



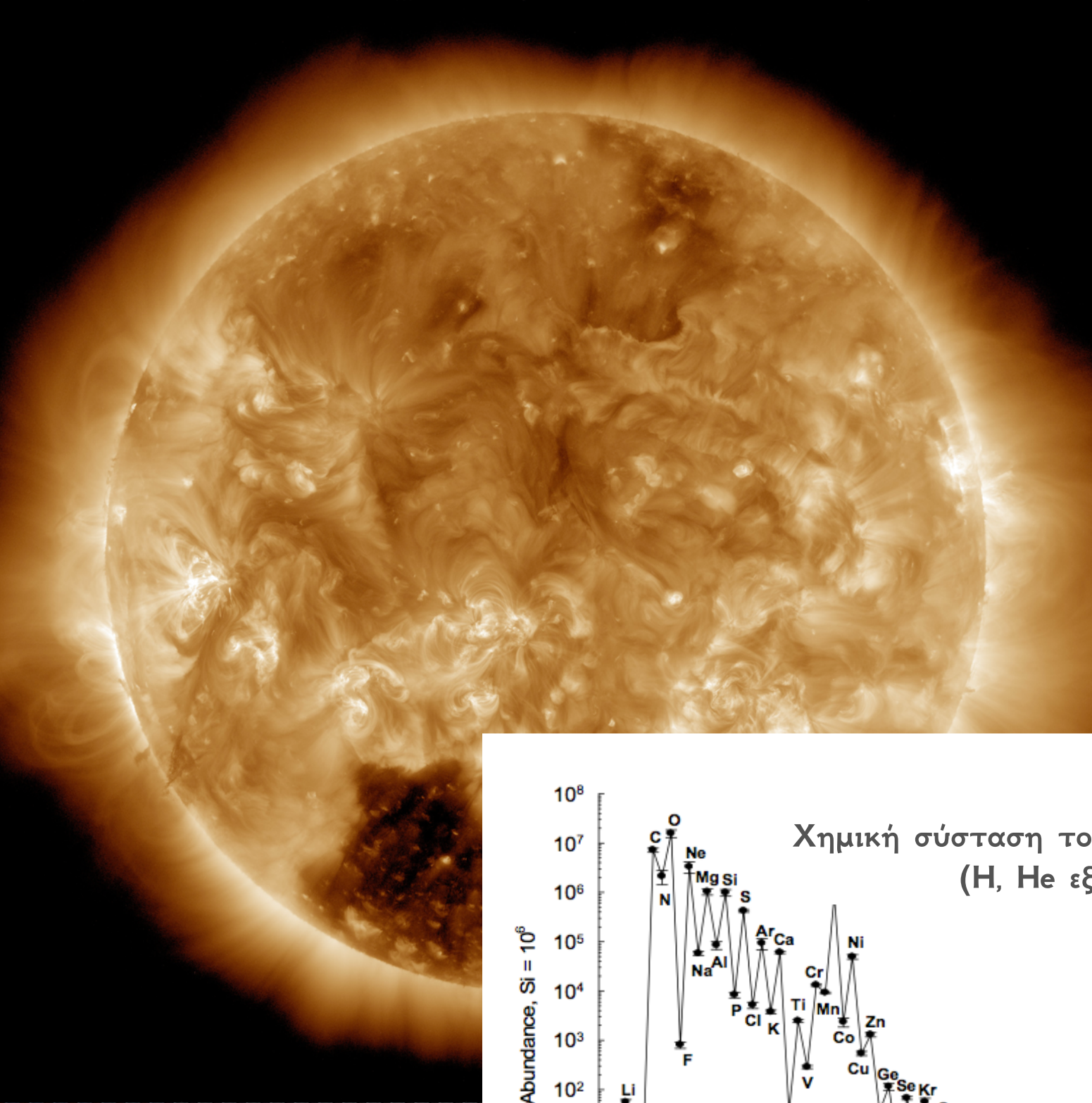
U.S. DEPARTMENT OF
ENERGY

Office of
Science

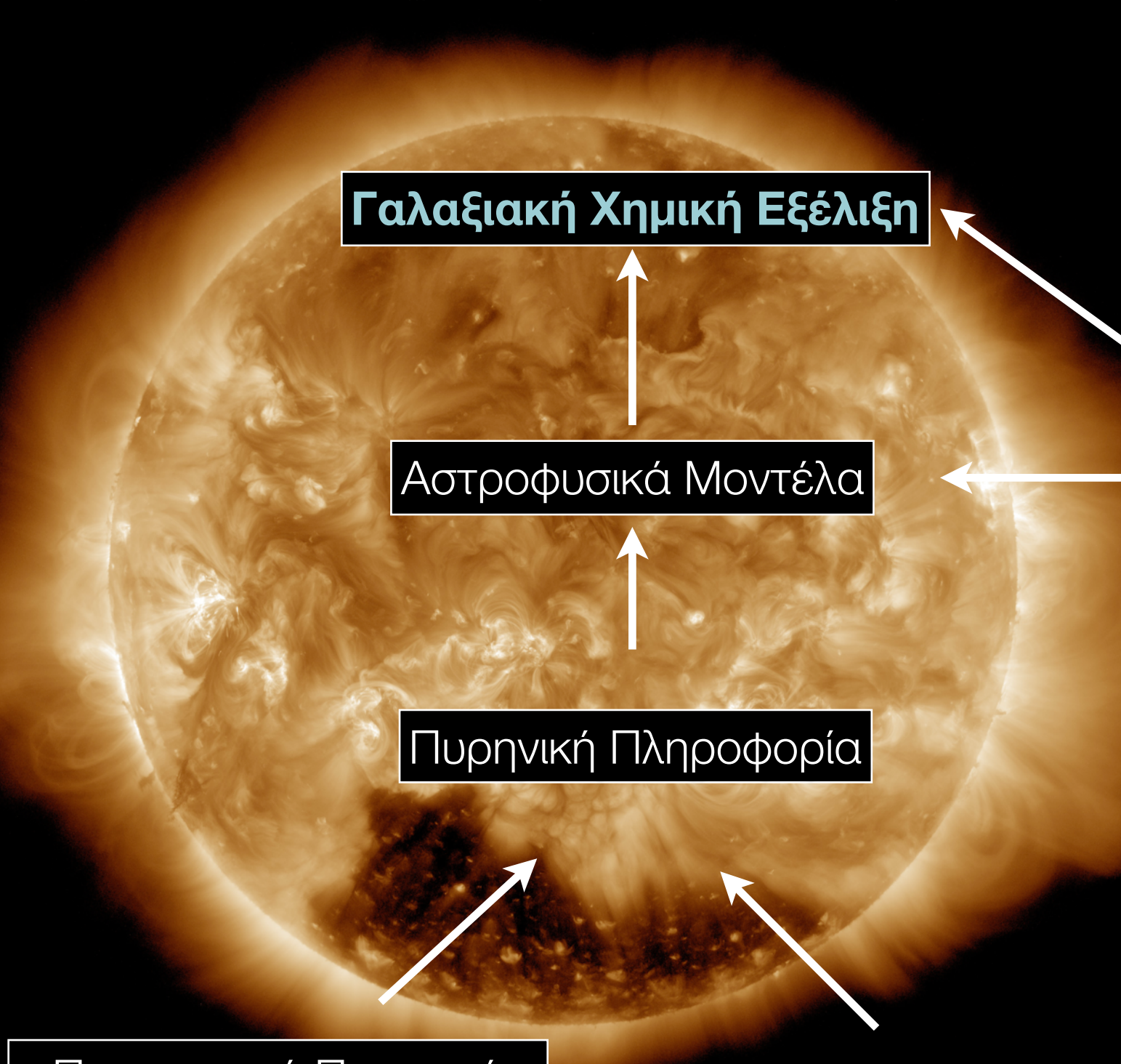
Βίαιοι θάνατοι, εκρηκτικές γεννήσεις και πυρηνικές αντιδράσεις στα άστρα. Ανοιχτά ερωτήματα για την προέλευση των βαρέων στοιχείων

Γ. Περδικάκης, Central Michigan University





Lodders et al 2010



Γαλαξιακή Χημική Εξέλιξη

Αστροφυσικά Μοντέλα

Πυρηνική Πληροφορία

Πειραματική Πυρηνική Φυσική

Πυρηνική θεωρία

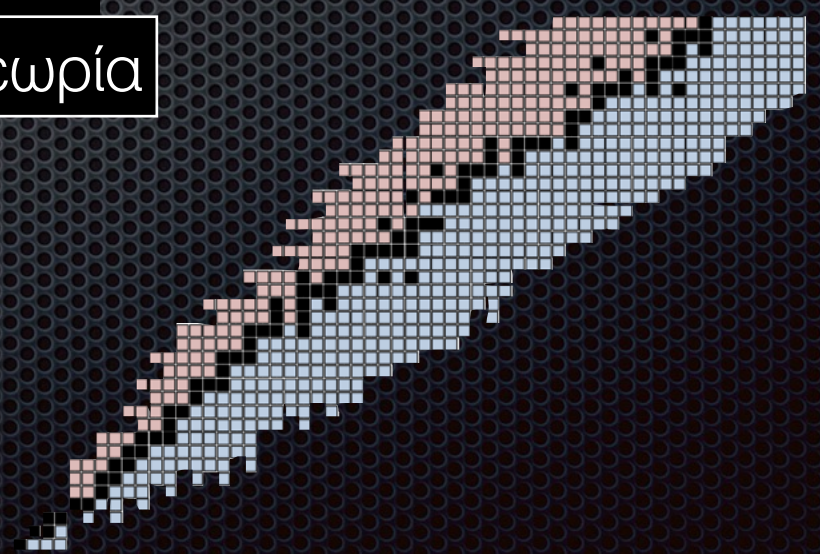


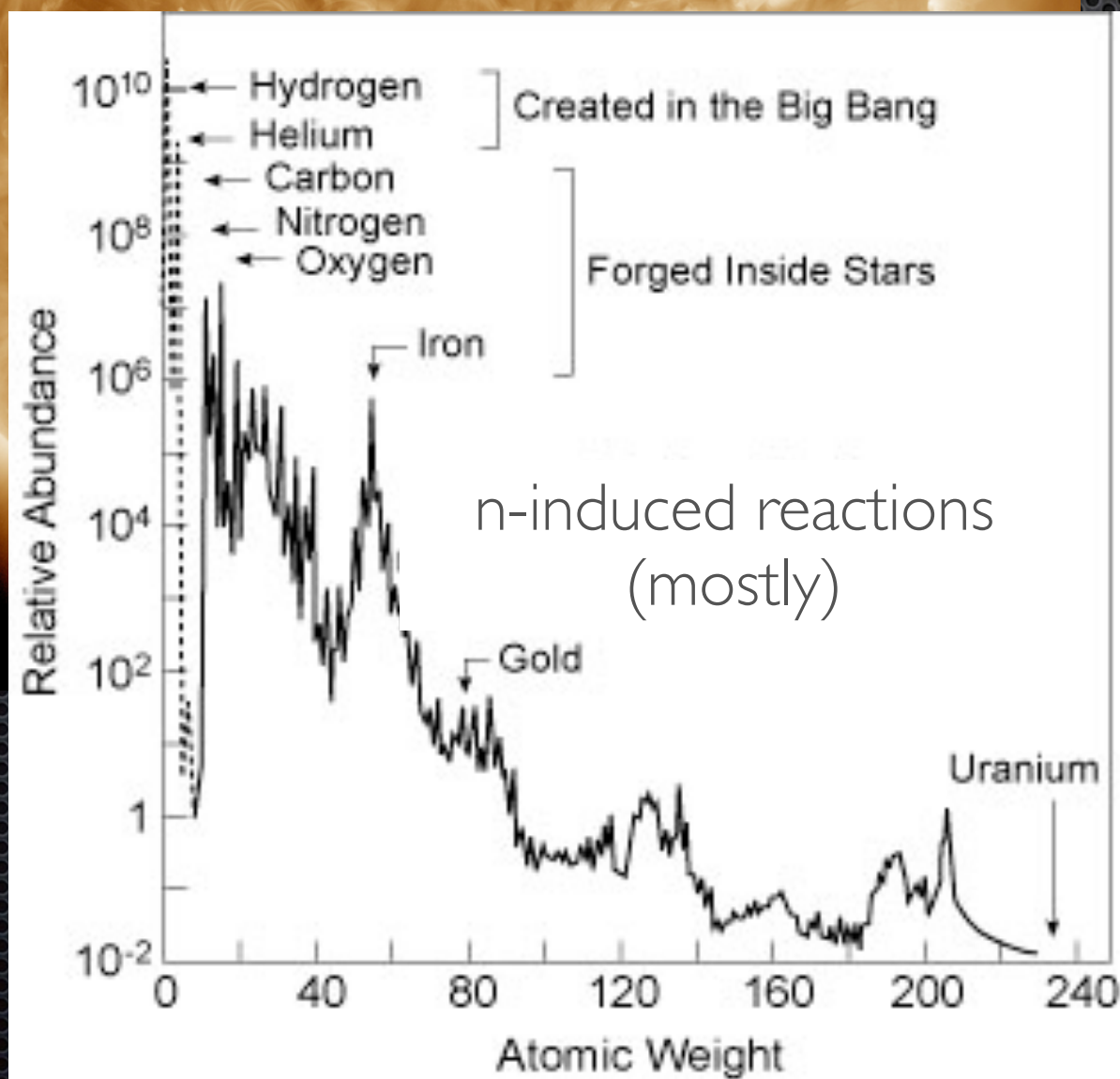
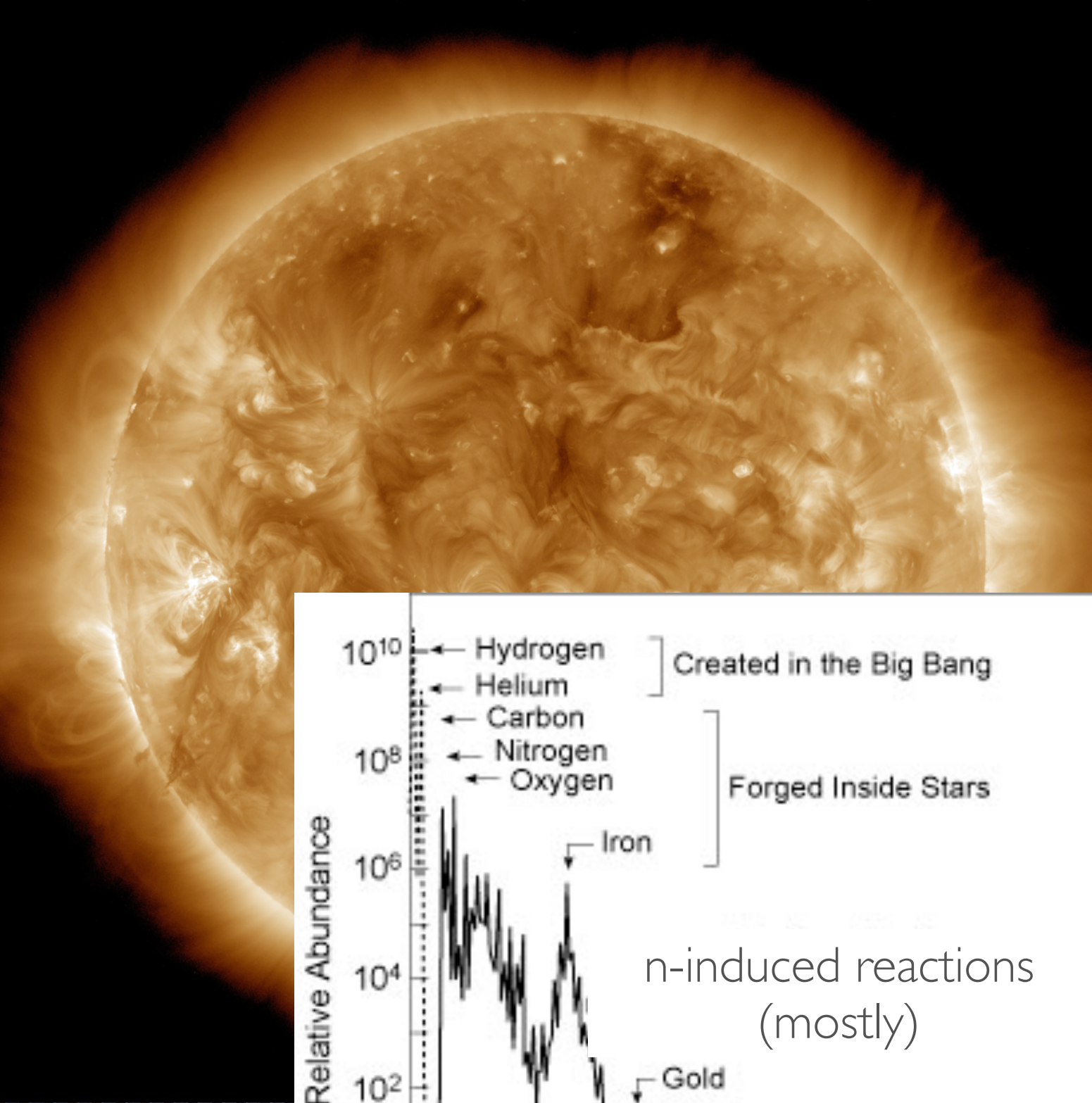
Παρατηρησιακή Αστροφυσική

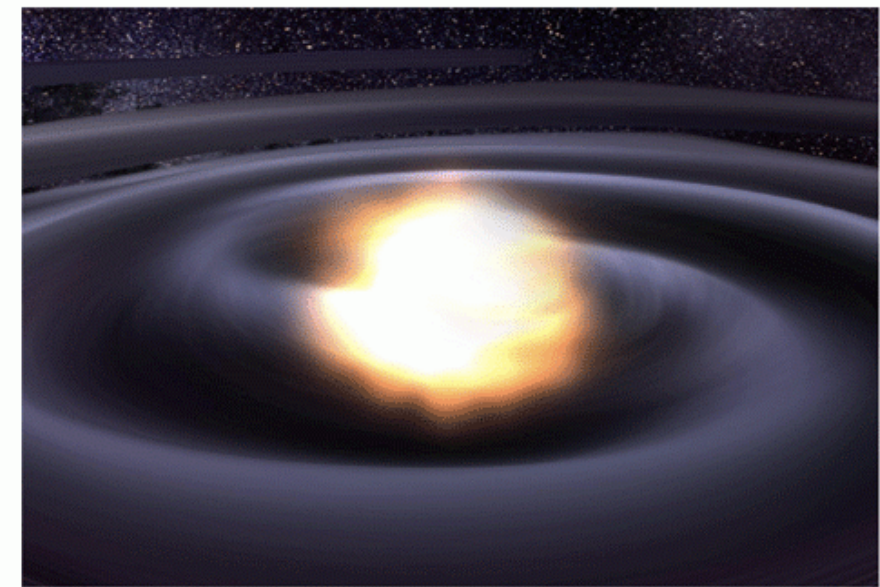
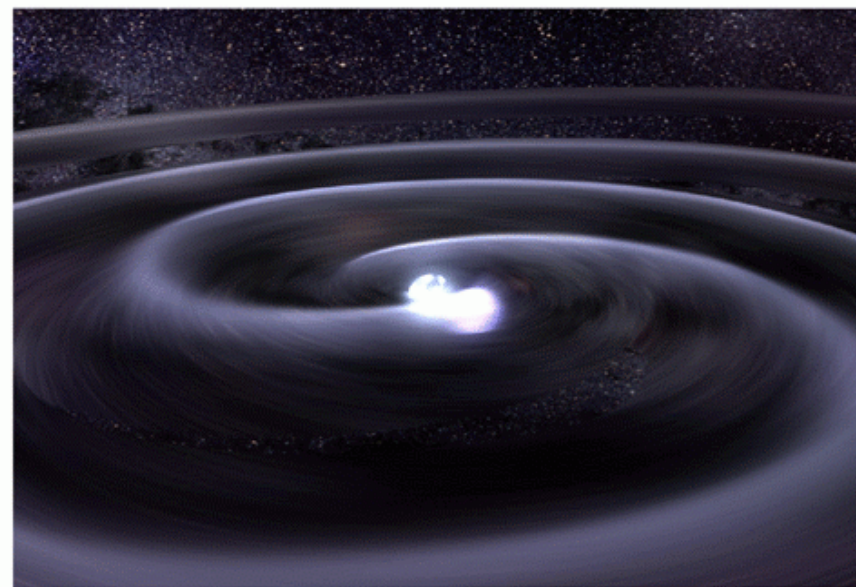
purple, 1 cm clasts, are CAIs (calcium-aluminum-rich inclusions). They were the first materials to condense in the cooling early Solar nebula. These clasts

- Φάσματα (Μεγάλα Τηλεσκόπια)
- Πλανητική (γήινη) ύλη, Μετεωρίτες
- Μεσοαστρικός χώρος (Διαστημικές αποστολές)

