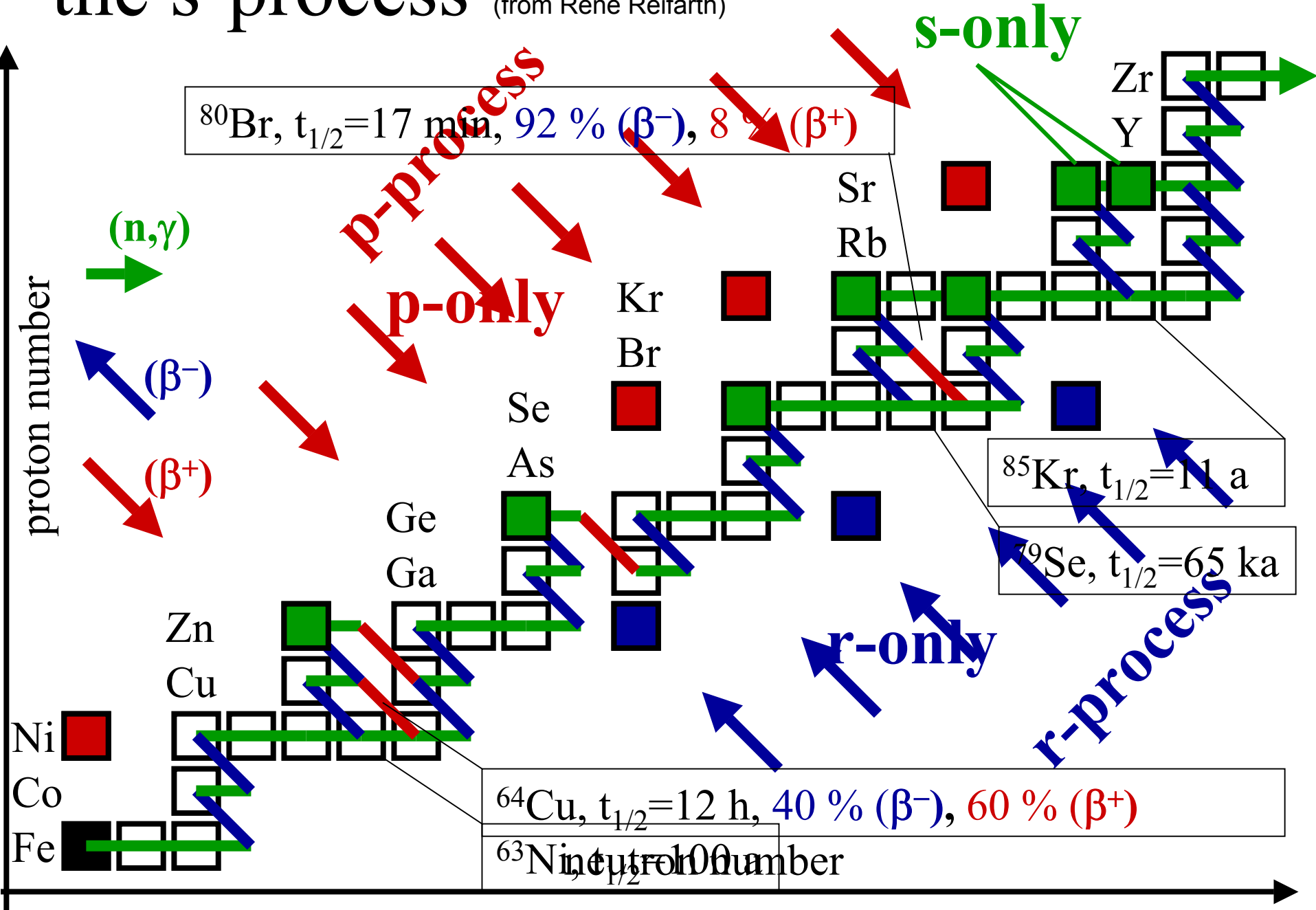
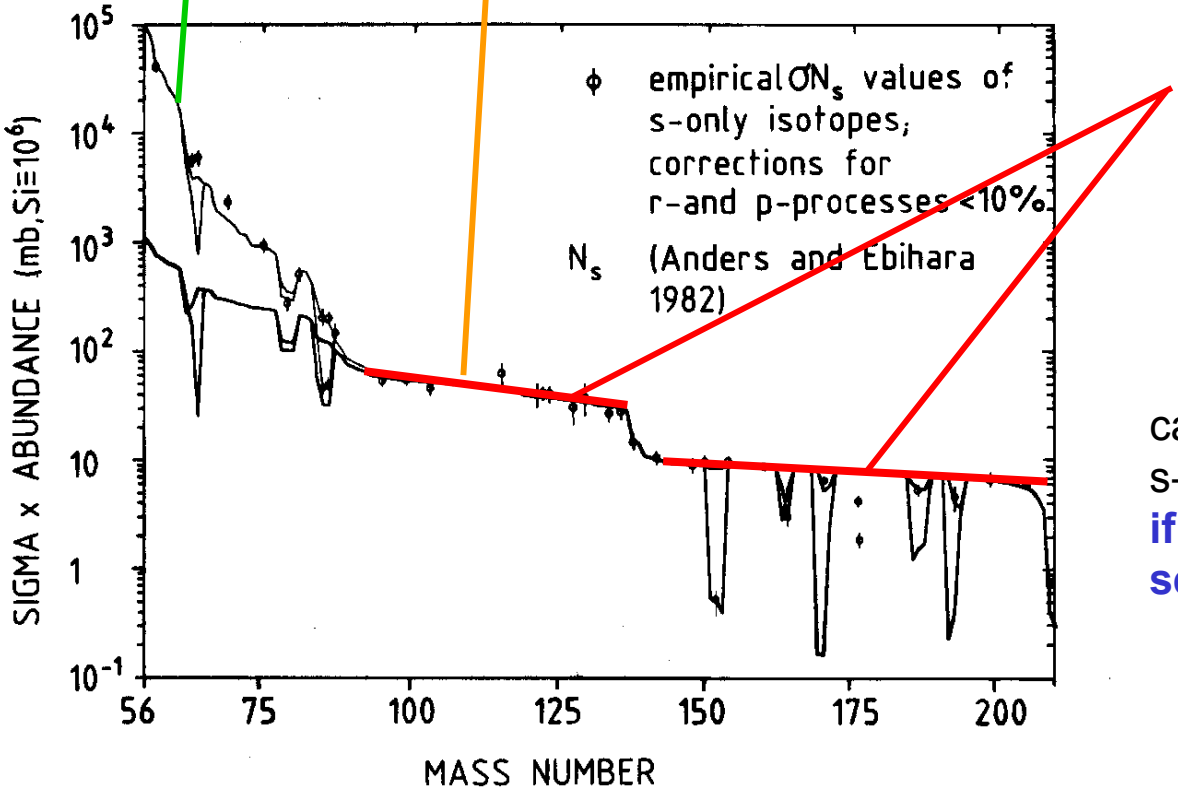
the s-process (from Rene Reifarth)



