Comparison Between Measured Gamow-Teller Distributions and the Corresponding Electron Capture Rates for pf-shell Nuclei in Pre-supernova Stars

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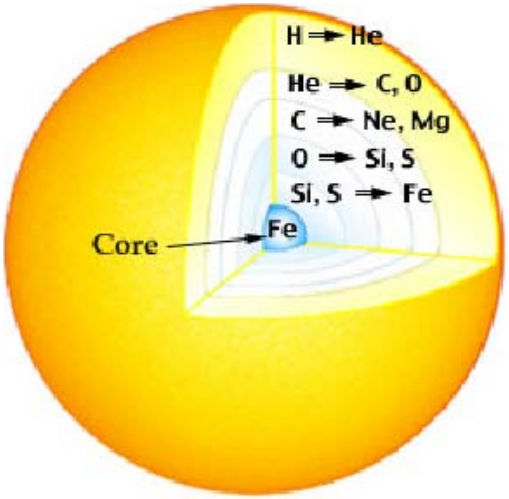
Electron Capture and Supernovae

Electron Capture:

$e^- + A(Z,N) \rightarrow A(Z-1,N+1) + \nu_e$

Core-Collapse Supernova



http://www.solstation.com/x-objects/xte-bh.htm

Type Ia Supernova

David A.Hardy
www.astroart.org & PPARC

Influences Dynamics of Supernova

Provide constraints on models

Electron Capture and B(GT)

Electron Capture ⇒ Gamow-Teller Transitions:

Gamow-Teller (GT)

(spin-flip)

$\Delta S = 1$, $\Delta L = 0$, $\Delta J = 1$, $\Delta T = 1$

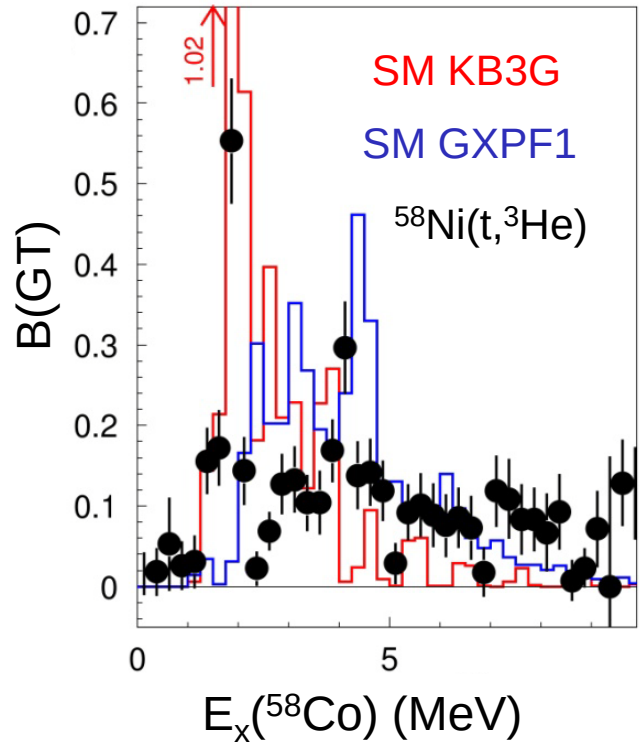
Transition Strength = B(GT)

B(GT) measured via charge-exchange

(n,p), (d,^{2}He), (t,^{3}He)

e.g. t + ^{58}Ni → ^{58}Co + ^{3}He

A.L. Cole et al. 2006



$$B(GT) \propto \frac{d\sigma(q=0)}{d\Omega}$$

Electron Capture Rate ∝ B(GT)

Core-Collapse Supernova and B(GT)