- Ενεργές Διατομές
- Πυρηνική Δομή
- Μάζες



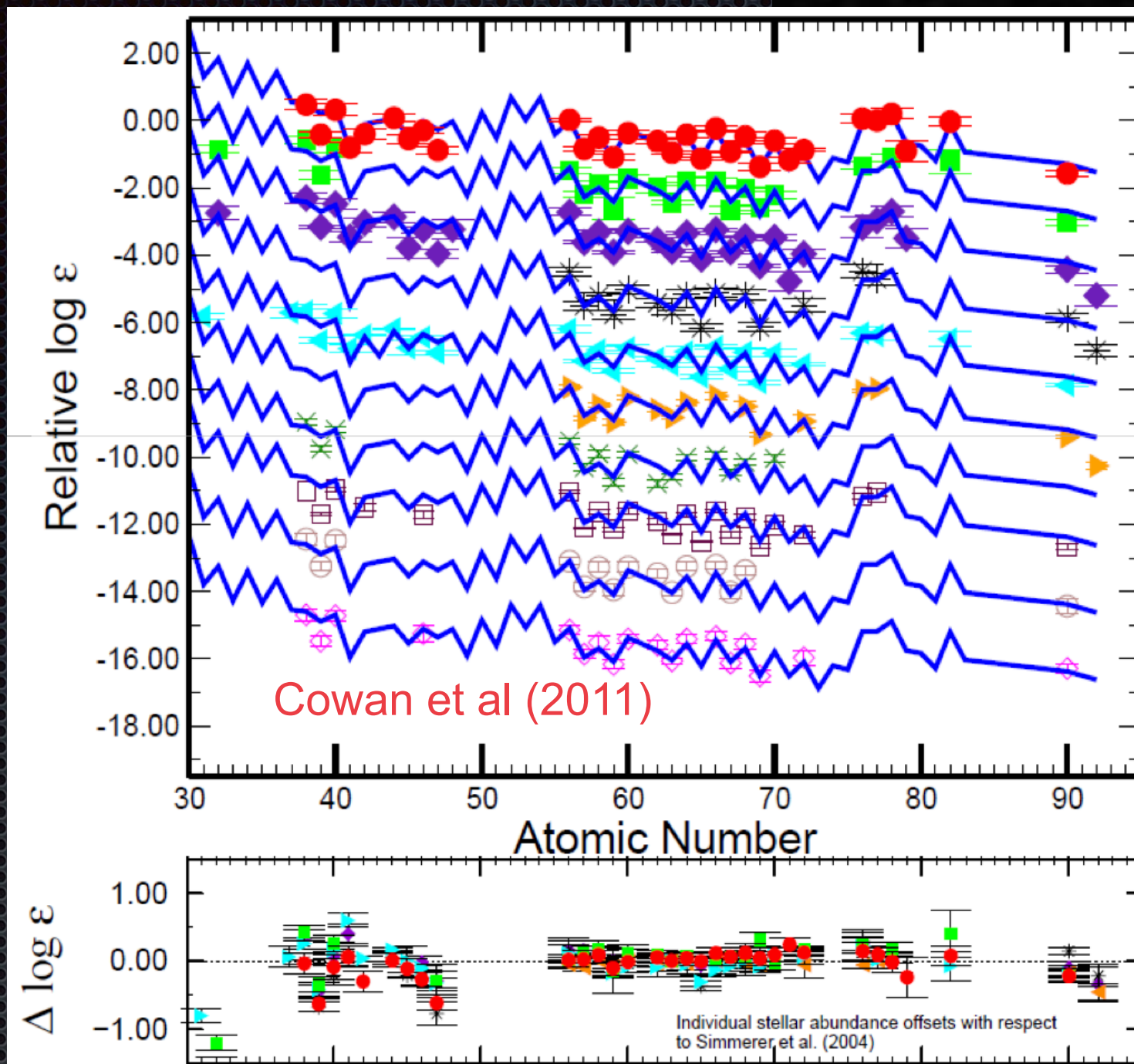




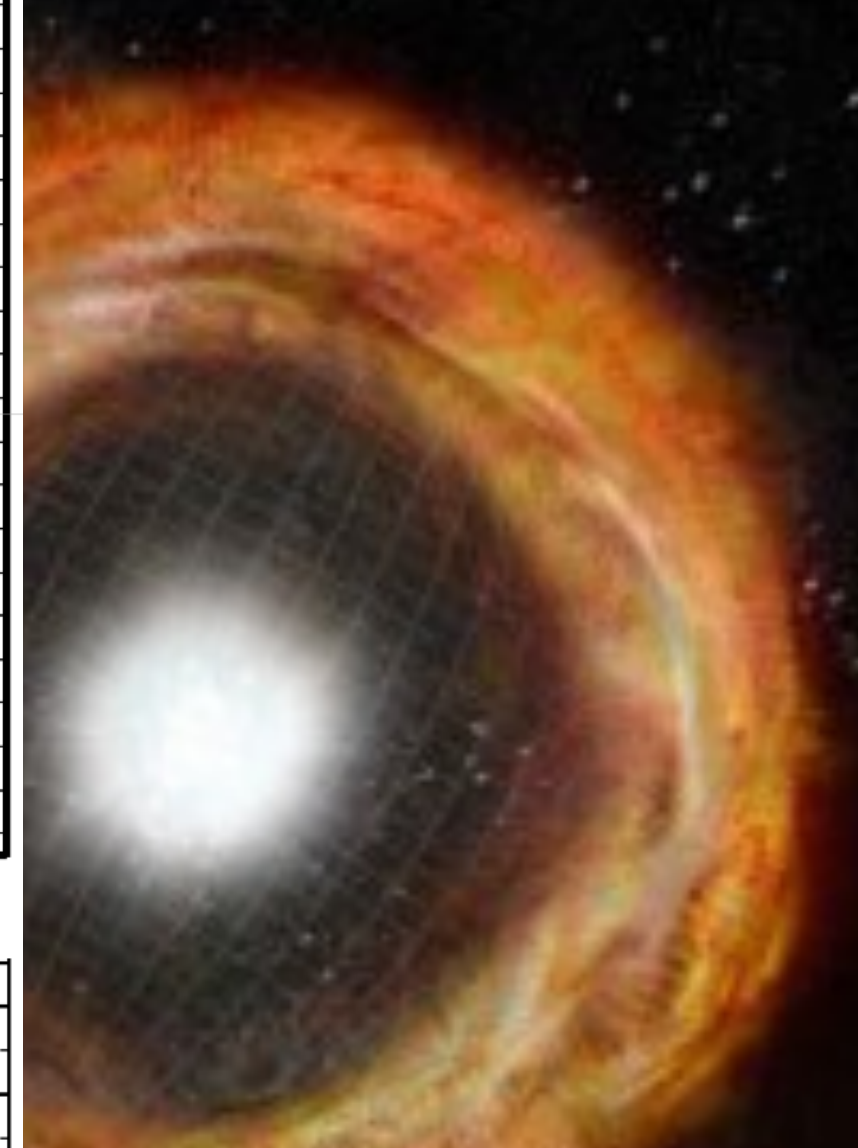
Υπέρ: Ιδανικές συνθήκες

Κατά: Δεν έχουμε ακόμα αδιαμφισβήτητη παρατήρηση, σπάνιο φαινόμενο

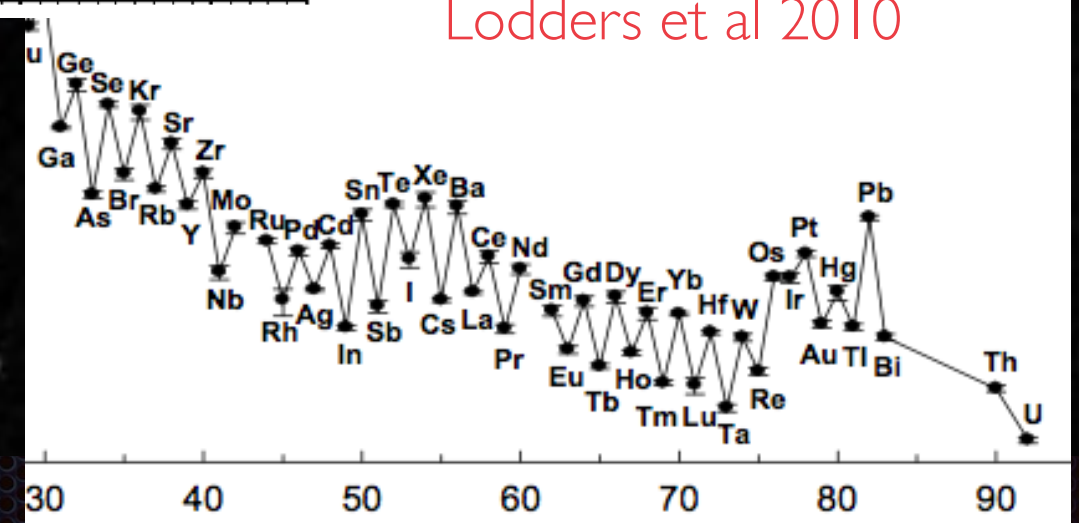
ΑΣΤΡΙΚΗ ΑΡΧΑΙΟΛΟΓΙΑ - ΜΕΛΕΤΩΝΤΑΣ ΤΑ ΠΑΛΑΙΟΤΕΡΑ ΑΣΤΡΑ



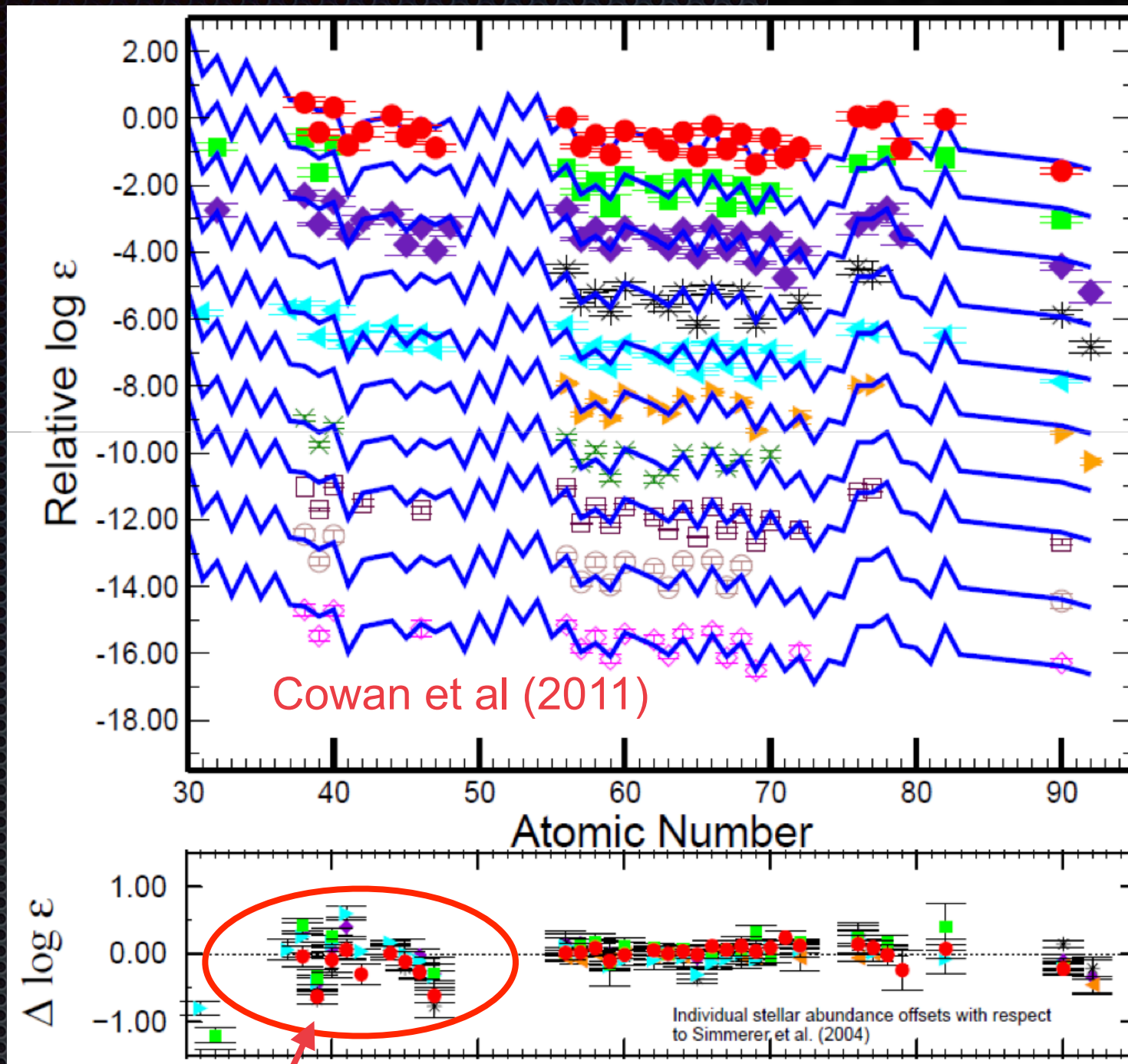
Διατριβή Π. Γάστη



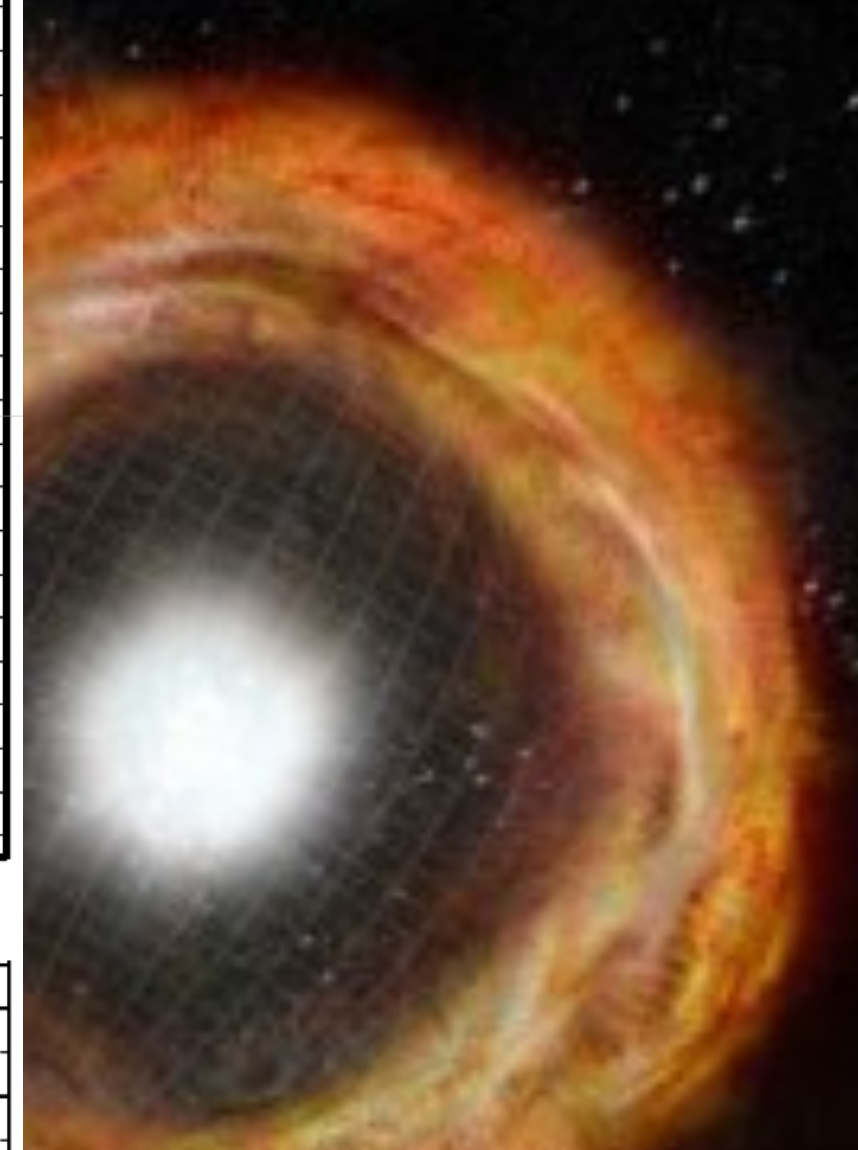
Lodders et al 2010



ΑΣΤΡΙΚΗ ΑΡΧΑΙΟΛΟΓΙΑ - ΜΕΛΕΤΩΝΤΑΣ ΤΑ ΠΑΛΑΙΟΤΕΡΑ ΑΣΤΡΑ

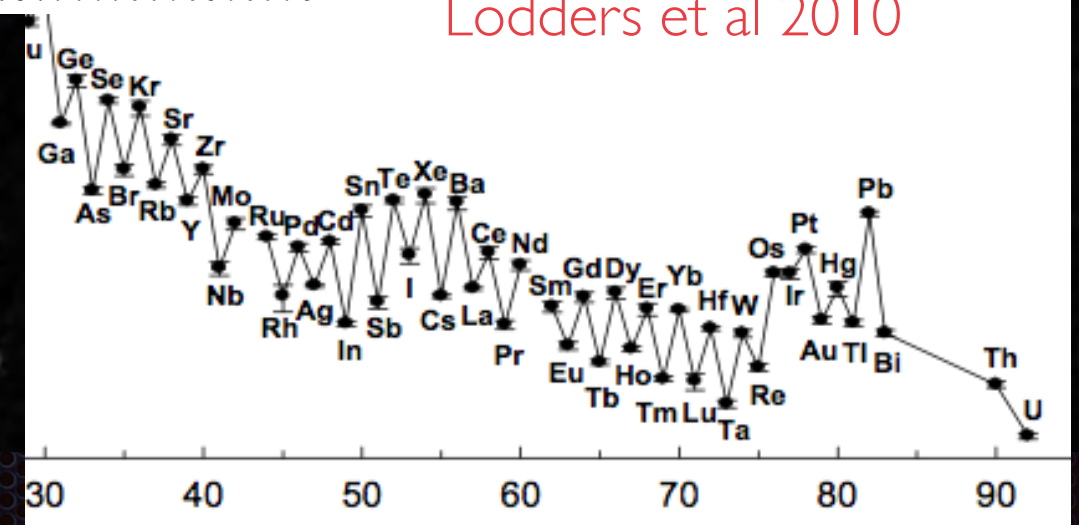


Διατριβή Π. Γάστη

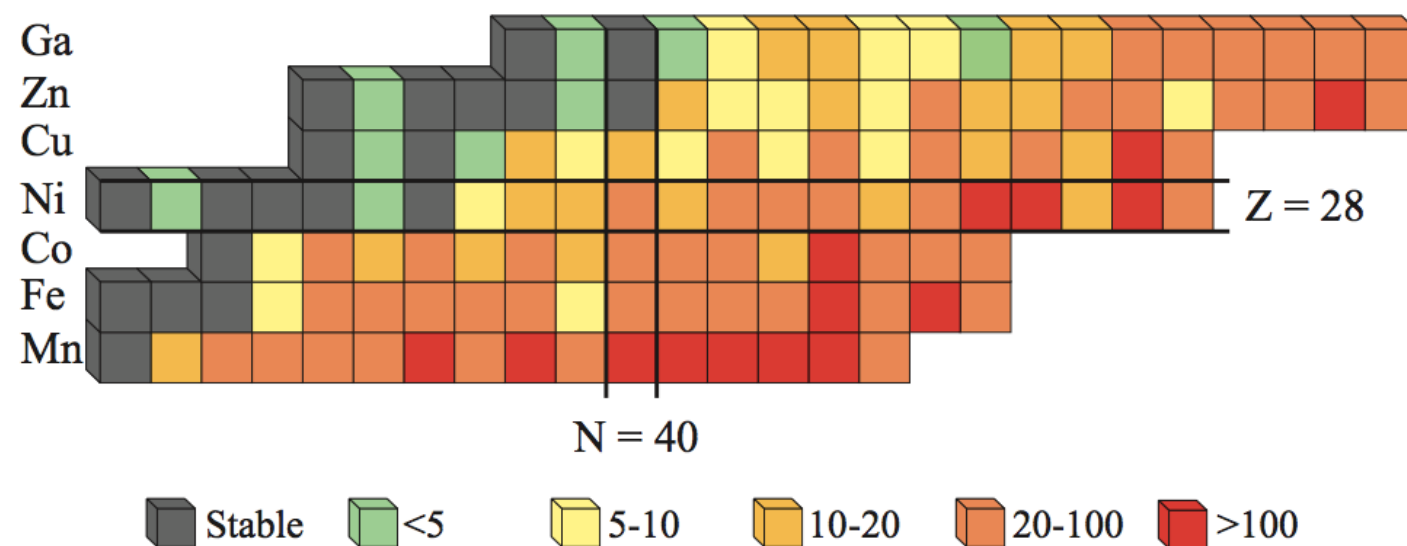
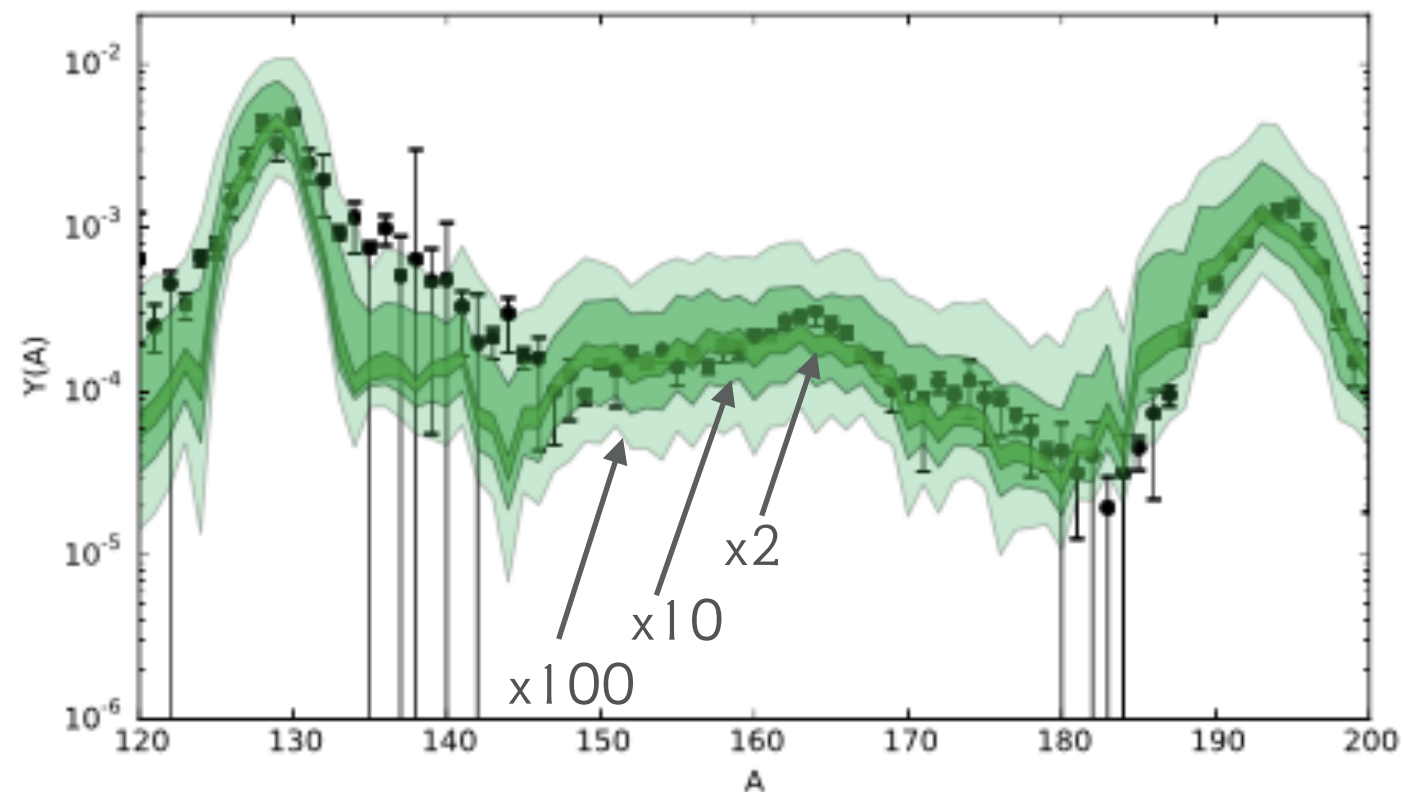


