# Reduced Uncertainties for Minor Actinides

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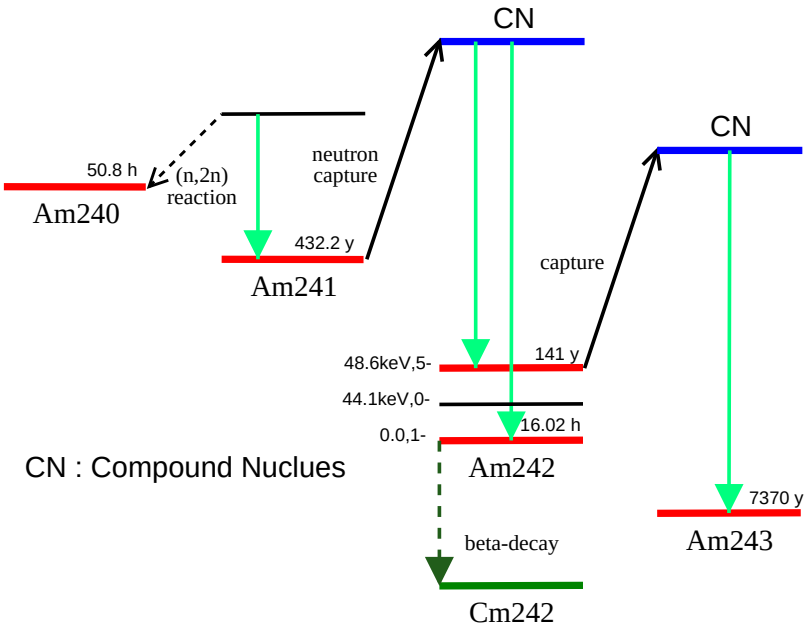
# Introduction

## Nuclear Data Evaluation for Minor Actinides

- MA data for applications:
  - nuclear transmutation
  - accelerator driven system
  - high burn-up reactor calculation
  - Np, Pu, Am, Cm, etc.
- Status of MA nuclear data
  - highly accurate data are limited
    - experimental data are scarce
    - evaluations rely strongly on theo-retical calculations
  - improvement of the MA data are of international interest




- Important nuclear data — reaction cross sections (total, elastic, inelastic, capture, fission, 2n, 3n, . . .), fission energy spectrum, and $\nu$

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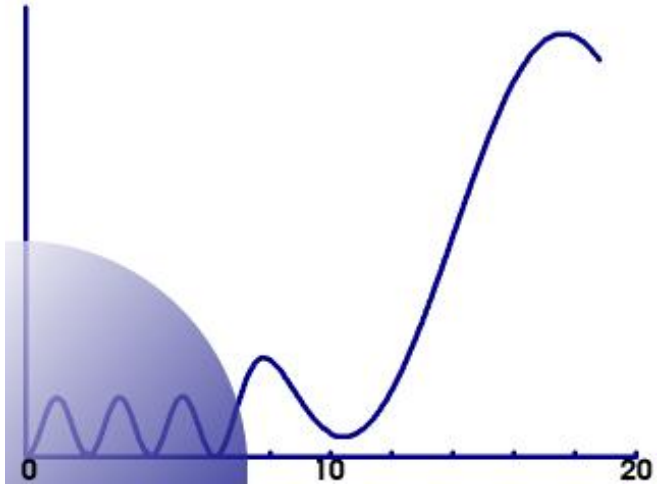
# Evaluation Procedure

