Mass of ^{56}Cu and its impacts on rp-processes

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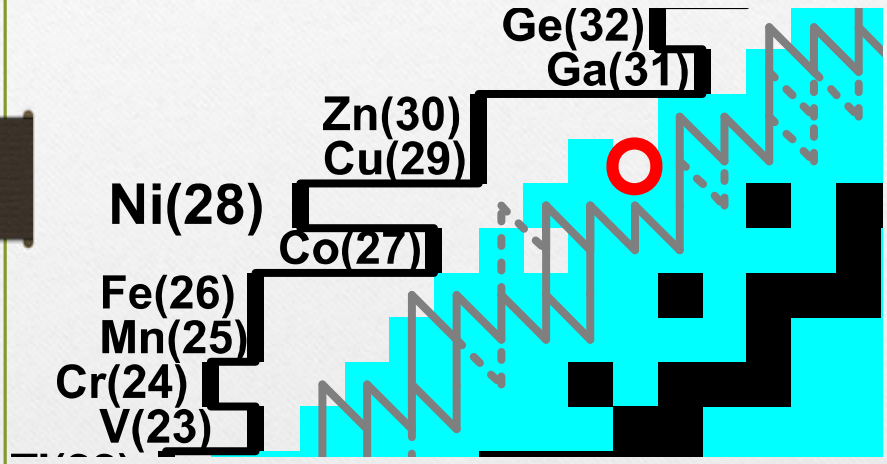
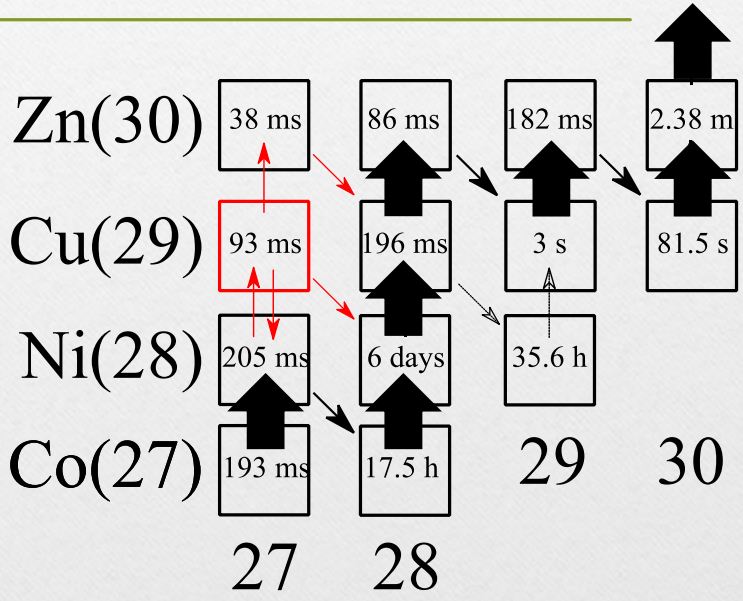
Outlines

- Motivation
- Experiment and results
- Net-work Calculations and conclusions
- Summary

Motivation





Effects of m(^{56}Cu) on rp-process around ^{56}Ni ?

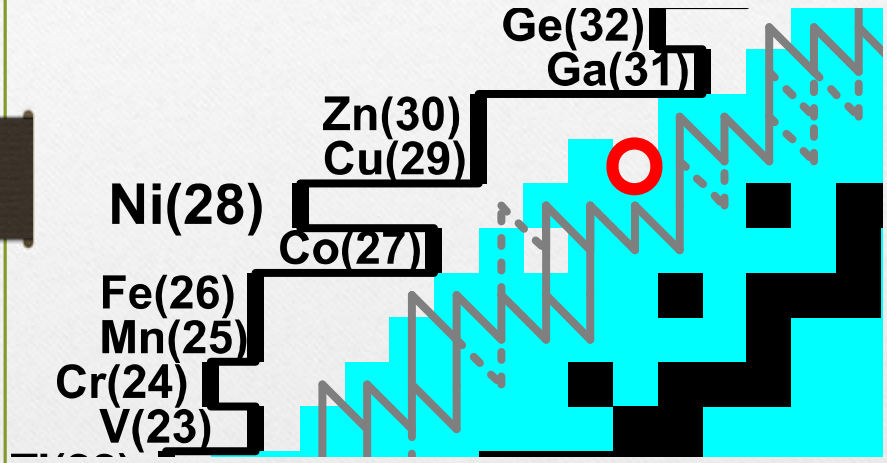
Half-life[NNDC]

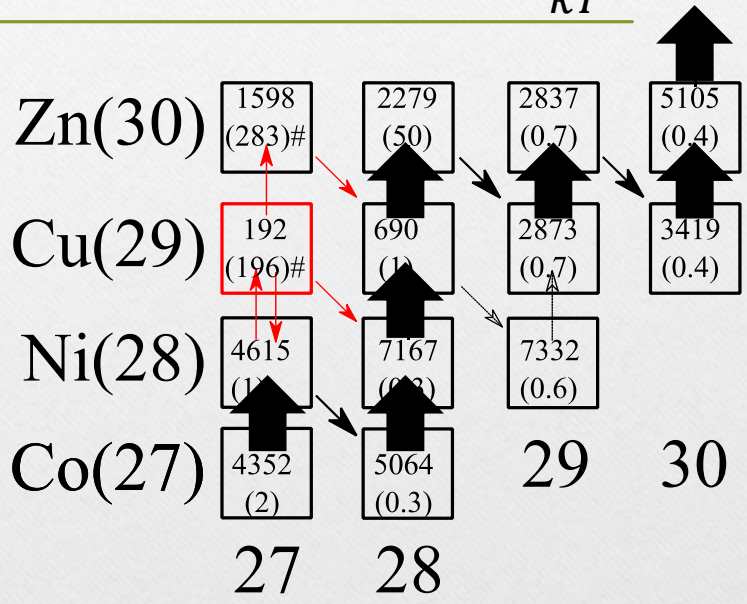
O. Forstner et al. PRC 64, 045801(2001)

Motivation

$(p,\gamma) \rightleftharpoons (\gamma,p)$ equilibrium

$$\lambda_{(\gamma,p)} \propto \langle \sigma v \rangle_{(p,\gamma)} * \exp[\frac{S_{p\ (Z+1,N)}}{kT}]$$





Effects of m(^{56}Cu) on rp-process around ^{56}Ni ?

