



EUROPEAN UNION



Extreme Light Infrastructure - Nuclear Physics
(ELI-NP)

The electric dipole response of nuclei with $Z < 50$

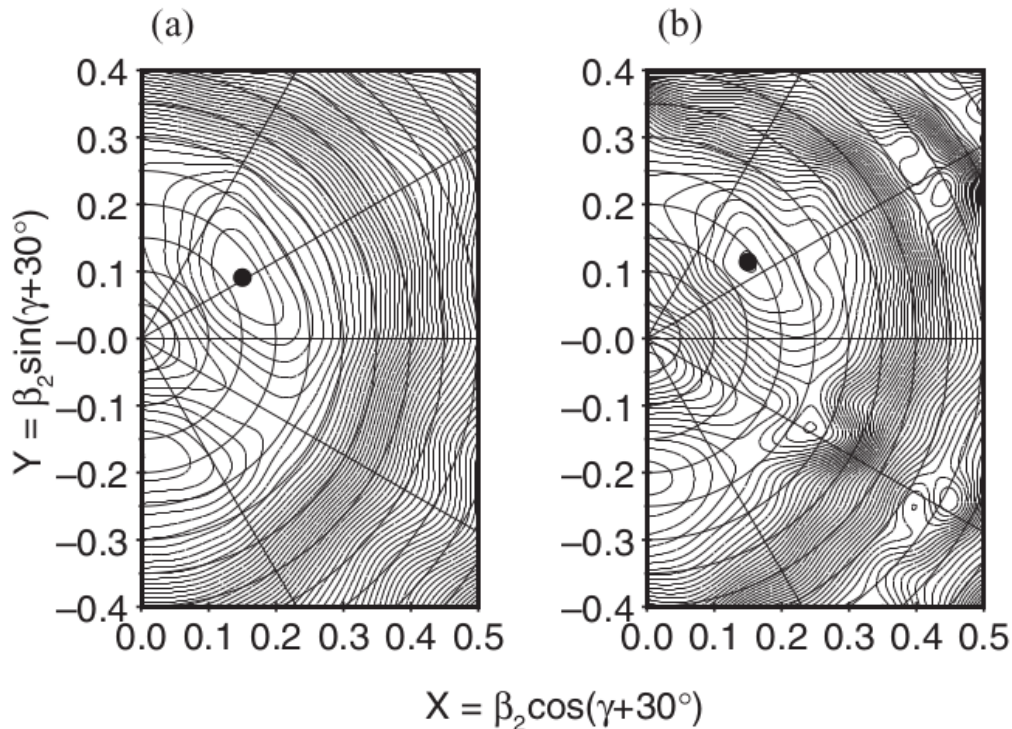
10th Workshop on Nuclear Level Densities and
Gamma Strength – 19 May 2026

TEODORA-MARIA SEBE

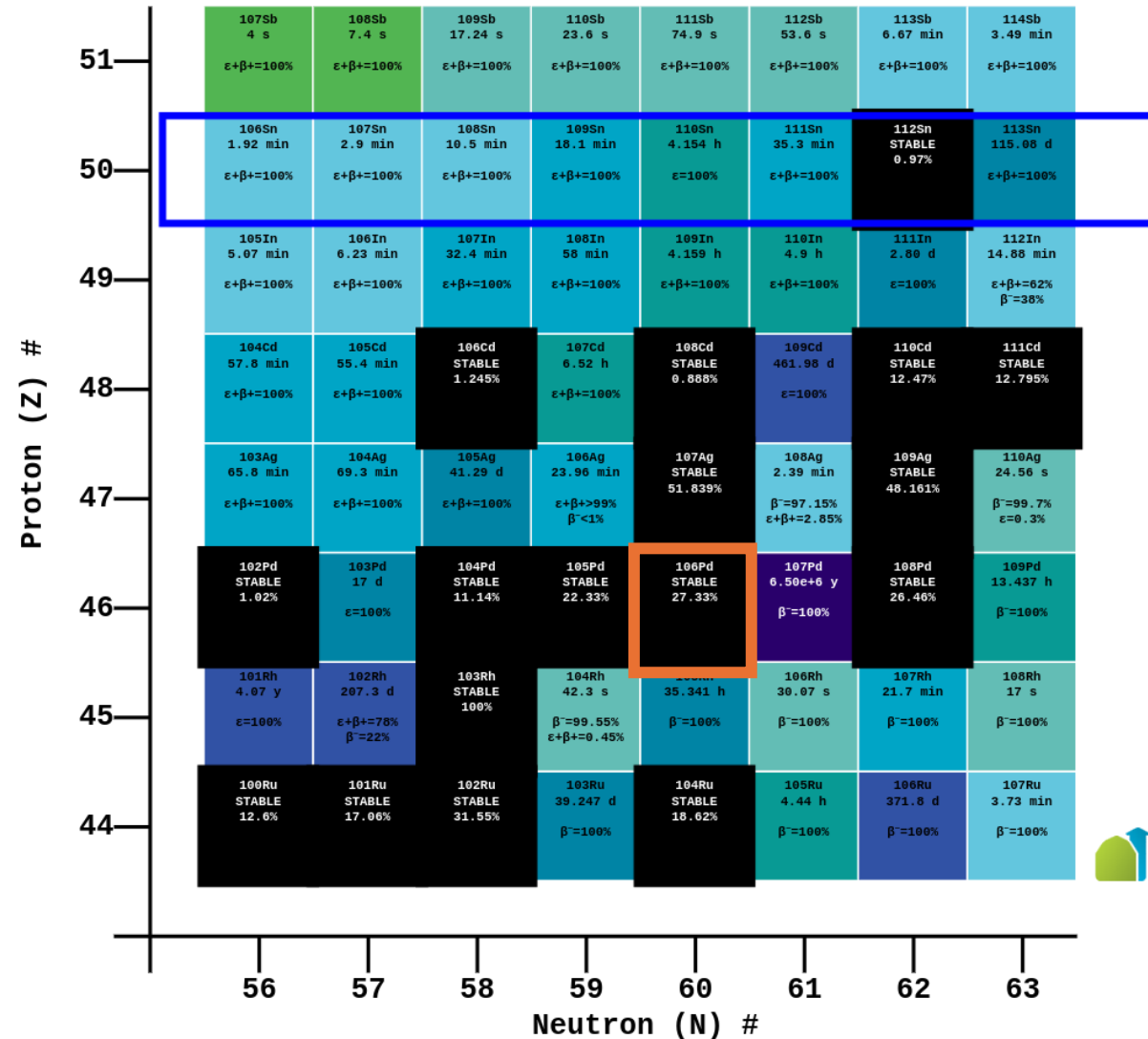


Objectives

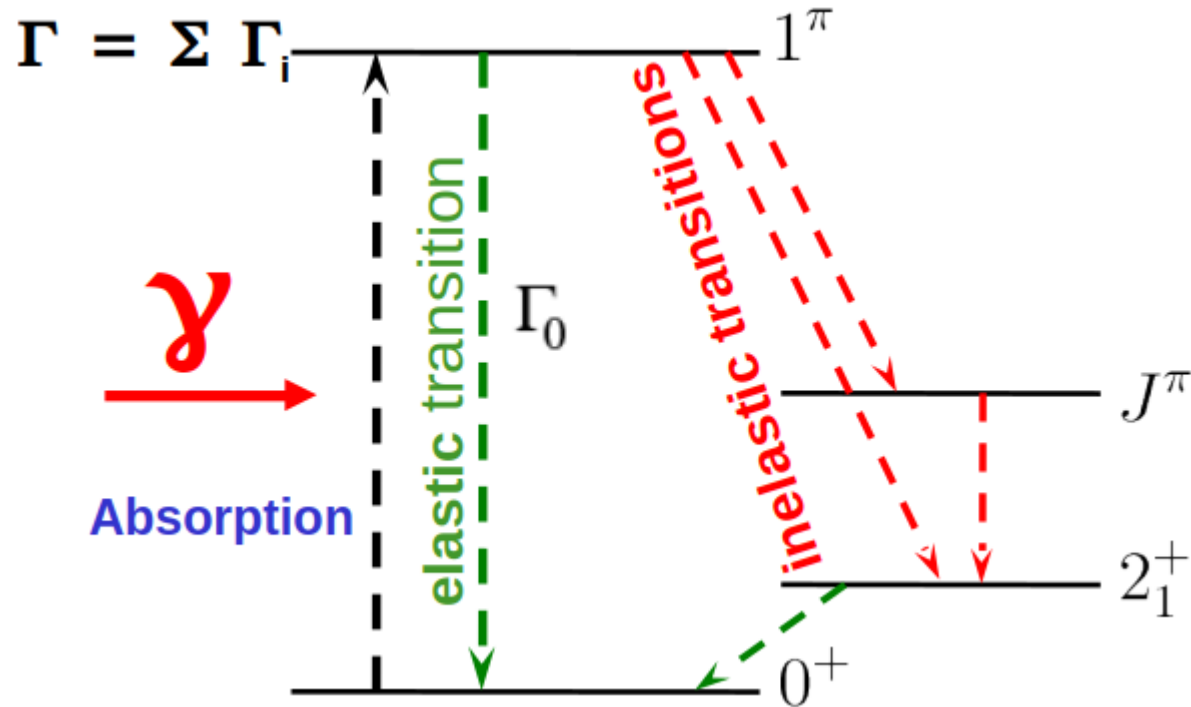
- Determination of the E1 strength
- Determination of the dependence of the E1 strength in the transition region from vibrational to rotational nuclei
- The low-lying E1 states in the transitional Pd nuclei are expected to be weak and strongly fragmented



Potential energy surfaces of the lowest-lying band structures in ^{106}Pd calculated within the tilted-axis cranking model (C.E. He et al., Phys. Rev. C 86, 047302 (2012))



Position of the ^{106}Pd nucleus in the nuclear chart (<https://www.nndc.bnl.gov/nudat3/>)



