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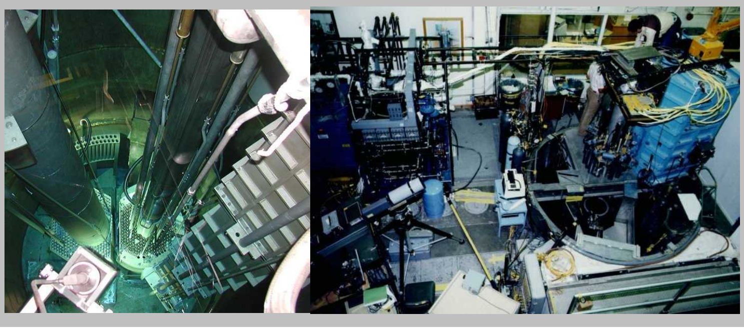

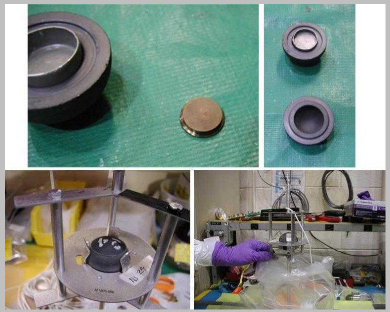

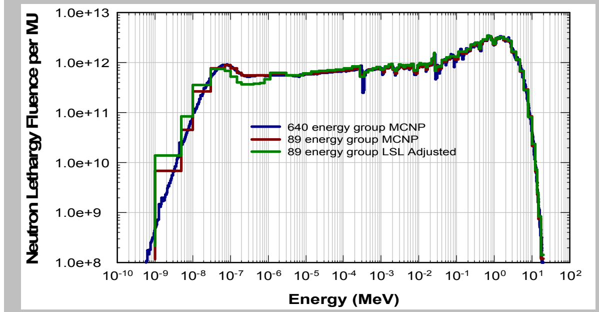

Toward an International Spectrum Adjustment Intercomparison

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Introduction

So you want to know what is happening in your reactor…

- Integrated quantities like power are relatively easy to determine via thermal measurements
- Differential/spectral quantities are much more challenging

Problem: What is the spectrum of neutron energies at a given location in a reactor?

