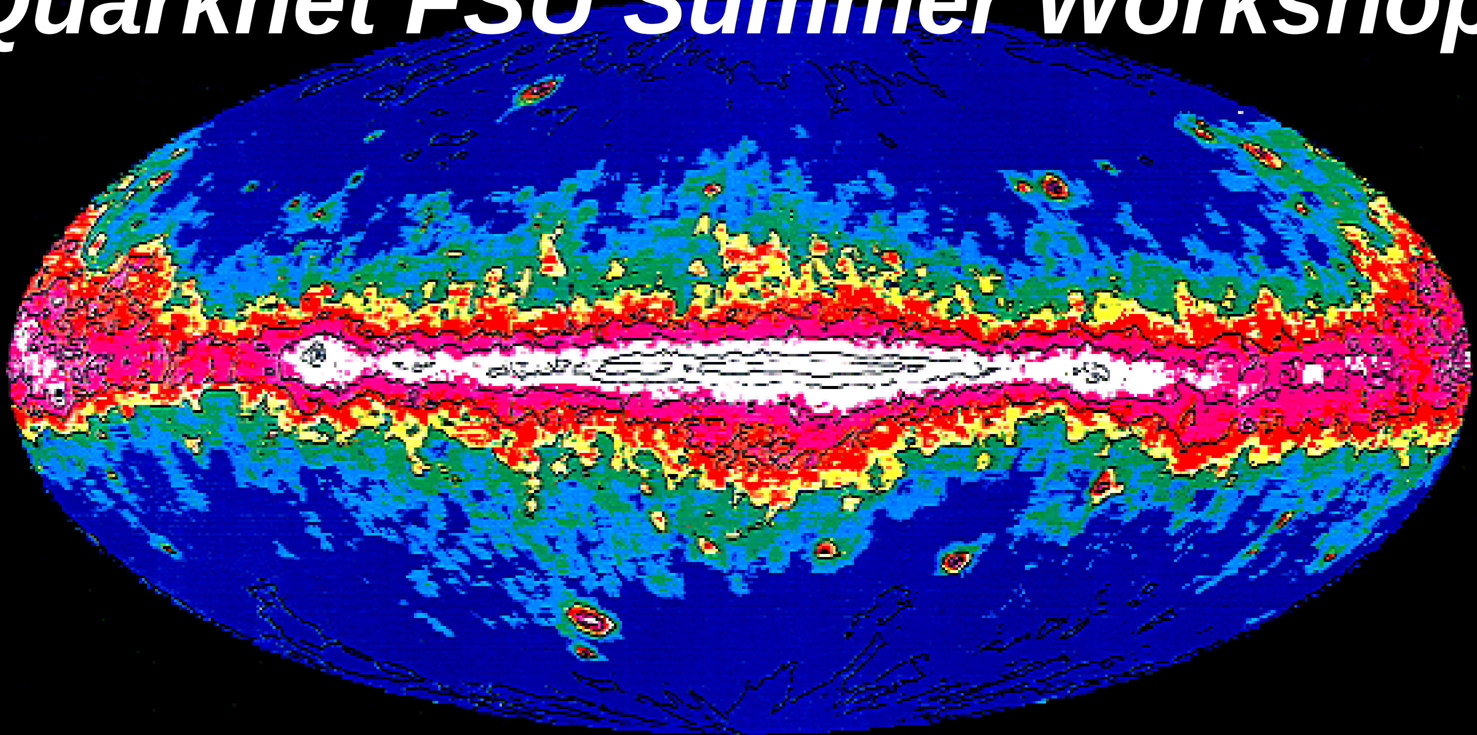
Topics in Nuclear Astrophysics

Quarknet FSU Summer Workshop



<u>Sergio Almaraz-Calderon</u>

Department of Physics, Florida State University

salmaraz@physics.fsu.edu

07/29/2016

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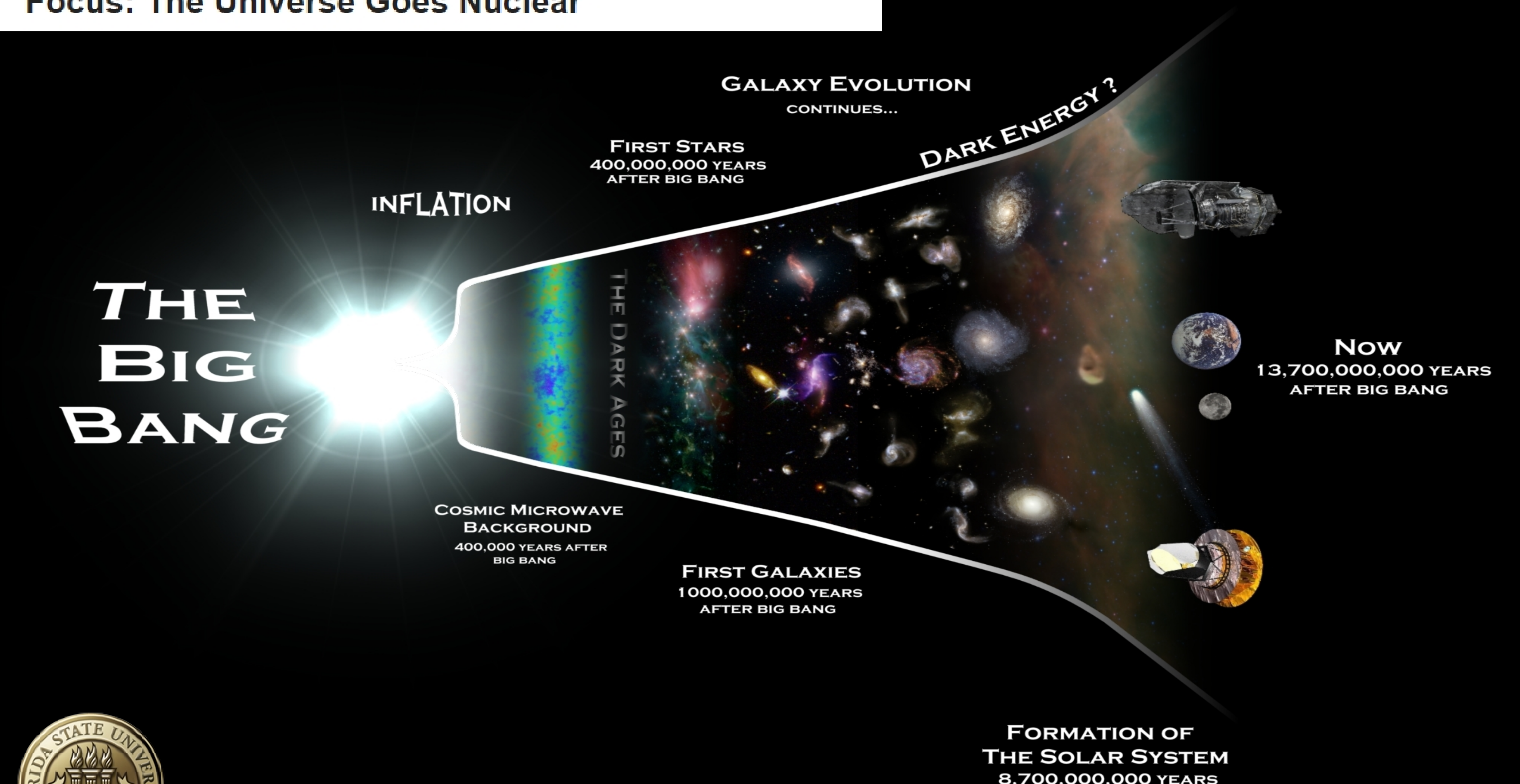
Focus: The Universe Goes Nuclear

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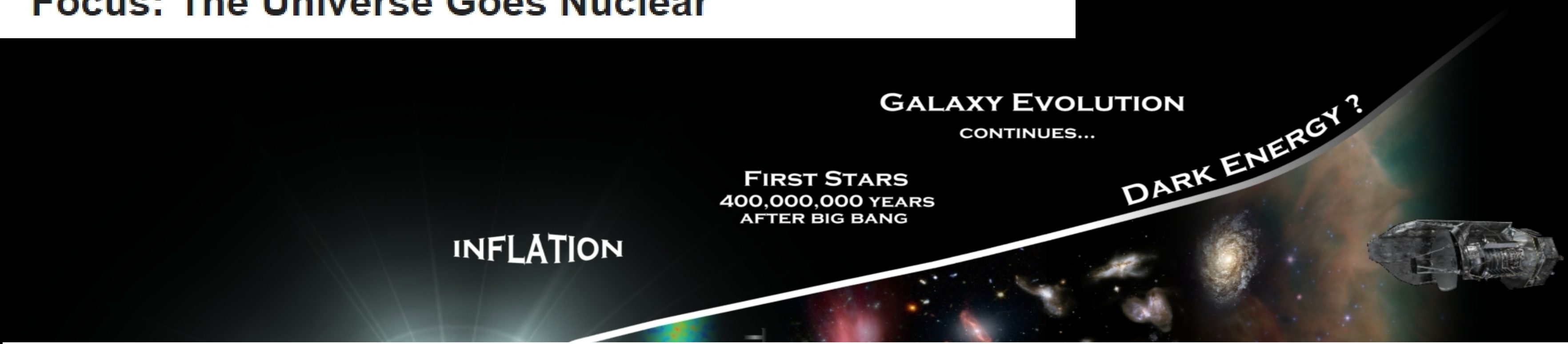
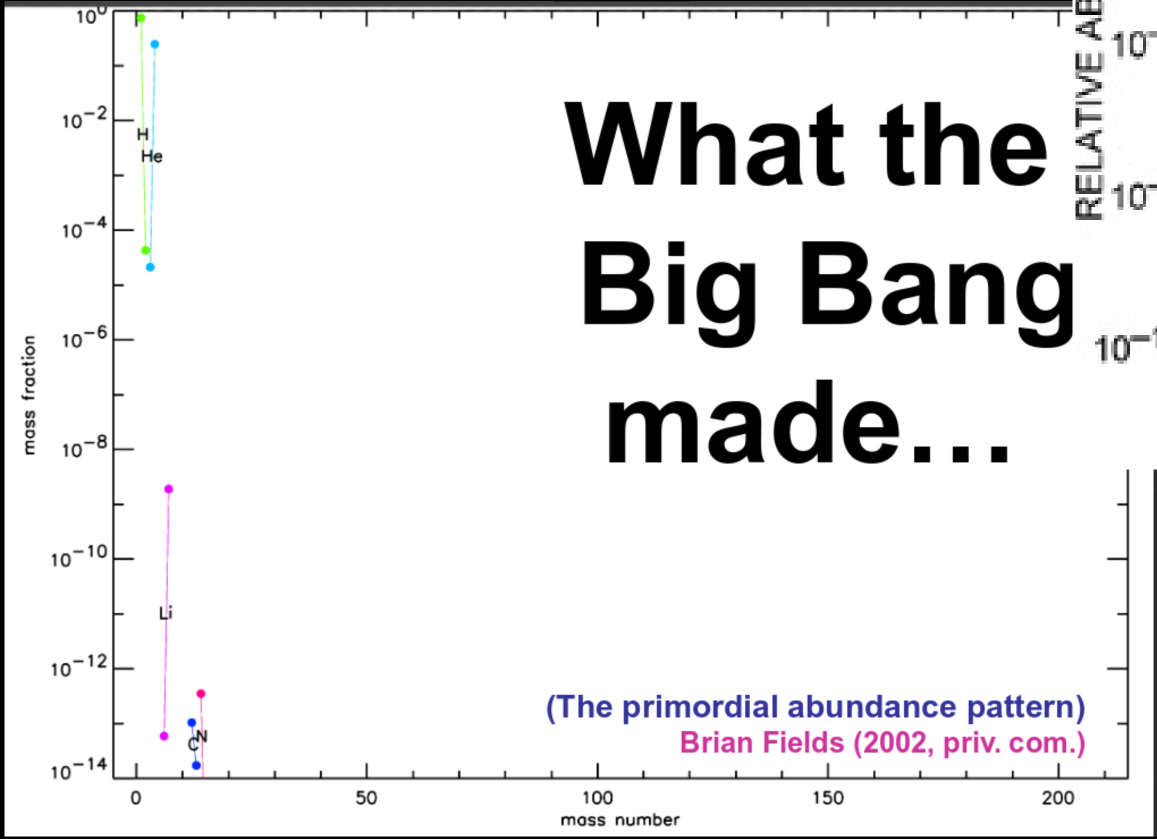
Focus: The Universe Goes Nuclear

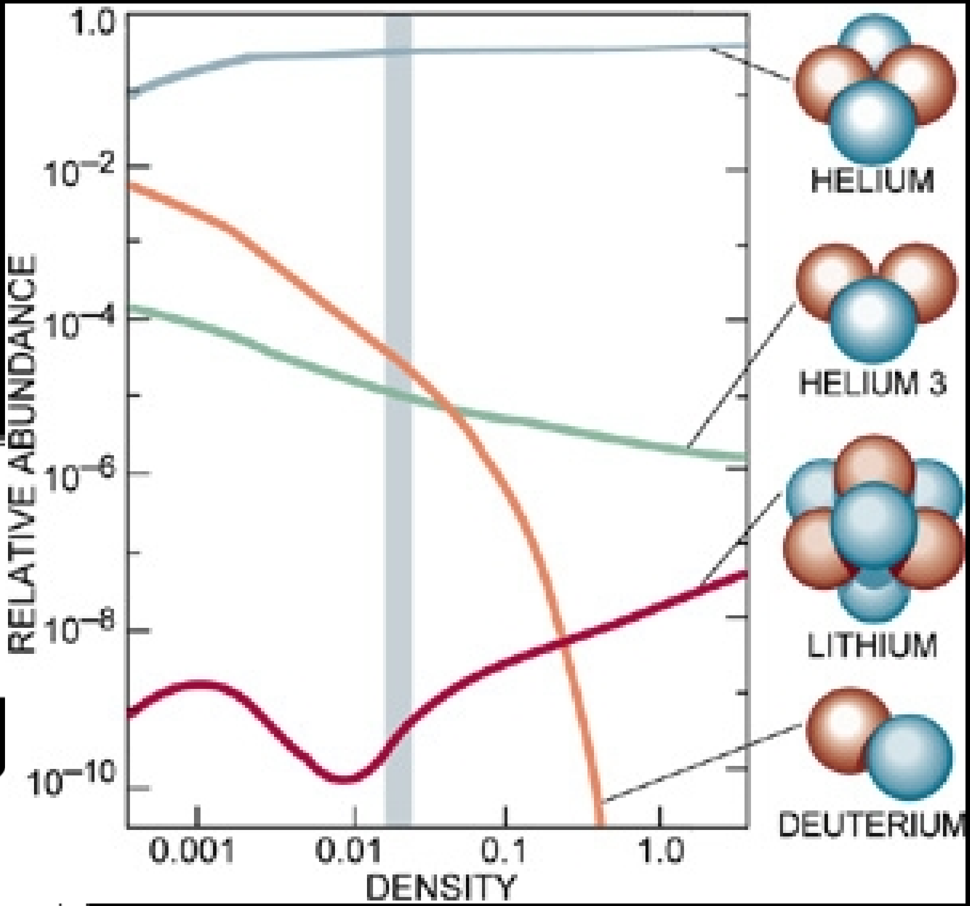


<u>Understand nuclear processes in stellar environments:</u>

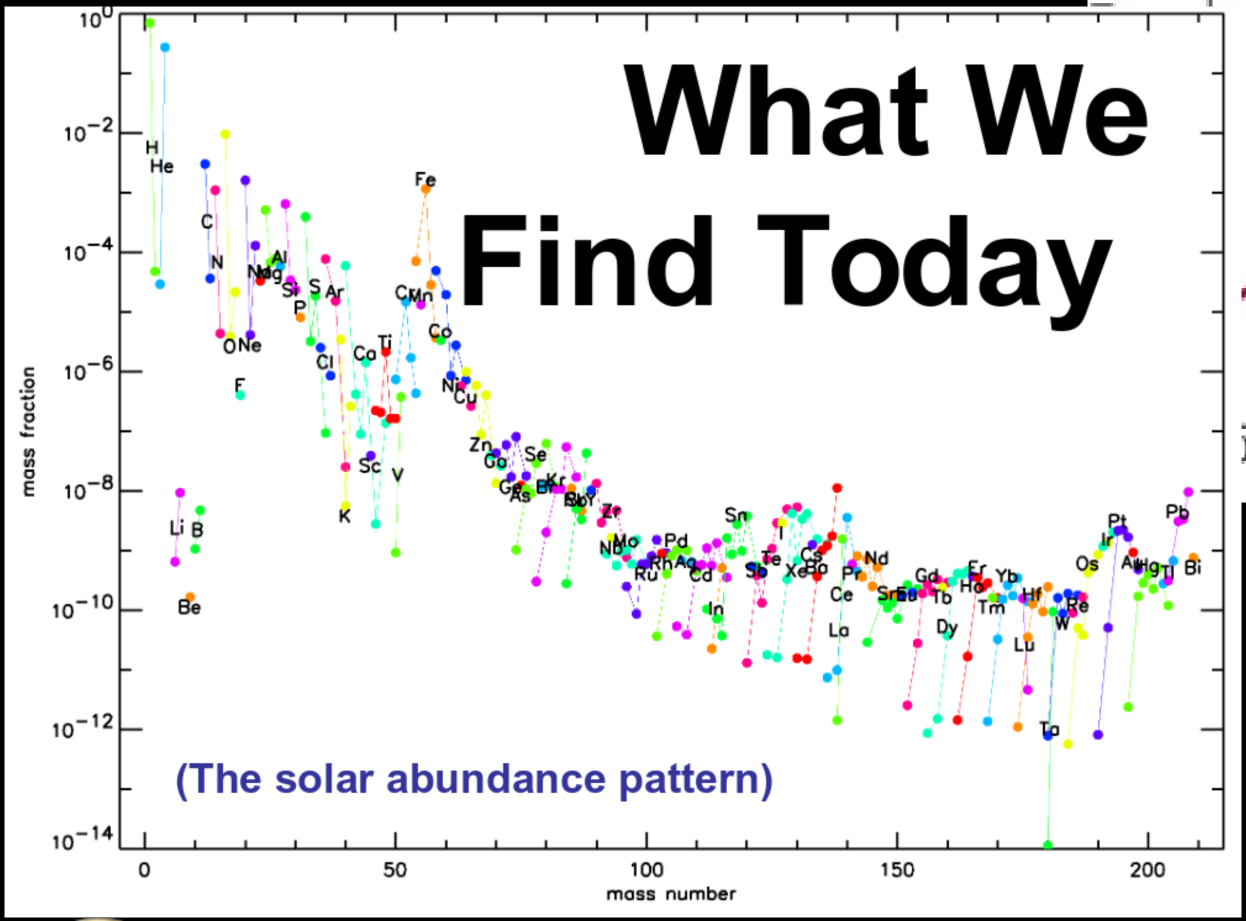
- Stellar Nucleosynthesis
- Energy generation
- Time scales of stellar events

