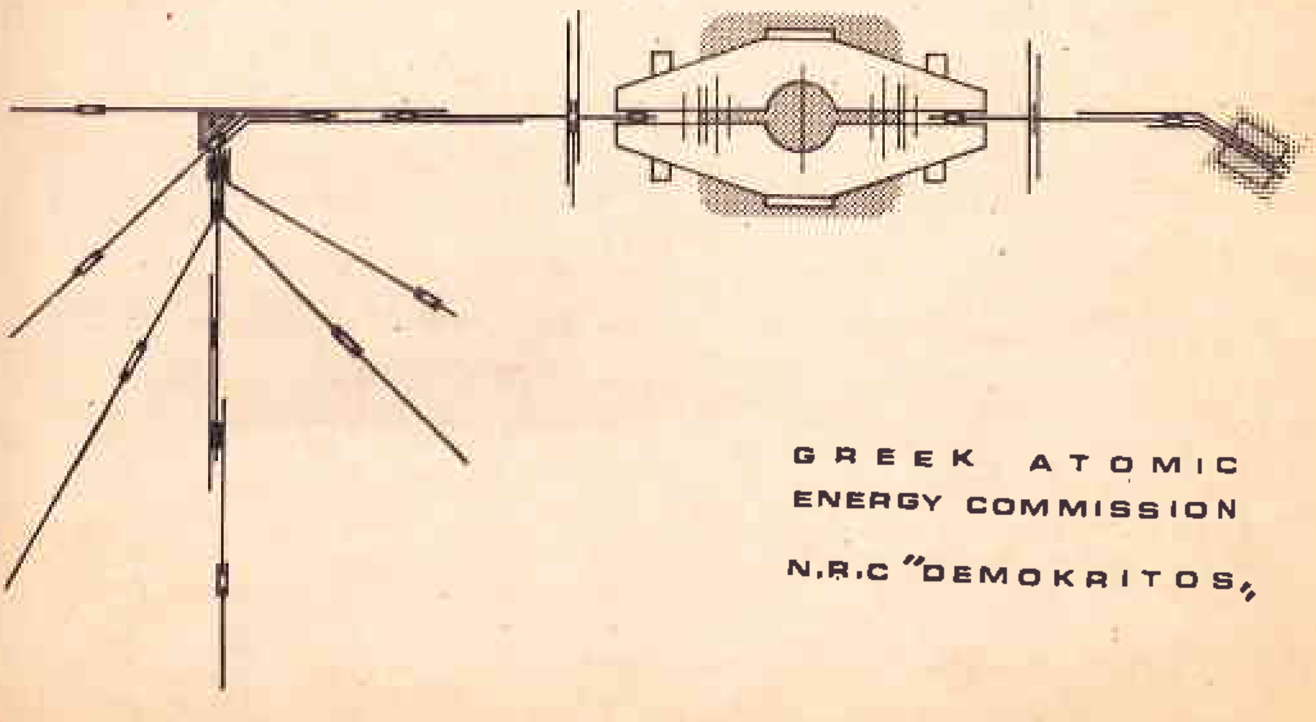
TANDEM
ACCELERATOR LABORATORY
ANNUAL REPORT
1975



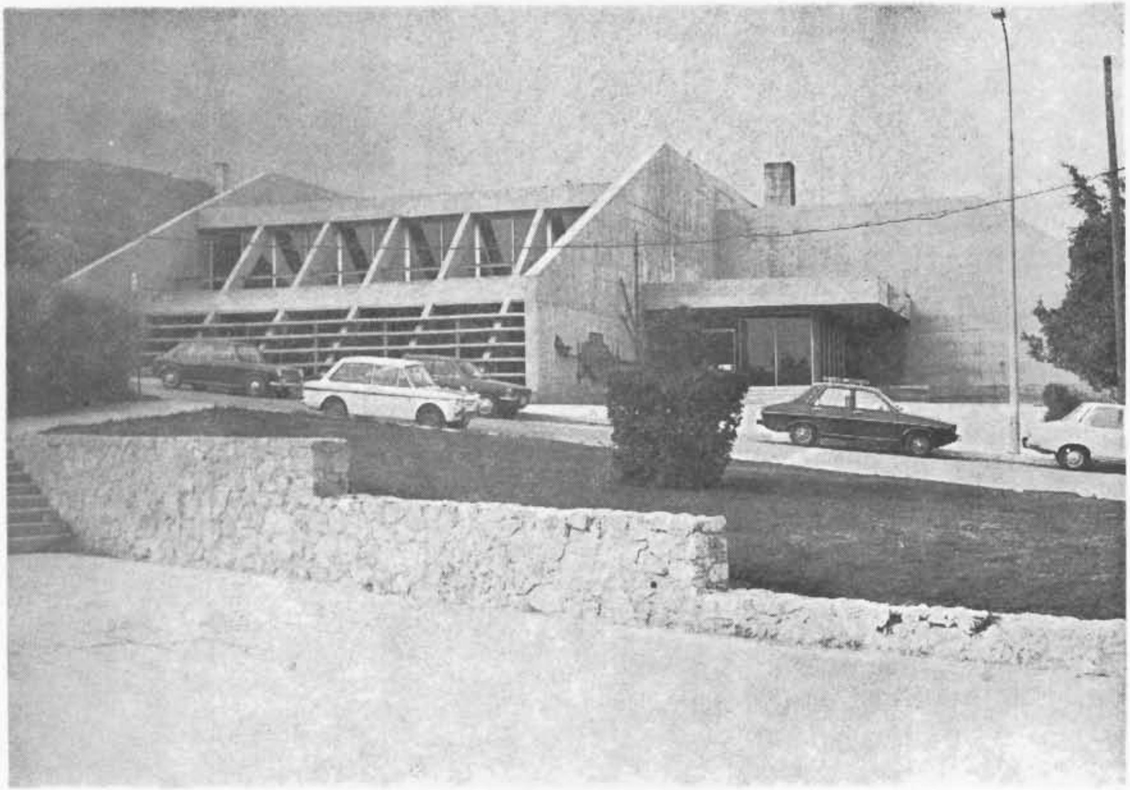
GREEK ATOMIC
ENERGY COMMISSION
N.R.C "DEMOKRITOS"

NUCLEAR RESEARCH CENTER DEMOKRITOS

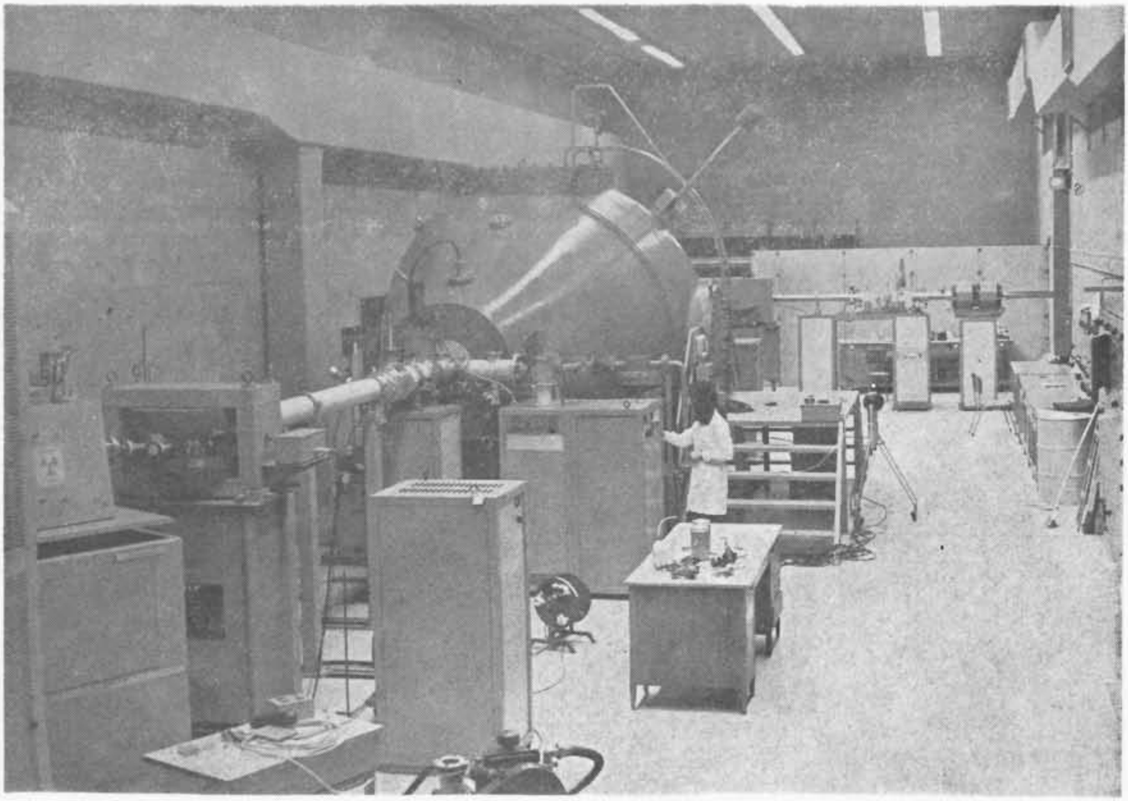
TANDEM ACCELERATOR LABORATORY

ANNUAL REPORT 1975

Editors: T. Paradellis
E. Patsadeli



Tandem Accelerator Building



Overall view of the T11/25 Accelerator
Ion source on the left side of the picture

I N D E X

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Introduction

Having passed the final acceptance tests in Dec 1974, the year of 1975 was the first year with the accelerator in full operation. The N.R.C. DEMOKRITOS accelerator is a T 11/25 Tandem Van de Graaff accelerator manufactured by High Voltage Engeneering Corporation. It has a maximum voltage of 5.5 MV and proton currents up to 100 μA.

