CNEA NT - 23/78

Progress Report
1976 - 1977
Department of Physics
Nuclear Physics

Comisión Nacional
de Energía Atómica

Dirección de
Investigación y Desarrollo

Gerencia de
Investigaciones

Buenos Aires - Argentina
1978

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INTRODUCTION

The time interval covered by this report has been particularly prolific. Above everything else it will remain in our minds as the time in which the new 20 MV Heavy Ion Tandem Accelerator was purchased.

This significant step, of utmost importance for the future of physics in Argentina, occupied a substantial fraction of the total effort carried out by the Department. Nevertheless, the research activities and services were neither interrumpted nor weakened. On the contrary, it is even possible to appreciate an increase in the research activities undertaken within the last two years.

During this period of time the participation of scientists from other institutions in our own programs grew considerably, as well as our interaction with other laboratories throughout the world and this has undoubtedly had a visible effect in the overall output.

It is also noteworthy that the most ambitious plan of incorporation of young physicists ever to take place in the Department was conceived during 1976, with a view towards an adequate use of the 20 MV Tandem Accelerator facility, In its first stage, carried out in 1977 eight graduate students were selected as fellowship holders, and having satisfactorily fulfilled all tests after a full year of courses and laboratory training, they were recently appointed as junior members of the staff. We regard this program of incorporating new well selected and trained young people as crucial for the future. The program will continue with another group of students to be incorporated in 1978.

In 1976 the proposal for a Heavy Tandem Accelerator was approved by the authorities of CNEA and preliminary discussions with High Voltage Co. and National Electrostatics Co. took place. In 1977, after bids had been received from both companies, the decision of purchasing a 20 UD Pelletron Accelerator from National Electrostatics Co. was taken. Such a decision was based on a thorough technical analysis to which it concurred the extremely valuable contribution of colleagues abroad, experts in this field, to whom we are deeply indebted for thier advice and generous help.

The possibility to meet our original schedule of signing the contract with National Electrostatics Co. during 1977 became a reality. Construction of the accelerator started December 1, 1977 and it is scheduled to take 32 months, allowing the facility to become operational during 1982. The processes involved were of course, not free from all kinds of problems,several quite unexpected and some even amusing. However we do bear in mind that the struggle has just started and that there is a lot of work to do before we reach our goal. We very much hope that we will be able to follow our schedule as to allow a succesful completion of the project.

As for the research program of the Nuclear Physics Branch of the Department, this report gives a reasonably comprehensive account of what has been achieved. In order to improve the perspective of the work described here, we would like to point out some of the more important results.

The study of doubly odd nuclei, started four years ago, yielded new interesting results. The investigation of ^{78}Rb, which confirmed the hypothesis of the existence of a band structure similar to that previously observed in ^{76}Br, was carried out with the fruitful collaboration of the Instituto de Física de Sao Paulo, As a byproduct preliminary data on ^{74}Br was also obtained from this investigation. The elucidation of the nature of two isomers in ^{66}Ga and ^{68}Ga through the measurement of their magnetic dipole moments was done in collaboration with Brookhaven National Naboratory. Also a magnet, built together with the Porto Alegre Group, was installed in the (α,xn) beam line of the Synchrocyclotron, enabling us to measure the g-factor of an isomeric state in ^{70}As. Following the line of collaboration with other laboratories, the high spin structure of ^{144}Gd finally emerged after a long and careful evaluation of the data with the Julich Group and the Cyclotron Institute of the Texas A & M University. Likewise a very interesting study of ^{198}Te started in CNEA was completed in both Julich and Munich.

In the framework of the recently formulated Nuclear Field Theory (NFT) a new step was achieved in establishing the nature of one of the four rules which constitute the basic tools for the application of the theory, whose significance had remained obscure until now. An application of the NFT to nuclear reactions shows the need of a hitherto neglected correction which in turn affects the deduced values of the multipole deformations. In addition, the work on a perturbative description of superconductivity yielded evidence that the NFT can be extended to deformed systems. Work that is now in progress is concerned with the demonstration that the use of conventional prescriptions for the definition of generalized coordinates in Time Dependent Hartree-Fock (TDHF) leads to ambiguities.

The Technical Support Group continued to provide the requiered assistance making possible the continuation of the research activities based on the Synchrocyclotron and Cascade accelerators, although owing to the age of these machines the difficulties are increasing every year, both in magnitude and frequency.

It was in our last Progress Report that we expressed our hope that Edgardo Ventura would be once more the editor. This has very fortunately been the case and we should warmly aknowledge his effort and ability to put the material in adequate form. Many thanks are also given to Mrs Cristina Ceballos for her patience in typing and correcting the manuscript and to Mr Binda for his help in printing this report.

June, 1978

Mario A.J. Mariscotti
Chairman
Department of Physics

T A B L E   O F   C O N T E N T S

EXPERIMENTAL PHYSICS

THEORETICAL PHYSICS

INSTRUMENTATION AND DEVELOPMENT

Experimental Physics

Gamma Ray Spectroscopy
High Spin States
Magnetic Moments
Radioactivity
Hyperfine Interactions

I. GAMMA RAY SPECTROSCOPY FROM (α,xn) AND SIMILAR REACTIONS

I.1. High Spin States in ^{49}Ti and ^{50}Ti

E. Ventura, M. Behar*, A. Filevich, G. García Bermúdez and M.A.J. Mariscotti.

As part of our current programme to study (α,xnγ) reactions we have investigated the reactions ^{48}Ca(α,2n) and ^{48}Ca(α,3n) with the aim of exciting high spin states in the residual nuclei ^{50}Ti and ^{49}Ti, respectively.

A 5 mg/cm^2 ^{48}Ca target (96.8% enriched in ^{48}Ca) was bombarded with α-particles from the Buenos Aires Synchrociclotron in the energy range E_α = 30-55 MeV. Gamma rays were detected by means of two Ge(Li) detectors placed at opposite sides of the beam line. The identification of the transitions corresponding to the observed gamma rays was obtained from measurements of excitation functions, γ-γ coincidences and where possible from the previously known spectra in the literature.

Excitation functions for the observed γ-rays were measured in the energy range E_α = 30-55 MeV in 5 MeV intervals. Fig.I.1.1 shows the results of these measurements for the ^{48}Ca(α,2nγ), ^{48}Ca(α,3nγ)and ^{48}Ca(α,4nγ) reactions. It is readily apparent from this figure that reactions involving two, three and four neutrons are easily distinguished from each other.

Gamma-Gamma coincidence measurements were performed in both residual nuclei ^{49}Ti and ^{50}Ti. Gates were set at the 229, 405 and 524 keV transitions in ^{50}Ti and at the 785 and 963 keV transitions in ^{50}Ti. The corresponding coincidence spectra obtained are shown in Fig.I.1.2.

Angular distributions were measured in the angular range 65° $\leq \theta \leq$ 145° with respect to the beam direction. The normalized peak areas were fitted to the expression

$$W(\theta)= \{1 + \sum_{\ell\,\mathrm{even}}^{4} A_\ell P_\ell(\cos\theta)\}$$

Fits including an ℓ = 4 term yielded a coefficient A_4 consistent with zero. Therefore fits only including terms up to ℓ = 2 were made. The results of these measurements are shown in Fig.I.1.3 and the corresponding values of the coefficients listed in Table I.1.1.

The measurements described in the preceding paragrphs allowed us to construct the energy level diagrams shown in Fig.I.1.4. No low spin states are excited in the $^{48}Ca(\alpha,3n)^{49}Ti$ reaction with observable intensity. Instead we have obtained reasonable evidence for a streched E2 cascade involving the 1545 keV, $J^{\pi} = 11/2^{-}$ and the 2508 keV, $J^{\pi} = 15/2^{-}$ states. Those states have been previously observed through charged particle reactions, especially in the $^{51}V(d,\alpha)^{49}Ti$ reaction[1], but their assignments could not be determined . In addition we propose a state at 3293 keV, $J^{\pi} = (17/2^{-})$ which decays to the $J^{\pi} = 15/2^{-}$ state through the 785 keV transition. Owing to the fact that the 785 keV line appears as part of a very close doublet, its character could not be definitively established.

In the case of ^{50}Ti, we have observed three new transitions which we interpreted as deexciting the states at 3605, 3834 and 4644 keV in addition to those deexciting the previously known $J^{\pi} = 2^{+}$, 4^{+} and 6^{+} states at 1554, 2676 and 3200 keV, respectivel. From angular distribution measurements tentative spin assignments of (7) and (8) can be made for the 3605 and 3834 keV states, respectively.

The close agreement between the energies of the $J^{\pi} = 2^{+}$ and 4^{+} states in ^{50}Ti and the energies of the $J^{\pi} = 11/2^{-}$ and $15/2^{-}$ states in ^{49}Ti resembles the most prominet feature of the rotation-aligned coupling scheme of Stephens et al.[2] Since this scheme applies for nuclei with small deformations, it may be difficult in some cases to experimentally distinguish it from the weak coupling model. In the present case however there is previous information[3] which indicates that the $11/2^{-}$ state is a member of the $|f^{-1}_{7/2} \times 2^{+}>_{J^{\pi}}$ multiplet and therefore the valid description in this case is that given by the weak coupling model.

Note added in proof: Recent work by B. Haas et al[3] in ^{50}Ti shows an additional transition of 2937 keV giving rise to an excited 7^{+} state at 6135 MeV excitation in ^{50}Ti. On top of this level these authors place the 405, 229 and 810 keV transition observed in the present work with spin and parities assigments of $J^{\pi} = 8^{+}$, 9^{+} and 10^{+} respectively.

Since we were unable to observe γ-rays above 2 MeV, the 2937 keV transition was missed.

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* Present Adress: Department of Physics, University of Rio Grande do Sul, Brasil

1 S.A. Andersen, O. Hansen, L. Vistisen, R. Chapman and S. Hinds, Nucl. Phys. A125 (1969) 65.

2 C. Pomar, M.C. Simon and M.A.J. Mariscotti, 55a. Reunión de la Asociación Física Argentina, San Luis, 1971.

3 B. Haas et al Phys. Rev. Letters, 40 (1978) 1313

TABLE I.1.1.

Angular distribution coefficients

Nucleus	E_γ (keV)	A_2
^{50}Ti	229	0.34 ± 0.07
^{50}Ti	405	0.45 ± 0.17
^{50}Ti	524	0.31 ± 0.05
^{50}Ti	1122	0.24 ± 0.04
^{50}Ti	1554	0.17 ± 0.04
^{49}Ti	785	0.38 ± 0.04
^{49}Ti	963	0.39 ± 0.08
^{49}Ti	1545	0.25 ± 0.05

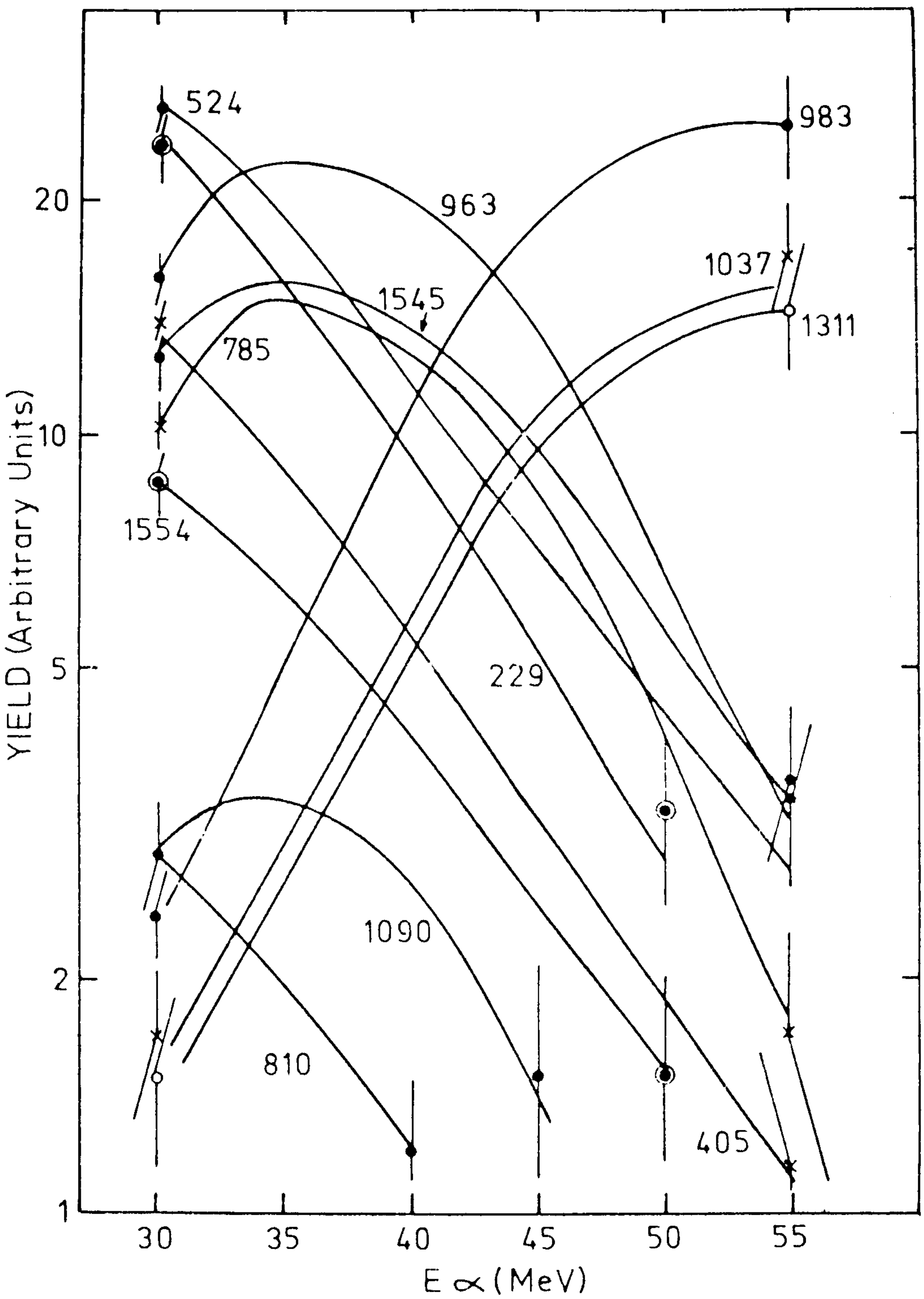

Fig. 1.1.1. Excitation functions of gamma rays following the $^{48}Ca(\alpha,2n\gamma)$, $^{48}Ca(\alpha,3n\gamma)$ and $^{48}Ca(\alpha,4n\gamma)$ reactions.

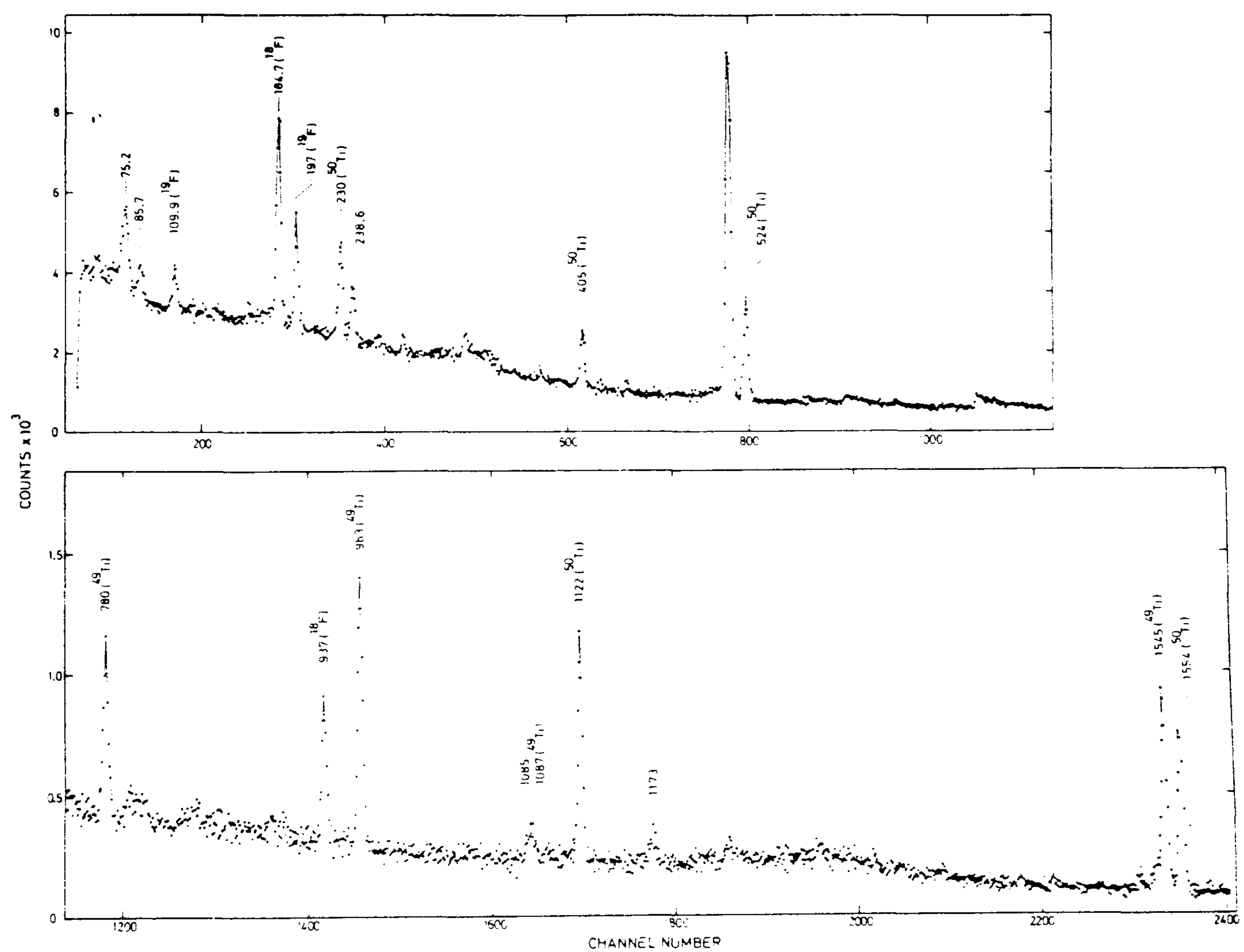

Fig.I.1.2. Gamma-Gamma coincidence spectra observed in the present work. The gate set at 963 keV corresponds to transitions in ^{49}Ti. All other gates correspond to transitions in ^{50}Ti.

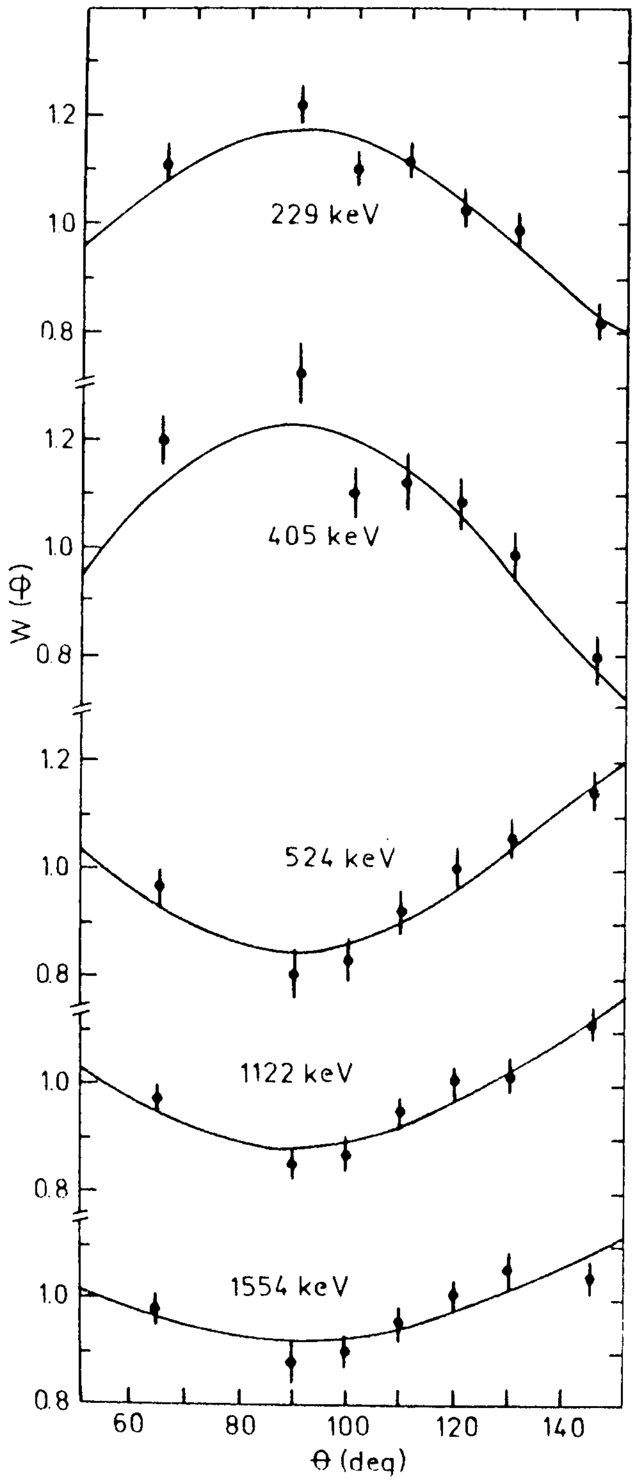

Fig.I.1.3 (a) Gamma ray angular distributions following the $^{48}Ca(\alpha,2n\gamma)^{49}Ti$ reaction.

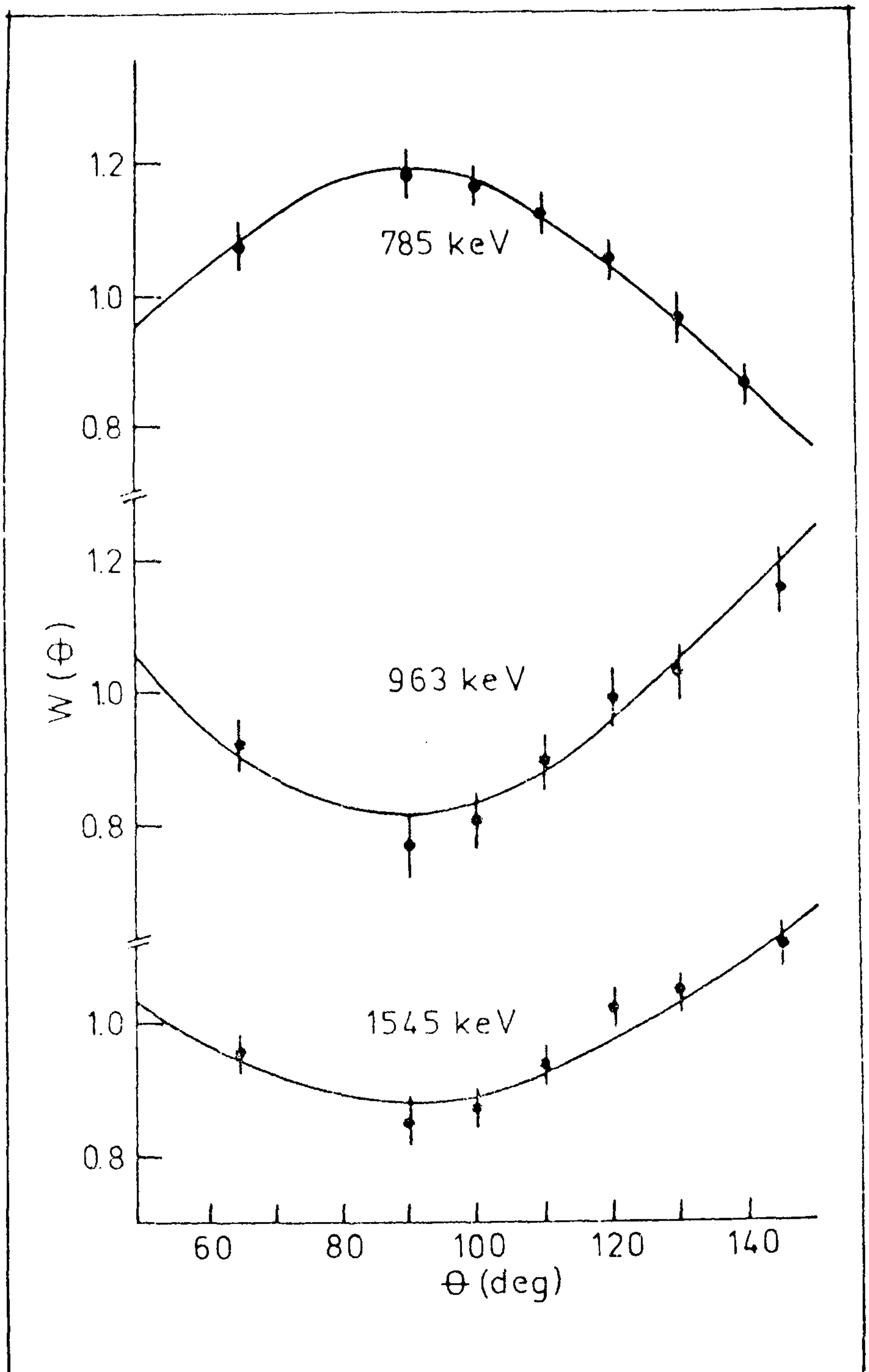

Fig. 1.1.3 (b) Gamma ray angular distributions following the $^{48}Ca(\alpha,3n\gamma)^{49}Ti$ reaction.

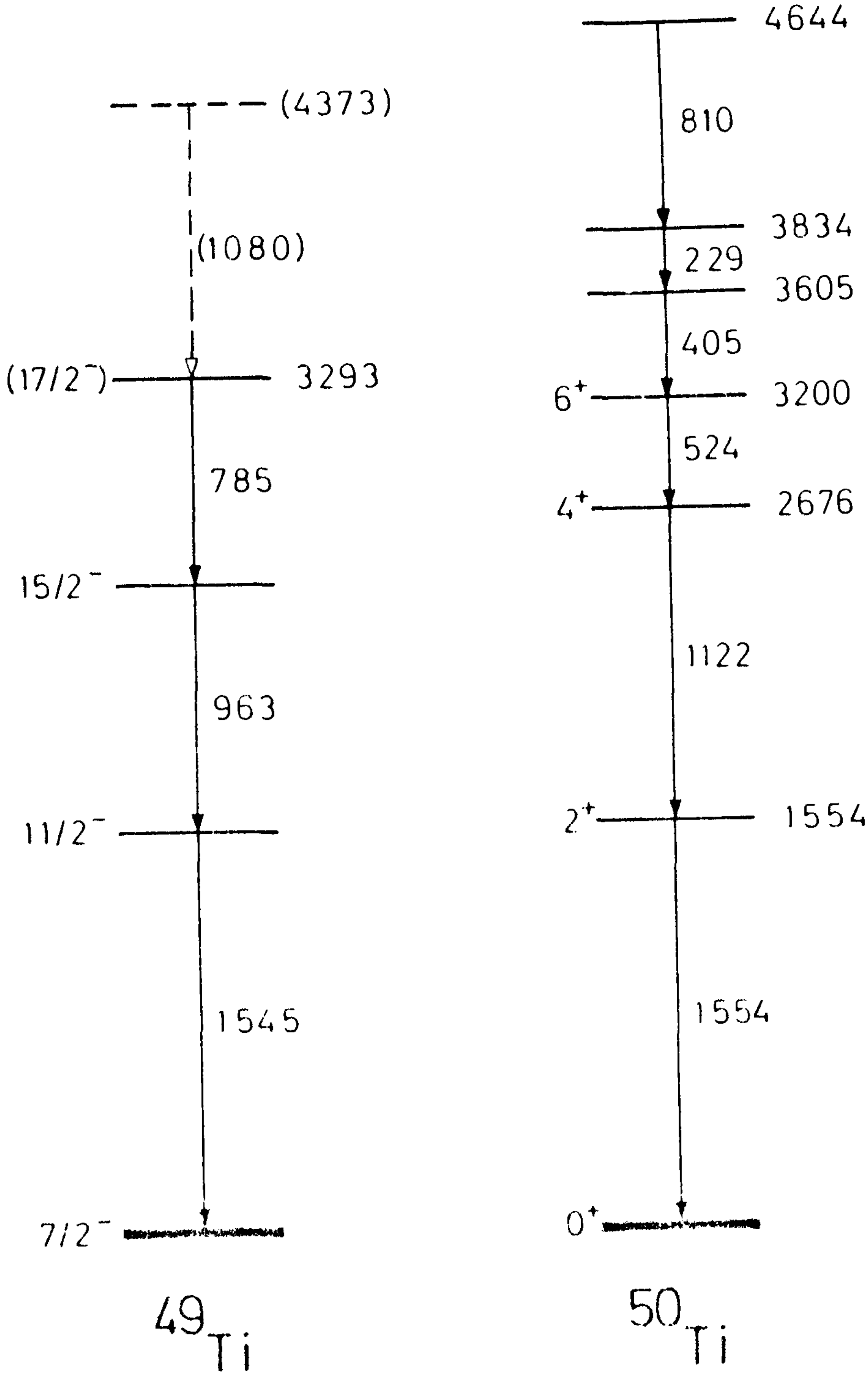

Fig. 1.1.4. Level schemes of ^{49}Ti and ^{50}Ti as observed in the present work.

