Evaluation of Neutron Cross Sections with covariances for Curium Isotopes

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Contents

- ✓**Introduction**
- ✓**Neutron cross section evaluation**
- ✓**Covariance evaluation**
- ✓**Conclusions**

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Introduction

- ✓ Need for the improved neutron cross section data with covariances of Minor Actinides (MA) for Advanced Fuel Cycle (AFC) and safeguards
- ✓ A KAERI-ORNL collaborative work under International Nuclear Energy Research Initiative (INERI) program
  - ➢ Selected Nuclides: ^{237}Np, ^{240}Pu, and $^{240\text{-}250}$Cm
  - ➢ ORNL: RR and URR
  - ➢ KAERI: Fast region
- ✓ Evaluation of fast region
  - ➢ Neutron cross section evaluations employ a consistent set of model and parameters for all isotopes.
  - ➢ Evaluations of covariances are consistent with those of cross sections

Cross section evaluation

- ✓ Nuclear Reaction Model Code: Empire-3
- ✓ OMP from RIPL-3
  - ➢ An isospin-dependent coupled-channels optical model potential containing the dispersive term (DCCOMP) suggested by Capote *et al.*. (RIPL # 2408)
- ✓ Empire-specific level densities
- ✓ Gamma strength functions developed by Plujko (MLO1)
- ✓ A Double humped fission barrier