During the first year, research was concentrated in the areas of heavy ion reactions, inelastic scattering, γ-ray spectroscopy, charged particle induced X-rays and theoretical nuclear physics. Much work had to be done in trying out new experimental apparatus and learning to optimize the operation of the accelerator.

In-beam and off-beam gamma ray spectroscopy has been productive in its investigation of nuclear properties in Cu, Ga and Sm isotopes. The heavy ion work on α-transfer around the Coulomb barrier, mass measurements via the (^{16}O,2p) reaction and spin flip reactions with ^{14}N have shown very promising results. The development of an external proton beam for particle induced X-ray excitation has been useful in analyzing samples that cannot be introduced into vacuum. The X-ray fluorescence method on the other hand produced some standard ways for a quick and reliable element microanalysis of several types of samples.

On the theoretical side, calculations have been performed on ^{36}S, ^{95}Tc and ^{94}Mo. Of particular interest are the results of a "realistic" shell model calculation on ^{95}Tc which explain satisfactorily the nuclear properties of about 40 levels.

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The VMI model was extended to include in the rotational band a 0^+ and a second 2^+ excited levels in some nuclei. The same model was applied in explaining the back-bending phenomenon. Work was also continued on the isomorphic model in the s-d shell.

Our graduate student population has had a manyfold increase. Collaboration with the University of Athens and University of Ioannina has been very fruitful as in the past. We have had a number of visitors from abroad that contributed appreciably in our scientific effort.

It has indeed been very gratifying to see that our technical personnel was fully trained to handle the problems connected with the accelerator and the on-line computer. In many instances their unselfish efforts contributed in the smooth operation of the laboratory.

G. Vourvopoulos

I. HEAVY ION REACTIONS

1. *Mass Measurements of Neutron-Rich Light Isotopes*.

A. D. Panagiotou*, E. Kossionides, G. Vourvopoulos,
P. Kakanis, E. Gazis, N. Xiromeritis and D.K. Scott**.

The purpose of this programme is to measure the mass of new neutron-rich isotopes, employing a rather novel method. The measurement of the masses of nuclei far from the valley of stability is very important because it provides a sensitive test of various empirical mass formulae, which fit the measured masses near the bottom of the valley of stability but may diverge further away. Furthermore, it is important to improve the accuracy of the known masses, which have been measured with the aid of other methods. The heavy ion reactions, procceeding via the formation of a compound nucleus, are a very useful tool for producing neutron-rich isotopes. In this manner we plan to carry out mass measurments of new isotopes, such as ^{29}Mg, ^{34}Si by employing reactions such as $^{A}_{Z}X(^{18}O,2p)^{A+16}_{Z+6}Y$ and directly detecting the two protons emitted from the compound nucleous in the formation of the new isotopes. Experimentally, for the detection of the emitted light particles we employ a triple $\Delta E,E,A/C$-telescope, comprised of surface barrier detectors and use the method of particle identification. We detect both emitted protons in a single telescope, using the empirical property that the 2p's, depending on their relative energies are identified as "^{4}H" to "^{6}H" in the mass spectrum. The mass and corresponding energy spectra are stored and analysed by the on-line PDP-15 computer of the Tandem Accelerator Laboratory. By setting windows on particle groups in the P.I.spectrum the information of each particle group is routed to diferent energy spectra. From the measured energy of the two protons leading to the ground state of the new isotope and the other known quantities, such as the mass and energy of the projectile and the masses of target and the two protons we extract information concerning the above mentioned isotope mass.

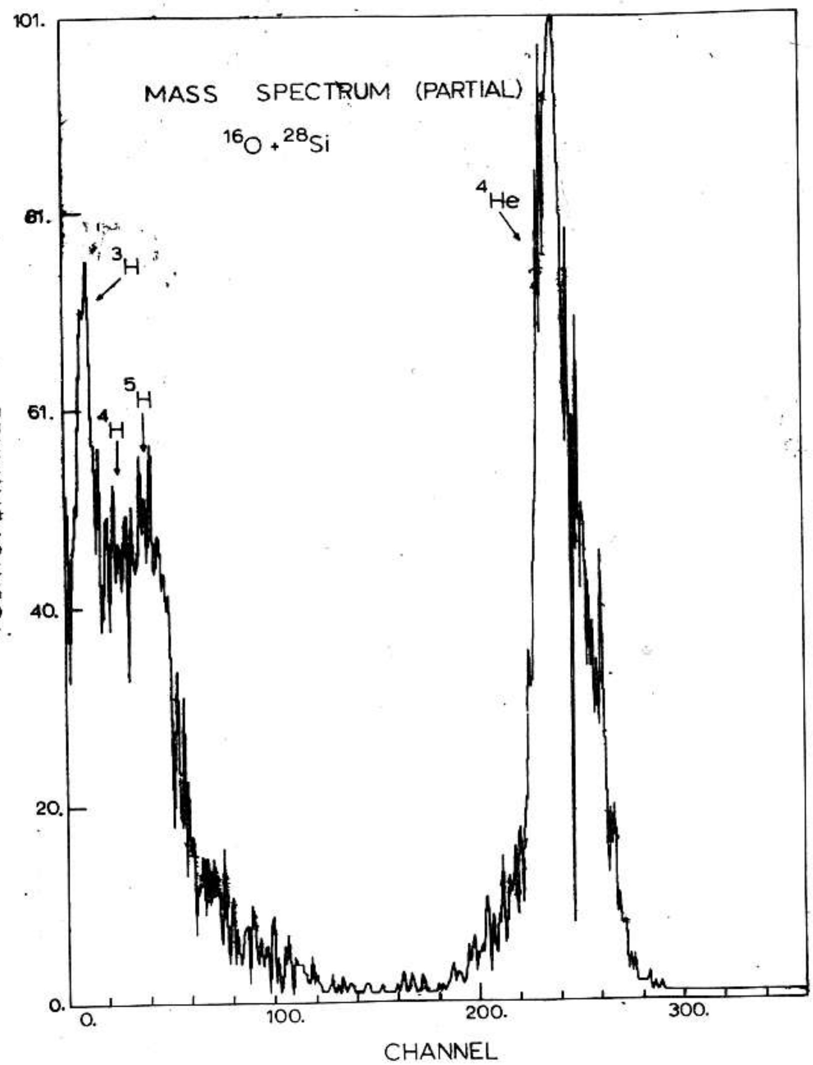

Fig.1 Partial Mass Spectrum from the reaction $^{28}Si(^{16}O,2p)^{42}Ca$.

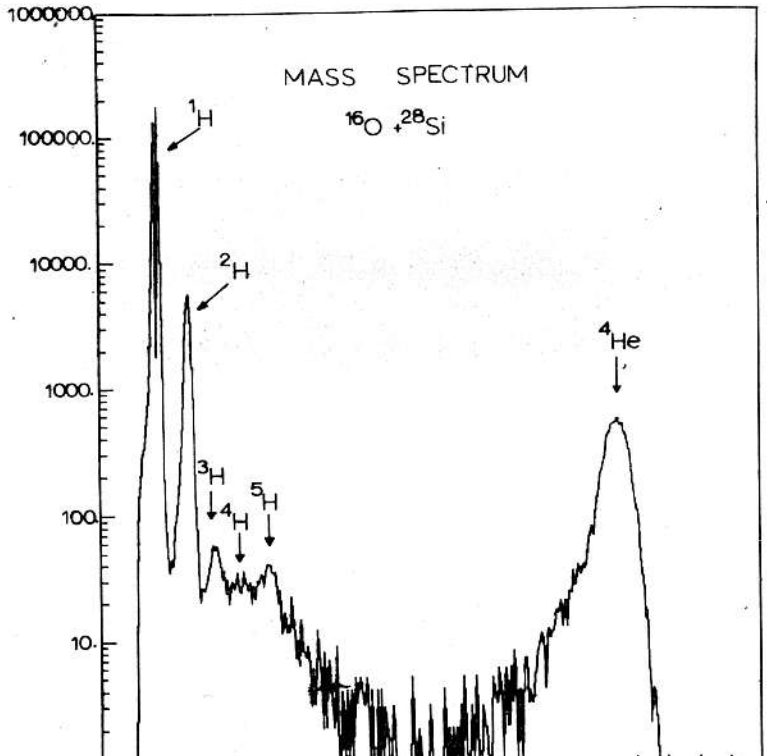

Fig.2 Total Mass Spectrum from the reaction $^{28}Si(^{16}O,2p)^{42}Ca$.

To test and develop the method the reaction $^{28}Si(^{16}O,2p)^{42}Ca$ was carried out and the mass and energy spectra of p, d, t and "^{4}H" were obtained. The measurements were taken at 0^{o} because here the kinematic broadening is very small for large $\Delta\theta$ and so we can use a rather large solid angle. A Au foil is placed after the target to stop the ^{16}O beam. Relatively fast timing is used and time-resolution of about 4nsec (F.W.H.M.) has been obtained. An efford to reduce this to less than 1nsec is under way. Figs 1 and 2 show a typical mass spectrum of $^{28}Si(^{16}O,2p)^{42}Ca$. The energy resolution in the energy spectrum is 800 keV, due to the very large acceptance angle ($\pm 3.8^{o}$) at 30^{o}. It is possible to make better energy resolution by reducing the acceptance angle. Currently we are obtaining an angular distribution of the reaction $^{28}Si(^{16}O,2p)^{42}Ca$ to determine the shape of the distribution. Actual mass measurements will follow.

