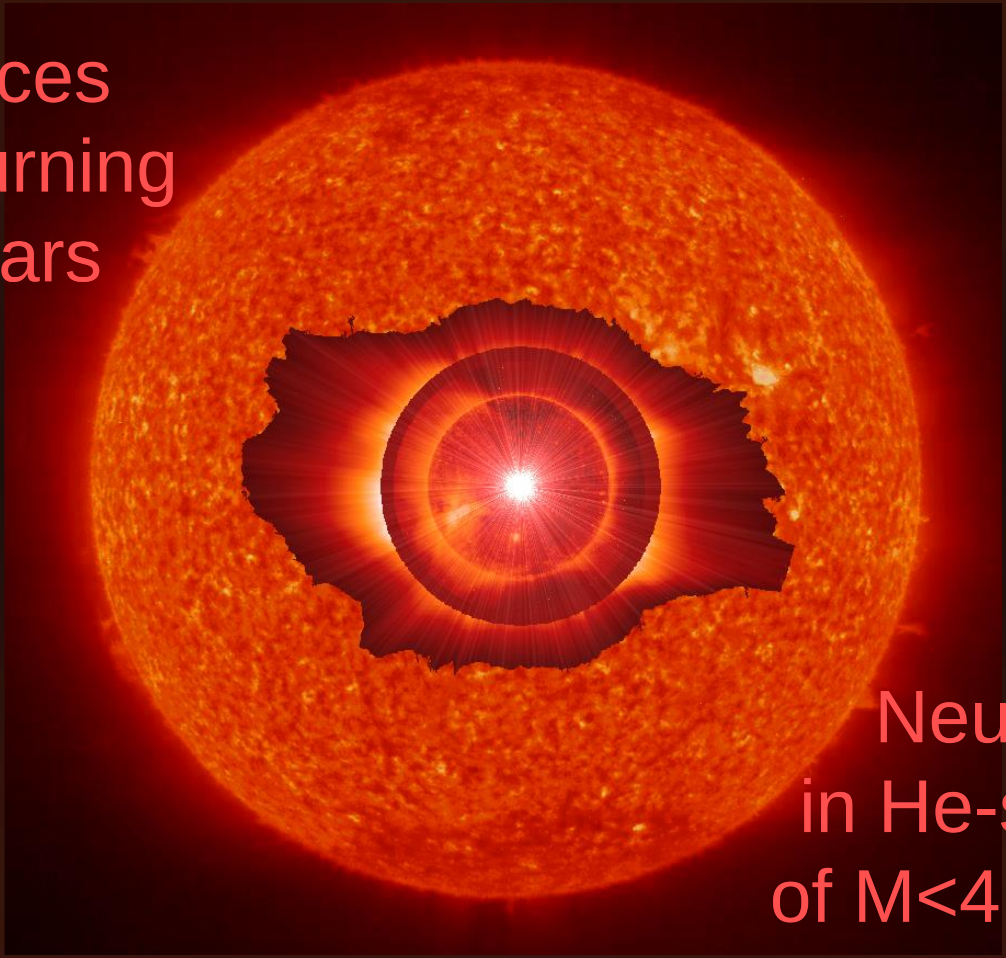
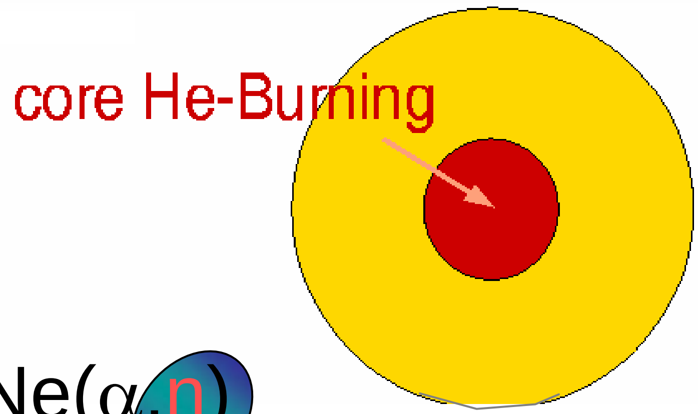
Helium Burning in Stars II

Neutron sources
in He-core burning
of massive stars

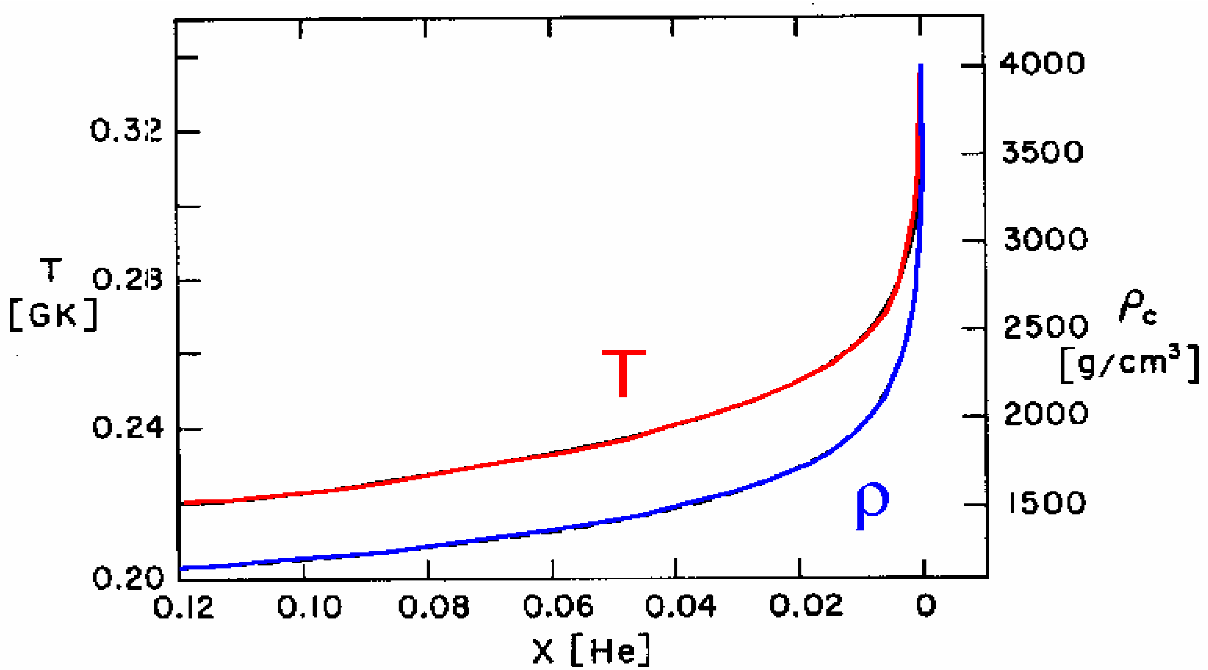


Neutron sources
in He-shell burning
of $M<4M_\odot$ AGB stars

Stellar Neutron Sources in massive Stars



$^{14}N(\alpha,\gamma)^{18}F(\beta^{+}\nu)^{18}O(\alpha,\gamma)^{22}Ne(\alpha,n)$



T-dependent increase of n-production

Reaction network for n-sources

$$\frac{dY_{^{14}N}}{dt} = -Y_{^{14}N} \cdot Y_{^{4}He} \cdot \rho \cdot N_A \langle \sigma \upsilon \rangle_{^{14}N(\alpha,\gamma)}$$

$$\frac{dY_{^{18}F}}{dt} = -Y_{^{18}F} \cdot \lambda_{^{18}F(\beta^+)} + Y_{^{14}N} \cdot Y_{^{4}He} \cdot \rho \cdot N_A \langle \sigma \upsilon \rangle_{^{14}N(\alpha,\gamma)}$$

$$\frac{dY_{^{18}O}}{dt} = -Y_{^{18}O} \cdot Y_{^{4}He} \cdot \rho \cdot N_A \langle \sigma \upsilon \rangle_{^{18}O(\alpha,\gamma)} + Y_{^{18}F} \cdot \lambda_{^{18}F(\beta^+)}$$

