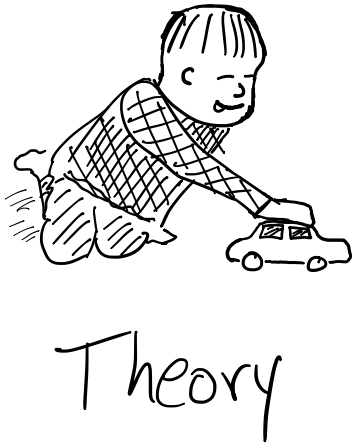
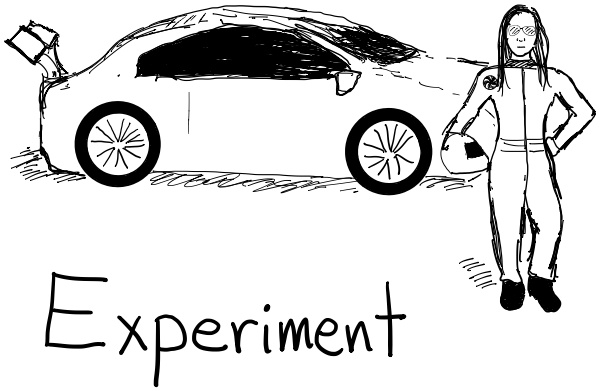
Science Opportunities at ARIEL

A theorist's perspective

Ragnar Stroberg

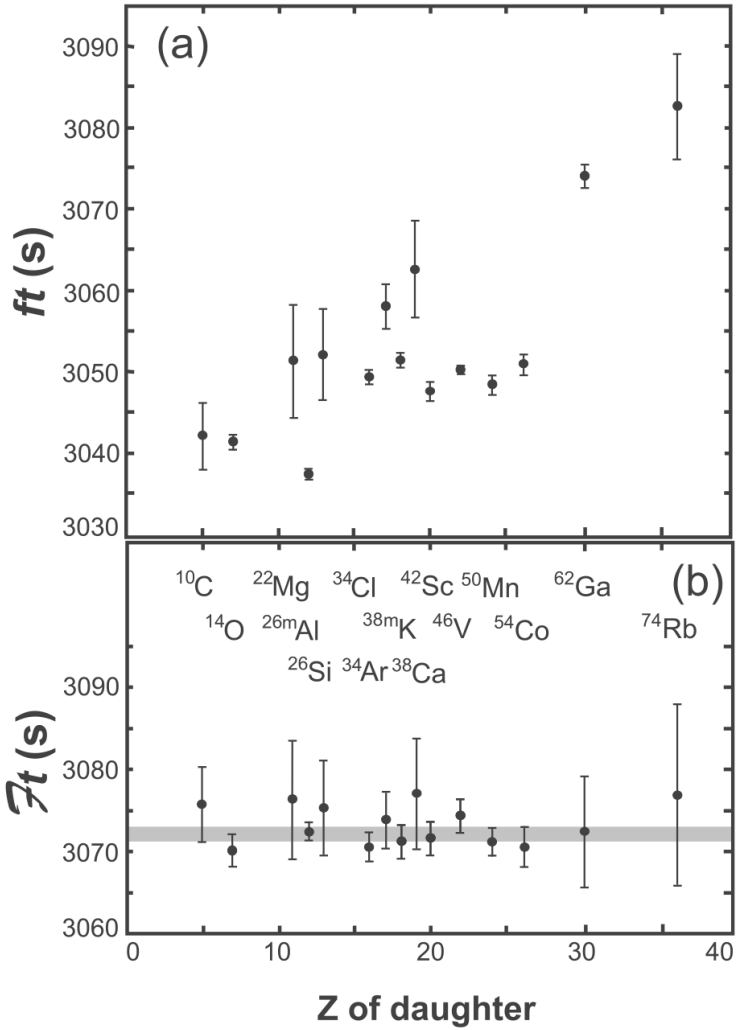
ARIEL Day
Science Week
July 31-Aug 4, 2023
TRIUMF, Vancouver, BC

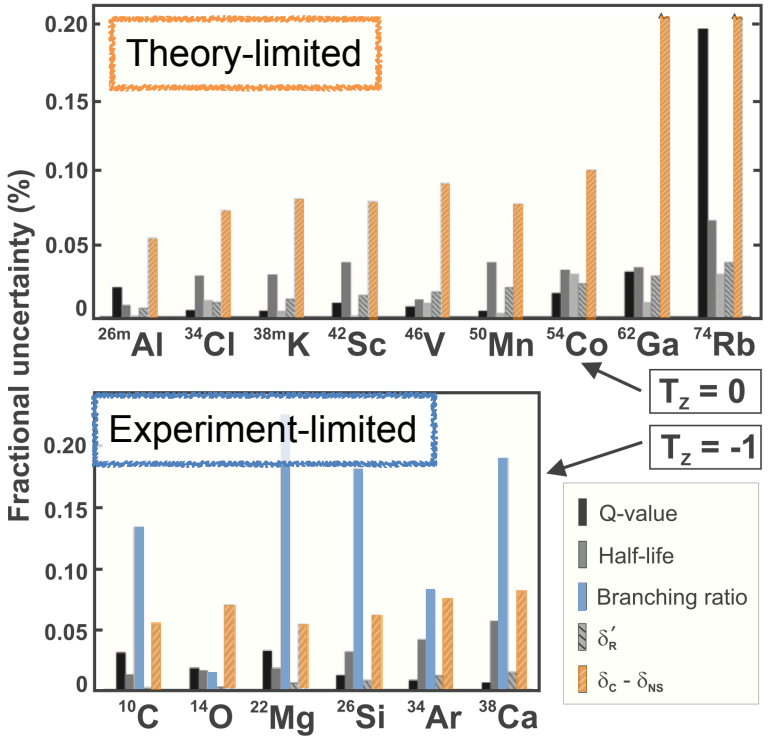




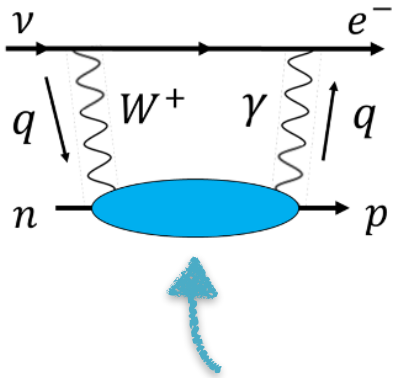
Superallowed $0^+ \rightarrow 0^+$ decays

$$\mathcal{F}t \equiv ft(1+\delta_R')(1+\delta_{NS}-\delta_C) = \frac{K}{2G_V^2(1+\Delta_R^V)}$$