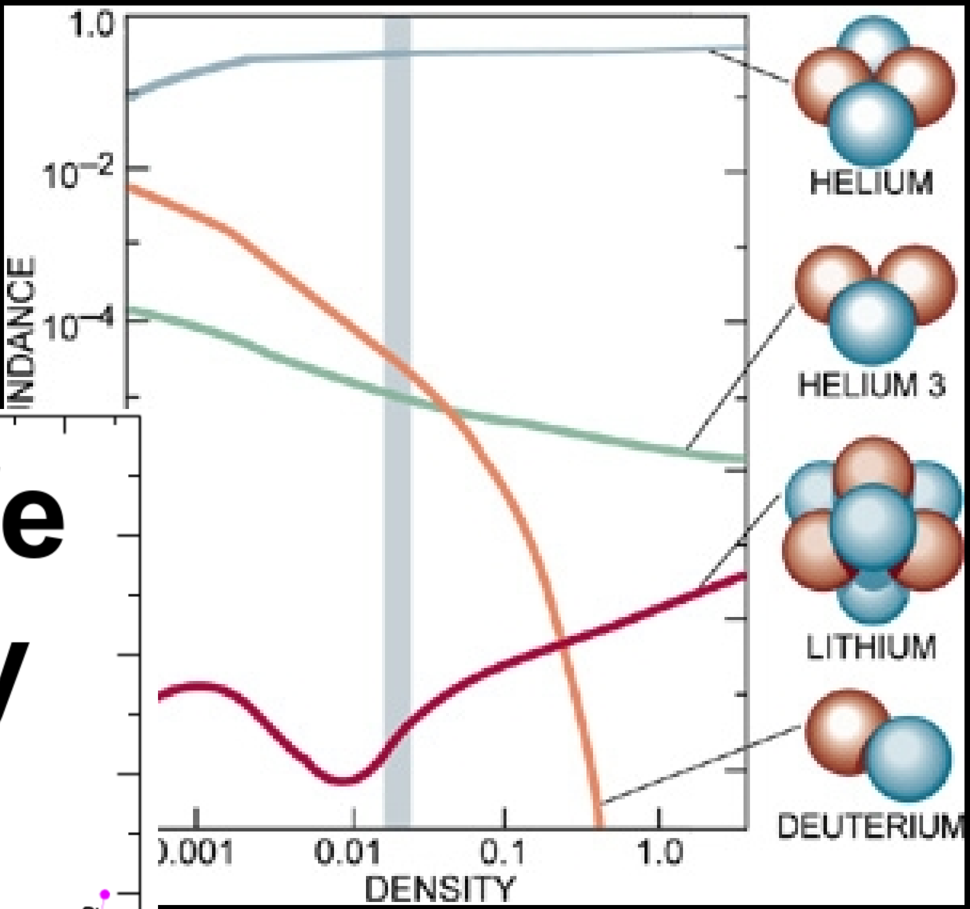
What the Big Bang made…





What We Find Today

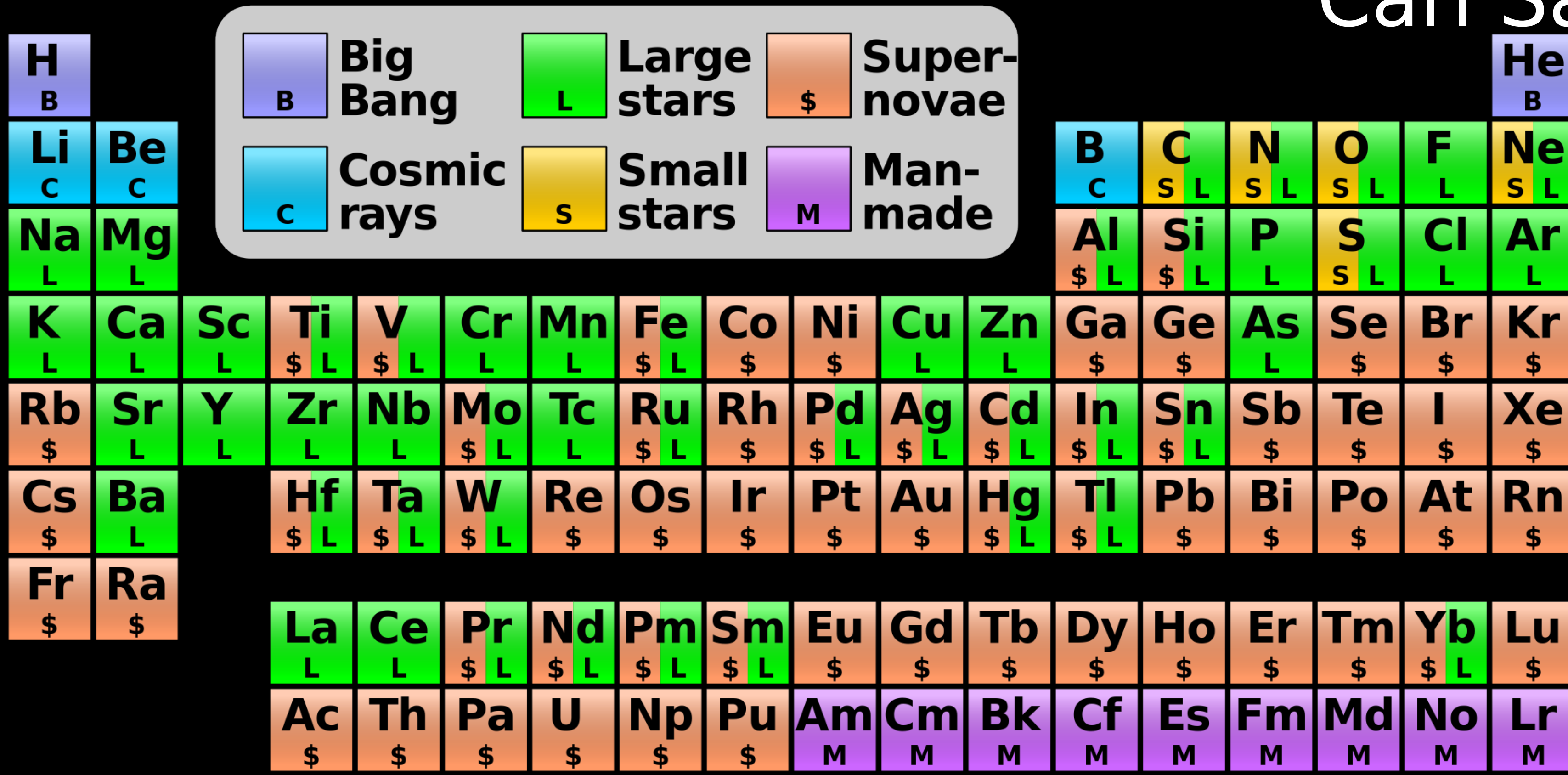




Stellar nucleosynthesis is the synthesis of elements from primordial **H** and **He**

“ We are made of star stuff ”

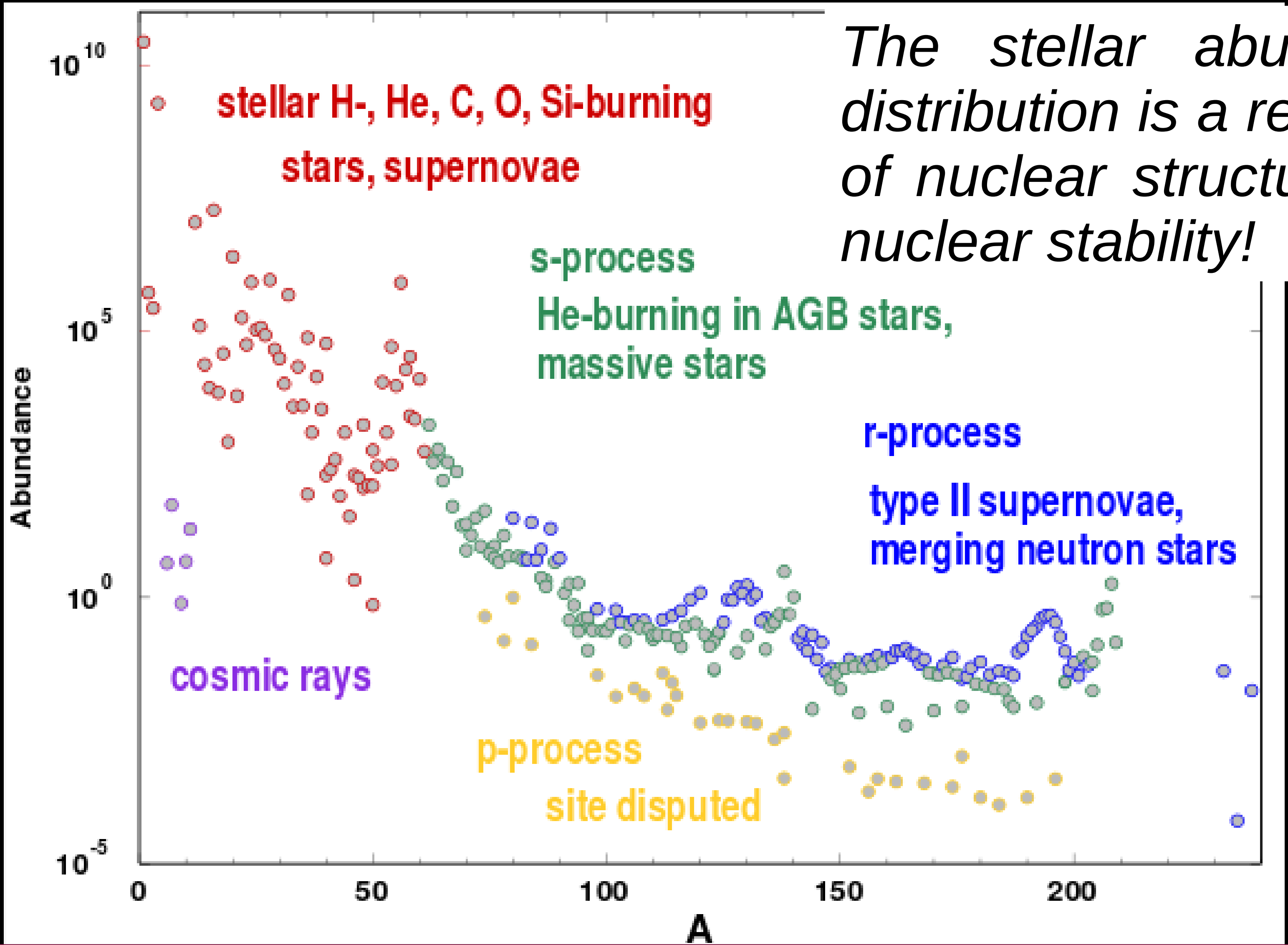
Carl Sagan



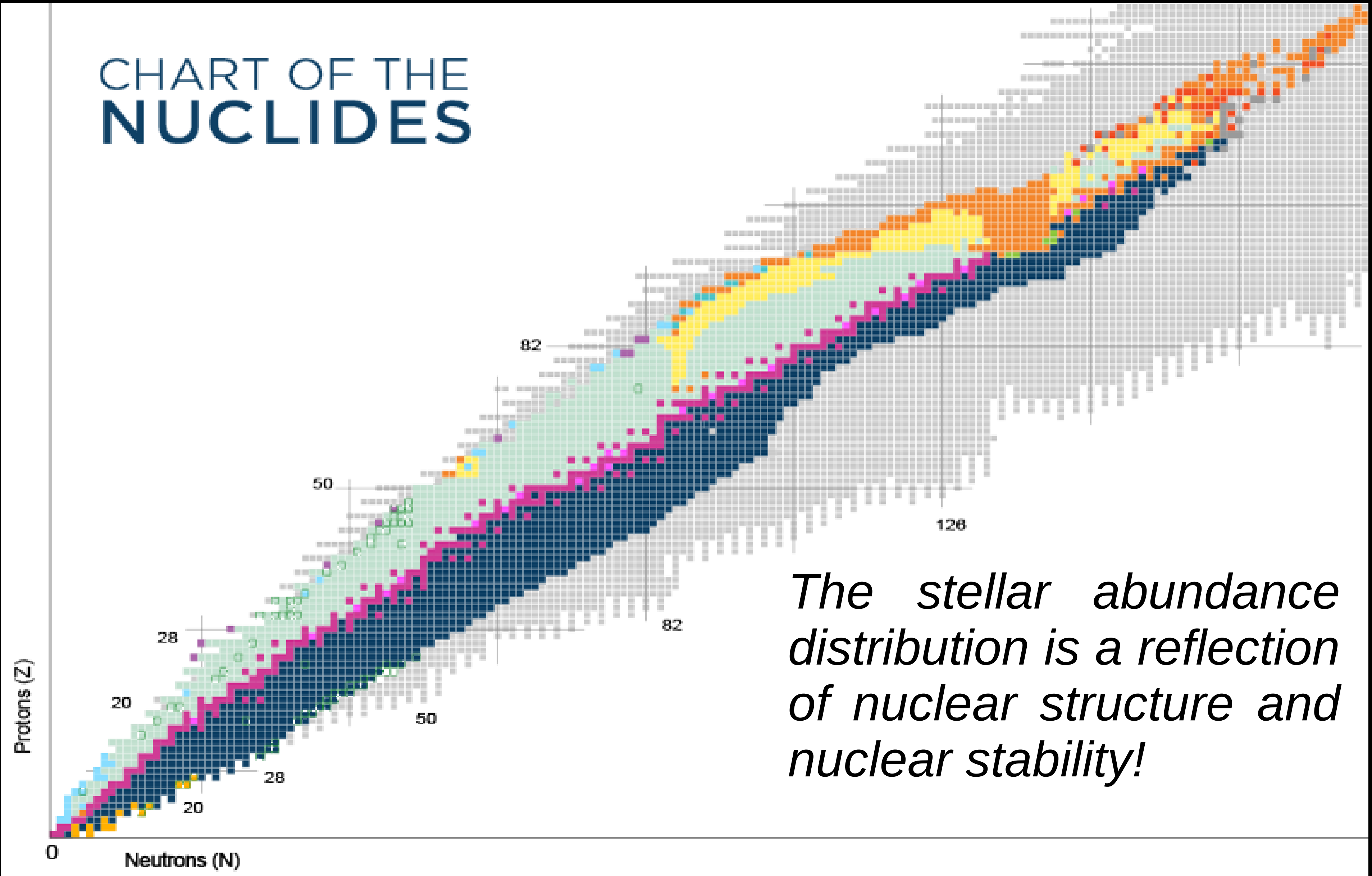
Each heavy atom in our body was build and processed through about 100 – 1000 star generation since the big bang!!!

What are the processes that make up the elements in the universe?

Galactic abundance distribution



The stellar abundance distribution is a reflection of nuclear structure and nuclear stability!



