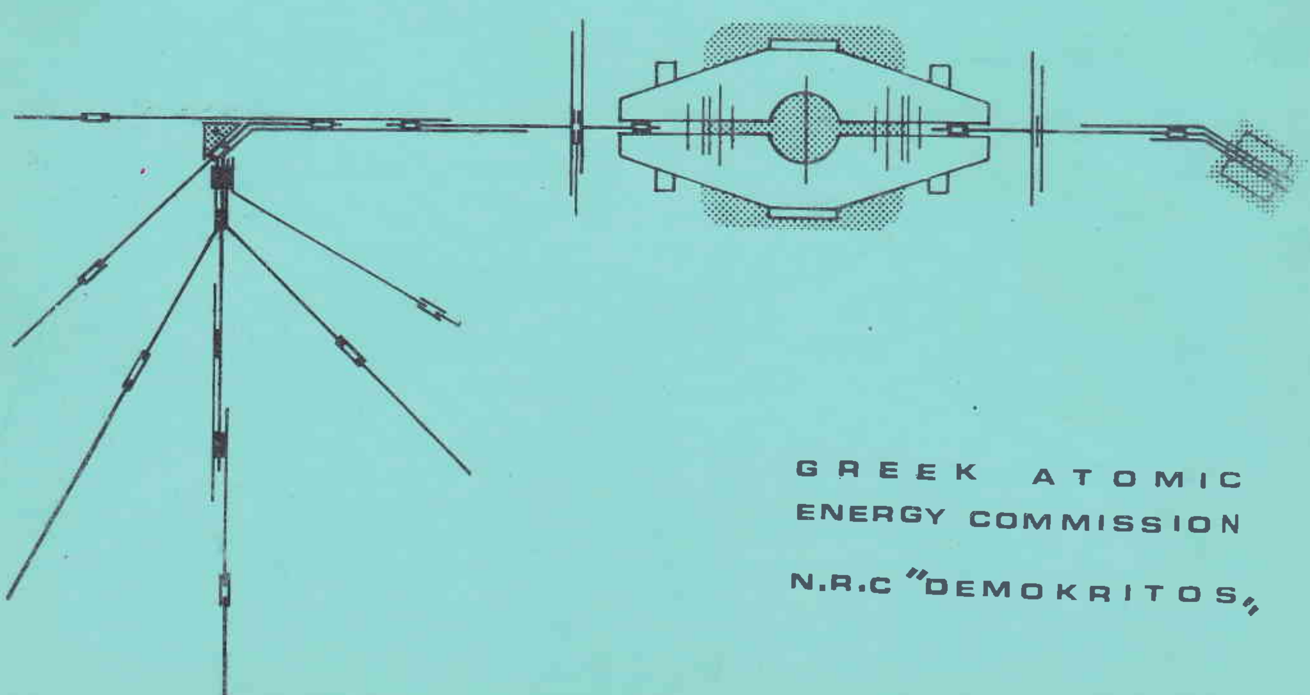
TANDEM
ACCELERATOR LABORATORY
ANNUAL REPORT
1977



GREEK ATOMIC
ENERGY COMMISSION

N.R.C "DEMOKRITOS"

NUCLEAR RESEARCH CENTER DEMOKRITOS

TANDEM ACCELERATOR LABORATORY

ANNUAL REPORT 1977

Editors: Th. Paradellis, C.A. Kalfas

A C K N O W L E D G M E N T

The Editors wish to acknowledge the help of Mr. F. Trouposkiadis and Mrs. A. Dimitriou in the preparation of this report.

I N D E X

INTRODUCTION

This report describes the research performed in our laboratory during 1977. The research revolved around the general guidelines established in the previous years, i.e heavy ion reactions, induced X-rays, γ-ray spectroscopy and theoretical nuclear physics.

In heavy ion reactions, study of resonances in several heavy ion systems in the s-d shell was initiated. A number of new resonances were identified and an effort has been made to understand the origin of these resonances. A systematic study has also been carried out with data from directional correlation measurements of γ-rays emitted in heavy ion reactions. The purpose of the study was to determine the dependence of the substates population distribution on the kind of projectile, the spin of the residual state and the electromagnetic deexcitation from above.

Spectroscopic information for a number of nuclei were extracted utilizing reactions such as (p,nγ), (p,p′γ) and (H.I, xyγ).

In the field of induced X-rays , both methods, PIXE and XRF were used extensively for quantitative and qualitative measurements of trace elements. The methods were applied in problems connected with air pollution, skin cancer, mineral content of ores, etc.

As an application of nuclear physics techniques in other research areas, the method of perturbed angular correlations of γ-rays was applied to the study of biological macromolecules.

On the theoretical side, the VMI model was extended to lighter nuclei that exhibit backbending phenomena, a d the isomorphic model was employed for the prediction of stable super-heavy elements. Considerable work was also performed in heavy ion reactions where an α-cluster is transferred and where both modes, direct and exchange are competitive.

In the technical field, the installation of an inverted sputter source, extended the heavy ion capabilities of the laboratory. Having also solved our problem of tube damage we have had no particular difficulty in voltage holding.

As in the previous years, we benefitted from useful collaboration with colleagues from the Greek Universities and from abroad.

No laboratory can really function properly without the dedicated effort of its technical and administrative staff and we take this opportunity to acknowledge their work.

George Vourvopoulos

I HEAVY ION REACTIONS

1) *^{20}Ne α-Spectroscopic Factors through the ^{16}O (^{16}O, ^{20}Ne)^{12}C Reaction*

N.Xiromeritis, G.Vourvopoulos, E. Kossionides, P.Kakanis and E.Gazis.

The completed study of the α-spectroscopic factors for the ground state and 1.63 MeV state of ^{20}Ne and in the energy region between 28 and 35 MeV leads us to the following conclusions.

a) The DWBA theory is adequate in describing the reaction over the energy region it was studied.

b) The spectroscopic factors derived are in good agreement with the theoretical predictions, differing appreciably however from most of those derived from light ion experiments .

c) The relative spectroscopic factor i.e. the ratio of the spectroscopic factors for the ground state to the 1.63 MeV state, remains constant from 28 to 35 MeV strengthening even more the adequacy of the DWBA method of analysis.

2) *Resonant Behaviour of the ^{12}C + ^{12}C System*

X.Aslanoglou, G. Vourvopoulos, G. Andritsopoulos+ and P. Bakoyeorgos.

In order to study the fine structure of the $^{12}C + ^{12}C$ system an excitation function was taken in the region of 7-10.5 MeV (center of mass system) detecting gamma rays emitted from the decay of the system. A typical gamma ray spectrum at 20 MeV (lab) is shown in fig. 1. The gamma rays spectra afforded the simultaneous investigation of the ^{23}Na + p, ^{23}Mg + n, and ^{20}Ne + a channels since the gamma rays emmitted from the first excited states of the ^{23}Na, ^{23}Mg and ^{20}Ne nuclei carry most of the needed information for the probability of their formation.

Fig. 2. shows the excitation function for the p and n channels. The correlated anomalies at 7.75, 9.7, 8.3 8.9 MeV (C.M) confirm their assignment as resonances in the $^{12}C + ^{12}C$ system as seen through particle detection experiments .

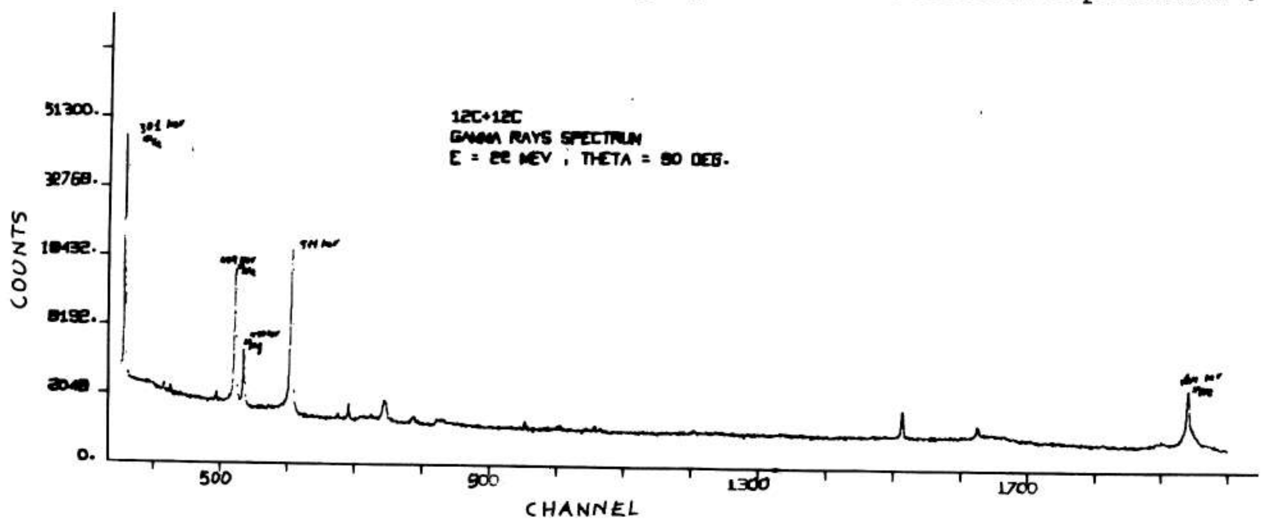


Fig. 1. Gamma ray spectrum from the ^{12}C + ^{12}C reaction. The gamma rays of interest are the 439 keV (^{23}Na), 450 keV (^{23}Mg) and 1634 keV (^{20}Ne).

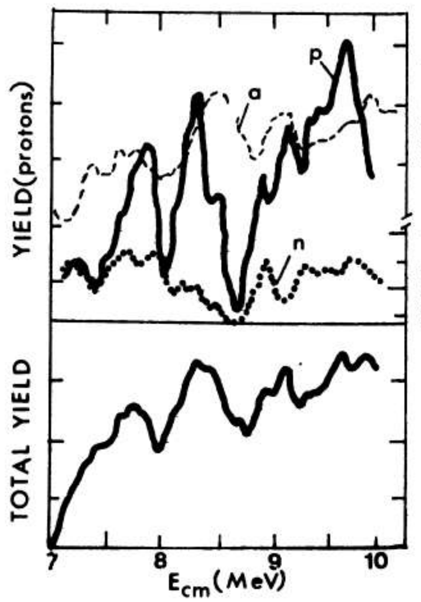


Fig.2. Excitation functions for the α,p and n channels from the $^{12}C+^{12}C$ reaction.

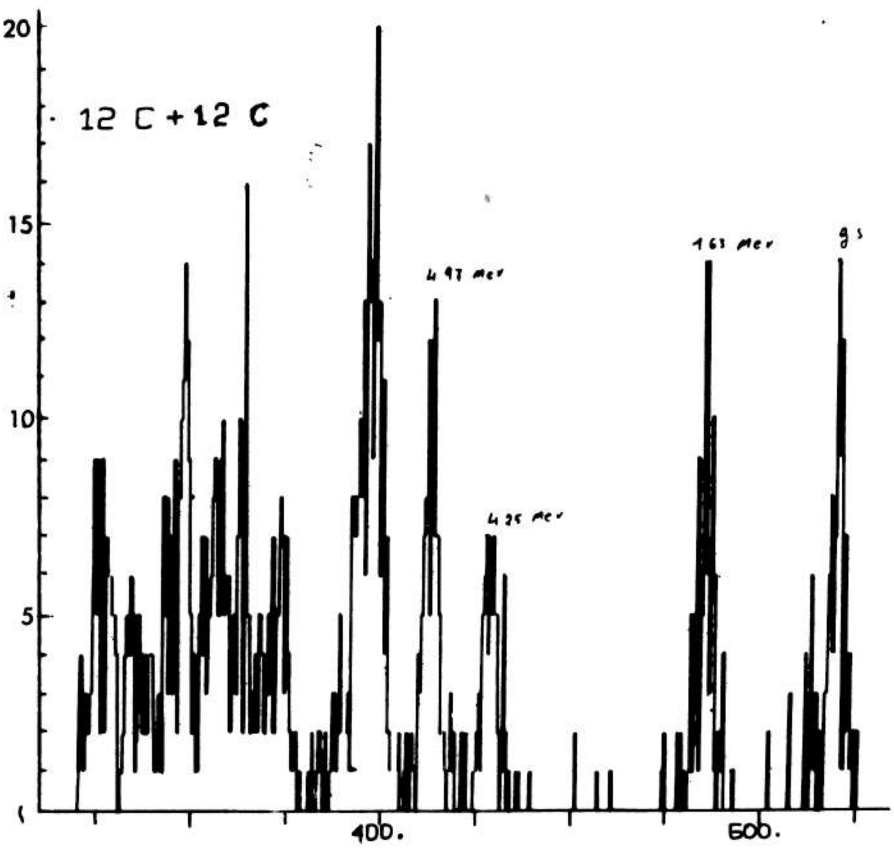


Fig. 3 ^{20}Ne Spectrum from the ^{12}C $(^{12}C,\alpha)$ ^{20}Ne reaction at E_C(CM) =7.3 MeV

For the 7.3 MeV (C.M.) anomaly which has not been previously observed further data were taken through the $^{12}C(^{12}C,\alpha)^{20}Ne$ reaction. Fig. 3 shows the ^{20}Ne spectrum at the above energy. An angular distribution as shown in Fig.4 indicates that the 7.3 MeV (C.M.) anomaly is a resonance in the $^{12}C + {}^{12}C$ system with a possible spin and parity of 2^+. Further experiments are being carried out to uniquely establish the spin and parity of that resonance.

