Nuclear Rates Review

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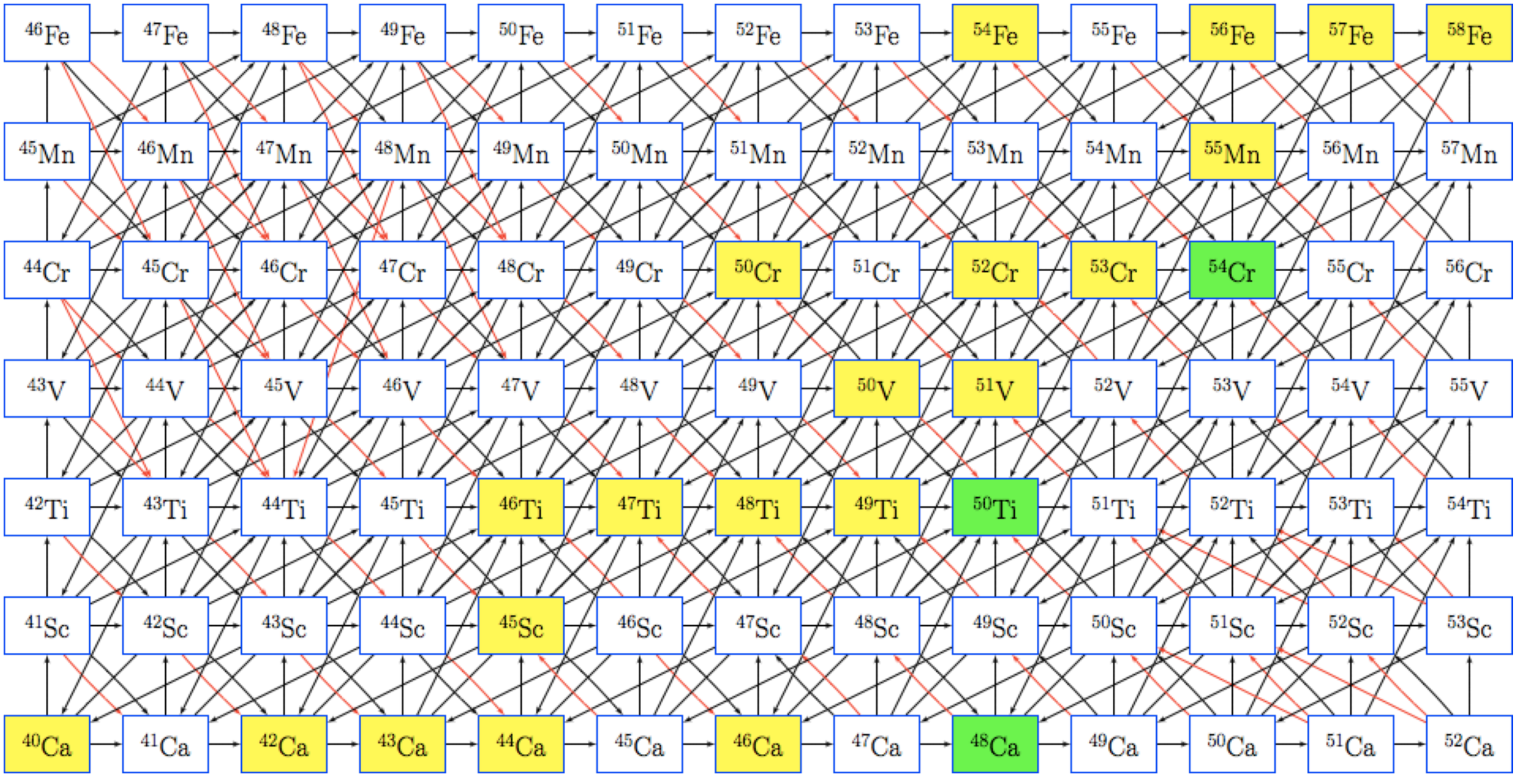
^{46}Fe	^{47}Fe	^{48}Fe	^{49}Fe	^{50}Fe	^{51}Fe	^{52}Fe	^{53}Fe	^{54}Fe	^{55}Fe	^{56}Fe	^{57}Fe	^{58}Fe
^{45}Mn	^{46}Mn	^{47}Mn	^{48}Mn	^{49}Mn	^{50}Mn	^{51}Mn	^{52}Mn	^{53}Mn	^{54}Mn	^{55}Mn	^{56}Mn	^{57}Mn
^{44}Cr	^{45}Cr	^{46}Cr	^{47}Cr	^{48}Cr	^{49}Cr	^{50}Cr	^{51}Cr	^{52}Cr	^{53}Cr	^{54}Cr	^{55}Cr	^{56}Cr
^{43}V	^{44}V	^{45}V	^{46}V	^{47}V	^{48}V	^{49}V	^{50}V	^{51}V	^{52}V	^{53}V	^{54}V	^{55}V
^{42}Ti	^{43}Ti	^{44}Ti	^{45}Ti	^{46}Ti	^{47}Ti	^{48}Ti	^{49}Ti	^{50}Ti	^{51}Ti	^{52}Ti	^{53}Ti	^{54}Ti
^{41}Sc	^{42}Sc	^{43}Sc	^{44}Sc	^{45}Sc	^{46}Sc	^{47}Sc	^{48}Sc	^{49}Sc	^{50}Sc	^{51}Sc	^{52}Sc	^{53}Sc
^{40}Ca	^{41}Ca	^{42}Ca	^{43}Ca	^{44}Ca	^{45}Ca	^{46}Ca	^{47}Ca	^{48}Ca	^{49}Ca	^{50}Ca	^{51}Ca	^{52}Ca


46Fe 47Fe 48Fe 49Fe 50Fe 51Fe 52Fe 53Fe 54Fe 55Fe 56Fe 57Fe 58Fe
45Mn 46Mn 47Mn 48Mn 49Mn 50Mn 51Mn 52Mn 53Mn 54Mn 55Mn 56Mn 57Mn
44Cr 45Cr 46Cr 47Cr 48Cr 49Cr 50Cr 51Cr 52Cr 53Cr 54Cr 55Cr 56Cr
43V 44V 45V 46V 47V 48V 49V 50V 51V 52V 53V 54V 55V
42Ti 43Ti 44Ti 45Ti 46Ti 47Ti 48Ti 49Ti 50Ti 51Ti 52Ti 53Ti 54Ti
41Sc 42Sc 43Sc 44Sc 45Sc 46Sc 47Sc 48Sc 49Sc 50Sc 51Sc 52Sc 53Sc
40Ca 41Ca 42Ca 43Ca 44Ca 45Ca 46Ca 47Ca 48Ca 49Ca 50Ca 51Ca 52Ca