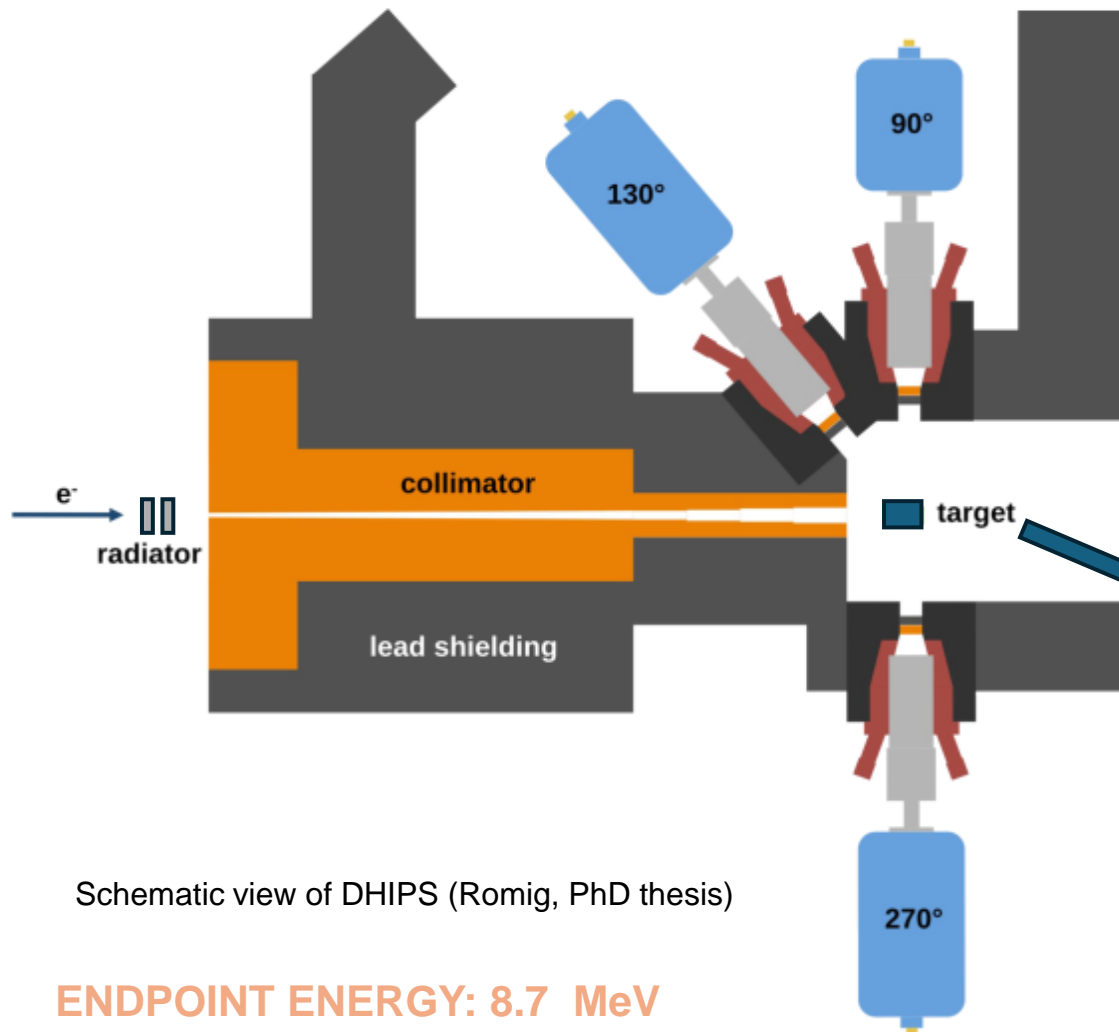
Spectroscopic quantities in NRF experiments:

- integrated photonuclear resonance cross sections $I_{s,f}$
- parity quantum numbers π of nuclear levels
- γ -ray transition energies E_γ
- total level widths Γ
- level lifetimes τ
- spin quantum numbers J of nuclear levels
- decay transition strengths $B(\Pi L; J_\pi \rightarrow J_{ff})$
- multipole-mixing ratios δ of γ -ray transitions

...

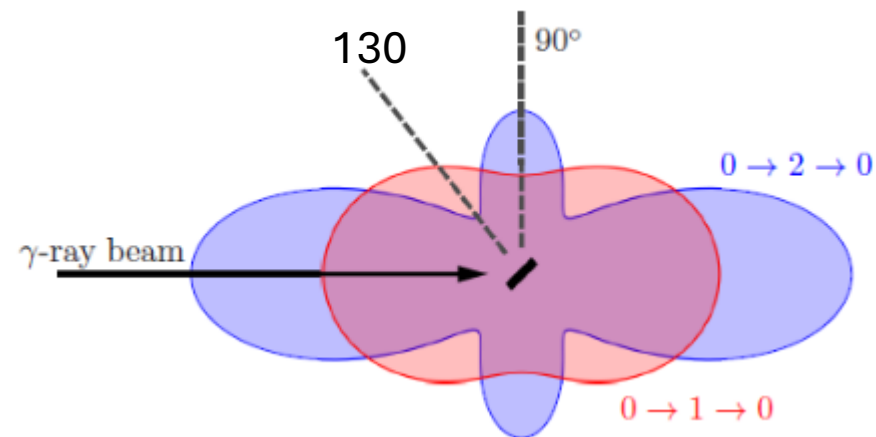
Experimental Setup

- The NRF experiment has taken place at TU Darmstadt, at **DHIPS** (Darmstadt High Intensity Photon Setup)



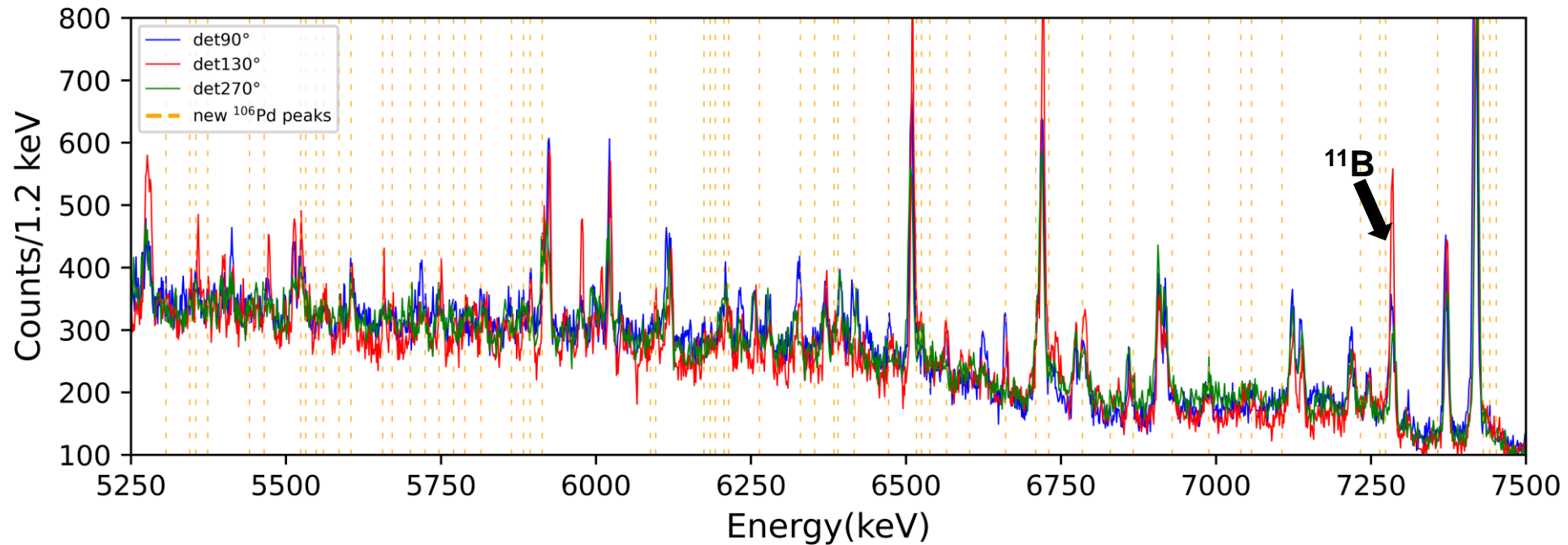
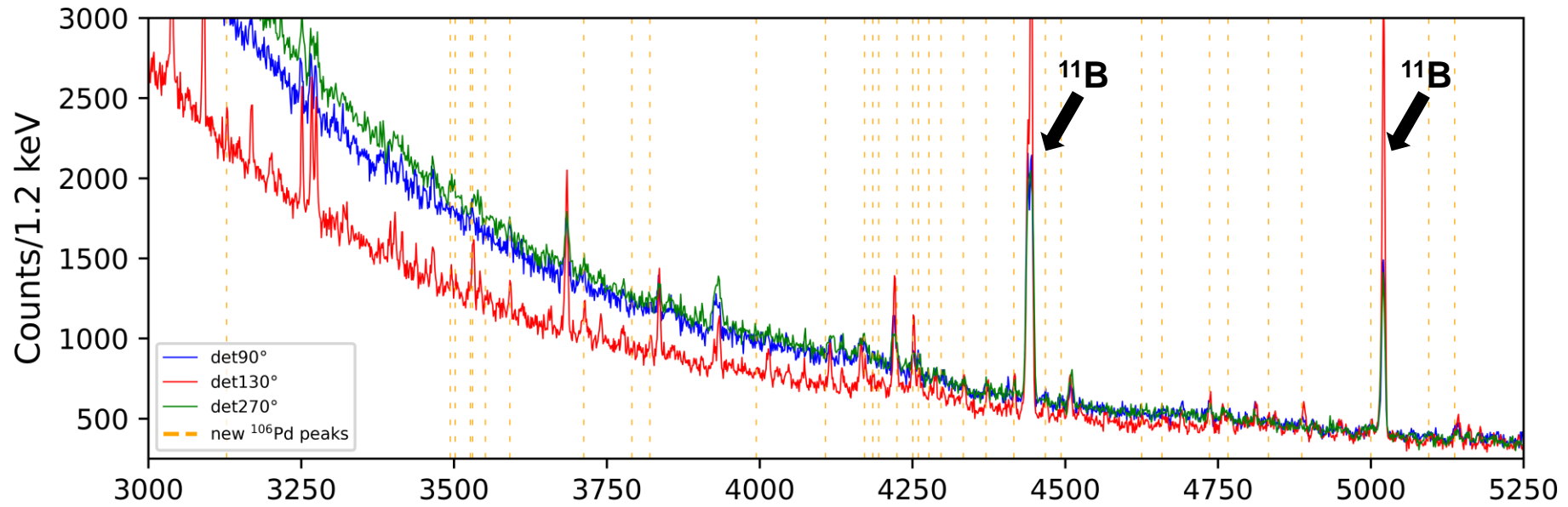
Schematic view of DHIPS (Romig, PhD thesis)

