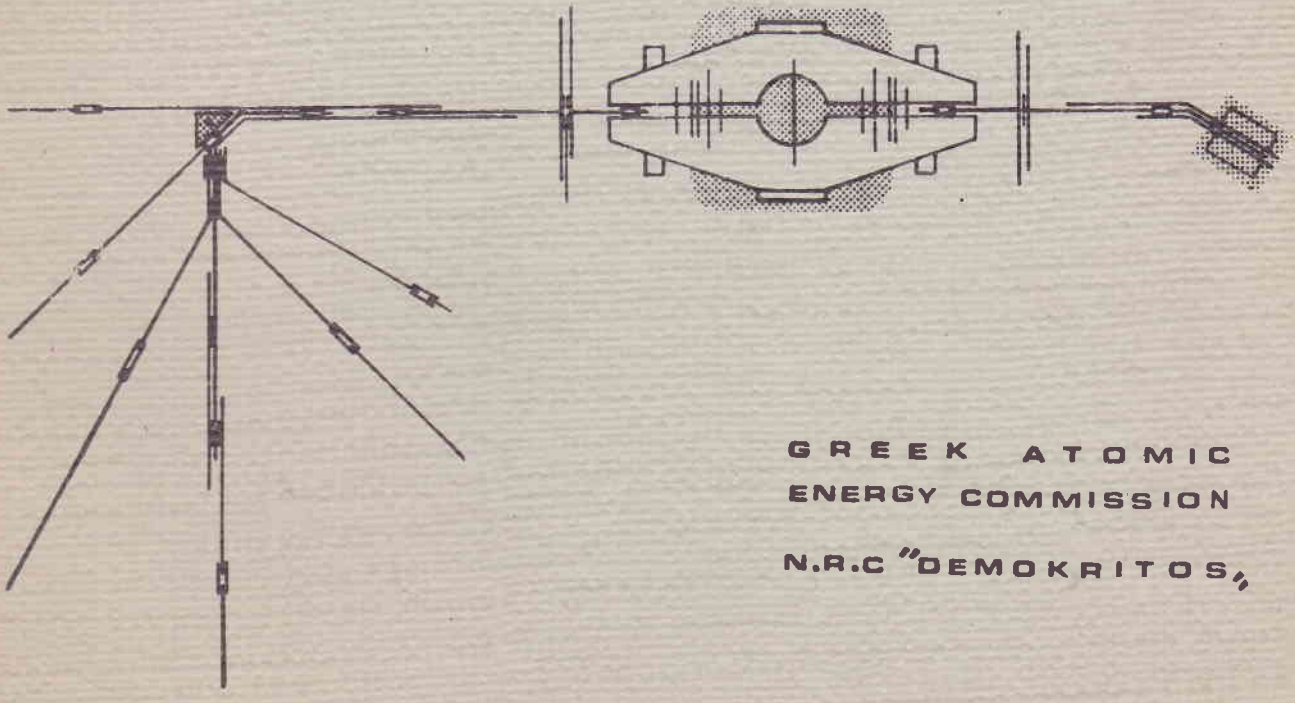
TANDEM
ACCELERATOR LABORATORY
ANNUAL REPORT
1981-1982



GREEK ATOMIC
ENERGY COMMISSION

N.R.C "DEMOKRITOS"

NUCLEAR RESEARCH CENTER DEMOKRITOS

TANDEM ACCELERATOR LABORATORY

ANNUAL REPORT 1981-1982

Editor : G. S. Anagnostatos

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Introduction

The areas of research established in our laboratory a few years ago were also followed during the report years. A balance between nuclear research and applications of nuclear techniques, however, has been stabilized at about 50 percent for each.

The study of mechanisms of heavy ion reactions, e.g. in the competition between exit channels producing the same residual nucleus, the study of nuclear spectroscopy, e.g., in the cases of Ga and Te isotopes, and also the applications, e.g., postoperative changes in elemental values, have produced very intersting results. In nuclear theory, advances have been made in the isomorphic model, e.g, the kinetic energy determinations and symmetry break in the rare earth nuclei, and in other topics of current interest, e.g. double β- decay and fractional parentage coefficients.

The sectors of development, and of data collection and processing have experienced major improvements. A Prime-750 computer is now available in our laboratory and has substantially improved our experimental and theoretical investigation. Also, the development for the new CAMAC- and PRIME-based data collection system is in progress. Other major improvements are the installation of a three-quadrupole spectrometer for the study of (n, charged particle) reactions and the facility for the production of ^{67}Ga for medical use. The researchers in our laboratory, however, feel strongly the energy limitations imposed by the low terminal voltage and hope that adequate funds can be given for the necessary post accelerator.

Finally, we would like to repeat once again that the dedication and quality of our technical and administrative personnel is especially appreciated.

I. HEAVY ION REACTIONS

Competition between exit channels producing the same residual nucleus in heavy-ion reactions

A. Aravantinos, E. Gazis[+], C. Papadopoulos[+] and A. Xenoulis

Recently, the competition between pn and d evaporation leading to production of the same residual nucleus has been measured[1] for several heavy-ion nuclear reactions, each at several bombarding energies, for target-projectile combinations resulting in compound nuclei $19 \leq A \leq 71$.

By an association of the $\log(\sigma_{pn}/\sigma_d)$ with the quantity $E_{cm}^{bomb} + Q_{pn}$, which represents the maximum excitation energy available to the residual nucleus, a systematic trend emerged, illustrating a nearly linear dependence for almost all of the reactions investigated. These systematics offered the possibility to describe, and thus predict, the competition between pn and d emission by the following exponential relationship[1]:

$$\sigma_{pn}/\sigma_d = 0.83 \times \exp\{0.19\ (E_{cm} + Q_{pn})\}, \qquad (1)$$

where the quantity $(E_{cm} + Q_{pn})$ is expressed in MeV.

Eq. (1) has been already utilized in the literature for the prediction of competition in lifetime studies with the Doppler-shift-attenuation method where it is known that the pn and d exit channels result in quite different nuclear recoil effects.

Beyond its immediate utility, however, it is considered important to investigate the theoretical significance of the systematic trend demonstrated by Eq. (1).

Extensive calculations of pn and d cross sections for several reactions and bombarding energies are carried out with the Hauser-Feshbach formalism, in order to determine whether compound nucleus formation is the dominant reaction mechanism causing the experimentally observed systematic behavior. This conclusion will, in turn, permit to interpret "pathological" cross section values of pn and d which, in cases such as ^{6}Li induced reactions or quasimolecular resonances, have been found to deviate from the systematic trend.

Finally, competition between cluster versus multiparticle emission has been observed and measured in several various exit channels, such as p2n/dn/t, 2pn/dp and αpn/αd. Among those an outstanding case is the ^{4}He emission channel, for which it has been observed that, when the bombarding energy is sufficiently high to overcome the ^{4}He binding energy, the ^{4}He emission is almost completely replaced by dd and 2p2n emission.

Reference

1. A.C. Xenoulis et al, Phys. Lett 106B (1981) 461

+Physics Laboratory II, National Technical University of Athens, Athens, Greece

On the reaction mechanism of ^{7}Li induced reactions

S. Kossionides, H. Gemmeke,[+] I. Koenig,[+] D. Fick,[+] K.H. Moebius,[++] P. Egelhof,[++] D. Presinger,[++] E. Steffens[++]

The investigation of the reaction ^{7}Li on ^{51}V has shown that the cross section is sensitive to the orientation of the deformed ^{7}Li nucleus with respect to the beam axis [1]. The experiments were performed with the aligned beam from the Heidelberg EN-Tandem [2] and the orientation was varied by switching the alignment of the beam on and off at intervals of approximately 2 secs.

The results can be understood with a simple model which parametrizes the transmission coefficients as a function of the distance of closest approach. This distance varies with orientation for the same l-value [1].

For a more detailed understanding of the reaction mechanism, the light charged particles emerging from the reaction were now detected with counter telescopes [5]. Energy spectra and angular distributions were obtained at E(Li) = 20 MeV with aligned and non-aligned beams. The analysing power $T_{20}(0)$ was obtained which is defined as:

$$T_{20}(\theta) = (\sigma_{pol}(\theta) / \sigma_{unpol}(\theta) - 1) / t_{20} \qquad (1)$$

where t20 is the alignment of the beam (monitored throughout the experiment [3]).

The results are presented in Fig. 1 to 4. The assymetry of the cross section around 90 degrees points to a significant contribution from direct processes. This is supported by the distribution of T20(E) which can be understood within the simple model applied so far. In a direct reaction, contributions to forward angles come from collisions with large impact parameters, while the backward angles are fed by collisions with small impact parameters. As can be seen from Fig.5, with the particular alignment chosen, the aligned projectile has more overlap with the target at large impact parameters than the unaligned projectile.

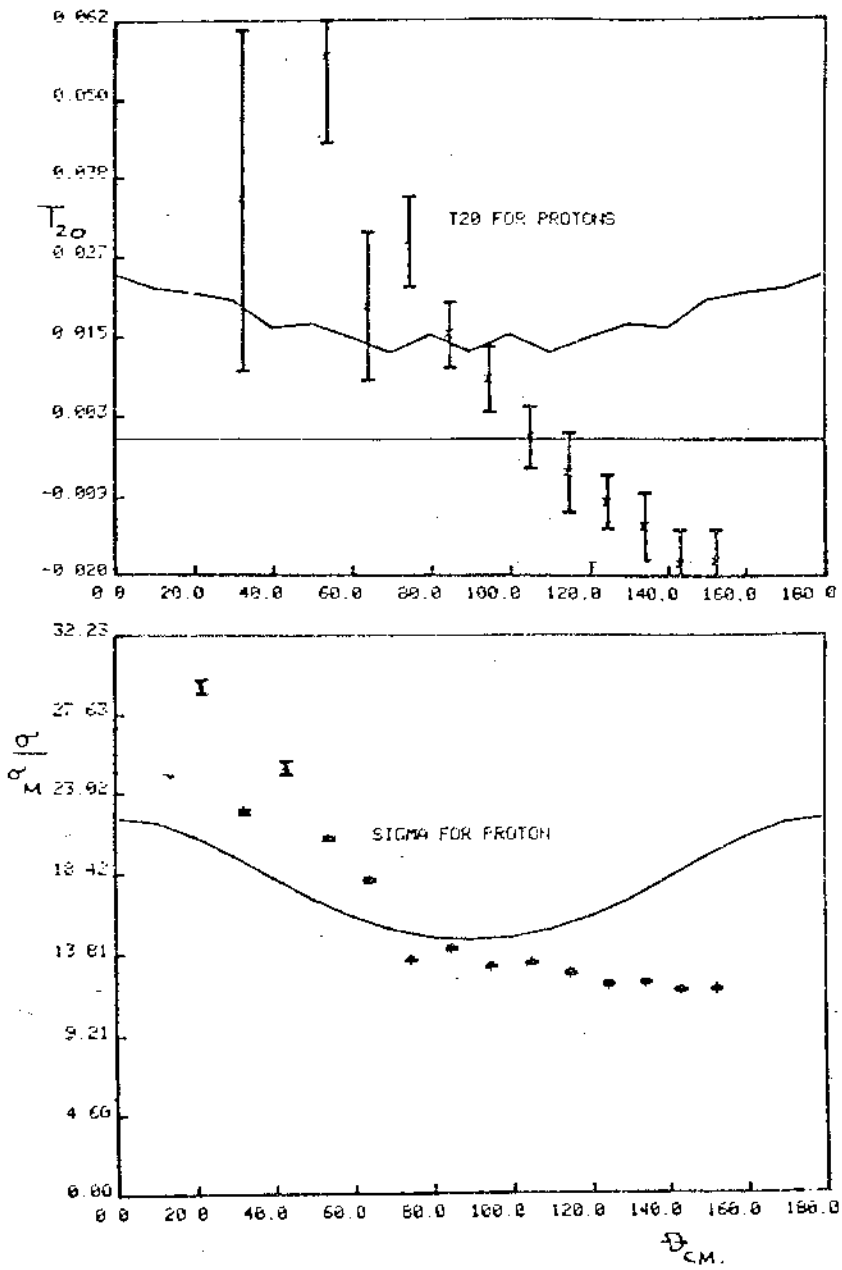

Fig. 1.2 Analysing power and Cross Section for protons
Continuous line is the STATIS estimate.

