Present results of ^{3}He + ^{3}He reaction cross section measurement

T. Itahashi[a], M. Komori[b], N. Kudomi[a], K. Kume[a], Y. Nagai[a] M. Ohsumi[b], K. Takahisa[a], H. Toki[a], H. Ejiri[a], H. Ueda[a], and S. Yoshida[a],

[a]*Research Center for Nuclear Physics (RCNP), Ibaraki, Osaka 567-0047, Japan*
[b]*Dept. of Phys. Facl. of Sci. Osaka Univ., Toyonaka, Japan*

Of the reactions in the solar combustion, such as d+p→^{3}He+γ, ^{3}He+^{3}He→2p+α, and ^{3}He+α→^{7}Be+γ, we have focused on the cross-section measurement of the ^{3}He+^{3}He reaction at the effective energy E_{cm}=17-27 keV. The reaction manifests the so-called neutrino problem in the sun and can be used to verify the standard solar model[1]. Currently the LUNA group in the Laboratori Nationali del Gran Sasso (LNGS) has presented data down to 20.7 keV center of mass energy [2].

The experimental apparatus, OCEAN was developed. An intense ion source that can produce ^{3}He^{1+} and ^{3}He^{2+} ions is essential for the present study. The total current obtained so far was 3010 μA at the source extraction and 1203 μA ^{3}He^{1+} at target position. We have further investigated the operational conditions in order to get a larger current($\geq$100 μA) of ^{3}He^{2+} ions. It is also helpful to study the reaction in a wider energy range[6]. The required energy range of ^{3}He ions should be between 30 to 50 keV, in which the astrophysical S-factor data for ^{3}He+^{3}He fusion reaction can be deduced. The low energy beam transmission efficiency from the ion source through the target is about 30%. The windowless gas target for a study of ^{3}He+^{3}He reaction consists of differential pumping and gas recirculation and purification system. The beam calorimeter was designed and fabricated so as to determine the number of incident particles. Charge integration with a usual Faraday cup and a commercial current integrator is difficult when a gas target is used, because of charge exchange effects in the ion beam. In the present calorimeter a heat flux sensor (OMEGA HFS-3) is used to measure the heat transfer from a hot part to a cold part [9]. In order to detect the reaction particles by ^{3}He+^{3}He reaction, where Q-value is 12.86 MeV, we should install the counter telescopes which surrounds the gas target. Four ΔE-E telescopes placed around the beam axis are planned for the two proton coincidence measurement. The ΔE and E detectors in each telescopes have an active area 2500 mm^2, the ΔE detector has a thickness of 140 μm and the E detector has a thickness of 1500 μm. We are employing the Monte Carlo calculation with GEANT3 program code to find the optimum detector set up for an efficient and background free measurement. The expected ultra rare reaction rate is around a few events per day or less, and the typical single background rate of the silicon detectors is one event per hour or more. To remove such accidental events, two proton coincidence is required for the identification of the present reaction. Here the fake events with the condition of pp-coin are contributed as an accidental coincidence of two protons from two events of ^{3}He(D,p)^{4}He reaction. Here, the consistency between Monte Carlo calculation and experiment was checked by ^{3}He+D reaction by reserving the deuteron as a target gas. This reaction is very useful to check the experimental situation and simulation code because: 1.) The generated proton from ^{3}He+d reaction has energy of 14.7 MeV, thus the response of the detector is simple. 2.) The energy of proton from this reaction is in the same range of ^{3}He+^{3}He reaction. 3.) The cross section of ^{3}He+d reaction is six orders of magnitude larger than the ^{3}He+^{3}He reaction, thus the larger statistics is available. From this test experiment, the systematic error from this part was found to be about 3%.

