CEBAF PROPOSAL COVER SHEET

This Proposal must be mailed to:

CEBAF
Scientific Director's Office
12000 Jefferson Avenue
Newport News, VA 23606

A. TITLE:

Identification of Structures in the $\Delta(1232)$ Resonance Region in ^{208}Pb

B. CONTACT PERSON:

ZEIN-EDDINE MEZIANI

ADDRESS, PHONE, AND ELECTRONIC MAIL ADDRESS:

DEPARTMENT OF PHYSICS, STANFORD UNIVERSITY

MEZIANI@SLACVM

C. IS THIS PROPOSAL BASED ON A PREVIOUSLY SUBMITTED LETTER OF INTENT?

[ ] YES [X] NO

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Exhibit 9: CEBAF Proposal Cover Sheet

A proposal to CEBAF for the

Identification of Possible Structures in the $\Delta(1232)$ Resonance Region for Heavy Nuclei

by

J. Gomez, J. Mougey, A. Saha, S. Nanda, P.E. Ulmer

Continuous Electron Beam Facility, Newport News, 23606 VA

J. Morgenstern

DAPNIA/SPN C.E.N Saclay, Gif-sur-Yvette F-91191 France

R. Gilman

Department of Physics, Rutgers University, Rutgers

R. M. Sealock, O.A. Rondon

Department of Physics, University of Virginia, Charlottesville 22901 VA

G. Petratos†

Stanford Linear Accelerator Center, Stanford 94309 CA

D. Kawall, Z. Meziani(*Spokesman*)

Department of Physics, Stanford University, Stanford 94305 CA

P. Souder

Department of Physics, Syracuse University, Syracuse

C.J. Martoff

Department of Physics, Temple University, Philadelphia

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Abstract

We propose investigating the apparent peak structure in the Δ resonance region in heavy nuclei (^{208}Pb). This experiment is proposed to primarily confirm or disprove the presence of structure which is suggested by existing data. If confirmed, this structure would be a challenge to the present theoretical understanding of the Δ-Nucleus dynamics.

1. Introduction

While electroproduction of the Δ resonance on the **nucleon** has been extensively studied during the last decade there has been a limited set of experiments[1-5] that explicitly studied the production of the Δ resonance in nuclei using an electron beam as a probe. The first systematic data of electroproduction of the Δ on nuclei using inclusive electron scattering were taken using the LUE-2000 accelerator[6] at the Ukrainian Academy of Sciences, followed by data taken at DESY on two light nuclei (^{6}Li and ^{12}C) providing quantitative information on the Δ production in nuclei. These studies were performed as part of the high energy physics program and were more a survey type of experiment. Nevertheless, in the first experiments by Titov, *et al.*, the important conclusion concerning A independence of the electroproduction cross section was already clearly stated. Quoting Titov, *et al.* "*the cross section per nucleon at the electroproduction maximum is the same within experimental errors for all nuclei and is close in absolute value to the cross section for the free nucleon.*" The data were also compared to early calculations of pion electroproduction using the Fermi gas model and assuming a zero width for the Δ resonance. At that time no complete calculation of the competing processes involved in the total cross section was presented. The analysis performed was a fitting procedure of the resonant cross section extracting parameters useful for phenomenological evaluations of the cross sections and future reference. No realistic calculations for electroproduction in nuclei were performed (for example, exchange current contributions to knock-out of two nucleon were not considered at all).

The interest in the Δ resonance arose again when the electromagnetic probe facilities of nuclear physics reached higher energies allowing the excitation energies to reach the Δ resonance region. The effort focussed on the study of changes of the resonance properties due to the nuclear medium. Experimentally, it translates into a study of the change in the natural width and position of the Δ resonance in the nucleus compared to the free one. Questions were addressed not only to understand the Δ-nucleus interaction, but also to look for modifications of the intrinsic electromagnetic properties of the Δ in the nuclear medium. While few data were available in this very initial study, many models began to be developed to understand quantitatively the electroproduction data in the Δ resonance region. Different approaches were developed by various authors.

