Inelastic Gamma Cross Sections in Reaction Evaluations

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BROOKHAVEN NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

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Why are γ's important?

- Inelastic gammas account for around 10% of the gamma heating in a nuclear reactor *

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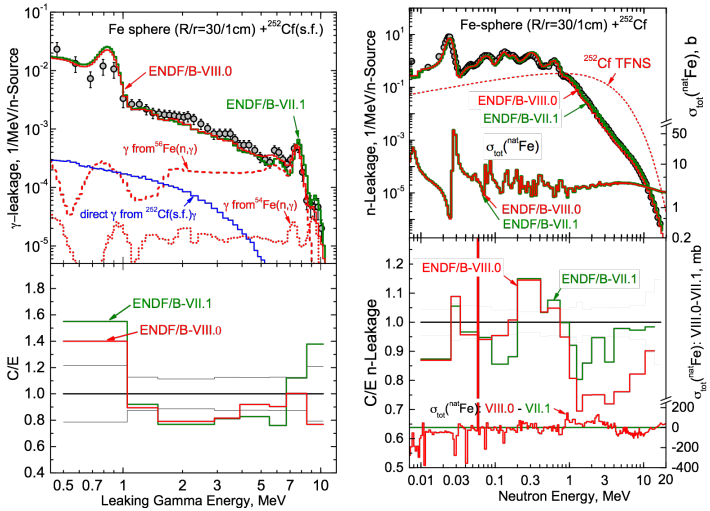

Leakage experiment consisting of ^{252}Cf source inside an iron sphere

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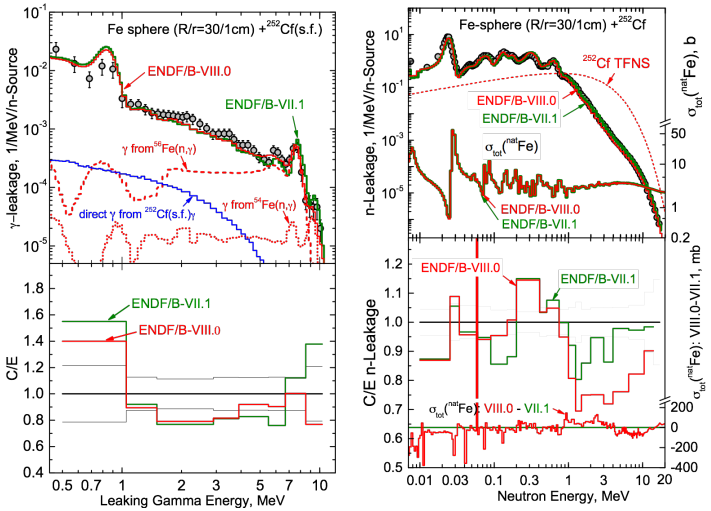

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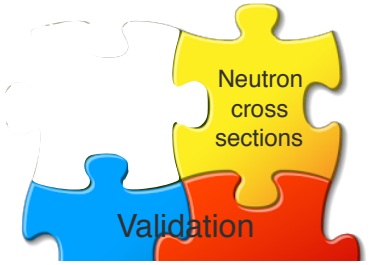
Consistency!!

Consistent performance across different kinds of benchmarks: right answer for the right reasons!



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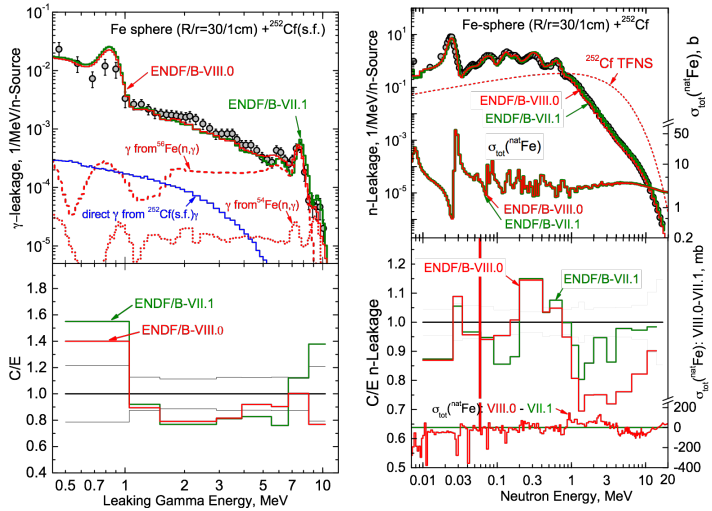

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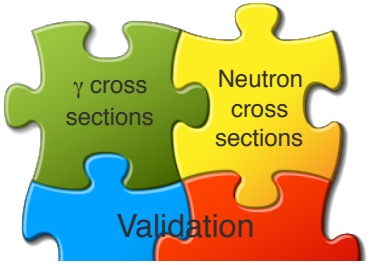

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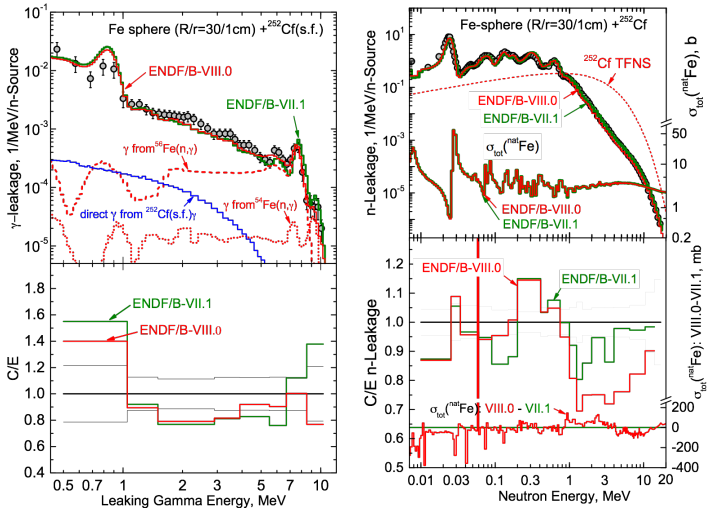

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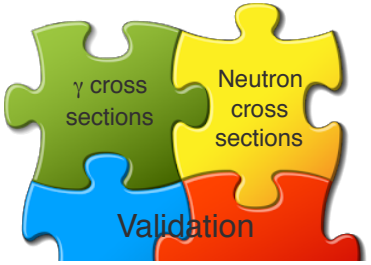

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However…

- Lack of integral benchmarks for neutron-induced gamma production in the fast region.
- Baghdad Atlas (see A. Lewis' talk) may help evaluations for which enough partial γ data are not available (e.g. ^{181}Ta).

