Group Meeting 11.22

Reading PHY REV LET 129, 132701 (2022)

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

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Overview

With the unique energy ($E_{cm} = 0.24 - 0.59 MeV$) and ultralow neutron background in the deep underground lab.

$$S(E) = \frac{E}{exp(-2\pi\eta)}\sigma(E)$$

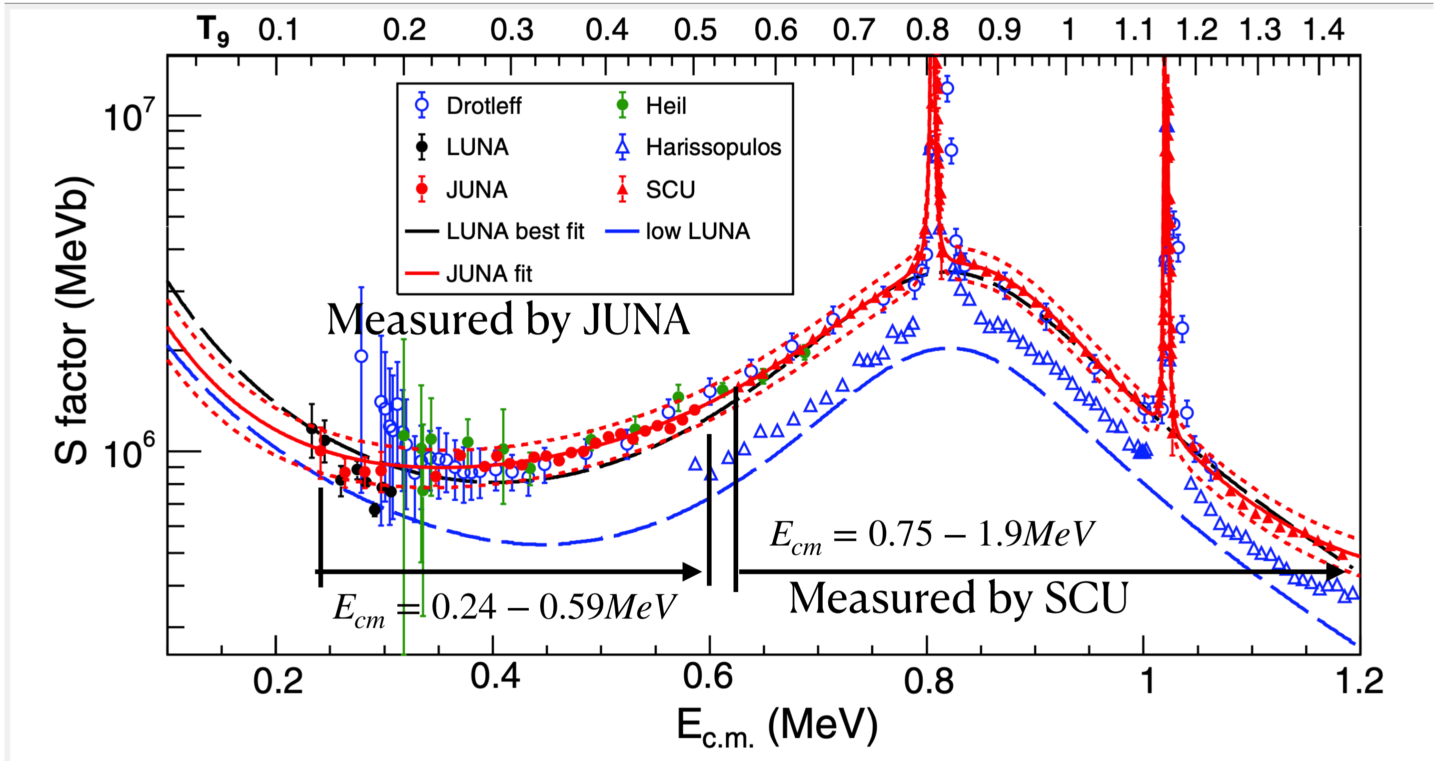

FIG1: The S factor of the experiment measured by JUNA and SCU.

