Linear Polarization Measurement on Gamma Rays from Non-Oriented Nuclear States

Ms Beatrice Similindi

Supervised by: Dr S.N.T Majola

Co-Supervised by: Dr E.A. Lawrie

University of Johannesburg

OBJECTIVES

- Develop a technique to measure linear polarization of γ rays emitted from non-oriented nuclear states for the clover detectors of the iThemba LABS AFRODITE and GAMKA arrays.
- Use the technique to measure the polarization sensitivity $\mathrm{Q}(\gamma)$ of the clover detectors using $^{152}\mathrm{Eu}$ radioactive sources.
- Deduce the angular correlation coefficients for all the γ rays observed in the beta decay of $^{152}\mathrm{Eu}$ source collected with the GAMKA array.
- Combine angular correlation and linear polarization to deduce the mixing ratios for γ rays with mixed multipole nature.

GAMMA DECAY

- Gamma radiation
- Gamma spectroscopy
- Linear polarization

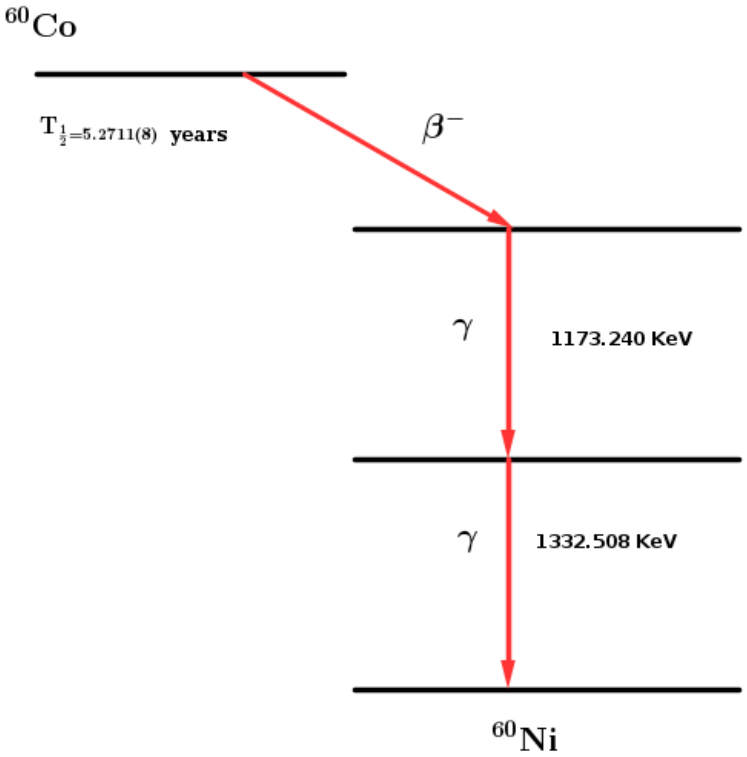
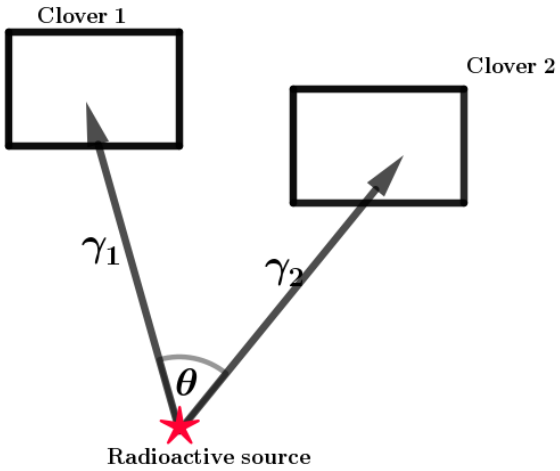


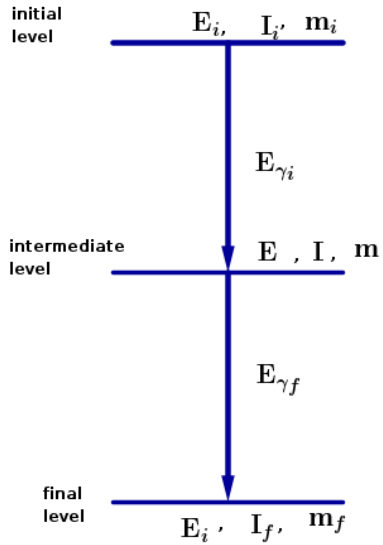
Figure 3.

ANGULAR CORRELATIONS

- This methods creates orientation by observing sequential γ radiation.



