ID de la contribución : **889**

Tipo : **no especificado**

Recent results of experiment IS690: Exploring the excited structure of ^{11}Li through (t,p) reactions at CERN-ISOLDE

martes, 19 de noviembre de 2024 16:58 (7)

Halo nuclei are a group of nuclei characterized by a low binding energy for their last nucleons, situated in low orbital momentum states and, as a consequence, an unusually large spatial extension that deviates from the standard $r = r_0 A^{1/3}$ relation. The first empirical observation of this behaviour came from experimental measurements of the interaction cross-section for neutron-rich nuclei, specifically the scattering cross-section of Lithium isotopes. As the number of neutrons approached the dripline, the interaction radius deviated from theoretical predictions, with ^{11}Li being the most noticeable case [1]. This discovery was interpreted as a new type of nuclear structure [2], formed by a compact core and an external set of nucleons. This hypothesis was confirmed a few years later in ^{11}Li break-up experiments [3].

^{11}Li can be considered the archetype of a two-neutron halo: a three-body system formed by two weakly correlated neutrons loosely bound to the ^{9}Li ground state (g.s.) [4]. Despite being intensively studied for a long time, there are still open questions regarding the structure of ^{11}Li. While the g.s. is known to be a mixture of p ($59(1)\%$), s ($35(4)\%$), and d ($6(4)\%$) waves [5], knowledge of higher-energy resonant states (no excited states are bound in ^{11}Li) is not well settled, as different reaction studies give different results.

The low-lying continuum spectrum of ^{11}Li is dominated by broad dipole structures observed in several experiments, while narrower resonances have been proposed up to 6.2 MeV. Recent results on the low-lying continuum structure in ^{11}Li have been obtained from inelastic p- and d-scattering at TRIUMF [6,7]. The elastic cross-sections obtained from both experiments are consistent; however, the inelastic scattering results indicated a resonant state at 0.80(4) MeV, $\Gamma = 1.15(6)$ MeV for proton inelastic scattering [7], and this same resonance was characterized to be at 1.03(4) MeV, $\Gamma = 0.51(11)$ MeV with deuteron scattering [6]. However, a more relevant question concerns the physical process involved: excitation to resonance or direct excitation to the continuum?

Most experiments that explore the excited structure of ^{11}Li start from ^{11}Li g.s, which is promoted to excited levels. The only exception is the study of the (very complex) ^{14}C(π^-,p+d) reaction [8], whose results were limited by low resolution. The MAGISOL collaboration has performed an experiment, IS690 [9], intending to probe the excited structure of ^{11}Li through an alternate approach: populate directly the excited states of ^{11}Li using a two-neutron transfer reaction ^{9}Li(t,p)^{11}Li, and obtain information of the excited states through the momentum distribution of the residual proton. This experiment complements the ^{11}Li(p,t)^{9}Li experiment carried out at TRIUMF [10], additionally, knowledge of the elastic scattering channel can be employed to fix optical potentials in the theoretical models.

IS690 took place at the Scattering Experimental Chamber (SEC) in the HIE-ISOLDE facility at CERN between the 14th and 22nd of October 2024. A post-accelerated 7 MeV/u ^{9}Li beam was impinged on a ^{3}H target (^{3}H absorbed in a thin Ti-foil at a ratio of $\sim$0.4/1). The energy of the incoming ^{9}Li beam, 7 MeV/u, was chosen to facilitate the 2n transfer while reducing the number of additional open channels. An upgraded detection setup was prepared to detect the emitted protons from the ^{9}Li(t,p)^{11}Li reaction and distinguish them from background reactions, especially ^{9}Li(p,d)^{10}Li and elastic channels, as well as protons from Ti(t,p). The setup offered optimal angular coverage and consisted of three detector structures: (a) five particle telescopes (DSSD+PAD) forming a pentagon around the target, (b) a frontal telescope formed by two S3-CD detectors, and (c) a backward S5 detector to detect backward protons.

In this contribution, we will give an overview of the experiment and a summary of the (very recent) data obtained, along with our preliminary analysis.

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Abstract

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Clasificación de la sesión : Red FNUC (Red Temática de Física Nuclear)

Clasificación de temáticas : Red Temática de Física Nuclear (FNUC)