Decay Studies for Symmetries, Neutrinos, Astrophysics, Structure: Selected Topics

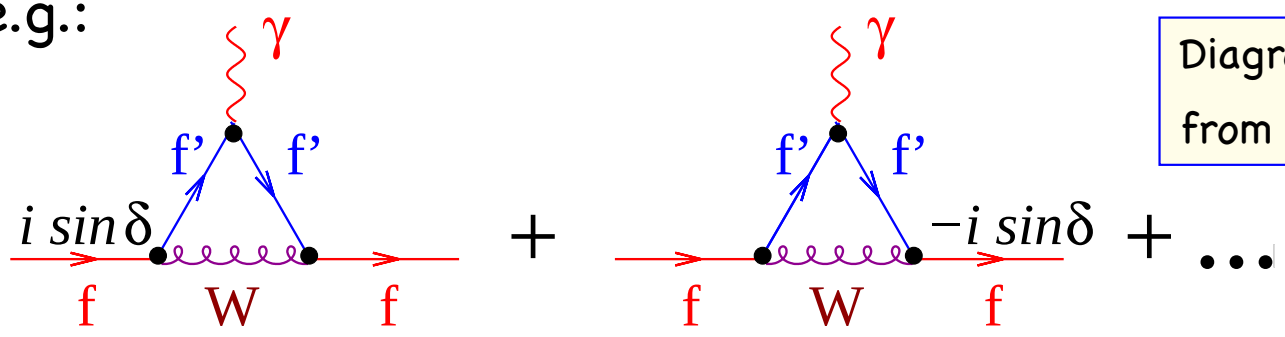
J. Engel

August 17, 2012

Electric Dipole Moments: Why Do We Care?

EDMs $\Leftrightarrow$ CP violation $\Leftrightarrow$ phase in amplitudes

Standard model has only one phase. Diagrams cancel to high order, e.g.:



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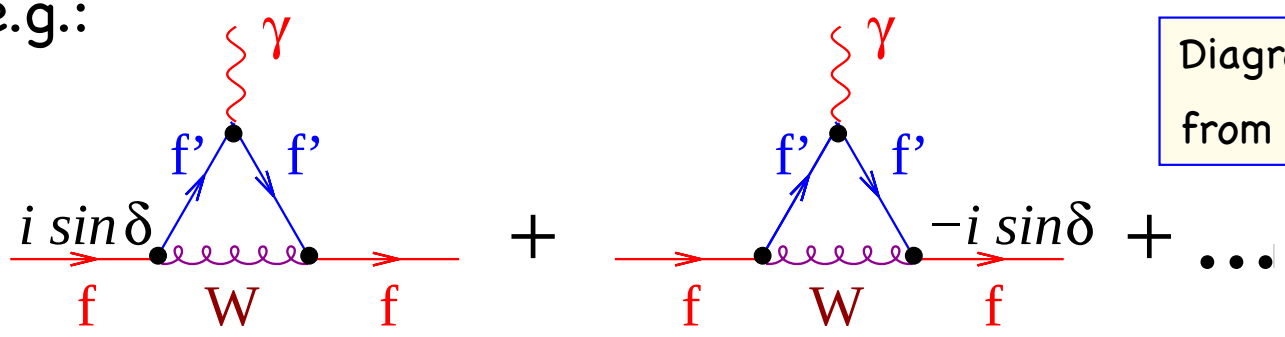

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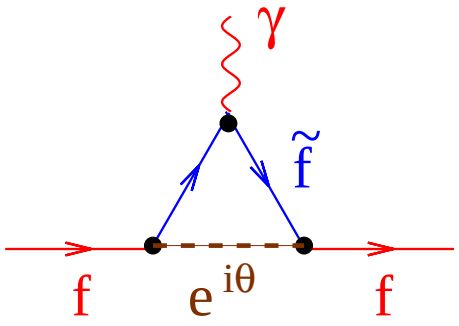

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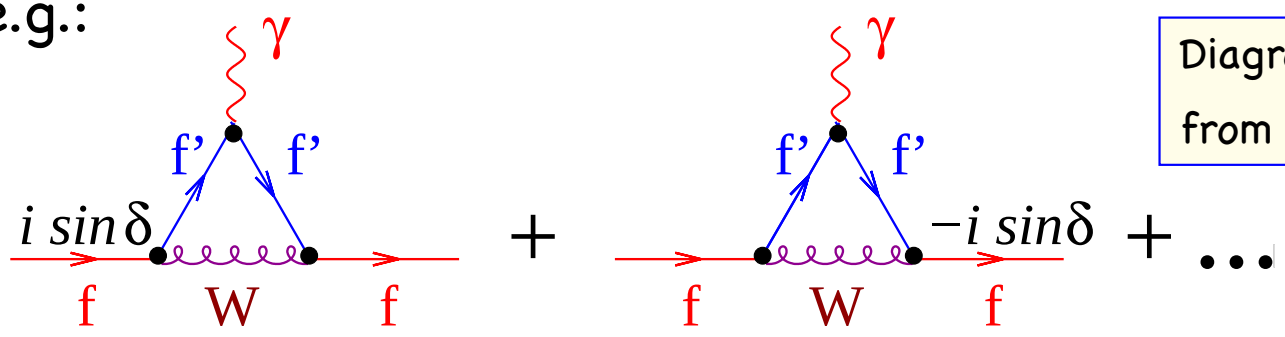

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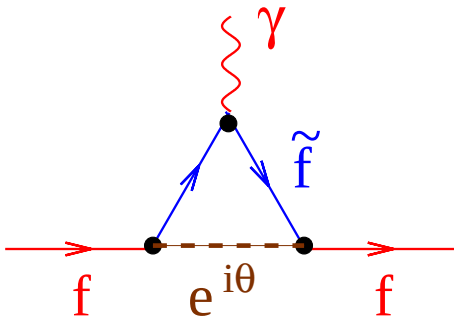
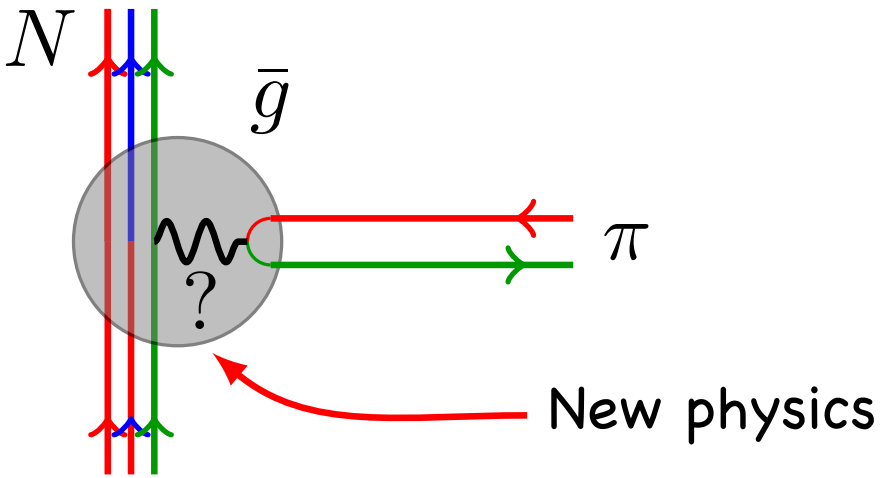


Thus, EDMs are insensitive to standard-model $\not{CP}$, but **sensitive to extra-standard-model** $\not{CP}$. Limits from atoms and neutrons, have already made SUSY a difficult proposition.