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2. *Heavy Ion Transfer Reactions - α-particle Transfer*.

N. Xiromeritis, A.D. Panagiotou*, E. Kossionides,
G. Vourvopoulos, E. Gazis and P. Kakanis

The purpose of this experiment is the examination of "α-particle spectroscopic factors" for 4n nuclei, such as ^{12}C, ^{24}Mg, ^{28}Si and the variation of the spectroscopic factor as a function of the incident-particle energy. The reactions employed are $(^{16}O,^{12}C)$ and $(^{16}O, ^{20}Ne)$. The ^{16}O ions are accelerated by the Tandem Van de Graaf Accelerator to a maximum energy of 40 MeV. The detector telescope consists of a ΔE=9μm, an E=50μm and a thick anti-coincidence detector.

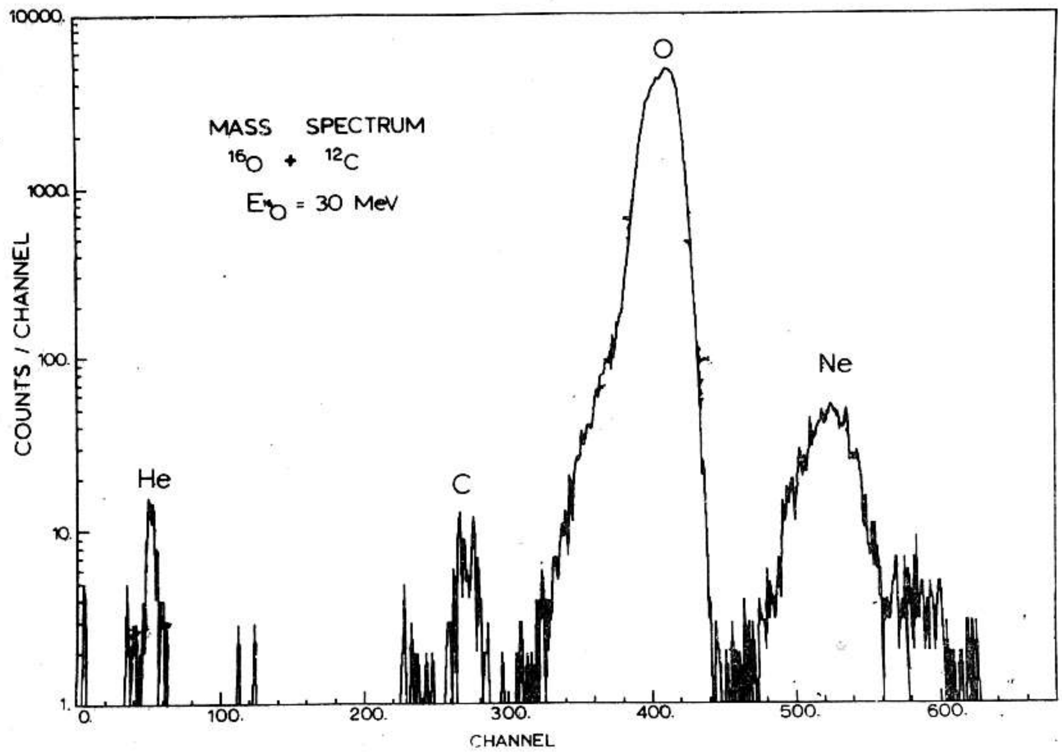

Fig.3 Mass Spectrum from the reaction $^{16}O(^{12}C,X)Y$.

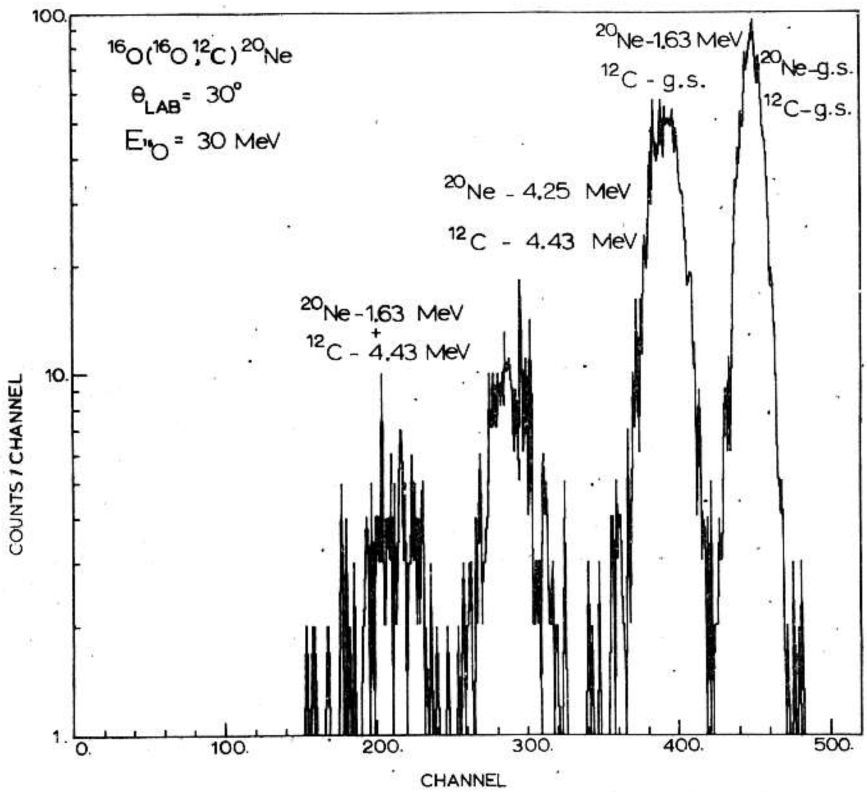

Fig.4 ^{20}Ne Spectrum from the $^{16}O(^{16}O,^{12}C)^{20}Ne$ reaction.

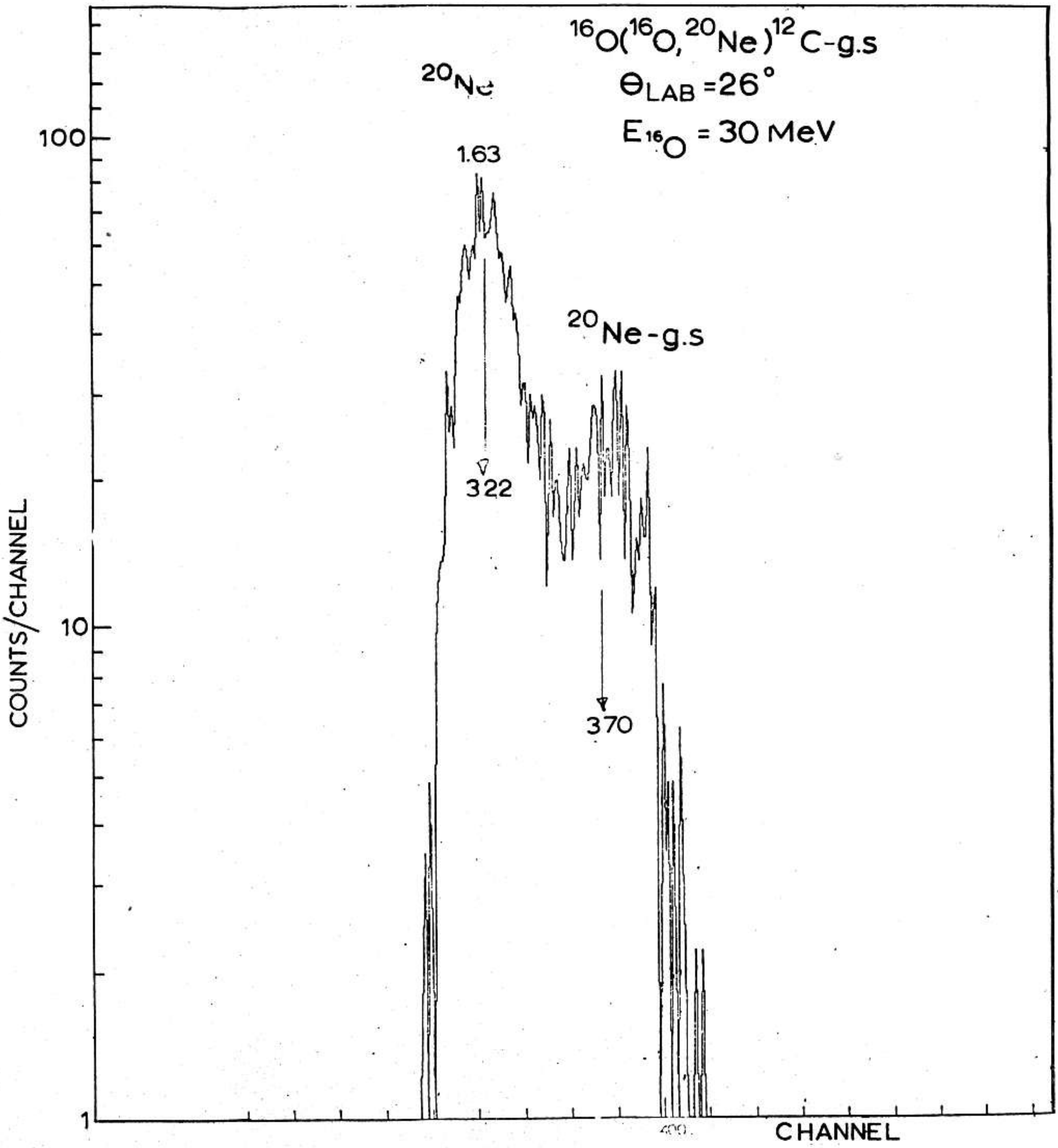

Fig.5 ^{20}Ne Spectrum from the $^{16}O(^{16}O,^{20}Ne)^{12}C$ reaction.