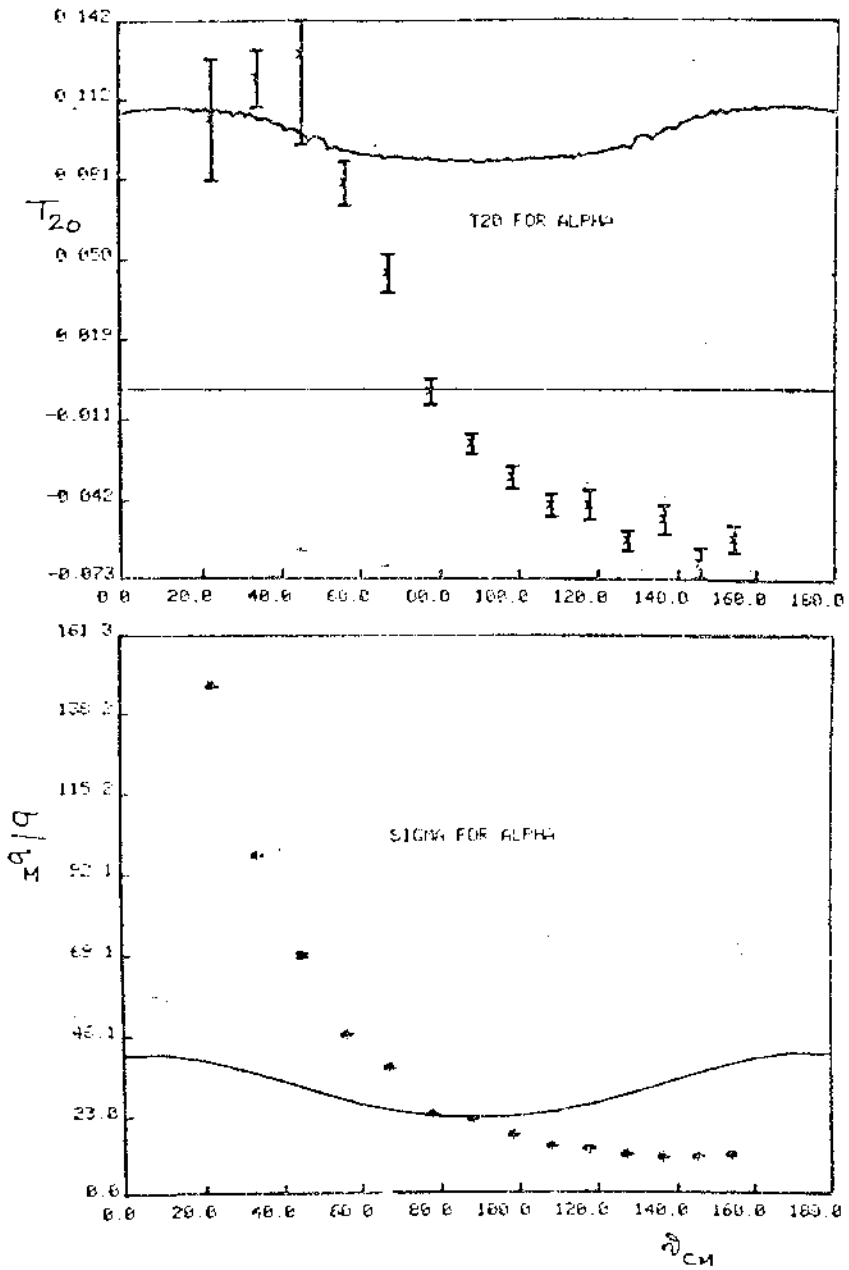

Fig. 3,4 Analysing power and Cross Section for alphas
Continuous line is the STATIS estimate.

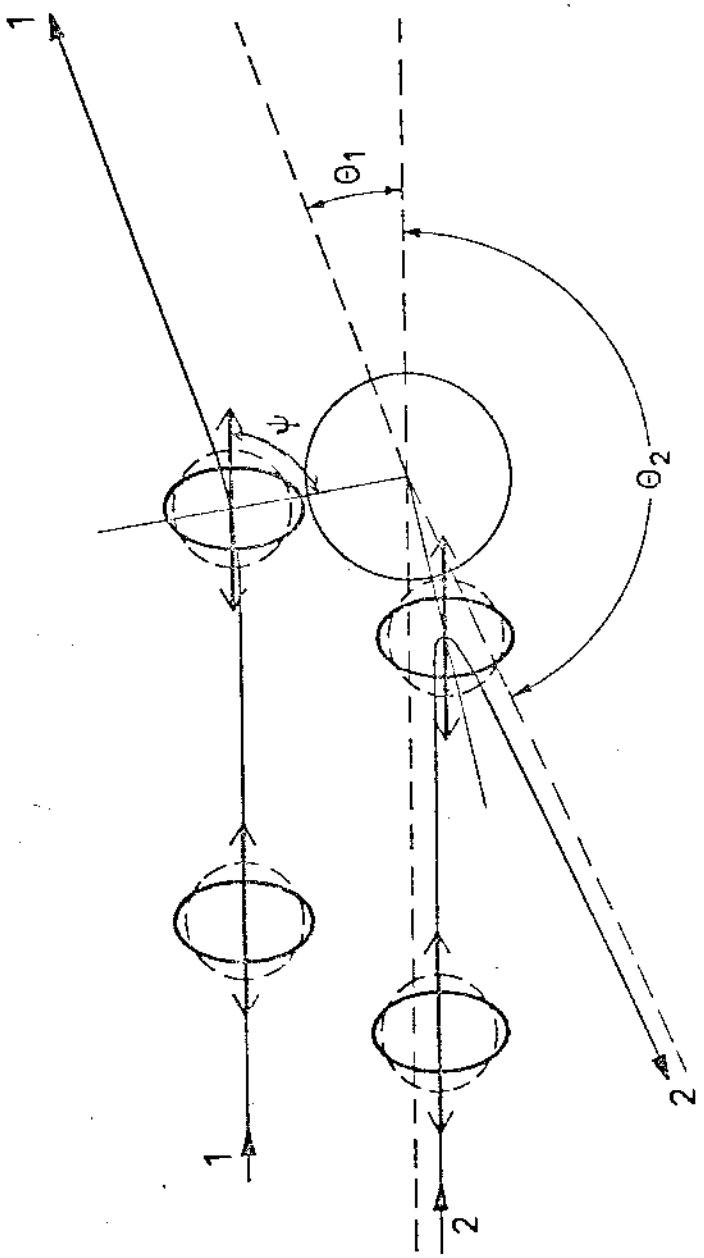

Fig. 5. Definition of the variables for aligned and non-aligned ^{7}Li reactions.

This leads to positive values for T20. The opposite holds for small impact parameters leading to negative values of T20 at back angles.

Computing T20(θ) from a direct reaction model is still not possible for the energy-integrated cross section. On the other hand, a small modification of the code STATIS by Stockstadt [4] has made it possible to estimate the average contribution to $T_{20}(\theta)$ from compound nucleus processes. To this end it was assumed that the incomming Li moves on Coulomb trajectories. Then the angle ψ (Fig. 5) can be computed as a function of the impact parameter b and this related to l classicaly to yield:

$$t_g(\psi) = \frac{2.\ell.\hbar}{Zze^2\sqrt{(2M/E)}} = \ell.\Gamma(E) \qquad (2)$$

This together with the relation:

$$R(\psi) = R0\ \{1 + \beta.Y20(\psi)\} = R0\ \{1 + \beta\ .\ \sqrt{(5/4\pi)}\ P2(\cos\psi)\} \qquad (3)$$

for the radius leads to an ℓ-dependence of the form:

$$R(1)/R0 = 1 + (\beta/2)\ .\ \sqrt{(5/4\pi)}\ .\ \left\{\frac{3}{1+\ell^2.\ F^2} - 1\right\} \qquad (4)$$

In STATIS the channel radius is parametrised as:

$$RC = R0\ (A_1^{1/3} + A_2^{1/3}) \qquad (5)$$

and by replacing RC by:

$$RC = R0\ \left(A_2^{1/3} + \frac{R(1)}{R0}\ .\ A_1^{1/3}\right) \qquad (6)$$

we obtain a form which can be used for calculating the aligned and non-aligned cross sections. For the later case we simply use β=0.

The parameters for the exit channels were not varied since STATIS does only consider two-body final channels. The experimental results however show that in all channels at least one neutron is evaporated together with the charged particle. Therefore the absolute cross-sections obtained from STATIS cannot be compared to the experiment. The only value of these calculations is to uncover systematic trends of the cross sections.

As a first test, the angular distributions of evaporated protons were calculated. The center-of-mass energy was fixed at 8.7 and 17.5 MeV, values which correspond to the two endpoints of the measured excitation function. STATIS produces the angular distribution of particles leaving the residual nucleus in a state of definite energy, spin and parity. For the proper calculation of the energy-integrated angular distributions a density of states function should be folded into it. In the present case a simplified approach was taken, which seems to be justified by the results. The emerging protons were assumed to leave the residual nucleus ^{57}Mn to an excitation of 10 and 16 MeV. This corresponds roughly to the endpoints of the measured proton spectrum. The spins considered for the 'excited states'were 1/2, 5/2, 9/2, 15/2, 19/2. A weighted sum of the results is plotted in Figs. 1 and 2

As expected from the theory of compound perocesses the distributions of both the cross section and he analysing power are symmetric around 90 degrees since parity is conserved. From the detailed results it can be observed that the variation of the analysing power with angle is within the numerical accuracy of the results for the cross section although a trend may be observable in some cases.

Another trend is that the average analysing power is of the same sign and the same order of magnitude as the one obtained from total cross sections. This indicates that the entrance channel is the main 'source' of the analysing power while the exit channel influence is limited.

The main trend is, however, that the average analysing power is a function of the c.m.- energy and the spin only, although the cross section varies sometimes considerably with excitation energy in the compound nucleus. Whether this property can be used for spin determination in compound nuclear reactions requires further testing.

The calculations were extended to evaporating alpha-particles. Again the c.m. energy was fixed at 8.7 and 17.5 MeV while excitations of 8, 14 and 20 MeV and spins of J=0, 4, 8 and 12 in ^{54}Cr were tested. A weighted average of the results is plotted in Figs3,4 .Two main features can be observed:

The angular distribution of T20 shows large variations with angle and the average analysing power depends now also on the excitation energy as well as the spin and the c.m. energy.

Both effects must be related to the larger angular momentum carried by the alpha particle as compared to the proton.

What certainly emerges from these preliminary results is, that the interpretation of the assymmetry observed in the experimental angular distributions of both the cross-section and the analysing power, must be sought in the frame of a direct reaction model.