Landscape for Reaction Rates

s process

^{54}Fe ^{56}Fe ^{57}Fe ^{58}Fe ^{60}Fe

^{55}Mn

^{50}Cr ^{52}Cr ^{53}Cr ^{54}Cr

^{50}V ^{51}V

^{46}Ti ^{47}Ti ^{48}Ti ^{49}Ti ^{50}Ti

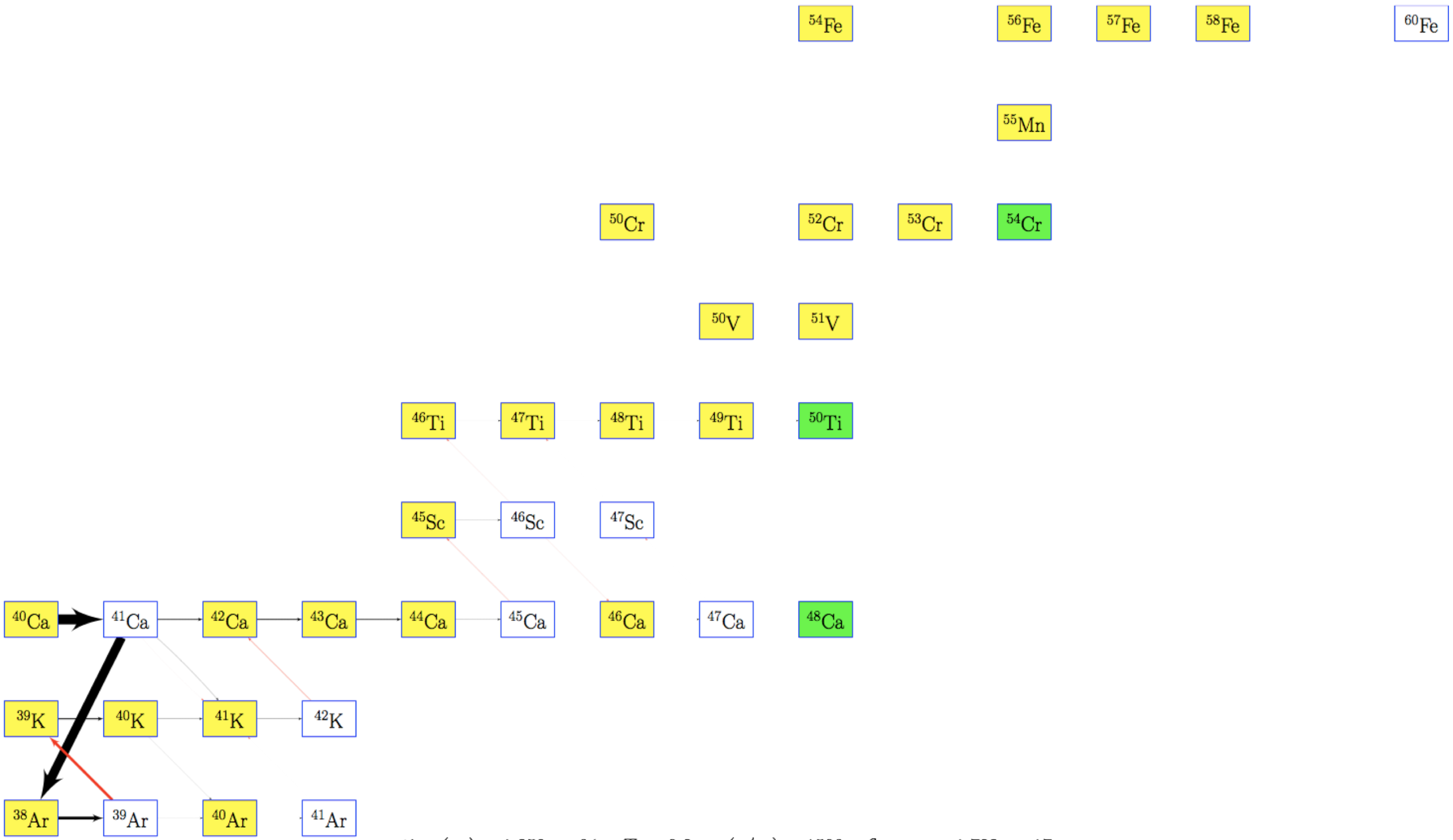
^{45}Sc

^{40}Ca → ^{41}Ca ^{42}Ca ^{43}Ca ^{44}Ca ^{46}Ca ^{48}Ca

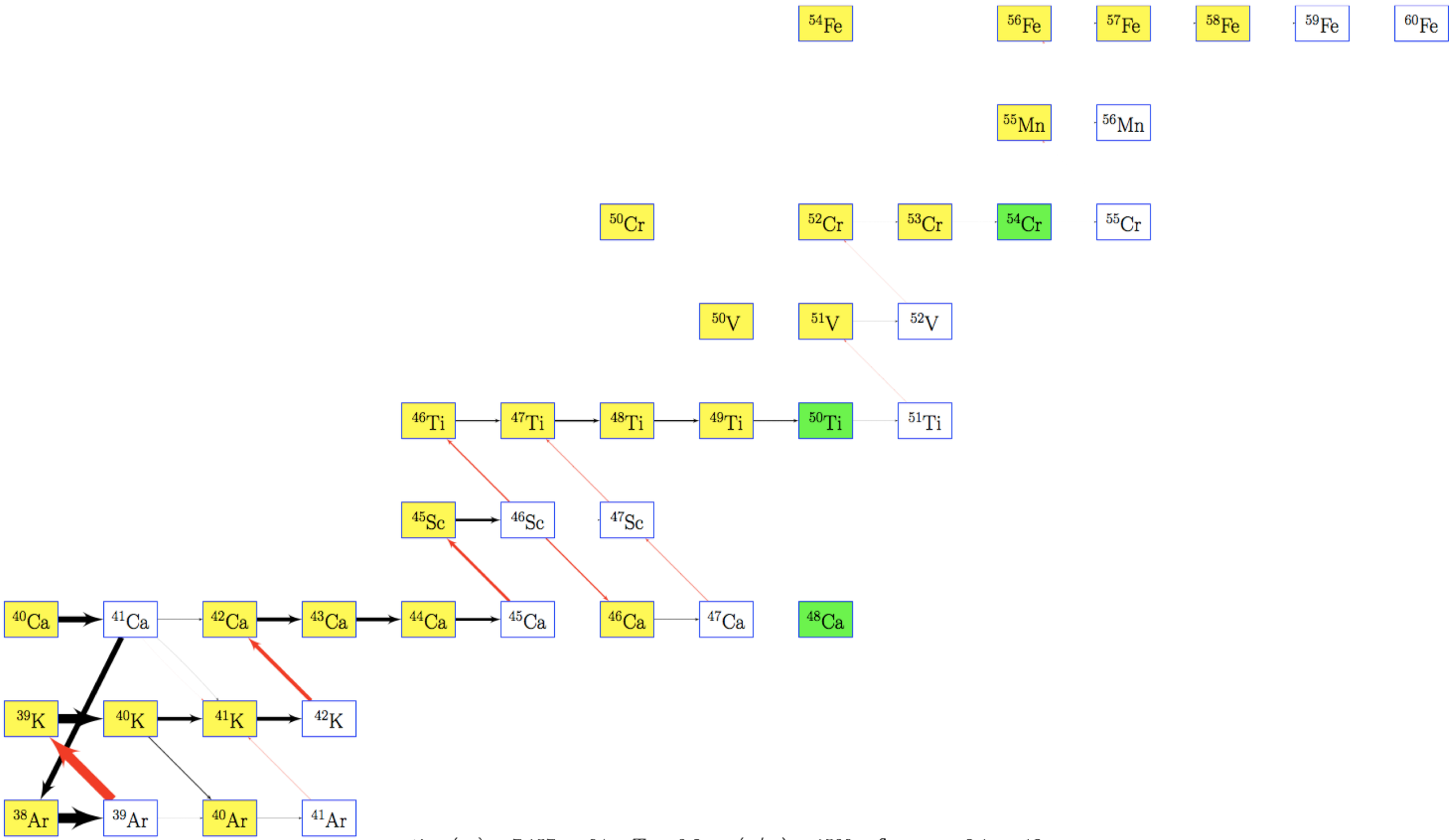
^{39}K ^{40}K ^{41}K

^{38}Ar ^{40}Ar

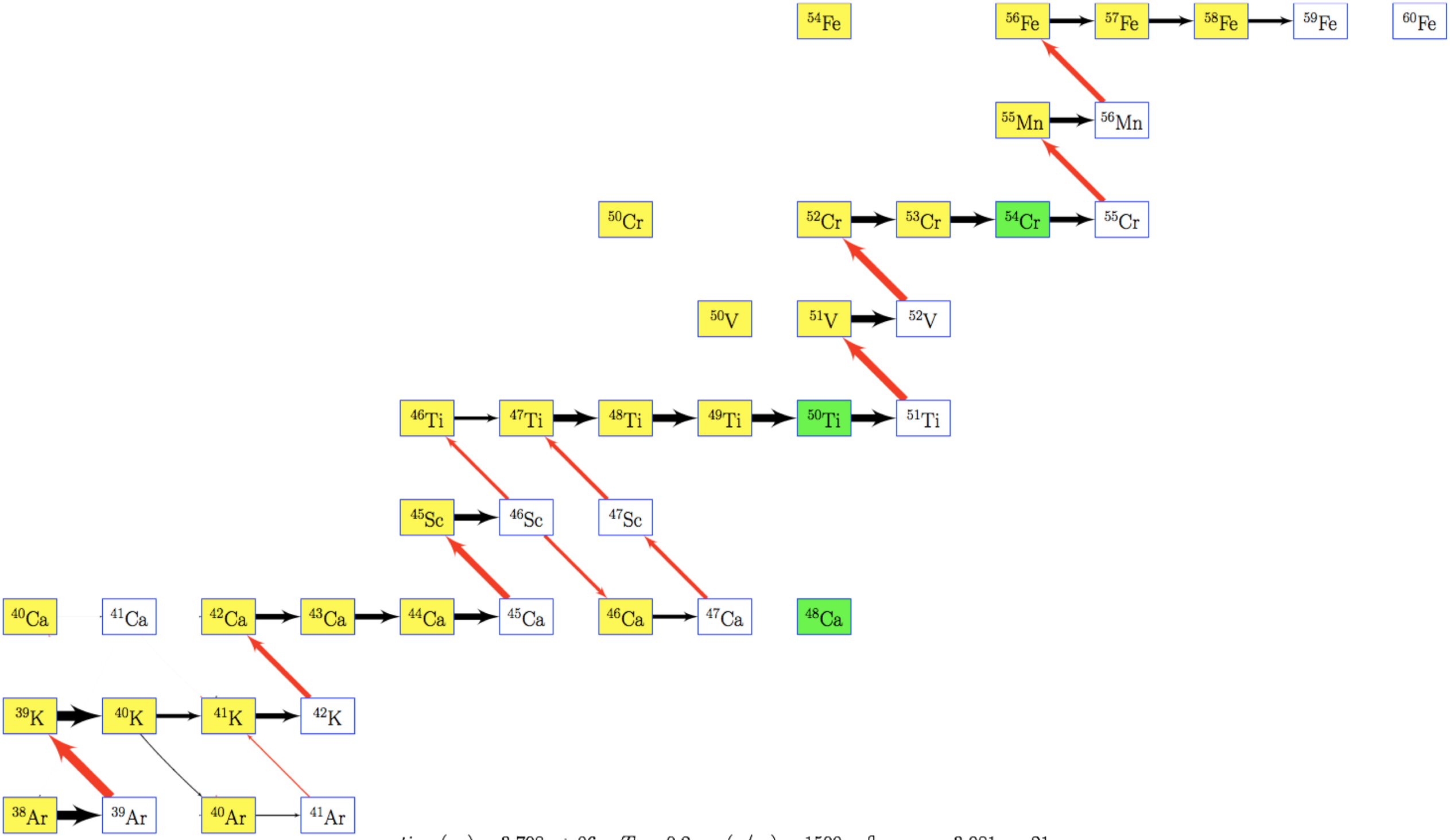
$time(yr) = 0.07575$ $T_9 = 0.2$ $\rho(g/cc) = 1500$ $\text{flow}_{max} = 5.496e-17$