(a)



(b)

- Angular correlations

$$W(\theta) = \sum_{n=0,2,4} a_n P_n(\cos\theta), \quad a_n = A_n(1)A_n(2). \tag{1}$$

LINEAR POLARIZATION MEASUREMENTS

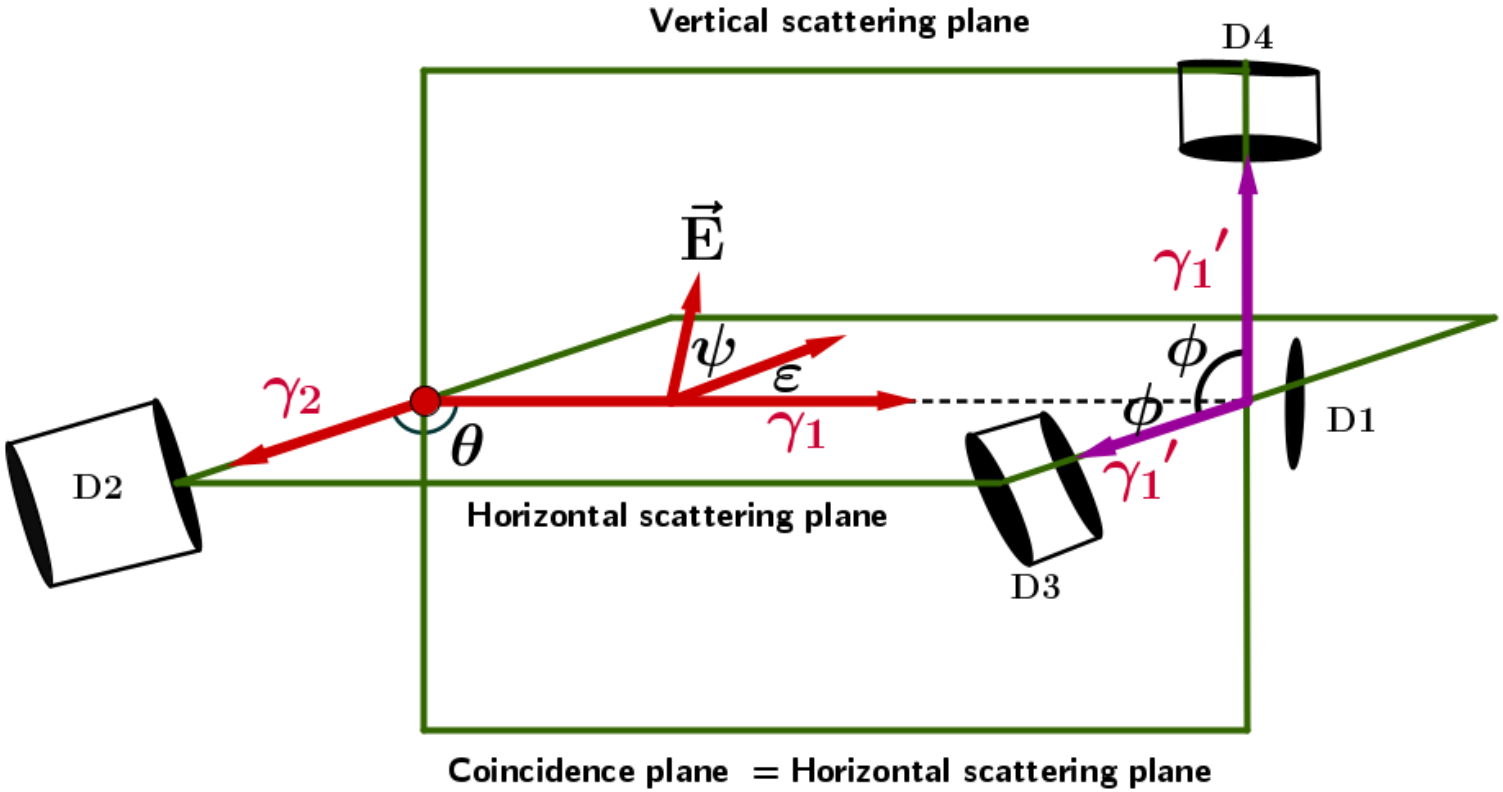


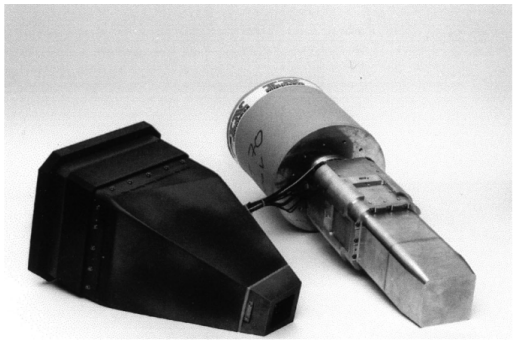
Figure 5.