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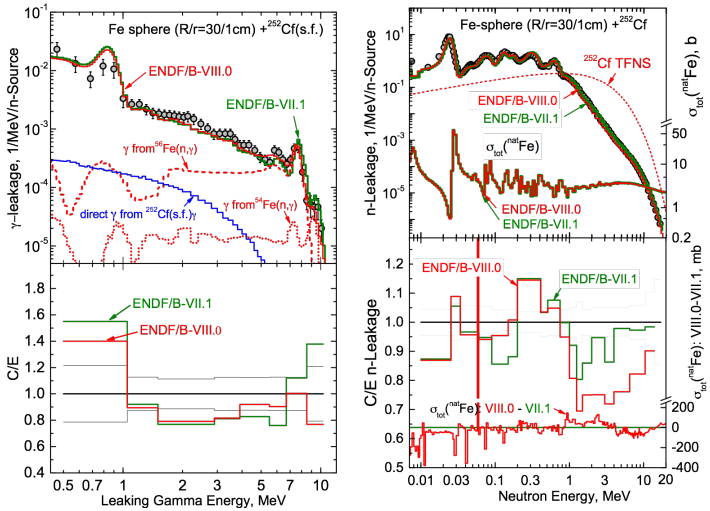

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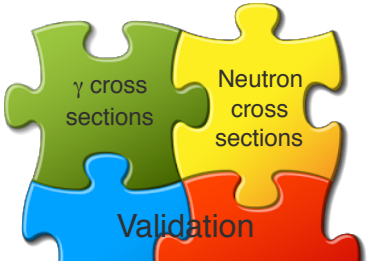

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- Here we discuss evaluations of inelastic gammas for Fe and Cr, which are important structural materials
- Same consideration applies to many others that need similar investigation, e.g. ^{238}U (ongoing evaluation of inelastic γ's at BNL)

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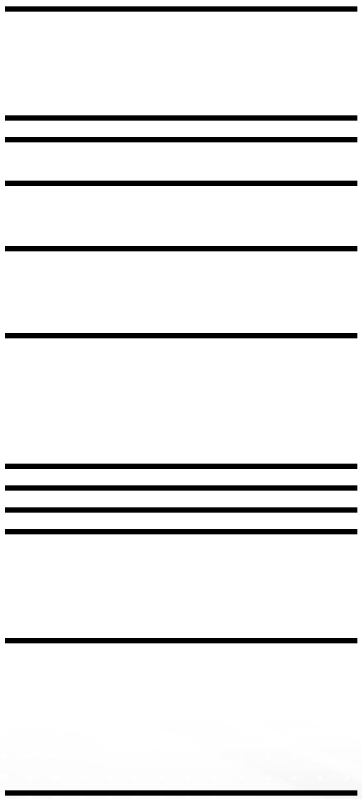

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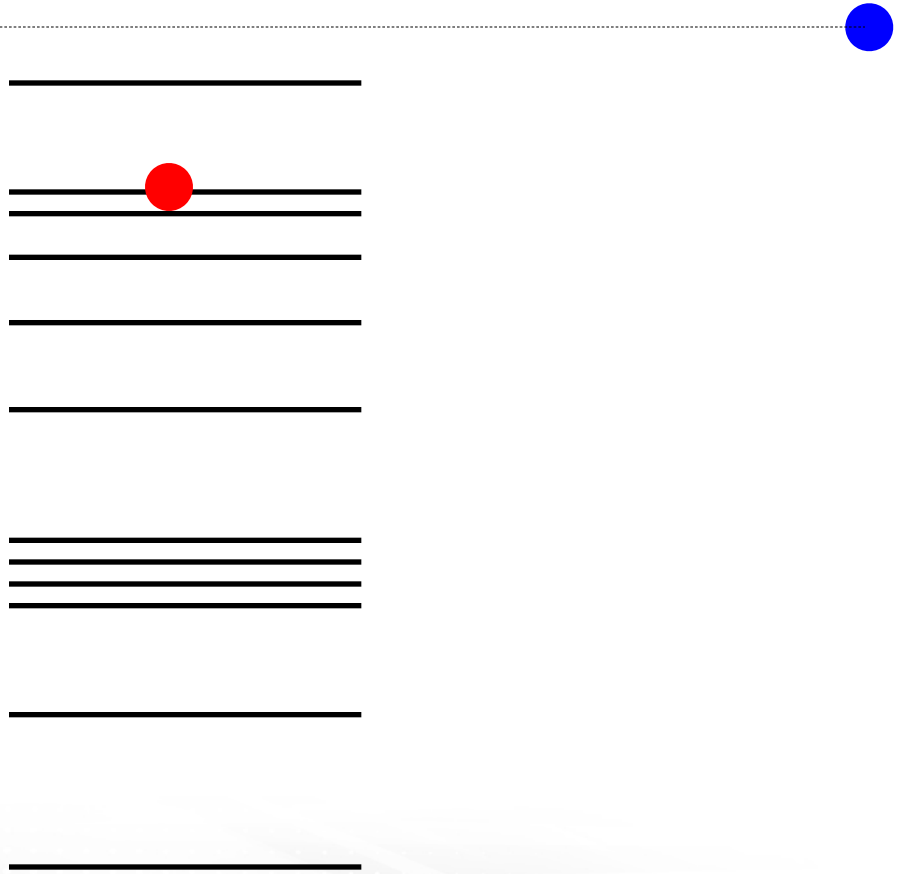

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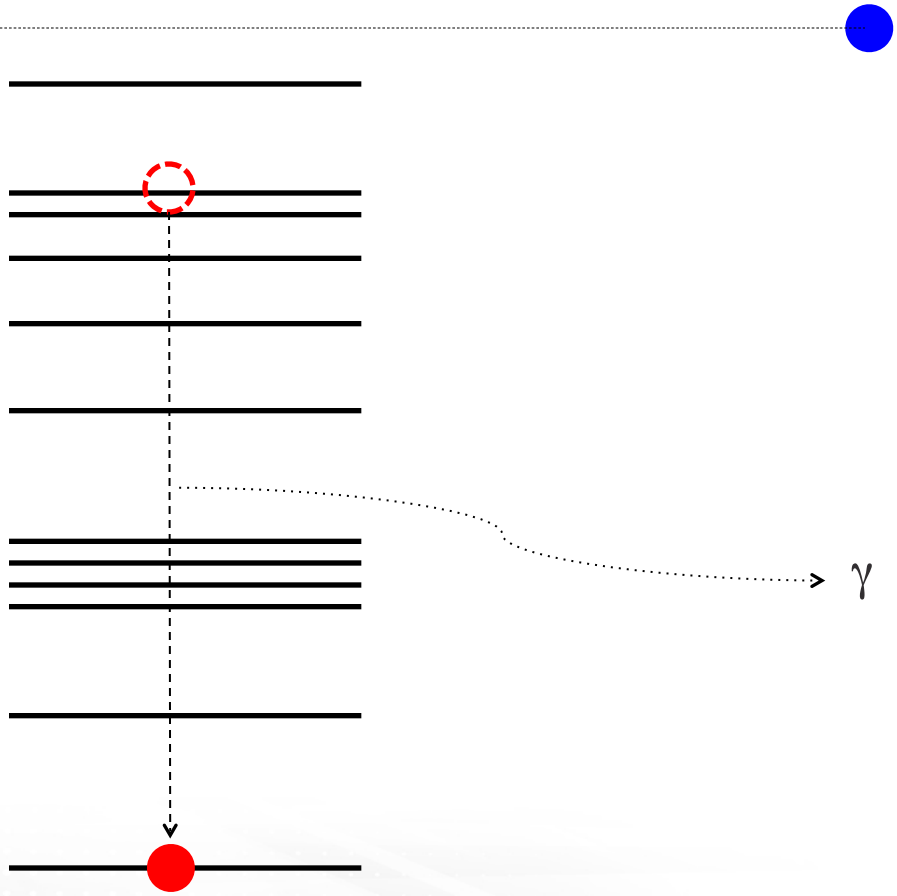