$time(yr) = 1.259e+04 \quad T_9 = 0.2 \quad \rho(g/cc) = 1500 \quad \text{flow}_{max} = 1.722e-17$



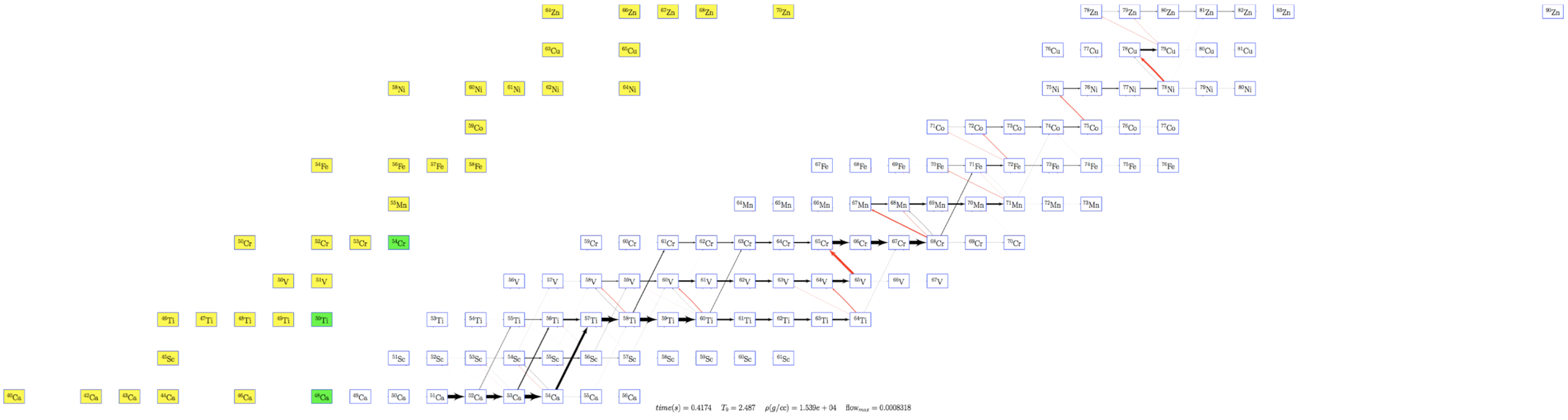
$time(yr) = 7.157e+04 \quad T_9 = 0.2 \quad \rho(g/cc) = 1500 \quad \text{flow}_{max} = 3.1e-18$

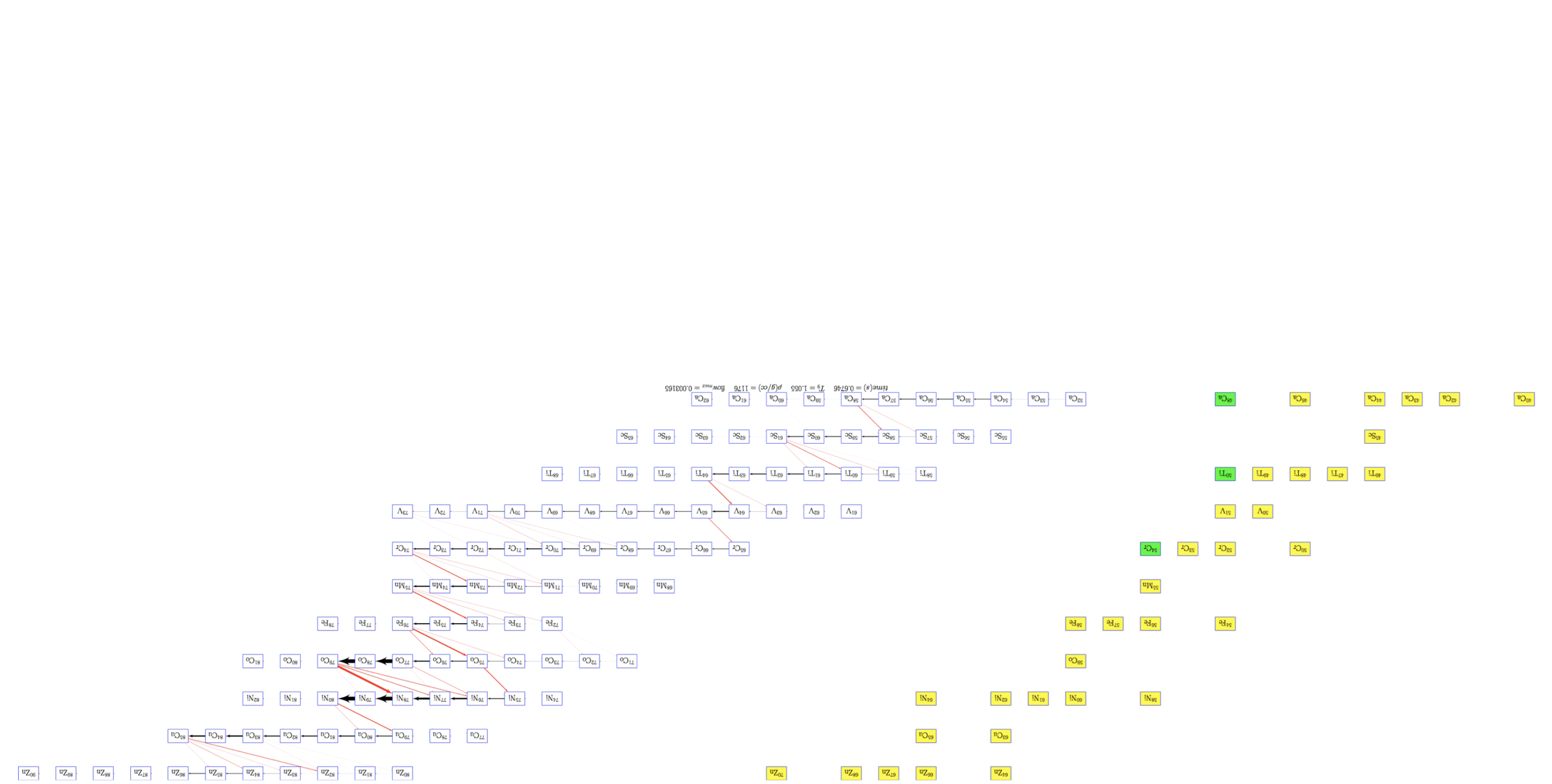


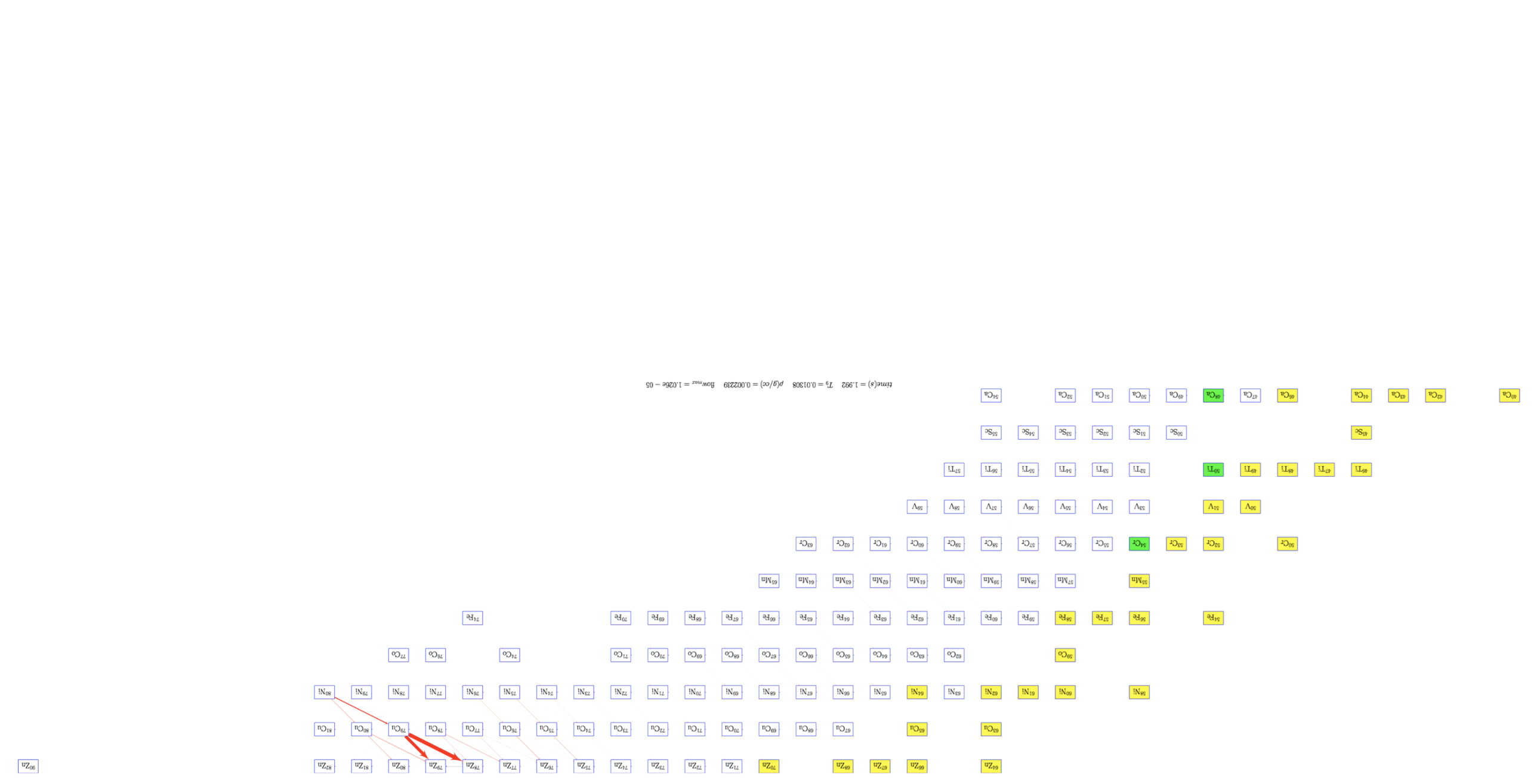
$time(yr) = 3.798e+06 \quad T_9 = 0.2 \quad \rho(g/cc) = 1500 \quad \text{flow}_{max} = 3.981e-21$

