Investigation of the Pygmy Dipole Resonance in atomic nuclei using photon scattering experiments

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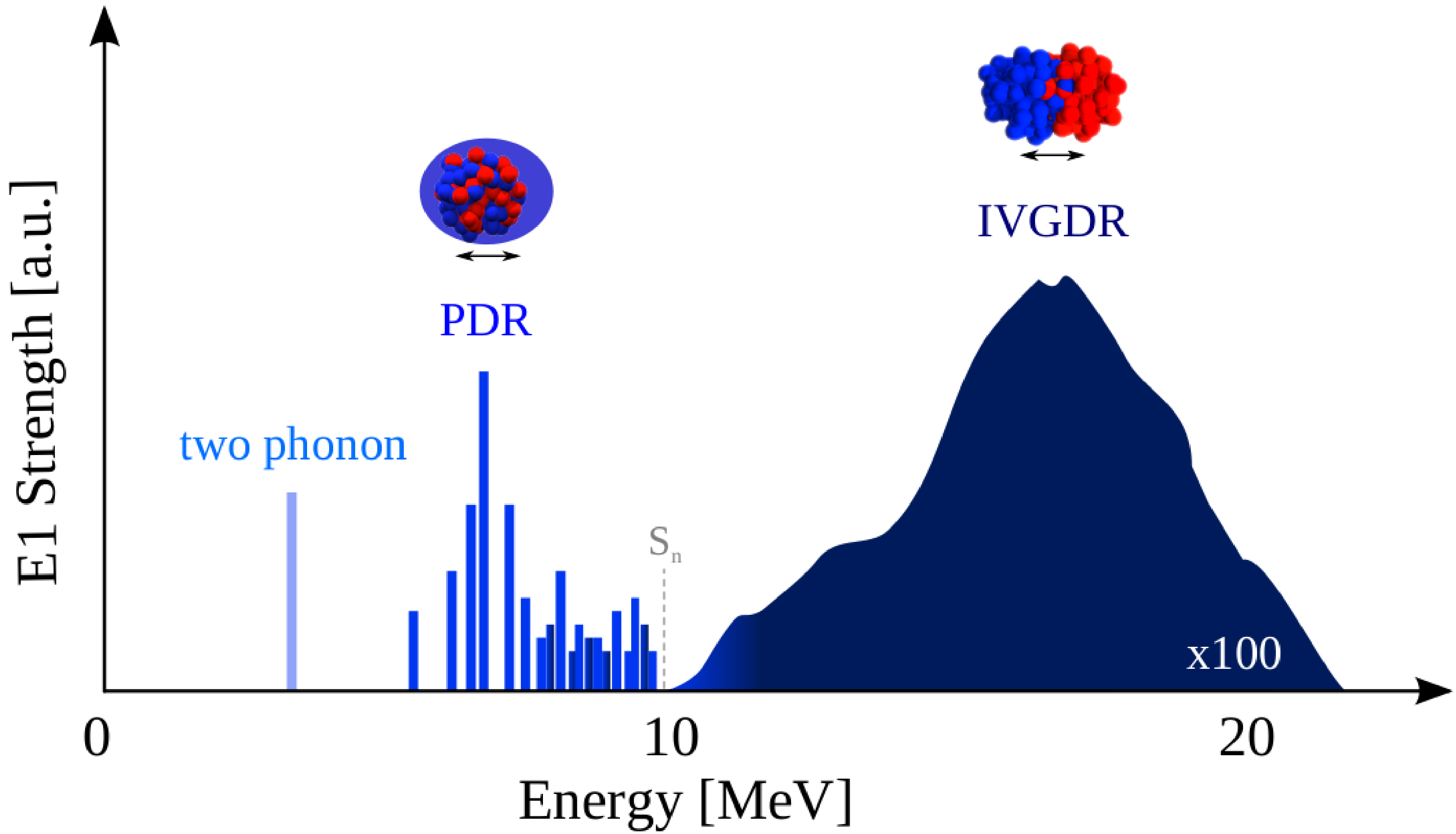
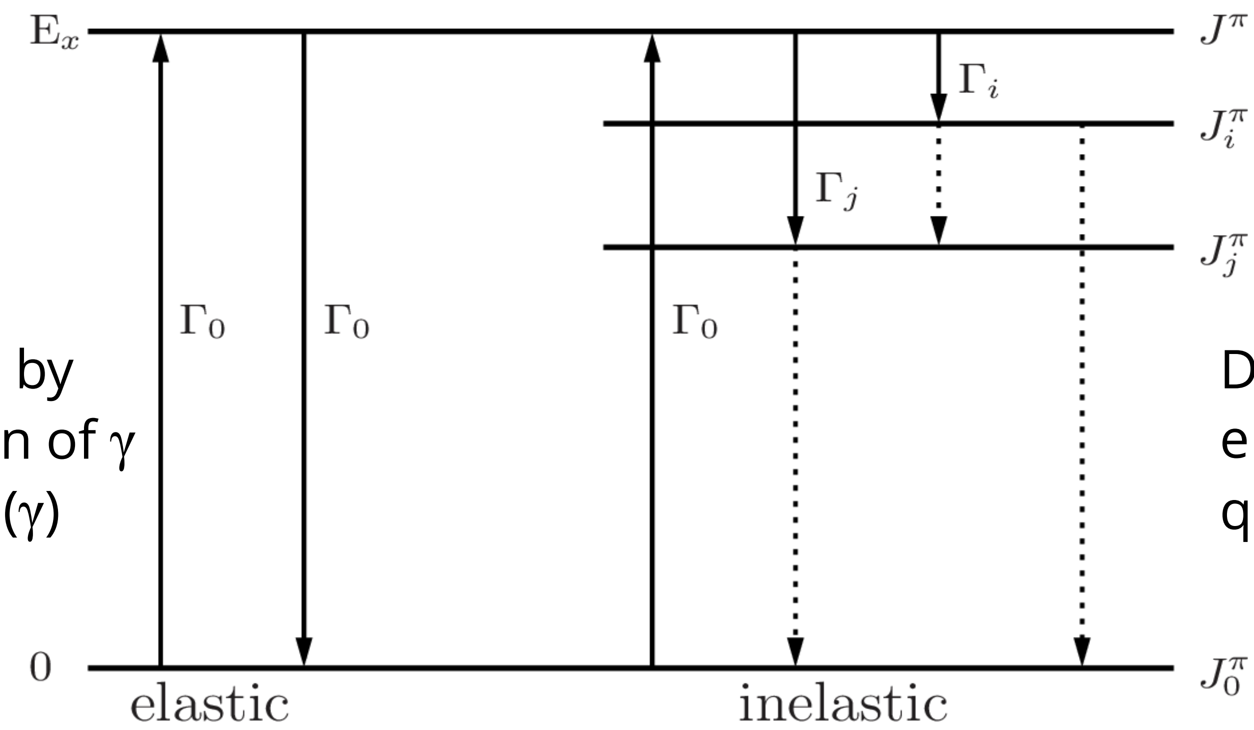
Motivation



V. Derya, Dissertation Thesis 2014, University of Cologne

Nuclear Resonance Fluorescence (NRF)

Excitation by absorption of γ quantum (γ)



De-excitation by emission of γ quantum (γ')

