Observation of isoscalar and isovector dipole excitations in ^{20}O[†]

N. Nakatsuka,[*1,*2] H. Baba,[*2] N. Aoi,[*10] T. Aumann,[*3] R. Avigo,[*5,*14] S. R. Banerjee,[*12] A. Bracco,[*5,*14] C. Caesar,[*3] F. Camera,[*5,*14] S. Ceruti,[*5,*14] S. Chen,[*13,*2] V. Derya,[*4] P. Doornenbal,[*2] A. Giaz,[*5,*14] A. Horvat,[*3] K. Ieki,[*11] N. Imai,[*7] T. Kawabata,[*1] K. Yoneda,[*2] N. Kobayashi,[*8] Y. Kondo,[*9] S. Koyama,[*8] M. Kurata-Nishimura,[*2] S. Masuoka,[*7] M. Matsushita,[*7] S. Michimasa,[*7] B. Millon,[*5] T. Motobayashi,[*2] T. Murakami,[*1] T. Nakamura,[*9] T. Ohnishi,[*2] H. J. Ong,[*10] S. Ota,[*7] H. Otsu,[*2] T. Ozaki,[*9] A. T. Saito,[*9] H. Sakurai,[*2,*8] H. Scheit,[*3] F. Schindler,[*3] P. Schrock,[*3] Y. Shiga,[*11,*2] M. Shikata,[*9] S. Shimoura,[*7] D. Steppenbeck,[*2] T. Sumikama,[*6,*2] I. Syndikus,[*3] H. Takeda,[*2] S. Takeuchi,[*2] A. Tamii,[*10] R. Taniuchi,[*8] Y. Togano,[*9] J. Tscheuschner,[*3] J. Tsubota,[*9] H. Wang,[*2] O. Wieland,[*5] K. Wimmer,[*8,*2] Y. Yamaguchi,[*7] and J. Zenihiro[*2]

The electric dipole response, or $E1$ response, is one of the most interesting properties of atomic nuclei. In medium to heavy neutron-rich nuclei, the electric dipole excitation is fragmented into a low-energy region around the neutron separation energy, so-called Pygmy dipole resonance.[1,2] Recent experimental studies on ^{40,48}Ca,[6] ^{74}Ge,[7] ^{124}Sn,[8] ^{138}Ba,[9] and ^{140}Ce[9,10] have demonstrated that low-energy dipole excitations exhibit a specific isospin character, sometimes referred to as "isospin splitting." They demonstrated that some dipole excitations, mostly in the low-energy region, were populated by both isoscalar and isovector probes. In this work, the isospin character of low-energy dipole excitations in neutron-rich unstable nucleus ^{20}O was investigated, for the first time in unstable nuclei. The experiment was performed at Radioactive Isotope Beam Factory (RIBF). The ^{20}O beam impinged on two different reaction targets, a 2.45(5) mm gold target as an isovector probe, and a 317(28) mg/cm^2 liquid helium target as an isoscalar probe. The decay γ rays from the excited beam particles were detected with large volume LaBr$_3$ crystals from INFN Milano.[3] Two low-energy dipole states at energies of 5.36(5) MeV (1_1^-) and 6.84(7) MeV (1_2^-), previously known to be populated by the Coulomb excitation,[4,5] were consistently populated both by the isoscalar and isovector probe. The decay scheme of those states were determined by the γ-γ coincidence analysis, and the decay branch via the 2_1^+ state (1.67 MeV) was observed.

In order to extract the cross sections and transition strengths, a distorted-wave Born approximation (DWBA) analysis was performed by using the Ecis97 code.[12] As nuclear potential, we employed the theoretically developed global optical potential described in Refs. 13–15). The transition strengths of the 1^- states were determined in the same manner, by including both the Coulomb and nuclear contributions in either system, with the assumption that the Coulomb potential contributed only to the isovector dipole strength and the nuclear potential contributed only to the isoscalar dipole strength. The Harakeh-Dieperink dipole form factor[11] was employed to determine the isoscalar dipole strength. The strengths were determined so that the experimental cross sections from both the ^{20}O+α and ^{20}O+Au systems were reproduced by the same isoscalar and isovector dipole strengths. The 1_1^- state (5.36(5) MeV) had an isoscalar dipole strength of 2.70(32)% in ISD EWSR, while the 1_2^- state (6.84(7) MeV) had a strength of 0.67(12)% in Isoscalar dipole energy-weighted sum-rule fraction (ISD EWSR). These states, however, have comparable isovector dipole strengths: $B(E1)\uparrow = 3.57(20) \times 10^{-2}$ e^2fm^2 for the 1_1^- state and $B(E1)\uparrow = 3.79(26) \times 10^{-2}$ e^2fm^2 for the 1_2^- state. The results indicate that low-energy dipole excitations in ^{20}O exhibit a dual character. The difference in isoscalar response suggests that these states have different underlying structures.

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*1 Department of Physics, Kyoto University
*2 RIKEN Nishina Center
*3 Institut für Kernphysik, Technische Universität Darmstadt
*4 Institut für Kernphysik, Universität zu Köln
*5 Istituto Nazionale di Fisica Nucleare Milan
*6 Department of Physics, Tohoku University
*7 Center for Nuclear Study, The University of Tokyo
*8 Department of Physics, The University of Tokyo
*9 Department of Physics, Tokyo Institute of Technology
*10 Research Center for Nuclear Physics, Osaka University
*11 Department of Physics, Rikkyo University
*12 Variable Energy Cyclotron Centre, The Indian Department of Atomic Energy
*13 School of Physics, Peking University
*14 University of Milan

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