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On the nature of the Pygmy Dipole Resonance in ^{68}Ni

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Summary. — We report results obtained studying the Pygmy Dipole Resonance (PDR) in ^{68}Ni. The experiment was undertaken at INFN-LNS in Catania by means of an isoscalar probe, above the neutron emission threshold. In detail, we show the method used to obtain information about the neutron decay channel of the PDR.

1. – Introduction

During the 60s an accumulation of the γ-rays E1 strength around the nucleon binding energy was observed. This accumulation has been called Pygmy Dipole Resonance (PDR) for the smaller strength in comparison to the Giant Dipole Resonance (GDR) one. Several experimental and theoretical studies proved that the PDR is an excitation mode connected to the neutron excess in nuclei, and its strength is higher in unstable neutron rich nuclei with respect to the stable ones [1-4]. One of the PDR main characteristics is the behavior of the isoscalar and isovector transition densities having at the surface the same order of magnitude. This leads to the PDR population using both isoscalar and isovector probes. The investigation of the PDR is important not only for the knowledge of the nuclear structure but also for the connection with the symmetry energy of the Equation of State (EOS) of the nuclear matter. Due to the link of the PDR with the neutron excess, through the Pygmy Dipole Strength (PDS) it is possible to evaluate the thickness of the neutron skin, that is related to the EOS. This means that the study of the PDS can constrain the symmetry energy [5]. One of the major task of nuclear physics is to determine a parametrization of the symmetry energy, which can provide a unified picture of the nuclear properties; this is useful also to give information concerning objects as the neutron stars. Furthermore, the PDR has a strong connection also with the r-process responsible of the nucleosynthesis of elements heavier than iron [6]. In this framework, a better knowledge of the PDR properties could be a link to understand the neutrons stars starting from the study of the neutron skin in nuclei, and it could provide useful information in the present multimessenger era. Several experiments have been performed on stable nuclei below the neutron separation threshold [1]. The study of the PDR on unstable nuclei has been performed mainly using isovector probes [2]. In order to have a more exhaustive frame of the PDR properties it is necessary to study the PDR in several mass regions, using both probes. At INFN-LNS we carried out an experiment aimed, for the first time, at investigating the PDR in the unstable nucleus ^{68}Ni, using an isoscalar probe, *i.e.*, a ^{12}C target, above the neutron emission threshold. We used a primary ^{70}Zn beam, accelerated to an energy of 40 A MeV by means of the Superconducting Cyclotron (CS), and a ^{9}Be target placed at the exit of the CS. We used the ^{70}Zn+^{9}Be projectile fragmentation reaction to produce, with the in flight method, the exotic beams. The exotic beams were delivered by means of the FRIBS@LNS facility [7]. In the reaction ^{70}Zn+^{9}Be a multitude of nuclei are produced, indeed in the FRIBS facility a tagging system [8] has been developed to event-by-event identify the isotopic composition of the exotic beam and to select the ^{68}Ni beam. In order to detect the reaction products we used the FARCOS array [9, 10], while to detect the γ-rays as well as the neutrons we used the CHIMERA multidetector [11]. The main goal of this experiment was the study of the γ-rays decay channel of the PDR reported in refs. [12, 13].

2. – Data analysis and results

To obtain information about the neutron decay channel of the PDR we have to use an indirect method, as for instance the one described in ref. [14]. In particular, this

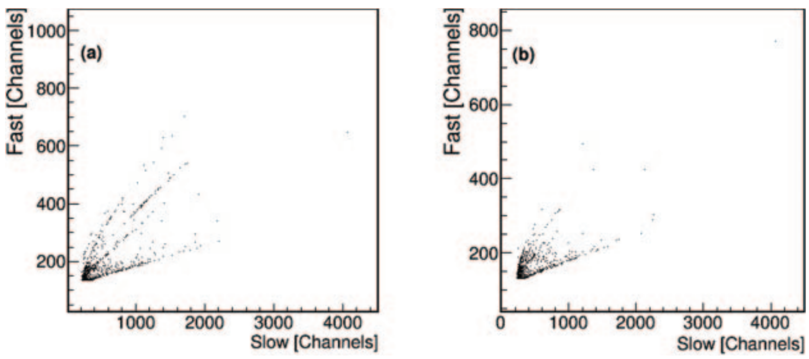

Fig. 1. – In the figures two fast-slow plots are shown, for a telescope not covered by the FARCOS array (a) and for a telescope covered by the FARCOS array (b).