For the identification of the heavy particles, an empirical method is employed based on the following observation: the energy deposited in the ΔE-detector is almost the same for all the available energies of the heavy particles in our reactions, while the energy deposited in the E-detector varies very strongly with the particle's energy. By dividing the E pulse by a number and adding this to the ΔE pulse, an almost constant number K for each element is derived independent of the particles energy, i.e.

$\Delta E_j + \frac{E_j}{X} = K_j$ where j corresponds to each element.

Separate energy spectra for each element are obtained by setting "windows" on each particle group in the mass spectrum. Fig. 3 shows the mass spectrum obtained in the reaction $^{16}O+^{12}C$ at 30 MeV. Similar spectra have been obtained in the reaction $^{16}O+^{16}O$. The clear identification of C, O, Ne etc is evident. Figs 4 . 5 show the ^{12}C -and ^{20}Ne- particle energy spectra obtained in the α-stripping and pick-up reactions of $^{16}O+^{16}O$. The energy resolution for ^{20}Ne is very bad, due to the kinematic broadening. In particular Fig. / shows the identified states of ^{20}Ne, which are the ground state the 1.63 MeV and the 4.25 MeV states. The last one is mixed with the 4.43 MeV excited state of ^{12}C. We also identify the 4.43-^{12}C+1.63-^{20}Ne state. States of higher excitation are not seen because of the thickness of the ΔE-detector. The resolution in this spectrum is ~ 400 keV (F.W.H.M.) Fig.5 shows the energy spectrum of ^{20}Ne. We see only the ground state and the 1.63 MeV excited state again due to the thickness of the ΔE-detector. Also the energy resolution is very bad 1.3 MeV (F.W.H.M.). An angular distribution for both reactions on ^{16}O is in progress and the work will be extended to other 4n-nuclei.

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3. *The* $^{16}O(^{16}O,\alpha)^{28}Si$ *Reaction*

J.D. Fox*, G. Vourvopoulos and S. Kossionides

The excitation function at 0^{o} has been measured for incident energies of ^{16}O from 17 to 32.4 MeV and for α particles leeding to the ground and first excited states of ^{28}Si. The data (shown in Fig. 6) are being analysed in order to determine if in addition to the statistical fluctuations some effects of precompound correlations between the Oxygen Ions can be detected.

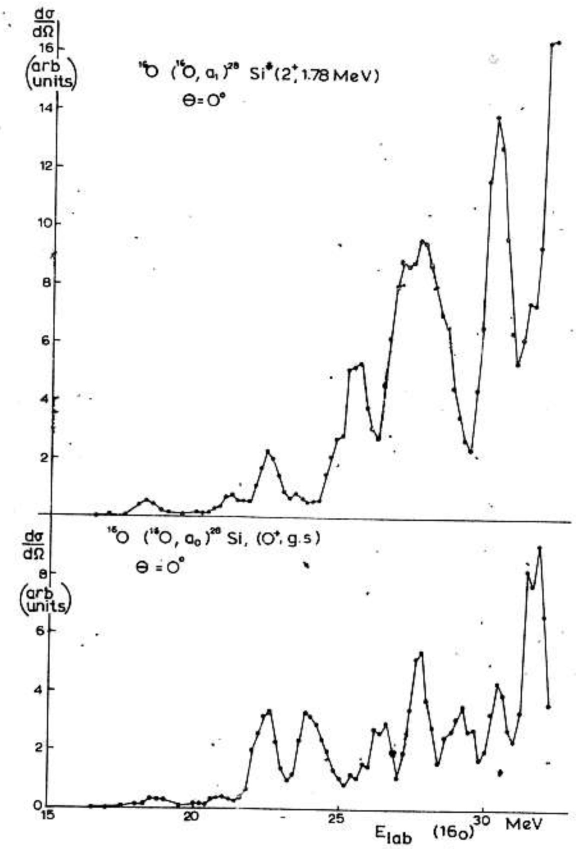

Fig.6 Excitation functions for the ground (0^+) and 1.78 MeV (2^+) states in ^{28}Si.

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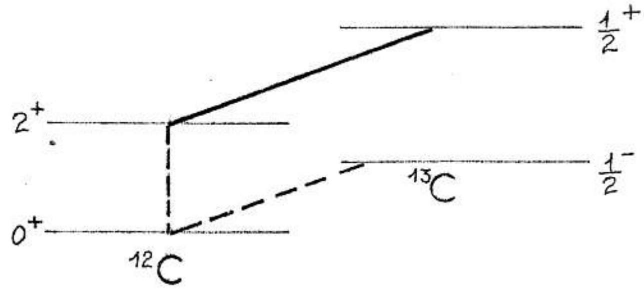
4. *Investigations of Transitions to the $2S_{1/2}$ States in the Mass-13 System.*

P.A. Assimakopoulos, A.G. Hartas, C.T. Papadopoulos,
G. Andritsopoulos*, N.H. Gangas* and K. Nagatani**.

An anomalous angular distribution populating the first excited state (3.09, $\frac{1}{2}^+$) in ^{13}C and (2.37, $\frac{1}{2}^+$) in ^{13}N has been observed during the investigation of the reaction $^{12}C(^{14}N,^{13}N)^{13}C^*$ and $^{12}C(^{10}B,^{9}Be)^{13}N$ at 100 MeV. Since the above transitions are expected to occur between a $1P_{1/2}$ and $2S_{1/2}$ orbits, the angular momentum transfer is unity. Thus the experimental angular distribution should show a characteristic oscillatory pattern, if one assumes a direct one-step reaction mechanism. Under the above circumstances one expects an exact DWBA calculation should fit the experimental results well. However, it was found that even though there were oscillations in the data, the $l=1$ theoretical fit was completely out of phase with the observed experimental angular distribution which, curiously, had a strong resemblance to an $l=0$ angular distribution. Additionally the corresponding spectroscopic factor for $2S_{1/2}$ strength was found very small. This is very important, since this state has been one of the basic states in Shell Model Theory. The above observations clearly support the belief that a one-step reaction mechanism, even with the inclusion of finite range and recoil, is not capable of satisfactorily explaining heavy-ion induced one-nucleon transfer to the first excited $2S_{1/2}$ states in the mass-13 system. It was therefore decided to perform additional experiments and make extensive calculations including multistep processes for the $2S_{1/2}$ states, as indicated in this mass region and at various energies (see for example the following figure).



In the frame of the above considerations we performed some preliminary experiments with the DEMOKRITOS Tandem accelerator. The investigated reaction was $^{12}C(^{14}N, ^{13}C)^{13}N^*$(proton transfer) and $^{12}C(^{14}N, ^{13}N)^{13}C^*$(neutron transfer). Natural carbon targets of 50 μg/cm^2 were bombarded by 25 and 30 MeV ^{14}N beam. The outgoing heavy ions were detected by using a two detector telescope and particle identification techniques in the PDP-15 computer. Preliminary results have exhibited weak population of the ^{13}C state at 3.09 MeV which has indicated the necessity of perfecting the computer particle identification techniques for the separation of carbon and nitrogen isotopes. Future runs are also scheduled with the employment of two detector telescopes in the anticoincidence mode, placed at pairs of angles predicted by the kinematics of the reaction.

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II. GAMMA RAY SPECTROSCOPY

1. *^{150}Sm from the Decay of ^{150}Pm*

C.A. Kalfas, A. Xenoulis and T. Paradellis.

Gamma-gamma directional correlation techniques employing a Ge(Li)-NaI(Tl) system were used to investigate the de-excitation mechanism and character of several states in ^{150}Sm, following the decay of ^{150}Pm. Spins of certain levels and multipole mixing ratios of transitions from the quadrupole and octupole quasi-vibrational bands were determined. The experimental mixing ratio values are compared with the theoretical prediction of Kumar and with corresponding values in neighbouring nuclei.

