HIGH PRECISION STUDIES OF DIRECTIONAL CORRELATIONS

using multidetector systems

Mohsen El-khosht
M.Sc.

STOCKHOLM 1980

بسم الله الرحمن الرحيم

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av

Mohsen El-khosht
M.Sc.

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The first part deals with gamma-gamma directional correlations measurements. A total of 27 cascades have been studied in ^{97}Tc, ^{206}Pb and ^{206}Bi. We obtain information on the angular momenta of levels, multipolarities of electromagnetic transitions and further, reduced transition probablities.

The later part of this thesis describes a determination of anisotropic directional correlation between gamma-rays and Lx-rays in ^{160}Dy. To our knowledge this is the first observation of an anisotropic correlation between gamma rays and x-rays following internal conversion.

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DEDICATED TO:

My native country *EGYPT*
My home town *MATAI*
My parents, brothers and sisters
My wife *ADALAT* and daughter *EL-SHAIMAE*

CONTENTS

INTRODUCTION

This thesis focuses on two applications of the method of directional (angular) correlations. The first part of the thesis concerns the spatial correlation between gamma quanta emitted in two or more cascading nuclear transitions. The theory of these correlations is well established and has been reviewed by several authors for instance, ref. 1). Different experimental methods have been developed and directional correlation measurements have provided a large quantity of precise information concerning the angular momenta of nuclear states and the multipolarities of nuclear electromagnetic transitions.

In the later part of the thesis we investigate in one specific case the directional correlation between a nuclear gamma ray and atomic X-rays. The possibility of an anisotropic directional correlation between X-rays and γ-rays was first considered 2) in 1954. If the nuclear gamma transition and the atomic X-ray transition are causally connected through orbital electron capture,EC, or internal electron conversion,IC, and if the spins of the intermediate nuclear and atomic states are greater than 1/2 then the spatial correlation of the quanta may be anisotropic. The theory of γ-Lx-ray directional correlation following orbital electron capture or internal electron conversion was originally formulated 3) in 1958. Until now, however, there has been no convincing experimental demonstration of the exsistence of such anisotropic correlations.

Almost without exception the directional correlations reported in this thesis have been measured using multidetector systems in highly symmetric configurations. These systems characteristically have a large efficiency and minimize the influence of systematic sources of error,enabling an accurate determination of the directional correlation also for weak cascades. Of the 28 cascades studied in this thesis the present results were the first ones reported in 26 cases.

1. OUTLINE OF THE THESIS

The thesis consists of this short summary and the following papers :

P 1. On the performance of the Stockholm MCG, S. Beshai, M. El-khosht and L. Gidefeldt, USIP Report 76-03 (1976).

P 2. Gamma-Gamma Angular Correlation Studies in ^{97}Tc, S. Beshai, M. El-khosht, L. E. Fröberg and L. Gidefeldt Z. Phys. A 282, 283-289 (1977).

P 3. Gamma-ray multipolarities in ^{206}Pb studied by Gamma-Gamma Directional Correlations, Chr. Bargholtz, S. Beshai, M. El-khosht, B. Sundström and C. Wiktorsson, Nucl. Phys. A 342, 485-496 (1980)

P 4. Gamma-Gamma Directional Correlations in the decay of ^{206}Po, M. El-khosht, K. Fransson, B. Sundström and S. Beshai , USIP Report 80-06 (1980)

P 5. Anomalous Gamma-ray-Lx-ray Directional Correlations in ^{160}Dy, Chr. Bargholtz, J. Becker, S. Beshai, M. El-khosht, K. Fransson and B. Sundström, Phys. Rev. C 21, 1078-1085 (1980)

2. DIRECTIONAL CORRELATION COEFFICIENTS OF GAMMA-GAMMA CASCADES

A gamma-gamma cascade $I \rightarrow I' \rightarrow I$ in which two multipole components L_n and $L'_n = L_n + 1$ contribute to each of the two transitions, the most convenient form of describing the (unperturbed) directional correlation function $W(\theta)$

$$W(\theta) = \sum_{k=0}^{k_{max.}} A_k Q_k P_k (\cos \theta)$$

The summation index k is even and governed by the selection rule:

$$0 \leq k \leq \min (2I, L_1 + L'_1, L_2 + L'_2)$$

A_k are the angular correlation coefficients, $A_0 = 1$ is the normalization always used. The functions $P_k (\cos \theta)$ designate the k th-order Legendre polynomial and θ is the angle between the emitted gamma rays. The Q_k are attenuation factors arising from the finite solid angle of the detectors and dependent upon the detector dimensions, the source to detector distance, photon energies and the source dimensions. Higher terms than k=4 have not yet been observed. The energies that normally are available in radioactive decays are such that multipoles with $L > 2$ possess a half-life $> 10^{-6}$ s. It is experimentally difficult or even impossible to measure a directional correlation function of a cascade involving an intermediate state with so long a half-life. The usual two

normalized coefficients of the directional correlation A_2 and A_4 depends on the spins of the nuclear states involved and the gamma ray multipolarities. The mixing ratio $\delta(\gamma)$ is introduced as a measure of the ratio of the L'-pole to the L-pole transition amplitude. The correlation coefficients are thus generally functions of the mixing ratios (δ_1 and δ_2) of the two transitions. The expression of the multipole mixing ratio $\delta(\gamma)$ of the transition $i \rightarrow f$ being given by

$$\delta(\gamma) = \frac{\langle f \,||\sigma' L'|| \, i \rangle}{\langle f \,||\sigma L|| \, i \rangle}$$

Here $\sigma' L'$ and σL designate the two multipole operators of lowest order pertinent to the transition. The ratio of the total intensity of L'-pole to that of the L-pole is then equal to δ^2. The measured magnitude and sign of the mixing ratio can be used as a critical test of the predications from nuclear models. The sign of the mixing ratio in this work is defined in accordance with the use of emission matrix elements throughout 4). The coefficient

$$A_k = A_k(\gamma)_1 \; A_k(\gamma)_2 \qquad \text{and}$$

$$A_k(\gamma)_1 = \frac{F_k(L,L,I,I) + (-1)^{L-L'} 2\delta_1 F_k(L',L,I,I) + \delta_1^2 F_k(L',L',I,I)}{1+\delta_1^2}$$

and similar for the directional distribution coefficient $A_k(\gamma_2)$ but without the phace factor $(-1)^{L-L'}$. The F_k coefficients are tabulated constants derived from angular momentum considerations 1).

