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Some insights on the ^{4}He mysteries from α – scattering measurements

Content

The light nuclei attract the interest of the nuclear physics community for decades, however, we are still far away from their complete understanding. A notable example is the ^{4}He, a simple and very stable nucleus constituted by two protons and two neutrons. Since a fundamental theory which describes nuclei starting from quarks and gluons as the elementary constituents is still missing, ^{4}He can be modelled in terms of four nucleons requiring the solution of a quantum mechanical 4-body problem, where nuclear interactions are a key element. Nowadays, ab-initio theories can correctly describe the ground –state properties of many nuclei (including the ^{4}He(0_1^+)), however, the description of the ^{4}He first excited state (0_2^+), a resonant state with a centroid slightly above the proton emission energy threshold, still represents a challenge [1-6]. Recent results focusing on the first excited resonant state of ^{4}He nucleus, reveal a puzzling situation potentially calling for missing physics in our best known nuclear forces and, consequently, in our understanding of the nuclear phenomenology. Furthermore, the results from several available studies present discrepancies on the determination of the ^{4}He(0_2^+) resonance energy, width and line shape.
Into this context, we performed new measurements of the ^{4}He(0_2^+) resonance by ^{4}He + ^{4}He scattering at the MAGNEX facility [7] of INFN –Laboratori Nazionali del Sud, featuring data of unprecedented sensitivity and state-of-art analyses of the spectral line shape and the scattering cross sections. Our experimental data on the line shape of the ^{4}He(0_2^+) and on elastic and inelastic differential cross section angular distributions allow for a novel insight on the relevant role of the interference between the resonance and the underlying non-resonant continuum. Our consistent analysis of the complete set of the experimental observables shows a satisfactory description of the data within the known physics of nuclear interactions however, calling for a revision of the existing nuclear models for resonant states.

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