Sp (keV)[AME2012]

O. Forstner et al. PRC 64, 045801(2001)

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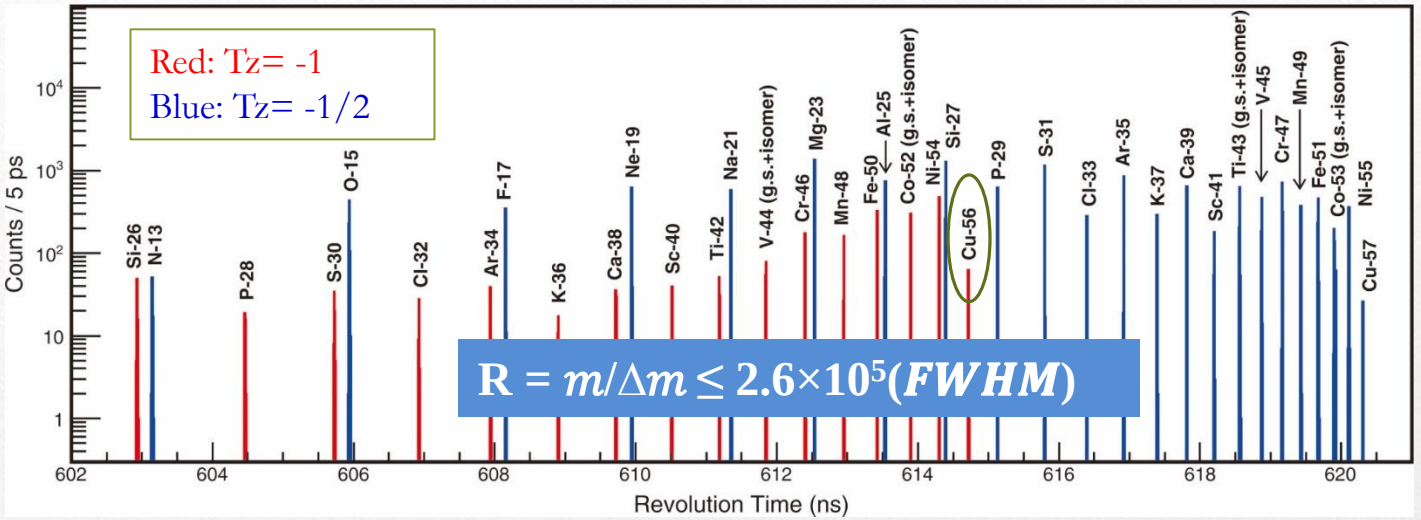
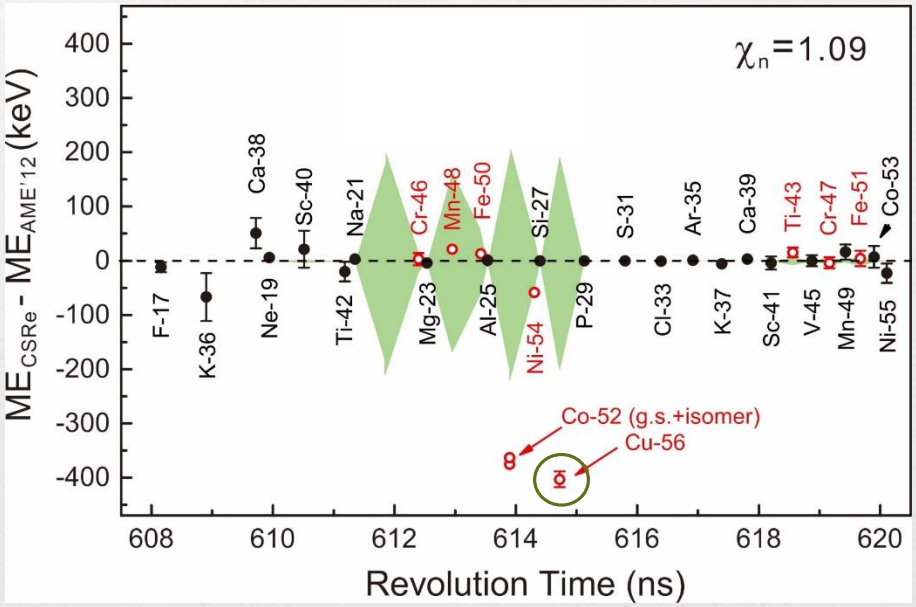
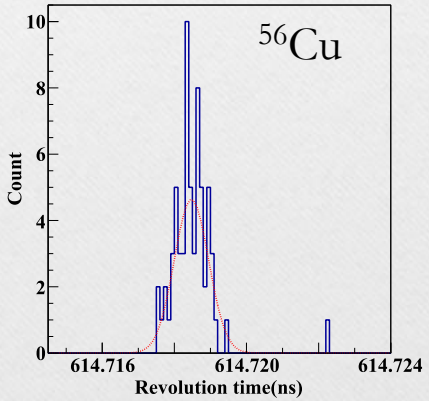