Table I. Excitation function of the reaction $^{7}Li + {}^{51}V$

		THEORY			EXPERIMENT	
ECM	BETA	SIGMA0	SIGMAP	T20	SIGMA0	T20
8.70	-0.180	57.10	44.20	-0.2259	55 ± 6	-0.286±0.056
9.60	-0.180	131.90	103.10	-0.2183	142 ± 14	-0.222±0.030
10.45	-0.120	255.60	224.40	-0.1221	261 ± 29	-0.118±0.012
11.40	-0.100	437.80	410.50	-0.0624	447 ± 45	-0.056±0.008
12.20	-0.100	597.80	577.30	-0.0343	600 ± 66	-0.014±0.007
13.95	-0.100	890.90	889.70	-0.0013	850 ± 93	+0.001±0.003
15.75	-0.160	1143.80	1166.00	0.0194	1127 ±123	+0.026±0.005
17.50	-0.160	1339.80	1377.80	0.0283	1237 ±148	+0.028±0.006

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{1} K.- H. Moebius et al., Phys. Rev. Lett. 46 (1981) 1064.

{2} E. Steffens et al., Rev. Phys. Appl. 12 (1977) 1567.

{3} P. Zupranski et al., Nucl. Instr. Meth. 167 (1977) 1567.

{4} R. G. Stockstadt, Wright Nucl. Structure Lab., Yale University, Internal Report 52, 1972, (Unpublished).

{5} S. Kossionides et. al., Fizika, 23, Supp. 1 (1981) g.

(+) Fachbereich Physik der Philipps-Universitaet Marburg, D-3550 Marburg 1.

(++) Max-Planck-Institut fuer Kernphysik, 69 Heidelberg 1.

II. GAMMA RAY SPECTROSCOPY

Low spin states in ^{65}Ga

T. Paradellis

The ^{64}Zn (p,γ) ^{65}Ga reaction using a 4mg/cm^2 thick Zn64 target is studied at about 3 MeV proton bombarding energy.

Several low lying levels have been identified in ^{65}Ga and unique spin and parity assignments has been determined. Multipolarities of several transitions has been established. The levels identified, with an established J^π are listed in Table I.

Table I.

Level (keV)	J^π	Level (keV)	J^π
62	$1/2^-$	1353.1	$7/2^-$
190.8	$5/2^-$	1374.3	$5/2^-$
649.6	$3/2^-$	1469.9	$5/2^-$
809.0	$5/2^-$	1662.6	$3/2^-$
814.9	$(1/2,3/2)^-$	1879.4	$5/2^-$
1075.9	$7/2^-$	1982.4	$7/2^-$
1287.0	$9/2^-$	2037.4	$9/2^+$
1298.4	$3/2^-$		

Further analysis is in progress to determine the properties of some higher lying states.

Excited states in ^{68}Ge and ^{69}Ge studied by the ^{64}Zn (^{7}Li, pxnγ) reaction

T. Paradellis and C.A. Kalfas

Excited states in ^{68}Ge and ^{69}Ge populated in the ^{64}Zn + ^{7}Li reaction at 18 MeV bombarding energy are studied. Angular distribution and centroid shift measurements are used to determine spin and mean lives in the nuclei. The first 2^+ state in ^{68}Ge has been remeasured to have a mean life of (2.6 ± 0.3) ps. In ^{69}Ge discrepancies among different publisehd works are discussed. The experimental evidences are in favor of description of the positive parity states in ^{69}Ge, where a $g_{9/2}$ neutron is coupled to a ^{68}Ge even-even core.

The following table list the measured lifetimes for ^{69}Ge levels.

T a b l e I.

Level (keV)	γ ray used (keV)	F(τ)	Present [a]
1195.7	821.7	0.13(2)	1.4 ± 0.3
1350.7	952.7	0.108(6)	0.85 ± 0.10 [b]
1407.2	1009.2	0.050(10)	2.5 $^{+1.0}_{-0.6}$ [b]
1430.3	1430.3	0.20(3)	0.75 ± 0.20
1591.1	778.9	0.19(4)	0.80 $^{+0.40}_{-0.20}$
2018.3	667.6	0.071(19)	2.7 ± 0.7 [b]
2483.3	1076, 1132	0.11(1)	1.9 $^{+0.8}_{-0.4}$
2755.5	1348.3	0.19(3)	0.8 ± 0.2
3076.3	1669.1	0.10(3)	2.1 $^{+1.7}_{-0.6}$
3157.5	1139.1	≤ 0.09	≥2.5

[a] Assuming τ_s = 0.1 ps side feeding.

[b] Corrected for feeding from above.

Structure of ^{121}Te nucleus by the ^{121}Sb (p,n,γ) ^{121}Te reaction

T.N. Paradellis, E.N. Gazis[+], C.T. Papadopoulos[+] and R. Vlastou[+]

Energy levels and electromagnetic transitions of ^{121}Te were studied through the ^{121}Sb (p,nγ) ^{121}Te reaction at bombarding energies between 3.4 and 5.0 MeV at 0.2 MeV energy steps.

Single γ-ray spectra were obtained at $\theta_\gamma = 0^o$, 30^o, 45^o, 55^o, 70^o and 90^o as well as γ-γ coincidence spectra at 90^o.

The level and decay scheme of ^{121}Te nucleus has been determined up to about 1340 keV excitation energy. Several of the states previously observed (Ref. 1,2,3) has been also observed but considerable changes have been made to the existing level scheme.

The determination of spin and parity of the identified states of ^{121}Te is at present being carried out from the single γ-ray angular distribution measurements with the aid of the Hauser-Feshbach theory for compound nuclear reactions.

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1) T. Tamura et al, Nucl. Data sheets 26 (1979) 385
2) V. Hageman et al, Nucl. Phys. A329 (1979) 157
3) N.A. Bonch-Osmolovskaya et al, Izr. Ak. N.SSSR Ser Fiz 44 (1980) B

[+]Physics Laboratory II, National Technical University of Athens, Athens, Greece.

III. APPLIED ATOMIC AND NUCLEAR PHYSICS

Postoperative changes in serum copper value

G. Gregoriadis[+], N.S. Apostolidis[+], A.N. Romanos[+], and T. Paradellis

The serum copper concentration has been determined and observed postoperatively in patients undergoing herniorrhaphy, hemicolectomy or abdominoperineal resection of the rectum.

It has been found that those who underwent herniorrhaphy had, preoperatively, a normal serum copper concentration, which increases significantly from the second postoperative day.

Those patients who had carcinoma of the colon or rectum had preoperatively, significantly higher serum copper concentrations in relation to healthy persons. After a slight decrease by the second postoperative day, the serum copper value of these patients showed a slight increase from the fourth postoperative day when compared with the preoperative levels.

Table I. Comparison of copper serum concentration preoperatively among various patient groups

	No of patients			Serum Cu, μgm/100ml		
Group	Men	Women	Total	Men	Women	Total
Healthy control	10	10	20	102±16	122±16	112±18
Hernia	9	6	15	109±11	117±15	112±13
Totals	19	16	35	106±14	120±15	112±16
Cancer of the colon and rectum	14	8	22	141±23	163±26	149±26
Cancer of the ovaries		3	3		227±68	227±68
Cholelithiasis	3	7	10	145±21	139±38	141±33

Table II. Variations postoperatively of serum copper concentration among the various patient groups

Group	Value, micrograms per 100 milliliters				
	Preoper.	t= 2nd day	t= 4th day	t= 6th day	t=12th day
Herniorrhaphy.....	112 ± 13	138 ± 20	145 ± 23	143±24	
Hemicolectomy	149 ± 26	145 ± 25	151 ± 21	157±25	163± 20
Cholecystectomy.....	141 ± 33	151 ± 25	161 ± 26	159±27	

+ 1st Surgical Clinic, Medical School, Athens University, Athens, Greece

++ Tandem Laboratory, NRC Democritos

For an example see Figs,1 and 2

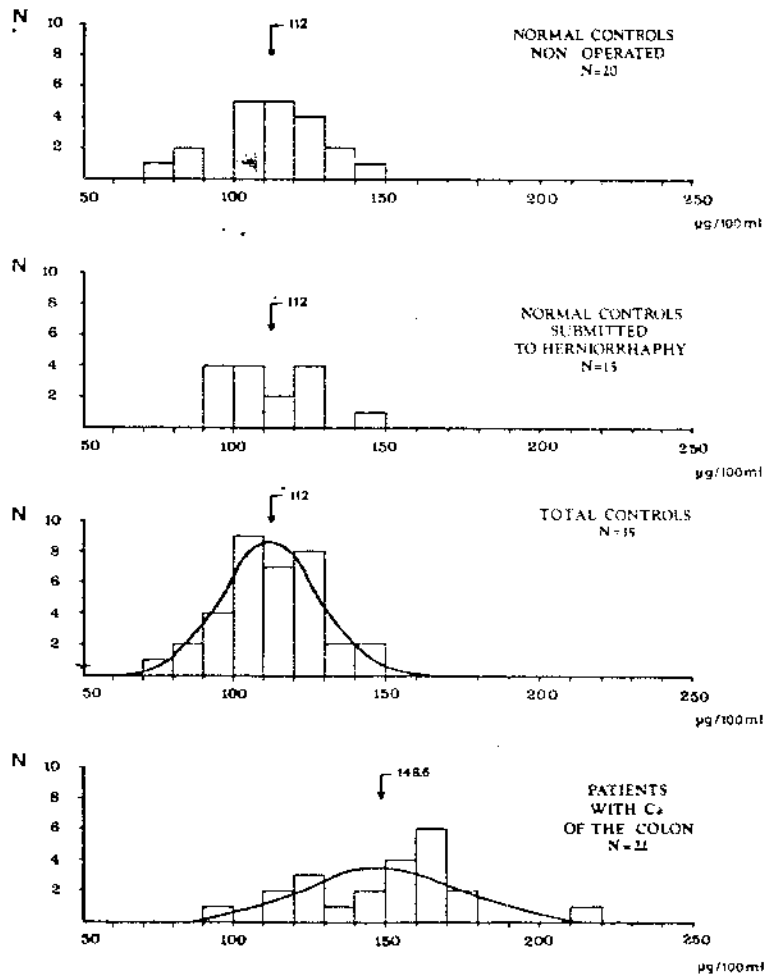

Fig. 1. Histogram of serum copper concentration data

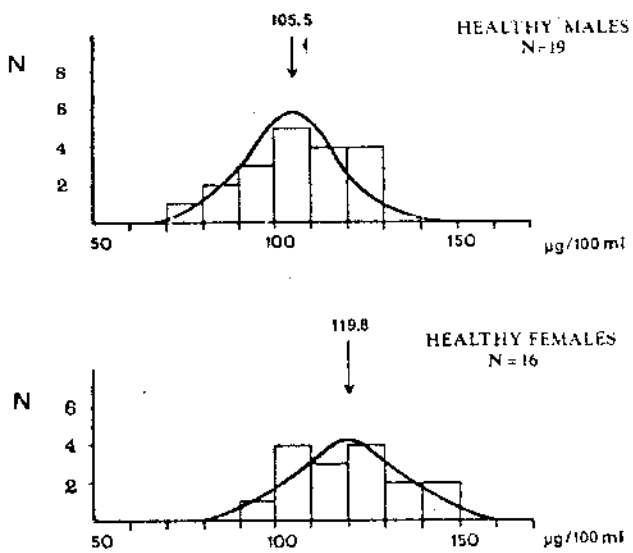

FIG. 2. Histogram shows the distribution of serum copper concentration among healthy men and women.

