Study of the K quantum number of pygmy states in ^{154}Sm

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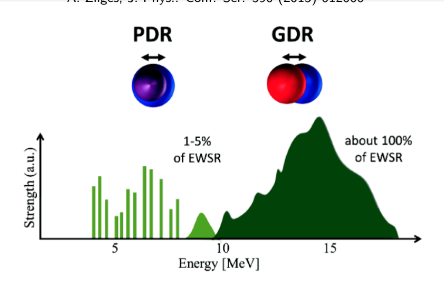
Introduction

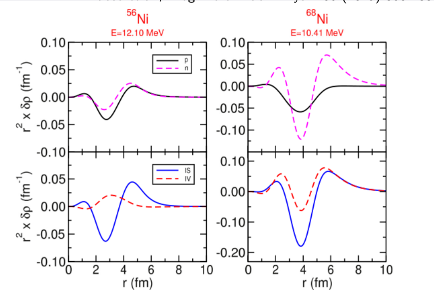
- An enhancement of the γ-ray strength around 5–7 MeV was observed through (n,γ) in various isotopes in the 1950s and 1960s by Bartholomew et al.
- This strength was referred to as the **Pygmy Dipole Resonance** (PDR) by Brzosko *et al.* in 1969.
- PDR - An oscillations of excess neutrons against an inert core with $N \simeq Z$ by R. Mohan *et al.* in 1971.

A. Zilges, J. Phys.: Conf. Ser. 590 (2015) 012006



The splitting of the $E1$ strength into the PDR and the GDR.

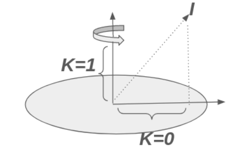
A. Bracco et al., Prog. Part. Nucl. Phys. 106 (2019) 360-433



Transition densities of the low-lying E1 state for ^{56}Ni and ^{68}Ni.

Role of nuclei deformation on the PDR

- Nature and behaviour of the PDR with neutron excess defies interpretation.
- Most affected are the predictive power for exotic nuclei.
- Most studies of the PDR are on spherical nuclei; the role that nuclear deformation plays on the PDR is yet to be understood.
- The principle aim of this study is to investigate the impact of ground state deformation on the properties of the PDR in ^{154}Sm.
  1. Measure the cross-sections of the individual states contributing to the PDR .
  2. Extract the associated K quantum numbers in ^{154}Sm.

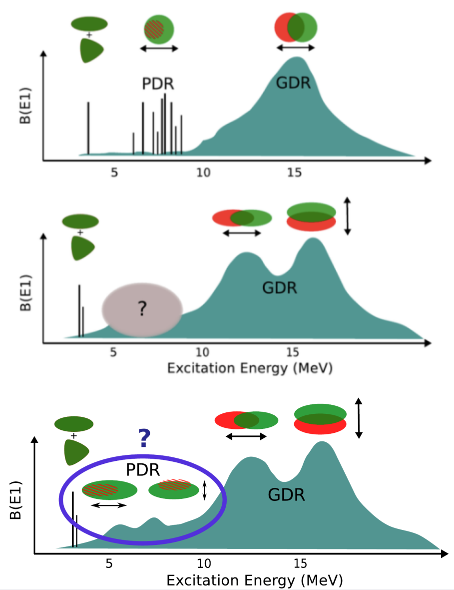


Angular K quantum numbers for a deformed nucleus.

Role of nuclei deformation on the PDR

- Collective picture;
  ●A possible double-hump structure in the PDR, resembling that observed in the GDR could be expected.

- Potential interpretation: Deformed proton-neutron saturated core, oscillating against a neutron skin along two different axes.

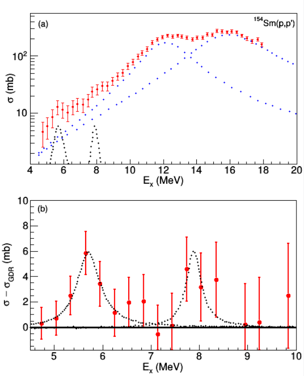


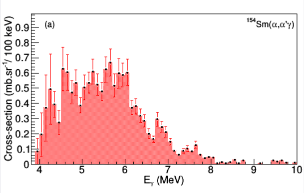
Demostration of the B(E1) response in heavy deformed nuclei.

Experimental signatures of the PDR in ^{154}Sm

H.Jivan, L.Pellegri, P von Neumann-Cosel, A. Tamii to be published.

