Experimental report

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Proposal: 3-07-372 **Council:** 10/2016

Title: Hunting for the gamma-decay of 7Liinto the continuum by the cold neutron capture reaction 6Li(n,gamma)7Li

Research area: Nuclear and Particle Physics

This proposal is a new proposal

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Instrument	Requested days	Allocated days	From	To
PF1B	20	16	24/01/2017	09/02/2017

Abstract:

We propose to perform an indirect measurement of the γ-decay of 7Li into the continuum, after cold neutron capture on 6Li. The focus will be, in particular, on gamma rays sampling the region as close as possible to the 4He+3H dissociation threshold at 2.468 MeV. The γ emission from the n-capture state into the continuum will be deduced from the missing energy, i.e., the difference between the energy of the capture state and the sum energy of 4He and 3H, measured with high energy resolution by a setup of double sided silicon strip detectors.
This investigation will provide the first experimental information on γ-decay between states in the continuum, which is relevant for basic reactions of astrophysics importance and also for the understanding of the structural properties of the unbound 7Li system.

We have performed a first attempt to measure, indirectly, the γ-decay of ^{7}Li into the continuum, after cold neutron capture on ^{6}Li. The aim is to deduce the γ emission from the n-capture state (at 7.251 MeV) into the continuum from the missing energy, i.e., the difference between the energy of the capture state and the sum energy of ^{4}He and ^{3}H, measured with high energy resolution. The setup consisted of two 60 μm thick double sided silicon strip detectors (DSSSD), with 16x16 strips and an active area of 50x50 mm^2. The detectors were placed at 61 mm from the target, on opposite sides, as schematically illustrated in Fig. 1 (right). The Si detectors, manufactured by MICRON, had a special design in order to reduce dead layers (the Al contact was a grid covering 2% only of the surface). Their energy resolution was 35 keV [1].
The ^{6}Li target was a thin ^{6}Li ion-implanted sample, produced at University of Mainz by implanting 30 keV ^{6}Li ions into a 0.64 μm thick high purity Al foil (for a total of 2.8 10^{16} implanted ^{6}Li ions). The implantation profile, as calculated by the SRIM software [2], is shown in Fig. 1, left.

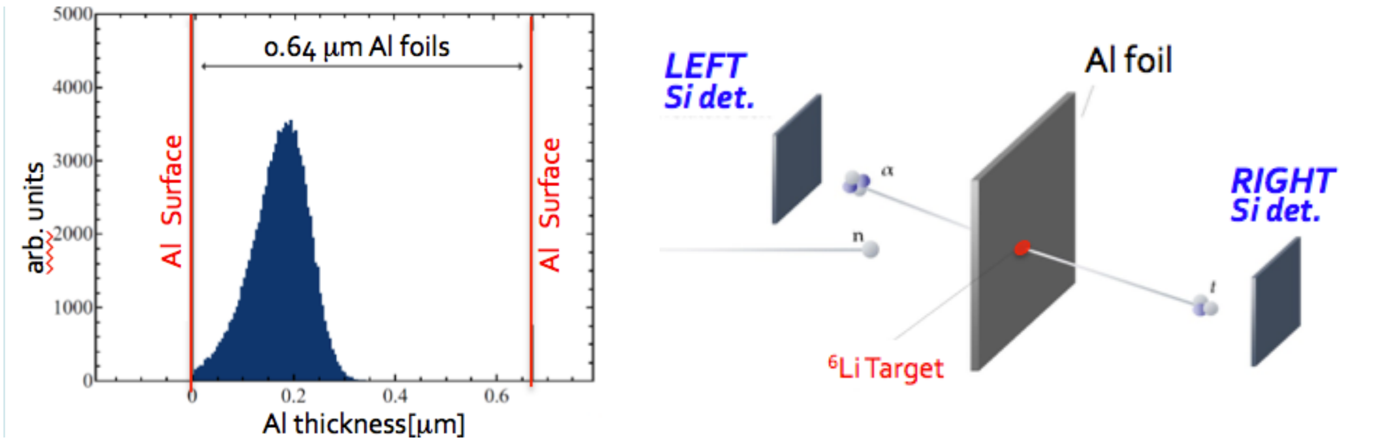

Figure 1. *Left: implantation profile of ^{6}Li into a high purity Al foil, 0.64 μm thick. Right: schematic drawing of the detection setup, consisting of two double sided Si strip detectors, placed at 61 mm from the target, on opposite sides.*

