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# Neutrons in astrophysics

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***Town Meeting on IFMIF/ELAMAT***
***Complementary Scientific Program***
***Rzeszów University of Technology***
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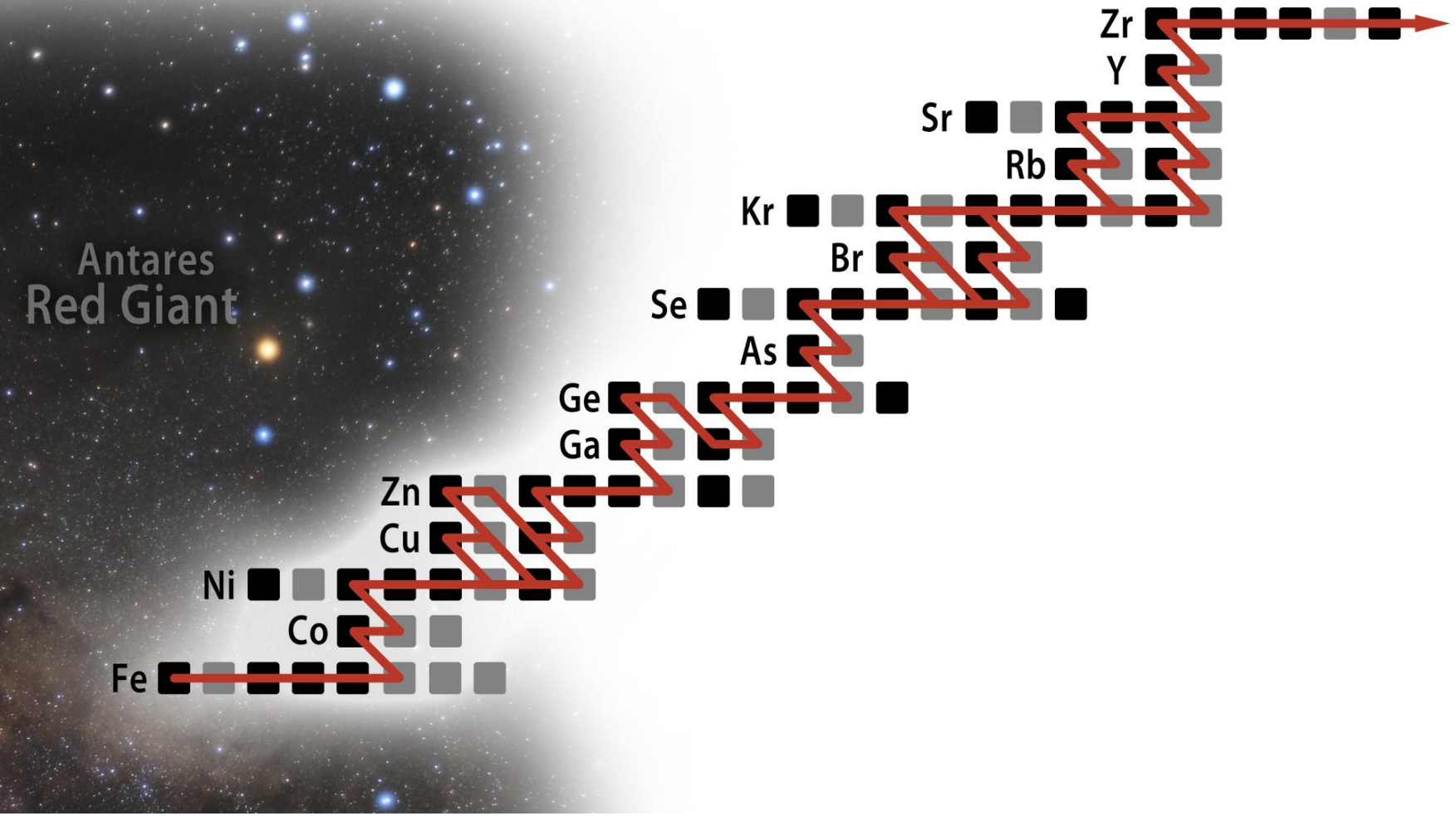
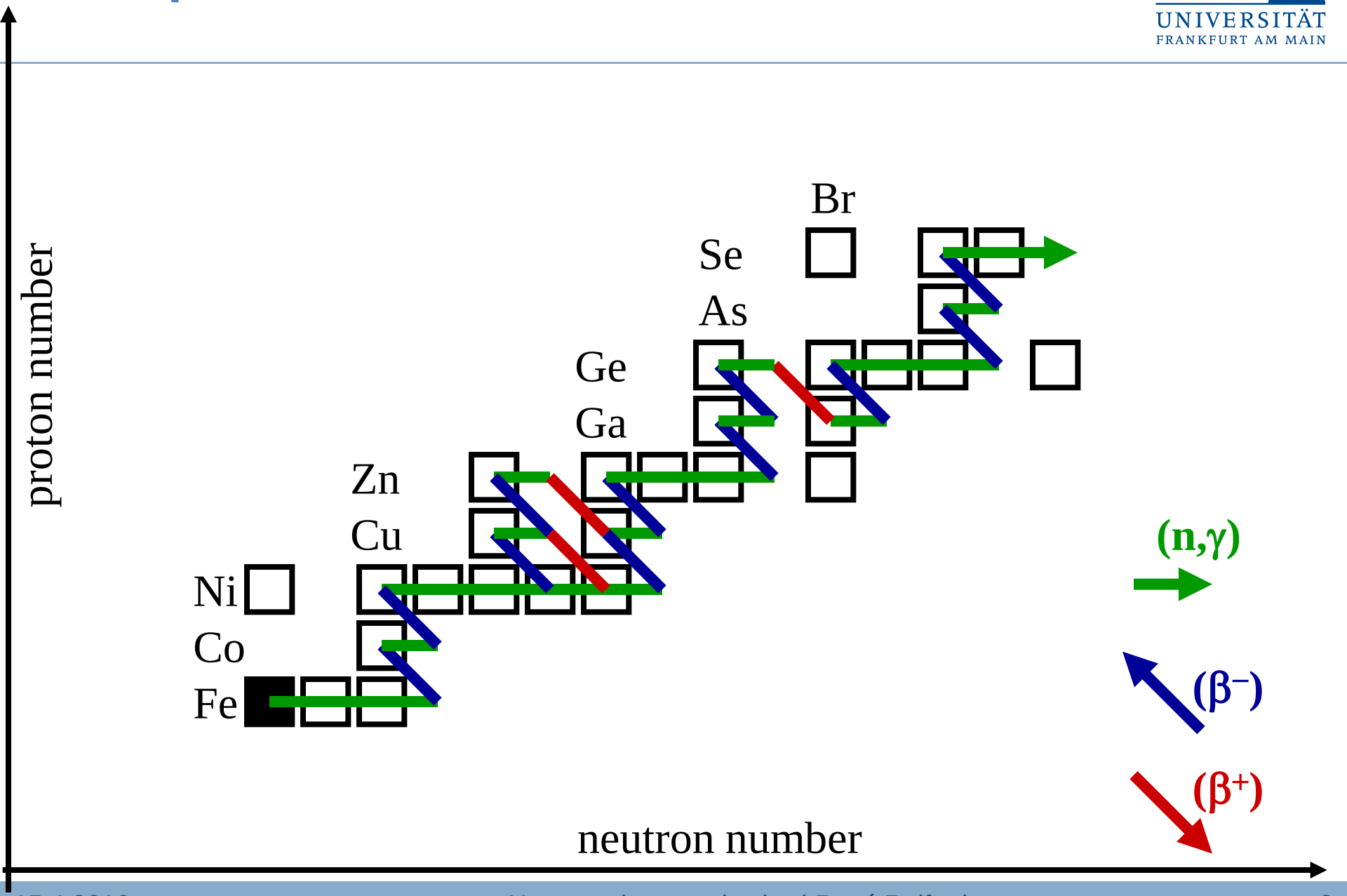
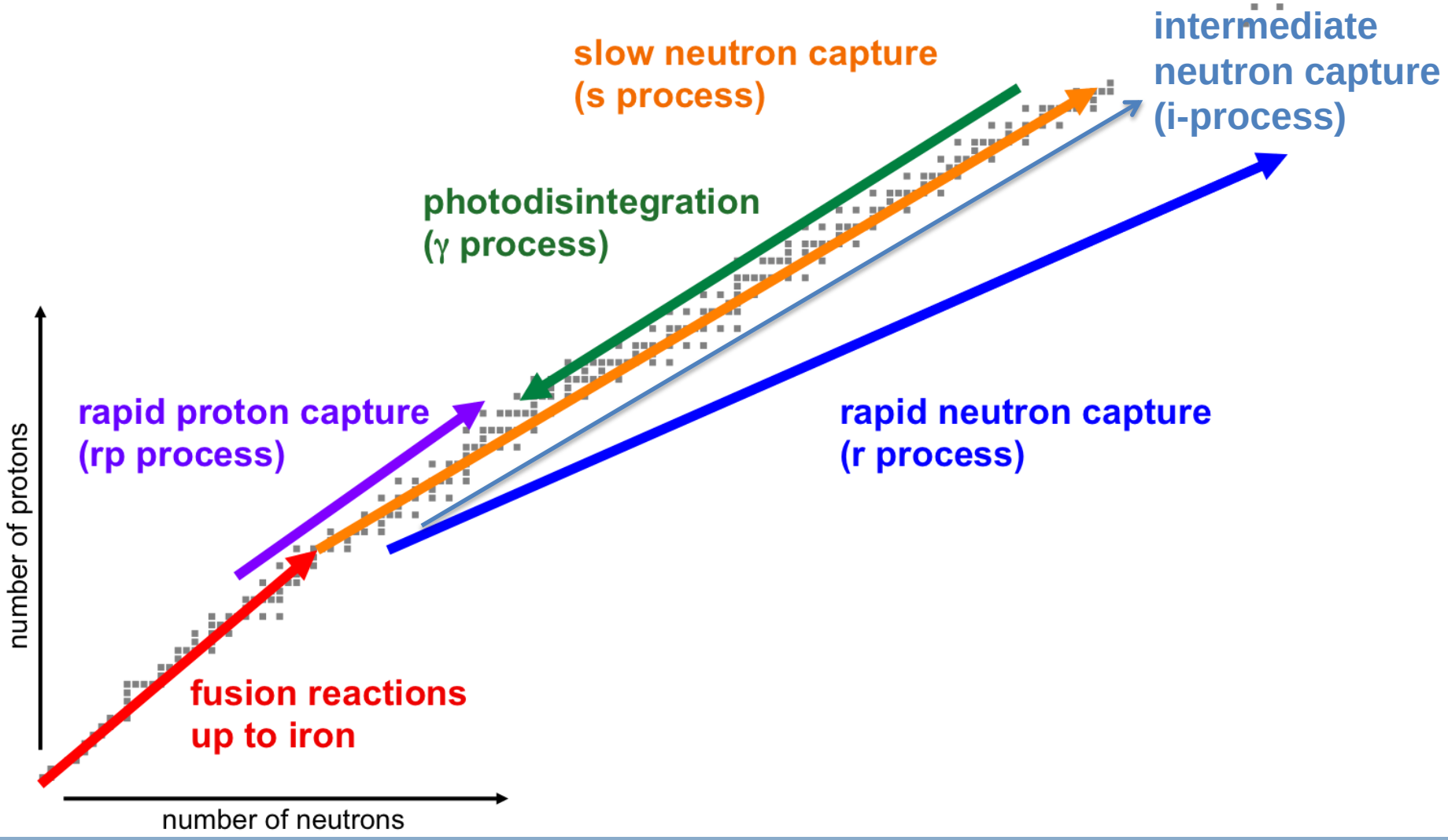
# Nucleosynthesis – tales from the past