There are at most five unknown parameters determining the directional correlation three spins and two mixing ratios. A unique solution of the problem can in general not be obtained from this measurement alone since the directional correlation measurement yields only two coefficients. However, supplemented with information from other experiments like internal conversion coefficients and ft-values the directional correlation technique is one of the most powerful for the determination of spins and multipolarities.

3. ANISOTROPIC DIRECTIONAL CORRELATION OF GAMMA RAYS AND X-RAYS

Under certain conditions an anisotropic directional correlation can be expected between nuclear gamma rays and atomic X-rays following internal conversion. Given the nuclear cascade

$$j_0 \xrightarrow[L_\gamma]{\gamma\,1} j_1 \xrightarrow[L_{IC}]{IC} j_2$$

, the internally converted transition creating a vacancy in the electron shell with angular momentum J_0 which in term will be filled through X-ray transitions to higher lying shell, $J_0 \xrightarrow[L_x]{x} J_1$.

A nescessary condition for the directional correlation to be anisotropic is that the angular momentum of the intermediate nuclear state, j_1 , and intermediate atomic state, J_0 , are greater than 1/2 . Consequently the L_3 $(2P_{3/2})$ subshell is the lowest atomic intermediate state that can lead to anisotropy. The directional correlation function is given by

$$W_{\gamma x}(\theta) = 1 + \sum_{k=2,4} A_k P_k(\cos\theta)$$

where

$$A_k = A_k(L_\gamma, L'_\gamma, j_0, j_1)\; A_k(L_x, L'_x, J_1, J_0)\; U_k(L_{IC}, L'_{IC}, j_1, j_2, J_0)$$

$A_k(L_\gamma, L'_\gamma, j_0, j_1)$ is defined in the usual way in terms of the mixing ratio $\delta(\gamma)$ and $A_k(L_x, L'_x, J_1, J_0)$ is the same quantity but for the X-ray transition.

$U_k(L_{IC}, L'_{IC}, j_1, j'_2, J_0)$ depends on the mixing ratio δ_{IC} of the internally converted transition, ref. 6)

$$= \frac{G_k(L,L',j_2,j'_1,J_0) + 2\delta_{IC} G_k(L,L',j_2,j'_1,J_0) + \delta_{IC}^2 G_k(L,L',j_2,j'_1,J_0)}{G_0(L,L',j_2,j'_1,J_0) + \delta_{IC}^2 G_0(L,L',j_2,j'_1,J_0)}$$

with

$$G_k(L,L',j_2,j'_1,J_0) = (2J_0+1)^{3/2} \left(\frac{(2L+1)(2L'+1)(2j_1+1)}{L(L+1)\,L'(L'+1)}\right)^{1/2}$$

$$\times W(j_2 L j_1 k; j_1 L') \sum_j (2j+1) \begin{pmatrix} j & J & L \\ -1/2 & 1/2 & 0 \end{pmatrix} \begin{pmatrix} j & J & L' \\ -1/2 & 1/2 & 0 \end{pmatrix}$$

$$\times W(J_0 j k L; L' J_0) \; X_{Lj} \; X^*_{L'j}$$

The quantities X_{Lj} are linear combinations of radial integrals R_i involving only the electron wave function. For electric conversion they are given by

$$X_{Lj}(E) = L(R_3 + R_4 - R_5 + R_6) + (k-k)(R_5 + R_6)$$

where k is the quantum number defining both the parity and the angular momentum of the ejected electron $j=|k| - 1/2$ and k_0 is the same quantum number for the bound electron.

$W(j_2\ L\ j_1\ k;j_1\ L')$ is the Racah function.

$$G_0(L,L,j_2,j_1,J_0) = \frac{\beta(L,J_0)}{\pi\alpha E}$$

where $\beta(L,J_0)$ is the internal conversion coefficient, $\alpha=1/137$ is the fine structure constant and E is the transition energy in units of $m_o c^2$.

The X-ray transitions that follow a vacancy in the L_3 subshell should be divided into three groups according to their energies since no presently available detector is able to resolve the L-multiplet . These groups are L_ℓ which corresponds to the single transition $M_1 \rightarrow L_3, L_\alpha$ which is a mixture of two transitions $M_5 \rightarrow L_3$ and $M_4 \rightarrow L_3$ and L_β which again is a mixture where the dominant transitions are L_{β_2}, L_{β_6} and $L_{\beta_{15}}$ corresponding respectively to the initial levels N_5, N_1 and N_4.

Finally, the theoretically predicated value of the anisotropy has to be corrected for the contribution from isotropic X-rays.