The sites of the s-process

weak s-process: core He/ shell C burning in massive stars

main s-process: He shell flashes in low mass TP-AGB stars



approx. steady flow

$$Y\lambda \propto Y\sigma_{(n,\gamma)} \approx \text{const}$$

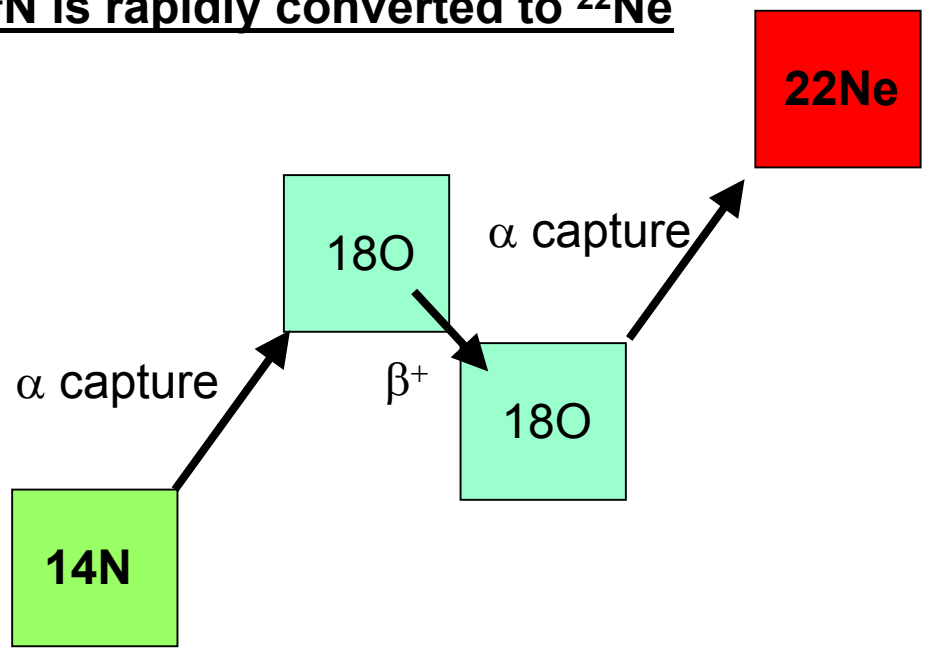
can easily interpolate s-contribution for s+r-nuclei **if neutron capture cross sections are known**

The weak s-process

Site: Core He burning (and shell C-burning) in massive stars (e.g. 25 solar masses)

He burning core contains initially ^{14}N

^{14}N is rapidly converted to ^{22}Ne



Towards the end of He burning T~3e8 K: **^{22}Ne(α,n)** provides a neutron source