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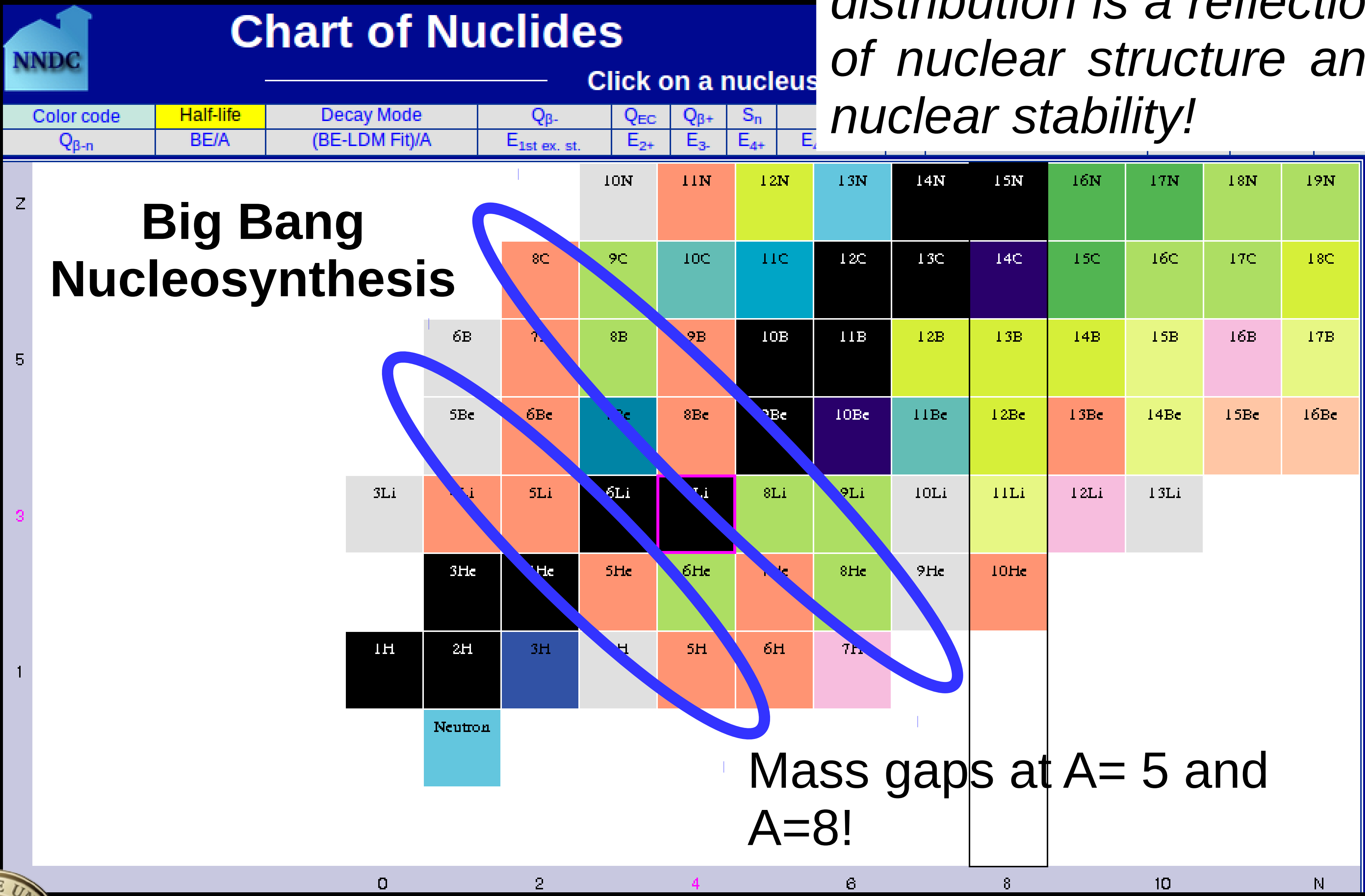
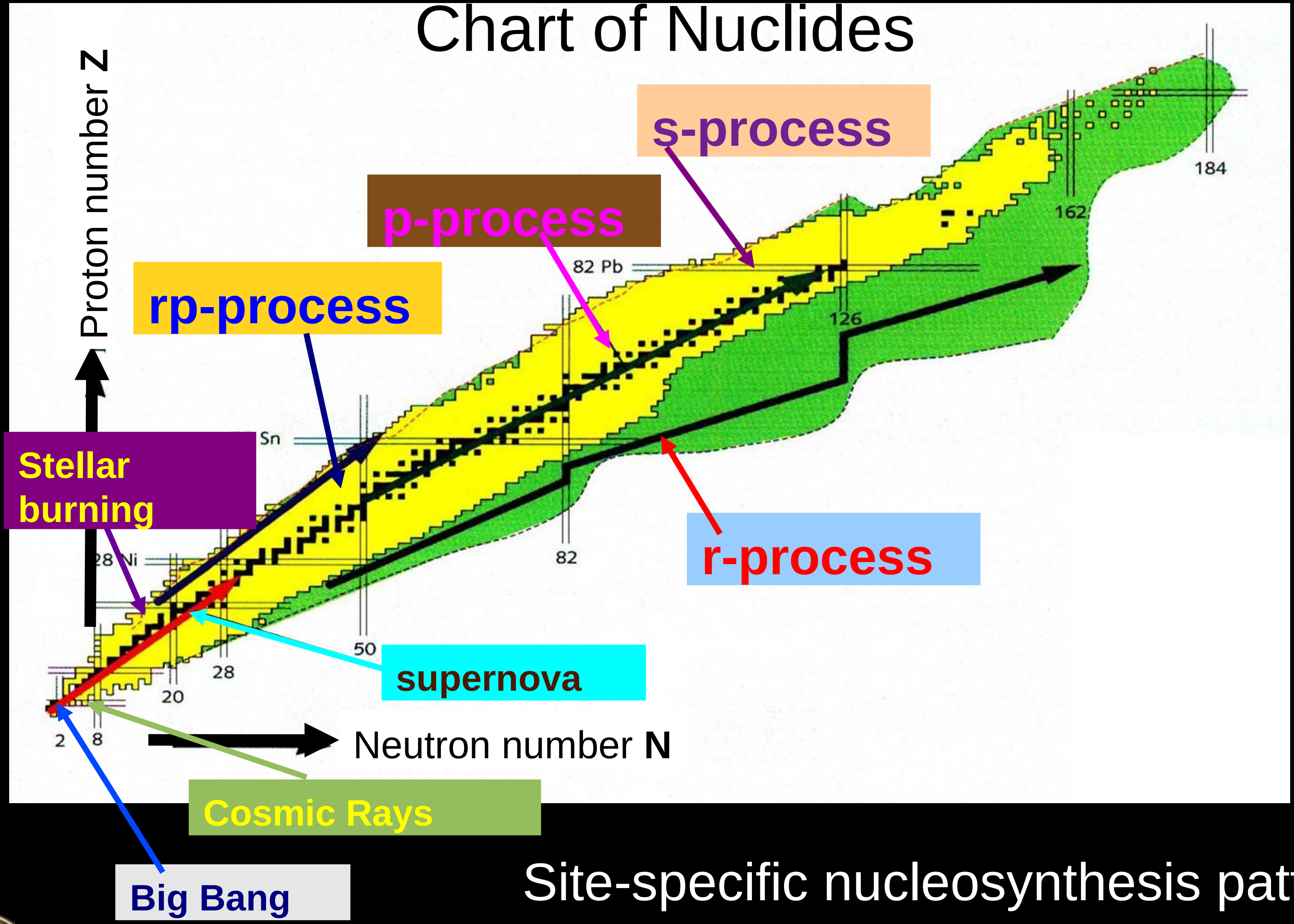


Mass gaps at A= 5 and A=8!

Nucleosynthesis processes

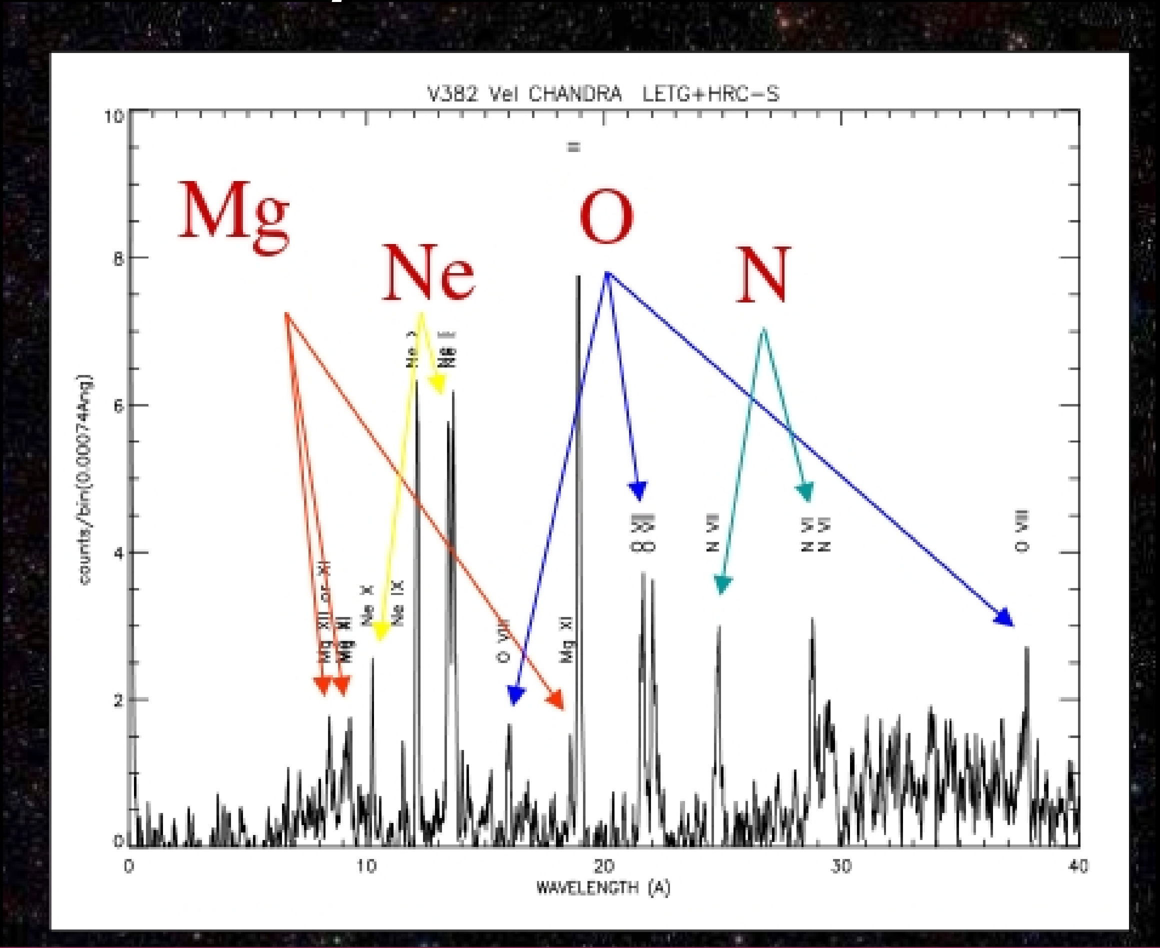


Site-specific nucleosynthesis patterns

Observational evidence

Signatures reflect dynamics and energetics of nucleosynthesis processes in stellar environments of certain temperature and density conditions

a) Elemental and isotopic abundances in stellar spectra

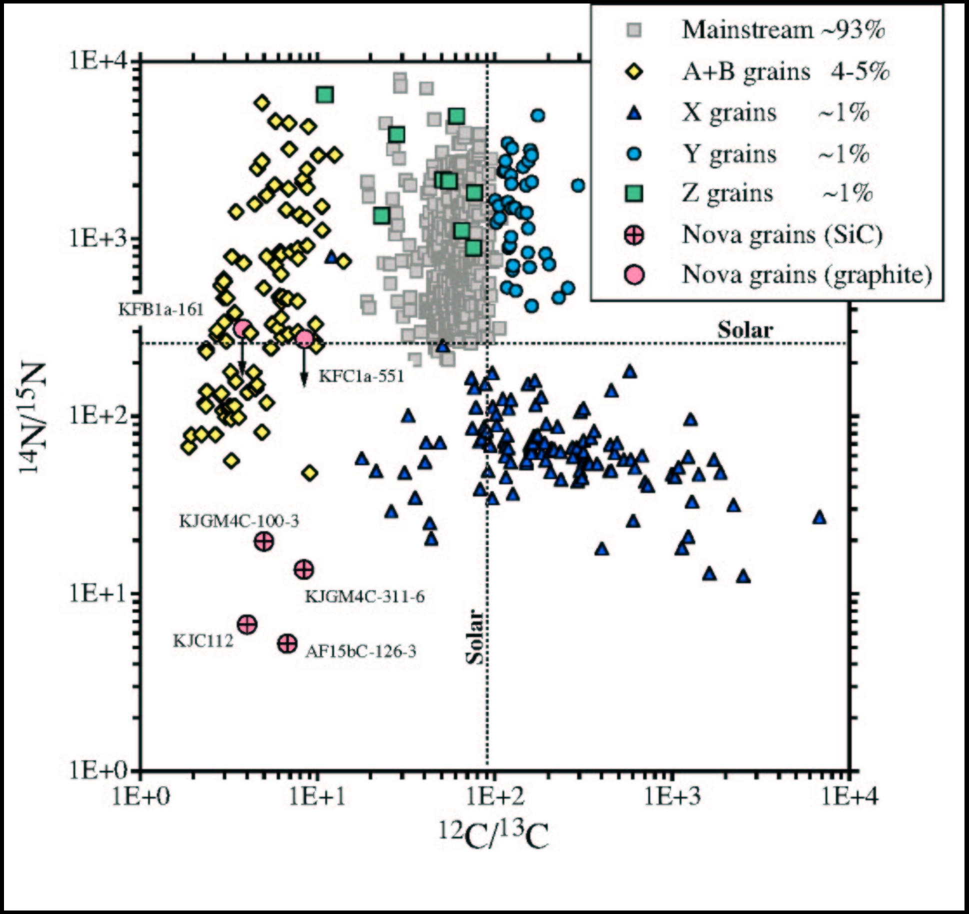


Nova (Chandra Telescope)

Observational evidence

Signatures reflect dynamics and energetics of nucleosynthesis processes in stellar environments of certain temperature and density conditions

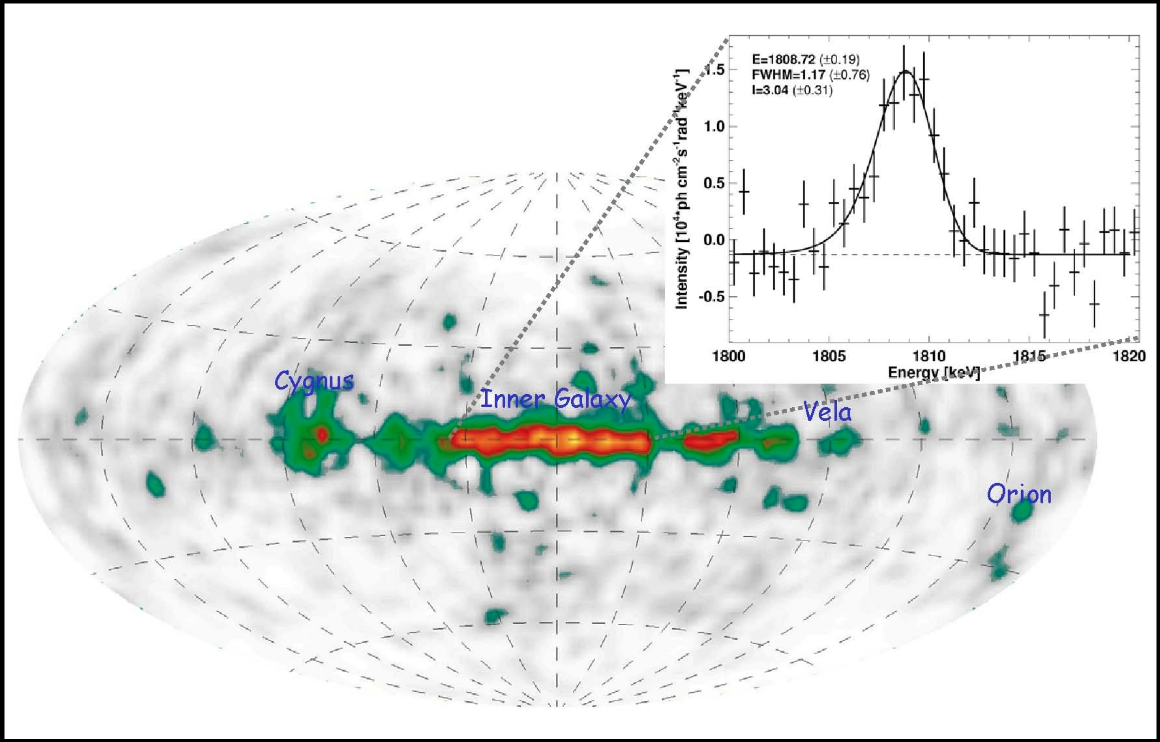
b) Isotopic abundances in meteoritic inclusions