How Things Get EDMs

Starting at most fundamental level and moving up:

- Underlying fundamental theory generates three T-violating πNN vertices:



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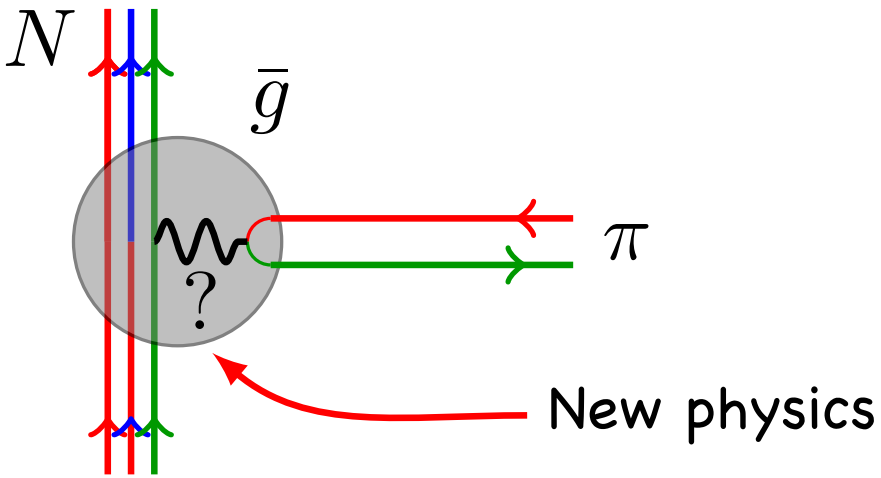
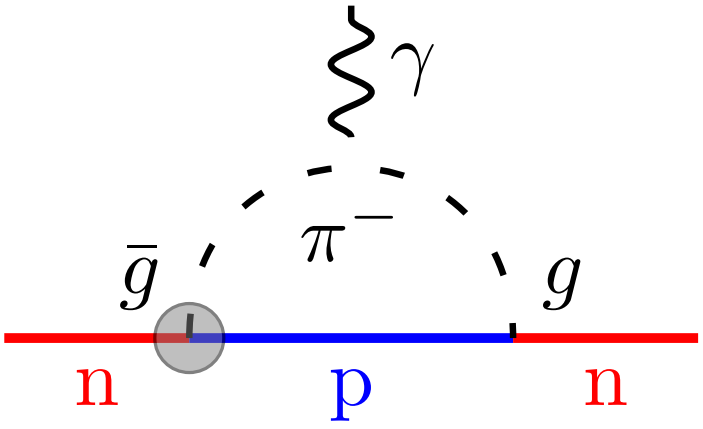
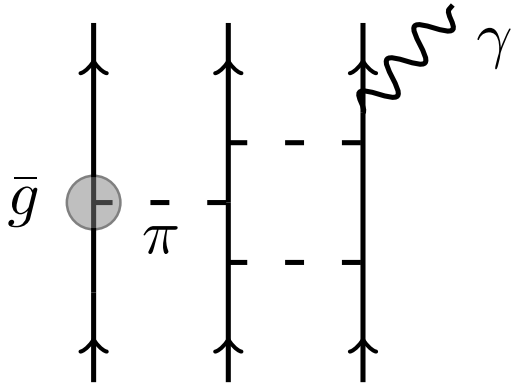


- Then neutron gets EDM from diagrams like this:



How Atoms Such as ^{225}Ra Get EDMs

- Nucleus can get one from nucleon EDM or T-violating NN interaction V_{PT} :



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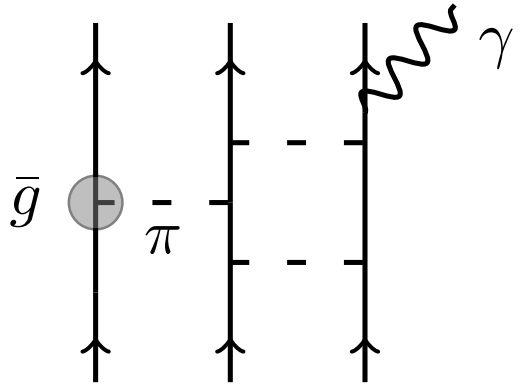

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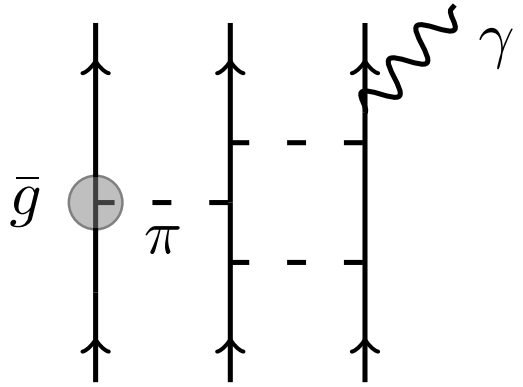

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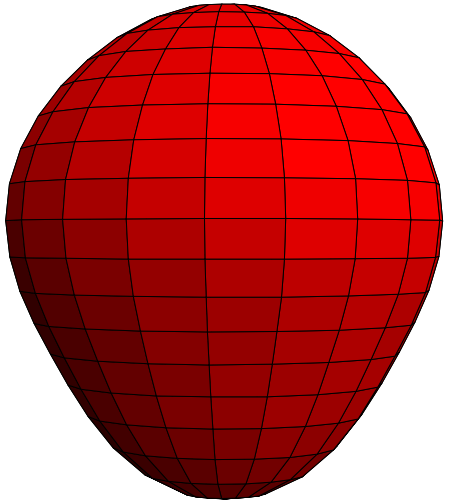
Job of nuclear physics: determine dependence of $\langle S \rangle$ on the $\bar{g}$'s.