The experiment ran smoothly for 20 days, at PF1B, employing a collimated neutron beam of ~$2\cdot10^8$ n/cm^2/s. All 64 strips of the Si detectors were carefully calibrated using the ^{6}Li(n,α) and ^{10}B(n,α) reactions, and corrections were made for energy drifts over the long period of measurement. Fig. 2 shows examples of particle spectra recorded in the Left and Right detectors, in given pixels (defined following the scheme in the insets), for the reaction n+^{6}Li→ ^{4}He + ^{3}H. The sharper more energetic peaks are associated to the tritons, the wider ones at lower energy to the ^{4}He particles. As expected the ^{4}He ions clearly show a worse energy resolution, especially in the case of the Right detector, i.e., when they are detected after passing through the thicker Al layer (see Fig. 1).
In the analysis, a number of conditions were imposed, in particular: i) multiplicity M = 4 (i.e., both x and y signals are requested in each detector), ii) E_x-E_y ≤ +/-ΔE (i.e., the energy recorded in the x and y strips should be equal, within the detector energy resolution), and iii) ^{4}He and ^{3}H particles should be emitted at 180° (momentum conservation). The energy of the ^{4}He and ^{3}H particles were reconstructed taking into account the energy losses into the various material, resulting in energy thresholds of about 240 keV and 320 keV, respectively.
Figure 3 shows the energy distribution of the coincidence events recorded by the Si detectors placed at the Left and Right side of the target (see Fig. 1). It is found that the majority of the events (~ $6.1\cdot10^8$) comes from the instant break-up of ^{7}Li into ^{4}He and ^{3}H, at the capture level. The dotted line corresponds to the region of interest for the measurement of the emission of a γ-ray from the capture state, before the break up into ^{4}He and ^{3}H (i.e., defined by the energy condition E(^{3}H)/E(^{4}He) = 4/3, for a ^{4}He particle detected in the Left detector).
It is found that the matrix is significantly contaminated by event distributions coming from random coincidences, in particular associated to neutron capture on ^{10}B, present in the contact of the Si detectors.
This restricts the energy region available for the analysis and allows to extract only an upper limit for the cross section of the γ decay in the continuum. A short paper is in preparation, reporting these results.

