Evaluation of ^{23}Na Cross Sections for Nuclear Data Assimilation

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5th November, 2009

Introduction

✓ Definition of Nuclear Data Assimilation (NDA)

$$G + \delta G \rightarrow \frac{\partial G}{\partial \sigma} \rightarrow \frac{\partial \sigma}{\partial a} \tag{1}$$

✓ Importance of NDA (correlation from a model): it is ideally possible to create validated files which are physically consistent.

✓ Goal is to generate ENDF file fully based on nuclear model parameters

– Not trivial because there are deficenties in nuclear models

– ENDF format important because independent from group energy structure

Assumptions

- ✓ EMPIRE can reasonably reproduce ENDF/B-VII.0 ^{23}Na cross sections on multigroup level with a proper set of nuclear physics parameters $\mathbf{p} = \{p_1, \ldots, p_k\}$, including both Resolve Resonance Region (RRR) and fast neutron region.
- ✓ Covariance matrix of parameters p_k can be estabilished, at least, as diagonal matrix containing Δp_k
- ✓ Calculate sensitvities in multigroup representation for the above set of parameters
- ✓ There is a clean integral experiment of reactor quantity R which can provide sufficient feedback to update evaluation

Data Assimilation: Procedures

- Calculate parameter sensitivities, $S_{Ik} = \partial\sigma_I/\partial p_k$, where σ_I is multi-group cross section in the I-th bin.

✓ Calculate integral sensitivities, $D_I = \partial R/\partial\sigma_I$, and then

$$\frac{\partial R}{\partial p_k} = \sum_I D_I\, S_{Ik}$$

✓ Constrained by integral quantity uncertainty

$$(\Delta R)^2 = \sum_{k\ell} \frac{\partial R}{\partial p_k} \langle \Delta p_k\, \Delta p_\ell \rangle \frac{\partial R}{\partial p_\ell}$$

Data Assimilation: Procedures

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✓ Parameter sensitivity matrices, $S_{Ik} = \partial\sigma_I/\partial p_k$, in group structure representation are obtained by

EMPIRE	$p_k \pm \Delta p_k$
EMPEND	$\sigma(p_k \pm \Delta p_k) \equiv \sigma^{\pm}$
NJOY	$\sigma_I^{\pm} = \sum_i \alpha_{Ii}\sigma_i^{\pm}$

$$S_{Ik} = \frac{\sigma_I^+ - \sigma_I^-}{2\Delta p_k} = \sum_i \alpha_{Ii} \frac{\sigma_i^+ - \sigma_i^-}{2\Delta p_k}; \qquad \alpha_{Ii} = \phi_i / \sum_i \phi_i$$

