Estimates of ^{55}Mn and ^{90}Zr neutron cross-section covariances

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November 5, 2008

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Introduction

- ✓ Neutron cross-section covariance estimates of ^{55}Mn and ^{90}Zr
- ✓ The method to estimate covariances at BNL $\rightrightarrows$
  - Resonance region : Covariance module & ATLAS (BNL)
  - Fast neutron region : Bayesian code KALMAN (LANL)
- ✓ Essential point in our methodology is
  - resonance parameters from ATLAS and, eventually, their correlations.
  - the estimate of model parameter uncertainties, second, the selection of reliable experimental data and related (statistical and systematical) uncertainties.

Goal: cross sections and covariances

- **Materials**
  - ^{55}Mn and ^{90}Zr
- **Cross sections**
  - Estimated cross sections, $\sigma(E)$, should coincide with evaluated cross sections in the ENDF/B-VII.0 library: $\sigma(E;\mathbf{x}) \simeq \sigma_{\text{B-VII.0}}(E)$
- **Reaction-types and covariances**

Total	- MT=1
(n,n')	- MT=4
$(n,2n)$	- MT=16
(n,γ)	- MT=102

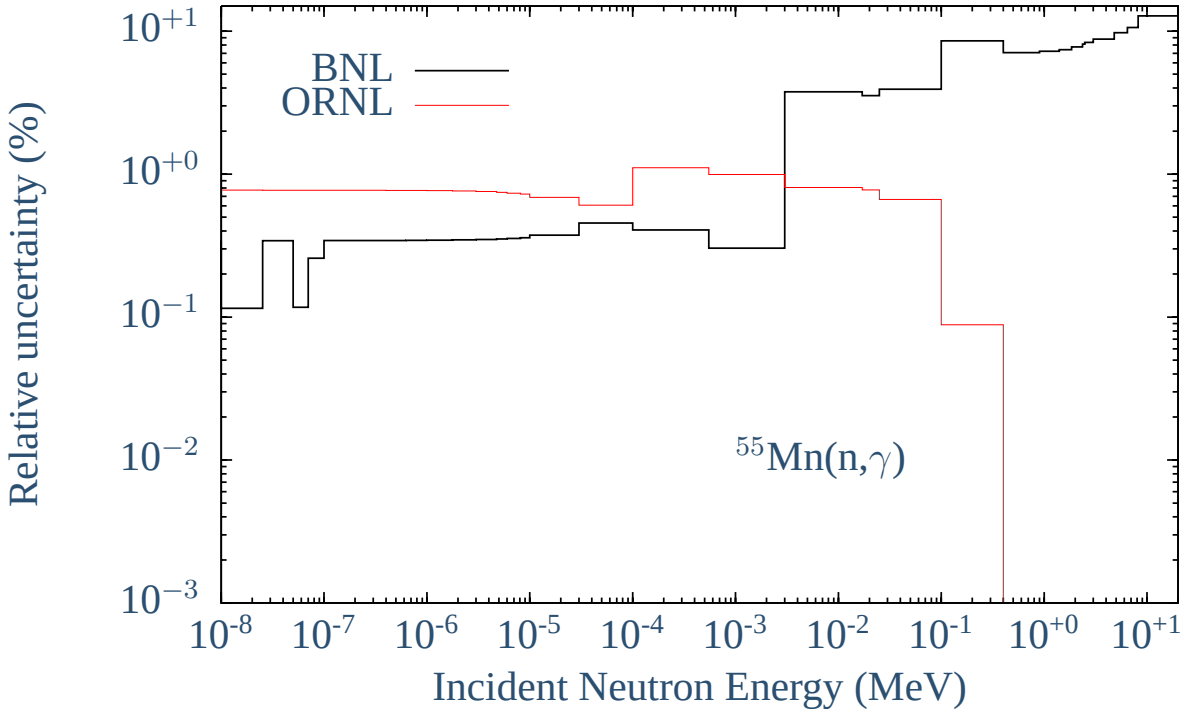
$$\mathcal{D}[\mathbf{x}] \equiv \langle \Delta x_\ell \Delta x_m \rangle$$

$$\mathcal{D}[\boldsymbol{\sigma}] \equiv \langle \Delta\sigma_i \Delta\sigma_j \rangle$$