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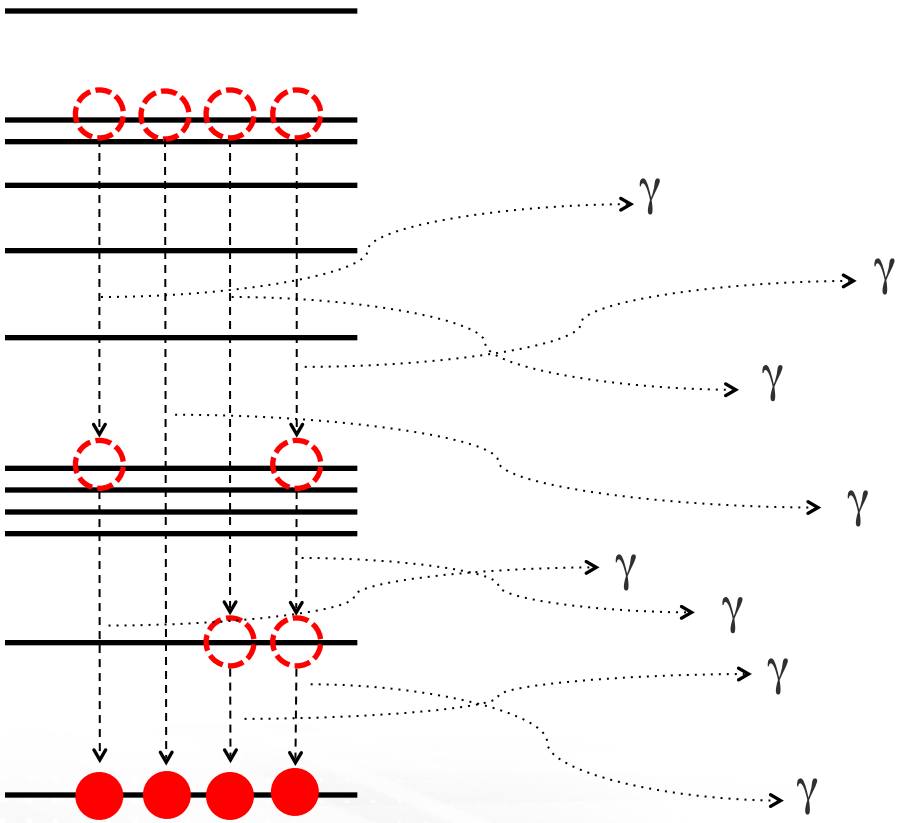
There are more ways for this to happen…

Population and decay scheme depend on reaction mechanisms and structure properties:

- Branching ratios
- Level couplings
- Deformations
- Level densities[1,2]
- γ strength functions
- Spins/parities
- …



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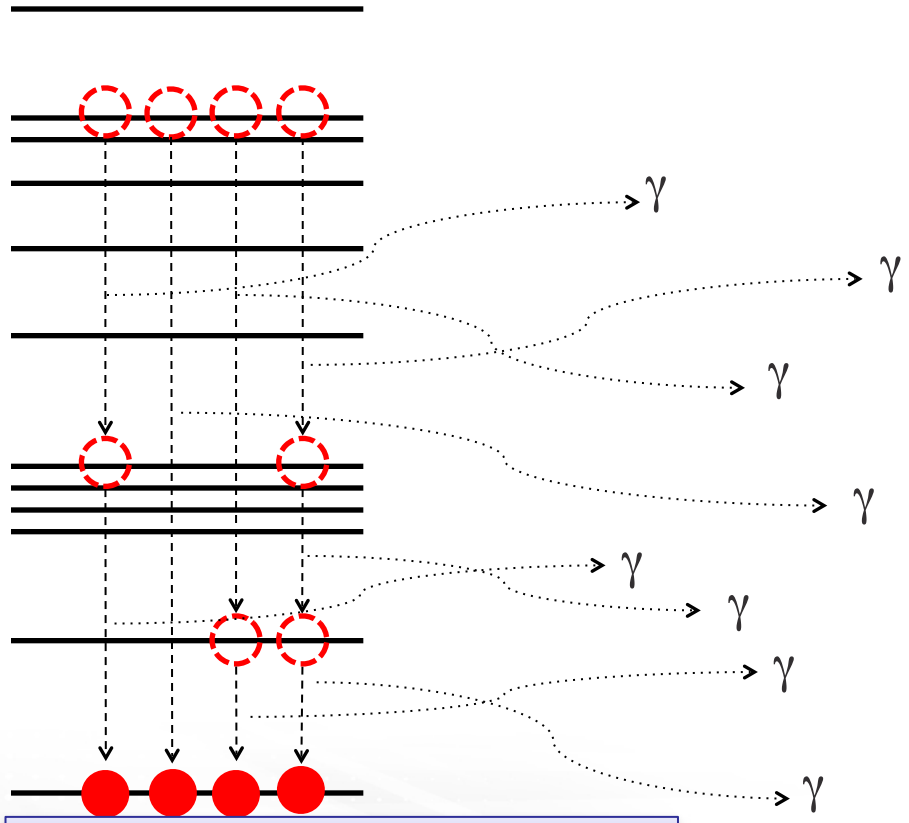

Direct correlation between neutron and gamma inelastic cross sections.

