

# r-process dispersion in metal-poor globular clusters

Ian U. Roederer  
Carnegie Observatories





(Clara)

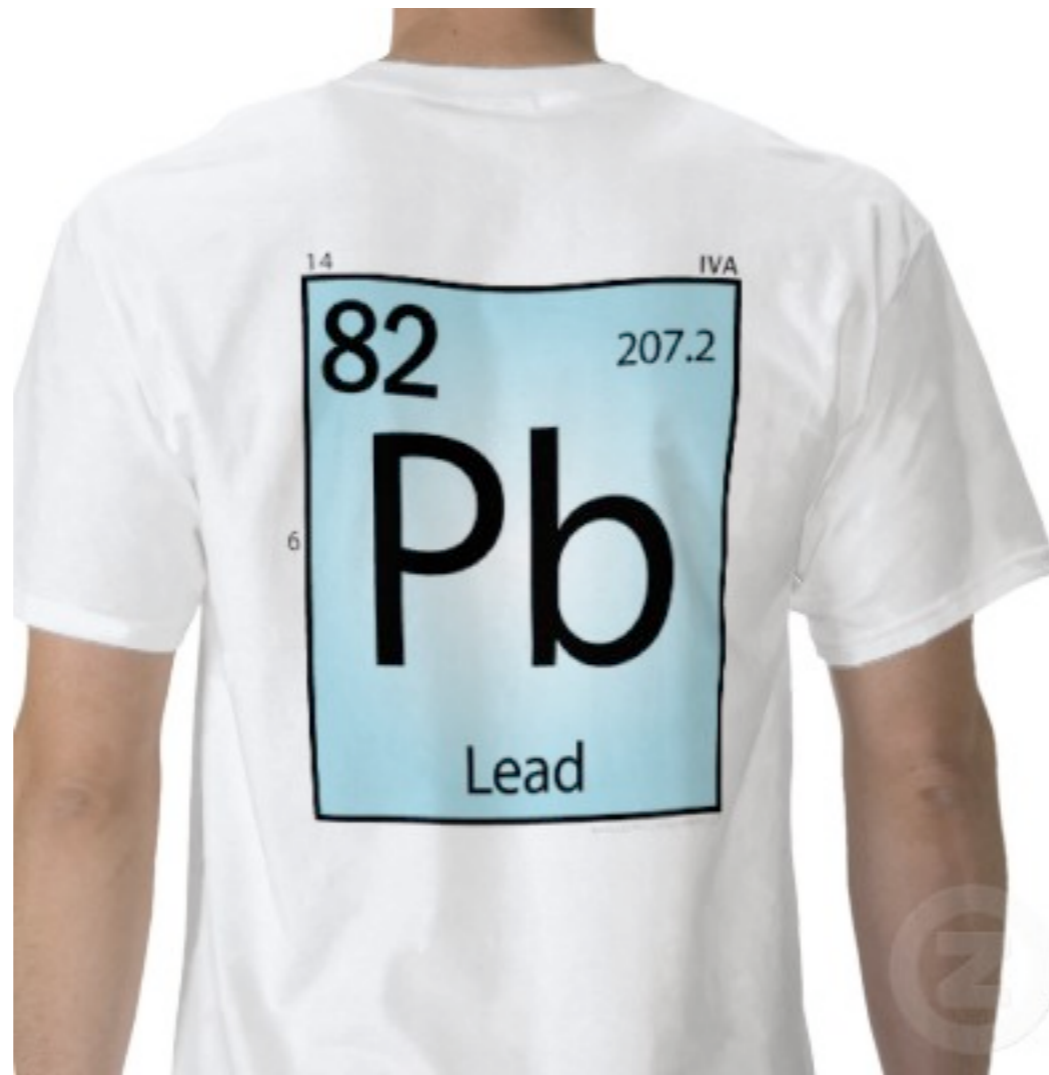


"Where's the beef?"



"Where's the ~~beef?~~  
*lead*"



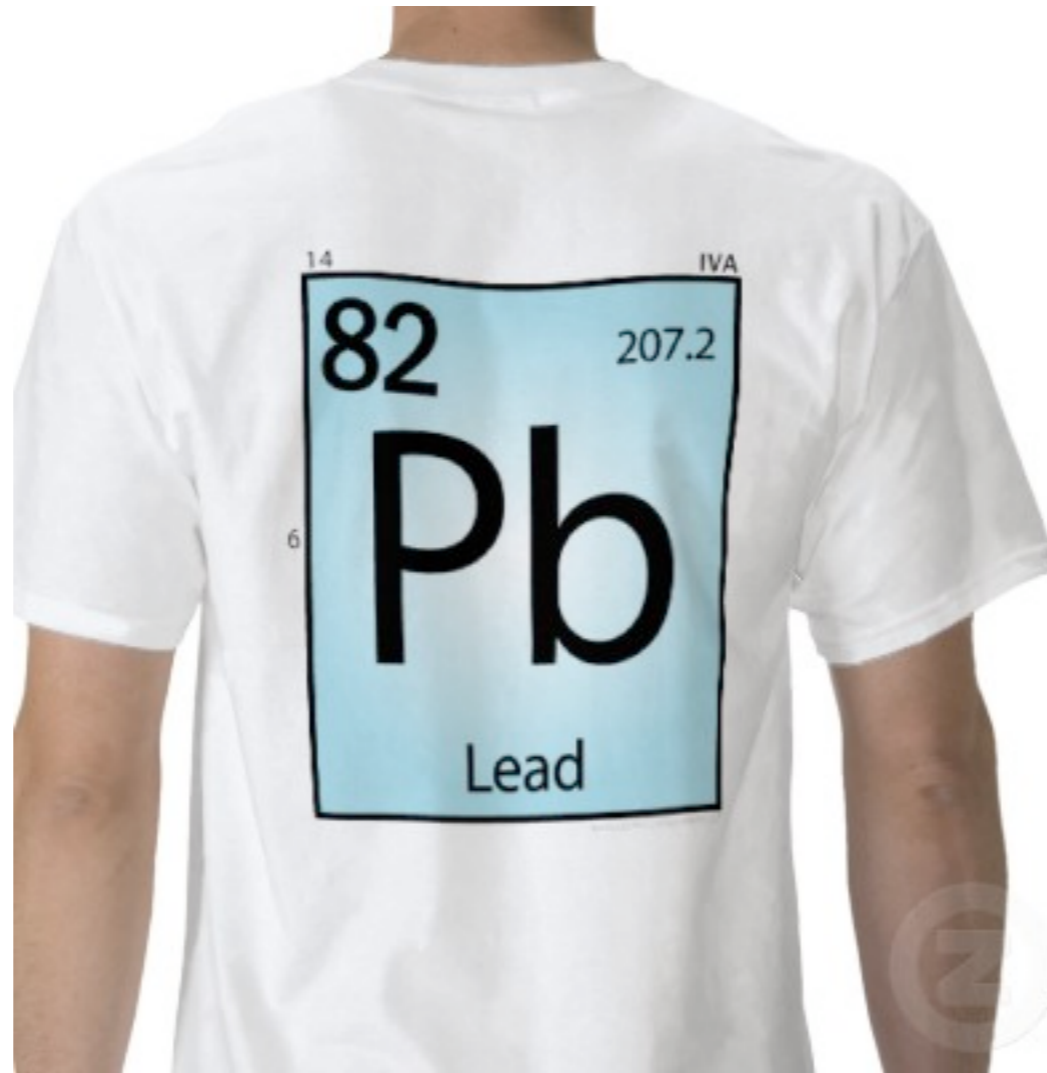


$^{204}\text{Pb}$

$^{206}\text{Pb}$

$^{207}\text{Pb}$

$^{208}\text{Pb}$







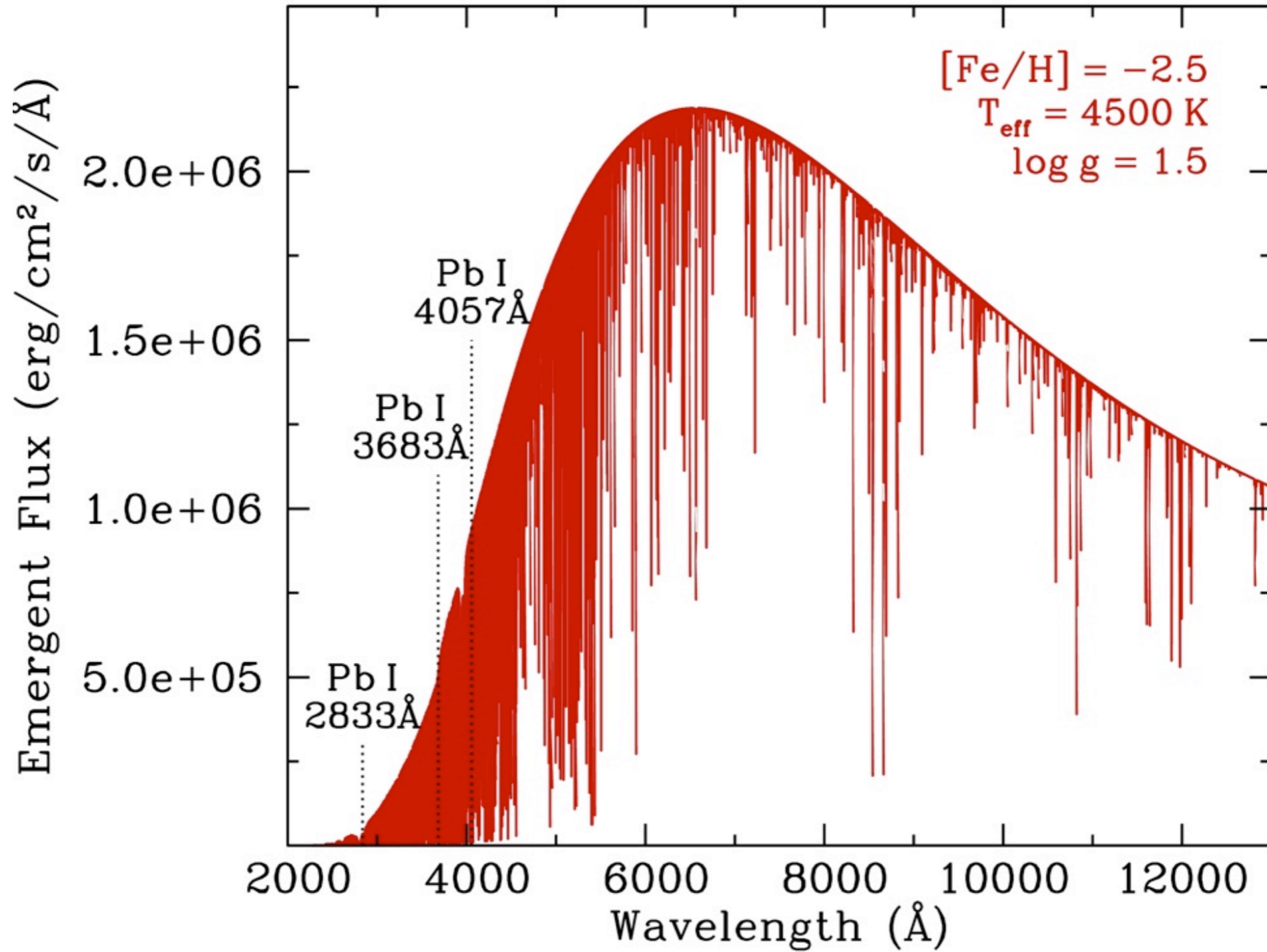


Pb I  
4057 Å

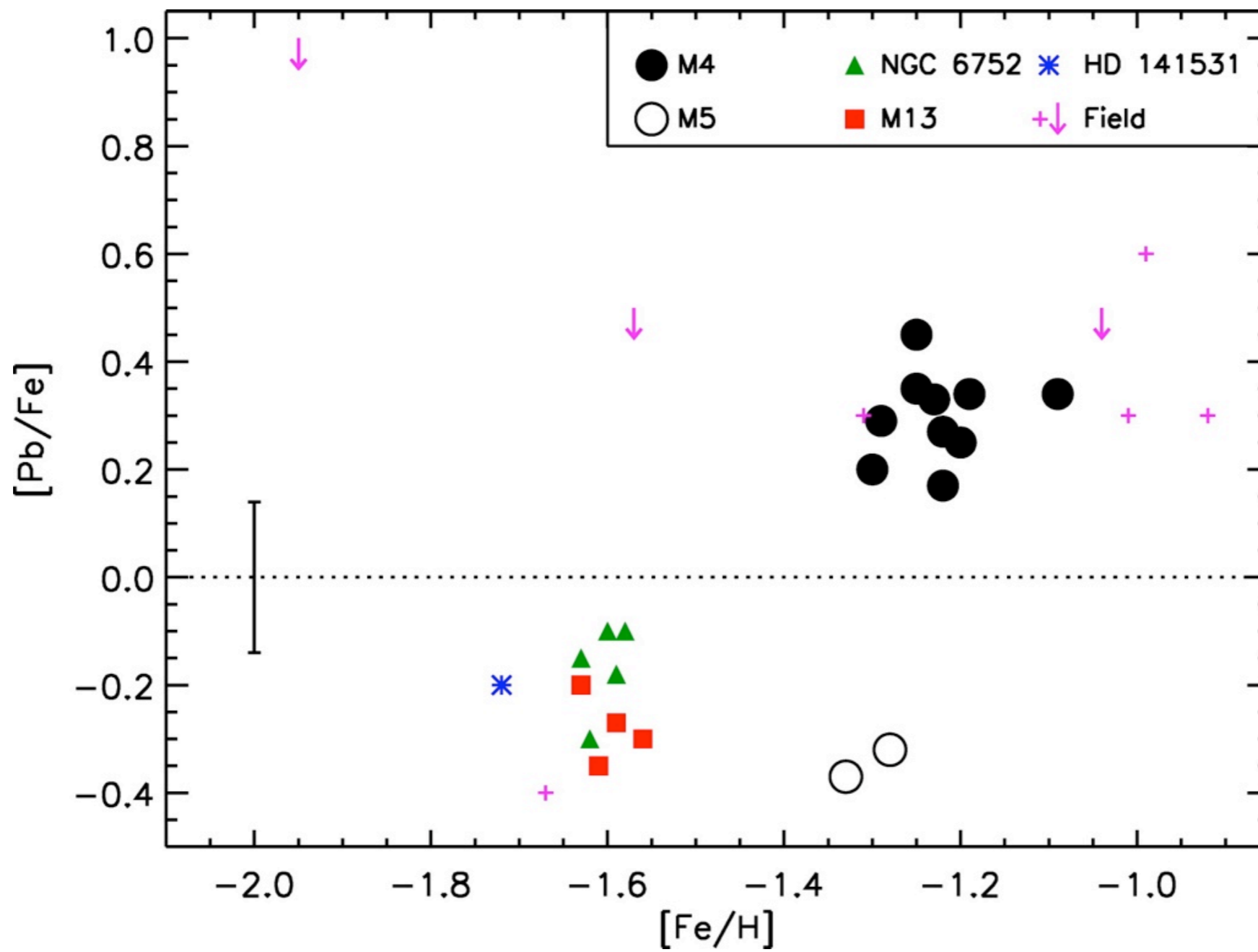
Pb I  
3683 Å

Pb I  
2833 Å

# TYPICAL METAL-POOR RED GIANT





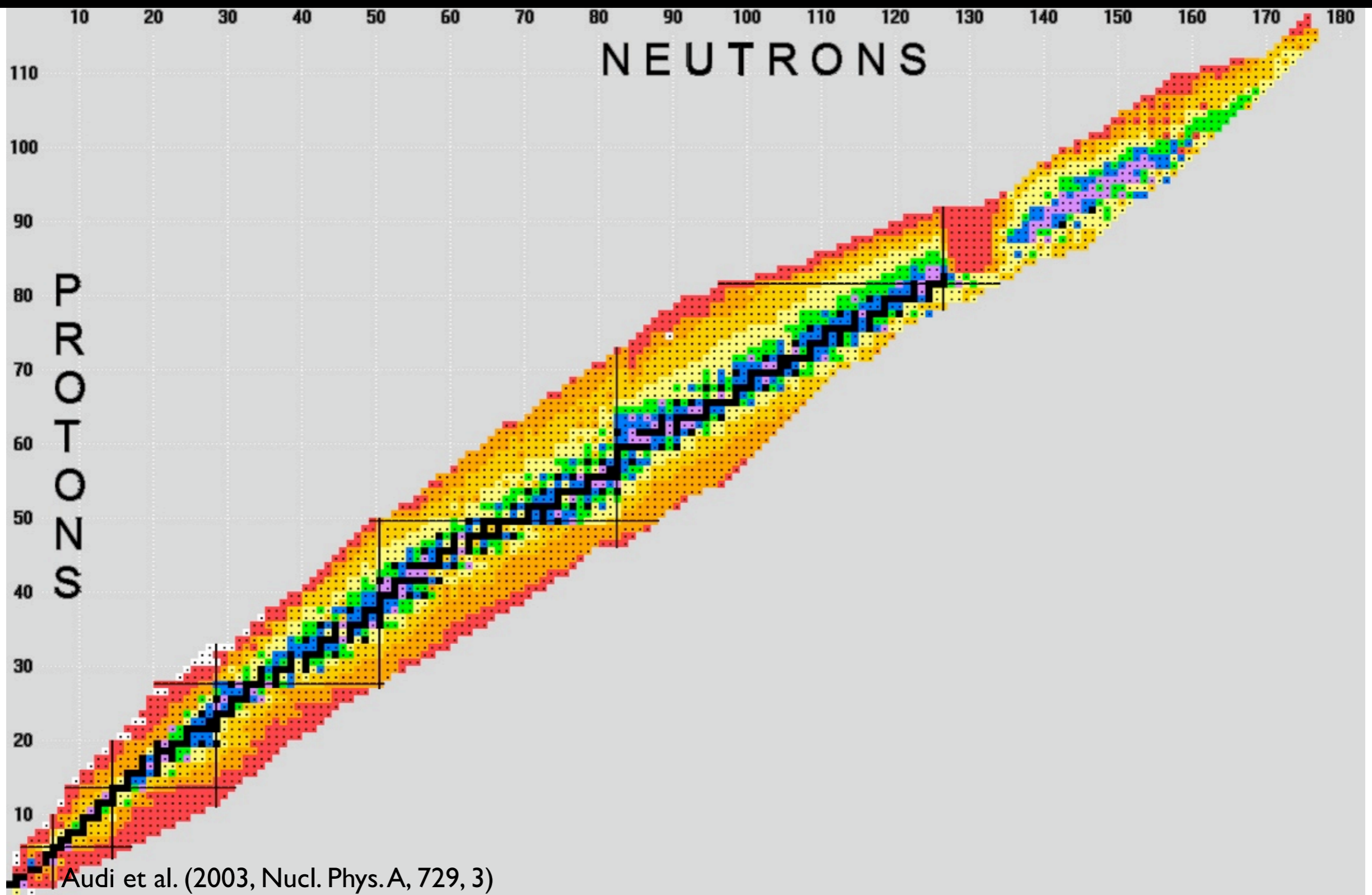


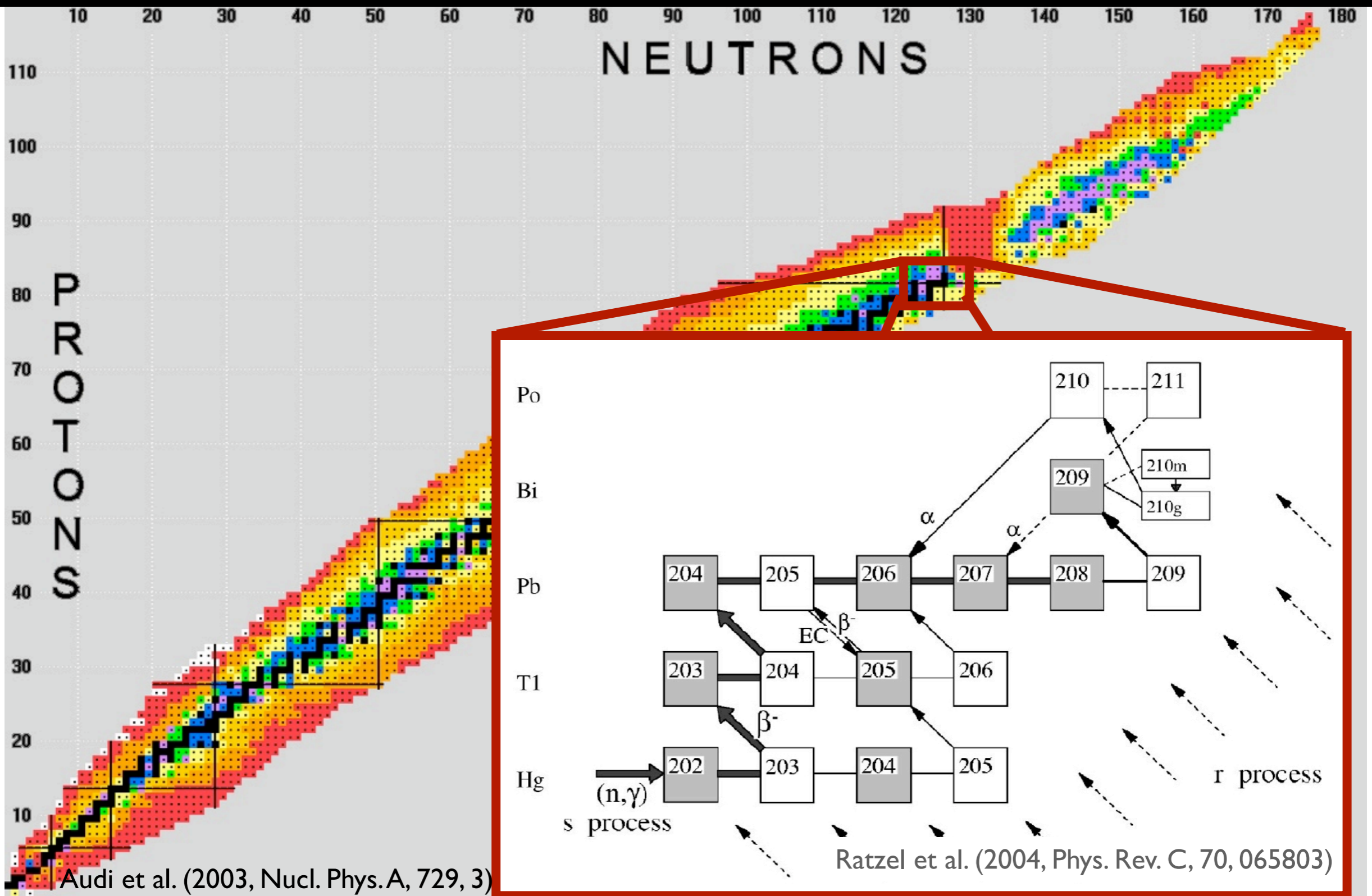


"Where's the lead?"

"What lead abundance is normal for metal-poor stars?"

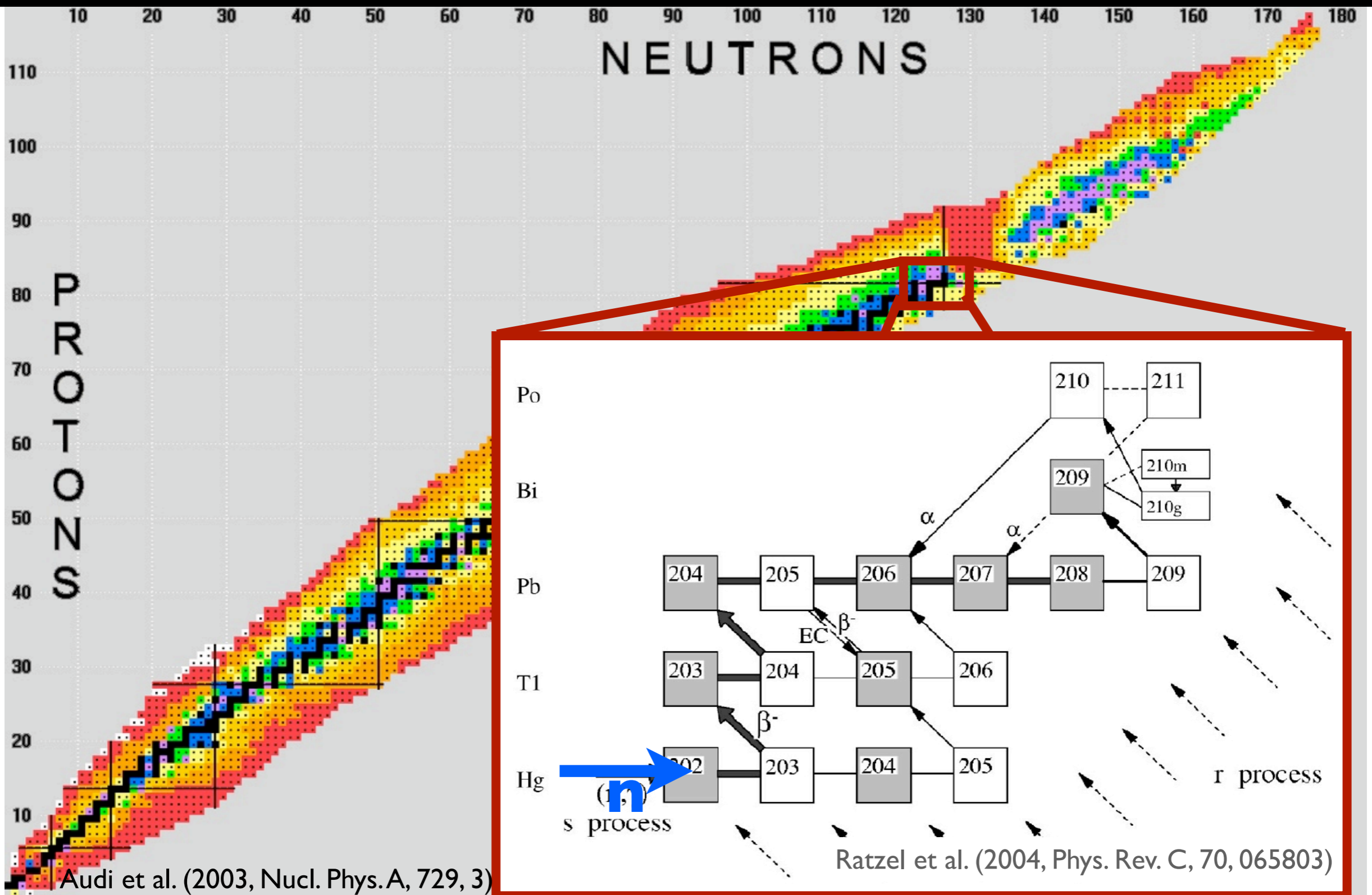


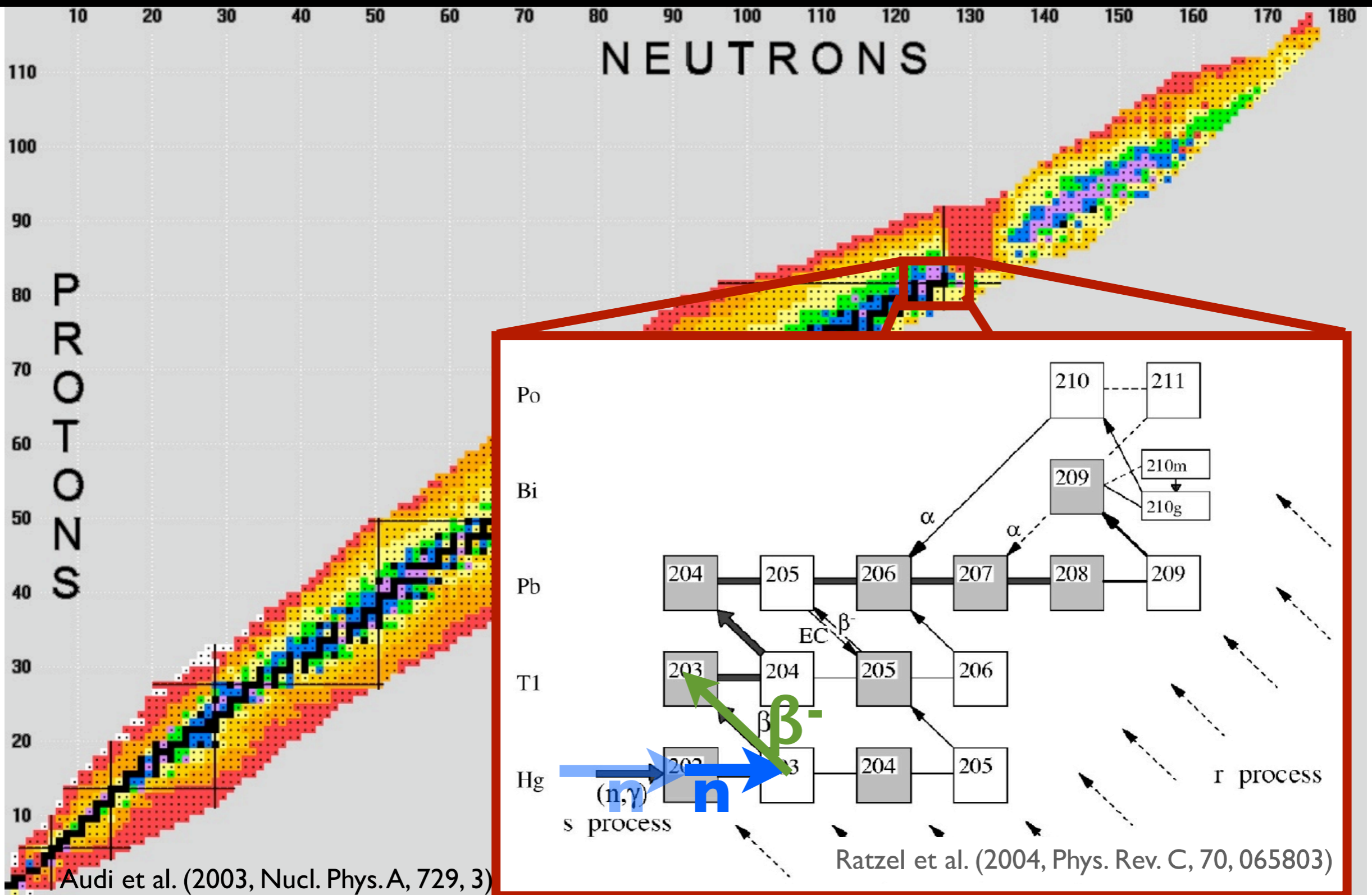




Audi et al. (2003, Nucl. Phys.A, 729, 3)