Data Assimilation: Procedures

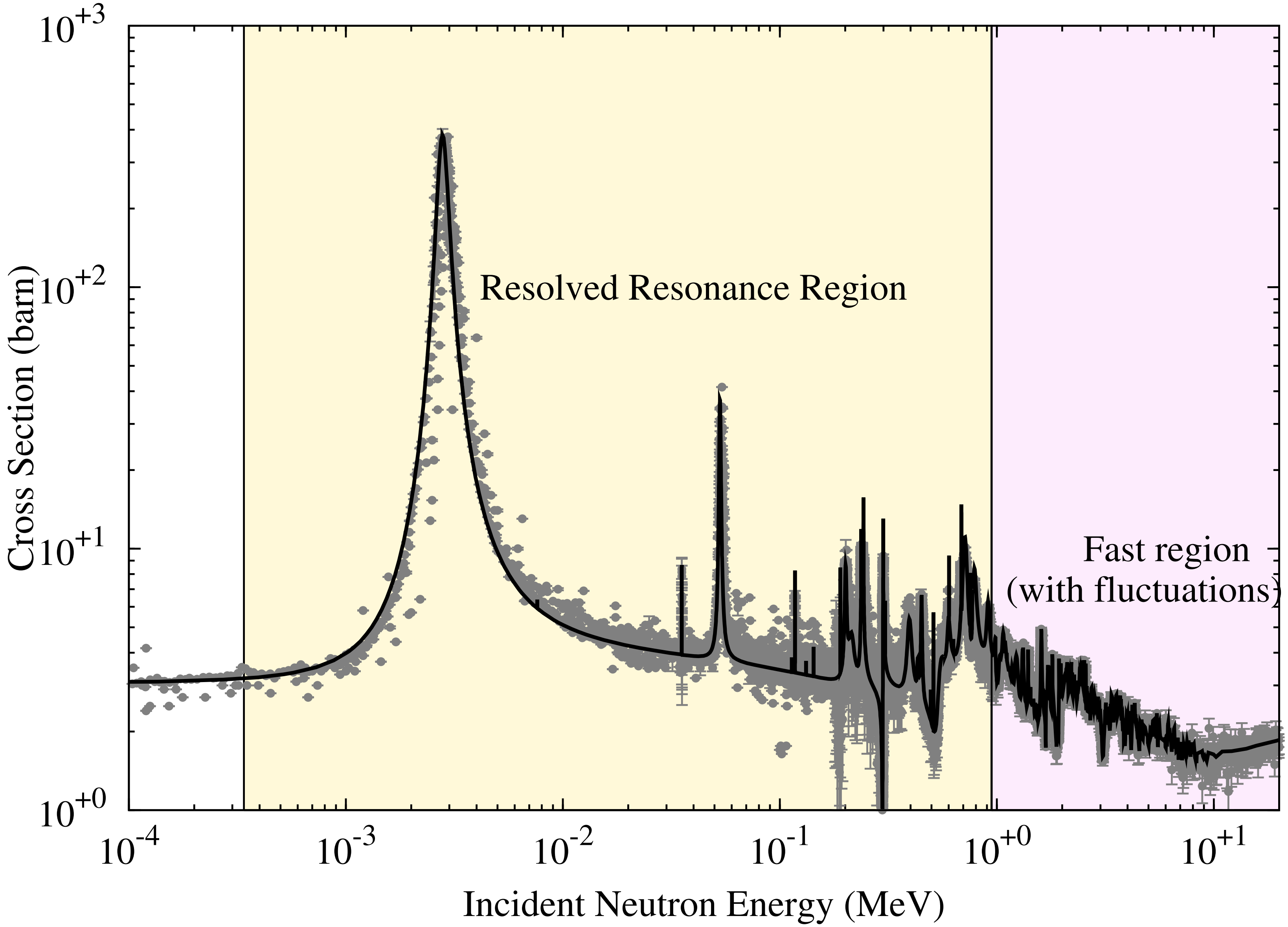
$$S_{Ik} = \frac{\sigma_I^+ - \sigma_I^-}{2\Delta p_k} = \sum_i \alpha_{Ii} \frac{\sigma_i^+ - \sigma_i^-}{2\Delta p_k}; \qquad \alpha_{Ii} = \phi_i / \sum_i \phi_i$$

$$\langle \Delta\sigma_I \Delta\sigma_J \rangle = \sum_{k\ell} S_{Ik}^{\mathrm{T}} \langle \Delta p_k \Delta p_\ell \rangle S_{J\ell}$$

$\langle \Delta p_k \Delta p_\ell \rangle$ is the covariance matrix of parameters in RRR and fast neutron region.

- In RRR uncorrelated parameters where their uncertainties are taken from ATLAS (S.F. Mughabghab)
- In Fast neutron region uncertainties and correlations of parameters derived from KALMAN code

