Covariance Activities at KAERI

Young-Sik Cho

Korea Atomic Energy Research Institute

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KERCEN Updated

- Originally developed by BNL+KAERI to generate covariances at the resonance region using kernel approximation to address some issues:
  - File 32 processing issues such as
    - decline of uncertainties after collapsing covariances into multigroup representations.
    - discrepancies between NJOY and PUFF in processing File 32.
  - Proper handling of scattering radius uncertainty.

- Recently updated to accommodate the MLBW formalism in addition to kernel approximation.
- One of its purposes is to validate kernel approximation, with more accurate formalism but based on the similar methodology.

- Uses a transparent formalism (using kernel approximation or new MLBW) based on resonance parameter uncertainties from the *Atlas of Neutron Resonances*.
- Handles scattering radius uncertainty explicitly.
- Produces MF33 bypassing MF32 processing issues.
- Correlations have to be supplied by an evaluator.

Error Propagation Equation

- Uncertainty of average cross section

$$< \delta\bar{\sigma}\delta\bar{\sigma} >= \sum_{i,r,i',r'} \frac{\partial\bar{\sigma}}{\partial p_{i,r}} < \delta p_{i,r}\delta p_{i',r'} > \frac{\partial\bar{\sigma}}{\partial p_{i',r'}},$$

where $< \delta p_{i,r}\delta p_{i',r'} >$ is covariance of resonance parameters.

- Sensitivity

$$\frac{\partial\bar{\sigma}}{\partial p_{i,r}} = \sum_{r'} \frac{\partial\bar{\sigma}_{r'}}{\partial p_{i,r}} = \frac{\partial\bar{\sigma}_{r}}{\partial p_{i,r}} \qquad \text{where } i = \gamma, n \qquad \text{(kernel)}$$

- In KERCEN, entire resonance energy region is divided into smaller regions called bin. Resonance-potential scattering, scattering-scattering, capture-capture and scattering-capture and bin-bin correlations are supplied as input.

Multilevel Breit-Wigner (1)

- Average cross section (in the arbitrary energy bin)
  - for capture

$$\sigma_\gamma(E) = \sum_l \sum_r \sigma_{mr} \frac{\Gamma_{\gamma r}}{\Gamma_r} \varphi(\theta, x) \ , \ \sigma_{mr} = \frac{4\pi}{k^2} g_J \frac{\Gamma_{nr}}{\Gamma_r} \quad \Rightarrow \quad \boxed{\bar{\sigma}_\gamma = \frac{1}{\Delta E} \int_{E_1}^{E_2} \sigma_\gamma(E) dE}$$

  - for scattering

$$\sigma_n(E) = \frac{\pi}{k^2} \sum_l \left[\sum_J g_J \left\{ \left(1 - 2\cos 2\phi_l - \sum_r \frac{\Gamma_{nr}}{\Gamma_r} \frac{2}{1+x_r^2} \right)^2 + \left(\sin 2\phi_l + \sum \frac{\Gamma_{nr}}{\Gamma_r} \frac{2x_r}{1+x_r^2} \right)^2 \right\} + 2D_l \left(1 - \cos 2\phi_l \right) \right]$$

$$\Rightarrow \quad \boxed{\bar{\sigma}_n = \frac{1}{\Delta E} \int_{E_1}^{E_2} \sigma_n(E) dE}$$

Multilevel Breit-Wigner (2)

- Sensitivity to a resonance parameter
  - for capture

$$\frac{\partial \bar{\sigma}_\gamma}{\partial \Gamma_n} = \frac{1}{\Delta E}\int_{E_1}^{E_2} \frac{\partial \sigma_\gamma(E)}{\partial \Gamma_n} dE, \qquad \frac{\partial \bar{\sigma}_\gamma}{\partial \Gamma_\gamma} = \frac{1}{\Delta E}\int_{E_1}^{E_2} \frac{\partial \sigma_\gamma(E)}{\partial \Gamma_\gamma} dE,$$

  - for scattering

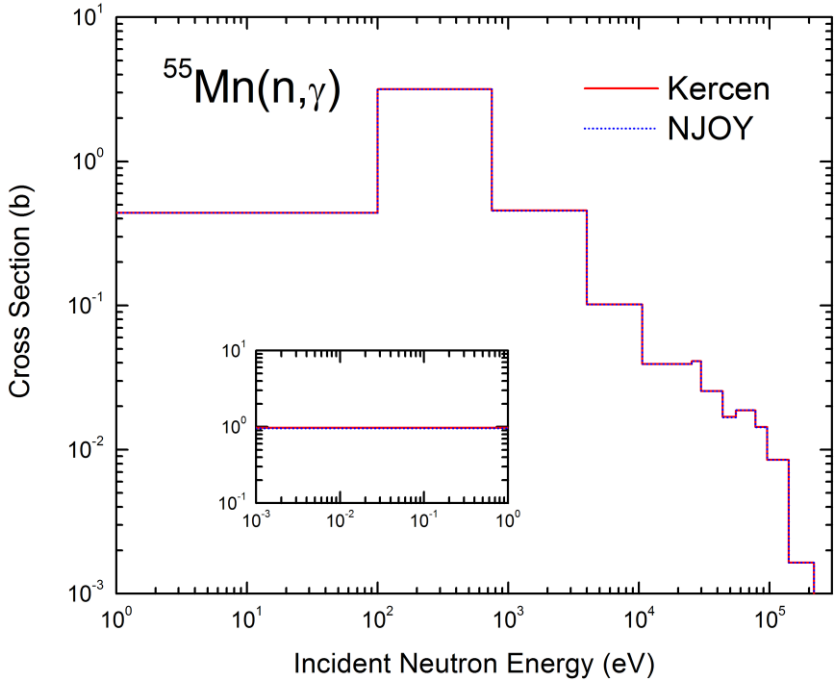
$$\frac{\partial \bar{\sigma}_n}{\partial \Gamma_n} = \frac{1}{\Delta E}\int_{E_1}^{E_2} \frac{\partial \sigma_n(E)}{\partial \Gamma_n} dE, \qquad \frac{\partial \bar{\sigma}_n}{\partial \Gamma_\gamma} = \frac{1}{\Delta E}\int_{E_1}^{E_2} \frac{\partial \sigma_n(E)}{\partial \Gamma_\gamma} dE,$$

