Dosimetry User's Perspective on Covariance Needs

Presentation to: Workshop on Neutron Cross Section Covariances

At: Port Jefferson, NY
On: June 24-29, 2008

Session 1: User's Perspective

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Outline

- Scope of dosimetry applications
- Major dosimetry concerns
- Details of dosimetry needs
- Balance of dosimetry needs
- Path forward

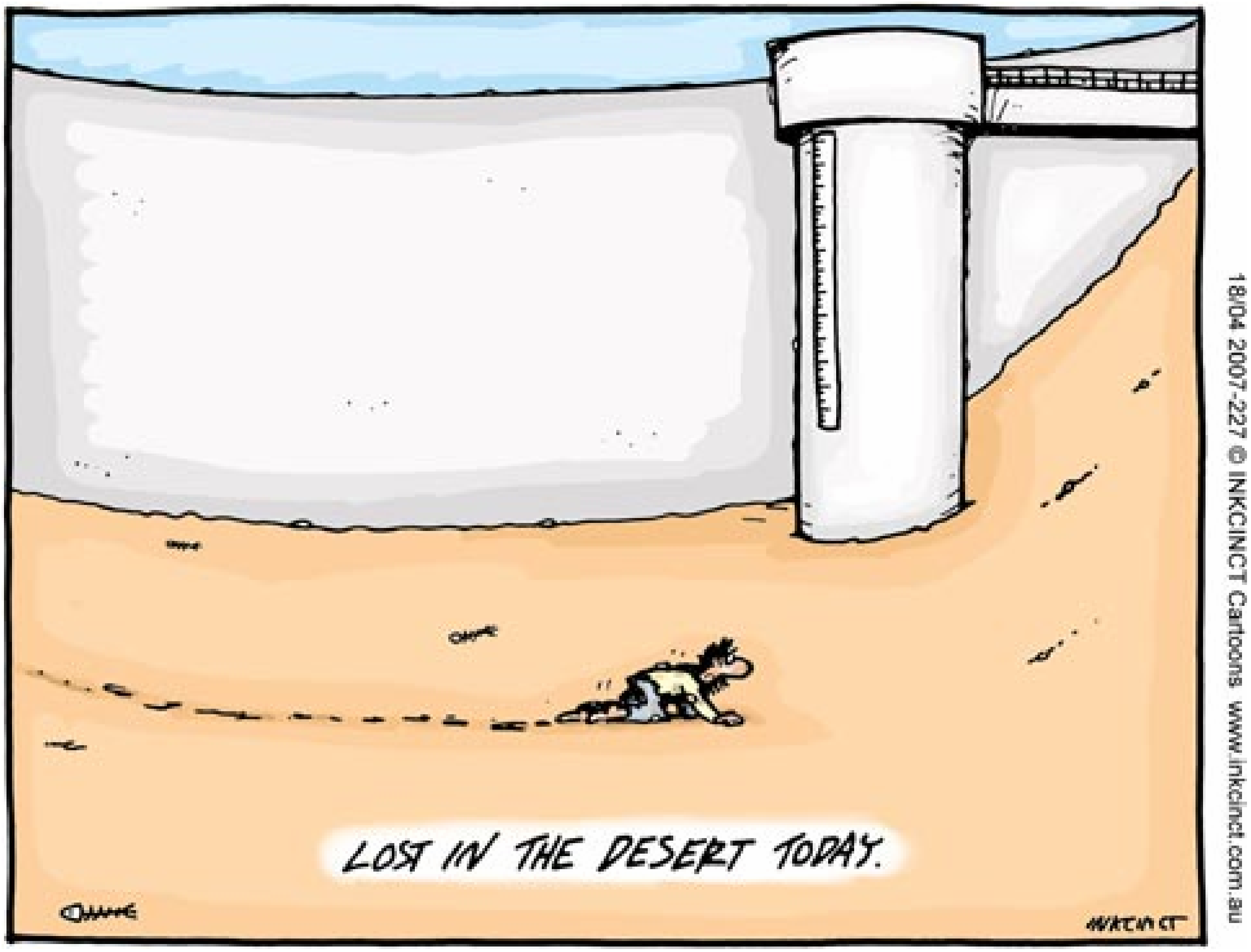
Application Priorities

- **Important Dosimetry Applications**
  - **Neutron spectrum adjustment**
  - **Fluence monitors**
  - **Material identification**
  - **Secondary gamma environments**

Application 1: Spectrum Adjustment

- **Methods**
  - Iterative, e.g. SAND-II, GRAVEL
  - Least squares, e.g. LSL-M2, STAY'SL
  - Maximum entropy, e.g. MAXED
  - Bacchus-Gilbert, e.g. UFO
- **How important are cross section covariance matrices?**
  - Answer varies with specific application
  - Previous REAL-80/84 series of comparison indicates this is very important
- **How important is trial spectrum**
  - Recent work suggests it can be very important
  - So, what about covariance for trial spectrum?