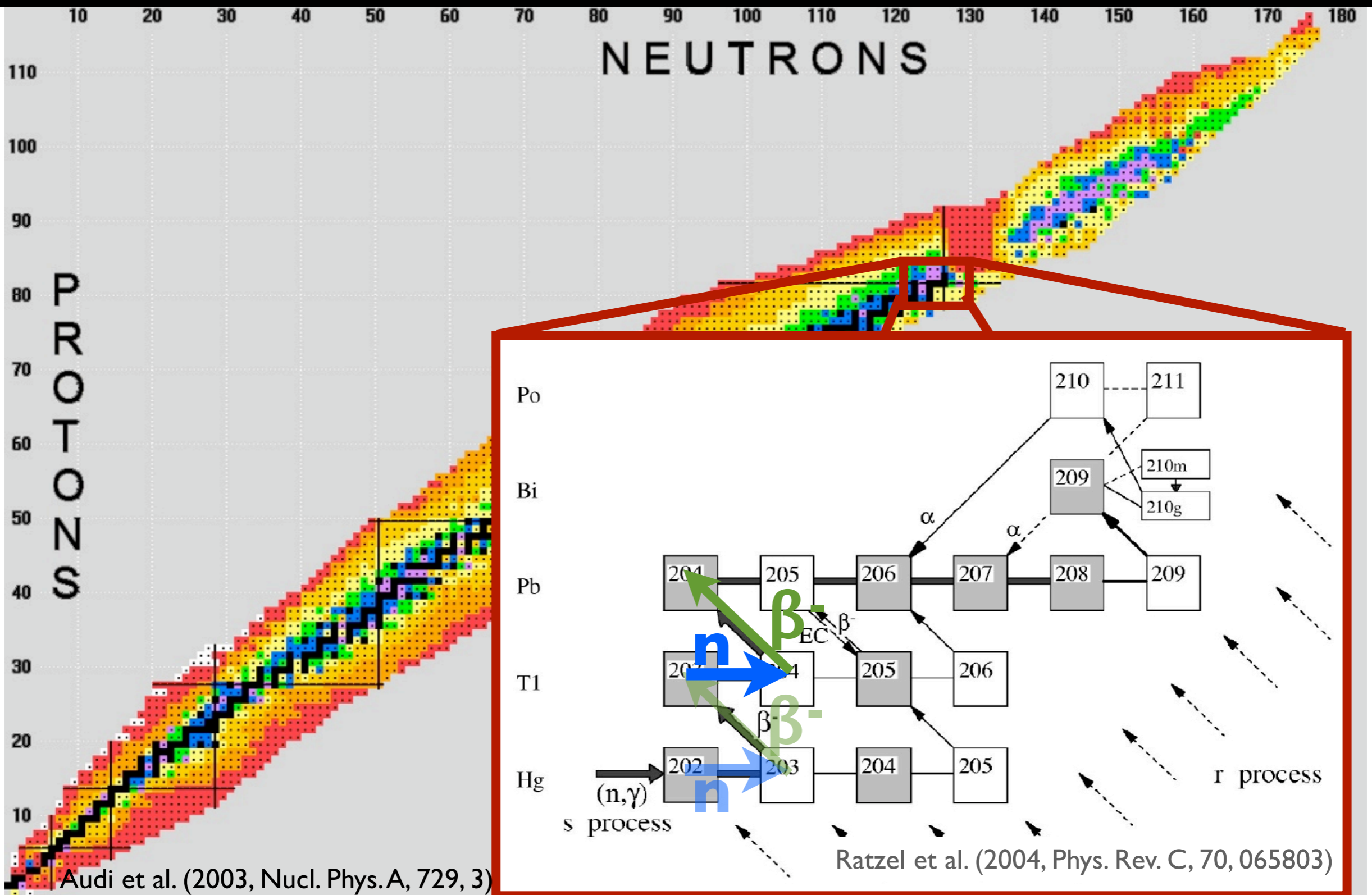
Ratzel et al. (2004, Phys. Rev. C, 70, 065803)



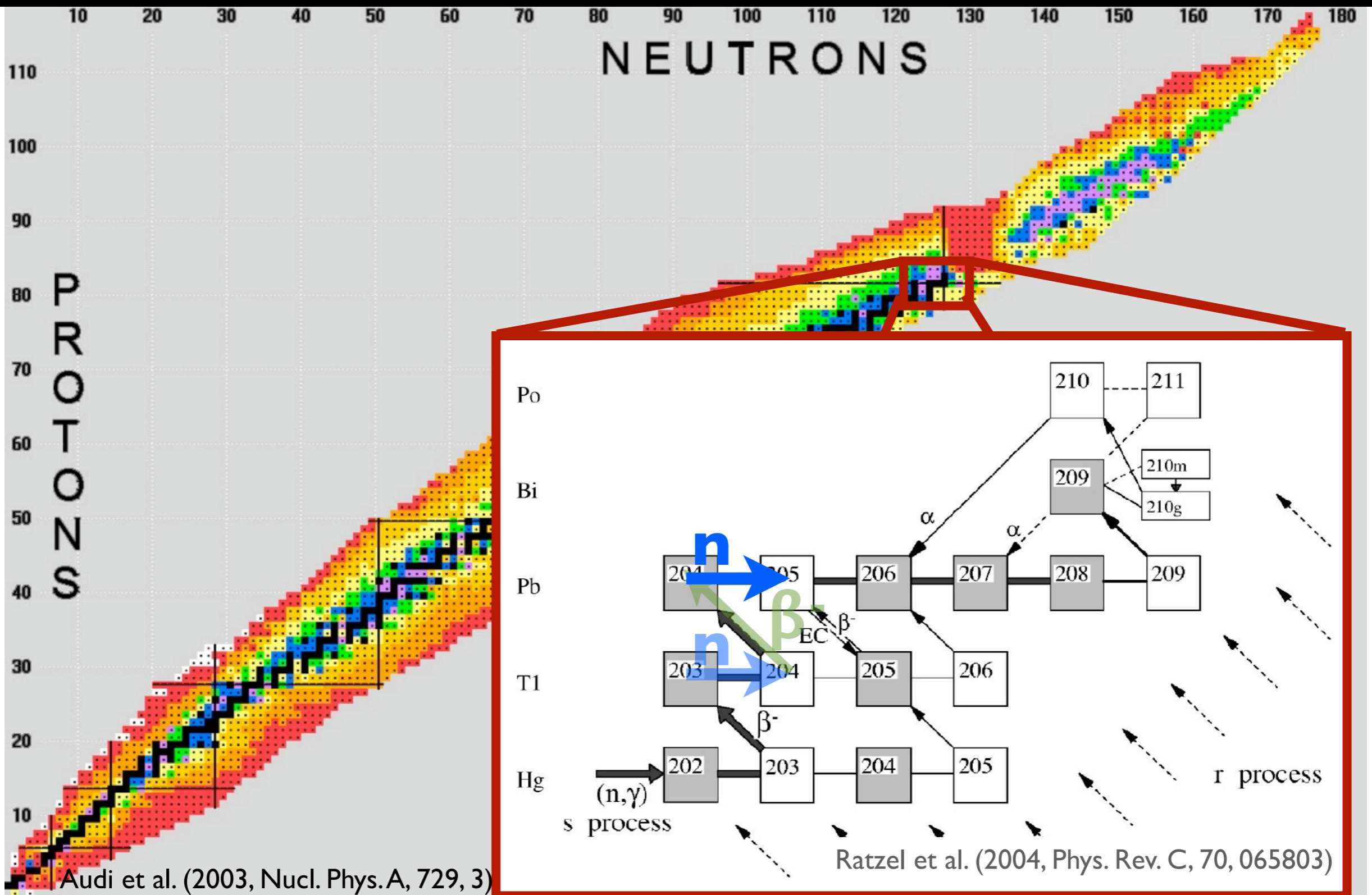


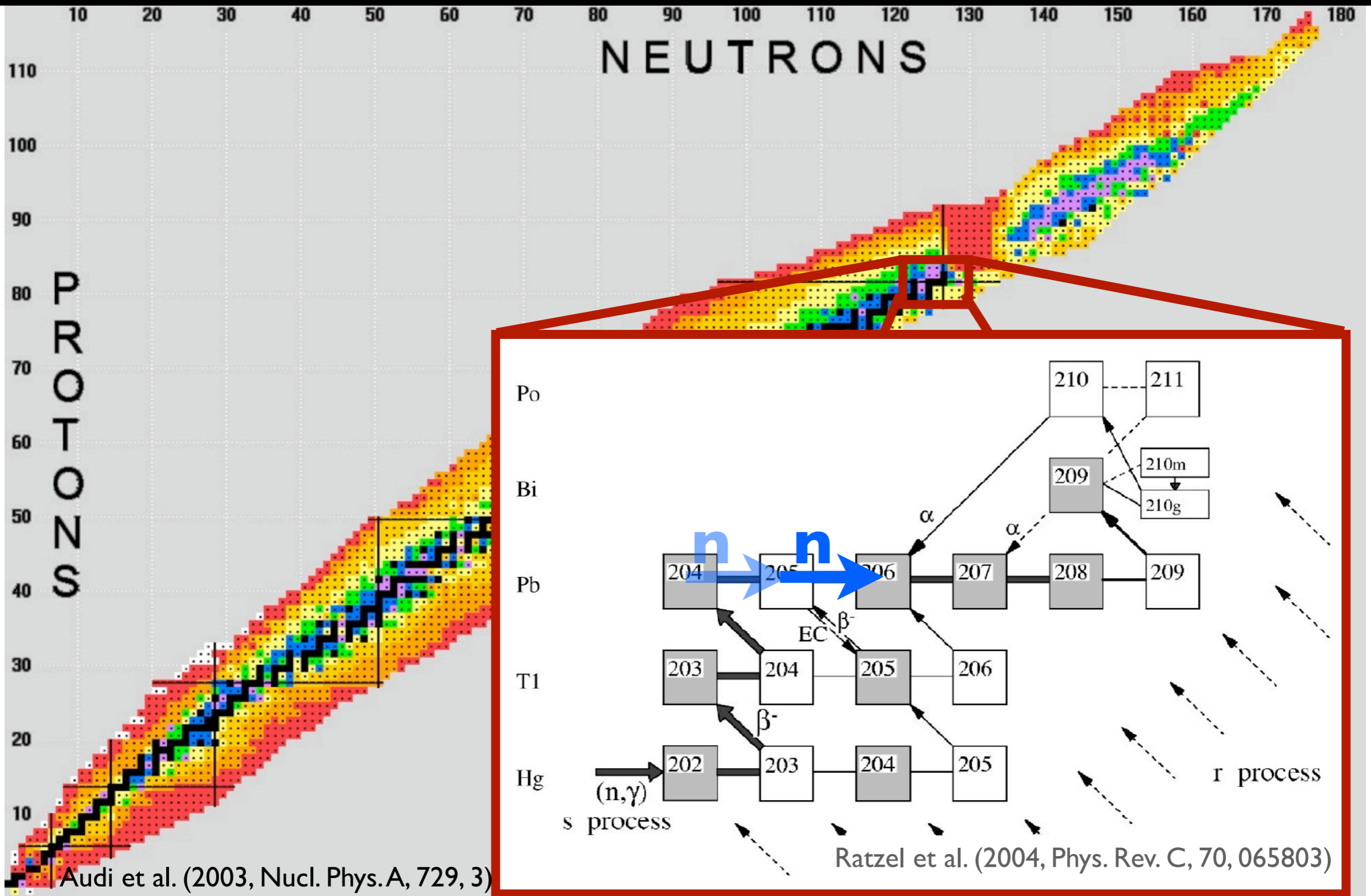
Audi et al. (2003, Nucl. Phys.A, 729, 3)

Ratzel et al. (2004, Phys. Rev. C, 70, 065803)

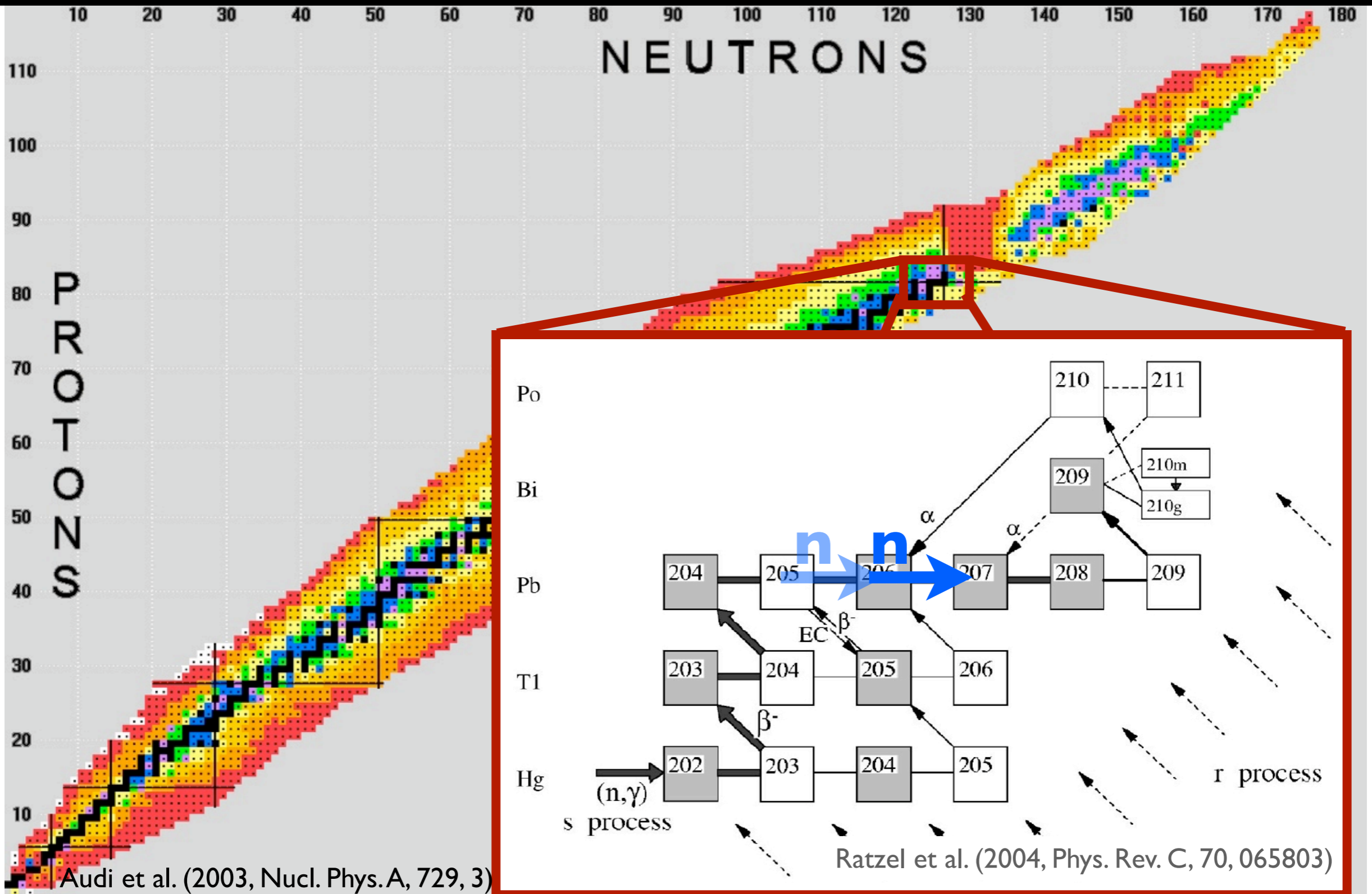




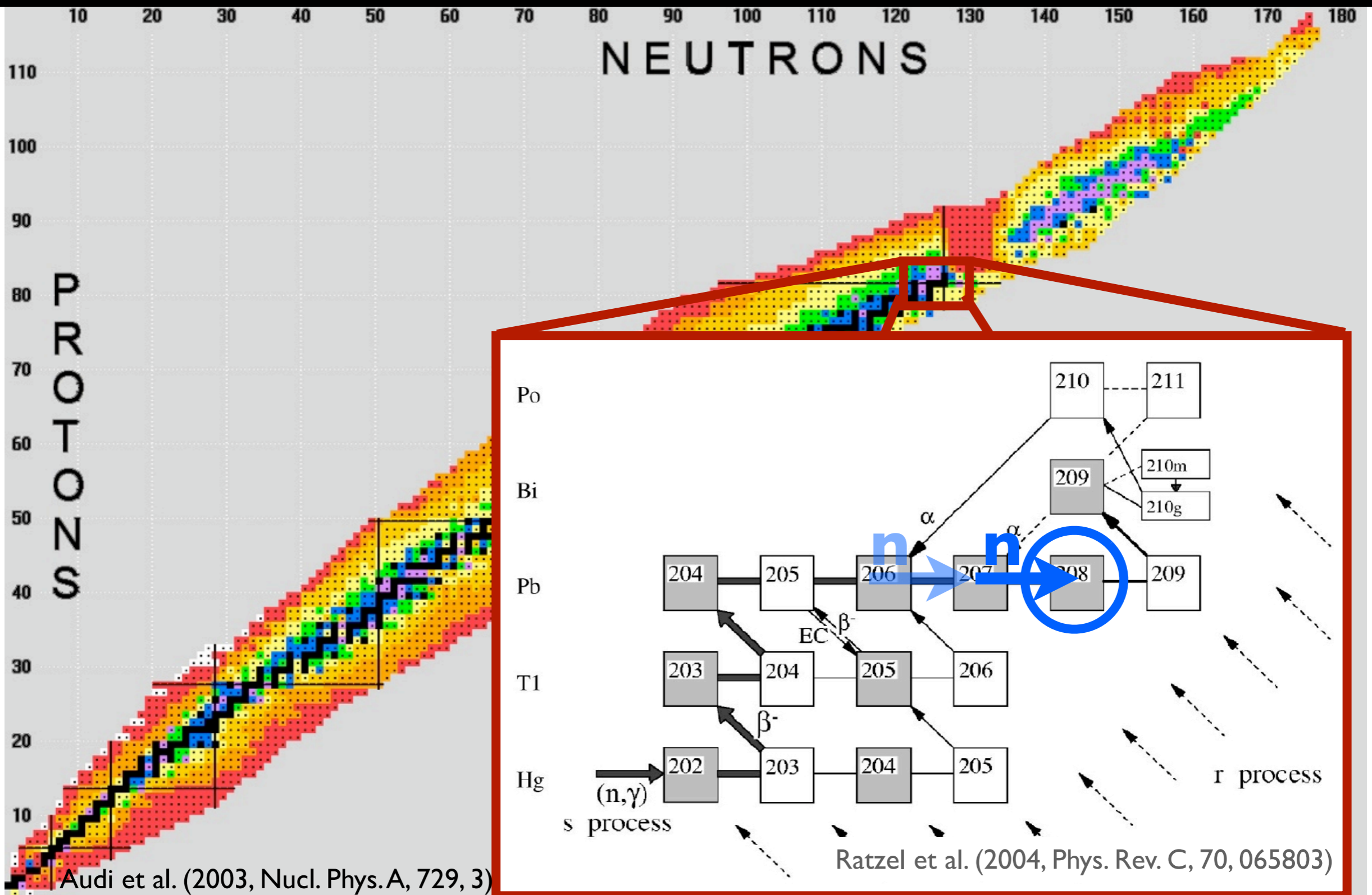




Audi et al. (2003, Nucl. Phys.A, 729, 3)

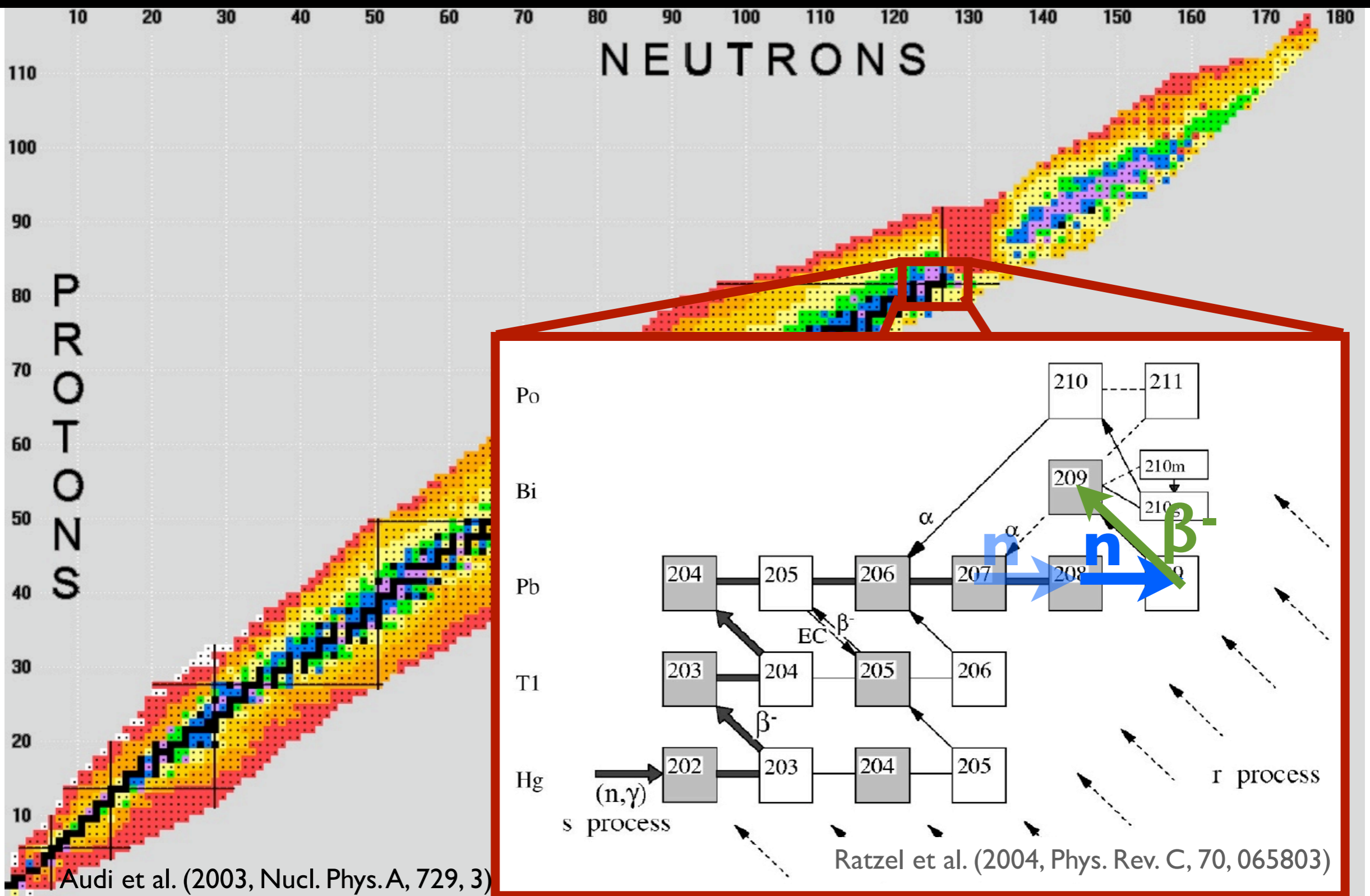


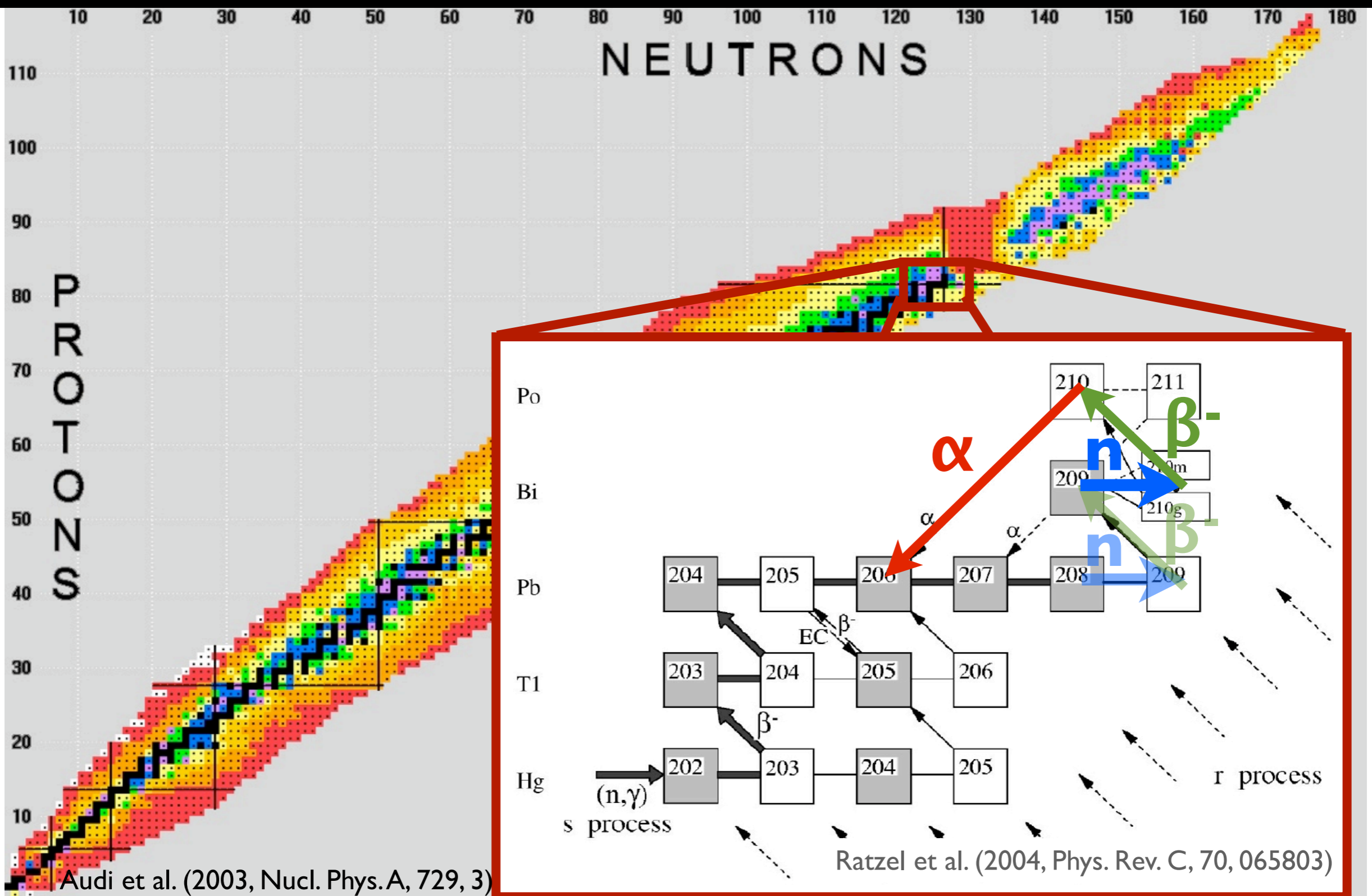
Audi et al. (2003, Nucl. Phys.A, 729, 3)



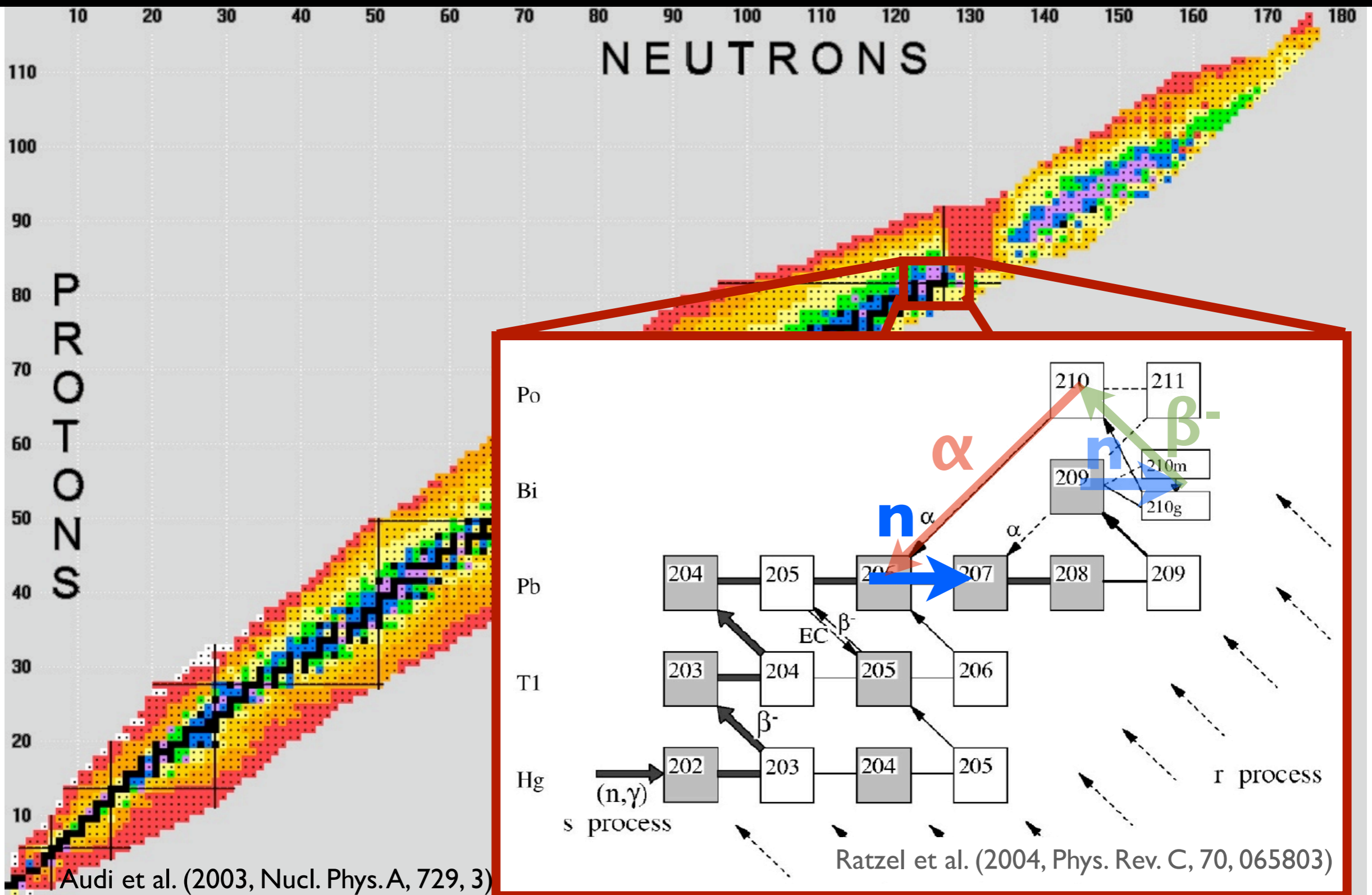
Audi et al. (2003, Nucl. Phys.A, 729, 3)

