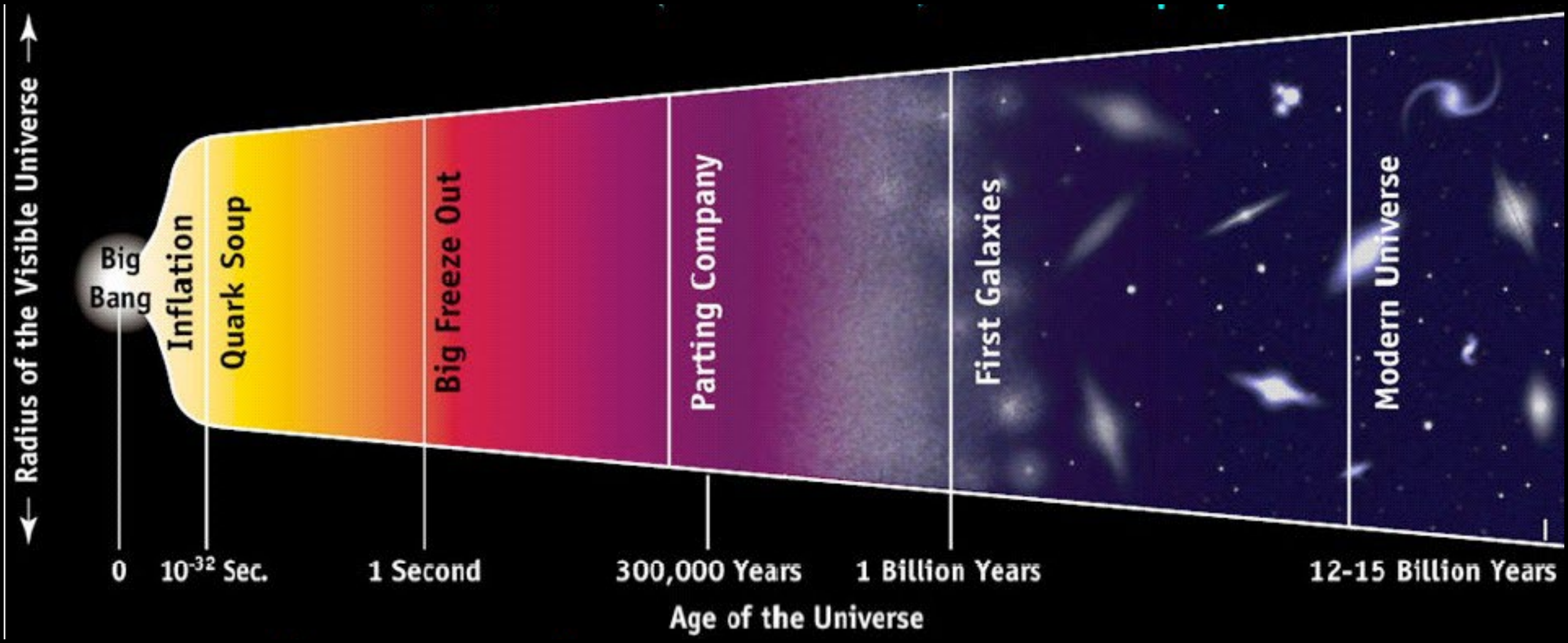
A brief history of the universe – and how we contribute

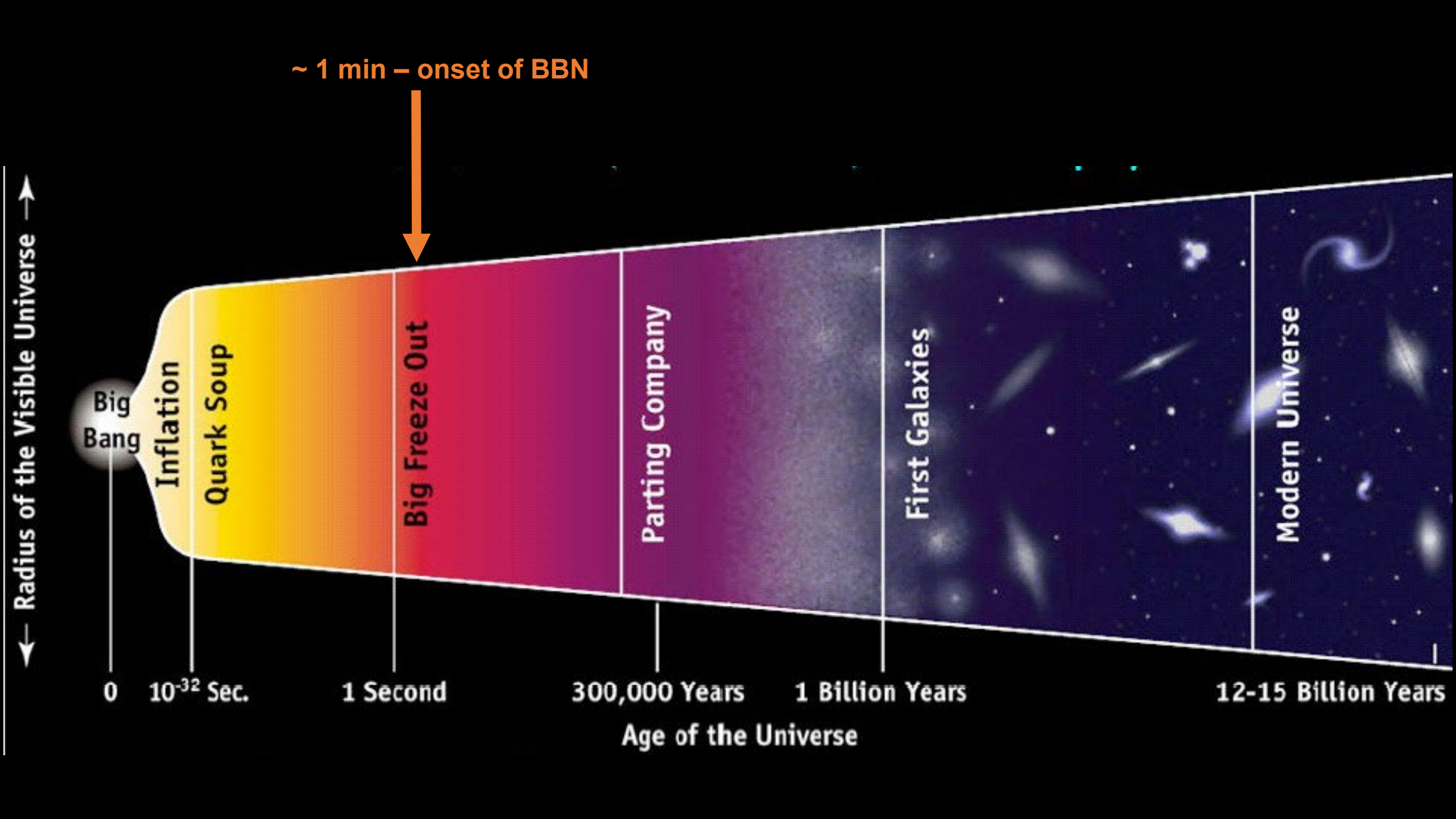
René Reifarth

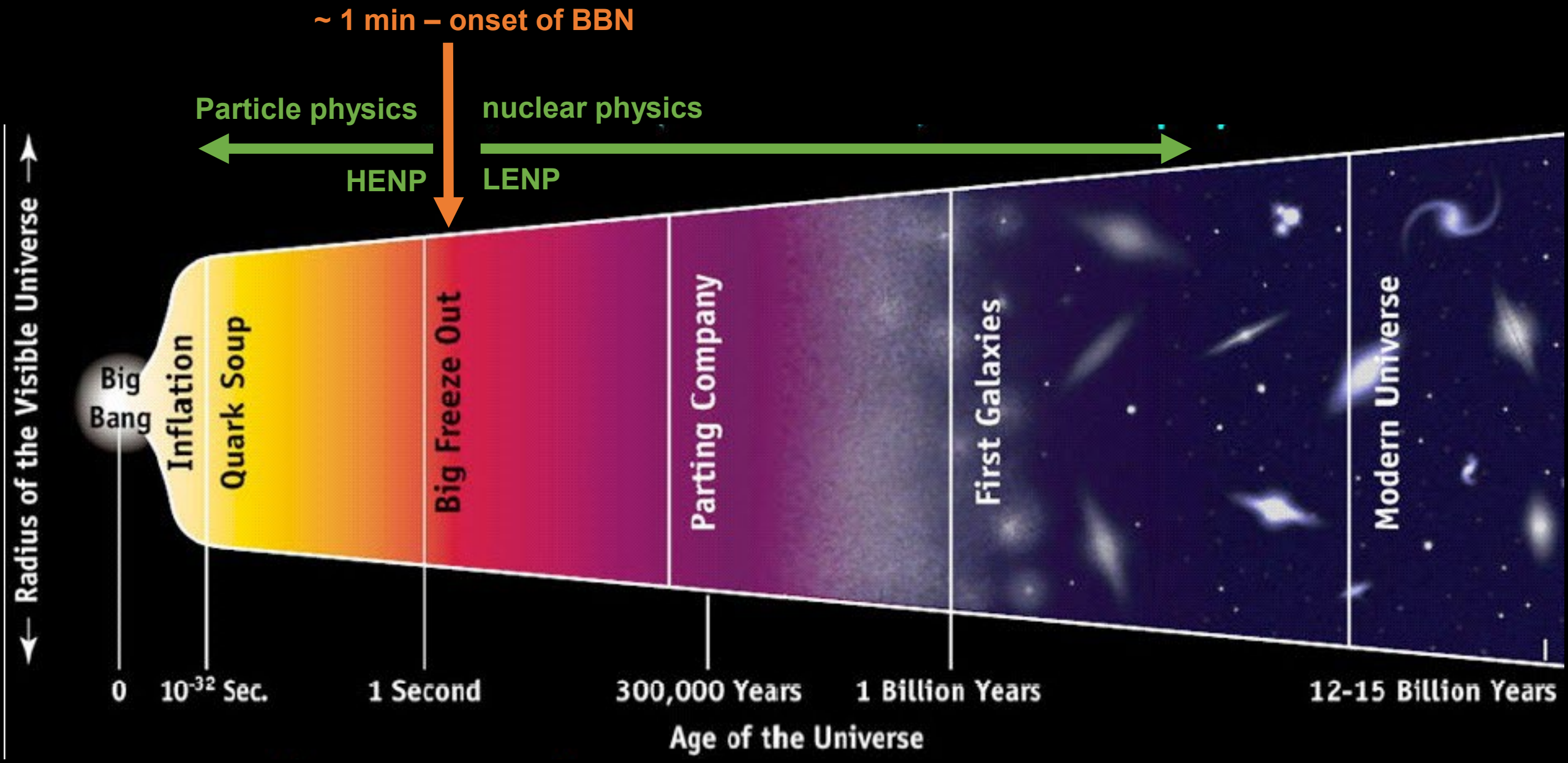
P-3, LANL

P-3 seminar
1. November 2023, LANSCE, LANL, USA

The history of the universe – as we believe it




~ 1 min – onset of BBN
Radius of the Visible Universe
Big Bang
Inflation
Quark Soup
Big Freeze Out
Parting Company
First Galaxies
Modern Universe
0
10-32 Sec.
1 Second
300,000 Years
1 Billion Years
12-15 Billion Years
Age of the Universe


~ 1 min – onset of BBN
Particle physics
nuclear physics
HENP
LENP
Radius of the Visible Universe
Big Bang
Inflation
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Big Freeze Out
Parting Company
First Galaxies
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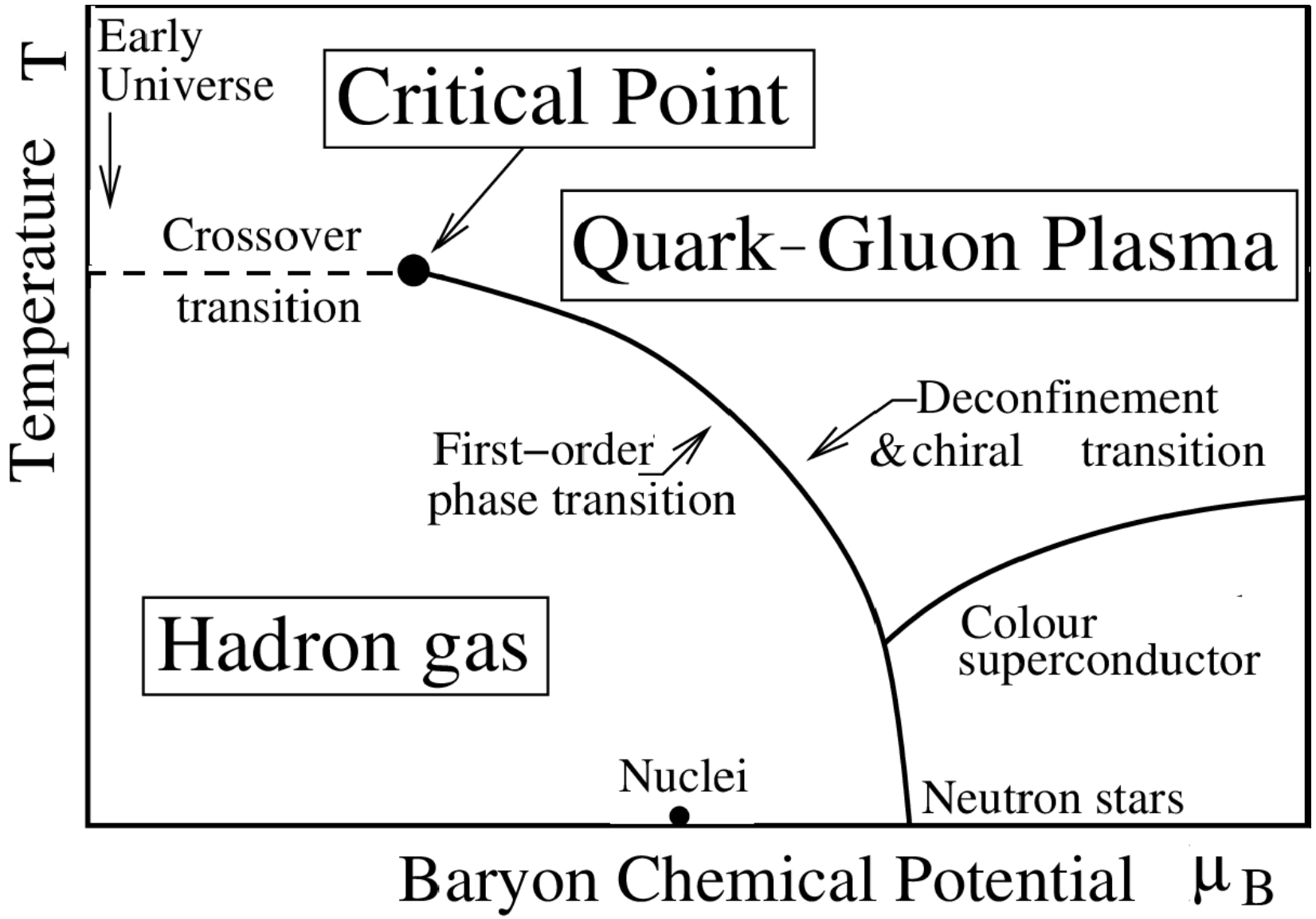
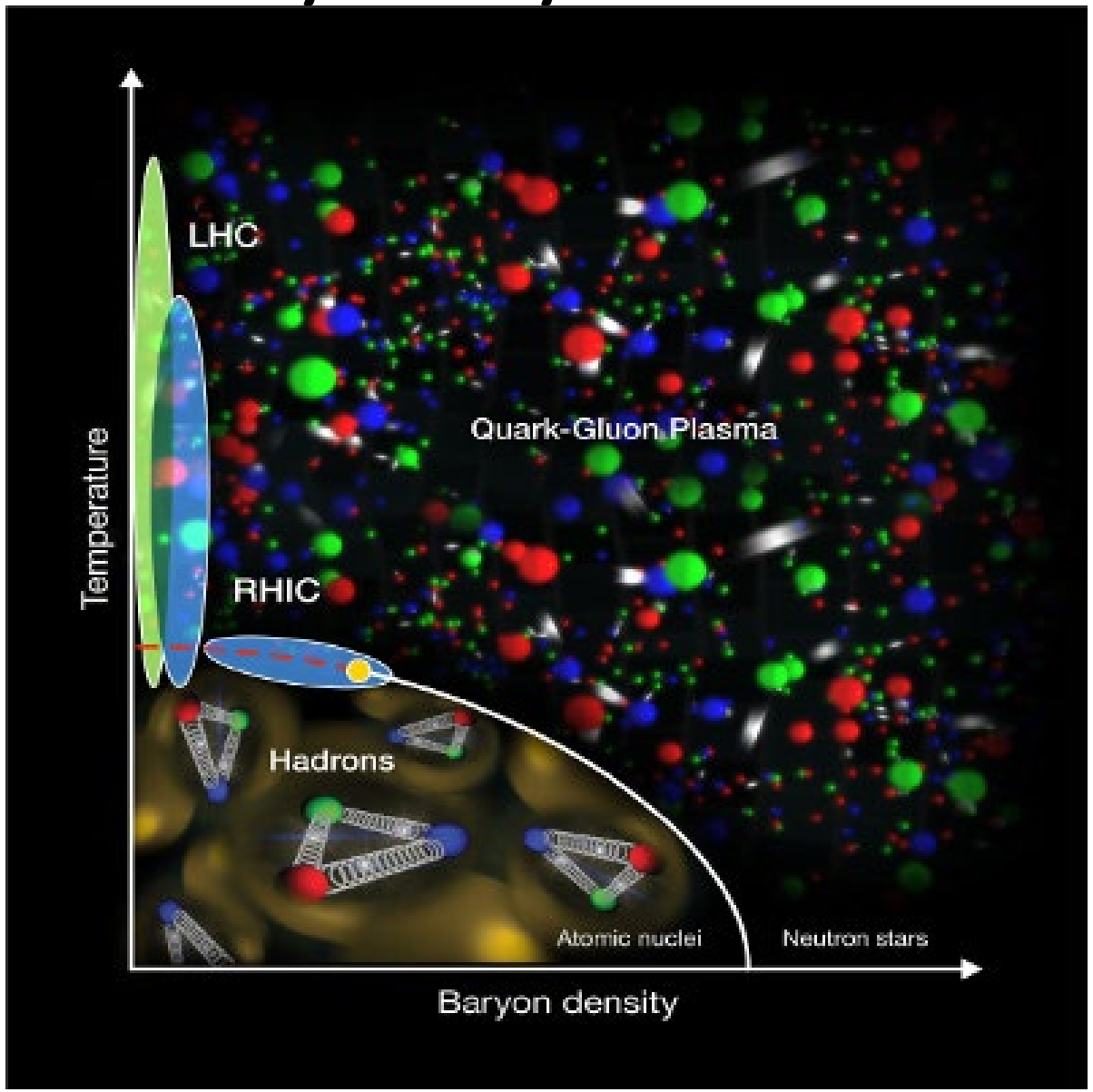
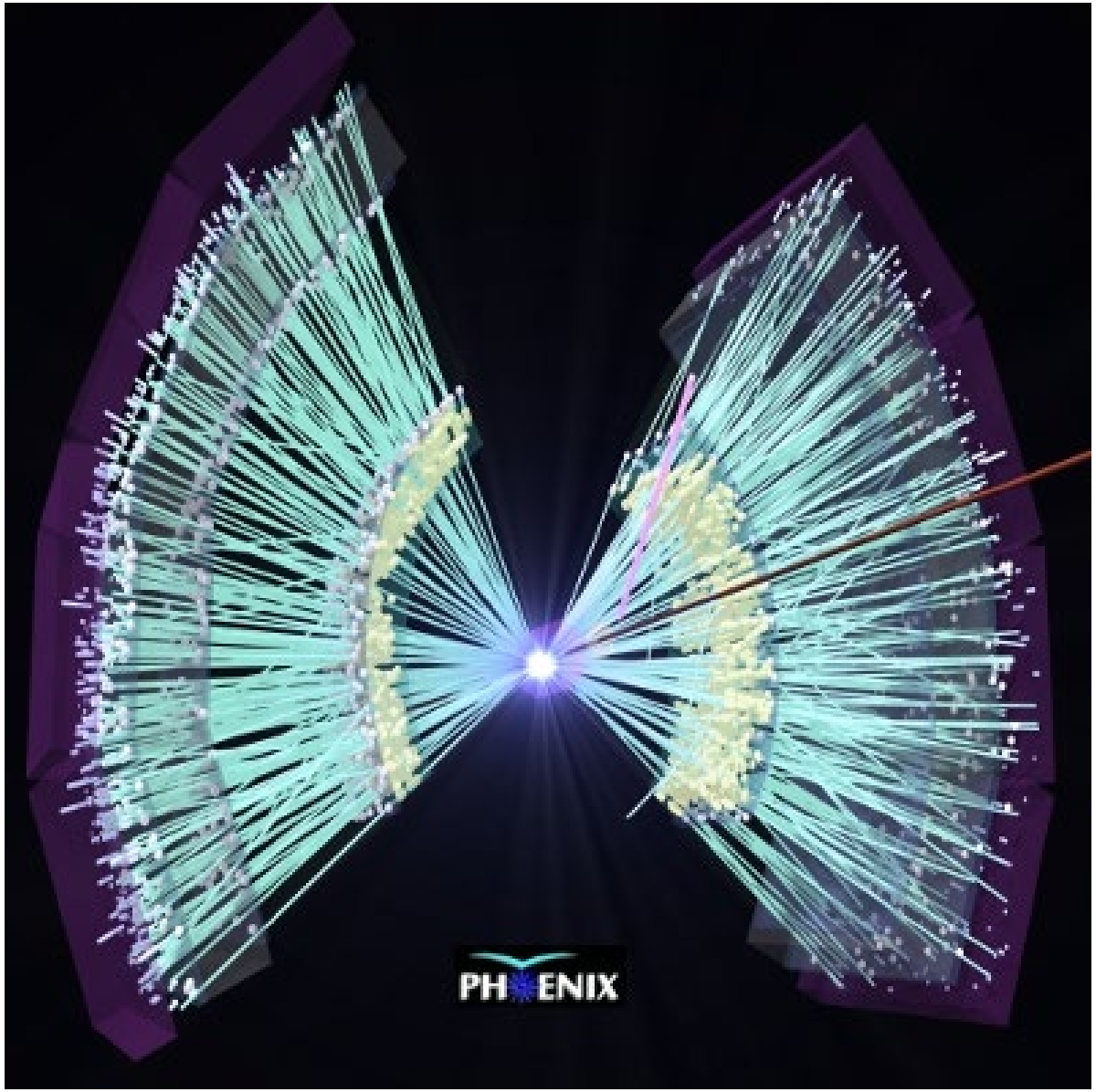
Age of the Universe