r process

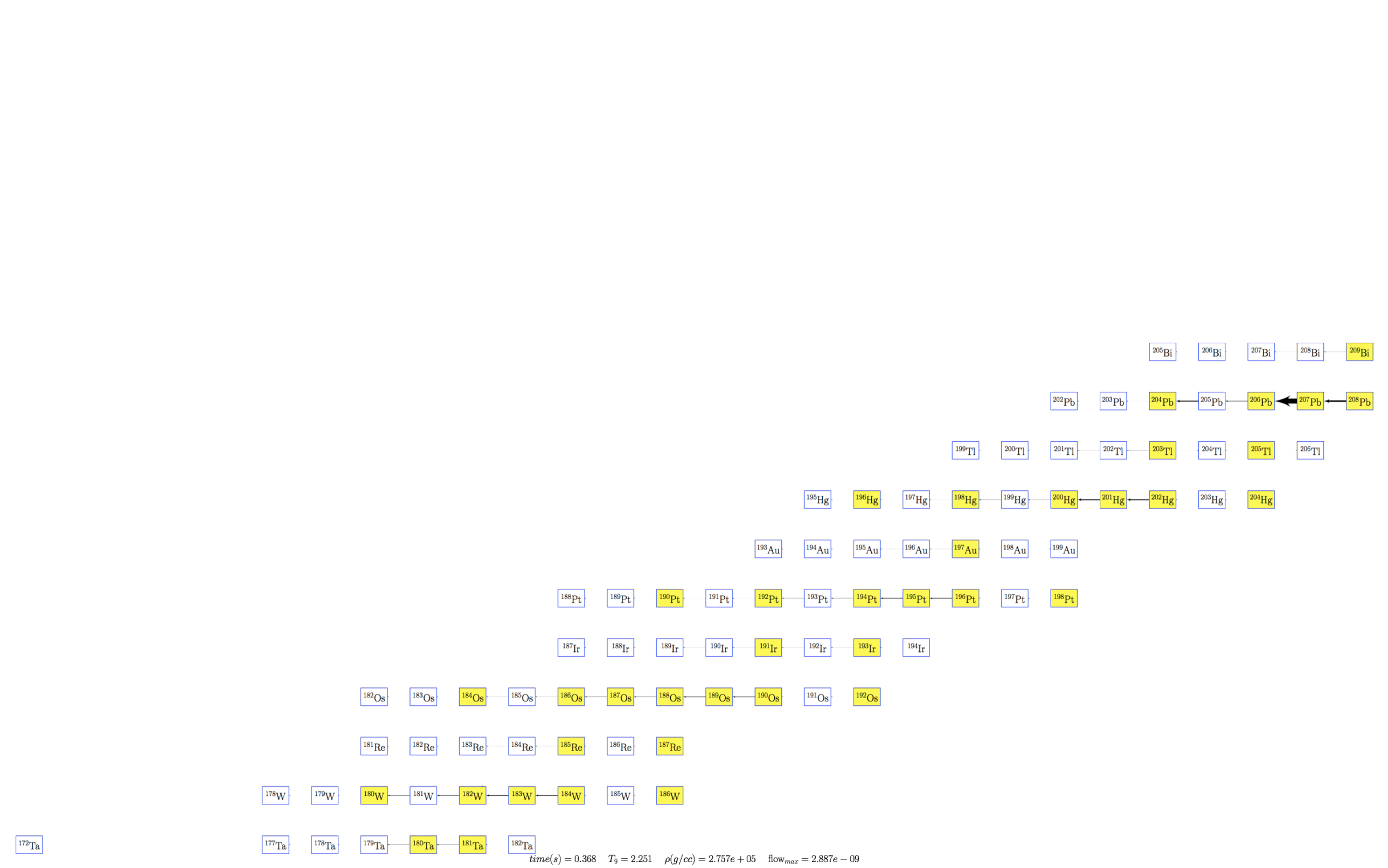
$time(s) = 0.1424 \quad T_9 = 6.222 \quad \rho(g/cc) = 2.409e+05 \quad \text{flow}_{max} = 0.0007999$


^{64}Zn ^{66}Zn ^{67}Zn ^{68}Zn ^{70}Zn
^{63}Cu ^{65}Cu
^{58}Ni ^{60}Ni ^{61}Ni ^{62}Ni ^{64}Ni
^{59}Co
^{54}Fe ^{56}Fe ^{57}Fe ^{58}Fe
^{55}Mn
^{50}Cr ^{52}Cr ^{53}Cr ^{54}Cr
^{50}V ^{51}V
^{46}Ti ^{47}Ti ^{48}Ti ^{49}Ti ^{50}Ti
^{45}Sc
^{40}Ca ^{42}Ca ^{43}Ca ^{44}Ca ^{46}Ca ^{48}Ca ^{49}Ca ^{50}Ca
^{51}Ca ^{52}Ca ^{53}Ca ^{54}Ca ^{55}Ca ^{56}Ca
^{51}Sc ^{52}Sc ^{53}Sc ^{54}Sc ^{55}Sc ^{56}Sc ^{57}Sc ^{58}Sc ^{59}Sc ^{60}Sc ^{61}Sc
^{53}Ti ^{54}Ti ^{55}Ti ^{56}Ti ^{57}Ti ^{58}Ti ^{59}Ti ^{60}Ti ^{61}Ti ^{62}Ti ^{63}Ti ^{64}Ti
^{56}V ^{57}V ^{58}V ^{59}V ^{60}V ^{61}V ^{62}V ^{63}V ^{64}V ^{65}V ^{66}V ^{67}V
^{59}Cr ^{60}Cr ^{61}Cr ^{62}Cr ^{63}Cr ^{64}Cr ^{65}Cr ^{66}Cr ^{67}Cr ^{68}Cr ^{69}Cr ^{70}Cr
^{64}Mn ^{65}Mn ^{66}Mn ^{67}Mn ^{68}Mn ^{69}Mn ^{70}Mn ^{71}Mn ^{72}Mn ^{73}Mn
^{67}Fe ^{68}Fe ^{69}Fe ^{70}Fe ^{71}Fe ^{72}Fe ^{73}Fe ^{74}Fe ^{75}Fe ^{76}Fe
^{71}Co ^{72}Co ^{73}Co ^{74}Co ^{75}Co ^{76}Co ^{77}Co
^{75}Ni ^{76}Ni ^{77}Ni ^{78}Ni ^{79}Ni ^{80}Ni
^{76}Cu ^{77}Cu ^{78}Cu ^{79}Cu ^{80}Cu ^{81}Cu
^{78}Zn ^{79}Zn ^{80}Zn ^{81}Zn ^{82}Zn ^{83}Zn ^{90}Zn
$time(s) = 0.4174$ $T_9 = 2.487$ $\rho(g/cc) = 1.539e+04$ $\text{flow}_{max} = 0.0008318$