Fig. 2. Histogram shows the distribution of serum copper concentration among healthy men and women

IV. THEORETICAL NUCLEAR PHYSICS

Symmetry break in the rare earth nuclei

G.S. Anagnostatos

The shell model assumption that the individual nucleons in a nucleus move relatively freely in well -defined single-particle orbitals is here understood as a consequence of a dynamic equilibrium of nucleons. In particular we consider a specific equilibrium valid whatever the law of nuclear force may be {1} , which leads uniquely to momentary dynamic average forms for the nuclear shells (presented by the limited number of equilibrium polyhedra with symmetry properties consistent with the independent particle total spin assignment {2}) in agreement with the magic numbers. What the vertices of these polyhedra actually represent are the most probable positions of the nucleons, due to their "mutual repulsion" which ensures regions of maximum probability disposed over the surface of each shell. These polyhedral shells, superimposed in the most symmetric way, define the angular part (tested by electric quadrupole moments of open-shell nuclei {3}) of the momentary nuclear structure of the closed-shell nuclei from ^{4}He to ^{208}Pb. The radial part of this structure is defined by the closest-packing of these polyhedral shells when the nucleons are presented by "hard spheres" of definite sizes (tested by rms radii for protons and neutrons).

In order to accommodate all nuclear shells up to N=Z=82, each equilibrium polyhedron is used once. For heavier neutron or proton shells the same polyhedra are used, but for reasons of least energy, sets of nucleons, instead of individual nucleons, have their most probable positions at the polyhedral vertices. Specifically for the rare earth region, only the last neutron shell possesses sets. The symmetry of the previous shells requires that each set consists of three neutrons. Before the formation of the next neutron shell at N=126, we have symmetry break in the range from N=90 to N=114, in the sense that rotational invariance {1} for most probable positions (a prerequisite for dynamic equilibrium) is non-existent only in this region. This break is in very good agreement with the experimental data and also with another symmetry break in a study of orbital angular momentum quantization of direction {?}. This break could be responsible for the very strong deformation of the rare earth nuclei.

{1} J. Leech, Math. Gaz. 41 (1957) 81

{2} G.S. Anagnostatos, J. Yapitzakis and A. Kyritsis, Lett. Nuovo Cimento 32 (1981) 332

{3} G.S. Anagnostatos, S. Touliatos, A. Kyritsis and J. Yapitzakis, Atomkernenergie 35(1980) 60

Comments on 'A relation between average kinetic energy and mean-square radius in nuclei'[+]

C.N. Panos[‡] and G.S. Anagnostatos

While for a selection of self-consistent field calculations, using Hartree-Fock and Bruckner-Hartree-Fock theories, Svenne {1} finds that the average kinetic energy per particle in nuclei is inconsistent with the kinetic energy coming from the single-particle sum rule {2} (Koopman's theorem), when the isomorphic model {3} is considered the two kinetic energies become consistent, Here, ^{16}O and ^{40}Ca are taken as examples.

In the paper by Svenne the empirical average kinetic energy per particle ($<T>$) coming from the Koopman theorem (without allowing for rearrangement), i.e.

$$<T> = \frac{1}{A} \left(2E - \sum_{\lambda}^{A} \varepsilon_{\lambda} \right) \qquad (1)$$

(where E is the total binding energy and ε_{λ} the single -particle energy at a state λ), is compared with the estimates of the kinetic energy from a selection of self-consistent field calculations. Svenne concludes that this comparison is not satisfactory. Because of the importance of Eq. (1) in nuclear physics, we found it tempting to re-examine this comparison using a model (the isomorphic model) different from those considered in Svenne's paper.

The kinetic energy in the present paper, as in Svenne's paper, is calculated considering the sum of the kinetic energy due to confinement of the nucleons in the nuclear volume of radius R_{max} and of the kinetic energy due to rotation of nucleons. Here the rotation of a nucleon refers to the rotation of the most probable position of this nucleon, in the momentary picture of the nucleus in Fig. 1, around its orbital angular momentum (OAM) axis, i.e.{1}

$$<T>_{n,l,m} \geq \frac{\hbar^2}{2M} \left(\frac{1}{R^2_{max}} + < \frac{L^2}{\rho^2_{n,l,m}} > \right) = <T_1> + <T_2>_{n,l,m} \qquad (2)$$

where R_{max} is the outermost polyhedral radius (R) plus the relevant nucleon radius (r_n = 0.974 fm or r_p = 0.860 fm), i.e. the radius of the nuclear volume in which the nucleons are confined, M is the nucleon mass and $\rho_{n,l,m}$ is the distance of the vertex (n,l,m) from the axis ${}_n\theta_l^m$, i.e. the radius of the classical orbit of the most probable position of the nucleon (τ,n,l,m,s).

$<T>_{n,l,m}$ for each nucleon takes its minimum value when the radius $\rho_{n,l,m}$ takes its maximum value. Since, at least for all the cases of Fig. 1, all axes of rotation are axes of symmetry, the radii ρ_{max} for each value of l are equal to the value of ρ given in the relevant block of Fig. 1.

Numerical values of $<T_1>$, $(\Sigma_{n,l,m} <T_2>_{n,l,m})$ /A and $(\Sigma_{n,l,m} <T>_{n,\ell,m})$ /A for the model from Eq. (3) (where A is the mass number of the nucleus, the summation includes all quantum states present in this nucleus and values of R and ρ come from Fig.1) are listed in columns 5,6 and 7 of Table I, respectively, for both ^{16}O and ^{40}Ca. In columns 8 and 9 the model, and the experimental E/A values are listed for both nuclei. These values for the model are estimated from Eq. (1) using the empirical ε_λ values {4} listed in the first column of the table. The comparison is very good and becomes even more impressive if one considers the crude character of the inequality (2). This inequality permits larger values for $<T_1>$ (than those taken in Table I) and thus permits new values of $<T>_{model}$ and $(E/A)_{model}$ closer to $(E/A)_{expt}$. Calculations and comparisons of values of C listed in Table I will be discussed together with those values in Table II.

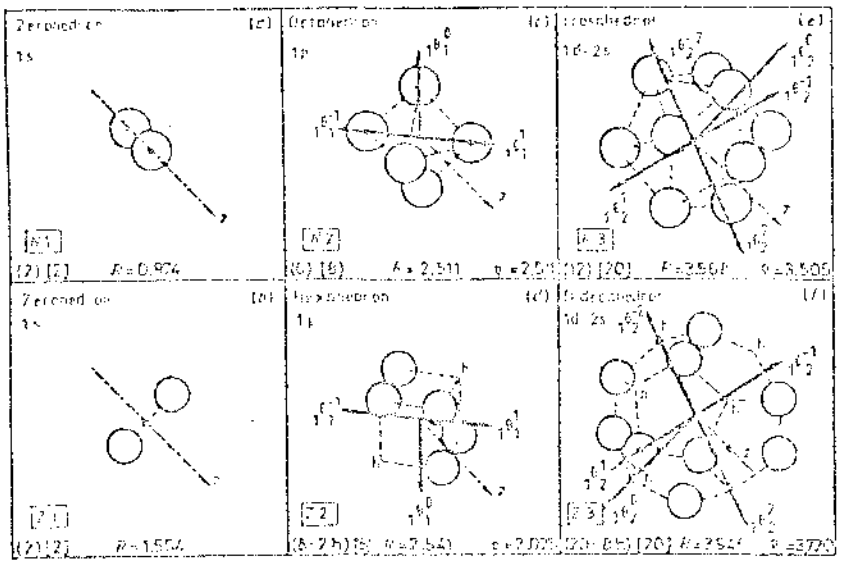

Fig. 1. The isomorphic model for the doubly closed-shell nuclei up to ^{40}Ca. The regular polyhedra in row 1 stand for the noncentrary dynamic average forms for neutrons of the 1s(a), 1p (c) and 1d-2s(e) shells, while the polyhedra in row 2 stand for the average forms of the same shells for protons. The vertices of polyhedra stand for the most probable positions of nucleons in definite quantum states (τ,n,l,m,s).Axes marked ${}_n\theta_l^m$ precisely represent orbital angular momentum axes with definite n, l and m values, and may be used for the assignment of quantum states to the polyhedral vertices. The letters h stand for the empty vertices (holes).The z axis is common for all polyhedra when these are superimposed with a common centre and with relative orientations as shown. At the bottom of each block the number of succession of the neutron (N) or proton (Z) shell is shown inside a box. Underneath this box, the number of vertices of the specific polyhedron and the number of holes (where they exist) are given in parentheses, while inside square brackets the cumulative number of most probable nucleon positions is given. Values of R give the radii of the spheres excribed to the polyhedra, while values of ρ give the maximum distances of the vertices states (τ,n,l,m,s) from the axes ${}_n\theta_l^m$ (which stand for the radii of the classical orbits of the most probable nucleon positions). The backside (hidden) vertices of the polyhedra are not shown in the figure[3].

In Table II values of ε_λ, E/ A and $\langle r^2 \rangle^{1/2}$ from experiments (taking, for this table only and for reasons of better comparison, the experimental values used in Svenne's paper) and from a selection of self-consistent field calculations for ^{16}O {1} are listed. From these values the quantities $\langle T \rangle$ and C (see also the relevant columns of Table I) are calculated using Eqs.(1) and (6), respectively (where applicable):

$$C = \frac{1}{2} \langle T \rangle \langle r^2 \rangle \qquad (3)$$

We see that our value of E/A is closer to the experimental value than those values coming from the different self-consistent calculations of the Hartree-Fock (HF) and Bruckner-Hartree-Fock (BHF) theories listed in Table II.

Also, our results for C are, as desired {1}, much smaller than the harmonic oscillator (HO) value determined for closed-shell nuclei from

$$C_{HO} = \frac{\hbar^2}{A^2 M} \left(\sum_\alpha (2j_\alpha + 1)\,(2n_\alpha + \ell_\alpha - 1/2) \right)^2 , \qquad (4)$$

where the sum extends over all occupied oscillator states $(n_\alpha, l_\alpha, j_\alpha)$, A is the mass number of the nucleus and M is the nucleon mass. Moreover, our value of E/A lies very close to those values coming from the renormalised Bruckner-Hartree-Fock (RBHF) and the density-dependent Hartree-Fock (DDHF) theories also given in Table II.

In conclusion, we may say that the single-particle sum rule of Eq. (1), in contradiction to the conclusion of Svenne's paper for the selection ofself-consistent calculations considered there, is consistent with experimental quantities (i.e. values of ε_λ and E/A) when for the average kinetic energy per particle in Eq. (1) the isomorphic model is considered as a single-particle nuclear structure model. This conclusion, of course, does not al all devaluate the importance of renormalised self-consistent field theories (mentioned in Svenne's paper) for obtaining consistency in Eq. (1).

Table. I. Single-particle energies (MeV), average kinetic energies per particle (MeV) from Eq. (2), $(E/A)_{model}$ and $(E/A)_{expt}$ (MeV), charge RMS radii (fm) and values of C (MeV fm^2) from Eq. (3), except for C_{HO} which comes from Eq. (4).