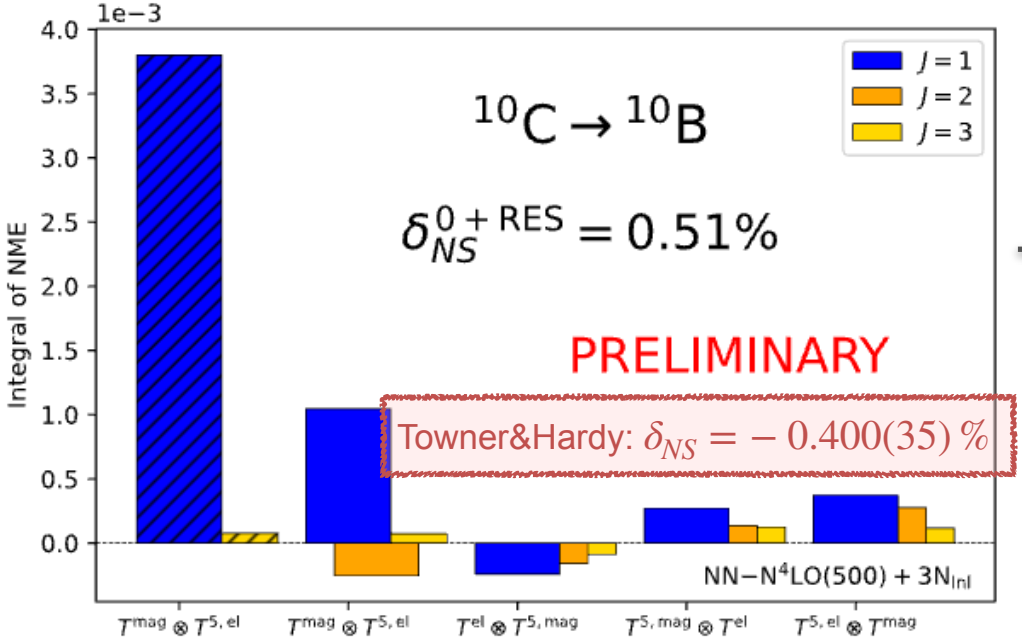


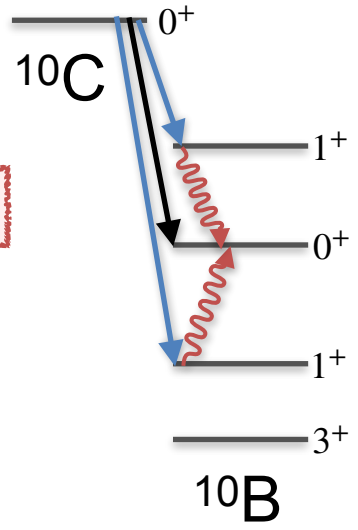


Theory progress on the δ_{NS} correction



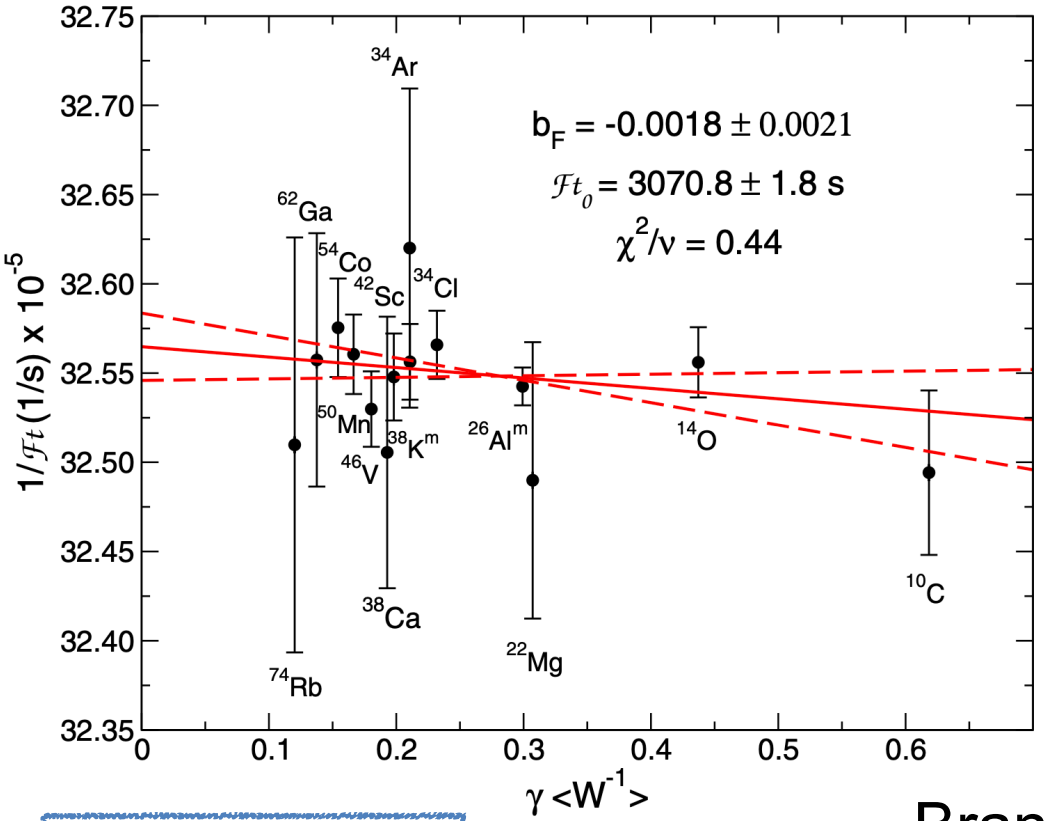
proton propagating in-medium





$$\delta_{NS} = 2\left[\Box_{W\gamma}^{nuc} - \Box_{W\gamma}^{free\ n}\right]$$

NCSM calculations by M. Gennari, M. Drissi, and P. Navrátil



Dunlop+ PRL 116 172501 (2016)

Search for a scalar weak current

$$C_S\,\bar{\psi}_p\psi_n\,\bar{\phi}_e(1+\gamma_5)\phi_{\bar{\nu}}$$

$$\mathcal{F}t \rightarrow \mathcal{F}t\left(1+b_F\gamma\left\langle\frac{1}{W}\right\rangle\right)$$

