Cluster structure of neutron-rich beryllium isotopes investigated by cluster quasi-free scattering reaction

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Clustering is known for long as an important and general feature of atomic nuclei. So far alpha-particle clustering has dominated cluster states studies among all other possible partitioning. Thus, nuclei with even and equal numbers of protons and neutrons (the so-called alpha-conjugate nuclei) have been extensively studied. A few decades ago, some general properties of clustering in nuclei have been stressed, *e.g.* its preferential occurrence close to cluster decay thresholds rather than in ground-states.[1] The situation might be somewhat different in exotic nuclei for which well developed cluster configurations may occur in ground-states, even though located well below the corresponding cluster threshold. The SAMURAI12 experiment aims to investigate the cluster structure of neutron-rich beryllium isotopes using the cluster quasifree scattering reaction $(p, p\alpha)$ in inverse kinematics. Such an approach has been recently emphasized as a suitable method to investigate how α cluster states are spatially developed.[2] Beryllium isotopes are of special interest in relation with clustering. The ^{8}Be nucleus is famous for its developed α–α structure, well reproduced by *ab initio* calculations. Antisymmetrized Molecular dynamics calculations predict the occurrence of α–α core up to the dripline, neutrons occupying molecular orbits around this core. The purpose of the SAMURAI12 experiment is to study the $(p, p\alpha)$ reaction on neutron-rich Beryllium isotopes up to the dripline.

The experiment was performed using the SAMURAI large-acceptance spectrometer during the spring campaign of 2018. Secondary ^{10,12,14}Be beams at nearly 150A MeV were produced by fragmentation of a 230A-MeV ^{18}O primary beam. using the BigRIPS separator. To study the $(p, p\alpha)$ reaction in inverse kinematics, a new setup combining several elements was developed. The first component was the solid hydrogen target (SHT) system associated with the ESPRI setup.[4] This system allows to prepare a target foil of typically 1–3 mm thickness with a diameter of 3 cm, well adapted for our study. A new target chamber dedicated to the SAMURAI12 experiment has been built with new apertures allowing detection of protons at the relevant angles. A new target frame was also built for the production of a 2 mm thick foil which was used in the experiment. For recoil proton detection, the ESPRI Recoil Proton Spectrometer (RPS) system was implemented. It is composed of 3 stages: 1. Multiwire drift chamber (MWDC) for scattering angle determination, 2. plastic detector of 4 mm thickness and 3. NaI rods. The system was installed in a two-arm configuration identical to the one used during the SAMURAI13 experiment.[4] The two arms were placed at 95 cm from target, covering an angular range of 50°–70°, corresponding to about 40°–70° in center of mass (CM) for the free $p + \alpha$ elastic scattering. Detection of alpha clusters was insured by two telescopes composed of Silicon and CsI(Tl) detectors placed at forward angles to cover the angular range 4°–12°. The first layer was a double-sided Silicon detector (DSSD), 62 × 62 mm active area with 32 strips on each side. The second stage was composed of CsI(Tl) crystals 2.5 × 2.5 cm^2, 6 cm long, from the FARCOS array. Energy range of the clusters was 100 $\sim$ 150 MeV/nucleon. A dedicated energy calibration run with a (secondary) alpha beam was used in order to achieve precise energy calibration needed to deduce the missing mass. The detection of the ^{4,6,8}He beam-like velocity residues near zero degrees produced in the ^{10,12,14}Be$(p, p\alpha)$ reactions was performed using the SAMURAI spectrometer and its standard detectors.[5] The residue scattering angle was measured using the Forward Drift Chamber 0 (FDC0) placed upstream of the SAMURAI entrance. After the exit window of SAMURAI, rigidity measurement and particle identification of the residues were insured by the Forward Drift Chamber 2 (FDC2), and the HODP and HODF walls of plastic hodoscopes composed of 16 and 24 slats of BC408 scintillators, (of dimensions 120 × 10 × 1 cm^3), respectively. For complementary invariant mass studies, the neutron multi-detector NEBULA was also included in the setup. The data analysis is undergoing, presently focusing on the calibrations runs of forward telescopes with alpha secondary beams. A detailed uniformity response study of CsI(Tl) modules is being performed owing to the position information provided by the DSSD.

References

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