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Calibration of Detectors for Studying the $^{19}F(p,\alpha)^{16}O$ Reaction at Astrophysical Energies *via* the Trojan Horse Method

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Abstract. An experiment was performed by means of Trojan Horse Method (THM) at the LNS Tandem in Catania. The investigation of the relevant $^{19}F(p,\alpha)^{16}O$ two-body reaction was performed by selecting the quasi free (QF) contribution of the $^{19}F(^{2}H,\alpha^{16}O)n$ three-body reaction, using the deuteron target as TH nucleus. The aim of this measurement is to obtain the $^{19}F(p,\alpha)^{16}O$ cross section. The experimental set-up and the calibration of the detectors will be presented.

INTRODUCTION

An experiment dedicated to the measurement of the $^{19}F(p,\alpha)^{16}O$ reaction was already performed and published [1,2,3] showing very promising results even if they are affected by a lack of statistics. In this work a new experimental setup devoted to overcome the problems faced in the first series of measurements and the calibration of the detectors are presented.

EXPERIMENTAL SET-UP

The experiment was performed at the Laboratori Nazionali del Sud in Catania, Italy. The Tandem accelerator provided a 55 MeV ^{19}F beam. Thin deuterated polyethylene target (CD_2) of about 100 μg cm^{-2} was placed at 90° with respect to the beam direction. The experimental setup consisted of two ΔE–E telescopes used to distinguish oxygen nuclei. The telescope consisted of an ionization chamber (IC) as a ΔE stage and a silicon position-sensitive detector (PSD1) as an E stage on one side with respect to the beam direction, and two additional silicon PSDs on the

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opposite side optimized for coincident detection of alpha particles (PSD2 and PSD3). A symmetric setup allowed to double statistics. A schematic view of the used setup is shown in Figure 1 and the angles are presented in Table 1.

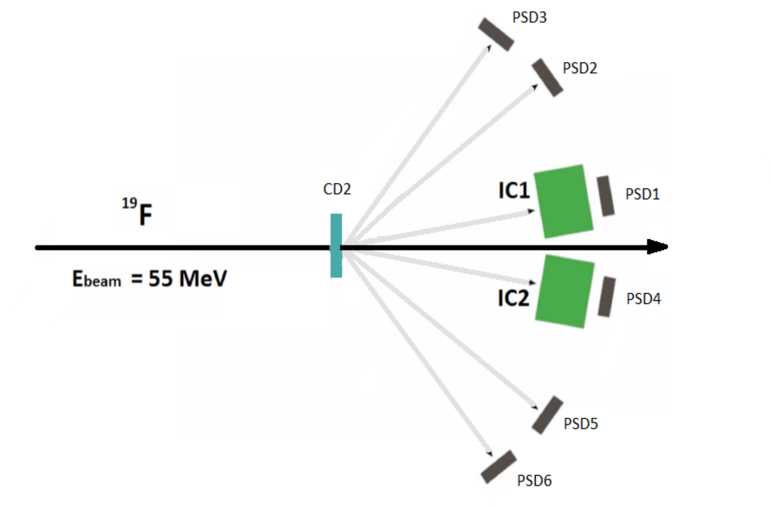

FIGURE 1. Schematic view of the experimental set-up. The ^{19}F beam was impinging on a CD_2 target. The emitted particles were detected by four PSDs and by two ΔE−E telescopes.

TABLE1. Detectors angles

PSD	1	2	3	4	5	6
θ (deg)	4-12	20-38	40-58	4-12	20-38	40-58

ENERGY AND POSITION CALIBRATION

In this work, the focus is on the calibration of PSD1, PSD6 and IC1 detectors. The energy is correlated with the signals by a linear relation: $E_{PSD}[MeV]=a+bE_{ch}$. In order to obtain a and b from a fitting procedure one must be able to identify peaks in the P(ch) versus E(ch) 2D-spectrum, and to associate those peaks with proper energy values, as demonstrated in Figure 2. The energy calibration was performed with the 8-peak alpha source. Using the LISE++ simulation program [4], also the energy loss inside the target is taken into account.

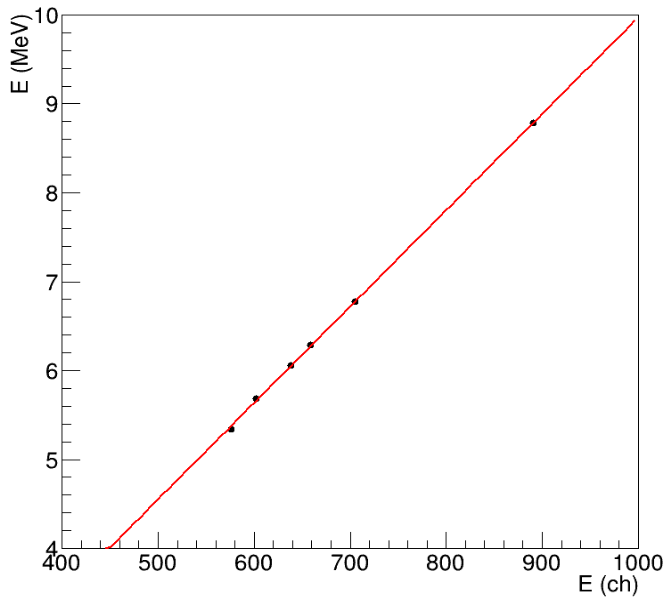

FIGURE 2. Energy calibration of PSD6 using the alpha source.

