Investigation of Pygmy Dipole Resonance in neutron rich exotic nuclei

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Abstract

The electric dipole response of atomic nuclei is presently attracting large attention from the nuclear physics community. In particular the E1strength, located around the particle separation energy (6-12 MeV) , commonly called Pygmy Dipole Resonance (PDR), is the object of a large experimental and theoretical effort to investigate the properties and the correlations with nuclear structure. In spite of the large amount of data about E1 strength distribution in stable nuclei, very few data are available in neutron rich exotic nuclei. A measurement to search for the pygmy dipole resonance in ^{64}Fe and ^{62}Fe nuclei was performed in GSI in 2012 and concluded in 2014, during the PreSPEC – AGATA experimental campaign. The PDR excitation was obtained through relativistic Coulomb excitation in inverse kinematics. This reaction mechanism coupled with the detection of gamma rays emitted by excited nuclei is a well established experimental technique to investigate nuclear properties in the energy region of pygmy.

1 Introduction

The E1 response of atomic nuclei has provided in the past important information about nuclear structure. In particular Giant Dipole Resonance (GDR) has proved to be one of the building blocks for nuclear models. The GDR dominates the dipole response of nuclei in all region of mass; it was widely studied and used as a tool to investigate nuclear features.

In last decades, the so-called Pygmy Dipole Resonance (PDR) has attracted a lot of interest: in spite of the fact its nature has not been fixed yet, connections with both nuclear structure and astrophysics were demonstrated [1,2,3]. An amount of E1strength, corresponding to few percentage of the total strength, was measured around one particle separation energy in wide regions of mass[4]. A systematic experimental investigation has been carried on about stable nuclei, while data available about exotic nuclei are still scarce.

2 The experiment and the data analysis

The measurement here discussed was performed at GSI laboratories, during PreSPEC-AGATA campaign[5], aiming to investigate the dipole response below the particle threshold of exotic Iron isotopes ^{62,64}Fe. In particular this will provide the evolution of this dipole strength at varying the neutron number. Analogue measurements were already performed for stable nuclei [6]: this measurement will allow to add information in exotic medium mass region.

The experimental technique used in this experiment, consisted in relativistic coulomb excitation in inverse kinematics coupled with the gamma decay measurement. The advantage of coulomb interaction at relativistic beam energy consists in a selection of dipole excitation against higher multipolarities.

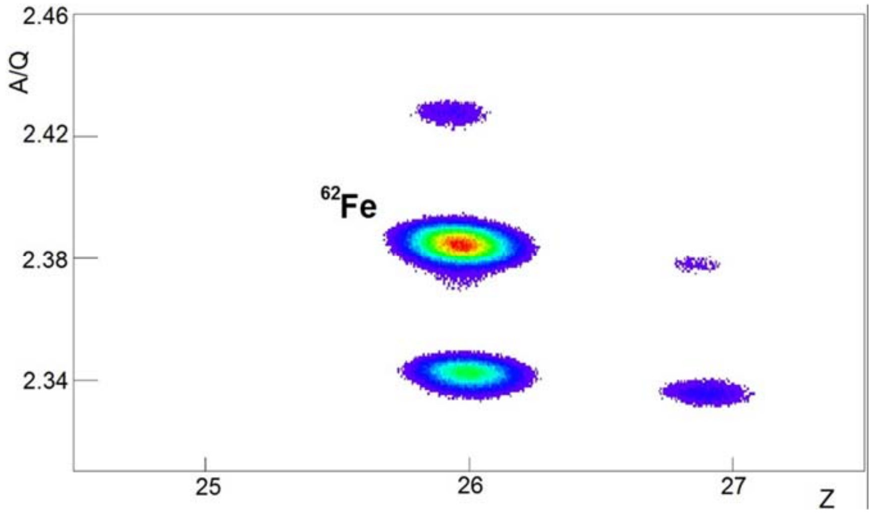

Fig. 1: Exemplum of identification of the beam impinging on secondary target.

