INDC(IND)-10/G

B.A.R.C.-459

B.A.R.C.-459

'सत्यमेव जयते'

GOVERNMENT OF INDIA
ATOMIC ENERGY COMMISSION

VAN DE GRAAFF LABORATORY PROGRESS REPORT

Compiled by

T. P. David
Nuclear Physics Division

BHABHA ATOMIC RESEARCH CENTRE
BOMBAY, INDIA
1970

B.A.R.C.-459

B.A.R.C.-459

GOVERNMENT OF INDIA
ATOMIC ENERGY COMMISSION

VAN DE GRAAFF LABORATORY PROGRESS REPORT

Compiled by

T. P. David

Nuclear Physics Division

BHABHA ATOMIC RESEARCH CENTRE

BOMBAY, INDIA

1970

CONTENTS

INTRODUCTION

This report summarises the operation and utilization of the 5.5 MeV Van de Graaff Accelerator at Trombay during the period 1st July 1968 to 31st December 1969. The accelerator was available for research from February 1962 and has now completed 8 years of operation. From the end of 1964 it has been working on a round-the-clock 7 day week schedule.

Towards the end of 1968 it became increasingly clear that smooth operation of the machine at higher energies would not be possible without replacement of the accelerating tube which had developed cracks on a large number of glass sections. The accelerator was shut down for major maintenance work in April 1969 and the accelerating tube was replaced. A 5-port beam switching magnet which was fabricated in the laboratory was installed. Other major maintenance work completed during this period are detailed in the report.

After the reassembly of the accelerator in June 1969 the machine was calibrated and stable operation of the machine was achieved up to the rated energy of 5.5 MeV. The machine operation efficiency has improved considerably after the overhaul.

Brief accounts of research work carried out with the accelerator during the period under review are summarised in this report.

ACCELERATOR OPERATION

I. Analysis of machine operation

1) July 1968 - March 1969

   Machine operated for - 3600 hrs.

   Research utilisation - 2780 hrs.

2) April 1969 - May 1969

   The accelerator was used for major maintenance work:

   Installation of the new accelerating tube

   Installation of a 5-port switching magnet

3) June 1969 - September 1969

The machine was conditioned to 5.5 MeV and alignment and testing of 5 port switching magnet was carried out. Installation of beam extension tubes with quadrupole focusing lenses, vacuum systems, and beam deflectors was completed. The shaft of the bottom belt drive pulley was remetalled and machined during this period and new bearings were fitted. The accelerator was operated for a total of 1280 hours during this period. The accerlator was used for 48 hours for research experiments.

4) October 1969 - December 1969

   Machine operation 1667 hrs.

   Research utilisation 1434 hrs.

II. Major work done during the April-May'69 shut down period:

1) Accelerator support column

All 12 support column sections were dismantled. It was noticed that the glass mounting blocks and the locating stud plates fixed to the top and bottom of the column sections had shifted from the original positions. This caused a tilt, observed earlier, over the entire support column. One of the sections had also developed a crack on a metal weld and was replaced by a new column section.

Each column section was dismantled and the glass mounting blocks and stud plates were refixed with vinyl in the proper positions with the help of special jigs fabricated for the purpose. The column sections were then reassembled with shims wherever necessary to ensure horizontal and vertical alignment during the assembly of the column sections.

2) Accelerating and differential pumping tubes

Both the sections of the new accelerating tube were coupled and installed in position. The differential pumping tube was cleaned and installed. Three glass sections of the differential tube were found to have developed large cracks and have been electrically shorted along with the corresponding sections on the accelerating tube to avoid further damage. The tube heads were then mounted and coupled and the focusing electrode was aligned.

3) Column resistors

All the column resistors were removed and tested. These were graded as per their measured values and installed in the column assembly.

4) Charging Belt

The charging belt was replaced as the old one was worn out.

5) Corona assembly

Recurrent trouble from the corona assembly due to rusting and consequent loss of insulation was stopped by nickel plating the mounting plate.

6) Beam tubes

All extension tubes, gate valves, control and beam limiting slits and the analysing chamber were removed, cleaned, tested and reassembled.

7) Belt drive

The coupling and drive shaft of the belt drive pulley was found to have worn out. The shaft has been re-metalled, machined and fitted with new bearings. The coupling blocks were fitted with new bushings as was found necessary. The pulley was fixed back, coupled and aligned with the drive motor.

8) Miscellaneous accelerator components

All other components such as column springs, control drive system, terminal assembly, charging system, gas supply system and units in the control console were cleaned and tested.

9) Gas Compressor

This unit developed a leak through the shaft while in operation. The shaft rings were removed, ground and fitted back.

10) Gas Dryer

The preheater and heaters embedded in the adsorber drums had been a frequent source of trouble. Nichrome heater wire has been wound on formers fabricated in the laboratory and fitted in place of the original heaters. These have since been giving satisfactory service.

11) 90° Beam Analysing Magnet

The water cooling tubes soldered on to either side of the coil formers had developed leaks at a number of places. The coils were removed along with the pole pieces. The coil former plates were removed and the water cooling tubes were replaced by new copper tubes. The coils were then taped afresh and installed in position. The beam analysing chamber was vacuum tested and installed in the pole gap. Tube extensions were then connected up and the magnet was levelled and aligned.

III. Ion Source

Ion sources used with the accelerator are fabricated in the laboratory as has been reported earlier[1]. Such source assemblies have been in use since 1965. Sources, using a modified design for the canals are in use since April 1968, and are giving very satisfactory service. It should be mentioned here that one such ion source assembly has given a record

1) Van de Graaff Laboratory Progress Report T.P. David AEET-254 (1966)6.

service of 2532 hours.

Components for a versatile ion source test bench to enable a comprehensive study of the laboratory assembled ion sources are under fabrication. A suitable focusing system and bending magnet assembly have been incorporated in this set up so that a mass analysis of the total beam output from the source bottle can also be carried out.

IV. Five-Port Beam Switching Magnet

The five port beam switching magnet constructed in this laboratory earlier[1)] with beam ports at -45°, -25°, 0, +25° and +45° was installed along with its associated power supplies and controls in May 1969. All the beam ports have been provided with current stabilizer slits and are connected through a selector switch to the auxiliary coil supply. Two 2" diffusion pumps have been installed on the switching chamber section. Quadrupole focusing lenses[2)] have been provided in all beam ports. These have been found to be extremely useful for focusing the beam on to targets which are generally 6 to 8 meters away from the accelerator control slits. The magnet has been in use since the experiments started on the various ports.

The performance of the magnet has been very satisfactory and the magnet power supply has been found to be very stable. The feed back control system using the insulated beam defining

---

1) Van de Graaff Laboratory Progress Report - T.P. David BARC-364 (1968)7

2) Van de Graaff Laboratory Progress Report - T.P. David AEET-214 (1965)8.

slits in conjunction with the auxiliary coil and power supply has been very useful and has eliminated the need to adjust the switching magnet current frequently during the course of an experiment. A schematic diagram of the experimental set up after the installation of the 5-port beam switching magnet is shown in Fig.1.

RESEARCH EXPERIMENTS

1. Spacing of Class II Levels in the Fission on ^{240}Pu - D.K. Sood and N. Sarma - A modified correlation analysis of high resolution fission cross sections is suggested which would yield more reliable estimates of the spacing, $\bar{D}_{II}$ of the class II levels. Subsequent analysis of the reaction $^{239}Pu(n,f)$ gives the value of $\bar{D}_{II}$ as 225 $\pm$ 25 eV for the nucleus ^{240}Pu.

Published in Phys. Lett. 30B (1969)523.

2. Analysis of the $^{6}Li(p,pd)^{4}He$ Reaction - A. K. Jain, N. Sarma and B. Banerjee* - A fully antisymmetrised cluster-model wave function for ^{6}Li is used for calculating the matrix element of the reaction $^{6}Li(p,pd)^{4}He$. The calculations are carried out in plane-wave impulse approximation and the effect of the various terms arising from antisymmetrisation is discussed.

Published in Il Nuovo Cimento Vol. LXII B, N.2.(1969).

3. Distorted wave Analysis of Deuteron Knockout From ^{6}Li - A. K. Jain, N. Sarma and B. Banerjee* - The $^{6}Li(p,pd)^{4}He$ reaction has been analysed using the cluster model for ^{6}Li. The antisymmetrisation of the target wave function and the

---

* Tata Institute of Fundamental Research, Bombay

distortion of the incident and outgoing waves have been included. It is shown that the intercluster wave function given by the usual cluster models is inadequate and must be modified to have the correct asymptotic behaviour to reproduce the experimental p-d angular correlation. The inclusion of distortions is shown to be essential for obtaining the correct value of the differential cross section.

To be published in Nucl. Phys.

4. <u>Study of the Low-Lying Levels of ^{27}Mg by Angular Correlation Measurements in the Reaction ^{26}Mg(d, pγ)^{27}Mg</u> - M. A. Eswaran, M. Ismail and N.L. Ragoowansi - Proton-gamma ray angular correlation measurements have been made in the reaction ^{26}Mg(d,pγ)^{27}Mg using a deuteron beam from the accelerator. The protons from the reaction were detected in a semiconductor annular detector with its axis at 180° to the beam and the gamma rays, in coincidence with the selected groups of protons, were detected in a 12.7 cm dia. x 15.2 cm long NaI(Tl) scintillation detector at seven angles between 0° and 90° in steps of 15°. Such angular correlation data were recorded using a fast-slow coincidence arrangement of resolving time 2τ = 50 ns in conjunction with one 20 channel and one 400 channel pulse-height analyser.

