Limits on the molecular resonance strengths in the $^{12}C+^{12}C$ fusion reaction

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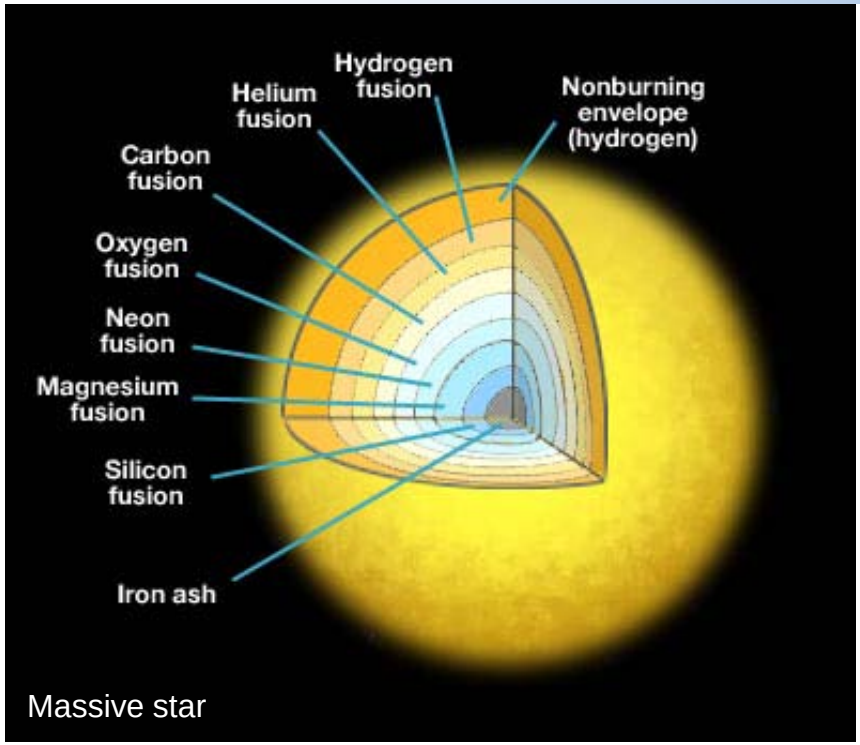
Outline

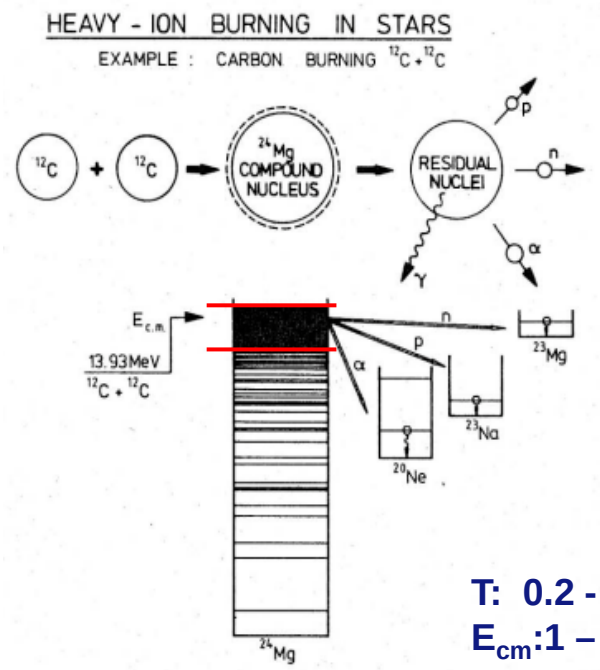
- Carbon burning in stars
- Molecular resonances in $^{12}C+^{12}C$ fusion
- Fusion reactions of carbon isotopes
- Limits on the resonance strengths
- Future work

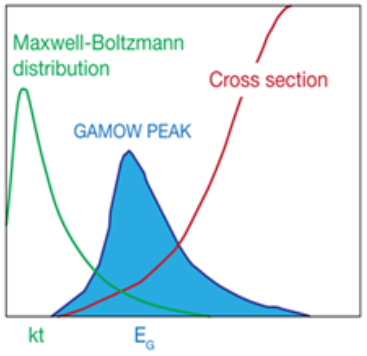
Carbon burning in stars



Massive star

$$^{12}C + {}^{12}C \rightarrow {}^{16}O + 2^{4}He$$
$$\rightarrow {}^{20}Ne + {}^{4}He$$
$$\rightarrow {}^{23}Na + p^{+}$$
$$\rightarrow {}^{23}Mg + n$$
$$\rightarrow {}^{24}Mg + \gamma$$