Overview

Let's consider the relationship between reaction rates and S factors.

n_1: the number density of particle 1
n_2: the number density of particle 2
$v = |\mathbf{v_1} - \mathbf{v_2}|$: the relative velocity

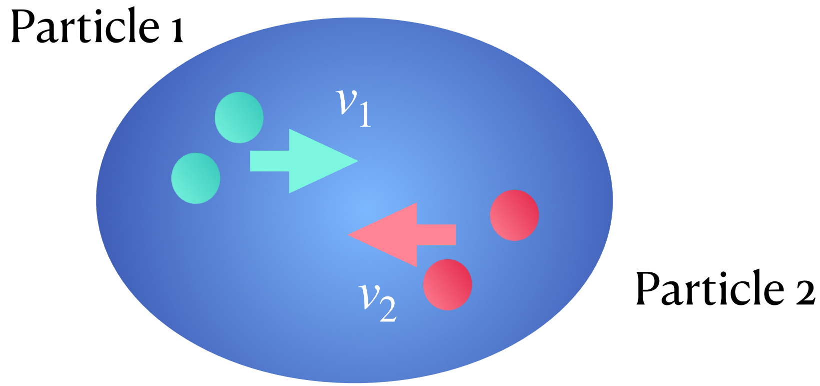

FIG2: The reaction in a plasma, like a sun.

Consider particle 2 as the Tagert.

The flux of particle 1

$$j = n_1 v$$

The scatterings rate for a Tagert

$$\sigma j = \sigma n_1 v$$

Overview

Let's consider the relationship between reaction rates and S factors.

The reaction rate:

$$r_{12} = n_1 n_2 \sigma v$$

$$\langle \sigma v \rangle = \int_0^\infty \sigma(E)\phi(v)v \, \mathrm{d}v$$

$$r_{12} = n_1 n_2 \langle \sigma v \rangle$$

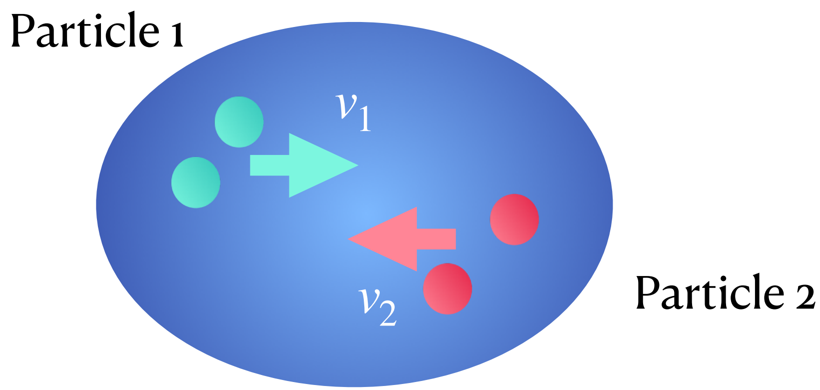

FIG2: The reaction in a plasma, like a sun.

Consider the v satisfying Maxwell-Boltzmann distribution

$$\Phi_i\left(\mathrm{v}_i\right) = \left(\frac{m_i}{2\pi k_B T}\right)^{\frac{3}{2}} \exp\left(-\frac{m_i v_i^2}{2k_B T}\right)$$

Overview

Let's consider the relationship between reaction rates and S factors.

$$\langle \sigma v \rangle = \iint \sigma(\mathrm{E}) \left| \mathbf{v}_1 - \mathbf{v}_2 \right| \Phi_1\left(\mathbf{v}_1\right) \Phi_2\left(\mathbf{v}_2\right) \mathrm{d}\mathbf{v}_1 \, \mathrm{d}\mathbf{v}_2$$

$$\mathbf{v}_1 = \mathbf{V} + \frac{m_2}{m_1 + m_2}\mathbf{v}$$

$$\mathbf{v}_2 = \mathbf{V} - \frac{m_1}{m_1 + m_2}\mathbf{v}$$

Gamow fuction

$$\langle \sigma v \rangle = \left(\frac{8}{\pi\mu}\right)^{1/2} \frac{1}{kT^{3/2}} \int_0^\infty \sigma(E) E \exp\left(-\frac{E}{kT}\right) d\mathrm{E}$$

$$S(E) = \frac{E}{exp(-2\pi\eta)}\sigma(E)$$

$$E_G = 4\pi^2\eta^2$$

$$\langle \sigma v \rangle = \sqrt{\frac{8}{\pi\mu_{12}\left(k_B T\right)^3}} \int_0^\infty S(E) \exp\left(-\frac{E}{k_B T} - \sqrt{\frac{E_G}{E}}\right) dE\,.$$