Nucleus	State λ	Proton ε_λ [a]	Neutron ε_λ [a]	$\langle T_1\rangle_{model}$	$\langle T_2\rangle_{model}$	$\langle T\rangle_{model}$	$(E/A)_{model}$	$(E/A)_{expt}$	$\langle r^2\rangle^{1/2}_{model}$ [b]	$\langle r^2\rangle^{1/2}_{expt}$ [c]	C_{model}	C_{HO}
^{16}O	$1s_{1/2}$	40.5	44	1.79	6.08	7.87	8.12	7.98	2.47	2.61 ± 0.14	23.8	52.4
	$1p_{3/2}$	18.4	21.9									
	$1p_{1/2}$	12.1	15.7									
^{40}Ca	$1s_{1/2}$	65	(72)	0.90	7.21	8.11	9.03	8.55	3.49	3.43 ± 0.07	49.4	93.2
	$1p_{3/2}$	(32.1)	(39.1)									
	$1p_{1/2}$	24.5	(31.5)									
	$1d_{5/2}$	15.1	21.9									
	$2s_{1/2}$	10.9	18.2									
	$1d_{3/2}$	8.3	15.6									

[a] Single-particle energies (ε_λ) for ^{16}O come from Hodgson {4} except for $1s_{1/2}$ state energies which come from Pugh {4} because of their significantly smaller experimental error. These energies for ^{40}Ca come from Swift and Elton {4}. Values in brackets come from theoretical calculations also given by Swift and Elton.

[b] Charge $\langle r^2\rangle^{1/2}_{model} \equiv (\Sigma_{i=1}^{Z} R_i^2/Z + \alpha^2)^{1/2}$, where $\alpha = 0.80$ fm stands for the proton charge RMS radius and R_i is the radius of the ith proton's most probable position from Fig. 1 {3}.

[c] See de Jager *et al.* {5}

Table II. The single-particle sum-rule average kinetic energy per particle <T> for a selection of self-consistent field calculations for ^{16}O. $<T>_{model}$ is calculated using Eq.(2) from the geometrical quantities R and ρ in Fig. 1. C is calculated from values of <T> and $<r^2>$ using Eq. (3) except for C_{HO} where, Eq. (4) is used. Energies are in MeV and radii in fm.

Theory	Reference	$s_{1/2}$	$p_{3/2}$	$p_{1/2}$	E/A	$\langle T \rangle$	$\langle r^2 \rangle^{1/2}$	C
	Experiment	−40 ± 8	−21.8	−15.7	−7.98		2.73	
	Kerman *et al* (1966)	−48.7	−19.7	−9.5	−2.41	19.58	2.28	55.5
	Kerman (1969) (including CM)	−50.6	−23.1	−11.6	−3.35	19.4	2.28	53.0
HF	Davies *et al* (1966)	−40.6	−16.2	−16.2	−4.83	12.64	2.91	53.5
	Tarbutton and Davies (1968)	−47.9	−20.8	−15.0	−4.62	16.88	2.54	54.5
	Vautherin (1969)	−48.3	−23.5	−17.3	−6.05	16.05	2.66	56.8
	Kakkar and Waghmare (1971)	−42.0	−13.5	−11.3	−2.11	15.86	2.42	46.4
BHF	Brueckner *et al* (1961)	−44.3	−19.0	−14.9	−2.02	20.26	2.41	58.8
	Davies *et al* (1969)	−43.8	−20.3	−15.9	−3.84	17.39	2.46	52.6
RBHF	Becker *et al* (1974)	−39.3	−19.3	−15.6	−8.00		2.29	
DDHF	Campi and Sprung (1972)	−36.4	−21.2	−15.8	−7.68		2.69	
HO	Harmonic oscillator				−7.30		2.47	52.4 23.8
IM	Isomorphic model							

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‡Physics Department, University of Ioannina, Ioannina, Greece

Kinetic energy of ^{16}O and ^{40}Ca

C.N. Panos[+] and G,S. Anagnostatos

In Table I we present the results on kinetic energies of ^{16}O and ^{40}Ca derived by three different approaches.

The first approach uses the single-particle sum-rule {1}

$$\langle T\rangle = 1/A(2E - \sum_{\lambda}^{A} \varepsilon_{\lambda}) ,$$

where E is the experimental iotal BE and ε_{λ} the experimental single-particle energy at a state λ.

The second approach employes the formula

$$\langle T\rangle = \frac{1}{2} \{\sum_{\substack{\text{all}\\ \text{nucleon}\\ \text{pairs}}} V_{ij} - \sum_{\substack{\text{all}\\ \text{proton}\\ \text{pairs}}} \frac{e^2}{|r_i - r_j|} - E\},$$

where V_{ij} and $e^2/|r_i-r_j|$ are the PE and the E_c from the interaction of two nucleons i and j, according to the potential of Ref. {2} and the Coulomb potential, respectively, for the proton and neutron distributions given in Ref. (2).

The third approach utilizes the inequality of Ref. {3},

$$\langle T\rangle \geq \sum_{i} \frac{\hbar^2}{2M} \left(1/R_{max}^2 + \left\langle \frac{L^2}{\rho_i^2} \right\rangle\right).$$

The first term expresses the part of KE due to the confinement of the nucleons in the nuclear volume of radius R_{max} and the second term the part of KE due to the rotation of nucleons, where ρ_i is the radius of the nucleon i most probable orbit, according to the isomorphic model {4}.

Table I .Kinetic energies of ^{16}O and ^{40}Ca in units MeV/nucleon

Nuclei	Approach 1	Approach 2	Approach 3	RBHF	DDHF
^{16}O	"8.18"	7.19	7.87	"7.38"	"8.29"
^{40}Ca	"9.06"	8.76	8.11		

As one may see from the table, there are good agreements among the results of the three different approaches, which is important, since as noted in Ref.{3} the KE from a collection of self consistent field calculations do not agree (by a factor of about 2.5) with the KE from the sum-rule (approach 1)

The approximate values of KE from the renormalized Bruckner Hartree-Fock (RBHF) and the density-dependent Hartree Fock (DDHF) theories {3}for ^{16}O are also given for comparison. The isomorphic KE (approach 3) lies between these two values.

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+Physics Dept, University of Ioannina, Ioannina, Greece

On the applicability of the Hill determinant and the analytic continued fraction method to anharmonic oscillators

G.P. Flessas[+] and G.S. Anagnostatos

We finish a line of argument started in an earlier paper and show that the application of the Hill determinant and the associated analytic continued fraction method for the calculation of eigenvalues of anharmonic oscillators is of dubious validity and may thus lead to erroneous results. In this context some theorems concerning the eigenvalues of the λx^4 and the doubly anharmonic oscillators are proved.

The Hill determinant method has been used {1} for the calculation of the ground-state eigenvalues of the λx^{2m} anharmonic oscillator. Along these lines and by application of the analytic continued fraction method, which is mathematically equivalent to the Hill determinant approach, Singh et al{2} treated the doubly anharmonic oscillator $ax^2 + bx^4 + cx^6$. Recently Datta and Mukherjee{3} have applied exactly the same procedure to the interaction $V(r) = -\alpha/r + br + cr^2$.

In a previous paper {4} we discussed the aforementioned method and verified its inadequacy for the calculation of the energy spectrum of the Datta and Mukherjee potential. In this work we whow the Hill determinant technique to be wanting also in the case of the oscillator with either quartic or quartic and sextic anharmonicity. These findings prove, therefore, that the above technique should not be used without a proper incorporation into it of the main physical requirement that the wavefunction of the relevant Schroedinger equation is normalisable.

In summary, we have verified that the methods used in the context of the Mathieu (or more generally the Hill) differential equation are not, nor should they be, directly applicable to the equations obtained in relation to various anharmonic oscillators. In these procedures the requirement that the wavefunction remains normalisable has to be incorporated so as to ensure that the values we obtain for E are the physically correct ones. No general method for doing this seems to exist{5} and thus one is forced to carry out rather extensive investigations for every potential under consideration.

To our knowledge the only known exact solutions for anharmonic oscillators can be written as either (exponentials) x (polynomials){6} or as definite integrals {7} . In both cases the actual notion of the Hill determinant or the analytic continued fraction method is irrelevant,since we obtain the above solutions either by rigorously truncating infinite series, whose behaviour for $|x| \to \infty$ may generate an unphysical wavefunction , or by representing the wavefunction $y(x)$ as an integral with $y(x) \to 0$ for $|x| \to \infty$

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+Department of Natural Philosophy, The University, Glasgow G12 8QQ, UK.

Double β-decay nuclear matrix elements for the A=48 and A=58 systems

L.D. Skouras and J.D. Vergados[+]

The nuclear matrix elements entering the double β-decays of the ^{48}Ca-^{48}Ti and ^{58}Ni-^{58}Fe systems have been calculated using a realistic two nucleon interaction and realistic shell model spaces. Effective transition operators corresponding to a variety of gauge theory models have been considered. The stability of such matrix elements against variations of the nuclear parameters is examined. Appropriate lepton violating parameters are extracted from the A=48 data and predictions are made for the life times of the positron decays of the A=58 system.

[+]Physics Department, University of Ioannina, Ioannina, Greece

1. *Generalized fractional parentage coefficients*

L. D. Skouras and S. Kossionides

The concepts of the fractional parentage coefficients has been generalized to the case of many orbitals. Thus for any distribution of n particles (n>0) among k orbitals (k>0), to be denoted by:

$$C^n = j_1^{n_1} j_2^{n_2} \cdots j_k^{n_k} \qquad \sum_{i=1}^{k} n_i = n \tag{1}$$

states can be constructed in the {J,T} scheme which are antisymmetric in the exchange of any two particles. To describe uniquely such states, in addition to C^n, J, T a fourth "quantum number "M is needed, which serves to distinguish between orthogonal states that have the same C^n, J, T. Thus:

$$\langle C^n\, S\, T\, M | C^n\, S'\, T'\, M' \rangle = \delta_{C^n C^n}\, \delta_{SS'}\, \delta_{TT'}\, \delta_{MM'} \tag{2}$$

To perform shell-model calculations in the basis of states $|C^n\, JTM\rangle$ the coefficients in the following expansions need to be known:

$$|C^n S T M\rangle = \sum_{i=1}^{K} \sum_{S_1 T_1 M_1} [j_i, C_i^{n-1}\, S_1 T_1 M_1; JT | C^n S T M\rangle \times |j_i, C_i^{n-1}\, S_1 T_1 M_1; JT\rangle \tag{3}$$

$$|C^n S T M\rangle = \sum_{i\le j}^{K} \sum_{\substack{S_1 T_1 \\ S_2 T_2 M_2}} [(j_i j_j) S_1 T_1, C_{ij}^{n-2}\, S_2 T_2 M_2; JT | C^n S T M\rangle \times |(j_i j_j) S_1 T_1, C_{ij}^{n-2}\, S_2 T_2 M_2; JT\rangle \tag{4}$$

where:

$$C_i^{n-1} = j_1^{n_1} \cdots j_i^{n_i - 1} \cdots j_k^{n_k} \qquad , C_{ij}^{n-2} = j_1^{n_1} \cdots j_i^{n_i - 1} \cdots j_j^{n_j - 1} \cdots j_k^{n_k} \tag{5}$$

The states which appear on the r.h.s of (3) and (4) are not totally antisymmetric. They are antisymmetric only in the particles which appear in them.

