Nuclear Resonance Fluorescence on ^{106}Pd

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Young Researchers and Young Engineers Days

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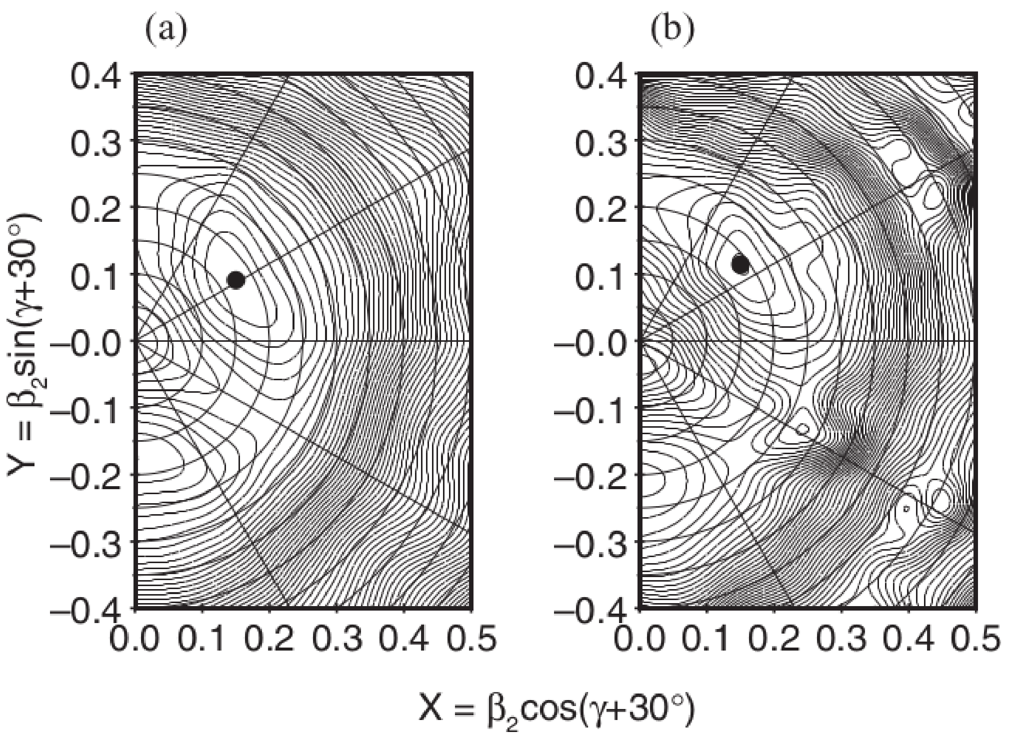
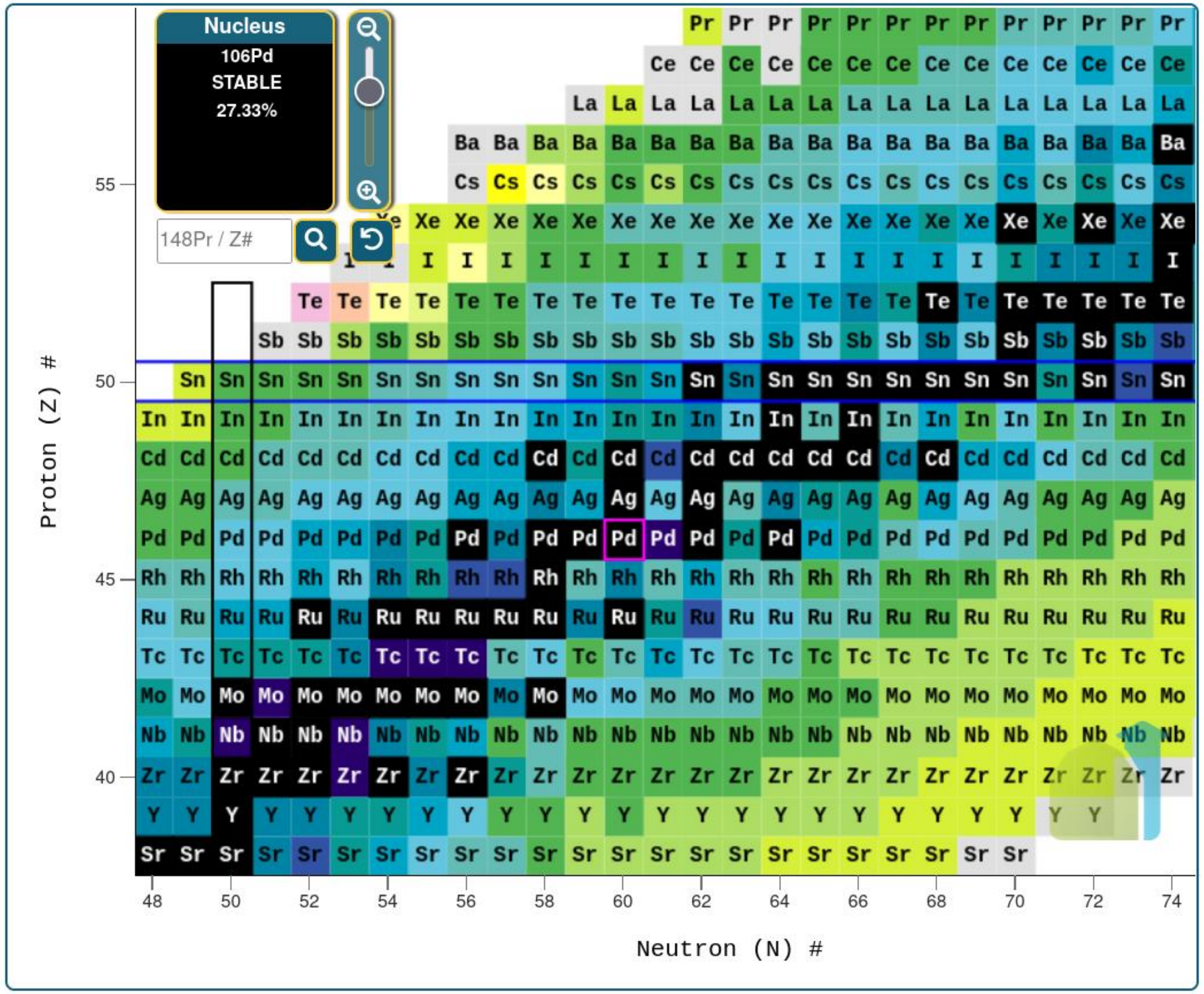
Objectives