Primarily these are due to secondary vacancies in the L_3 subshell. These vacancies are either caused by IC in the K shell followed by a $K \rightarrow L_3$ transition or they result from conversion in the L_1 and L_2 subshells followed by Coster-Kronig transitions. The L_β-group is dominated by the isotropic lines L_{β_1} depopulating the L_2-subshell. The corrected A_k^{corr} for γ-Lx cascade from all these effects is given by

$$A_k^{corr}(\gamma\text{-}L_\ell) = (1+S_1)^{-1} A_k(\gamma\text{-}L_\ell)$$

$$A_k^{corr}(\gamma\text{-}L_\alpha) = (1+S_1)^{-1} A_k(\gamma\text{-}L_\alpha)$$

$$A_k^{corr}(\gamma\text{-}L_\beta) = (1+S_2)^{-1} A_k(\gamma\text{-}L_\beta)$$

where $A_k(\gamma\text{-}L_\alpha)$ and $A_k(\gamma\text{-}L_\beta)$ are the average directional correlation coefficient because the L_α and L_β radiations are a mixture of several transitions. The hindrance factors S_1 and S_2 are the ratio between the isotropic and the anisotropic γ-L_3 coincidence counting rates, and it is easy to show that they are given by the following expressions :

$$S_1 = \frac{\alpha(K)}{\alpha(L_3)} \left(n_{kL_3}^{(A+R)} + n_{kL_3}^{(A)} \left(f_{13} + f_{12} f_{23} \right) \right.$$

$$\left. + n_{kL_2}^{(A+R)} f_{23} + \frac{\Gamma(L_1 L_2)}{\Gamma(K)} f_{23} f_{13} \right)$$

$$+ \frac{\alpha(L_1)}{\alpha(L_3)} \left(f_{13} + f_{12} f_{23} \right) + \frac{\alpha(L_2)}{\alpha(L_3)} f_{23}$$

$$S_2 = S_1 + \frac{w_2 P(L_{\beta_1}) P(L_3)}{w_3 P(L_2) P(L_\beta)} \left(\frac{\alpha(L_2)}{\alpha(L_3)} + \frac{\alpha(L_1)}{\alpha(L_3)} f_{12} \right.$$

$$\left. + \frac{\alpha(K)}{\alpha(L_3)} \left(n_{kL_2}^{(A+R)} + n_{kL_1}^{(A)} f_{12} \right) \right) .$$

In the above equations $\alpha(i)$ denote the internal conversion coefficient for the shell i. The n_{kL_i} is the average number of L_i vacancies per ionization in the K shell produced by Auger ,A, or radiative transitions ,R . The $\Gamma(L_i, L_j)$ are the K-$L_i L_j$ Auger transition probabilities and $\Gamma(K)$ is the total K shell width. The $P(L_i)$ are the X-ray emission rates and , as usual, w_i and f_{ij} denote respectively the fluorescence and Coster-Kronig yields.

4. EXPERIMENTAL TECHNIQUES

Gamma-gamma directional correlations were measured with the Stockholm multichannel goniometer, MCG. In its original version the MCG utilizes 8 NaI(Tl) detectors placed on an annular table around a central source 6). Coincidences from a total of fifty-six detector combinations are recorded simultaneously. The 56 time spectra are stored in the memory of a multichannel analyser, each being displayed over 64 channels. The data are transferred to punched paper tape and analysed in a computer. First the background of random coincidences are estimated from the flat background surrounding the coincidence peak and are subtracted from the total number of counts in the peak to obtain the number of true coincidences.

The true coincidence data are analysed using the program SAVEL. This program essentially makes a least squares fit according to the procedure described in ref. 6). It allows any number of detectors or coincidence channels to be excluded from the analysis. The fitted A_2 and A_4 values and their associated standard deviations are given as results from the analysis. The goodness of fit is indicated by the result of a chi-square test.

In addition to the high efficiency of the system, the influences of varying detection efficiencies ϵ_i and ϵ_j and coincidence couplings g_{ij}, due to decreasing source strength during a measurement and due to imperfecations in the electronics as a source of any systematic errors in the resulting values for the directional correlation coefficients have been shown to be quite negligible 6).

When studing a complex decay the uncertainties due to the inherent poor energy resolution of NaI(Tl) detectors may be overcome, by replacing any two NaI(Tl) detectors by high resolution Ge(Li) detectors, exchanging the time representation of the data by an energy representation 7). In this case the number of coincidence combinations are reduced to twelve. The 12 Ge(Li) coincidence spectra and the associated 12 random coincidence spectra will be registered simultaneously, displayed over 128 channels each. A top view of the detector table with 6 NaI(Tl) and 2 Ge(Li) detectors is shown in fig.(1).