Angular correlation data have been obtained corresponding to proton groups feeding the 0.984, 1.69 and 1.94 MeV excited states in ^{27}Mg and the de-excitation gamma rays, from these states. The data have been analysed by writing a computer programme SIMCOR for the CDC-3600 computer using an analysis procedure which is independent of any assumption regarding reaction mechanism. From this analysis spin assignments of 3/2, 5/2 and 5/2 have been made for the 0.984, 1.69 and 1.94 MeV levels. The multipole mixing ratios of the transitions 1.94 ⟶ 0.984 MeV and 1.69 ⟶ 0 MeV have been determined as well as the branching ratios of the levels at 1.69 and 1.94 MeV.

Published in the 'Physical Review Vol.185(1969)1458.

5. Isobaric Analogue States in ^{73}As - M. G. Betigeri, C. M. Lamba, D. K. Sood, N. S. Thampi and N. Sarma - States have been observed in the compound nucleus ^{73}As through the study of elastic scattering of protons on ^{72}Ge which are the isobaric analogues of the first five low lying levels of ^{73}Ge. Two of these being 1 = 4 transitions are not observed in the present study because of the low barrier transmission. l-values have been assigned to the states from analysis of the differential cross sections. The results are compared with available evidence from other experiments on ^{73}Ge.

Published in Nucl. Phys. A 133 (1969)465.

6. <u>Measurement of the Total $^{48}Ca(p,n)^{48}Sc$ Reaction Cross Section Around the Isobaric Analog States A E_p = 1.976 MeV</u> - K. K. Sekharan and M. K. Mehta - The total (p,n) cross section for the reaction $^{48}Ca(p,n)^{48}Sc$ has been measured using a calibrated 4π neutron counter in the bombarding energy range 1.90 to 2.05 MeV. The cross section was measured in steps of 0.6 KeV, the overall resolution being 1.8 KeV for 2 MeV protons. The results are shown in the accompanying figure 2.

These resonances represent the splitting of the known isobaric analog of the ground state of ^{49}Ca[1,2,3]. The resonances numbered 1-7 were also observed by G.Chilosi et al[4] in the $^{48}Ca(p,n)^{48}Sc$ experiment. The resonance energies in the present work agree with their values within ± 2 KeV.

The total widths, Γ of resonances numbered 3, 4 and 5 have been determined. Because of the limitations imposed by the 1.8 KeV resolution only upper limits could be fixed for the other resonances. The proton partial widths, Γ_p and the neutron partial width Γ_n for these resonances were calculated from the maximum cross section, σ_{max} at the resonances and the total widths using the Breit - Wigner single level expression. The probable error in the cross sections is ± 15% mainly due to the error in the efficiency (12%) of the 4π neutron counter and the error in the target thickness measurement (8%). The accompanying table lists the relevant quantities determined in this experiment.

C.M. E_{res} $\pm$ 2 KeV	C.M. σ_{max} $\pm$ 15%	J^{π} (ref.3)	Γ KeV	Γ_p KeV	Γ_n KeV
1.910	30	$(3/2^-)$	1	-	-
1.920	55	$3/2^-$	1	1	-
1.925	91	$(3/2^-)$	2.5$\pm$.6	2.41$\pm$.8	.09
1.936	93	$3/2^-$	3.4$\pm$.6	3.28$\pm$.8	.12
1.944	42	$(3/2^-)$	2.4$\pm$.6	2.36$\pm$.7	.04
1.952	26	$(3/2^-)$	1	--	-
1.957	12		1	-	-
1.971	28		1	1	-

The maximum cross section for the resonances 3 and 4 are 91 $\pm$ 14 mb respectively, while the corresponding values reported by Chilosi et al are 60 $\pm$ 16 and 50 $\pm$ 8 mb. The resonances numbered 8, 9 and 10 are also not observed in the previous work. The higher cross sections and the presence of the extra resonances may be due to the fact that in this experiment the total neutron yield has been measured while in the previous experiment the yield of only the 780 KeV γ-rays, which accompany the emission of neutrons leading to the fifth excited state at 1402 KeV in ^{48}Sc was measured. The error on the partial widths in this experiment vary from 23% to 29%, the error on the total width Γ, being the major contribution. If identification is made between the resonances 3, 4 and 5 with the resnonances at 1964 ± 2, 1975 ± 2 and 1982 ± 2 KeV observed by Vingiani et al in the $^{48}Ca(p,p)^{48}Ca$ experiment, the total widths, as well as partial widths Γ_p have large disagreement. The resonance at E_p = 1.982 MeV has been reported to be a combination of two resonances by Willijelm et al[3]. The agreement between the experimental data obtained by this group and the present work is good. The difference in the proton partial widths may be due to the use of single level formula in the present work.

The spectroscopic factor for the resonance 4 can be calculated from the expression $S_{pp} = (2T_o + 1) \; (\Gamma'_p / \Gamma_{sp})$ where Γ_{sp} is the theoretical single proton width evaluated by Jones et al. We get a value of $S_{pp} = 1.09 \pm 0.26$ which agrees within experimental error with the factor $S_{dp} = 1.03$ for the present level i.e. the ground state of ^{49}Ca determined from stripping experiment.

1) K. W. Jones, J.P. Schiffer, L.L. Lee,Jr., A. Marinov and J. L. Lerner, Phys. Rev. 145 (1966)984

2) G.B. Vingiani, G. Chilosi and W. Bruyrestayn, Phys. Letters 26B (1968)285

3) P. Wilhjelm,G.A. Keyworth, J.C. Browne, W.P. Beres, M. Divadeenam, H.W. Newson and E.G. Bilpuch Phys. Rev. 177 (1969)1553

4) G. Chilosi, R.A. Ricci and G.B. Vingiani Phys. Rev. Letters 20 (1968)159.

7. Total Cross-Section Measurement in the $^{37}Cl(p,n)^{37}Ar$ Reaction - S. K. Gupta, S. S. Kerekatte and A. S. Divatia - The (p,n) reaction on ^{37}Cl target was investigated to identify the isobaric analog resonances in the nucleus ^{38}Ar corresponding to the parent nucleus ^{38}Ar. Below the threshold of this reaction the analogs of $^{38}Cl(1)$ and ^{38}Cl (2) (we denote the nth excited state of ^{38}Cl as $^{38}Cl(n)$) have been observed in $^{37}Cl(p,\alpha_0)^{34}S$ reaction[1]. As $\Gamma/D < 1$ for T< states at this excitation of the compound nucleus, many split components of the analogs have been observed. In the energy range E_p = 1.64 - 2.50, scanned by us, the analogs of $^{38}Cl(3-8)$ are expected.

A natural NaCl (24.76% ^{37}Cl) target,~7.6 MeV thick for 1.7 MeV protons was used. A 4π-geometry neutron counter was used to measure the yield of the reaction. The data was taken in 2 KeV steps and was reproducible. The absolute cross section was obtained using the absolute measurement of Johnson et al[2] in the same reaction. The absolute cross section has an error ± 15%. The measured excitation function is shown in Fig. 3.

The Coulomb displacement energy for ^{38}Cl - ^{38}Ar pair was assumed to be 6.405 MeV. The excitation energies of the analog states were calculated using this value. As may be seen from fig. 3, there is an indication of two broad structures enveloping many narrow resonances. A very clear identification of analog states is therefore not possible. For a crude analysis we derive an expression for the energy integrated cross reaction using the expression given by Johnson et al[3] based on the work of Robson et al[4]. An approximate expression for the energy integrated cross section is

$$\sigma^{I}_{pn}(res) = \int_{-\infty}^{\infty} \sigma_{pn}(res)\, dE \simeq \text{Constant}\left[(2J+1)S_n\right] P_p$$

where J is the spin of the resonance, S_n is the spectroscopic factor obtained from the (d,p) reaction and P_p is the penetration factor. Using the (d,p) data the relative values of σ^{I}_{pn} were calculated. The calculated positions and itensities have been plotted in Fig.3. We find that

$$\int_{1.925\,MeV}^{2.150\,MeV} \sigma_{exp}\, dE \Big/ \int_{2.150\,MeV}^{2.387\,MeV} \sigma_{exp}\, dE = 0.88$$

In the range 1.925 MeV to 2.150 MeV three resonances 4,5 and 6 are expected to occur and in the range 2.150 MeV–2.387 only resonance[4] 8 is expected. If we assumed that there is no non-resonant contribution, we get using expression(1) $\sum_{i} \sigma^{I}(i) \Big/ \sigma^{I}_{(4)} = 0.96$. This is in good agreement with the experimental value. Further measurements are necessary to draw definite conclusions

1) B. Bosnjakovic, J.A. Von Best, J. Bouwmeester, Nucl.Phys.A94 (1967)625

2) C.H. Johnson, A.Galonsky and J.P. Ulrich, Phys.Rev.109 (1958)243

3) C.H. Johnson, R.L. Kernell and S. Ramavataram, Nucl.Phys. 107 (1968)21

4) D. Robson, J.D. Fox, P. Pichard and C.F. Moore, Phys. Letters 18(1965)86

5) J.Rapaport and W.W. Buechner, Nucl.Phys.83(1966)30.