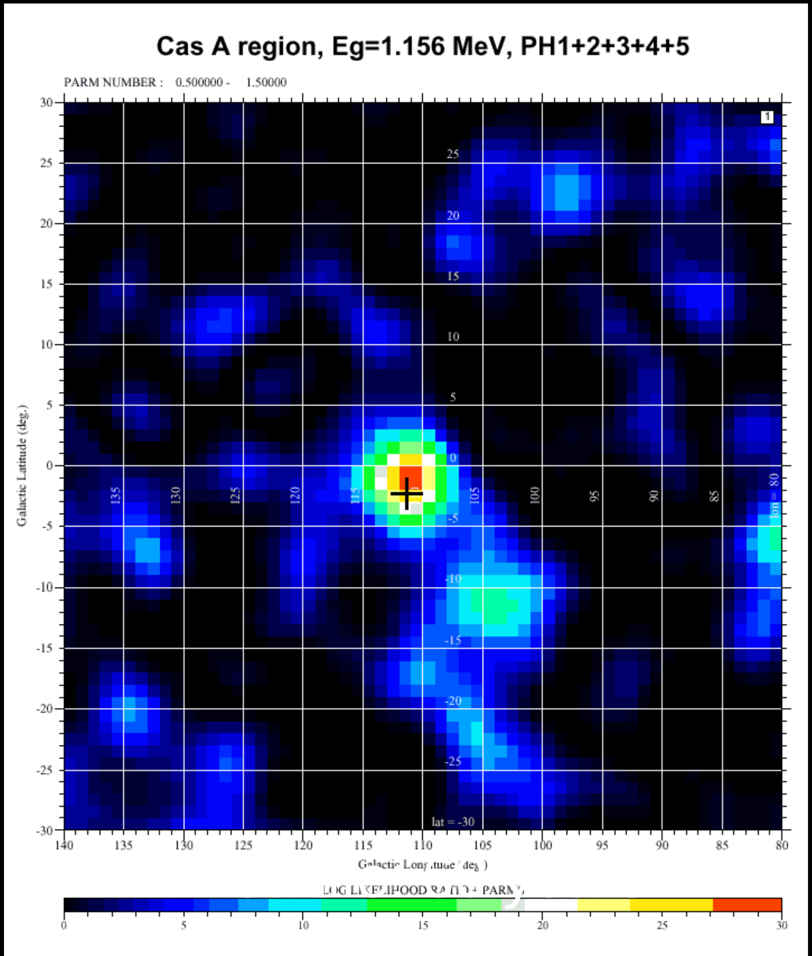


Observational evidence

Signatures reflect dynamics and energetics of nucleosynthesis processes in stellar environments of certain temperature and density conditions

c) Long-lived galactic radioactivity





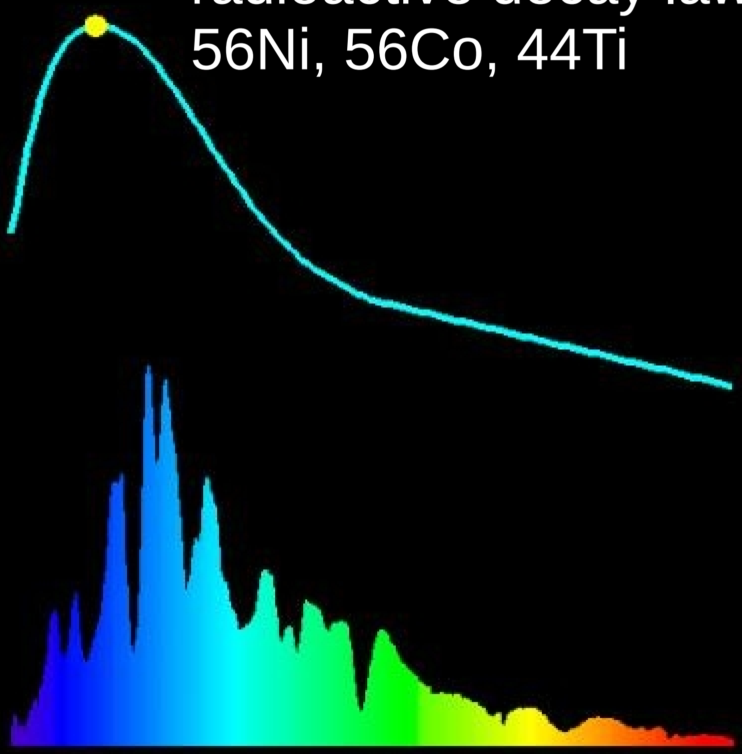
26Al Half life: 700,0000 year

Observational evidence

Signatures reflect dynamics and energetics of nucleosynthesis processes in stellar environments of certain temperature and density conditions

d) Light curve and spectral emission

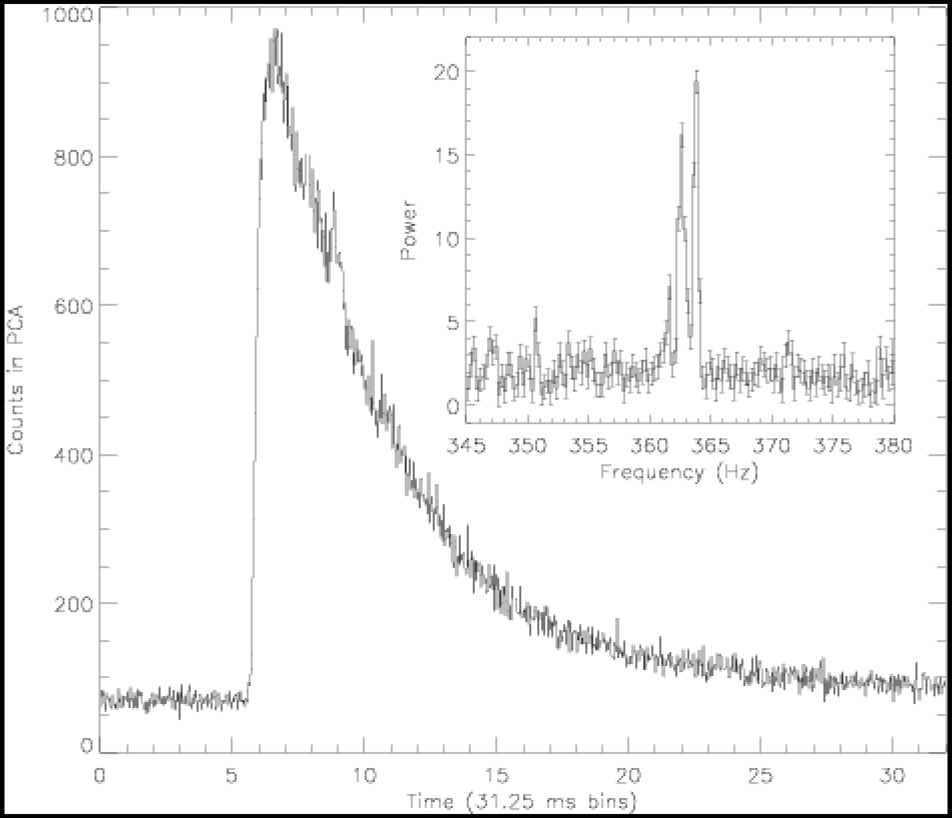
SN-Light curve follows the radioactive decay law
56Ni, 56Co, 44Ti



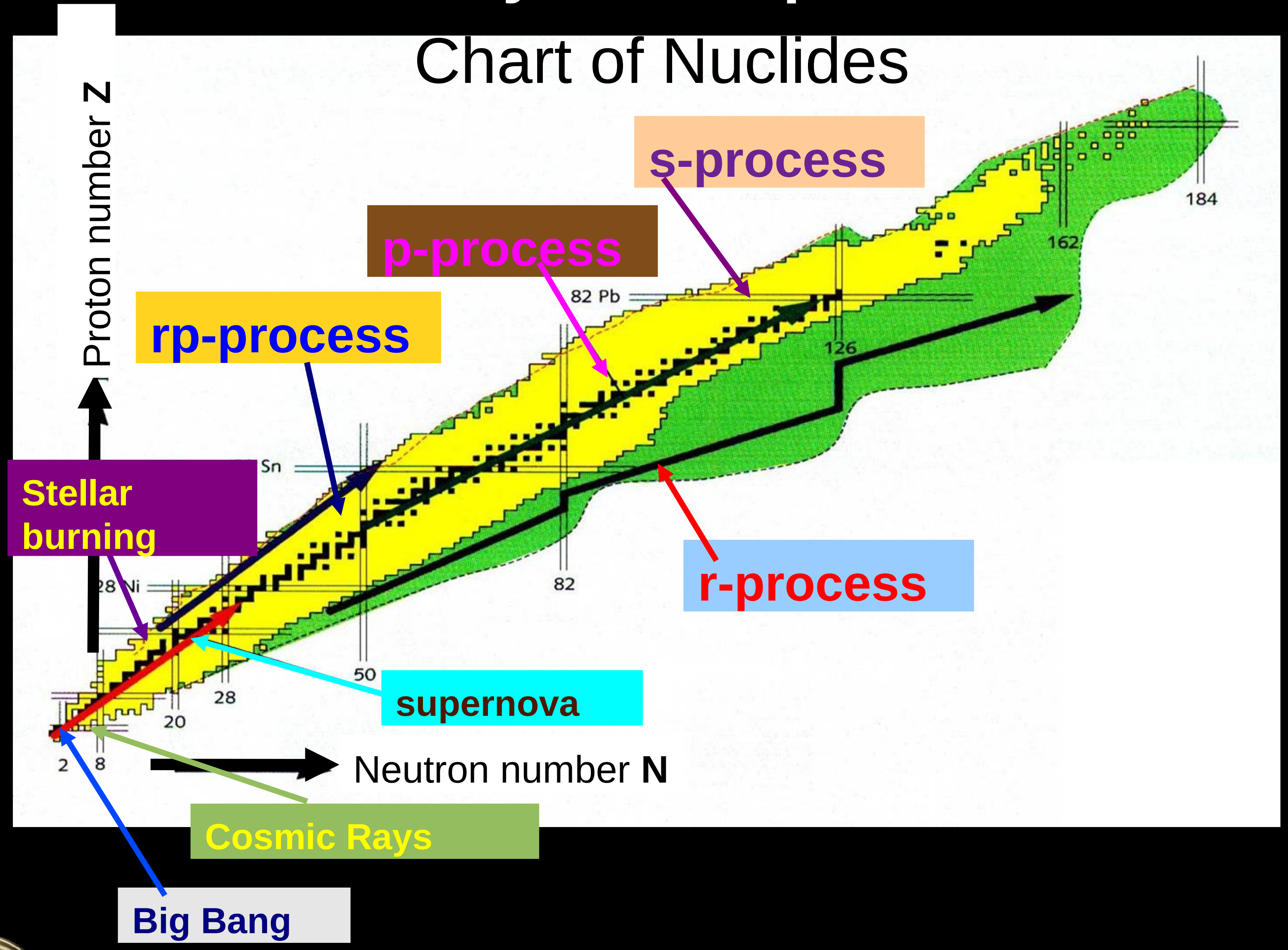
Observational evidence

Signatures reflect dynamics and energetics of nucleosynthesis processes in stellar environments of certain temperature and density conditions

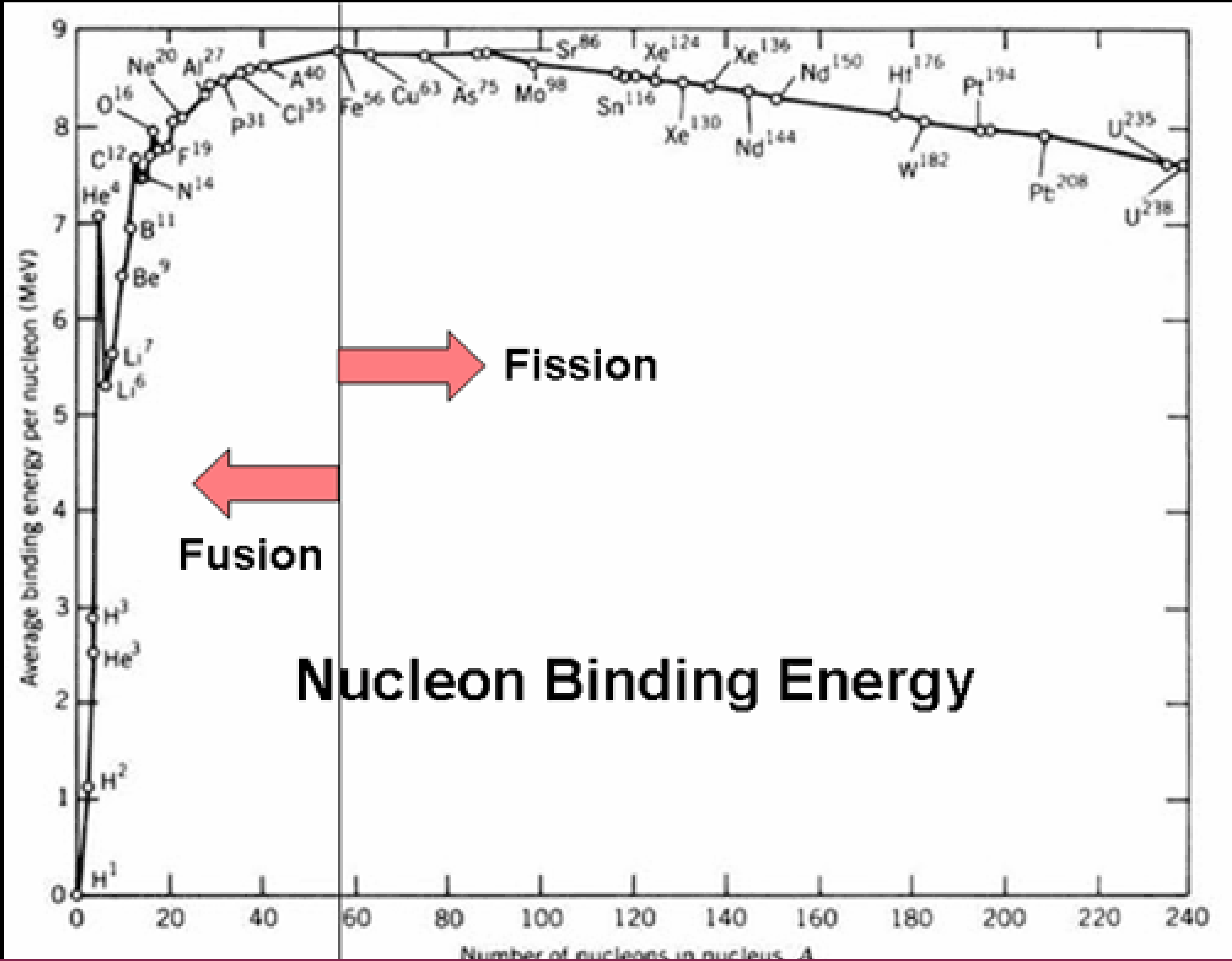
e) Time scale of rapid explosive events



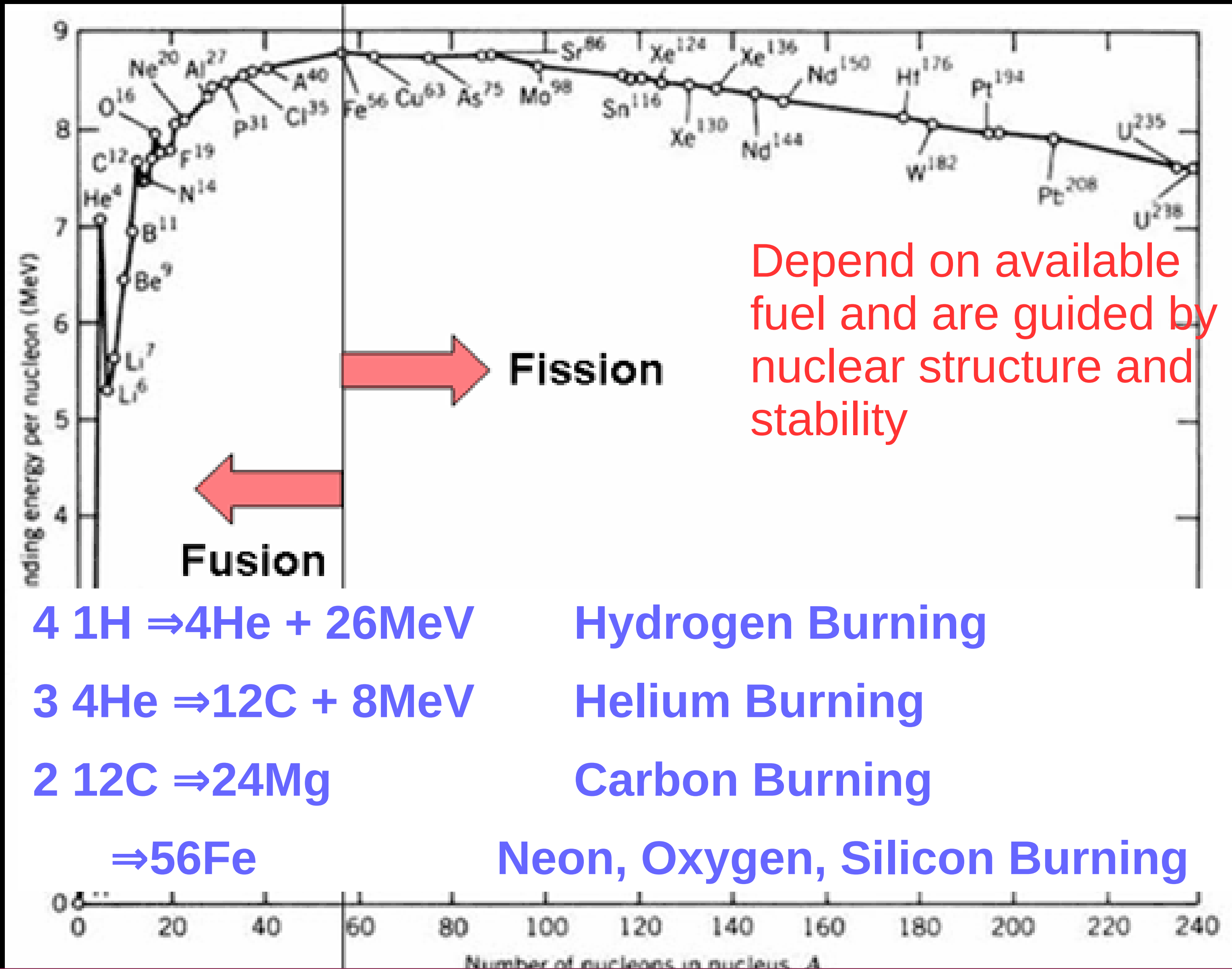
Nucleosynthesis processes



Charged Particle induced Nucleosynthesis Processes in Stars



Charged Particle induced Nucleosynthesis Processes in Stars



Depend on available fuel and are guided by nuclear structure and stability

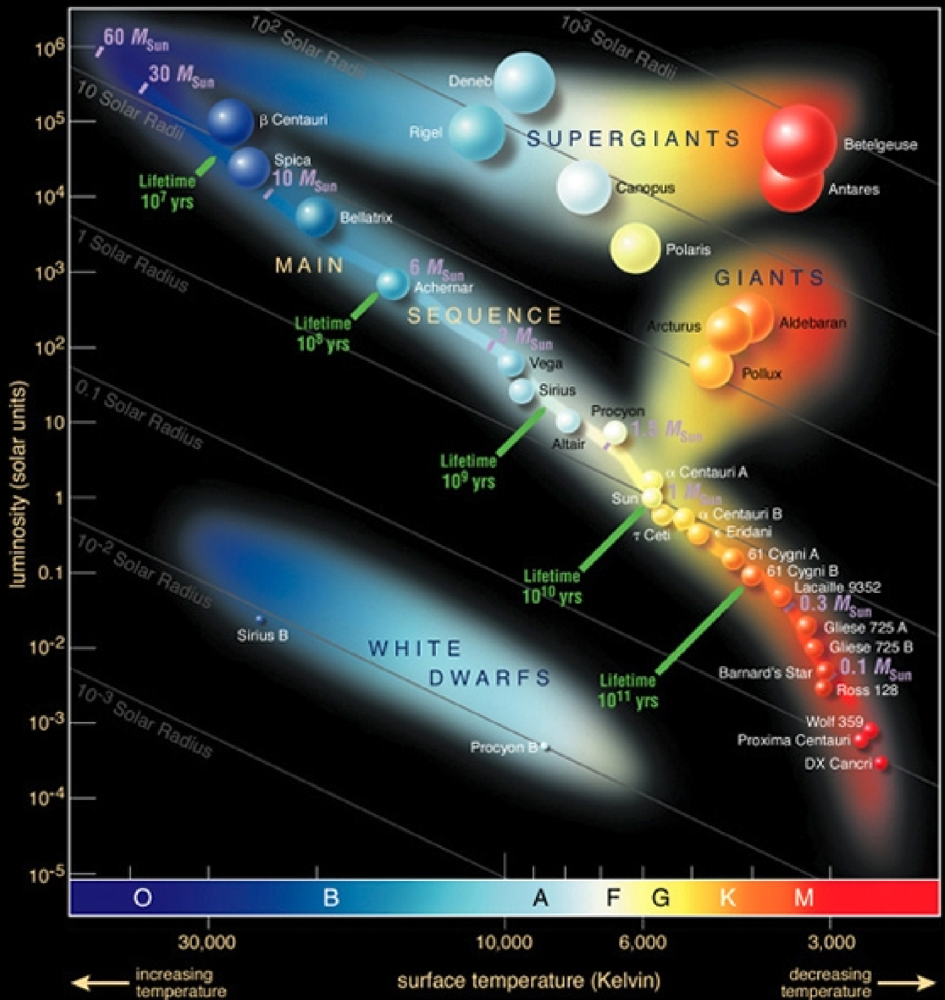
4 1H ⇒4He + 26MeV — **Hydrogen Burning**

