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

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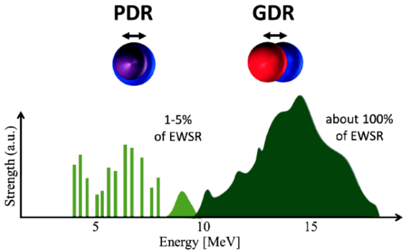
SAIP Conference 2025, Wits, Johannesburg

July 9, 2025

Introduction

- Understanding the structure of atomic nuclei is essential to nuclear physics and its applications in areas such as astrophysics.
- An area of growing interest in nuclear physics is the study of the **Pygmy Dipole Resonance (PDR)**.
- **PDR** is described as oscillations of excess neutrons against an inert core with $N \simeq Z$, as first described by R. Mohan *et al.* in 1971.
- A concentration of $J^{\pi} = 1^{-}$ states located around the neutron threshold.

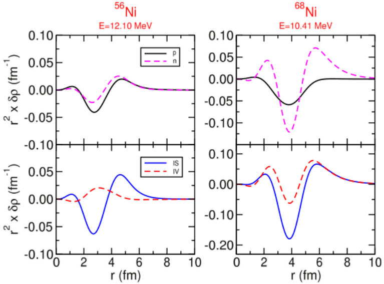
A. Zilges, J. Phys.: Conf. Ser. 590 (2015) 012006



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

Inside the nucleus-Transition densities of the PDR

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

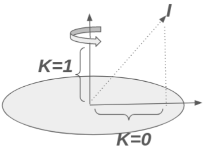


Transition densities of the low-lying E1 state for ^{56}Ni and ^{68}Ni.

- There has been some objections against such a simplistic collective picture of the low-lying $E1$ strength.
- Some studies shows some $E1$ strength in the PDR region in nuclei with little or no neutron skin.
- The features of the PDR are currently debated and the landscape of low-lying $E1$ states remains open.

Role of nuclei deformation on the PDR-Objectives of the study

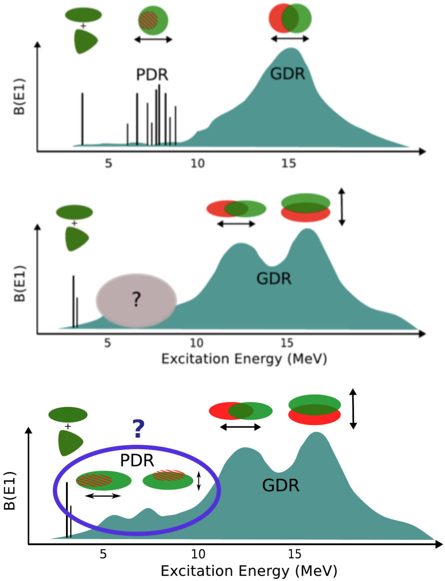
- Nature and behaviour of the PDR defies interpretation.
- The most affected are the predictive power for exotic nuclei.
- Most studies of the PDR are on spherical nuclei; the role that nuclear deformation plays on the PDR is yet to be understood.
- The main objective of this study is to investigate the impact of ground-state deformation on the properties of 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

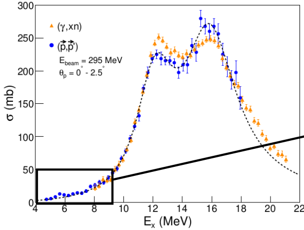
- Collective picture;
  - •A possible double-hump structure in the PDR, resembling that observed in the GDR could be expected.
- Potential interpretation:
  - •Deformed proton-neutron saturated core, oscillating against a neutron skin along two different axes.



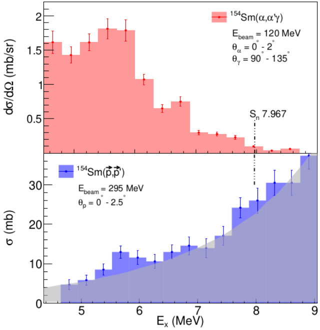
Demostration of the B(E1) response in heavy deformed nuclei.

L.Pellegri, H.Jivan, P von Neumann-Cosel, A. Tamii et al.

- PDR Single-hump structure observed in ^{154}Sm through (p,p′) on the IVGDR dataset.



GDR study



Comparisons of ^{154}Sm$(\alpha, \alpha'\gamma)$ and ^{154}Sm(p,p′).

- PDR Single-hump structure observed through ^{154}Sm$(\alpha, \alpha'\gamma)$.
  - **IS probe**

- The current study is expected to give **complementary information** on the role of deformation in the PDR region.

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

- Measurements by the asymmetry method: to distinguish $E1$ and $M1$ states.

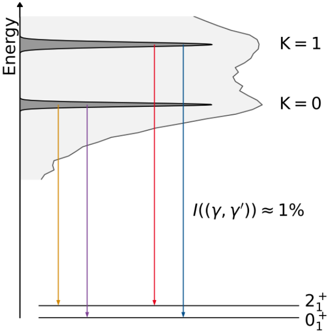
$$\epsilon = \frac{A_{\|} - A_{\perp}}{A_{\|} + A_{\perp}} \tag{1}$$

- The branching ratio between decay to the 0_1^+ and 2_1^+, according to the Alaga rules

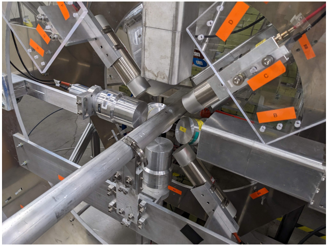
$$R = \frac{B(1^- \rightarrow 2^+)}{B(1^- \rightarrow 0^+)} \tag{2}$$

is 0.5 for K=1 and 2 for K=0.