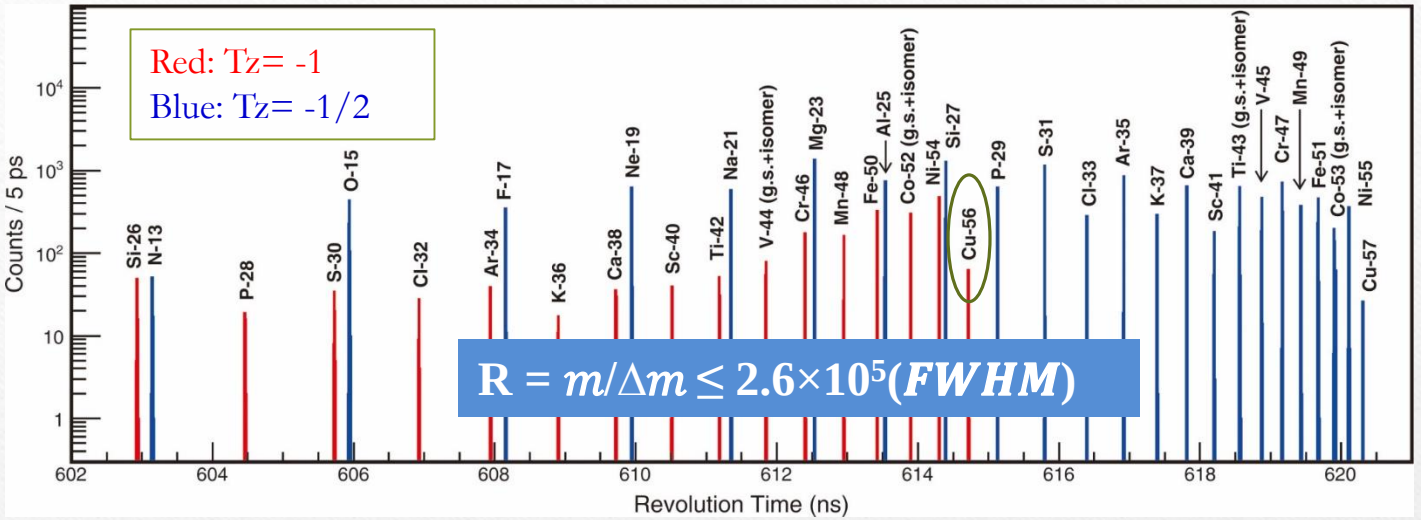


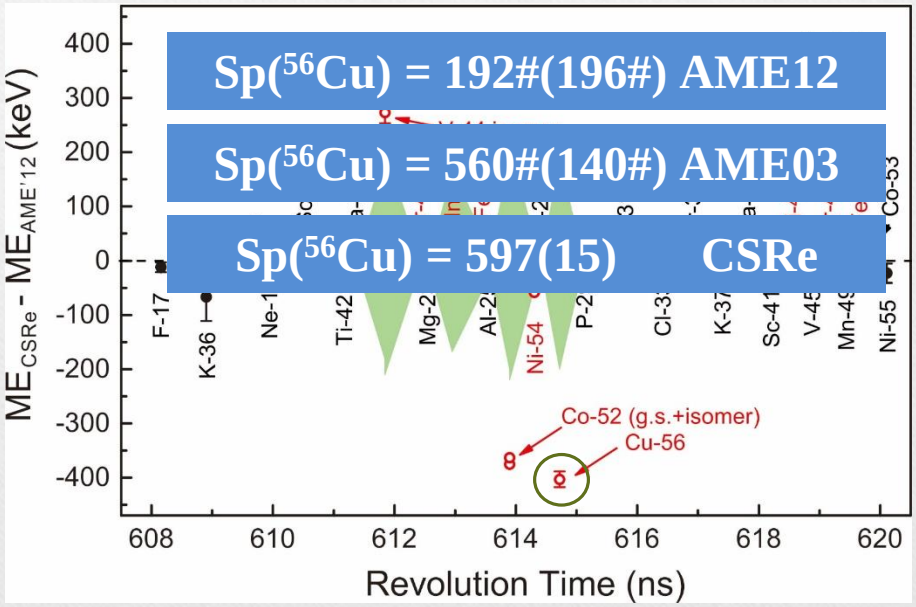


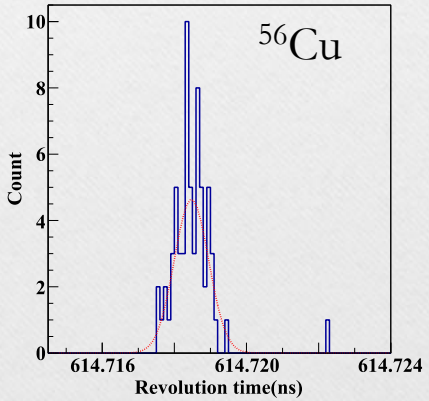
Nuclide	N	$T_{1/2}$
^{56}Cu	64	93ms

Data accumulated for 2 days

Preliminary results







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Input parameters of NucNet code[1]

H. Schatz et al., PRL **86**, 3471 (2001)

- Initial abundance:

  $Y(^{1}H) = 0.658$, $Y(^{4}He) = 0.0855$, $Y(^{12}C) = 1.67e\text{-}6$

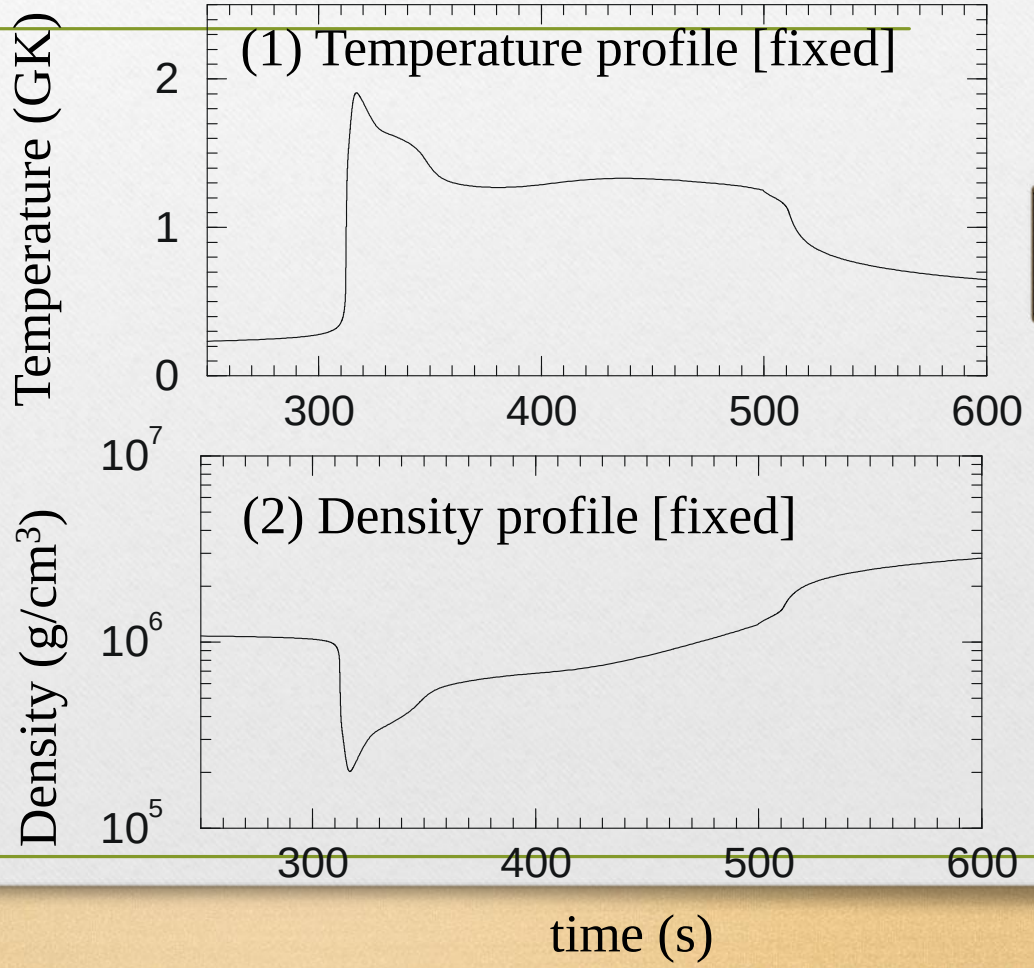
- Temperature profile fixed
- Density profile fixed
- Mass database: AME2003
- Reaction rate database: JINA-ReaclibV0.5
- Change m(^{56}Cu) to see the effects