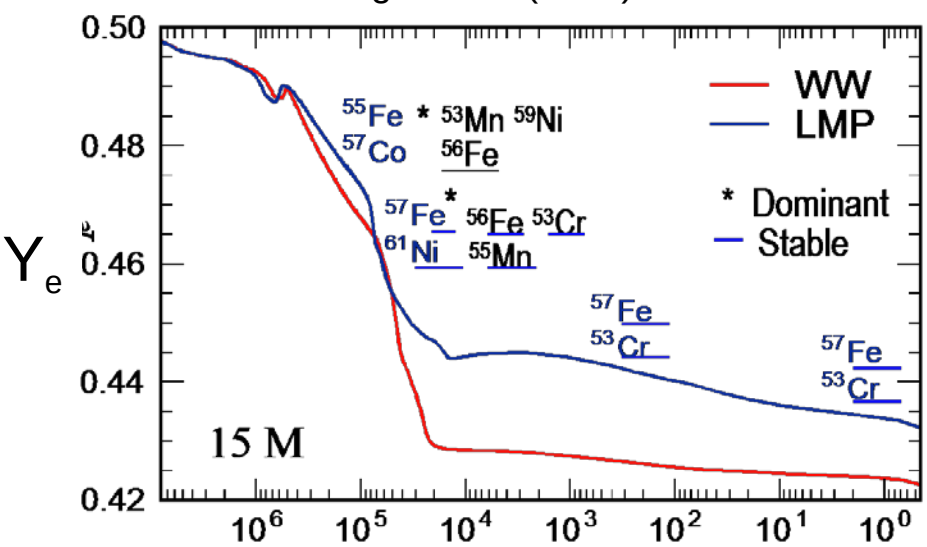
Electron Capture Rate $\propto$ B(GT)

Consider two models for calculating B(GT)

WW (Woosley, Weaver)
Fuller, Fowler, Newman (FFN) Weak Interaction rates
- Independent Particle Model (IPM)
- No interaction b/t valance nucleons

LMP (Langanke, Martinez-Pinedo) & Heger, Langanke, LMP Weak Interaction rates
- Shell Model (SM) Calculations
- Interaction b/t valance nucleons leads to fragmentation and quenching of B(GT)

Heger et al. (2001)



- pf-shell nuclei A~45-65 important
- Stable and Radioactive Nuclei
- Several Nuclei are important

Can Not Measure them all

Calculate and Compare

Systematically compare B(GT) distributions and Electron Capture rates for pf-shell nuclei, A~45-65

