

Next to Next to Lowest Order Electromagnetic Decay Multipolarities for Angular Distributions and Linear Polarization Measurements

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Introduction

Most of the time, for in beam gamma ray spectroscopy, the electromagnetic decay associated with de-excitation of an excited state of an aligned nucleus from the state $J_i^\pi \rightarrow J_f^\pi$ can have multiple allowed multipolarities L , and the most common multipolarities that have been studying are the lowest order $L_1 = |J_i - J_f|$ up to the next to lowest order $L_2 = L_1 + 1$. Here, we try to explore the additional role of the next to next to lowest order $L_3 = L_1 + 2$ multipolarity for the angular distributions and linear polarization measurements.

Experimental Details

The experiment was carried out at the John D. Fox Laboratory at Florida State University using Clarion2-Trinity array [1] with the following description:

- $^{16}\text{O} + ^{18}\text{O}$ at $E_{\text{lab}} = 30$ MeV.
- 9 HPGe Clovers+ BGO Shields arranged at: $\theta = (48.24^0, 90.0^0, 131.75^0, 150^0)$.
- 26 charged particle detector arrays at two forward angles 19^0 and 39^0 .
- Beam on Target rate 100 nA.
- Data were stored in singles mode.
- Each Physics event is distinguished based on the coincidence with protons or alphas or both along with the gamma ray as shown in Fig.1.