Laget's model[8] as can be seen in Fig. 1 relies on the calculation of the reaction mechanism in the nucleus as a quasifree process, involving basically a convolution between the momentum distribution of the nucleons in the nucleus with the elementary cross section of pion electroproduction using the Blomqvist and Laget operator[9] including the non-resonant terms known as the Born terms in addition to the Δ contribution. Exchange current contributions were included through the quasi-deuteron model, however the calculation does not include the final state interaction, of the Δ with the recoil nucleus, and of the nucleon and pion.

A second model[10] known as the Δ-hole model was developed, where special care was taken for evaluating medium effects on the Δ such as Pauli blocking of the Δ decay and the damping through ΔN→NN. Nevertheless, the Born terms had to be put explicitely in this model. Fig. 2 shows the comparison of this model to the data in the case of light nuclei. As shown no structure is expected to emerge in this model.

In a third model, developed by Huber and Klingenbeck,[11] the Δ electroexcitation in nuclei is described using the eigenmodes of the corresponding many baryon system. This model was put forward as a realistic approach to explain the strength excess found in the so called dip region in inelastic electron scattering. The ΔN dynamics beyond a quasifree picture is emphasized in this approach.

The first two theoretical calculations reproduce fairly well the magnitude of the data at the top of the resonance region; nevertheless, there are no indications in either model that possible structures in the shape of the cross section would emerge from any specific process. However, in the last model[11], there is a possibility of a giant resonance like reaction in the intermediate state and it is clearly stated that angular dependence is important in the selection of different multipole contributions to the multipole expansion of the scattering matrix. Although no calculations were performed over the full Δ region at large scattering angles we speculate that this model could predict the existence of oscillations in the inclusive cross section spectrum over the Δ region.

Finally we mention that a theoretical investigation of the production of the Δ in bound state orbits of a mean potential was performed by Do Dang[12] . This investigation was aimed at explaining the excess strength in the dip region. We show in Fig. 3 the relative contribution of the direct process and the bound states process for different mean field potential seen by the Δ resonance after it is created. It is clear in this model, due to the special Δ-bound- state contribution in the dip region a bump would appear on the total cross section.

2. Motivation

In the sample of data taken during the last five years at several electron accelerator laboratories, it is interesting to notice that the data on heavy nuclei loose their smooth excitation energy dependence as the momentum transfer increases. This is shown in Fig. 4. For example, a close inspection of the data set of reference 5 reveals several statistically significant "glitches". While uncontrolled systematic errors were suspected they were never confirmed by any change in detector or beam characteristic It appears from the available data that at some momentum transfer a different process is emerging above the process known as the direct mechanism of Δ production and subsequent decay. Although a strong signature is not yet clear, as not enough high precision data are available, we are still left with the strong suspicion that either the most convincing experimental data are wrong or that it is a real phenomenon of the Δ-nucleus system that is not yet understood.

Since there is no clear understanding of what the mechanism could be we can only, at the present time, offer a phenomenological criteria of the kinematical region where the structure is most likely to emerge from the well known "background" processes. At this stage our guess for the kinematics where these structures are enhanced is summarized below:

- The existing data suggests that it is most likely that the structure will emerge from the "background" if the relative magnitude of the cross section in the the quasielastic region is equal or smaller than that of the Δ region cross section. In this case the "background" is the direct $\pi - N$ decay of the Δ resonance in the nucleus combined with the non-resonant electroproduction of pions. In fact, this criteria goes well with the angular dependence of the cross section of the Δ resonance compared to that of the quasielastic process.

- We do not expect to see any structure at low momentum transfer, that is around 0.1 $(\mathrm{GeV/c})^2$. In this region, the mechanism responsible for the observed structure is weak and the main channel that provides the strength in the Δ region is the Δ formation and decay through the $\pi - N$ channel. At this transfer the quasielastic cross section is typically three times larger than the Δ cross section.

3. Experiment

From the experimental point of view, our main concerns in this measurement are related to the elimination all possible sources of background that would give rise to a spurious structure in the data. We wish to confirm or disprove the existence of structure in the Δ region in heavy nuclei. The experiment is a standard inclusive experiment where we want to concentrate especially on the Δ resonance region. Very high statistics is needed for this measurement (of the order of 1%) and good energy resolution is necessary (we shall bin the data by 5 MeV in excitation energy). Our goal is to be able to already see the structure early in online analysis, since we are not concerned with the absolute value of the cross section but rather with its relative value across the excitation energy of the Δ region. It is also true that performing the radiative correction on the data will only improve the ratio of "signal"(meaning the structure) over "background" (meaning the direct Δ process strength).