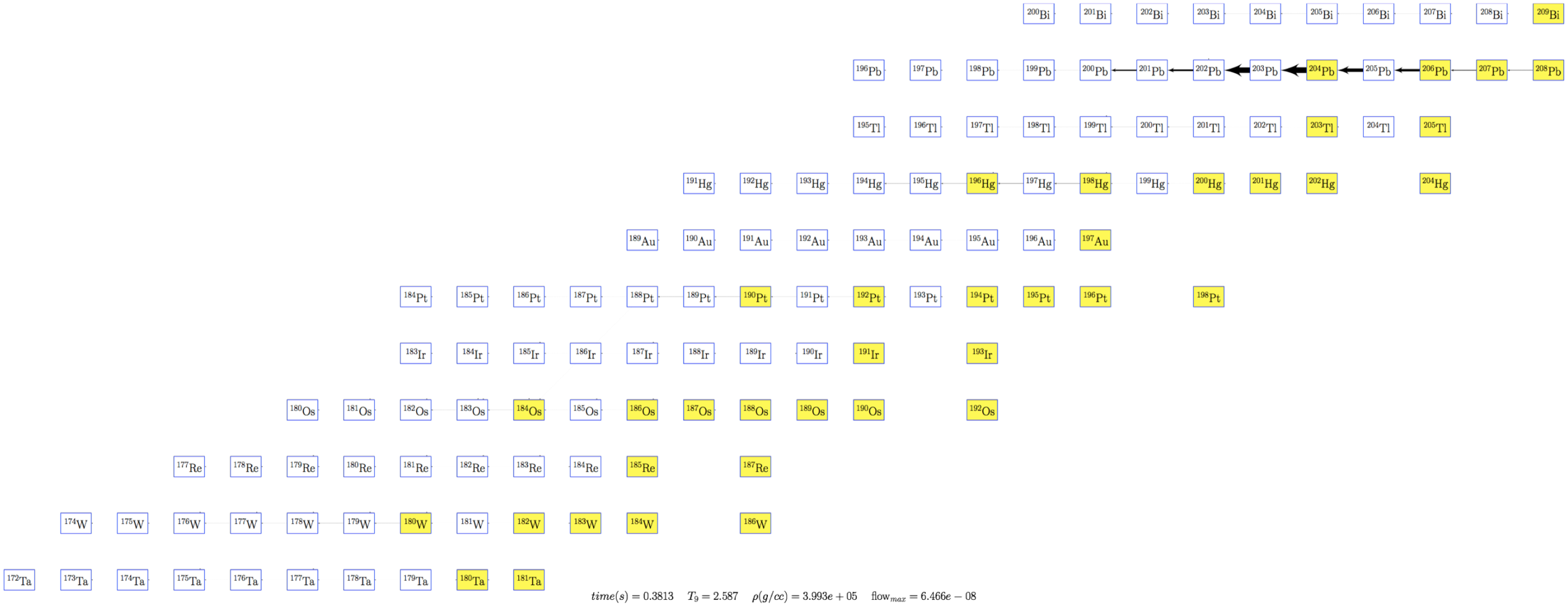

time(s) = 0.5746 T_g = 1.055 ρ(g/cc) = 1176 flow$_{max}$ = 0.003165


time(s) = 1.992 T_g = 0.01308 $\rho(g/cc)$ = 0.002239 flow$_{max}$ = 1.026e − 05

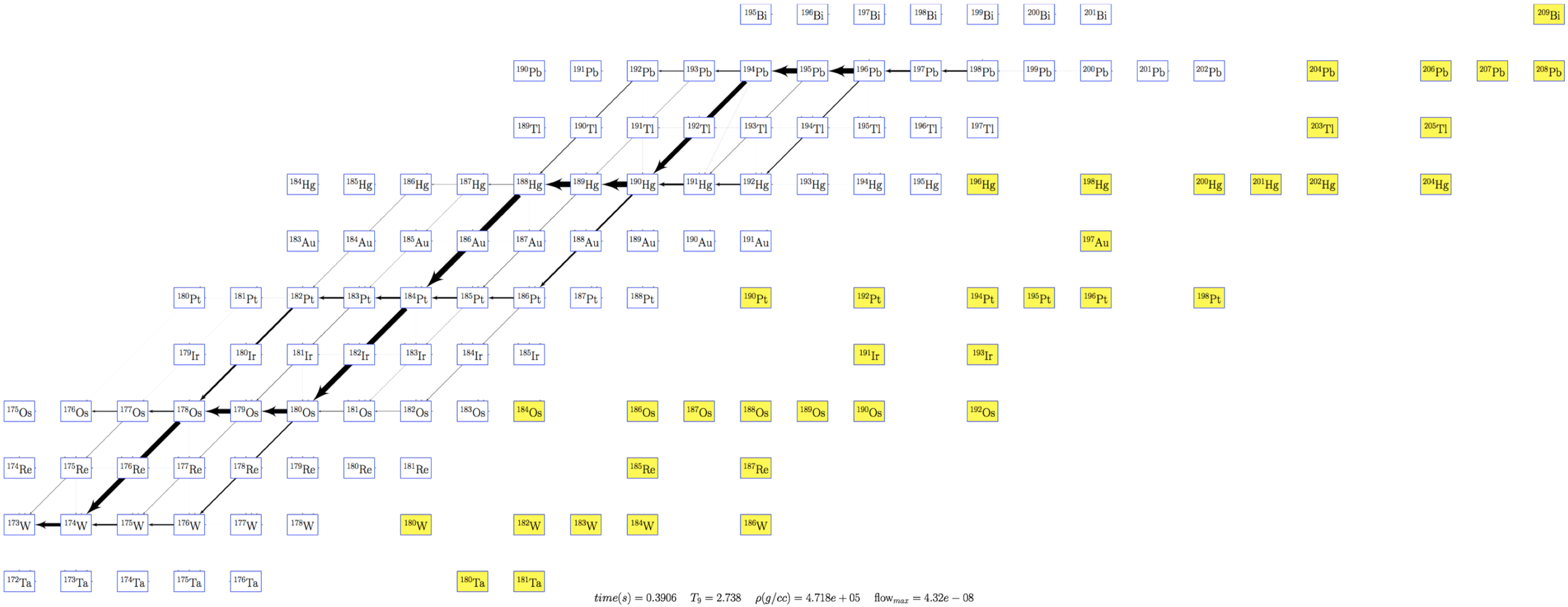
p process



$time(s) = 0.368 \quad T_9 = 2.251 \quad \rho(g/cc) = 2.757e+05 \quad \text{flow}_{max} = 2.887e-09$



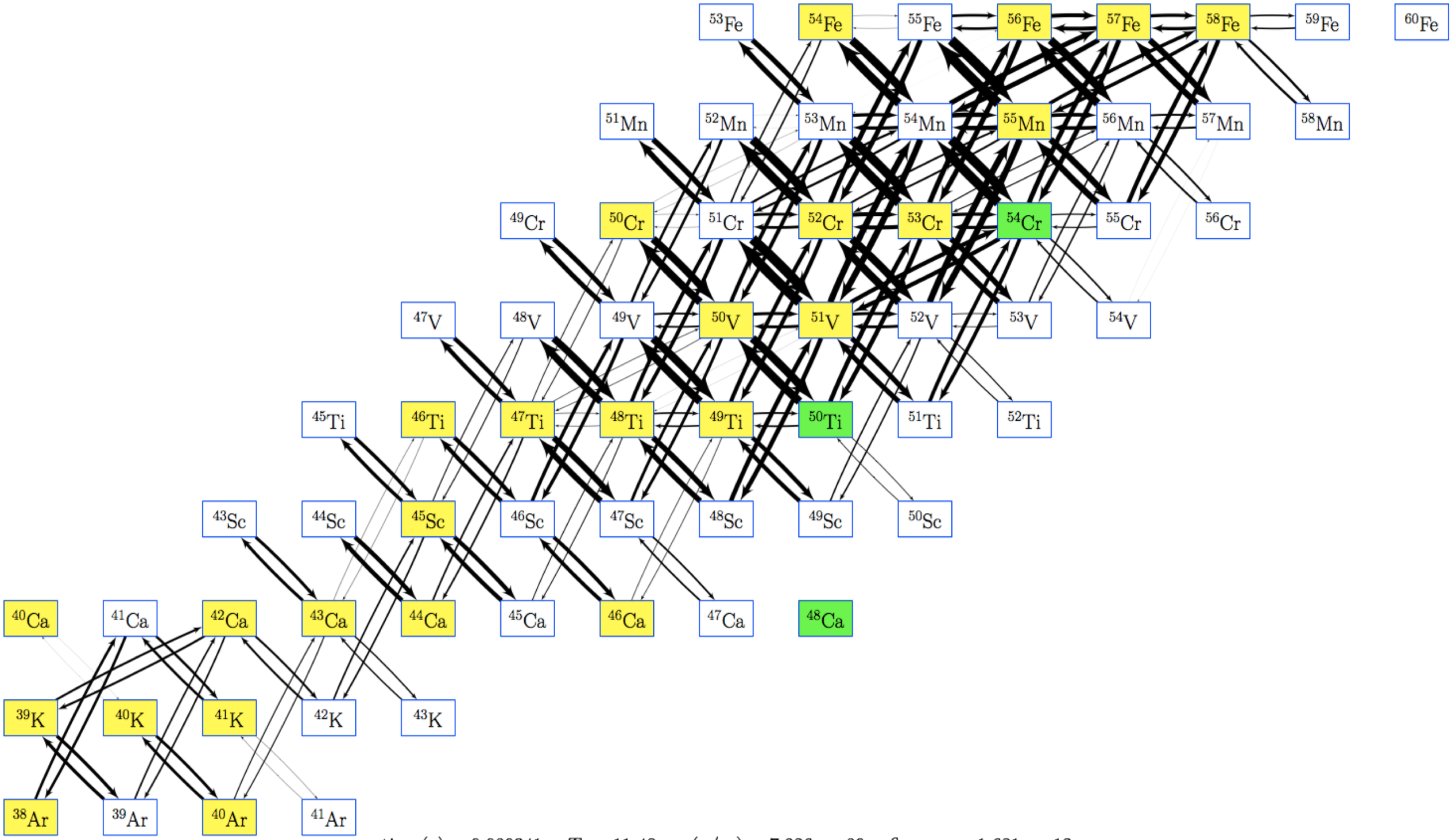
$time(s) = 0.3813 \quad T_9 = 2.587 \quad \rho(g/cc) = 3.993e+05 \quad \text{flow}_{max} = 6.466e-08$