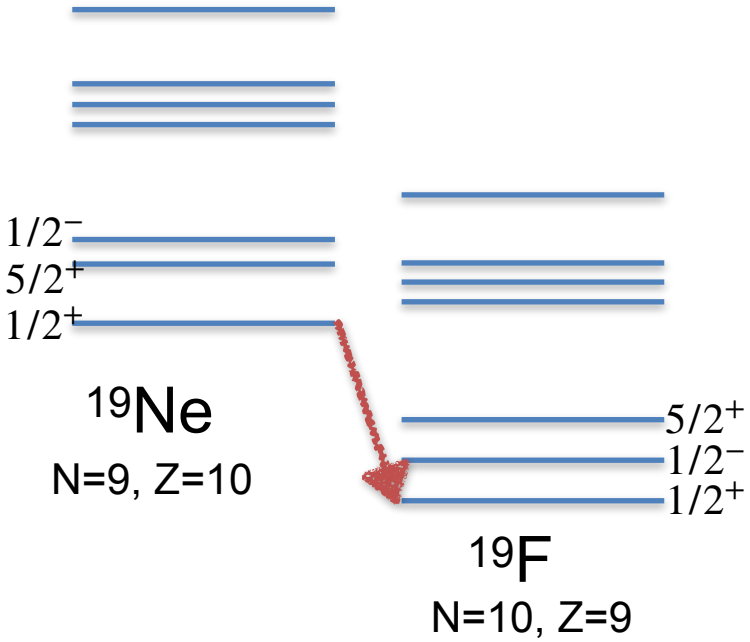
$$b_F = -2\frac{C_s}{C_V}$$

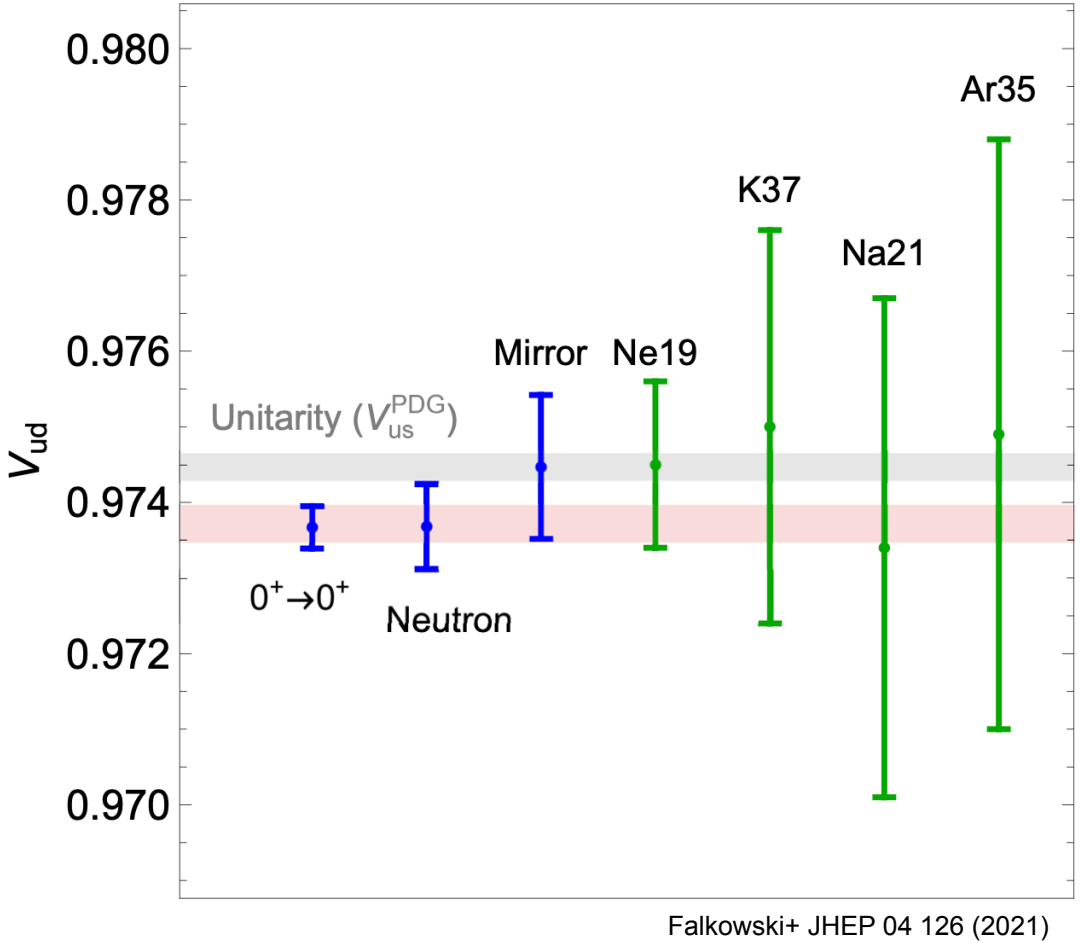
Branching ratio:

Savard (1995): 1.4625 ± 0.0020 (stat) ± 0.0015 (syst)

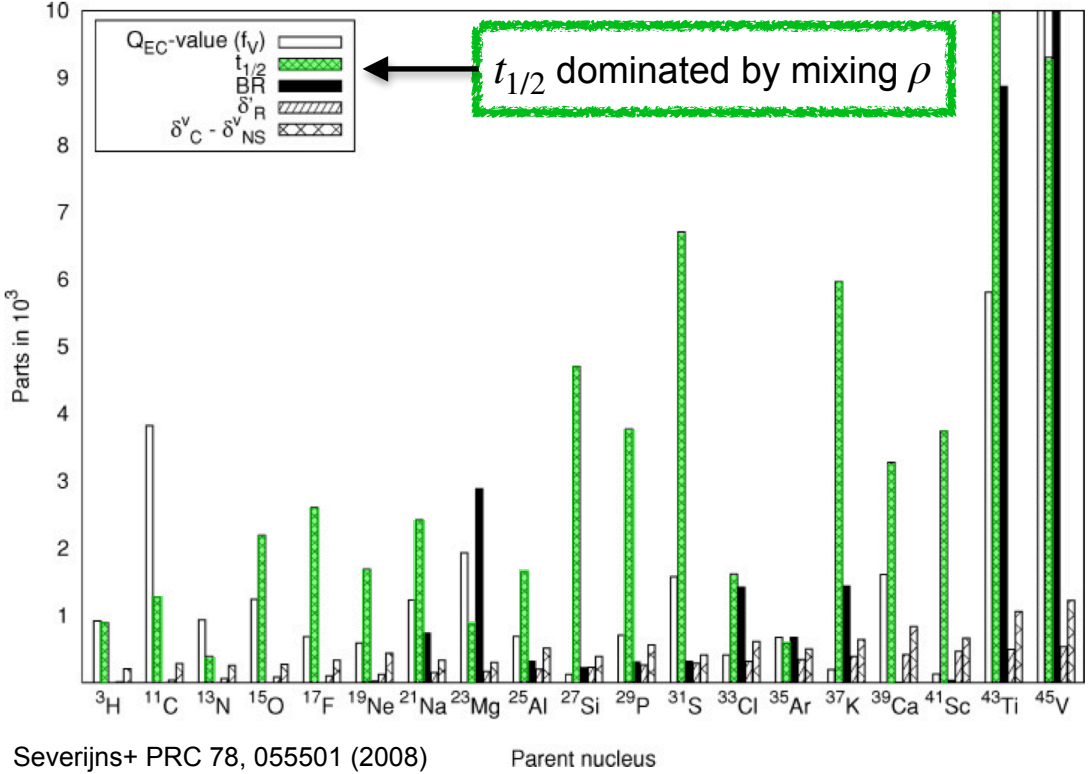
Fujiwara (1999): 1.4664 ± 0.0038 (stat) ± 0.0006 (syst)

Superallowed mirror decays





Falkowski+ JHEP 04 126 (2021)



Severijns+ PRC 78, 055501 (2008)

$J_f = J_i \neq 0$ both Fermi and Gamow-Teller are possible.

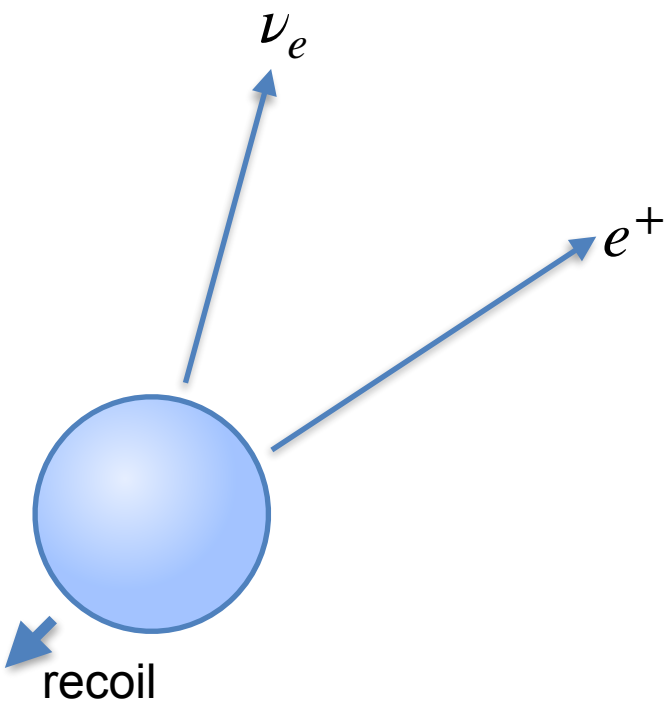
Fermi-Gamow-Teller mixing ratio

$$\rho = \frac{C_A M_{GT}}{C_V M_F}$$

needs to be measured.

Measuring the mixing ratio ρ

$$\frac{dw}{dE_e d\Omega_e d\Omega_\nu} \sim 1 + a_{\beta\nu}\frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} + b_F \frac{m_e}{E_e}$$

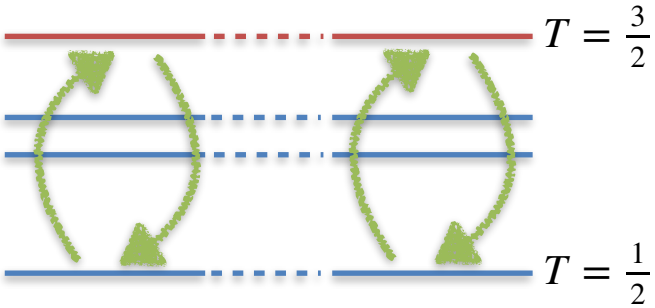


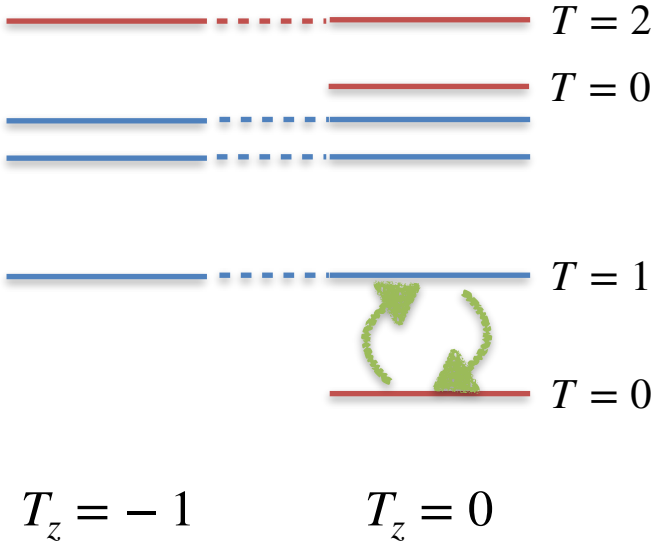
Beta-neutrino asymmetry
(in the Standard Model)

