2 - 10 Progress of the Nuclear Astrophysics Group in 2016

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The scientific program of the group covers big bang nucleosynthesis, hydrostatic burning in stars and explosive nucleosynthesis in supernova. By considering non-equilibrium statistics, we suggest a possible way to solve the Li problem in big bang nucleosynthesis. The ${}^{13}C(\alpha,n){}^{16}O$ is the major neutron source for the s-process happening in AGB stars. The ${}^{19}F(p, \alpha){}^{16}O$ is relevant to the production of fluorine. We are developing experimental platforms to study the important reaction for the first time directly at their stellar energies in Jinping Underground Laboratory. The ${}^{59}Fe$ stellar decay rate is important for the production of ${}^{60}Fe$, an important isotope whose gamma ray has been observed by satellites. We determine its stellar decay rate for the first time using experimental B(GT) strength. The new rate reduces the discrepancy of the ${}^{60}Fe$ yields between the model predictions and the observations. The underground experiment is expected to begin in 2018. The ${}^{12}C{+}^{12}C$ reaction rate is highly uncertain By collaborating with IFNN at Romania, the fusion cross section of ${}^{12}C{+}^{13}C$ has been measured down to 0.9 nb. Our results rule out the existence of S-factor maximum predicted by the systematical study and confirm the predictions of other theoretical models, such as Equivalent Square Well mode and coupled channel calculation based on M3Y+Rep. As a result, the uncertainty of the ${}^{12}C{+}^{12}C$ is greatly reduced. The ambiguous ${}^{13}N(\alpha, p) {}^{16}O$ reaction rate is a limitation of the study of A+B grain produced by explosive nucleosynthesis in supernova. We are trying to determine the ${}^{13}N(\alpha, p){}^{16}O$ reaction rate by studying its inverse reaction ${}^{16}O(p, \alpha){}^{13}N$.

The group is also developing active target to study the (α, p) process in X-ray burst and the fusion reactions in the crust of neutron star. While the incident particle continuously loses its energy within the gas of the active target, it has a possibility to react with the target nuclei, such as ⁴He, ¹²C or ¹⁶O. Active target and its auxiliary detection systems record the detailed information of incident and outgoing particles with which the reaction energy and reaction channel are uniquely determined. We have developed a prototype with which the scattering and fusion reaction events have been observed. A full scale active target is being constructed. The first experiment is expected to take place in the late of 2017.

2 - 11 Stellar β -decay Rate of ¹³⁴Cs

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¹³⁴Cs a branching point in s-process path which is shown in Fig.1. The branching ratio is defined as $f_{\beta} = \lambda_{\beta} / (\lambda_{\beta} + \lambda_{n})$.



Fig. 1 s-process path in the vicinity of the branching point $^{134}\mathrm{Cs.}$

It could be deduced from the abundance of ¹³⁴Ba and ¹³⁶Ba since ¹³⁶Ba goes through both decay and neutron-capture of ¹³⁴Cs while ¹³⁴Ba only experiences decay channel^[1].

Due to both ¹³⁴Ba and ¹³⁴Ba are pure s-process nuclei, this branching point is a good approach to determine the s-process parameters. With temperaturedependent β -decay rate of ¹³⁴Cs, the temperature of s-process could be deduced.

At stellar temperature, the excited states could be thermally populated hence the decay rate is different to the terrestrial rate. ¹³⁴Cs has a 2.1 a half-life in laboratory. However, at 0.3 GK, a typical temperature of s-process, the decay rate would be ~500 times faster according to Takahashi^[2]. With this decay rate, a temperature $T \sim 0.18$ GK of s-process is deduced. It is lower than that deduced from other branching points, *e.g.*, ¹⁵¹Sm/¹⁵⁴Eu^[3] and ¹⁷⁶Lu^[4] both of which give a temperature at about 0.3 GK. Therefore, the better determination of the stellar β -decay rate of ¹³⁴Cs is essential for nucleosynthesis study.

The Takahashi's rates are based on outdated nuclear database and empirical transition strength. Here we employ shell model (SM) calculation to update ¹³⁴Cs stellar β -decay rates. Fig. 2 shows the ratio of the decay rates obtained by SM to Takahashi's rate. One can see that SM values are significantly smaller than Takahashi's rate.