8. <u>Elastic Scattering of Protons of ^{66}Zn</u> - M. G. Betigeri, C. M. Lamba, D. K. Sood, N. S. Thampi and N. Sarma - Excitation functions of elastically scattered protons from ^{66}Zn was studied in the energy range of 2.660 - 4.1 MeV in steps of 5 KeV. Resonances in the compound nucleus ^{67}Ga have been observed at energies corresponding to 2.909, 3.009, 3.200, 3.800 and 3.943 MeV which are analogues of the low lying states in ^{67}Zn nucleus namely 93, 184, 390 928 and 1142 KeV excitation. The analogue of the ground state which is an 1 = 3 transition and the 602 KeV excited state which is an 1 = 4 transition as known from (d,p) studies are not excited in the present study due to low barrier transmission. The shapes of the resonances at 3 angles namely 90°, 125° and 165° indicate that all the resonances have 1 = 1 shape.

9. <u>Nilsson Model Interpretation of the Low-lying levels of ^{27}Mg</u> - M.A. Eswaran - With a view to compare the properties of the low-lying excited states of ^{27}Mg(see article No.4) with the predictions based on the single-particle collective model of Nilsson[1)], the calculations have been made for the branching ratios of the levels and multipole mixing ratios of the gamma ray transitions, as a function of the deformation parameter for both prolate and oblate assignments for ^{27}Mg. According to prolate assignment the first excited state at 0.984 ($3/2^+$) is the second member of the ground state rotational band based on the orbit 9($1/2^+$) of Nilsson, where as

the oblate assignment for ^{27}Mg will leave this 0.984 MeV state as the head of $K = 3/2^+$ band, based on the orbit 8 $(3/2^+)$.

The experimentally observed values for the branching ratios of the levels 1.69 and 1.94 MeV and the multipole mixing ratios of the transitions 1.94 → 0.984 MeV and the 0.984 → 0 MeV have been compared with the above model calculations. These comparions, as well as the comparison of the value of the decoupling parameter required to fit the energy sequence of the various choices for the members of the K = 1/2 ground state rotational band, with the model calculations, support the prolate assignment to ^{27}Mg corresponding to $\eta = +2$ ($\delta = 0.15$) with the choice of levels at 0, 0.984 and 1.94 MeV as members of the ground state rotational band based on orbit 9. On this basis the 1.69 MeV $(5/2^+)$ state is conjectured to be the core excited state, corresponding to a vacancy in the orbit $5(5/2^+)$, due to excitation of a neutron from orbit 5 to orbit 9.

1) S. G. Nilsson, Kgl. Danske, Videnshab, Mat-Fys. Medd. 29 No. 16(1955).

10) <u>The Reaction $^{26}Mg(^{3}He,p)^{28}Al$</u> - M.A. Eswaran, M. Ismail, and N.L. Ragoowansi - Using an enriched isotopic target of ^{26}Mg and 4.25 MeV beam of ^{3}He particles, proton groups feeding upto the fifth excited state in ^{28}Al have been observed in the reaction $^{26}Mg(^{3}He,p)^{28}Al$, using a 600 μ thick semiconductor detector at 0° to the beam. This reaction has not been reported till now in the published literature. It is proposed to continue the studies on this reaction with a view to obtain information on the low lying states of ^{28}Al by coincidence observation of protons and the de-excitation gamma rays.

11. Angular Distribution of Gamma-Rays from $^{59}Co(p,n\gamma)^{59}Ni$ and $^{51}V(p,n\gamma)^{51}Cr$ Reactions - B. Lal* and Baldev Sahai* - The study of angular distribution of gamma-rays from the $(p,n\gamma)$ reactions at low bombarding energies yields valuable information about the level spins and multipole mixing ratios of the gamma transitions, if the conditions are suitable for the validity of compound nuclear (CN) statistical model. Comparison of experimental distribution with the predictions of the Hauser-Feshbach-Satchler formalism of the CN statistical model as modified by Sheldon[1] by taking into account the effect of spin-orbit interactions enables one to extract electromagnetic decay properties of the low-lying states in the residual nucleus.

We have studied the $^{59}Co(p,n\gamma)^{59}Ni$ and $^{51}V(p,n\gamma)^{51}Cr$ reactions. The Q values for these reactions are-1.856 and - 1.534 MeV respectively. The negative Q values of these reactions allow successive levels in the residual nuclei to be populated near threshold by suitably varying the bombarding energy.

The targets of ^{59}Co and ^{51}V were prepared by vacuum-evaporation of chemically pure elements (purity better than 99.9%) on gold foils. Target thicknesses of about 800 $\mu g/cm^2$ were achieved by this method.

The target was kept at an angle of 45° with respect to the beam direction and angular distributions were taken from

---

* Tata Institute of Fundamental Research, Bombay.

0° to 90° in steps of 15°. The corrections due to the absorption in the target backing and target holder were made by taking angular distribution of gamma rays of comparable energies from radioactive sources under identical conditions.

In addition to the angular distribution of gamma-rays, excitation functions of gamma-rays from these two reactions were also taken using a 30 c.c. Ge(Li) detector kept at an angle of 90° with respect to the beam direction. The excitation functions were taken with the aim to ensure that the yield increases monotonically justifying the application of the CN statistical model. Each angular distribution has been averaged over two incident energies separated by 50 KeV to reduce the effect of level density fluctuations.

Fig.4 and 5 show the excitation function of gamma-rays from the two reactions respectively. The excitation functions show a reasonably smooth variation with energy.

Values of the Legendre polynomial coefficients obtained by fitting the angular distribution data to the expression.

$$W(\theta) = 1 + a_2 P_2(\cos \theta) + a_4 P_4(\cos \theta)$$

are given below

Reaction	E_γ(KeV)	a_2	a_4
$^{51}V(p,n\gamma)$	748	= 0.154 ± 0.080	0.044 ± 0.0906
"	1170	- 0.0625 ± 0.0782	0.0363 ± 0.0931
$^{59}Co(p,n\gamma)$	340	- 0.0024 ± 0.0786	0.109 ± 0.0964
"	470	0.039 ± 0.134	- 0.125 ± 0.170

Theoretical calculations are in progress. A computer program Hauser - Feshbach Model[2)] has been modified to extract multipole mixing ratios.

1) E. Sheldon, Rev. Mod. Phys. 35 (1963)795; E.Sheldon and D.N. Van Palter, Rev. Mod. Phys. 38(1966)143.

2) K.V.K. Iyengar, B. Lal and S.K. Gupta, Nucl. Phys. A103 (1967)592.

12. Excitation Function for $^{75}As(p,n\gamma)^{75}Se$ Reaction - Baldev Sahai*, B. Lal*, K.V.K. Iyengar*, P.J. Bhalerao and M.V. Vaze - A 30 cc Ge(Li) detector has been used for the measurement of the yield of gamma rays of energies upto 1450 KeV from a thick target of ^{75}As. The Q value of this reaction is - 1.65 MeV. The excitation function was taken from E_p= 1.5 to E_p = 4.0 MeV using a TMC 400 channel analyzer. Low energy gamma rays were also studied separately by expanding the spectrum so as to cover the energy scale upto 550 KeV within 400 channels. It is proposed to study gamma-gamma coincidences to establish the levels in ^{75}Se about which there is not enough published information.

13. Lifetime of the 287 KeV level in ^{75}Se - Baldev Sahai*, B. Lal*, P.J. Bhalerao and M.Y. Vaze - 287 KeV state is the second excited state in ^{75}Se. This state can be populated either by position decay of ^{75}Br or by (p,n) reaction above about 2 MeV incident proton energy. Half of this state was

---

* Tata Institute of Fundamental Research, Bombay.

found to be less than 2 nanoseconds by Labkowicz and Marmier[1] and 1 ns by Tubbs[2]. However, a measurement by Richter[3] et al gave the half life as 30 ns as measured by a pulsed beam Van de Graaff accelerator where the start-stop pulses were the 287 KeV gamma ray and the pulsed beam itself. To clear up this controversy a measurement of the lifetime of this state was carried out at E_p = 2.70 MeV. It is found that the lifetime as measured by taking coincidences between the cascade gamma rays of energy 141 KeV and 287 KeV is about 35 $\pm$ 5 n.s. which seems to be in better agreement with Richter et al rather than the other measurements. The difficulties arise mainly because of interference by gamma rays of comparable energies excited in ^{75}As itself. Counting statistics was rather poor. It is proposed to improve the counting statistics of this experiment to give a more precise value.