Lesson Learned

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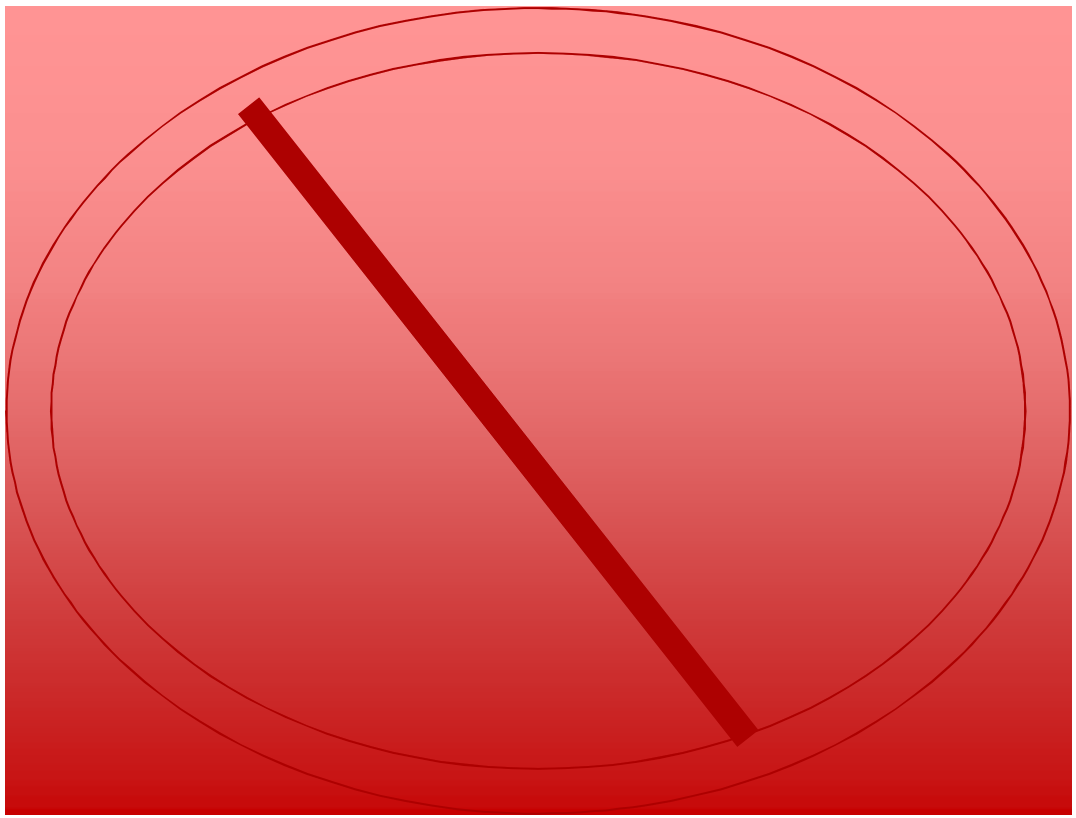
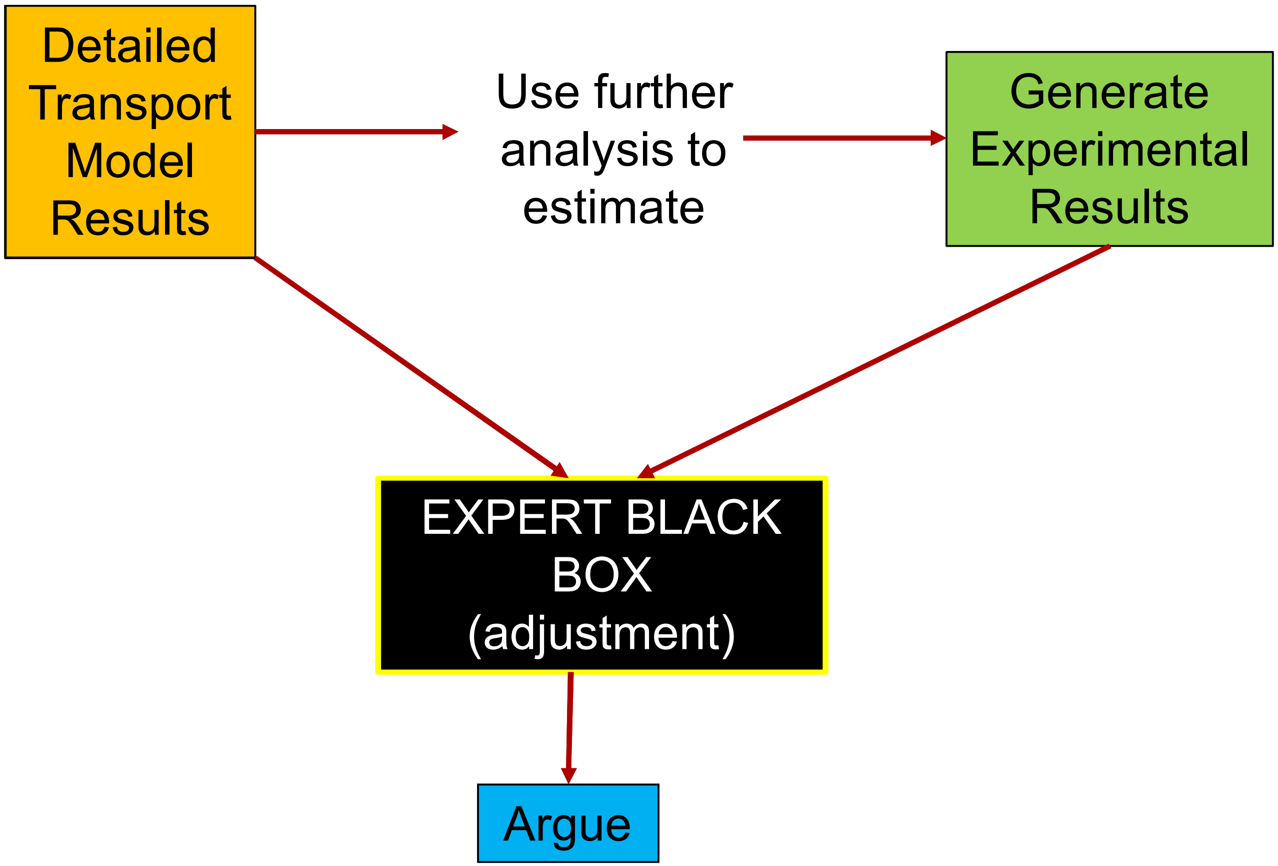
- Never trust a model
  - …without strong experimental confirmation