$$a_{\beta\nu} = \frac{1 - \rho^2/3}{1 + \rho^2}$$

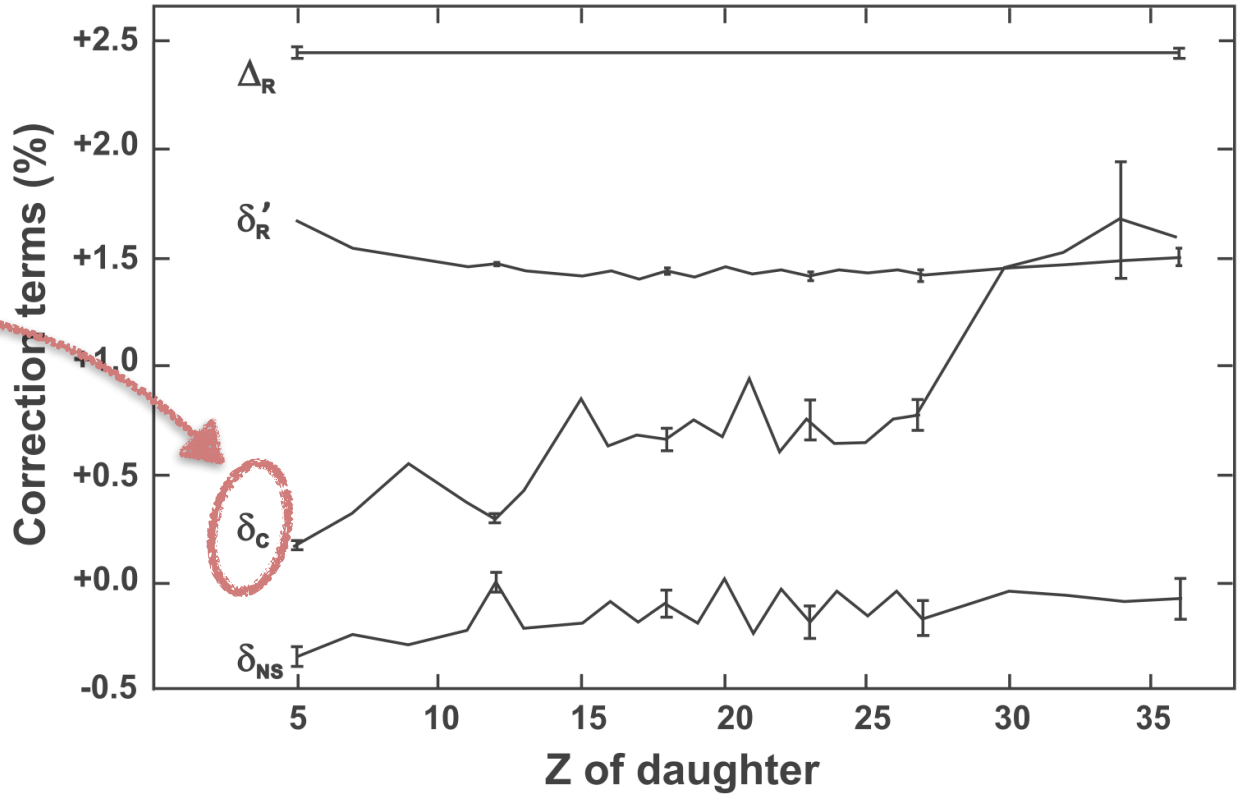
Why is this helpful from the theory perspective?

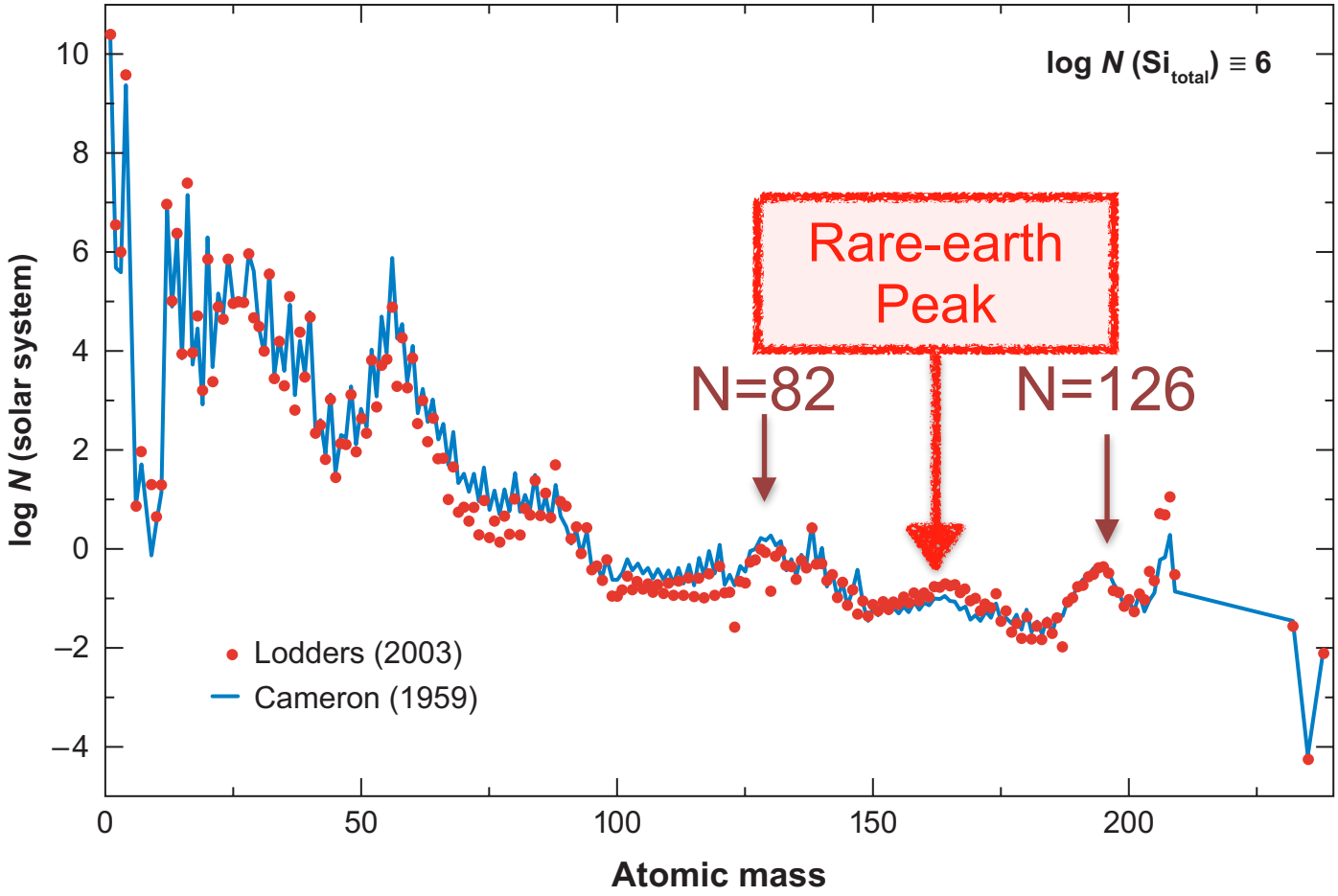
Isospin mixing is similar in both nuclei, so errors will (🤞) tend to cancel out.