Sp(^{56}Cu) = 0.19 MeV (old) → **Sp(^{56}Cu) = 0.56 MeV (new)**

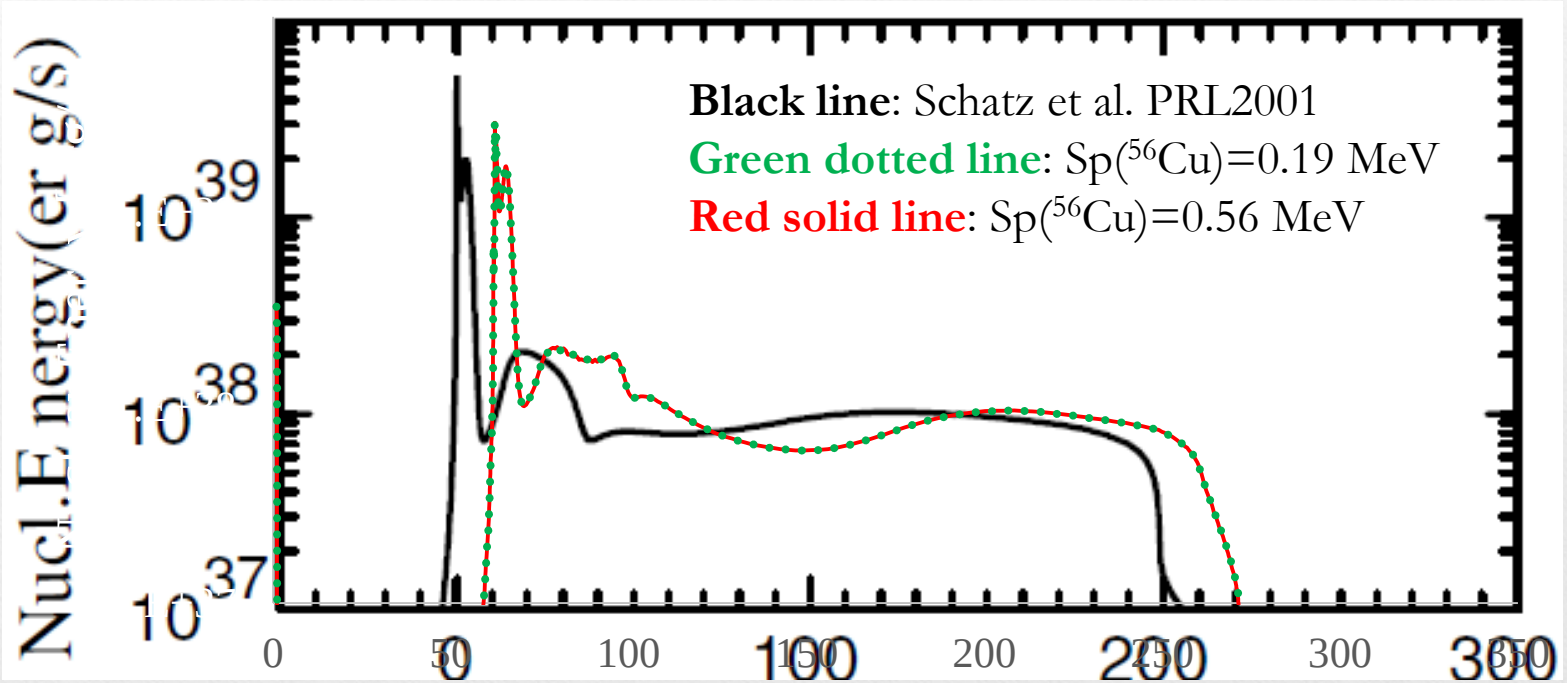
[1] https://sourceforge.net/p/nucnet-projects/wiki/jina_to_webnucleo/

Input parameters of NucNet

- Long burst
- H. Schatz et al., PRL **86**, 3471 (2001)



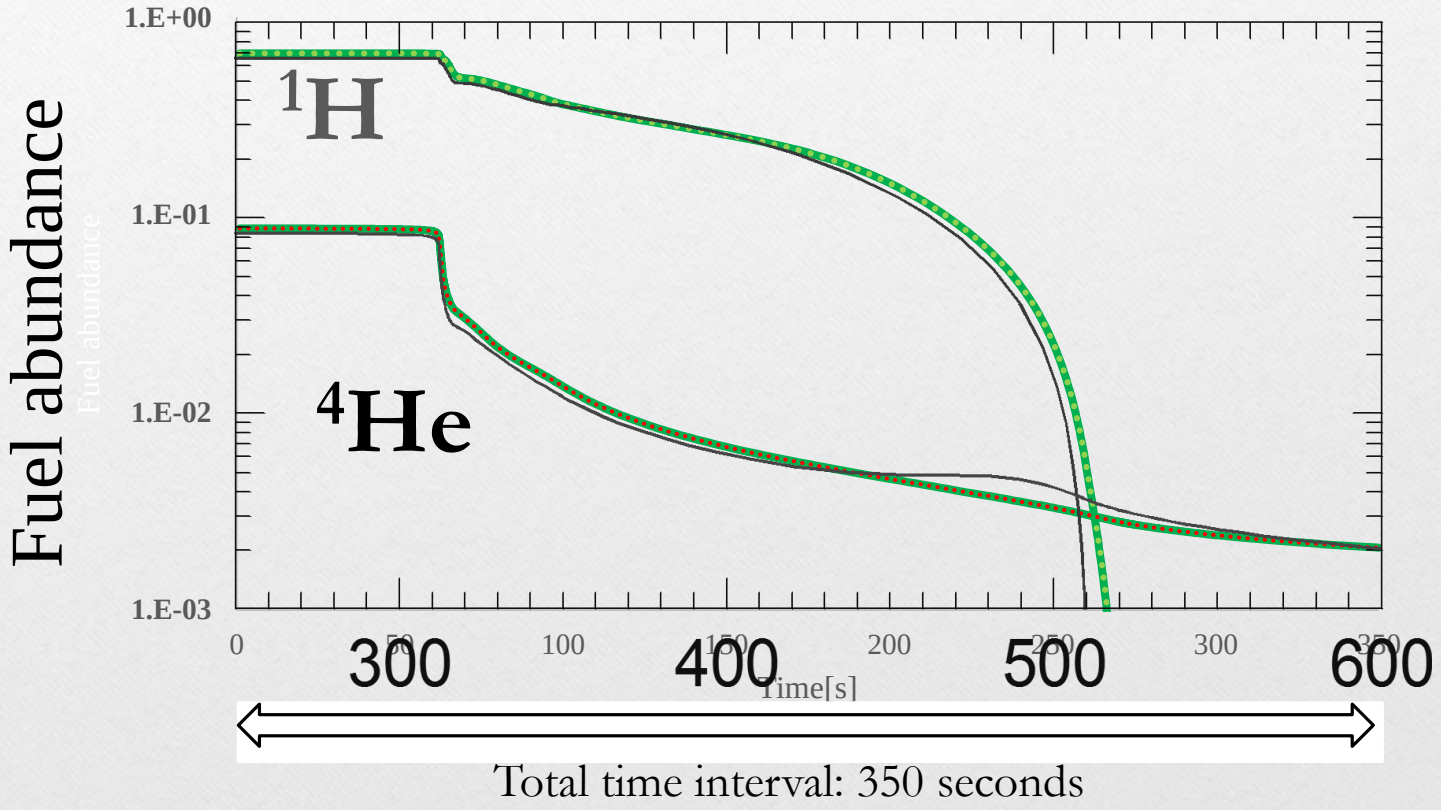
Nuclear reaction energy VS Time



The area of the green and red curves differed only by 1.8e-5

Black line: Schatz et al. PRL2001
Green dotted line: Sp(^{56}Cu)=0.19 MeV
Green solid line: Sp(^{56}Cu)=0.56 MeV