- Determination the E1 strength
- Determination of the dependence of the E1 strength in the transition region from vibrational to rotational nuclei



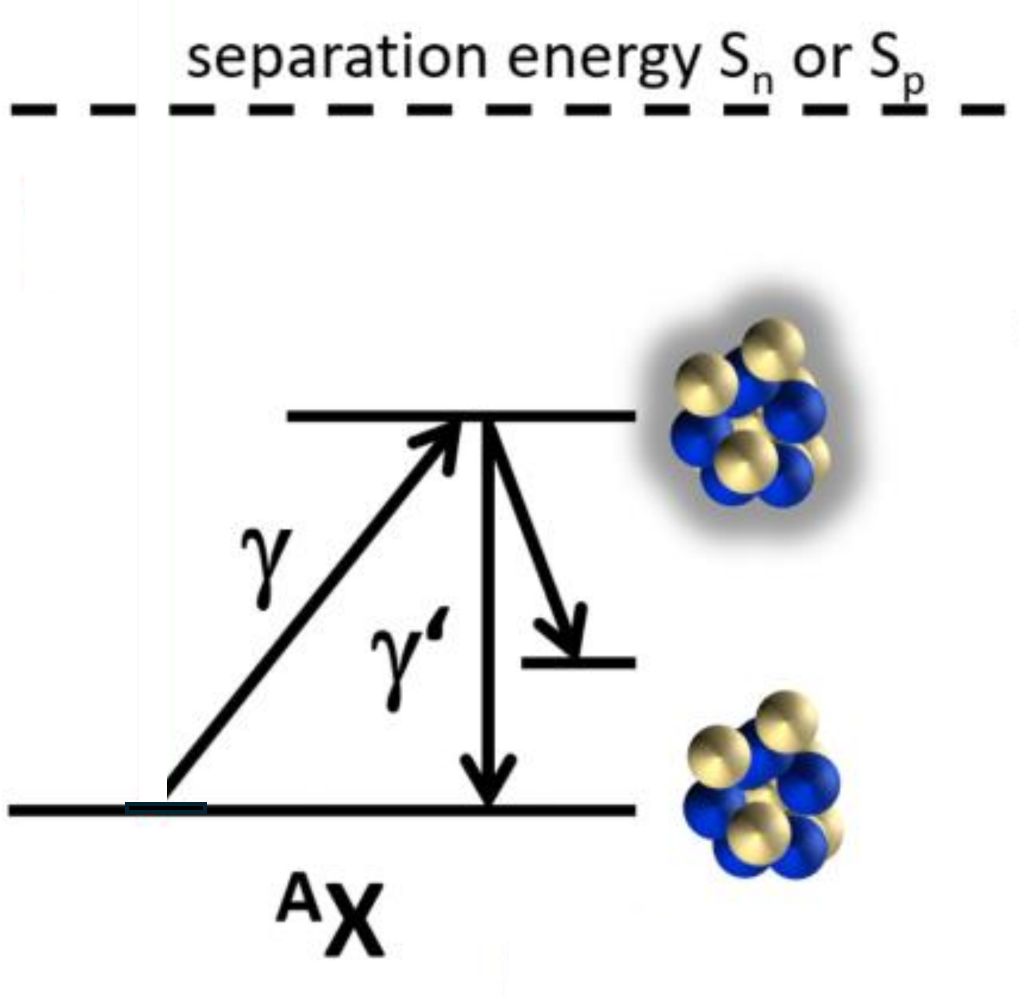
Potential energy surfaces of the lowest-lying band structures in ^{106}Pd calculated within the tilted-axis cranking model (C.E. He et al., Phys. Rev. C 86, 047302 (2012))