Off-diagonal covariance

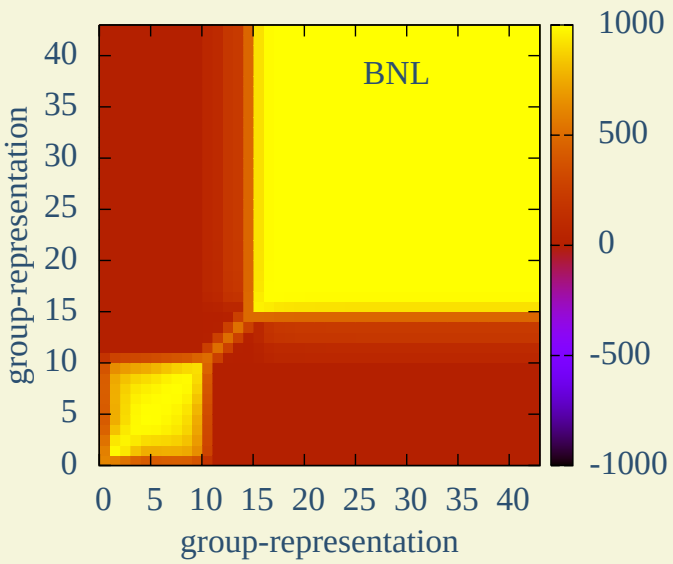
$$\mathcal{C}[\boldsymbol{\sigma}^{(\mu)}, \boldsymbol{\sigma}^{(\nu)}] \equiv \langle \Delta\sigma_i^{(\mu)} \Delta\sigma_j^{(\nu)} \rangle$$

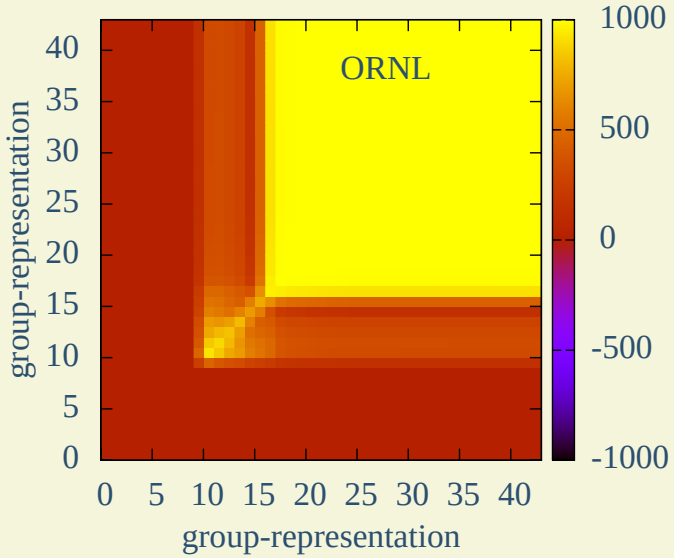
Resonance region: file 32



Relative uncertainties (44-group representation):
BNL→ resonance parameters and related uncertainties (ATLAS)
ORNL taken from ENDF/A

Resonance region: file 32





^{55}Mn(n,γ) correlation matrix comparison (44-group representation)

Model parameters: fast neutron region

Table 1: Uncertainties (in %): r - radius, a - diffuseness, V - real depth, W - imaginary depth. The subscripts v, s, and w, respectively, denote real volume, real surface, and imaginary surface.

Δr_s^{tg}	Δr_v^{tg}	Δr_w^{tg}	ΔV_v^{tg}	ΔW_s^{tg}
3-5	5	5	5	3-5
ΔW_v^{tg}	Δa_s^{tg}	Δa_v^{tg}	ΔV_v^{np}	ΔW_s^{np}
5	5	5	5	5

Table 2: Uncertainties (in %): $\tilde{a}$ - total level density, $\tilde{g}$ - single-particle level density, f_γ - γ-strength functions, and mfp - nucleon mean-free path; Def - deformation in DWBA.