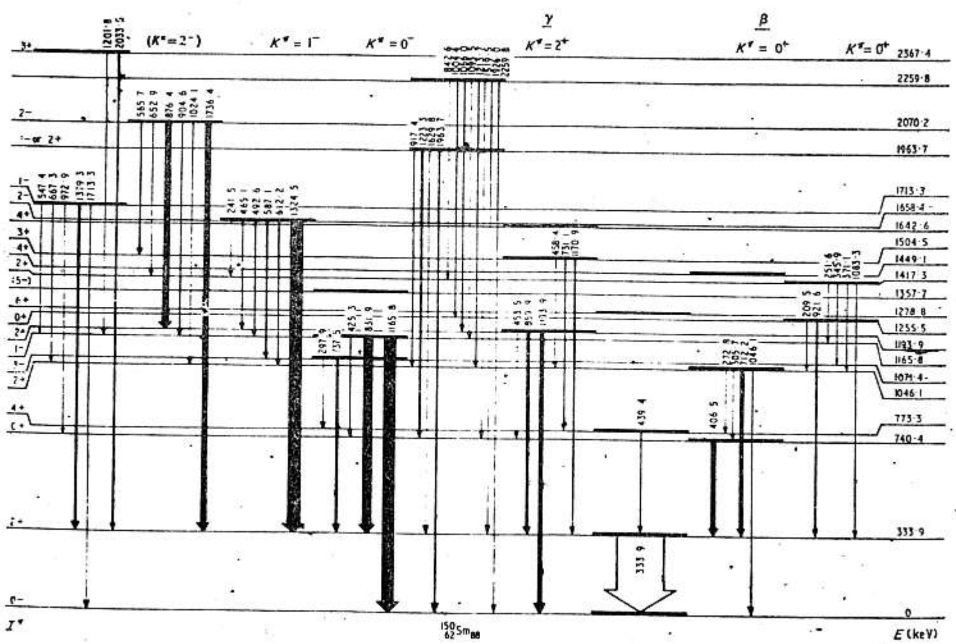

Fig.7 A simplified version of the level structure of ^{150}Sm populated following the β^- decay of ^{150}Pm(2.68h). The thickness of the line indicates the approximate intensity of the γ transitions.

2. *^{148}Sm from the Decay of ^{148}Pm*

C.A. Kalfas and T. Paradellis

In order to extend the information concerning the excitation and de-excitation mechanism in even-even nuclei of the transitional region around A≈150, investigation using γ-γ correlation techniques is continued in ^{148}Sm, studied from the decay of ^{148}Pm. The parent nucleus is produced by (p,n) reaction in mass separated ^{148}Nd at Ep=10 MeV. Analysis of the data is currently under way. Further experiments are planned in collaboration with Sussex University where use is made of a low temperature refrigerator (~15 mK) in order to measure the angular distribution of γ-rays from polarized nuclei. Finally, Ge(Li)-Ge(Li) coincidence system will be used in order to resolve some ambiguities in the level structure of ^{148}Sm.

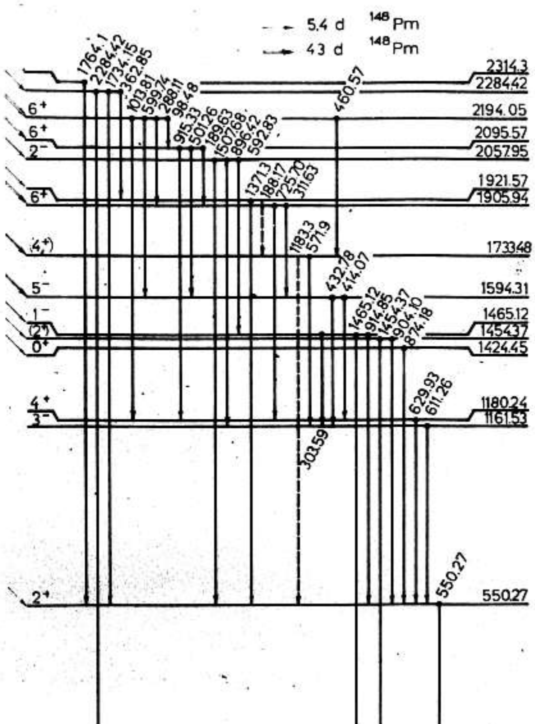

Fig.8 The excited states of ^{148}Sm observed in the decay of 41 d and 5.3 d ^{148}Pm nucleus.

3. *Study of ^{97}Tc by $^{97}Mo(p,n\gamma)$ Reaction.*

A. Xenoulis, T. Paradellis and M. Pantazi.

The level structure and the decay properties of levels in ^{97}Tc are investigated via prompt γ-ray spectroscopy following the ^{97}Mo(p,nγ) reaction with proton energies between 3 and 6 Mev. Measurements of excitation functions and angular distribution measurements have been performed.

4. *Electromagnetic Properties of States in ^{92}Mo from the $^{92}Mo(p,p'\gamma)$ Reaction.*

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

Levels in ^{92}Mo were studied through the ^{92}Mo(p,p'γ) reaction at incident proton energies E_p=7.0, 7.6 and 8.5 MeV. Singles γ-ray spectra were obtained with a Ge(Li) detector at angles of observation $\Theta_\gamma=0^o$, 30^o, 55^o, 70^o, 90^o and 125^o. Level and transition energies were extracted from the $\Theta_\gamma=90^o$ spectra with an accuracy better than ±0.5 keV. Branching ratios were extracted from the $\Theta_\gamma=55^o$ spectra. For transitions demonstrating an energy shift with respect to the angle of observation, the corresponding lifetime of the state was determined through the Doppler Shift Attenuation Method. The analysis of angular distributions yielded multipole mixing ratios and J^π values for several states. The experimental information obtained in this work was employed to calculate reduced transition probabilities. The properties of low lying states in ^{92}Mo strongly indicate that this nucleus may be described in the framework of the shell model by considering simple configurations of four protons occupying the $p_{1/2}$ and $g_{9/2}$ orbitals outside an inert ^{88}Sr core.

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*Doctoral Thesis
**University of Ioannina

5. *Gamma-gamma Correlations in ^{69}Ga.*

T. Paradellis, A. Xenculis and C.A. Kalfas.

Employing a Ge(Li)-NaI (Tl) detector system, gamma-gamma directional correlations for nine cascades in ^{69}Ga have been measured. The result of the present measurements combined with other existing data allowed the adoption of a $5/2^-$ spin and parity for the 1106.4 keV level, and a $7/2^-$ for the 1336.1 and 1487.5 keV levels. A tentative $7/2^-$ spin and parity has been adopted for 1923.1 keV level. Mixing ratios have been determined for six transitions. The data obtained are utilized to extract M1 and E2 reduced transition probabilities. A comparison of the experimental data is made with the predictions of the one particle-core and three particles-core coupling models.

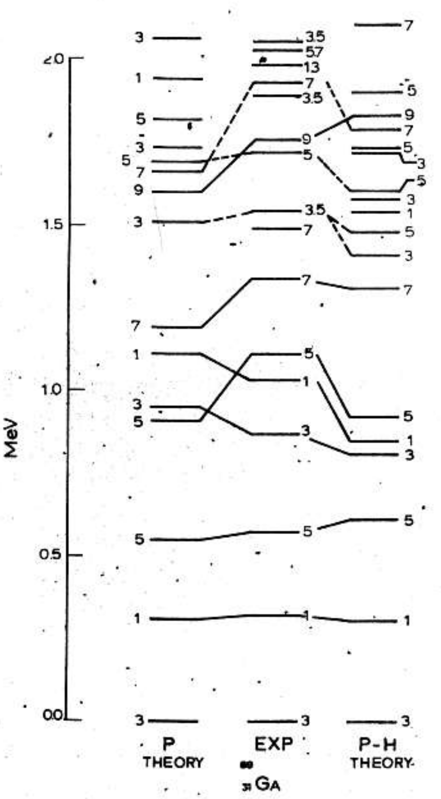

Fig.9 A comparison of the one particle (P-H) and three particle (P)-core model states with the experimental data in ^{69}Ga.

6. *The $^{67}Zn(p,n\gamma)^{67}Ga$ Reaction.*

T. Paradellis, C.A. Kalfas and A. Xenoulis.

A 79% enriched ^{67}Zn target, 4 mg/cm^2 thick has been bombarded with protons. Gamma ray spectra obtained at 90^o to the beam axis at E_p=3.3,3.6,3.7,3.8,3.9,4.1 and 4.3 MeV allowed the identification of levels in Ga67 up to 2.407 MeV excitation. Angular distribution and centroid shift data have been collected at $\bar{E}_p$=3.65 and 4.16 MeV. The analysis of the $\bar{E}_p$=3.65 MeV angular distribution data, allowed the unique spin assignment for severel levels. The excited states of ^{67}Ga (in keV) and the adopted spin and parity assignment from the E_p=3.65 MeV experiment, are the following. 167.05(1/2$^-$), 359.10(5/2$^-$), 828.10(3/2$^-$), 910.92(5/2$^-$), 1081.72(1/2$^-$), 1202.25(7/2$^-$), 1412.63(7/2$^-$), 1519.12(9/2$^-$), 1555.55(5/2$^-$), 1639.37(3/2$^-$). The data at 4.2 MeV are currently analyzed.

7. *Study of ^{63}Cu and ^{65}Cu Through Proton Inelastic Scattering.*

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

The gamma-ray de-excitation of the first twenty four states of ^{63}Cu amd the first twelve states of ^{65}Cu was studied by means of the ^{63,65}Cu (p,p'γ) reactions. Thick targets of copper enriched in ^{63}Cu and ^{65}Cu were bombarded at incident proton energies E_p=4.2, 5.0 and 6.0 MeV. Singles gamma-ray spectra were obtained with a Ge(Li) detector at angles of observation Θ_γ=0^o, 30^o, 55^o, 90^o and 125^o. Through these measurements transition energies, levels, branching ratios and lifetimes of states via the Doppler shift attenuation method were established. A striking overall similarity in the decay schemes of the two nuclei is observed. The angular distributions obtained are being analysed in the frame-work of the Hauser-Feshback theory for the determination of multipole mixing ratios and J^π values for several states.

More recent Ge(Li)-Ge(Li) coincidence measurements are also being analysed for the incorporation into the level schemes of several unidentified transitions observed in the spectra.