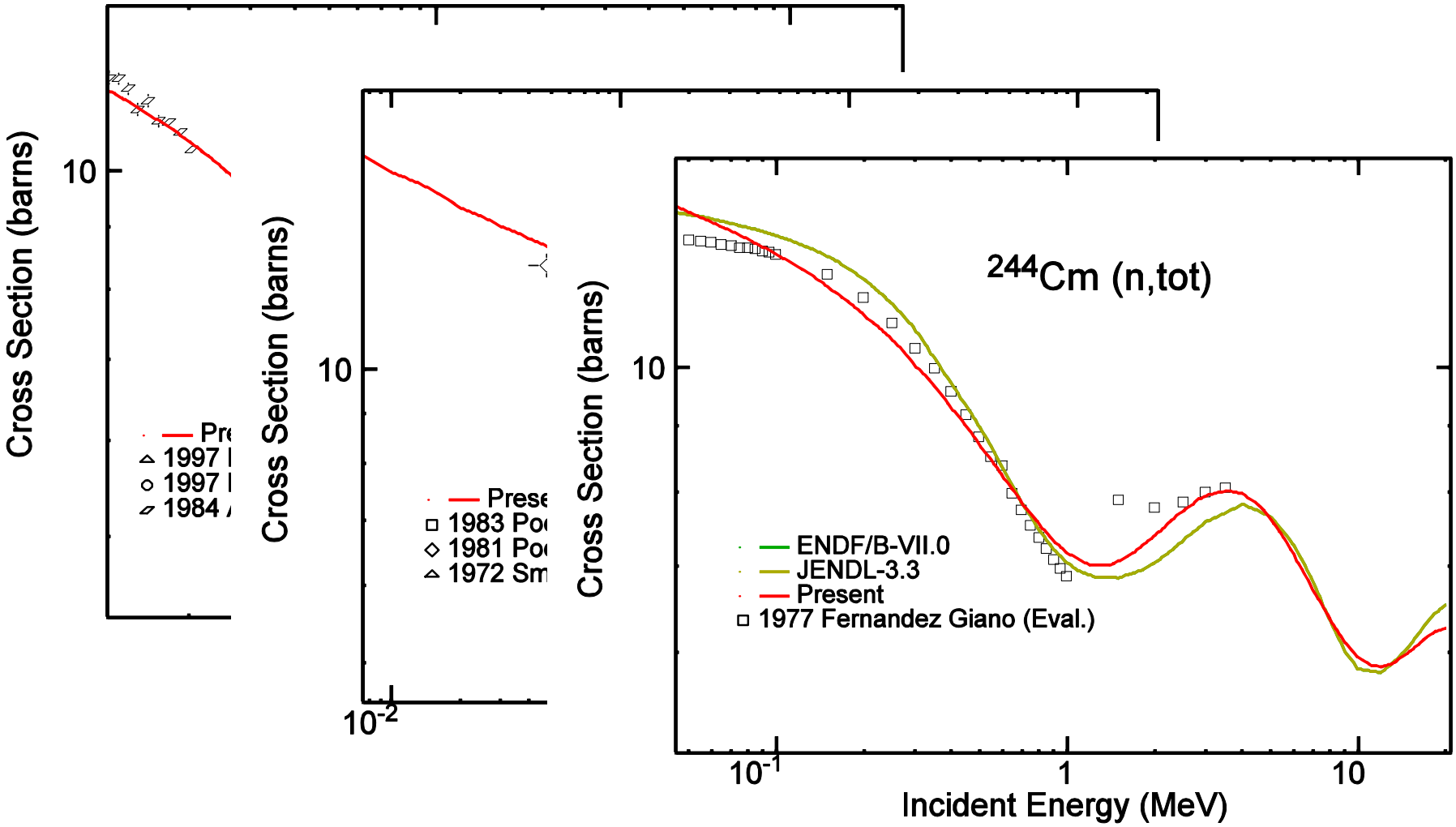
Covariance evaluation

- ✓ EMPIRE-KALMAN
- ✓ Mid-step to generate the covariances with high fidelity
  - ➢ Covariance evaluations are consistent with the those of cross sections. So, Sensitivity matrices were constructed by using the Empire input
- ✓ Model parameters considered to construct sensitivity matrices
  - ➢ OMP: Real volume depth, imaginary surface depth
  - ➢ Sytematics values for level density parameter
  - ➢ Parameters of fission barrier
  - ➢ Emission width of gamma
  - ➢ Pre-equilibrium strength

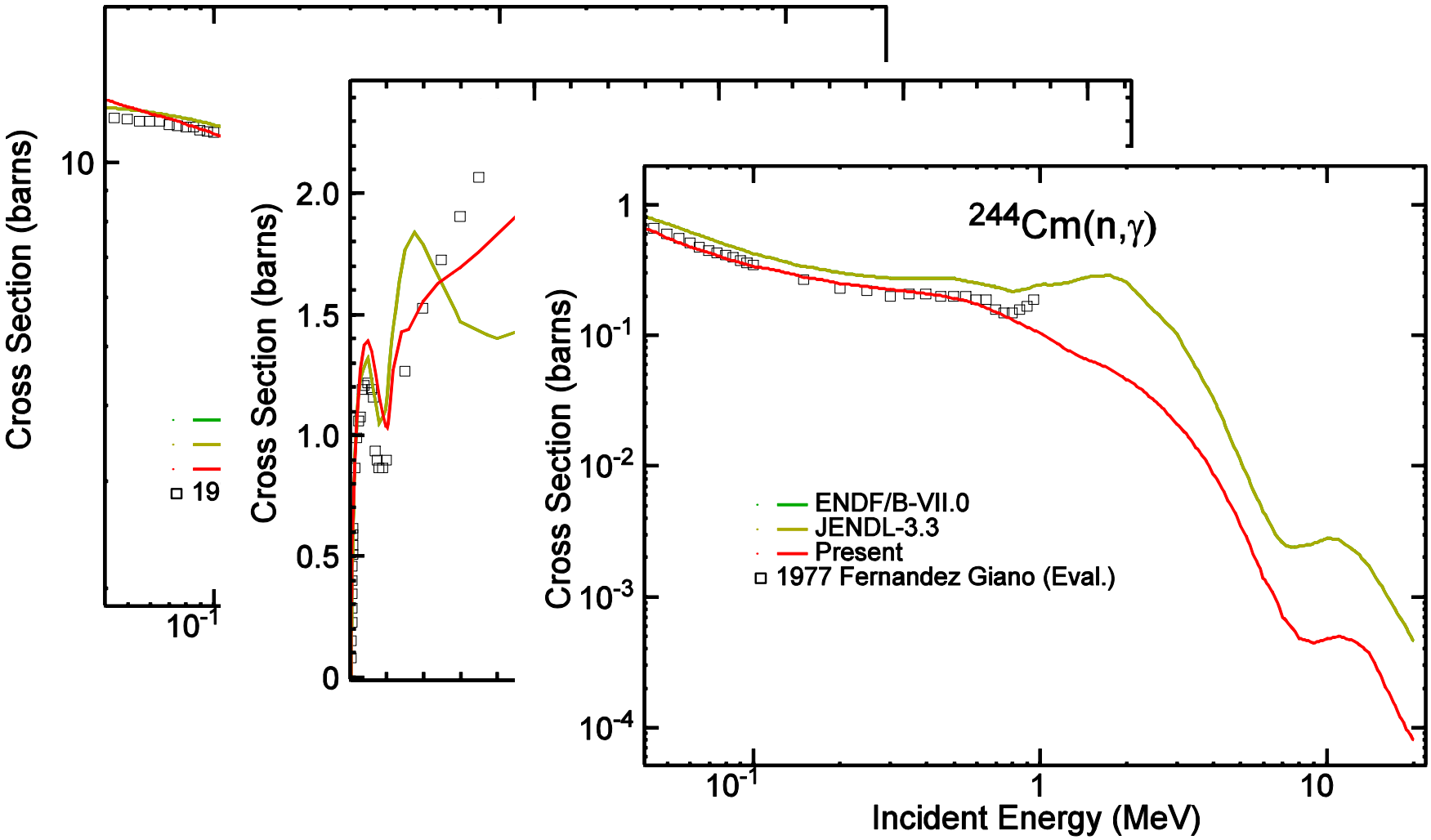
Neutron cross section evaluation

- ✓ Cm isotopes with half-life over than 1-day: $^{240\text{-}250}$Cm
- ✓ Newly calculating for all physical quantities such as energy and/or angular distributions as well as cross sections, but, at the moment, taking from JENDL-3.3 for nu-bar and fission neutron spectrum
- ✓ Simultaneous evaluation
  - ➢ Critical model parameters such as OMP and asymptotic value of LDP vary smoothly as function of mass number.
  - ➢ Using experimental data for neighboring isotope to constrain model parameters when no measurements are available
  - ➢ Model parameters of fission barriers depending on characteristics of even- or odd- nuclides