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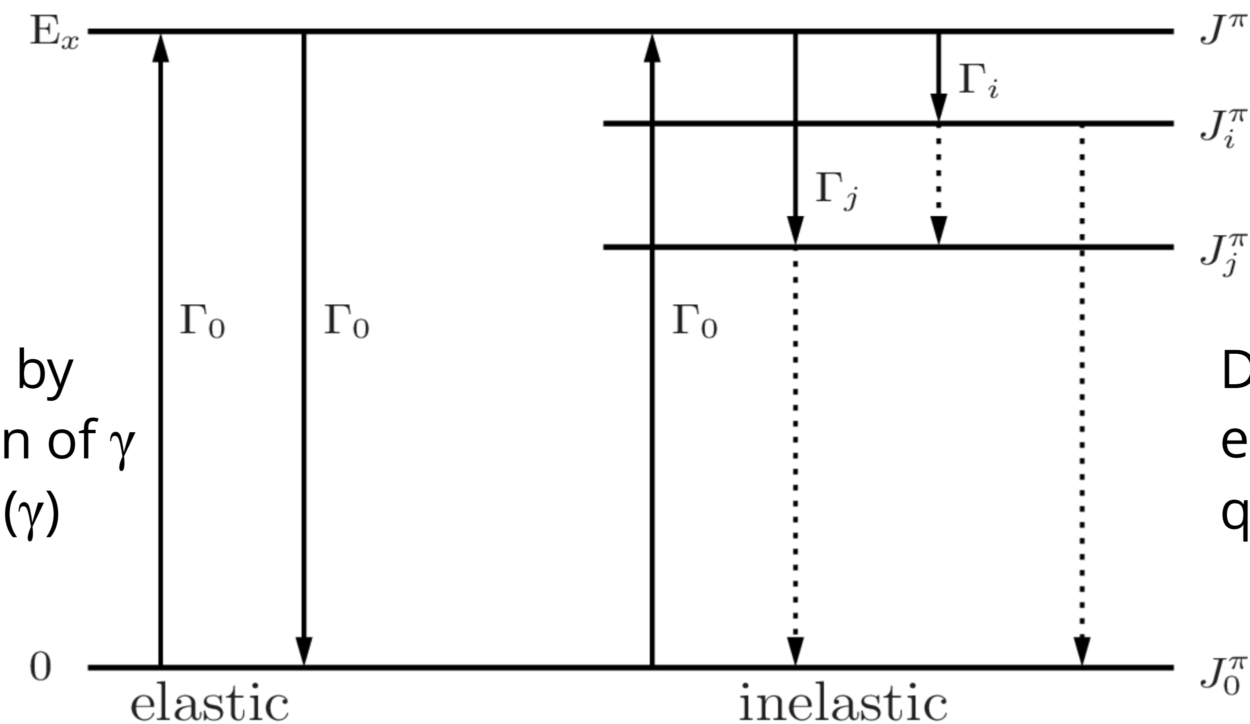
Excitation by absorption of γ quantum (γ)

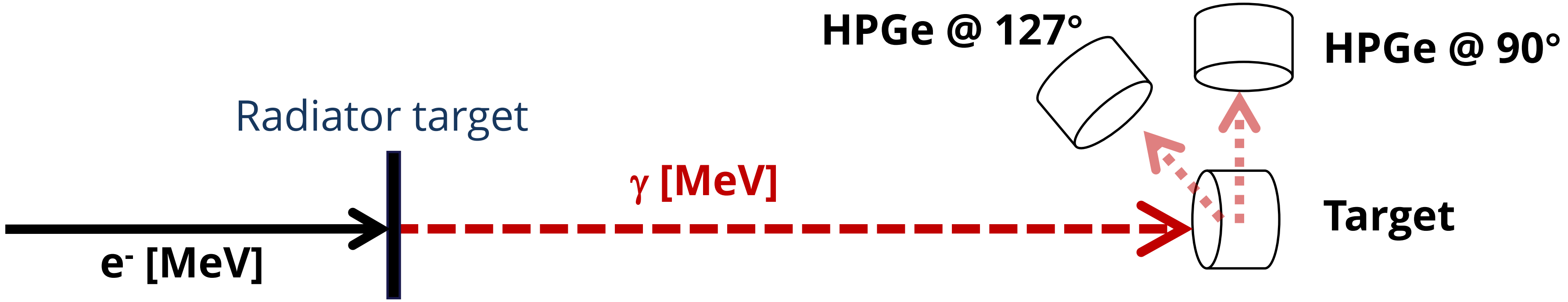


De-excitation by emission of γ quantum (γ')

- Level energies
- Spin quantum numbers
- Parity quantum numbers

- Level lifetimes and total decay widths
- γ-decay branching ratios Γ_f/Γ_0

Photon source: Bremsstrahlung



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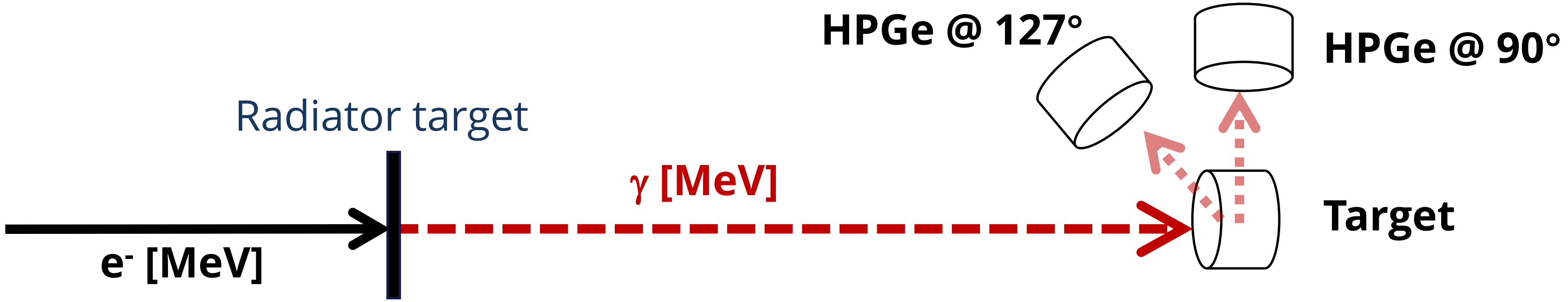

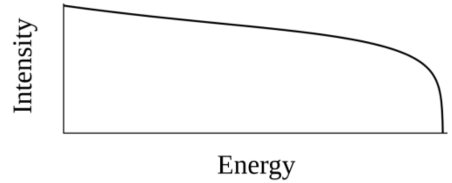

- Mainly unpolarized, continuous photon flux
- Spin quantum number assignment
- Advantage
  - Investigation of large energy range in one experiment
  - Use of calibration standard for absolute photon flux determination

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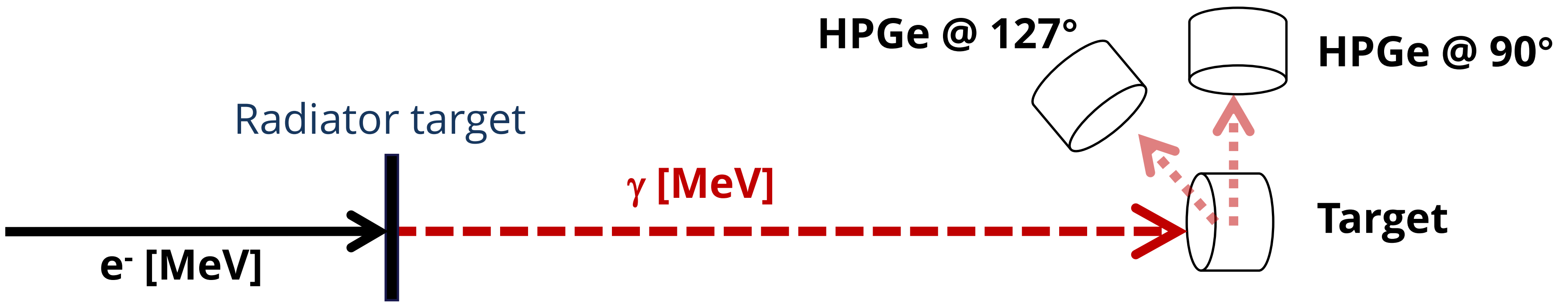