Lodders et al 2010

Διεργασία LEPP
(Lighter Element Primary Process)
(Μηχανισμός Άγνωστος)
Qian and Wasserburg, 2007
Montes et al., 2007

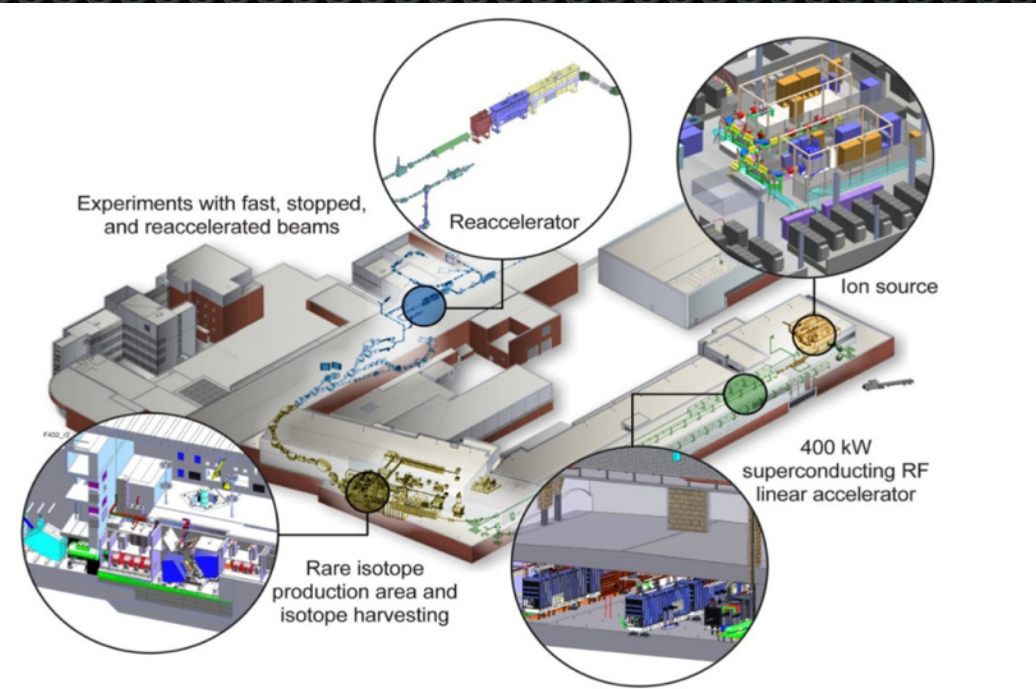


Σημασία της Υπολογιστικής αβεβαιότητας

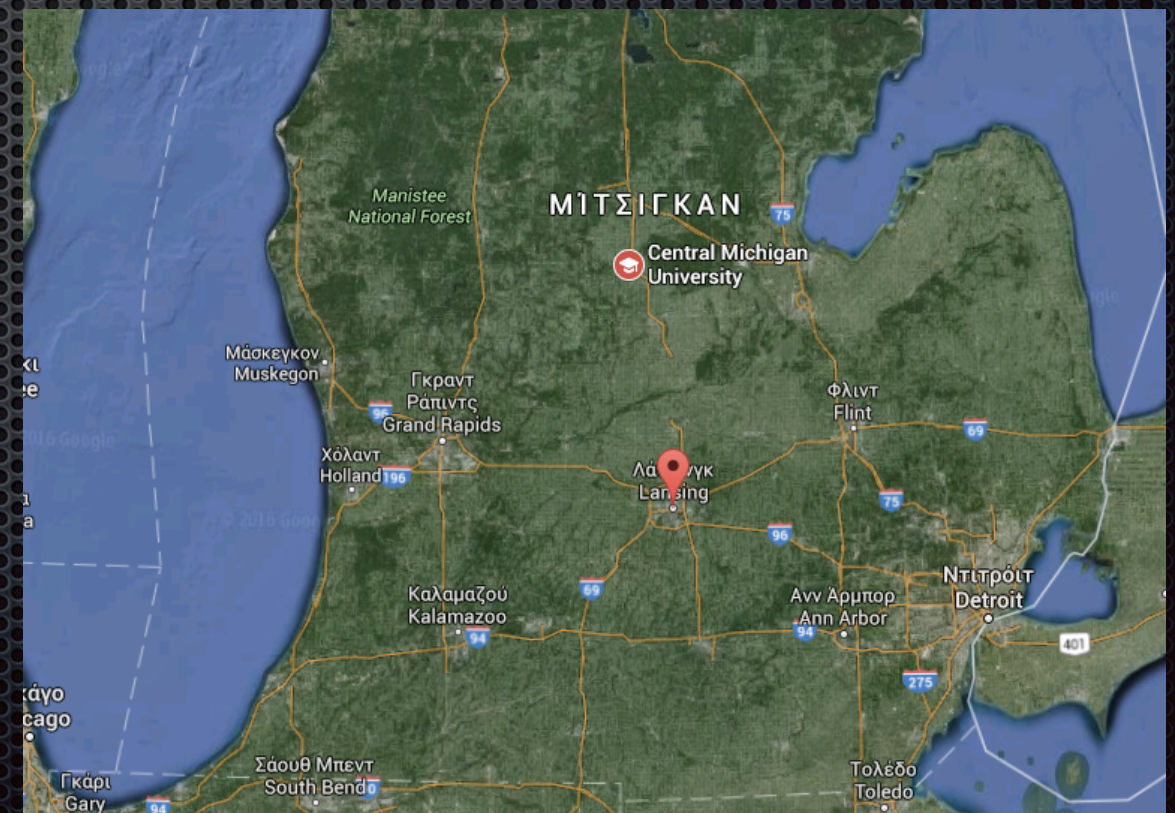
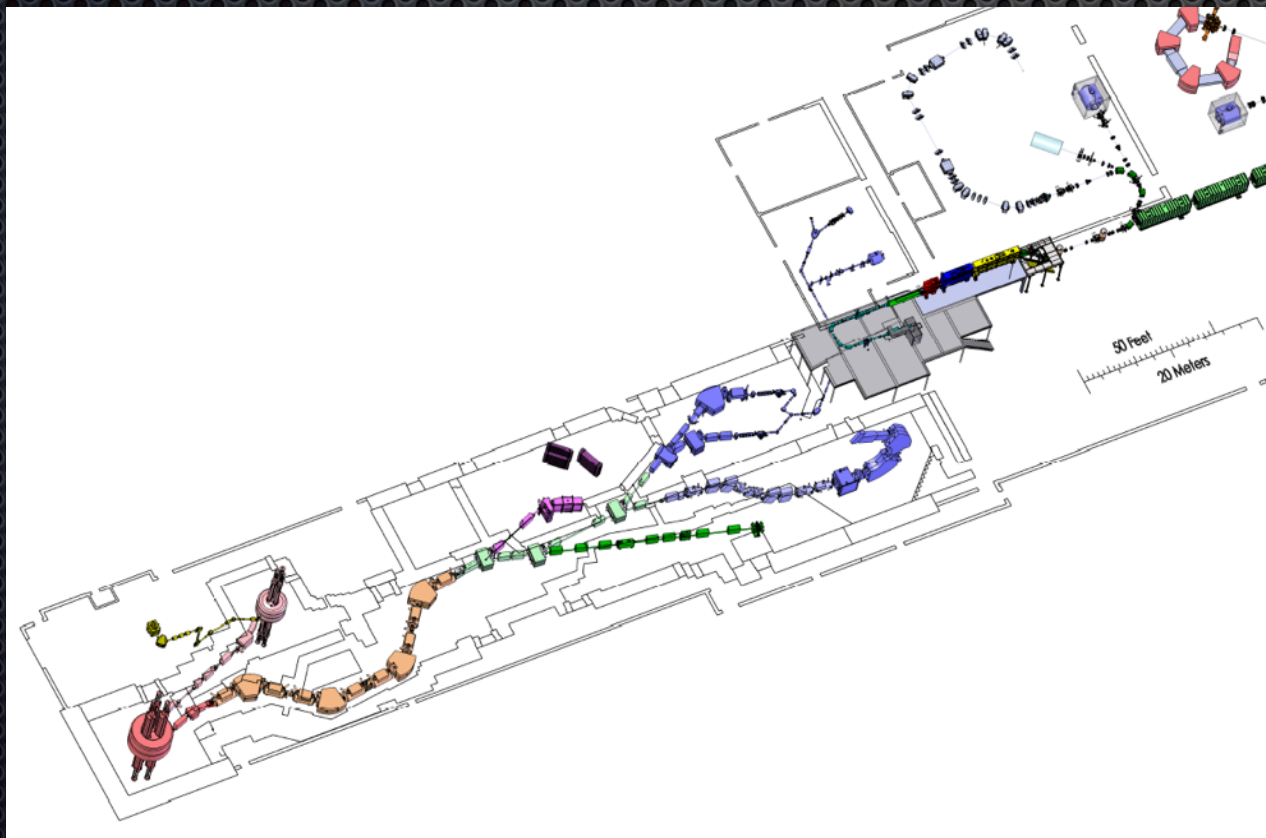


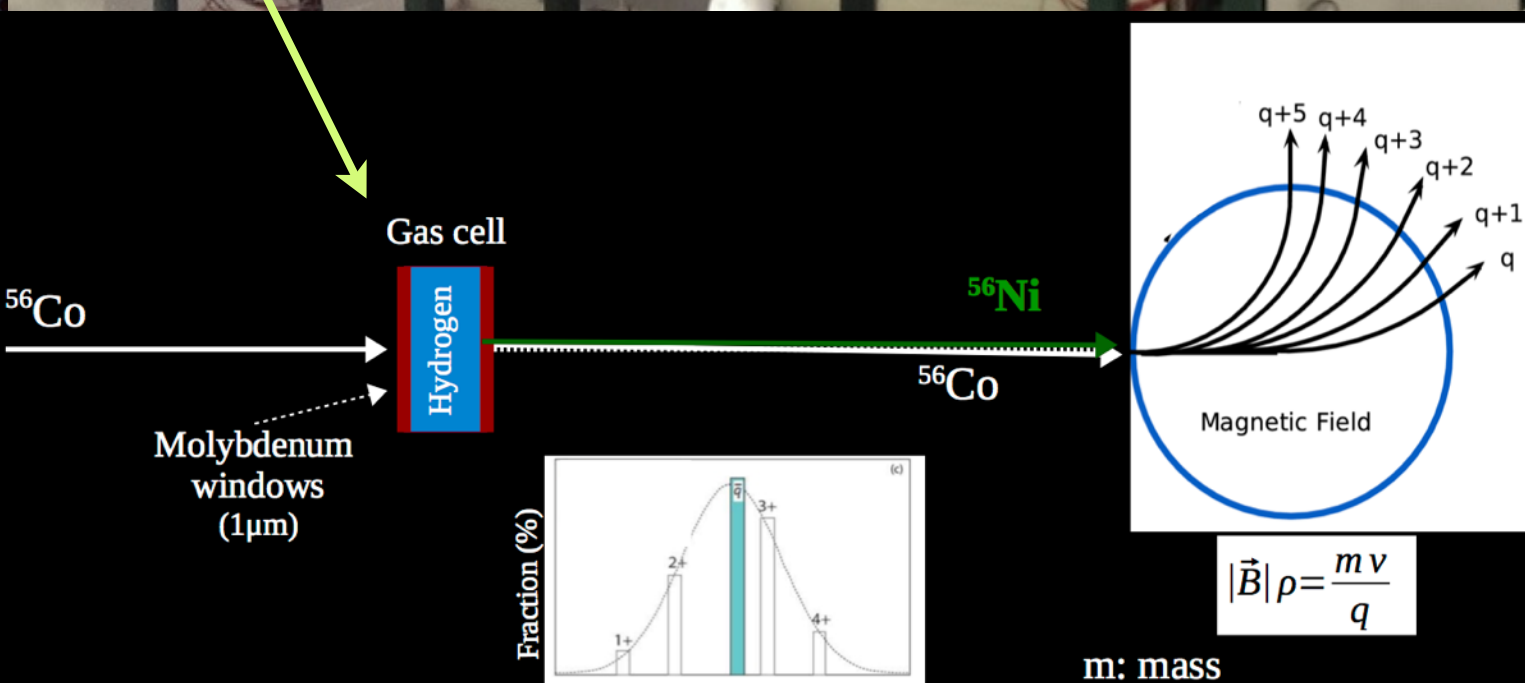
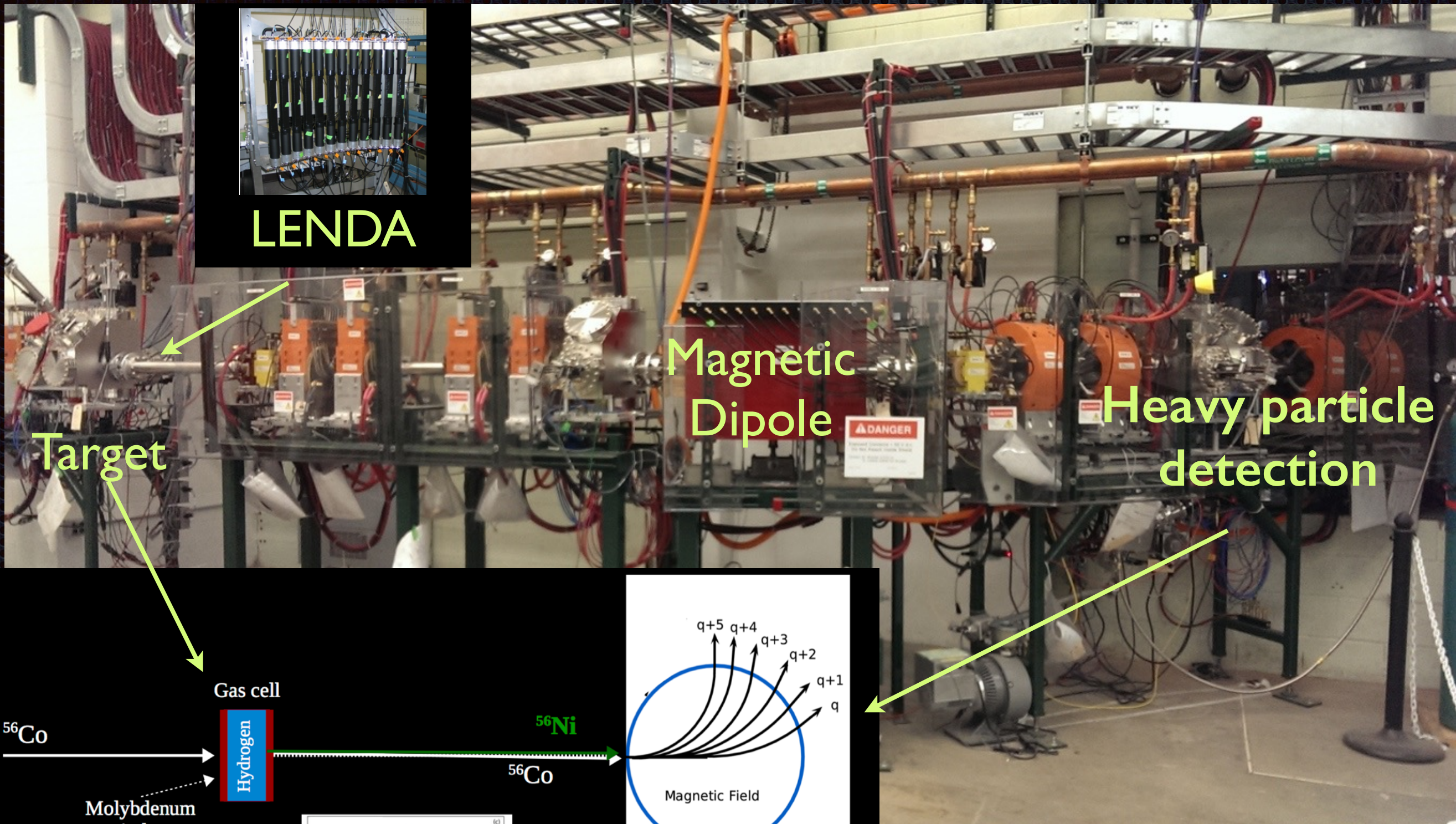
Διατριβή Σ. Νίκα

FRIB, 2020: Ο ισχυρότερος επιταχυντής ραδιενεργών ισοτόπων στον κόσμο



NSCL, τώρα: Πειράματα στον ισχυρότερο επιταχυντή ραδιενεργών ισοτόπων στην Αμερική





$$|\vec{B}| \rho = \frac{m v}{q}$$

m : mass
 v : velocity
 q : charge
 ρ : radius of curvature

P. Gastis et al, NIM B 2016



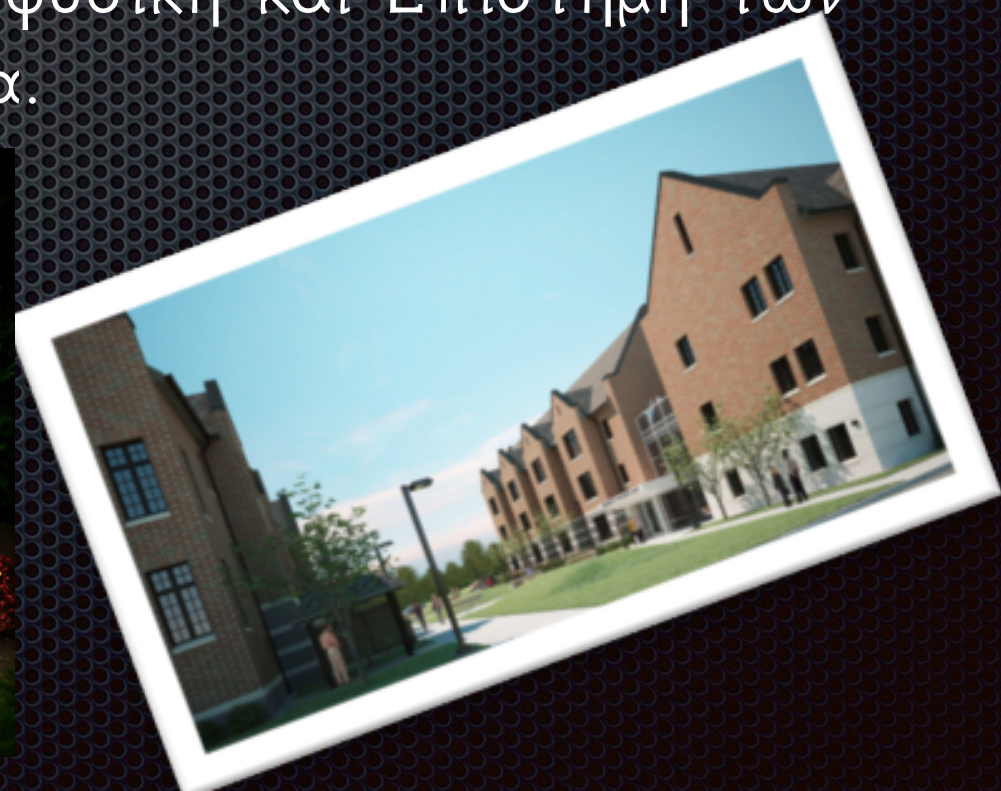
Ανάμεσα στα 100 μεγαλύτερα πανεπιστήμια στην Αμερική (28000 φοιτητές)

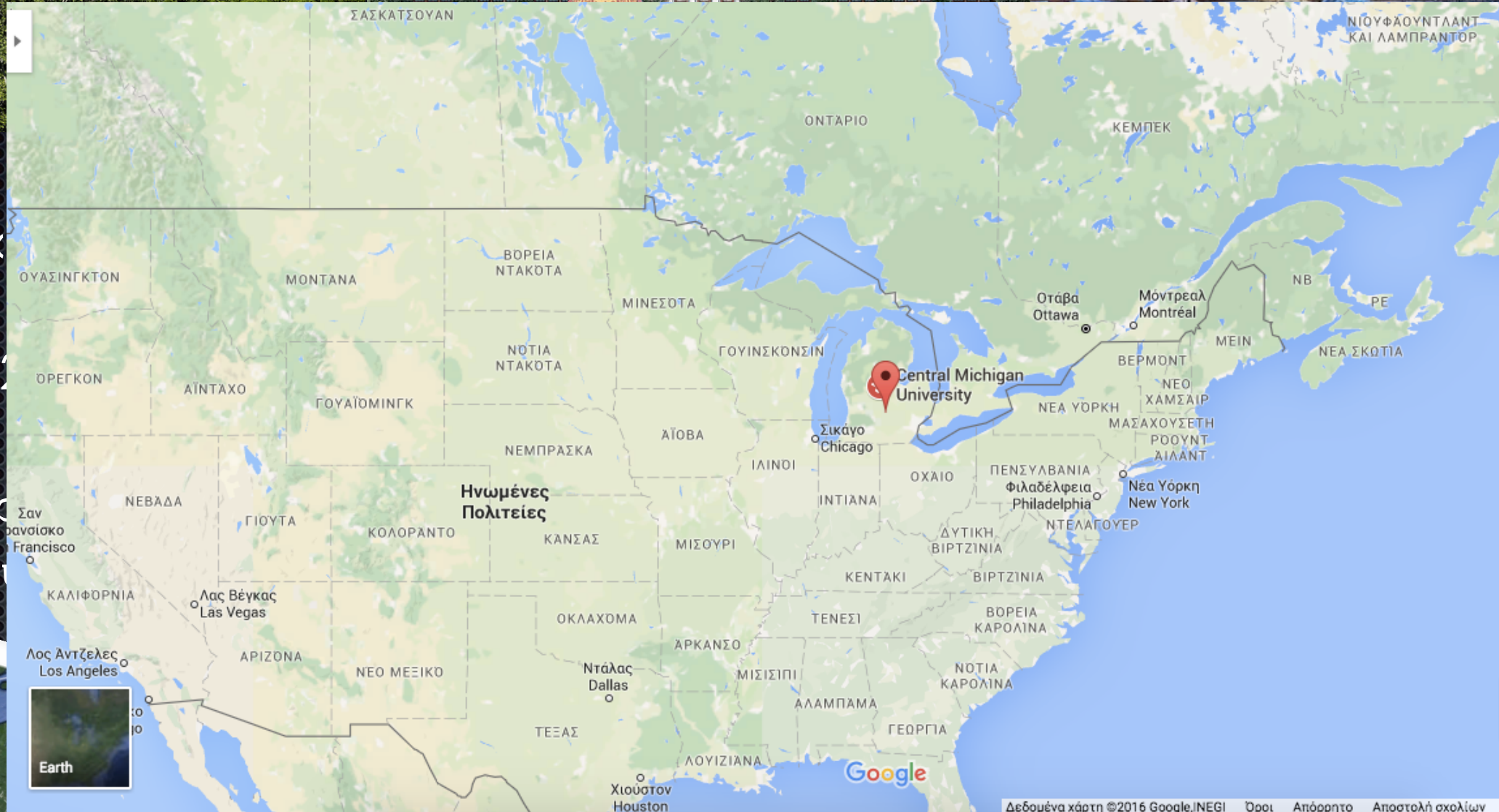
Ένα από τα πιο εξειδικευμένα τμήματα φυσικής:

42% Πυρηνική φυσική, 42% Επιστήμη υλικών, 16% Αστρονομία

Η μονη ομάδα πυρηνικής φυσικής που είναι τμήμα του εθνικού εργαστηρίου παραγωγής δεσμών από σπάνια ραδιενεργά ισότοπα (NSCL/FRIB)

Μεταπτυχιακές σπουδές MS και PhD σε Πυρηνική φυσική και Επιστήμη των υλικών, MS σε Αστρονομία.





