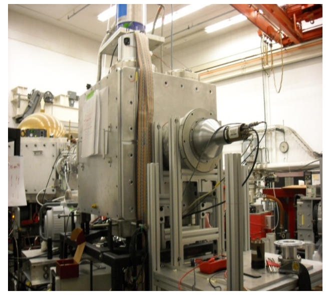
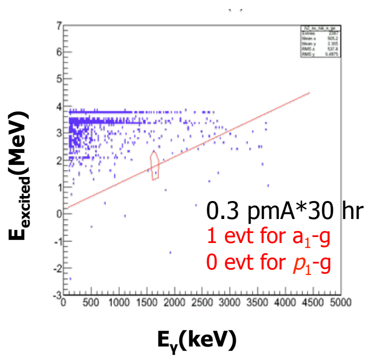
Joint Institute for Nuclear Astrophysics

Experimental studies of the $^{12}C+^{12}C$ fusion reaction at astrophysical energies

The $^{12}C+^{12}C$ fusion reaction plays a crucial role during stellar evolution and explosions like superbursts. However, its cross section has not been measured at astrophysically relevant energies, despite numerous studies, due to the extremely low reaction cross sections and the large background. We developed an efficient thick-target method using large-area silicon strip detectors to make such measurements possible. Experiments at unprecedentedly lower energies will be performed using coincidences between a silicon-detector array (SAND) and a HPGe detector array (GEORGINA), at the new high-current St. Ana accelerator at Notre Dame. To complement the coincidence method, a solenoid spectrometer similar to the HELIOS at ANL has been constructed and will be used to measure the $^{12}C+^{12}C$ cross sections as well. This project will hopefully verify if the resonance around 2.1 MeV exists or not.





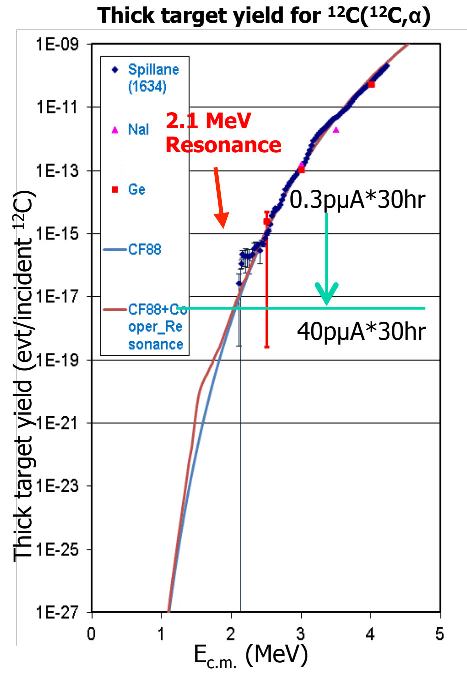
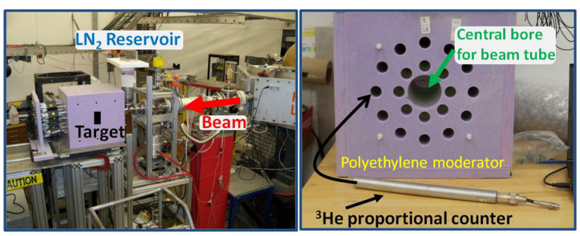
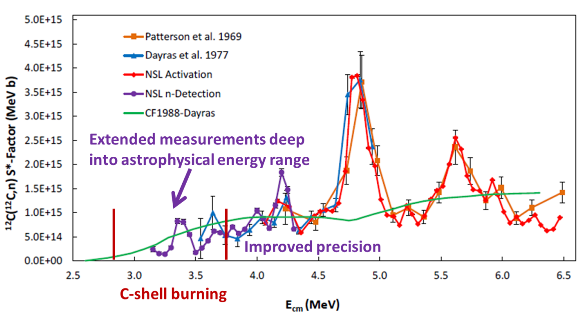


Fig.1. Top left panel shows the experiment setup. Bottom left panel shows α/p-γ coincidences, one event was collected at E_{cm}=2.5 MeV. Right panel shows the thick target yield of $^{12}C(^{12}C, \alpha)$.





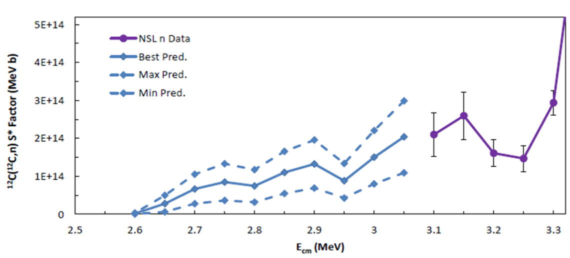


Fig.2. Top panel shows the setup (left) and ^{3}He counter array (right) used for the neutron detection experiment. Middle panel shows cross section factor (S*) results for both ND and previous measurements with statistical model extrapolation (green). Bottom panel shows the new extrapolation and uncertainty based on measurements of the mirror reaction.

The $^{12}C+^{12}C\rightarrow^{23}Mg+n$ reaction is a potential neutron source for the weak s-process occurring in shell-carbon burning of massive stars. The uncertainty in this reaction rate limits our understanding of the production of elements in the range $60 < A < 90$. Current stellar models must rely on the smooth extrapolation of a dubious statistical model calculation based on experimental data taken at energies well above the Gamow window. At Notre Dame, this reaction cross section has been measured using two independent techniques: detecting the residual β-activity of ^{23}Mg and direct neutron detection. The latter is highlighted in Fig. 2 showing successful cross section measurements deep within the astrophysical energy range. For the remaining unmeasured energies, an improved extrapolation based on the mirror reaction $^{12}C+^{12}C\rightarrow^{23}Na+p$ has been applied which includes a quantitative uncertainty determination. With these results, a precise astrophysical reaction rate is finally established for stellar models.

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Publications:
B. Bucher et al. Ser. 381 012121;
B. Bucher et al. 2013 J. Phys.: Conf. Ser. 420 012141
X. Fang et al. 2013 J. Phys.: Conf. Ser. 420 012151

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