Why has ENDF/B-VII abandon us? Walled us out?

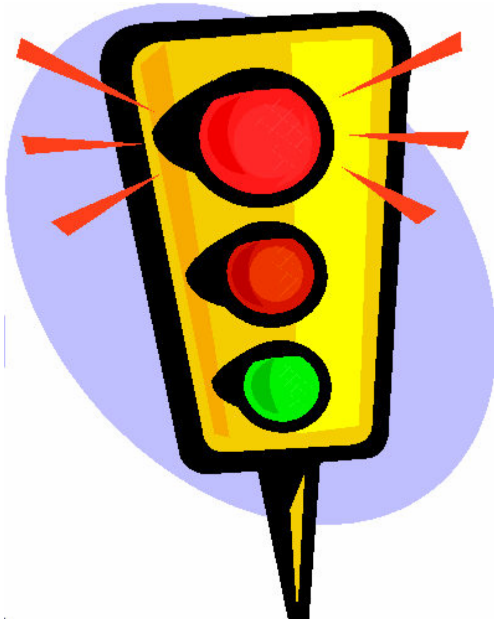


CSEWG ENDF/B-VII Issues

- You took away almost <u>ALL</u> of our covariance data
  - Dosimetry reactions of interest to us were generally eliminated
  - Even the <u>standard</u> reactions that we use have a covariance only over a restricted energy range
- We need to tell users why we do not use/recommend ENDF/B-VII data
  - Telling them we recommend use of the ENDF/B-VI dosimetry cross section, which is the same as the ENDF/B-VII values, starts a very confusing dialog

CSEWG Rating of Older ENDF/B-VI Covariance Data

- CSEWG followed a rigorous process for evaluating older data
- Problem is the results of the rating:
  - We clearly do not want wrong/bad data
  - But we do not want NO data either
- Maybe the bar was set too high
  - Suggest <u>accepting</u> yellow and green ratings and only <u>eliminating</u> red rated reactions
  - It is understood that an over-estimate of the uncertainty can be almost as bad as an under-estimate



What is our real request?

- **We are not, in general, requesting smaller uncertainties – just an estimate of the current uncertainty.**
  - **All covariance data does not have to be of "<u>standard</u>" quality. There is a role for "<u>reference</u>" quality data.**
  - **The covariance must be consistent with the actual cross section – and not an independent quantity. "<u>controlled</u>" quality data is not useful.**
- **Why even give us the cross section data if you really have no estimate of the uncertainty?**
  - **If you have an "expert judgment" we will even go with that – but we can not use data with unstated uncertainty.**
  - **Dosimetry users can not be trusted to provide this "expert judgment". The evaluator or evaluation community must provide this.**

Covariance for ^{235}U Fission Spectrum

- **Motivation**
  - Good covariance data has only been published for ^{252}Cf. ^{235}U covariance will drive the *a priori* spectrum covariance
  - Two parameter Watt fission representation inadequate. Replacement will also be used in updated radiation transport calculations
- **Deficiency**
  - For 2-parameter shape (highly correlated) a single good threshold sensor can result in an unrealistically small *posteriori* uncertainty for high energy spectrum tail.
- **Request**
  - Covariance for ^{235}U fast fission neutron spectrum of similar detail (not necessarily accuracy) as in ^{252}Cf spontaneous fission.

^{nat}Cd Request

- **Motivation**
  - Cd is used as a cover for activation foils
  - It moves the dosimeter response above thermal energy region
- **Deficiency**
  - Systematic offsets in spectrum adjustments are seen in epi-Cadmium region
  - Is this an issue with the Cd cross section here? the *a priori* spectrum/uncertainty? a biased adjustment process for covers?
- **Request**
  - Uncertainty/covariance data so that we can evaluate where the cause of the adjustment problem

New Cover Materials

- ^{nat}Gd is now being used as a foil cover
  - Not as good a cover for shifting energy response, but it avoids ES&H issues associated with ^{nat}Cd
  - New ENDF/B-VII cross sections are now available, and has high/fast energy (> 1 keV) covariance data for total, elastic, and (n,γ) reactions.
  - Analysis of cover correction with uncertainty is pending.
    - » What do we do for covariance/uncertainty for energies < 10 keV.

