# Experimental report

10/02/2019

**Proposal:** **3-07-382** **Council:** 4/2018

**Title:** Hunting for the g-decay of 7Li into the continuum by the cold neutroncapture reaction 6Li(n,γ)7Li: a second attempt

**Research area:** Nuclear and Particle Physics

**This proposal is a new proposal**


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**Samples:** 6Li

| Instrument | Requested days | Allocated days | From | To |
|---|---|---|---|---|
| PF1B | 20 | 20 | 12/09/2018 | 26/09/2018 |


**Abstract:**

We propose a follow up experiment to measure the g decay of 7Li into the continuum, after cold neutron capture on 6Li (at 7.251 MeV). In a first run, the g emission was reconstructed from the missing energy, which can be deduced from the energy of 4He and 3H, measured by a pair of Si DSSD detectors. The data set was significantly contaminated by background events from random coincidences from neutron capture on 10B, imposing a significant limitation to the cross section estimate - upper limits, in two restricted regions of the 7Li excitation energy spectrum, were obtained. The results are in accordance with newly developed calculations based on the 7Li cluster model.
In the new measurement, the setup will be improved by requiring a narrow coincidence time window between 4He and 3H particles. A thinner Al foil will be used to implant the 6Li ions, thus lowering the particle detection energy thresholds. Two/three scintillators made of novel materials (CLLB, CLYC or LaBr3) will also be added to monitor the environmental background from gamma and neutron interactions in view of future direct measurements of the g decay of 7Li into the continuum.

## REPORT on the first part of EXPERIMENT 3-07-382

In September 2018 we have performed at PF1B part of experiment 3-07-382, but only 15 days (including 2 days of setting up) out of the 20 allocated days could be scheduled.
The experiment attempts 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 particles, measured with high-energy resolution. The experiment is technically challenging, since the effect is expected of the order of $10^{-5}$, or less, of the capture cross section.
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 45 mm from the target, on opposite sides. 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 2018 run was the second attempt of this type of measurement. It followed a first run performed in January 2017 and described in the experimental report 3-07-372. There were mainly two differences from the first run:

1) the $^{6}$Li target was made of 39 μg/cm$^2$ of $^{6}$LiF evaporated, very uniformly, on a 30 μg/cm$^2$ carbon backing. On the contrary, the target used in the 2017 run 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);

2) the acquisition system was improved with the use of four TDC modules from CAEN (128 channels CFD fractions 30% and 80%), which allows, during the analysis, to impose a narrow coincident gate between the $^{4}$He and $^{3}$H particles measured in the two Si detectors. In the 2017 run, the electronics chain was limited to the energy information collected with shaping amplifiers and peak sensing ADC, and the acquisition trigger was given by a wide coincidence between the two detectors.

A very preliminary analysis has been performed for the 2018 data. Fig. 1 shows examples of particle spectra measured with Left and Right DSSSD detectors, for pixel marked in the schematic detector diagram. The left peak corresponds to α particles, the sharper ones, on the right, to tritons. A clear improvement in both energy resolution and symmetry of the measured peaks can be easily observed, as compared to equivalent spectra recorded during the 2017 run (see Fig. 2 of report 3-07-372). The improvement is attributed to the quality of the target which offers a much thinner layer of material to the passage of the particles.

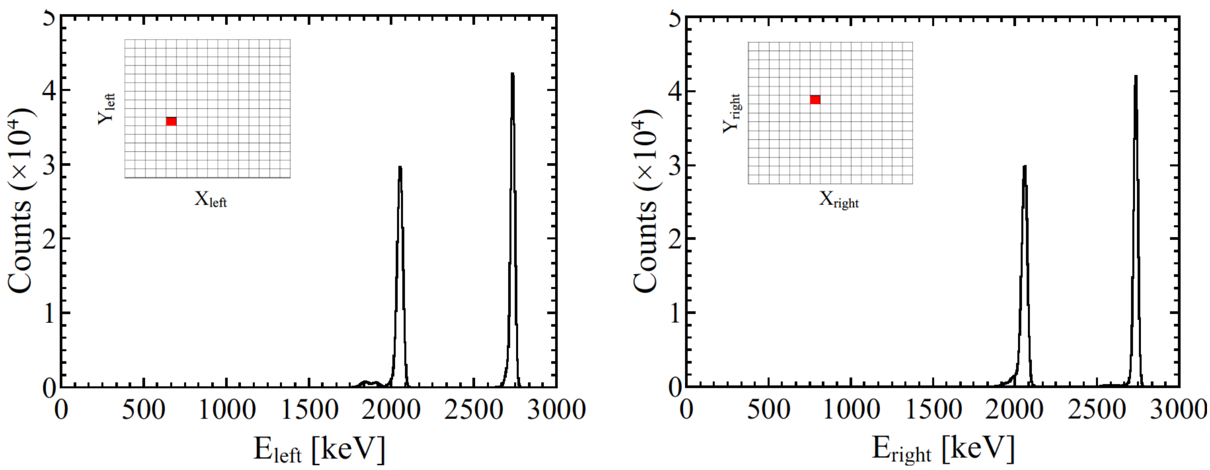


***Figure 1.*** *Examples of particle spectra measured with Left and Right DSSSD detectors in the reaction* $^{6}$Li(n,$^{4}$He)$^{3}$H, *for the pixels indicated in the schematic detector diagram. The left peak corresponds to α particles, the sharper ones, on the right, to tritons.*

Figure 2 shows the energy distribution of the coincidence events, collected during the 2018 run, recorded by the Si detectors placed at the Left and Right side of the target.
It is found that the majority of the events (~ $7.6 \cdot 10^8$) 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 $E(^3H)/E(^4He) = 4/3$, for a $^4$He particle detected in the Left detector).