1.2. The First $9/2^+$ State in ^{75}Br and Evidence for Maximum Deformation at N $\sim$ 42.

M. Behar*, A. Filevich, G. García Bermúdez and M.A.J. Mariscotti.

Contrary to what one could expect from a simple shell model picture, the excitation energy of the $9/2^+$ states in odd Z nuclei in the pf shell varies considerably as a function of N. In the ^{77,79,81}Br isotopes the energy of these states decreases with N from 0.5 to 0.1 MeV. On this basis it was suspected that the $9/2^+$ states in ^{73}Br and ^{75}Br should lie at very low energies (E_x < 100 keV) but previous investigations have failed to find them[1].

We have searched for this state in ^{75}Br using the ^{75}As(α,4n) reaction at 55 MeV. Measurements of γ-γ coincidence, timing and γ-ray angular distributions have led to the level scheme in Fig.1.2.1. The $9/2^+$ state is seen to lie at 694.6 keV indicating the existence of a sharp break in the above mentioned trend. Fig.1.2.2 shows the sistematics of the $9/2^+$ states in this region of the nuclear chart. It can be observed that the upward change in the systematics for the Br isotopes is similar to that found in the As isotopes. In both cases the minimum is reached for N $\sim$ 42. In the framework of the Coriolis calculations of Scholz and Malik[2] the present results show that (a) maximum of deformation for the Br isotopes is found at N = 42. Noting in this connection that rotational bands have been found in neighbouring isotopes like ^{73}Se, ^{75}Se, ^{76}Br, ^{77}Br, ^{78}Rb and ^{80}Rb; and (b) the existence of a close ($5/2^+$, $9/2^+$) doublet in the most deformed isotope ^{77}Br shows that the deformation in this region is positive.

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* Present Adress:Department of Physics, University of Rio Grande do Sul, Brasil.

1 G. Murray et al. Nucl. Phys. A142 (1970) 21.

2 W. Scholz and F.B Malik, Phys. Rev. 176 (1968) 1335.

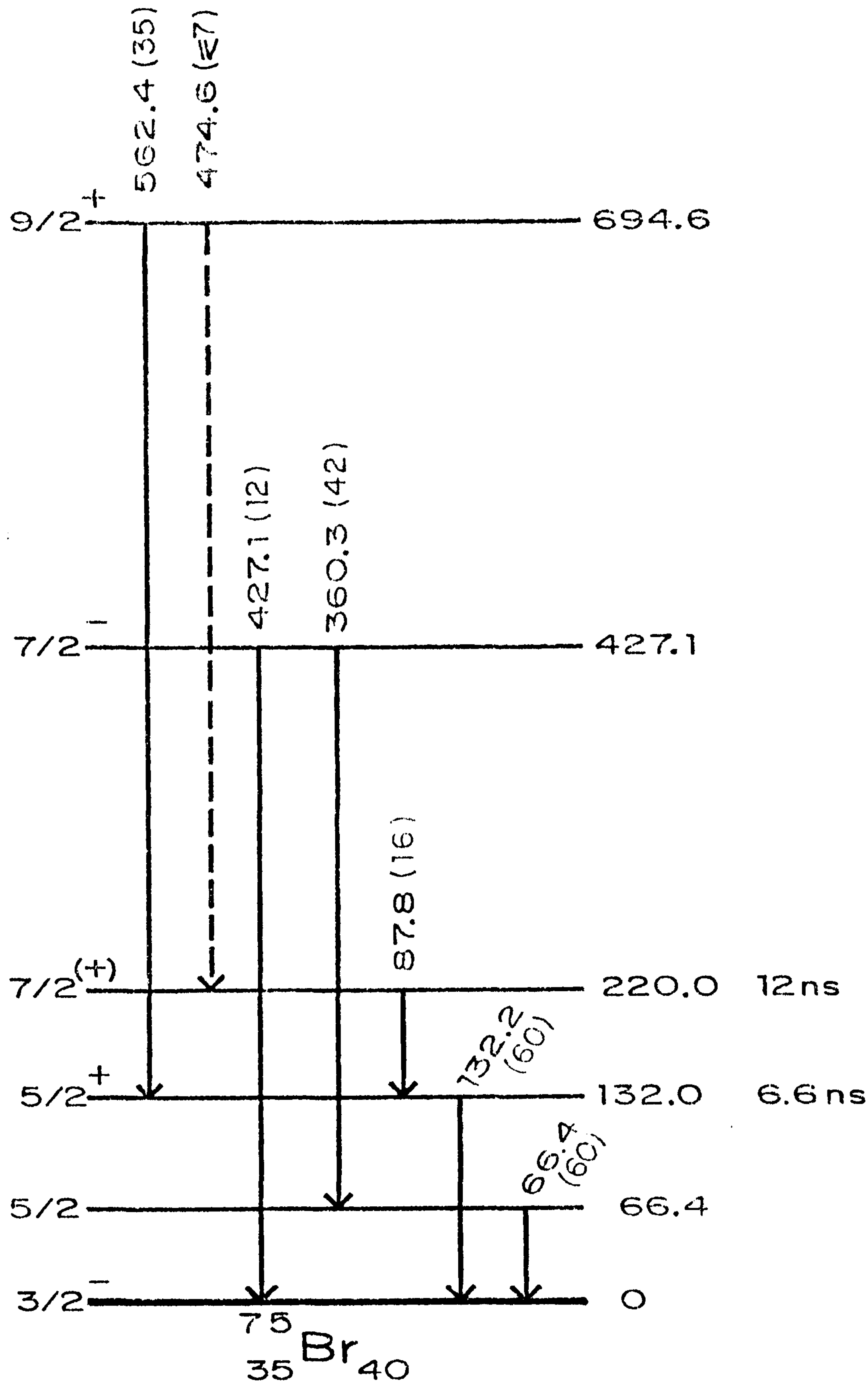

Fig. 1.2.1. Observed level scheme of ^{75}Br.

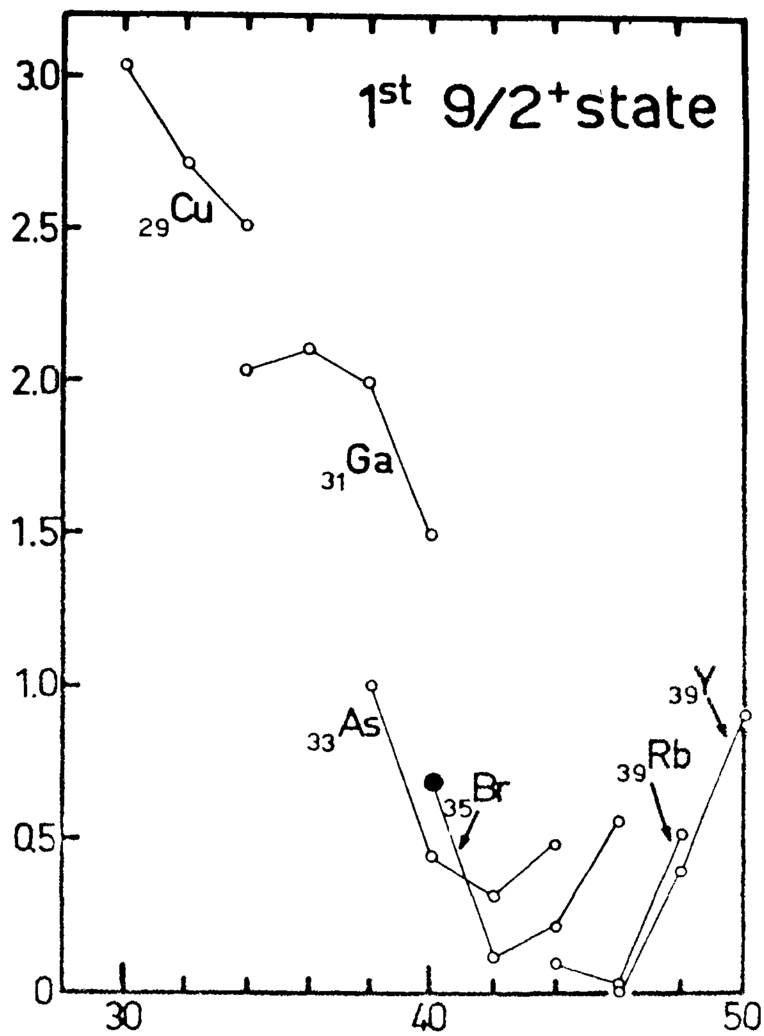

Fig.1.2.2. Systematics of the energy of the first $9/2^+$ state in odd-Z isotopes. The solid dot corresponds to the present result.

1.3. Level Structure of ^{76}Br from the ^{75}As(α,3nγ) reaction.

M. Behar*, A. Filevich, G. García Bermúdez and M.A.J. Mariscotti.

Unlike ^{78}Br and ^{80}Br, the isotope ^{76}Br has a ground state with spin-parity 1^- (instead of 1^+). The negative parity implies that the odd neutron lies in a deformed Nilsson orbit with $g_{9/2}$ parentage. Actually it has been suggested[1] that the neutron configuration is well represented by the $5/2^+$ groundstate of ^{75}Se. Thus the coupling of this state with a $p_{3/2}$ or $f_{5/2}$ proton would give rise to the ^{76}Br ground state. Since this hypothesis involves the assumption of non-spherical states, one may expect to observe some kind of band structure in ^{76}Br. To investigate this possibility we have used the ^{75}As(α,3nγ) reaction that favors the population of high-spin states.

From the study of excitation functions, γ-γ coincidences and γ-ray angular distributions we obtain the level scheme shown in Fig.1.3.1. The observed levels are different from those obtained from the radioactive decay. The spin-sequence I = 1,2,...,6, energy spacings and decay pattern suggest a rotational structure. From the comparison of this band with the predictions of the I(I + 1) law a fairly good fit is obtained with a moment of inertia $\theta/\hbar^2 = 0.014$ keV^{-1} which is quite similar to that found in neighbouring nuclei. However deviations from the pure I(I + 1) rule, typical of Coriolis mixed band are apparent. These deviations are shown in Fig 1.3.2 and are compared with those from the excited states proposed by Nolte et al. for ^{77}Kr [2]. The parallelism between the broken lines is remarkable, suggesting that removing a $p_{3/2}$ proton from the ^{77}Kr "core" does not influence significantly the Coriolis interaction.

The idea that ^{77}Kr may play the role of an odd A "core" is strengthened by the fact that the first two excited states in ^{76}Br and ^{77}Kr lie at very similar energies.

Such a hypothesis has been further explored by studying ^{78}Rb (see next paper in this report).

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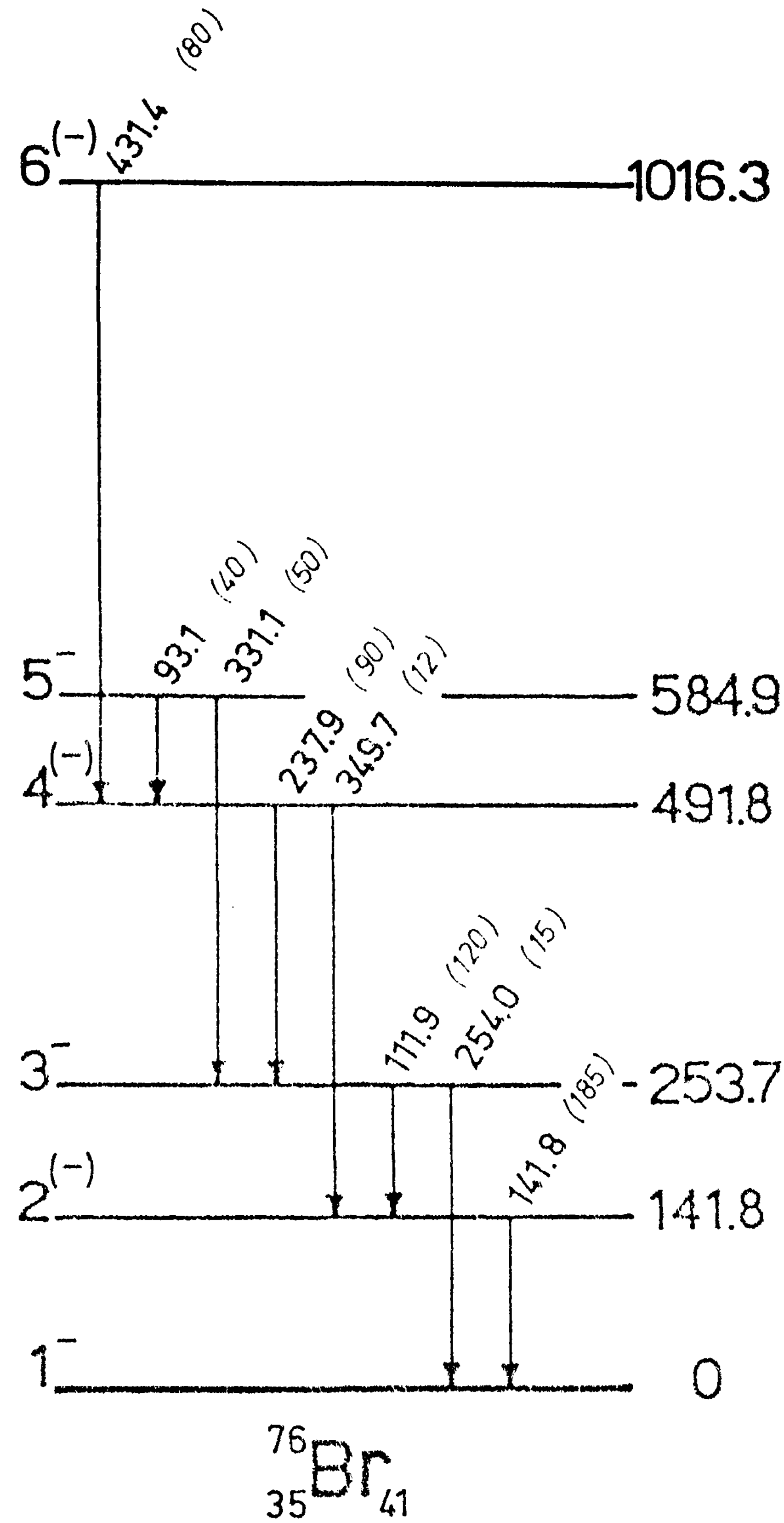
* Present Adress: Department of Physics, University of Rio Grande do Sul, Brasil.

[1] D. Lode, W. Pessara, H. Ahlsson and E. Roeckl, Z. Phys 260 (1973) 253.

[2] E. Nolte, P. Vogt and H. Morinaga, Fizica 7 (1975) 144.



<u>Fig. I.3.1.</u> Energy levels of ^{76}Br and their decay scheme

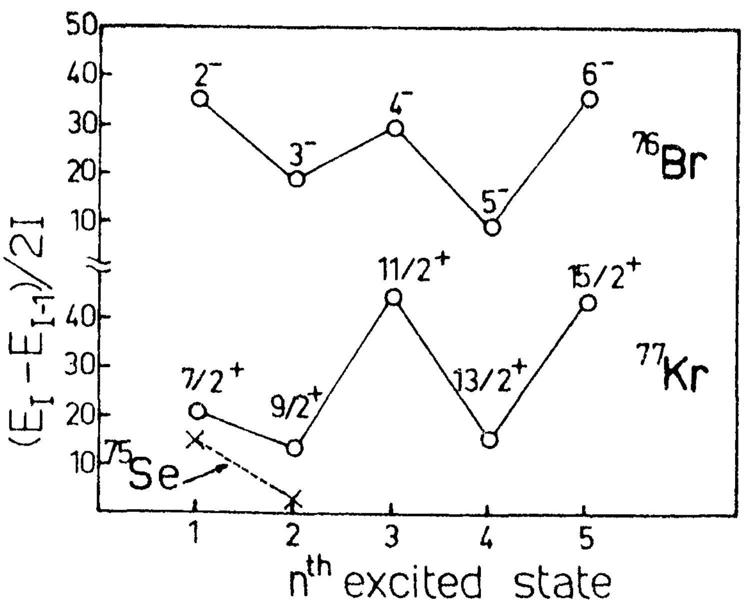


Fig. I.3.2. The quantity $(E_I - E_{I-1})/2I$, which for a good rotator equals the constant $\hbar^2/2\theta$, is plotted for the different members of the ground state bands observed in both ^{76}Br and ^{77}Kr. The corresponding data for the first two positive parity states in ^{75}Se are also included. The plot shows a remarkable parallelism between ^{76}Br and ^{77}Kr with respect to the Coriolis deviations from the $I(I + 1)$ law.

1.4. The Ground State Band in ^{78}Rb.

G. García Bermúdez, M.A.J. Mariscotti, J.C. Acquadro*, A.Lépine*
M.N. Rao* and W. Seale*.

The present study was prompted by the recent observation[1] of an unexpected parallelism between the band built on the 1^- ground state of the doubly odd nucleus ^{76}Br[1] and that built[2] on the $5/2^+$ ground state of the odd-A next neighbour ^{77}Kr. Particularly the energies of the two first excited states in both bands are quite similar and the level staggering stemming from the Coriolis interaction follows the same pattern. For this reason it was of interest to investigate the possibility that such regularities also took place in the next isotone ^{78}Rb. Until now only a 6 m isomer of ^{78}Rb was known to lie at 103.4 keV above the 17.5 M ground state.

In this work levels in ^{78}Rb were excited through the ^{64}Zn(^{16}O,np) reaction between 40 and 50 MeV. Using two similar Ge(Li) counters single γ-ray spectra were simultaneously taken at 0° and 90° with the purpose of obtaining information on excitation functions, lifetimes and transition multipolarities. In addition 1024 X 1024 channel coincidences were recorded. The isotopic identification was checked by making a detailed balance between the prompt peak and the intensity of γ-rays observed from the radiactive decay to the known ^{78}Kr daughter. The level scheme proposed for ^{78}Rb is shown in Fig.1.4.1. The energies follow approximately the $I(I + 1)$ rule although the staggering effect is apparent. The band in ^{78}Rb is found to be quite similar to that in ^{76}Br so that the previously noted parallelism between the later and the $5/2^+$ band in ^{77}Kr, also applies to the case of ^{78}Rb. A comparison of the relevant data for these three nuclei is shown in Fig.1.4.2. It is seen that the first excited states lie at very similar energies. This result implies different moments of inertia. The upper levels of the odd-A nucleus ^{77}Kr lie higher that those in the doubly odd isotones. For these states the moments of inertia tend to be the same. Calculations directed to increase our understanding of this phenomenon are presently being carried out.

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* Instituto de Física,Universidade de Sao Paulo, Sao Paulo, Brasil.

1 M. Behar et al. Nucl. Phys. A282 (1977) 331.
2 E. Nolte et al. Fizika 7 (1975) 144.

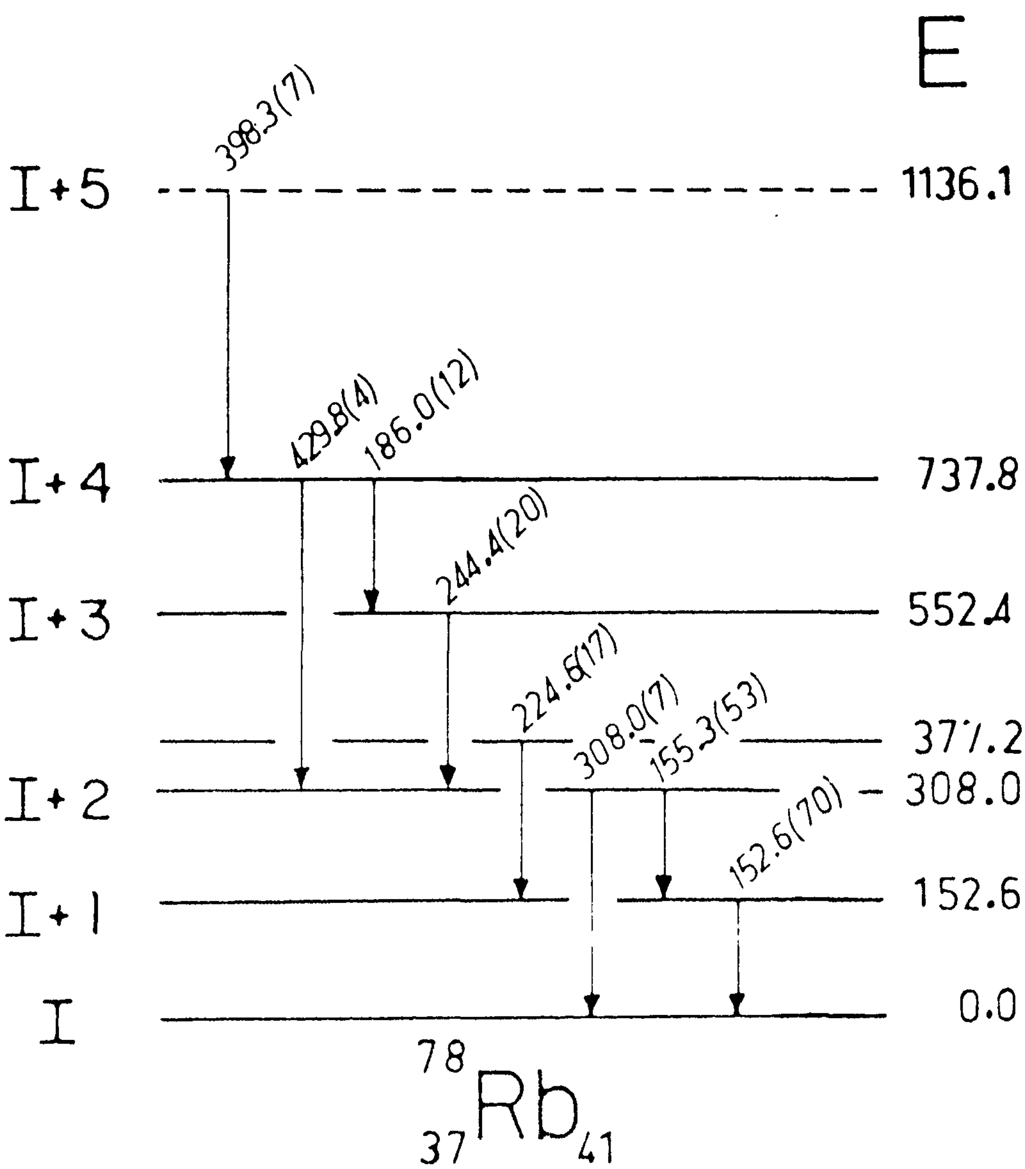

Fig. I.4.1. Observed level scheme of ^{78}Rb. The spins of the 152.6, 308.0, 552.4, 737.8 and 1136.1 keV levels form a sequence I + 1, I + 2, ... where I is the spin of the band head. The ambiguity remains as to whether the band head corresponds to the high spin 6 m isomer or the low spin 17.5 m isomer.

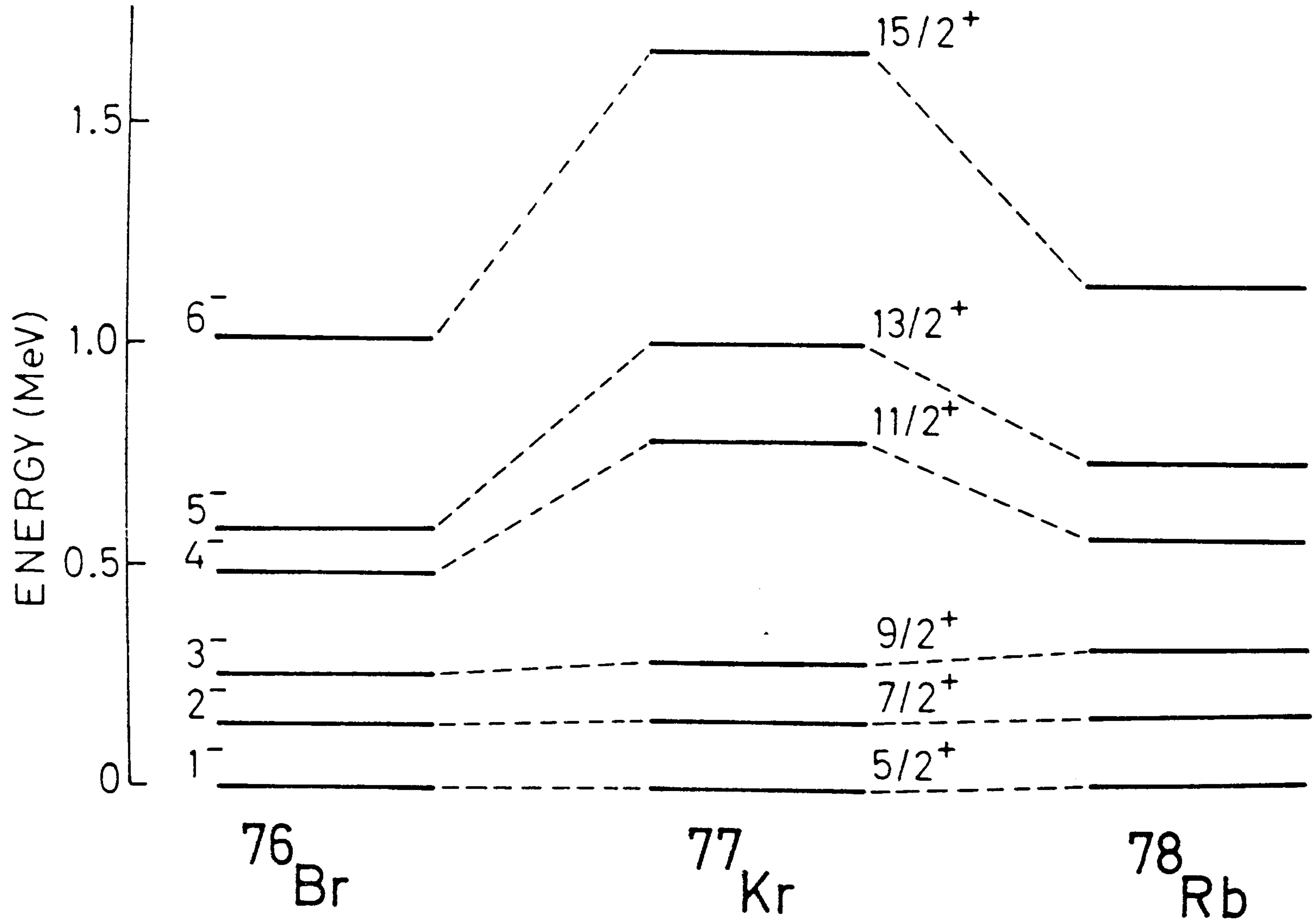

Fig.1.4.2 Comparison between energy levels of the nuclei ^{78}Rb, ^{77}Kr and ^{76}Br.

1.5 Level Structure of ^{80}Rb Studied with the ^{79}Br(α,3n) Reaction.

M. Behar*, A. Filevich, G. García Bermúdez and M.A.J. Mariscotti.

The present study of levels of ^{80}Rb populated through the (α,3nγ) reaction on ^{79}Br has been undertaken as part of a program to investigate doubly odd neutron-deficient nuclei in the 28 $\leq$ N, Z $\leq$ 50 region. It is known that intermediate values of deformation are found in this region of the periodic table. This is for instance, reflected in the marked variation of the $9/2^+$ state energies with neutron number in the odd-Z Rb isotopes. It is therefore attractive to explore whether this circunstance is reflected in the structure of ^{80}Rb. Our knowledge of this nucleus was until now limited to the results obtained from the radioactive decay of ^{80}Sr[1]. From the study of excitation functions, γ-γ coincidences and angular distribution, we obtain the level scheme shown in Fig.1.5.1. Comparing our results with those from the decay work, only the level at 175.6 keV is common to both studies. An interesting feature of the present level scheme is given by the spin sequence I = 1,2,3 and 4, energy spacing and decay patterns of the levels situated at 0,175.6, 375.9 and 472.5 keV. Assuming that the 175.6 and 472.5 keV levels have positive parity, this sequence can be compared with the predictions of the I(I + 1) law with a moment of inertia $J_o/\hbar^2$ = 0.016 ± 0.03 Kev^{-1}. It is noteworthy that similar moments of inertia are found in the odd-A neighboring nuclei. Searching for similar patterns in this region of the periodic table it is striking to observe that part of the level scheme of ^{68}Ga and ^{64}Cu [2] are almost identical with the band found in ^{80}Rb. A comparison of these data is shown in Fig.1.5.2.

The shell-model configuration $|\pi p3/2, \nu\ f5/2|\ I^{\pi} = 1^+,\ldots,4^+$ could provide a basis on which a description of this band structure could be attempted for ^{64}Cu and ^{68}Ga, but not for the heavier isotopes ^{80}Rb. Alternatively,in view of the similar structures in the three isotopes one can try a common description in terms of a rotational scheme. As in the case of ^{80}Rb, such an interpretation is also supported by the observed rotational bands in the odd-A neighbours of ^{64}Cu and ^{68}Ga, the isotopes ^{63}Cu and ^{67}Ga, respectively. The deformations and configurations assumed for the $K^{\pi} = 1^+$ bands are:

NUCLEI	ε	CONFIGURATION
^{80}Rb	0.2	$\pi\ \frac{3}{2}\ [301],\ \nu\ \frac{1}{2}\ [301]$
^{68}Ga	0.2	$\pi\ \frac{1}{2}\ [310],\ \nu\ \frac{3}{2}\ [301]$
^{64}Cu	0.14	$\pi\ \frac{1}{2}\ [321],\ \nu\ \frac{3}{2}\ [301]$

It is interesting to find that it is possible to obtain $K^{\pi} = 1^{+}$ wave functions with similar deformations for the three nuclei, in spite of their different nucleon number. The validity of these proposed Nilsson configurations can be tested by comparing the predicted mixing ratios δ for differents transitions of the cascade with those deduced from the angular distribution data. The results are shown in Fig.I.5.3. Although the error bars are large, the results seen to yield a fair indication that the proposed description is basically correct.