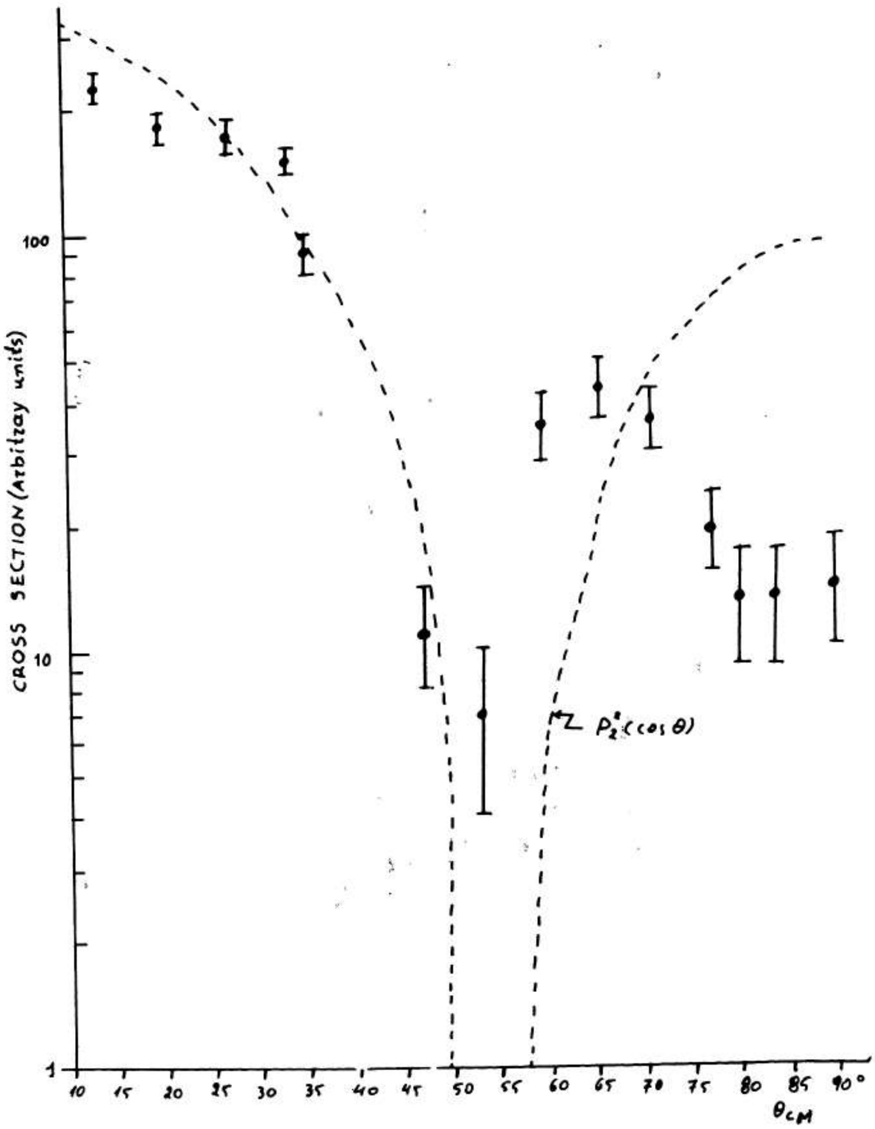


Fig.4
Angular distribution at E(CM)=7.3 MeV of the α-particles leading to the ground state of ^{20}Ne.

+ University of Ioannina

3) *A 5^- Resonance at the $^{12}C + ^{16}O$ System*

N. Cindro+, X. Aslanoglou, G. Vourvopoulos,
G. Andritsopoulos++, P. Assimakopoulos, and P.Bakoyeorgos.

An excitation function for the $^{16}O + ^{12}C$ system was taken in the region of 22-30 MeV (Lab) through the ^{12}C $(^{16}O, \alpha)$ ^{24}Mg reaction. A number of α-groups populating states of ^{24}Mg were measured as can be seen in Fig. 1.

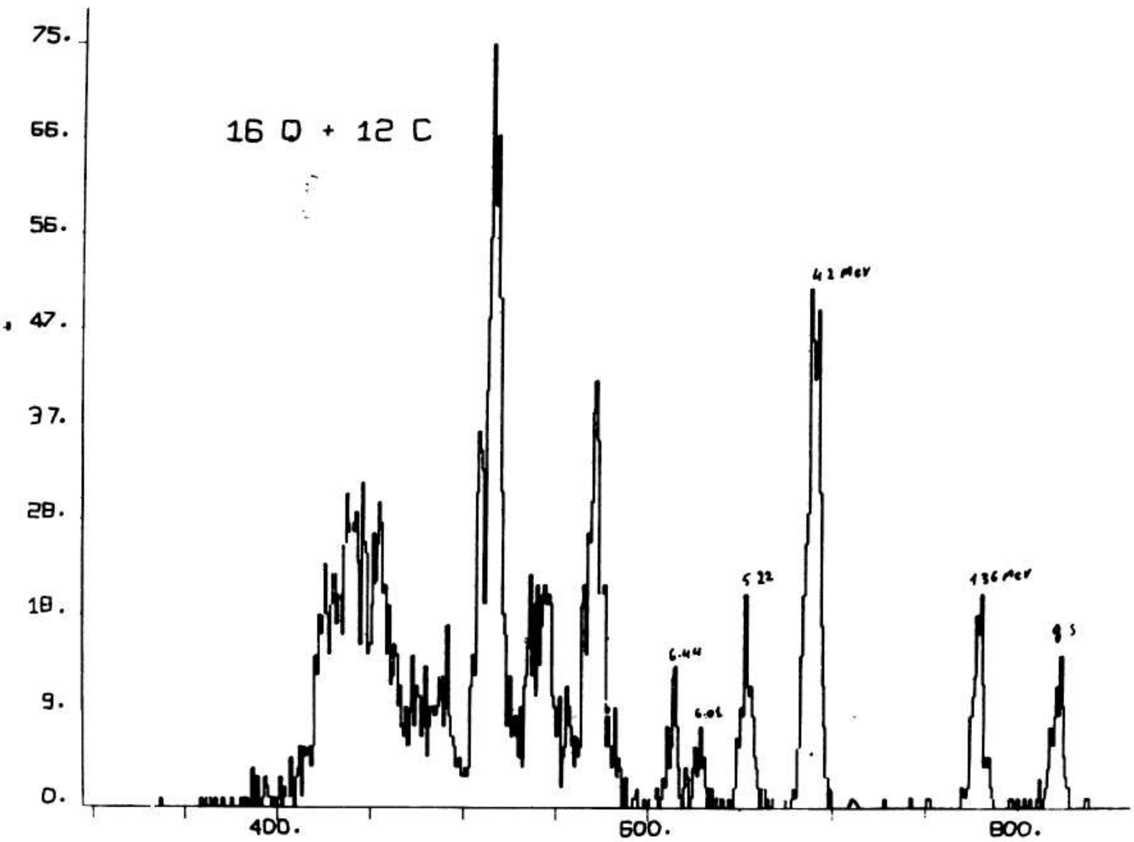


Fig. 1 ^{24}Mg spectrum from the $^{12}C(^{16}O,\alpha)$ ^{24}Mg reaction at E_L=25 MeV.

The excitation function (Fig.2) shows a correlation of the 26.0 MeV anomaly in several outgoing channels. The angular distribution for the alpha particles leading to the ground state of ^{24}Mg is shown in Fig.3 at E_{lab}=26.0 MeV. This distribution has a pure p_5^2 (cos Θ) behavior, which reflects the existence of a J^π=5$^-$ resonance in ^{28}Si at E_x=27.9 MeV.

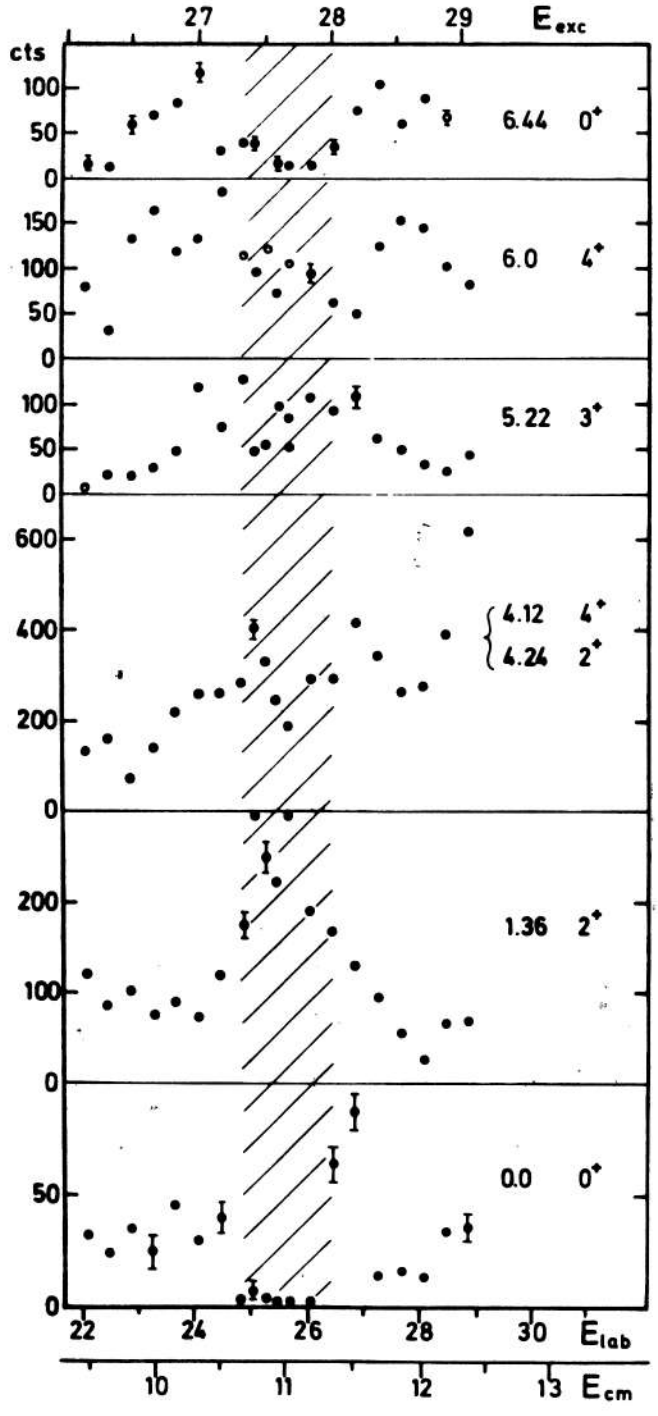


Fig. 2 The excitation function of the ^{12}C (^{16}O,α) ^{24}Mg reaction for the ground and six low lying states of ^{24}Mg. The shaded area maps the region of the observed anomaly.

