Investigation of Pygmy Dipole Resonance in neutron rich exotic nuclei

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Outlines

- Pygmy Dipole Resonance
- E1 strength investigation of $^{62,64}$Fe nuclei with relativistic coulomb excitation
- PreSPEC-AGATA setup at GSI
- Preliminary results about $^{62,64}$Fe
- Next investigation: $^{70}$Ni isotope
- Conclusions
Pygmy Dipole Resonance in neutron rich nuclei

E1 strength response measured in neutron rich stable nuclei

accumulation of strength around and above neutron separation energy
interpret as a collective motion called Pygmy Dipole Resonance (PDR)

Relevant for nuclear structure:
neutron skin thickness [PRC 76, 051603(R) (2007)]

Equation of State (symmetry energy term) [PRC 81,041301(R)(2010)]

A lot of open points about PDR:
Isoscalar/isovector character
Collectivity
...

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Pygmy Dipole Strength in astrophysics

Relevant connection with astrophysics:

- Neutron star structure
  - Radius estimation [J. Phys. 420 012143]

- Nucleosynthesis
  - Influence on r-process [PRC 91, 044318 (2015)]
Iron isotopes

γ ray- Strength function measured for $^{56}$Fe

Theoretical predictions show dipole strength around 10 MeV and also below the threshold for $^{62,64}$Fe

For the first time E1 strength distribution below the threshold will be studied for exotic isotopes at varying of the neutron number
Relativistic coulomb excitation of Pygmy Dipole Strength

High selectivity

No neutron-threshold effect

Pygmy Dipole Strength measured for the first time in exotic nuclei: 
$^{62,64}$Fe coulomb excitation experiment in GSI

NPA 693, 90 (2001)
Relativistic coulomb excitation selection @ GSI

Identification of beam of interest

Scattering angle

Identification of reaction products

$E (\text{arb. Un.})$

$\Delta E (\text{arb. Un.})$

$A/Q$

Identification of reaction products

$mrad$

$5 \times 10^3$

$250$

$200$

$150$

$100$

$50$

$0$

$4$

$8$

$12$

$16$

$20$
AGATA array provides an high resolution energy in gamma detection, suppression of the doppler broadening and suppression of background.

HECTOR array (LaBr$_3$:Ce and BaF$_2$ scintillator detectors) provides efficiency in a wide range of angles.

AGATA coupled with HECTOR allows to cover a wide angular range. This can be used to prove the multipolarity of gamma rays detected. In addition, backward scintillators can be used for the estimation of background.
Low energy spectra @ GSI

Thick target and relativistic (440 MeV/nucl.) beam required a fine tuning of PreSPEc and AGATA detectors to observe $2^+$ state decay for both iron isotopes.

$B(E2)$ of $2^+$ decay is known and it is used as a benchmark to extrapolate $B(E1)$ of high energy state.
High energy spectra

AGATA $^{62}\text{Fe}^*$
Preliminary

Counts
$E_\gamma$ [keV]

AGATA $^{64}\text{Fe}^*$
Preliminary

Counts
$E_\gamma$ [keV]

Evaluation of background with backward detectors (target emission predominant respect to projectile)
CASCADE code used to evaluate target (red) and projectile (green) statistical decay

TARGET

PROJECTILE

142°
Results about E1 strength

After background subtraction structures around 6-7 MeV remain.

Using the 2+ state decay measurement as a benchmark, it was possible to extract $B(E1)$ from this high energy statistics.
Results about E1 strength

Angular distribution was used to prove the E1 character of states above 6 MeV.

The ratio between distribution of statistics from $2^+$ decay and statistics above 6 MeV was compared with the expected ratio between E2 and E1 emission.
Results about E1 strength

Preliminary B(E1) estimation shows similar trend with summed B(E1) obtained in other papers.

The well known challenge of understanding the r-process abundances requires measurements of the E1-strength function especially towards the neutron-drip line.

Phys. Rev. Lett. 112, 072501
70Ni measurement @ Riken

Experiment at Riken laboratory to measure PDR in 70Ni with NaI (DALI) and LaBr3:Ce detectors.

Theoretical prediction

2^+ state decay already identified

→ soon high energy states

[Graph showing energy levels and decay modes]

Preliminary

2^+ 1260 keV

Ground State

[Graph showing energy levels and decay modes]
Conclusions

- E1 strength accumulation at one particle separation energy has attracted interest because it is relevant for both nuclear structure and astrophysics.
  A lot of data available for stable nuclei, data about exotic nuclei very scarce.

- Measurement of E1 response of $^{64,62}$Fe by relativistic coulomb scattering at GSI laboratories.

- First preliminary evaluation of summed $B(E1)$ around one particle separation energy was achieved.

- Interesting data about E1 response of $^{70}$Ni were collected in Riken experiment.
Thank you for your kind attention
The width of structures at high energies is consistent with energy resolution of AGATA.
PreSPEC-AGATA setup

PreSPEC setup in GSI laboratory allows to produce radioactive beams at relativistic energies and select in flight the isotopes of interest (FRS)

The LYCCA calorimeter allows to select the product of reaction on secondary target

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