→ preexisting Fe (and other nuclei) serve as seed for a (secondary) s-process

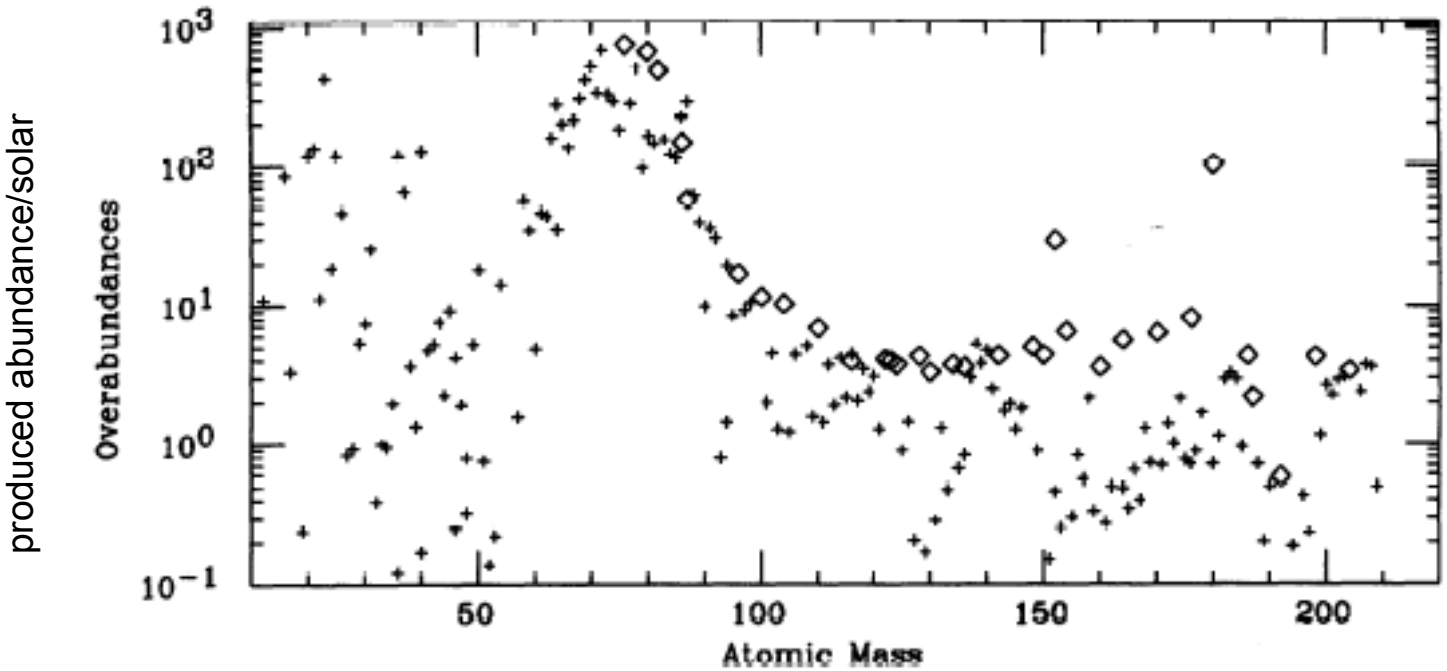
Typical conditions (Raiteri et al. ApJ367 (1991) 228 and ApJ371(1991)665:

Temperature	2.2 - 3.5 e8 K
Density	1 - 3e3 g/cm^3
Average neutron density	7e5 cm^{-3}
Peak neutron density	2e7 cm^{-3}
Neutron exposure τ *)	0.206 / mb

