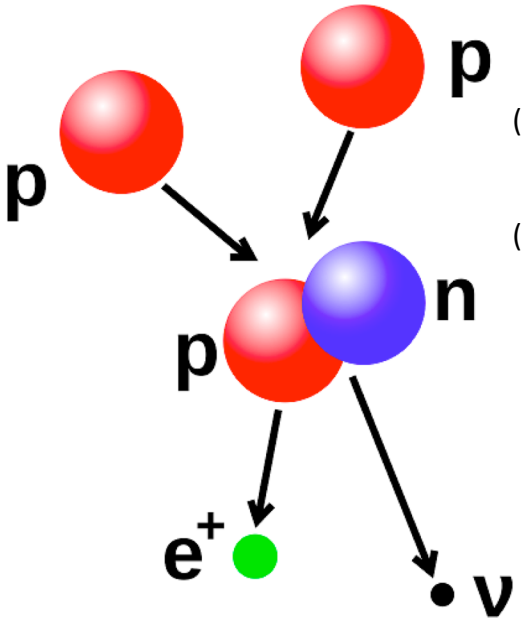
First step of the "p-p Chain" of reactions



2 steps required:

(1)Proton tunnels through Coulomb barrier

(1)Proton undergoes β^+ decay and converts into neutron (which stay bound in the nucleus) and emits a positron and neutrino (which both escape the nucleus)

β^+ decay SLOW – controlled by the weak nuclear force.

PP Chains of Hydrogen Fusion in Sun-Like Stars

$$^1H + {}^1H \rightarrow {}^2H + e^+ + \nu$$

$$^2H + {}^1H \rightarrow {}^3He + \gamma$$

PPI ~ 69% | ~ 31%

$$^3He + {}^3He \rightarrow {}^4He + 2\,{}^1H \qquad {}^3He + {}^4He \rightarrow {}^7Be + \gamma$$

PPII ~ 99.7% | PPIII ~ 0.3%

$$^7Be + e^- \rightarrow {}^7Li + \nu \qquad {}^7Be + {}^1H \rightarrow {}^8B + \gamma$$

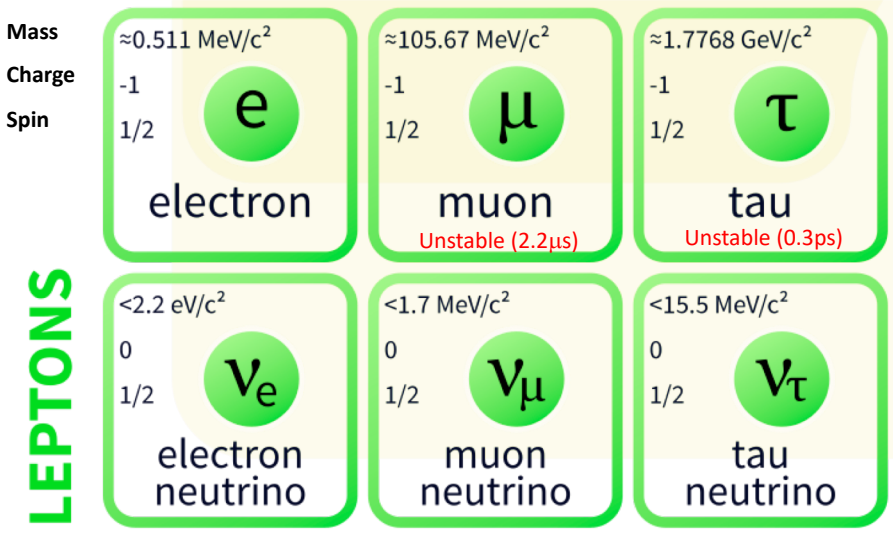
$$^7Li + {}^1H \rightarrow 2\,{}^4He \qquad {}^8B \rightarrow {}^8Be + e^+ + \nu$$

$$^8Be \rightarrow 2\,{}^4He$$

Table 7.2
Thermonuclear energy-release parameters for the princip
cycle. The third column gives the energy carried off by th
reaction.