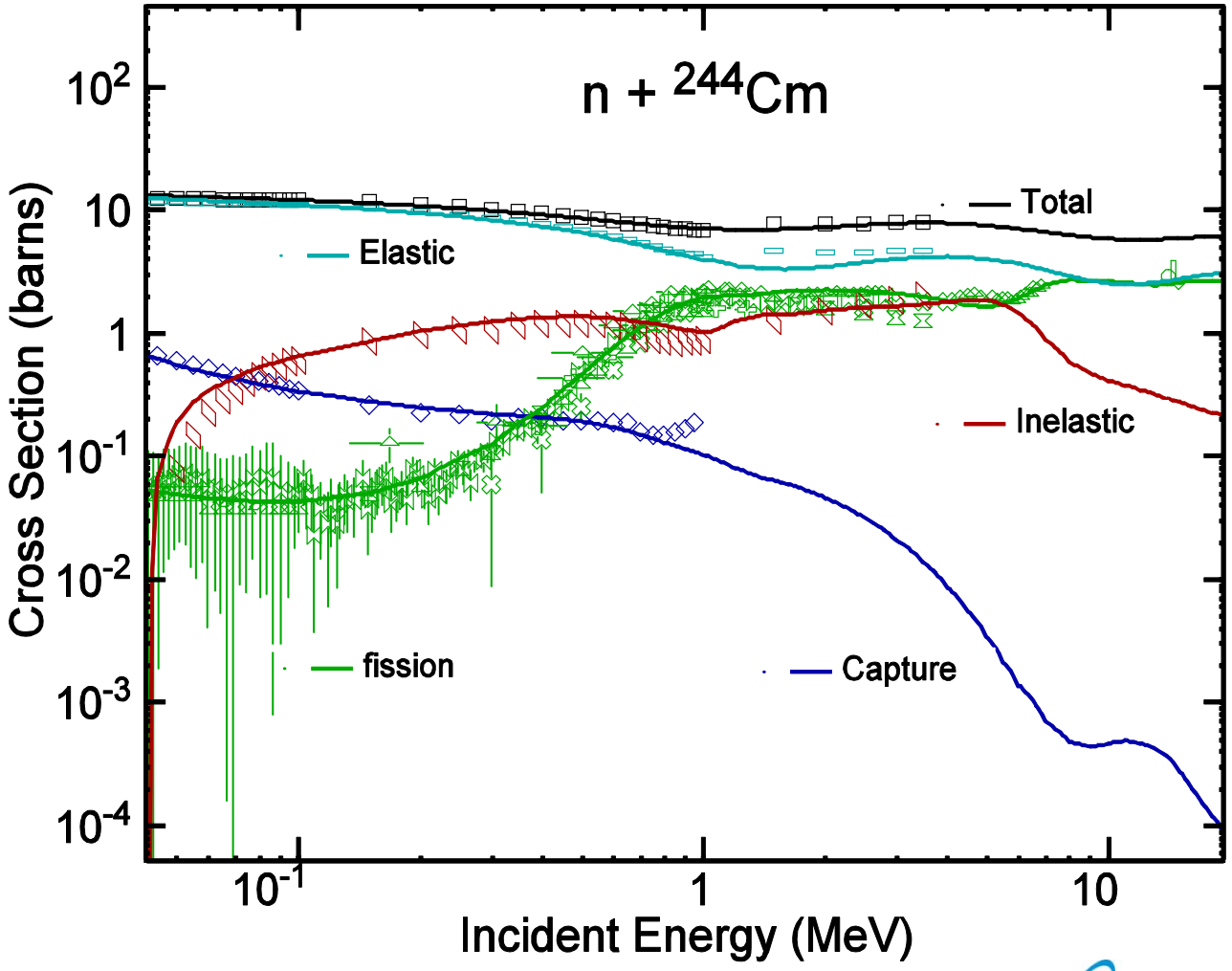
Total cross sections using DCCOMP for actinides