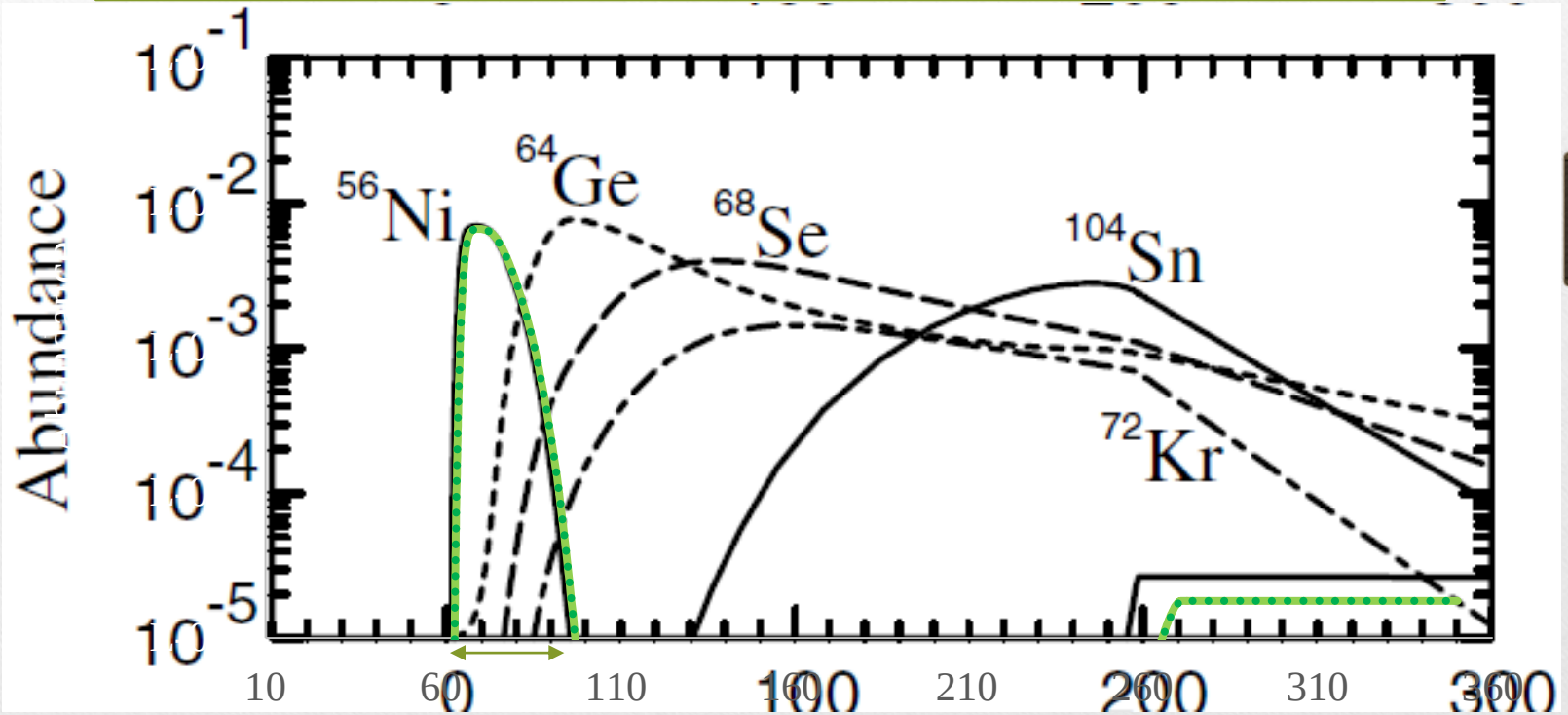
Fuel abundance VS Time



The change of the area of the curves due to the m(^{56}Cu)-change were : $1-9.7\times10^{-5}$, (for ^{1}H) and $1+4.3\times10^{-6}$ (for ^{4}He)[Solid line Vs dotted line].

Black line: Schatz et al. PRL2001
Green dotted line: Sp(^{56}Cu)=0.19 MeV
Red solid line: Sp(^{56}Cu)=0.56 MeV

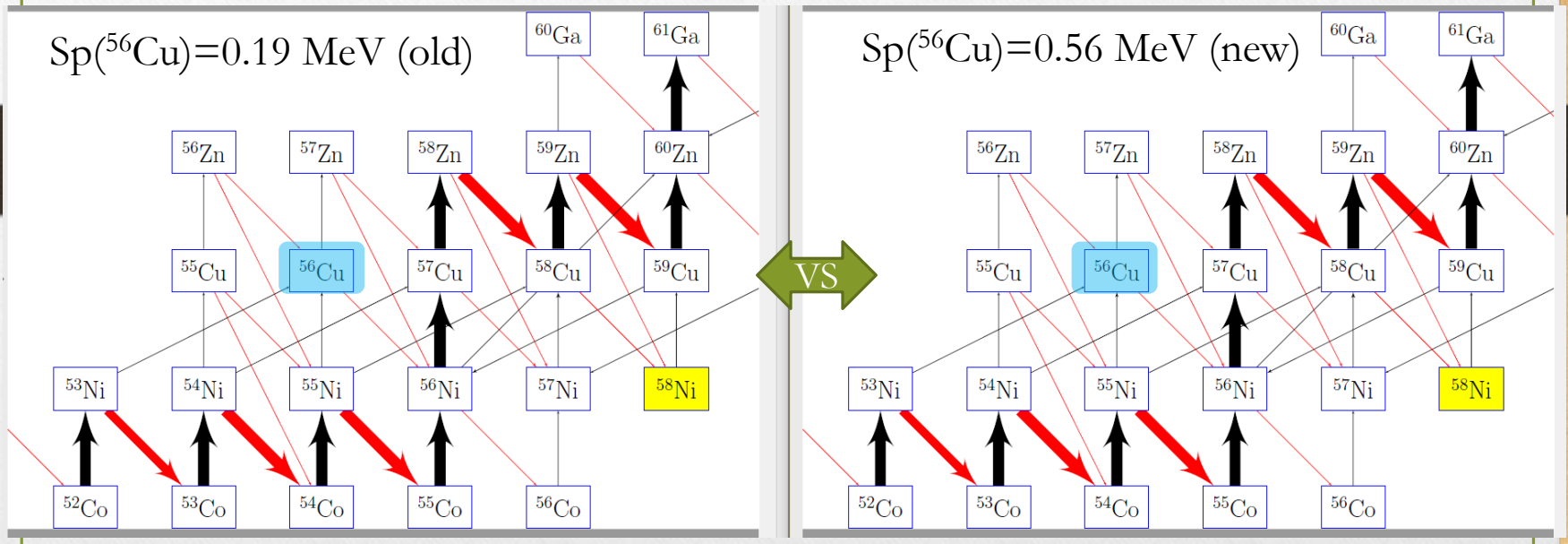
Abundance of ^{56}Ni VS Time



Area of the curves was changed by : $1+2.1\times10^{-4}$ (for ^{56}Ni)[Solid Vs dotted line].