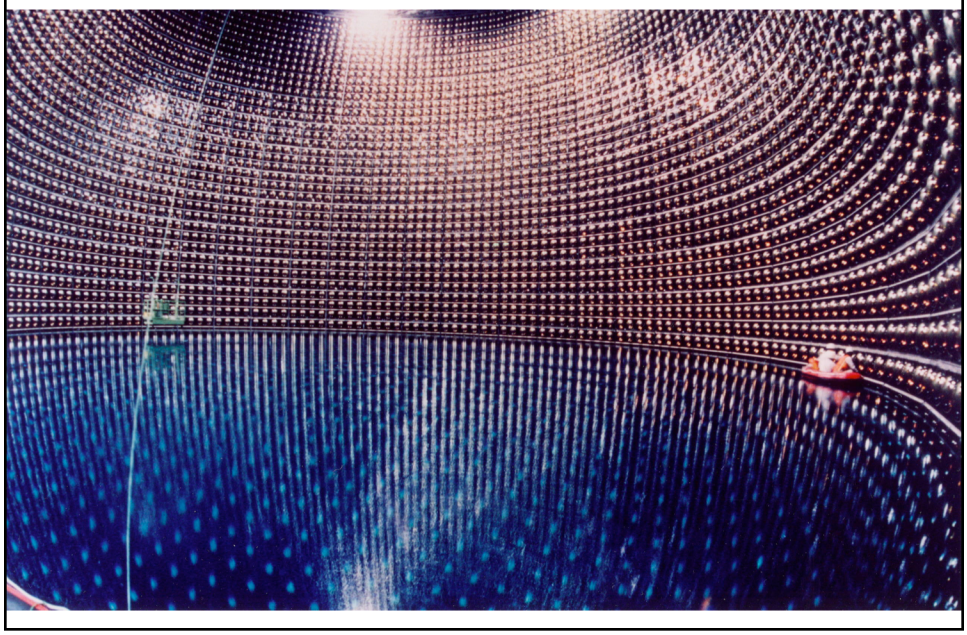
Reaction[a]	*Q* value, MeV	Average ν loss, MeV
The pp *chain*		
$H^1(p, \beta^+\nu)D$	1.442	0.263
$D(p, \gamma)He^3$	5.493	
$He^3(He^3, 2p)He^4$	12.859	
$He^3(\alpha, \gamma)Be^7$	1.586	
$Be^7(e^-, \nu)Li^7$	0.861	0.80
$Li^7(p, \alpha)He^4$	17.347	
$Be^7(p, \gamma)B^8$	0.135	
$B^8(\beta^+ \nu)Be^{8*}(\alpha)He^4$	18.074	7.2

