The Joint Institute for Nuclear Astrophysics

$^{19}F(p,\gamma)$ and Closure of the CNO Cycle

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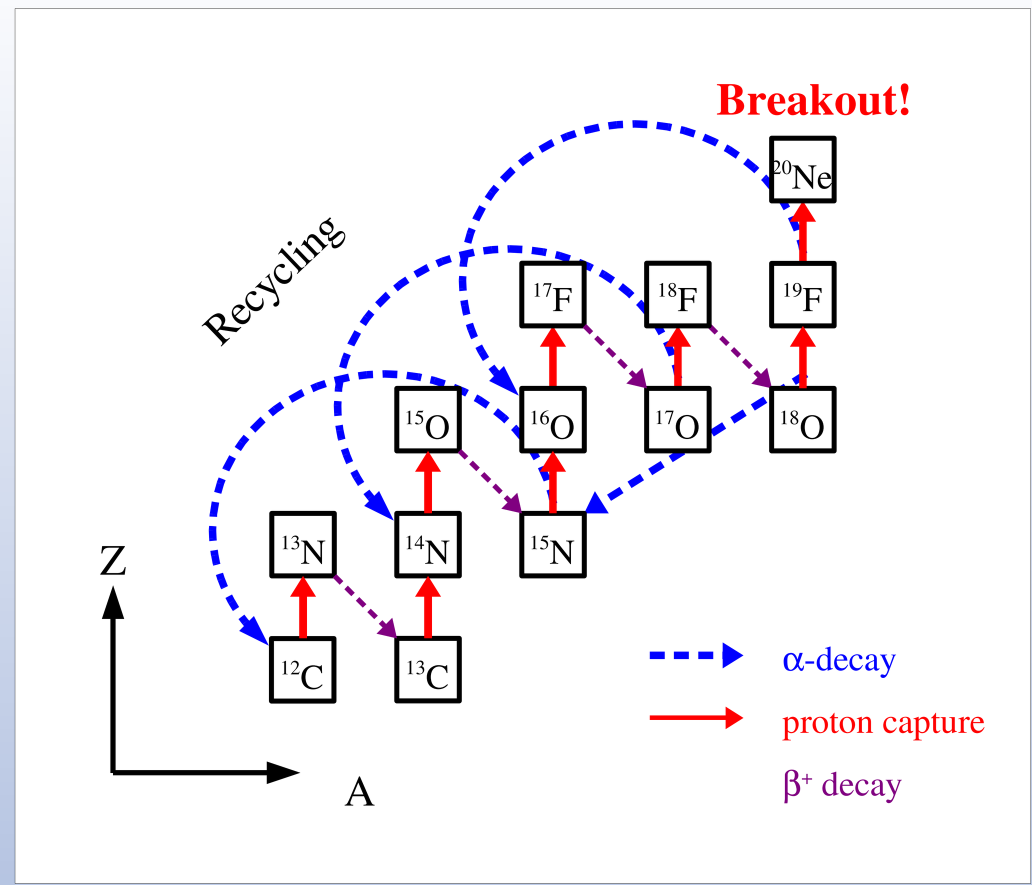
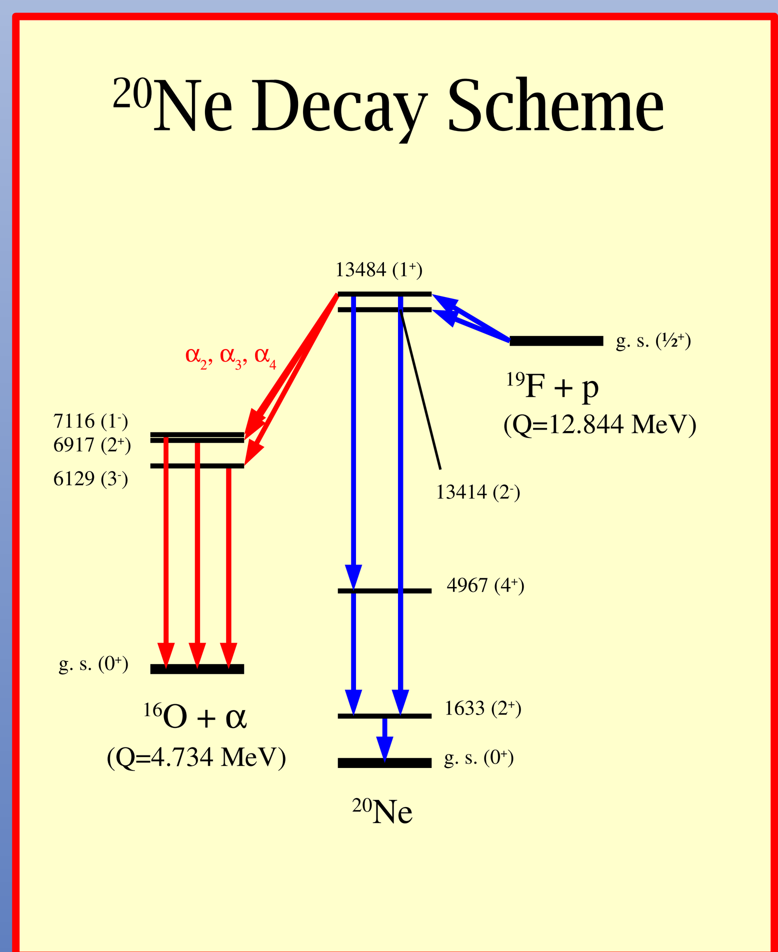
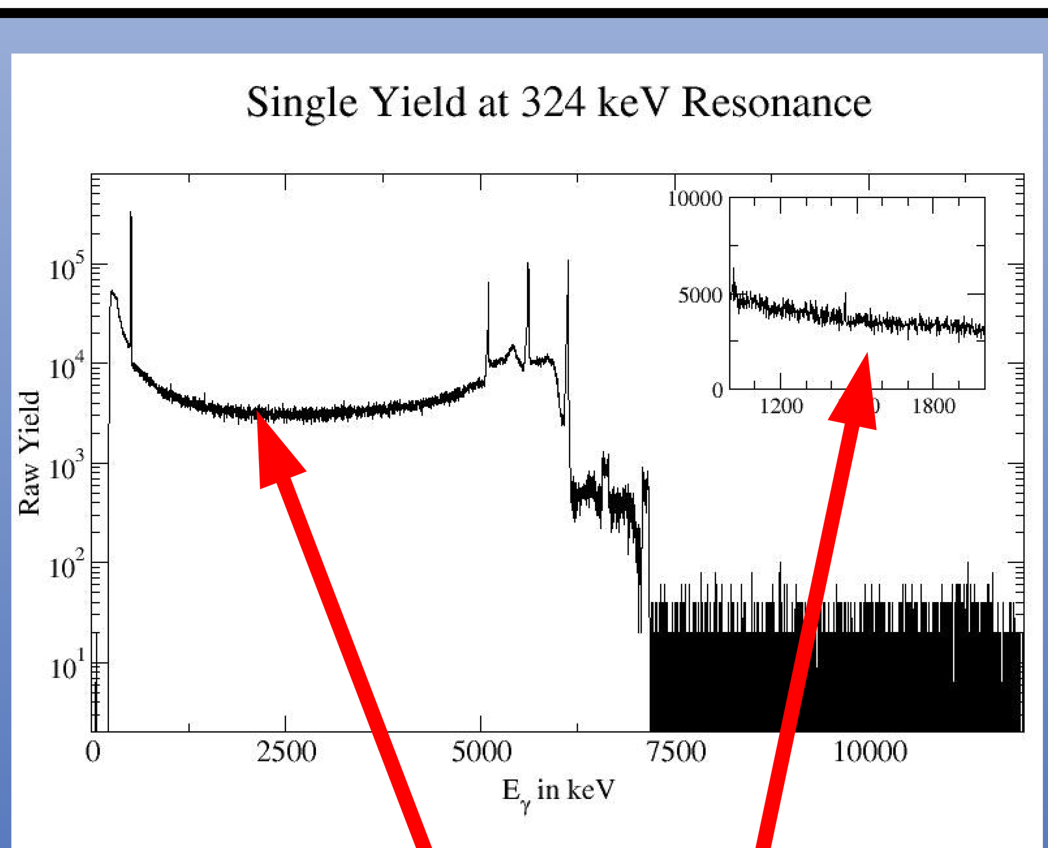
The cold CNO cycle is the primary energy generation mechanism for stars slightly more massive than the sun ($M > 1.5\ M_{sun}$). Although some of the reactions have recently been measured at stellar energies, the reaction rates are primarily determined by the extrapolation of the experimental measurements to astrophysically interesting energies. For quiescent hydrogen burning, the temperatures (and thus energies) are sufficiently low as to make laboratory measurements extremely difficult.