Note: linear scale

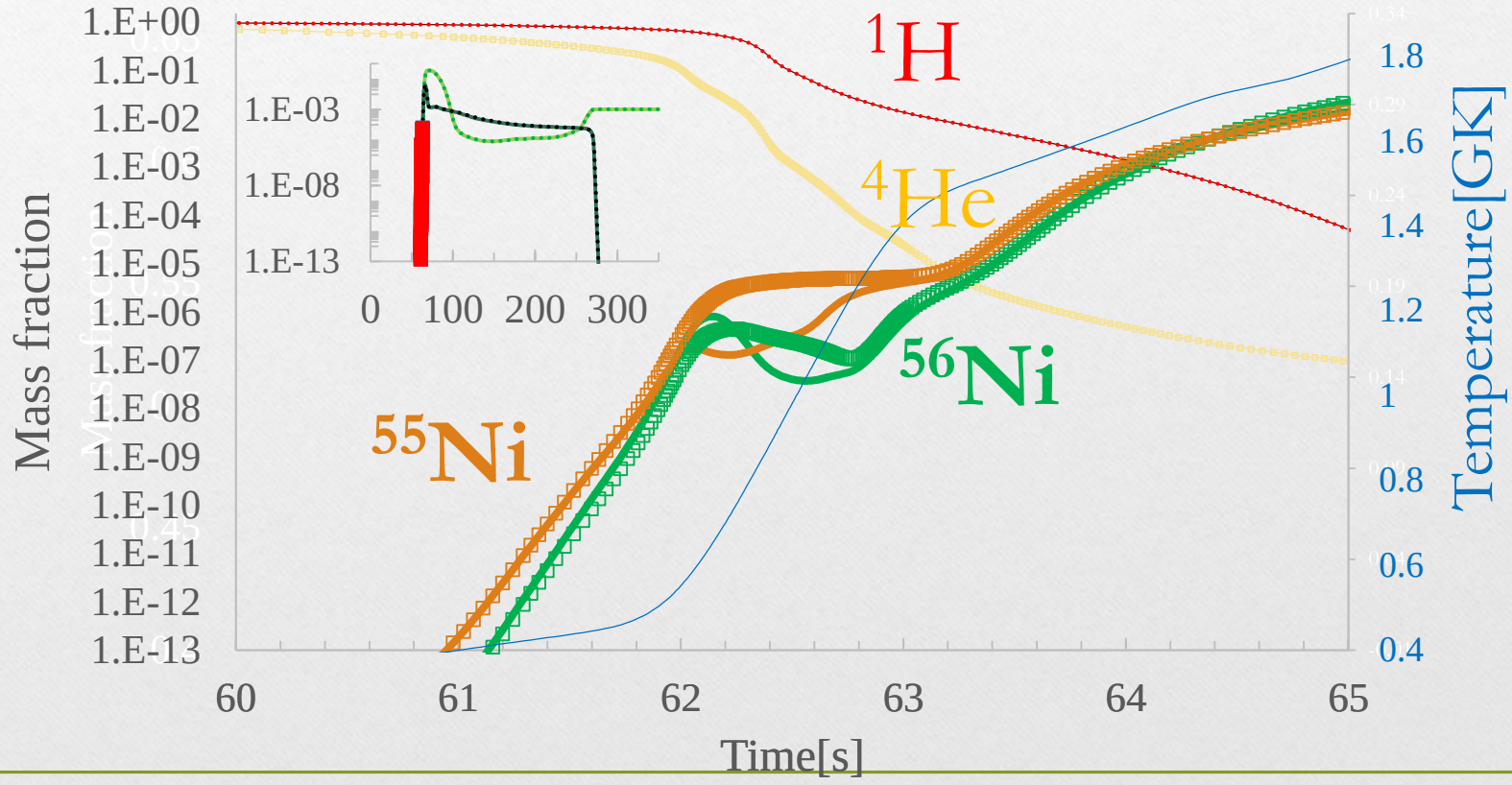
Time-integrated net flow around ^{56}Ni



Conclusion: No significant influence on rp-process path around ^{56}Ni. The rp-process mainly go through ^{56}Ni via ^{56}Ni(p,γ)^{57}Cu(p,γ) towards heavier elements

NucNet calculations:
Dotted lines: Sp(^{56}Cu)=0.19 MeV
Solid lines: Sp(^{56}Cu)=0.56 MeV