The results for the measurement of ^{3}He+^{3}He reaction are summarized in Table 1. The effective region for true reaction on E-ΔE plot was estimated as the followings. 1)The real ^{3}He+^{3}He reaction was generated by Monte Carlo simulation. 2)The Background contribution from ^{3}He+D reaction was generated by Monte Carlo simulation, and those of cosmic rays, electrical noise and so on,

Table 1: Summary of present experiment. L.T. : Live Time, B.C. : Beam Current, T.P. : Target Pressure, T.T. : Target Temperature, C.S. : Cress Section, True : ^{3}He+^{3}He, BG1 : BG ^{3}He+d, BG2 : BG Other, Cnt : Counts.

| E_{cm} (keV)	L.T. (sec)	B.C. (μA)	T.P. (Torr)	T.T. (°C)	True (Cnt)	BG1 (Cnt)	BG2 (Cnt)	C.S. (barn)	S-Fac (MeV·b)
45.3	94857	104.	7.51×10^{-2}	27.1	3225	18.3	2.0	1.43×10^{-8}	5.03
43.3	80357	91.5	6.79×10^{-2}	27.3	1339	6.6	1.7	8.81×10^{-9}	5.01
41.3	80034	99.9	6.79×10^{-2}	27.1	939	6.3	1.7	5.65×10^{-9}	5.38
39.3	84892	87.5	7.31×10^{-2}	27.0	535	5.3	1.8	3.23×10^{-9}	5.33
37.3	156324	112.	8.25×10^{-2}	29.3	770	17.0	4.1	1.83×10^{-9}	5.43
35.2	339950	100.	8.21×10^{-2}	29.3	770	21.4	8.9	9.43×10^{-10}	5.60
33.1	615383	103.	8.25×10^{-2}	30.4	691	11.4	16.2	4.52×10^{-10}	5.48
31.2	529921	93.7	8.70×10^{-2}	31.2	293	5.02	13.9	2.33×10^{-10}	6.07
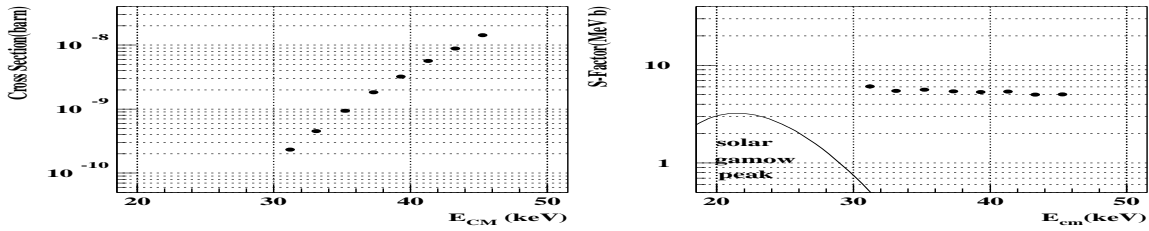
Figure 1: Cross section and S-Factor from this measurement.

were obtained by the experimental background run. 3)ΔE and E distribution was divided into 16000 partitions, and signal to noise ratio were evaluated by taking into account above three component in each partition. From this procedure, cross sections for true reaction and S-factors were obtained. Fig. 1 shows the obtained cross sections and S-factors.

References

[1] J. N. Bahcall, et al., Rev. Mod. Phys. 54 (1982) 767.

[2] M. Junker, et al., Phys. Rev. C57 (1998) 2700 ; C. Arpesella et al., Phys. Lett. B389 (1998) 452 ; U. Greife et al., Nucl. Inst. Meth. A350 (1994) 327.

[3] T. Itahashi, et al., Rev. Sci. Inst. 69 (1998) 1032 ; T. Itahashi, et al., The 11th Symp. on Acc. Sci. and Tech., Hyogo, Japan, p. 45.; T. Itahashi, et al., Rev. Sci. Inst. 71 (2000) 1075.

[4] P. Sortais, et. al., Proc. of the 12th Int. WS on ECR IS, RIKEN, Japan (1995) p. 45.

[5] K. Takahisa et al., 24th INS Symp. on ECR IS and their Appl., April 25-27, RIKEN (1995) p.115, and *RCNP Annual Report*, RCNP (1994) p.190.

[6] G. Fiorentini, et al., Z. Phys. A350, (1995) 289.

[7] K. Langanke, et al., Phys. Lett. B369 (1996) 211.

[8] U. Greife, et al., Z. Phys. A351, (1995) 107.

[9] N. Kudomi, et al., *Rev. of Sci. Instr.* **72**, 2957(2001).