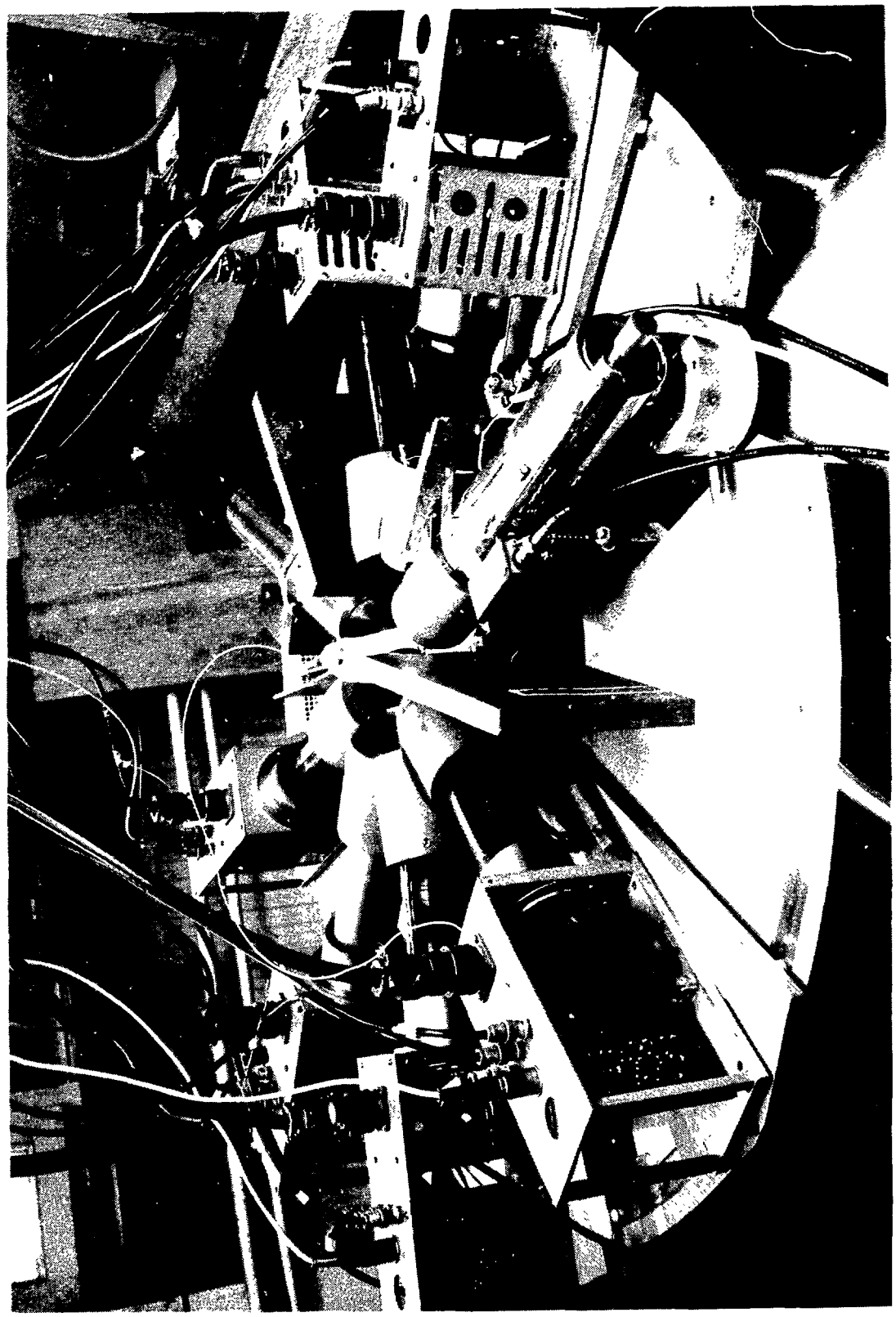

Fig. 1) A top view of the detector table with 6 NaI(Tl) and 2 Ge(Li) detectors.

The coincident energy spectra are analysed using a least squares fitting procedure and assuming the peaks to be of gaussian form placed on a background that can be approximated with a forth order polynomial. The output results are the calculated peak area, peak center and gauss width with their associated uncertainties and a plot of the fitted region of the spectrum. The goodness of the fit is determined by a chi-square test. Finally, the true coincidence data are analysed by the program SAVEL (above).

Most of the measurements of gamma ray-X-ray directional correlations were done using a four detector setup with 2-coaxial Ge(Li) detectors (FWHM=2.1 keV at 1.3 MeV) for the γ-rays and 2 planar Ge(Li) detectors (FWHM=175 for one and 250 eV for the second detector at 5.9 keV) for X-rays, see fig.(2).

The four coincident X-ray spectra, two at 90^{o} and two at 180^{o}, were recorded in two MCA together with their corresponding spectra of random coincidences. The spectra from one of the detectors being displayed over 1000 channels each and the spectra from the other displayed over 256 channels.

Some of the measurements were done using a two detector setup with one automatically movable planer Ge(Li) detector(for the X--rays) in coincidence with one coaxial Ge(Li) detector (for the γ-ray) which was fixed with respect to the source. Two coincident X-ray spectra and two spectra of random coincidences were recorded in one MCA for the detector positions 90^{o} and 180^{o}. The singles Lx-ray spectra (for normalization) were recorded simultaneously in another MCA.