Treatment of Activation Measurements

- **How important is this covariance?**
  - **Still under investigation**
  - **New applications are developing a refined approach that will be used to test importance**
  - **Uncertainty contributions:**
    - » **HPGe efficiency calibration curve**
    - » **Energy of gamma line read**
    - » **Multiple reactions from same foil**
    - » **Multiple readings on different counters**
    - » **Sampling uncertainty**
    - » **Summing corrections**
    - » **Detector design – e.g. dead oxide layer for low energy photons, sensitive detector volume**
  - **Correlation between bare and covered cross sections is important**
    - » **Treat as two/three uncorrelated reactions; B4C covered; Cd-B4C covered; bare-Cd-B4C covered**

PKA Recoil Uncertainty for Si, GaAs, and Fe

- **Motivation**
  - **Standards require uncertainty for exposure metrics**
    - » **Fe dpa for PWR/LWR material embrittlement**
    - » **Si displacement kerma for electronic device gain degradation**
    - » **GaAs for displacement kerma and damage deviation due to FP recombination in clusters**
- **Deficiency**
  - **Cross section uncertainty for all reactions in Si, Fe, Ga, and As**
  - **Recoil spectrum definition – File 5/6 – and uncertainty**
- **Request**
  - **Cross section covariance data for these materials**
  - **Reaction-dependent recoil particle energy uncertainty – maybe covariance – File 35**
  - **Sufficiency of File 35 format not clear – need data for theses materials to look at impact**

Special Dosimetry User Needs

- **Attach to ENDF File 1 data the relative abundance for isotope**
  - **Critically important for ^{58}Fe, an important dosimetry reaction, where the abundance has varied significantly over the years – and users have no idea how to combine the abundance they assume in their activation analysis with that used for the cross section evaluation**
- **Link to state-of-the-art decay data (gamma decay energies, photon yield, and branching ratios)**
  - **Independent of cross section, so it can be provided by dosimetry community in separate document**

Dosimetry Need – ~ 1-MeV Response Sensor

- **Motivation**
  - **Fast neutron (0.1 – 3 MeV) damage dominates many damage mechanisms. This energy does not have good, easy-to-read dosimetry reactions.**
- **Deficiency**
  - **Current – inadequate – sensors: ^{237}Np(n,f), ^{93}Nb(n,n'), ^{103}Rh(n,n'), ^{115}In(n,n'), Si transistor gain degradation**
- **Request**
  - **Cross sections for alternate candidate reactions**

Additional Need: ^{58}Ni(n,p)^{58m}Co BR Uncertainty

- **Motivation**
  - **^{58}Ni(n,p)^{58}Co reaction is an important monitor foil for research reactors. It has a high energy sensitivity (> 3-MeV) that makes it idea.**
- **Deficiency**
  - **The reading of this foil must be delayed due to decay of ^{58}Ni(n,p)^{58m}Co product**
- **Request**
  - **Energy-dependent branching ratios for this reaction to the ground and metastable state – and uncertainty in the bracnhing ratio**
    - » **Hetrick personal communication currently used for this early-reading, but no uncertainty data is available.**

Dosimetry Need – High Energy Cross Sections

- **Motivation**
  - Fusion community needs improved dosimetry for material damage. Simulators (IFMIF) have neutron components up to ~60 MeV
- **Deficiency**
  - Need high fidelity cross sections and covariance data in this range
  - Highly correlated smooth cross sections provide little sensitivity for spectrum adjustments
- **Request**
  - Candidate reactions have been identified. Covariance data required.

Related Issues

- **Diagonal covariance matrices have been accepted – but with great reluctance.**
- **Too large of a cross section uncertainty will permit the spectrum adjustment to be driven by the *a priori* spectrum.**
  - ***a priori* spectrum uncertainties and covariance are much more poorly known/defined**
- **Chi-squared per degree-of-freedom is an important metric in the spectrum adjustment. Poor covariance estimates defeat the value of this metric.**

Role for Low Fidelity Covariance Data

- **Low fidelity effort focuses on use of parametric variation in nuclear physics models, e.g. EMPIRE**
  - **Calculation-only approach not sufficient for dosimetry purposes**
  - **Experimental data <u>must</u> play a role**
  - **Covariance we use <u>must</u> be related to the cross section used – not appended to a different evaluation that had different development roles – ASTM E1018**
  - **Uncertainty in physics models – not just parametric variation – needs to be incorporated**
    - » **E.g. Issue with Watt fission spectrum in LEPRICON methodology**

Need for Expanded Covariance Matrices

- **Types of expanded considerations:**
  - **Cross reaction**
  - **Cross material**
- **Need:**
  - **Not clear, we need some sensitivity studies here**
- **Status:**
  - **Expanded covariance for reactions and recoil spectrum are believed to be more important, at this time, for most dosimetry applications.**
  - **A simultaneous fitting of important dosimetry reactions is desired, i.e. GLUCS-like**