14. Determination of Width and Resonance Energy of the 7.01 MeV Level in ^{10}B and Comparison f the Experimentally observed Spin with Intermediate coupling calculations - M. Balakrishnan, M. K. Mehta and A.S. Divatia - The resonance energy and width of the resonance around 7 MeV excitation in ^{10}B was determined more accurately by shape fitting of the elastic scattering cross section of alphas on ^{6}Li. Since the level was broad, it was not easy to read the resonance energy accurately from the phase change in the interference shapes. The channel radius

was not very sensitive to the shapes and so we have chosen γ_o = 1.3 for ^{4}He and γ = 01.7 for ^{6}Li, which gave a channel radius of 5 fermi. Fig.6 shows the shapes calculated for two angles of 90° and 141° cm.corresponding to three possible resonance energies, keeping the width Γ constant, after averaging over target thickness. From the relative shifts in the resonance pattern, it can be seen that the resonance energy E = 4.250 agrees better, than the other two cases. Fig.7 shows the variation in level width Γ for resonance energy of 4.250 MeV. From the shapes at the two angles of 90° and 141° cm., it can be seen that the width lies between the two values of 52.4 KeV and 130 KeV and more near to the 130 KeV value. After various trial values a value of 110 $\pm$ 15 KeV was fixed for this level. In all these calculations we have used the spin parity assignment[1)] of 2^+.

From the large elastic alpha channel width it can be said that this level is most likely a T = 1 state.

Fig.8 shows a comparison of the recent intermediate couple calculations available in ^{10}B, for normal parity state with the 2^+ level analysed in this study. From the two calculations one by Amit and Katz[2)] and the other by Cohen and Kurath[3)], it can be said that both these calculations do not show a $(2^+,0)$ state around 7 MeV, though Cohan and Kurath calculation show better agreement with experiment. Since there are no unaccounted levels in ^{10}B up to 10 MeV in Kurath's calculations for a $(2^+,0)$ level, it is quite unlikely that this level belong to the 1 p shell, if this spin, parity and isospin assignment is correct. Then the most probable configuration seems to be 1 S^4 $1p^4(S,d)$.

1) M. Balakrishnan, M.K. Mehta and A.S. Divatia, Proc. Nucl. Phys. and Solid State Phys. Symp. India Vol.II (1968)44.

2) D. Amit and A. Katz, Nucl. Phys. 58(1964)388

3) S. Cohen and D. Kurath, Nucl. Phys. 73 (1965)1.

15. The Reaction $^{19}F(d,\alpha)^{17}O$ - M.G. Betigeri, C.M. Lamba, D.K. Sood, N. S. Thampi and N. Sarma - In the incident deuteron energy range, 2.0 - 5.2 MeV, the excitation functions for the α - groups corresponding to the lowest three states in ^{17}O in the reaction $^{19}F(d,\alpha)^{17}O$ and for the elastic scattering of deuterons on ^{19}F have been studied. The excitation functions indicate the presence of wide structures. The angular distributions on and off the resonances have been measured. Examination of the correlation functions and the analysis of the angular distribution in terms of Legendre polynomials indicate a high direct reaction component. The results are discussed in terms of the intermediate structure model of Izumo.

To be published in Energia Nucleare

16. Neutron Induced Reaction - M.G. Betigeri, C.M. Lamba, D.K. Sood, N.S. Thampi and N. Sarma - A counter telescope to

discriminate between the charged particles i.e. protons and deuterons, from neutron induced reactions has been set up. The reaction $^{19}F(n,d)$ has been studied. The angular distribution indicates an $l = 0$ transition leading to the ground state of ^{18}O. The neutron flux was measured by counting the associated α - particles in the reaction $D(t,n)^4He$. The absolute cross section at $\theta_{lab} = 0°$ agrees with earlier measured values. The angular distribution has been fitted by DWBA theory. The computer code DWUCK was used with the CDC 3600.

This work was done at the Cascade Generator, T.I.F.R., Bombay. Reported at the Nucl. Phys. & Solid State Phys. Symposium, India (1969).

17. Angular Anisotropy of Fission Fragments in the Neutron Induced Fission of ^{235}U - D. M. Nadkarni and S. S. Kapoor - Recent studies of the angular distribution of fission fragments in the fission of heavy nuclei following direct reactions have indicated some evidence for a rather large pairing energy gap in the transition state spectra of even-even fissioning nuclei. In the present work the transition state nucleus ^{236}U has been investigated by measuring the angular distributions of fission fragments in the fission of ^{235}U induced by mono-energetic neutrons of 20 different neutron energies ranging from 0.1 to 3.1 MeV. The measurements were made with a set-up consisting of three semiconductor detectors which recorded the energy spectra

of fission fragments emitted at the average angles of 0°,45° and 90° with respect to the incident neutron direction. The relative solid angles of detection for the three detectors were experimentally determined using isotropic fragment distributions in the case of thermal neutron induced fission of ^{235}U. For each neutron energy the angular anisotropy was obtained by a least squares fit to the measured angular distributions taking into account the angular resolution effects due to the finite size of the target and detectors. The parameter K_0^2 of the assumed Gaussian distribution of the K-states at the transition state nucleus was then determined for each neutron bombarding energy using the theoretical expression for the angular anisotropy which includes the effects of target spin and nuclear deformation. The average orbital angular momenta of the fissioning nucleus for different bombarding energies were evaluated using optical model neutron transmission coefficients. The observed variation of K_0^2 with excitation energy shows a steep increase in the value of K_0^2 at an excitation energy of 2.0 $\pm$ .1 MeV above the fission threshold. This increase in the value of K_0^2 has been interpreted as the onset of two quasi-particle excitations of the highly deformed transition state nucleus, ^{236}U. At excitation energies below the two quasi-particle excitation low values of K_0^2 are expected, whereas fairly high values of K_0^2 were observed in the present work. This suggests that the statistical assumption of a Gaussian distribution of K-states below the two quasi-particle excitation energy may not be valid because only a restricted number of vibrational K-states are available.

Submitted to the IAEA Symposium on Phys.and Chemistry of Fission - Vienna, 28 July - 18 August 1969.

18. <u>On the Constants of Charged Particle Identifier</u> - S.K. Gupta - Two methods to calculate the constants F and E_0 for the charged particle identifiers using the relationship,product $P = \Delta E(E + F \Delta E + E_0)$ have been described. Such constants have been calculated for silicon detectors. The extensions to other detectors have been pointed out. The limitations of the methods in practical cases have been discussed. A method to set the constants in the actual mullilplier circuits has also been discussed.

Reported at the Nucl.Phys. and Solid State Phys.Symposium India (1969).

19. <u>Monte Carlo Calculations of Gamma Ray Response Characteristics of Cylindrical Ge(Li) Detectors</u> - B. Lal* and K.V.K. Iyengar* - Monte Carlo calculations have been made to compute the full energy peak efficiencies and the double escape peak efficiencies for right circular cylindrical Ge(Li) detectors for point gamma-ray sources. The full energy peak efficiencies are calculated in the gamma-ray energy range from

---

* Tata Institute of Fundamental Research, Bombay.

100 KeV to 2.5 MeV and the double escape peak efficiencies are calculated in the range from 1.7 MeV to 4.0 MeV All calculations have been made for source to detector distance of 5 cm. Various detector sizes have been considered with surface area varying from 2.5 cm^2 to 8.0 cm^2 and the thickness varying from 2.0 to 10.0 mm. The results are compared with the calculations of earlier workers and also with some of the experimental investigations. A code "MONTCARL" has been developed for this purpose in FORTRAN language for the CDC 3600 computer. The same code can be used to calculate the response function of the detector to gamma-rays. One such calculation has been made for monoenergetic gamma-rays and compares very well with the experimental results.

20. Differential Equation for Logarithmic Derivative and Its Application - S.K. Gupta - Using a simple transformation the radial Schrodinger equation has been transformed into a first order differential equation of the Riccati type. This equation offers possibilities for simplifying calculations. It has been used to derive recursion relations for different l-values and to calculate an asymptotic solution for the Coulomb potential. The equation can also be applied to calculate the transmission coefficients and the elastic scattering cross-section using the optical potential.

Abstract of a paper submitted at the Nucl.Phys. and Solid State Phys. Symposium, India, 1969.

21. Mossbauer Effect Studies Following Coulomb Excitation - J.K. Srivastava*, R.P. Sharma* and K.G. Prasad* - Mossbauer effect measurements were carried out on the 14.4 KeV state of ^{57}Fe, populated in the Coulomb excitation by 4 MeV alpha particles. The 14.4 KeV gamma ray was detected in coincidence with 122 KeV gamma ray to reduce the general back ground in the low energy region. A sinusoidal drive with a stainless steel absorber (enriched in ^{57}Fe) was used to record the Mossbauer spectrum(Fig.9.) It is clear from Fig.9 that such studies can be carried out in favourable cases. In addition to Coulomb excitation, other reactions can also be used. Further work in this direction is being planned.

22. Perturbed Angular Correlation Following Coulomb Excitaion - A.P. Agnihotri*, H.G. Devare*, S.H. Devare*, M.C. Joshi* and P.N. Tandon* - Previous preliminary measurements on the Coulomb excitation of target nuclei (pt,Au) in Iron medium (alloys, $PtFe_3$) were reinvestigated with Ge(Li) detector. Similar measurements on the rare-earth isotopes deposited ($\simeq$ 100/ μgm/cm^2 thick) on Fe foil were also made. Typical spectra are shown in the Figs. 10 and 11.