Approach adopted for ^{23}Na



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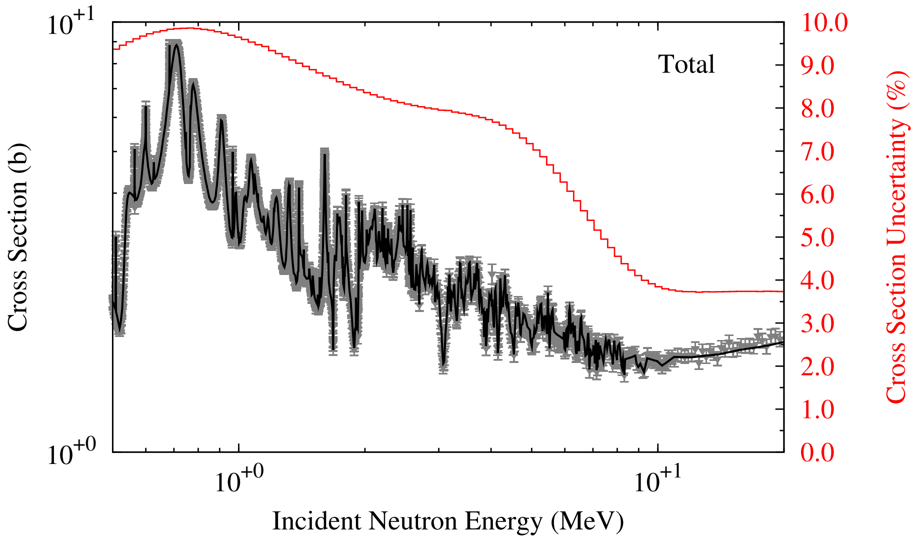