Elastic, Inelastic, Capture for ^{244}Cm



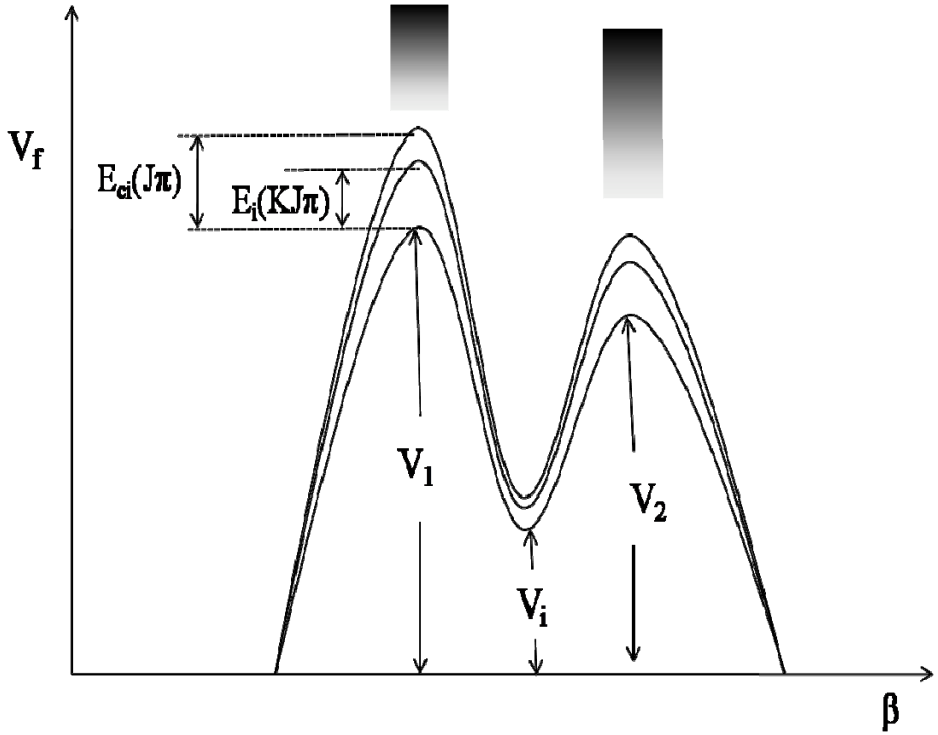
Neutron cross sections for ^{244}Cm



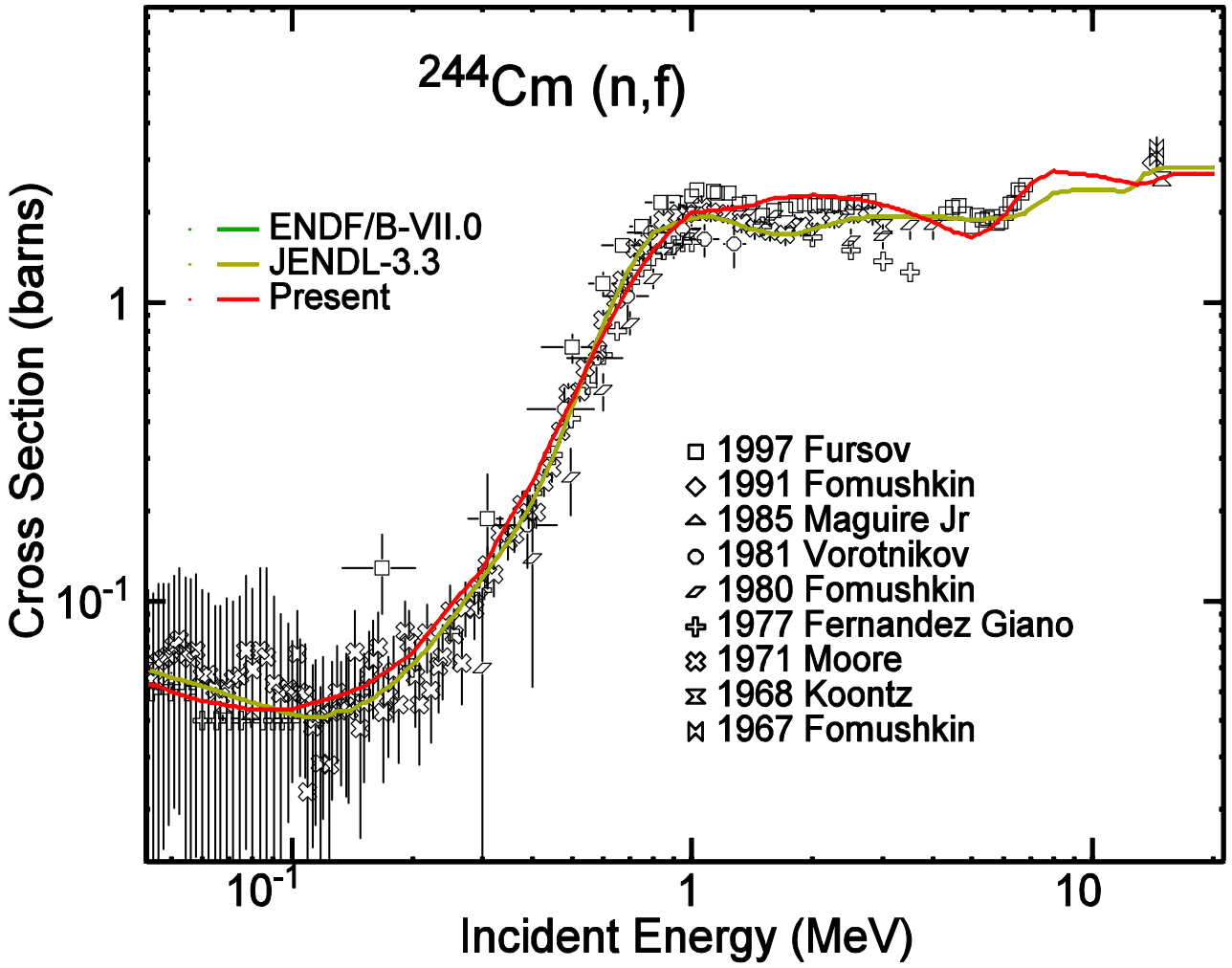
Fission cross sections

$$V_i(\beta) = E_{fi} \pm \frac{1}{2}\mu\hbar^2\omega_i^2(\beta - \beta_i)^2$$

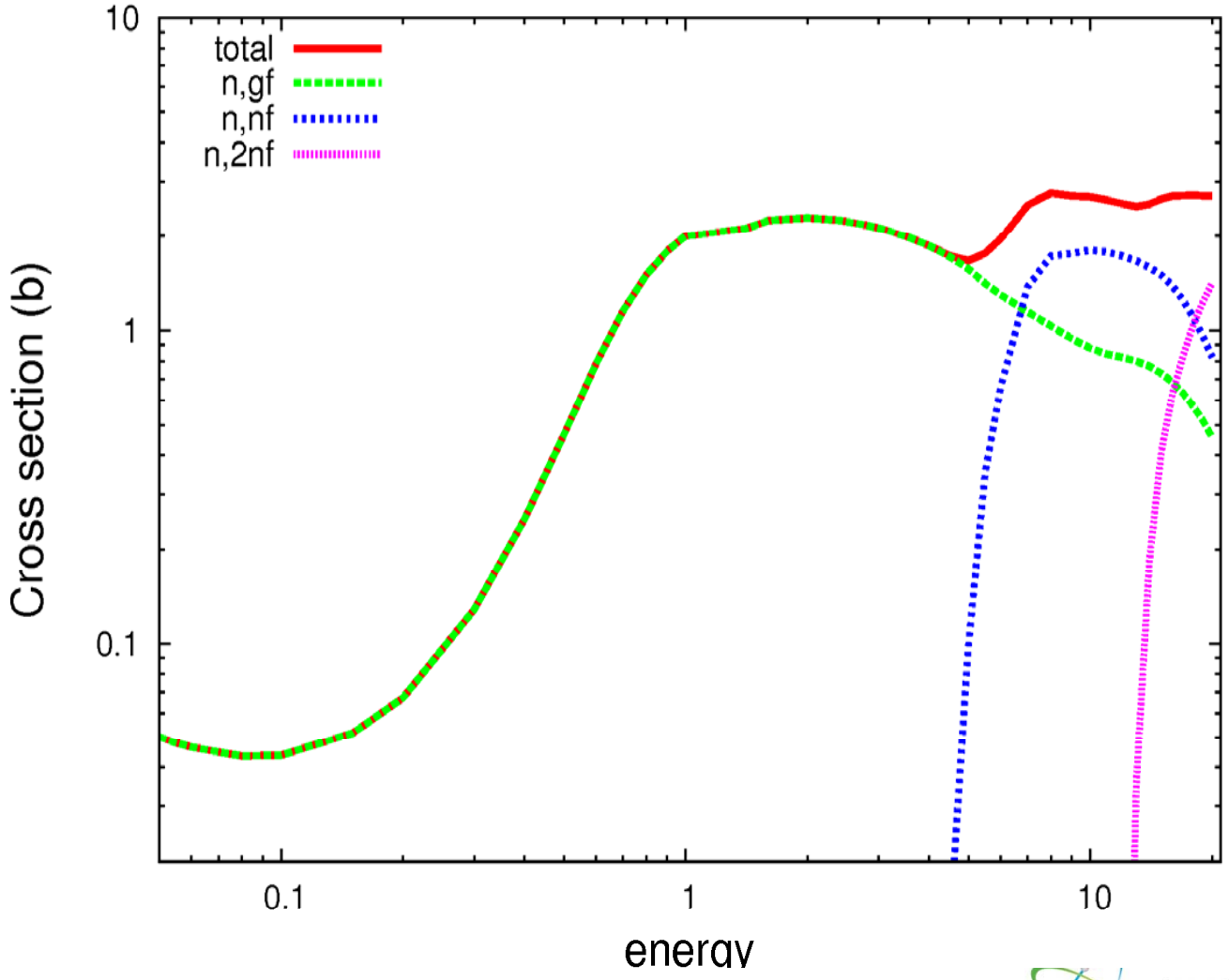
where *i* is the number of barriers or wells, the energies E_{fi} represent maxima of V_i (barrier (+)), and minima (well (-)). β_i are the corresponding abscissa, the harmonic oscillator frequencies w_i define the curvature of each parabola, and μ is the inertial mass parameter