Fundamental Particles – Leptons

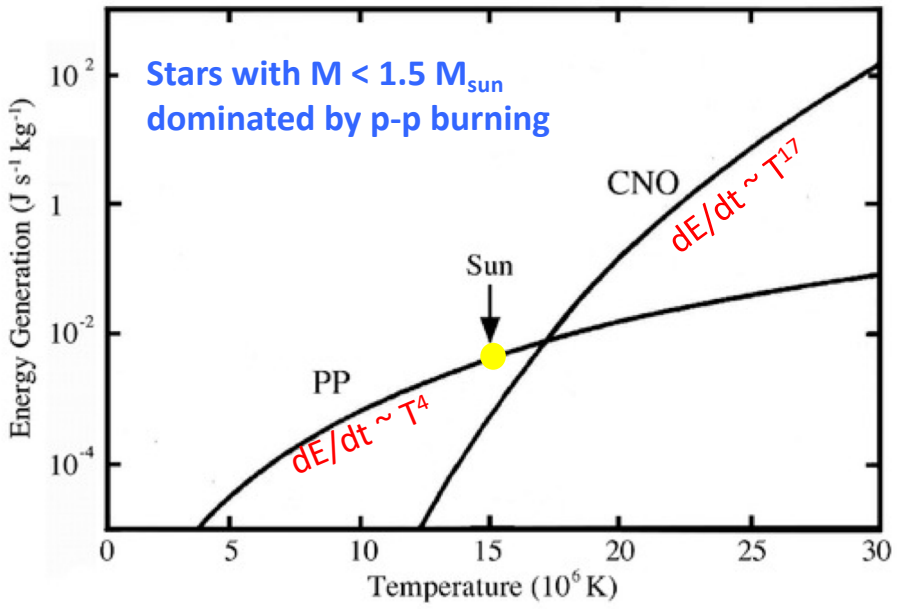


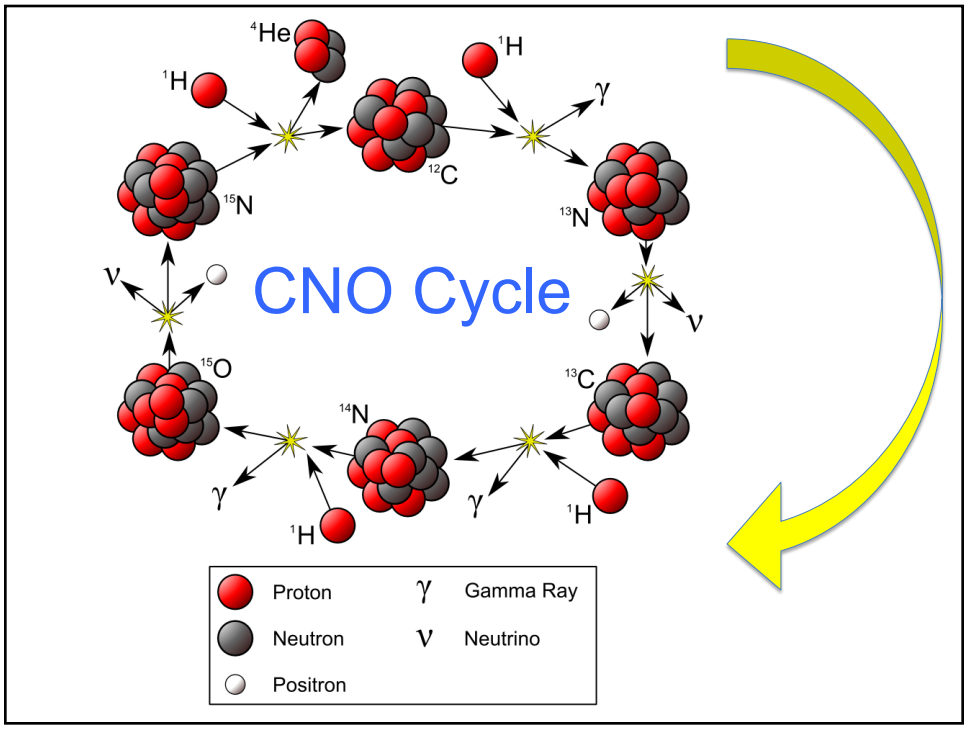
There are 3 "flavors" of neutrinos and a neutrino can "oscillate" between the flavors. This affects the neutrino flux from the Sun