- Observed double-hump structure of the PDR in ^{154}Sm through (p,p′).
  - **Could be connected to the splitting of the K quantum number.**
- Single-hump structure observed through ^{154}Sm$(\alpha, \alpha'\gamma)$.
  - **IS probe$\rightarrow$ Possible K mixing.**
- Current study expected to give info on the K values in the PDR region.

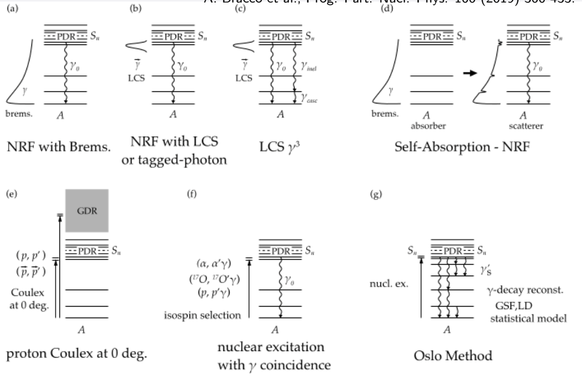




Photoabsorption cross section comparisons of ^{154}Sm$(\alpha, \alpha'\gamma)$ and ^{154}Sm(p,p′).

Techniques for exciting the PDR

A. Bracco et al., Prog. Part. Nucl. Phys. 106 (2019) 360-433.



Schematic representation of the main experimental methods used in the study of low-lying dipole strength and its decay modes

(C)

- Quasi-monoenergetic, polarised photon beam utilised at HIγS.
- Cascade decay measurements

How to measure the K components at the High Intensity γ-ray Source (HIγS)

- The setup allows for measurements by the asymmetry method of the character of the populated transitions.
  - $\bullet \rightarrow$ **to distinguish between the contribution of $E1$ and $M1$ states.**
- The asymmetry (ϵ) of an excited state is estimated by

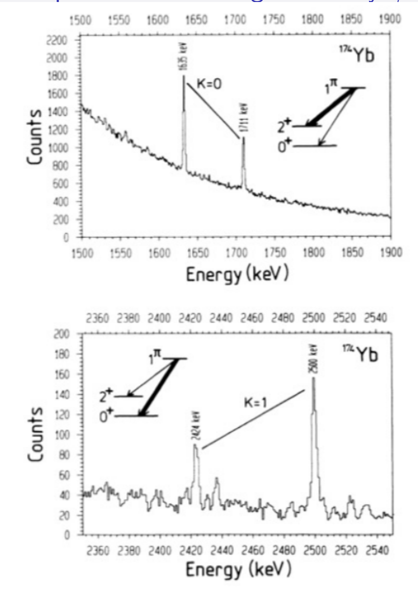
$$\epsilon = \frac{A_{\parallel} - A_{\perp}}{A_{\parallel} + A_{\perp}} \tag{1}$$

- The high beam resolution mode (<2%) allows for the measurement of the decay branching ratio to the first 2^+ (82 keV) state;
- To extract the K values for the pygmy states the branching ratio between decay to the g.s. and first 2^+ state must be measured. According to the Alaga rules the ratio

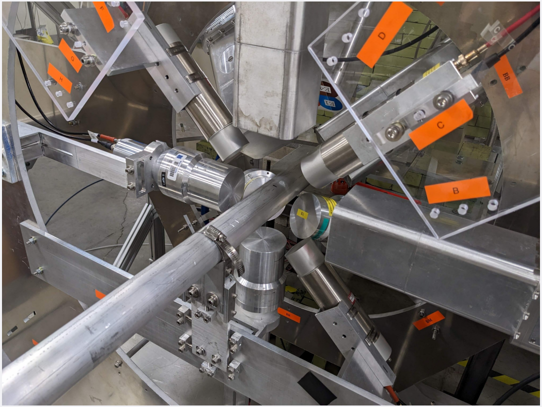
$$R = \frac{B(1^- \rightarrow 2^+)}{B(1^- \rightarrow 0^-)} \tag{2}$$

  is 0.5 for K=1 and 2 for K=0 (might not hold at these higher energies).

How to measure the K components at the High Intensity γ-ray Source (HIγS)



Experiemental Setup at the High Intensity γ-ray Source (HIγS).