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* Present Adress: Department of Physics, University of Rio Grande do Sul, Brasil

1 R. Broda, A.Z. Hrynkiewicz, J. Styczen and W. Walus, Nucl. Phys. A216 (1973)

2 C. Pomar, P. Kleinheing, R.M. Lieder, M.A.J. Mariscotti, O.W. Schult, to be published.
C. Pomar, Thesis, University of Cuyo, Argentina, 1976, (unpublished).

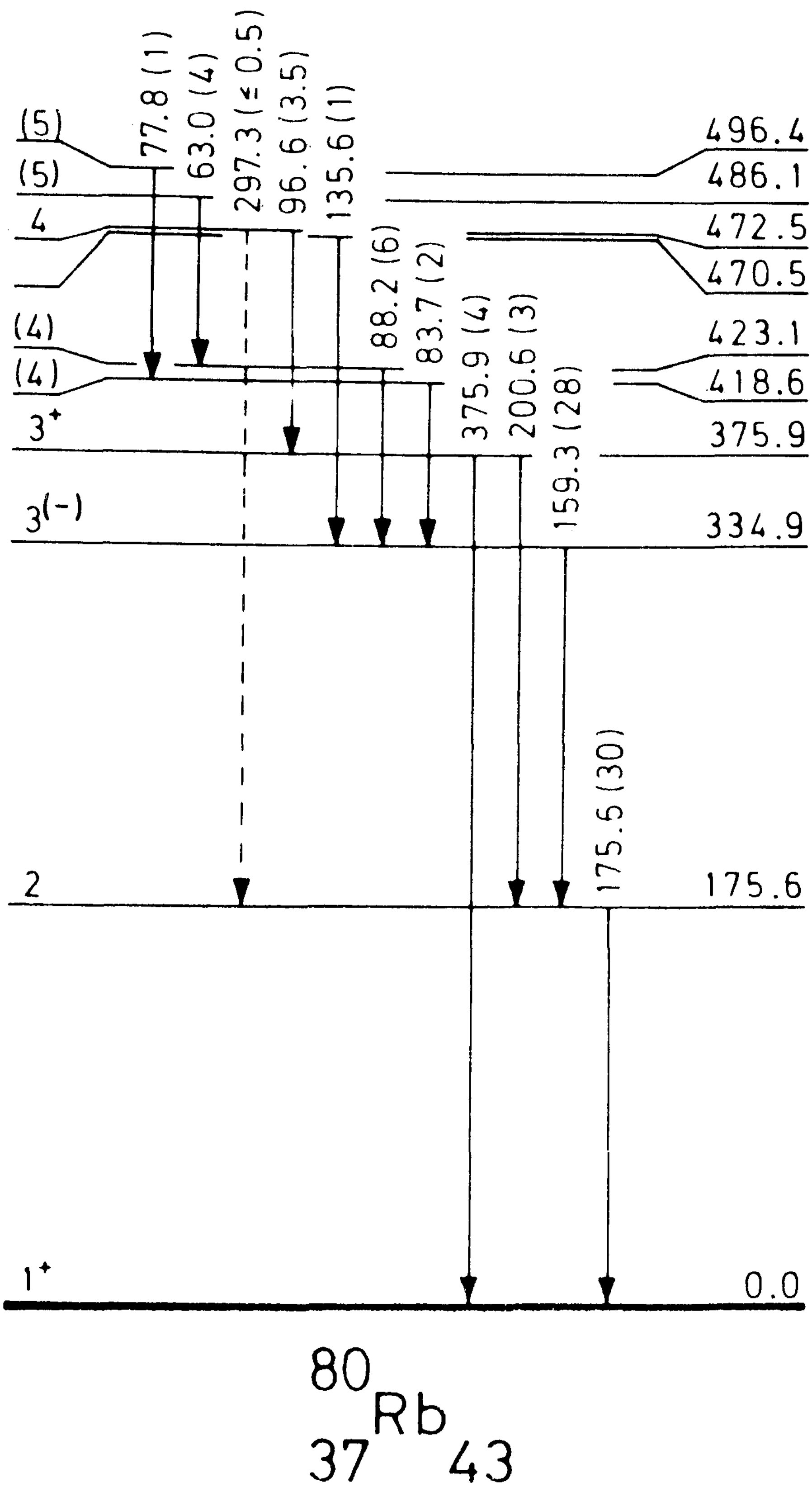

Fig. 1.5.1. Level scheme of ^{80}Rb obtained in the present work.

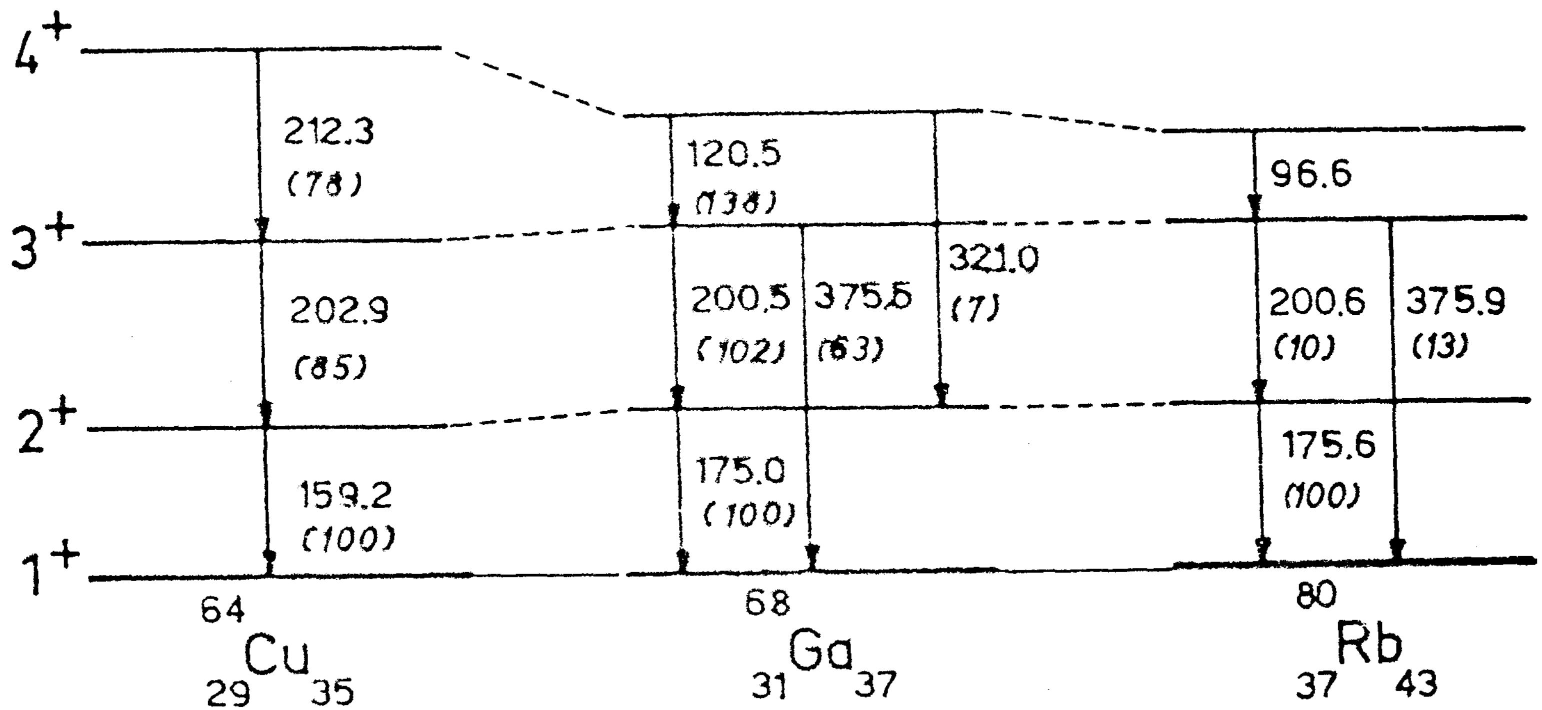

Fig. 1.5.2. Partial level scheme for ^{64}Cu, ^{68}Ga and ^{80}Rb.

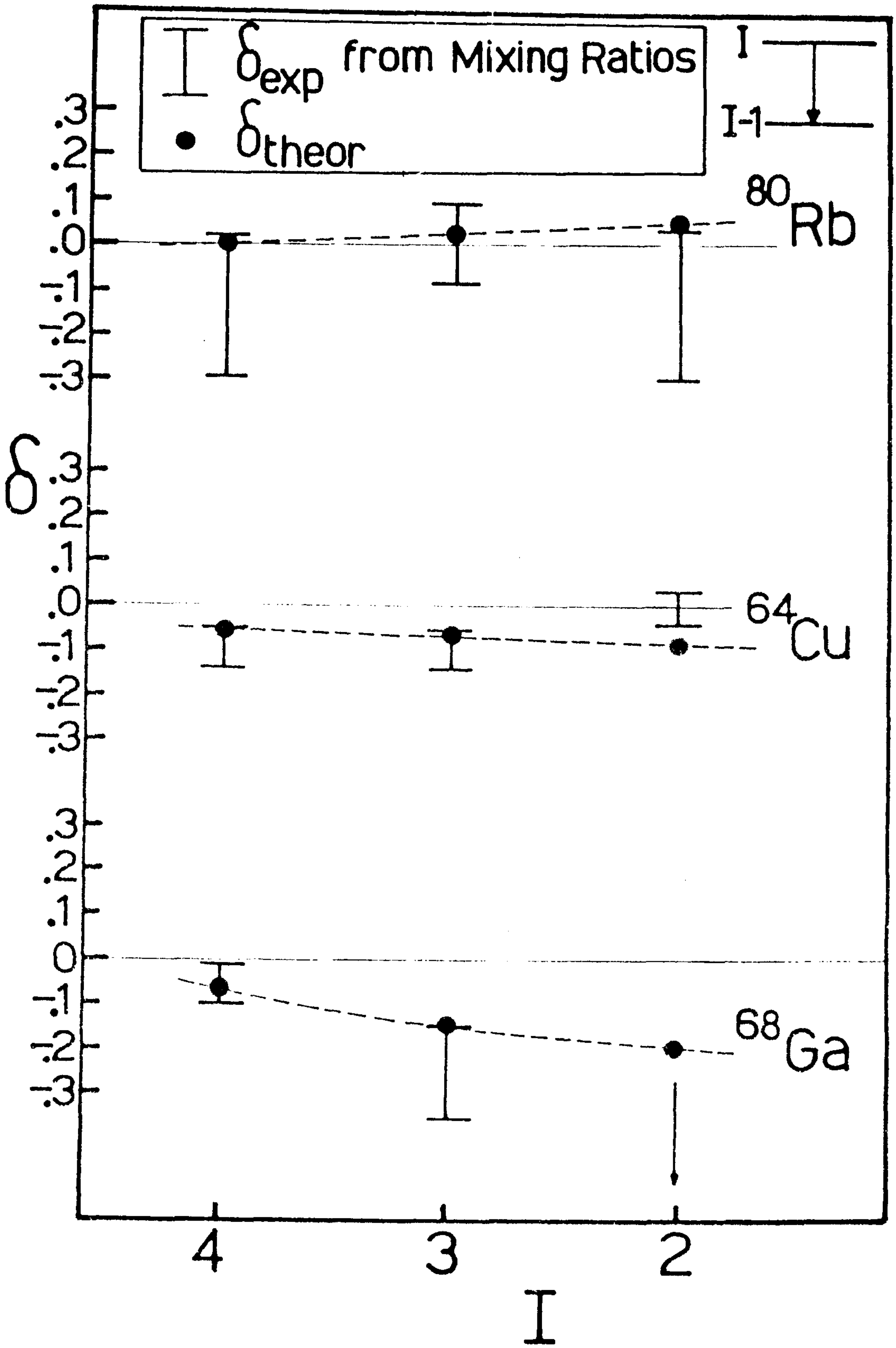

Fig.I.5.3. Predicted and experimental mixing ratios for I → (I-1) transitions of the quasirotiational bands in ^{64}Cu, ^{68}Ga and ^{80}Rb.

1.6. Study of ^{82}Rb

M. Behar*, A. Filevich, G. García Bermúdez, M.A.J. Mariscotti and L. Szybisz**.

Following previous investigation[1,2] in ^{78}Rb and ^{80}Rb, we have studied the $^{81}Br(\alpha,3n\gamma)$ reaction to observe excited levels in ^{82}Rb.

Up to now only the 1^+(1.25 m) ground state and a 5^-(6.2 h) isomer were known in ^{82}Rb.

Table 1.6.1. lists the energies, intensities and angular distribution coefficients of the γ-rays identified with ^{82}Rb. The identification was achieved by studying the excitation functions in the $30 < E_\alpha < 55$ MeV interval, and was complemented by the γ-γ coincidence data (Table 1.6.2.).

The coincidence results indicate the existence of a single γ-ray cascade through which the residual nucleus decays, comprising the 123.2, 64.5, 45.9, 562.7 and 621.4 keV γ transitions (in order of decreasing intensity). The angular distribution coefficients of these lines are typical of $\Delta I = 1$ transitions Hence, the γ-ray cascade is likely to correspond to a band with a spin sequence of I, I+1, I+2,... as found in ^{78}Rb and ^{80}Rb. However the spin-parity I^π of the band head remains to be elucidated.

Further experiments on this nucleus are now in progress.

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TABLE I.6.1.

Summary of results of the present experiment

Energy (kev) (±0.2)	Intensity (±10%)		A_2
45.9	100	(205) [a]	-0.62 ± 0.20
64.5.	190	(266) [a]	-0.42 ± 0.04
91.0	14		-0.13 ± 0.02
123.2	340		-0.41 ± 0.04
415.7	54		
417.8	11		
562.7	123		-0.48 ± 0.03
621.4	30		
980.5	13		

a) These values correspond to total intensities by assuming dipole conversion coefficients.

TABLE I.6.2.

The $\gamma-\gamma$ coincidence intensities from the present experiment[a)]

Gate / E_γ (keV)	45.9	64.5	91.0	123.2	562.7	621.4
45.9	-	110	W	124	91	20
64.5	100	-	W	250	200	58
123.2	40	105	W	-	60	15
562.7	98	100	W	124	-	60

a) Intensities correscted with the detector efficiency are given in arbitrary units. The letter W denotes weak coincidence.

1.7. High Spin States in ^{89}Y

M. Davidson*, J. Davidson*, M. Behar**, G. García Bermúdez and M.A.J. Mariscotti.

States in ^{89}Y were studied by means of the $^{87}Rb(\alpha,2n)$ reaction with bombarding energies between 30 and 55 MeV. Single γ-ray spectra up to 3.5 MeV, excitation functions, γ-ray angular distributions and γ-γ coincidence were measured using ~7% efficiency Ge(Li) detectors. Several strong low energy γ-rays were observed, which could not be fitted in to the level scheme below 3.2 MeV. Coincidence measurements with the high energy lines which depopulate the first states show that these new γ-rays correspond to transitions between states above 4.4 MeV. The level scheme of ^{89}Y is shown in Fig. 1.7.1. The indicated properties of levels below 3.2 MeV were known from previous work[1]. Our angular distribution measurements agree with the previously assigned spins and parities for these levels except for the one at 2894.1 keV. This state decays via the strong 1985 keV γ-ray which shows positive anysotropy. We thus tentatively assign I^{π} = (13/2+) to this level. With this exception and that of the 1107.0 keV line, which have A_2 positive, all other lines show dipolar character. These together with the non-observation of crossover transitions lead us to propose tentatively the spins and parities indicated for the upper levels. There is no simple shell model configuration capable of explaining these high spin values. On the other hand, the first states of ^{89}Y can be interpreted as arising from the coupling of a g9/2 proton with ^{88}Sr core. Indeed, above the first three levels, which can be assigned to the p1/2, g9/2 and p3/2 orbits, there is a multiplet of levels lying close to the energy of the $(\pi g9/2\ ^{88}Sr_{2+})$ and $(\pi g9/2\ ^{88}Sr_{3-})$ states. Likewise the levels observed above 4.4 MeV can be associated with the $(5)^-$, $(6)^-$ and $(7)^-$ states found in ^{88}Sr[2]. Inasmuch as this assumption is correct, the spectrum of high spin states in ^{88}Y should be similar to that in ^{87}Sr as in the latter case the spectrum should arise from the coupling of a g9/2 neutron hole (instead of a g9/2 proton) with the ^{88}Sr core. This appears to be the case as shown in Fig. 1.7.2 where the level schemes of the three isotopes are compared.

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1 Nuclear Data Sheets, 16 (1975) 445.
2 S.E. Arnell et al., Nucl. Phys. A241 (1975) 109.

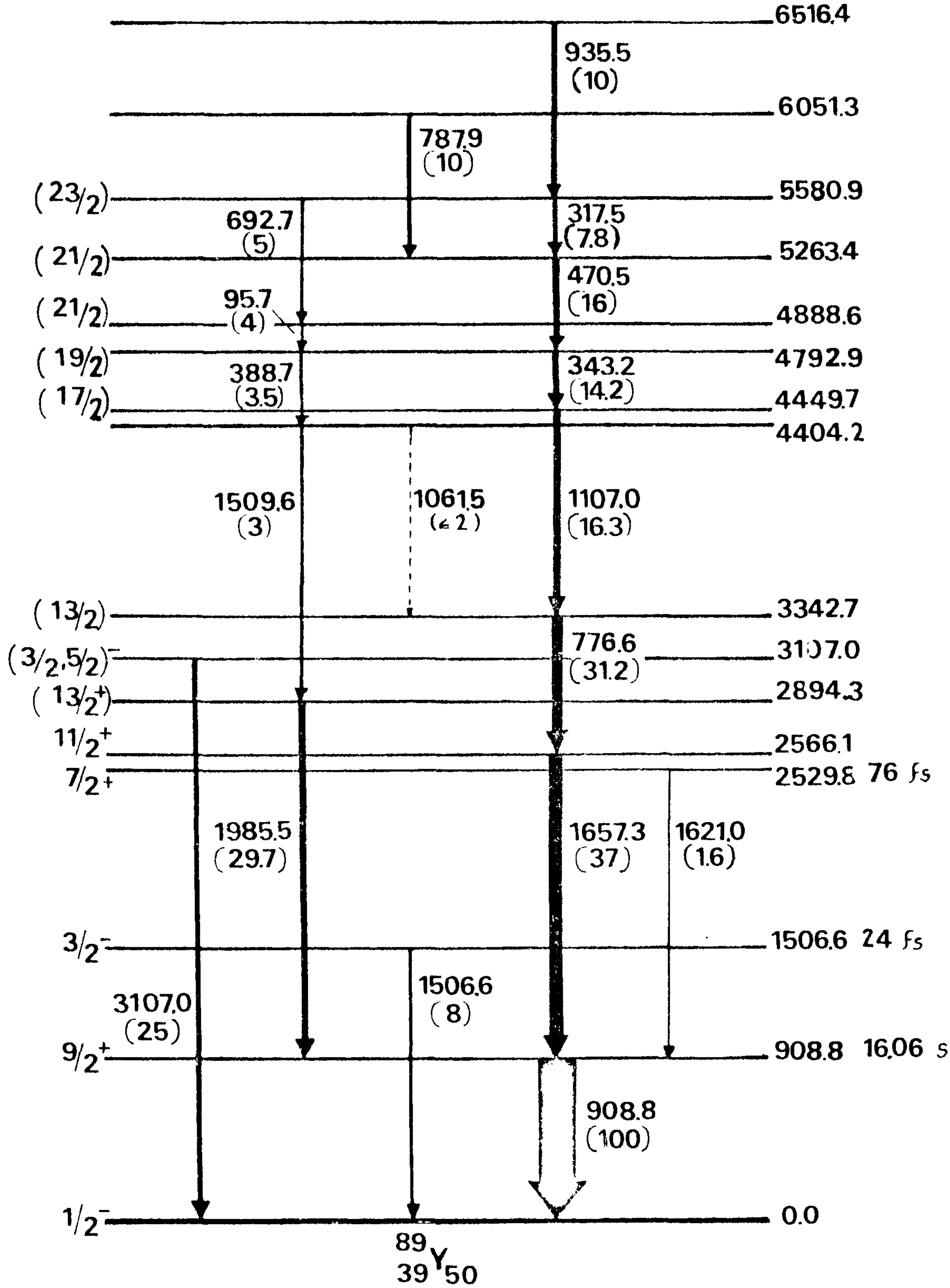

Fig. 1.7.1. Level scheme and decay pattern of ^{89}Y obtained in the present work.

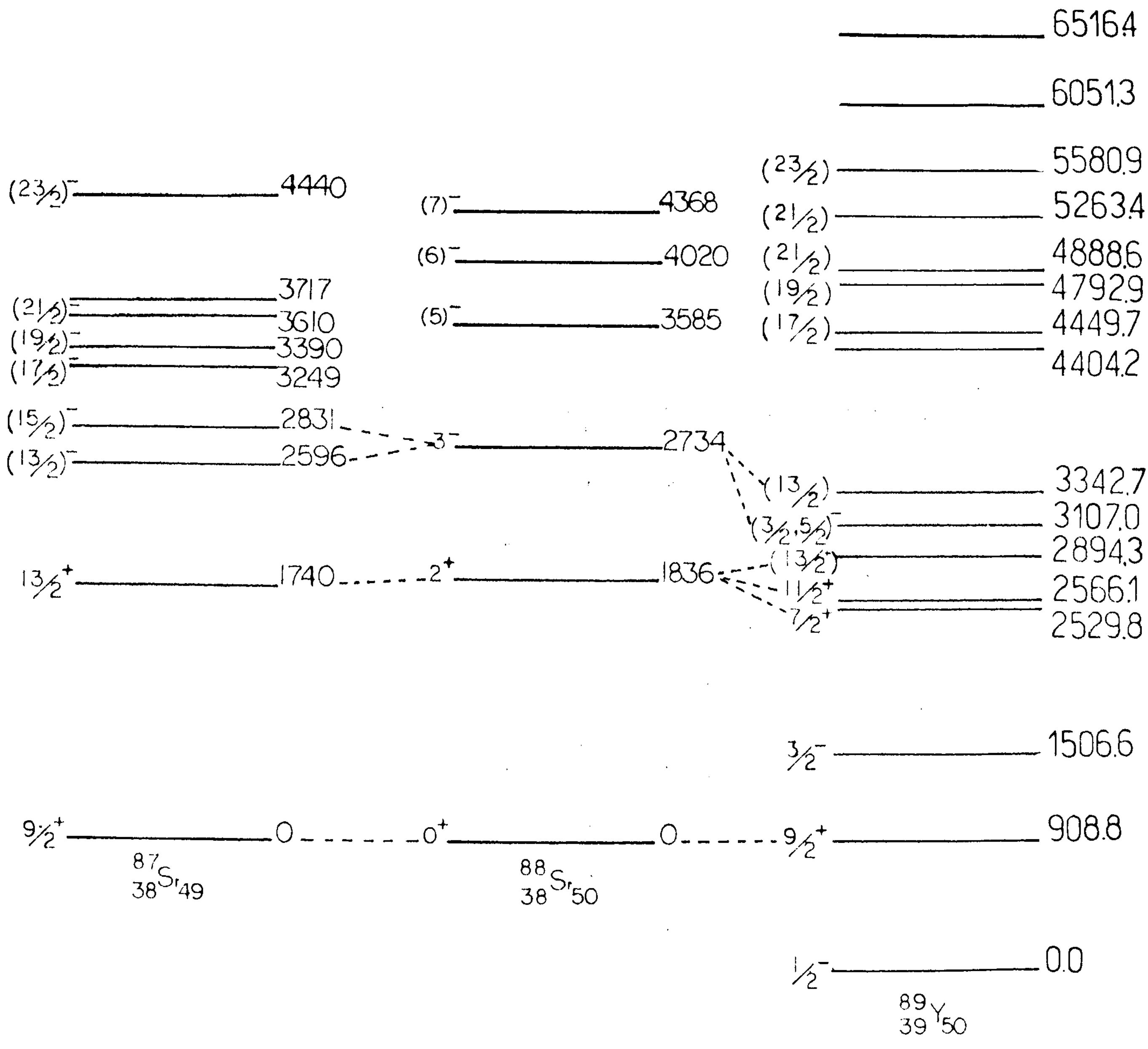

Fig.1.7.2. Level scheme of ^{89}Y (right) compared with high spin states in ^{87}Sr and ^{88}Sr (Ref.2)

1.8 Study of ^{144}Gd through the ^{144}Sm(α,4n) Reaction.

M.A.J. Mariscotti, H. Beuscher*, W.F. Davidson**, Y. Gono**, H.M. Jager**, R.M. Lieder**, M. Müller Veggian**, A. Neskakis** and D.R. Zolnowski***.

The present study of ^{144}Gd was undertaken with the purpose of obtaining information on the transitional propertiesof the N = 80 isotones where considerable admixture of single particle and collective degrees of freedom is expected to occur. In fact ^{144}Gd, the heaviest N = 80 isotone so far studied, exhibits the largest E_4/E_2 ratio. On the other hand, high spin-two neutron hole states, involving the $h_{11/2}$ orbit should predominate in the single particle states.

Prior to this investigation only two transitions of 743 and 1001 keV were known from a study by Habs et al[1]. These transitions were identified as deexciting the lowest 2^+ and 4^+ states.

Excitation functions, γ-ray angular distributions, four dimensional coincidence spectra involving $E_{\gamma 1}$, $E_{\gamma 2}$, $t_{\gamma 1 \gamma 2}$ and t -beam were measured by bombarding ^{144}Sm with the beam of the JULIC Cyclotron. Conversion coefficients for the delayed transitions were obtained from in-beam measurements of delayed conversion electron spectra carried out at the Texas A & M Cyclotron with a spectrometer consisting of a steering magnet and a cooled Si(Li) detector[2]. The maximun cross section for the ^{144}Sm(α,4n) ^{144}Gd reaction was found at E_α = 67 MeV.

The level scheme resulting from this study is shown in Fig.1.8.1. Below spin 10^+ only two excited states have positive parity; i.e, the 2^+ and 4^+ states. These two states are in agreement with the results of Habs et al.[1]. Members of the quasi ground band with larger spins are not observed. A plot of the available data on 6^+ states in the vicinity of ^{144}Gd yields an extrapolated value of $E_{6^+} \sim 2.37$ MeV or approximately 100 keV below the 7^- isomeric state. This estimated value is in agreement with the experimental observation if the 7^- to 6^+ E1 transition is hindered about 10^6 times. A similar hindrance is found for the 87.4. keV E1 transition depopulating the 10^+ isomer at 3433.0 keV.

Between the 4^+ and 10^+ states, negative parity states are the yrast states in ^{144}Gd. The 7^- isomer has also been found in the lighter isotones ^{142}Sm (ref.3), ^{140}Nd (ref.4) and ^{138}Ce (ref.4) and has been interpreted as a $\{\nu h_{11/2}^{-1}\ \nu d_{3/2}^{-1}\}$ two neutron hole state[4]. The same configuration as well as the

$\{\nu h_{11/2}^{-1}, \nu s_{1/2}^{-1}\}$ probably predominate in the wave function of the 5^- state at 2302. However the lifetime is up to ten times shorter that the calculated value.

The 10^+ isomeric state at 3433 keV has a similar excitation energy as the proposed 10^+ isomer in ^{138}Ce at 3538 keV[5] and can be interpreted as a $\nu h_{11/2}^{-2}$ two neutron hole state.

The 11^+ and 12^+ states above the 10^+ isomer are found to be populated in the reaction with an unusual high degree of alignment (α_2 = 0.96 ± 0.04). This alignment is not preserved below the isomer where α_2 ~0.2 - 0.3. The 711.3 keV line shows an E_2 admixture of the order of 20%.

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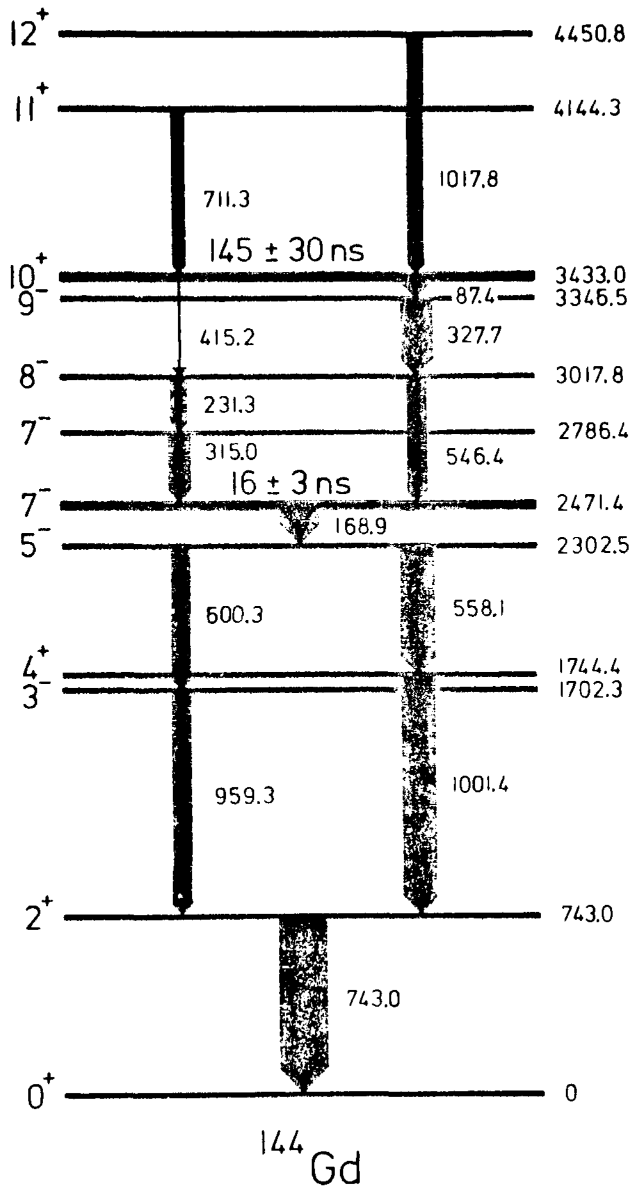

Fig.1.8.1. Level scheme of ^{144}Gd.