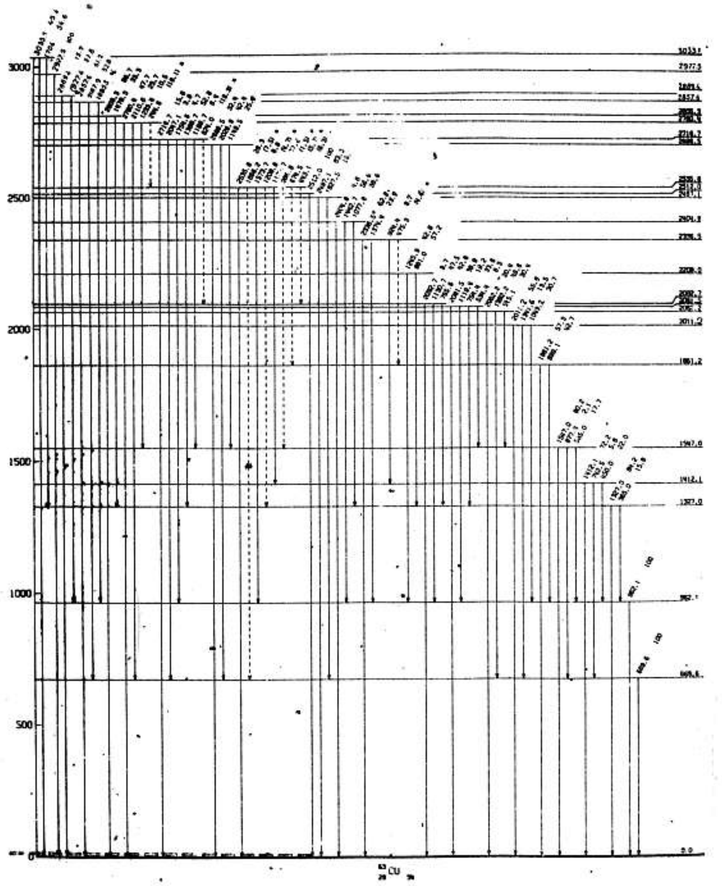

Fig.10 The excited states of ^{63}Cu

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8. *Study of ^{63}Zn and ^{65}Zn through the ^{63,65}Cu(p,nγ)^{63,65}Zn Reaction.*

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

Excited states of ^{63}Zn and ^{65}Zn are being studied in conjuction with the work on the odd-copper isotopes described above. Through a progressive increase of the incident proton energy on isotopically enriched ^{63,65}Cu targets, transitions in $^{63,65}Zn$ become dominant in the singles γ-ray spectra. In this manner several new transitions in the odd-zinc isotopes have been identified while the excitation energies of levels known from previous work have been measured with increased accuracy. To this end singles γ-ray Ge(Li) spectra have been obtained at incident proton energies of E_p=5.2, 6.0 and 7.0 MeV, at angles of observation Θ_γ=0°, 30°, 55°, 70°, 90° and 125°. The angular distributions are being analyzed for the determination of branching ratios, multipole mixing ratios and J^π values in the frame work of the Hauser-Feshbach theory. Recent Ge(Li)-Ge(Li) coincidence measurements are employed for the identification of several unknown transitions. The analysis of these data is still in progress.

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*University of Ioannina, Ioannina

9. *The $^{16}O(Mn^{55},xnyp)$ Reaction*.

G. Costa* and T. Paradellis

A thick target of ^{55}Mn has been bombarded with 40.8 MeV 7^+ ^{16}O. Gamma-ray spectra have been obtained at 90°. The preliminary data indicate that the main reaction channels are $^{69}Ge+pn$, $^{68}Ge+p2n$, $^{69}As+2n$, $^{68}Ga+2pn$. Gamma-gamma coincidences, singles γ-ray distributions and absolute cross section measurements are in progress.

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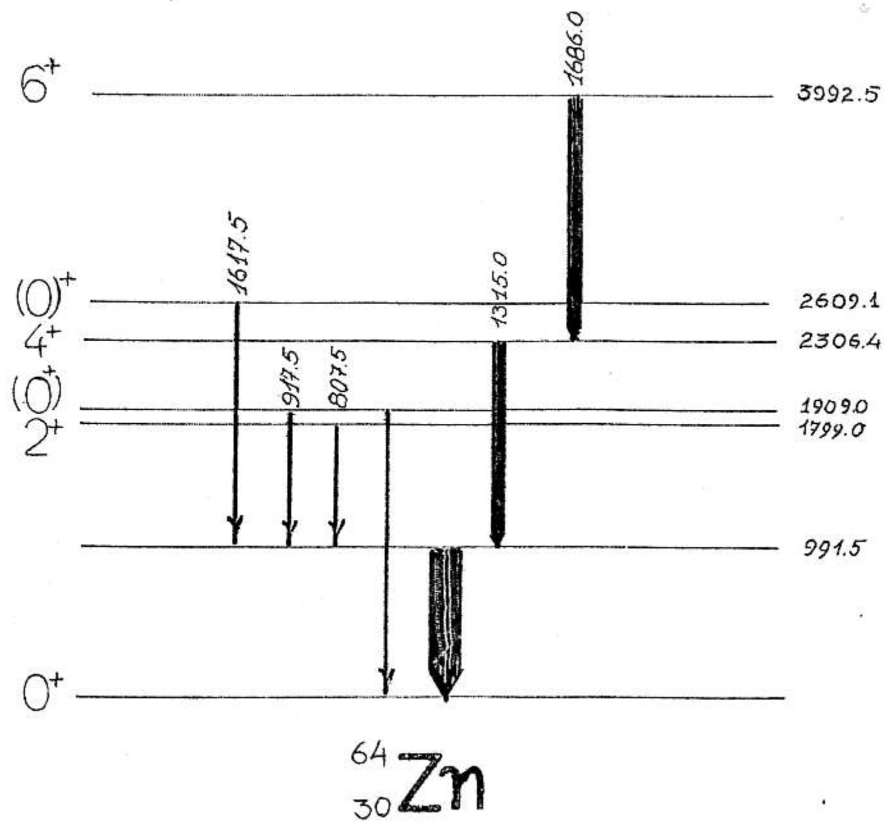
10. *The $^{16}O(^{51}V,xn\gamma p)$ Reaction.*

T. Paradellis and G. Vourvopoulos

A thick ^{51}V foil has been bombarded with ^{16}O ions of energy ranging from 32 to 40 MeV. Gamma-ray spectra obtained at 90^{O} indicate that the main reaction channels at 40 MeV are ^{64}Zn+p2n, ^{65}Zn+pn, ^{65}Ga+2n, ^{64}Cu+2pn. Gamma-gamma coincidences, γ-ray distributions and cross-section measurements are continued to clarify the decay schemes of the residual nuclei. Some preliminary results for the low lying states of ^{64}Zn are given in Fig.11:



III. X - RAYS

1. *Utilization of External Proton Beam for Elemental Microanalysis*

A. Katsanos, A. Xenoulis, A. Hatjiantoniou and R.W. Fink*

An external proton beam facility has been constructed which permits elemental microanalysis, based on the detection of characteristic X rays, to be performed on samples in atmospheric pressure. The sensitivity of the method equals that of the internal beam, where the sample is placed in the accelerator vacuum, while there exists a number of obvious practical and other more fundamental advantages of the external beam.
The 3 MeV protons exit the vacuum of the accelerator through a 0.008 mm thick Be window. The Be window was found to be the most satisfactory of a series of materials tested. The facility has been already used for the elemental analysis of different kind of samples such as biological, environmental, and mineral.

* Permanent address Georgia Institute of Technology, Atlanta Georgia, U.S.A.

2. *Analysis of Ancient Blue Pigments.*

S. Fillipakis*, V. Perdikatsis** and T. Paradellis

Samples of blue pigments obtained from old Greek paintings dated from 500 to 2500 B.C. collected from different archeological places of Greece (Knossos, Mycenae, Pylos, Tiryns and Thera) have been analysed by XRF in our laboratory. This study was combined with crystal diffraction studies and mineralogical examination of the samples.

The results indicate that two types of blue pigments were used.
1. The so called Egyptian blue which is an artificial complex salt of Si, Cu and Ca. In the most of these samples, quantities of Sn, Pb and As have been found which indicate that probably the Cu used in the production of the pigment originated from bronze filings, slag from bronze-smelting furnaces or bronze corrosion products.
2. A natural pigment containing mainly Iron. Diffraction analysis of the samples indicate that the mineral used, was the so called glaucophane. In the case of Knossos this pigment has been traced only in samples dated 1700-1500 BC.

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*X-Rays Laboratory, Dept of Physics, NRC DEMOKRITOS, Greece
**Geological Intitute of Greece

3. *Measuring Target Thickness by X-Ray-Fluorescence*

T. Paradellis

A method has been developed for measuring thicknesses of thin targets used in nuclear physics experiments. The method which covers all elements above Ca is based on the yield measurement of X-rays of the target, excited by other X or γ-rays from a radioactive source. This yield, for thin targets, is proportional to thickness. Significant effects may arise from X-rays excited in the backing material, whenever the energy of these X-rays is above the K-edge of the measured target. Thus for example, the calibration line for targets made from Iron on Carbon foils does have a different slope from the corresponding line for Iron targets deposited on Gold Backings. The calibration lines constructed with and without Au and Ta backings have been used to measure targets of known thickness evaporated on C, Au ar Ta. In all cases the agreement was better than 5%. The estimated uncertainty of the method is about the same order.

