



Test of extrapolating models for heavy ion fusion reactions at extreme sub-barrier energies



The heavy-ion fusion reactions between ^{12}C and ^{16}O isotopes, namely $^{12}\text{C}+^{12}\text{C}$, $^{12}\text{C}+^{16}\text{O}$ and $^{16}\text{O}+^{16}\text{O}$, are crucially important in a wide variety of stellar burning scenarios. These reactions represent key processes in nuclear astrophysics since they influence not only the nucleosynthesis, such as the production of ^{26}Al and ^{60}Fe , but also the subsequent stellar evolution. At present, these reactions have only been measured down to energies which are much higher than the energies of astrophysical interest. An extrapolation towards the relevant astrophysical energies is inevitable with the existing experimental data. The situation is even more complicated by the strong, relatively narrow resonances in some reactions, such as $^{12}\text{C}+^{12}\text{C}$ and $^{12}\text{C}+^{16}\text{O}$. Traditionally, optical model or equivalent square-well optical model (Fowler model) are used to fit the average cross section and predict the reaction cross sections at the energies of astrophysical interest. Recently, a new model, the hindrance model, was proposed to provide systematic fits to fusion reaction data at extreme sub-barrier energies. The goal of this project is to test these models by pushing the lowest measured energies down towards the astrophysics relevant region.

The $^{12}\text{C}+^{13}\text{C}$ reaction is chosen to test the models because its entrance channel is similar to that of the $^{12}\text{C}+^{12}\text{C}$ system but without the strong interference from resonances. The $^{12}\text{C}(^{13}\text{C},^{24}\text{Na})\text{p}$ reaction has been measured in an energy range from $E_{\text{cm}}=2.6$ MeV to 4.77 MeV by detecting the residual activity of the ^{24}Na . With the β - γ coincidence technique, we have pushed the lowest measured cross section from the published $10 \mu\text{b}$ down to 10nb . A preliminary result is shown on the right.

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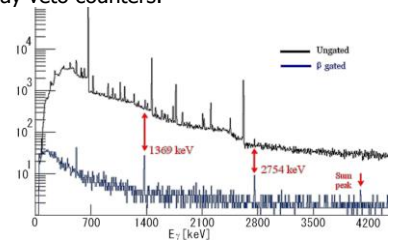
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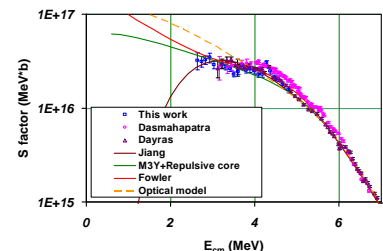
The 10-MV FN Tandem at Notre Dame. Using terminal gas stripping, more than $1 \mu\text{A}$ ^{13}C beam was delivered on target.



The ^{24}Na decay counting station consists of two clover detectors, 1 compact plastic β -counter and several fiber plastic cosmic ray veto counters.



Sample γ -ray spectrum obtained with and without the β -ray gate.



Comparison between experimental data (shown as points) and theoretical calculations. Two hindrance models, phenomenological model (Jiang) and microscopic model (M3Y interaction with repulsive core), are shown here. The Fowler model (equivalent square well optical model) is the one used in the current reaction rate library to predict fusion cross sections at astrophysical energies. While the optical model fails, both Fowler model and the hindrance models provide good description of the experimental data.