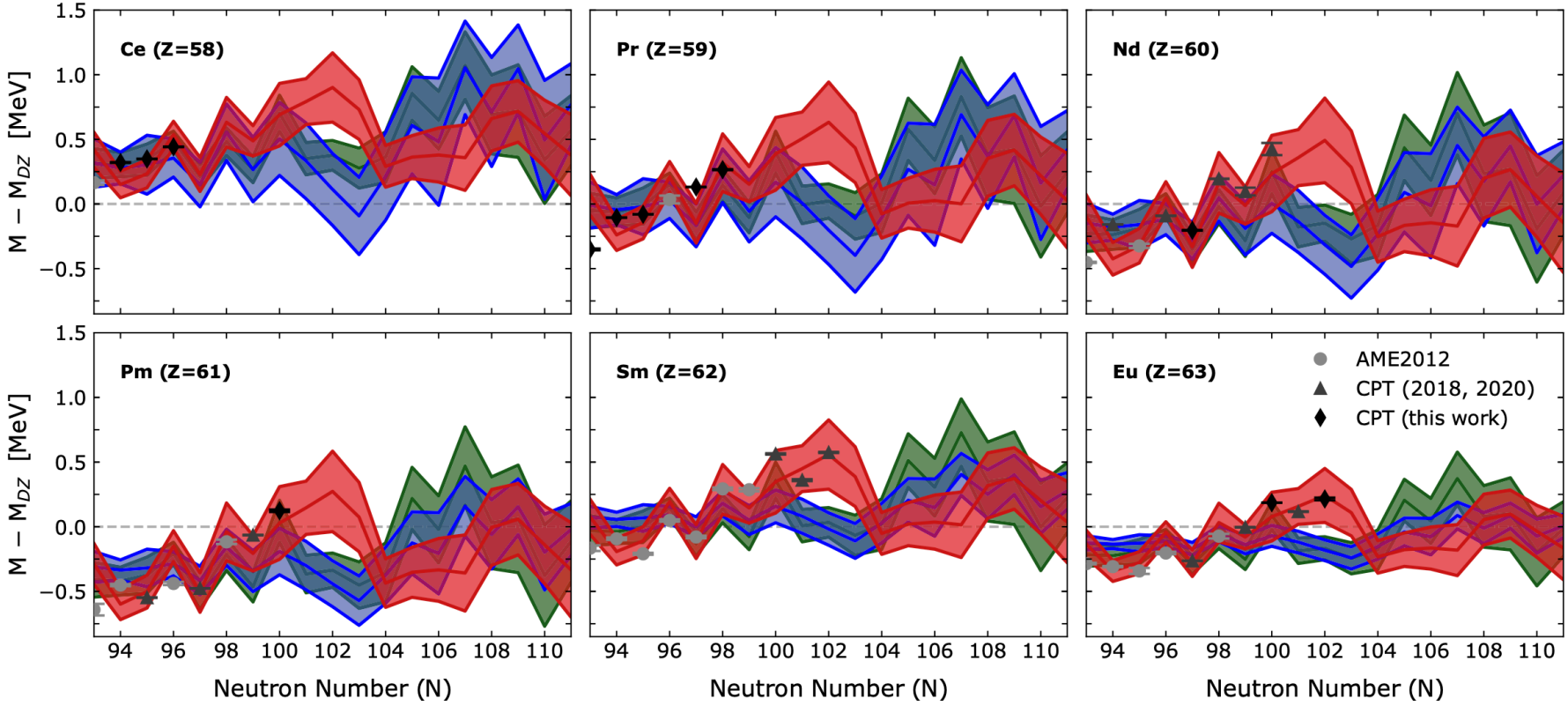


- Z dependence dominated by δ_C
- Critical for testing CVC / searching for scalar currents.



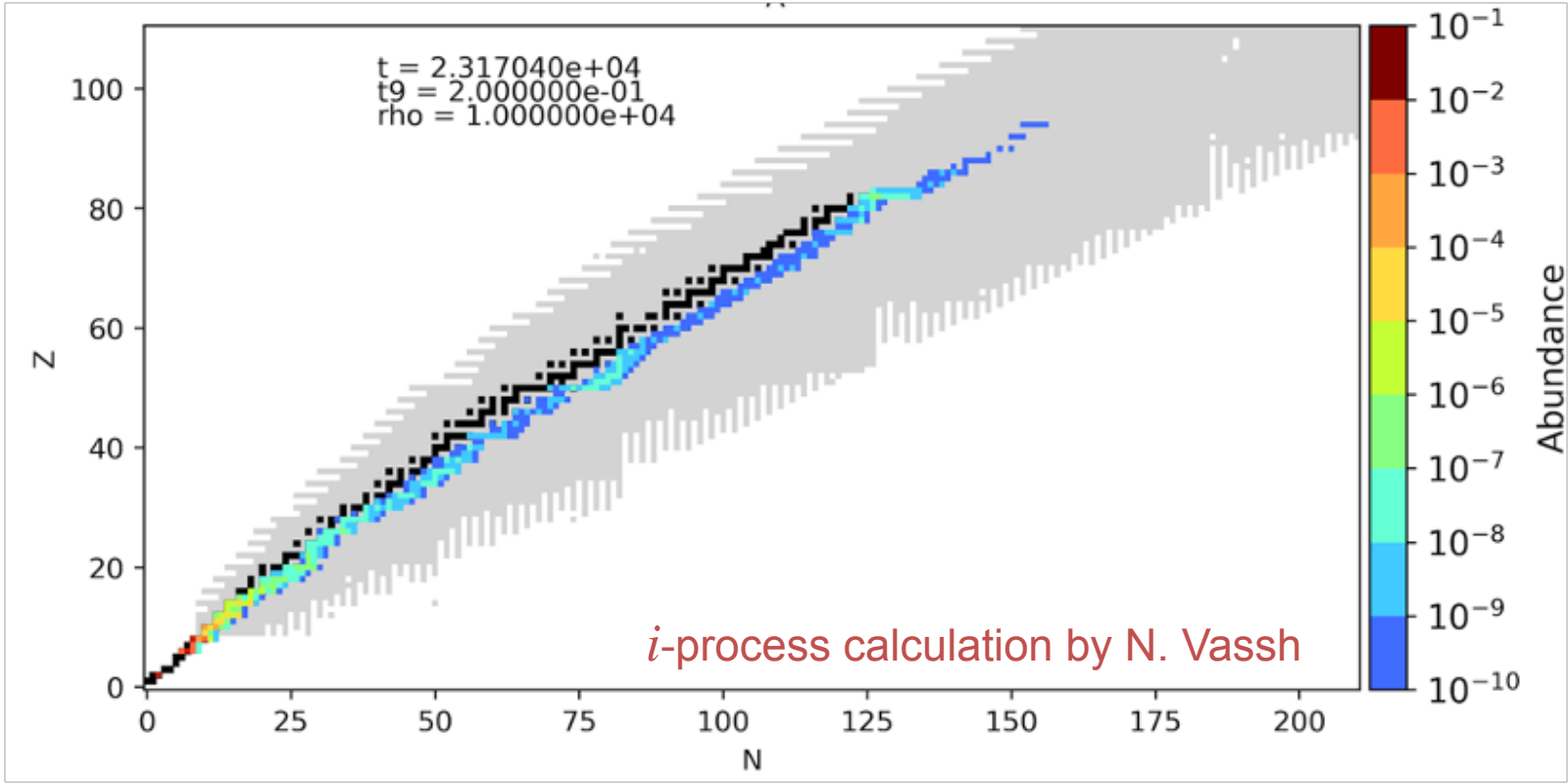

log N (Si$_{total}$) ≡ 6
Rare-earth Peak
N=82
N=126
log N (solar system)
Lodders (2003)
Cameron (1959)
Atomic mass
10
8
6
4
2
0
−2
−4
0
50
100
150
200