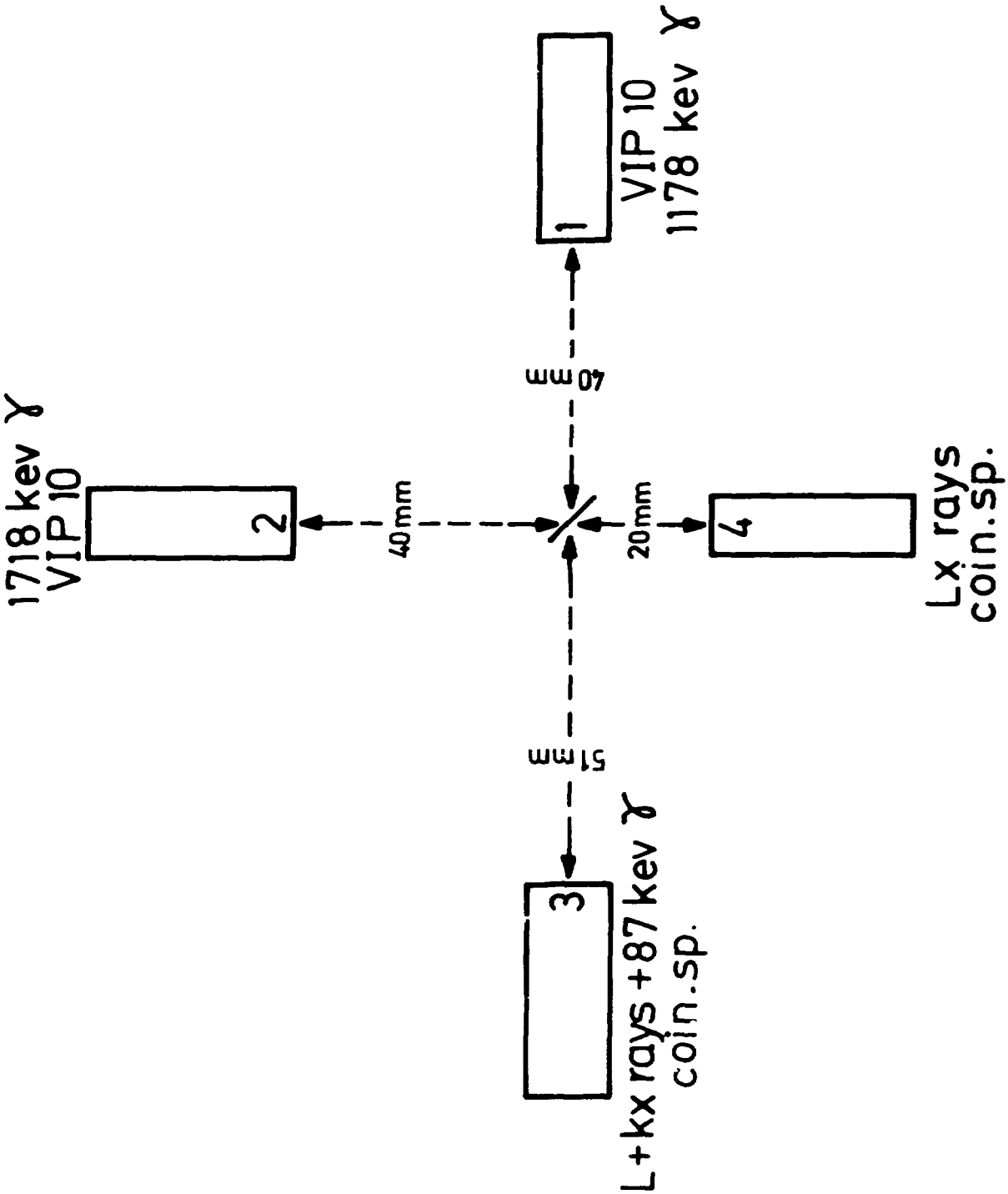

Fig. 2) A four Ge(Li) detectors configuration, γ-ray detected by detectors 1 and 2 and X-rays recorded by detectors 3 and 4. The source was mounted in the plane of the detectors at angle of 45^{o} to all detectors.

5. Presentation of the papers

ON THE PERFORMANCE OF THE STOCKHOLM MCG

The efficiency of the two versions of the MCG was determined from simulated data with the focus on the statistical uncertainty (standard deviation) of the directional correlation coefficients. This is a major source of experimental uncertainty and will shadow most effects of systematic errors. The result show that statistical uncertainty in the A_2 and A_4 coefficients is very little affected by the actual A_2 and A_4 values but that it is slightly more dependent on the detector configuration chosen.

The statistical uncertainty is compared to that obtained in the same time with a 2-detector arrangement with one coincidence channel. The uncertainty from the 56-channel MCG is shown to be smaller by a factor of 6.5 and that from the 12-channel system is smaller by a factor of 2.3 and 3 for A_2 and A_4 respectively.

The effect of poor spatial adjustement of the detectors was also investigated. It was found that the 12-channel MCG is somewhat more sensitive to this source of systematic error. However, for reasonable maladjustments ($\leq 1^{o}$) these systematic errors are small compared to the statistical uncertainties encountered in most directional correlation measurements.

GAMMA-GAMMA ANGULAR CORRELATION STUDIES IN ^{97}Tc

The gamma-gamma directional correlation technique has been used in an investigation of the decay of ^{97}Ru. In this decay levels are populated in ^{97}Tc up to at least 995 keV. The spins and parities of some of these levels as well as the multipolarities of some of the transitions are uncertain. Five cascades in ^{97}Tc have been studied by the use of the MCG . The experimentally obtained further information on these points.

During the measurements, the activity (produced by the ^{96}Ru(n,γ)^{97}Ru reaction, from enriched ^{96}Ru> 97 %) as ruthenium chloride was contained in a small plastic cylinder 15 mm high and with an inner diameter of 6 mm. The directional correlation coefficients obtained were corrected for the finite solid angle of the detectors as well as for the size of the source. The activities due to impurities were identified from gamma spectra recorded at different times after irradiation. A typical gamma-ray spectrum is shown in fig.(3).

The decay properties of levels in ^{97}Tc up to 995 keV have been investigated later by Landsberger et al. 8) via a spectroscopy study of the γ-radiations following the bombardment of protons with energies from 2.0 to 5.2 MeV on enriched ^{97}Mo targets ^{97}Mo (p,nγ) reaction). The spins and parities of levels and δ(E2/M1) for transitions in ^{97}Tc are extracted from the measurements of angular distributions.