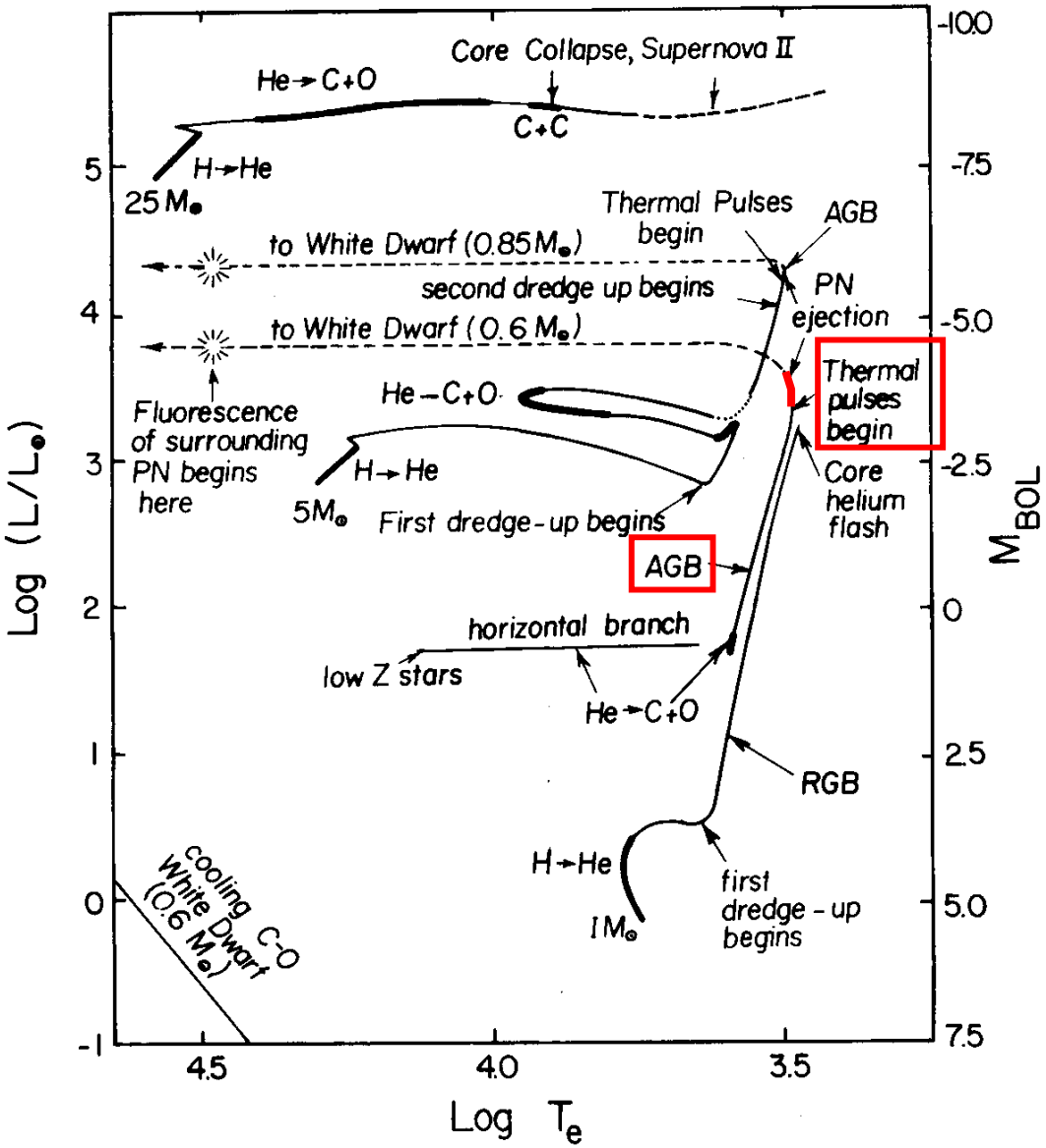
*) time integrated neutron flux

$$\tau = \int j_n(t)dt$$

Results:

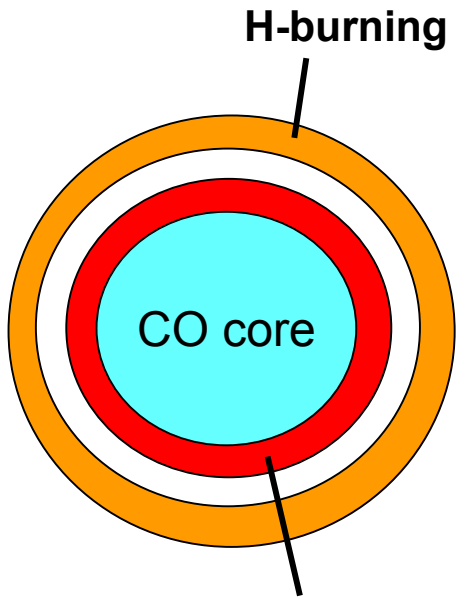


The main s-process