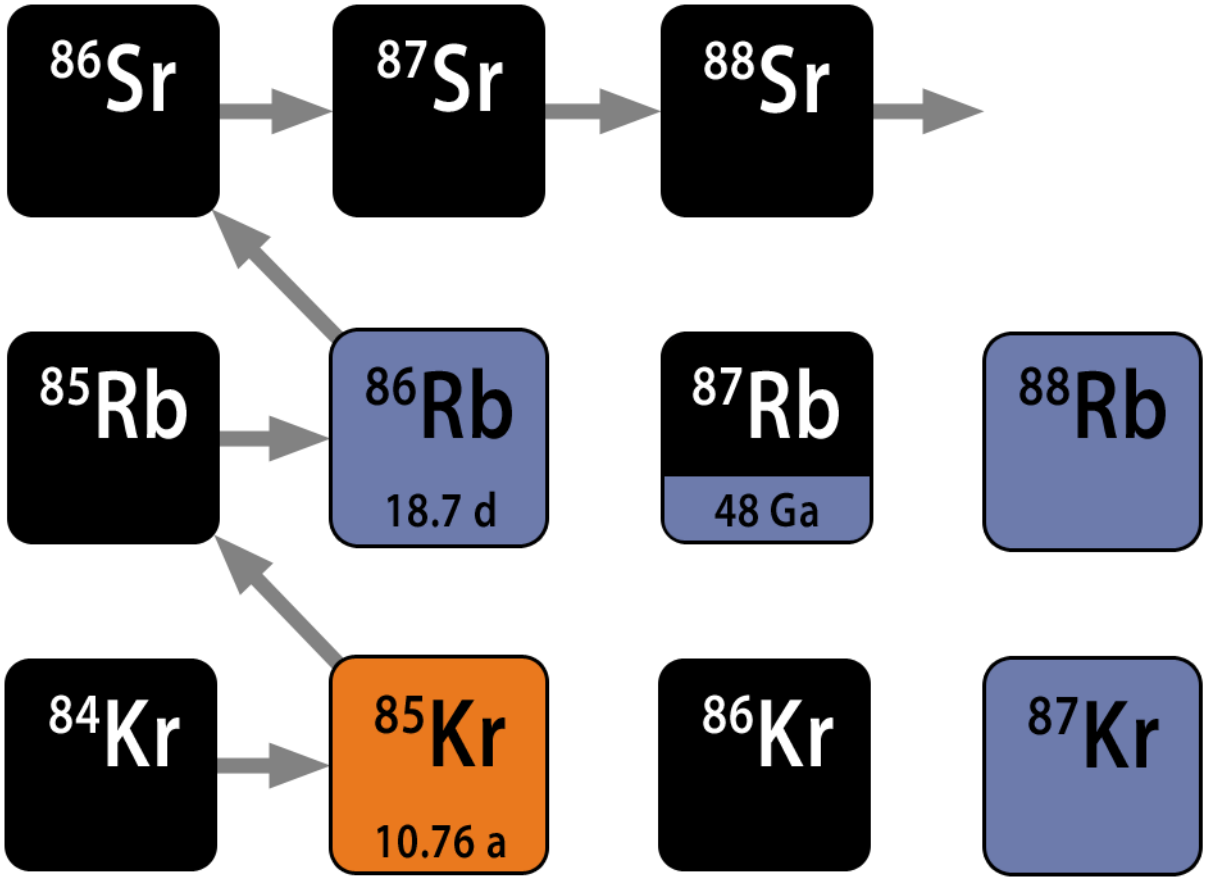
# The s-process



# The nucleosynthesis of the elements



# Radioctive isotopes in the s-process



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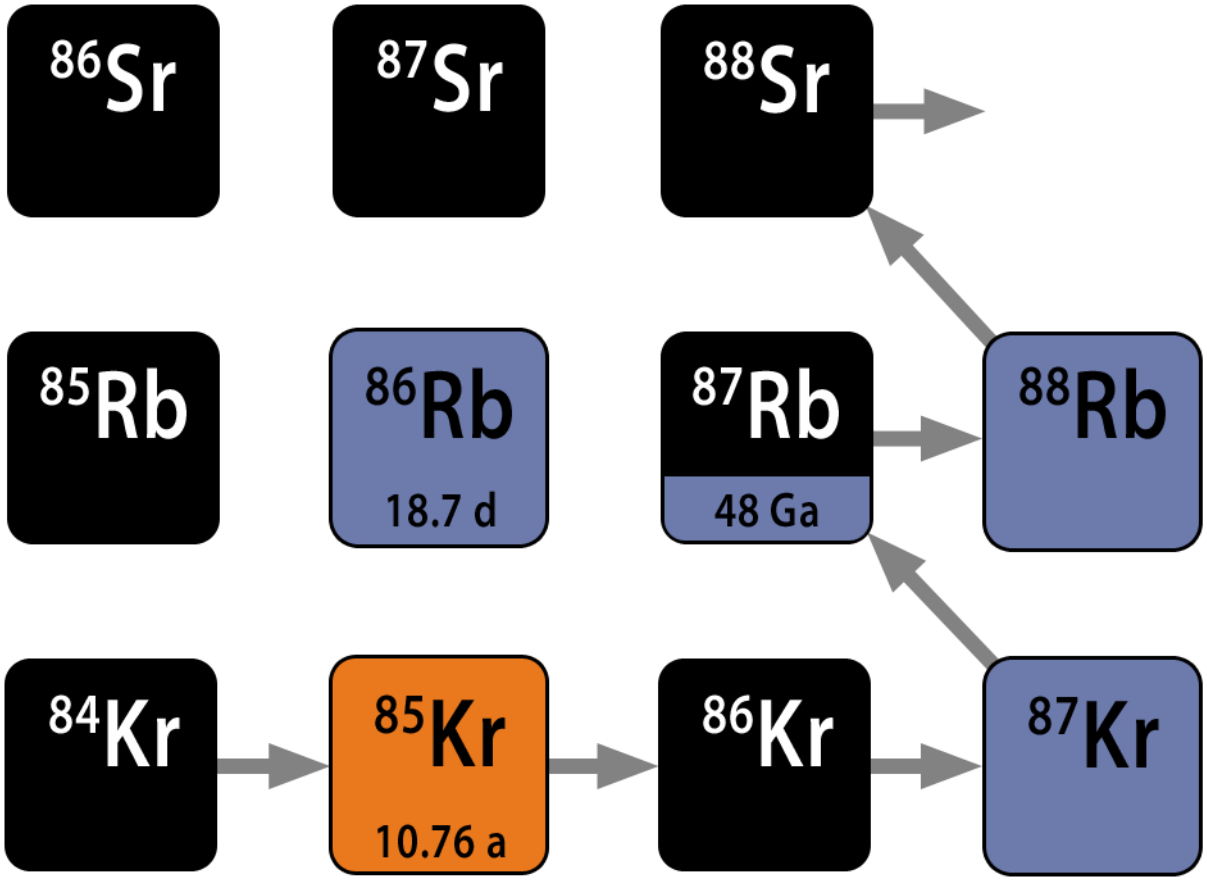