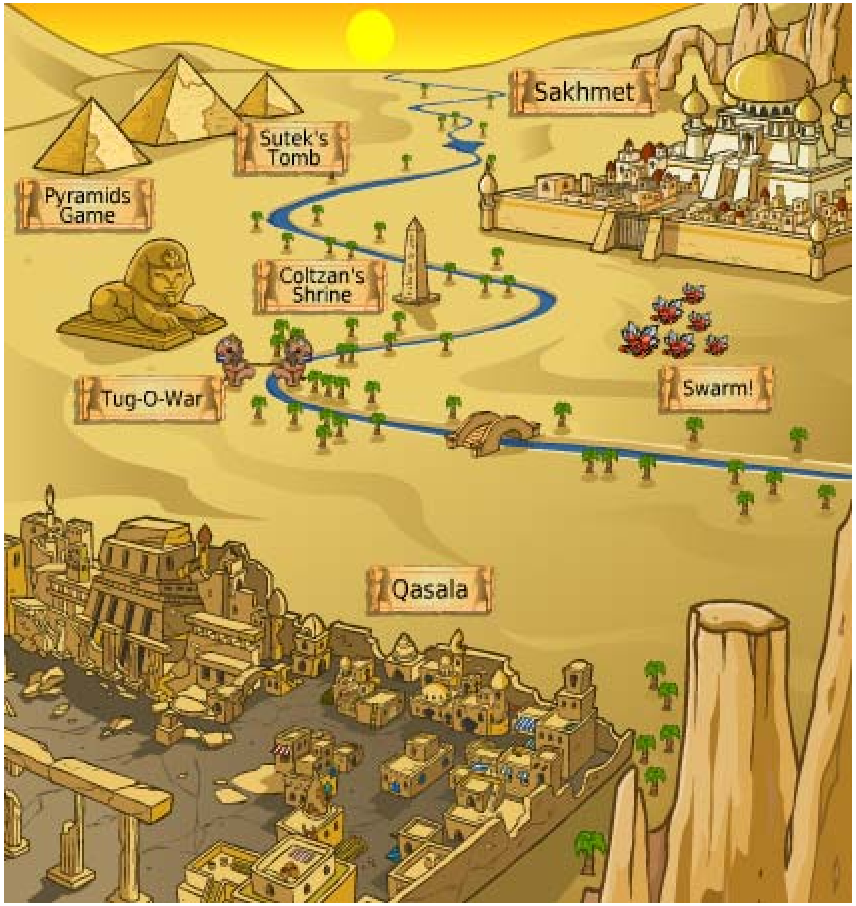
Application 2: Material Identification, Secondary Gamma Environments

- **Uncertainties for prompt gamma emission data**
  - **Energies and yield**
  - **Reference data now available and used in latest ENDF/B-VI Rel. 8 cross sections.**
    - » **recent IAEA PGNA work and their Frankle-Reedy and Budapest data**

Path Forward

- **Address covariance for ENDF/B-VII cross sections**
  - **?? Include dosimetry sub-library**
  - **?? Add in covariance matrices that should be usable by the dosimetry community even if they do not have extensive parameter variations of the supporting nuclear model calculations**
- **Continue with current cross section evaluation community emphasis on covariance matrices for all quantities**

Maybe this dialog will act as a map for both communities



Are we too greedy in our request?

Dosimetry users are making significant requests from cross section community. Do we have a balanced perspective?

- **We may be demanding, but we do have a balanced approach**

Spectrum Adjustment Refinements in Current Use

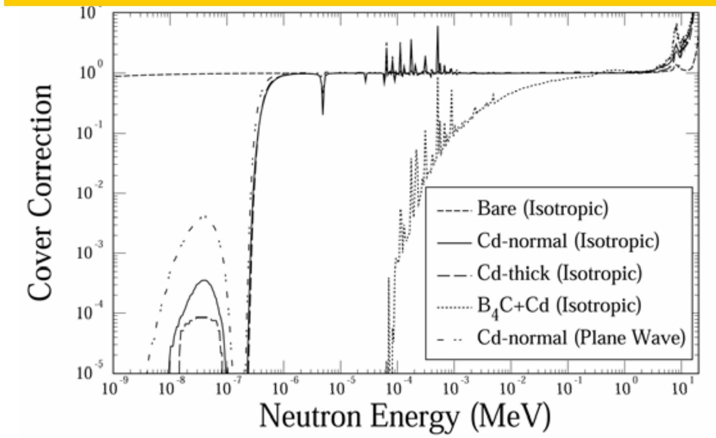
- Detailed *a priori* spectrum with structure
- Iterative unfolds that:
  - preserve this *a priori* structure – smooth adjustment, not trial spectrum
  - MC perturbation of trial spectrum to obtain uncertainty metric
- Cover treatment, beyond attenuation
- Covariance for *a priori* calculated spectrum