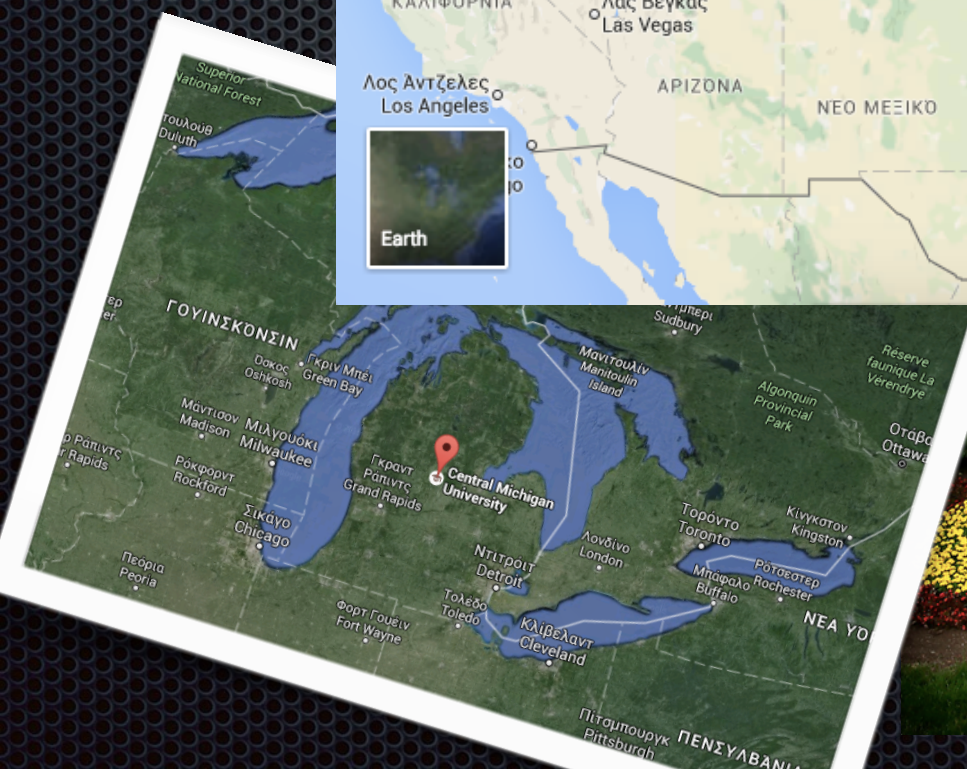
Ανάμεσα

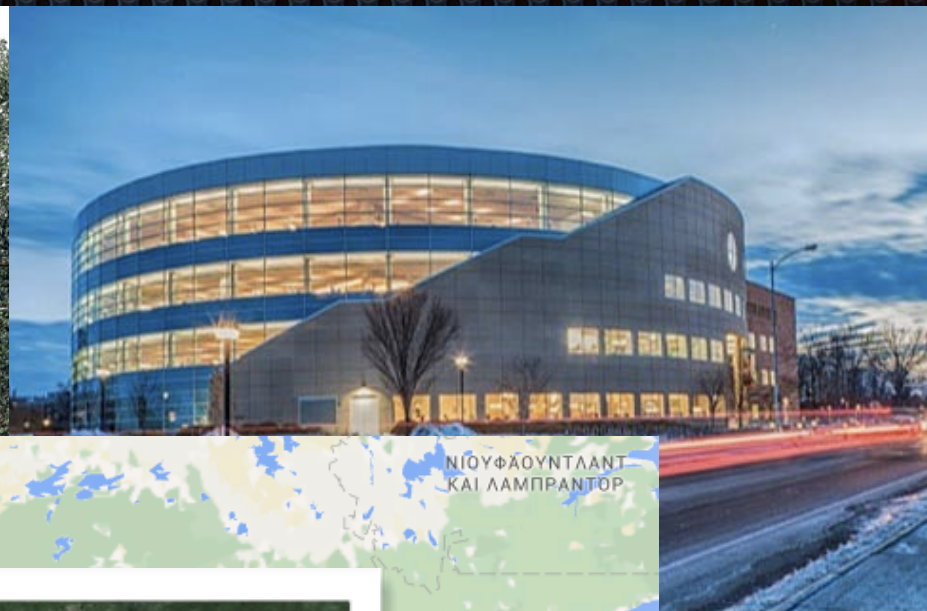
42

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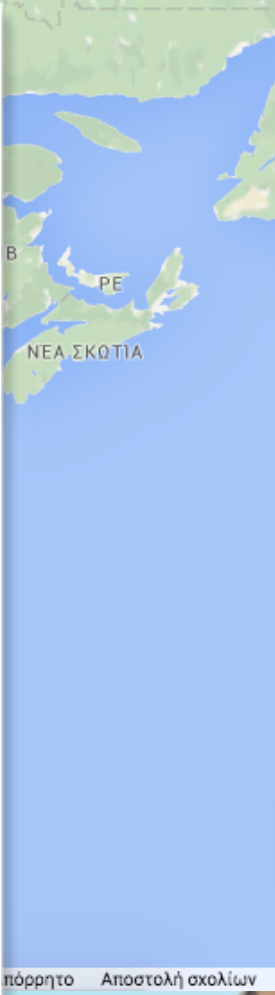
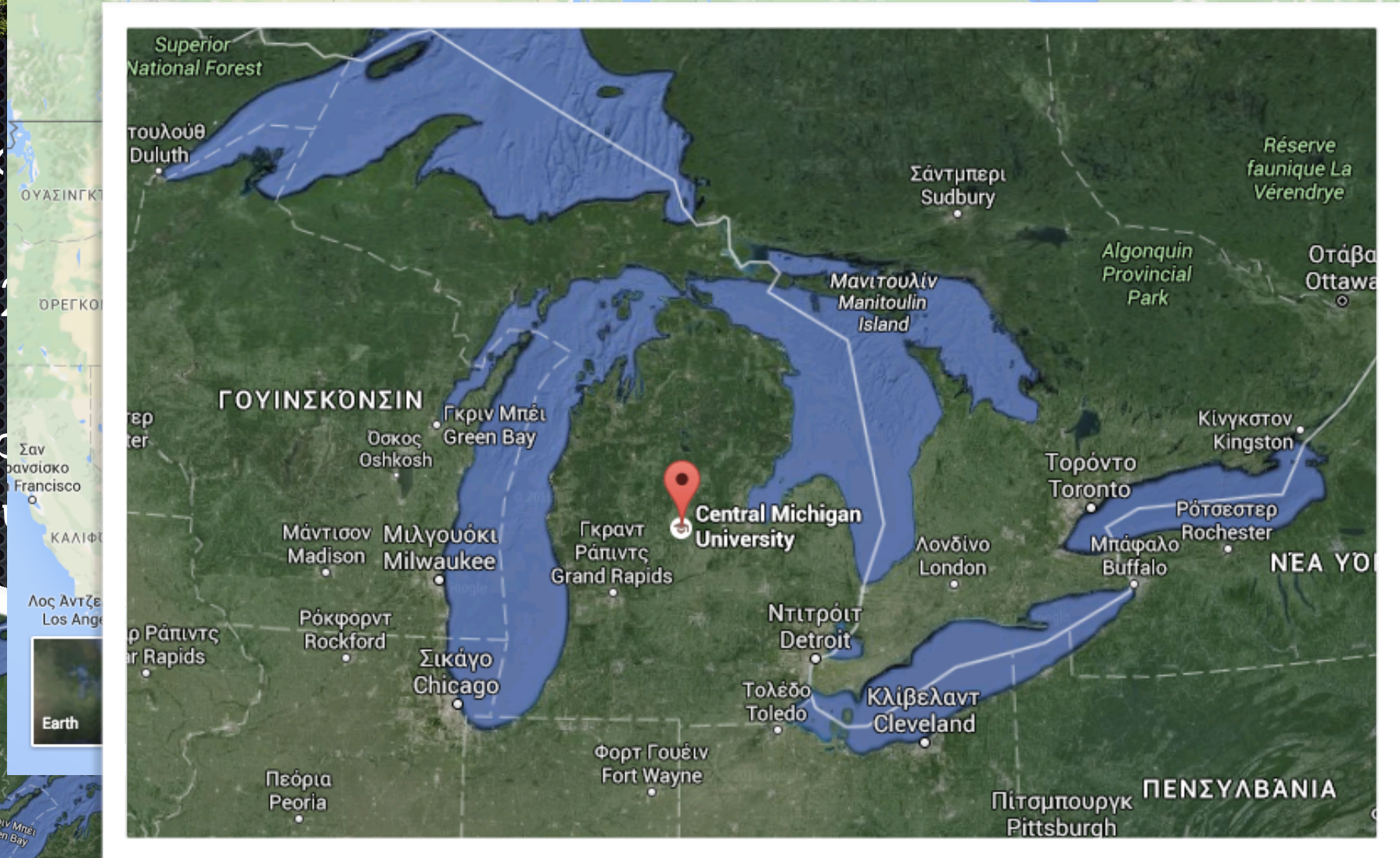
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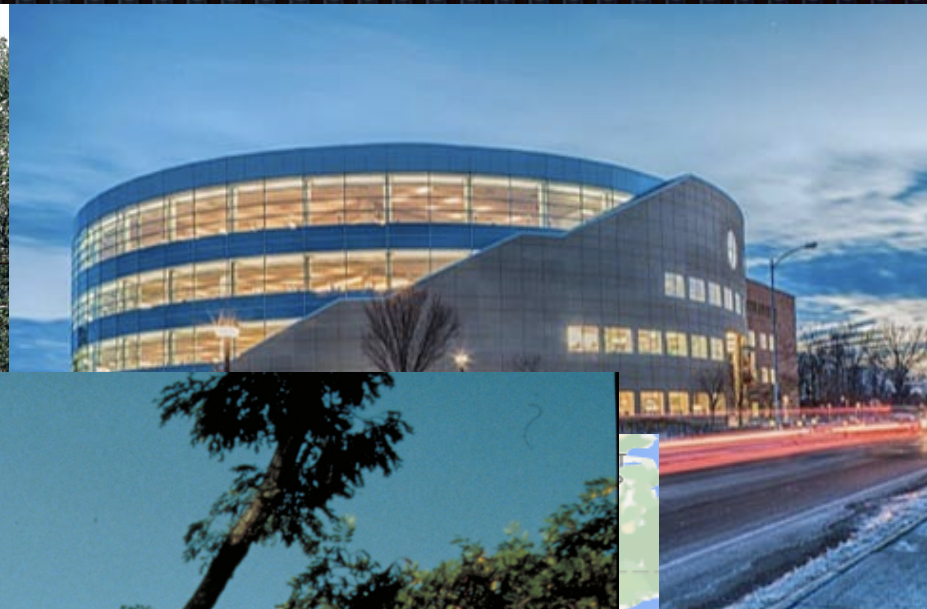
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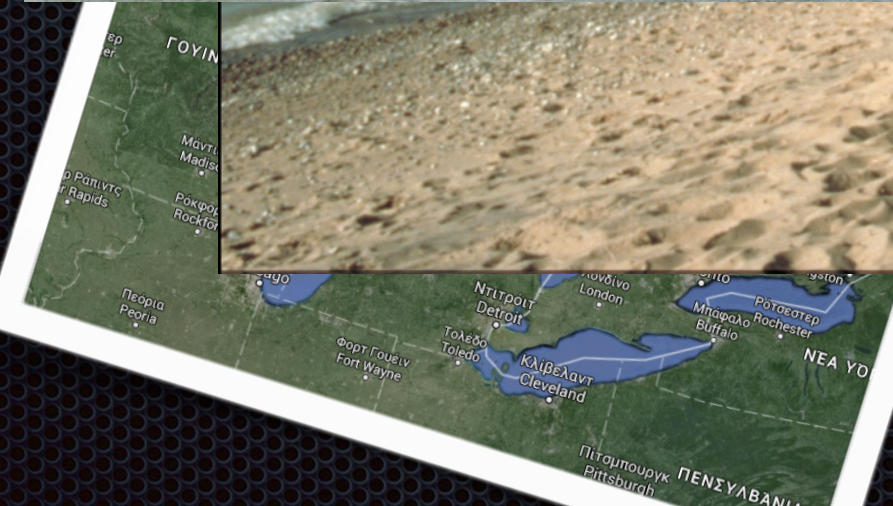
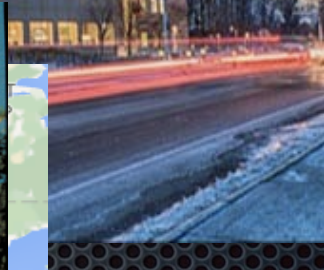
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R. M. Almus
P. Gastis
M. Horoi
S. Nikas
M. Redshaw



T. Anderson
A. Aprahamian
R. Avetisyan,
A. A. Bataglia,
M. Beard
W. Bauder
B. M. Bucher,
C. R. Casarella,
P. Colon,
A. M. Long,
W. Lu,
S. Lyons,
S. T. Marley,
K. M. Ostdiek,
D. Robertson
M. Skulski
K. I. Smith,
M. K. Smith,
E. J. Stech,
W. Tan,
R. Talwar,
M. Wiescher



S. Lipschutz,
F. Montes
T. H. Redpath
A. Spyrou,
R. G. T. Zegers



A. Voinov



C. Fröhlich



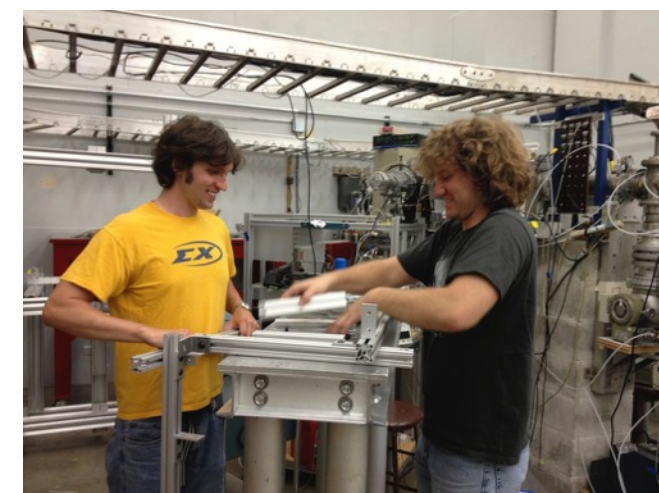
K. Wimmer



D. Hatcher

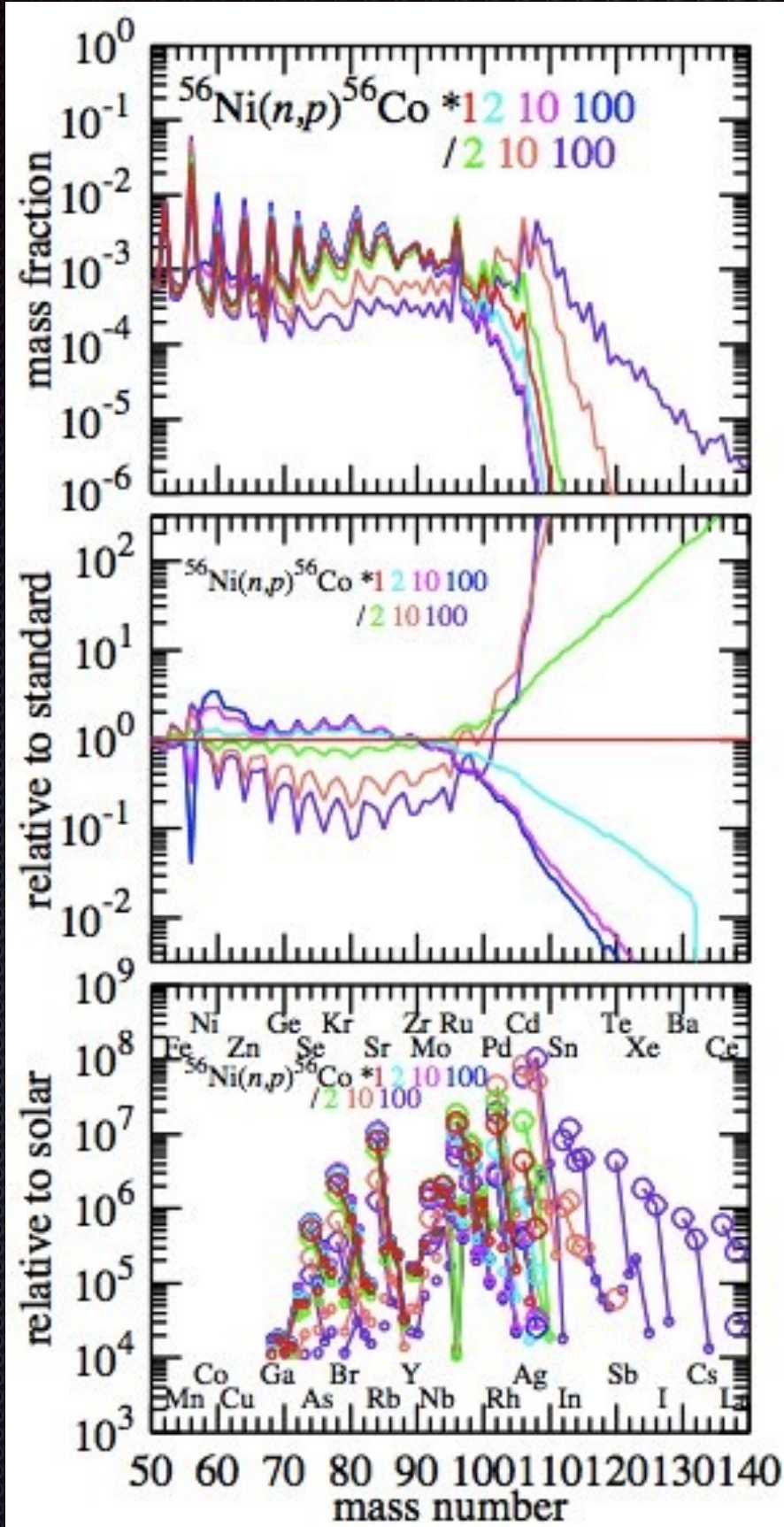


A. Kontos



Award No. DE-SC0014285

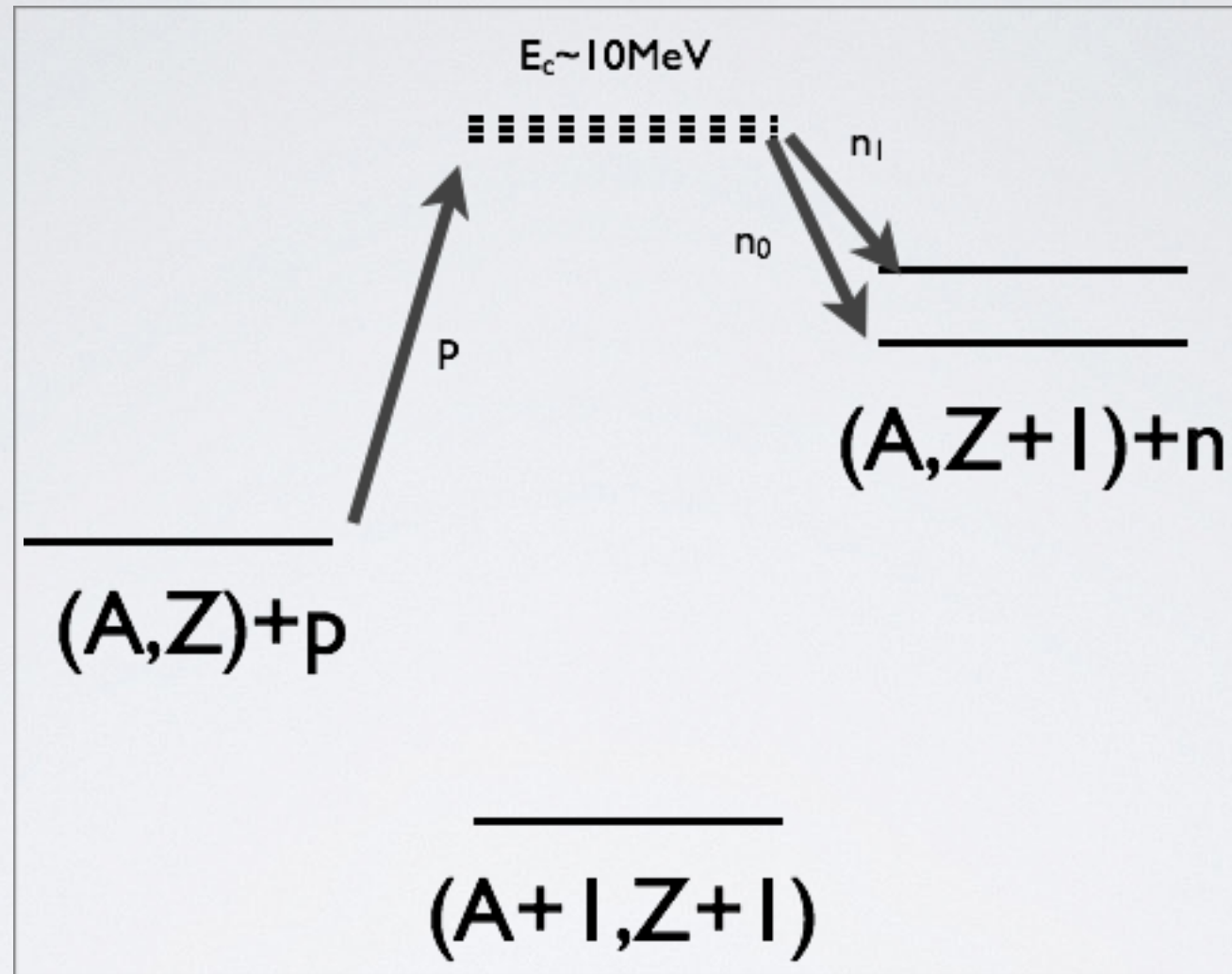
EFFECT OF NUCLEAR PHYSICS INPUT ON NUCLEOSYNTHESIS



- $0 < E_n < 1 \text{ MeV}$ $1.5\text{GK} < T < 3\text{GK}$
- compound nucleus process
- (most) important reaction rate: $^{56}\text{Ni}(n,p)$
- proton rich, unstable nuclei
- **no experimental data**

How can we constrain the key reaction rates?