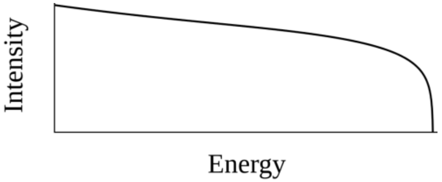

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- Spin quantum number assignment
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  - Investigation of large energy range in one experiment
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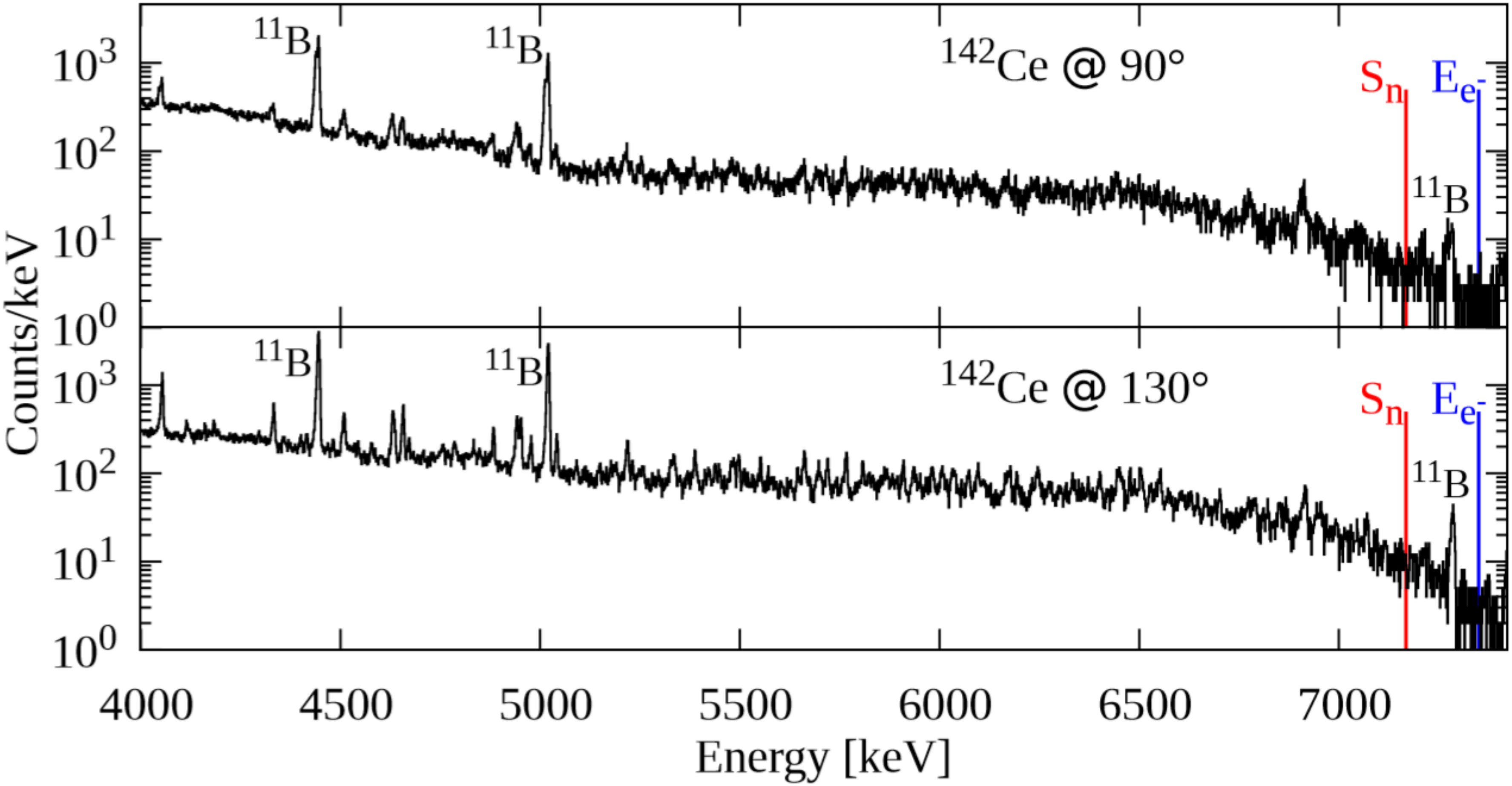
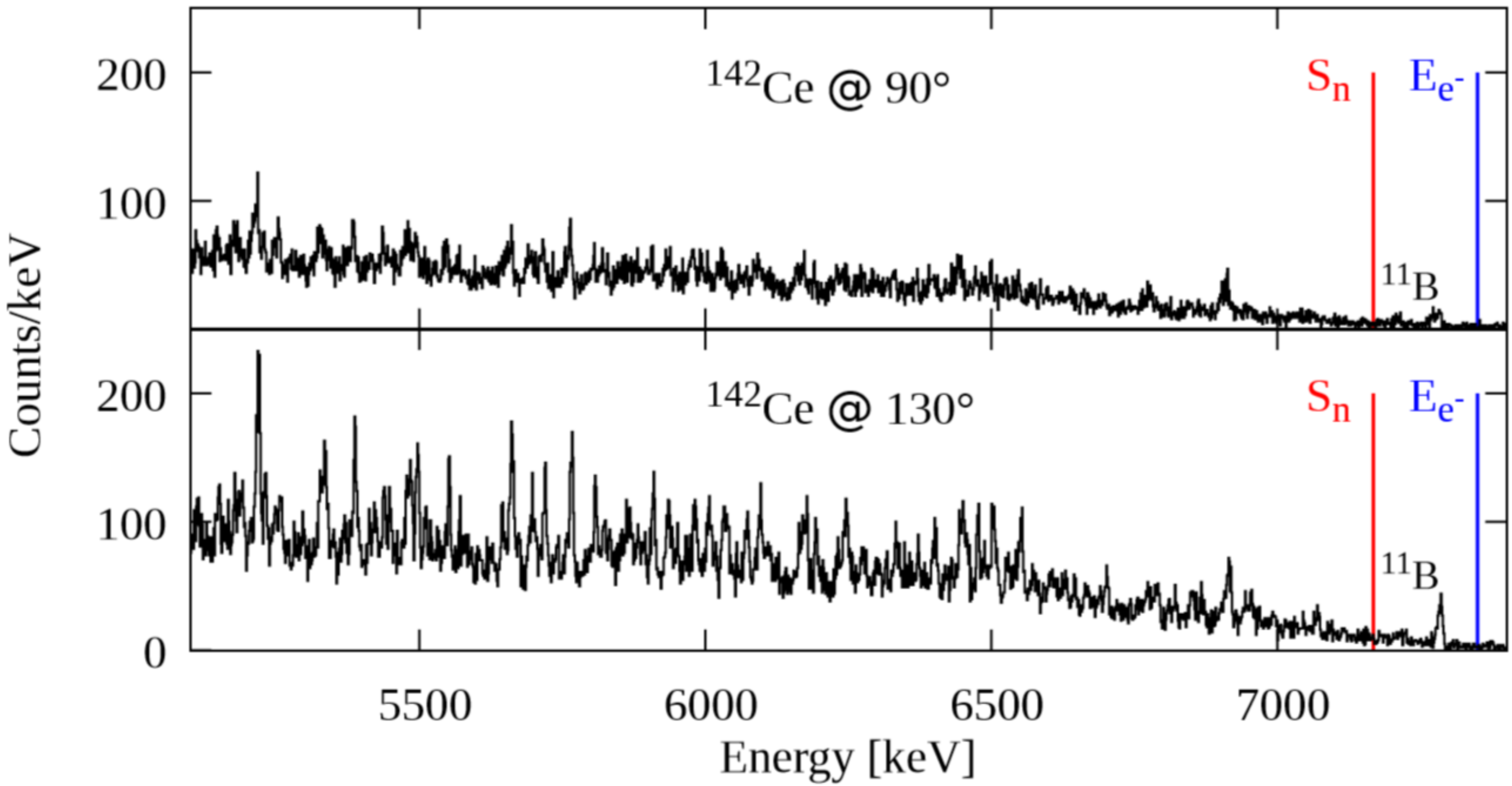
- Examples:
  - DHIPS (TU Darmstadt, Germany)
  - γELBE (Helmholtzzentrum Dresden-Rossendorf, Germany)

Analysis of ^{142}Ce – Experiment at DHIPS



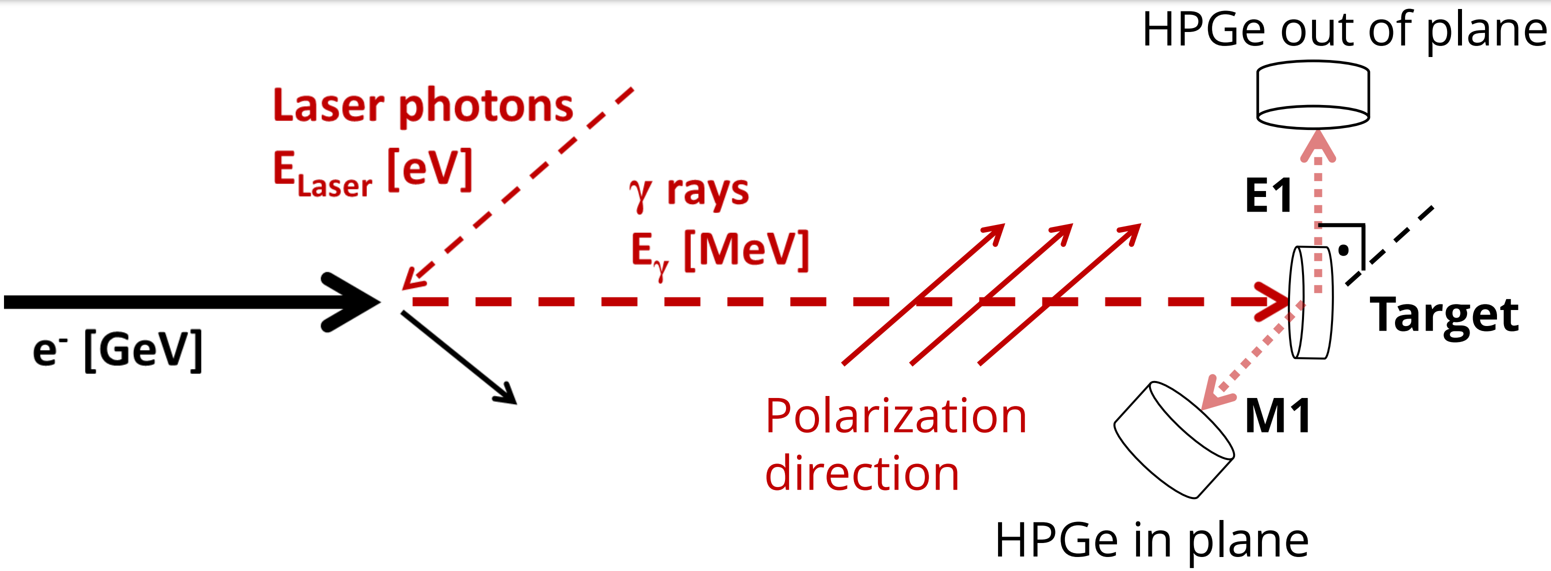
^{11}B used as calibration standard

Analysis of ^{142}Ce – Experiment at DHIPS



Many transitions in PDR region

Photon source: Laser Compton Backscattering (LCB)