Mass data favor “hot” outflow scenario



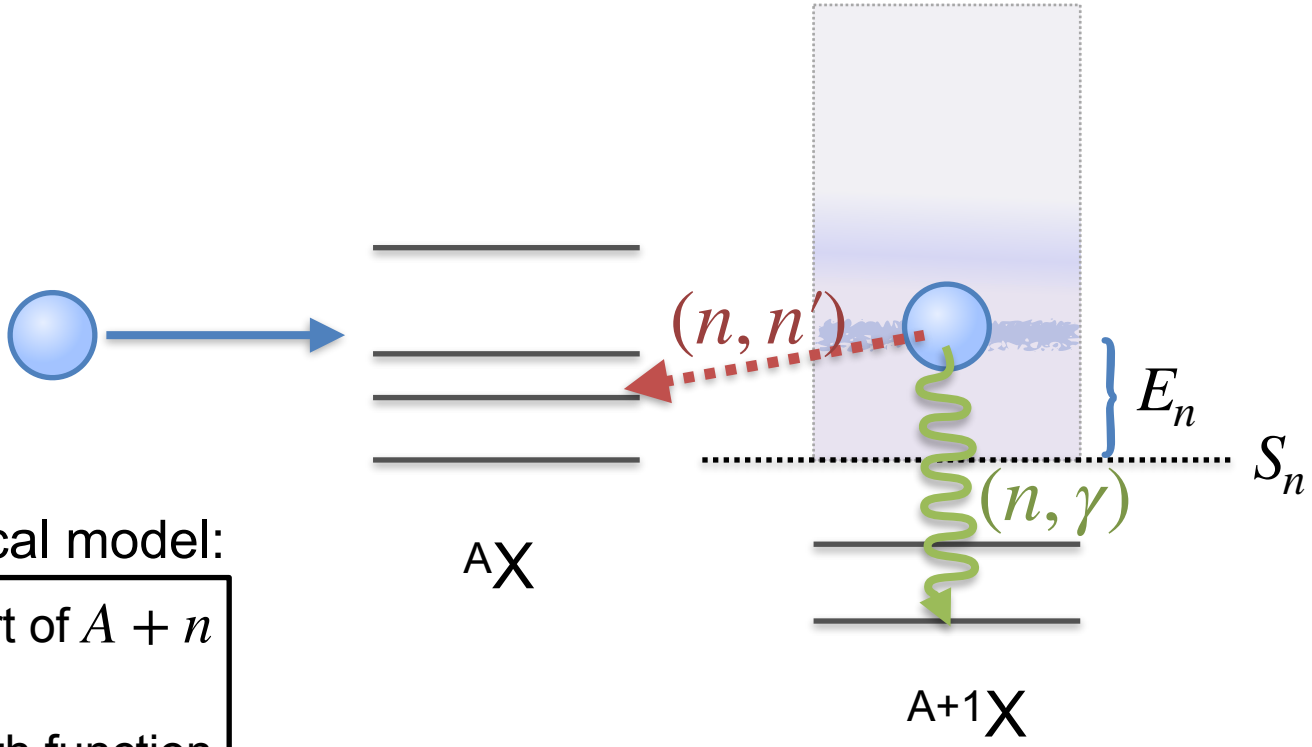
Orford, Vassh,+ PRC 105,L052802 (2022)

Does the i-process contribute to the rare-earth peak?



Neutron capture (n, γ)

$$\sigma_{n,\gamma}^{if} \sim \frac{T_n^i T_\gamma^f}{\sum_{x,f} T_x^f}$$

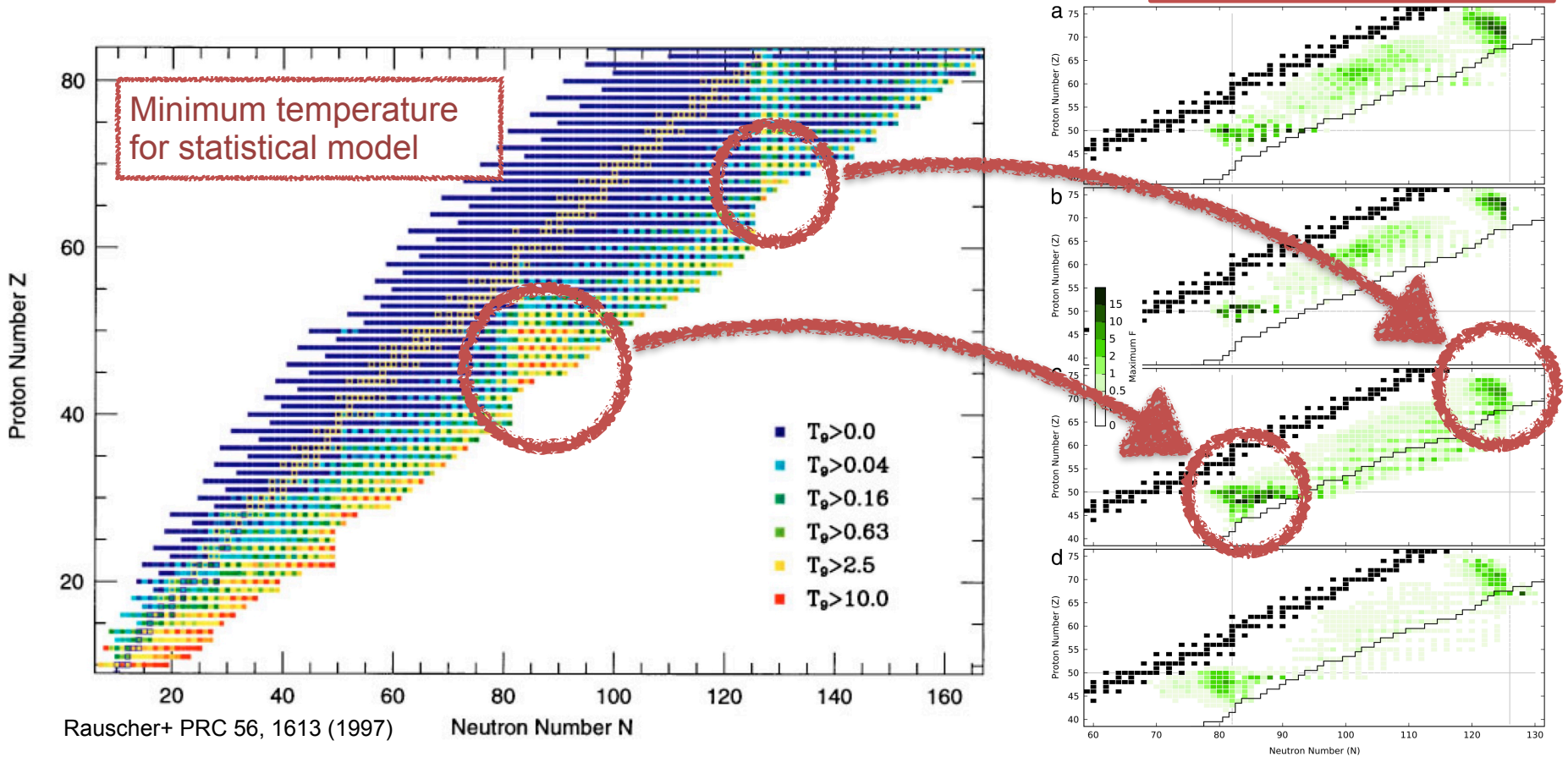


Ingredients to statistical model:

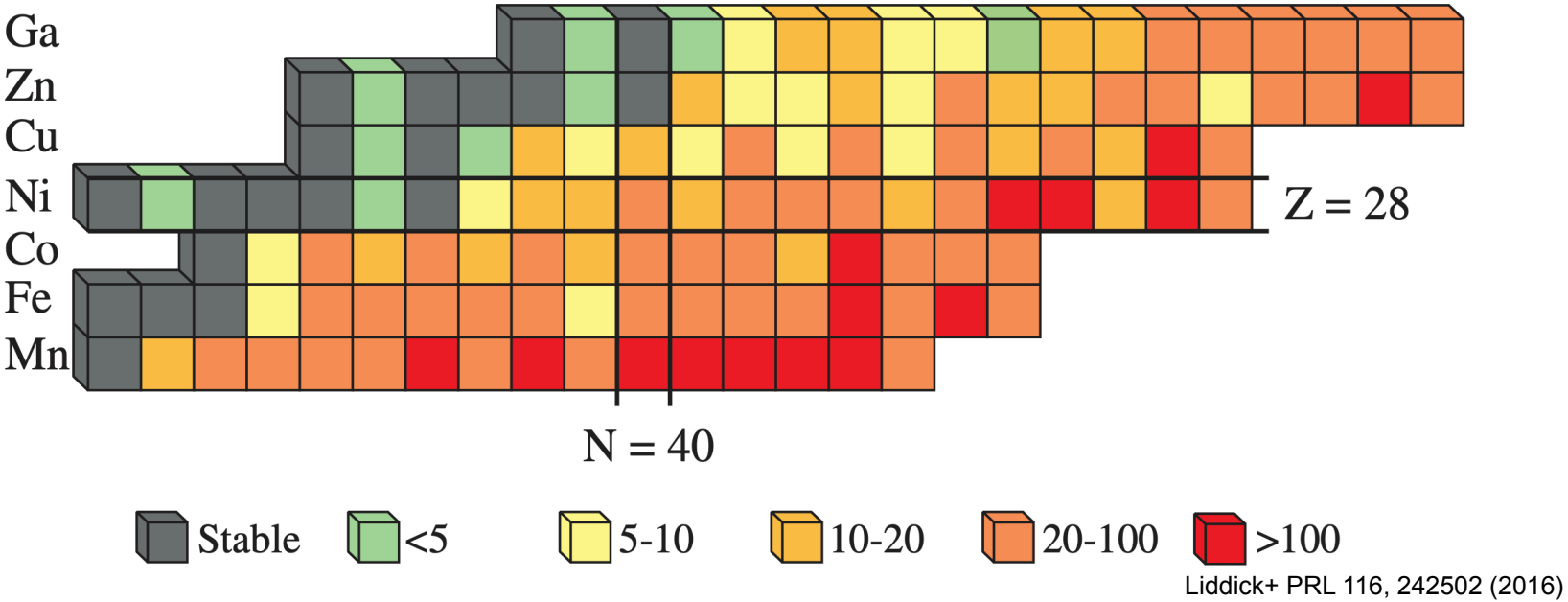
- T_n from imaginary part of $A + n$ optical potential
- $T_\gamma \rightarrow$ gamma strength function
- Level densities $\rho(E)$

When can the statistical model be used?

Sensitivity of r-process abundance on (n, γ) rate



Ratio of highest to lowest predicted (n,γ) rates with different models for the level density and γ-strength function*

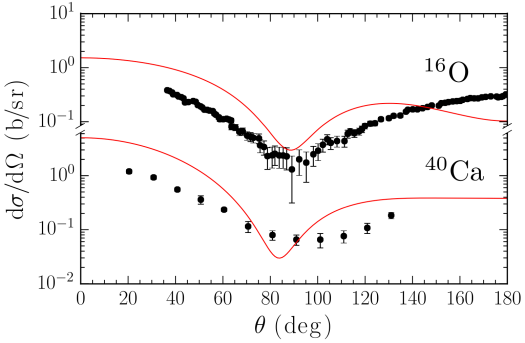


Liddick+ PRL 116, 242502 (2016)

*but optical model only varied between KD and JLM (validated on stable targets).

Ab initio neutron-nucleus optical potentials

Self-energy



Coupled cluster

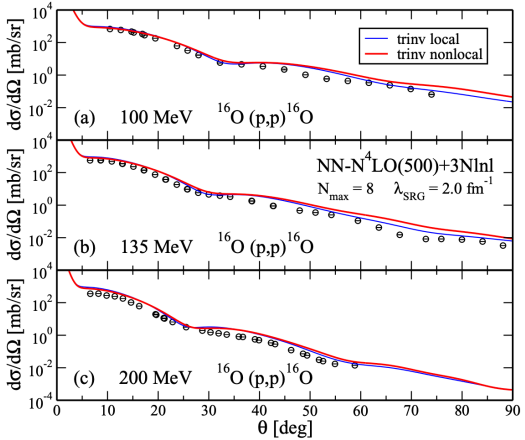
Rotureau+ PRC 95 024315 (2017)

Self-consistent Green's function

Idini, Barbieri, Navrátil PRL 123 092501 (2019)

Not enough absorption (poor description of compound nucleus states)

Multiple scattering



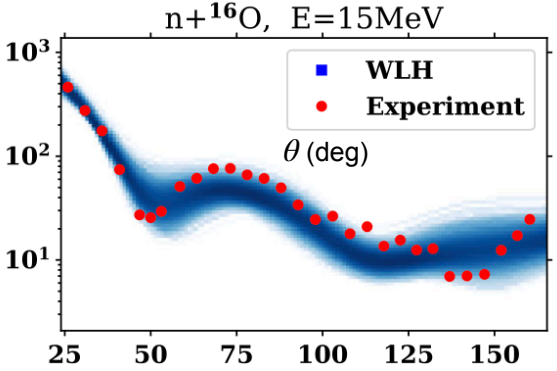
No-core shell model

Gennari+ PRC 97 034619 (2018)

Burrows+ PRC 99 044603 (2019)

Applicable at high energies $\gtrsim 100$ MeV

Nuclear matter + Local density approx.



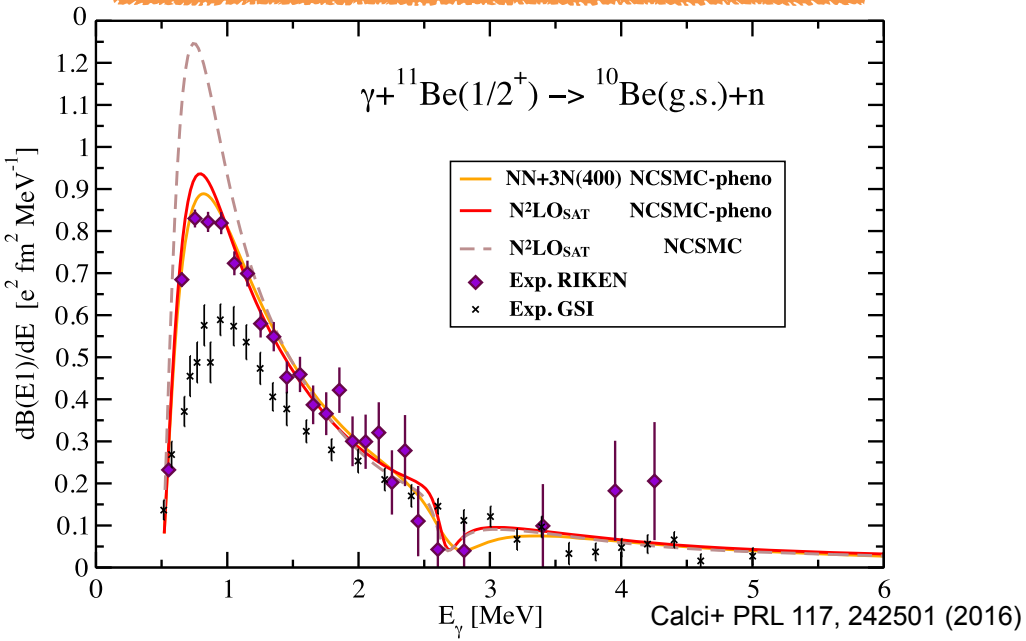
Many-body perturbation theory

Whitehead, Lim, Holt PRL 127 182502 (2021)