The very early universe



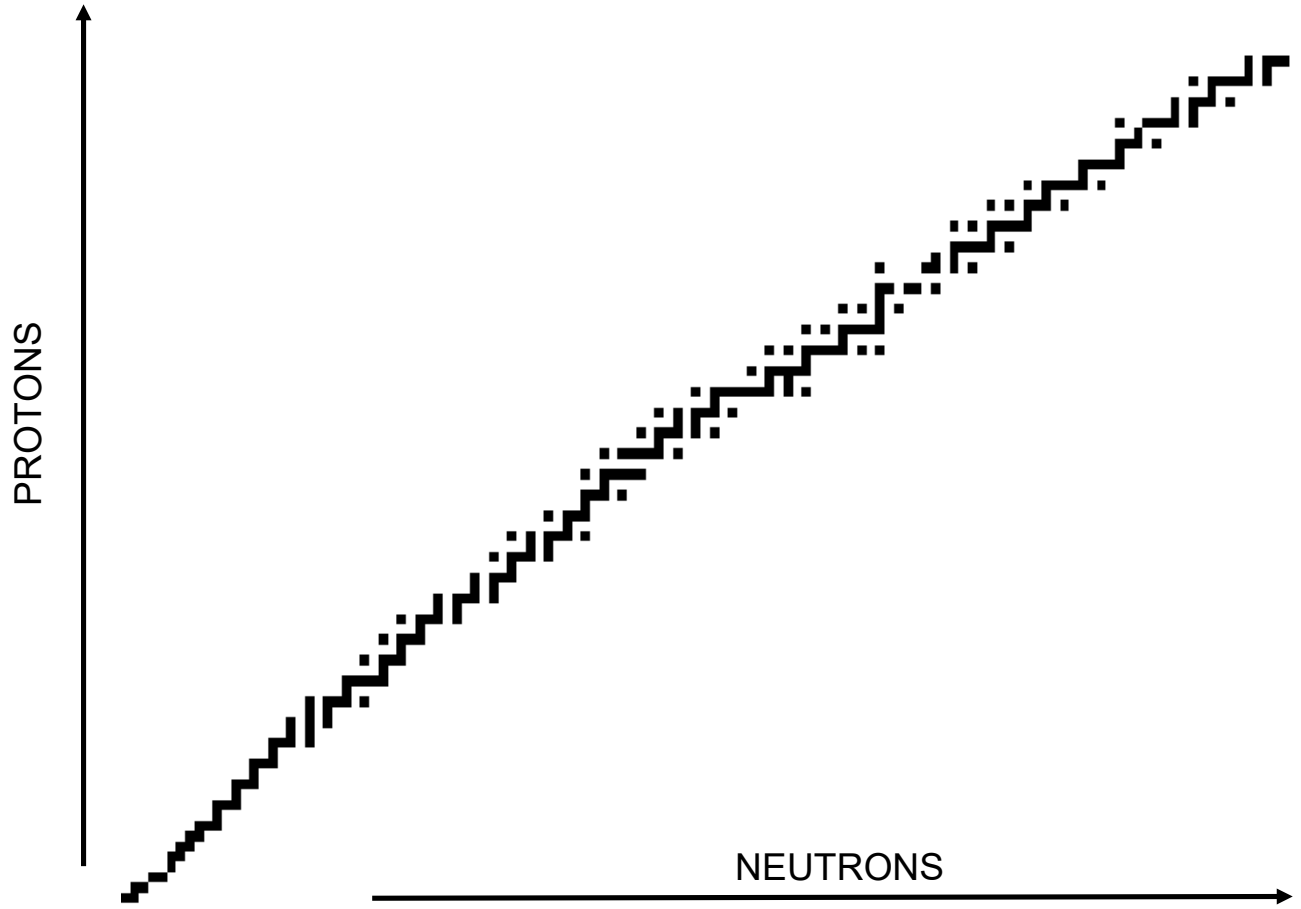
The very early universe - HENP



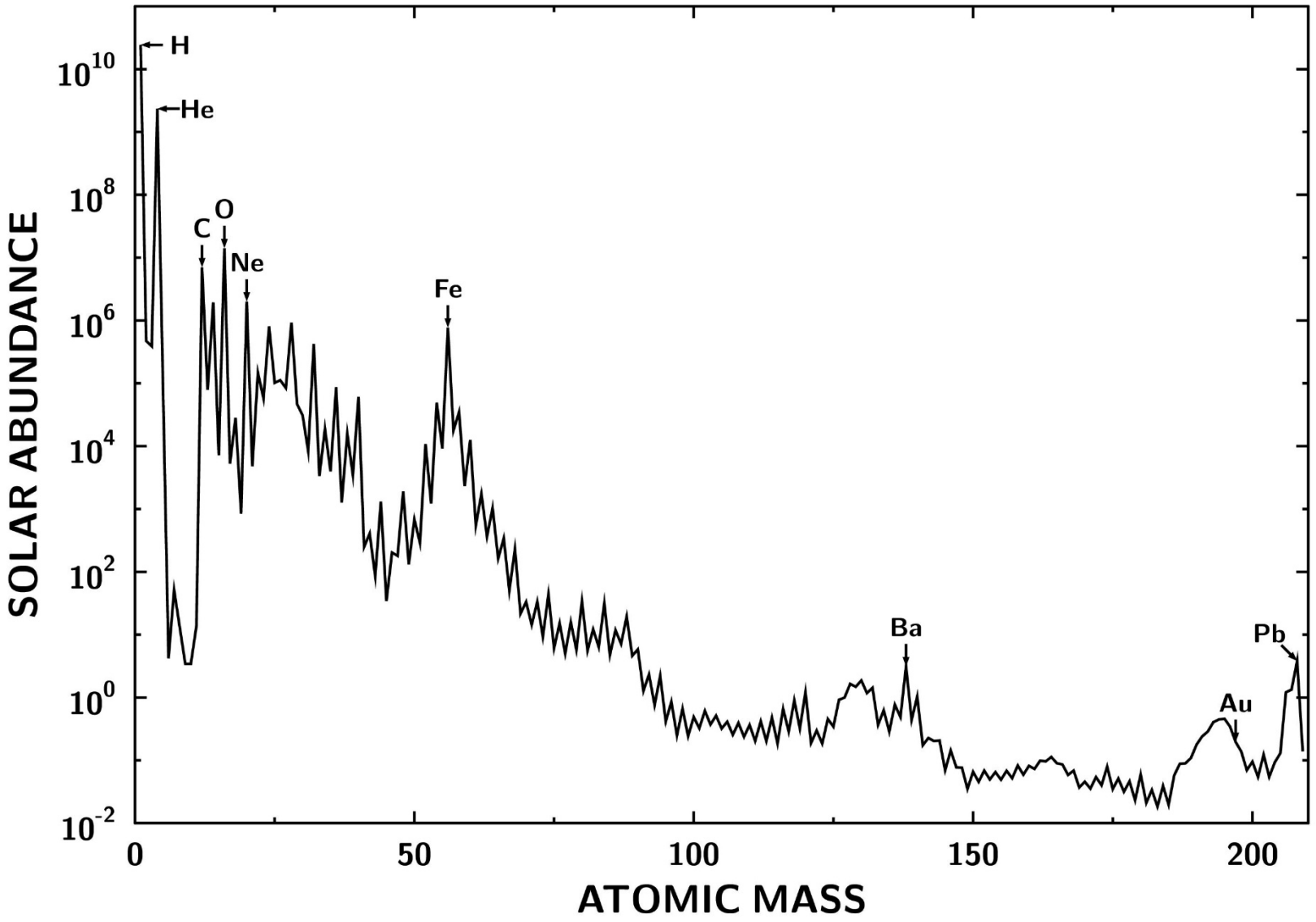


From PHENIX website – phenix.bnl.gov

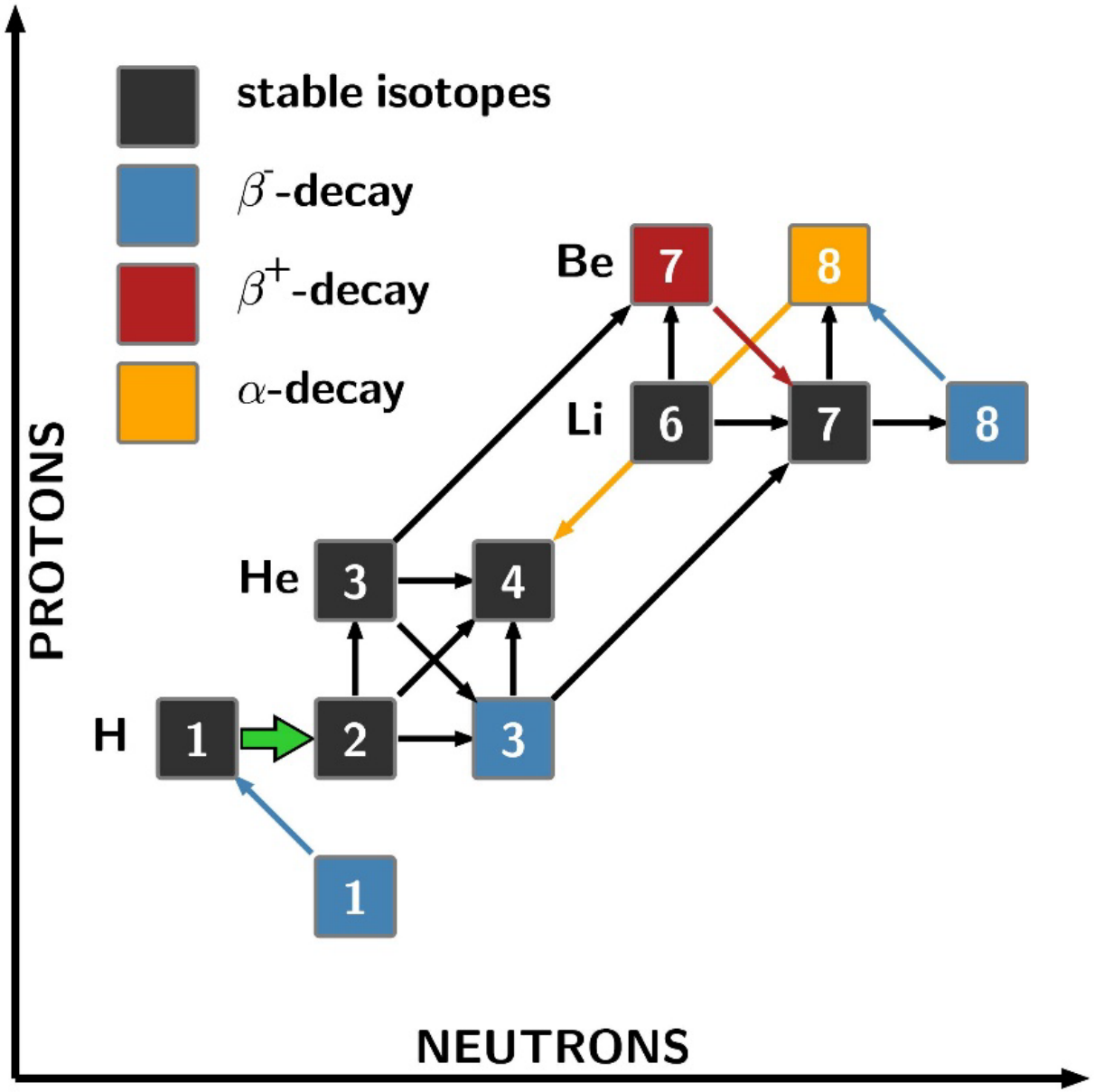
The chart of stable nuclei



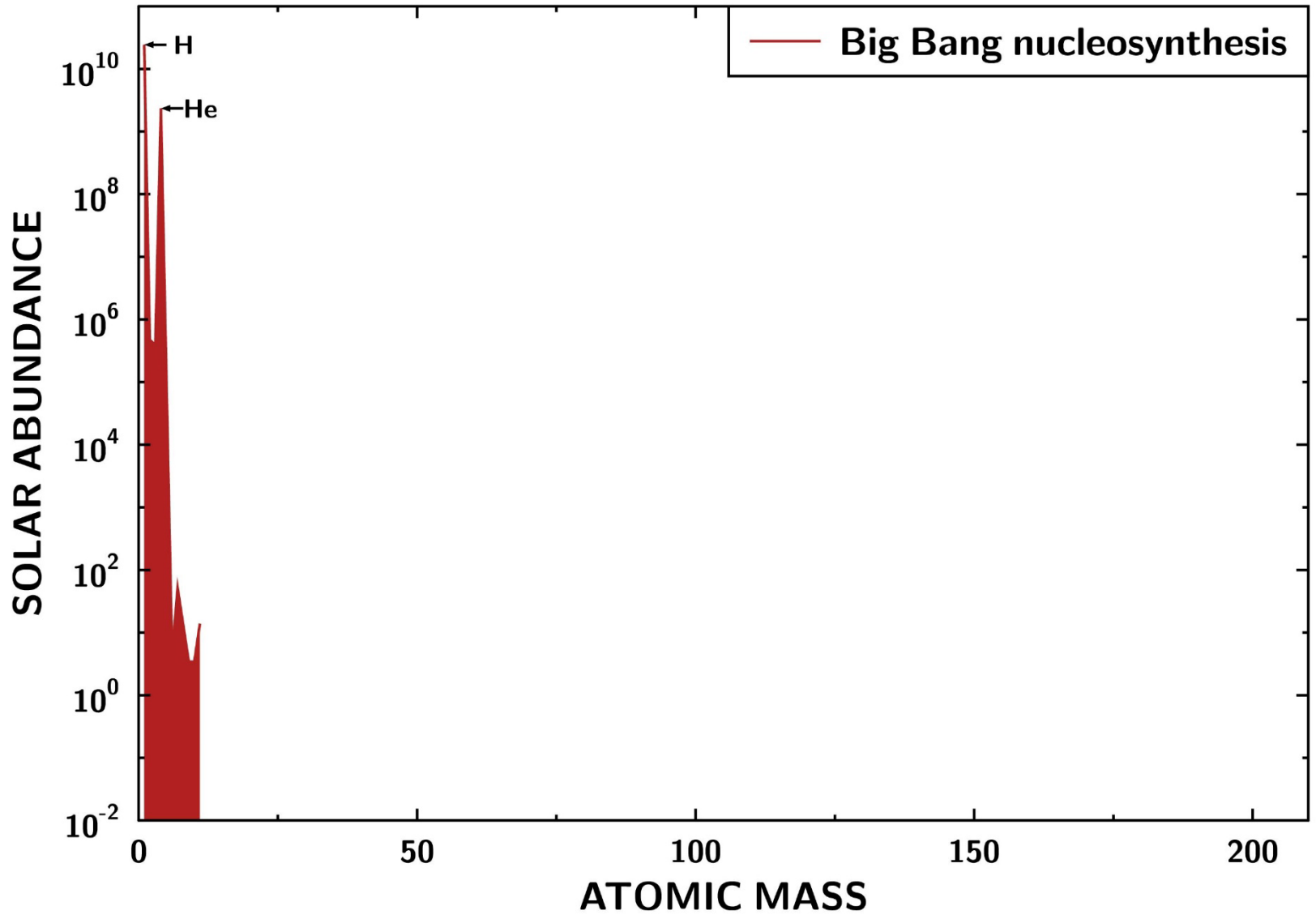
Solar abundances



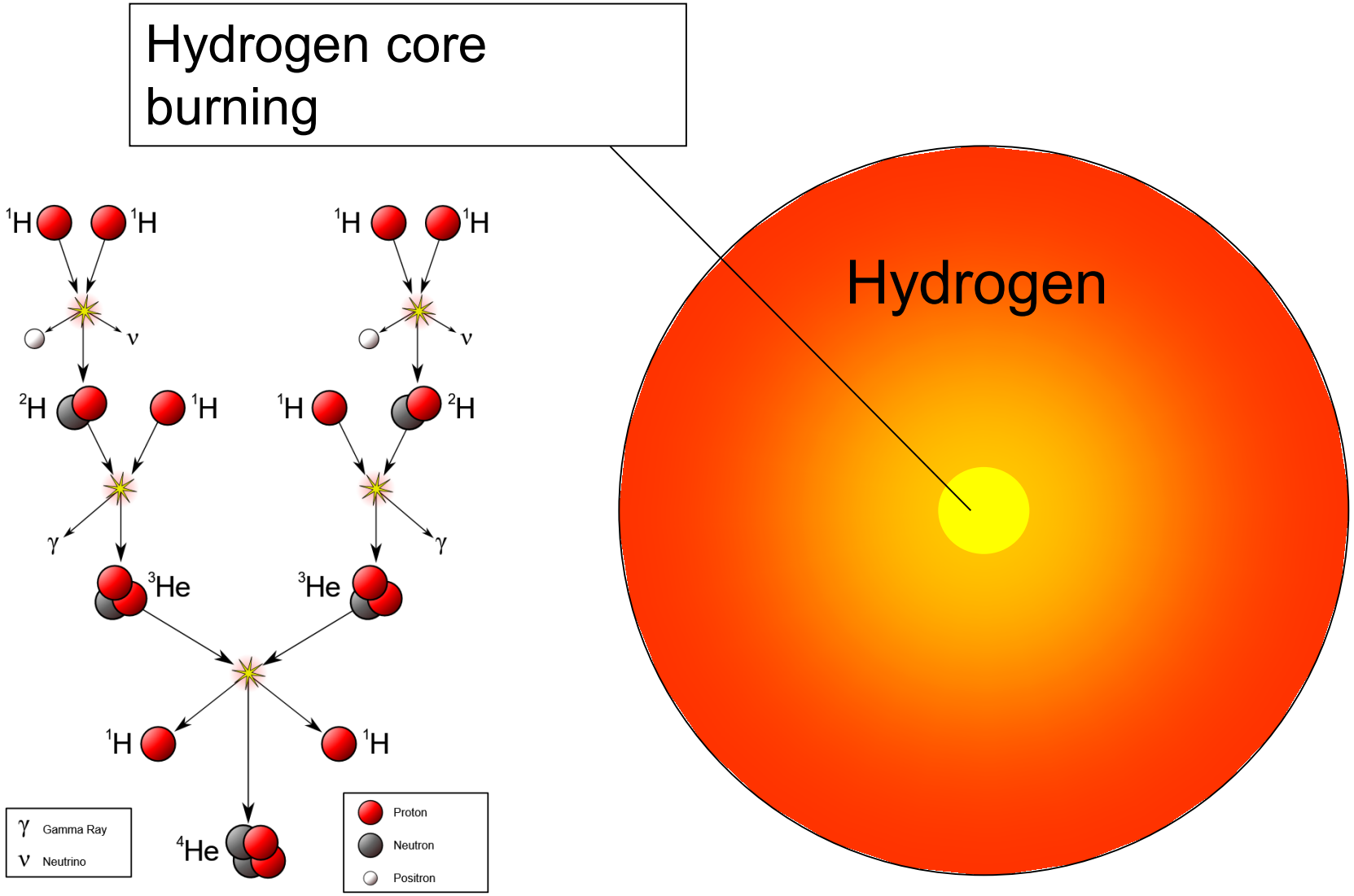
Big Bang Nucleosynthesis



First elements – H, He

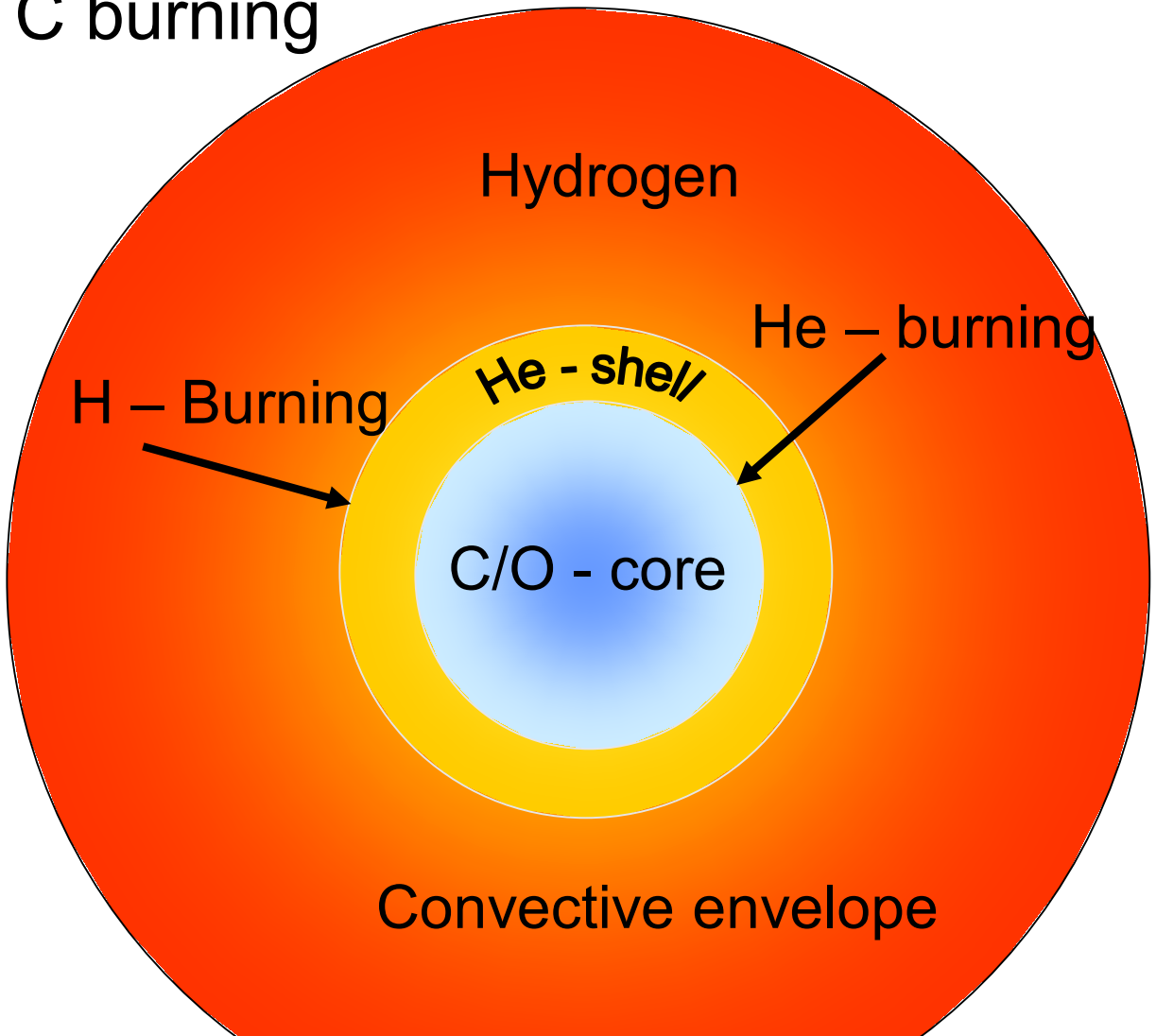