Site: low mass TP-AGB stars

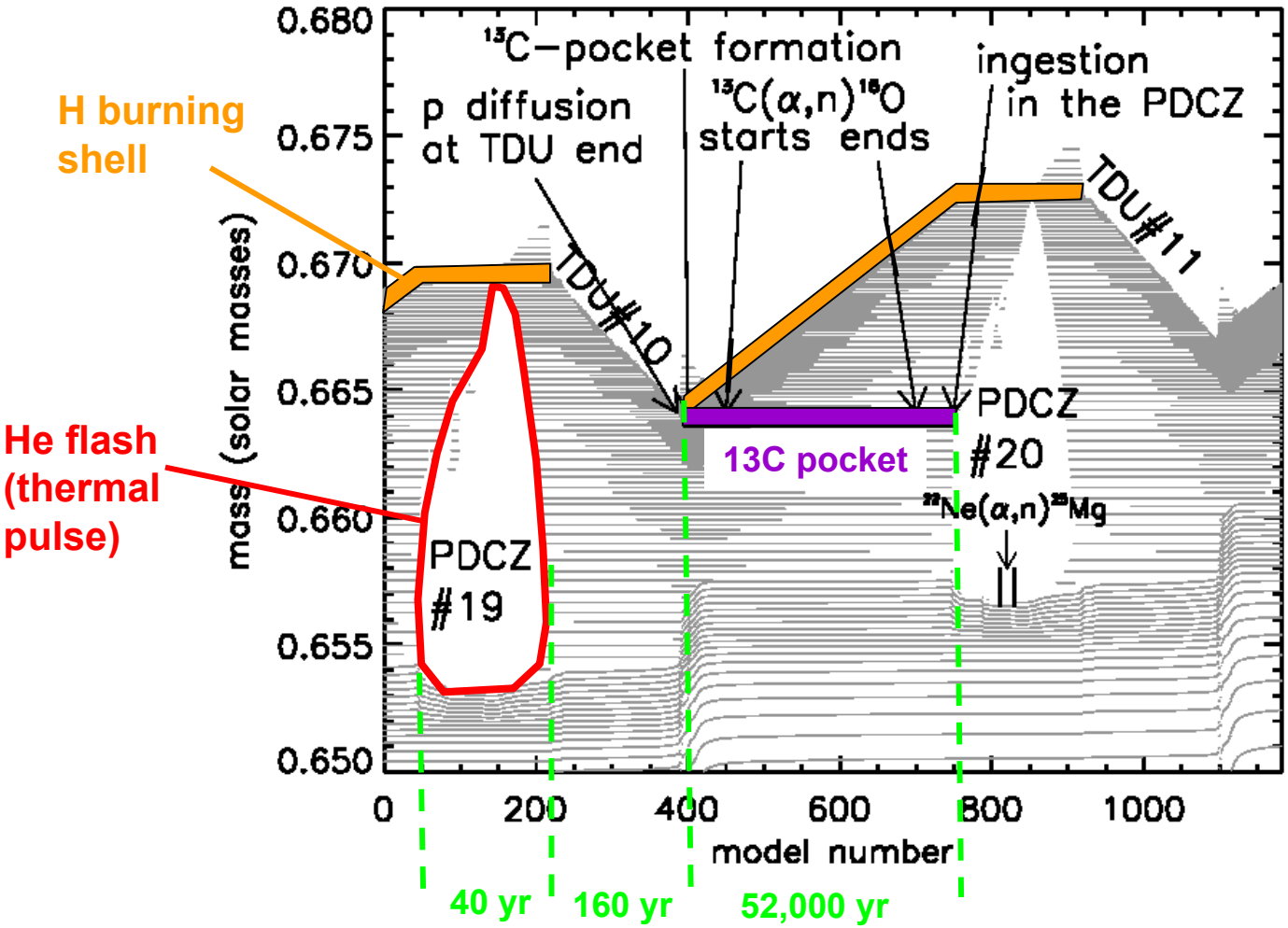
(thermally pulsing stars on the asymptotic giant branch in the HR diagram, 1.5 - 3 solar masses)



