Low Energy Neutron Production

Neutron production

$p + p \longrightarrow n + \ldots$

$p + {}^4He \longrightarrow n + \ldots$

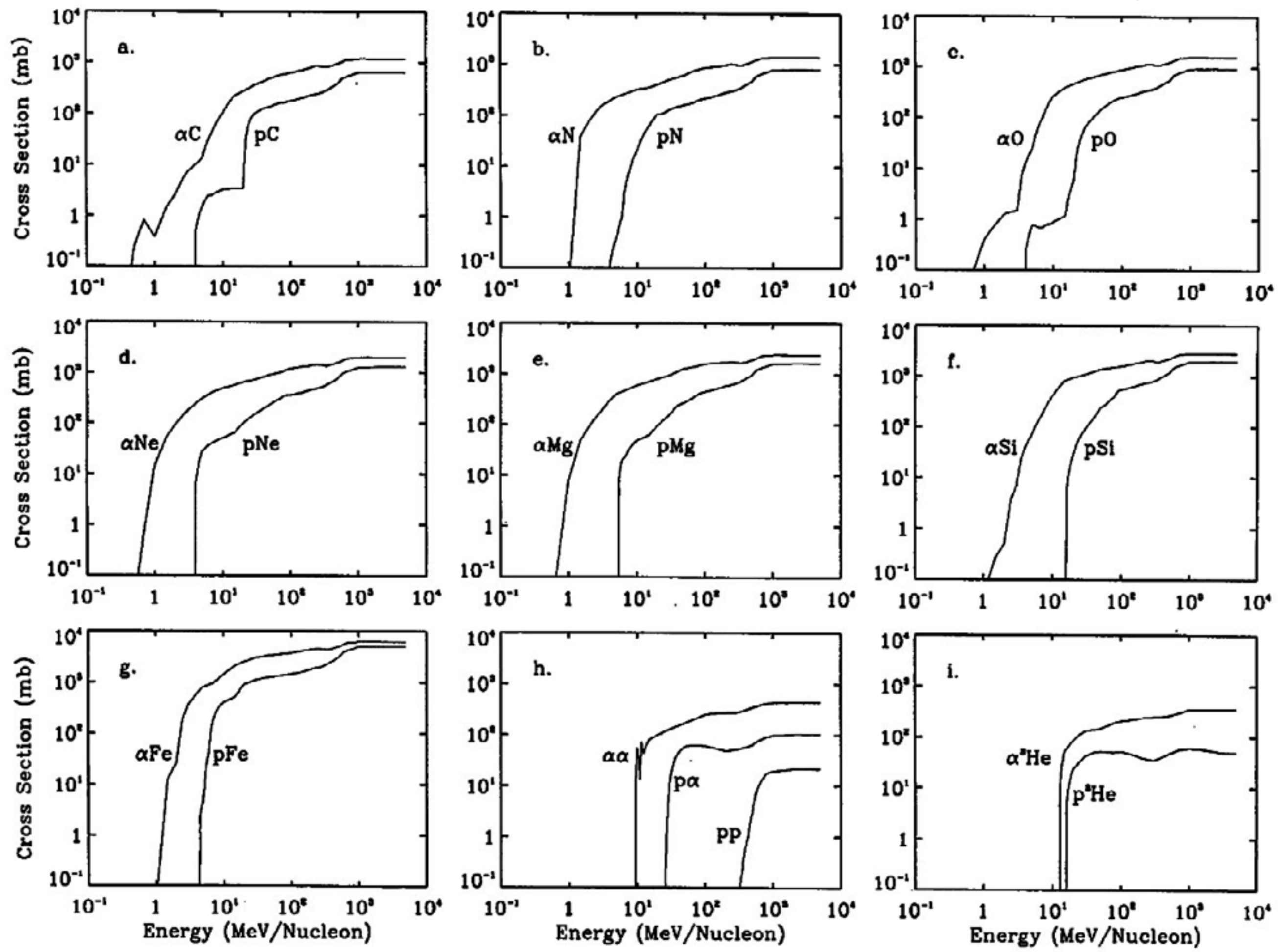
$\alpha + \alpha \longrightarrow n + \ldots$