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

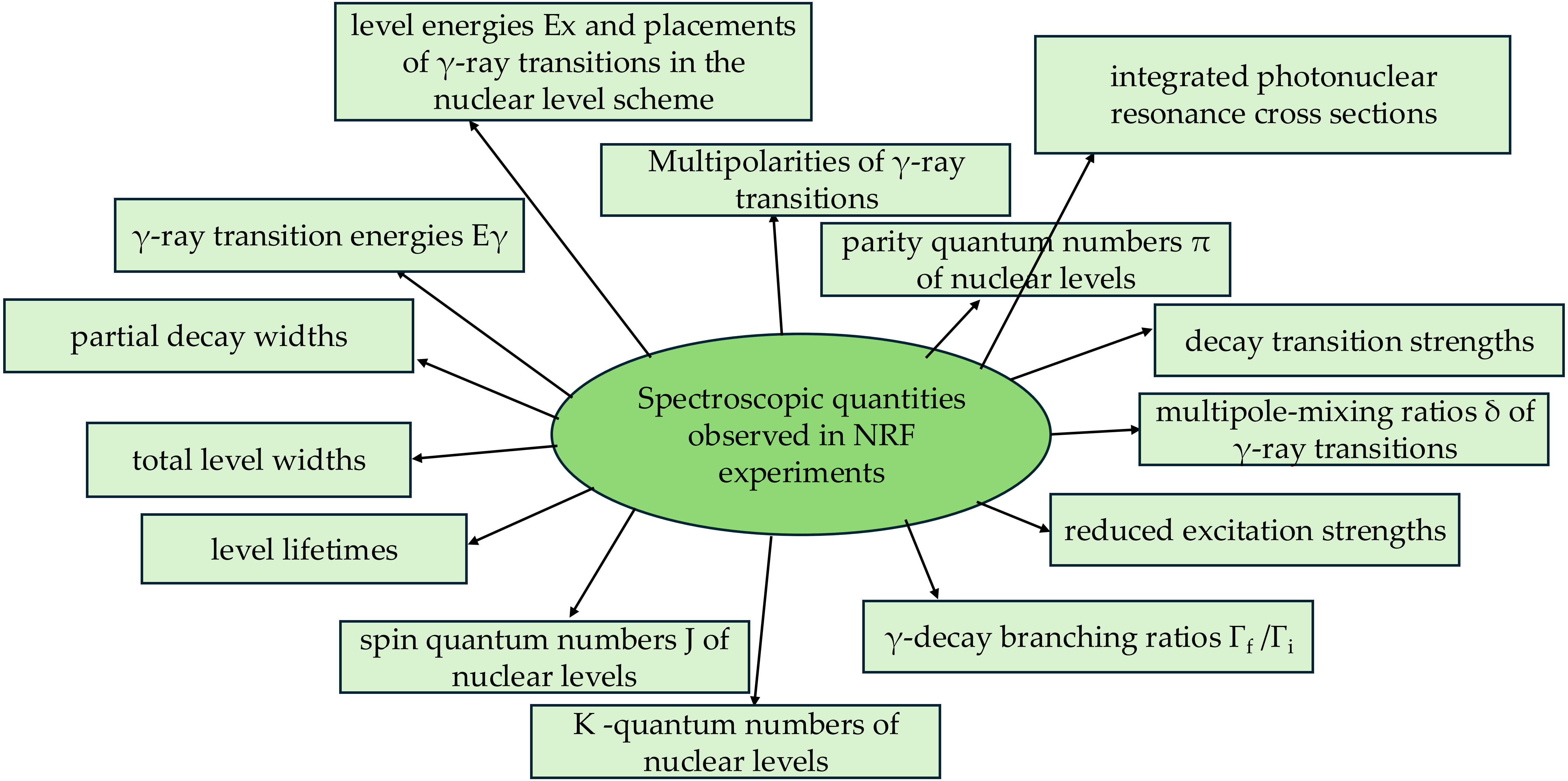
- The low-lying E1 states in the transitional Pd nuclei are expected to be weak and strongly fragmented