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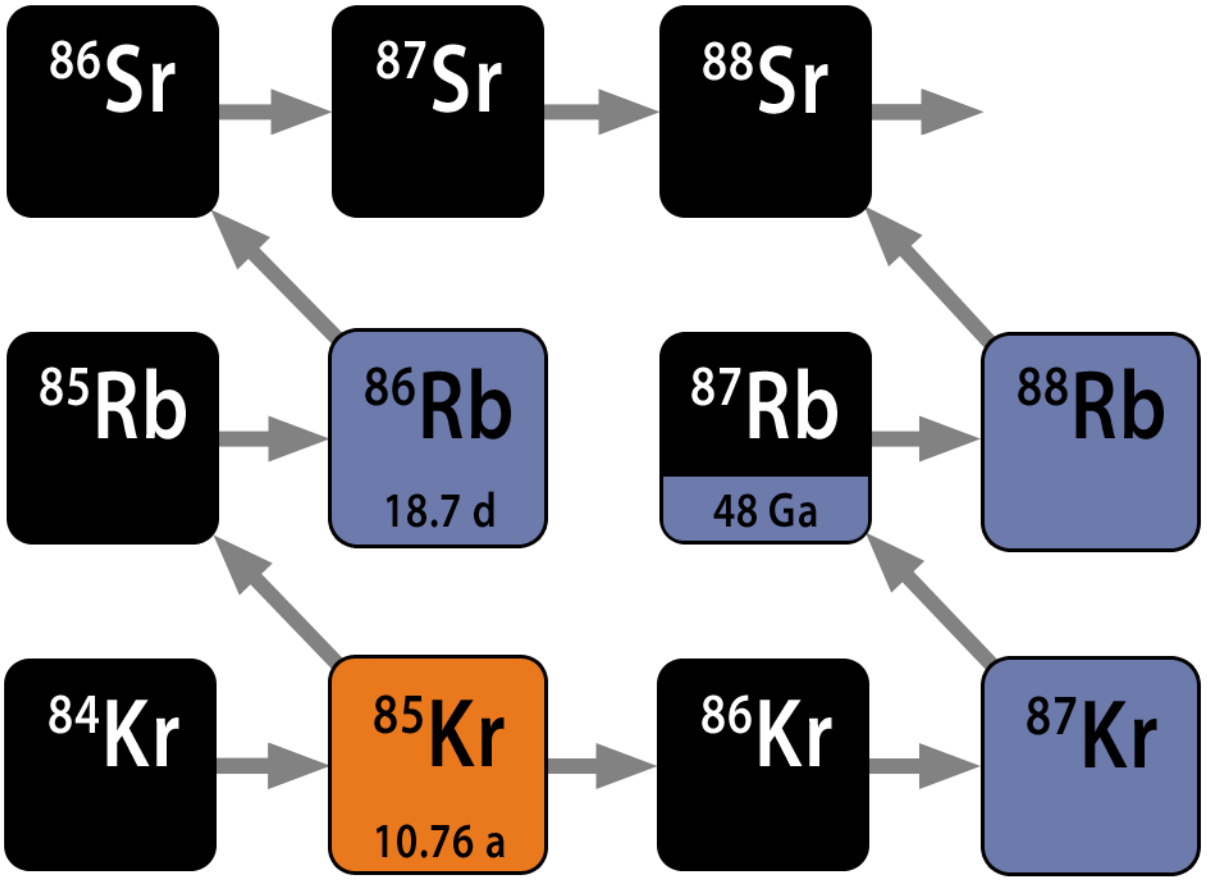
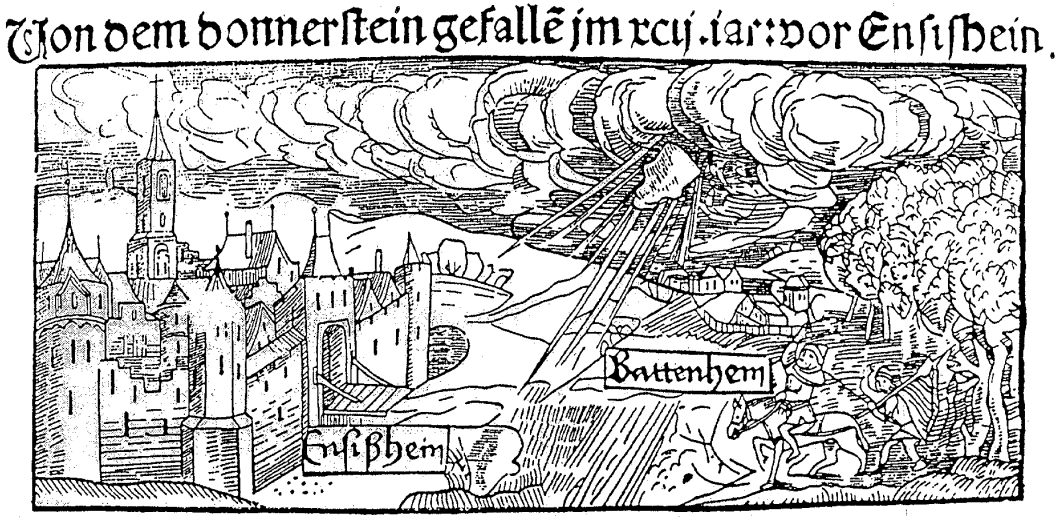
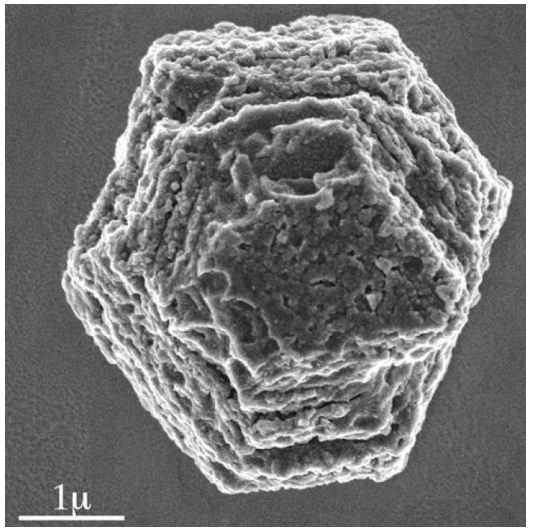
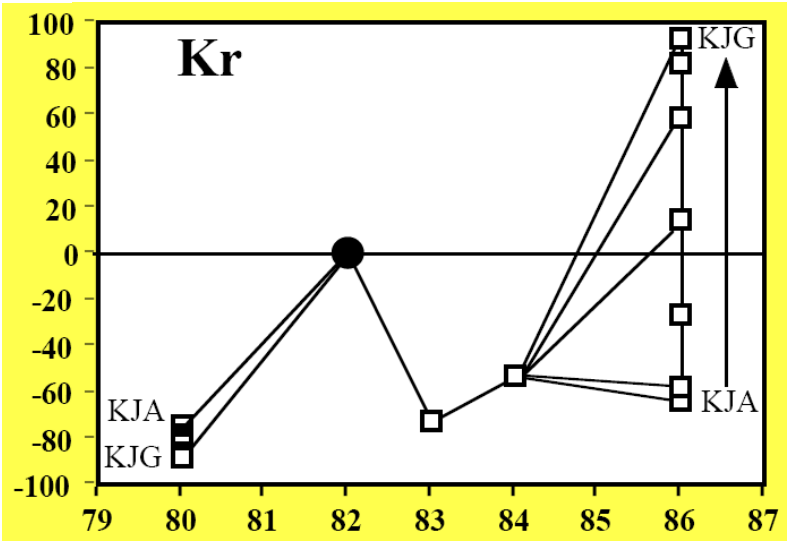