Octupole Deformation and Schiff Enhancement



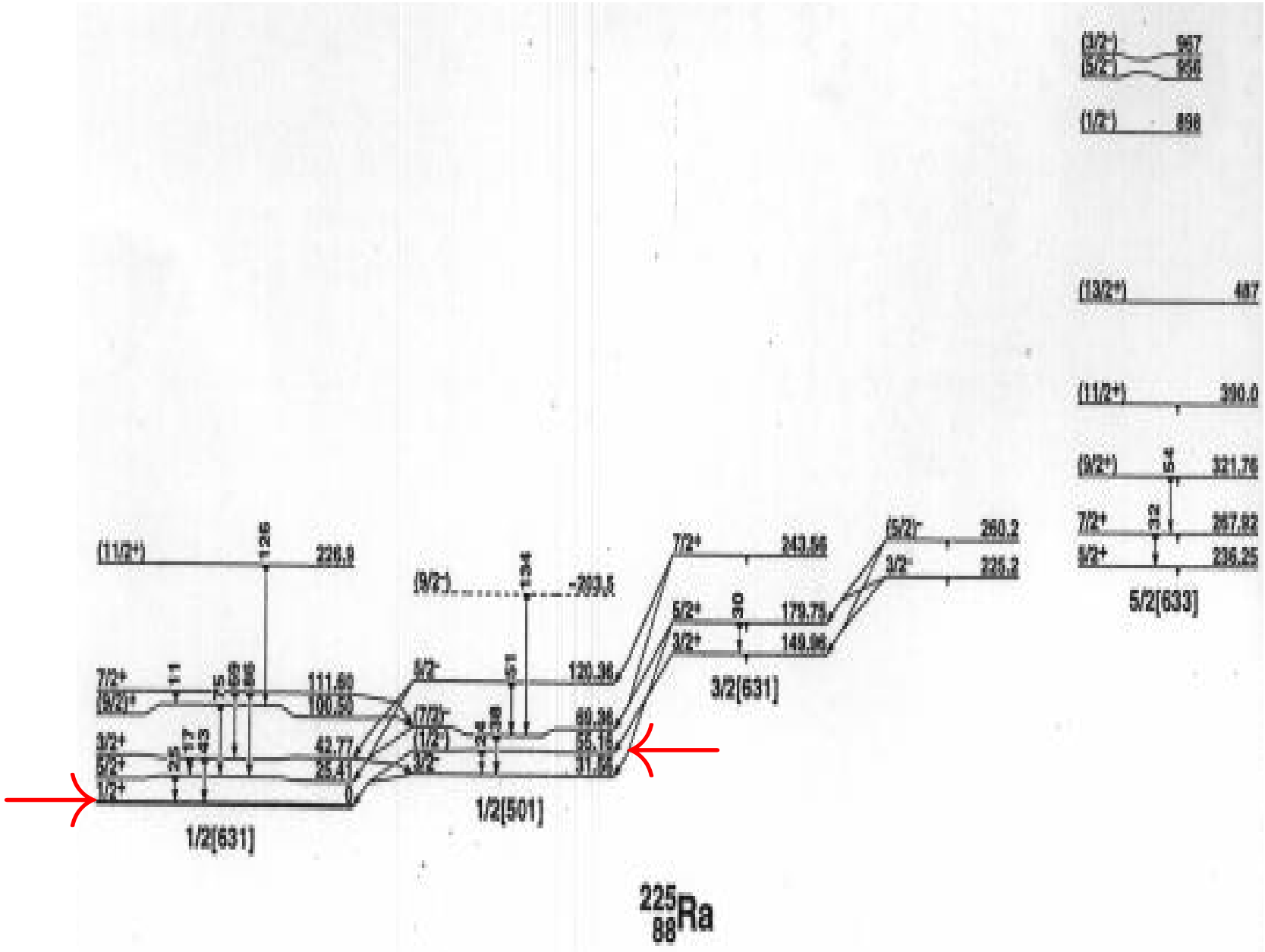
Calculated ^{225}Ra density

Ground state $|0\rangle$ has nearly-dengerate partner $|\bar{0}\rangle$ with same opposite parity and same intrinsic structure, so:

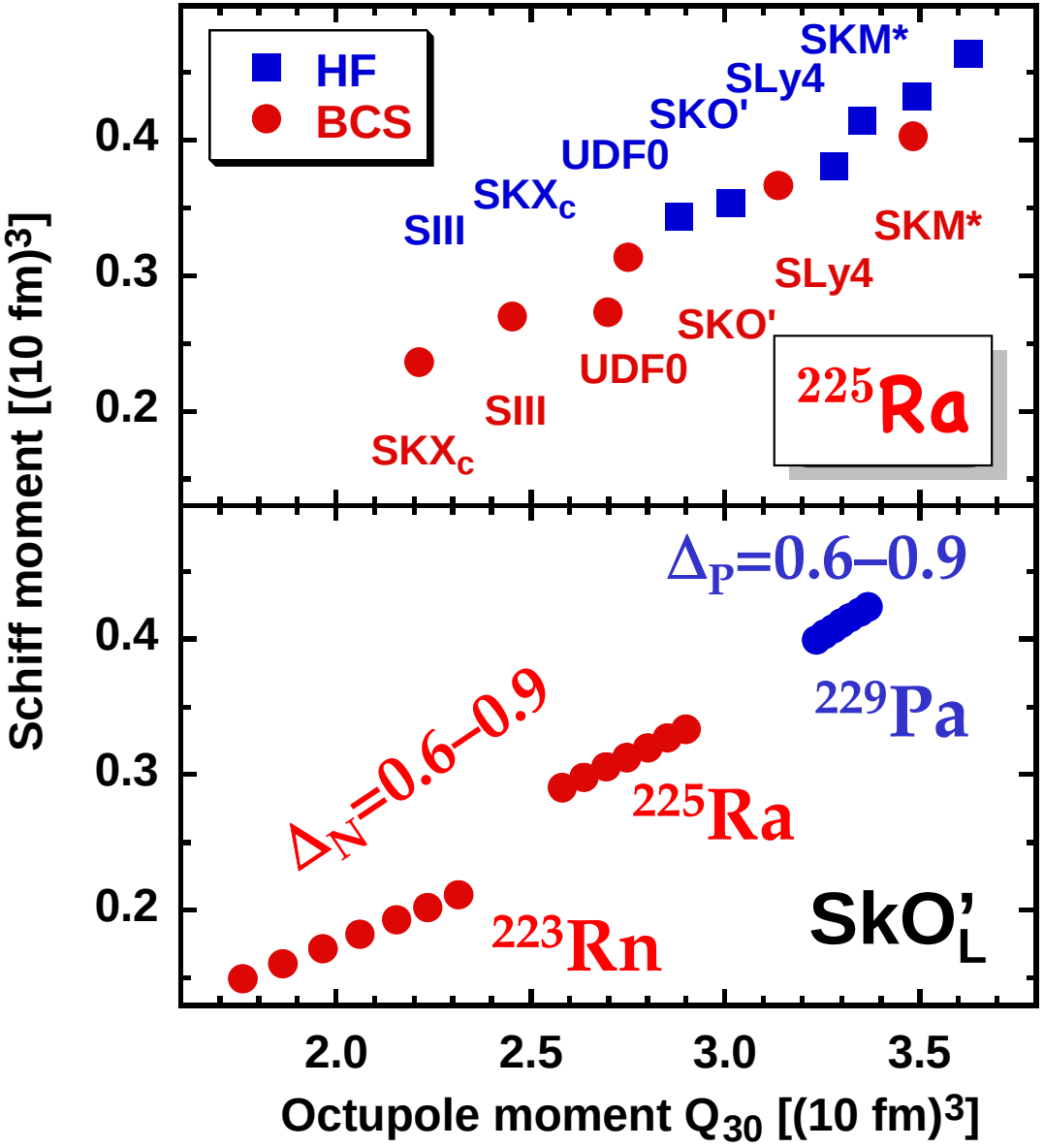
$$\langle \vec{S} \rangle \xrightarrow{\text{pert. thry.}} \frac{\langle 0| \vec{S} |\bar{0}\rangle \langle \bar{0}| V_{PT} |0\rangle}{E_0 - E_{\bar{0}}} + \text{c.c.} \quad \propto \quad \boxed{\frac{\langle \vec{S} \rangle_{\text{intr.}} \langle V_{PT} \rangle_{\text{intr.}}}{E_0 - E_{\bar{0}}}}$$

$\langle \vec{S} \rangle$ is large because $\langle \vec{S} \rangle_{\text{intr.}}$ is collective and $E_0 - E_{\bar{0}}$ is small.