Cover Treatment

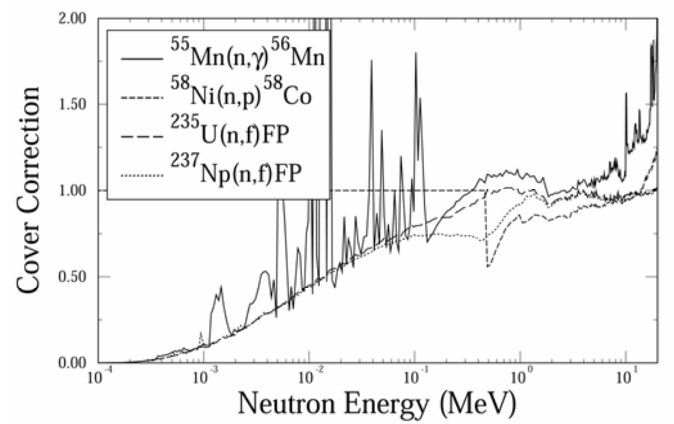
- We have moved past a simple exponential attenuation model
  - Use energy-dependent adjoint response
  - Captures self-shielding when a thick cover is used
- Issue with cover-to-cover thickness variation from dosimetry suppliers
  - Now use specific thickness measurements
- Perturbation of free field spectrum by cover is addressed
  - No foil stacking in B_4C covers
  - Single B_4C covers per irradiation with monitor foil
  - Even monitor foil perturbation is an issue

Cover Correction Factors

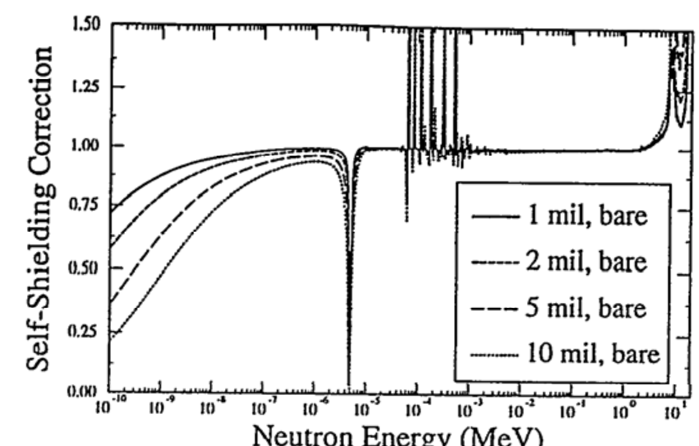
Effect of covers on $^{197}Au(n,\gamma)$