# Meteorites – hints from the sky

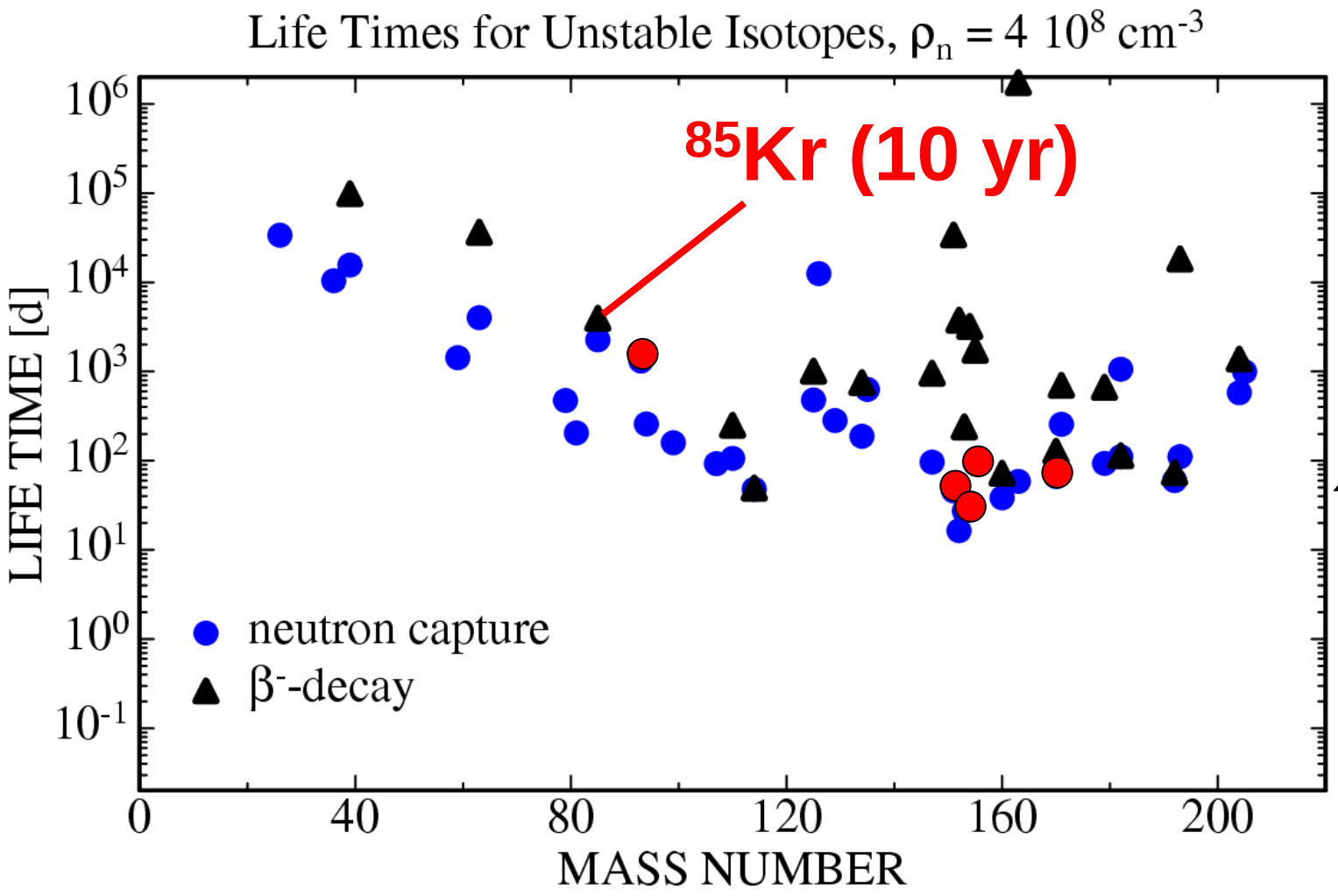



Meteorites contain presolar grains!