Indirect way: If we cannot do (n,p) then perhaps (p,n)?



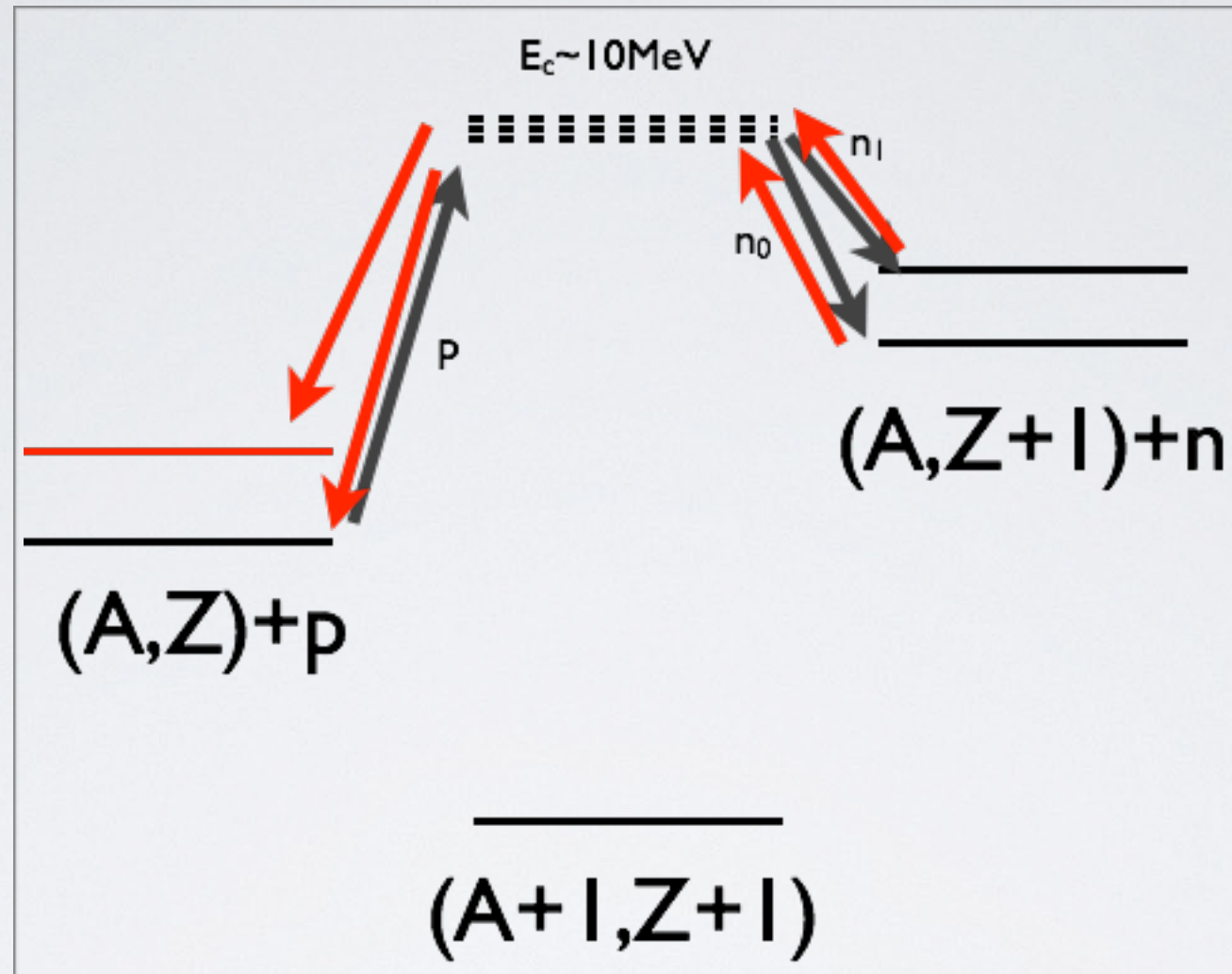
Can we constrain the relevant p, n widths for $^{56}\text{Ni}(n,p)^{56}\text{Co}$?

“Investigation of the role of the vp process in the synthesis of heavy elements through the reaction $^{56}\text{Co}(p,n)^{56}\text{Ni}$ in inverse kinematics at ReA3”

G. Perdikakis et al, Proposal 14061 to NSCL PAC 38, April 2014 (approved)

Also DE-SC0014285, Department of Energy

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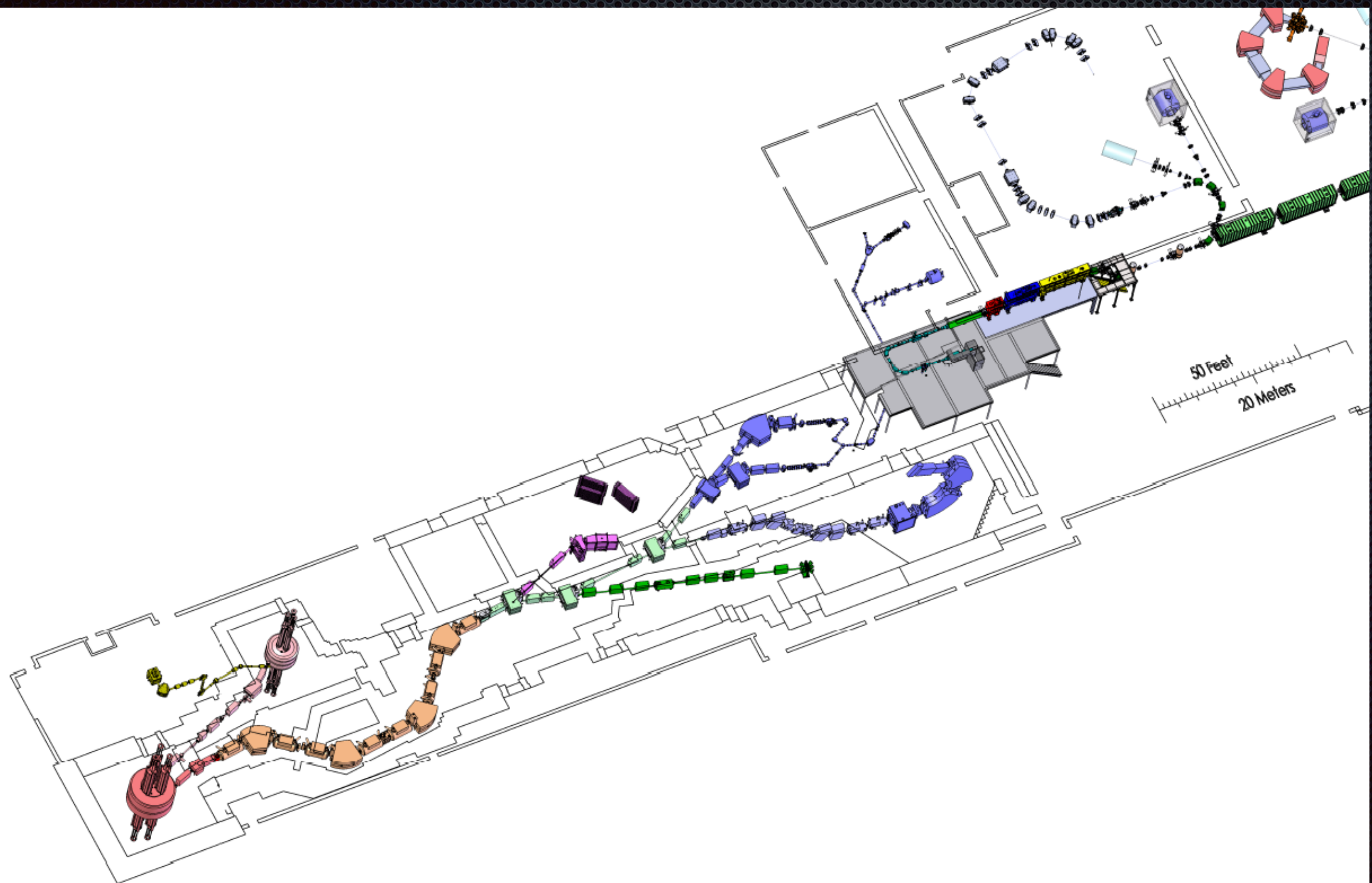


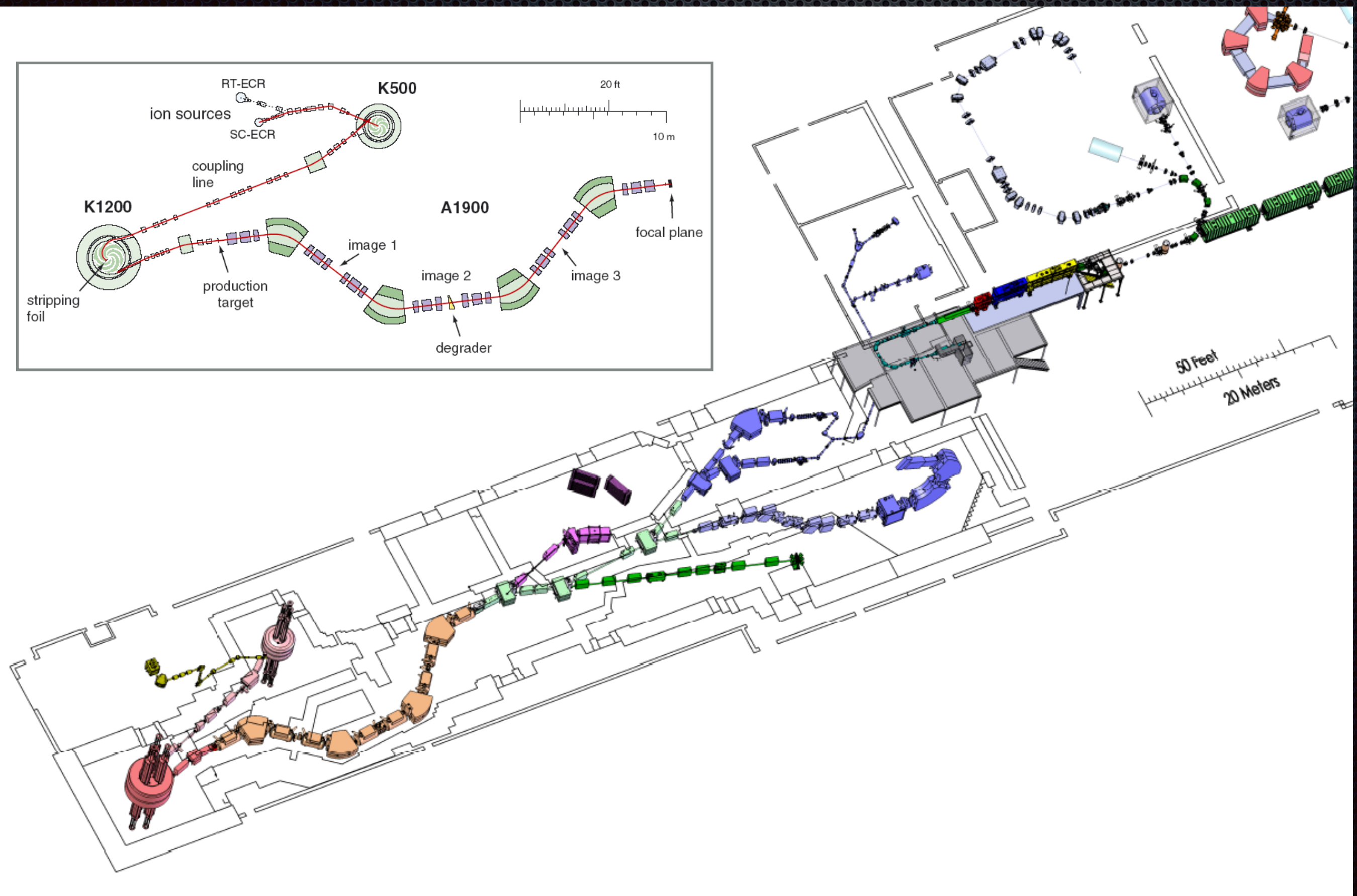
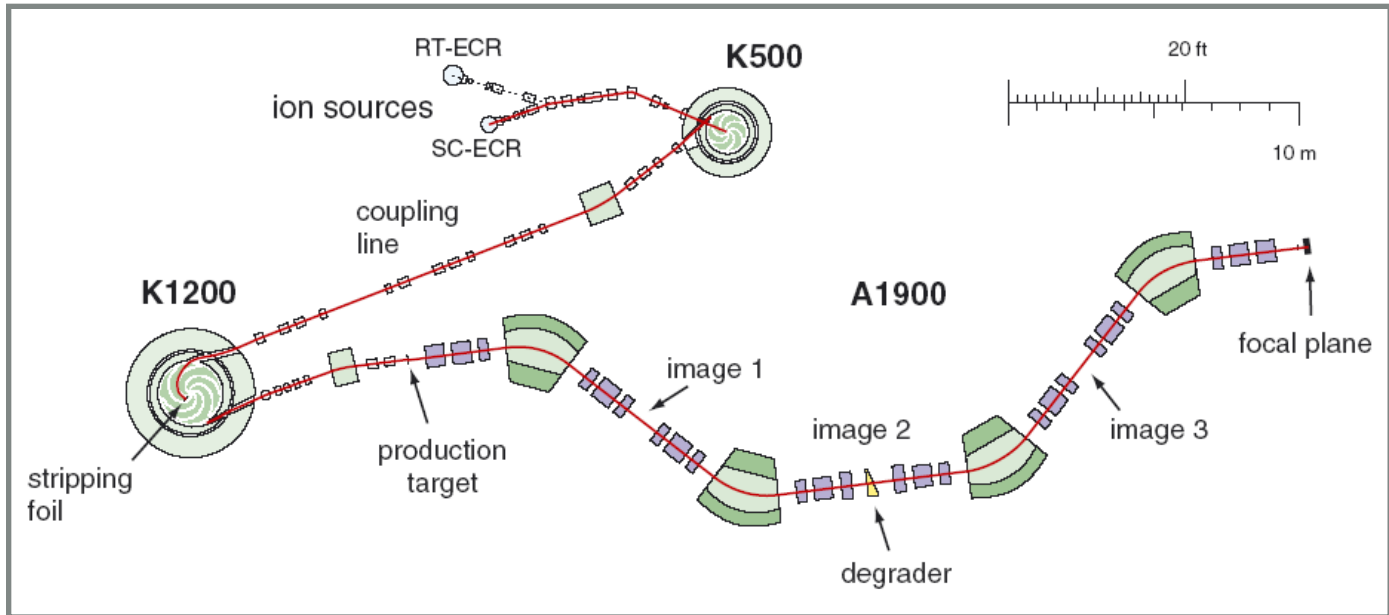
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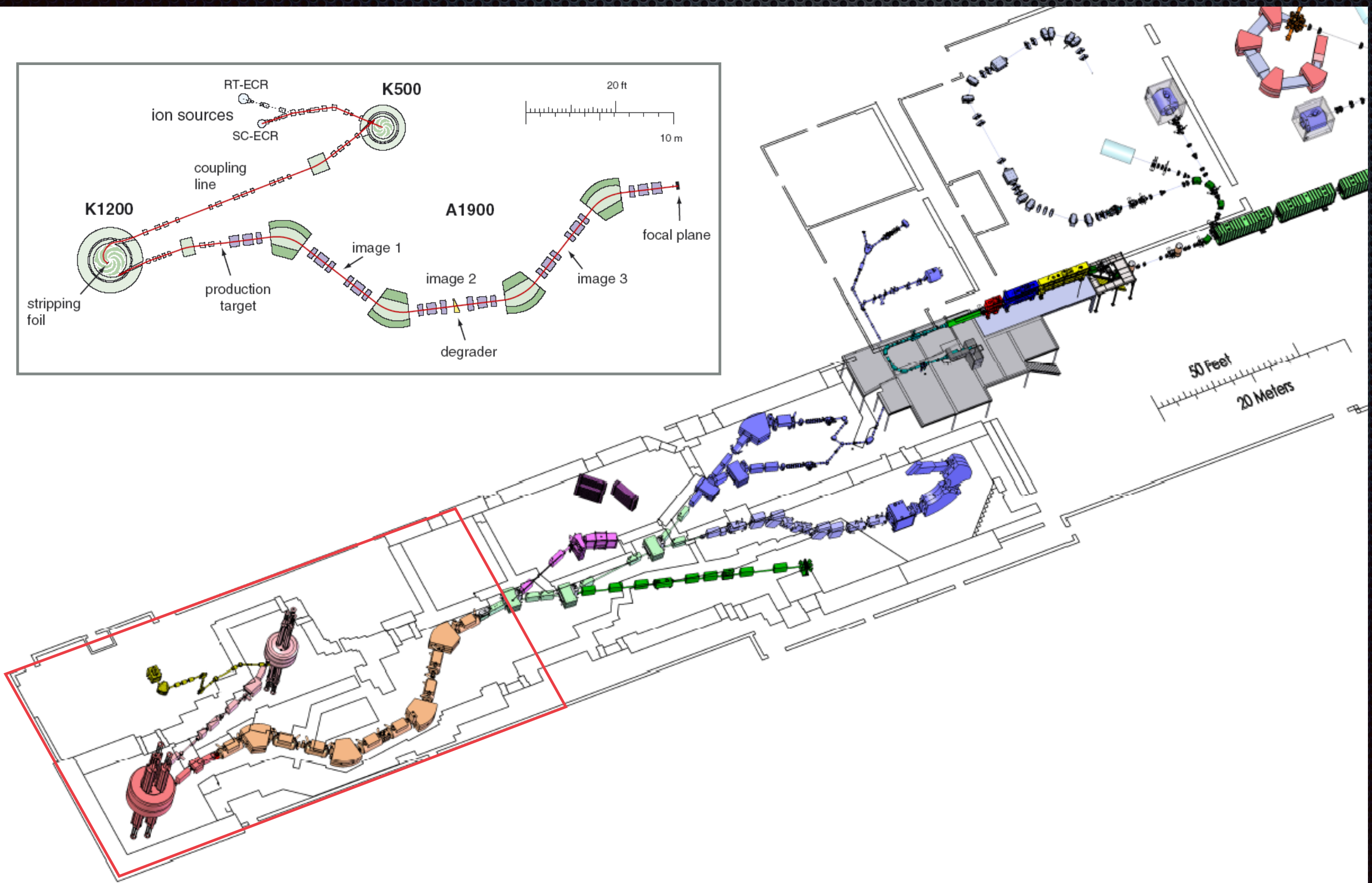
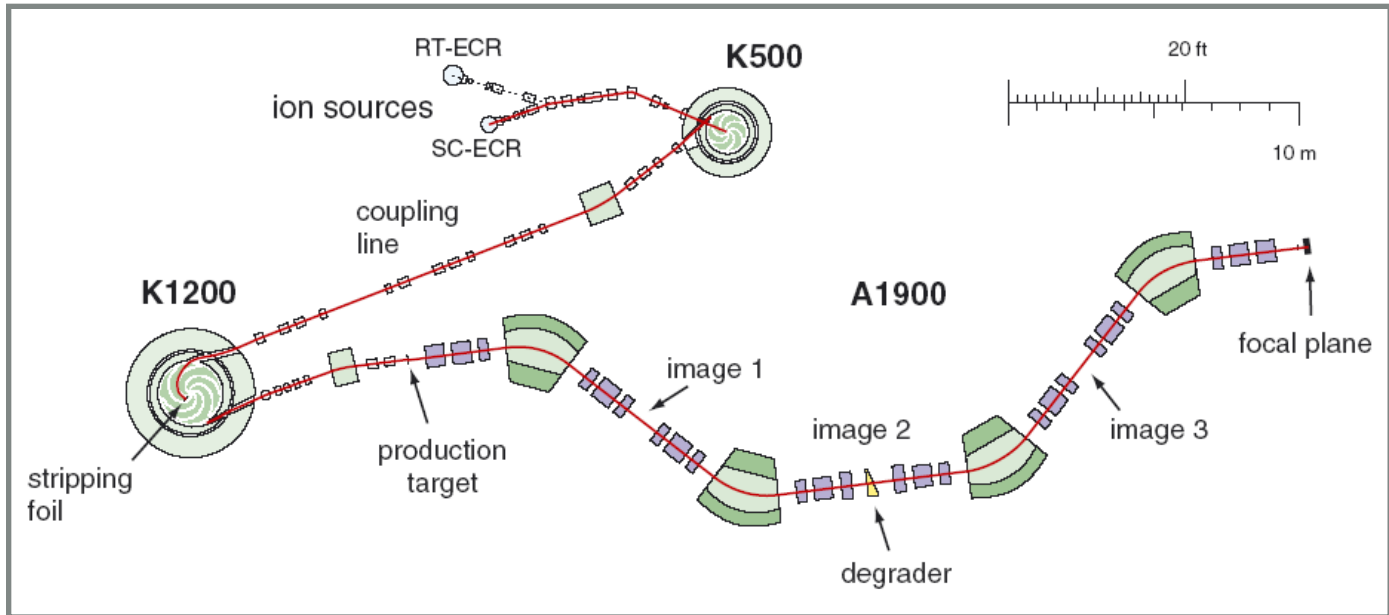
“Investigation of the role of the vp process in the synthesis of heavy elements through the reaction $^{56}\text{Co}(p,n)^{56}\text{Ni}$ in inverse kinematics at ReA3”