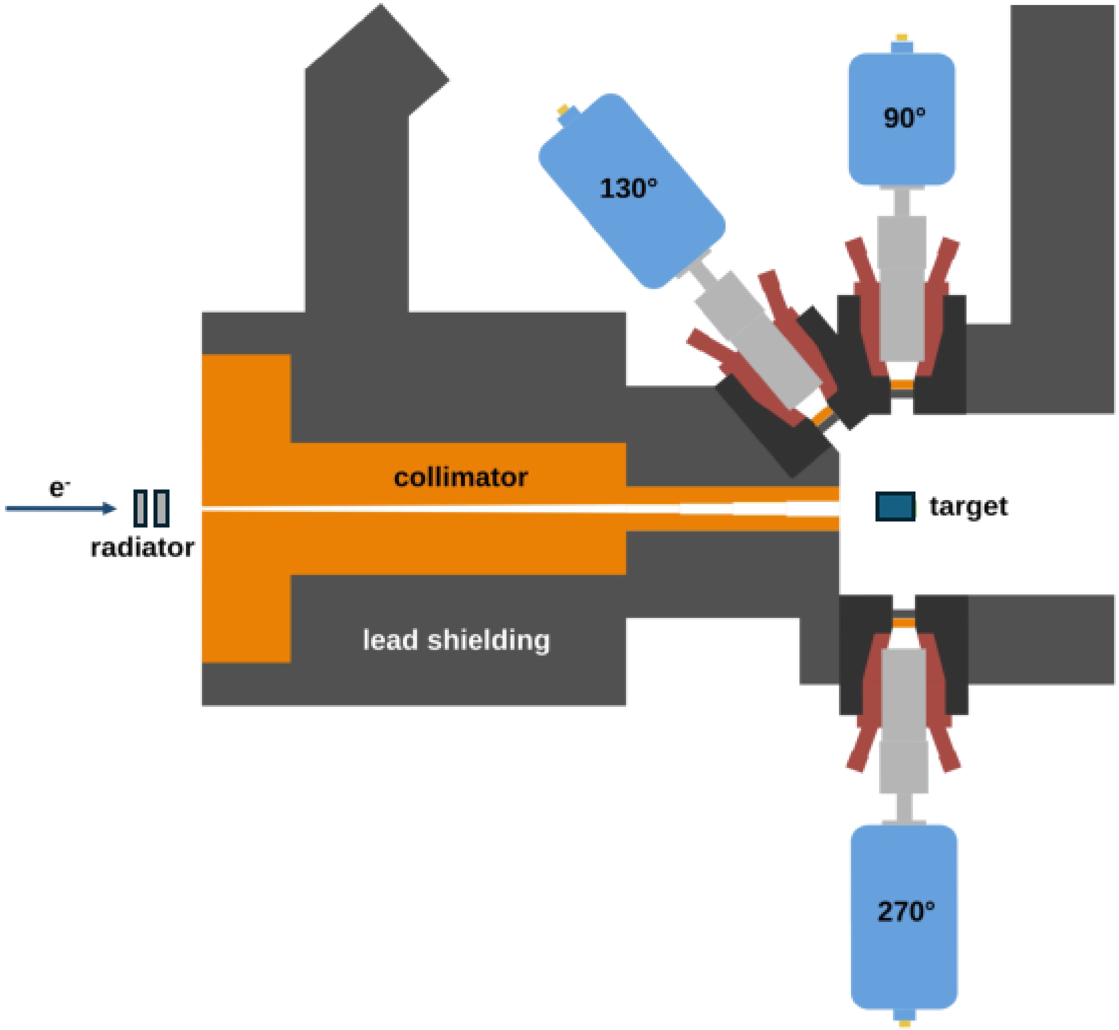
Nuclear Resonance Fluorescence



NRF scheme (A. Zilges, , D.L. Balabanski, J. Isaak, N. Pietralla, Progress in Particle and Nuclear Physics **122** (2022))

Nuclear resonance fluorescence = the phenomenon of a photonuclear two-step process, consisting of the resonant absorption of electromagnetic quantum by an atomic nucleus and the subsequent re-emission of γ radiation, represents a resonant photon-scattering reaction (γ, γ′) on a nucleus


level energies Ex and placements of γ-ray transitions in the nuclear level scheme
integrated photonuclear resonance cross sections
Multipolarities of γ-ray transitions
γ-ray transition energies Eγ
parity quantum numbers π of nuclear levels
partial decay widths
decay transition strengths
Spectroscopic quantities observed in NRF experiments
multipole-mixing ratios δ of γ-ray transitions
total level widths
reduced excitation strengths
level lifetimes
spin quantum numbers J of nuclear levels
γ-decay branching ratios Γf /Γi
K -quantum numbers of nuclear levels

