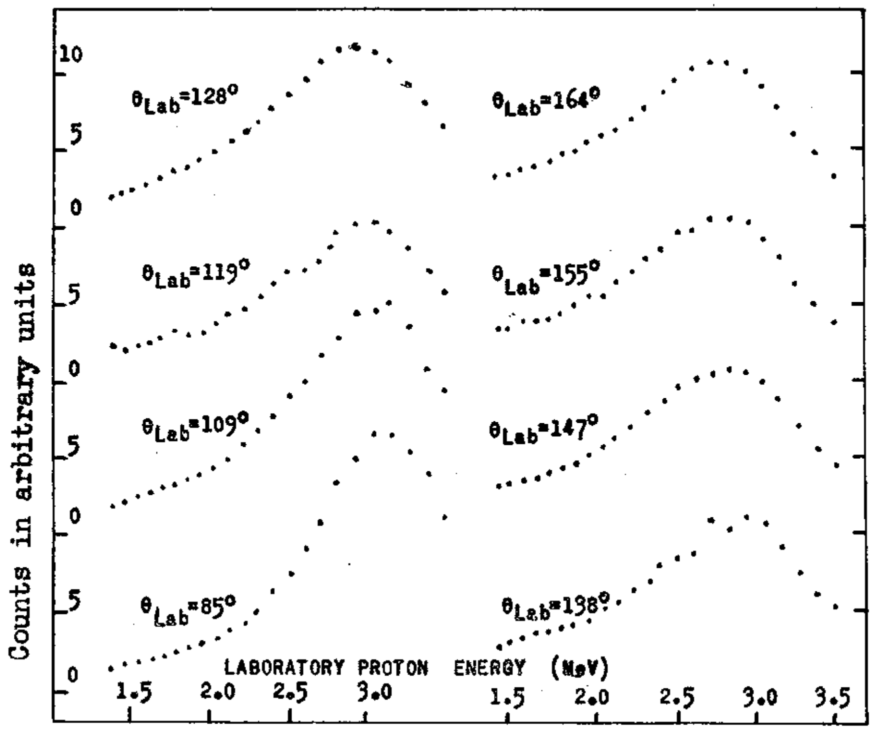

Fig. 1 - Excitation curves for the $Li^7(p, \alpha)\,\alpha$ reaction up to 3.5 MeV proton energy.