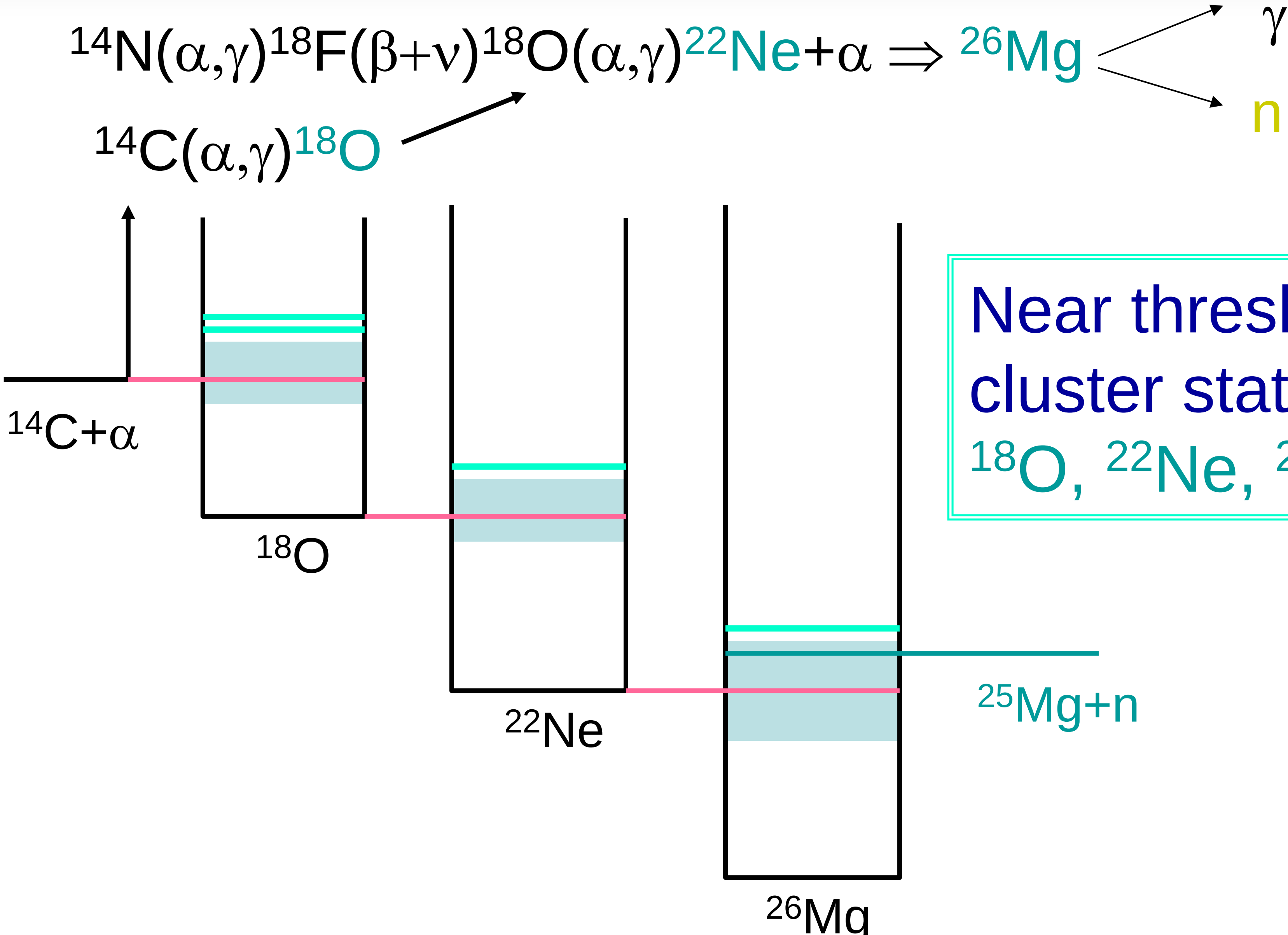
$$\frac{dY_{^{22}Ne}}{dt} = -Y_{^{22}Ne} \cdot Y_{^{4}He} \cdot \rho \cdot N_A \langle \sigma \upsilon \rangle_{^{22}Ne(\alpha,n)} + Y_{^{18}O} \cdot Y_{^{4}He} \cdot \rho \cdot N_A \langle \sigma \upsilon \rangle_{^{18}O(\alpha,\gamma)}$$

$$\frac{dY_n}{dt} = -Y_n \cdot \lambda_{n(\beta^-)} - \sum_X Y_X \cdot Y_n \cdot \rho \cdot N_A \langle \sigma \upsilon \rangle_{X(n,\gamma)} + Y_{^{22}Ne} \cdot Y_{^{4}He} \cdot \rho \cdot N_A \langle \sigma \upsilon \rangle_{^{22}Ne(\alpha,n)}$$

Neutron production through $^{22}Ne(\alpha,n)^{25}Mg$ depends on reaction rates of this sequence

T=1 nuclei, neutron sources

$^{14}N(\alpha,\gamma)^{18}F(\beta+\nu)^{18}O(\alpha,\gamma)^{22}Ne+\alpha \Rightarrow {}^{26}Mg$

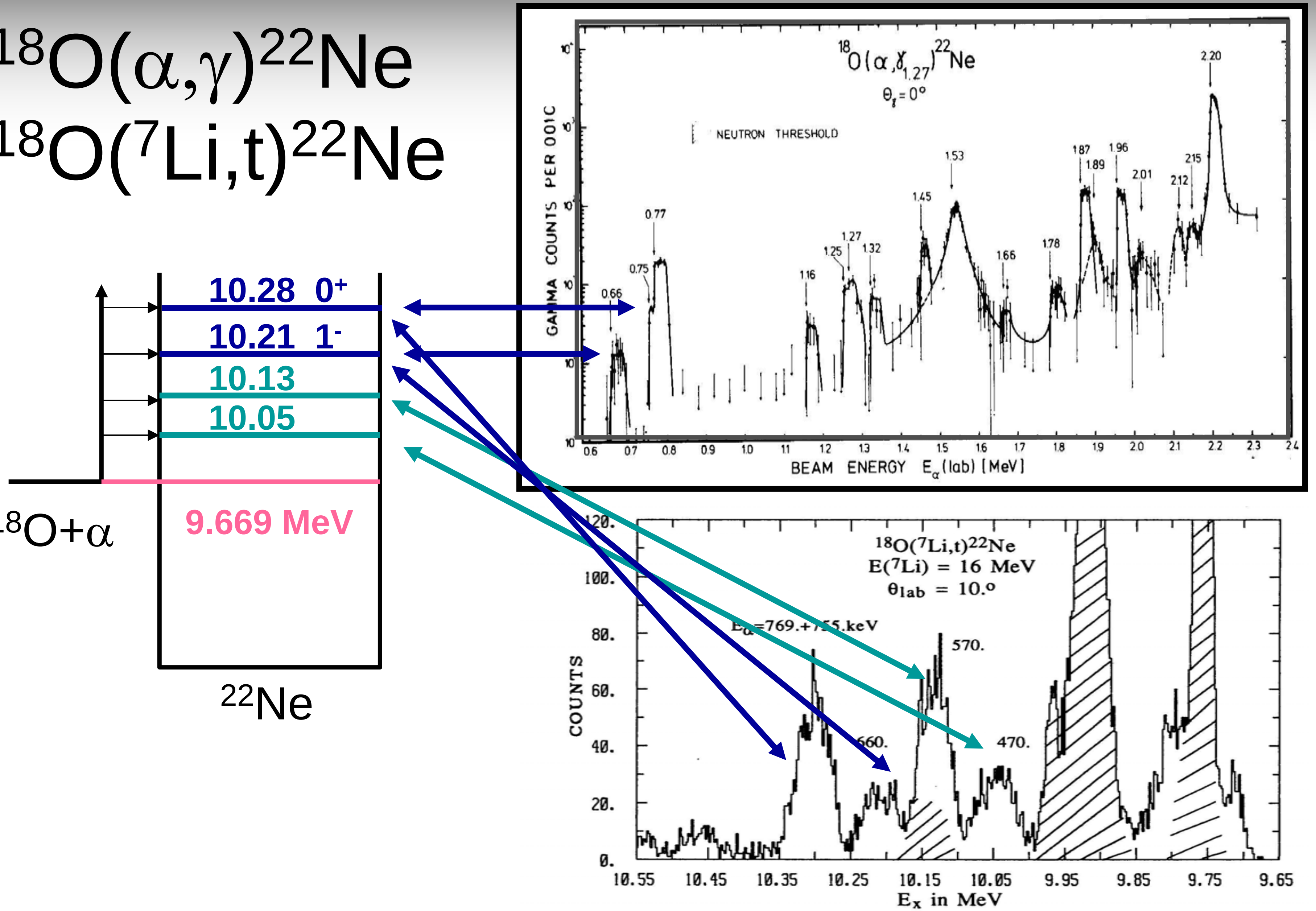


Near threshold cluster states in: ^{18}O, ^{22}Ne, ^{26}Mg?