The coefficients of these expansions are termed in the following (m,n-m) generalized fractional parentage coefficients or GFPCm (m=1 in (3), m=2 in (4)). Knowledge of these coefficients results in an easy determination of the matrix elements of any operator. Thus for example:

$$\langle C^n\ JTM|V|\ C^n\ JTM'\rangle = \sum \langle j_i\ j_j\ ;\ J_1\ T_1|\ V\ |j_1\ j_m\ ;\ J_1\ T_1\rangle \times$$

$$\{((J_i\ J_j)\ J_1\ T_1,\ C^{n-2}_{ij}\ J_2\ T_2\ M_2\ ;\ JT|\}\ C^n\ JTM\ \}\ \times \qquad (6)$$

$$\{(j_1\ j_m)\ J_1\ T_1,\ C^{n-2}_{ij}\ J_2\ T_2\ M_2\ ;\ JT|\ \}\ C^{\ n}\ JTM'\}$$

Two programs were developed for the use of the above formalism. The first, GFPC1, performs the following tasks:

a) It constructs an orthonormal set of states $|C^n\ JTM\rangle$ for all possible distributions C^n of n particles among k given orbitals for all possible values of {J,T}

b) It calculates the{1, n-1} GFPC of these states.

The second program, called GFPCM, uses the results of GFPC1 to calculate the {m,n-m} GFPC for $2 \leq m \leq n$. An application program, called SMGFP, which performs calculations in the model space defined by one set of GFPC is also available. A more general shell-model code, which will work in a model space defined by several non-equivalent groups of orbitlas (i.e. several sets of GFPC) is under development.

The creation and use of the GFPCm has been made easy by the development of a filing system which is accessed from the application programs through standard FORTRAN calls. This filing system allows fast retrieval of the GFPC by the application programs and it is equally portable as the programs generating and using the GFPC. It uses standard FORTRAN 77 direct access input/output and makes all input/output operations transparent to the user.

The portability of the system is enhanced by the provision of common variables which hold the system dependent characteristics while all application dependent characteristics are passed as arguments in the calls of the filing system subroutines.

Safety features have been built into the system which ensure that if a program abort happens during the creation of the GFPC- files most of the work done so far will be saved. These same features allow also the extension of the GFPC files with minimal restrictions on the sequence.

The program package was tested up to now for the generation and retrieval of GFPCm coefficients for m=1 to 4 and up to n=10. Up to four orbitals were included in the calculation.

V. DEVELOPMENT

A facility for the investigation of (n, charged particle) reactions

G. Vourvopoulos, E. Kossionides and T. Paradellis

The (n, charged particle) facility has now been completed and pending the arrival of the quadrupole power supplies will be soon operational. Fig.1 shows an overview of the facility. It is composed of a gas cell and a magnetic quadrupole triplet. The gas cell is capable of producing monochromatic neutrons of variable energy between 5 and 25 MeV with a total energy spread < 400 keV and an intensity $\sim 10^7$ n/cm^2/sec. The initial operation of the gas cell with Deuterium will offer a neutron energy range between 5 and 13 MeV. The quadrupole triplet offers a 17 msr solid angle for the detection of charged particles at a distance of 2.65 meters from the target onto which the (n, charged particle) reactions take place. The triplett is mounted on a rotating platform capable of covering angles between -30^0 and 140^0. Initial experiments will involve the measurement of (n,d) cross sections for materials important in fusion technology and investigation of nuclei removed from the stability line, such as ^{61}Fe.

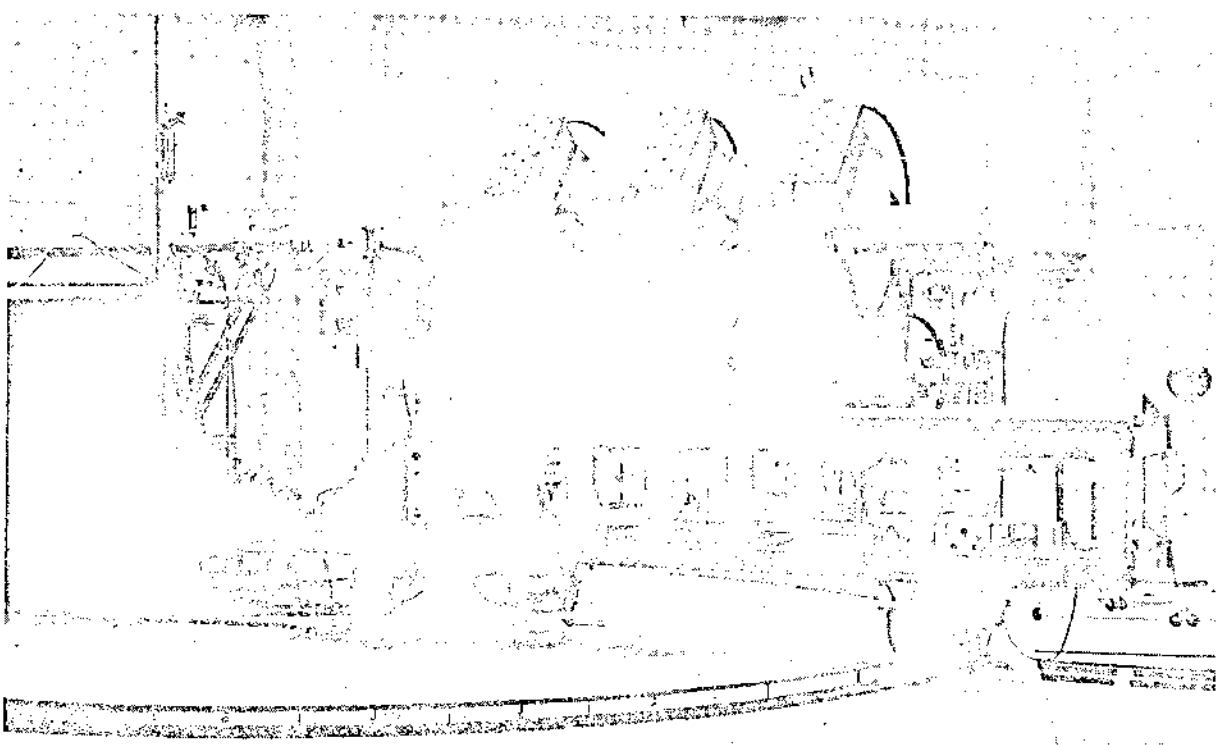

Fig. 1. An overview of the facility

Production of ^{67}Ga for medical use

T. Paradellis and G. Vourvopoulos

The production of the $T_{1/2}$= 78.6h ^{67}Ga is based on the $^{66}Zn(d,n)$ reaction. For the routine production, natural zinc which contains 27.8% ^{66}Zn is used in its metallic form. The metal is electroplated onto a copper backing to establish good thermal conductivity under heavy deuteron bombardment. In the electroplating procedure a modified version of the technique proposed by Neinrinckx (2) is used.

The electrolysis cell made out of a cube of plexiglass has approximate dimensions of 5 X 5 X 5 cm^3. On one side of the cell a 3.1 cm hole is drilled which is sealed by the copper cathode, a disk of 3.1 cm diameter and 0.5 cm thickness, through a rubber o-ring. The cathode in the cell is facing the electrolytic solution which has a volume of about 30cm^3. For an anode a platinum wire is used. The electrolytic solution is made by disolving 90g of $ZnCl_2$ in 1ℓ of 1N solution of HCl acid. Prior to electrolysis the copper anode is etched with nitric acid, then cleaned and dried.

About 6V DC are applied to the cell and the electrolytic solution is added to the cell. Every ten minutes the polarity of the cell is reversed for a few seconds. This operation results in a uniform and smooth electrodeposition of zinc. In about 90 min., zinc is electroplated to a thickness of about 150 mg/cm^2.

The copper disc with the electroplated zinc on it, is placed on a holder as shown in Fig.1. Both, the back of the copper disc and the surface of the cooling block are polished for maximum heat removal from the target. Cooling is maintained by passing chilled demineralized water through the coolinb block. The heat removal is such that the target suffers no visual changes after a 5 hour bombardment with 25-30mA of deuterons. The straight through port of the switching magnet is used for the bombardment. The target is located about 6m from the quadrupole which focuses the deuteron beam after the analysing magnet.

A 1.5 cm tantalum apperture is located about 20 cm from the target in order to define the beam in the central part of the target. The beam is defocused so that the beam spot size on the target has a diameter of 1 cm. Beam alignment is such that nearly all produced radioactivity is on the target and very little on surrounding beam parts.

The measured reaction yield at E_d= 7,8.4 and 9 MeV is shown in part I of Table I along with the maximum expected yield from a thick target as deduced by Steyn and Meyer (3). A good agreement is indicated by the data. In part II repeated measurements of the yield at E_d=8.4 MeV with different bombarding currents indicate that no thermal effects are observed on the target.

TABLE I. ^{67}Ga yield parameters from the ^{66}Zn(d,n) ^{67}Ga reaction

Part I			Part II	
yield (μCi/μA.h)			E_d=8.4 MeV	
E_d	Exp	Maxim.expected	Average current (μA)	Yield (μCi/μA)
7.0	28 ± 1	30	21	67
8.4	63 ± 7	76	22	55
9.0	90 ± 7	99	28	70
10.0	not measured	140	30	60

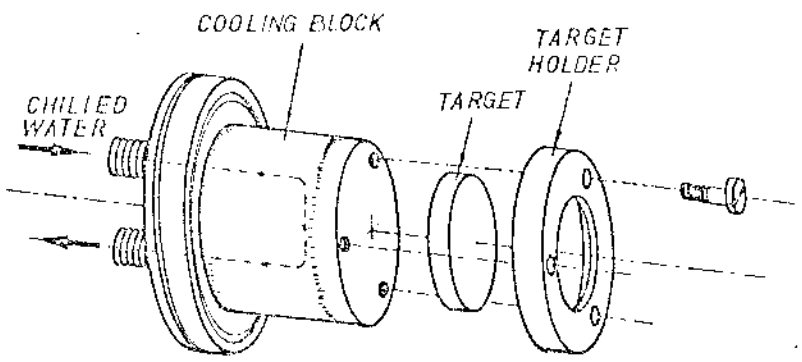

Fig. 1. The target assembly

VI. DATA COLLECTION AND PROCESSING

The new Computer System

After more than ten years of faithfull service the computer supporing the On-Line system of the laboratory, a PDP-15, has reached "retirement condition". To replace it, a PRIME-750 was purchased which is being linked to the experimental electronics through a CAMAC Branch Driver (Bi-Ra 1260). The new computer being a time sharing system will also help to relieve the bottleneck created by the old single user system in off-line data reduction and analysis.

The system consists of a 32-bit PRIME-750 CPU with 1Mbyte of memory, one 45 ips Magnetic Tape drive and a 64Mbyte Disk drive. Expansion with a second tape and a second disk drive is considered for 1983 to ensure fail-safe operation of the system.

On the CAMAC side a type A2 create controller (Bi-Ra 1302), a 16k, 24bit Incrementing Memory (NE-9082) for Multichannel Operation and a twelve-input nuclear ADC (LeCroy 2259A) have been pruchased, while some CAMAC units are beeing developed.

System administration

K. Demakou, V. Katselis and S, Kossionides

With a system more complex than the PDP-15, a rudimentary computing service and system administration must be setup, At the end of the report period this consisted of:

- Weekly backup and daily incremental save to tape covering the period of the most recent two weeks.
- Dump of not frequently used files to tape to free disk space
- Adaptation of several user programs for data processing or analysis transported from other installations.
- Programming advice to users "converting" to PRIME

Among the programs available for general use are the following:

RKINE	A program which calculates relativistic two-body kinematics.
MINUIT	The well known package for minimization of functions.
STATIS	The Hauser-Feshbach code of R.G.Stockstadt used for average cross-section calculations.
QUAD	A program for the imaging of Ion Beams with quadrupoles
BEAM	A program computing Tandem parameters for the extraction of specific ion beams.