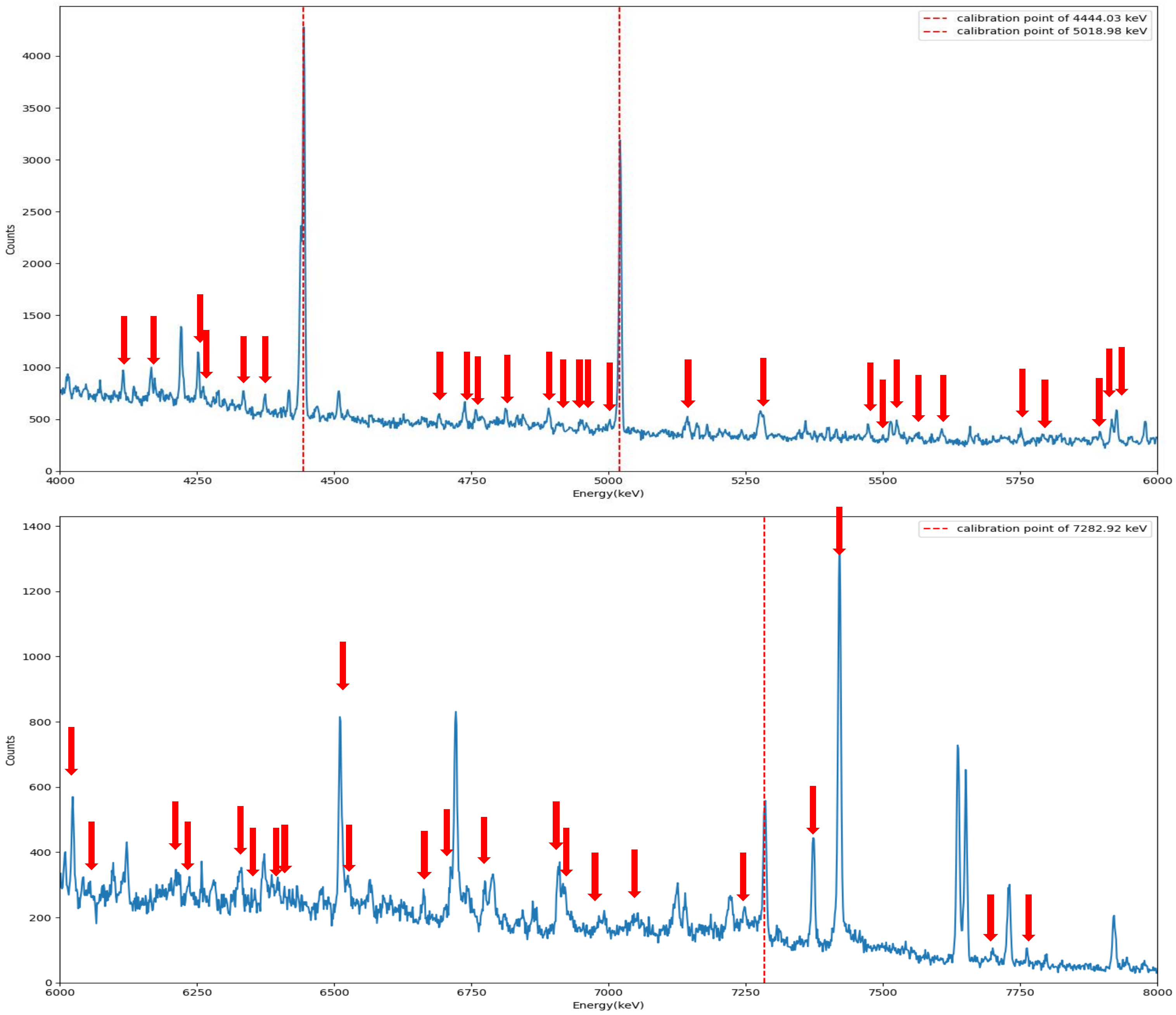


Schematic view of DHIPS (Romig, PhD thesis)

^{106}Pd target

Experimental setup

Energy-channel calibration: ^{11}B



53 new ^{106}Pd peaks

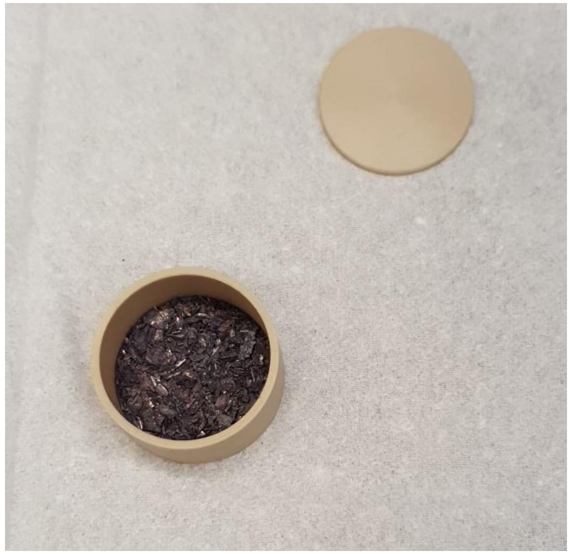
Partial gamma-ray spectrum obtained from the NRF experiment on ^{106}Pd

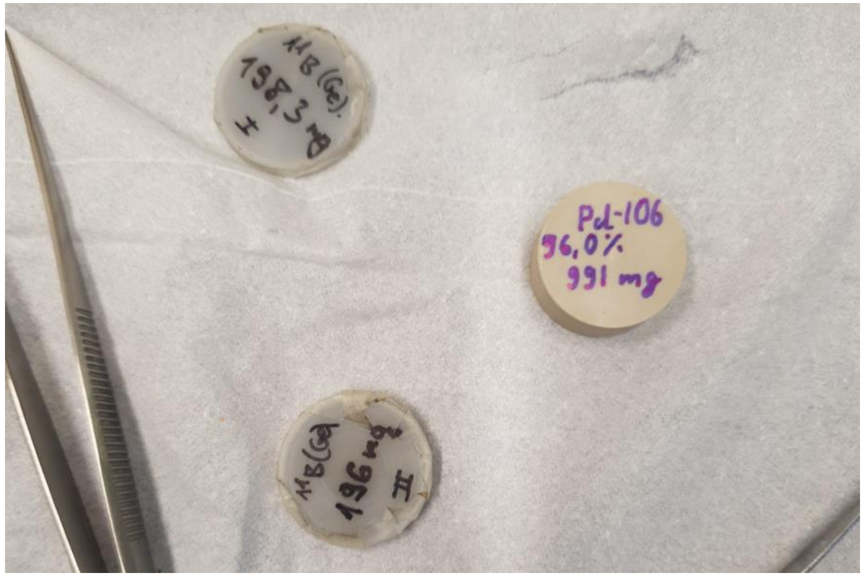
NRF reactions → Integrated cross section