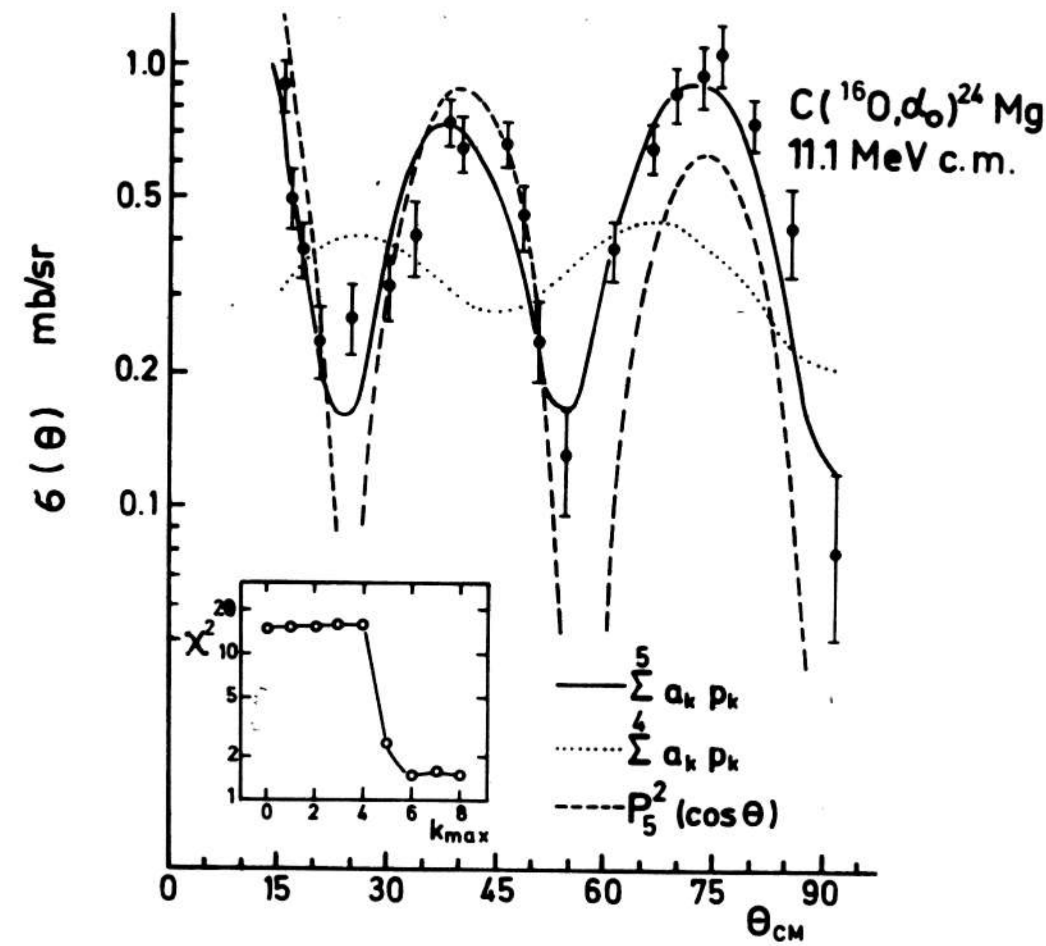


Fig. 3 The experimental angular distribution of the ^{12}C ($^{16}O,\alpha_o$) reaction and various fits.

Because of the large width of the resonance angular distribution measurements were also taken at E_{lab}=25.0 MeV with the same 50μg/cm^2 ^{12}C target, covering a 200 keV region of the resonance. The results were similar to those of E_{lab}=26.0 MeV. Measurements taken off resonance indicate n0 similar structure as that of the resonance.

++ University of Ioannina, Greece
\+ R.Boskovic Institute, Zagreb, Yugoslavia

II GAMMA RAY SPECTROSCOPY

1) *The ^{29}Si (^{16}O,xy γ) Reaction*

E. Adamides and A.C.Xenoulis

Excitation functions of γ rays produced by the reaction ^{29}Si (^{16}O,xy γ) have been determined at bombarding energies E (^{16}O)=27,29,31,33 and 35 MeV. These measurements were utilized in order to extract the population of several residual states which is caused exclusively by the nuclear reaction as a function of bombarding energy. Many exit channels, such as 2p,pn,n,p,2np, 2pn, α,αp and αn, were observed to carry out the reaction. However, the pn and 2p were the predominant exit channels and also the only exhibiting high-spin selectivity. Thus, mainly yrast states were observed in ^{43}Sc and ^{43}Ca up to $19/2^+$ J^π value.

Angular distributions of γ transitions deexciting the ^{43}Ca and ^{43}Sc have been obtained at 31.5 MeV and analyzed with a theoretical method developed in this laboratory. It may be interesting to mention that the angular distribution coefficients measured in this work agree within the experimental error with those measured by Poletti et al[1], where a different nuclear reaction, ^{27}Al (^{19}F,xy) was used. This may be interpreted as evidence against the "random walk" hypothesis about the width of the magnetic substates population distribution.

We intend to measure the same distributions at different bombarding energies in order to clarify whether or how they depend on the energy of the bombardment.

1. A.R. Poletti, E.K. Warburton, J.W. Olness, J.J. Kolata and P. Corodetzky, Phys. Rev. 13C 1180 (1976)

2) *Study of the ^{13}C (^{18}O,xγ) Y Reaction**

E. N. Gazis, A. Xenoulis , P. Kakanis and A.D. Panagiotou.**

In our program of investigating the properties of neutron rich light nuclei and the reaction mechanism involved we studied the ^{13}C (^{18}O,xγ) Y reaction at incident beam energies between 22 and 31 MeV in the laboratory. A ^{13}C target of about 150 μgr/cm^2 Au backing, was bombarded by $^{18}O^{5+6+}$ ions, obtained from an inverted sputter ion source by introducing ^{18}O (95% enrichment) water vapor . Beam currents of about 180 nA were obtained on target.

At first we have obtained single γ-spectra for many energetically available exit channels. It was found that the strongest channels are the following.

^4He	3n	(^{25}Mg)
p	3n	(^{27}Al)
p	2n	(^{28}Al)
	2n	(^{29}Si)

This observation is in marked difference with the well studied reactions $^{16}O + {}^{12}C$, $^{16}O + {}^{16}O$, $^{12}C + {}^{12}C$ (ref. 1-3) . The difference in the exit channels is probably due to the fact that in our reaction the compound nucleus, $^{31}Si^*$ has a large excess of neutrons which are preferentially emitted.

Fig. 1. shows a typical single γ-ray spectrum, in which we have identified the strongest transitions . The energy callibration is correct within ± 1 keV.

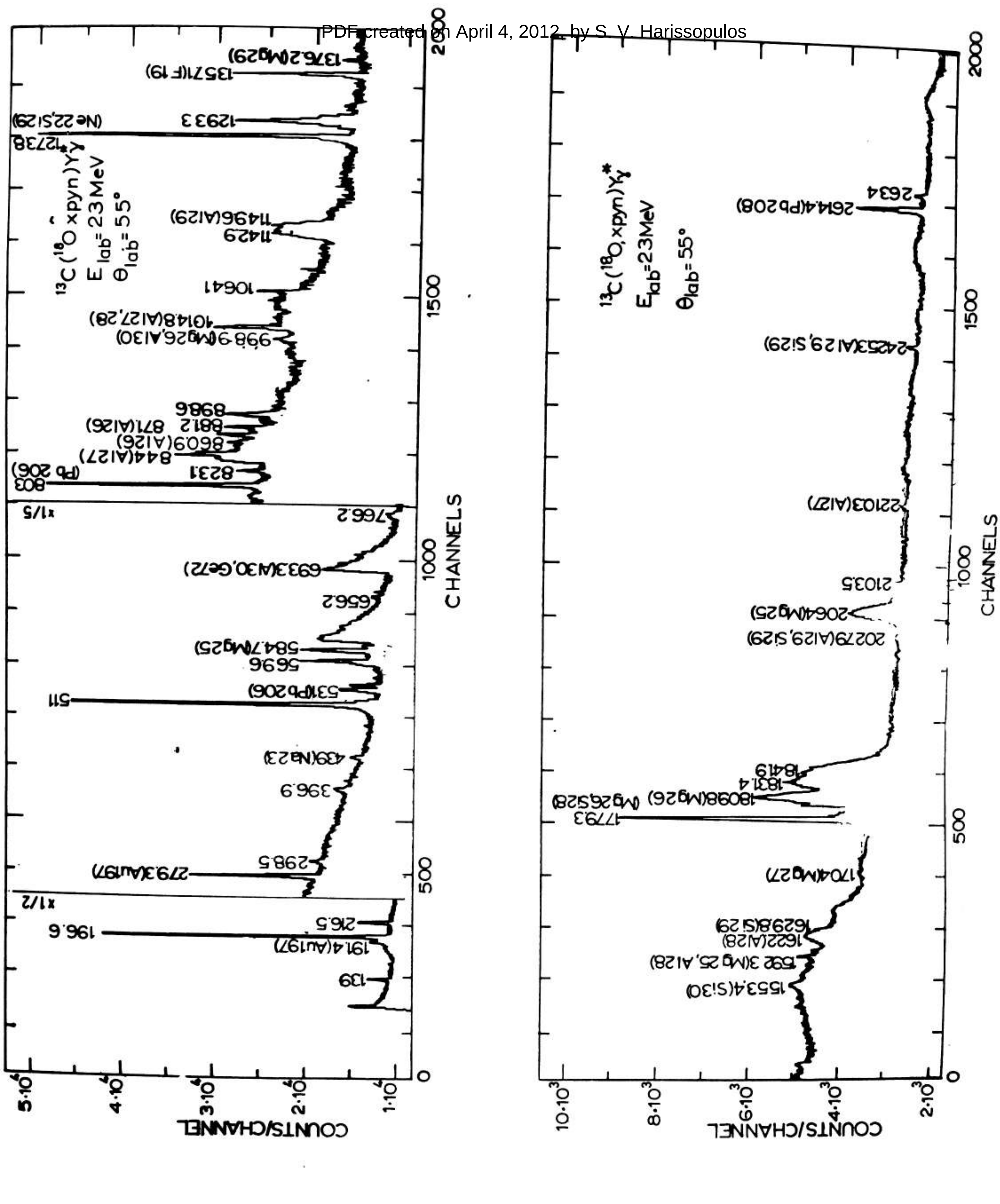


Fig. 1. The spectrum emitted in the reaction ^{13}C (^{18}O,xpyn) $Y^{*}\gamma$ at 23 MeV incident energy.

We have also obtained excitation functions for the str ngest channels in the energy range of 22.5 to 30.8 MeV and letecting lab. angle of 55^{o}. We are currently in the process of comparing this yeld curves with the theoretical predictions of the particle-evaporation code CASCADE (ref. 4)

The code CASCADE has been adopted and tested for operating in the IBM-375/145 and CDC-7700 Ciber Computers. It calculates the mass and Z-distribution of the evaporation particles in a fussion heavy ion reaction. It starts from an excited compound nucleus, calculates decay widths for neutron, proton, α and γ emission using the Hauser-Feschbach formula and generates population matrices (in an excitation energy-angular momentum play) for the daughter nuclei.

The code CASCADE (ref.5) which is used for extracting nuclear life times from analysis of the shapes of γ-rays obtained in Doppler Shift attenuation experiments, has also been rearranged and tested for operating in the CDC-3300 Computer of N.R.C. Demokritos. It should be mentioned that the shape method gives the best results, when the Doppler shifts are rather large and therefore, is particularly suited for heavy ion reaction spectroscopy.

1) Nucl. Phys. A179 (1972), 594
2) Phys. Rev. C13 (1976) , 156 Nucl.Phys. A238 (1975) 409
3) Phys. Rev. Lett 37(1976), 321
4) The code was kindly supplied to us by Dr. Pühlofer, G.S.I Darmstadt, Germany
5) The code was kindly supplied to us by Dr. Warburton, Brookhaven National Laboratory, USA

3) *Interpretation of Directional Correlation Behavior of Electromagnetic Radiation Emitted in Heavy-Ion Reactions*

E. Adamides and A.C. Xenoulis

Without any assumption about reaction mechanism we have employed a two-dimensional fitting procedure in order to extract information about J,δ and magnetic population distribution values from directional correlation measurements of γ-rays emitted in heavy-ion reactions. We have carried out a systematic study in order to determine the dependence of the substates population distribution on the kind of projectile, the spin of the residual state and the effect of the electromagnetic deexcitation from above. The theoretical predictions were compared with the results of a consistent analysis of experimental distributions. With the results obtained we can conclude the following:

1. Often the electromagnetic transitions are stretched but by no means always.

2. In order to evaluate the substates distribution caused by the reaction one has to take into account the electromagnetic cascade feeding from above. On the contrary, the δ values are not affected by the cascade corrections.

3. The almost universally assumed insensitivity of A_2 and A_4 values to the substates distribution width used in the correlation has been seen to be only circumstantially true.

4. The comparison of the magnetic substates population width of levels excited in the same exit reaction channel shows that it does not remain constant, but that it may change from level to level.

5. The overall comparison of population width caused by different exit channels shows that this does not depend on the number of emitted particles.

Our data indicate that the present methods may be used in order to clarify the mechanism of heavy-ion reactions.

4) *Study of the $^{55}Mn + ^{16}O$ reaction*

C.Lebrun*, D.Ardouin*, F.Guilbault*, B. Remaud*, T.Paradellis, G.Costa**, R.Seltz**, M.Vergnes***, G.Berrier***

From the analysis of the induced radioactivity as well as the on line singles spectra the formation cross section of many exit reaction channels have been determined as follows:

Cross section in mb

Bomb.Energy (MeV)		37.5	40.0	42.5	45.0	47.5	50
Nucleus	channel						
Ge69(R)	pn	7±2	31±7	67+15	142±28	210±35	210±35
As69(R)	2n	13±2	34±5	50±8	65±11	69±12	74±10
Zn68(I)	3p	0.4±0.1	2.2±0.4	4.7±0.8	7±1	8.8±1.5	18±3
Ga68(R)	2pn	1.8±0.4	7.3±1.2	21±4	40±8	60±10	152±25
Ge68(I)	p2n		19±3	37±6	63±11	90±20	190±40
As68(R)	3n		0.16±0.04	0.28±0.07	0.90±0.18	2.3±0.5	8.4±1.6
Zn66(I)	3p2n	1±0.2	4.6±0.8	7.3±1	10.5±2	12±2	19±3
Ga66(R)	2p3n	4.6±0.8	16.5±3	28±4	47±10	67 ±15	120±20
Ga65(R)	2p4n	0.07±0.02	0.42±0.09	1.4±0.3	3.7±0.7	7.9± 1.5	16±3

(R) From radioactivity data

(I) In beam data. Total cross-section is estimated from the $2_1^+ \rightarrow 0^+$ γ ray yield assuming that 90% of the transitions in the even even nuclei proceed through this state.