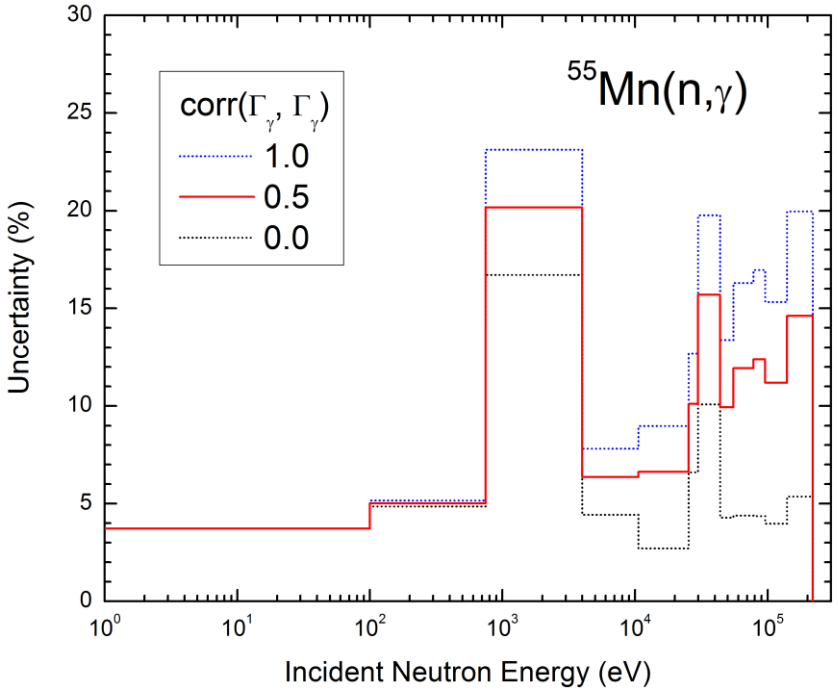
analytically obtained

$\frac{\partial \bar{\sigma}_n}{\partial R'}$? by observing variation of average scattering cross section due to deviation of R'

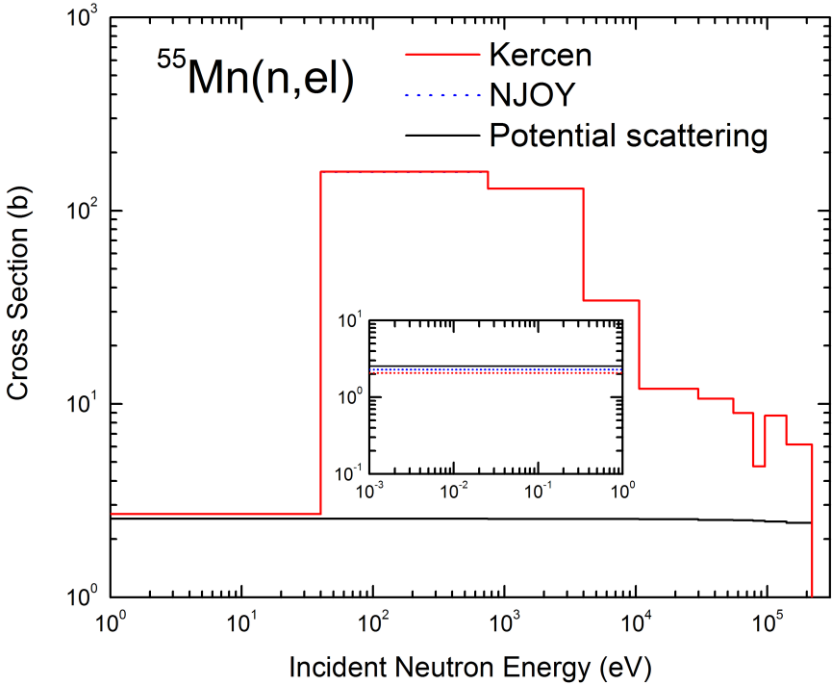
$$\frac{\partial \bar{\sigma}_n}{\partial R'} \delta R' \approx \delta \bar{\sigma}_n \left(R' \rightarrow R' + \delta R'\right)$$