Spectrum Characterization Process

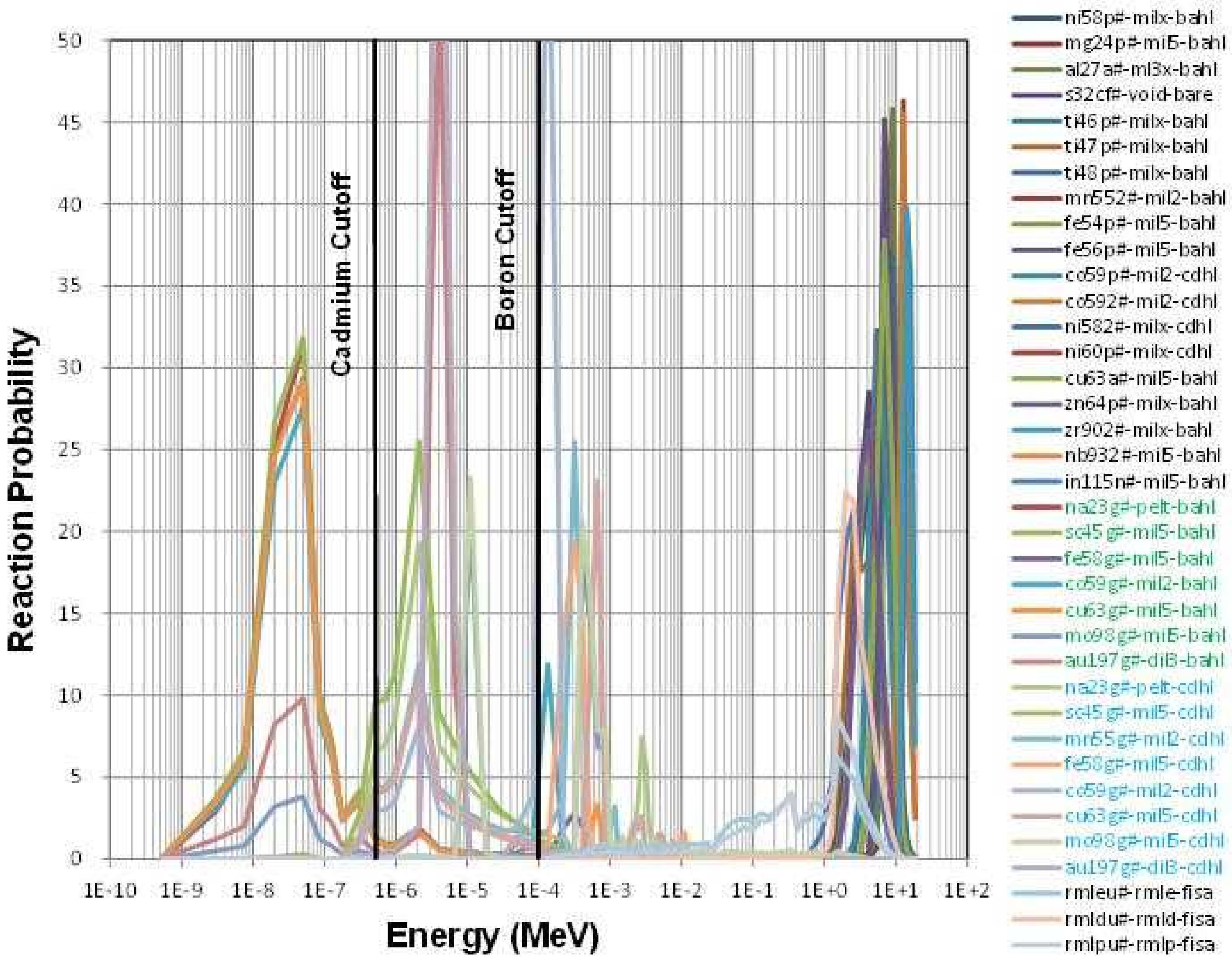
(In one simple chart)