Still semi-phenomenolgical

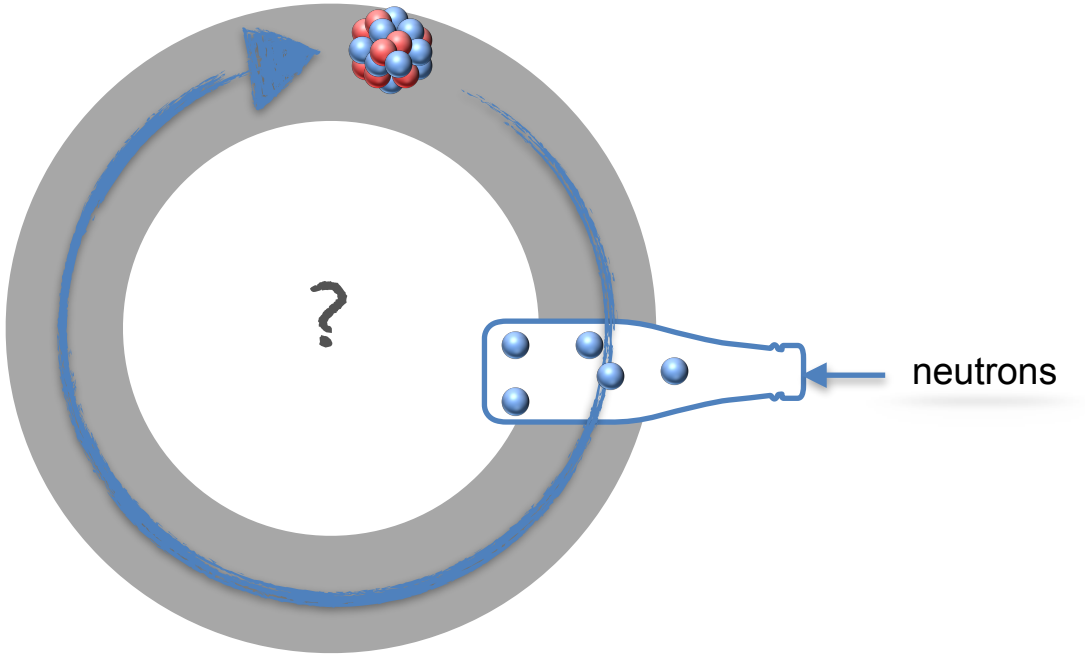
Ab initio neutron-nucleus optical potentials

No-core shell model w/continuum

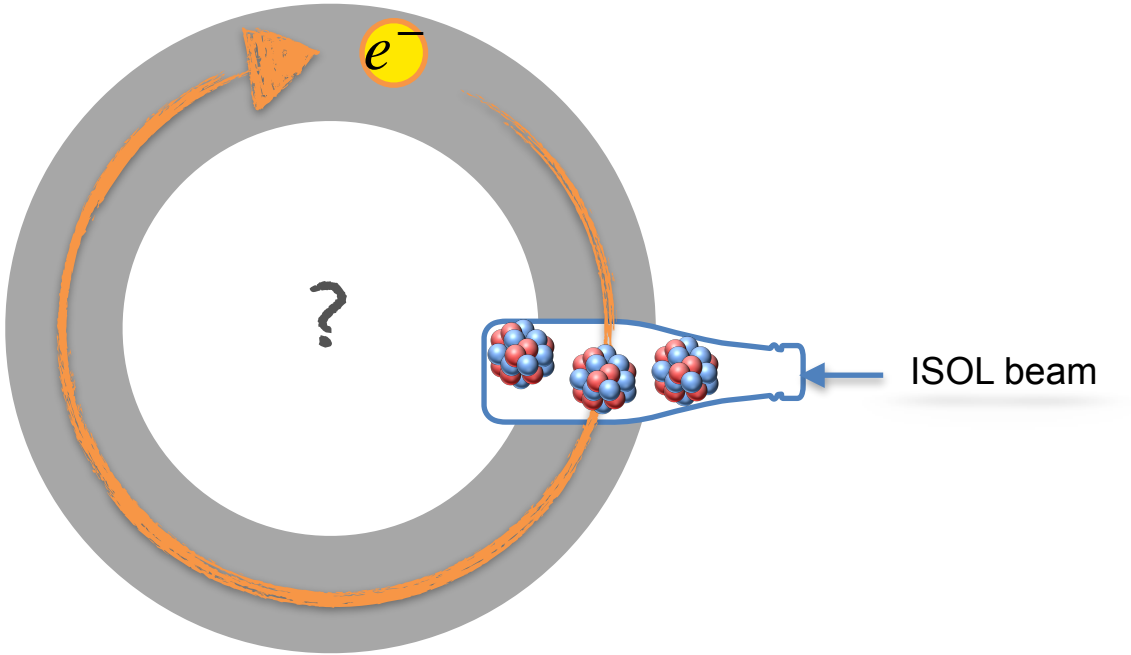


Limited to light systems

TRIUMF Storage Ring (TRISR)

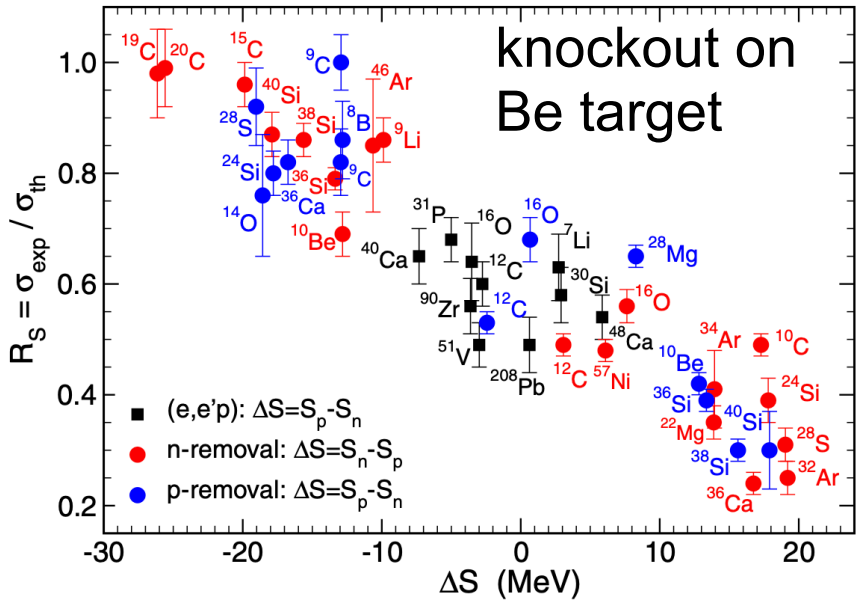


Electron scattering from unstable isotopes with SCRIT

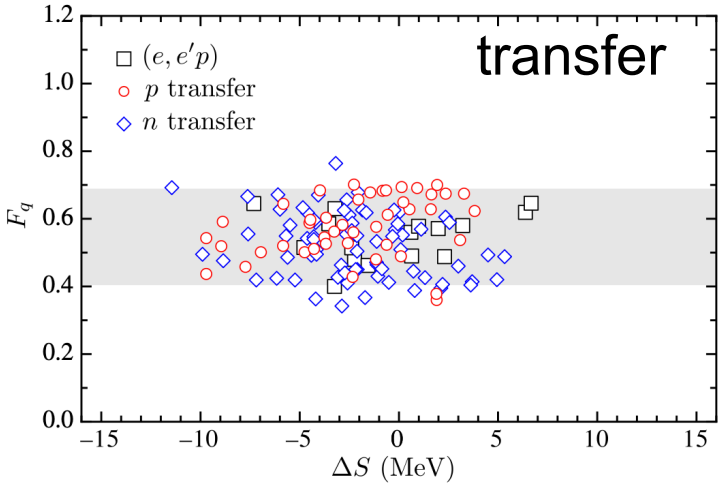


See Tsukada+ PRL 118, 262501 (2017)

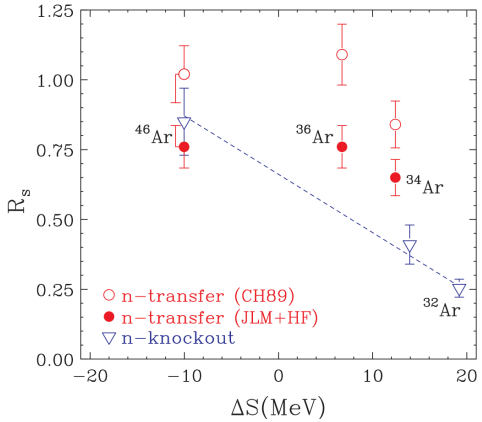
Asymmetry dependence in knockout



Tostevin, Gade PRC 90 057602 (2014)



Kay, Schiffer, Freeman PRL 111 042502 (2013)



Lee+ PRL 104 112701 (2010)


Thank you!