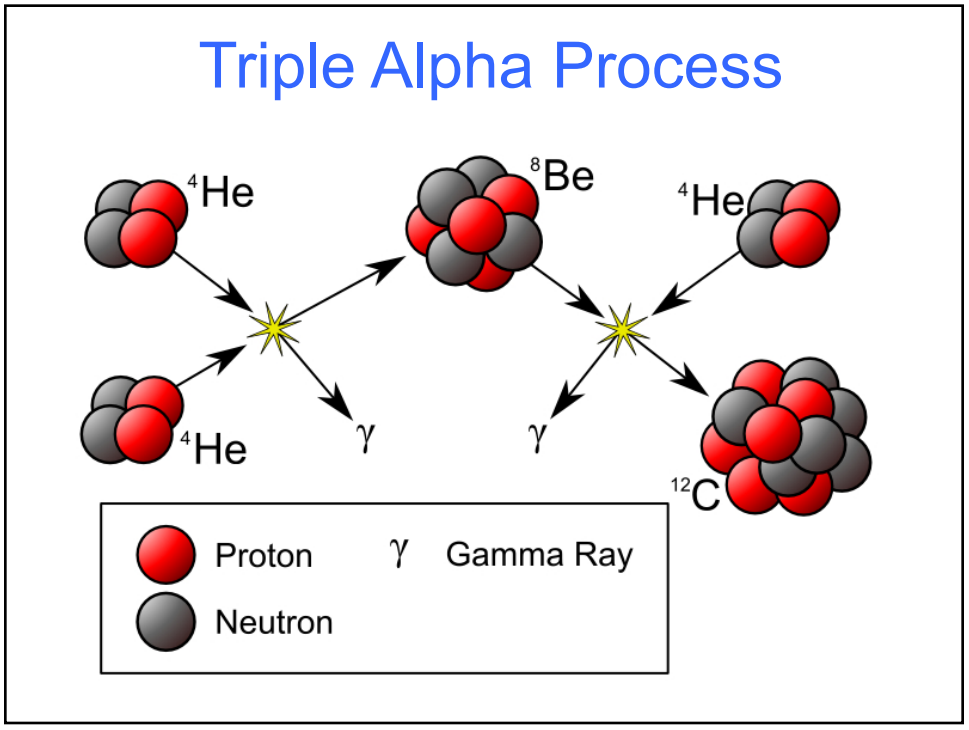
Neutrino Detector



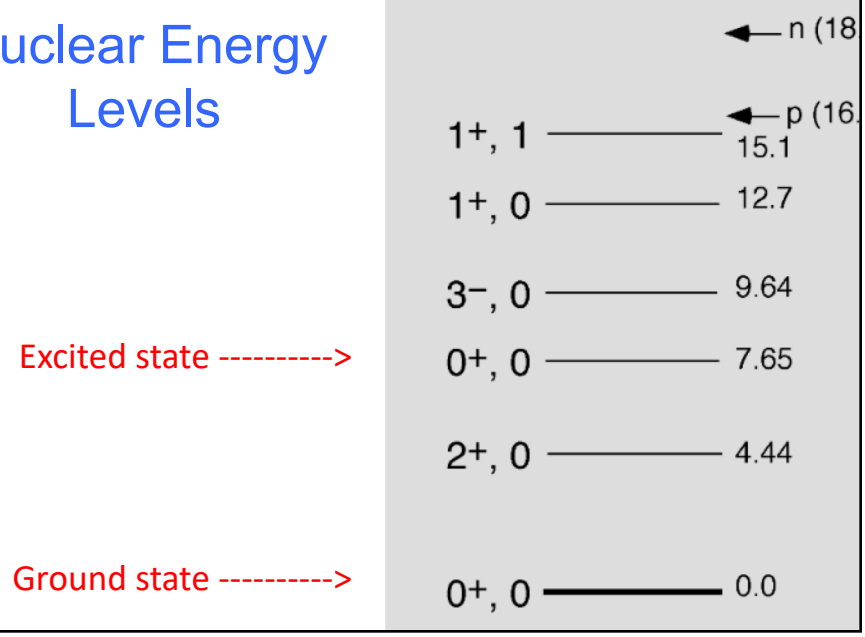
dE/dt vs. Core Temperature



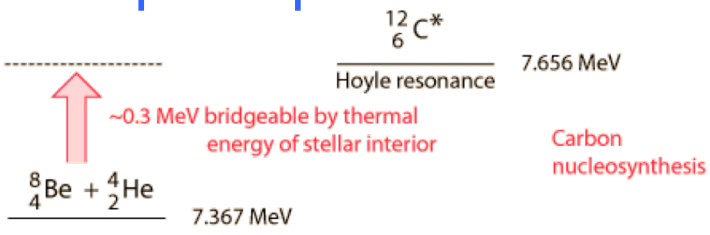

CNO Cycle
^{4}He
^{1}H
^{12}C
^{1}H
γ
^{15}N
^{13}N
ν
ν
^{15}O
^{13}C
^{14}N
γ
γ
^{1}H
^{1}H
Proton
Neutron
Positron
γ Gamma Ray
ν Neutrino


Triple Alpha Process
^{4}He
^{8}Be
^{4}He
^{4}He
γ
γ
^{12}C
Proton
Neutron
γ Gamma Ray

