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^{7}Be(n,p) cross section measurement for the Cosmological Lithium Problem at the n_TOF facility at CERN

Lucia Anna Damone[1,⋆], *N.* Colonna[1], *M.* Barbagallo[1,2], *M.* Mastromarco[1], *J.* Andrzejewski[3], *P.* Finocchiaro[4], *L.* Cosentino[4], and ***The n_TOF Collaboration***

[1] *INFN, Bari*
[2] *CERN*
[3] *University of Lodz, Poland*
[4] *INFN Laboratori Nazionali del Sud, Catania, Italy*

Abstract. One of the most puzzling problems in Nuclear Astrophysics is the "Cosmological Lithium Problem", i.e the discrepancy between the primordial abundance of ^{7}Li observed in metal poor halo stars [1], and the one predicted by Big Bang Nucleosynthesis (BBN). One of the reactions that could have an impact on the problem is ^{7}Be(n,p)^{7}Li. Despite of the importance of this reaction in BBN, the cross-section has never been directly measured at the energies of interest for BBN. Taking advantage of the innovative features of the second experimental area at the n_TOF facility at CERN, an accurate measurement of ^{7}Be(n,p) cross section has been recently performed at n_TOF, with a pure ^{7}Be target produced by implantation of a ^{7}Be beam at ISOLDE. The experimental procedure, the setup used in the measurement and the results obtained so far will be here presented.

1 Introduction

Theoretical models of the Big Bang Nucleosynthesis (BBN), i.e. the production of light elements in the first few minutes of the life of the Universe, correctly predict the abundance of all primordial elements except for ^{7}Li that is overestimated by a factor of 3-5. This significant discrepancy between observation and predictions is known as the cosmological lithium problem (CLiP) [2]. Since 95% of the primordial ^{7}Li is produced by the electron capture decay of ^{7}Be, a higher destruction rate of ^{7}Be can solve or at least partially explain the CLiP. In this scenario, reactions induced by neutrons on ^{7}Be, in particular the ^{7}Be(n,α)^{4}He and the ^{7}Be(n,p)^{7}Li reactions, could play an important role in explaining this discrepancy. However, data on these reactions have been so far scarce or completely missing. The recent construction of a second experimental area (EAR2) at n_TOF (Neutron Time of Flight) characterized by an extremely high instantaneous neutron flux (10^8 n/cm^2/pulse), a good energy resolution and a low repetition rate, offered the unique opportunity to perform time-of-flight measurements of ^{7}Be(n,p)^{7}Li and ^{7}Be(n,α)^{4}He cross sections over a wide energy range (from thermal up to 1 GeV), covering the one of interest for the Big Bang Nucleosynthesis. Results on the latter reaction have already been published [3]. Preliminary results on the (n,p) reaction are here reported.

2 Experimental Setup

At n_TOF the neutron beam is produced by spallation of a pulsed proton beam from the CERN Proton Synchrotron accelerator (PS), with momentum of 20 GeV/c, impinging on a cylindrical lead target surrounded by water for cooling and neutron moderation purposes. For the first 13 years of operation, only one experimental area was available (EAR1) [4]. In 2014, a new experimental hall located on the vertical direction at 20 m distance from the spallation target, the so-called n_TOF-EAR2 [5][6] was completed and became operational. The main advantage of this new measuring station with respect

⋆e-mail: lucia.damone@ba.infn.it

to the existing one consists in a flux up to 40 times higher. Combined with the shorter time-of-flight at a given energy, 10 times lower than EAR1 due to the shorter flight-path, the higher flux results in more than two orders of magnitude higher signal-to-background ratio for radioactive samples. These features of the EAR2 neutron beam open the way to measurements of neutron-induced reactions on very thin samples, reactions of low cross sections or radioactive isotopes with short half-life such as the ^{7}Be (53 days). The measurement of the ^{7}Be(n,p)^{7}Li reaction was performed using a telescope made of two Silicon strip detectors placed off the neutron beam track (see Figure 1) [7]. The system was calibrated by means of the well known ^{6}Li(n,α)^{3}H reaction, whose cross-section is standard from thermal energy up to 1 MeV.

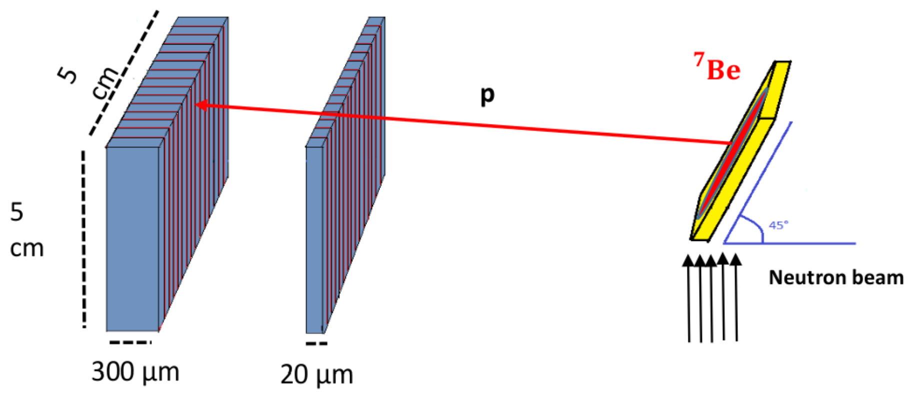

Figure 1: Schematic view of the of the experimental setup. In yellow the support for ^{7}Be, 1.5x1.5 cm^2; in red the ^{7}Be deposit of 2.5 mm radius. The Silicon strip detectors are in blue. The ΔE is 20 μm thick, while E 300 μm.