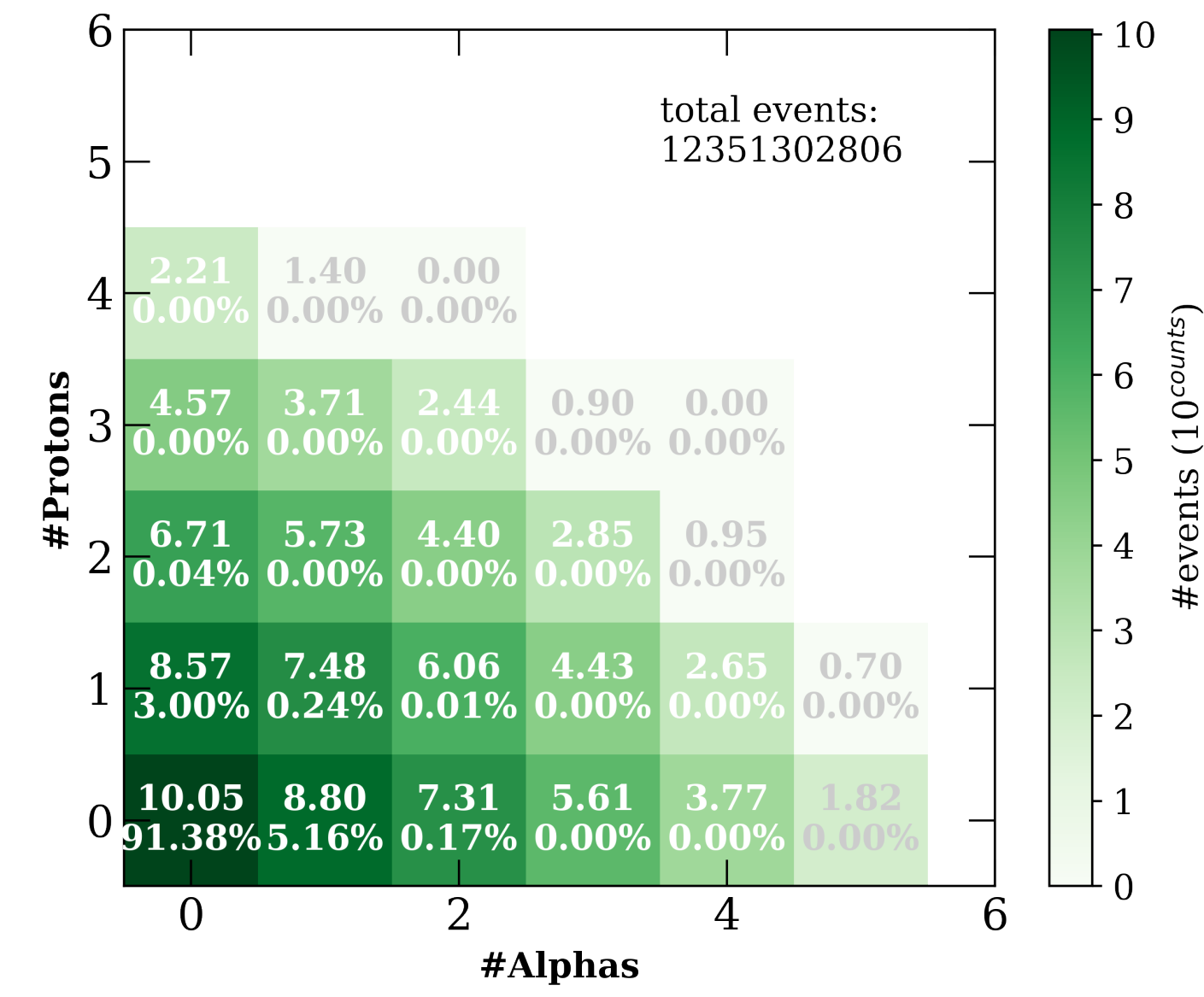


Figure: Event by Event Light Charged Particle Multiplicities in Coincidences with gamma ray in $^{16}\text{O} + ^{18}\text{O}$ from Clarion2-Trinity.

Protons and Alphas were identified through the utilization of PSD from the waveform stored as QDC sum and distinguished based on the peak, tail and the integrated sum of the waveform from the charged particle detector hits via:

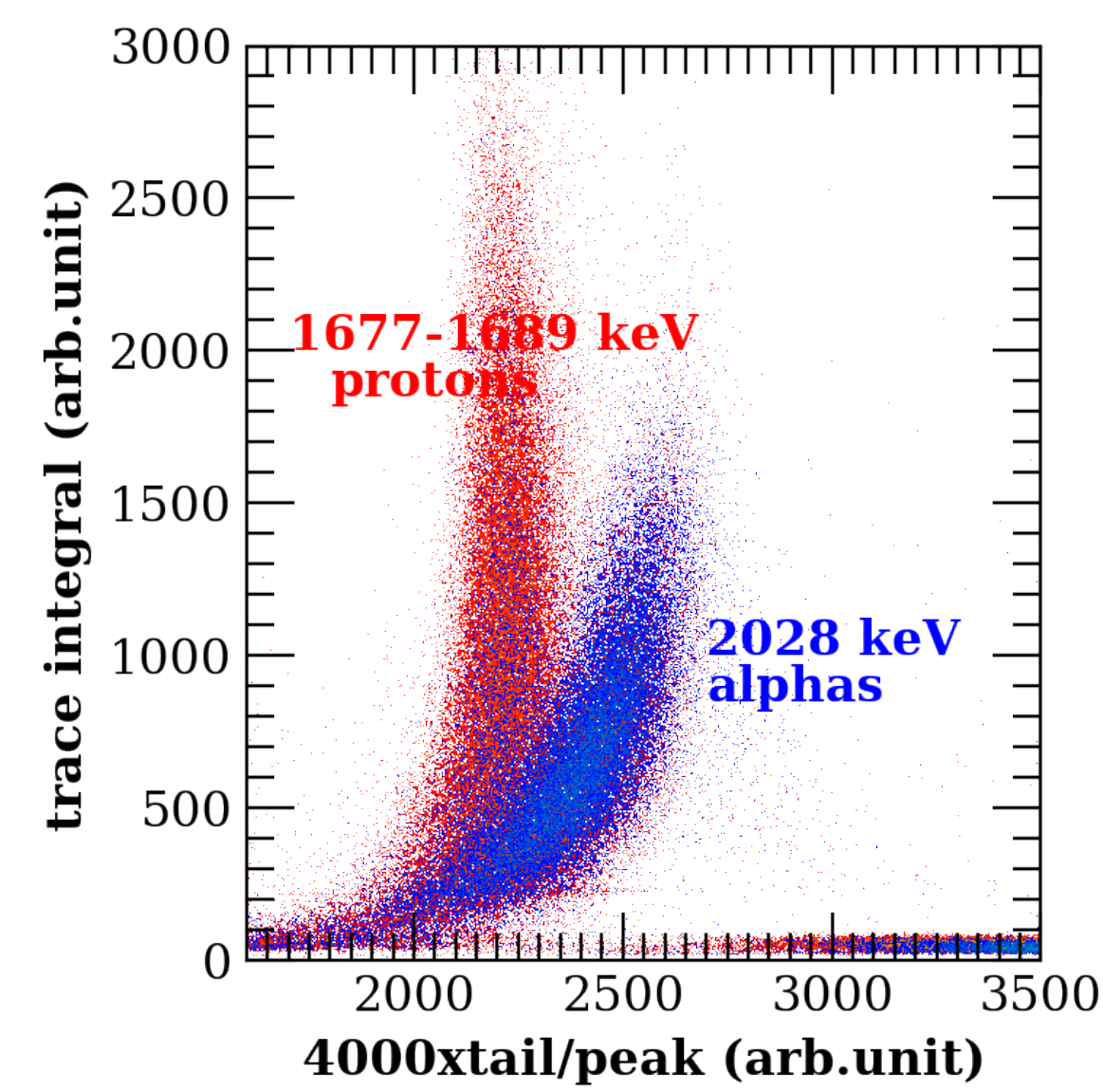


Figure: Gamma Gated PID from $^{16}\text{O} + ^{18}\text{O}$ data.

$$\begin{aligned} \text{peak} &= \text{QDC}[3] - \frac{20}{31 + 29} (\text{QDC}[0] + \text{QDC}[1]), \\ \text{tail} &= \text{QDC}[5] - \frac{55}{31 + 29} (\text{QDC}[0] + \text{QDC}[1]), \\ \text{tracesum} &= \text{QDC}[2] + \text{QDC}[3] + \text{QDC}[4] + \text{QDC}[5] \\ &\quad + \text{QDC}[6] - \frac{115}{31 + 29} (\text{QDC}[0] + \text{QDC}[1]). \end{aligned} \quad (2)$$

To get better selectivity when applying cuts mainly at lower energy where the separation between protons and alphas tend to disappear, PID is made based on coincidences with the known strong gamma ray from the channel that we are looking at.

Formalism

The electromagnetic decay from an excited state of aligned nuclei can be studied without any dependency with the model. By expanding the formalism of angular distributions from [3], the expression of angular distributions as measured with respect to the beam axis θ is described by:

$$\begin{aligned} W_K(\theta) &= B_K(J_i) P_K(\cos \theta) [\\ &\quad R_K(L_1 L_1 J_i J_f) + 2R_K(L_1 L_2 J_i J_f) \delta_{21} \\ &\quad + 2R_K(L_1 L_3 J_i J_f) \delta_{31} \\ &\quad + 2R_K(L_2 L_3 J_i J_f) \delta_{31} \delta_{21} \\ &\quad + R_K(L_2 L_2 J_i J_f) \delta_{21}^2 + R_K(L_3 L_3 J_i J_f) \delta_{31}^2]. \end{aligned} \quad (3)$$

If the gamma ray detector is sensitive with the linear polarization, eq.(3) can be modified to include the role of polarization factor γ , in which by extending the formalism done by ref.[2], the polarized intensity $W(\gamma, \theta)$ would be:

$$\begin{aligned} W_K(\theta, \gamma) &= B_K(J_i) P_K(\cos \theta) [R_K(L_1 L_1 J_i J_f) + 2R_K(L_1 L_2 J_i J_f) \delta_{21} \\ &\quad + 2R_K(L_1 L_3 J_i J_f) \delta_{31} + 2R_K(L_2 L_3 J_i J_f) \delta_{31} \delta_{21} \\ &\quad + R_K(L_2 L_2 J_i J_f) \delta_{21}^2 + R_K(L_3 L_3 J_i J_f) \delta_{31}^2] \\ &\quad + B_K(J_i) (\cos 2\gamma) P_K^{(2)}(\cos \theta) [\\ &\quad + (\pm)_{L_1} \kappa_K(L_1 L_1) R_K(L_1 L_1 J_i J_f) \\ &\quad + (\pm)_{L_2} 2\kappa_K(L_1 L_2) R_K(L_1 L_2 J_i J_f) \delta_{21} \\ &\quad + (\pm)_{L_3} 2\kappa_K(L_1 L_3) R_K(L_1 L_3 J_i J_f) \delta_{31} \\ &\quad + (\pm)_{L_3} 2\kappa_K(L_2 L_3) R_K(L_2 L_3 J_i J_f) \delta_{31} \delta_{21} \\ &\quad + (\pm)_{L_2} \kappa_K(L_2 L_2) R_K(L_2 L_2 J_i J_f) \delta_{21}^2 \\ &\quad + (\pm)_{L_3} \kappa_K(L_3 L_3) R_K(L_3 L_3 J_i J_f) \delta_{31}^2]. \end{aligned} \quad (4)$$

Determination of the Alignment Width σ

- The alignment factor contained within the $B_K(J_i)$ factor in eq.(3,4) is proportional to the magnetic distribution of projected initial spin $w(m_i)$.
- The distribution of $w(m_i)$ is assumed to be a Gaussian centered around $\mu = 0$ with the width σ which is determined from the known states.
- In this analysis, σ is chosen to be 1.5 for the majority of gamma transitions.