$time(s) = 0.3906 \quad T_9 = 2.738 \quad \rho(g/cc) = 4.718e+05 \quad \text{flow}_{max} = 4.32e-08$

$time(s) = 100 \quad T_9 = 0.528 \quad \rho(g/cc) = 4448 \quad \text{flow}_{max} = 8.272e-25$

Full vs. Net Flow



$time(s) = 0.009341$ $T_9 = 11.48$ $\rho(g/cc) = 7.926e+09$ $\text{flow}_{max} = 1.631e+12$

$time(s) = 0.009341$ $T_9 = 11.48$ $\rho(g/cc) = 7.926e+09$ $\text{flow}_{max} = 0.1429$

Experimental Reaction-Rate Considerations

- Measured in Gamow window?
- All resonances accounted for?
- Screening?
- Contribution of excited states?

Theoretical Reaction-Rate Considerations

- Accuracy of the nuclear data input, if available (e.g., reaction Q value)
- Validity of the treatment of the calculation (typically Hauser-Feshbach)
- Contribution from excited states

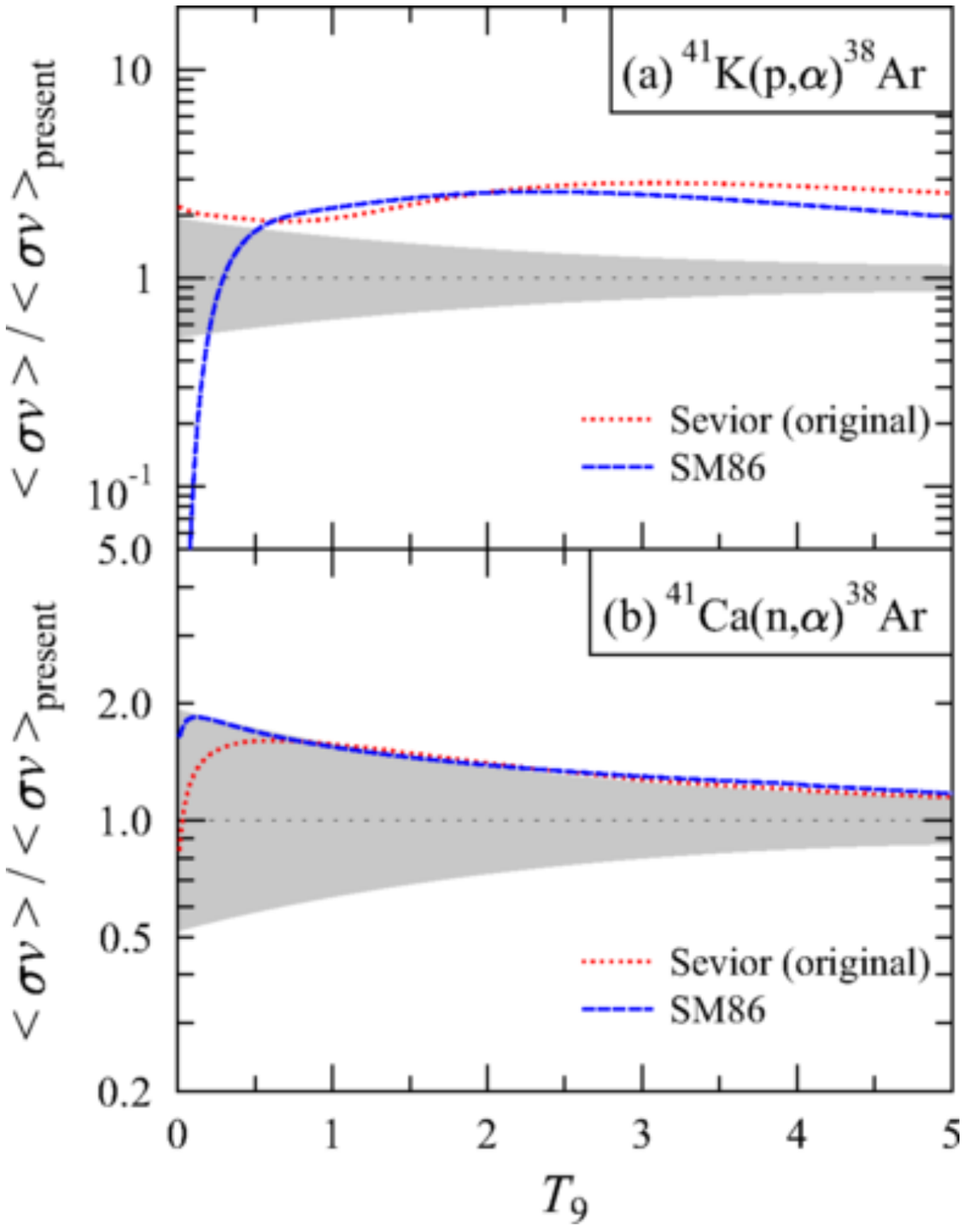
Four Requirements for Meaningful Nuclear Reaction Cross Section Measurements (The et al. 1998)

1. An appropriate astrophysical model of a process significant for nucleosynthesis.

2. An observable from that process, usually an abundance result that is either known or measurable.

3. The dependency of the value of the observable on the value of a nuclear cross section.

4. An experimental strategy for measuring that cross section, or at least of using measurable data to better calculate it.


(a) ^{41}K(p,α)^{38}Ar
Sevior (original)
SM86
(b) ^{41}Ca(n,α)^{38}Ar
Sevior (original)
SM86
$< \sigma v > / < \sigma v >_{present}$
T_9
10
1
10^{-1}
5.0
2.0
1.0
0.5
0.2
0
1
2
3
4
5