How to Adjust a Spectrum

- Start with an excellent model and estimate all activities
- Assess foils that will derive maximum benefit, including use of multiple species from a single foil. Foil selection is CRITICAL!
- **Expose, measure and adjust**
- Perform spatial assessment and monitor shot-to-shot variations
- Use spectrum modifiers with fission foils and thermal activation monitors
- Demand *expert* judgement during final analysis

Activation Foil Selection



Reaction	Mass%	t 1/2
27Al(n-p)27Mg	1.000	9.5 min
115In(n-γ)116mIn	0.958	54.3 min
164Dy(n-γ)165Dy	0.285	2.3 hr
55Mn(n-γ)Mn56	1.000	2.6 hr
56Fe(n-p)56Mn	0.919	2.6 hr
115In(n-n')115mIn	0.958	4.5 hr
63Cu(n-γ)64Cu	0.685	12.7 hr
65Cu(n-2n)64Cu	0.315	12.7 hr
64Zn(n-p)64Cu	0.472	12.7 hr
23Na(n-γ)24Na	1.000	15 hr
24Mg(n-p)24Na	0.780	15 hr
27Al(n-α)24Na	1.000	15 hr
186W(n-γ)187W	0.288	1.0 d
58Ni(n-2n)57Ni	0.672	1.48 d
48Ti(n-p)48Sc	0.739	1.8 d
197Au(n-γ)198Au	1.000	2.7 d
98Mo(n-γ)99Mo	0.247	2.74 d
90Zr(n-2n)89Zr	0.507	3.27 d
47Ti(n-p)47Sc	0.0730	3.3 d
93Nb(n-2n)92mNb	1.000	10.1 d
32S(n-p)32P	0.947	14.2 d
58Fe(n-γ)59Fe	0.003	44.5 d
59Co(n-p)59Fe	1.000	44.5 d
94Zr(n-g)95Zr	0.179	64.0 d
59Co(n-2n)58Co	1.000	70.9 d
58Ni(n-p)58Co	0.672	70.9 d
45Sc(n-γ)46Sc	1.000	83.8 d
46Ti(n-p)46Sc	0.079	83.8 d
181Ta(n-γ)182Ta	0.999	114 d
64Zn(n-γ)65Zn	0.472	243 d
109Ag(n-γ)110mAg	0.486	249 d
55Mn(n-2n)Mn54	1.000	312 d
54Fe(n-p)54Mn	0.056	312 d
59Co(n-γ)60Co	1.000	5.3 y
60Ni(n-p)60Co	0.268	5.3 y
63Cu(n-α)60Co	0.685	5.3 y

Single Foil "Sets"

Require same day counting

Require long count times, usually much later

TABLE KEY
Too short lived
Beta Decay
Dead time limited
High E Threshold
Low Mass %
Competing Reactions
Acceptable

Fielding the Dosimetry

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Final Steps via ASTM E720

The analyst must then choose one of the following alternatives:

- Leave out reactions which have demonstrated consistent deviations;
- Seek better cross-section sets; or
- Assign wide error bars or low statistical weight to these reactions.

In other words the options amount to:

- IGNORE DATA! (*This is the preferred method in the standard!*)
- Undertake cross-section measurements in addition to spectra characterization work
- Assume the data and/or the model are bad, but use anyway.

International Benchmark Questions

- What effect does expert judgement have on this problem?
  - What reactions are ignored?
  - Can acceptable limits be formally codified?
- What are the sensitivities to initial conditions, both spectrum and covariance?
- How does the reactor field affect the answer, specifically thermal versus fast reactor environments?
- Nuclear data is an important consideration as well