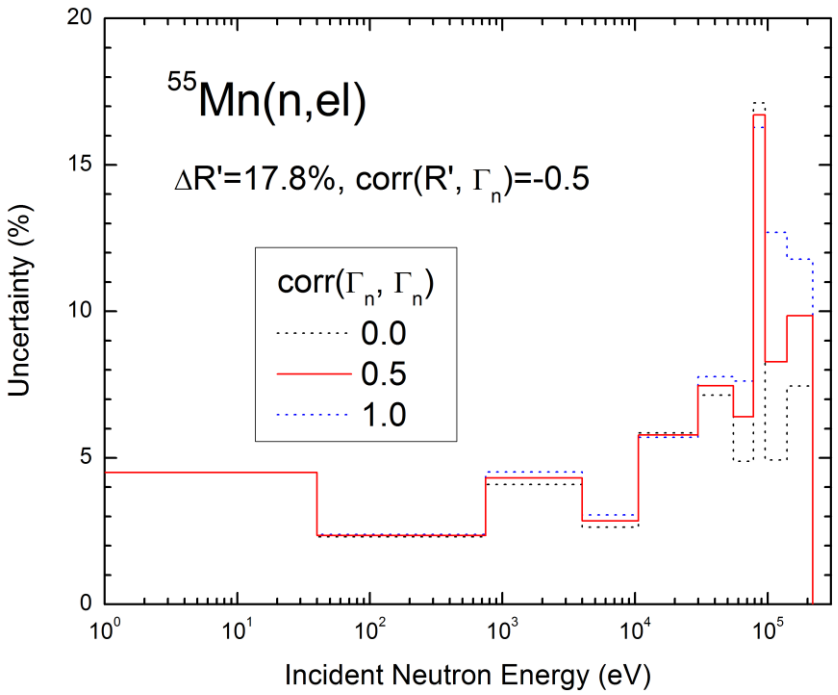
^{55}Mn, capture



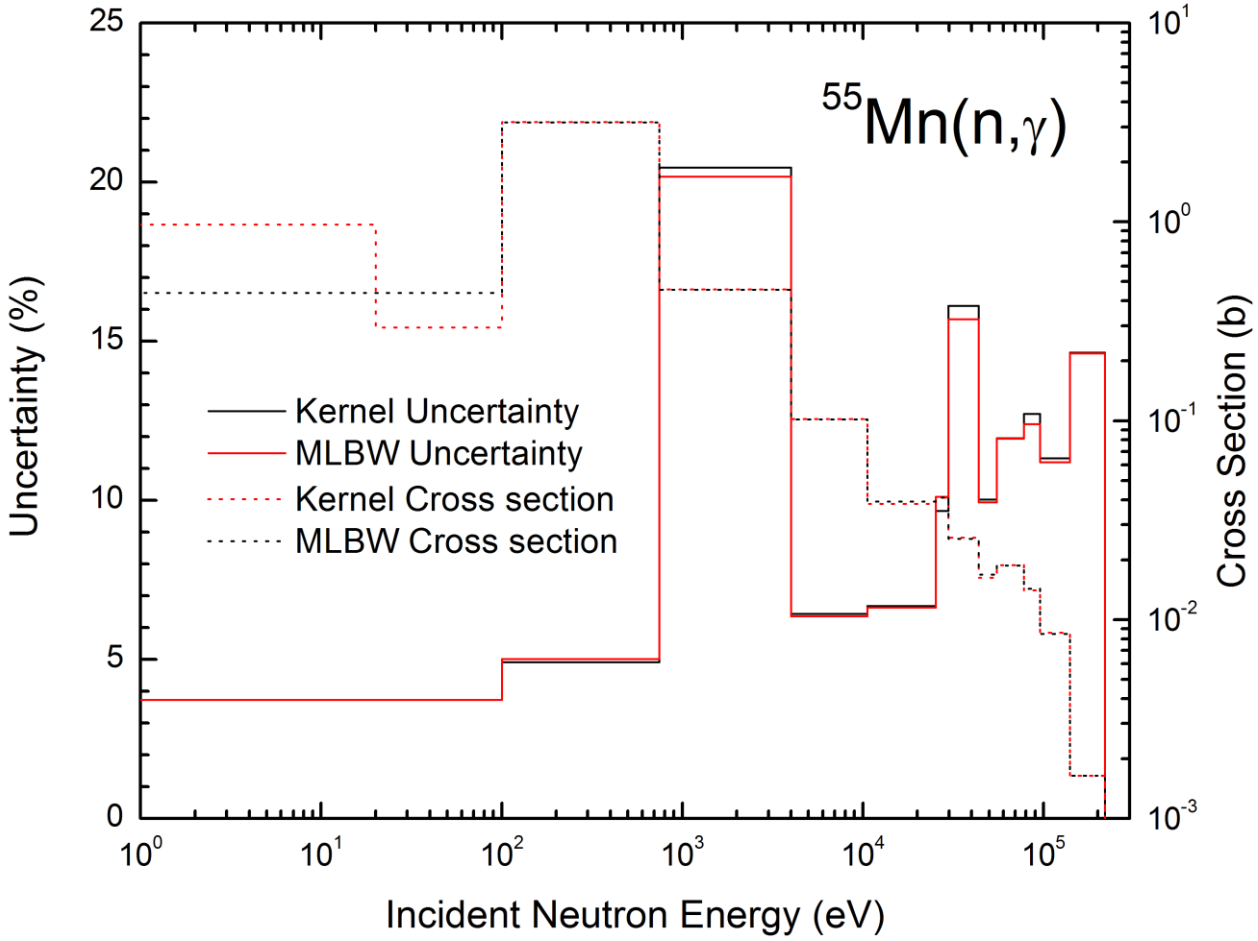


^{55}Mn, scattering