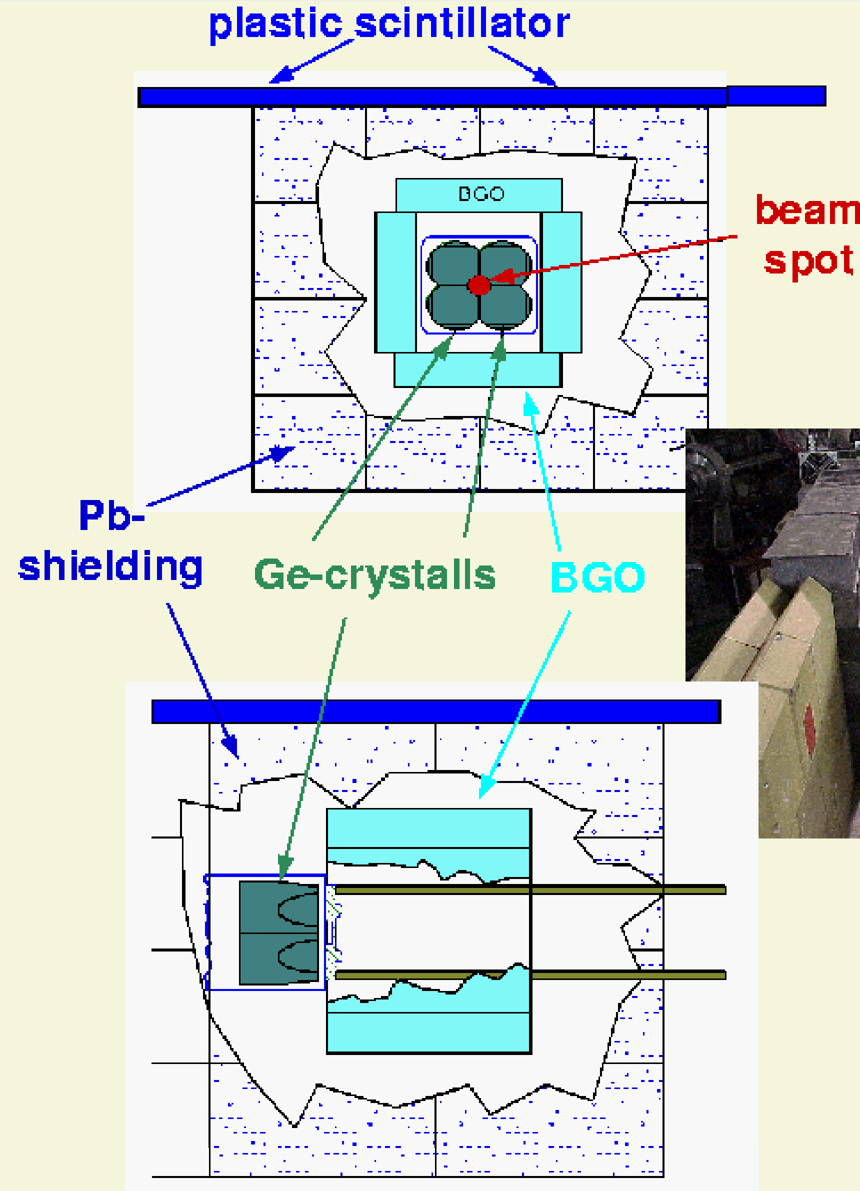
Search for α-cluster in:

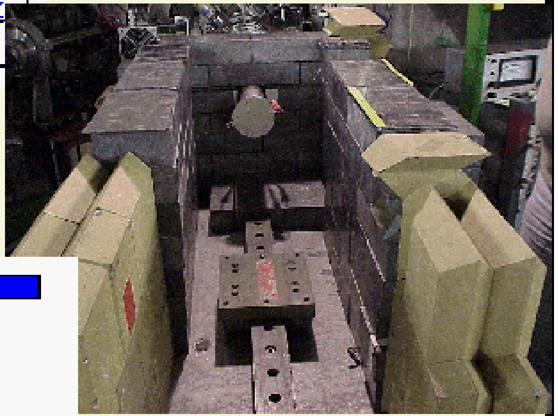
$^{18}O(\alpha,\gamma)^{22}Ne$

$^{18}O(^{7}Li,t)^{22}Ne$



Experimental Set-Up





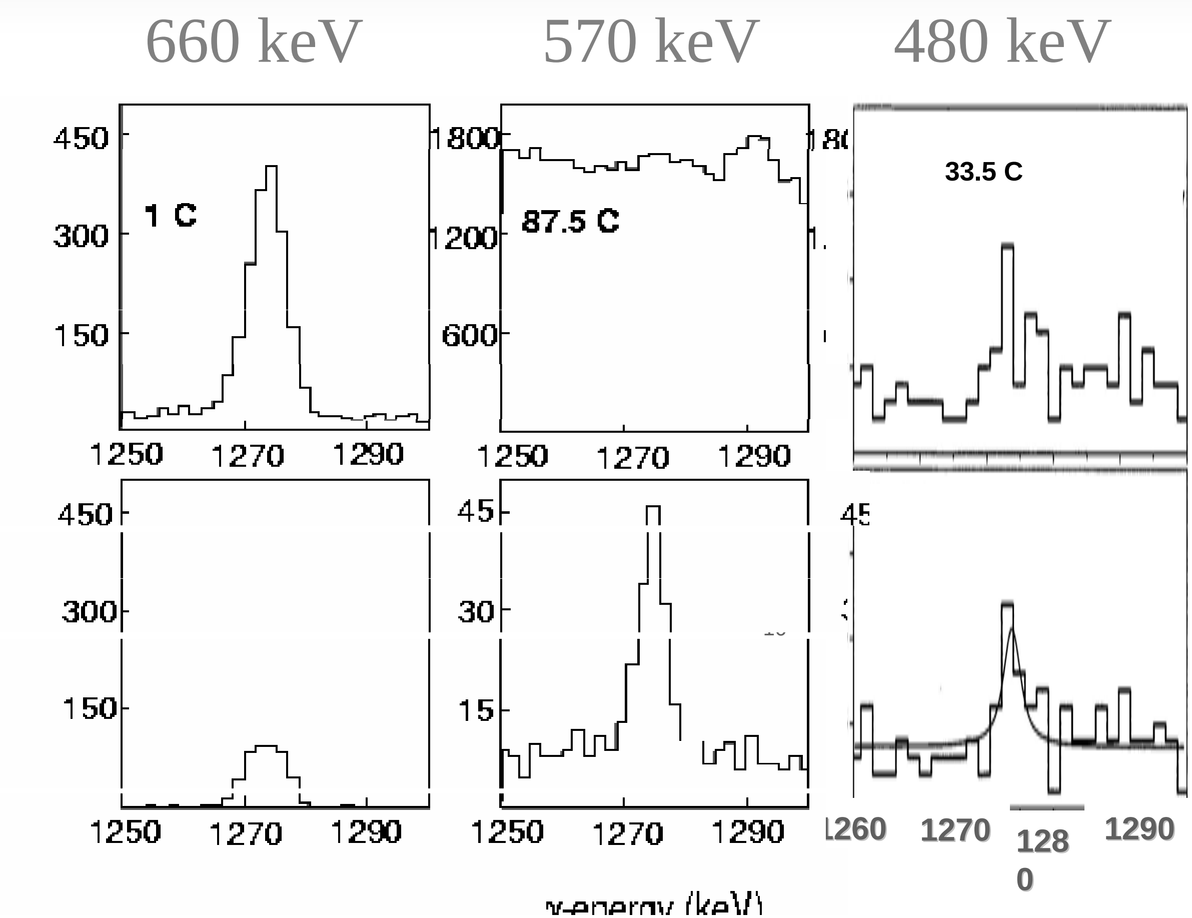
Lead shielding
for room BG

Anti coincidence
suppression of
Cosmic Ray BG

Ge-BGO coincidence
signal requirements
For event identification

Ge-Clover Add-Back
Mode for γ-efficiency
enhancement

α strength of threshold resonances



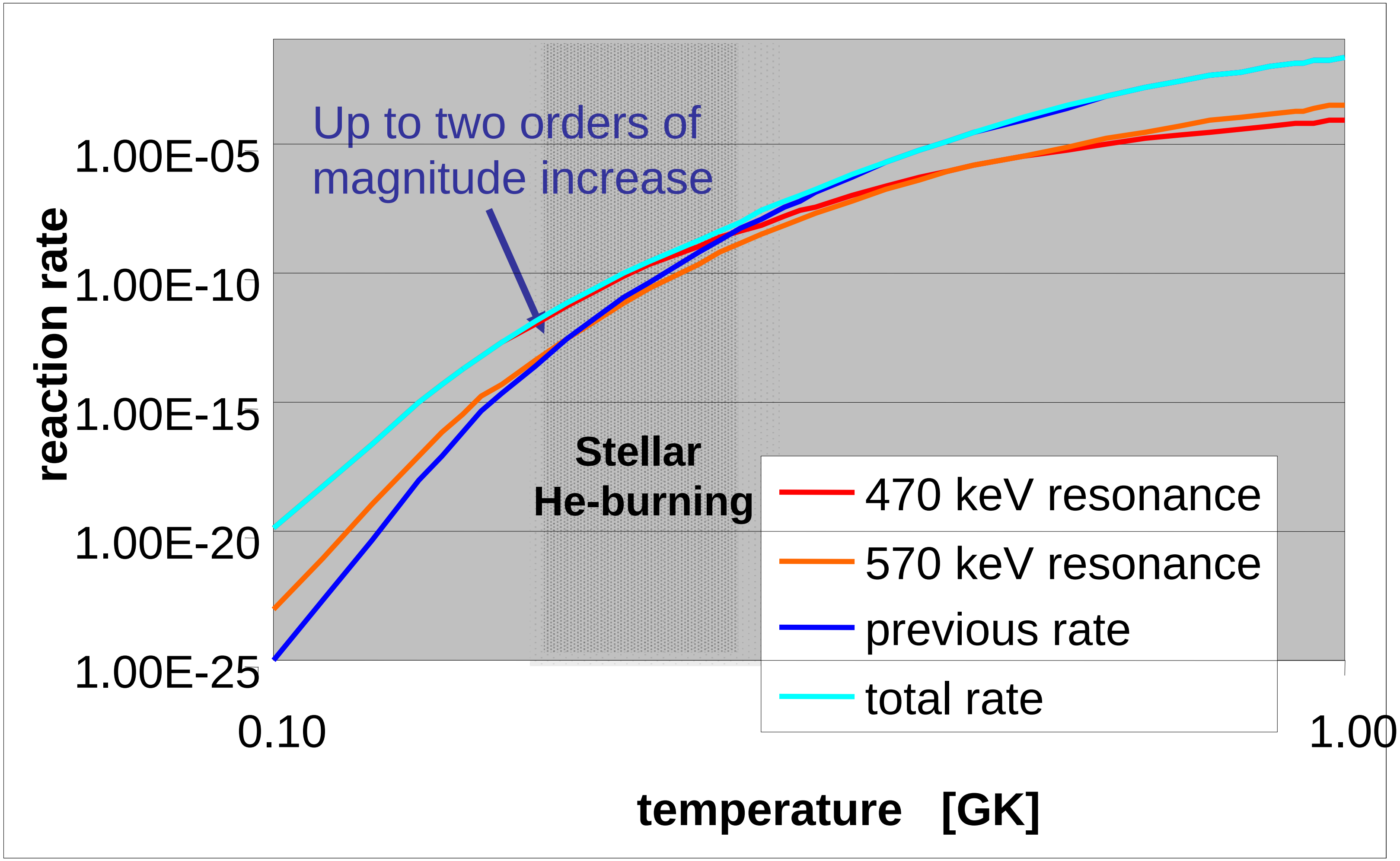
10.28 0^+ $\theta_\alpha^2=0.02$

10.21 1^- $\theta_\alpha^2=0.06$

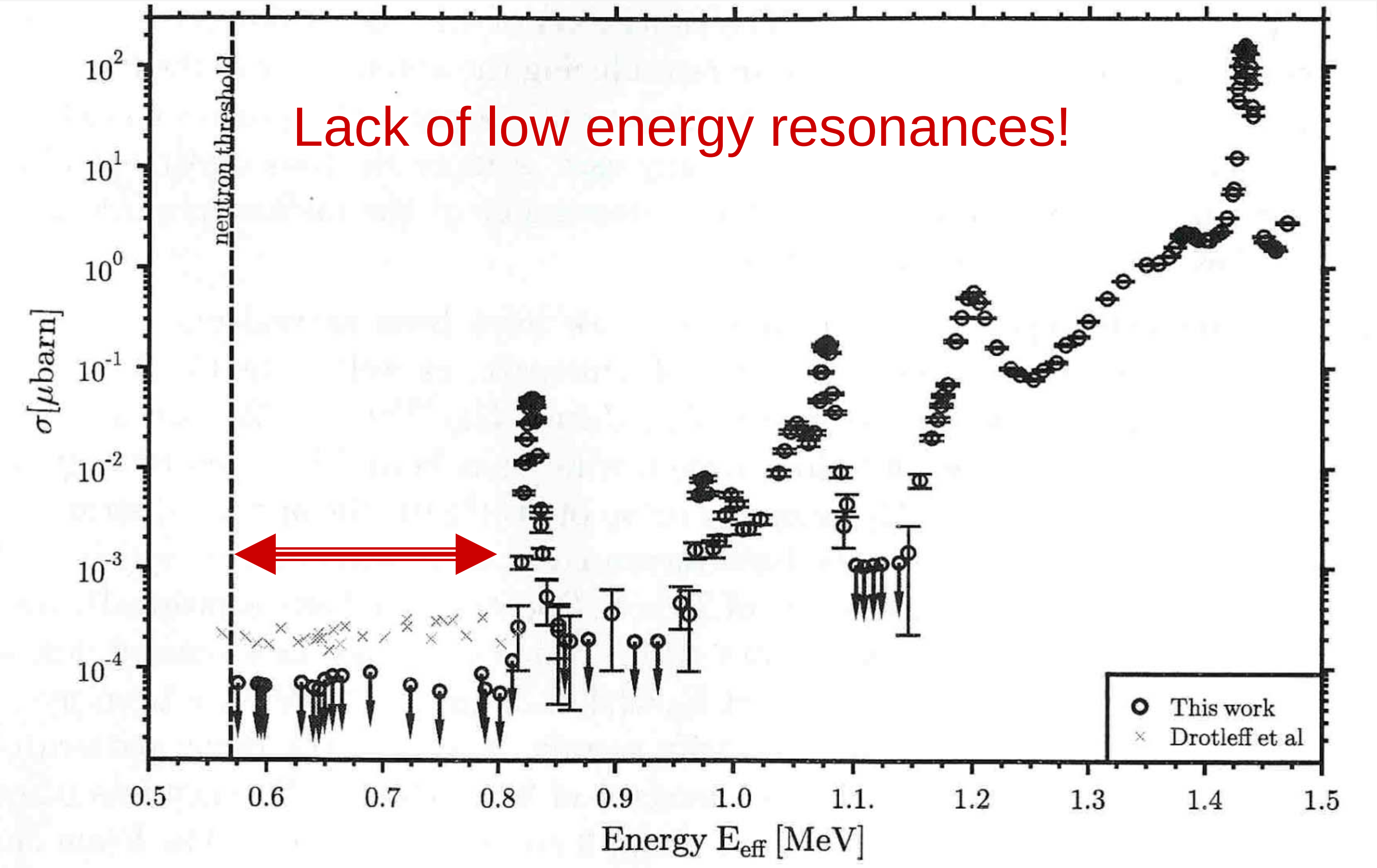
10.13 2^+ $\theta_\alpha^2=0.04$

10.05 1^- $\theta_\alpha^2=0.07$

$^{18}O(\alpha,\gamma)^{22}Ne$ reaction rate