1.9 Study of ^{198}Tl

A.J. Kreiner*, M. Fenzl**, S. Lunardi***, M.A.J. Mariscotti.

Doubly odd thallium isotopes have been investigated in the past mainly through the electron capture decay of the ground states of the corresponding lead isotopes[1,2]. In this process only the low energy, low spin part of the spectra is reached. Also some studies concerning high-spin long-lived isomers have been carried out through (p, n)[3] and(H.I.,xn)[4] reactions. From this work the γ-decay of these 7^+ states to the ground state is known. Until now no in-beam measurements of the promt γ-rays following the productions of these nucleides have been made. On the contrary, the situation is very different in the odd-mass thallium's.

Many of them have been studied with heavy-ion reactions[5,6]. Well established evidence now exists for the occurence of rotational bands based on the 9/2-[505]proton Nilsson state with oblate deformation. These states display tha right features as to allow an interpretation in terms of a so called strongly coupled band, This is the typical situation for a particle well above the Fermi surface coupled to an oblate core[7].

A very interesting phenomenon takes place here, which can be understood as a shape transition. Thallium is spherical in the ground state; it is just one single hole in a lead core. When the odd-proton jumps to the next higher-lying major shell we are left over with a Hg core and the polarizing effects of the particle in the high-single j equatorial orbital (J_p^Π = 9/2, Ωp = 9/2). In this situation it is energetically more favourable for the system to adopt a certain permanent oblate deformation, although it is not clear up to now to what extent the wave function is spread out in the β-γ plane[8]. We believe now that it is very likely that such a behaviour is also realized in even-mass thallium nuclei.

The experimental information obtained in this work is the result of measurements done in three different laboratories.

The first set of experiments were performed with the α-particle beam from the Buenos Aires synchrocyclotron at the AEC of Argentina. This work comprises the measurements of γ-ray excitation functions, activity spectra, a preliminary run of γ-γ coincidences and the search for isomerism in the μsec region, making use of the natural time structure of the beam. The second one was done with a similar beam from the Julich isochronous cyclotron, with which γ-ray angular distributions, γ-γ coincidences and time distributions in the nsec region were obtained. Conversion electron spectra were measured at the Bonn University's variable energy cyclotron making use of the orange β-spectrometer facility.

Two "rotational like" structures were found based on isomeric states at 934,3 keV ($J^{\pi} = 8^{-}$, T1/2 = 12.3 ± 0.3 ns) and 6871 keV ($J^{\pi} = (5)^{+}$ T1/2 = 150 ± 40 ns). The level scheme is shown in Fig I.9.1. The intrinsic structure of the band on the 8^{-} isomer is interpreted as the coupling of a $h_{9/2}$ proton quasiparticle strongly coupled to the nuclear symmetry axis of the oblate core and a rotation-aligned $i_{13/2}$ quasineutron. According to the positions of these orbitals relative to the Fermi levels of both types of nucleons in our case, the coupling at a right angle of the corresponding angular momenta becomes the energetically most favourable one. A vector model diagram of the band-head-state structure and the approximate good quantum numbers of the system are shown in Fig. I.9.2. $\hat{e}_{I}^{\perp}$ denotes a unit vector pointing in the direction of the component of $\vec{I}$ perpendicular to the symmetry axis. Thus, $\hat{e}_{I}^{\perp} \cdot \vec{j}_{n}$ measures the neutron aligment. The diagonalization of the particle-rotation coupling Hamiltonian[9] within the $\{\pi h_{9/2}, \nu i_{13/2}\}$ configuration space and also the subsequent calculation of electromagnetic properties lends support to this description.

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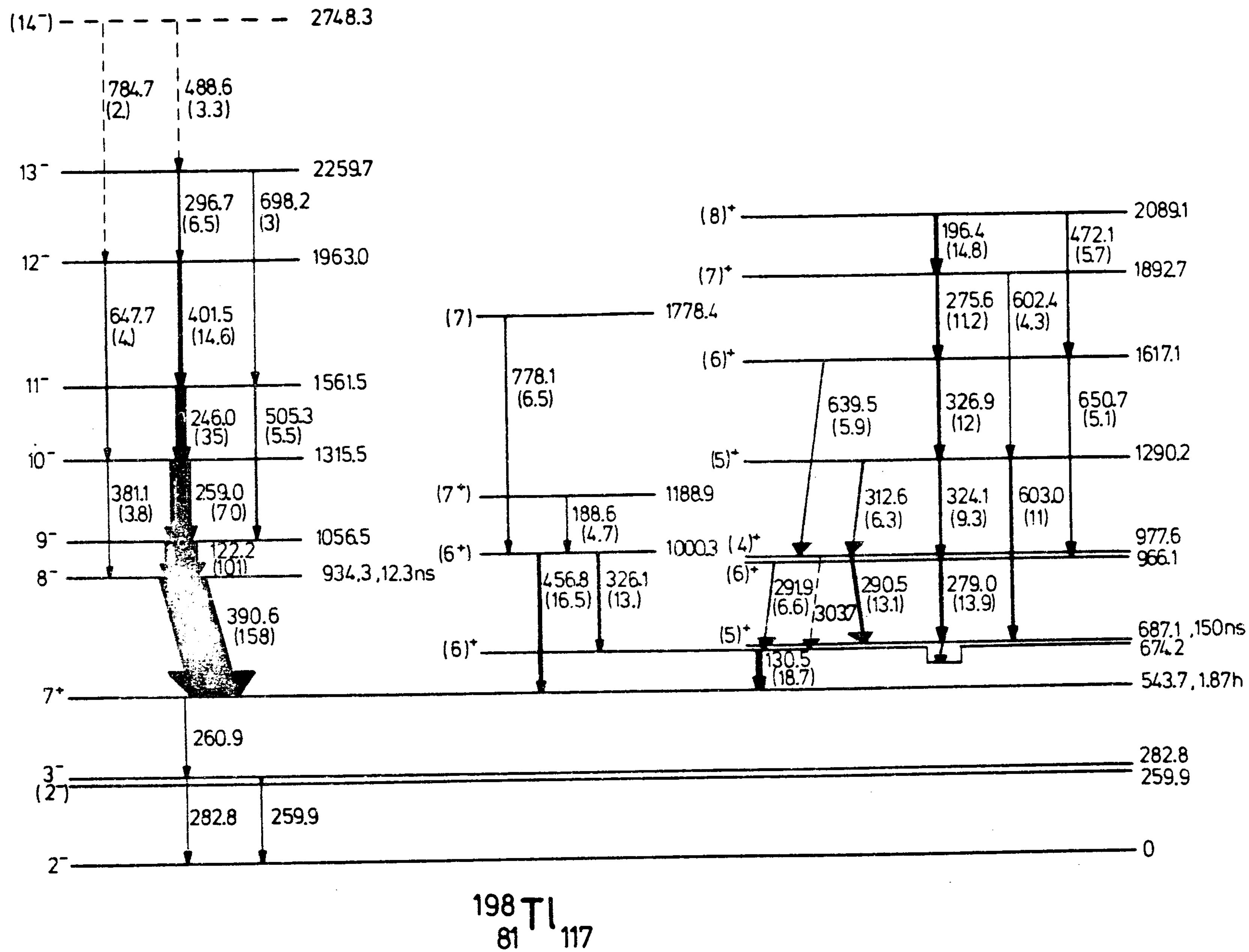

<u>Fig. i.9.1.</u> Level scheme of ^{198}Tl.

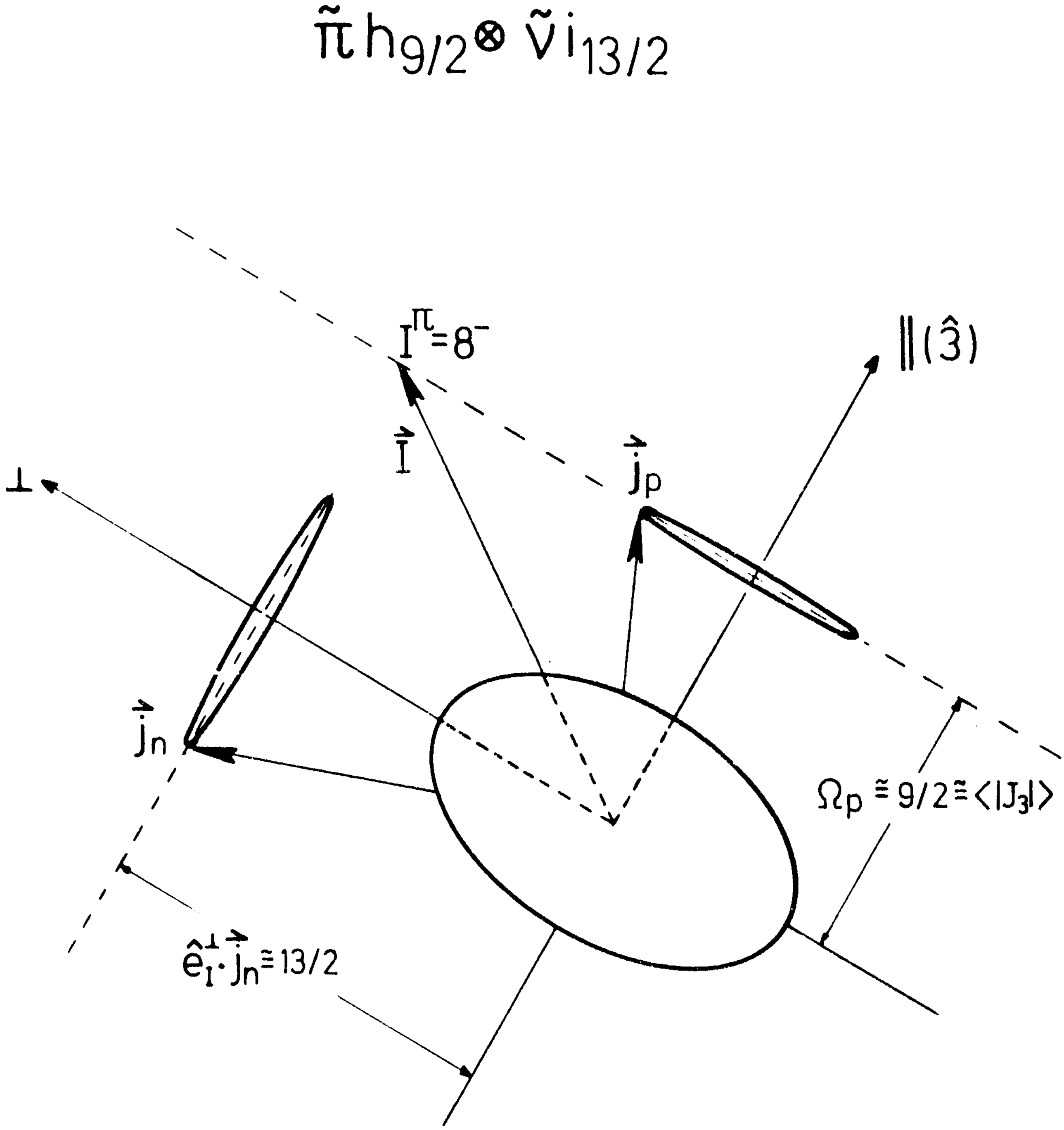

Fig.1.9.2. A vector model representation of the structure of the rotational band based on the 8^- isomeric state.

II. MAGNETIC MOMENTS OF EXCITED STATES

II.1. Lifetimes and g-factors of the 6^- and 7^- isomers in ^{66}Ga and ^{68}Ga.

A. Filevich, A. Ceballos, M.A.J.Mariscotti, P. Thieberger* and E. der Mateosian*.

The excited states of the odd-odd nuclei $^{66}_{31}Ga_{35}$ and $^{68}_{31}Ga_{37}$ were studied by Pomar et al[1]. Isomeric states of spin 6^- in ^{66}Ga (1440.9 keV, $T_{1/2}$ ~100 ns) and 7^- in ^{66}Ga (1229.6 keV, $T_{1/2}$ ~85 ns) were found [1,2]. These states are expected to share configurations in which the odd neutron is in the $g_{9/2}$ orbital. As shown in Fig. II.1.1 a plot of the energy of the first 6^- state in the doubly odd nuclei ^{62}Cu, ^{64}Cu, ^{66}Ga and ^{68}Ga as a function of N, exhibits a tendency similar to that of the $9/2^+$ first excited states of the neighboring odd-Zn isotopes. Since these $9/2^+$ states are known to be rather pure $g_{9/2}$ neutron shell-model states, the indicated similarity seems to confirm that the lowest negative parity state in ^{66}Ga and ^{68}Ga involve the $\nu g_{9/2}$ configuration.

In the present work the g-factors of the 6^- and 7^- states in ^{66}Ga and ^{68}Ga have been measured in order to investigate the above mentioned assumption. In order to have the product nucleus in a ferromagnetic environment the ^{56}Fe (^{13}C,2np)^{66}Ga and ^{56}Fe(^{15}N,n2p)^{68}Ga reactions were used A target of natural Fe (natural abundance 91%) was bombarded with ^{13}C and ^{15}N beams from the Brookhaven National Laboratory MP Tandem Accelerator. The target was a 0.1 mil thick natural iron strip, placed across the pole pieces of a small (~1000 G) permanent magnet used to saturate the internal hyperfine field. The interaction between this field and the magnetic moment of the product nuclei causes their precession, which was observed externally through the rotation of the angular distribution of the emitted γ-rays by the Time Differential Perturbed Angular Distribution (TDPAD) method. Several independent runs were performed with ^{13}C and ^{15}N beams using a single, 10% efficiency, Ge(Li) detector, repeatedly placed in sequence at + 45° and - 45° with respect to the beam direction.

The half lives of the $J^\pi = 6^-$ and $J^\pi = 7^-$ levels in ^{66}Ga and ^{68}Ga were remeasured to improve the accuracy of the previously reported values [1,2]. The time distribution measurements were performed using the pulse beam facility of the tandem accelerator. The width of the beam pulses was about 7 ns and the repetition rate was 4 MHz. The time-to-amplitude converter was calibrated by means of a model TC850 Tennelec time calibrator[3]. The results yield the values

$$T_{1/2}(J^{\pi} = 6^-, {}^{66}Ga) = 57.3 \pm 1.4 \text{ ns and}$$

$$T_{1/2}(J^{\pi} = 7^-, {}^{68}Ga) = 64 \pm 2 \text{ ns}$$

Fig.II.1.2 show the experimental results for both nuclei. The solid lines are the best fit to the experimental points and correspond to the function

$$R(t) = K|\sin 2\omega_L t \quad \exp(-\lambda T) \sin 2\omega_L (t+T)|$$

where T is the time elapsed between two sucessive beam bursts and the contribution from the previous beam burst (aproximately 7%) is accounted for by the second term. Table II.1.1 shows the resulting values of ω_L, $T_{1/2}$ and A_2 coefficients.

The g-factors are obtained from the relation

$$g = \frac{\omega_L \hbar}{\mu_N B}$$

where B is the magnetic field at the site of the nucleus. Using the spin-echo-technique, Kontani and Itoh[4] have measured the absolute value of the hyperfine magnetic field of Ga en Fe at 4.2° K to be $|B(Ga/Fe, T = 4.2°K)| = 110 \pm 3$ kG. By taking into account the Fe magnetization curve a correction of -2.6% must be applied to obtain the magnetic field at room temperature. This yields $|B(Ga/Fe, \text{room } T)| = 107 \pm 3$kG. Krõlas[6] used the g-factor of the known 43.7 keV isomeric state in ^{66}Ga to determine the sign and amplitude of the same quantity, obtaining a somewhat different value $B(Ga/Fe, \text{room } T) = -(94 \pm 5)$kG. with these values of the magnetic field and our results for the Larmor precession frequency we obtain the g-factors shown in Table II.1.2.

Within the framework of the shell model there is only one possible configuration to explain a low lying 7^- state such as that found in ^{68}Ga, namely $\{\pi f_{5/2}, \nu g_{9/2}\}_{7^-}$ and two configurations for a 6^- state in ^{66}Ga, which are $\{\pi f_{5/2}, \nu g_{9/2}\}_{6^-}$ and $\{\pi p_{3/2}, \nu g_{9/2}\}_{6^-}$

For the proton and neutron g-factors we can use the Schmidt values computed for the corresponding assumed single particle configurations. However, the systematics show that, in general, the experimental values depart considerably from those predicted by the Schmidt formula.

It has long been recognized that such deviations are mainly due to core polarization effects[7,8,9]. By taking these into account the agreement with the measured g-factors of odd-nuclei is considerably improved.

In our case of odd-odd nuclei these effects are best taken into account by using the g_p and g_n values experimentally determined for the corresponding states in the odd-A neighbors.

In Table II.1.3 the g-factors measured in the present work are compared to those obtained by assuming g_p and g_n as given by either the pure single particle model (under column labelled "Schmidt"), or the experimental values obtained from neighboring nuclei (column labelled "Emp"). It is seen that a reasonable agreement is obtained with the empirical g_p and g_n for the 7^- state in ^{68}Ga assuming the $\{\pi f_{5/2},\nu g_{9/2}\}_{7^-}$ configuration while the Schmidt prediction yields the opposite sign. The measured g-factor for the 6^- state in ^{66}Ga is close to the calculated value assuming the $\{\pi p_{3/2},\nu g_{9/2}\}_{6^-}$ configuration and the empirical figures for g_p and g_n. However a small mixing of the $\{\pi f_{5/2}, \nu g_{9/2}\}_{6^-}$ term can not be ruled out. In fact if one assumes that the wave functions is

$$\Psi_{6^-}(^{66}\mathrm{Ga}) = \sqrt{1-\beta^2}\,\{\pi p_{3/2},\nu g_{9/2}\}_{6^-} + \beta\{\pi f_{5/2},\nu g_{9/2}\}_{6^-}$$

the present measurement yields $\beta^2 = 0.20$

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TABLE II.1.1

Larmor frequency and related data for the isomeric 6^- and 7^- states in ^{66}Ga and ^{88}Ga

Nucleus	Line (keV)	Period (ns)	$T_{1/2}$ (ns)	A_2	ω_L (Mhz)
^{66}Ga	933	48.9(.7)	57.6(1.6)	-0.035(.006)	64.2(.9)
	834	49.8(.8)	56.5(2.7)	-0.031(.006)	63.1(1.0)
	600	45.7(1.6)	54.6(2.7)	0.017(.007)	68.7(2.4)
	448	48.5(.5)	60.2(2.8)	-0.056(.008)	64.8(.6)
average		48.7(.4)	57.3(1.2)		64.5(.1)
^{68}Ga	607	59(1)	64(2)	-0.10(.01)	53.2(.1)

TABLE II.1.2

g-factors for the 6^- and 7^- isomeric states of ^{66}Ga and ^{68}Ga, obtained in the present work.

Nucleus	$J\pi$	g-factor determined by using magnetic field B from		weighted average
		Ref.4	Ref.6	
^{68}Ga	6^-	0.125(0.04)	0.143(.008)	0.129(.003)
^{68}Ga	7^-	0.103(.003)	0.118(.007)	0.105(.003)

TABLE II.1.3

g- factors of the 6^- and 7^- isomeric states in the odd-odd ^{66}Ga and ^{68}Ga.

Nucleus	Configuration	Schmidt[a)]	Emp.[b)]	Exp.
^{68}Ga	$\{\pi f_{5/2}, \nu g_{9/2}\}_{7^-}$	-0.150	+0.087	0.105(.003)
^{66}Ga	$\{\pi f_{5/2}, \nu g_{9/2}\}_{6^-}$	-0.187	+0.046	20% } 0.129(.003)[c)]
^{66}Ga	$\{\pi p_{3/2}, \nu g_{9/2}\}_{6^-}$	+0.314	+0.150	80% }

a) value obtained using the result of the pure single particle model (see Table 3) for g_p and g_n

b) value obtained using the empirical data for g_p and g_n from neighboring odd-A nuclei (see Table 3)

c) see text.

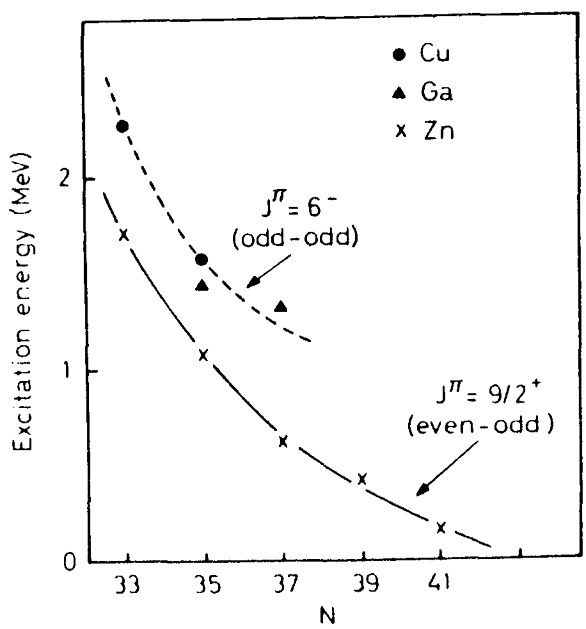
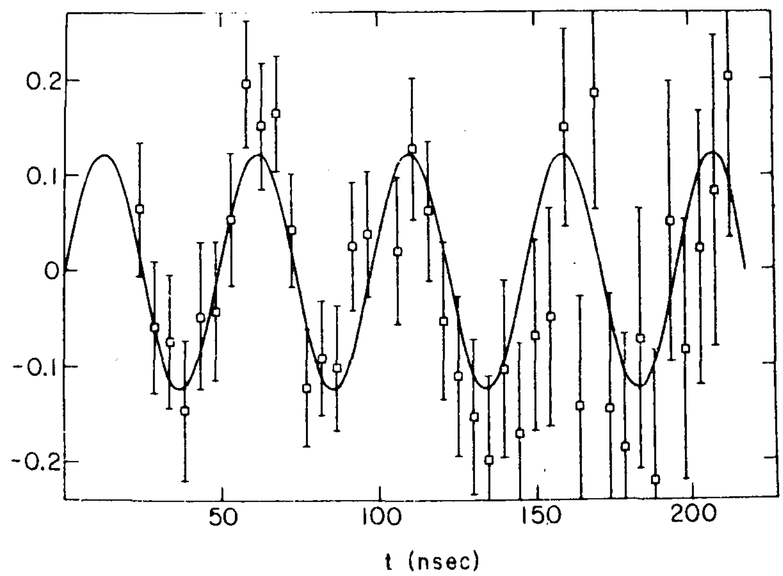
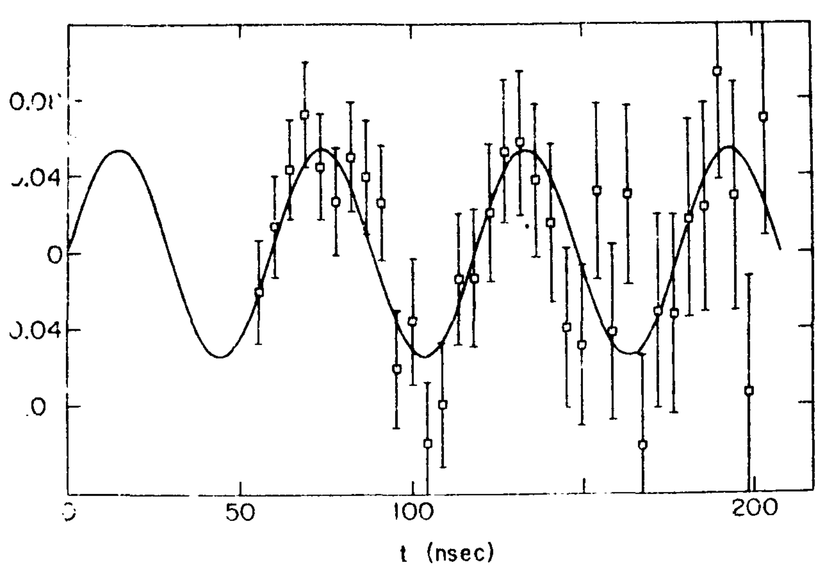


Fig. II.1.1. Energies of the first 6^- state in doubly-odd nuclei $^{62,64}Cu$ and $^{66,68}Ga$ as a function of N. The excitation energies of the first $9/2^+$ states in the odd-A Zn isotopes are shown for comparison.



<u>Fig. II.1.2.(a)</u> Larmor precession of the 6^- isomeric state in ^{66}Ga observed through the rotation of the angular distribution of the 448 keV γ-ray.



<u>Fig.II.1.2.(b)</u> Larmor precession of the 7^- isomeric state in ^{68}Ga observed through the rotation of the angular distribution of the 607.3 keV γ-ray.

II.2. Magnetic Moment of the 887.9 keV State in ^{70}As.

M. Behar*, A. Filevich, G. García Bermúdez, E. Ventura and F. Zawislak**.

Preliminary measurements of the magnetic moment of the 887.9 keV (4.4 nsec) state in ^{70}As (see Fig.II.2.1.) were carried out by means of the integral perturbed angular correlation method.

The ^{70}As 887.9 keV state was excited through the $^{69}Ga(\alpha,3n)^{70}As$ reaction by means of the α-beam from the Buenos Aires Synchrocyclotron at an incident energy $E_\alpha = 45$ MeV. The target consisted of 5 mg/cm^2 Galium Oxide enriched to 99.7% in ^{69}Ga. Two Ge(Li) detectors placed at opposite sides of the target were used to detect the de-exciting γ-rays.

The unperturbed angular distribution of the γ-rays de-exciting the 887.9 keV state were measured independently with each detector at a distance of 10 cm from the target in the angular range $\theta_{lab} = 60° - 145°$. The averaged measured distribution was fitted to the expression

$$W(\theta) = 1 + a_2Q_2P_2(\cos\theta) + a_4Q_4P_4(\cos\theta)$$

where the coefficients a_k depend on the population parameters, and the coefficients Q_k are attenuation factors arising from the finite detector solid angles. The result we obtained was

$$W(\theta) = 1 - (0.224 \pm 0.032)P_2 + (0.020 \pm 0.040)P_4$$

The measurement of the magnetic moment was carried out with the detector placed at the optimum slope angle in an external magnetic field of 6.25 kGauss. The direction of the magnetic field was periodically reversed and spectra were separately stored for each field direction. The peak sums from the transitions de-exciting the 887.9 keV state were then formed into the usual double ratio so as to minimize systematic errors.

The preliminary value obtained for the g-factor of the 887.9 keV state is $g = +0.64 \pm 0.08$. More work is currently being done to reduce the experimental error.