$\Delta\tilde{a}^{cn}$	$\Delta\tilde{a}^{tg}$	$\Delta\tilde{a}^{n2n}$	$\Delta\tilde{a}^{np}$	$\Delta\tilde{g}^{np}$	$\Delta\tilde{g}^{tg}$	Δf_γ	Δmfp	ΔDef
15	15	15	15	15	15	10-15	25	35

Evaluation method: fast neutron region

$$\boldsymbol{\sigma}(\mathbf{x}) = (\sigma_1(\mathbf{x}),\ldots,\sigma_r(\mathbf{x}))^{\mathrm{T}} \quad \text{with} \quad \sigma_i(\mathbf{x}) \equiv \sigma(E_i;\mathbf{x})\,,$$

$$\dot{\boldsymbol{\sigma}}(\mathbf{x}) = \frac{\partial\boldsymbol{\sigma}(\mathbf{x})}{\partial\mathbf{x}'} \equiv \left[\left(\frac{\partial\sigma_i(\mathbf{x})}{\partial x_j}\right)\right] \quad \text{(sensitivity matrix)}\,,$$

$$\mathcal{D}[\boldsymbol{\sigma}]_{\mathbf{x}} = \dot{\boldsymbol{\sigma}}\,\mathcal{D}[\mathbf{x}]\,\dot{\boldsymbol{\sigma}}^{\mathrm{T}} = \mathcal{D}[\dot{\boldsymbol{\sigma}}\mathbf{x}] \quad \text{(prior covariance matrix)}\,.$$

$$\mathbf{y} = \mathbf{x} + \mathcal{D}[\mathbf{x}]\dot{\boldsymbol{\sigma}}^{\mathrm{T}}(\mathcal{D}[\boldsymbol{\sigma}] + \mathcal{D}[\boldsymbol{\eta}])^{-1}(\boldsymbol{\eta} - \boldsymbol{\sigma}(\mathbf{x}))\,,$$

$$\mathcal{D}[\mathbf{y}] = \mathcal{D}[\mathbf{x}] - \mathcal{D}[\mathbf{x}]\dot{\boldsymbol{\sigma}}^{\mathrm{T}}(\mathcal{D}[\boldsymbol{\sigma}] + \mathcal{D}[\boldsymbol{\eta}])^{-1}\dot{\boldsymbol{\sigma}}\,\mathcal{D}[\mathbf{x}]\,,$$

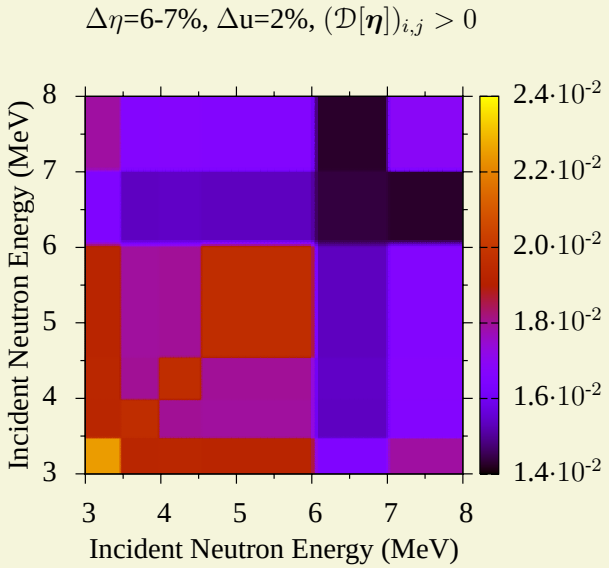
$$\mathcal{D}[\boldsymbol{\sigma}]_{\mathbf{y}} = \dot{\boldsymbol{\sigma}}\,\mathcal{D}[\mathbf{y}]\,\dot{\boldsymbol{\sigma}}^{\mathrm{T}} = \mathcal{D}[\dot{\boldsymbol{\sigma}}\mathbf{y}] \quad \text{(post covariance matrix)}\,.$$

