Deep Underground Laboratory Measurement of $^{13}\mathrm{C}(\alpha, n)^{16}\mathrm{O}$ in the Gamow Windows of the s and i Processes

Hao Liu
Zetian Ma

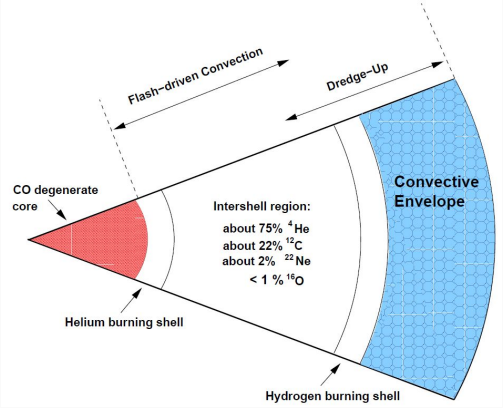
Overview

- The ^{13}C(α,n)^{16}O reaction is the main neutron source for s-process and i-process in asymptotic giant branch (AGB) stars.
- Performed the first consistent direct measurement in the range of $E_{c.m.} =$ 0.24 to 1.9 MeV
- Used R-matrix to obtain the S-factor at $E_{c.m.} <$ 0.24 MeV

Background: AGB star evolution

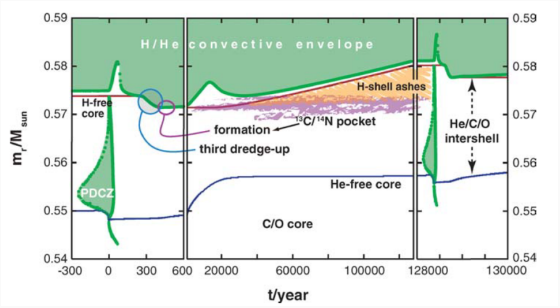
TP-AGB:

- Interpulse phase: H shell provide most surface luminosity.
- Thermal pulse: He shell burns brightly.
- Power down phase: He intershell becomes convective; star expands and cools in the outer layers; H-burning is temporarily terminated.
- Third dredge-up phase.



Background: Origin of ^{13}C

- protons are mixed from the convective envelope into the He-intershell
- Protons are captured: $^{12}\mathrm{C}(p,\gamma)^{13}\mathrm{N}(\beta^-,\upsilon)^{13}\mathrm{C}$
- formation of the ^{13}C pocket, a thin layer enriched in ^{13}C, beneath the bottom of the convective envelope



i-process

approximate number density of neutrons required for s-process is $N_n = 10^5$ cm^{-3}, for r-process $N_n = 10^{23}$ cm^{-3}.

At $T_9 = 0.2$, neutron density is around 10^{14}-10^{16} cm^3

This allow some form of intermediate neutron process (i-process)

The importance of measuring $^{13}C(\alpha,n)^{16}O$ rate

$^{13}C(\alpha,n)^{16}O$ rate determines the neutron density, therefore influence the s and i process and the final isotopic production:

For a one-dimensional models of metal-poor low-mass AGB model: 'a factor of 2 variation of the $^{13}C(\alpha,n)^{16}O$ rate changes the i-process production by orders of magnitude.'

s-process branchings yields important information on stellar parameters like temperature, neutron density, mass density and even convection time scales during the s process.