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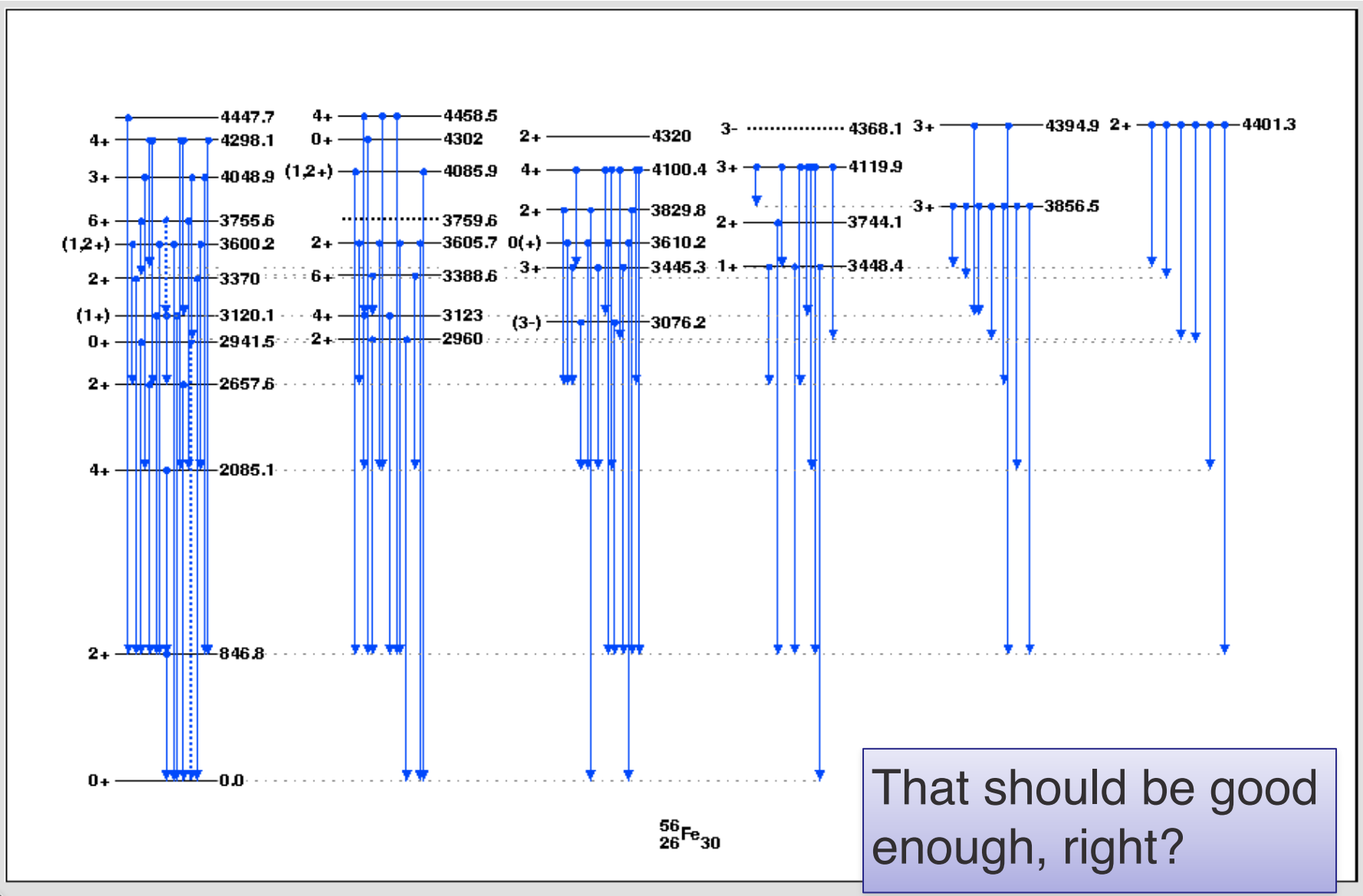
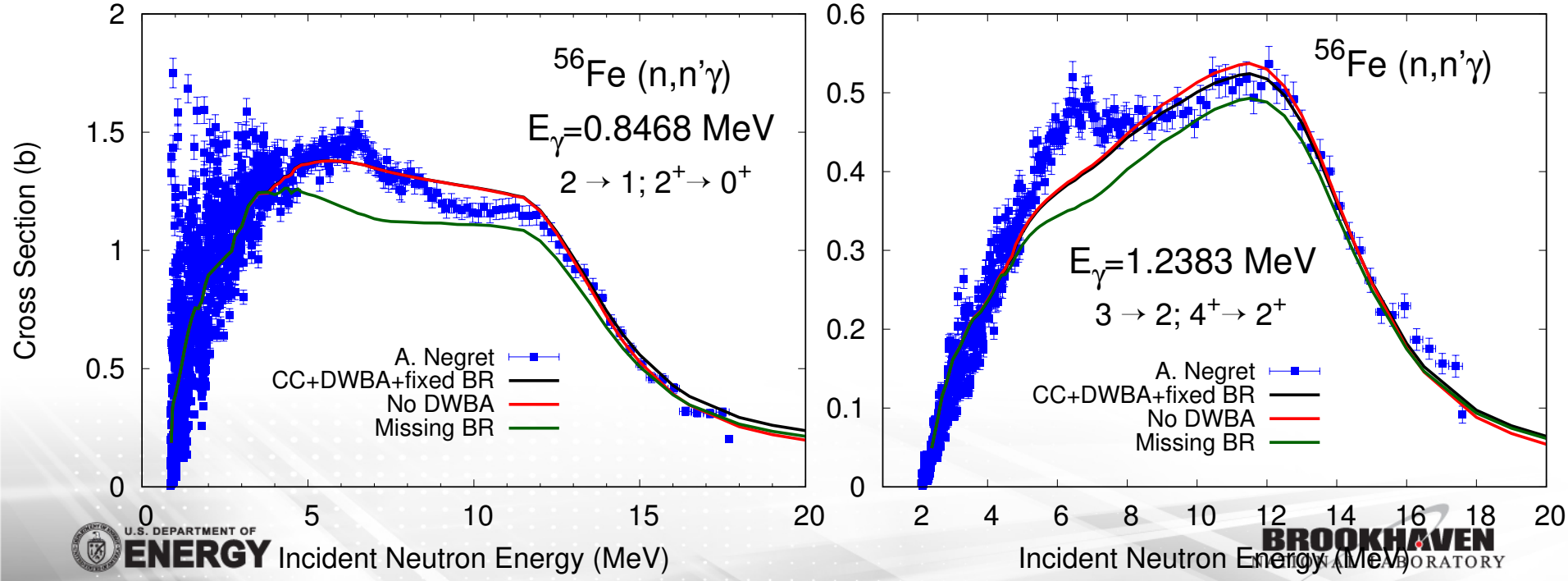
^{56}Fe has only 5 missing branching ratios (< 4.5 MeV)!



That should be good enough, right?

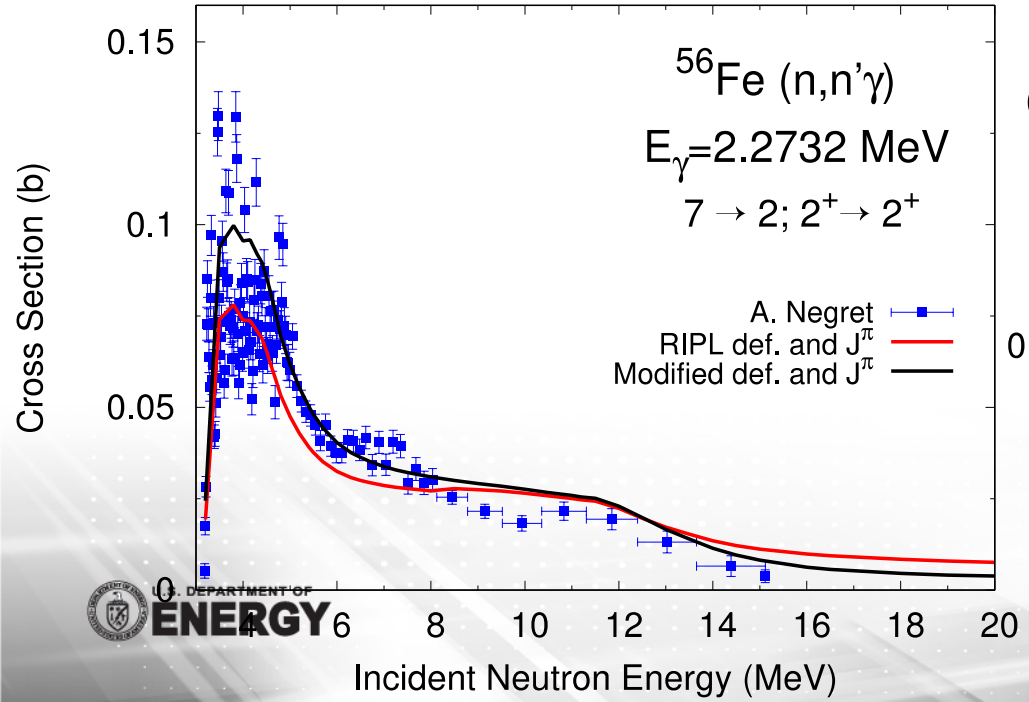
Gaps in ^{56}Fe decay scheme can be relevant

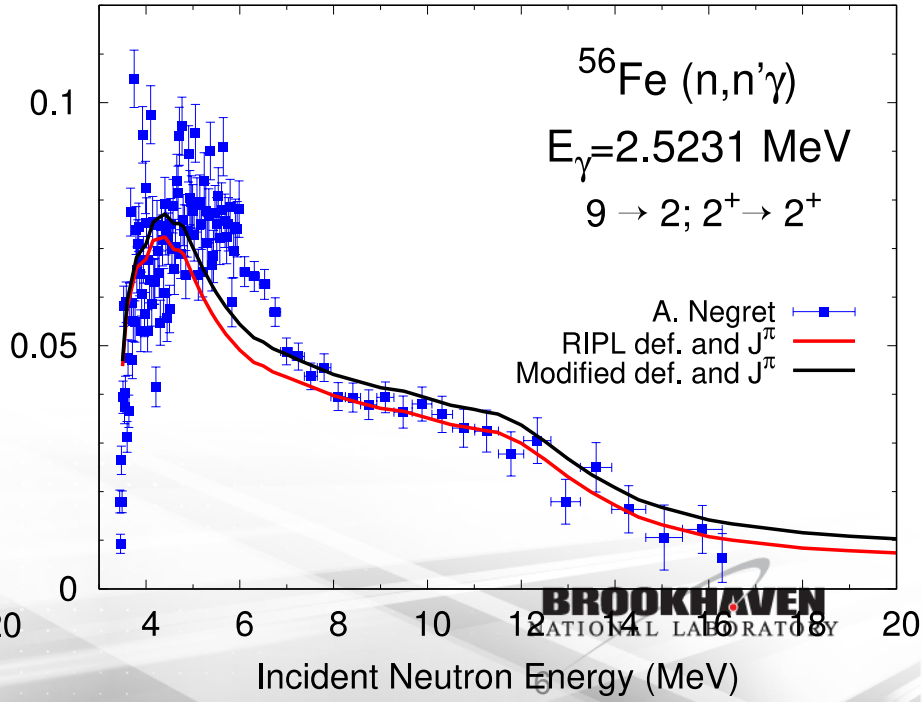
- Reaction codes **must** make a decision about such decays
- In many codes direct transition to g. s. is assumed
- Set of prescriptions: better choices for missing transitions