Xenoulis and Kalfas 9) later also reported measurements with purpose to clarify level scheme and decay properties of states in ^{97}Tc up to 2208 keV. Spins and parities have been proposed for several levels and mixing ratios deduced for numerous transitions. The present results of E2/M1 mixing ratios for 460.6 and 569.3 keV transitions (depopulating the 785.0 keV level) are -0.01(10) or -0.16(4) and 0.13(5) or 2.8(5) respectively. The δ(460.6)

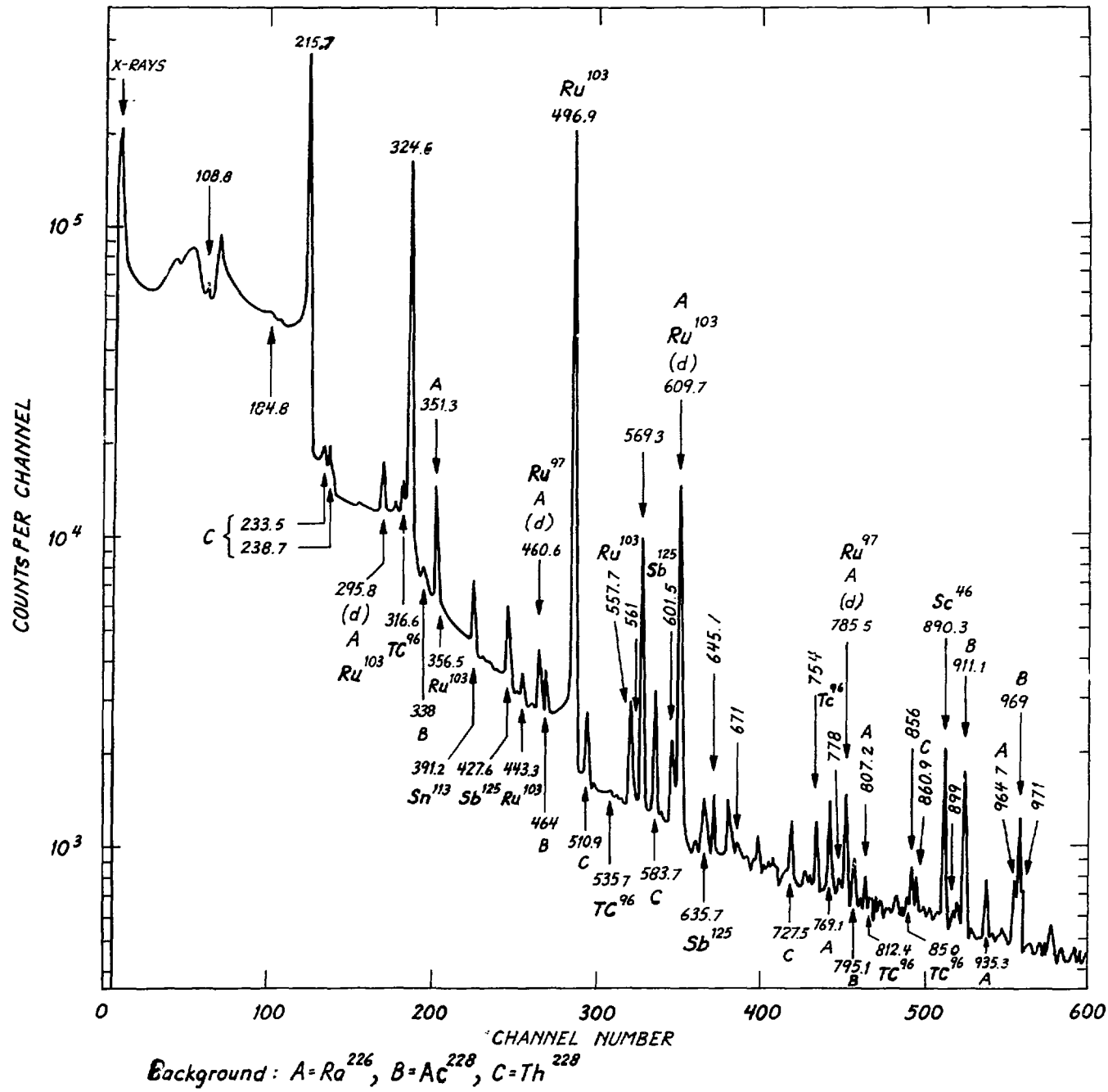

Fig. 3) Gamma ray spectrum from one of the sources recorded with a Ge(Li) detector (FWHM=2.1 keV at 1.3 MeV) 24 hour after the irradiation. The γ-rays labelled only by energy have been assigned to the decay of ^{97}Ru. Double peak is shown as d and A, B and C for the background peaks.

deduced from an angular correlation measurement 10) and angular distribution measurement 9) are in agreement only with the first result -0.01(10). However, ref. 10) agree (in two standard deviations) with the second solution -1.6(4). Also δ(569.3) deduced from the two measurements (above) together with an experiment of nuclear orientation by Berclay et al. 11) are in agreement with the first result 0.13(5).

Earlier experiments suggest the spin of the 785.0 keV state to be 5/2 or 7/2. The present result is only compatible with spin 5/2 which confirmed by the refs. 8 , 9 and 10).

The present value for the A_2-coefficient of the 754.0-215.7 keV cascade together with the mixing ratio of the 215.7 keV transition is consistent with both a $5/2^+$ and a $7/2^+$ assignment to the level 969.7 keV. The results of refs. 8 and 9) are only compatible with spin $7/2^+$. The present results for E2/M1 mixing ratios are summarised in table 1 with a comparison with the results of other measurements using different techniques.

Table(1)

E(keV)	Present result	Other results	
108.8	1.6(4)		
215.7	0.20(5)	$0.5^{+0.08}_{-0.11}$	a
		0.31(5)	b
		0.27(2)	d
460.6	-0.01(10) or -1.6(4)	$0.5^{+0.1}_{-0.4}$	b
		$-0.56^{+0.43}_{-0.31}$	c
569.3	0.13(5)	$0.67^{+0.24}_{-0.67}$	b
		0.12(5)	d
		0.128(14)	c
645.2	0.37(24) or 1.88(97) * (I^{π} (969.7) $=7/2^{+}$)	$-1.15^{+0.87}_{-0.81}$	a
754.0	-3.9(7) (I^{π} (969.7) $=7/2^{+}$)	<-0.8	a
		-2.2(8)	b

a) S. Landsberger, R. Lecomte, P. Paradis and S. Monaro, Nucl. Phys. A 339, (1980) 238-252
b) A. C. Xenoulis and C. A. Kalfas, Phys. Rev. C 20, (1979) 145-163
c) K. S. Krane and J. M. Shobaki, Phys. Rev. C 4, (1977) 1589.
d) J. A. Berklay, S. S. Rosenblum, W. A. Steyer and K. S. Krane Phys. Rev. C 14, (1976) 1183
* Used the lower limit of the directional correlation A_2 (645.2-324.6) =0.09(4).