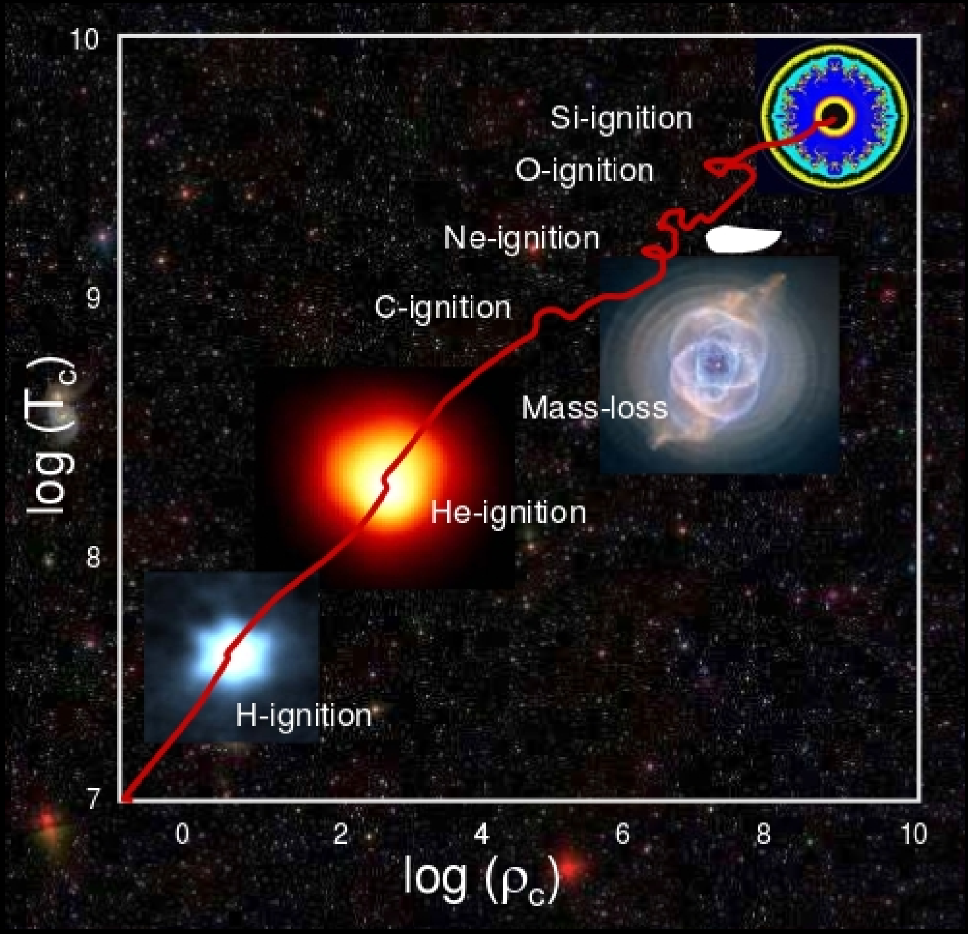
3 4He ⇒12C + 8MeV — **Helium Burning**

2 12C ⇒24Mg — **Carbon Burning**

⇒56Fe — **Neon, Oxygen, Silicon Burning**

Hertzsprung Russell Diagram





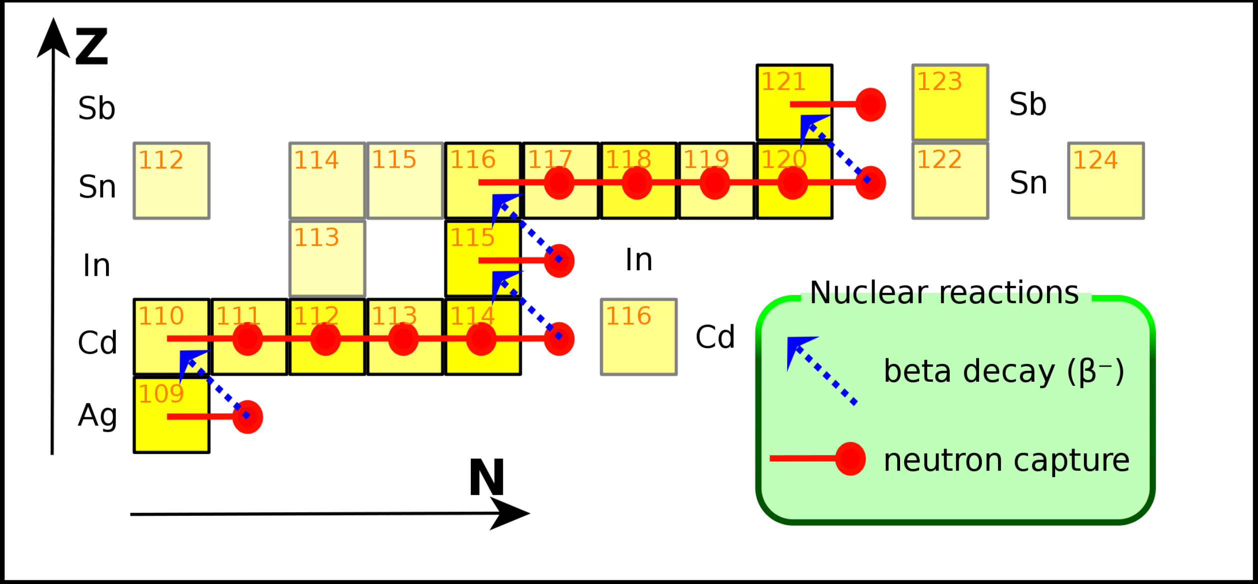
Nucleosynthesis beyond A=56

Neutron induced nucleosynthesis:

s-process: slow build up of A>56 by n-capture & β-decay on 56Fe seed

r-process: rapid build up by multiple n-capture to (n,γ)-(γ,n) equilibrium

Metal poor stars and AGB stars



Nucleosynthesis beyond A=56

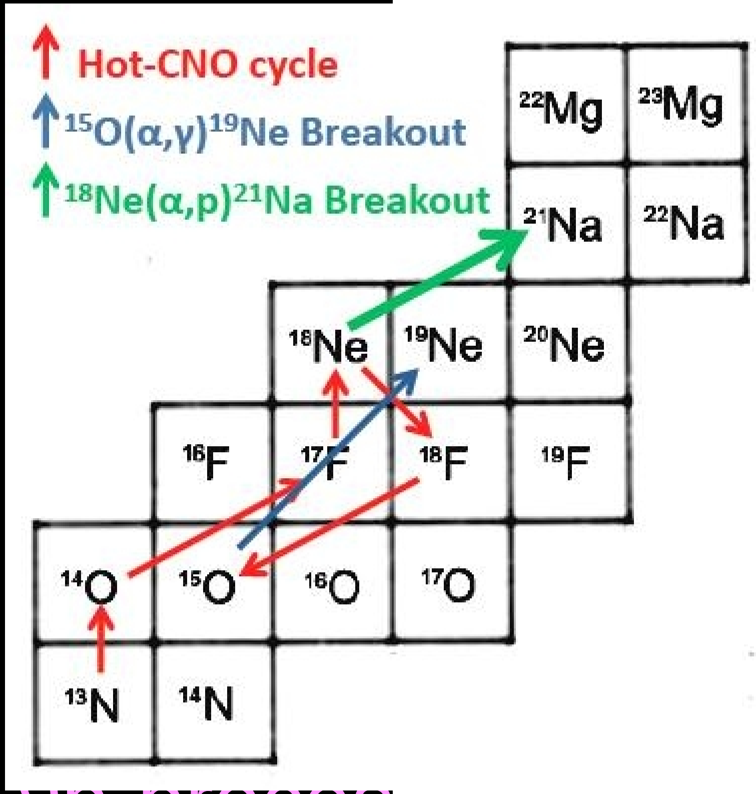
High temperature hydrogen and helium burning:

rp-process: by feeding hydrogen into hot environment (accretion)

αp-process: by feeding helium into hot environment

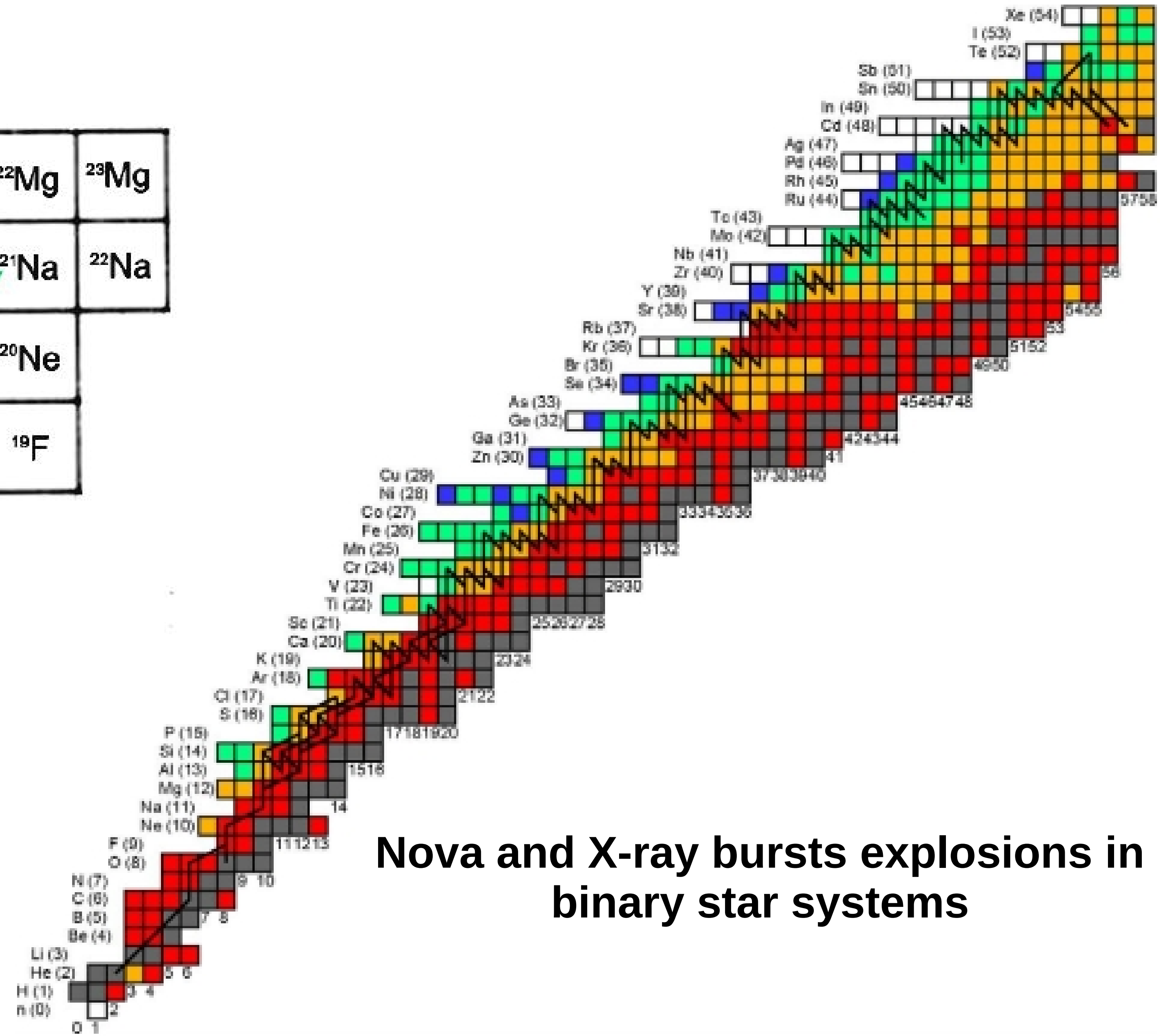
νp-process: by providing n-flux through neutrino induced reactions