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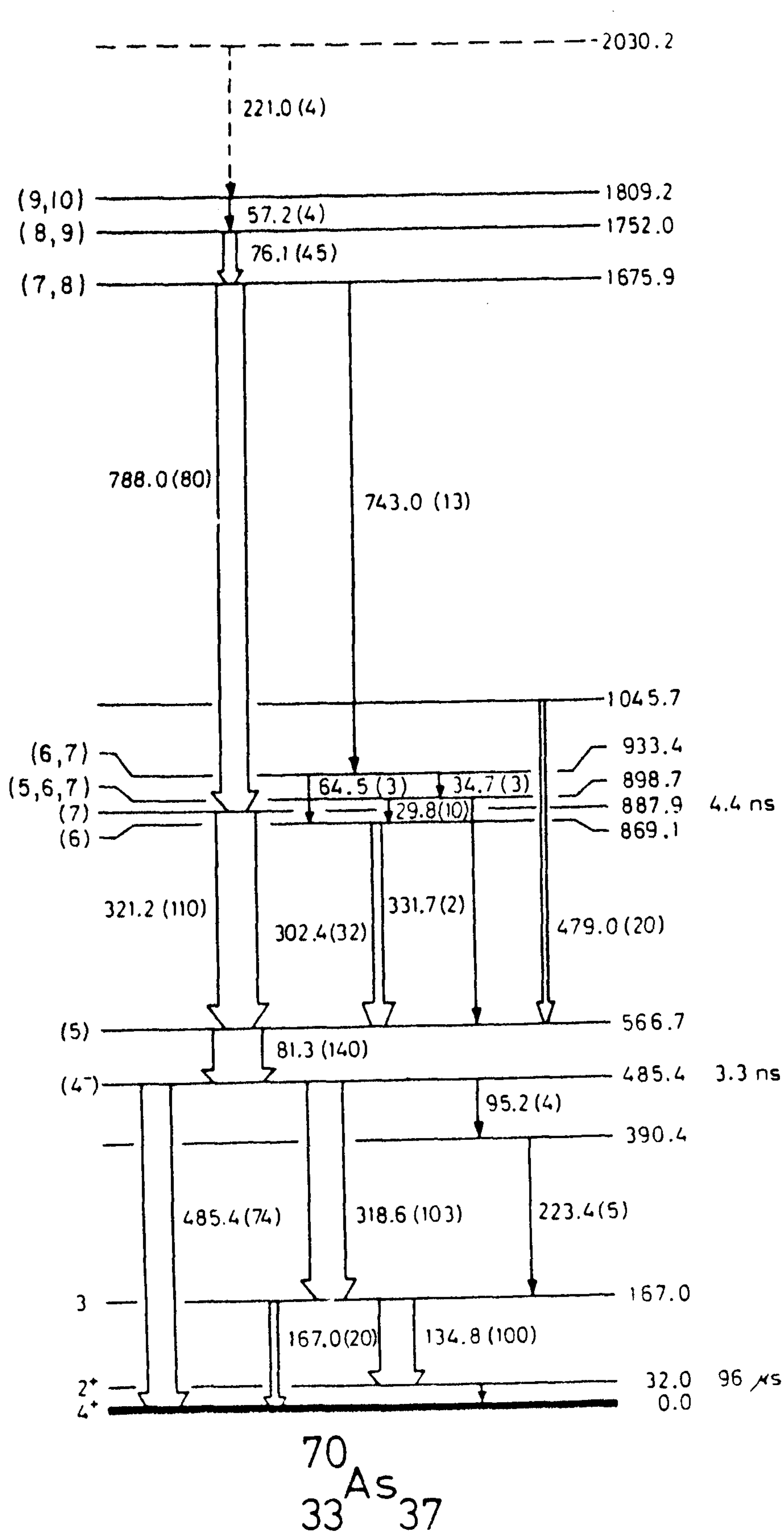
2030.2
221.0 (4)
(9,10)
1809.2
57.2 (4)
(8,9)
1752.0
76.1 (45)
(7,8)
1675.9
788.0 (80)
743.0 (13)
1045.7
(6,7)
933.4
(5,6,7)
64.5 (3)
34.7 (3)
898.7
(7)
29.8(10)
887.9
4.4 ns
(6)
869.1
321.2 (110)
302.4(32)
331.7(2)
479.0 (20)
(5)
566.7
81.3 (140)
(4⁻)
485.4
3.3 ns
95.2 (4)
390.4
485.4 (74)
318.6 (103)
223.4(5)
3
167.0
167.0(20)
134.8 (100)
2⁺
32.0
96 μs
4⁺
0.0
$^{70}_{33}As_{37}$

III. RADIOACTIVITY

III.1. Level Spin and Multipole mixing Ratios of the Transitions in ^{94}Mo.

M. Behar, A. Filevich, G. García Bermúdez and C. Alonso Arias.

The decay of ^{94}Tc to levels of ^{94}Mo has been extensively studied but despite the rather numerous investigations through electron capture decay of ^{94}Tc [1-3] and reaction experiments such as (α,xn)[4], $(^{3}He,d)$[5], (α,α')[6], and (p,p)[7], there still exist uncertainties about spin and parity assignments.

Previous investigations of the decay scheme of ^{94}Mo led to the partial level scheme shown in Fig. III.1.1. Prior to the present experiment the 2872.5 keV and the 3339.5 keV levels had no definite spin assignments and the mixing ratio of the γ-ray transitions were not known.

The present experiment was undertaken in order to determine two level spins in ^{94}Mo populated from the decay of ^{94}Tc and to find the multipolarities of several γ transitions, γ-γ directional correlation measurements and polarization-directional correlation measurements were performed with the result of a unique interpretation of the data.

The ^{94}Tc activity employed in this investigation was produced through the $^{93}Nb(\alpha,3n)^{94}Tc$ reaction at E_α = 45 MeV. The γ-γ coincidence spectrometer consisted of a Ge(Li) detector and a NaI(Tl) scintillation counter in the othe channel. The γ-γ (90°L.P.) spectrometer consisted of a planar square Ge(Li) detector used as a polarimeter and a NaI(Tl) scintillator. The experimental arrangement used in the present work has been described in Ref.8. The experimentally determined parameter was the assymetry ratio β = N/N where N and N are the counting rates with the long axis of the detector parallel and perpendicular respectively to the polarization plane. The results obtained from both measurements are summarized en Table III.1.1.

Previous radiactive works[1-7] were unable to uniquely assign spins to the 2872 and 3339 keV levels. From (α,xn)[4] reactions, $I^\pi = 6^+$ was assigned to the level of 2872 keV but from $(^{3}He,d)$ experiments[5], a $I^\pi = (8)^+$ level at 2875 keV was reported. Our result assigns $I^\pi = 6^+$ in agreement with the work of Ref.4. From the decay works [2,3] $I^\pi = 6^+$ was tentatively assigned to the 3339.5 keV level. The present work confirms without doubt such assignement resulting a pure M1 character for the 916 keV transition.

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TABLE III.1.1.

Comparison between experimental results as obtained for directional correlation and polarization-directional correlation experiments.

Cascades keV	Spin sequence J_i^π J_f^π	δ*	Calculated $\beta = \frac{N_\perp}{N_\parallel}$	Measured β
650-703	$6^+ - 4^+$	-	1.055	1.053±0.008
672-703	$0^+ - 2^+$	-	1.055	1.049±0.006
449(350)703	$8^+ - 6^+$	0.15±0.03	1.035±0.01	1.09±0.02
	$7^+ - 6^+$	0.50±0.16	0.92±0.01	
	$6^+ - 6^+$	$-0.04^{+0.08}_{-0.04}$	1.092±0.020	
		-0.68±0.16	1.034±0.01	
916(350)703	$5^+ - 6^+$	-0.45±0.05	0.905±0.005	1.09±0.03
	$6^+ - 6^+$	-0.04±0.04	1.092±0.02	
		-0.70±0.10	1.03 ±0.01	

* Deduced values from the present work.

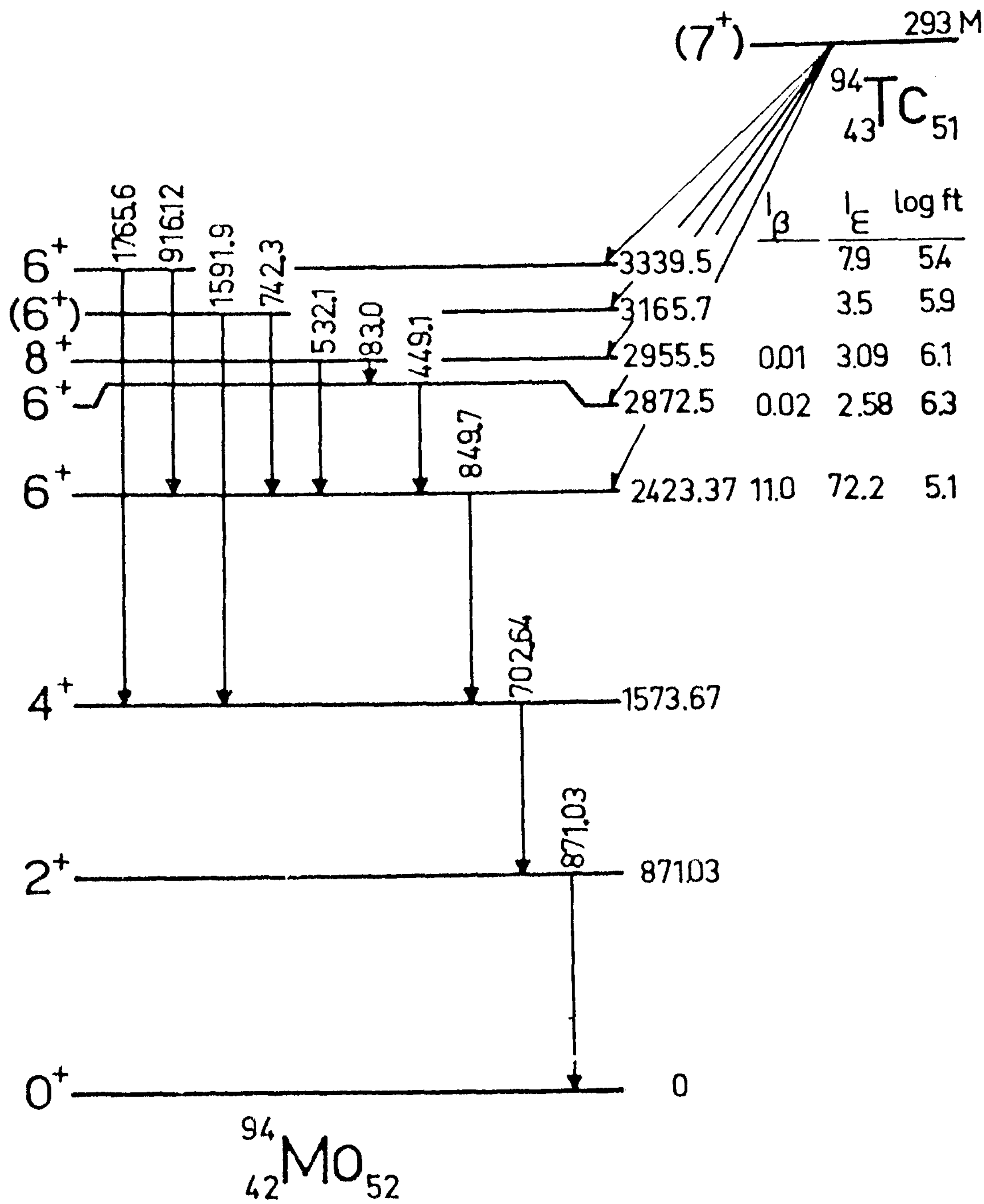

Fig.III.1.1. Decay scheme of ^{94}Tc. Our spin parity assignement for the 2872.5 and 339.5 keV levels are both $J^{\pi} = 6^{+}$.

III.2. On a Reevaluation of the 412 keV ^{198}Au Gamma-Ray Energy Standard[1]

E. Achterberg.

In the course of a revision of the literature on the best recent values available for precision gamma-ray energy calibrations it was concluded that it is now possible to provide an improved estimate for the energy of the 412 keV transition following ^{198}Au beta decay, long used as a standard reference. The value 411.794 (7) keV presently in use is based essentially on the results of the 1963 Murray et al. experiment[2] in which they compared the energy of this gamma ray with that of annihilation radiation, using an iron-free magnetic spectrometer and a suitable electron converter. The result of this measurement has been updated, once by Murray et al. themselves[3], and once by Kern[4], but no new experimental evidence was advanced by either of them to contribute to an improved foundation of this quantity. In the meantime, many improvements in the curved-crystal diffraction spectrometer technique, providing significantly lower error estimates, have made the magnetic spectrometer practically obsolete as regards precision measurements in this energy range In the present work we discuss some selected crystal spectrometer measurements of the last 10 years, which imply a determination of the ratio of the energy of the 412 keV transition to that of the $WK_{\alpha 1}$ Xrays. A good consistent set from several groups is found,allowing the extraction of a reliable mean value. On the other hand, the latest adjustment of the fundamental physical constants by Cohen and Taylor[5] provides values for $m_o c^2$ and for the X-ray energy scale of satisfactory consistency. This fact allows us to obtain a value for the ^{198}Au reference energy using the mean value of 6.942152 (14) found here for the $E(^{198}Au)/E(WK_{\alpha 1})$ ratio, and compare it to our recalculation of the Murray et al. result. The excellent agreement between these two different calculations leads us to propose the adoption of the value

$$E(^{198}Au) = 411.8016\ (22)\ \text{keV}\ [5.4\text{ppm}]$$

as the new energy reference standard, based on the 1973 set of fundamental constants.

The question of the agreement or disagreement of this value with some other tentative proposals published earlier is discussed. Beer and Kern[6] suggest a reevaluation of the Murray et al. experiment, based on a proposed modification in the $K_{\alpha 1}$ X-ray energy involved in the calculations of that measurement, whithout actually using the resulting value themselves in their following work. Borchert[7] comments on the fact that his remeasurement of the $E(^{198}Au)/E(WK_{\alpha 1})$ ratio. together with the result of the 1973 adjustment of the fundamental constants, implies a new value for the Au standard, without either adopting this new scale in his own later work[8]. Van Assche et al.[9] made a new attempt to relate the 412 keV energy to that of annihilation radiation, as in the Murray et al. experiment, this time based on crystal diffraction techniques. While their result is consistent with our proposed value, we believe that it should be revised downward by about 5 eV, mainly because of new estimates for the positron work function in Cu, which lead to a lower annihilation radiation energy[10]. Such a "revised" result is in still better agreement with our proposal. The case of the measurements of Deslattes et al[11] is more difficult to explain. Their result of 411.8062 (14) keV disagrees strongly with our proposed value. While they stress the fact that their result should be accorded only a preliminary character, it would be desirable to be able to point out some specific cause for the disagreement. Their value for the ^{198}Au energy implies a $E(^{198}Au)/E(WK_{\alpha 1})$ ratio which is significantly higher than the average obtained in our work, and in fact is higher than the biggest individual experimental value which enters that average. This appears to point to some source of systematic error either in their series of measurements or in all the other crystal spectrometer measurements used by us,performed with different instruments in several laboratories.

In a paper to be submitted for publication on this work we include a fuller account of all the points mentioned above, as well as a short discussion of the present state regarding the consistency of the energy scales in use for gamma-ray calibrations.

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11 R.D. Deslattes, E.G. Kessler, W.C. Sauder, A. Henins, in Atomic Masses and Fundamental Constants 5, Ed. J.H. Saunders and A.H. Wapstra (Plenum Press, New York, 1976)p. 48.

III.3. Factibility of Producing ^{11}C for Radiopharmaceutical use

A. Ceballos, A. Filevich, N. Fazzini, J.C. Rodriguez, H. Albani*
C. Arciprete*, V. Pecorini and A.E.A. Mitta*.

The feasibility of producing ^{11}C and other short lived isotopes for pharmaceutical use is presently being investigated through a joint collaboration between the Department of Physics and the Laboratory the Labelled Molecules. This project is partially supported by the IAEA Contract RB 1945.

In order to become familiar with this technology we are using the Buenos Aires Synchrocyclotron internal deuteron beam to produce the reaction $^{10}B(d,n)^{11}C$. We designed and constructed a small reaction chamber to be placed in the acceleration chamber of the synchrocyclotron (see Fig.III.3.1). This chamber has a thin 0.05 mm entrance window made of brass and is supported by a specially designed telescopic stem which allows irradiation of the boron target at any deuteron energy between 5 and 27 MeV, and hence to search for the maximum overall production efficiency. In order to obtain ^{11}C in form of $^{11}CO_2$ it is convenient to heat up the target material to a temperature of about 400° C. In preliminary tests this has been easily achieved using the energy released by the beam in the target holder, which has been provided with thermal and electrical insulation from the cooled chamber walls.

The short lived, cyclotron produced $\beta+$ emitters are specially atractive for nuclear medicine because of the following reasons:

a) Possibility of spatial localization of emitter through the coincidence observation of the two 511 keV γ-rays emitted in the annihilation process.

b) High attainable specific activity, which permits to employ labelled chemicals which cannot be used with conventional tracers because of their high toxicity.

c) The relatively short lifetime which allows to visualize internal organs avoiding the application of high dose to the patients.

d) Isotopes in the light region of the periodic table produced by this technique are able to be introduced as markers in hundreds of organic compounds of biological interest.

In order to extract the labelled $^{11}CO_2$ we'll follow the technique of Clark[1] with a carrier gas flowing during irradiation. The labelled gas will either be trapped in molecular sieve columns or condensed in cryogenic baffles to be confortably transported and released in the moment of utilization.

We expect that these preliminary work will give us a convenient background to support a dedicated group in the case a compact cyclotron for isotope production is purchased by CNEA.

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* Direccion de Operaciones, Gerencia de Radioisótopos y Radiaciones.

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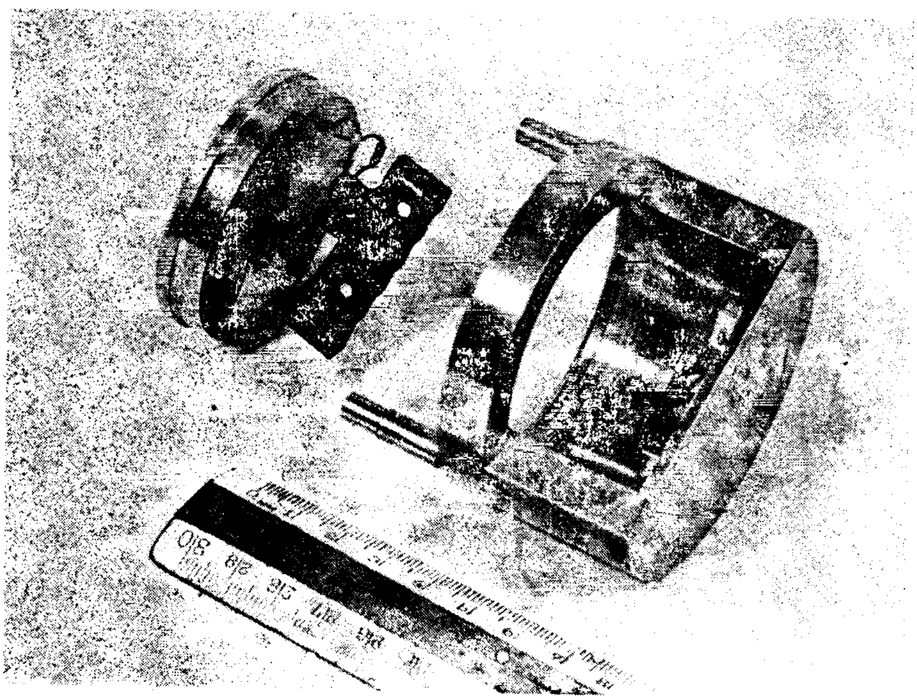

Fig.III.3.1. Small reaction chamber to be placed in the acceleration chamber of the Synchrocyclotron.

IV. HYPERFINE INTERACTION

IV.1. Quadrupole Nuclear Interaction in ^{73}As produced by the $^{72}Ge(\alpha,3n)^{73}Se$ reaction.

M. Behar, G. García Bermúdez, A. Filevich, R.P. Livi* and F.C. Zawislak**.

The present work reports for the first time TDPAC (Time-Differential Perturbed Angular Correlation) measurements in a semiconductor cubic lattice damaged by α-particle irradiation. The experiment consists in bombarding polycrystalline Ge powder at the temperatures of 77° and 300° K with 45 MeV α-particles, thus producing ^{73}Se in Ge lattice. The ^{73}Se ions after coming to rest somewhere in the cubic lattice, decay to ^{73}As which has a 7 nsec isomer with $I = 5/2$. This level is exposed to hyperfine interactions which can be accurately measured by the TDPAC technique. The angular correlation attenuation coefficient can be expressed by:

$$G_{kk}(t) = \sum_n \sigma_{kn} \cos(n\omega_0 t) \exp(-\delta/2 \; n\omega_0 t)$$

where the amplitudes σ_{kn} and the frequency ω_0 are related to the nuclear quadrupole frequency ω_Q. The term $\exp(-\delta/2 \; n\omega_0 t)$ gives the Lorentzian distribution of frequencies with a width δ. Table IV.1.1 and Fig. IV.1.1 show the results of the measurements done at both temperatures. Considering the data at 300° K, we note that initially the interaction is characterized by a sharp frequency (see Fig. VI.1.1.(a). An estimate of the electric field gradient (EFG) gives a value of 10^{18} V/cm^2 in qualitative agreement with the assumption that the interaction is caused by single vacancies nearest neighbours n.n to the decaying ions. The 300° K data also show a fast decrease of the quadrupole interaction strength, with increasing time t_{ab} and an increase of the frequency distribution δ. Assuming that the healing effect is caused by migration of vacancies to some sink, one obtains an activation energy of $E_m = 1.05$ ev which is in agreement with the one obtained by Hirata[1] for the second annealing stage at room temperature of a n-type germanium bombarded by electrons. After 36 hs, we also observe an almost complete recovery of the sample, Fig.IV.1.1(b) The results obtained at 77° K show very interesting features. Initially, two different quadrupole interactions with equal weight are observed Fig.IV.1.1.(c) and, after t_{ab} = 36 hs, the higher frequency component completely disappears and a substantial decrease in the lower frequency distribution is noted. These facts show that at the beginning two kinds of defects are formed, and they anneal at different rates, remaining only one after 36 hours. Several conclusions can be drawn from the present experiment:

a) The radiation damage caused by α-particle irradiation in Ge is similar to the one produced by electrons.

b) The very high frequency measured at 77° K corresponds to an EFG of about 10^{19} V/cm^2 which is one order of magnitude larger that the field observed in Ge at 300° K and also one order of magnitude larger that the high field in Ag metal[2]. This result suggests that the defects lay closer to the probe nuclei that the normal lattice n.n positions. Consequently, such a large field can be interpreted as caused by interstitials and/or close-pairs formed during the process of α-irradiation.

c) The presence of so strong "induced" quadrupole interactions produced by radiation damage mustbe considered in any angular distribution or g-factor measurement. If the lifetime of the excited state is in the nsec region, considerable attenuation in the results is to be expected due to the produced high quadrupole interactions.

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1 Hirata, Japanese Journal of Appl. Physics 12 (1973) 577

2 M. Behar and R.M. Steffen, Physical Rev. Letters 29 (1972) 116.

TABLE 1

Parameters from the analysis of the $G_{22}(t)$ curves

Temperature of the foil (°K)	Time t_{ab} after irradiation (hs)	ω_1 (MHz)	δ_1	ω_2 (MHz)	δ_2
300	3	117 ± 14	.06 ± .03	-	-
	6	34 ± 10	.23 ± .10	-	-
	9	25 ± 15	.40 ± .15	-	-
	36	3.5 ± 6	.45 ± .15	-	-
77	3	1320 ± 30	.02 ± .02	780 ± 30	.26 ± .10
	36	-	-	800 ± 30	.02 ± .04

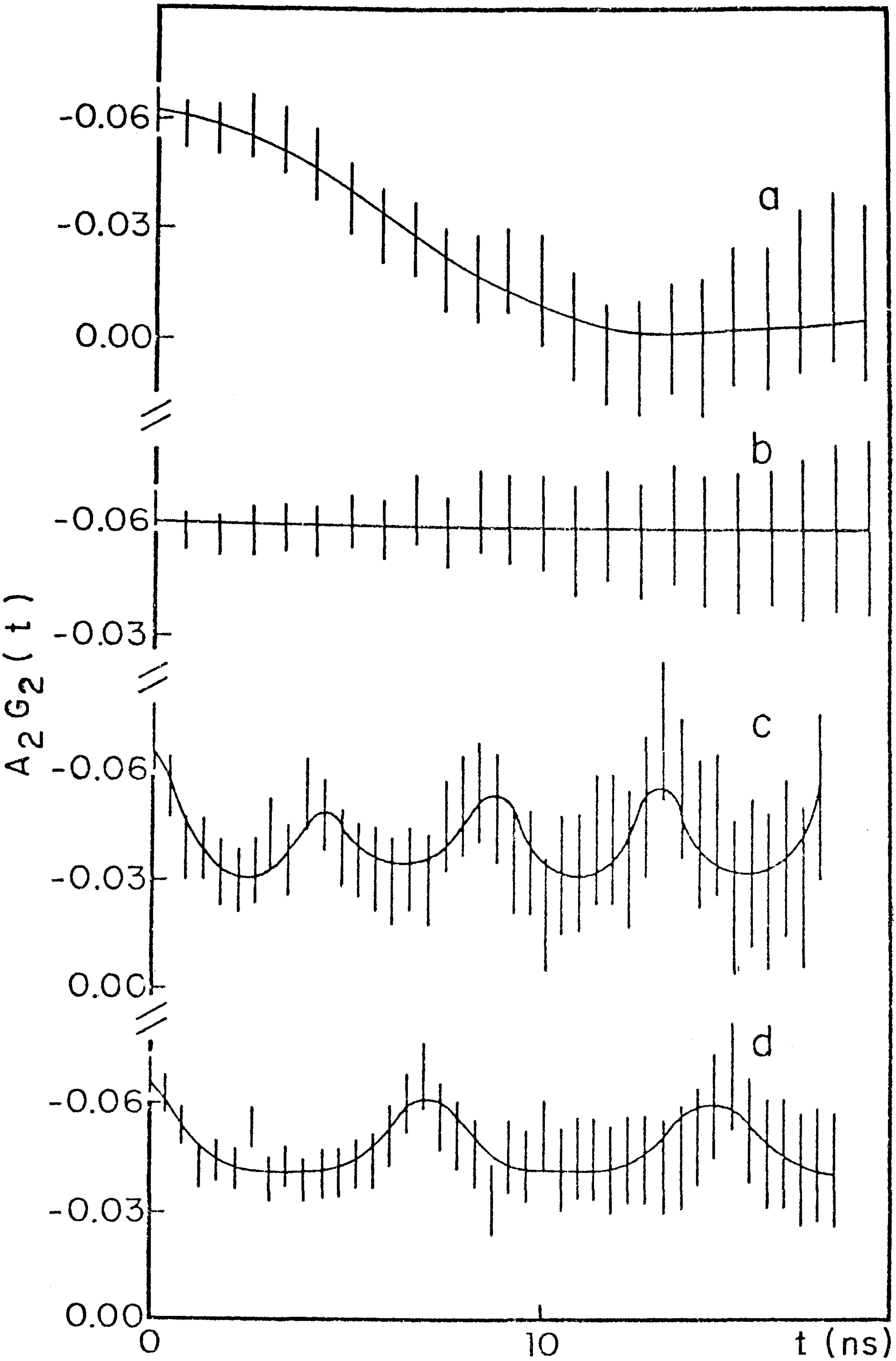

Fig.IV.1.1. Time differential attenuation coefficient $A_{22}\ G_{22}\ (t)$: (a) and (b) at 300° K for 3 and 36 hs after irradiation; (c) and (d) at 77° K, also for 3 and 36 hs after irradiation.

IV.2. Trapping of Vacancies in Quenched Silver.

C. Alonso Arias, J. Fernandez Niello, M. Behar*, A. Filevich and G. García Bermúdez.

In the last years, the Time-Differencial Perturbed Angular Correlation technique has been widely used in order to observe Electric Field Gradients (EFG) generated by impurities or vacancies in cubic metals.

In the work of Behar et al[1]. cubic silver metal was irradiated with α particles and two different quadrupole interactions were observed with the probe ^{111}In. The first one was characterized by a low and broad frequency ω_l = 1.57 MHz and δ = 0.35 and the second by a high and sharp frequency $\omega_h \simeq$ 160 MHz with δ = 0.01. Both interactions were attributed to vacancies generated by the Ag(α,2n)^{111}In reaction. The former due to vacancies situated at various atomic distances from the probe and the latter due to vacancies situated at the nearest neighbour sites. The conclusions that the vacancies are responsible for the generation of EFG, was reached after studyingthe dynamics of both quadrupole interactions or, in other words, after the evaluation of the activation energy of the defects.

In the present work we report on the quadrupole interaction observed after trapping of a thermally produced defect.

The experiment consisted in bombarding silver metal foils of 0.05 mm thick with 45 MeV α-particles producing ^{111}In in the Ag lattice. The foils were then quenched from several temperatures T_Q to 250°K and quickly transferred into liquid nitrogen.

Fig. IV.2.1(b) shows the $G_{22}(t)A_{22}$ curve for an annealed sample with slow cooling. Fig.IV.2.1(a) instead, shows the result for a typical quenched sample. The theoretical parameters which fitted the experimental curve were ω =(190 ± 5) MHz, δ = 0.30 and η = 0.01. About 89% of the probe nuclei felt this high and unique quadrupole interaction while the remaining 11% did not feel any EFG. The annealing temperature T_Q was varied between 1073°K and 673°K with no significant variation of the parameters ω,δ and η.

Since in the temperature range of about 720°K, monovacancies are the only thermally activated defects, we can conclude that the observed EFG is generated by monovacancies situated at the nearest neighbour sites of the ^{111}In probe. Therefore we arrive at the same conclusion as Behar et al[1]. Moreover, the present measured frequency is of the same order of magnitude as the one they measured.

The small variation and dispersion in the frequency could be attributed to lattice distortion produced during the quenching process.

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[1] M. Behar and R.M. Steffen, Physical Rev. C7 (1973) 788.