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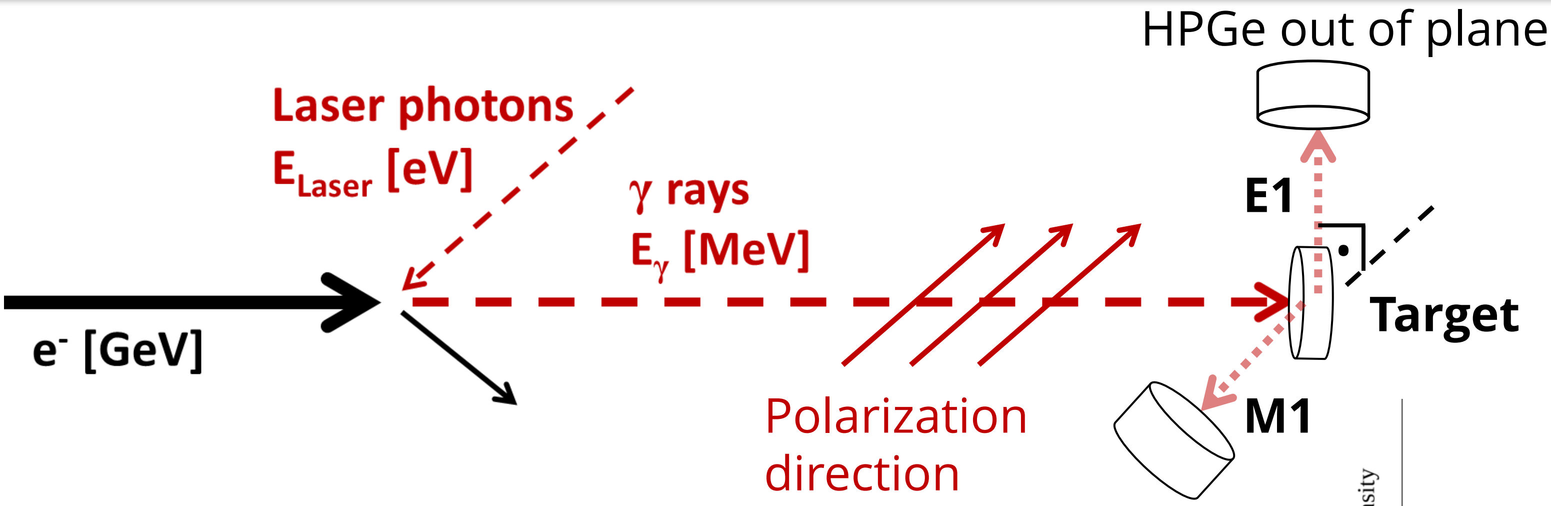

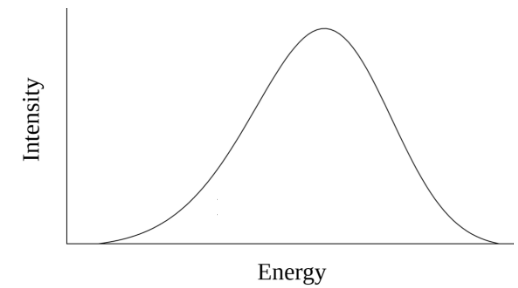

- LCB conserves polarization
- Advantage
  - Linearly polarized photons → Parity quantum number assignment
  - Quasi-monoenergetic γ-ray beam → Decay branching ratios and unresolved strength

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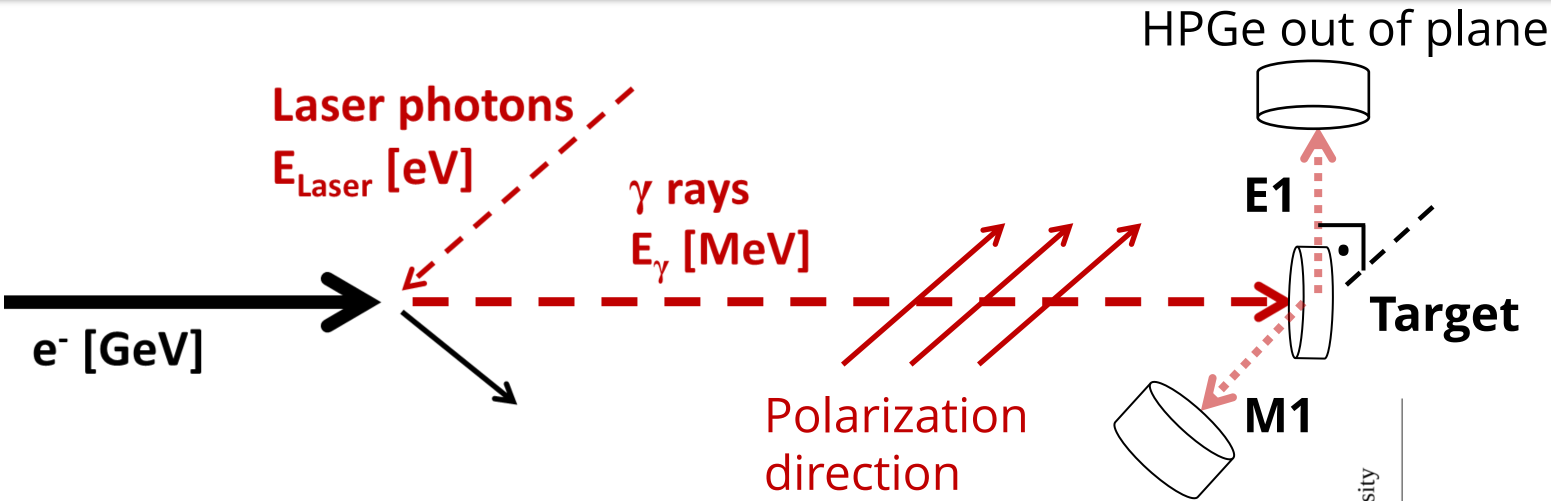