First stars after 500 million years

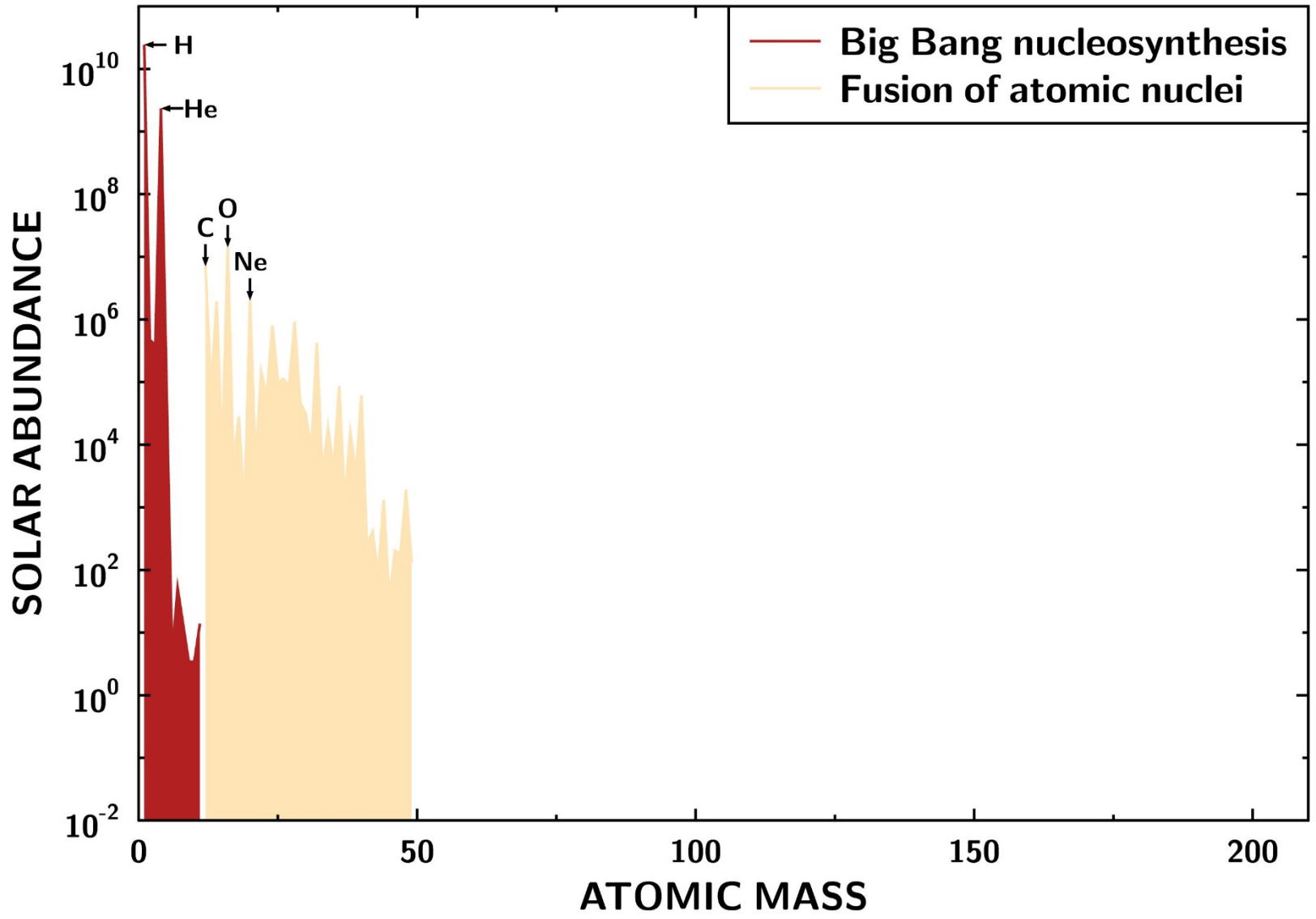


Onion structure

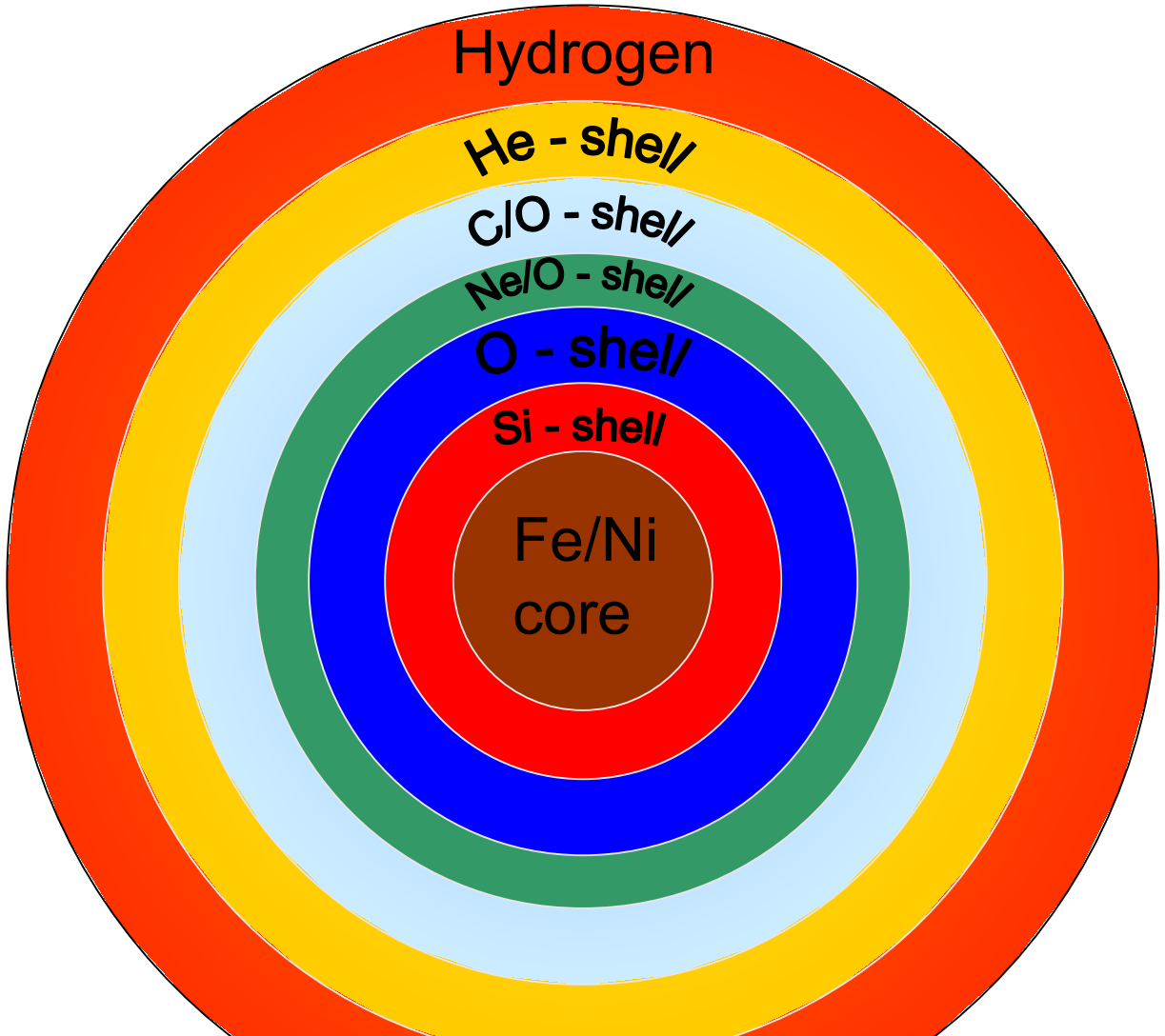
Later stages: H, He, C burning



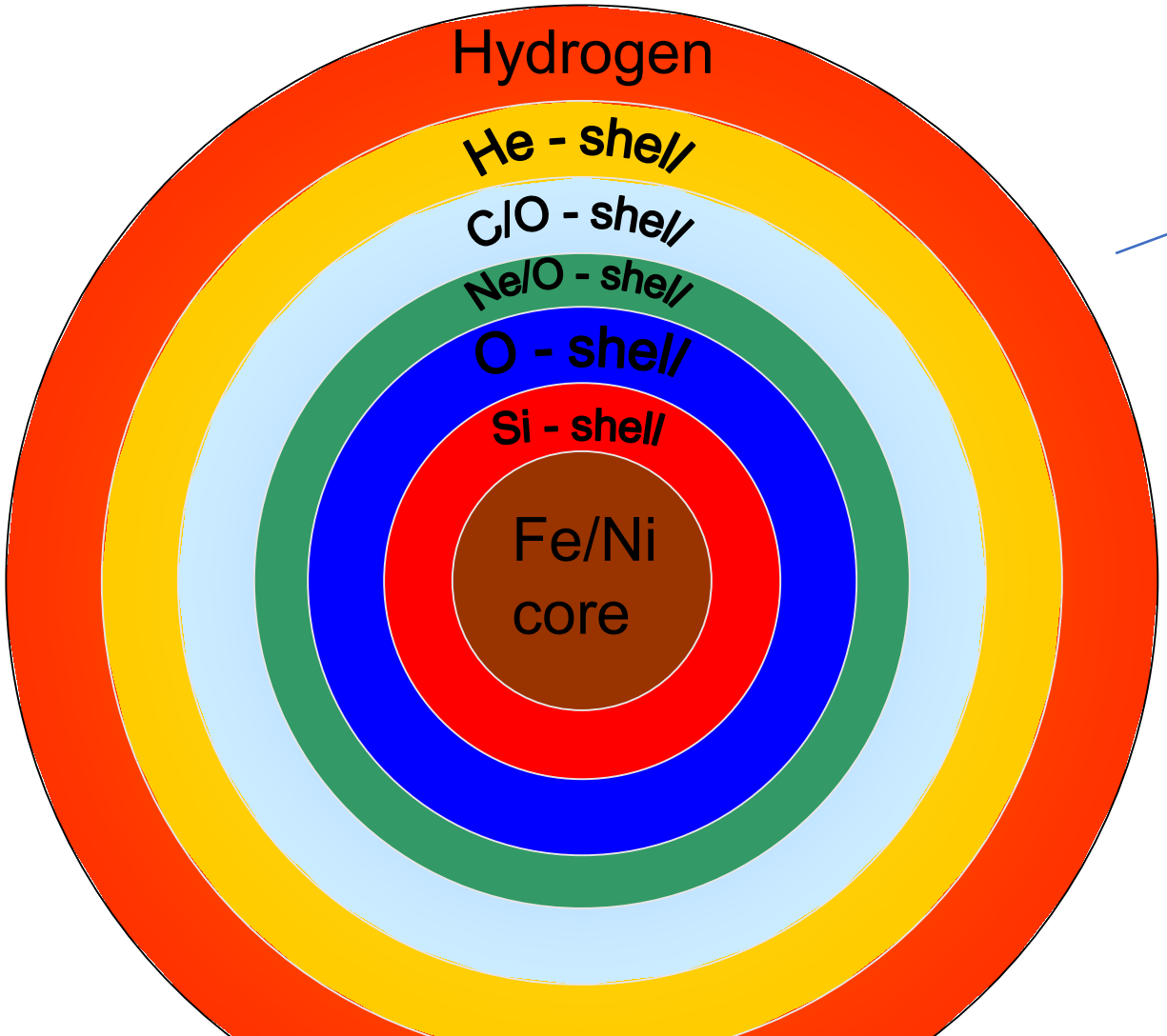
Energy source of stars

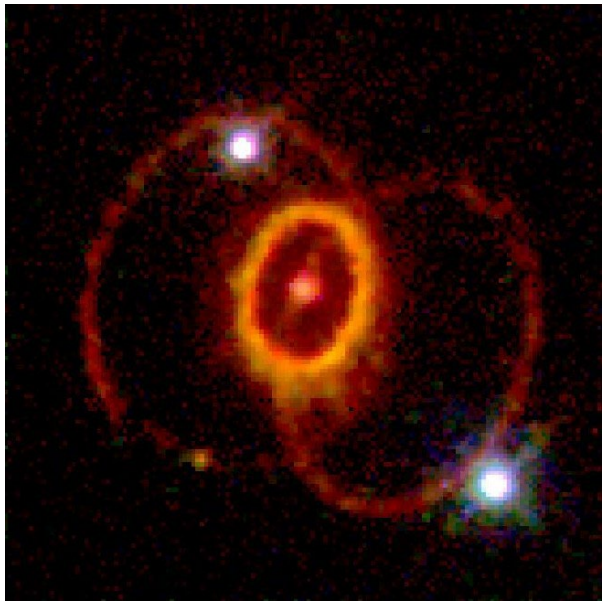


Massive stars – early death



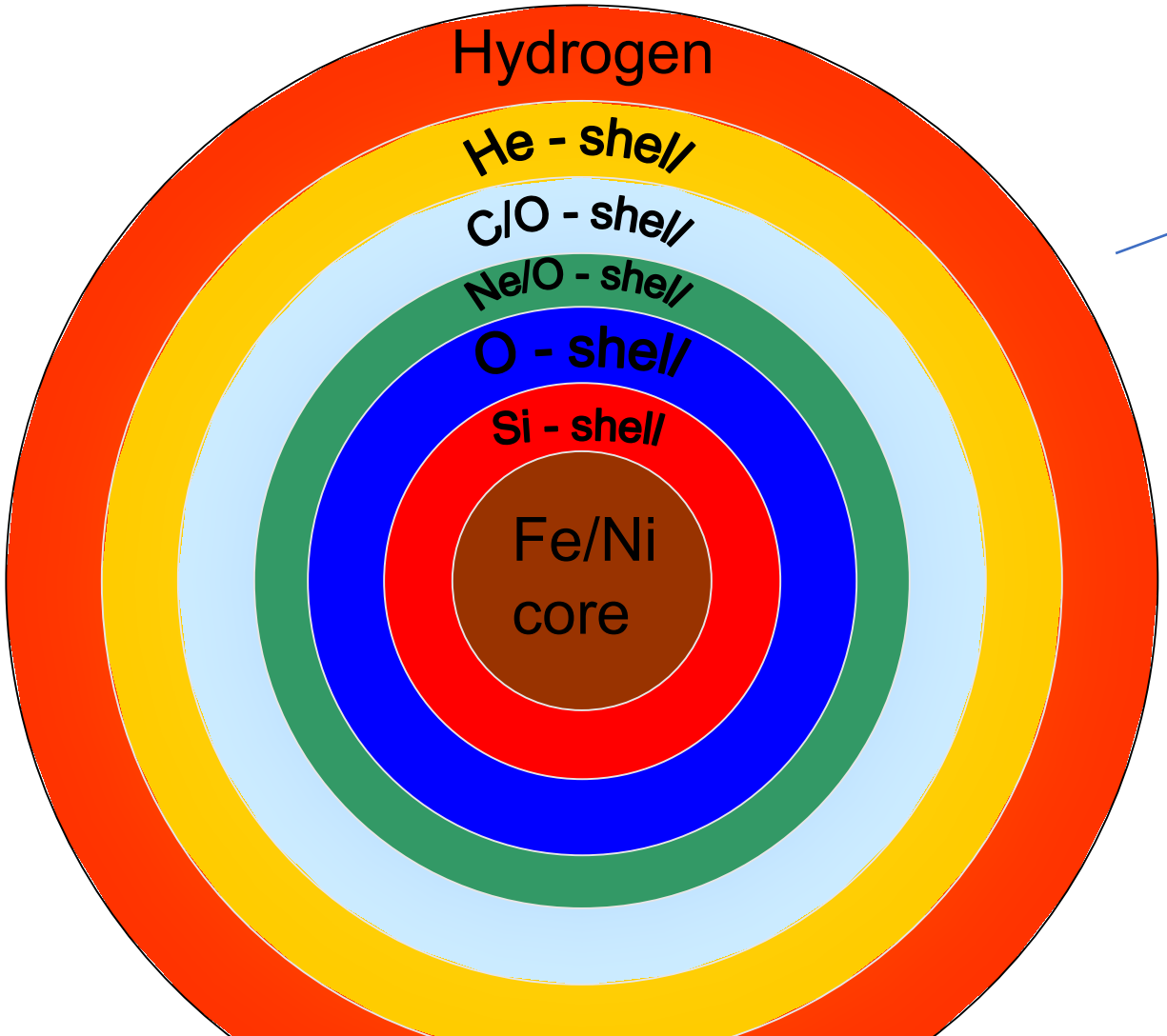
Massive stars – early death

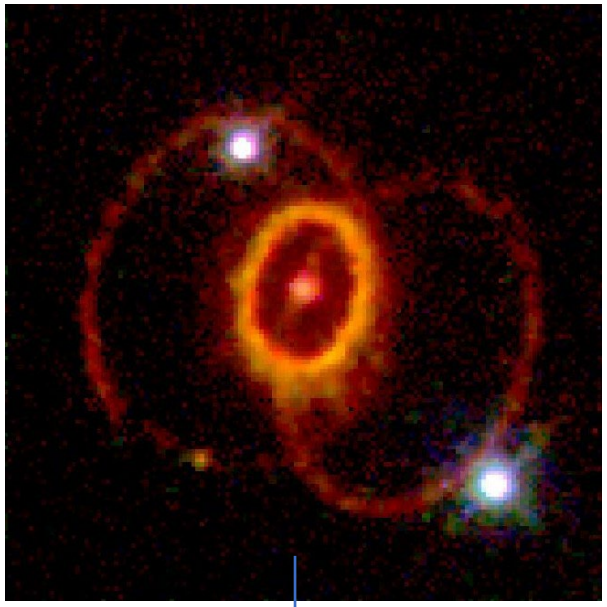