ENDPOINT ENERGY: 8.7 MeV

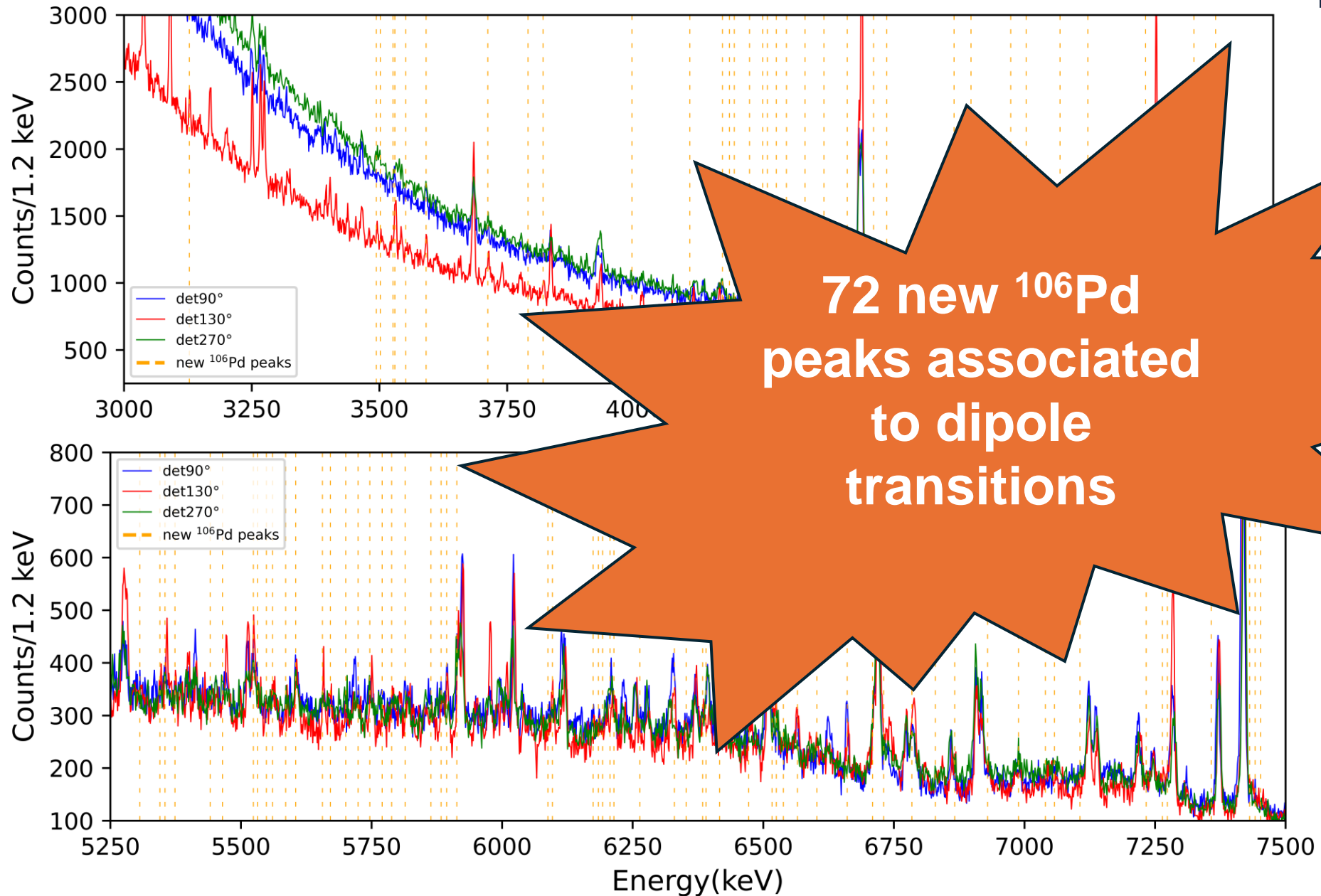


^{106}Pd target

^{106}Pd Spectra in the 3.5-7.5 MeV region



^{106}Pd Spectra in the 3.5-7.5 MeV region



NRF Reactions: Number of Target Nuclei

Final goal: calculating the integrated cross section

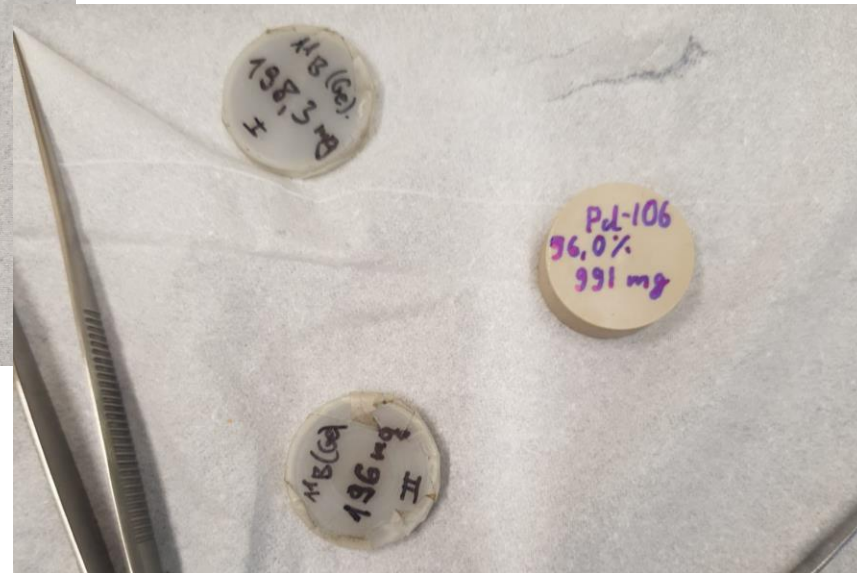
$$A_{j \rightarrow k} = N_T \cdot \varepsilon_{rel} (E_j - E_k) \cdot N_\gamma(E_j) \cdot I_{j \rightarrow k} \cdot W_{i \rightarrow j \rightarrow k}^{eff}(\Theta, \Delta\Omega)$$

Number of counts

Fitting

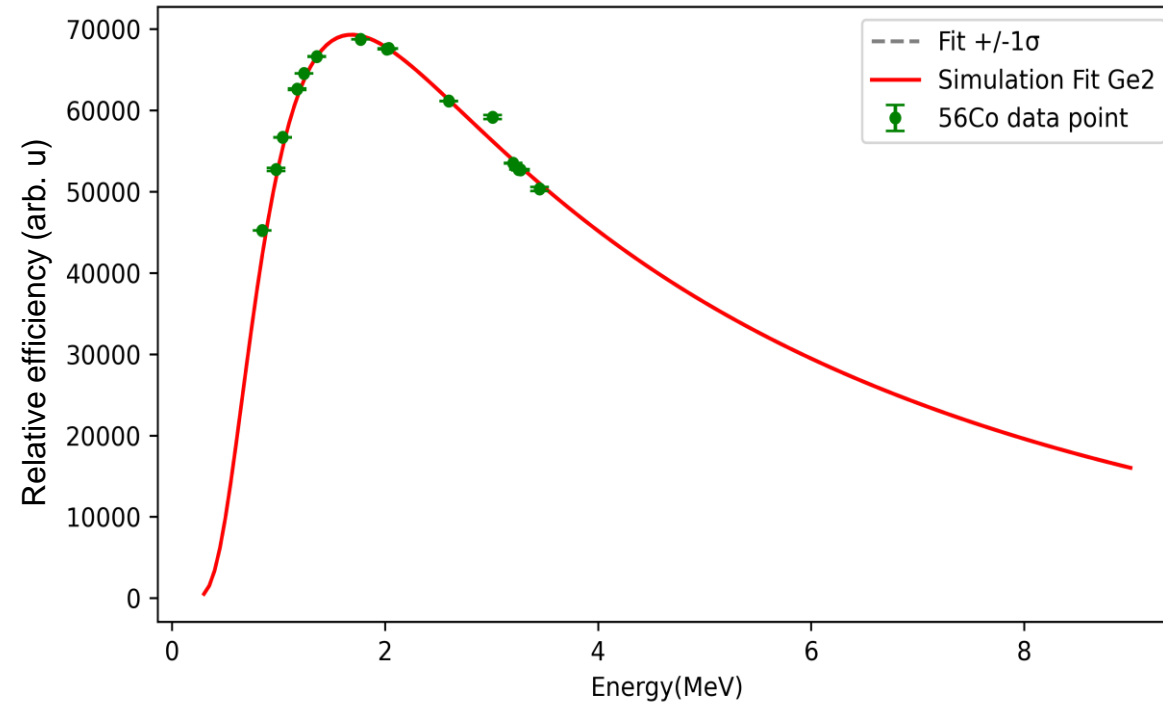


^{106}Pd mass: 0.991(1)g



$$A_{j \rightarrow k} = N_T \cdot \varepsilon_{rel}(E_j - E_k) \cdot N_\gamma(E_j) \cdot I_{j \rightarrow k} \cdot W_{i \rightarrow j \rightarrow k}^{eff}(\Theta, \Delta\Omega)$$