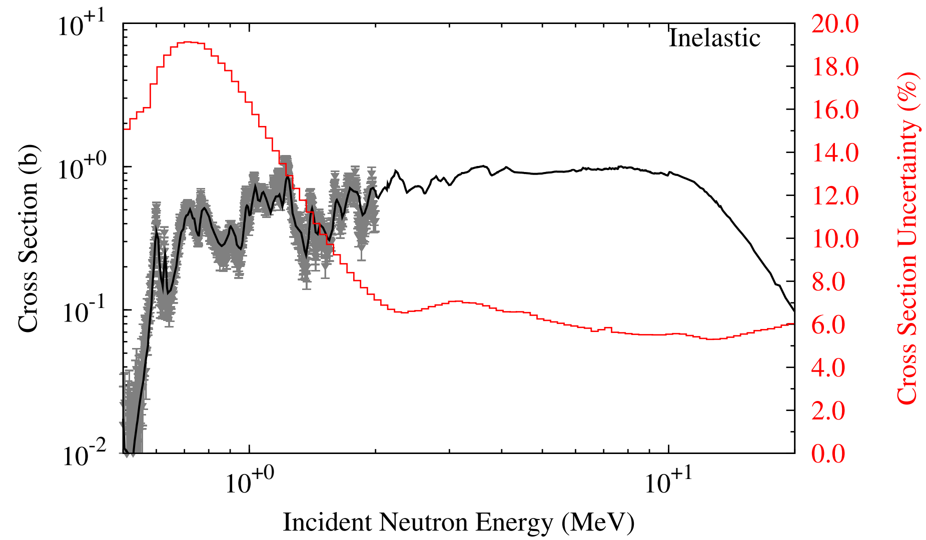

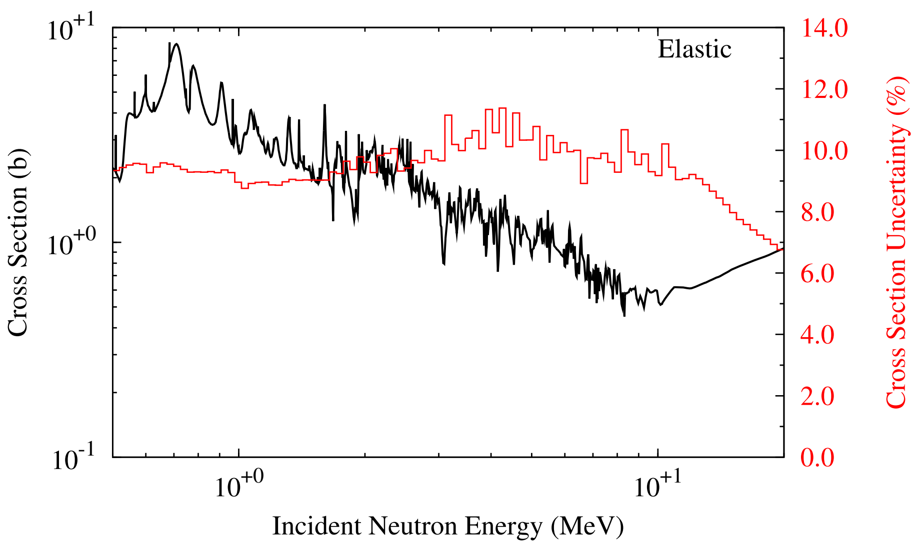

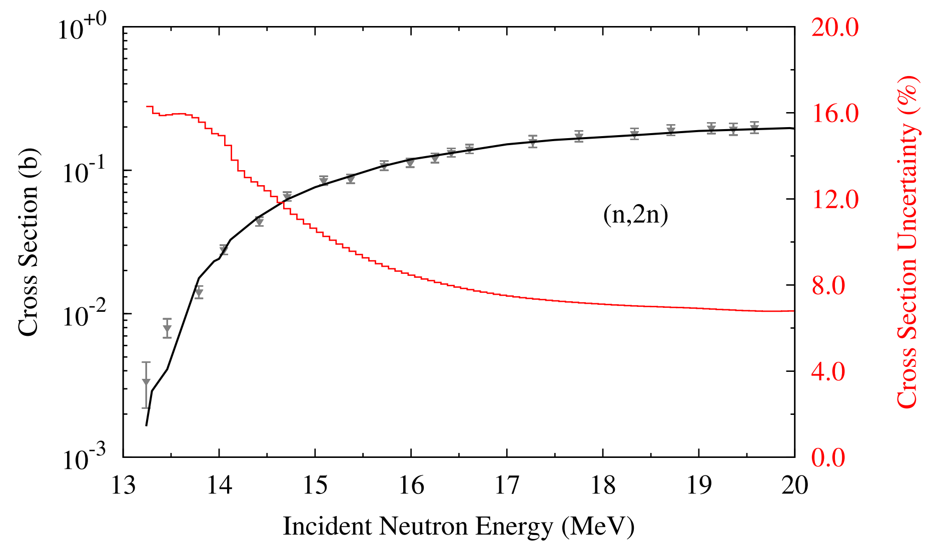

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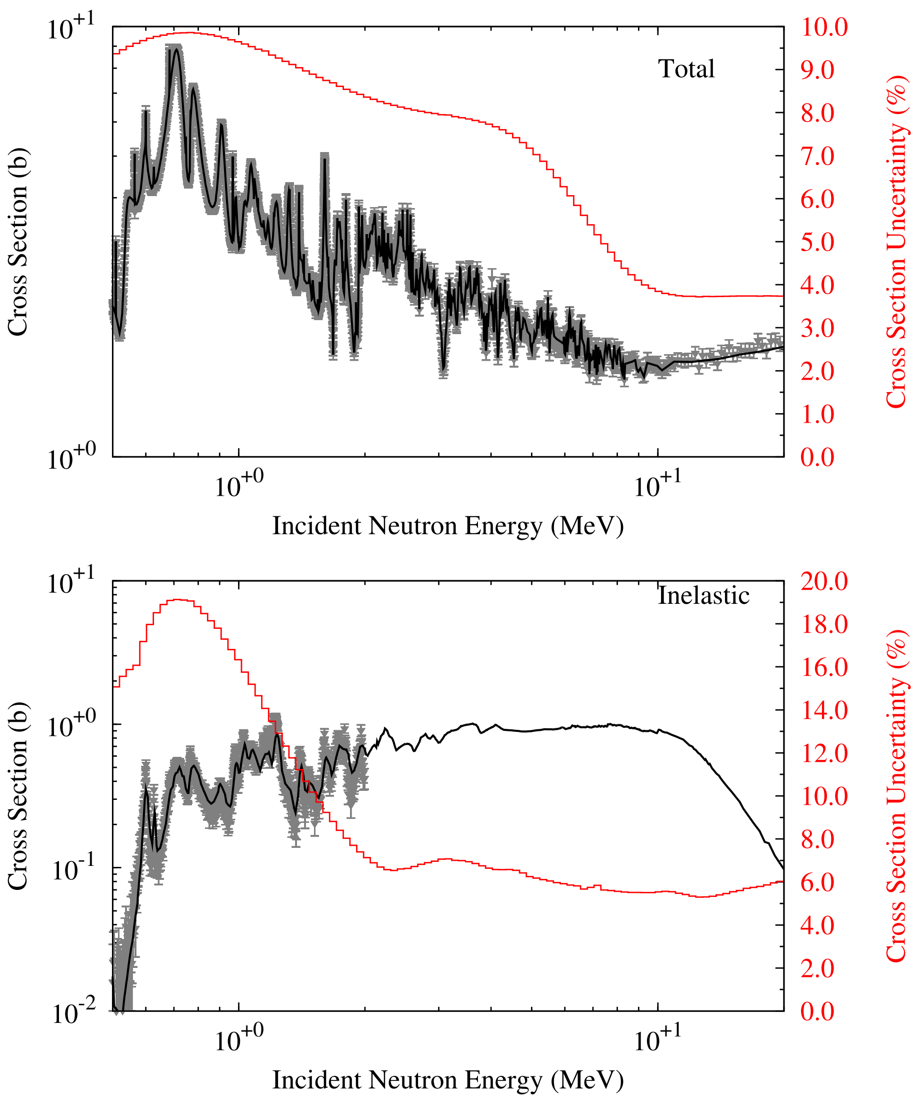