Ratzel et al. (2004, Phys. Rev. C, 70, 065803)



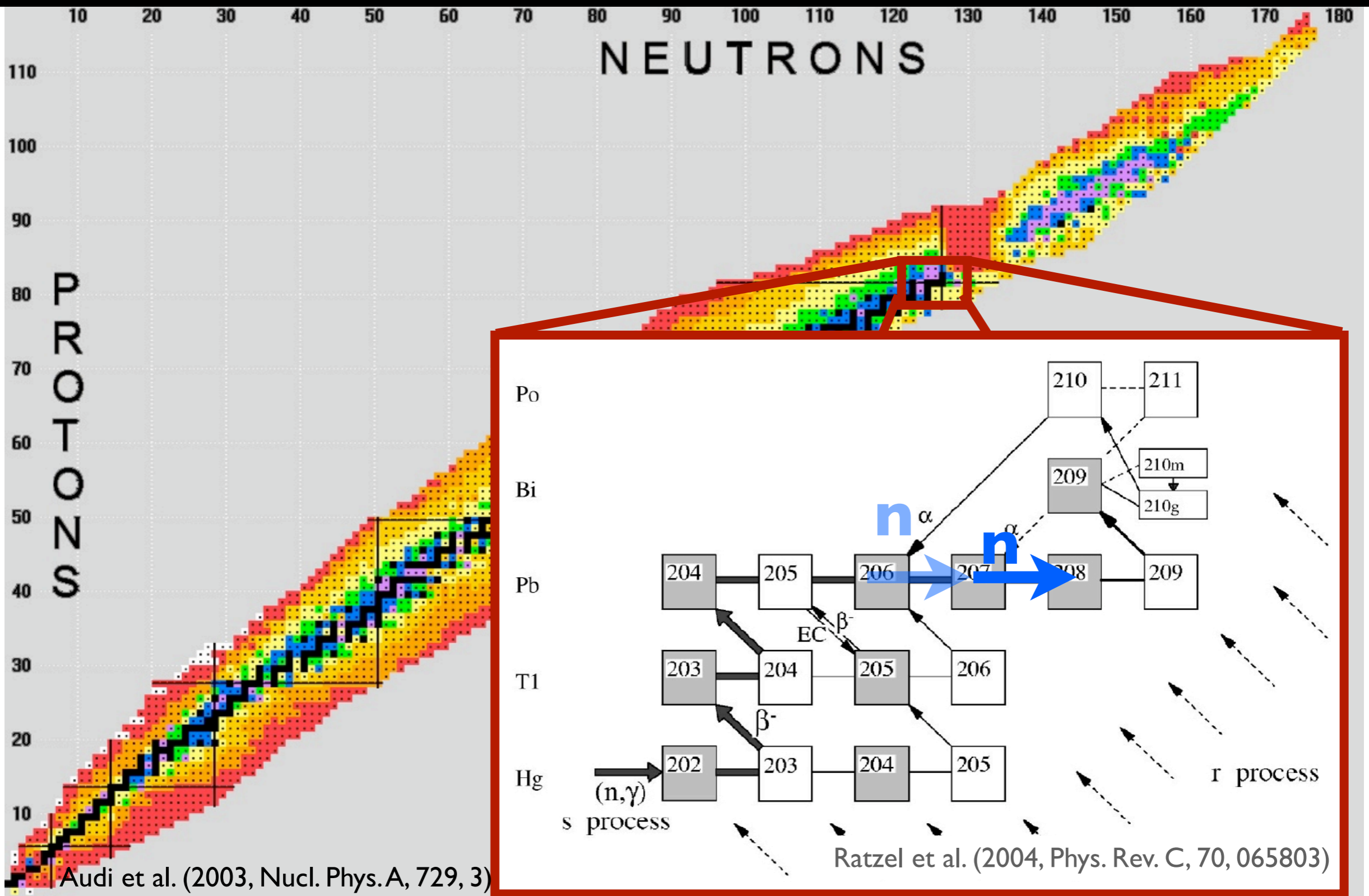


2 Audi et al. (2003, Nucl. Phys.A, 729, 3)



2 Audi et al. (2003, Nucl. Phys.A, 729, 3)

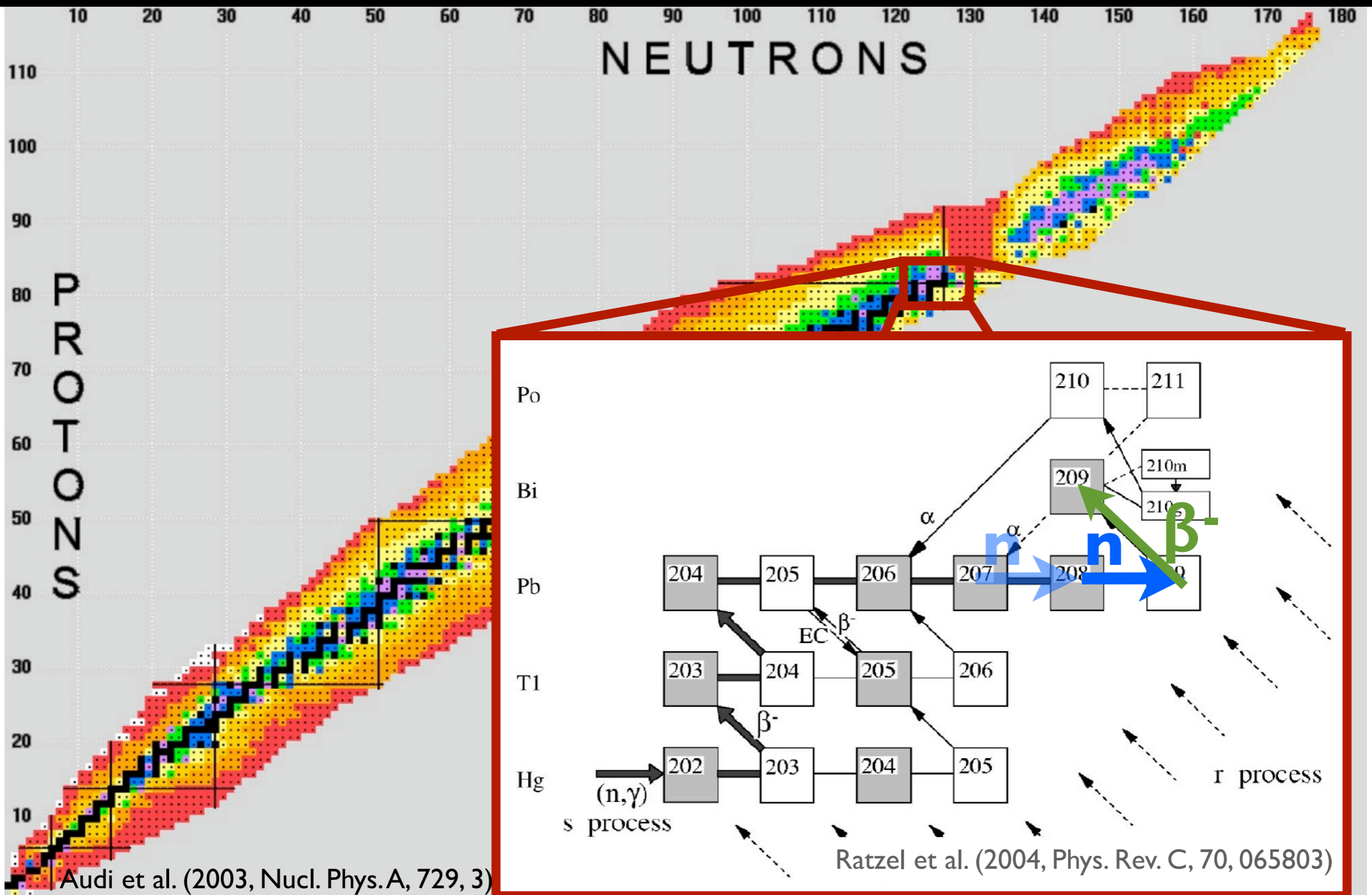
Ratzel et al. (2004, Phys. Rev. C, 70, 065803)



Audi et al. (2003, Nucl. Phys.A, 729, 3)

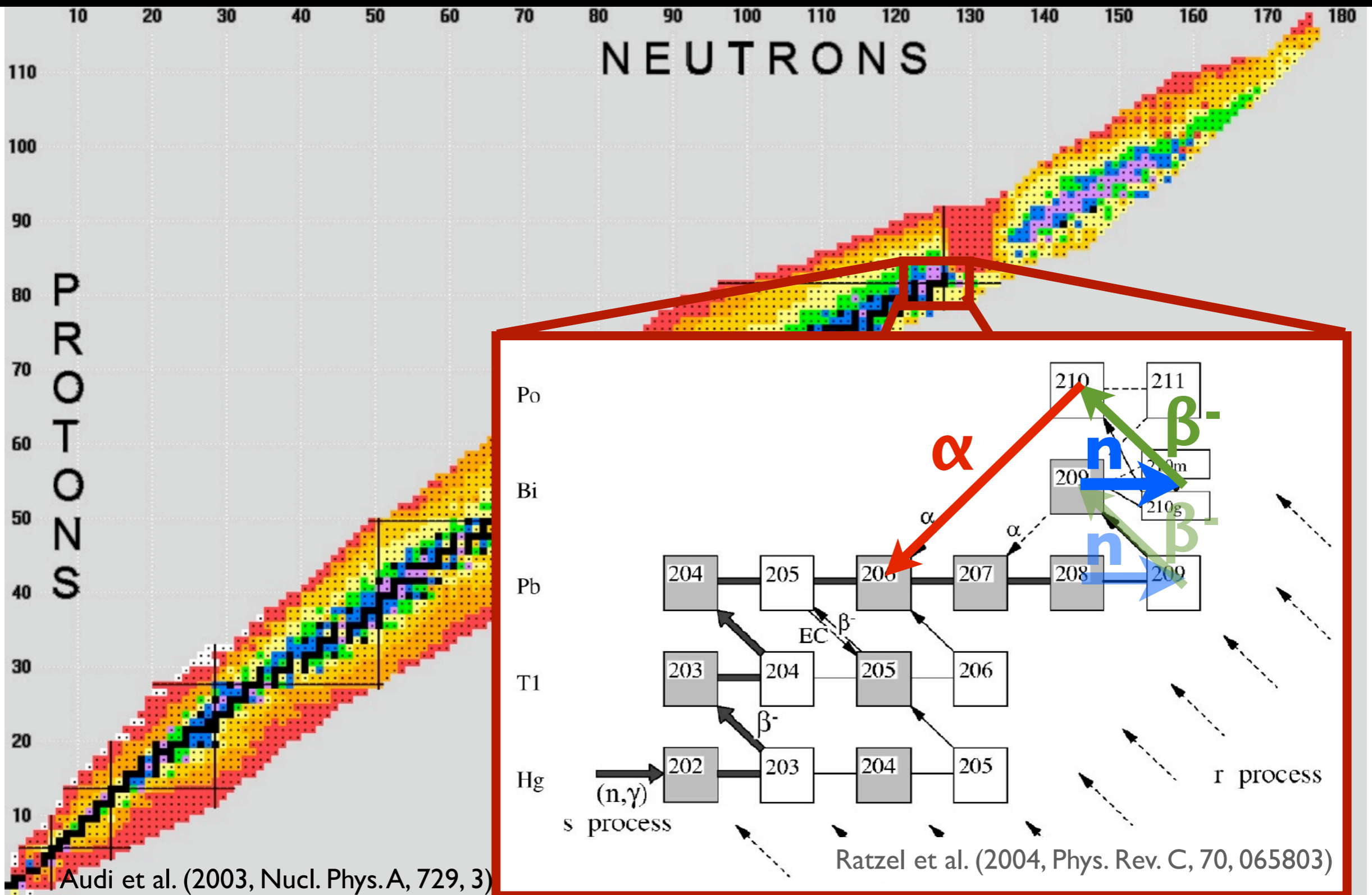
Ratzel et al. (2004, Phys. Rev. C, 70, 065803)





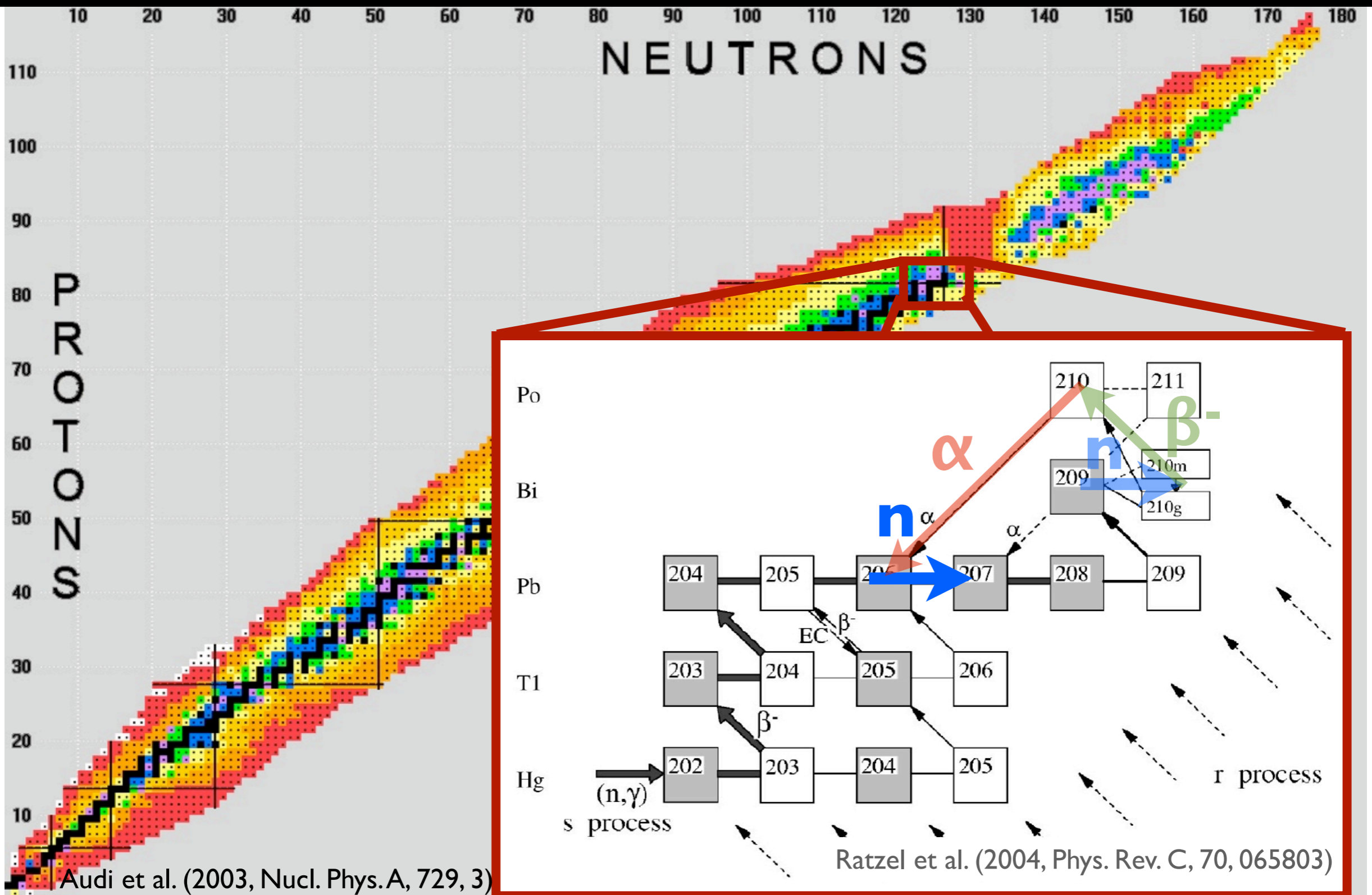
Audi et al. (2003, Nucl. Phys.A, 729, 3)

Ratzel et al. (2004, Phys. Rev. C, 70, 065803)

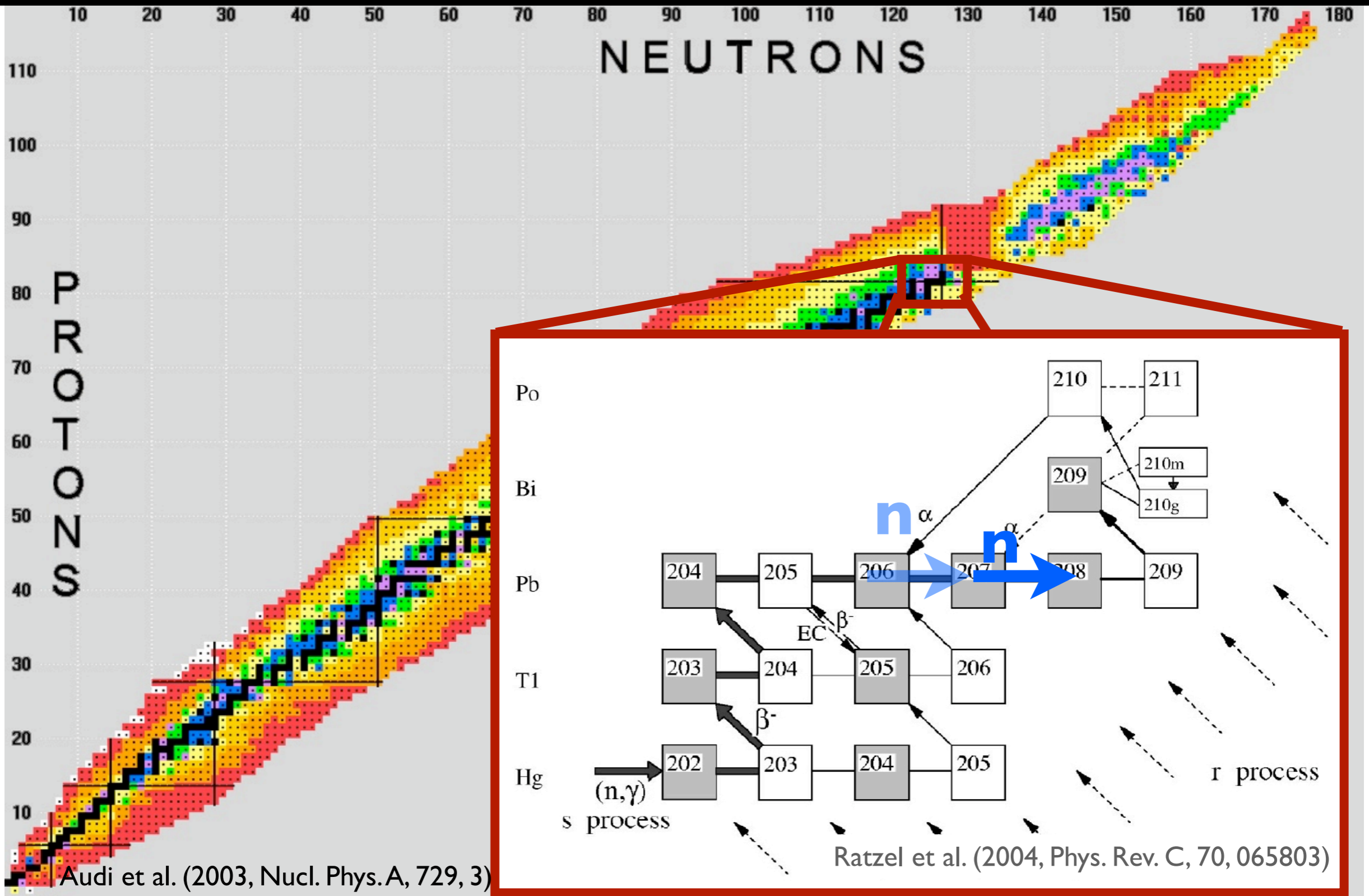


Audi et al. (2003, Nucl. Phys.A, 729, 3)

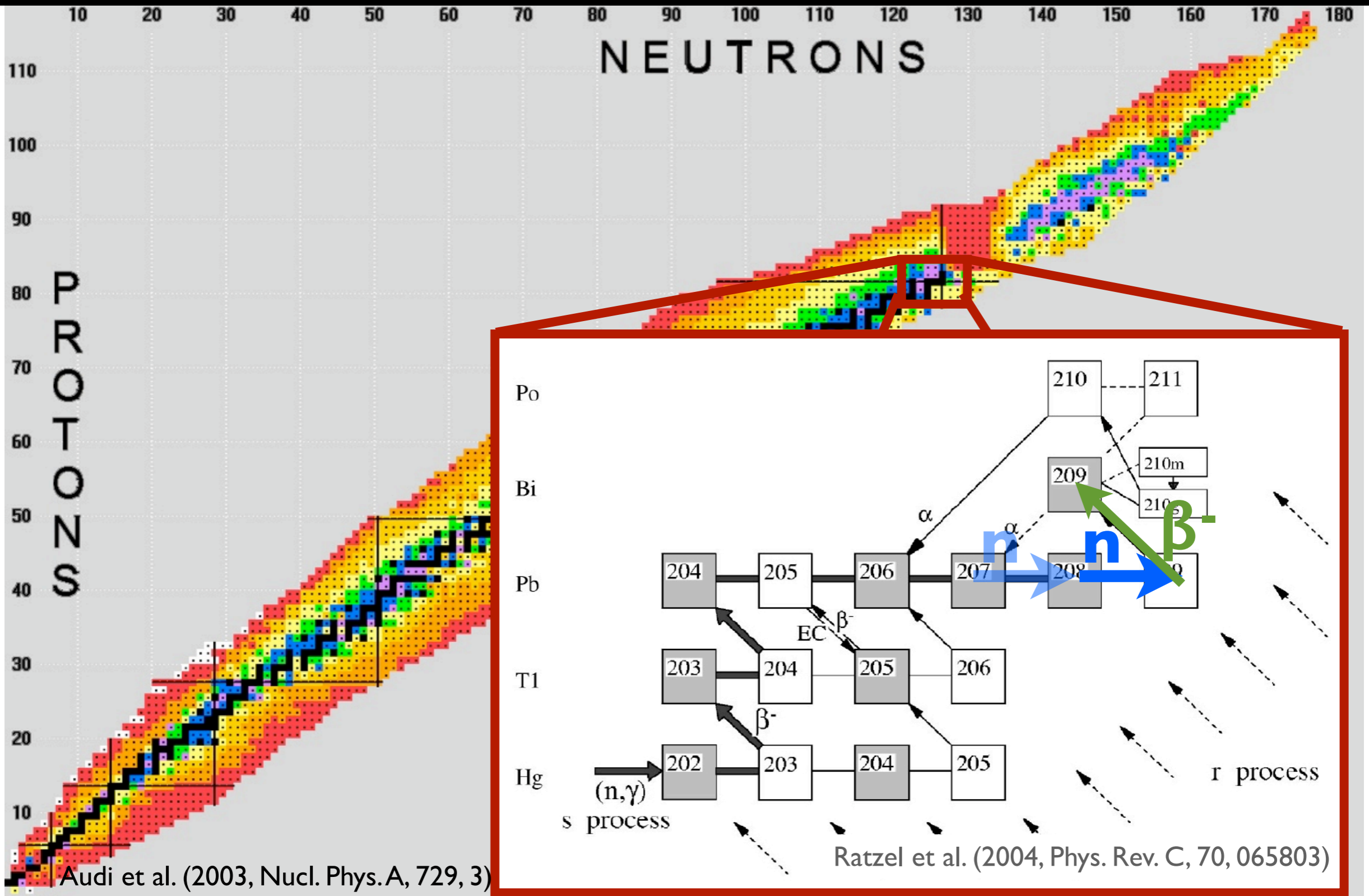
Ratzel et al. (2004, Phys. Rev. C, 70, 065803)



Audi et al. (2003, Nucl. Phys.A, 729, 3)