Currently the γ-γ coincidence spectra, accumulated at 47.5 MeV bombarding energy, are analyzed to establish the decay scheme of the ^{69}Ge, ^{68}Ge, ^{69}As, ^{68}Ga and ^{66}Ga nuclei.

* Institute de Physique de Nantes, France
** Centre Nucleaire de Recherche de Strasbourg, France
*** Institut de Physique Nucleaire d'Orsay.

5. *Excited States in ^{69}Ga Observed in the (p,p′γ) Reaction*

T.Paradellis , and G. Vourvopoulos

Angular distributions and Doppler shifts of the γ-rays deexciting levels in ^{69}Ga were taken at several bombarding energies between 3 and 5 MeV.

The analysis of the data supports the following spin and mean lives for the excited states of ^{69}Ga populated in the (p,p′γ) reaction.

Level (keV)	J^{π}	τ (ps)
318.7	$1/2^-$	
574.2	$5/2^-$	
872.1	$3/2^-$	0.36±0.05
1028.5	$1/2^-$	1.8 ±1.5
1106.8	$5/2^-$	0.33±0.05
1136.6	$7/2^-$	2±1
1487.9	$7/2^-$	
1525.2	$3/2^-$	

The interesting feature is that the spin of the 1106.8 keV level has been shown to be $5/2^-$ indeed as previous γ-γ distribution results suggested[1], and not $3/2^-$ as it was widely accepted. This result is in agreement with the core particle model which suggests a $5/2^-$ assignment for the 1106 keV level.

1. T.Paradellis, A.C.Xenoulis, C.A.Kalfas Z.Physik A275 (1975) 269

6) *Excited States in ^{69}Ge Studied in the $^{69}Ga\ (p,n\gamma)\ ^{69}Ge$ Reaction*

T. Paradellis, I. Galanakis, and G. Vourvopoulos

The $^{69}Ga\ (p,n\gamma)\ ^{69}Ge$ reaction has been studied at bombarding energies from 3 to 5.2 MeV . Excitation functions, population cross section, angular distributions and Doppler shift measurements resulted in the identification of the following level in ^{69}Ge.

Level (keV)	J^{π}	τ (ps)
0.0	$5/2^-$	
232.7	$3/2^-$	
373.9	$3/2^-$	
397.9	$9/2^-$	
812.2	$5/2^+$	
862.0	$7/2^-$	4±2
933.1	$5/2^-$	2.2±1.0
994.9	$1/2^-$	1.8±1.0
1195.7	$5/2^-$	0.8±0.2
1210.1	$7/2^+$	
1278.3	$1/2^-$	2.6±1.7
1306.9	$3/2^-$	0.72±0.25
1350.4	$11/2^+$	0.72±0.16
1414.8	$5/2^-$	1.4±0.6
1430.3	$9/2$	0.78±0.20
1432.3	$3/2^+$	
1466.0	$9/2^+$	3±2
1478.7	$7/2^-$	0.43±0.12
1539.2	$3/2^{(-)}$	0.51±0.20
1590.8	$7/2^+$	3±2
1601.2	$5/2^+$	0.75±0.25

7) *Study of Zn^{64} through the $Zn^{64}(p,p'\gamma)$ Reaction*

J. Galanakis and T. Paradellis

A 99.08 % enriched Zn^{64} target $4 mg/cm^2$ thick has been bombarded with protons at E_p=7.5, 6.5, 5.5 MeV. Single γ-ray spectra were obtained with a Ge(Li) detector at $\vartheta^o=90^o$ with respect to the beam direction. In these spectra some rays were observed due to the $Zn^{64}(p,\alpha\gamma)Cu^{61}$ and $Zn^{64}(p\gamma)Ga^{65}$ reactions. Through the collected data, a decay scheme has been constructed with the following levels. (in keV):

991.5	1799.7	1910.0	2306.7	2609.4	2737.0	2980.6
2998.5	3006.3	3077.3	3094.8	3187.0	3206.3	3260.9
3296.3	3365.5	3422.8	3598.2	3702.2	3718.0	3791.4
3851.0	4131.0	4202.9	4254.6	4847.0	6125.4	

Angular distribution and lifetime measurements are in progress.

8) *High-Spin States and Multipole Mixing Ratios of Transitions in ^{94}Mo*

C.A. Kalfas, S.P. Papaioannou, E. Adamides and A. Xenoulis

In relation with our systematic efford to determine the nature of nuclei in the proton $(1g_{9/2})$ region we have measured directional correlations for 8 γ-γ cascades in ^{94}Mo populated in the decay of a 7^+ metastable state of ^{94}Tc, employing a NAI (Tl) - Ge (Li) coincidence system.

Our results, which were obtained by properly averaging five independent measurements, were firstly utilized to establish an unambigurous 6^+ assignment to the 2423.4-keV level, a fact which was decisive in order to interpret the character of electromagnetic transitions from higher lying states. Thus, the γ-rays at 532.1, 849.7 and 871.0 keV were found pure quadrupole originating from 8^+ , 6^+ and 2^+ states, respectively. γ rays at 449.1, 742.3 and 916.1 keV were determined to have unique E2/M1 mixing of 0.07 ± 0.09, $0.17^{+0.28}_{-0.49}$ and $-0.28^{+0.24}_{-0.28}$ δ value, respectively, all originating from 6^+ states in ^{94}Mo.

The mixing ratios observed indicate the prodominent single-particle character of the commensurate states in ^{94}Mo.

9) *^{94}Mo (p,p',γ) ^{94}Mo and ^{94}Mo (p,nγ) ^{94}Tc Reactions Studies*

E. Adamides and A.C. Xenoulis

Angular distribution and Doppler shift measurements of the γ rays emitted in the reaction ^{94}Mo (p,nγ) ^{94}Tc at Ep=6 MeV have been carried out and analyzed in order to extract mixing ratios of transitions and spin and life-times of levels below 1 MeV of excitation in ^{94}Tc.

In order to extend the investigation of the structure of ^{94}Tc above 1 MeV of excitation we have bombarded ^{94}Mo targets at Ep=6.7, 7.0, 7.4 and 8.0 MeV. In these experiments many γ rays come from previously unobservedlevels in ^{94}Mo and from levels in ^{94}Tc above 1 MeV of excitation where the structure of ^{94}Tc is totally unknown. More measurements, such as particle -γ coincidence, γ-γ coincidence and excitation functions, are necessary to clear these problems.

10) *Structure and Directional-Correlation Measurements in ^{97}Tc from ^{97}Mo (p,n) $^{97}Tc^{*}$ (γ) Spectrometry*

A.C. Xenoulis and C.A. Kalfas

The level structure and the decay properties of levels in ^{97}Tc up to 2150 keV of excitation have been investigated via measurements of excitation functions and Ge (Li) - Ge (Li) γγ-coincidence experiments following the ^{97}Mo (p,nγ) reaction with proton energies between 1.5 and 8.0 MeV . From this measurements and from γ-ray energy and directional correlation measurements an extended level scheme of ^{97}Tc has been obtained which includes 73 states with $J^{\pi} \geq 13/2^{+}$ among which 50 states have not been previously observed. The directional correlation measurements for 40 transitions provided J^{π} assignments and multipole mixing ratios from the analysis via the compound statistical theory for nuclear reactions. The results obtained in this work, part of which for the lower lying states we show in Fig. 1, indicate that the structure of ^{97}Tc is much more complex than what it was believed until recently. A comparison of the present data with recent theoretical calculations indicated a qualitative agreement between theory and experiment and only for the very few first excited states.

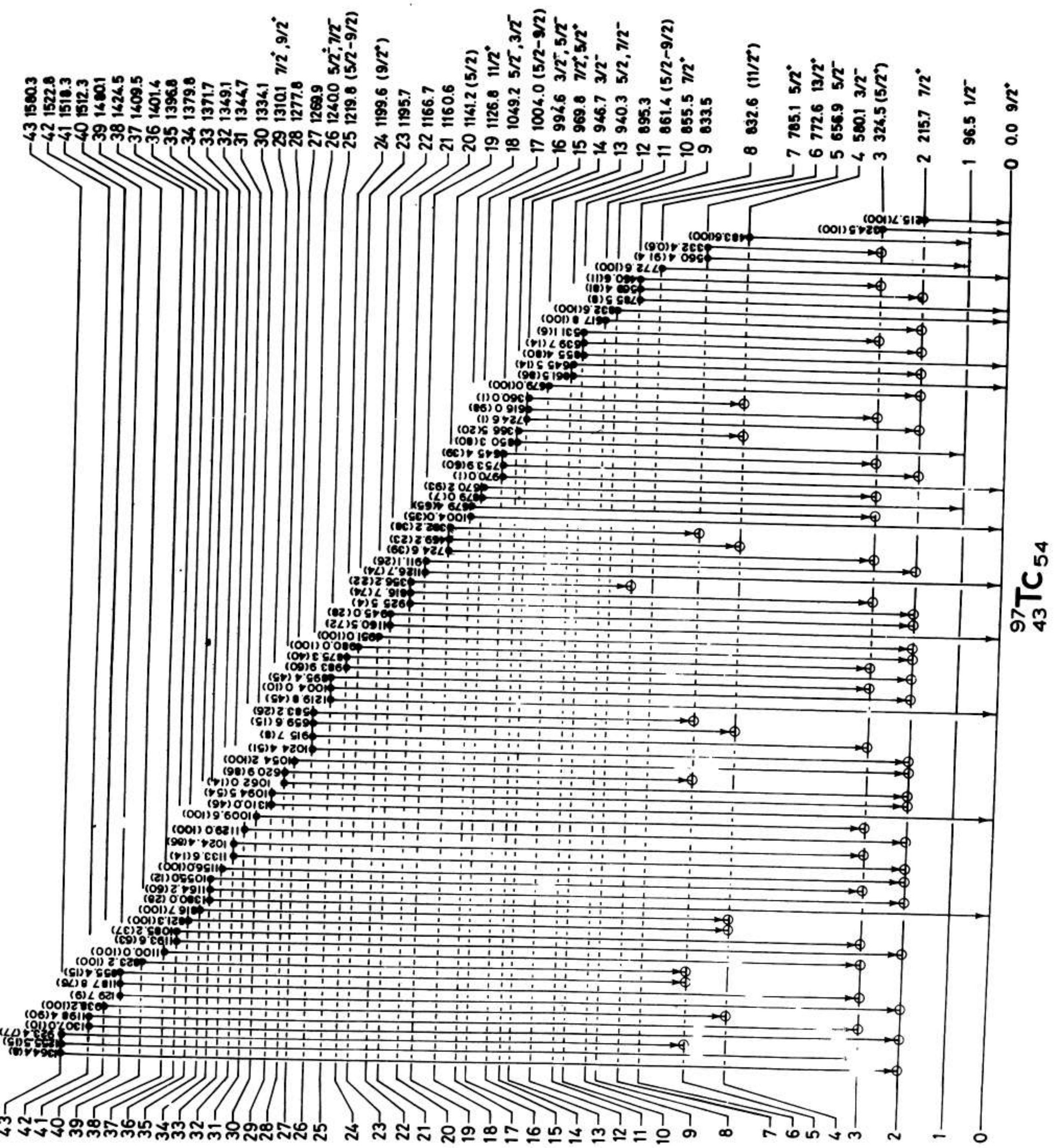


Fig. 1

Level structure of ^{97}Tc.

III APPLIED ATOMIC AND NUCLEAR PHYSICS

A. X-RAYS SPECTROSCOPY

1) *Sensitivity of the External Beam PIXE Elemental Analysis Method**

A. Katsanos and A. Hadjiantoniou

The sensitivity and limitations of the external beam PIXE method was investigated for the elemental analysis of thin and thick targets of various matrices. The targets used were thin metallic foils 20 to 100 $\mu g/cm^2$ on mylar backing, and thick samples of mixtures of various compounds in the form of high density pellets prepared under standardized conditions.

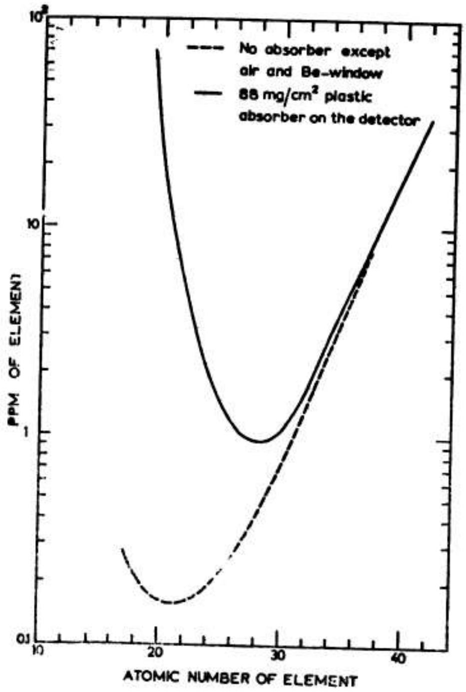


Fig. 1.