unstable - burns in flashes (thin shell instability)

H/He burning in a TP-AGB star

- number of He flashes in stars life: few – 100
- period of flashes: 1000 – 100,000 years



s-process in:

- **He flash via ^{22}Ne(α,n)**
- **^{13}C pocket via ^{13}C(α,n)**

(Lugaro et al. ApJ586(2003)1305)

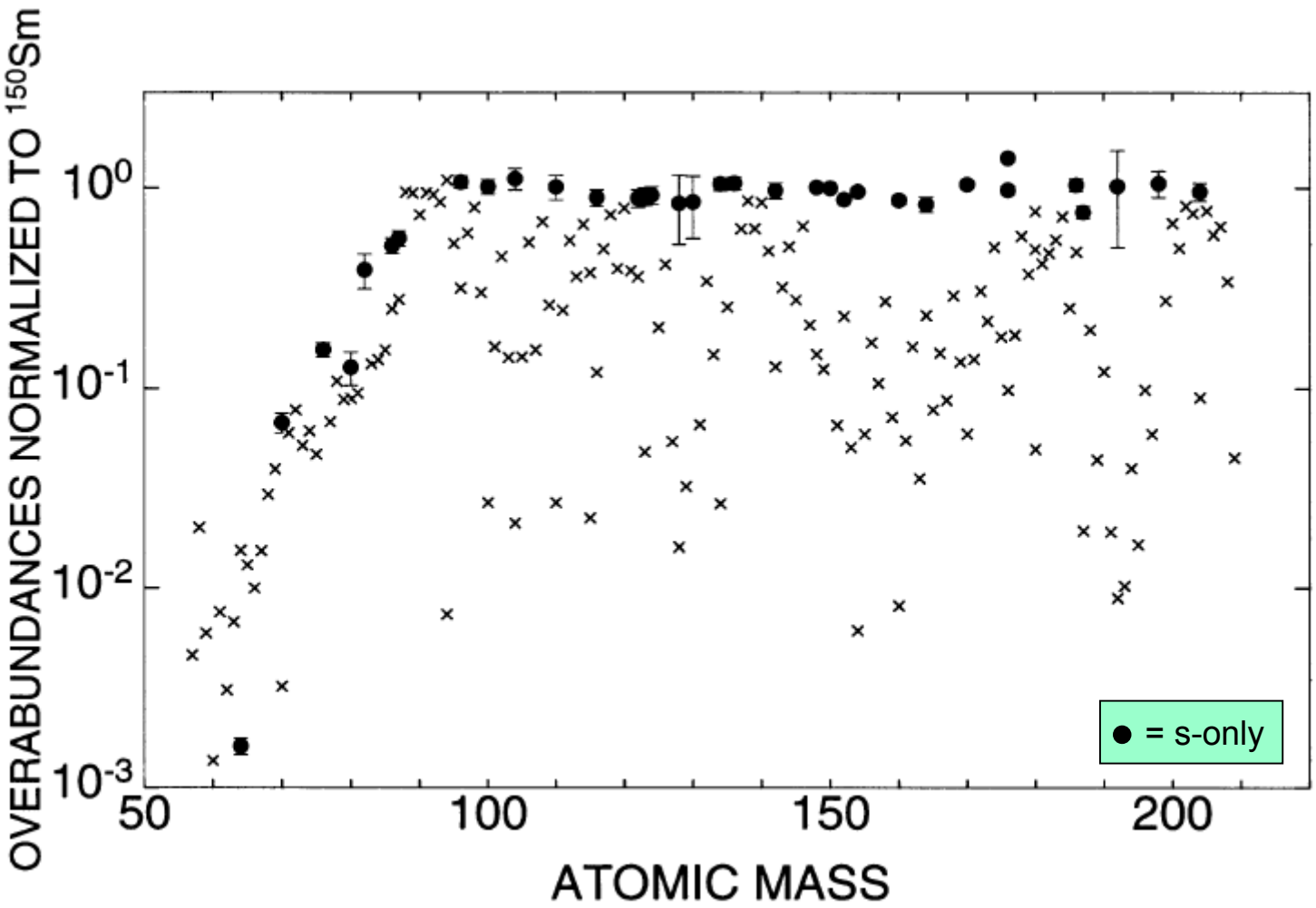
Conditions during the main s-process

	$^{13}C(\alpha,n)$ in pocket	$^{22}Ne(\alpha,n)$ in He flash
Temperature	0.9 x 10^8 K	2.7 x 10^8 K
Neutron density	7 x 10^7 cm^{-3}	10^{10} cm^{-3}
Duration	20,000 yr	few years
Neutron exposure τ *)	0.1 / mb	0.01 / mb

weaker but longer
main contribution
(90% of exposure)

short, intense burst
slight modification
of abundances
(branchings !)

Results for main s-process model

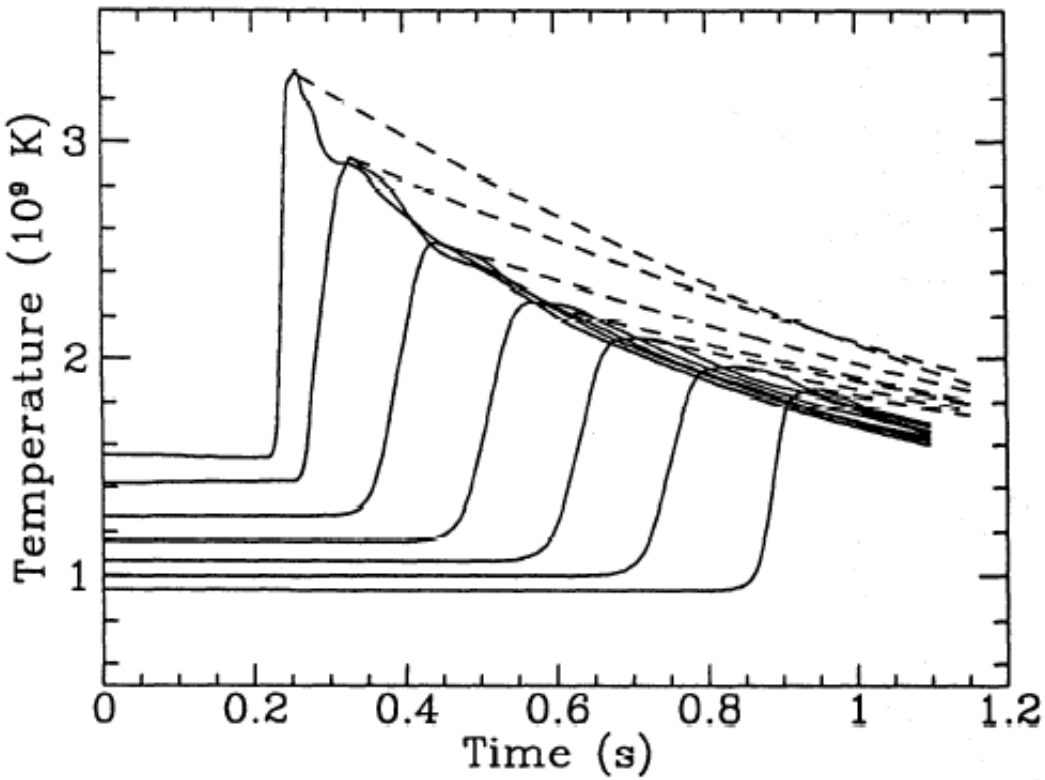


(Arlandini et al. ApJ525 (1999) 886)

The p-process

- produces p-rich, usually rare (0.1-1% isotopic fraction), stable isotopes
- Site: Supernova shock passing through O-Ne layers of progenitor star

Conditions at different locations in O/Ne layers during a Supernova:



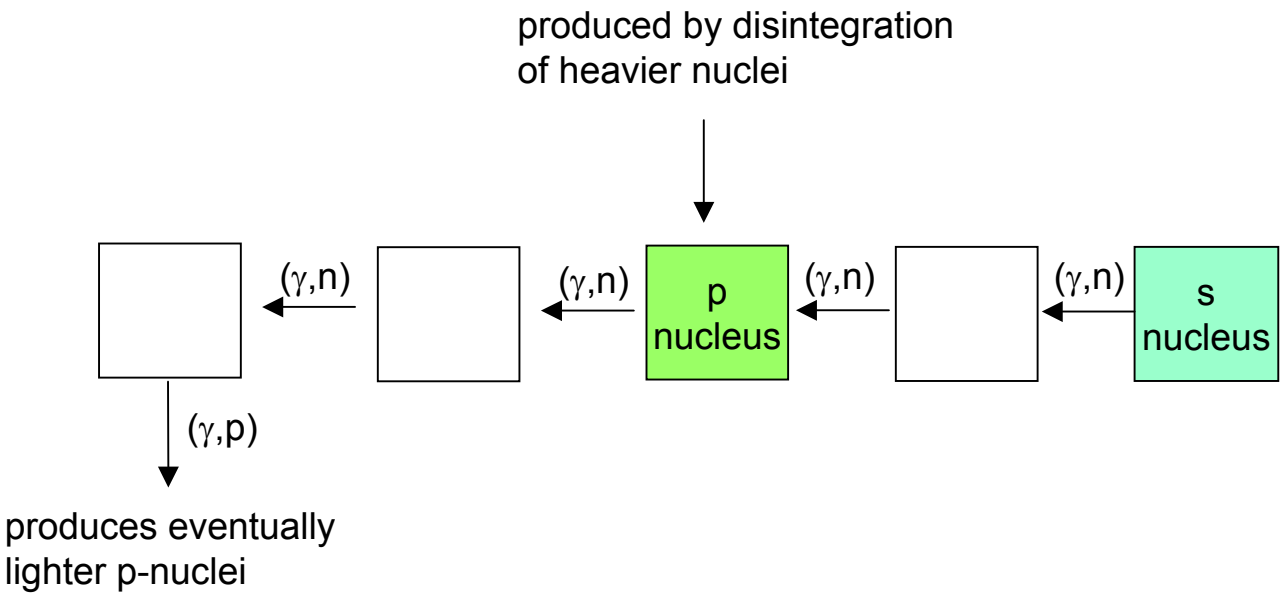
(Rayet et al. A&A298 (1995) 517)

p-process mechanism

Secondary process. Seed: previous s-process in low mass star)

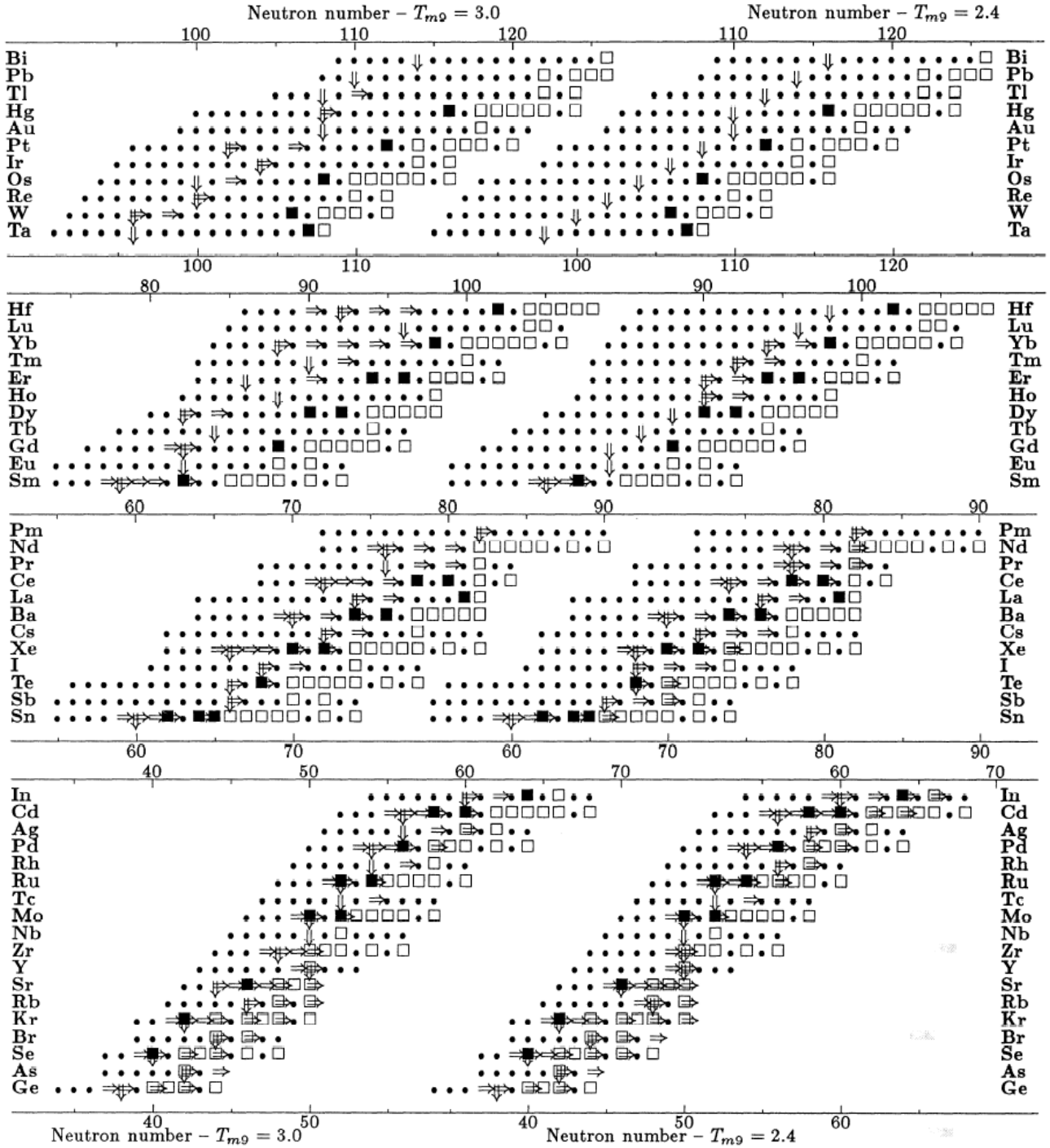
Series of
- (γ,n)
- (γ,p)
- (γ,α)