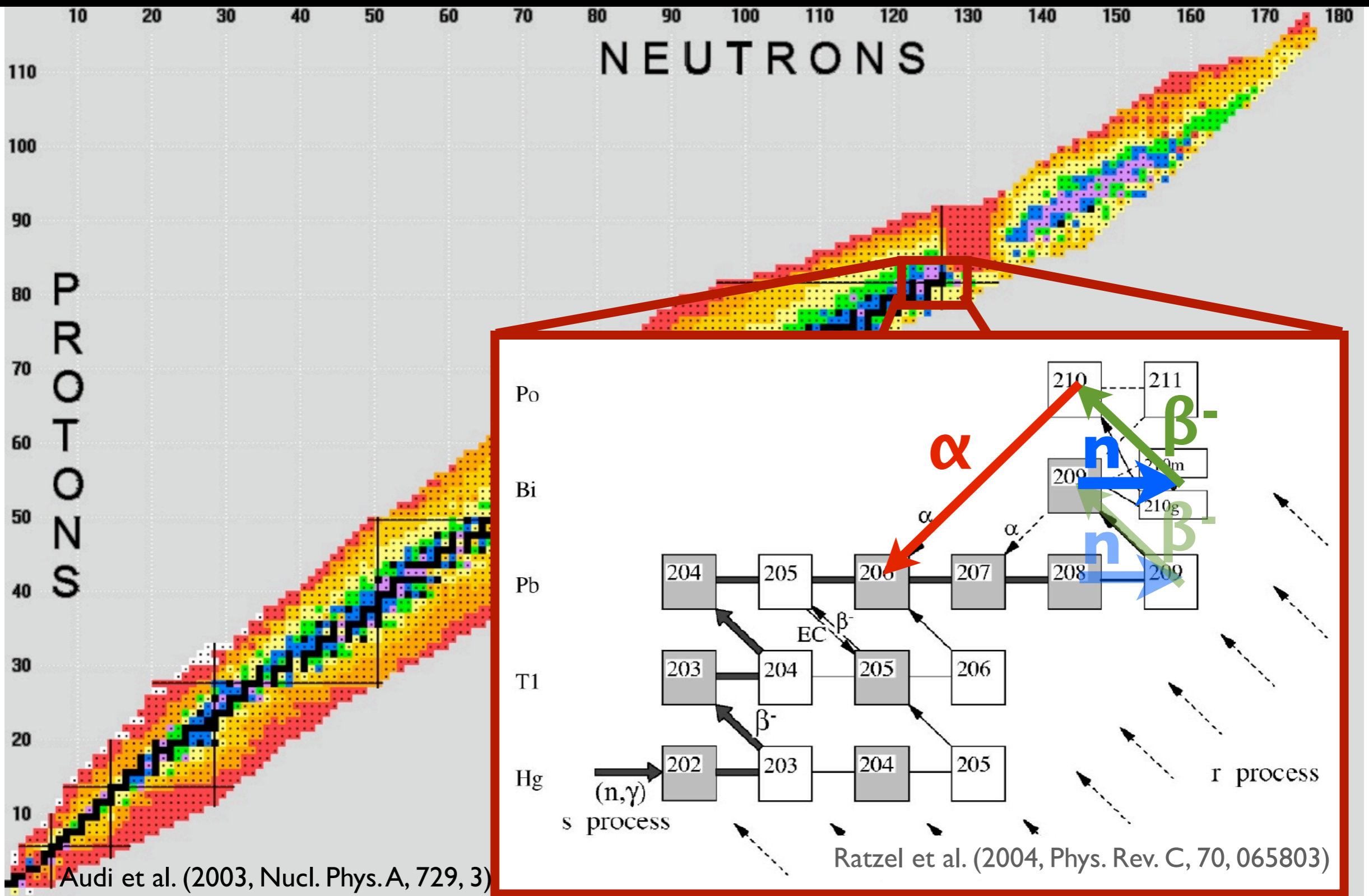


0 Audi et al. (2003, Nucl. Phys.A, 729, 3)

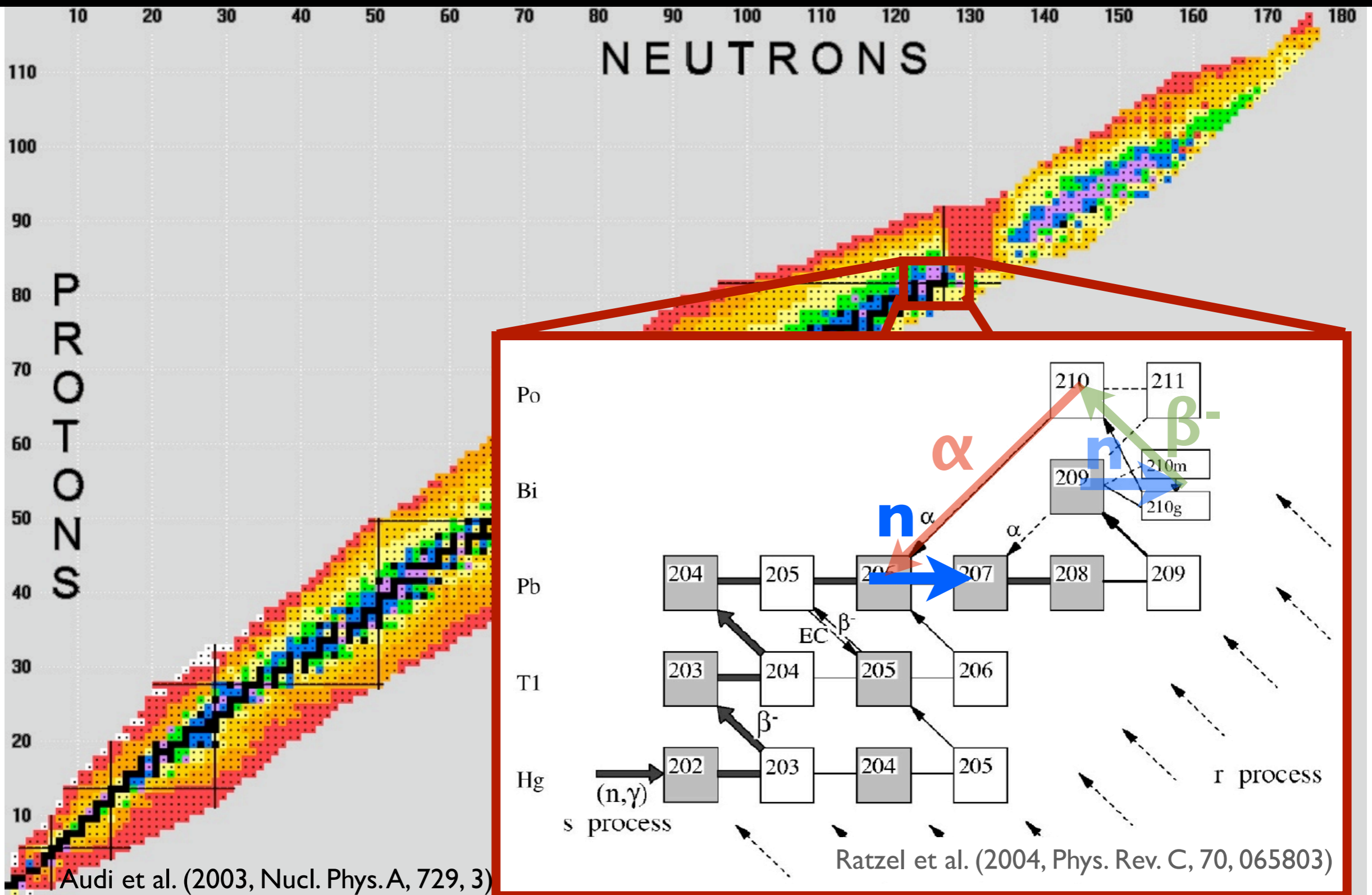


0 Audi et al. (2003, Nucl. Phys.A, 729, 3)

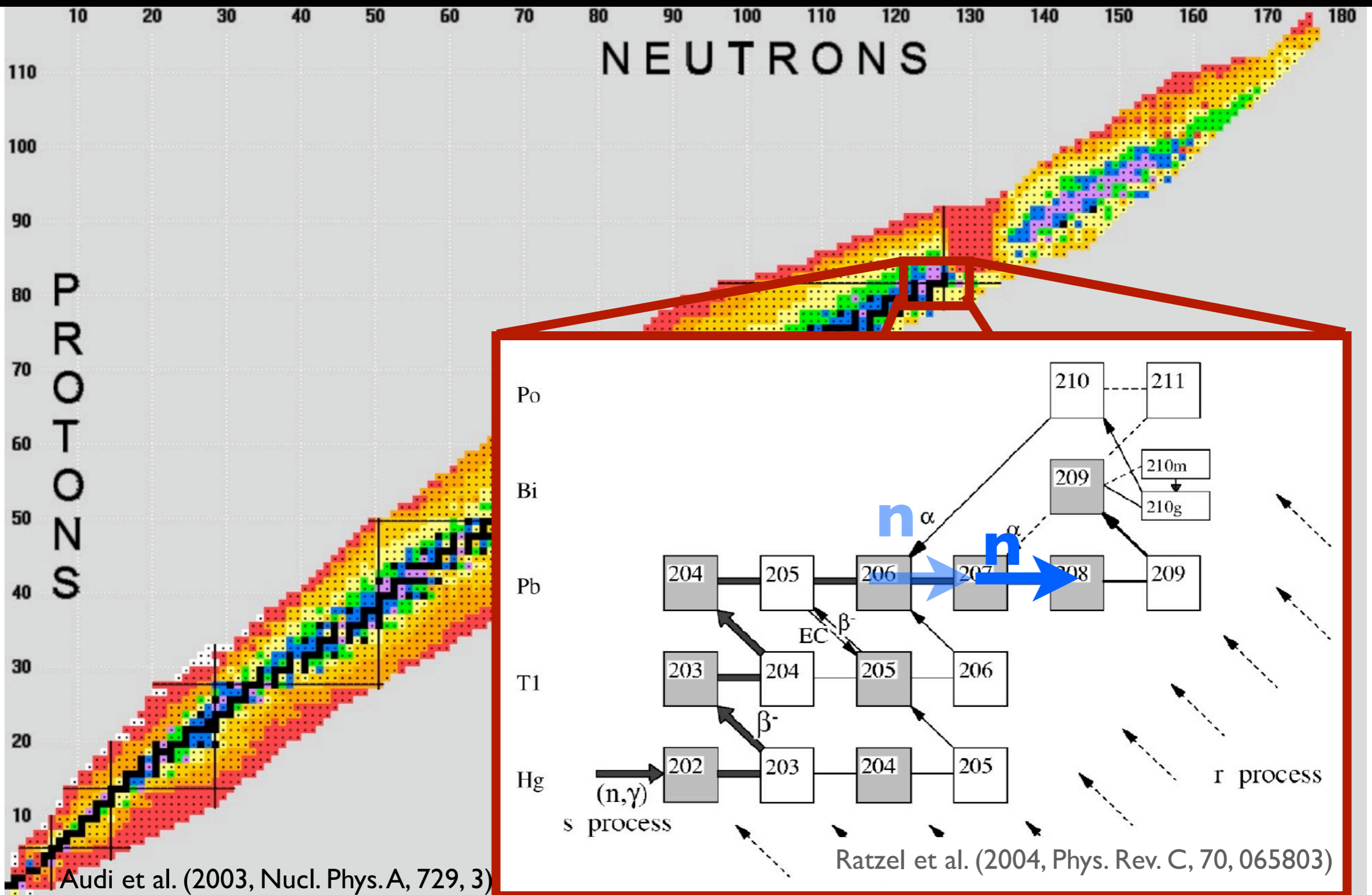
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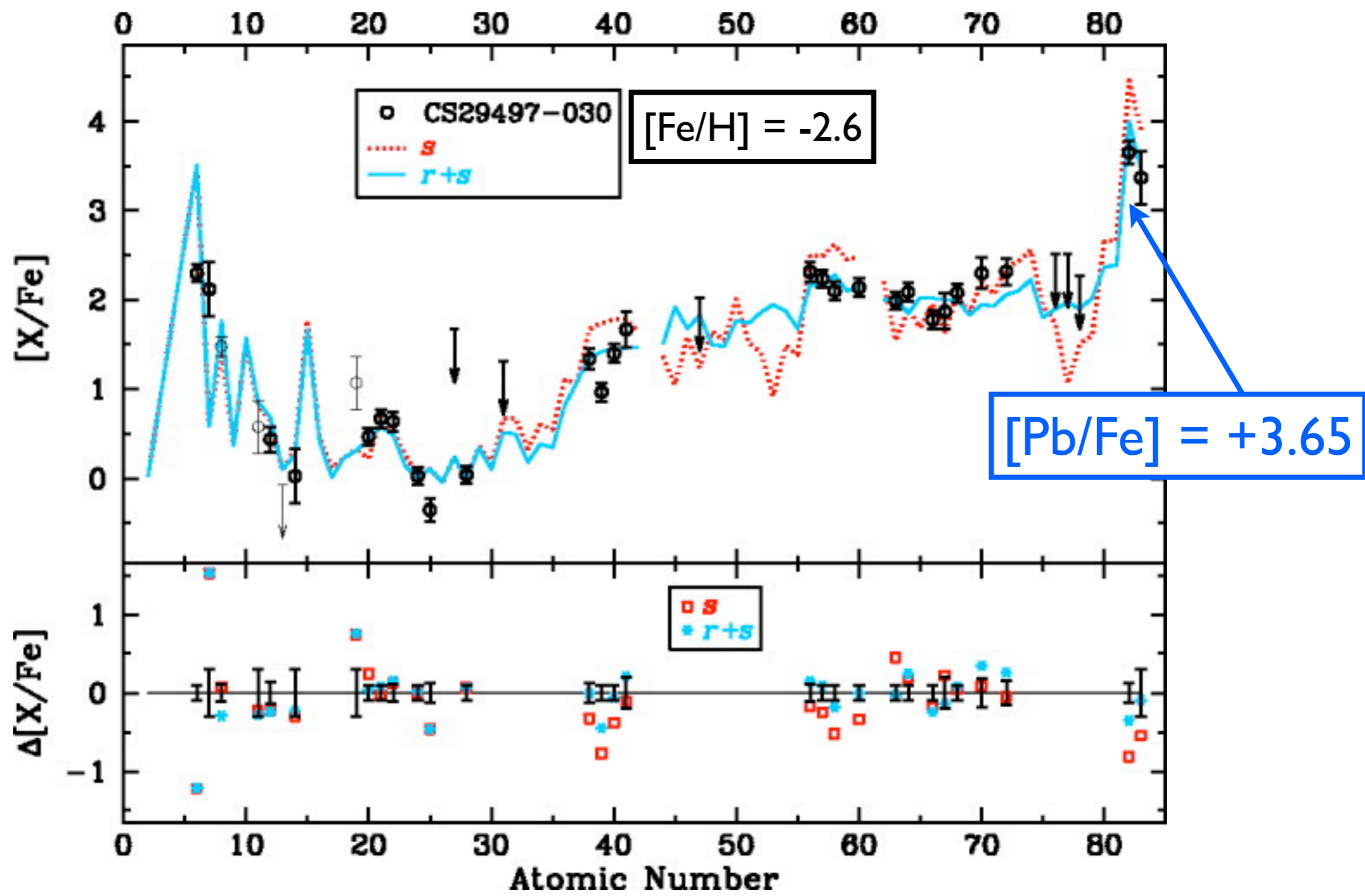


X Audi et al. (2003, Nucl. Phys.A, 729, 3)

Ratzel et al. (2004, Phys. Rev. C, 70, 065803)

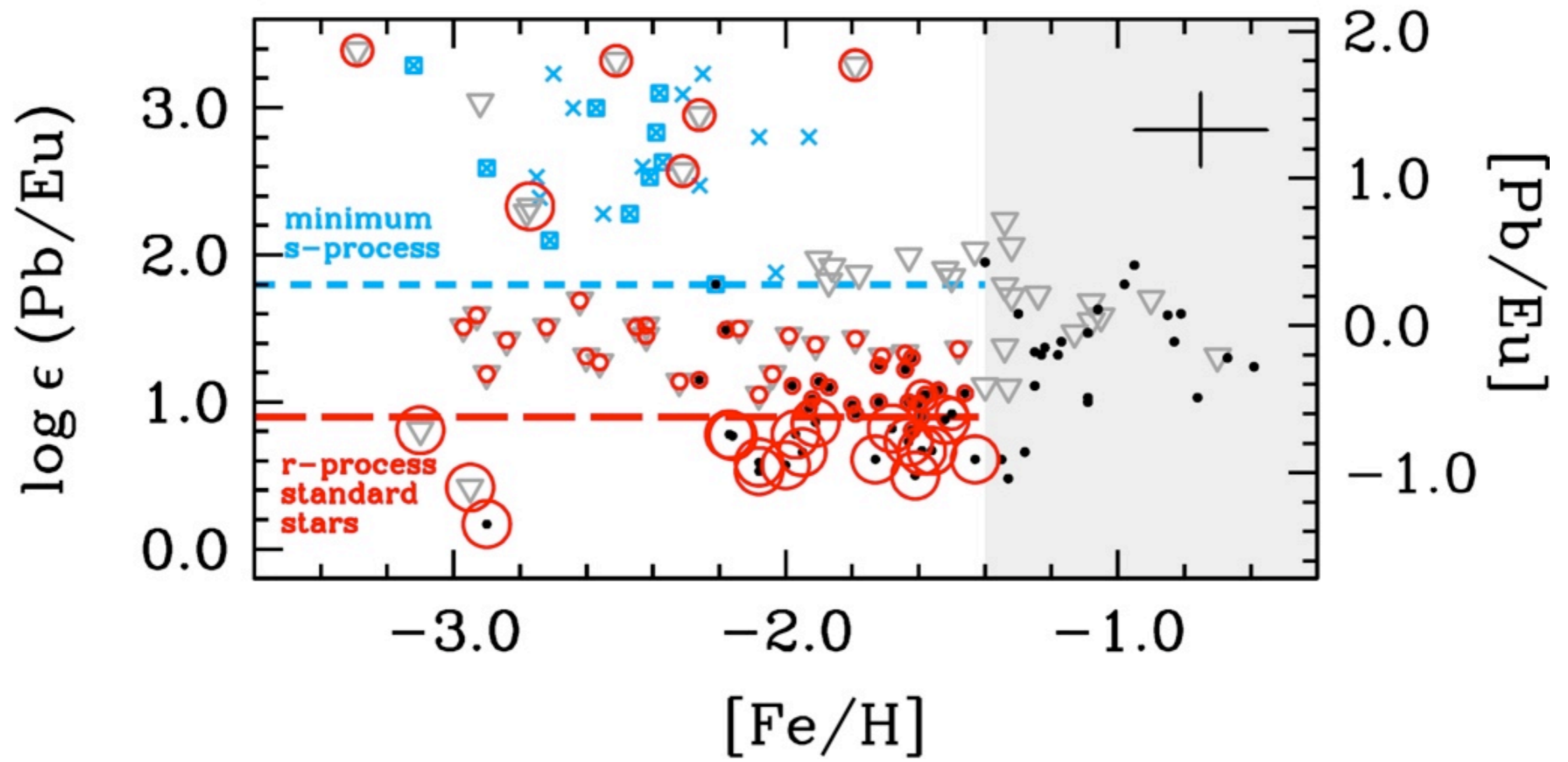


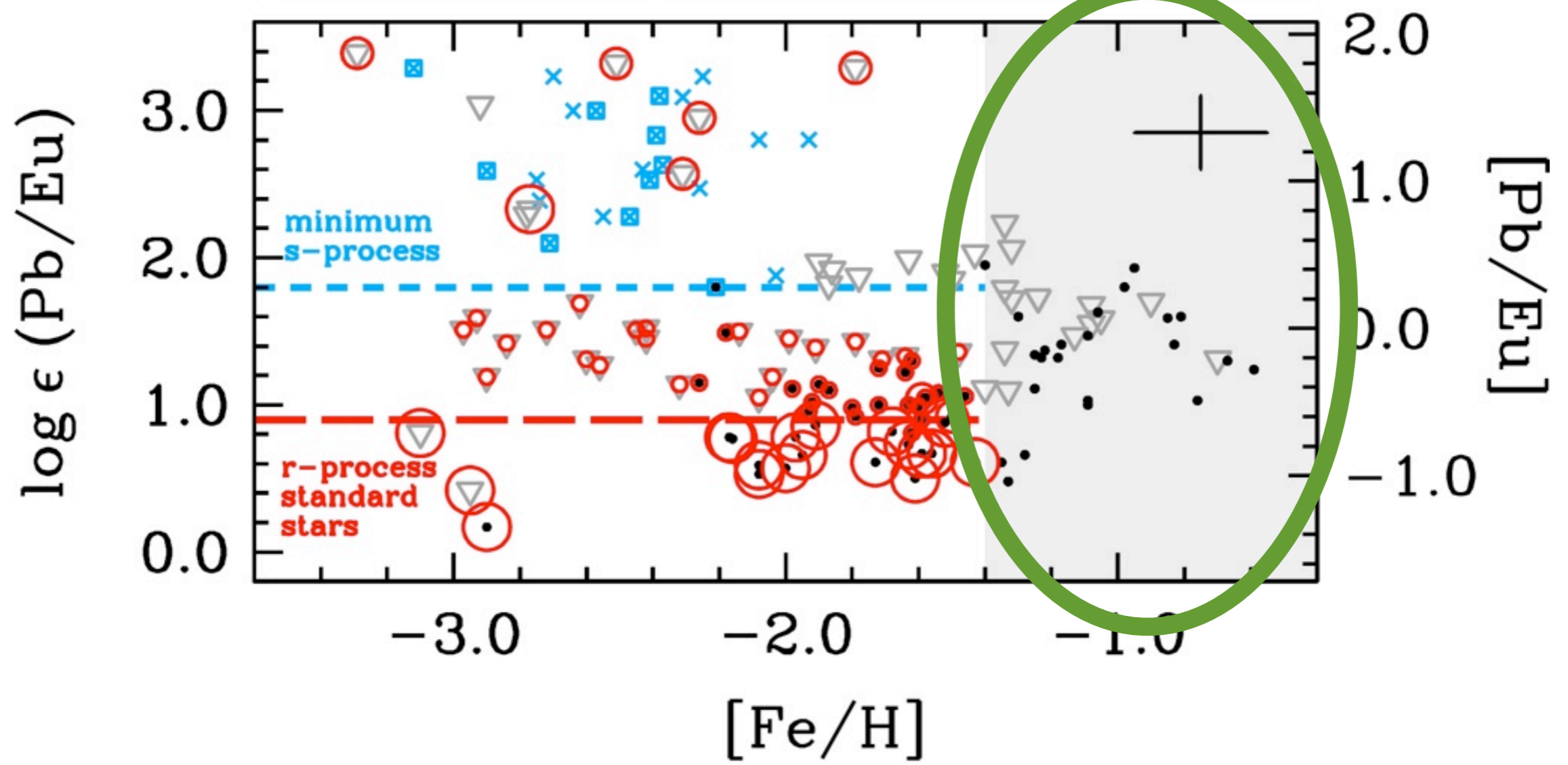


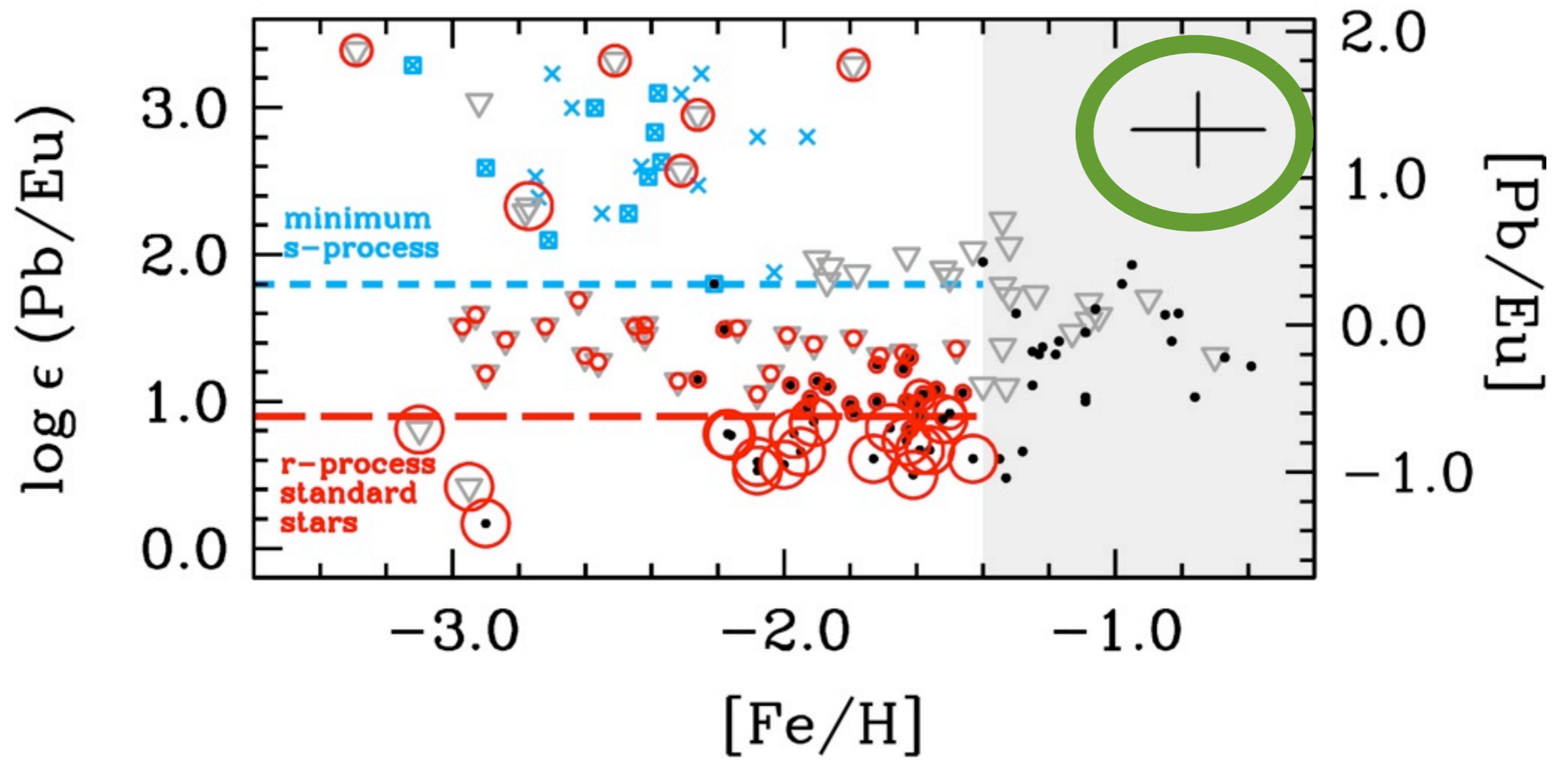


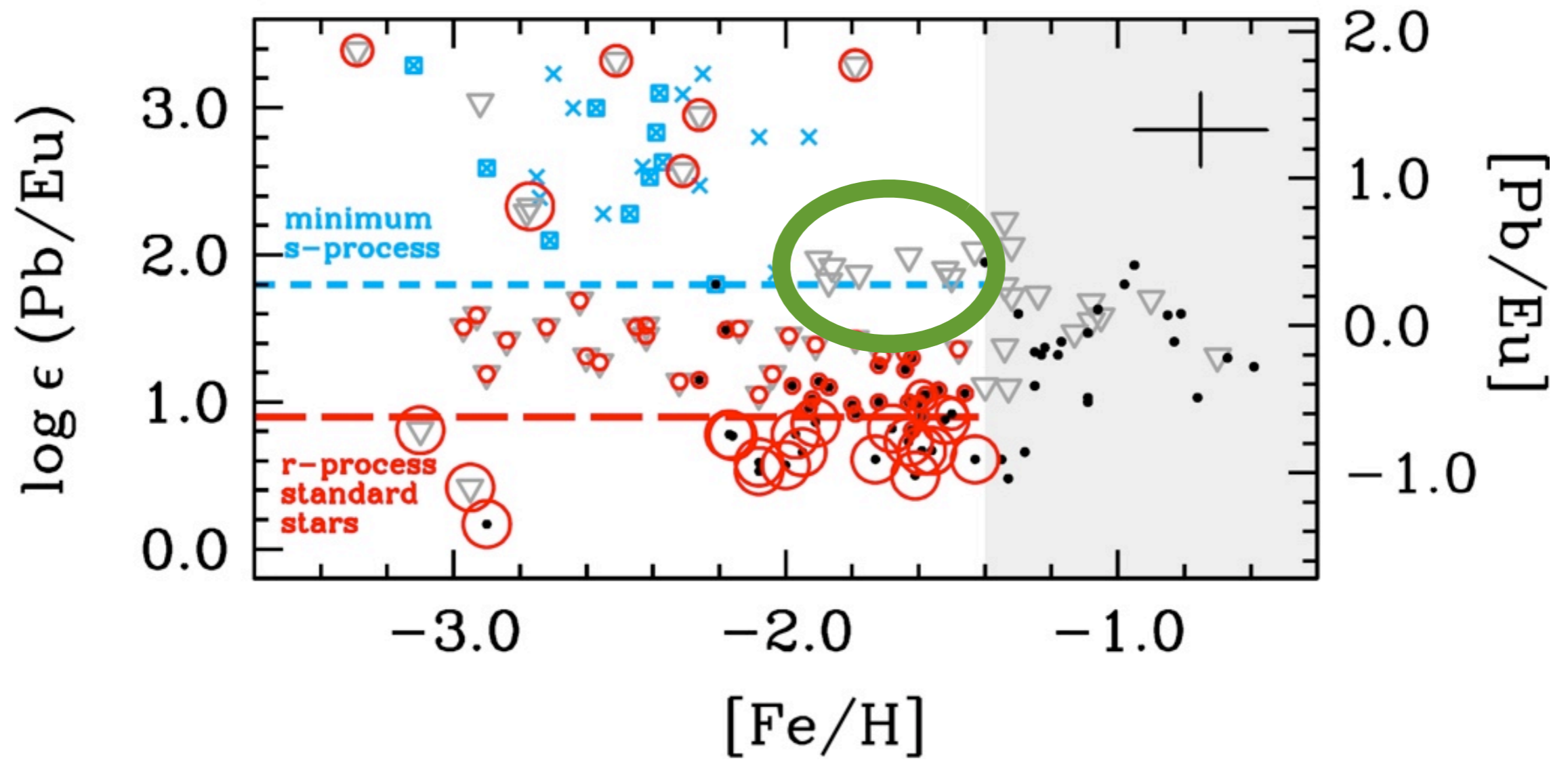
At low metallicity, enhanced lead may be the best indicator of s-process nucleosynthesis.