- Degree of linear polarization $\mathrm{P}(\theta)$

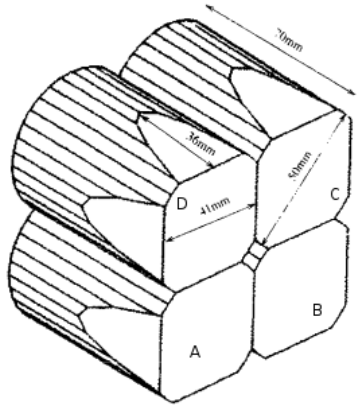
$$\mathrm{P}(\theta) = \frac{W(\theta, \psi = 0°) - W(\theta, \psi = 90°)}{W(\theta, \psi = 0°) + W(\theta, \psi = 90°)}, \qquad (2)$$

DETECTION OF GAMMA RAYS

- Clover detectors



(a) BGO shield & clover detector



(b) HPGe crystals

- Polarization Anisotropy A_p

$$A_p = \frac{aN_v - N_h}{aN_v + N_h} \tag{3}$$

- Polarization Sensitivity, $Q(\gamma)$.

$$Q(\gamma) = \frac{A_p}{P(\theta)} \tag{4}$$

TECHNIQUE WITH THE AFRODITE AND GAMKA ARRAY

- The technique was developed for the iThemba LABS AFRODITE array for the clover detectors positioned at $45°, 90°$ and $135°$ and the GAMKA array mounted on the new Dandelion frame with more angles.

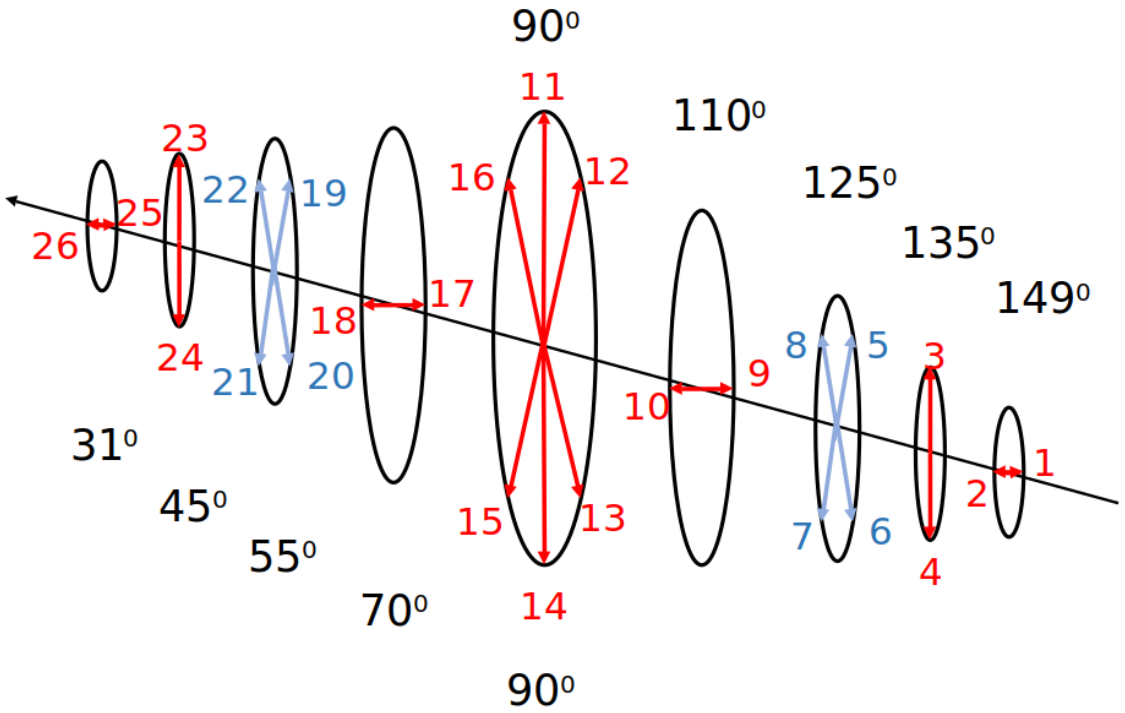


Figure 7.