$\left.\begin{matrix} p \\ \alpha \end{matrix}\right\} + {}^{12}C \longrightarrow n + \ldots$

and inverse reactions

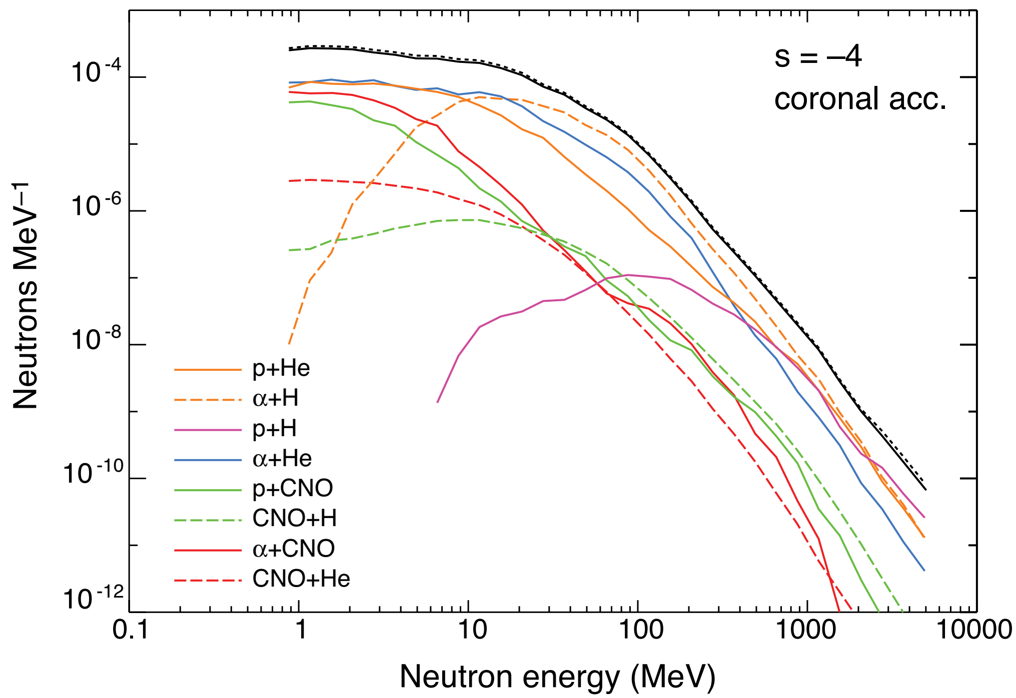
TABLE 1
Targets, Projectiles, and Neutron Production Threshold Energies (MeV per Nucleon)

Isotopes	Proton	α-Particle
^{1}H	292.3	25.7
^{3}He..........	10.3	5.5
^{4}He..........	25.7	9.5
^{12}C	19.6	2.8
^{13}C	3.2	Exothermic
^{14}N..........	6.3	1.5
^{15}N..........	3.7	2.0
^{16}O	17.2	3.8
^{18}O	2.5	0.2
^{20}Ne	15.4	2.2
^{22}Ne	3.8	0.15
^{24}Mg	15.0	2.1
^{25}Mg	5.3	Exothermic
^{26}Mg	5.0	Exothermic
^{28}Si..........	15.6	2.3
^{29}Si..........	5.9	0.4
^{56}Fe..........	5.5	1.4
^{54}Fe..........	9.2	1.6