Also, uncertain spin, parities and DWBA deformations can be impactful

- Testing sensitivity to J^{π} and DWBA deformations:
  - Changed level 7 from 1^+ to 2^+
  - Increased def. of level 9 from 0.05 to 0.075
  - Increased def. of level 23 from 0.03 to 0.10
  - Increased def. of level 12 from 0.039 to 0.089





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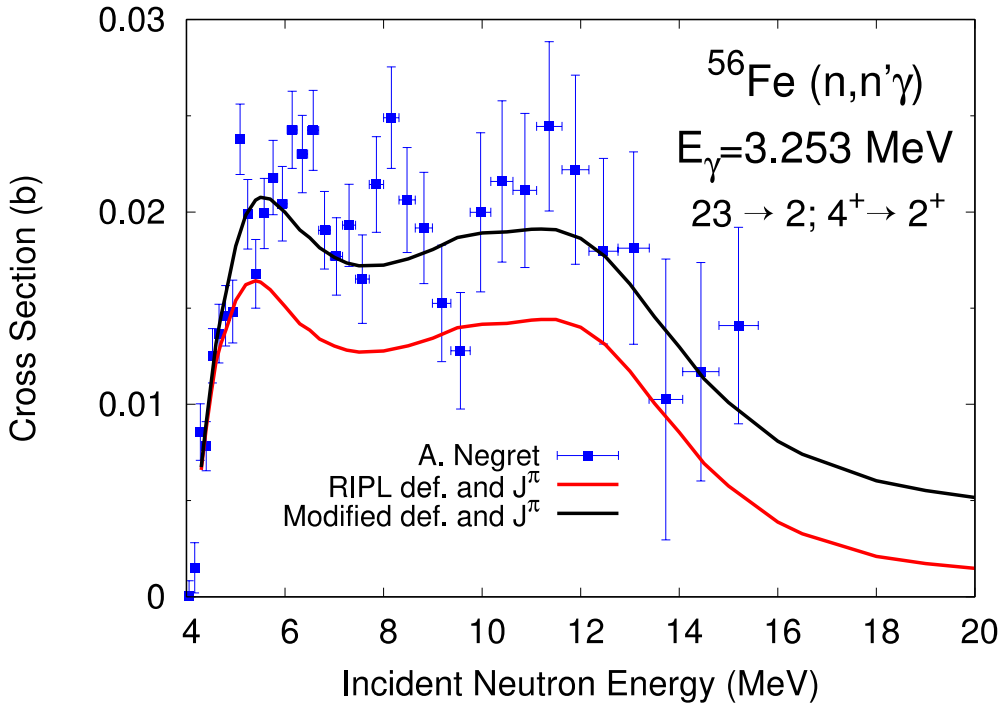
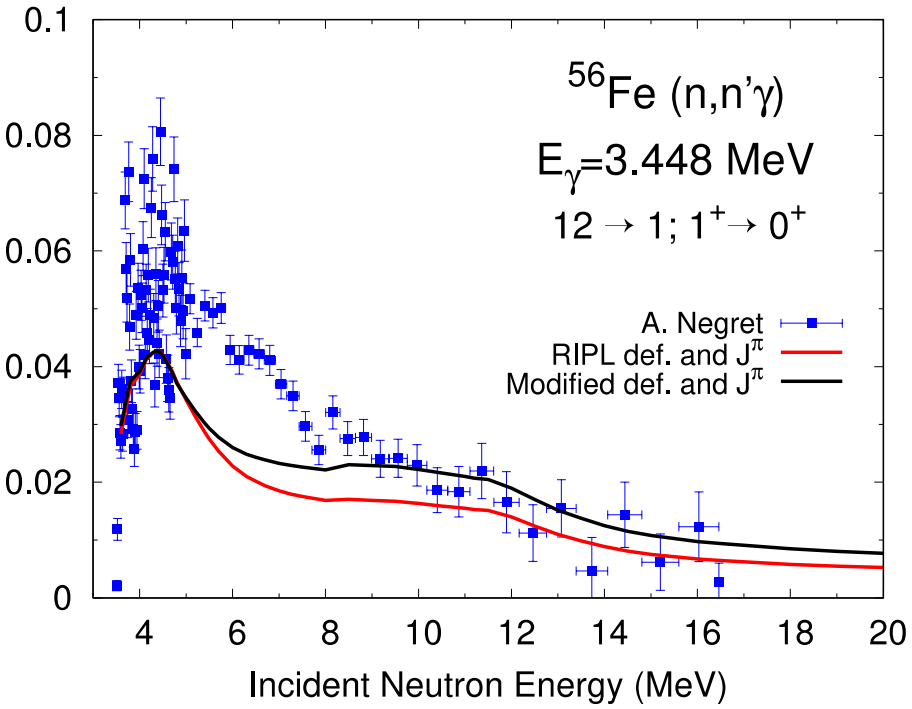
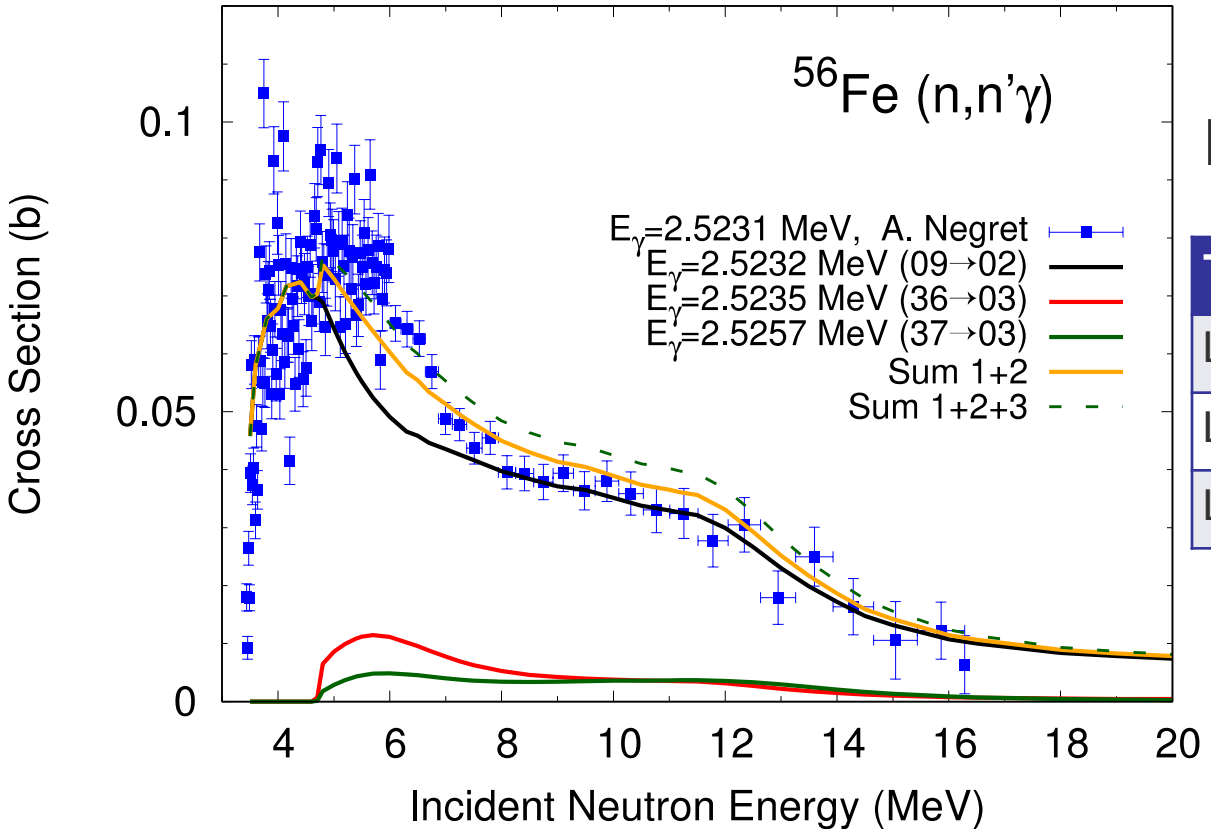