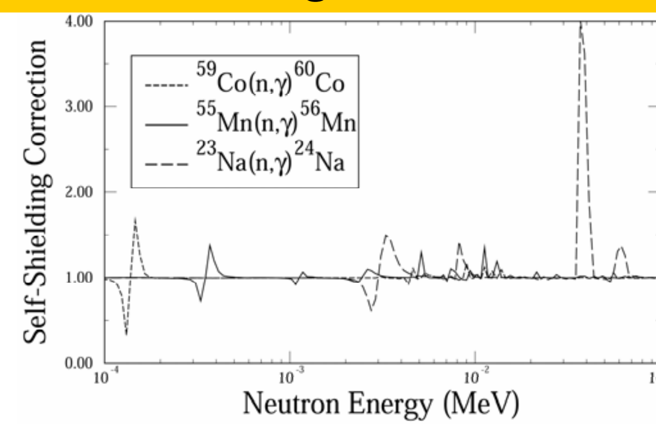
Effect of B_4C+Cd for reactions



Self-shielding on $^{197}Au(n,\gamma)$



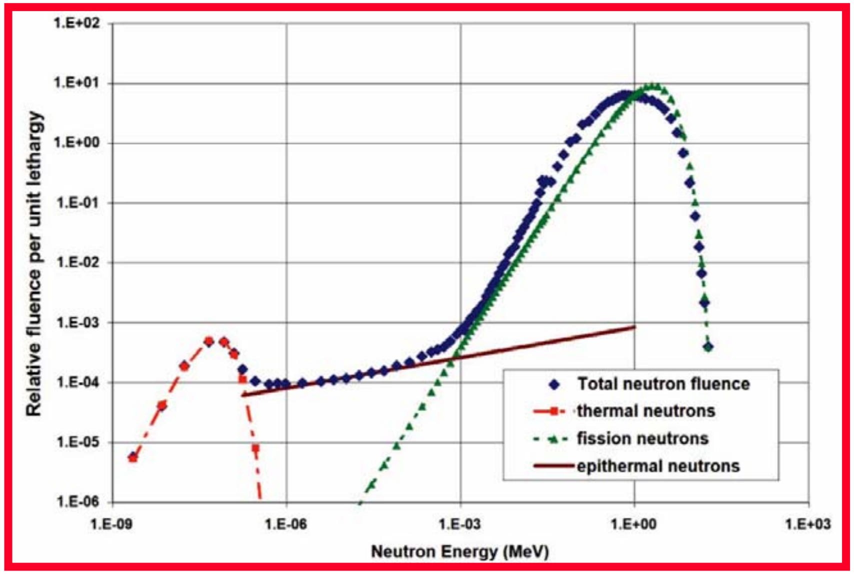
Self-shielding on reactions



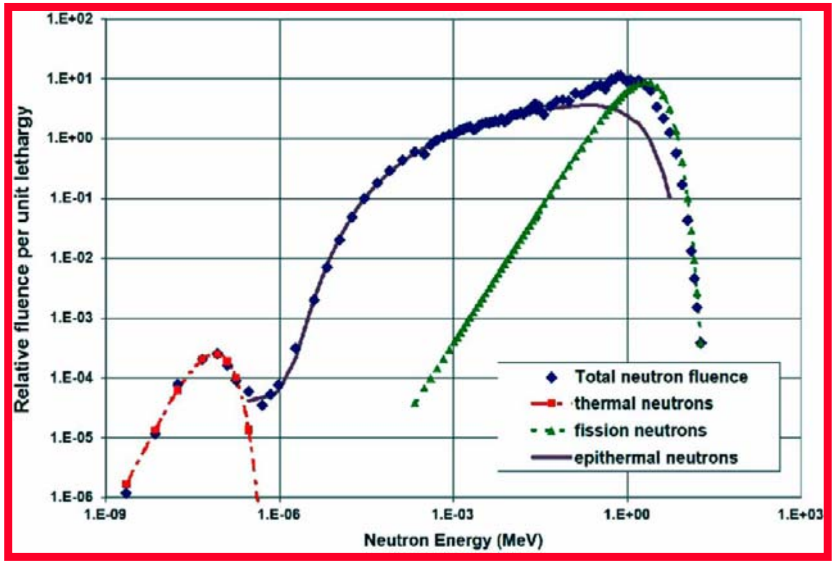
Covariance in *a priori* Spectrum

Use fission, 1/E$^{\alpha}$, and Maxwellian components coupled with transitional regions as determined by fit to *a priori* spectrum

