EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Measurement of ^{7}Be(n,α)^{4}He and ^{7}Be(n,p)^{7}Li cross sections for the Cosmological Lithium Problem

Addendum to CERN-INTC-2014-049/INTC-P-417

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Abstract: In the 47th Meeting, INTC approved the first part of a proposal aimed at the measurements of ^{7}Be(n,p)^{7}Li and ^{7}Be(n,α)^{4}He reactions of interest for the cosmological Lithium problem [1], to be performed in the second experimental area (EAR2) at n_TOF. In that first part, in order to study the feasibility of the (n,α) measurement, we requested 1.5x10^{18} protons to perform a test on a possible experimental setup. We report here the results of the detector tests, and present the final proton request for the two measurements.

Requested protons at n_TOF: 5.0x10^{18} protons on target for ^{7}Be(n,α)^{4}He
Requested protons at n_TOF: 1.5x10^{18} protons on target for ^{7}Be(n,p)^{7}Li
Experimental Area: EAR-2

1 The ^{7}Be(n,α)^{4}He measurement

We have tested a configuration of the experimental setup consisting of a sandwich of 140 μm Silicon detectors with a converter deposit between them, inserted directly in the neutron beam at EAR2. The main issues to be investigated were the background induced by the beam, and especially, the effect of radiation damage on the Silicon detectors. The test was performed during the commissioning at the end of 2014 and in the first part of 2015. The Si sandwich, with a LiF converter in between, was mounted at a height of 3 m from the floor of EAR2. This position is approximately 1.5 m higher than the "standard" sample position, and closer to the beam dump, so that the detectors were subject to a worse background condition than expected during the final measurement. Since the test was run in parallel with the commissioning, we were able to profit from sligthly more protons than requested, i.e. 2.0x10^{18} protons. During the test the reverse currents of the two Silicon detectors were monitored. Furthermore, signals produced by tritons and alpha particles from the ^{6}Li reaction were recorded, in order to check for a possible degradation of the performances of the detectors.

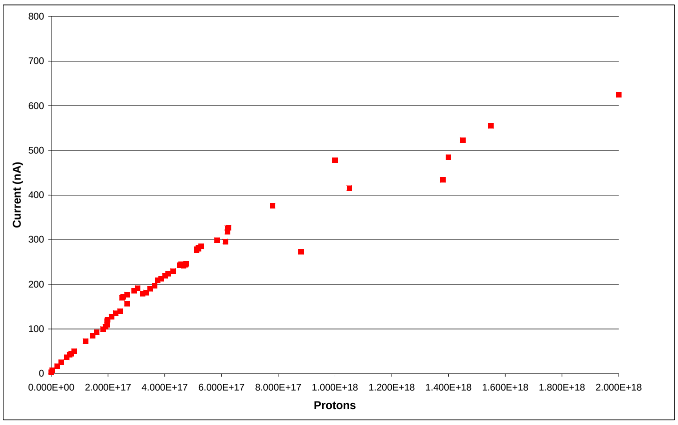


Figure 1: Reverse current as a function of protons delivered at the spallation target.

As reported in Fig.1, the reverse current was found to increase linearly with the number of protons at a rate of 400 nA/1x10^{18} protons, which according to count rate estimation later reported, would lead to a final reverse current at the silicons equal to 2.0 μA; this final value, considering also results from other silicon detectors installed and used at n_TOF since many years, will not affect the performances of the devices. Moreover, neither the noise nor the energy resolution of the detector showed a significant worsening. Figure 2 compares the energy spectrum in one of the two detectors at the beginning and at the end of the test. As can also be appreciated in the figure, the background is mostly concentrated in the low-amplitude region (we remind that we expect to detect in the ^{7}Be(n,α)^{4}He measurement alfa-particles of 8 MeV in coincidence).