$$A_{j\to k} = N_T \bullet \varepsilon_{rel}(E_j - E_k) \bullet N_\gamma(E_j) \bullet I_{j\to k} \bullet W_{i\to j\to k}(\theta)$$

NRF reactions

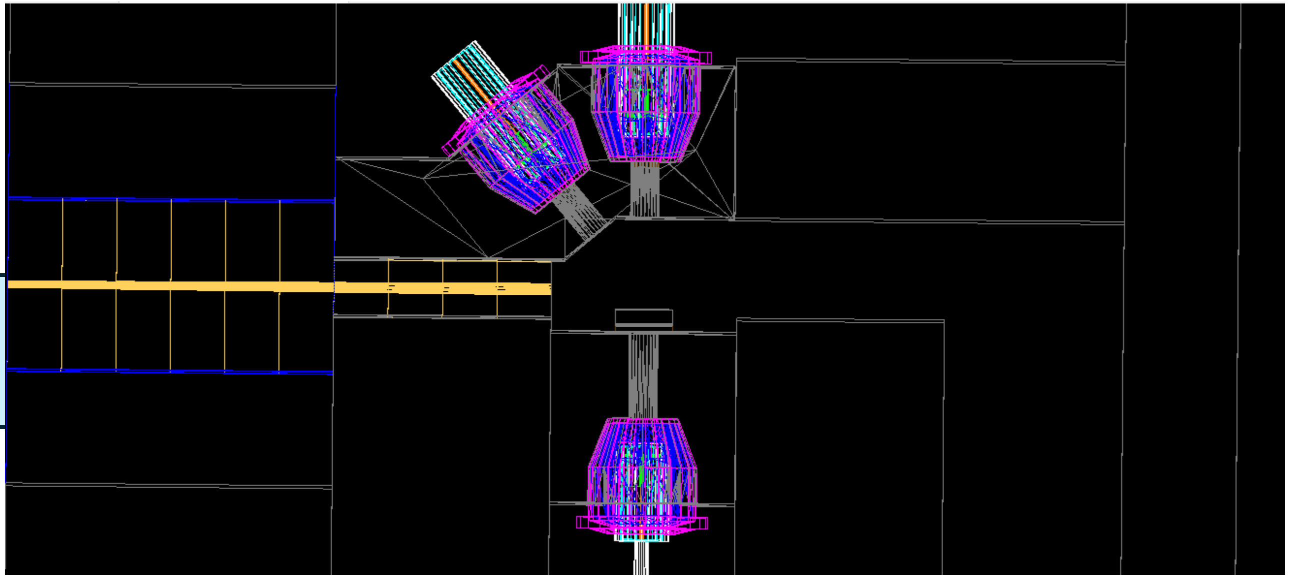
$$A_{j\to k} = N_T \cdot \varepsilon_{rel}(E_j - E_k) \cdot N_\gamma(E_j) \cdot I_{j\to k} \cdot W_{i\to j\to k}(\theta)$$