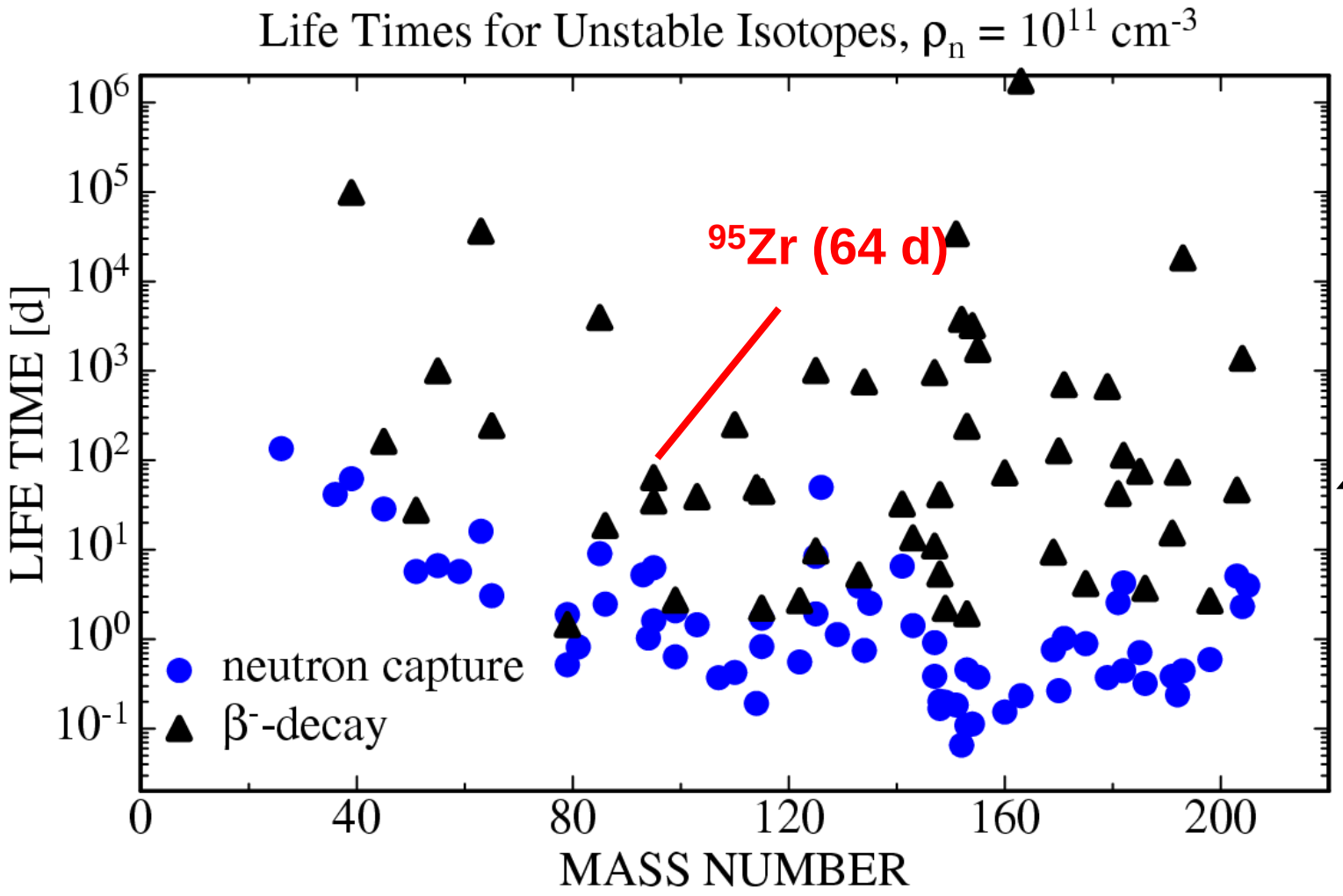


# s-process models - classical s-process




$$\lambda_n > \lambda_\beta$$

# s-process models – T-AGB stars, $^{22}$Ne phase

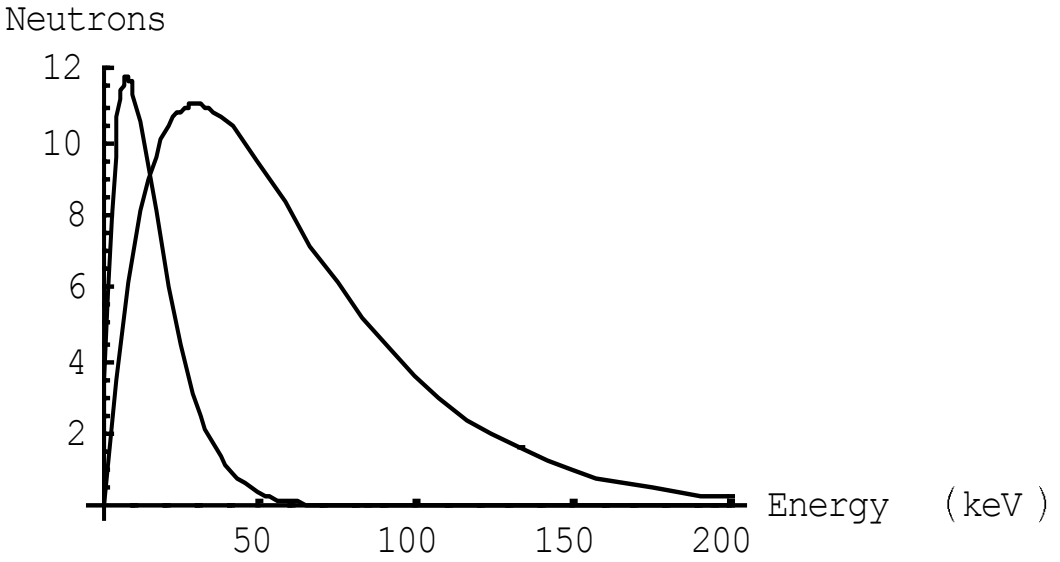


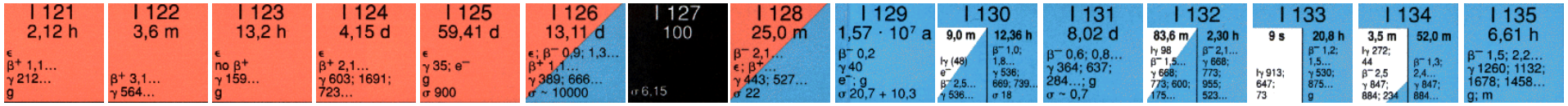

$$\lambda_n > \lambda_\beta$$

**Couture & Reifarth, ADNDT, 93 (2007) 807**

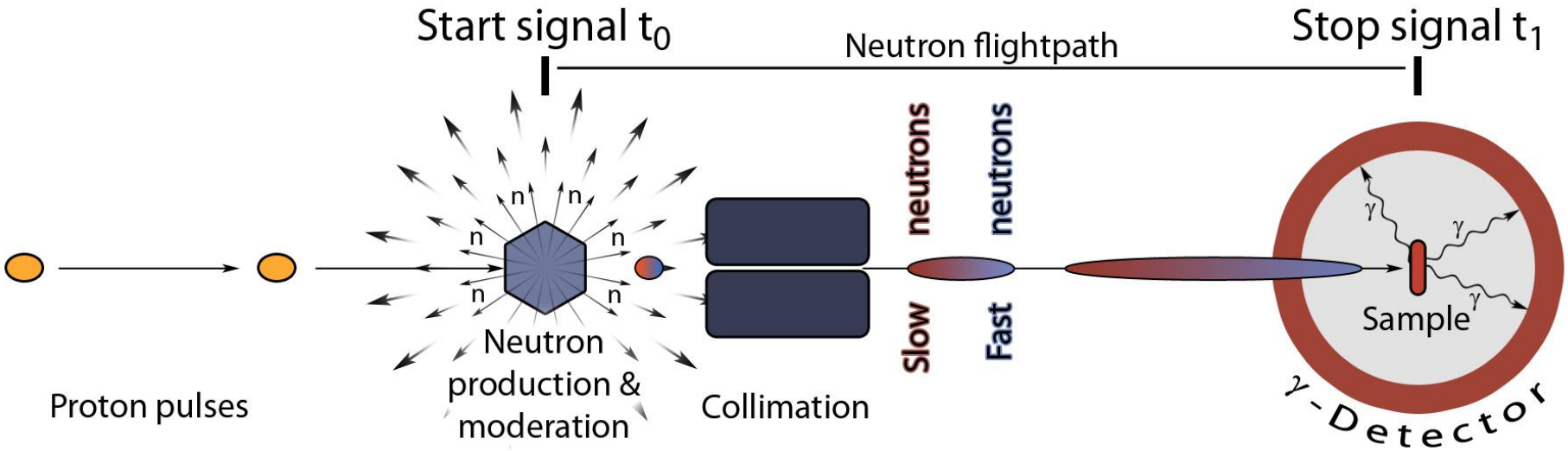
# What's needed?

## Neutron induced Reaction rates (1-500 keV)



# Neutron Captures – time-of-flight technique




- the TOF-technique is the only generally applicable method the determine energy-dependent neutron capture cross sections
- beam pulsing & distance to the neutron production site significantly reduce the number of neutrons available on the sample

**Reifarth et al. J. Phys. G: Nucl. Part. Phys. 41 (2014) 053101**

# What's needed?

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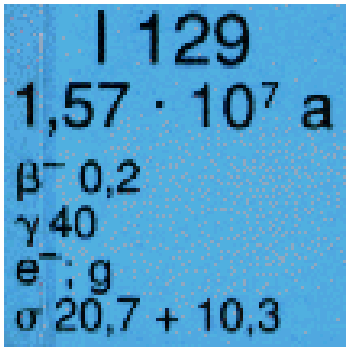
## Half life times!