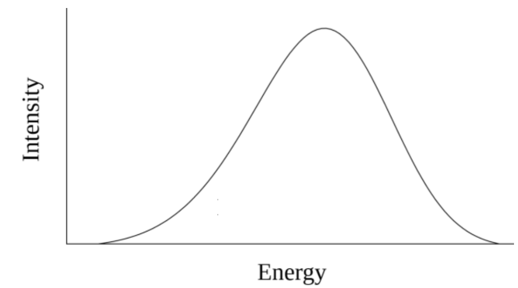

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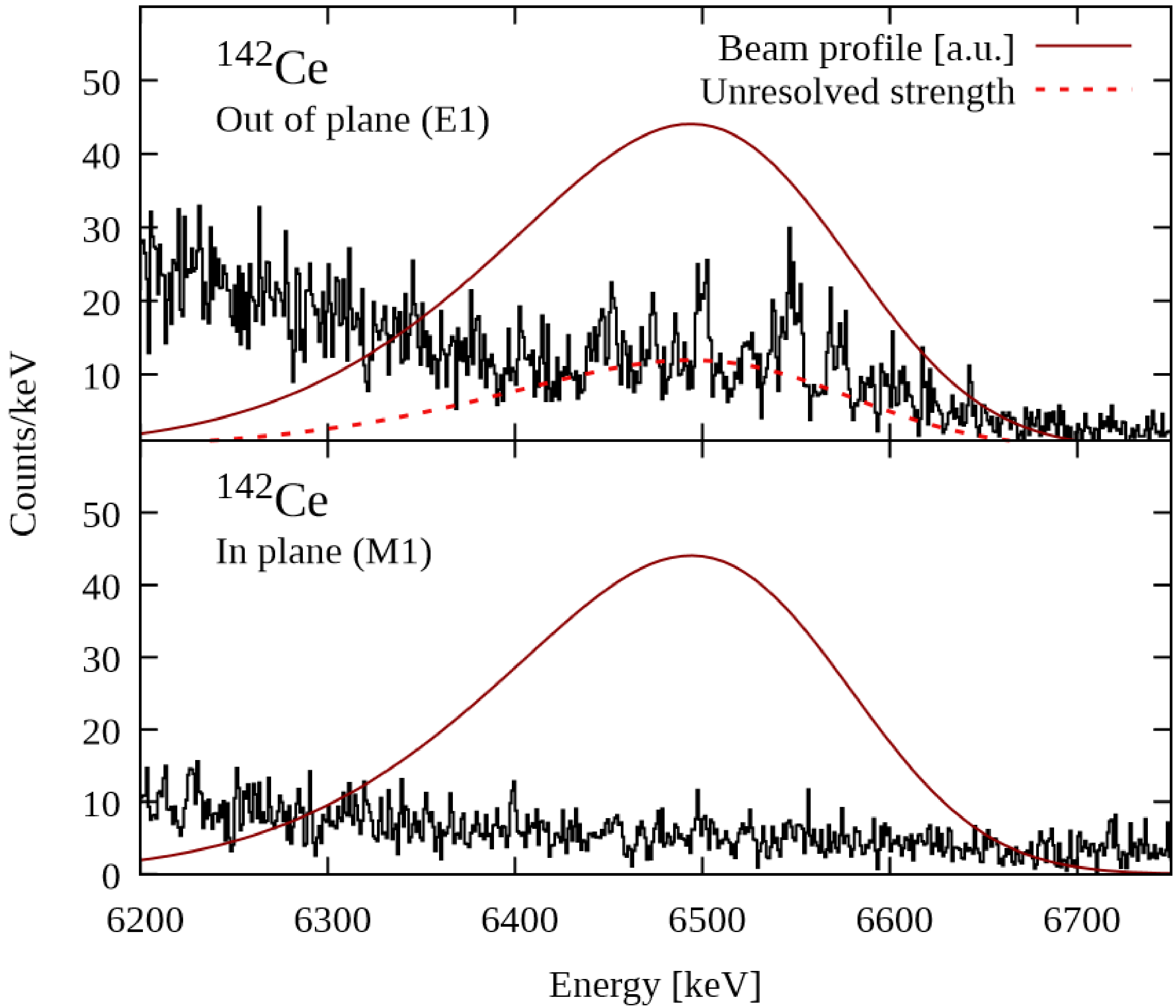
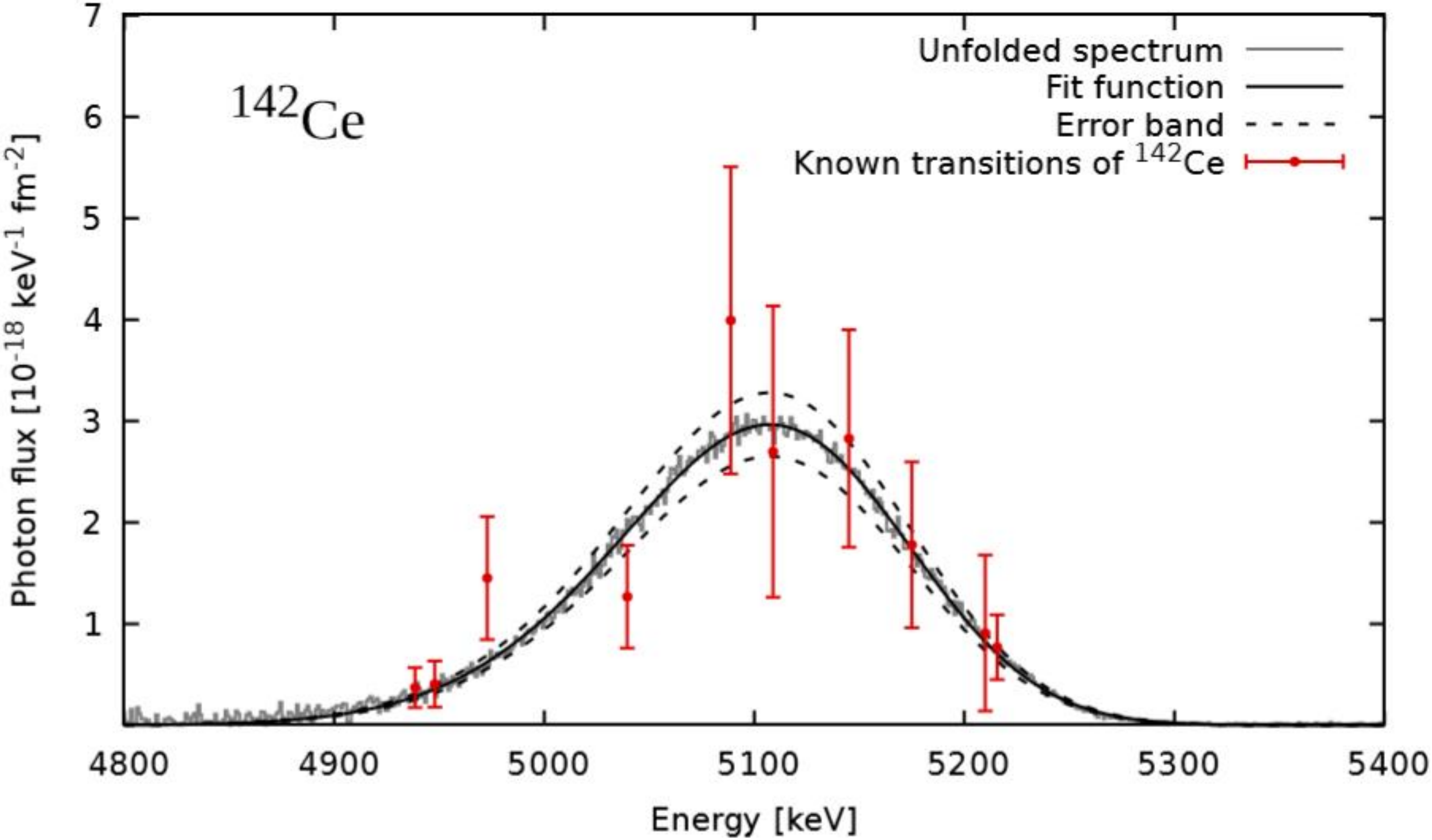
- Examples
  - New Subaru (University of Hyogo, Japan)
  - HIγS (Duke University, USA)
  - ELI-NP (Romania)