The on-line programming system

S. Kossionides

A system of user programs is being developed which will allow On-Line Data Collection through CAMAC as well as Off-Line Data Reduction and Processing of data from tape or disk.

The system will run under a Command Monitor called ZEUS (for Zero Experience Users Software) which will be fully transparent. This means, that it will trap only the ZEUS-Commands passing all PRIMOS-Commands to the operating system.

For the On-Line Data Collection, the CAMAC Routines as supplied by PRIME will be initially used although some modifications to the DMT Transfer routine seem necessary and will be done in the future.

The system of On-Line programs will be built along the ideas developed in discussions with H. Gemmeke and H. Essler during my sabbatical in Heidelberg. Each command (e.g. DISPLAY, ACCUMULATE, SETUP) will be implemented as a separate user program and loaded as a PRIMOS command. These user programs will communicate through the shared common area. The main advantages of such a structure are that new commands can be added without recompilation and reloading of the whole system and that the user remains always at the system command monitor (PRIMOS) level.

Both advantages weigh enough to offset the disadvantage that the layout of the shared common area must be very carefully planned at the beginning.

To facilitate this planning a 'Top Down' approach was adopted for the development of the On-Line system. First, ZEUS-commands were developed which perform the linking of a running user program to the ZEUS shared common area and the installation of the command running the program.

Then, simplified frame programs implementing the basic system commands have been written. These programs are used to test the basic mechanisms of inter-program communication and establish the type and size of entries in the shared common area.

At the stage of this writing, the frames for data display, CAMAC read and event-by-event write to tape have been tested.

A data transfer link between the PDP and Prime computer

S. Kossionides, V. Katselis and A. Chionakis

Introduction

In the following the linking of two very different computer systems will be described. One is our old PDP-15/76 data collection system. The other our new PRIME-750 time sharing system. Until the PRIME takes over the data collection tasks, a link was needed to transfer data between the two systems.

The PDP has a 7-track transport. Thus Magnetic tape was dropped as the linking medium. A serial data link appeared to be the cheapest solution. On the way it proved to be also the most flexible since it provides a means of 7-track to 9-track data conversion.

The utilization of serial links in configuring computer networks is now a standard practice. The only prerequisite is that all computer systems involved in the network support multiple terminal lines and some form of communications protocol. In the case presented here the situation is rather different. The 'network' consists of only two systems and only one supports multiple terminal lines. Also the network will only be needed for the transition phase until the new system becomes fully available to the users. Thus the investment in money and effort should be kept to a minimum.

Design description

The design objectives were set to the absolute minimum in order to minimize the implementation time. Thus the link gives access from the PDP to the PRIME file-system and allows bidirectional transfer of data. Transfer to PRIME peripherals (e.g. magnetic tape) was left to the PRIME side. No effort was spent to implement a standard communication protocol. Instead, a simple handshake with function prompts and diagnostic replieswas prefered.

On the PDP side the link is established through the LT15 Second Teletype Interface which was factory wired but not implemented. Standard DEC modules were used with the exception of a clock module for 9600 baud operation. This was constructed to look like a standard DEC TTY-clock module. The Handler makes the link look like a standard file oriented peripheral recognising all operations and data modes generated by PDP programs. This allows users to transfer data directly between any of the existing PDP programs and the PRIME file-system.

As the PDP is a single user system and program development time must be taken from the data collection and processing activites, it was also decided to develop the link in two phases. A minimum driver was written to transfer the source file of itself to the PRIME where editing could be done conveniently, and back to the PDP for compilation and testing. Thus the link 'bootstraped'itself to full power.

On the PRIME side a FORTRAN program was written which runs as a PHANTOM in the background. It recognizes the prompts from the link, opens files in the UFD PDPDAT and performs the transfers replying to the PDP with the OK or error prompts.

Implementation results

The link operates now bidirectionally at 9600 baud transferring ASCII files between the two systems. This gives already the advantage of keeping all program source files on the PRIME disk and compiling them directly from there. Thus the limited disk space on the PDP is freed for binary file storage.

Some timing problems exist which cause sometimes the transmission of double lines to the PRIME which is easily corrected with the editor.

The transfer of binary data from the PDP to the PRIME will not be implemented due to the problems associatad with the differend word lenghts of both computers. This is not a serious problem, since data written in binary form to tape by the On-Line programs can be transfered over the link using a specially written conversion routine.

An Optically isolated data link

A. Chionakis, V. Katselis and S. Kossionides

The measuring electronics of the laboratory are fed by an electrical supply which is isolated from the accelerator and general supplies to reduce the electrical noise associated with general electromechanical equipment.

The computer is linked to the measuring electronics and it must also be fed by the same "clean"power supply. Remote terminals,however, can be plugged into any type of supply and would thus introduce ground loops. To overcome this problem the Data Link was developped.

All components of the link are contained in one case which is grounded at the clean earth. It contains two power supplies, one grounded at the clean earth and the other at the normal earth. The first supplies signal conditioning devices for the RS-232 standard linked to the computer. The second supplies similar devices driving the telefon lines. Between the two, optical isolators (4N37) couple the two channels providing isolation of the earths. Room for eight channels has been provided in the case. Currently only four are implemented.

The link has been tested with speeds up to 9600 baud and distances of 200 m and operates without loss of data.

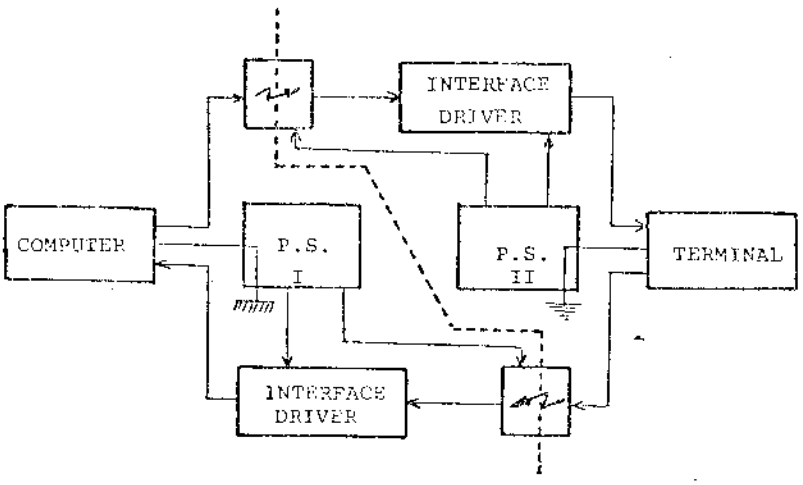

Fig. 1. Block diagram of the data link

An ADC multiplexor for CAMAC based memory

A. Chionakis, V. Katselis and S. Kossionides

An ADC multiplexor has been designed which will interface the Nuclear ADC's available in the Laboratory to the NE-9082 memory unit based in the CAMAC crate. This memory unit contains 16k,24 bit words and will perform an increment cycle for every address presented to it through an external bus. Thus the computer is not overloaded with the simple multichannel task. Also, the access rate of the NE-9082 being 0.9 MHz allows a compound data rate which is well above the maximum of 10k counts/sec supported by the available nuclear electronics for each ADC.

The multiplexor will convert the relative address generated by each of four ADC's to an absolute address for the memory. It will also sequence simultaneous requests to avoid conflicts of access to the memory. A 'round robin' selection of the ADC's was adopted to give each ADC equal priority and distribute evenly the dead time associated with the Read-out process.

A simplified design was adopted which routes each ADC to its own quadrant of memory. Stepping through the quadrants or other subgroups or routing of an ADC to various subgroups depending on logical conditions will be implemented at a later stage.

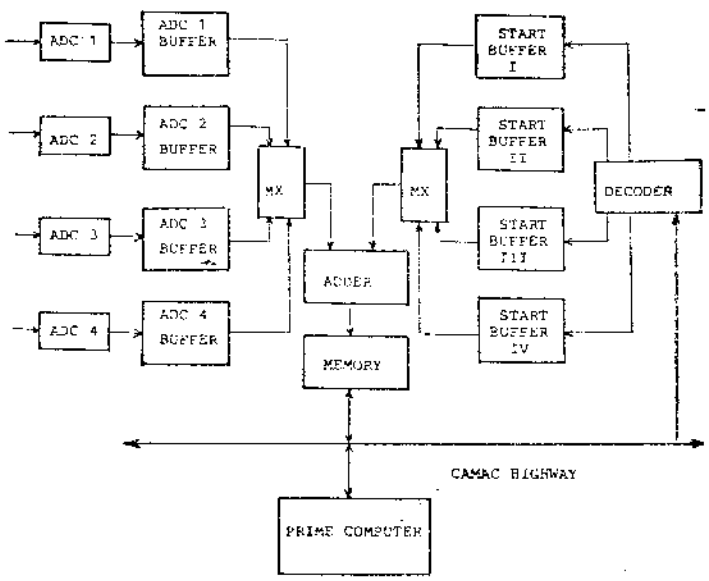

Fig. 1. Block diagram of the multiplexes

A five input CAMAC scaler

A. Sokos, V. Katselis and S. Kossionides

The laboratory will use CAMAC for data collection as well as for controling experimental equipment through the PRIME Computer. In order to gain experience in developing and constructing CAMAC units, the simplest such unit was designed. It is a Five Input Scaler with Display. The unusual number of inputs was dictated by the space available on the Standard wire-wrap CAMAC board.

Each scaler has six decades and operates in excess of 1 MHz. The contents of any scaler can be directed by front pannel switch to a six-digit LED display. After testing on a breadboard the unit is now at the stage of wire-wrapping.

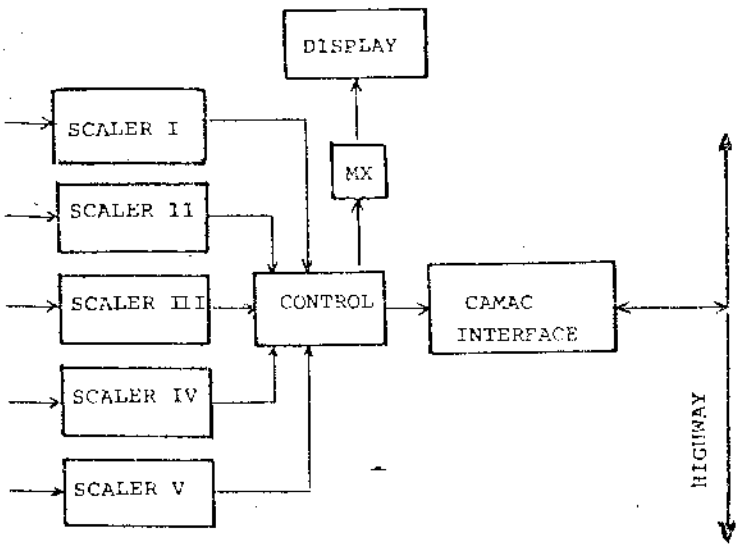

Fig. 1. Block diagram of the Scaler

General electronic maintenance

A. Sokos, A. Chionakis and V. Katselis

During the report period a number of units were repaired by the maintenance personnel ranging from the RK05 Disk drive of the PDP-15/76 to NIM electronics and power supplies. In almost every case the repair time was satisfactorily short. However some repairs, especially of PDP-15 peripherals, were delayed until components could be traced.

VII. ACCELERATOR OPERATION

A. Asthenopoulos, N. Andreopoulos, N. Divis, N. Iliadis, N. Papakostopoulos and G. Prokos.

During the years 1981 and 1982 the Tandem was utilized for a total of 2850 hours. Fig. 1 shows the beam time percentage versus terminal voltage. There has been a heavy use of the accelerator in low voltages these two years which is due to the choices of the experiments performed.