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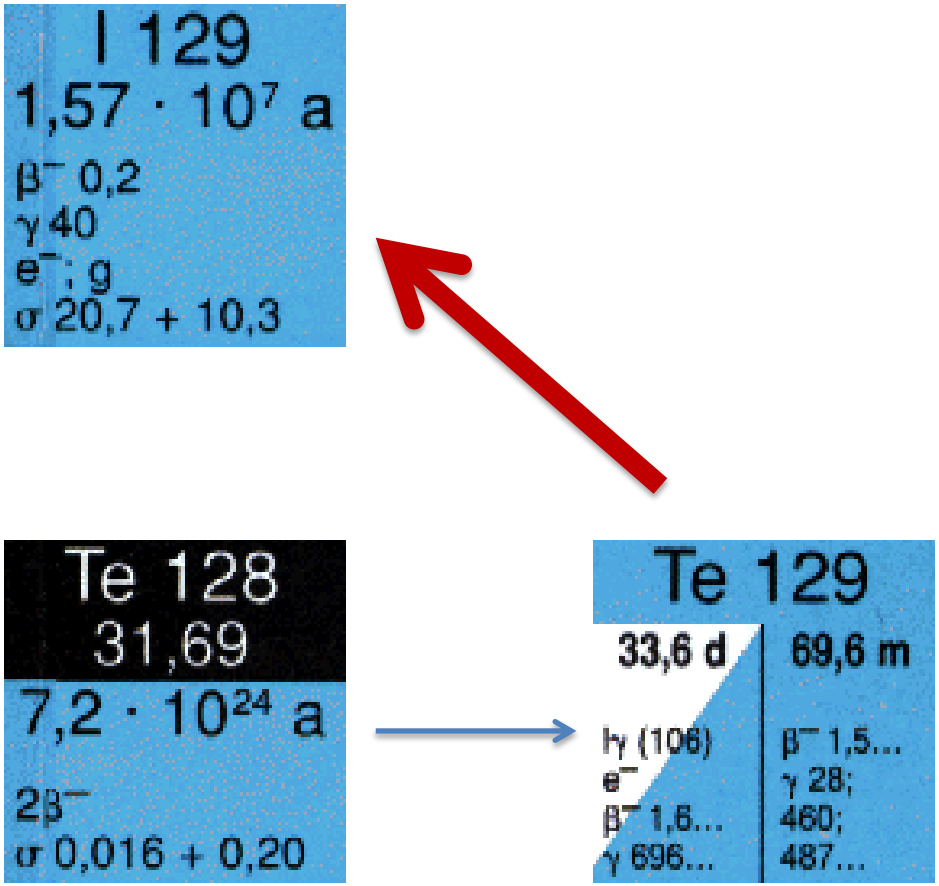
## Half life times!



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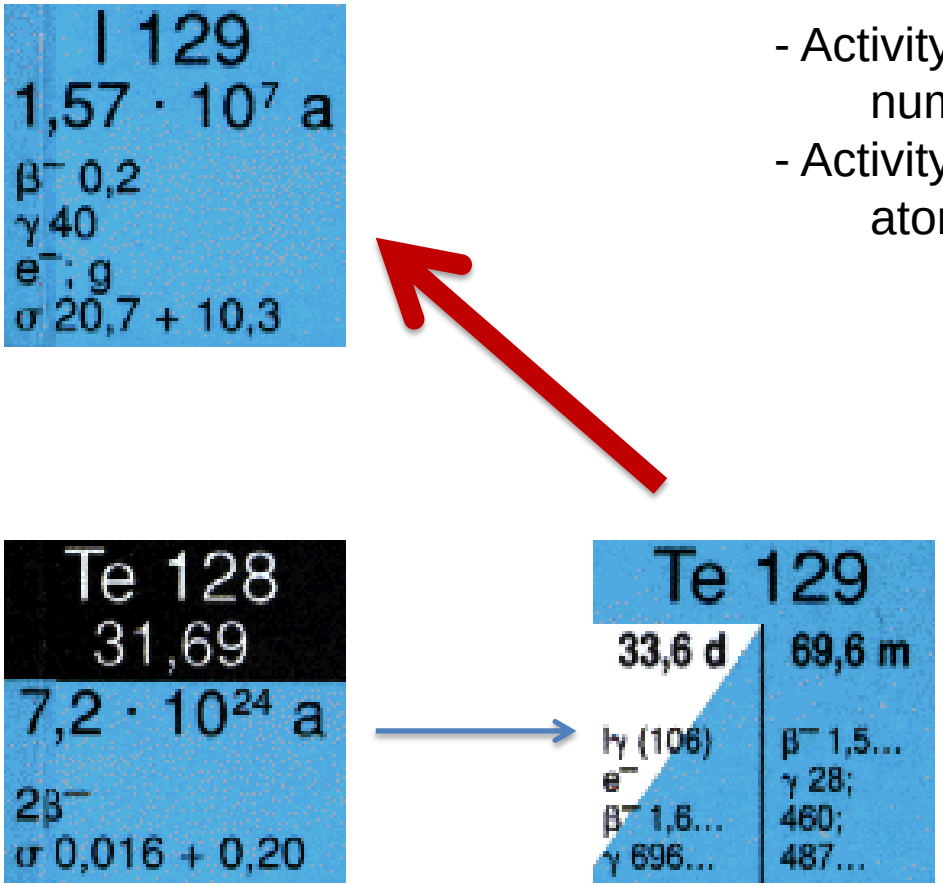
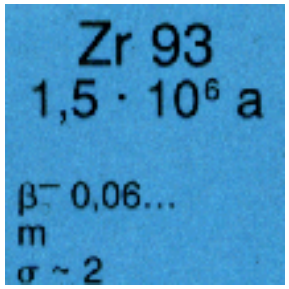



- Activity of parent determines number of atoms produced
- Activity of daughter with number of atoms gives half life of daughter