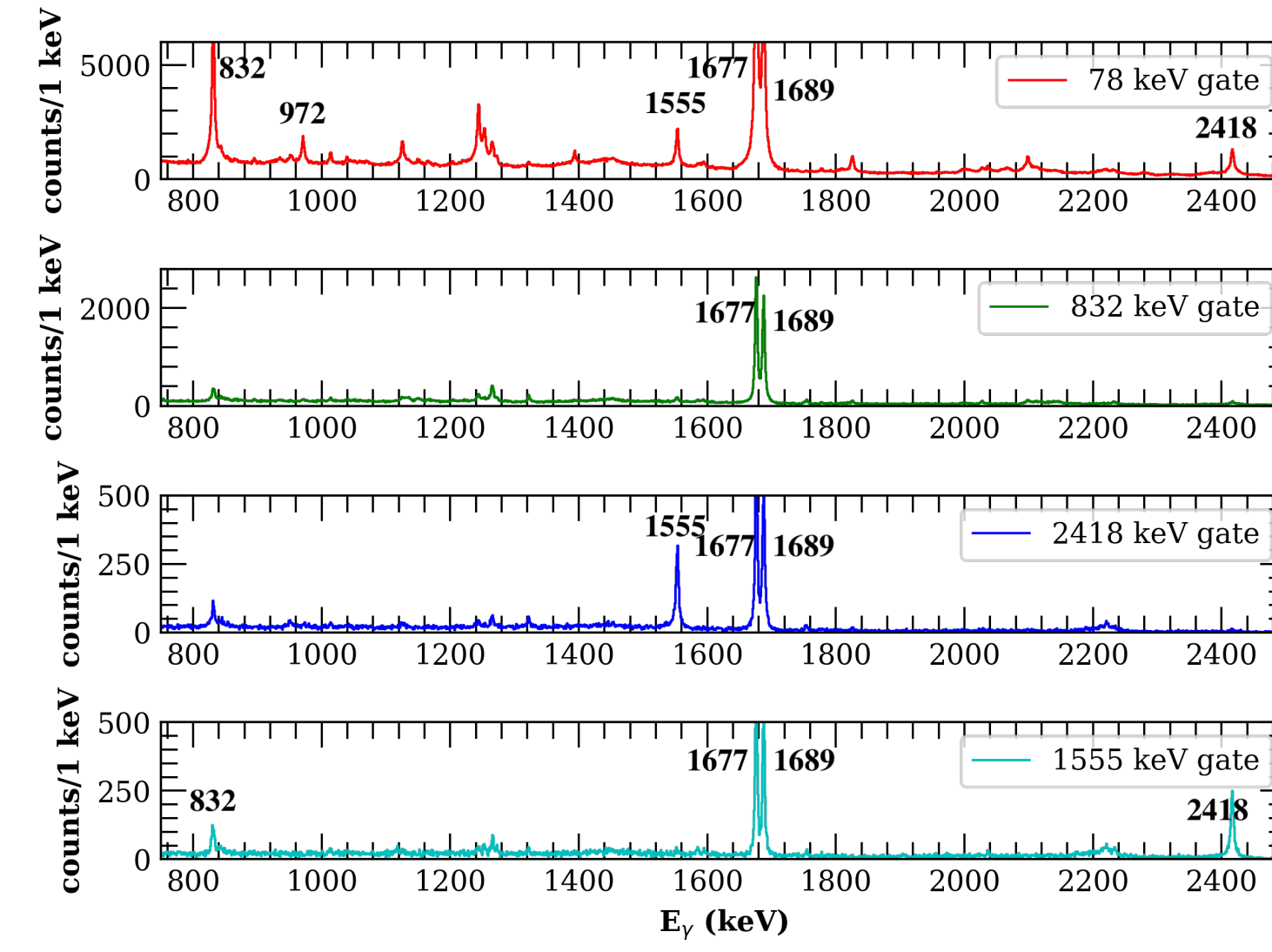


Figure: A representative of gamma gated projection from proton gated gamma-gamma matrix that leads to several gamma transitions in ^{32}P .