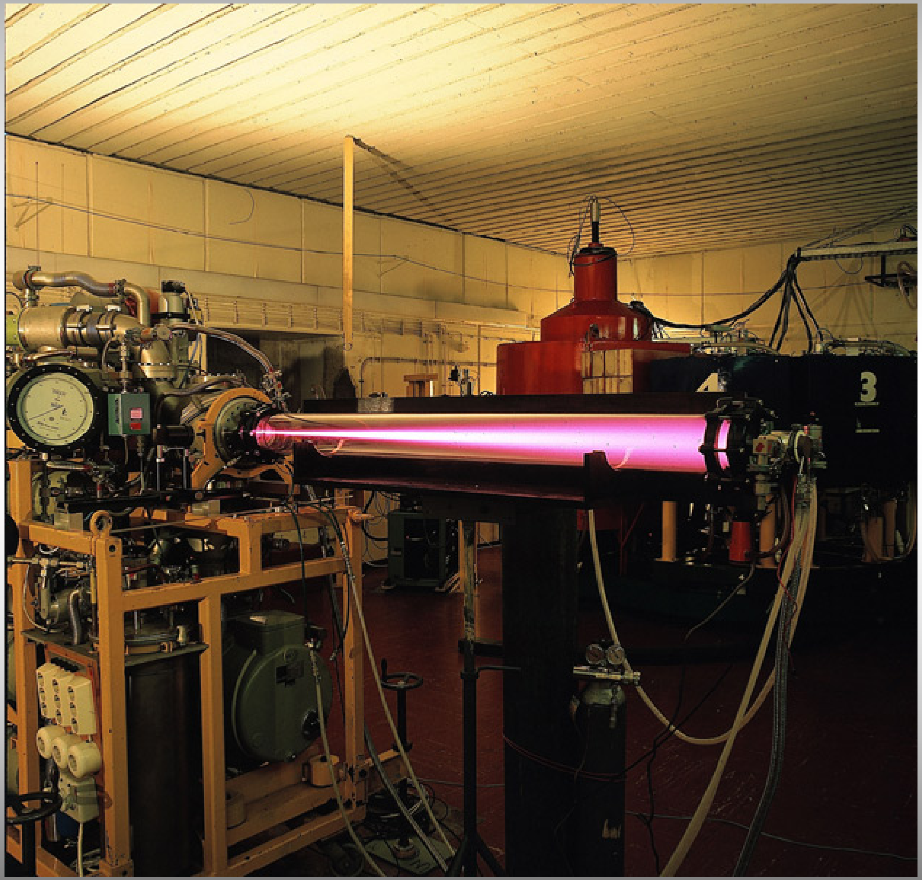


Example: $^{22}Ne(\alpha,n)^{25}Mg$

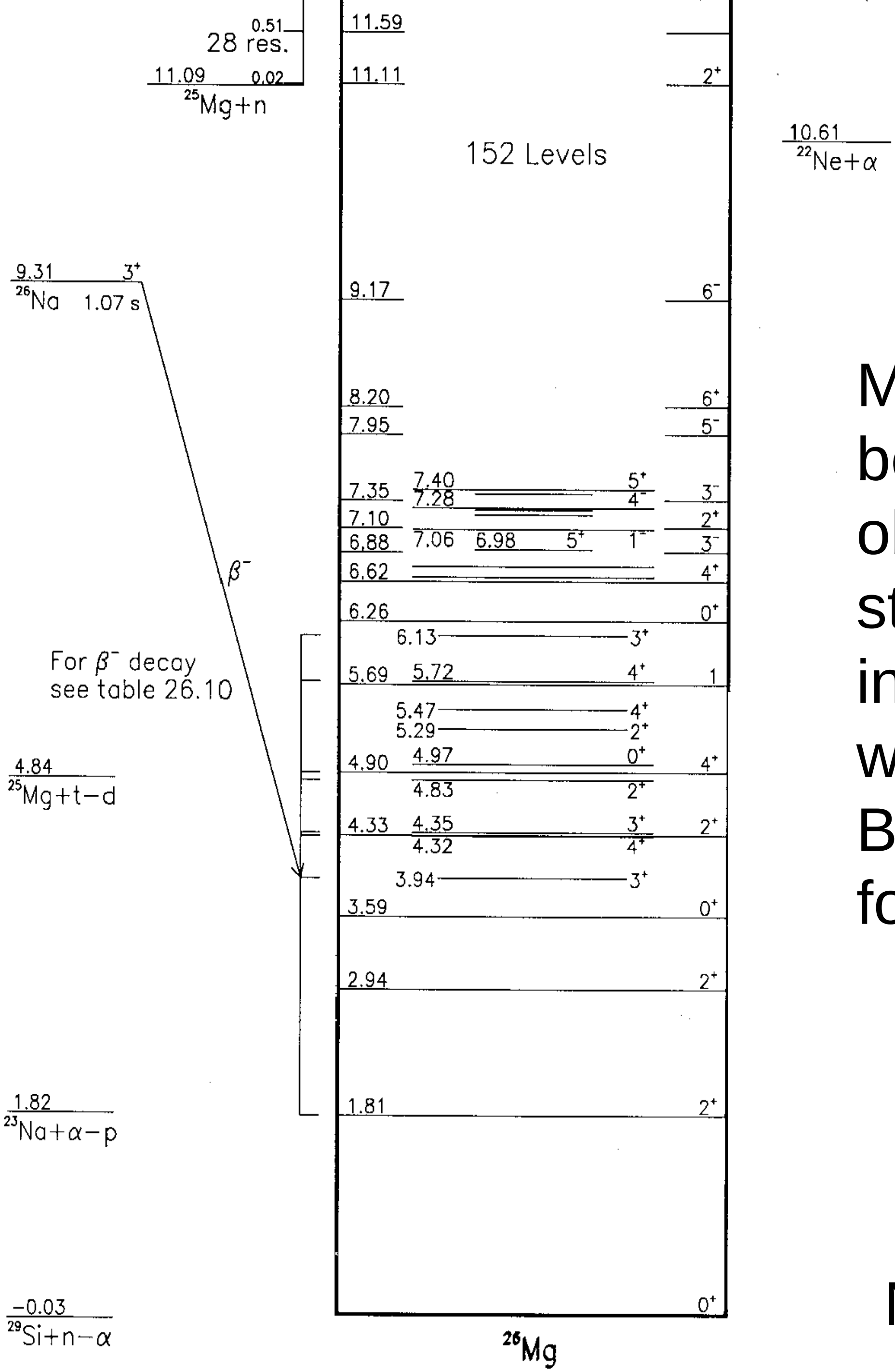


The potential existence of low energy resonances causes considerable uncertainty in reaction rate

Measurement with gas target



Low energy beam into extended ^{22}Ne gas-target



Present status on reaction rates

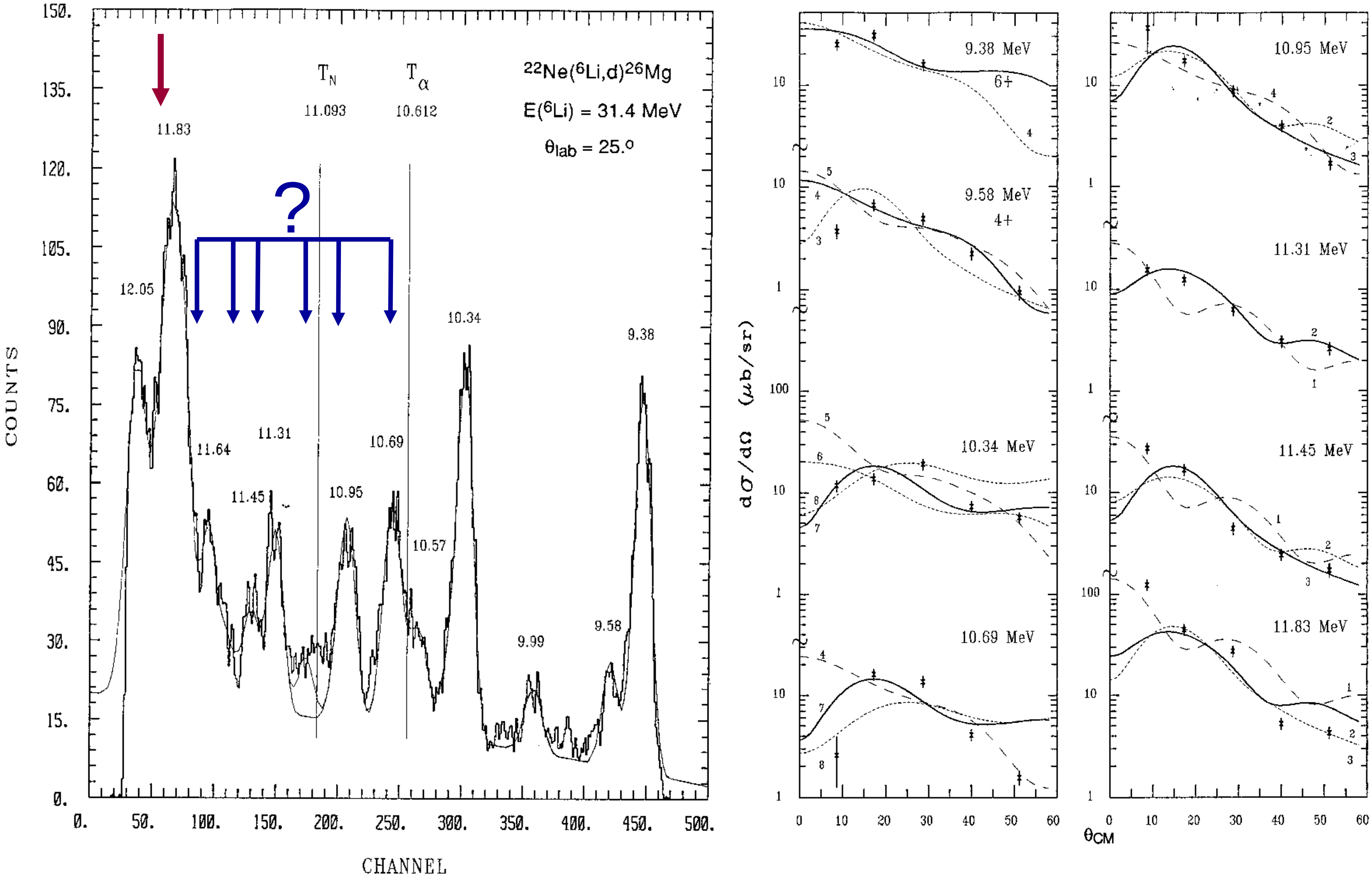
More than ~60 resonance levels between Q=10.61 MeV and the observed E_x=11.59 MeV resonant state! Observed are 28 resonances in the ^{25}Mg(n,γ) reaction channel which my show up in 22Ne(α,n). But the ^{22}Ne+α capture is selective for natural parity states:

$$\pi = (-1)^{\ell_\alpha}$$

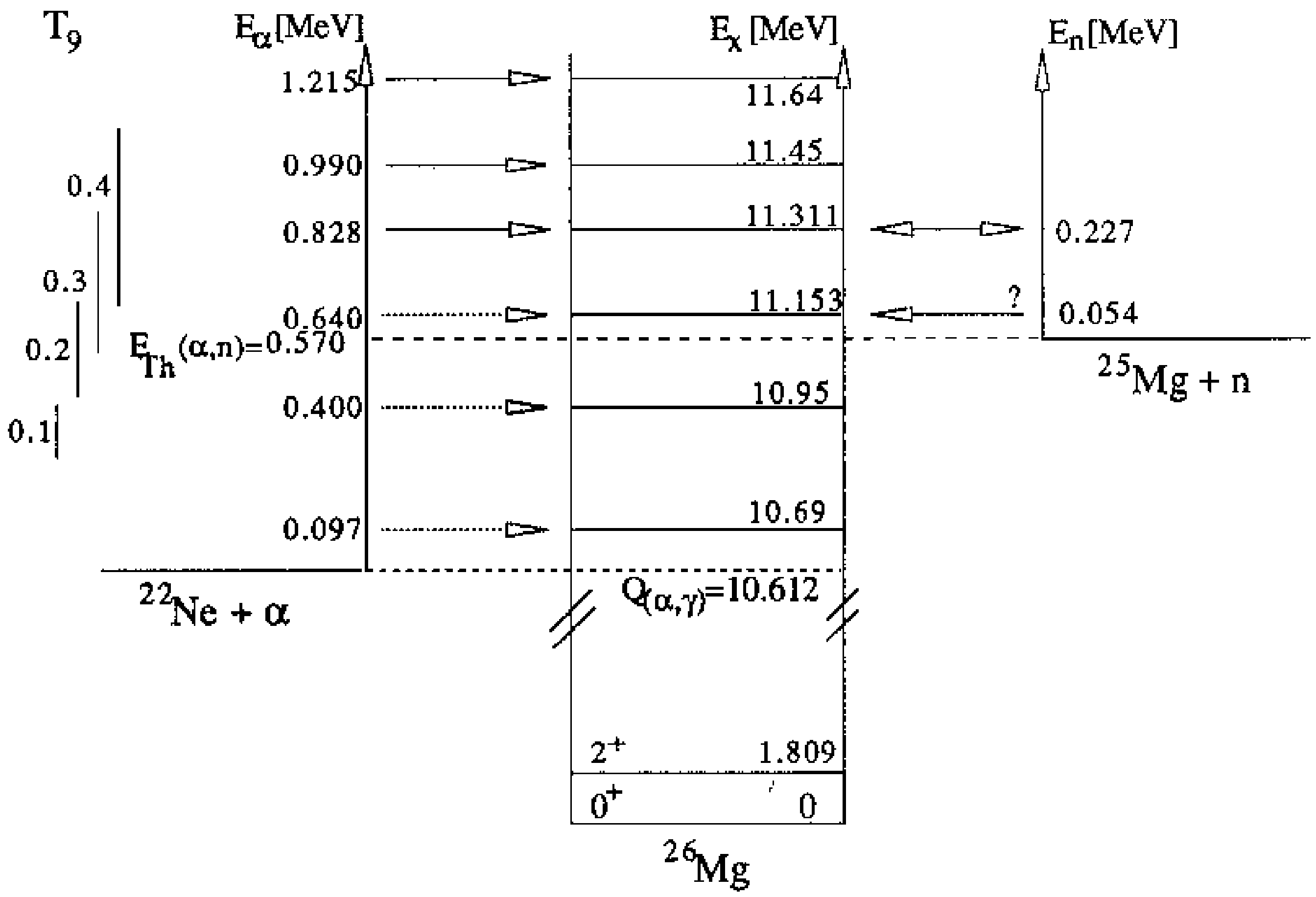
$$J^{\pi} = 0^{+}, 1^{-}, 2^{+}, 3^{-}, 4^{+}, 5^{-} .....$$

Not all states will contribute!