^{142}Ce – HIγS spectra



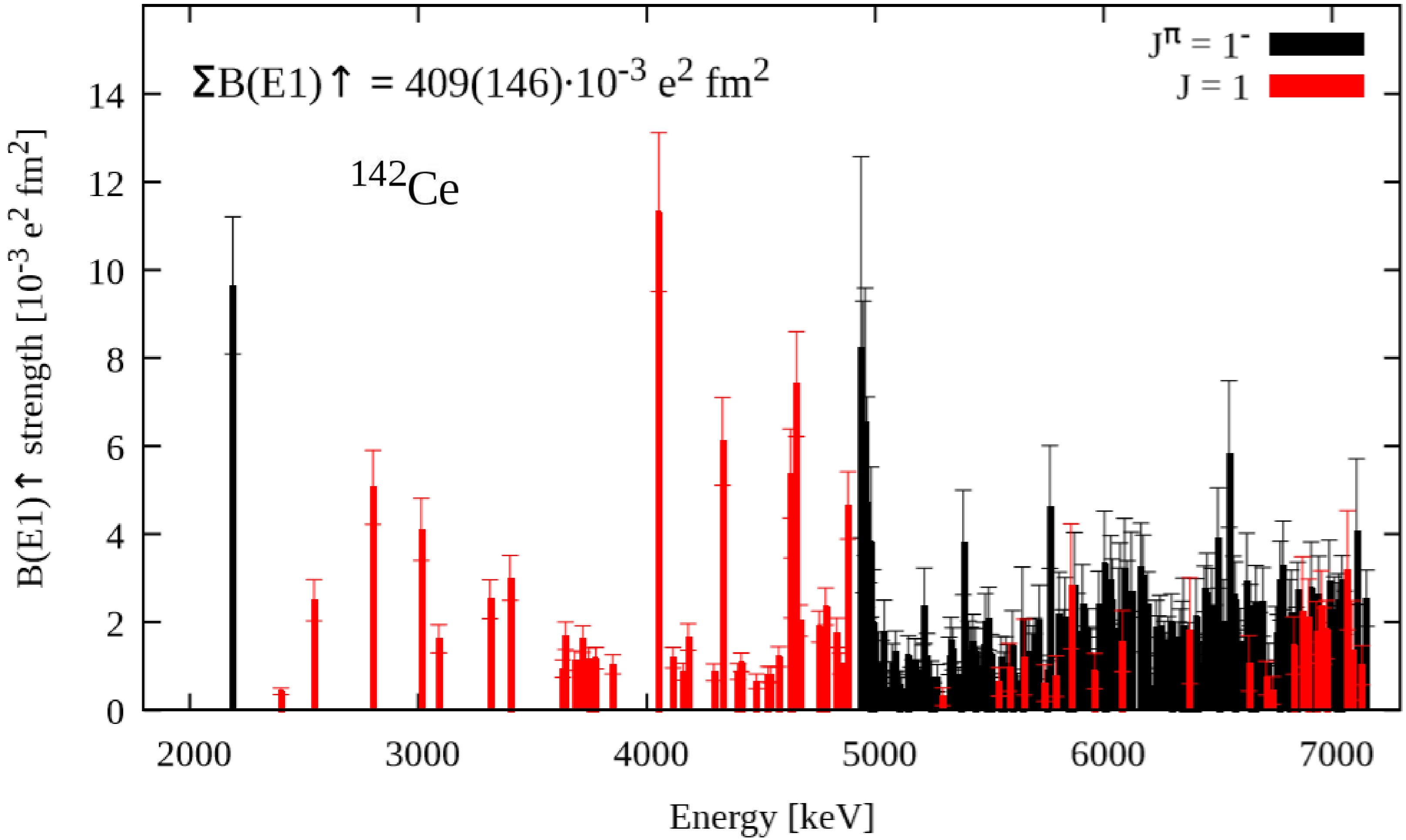
- Weak transitions below sensitivity limit appear as unresolved strength
- Absolute photon flux determination very difficult

HIγS – Photon flux calibration



Photon flux is determined by known transitions of target nucleus from bremsstrahlung measurement

Combination of complementary experiments

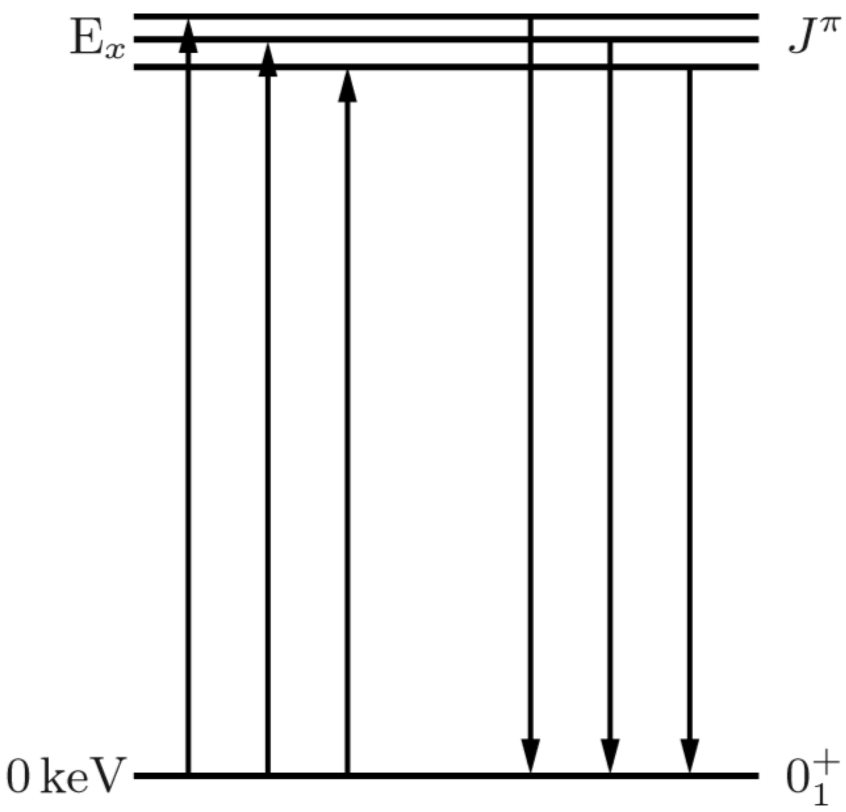


205 J = 1 states and for 139 states negative parity quantum numbers were determined

Parity of two-phonon state taken from A. Gade *et al.*, PRC **69**, 054321 (2004)

Average cross sections

$$\sigma_{\gamma\gamma} = \frac{A(total)}{N_T \cdot W \cdot \bar{\varepsilon} \cdot \int_0^{\infty} N_\gamma \, dE_\gamma} \quad \text{(elastic)}$$



