Low-energy dipole excitation (LED) in atomic nuclei attracts a lot of attention recently for its role in the nuclear-astrophysical process and the nuclear equation of state (EoS). For the nuclear-astrophysical interest, the photo-absorption cross sections have been measured in various nuclei including the unstable nuclei. For the role of LED on the EoS, not only measuring the photo-absorption cross sections but also well understanding of the structure of the LED is necessary.

Recent studies showed that the LED has both Isoscalar and Isovector strengths. The character is called the Isospin splitting, and recognized as a new clue to understand its structure. According to the studies on a set of stable nuclei, ^{40,48}Ca, ^{74}Ge, ^{124}Sn, ^{138}Ba, and ^{140}Ce, the LED can be classified into two components with different Isospin structures: the lower excitation-energy component mainly has Isoscalar strength closer to the pure Isoscalar dipole excitation, and the higher excitation-energy component mainly has the Isovector strength closer to the Isovector giant dipole resonance (IVGDR). This tendency is common to all measured nuclei and the understanding of this mechanism is important to understand the structure of the LED.

Extending the study on the Isospin splitting of the LED into the neutron-rich unstable nuclei is important to reveal its underlying structure. Recently a few studies on the neutron-rich unstable nuclei, ^{68}Ni, $^{129-132}$Sn, ^{133,134}Sb indicated that the Isovector strength of the LED is enhanced on such nuclei compared with the stable nuclei on the same isotopic chain. This enhancement was once interpreted as the collective excitation mode of excess neutrons, phenomenologically described as neutron skins oscillating against the nuclear core. However recent studies of Isospin splitting observed in neutron-rich stable nuclei focusing suggest that such interpretation is not sufficient, and the mechanism of enhancement is still under discussions. For this reason, measuring Isoscalar dipole strengths on neutron-rich unstable nuclei can possibly provide a new insight into the mechanism of enhancement.

The present work investigated the Isospin characters of the LEDs on neutron-rich unstable ^{20}O, for the first time in unstable nuclei. It was an ideal nuclei to investigate, since it is known to have LED states with significant Isovector dipole strengths, and their Isoscalar strengths were unknown. From experimental point of view, the limited level density specific to light nuclei enabled us to access the excited states via well-established in-beam γ-ray spectroscopy. Recently built Radioactive Isotope Beam Factory (RIBF) cyclotron complex of RIKEN Nishina Center enabled us to access high-intensity beam of ^{20}O via the projectile fragmentation reaction. Owing to its high-intensity beam, a new challenge, the inelastic scattering of the α particles on unstable nuclei became possible.

The inelastic scattering of α particles was employed as a predominant Isoscalar probe. The Coulomb excitation using a gold target was employed as a predominant Isovector probe. The experiment was carried out in inverse kinematics, where the unstable neutron-rich ^{20}O with the incident energy of 276(9) MeV/nucleon was the beam. In-beam γ-ray spectroscopy technic was used to identify the dipole excitations and to measure the excitation cross sections. The Isoscalar and Isovector dipole strengths of the two 1^- states at the energies of 5.36(5) MeV (1^-_1) and 6.84(7) MeV (1^-_2) were determined independently via distorted-wave Born approximation (DWBA) analysis. The optical potentials were based on theoretical calculations developed by T. Furumoto, and Harakeh-Dieplink macroscopic Isoscalar form factor was employed.

The results showed that the two states have similar Isovector strengths, 3.57(20) $\times$

10^{-2} (1_1^-) and 3.79(26) $\times$ 10^{-2} (1_2^-) e^2fm^2 respectively, however significantly different Isoscalar strengths, exhausting 2.70(32) % (1_1^-) and 0.67(12) % (1_2^-) respectively of Isoscalar dipole energy-weighted sum rule (ISD EWSR). The difference in the Isoscalar strengths suggested that these two states have different underlying structures. Comparison with the theoretical prediction based on the random-phase approximation (RPA) suggested that the 1_2^- state with smaller Isoscalar strength may derive from the proton excitations, unlike the calculation based on the shell model predicting the valence-neutron contributions discussed in the previous studies. However the other state 1_1^- with strong Isoscalar strength cannot be reproduced by the theory. Comparison with the LED observed in $N = Z$ nuclei in the oxygen isotope, ^{16}O, which has strong Isoscalar strength exhausting 4.2 % of ISD EWSR with negligible Isovector strength at 7.12 MeV, the 1_1^- state has similar Isoscalar strength however significantly stronger Isovector strength.

It was revealed that the LED with strong Isoscalar strength similar to that observed in the $N = Z$ nuclei exists in neutron-rich unstable nuclei. Such state is hardly interpreted as the valence-neutron excitations. Similarly strong Isoscalar strengths are also observed in neutron-rich calcium isotopes, ^{48}Ca. Further theoretical studies that can explain strong Isoscalar strengths are desired.