Evaluation method: fast neutron region

$$\mathcal{D}[\boldsymbol{\eta}] = \mathbf{U} + \mathbf{W}\,,$$

where

$$(\mathcal{D}[\boldsymbol{\eta}])_{i,j} = \begin{cases} u_{i,j} + w_{i,j} & i = j \\ w_{i,j} & i \neq j \end{cases}$$



$$\mathbf{y} = \mathbf{x} + \mathcal{D}[\mathbf{x}]\dot{\boldsymbol{\sigma}}^{\mathrm{T}}(\mathcal{D}[\boldsymbol{\sigma}] + \mathcal{D}[\boldsymbol{\eta}])^{-1}(\boldsymbol{\eta} - \boldsymbol{\sigma}(\mathbf{x}))\,,$$

$$\mathcal{D}[\mathbf{y}] = \mathcal{D}[\mathbf{x}] - \mathcal{D}[\mathbf{x}]\dot{\boldsymbol{\sigma}}^{\mathrm{T}}(\mathcal{D}[\boldsymbol{\sigma}] + \mathcal{D}[\boldsymbol{\eta}])^{-1}\dot{\boldsymbol{\sigma}}\,\mathcal{D}[\mathbf{x}]\,,$$

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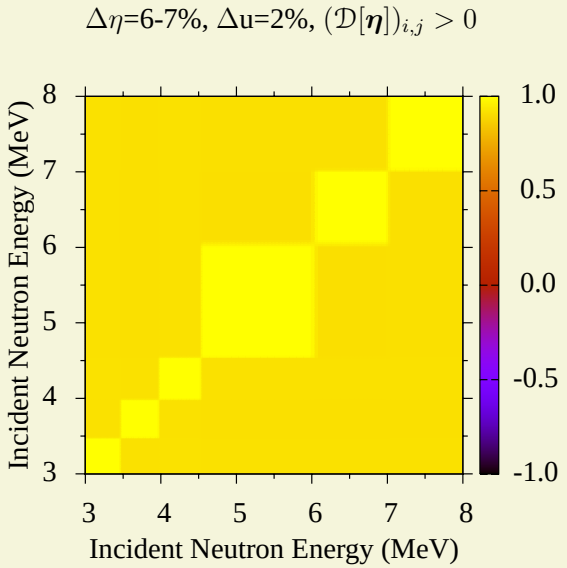
Evaluation method: fast neutron region

$$\mathcal{D}[\boldsymbol{\eta}] = \mathbf{U} + \mathbf{W}\,,$$

where

$$(\mathcal{D}[\boldsymbol{\eta}])_{i,j} = \begin{cases} u_{i,j} + w_{i,j} & i = j \\ w_{i,j} & i \neq j \end{cases}$$