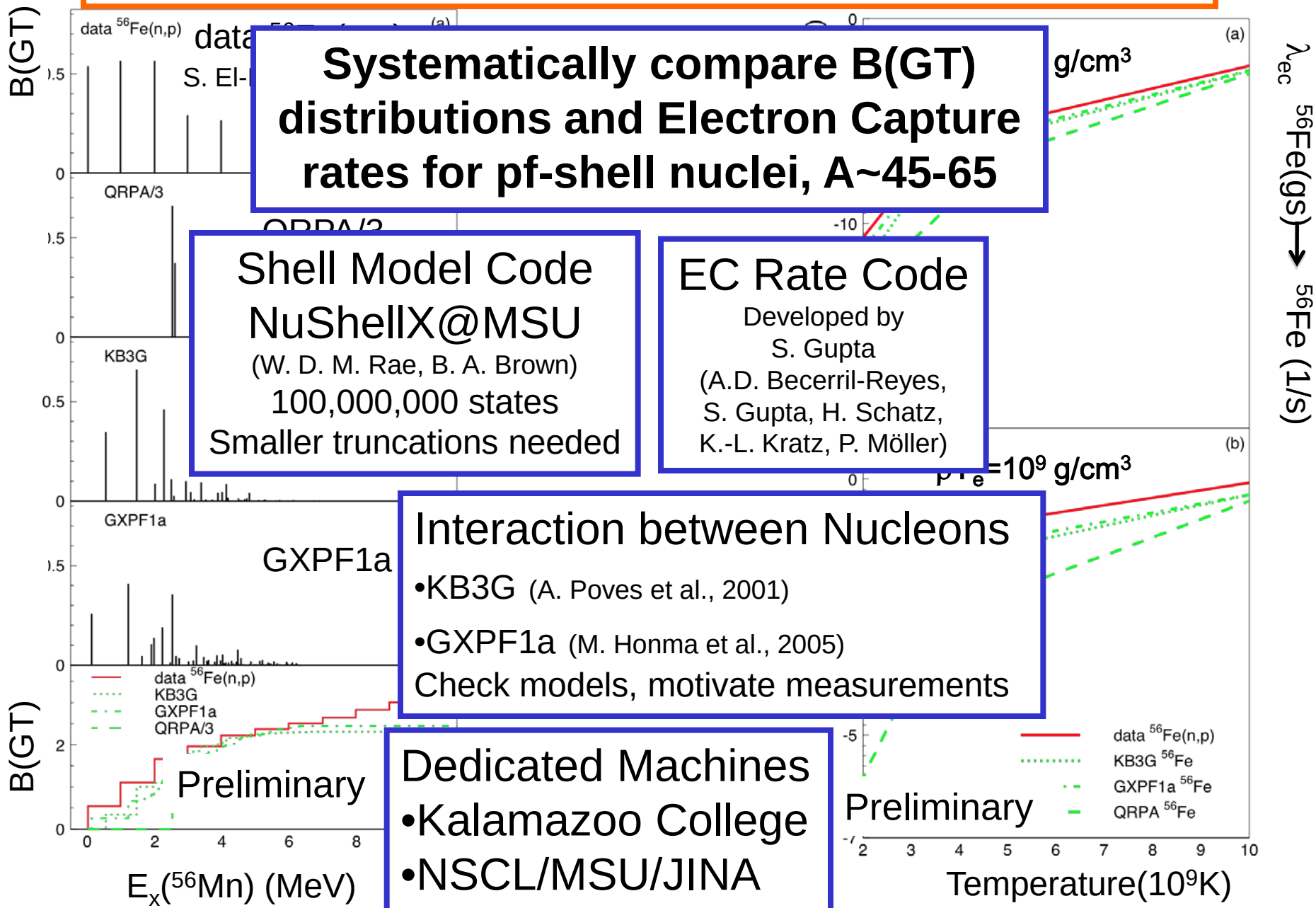
Shell Model Code
NuShellX@MSU
(W. D. M. Rae, B. A. Brown)
100,000,000 states
Smaller truncations needed

EC Rate Code
Developed by
S. Gupta
(A.D. Becerril-Reyes, S. Gupta, H. Schatz, K.-L. Kratz, P. Möller)

Interaction between Nucleons
- KB3G (A. Poves et al., 2001)
- GXPF1a (M. Honma et al., 2005)

Check models, motivate measurements

Dedicated Machines
- Kalamazoo College
- NSCL/MSU/JINA



Where to Start?

Nuclei for which there exist measured B(GT):
^{45}Sc,^{48}Ti,^{50}V,^{51}V,^{55}Mn,^{54}Fe,^{56}Fe,^{59}Co,^{58}Ni,^{60}Ni,^{62}Ni,^{64}Ni,^{64}Zn

B(GT) measured via charge-exchange

(n,p), (d,^{2}He), (t,^{3}He)