The common problem in looking for new structures is to eliminate all possible sources of errors due to the detection method. We want to ensure that these structures are reproducible, and that they are not related to inefficiencies of the detector. For example, inefficient wires in a proportional chamber that is located at the momentum focal plane of any spectrometer could give rise to structures in the the energy excitation spectrum of the cross section. The method of measurement proposed is as follows.

We propose to make a measurement of the inclusive cross section across the quasielastic and the Δ resonance region on ^{208}Pb. The measurement will be performed at one incident energy 1.6 GeV and three angles 20°, 37.5° and 55°. The angle change allows us to vary the momentum transfer from 0.1 to 0.4 $(\mathrm{GeV/c})^2$ and fullfil the phenomenological criteria expressed above namely changing the ratio in the magnitude of the quasielastic peak compared to that of the Δ peak. The choice of the incident energy is dictated by the limitation in the scattered electron energy acceptable in this experiment. An experimental criterion for keeping low energy background electrons away from detection is to restrict the scattered electron energy to be greater than one third of the incident energy.

The resolution of the HRS spectrometer will be adequate for binning the data by 5 MeV in excitation energy. The energy resolution will help us to identify the presence of a reasonably narrow structure. To avoid spurious detector effect, the data at each angle in the Δ region will be taken at three overlaping spectrometer momentum settings allowing us any possible structure unambiguously.

We will take data using two different openings of the solid angle of the spectrometer. In the first case we can allow the full acceptance of the HRS. In the second case we'll take a solid angle half as large. The two measurements will inform us of the presence of unwanted background (for example scattering on the poles of the spectrometer).

It is important to choose as thin a target as possible to minimize the external radiative effect due to the target on the incident and scattered electrons since if there is a resonant behavior it will be smoothed out when the radiation effects are convoluted with cross section. This is easily done since the cross sections are reasonably large. The radiative correction unfolding procedure would requires cross sections measurements at even lower incident energies, therefore we plan to use a model to evaluate the cross sections.

In the case of a null result we intend to have a draft paper complete by the end of the data taking session. Apositive result will lead to a proposal to study the A and Q^2 dependence of the phenomenon.

4. Rates and Beam Time request

We have used the cross section measurement of reference[5] to estimate the rates assuming the parameters listed in Table 2. The average cross section is about 400pb/MeV/sr/Nucleon at 15° scattering angle and 60pb/MeV/sr/Nucleon at 35°. For our target choice (^{208}Pb), the smallest rate occurs at large angle and is of the order of 1 count/sec in a bin of 5 MeV or 18 counts/sec over the full momentum acceptance. We are aiming at a 1% statistical uncertainty in a 5 MeV bin this translates into 2.7 hours of data taking for each momentum setting.

Given the momentum acceptance of the HRS (10%), we will take five momentum settings per angle including the overlap measurements.

It will take 10 hours on average to acquire a full spectrum at each incident energy and angle. The last angle mesaurement will be repreated with a smaller solid angle to test the background that could be generated inside the spectrometer due to pole face scattering for particles at the edge of the beam envelope. Hence for 3 angles, and repeating the measurement at 35° with two solid angles we'll need three days (72 hours)including 25% contingency.

Table 1. Kinematics for the experiment

E_i = 1.6 (GeV)	Binding energy = 0.045 (GeV)		
$\theta(deg)$	15	25	35
ω_{qe} (GeV)	0.088	0.220	0.377
ω_{Δ} (GeV)	0.408	0.513	0.636
e_{qe} (GeV)	1.512	1.3795	1.223
e_{Δ} (GeV)	1.192	1.087	0.9363
Q^2_{qe} $(GeV/c)^2$	0.164	0.414	0.708
Q^2_{Δ} $(GeV/c)^2$	0.130	0.325	0.542

Table 1 . Experiment parameters

Summary for Experiment Parameters	
Incident beam Energy	1.6 GeV
Scattering angles	20°,37.5°,55°
Average beam current	20. μA
HRS solid angle	8.,4. msr
HRS momentum Acceptance	10.%
Target thickness	50mg/cm^2= 8.310^{-3} r.l.
Time needed + contingency	72 hours