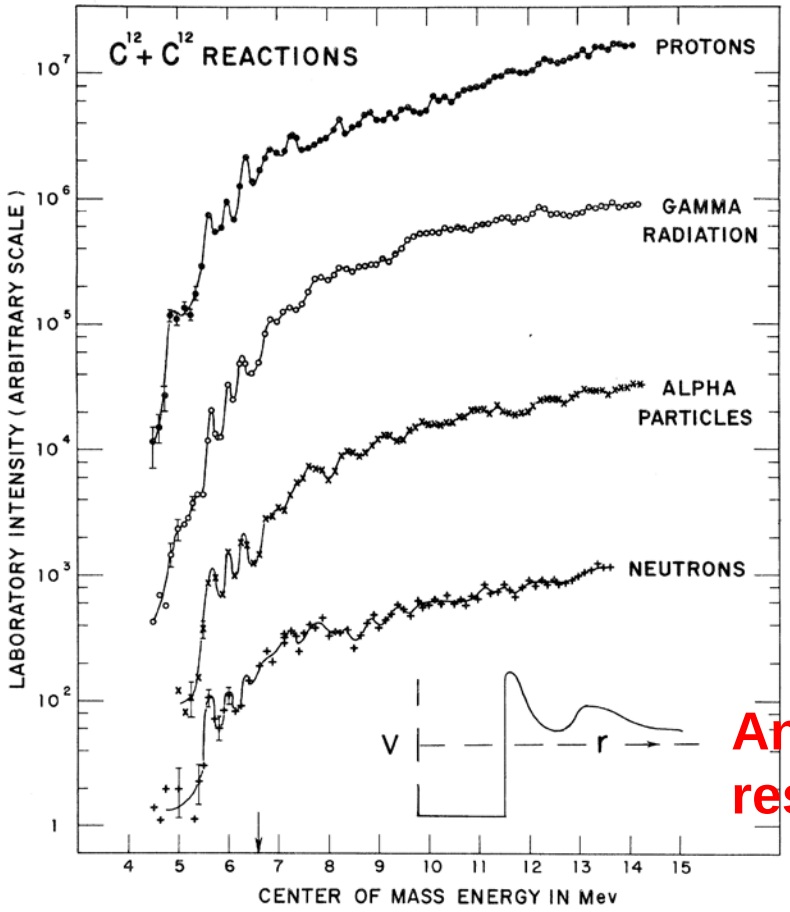


Gamow peak energy for $^{12}C+^{12}C$: E ≈ 1.5MeV

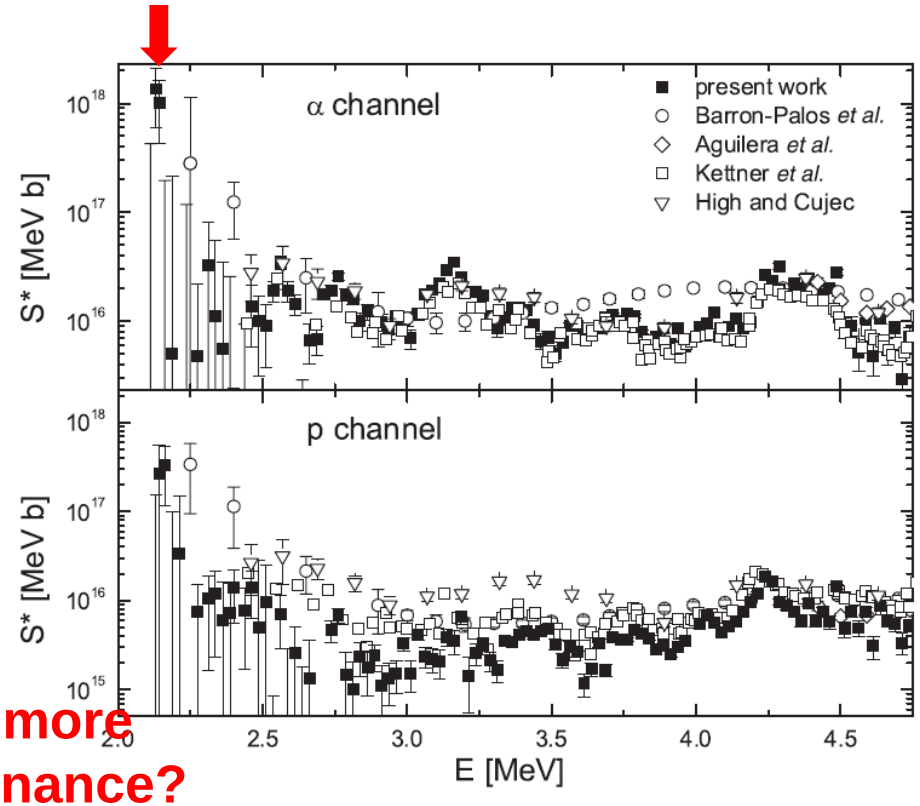
T: 0.2 - 1.2GK
E_{cm}:1 – 3 MeV

Cauldrons in the Cosmos, C.E. Rolfs et al.