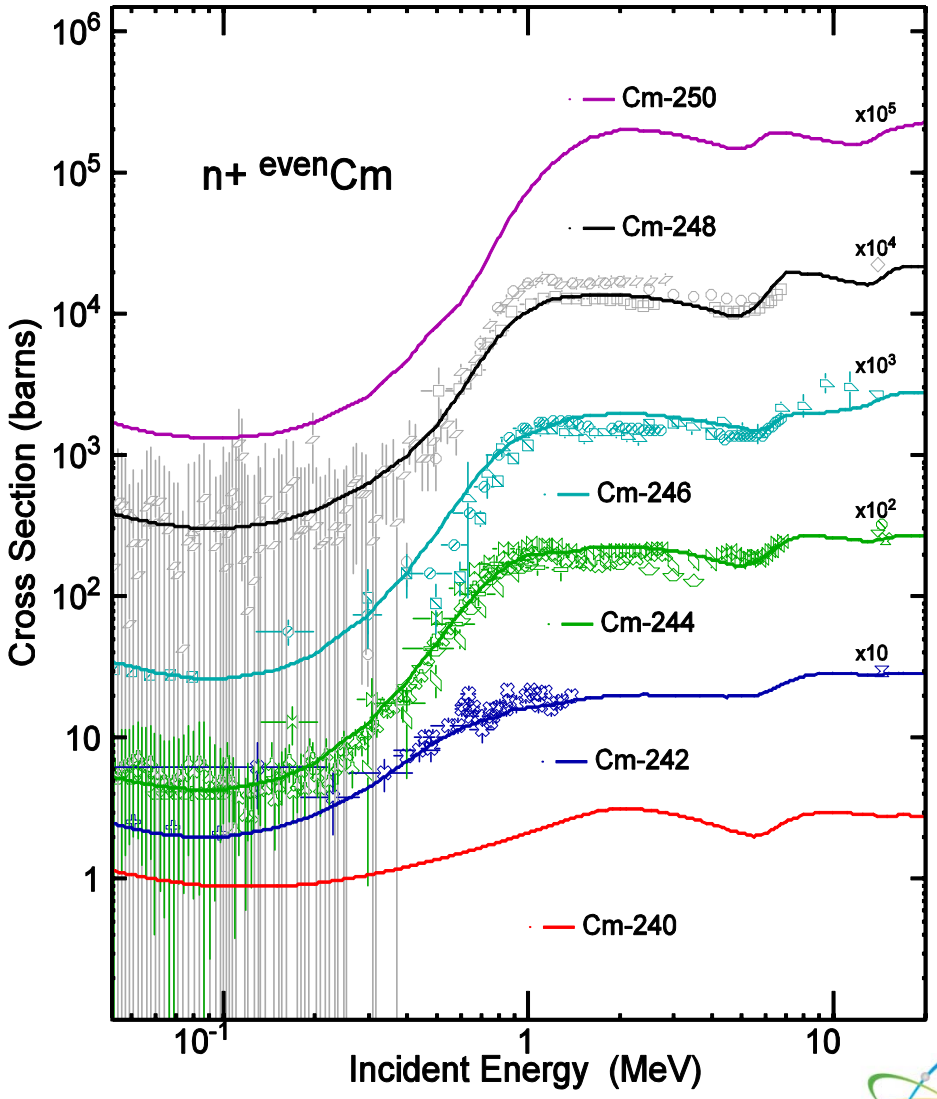
Fission cross sections for ^{244}Cm



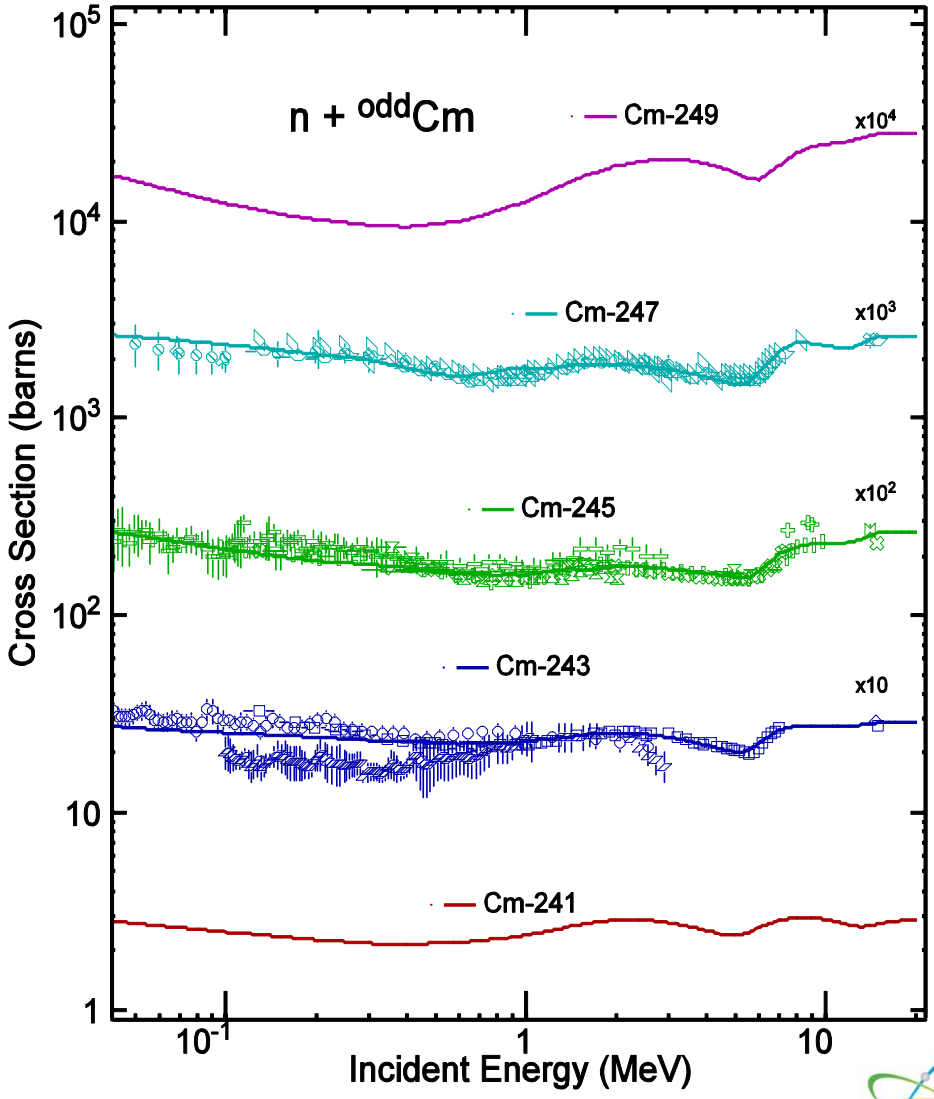
Fission channels for ^{244}Cm



