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Structure of Ca isotopes at N = 34 shell closure and above

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The studies in the past decades revealed that the canonical magic numbers established for stable nuclei may not extend their universality to exotic nuclei, while new magic numbers emerge in some nuclei [1]. These new features often can be traced back to certain characteristic mechanisms of nuclear forces [1,2], for instance, the tensor force, which can vary the spin-orbit energy splitting and result in changes of shell structures. Discovering and interpreting these new features provide a fundamental test for the understanding of nuclear forces, and play a key role in the prediction of the dripline in the Segrè chart of nuclides. The calcium isotopes, with 20 protons (Z=20) forming the closed proton shell, exhibit a high sensitivity of the shell evolution according to the neutron number. In the neutron-rich side, signatures of new magic numbers or sub-shell closures have been found at N=32 and 34 [3,4], and interpreted as a consequence of the absence of a tensor attraction between valence protons and neutrons. For the N=34 sub-shell closure, the first experimental evidence was presented by the measured large E(2+1) in 54Ca [4]. It was then supported by the mass measurements of 55-57Ca isotopes [5]. Following these studies, we further investigated the nature of N=34 sub-shell closure by knockout reactions, and the structural evolution of calcium isotopes above the N=34 sub-shell closure.
The experiments were carried out at RIBF using the intense radioactive beams provided by the BigRIPS separator. A thick liquid hydrogen target of the MINOS device was used to induce the knockout reactions, and the DALI2+ high-efficiency array was arranged around the target for the detection of de-excitation γ rays of reaction products. The reaction products were identified by the SAMURAI spectrometer. The exclusive cross sections and momentum distributions of the 54Ca(p,pn)53Ca reaction channel were measured in the experiment, which provide access to the neutron occupation number of the 54Ca ground state and spin parity of the 53Ca final states [6]. Moving beyond the N=34 sub-shell closure, the first spectroscopy measurements of 56,58Ca were performed. The obtained results are confronted with state-of-the-art ab initio and shell-model calculations, permitting a sound prediction on the structure of 60Ca and the dripline of calcium isotopes [7]. In this talk, the physics interests of the calcium isotopes, the descriptions of the experiments and the discussions of the results shall be given in details.

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