The $^{19}F(p,\gamma)$ reaction is the last breakout reaction in a cyclic process. Any material that flows through the (p,γ) branch rather than recycling back to ^{16}O via $^{19}F(p,\alpha\gamma)$ will be lost from the cycle and cannot serve as a further catalyst.

The Cold CNO Cycle



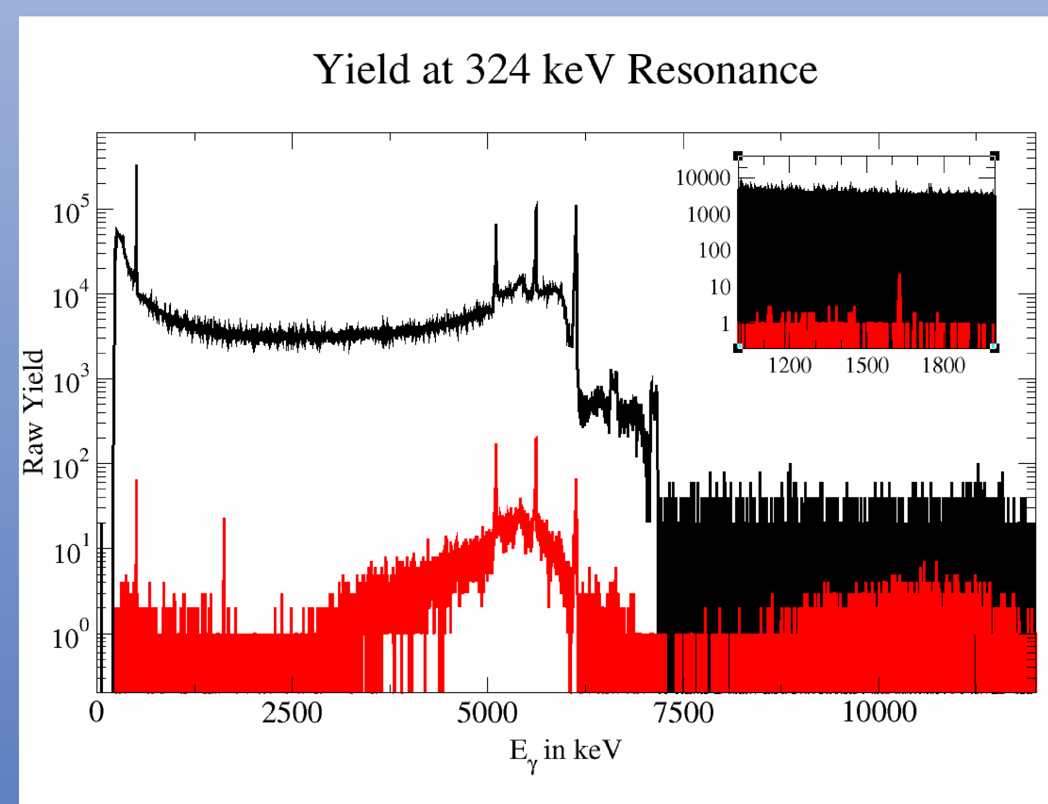




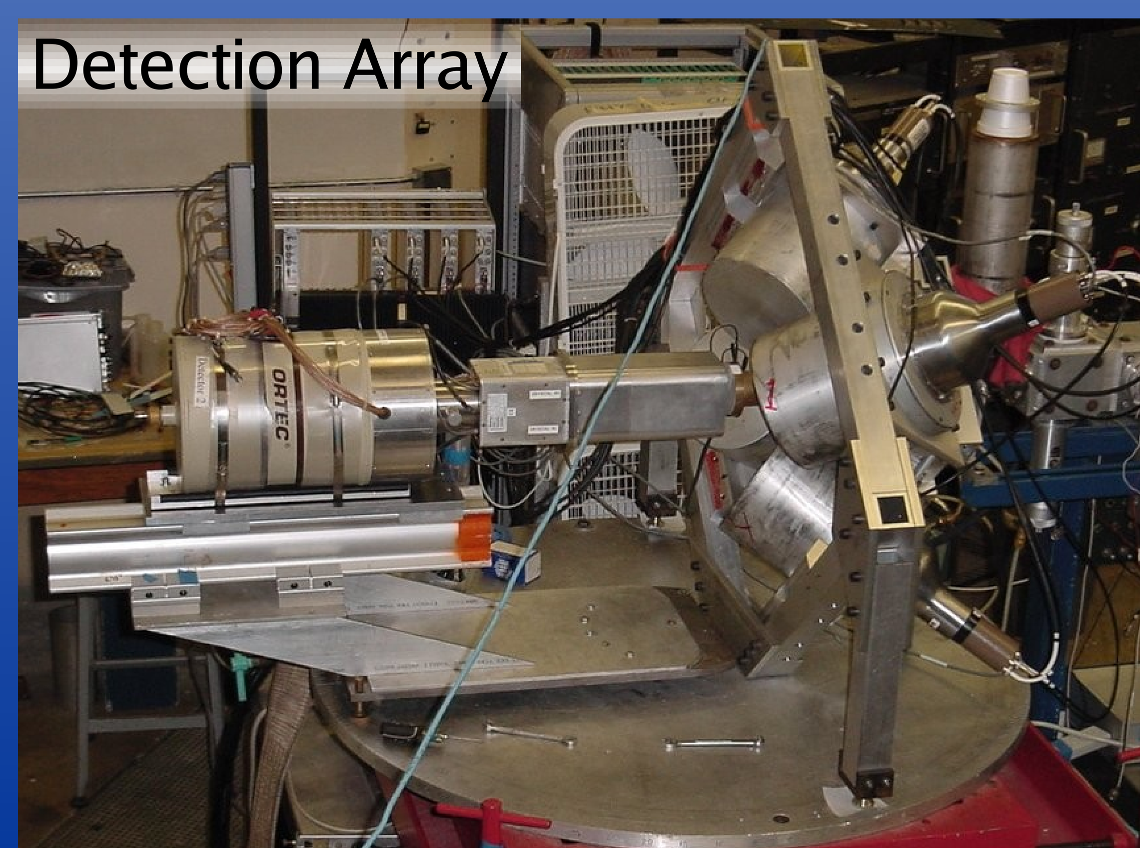
Region of Interest for $^{19}F(p,\gamma)$ hidden by Compton Continuum from $^{19}F(p,\alpha\gamma)$

Measurements of the reaction are complicated by the strong background from the $^{19}F(p,\alpha\gamma)$ reaction. In order to try to isolate the reaction of interest, the 6-7 MeV lines shown to the right must be suppressed since the (p,αγ) reaction is orders of magnitude stronger.

An array of 4 NaI(Tl) detectors was used together with an HPGe clover detector to detect the total gamma ray cascade. The difference in gamma-ray multiplicity and cascade energy was then used to clean the spectrum.