It was decided to make the perturbed angular distribution of Coulomb excited gamma rays from ^{194}Pt and ^{196}Pt. A thick target of $PtFe_3$ was fixed between pole tips of a polarising electro-magnet. In order to avoid heating during the

---

* Tata Institute of Fundamental Research, Bombay

bombardment, the target was cooled by liquid nitrogen (cold finger tip arrangement). The α-particle beam spot on the target was adjusted to coincide, within 1/2 mm, with the centre of the angular correlation table by a set of collimators. The centring was checked by placing a radioactive source at the position of the target. The gamma rays were viewed by four NaI(Tl) detector systems placed at different angles with respect to the direction of the incident beam.

The intensity of the particle beam on the target was monitored by a surface barrier detector placed at a fixed angle. The gamma ray spectra from the four detectors were recorded in the four subgroups of a multi-channel analyzer. Angular distribution was measured. To study the perturbation, the polarising magnetic field, which was perpendicular to the plane of detectors, was applied and measurements were recorded for both directions of the field. Several similar cycles of measurements were made. These measurements indicated perturbation of the angular distribution due to internal magnetic field acting on the Coulomb excited nuclei. However, the magnitude of the observed effect could not be estimated accurately due to the poor energy resolution of the detectors. It is planned, in the next attempt, to use improved technique, Ge(Li) detector and back-scattered particle-γ coincidences.

23. <u>Study of the Thermoluminescence Behaviour of Solids under</u>

Atomic Displacements - J. M. Luthra* - The machine was used for irradiating crystals in vacuum with H^+ and He^+ ions. For that purpose the required target chamber was designed and fabricated. A few samples of single crystals of MgO, $CaCO_3$ and $BaSO_4$ were irradiated with H^+ and He^+ ions (2-4 MeV energy) for different doses. The current was kept low to avoid thermal annealing. The main aim of such irradiation is to introduce atomic displacements in the crystals and to study the role played by them on the thermoluminescence behaviour of solids. It has been observed that the particle irradiation of these crystals induces thermoluminescence peaks in their glow curves which is not induced by ionising radiations.

---

* Chemistry Division

INSTRUMENTATION

1. A Target Chamber for Charged Particle Capture Reactions - M. Ismail and M. A. Eswaran - A thin-walled target chamber with provision to mount water-cooled targets on metallic backing, has been designed and has been fabricated in the divisional workshop. This chamber, made of 5 cm diameter, 0.8 mm thick stainless steel tube, is particularly suitable for the use with the 30 cc Ge(Li) gamma ray detector in charged particle capture gamma ray studies.

2. A Nanosecond Time-to-Amplitude Converter System for Neutron Time-of-Flight Studies - N. L. Ragoowansi and M. A. Eswaran - A time-to-amplitude converter system for nanosecond region, for neutron-gamma ray coincidence studies in nuclear reactions has been constructed to enable neutron time-of-flight studies using the associated gamma ray to give the starting signal. This time-to-amplitude converter, associated with a fast-slow coincidence system, is based on circuitry published in reference[1]. The linearity of the time-to-amplitude converter has been checked in the range 5 to 150 nanoseconds using a pair of scintillation counters and a ^{60}Co gamma ray radioactive source.

1) R.B. Tomlinson and R.L. Brown. IEEE Transactions on Nuclear Science (1964)p.28.

INDIAN NUCLEAR DATA GROUP

M. Balkrishnan (Secretary), H.G. Devare*, A. S. Divatia (Convener), S.S. Kapoor, D. N. Kundu**, V. C. Deniz, B. P. Rastogi and N.S. Satya Murthy.

1. Progress Report on Nuclear Data activity - a report entitled "Progress Report on Nuclear Data Activities in India V" was compiled and published as a B.A.R.C. Report (BARC-401).

2. Participation in CINDA activity was continued by sending the relevant data in CINDA forms to IAEA.

3. Three more entries were sent to DASTAR (Data Storage and Retrieval System).

4. ENEA Computer Programme Library

In connection with computer programme Library, eight programme abstracts were sent to the computer program library of the European Nuclear Energy Agency. These abstracts are to be included in the compilation of the computer programme abstracts published by ENEA.

A few programmes on magnetic tapes which were requested, were received from ENEA for use in India.

---

* Tata Institute of Fundamental Research, Bombay

** Saha Institute of Nuclear Physics, Calcutta

5. Measurement of Cross-Sections

i) $^{48}Ca(p,n)^{48}Sc$ Reaction

The absolute total cross section for the reaction $^{48}Ca(p,n)^{48}Sc$ has been determined in the bombarding energy range 1.90 to 2.05 MeV in 0.6 KeV steps. The total widths and partial proton and neutron widths of the resonances have been obtained.

ii) $^{37}Cl(p,n)^{37}Ar$ Reaction

The cross section of the $^{37}Cl(p,n)^{37}Ar$ reaction has been measured in 2 KeV steps at proton energies ranging from 1.64 MeV to 2.50 MeV.

Two meetings of the INDG were held during the period.

LAYOUT OF EXPERIMENTAL AREA

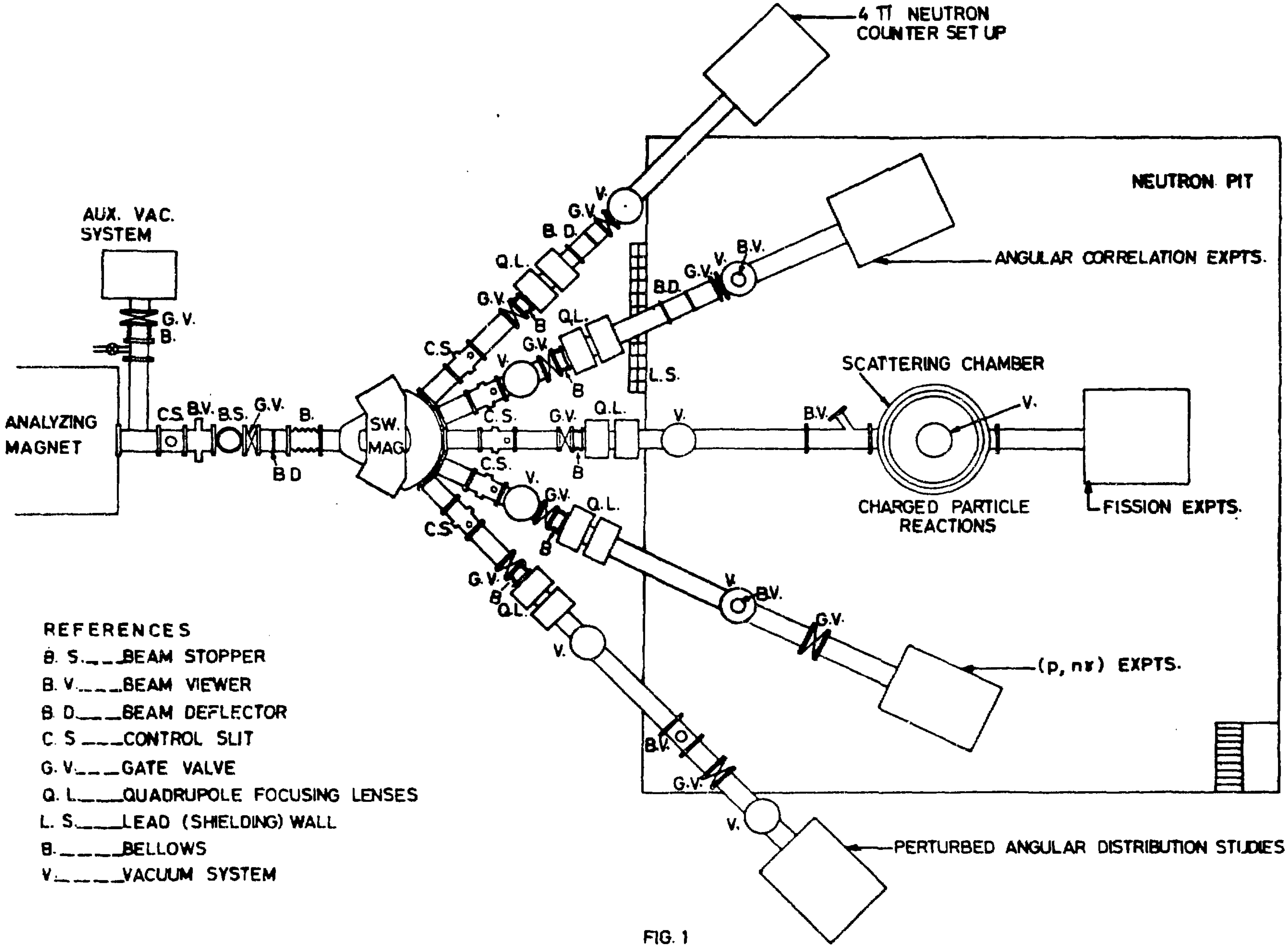
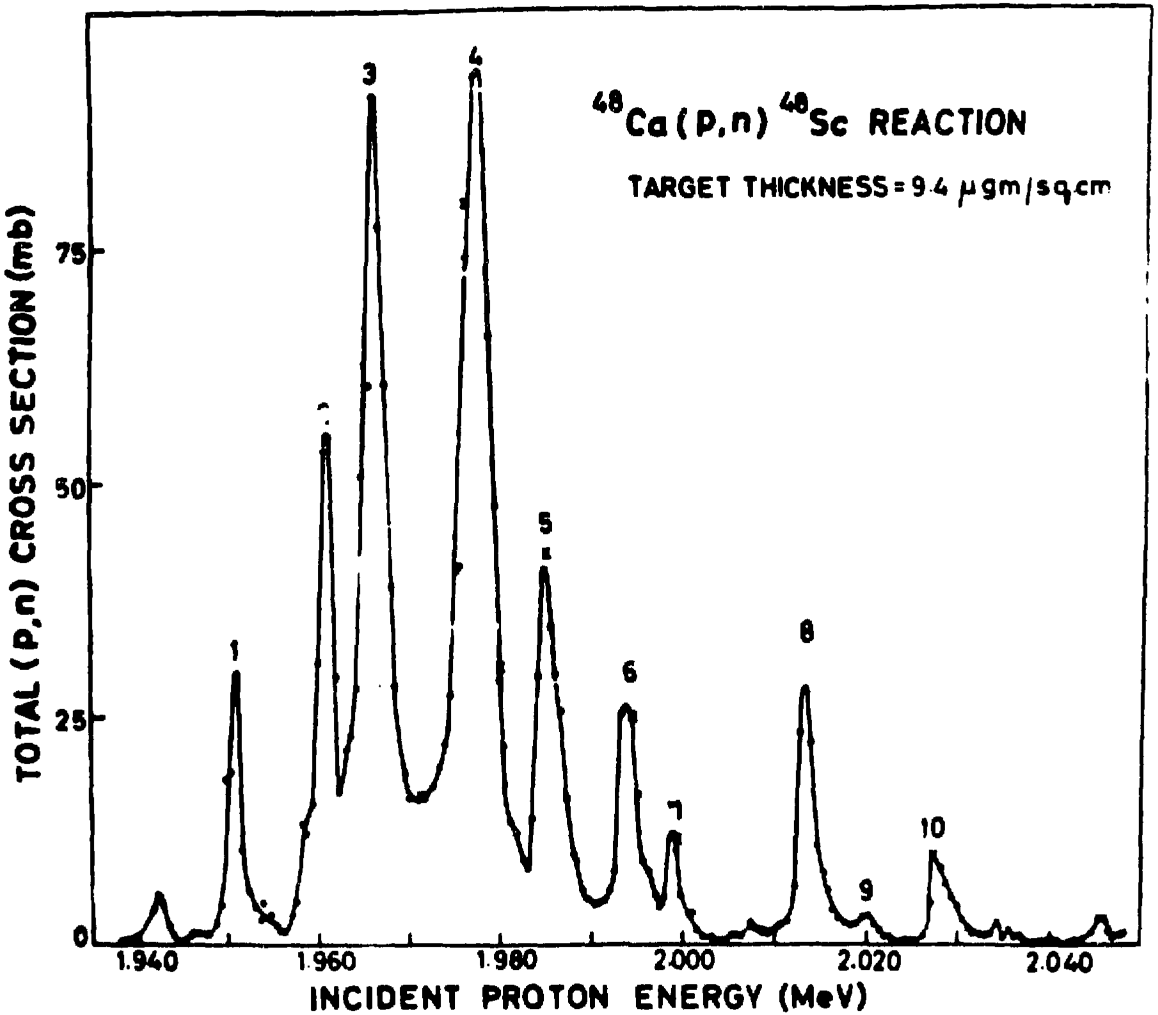