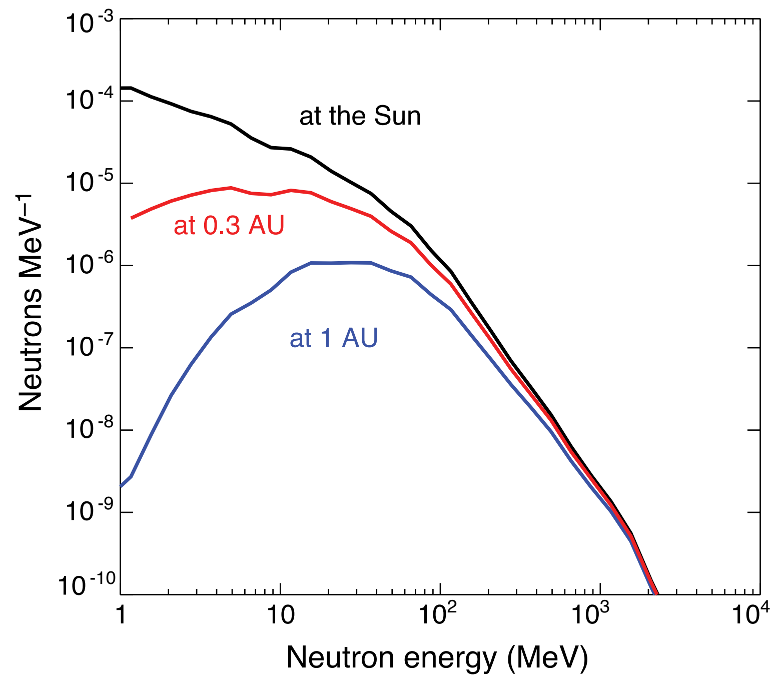
Hua et al. 2002

Neutron Production from Typical Flare Ion Spectra



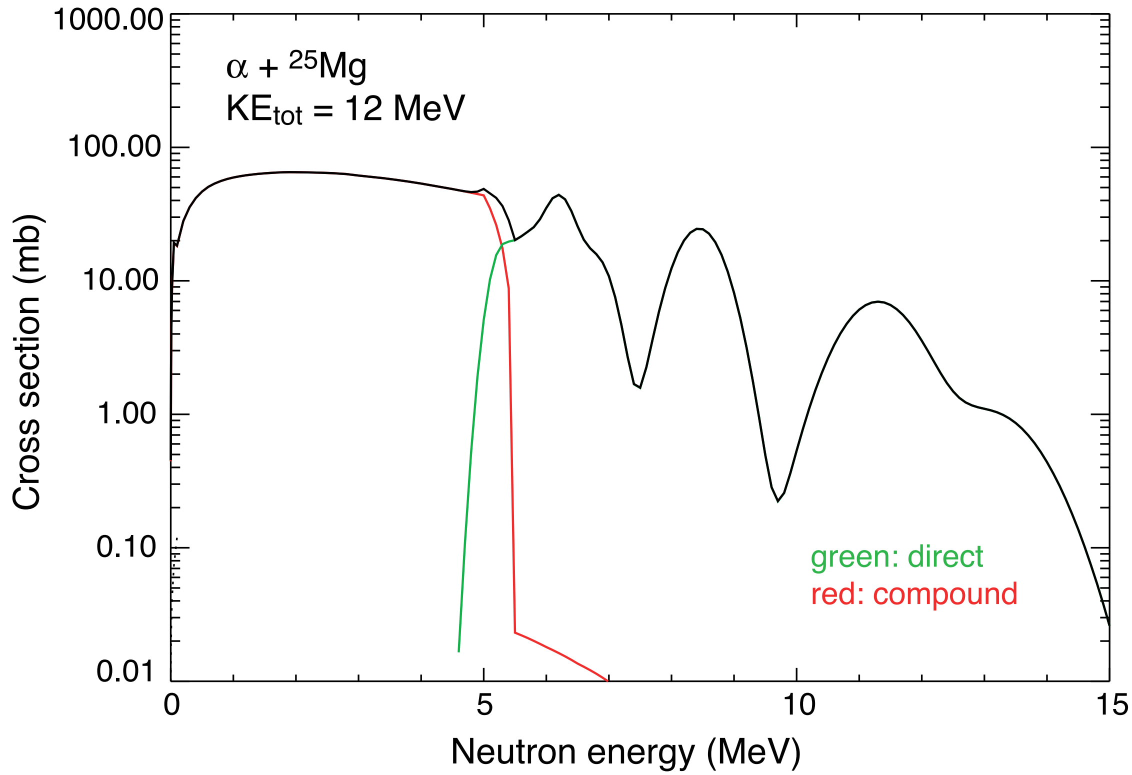
Neutron Decay

Neutron lifetime (τ_{mean} = 886 s) alters kinetic energy spectrum with distance from Sun