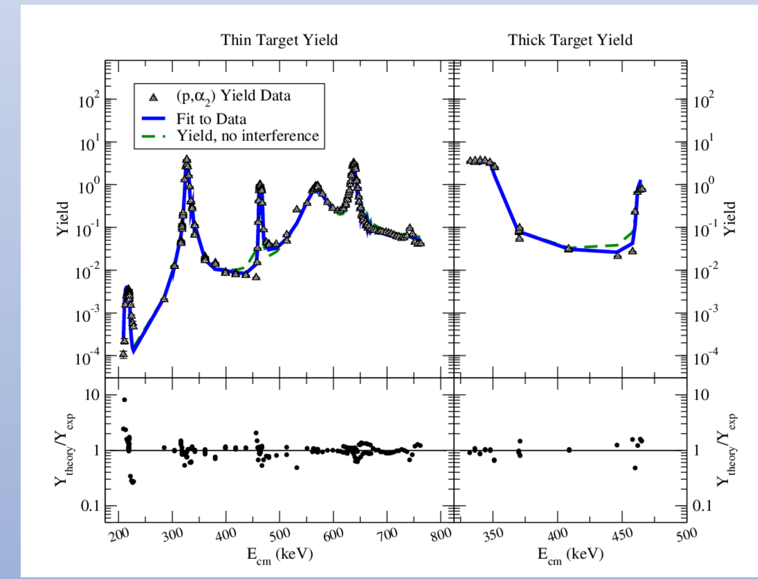


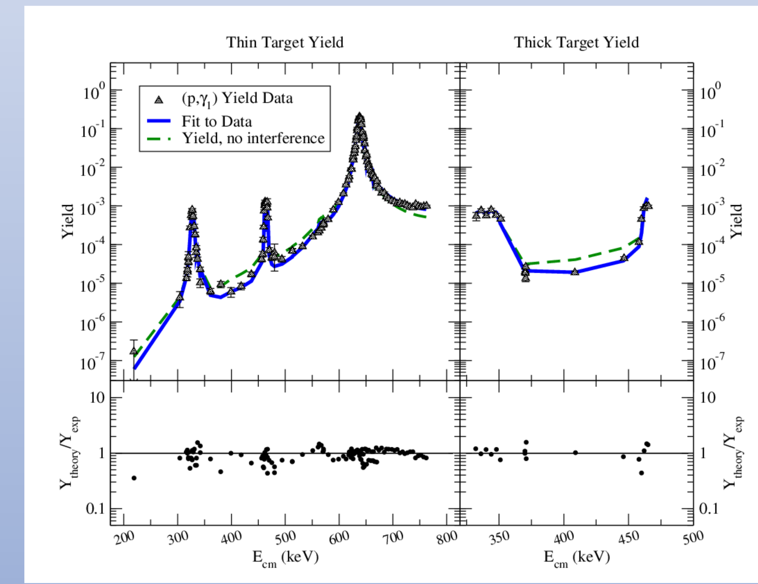
Achieves > 10^3 Suppression of (p,αγ) events!