Fast Burst Reactor



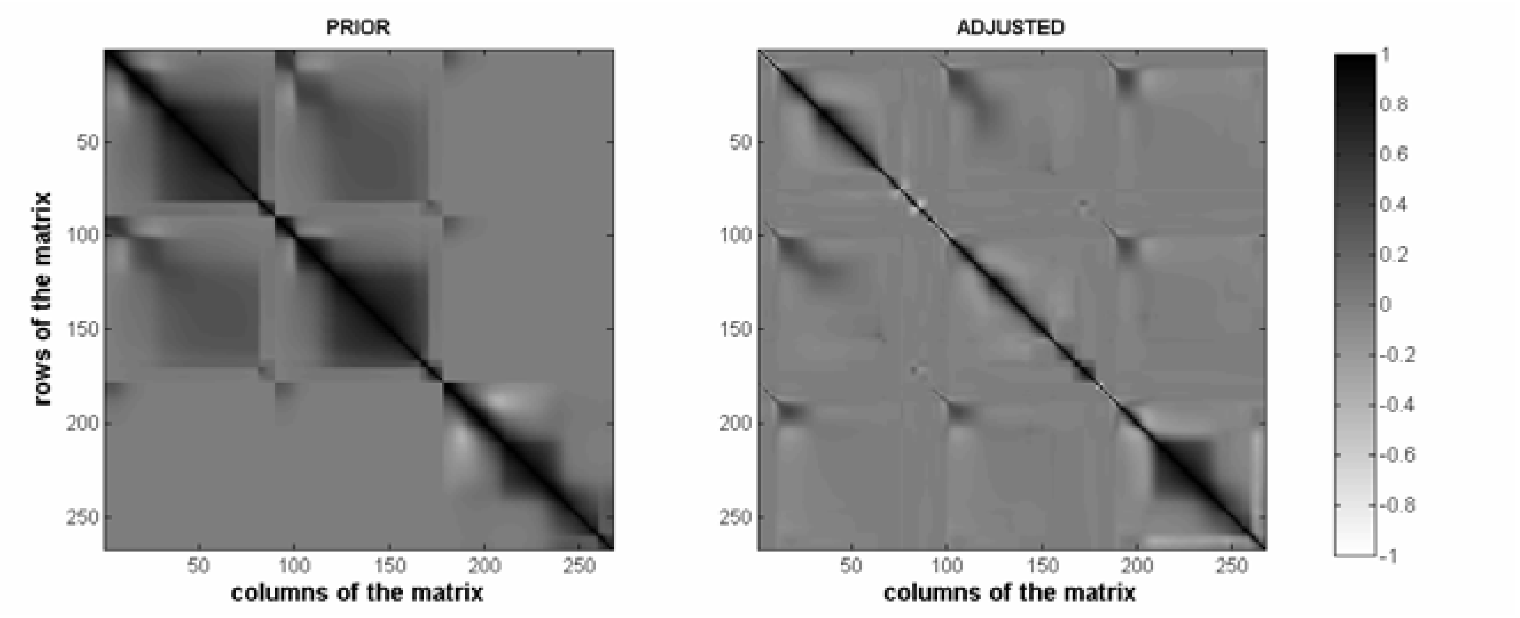
ACRR PbB Bucket



Simultaneous Spectrum Adjustment: Neutron Spectrum

Simultaneous spectrum adjustment:

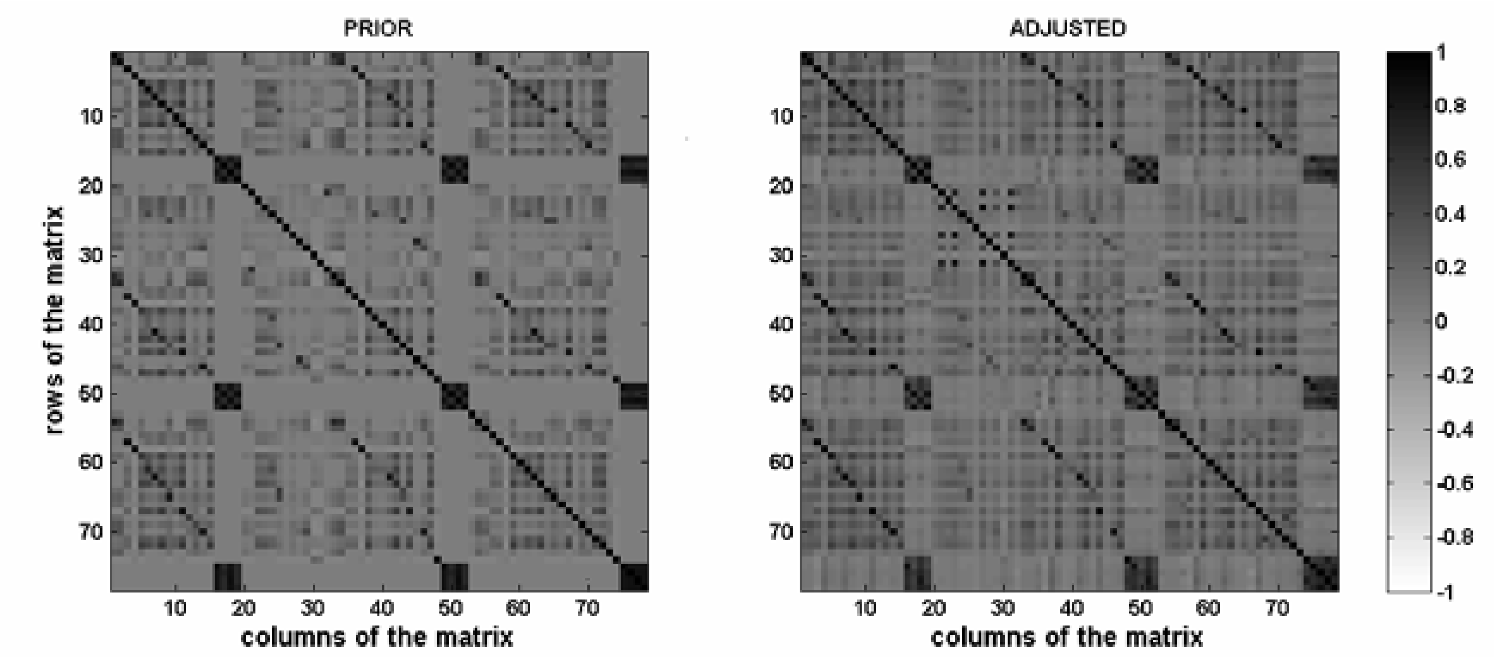
- **fast burst reactor cavity**
- **pool-type reactor cavity**
- **pool-type reactor in PbB bucket**



