Pygmy Dipole Resonance in ^{208}Pb

M.A. Deleplanque[1], L.W. Phair[1], P. Fallon[1], M. Wiedeking[1], F.S. Stephens[1], I.Y. Lee[1], A.O. Macchiavelli[1], R.M. Clark[1], M. Cromaz[1], L. Moretto[1], S. Sinha[1], M. Descovich[1], E. Rodriguez-Vieitez[1], L. Bernstein[2], J. Burke[2], J. Church[2], E.B. Norman[2]

[1] Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720

[2] Lawrence Livermore National Laboratory, Livermore, California 94551

Pygmy Dipole Resonances (PDRs) are interesting because they are a collective mode excited in neutron-rich nuclei and they can potentially help reveal the structure of exotic nuclei produced in exotic beam accelerators such as the proposed sRIA in the USA. In contrast to the Giant Dipole Resonance (GDR), which is an oscillation of protons against neutrons, the PDR is thought to be an oscillation of a neutron skin against an N=Z core, and therefore it should be more excited in neutron-rich nuclei. Its strength resides around the neutron separation energy.

PDRs have been studied primarily using the Nuclear Resonance Fluorescence (NFR) technique. They are excited by photons from a bremsstrahlung radiation produced by electrons impinging on a Cu "bremstarget". The PDR deexcitation is observed in a few high resolution HPGe γ-ray detectors in singles. Such a method has two drawbacks: the photon excites only the 1p-1h component of the PDR states, and the lack of γ-γ coincidences makes it difficult to observe branching ratios which can give information on the structure of these states. Rather, heavy-ion (HI) scattering would excite the mp-mh components of the states and γ-ray coincidences can be used.

As a first test case, we performed an inelastic scattering of ^{17}O on ^{208}Pb at 381 MeV (for which some data already existed [1]) at the LBNL 88-Inch Cyclotron, using the LIBERACE/STARS array. The scattered ^{17}O was identified in a Si E (1000μ)-ΔE (500μ) annular telescope (STARS) in the forward direction. Its distance to the target was such that it could detect the scattered particles at the grazing angle around 13^o to the beam and measure their energy. The LIBERACE array of 6 Compton-suppressed segmented clover HPGe detectors was used to detect the γ rays in coincidence with the scattered ions. Two clover detectors were at 90^o to the beam, two at 45^o and two at 135^o, providing multipolarity information.

The resolution of the Si telescope was good enough to separate ^{17}O from ^{16,18}O, as well as other ions also emitted in the reaction. Each of the ΔE and E detectors was segmented in 8 sectors (22.5^o each) and 16 rings (~ 1^o each). With this localization of the scattered ions, the γ ray energies could be corrected for the Doppler shift due to the recoil motion of ^{208}Pb. The ^{17}O projectile was chosen to minimize interference from projectile γ rays since the neutron binding energy is only 4.1 MeV.

The observed γ-ray spectrum in coincidence with ^{17}O of energy 2.7-11.6 MeV below the elastic peak, corresponding to the region of PDR in ^{208}Pb, is shown in Fig.1. In the lower γ-ray energy region, we see two of the lines from the 1^- states at 5.512 MeV and 6.26 MeV that are also seen in NRF [2], but with very different ratio. In addition, we see a line at 6.21 MeV that is not seen in NRF. We do not have enough statistics to look at its angular distribution and therefore determine the spin of the state.

We compared the observed yields of the ^{208}Pb states, 3^- (2.61 MeV), 2^+ (4.08 MeV) and 1^- (5.51 MeV), to the calculated ones using the Ptolemy code [3] for nuclear reactions. We did not take into account the γ-ray angular distributions in the data. We find agreement within a factor 2 to 3, which is not unreasonable given the large uncertainties in the experimental conditions.

We think we can observe γ rays in the full energy range of 5-8 MeV by increasing the statistics in the experiment a factor of 10 and therefore observe the excitation of the PDR in heavy-ion inelastic scattering. The improvements include: decreasing the leakage current in the Si detectors by cooling them, so that they can sustain more beam intensity; increase their segmentation (electronics) to define better the scattering angles and therefore decrease the Doppler broadening of the γ-ray lines; optimize the performance of all the components of the system.

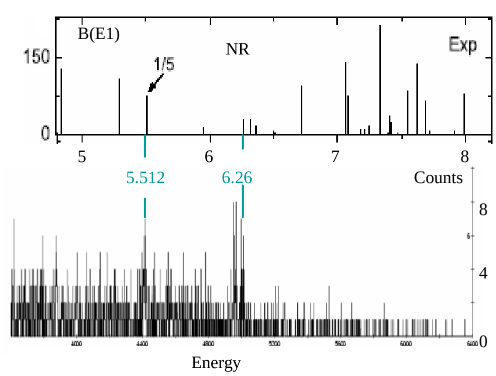

FIG. 1: Gamma-ray spectrum in coincidence with inelastic ^{17}O (bottom) compared with the excitation strength (in 10^{-3} e^2fm^2) from NRF (top).

REFERENCES

[1] J.R. Beene et al., Phys. Rev. C39, 1307 (1989).

[2] N. Ryezayeva et al., Phys. Rev. Lett. 89, 272502-1 (2002).

[3] M. Rhoades-Brown, M. H. Macfarlane, and S.C. Pieper, Phys. Rev. C21, 2417 (1980); C21, 2436 (1980).