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FIGURE CAPTIONS

1. Inclusive electron scattering cross section on ^{40}Ca, ^{48}Ca and ^{56}Fe at incident energy of 695 MeV/c and scattering angle 60°. The different curves are Laget's calculation of quasielastic contribution (dash-dotted line), two body emission through the quasideuteron model (dotted line), and the quasifree pion electroproduction (dashed line); the solid line is the total

2. Δ-hole model applied to the evaluation of the electroproduction cross section in nuclei reference[10]. The solid line is the full calculation , the long dashed line correspond to the calculation with H_Δ only which in the nuclear matter limit correspond to a Fermi gas calculation, short dashes decribe the sum of single nucleon cross section

3. Contributions of the Δ-quasi-elastic (solid curves) and the Δ-bound-state (dashed curves) processes for an inclusive (e,e') reaction. see reference 12 for details

4. ^{208}Pb inclusive cross section at 600 MeV incident energy and 35°,60°,75° scattering angles

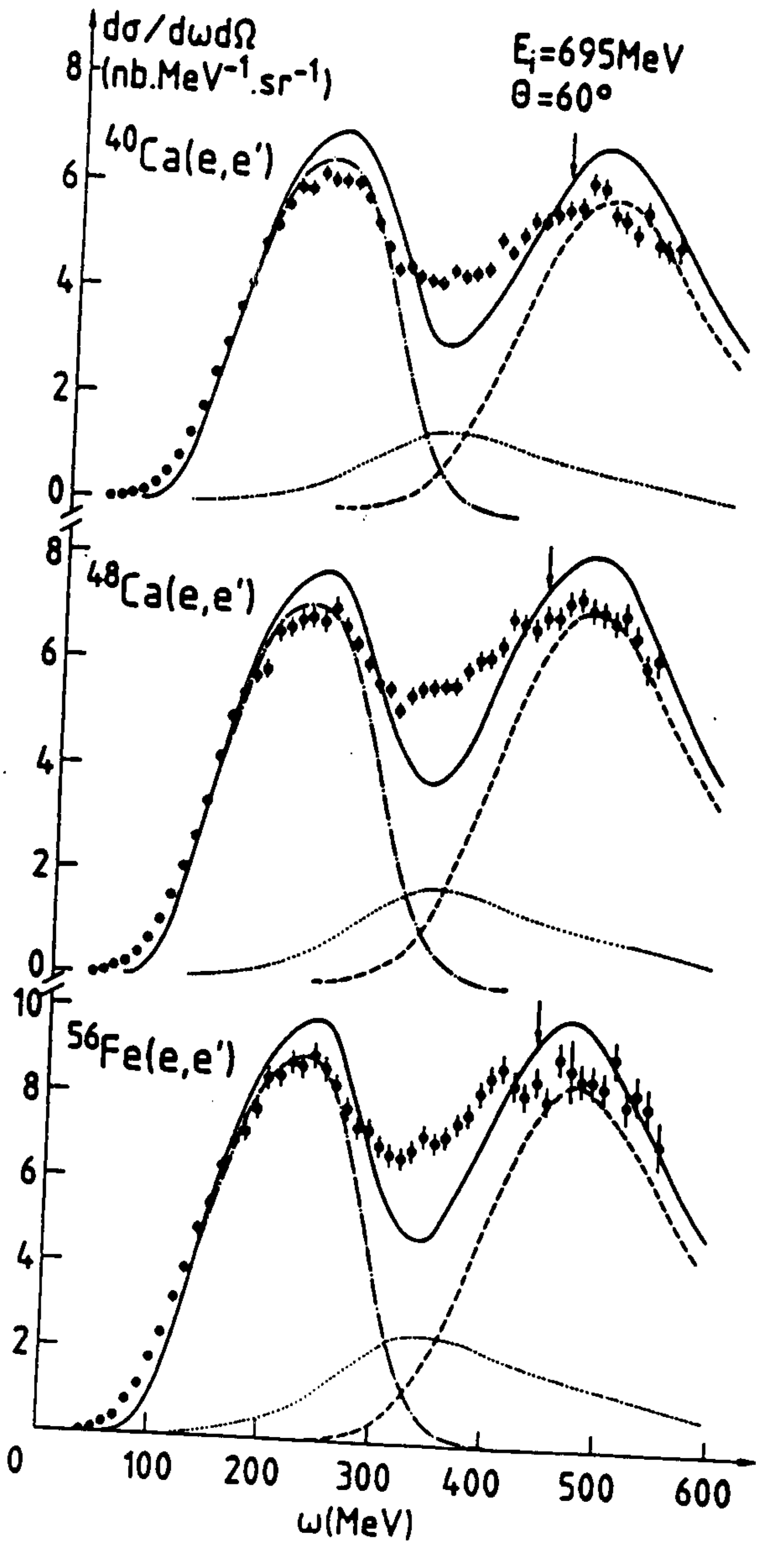
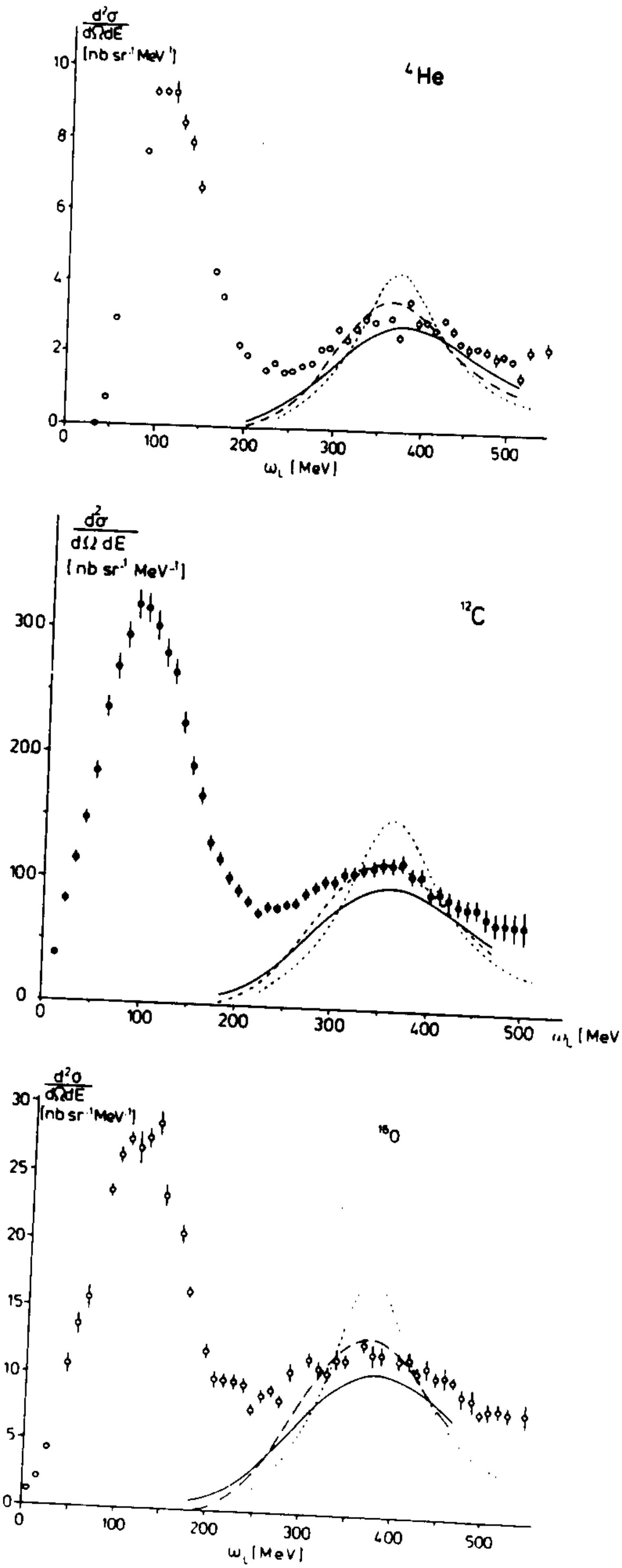

dσ/dωdΩ
(nb.MeV-1.sr-1)
Ei=695MeV
θ=60°
40Ca(e,e')
48Ca(e,e')
56Fe(e,e')
8
6
4
2
0
8
6
4
2
0
10
8
6
4
2
0
100
200
300
400
500
600
ω(MeV)

FIGURE 1.