Spectrum of ^{225}Ra



Decay Data Will Help Calculations



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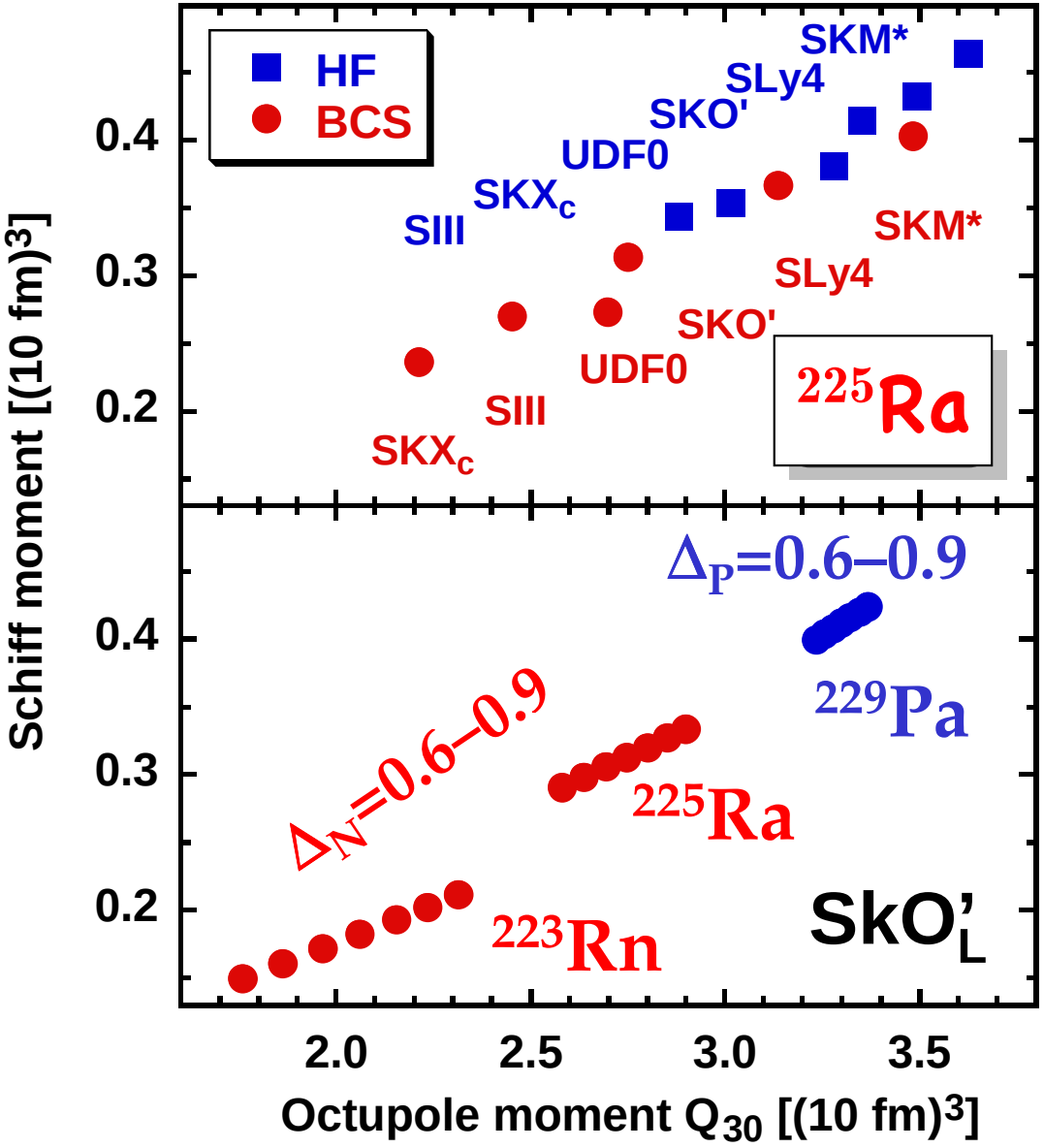

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To be measured at ISOLDE?

Neutrinos: What We Know and Don't Know

Come in three "flavors", none of which have definite mass.

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mass eigenstates
$m_i \lesssim 1$ eV

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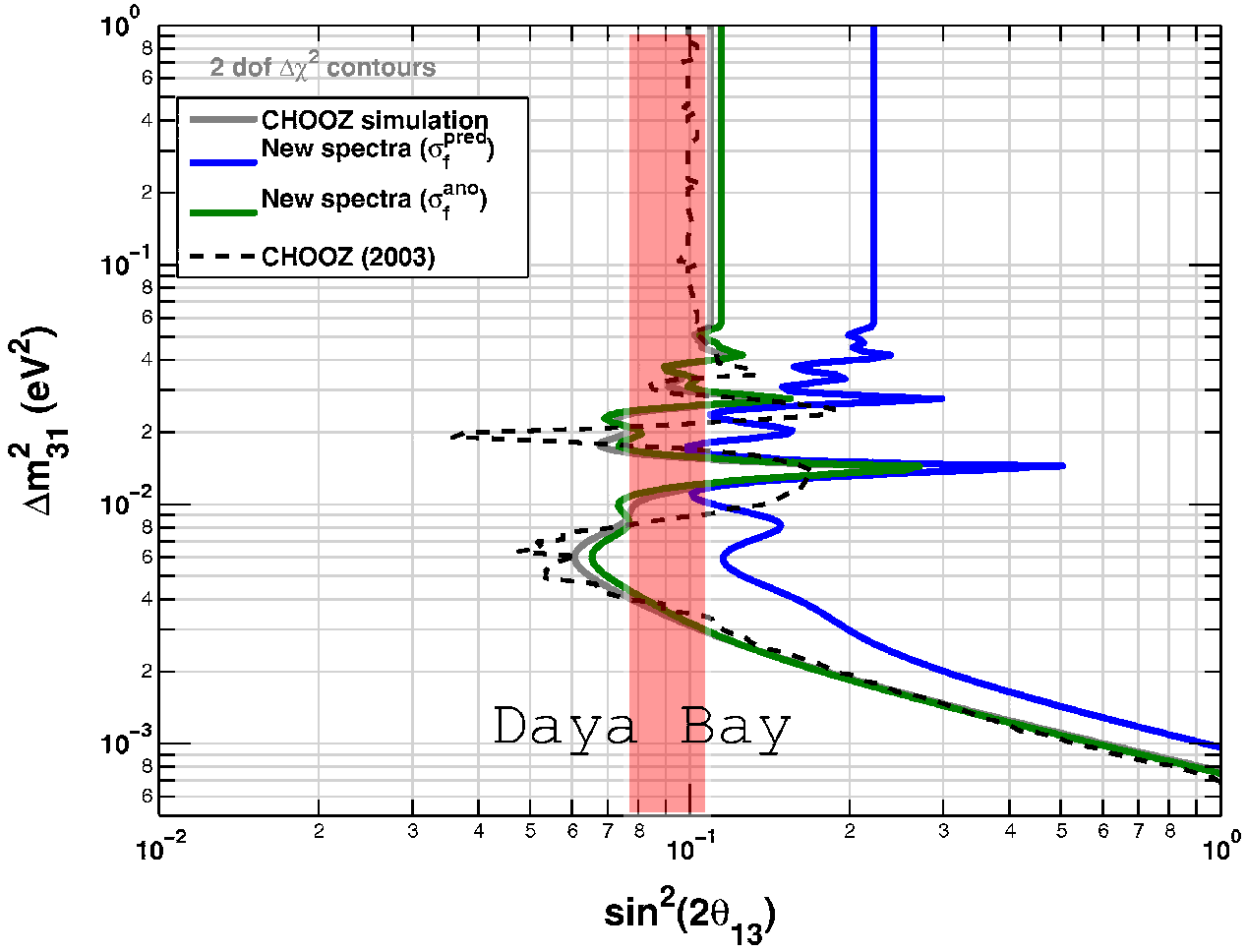
Don't know: hierarchy (inverted or normal), overall mass scale, whether ν's are Majorana, whether there are more (sterile) ν's.

Reactor Neutrino Anomaly

Reevaluation of reactor neutrino flux, in part from measured beta lifetimes of fission fragments, leads to 3% increase, problems for experiments, need for sterile neutrinos.