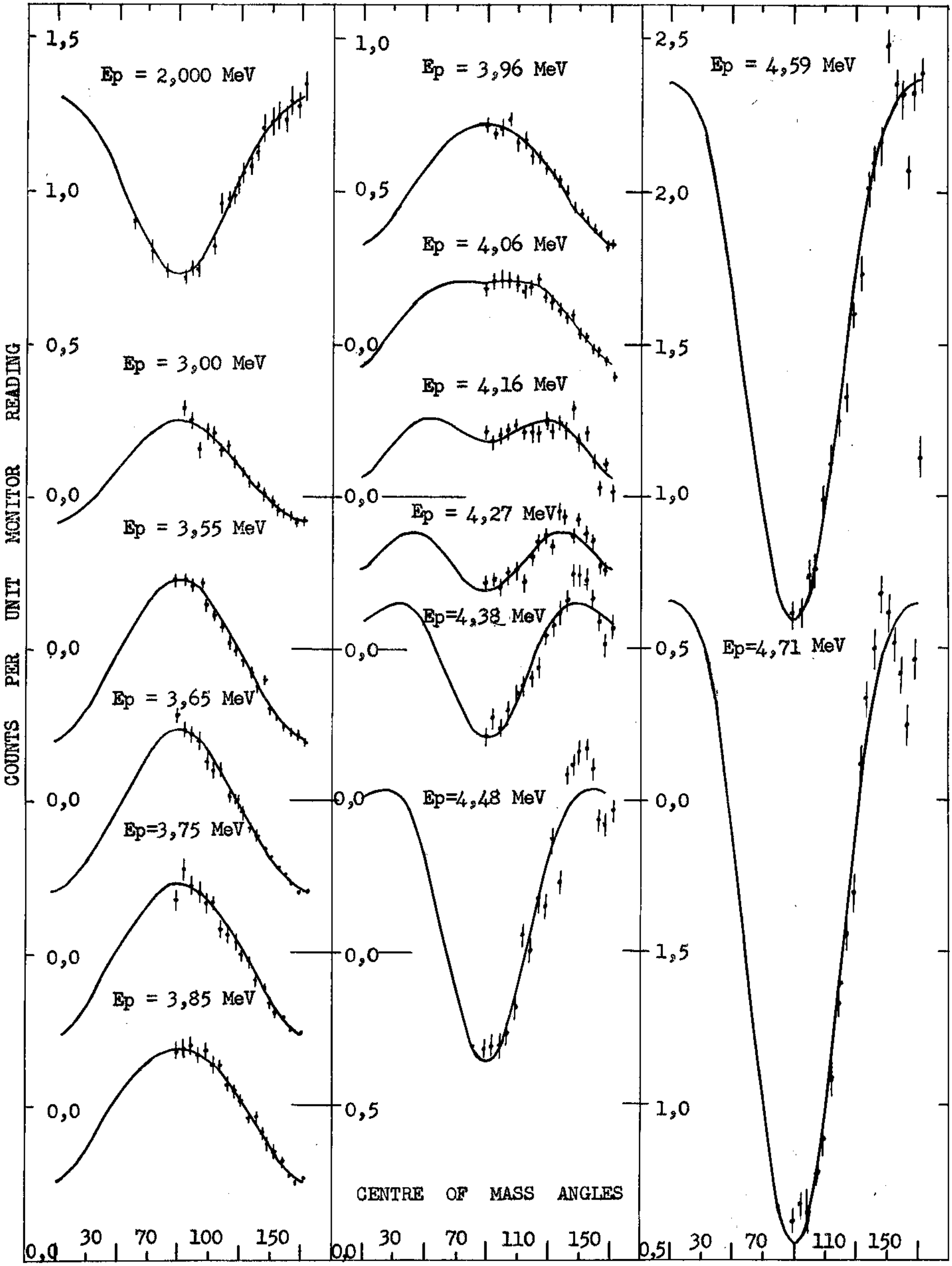

Fig. 2 - Angular distribution of α particles from the $Li^7(p,\alpha)\alpha$ reaction. The solid curves are least square fit to the polynomial $C(1 + A\cos^2\theta + B\cos^4\theta)$.