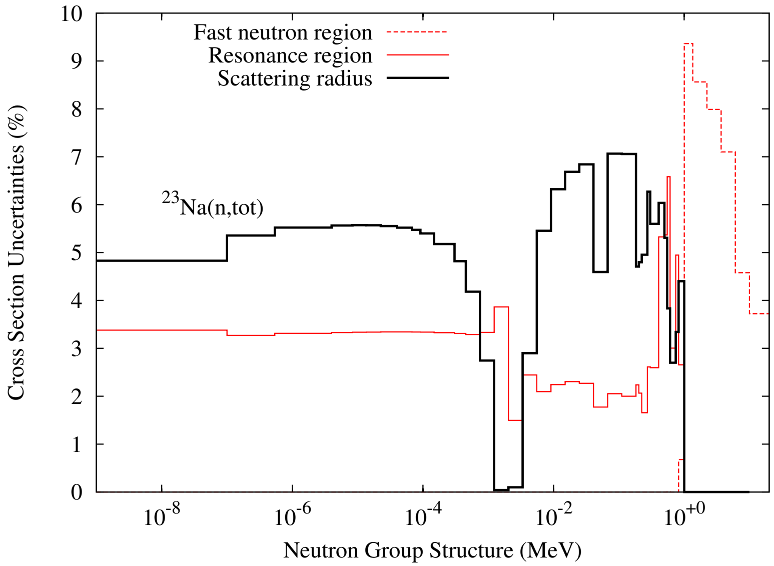
- ✓ High-resolution experiments contains fluctiations well into MeV region
- ✓ We were able to reproduce fluctuations via EMPIRE parameterization. It is complicated and time comsuming.
- ✓ Select parameters p_k and their covariances so that realistic cross section uncertainties are obtained (not trivial!)