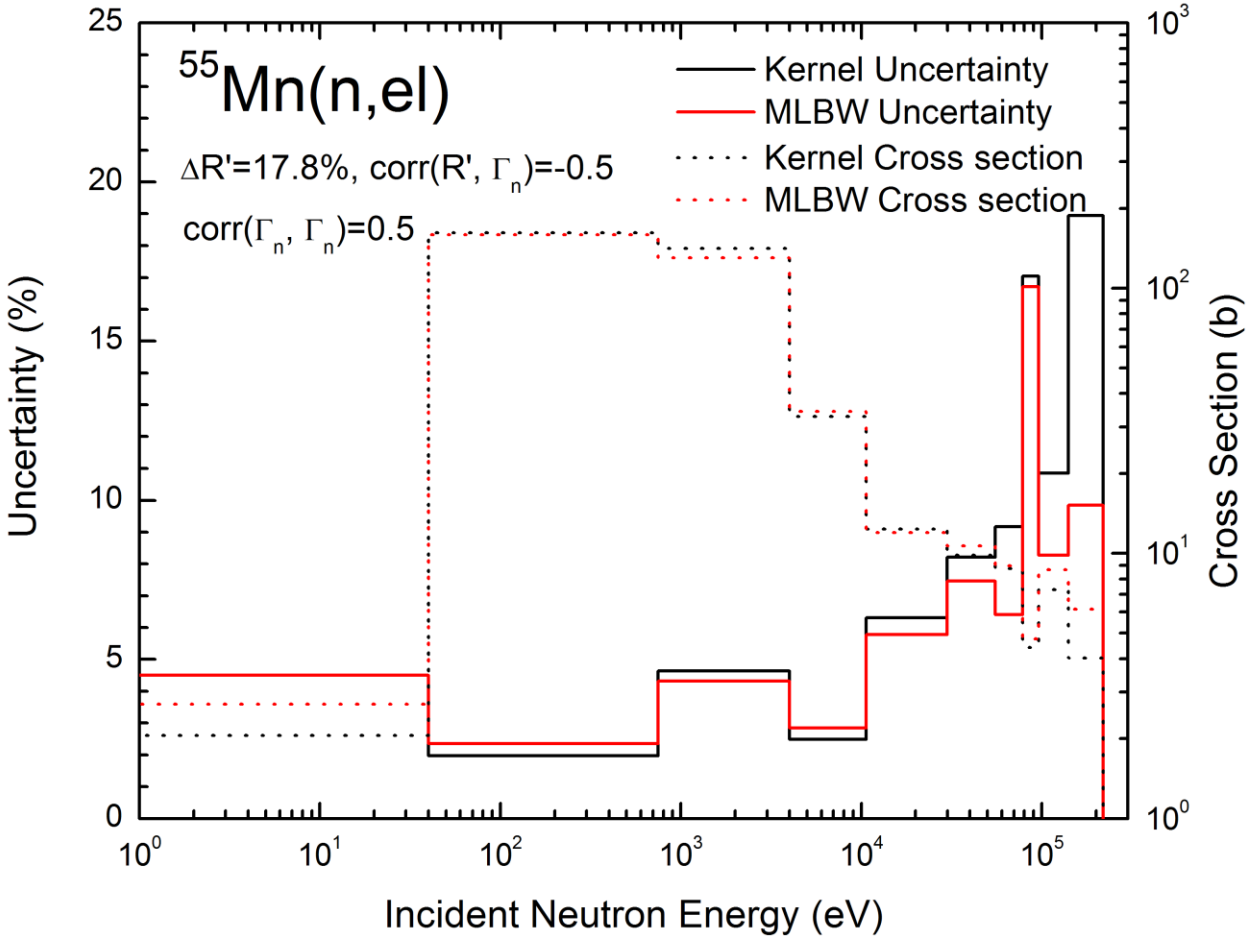




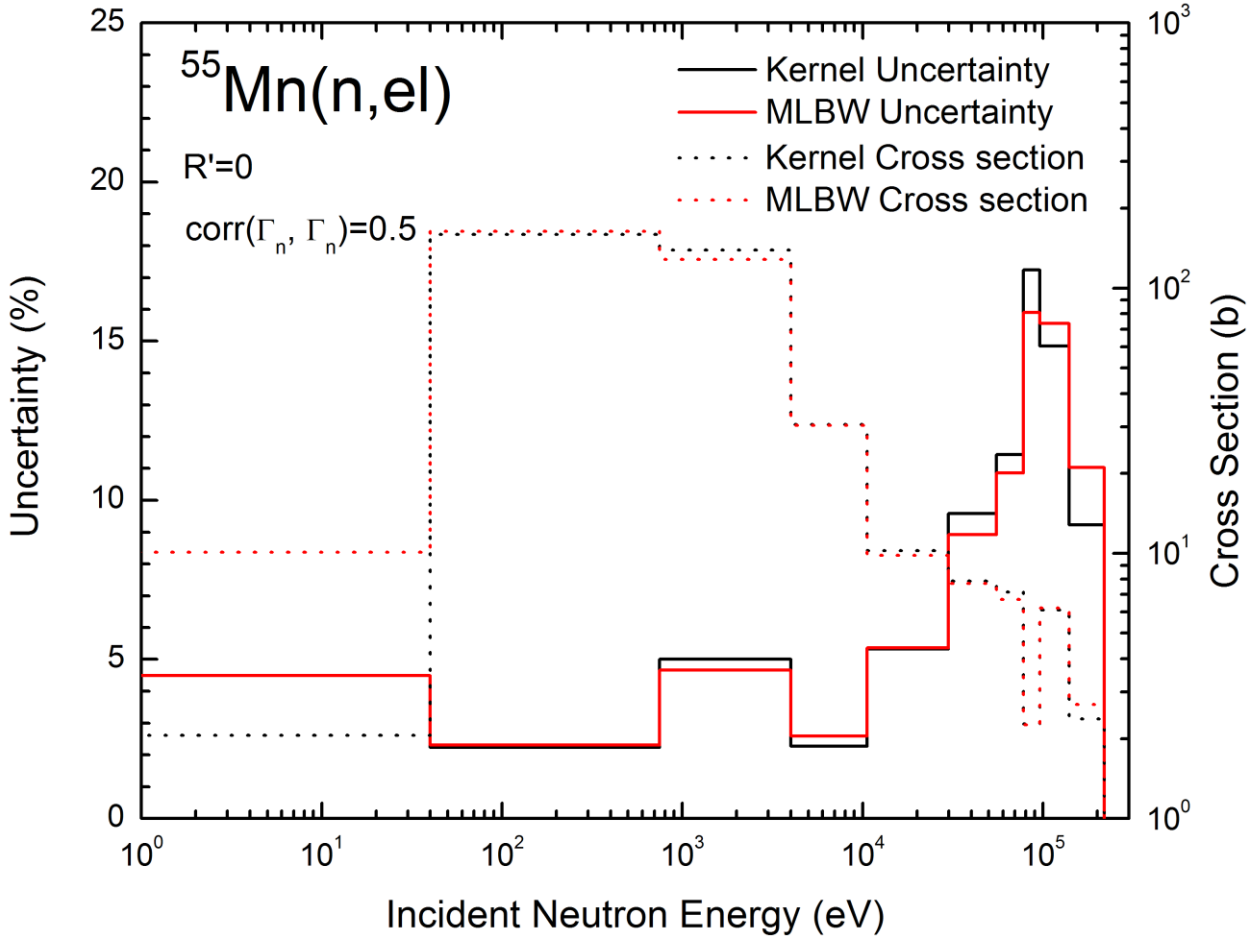
^{55}Mn, capture (Kernel vs. MLBW)