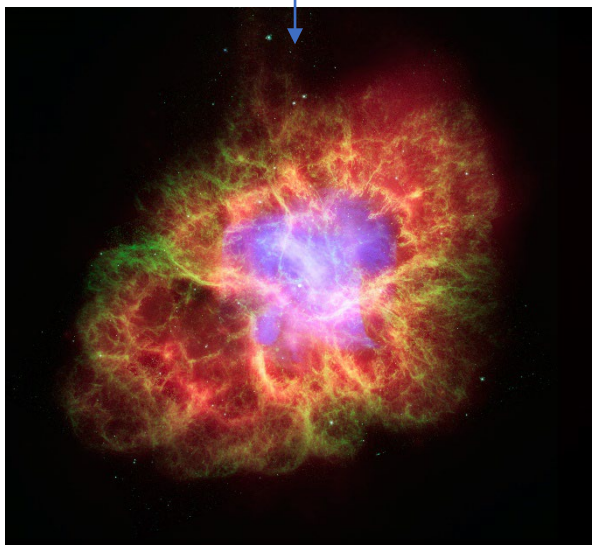


By NASA

Massive stars – early death

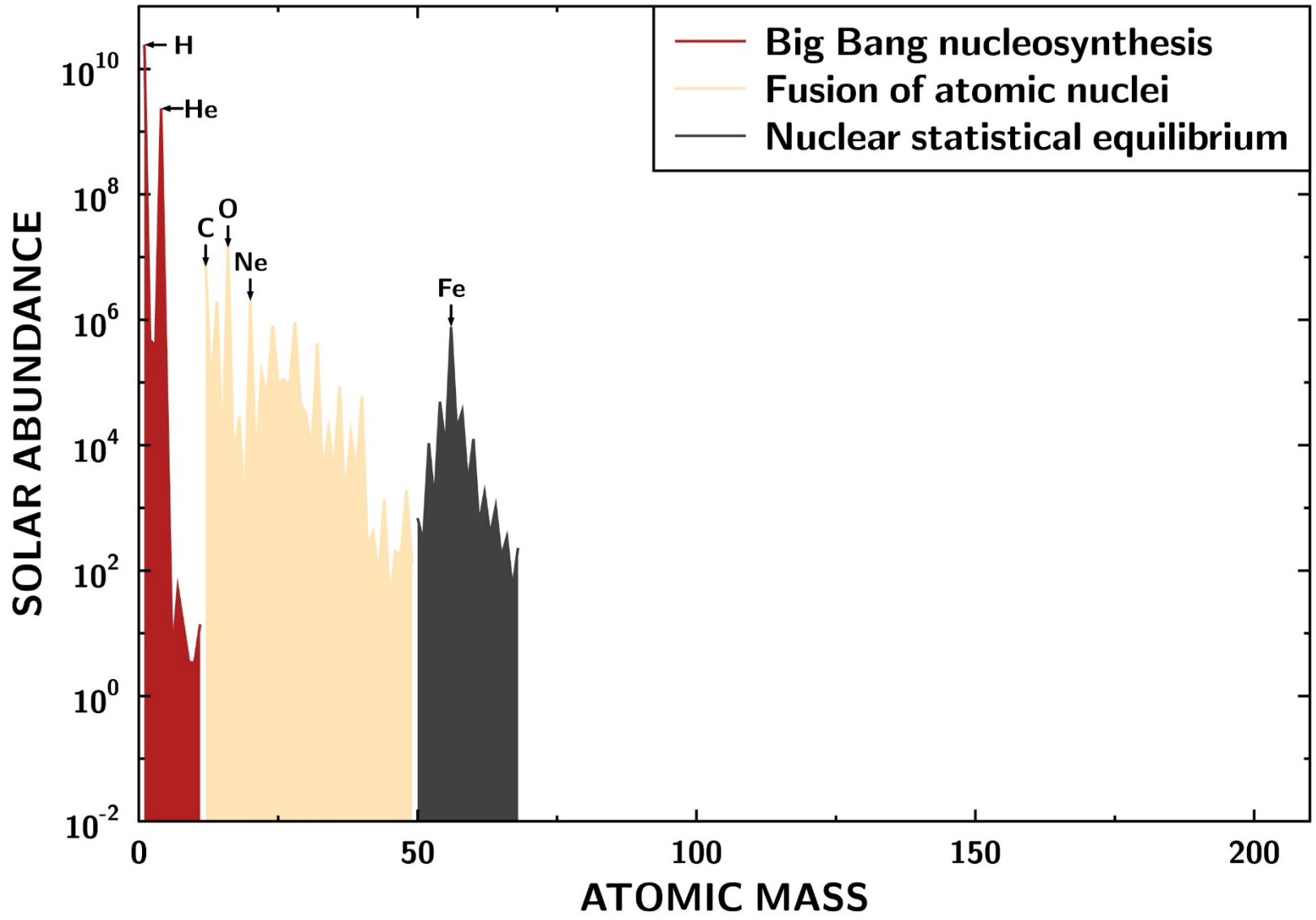




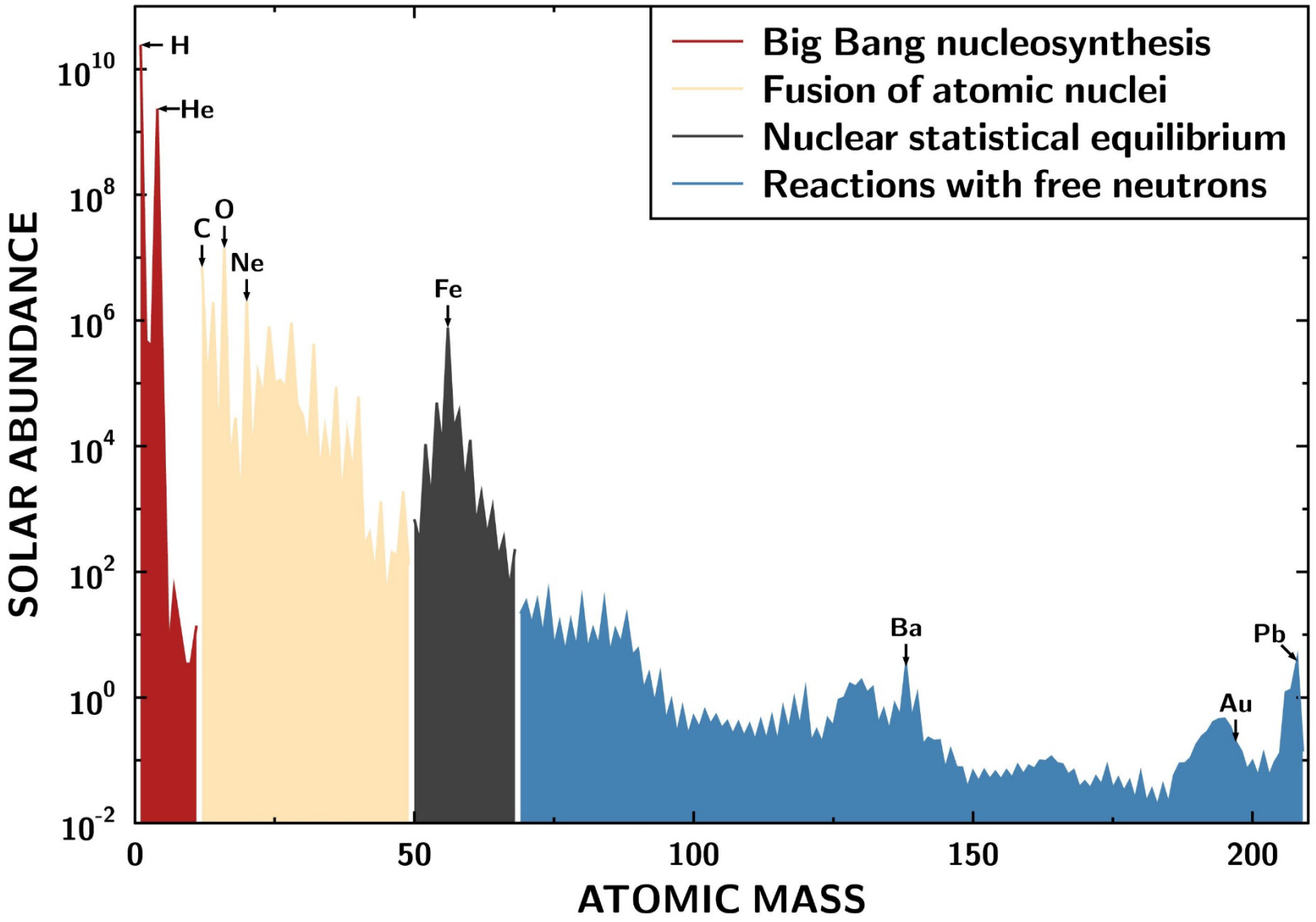


By NASA

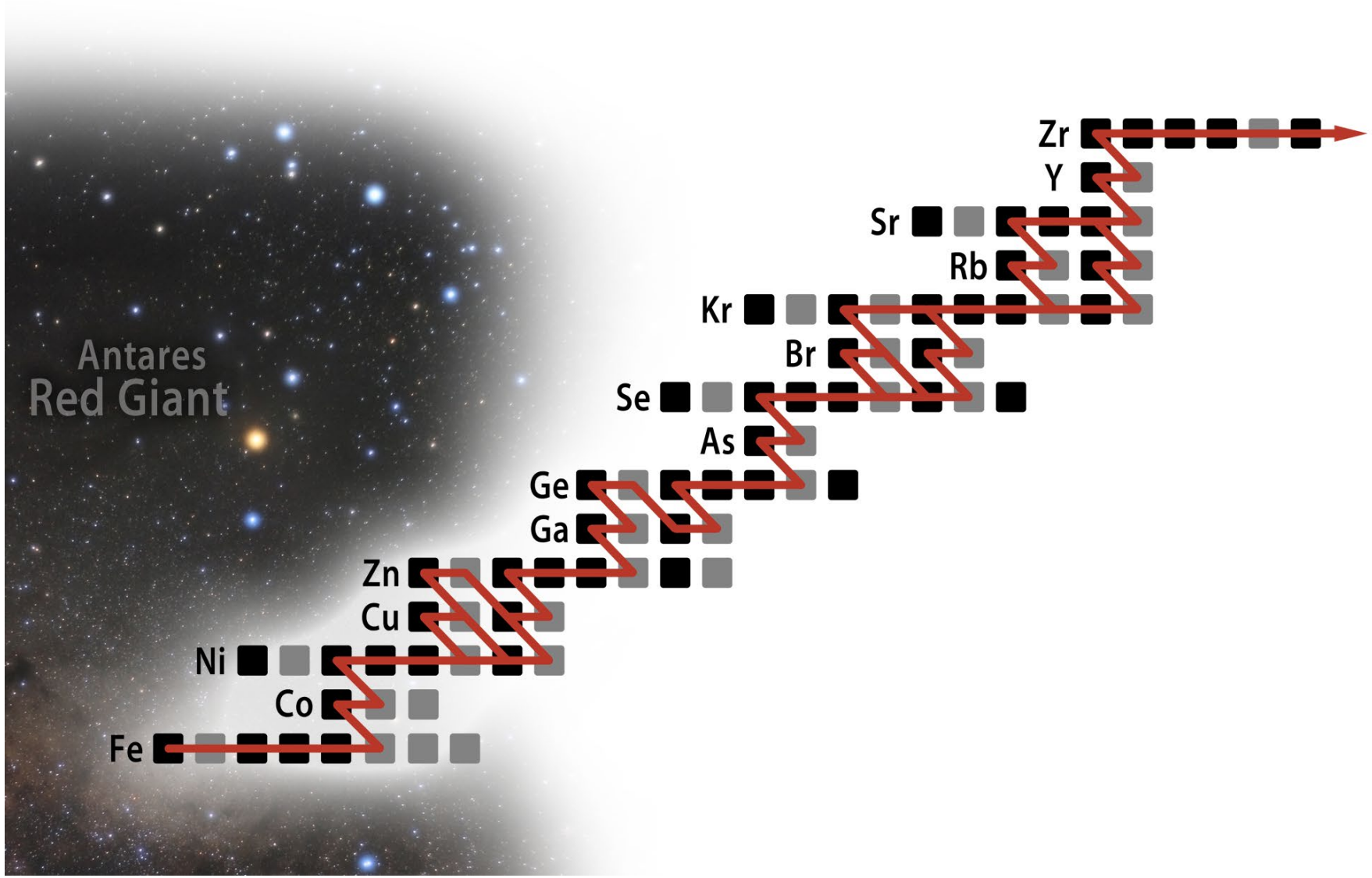
Iron – survival of the most stable



The synthesis of the elements

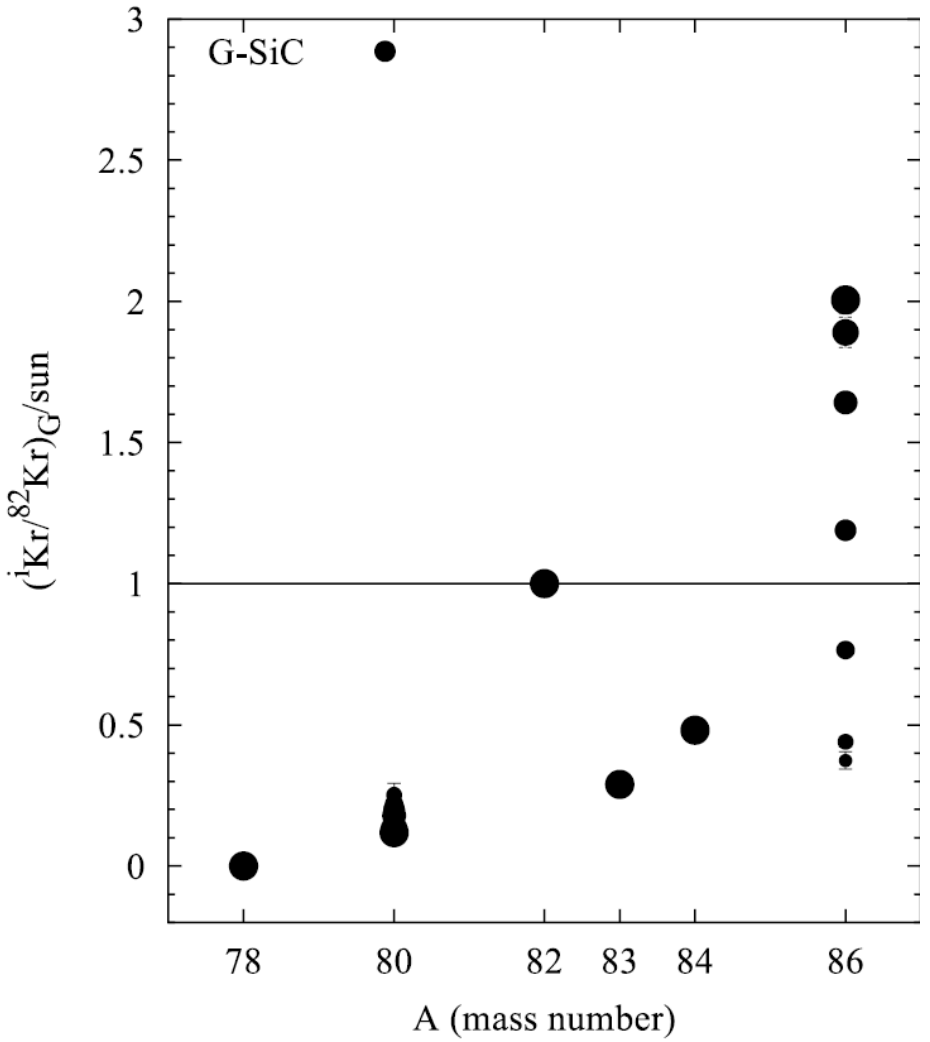


Neutron-induced nucleosynthesis

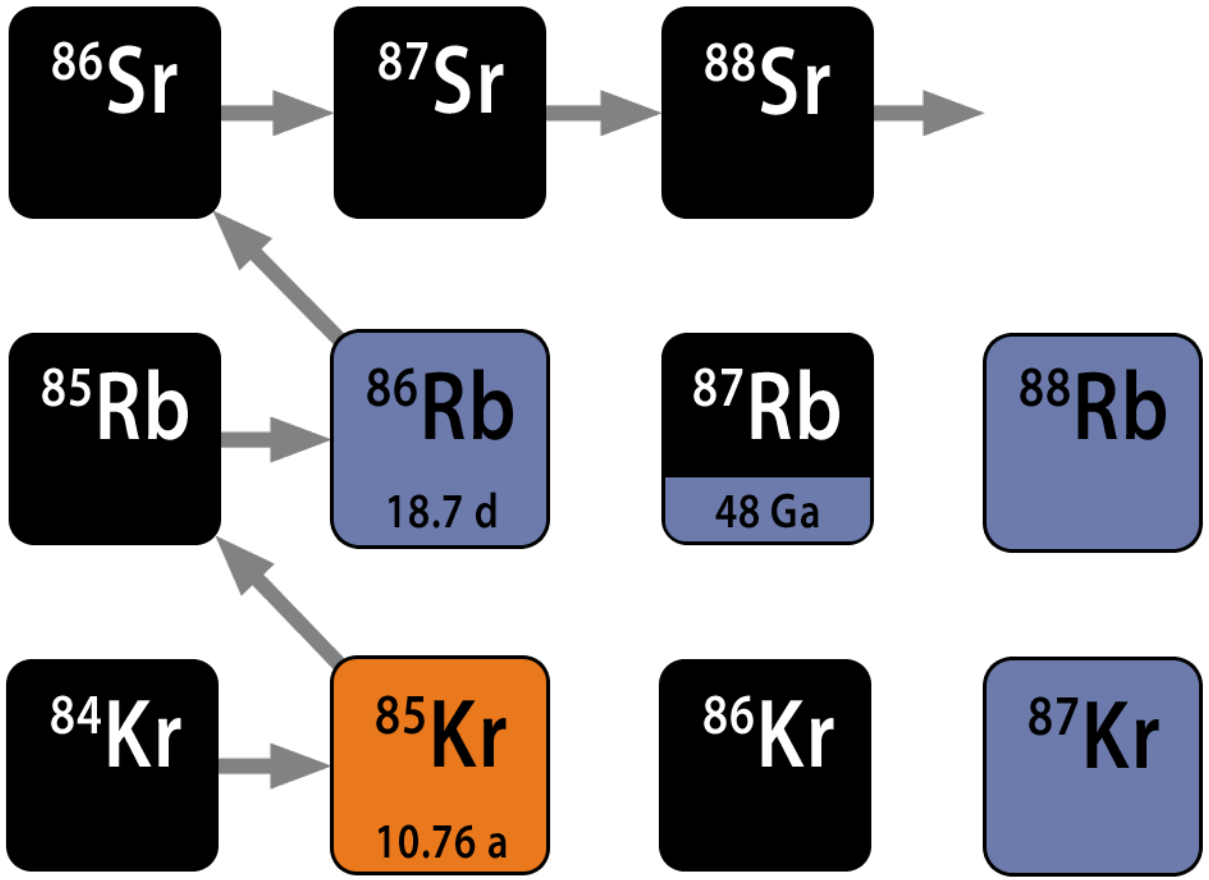


Meteorites and presolar grains