N



νp-proces

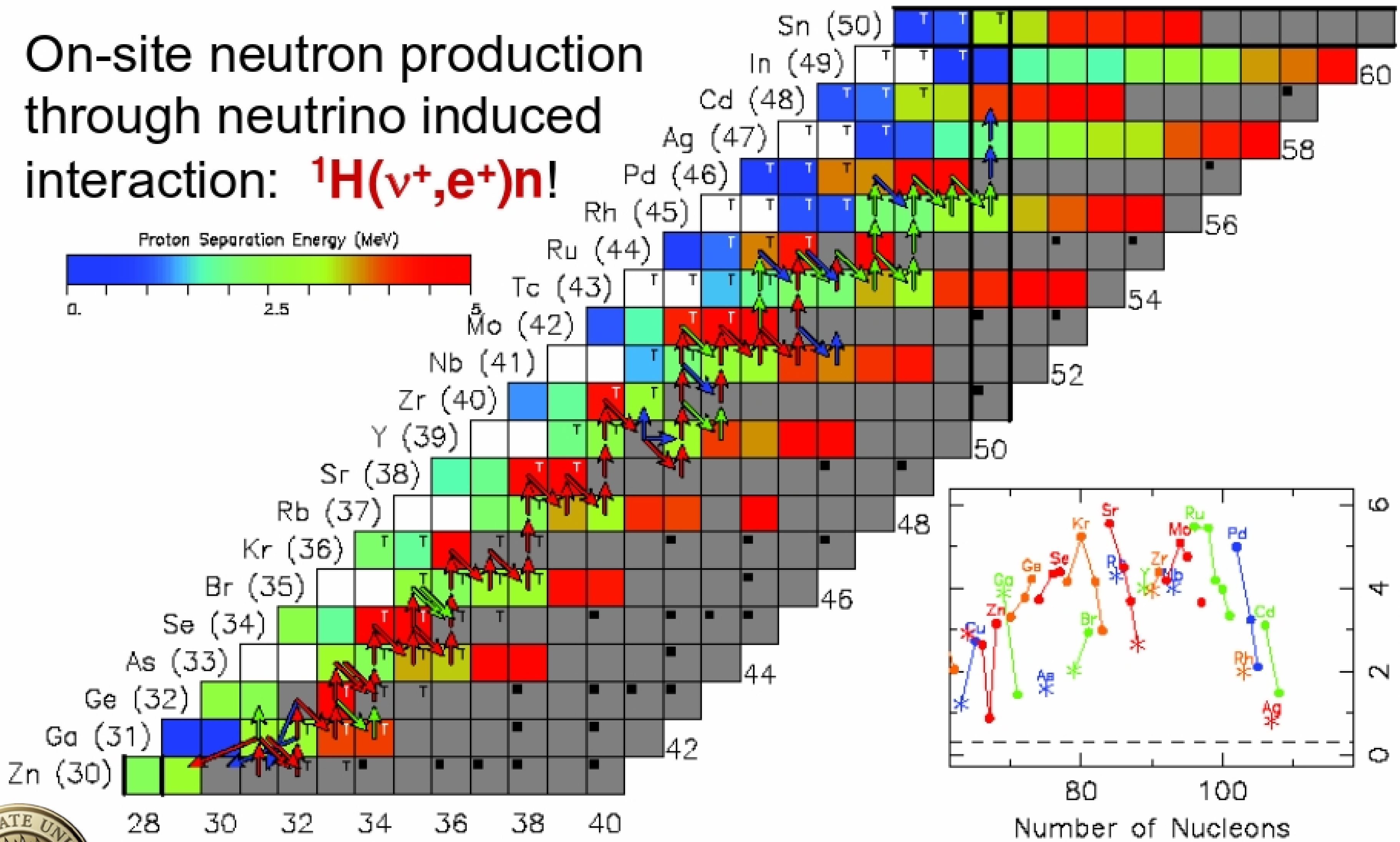
induced re



Nova and X-ray bursts explosions in binary star systems

νp-process in hydrogen rich, high neutron flux environments

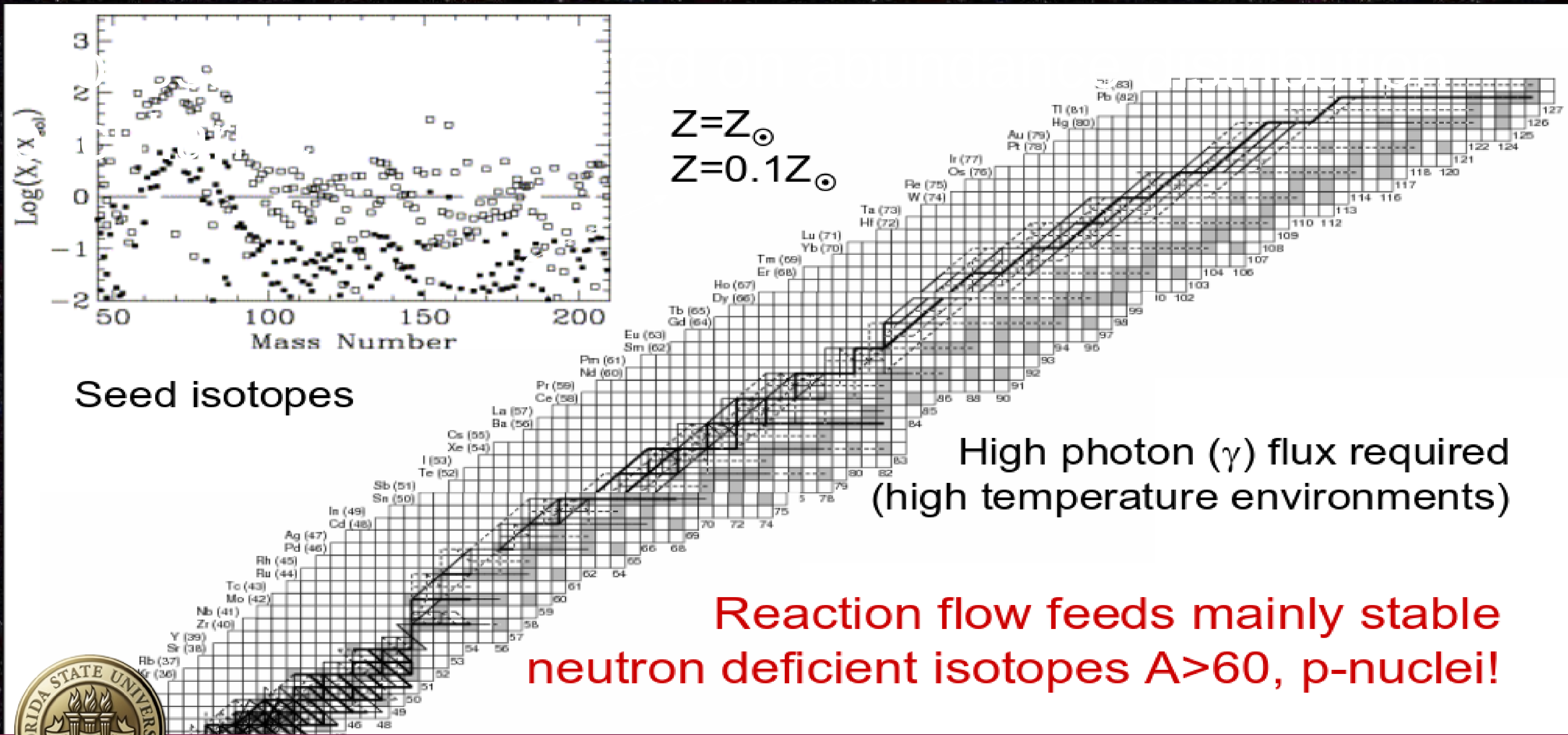
On-site neutron production through neutrino induced interaction: $^{1}H(\nu^{+},e^{+})n$!



Nucleosynthesis beyond A=56

High temperature photo-dissociation:

p-process: photo-dissociation of heavy element abundance seed.



From the Stars …
… to the Lab

John D. Fox Accelerator Lab Interactive Map

Control Facilities

Control Room
Computer Room
Gas Handling Room

TANDEM Vault

RF Source
SNICS
FN TANDEM

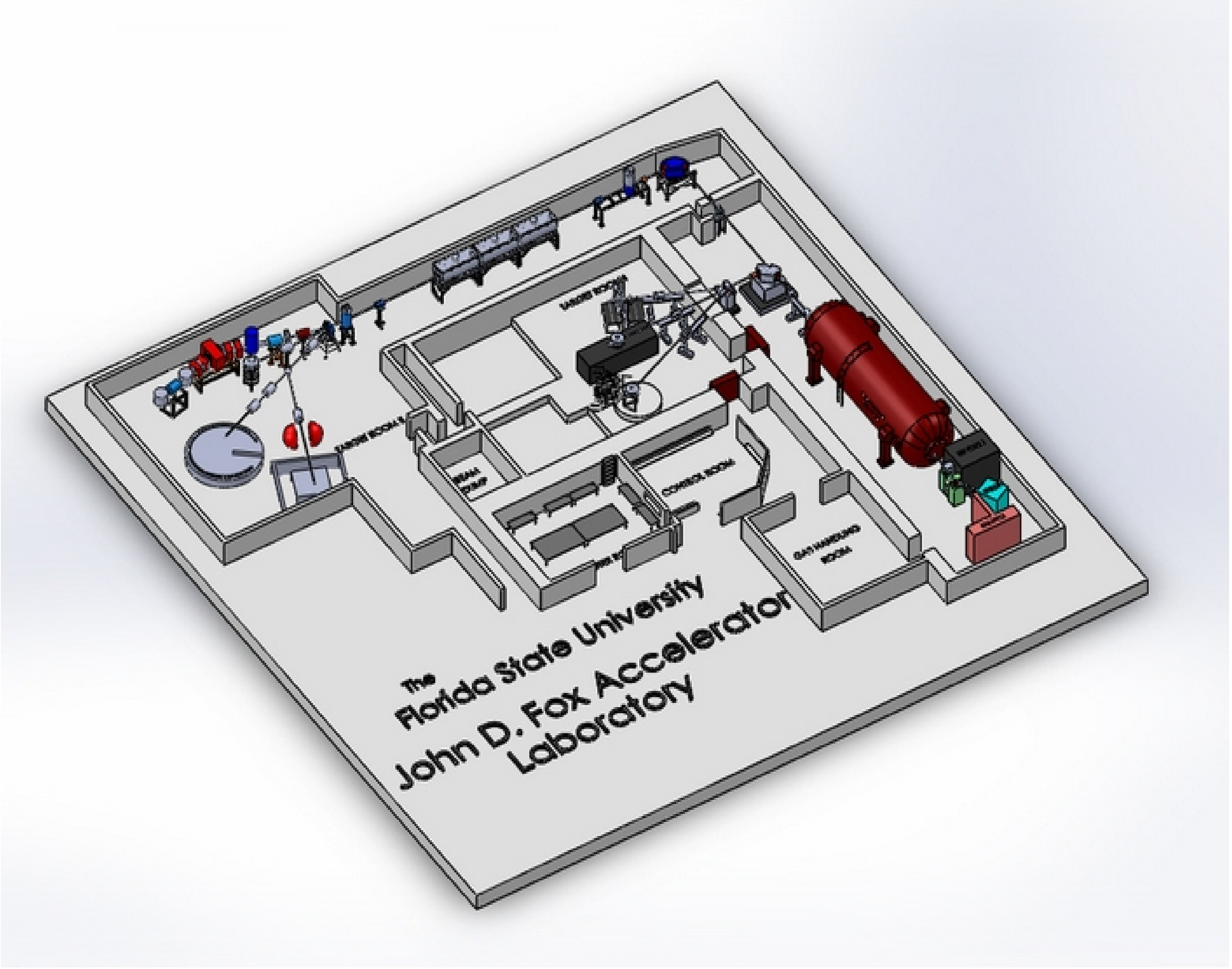
LINAC

Target Room I

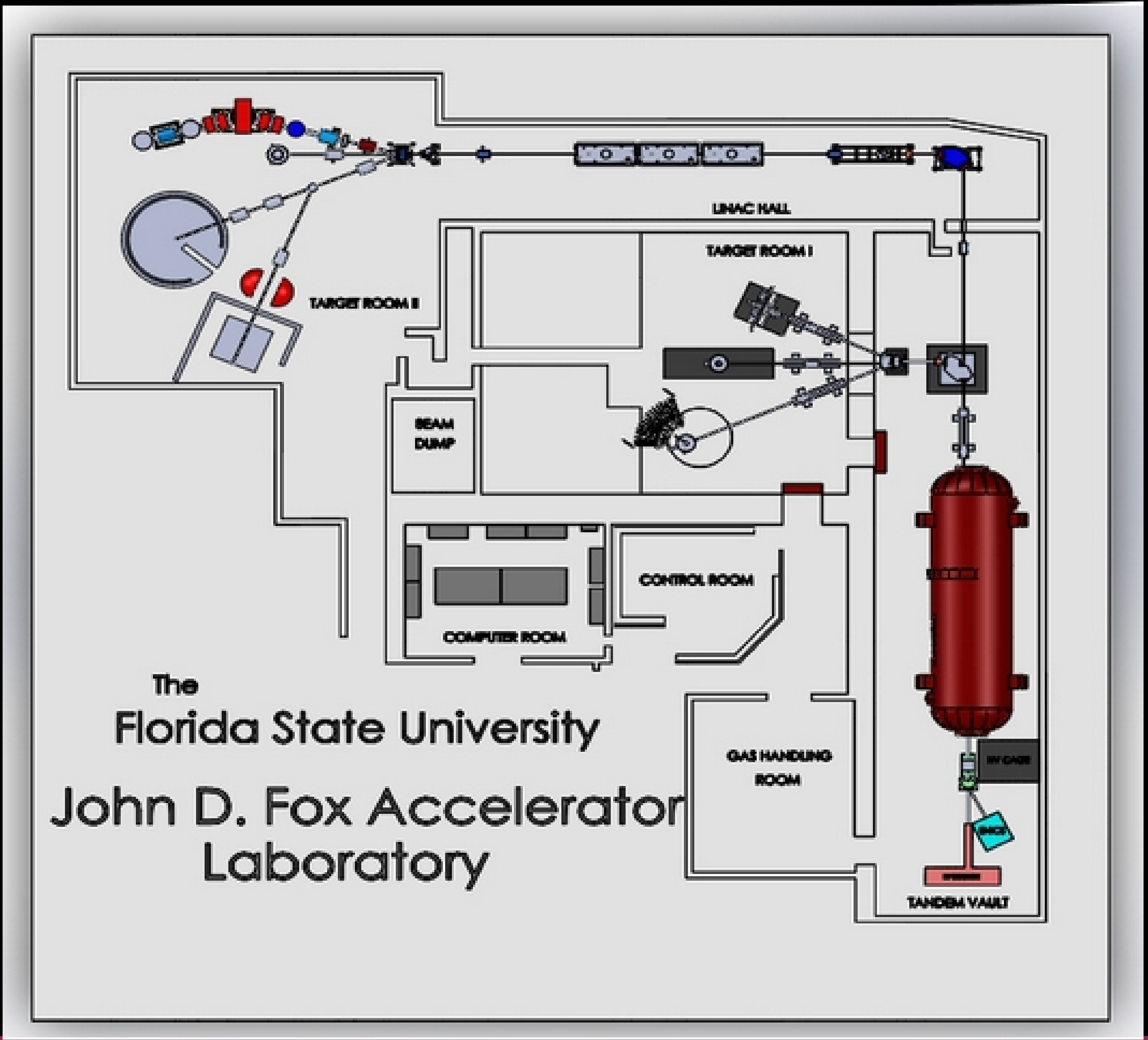
CLOVER
Myers Laser Table
CATRINA

Target Room II

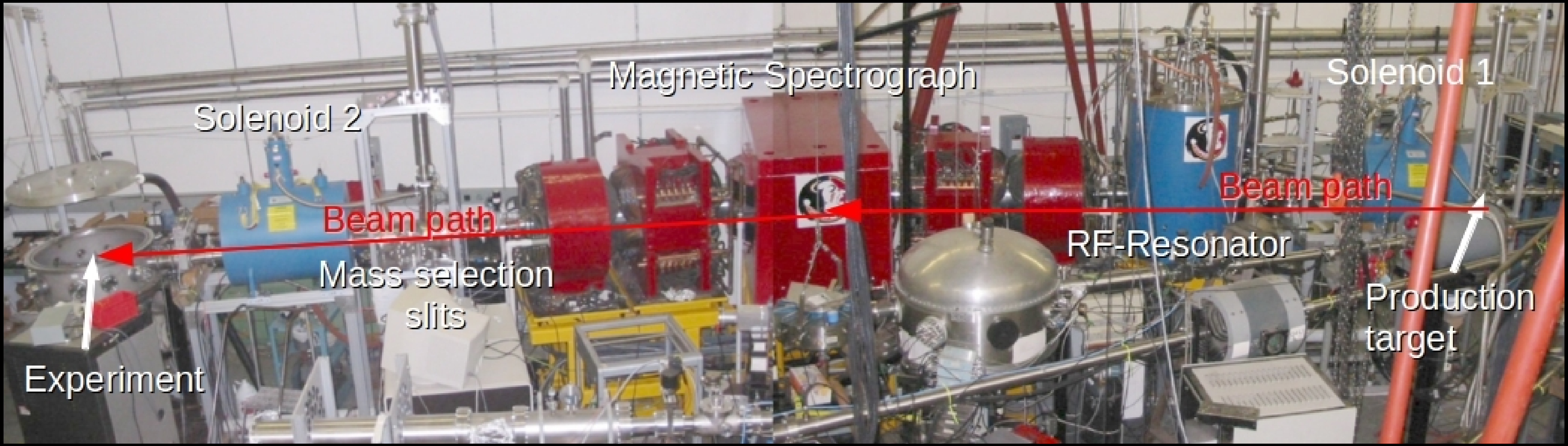
RESOLUT
Kemper Chamber
Spectrograph
mma Cave



Corner View | Top-Down View


LINAC HALL
TARGET ROOM I
TARGET ROOM II
BEAM
DUMP
CONTROL ROOM
COMPUTER ROOM
GAS HANDLING
ROOM
TANDEM VAULT
The
Florida State University
John D. Fox Accelerator
Laboratory

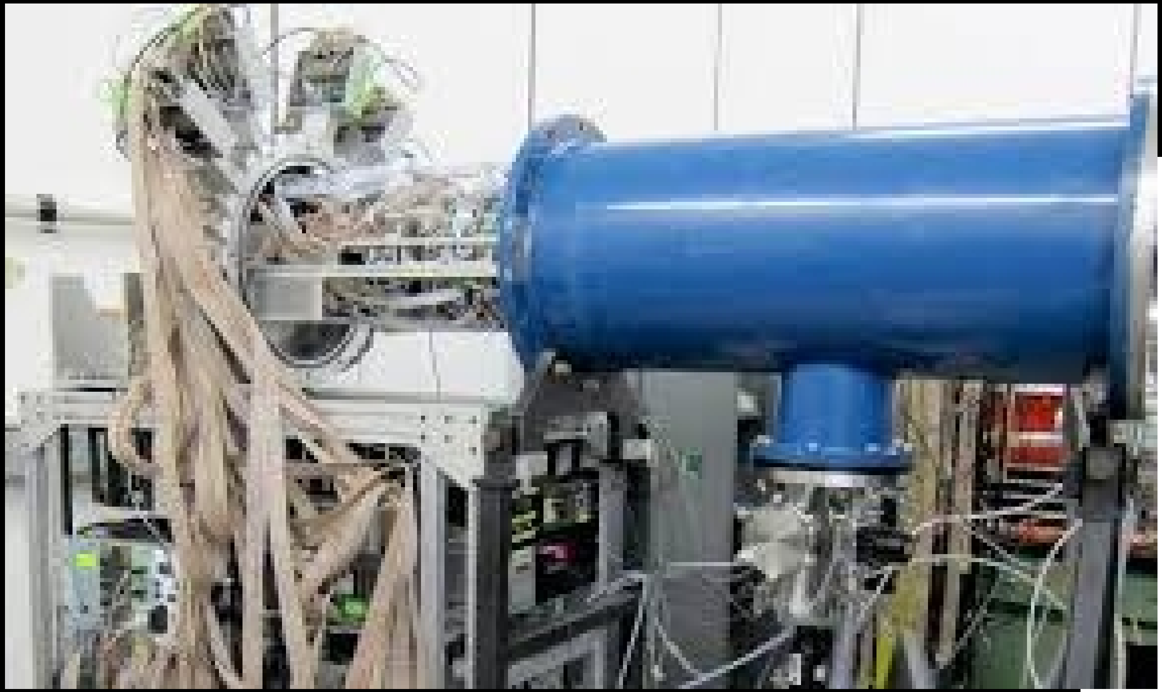
Many of the important reactions involve exotic nuclei and Radioactive ion beams! Study the nuclear structure properties of exotic nuclei.