photodisintegration reactions (also called γ-process)



p-process path

Rayet et al. A&A227(1990)271

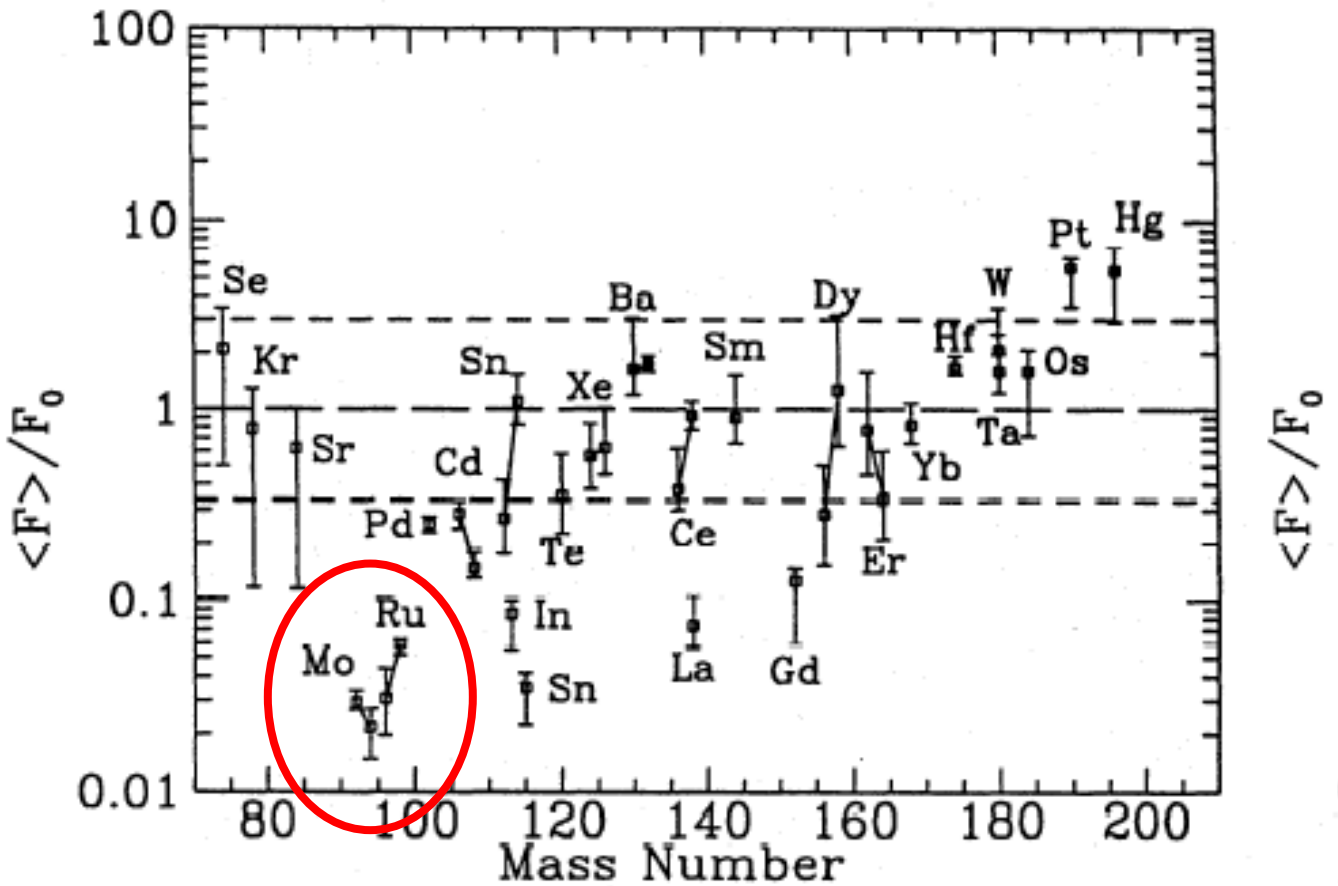


■ p-nuclei

→ (γ,n) flow stopped by (n,γ)

↓ flow proceeds via (γ,p) or (γ,α)

p-process model results



Mo-Ru underproduction problem (1-10% isotopic fraction !)

(Rayet et al. A&A298 (1995) 517)