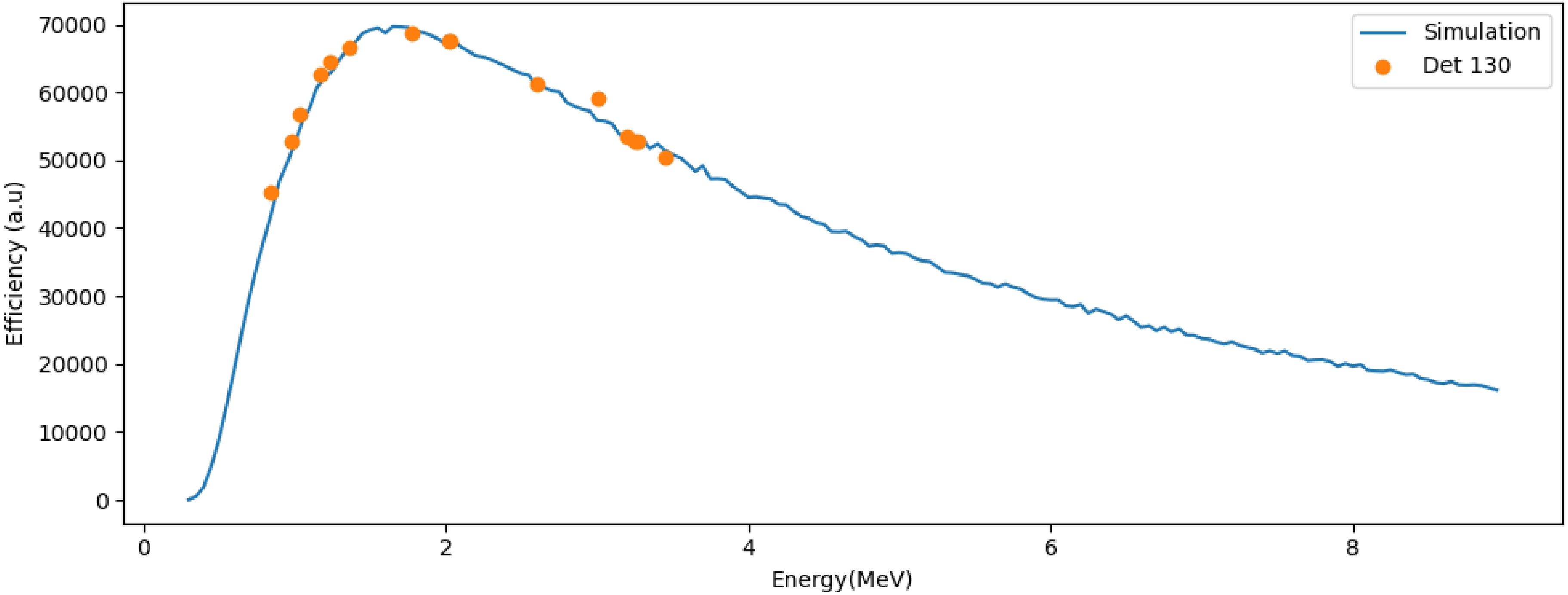




NRF reactions

$$A_{j\rightarrow k} = N_T \bullet \varepsilon_{rel}(E_j - E_k) \bullet$$



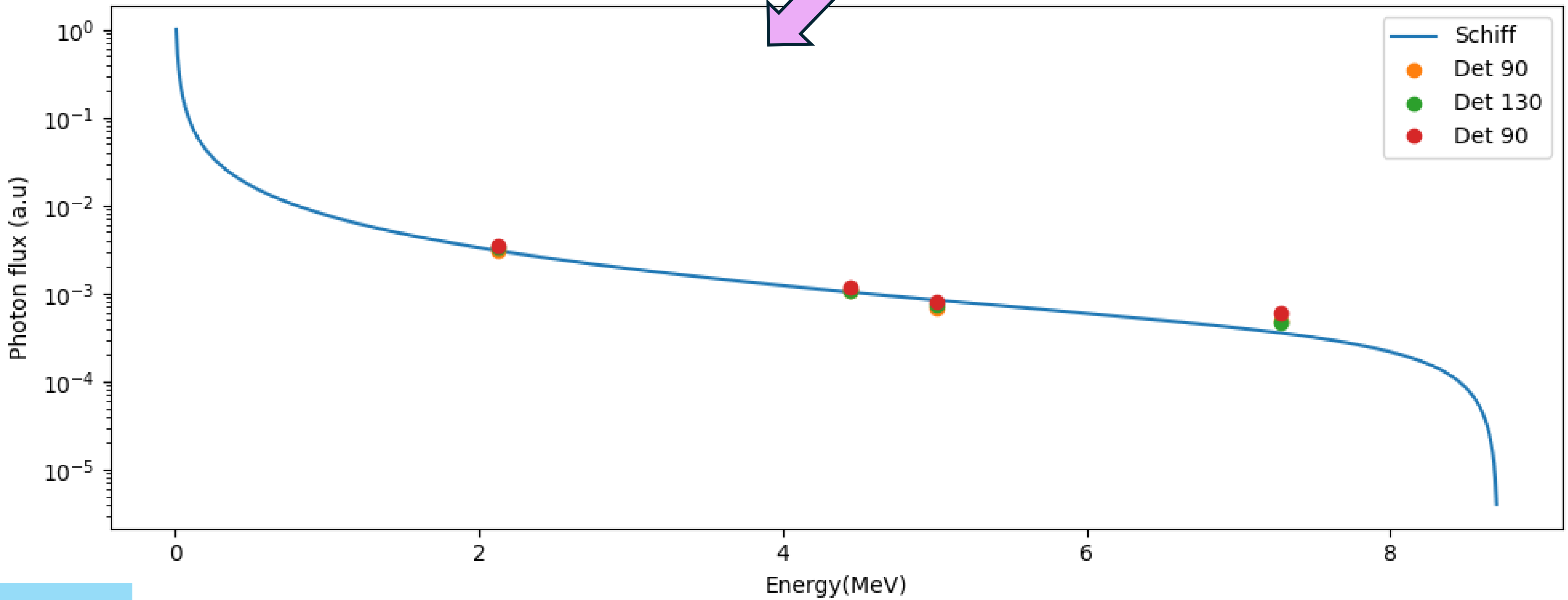


Geant4 simulations for relative efficiency calibrations

Calibration: ^{56}Co

NRF reactions

$$A_{j\to k} = N_T \bullet \varepsilon_{rel}(E_j - E_k) \bullet N_\gamma(E_j) \bullet I_{j\to k} \bullet W_{i\to j\to k}(\theta)$$