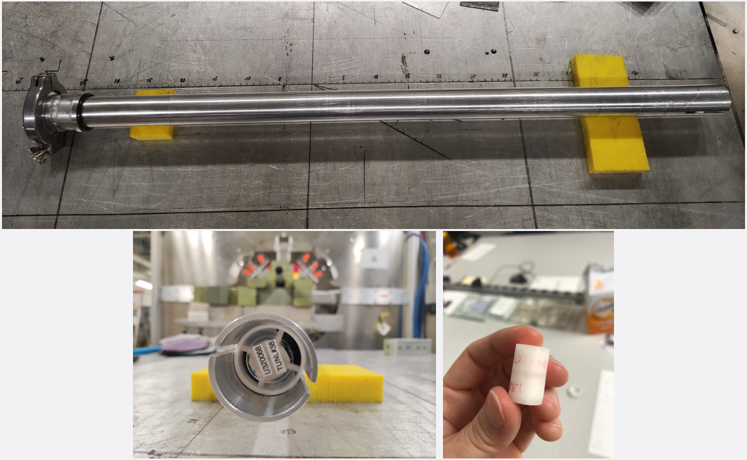


γ-ray detectors around the target position.

- 2.5g of ^{154}Sm in oxide form, enriched to >90% for the isotope of interest
- ^{154}Sm(γ,γ') with beam energy ranging from 3.83 to 7.05 MeV.
- 3 hours of beam time for every beam energy.
- 5 HPGe detectors, 4 $LaBr_3$:Ce and 3 $CeBr_3$ detectors.
- 1 HPGe at 0^{o} for beam profiling measurements.

Experiemental Setup at the High Intensity γ-ray Source (HIγS).

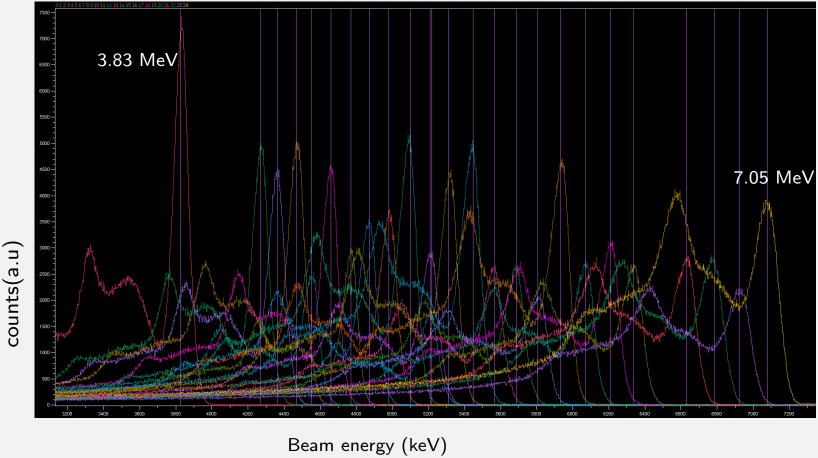
- Target-cylinder with a radius of 1 cm.



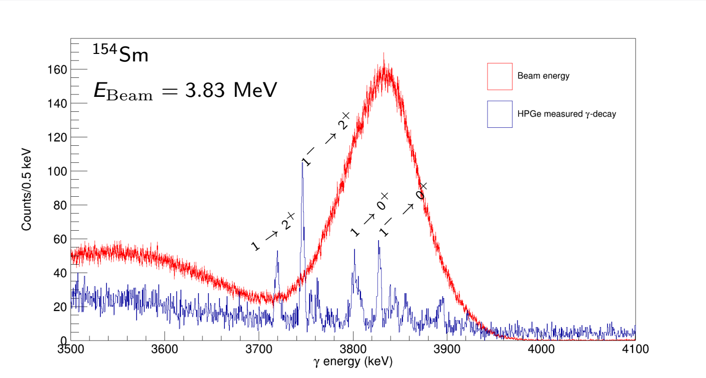
Target pipe, target holder inside the pipe and the target.

Beam Energy Profile

- 25 different beam energies.



Pre-liminary $^{154}Sm(\gamma, \gamma')$ spectrum



- **LCS** $\rightarrow$ Selectivity of the excitation energy.
- **HPGe** $\rightarrow$ Good resolution to separate decays to the g.s and the 2^+ state.

Summary and outlook

- **Challenge**: Previous efforts haven't provided a clear interpretation of PDR concerning neutron excess and deformation effects in nuclei.
- **Objective**: Understand the Pygmy Dipole Resonance (PDR) in deformed ^{154}Sm nucleus.
- **Methodology**: Utilize the (γ,γ') technique to investigate dipole states from 3.5 MeV to the neutron separation threshold (8 MeV).
- **Experimental Setup**: Employ the γ^3 setup at HIγS facility.
- **Identification**: Determine the K quantum number of different excited states and the PDR concerning excitation energy.
- **Comparative Analysis**: Compare results with data from other experiments to comprehensively understand PDR in deformed neutron-rich nuclei.

Collaborators

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