Nuclear Resonance Fluorescence of ^{242}Pu

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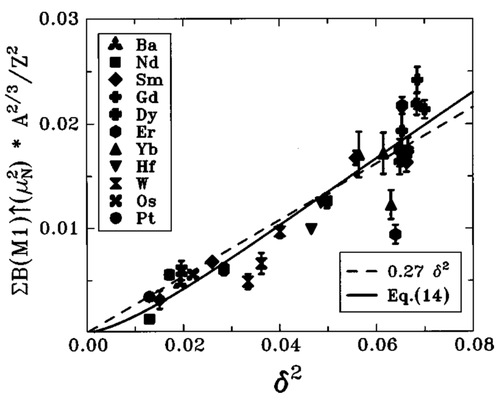
Motivation

Transuranium actinide region

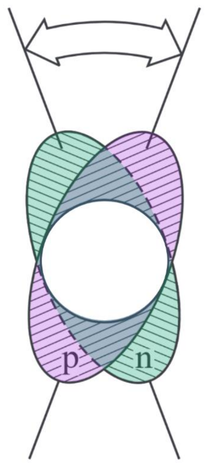
- Available data on photonuclear reactions is sparse (^{239,240}Pu, ^{237}Np) W. Bertozzi *et al.*, Phys. Rev. C **78** (2008) 041601; B. Quiter *et al.*, Phys. Rev. C, **78** (2012) 034307; C. Angell *et al.,* Phys. Rev. C **82** (2010) 054310
- So far, only lifetime of 2_1^+ state of ^{242}Pu determined M. J. Martin and C. D. Nesaraja, NDS **186** (2022) 261
- ^{242}Pu is now heaviest isotope studied with nuclear resonance fluorescence (NRF)



N. Pietralla *et al.*, Phys. Rev. C **58** (1998) 184

The scissors mode

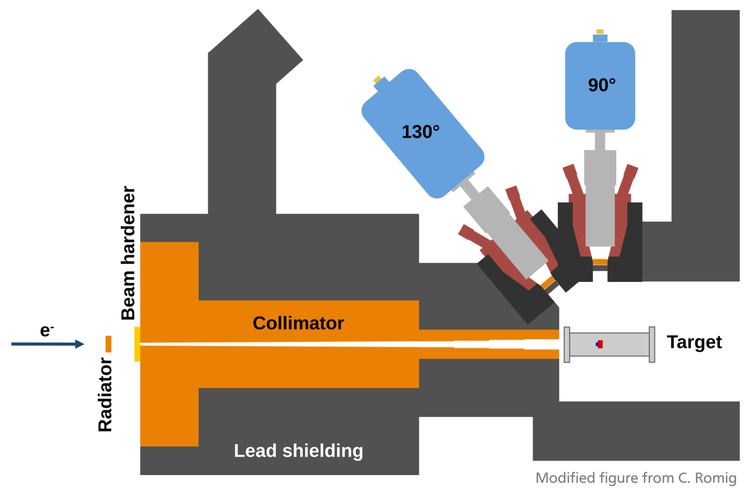
- Collective isovector M1 excitation in deformed nuclei
- Energetically low-lying (rare earth region ~3 MeV) F. Iachello, Nucl. Phys. A **358** (1981) 89
- Fragmented 1^+ states in even-even nuclei
- Two-rotor model: *Counter-rotational oscillation of the deformed proton against the deformed neutron body.* N. Lo Iudice and F. Palumbo, Phys. Rev. Lett. **41** (1978) 1532
- First experimental discovery in ^{156}Gd with (e,e') at Darmstadt 1983 D. Bohle *et al.*, Phys. Lett. B **137** (1984) 27



K. Heyde *et al.,* Rev. Mod. Phys. **82** (2010) 2365

Setup

Darmstadt High-Intensity Photon Setup

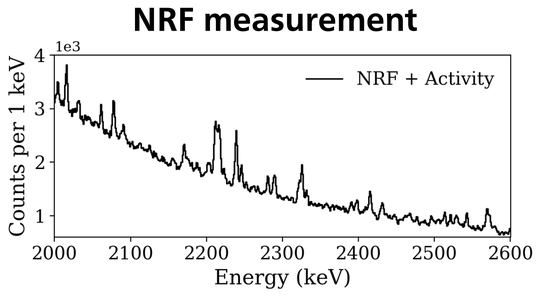


Modified figure from C. Romig

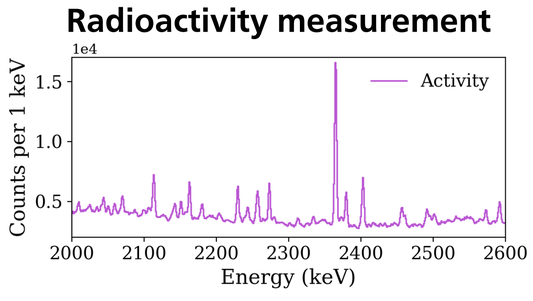
- Monoenergetic e⁻-beam provided by the **S-DALINAC**
- Bremsstrahlung with an endpoint energy of 3.7 MeV
- High Purity Germanium detectors with BGO shielding