Overview

Gamow fuction

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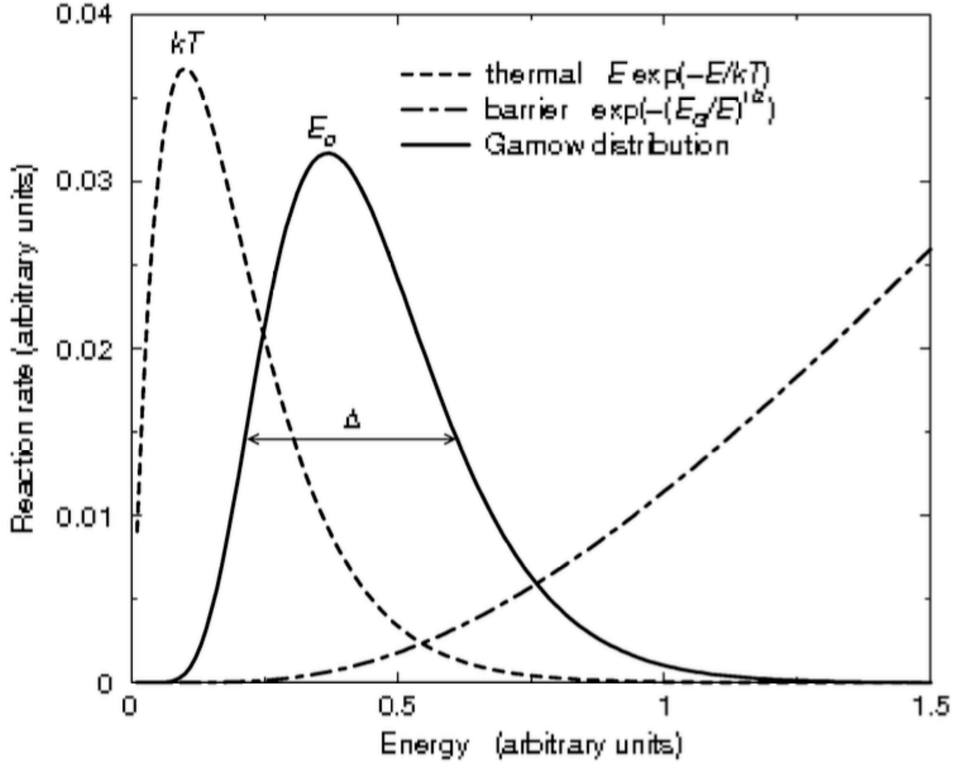