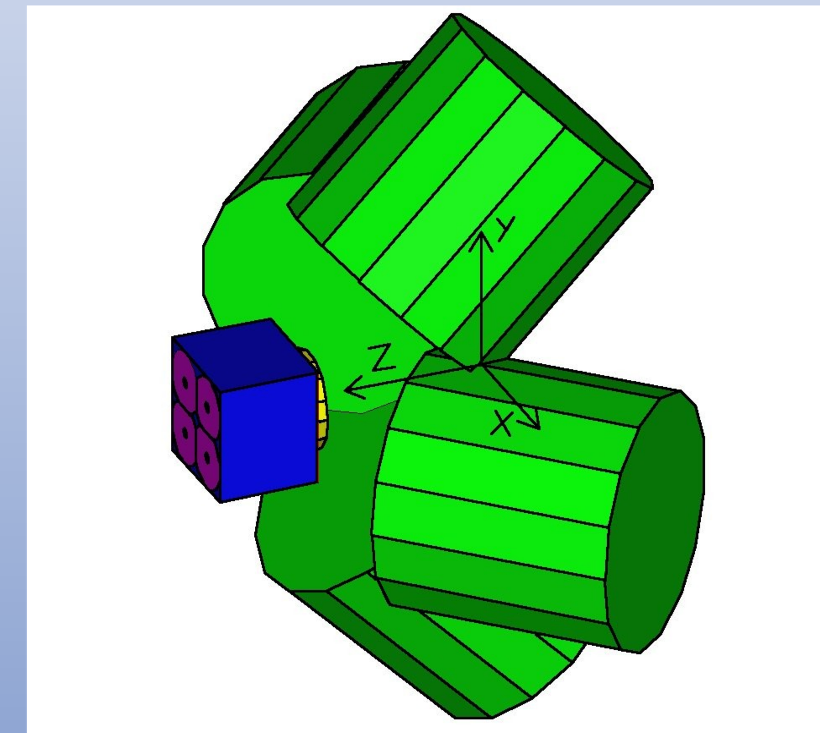


GEANT simulations coupled with calibrations from states in ^{28}Si allowed the determination of the efficiency of the array so that the determination of the resonance parameters and sign of the interference terms could be determined simultaneously for the (p,γ) and (p,αγ) channels. The data was fit with Breit-Wigner resonance shapes including interference terms. This is the first measurement of the sign of the interference terms in the (p,γ) channel. The sign of the interference terms is the largest uncertainty (50%) in the present astrophysical reaction rate.

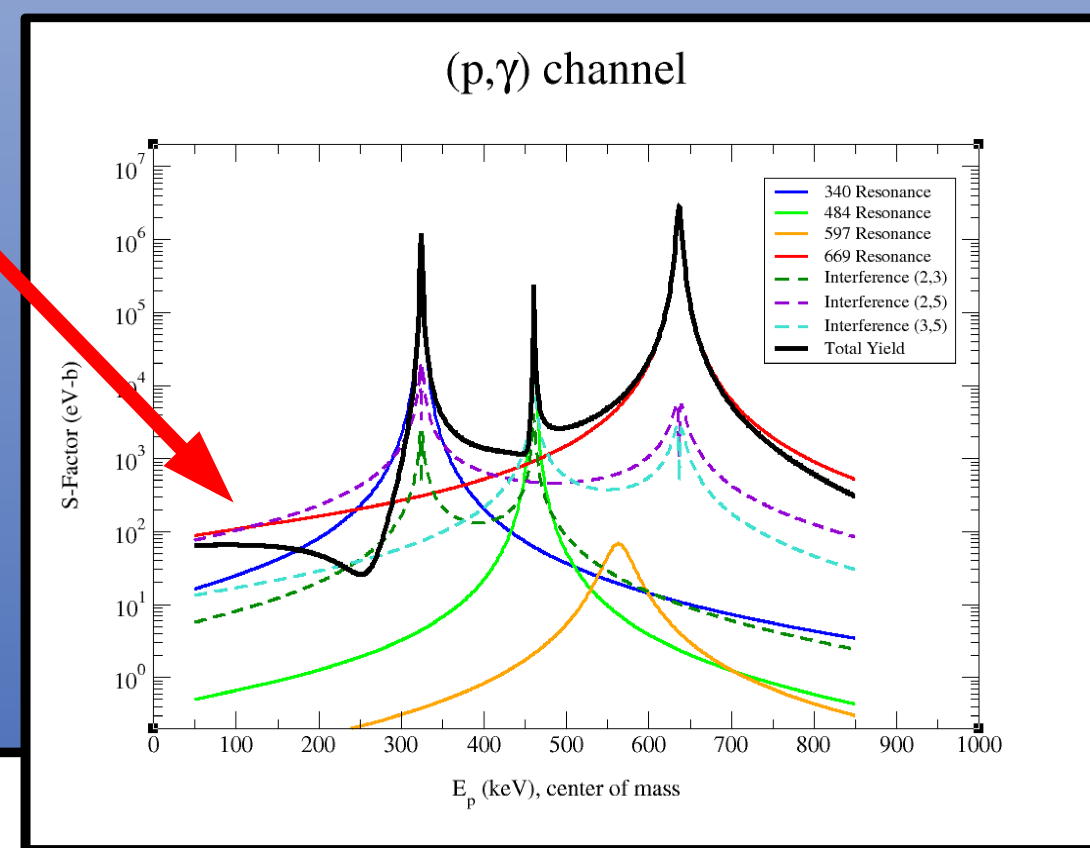
The final reaction rates and their effect on the production of ^{20}Ne is presently being determined and will be published shortly.