The radioactive ^{62,64}Fe beams were produced by fragmentation of the primary ^{86}Kr beam delivered by the SIS synchrotron at 700 or 900 AMeV and focused on a Be target. The ions of interest were identified, selected and transported with the fragment separator FRS (Fig.1). The beam cocktail at 400-410 AMeV was then impinging on the Pb target (1 g/cm^2 thick) or Au target (2 g/cm^2 thick), which were surrounded by the γ-ray detectors. Coulomb excitation events were selected using LYCCA array [7]. E-ΔE telescopes provided identification of products from reactions on the secondary target, while ion tracking detectors were used to reconstruct the beam scattering angle. Selection of ^{62,64}Fe ions impinging and outgoing from the secondary target coupled with a required forward scattering angle, corresponding to a minimum impact parameter higher than 14 fm, guaranteed a pure coulomb interaction dataset.

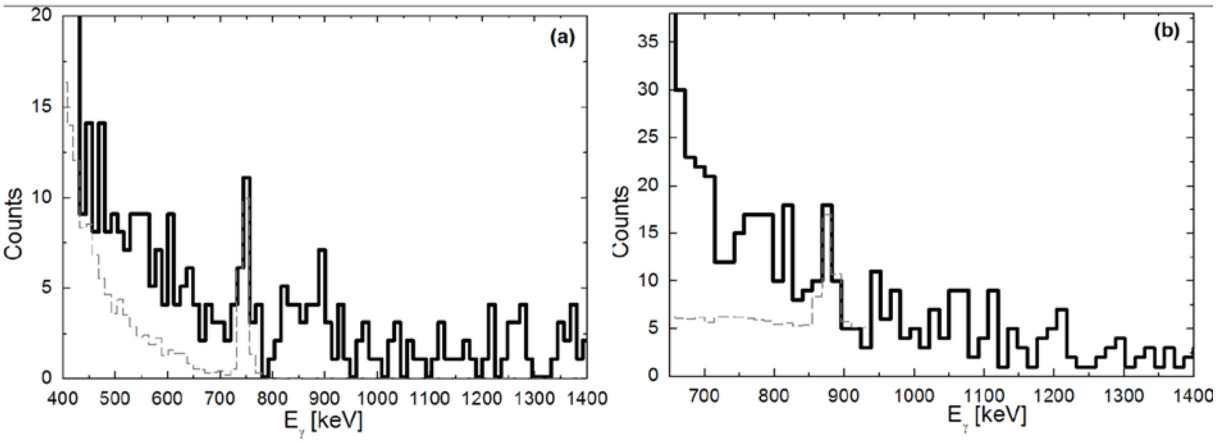

Fig. 2 : (a) AGATA energy spectrum for 64Fe with a peak at first 2+ state energy (746 keV); (b) AGATA energy spectrum for 62Fe with a peak at first 2+ state energy (877 keV). In both panels dashed line represents GEANT4 simulations

The gamma decay measurement was performed using AGATA array[8] combined with LaBr scintillators array (HECTOR$^+$, [9]). AGATA array provided high energy resolution, thanks to the intrinsic properties of HPGe detectors and also the electronical segmentation that is exploited to reduce the Doppler broadening. In addition γ-ray tracking algorithms[10] were used for background suppression. LaBr scintillators, on the other hand, are characterized by high efficiency and good timing. AGATA γ-ray spectra at low energy, related to coulomb excitation dataset, show a peak at the energy