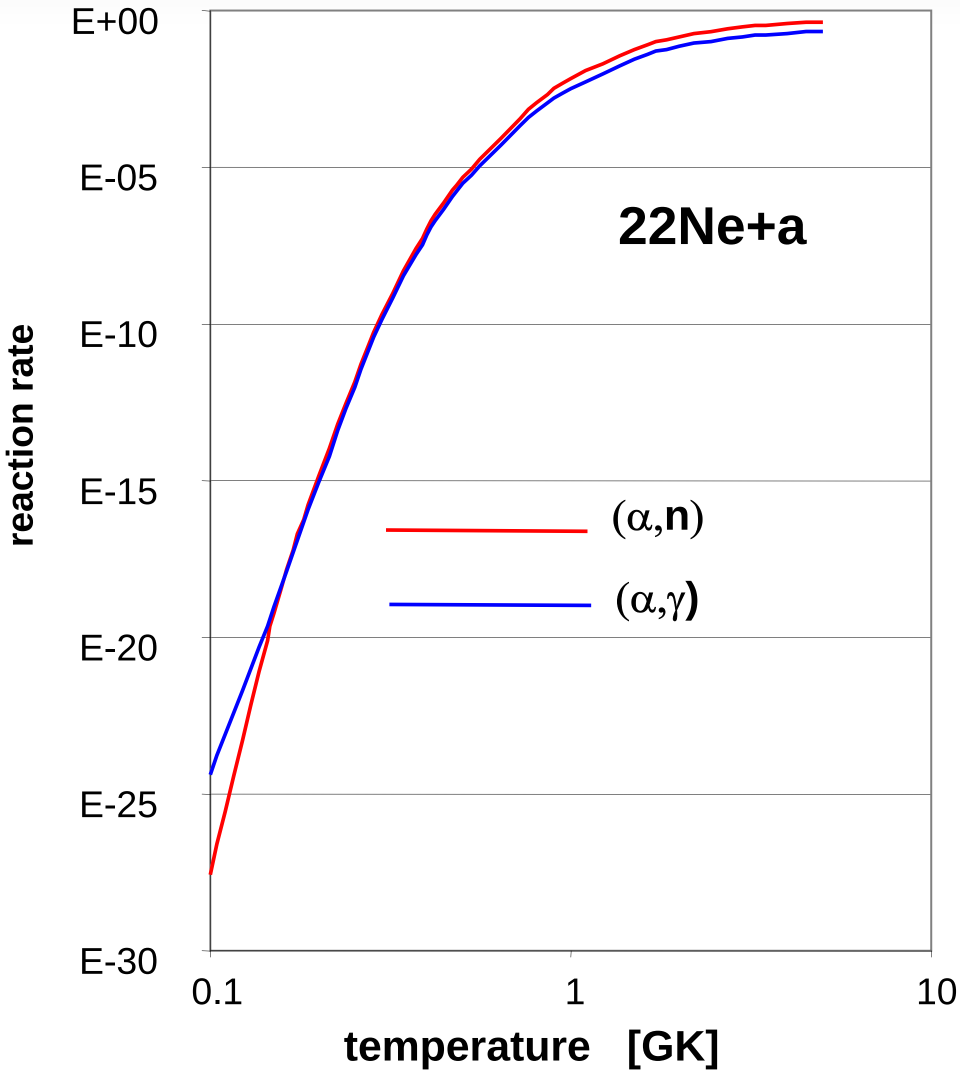
α-transfer studies of ^{26}Mg

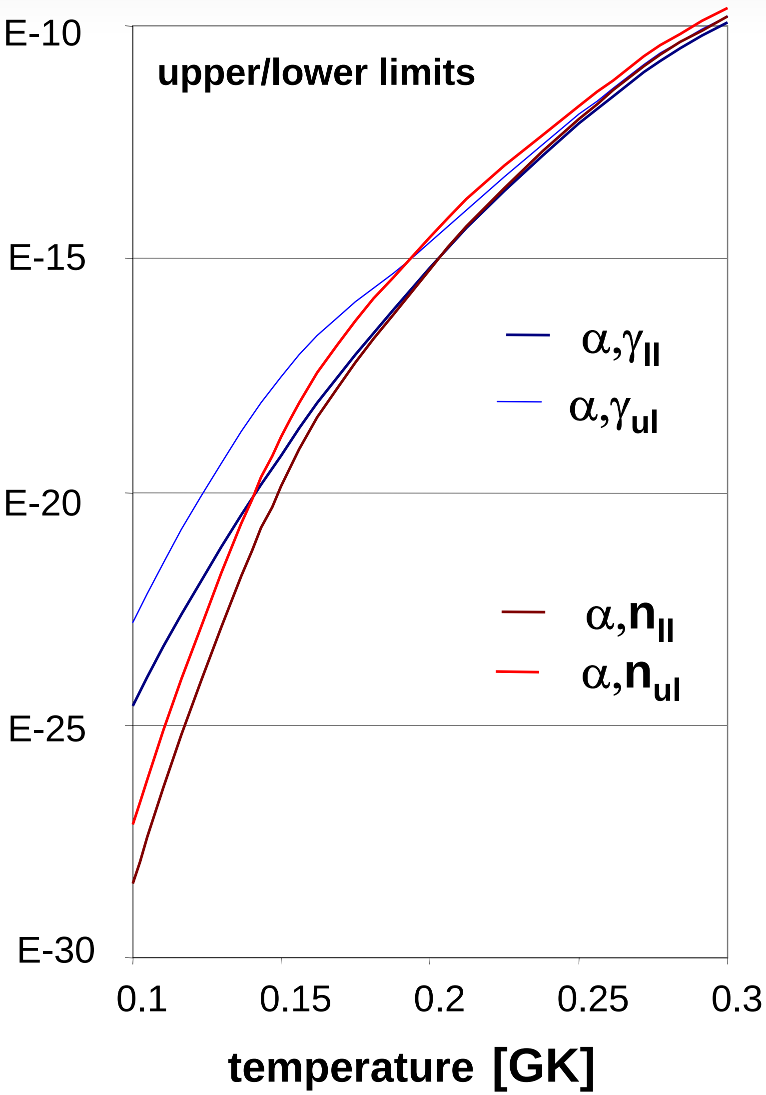


What is the present information?

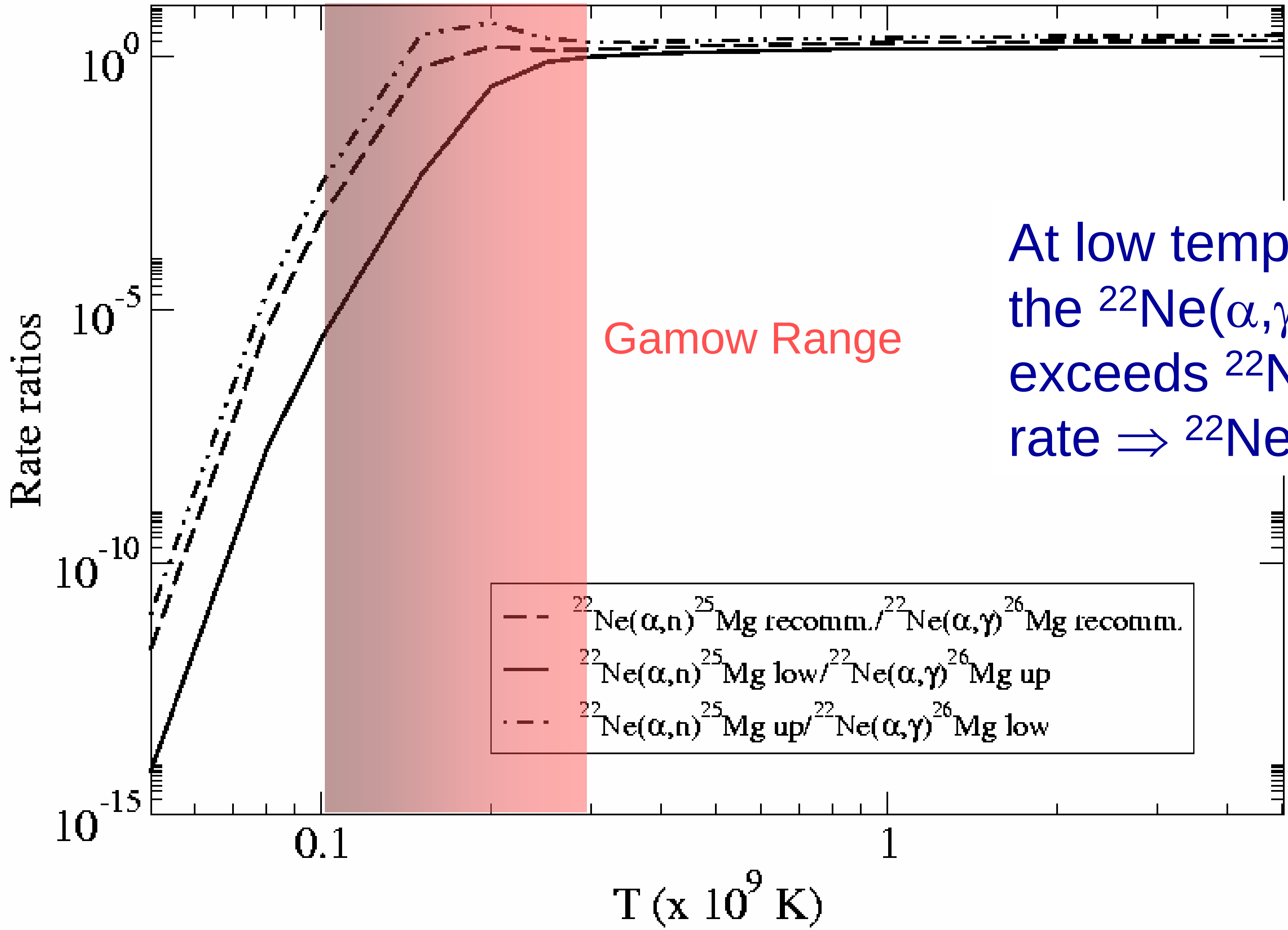


reaction rate limits



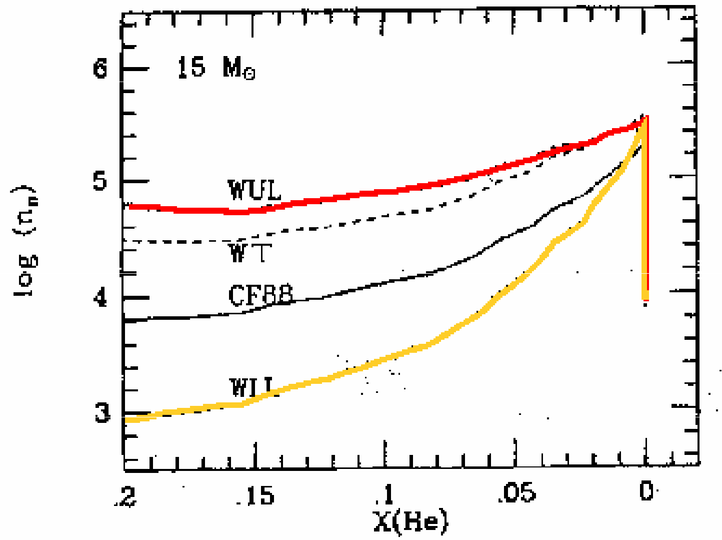


Neutron production conditions

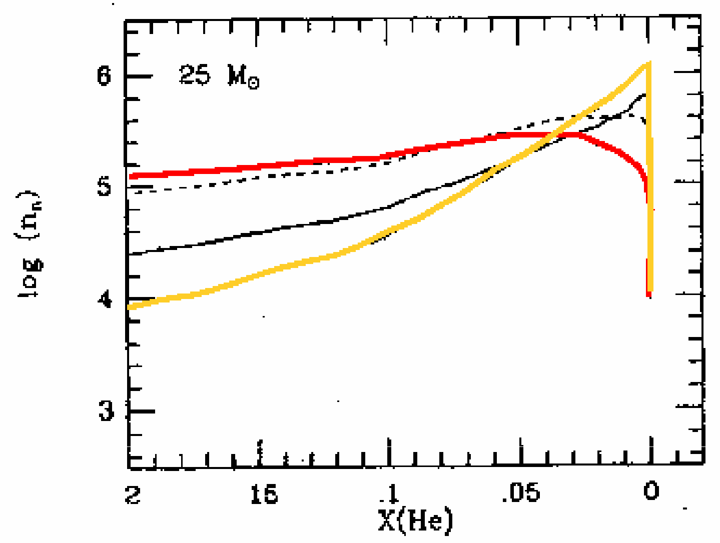


At low temperatures the $^{22}Ne(\alpha,\gamma)$ rate exceeds $^{22}Ne(\alpha,n)$ rate $\Rightarrow$ ^{22}Ne depletion