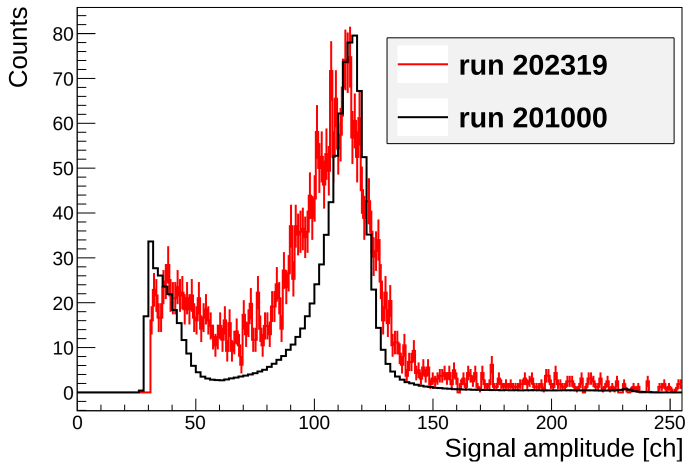


Figure 2: Signal amplitude spectrum at the beginning of the test and after 2.0x10^{18} protons.

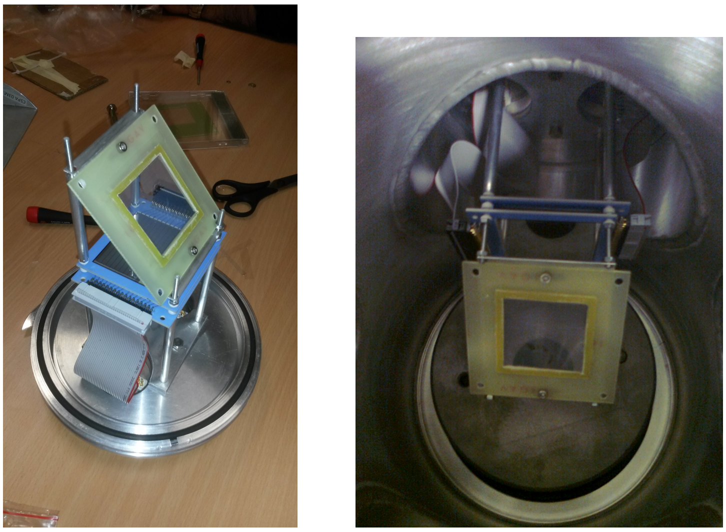
The test also provided indication on the highest measurable neutron energy, limited by the γ-flash. With a lin-log Mesytech preamplifier, signals were recorded up to few tens of keV. A further improvement is expected from the use of fast current preamplifiers, currently being tested.
A separate test was performed at PSI to estimate the response of the detectors to the very high activity of the ^{7}Be sample. In this case, a deposit of only 50 MBq, compared to the total 50 GBq proposed for the final measurement, was used. The results of the test, extrapolated to the final activity, indicates that a count-rate as large as few MHz is expected, with a sizable pile-up probability. However, most of the signals are below 300 keV deposited energy, so that a threshold of 1 MeV should be enough to suppress a very large fraction of it, even in the presence of a large pile-up. In this case as well a fast current preamplifier will help reducing the pile-up probability and the consequent extension of the background spectrum.
Based on the results of the tests no major problems are foreseen for the measurement, from the point of view of the experimental setup. One of the critical issues that had also to be addressed regarded the preparation of the sample, the mounting of the detectors and sample in a suitable housing and on the beam line. This is particularly challenging considering the extremely high total activity of the sample, 50 GBq, (corresponding to 5 GBq of 478 keV γ-rays). To this end, a chamber has been already constructed and shipped to PSI, where the ^{7}Be sample will be prepared. A picture of the chamber is shown in Fig. 3.
Once the sample is mounted, the chamber will be sealed, enclosed in a thick Pb shielding and shipped to CERN where it will be mounted on the beam of EAR2, inside and additional thick Pb

Figure 3: The scattering chamber built for the measurement.

shielding. Regarding sample preparation, the n_TOF groups at PSI has already performed some test of ^{7}Be deposition on thin polyimide films provided by EC-JRC-IRMM, and on electrodeposition on C backings. In principle, we should be ready to perform the measurement as soon as the Be separation is performed at PSI, late in the summer.
Considering the status of preparation of the measurement, we request 5.0x10^{18} protons to perform the measurement. The count-rate estimation is the same as reported in the first part of the proposal already accepted, as the decrease of the amount of ^{7}Be indicated here (50 GBq in place of 100 GBq indicated previously) is compensated by the neutron flux that, after the 2014 commissioning, is well known to be at least two times bigger than the conservative value used in calculations in Ref. [1].