FIG. 1



$^{48}Ca(p,n)^{48}Sc$ REACTION
TARGET THICKNESS = 9.4 μgm/sq.cm
TOTAL (p,n) CROSS SECTION (mb)
INCIDENT PROTON ENERGY (MeV)
0
25
50
75
1.940
1.960
1.980
2.000
2.020
2.040
1
3
4
5
6
7
8
9
10

FIG-2

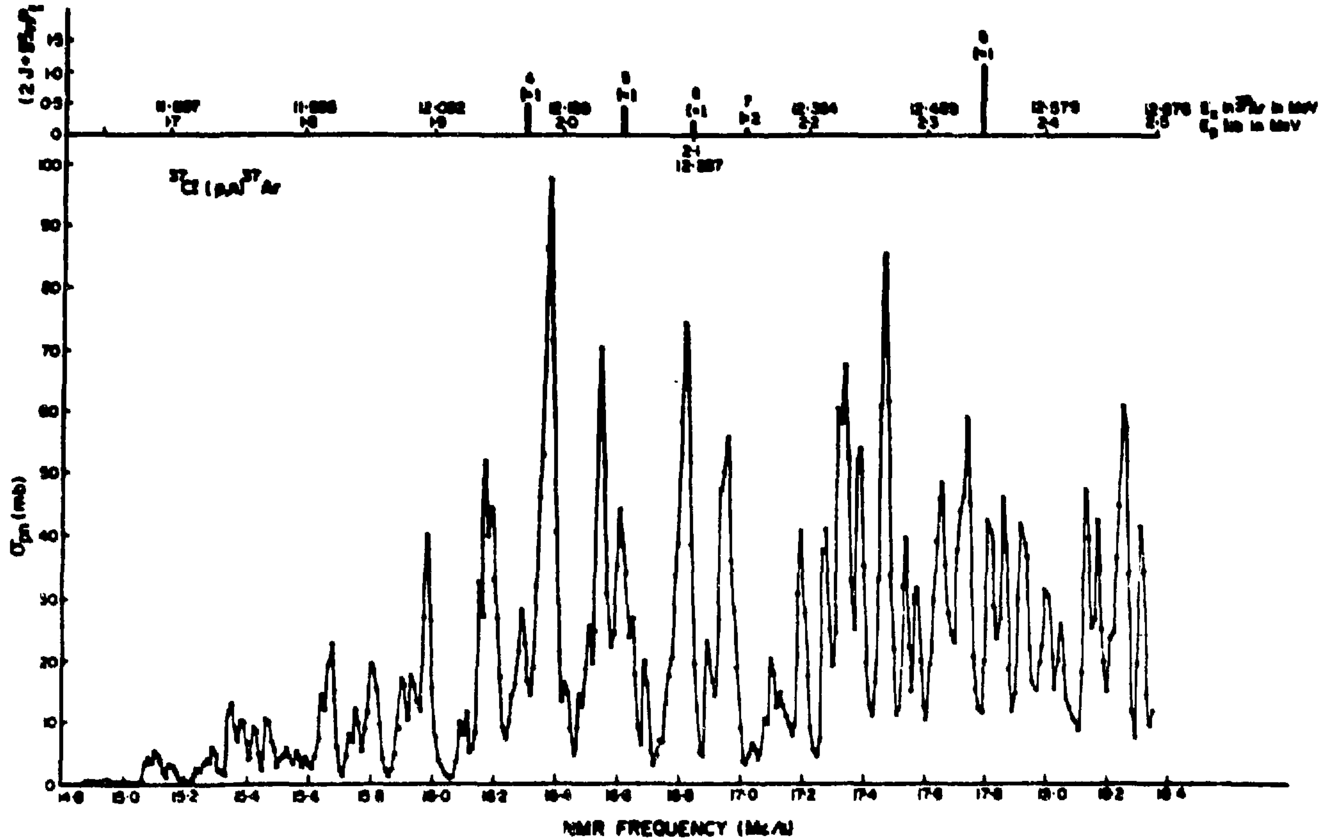
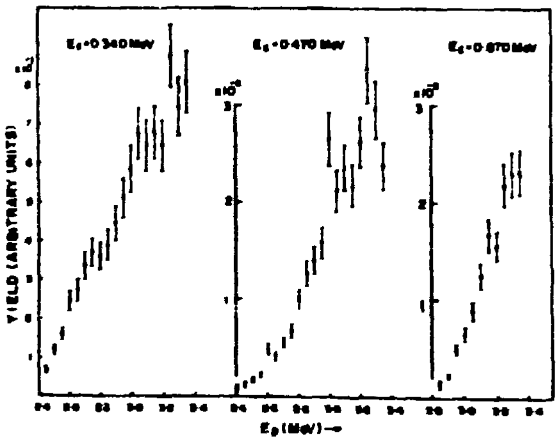
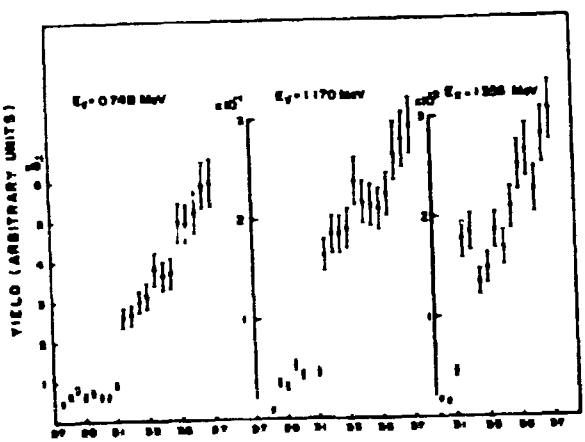