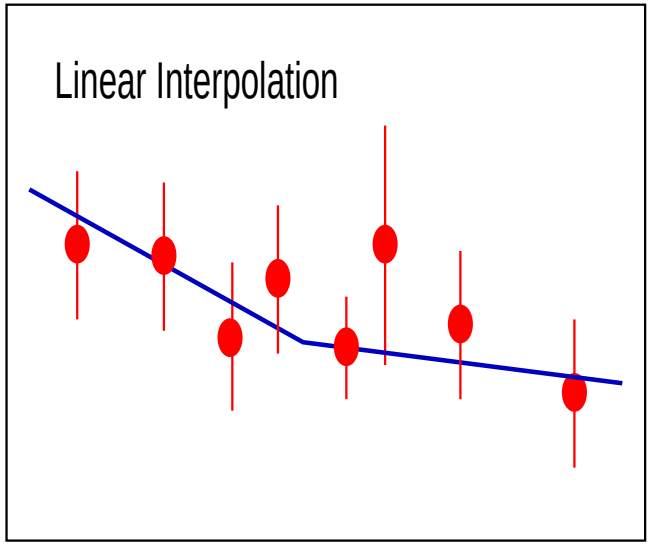
## Nuclear Models Used

- Evaluation with theoretical calculations
- Nuclear reaction codes
  - Optical and CC models
    - ECIS, CoH
  - Hauser-Feshbach with Pre-Equilibrium
    - GNASH, EMPIRE, TALYS
    - Cross sections for 1 keV to 200 MeV

## Bayesian Analysis

- Evaluation based on experimental data
- Statistical analysis codes
  - SOK least-squares fitting
  - GLUCS least-squares fitting
  - KALMAN model parameter adjustment
- Those give us a covariance matrix too

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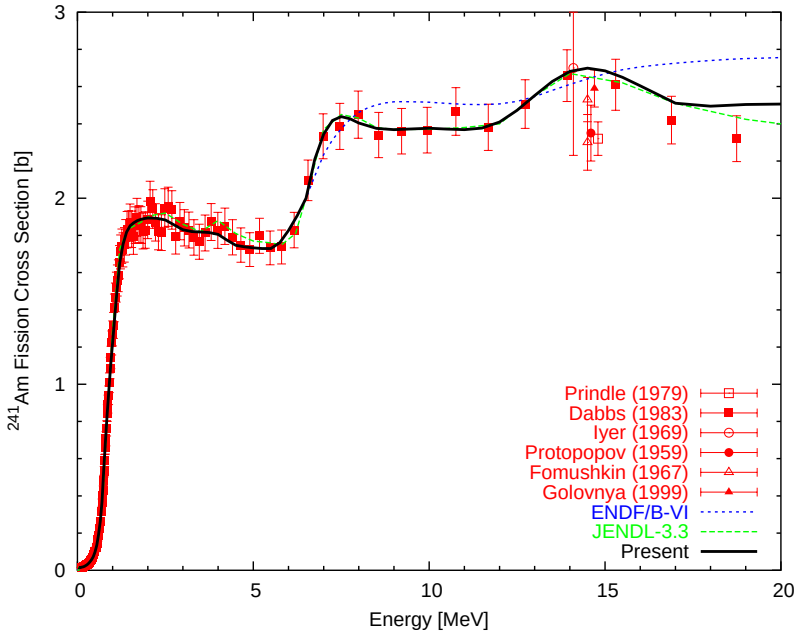
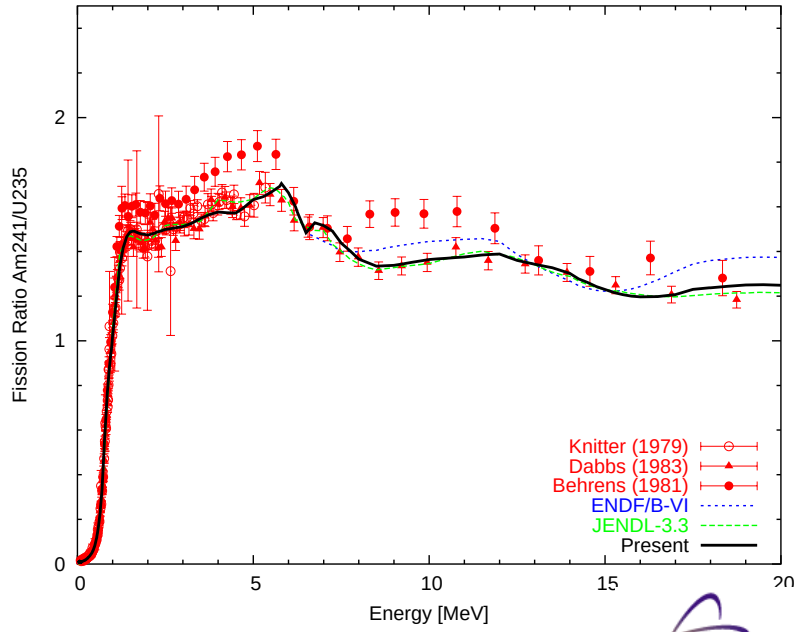
# Fission Cross Section - Am-241