2 The ^{7}Be(n,p)^{7}Li measurement

In this case as well we have successfully tested an experimental setup to be used for this measurement. The detectors were prepared by the n_TOF group of Univ. of Lodz, consists in a Si E-ΔE telescope, made of 16-strip 20 μm thick Si followed by a 300 μm thick one. The telescope will be mounted outside the neutron beam, at a 45 degrees angle, viewing the sample. This configuration has recently been tested, with a LiF neutron converter in the beam, mounted inside the vacuum chamber of the SiMon2 detector. Suitable high-capacitance preamplifiers have been chosen for the ΔE detector. Two pictures of the setup are shown in Figure 4(a) and Figure 4(b).
The results of the test is shown in Figure 5. Very clean signals are observed for both detectors, with clear coincidences between the ΔE and E detector. We remind that only the 2.7 MeV tritons are able to cross the ΔE detectors, while the alpha particles are stopped inside it. The telescope will be very useful to identify protons from the (n,p) reaction, and distinguish it from competing reaction. Another issue related to this measurement regards the sample preparation. Contrary to the (n,α) reaction, whose identification is based on the detection of coincidences



(a) (b)

Figure 4: Fig. 4(a): The silicon E-ΔE telescope used at n_TOF. Fig.4(b): The detector inside the SiMon2 chamber placed in the second experimental area.

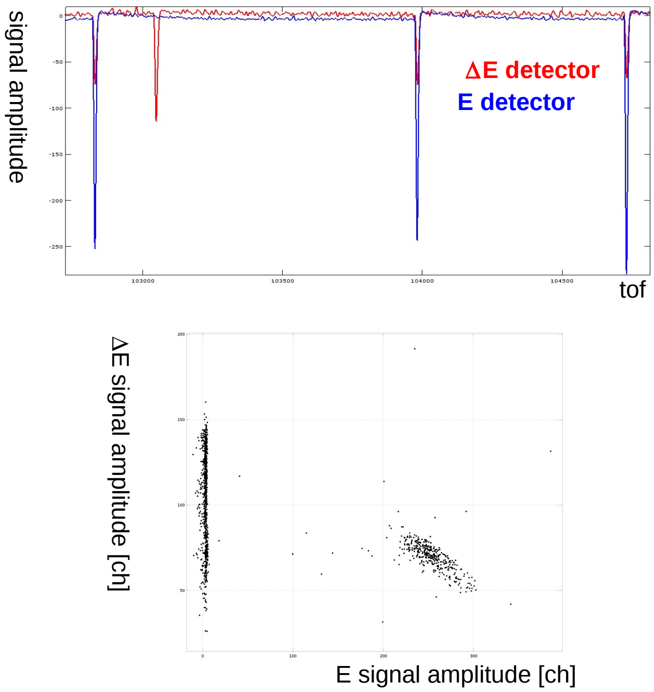


Figure 5: Signal detected in the the ΔE and E detector (red and blue curve respectively) as a function of time of flight(upper panel). E-ΔE matrix showing the tritons region (lower panel).

of high-energy alpha-particles, for the (n,p) reaction a pure ^{7}Be sample has to be produced. Isotope separation will be performed at ISOLDE, in 2016, and 3 shifts of offline ISOLDE mass separation have been already allocated in [1]. In this case as well, a thin C backing will be used, in which ^{7}Be will be implanted. The vacuum chamber to be used for this experiment is the same as the one used for SiMon2. Based on the estimates reported in the first proposal, we confirm that a sufficient statistics will be collected with 1.5x10^{18} protons. We ask the approval of this request.

Summary of requested protons at n_TOF: 5.0x10^{18} protons on target for (n,α) reaction and 1.5x10^{18} for (n,p) reaction ; EAR-2.

References

[1] M. Barbagallo et al., CERN-INTC-2014-049/INTC-P-417