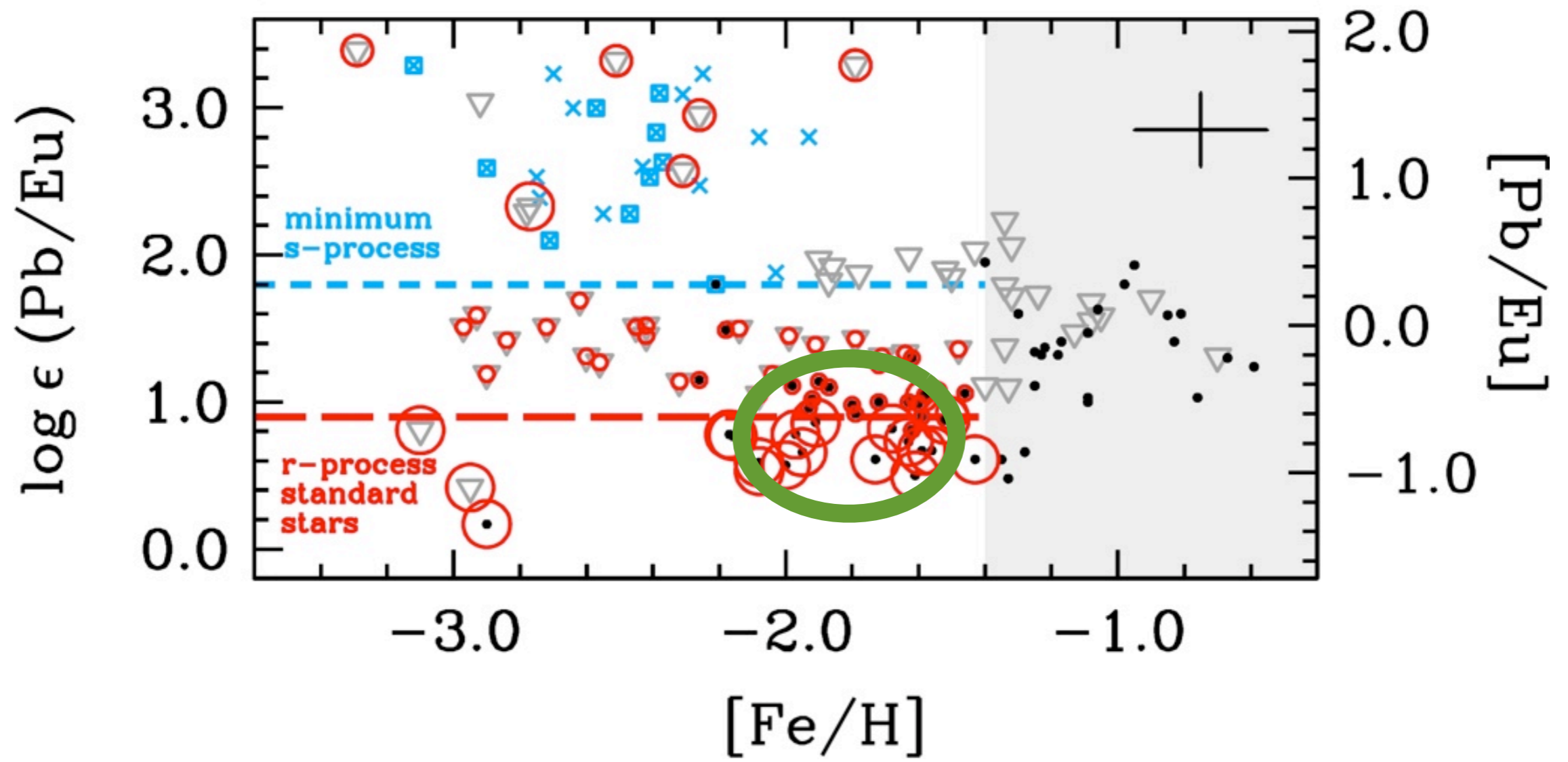


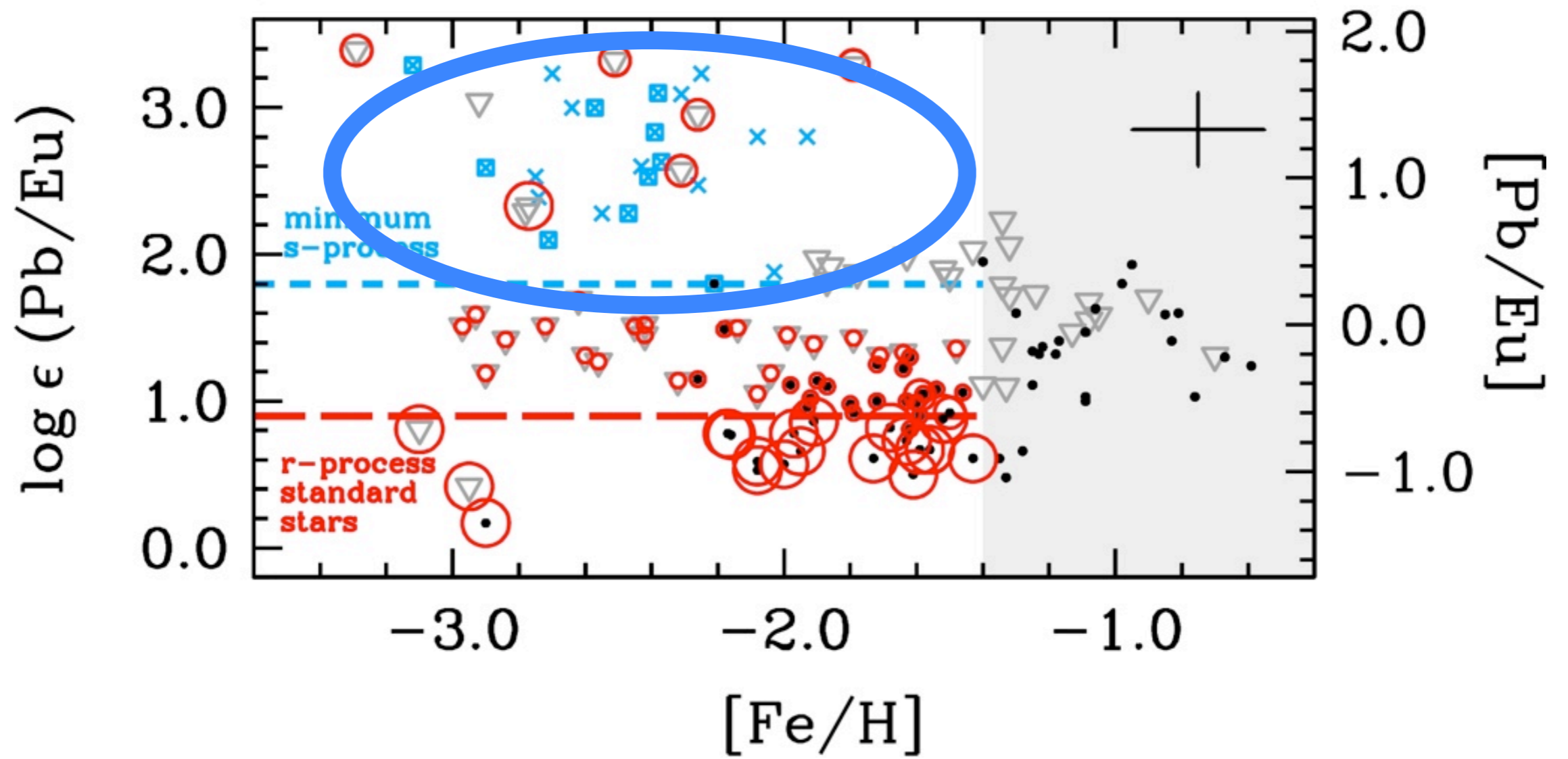


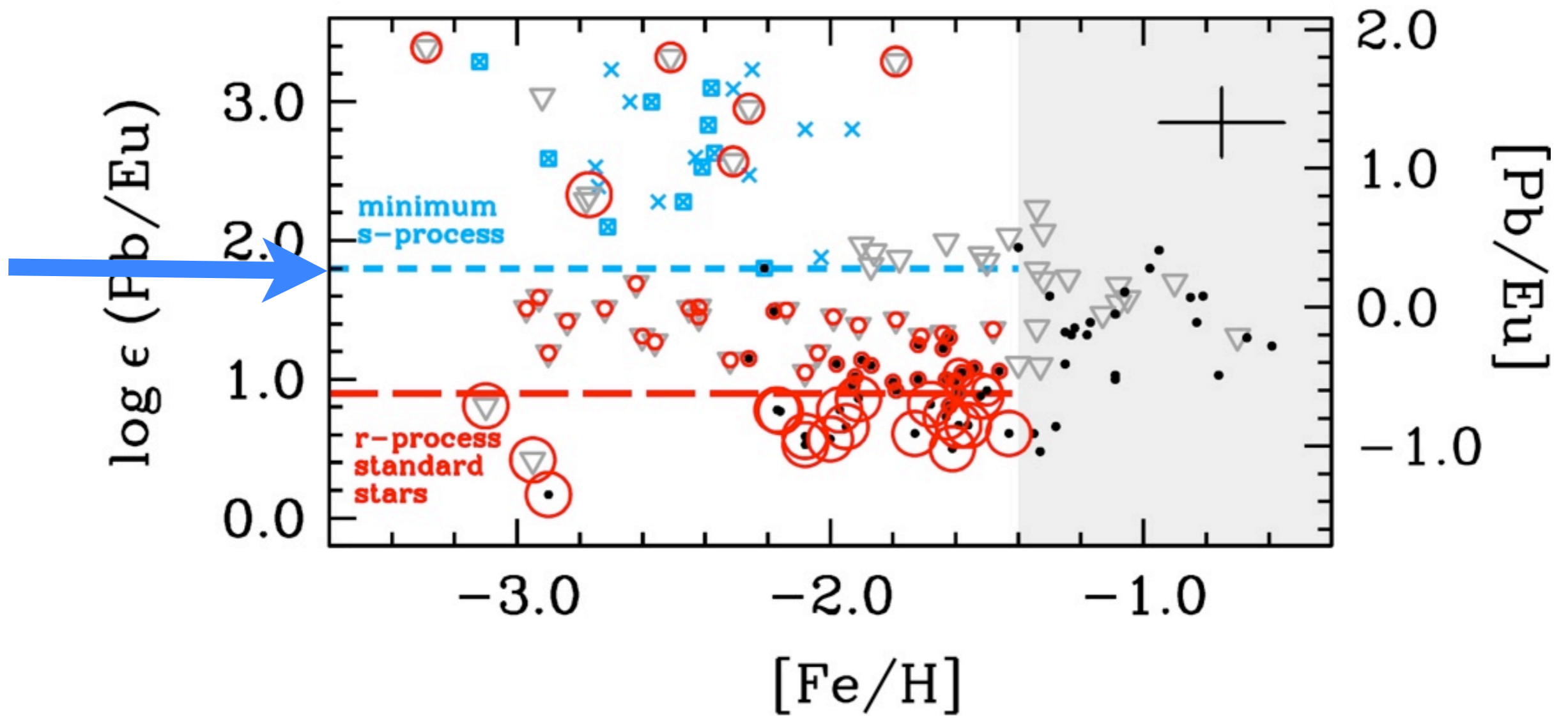


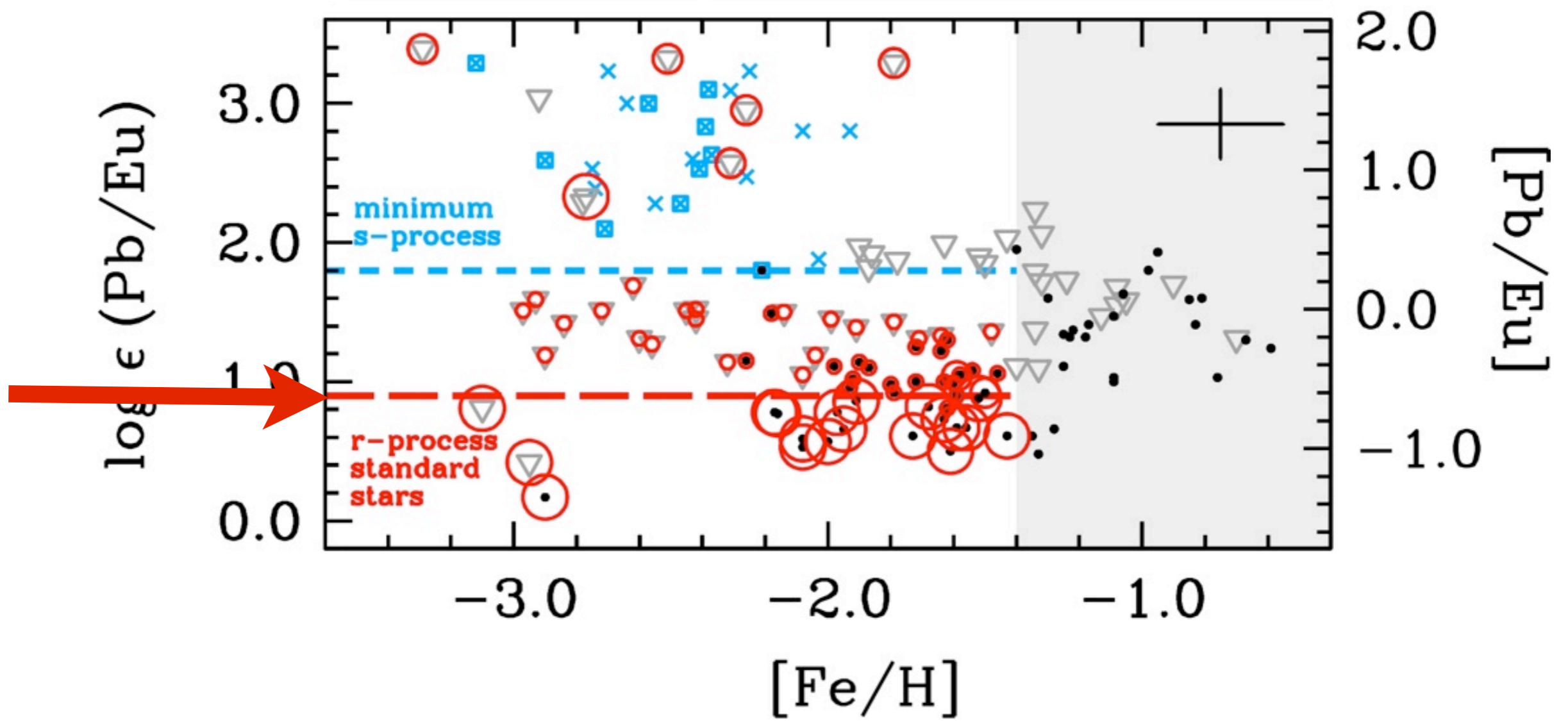




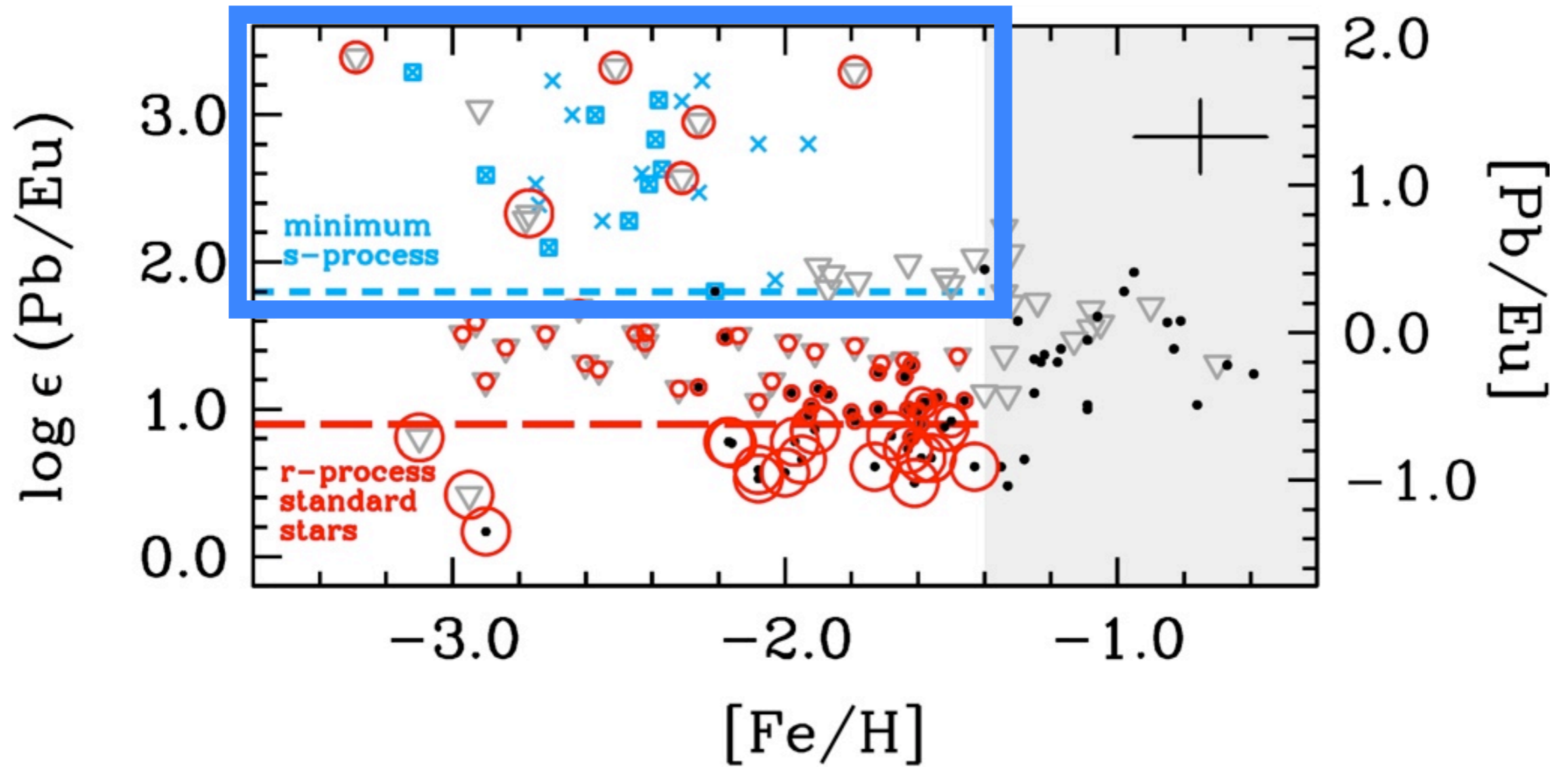




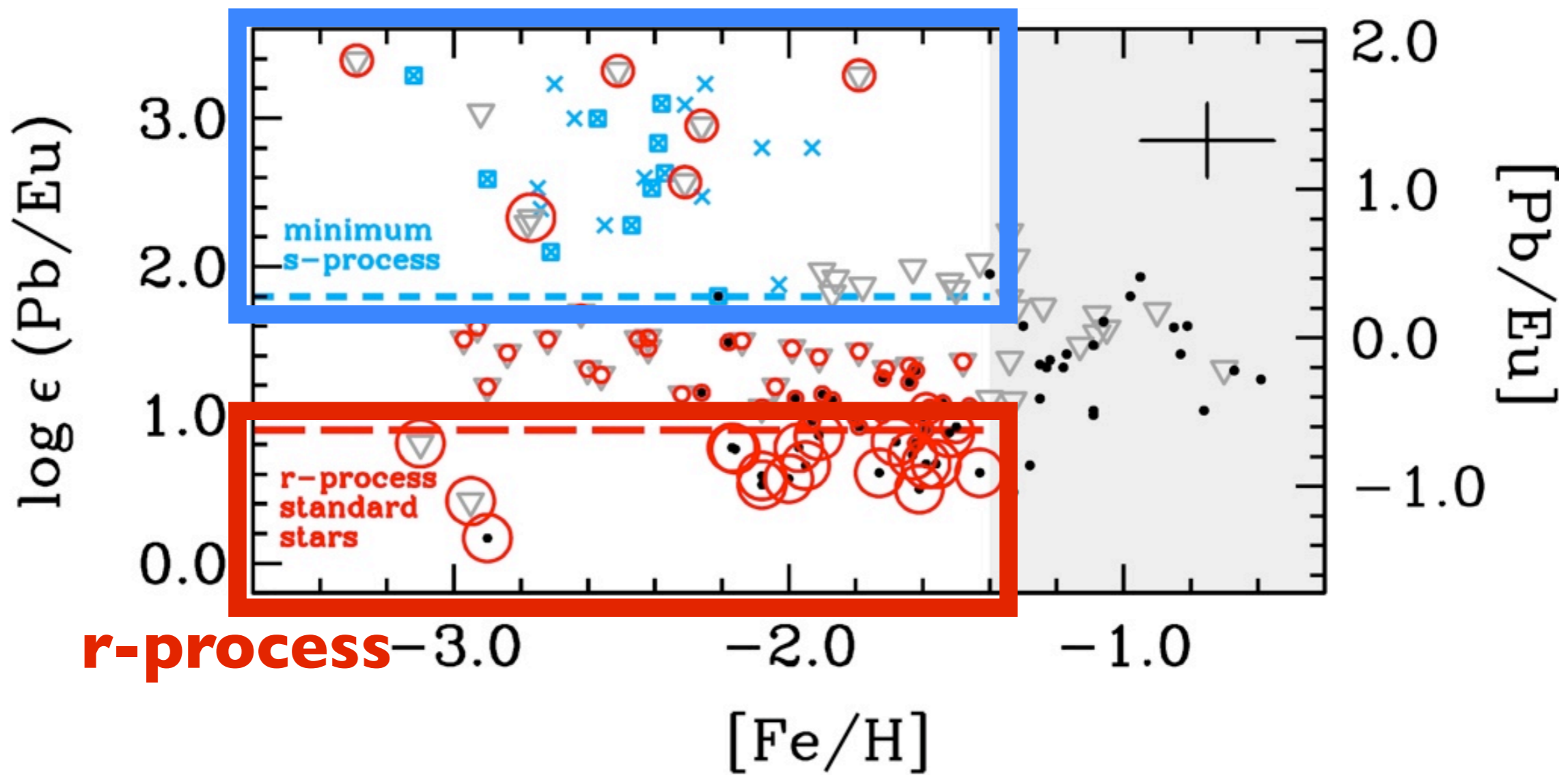




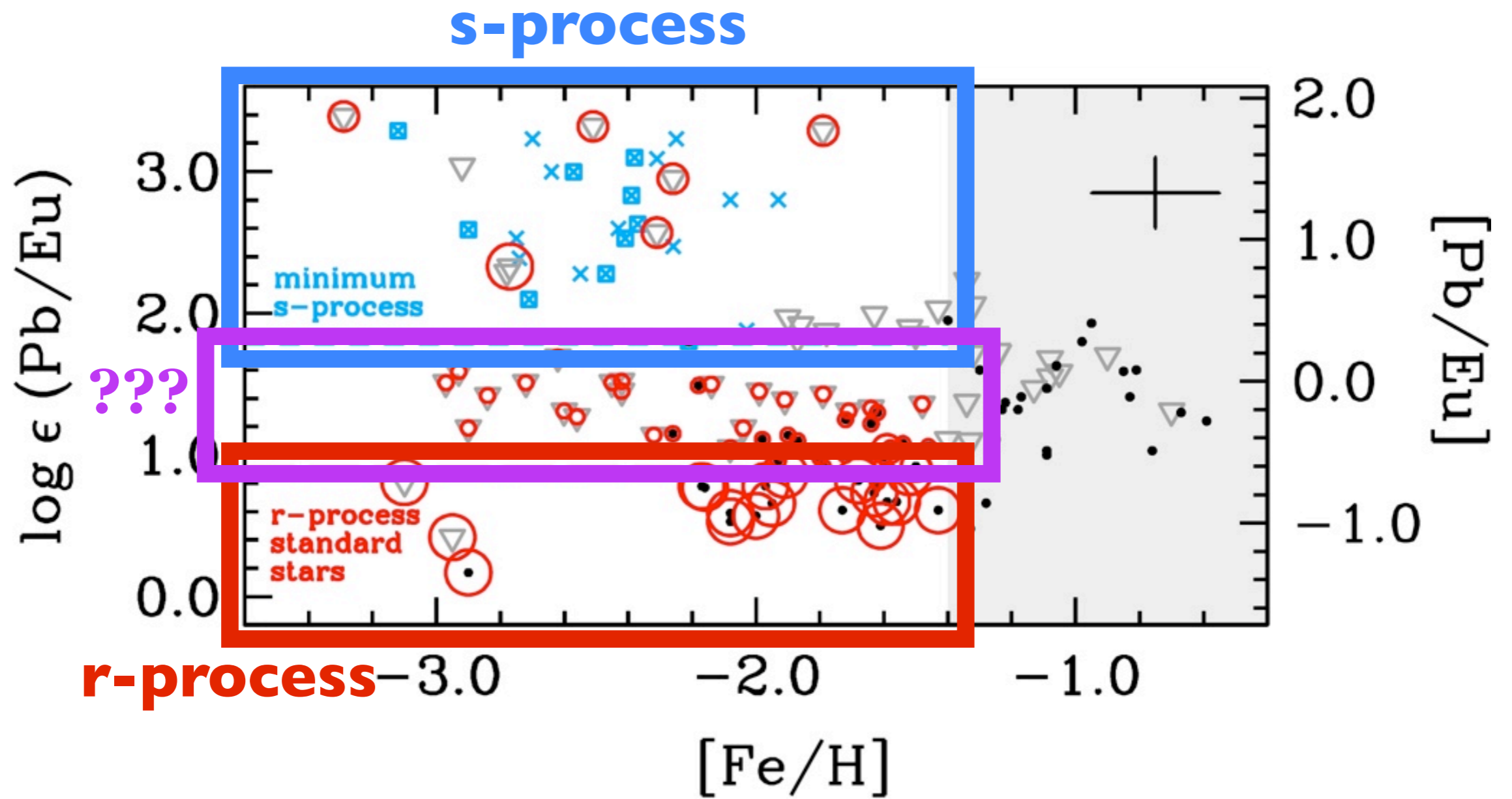
# s-process

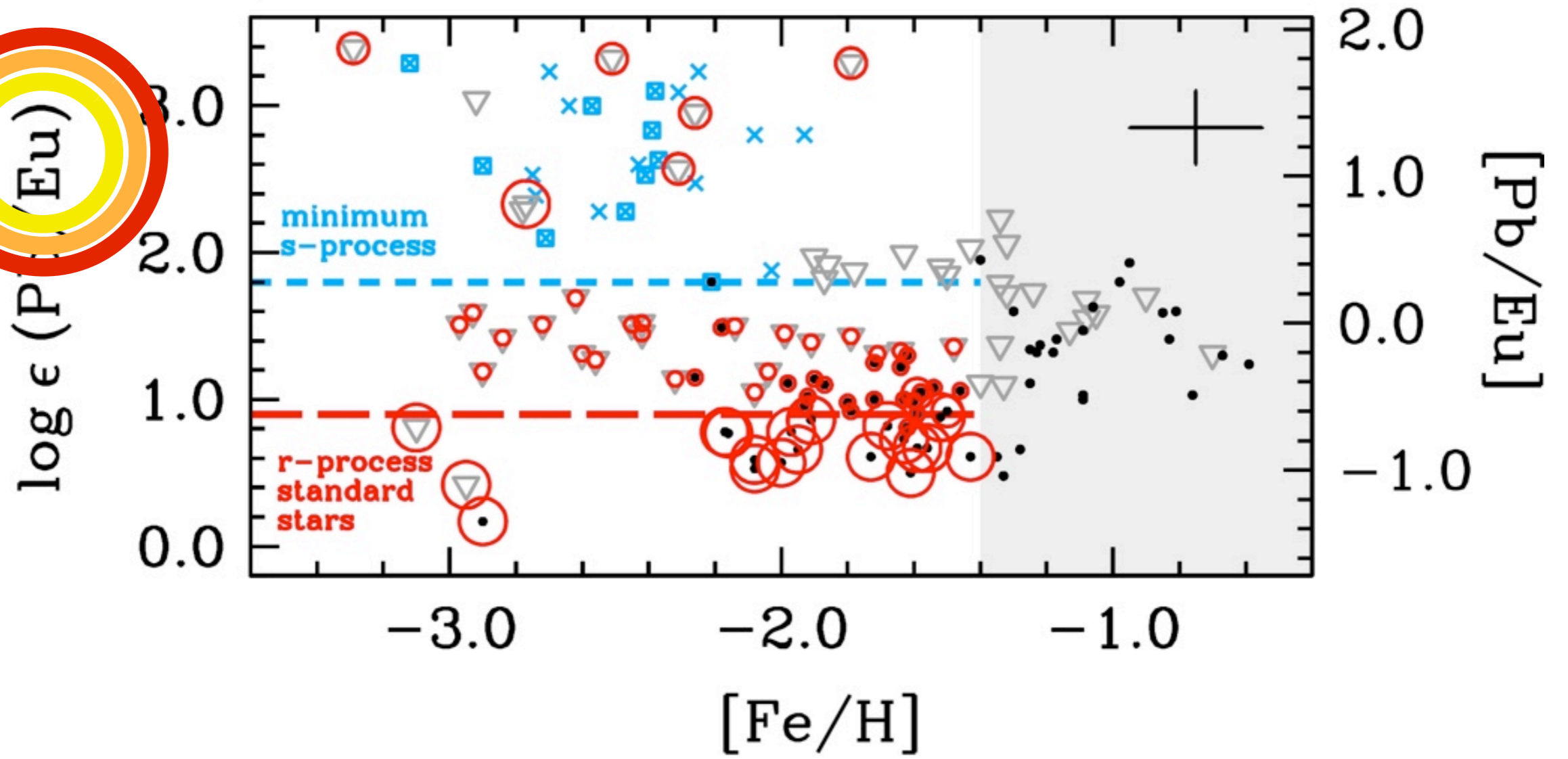


**s-process**

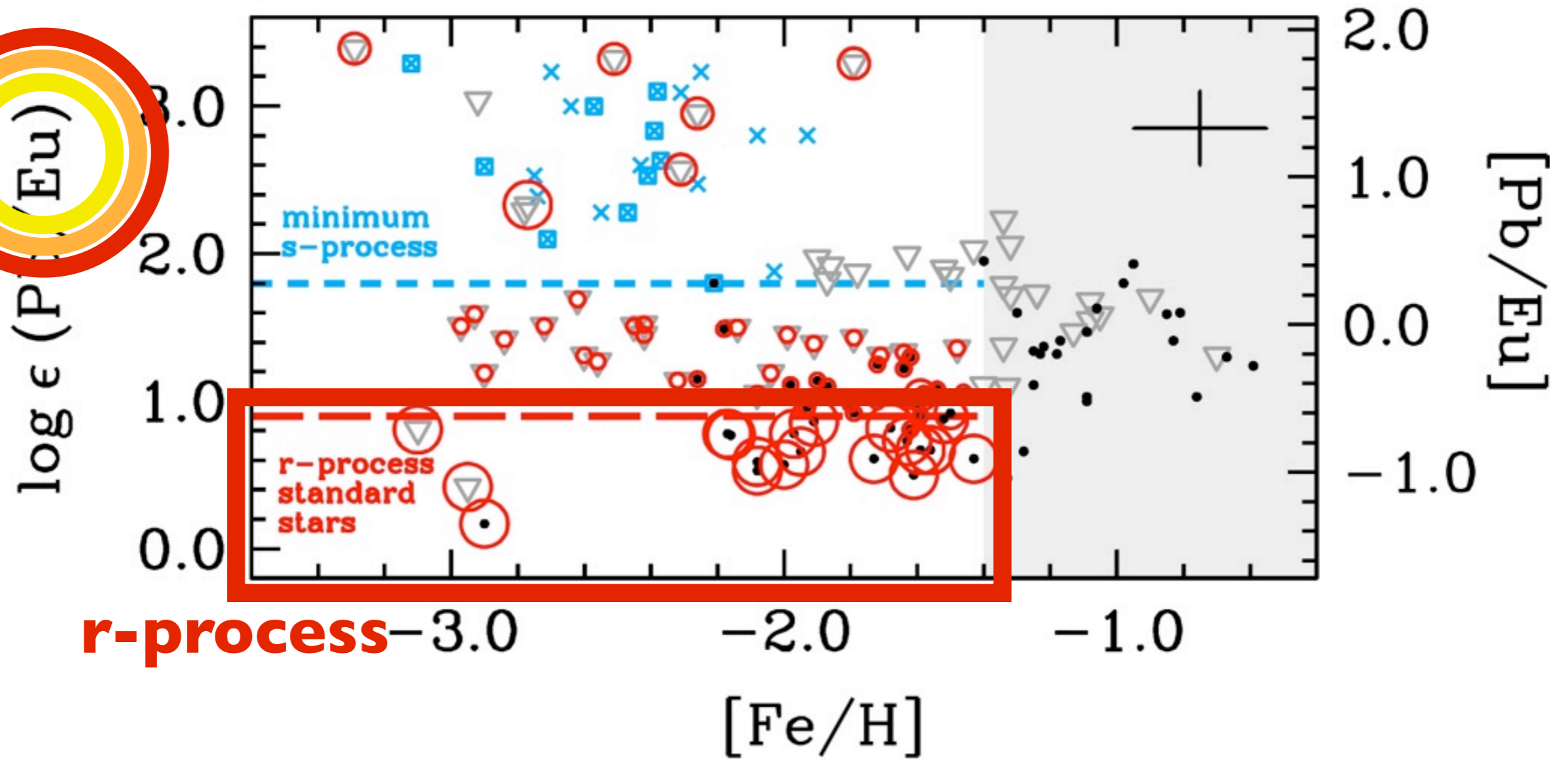


**r-process**

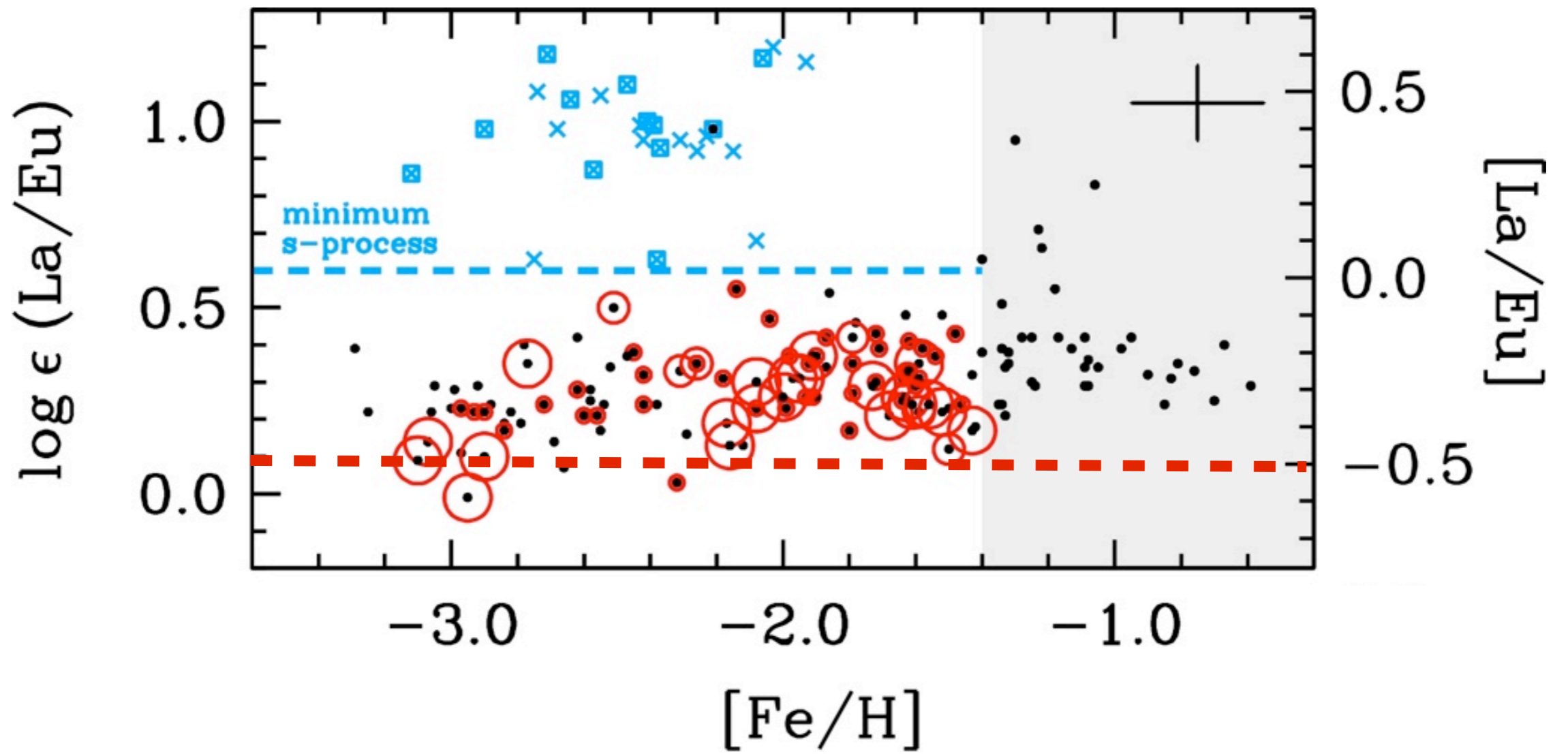


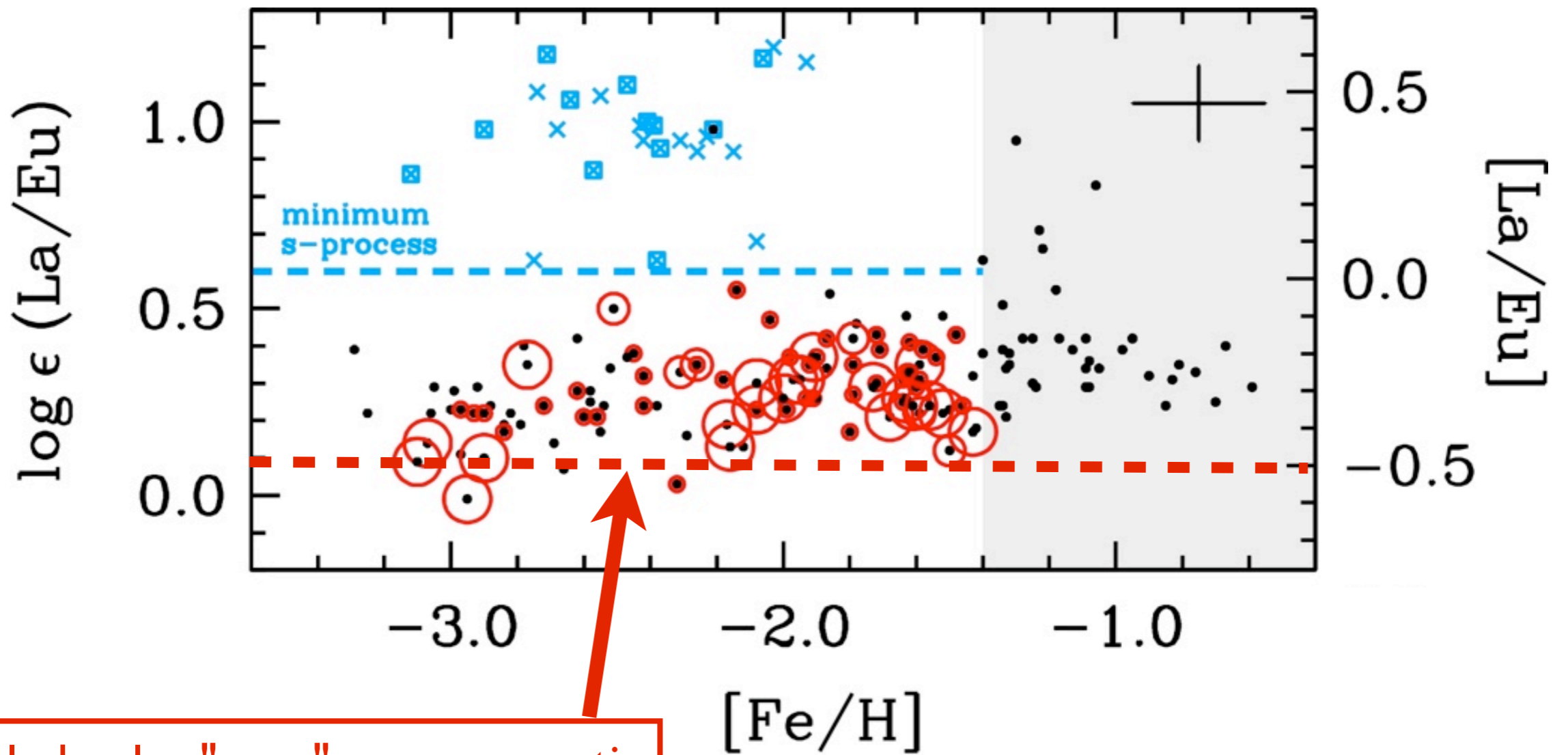