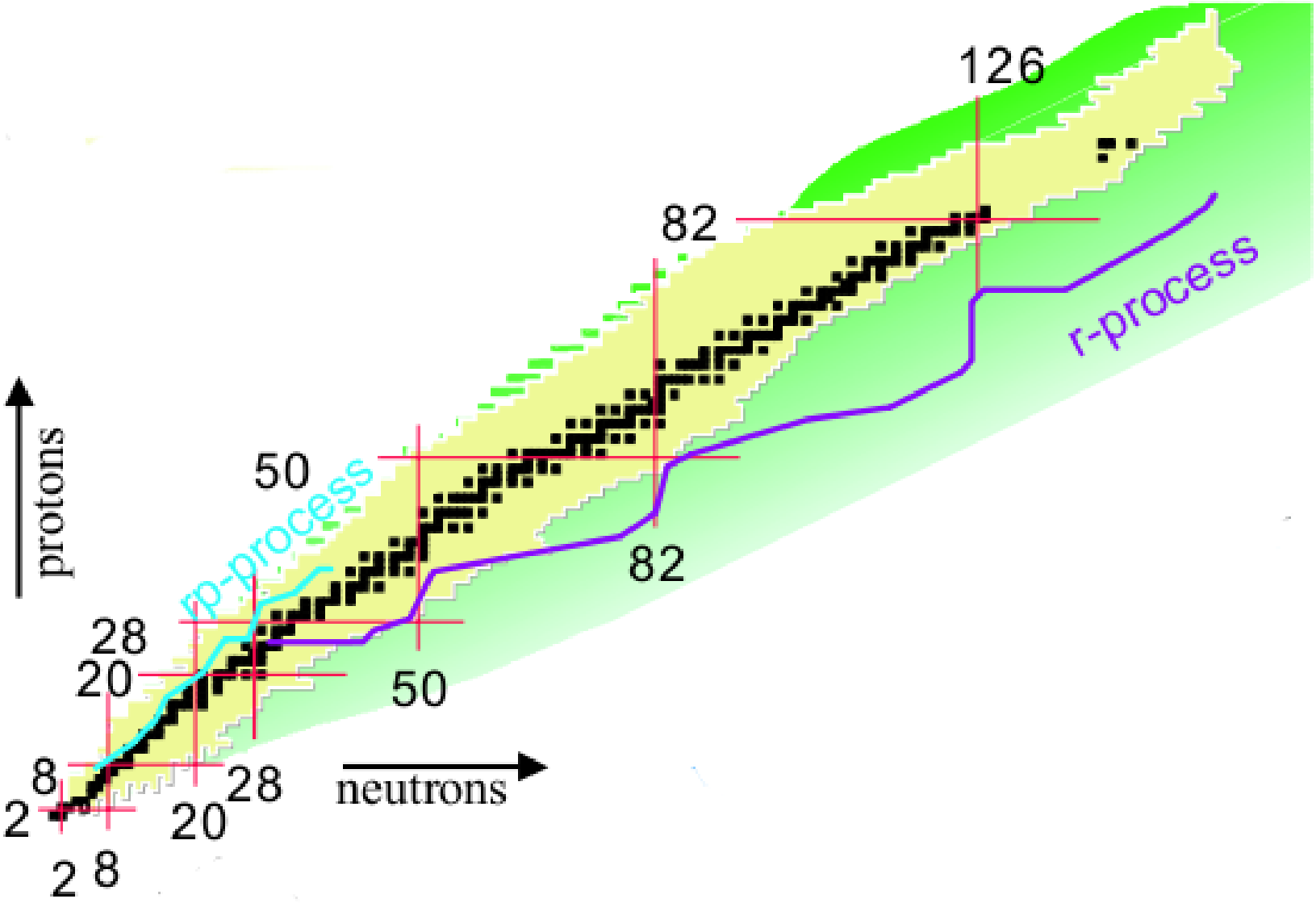


Is There Really an Anomaly?

One could measure lifetimes of more fission fragments (or remeasure suspect ones), especially the least stable, with large Q values.

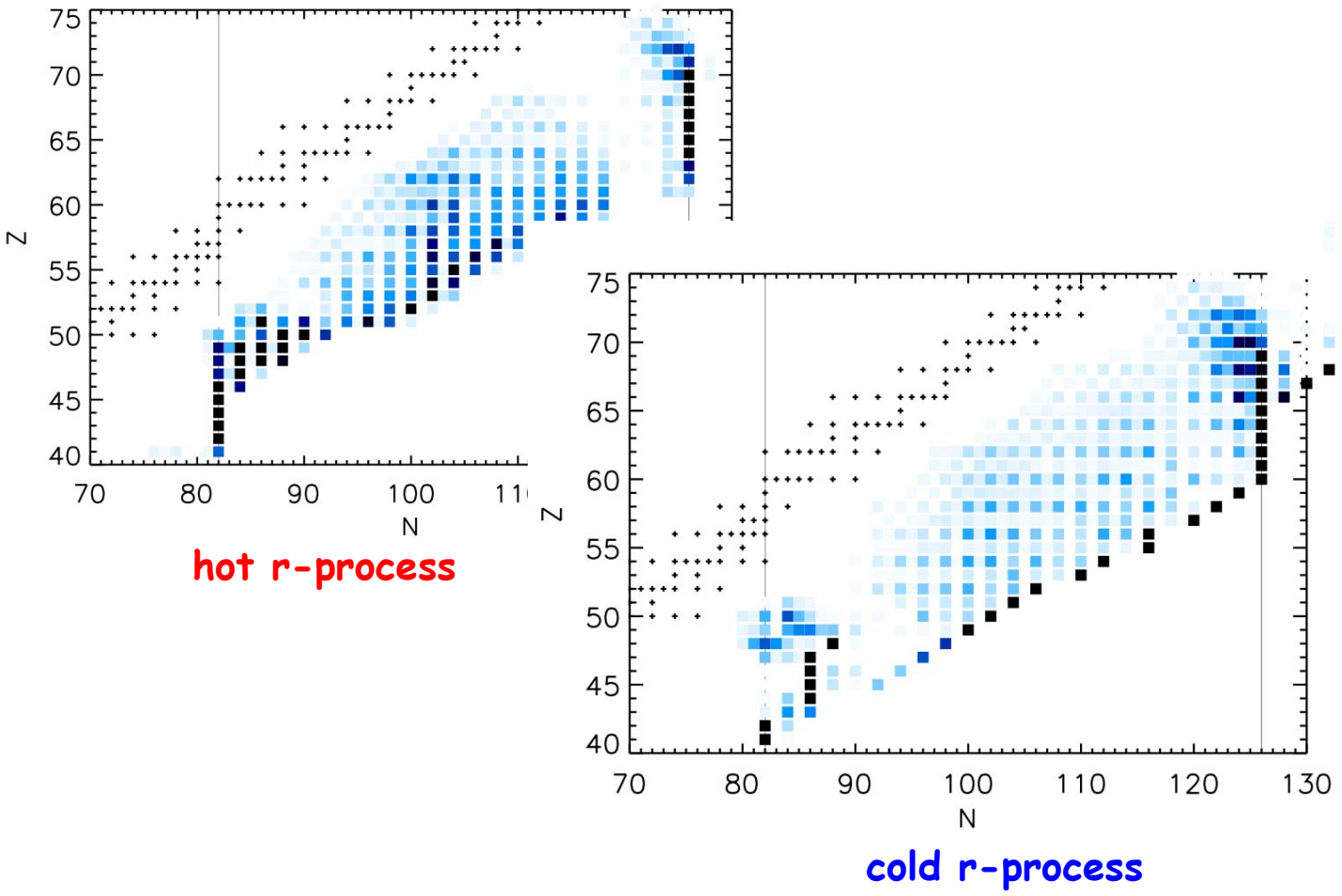
Some forbidden decays from such isotopes are treated as unique, even though they are not. Important, therefore, to know shape of beta spectra.