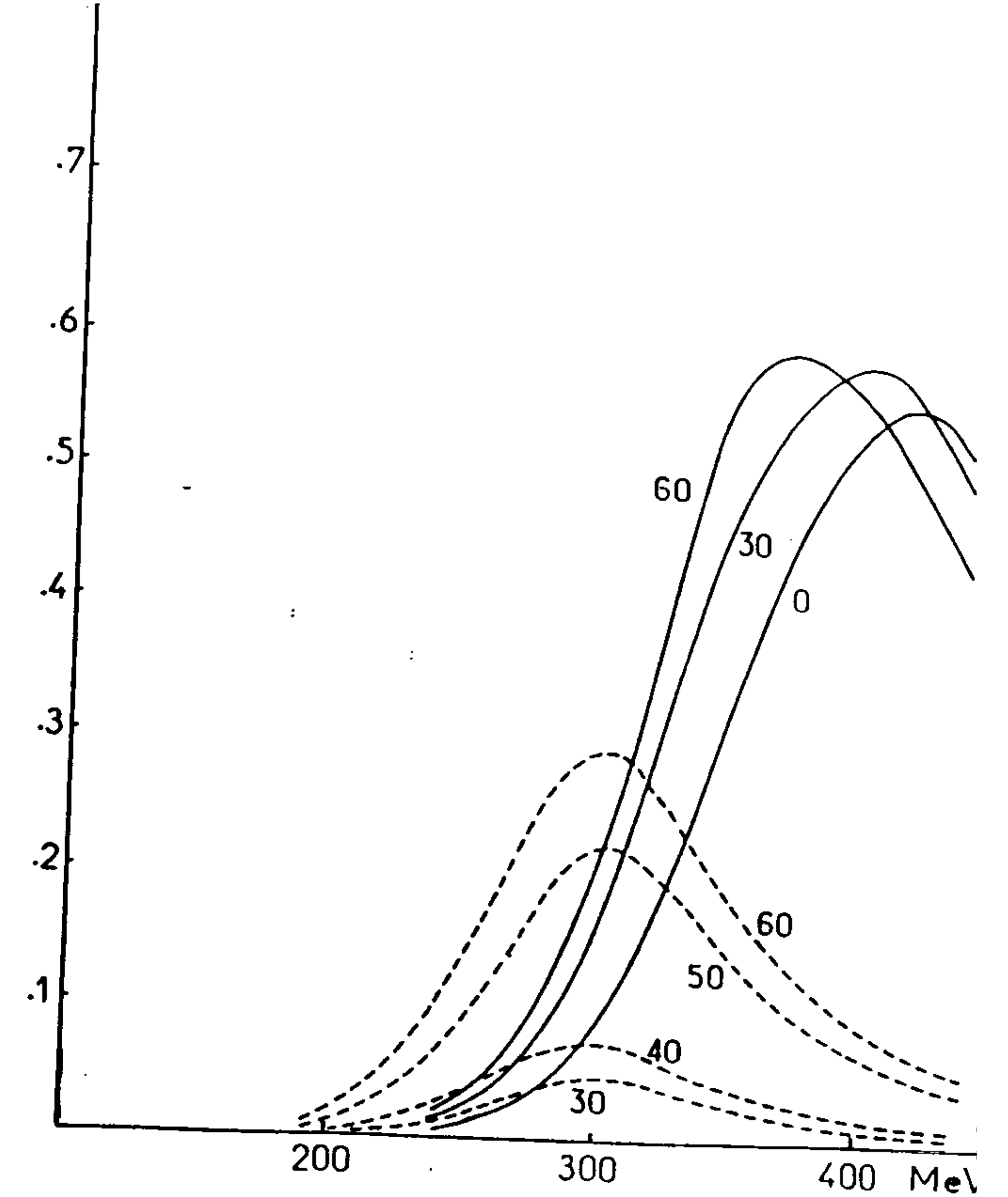


d²σ/dΩdE [nb sr⁻¹ MeV⁻¹]
⁴He
ω_L [MeV]
d²σ/dΩ dE [nb sr⁻¹ MeV⁻¹]
¹²C
ω_L [MeV]
d²σ/dΩdE [nb sr⁻¹ MeV⁻¹]
¹⁶O
ω_L [MeV]

FIGURE 2

30	0 1	-14.04 -3.03
40	0 1	-21.77 -8.57
50	0 0 1 2	-29.86 -1.74 -14.93 -.65
60	0 0 1 2	-38.19 -5.70 -21.82 -5.47

FIGURE 3.