DETECTOR POSITIONS

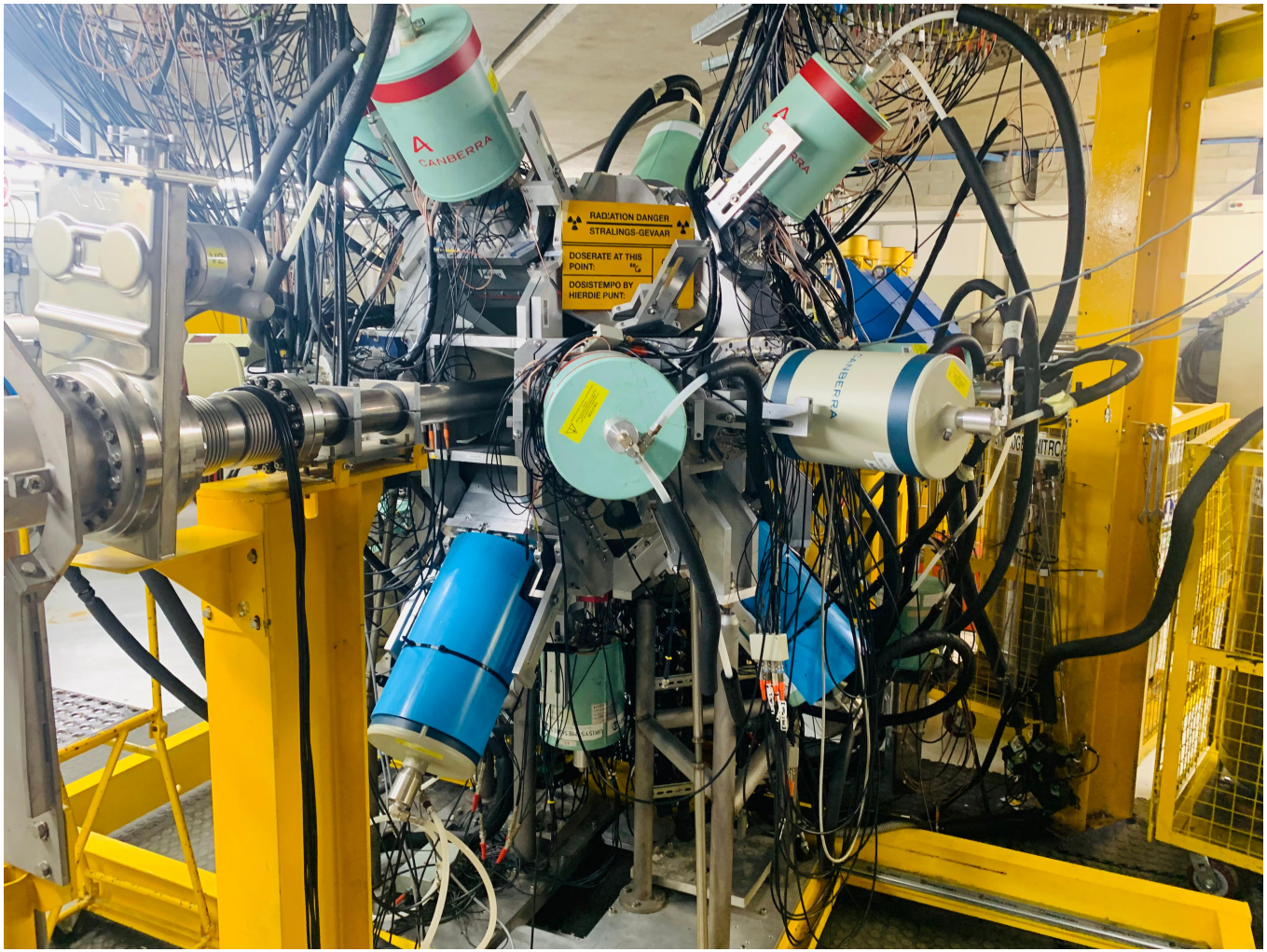


Figure 8.

ANGULAR CORRELATION RESULTS

- Angular correlation function $W(\theta)_{\text{exp}} = \frac{A_\gamma}{\varepsilon_i}$