↑ Number of counts
↑ Fitting
↑ Number of target nuclei
↑ Weighting

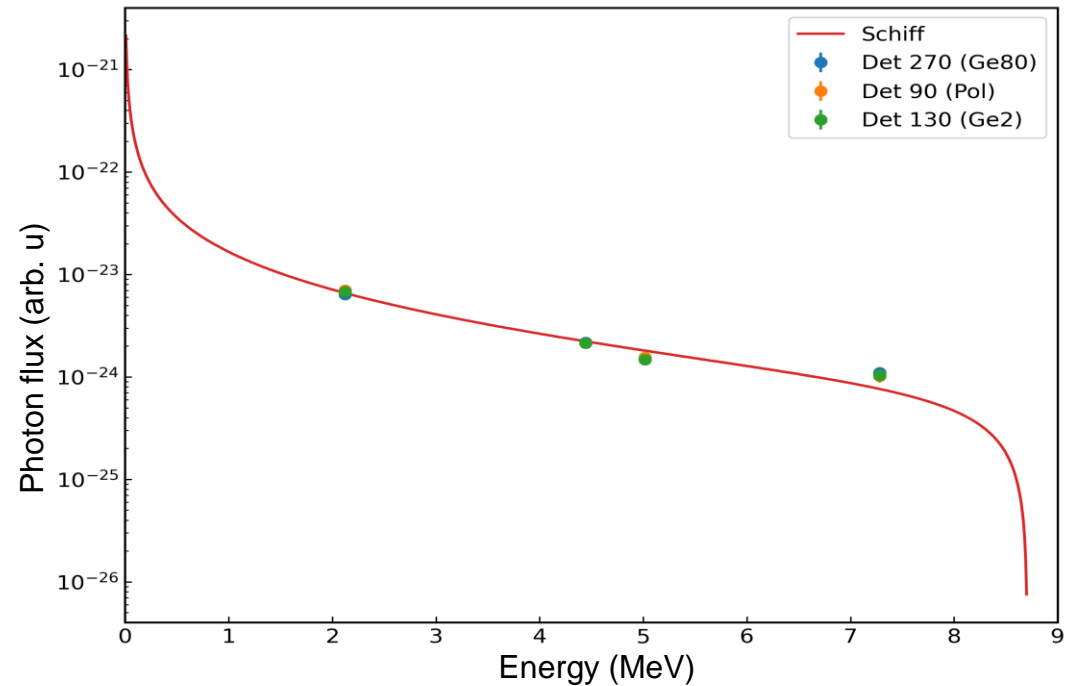


- A ^{56}Co source was used for calibrations
- GEANT4 simulations were used to determine the efficiency for the rest of the spectra

NRF Reactions: Photonflux calibrations

$$A_{j \rightarrow k} = N_T \cdot \varepsilon_{rel}(E_j - E_k) \cdot N_\gamma(E_j) \cdot I_{j \rightarrow k} \cdot W_{i \rightarrow j \rightarrow k}^{eff}(\Theta, \Delta\Omega)$$

Number of counts (Fitting) → $A_{j \rightarrow k}$
Number of target nuclei (Weighting) → N_T
Relative efficiency (GEANT4 Simulations) → $\varepsilon_{rel}(E_j - E_k)$
 $N_\gamma(E_j)$ (Photon flux) → $N_\gamma(E_j)$
 $I_{j \rightarrow k}$ (Branching ratio) → $I_{j \rightarrow k}$
 $W_{i \rightarrow j \rightarrow k}^{eff}(\Theta, \Delta\Omega)$ (Angular distribution) → $W_{i \rightarrow j \rightarrow k}^{eff}(\Theta, \Delta\Omega)$

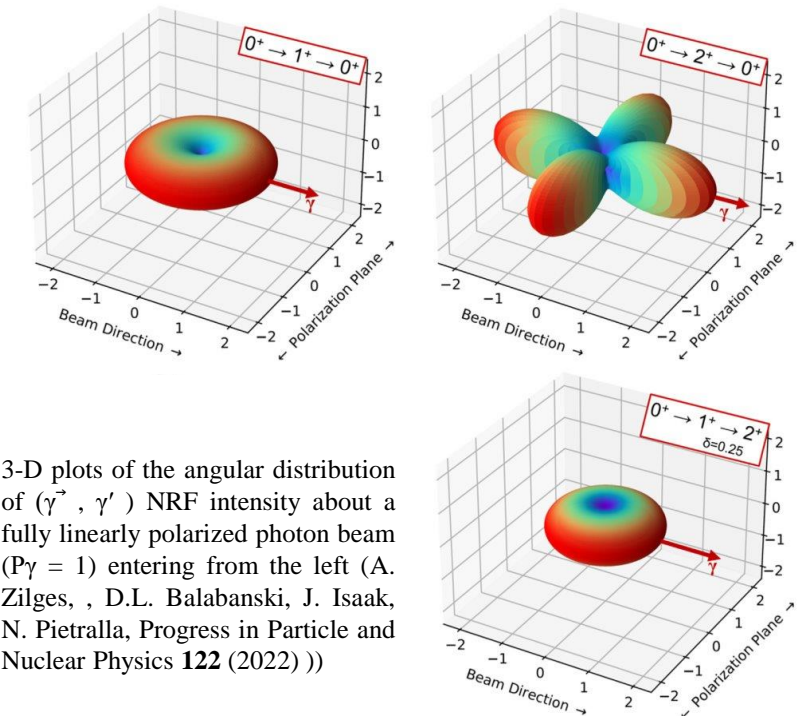
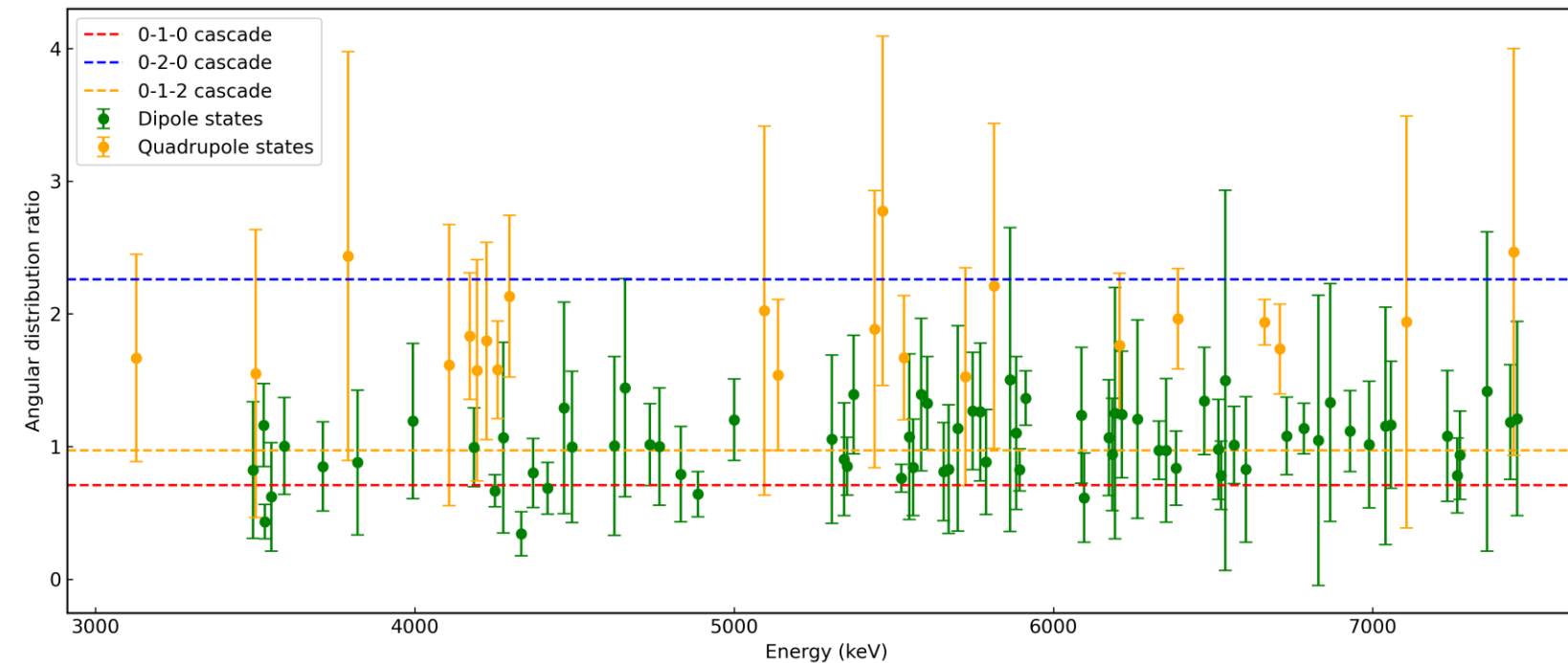


Obtained from Schiff's formula

NRF Reactions: Angular distribution

$$A_{j \rightarrow k} = N_T \cdot \varepsilon_{rel}(E_j - E_k) \cdot N_\gamma(E_j) \cdot I_{j \rightarrow k} \cdot W_{i \rightarrow j \rightarrow k}^{eff}(\Theta, \Delta\Omega)$$

- Depends on the spins of the states involved in the cascade
- Can be calculated from the theory of electromagnetism and yield for an unpolarized photon beam