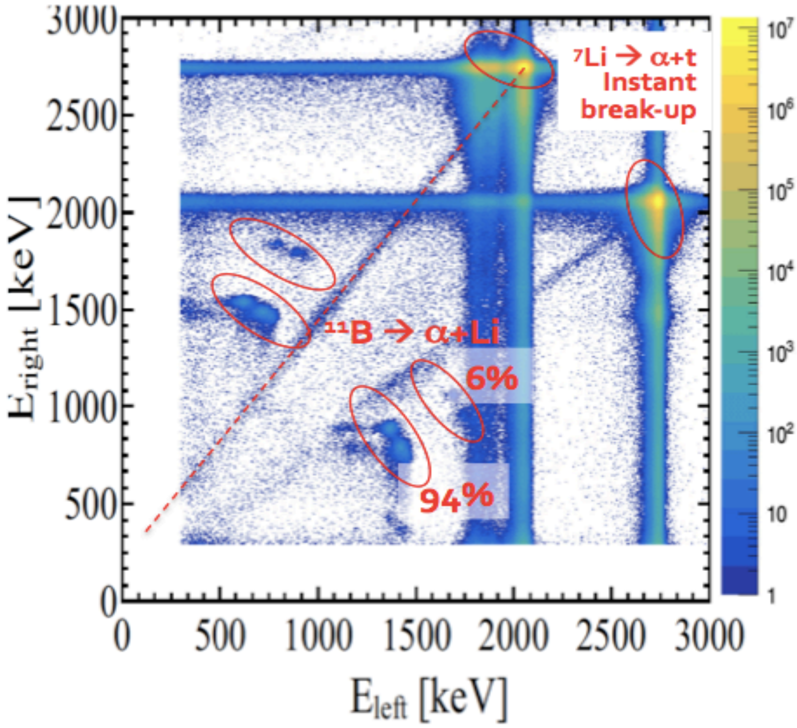


***Figure 2.*** *Energy distribution of coincidence events recorded by the Si detectors placed at the Left and Right side of the $^6$Li target. Circles indicate loci associated to the break-up of $^7$Li from the capture state, as well as contaminants arising from neutron capture on $^{10}$B, present in the detector contacts. The dotted line corresponds to the region defined by the energy condition $E(^3H) /E(^4He) = 4/3$ 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).*

It is found that the quality of the 2018 matrix is significantly improved with respect to the equivalent matrix from the 2017 experiment (see Fig. 3 of the experimental report 3-07-372). The main reason is the superior energy resolution, owing to a better quality target, as discussed in connection with the spectra shown in Fig. 1. A clear background reduction is also observed at low energy, as a consequence of a significant rejection of spurious events, which in this first step of the analysis are simply excluded by requesting both Energy and Time signals, for each event.

The most striking feature of the matrix of Fig. 2 is the evidence of a statistically significant event distribution along the $E(^3H) /E(^4He) = 4/3$ energy line, namely along the line which is relevant for the reconstruction of the γ decay in the continuum of $^7$Li. Such a distribution was barely visible in the 2017 matrix, as a consequence of the much higher background and worse energy resolution.
In the present condition, it is found that the 2018 matrix points to an effect, for the γ decay in the continuum, of the order of $3\ 10^{-6}$ of the capture cross section.

In order to confirm the result, a more detailed analysis will be needed, including, for example, a careful time coincidence gate between the left and right detectors. Particle identification techniques will also be exploited, making use of the energy and time information coming respectively from the preamplifier and two Constant Fraction Discriminators (CFD amplitude fractions 30% and 80%).

It is important to note that a close look at the individual channels of the electronic chain pointed to the existence of (very minor) undershoot and/or spikes in the electronic signal coming for a limited number of detector channels, as shown for example in Fig. 3. Although such effects could be considered negligible, a new run of comparable statistics, acquired with optimum electronics conditions, would be very desirable.
This would rule out the possibility of artefacts in the event distributions, associated to electronics settings or detector responses, in particularly along the $E(^3H) /E(^4He) = 4/3$ energy line where the effect of interest (extremely weak) is expected to appear.

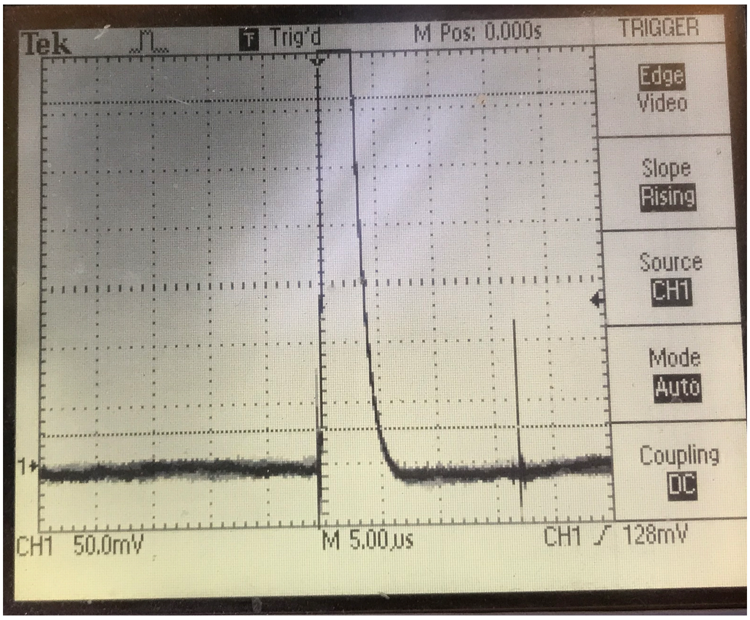


***Figure 3.*** *Example of output signal from one channel of the shaping amplifier used in the September 2018 run. A minor undershoot of the baseline signal is visible, together with a spike.*