FIG -3



FIG·4



FIG·5

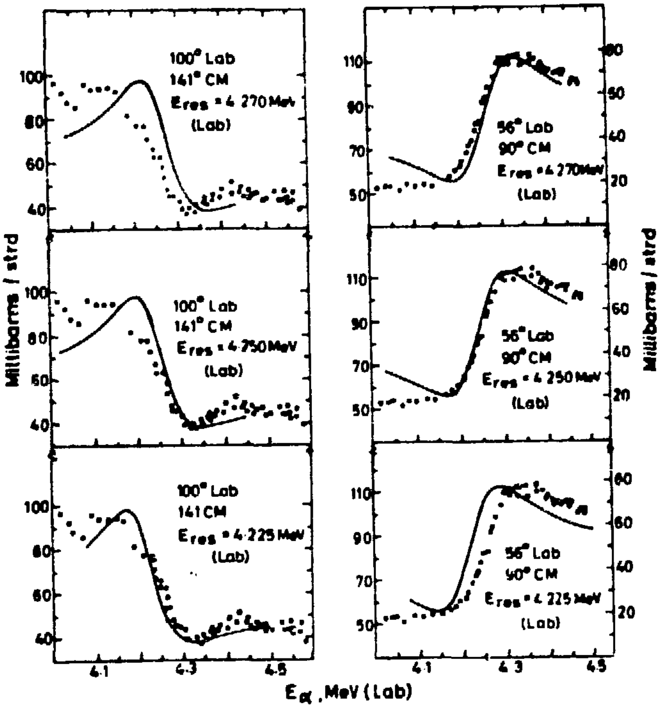
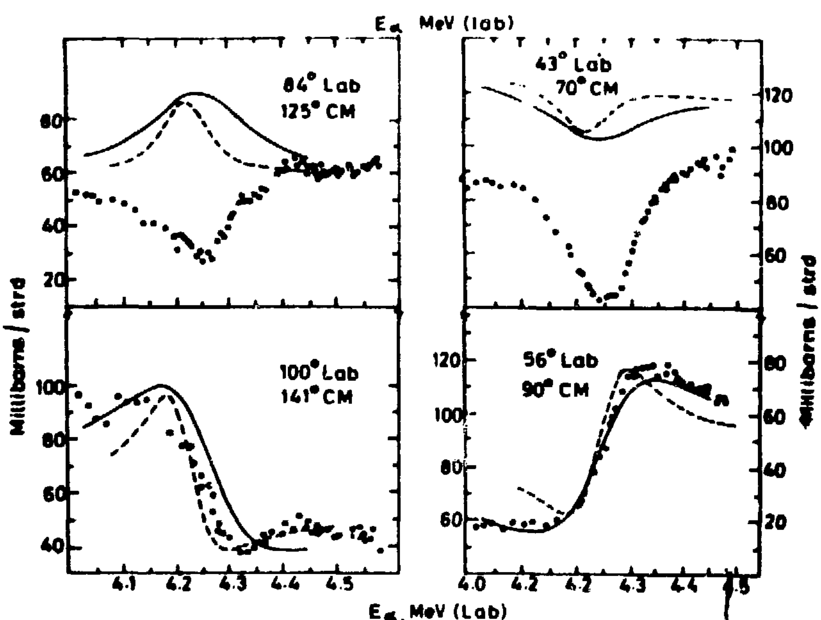


FIG-6



—— Γ_{cm} = 130 KeV, Eres = 4.250 MeV

----- Γ_{cm} = 52.4 KeV, Eres = 4.250 MeV

FIG-7

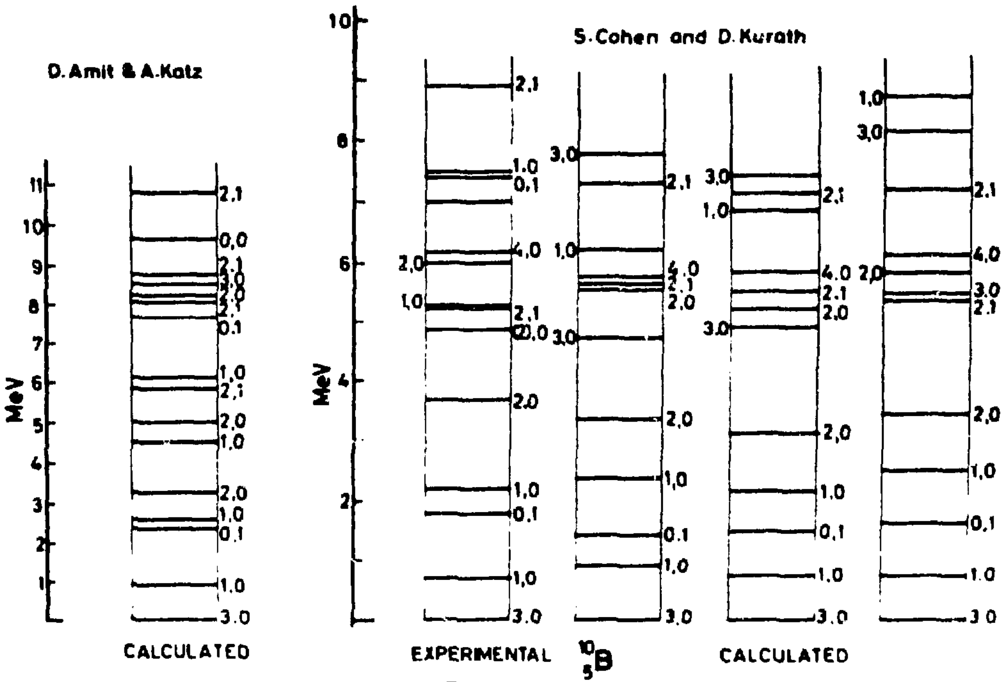
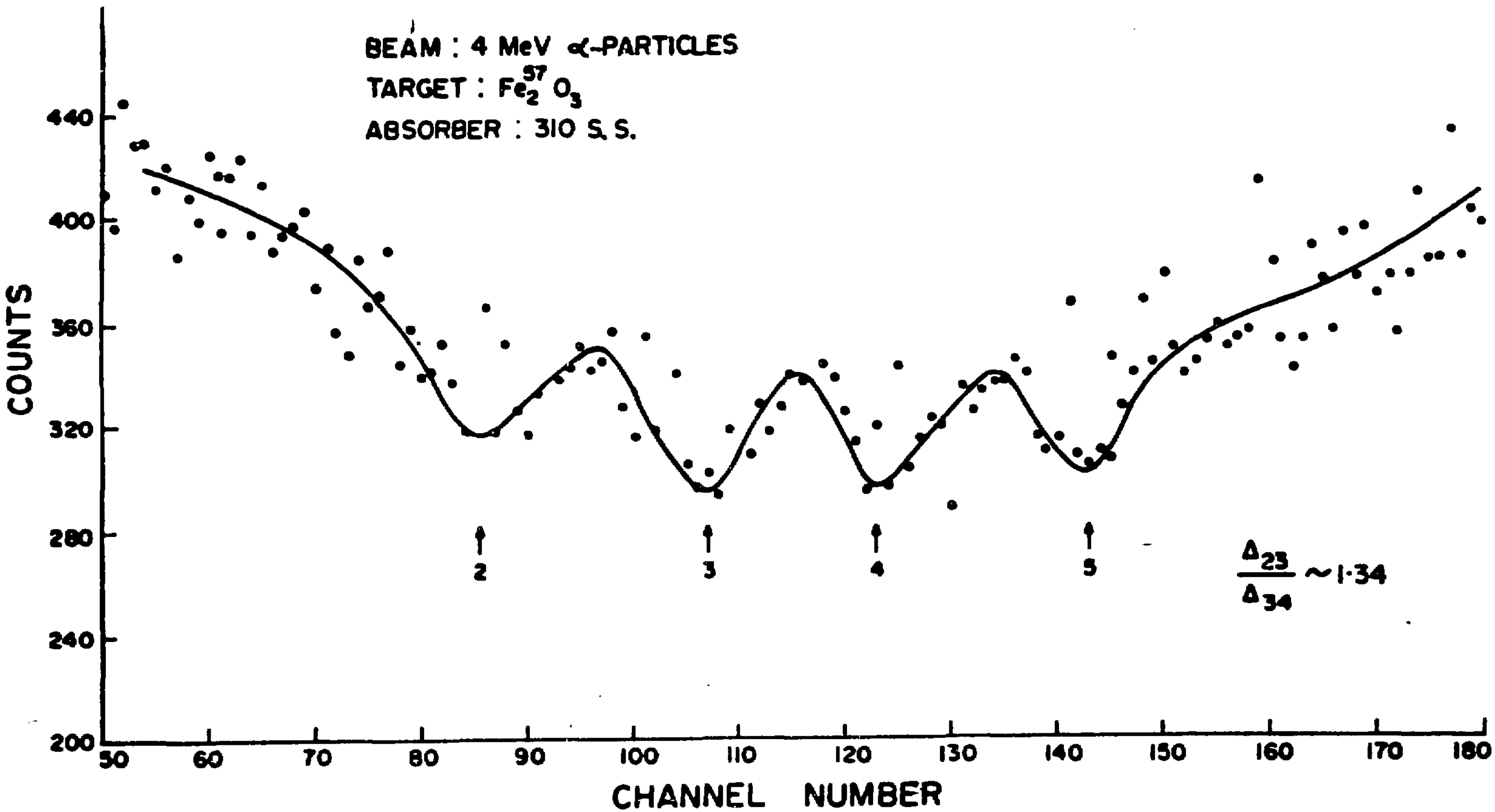
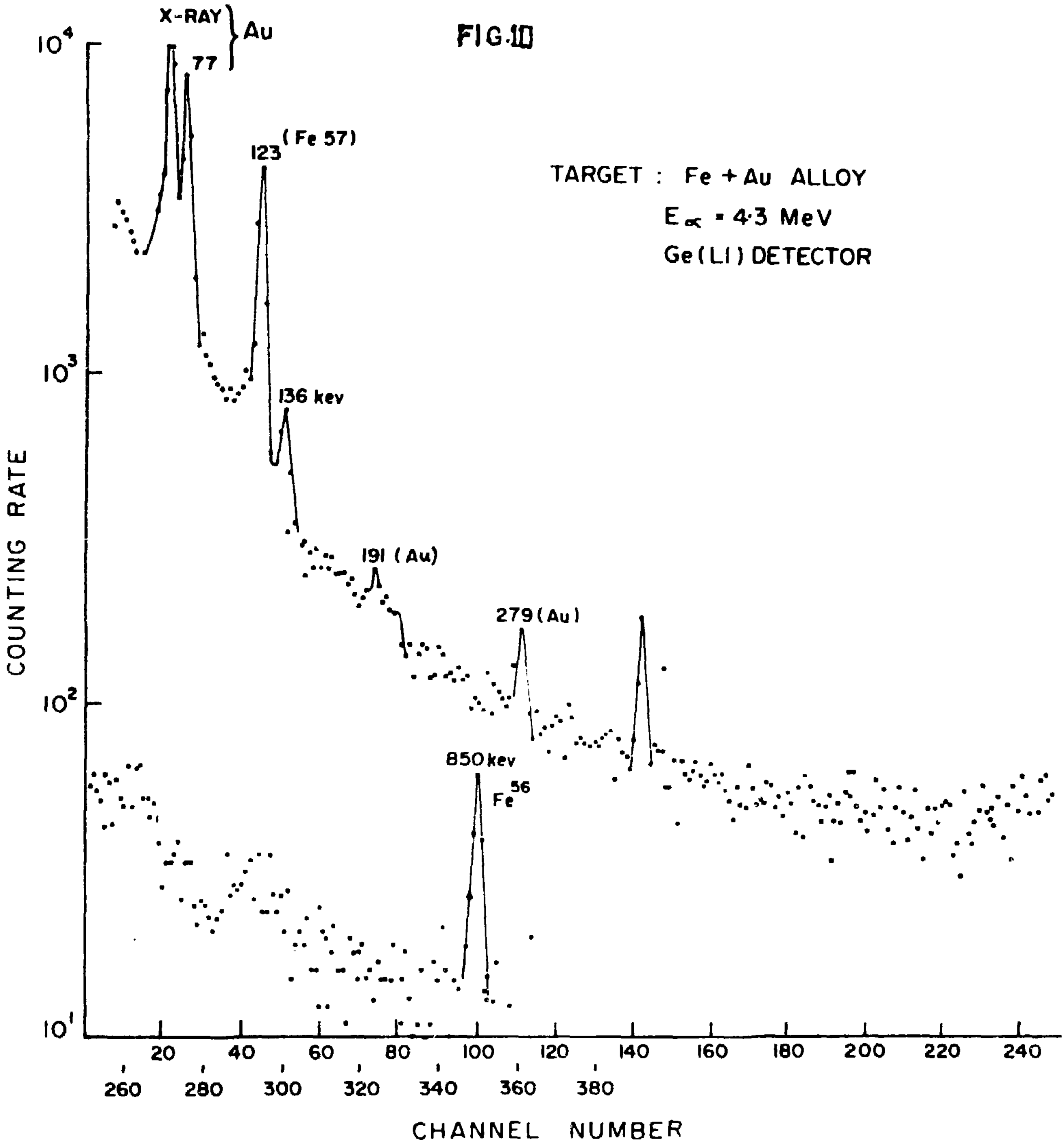