e.g. t + ^{58}Ni → ^{58}Co + ^{3}He

$$B(GT) \propto \frac{d\sigma(q=0)}{d\Omega}$$

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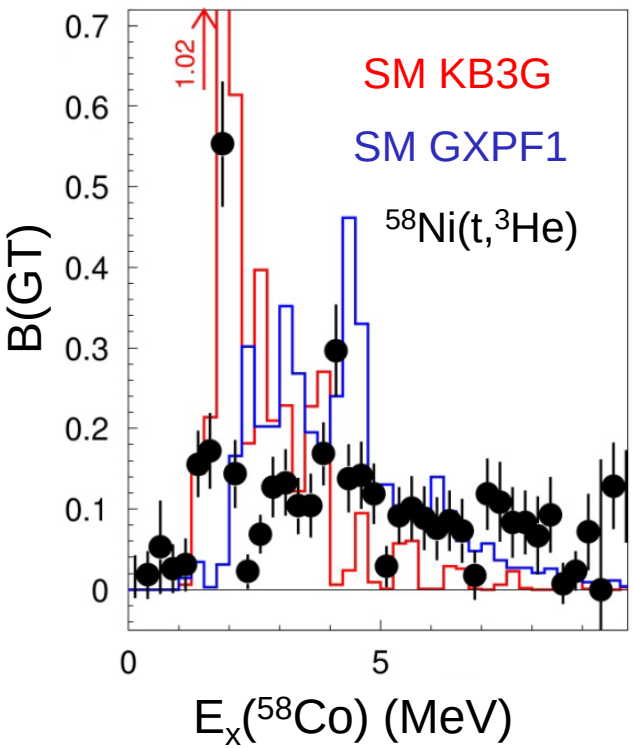
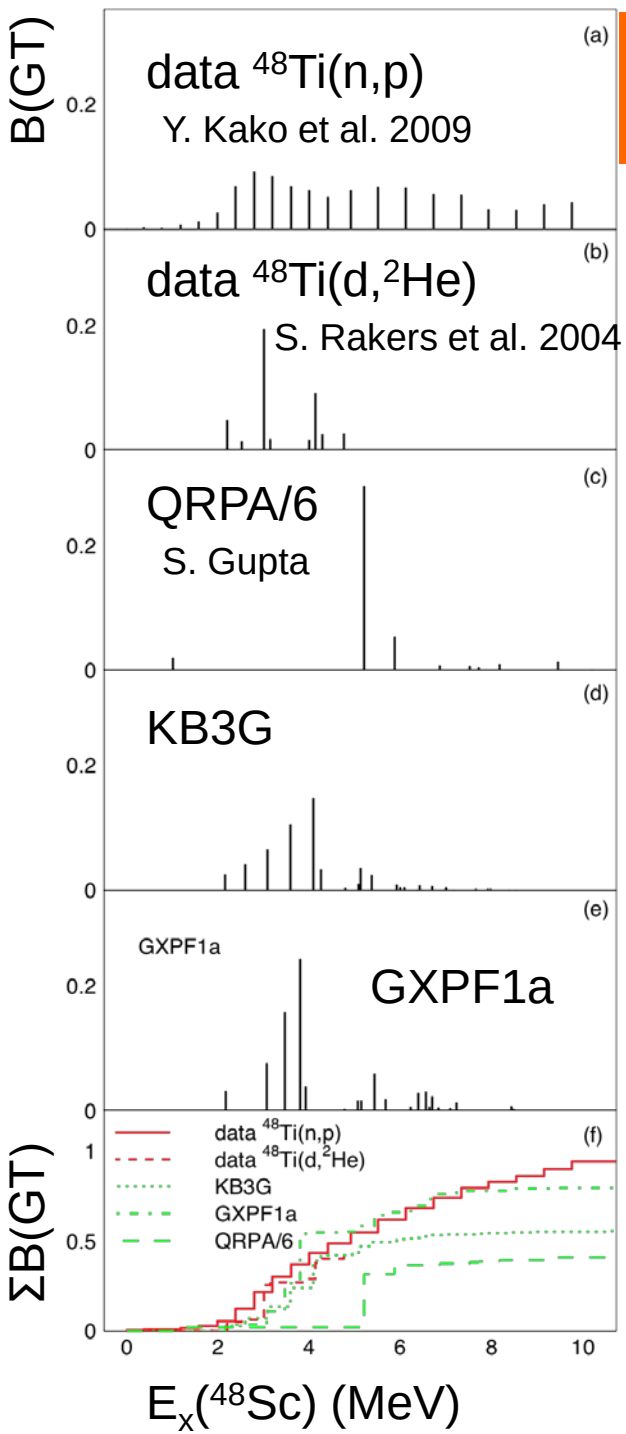
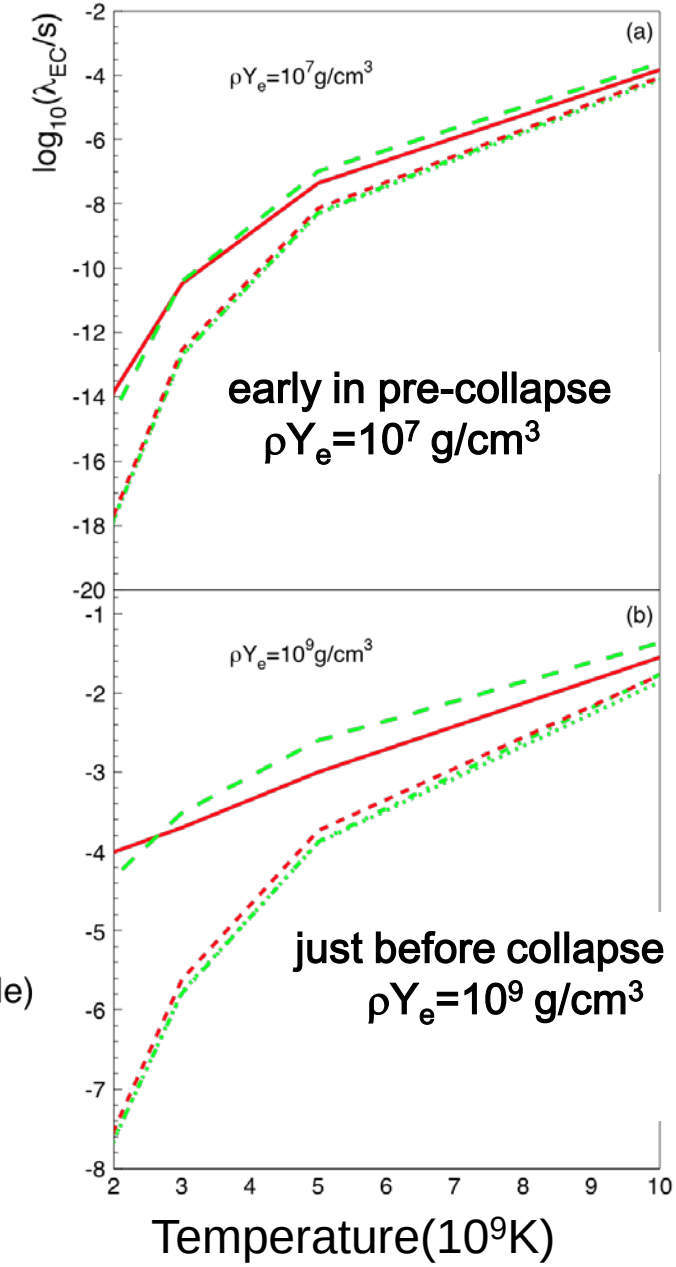


