2 - 15 $^{16}O+^{40}Ar$ Experiment Using TPC at RIBLL1

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It has been proposed that fusion reactions between neutron-rich light nuclei, for example ^{24}C, ^{24}O and ^{28}Ne, may contribute to achieving the ignition temperature for explosive carbon burning process during superbusrsts[1,2]. Studies of fusion reactions involving neutron-rich nuclei are beyond ordinary experimental techniques, since the intensity of radioactive beam become low for these measurements[3]. The active target technique using TPC (Time Projection Chamber), with properties of multi-sampling, high efficiency and low background, is a suitable solution to the problem. This experiment was performed at RIBLL1 in Lanzhou. An ^{16}O beam, with energy of 7.723 MeV/u, impinged in a 48-channel GEM-TPC which was filled with P10 gas (90%Ar +10%CH_4) serving as both target and detector. The detection efficiency reached almost 100% and the energy resolution was around 4.5%.

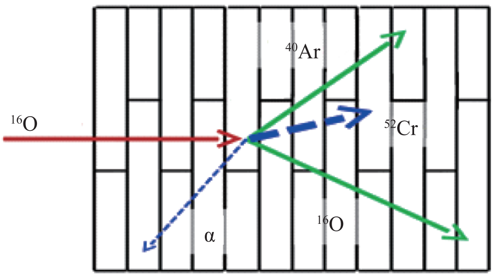

Fig. 1 (color online) Schematic view of the readout structure.

The readout pads of anode are adopted from that of MUSIC at Argonne, as shown in Fig. 1[4]. Along the beam direction, the anode is divided into strips. Each strip is subdivided into a long and a short pad. In a fusion reaction, the light particle (such as p, α) evaporated from the compound nucleus always generates a signal that is below the threshold. Therefore, only the energy deposition of the evaporation residue can be detected in the long or short pad of one anode strip. On the other hand, for elastic or inelastic scattering events, there will be hits on both sides of pads. By this "double hits" method, most of the scattering events can be ruled out. However there will be no "double hits", while the scattering angle of the particles is around 90°, or the energy of the scattered ion remains to be not large enough for it to pass through a strip. In these cases, the figure of energy deposition versus strips was discussed. It can be observed that in such events there are often two peaks suggesting two heavy particles, as is shown Fig. 2 (a).

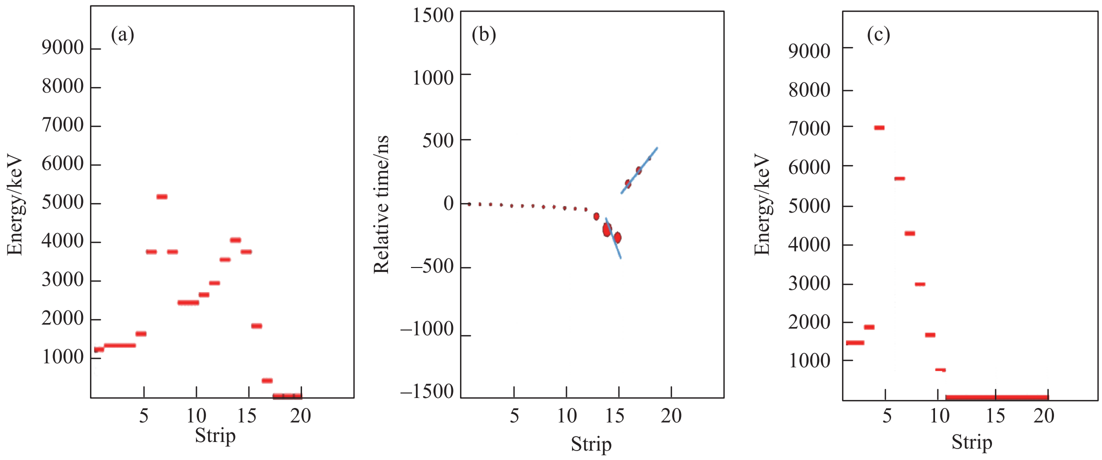

Fig. 2 (color online) (a) A scattering event with two peaks. (b) The relative time of heavy ions on different strips. (c) A confusing event with both fusion and scattering characteristics.

One disadvantage of the anode structure is that it fails to recognize the scattering events occurred in a plane perpendicular to the anode plane. Superior to the MUSIC, we can additionally obtain the relative time of the drifting electrons, which indicates the tracks of heavy ions along the drifting direction. Since analog electronics were used in the measurement, signals of two tracks on the same pad overlap and there remains only one relative time on each pad (as is shown in Fig. 2 (b)).

Although several methods have been utilized to discriminate scattering and fusion events, there remain some events which appear to have both profiles of scattering and fusion reactions. Fig. 2(c) shows an event which is recognized as a fusion event, while its energy deposition in the detector is much greater than normal fusion residues. One non-negligible cause is the gain non-uniformity in the detector that influences the event reconstruction and then the event identification.