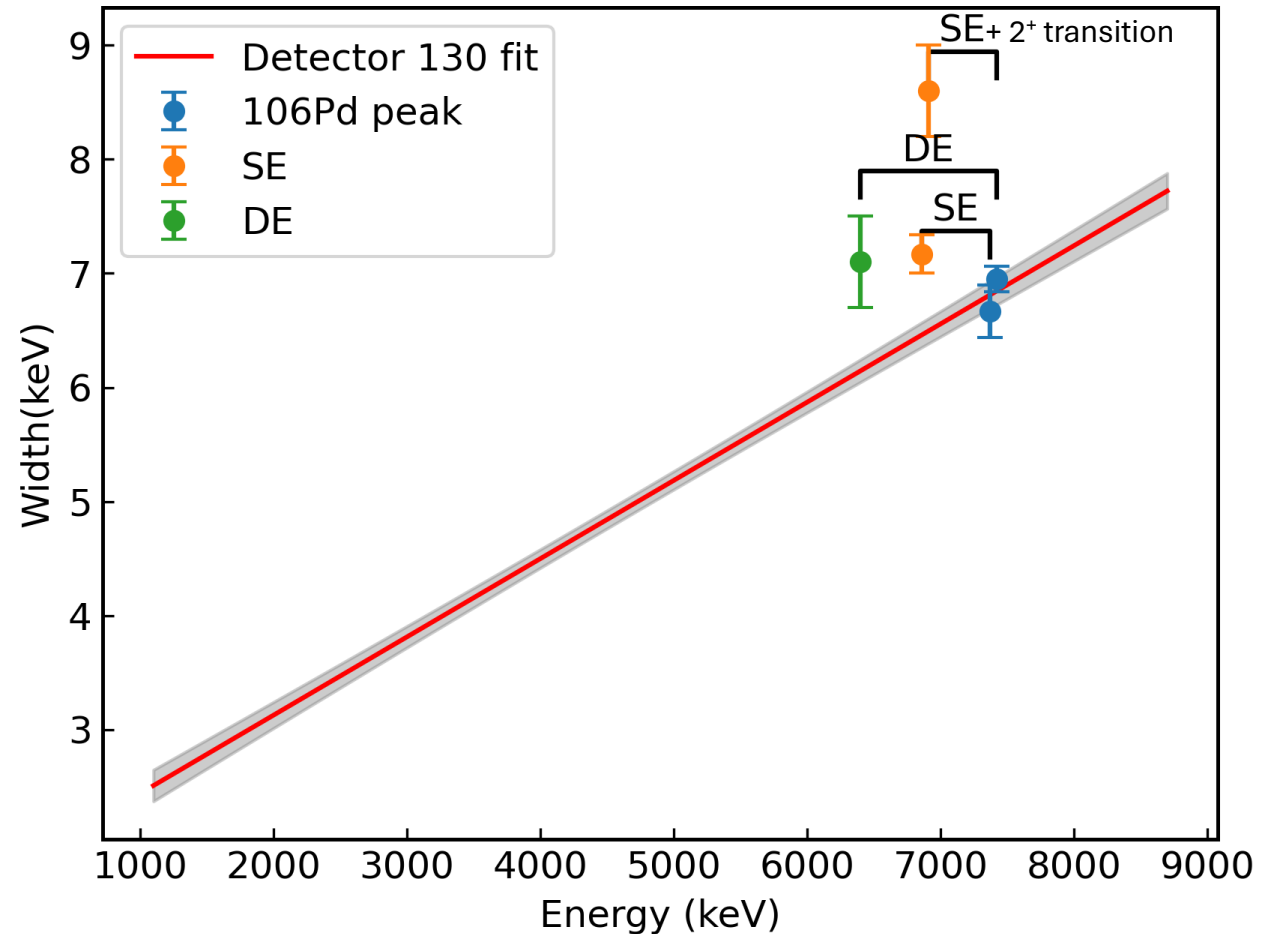


3-D plots of the angular distribution of $(\gamma^{\vec{r}}, \gamma')$ NRF intensity about a fully linearly polarized photon beam ($P_\gamma = 1$) entering from the left (A. Zilges, D.L. Balabanski, J. Isaak, N. Pietralla, Progress in Particle and Nuclear Physics **122** (2022))

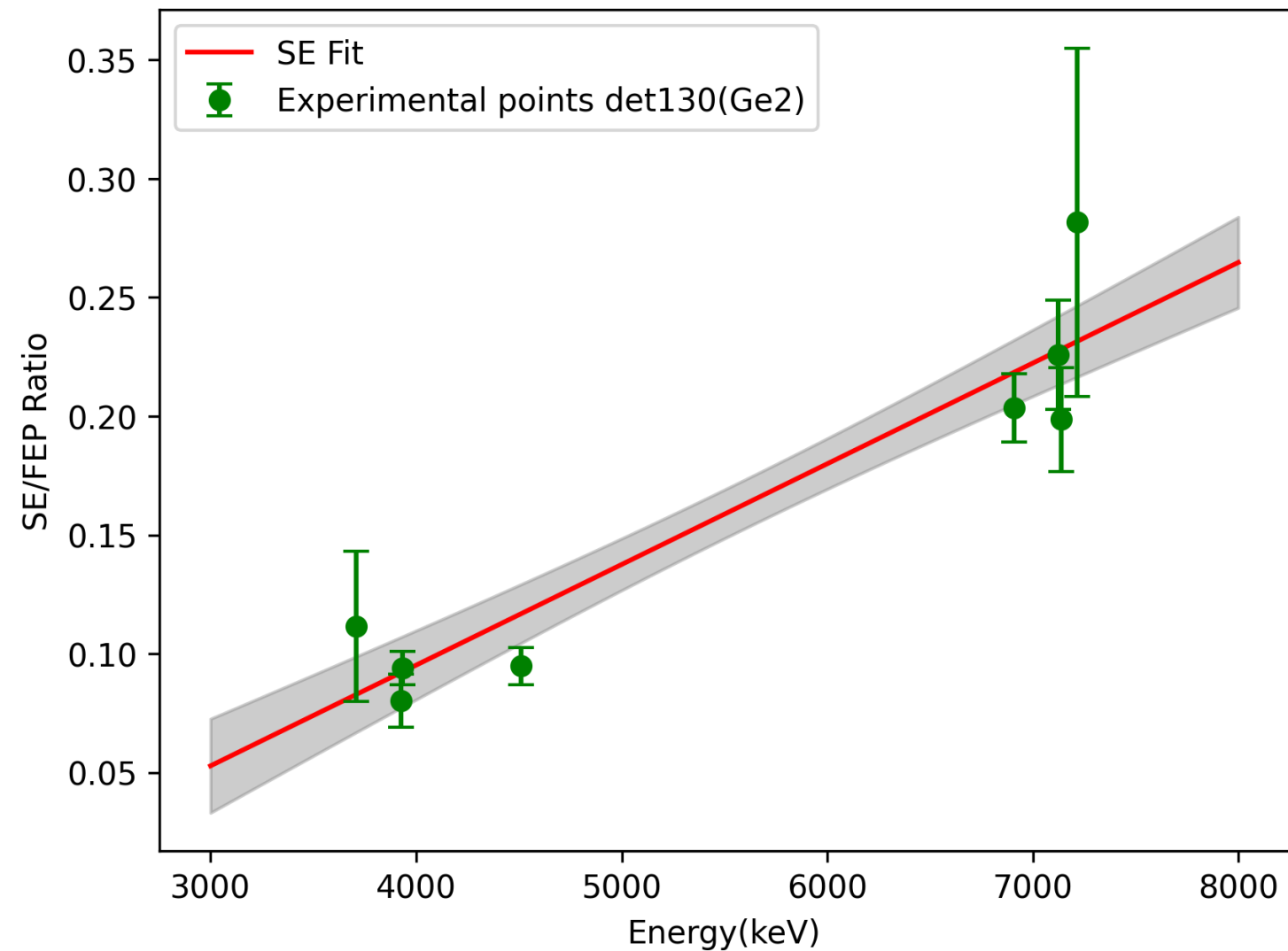
Main issue: the first 2+ level is situated at 511.82 keV

→ Makes it difficult to differentiate between a SE and a transition to the first 2+

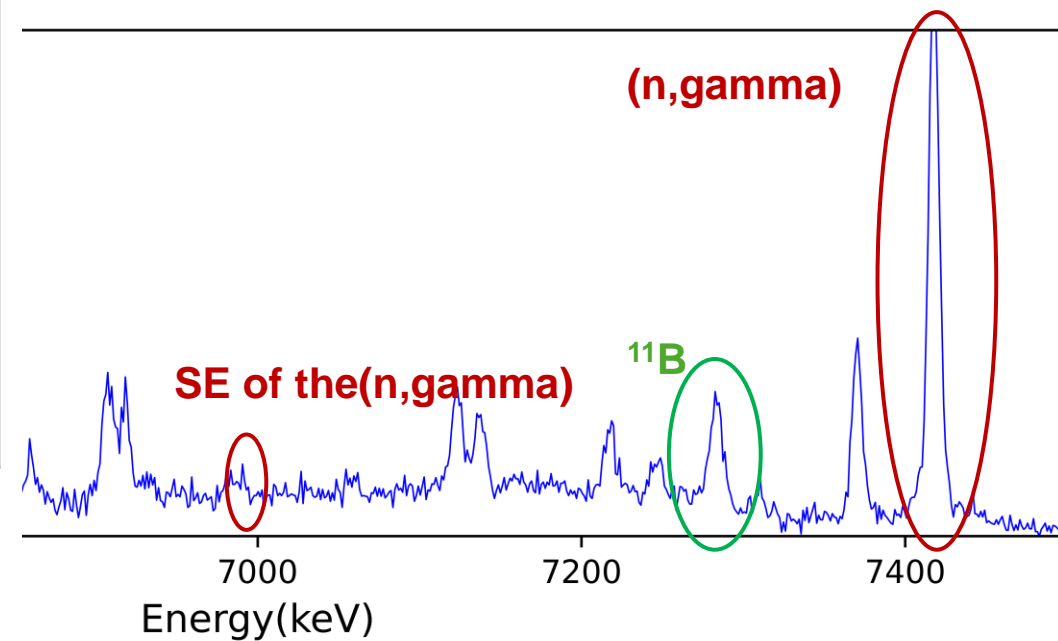
Example of width interpretation in case of a 2+ transition and a SE in a peak