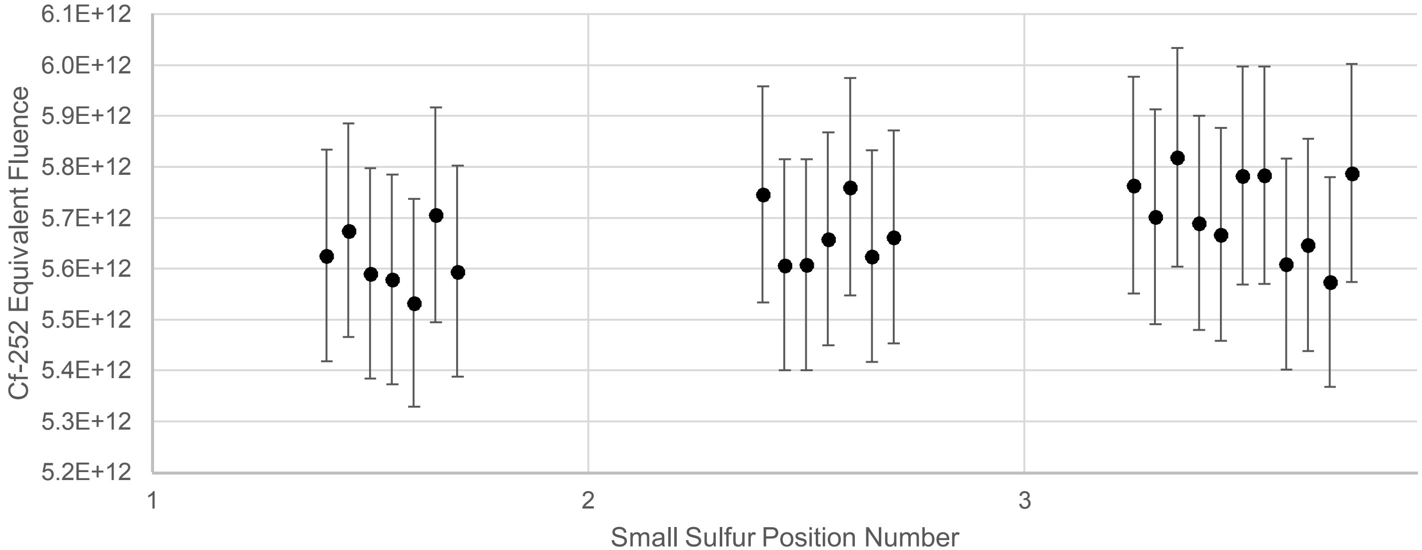
Converging on a Standard

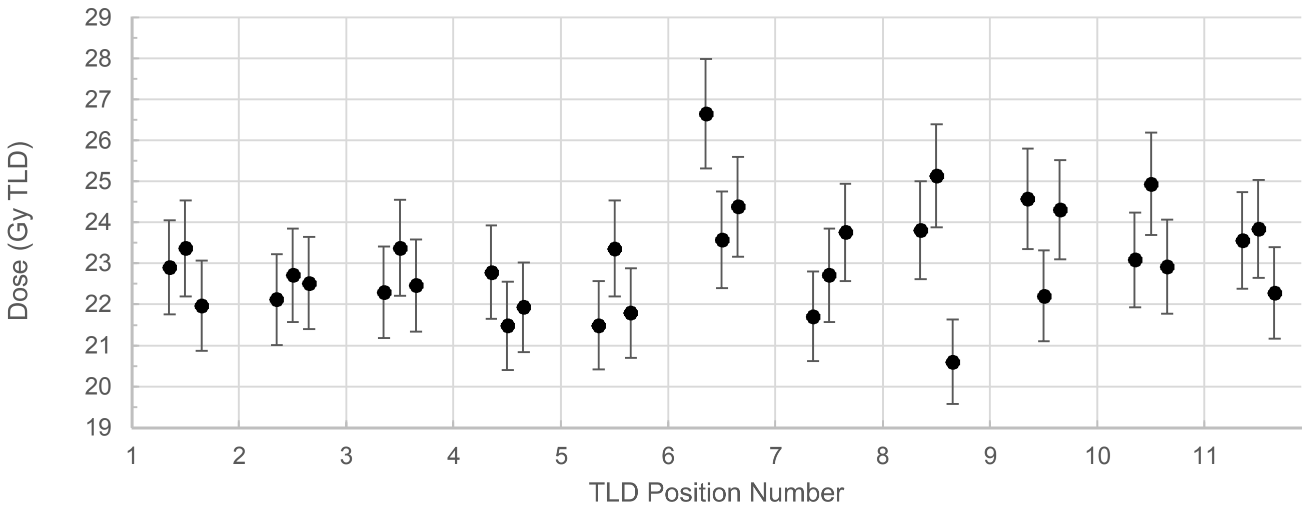
- One intercomparison leads to another—metrology best practices prompted this study. Two laboratories will agree on all activation results. The pedigree of all measurements and uncertainties will be excellent.
- The Fast Burst Reactor at White Sands Missile Range is a bare, enriched, unmoderated critical assembly.
  - Relatively simple to model and ample sample spaces for simultaneous exposure of all dosimetry
- For our exposure, the reactor was operated in steady state, and all dosimetry was fielded at core center line at a distance of 60 cm.
- All data and a priori assumptions will be shared among participants and final spectra evaluated.