Simultaneous Spectrum Adjustment: Activities

Simultaneous spectrum adjustment:

- **fast burst reactor cavity**
- **pool-type reactor cavity**
- **pool-type reactor in PbB bucket**



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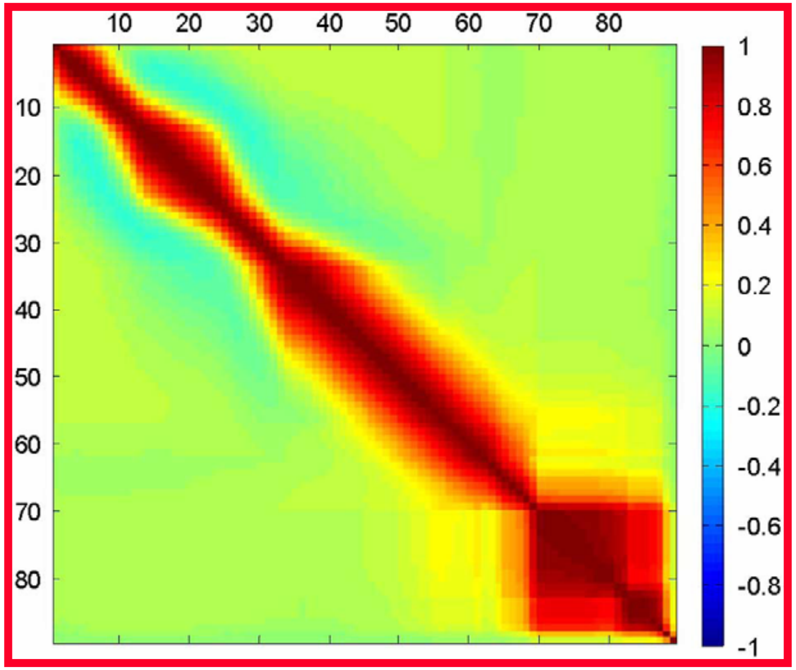
Covariance in *a priori* Spectrum

Example of constructed *a priori* spectrum covariance matrices

Fast Burst Reactor



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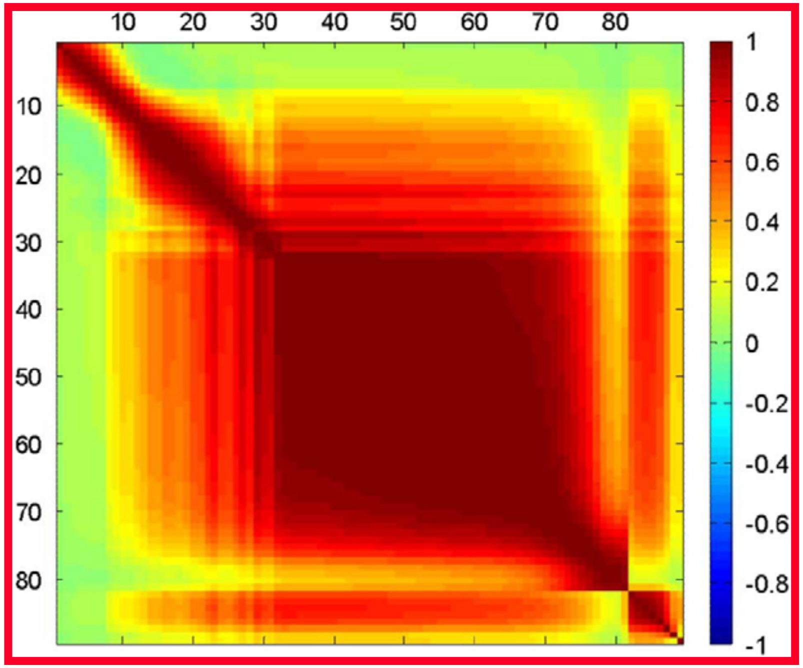

Dosimetry Priorities

- **High quality cross sections with covariance for reactions used**
- **Fission spectrum covariance to assist *a priori* spectrum covariance**
- **Cd covariance matrices**
- **Recoil spectrum covariance matrices for Si, Ga, As, Fe**
- **High energy dosimetry reaction covariance matrices**

Questions???

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Example Double Ratios of Activation Foils