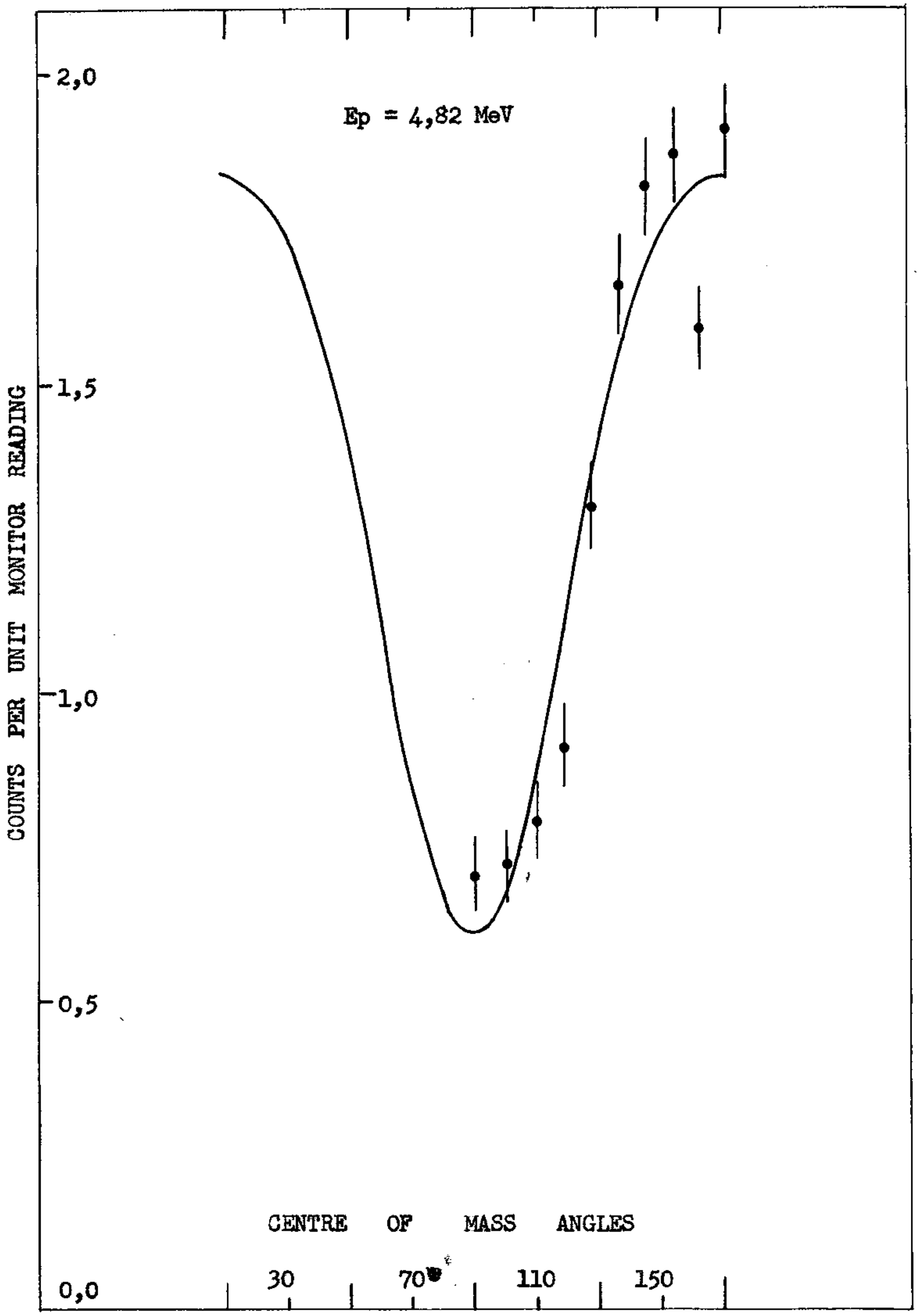

Fig. 3 - Angular distribution of α particles from the $Li^7(p,\alpha)\alpha$ reaction for Ep = 4,82 MeV. The solid curve is the least square fit to $C(1 + A\cos^2\theta + B\cos^4\theta)$.