$^{48}Ti \rightarrow {}^{48}Sc$

Preliminary

$\lambda_{ec} \propto B(GT)$, state energy and strength





λ_{ec} ^{48}Ti(gs) → ^{48}Sc (1/s)

data ^{48}Ti(n,p)

data ^{48}Ti(d,^{2}He)

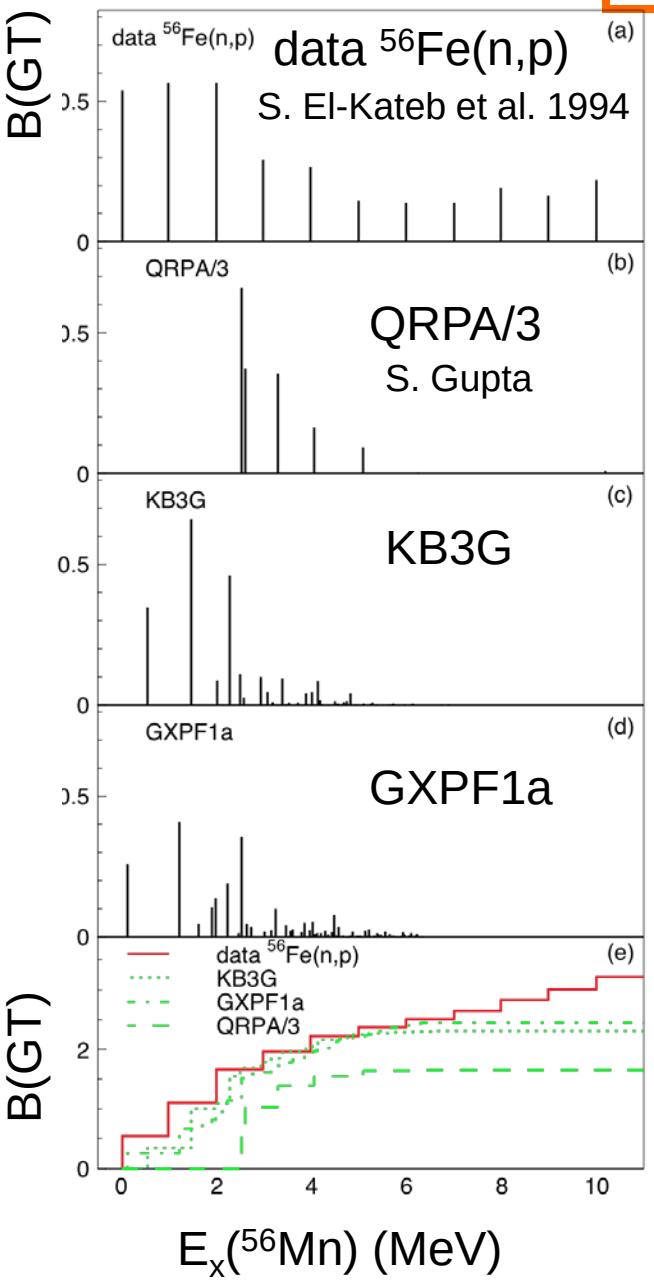
KB3G ^{48}Ti

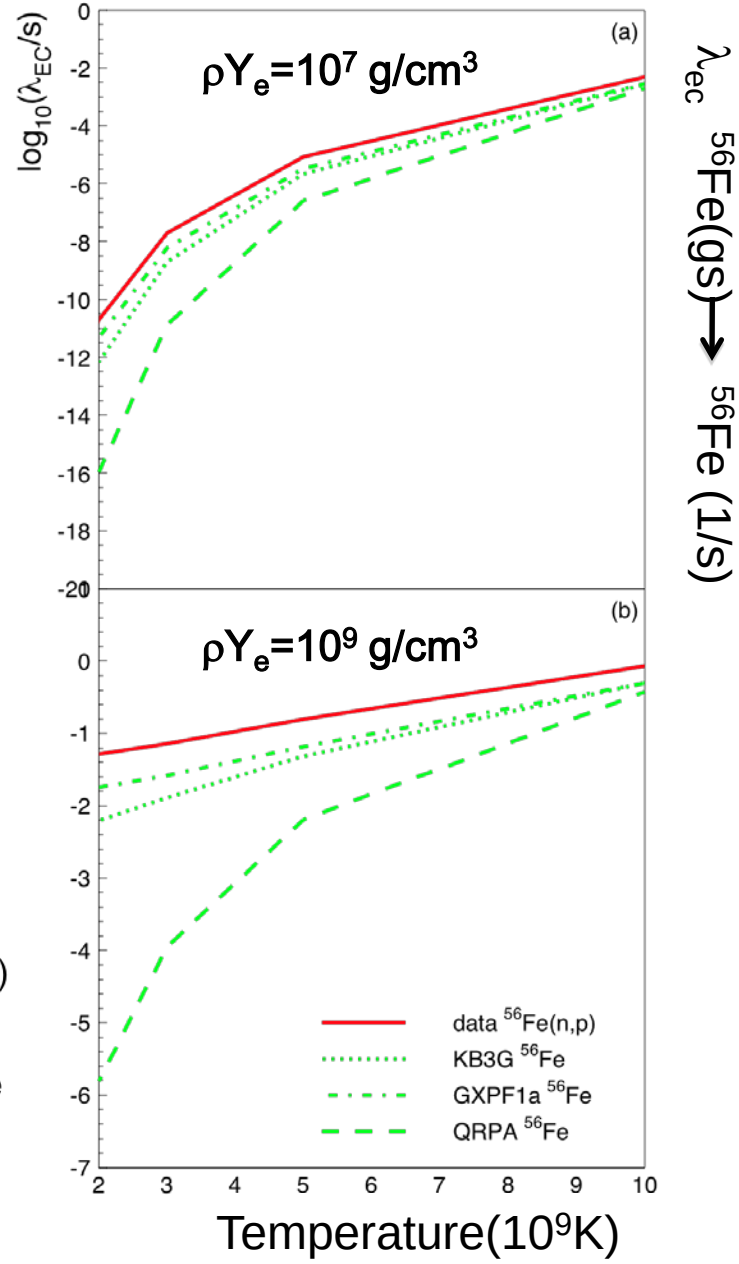
GXPF1a ^{48}Ti

QRPA ^{48}Ti

$^{56}Fe \rightarrow {}^{56}Mn$

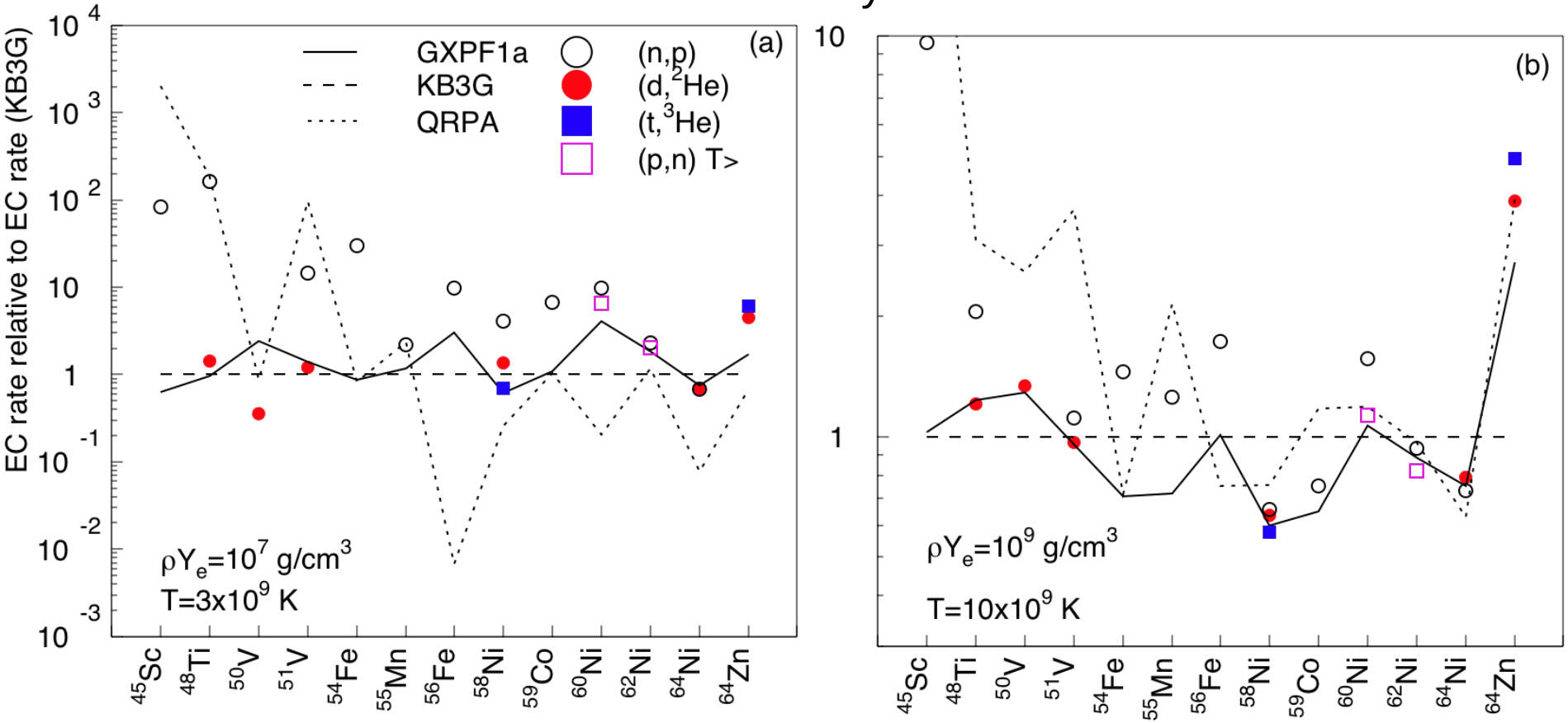
Preliminary