## Least-Squares Fitting

- The experimental data included were, absolute measurements of $^{241}$Am$(n, f)$ and ratio to $^{235}$U$(n, f)$.
- New standard evaluation for $^{235}$U
- The LSQ fitting was made with a generalized least-squares fitting code
  - The fission cross section data are often high quality, and this procedure allows us to try to resolve discrepancies in measured values to determine the best value.
  - Based on the Bayesian statistics.
- Inconsistent with full model calculated evaluations

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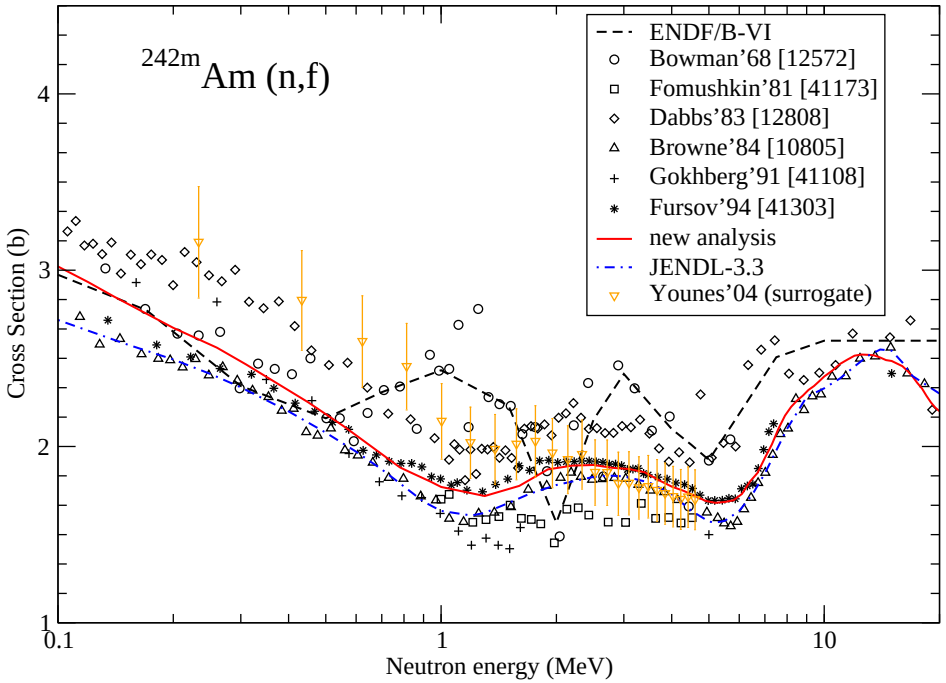
# Fission Cross Section - Am-242m

## Least-Squares Fitting

- The experimental data included were, the ratio to $^{235}\mathrm{U}(n,f)$ and $^{239}\mathrm{Pu}(n,f)$.
- New evaluations for $^{235}\mathrm{U}$ and $^{239}\mathrm{Pu}$ done by LANL, T16 were used.
- New fission data of Younes *et al.* were also included, which were obtained with the "surrogate technique."




The new evaluation basically follows the experimental data of Browne *et al.* and Fursov *et al.* The surrogate data also support our evaluation in the MeV energy range, however, the data seem to be higher at low energies.

We often have to predict fission cross sections by model, because the fission data of MA are not always available.