D. Amit & A. Katz
S. Cohen and D. Kurath
MeV
MeV
CALCULATED
EXPERIMENTAL
CALCULATED
$^{10}_{5}B$

FIG. 8



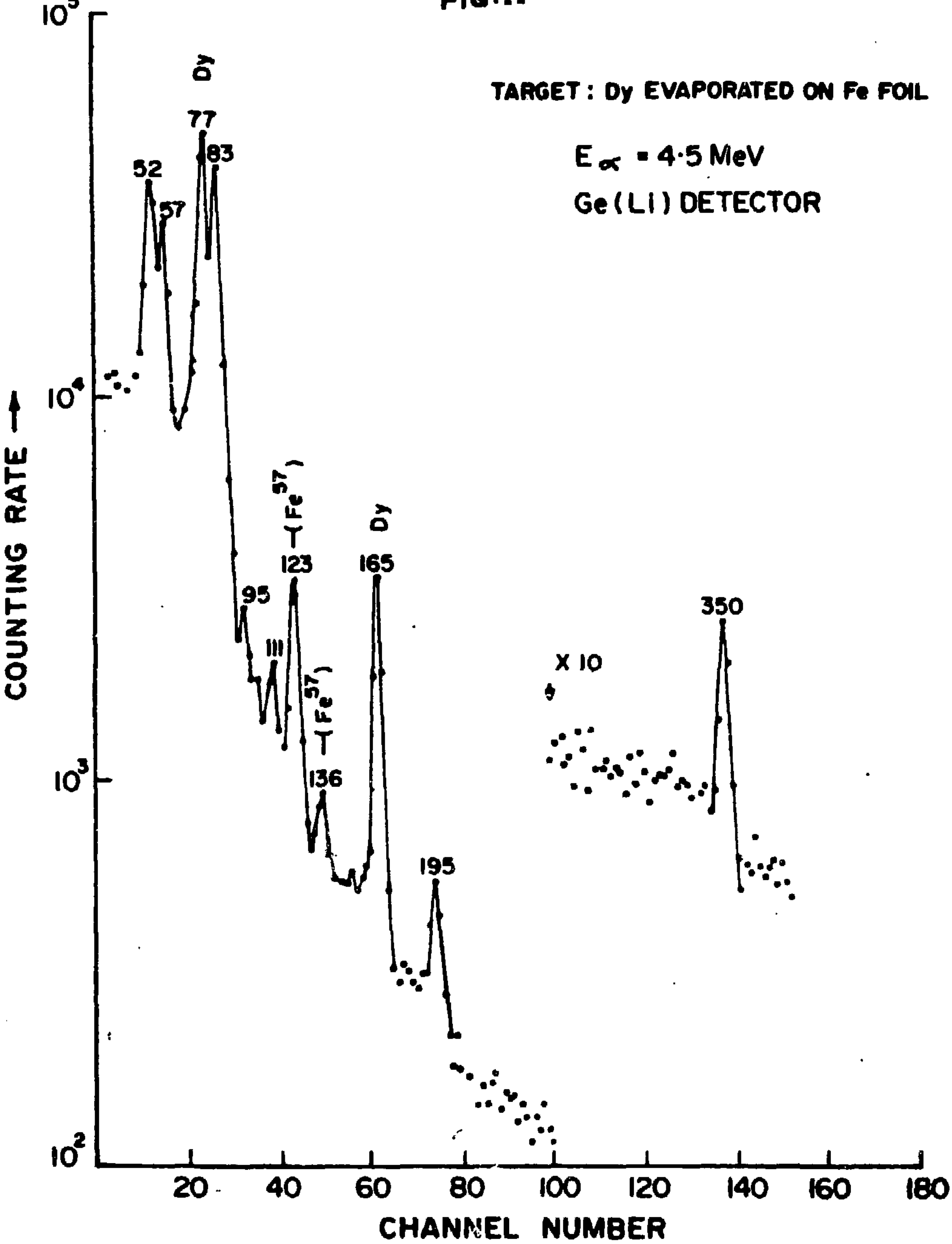
BEAM : 4 MeV α-PARTICLES
TARGET : $Fe_2^{57}O_3$
ABSORBER : 310 S. S.
COUNTS
440
400
360
320
280
240
200
50
60
70
80
90
100
110
120
130
140
150
160
170
180
2
3
4
5
$\frac{\Delta_{23}}{\Delta_{34}} \sim 1.34$
CHANNEL NUMBER

FIG-9



X-RAY
Au
77
FIG.10
123 (Fe 57)
TARGET : Fe + Au ALLOY
Eα = 4.3 MeV
Ge(LI) DETECTOR
136 kev
191 (Au)
279 (Au)
850 kev
Fe 56
COUNTING RATE
10^4
10^3
10^2
10^1
20 40 60 80 100 120 140 160 180 200 220 240
260 280 300 320 340 360 380
CHANNEL NUMBER

FIG. 11


TARGET : Dy EVAPORATED ON Fe FOIL
E_α = 4·5 MeV
Ge(Li) DETECTOR
COUNTING RATE →
CHANNEL NUMBER
Dy
77
83
52
57
95
111
123
(Fe57)
136
(Fe57)
Dy
165
195
X 10
350
10^5
10^4
10^3
10^2
20
40
60
80
100
120
140
160
180