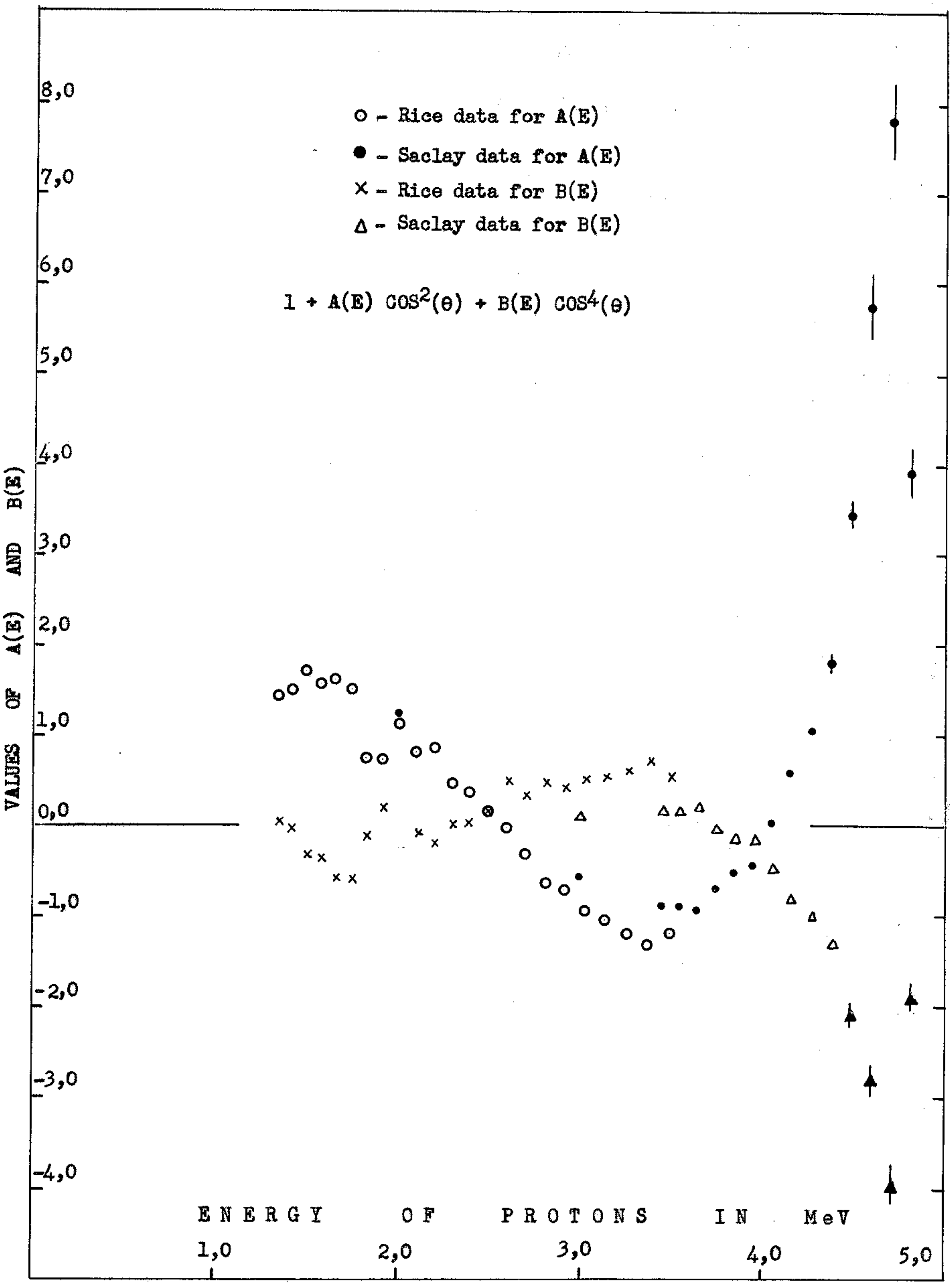

Fig. 4 - Variation of the coefficients A(E) and B(E) with incident proton energy.

