Measurements of neutron capture reaction relevant to r-process via Coulomb breakup of ^{32}Mg RIB

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Introduction

The Rapid Neutron Capture or *r-process* nucleosynthesis, responsible for synthesis of $\sim 50\%$ of the heavy nuclei in the universe, is known to occur in Core-collapse Supernovae (CCSNe) and Neutron Star Mergers (NSM). There are many reaction network codes, which are used to theoretically model this r-process. According to the ν-driven wind model, (n,γ) capture rate of light neutron-rich nuclei might play a role in determining the r-process abundance of elements [1]. But experimental measurements related to such reactions are extremely difficult owing to instability of the reactants involved. Hence, r-process simulations usually takes into account theoretical reaction rates from *Hauser-Feshbach* (HF) statistical model calculations, e.g. T. Rauscher calculations [2]. In the present work, we have performed experimental measurements of ^{31}Mg$(n,\gamma)^{32}$Mg capture cross-section and

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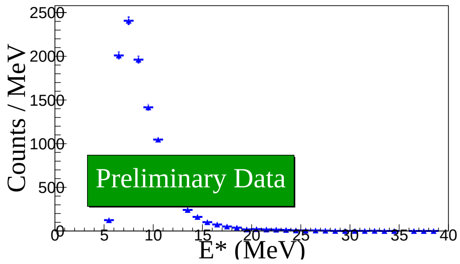

FIG. 1: Raw distribution of Excitation Energy, E^* of ^{32}Mg on ^{208}Pb target from Eq 1.

obtained the reaction rate through the indirect method of *Coulomb breakup* (theory discussed in [3–5]) and compared with HF calculations.

Experiment

The neutron dissociation reaction, $^{32}\text{Mg} \to {}^{31}\text{Mg}+n$ is induced via Coulomb breakup of ^{32}Mg RIB off a ^{208}Pb target at $\sim 400A$ MeV. The experiment was performed at GSI, Darmstadt, Germany using the FRS-LAND setup (**S306:GSI**). The same reaction was further performed with ^{12}C as target and also in absence of any target, for background estimation. Details of experiment can be found in [6].

Data analysis

The **differential cross-section**, $d\sigma/dE^*$ of $^{31}\text{Mg}+n$ break-up channel is measured via invariant mass analysis as:

$$E^* = \sqrt{m_f^2 + m_n^2 + 2m_f m_n \gamma_f \gamma_n \times (1 - \beta_f \beta_n cos\theta)} - M \quad (1)$$

Where, f and n refers to the fragment (^{31}Mg) and the dissociated neutron, respectively, while M is mass of the projectile, ^{32}Mg. The reaction on Pb target comprises contributions from both Coulomb (electromagnetic) and nuclear interactions. In order to eliminate said nuclear component, the data with ^{12}C as target is used and a pure Coulomb, $d\sigma/dE^*$ is obtained. Further correcting the same for instrumental *efficiency* and *acceptance*, we find the **photo-dissociation cross-section**, $\sigma_{\gamma,n}$. The inverse **capture cross-section** $\sigma_{n,\gamma}$ is then calculated via principle of *detailed balance*, followed by the astrophysical **reaction rate**, $N_A\langle\sigma_{n,\gamma}v\rangle$. Detailed calculation scheme had been discussed in [4, 5]. The experimental reaction rate is compared with the HF calculations of `TALYS` code and T. Rauscher code, widely used in r-process simulations. At temperatures relevant to *strong r-process* i.e. in NSMs ($\sim$ 6 GK), the two models lie very close to our results, with a relative difference of $\sim$ 20-30%. But, the difference with theory becomes much larger in lower temperature regimes of *weak r-process* occurring in CCSNe, a trend which is also observed in [7]. Further details of the analysis and the results will be discussed in the conference.

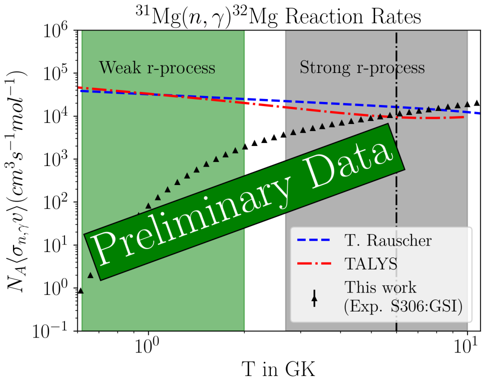

FIG. 2: Comparison of experimental and theoretical astrophysical reaction rates.

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