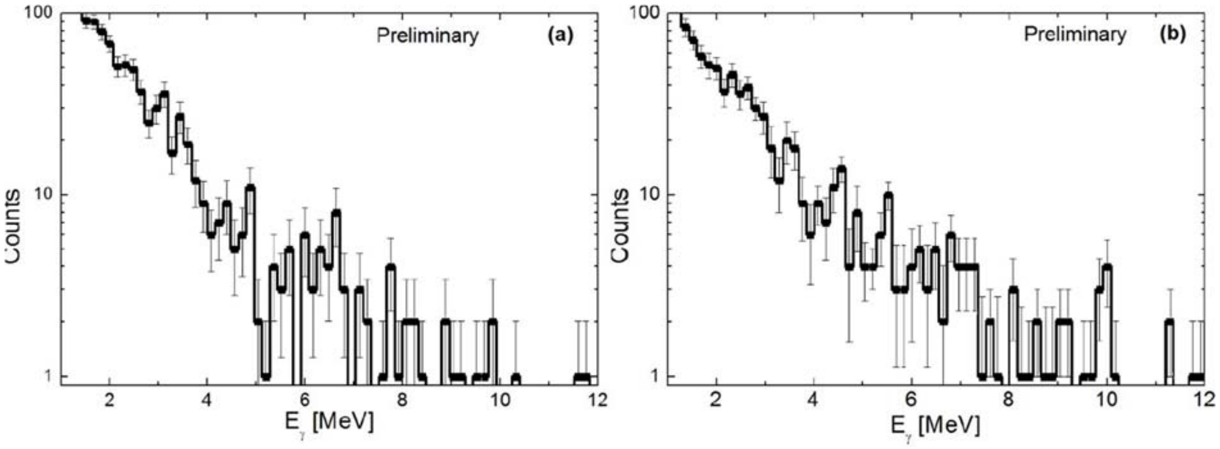

Fig. 3 : panel (a), Preliminary AGATA energy spectrum for 64Fe in the range 1-12 MeV. Panel (b), Preliminary AGATA energy spectrum for 62Fe in the range 1-12 MeV.

of the first 2^+ state decay for both the isotopes, 746 keV for ^{64}Fe and 877 keV for ^{62}Fe (Fig. 2a,b). The width of the measured peaks was also compared with the width expected by GEANT4[11] simulations for AGATA detectors. The comparison shows a good agreement between measurement and simulation. 2^+ state decay measurement is a key point because it provides a normalization for cross section, essential to deduce the B(E1) values related to high energy γ-ray transitions.

Preliminary AGATA high energy γ-ray spectra, shows some structures in the energy range of 6-8 MeV (Fig. 3). The multipolarity character of this γ-ray data was investigated. We evaluated the ratio between the E2 and E1 emission at different summed angles, this ratio was compared with the ratio between the summed angular distribution of data from 2^+ decay and the data above 6 MeV. As shown in Fig. 4, though the width of error bars is quite large, the experimental data follows the expected trend. This comparison, coupled with reaction mechanism that select dipole excitation, shows that the high energy data are related to E1 transitions.

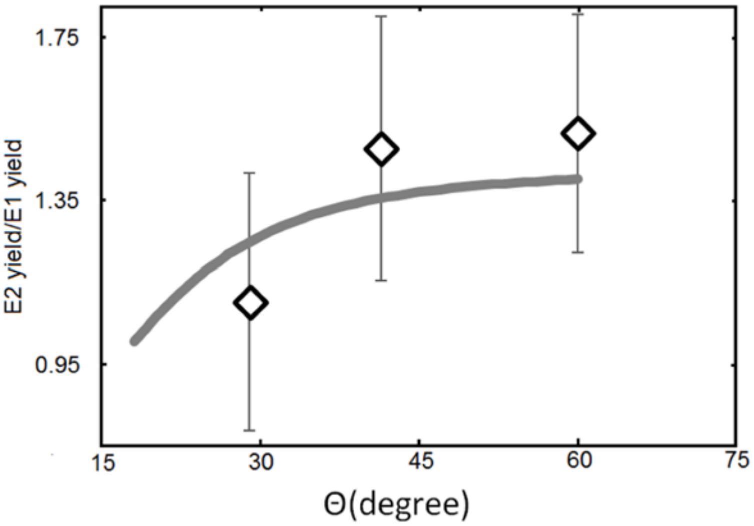

Fig. 4: Ratio of E2 yield with E1 yield at different summed angles. Grey line is the expected trend, considering the beam energy and the efficiency of gamma detectors; the squared points the experimental data.

3 Conclusion

A measurement of E1 response of ^{62,64}Fe below the one particle separation energy was performed in GSI laboratories during PreSPEC-AGATA experimental campaign. The experimental investigation consisted in relativistic coulomb excitation in inverse kinematics and measurement of the gamma decay. The data analysis is still on going. The results obtained at this point of the analysis show that the data collected will allow to evaluate the B(E1) values of high energy γ-ray transition for both of the nuclei.

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