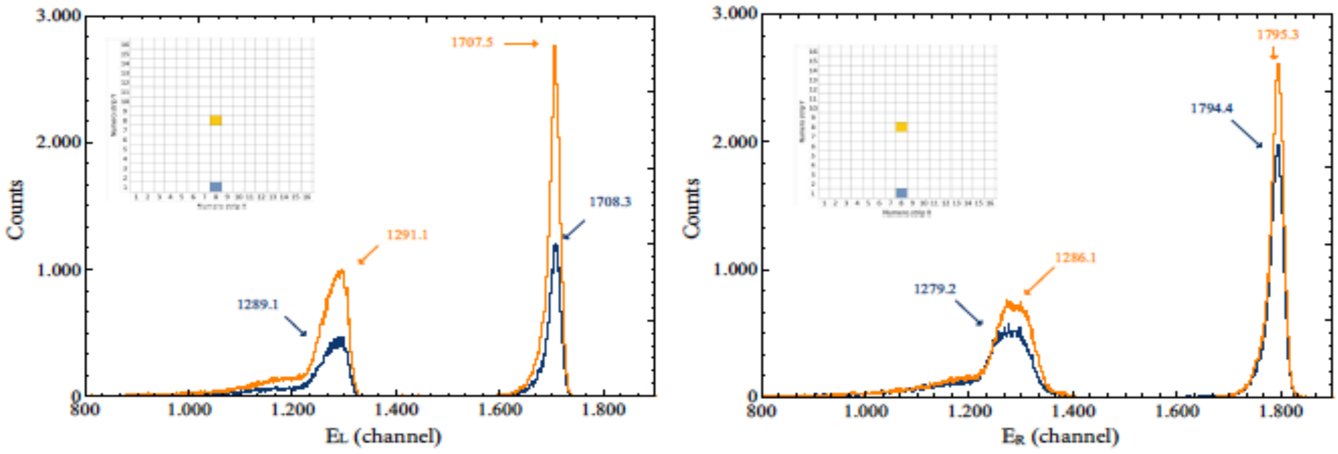

Figure 2. *Examples of particle spectra measured with Left and Right DSSSD detectors in the reaction* ^{6}Li(n,^{4}He)^{3}H, *in the pixels (1,8) and (8,8) - the pixel code is given in the legend. The left peak corresponds to α particles, the sharper ones, on the right, to tritons.*

A new measurement is currently being planned, with improved experimental setup.
In particular, we aim at strongly reducing the background contaminants by requiring a narrow coincidence gate between ^{4}He and ^{3}H particles, by using electronic timing. Moreover, a thinner Al foil will be used to implant the ^{6}Li ions, in order to minimize the energy losses of ^{4}He and ^{3}H particles in the sample, thus lowering further the energy thresholds.

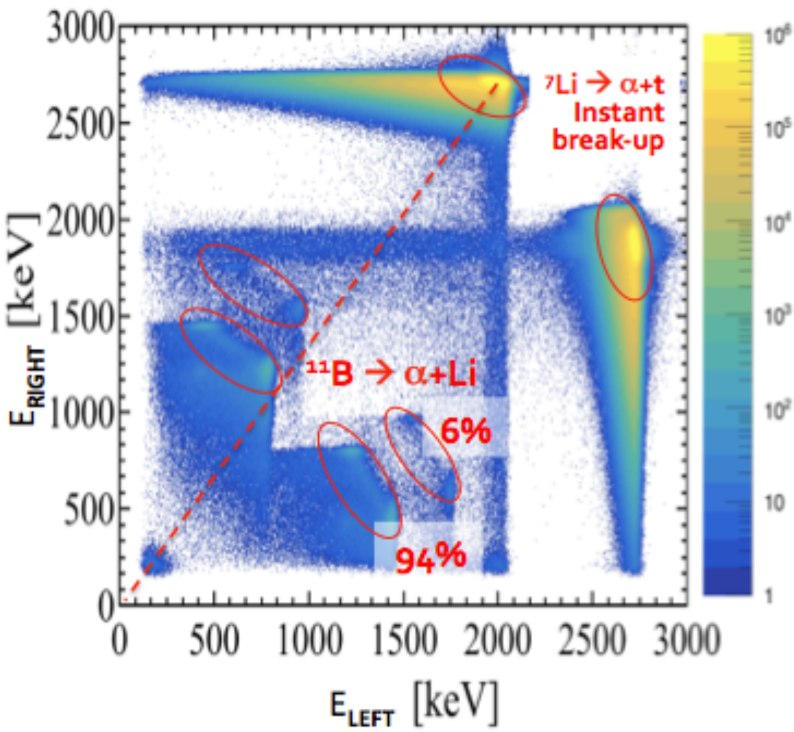

Figure 3. *Energy distribution of coincidence events recorded by the Si detectors placed at the Left and Right side of the* ^{6}*Li target (cfr., Fig. 1). Circles indicate loci associated to the break-up of* ^{7}*Li from the capture state, as well as contaminants arising from neutron capture on* ^{10}*B, present in the detector contacts. The dotted line corresponds to the region defined by the energy condition* $E(^{3}H)/E(^{4}He) = 4/3$ *which is relevant for the reconstruction of the γ decay in the continuum of* ^{7}*Li (for alpha particles detected in the Left Si detector only).*

[1] O. Tengblad et al., Nucl. Inst. Meth. A 525, 458 (2004).
[2] J.F. Ziegler, "SRIM, the Stopping and Range of Ions in Matter", SRIM Company, (2008).