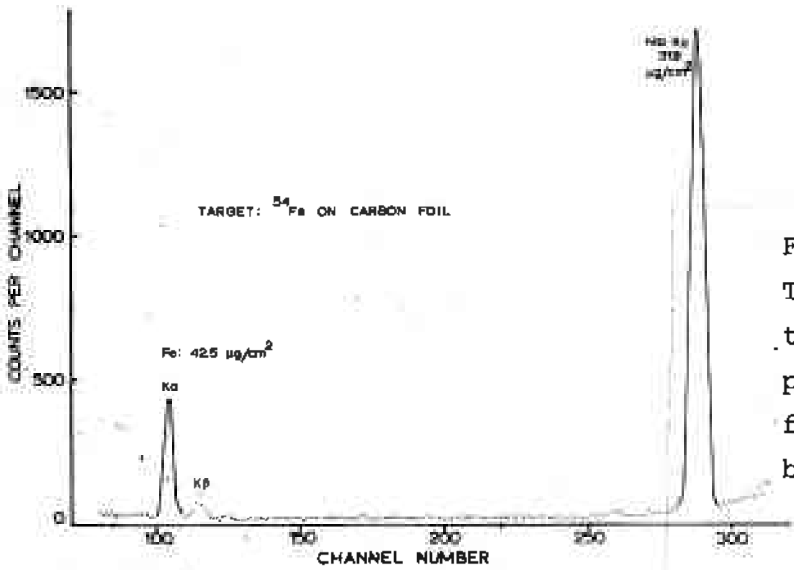

Fig.12
The X-ray spectrum of a target obtained by evaporation of ^{54}Fe oxide from a Mo boat on a C backing

4. *Air Pollytion Measurements.*

T. Paradellis and V. Katselis

Air dust samples collected on cellulose filter, Whatman 41, from the industrial city of Elefsis located 22 km west of Athens, were analysed by XRF for the presence of heavy metals.
The results found for the main trace elements are:

ELEMENT	AVERAGE	MAXIM record	MINIMUM record	AVERAGE zero wind	non zero wind
		in µg/m^3			
Calcium	63	162	11.5	84.5	44.7
Iron	5.3	13.9	0.8	7.08	3.7
Lead	0.78	5.3	0.045	1.22	0.59
Zinc	0.27	1.0	0.038	0.33	0.22

IV. THEORETICAL NUCLEAR PHYSICS

1. *Even Parity States of ^{46}Ti.*

L.D. Skouras

The even parity states of ^{46}Ti are calculated in the augmented basis of 6-particle and 8p-2h configurations. A deformed scheme is adopted and only the states that arise from the lower intrinsic wave functions are considered. Apart from the 2_2 2_1 mixing ratio the theoretical results are found to be in good agreement with experiment for both energy levels and transition rates.

2. *An Extended Shell Model Calculation on ^{36}S.*

L.D. Skouras

A shell model calculation has been performed on the even parity levels of ^{36}S. Full configuration mi ing has been considered by allowing the four proton holes to occupy all the orbitals of the Sd shell. Although the model reproduces satisfactorily the low-lying energy levels of the nucleus, the calculated transition rates are found to be in bad agreement with experiment. It has been found, however, that agreement with experiment drastically improves, if the shell model basis is augmented by a limited number of 6h-2p configurations. The latter arise by exciting two neutrons from the Sd to the fp shell orbitals and are conveniently constructed using a deformed scheme.

3. *A Shell Model Calculation on ^{95}Tc.*

C. Dedes* and L.D. Skouras

A shell model calculation has been performed on the even parity states of $^{95}_{43}$Tc. The basis vectors are constructed by coupling all $(g9/2)^3$ proton states to all possible two neutron states that arise by considering the 1d5/2, 2S1/2, 1d3/2 and 0g7/2 arbitals. The calculation has been carried out with a "realistic" interaction and the usual second order perturbation corrections have been taken into account for the construction of the appropriate "effective" interaction. The theoretical results are found to be in very good agreement with experiment as far as the energy spectrum is concerned. Thus the model predicts at approximetely the correct energy all levels that have been observed up to 5.6 MeV excitation energy. Moreover it predicts a number of additional levels that quite possibly have not been observed yet due to the complexity of the nucleus. The calculation of the transition rates is currently under way.

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* University of Ioannina, Ioannina

4. *Interpretation of the Non-Zero Energy for $I^{\pi}=0^+$ and the Break in Mallmann's Curves.*

G.S. Anagnostatos

The non-zero energy of the zero angular momentum state and the break in Mallmann's curves - two previously observed problems during the phenomonological analysis of the ground-state bands in doubly even nuclei with negative ground-state moments of inertia ($\mathcal{J}_0<0$) - are investigated in this paper. Their interpretation is based on the VMI model and yet uses angular speed (ω) as an independent variable. It is shown that the non-zero energy corresponds to a new 0^+ member of the ground-state bands. Moreover, for nuclei in the interval $-\frac{1}{27} \leq I(I+1)C/\ o^3 \leq 0$, when I=2, the existence of an additional new 2^+ level is derived, which leads to the general pattern I^π=g.s., 2^+, 0^+, 2^+, 4^+, 6^+.... The introduction of these two levels points to an interpretation of the break in Mallmann's curves at R_4=1.482 rather than at R_4=1.825, as found by Mariscotti.

5. *Static Properties of Nuclei in the s-d Shell.*

G.S. Anagnostatos

An extension of the isomorphic model (initially applied to the closed-shell nuclei at the ground state) into the region of open-shell nuclei is prosented. The isomorphic model is a new general nuclear structure model, primarily classical in its present form, based on high spatial symmetry. Properties successfully examined here are neutron, proton, and mass r.m.s. radii, quadrupole moments, and Coulomb energies for twenty-seven nuclei in the s-d shell and for ^{16}O. The proton distribution gives radii within the experimental error in almost all cases. Strings of isotopes (isotones) are predicted to have the same proton (neutron) radii, which is experimentally justified within the experimental error. The quadrupole moment predictions in twenty cases are identical to the experimental values.

PDF created on January 29, 2012 by S.V.Harissopulos

6. *Solar Abundances of Nuclei and Nuclear Structure.*

G. S. Anagnostatos

Some new features of the solar abundance distribution curve have been studied which may prove useful in the development of a more comprehensive theory of the element formation. In addition, some interesting and hitherto unknown neutron excess versus neutron number correlations have also been found.

7. *Dynamic Properties of Nuclei in the s-d Shell.*

G.S. Anagnostatos

This work refers to the same nuclei as in the previous work [illegible] and deals successfully with their spins, parities and magnetic dipole moments.

8. *On the Nature of Backbending.*

G.S. Anagnostatos

An interpretation of backbending is attempted by assuming first that the "restoring force constant C" is not really a constant for high angular momentum states, but a function of the moment of inertia and second that, besides the stretching of nuclear dimensions, a distortion of nuclear shape occurs at these states.

V. DATA COLLECTION AND PROCESSING

1. *Facilities Available*

At the end of the report year facilities available for data collection include:

a. A PDP 15/76 Computer with 16 k of 18 bit memory, cartridge disk, CENTRONICS printer, 7-track magnetic tape transport, DEC-tape, display with light-pen and console teletype. The disk, printer and magnetic tape are new additions. With these the new on-line software will be installed and event-by-event collection of data will be possible. Four NS624 ADC's are inter-faced to the computer.

b. An NS600 Multichannel Analyser with 4 k Memory which is used mainly for X-ray and γ-ray work.

c. Five Ge(Li) and Si(Li) detectors of various sizes.

d. An "almost sufficient" number of nuclear electronics units either purchased of constructed localy (Demokritos 8000 Series, NIM standard)

2. *Support*

S. Kossionides, V. Katselis, A. Sokos, A. Chionakis

The Electronics Workshop has been occupied with the maintenance of the computer and the measuring electronics of the Laboratory. Some minor units (e.g. a 1 kV power supply for the light pen) were also constructed. During the report year three new programs have been added to the On-Line Library.

a. DETECT which is a simulator of the Mass Identifier beeing developed.

b. GOLDIE which allows digital windows to be set on the spectrum from one ADC and routes the data from a second ADC to different memory areas depending on the results of a comparison to the windows.

c. TOTA which is a modification of GOLDIE and uses for the routing of energy spectra mass values computed from E and Time of Flight information.

3. *Mass Identifier*

V. Katselis and S. Kossionides

The development of a special purpose processor is in the final stage. This processor will speed up the mass calculations needed by several experimental programs for particle identification. It will directly access lists of ΔE and E stored in memory and deposit the result of the calculation in another list. Thus the processor can be used for either on-line or off-line mass calculations. After the succesful simulation, the device has been designed to realize the flow-chart of fig.13. Currently the layout of modules and the wiring plans are beeing prepared.