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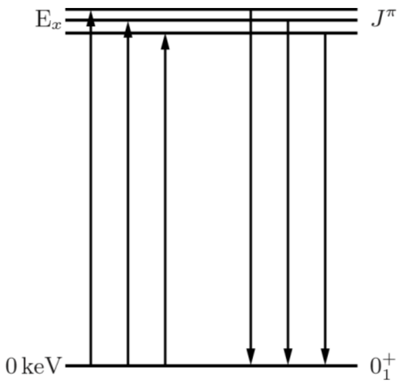
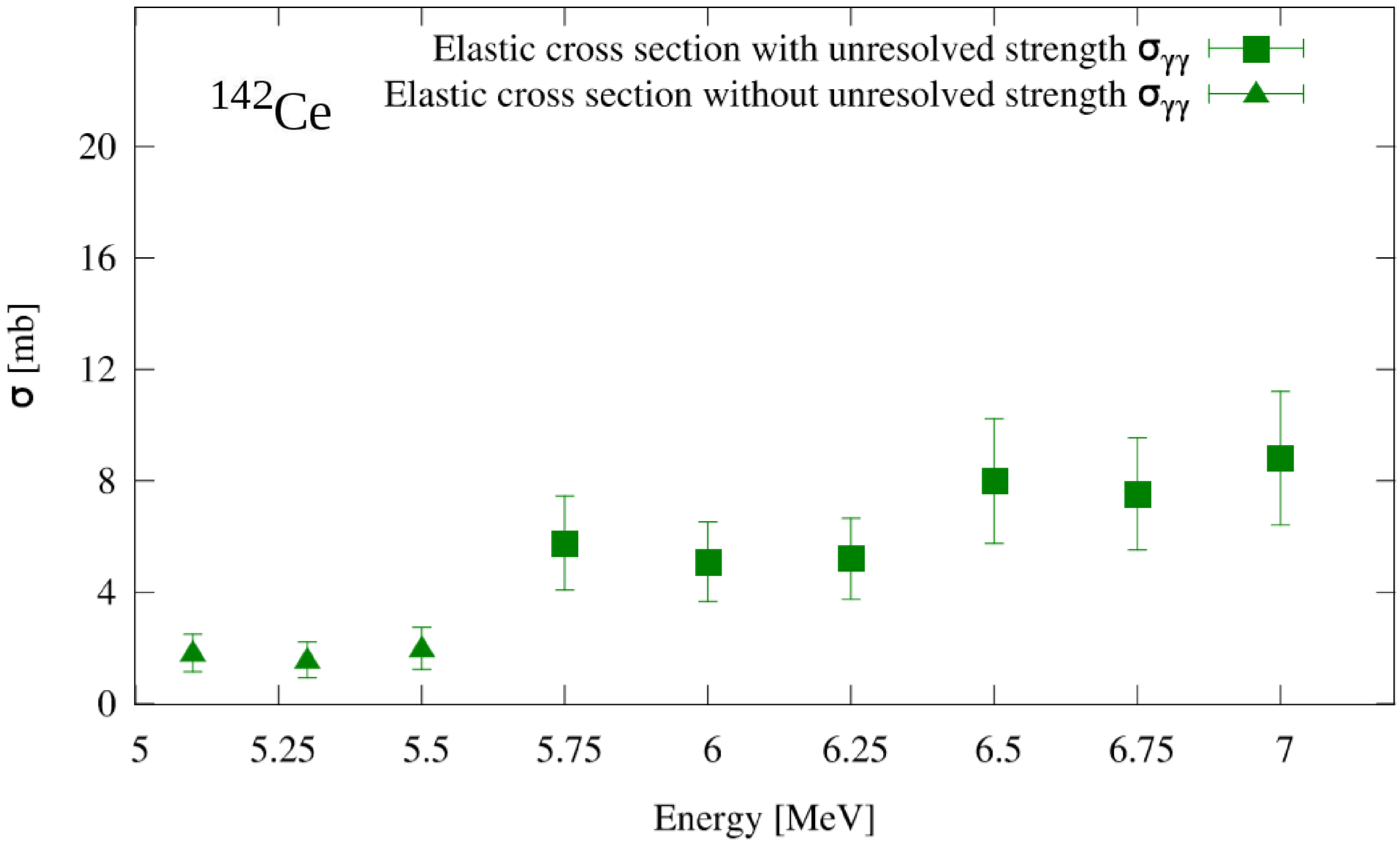
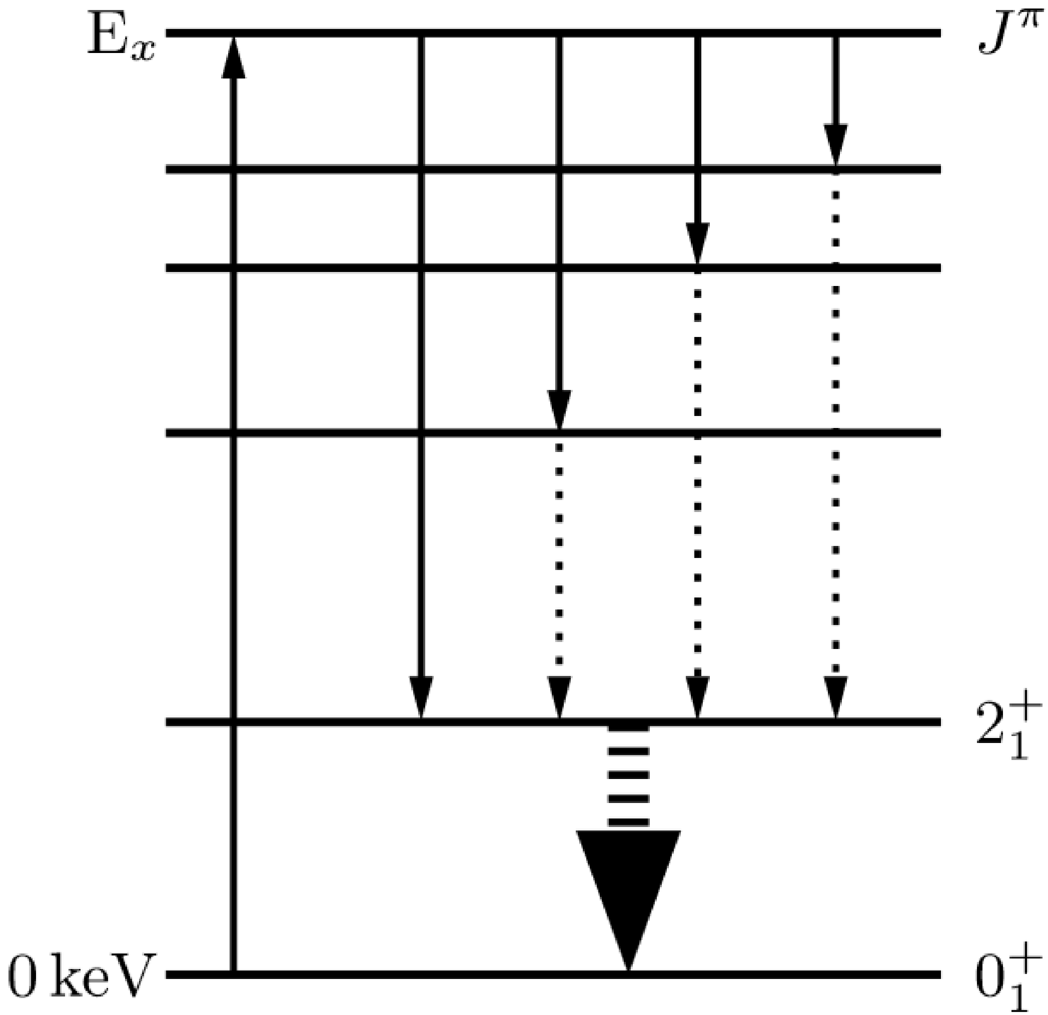




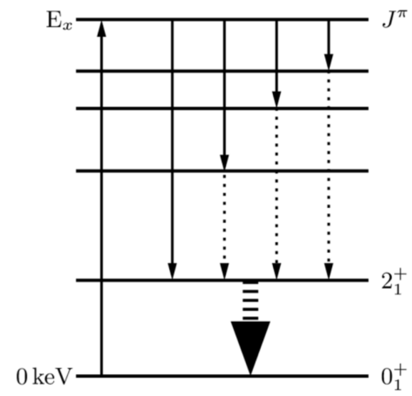
Average cross sections

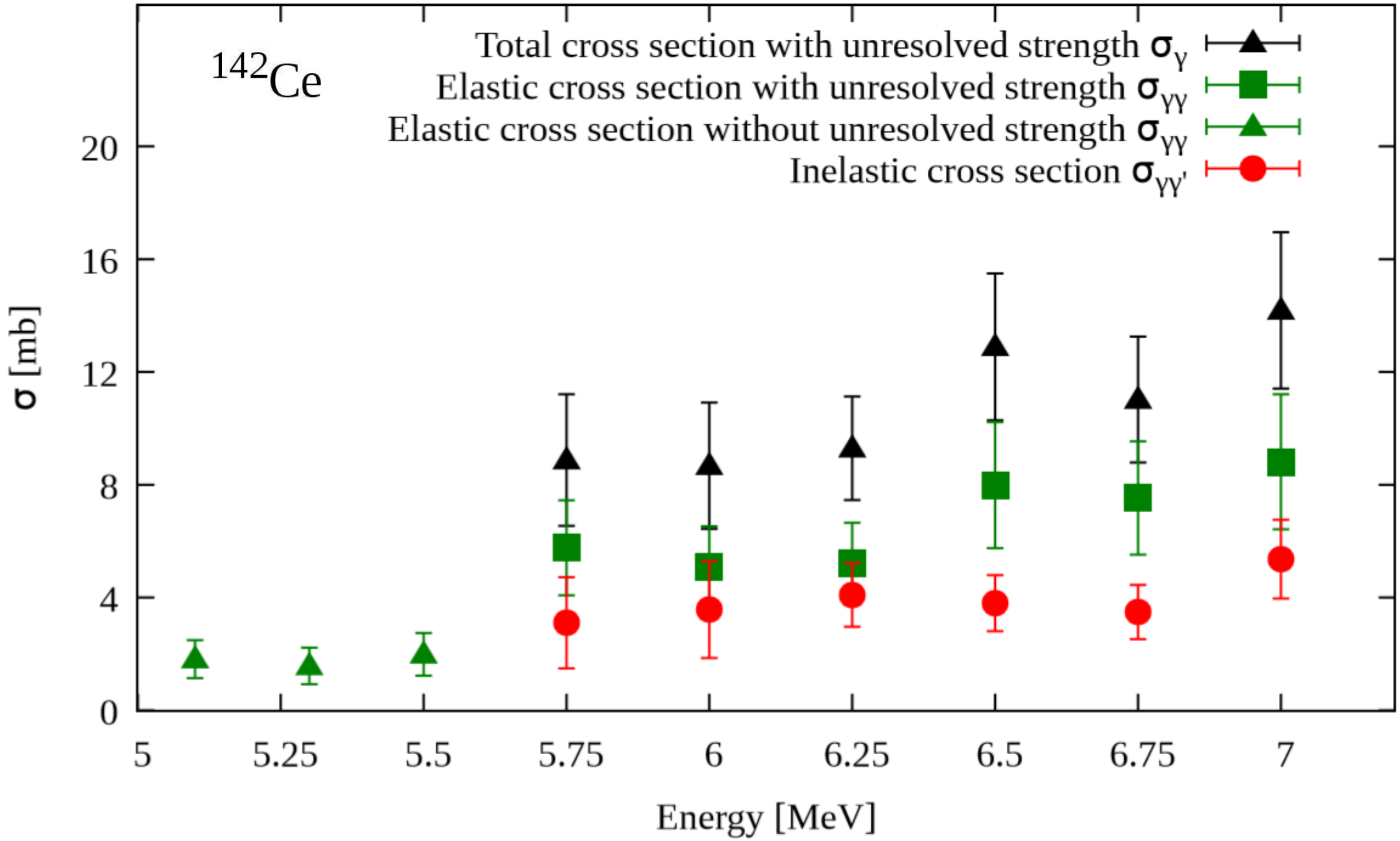
2_1^+ state acts as funnel → Serves as estimation of inelastic decays