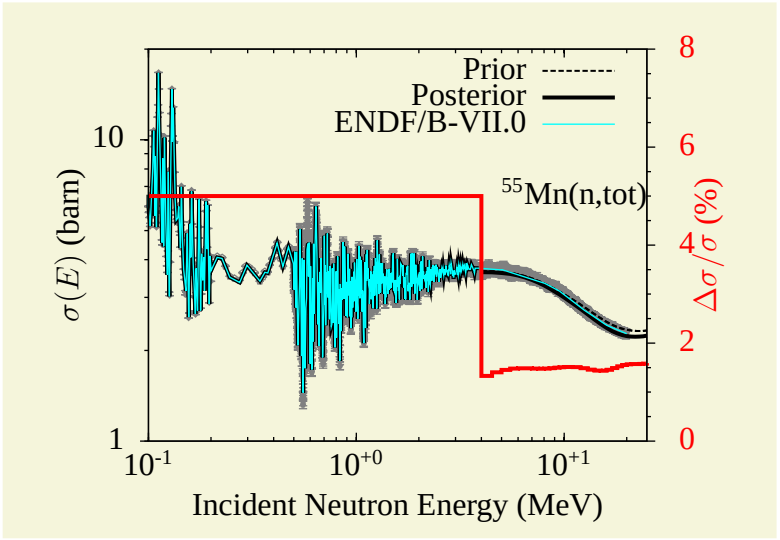


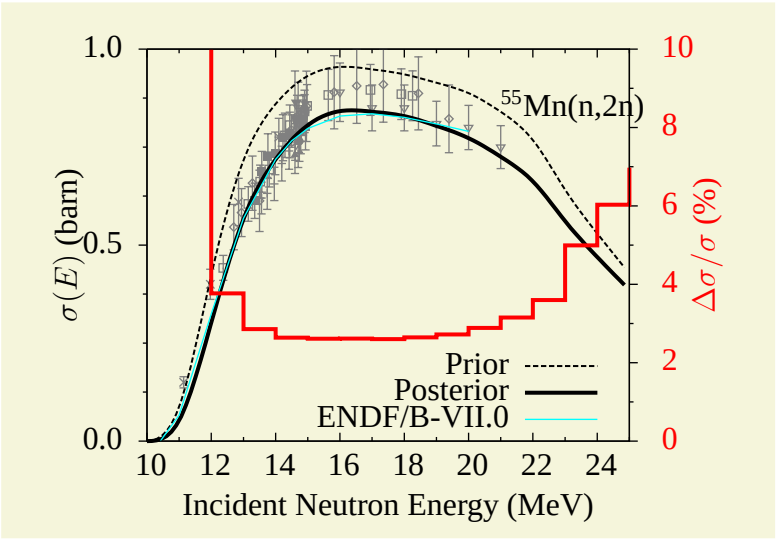
$$\mathbf{y} = \mathbf{x} + \mathcal{D}[\mathbf{x}]\dot{\boldsymbol{\sigma}}^{\mathrm{T}}(\mathcal{D}[\boldsymbol{\sigma}] + \mathcal{D}[\boldsymbol{\eta}])^{-1}(\boldsymbol{\eta} - \boldsymbol{\sigma}(\mathbf{x}))\,,$$

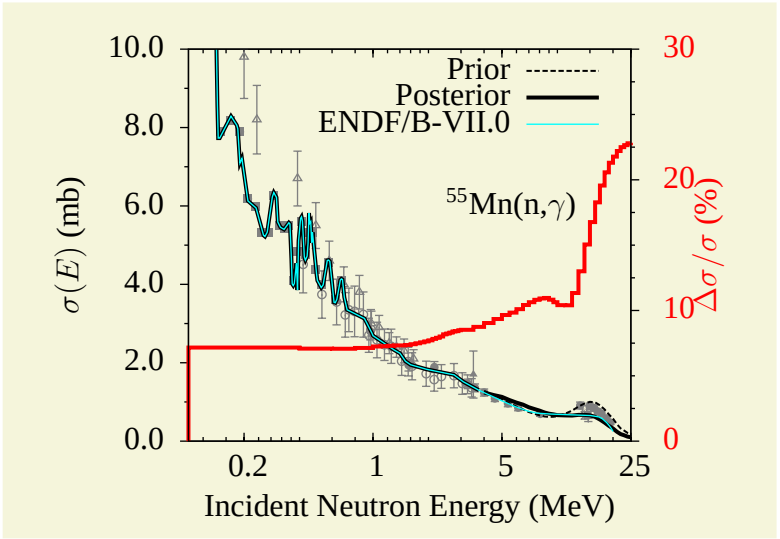
$$\mathcal{D}[\mathbf{y}] = \mathcal{D}[\mathbf{x}] - \mathcal{D}[\mathbf{x}]\dot{\boldsymbol{\sigma}}^{\mathrm{T}}(\mathcal{D}[\boldsymbol{\sigma}] + \mathcal{D}[\boldsymbol{\eta}])^{-1}\dot{\boldsymbol{\sigma}}\,\mathcal{D}[\mathbf{x}]\,,$$