**r-process**





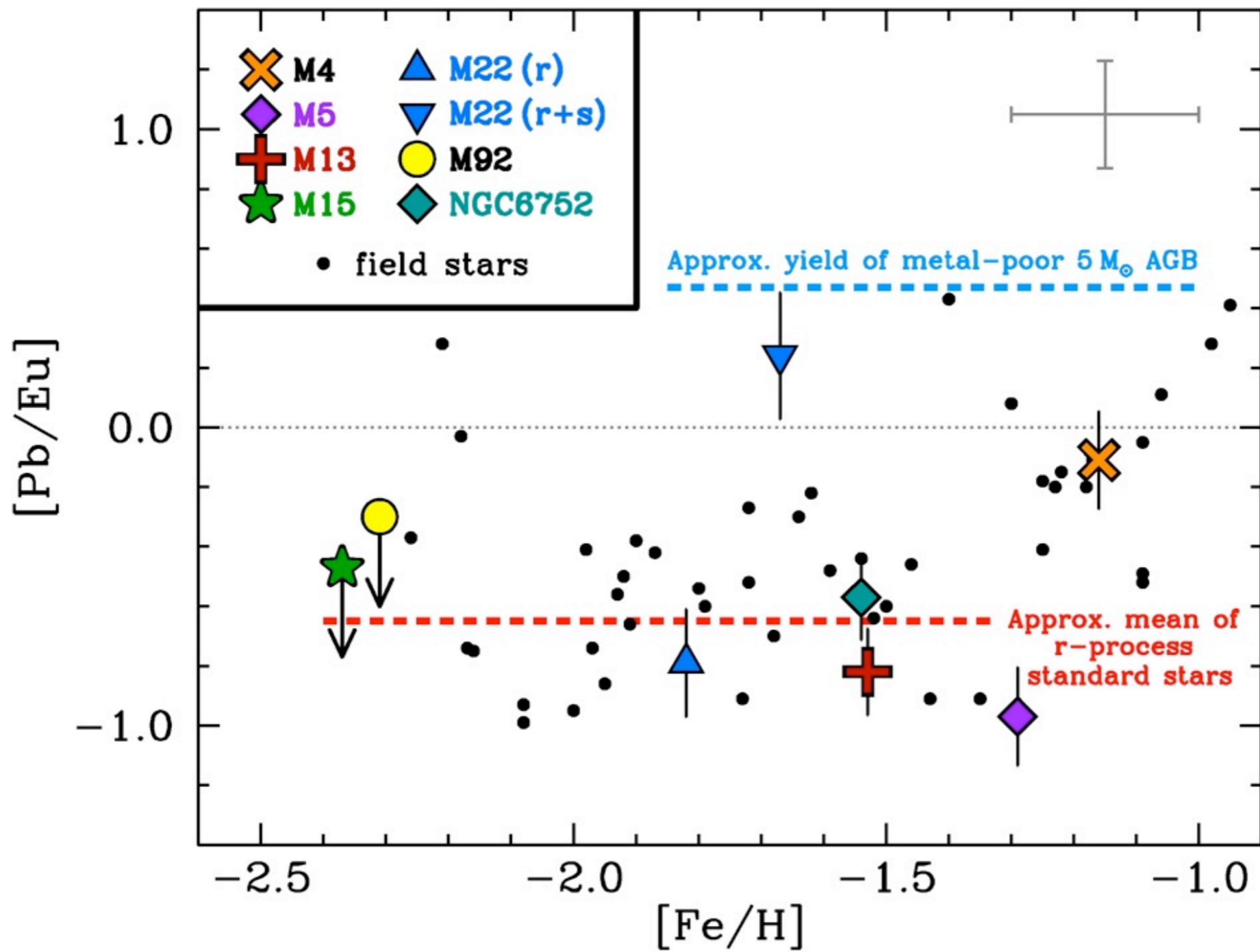


Exercise **CAUTION** when using  
solar r- and s-process decompositions  
to interpret other stars!

Better:

use abundance patterns from  
other metal-poor stars!





Roederer et al.  
(2011, ApJ, submitted)

DATA FROM:

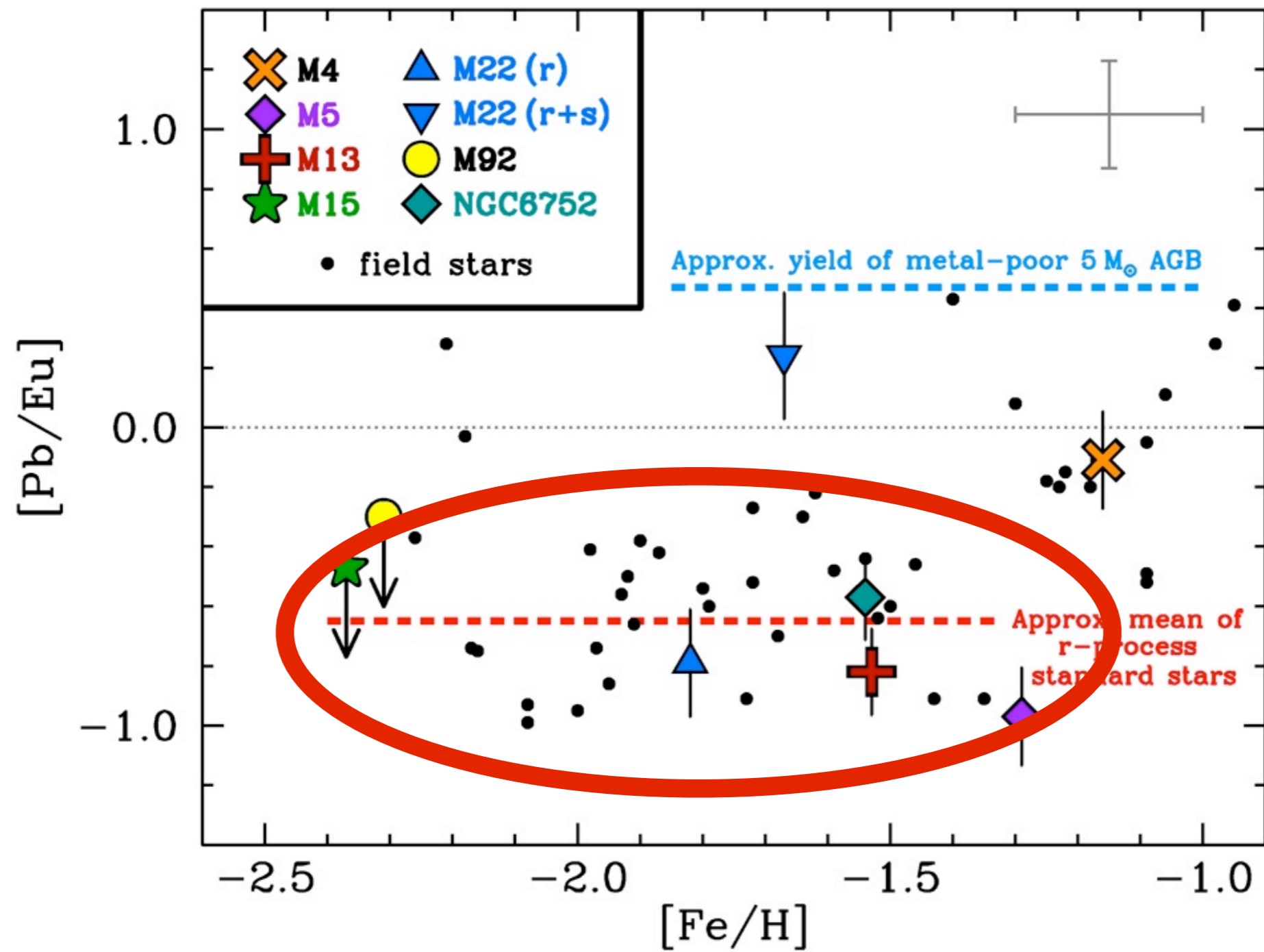
Yong et al.  
(2006, ApJ, 639, 918),  
(2008, ApJ, 673, 854)

Roederer et al.  
(2010, ApJ, 724, 975)

Sobeck et al.  
(2011, AJ, 141, 175)

Roederer & Sneden  
(2011, AJ, 142, 22)