Molecular resonances in $^{12}C+^{12}C$ fusion



Molecular resonances in the $^{12}C+^{12}C$ fusion reaction measured by Almqvist et al., in 1960



Any more resonance?

Most recent S(E)* factor (Modified S(E) factor) of the fusion process $^{12}C+^{12}C$ measured by Spillane et al., in 2007

50 years later….

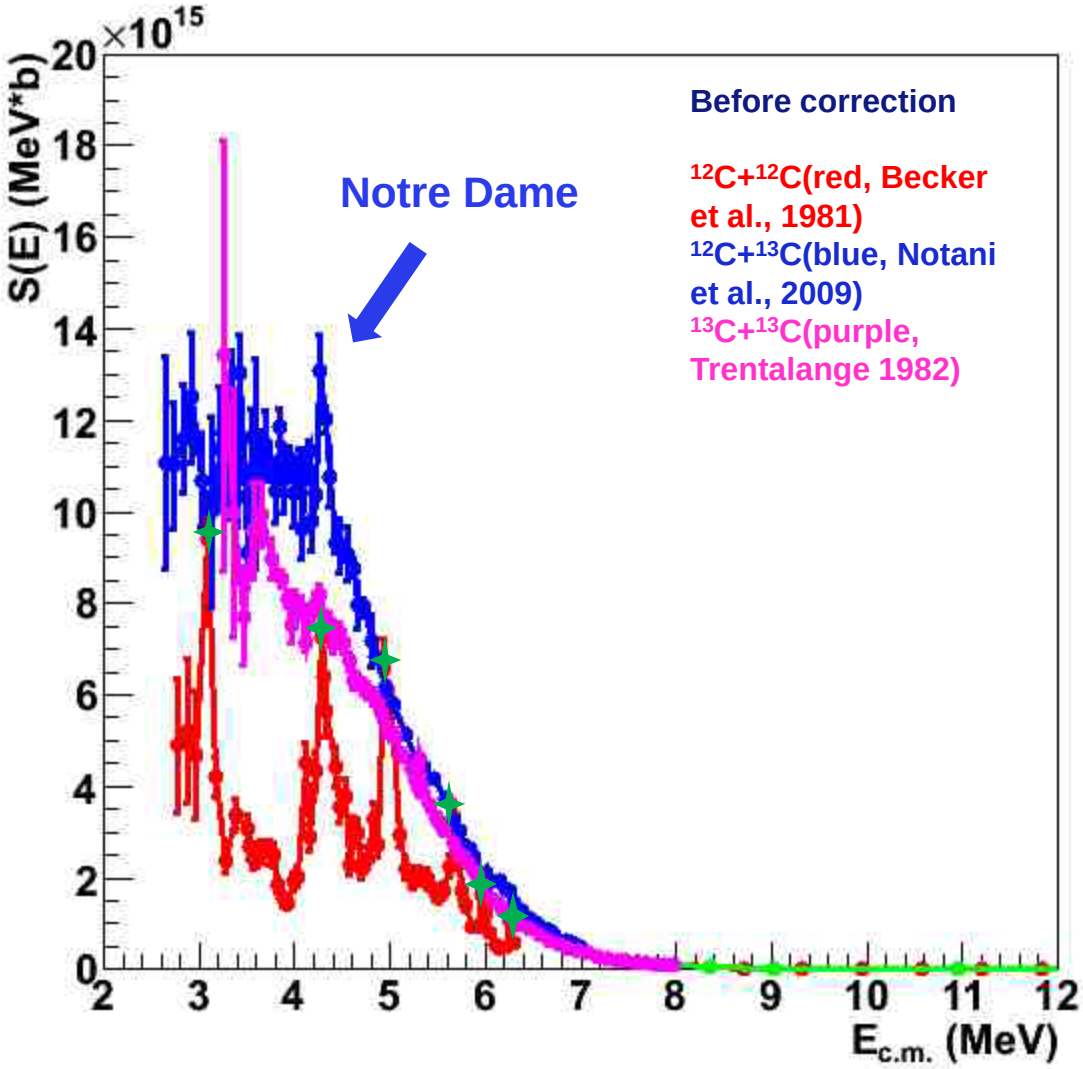
➢Compare the $^{12}C+^{12}C$ reaction with carbon isotope fusion reactions, $^{12}C+^{13}C$ and $^{13}C+^{13}C$. Because of their similarities in mass, charge, and nuclear structure, comparing the cross sections of the $^{12}C+^{12}C$ with these other two carbon isotope fusion reactions may help us better understand the resonances in the $^{12}C+^{12}C$ fusion reaction.