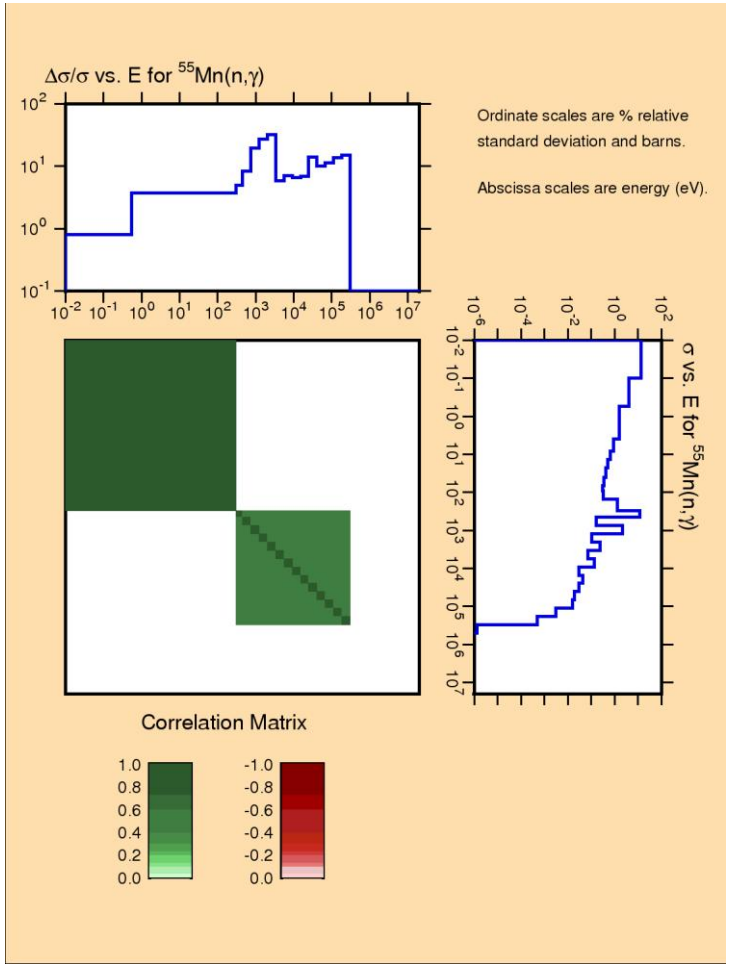
^{55}Mn, scattering (Kernel vs. MLBW)

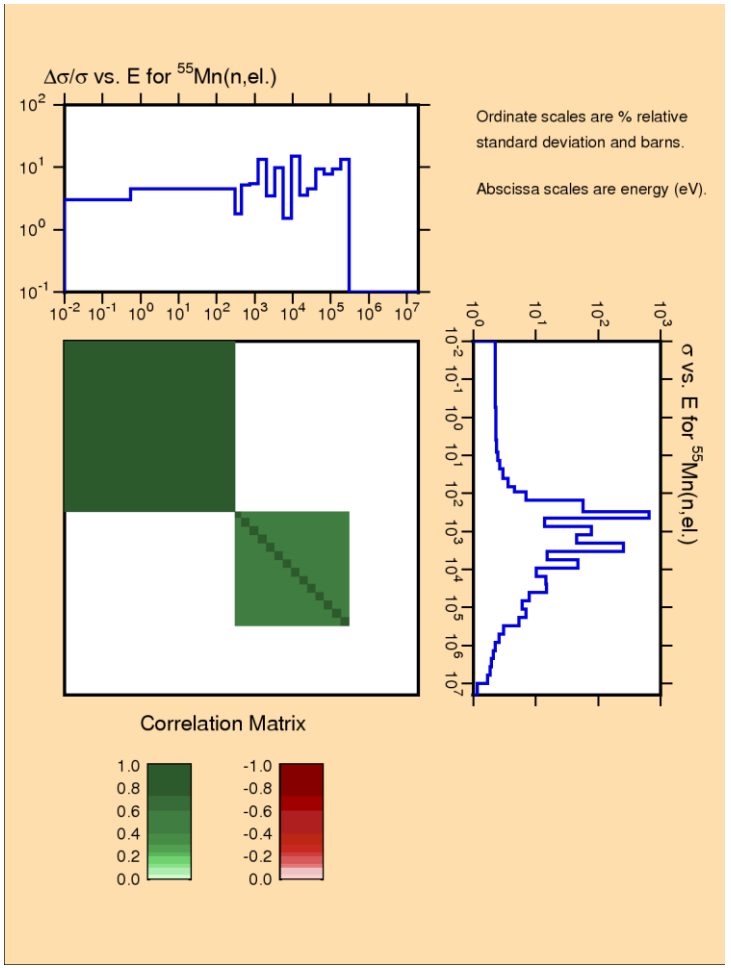


^{55}Mn, scattering (Kernel vs. MLBW)



Covariances for ^{55}Mn





Covariance Evaluations (H.I. Kim)