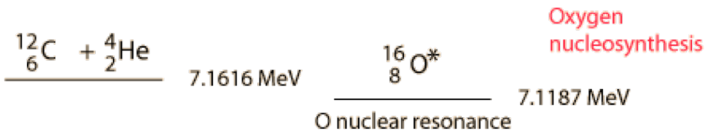
^{12}C Nuclear Energy Levels



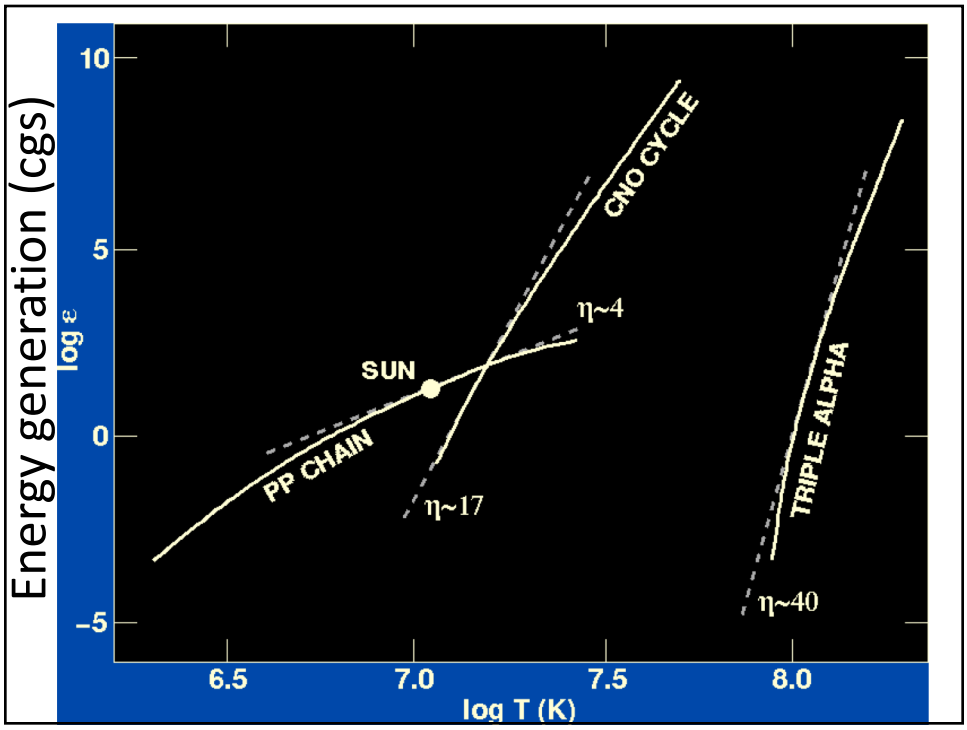
Triple Alpha Process



The nuclear resonance of carbon increases the rate of carbon production in stellar interiors.