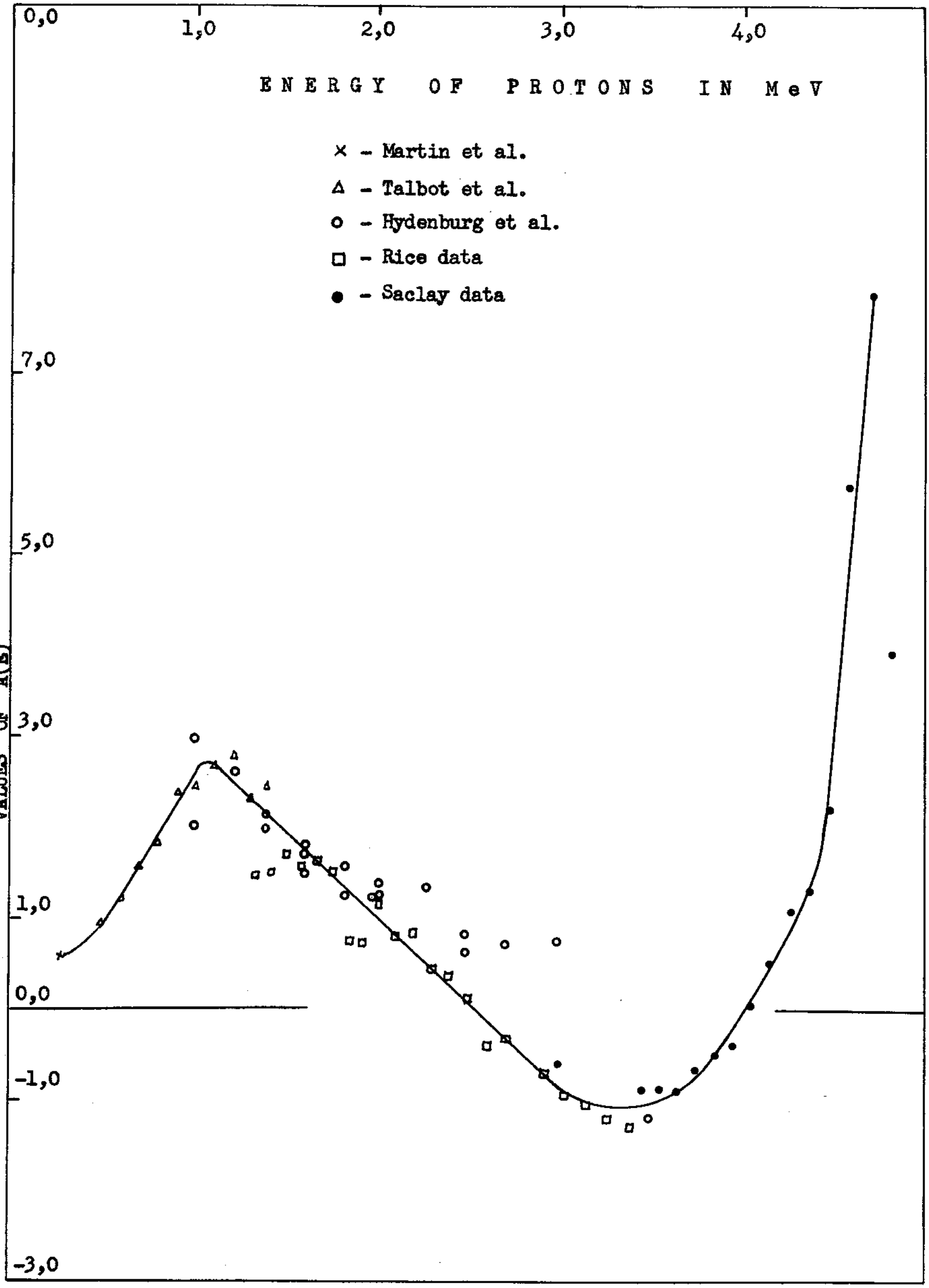

Fig. 5 - Comparison of the variation of A(E) with incident proton energy with the results of earlier workers.

