Study of $^3He(n,p)^3H$ reaction at cosmological energies with trojan horse method

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Abstract. In the network of reactions present in the Big Bang nucleosynthesis, the $^3He(n,p)^3H$ 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 $^3He(n,p)^3H$ 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 Big Bang cosmological model. Within BBN has been chosen a series of reactions which converts the initial protons and neutrons into helium isotopes and ^7Li. Cosmological parameters and reaction rates are used as physics input of the model to calculate primordial abundaces. Among the 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 are present (e.g. [1] and reference therein), difficulties arise expecially 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 orden 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: deuteron breaks up into a neutron (participant) and a proton (spectator).

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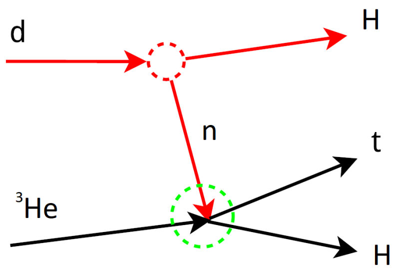

Figure 1. Sketch of the process: deuteron breaks up into a neutron (participant) and a proton (spectator) in a quasi-free process.

2 The experiment

In the preparatory phase the most suitable angular range and energy region to favour the quasi-free mechanism were defined using a Montecarlo simulation. 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 (DE1) for particle identification. The ^{3}He beam, delivered at a total kinetic energy of 9 MeV by the Notre Dame Tandem, impinged on a 100 $\mu g/cm^2$ deuterated polyethylene target, manufactured at the LNS target laboratory. Two symmetrical monitor detectors were placed at 40° on both sides of the beam to check the beam symmetry. Besides, 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 perform 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 in ROOT format.

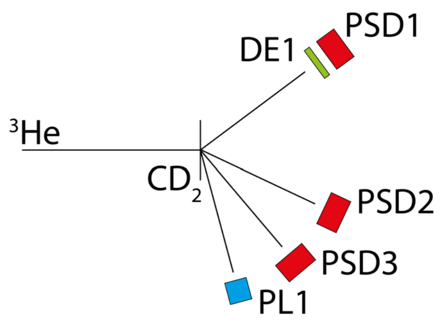

Figure 2. Experimental set-up adopted in the present run.

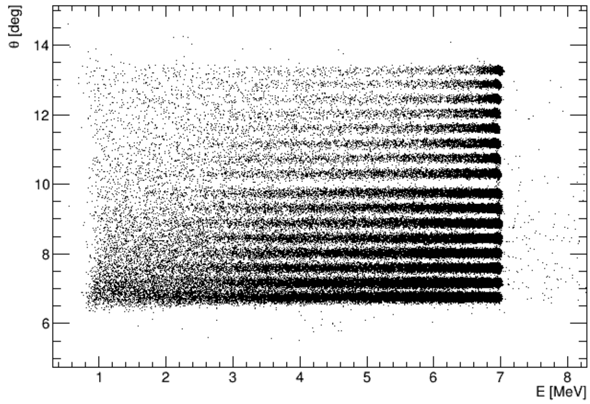

Figure 3. PSD1 angle vs. energy plot after position and energy calibration.

3 Particle identification

The first step, after calibration, is the event selection to obtain the particle identification. ΔE-E plot, obtained by telescope 1, with good separation shows the following nuclides: ^{3}He beam, Tritium, Deuterium. In order to identify the $^{3}He(d, pt)H$ channel (3-body process) we selected data originated from tritium locus (figure 4). Data analisys is still in progress, to definitely select the Q-value spectrum for the 3-body reaction.

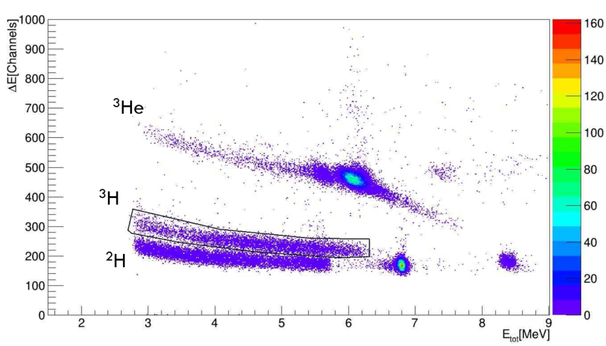

Figure 4. ΔE-E plot for particle identification. Tritons data have been gated with a graphical cut on this plot, shown as a solid line.

References

[1] C. Brune et al., Phys. Rev. C472 (1999) 376.
[2] R.G. Pizzone et al., Astrophysical Journal ,786, 112 (2014).
[3] L. Lamia et al., Astrophysical Journal 879, 23 (2019).
[4] A. Tumino et al., 2014, Ap. J., 785, 96.
[5] C. Spitaleri, Proc.of the 5th Winter Sch. on Hadronic Physics, Folgaria(TN), Italy(1990).
[6] C. Spitaleri et al., EPJ(2016) A52, 77.