➢To remove the Coulomb barrier penetration effect in the fusion process, we have introduced the cross section factor:

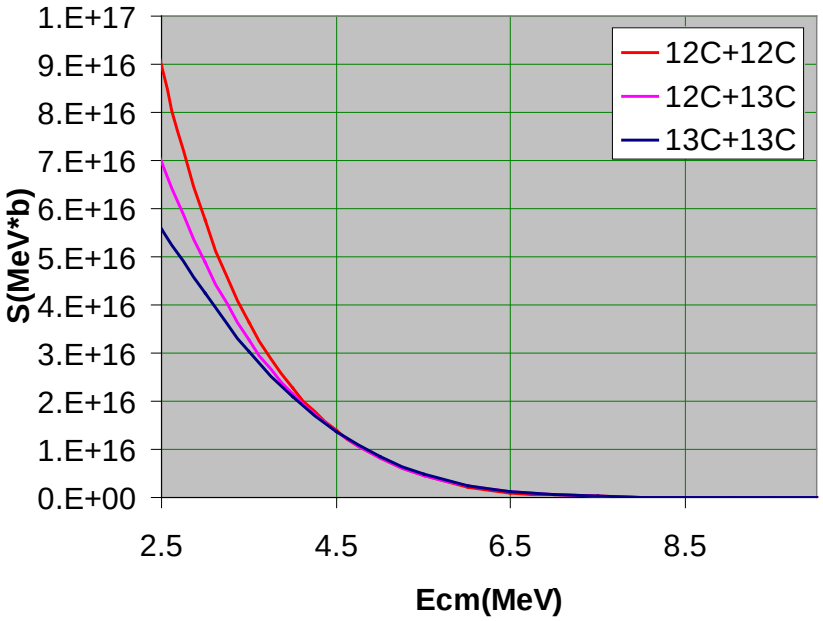
$$S(E)=\sigma(E)\, E \exp(87.21/E^{1/2})$$

	Reduced mass	Radius (fm)
12C+12C	6	5.77
12C+13C	6.33	5.85
13C+13C	6.5	5.93

Fusion reactions of carbon isotopes



Isotope effect



Difference in **mass** and radius
→Difference in cross section
(using CCFULL)