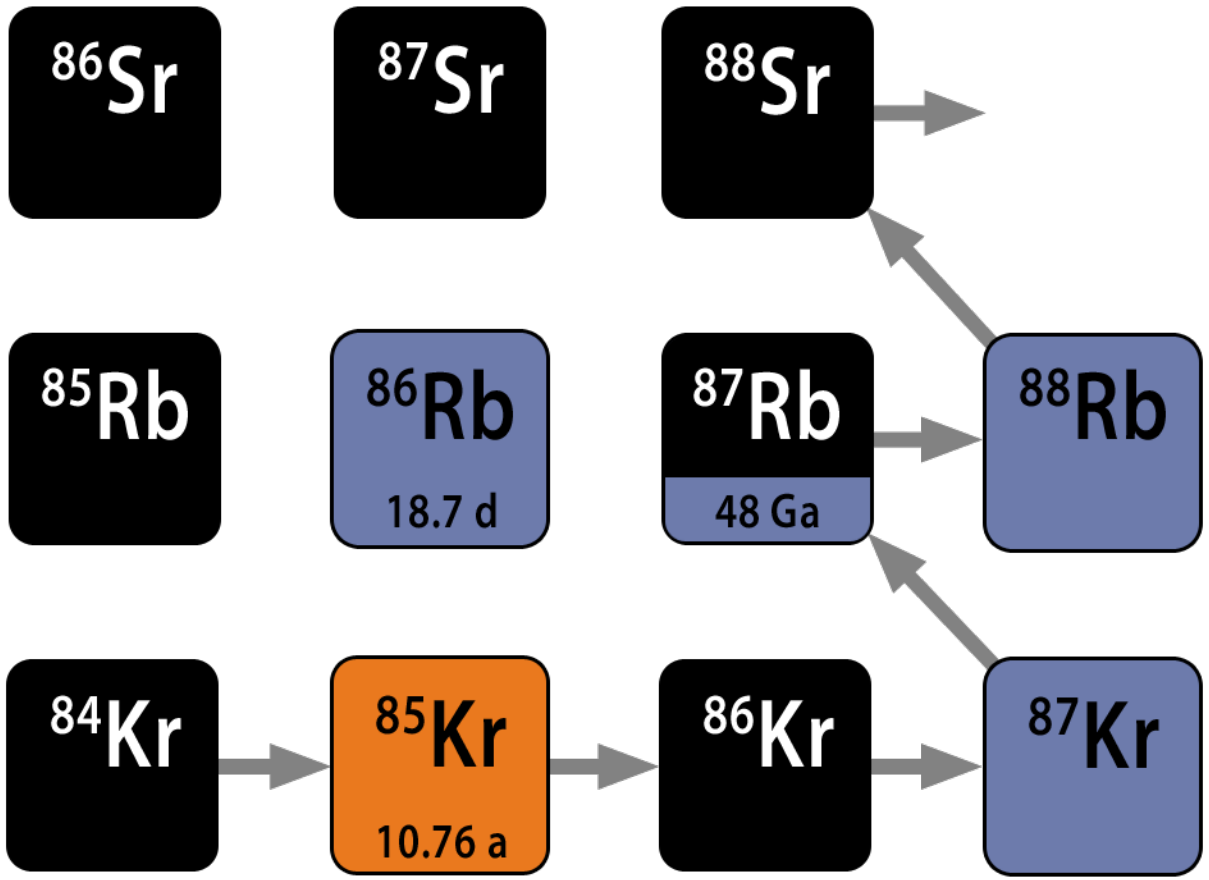
Meteorites and presolar grains



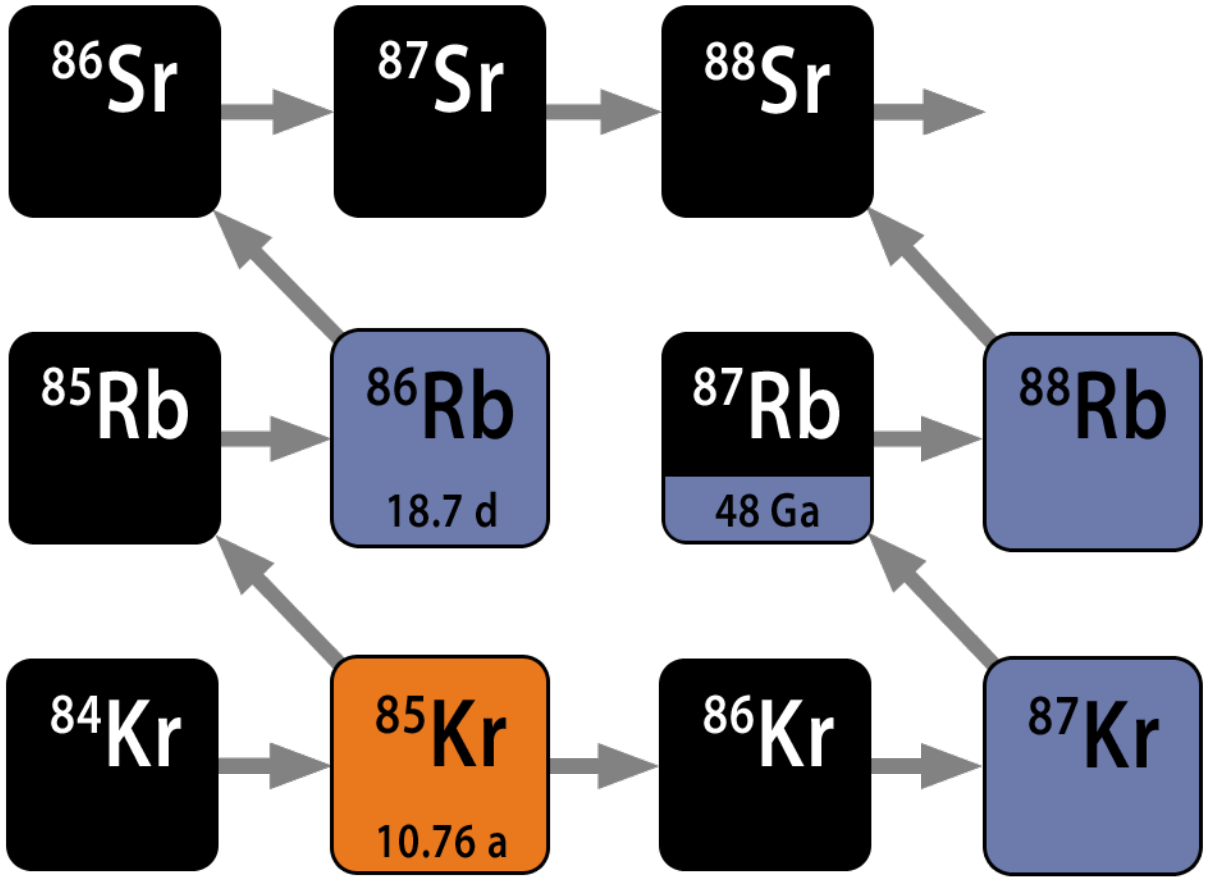
Branches in the synthesis paths



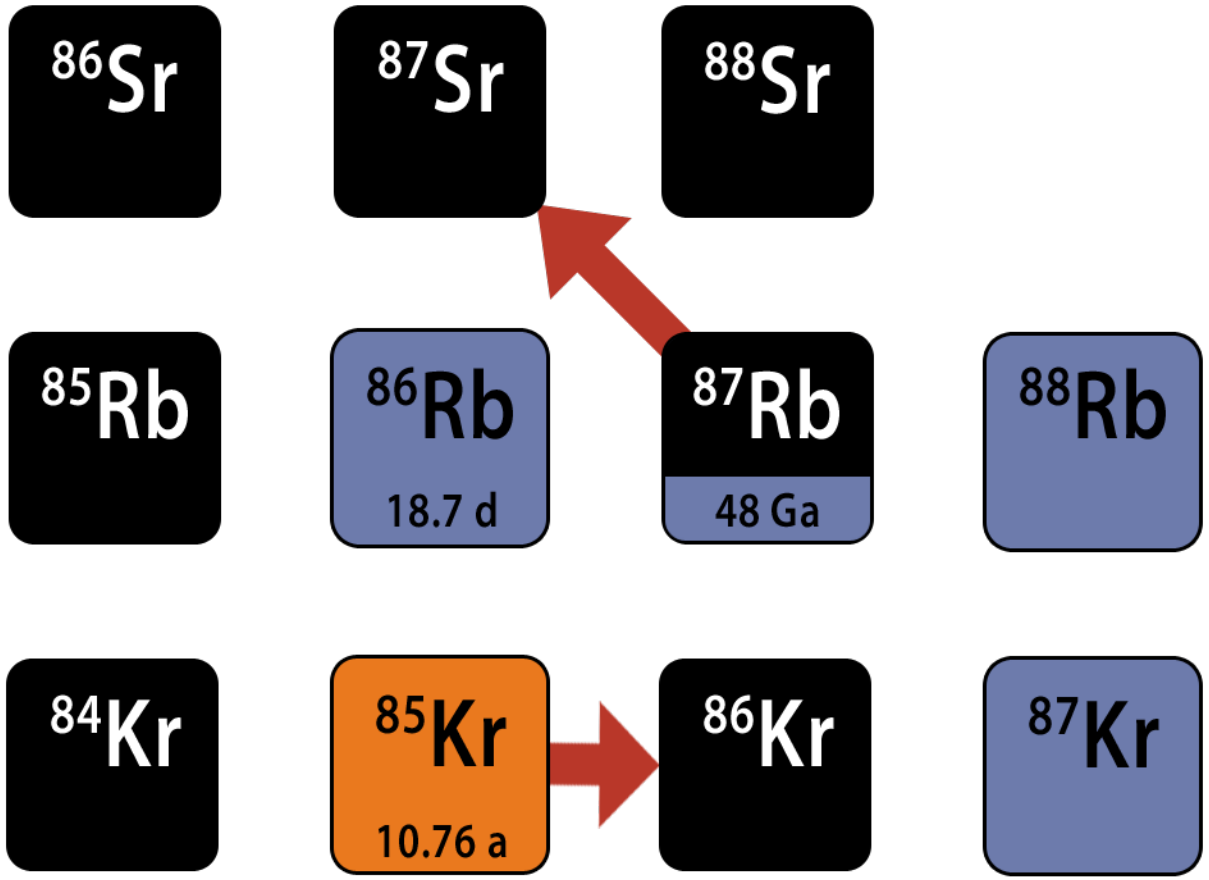
Branches in the synthesis paths



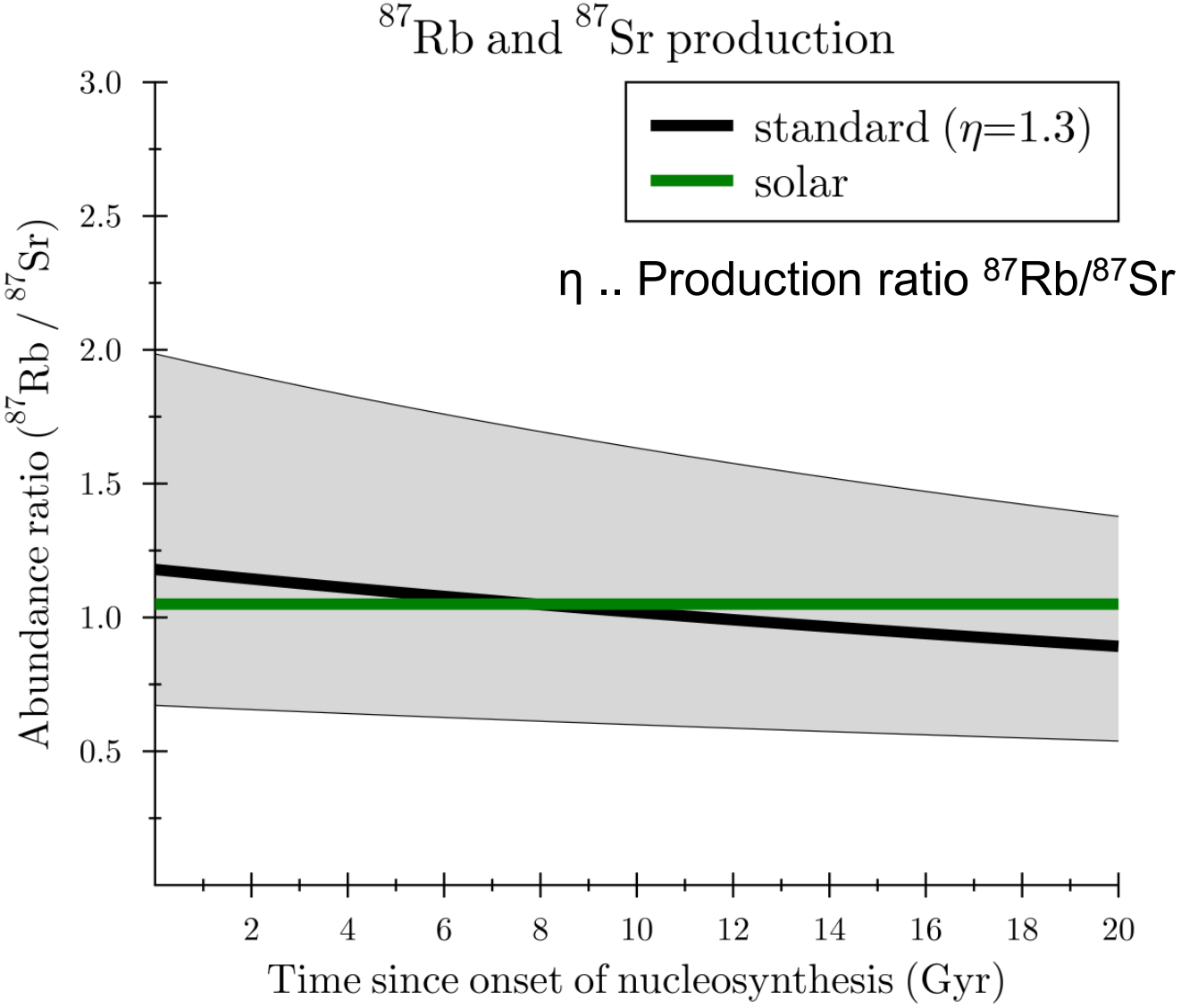
Branches in the synthesis paths



Branches in the synthesis paths

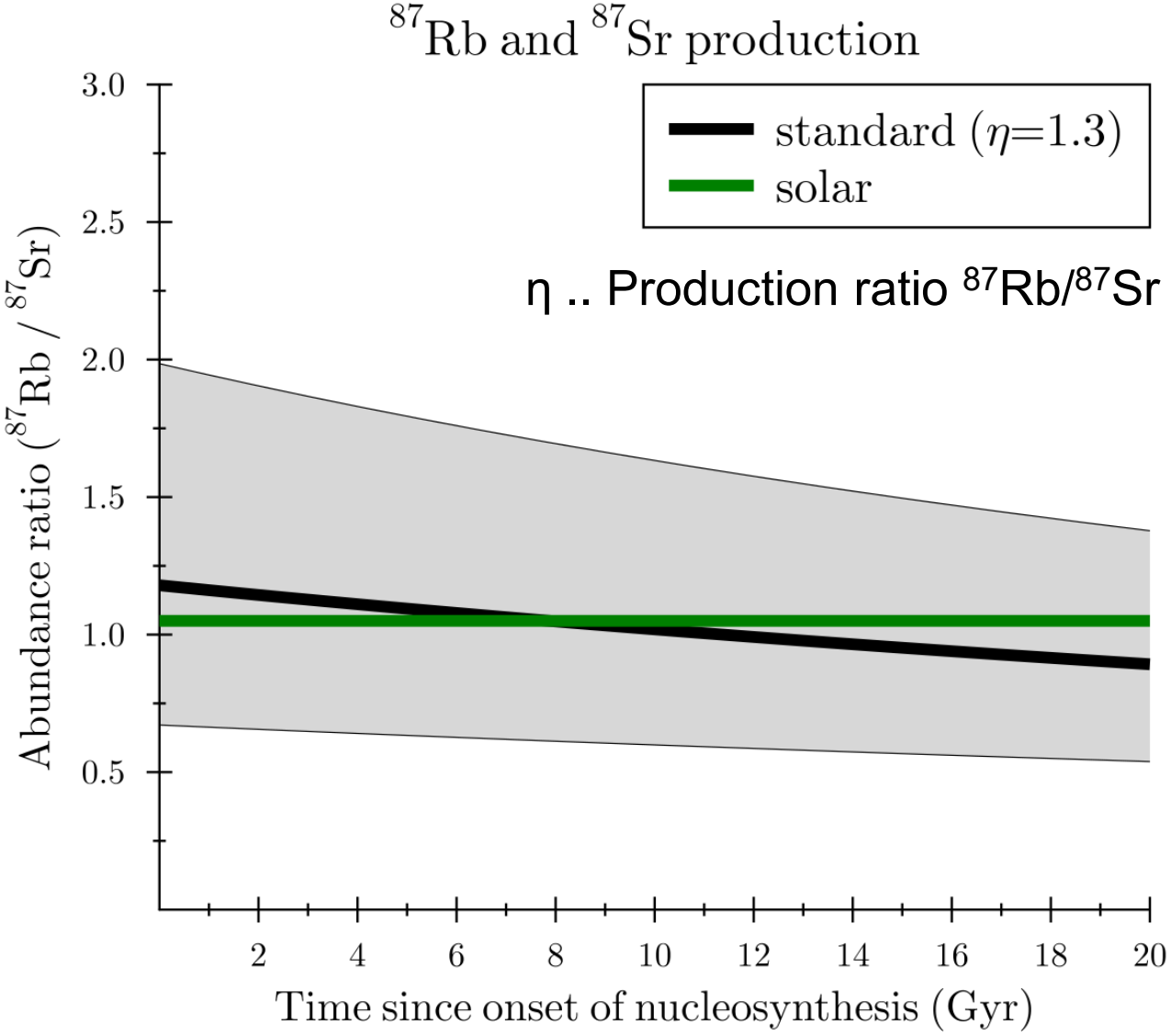


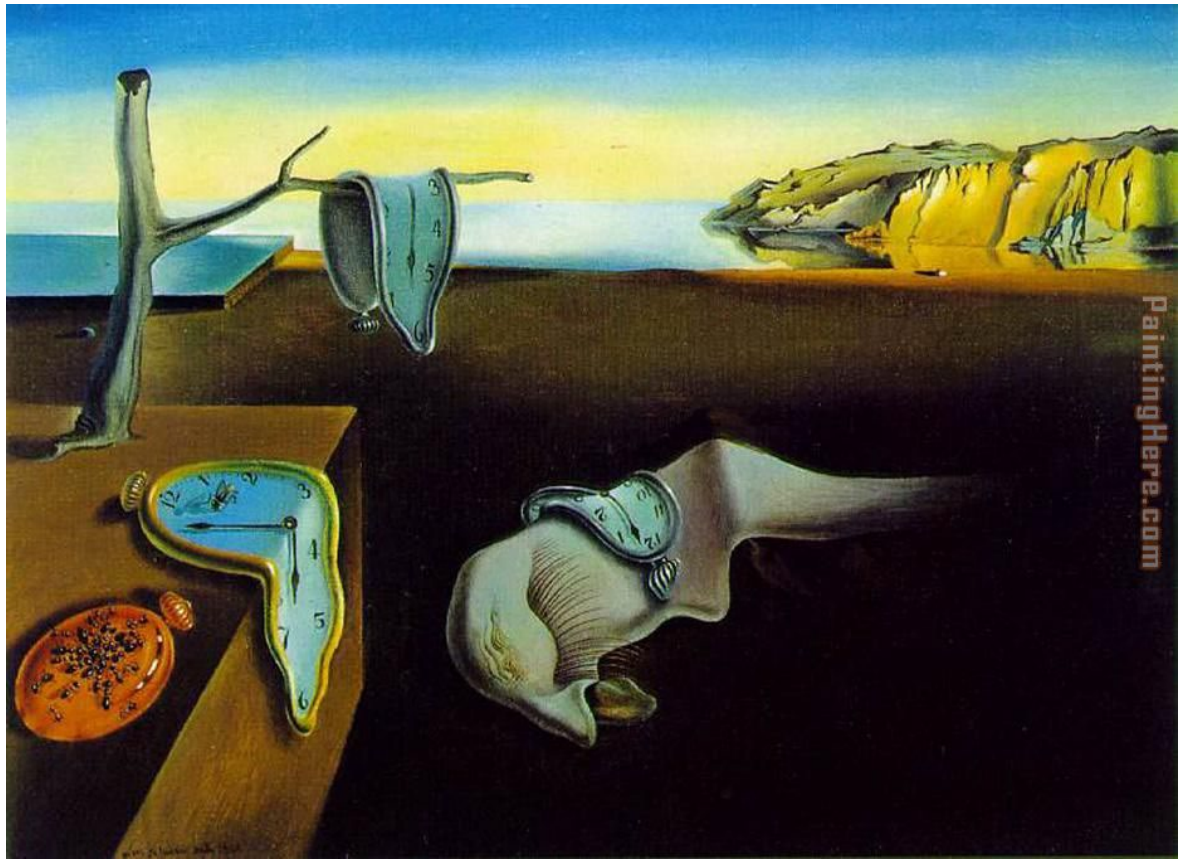
Cosmochronometer

