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Indirect study of the $^3He(n,p)^3H$ reaction at cosmological energies

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Abstract. In the network of reactions present in the Big Bang nucleosynthesis, the $^3He(n,p)^3H$ reaction has an important role which impacts the final ^7Li abundance. The Trojan Horse Method (THM) has been applied to the $^3He(d,pt)H$ reaction in order to extract the astrophysical S(E)-factor of the $^3He(n,p)^3H$ reaction in the Gamow energy range. The experiment will be described in the present work together with the first preliminary results.

1. Introduction

Big Bang nucleosynthesis (BBN) is one of the cornerstones of the Big Bang cosmological model. Cosmological parameters and reaction rates are used as physics input of the model to calculate primordial abundaces. Among these 12 reaction rates of great impact on the model, the $^3He(n,p)^3H$ is one particularly complex to get, because of the neutron in the entrance channel. Although direct measurements have been performed (e.g. [1] and reference therein), difficulties arise especially in the low-energy region, that is interesting for the BBN scenario, namely 10-900 KeV (Gamow window). For this reason, indirect methods can play an important role, as previously done for other reactions [2][3][4]. The THM [5][6] has been applied to $^3He(d,pt)H$ reaction in order to extract information on $^3He(n,p)^3H$ reaction cross section at astrophysical energies. The quasi-free process, on which THM is based, is sketched in figure 1: A deuteron breaks up into a neutron (participant) and a proton (spectator).

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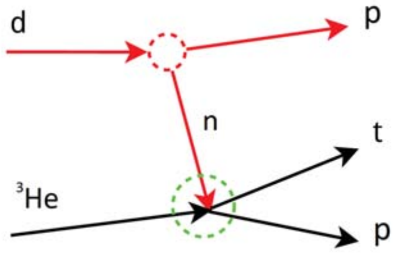

Figure 1. Sketch of the process: A deuteron breaks up into a neutron (participant) and a proton (spectator) in a quasi-free process.

2. The experiment

In the preparatory phase the best angular and energy region was seeked, using a Montecarlo simulation, to favour the quasi-free mechanism. Detectors were placed as sketched in figure 2. Three position sensitive detectors, 1000 μm thick (PSD 1-3), were used; PSD1 was coupled with a 35 μm thin silicon detector for particle identification. The ^3He beam, delivered at a total kinetic energy of 9 MeV by the University of Notre Dame FN Tandem, impinged on a 100 $\mu g/cm^2$ deuterated polyethylene target, manufactured at the LNS target laboratory. Two symmetrical monitor detectors were placed on both sides of the beam to check the beam symmetry. Another point-like silicon detector (PL1) was placed at 45° for on-line monitoring the target thickness during the experiment. PSD angular positions were measured by optical means with an accuracy of 0.2°, as required by THM. Calibration runs were performed using a standard alpha source and proton scattering on a gold target at various energies ranging from 3.5 to 9 MeV. In such runs, grids with equally spaced slits were placed in front of each detector in order to measure the angular calibration. The result is portrayed in figure 3, where a typical spectrum is plotted for PSD1 after energy and angular calibration. The data acquisition system triggered when outcoming particles impacted simultaneously in two of the PSD detectors. Then data were stored in the DAQ system owned by Notre Dame University and converted to the ROOT format.

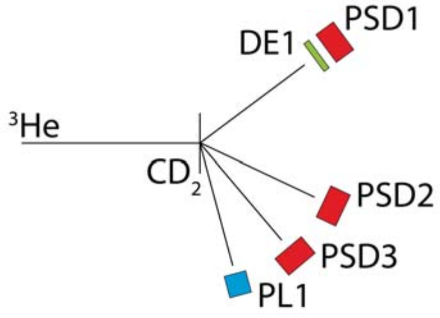

Figure 2. Experimental set-up adopted in the present run.

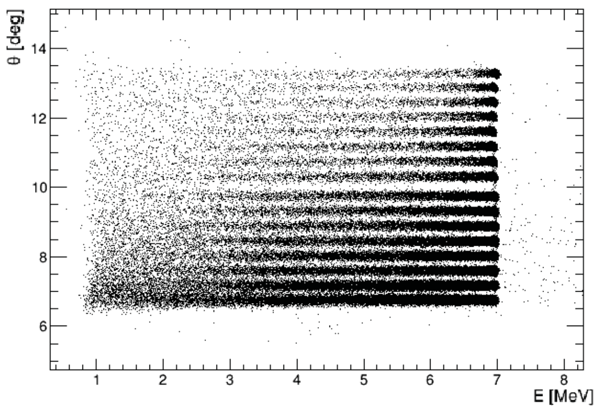

Figure 3. PSD1 position vs. energy plot after position and energy calibration.

3. The particles identification

The first step after calibration is the event selection to obtain the particle identification. The ΔE-E plot, obtained by telescope 1 shows the following nuclides: ^3He, Tritium, Deuterium. In the figure 4 is possible to see the data selected to identify the $^3He(d,pt)H$ reaction.

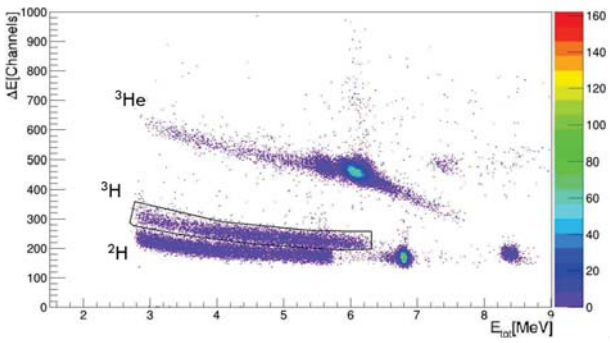

Figure 4. ΔE-E plot for particle identification. Tritons data have been gated with a graphical cut on this plot, shown as a solid line.

4. Q-value

The correct identification of the reaction channel is supported by the -1.46 MeV peak for the $^3He(d,pt)H$ reaction in the Q-value spectrum (figure 5). The Q-value spectrum was obtained measuring the energies by the detectors and reconstructing the energy of the third particle through kinematic relations. As the figure 5 shows, the experimental peak is around -1,5 MeV, but through more statistic it could be possible to better discriminate the -1.46 MeV peak from other processes. Data analysis is still in progress, to definitely select the quasi-free process and carry on the subsequent data process as in the THM prescriptions[6].

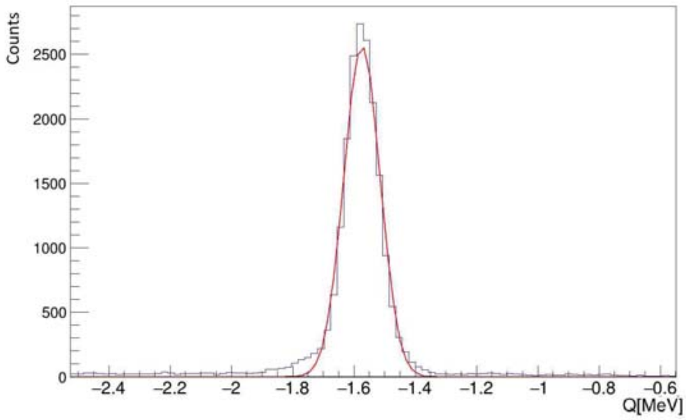

Figure 5. Q-value spectrum for $^3He(d,pt)H$ reaction (-1.46 MeV).

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