Calibration: ^{11}B

Schiff formula for photon flux calibration

NRF reactions

$$A_{j\to k} = N_T \bullet \varepsilon_{rel}(E_j - E_k) \bullet N_\gamma(E_j) \bullet I_{j\to k} \bullet W_{i\to j\to k}(\theta)$$

$$W(\theta) = 1 + \frac{1}{(1+\delta_1^2)(1+\delta_2^2)}(p_2 P_2(cos\theta) + p_4 P_4(cos\theta))$$

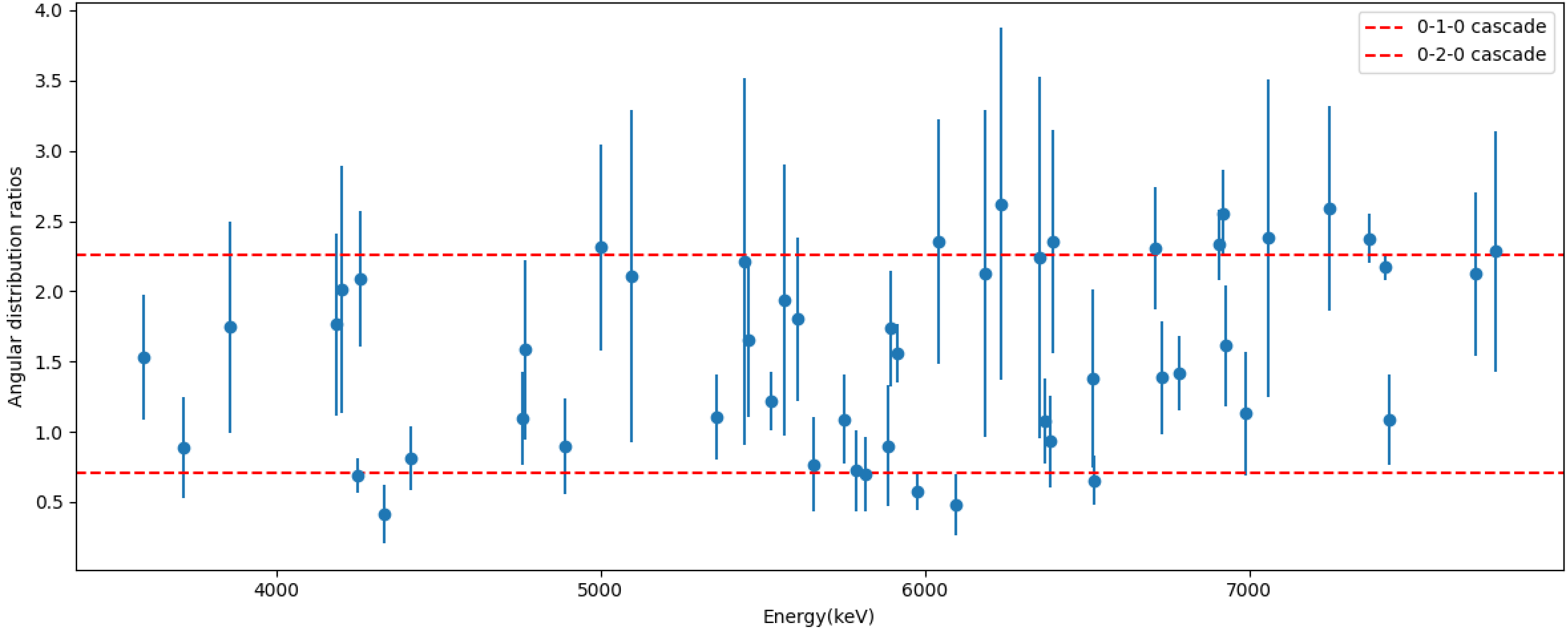
$$W_{0^+\to 1\to 0^+}(\theta) = 1 + \frac{1}{4}(3\cos^2\theta + 1)$$

$$W_{0^+\to 2\to 0^+}(\theta) = \frac{5}{4}(1 - 3\cos^2\theta + 4\cos^4\theta).$$

$$w_{0^\pm\to1^\pm\to0^\pm} = \frac{W_{0^\pm\to1^\pm\to0^\pm}(90^\circ)}{W_{0^\pm\to1^\pm\to0^\pm}(130^\circ)} = 0.734$$

Angular distributions ratios

$$w_{0^\pm\to2^\pm\to0^\pm} = \frac{W_{0^\pm\to2^\pm\to0^\pm}(90^\circ)}{W_{0^\pm\to2^\pm\to0^\pm}(130^\circ)} = 2.226$$



Angular distribution ratios

Conclusions

- New peaks observed between 4000-8000 keV
- Both dipole and quadrupole reduced transition strengths have been determined
- E1 states in ^{106}Pd are weak and highly fragmented
- Another experiment, at higher energy must be performed at the TUNL Labs in Durham, NC, USA
- For the future: similar experiments must be performed on ^{104,108}Pd

Thank you for your attention!