Two different ^{7}Be samples of 20 MBq and 1.1 GBq respectively were prepared starting from 200 GBq ^{7}Be solution collected at Paul Scherrer Institute (PSI). The samples were produced at ISOLDE by implantation of a beam of ^{7}Be at 35 keV on an Aluminum backing.

3 Data analysis

Once the samples were prepared, they were placed in the neutron beam line at EAR2 inside the vacuum chamber hosting a silicon telescope. Protons emitted in the ^{7}Be(n,p)^{7}Li reaction were detected and identified, as shown in the E-ΔE matrix of the events detected in the telescope (Figure 2). The red circle indicates the region of protons from the ^{7}Be(n,p)^{7}Li reaction.

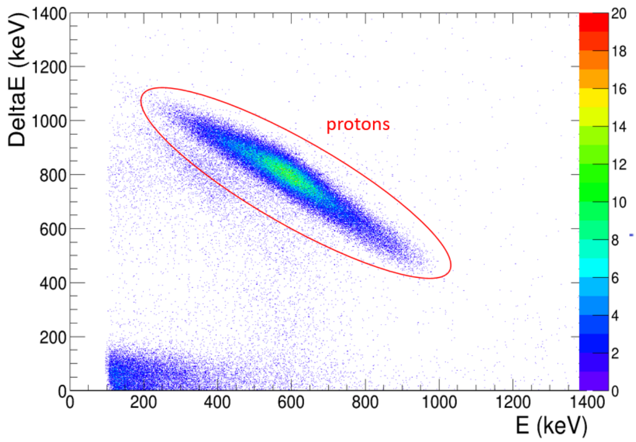

Figure 2: Coincidence of protons between the strips of the two array of Silicon detectors.

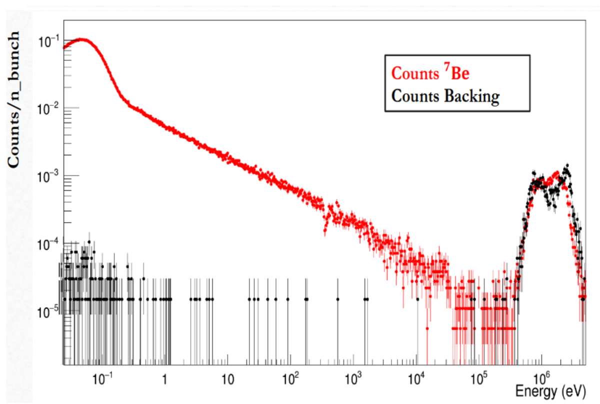

Figure 3: Comparison between the counts collected with the ^{7}Be sample, in red, and the dummy aluminum target, in black.

We did also a study of the background, obtained by comparing the counts collected with the ^{7}Be sample and the ones from the backing. The signal/background ratio is good up to a few hundred keV, while above this energy the background related to the ^{14}N(n,p) reaction dominates (Figure 3). In order to calibrate the detector and make a reference measurement, prior to the ^{7}Be(n,p)^{7}Li measurement, the ^{6}Li(n,α)^{3}H reaction, whose cross section is standard, was measured and the result compared with the evaluation from ENDF/B-VII.1 [7], as shown in Figure 4. A good agreement, within 5%, from thermal neutron energy up to 1 MeV has been observed.

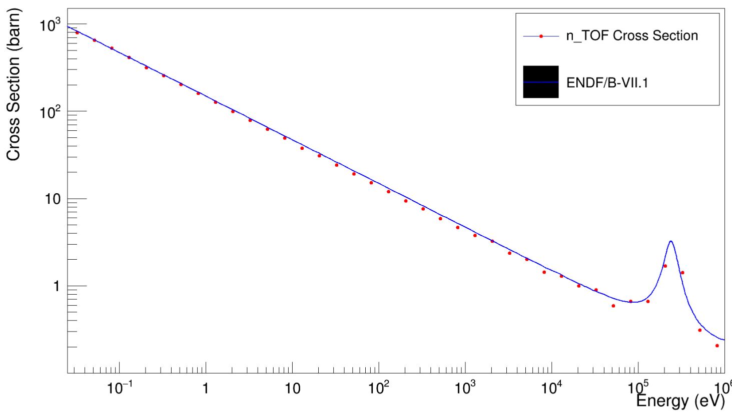

Figure 4: Comparison between our measured ^{6}Li(n,α)^{3}H cross section and the evaluation from ENDF/B-VII.1 data library.

4 Conclusions

The ^{7}Be(n,p)^{7}Li cross section measurement has been performed for the first time covering the energy range of interest for the Cosmological Lithium Problem (20-200 keV) in the second experimental area (EAR2) at n_TOF, using 1.1 GBq and 20 MBq pure ^{7}Be samples implanted at the General Low Mass (GLM) beam line of the ISOLDE facility, starting from a 200 GBq ^{7}Be solution collected at PSI. The ^{7}Be(n,p)^{7}Li cross-section has been measured with the two different samples and the results are in a very good agreement. Analysis is in progress to extract the absolute value and energy dependence of this important reaction, and determine its influence on the CLiP problem.

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