Talwar+ 2018

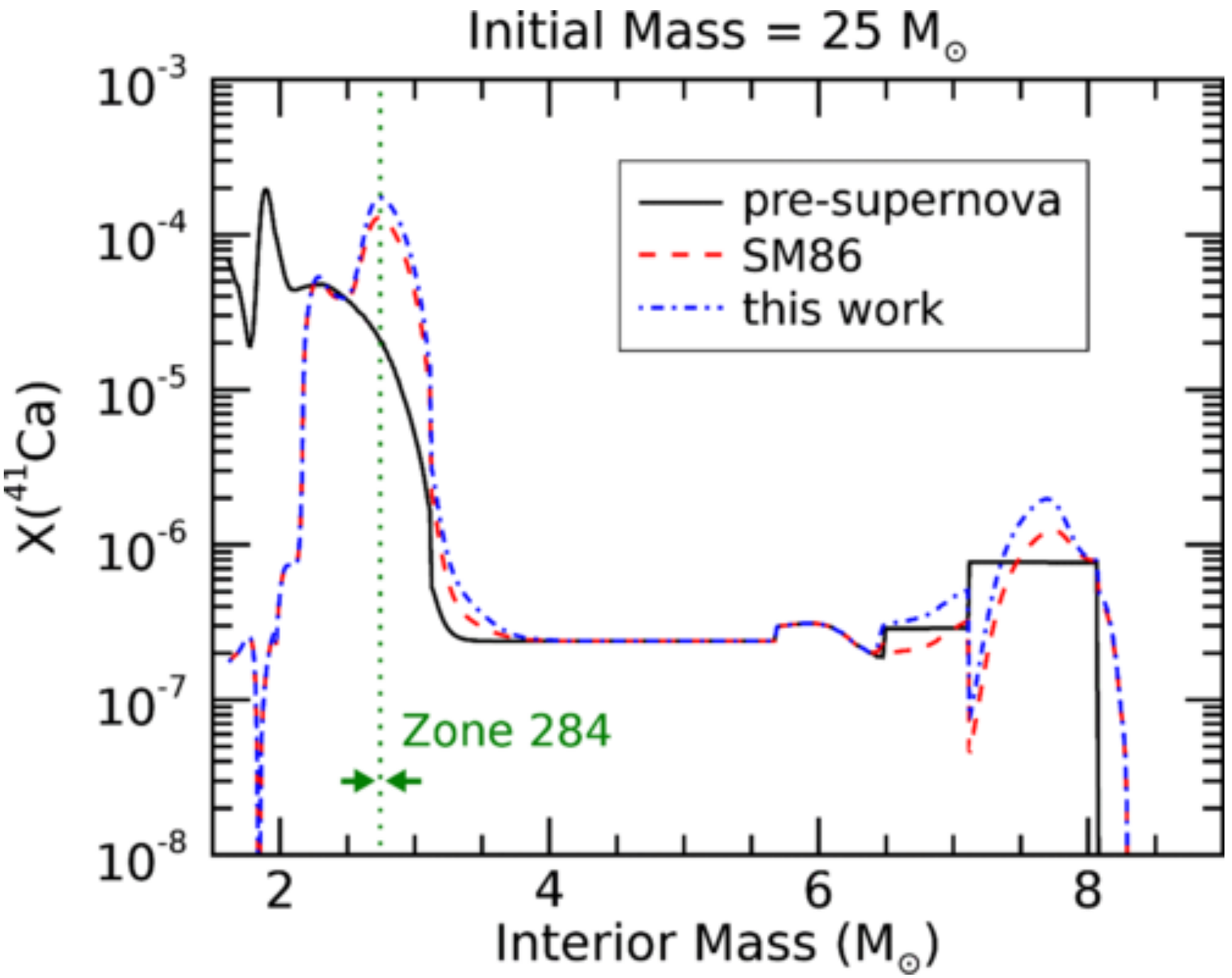
time (s) = 1.63e-01

T_9

10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}

0 2 4 6 8 10 12 14

$M_r(M_\odot)$



~20% increase in yield from massive stars

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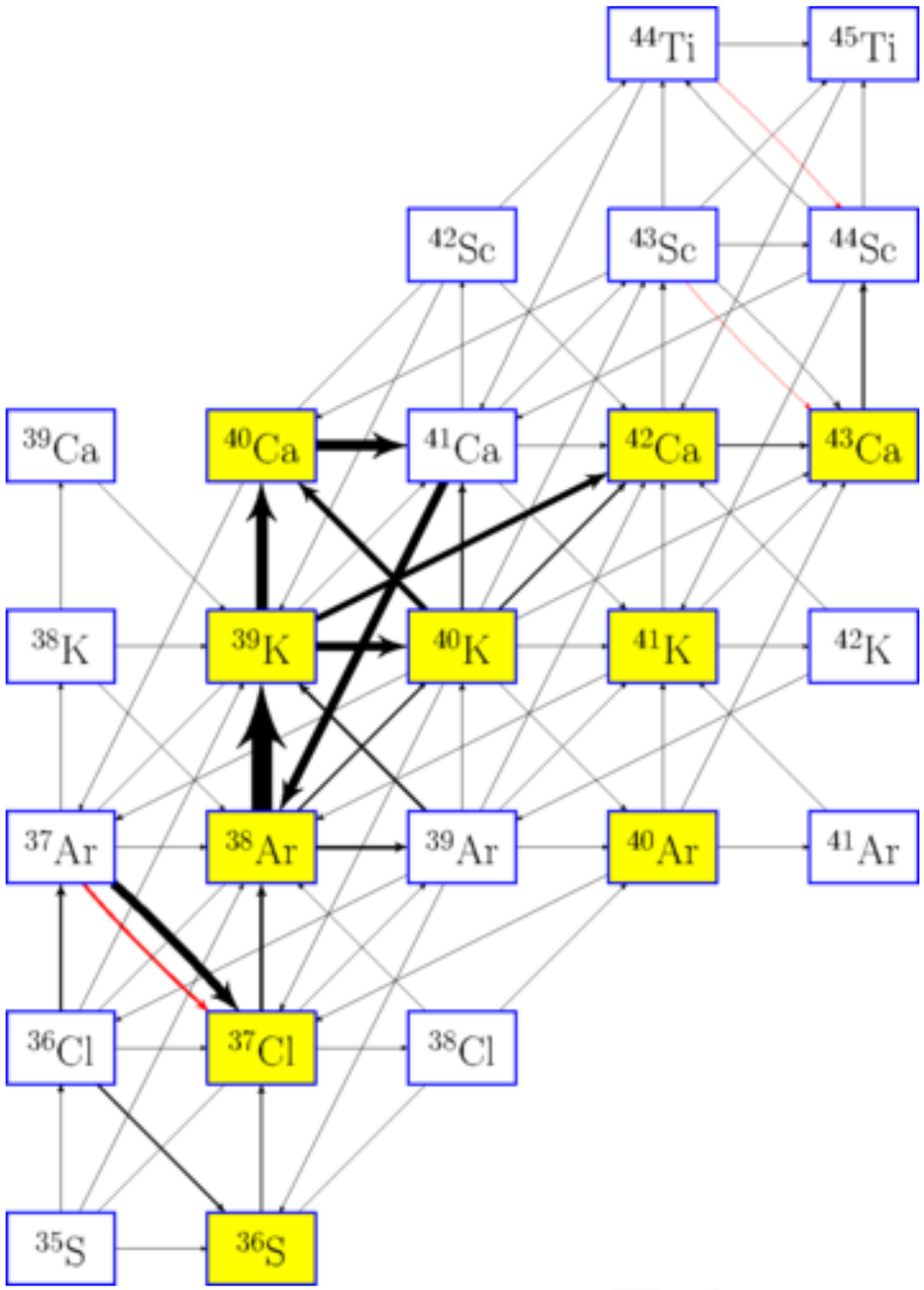
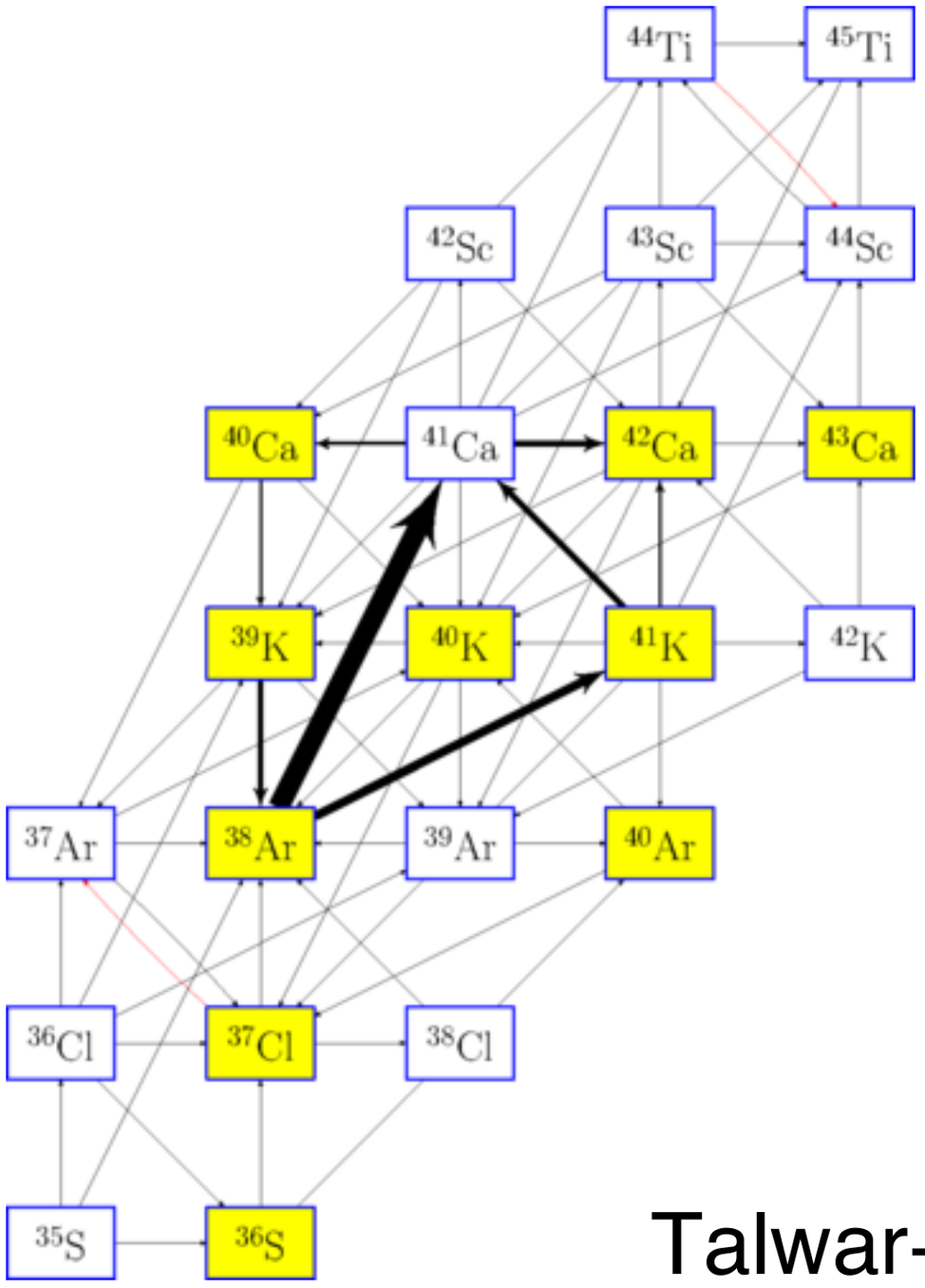
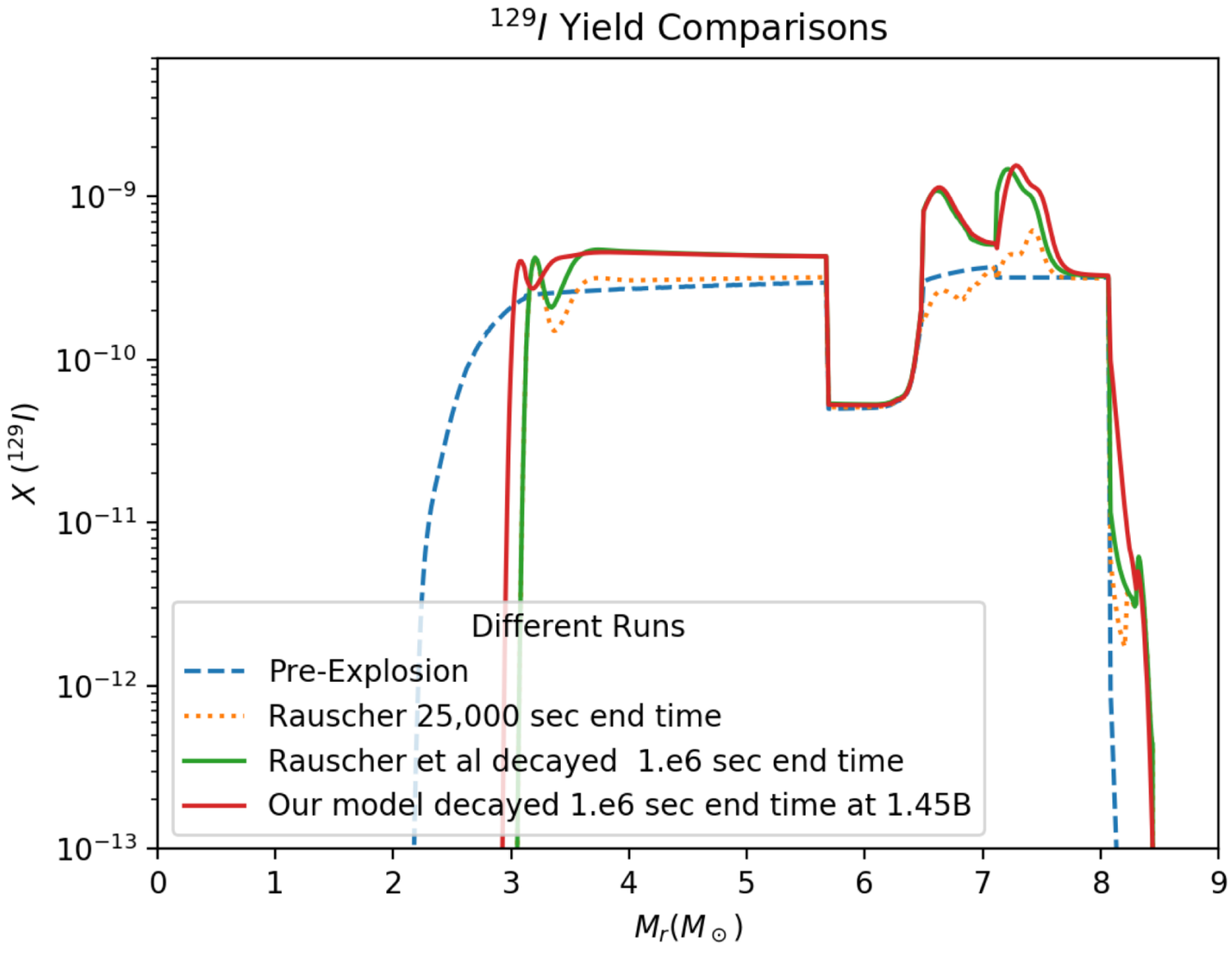
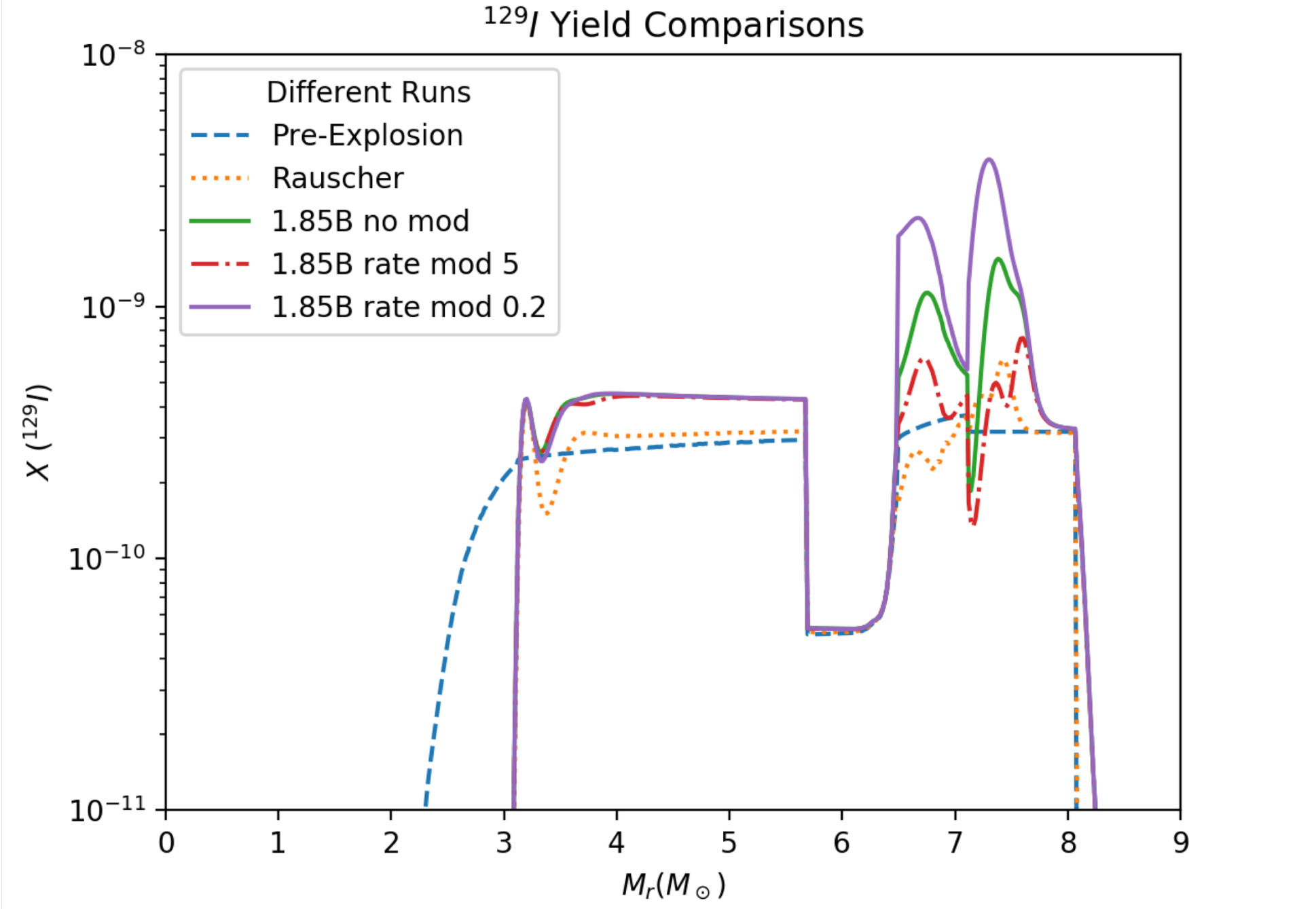

^{44}Ti
^{45}Ti
^{42}Sc
^{43}Sc
^{44}Sc
^{39}Ca
^{40}Ca
^{41}Ca
^{42}Ca
^{43}Ca
^{38}K
^{39}K
^{40}K
^{41}K
^{42}K
^{37}Ar
^{38}Ar
^{39}Ar
^{40}Ar
^{41}Ar
^{36}Cl
^{37}Cl
^{38}Cl
^{35}S
^{36}S

Talwar+ 2018


^{44}Ti
^{45}Ti
^{42}Sc
^{43}Sc
^{44}Sc
^{40}Ca
^{41}Ca
^{42}Ca
^{43}Ca
^{39}K
^{40}K
^{41}K
^{42}K
^{37}Ar
^{38}Ar
^{39}Ar
^{40}Ar
^{36}Cl
^{37}Cl
^{38}Cl
^{35}S
^{36}S

Talwar+ 2018


^{129}I Yield Comparisons
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
$X\ (^{129}I)$
0
1
2
3
4
5
6
7
8
9
$M_r(M_\odot)$
Different Runs
Pre-Explosion
Rauscher 25,000 sec end time
Rauscher et al decayed 1.e6 sec end time
Our model decayed 1.e6 sec end time at 1.45B



^{129}Te(n,γ)^{130}Te

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