In the coming year, the existing electronics will be replaced by the GET digitized electronics so that the drift time for each particle of scattering events can be separated clearly. 256-channel readout pads will be employed for detailed information to enhance the discrimination. With these developments, it can be expected to identify the scattering and fusion events more effectively.

References

[1] A. Cumming, L. Bildsten, Astrophys. J, 559(2001)L127.

[2] M. Beard, A. V. Afanasjev, L. C. Chamon, et al., At. Data Nucl. Data Tables, 96(2010)541.

[3] B. B. Back, H. Esbensen, C. L. Jiang, et al., Rev. Mod. Phys., 86(2014)317.

[4] P. F. F. Carnelli, S Almaraz-Calderon, KE. Rehm, et al., Nucl. Instr. and Meth. A, 799(2015)197.

2 - 16 Experimental Study of ^{13}N(α,p)^{16}O at the Stellar Energies*

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The presolar SiC grains[1] carry the original stellar nucleosynthesis signature. Their isotopic anomalies compared to the sun are the strong constrains in the supernovae (SN) model calculations. The ^{15}N-excess in some SiC-AB grains (^{12}C/^{13}C<10 and ^{14}N/^{15}N<272) is one of the challenges of core-collapse supernovae (CCSNe) models[2]. Recently, Pignatari pointed out that the entrainment of H-rich material into the He shell before the SN explosion allows the coproduction of ^{13}C, ^{15}N and ^{26}Al, which provides a new production scenario for SiC-AB grains[2]. In the He shell nucleosynthesis, the ^{13}C is produced through ^{12}C(p,γ)^{13}N(β$^+$ν)^{13}C reaction. The ^{14}N is synthesized through ^{13}N(n,γ) and ^{13}C(p,γ) reactions. In the SN He shell buring temperature (T ∼0.4∼0.8 GK), ^{13}N(α,p)^{16}O reaction is the main destruction of ^{13}N. Since there is no experimental reaction rate at the stellar low energy region (0.4∼1.2 MeV), the reaction rate predicted by the statistic model exists large uncertainty[3,4], which affects the abundance of ^{13}C and ^{14}N significantly. Therefore, it is important to determine the reaction rate from experimental reaction cross section at the stellar low energy region.

The direct measurement of ^{13}N(α,p)^{16}O at $E_{\rm cm}$=0.4∼1.2 MeV is still limited by the ^{13}N beam intensity (<10^{5}pps). Statistic model calculation predicts that the probability of ^{13}N(α,p)^{16}O* is four orders of magnitude less than ^{13}N(α,p)^{16}O. Thus, the inverse reaction measurement is a better choice. Here we propose to measure ^{16}O(p, α)^{13}N reaction cross section in the corresponding range, $E_{\rm cm}$=5.7∼6.3 MeV, where the main contribution is from the resonance at $E_{\rm cm}$=5.96 MeV ($E_{\rm x}$=6.56 MeV, J^π=1/2$^+$) and deduce the ^{13}N(α,p)^{16}O reaction cross section using detail balance principle and R-Matrix calculation.

The experiment was performed at RIBLL1 in IMP. A 114 MeV ^{16}O beam, produced by SFC and improved by RIBLL1, was irradiated to a 6.7 mg/cm^2 thick (CH$_2$)$_n$target. One Single Si Detector (SSD) and a telescope, consisting of a SSD and a Double-sided Si Strip Detector (DSSD), were placed at the forward angles to measure ^{13}N and α partilces, respectively, as shown in Fig. 1(a). The energy correlation of ^{13}N and α is presented in Fig. 1(b). The band inside the area enclosed by the open circles in the figure is the strong correlation band of ^{13}N and α. Using the two particle energies and the emitting angle of α recorded by DSSD, the reaction kinematic was

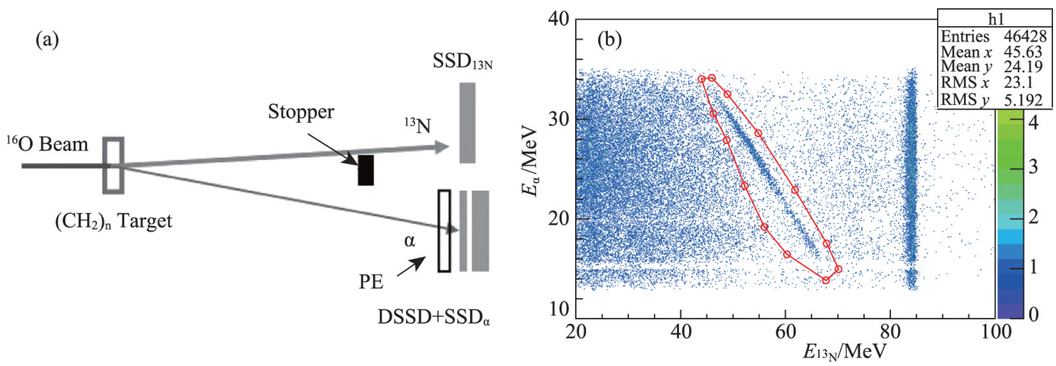

Fig. 1 (color online) (a) The experimental setup. (b) The energy correlation of α and ^{13}N.