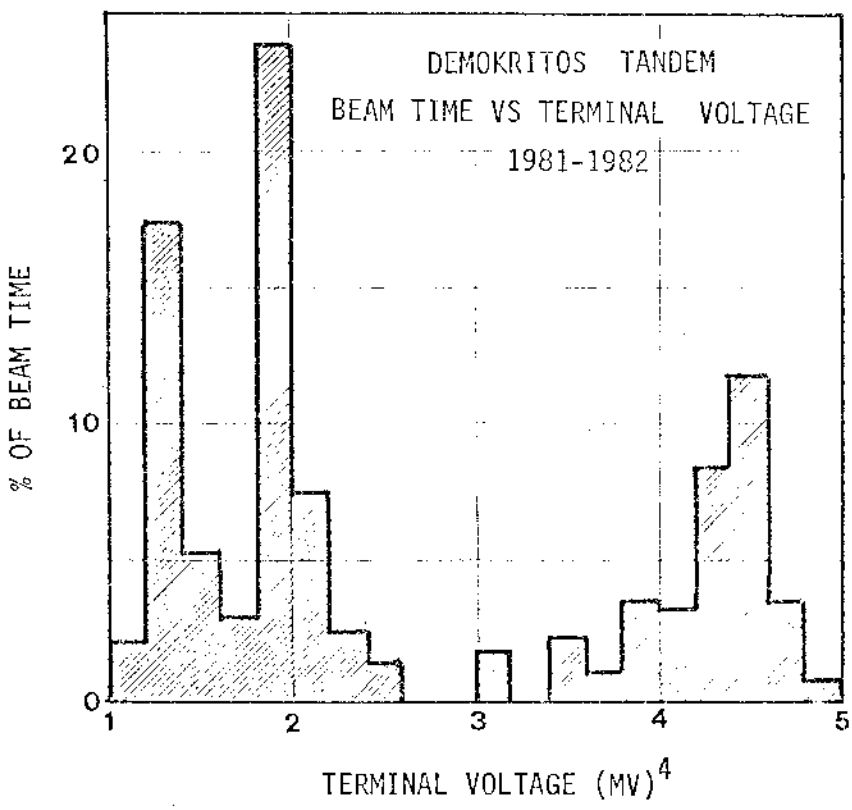

Fig. 1. Beam time versus terminal voltage.

VIII PERSONNEL

Research Staff

Dr. G. Vourvopoulos, Director (till 1-10-82)
Dr. G. Anagnostatos
Dr. T. Anagnostopoulos (since July 1, 1982)
Dr. C. Kalfas
Dr. A. Katsanos
Dr. V. Katselis
Dr. E. Kossionides , Program coordinator (since 1-10-82)
Dr. Th. Paradellis
Dr. L. Skouras
Dr. A. Xenoulis

Graduate Students

C. Aidonidou
A. Aravantinos
X. Aslanoglou
P. Bakoyeorgos
N. Kallithrakas-Kontos
T. Kosmas
E. Paleodimopoulos
S. Papaioannou
M. Pilakouta
J. Sinatkas
J. Varvitsiotis
G. Zouganellis (part of 1982)

Scientific Associates

Prof. G.	Andritsopoulos	(Univ. of Ioannina)
Prof. P.	Assimakopoulos	(Univ. of Ioannina)
Dr. E.	Gazis	(Nat. Technical Univ. of Athens)
Mr. G.	Gregoriades	(Univ. of Athens)
Dr. A.	Hadjiantoniou	(N.R.C. "Demokritos")
Dr. P.	Kakanis	(Ministry of Labor)
Dr. E.	Mavrommati-Fountou	(Univ. of Athens)
Dr. K.	Papadopoulos	(Nat. Technical Univ. of Athens)
Mr. N.	Panayotakis	(Syngrou Hospital, Athens)

Dr. C. Panos	(Southeastern College, Athens)
Miss M. Tzoumezi	(Univ. of Thessaloniki)
Dr. R. Vlastou	(N.t. Technical Univ. of Athens)
Mr. J. Yapitzakis (till end 1981)	(Univ. of Athens)

Operational Staff

Accelerator Support Group

N. Andreopoulos
A. Asthenopoulos
N. Divis
N. Iliadis
N. Papakostopoulos
G. Prokos

Electronics Group

A. Chionakis
A. Sokos

Computer Programmer

Mrs. K. Demakou, B.S. Mathematics

Machine Shop

O. Topikoglou

Graphics

F. Trouposkiadis

Secretariat

Mrs. A. Demetriou

IX. PUBLICATIONS

A. Papers published in 1981 and 1982

1. G.S. Anagnostatos, J. Yapitzakis, and A. Kyritsis
"Rotational Invariance of Orbital-Angular Momentum Quantization of Direction for Degenerate States"
Lett. Nuovo Cimento 32 (1981) 332

2. G.S. Anagnostatos, D. Demakos, and A. Vassiliou
"Initial Values of Parameters for Variable-Moment-of-Inertia Models"
Comp. Phys.Communications 24 (1981) 197

3. G.S. Anagnostatos, C.N. Panos
"Effective two-nucleon Potential for High-Energy Heavy-Ion Collisions.
Phys. Rev. C26 (1982) 280

4. C.N. Panos, G.S. Anagnostatos
"Comments on a Relation between Average Kinetic Energy and Mean-Square Radius in Nuclei"
J. Phys. G ; Nucl. Phys. 8, (1982) 1651

5. G.P. Flessas, G.S. Anagnostatos
"On the Applicability of the Hill Determinant and the Analytic Continued Fraction Method to Anharmonic Oscillators."
J. Phys. A: Math. Gen. 15 (1982) L537

6. E. Adamides, L.D. Skouras and A.C. Xenoulis
"Structure of low-lying states in ^{94}Mo"
Phys.Rev. C5 (1981) 216

7. E. Adamides, L.D. Skouras and A.C. Xenoulis
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Phys. Rev. C24(1981) 1429

8. P. Bakoyeorgos, T. Paradellis, P.A. Assimakopoulos
"Excited states in ^{69}Ga"
Phys. Rec. C25 (1982) 2947

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"Effects of inoculation onelemental uptake by plants grown on saline soils"

Folia Microbiol. 27(1982) 278

10. E.N. Gazis, P. Kakanis and A.C. Xenoulis
"Contribution of unbound deuteron disintegration to the reaction $^{12}C(^{16}O,pn)^{26}Al$"

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11. G. Gregoriades, N. Apostolides, A. Romanos, T. Paradellis
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12. Y. Maniatis and A.A. Katsanos
" Technological Examination of Low Fired Terra Cotta Status from Aghia Irene Keas"

Archaeometry 24 (1982) 191

13. C.T. Papadopoulos, A.C. Xenoulis , P. Bakoyeorgos, G. Andritsopoulos, P.A. Assimakopoulos, N.H. Gangas, A.G. Hartas
"Electromagnetic Properties of Statesin ^{63}Zn through the ^{63}Cu (p,n) ^{63}Zn Reaction.

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"Excited states in ^{68}Ge and ^{69}Ge studied by the ^{64}Zn (^{7}Li,pxnγ) reaction "

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15. T. Paradellis, G. Vourvopoulos, G. Costa and E. Sheldon
"Use of the (p,γ) reaction ofsemi-thick targets in the spectroscopy of odd mass nuclei"

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16. D. Pocanic, G. Vourvopoulos, X. Aslanoglou and E. Holub
"Possible evidence for the existence of intermediate resonant structure in the $^{9}Be + ^{13}C$ heavy-ion system"

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17. D. Skiotis, T. Paradellis and V. Katselis
"A survey of catalysts for the oxidation of SO_2 in dusts settled on marble monuments "

Clean Air Feb. (1981) 13

18. A.C. Xenoulis,C,E. Douka, J. Paradellis and A. Katsanos
"Stopping power effects in the determination of ^{14}N by a resonance reaction"

J. Rad. Chem. 63 (1981) 65

19. A.C. Xenoulis, A.E. Aravantinos, C.J. Lister, J.W. Olness and R.L. Kozub
"Systematics of the competition between pn and d emission in Heavy-Ion induced Nuclear reactions"

Phys. Letts. 106B (1981) 461

B. *Papers accepted for publication to appear in 1983*

1. C.E. Douka, A.C. Xenoulis and T. Paradellis
"Interaction between microorganisms, chemical composition and environment in salt-affected soils"
Folia Microbiol.

2. G. Gregoriades, N. Apostolides, A. Romanos and T. Paradellis
"A comperative study of trace elements in normal and cancerous colorectal tissues"
Cancer

3. G.A. Mourkides, A.A. Katsanos and M. Tzoumezi
"Elemental analysis of water and sediments by external beam PIXE, Part 1, Vesoritis Lake, Greece"
Chemistry in Ecology

4. A.C. Xenoulis, A.E. Aravantinos and C.E. Douka
."The stability of biological speciments during charged particle bombardment"
J. Radioan, Chem.

5. G. Vourvopoulos
"Heavy ion resonances in the s-d shell"
IEEE Transactions on Nuclear Science

C. *Conferences - Reports - Dissertations*

1. G.S. Anagnostatos and C.N. Panos
"Nucleon distributions and a two-nucleon potential"
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"A nucleon-nucleon potential"
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A. Katsanos and G. Vourvopoulos
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9. C. Douka, A. Xenoulis and T. Paradellis
"Elemental composition of manganese concretions from soil"
5th Int. Symp. on "Environmental biochemistry ", Stockholm, 1981

10. C. Douka, A. Xenoulis, A. Nychas and G. Bannon
"Factors affecting symbiotic nitrogenfixation using N-15 isotope"
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"Residual nucleus formation by different exit channels"
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12. G. Vourvopoulos, X. Aslanoglou, G. Andritsopoulos, E. Holub and D. Pocanic
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13. G. Vourvopoulos, E. Kossionides and T. Paradellis
"A facility for the investigation of (n, charged particle) reactions"
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14. G. Vourvopoulos
"Heavy ion resonances in the s-d shell"(invited paper)
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15. A. Xenoulis, C. Douka and T. Paradellis
"Effects of conditions of growth on the elemental composition of plants"
Panhellenic Congress on "Agricultural research "Chalkidiki, 1981

1. V. Katselis and T. Paradellis
"Metal concentration in the air of a suburb of Athens"
Greek AEC, DEMO report 81/11, 1981

2. V. Katselis and T. Paradellis
"A study of the concentration of certain inorganic air pollutants in the city of Elefsis
Greek AEC, DEMO report 81/13, 1981

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Greek AEC, DEMO report 82/13, 1982

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1. G. Gregoriades
" The study of Zn, Cu, Mn, Pb, Ni and Rb trace elements in intestinal cancer"

Doctorate Thesis, Medical School, University of Athens, 1981
Laboratory advisor: Dr. T. Paradellis
Professor: N. Romanos

2. X. Aslanoglou
"Nuclear resonance phenomena in the systems ^{12}C-^{12}C, ^{9}Be-^{12}C and ^{18}O-^{12}C"

Doctorate Thesis, Department of Physics, University of Ioannina, 1982
Laboratory advisor: G. Vourvopoulos
Professor: G. Andritsopoulos

3. P. Bakoyeorgos
"High spin states in ^{67}Ga and ^{69}Ga"

Doctorate Thesis, Department of Physics, University of Ioannina, 1982
Laboratory advisor: Dr. T. Paradellis
Professor: P. Assimakopoulos