Elastic transfer enhancement in 12C+13C

	Reduced mass	Radius (fm)
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12C+13C	6.33	5.85
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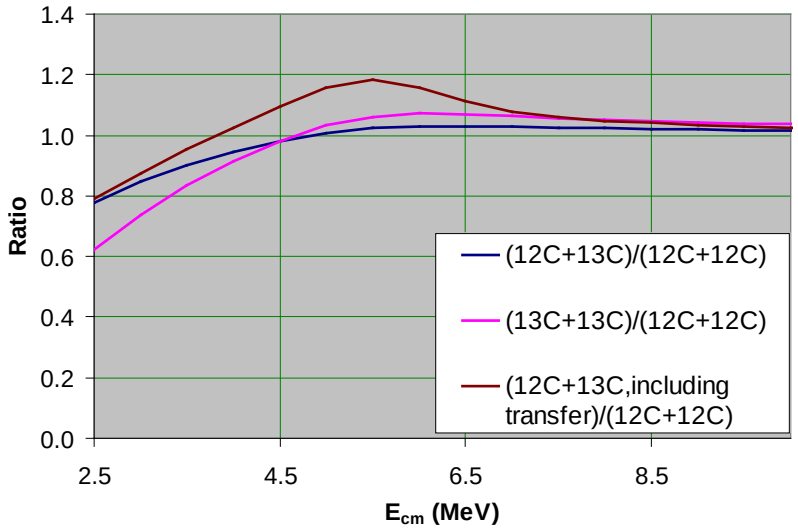
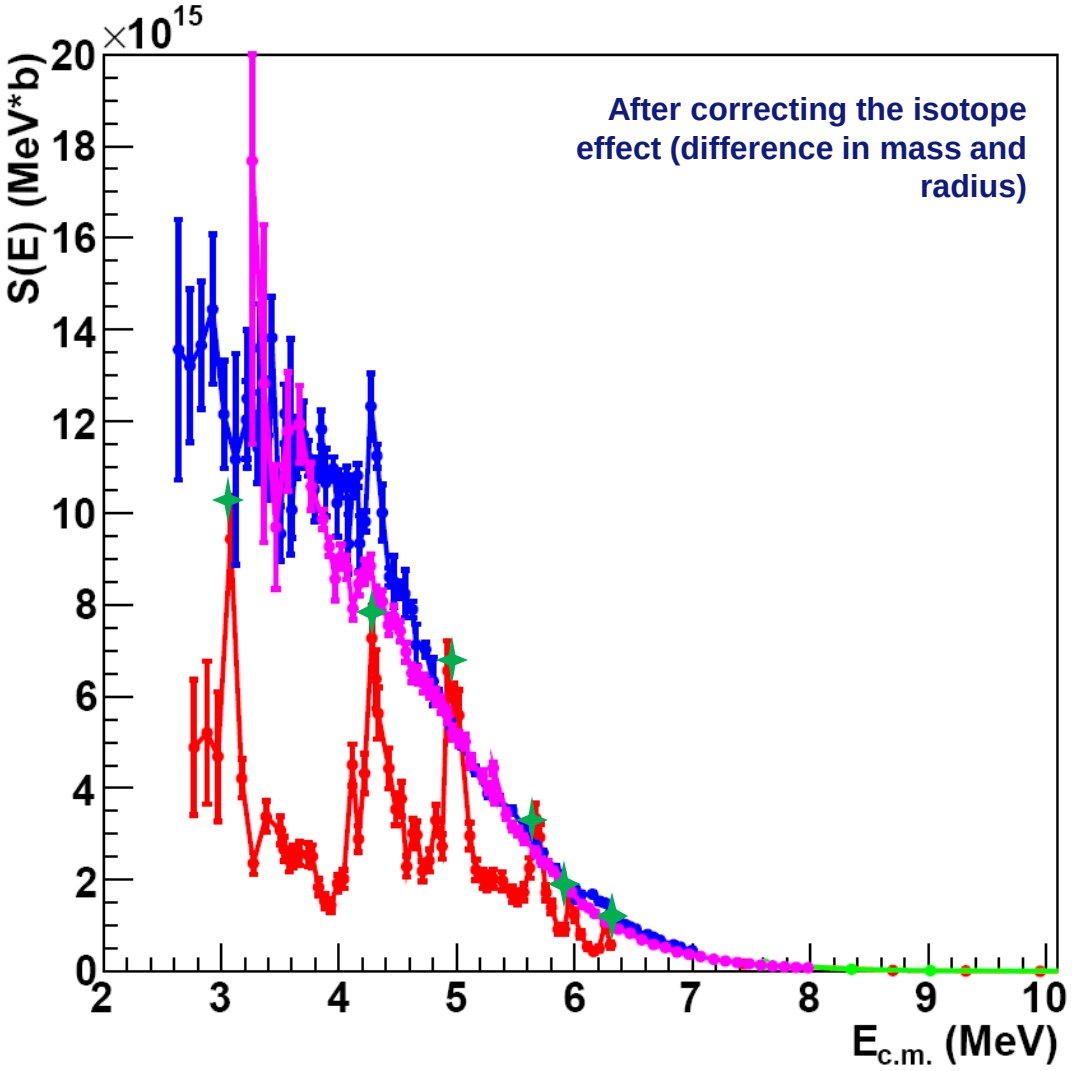
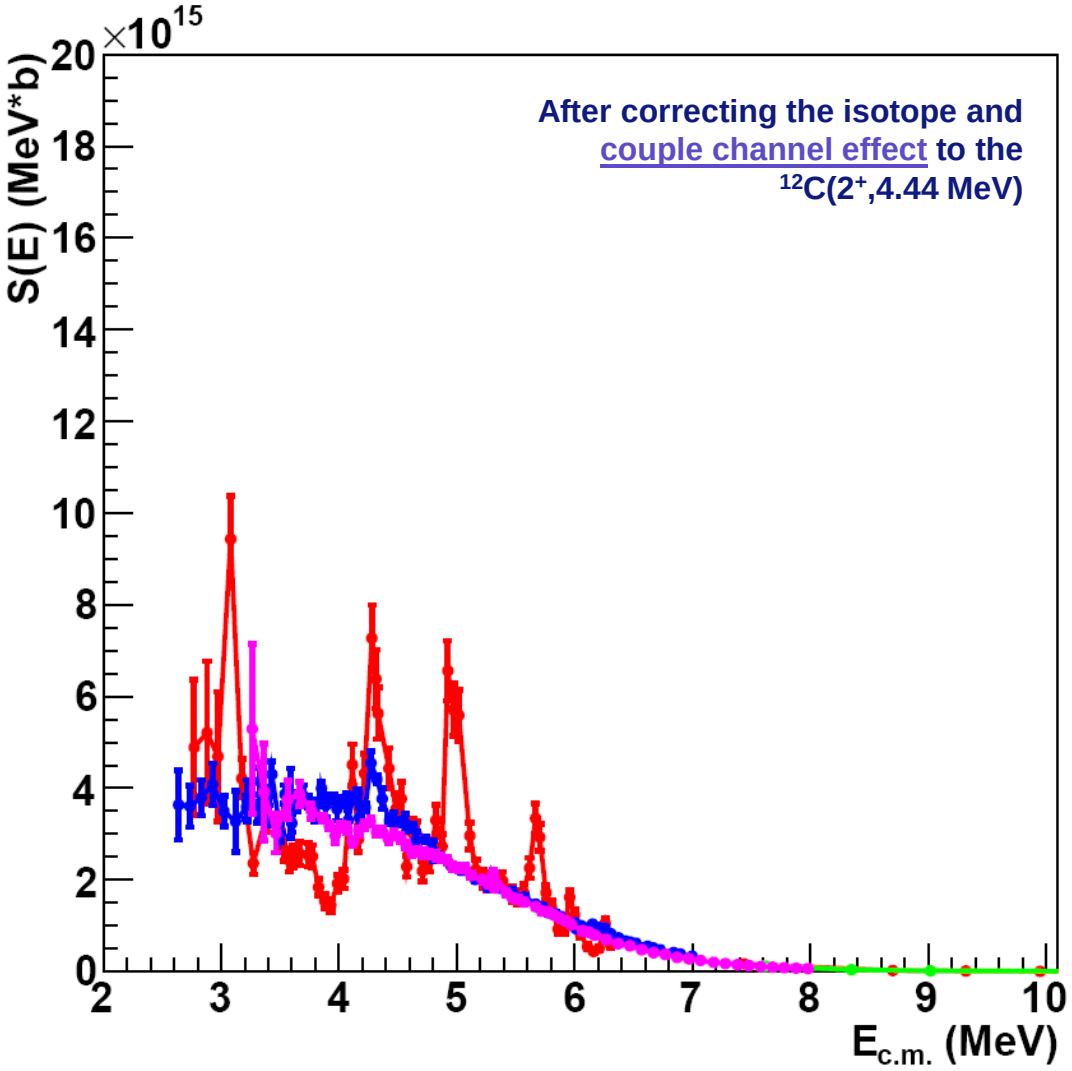