For position calibration, a mask with equally spaced slits was placed in front of the PDSs. Using an optical system, the correlation between angles and slits was made. Once a slit is fixed, a linear dependency between position and energy is established, and a linear fit procedure can be performed: $P_{Ch}=a(\vartheta)+b(\vartheta)E_{Ch}$, as seen in Figure 3. In order to obtain a correspondence between the signals coming form the detector and the angle θ corresponding to the position at which the signal was generated, linear fits on the a(θ) and b(θ) parameters are performed: $a(\vartheta)=a_1+a_2\vartheta$; $b(\vartheta)=b_1+b_2\vartheta$. The final calibration of PSD6 is shown in Figure 4.

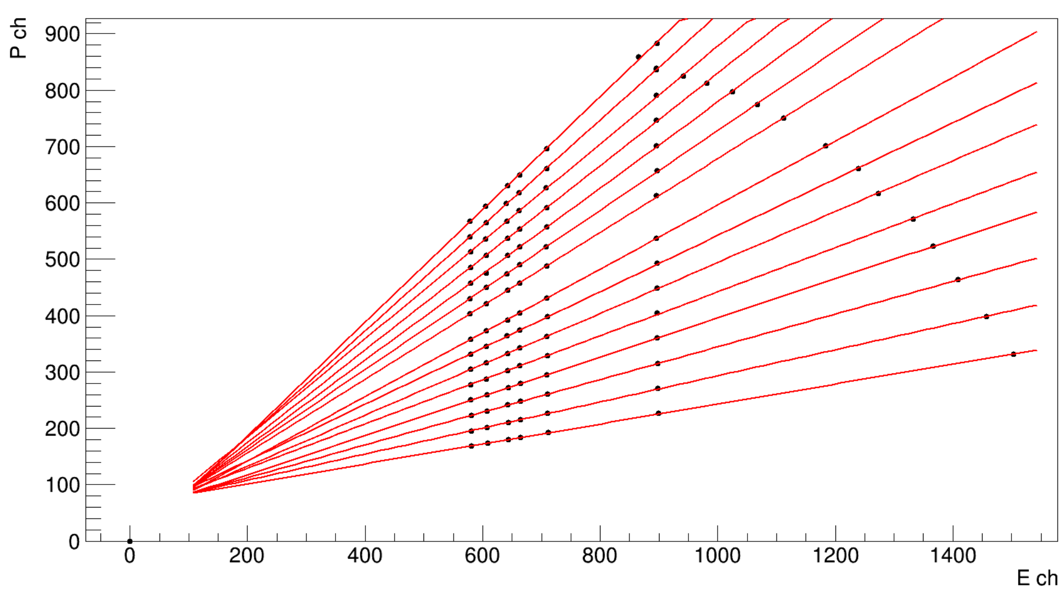

FIGURE 3. Position channel versus energy channel in PSD6, with the mask placed in front of the detector.

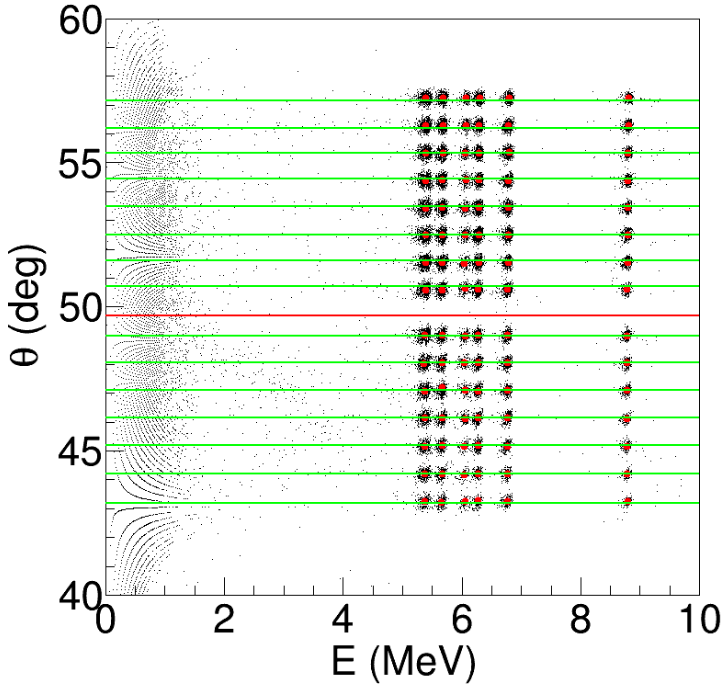

FIGURE 4. Final calibration of PSD6. Each green line represents a slit of the mask and the red line represents the middle of the mask.