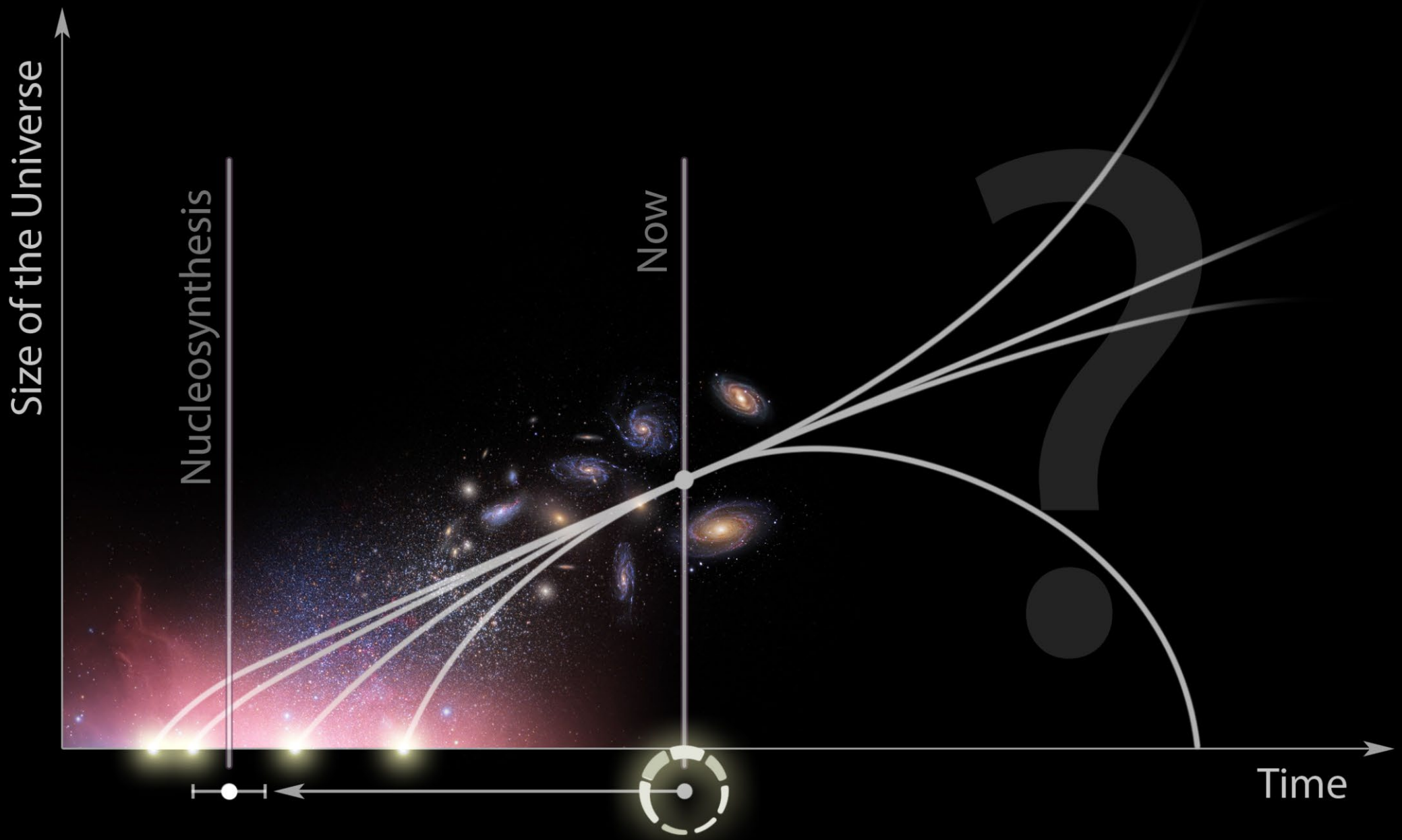


η .. Production ratio ^{87}Rb/^{87}Sr

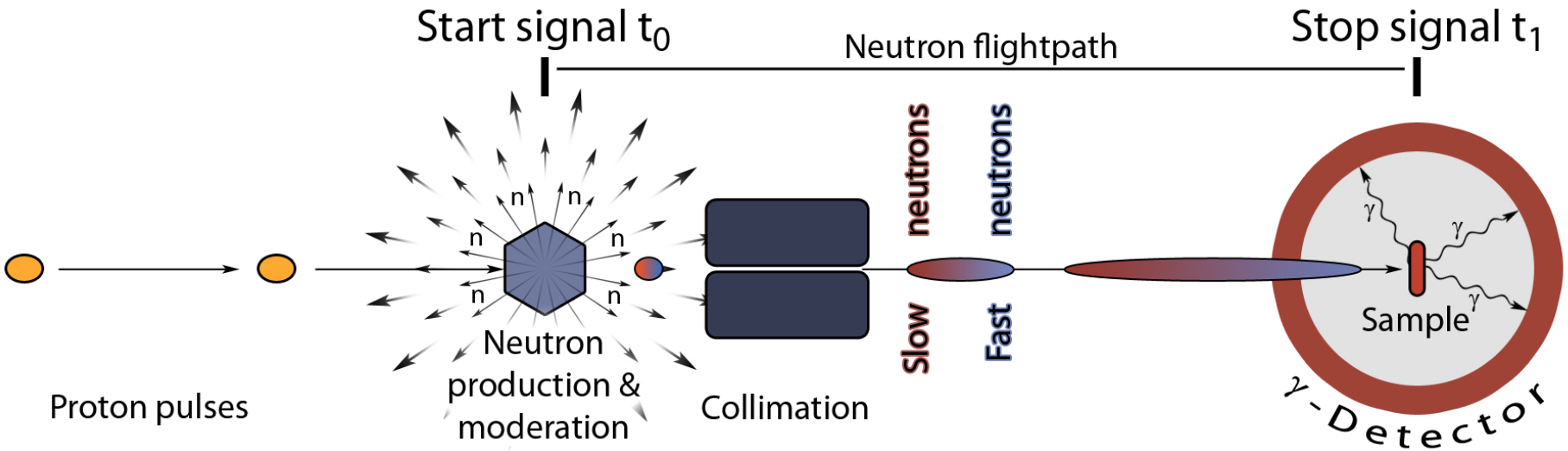
Cosmochronometer





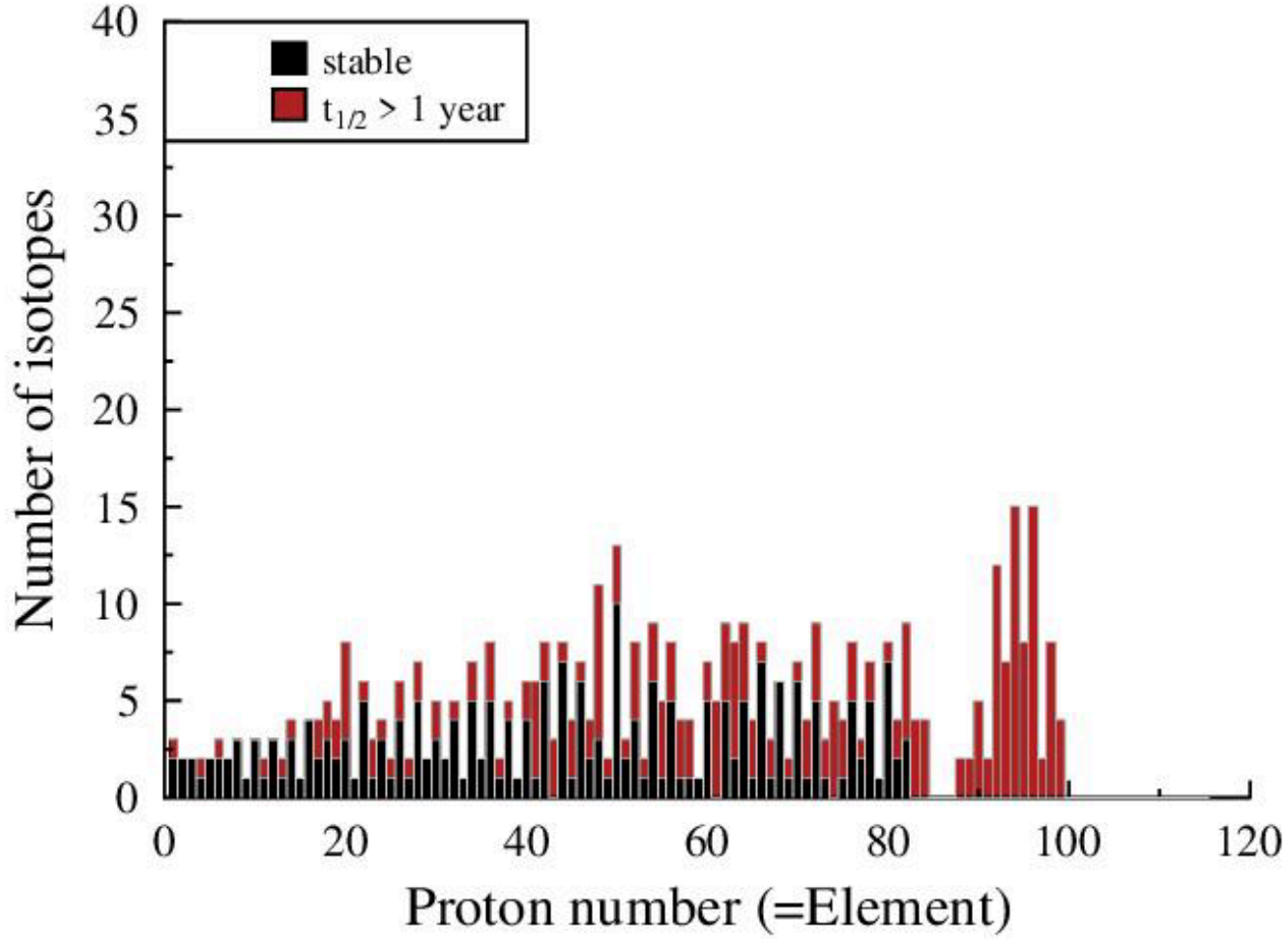

Size of the Universe
Nucleosynthesis
Now
?
Time

Neutron Rections via time-of-flight technique

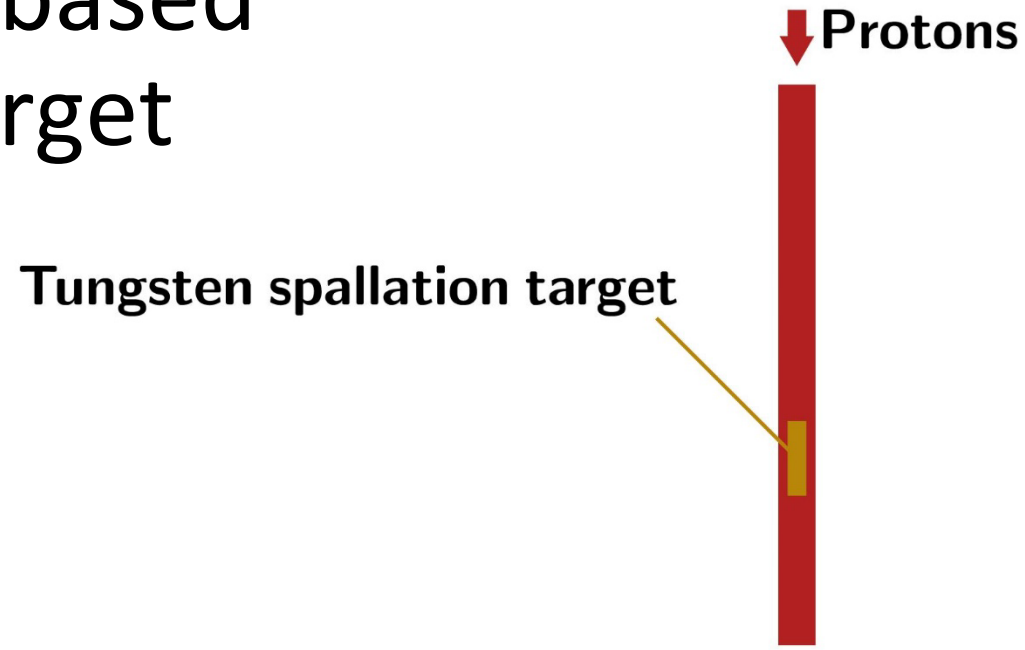


Reifarth et al., Journal of Physics G 41 (2014) 53101

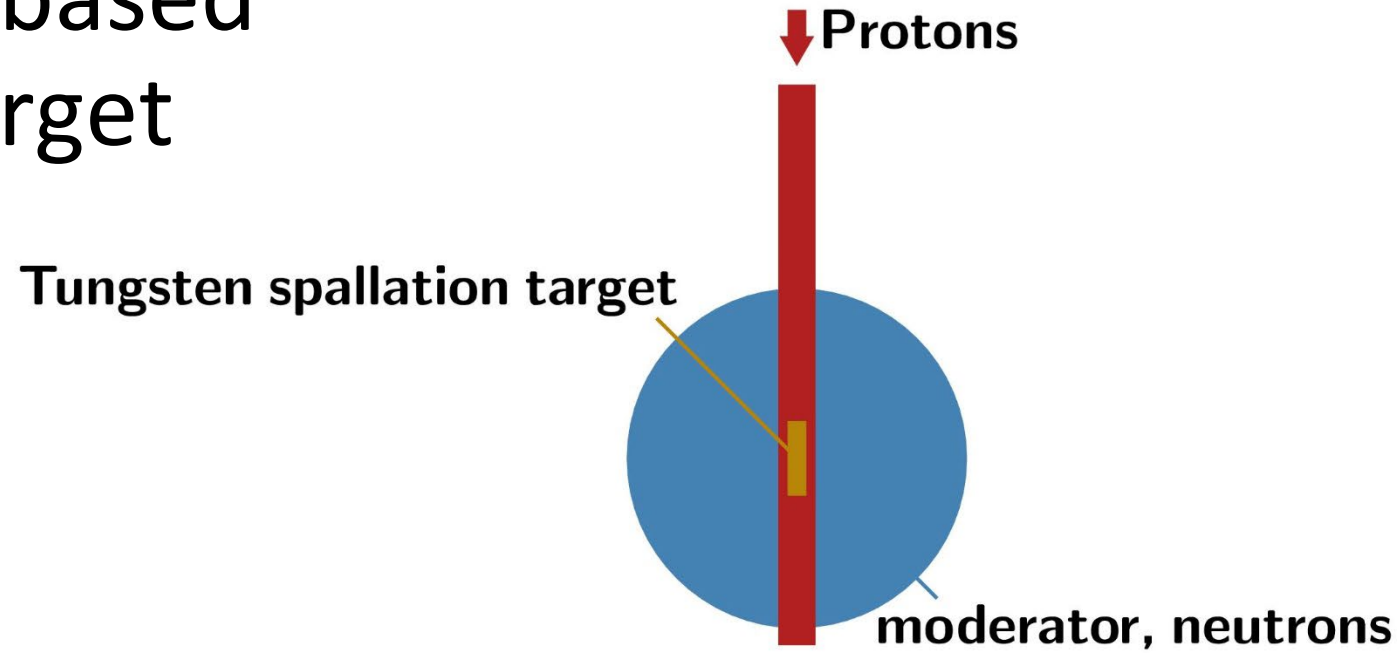
State of the art 2020 (e.g. **DANCE**)