Roederer et al.  
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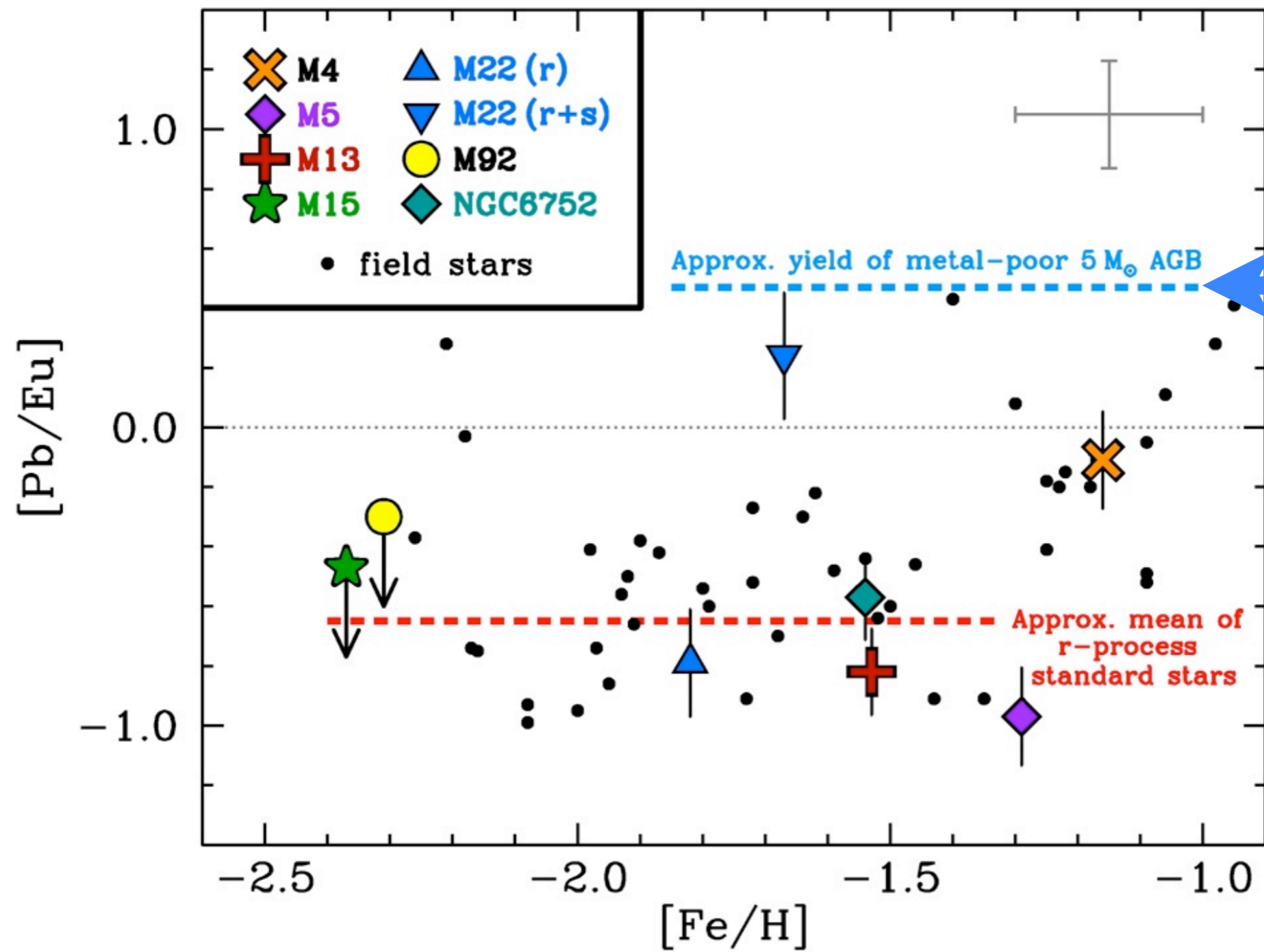
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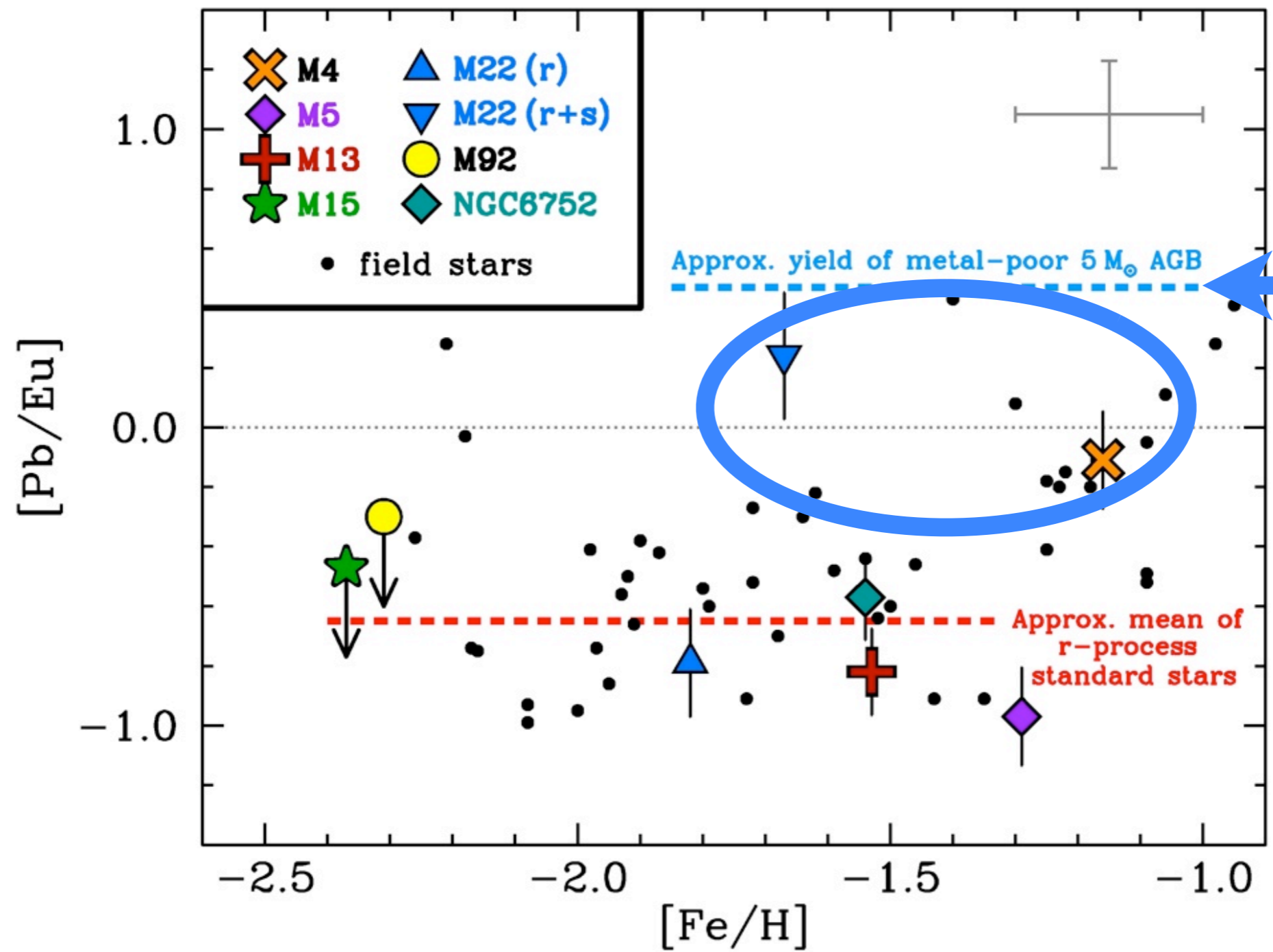
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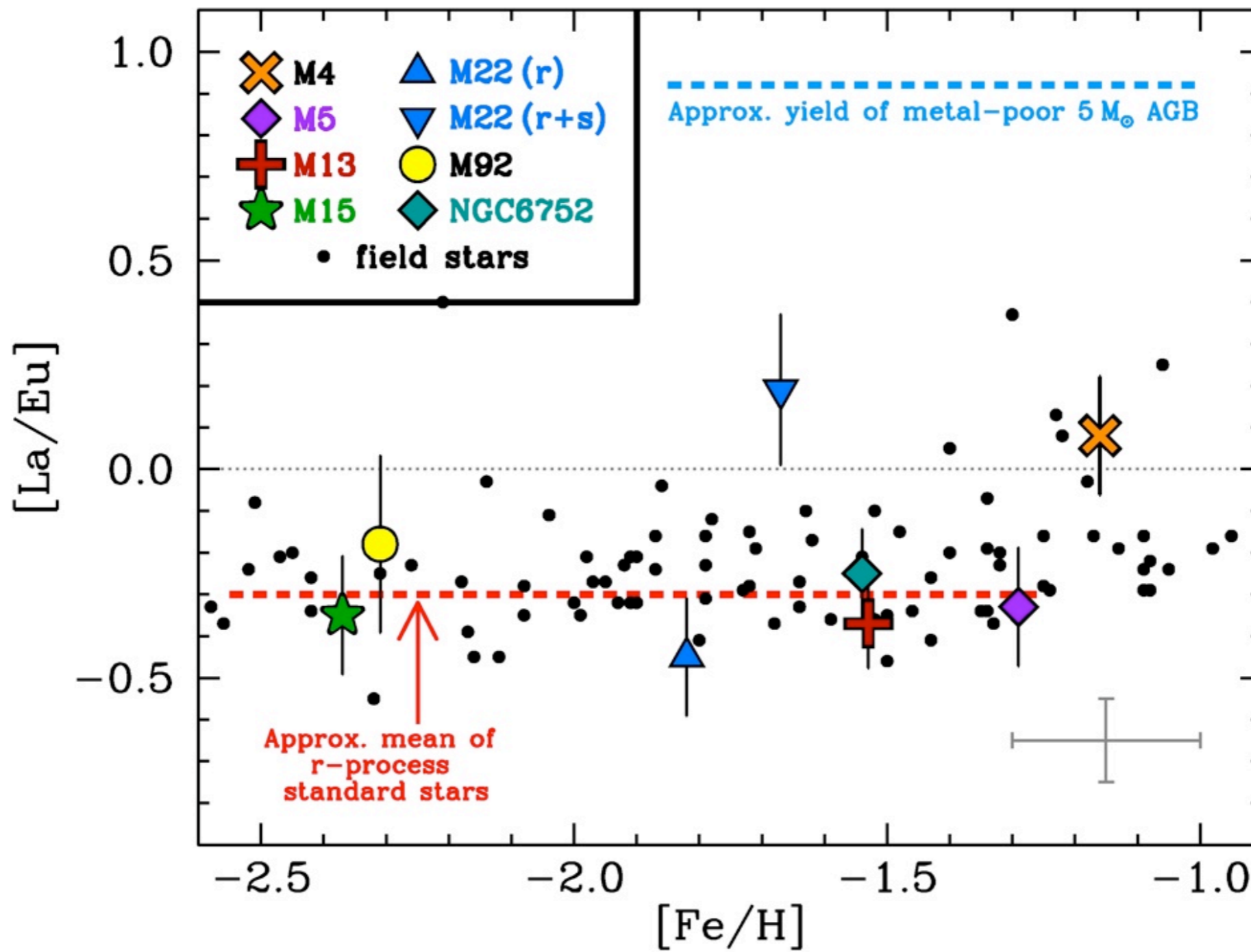
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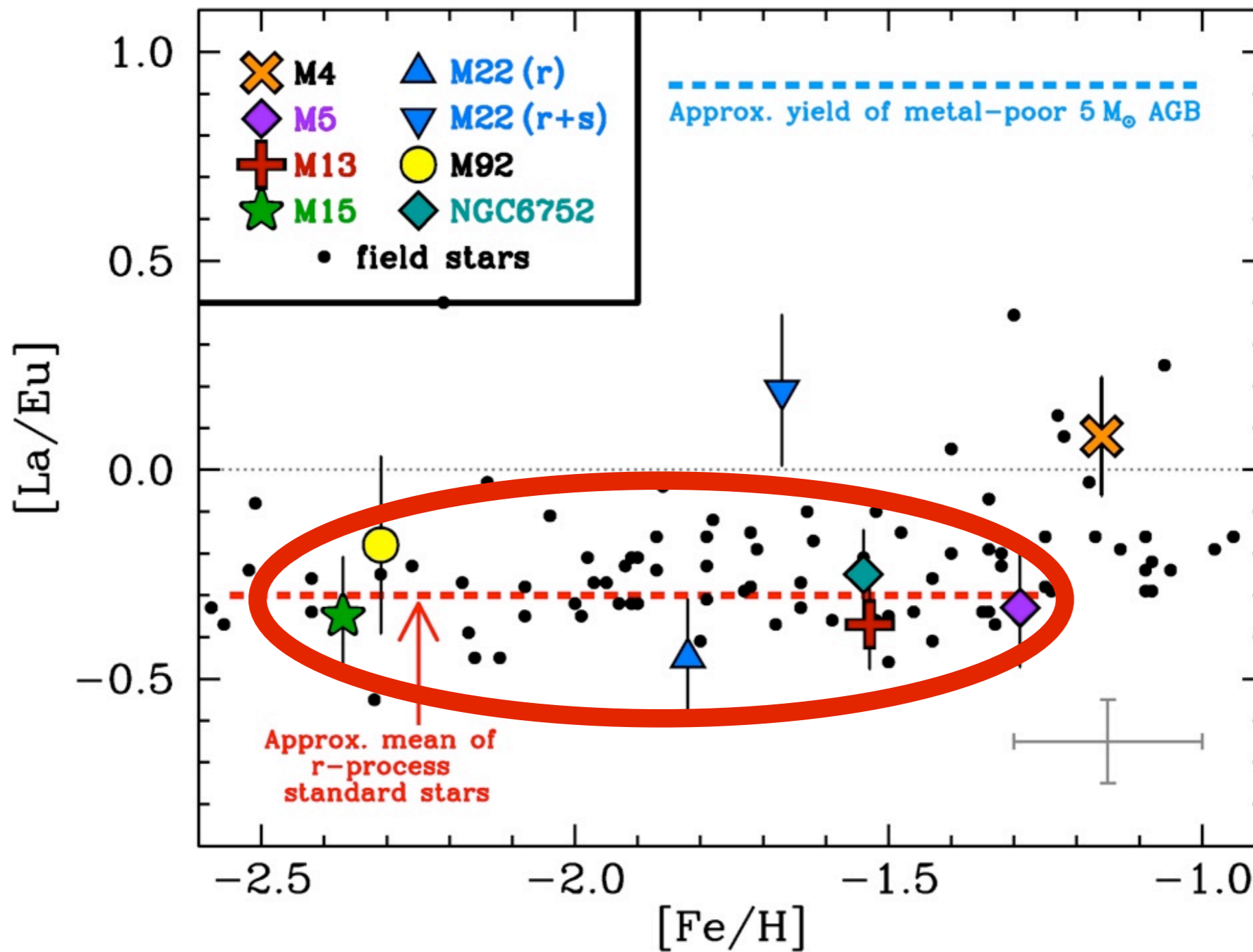
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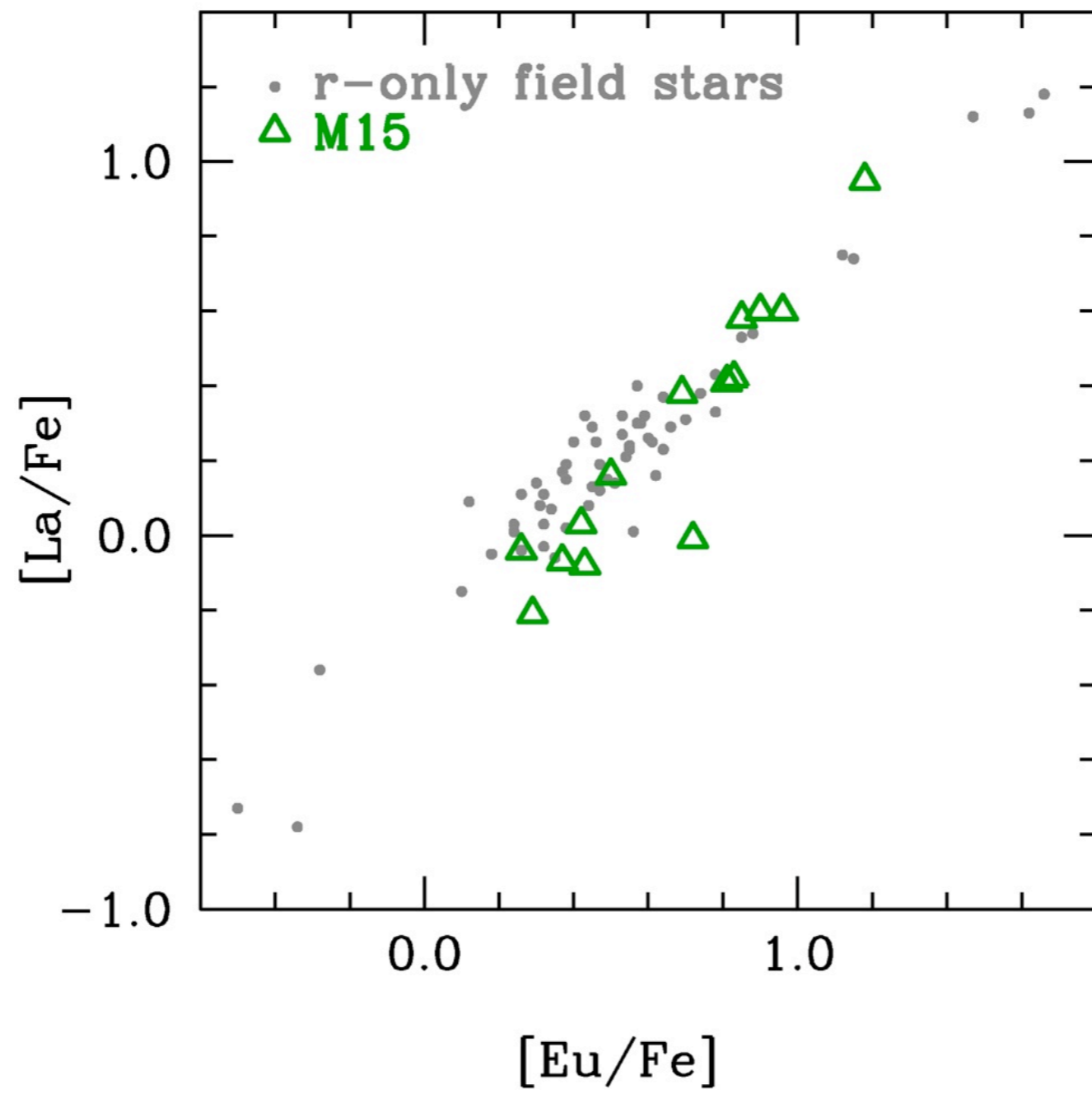
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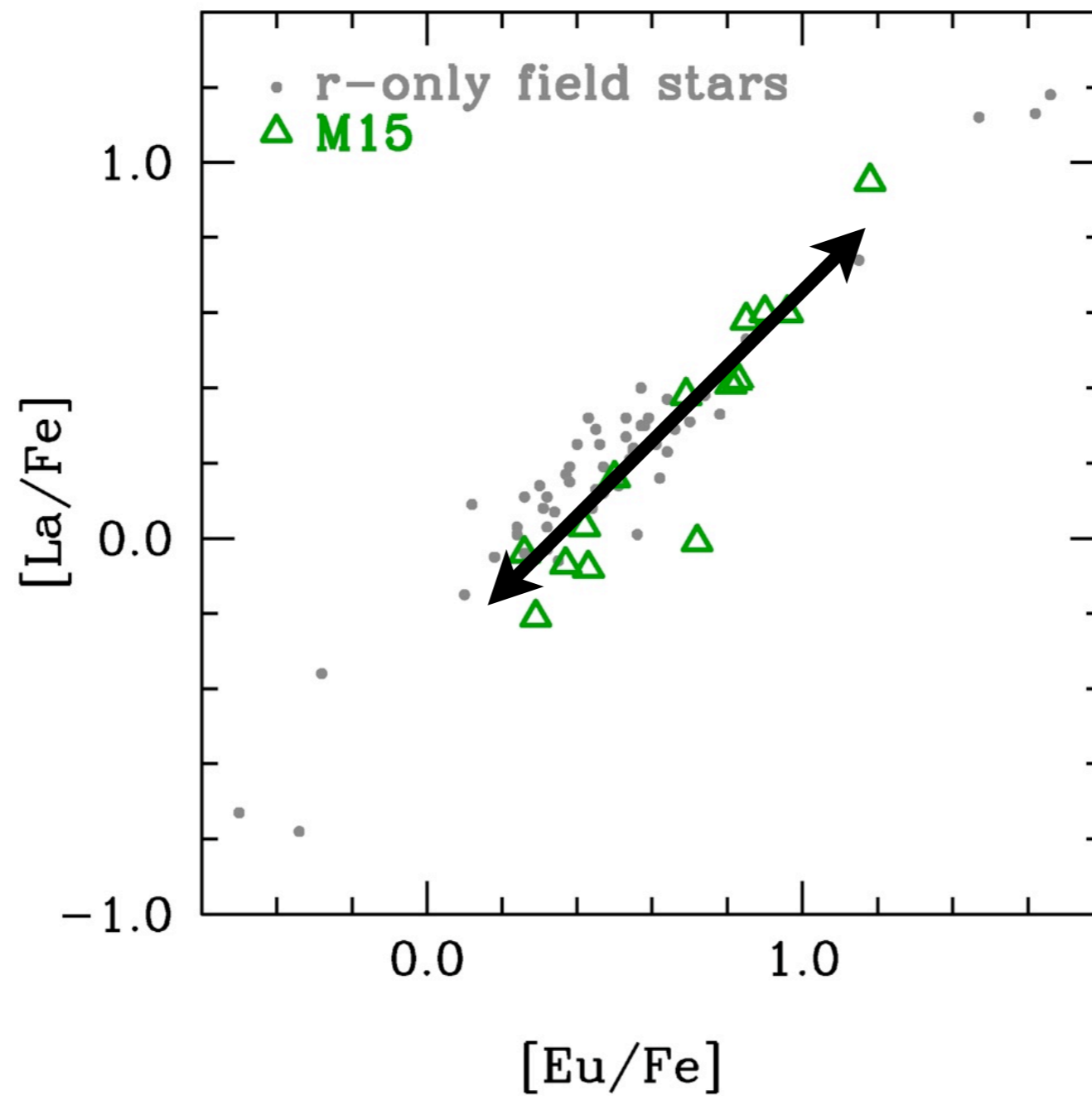
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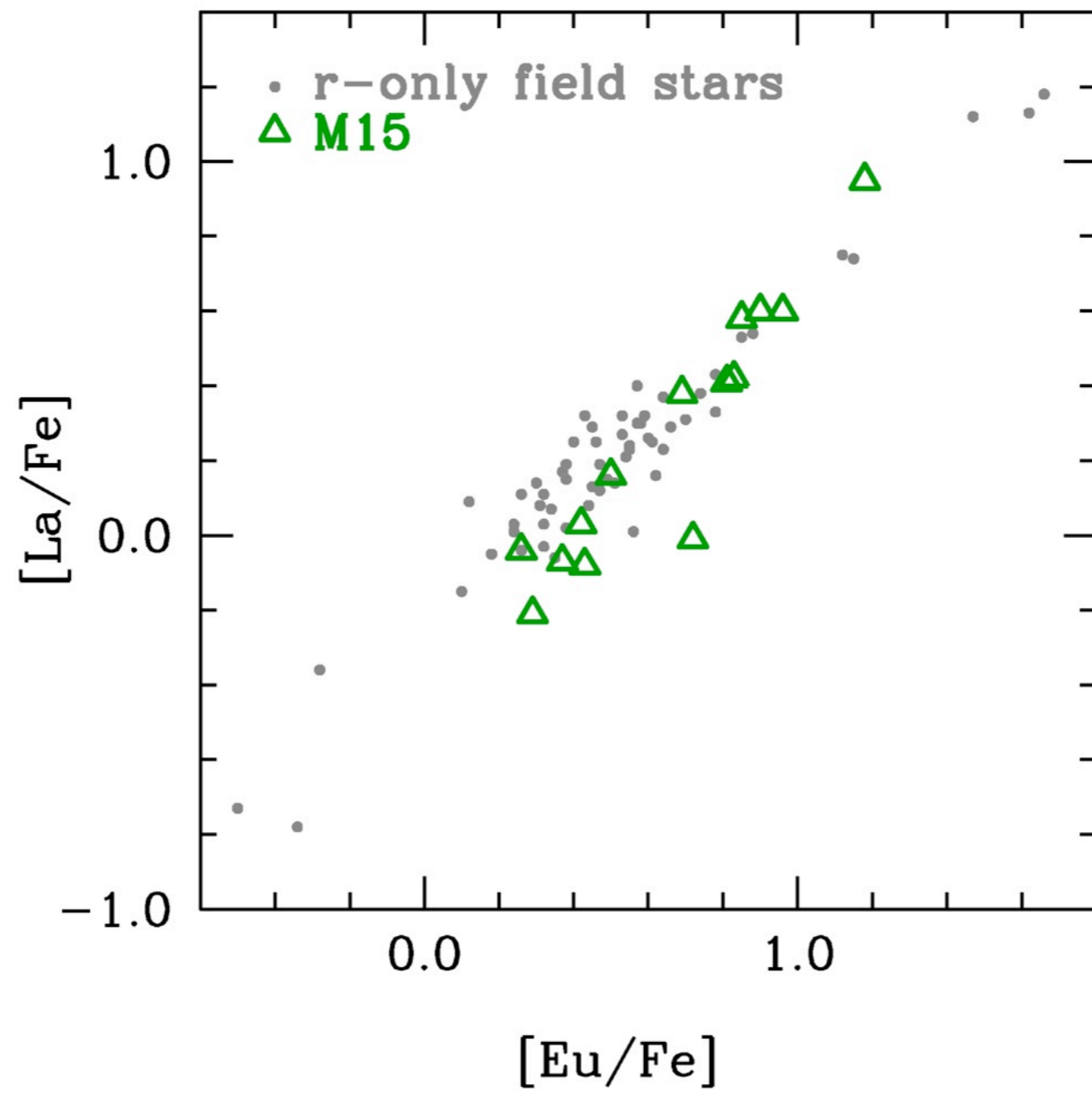
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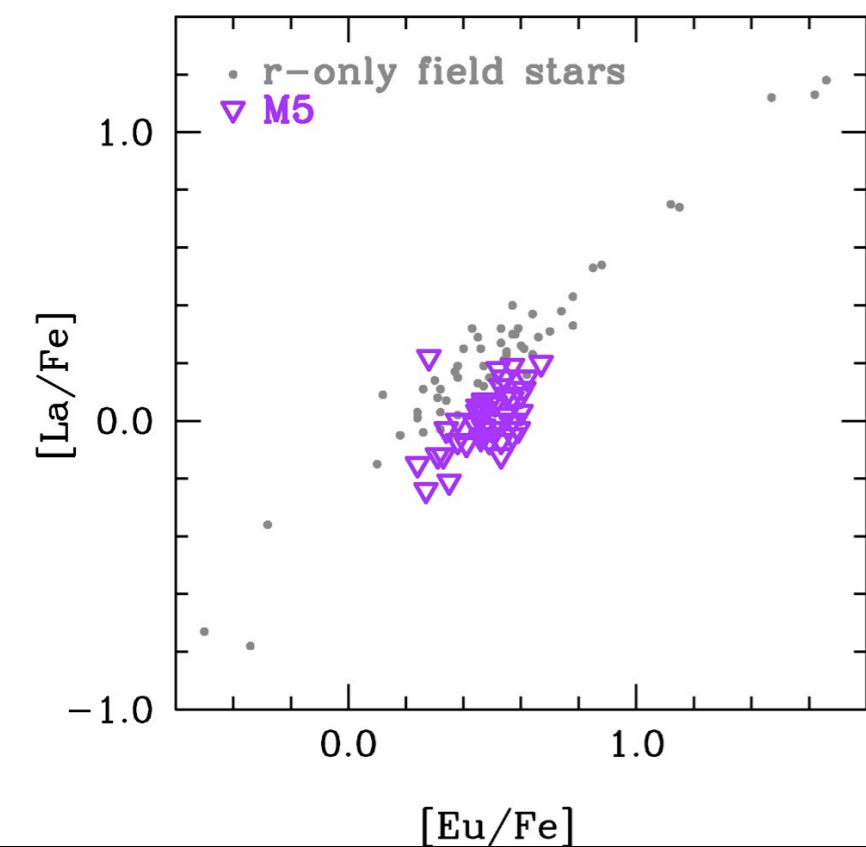
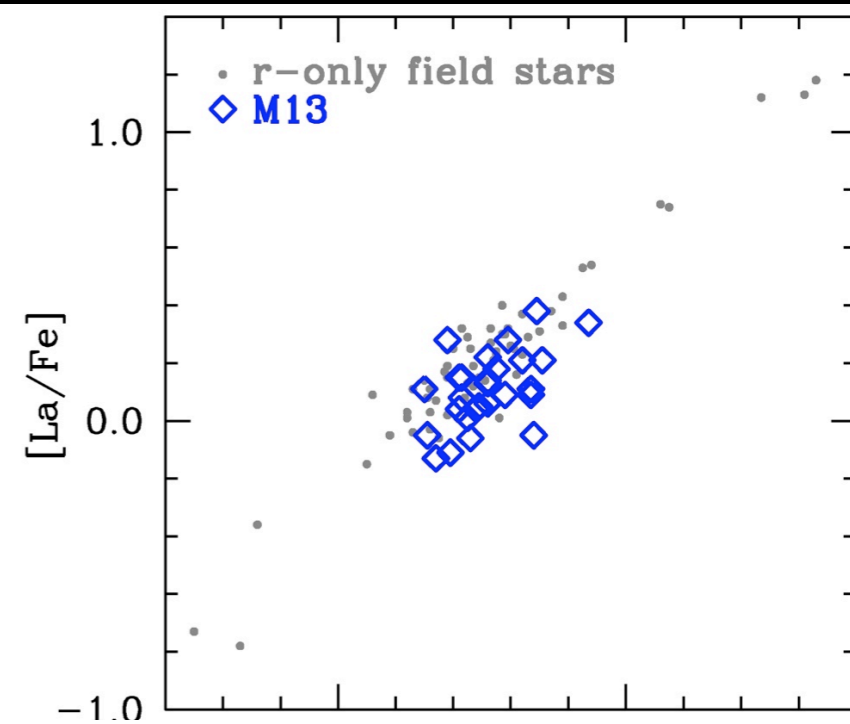
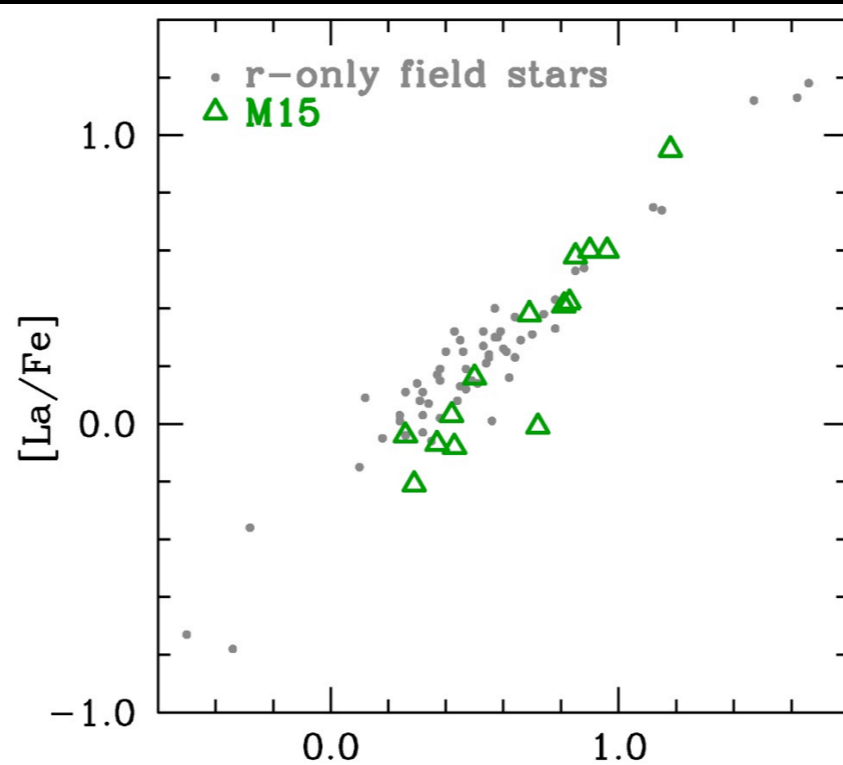
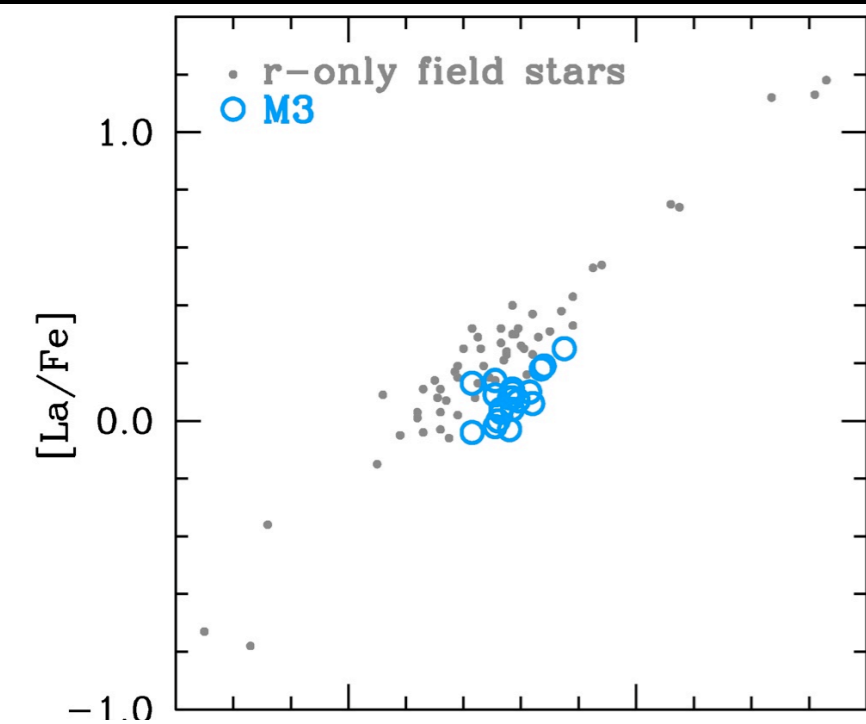




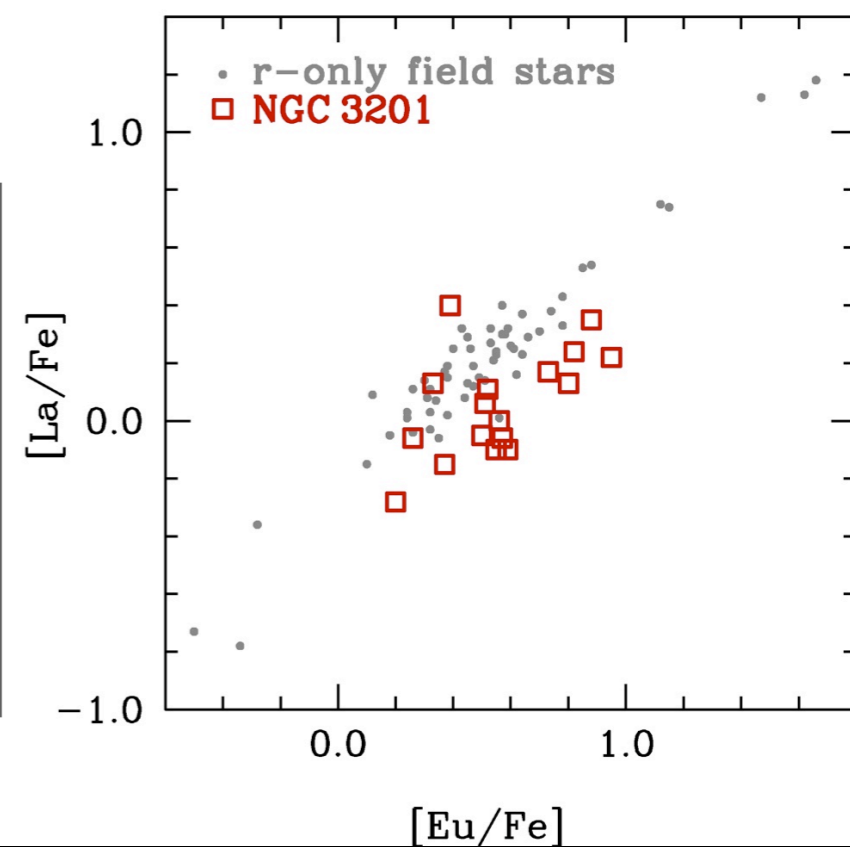


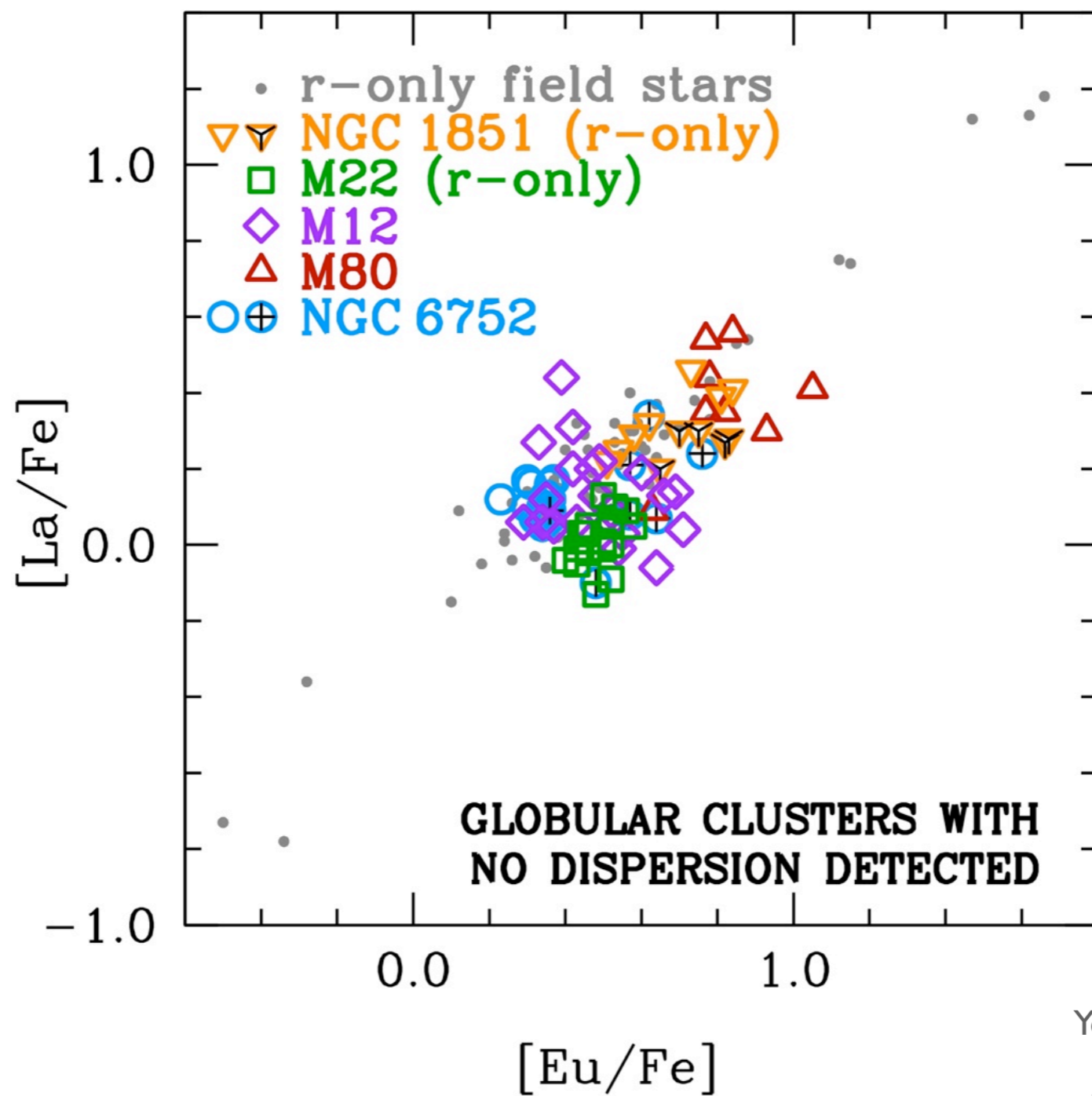




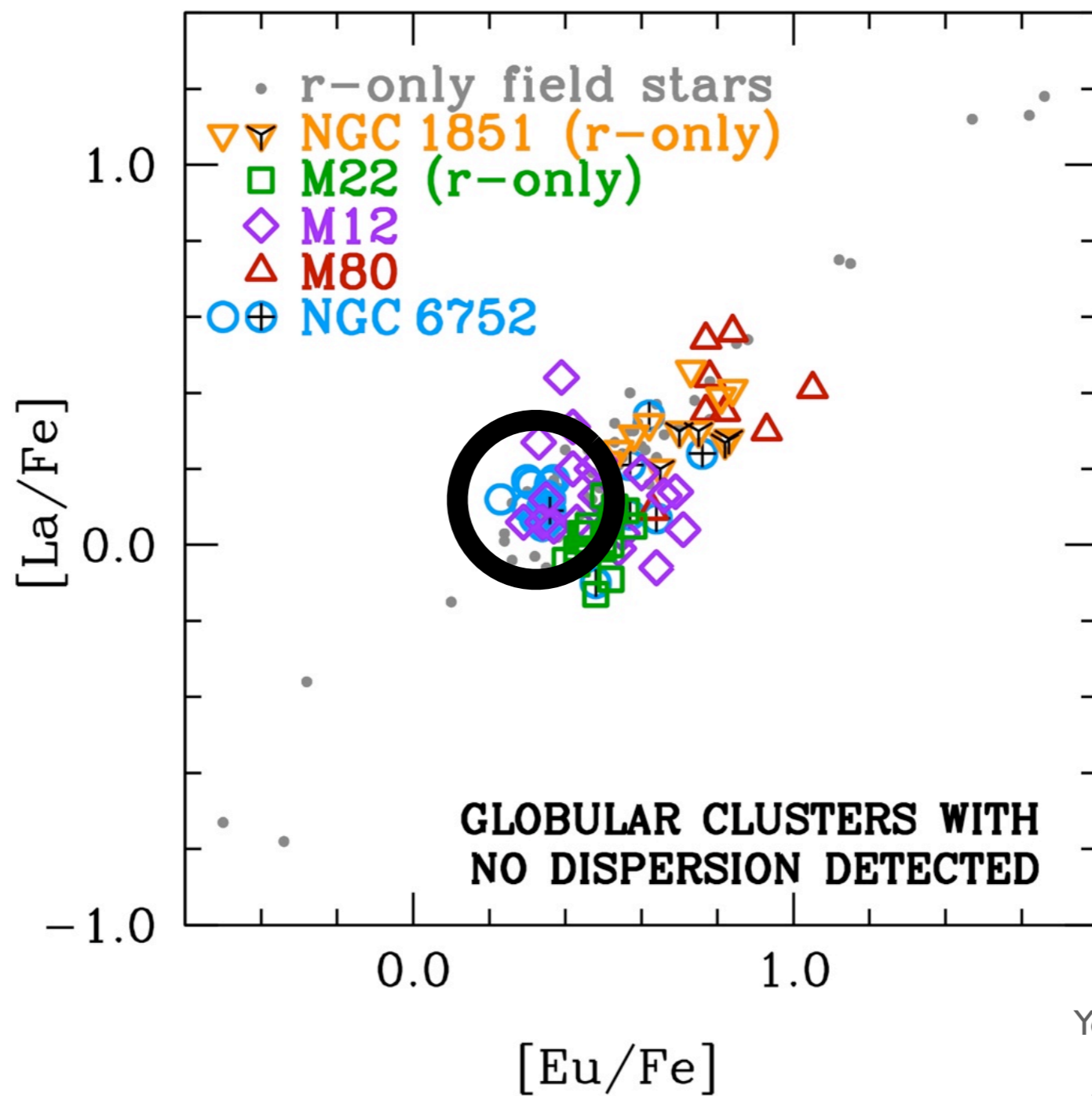


Roederer (2011, ApJ, 732, L17)  
 DATA FROM:  
 Gonzalez & Wallerstein (1998, AJ, 116, 765)  
 Sneden et al. (2004, AJ, 127, 2162)  
 Cohen & Melendez (2005, AJ, 129, 303)  
 Otsuki et al. (2006, ApJ, 641, L117)  
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 Lai et al. (2011, AJ, 141, 62)  
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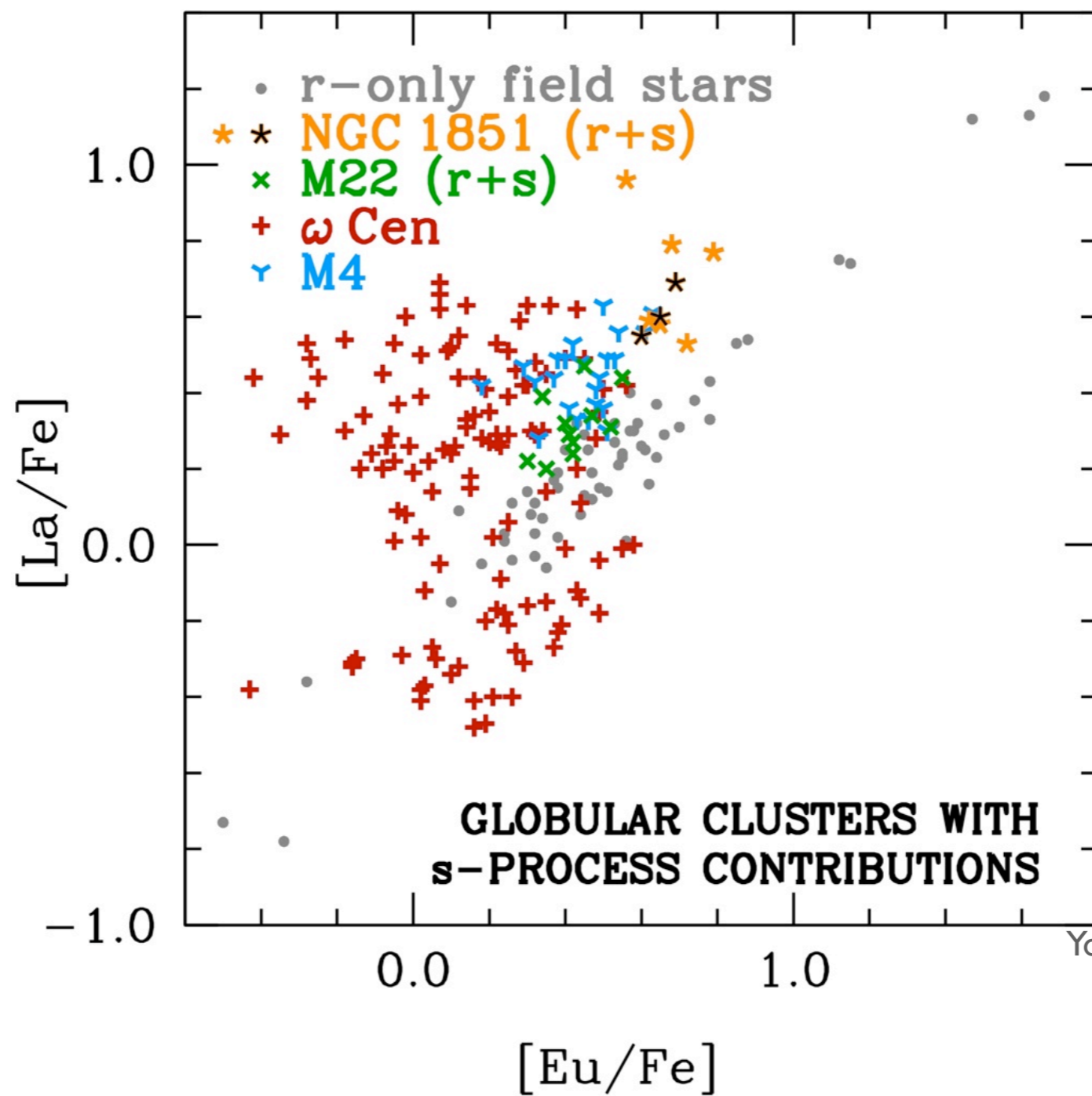