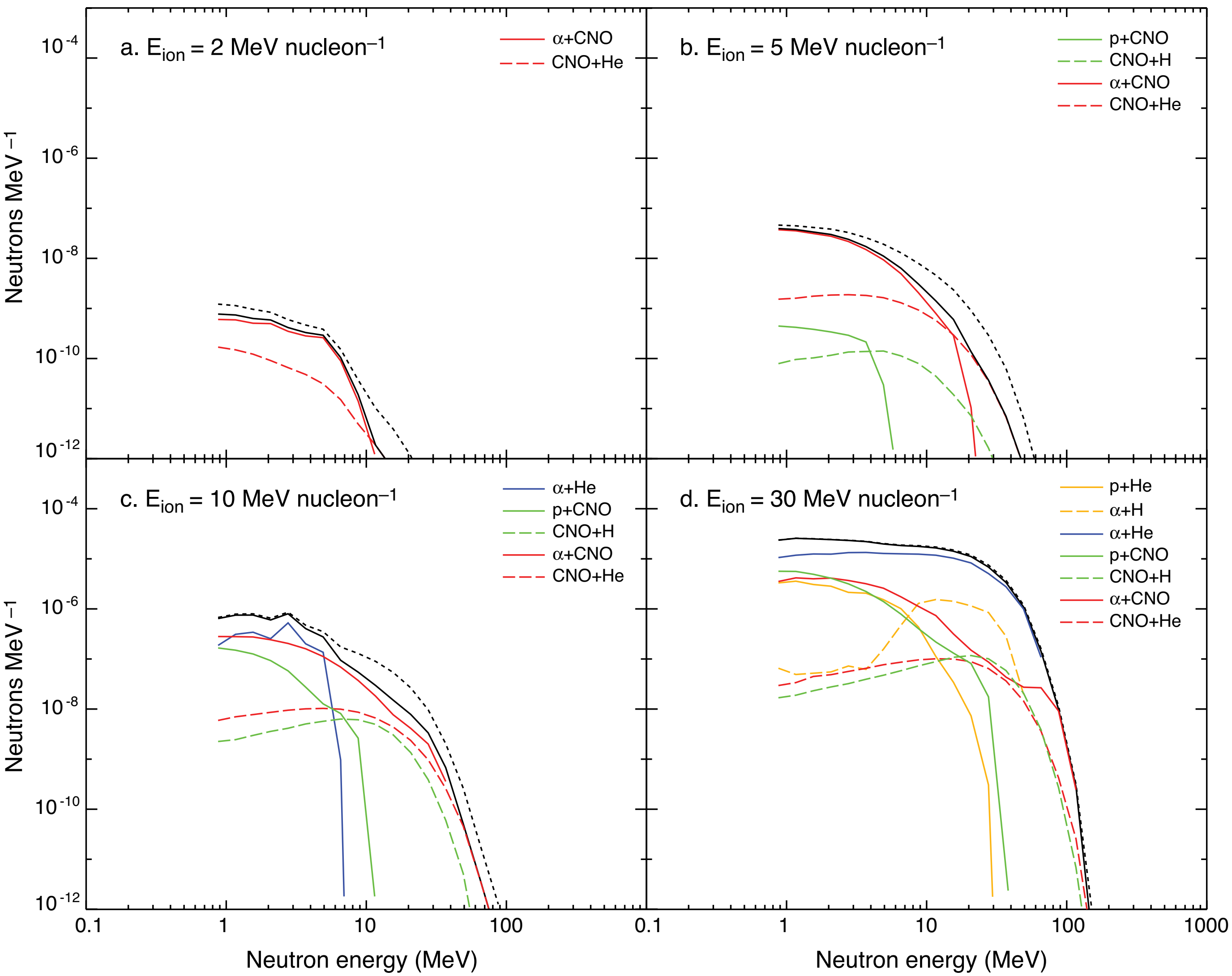


Improvements to the Neutron Production Code

To provide information about low-energy neutron production, we used the global-nuclear theoretical program TALYS. (Koning, Hilaire & Duijvestijn 2005; Koning & Duijvestijn 2006) **TALYS is software for the simulation of nuclear reactions using state-of-the-art nuclear models and comprehensive libraries of nuclear data, developed at NRG Petten, the Netherlands and CEA Bruyeres-le-Chatel, France.**



Neutron Spectra from Low-Energy Nuclear Reactions



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Sensitivity Comparison of Direct Detection of Low-energy Neutrons vs. Inferred Detection via the Neutron-Capture Line

Neutron production at the Sun is always accompanied by neutron-capture line production.

This very-strong and very-narrow line is easily detected by moderately-sized gamma-ray detectors at Earth.

At 0.48 AU, the 1–10 MeV neutron flux is comparable to the neutron-capture line flux at 1 AU.

For Earth-orbiting gamma-ray detectors, $A_{eff} \sim 50$ cm^2

For inner-heliosphere neutron detectors (such as MESSENGER), $A_{eff} \sim 10$ cm^2.

However, at 30 R_S, the neutron flux is >20 times the neutron-capture line flux at 1 AU!