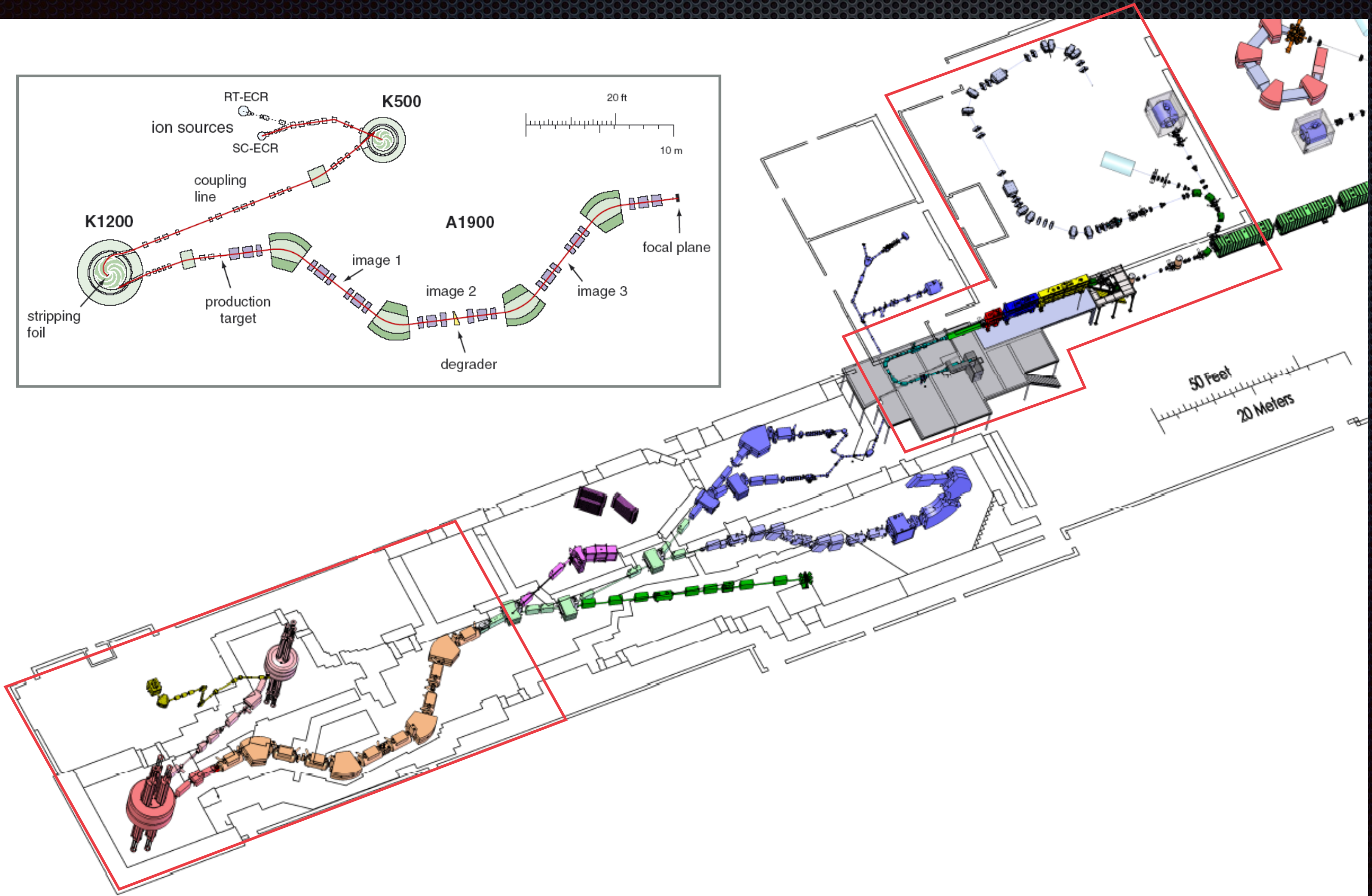
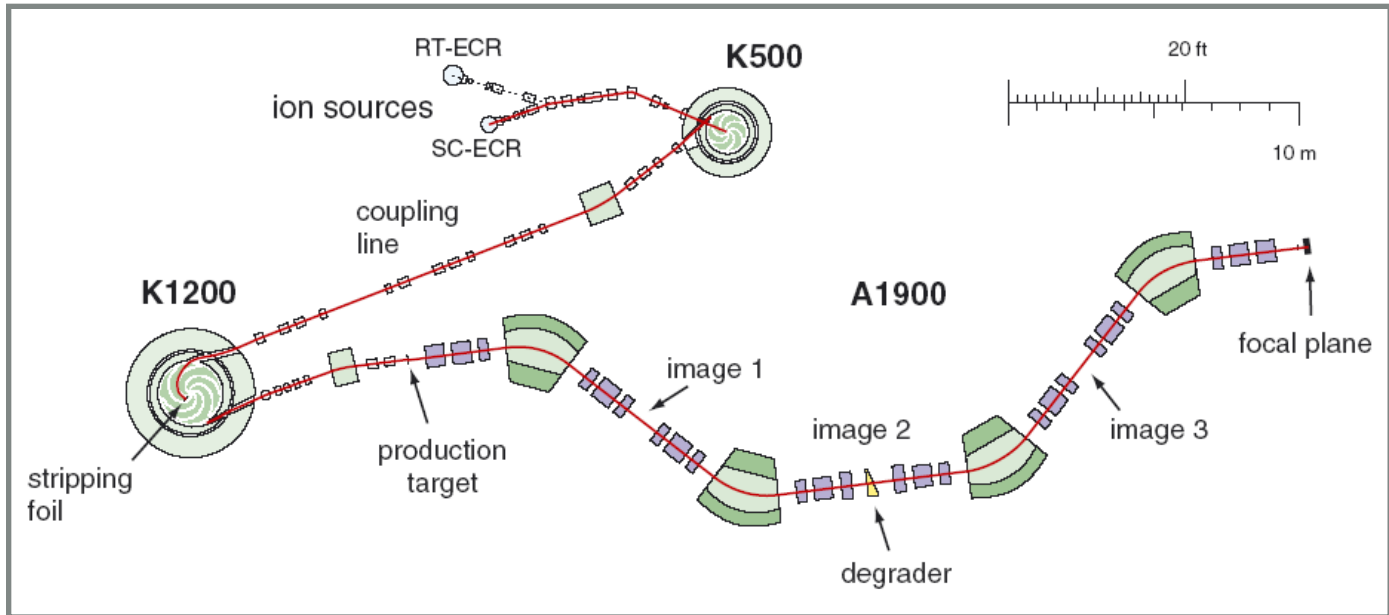
G. Perdikakis et al, Proposal 14061 to NSCL PAC 38, April 2014 (approved)

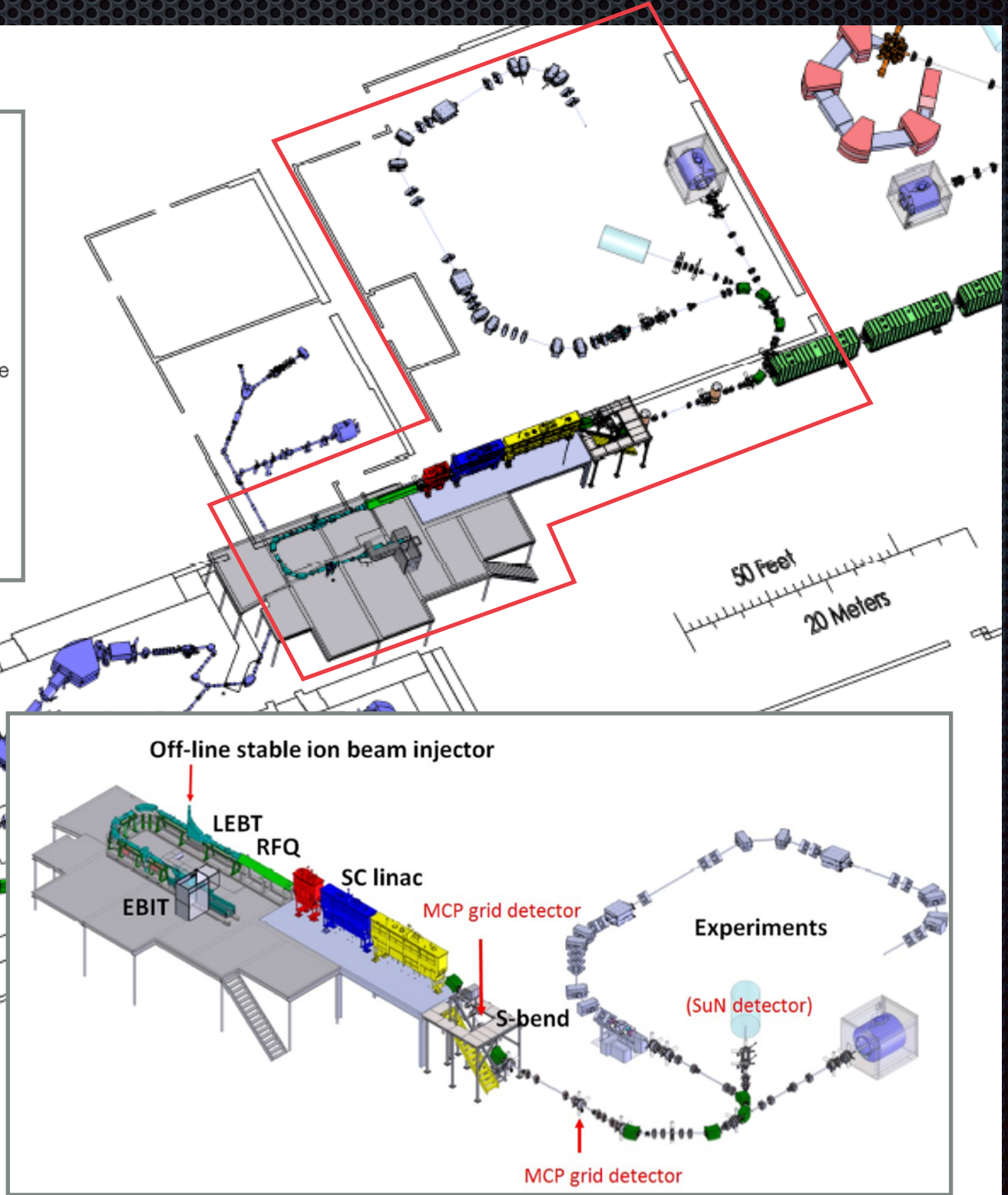
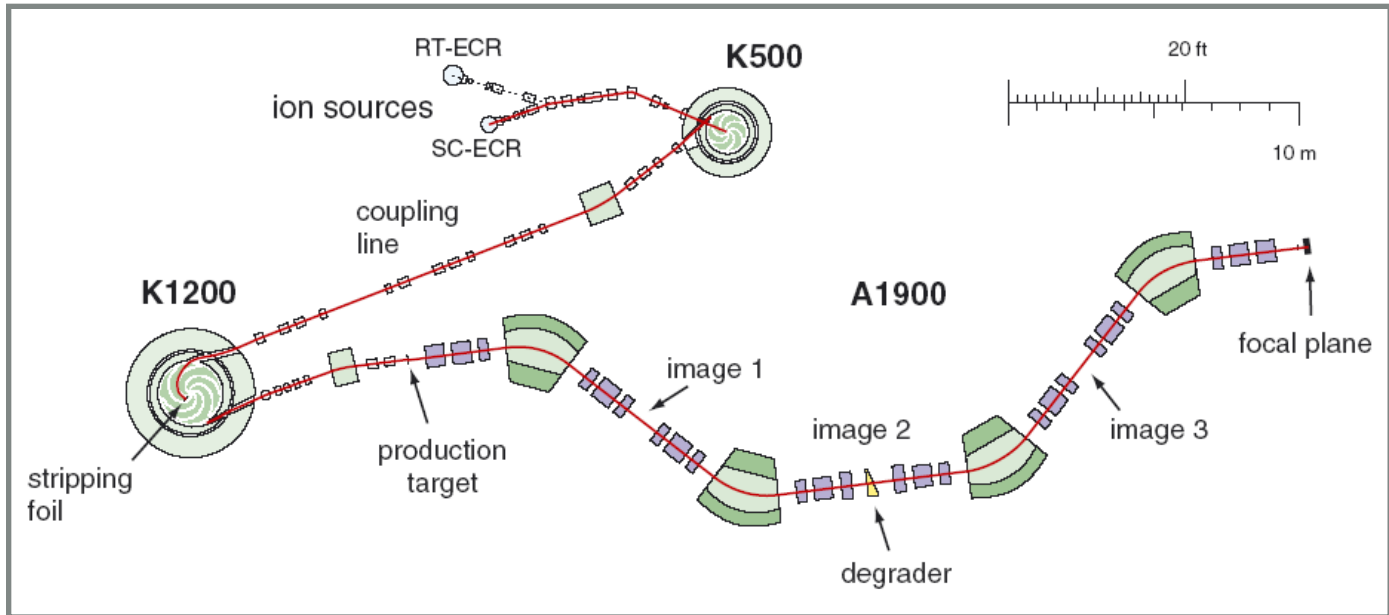
Also DE-SC0014285, Department of Energy





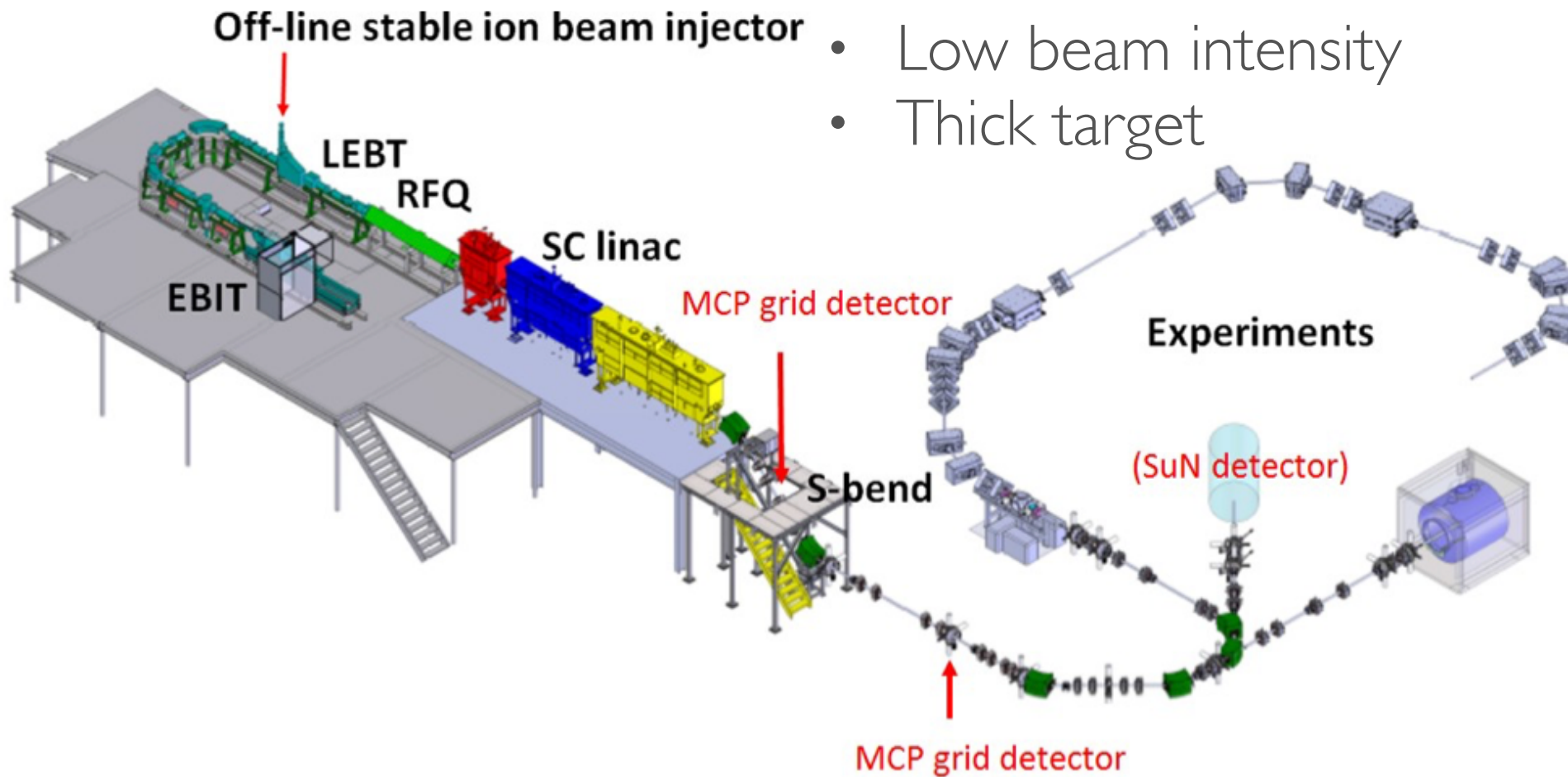






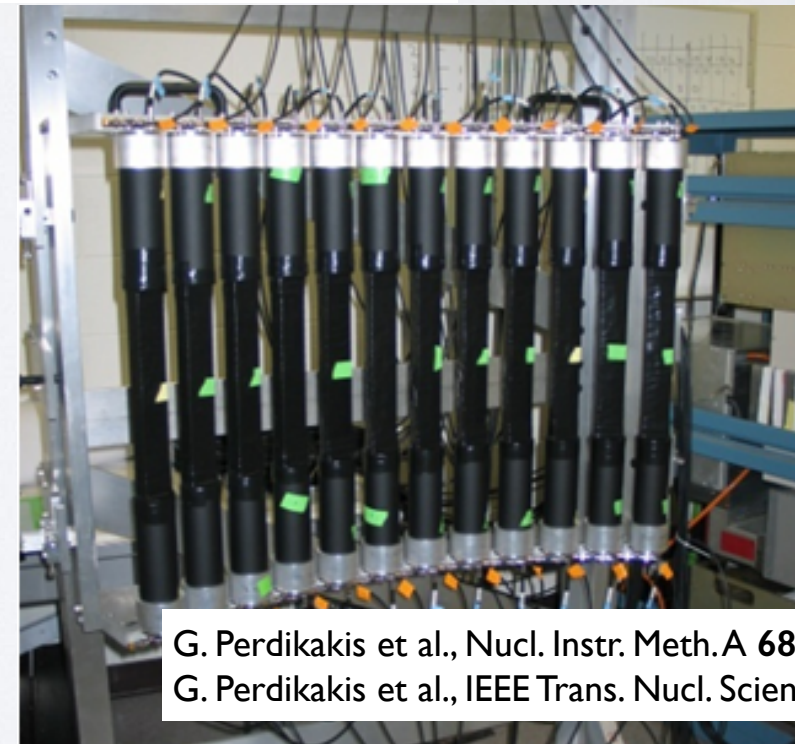
ReA 3

- $E_{\text{beam}} \sim 5 \text{ MeV/u}$
- $E_n = 1 - 2 \text{ MeV}$
- Inverse kinematics
- Low beam intensity
- Thick target



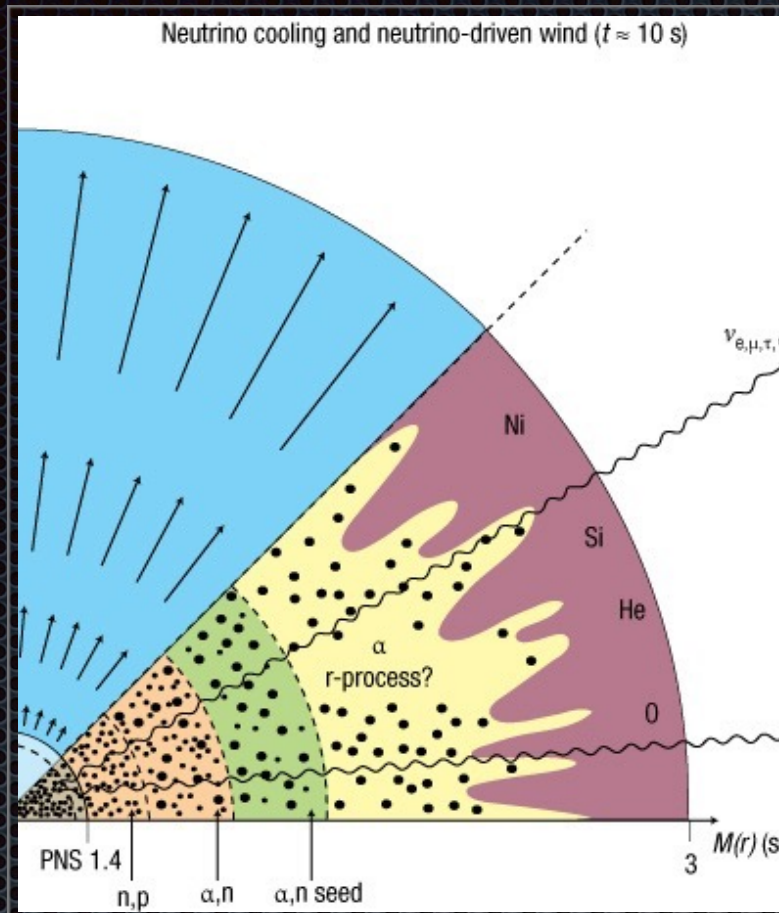
LEND A

- 24 plastic scintillator bars
- timing resolution $\sim 400 \text{ ps}$
- Angle resolution $2^\circ @ 1 \text{ m}$
- Coverage: 45° lab angle
- Efficiency $> 20\%$ below 4 MeV
- $E_n \geq 130 \text{ keV}$