Determination Sensitivity vs. atomic number

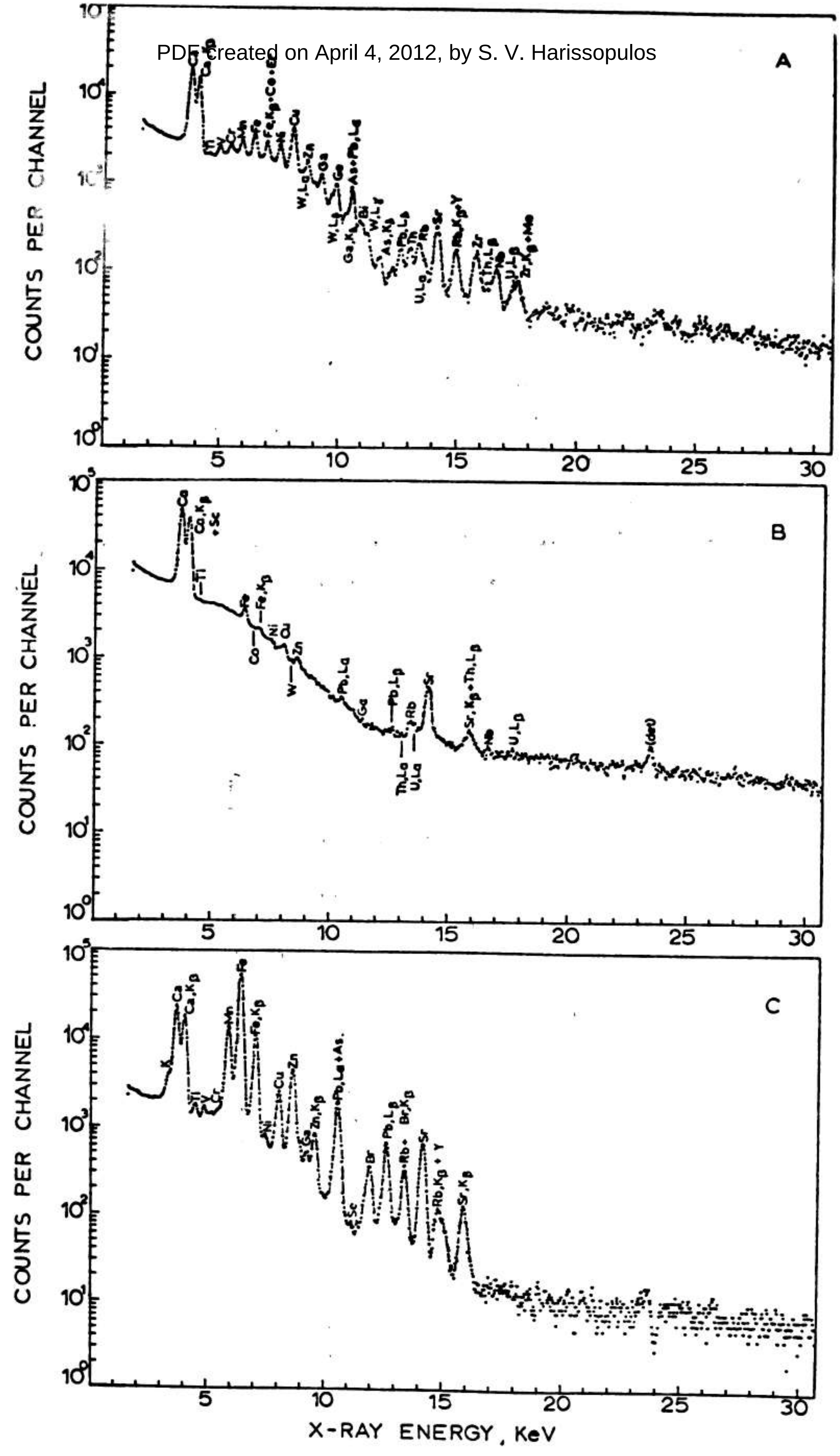


Fig. 2.

The X-ray spectra of some NBS standards

In Fig. 1 curves of sensitivity limits for the detection of the various elements in thick targets are presented as a function of atomic number. One may generally say that sensitivities for ashed biological tissue or blood samples vary from 0.01 to 0.5 ppm for Z varying from 30 to 45 for the K-lines and similarly for Z from 50 to 90 for the L-lines. Gaseous targets are analysed by irradiation in a special cell. The sensitivities vary between 1 to 10 ppm at atmospheric pressure. Liquid samples are prepared by liquid deposition on various porous backings and the observed detectable limits are again in the sub-ppm level. Finally, sensitivities of 1 to 10 ppm and selectively up to 0.1 ppm, have been obtained for thick ore samples.

For testing the above conclusions, several standards from the NBS of the USA were analyzed. The X-ray spectra for NBS Glasses 612 and 614 containing several elements in the 50 ppm and 1 ppm regions, respectively, are displayed in Figs. 2A and 2B. In Fig. 2C the X-ray spectrum of NBS orchard leaves is shown.

* Supported in part by the International Atomic Energy Agency, Vienna, Austria.

2) *Correlation Study of Trace Elements in Skin Cancer Tissues by the PIXE Microanalysis Method*

A. Hadjiantoniou, A. Katsanos J. Stratigos[+] and J.Capetanakis[+]

A program for analysis of skin cancerous and precancerous tissues and comparison with healthy ones has been started, in order to establish variations in the concentration of various trace elements. The elemental analysis is performed by Proton Induced X-ray Emmission Spectroscopy (PIXE) at the Tandem Accelerator Laboratory of the Demokritos N.R.C. utilizing the external proton bean facility established in this laboratory. Skin tissue samples are collected at the "A" Sygrou Hospital, Department of Dermatology, University of Athens. The results obtained so far indicate correlation between malignancy of the skin tissue and an increased concentration of certain metallic elements such as Ni and Pb.

+ Sygrou Hospital of Athens

3) *Air Pollution Measurements*

V.Katselis and T.Paradellis

During the year, samples of airborn particulates have been collected from the industrial city of Elefsis (22km west of Athens) and from the site of the NRC Demokritos (East outskirts of Athens). So far the analysis of the data from the city of **Elefsis** shows a strong decrease of the Ca content of the atmosphere in comparison with the measurements conducted two years ago. In particular the average Ca content has fallen from 63 $\mu g/m^3$ (1975) to 28 $\mu g/m^3$ (1977). This decrease can be attributed to the new electrostatic filters in the Portland cement industries of the region.

On the other hand, the levels of Fe (due to the activities of the steel industry) remained constant at the level of 5.3 $\mu g/m^3$. Although the Br content (due to car exhausts) rose slightly from 76ng/m^3 (1975) to 83ng/m^3 (1977) the Pb content rose from 0.78 $\mu g/m^3$ to 1.15 $\mu g/m^3$. Based on the PB:Br ratio which is expected to be about 5 for car exhaust, most of the Pb observed can be certainly attributed to other polluting causes. In some days as much as 8 $\mu g/m^3$ of Pb have been measured while the Br level remained to about 76 ng/m^3.

It is very probable that this excessive increase in Pb is associated with the large increase observed in the Zn content which rose from 0.27 $\mu g/m^3$ in 1975 to 0.70 $\mu g/m^3$ in 1977. Since both Zn and Pb are used extensively in paint manufacturing, the paint industries of the region may be responsible for the Pb and Zn air contamination. As for the Pb specifically, leackage of Pb compounds from the oil refineries of the region or from coal burning cannot be excluded.

4. *Determination of Trace Elements in Geological Samples*

T. Paradellis and V. Perdikatsis[+]

In the context of this program XRF is used to determine trace elements in granites . A ^{109}Cd source is used and a correction is made based on an average attenuation curve for self absorbing, which is determined from the average composition of granites in Si, O, Al, Mg and Fe.

Two international geological standards, the granodiorit USGS-GSP 1 and granit USFS-G2 have been analyzed by this method. Within experimental error an excellent agreement is obtained between the measured and the quoted standard composition of trace elements.

+ Institute for Geological and Mining Research, Athens

5) *Search for Superheavy Elements Using XRF*

T. Paradellis

A program has been initiated for a search of superheavy elements, using photon induced X-ray fluorescence.

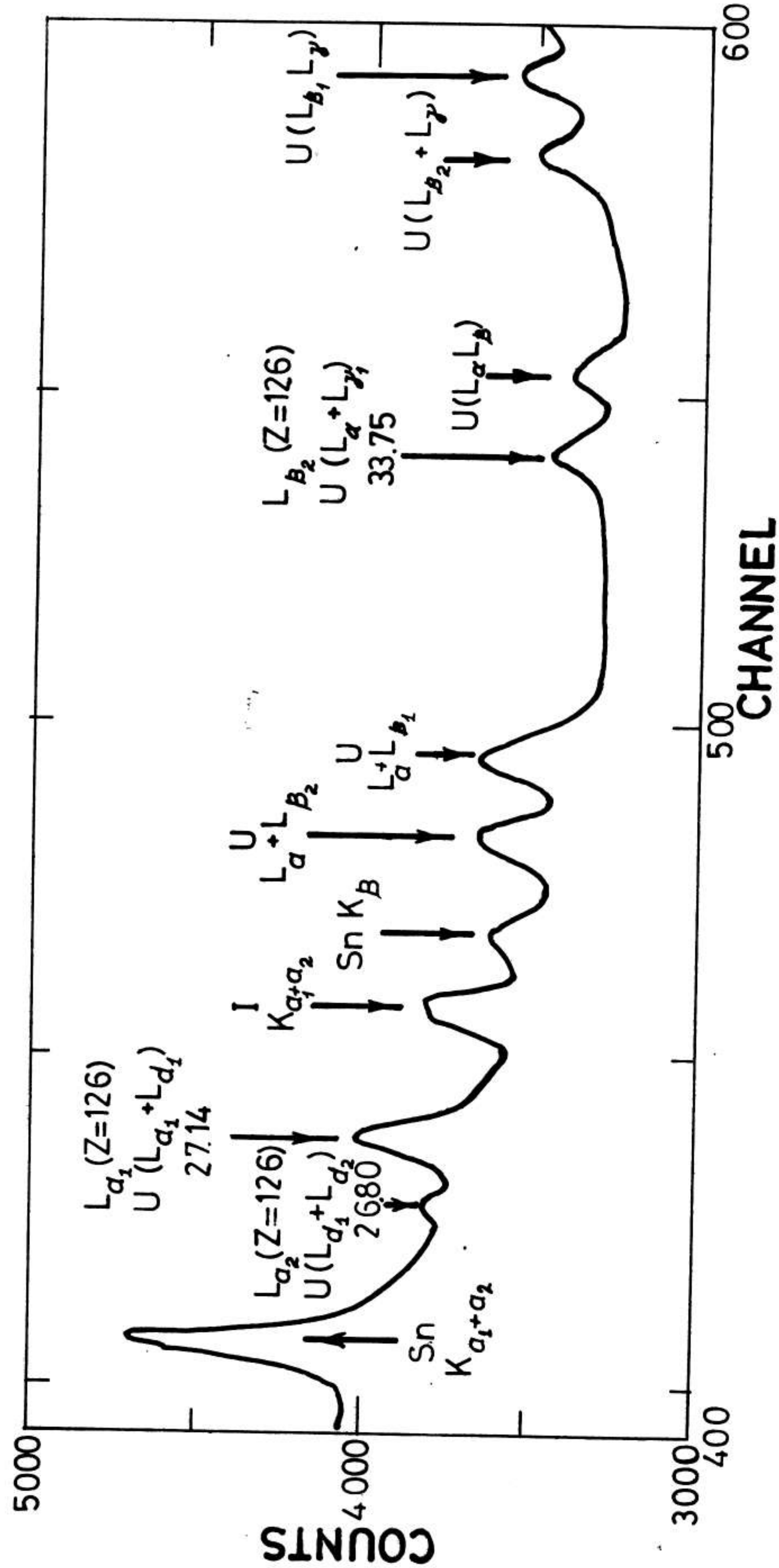
The project is based on the attempt to observe the characteristic L_α, L_β, L_1 X rays of any superheavy element existing with $Z \leq 130$ as a trace impurity in different samples. Since it is difficult to guess on the chemistry of unknown elements, it is believed that if such elements exist in nature they may be found as trace contaminants in chemically enriched rare earths, lead, bismuth, thorium or Uranium salts.

A 5mC ^{241}Am radioactive source in capsule has been used in Π geometry to excite a thick Uranium oxide sample enriched to 99% in U. A spectrum of 48 hrs run is shown in fig.1.

The famous peak at 27.20 keV observed by Gentry et al and attributed to element Z=126 ($L\alpha_1$) is also observed as well as other peaks at 26.8 and 33.78 keV which could be attributed to the $L\alpha_2$ and L_β lines of the same element.