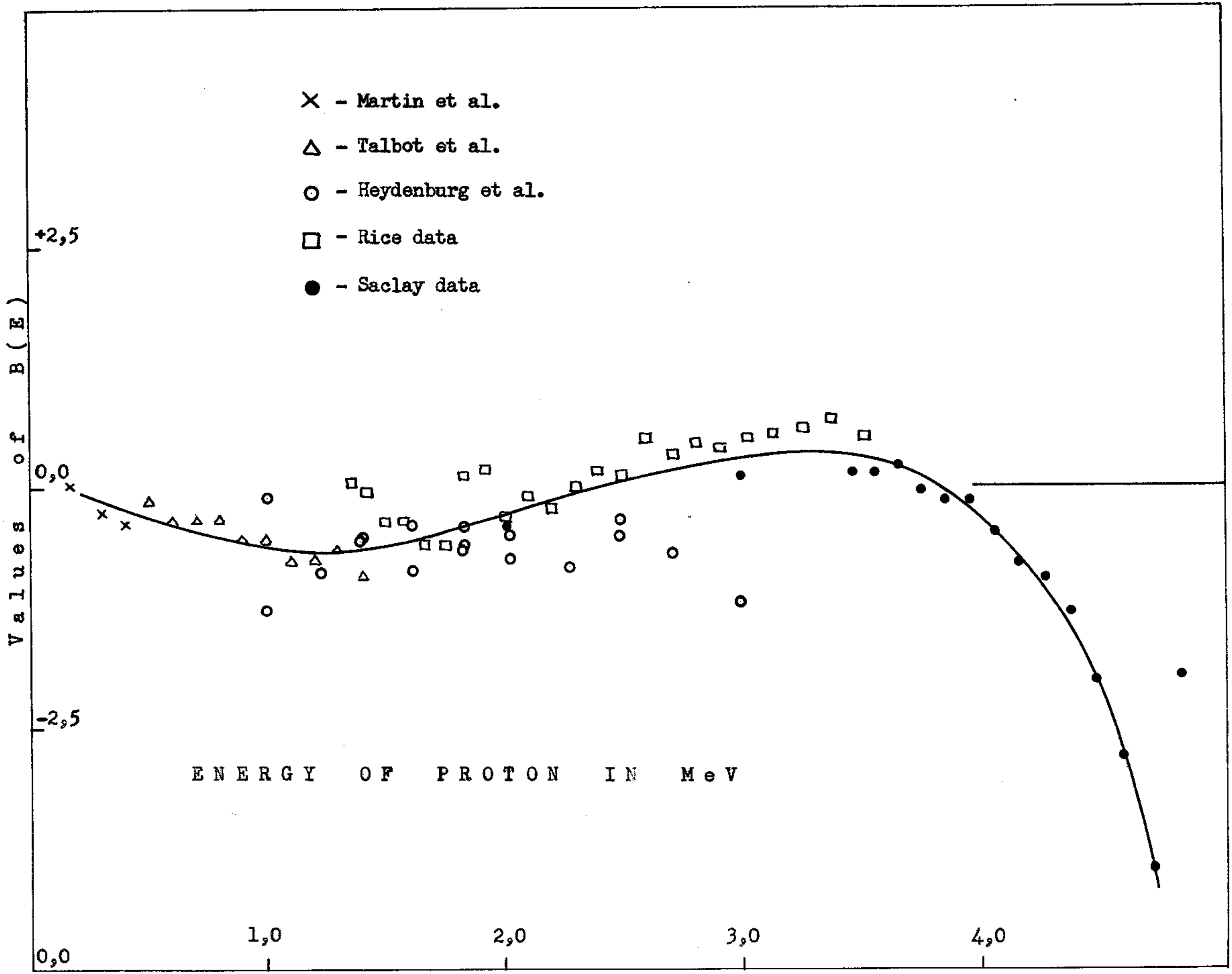

Fig. 6 - Comparison of the variation of B(E) with incident proton energy with the results of earlier workers.

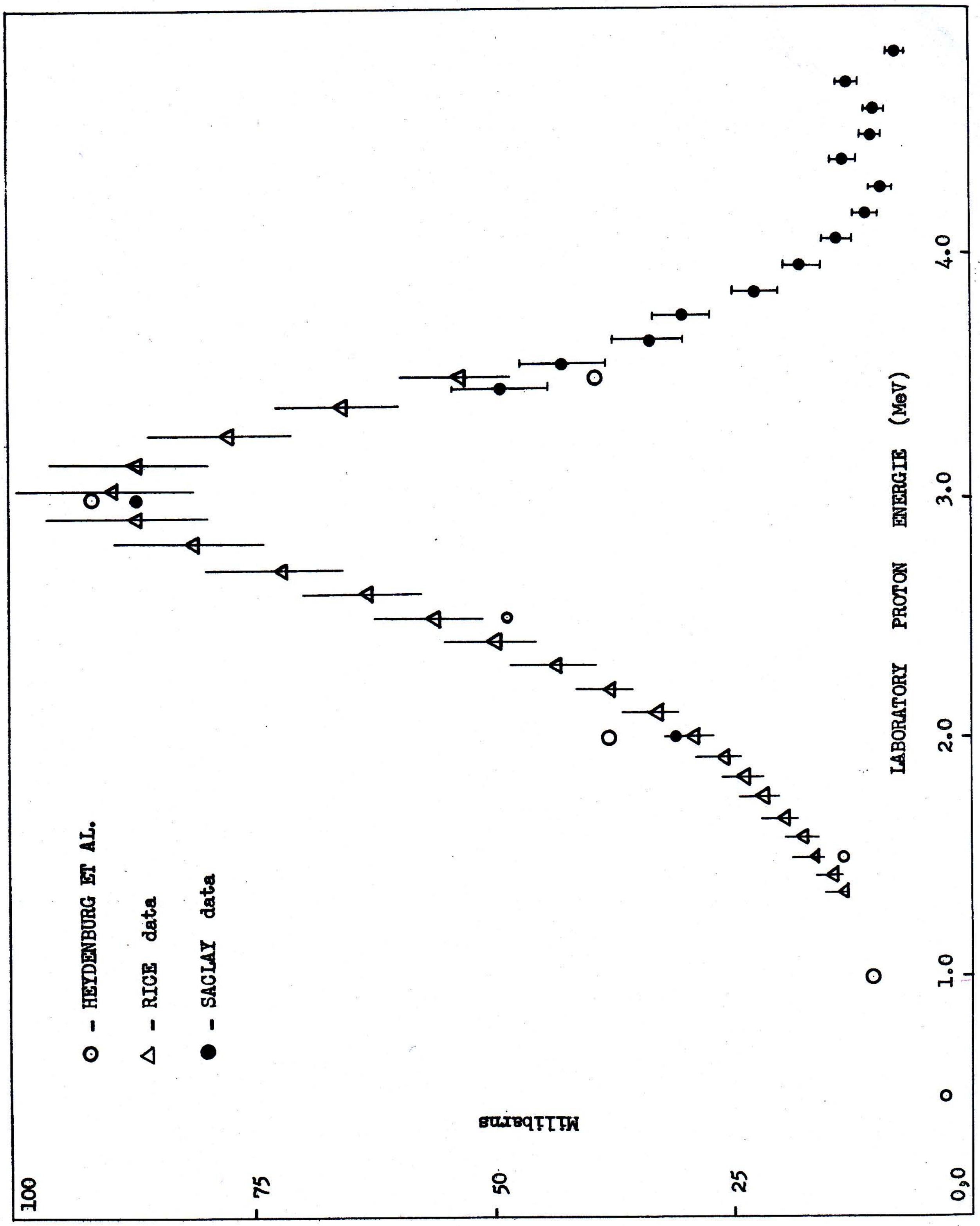

Fig. 7 - Total cross-section curve for $Li^7(p,\alpha)\alpha$ reaction.