- EMPIRE-KALMAN used
- Covariances above resonances
  - Sensitivity matrices from 5 ~ 10 % variations of model parameters around optimal value
  - Using uncertainties of measurements if available
  - Using pseudo data with 10% uncertainty for the cross section of model calculation if no measurement is available
- Covariance files in ENDF-6
  - MF33 generated
    - MT=1,2,4,16,17,18,22,24,(51-91),102,103,107
  - MF32 from ORNL for (^{237}Np, ^{240}Pu, ^{244}Cm)
  - Getting from JENDL-4 (nu-bar, fission neutron spectra, MF 31)

Experimental Data

^{237}Np		^{240}Pu	
total	Kornilov, Lychagin, Auchampaugh	total	Poenitz, Smith
elastic	Hoffman (?)	elastic	Smith
capture	Esch, Buleeva, Trofimov, Weston, Lindner, Stupegia, Hoffman	capture	Ivanov, Weston
fission	Basunia,Lisowski, Paradela, Cennini, Scherbakov, Meadows, Kobayashi, Jiacoletti, Brown, White,…	fission	Tovesson, Laptev, Gul, Aleksandrov, Cance, Meadows, Khan, Kari, Fomushkin, White, Ruddick, Nesterov, Henkel, …
(n,2n)	Gromova, Nishi, Landrum, Paulson		
(n,p)	Coleman		

✓ Problems

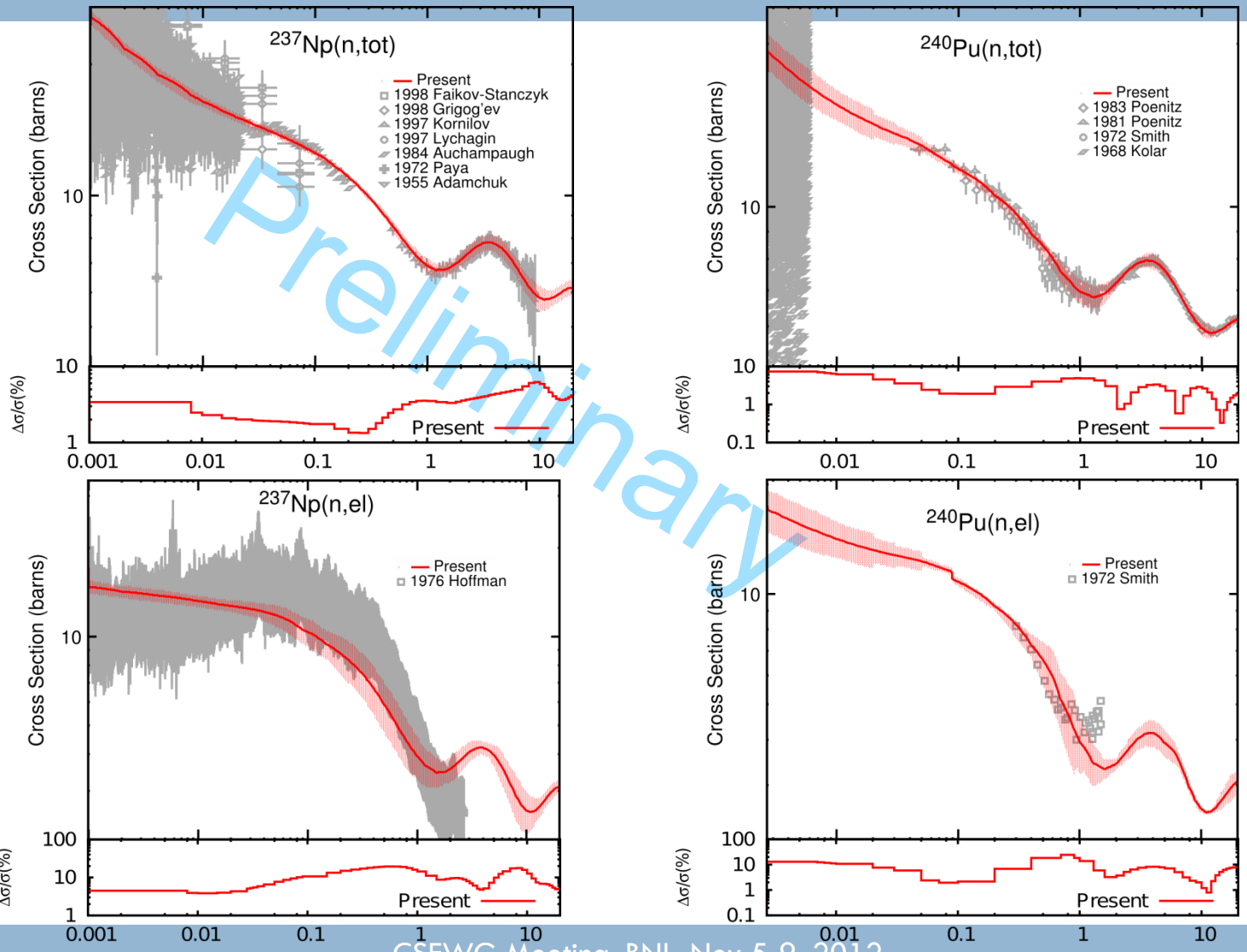
Too small uncertainties by too many measured data

- ❖ Increasing uncertainties using scaling factor based on systematic errors if available or eye-guide