Influence on mass fractions



5 seconds at the beginning of XRBs

NucNet calculations:
Dotted lines: Sp(^{56}Cu)=0.19 MeV
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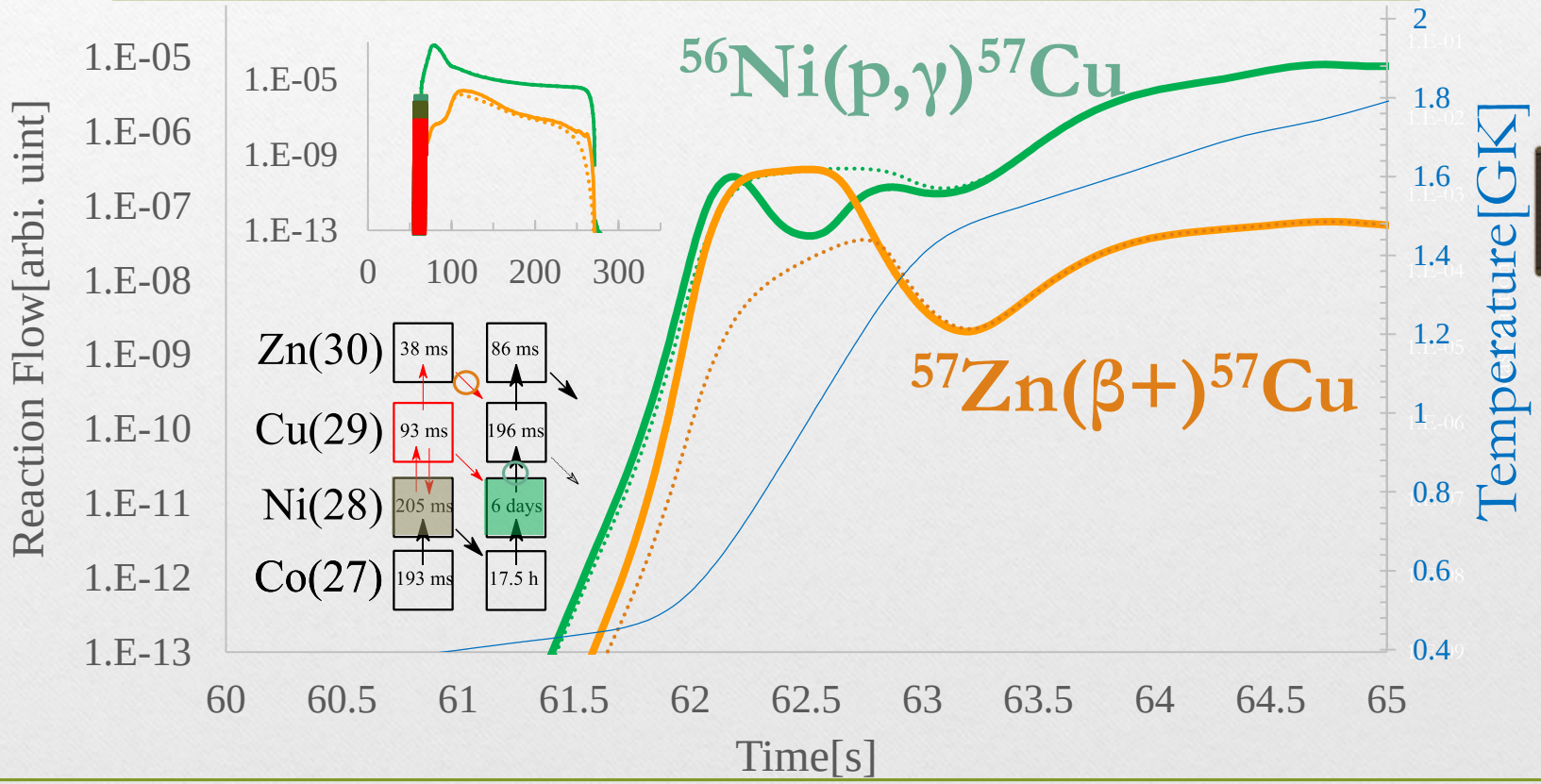
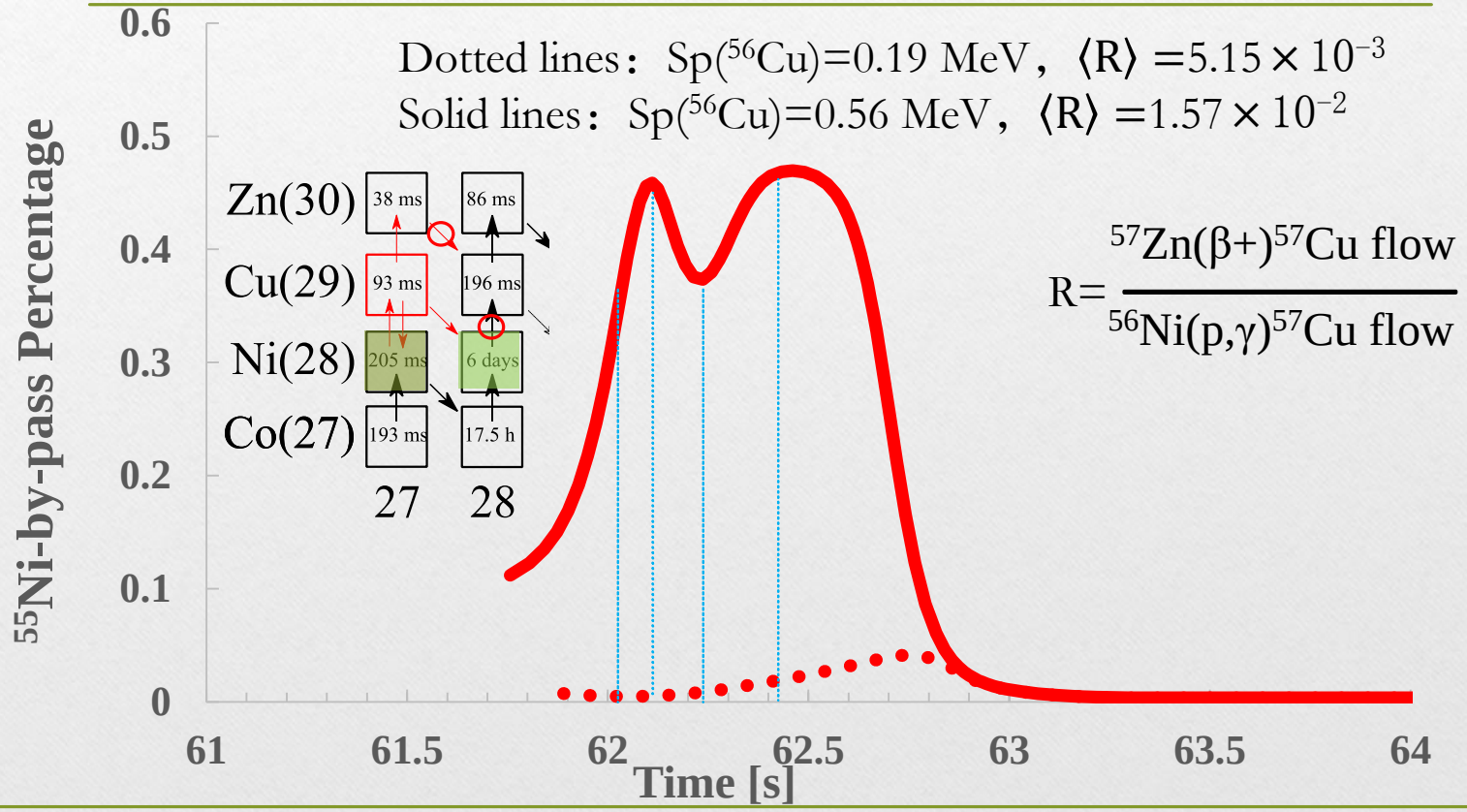
Influence on reaction flows