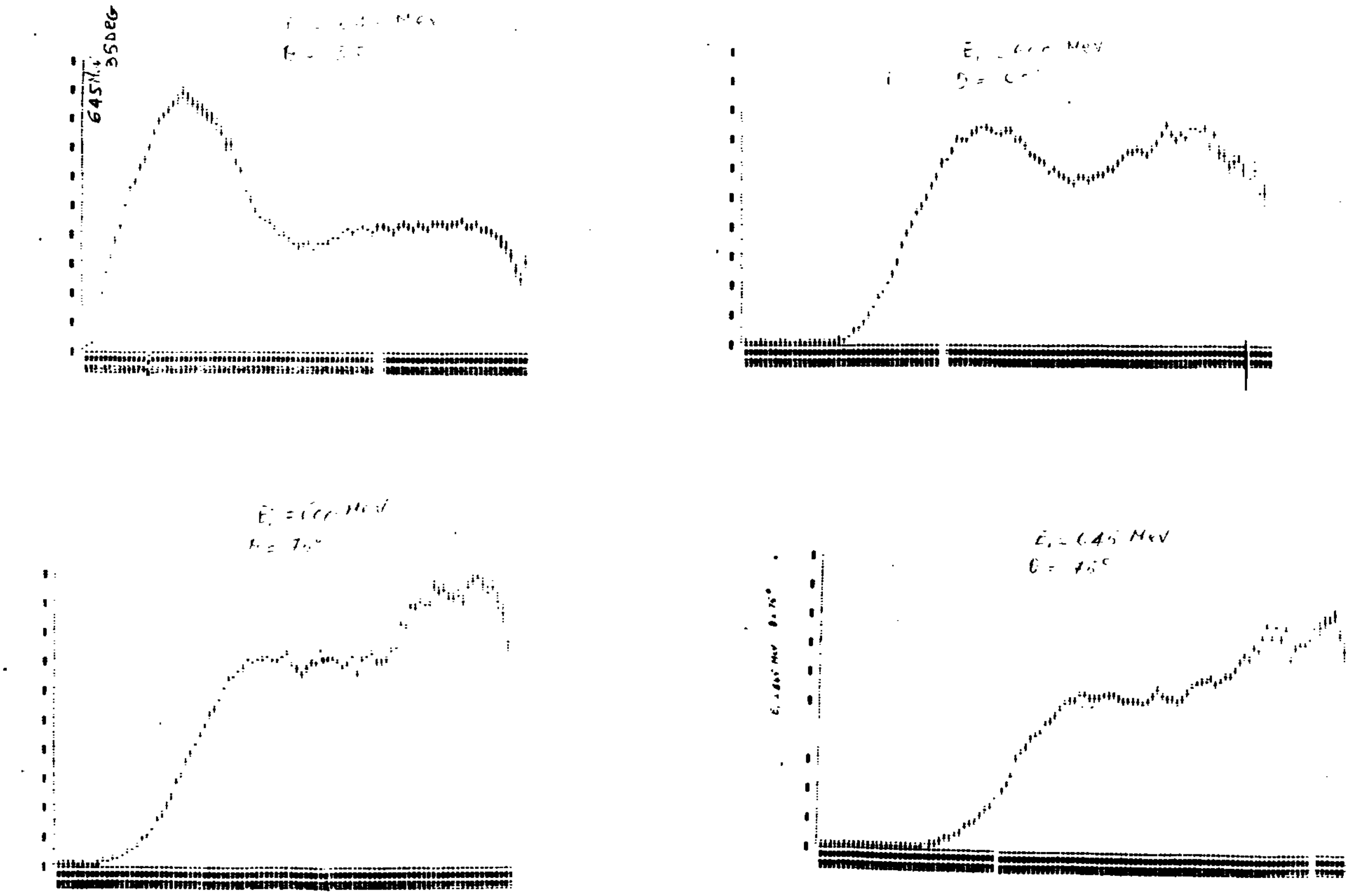


FIGURE 4.