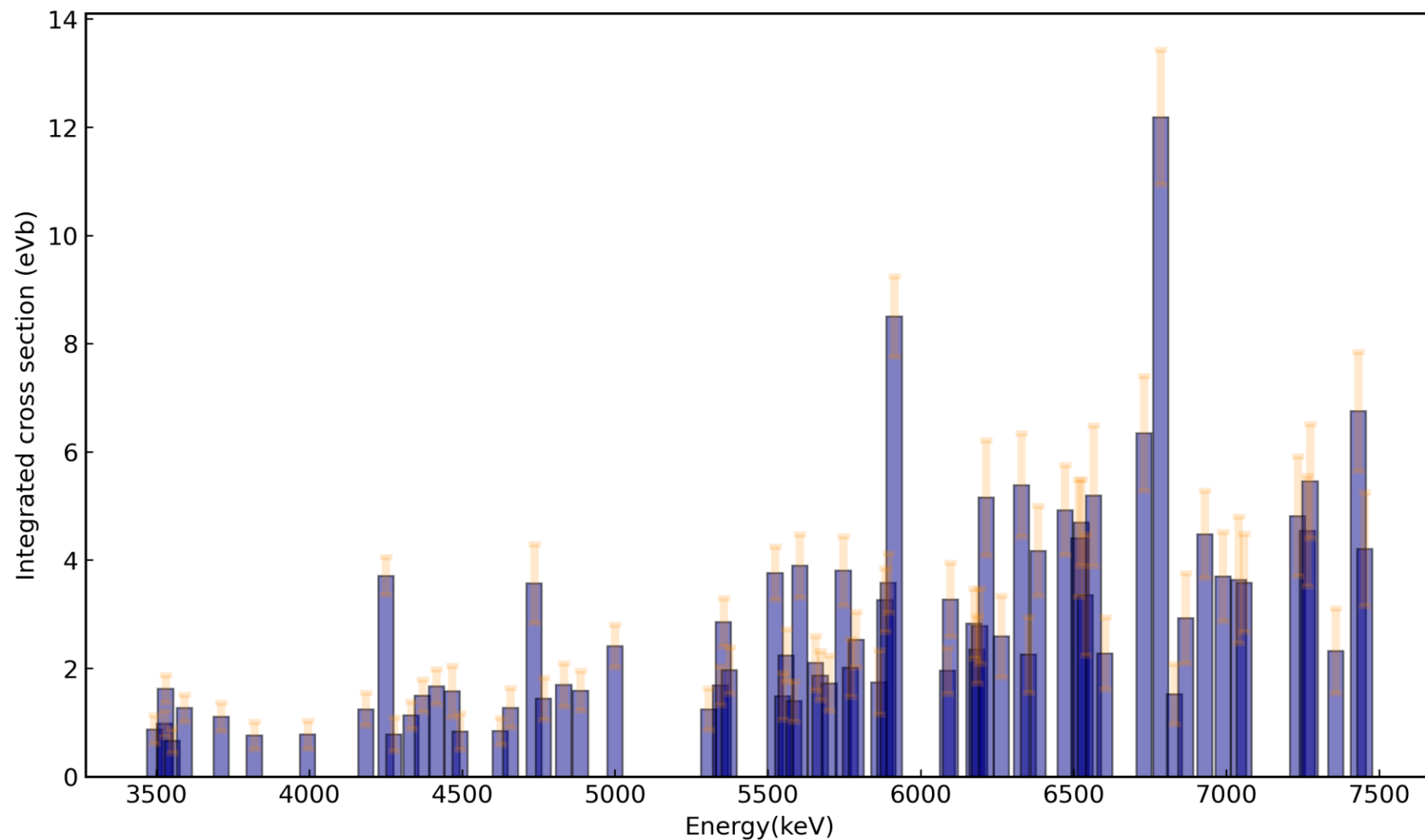
Single-Escape calibrations



SE calibration for the detector at 130 degrees



- The integrated cross section for the excited state – g.s transitions has been calculated, revealing the shape of the PDR.



Branching ratios can be obtained from:

$$I_{i \rightarrow f} = g\pi^2 \left(\frac{\hbar c}{E_i} \right)^2 \frac{\Gamma_0 \Gamma_f}{\Gamma}$$

$$\frac{\Gamma_f}{\Gamma_0} = \frac{I_{i \rightarrow f}}{I_{i \rightarrow 0}} = \frac{A_{i \rightarrow f} \epsilon_{\text{rel}}(E'_{\gamma, i \rightarrow 0}) W_{0 \rightarrow i \rightarrow 0}(\theta)}{A_{i \rightarrow 0} \epsilon_{\text{rel}}(E'_{\gamma, i \rightarrow f}) W_{0 \rightarrow i \rightarrow f}(\theta)}$$

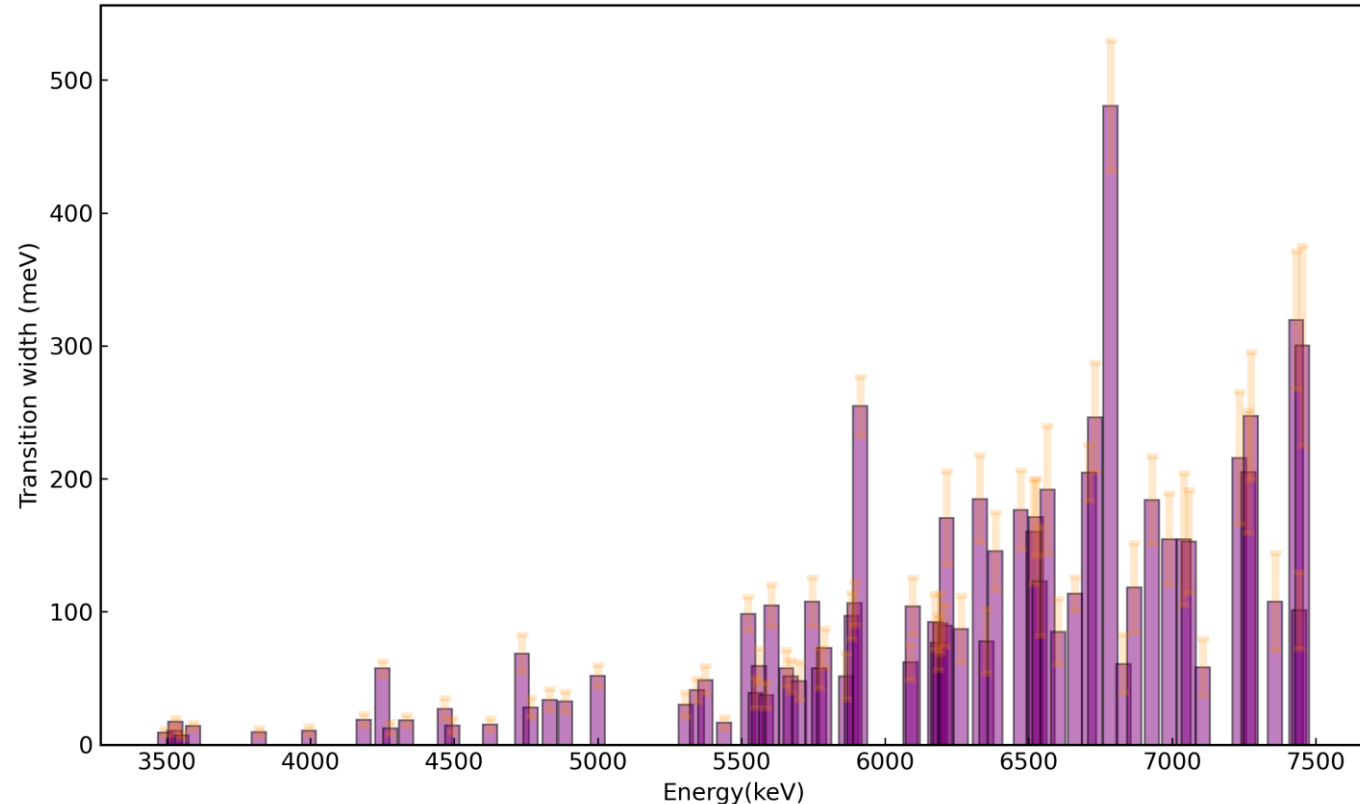
Conditions for a peak to be obtained from a branching transition instead of a ground-state transition:

1. The photon emitted after such a branching transition has the energy $E_\gamma \approx E_i - E_f$

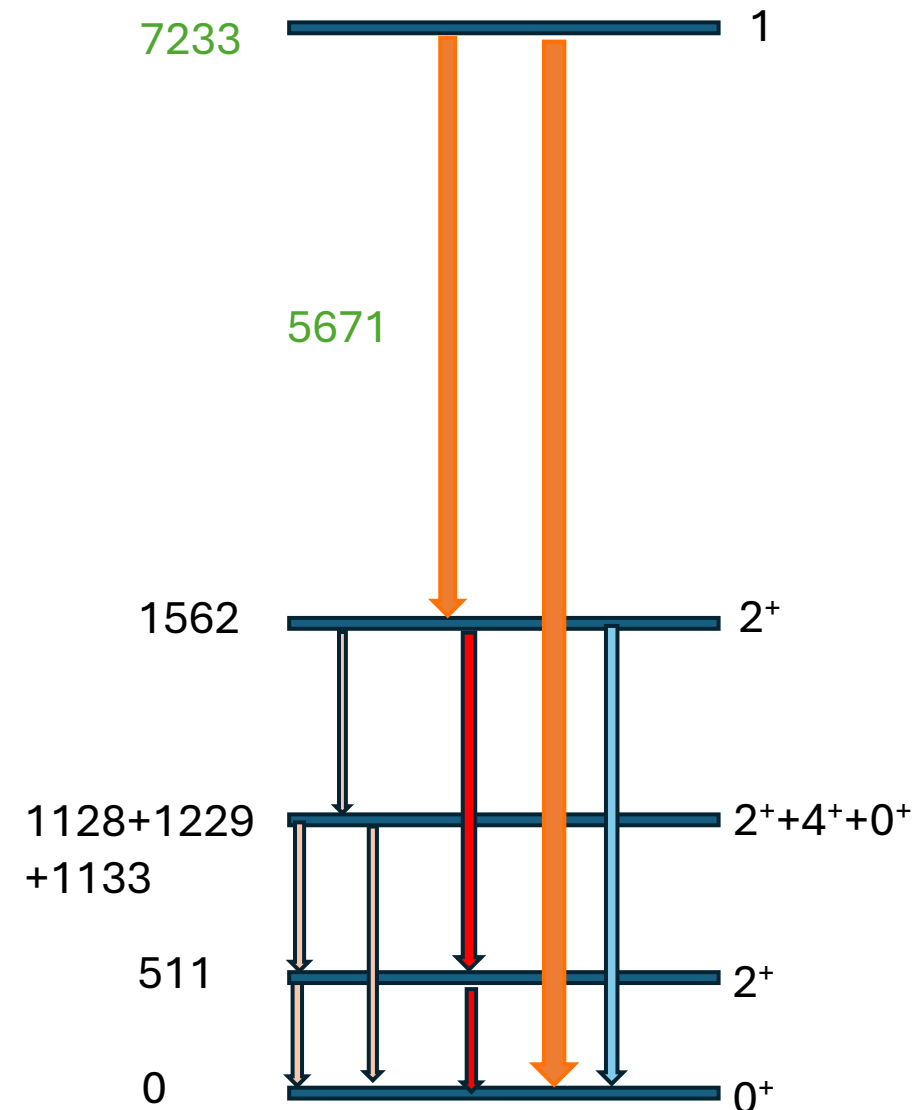
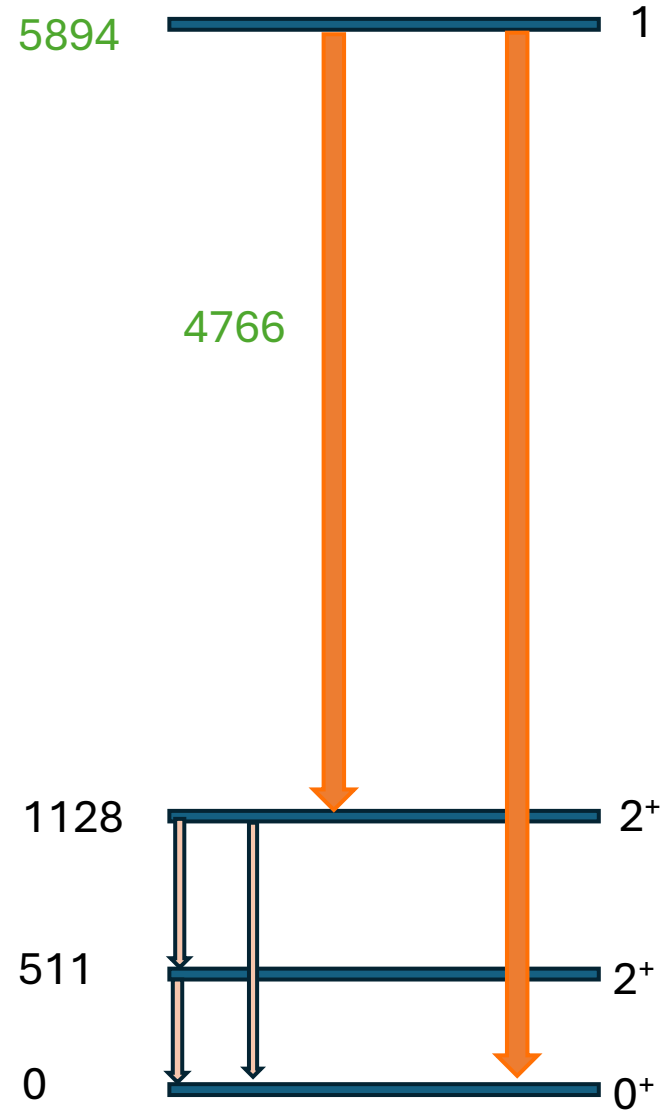
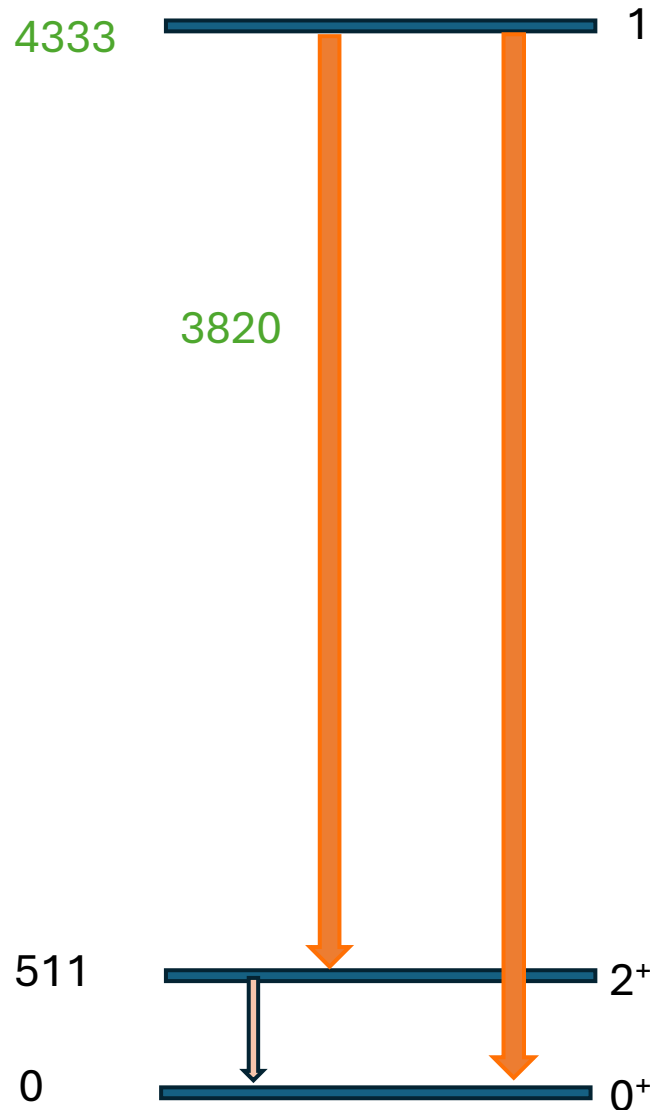
2. After looking into the angular distribution, checking if the transition is among the favoured ones

$$|J - J_f| \leq L \leq J + J_f$$

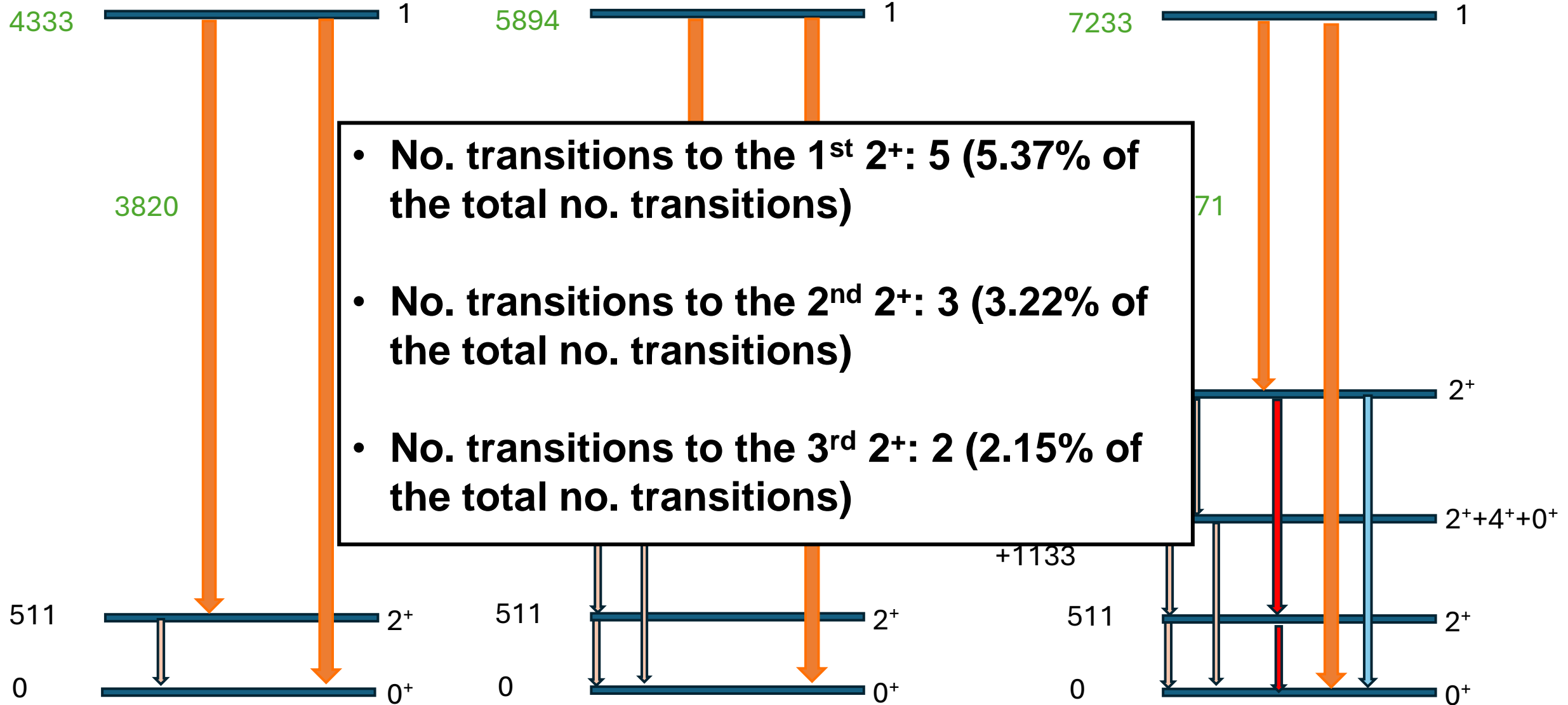
$$(-1)^L \pi \pi_f = \begin{cases} +1 & \text{for } \Pi = E \\ -1 & \text{for } \Pi = M \end{cases}$$