# $^{96}$Zr via (n,α)

## Half life times!



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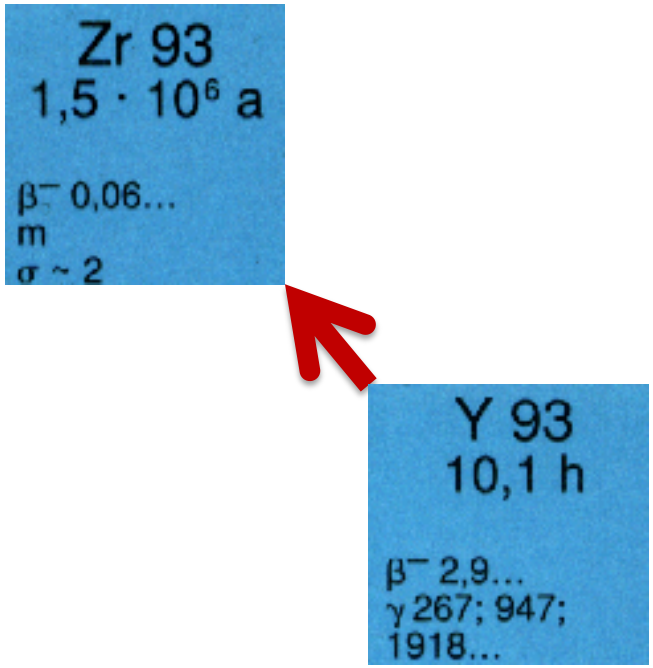

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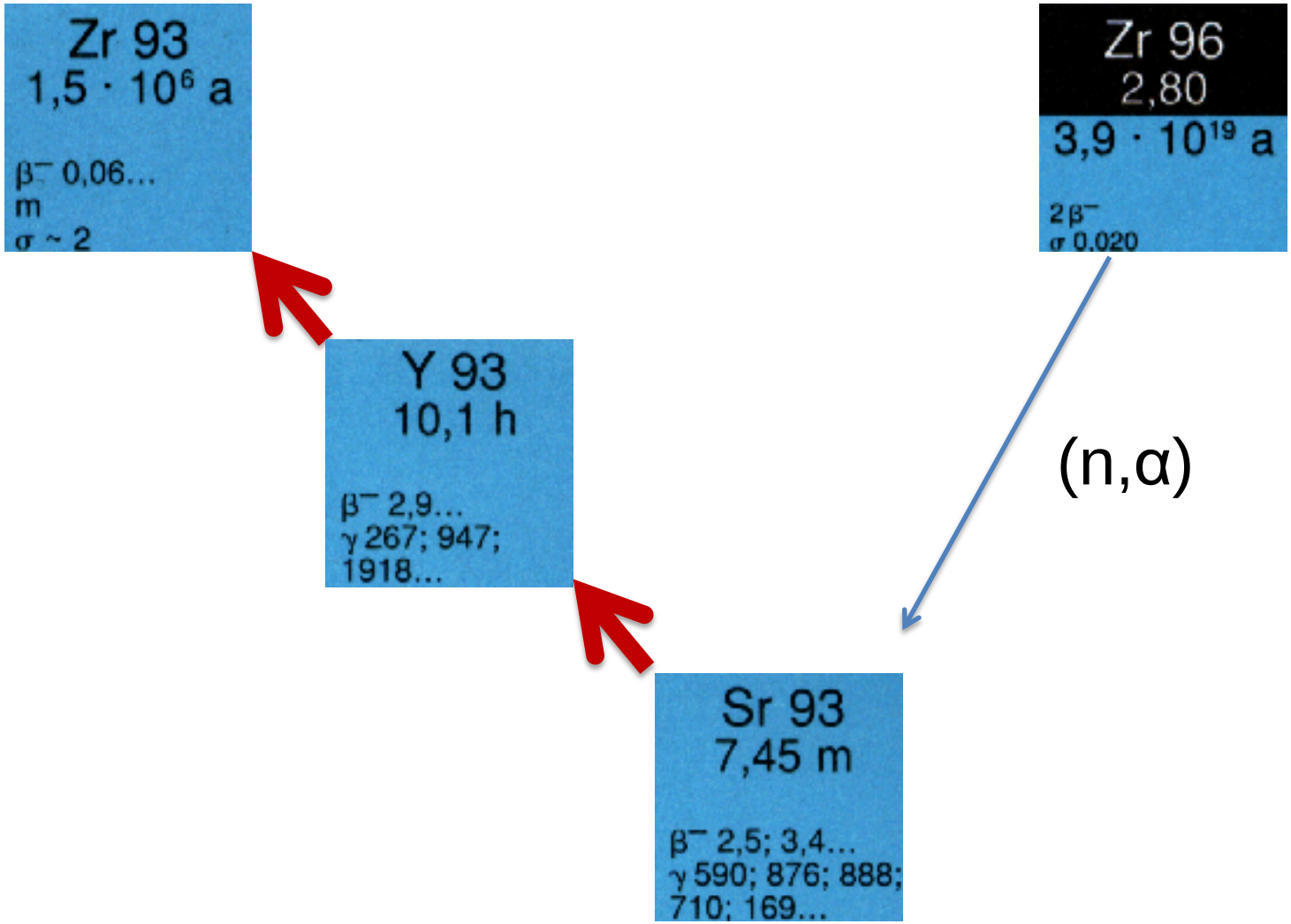


# Other important examples

**$^{82}$Se(n,α)$^{79}$Ge(β$^-$) $^{79}$As(β$^-$) $^{79}$Se(β$^-$):**

- $^{79}$Ge(1 min)
- $^{79}$As(8 min)
- $^{79}$Se(~3 10$^5$ yr)

# Other important examples

**$^{110}$Pd(n,α)$^{107}$Ru(β$^-$) $^{107}$Rh(β$^-$)$^{107}$Pd(β$^-$):**

- $^{107}$Ru(4 min)
- $^{107}$Rh(22 min)
- $^{107}$Pd(~7 $10^5$ yr)

# Other important examples

**$^{138}$Ba(n,α)$^{135}$Xe(β$^-$)$^{135}$Cs(β$^-$):**

- $^{135}$Xe(9.1 h)
- $^{135}$Cs(~2 10$^6$ yr)

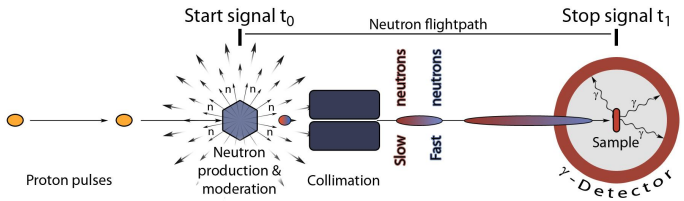
# Other important examples

**$^{132}$Xe(n,α)$^{129}$Te(β$^-$)$^{129}$I(β$^-$):**

- $^{129}$Te(33 d / 1 h)
- $^{129}$I(~15 10$^6$ yr)

# Summary

- **Neutron induced reaction studies require time-of-flight setup**




- **Isotope production is very attractive**
  - Sample production
  - Determination of long half lives