R Process and Beta Decay



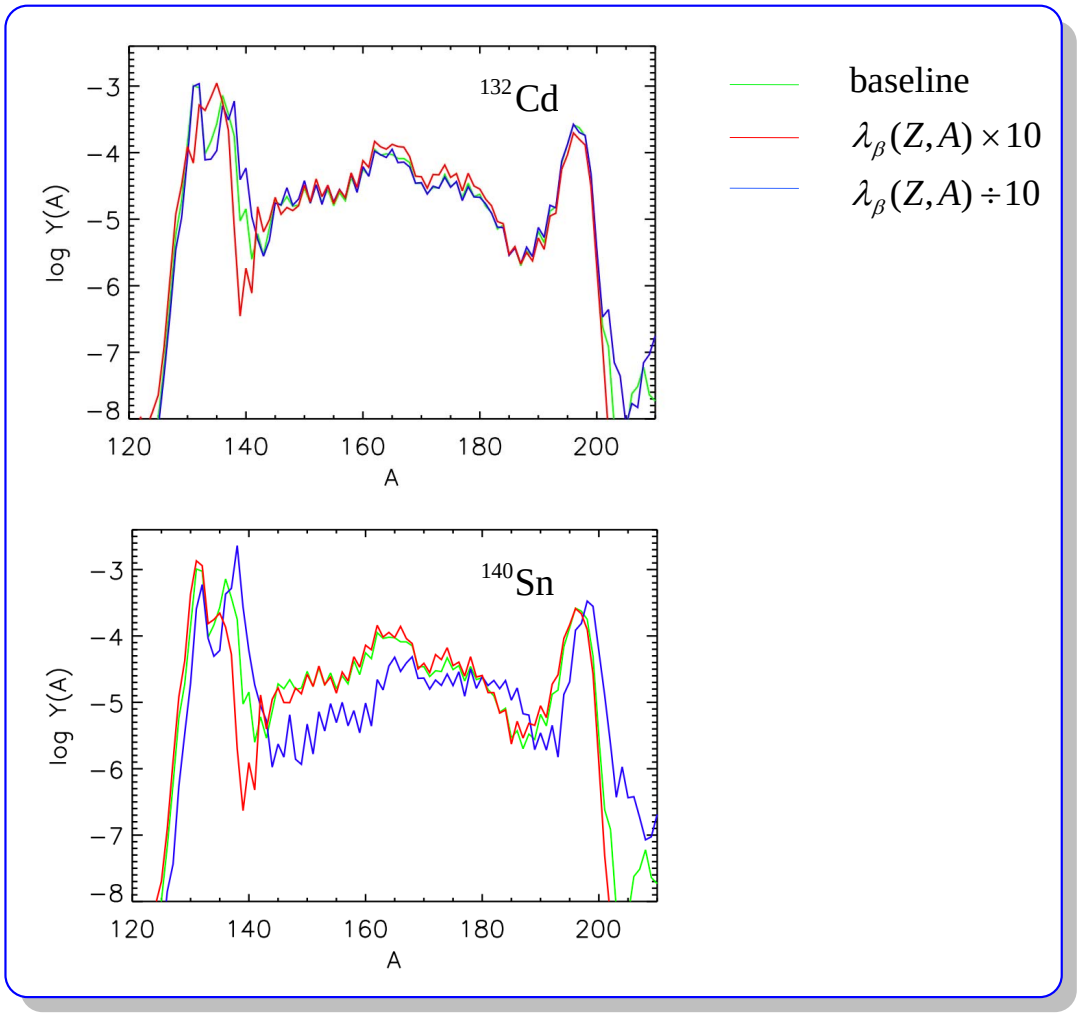
Effects of Beta-Decay Rates on R Process

From talk by Ani Aprahamian (on work with R. Surman): white-black = 0-10% effect in abundance pattern.



Effects on Abundances

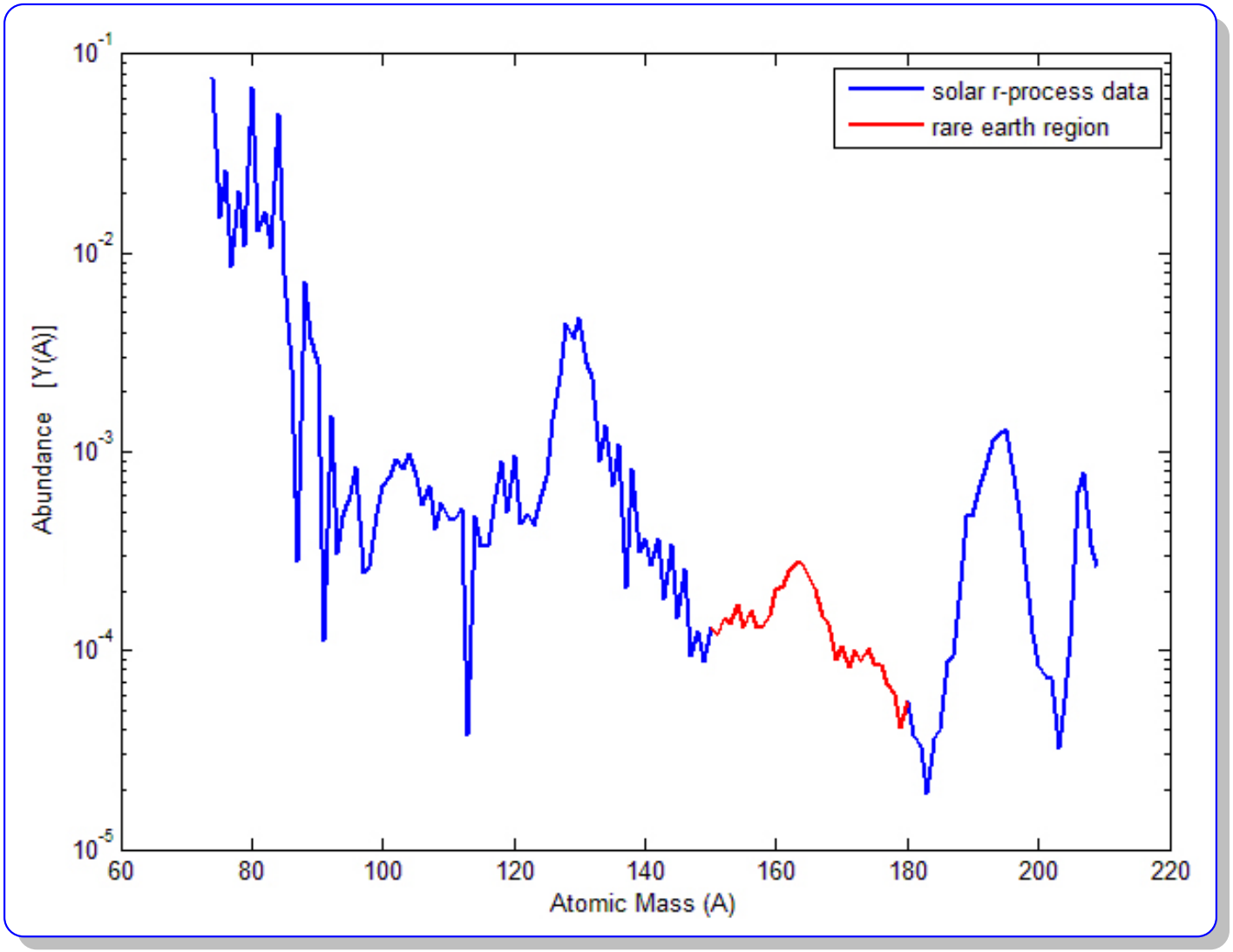
From same Ani talk:



Conclusion: need to measure selected rates. These are not really easy to calculate and it's possible to be off by a factor of 10 now and then.