Preliminary Activation Results

Isotope/Reaction	Cd Ratio
Ag-109	1.517
Au-197	1.618
Al-Au(0.1%)	1.107
Co-59(n, γ)	1.142
Co-59(n, p)	3.449
Cu-63	2.143
Mo-98	0.940
Na-23	3.344
In-115(n, n')	0.987
In-115(n, γ)	2.073
W-186	1.844

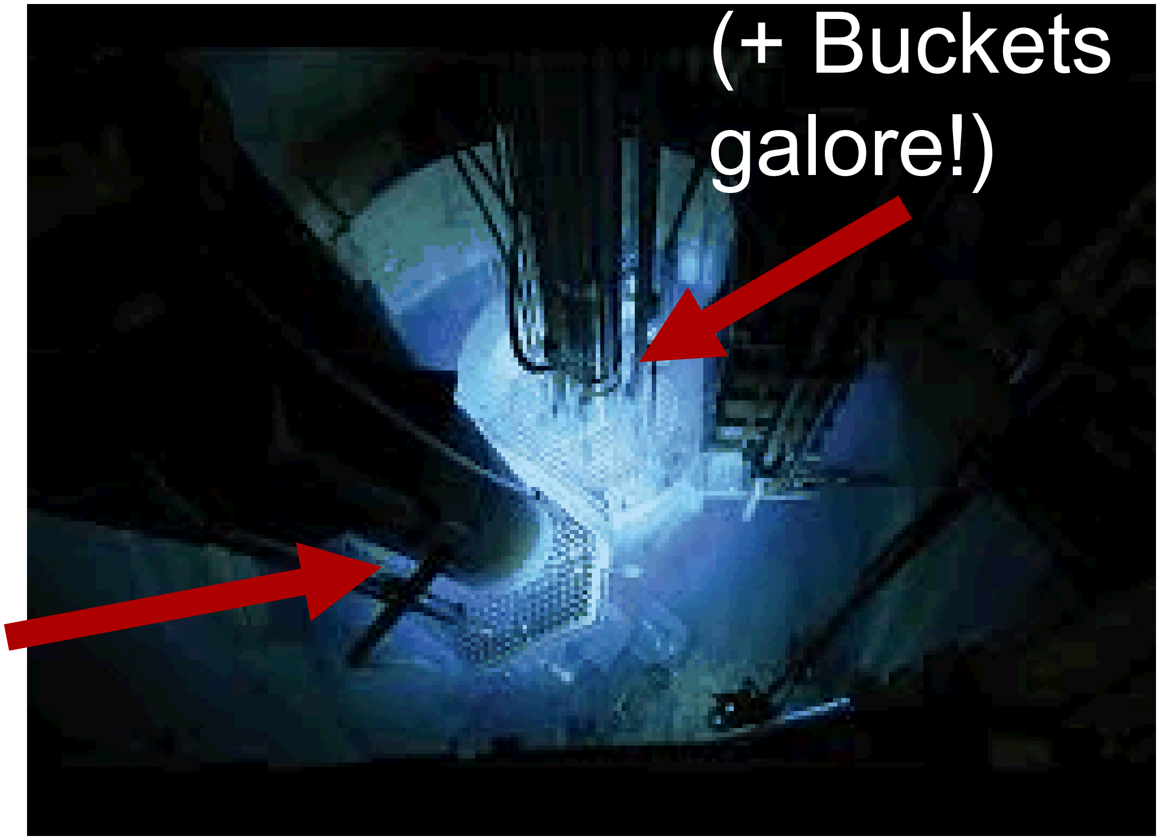
Spatial n/γ Profiles





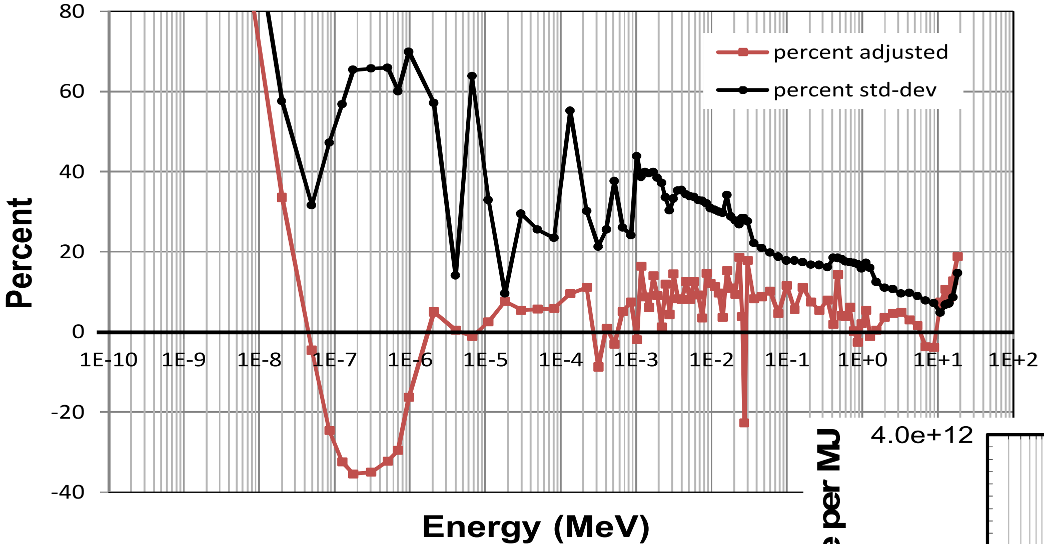
The Next Fields