Analysis

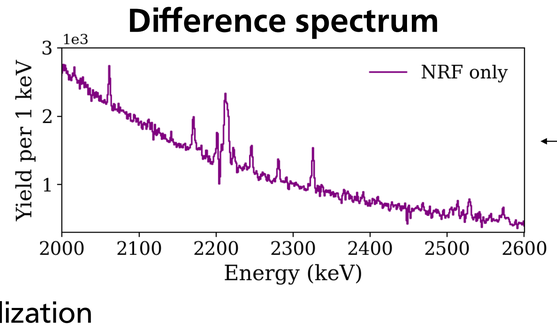
NRF measurement



Radioactivity measurement



Difference spectrum



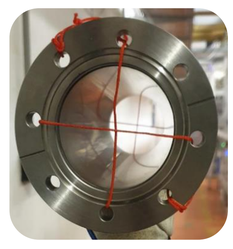
Procedure

- Efficiency normalization
- Subtraction of radioactivity and background measurements
- Note: Oversubtraction due to rate-dependent peak widths of the detectors

Experimental Details

Target

- 1.1 g of PuO_2
- Enrichment of ^{242}Pu >99.9 %
- Total activity of 371 MBq
- Provided by **H**elmholtz-**Z**entrum **D**resden-**R**ossendorf
- ^{27}Al as reference material
- PEEK box in sealed steel pipe
- Challenging radiation safety requirements



Target alignment

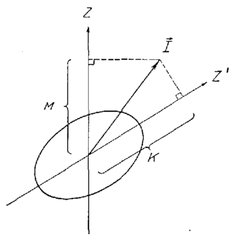
PEEK box | Al reference + steel pipe | Pressure test | Target monitoring

Results and Interpretation

Alaga rules

- Relation for transition strength ratios of axially-deformed rotational nuclei G. Alaga *et al.*, Dan. Mat. Fys. Medd. **29** (1955)
- Ratios depend only on Clebsch-Gordan coefficients (if no K mixing)
- Even-even deformed nuclei:

$$R_{\mathrm{Alaga}} = \frac{B(\Pi 1, 1^\pi \to 2_1^+)}{B(\Pi 1, 1^\pi \to 0_1^+)} = \begin{cases} 2, & K = 0 \\ 0.5, & K = 1 \end{cases}$$



Results and Interpretation

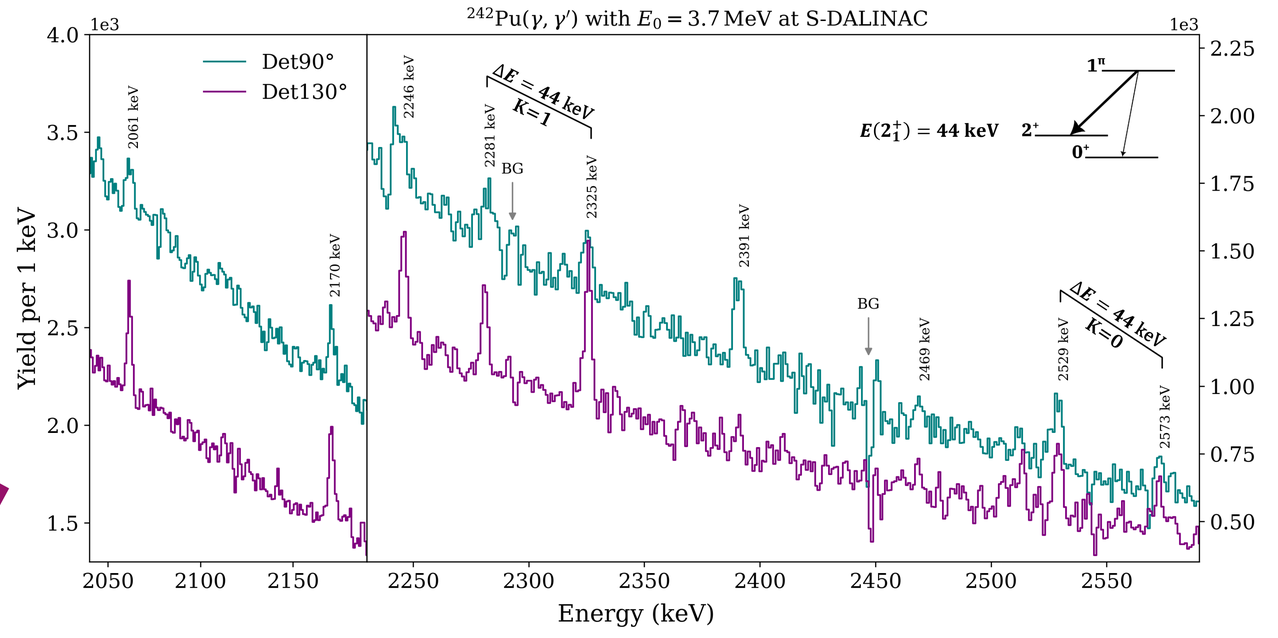
Preliminary

→ Ratios for Det130°: $\boldsymbol{R_1 = 0.65(6),\ R_2 = 1.93(26)}$

→ Potential scissors mode state at **2325 keV** with $\boldsymbol{B(M1)\uparrow = 0.17(4)\ \mu_N^2}$

(Statistical uncertainty from peak areas + 10 % systematic uncertainty)

Difference spectra



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