When there is experimental uncertainty and theoretical decisions have to be made, both DWBA deformations and spin/parity can be constrained through the inelastic gammas.

Transitions with similar Eγ



Exp. Eγ=2.5231 MeV

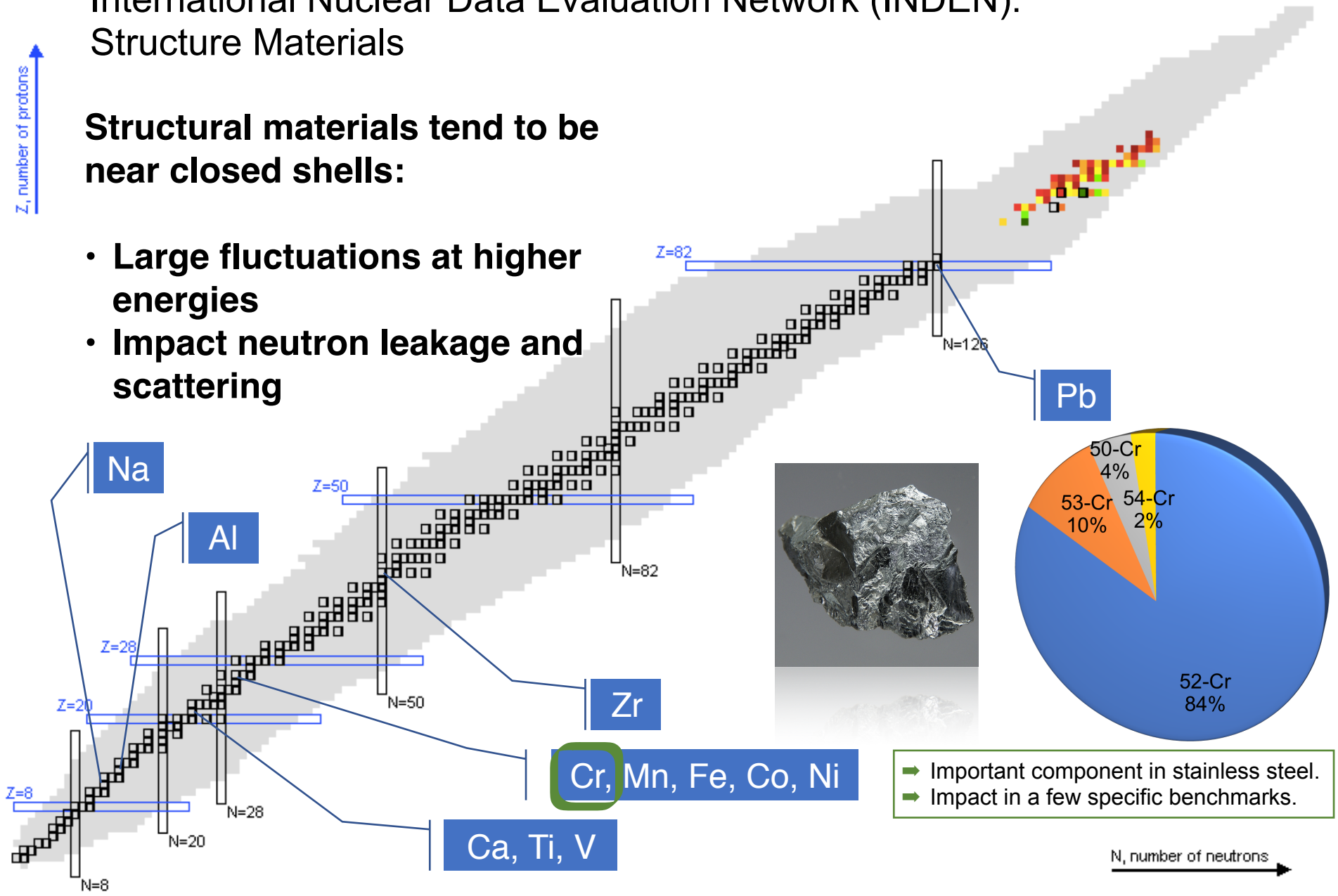
Trans.	Eγ (MeV)	Δ (keV)
Lvl 9 to 2	2.5232	0.1
Lvl 36 to 3	2.5235	0.4
Lvl 37 to 3	2.5257	2.6

Depending on the experimental resolution and on the proximity between γ's from different transitions, those cross sections have to be added together.

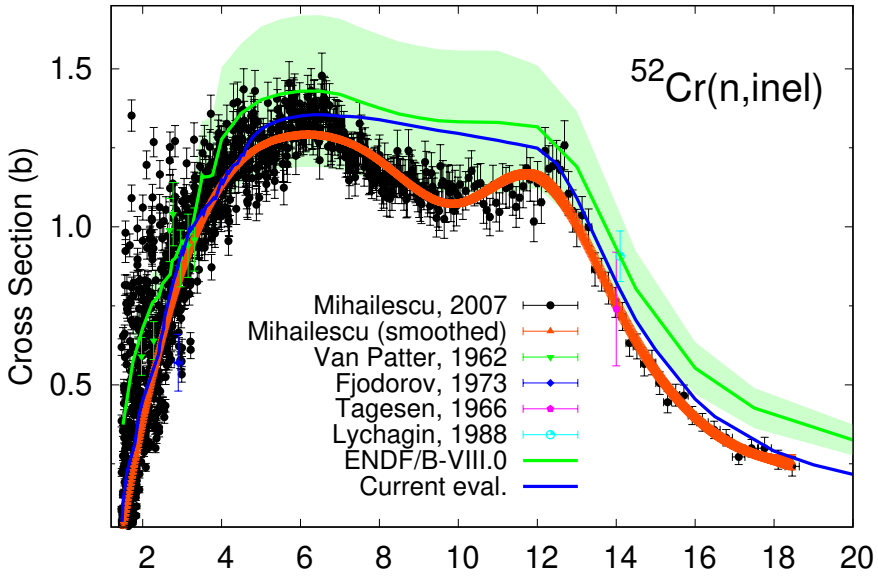
International Nuclear Data Evaluation Network (INDEN): Structure Materials