The problem here is that the energy of these lines and their intensity is close to the expected sum peaks of the U X-rays.

At the present stage of the work a 25mC ^{241}Am is in order, while a system of suitable absorbers which will reduce the number of U L X-rays reaching the Si (Li) detector is in the making. It is expected that with optimum conditions a 10^{-7} -10^{8} limit may be reached for the detection of any superheavy contaminant in the examined samples.


COUNTS
5000
4000
3000
400
500
600
CHANNEL
Sn $K_{\alpha_1+\alpha_2}$
L_{α_2}(Z=126)
U(L_{α_1}+L_{α_2})
26.80
L_{α_1}(Z=126)
U(L_{α_1}+L_{α_1})
27.14
I $K_{\alpha_1+\alpha_2}$
Sn K_β
U L_α+L_{β_2}
U L_α+L_{β_1}
L_{β_2}(Z=126)
U(L_α+L_{γ_1})
33.75
U(L_α L_β)
U(L_{β_2}+L_{γ})
U(L_{β_1} L_{γ})

6) *Molecular Motion of Polyglutamic Acid Studied by Perturbed Angular Correlation of Gamma rays.*

P.W. Martin[+], K. Skov[++] and C.A.Kalfas

The technique of perturbed angular correlations (PAC) of γ-rays has been applied to the study of biological macromolecules.

In these studies, a radioactive probe is attached to the molecule of interest and the coincidence counting rate, $W(\vartheta, t)$, of two successive γ-rays is measured as a function of the angle ϑ between their directions of propagation.

The present meausurements, incorporating ^{111}In as a label, were undertaken in order to investigate the potential of PAC as a quantitative tool in studying molecular dynamics of biological macromolecules. In this case two species of polyglutamic acid were investigated, one of molecular weight 14,700, the other of 98,000. The objective was to investigate whether PAC could differentiate the respective rotational correlation times of the molecules in aqueous solution and also to obtain information on the nature of the binding of the attached probe.

The results show that within experimental error, the ratio of the measured correlation times, $\tau_c(98{,}000)/\tau_c(14{,}000) = 10.3 \pm 4.0$, is consistent with the value ~ 13.5 expected on the basis of the molecular weights and viscosities. The effect of viscosity alone would produce only a factor of $\sim 2{:}1$ in this ratio, giving credence to the assertion that the ^{111}In is in fact bound to the polyglutamic acid and that in fact the results truly reflect the dynamics of molecular motion.

The consistency in the values for the quadrupole frequencies and asymmetry parameters also imply that the binding is specific, although for the purposes of this investigation, this need not necessarily have pertained. Presumably the polyglutamic acid binds to carboxyl groups along the polymer.

+ University of British Columbia, Physics Department

++British Columbia Cancer Institute.

7) *Production of ^{28}Mg*

S.Kossionides, and C. Kalfas

One of the isotopes used for medical applications is ^{28}Mg. The most commonly used reaction for its production by accelerators is ^{26}Mg (t,p) ^{28}Mg. This reaction cannot be considered for our accelerator since it would create tritium contamination problems, which the laboratory is not prepared to face. Thus, in the search for an alternative possibility we tried the reaction ^{23}Na (^{7}Li,2p) ^{28}Mg. Natural Soda ($NaCO_3$ pro analysi) was selected as the target since C and O cannot lead to ^{28}Mg. A few gramms of the powder were wrapped in thin Al foil thus creating a "thick" target which was bombarded with 20nA of $^{7}Li^{3+}$ at E=16 MeV for 19.5 hours. After irradiation the powder was transferred to a plastic cylinder and the γ-ray spectrum observed with a Ge-Li detector. All long lived activity could be attributed to the decay of ^{23}Na (^{7}Li,^{6}Li) ^{24}Na. From this decay the initial source strength was estimated to be 30nC. The contribution to this strength of the reaction ^{27}Al (^{7}Li,^{6}Be) ^{28}Mg can be considered as negligible since this reaction has a negative Q value (Q=-5.644 MeV) and the Al foil is thick enough to stop most of the ^{28}Mg from recoiling into the powder.

In any case, these qualitative results show that the reaction ^{23}Na (^{7}Li,2p) ^{28}Mg can not be used with our accelerator for the production of useful quantities of ^{28}Mg.

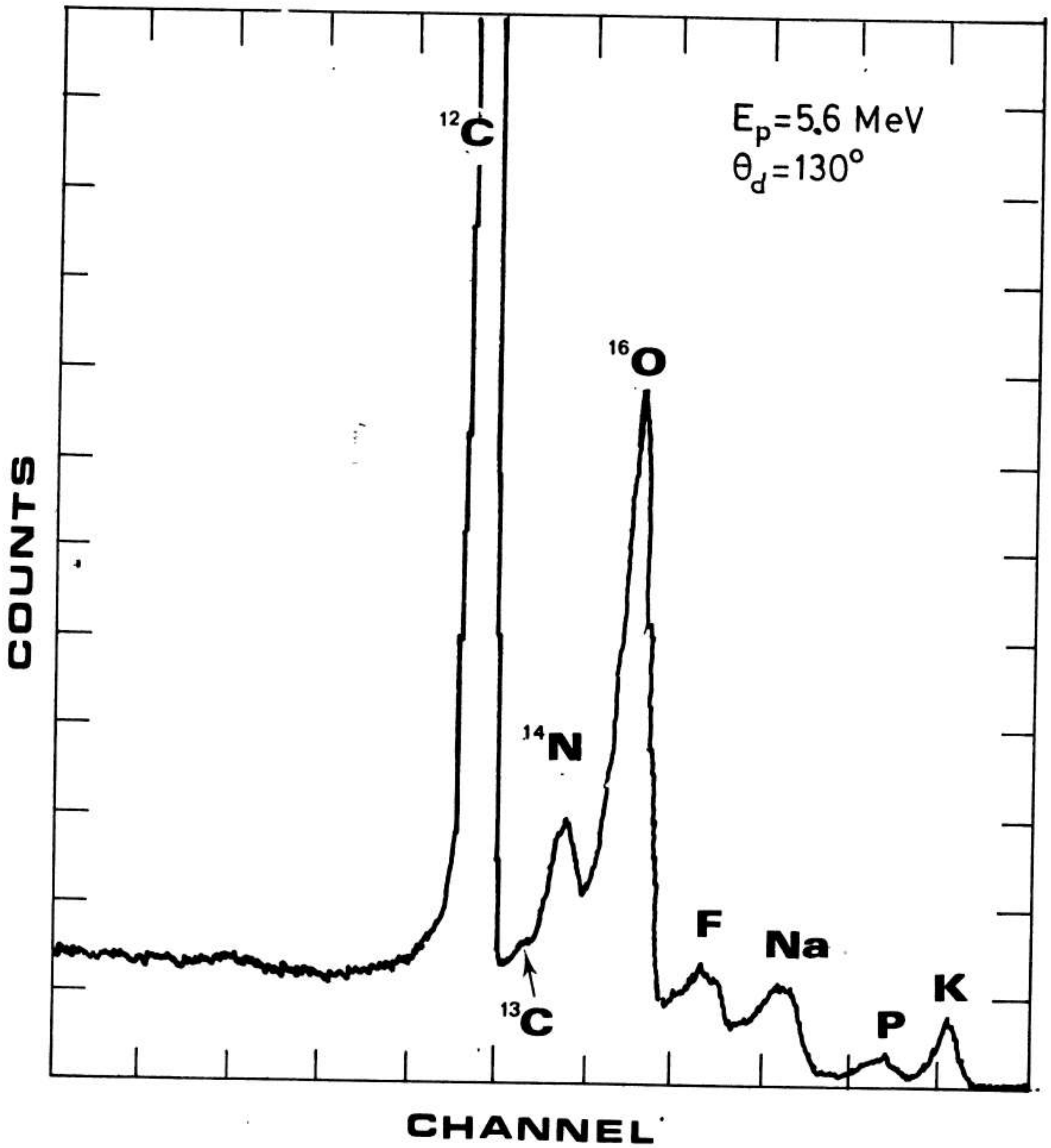
8) *Utilization of Proton Elastic Scattering as a Tool for Light Elements Microanalysis*

A.C.Xenoulis and A.Katsanos

It is well known that the elemental microanalysis methods utilizing X-ray spectrometry cannot be easily employed for the determination of elements lighter than Ca owing to the small energy of the corresponding characteristic X rays. On the other hand, the importance of light elements, especially in biological and agricultural projects, cannot be easily over-emphasized.

We have initiated a study in order to determine the feasibility of utilizing the property that the energy of an elastically scattered particle depends on the mass number of a scatterer for microanalysis of light elements. It should be pointed out that the main difficulty in such a method is presented by the small energy separation of elastic peaks from adjoint elements, which however varies with the energy of the bombardment and the angle of scattering. In order, therefore, to select the most favorable conditions for experimentation we have carried out theoretical elastic scattering predictions for all light elements up to K and for several bombarding energies and scattering angles.

Furthermore experimental measurements with several samples have been performed at an optimum beam proton energy of 7 MeV and backward detection angles. In Fig. 1 a proton spectrum of such an elastically scattered beam from a mixture of inorganic salts is shown, in which proton peaks corresponding to C,N,O,F, P and K can be observed. Our results indicate that this method may be applicable in the qualitative microanalysis oflight elements. The detection resolution, however, which is limited mainly due to sample thickness, must be considerably improved, especially for the determination of nitrogen.



C. INSTRUMENTATION

9) *Construction of a Gas Cell for Neutron Production*

G.Vourvopoulos

The need of a monochromatic neutron beam for (n, charged particle) experiments, led to the construction of a gas cell which could withstand high gas pressure and high beam currents. The cylindrical gas cell (3cm long, 1cm diameter) was fabricated from a 0.4 mm thick stainless steel tubing. Thin Mo windows (5 to 10 μm thick) are used as entrance foils. The back of the cell was made of a 0.2 mm platinum disc, which was used as a beam stop. During a number of tests beams up to 20μA of deuterons and pressures up to 2000 torr were utilized to ascertain the optimum foil thickness and gas pressure for the production of neutrons. The gas handling system has been constructed for the utilization of deuterium. The neutron producing reaction for the time being will be the D (d,n) ^{3}He reaction. At some later date the gas handling system will be able to accomodate Tritium for the T(dn,) ^{4}He reaction.

10) *Evaluation of the Efficiency in the Measurement of the ^2He Cross-Section*

P. Kakanis, E. Gazis, A.D. Panagiotou*

The reaction $^{12}C\ (^{16}O,^{2}He)\ ^{26}Mg$ was studied by detecting the ^2He, (Ref.1). ^2He is an unbound system, which breaks up into a pair of protons by its final state interaction.

If we assume a fixed break-up energy, the two protons are localised into a narrow cone, (Ref.2). The central axis of the cone is the direction of the original ^2He and the opening of the cone is limited by $(\vartheta/2)_{mx}=\arcsin\sqrt{\frac{E_b}{E}}$, where, E_b is the break-up energy and E the kinetic energy of the ^2He.

The probability distribution of the protons within the cone (with respect to the lab. system) is then proportional to the solid angle transformation. (We suppose that the decay is isotropic in the ^2He system).

$$P(r)=\frac{2\{1+K(1-2r^2)\}\ /\ (A^2+r^2)\ r}{A\{A^2+r^2(1-K)\}^{1/2}} \tag{1}$$

where: $K=\frac{E_b}{E}$, A is the distance of the detector from the target, and r is the radius of the cone at a distance A from the break-up point.

Evaluating this integral for all possible ^2He directions, encompassed by the detector solid angl , and dividing by the detector area, we obtain the geometric efficiency for ^2He detection with a circular counter of radius R:

$$W^{geom} = \frac{4}{\pi R^2} \int_o^R \int_o^{R-H} \int_o^{\{R^2-(X+H)^2\}^{1/2}} P(X,Y)\ H\ d\ Y\ dY\ dH; \qquad (2)$$

where H is the distance-on the detector-between the centre of the detector and the direction of ^2He.

In the actual case of ^2He, however, the disintegration energy of ^2He does not originate from the break-up of a narrow state, but is rather a broad distribution, described by the Watson-Migdal theory, (Ref. 3)

The angular distribution of the 2p's in the W.-M. formalism is given by:

$f(\Theta)=A'pp \int \Phi(E_b)\sqrt{\frac{E_b}{E}}\ dE_b$ (3) where $\Phi(E_b)$ is a function of the break-up energy and A'pp a function of the p-p scattering length (ref. 4)

Incorporating relation (3) in the geometric efficiency, we obtain finally the total efficiency for the detection of the break up protons:

$$W^{tot} = \frac{2A\tilde{p}p}{\pi R^2\sqrt{E}} \int_o^R \int_o^{R-H} \int_o^{\{R^2-(X+H)^2\}^{1/2}} \int_o^{E_b} HP(X,Y)\Phi(E_b)\sqrt{E_b}\,dYdXdHdE_b$$

The function Φ (E_b) in the last integral exists in tabular form: (Ref.3)

E_b (MeV)	0	1	2	3	4	5
Φ (E_b)	1.0	.82	.59	.40	.34	.31

We have evaluated this last integral with numerical methods, for $E_b^{(max)}$ =5MeV, and used it for an accurate calculation of the ^{2}He cross section in the reaction under consideration.