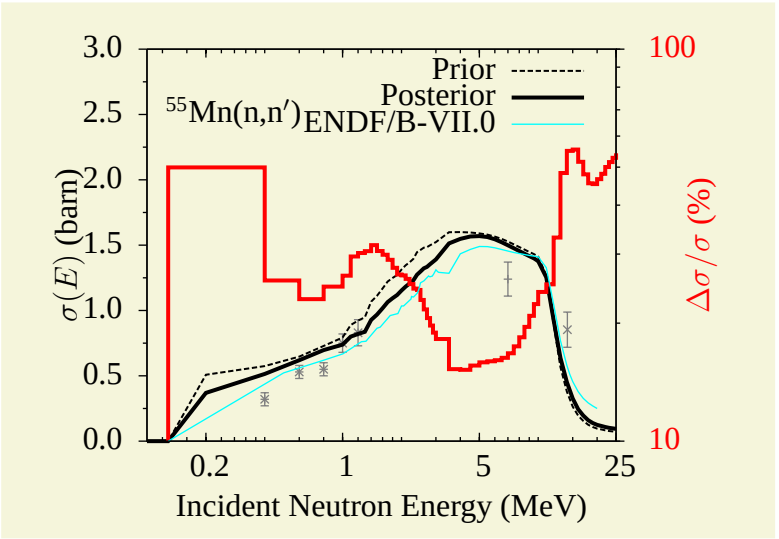
$$\mathcal{D}[\boldsymbol{\sigma}]_{\mathbf{y}} = \dot{\boldsymbol{\sigma}}\,\mathcal{D}[\mathbf{y}]\,\dot{\boldsymbol{\sigma}}^{\mathrm{T}} = \mathcal{D}[\dot{\boldsymbol{\sigma}}\mathbf{y}] \qquad \text{(post covariance matrix)}\,.$$

Results for ^{55}Mn (uncertainties)

