Nature of Pygmy Dipole Resonance in $^{74}\text{Ge}$

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The Pygmy Dipole Resonance

Oscillation of neutron skin against the core

PDR : Open questions

- How collective is it?
- How does PDR depend on N/Z?
- How PDR effects r-process nucleosynthesis?
- Is ‘isospin-splitting’ a general phenomenon?
The Pygmy Dipole Resonance

Oscillation of neutron skin against the core

Pygmy Dipole Resonance

Giant Dipole Resonance

- How collective it is?
- How does PDR depends on N/Z?
- How PDR effects r-process nucleosynthesis?
- Is ‘isospin-splitting’ a general phenomenon?

Use of complementary probes to reveal details of structure

- Photon scattering:
  - dominant isovector excitation (for E1)
  - interaction with whole nucleus (kR << 1)

- α scattering:
  - dominant isoscalar excitation
  - interaction dominant at the surface
Recent studies on
El Strength distribution using
\((\alpha, \alpha'\gamma)\) reaction
Recent studies on E1 Strength distribution using (H-Ion,H-Ion'γ) reaction

\[ ^{208}\text{Pb}(^{17}\text{O},^{17}\text{O}')^{208}\text{Pb} \]

F. Crespi et al., *PRC* 91, 024323 (2015)
F. Crespi et al., *PRL* 113, 012501 (2014)
Scenario so far regarding studies with heavy ion scattering reactions

- Studies are limited to 130 mass region (except few cases) are done on nuclei with relatively larger N/Z asymmetry.
- Isospin-splitting is found in most of nuclei.

- Need for investigation in other mass regions (also in nuclei with lower N/Z asymmetry)

- Experimental effort was made to study low lying dipole states in 74Ge at iThemba LABS.
  - N/Z = 1.32
  - Weakly deformed prolate in its ground state
Experiment in new region

Population of excited states via inelastic scattering of $^{74}$Ge using the following reaction $^{74}$Ge($^4$He, $^4$He$'$)$^{74}$Ge @ 48 MeV

For the detection of γ-rays
HPGe detectors in Clover arrangement
Nine Clover detectors.
(AFRODITE Array at iThemba LABS)

For the detection of charged particles
Telescope counters
(Double sided) Silicon Strip Detectors
Two Counters
Thickness ($\Delta E$) = 284 $\mu$m
Thickness (E) = 980 $\mu$m
At ± 45 degrees with respect to the beam axis
Experimental technique for the study of Pygmy dipole resonance

• Excitation energy of the system from the inelastically scattered alpha particles.
• Simultaneous detection of $\gamma$ decaying to the ground state.

$E_\gamma \approx E_x$

$\alpha - \gamma$ coincidence matrix

Excellent selection of $J^\pi = 1^-$ states
(for $E_x > 5$ MeV in even-even nucleus)
RESULTS

Raw Particle Identification plot

\[ \Delta E \]

\[ E \]

\[ ^{3}\text{He} \]

\[ ^{4}\text{He} \]

\[ p \]

\[ d \]

\[ t \]

\[ \alpha \text{ particle spectrum} \]  
(with \( \gamma \) in coincidence)

\[ \text{Counts} \]

\[ 0 \]

\[ 500 \]

\[ 1000 \]

\[ 1500 \]

\[ 2000 \]

\[ 2500 \]

\[ 3000 \]

\[ 3500 \]

\[ 4000 \]

\[ 4500 \]

\[ 5000 \]

\[ 5500 \]

\[ 6000 \]

\[ 6500 \]

\[ 7000 \]

\[ 7500 \]

\[ 8000 \]

\[ t_\alpha - t_\gamma_1 \ (\text{ns}) \]

\[ t_\alpha - t_\gamma_2 \ (\text{ns}) \]

\[ (\alpha - \gamma)_{\text{corr}} \]

\[ (\alpha - \gamma - \gamma)_{\text{corr}} \]

\[ (\alpha - \gamma - \gamma)_{\text{uncorr}} \]

Kinematic corrections.
Energy loss corrections in absorbers and target.
\( \alpha - \gamma - \gamma \) timing relationship

Red data are random events
Blue data are after random subtraction
Energy resolution ~ 250 keV
\[ |E_\alpha - E_\gamma| < 130 \text{ keV} \]

“•” represent known states from earlier works

“↓” indicate position of an absent transition observed in \((\gamma, \gamma')\) data
Comparison with $(\gamma, \gamma')$ data

Observations:

- Relatively larger isoscalar contribution for states $E < 5$ MeV.
- Relatively larger isovector contribution for states $E > 5$ MeV.

$(\gamma, \gamma')$ data taken from A. Jung et al., Nucl. Phys. A 584 (1995) 103.
Comparison with \((\gamma, \gamma')\) data

Theoretical calculations:
- RQTBA calculation.
- Qualitatively reproduces the trend of decreasing isoscalar strength with increasing excitation energy.

Comparison with \((\gamma, \gamma')\) data

**Theoretical Calculations:**
- RQTBA calculation.
- Qualitatively reproduces the trend of decreasing isoscalar strength with increasing excitation energy.
- Transition densities exhibit compressional mode at low energies and isospin mixed mode at higher energies.
Comparison to earlier work with $(\alpha, \alpha' \gamma)$ reaction

Observations:

- Stronger isoscalar response at low energies ($E < 5$ MeV) compared to earlier works.
- No isospin splitting in the pygmy region, i.e. $6 - 8$ MeV.
- Isoscalar response is same for dipole states in this energy region.

$(\gamma, \gamma')$ data taken from A. Jung et al., Nucl. Phys. A 584 (1995) 103.
Contribution of Coulomb interaction

For dipole states at $E = 4.55$ MeV

For dipole states at $E = 7.01$ MeV

$\theta_{\text{c.m.}}$ (deg)

$\frac{d\sigma}{d\Omega}$ (mb/sr)

DWBA Calculations (DWUCK4 code)
Using microscopic transitions densities from RQTBA calculations.

Negligible contribution from Coulomb interaction
Conclusions:

- Isospin splitting of PDR is not observed in $^{74}\text{Ge}$
- Relatively large isoscalar components of dipole states at lower energies ($E < 5$ meV)
- $\alpha$ and $\gamma$ interact differently with nucleus. (surface vs whole nucleus)
- Importance of complementary probe, alpha, in deducing information.
Collaboration


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Thank You
RESULTS cont....

Particle Spectrum with $\alpha$ banana gate

$\gamma$-ray Spectrum