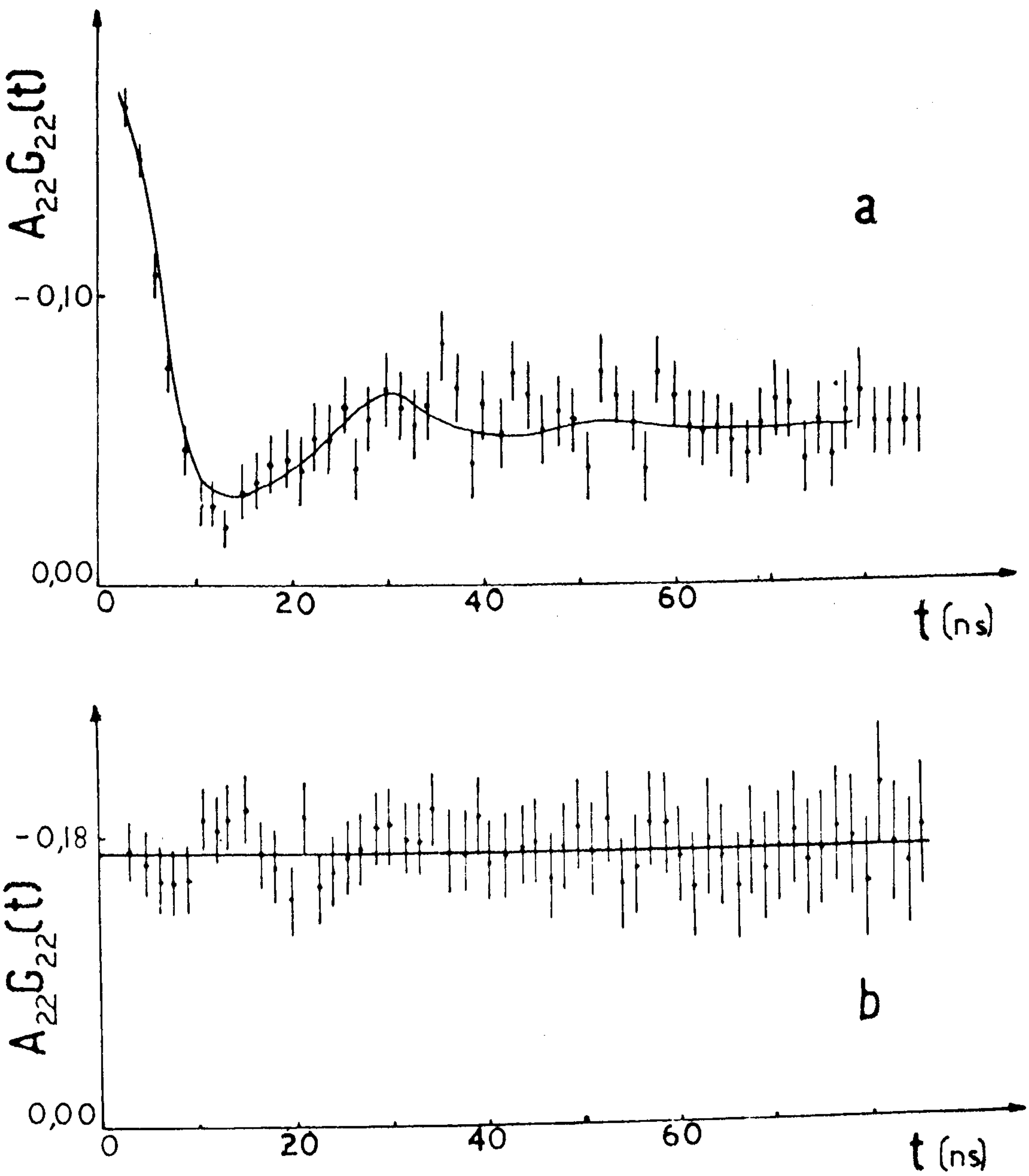

Fig.IV.2.1. (a) Result for a typical quenched sample (b) Annealed sample with slow cooling.

Theoretical Physics

Nuclear Structure
Nuclear Fieid Theory
Palring Vibrations
Nuclear Reactions

V. NUCLEAR STRUCTURE

V.1. Treatment of Spurious States in Nuclear Field Theory (NFT)

D.R. Bes, R.A. Broglia**, R. Liotta, B.R. Mottelson* and H.M. Sofia.

It is shown that spurious states are isolated in an explicit way within the framework of the NFT. For this purpose, the following model Hamiltonian is used:

$$H = H_{sp} + H_{int}$$

$$H_{sp} = 1/2 \sum_{m=1}^{\Omega} \varepsilon_m (a^+_{m_1} a_{m_1} - a^+_{m_{\bar{1}}} a_{m_{\bar{1}}})$$

$$H_{int} = - V A^+A \; ; \; A^+ = \sum_{m=1}^{\Omega} a^+_{m_1} a_{m_{\bar{1}}}$$

In the ground state, the single particle states $(m,\bar{1})$ are occupied and the $(m,1)$ empty. The RPA(TDA) is used to determine the Ω phonon energies ω_i and coupling vertices Λ_i. In the odd nucleus, there are Ω "proper" particle phonon states $|n_i = 1_i\; m,1 >$. However, there are only $(\Omega-1)$ two-particle one-hole states in which the odd-particle is in the state $(m,1)$. Therefore, a spurious state remains in the spectrum of the elementary modes of excitation.

The lower order corrections to the energy which do not contain bubbles are drawn in Fig.V.1.1.Iterating these processes to infinite order we obtain the following secular equation (within Bloch-Horwitz perturbation theory),

$$|(\omega_i - E)\, \delta_{ii'} + X_{ii'}\, (E)| = 0$$

$$X_{ii'} = - \Lambda_i \Lambda_{i'} \,/(E-\varepsilon_m - V)$$

The determinant yields:

$$\varepsilon - \varepsilon_m - V = \sum_{i=1}^{\Omega} \Lambda_i^2 \,/\, (\omega_i - E) \equiv F(E)$$

as the dispersion relation fixing the energies E_n of the states in the odd-system. The relation can be graphically shown in Fig.V.1.2. The energy $E = \varepsilon_m$ is always a double root since

$$\left(\frac{dF(E)}{dE}\right)_{E=\varepsilon_m} = \sum_i \Lambda_i^2 \;/\; (\omega_i - \varepsilon_m)^2 = 1$$

and the line $E-\varepsilon_m-V$ is at 45°. The remaining intersections of this line and the function F(E) gives rise to the (Ω-1) roots which coincide with the exact physical eigenvalues obtained from the exact solution of the model. The normalization N_n of the eigenvectors:

$$|n> = N_n \sum_i \frac{\Lambda_i}{E_n - \omega_i} |n_i = 1; m,1>$$

is determined from the overlaps

$$<n|n> = N_n^2 \left[\sum_i \frac{\Lambda_i^2}{(\omega_i - E_n)^2} - 1\right]$$

For $E_n = \varepsilon_m$ the factor multiplying N_n^2 zero. Thus, there are only (Ω-1) states which can be normalized. The full spuriosity of the basis has been concentred into a single state. For more details see[1].

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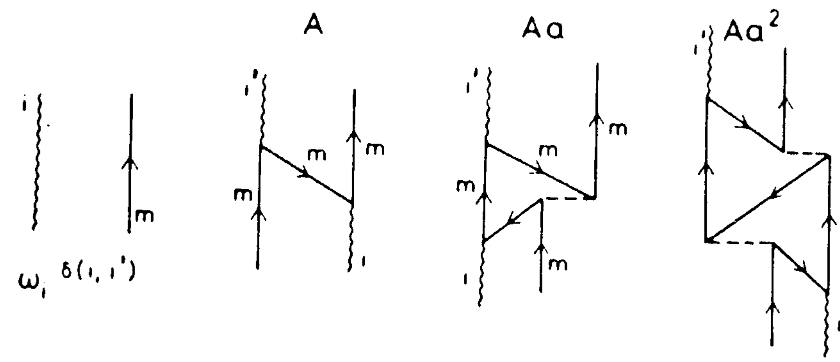
** The Niels Bowr Inst. Univer. of Copenhagen and Phys.Dept. SUNY at Stony Brook.

1 R.A. Broglia, B.R. Mottelson, D.R. Bes, R. Liotta and H.M. Sofia, Physics Letters, 69B (1976) 29.



$$A = -\frac{\Lambda_i \Lambda_i'}{E - \varepsilon_m} \qquad \boxed{\left| (\omega_i - E)\,\delta(i,i') - X_{ii'} \right| = 0}$$

$$a = \frac{V}{E - \varepsilon_m} \qquad X_{ii'}(E) = -A \sum_n a^n = -\frac{\Lambda_i \Lambda_i'}{E - \varepsilon_m - V}$$

Fig.V.1.1. Lower order contributions to the energy matrix elements between the basis states $|n_i = 1; m, 1\rangle$. The dotted line stands for the model bare interaction. The quantity $X_{ii'}(E)$ is the matrix element iterated to all orders in $1/\Omega$. The framed equation is the secular equation of the problem.

V.2. The Renormalization of Fermion and Boson States in NFT and the Proper Initial or Final States.

D.R. Bes, G.G. Dussel, R.P.J. Perazzo and H.M. Sofía.

Single Particle States

The single-particle states are renormalized by taking into account the emission and subsequent absortion of a phonon to all orders of perturbation theory. This is a generalization of the usual Hartree-Fock summation, with the aim of including more complicated kernels in the Dyson equation for Fermions.

The Ward identity provides a useful normalization condition to these dressed excitations.

It is also shown how to use the new excitations within the framework of the NFT by defining coupling constants in terms of the amplitudes of the dressed states in the bare ones, the RPA amplitudes and the fermion interactions.

The problems arising from the overcompleteness of the basis have to be treated as in the usual NFT: improper initial or final states (in the present case, the particle-phonon states) have their perturbed energy equal to the unperturbed value, and cannot be populated in any physical process.

The two level model with monopole interactions is trated as an example. For more details see reference 1.

Boson States

A renormalized boson propagator is obtained by inserting higher order processes in the Dyson equation. The Ward identity is trivially justified for particle-hole bosons and therefore it is necessary to take into account experimentally the normalization contribution of the intermediate states in the boson dressed propagators. The problem may be cast into the form of a linear algebraic matrix equation that allows a simple treatment of the normalization condition.The equation so obtained reduces to the Ward identity for particle-particle-bosons.

The many body foundation of the NFT[2,3] has been explicitly carried out for intermediate states. The rule concerning the proper initial or final states has only been proved in a heuristic way[1,4]. In the present work we provide a general foundation for this rule.

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V.3. High-Lying Pairing Resonances

R.A. Broglia* and D.R. Bes.

Pairing vibrations based on the excitation of pairs of particles and holes across major shells are predicted at an excitation energy of about $70/A^{1/3}$ MeV and carrying a cross-section which is 20%-100% of the ground state cross section.

The low-lying pair addition and substraction modes have been extensively studied. It is also possible to create pairing phonons in lower and higher shells. The giant pairing modes imply the coherent excitationof about $\Omega^{1/2}$ configurations of energy $2\hbar\omega$. The coupling of the particles to these modes renormalize the two nuclear transfer cross sections associated with the low-lying pairing modes. As a consequence the difference between the cross sections associated with pure two-particle configurations is strongly reduced. This effect agrees with the experimental fact that no $J = 0^+$ excited state has been observed on the $^{208}Pb(t,p)$ reaction.

The distinction between particles and holes is also achieved in superfluid nuclei for the case of two-particles-two hole excitations across a major shell. The excitation energy and the number of configurations are similar to the normal case. However, in the superfluid nuclei, the population of the ground state considerably increases.

There is an important difference between giant surface and pairing modes: the gap in the 2p-2h excitation spectrum is decreased by the presence of surface modes and it eventually disappears for surface deformed nuclei. In such case, the concentration of two-particle transfer strength in a single state cannot be expected. Thus the giant pairing modes are expected to be less stable than the giant surface modes as a function of a mass number. For more details, see ref 1)

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V.4. The Perturbative Treatment of Rotational Systems

D.R. Bes, R.A. Broglia*, G.G. Dussel and H.M. Soffa.

Rotations appear whenever the single-particle field violates a symmetry characteristic of the initial Hamiltonian. In nuclear physics the simplest problem of this kind arises in connection with the paring degree of freedom. States with the sameseniority can be grouped in a rotational band. In the case of 2Ω degenerate levels and seniority zero the eigenvalues of the pairing Hamiltonian are[1]:

$$E(\Pi) = -\frac{1}{4} G\Omega(\Omega+2) + G\Pi^2$$

where $\Pi = 1/2\ (N-\Omega)$ is the number of pairs of particles measured from the middle of the shell.

The problem may also be solved using the deformed potential

$$H'_p = -G\langle 0|P|0\rangle(P^+ + P) \quad ; \quad P^+ = \sum_{m>0} a_m^+ a_{\bar{m}}^+$$

The new basis is defined through the Bogoliubov-Valatin transformation. Expressing the original pairing Hamiltonian in terms of quasi-particles, we are left with a constant H_0 term, a (diagonal)term proportional to the number of quasi-particles and a residual interaction which we would like to treat in perturbation theory. Therefore, we have introduced the small parameter .Perturbation theory implies and expansion around X =0). Here we have the requirement that the expansion converges for X = 1.

A straightforward application of Rayleigh-Schroedinger Perturbation Theory yields, for the ground state energy

$$E(G.S.) = -\frac{1}{4} G\Omega^2$$

$$+ G\Omega \left(\frac{1}{4} + \frac{X^2}{16} + \frac{X^3}{32} + \frac{5X^4}{256} + \frac{7X^5}{512} + \frac{21X^6}{2048} + \ldots\right)$$

$$+ G \left(-\frac{X^2}{16} + \frac{X^3}{32} + \frac{X^4}{64} + \frac{5X^5}{512} + \frac{7}{1024} X^6 + \ldots\right) + G\Omega\ \ O(\Omega^{-2})$$

We notice that the terms proportional to $G\Omega$ and G are, respectively the power series expansion of

$$-\frac{1}{4} G\Omega \left[3 - X - 2(1 - X)^{1/2}\right] \underset{X\to 1}{\to} -\frac{1}{2} G\Omega$$

$$\frac{1}{16} G \left[4X - 3X^2 - 4X(1 - X)^{1/2}\right] \underset{X\to 1}{\to} \frac{1}{16} G$$

Therefore the exact g.s. energy is reproduced by the perturbation calculation to order $G\Omega$. The non-vanishing coefficient of the term proportional to G does not correspond to the exact result.

It can be shown (at least for small values of Ω) that there are always first order branch points of two coinciding eigenvalues for $|X|<1$.

It is plausible that these problems arise because there are excited states in the intrinsic system which correspond to a different orientation of the system (i.e., spurious states). This fact would suggest that the problem may only be solved through a careful consideration of the constraints implicit in the intrinsic system.

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V.5 Diagramatic Description of Superconductivity in a Single J-Shell

G.G. Dussel, R.D. Bes, R.P.J. Perazzo and H.M. Sofía

In a system of 2K particles moving in a single j-shell with degeneracy Ω and interacting through the pairing force, there are only two dimencionless parameters: K/Ω and $1/\Omega$. Assuming analiticity the matrix elements of any operator can be written as

$$<f|Q|i> = \sum_{n,m} a_{nm}\left(\frac{K}{\Omega}^{n}\right)\left(\frac{1}{\Omega}^{m}\right)$$

It is possible to sum the series corresponding to the lowest m (principal series) for the creation of two particles and for the energies of the excitations in the odd system. The equation describing the excitation of the odd system is shown in Fig.V.5.1, while the one corresponding to the creation of two particles is shown in Fig. V.5.2. This description will be exact in the limit of very large and it is different from the usual BCS approach. The difference lies in the self consistency condition that in BCS is:

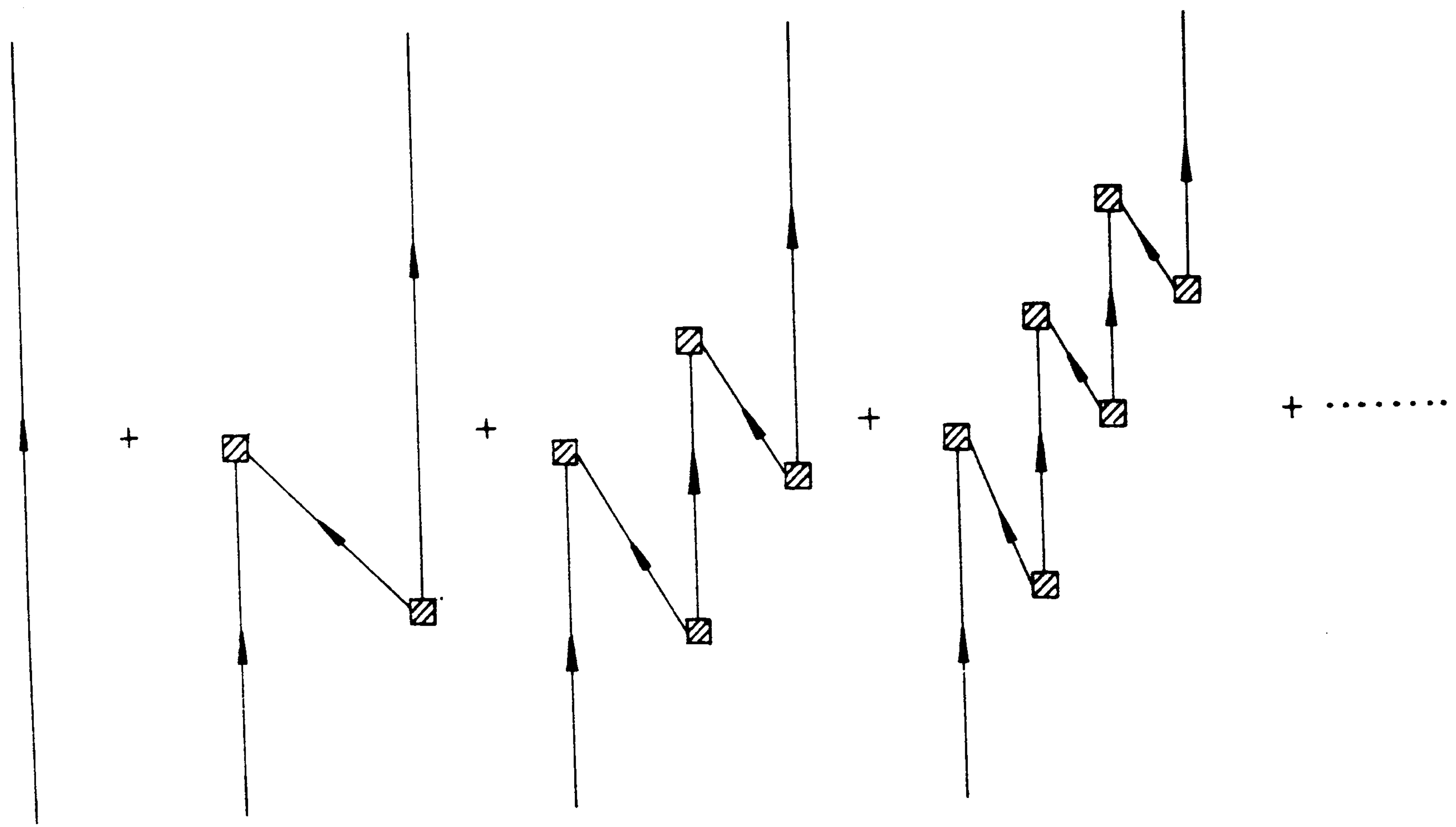
$$\Delta_{BCS} = G \sum_{1} <0|a_1 \; a_{\bar{1}}|0>$$

while in our method is

$$\Delta_{Diagramatic} = G \sum_{1} <0|a_1 \; a_{\bar{1}}|n>$$

where $|n>$ in the excitation shown in Fig.V.5.2.

It is found that the system of coupled equations reproduces the exact results for the energies of the odd and even systems as well as the matrix elements for the creation of one and two particles.



<u>Fig.V.5.1.</u> Description of the excitations in the odd system in the principal serie. The square represents the absortion or emition of the two particle excitations of a system with 2K particles.

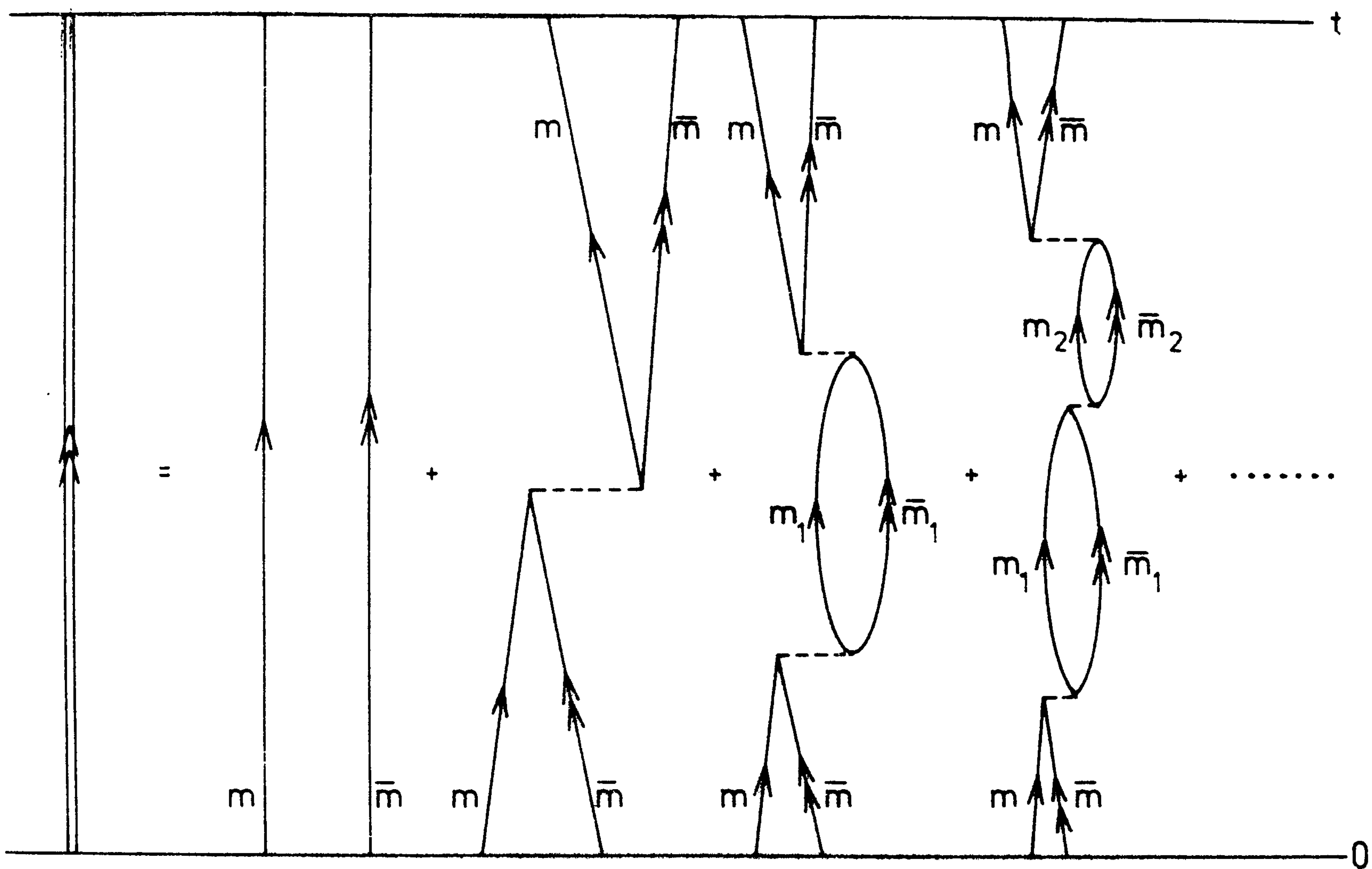


Fig.V.5.2. Description of the two particle excitations in the system with 2K particles in the principal serie.

V.6 The Perturbation Expansion of the Phonon-Phonon Interaction in NFT.

F. Bortignon*, R.A. Broglia** and D.R. Bes.

The ground state of ^{210}Pb and ^{206}Pb can be viewed as the lowest monopole pairing vibrations of ^{208}Pb. The "mass"(correlation energy) associated with these two modes is 1.237 MeV and 0.640 MeV respectively. The states $|I\rangle = |gs(^{210}Pb) \otimes gs(^{210}Pb)\rangle$ and $|II\rangle = |gs(^{206}Pb) \otimes gs(^{206}Pb)\rangle$ are the zeroth order approximation to the states $|gs(^{212}Pb)\rangle$ and $|gs(^{204}Pb)\rangle$, respectively.

An exact diagonalization of the pairing interaction in the Tamm-Dancoff approximation and for a system of four particles (holes) moving around the N = 126 closed shell gives ΔE_I = 267 keV and ΔE_I = 540 keV for the interaction energies of states $|I\rangle$ and $|II\rangle$, respectively (the corresponding experimental numbers being 169 keV and 706 keV). Thus for the case of (gs^{204}Pb) the interaction between two pairing bosons is of the order of their "mass". Consequently. one can expect convergence problems in the perturbative treatment of the problem.

The NFT results, obtained utilizing the Rayleigh-Schroedinger perturbation expansion are shown in Table V.6.1 as a function of the expansion parameter $1/\Omega$, Ω being the effective degeneracy of the valence shells. The strong convergence displayed by the expansion associated with both ΔE_I and ΔE_{II} indicates that the NFT partial summations provide a powerful technique with strongly anharmonic systems.

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TABLE V.6.1

The two- phonon pairing interaction associated with the ground states of ^{212}Pb and ^{204}Pb calculated in the framework of the NFT.

ΔE (keV)

Order	I	II
$1/\Omega$	262	474
$1/\Omega^2$	4.3	42
$1/\Omega^3$	0.4	14
	(266.7)	(530)
Exact	267	540

V.7 Application of the NFT to the two-particle, one-hole states of ^{209}Bi.

P.F. Bortignon*, R.A. Broglia**, D.R. Bes and R. Liotta.

The two-particle, one hole states in ^{209}Bi are described in the basis made up of surface phonons coupled to single-particle states $[\Gamma^{+}_{0\lambda} a^{+}_{k}]^{I}$ and pairing phonons coupled to single-hole states $[\Gamma^{+}_{2\lambda} a_{i}]^{I}$, within the nuclear field theory formalism.

In particular, the splittings in the septuplet of states[1] $|\Gamma^{+}_{03} a^{+}_{h_{9/2}}>$ were calculated by Hamamoto[2], including graphs (a)-(d) of Fig.V.7.1, who showed that they already yield the correct splitting of the levels in the septuplet (but for the $3/2^{+}$ state)

The small parameter upon which to expand in the NFT is Ω^{-1}, where Ω is the number of particle-hole states entering in the construction of the phonon. This number is of the order of the effective degeneracy of the valence shell. We assume that the particle vibration vertices are proportional to $\Omega^{-1/2}$ and the four point vertices to Ω^{-1}. Each independent summation over single-particle states yields a factor of Ω . Thus also diagrams (e)-(f), and the corresponding ones for the case of pairing phonons are included in the calculation.Nevertheless, they cannot be expected to yield a large contribution,since there is cancellation between graphs which involve a particle-particle interaction and those which involve a particle-hole interaction.

The $3/2^{+}$ member of the multiplet is populated by inelastic scattering and by one body pick up reaction on ^{210}Po. In both cases there is another $3/2^{+}$ state which is populated with an intensity of the same order of magnitude. In zero order, the inelastic scattering process is expected to populate only states of the septuplet, while the pick-up reaction feeds the state built out of a $d_{3/2}$ hole on ^{210}Pb. Therefore, in order to account for the properties of the $3/2^{+}$ member of the septuplet, it is necessary to couple both the particle-hole and the pairing phonons. The empirical evidence points to the fact that the states

$$|1> \; = \left[\Gamma^{+}_{03}\, a^{+}_{h_{9/2}}\right]^{3/2} |0>$$

$$|2> \; = \left[\Gamma^{+}_{20}\, a_{d_{3/2}}\right]^{3/2} |0>$$

are considered mixed. Use is made of the Bloch-Horowitz perturbation theory in order to construct the effective matrix elements M_{ab} (E) between the states $|1\rangle$ and $|2\rangle$, using all diagrams of Fig.V.7.1.

The unperturbed excitation energy of states $|1\rangle$ and $|2\rangle$ is 2.615 MeV and 2.733 MeV respectively. The two final energies (2.479 MeV and 3.079 MeV) are in close agreement with the experimental numbers (2.494 MeV and 2.950 MeV). The resulting wave functions are:

$$|I\rangle = 0.76|1\rangle - 0.53|2\rangle$$
$$|II\rangle = 0.80|1\rangle - 1.02|2\rangle$$

The fact that one of the amplitudes is even larger than one is consistent because the NFT eliminates spurious components in the basis and thus the amplitude of the surviving ones has to be increased.

The most striking consequence of including both (non-orthogonal) states $|1\rangle$ and $|2\rangle$ and to treat them as orthogonal states which are coupled by the NFT rules, is evidenced in the very different ratio of the (d,d') and (t,α) cross sections associated with the two $3/2^+$ states. While R_a = B (E3, 2.49 MeV)/B(E3,2.95 MeV) = 3.8 ± 0.8, the ratio $R_b = \sigma\{(t,\alpha), 2.49 \text{ MeV}\}/\sigma\{(t,\alpha), 2.95 \text{ MeV}\} = 0.8 \pm 0.3$.

Beacuse the component $|1\rangle$ carries basically all the inelastic strength while the (t,α) proceeds through the component of type $|2\rangle$, a treatment which neglects the non-orthogonality of the basis predicts $R_a = R_b^{-1}$.

The correct procedure requires to take into account diagrams of the inelastic and transfer matrices to the same order as the diagrams used in the construction of the energy matrix elements. The resulting theoretical ratios are R_a = 215/87 = 2.5 and R_b = 1.82/2.27 = 0.80, in close agreement with the experimental numbers.

A calculation including other multipolarities of the phonon is also performed. For more details see reference 3.