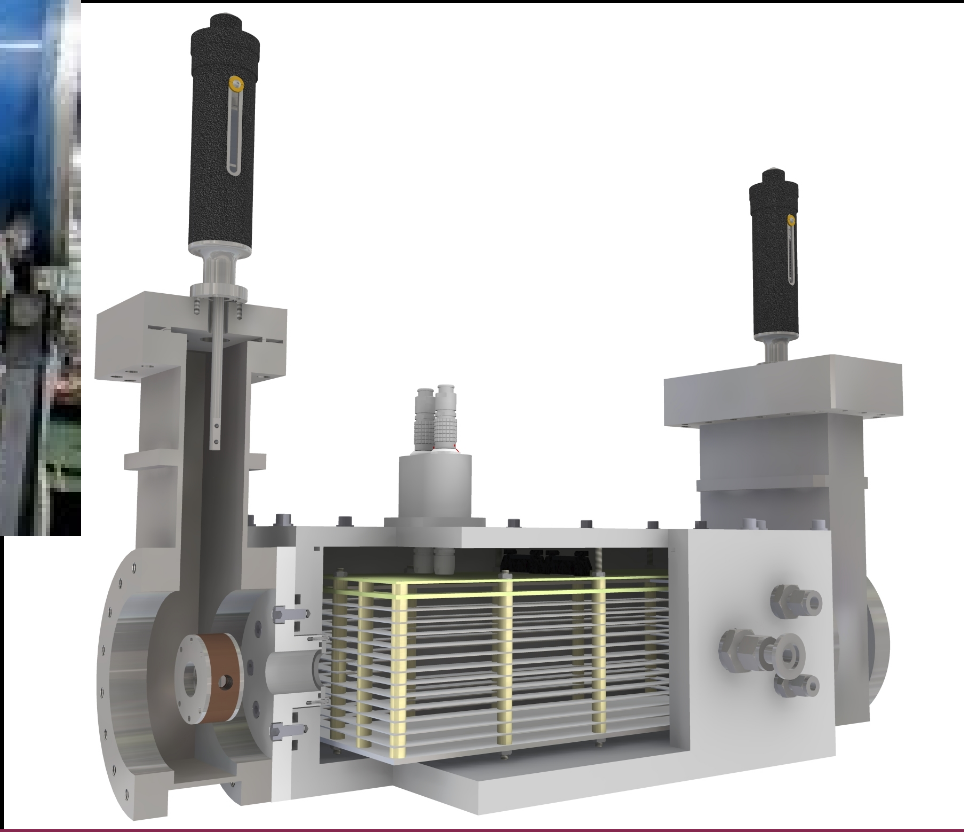


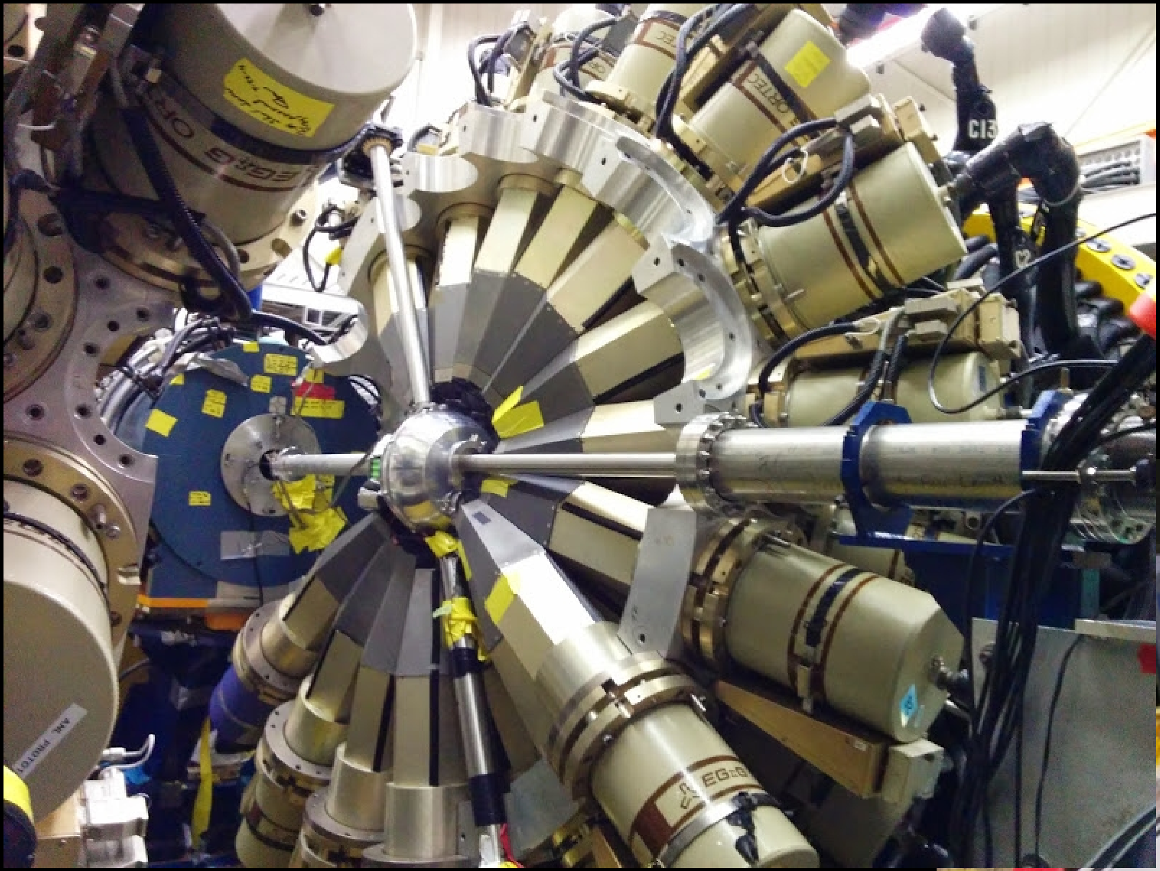
RESOLUT radioactive ion beam facility at FSU