Roederer (2011, ApJ, 732, L17)  
 DATA FROM:  
 Cavallo et al. (2004, AJ, 127, 3411)  
 Johnson & Pilachowski  
 (2006, AJ, 132, 2346)  
 Yong et al. (2006, ApJ, 639, 918)  
 Yong & Grundahl (2008, ApJ, 672, L29)  
 Carretta et al. (2010, ApJ, 722, L1)  
 Roederer et al. (2010, ApJ, 724, 975)  
 Marino et al. (2011, A&A, in press)



Roederer (2011, ApJ, 732, L17)  
 DATA FROM:  
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 (2006, AJ, 132, 2346)  
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 Yong & Grundahl (2008, ApJ, 672, L29)  
 Carretta et al. (2010, ApJ, 722, L1)  
 Roederer et al. (2010, ApJ, 724, 975)  
 Marino et al. (2011, A&A, in press)



Roederer (2011, ApJ, 732, L17)

DATA FROM:

Ivans et al. (1999, AJ, 118, 1273)

Yong & Grundahl (2008, ApJ, 672, L29)

Carretta et al. (2010, ApJ, 722, L1)

Johnson & Pilachowski

(2010, AJ, 722, 1373)

Roederer et al. (2010, ApJ, 724, 975)

Marino et al. (2011, A&A, in press)



r-process dispersion in globular clusters is:

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(I) common, but not ubiquitous



r-process dispersion in globular clusters is:

(1) common, but not ubiquitous

(2) not correlated with light element dispersion

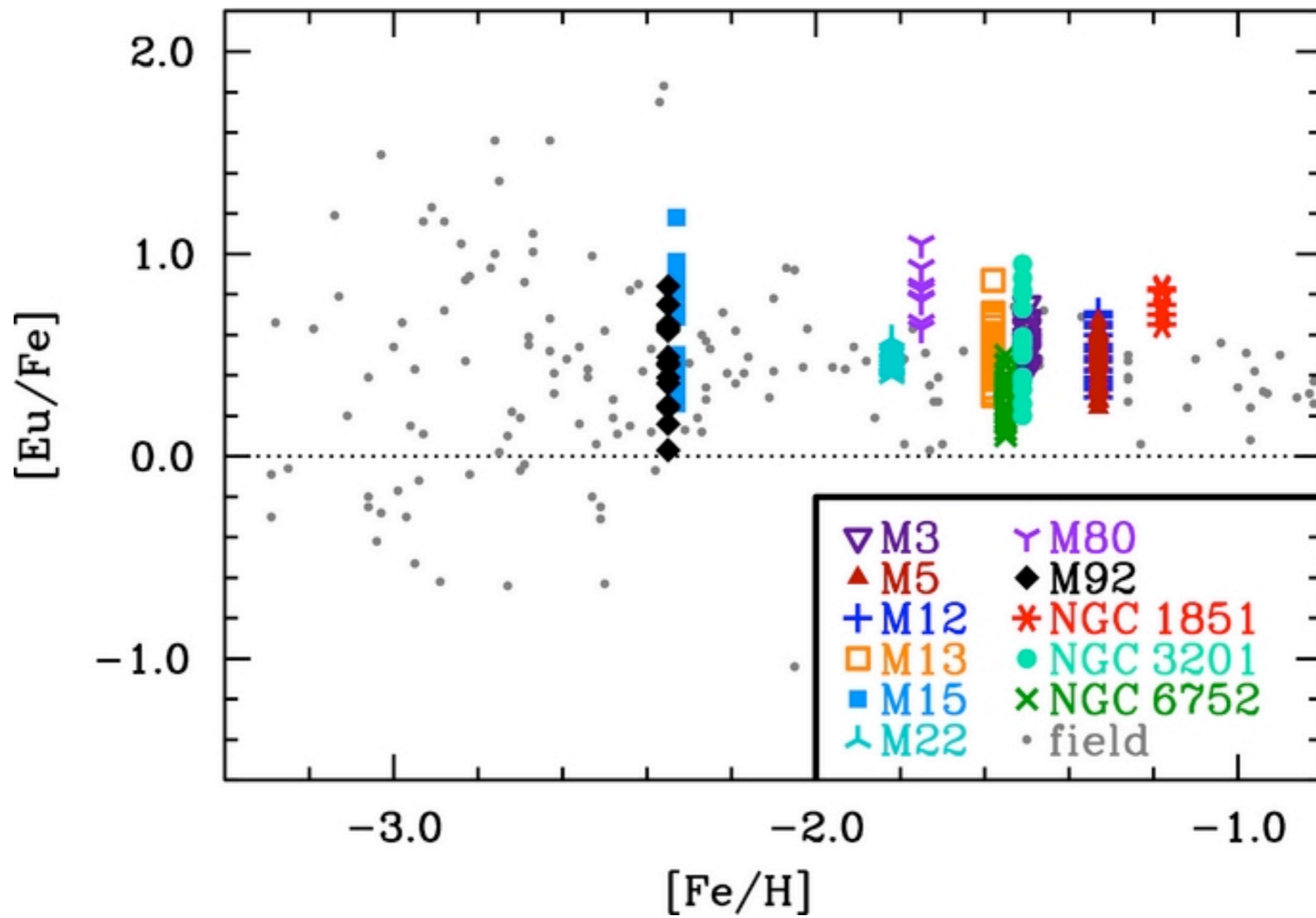
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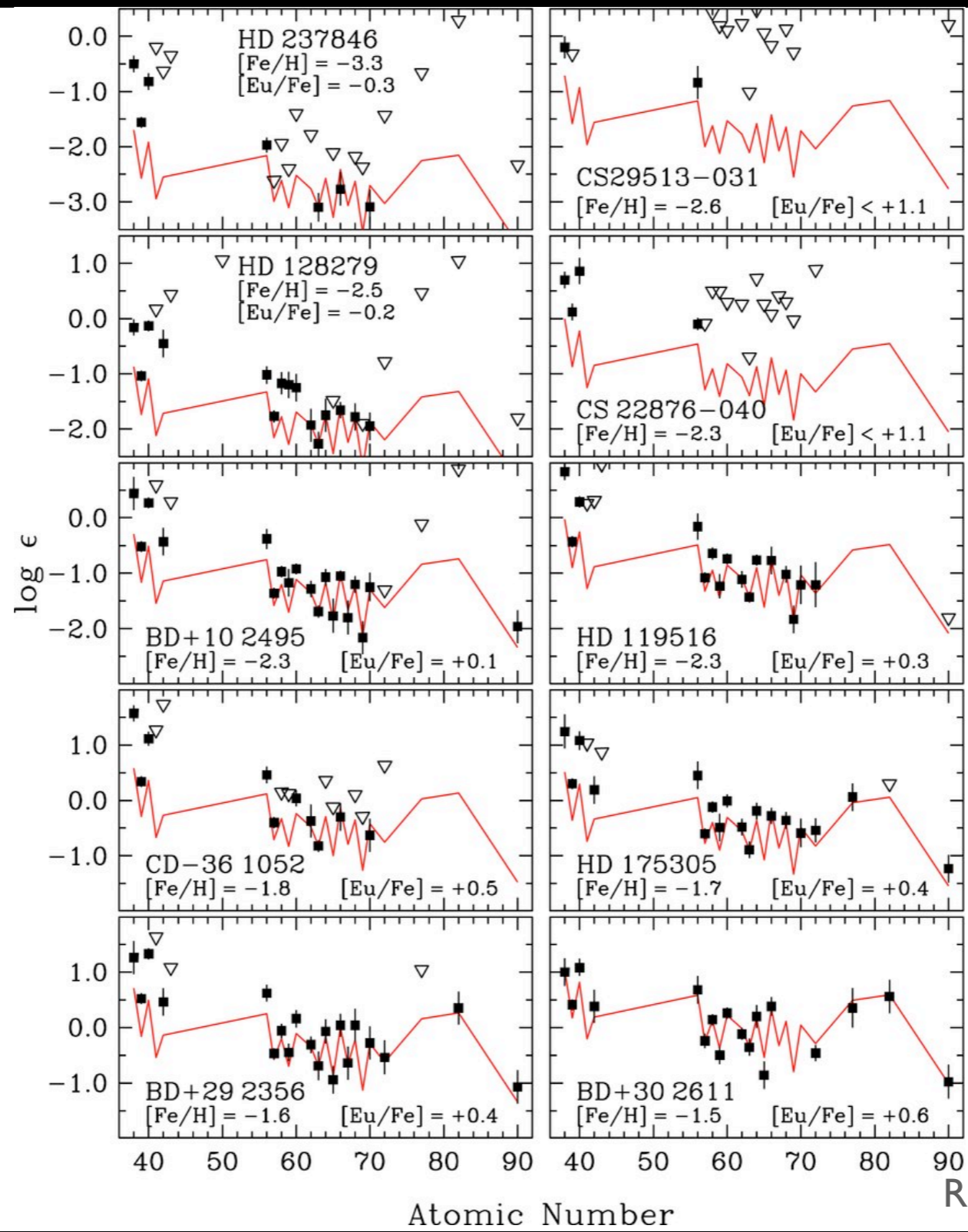
- (1) common, but not ubiquitous
- (2) not correlated with light element dispersion
- (3) not strongly correlated with cluster properties

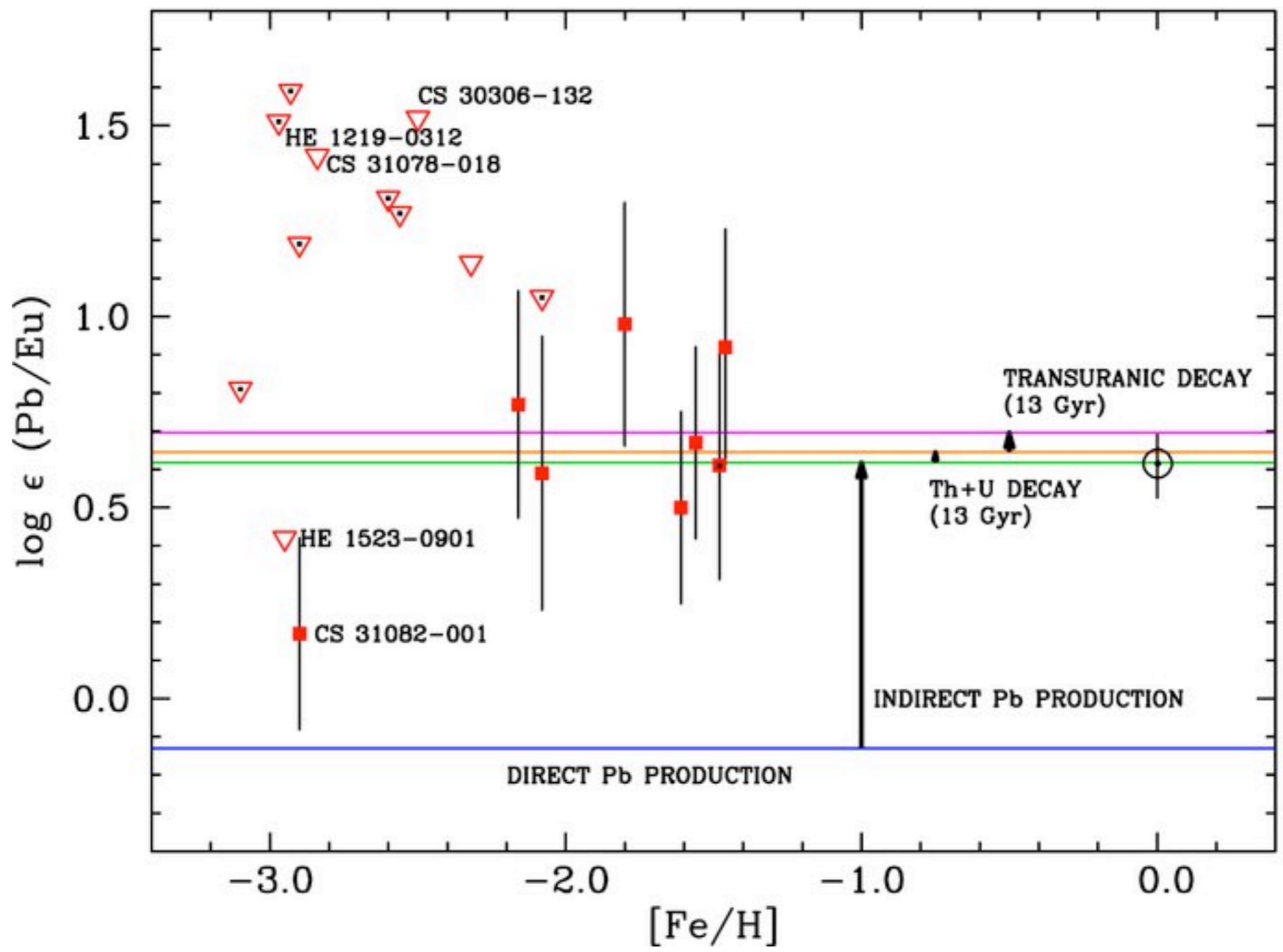
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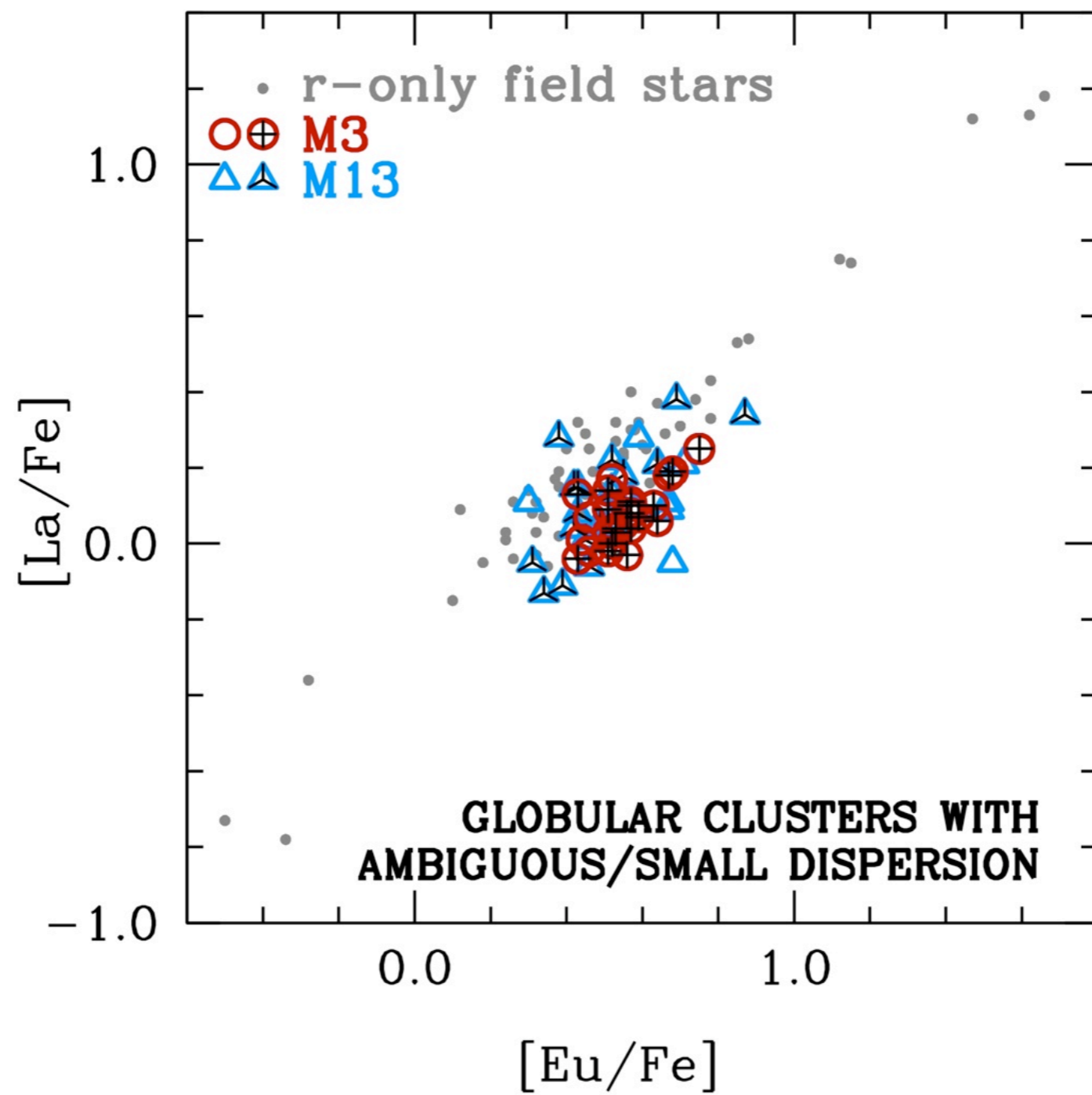
- (1) common, but not ubiquitous
- (2) not correlated with light element dispersion
- (3) not strongly correlated with cluster properties
- (4) interesting.



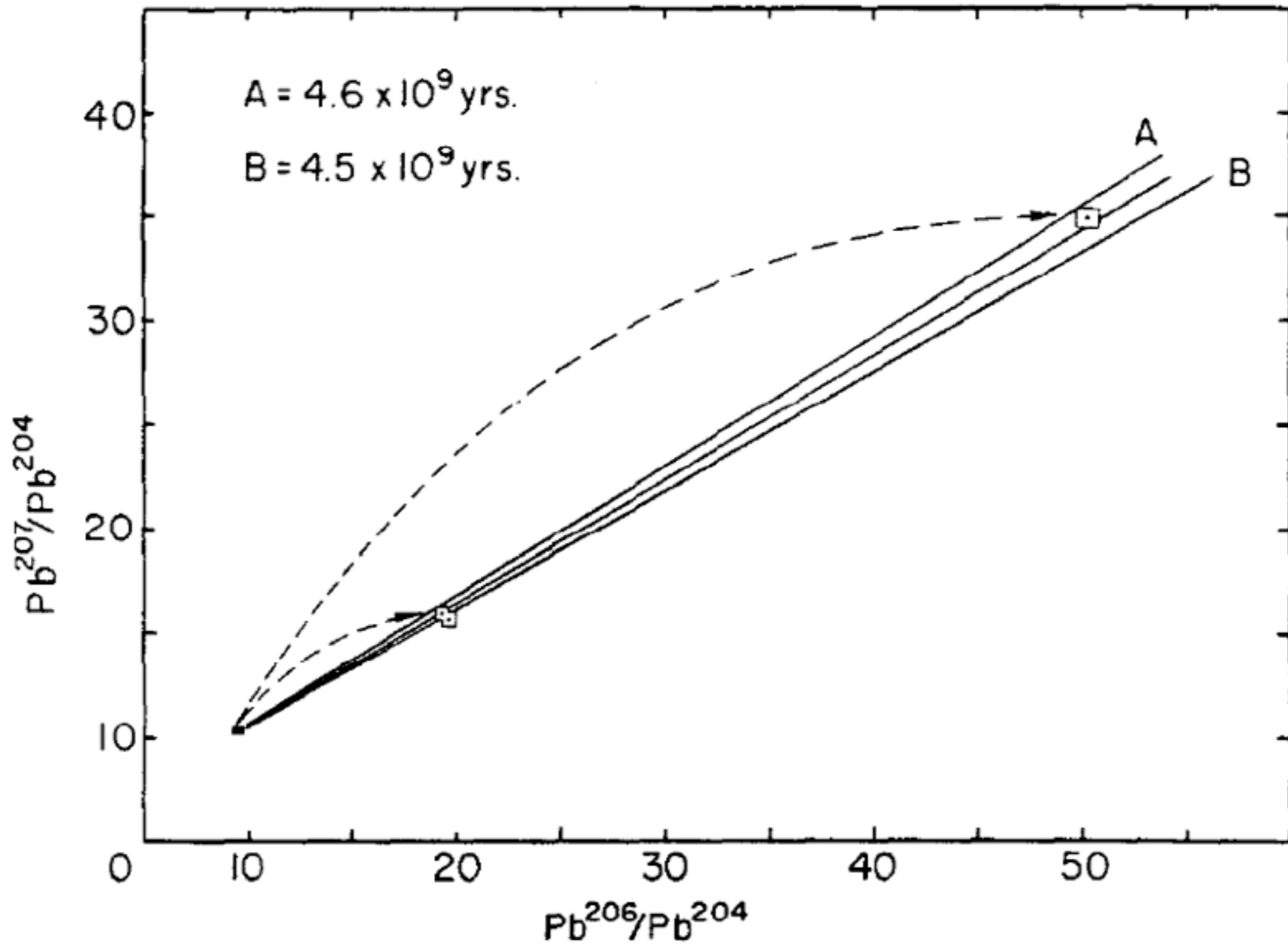




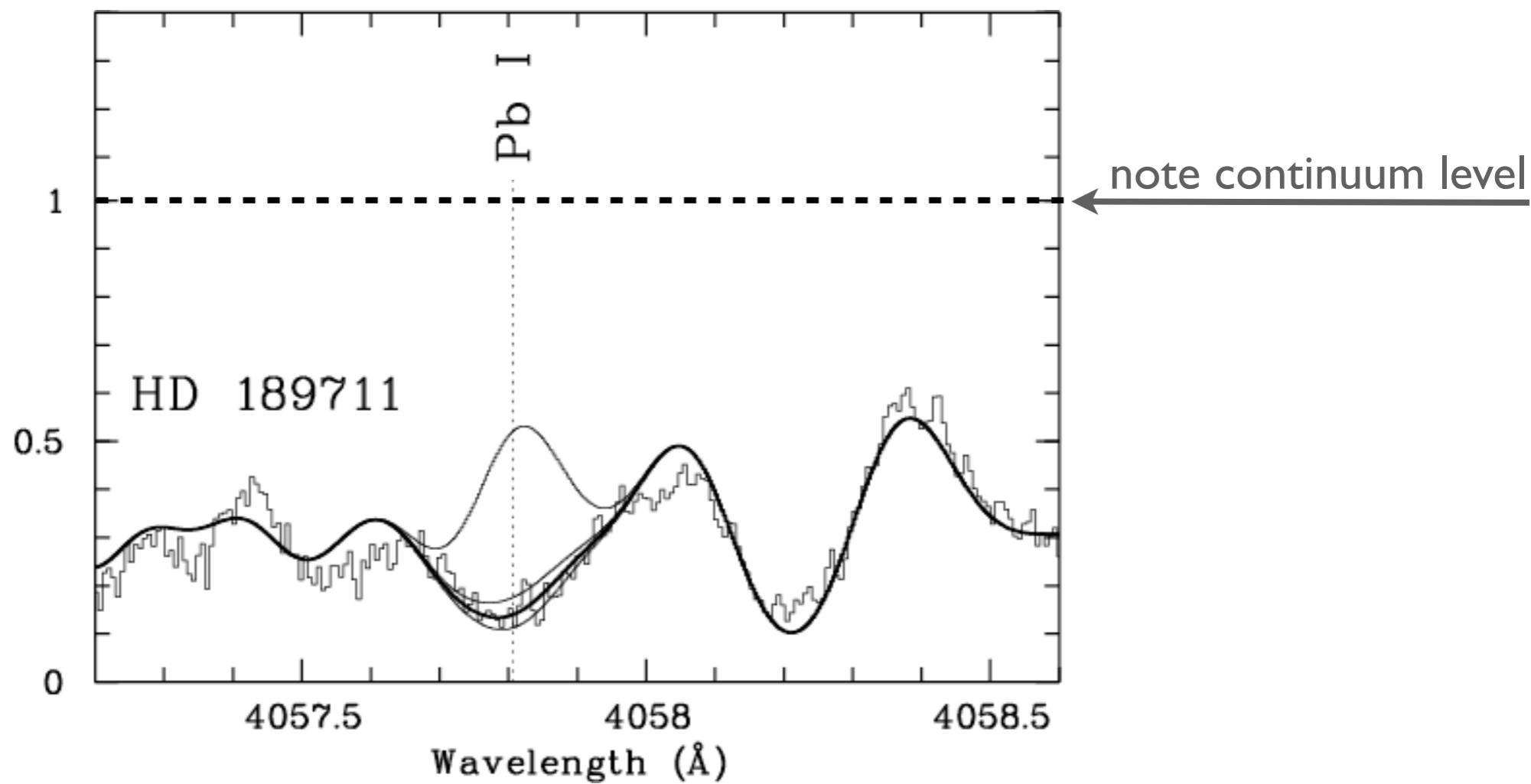




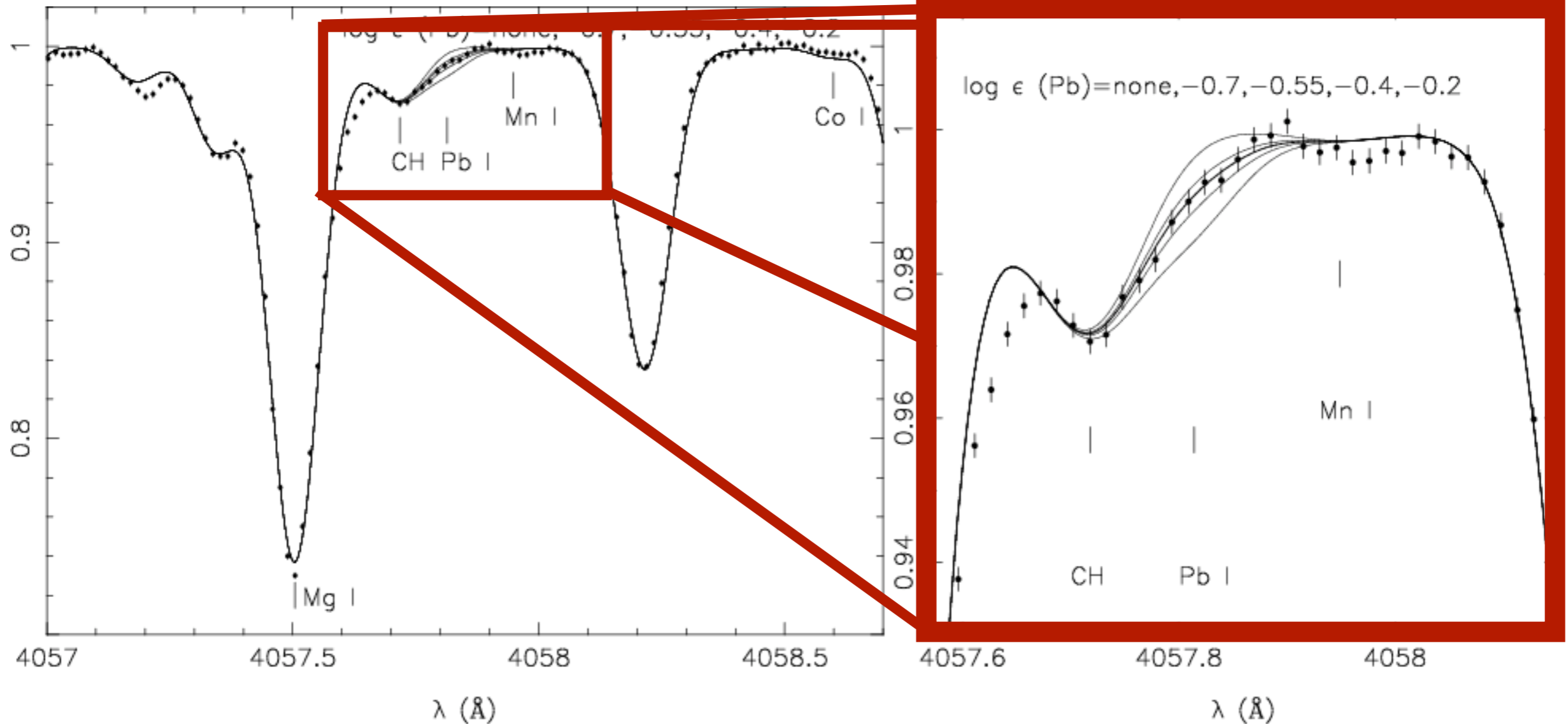




Patterson (1956, Geochim. et Cosmochim. Acta, 10, 230)



S/N = 600 from 17<sup>h</sup> with UVES



Plez et al. (2004, A&A, 428, L9)