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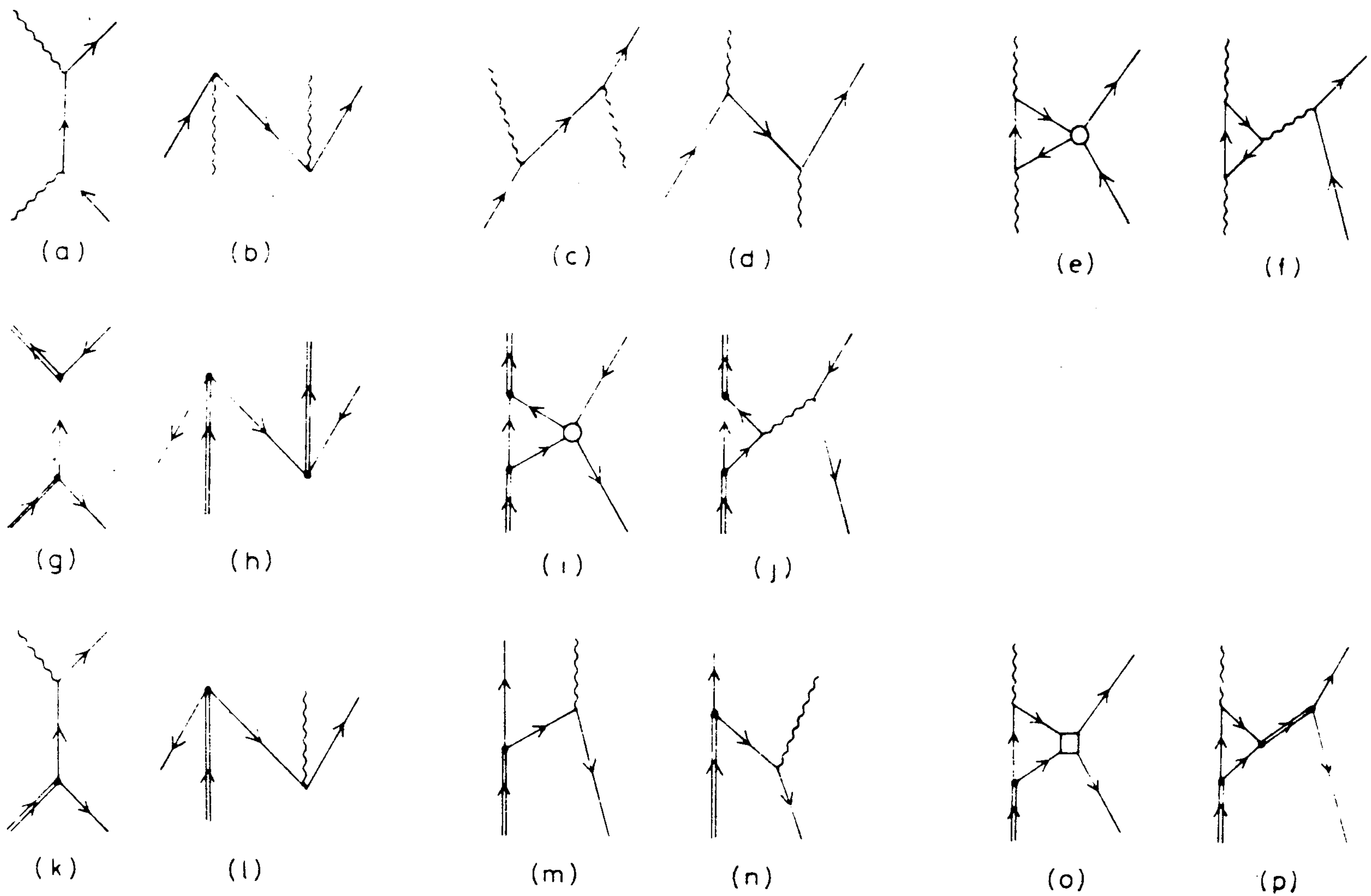

Fig.V.7.1. All the $1/\Omega$ contributions to the energy matrix elements of the effective Hamiltonian in the basis spanned by the vectors $|1\rangle, |2\rangle$. An open circle or an open square stands for the bare particle-hole and pairing multipole interaction, respectively

V.8. The Role of the Pauli Principle in the Spectrum of ^{211}Pb.

O. Civitarese*, R.A. Broglia** and D.R. Bes.

The low-lying spectrum of ^{211}Pb ($E_x \lesssim 2.5$ MeV) can be described in terms of the basis

$$|j\ (\nu) \otimes \lambda^{\pi}(^{210}\mathrm{Pb});\ j'>$$

where ($\lambda^{\pi}(^{210}$Pb)) labels the neutron pair addition modes of ^{208}Pb while $j(\nu)$ labels the fermion fields.

According to the NFT, the lowest order corrections to the unperturbed energy and zero order stripping amplitudes are given by graphs (b) (c) and (e) (f) of Fig. V.8.1. In the calculations given below only graphs (c) and (g) were included. They correspond to the Pauli principle corrections to the unperturbed values displayed in (a) and (d). For the case of ^{211}Pb the contributions of graphs (b) and (d) are about an order of magnitude smaller than the Pauli contributions.

Special care should be taken in the present case because of the existence of intermediate states (i.e. three particle states) with energies very close to the energy of the basis states.

This is exemplified by the behaviour of det $|M(E) - E|$, as a function of the energy and for the case of the $1/2^+$ states. The quantity M (E) is the energy matrix calculated in the Brillouin-Wigner perturbation theory. Out of the four roots found in the interval 1.8 MeV < E < 2.0 MeV, only two are physical, the other two being spurious, The norm

$$\frac{1}{\sqrt{N(E)}} = \left(1 - \frac{\partial M(E)}{\partial E}\right)^{-1/2}$$

associated with states I and IV is finite and close to one (cf.Fig.V.8.1 (h) while the states II and III are not normalizable and their one-particle stripping spectroscopic factors are approximately zero.

The approach for finding the eigensolutions described above was utilized for all the different spins and parities.

Although the main properties of the experimental spectrum are obtained, there is not enough distribution of strength between the different states with the dame spin, i.e. between the two $1/2^+$ states, the two $5/2^+$ states, etc. The calculations predict also two $7/2^+$ states while three have been observed experimentally.

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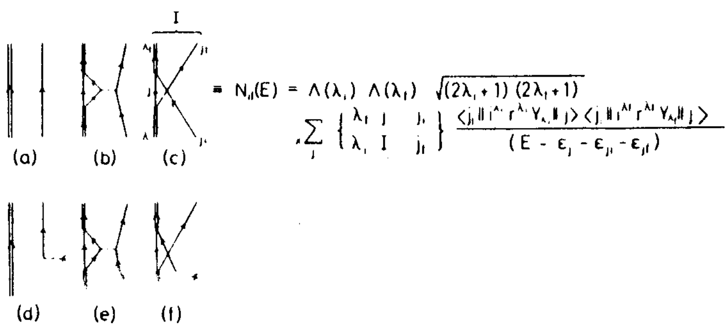

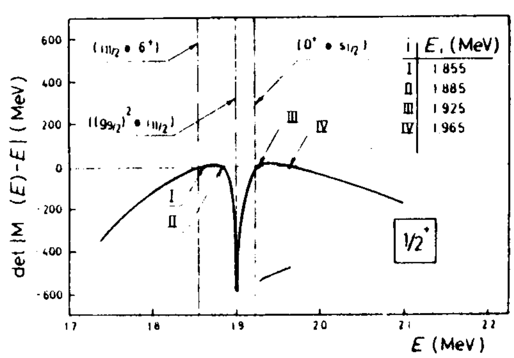

Fig.V.8.1. The zeroth order graphs for the energy of the three-particle levels of ^{211}Pb and for the stripping amplitudes associated with the ^{210}Pb(t,d)^{211}Pb reactions are displayed in (a) and (d) respectively. The lowest order graphs (i.e. $1/\Omega$) are shown in Figs.(b) and (c) (energy) and (e) and (t) (transfer). The analytic expressions $N_{if}(E)$ of graphs (c) is also shown.

V.9. Isospin of Pairing Modes: An Approximate Treatment without Violation of Conservation Laws.

F. Andreozzi*, A. Covello *, E.E. Maqueda and R.P.J. Perazzo.

We present here a treatment of the charge-independent pairing Hamiltonian which conserves both nucleon number N and isospin T. Our approach is an extension to the case of unlike nucleons of an equations-of-motion method which was proposed in [1] to treat pairing correlations in systems with an even number of identical particles. The practical importance of taking into account the isospin degree of freedom of the pairing force is related to the fact that is plays a major role in the description of the 0^+ states in the region around[2,3] A = 56.

We proceed as follows:

(i) The wave function for a system with an even number of particles N (we restrict ourselves to states with individual level seniorities of zero) is written

$$|NTT_z> = \sum_{jT'} C_{jTT'}(N)\{A^\dagger(j)|N-2\ T'>\}^T_{T_z}$$

where curly brackets denote isospin coupling.

(ii) The equations of motion for the operator $A^\dagger_\mu(j) = \sum_{m>0} \sum_{tt'} <\frac{1}{2}\ t\ \frac{1}{2}\ t'|1\mu> a^\dagger_{jmt}\ a^\dagger_{jmt'}$, are linearized: a homogeneous set of linear equations is obtained which determines the energies and the two particle amplitude $X_{jTT'}(N) = <NT||A(j)||N-2T'>$.

(iii) The calculation for the N-particle system is carried out through a step-by-step procedure starting from N = 0.

We show that our method leads to the exact results in the degenerate model. For non-degenerate levels, a calculation of the energies and two-particle transfer amplitudes to 0^+ states in the region around ^{56}Ni is in progress.

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V.10. Isovector Pairing Vibrations.

D.R. Bes, R.A. Broglia*, O. Hansen** and G. Nathan**.

The experimental corpus of L = 0 two-nuclear transfer reactions induced by light proyectiles on 1f-2p shell nuclei is reviewed. A DW analysis is performed using the same form factor for all addition type transfers, while another one is used for all removal transfers.

The consistency of the data material is verified i) by comparing reaction data obtained at different bombarding energies for one and the same final state ii) by studying the relative cross sections to adjacent members of the isobaric multiplet using the same optical model parameter for the t and h proyectiles[1]. These tests are generally satisfactory but have revealed problems with some data.

A unified picture of these processes is attempted in terms of pairing elementary modes of excitation (bosons) generated by fluctuations of the isovector pairing gap around the zero equilibrium position [2),3)]. It is shown that this band can be decomposed rather accurately into bands corresponding to pairing vibrational phonons generated by pairing correlations between identical particles. Thus, the majority of the 0^+ states excited in two-nucleon transfer reactions (excepting those implying $\Delta T = 0$ transitions) and having maximum isospin projection given rise to a proton and a neutron vibrational band.

The isovector property of the pairing phonons manifests itself in the $\Delta T = 1$ transitions to the analogue states and in the $\Delta T = 0$ transitions to the $T = T_z$, $T^\pi = 0^+$ states in odd-odd nuclei.

Systematic deviations from the harmonic predictions (anharmonicities) are found in the different bands: a) The rate of the increase of the two-particle transfer intensity with the number of phonons is slower than predicted. This anharmonicity is due to the Pauli principle; b) the excited states with the same isospin as the ground state, even if strongly populated in the two nucleon transfer processes are weaker than predicted by the harmonic model. Residual pairing interactions tend to produce a condensation of the bosons, namely a superconducting state draining strength from the excited into the ground state, c) the energy systematics reveals the existence of an interaction which splits states which differ only in the partial isospin t_a or t_r of the pair addition and pair removal mode, respectively.

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V.11. Time Dependent Variational Principle for Nuclear Collective Motion.

M. Saraceno.

A method for introducting collective parameters in a time dependent wave function has been derived with the view of unifying and generalizing several approaches which are currently being developed[1-3] in the study of large amplitude nuclear collective motion. The basic assumption is that the time development of the wave function occurs only through some collective parameters, that is:

$$|\Psi(t)\rangle = |\Psi(\alpha_1(t), \alpha_2(t)\ldots\alpha_n(t))\rangle$$

With this assumption the time dependent variational principle $\delta A\{\Psi\} = 0$, where

$$\delta A\{\Psi\} = \int_t^t \langle\Psi(\alpha_1..\alpha_n)| i \frac{\partial}{\partial t} - H |\Psi(\alpha_1\ldots\alpha_n)\rangle \, dt$$

yields the equations

$$\sum_j \eta_{ij} \frac{d\alpha_j}{dt} = \frac{\partial \mathcal{H}}{\partial \alpha_i}$$

where

$$\mathcal{H}(\alpha) = \langle\Psi(\alpha)|H|\Psi(\alpha)\rangle$$

$$\eta_{ij}(\alpha) = \frac{\partial Z_j}{\partial \alpha_i} - \frac{\partial Z_i}{\partial \alpha_j}$$

$$Z_i(\alpha) = \langle\Psi(\alpha)| - i \frac{\partial}{\partial \alpha_i} |\Psi(\alpha)\rangle$$

These equations determine the classical dynamics of the collective parameters. Their canonical structure has been investigated and can be implemented in terms of generalized Poisson brackets. The analysis of the matrix η_{ij} allows the identification of canonical coordinates, momenta and eventual constraints, and paves the way for the quantization of the collective motion.

Several approximations to this scheme yield well known results. In the first place if all the parameters are assumed small the equations of motion become equations for coupled harmonic oscillators. Normal modes and RPA bosons can then easily introduced in a standard way. In the second place assuming that the motion in such that the time odd parameters are always small, we obtain a version of the recently developed adiabatic theory of collective motion[1,2] with a classical hamiltonian quadratic in the momenta (but otherwise arbitrary in the coordinates).

As an illustration of the method the equations of motion have been obtained for the well known Lipkin model hamiltonian, and their solutions obtained in terms of elliptic functions. This will allow detailed comparison both with other approximations and with exact results.

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VI. NUCLEAR REACTIONS

VI.1. Isospin Coupled Channel Analysis of Two-Particle Transfer Reactions.

O. Dragún and E.E. Maqueda.

Direct two-nucleon transfer reactions populating isobaric multiplets have been analysed [1] using distorted waves of definite isospin (T). This was done in order to take into account the isospin dependence on the optical potential.

Previous treatment[2] maintain instead well defined the charges of the entrance and exit distorted waves channels all along the transfer process (Tz). This charge-approximation ignores the coupling produced by the isovector components of the optical potential. The effect of these components should be important mainly for higher isospin multiplets. In the approximation of ref.1) the nuclear isovector component is fully taken into account but the methodneglects a term arising from the Coulomb potential which may contribute significally between the nuclear and matching radii, although cancelling largely in the nuclear interior.

It is desirable to perform a calculation where no approximation in the treatment of the isospin terms is made. Here we present some results of a such coupled channel analysis (ISOCCBA) and compare them with those of the approximate treatments.

Figure 1 shows the results obtained for the case $/T_A - T_B/ = 0$.

We have choosen that example because the number of acting channels is a maximum and the influence of the isovector terms of the optical potential should be more important. The ratios R and f are defined by:

$$R = \frac{f(h,n)}{f(h,p)} \qquad f = \frac{d\sigma_{exp}}{d\sigma_{theory}}$$

where f is the normalization factor that depends on the overall theory to experiment angular distribution agreements rather than on particular angle fit.

The comparison between the approximations and the coupled channel results shows that the calculations in an isospin defined frame are in better agreement with the exact values than the charge defined treatment.

We can conclude that as with regard to the analysis of this type of reactions, the influence of the isovector component of the optical potential is of greater relevance than that of the channel coupling part of the Coulomb interaction.

The values of the optical model parameters and the references for the experimental data are given in ref.1).

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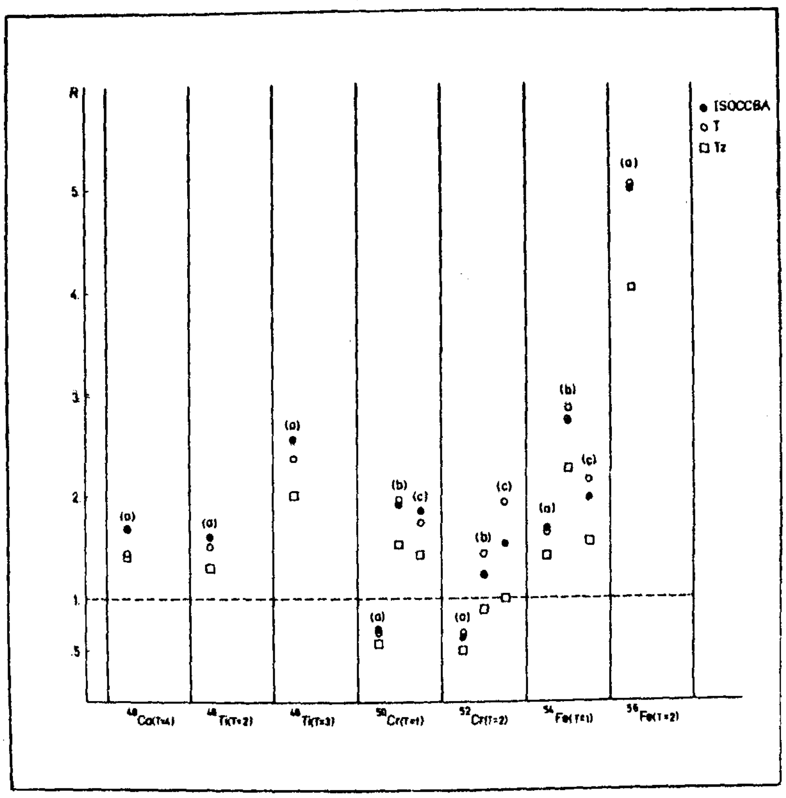

<u>Fig.VI.1.1.</u> Values of the ratio R displayed as function of the target nuclei for $\Delta T = 0$ reactions. Projectile energy in the (h,n) reaction (a) E_h = 18 MeV (b) E_h = 15 MeV (c) E_h = 13 MeV.

VI.2. Collective Treatment of the Pairing Hamiltonian. Analysis of Transfer Data for 88≤ A ≤96.

R.P.J. Perazzo, S. Reich and D.R. Bes.

The pairing degree of freedom is analysed in the 88≤ A ≤96 region involving the Zr, Mo and Ru isotopes. The region of our interest presents a large defect of protons with respect to the doubly magic core ^{100}Sm. Whenever one kind of particle is in large excess (or defect) with respect to a doubly closed shell, the proton and neutron systems tend to decouple. The residual pairing force that acts among the few neutrons of the same kind that are added (or substracted) from the core has to compete against a large single particle splitting. The proton holes are distributed among single particle levels that lie close to each other. Thus, the protons may be considered as being in a superfluid state and neutrons may be supposed to constitute a normal system.

This picture in which the proton system rotates in isospin and gauge space and neutrons perform harmonic Γ vibrations which allows to systematize the available (p,t), (t,p) and (h,n) data in this region.

A refinement of this scheme is obtained within the yrast framework[1]. This approach allows to take into account rotation-vibration couplings, choose the equilibrium superfluid deformation in a consistent way and introduce an anharmonic term in the potential energy surface V (Δ,Γ)

The experimental evidence is also analysed with a shell model diagonalization that helps to distinguish between coherent and incoherent (collective and non-collective) transitions.

The collective framework (rotation-vibration and yrast scheme) allows to group the states into families and the excitation energy systematics and trends of the transition rates are easily predicted. However, the inclusion of perturbative corrections demands a great computational effort that bears no proportion with the improvement obtained in the fitting of the experimental data.

The shell model diagonalization provides a more detailed fitting but cannot be extended to a wider range of masses or to heavier regions of the Periodic Table.

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1 D.R. Bes, G.G. Dussel, E. Maqueda, R.P.J. Perazzo, Nucl.Phys. A217 (1973) 93.

VI.3. Field Description of Inelastic Scattering.

G.G. Dussel, E.E. Maqueda and R.P.J. Perazzo.

The generalization of the nuclear field theory[1] to include continuum states, can shed new light on the properties of the coupling between scattering (projectile) and nuclear (target) coordinates.

We start by considering a Hamiltonian containing a two body interaction V with vertices involving both scattering ($\alpha,\beta\ldots$) and bound valence ($i.j,..$) orbitals. The latter may be assumed to contain all the Hartree-Fock contribution while the former are solutions of an average distorting (optical) potential. Out of all the vertices of V, we will consider those that involve one continuum fermion line in both the initial and final states and two bound fermion lines. All other possible terms of V are relevant to the inelastic scattering only through their contributions to the optical potential. The effect of the terms under consideration, as seen from either the target or the (structureless) projectile systems, is that of an external one-body operator.

$$\Sigma_{\alpha\beta}\, v_{\alpha\beta}\, a^{+}_{\alpha}a_{\beta} = \Sigma_{ij}\, w_{ij}\, a^{+}_{i}a_{j} = \Sigma_{\alpha\beta}\,\Sigma_{ij}\, V_{i\alpha,j\beta}\, a^{+}_{i}a_{j}a^{+}_{\alpha}a_{\beta} \tag{1}$$

Within the field theoretical languaje the operator (1), acting on a product (fermion-boson) space, has a fermion and a collective part. This coupling Hamiltonian is expressed as

$$\Sigma_{\alpha\beta}\, a^{+}_{\alpha}a_{\beta}\ \Big|\ \Sigma_{ij}\, V_{i\alpha,j\beta}\, a^{+}_{i}aj + \Sigma_{\substack{i>\varepsilon_F\\ j<\varepsilon_F}} V_{i\alpha,j\beta}\,\{\lambda_{ij}+\mu_{ij}\}\,\Gamma^{+}_{n} + \text{h.c.}\ \Big| \tag{2}$$

use has been made of forward (λ) and backward (μ) RPA amplitudes. The operator Γ^{+}_{n} creates the n-th collective (RPA) mode.

The present treatment, when compared with the current theories[2] of inelastic scattering, shows the following differences:

(i) the coupling is derived from a two body microscopic interaction and not from the dependence of the nuclear radius on the deformation parameters;

(ii) terms that are not linear in the collective variables do not occur in the coupling Hamiltonian;

(iii) within a phenomenological treatment an additional fermionic term should be included in the calculation of the matrix elements of the transition operator;

(iv) if a microscopic analysis or inelastic scattering is attempted, (2) contains fermion-boson vertices that allows to bring into consideration collective degrees of freedom.

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[1] D.R. Bes, G.G. Dussel, R.A. Broglia, R.J. Liotta and B.R. Mottelson, Physics Letters 52B (1974) 253.

[2] P.E. Hodgson, "Nuclear Reactions and Nuclear Structure", Clarendon Press, Oxford (1971), Chapter 13 and references therein.

Instrumentation and Development

Accelerator Operation
Detector Systems
Electronic Systems
Experimental Facilities
Computer Systems

VII. MACHINE DEVELOPMENT AND INSTRUMENTATION

VII.1. Synchrocyclotron.

VII.1.1. Repairs

N.A. Fazzini, J. Coralo, J. Garanzini, G. Ietri, A. Morales, M. Professi, J.c. Rodriguez and L. Schevenels.

The complete acceleration system of the Synchrocyclotron was disassembled to repair the false "D" that had deteriorated due to the use of a static polarization source. This source was used to increase the accelerator current.

The modulator was disassembled to change the rotor bearings and their carbon contacts.

New discs and capacitor spacers were built for the modulator, as the old ones had been in operation since 1954.

The rotor of the generator for the main magnet was partly rewound. This allowed physics experiments to continue with only a brief shutdown.

VII.2. Isotope Separator.

VII.2.1. Angular Correlation Table for on-line Use.

H. Gonzalez, J. Cava, A. Tersigni, D. D'Agostino and J. Vidallé.

An angular correlation table was designed and built for use with the isotope separator. The table was assembled and an exit-section from the separator was built,ending in a glass sphere used as a target chamber.

VII.2.2. Modification and Assembly of a new Ion Source.

J.J. Rossi, H. Gonzalez, A. Tersigni, R. D'Agostino, J. Vidallé, J. Orecchia, H. Huck and J. Dukelsky.

The ion source with ^{235}U inside the discharge chamber was modified to increase the uranium content and improve the adhesion method. The lens cooling system was redesigned as a continous air-flow circuit. During the assembly of this ion source, the whole system including the separator magnet was aligned and centered. At present the source is being tested on line to be used for the study of short-lived isotopes.

VII.3. Cascade Accelerator

VII.3.1. Construction of a New Final Section for the Accelerator Tube

H. Gonzalez and A. Tersigni.

A new final section for the accelerator tube was built with the aim of increasing the neutron flux and to improve maneuverability when changing the lithium targets.

VII.3.2. Repairs.

H. Gonzalez, A. Tersigni, R. D'Agostino, J. Vidallé and J. Orecchia.

The filter column of the accelerator was disassembled to change the lower capacitor, and the resistors coupled to the filter were repaired. This meant taking apart the whole accelerator cascade. The following repairs were also made:

- The silicon rectifiers were changed and rebuilt.
- The acceleration and focusing power sources were disassembled and rebuilt.
- The 200 Hz generator was rewound and dynamically balances.
- Additional shielding and security tasks were done in the high-voltage area and in the accelerator.

VII.4. Electronic Developments.

VII.4.1. Multidiscriminator for γ-γ coincidences

J. Mónico, J. Sinderman and S. Tau.

This equipment compares the digital output from a ADC to the state of a set of switches on the front panel. If a coincidence exists, it allows the storage in a certain sector of the multichannel memory of an event analyzed by another ADC. In this way, coincidence spectra are obtained with gates of high stability and precision. Automatic subtraction of the background is also possible. (see chapter VIII.1).

VII.4.2. Interface for event by event data collection.

S. Tau.

The multichannel analyzer memory was extended by an interface that allows its use together with a magnetic tape. After processing the data, biparametric spectra of 4096 x 4096 channels can be obtained.

VII.4.3. Control of an angular correlation table.

D. Camín, M. Satinosky and S. Swiszcz.

This equipment allows the automatic control of an angular correlation table and of its data gathering system. This has been divided into three regions each corresponding to a different angle of measurement.

VII.4.4. Interface between a Multichannel analyzer and a Computer.

C. Bolaños and M. Satinosky.

The memory of the multichannel has been increased by interfacing to a computer. By using the computer peripherals, the storage of information can be done in a faster and more ordered way.

VII.4.5. <u>6-Decade Compact Multiescalimeter.</u>

J. Mónico, J. Sinderman, M. Satinosky, S. Swiszcz and S. Tau.

This equipment consists of 6 escalimeters and a single digital display. Data can be accumulated simultaneously in each of them a read out through a parallel printer.

VII.4.6. <u>Static group for the Quadrupole Power Supply.</u>

C. Bolaños.

We continued the development and applications of a static 30 volt, 50 amp. group. It is completely transistorized and incorporates safety logics.

VII.5. Detector Developments.

VII.5.1. Ge(Li) Detector's Reactivation.

J. Nicolai, G. Martí, J.M. Risso and C. Giménez.

During their useful time-span, Ge(Li) detectors must be kept within an enviroment offering certain characteristics (temperatures, vacuum, étc), otherwise failure will occur.

In order to value the deterioration of the detectcrs and its causes, the curves of reverse leakage current and their capacity are analysed. For a detector operating under normal conditions, the reverse current should be kept below 0.5 nA and must be practically bias-Voltage independent. If it surpasses that value in 1 or 2 degrees, it indicates that the crystal's surface is affected by impurities deposited on it. When leakage current is quite over 0.5 nA (1 μA or more) and strongly bias-Voltage dependent, it points not only to a dirty surface, but also to the fact that there is a site of bulk current caused by thermal spatial charges not compensated, and to lithium precipitation in the N^+ zone. Normal capacity values are placed between 20 and 40 pF, what depends on the crystal's dimensions and geometry, C-V characteristic should reach the "plateau" with about 30 % of nominal bias voltage. If this is not so, it indicates there's been a lessening in the width, and a weakning of the compensated zone. Detectors that remain without liquid notrogen during some time, invariably show a C-V capacity curve strongly dependent on the tension, and their values are above capacity values under normal conditions.

The mothod we are summarizing hereunder was applied to several detectors having different characteristics, which had suffered damage as a consequence of vacuum failure, or of having remained at room temperature for some time. All of them had a cylindrical true-coaxal geometry with active volumes between 40 and 50 cm^3, and have been processed employing the usuañ methods.

This regeneration method consists in warming the crystal up to 10/30° C over room temperature, with reverse bias-Voltage applied on it; afterwards, the molecular sieve is cooled down, but the crystal's temperature is maintained for two hours, so that impurities on ots surface evaporate, for they are absorbed by the sealite, In this way, a decrease in the reverse leakage current detector curve is achieved.

To correct capacitance Voltage curve, and improve the intrinsic compensated zone of the crystal, one or more clean-up drifts are carried out at different temperatures, having a diffusion pump with L.N. trap performing a permanent cryostat evacuation.

Fig. VII.5.1.1. shows a summary of the results obtained for some of detectors to which this method was applied.

Detector N°1:

Current Versus Voltage curve was in poor condition, but is capacitance Voltage curve was alright, Three consecutive crioadsortion evacutaions were carried out on it, warming up the crystal to about (-50° C), but the results obtained were not satisfactory. Finally, it was decided to warm up the crystal to room temperature, evacuating it with diffusion pumps, in such condition, it was maintened for two hours, at +300 Volt bias and 40 mA inverse current. Afterwards, it was cooled down to L.N. temperature.

Detector N°2:

Owing to an accident, the liquid nitrogen evaporated, and remained for one mothat room temperature. Then, it was warmed up to approximately 30° C , and remained during two hours with 300 Volt bias, and 35 mA current, Afterwards, two-clean-up-drifts were carried out: one, at -25° C, during 24 hours; the other, at -80° C, during two-hours. Finally, it was made to reach the temperature of liquid nitrogen (-196° C), and was left still to rest two hours.

Detector N°3:

The Dewar, where the cryostat is, remained two days without liquid nitrogen. Before being processed, it offered no reaction. It was treated in identical way as Detector N°2.