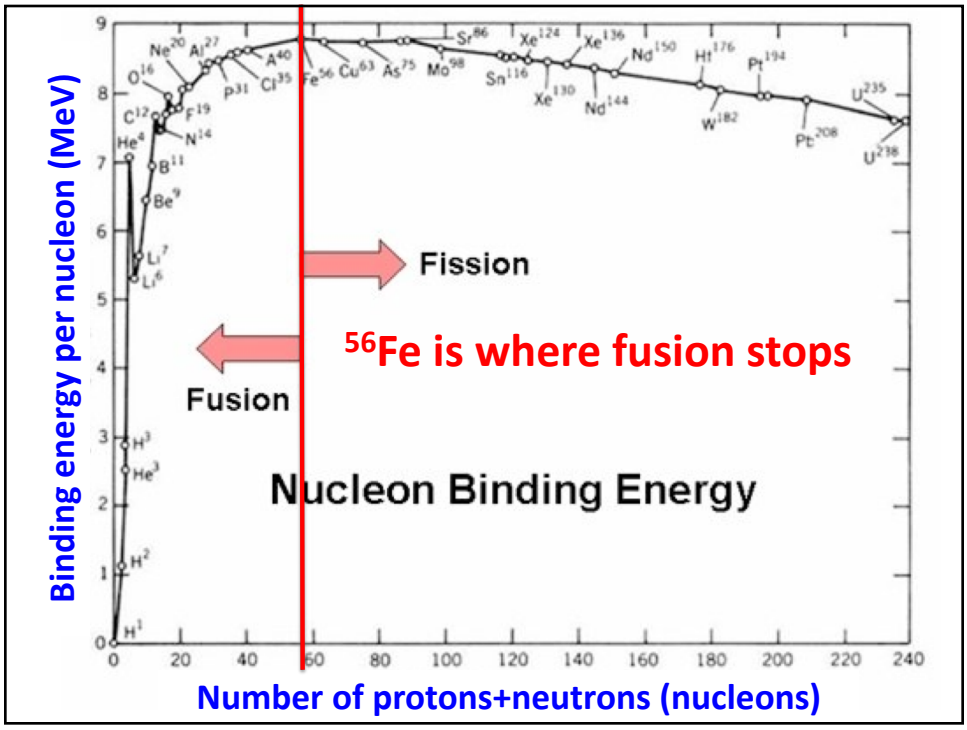


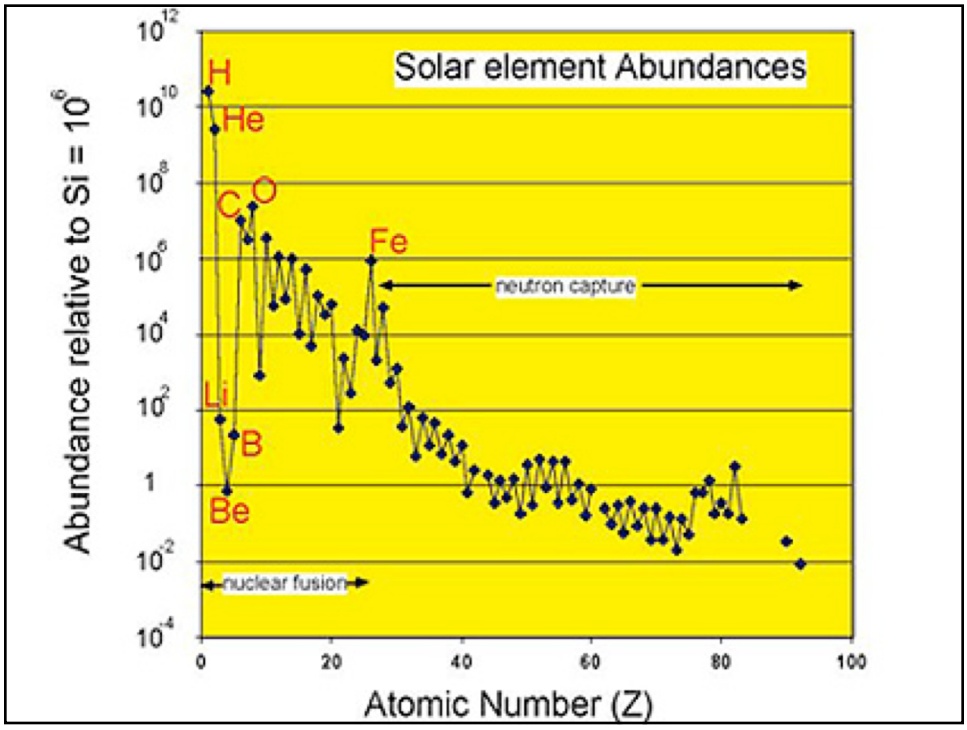
A nuclear resonance of oxygen is near, but below the energy of the carbon - helium combination, so it does not act to increase the rate of oxygen production at the expense of carbon.



Approximate Minimum Temperature for Nuclear Reactions

T	Reaction
1 x 10^6 K	^{2}H burning
10 x 10^6 K	p-p chain
18 x 10^6 K	CNO cycle
100 x 10^6 K	triple alpha
>600 x 10^6 K	C burning


Binding energy per nucleon (MeV)
Number of protons+neutrons (nucleons)
Fission
Fusion
56Fe is where fusion stops
Nucleon Binding Energy


Solar element Abundances
Abundance relative to Si = 10^6
Atomic Number (Z)
H
He
C
O
Fe
Li
B
Be
neutron capture
nuclear fusion