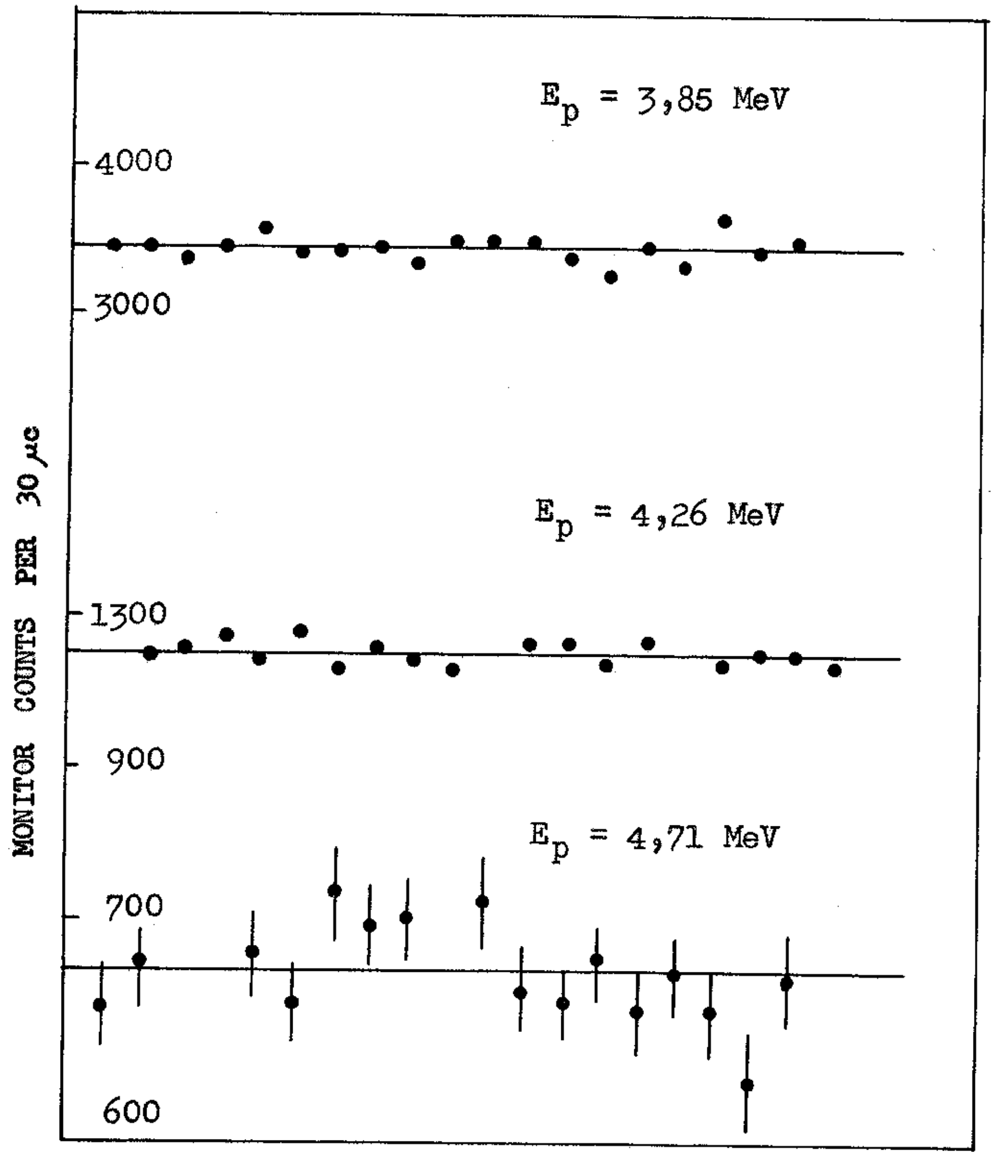

Fig. 8 - Monitor readings for the same angular distribution to show the stability of the monitor.