Fission cross sections for all even Cm isotopes



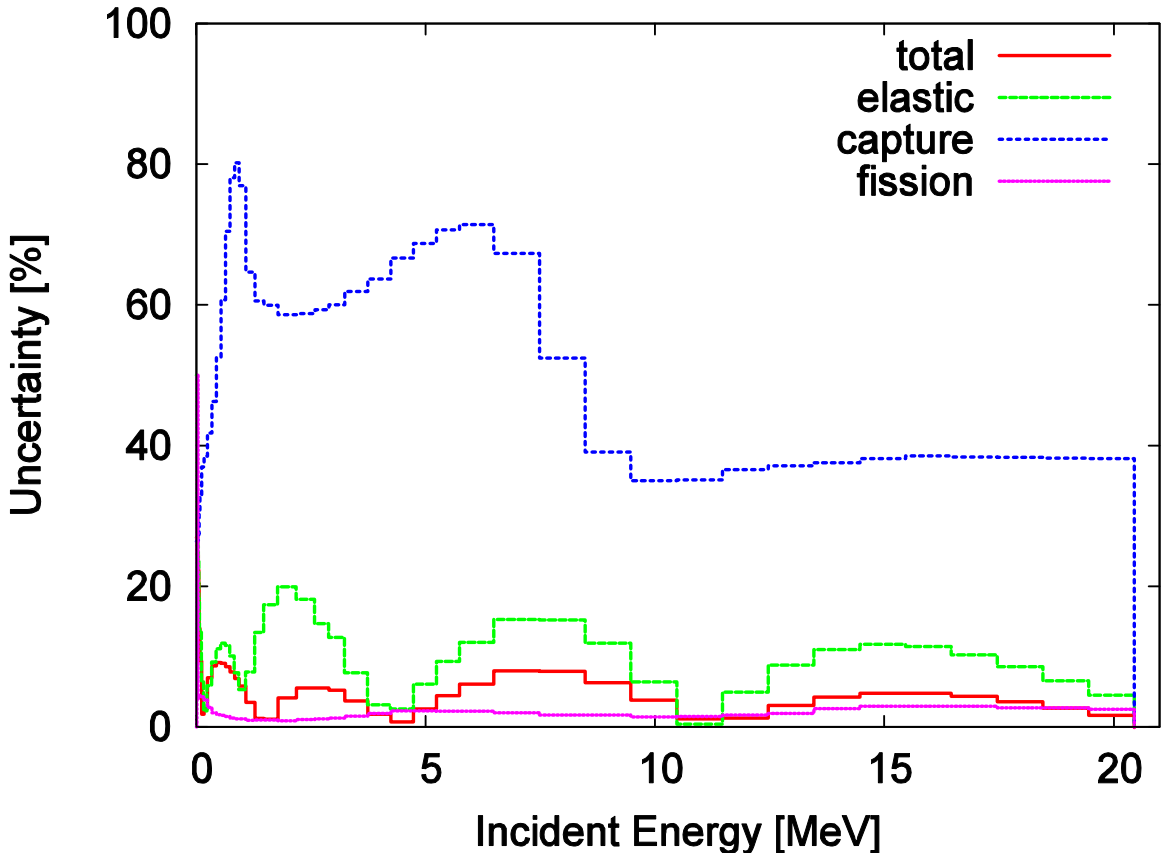
Fission cross sections for all odd Cm isotopes