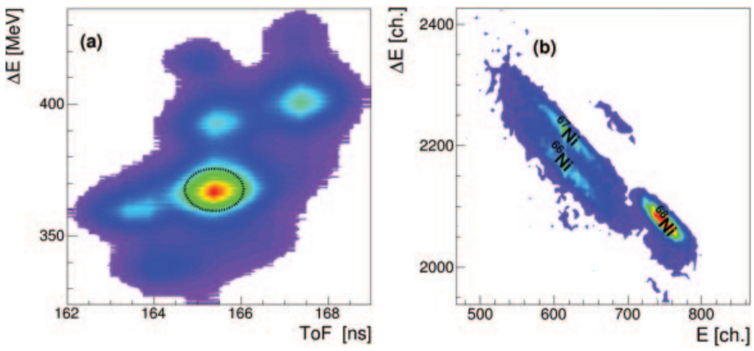

Fig. 2. – (a) ΔE-ToF plot obtained with the tagging system of the exotic beams. In this figure the ^{68}Ni beam is shown as a black circle. (b) ΔE-E plot obtained with the FARCOS array, in coincidence with the ^{68}Ni beam.

method consists in the detection of charged particles, produced by the neutrons interaction with the detectors, on the CsI(Tl) scintillators of the CHIMERA multidetector. The detection of charged particles, produced by neutrons interaction, is accessible by two approaches: either detecting charged particles on CsI(Tl) scintillators imposing that in the silicon detectors no particles are detected or detecting charged particles in the CsI(Tl) scintillators of the CHIMERA array covered by the detectors of the ancillary FARCOS telescopes. The study of the neutron decay is in any case difficult, because we do not have the information on the neutrons energy and this means that the observed charged particles could be due to neutrons produced by several reaction channels. However, the energy distribution can be obtained using appropriate simulations. We chose to start such data analysis using the second method, namely we considered just the telescopes of CHIMERA covered by the FARCOS array. During the experiment, FARCOS covered polar angles θ from 2° to 7°. Therefore, we considered the first rings of the CHIMERA array in order to select the telescopes covered by FARCOS. In fig. 1 the difference between the fast-slow plot of the CsI(Tl) not covered by FARCOS (a) and the fast-slow plot of CsI(Tl) covered by FARCOS (b) is evident. For each telescope covered

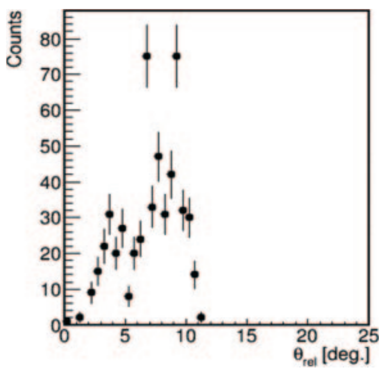

Fig. 3. – Relative angle θ between the ^{67}Ni detected with the FARCOS array (fig. 2(b)) and the charged particles detected with the CsI(Tl) scintillators of CHIMERA array covered by FARCOS (fig. 1(b)).

by FARCOS we performed graphical cuts to select the charged particles and to remove also the γ-rays region. This assumption could remove also some neutrons that produce γ-rays. Since we do not have a method to separate a n-γ reaction from a γ-γ reaction we prefer to remove this region at this stage of the data analysis. As mentioned we do not have the possibility to calculate the energy, therefore to extract information about the neutron decay of the PDR we calculated the relative angle θ between the ^{67}Ni ions, and the charged particles region observed in the CHIMERA CsI(Tl) telescopes. For this purpose, we performed coincidences between charged particles (fig. 1(b)), the ^{68}Ni beam, detected with the tagging system using the ΔE-ToF method (fig. 2(a)), and the ^{67}Ni fragments detected with the FARCOS array (fig. 2(b)). In fig. 3 we report the obtained relative angle. We are performing simulations [15] in order to understand whether the observed relative angle θ is compatible with neutrons emitted by the decay of the PDR.

3. – Conclusion

We have described the analysis method used to obtain information about the neutron decay channel of the Pygmy Dipole Resonance in the ^{68}Ni nucleus. For this purpose, we evaluated the relative angle θ between the ^{67}Ni detected with the FARCOS array, in coincidence with the ^{68}Ni beam, and the charged particles, produced by the neutrons interaction, observed in the CsI(Tl) scintillator of the CHIMERA array. The data analysis is still in progress, in particular we are performing simulations to evaluate the validity of the relative angle θ as a robust observable related to the neutron emission by the PDR decay.

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