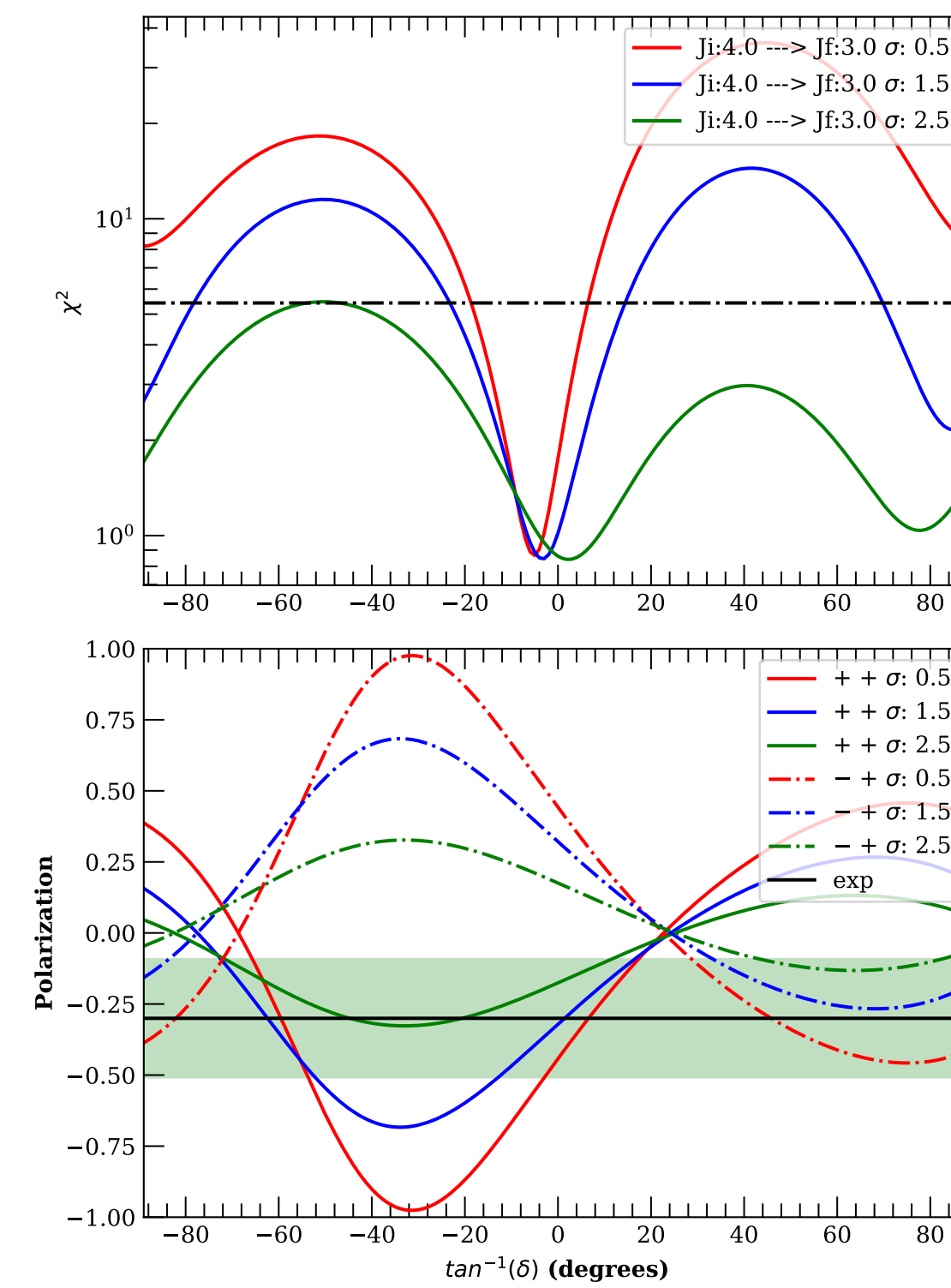


Figure: A representative of Angular Distribution (Top) and Linear Polarization (Bottom) Measurement from 972 keV gamma ray ($4^+ \rightarrow 3^+$) in ^{32}P from 1p channel using three differential values of magnetic alignment width σ . Amongst those, $\sigma = 1.5$ gives the closer agreement between the global minimum of χ^2 and the intersection of predicted polarization with the measured polarizations.

Results and Discussions