GAMMA-RAY MULTIPOLARITIES IN ^{206}Pb STUDIED BY GAMMA-GAMMA DIRECTIONAL CORRELATIONS

Directional correlations are measured for the first time for 17 cascades in the decay of ^{206}Bi. From the results we deduce the mixing ratio of 10 transitions. Prior to the present measurement there have been made two nuclear orientation experiments the result of which are incompatible. Our data can be used to distinguish between these two sets of results and we suggest that the results of McConnel et al. 12) should be disregarded.

If we accept the results of Kaplan et al. 13) as correct we obtain the following mixing ratios values for transitions in ^{206}Pb as shown in the table below (first column).

Transitions energy(keV)	Multipolarities	Mixing ratios		
		Using ref. 13)		Present in paper 3.
629	M1 + E2	-0.22(8)	*	-0.33(29)
1098	E1 + M2	0.006(16)	**	E1
1719	E1 + M2	0.003(20)	***	E1

* δ(E2/M1) for the 620 keV transition based on our results of the directional correlations A_2(620-398)=-0.12(3) and the corrected A_2(620-(1098)-881)= 0.17(13).

** δ(E2/M1) for the 1098 keV transition based on our results A_2 of the 497-1098 and 1098-881 keV cascades.

*** δ(M2/E1) for the 1719 keV transition based on our results A_2 of the 1719- 881, 1719- 344 and 1719-(344)- 537 keV cascades.

Further, fig.(4) presents δ(620,E2/M1) as a function of δ(1098, M2/E1) for A_2(620-1098)=-0.173(24). However, only one of tne two solutions is compatible with the result from measurements of L-subshell intensity ratios by Kanbe et al. 14) setting as limit to the E2-admixture of 6.3 % for the 620 keV transition .