Average cross sections

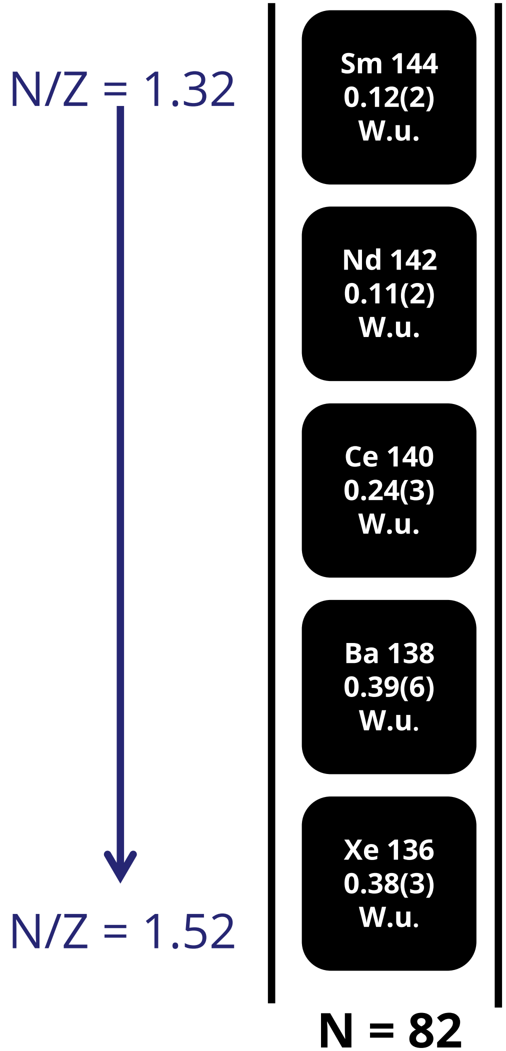
$$\sigma_{\gamma\gamma'} = \frac{A(2_1^+)}{N_T \cdot \overline{W} \cdot \varepsilon(2_1^+) \cdot \int_0^\infty N_\gamma \, dE_\gamma} \quad \text{(inelastic)}$$





Evolution of the PDR in the A ≈ 140 mass region

How does the **PDR evolve with increasing N/Z** ratio and **deformation**?



D. Savran *et al.*, PRC **84** (2011) 24326 ; R.-D. Herzberg *et al.*, PLB **390** (1997) 49 ;
B. Löher, Dissertation Thesis, Johannes Gutenberg-Universität Mainz (2014)

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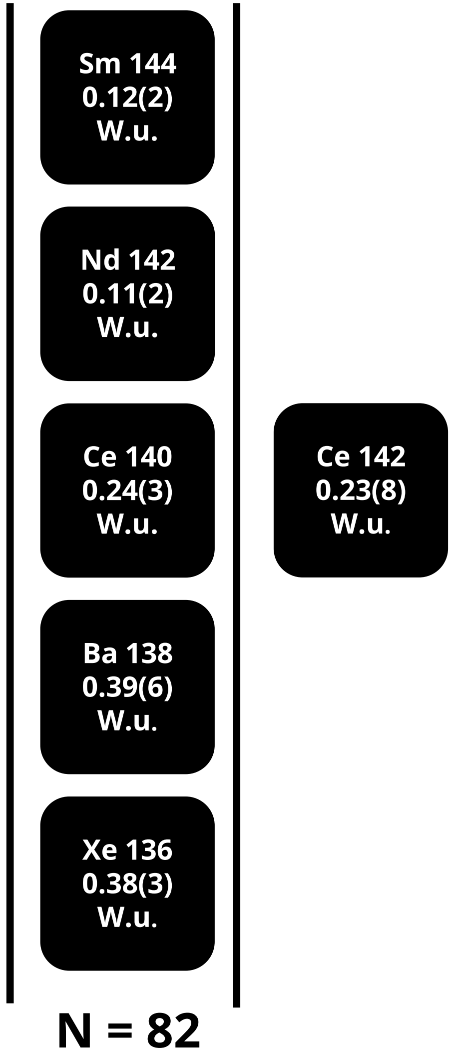

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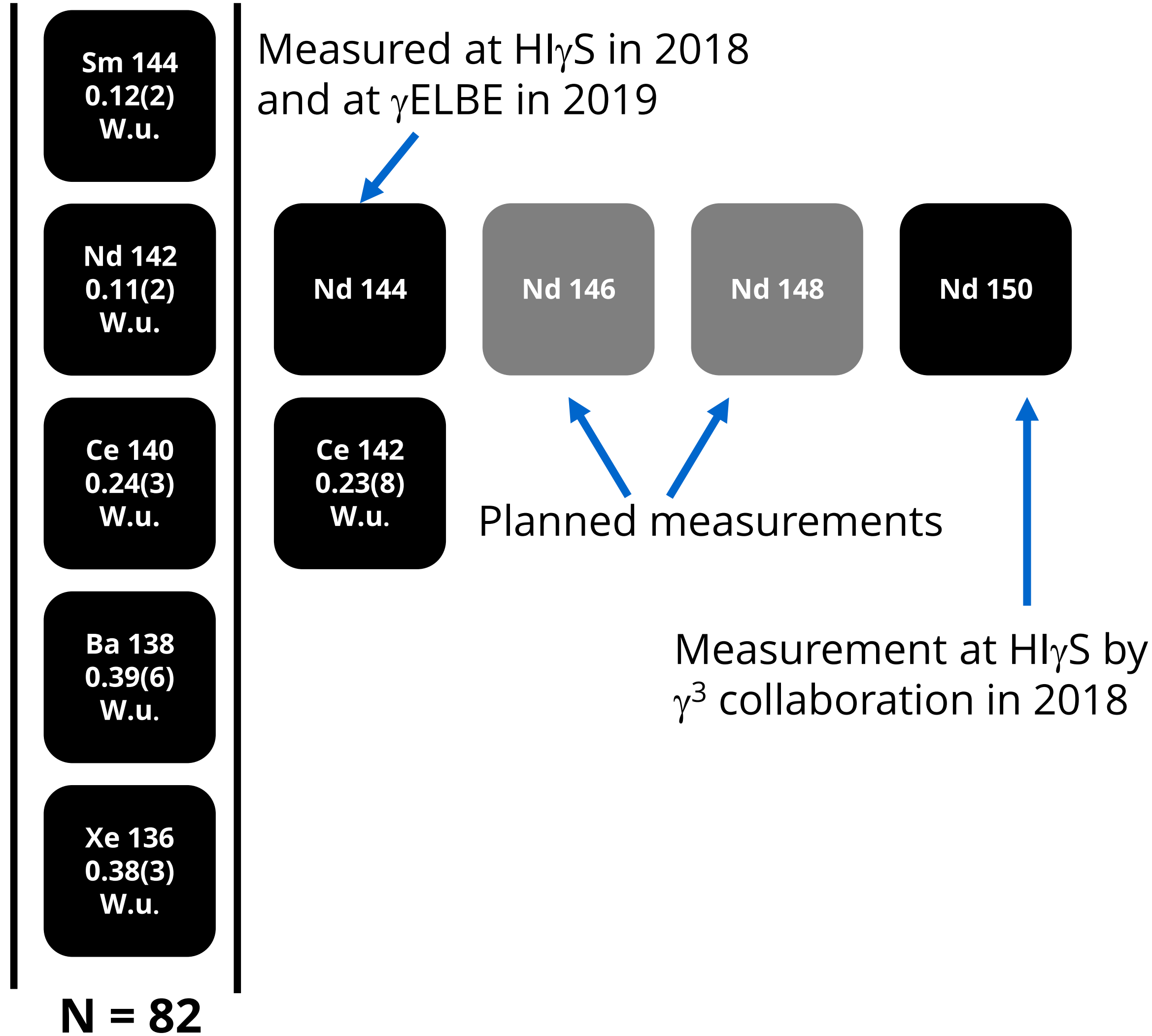

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Evolution of the PDR in the A ≈ 140 mass region

How does the **PDR evolve with increasing N/Z** ratio and **deformation**?

Low-abundant (< 0.5 %) nuclei → experiments at upcoming ELI-NP facility possible

Ce 136

Ce 138

Sm 144
0.12(2)
W.u.

Nd 142
0.11(2)
W.u.

Ce 140
0.24(3)
W.u.

Ba 138
0.39(6)
W.u.

Xe 136
0.38(3)
W.u.

N = 82

Measured at HIγS in 2018 and at γELBE in 2019

Nd 144

Nd 146

Nd 148

Nd 150

Ce 142
0.23(8)
W.u.

Planned measurements

Measurement at HIγS by γ^3 collaboration in 2018

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