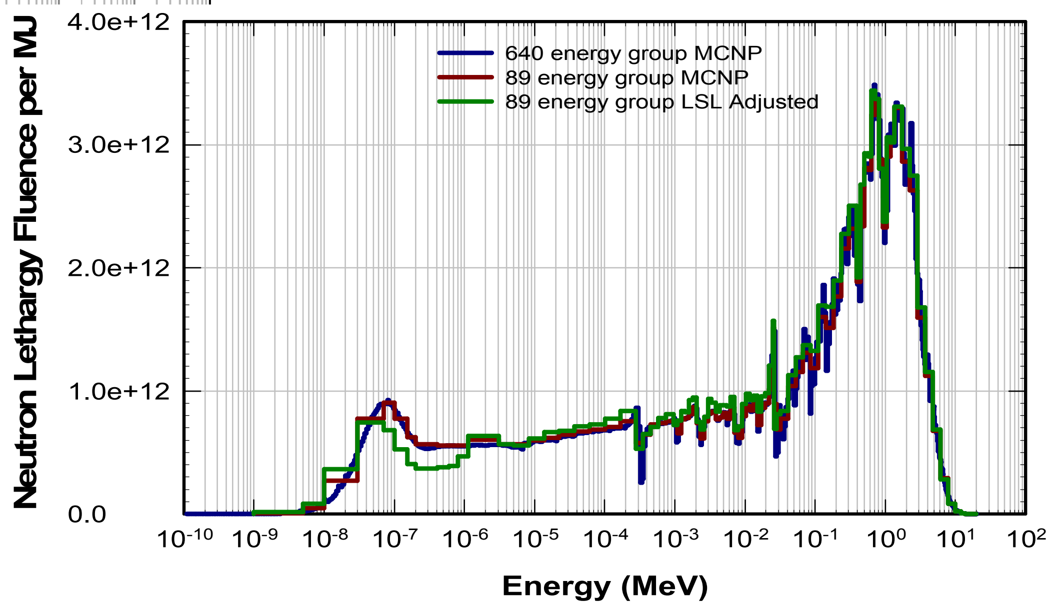
Central Cavity (+ Buckets galore!)



FREC

Typical Result:
ACRR Free Field Central Cavity





Interested?

- If you are interested in participating in the International Benchmark of Spectrum Adjustment Methods please contact me:

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Questions? Comments?