Result

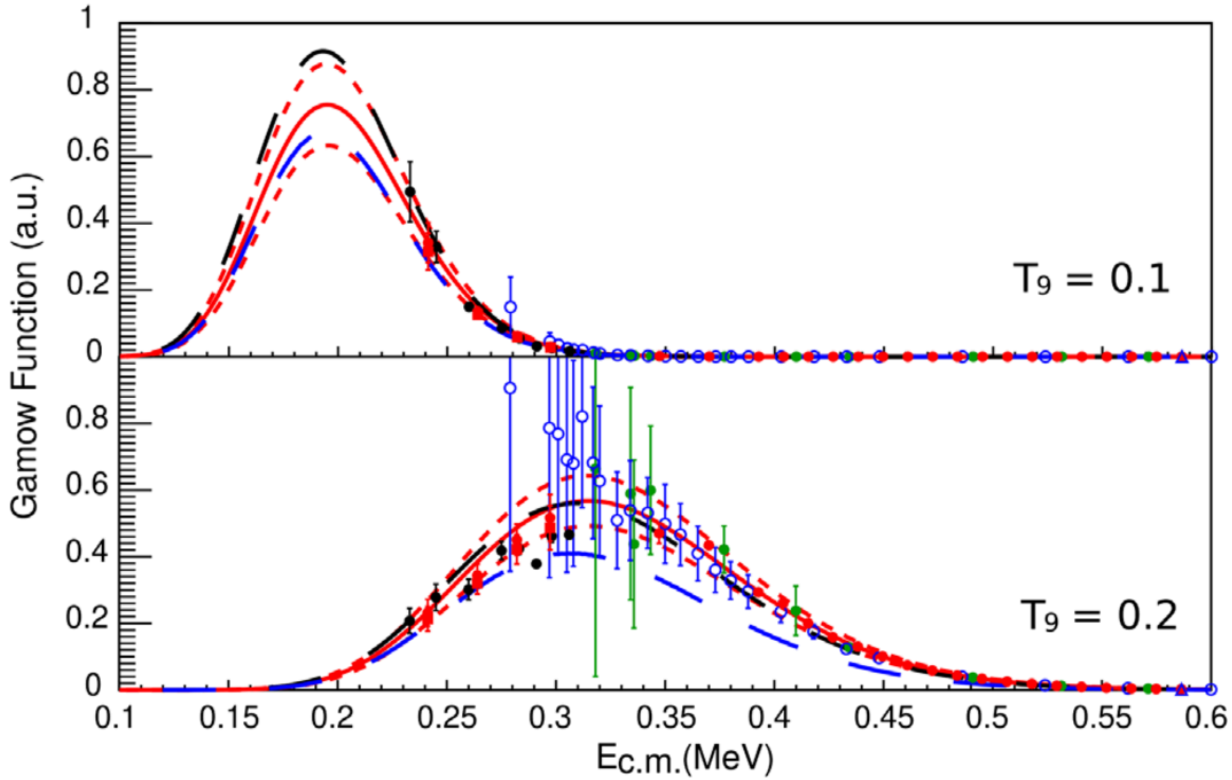

FIG4: The Gamow function $^{13}C(\alpha,p)^{16}O$ at $T_9 = 0.1, 0.2$

Result

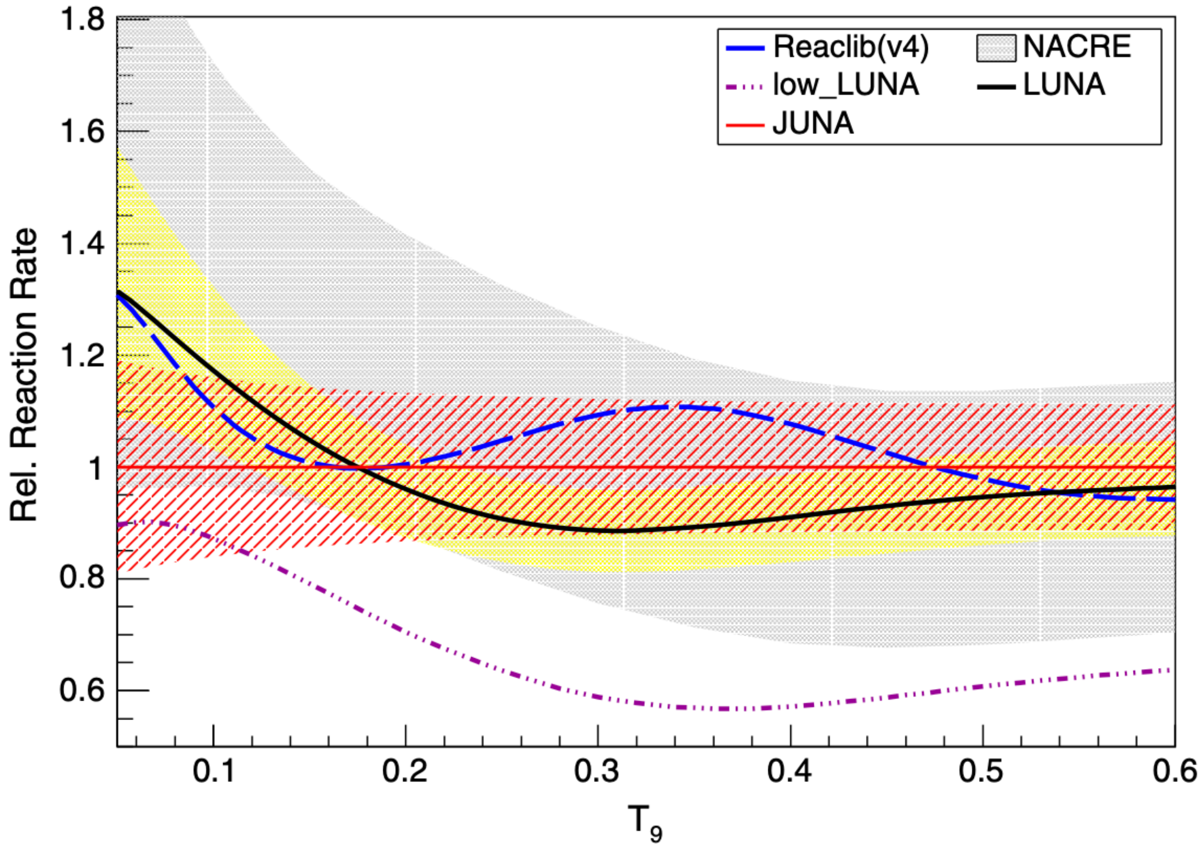

FIG5: The reation rate of $^{13}C(\alpha, p)^{16}O$ at $T_9 = 0.1{,}0.2$