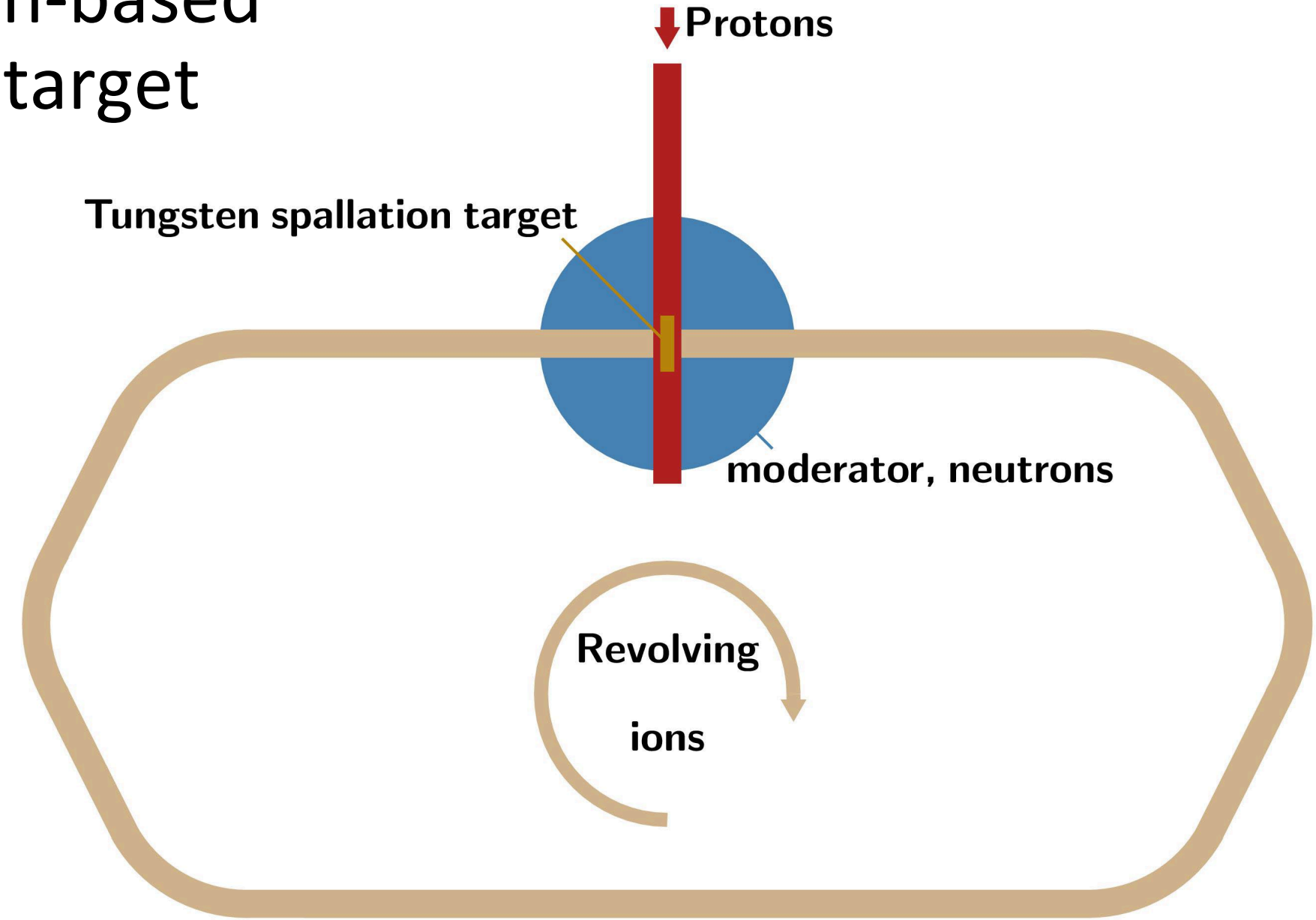
Spallation-based neutron target



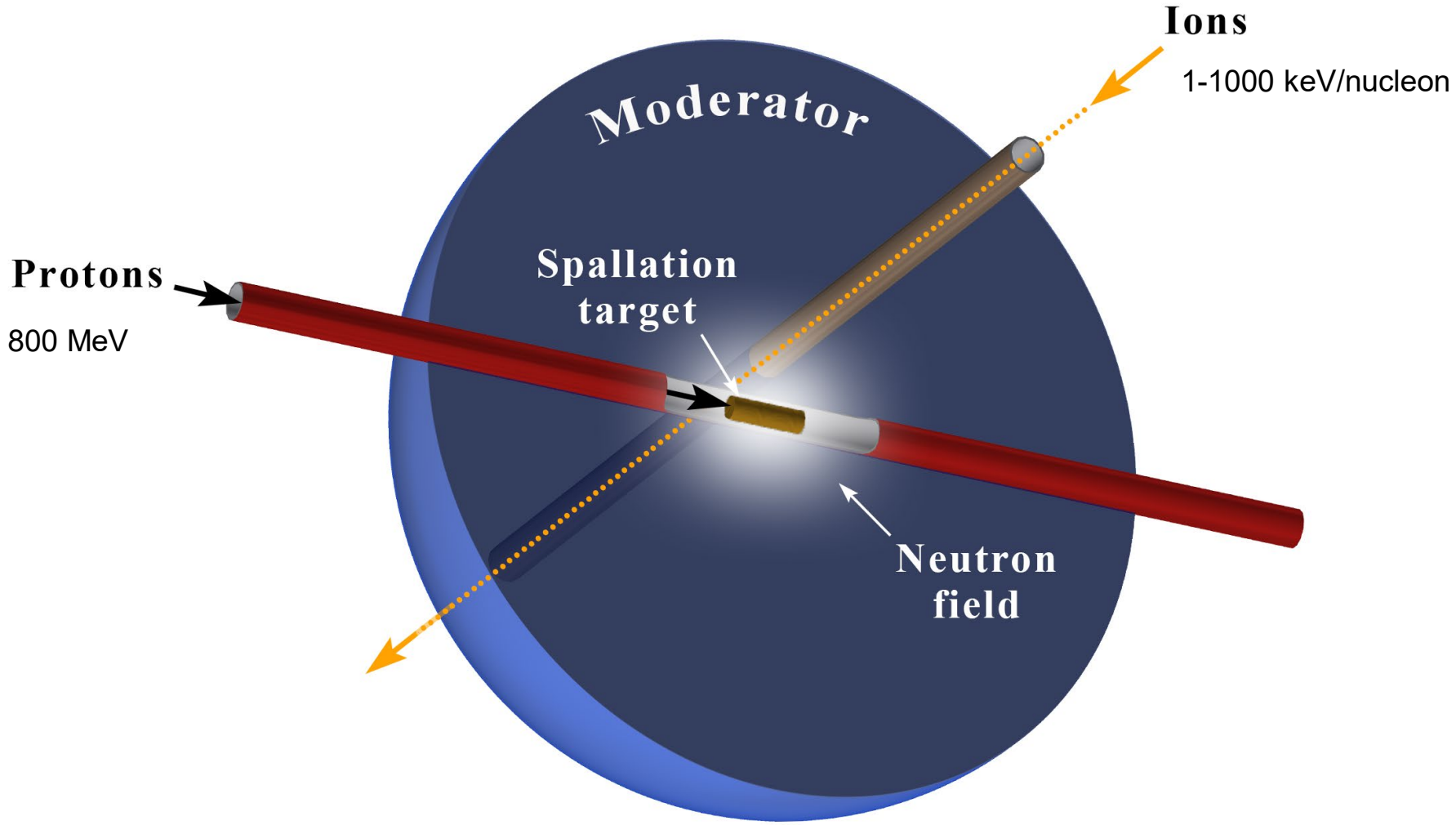
Spallation-based neutron target



Spallation-based neutron target

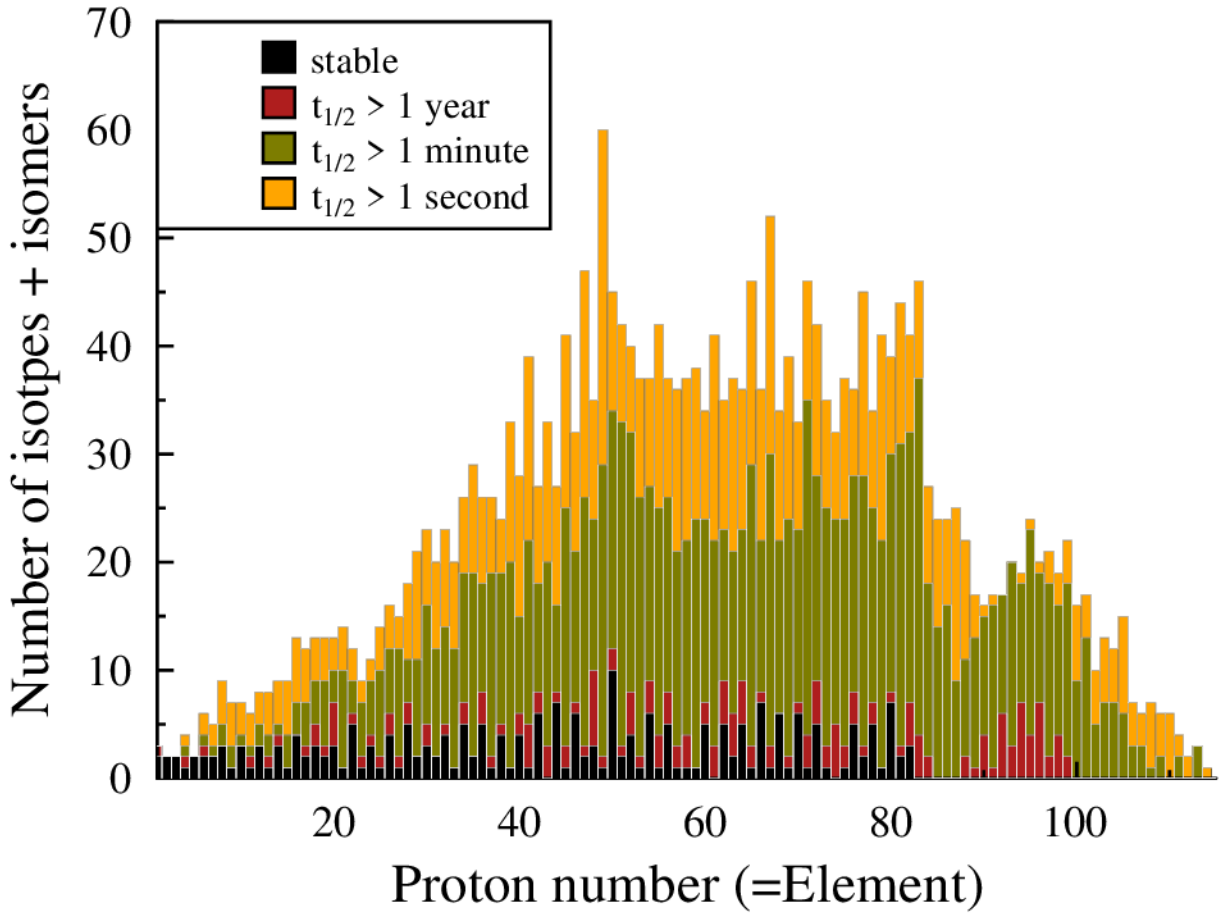


Proposed setup

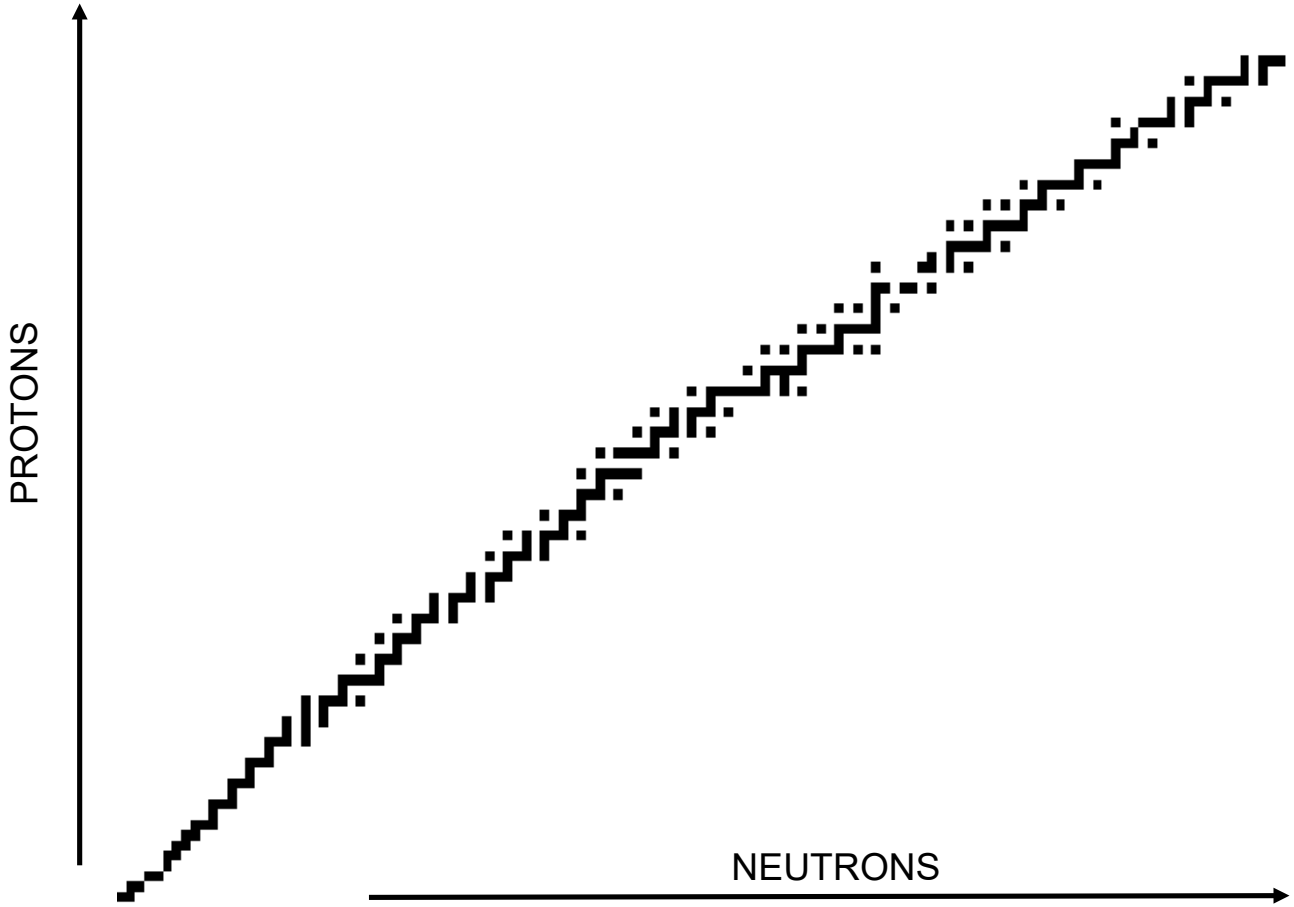


Reifarth et al., Phys. Rev ST Accelerator and Beams 20 (2017) 044701

State of the art 2035? (**N-TARGET+RING+ISOL**)