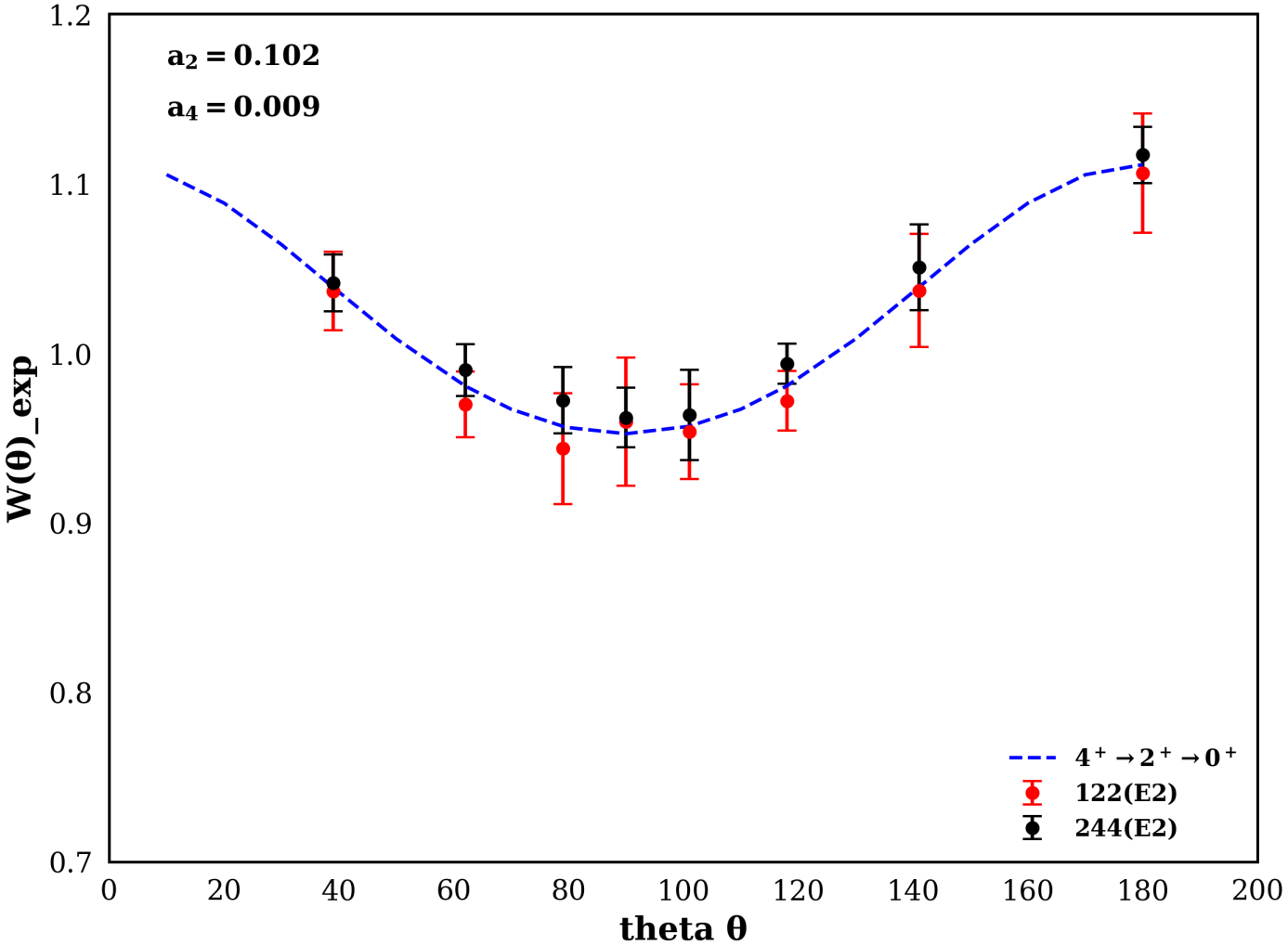


Figure 9.