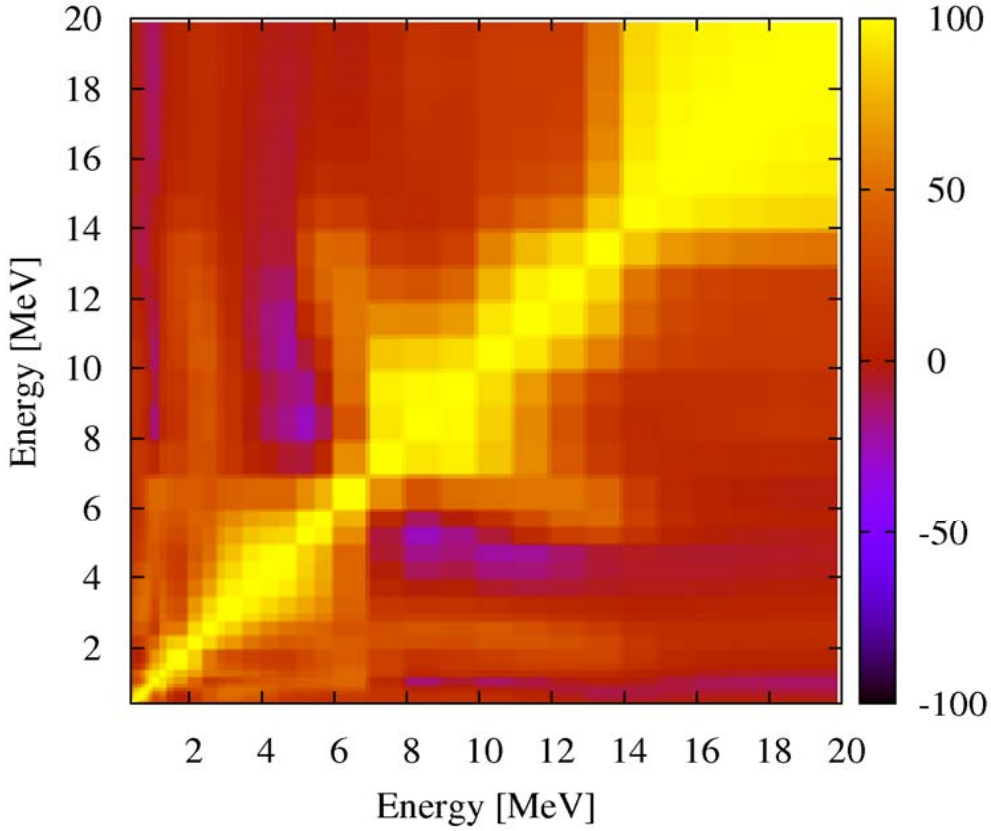
Covariances

- ✓ Generating covariances for cross sections:
  - Total, elastic, inelastic, capture, fission
    (n,2n), (n,*a*), (n,p)
- ✓ Model parameters varied in sensitivity calculations (~5 %)
  - OMP (2): Real volume depth, imaginary surface depth
  - Sytematics values for level density parameter(2)
  - Parameters of fission barrier (6)
  - Emission width of gamma (2)
  - Pre-equilibrium strength (2)

Comparison of uncertainty



Correlation of ^{244}Cm (n,f)



Summary

- ✓ We produced the neutron cross section files including covariances for $^{240-250}$Cm by employing a consistent sets of model and parameters.
- ✓ Sensitivity matrices were constructed by the model parameters varied within 5 % uncertainties.
- ✓ Covariances were generated by the EMPIRE-KALMAN module considering the sensitivity matrices and experimental data available.

Further works

- ✓ Obtaining more accurate neutron cross sections to reproduce better the experimental data available
- ✓ Reducing too much uncertainties appeared when no experimental data are available
- ✓ Adding covariances for discrete levels and energy/angular distributions as well as nu-bar