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Study of the resonance α+^{13}C interaction at low energies: Optimization of parameters of the beam shape

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For the improvement of the **^{13}C (α, α)^{17}O** elastic scattering cross-section measurement on the DC-60 accelerator, the characterization of the beam parameters within the experimental camera such as intensity profile is required. This article describes the preparations of the setup for such a measurement using the multi-channel PMT, plastic scintillator and the existing DAQ setup.

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1.Introduction

About half of all elements heavier than iron are produced in a stellar environment through the *s* process, which involves a series of subsequent neutron captures and *α* decays. The reaction ^{13}**C(*α,n*)**^{16}**O** is considered to be the main source of neutrons for the *s* process at low temperatures in low mass stars in the asymptotic giant branch (AGB). In order to understand better creation of such elements we need to imrove the understanding of creation of such elements, that is to obtain the excitation functions of the ^{13}**C (α, α)**^{17}**O** elastic scattering at the initial beam energy ^{13}**C** from 1.7Mev/A till energies close to zero by using the Thick Target Inverse Kinematics method (TTIK) [1]. The experiment will be conducted in Astana, KZ by using a new heavy ion accelerator DC-60 that provides ion beam with the energy 1.75 MeV/nucleon [1]. To improve the results and reduce errors, the profiling of the beam within the experimental camera is required. In this article, the detailed preparations for this measurement are described.

2.Experimental setup

An accelerated ***^{13}C*** beam enters scattering chamber filled with helium-4 (99.9%) passing through a thin window (with 2.5-µm havar film). Helium-4 plays role of target and degrader for entering beam. The pressure in the chamber is chosen such that the beam stopped in helium at a distance of 50 mm from the back wall of the chamber, where detectors placed. Detection is made by 15 square p-i-n Si detectors with an area of 100 mm2 and a thickness about 350 µm. The energy resolution of detectors was about 30 keV. [1]. Beam profiling are to be done both in vacuum and at working pressure to study the effects of the window separately.

For that we plan use Hamamatsu [2] 64-channel PMT (H7546B) with plastic scintillator in front of it, placed within the camera after the beam window. The PMT is to be placed at different distance from beam entering window to obtain the picture of beam development. In this way we get the beam function depending on distance from the source. Science run is done in the same way but without PMT inside the chamber.

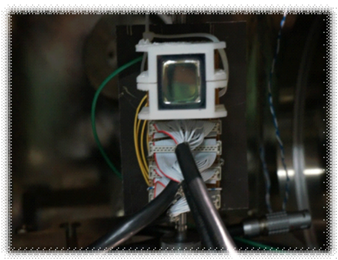 

Figure 1: PMT setup in the experimental chamber (left) and connection rig for PMT (right)

Experimental setup for calibration run is shown in Figure 1 (left) and consists of the following:

- H7546B PMT
- The PMT holder
- Connection rig
- ADC

The PMT holder was designed to fit inside the experimental chamber and then printed on a 3D-printer. The connection rig shown in Figure 1 (right) was done as a connection board between the PMT and the ribbon cables that take the signal out of the chamber via the vacuum-proof connectors in the walls.

3.DAQ

For the DAQ system, a fast stand-alone CAEN [3] DTT 5743 ADC model was chosen. With up to 3.2 Gs/s acquisition resolution and ability for self-triggering with different channels logic if necessary, this 8-channel ADC is easy and robust in operation. Eight of these units will be chained together with the common trigger. Trigger level and logic are software controlled thus could be adjusted remotely via USB port; the resolution is 12bit with the signal detection up to 2.5Vpp.

The home-written control software is based on the CAEN provided libraries and allows for saving the ADC signals from all units as a single file in ROOT [4] format to be analyzed off-line. It is a compressed binary tree common format that allows for fast event storage and access.

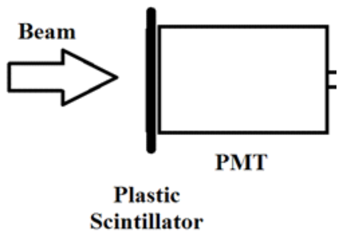

Figure 2: Experimental setup of test runs with alpha source

4.Plastic scintillator R&D

An Eljen [5] EJ201 plastic scintillator piece 30 mm x 30 mm x 4 mm will be used. The scintillator will be placed immediately in front of the PMT photocathode both to produce light from the beam and to protect the PMT face (Figure 2).

As the PMT pixels are very small (2x2mm) the scintillator can not be cut into such small pieces, thus a single piece has to be used. This will introduce channel cross-talk in addition to the anode cross-talk that already exists in the PMT. In order to study this additional cross-talk, the following steps are to be taken:

a) Use alpha source in front of the whole piece scintillator, scan the response of all channels.

b) Next, the scintillator piece will be grooved by ~0.3mm wide and 2mm deep grooves into the 8x8 pattern (Figure 3), grooves will be filled with TiO_2 , and cross talk will be measured again.

The 0.3mm is the inter-pixel distance so removing scintillator from this area does not impact on the device efficiency. As the low-energy carbon nuclei as well as alpha particles do not penetrate into the scintillator piece, a very deep groove is not required.

Beamline testing of measuring beam profile setup using both smooth and grooved plastic scintillator is planned for August 2015

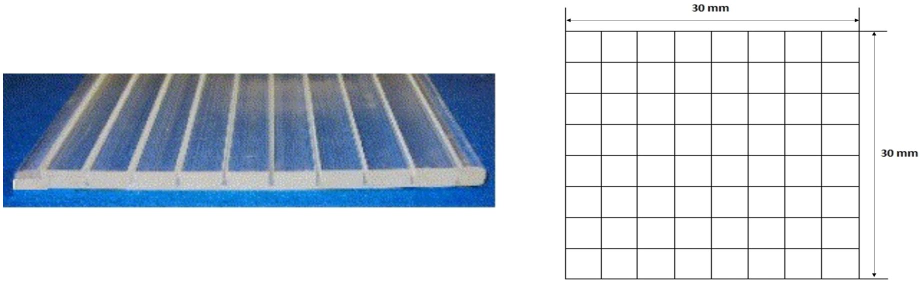

Figure 3: Example of scintillator with grooves [6] (left), groove pattern (right)

5.Conclusion

For the measurement of the beam profile, the part of the experimental setup has been tested separately, DAQ software is completed and plastic scintillator R&D is nearing completion with alfa-source test still in progress. The PMT model and the DAQ electronics have been chosen and aquired with testing underway in the designed and built connection setup. The beam-test part of the experiment was delayed for external resasons, but it is about to start by the end of the year. The data analysis including cross-talk interaction between channels will be completed after the initial beam test.

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