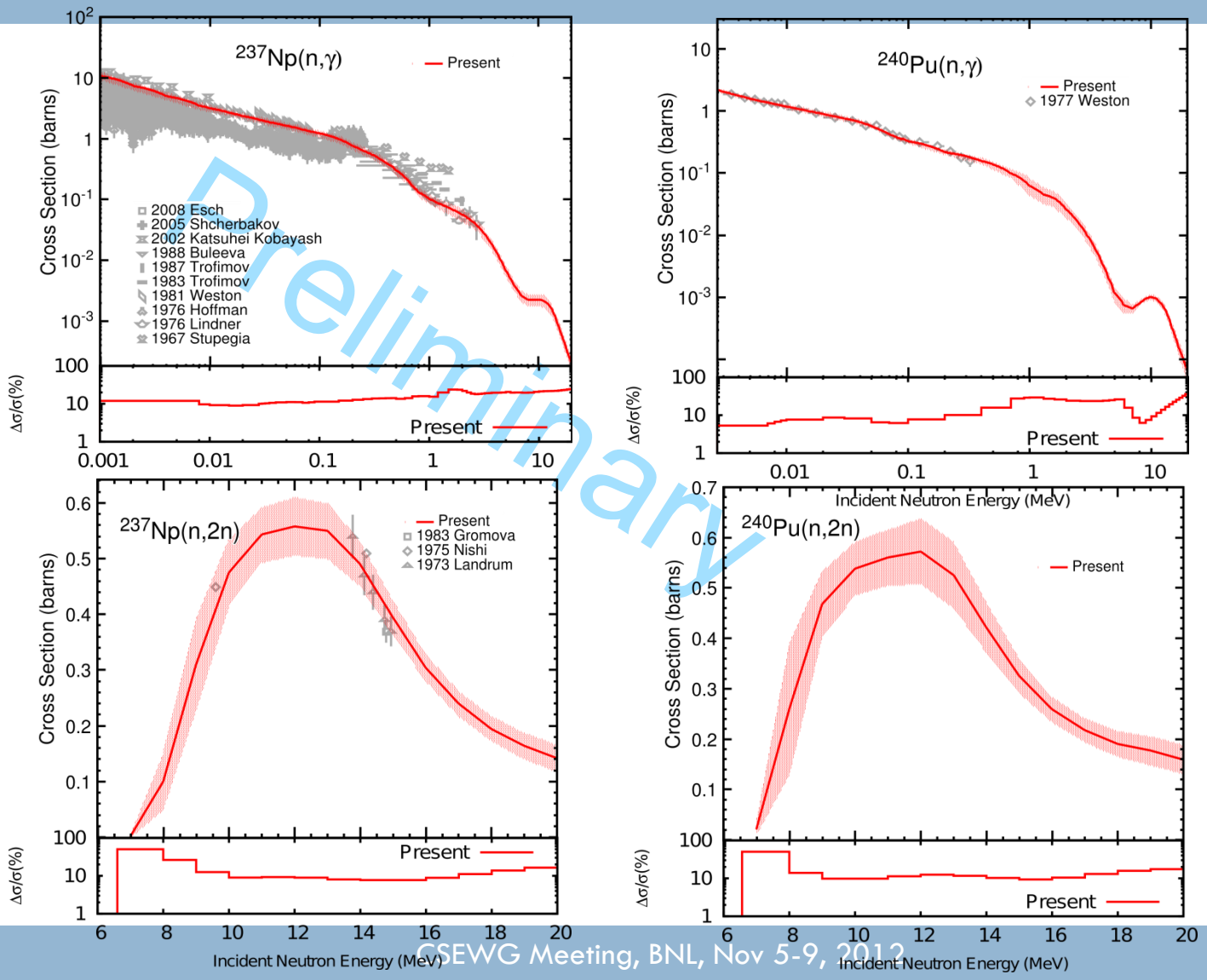
No measured data

- ❖ Introducing pseudo -data

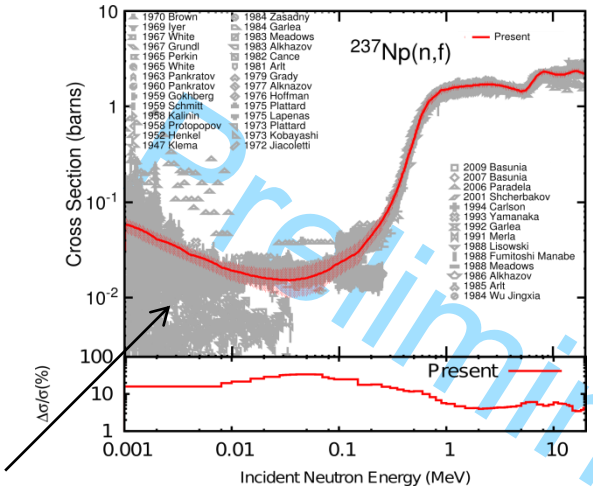
Results - total & Elastic

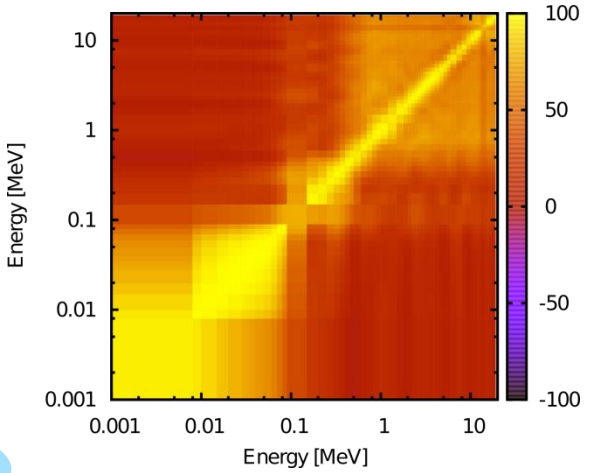


Results - Capture & (n,2n)