In Figure 5 the calibration of PSD1 is presented, which was made in a different way because PSD1 is used for detecting oxygen particles. For this calibration, few calibration runs with oxygen beam at different energies were performed measuring the scattering on a gold target. The energies of the oxygen beam were: 30, 37, 45, 55 MeV. The energy loss of the ^{16}O inside the target was also taken into account.

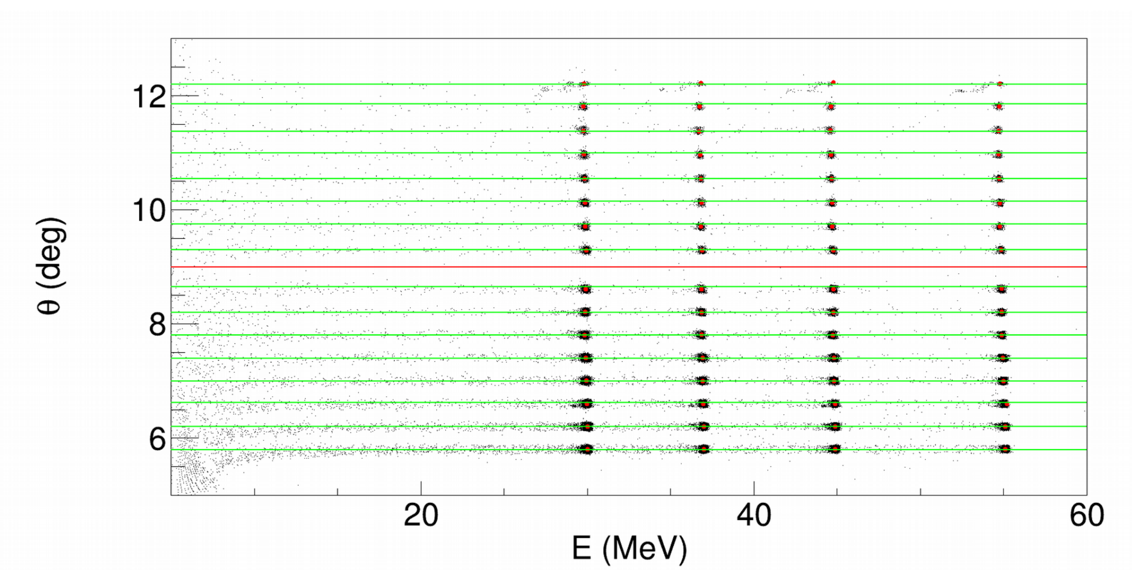

FIGURE 5. Final calibration of PSD1. Each green line represents a slit of the mask and the red line represents the middle of the mask.

IC1 is placed in front of PSD1. The calibration runs were performed with and without gas inside the IC in order to see the energy loss of particles inside gas. The energy loss measured in gas as a function of energy is shown in Figure 5. The ICs were filled with 50 mbar of isobutane.

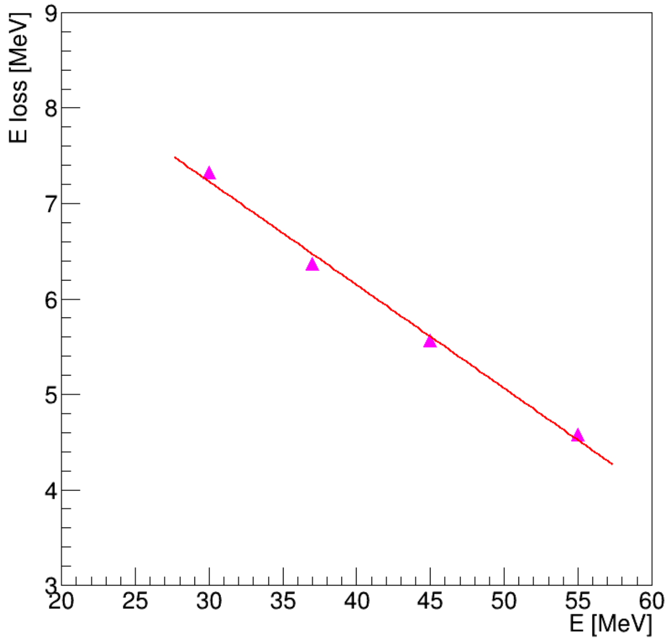

FIGURE 6. Energy loss of oxygen inside the IC.

Once calibration procedures are completed, it is possible to extract information about energies and positions of the incoming particles using the PSDs, and in particular PSD1 and PSD6 (optimized for alpha particle and oxygen detection, respectively). The next steps of a TH analysis are presented in Guardo, G. L et al. PRC 95 (2017) 025807 [5].

CONCLUSIONS

Such measurement at low energies is fundamental in the study of the known inconsistencies between model predictions and observations of ^{19}F abundances in AGB stars, and in its implications on stellar evolution models. For this reasons, an experiment was performed at LNS-Laboratori Nazionali del Sud. The Tandem accelerator provided a 55 MeV ^{19}F beam impinging on a thin deuterated polyethylene target (CD_2), with the aim to induce the ^{19}F(^{2}H,α^{16}O)n reaction. The detector calibration is presented here.

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