* Nuclear Physics Laboratory, University of Athens.

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IV THEORETICAL NUCLEAR PHYSICS

1) *A Study of ^{17}O*

H.A. Mavromatis and L.D. Skouras

In this work we study ^{17}O in a shell model space which includes all 1-particle , 2p-1h and 3p-2h states that are $2\hbar\omega$ in oscillator energy above.

The calculation involves setting up the three energy matrices (for j=5/2, 1/2 and 3/2) and then making convergence studies for the energy of the system, after first eliminating the unlinked graphs by means of O_2 box techniques similar to those of Krenciglowa and Kuo[1)]. The unlinked graphs arise because one is working in a finite space[2)] and must be eliminated in order to obtain linked plus folded graph expansions[3,4)].

The sensitivity of the convergence to a shift operator Λ which does not affect the overall results but which changes the contributions from various orders is also studied. It is shown that the case $\Lambda=0$ which corresponds to the choice of H_{osc} as zero-order part of the Hamiltonian does not produce convergence.

The results of the calculation have been obtained using both the original Sussex matrix elements[5)] as well as the modified saturating Sussex elements[6)].

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3) P.Goode, Nucl.Phys.A241 (1975) 311

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2) *An Extension of the VMI Model to Light Nuclei*

G.S. Anagnostatos

It has been noticed that $\mathcal{J}-\omega^2$ plots for ground state bands in light nuclei exhibit backbending like features[1] similar to the ones observed in heavy nuclei[2]. Extensions of the VMI model, e.g. VMI23 and VMI234, are in general capable of describing these features for heavy nuclei. These two extensions, however, are not sufficient to describe downbending features which are also observed in heavy and light nuclei. Recently, a unified VMI model was proposed[3] which incorporates both backbending and downbending features. In this new extension of the VMI model, the potential energy is a polynomial (in $\mathcal{J}-\mathcal{J}_0$) like in VMI23 and VMI234 and the kinetic energy includes, for the first time, higher order terms in I(I+1). The minimum number of terms depends, in the potential energy, on the number of roots of the equation $\partial\omega^2/\partial J=0$, and, in the kinetic energy, on the number of roots of the equation $\partial\mathcal{J}/\partial\omega^2=0$. (Both numbers are determined by simple observation of the corresponding $\mathcal{J}-\omega^2$ plot).

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3) *Maximum Abundant Isotopes*

G .S. Anagnostatos

In a recent publication[1] some new, hitherto unknown, features of the abundance distribution curve have been reported, which show an intrinsic consistency in the abundance distribution[2] and thus support the arguments for a common history of the elements during nucleosynthesis[3]. With the present communication an additional feature pointing to the same conclusion is reported.

In Fig. 1, the neutron excess number (N-Z) versus the neutron number (N) for all stable nuclides[4] is shown separately for even mass number, A (part a) and odd A (part b). The most stable isobar (i.e. the isobar with the least mass) for each A value is marked with a circle, while the other isobars, where they exist, are marked with squares.

As one can see from the figure, the neutron excess of the most abundant isotopes[4] of the elements (solid marks) has an overall linear dependence upon the neutron number for nuclei between neutron closed shells. (at N=8, 20, 50, 82 and 126), for the odd and for the even A nuclei. It is worth noting that if one considers for each element its isotope (if any) whose abundance is at least 50% of the abundance[4] of the maximum abundant isotope (half solid marks), it also follows the same linear dependence. These features, as the other features discussed in[1], cannot be explained by the Burbidge et al (B^2FH) cosmology[5] in which the abundances result from a mixture of products from several independent unrelated sources.

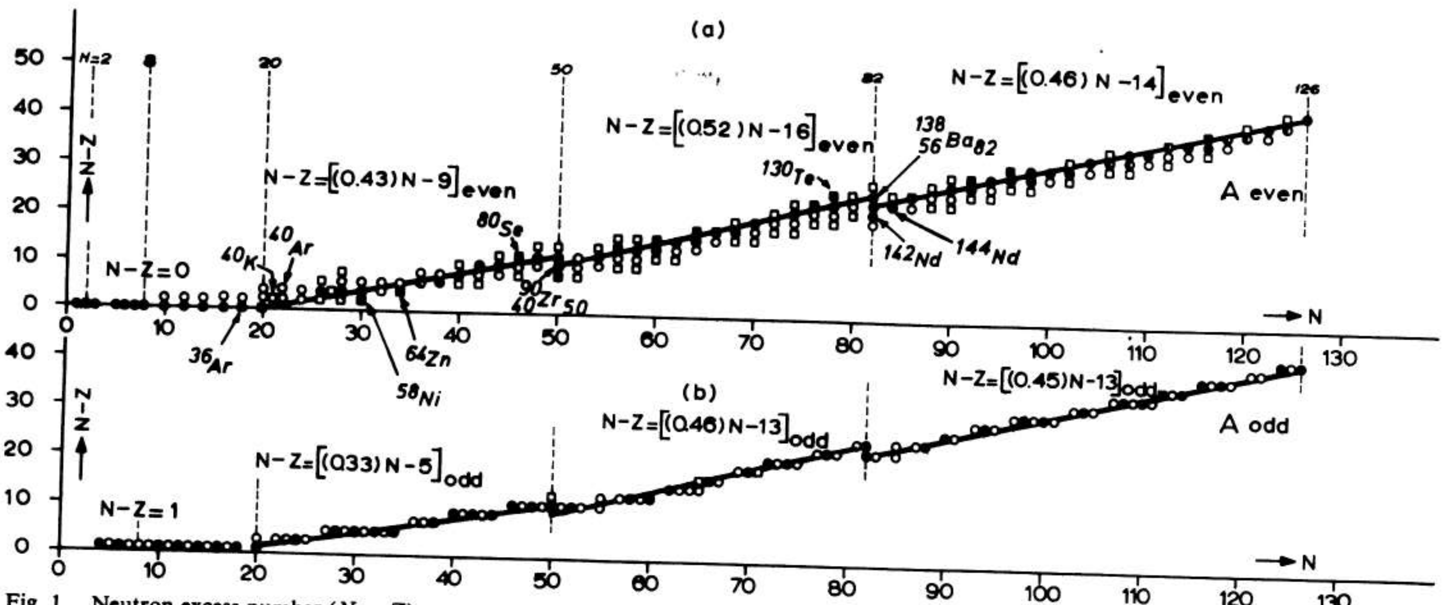

Fig. 1. Neutron excess number ($N - Z$) versus neutron number (N) of all stable isotopes of the elements, part (a) for even A, and part (b) for odd A. Circles indicate the most stable isobars; squares indicate the other isobars. The overall linear dependence of $N - Z$ upon N of the most abundant isotope of each element (solid mark) and of the isotope with abundance at least 50% of the abundance of the maximum abundant isotope (half solid mark) for nuclei between neutron closed shells (at N = 2, 8, 20, 50, 82 and 126) is apparent. The brackets in the corresponding least square fit equations stand for the closest integral numbers (even or odd as indicated) given by these equations. Nuclei labelled in the figure are discussed in the text.

It rather implies a common history of nuclides during nucleosynthesis , or at least during its ultimate phase[6)], in which the abundances of nuclear species were determined by the nuclear properties which define their yield in nuclear processes that lead to their formation[5)].

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4) *Super-Heavy Nuclei in the Framework of the Isomorphic Model*

G.S. Anagnostatos

In the last years a lot of theoretical and experimental work has been performed in searching for superheavy nuclei at possible new magic numbers beyond N=126 and Z=82. Depending on the model used, it has been found that the most probable next magic numbers may happen at Z≃114 or 126 and N≃184, or other neutron numbers. We wish to cross check these predictions with the isomorphic model.

As known, the isomorphic model[1-3] has succeeded in giving a sort of "structural " understanding of all known magic numbers, using the basic assumption that the nucleons are in dynamic equilibrium on spherical shells with central symmetry. The neutron number N=184, is not justified by the isomorphic model as a neutron magic number, since the difference of neutrons between N=126 and N=184, i.e. ΔN=58, cannot be reproduced by combinations of the numbers 12,20, and 30 which stand for the numbers of vertices of equilibrium polyhedra (namely, icosahedron, dodecahedron and icosidodecahedron) which in the model, represent the average shapes of nuclear subshells for heavy or superheavy nuclei. Considering a substantial split of the spin-orbit coupling for the harmonic oscillator potential level 2h, however, as in Fig. 1, the neutron number N=196 results, whose difference from N=126, i.e. ΔN=70, can be reproduced by the numbers 12,20, and 30. Thus the isomorphic model definitely favors N=196 instead of N=184 as the next neutron magic number. It is interesting to note that N=196 is supported by most modified harmonic-oscillator potentials[4-5].

The contribution to the next possible neutron magic number of two subshells from the higher harmonic oscillator shell (namely, 1j 15/2 and 2h 11/2) is reasonable

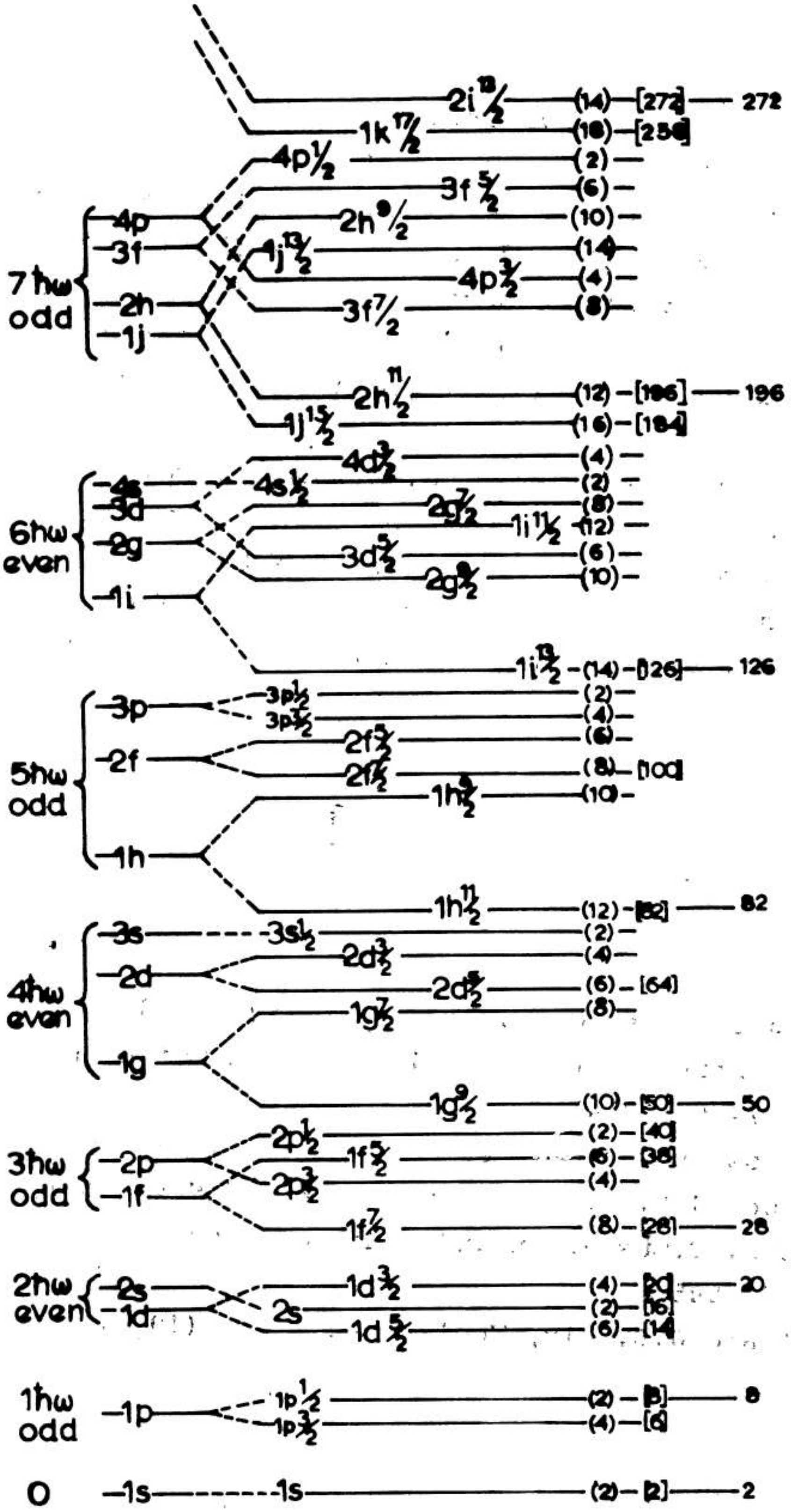

Fig. 1 Schematic diagram of nuclear level systems with spin-orbit coupling

in the following qualitative argument. As seen from Fig. 1, the splitting of levels due to the strong spin-orbit coupling in the first shells does not contribute to the formation of the magic numbers 2,8, and 20. Its contribution starts at the semimagic number 28 and becomes stronger at the heavier magic numbers (50, 82 and 126) Thus, an even stronger contribution to the superheavy magic number is not suprising.