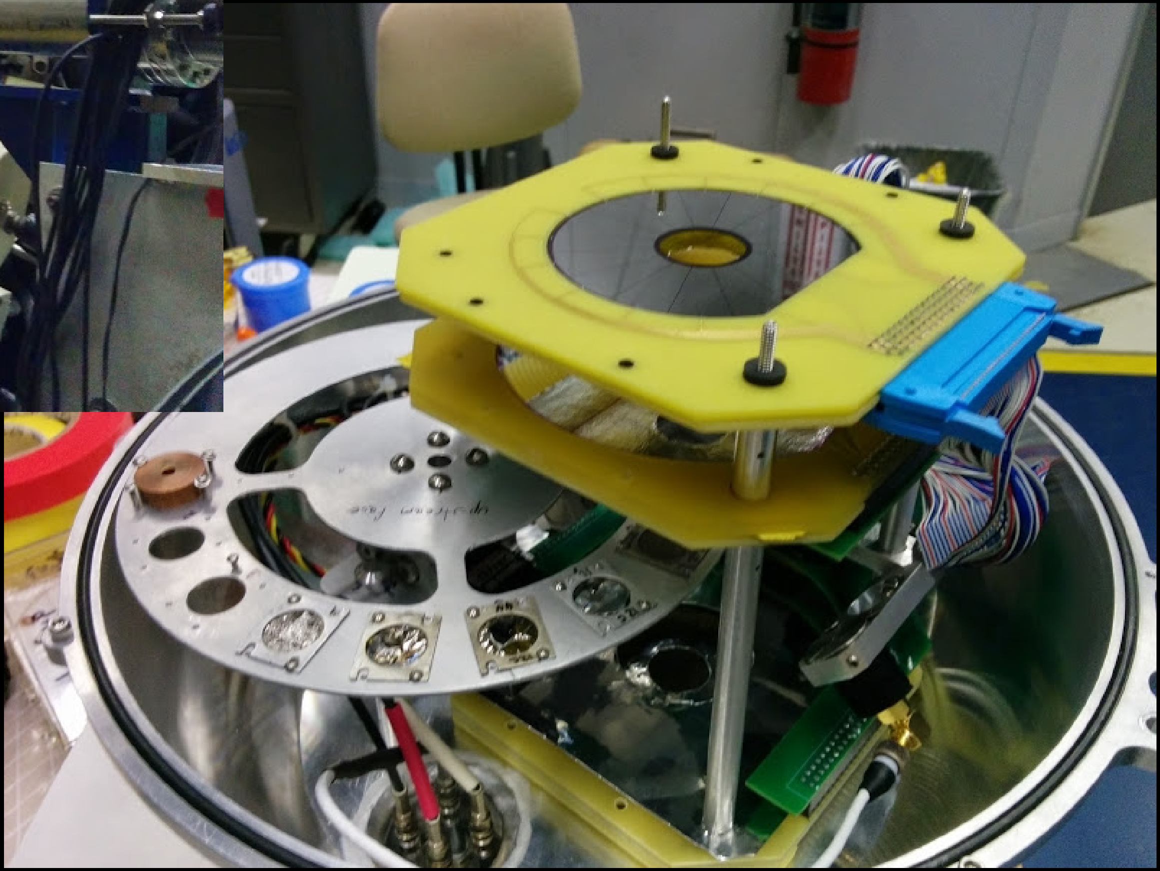
Radiation detection

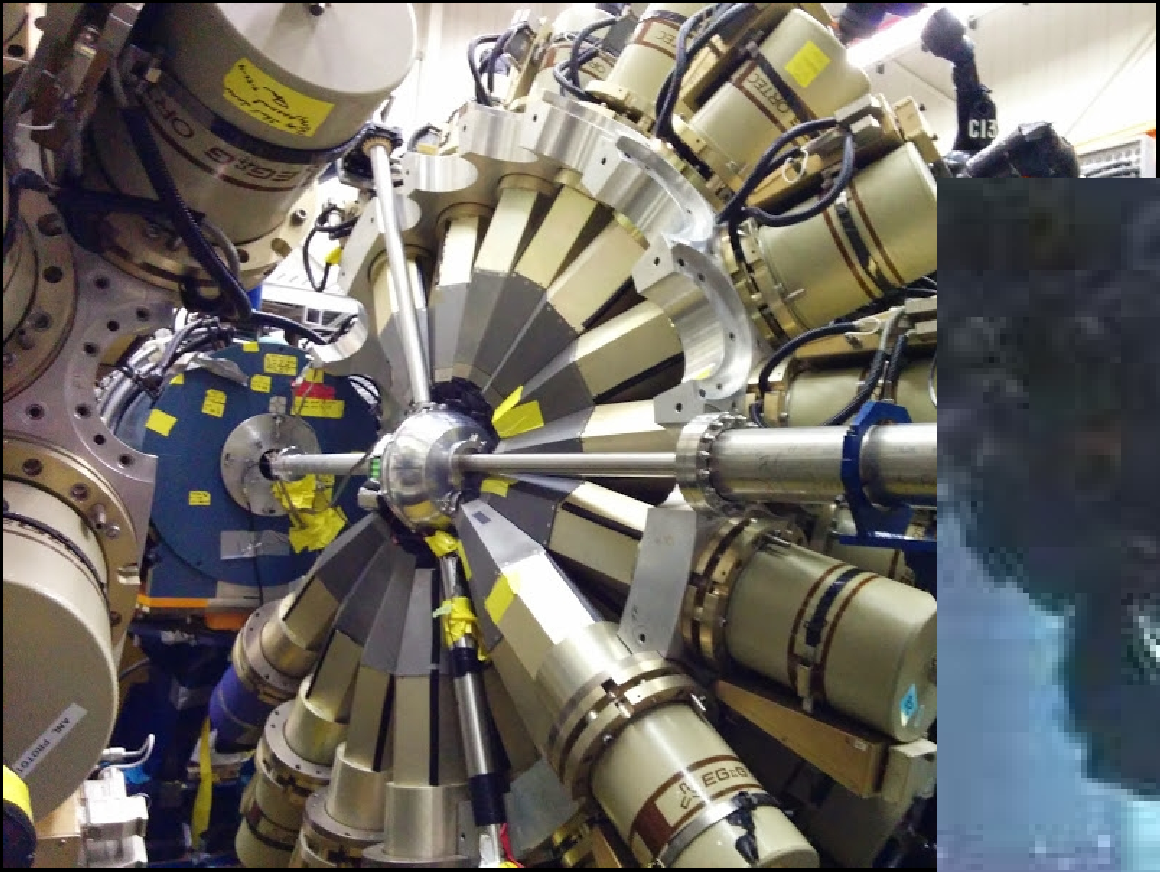
ACTIVE TARGET/DETECTORS



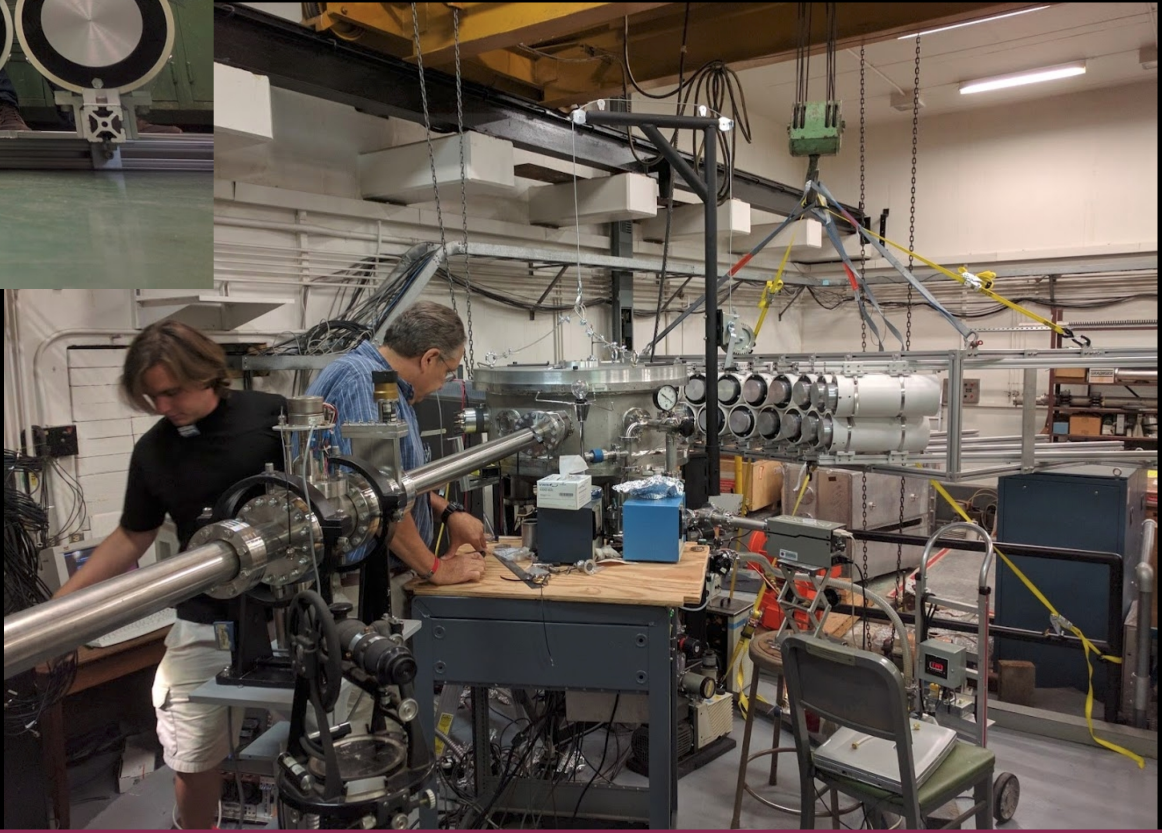


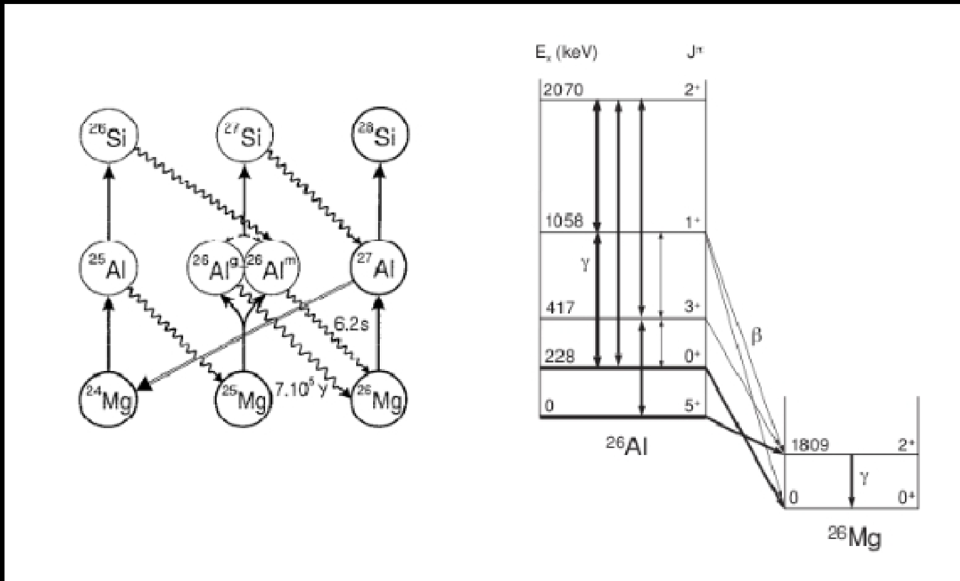

C13

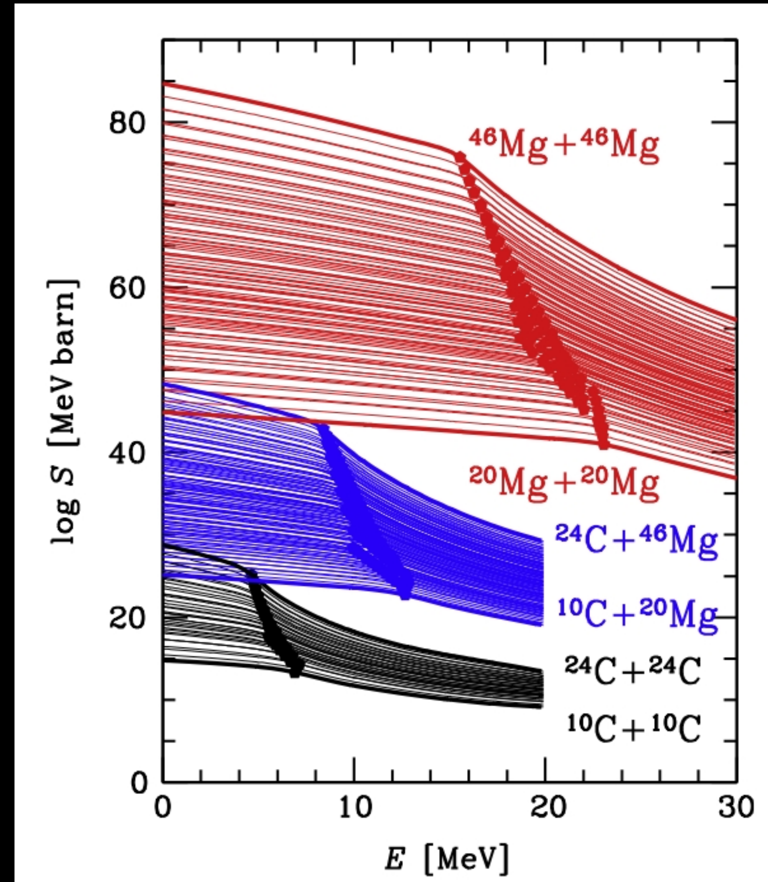


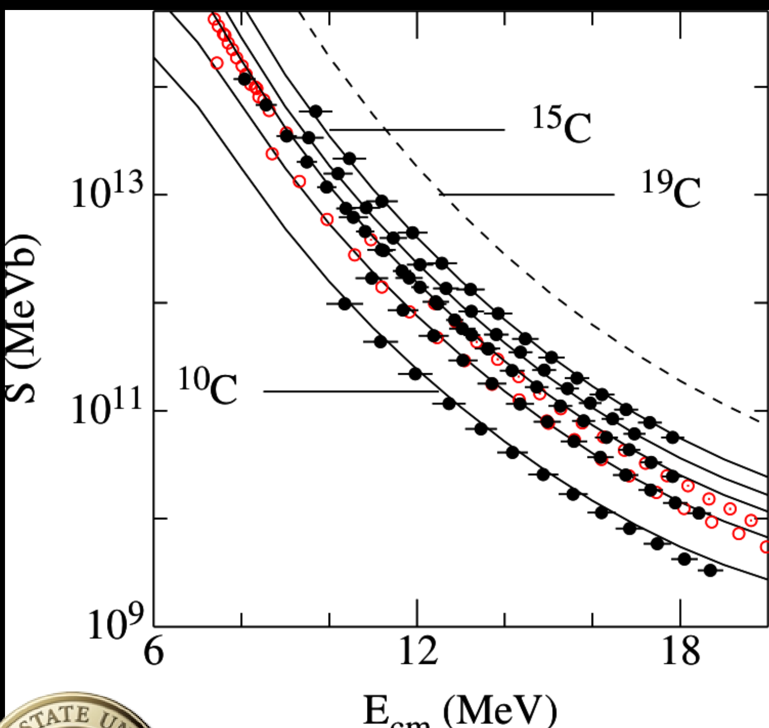


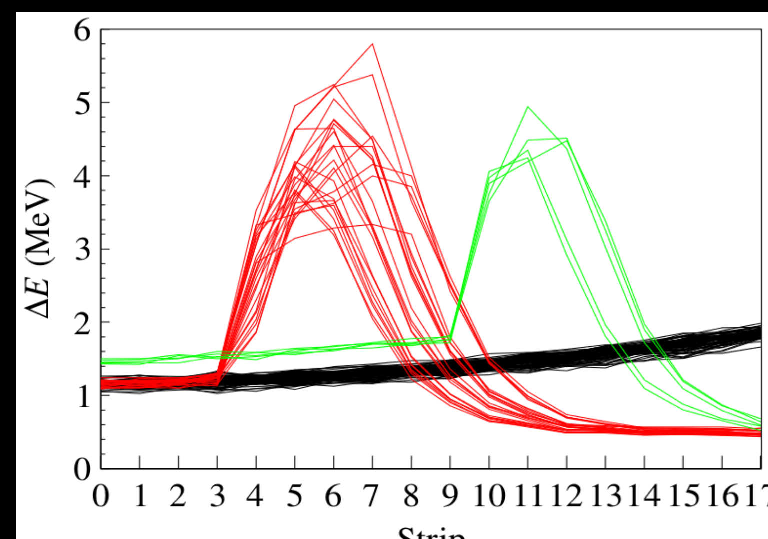

RAKE
SESSION

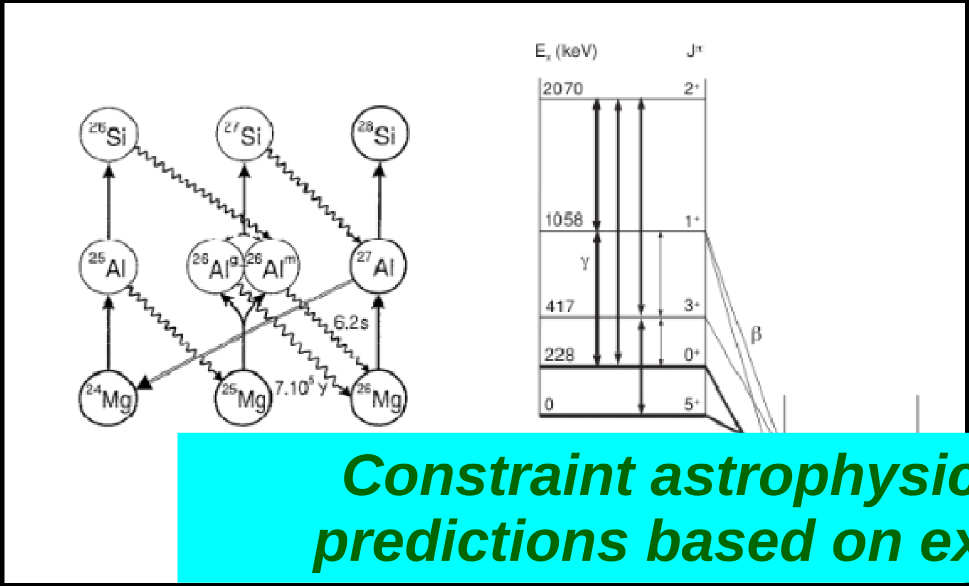


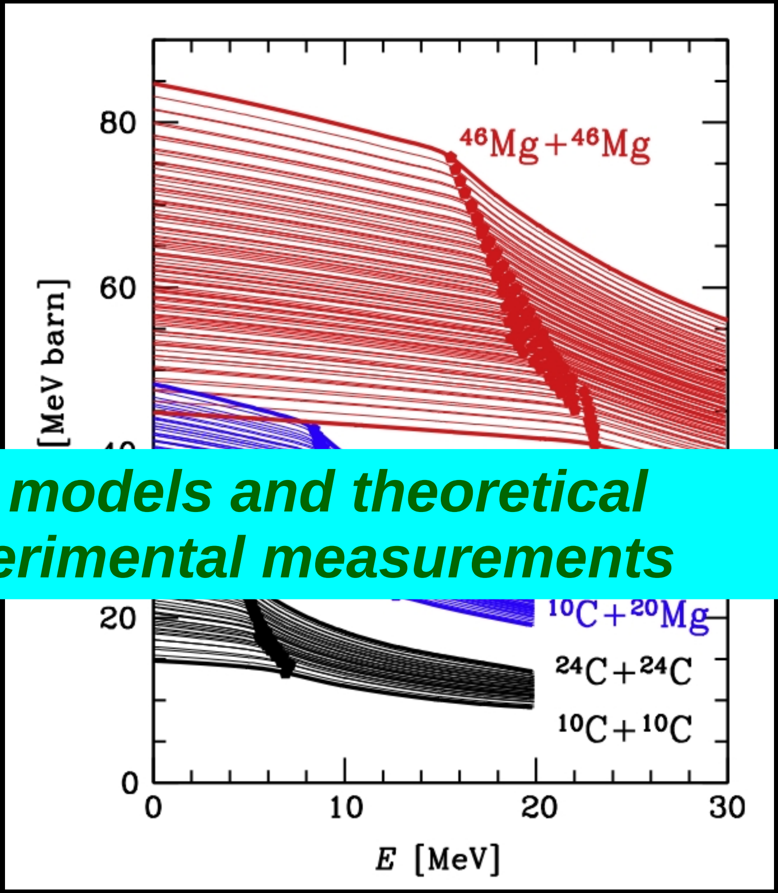

^{26}Si
^{27}Si
^{28}Si
^{25}Al
^{26}Al^{g}
^{26}Al^{m}
^{27}Al
6.2s
^{24}Mg
^{25}Mg
7.10^{5} y
^{26}Mg
E$_x$ (keV)
J$^\pi$
2070
1058
417
228
0
2$^+$
1$^+$
3$^+$
0$^+$
5$^+$
γ
β
^{26}Al
1809
0
2$^+$
0$^+$
^{26}Mg


log S [MeV barn]
E [MeV]
^{46}Mg+^{46}Mg
^{20}Mg+^{20}Mg
^{24}C+^{46}Mg
^{10}C+^{20}Mg
^{24}C+^{24}C
^{10}C+^{10}C

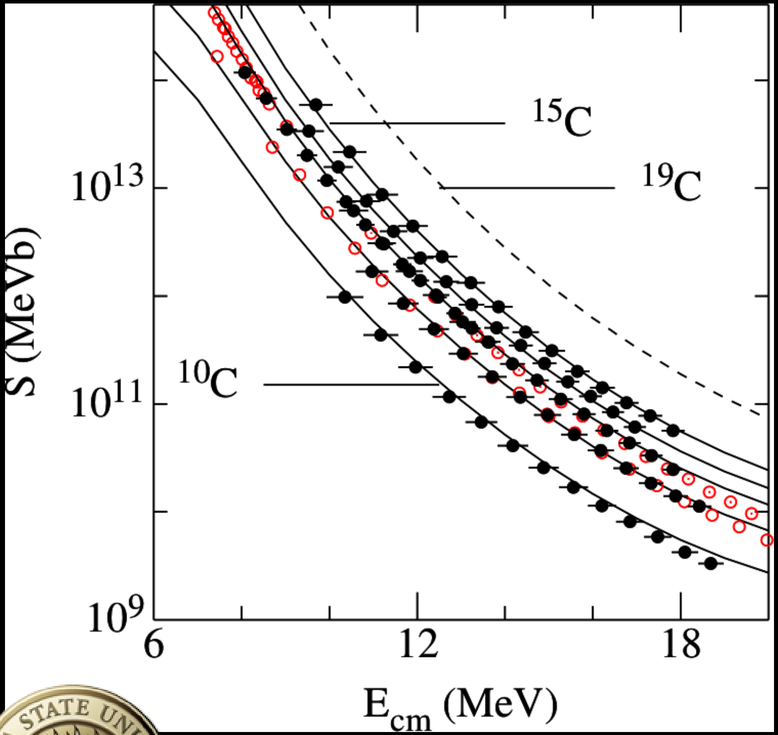

S (MeVb)
E$_{cm}$ (MeV)
^{15}C
^{19}C
^{10}C

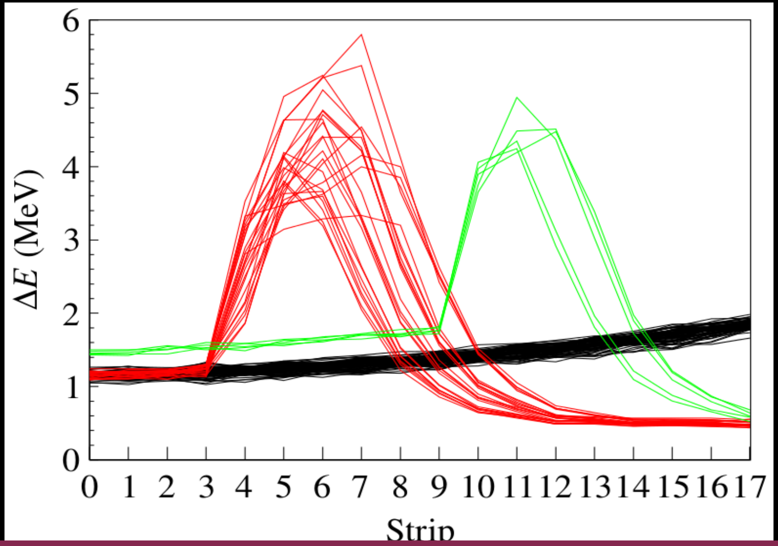

ΔE (MeV)
Strip

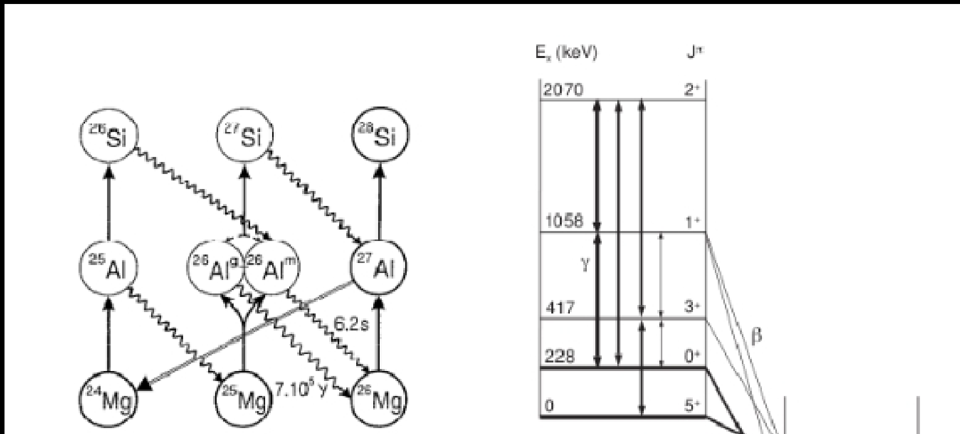


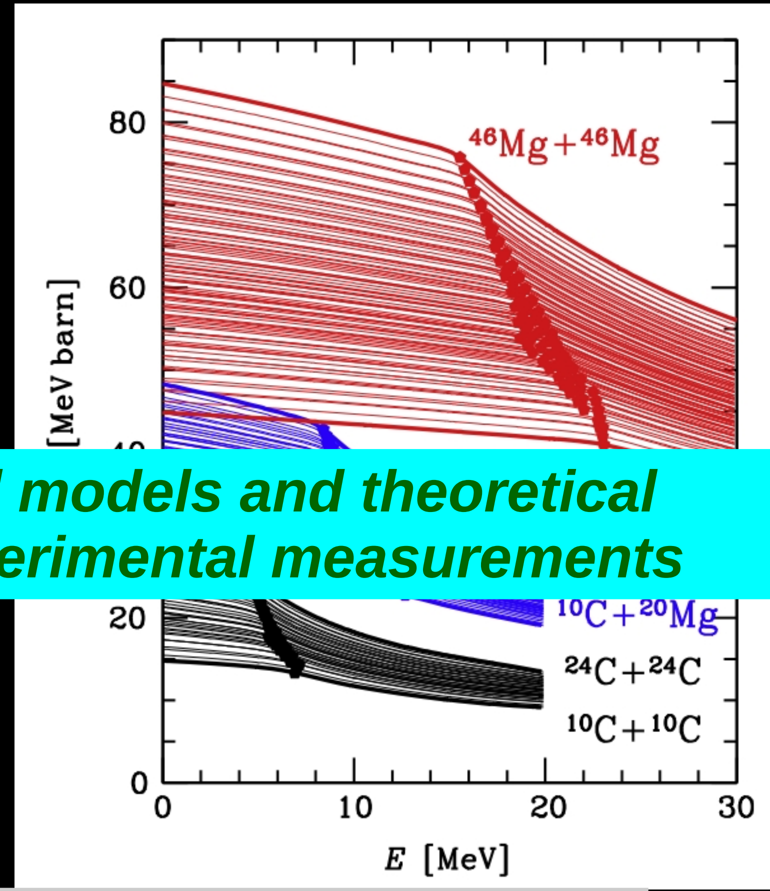


Constraint astrophysical models and theoretical predictions based on experimental measurements









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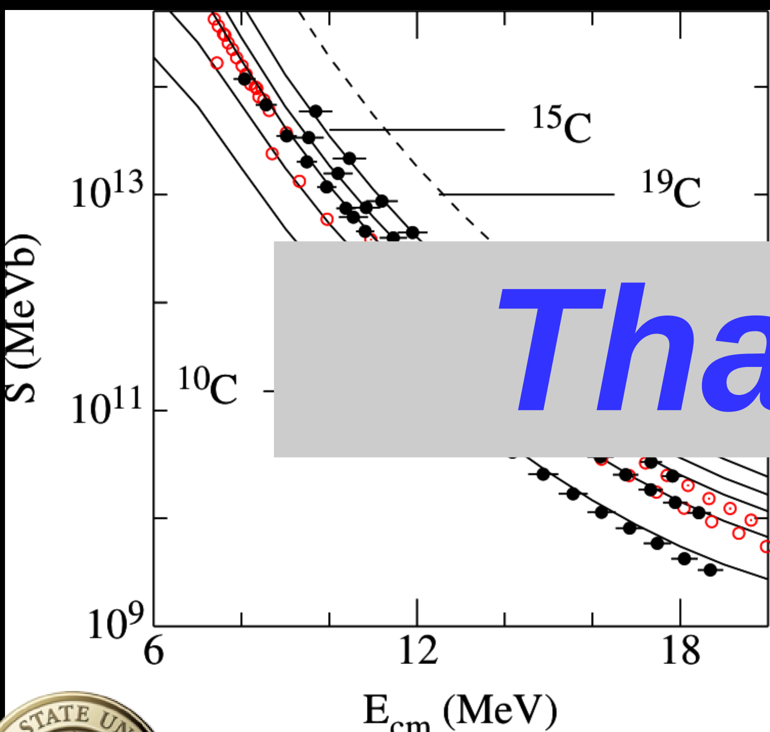

Thank you!