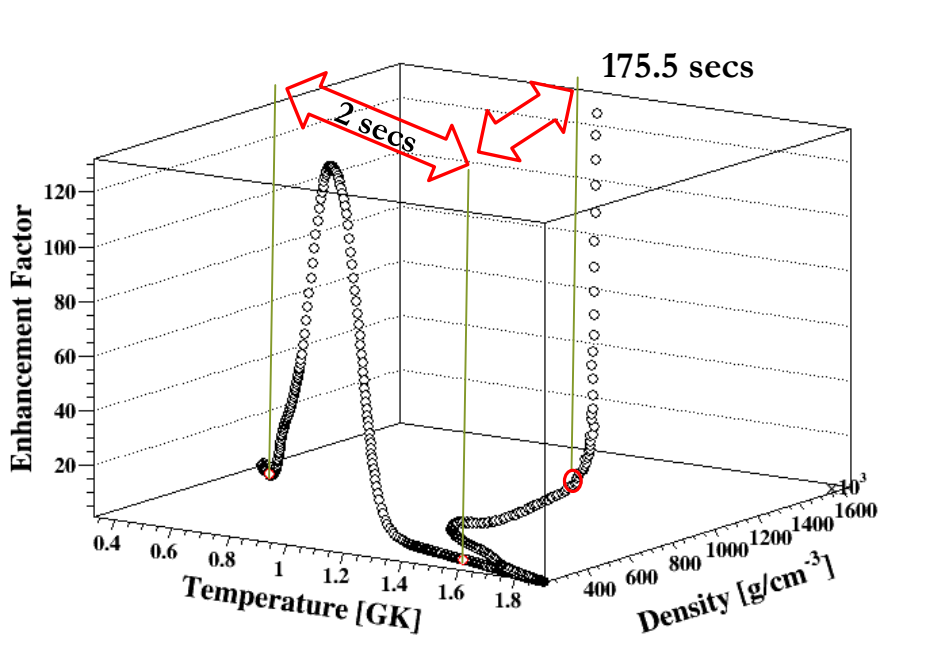


5 seconds at the beginning of XRBs

Influence on "^{55}Ni-by-pass" percentage

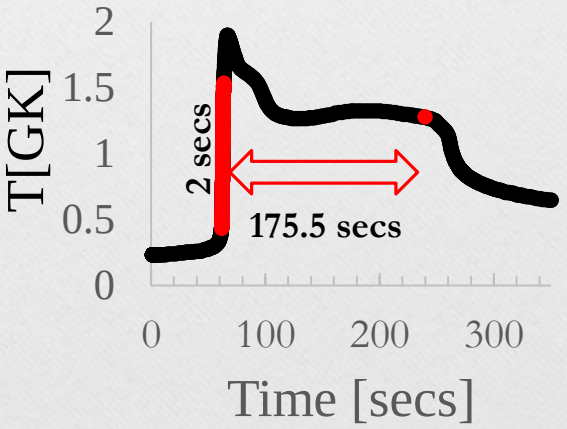


"^{55}Ni-by-pass" enhancement factor due to change of Sp(^{56}Cu)



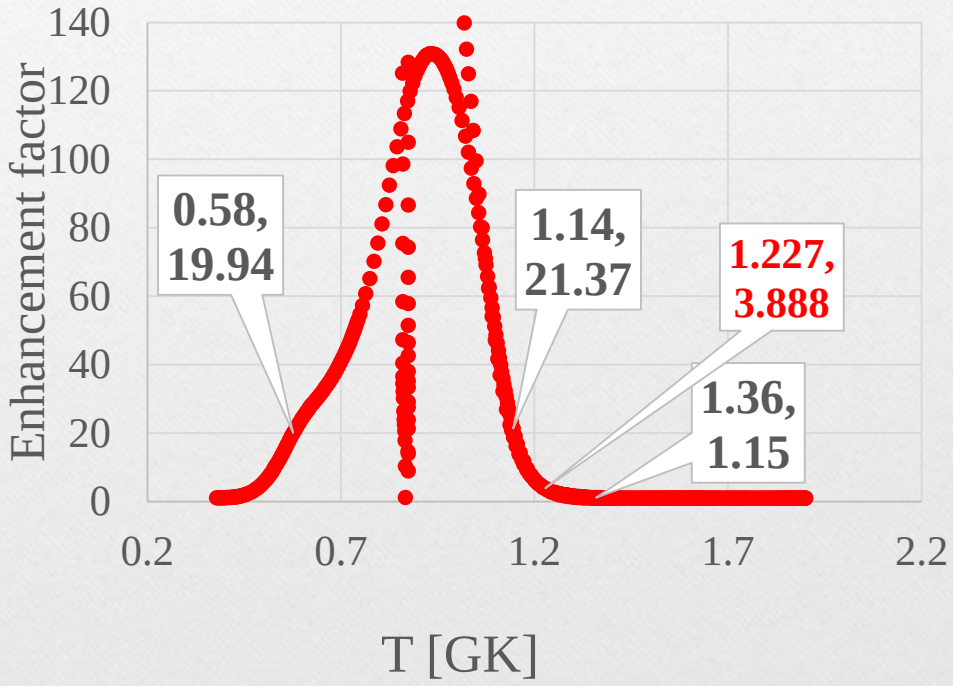
$$R = \frac{Flow(^{57}\mathrm{Zn}(\beta+)^{57}\mathrm{Cu})}{Flow(^{56}\mathrm{Ni}(p,\gamma)^{57}\mathrm{Cu})}$$

$$F = \frac{R@S_p(^{56}Cu) = 0.56\ MeV}{R@S_p(^{56}Cu) = 0.19\ MeV}$$



<T[GK]> = 1.229 GK

"^{55}Ni-by-pass" enhancement factor due to change of Sp(^{56}Cu)



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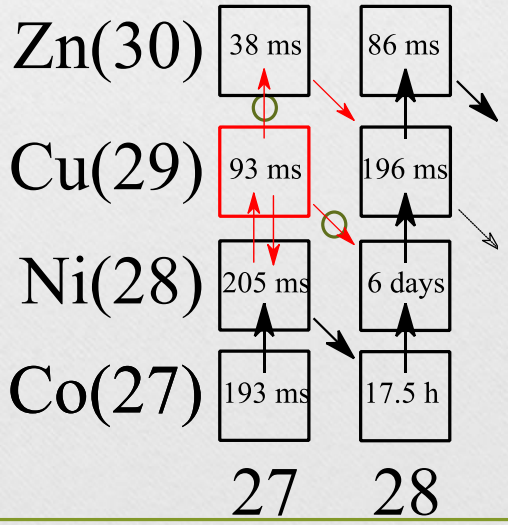

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Summary

- Sp(^{56}Cu) was changed from 0.19 MeV to 0.56 MeV to see the influence on the rp-process during X-ray burst
- For a particular X-ray burst [Schatz et al 2001], the change of Sp(^{56}Cu) had very small impact on the profile of fuel consumption (1e-5), on the nuclear energy generation (1e-5), on the mass fraction of ^{55}Ni and ^{56}Ni, on the overall reaction flow around ^{56}Ni.
- However, at the beginning of this X-ray burst when T< 1.22GK, the change of m(^{56}Cu) would have big influence on the "^{55}Ni-by-pass" reaction, enhancement factor of 130 at maximum was observed.

Many thanks to

- Kuoang Li, Xiaodong Tang , Yihua Lam
- Peng Zhang, Yuhu Zhang, Xiaolin Tu

Thanks for listening!