ANGULAR CORRELATION RESULTS

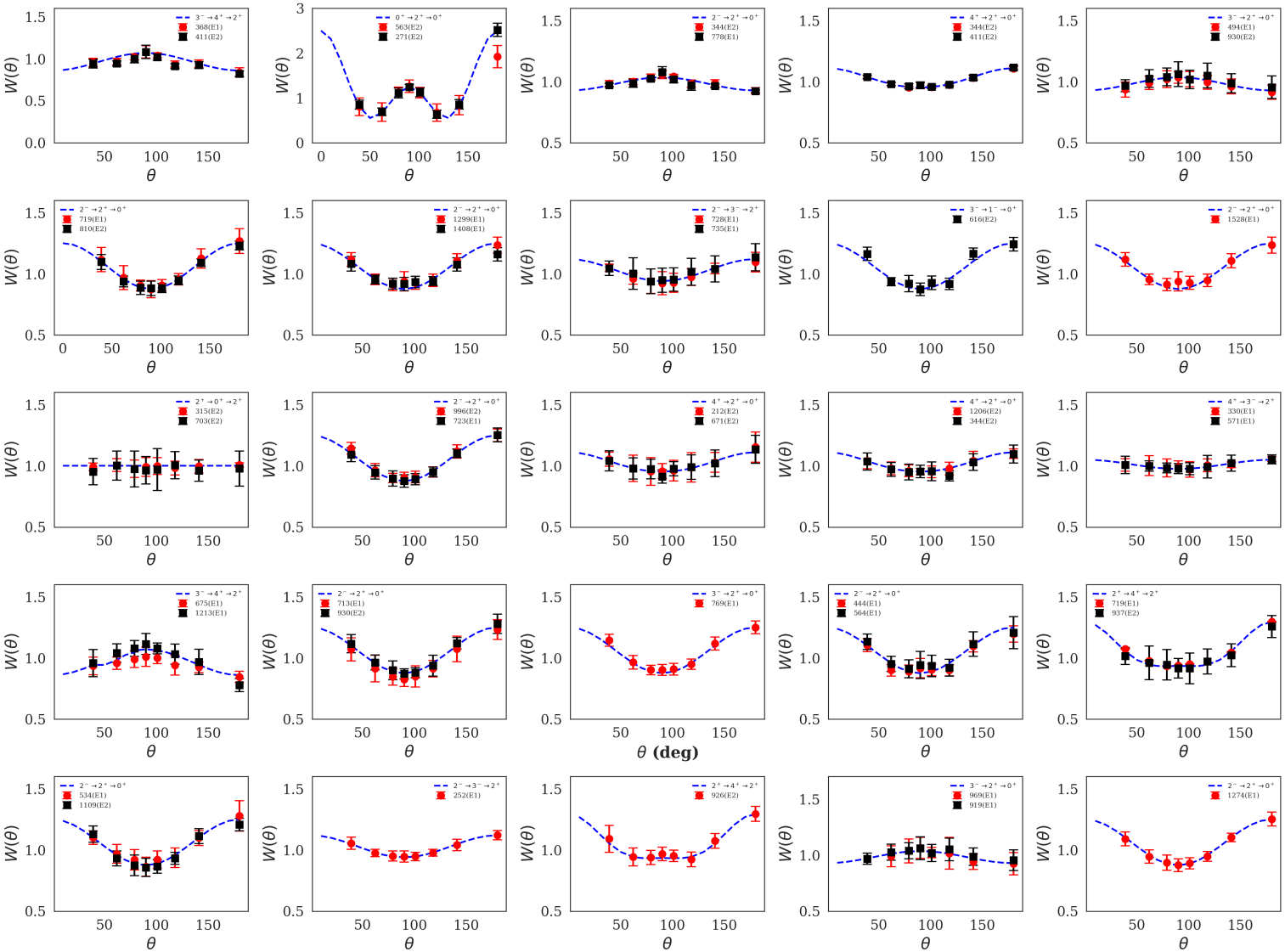


Figure 10.

POLARIZATION SENSITIVITY RESULTS

- Polarization sensitivity,

$$\mathrm{Q_{exp}}(\mathrm{E}_\gamma) = \mathrm{Q_{pt}}\left(\mathrm{E}_\gamma \cdot b_1 + b_0\right). \tag{5}$$

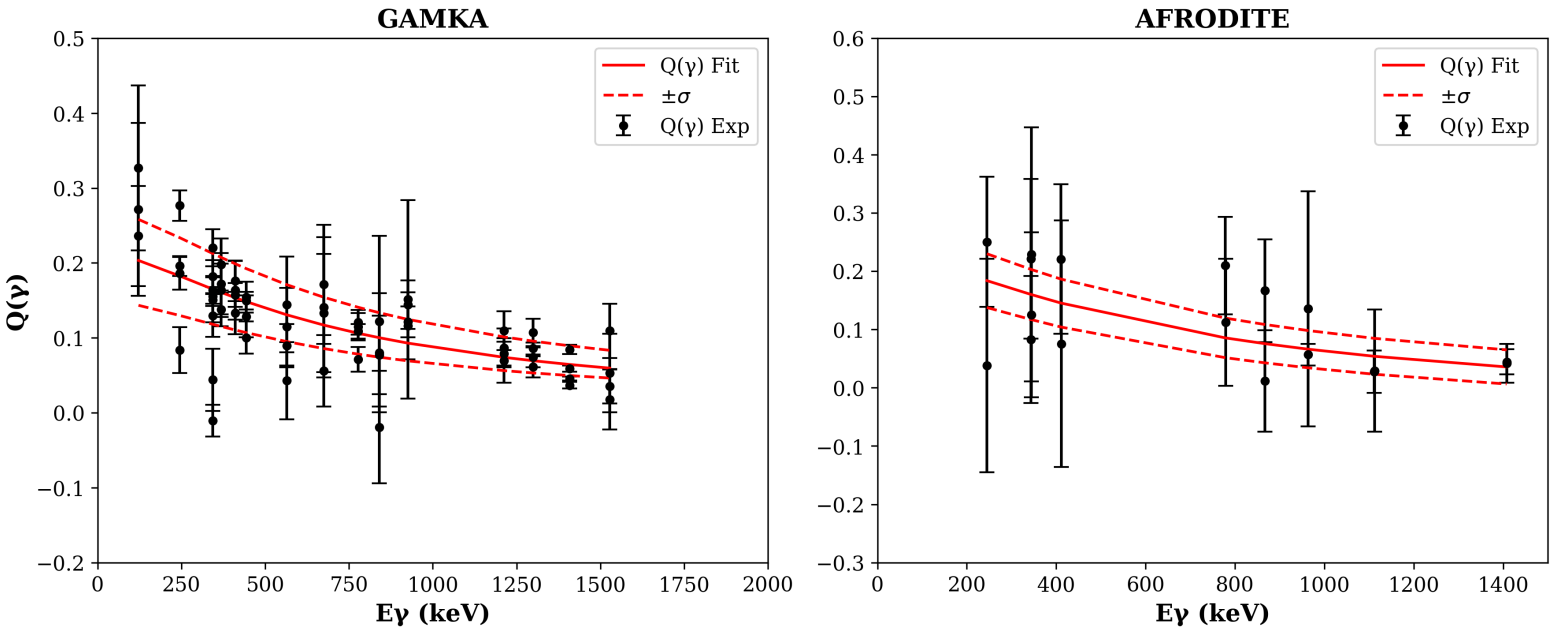


Figure 11.