Uncertainties of α-Capture Reaction Rates



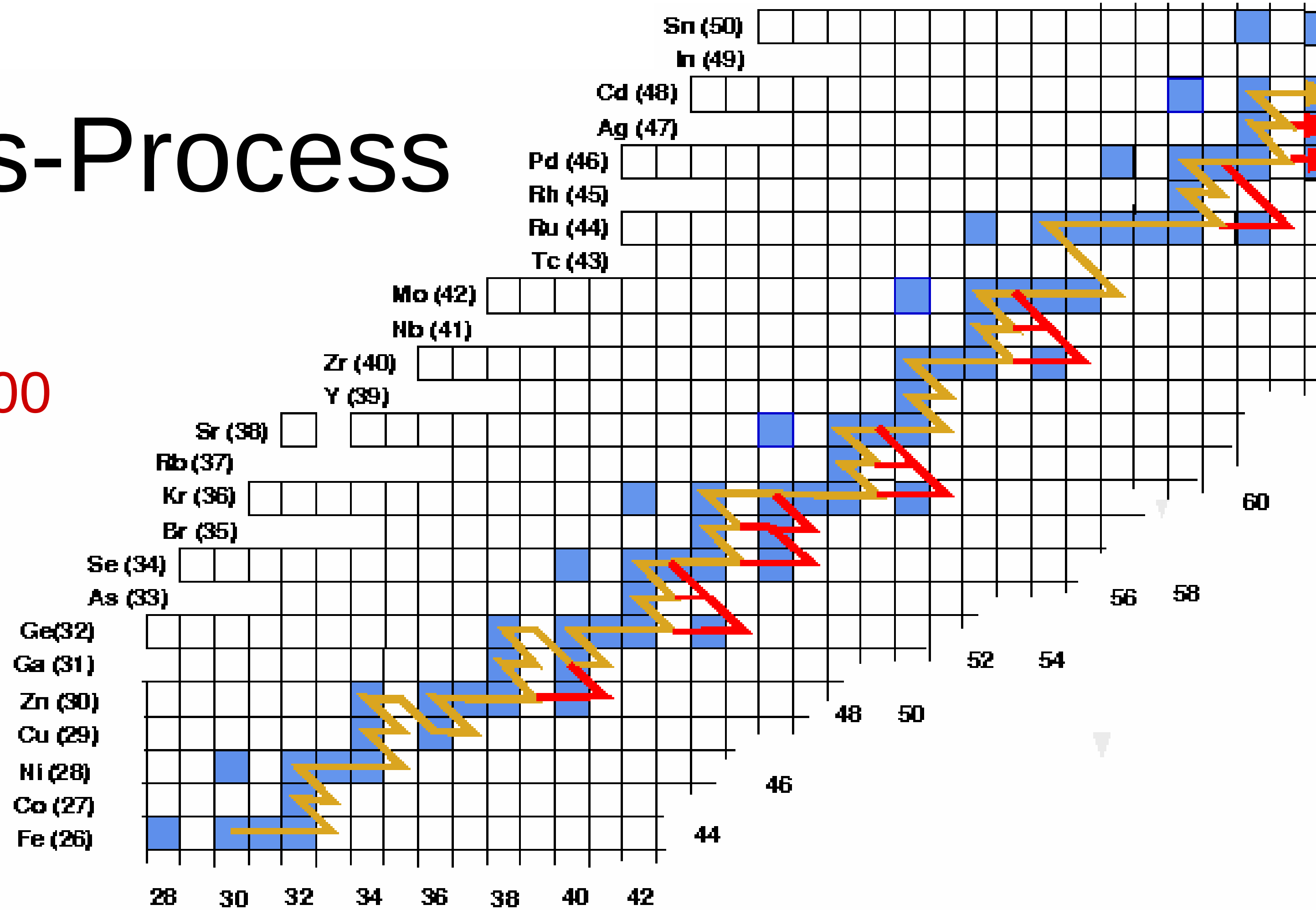
low rate: neutron production during the very last contraction phase before He exhaustion



high rate: neutron production during entire He burning phase

Weak s-Process

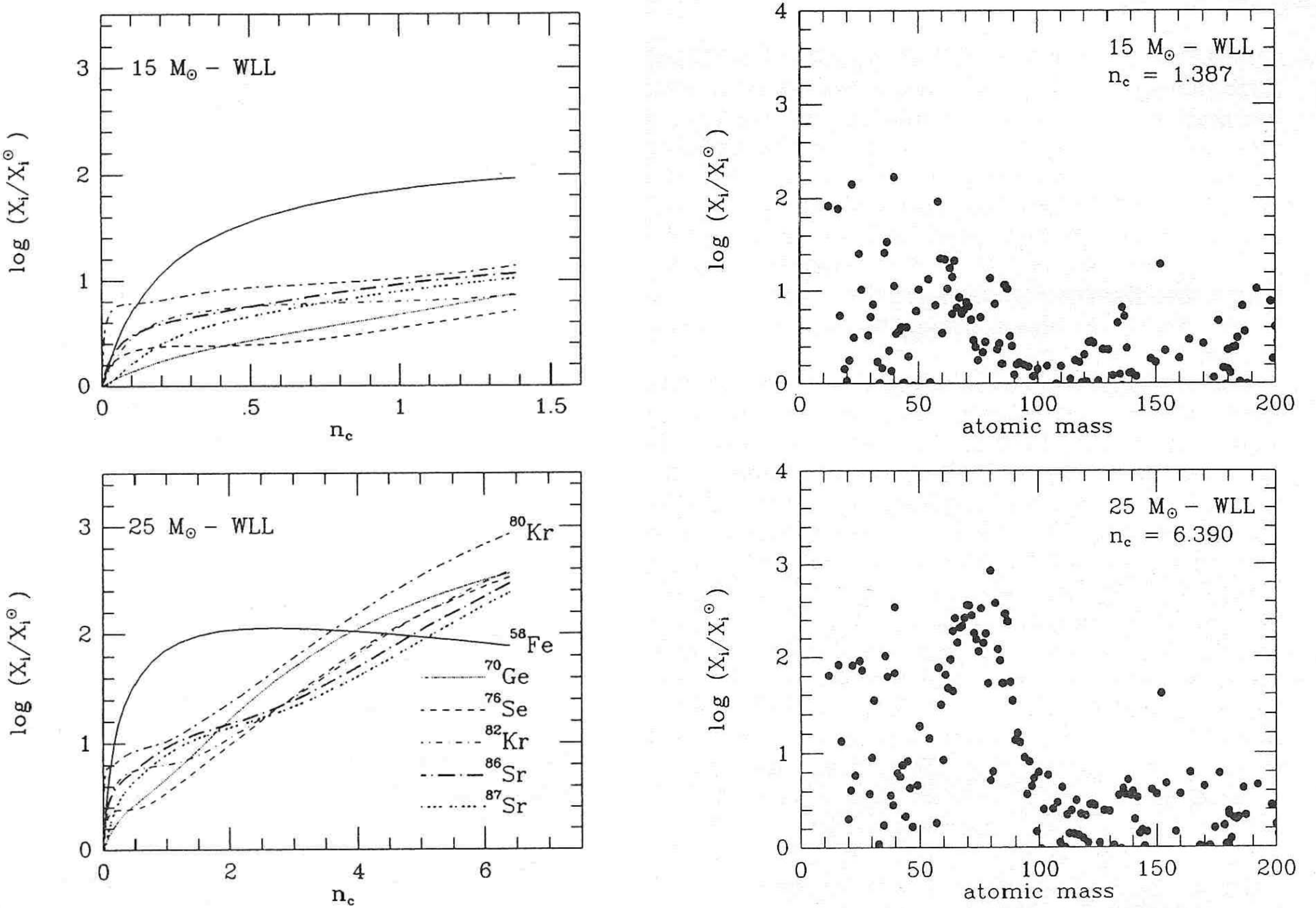
Leads to A~100



$$\frac{dY_n}{dt} = -\sum_X Y_X \cdot Y_n \cdot \rho \cdot N_A \langle \sigma \upsilon \rangle_{X(n,\gamma)} + Y_{^{22}Ne} \cdot Y_{^4He} \cdot \rho \cdot N_A \langle \sigma \upsilon \rangle_{^{22}Ne(\alpha,n)}$$

$$\frac{dY_{^{A+1}X}}{dt} = -Y_{^{A+1}X} \cdot Y_n \cdot \rho \cdot N_A \langle \sigma \upsilon \rangle_{^{A+1}X(n,\gamma)} + Y_{^AX} \cdot Y_n \cdot \rho \cdot N_A \langle \sigma \upsilon \rangle_{^AX(n,\gamma)}$$

Weak-s-process abundances



Multitude of open questions!

- impact of threshold cluster states in He burning
- low energy contributions to neutron sources
- neutron capture on light nuclei – neutron poison