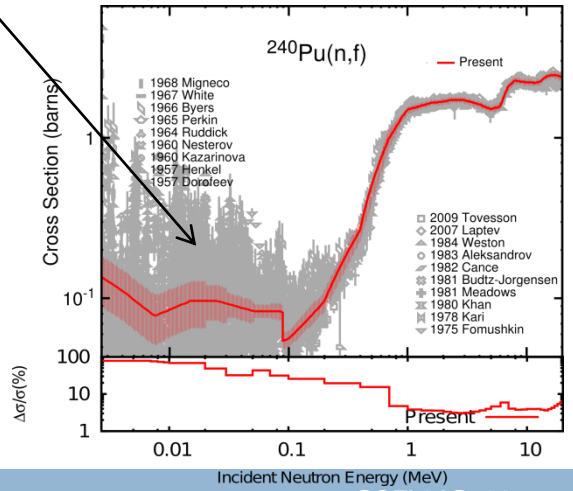


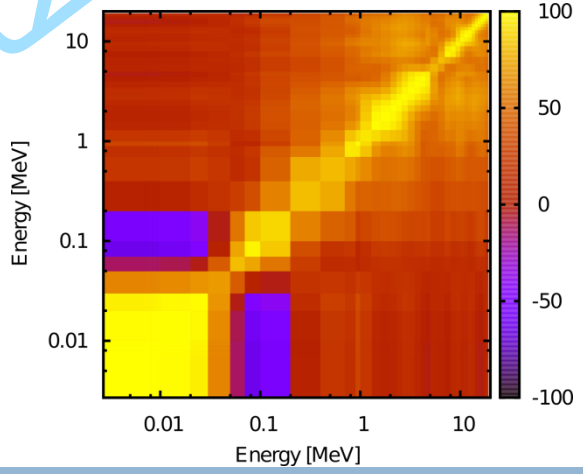
Results - Fission





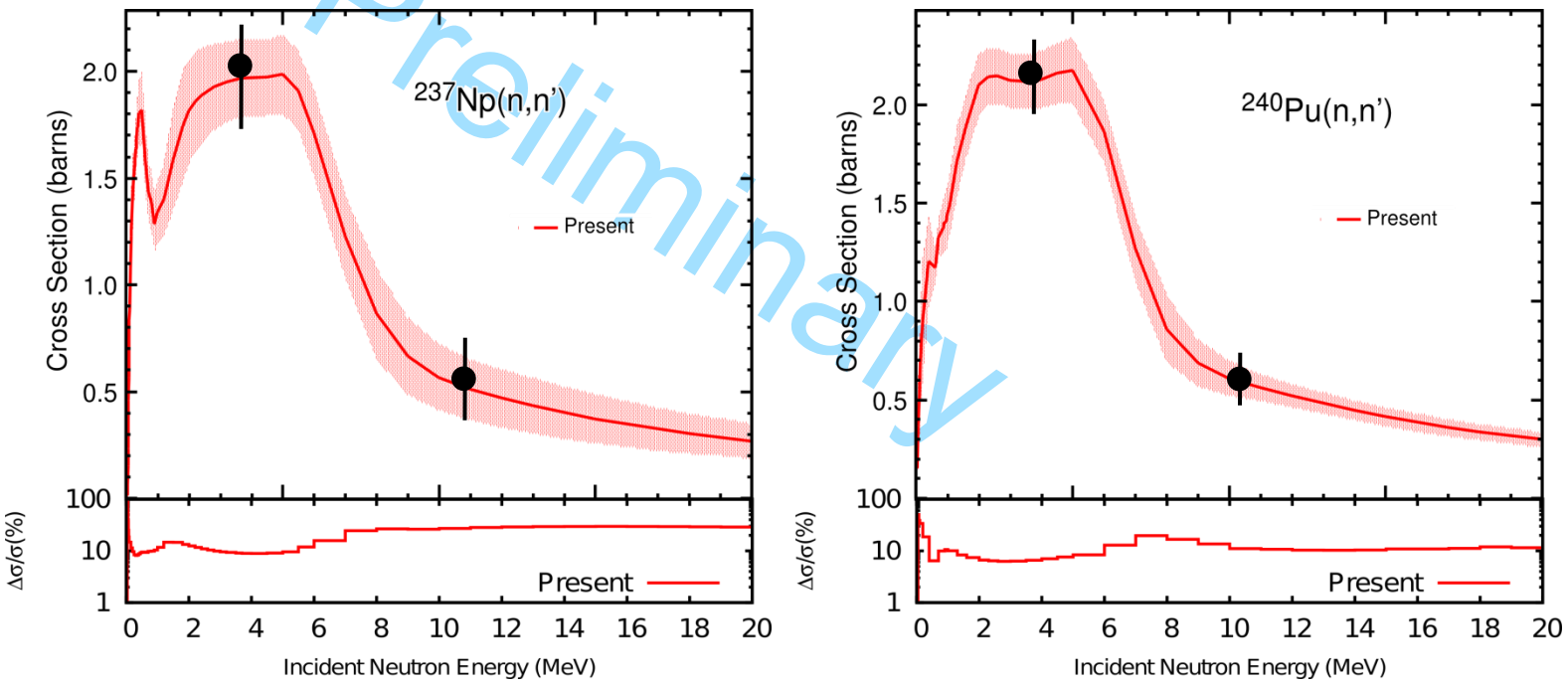
Not considered





Results - Inelastic

No measurement



Conclusions

- **Resonance region:**

- KERCEN has been updated to accommodate the MLBW formalism. It
  - uses transparent formalism,
  - bypasses File 32 processing issues,
  - handles scattering radius uncertainty explicitly,
  - takes inference effects into account.
- KERCEN has been tested for evaluating cross section uncertainties for the structural material, ^{55}Mn.

- **High energy region:**

- Neutron cross section files of ^{237}Np and ^{240}Pu at high energy region have been produced.
- Covariance matrices for ^{237}Np and ^{240}Pu were generated by the EMPIRE-KALMAN approach considering sensitivity matrices of model calculations and uncertainties of experimental data