MIXING RATIO RESULTS

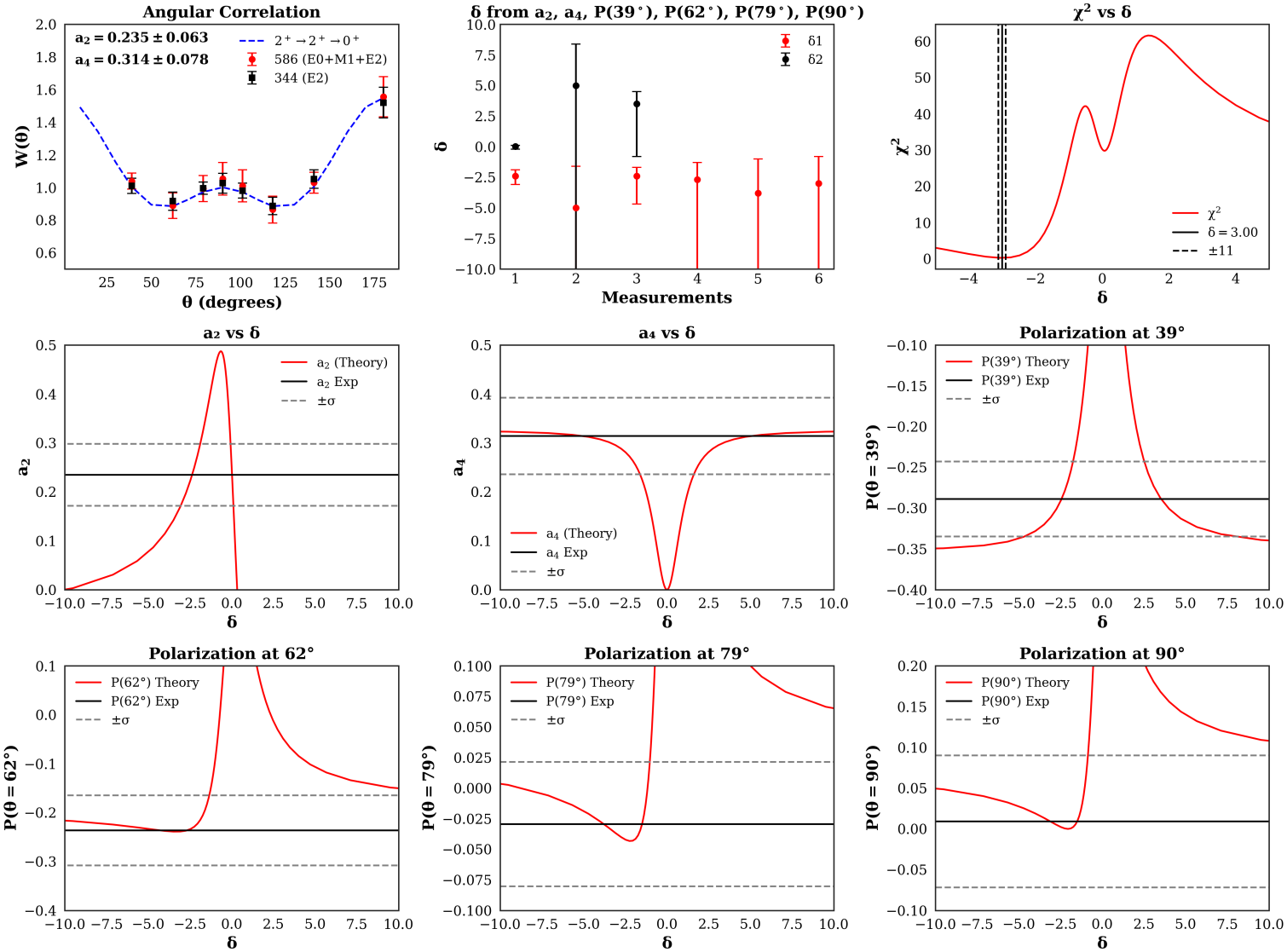


Figure 12.