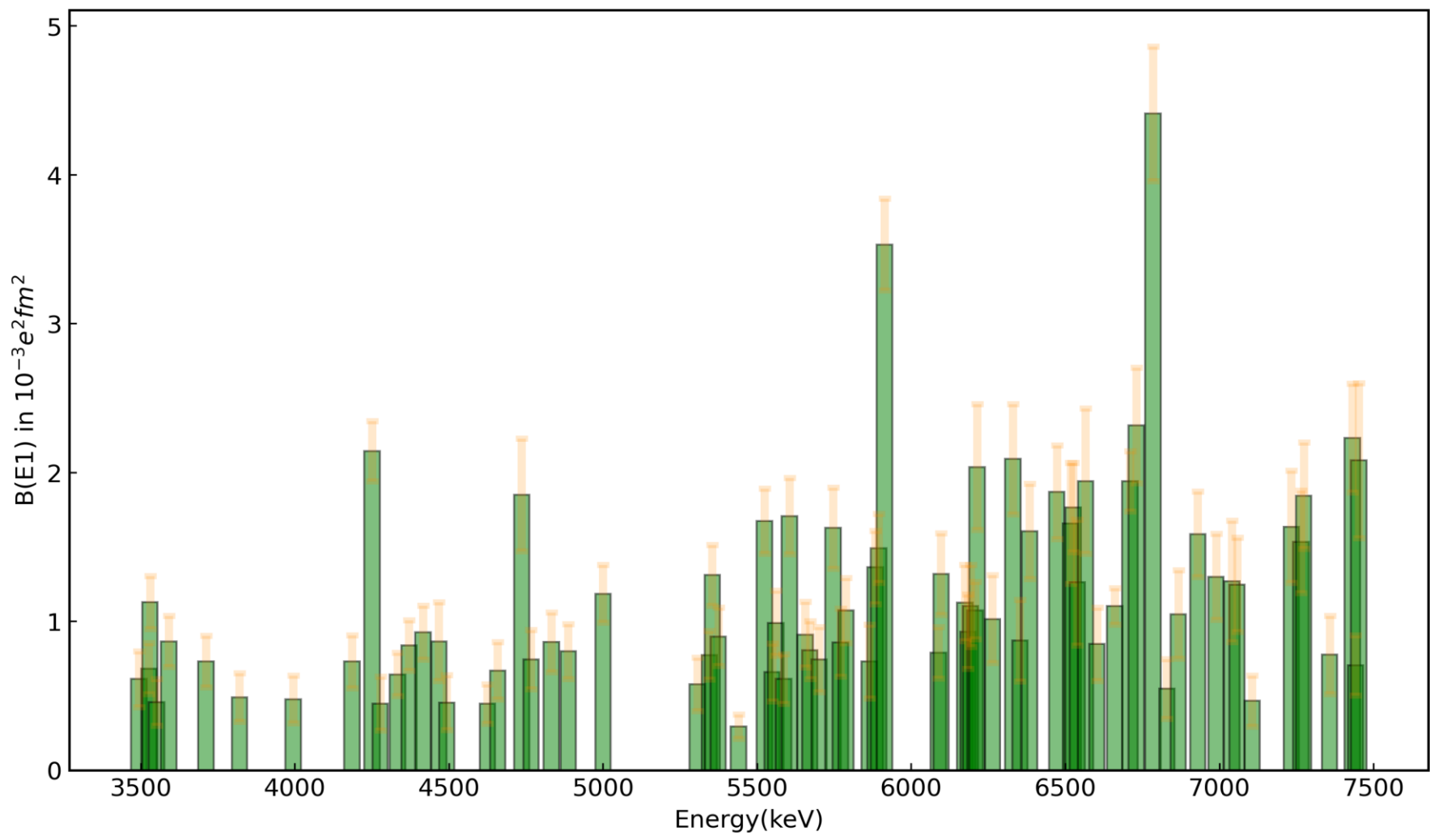
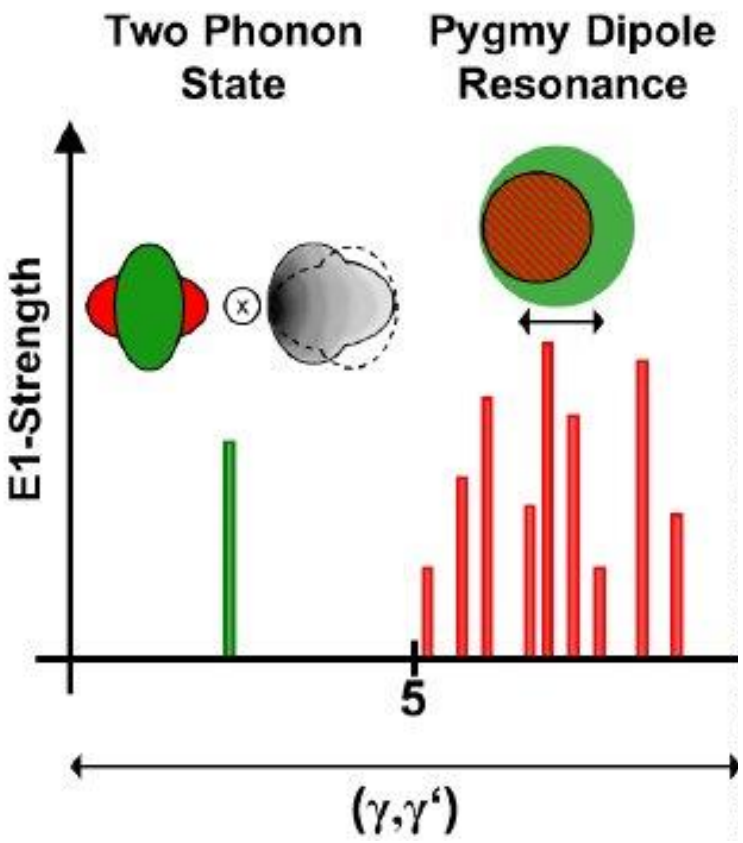
Branching to other 2+ states - examples



Branching to other 2+ states - examples

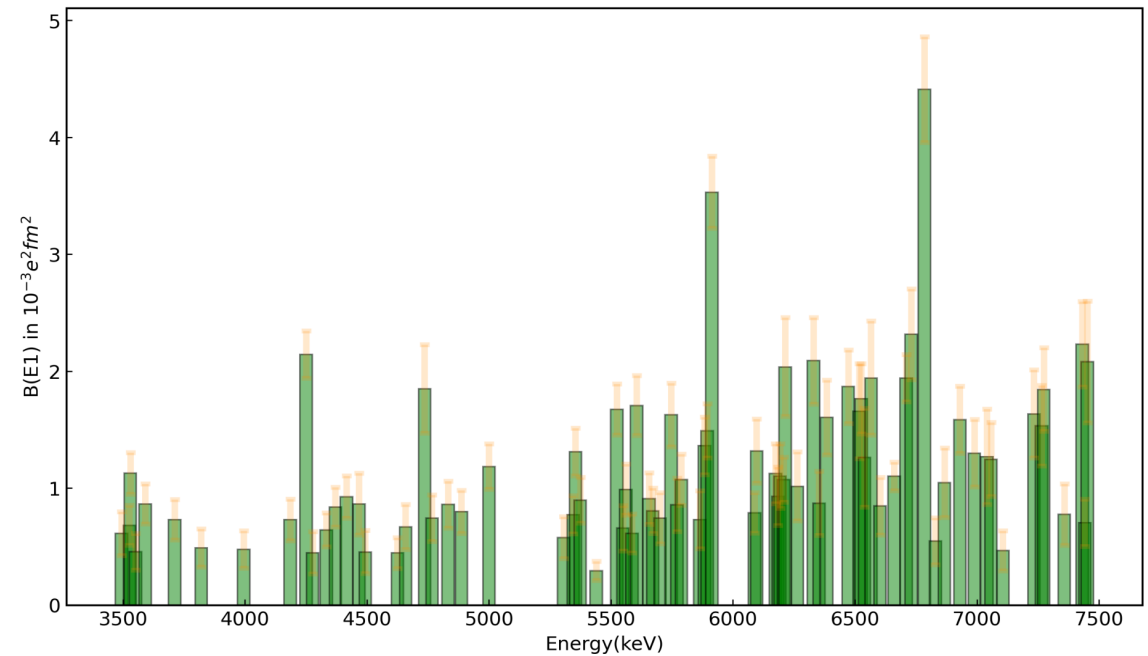
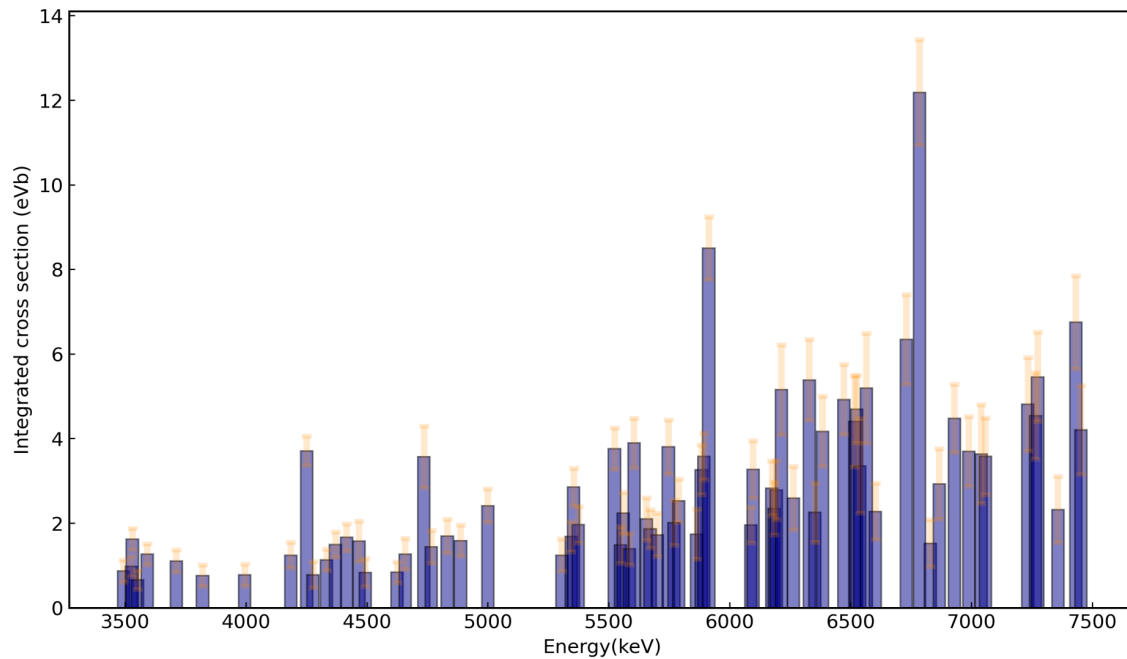


The PDR shape can be observed after the final calculations of the reduced dipole transition strength.



Conclusions and Outlook

- 72 new ^{106}Pd dipole transitions have been uncovered
- Preliminary results for the integrated cross section and the reduced transition strength have been calculated
- Another experiment at TU Darmstadt will take place this year, at a lower energy, reducing the effects from feeding
- In order to determine the parities, another experiment at TUNL Labs is necessary





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Thank you for your attention!



NRF Reactions: Checkpoint in ^{11}B

- The angular distributions for the ^{11}B calibration points were calculated and compared to literature values
- The results seem to agree