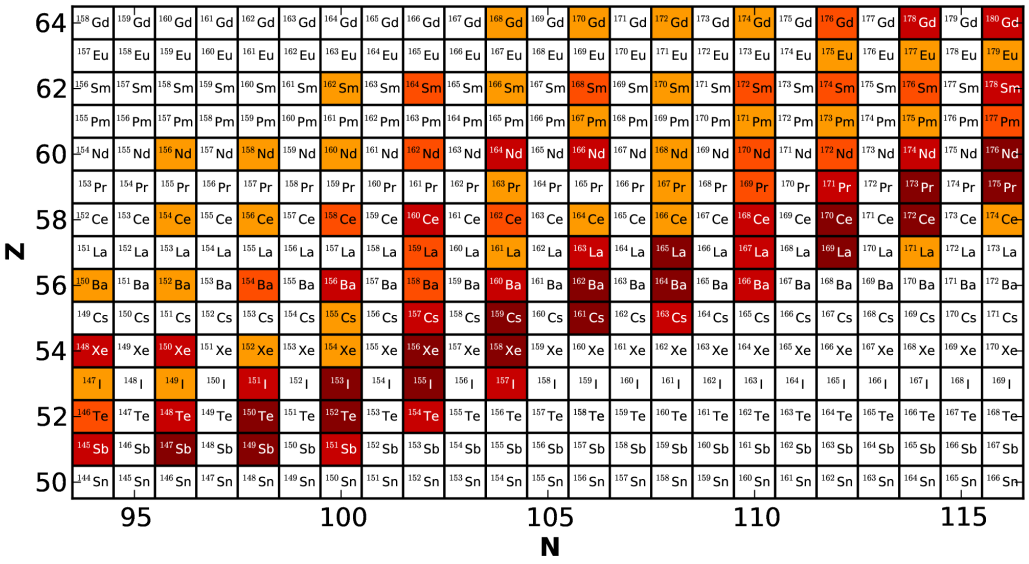
Similar Rare-Earth Study

Preliminary results by Mathhew Mumpower, Gail McLaughlin...



Important rates

Each beta-decay rate changed by a factor of 5

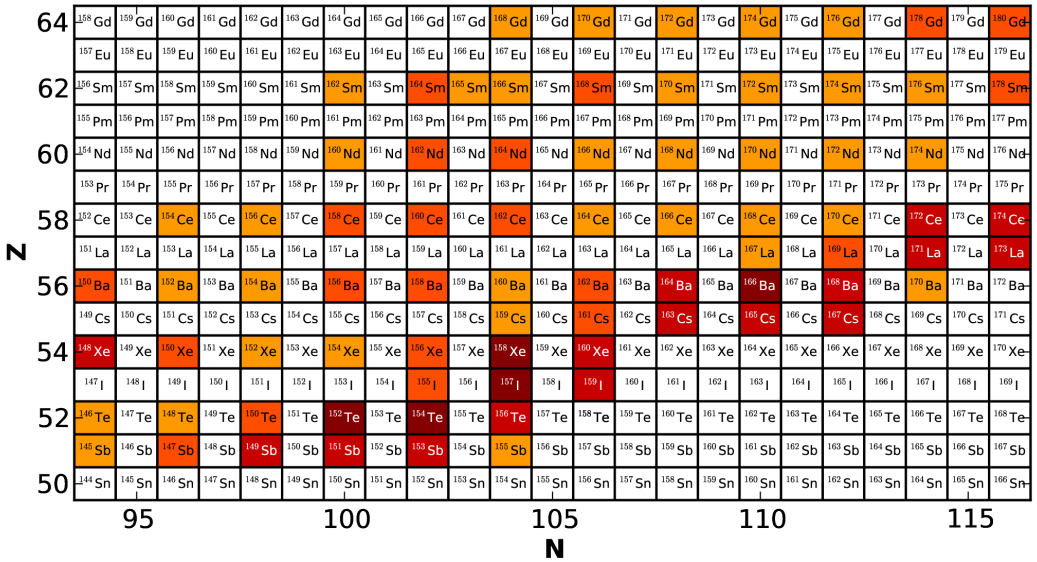


Hot conditions

Legend

Unchanged | Small Effect | Medium Effect | Large Effect | Largest Effect

Cold conditions



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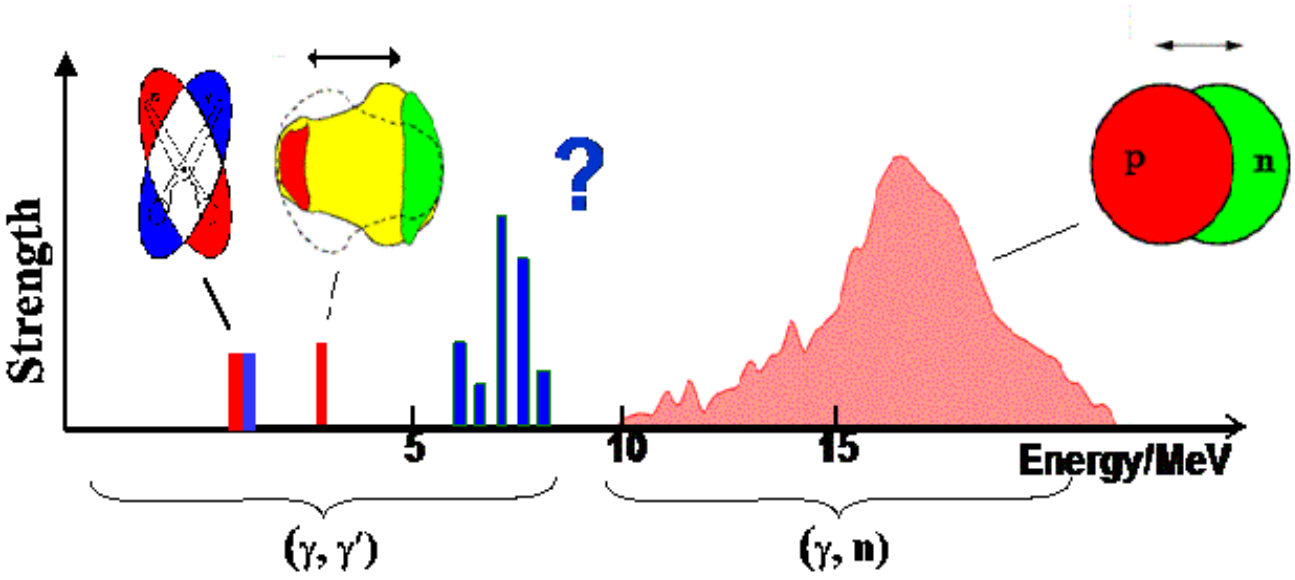
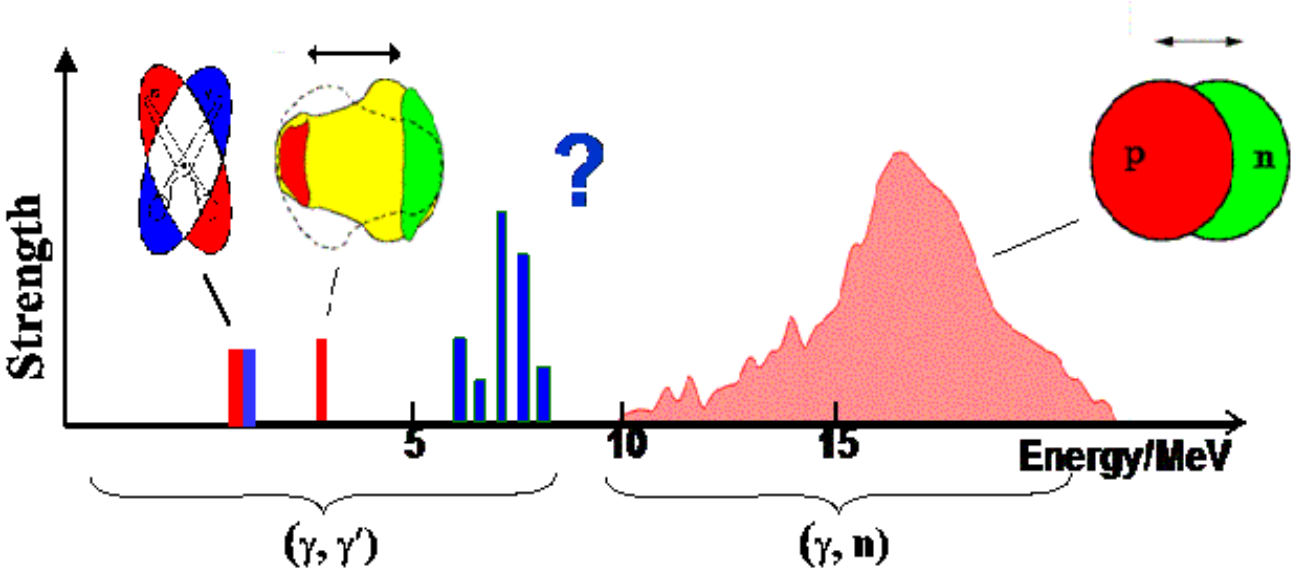
Excited states a different story. There are functionals for these but they are different from ground-state functional.