J. Kleemann, 4 th International Conference on Nuclear Ph



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



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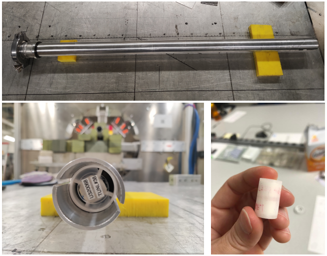
γ-ray detectors around the target position.

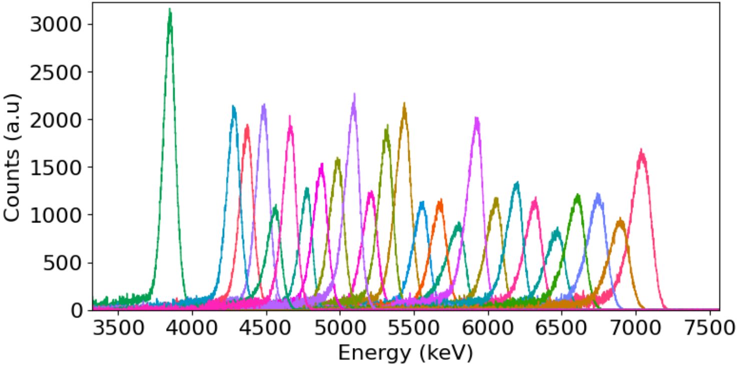


Target pipe, target holder inside the pipe and the target.

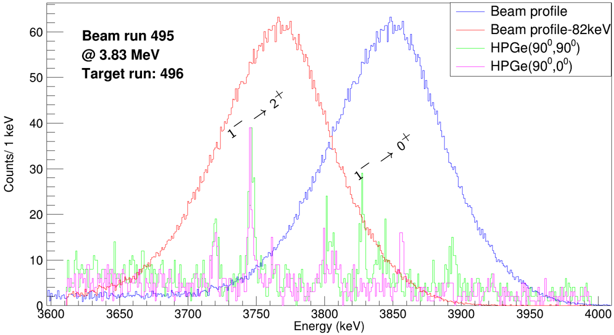
- 2.5g of ^{154}Sm in oxide form, enriched to >90% for the isotope of interest
- ^{154}Sm(γ,γ') with Laser Compton Scattered (LCS) beam energy ranging from 3.83 to 7.05 MeV.
- 3 hours of beam time for every beam energy.
- 5 HPGe detectors, 4 $LaBr_3$:Ce and 3 $CeBr_3$ detectors.
- 1 HPGe at 0^o for beam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

Beam Energy Profile

- 25 different beam energies.
- Good overlap-continuous scan of the excitation energy.



Pre-liminary spectrum



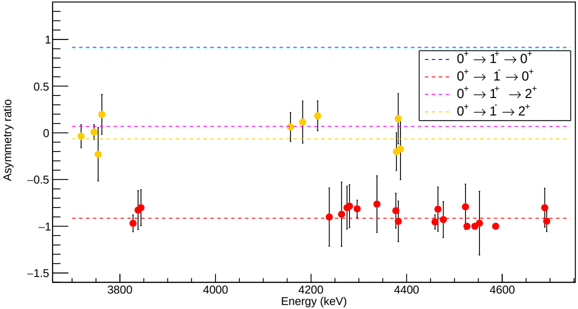
Beam profile (shifted and unshifted) over the two detectors that are perpendicular to each other.

- **Mono-energetic LCS** → Selectivity of the excitation energy.
- Measurements by the asymmetry method in the two perpendicular detectors.

Pre-liminary Asymmetry Ratios

For extraction of the asymmetry values, the theoretical equivalence (for comparison) is:

$$\epsilon = \frac{A_{\parallel} - A_{\perp}}{A_{\parallel} + A_{\perp}} = \frac{W^{\text{mean}}(k) - W^{\text{mean}}(l)}{W^{\text{mean}}(k) + W^{\text{mean}}(l)} \quad (3)$$



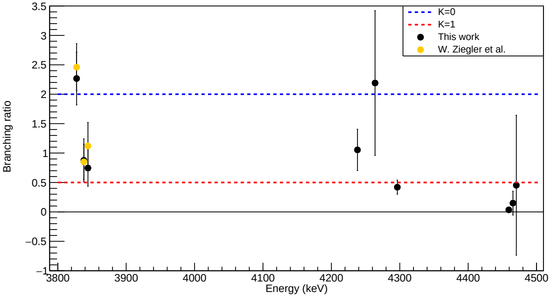
Comparison of the theoretical and experimental asymmetries for clover detectors at 0° and 90° to assign spins and parities.

Pre-liminary - Branching ratio and the associated K quantum numbers

- The branching ratio between decay to the 0_1^+ and 2_1^+, according to the Alaga rules

$$R = \frac{B(1^- \rightarrow 2^+)}{B(1^- \rightarrow 0^+)} \tag{4}$$

is 0.5 for K=1 and 2 for K=0.



Comparison of the branching ratios obtained in this experiment and by *W. Ziegler et al*

Summary and outlook

- **Challenge**: Previous efforts haven't provided a clear interpretation of PDR concerning 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 in the PDR region.
- **Experimental Setup**: Employ the γ^3 setup at HIγS facility.
- **Identification**: Determine the K quantum number of different excited states in the PDR region.
- **Comparative Analysis**: Compare results with data from other experiments to comprehensively understand PDR in deformed neutron-rich nuclei.

Collaborators

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This work is based on the research supported in part by the National Research Foundation of South Africa and the US Department of Energy.

Thank you, Ke a leboga, Dankie, Ngiyathokoza, Ngiyabonga, Nda livhuwa, Ndza khensa, Enkosi!!