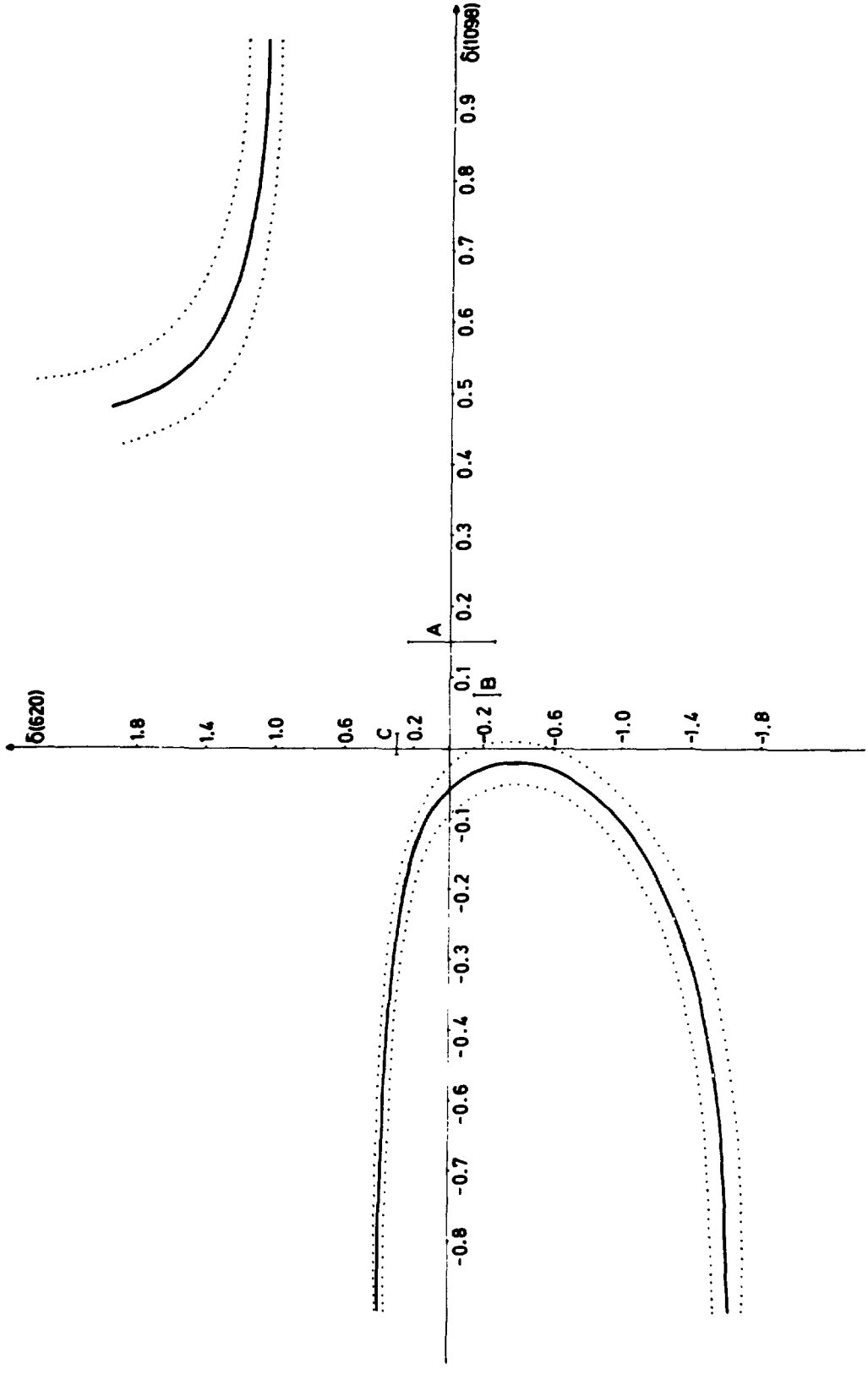

Fig. 4) The mixing ratio of the 620 keV transition as a function of the mixing ratio of the 1098 keV transition with A_2=-0.173(24). The limits from one standard deviation in A_2 are given by the dotted curves. Only one of the two solutions is compatible with conversion electron data 14), $|\delta(620)| < 0.250$ and shown as A. Present results using ref. 13), $\delta(620)$ and $\delta(1098)$ are shown with B and C respectively.

Due to the proximity of the Compton edge from the 1173 keV ^{60}Co gamma ray used in the thermometry,Kaplan et al. could not measure the anisotropy of the 1098 keV radiation with certainty. There is only one solution for the M2/E1 mixing ratio of the 1098 keV transition compatible with the present directional correlation results for the 497-1098 and the 1098-881 keV cascades. Assuming that the 881 keV transition is of pure E2 character and the E2/M1 mixing ratio of the 497 keV transition to be that deduced by Kaplan et al. The solution is δ(M2/E1)=0.006(16) and it is compatible with the measured A_4 coefficients. (For the 497-1098 keV cascade the A_4 coefficient lies within two standard deviations of the expected value.) This value of δ(1098) in the table is distributed around zero which satisfing our assumption of the pure E1 multipolarity for 1098 keV transition and recently, confirmed by ref. 15).

In the nuclear orientation experiment of Kaplan et al. the 1719 keV transition was assumed to have a pure E1 character. In order to lend support to this assumption, we analysed our directional correlation results for the 1719-881, 1719-344 and 1719-(344)-537 keV cascades. From the results for A_2 coefficients and assuming the 881 and 803 keV transitions to be of pure E2 multipolarity and the mixing ratios of the 344 and 537 keV transitions to be those deduced by Kaplan et al., we calculated δ(M2/E1)=0.003(20) for the 1719 keV transition.

GAMMA-GAMMA DIRECTIONAL CORRELATIONS IN THE DECAY OF ^{206}Po

This paper present the first measurements of directional correlations in the decay of ^{206}Po. A total of five cascades in ^{206}Bi have been investigated. From the results we deduce the mixing ratio for nine transitions.

Our results of these measurements improve the limits of most earlier found E2/M1 mixing ratios (L-subshell ratios measurements ref. 16)) of the above transitions . Four transitions are established definite E2-admixtures . Further, upper limits of the reduced electromagnetic transition probabilities B(E2) of these transitions are estimated. None of the obtained limits seems unreasonable.

ANOMALOUS GAMMA-RAY-Lx-RAY DIRECTIONAL CORRELATIONS IN ^{160}Dy

This paper, to our knowledge, is the first one to report an anisotropic directional correlation between gamma ray and Lx-rays following internal conversion. As a matter of fact it presents the strongest experimental evidence for such anisotropic correlations irrespective of the physical process creating the atomic vacancy. However, our result is in conflict with predications based on what appears to be a straight foreward application of directional correlation theory.

In an atempt to disclose any anomalies in the atomic transitions, the 87L (conversion electron)-Lx- ray directional correlation has been measured at this laboratory 17). The prelimenary result of this measurement represents the first known confirmation of theoretical predications for such correlations. The atomic trasitions responsible for the measured anisotropy in the e-Lx directional correlation experiment should be the same ones and appear with the same intensities as in the gamma ray-Lx--ray experiment following first order internal conversion in the L-shell. The source of our result therefore does not appear to be an anomelous intensity ratio for the L_{α_1} and L_{α_2} transitions. An experiment is at present under way studing a possible influence from high order effect in the internal conversion process.

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* Full name : Mohsen Anwar Murad El-khosht

** Permanent adress : Department of Physics,
Faculty of Science ,
Tanta University ,
Tanta , Egypt .

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THANK ALLAH

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ERRATA		IS	SHOULD BE
P 1	page :Introduction line no. 6	uzilizing	utilizing
	page 13, case 2.	55,90,135,180 270 and 315	55,125,180,270 300 and 330
	Fig 2 : B	55 in between detectors no. 3 and 4	70 in between detectors no. 3 and 4
P4	page 3, line no. 10	three	four
	page 6, line no. 25-27	is " The 980.2, 1114.5 and ... ...the electron capture decay.	

should be,
"The 980.2, 1114.5 and 1190.9 keV transitions depopulates the states 1^+ at 1389 keV , 1^+ at 1523.7 keV and (1^+) at 1600 keV respectively"

" " line no. 32 : Add new sentence before " Due to these contributions ....."

The new sentence is " Also the other possible spin 0^+ of the 1600 keV level is considered. "

Sammanfattning (Summary)			
	page 5, last line	26	25
	page 11, line no. 2	ref. 6	ref. 5
	page 13, line no. 5	lines	line
	page 20, line no. 20	targets	targets (
	" " last line	-0.16(4)	-1.6(4)
	page 24 line no. 22	δ(E2/M1)	δ(M2/E1)
	page 29,	ACKNOLEDGEMENTS	ACKNOWLEDGEMENTS

UNIVERSITY OF STOCKHOLM
INSTITUTE OF PHYSICS
VANADISVÄGEN 9
S-113 46 STOCKHOLM
SWEDEN

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