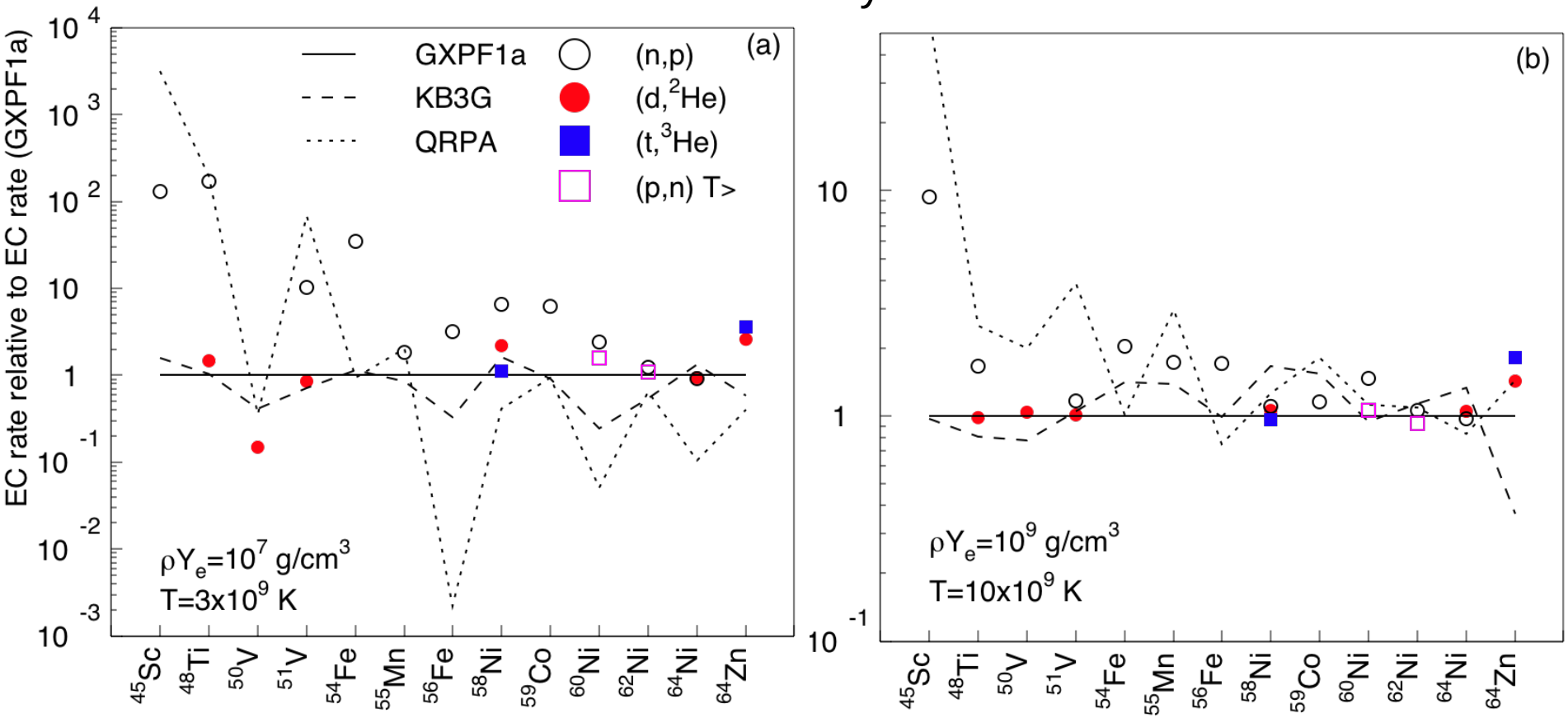
EC Rate Comparison: KB3G

Preliminary



EC Rate Comparison: GXPF1a

Preliminary



Collaboration

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