For protons the model predicts magic numbers at the same numbers with neutrons. Thus, Z=126 is very favorable. The Z=114, however, corresponds to subshell of the isomorphic model and thus we cannot choose between these two numbers, before some additional work has been performed on the model .

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5. *Study of Some Heavy-Ion Induced α-Transfer Reactions with DWBA*

E. Mavrommatis

A extensive study of some heavy-ion induced α transfer reactions within the framework of DWBA has been undertaken. Test and improvements of some assumptions are planned in an effort not only to obtain as close as possible agreement with the experimental angular dependence of the cross sections but also to extract reliable values for the α-spectroscopic factors. We have started with the reaction $^{16}O\ (^{16}O,^{20}Ne)\ ^{12}C$, which has been studied at some energies in our Laboratory[1], and with the DWBA formalism of Braun-Munzinger et al[2] (coded as BRUNHILD) , which allows approximately for recoil and finite range effects. The sensitivity of the results on the lower cut off radius and on the bound state and optical model potential parameters is currently investigated in detail. In parallel attempts are been made to approximate better the final bound state wave function using, instead of one, a sum of Hankel functions, to improve the calculation of the cluster wave function using other than Wood-Saxon potentials for the α-core interaction and to utilize another approximation for recoil. From the few results available up to now it seems that the reactions under study proceed predominantly by a one step transfer of an alpha paricle as suggested by the DWBA formalism assumed.

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6. *Jastrow Type Calculations for Nuclear Matter with the Normalization Condition*

E. Mavrommatis

Results are given of constrained Jastrow calculations for the energy per particle and the density of nuclear matter using the test potentials IY, OMY-6 as well as several others, and various correlation functions involving parameters. The constraint chiefly employed is the normalization condition in first order, a condition naturally entering the Jastrow formalism. The energy in the minimization is approximated by the first two and in some cases by the first three terms of its FIY cluster expansion. In addition to the three body terms in FIY expansion, the corresponding ones of the AHT expansion are also calculated for comparison. From the computations which were performed it seems that , at least in some cases, the normalization condition constitutes a quite satisfactory constraint leading, when used in low order calculations, to reliable results. Besides, conclusions are drawn as to the sensitivity of the results on the constraint, correlation function and minimized energy expression.

7. *A Previously Given Closed Form Energy Expression in Jastrow Calculations for Nuclear Matter*

E.Mavrommatis

In this paper we carry out Jastrow calculations for nuclear matter with the closed form energy expression of ref [1], which includes approximately terms higher than the second. We use the test potentials IY, OMY-4,OMY-6 and MSc and correlation functions involving parameters. Our aim is to investigate how the results derived previously with the two or the three-body energy[2] are altered if part of the higher terms are approximately included in the minimization, and whether subsidiary conditions can be avoided. From the preliminary results we have got it seems that a subsidiary condition is in most cases necessary to compensate the neglect of the other higher order terms. Calculations are therefore in process using in addition the normalization condition.

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V DATA COLLECTION AND PROCESSING

1. *Hardware Development and Maintenance*

V. Katselis, A. Sokos, A. Chionakis

1.1. Development

In the report year, development was again limited to small projects. The following became operational:

- A power supply for 5V, 10A, .01% regulation which will be used for the addition of new controllers to the PDP-15/76.
- A Module Test Panel for DEC M Series modules
- A line frequency driven digital clock with LED display
- A time out control for the valve connecting the Tank gas (SF_6) to the dew -point meter. The original , manually operated valve, was frequently left open with ensuing losses of tank gas. With the new control a solenoid valve is automatically closed after an adjustable time period (1-15 min) simplifying thus the operation of the dewpoint meter and securing the gas volume.

1.2 Maintenance

The main effort in this field was to use locally purchased components, as far as possible, instead of vendor supplied spares. This may cause minor changes in the layout of components if the replacement is not identical to the original component but leads in most cases to considerably shorter down-time for the equipment.

A frequent problem with the computer and related equipment was failure of the power pass transistors in DC power supplies. A cluster of such faults after the recent tempests in the Athens area has lead us to suspect main transients as the cause of such faults.

Thus the possibility of stabilizing the main supply to the data processing equipment is seriously considered.

The main maintenance tasks during the report year were the following:

- In the KSR35 and ASR33 Teletypes several worn parts were replaced mainly with parts made in the Laboratory's workshop.
- The RK-Disk Unit 1 had several problems with the + 15V power supply.
- The VR14 Display Unit has used up our supply of power transistors. It was successfully replaced with a H.P.1300A X-Y display system.
- The NS-630 multichannel Analyser has been under service for two lengty periods. Its DTL components are increasingly difficult to obtain signaling thus the approaching end of its useful life.
- Pocket calculators and their charging units were repaired.
- The control unit (Astrosystems Inc) and the associated power unit for the 70 cm scattering Chamber (Technolics Inc) needed repair twice (rectifier failures). Also the target positioning gears had to be reassembled and aligned.
- Finally, repairs of the nuclear electronics modules ranged from the ORTEC 120 charge sensitive preamplifier through amplifiers (ORTEC 451, 440A) and single channel analysers (ORTEC 420A, "ΔHM" 8025) to the Precision Pulse Generator (BNC PB-4).

VI ACCELERATOR OPERATION

1. *Operation*

N. Andreopoulos, Th. Asthenopoulos, N. Divis, G. Prokos and E. Serveta-Moshoti.

During 1977 the Tandem was utilized for a total of 2100 hours. The use of the accelerator was limited this year due to a two month shut down because of a damaged low energy tube. We have had in the past considerable difficulty in obtaining high voltages in the machine, with considerable tube sparking above 4.5 MeV. The problem was finally traced to radiation damage due to the rather high current proton beams (over 20μA) entering the accelerator with transmission of less than 60%. The problem was remedied with the installation of a second Einzel lens in the drift tube between the exit of the source inflection magnet and the entrance to the accelerator. We have thus achieved a transmission of better than 80% for all proton energies between 1 and 10 MeV. After 1500 hours of operation the repaired low energy tube does not show any signs of damage.

A new beam foil indicator was constructed to replace the original one which was based on electrical contacts and a light bulb system. The new one has an LED display and is fully transistorized.

VII PERSONELL

Research Staff

Dr. G. Vourvopoulos , Director
Dr. G. Anagnostatos
Dr. P. Assimakopoulos (till Sept. 1977)
Dr. C. Kalfas
Dr. A. Katsanos
Dr. E. Kossionides
Dr. Th.Paradellis
Dr. L. Skouras
Dr. A . Xenoulis

Graduate Students

E. Adamidis
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P. Bakoyiorgos
J. Galanakis
E. Gazis
P. Kakanis
S. Papaioannou
X. Xiromeritis

Scientific Associates

Prof. G. Andritsopoulos (Univ. of Ioannina)
Prof. P. Assimakopoulos (Univ. of Ioannina, since Sept. 1977)
Prof. A. Panagiotou (Univ. of Athens)
Dr. A. Hadjiantoniou (Demokritos)

Operational Staff

Accelerator Support Group

N. Andreopoulos
A. Asthenopoulos
N. Divis
G. Prokos
H. Serveta

Electronic Group

V. Katselis , B.S, Mathematics-Electronics

A. Chionakis

A. Sokos

Computer Programmer

Mrs. K. Dimakou , B.S. Mathematics

Machine Shop

O. Topikoglou

Graphics

F. Trouposkiadis

Visiting Scientists

Prof. B.Rossner, Technion Feb. 1977

Prof. P. Martin, British Columbia University
11/2- 11/5/78

Prof. G. Goldring , Weizmann Institute
26/6- 29 /6/77

Prof. P. Manakos, Darmstadt
6/9- 31/10/77

Prof. K. Nagarajan, Daresbury
8/10-10/10/77

VIII PUBLICATIONS

A. *Papers published in 1977*

1. C.Dedes and L.D. Skouras

"The even parity states of ^{94}Mo "

Phys. Lett 66B (1977) 417

2. L.D. Skouras and C. Dedes

"The even parity states of ^{95}Tc"

Phys. Rev. C15 (1977) 1873

3. H.Mavromatis, L.D. Skouras and C. Dedes

"Effective 3-body interaction in ^{93}Tc, ^{93}Mo and ^{94}Ru"

Phys. Rev. C16 (1977) 895

4. E. Mavromatis

"The Euler equation for the BDJ correlation function of a many fermion system when a closed form energy expression is used"

Nuov. Cim 38 (1977) 413

5. M. Grypeos , E. Mavromatis

"The functional derivative of the radial distribution function for a many-particle boson system"

Int. Journ. Phys. 16 (1977) 14

6. G.S. Anagnostatos

"Static properties of nuclei in the s-d shell."

Atomenergie 29 (1977) 207.

7. G.S. Anangnostatos

"Solar system abundances of nuclides and nuclear structure"

Astrophys. and Space Sc. 50 (1977) 445

8. C.A. Kalfas

"Structure of ^{148}Sm studied in the decay of ^{148}Pm and ^{148}Pm"

J.Phys G 3 (1977) 929

9. A.G. Hartas, G.T. Papadopoulos, P.A. Assimakopoulos, N.H.Gangas and G. Andritsopoulos

" States in ^{65}Cu from the ^{65}Cu (p,p'γ) reaction"

Nucl. Phys. A.279 (1977) 413

10. G.T. Papadopoulos, A.G. Hartas, P.A. Assimakopoulos, G. Andritsopoulos and N.H.Gangas.

" Electromagnetic properties of states in ^{63}Cu through the inelastic scattering of protons"

Phys. Rev. C 15 (1977) 1987

11. G. Vourvopoulos , O. Topikoglou and A. Asthenopoulos

"Performance of an inverted sputter source"

Rev. Phys. Appl. 12 (1977) 1463

12. A.D. Panagiotou, P. Kakanis, E.N. Gazis, E. Kossionides and N.Xiromeritis

"The (^{16}O,2p) reaction on light nuclei "

Jour. Phys. G 3 (1977) L85.

13. A.D. Panagiotou

"The $^{12}C+^{12}C \to a+^{20}Ne$ reaction mechanism and angular momentum effects".

Il Nuovo Cim. 37A (1977) 370

14. T. Paradellis

"Thin target thickness measurements by photon induced X-ray fluorescence"

Nucl Inst. Meth. 140 (1977) 205

15. T. Paradellis

"Excited states in ^{67}Ga observed in the ^{67}Zn(p,nγ) reaction"

Nucl. Phys. A279 (1977) 293

16. T. Paradellis

"Determination of trace elements in whole blood by photon induced X-ray fluorescence"

Eur. J. Nucl. Medic 2 (1977) 277

B. *Papers accepted for publication to appear in 1978*

17. T. Paradellis and V. Katselis

" X-ray fluorescence analysis of airborn particulates in an industrial Greek city."

J. Radioan. Chem. 42 (1978) 153

18. G. Vourvopoulos and T. Paradellis

"Fragmentation of the $g_{9/2}$ analog state in ^{55}Co "

Phys. Rev. C.

19. E. Mavromatis

"Jastrow type calculation for nuclear matter with the normalization condition"

Nucl. Phys. A.

20. G.S. Anagnostatos

"Maximum abundant isotopes correlation".

Astroph. and Space Sc.

21. A.G. Hartas and D.M. Van Patter

"The ^{63}Cu $(p,p'\gamma)$ reaction and the structure of ^{63}Cu ".

Nucl. Physics A.

22. P.W. Martin, C.A. Kalfas and K. Skov

"Molecular dynamics of polyglutamic acid studied by perturbed angular correlation of gamma rays".

J. of Chem. Physics

23. P.W. Martin, C.A. Kalfas and K. Skov

"Helix -random coil transition in polyglutamic acid observed by perturbed angular correlation of gamma rays".

Chem. Phys. Letters

IX ANNOUNCEMENTS

1. E. Mavromatis

"Jastrow type calculations in nuclear matter by means of the normalization condition".

The nucleon- nucleon Interaction Conference. Univ. of British Col. Vancouver June 1977.

2. A.D. Pangiotou, J. Kehayas, P. Kakanis, E.N. Gazis and A. Xenoulis.

"Mass measurements and nuclear structure investigation of light very neutron rich nuclei."

Proc. Int. Conf. on Physics of Medium Light Nuclei, Florence, 1977.

3. G. Vourvopoulos and T. Paradellis

" Decay of the $g_{9/2}$ analog state in Co^{55}".

Proc. Int. Conf. on Physics of Medium Light Nuclei, Florence, 1977.

4. G. Anagnostatos

" An extension of the VMI model to light nuclei".

Proc. Int. Conf. on Physics of Medium Light Nuclei, Florence, 1977.

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