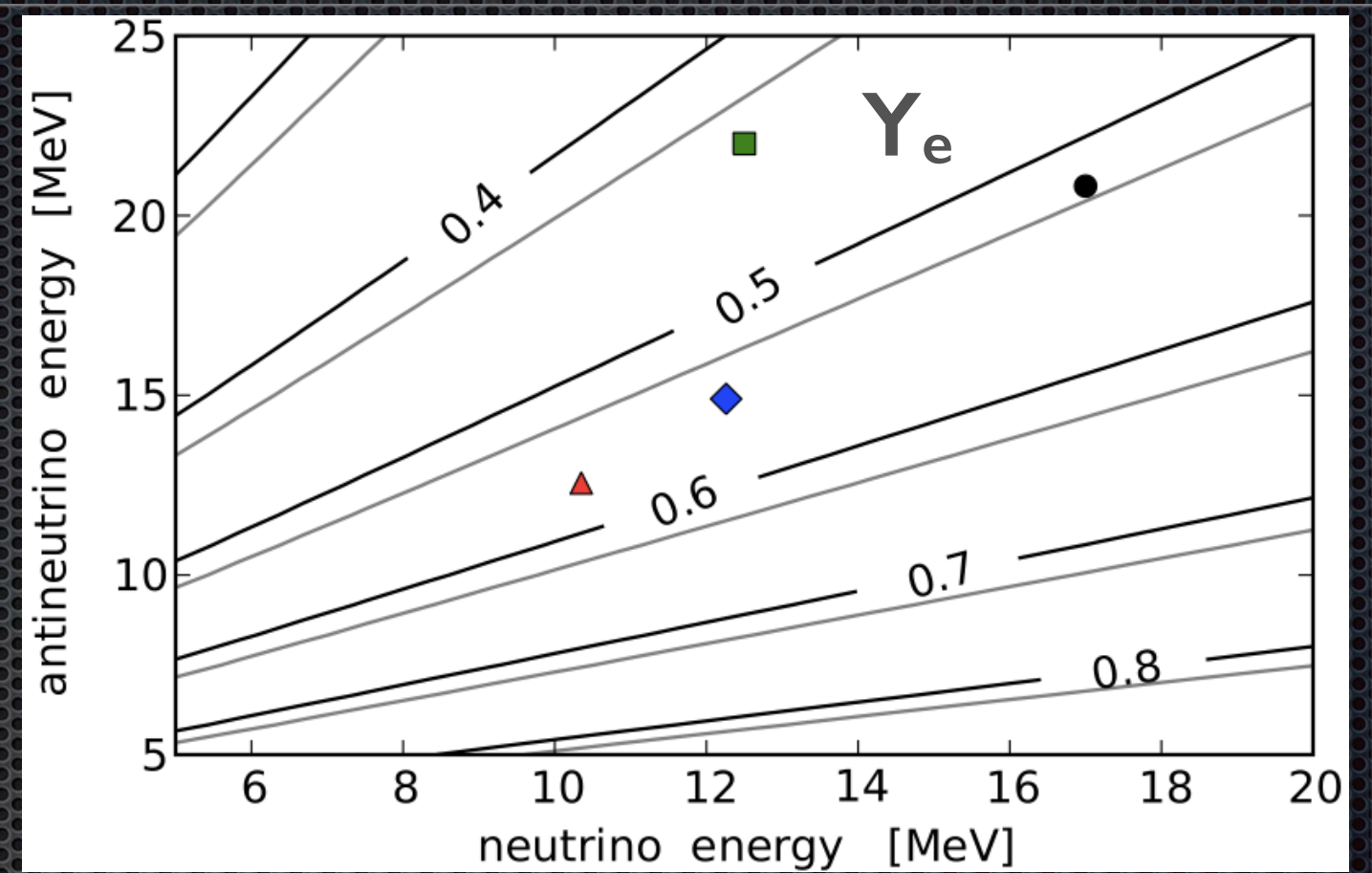


G. Perdikakis et al., Nucl. Instr. Meth. A **686**, (2012), 117
 G. Perdikakis et al., IEEE Trans. Nucl. Science **56**, (2009), 1174

ΑΣΤΡΙΚΟΣ ΑΝΕΜΟΣ ΝΕΤΡΙΝΩΝ



S.Woosley, H.T.Janka, 2005

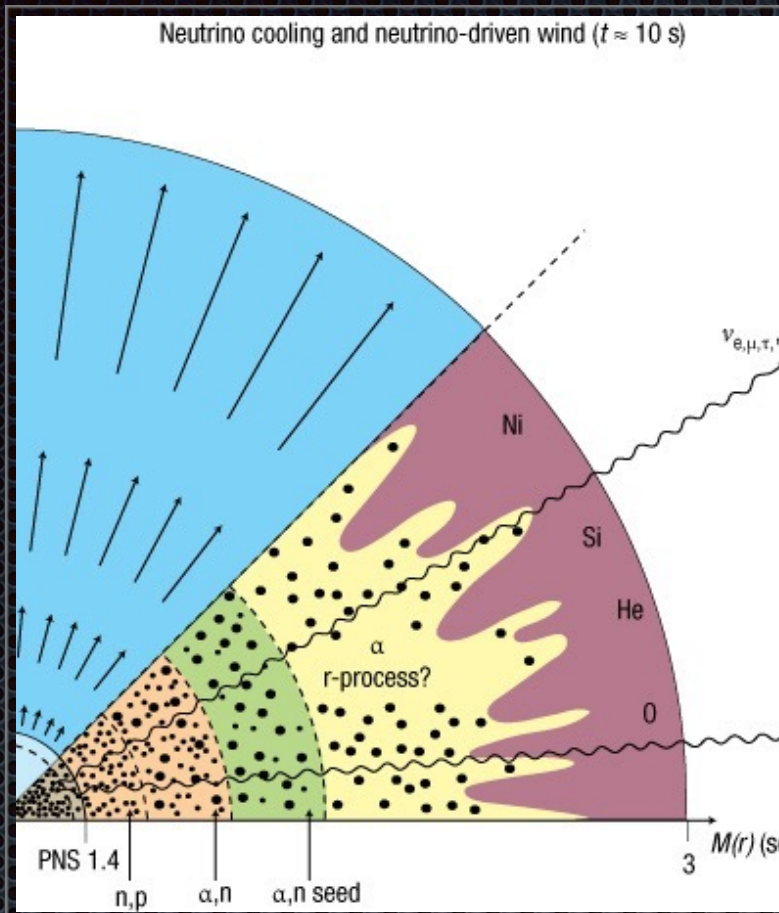


A.Arcones, and F.K.Thielemann, 2013

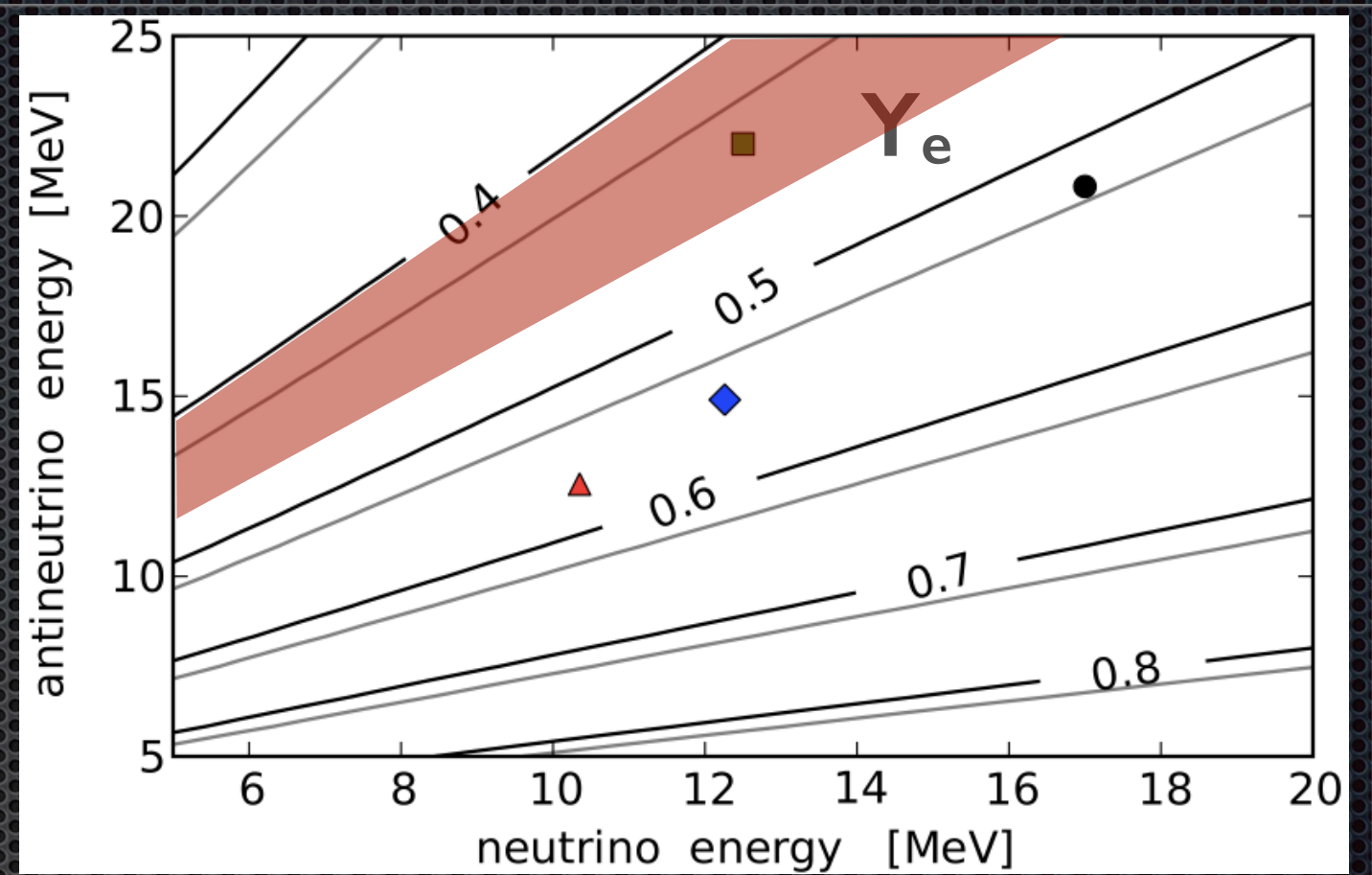
$$Y_e \approx \left[1 + \frac{L_{\bar{\nu}_e} (\epsilon_{\bar{\nu}_e} - 2\Delta + 1.2\Delta^2/\epsilon_{\bar{\nu}_e})}{L_{\nu_e} (\epsilon_{\nu_e} + 2\Delta + 1.2\Delta^2/\epsilon_{\nu_e})} \right]^{-1}$$

$Y_e < 0.5$, Πλεόνασμα νετρονίων
 $Y_e > 0.5$, Πλεόνασμα πρωτονίων

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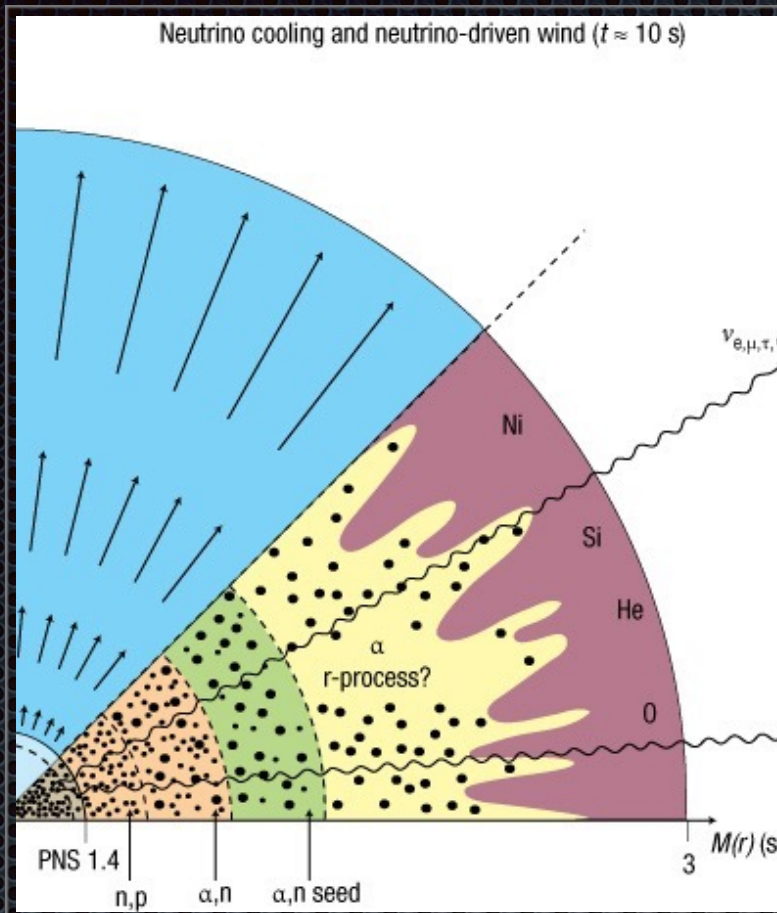


A. Arcones, and F. K. Thielemann, 2013

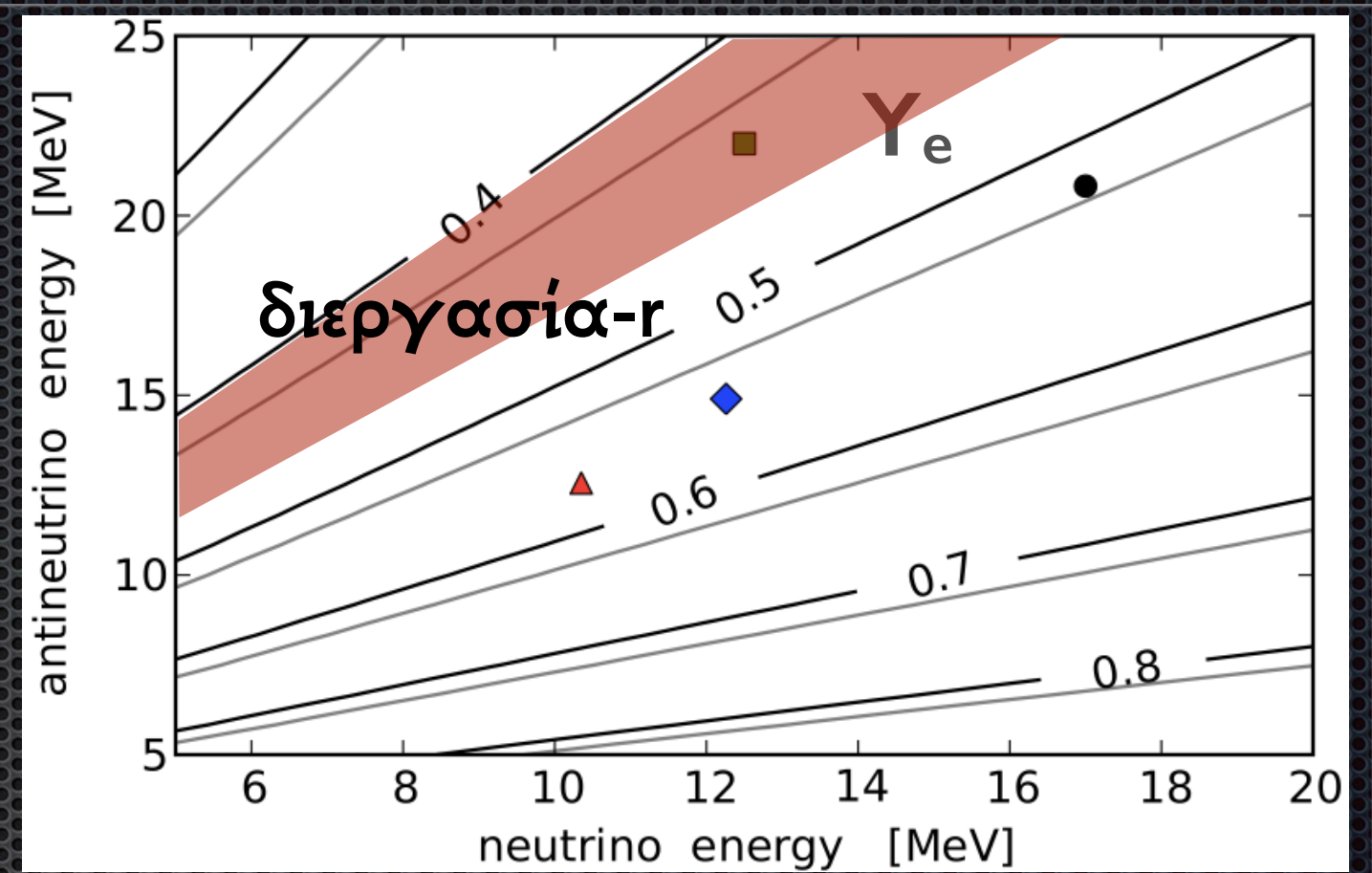
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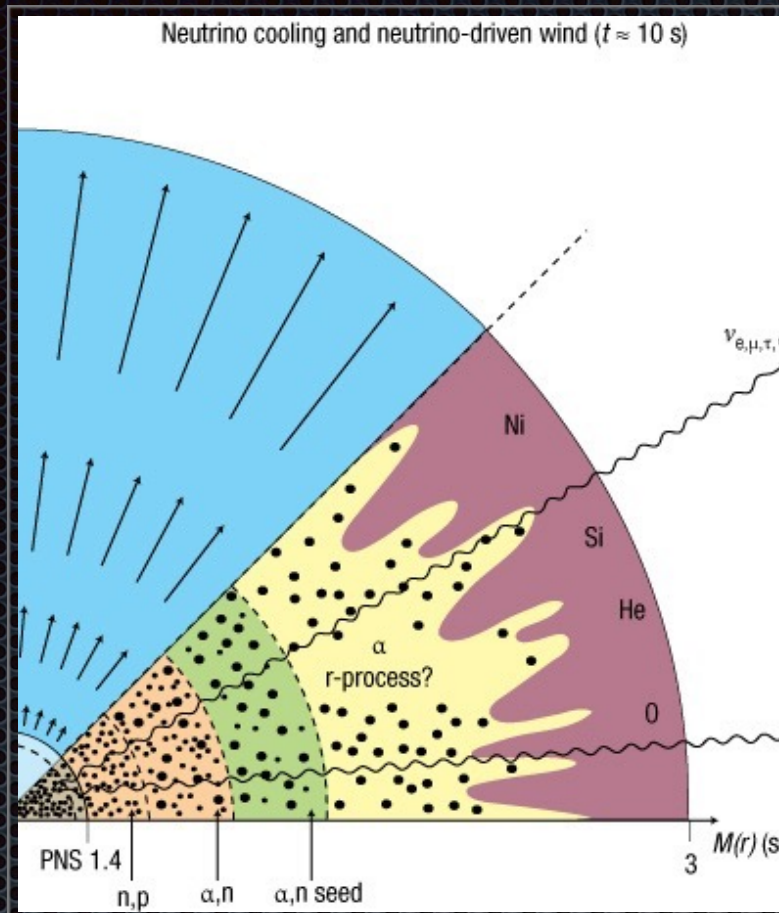