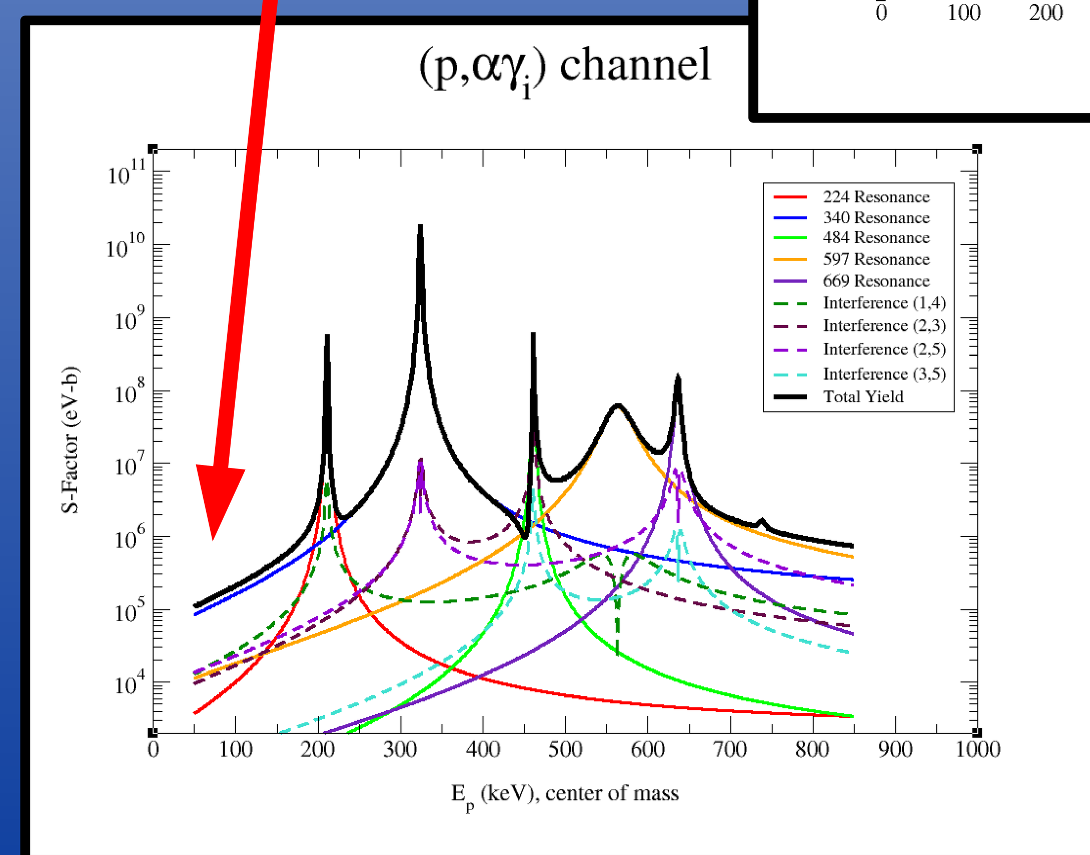






Note The important role played by the interference terms in the S-factor at low energies





This measurement of the interference will remove the largest remaining uncertainty in the astrophysical reaction rate.

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