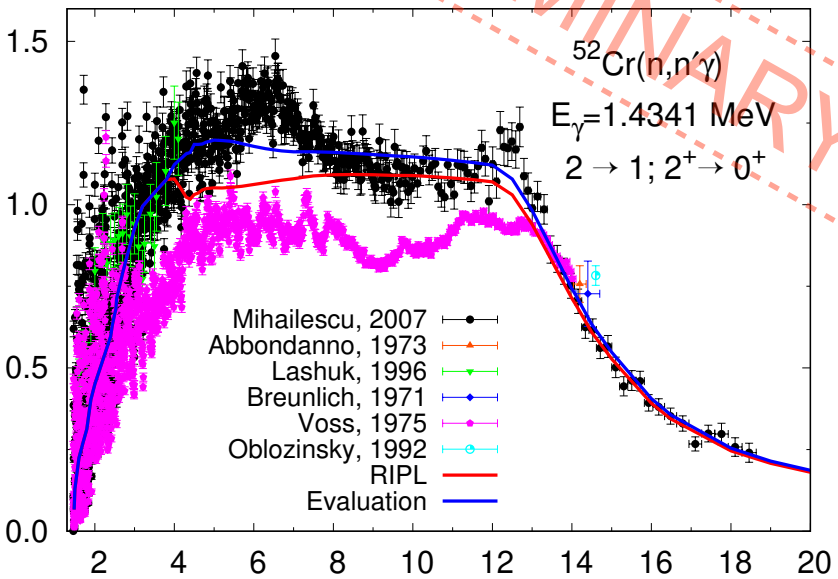
Structural materials tend to be near closed shells:

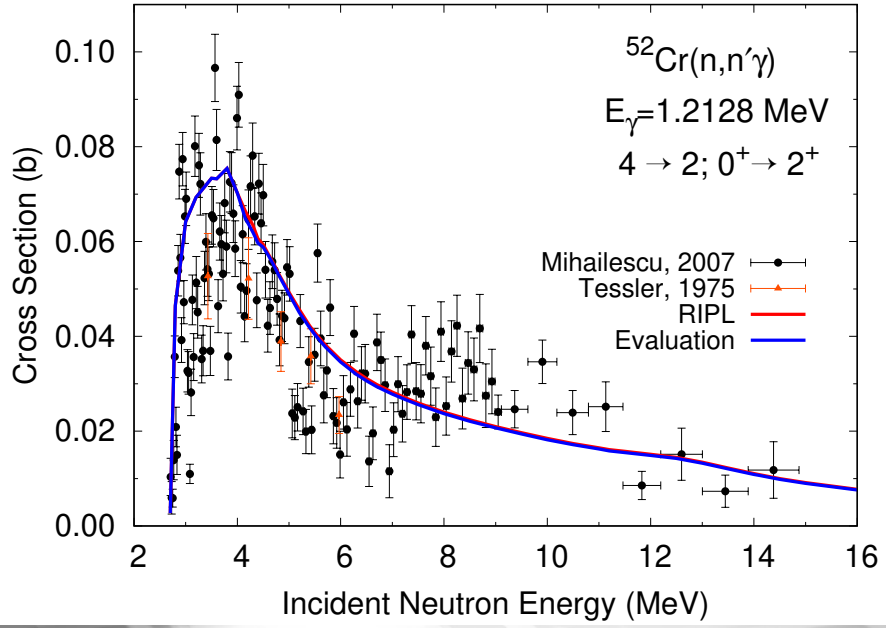
- **Large fluctuations at higher energies**
- **Impact neutron leakage and scattering**

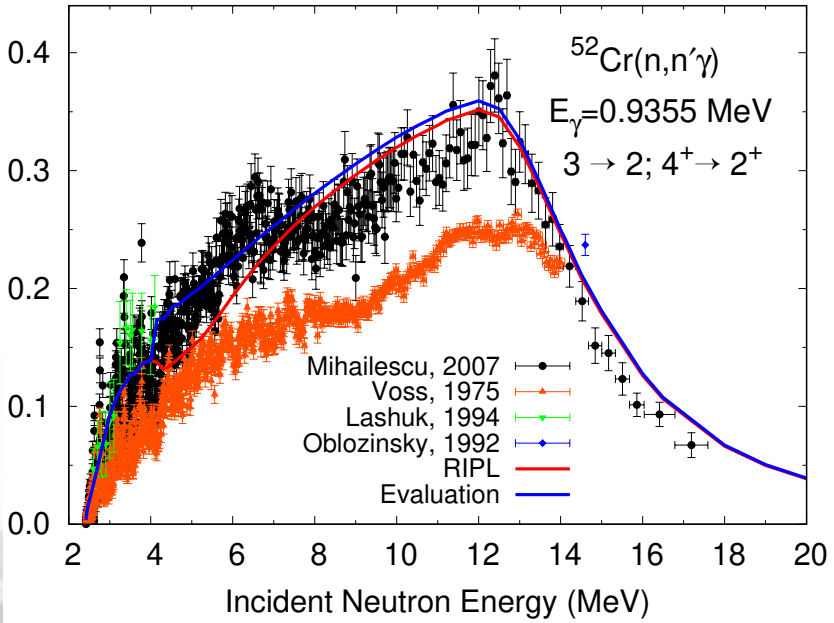


^{52}Cr: Consistent picture









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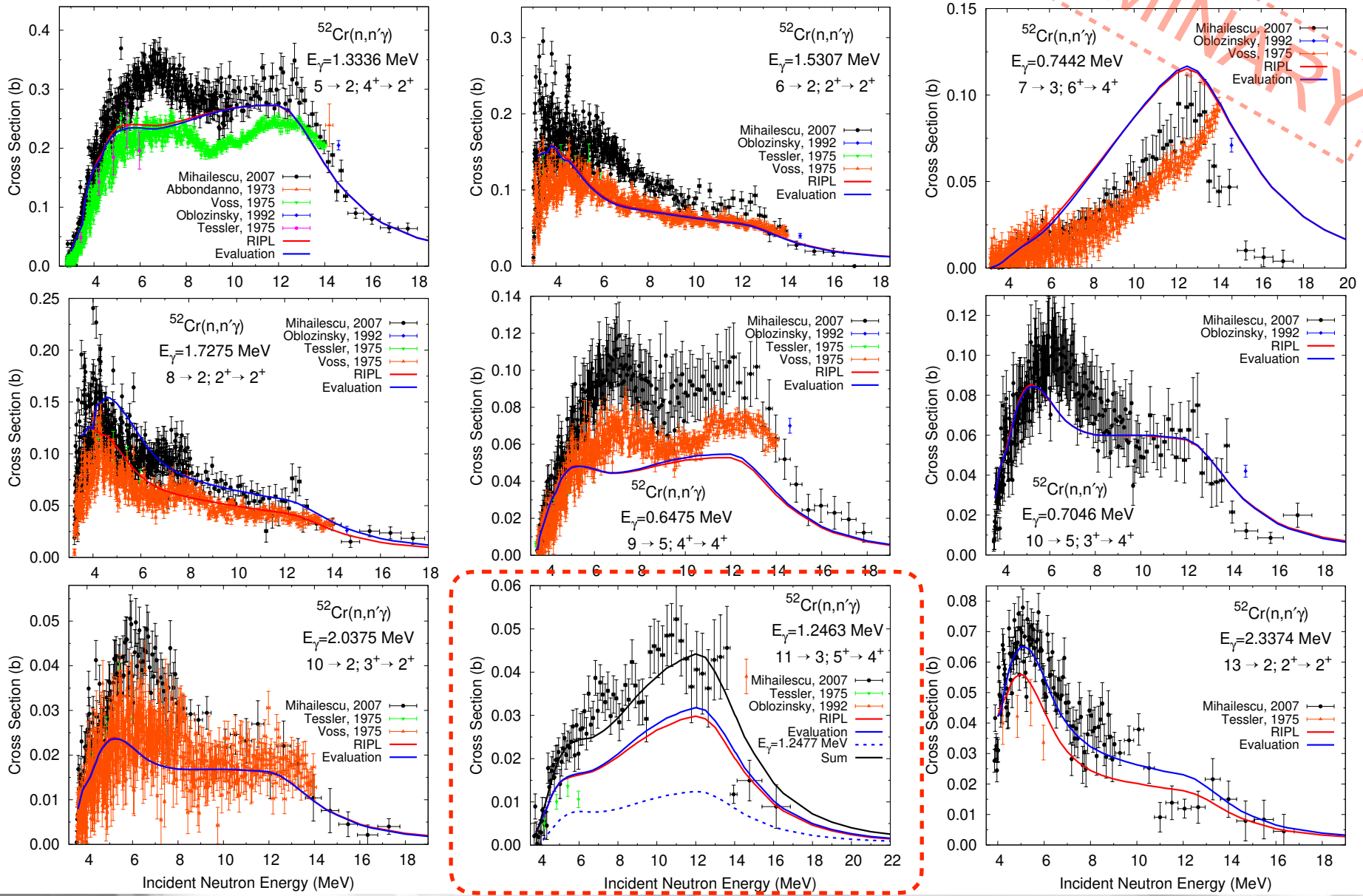