Adiabatic Limit



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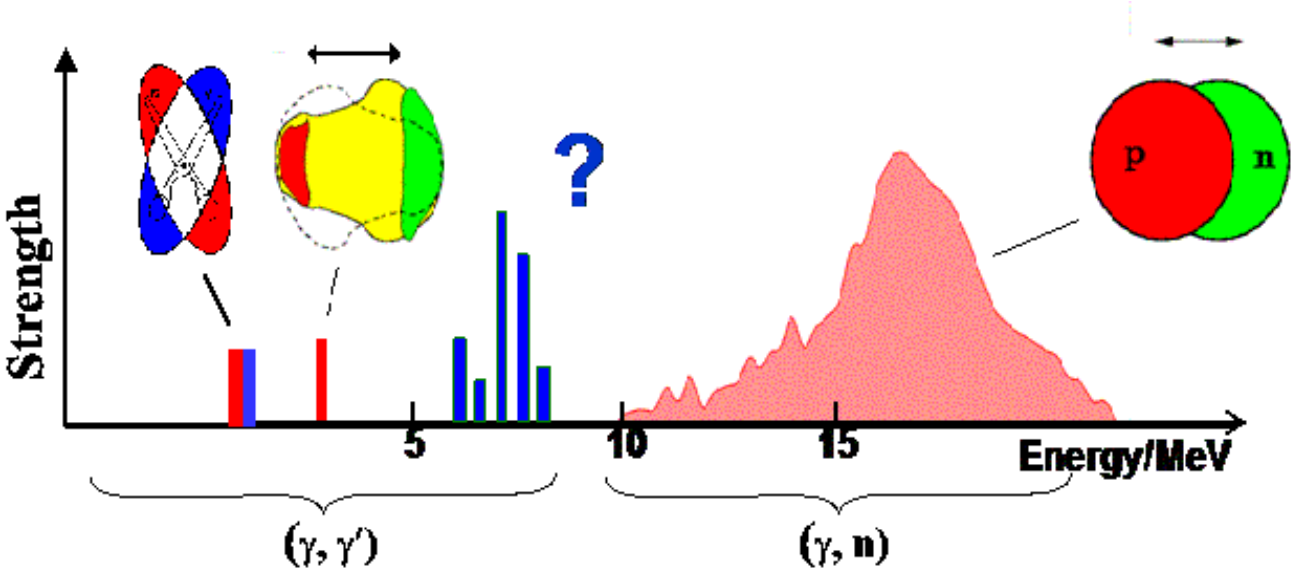

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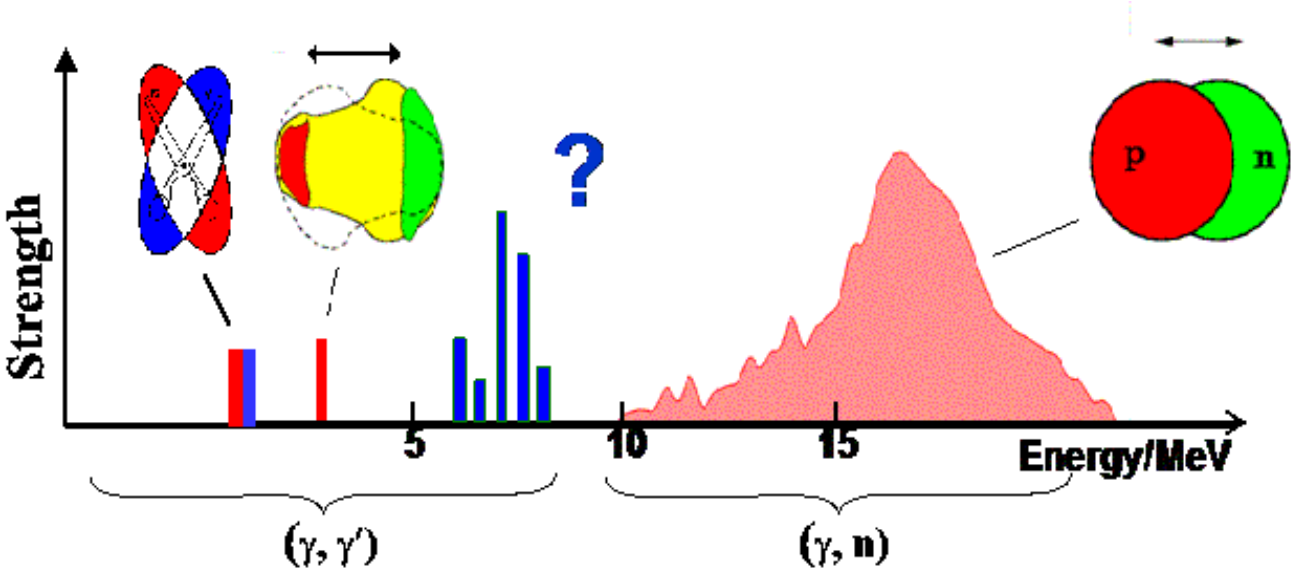

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Current local Kohn-Sham functionals describe only small-amplitude oscillations well. Can we improve functionals or must we abandon Kohn-Sham theory?

That's all.