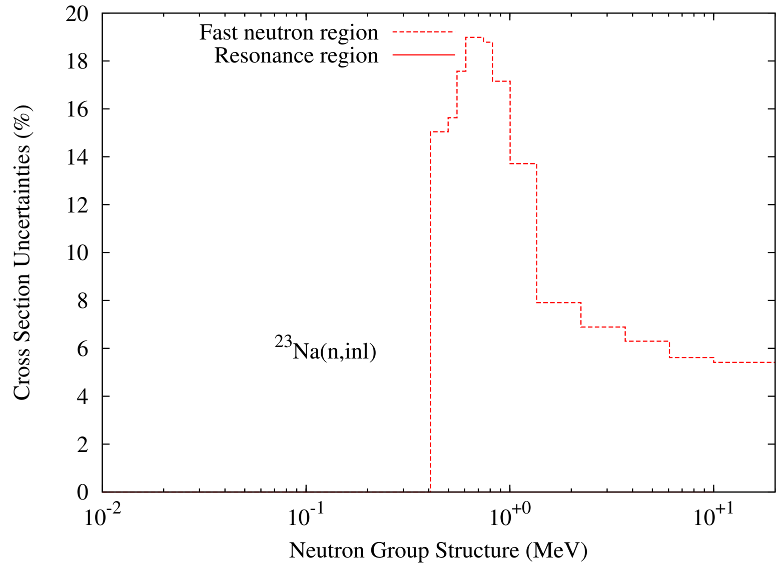
Model Parameters

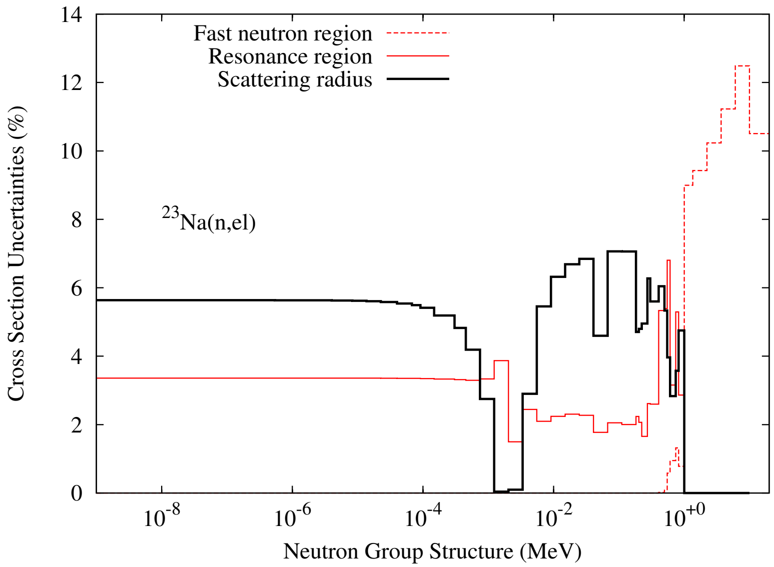
- ✓ In Resonance resolved region (Multi-level Breit Wigner), parameters ($E_0, \Gamma_n, \Gamma_\gamma$) for 41 resonances (up to 1 MeV), and related uncertainties = 103 parameters.
- ✓ In fast neutron region (optical model, Hauser fashbach, preequilibrium exciton model) = 31 parameters
- ✓ Fast neutron region (tuning) = 2 parameters

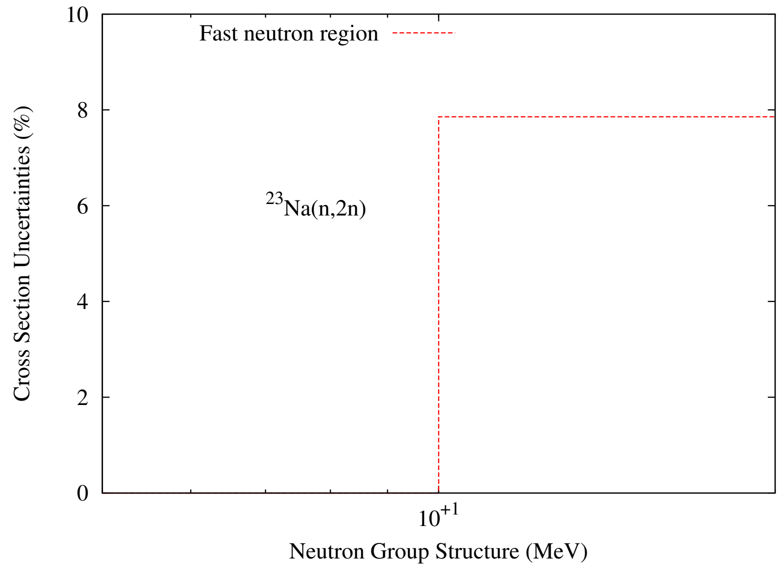
Covariance analysis performed (KALMAN) including selected experiments $\longrightarrow$ covariance in model parameter space produced.

Sensitivities and model parameters









Conclusions

- Cross section calculations (EMPIRE) using ENDF/B-VII.0 as reference
- Covariance analysis (KALMAN) to obtain realistic cross section uncertainties and related covariances. This provides also covariances in model parameter space.
- Sensitivities to 136 parameters were calculated and supplied to Idaho National Laboratory.