Summary

- Ideally, γ and *n* cross sections should be described consistently (differential and integral observables): Consistent performance across different kinds of benchmarks (criticality, shielding, etc.)
- Important to have most up-to-date information about level spins, parities, deformations, γ strength functions, branching ratios… Filling gaps in structure is very helpful.
- When there are experimental unknowns, (n,n'γ) c.s. bring additional constraints.
- Analysis of inelastic γ cross sections is an important tool that bridges structure and reactions: ^{56}Fe, ^{52}Cr, ^{238}U
- Ongoing awarded proposal involving the evaluation of inelastic γ's for ^{238}U (Vorabbi, Nobre, Brown, see L. Bernstein's talk): Testing new branching ratios.

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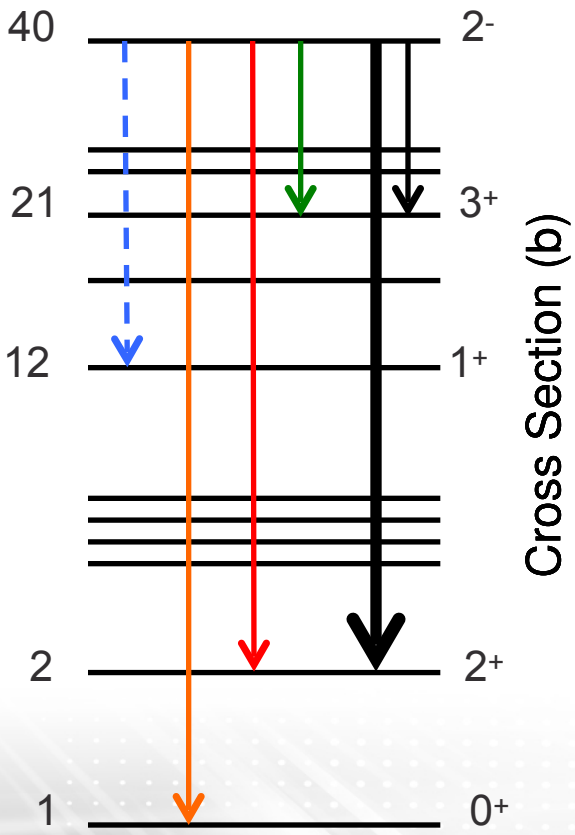
Data!!

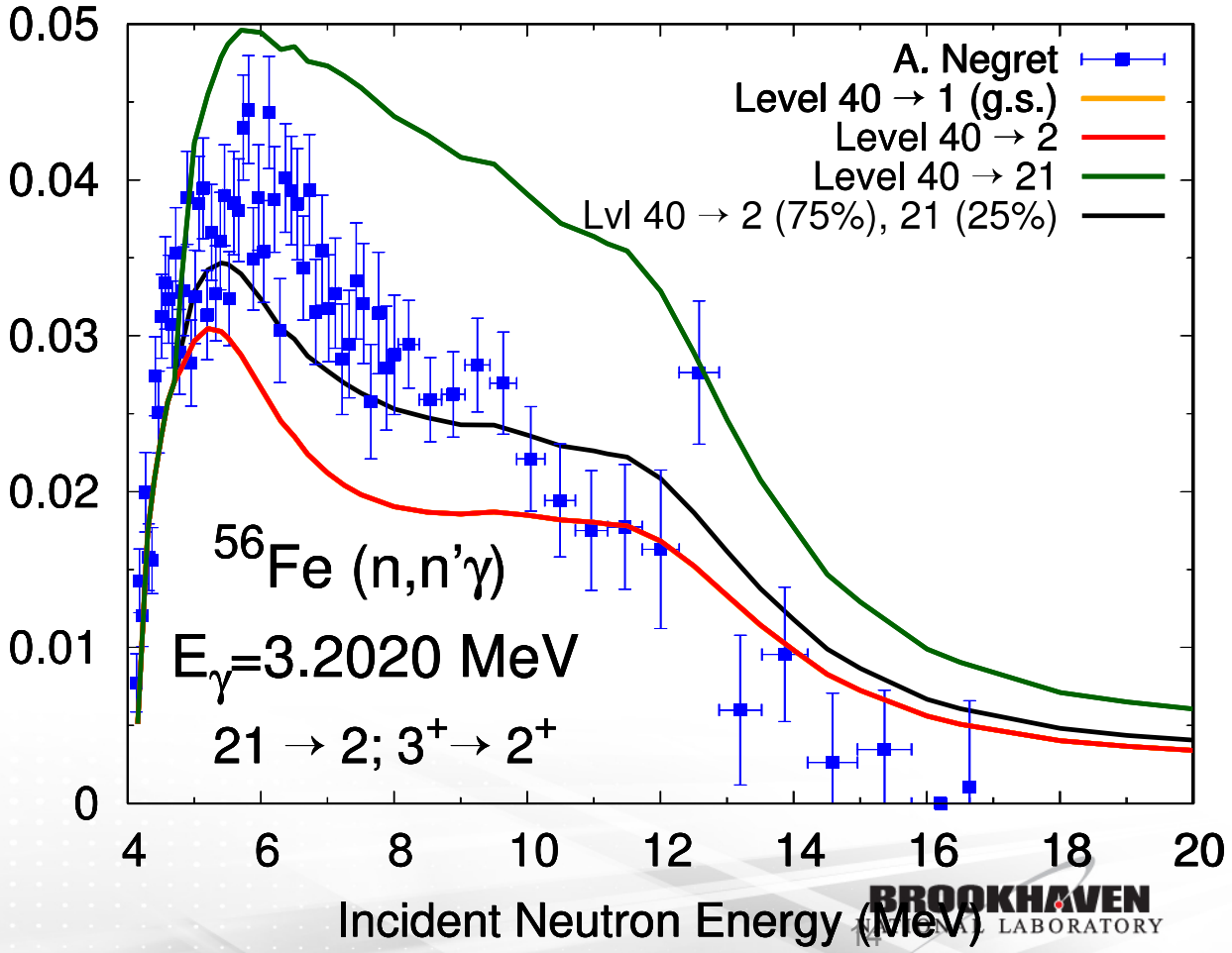
- Differential: inelastic cross sections (gamma/neutron)
- Integral: benchmarks to validate
- New experiments and/or easy access to measured but not readily-available data

Backup slides

Branching ratio for level 40

- Level 12, 1^+ and did not have any BR changed
- Level 40, 2^- had missing BR, assumed an E1 transition to 12





Effect of different γ strength function models