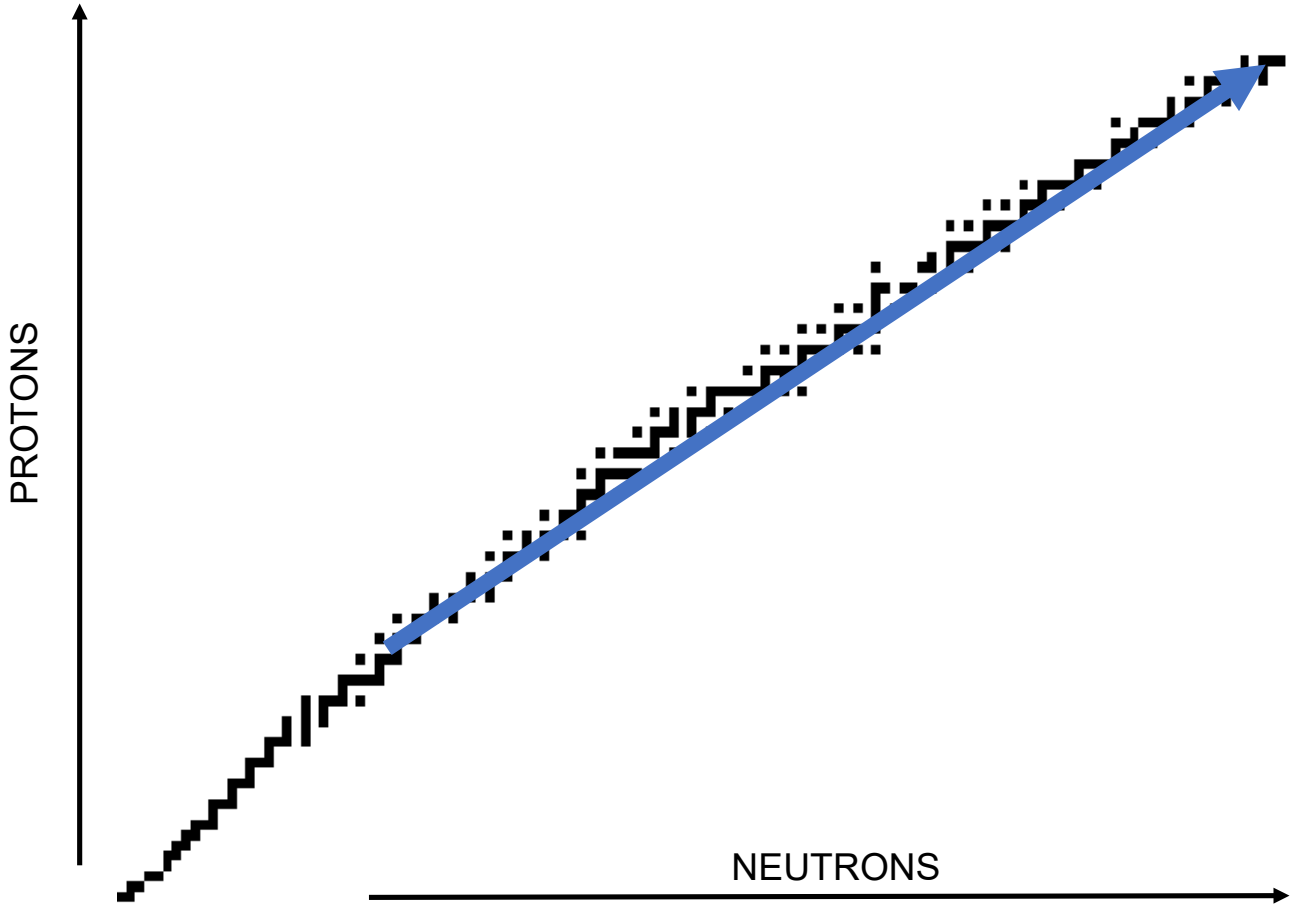


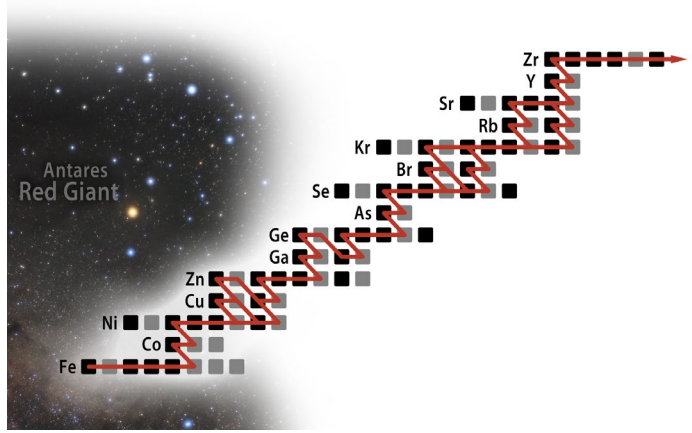
The production of stable nuclei



The production of stable nuclei

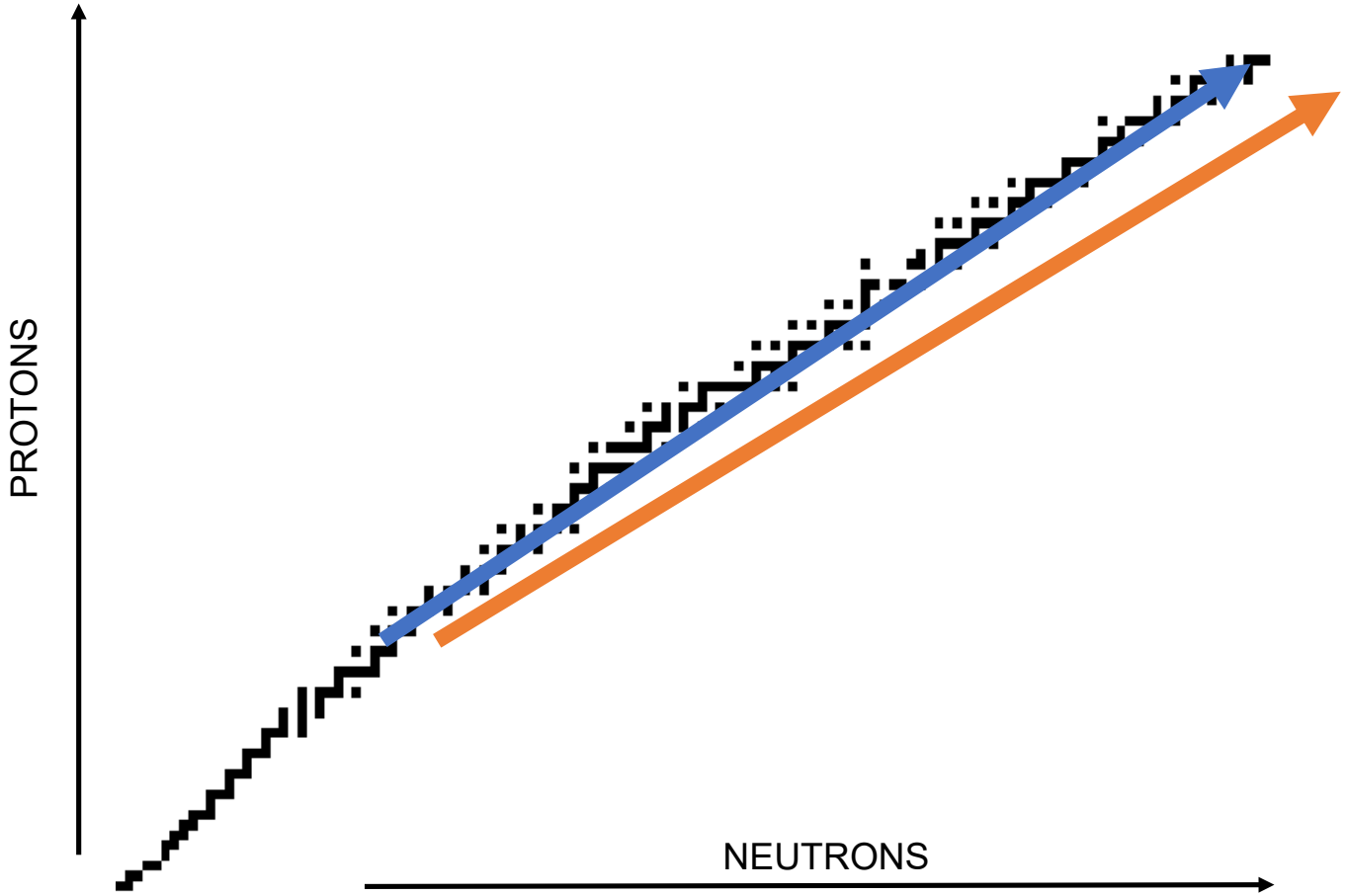
s-process: **completely covered**

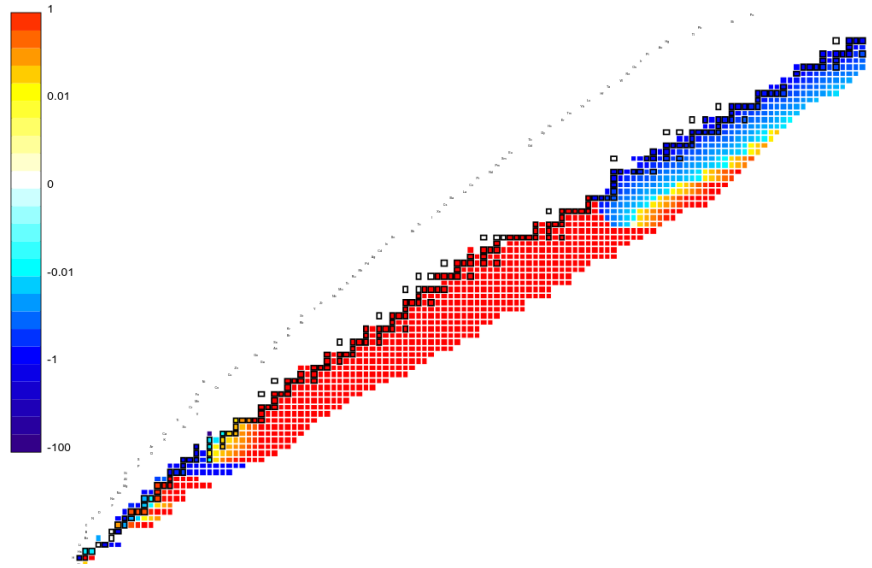




The production of stable nuclei

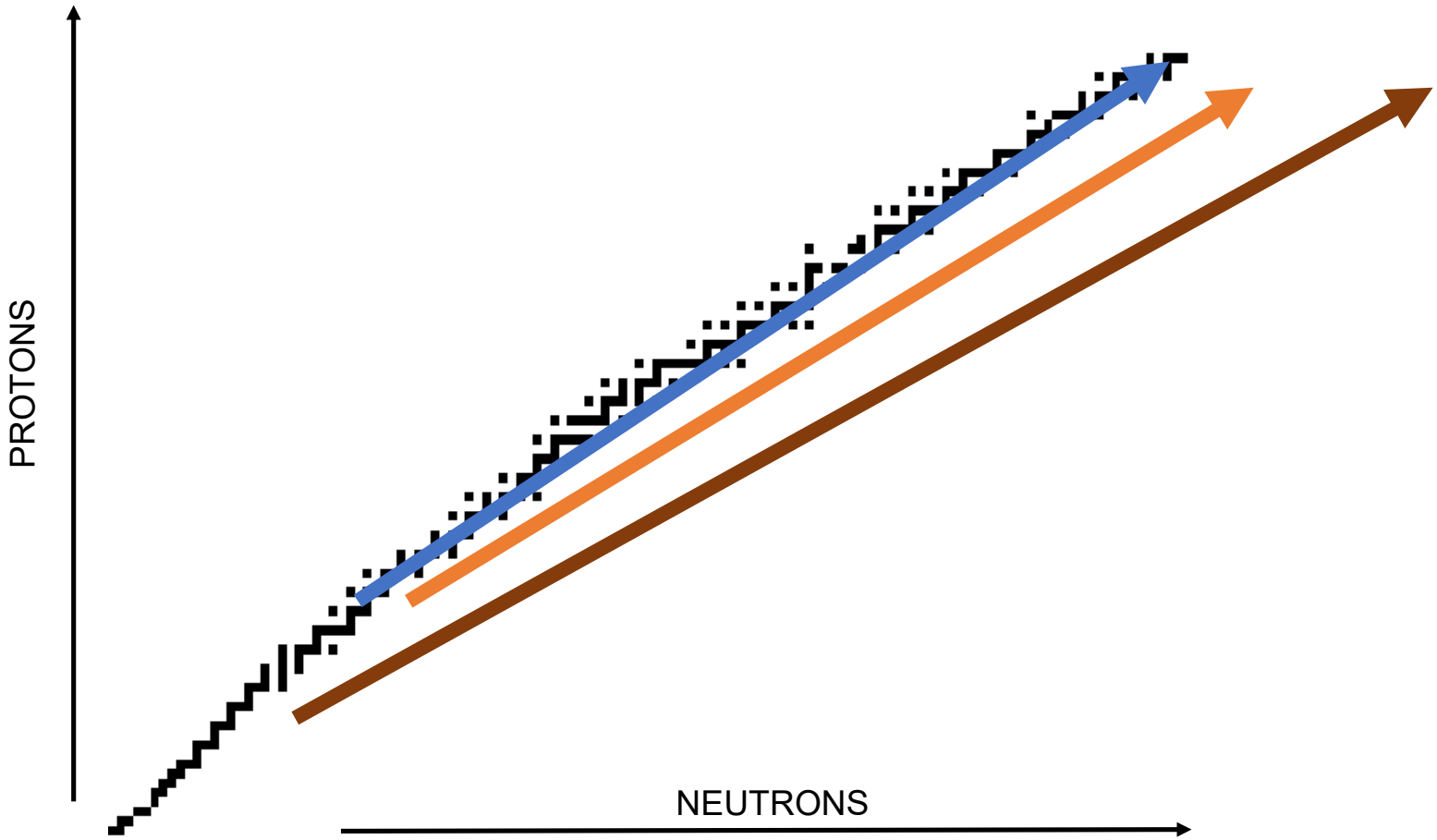
s-process: **completely covered**
i-process: **bottlenecks covered**





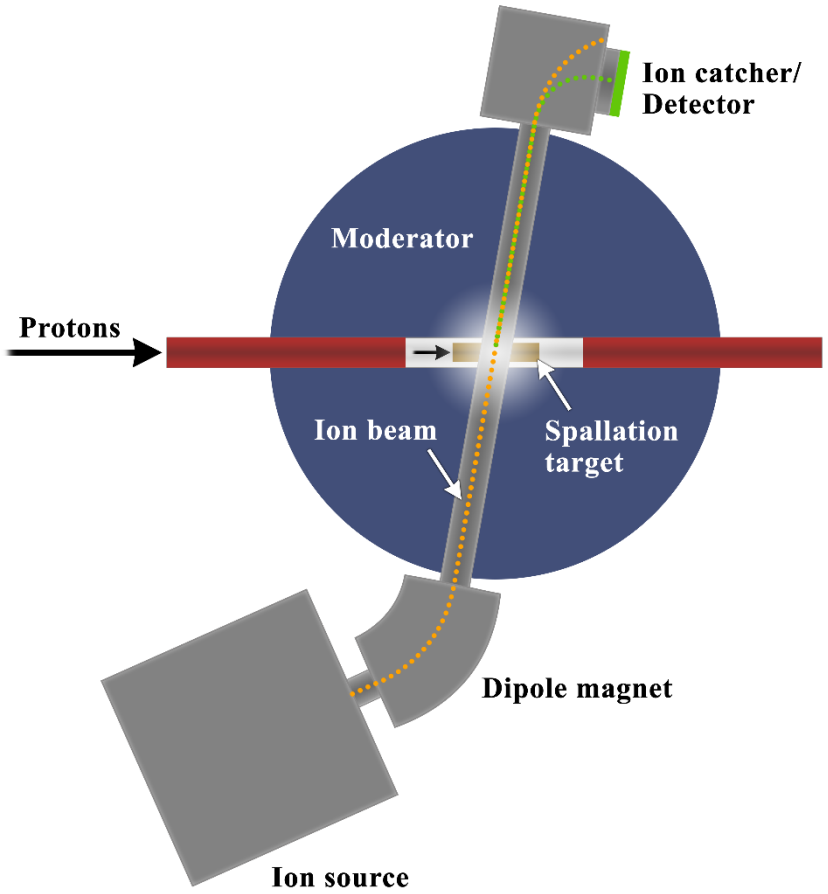
exp-astro.de/sensitivities

The production of stable nuclei



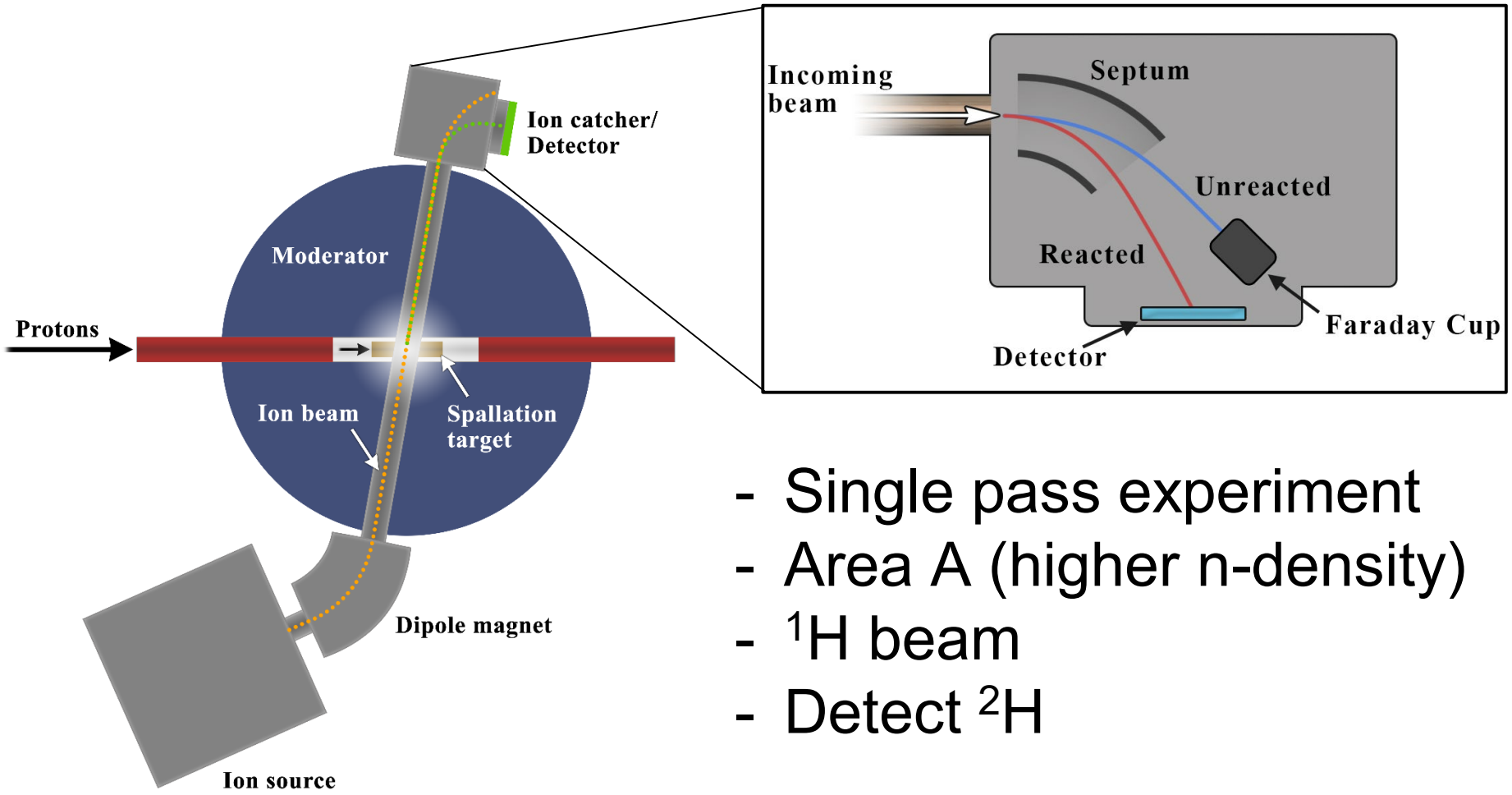
s-process: completely covered
i-process: bottlenecks covered
r-process: freeze out covered

First stage: A neutron target demonstrator (LDRD-DR)

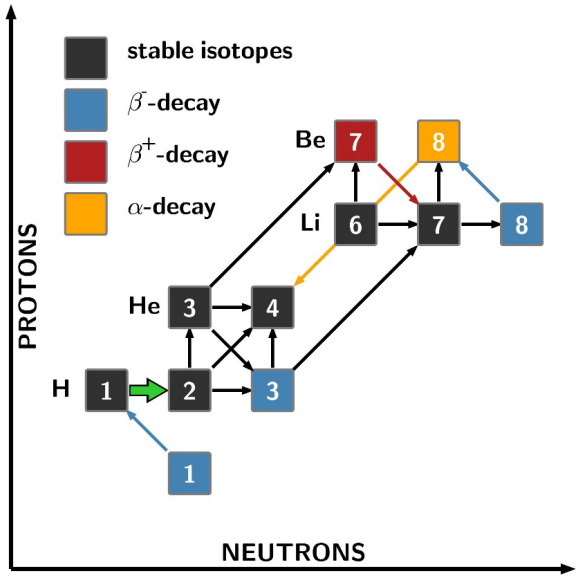


- Single pass experiment
- Blue room
- ^{84}Kr beam
- Detect decay of ^{85}Kr

Second stage: n+p -> D

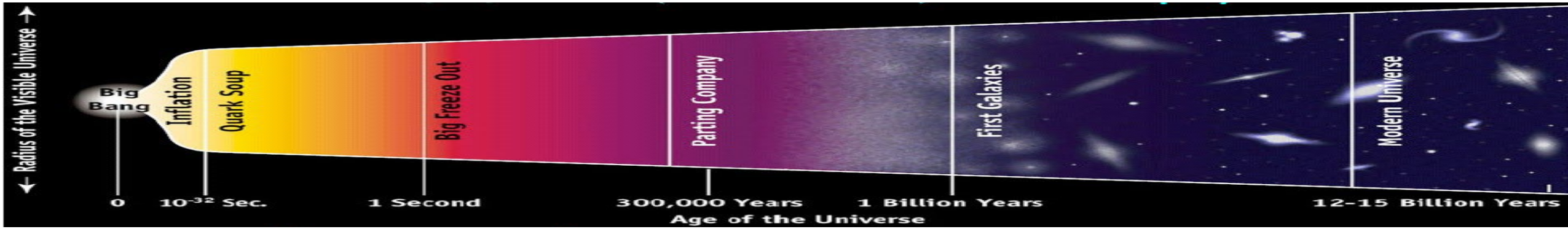


- Single pass experiment
- Area A (higher n-density)
- ^{1}H beam
- Detect ^{2}H



Summary

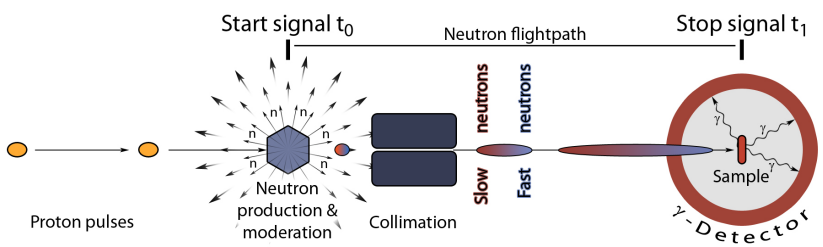
P-3

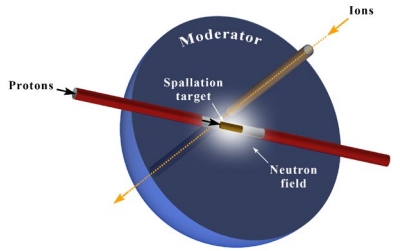


HENP

LENP

Neutrons





Thanks to … A. Cooper, A. Couture, H.Y Lee, Y. Litvinov, S. Mosby, J.M. O'Donnell, T. Stamatopoulos …