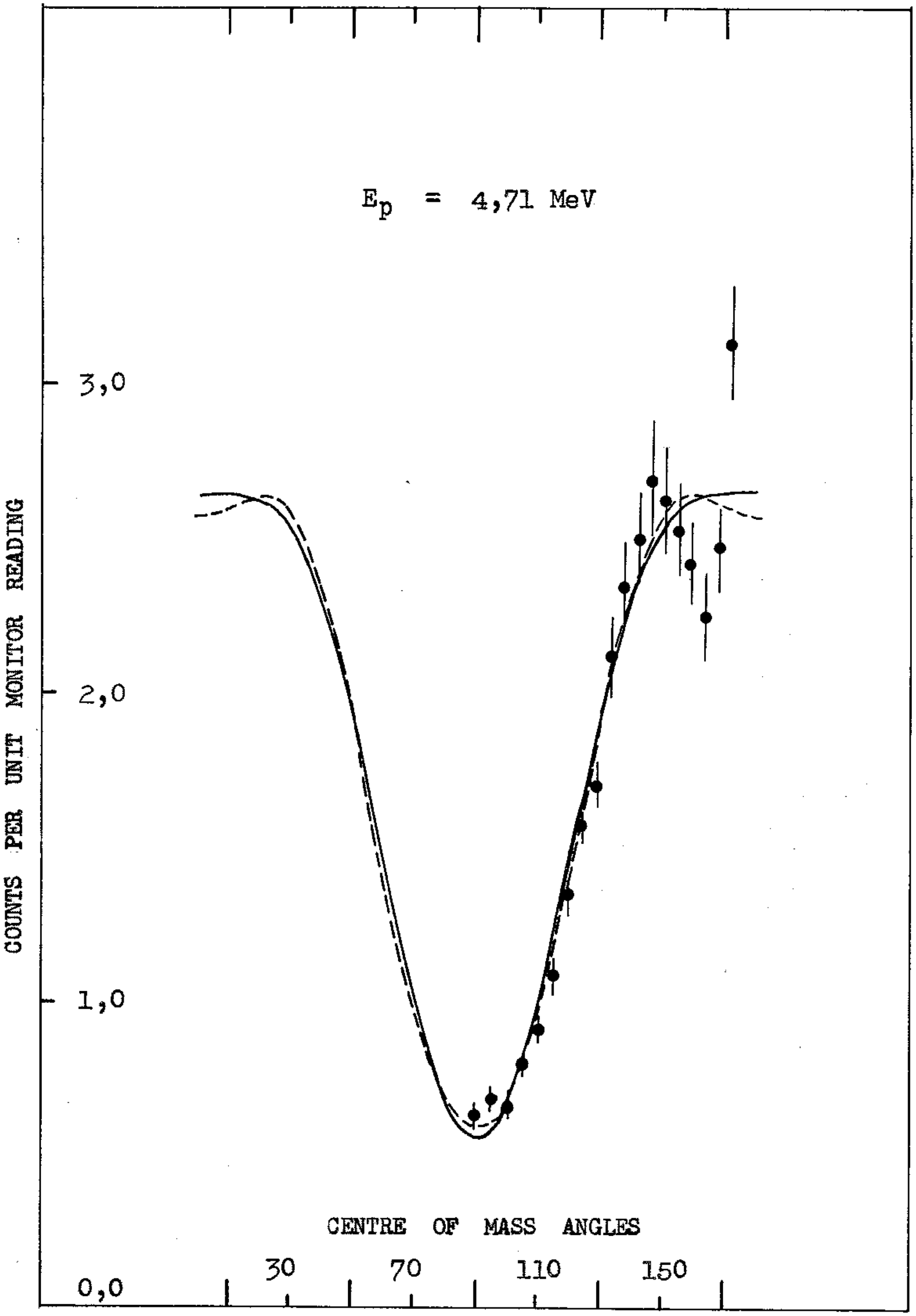

Fig. 9 - Comparison of the angular distribution at E_p = 4,71 MeV with least square fits of polynomials $C(1+A\cos^2\theta + B\cos^4\theta)$ and $C(1+A\cos^2\theta + B\cos^4\theta + D\cos^6\theta)$. Solid curve: polynomial up to $\cos^4\theta$. Dashed curve: polynomial up to $\cos^6\theta$.