A. Arcones, and F. K. Thielemann, 2013

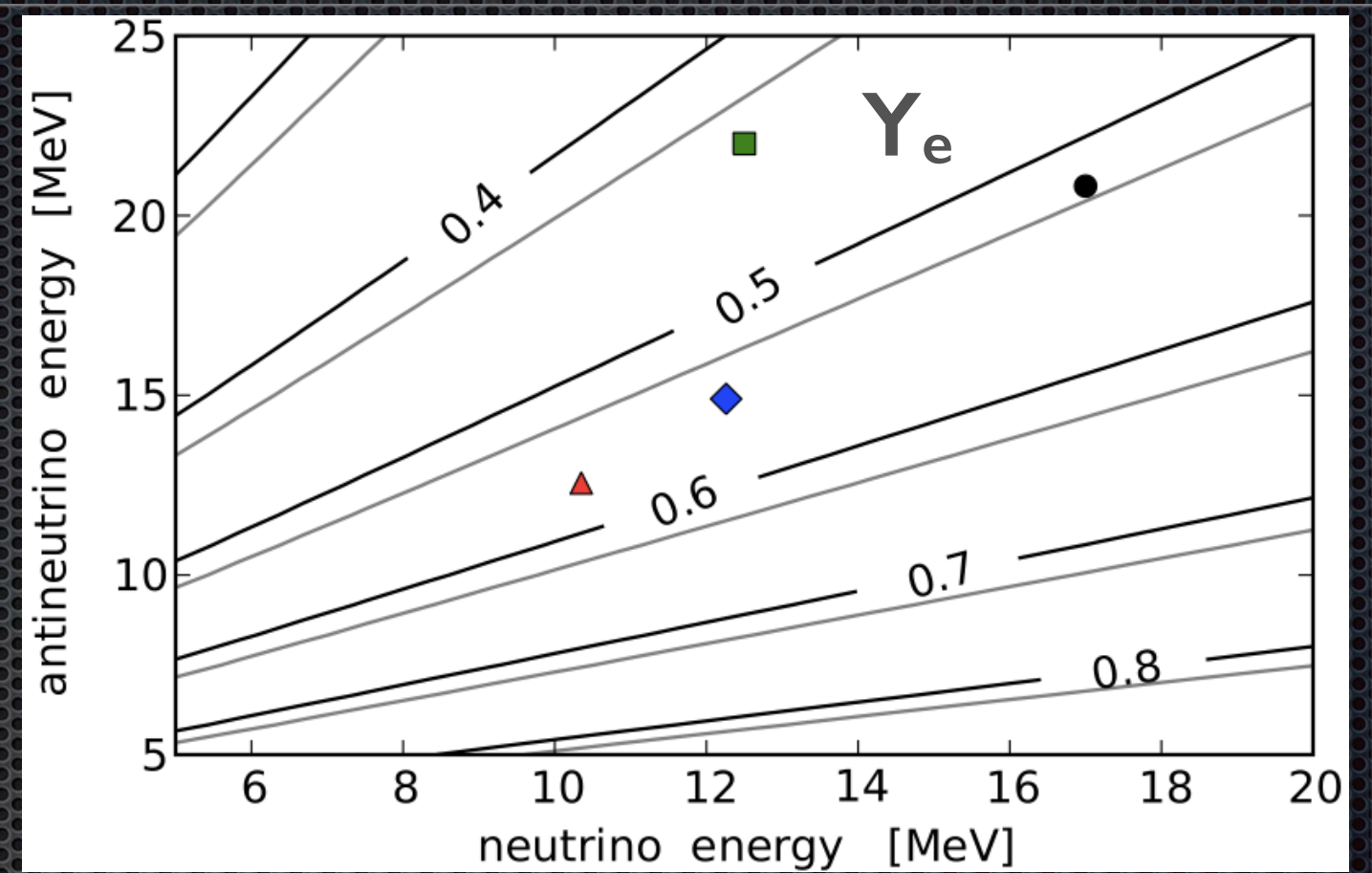
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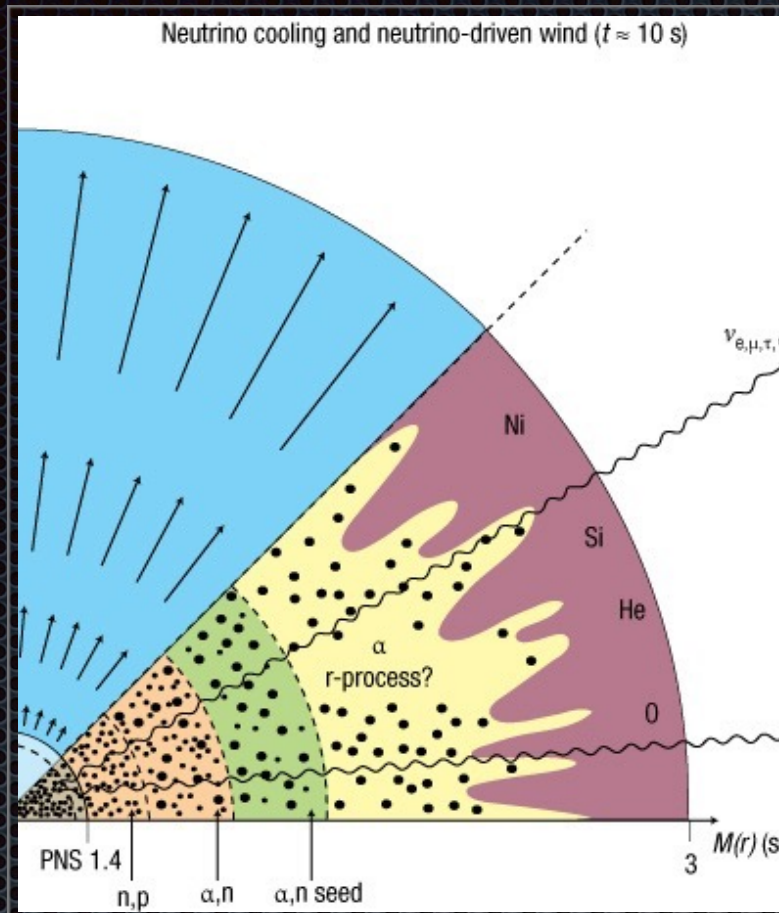


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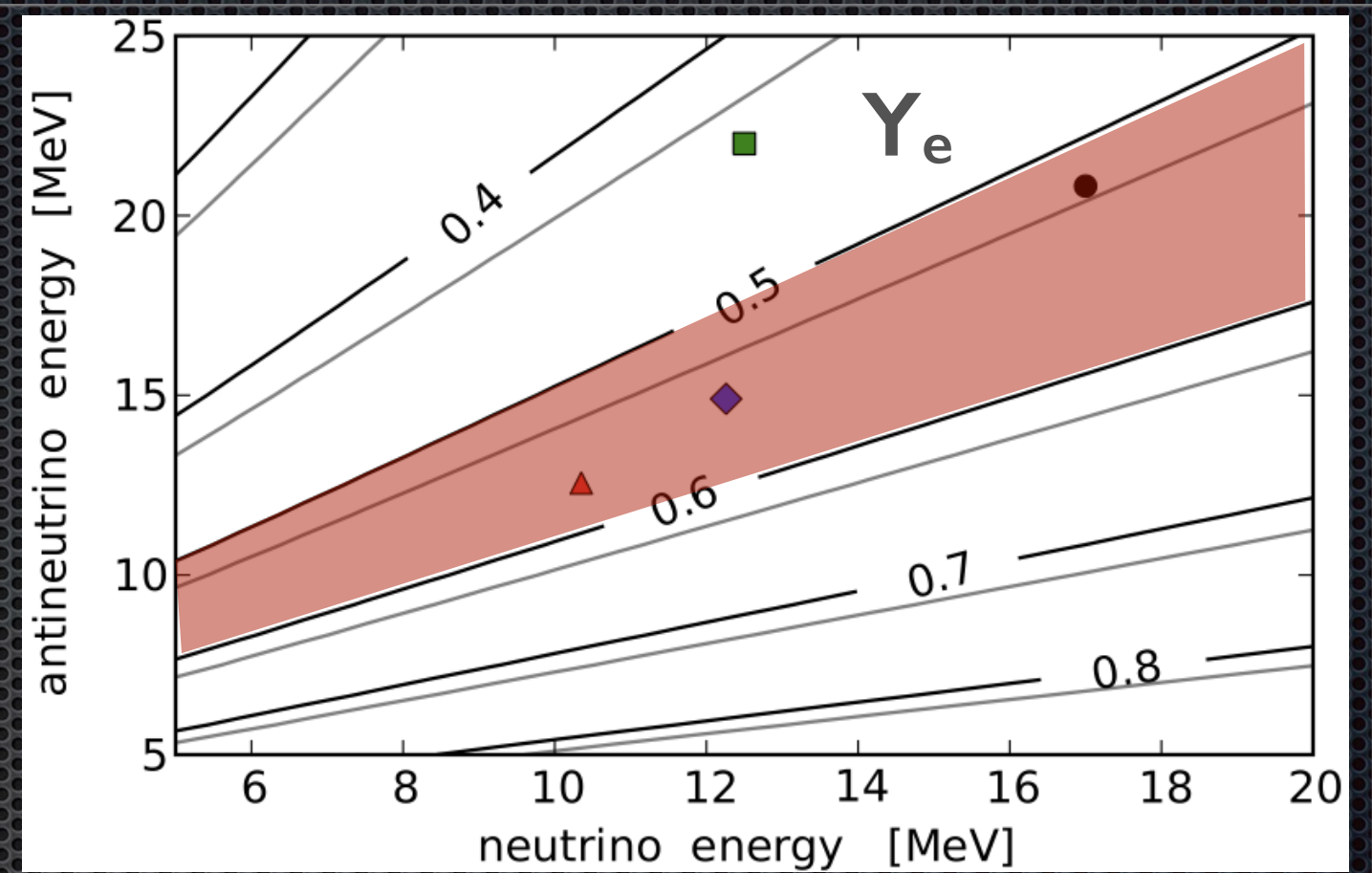
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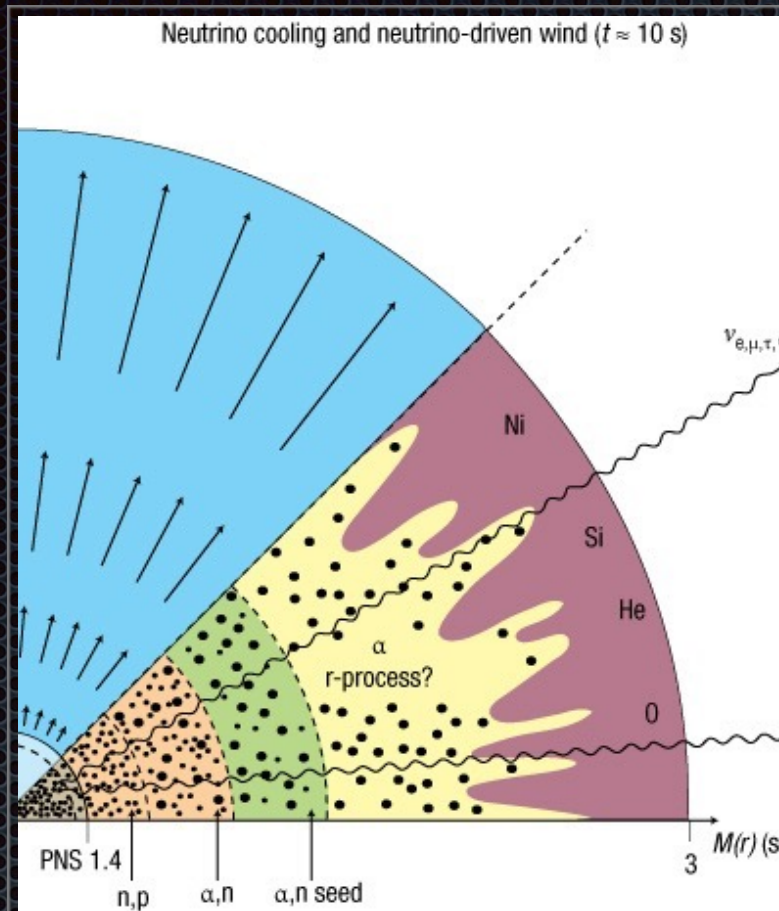


A. Arcones, and F.K Thielemann, 2013

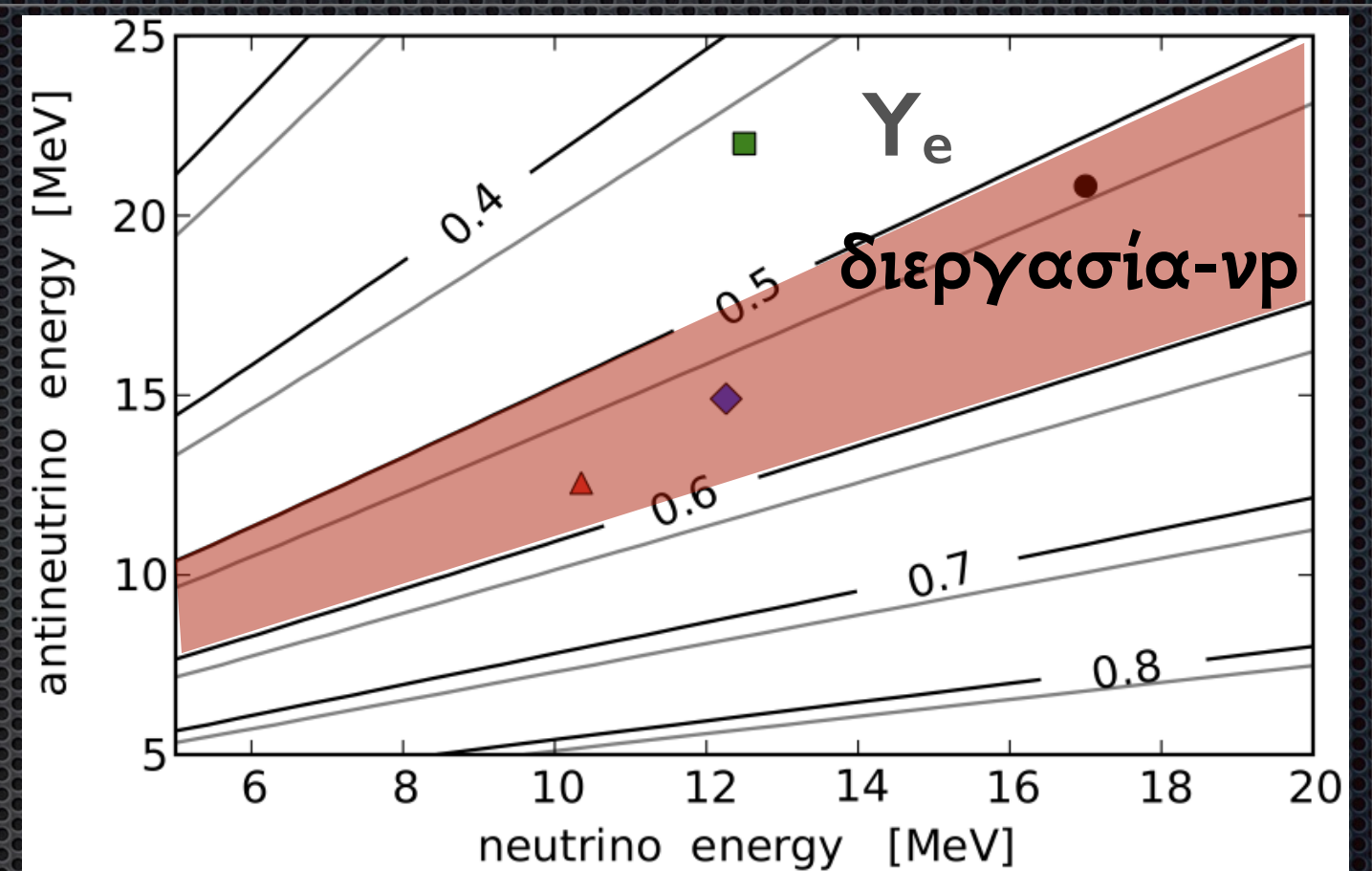
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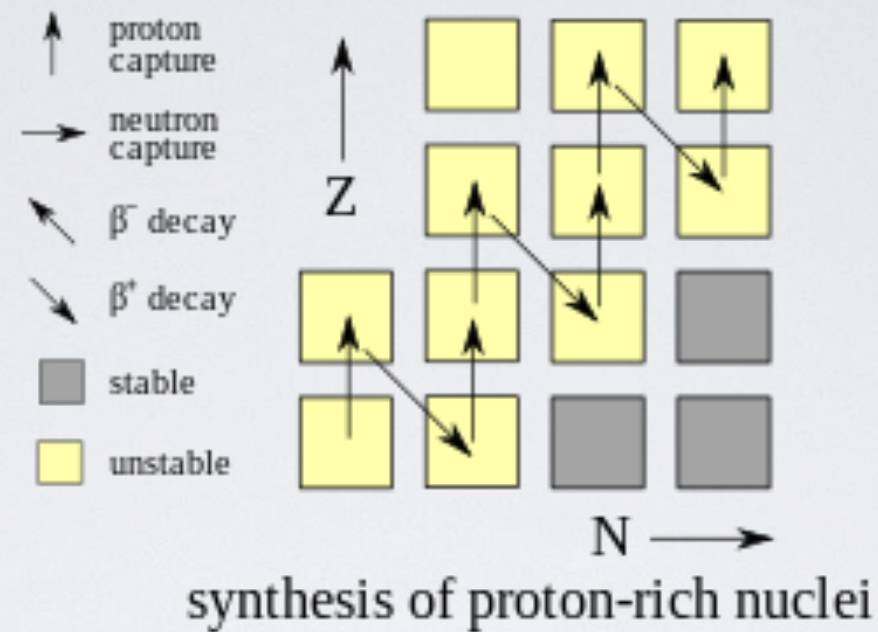


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$$Y_e \approx \left[1 + \frac{L_{\bar{\nu}_e} (\epsilon_{\bar{\nu}_e} - 2\Delta + 1.2\Delta^2/\epsilon_{\bar{\nu}_e})}{L_{\nu_e} (\epsilon_{\nu_e} + 2\Delta + 1.2\Delta^2/\epsilon_{\nu_e})} \right]^{-1}$$

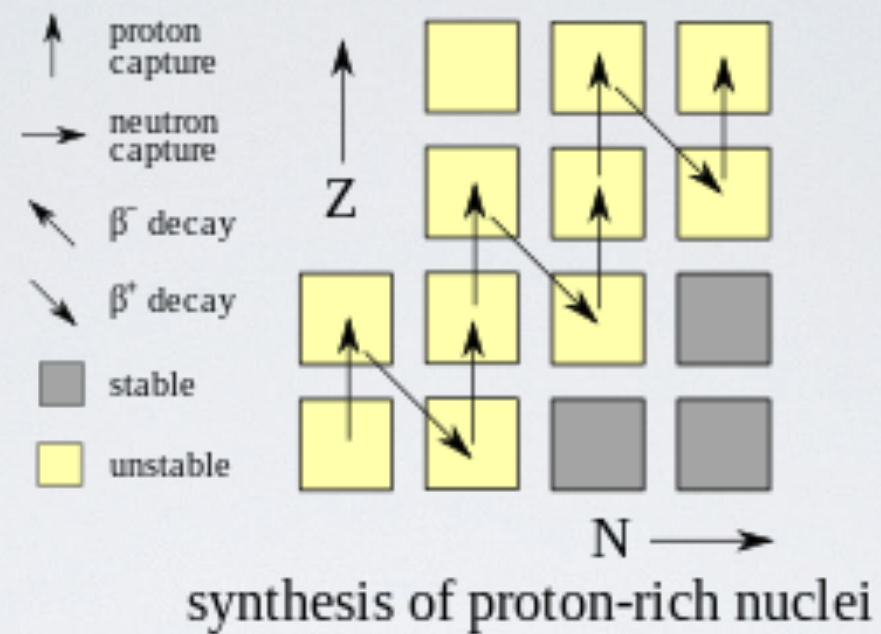
$Y_e < 0.5$, Πλεόνασμα νετρονίων
 $Y_e > 0.5$, Πλεόνασμα πρωτονίων

The neutrino-p process

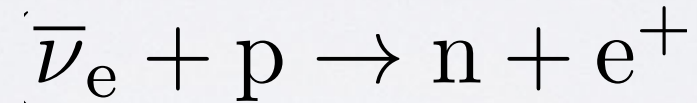


Should slow down at bottlenecks, e.g. ^{64}Ge (long beta-decay half life)

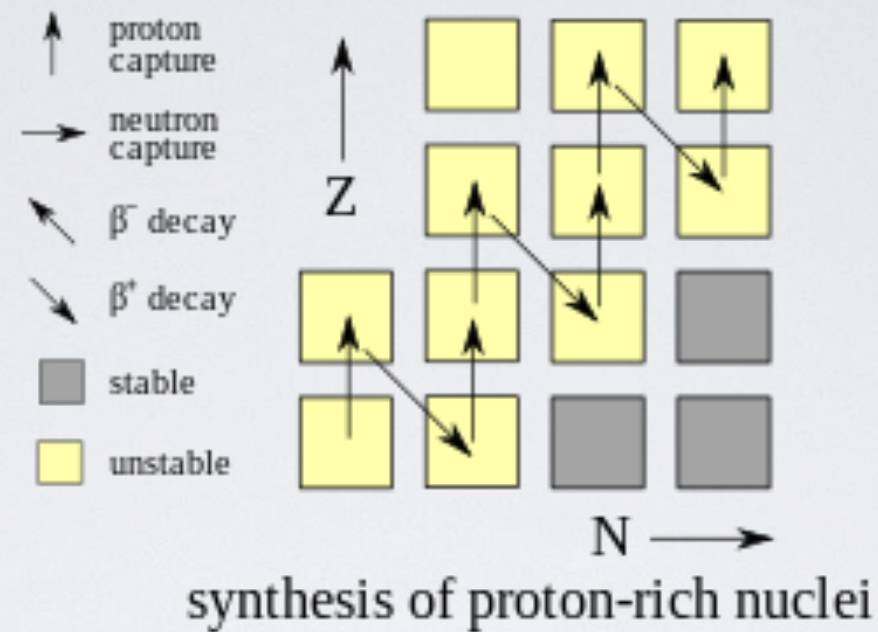
The neutrino-p process



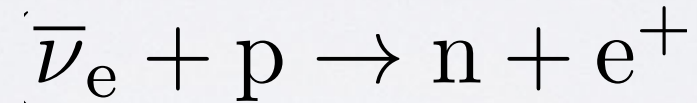
Should slow down at bottlenecks, e.g. ^{64}Ge (long beta-decay half life)



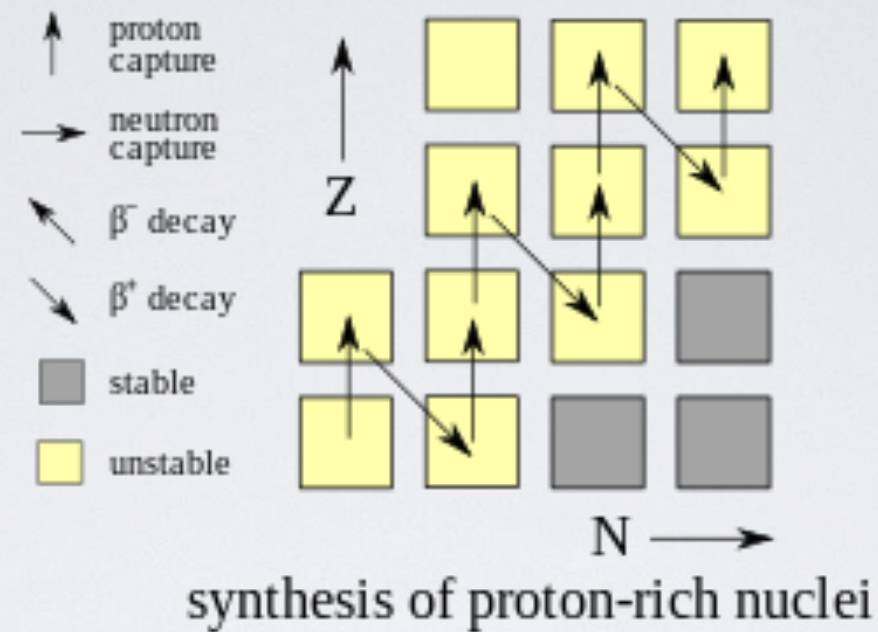
The neutrino-p process



Should slow down at bottlenecks, e.g. ⁶⁴Ge (long beta-decay half life)



The neutrino-p process



Should slow down at bottlenecks, e.g. ^{64}Ge (long beta-decay half life)