Combining angular correlation and linear polarization

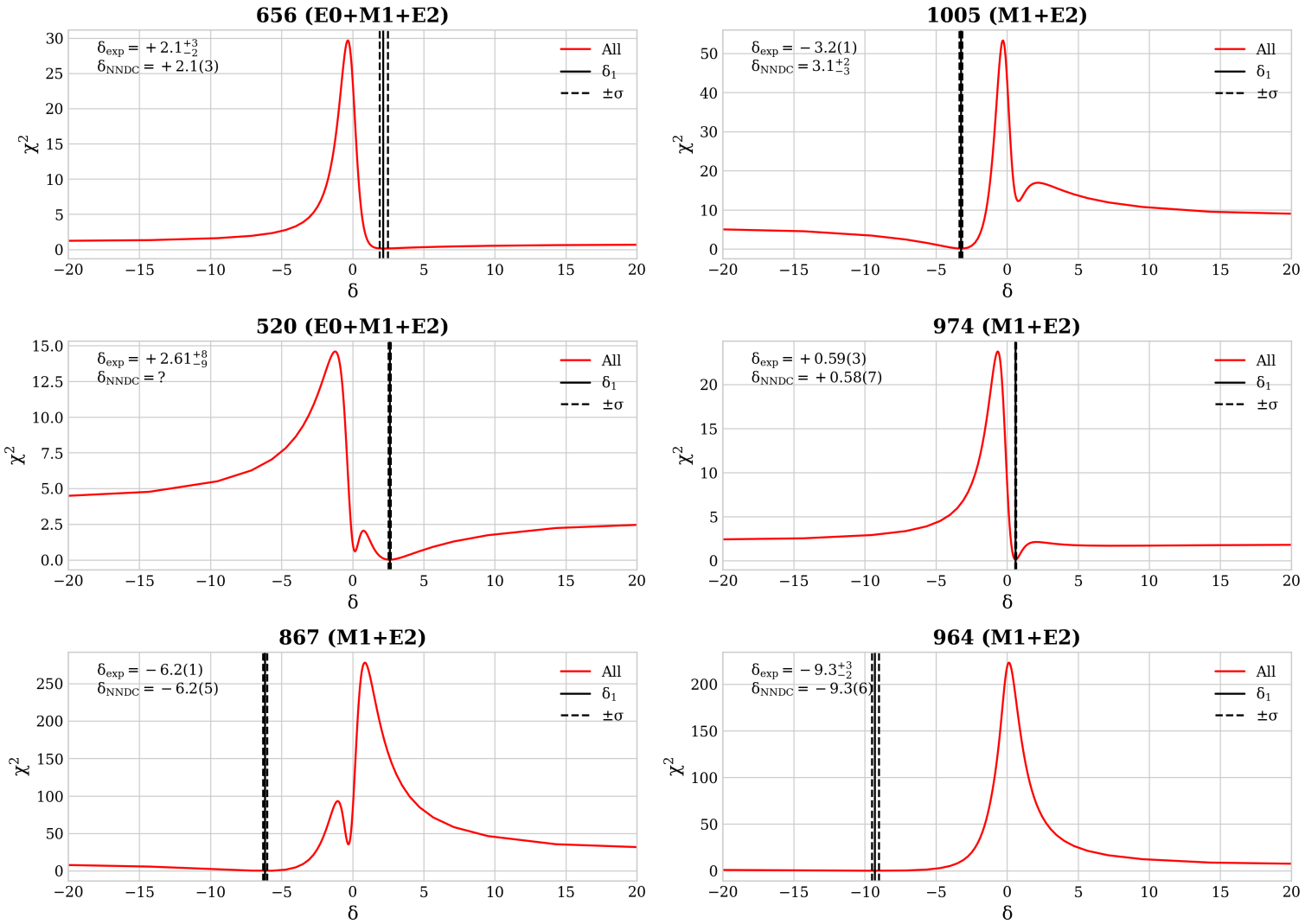


Figure 13.

Mixing ratios Results

Peak	Delta_1	Delta_2	NNDC
586(E0+M1+E2)	-3.00(11)		-3.05(14)
656(E0+M1+E2)	+2,1(+3-2)		2.1(3)
678(M1+E2)	+4.0(4)	0.11(+12-9)	+4.1(+17-11)
688(E0+M1+E2)	+10(+9-3)		+19(+5-4)
765(E0+M1+E2)	+4.3(+5-4)		+4.3(+7-6)
867(M1+E2)	-6.2(1)		-6.2(5)
488(M1+E2)	+5.4(3)	-0.05(+6-4)	+5.6(5)
964(M1+E2)	-9.3(+3-2)		-9.3(6)
1005(M1+E2)	-3.2(1)		-3.1(+2-3)
1112(M1+E2)	-8.5(+5-6)	-0.13(+10-12)	-8.7(6)
974(M1+E2)	+0.589(3)	+7.5(+22-4)	+0.58(7)
1090(M1+E2)	+18(+3-2)	-0.08(+4-5)	+22(+13-6)
794(M1+E2)	-1.01(10)		-0.4(+7-12)
675(M1+E2)	+2.3(1)		+2.2(4)
873(M1+E2)	-8.8(+7-6)	-0.59(4)	−9.4(4)
1348(M1+E2), J=2	+14(+11-9)		+12 (+9−4)
1348(M1+E2), J=3	-0.06(+8-9)		δ=−13(+4−7)
482(E0+M1+E2)	-14(+4-9)	+0.46(+13-10)	
526(E0+M1+E2)	-1.03(+3-7)		
503(M1+E2)	-0.06(8)		
538(M1+E2)	+0.24(+26-27)		
520(M1+E2)	+2.61(+8-9)	+0.165(6)	
324(M1+E2)	+0.16(+5-6)	+3.3(+9-6)	

Table 1.

SUMMARY

- Developed a polarization measurement technique for γ-rays from non-oriented nuclear states using clover detectors.
- Used the technique to measure polarization sensitivity for the clover detectors of the iThemba LABS AFRODITE and GAMKA array.
- Measured the angular correlation coefficients for more than 50 pure transitions for the γ rays observed in the beta decay of ^{152}Eu.
- Combined linear polarization and angular correlation measurements deduce the mixing ratio for mixed transitions.
- Measured mixing ratios for 24 γ rays with mixed nature 6 of which have been measured for the first time.

REFERENCES

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Thank You!