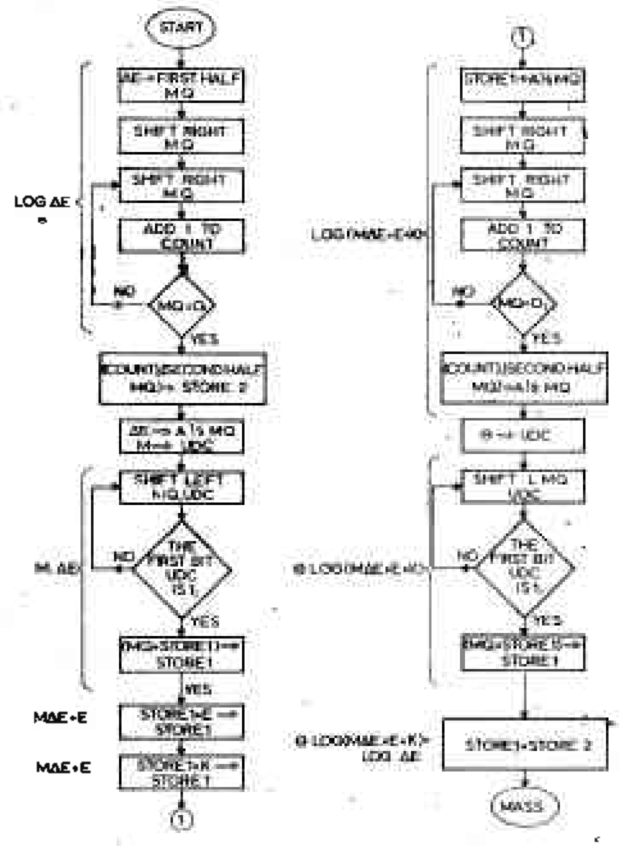

Fig.13 Flow chart of the Mass identification Process

1. *ANNA: An Interactive Program for Analysis of One-dimensional Pulse-height-Spectra**.

P.A. Assimakopoulos and S. Kossionides

An interactive program has been written for the PDP-15 computer as an aid in the analysis of one-dimensional nuclear data (e.g. γ-ray or charged particle spectra). It can however be used in all cases where histogram-type data with Poisson statistics is analyzed. The program makes heavy use of the CRT screen-Lightpen facilities of the PDP-15 for interaction with the data and is designed to run on a computer with the minimum of peripheral equipment, notably without a card reader or lineprinter - as is usually the case for computers employed mainly for on-line data acquisition. Due to these restrictions the source program is available only in the form of a DEC-Tape. The DEC-Tape contains all source (SRC) and binary (BIN) files, as well as the appropriate XCT and XCU files, compiled under the CHAIN system for single-command execution.

During operation a portion of the data is displayed on the CRT screen, an area of interest is indicated with the Lightpen and various processing commands are executed by changing the state of the ACCUMULATOR SWITCHES. A log of all operations and results is printed on the Teletype. Commands already incorporated in the system are: Control of I/O, polynomial fit to background, centroid and area of peaks, multiple (1 to 3) Gaussian fit. The statistical errors associated with each parameter are also computed. A copy of the program may be obtained from the CPC Program Library, Queen's University of Belfast, N. Ireland, under Catalogue Number ABMN.

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*To be published in Computer Physics Communications

5. *Kinematics of Three Body Reactions**.

P.A. Assimakopoulos

A review has been presented of the expressions employed in the evaluation of kinematic variables in reactions of the form $A+B \rightarrow a_1+a_2+a_3$. These bariables include the kinetic energy of particles in the final state, the relative final state interaction energy of each pair, the corresponding centre of mass angles and angles in the centre of mass system of an interacting pair. All variables are computed in program PAKINE3, which has been written for the CDC-3300 computer and is an extension of the program described in ref.(1). A second program, PAKIPLOT, produces a lineprinter 64×64 channel plot of the kinematic locus for the reaction. Both programs may be obtained from the CPC Program Library, Queen's University of Belfast, N. Ireland, under Catalogue Numbers ABMO and ABMP.

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*To be bublished in Computer Physics Communications

1) P. Assimakopoulos, Programm No. 3, NRCD/IDR, 1965;
DEMO 72/13, 1972

6. ACCELERATOR OPERATION

S. Valamontes, N. Andreopoulos, A. Asthenopoulos, G. Prokos

The accelerator was not heavily used during the course of the year and there were periods of rather small demand on beam time. The machine time distribution is as follows.

Total running hours	1668 hrs	
Charged Particle Induced X-rays	137 hrs	(8%)
Heavy Ion Reactions	698 "	(42%)
Nuclear Structure Spectroscopy	321 "	(19%)
Inelastic Scattering- -Gamma-ray Spectroscopy	332 "	(20%)
Accelerator Support Group	180 "	(11%)

A major shutdown was necessary in September to replace the low energy accelerating tube. It was found to be damaged (around the 25th electrode from the tank end) and the damage was attributed to secondary electrons emanating from the grided entrance lens. The grid was subsequently removed with an appreciable loss of transmission (from 75% at 2 MV to 40% at 4 MV) trough the machine. Several efforts are currently in progress to remedy the loss of transmission.

7. PERSONNEL

Research Staff

Dr G. Vourvopoulos, Director
Dr G. Anagnostatos
Dr P. Assimakopoulos
Dr A. Hartas (Research Associate)
Dr C. Kalfas
Dr A. Katsanos
Dr E. Kossionides
Dr A. Panagiotou (till Sept. 75)
Dr Th. Paradellis
Dr L. Skouras
Dr A. Xenoulis

Graduate Students

E. Gazis
P. Kakanis
M. Pantazi
K. Papadopoulos
N. Xiromeritis

Scientific Associates

Prof. G. Andritsopoulos (Univ. of Ioannina)
Prof. N. Gangas (University of Ioannina)
Prof. A. Panagiotou (University of Athens since Sept. 1975)
Dr S. Filippakis (N.R.C. DEMOKRITOS)

Operational Staff

Accelerator Support Group

S. Valamontes
N. Andreopoulos
A. Asthenopoulos
G. Prokos

Electronic Group

V. Katselis, B.S. Mathematics-Electronics
A. Sokos
A. Chionakis

Computer Programmer

Mrs K. Demakou, B.S. Mathematics

Machine Shop

F. Trouposkiades
O. Topikoglou

Visiting Scientists

Dr G. Costa	Centre de Recherches Nucléaires de Strasbourg, France (Nov. 10 - Dec.10)
Prof. S. Fallieros	Brown University, Providence R.I. USA (June 25 - July 25)
Prof. R. Fink	Georgia Institute of Technology, Atlanta Georgia, USA (Dec. 10 - Jan. 22)
Prof. P. Fisher	University of Oxford, England (July 14 - Aug. 10)
Prof. J. Fox	Florida State University, Tallahassee, Florida, USA (May 27 - June 27)
Prof. M. Greenfield	Florida A and M University, Tallahassee, Florida, USA (June 25 - Aug. 4)
Prof. K. Nagatani	Texas A and M University, College Station, Texas, USA (Nov. 15 - 30)
Prof. W. Nörenberg	University of Heidelberg, Germany (Sept.27 - Oct. 4)

8. LIST OF PUBLICATIONS

1. T. Paradellis and C.A. Kalfas
   Excited states in ^{107}Ag from the decay of ^{107}Cd
   Z. Physik 271 (1974) 71
   and Fizika 7 Suppl.2 (1975) 164

2. C.A. Kalfas, A. Xanoulis and T. Paradellis
   Transitional Nuclei: ^{150}Sm from the decay of ^{150}Pm
   Journal of Physics G 6 (1975) 613

3. A.C. Xenoulis
   Positive parity states in g9/2 odd-proton nuclei
   Fizika 7 Suppl. 2 (1975) 97

4. C. T. Papadopoulos, A.G. Hartas, P.A. Assimakopoulos, G. Andritsopoulos and N.H. Gangas.
   Electromagnetic properties of states in ^{92}Mo from the ^{92}Mo(p,p'γ) reaction
   Nuclear Physics A 254 (1975) 93

5. T. Paradellis, A. Xenoulis and C.A. Kalfas
   Gamma-gamma directional correlations in ^{69}Ga
   Z. Phys. A.275 (1975) 269

6. L.D. Skouras
   Even parity states in ^{46}Ti
   Jurnal of Physics G1 (1975) 438

7. G. Anagnostatos
   Interpretation of the non-zero energy for $I^{\pi}=0^{+}$ and the break in Mallman's curves.
   Nucl. Phys. A 246 (1975) 445

8. J. H. Hamilton, A.V. Ramayya, E.L. Bosworth, W. Lourens, J. D. Cole, B. Van Nooijen, G. Garcia-Bermudez, B. Martin, B.N. Subba Rao, H. Kawakami, L.L. Riedinger, C.R. Bingham, F. Turner, E.G. Zganjar, E.H. Spejewski, H.K. Carter, R.L. Mlekodaj, W.D. Schmidt-Ott, K.R. Baker, R.W. Fink, G.M. Gowdy, J.L. Wood, A. Xenoulis, B.D. Kern, K.J.Hofstetter J.L. Weil, K.S. Toth, M.A. Ijaz and K.F.R. Sastry
   Crossing of near-spherical and deformed bands in ^{186,188}Hg and new isotopes ^{186,188}Tl.
   Phys. Rev.Let. 35, No 9 (1975) 562-565

9. ANNOUNCEMENTS

1. A.G. Hartas, P.A. Assimakopoulos, C.T. Papadopoulos, G. Andritsopoulos and N.H. Gangas
   Study of ^{63}Cu and ^{65}Cu through proton inelastic scattering.
   Bull. Am. Phys. Soc. <u>20</u> (1975) 565

2. C.T.Papadopoulos, P.A. Assimakopoulos, A.G. Hartas, G.A. Andritsopoulos and N.H. Gangas
   Nuclear spectroscopy in ^{92}Mo.
   Bull. Am. Phys. Soc. <u>20</u> (1975) 719

3. G.S. Anagnostatos
   Nuclear radii in the s-d shell.
   Bull. Am. Phys. Soc. <u>20</u> (1975) 1184