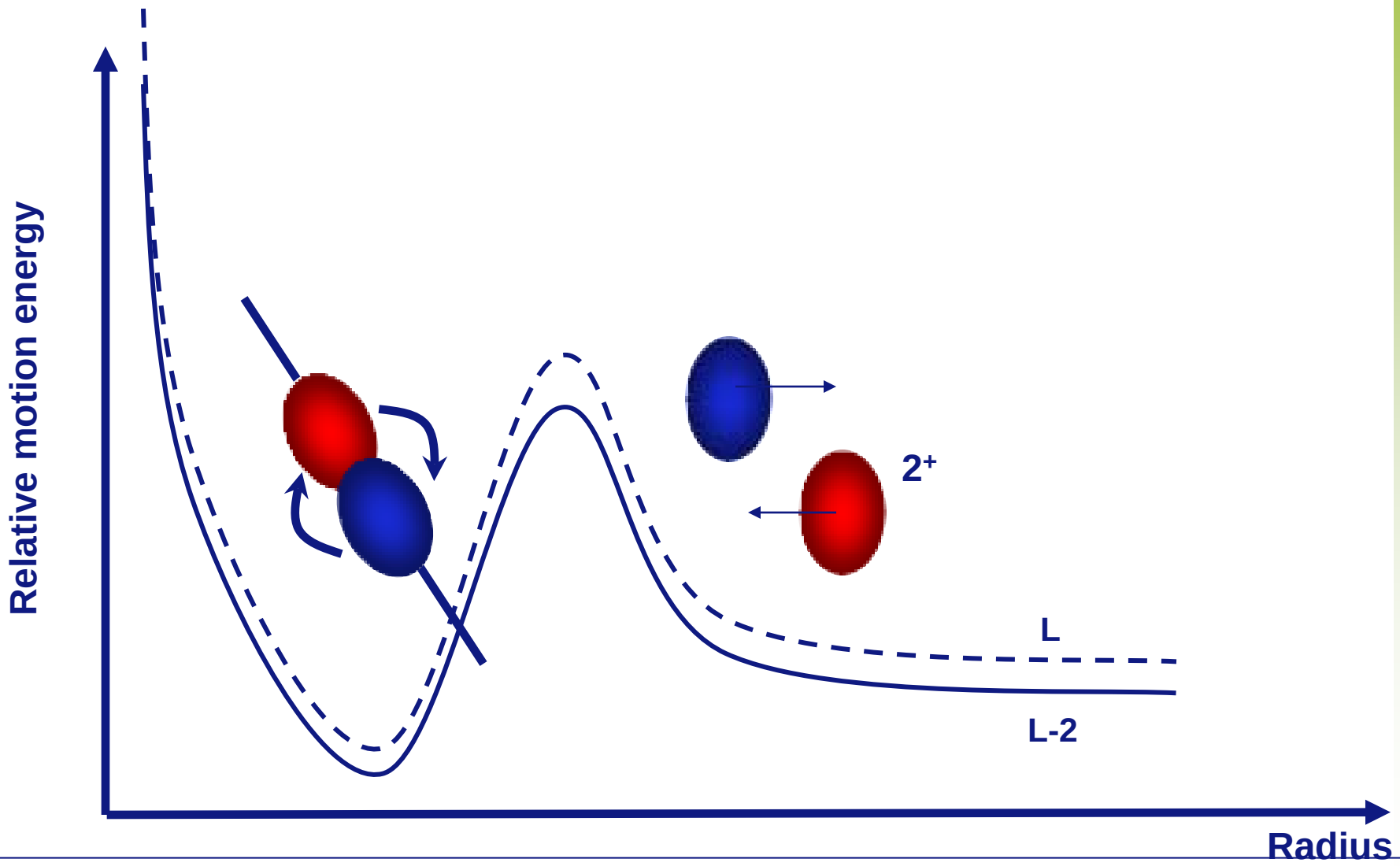
Fusion reactions of carbon isotopes



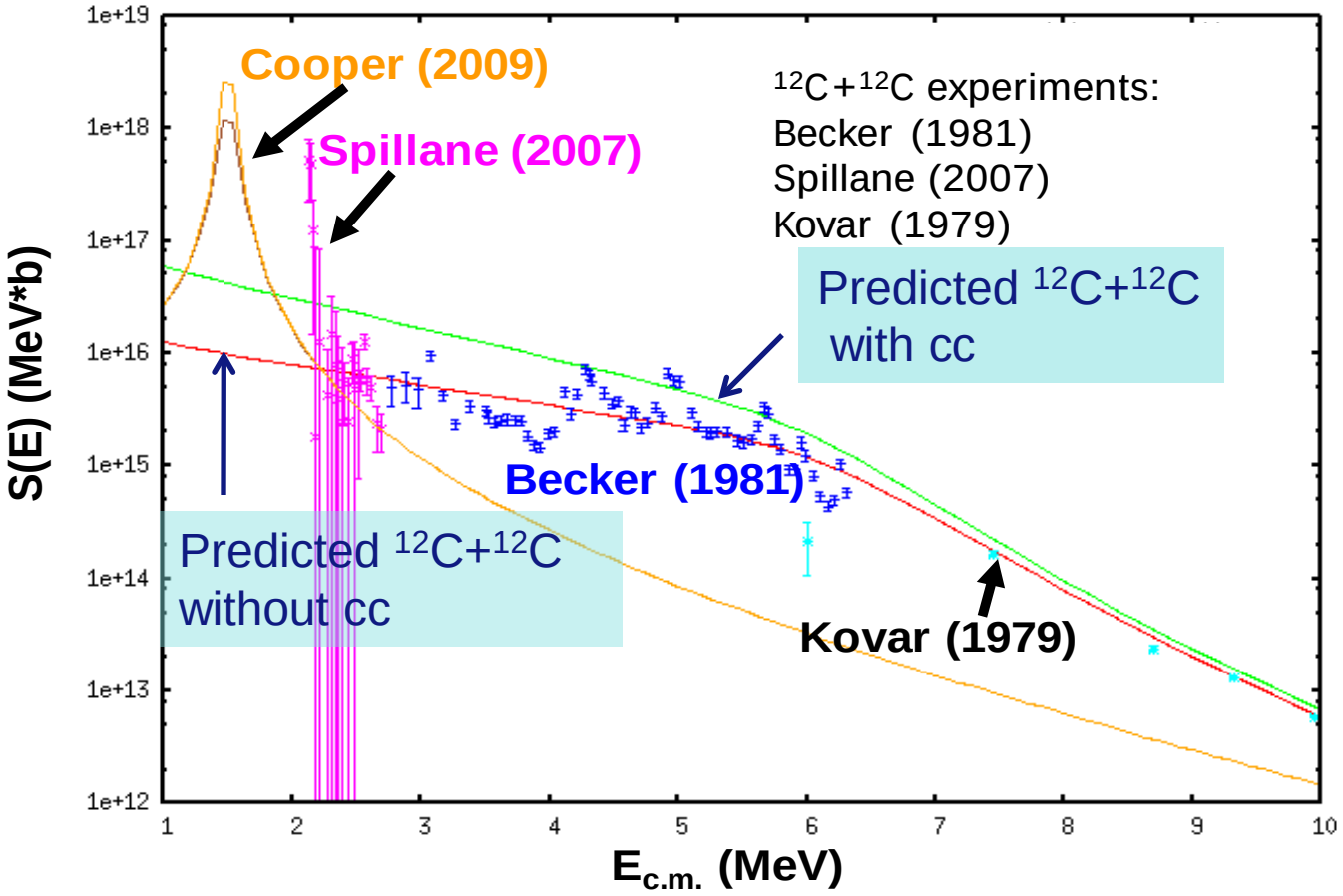
Fusion reactions of carbon isotopes



Nogami-Yamanishi Model



Limits on the resonance strengths



The predictions are compared with:

1) the resonance (Ecm=2.1 MeV) found by Spillane et al.;

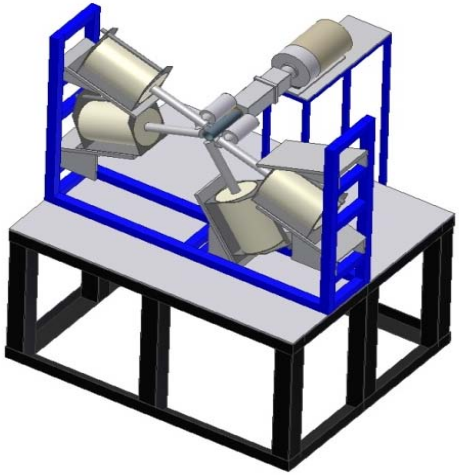
2) the resonance (Ecm=1.5 MeV) suggested by Cooper et al..

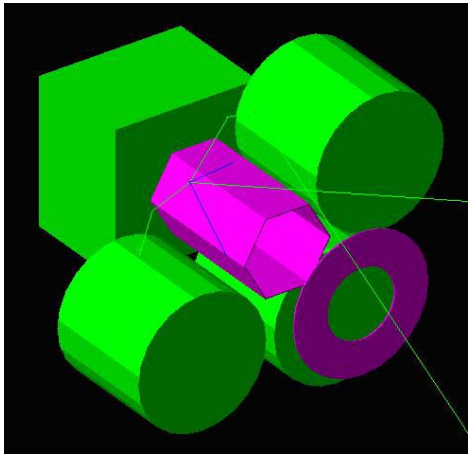
Both resonance peaks are well above the upper limits, therefore additional measurements are needed for verification.

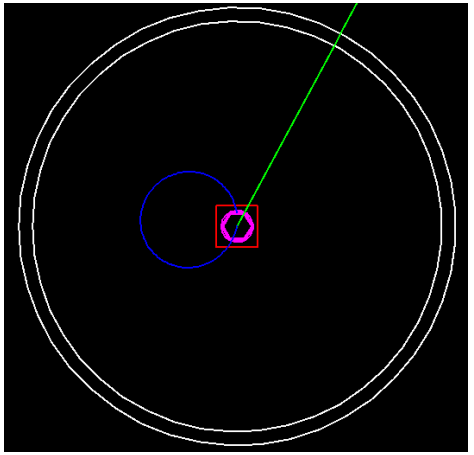
Push measurement towards lower energies

High current accelerator (>40 pμA) + highly efficient Si/Ge array

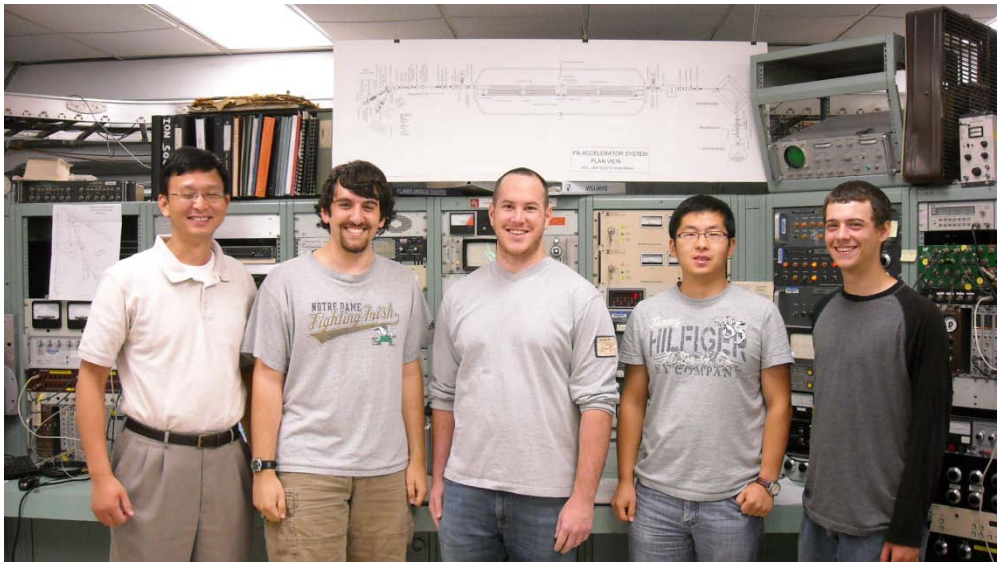
A 5 MV Pelletron with ECR source in terminal.







Special Thanks



Group members: Xiao-dong Tang, Brian Bucher, Justin Browne, Adam Alongi

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Thank You !