Detector N°4:

Energy resolution and Peak-to-Compton relation degraded slowly. Before being processed, it did not work. This one was treated exactly as Detector N°1, except that no previous evacuations with criogenic pumps were carried out: it was evacuated directly with dif-pump, instead.

Detector N°5:

Owing to a failure of the Dewar, it remained three days without liquid nitrogen, and it offered no reaction before being processed. It was treated in the same way as Detector N°2.

The method described above was successfully used with 10 detectors more, so that we have planty of data from where to infer general conclusions. Results have shown the following: 1) to evacuate with an oil difussion pump, having a big liquid nitrogen trap, is faster and more effective than with criogenic pumps. 2) if an oil difussion pump is employed, the time taken by the detector to repair is averaged substantially, because, in case of abnormalities caused by

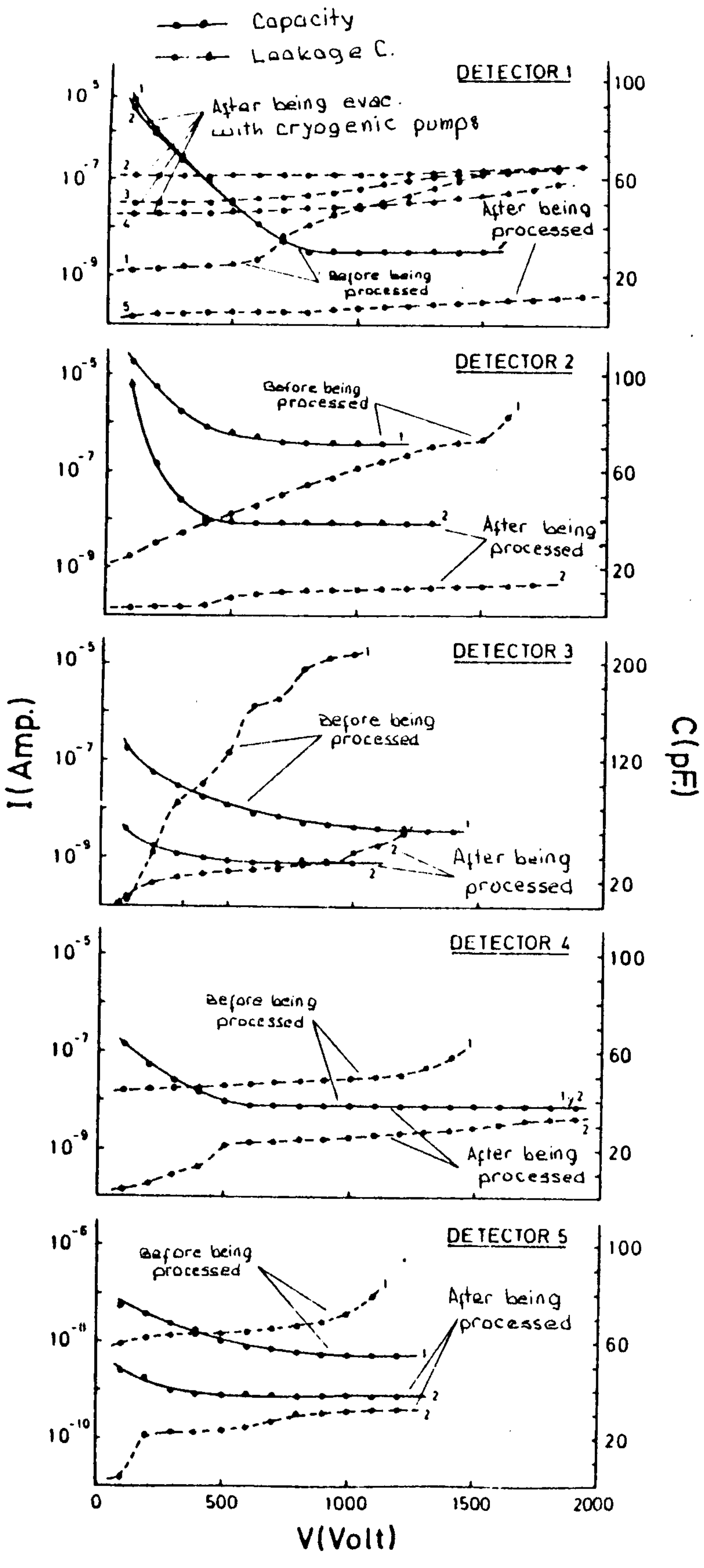

Fig. VII.5.1.1. Capacitance-Voltage and reverse leakage Current-Voltage curves for detectors N°1 - 5 as described in the text.

vacuum failure, the detector gests back to its starting point only one day after it has been processed; on the contrary, using crioadsortion evacuation, it takes three days, which means, on the whole a repair time of seven days, or even more, owing to the regeneration processes that the pump's molecualr sieve has to undergo between successive evacuations. 3) this methods proves that is effective to regenerate the characteristics of those detectors that heve remained for some time at room temperature, without being necessary to remove the crystal from the cryostat. 4) inverse leakage current and capacitance versus bias Voltage curves are the most secure source of information to analyze damages suffered by detectors.

VII.5.2. Improvements in the Li difussion process in Ge Crystals.
C. Giménez, J. Laffranchi and G. Martí.

A new system for Li difussion in large volume Ge crystals was developed The quality and uniformity of the diffused Li layer was improved and the total time for the process was shortened. This was accomplished mainly in the refrigeration stage by designing and constructing a liquid nitrogen cooling system

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VII.5.3. Design, Assembly and Measurements with a Collimated γ-beam to Study charge trapping in Ge(Li) detectors.
G. Martí.

Measurements with collimated γ-beams of various energies were performed to study surface and volume problems, charge trapping and electric field distribution in Ge(Li) detectors. For that purpose, a 1 mm diameter collimator was designed and built. Charge collection efficiency curves and sensitive zone profiles were meassured for two Ge(Li) detectors of coaxial symmetry.

VII.5.4. Design and Construction of a New Cryostat for Ge(Li) Detectors.
J. Laffranchi, J. Nicolai and C. Giménez.

Motivated by various problems with the design of the cryostat used for the fabrication of Ge(Li) detectors, an extensive modification was undertaken with the following characteristics.

- Less liquid nitrogen consumption
- A thinner window due to an improved design and better machining
- More static pumping capacity for degassing. This increases the detector's lifetime.
- The components were treated to improve their degassing properties.
- Improved security for the detector between the thermos and cryostat combination, and easier handling.
- Easier detector operation due to a greater distance from the liquid Nitrogen thermos.
- A metallic vacuum lock between the body and the cold finger has solved problems connected with the freezing of the O-ring.

VIII. IMPROVEMENTS OF THE EXPERIMENTAL FACILITIES

VIII.1. Digital Multidiscriminator for γ-γ Coincidences.

M. Behar*, A. Filevich, G. García Bermúdez, M.A.J. Mariscotti, J. Mónico, J. Sinderman**, S. Tau and P. Thieberger***.

Pulse height multidiscriminators have been used in this laboratory in order to perform γ-γ coincidences. In this system 4 analog discriminator windows are set simultaneously with 4 substracting background windows to observe γ-ray spectra in coincidence with 4 selected γ-rays.

This method has two main drawbacks:

a) The number of possible gates is limited because of the reduced number of available memory channels in the multichannel analyzer (4096).

b) The windows are often ill-defined because of shifts in the discriminator thresholds.

In addition the window limits are not sharply established because of their analog nature which makes it difficult to set the gates.

Problem a) is not solved with the multidiscriminator method. In fact a new magnetic tape station and an interface are being developed in this laboratory to overcome this difficulty. With this system coincidence spectra will be efficiently stored in list mode.

Problem b) could be solved by using digital multidiscriminators which are essentially free of shifts and always keep a perfect definition of the windows. Because of the long term gain stability of standard commercial amplifiers no gain drifts should be expected, even for long experiments.

A digital discriminator unit working in connection with an Intertchnique TRIDAC 4096 channel analyser with which up to 8 digital gates can be set simultaneously has been constructed.

In Fig. VIII.1.1. a block scheme of the system is presented in its operation mode. ADC 1 (display) feeds the MCA memory split into a number of subsections, according to the number of gates set on the selector sector. Signals from ADC 1 are thus routed and recorded in one of this subsections, ADC 2 (gating) feeds the multidiscriminator via 12 binary bits.

This information is codified into 4 octal digits. The multidiscriminator has 32 sets of 4 octal thunwheel switchs (total 132) with which 32 channels can be selected. These 32 sets are associated in 8 groups of 4 channels (0-7). The effective number of these groups can be varied in 4 binary steps (sector selector). Thus we can set either 8 gates of 4 channels, 4 gates of 8 channels etc. Furthermore, each group can be subdivided into 2 subgroups, "+" and "-" with the purpose of automatic addition of counts in the coincidence spectrum, in the case of coincidence with a peak, or subtraction, in the case of coincidence with a background section.

In Fig. VIII.1.2. the block scheme in the set up mode is shown. The setting of the gates over the particular region of interest is greatly facilitated by channel intensification on the analizer CRT display.

The time condition for the coincidence of two detector signals is established externally by means of a conventional fast coincidence circuit, using a windowed TAC to gate the ADC 2.

The digital multidiscriminator has been used in many experiments for a period of about a year. The system proved to be reliable and no troubles in its operation have been encountered. Familiarity with octal switches is rapidly acquired by the experimenter and the more complicated electronics for binary to decimal conversion was not found to be necessary. Fig.VIII.1.3. shows a portion of a typical coincidence spectrum obtained with the digital multidiscriminator The target was 10 mg of 70 Ge (0.5 cm^2 area) and was bombarded by 35 MeV α-particles from the synchrocyclotron. Two 40 cm Ge(Li) detectors connected in coincidence were used to perform this measurement[1].

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[**] Present adress: Medelec Corp. Buenos Aires Argentina.

[***] Department of Physics, Brookhaven National Laboratories, Upton, New York 11973, U.S.A.

[1] M.A.J. Mariscotti, M. Behar, A. Filevich, G.García Bermúdez, A.M. Hernández and C. Kohan, Nucl. Phys, A260 (1976) 109.

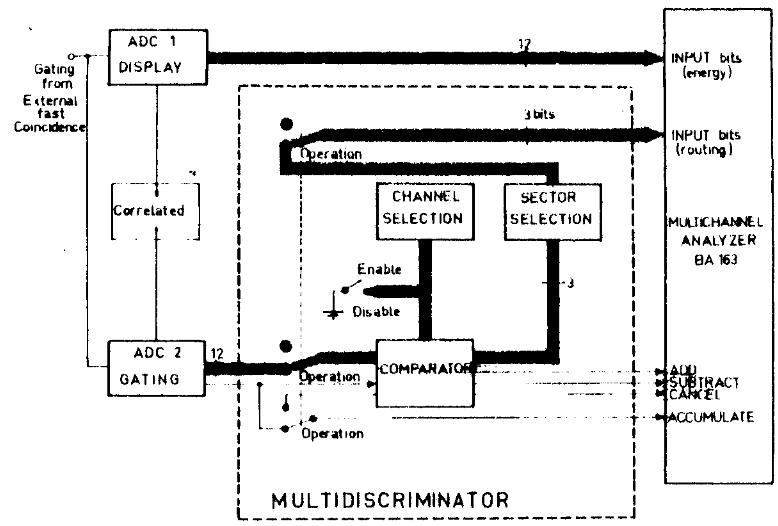

Fig.VIII.1.1. Simplified block-scheme of the multidiscriminator system in the operation mode.

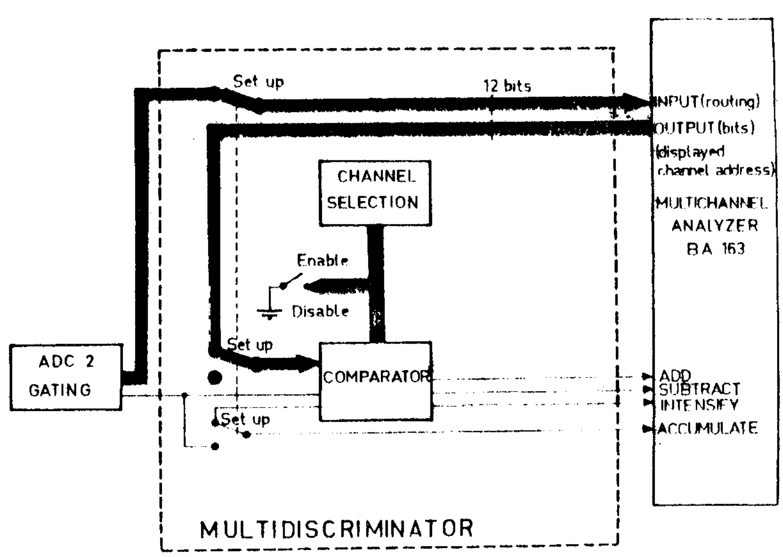

Fig.VIII.1.2. Simplified blok-scheme of the multidiscriminator system in set-up mode.

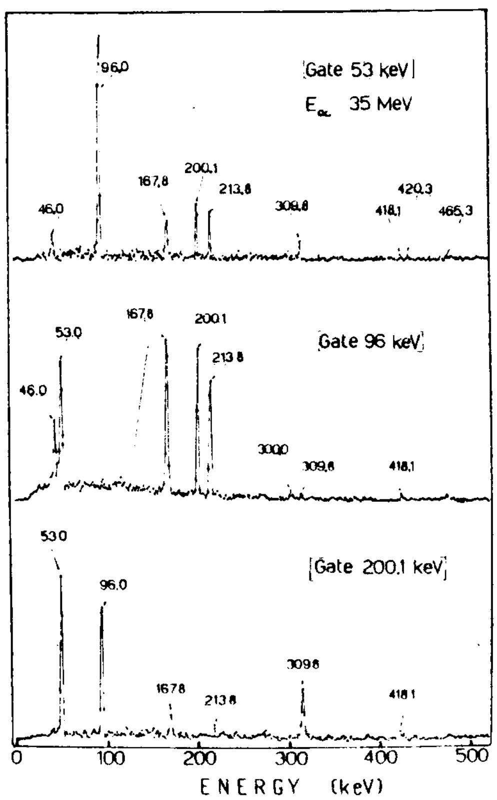

Fig.VIII.1.3. Portion of γ-γ coincidence spectra obtained by gating on the 53, 96 and 200.1 keV lines of ^{72}As. Target was ^{70}Ge bombarded with 35 MeV α-particles from the Buenos Aires Synchrocyclotron.

VIII.2. Angular Correlation Facility for on Line Measurements.

A.E.Ceballos, E.D. Duering, H.A. Huck, A. López García*, D.Otero
M.L. Pérez, A.N. Proto and E. Ventura.

An angular correlation facility has been attached to the Buenos Aires ISOL (On Line Isotope Separator) set up. The 110 cm diameter aluminium table has the possibility of controlling authomatically the motions of two of the three mounted detectors, allowing for any combinatio of Ge(Li) and/or NaI(Ti) detectors. Their positions can be varied in 5° steps.

The source holder consists of 20 mm diameter and 0.05 mm thick aluminium foil centered into a glass sphere mounted on-line with the isotope separator.

The γ-γ coincidence resolving time was set to $2\tau \tilde{} 40$ nsec. The coincidence signals were procesed by two 4096 channel analog-to-digital converters and both generated adresses stored on a magnetic tape buffer. The data on this tape were latter read back into the computer using a digital window placed at the position of the designed gating peak and an additional window near this peak to authomatically substract coincidences due to the Compton background. Simple spectra were taken simultaneously with the coincidence spectrum.

The source was accurately positioned with less than a one percent error. This was done measuring on-line the 258 and 1436 keV γ-ray transitionswith two GE(Li) detectors simultaneously. The former which was recorded at different angles belongs to the 14.2 min decay of ^{138}Xe and the latter recorded at a fixed angle to the decay of 32.2 min ^{138}Cs.

Dead time variations were kept within 1-2% as higher variations produced anomalous relations for the coincidence/singles ratio. In order to check the system the previously [1,2] measured 462-1436 and 2010-1436 keV angular correlations in ^{138}Ba were analysed. The results show very good agreement with those in Ref 2.

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* Departamento de Física, Universidad Nacional de La Plata, Argentina

1 B. Singh and M.W. Hohns, Nucl. Phys. A212 (1973) 382.
2 G.J. Basingerm W.C. Shick Jr. and W.L. Talbert Jr. Nucl. Instr. and Meth. 124 (1975) 381.

VIII.3. <u>Facility for on Line Observation of Perturbed Angular Correlation.</u>

N.A. Fazzini, J. Coralo, J. Garanzini, B. Ietri, A. Morales, M. Professi, J.C. Rodriguez and L. Schevenels.

A new on-line facility for measuring perturbed γ-ray angular correlations has been constructed in the external beam line of our synchrocyclotron. It consists of a versatile thinwalled plastic reaction chamber of cylindrical geometry, convenient for angular distribution measurements. In addition two recessed flat covers allow, upon rotation of the chamber, to locate one or two standard horizontal Ge(Li) detectors very close to the target (at about 1.5 cm) for γ-γ coincidence measurements.

The pole pieces of a small 8 Kg (at 1 cm gap) electromagnet fit in the cover holes of the chamber so that the gap size can be made adjustable. Vacuum seal is made against the polished chrome plated pole pieces by means of conventional o-rings.

The magnet has been constructed in collaboration with the Istituto de Física, Universidad do Río Grande do Sul, Porto Alegre, Brasil.

The facility has been used to measure the g-factor of the 887.9 keV state in ^{70}As.

IX. COMPUTATION

IX.1. Software Improvements for the Hewlett-Packard Computer

E. Achterberg.

Several improvements and new developments were provided for the software package available for use on the 2116B Hewlett-Packard minicomputer which forms an integral part of our HP 5406B nuclear data acquisition system. The data handling facilities were enhaced,with the inclusion of a new routine to read event-by-event biparameter mode magnetic tape files. Options now available include the simultaneous sorting into one-dimensional spectra using either up to 32 independent single windows, or up to 16 double windows, the ability to automatically account for Compton background events by using one half of the double windows in subtraction mode, and automatic spectrum length compression to fit into the available spectrum display regions (6 regions of 1024 channels each, 20 bits per channel). A version to display a single biparameter spectrum on the system scope directly as it is being read from the tape is also available.

A considerable amount of effort was devoted to the improvement of some of the data processing programs already mentioned in our previous report, and the development of some new ones. A short description is given below.

a) Anpix. This program for the least-squares fitting of gamma-ray spectra obtained with semiconductor detectors was significantly speeded up with the use of more efficient subroutines, providing a saving of almost 50% in computing. Typical times for a single peak are now 15-20 seconds on the HP minicomputer, while complex multiplets or long regions with the maximum allowed number of 10 peaks may take up to several minutes. Unfortunately, the gain in computing time is not wholly reflected in the total processing time due to the slow operation of the available output terminals (digital plotter and teletype). In general, fitting results are as good or better as can be achieved with the SAMPO program, due to the choice of a somewhat more realistic function to reproduce the peaks and the background, and to the closer user interaction with the program. Since there are no CPU time costs in our system, the slower processing time and the required operator supervision to establish analysis regions and to provide initial values for peak positions have been found worthwhile prices to pay.

b) Level. A new version of this program for the automatic construction of energy level scheme based on experimental gamma transition energies and intensities was also developed. Besides being somewhat faster than its predecessor, it now allows a better control over the rejection or acceptance of new proposed levels, thus diminishing the chances of including spurious levels due to accidental coincidences of energy sums.

c) Cobal. This new program calculates the coincidence intensity to be expected in quantitative gamma-gamma experiments for any pair of gamma rays seen in the corresponding singles spectra. The program will provide either individual coincidence peak intensities for selected gates specified by the user, or automatically step through the whole gamma ray list provided and print out all non-zero results. The calculations are performed taking into account all possible branchings linking the transitions allowed for by the given energy level scheme. For transitions with significant conversion it is desirable to provide good values for the transition intensities, either by use of measured electron conversion results, or from estimates based on the known or assumed multipolarity of the transitions, The comparison of the calculated intensities with the observed quantitative coincidence data will then provide a significant test of the correctness of the proposed level scheme. This is specially important in the case of the rather complex level schemes found for the relatively short-lived fission products studied in our on-line isotope separator facility.

d) Calib. This new program performs gamma ray energy calibrations using as fitting function a polynomial in the peak positions in the observed spectra. The difference with almost all other such routines available in most laboratories consists in that a bivariate fit is used to find the polynomial coefficients by adjusting sets of data obtained using standard calibration sources. The need for a bivariate fit is due to the fact that at present the relative errors with which peak positions in gamma-ray spectra may be determined are of the same order as those with which the calibration energies are known. The fitting routine may be used in an automatic mode in which polynomials of successively increasing degree are fitted to the same data, giving the user the choice of the optimum fit.

Besides the energies corresponding to the "unknown" peaks in the spectrum the program may also provide a tabulation of the energies and positions of the associated single and double escape peaks, as well as of the corresponding Compton edge and back-scattering "peak". This provides a valuable aid in unravelling the often quite complex gamma spectra seen in the decay of some short-lived fission products.

IX.2. Programming Guide for the Use of Job Control Cards on the IBM/370.

A. Diaz Romero.

A programming guide providing about 500 different models for the use of OS Job Control Cards for the IBM/370 has been compiled and will soon become available for the users of this machine. It comprises the following chapters:

(1) Operations involving the use of programs on punched card decks: compilation and execution of programs, including routines using different languages; punching of object decks; sharing of data between job steps.

(2) Use of disk-resident partitioned catalogued symbolic libraries: updating the library; compilation and execution of programs, including the option of using members of the same library as input and/or output data files; options involving the use of magnetic tapes.

(3) Use of disk-resident partitioned catalogued load module libraries: updating the library; execution of programs, including those requiring the linking with routines resident in the same library or submitted as card deck or magnetic tape files.

(4) Options involving the simultaneous use of symbolic and load modules, from partitioned catalogued libraries resident on separate disk volumes

(5) Uses involving operations with magnetic tapes: labelling of tapes; execution of programs from magnetic tape or subroutines which use magnetic tape data files; use of magnetic tapes as storage for symbolic or load modules, including the generation of partitiones libraries.

Appendix

Staff

Publications

PERSONNEL OF THE NUCLEAR PHYSICS GROUP

A. Research Staff

Achterberg, E.	
Bes, D *	
Ceballos, A.	
Dragún, O	
Dussel, G *	
Ferrero, A.	(1)
Filevich, A.	
García Bermúdez, G.	
Hernández, A.M.	(2)
Kreiner, A.	(3)
Liotta, R.	(4)
Maqueda, E.*	(5)
Mariscotti, M.A.J.	(Chairman, Department of Physics)
Otero D.	
Pérez Ferreira, E.	
Pérez, M. *	
Perazzo, R. *	
Pomar, C.	(6)
Proto, A.	
Reich, S.	
Rossi, J.	(7)
Saraceno, M.	
Sofía, H.	(8)
Ventura, E.	

B. Research Staff Associated to the Nuclear Physics Group

Behar, M *
Cambiaggio, M.
Davidson, J.
Davidson, M.
Hernández, E.S. *
Szybisz, L.

C. <u>Visiting Scholars</u>

Barret, B.	(University of Arizona, U.S.A.)
Berman, B	(L.L.L., California, U.S.A.)
Goldring, G.	(Weizmann Institute, Israel)
Kraner, H.	(BNL, New York, U.S.A)
Thieberger, P.	(BNL, New York, U.S.A.)
Zawislak, R.	(Univeristy of Porto Alegre, Brasil)

D. <u>Research Students</u>

Abriola, D.	(9)
Alonso Arias, C.	(9)
Berisso, M.	(9)
Duering, E,	(9)
Etchegoyen, A.	(9)
Fernández Niello, J.	(9)
Huck, H.	(9)
Pacheco, A.	(9)

E. <u>Programming Asistent</u>

Diaz Romero, A.

F. <u>Enginiering Staff</u>

Camín, D.	(10)
Fazzini, N.	
González, H.	
Hild, S.	
Marti, G.	
Milberg, J.	(11)
Mónico, J.	(11)
Nicolai, J.	
Requejo, R.	
Tau, S.	

G. Technical Staff

Bustos, J.

Bolaños, C.

Cava, G.

Coralo, J.

D'Agostino, R.

Garanzini, J.

Giménez, C.

Ietri, B.

Laffranchi, J.

Morales, A.

Orecchia, J (12)

Prieto, J.

Professi, M.

Pisso, J.

Rodriguez, J.

Satinosky, M. (13)

Schevenels, L

Schiavino, R.

Tersigni, A.

Vidalle, J.

H. Secretaries

Corvalán, J. (14)

García, J.L.U. (15)

Lires, S. (16)

Neufeld, M. (17)

I. General Maitenance Staff

Barzola, G.

De Brasi, O.

Gómez, D.

---

* Fellow of the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET).

(1) During 1976-1977 on leave at the Istituto di Science Fisiche Aldo Pontremoli, Universitá di Milano, Italy.
(2) Terminated July 1976. Present Adress: Department of Physics, University of Pittsburg, Pittsburgh, Penna, U.S.A.
(3) During 1976-1977 on leave at the Physik Department, der Technishe Universitat Munchen, Germany.
(4) Terminated June 1976. Present Adress: Niels Bohr Institute, Copenhague, Denmark.
(5) On leave at the Department of Physics, University of Sussex, Sussex, England.
(6) On leave at the Research Institute for Physics, Stockholm, Sweeden.
(7) During 1977 on leave at the Institute de Physique Nucleaire, Orsay, France.
(8) On leave at the Niels Bohr Institute, Copenhague, Denmark.
(9) Incorporated April 1977.
(10) During 1977 on leave at IAEA, Torino, Italy.
(11) During 1977 on leave at the Services d'Electronique, Centre d'Etudes Nucleares, Saclay, France.
(12) Incorporated December 1977.
(13) Incorporated July 1977.
(14) Terminated September 1977.
(15) Terminated November 1977.
(16) Terminated December 1977.

PUBLICATIONS OF THE NUCLEAR PHYSICS GROUP

Papers published or accepted during report period

- The Nuclear Field Treatment of Some Exactly Soluble Models
  D.R. Bes, R.A. Broglia, G.G. Dussel, R.J. Liotta y H.M. Sofía
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- Application of the Nuclear Field Theory to Monopole Interactions which include all the Vertices of a General Force
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- On the Many Body Foundation of the Nuclear Field Theory
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- In Beam Study of ^{144}Gd
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- The Renormalization of Fermion and Boson States
  D.R. Bes, G.G. Dussel, R.P.J. Perazzo and H.M. Sofía
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  D.R. Bes.

29 Reuniao Anual Sociedade Brasilera de Progreso das Ciencias, Fortaleza, 1977.

- Medidas de Vida Media dos Productos da reacoes ^{64}Zn, $^{60}Ni(^{16}O,xn)$
  G. García Bermúdez, M.A.J. Mariscotti y W. Seale.

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- El Sincrociclotron de Buenos Aires y su Papel en el Desarrollo Nuclear Argentino
  A.E. Ceballos y M.A.J. Mariscotti.

VI Reunión de la Asociación de Tecnología Nuclear, Córdoba 1977

- Factibilidad de Producción de Carbono 11 y Posterior Aplicación en Radiofármacos.
  A. Ceballos, A. Filevich, N. Fazzini, J.C. Rodriguez, H. Albani, C. Arciprete, V. Pecorini y A.E.A. Mitta
- Reactivación de Detectores de Ge(Li).
  C. Giménez, G. Martí, J. Nicolai y J.M. Riso.

C Internal Reports

- Estudio para la Instalación de un Acelerador Electrostático
  D.R. Bes, A.E. Ceballos, A. Filevich, M.A.J. Mariscotti, E. Pérez Ferreira, R. Requejo, J.J. Rossi y E. Ventura.

- Un Equipo para el Transvase Automático de Nitrógeno Líquido
  C.A. Bolaños, J.H. Sinderman, C. Saragovi Badler, F. Labenski y E. Frank
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- Determinación de la confiabilidad de programas de Análisis Automático de Espectros por el Método de simulación numérica
  A. Díaz Romero
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D Ph.D. Theses

- Alberto Filevich
  Universidad Nacional de Cuyo
  Propiedades de Isómeros de Alto Spin Obtenidos por Reacciones (α,xn) y Técnicas para su Observación por Haz pulsado (1976).

- Silvia Leonor Reich
  Universidad Nacional de Buenos Aires
  Modelos Colectivos de la Fuerza de Apareamiento (1976).

- Cayetano Pomar
  Universidad Nacional de Cuyo
  Sistemática de las reacciones $(\alpha, xnypz\alpha)$ en la Región de los Núcleos Livianos (1976).

E. Licenciatura Thesis

- Jorge Fernández Niello
Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Buenos Aires.
Filtro magnético para observar electrones de conversión en núcleos producidos por reacciones (α,xnyp).

- Cecilia Alonso Arias
Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Buenos Aires.
Determinación de Spines y razones de mezcla en el decaimiento del ^{94}Tc mediante correlaciones angulares gamma-gamma y gamma polarizada gamma.

- Hugo A. Huck
Instituto Balseiro, Universidad Nacional de Cuyo, Río Negro.
Correlaciones angulares en cascada γ-γ en ^{138}Ba.

- Edgardo R. Duering
Instituto Balseiro, Universidad Nacional de Cuyo, Río Negro
Correlaciones angulares en cascada γ-γ en ^{138}Ba.

IMPRESO EN CNEA - SEPTIEMBRE 1978