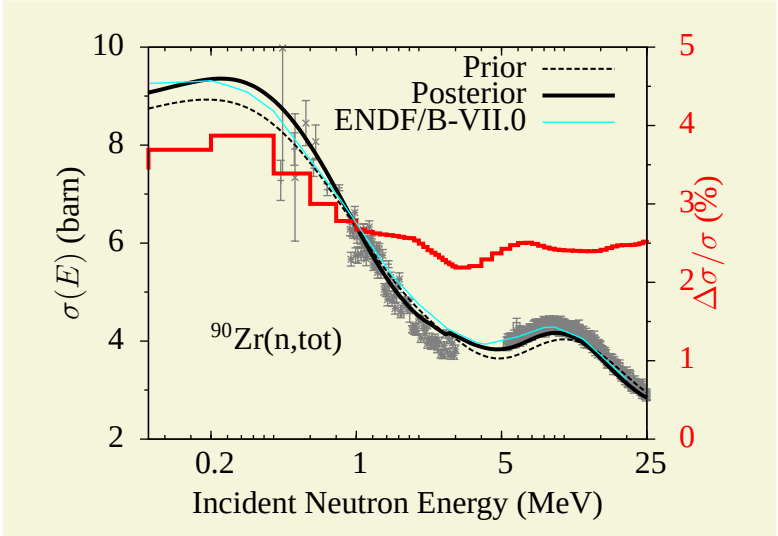


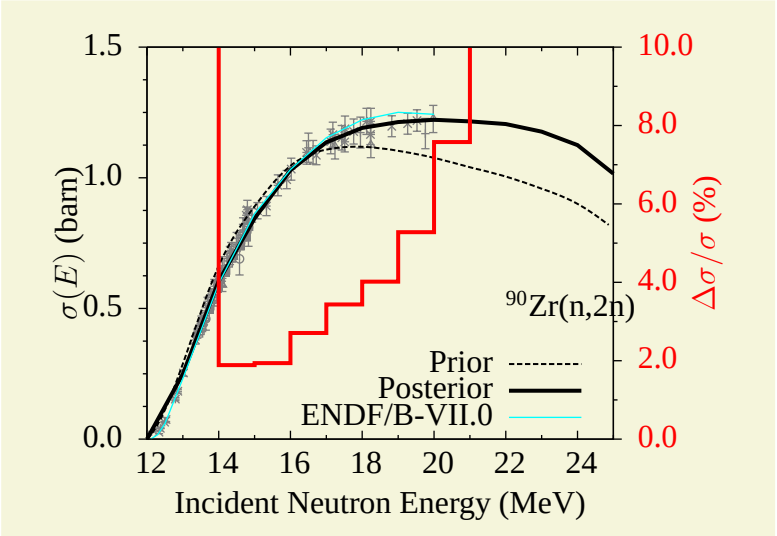


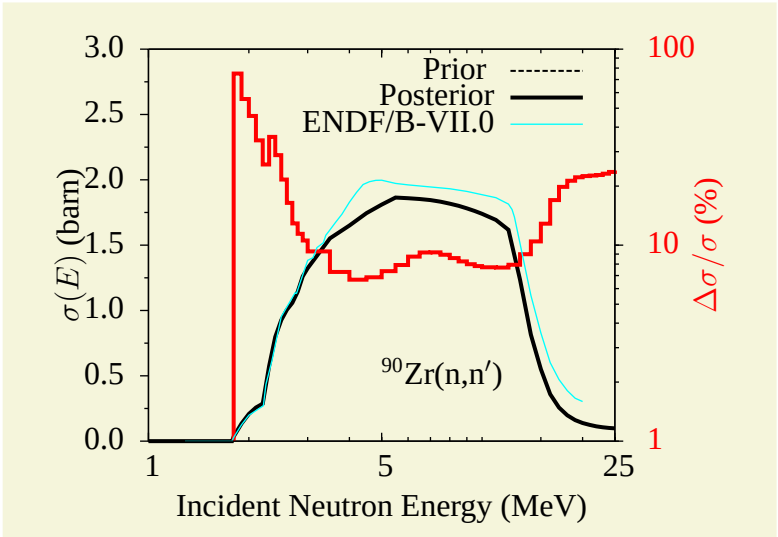


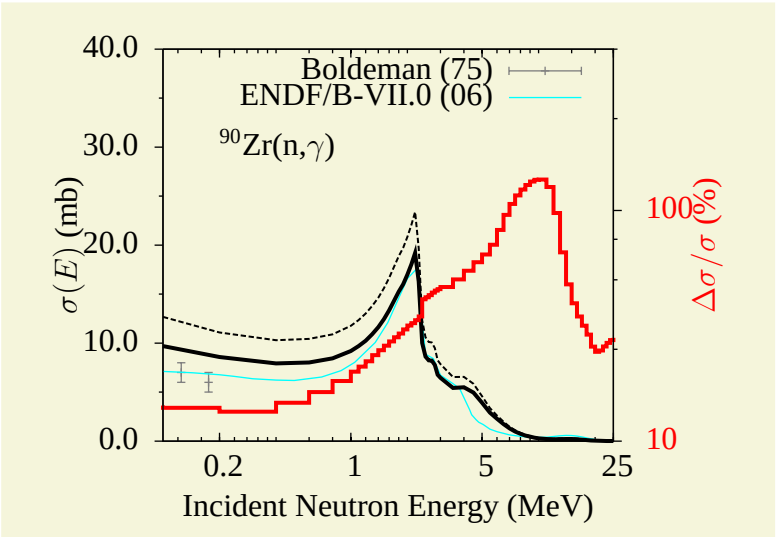


Results for ^{90}Zr (uncertainties)









Conclusions

- ✓ We produced estimates of covariances for ^{55}Mn and ^{90}Zr in resonance region and in fast neutron energy region coupled to the ENDF/B-VII.0 cross sections.
- ✓ Our results are based on the resonance module EMPIRE-ATLAS and the EMPIRE-KALMAN approach using statistical and systematic uncertainties taken from almost 30 selected experiments.

- ◔ Systematic analysis on the impact of correlation in resonance parameters.
- ◔ Improvements of prior cross sections and, consequently, of sensitivity matrices.
- ◔ Deeper analysis in the statistics and systematics of experimental data (in collaboration with Otto Schwerer).
- ◔ More accurate covariance analysis on other reaction-type such as (n,p) and (n,α).