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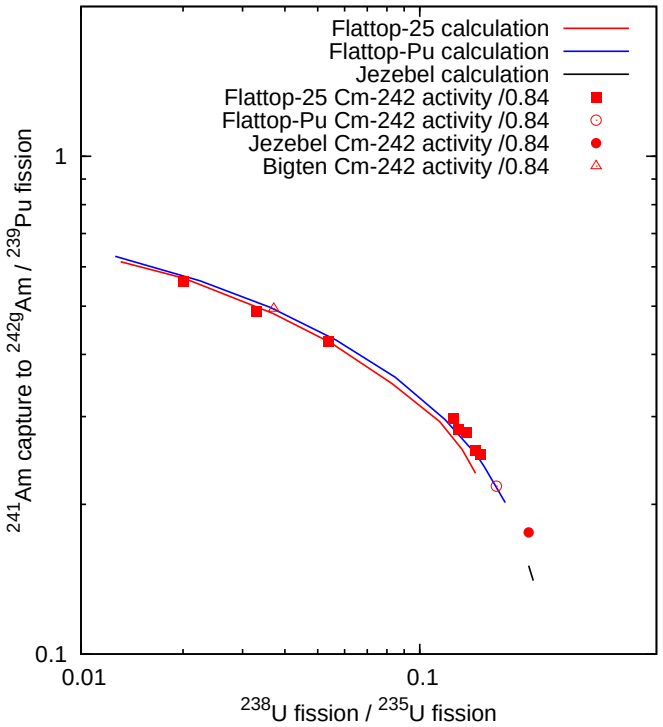
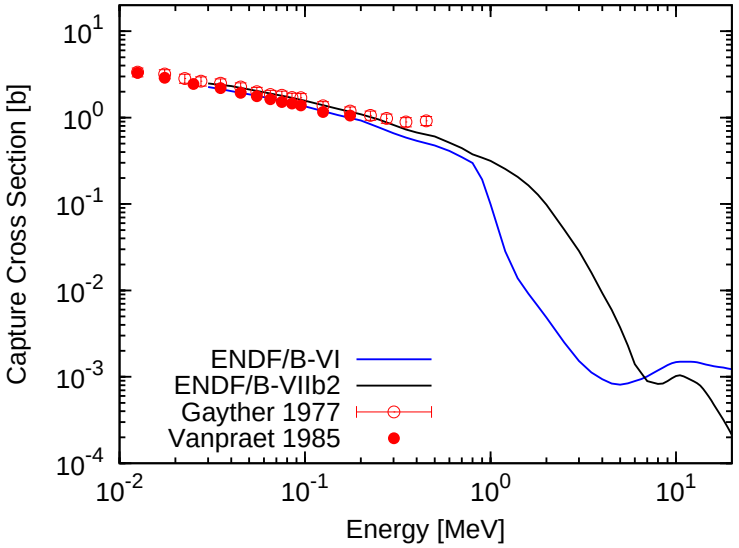
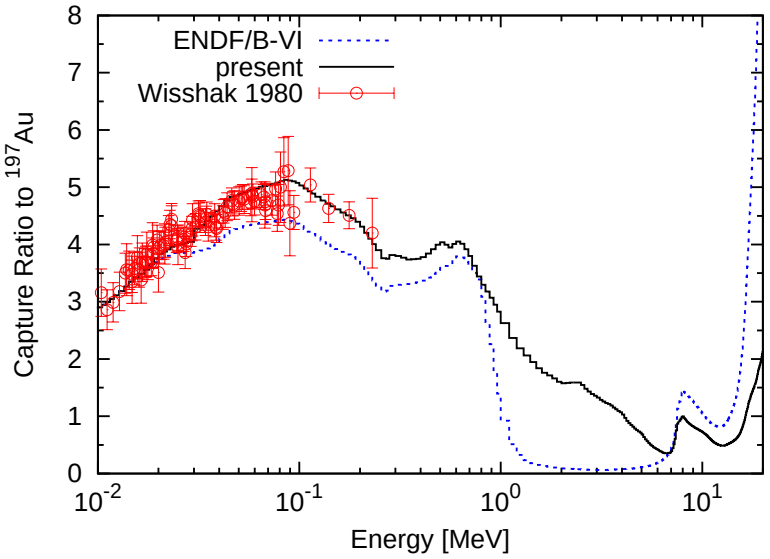
# Capture Cross Section - Am-241

## Statistical HF calculation

- For ENDF/B-VII, evaluation was made to reproduce:
  - Absolute capture measurement
  - Relative to $^{197}$Au
  - Integral data in fast assemblies

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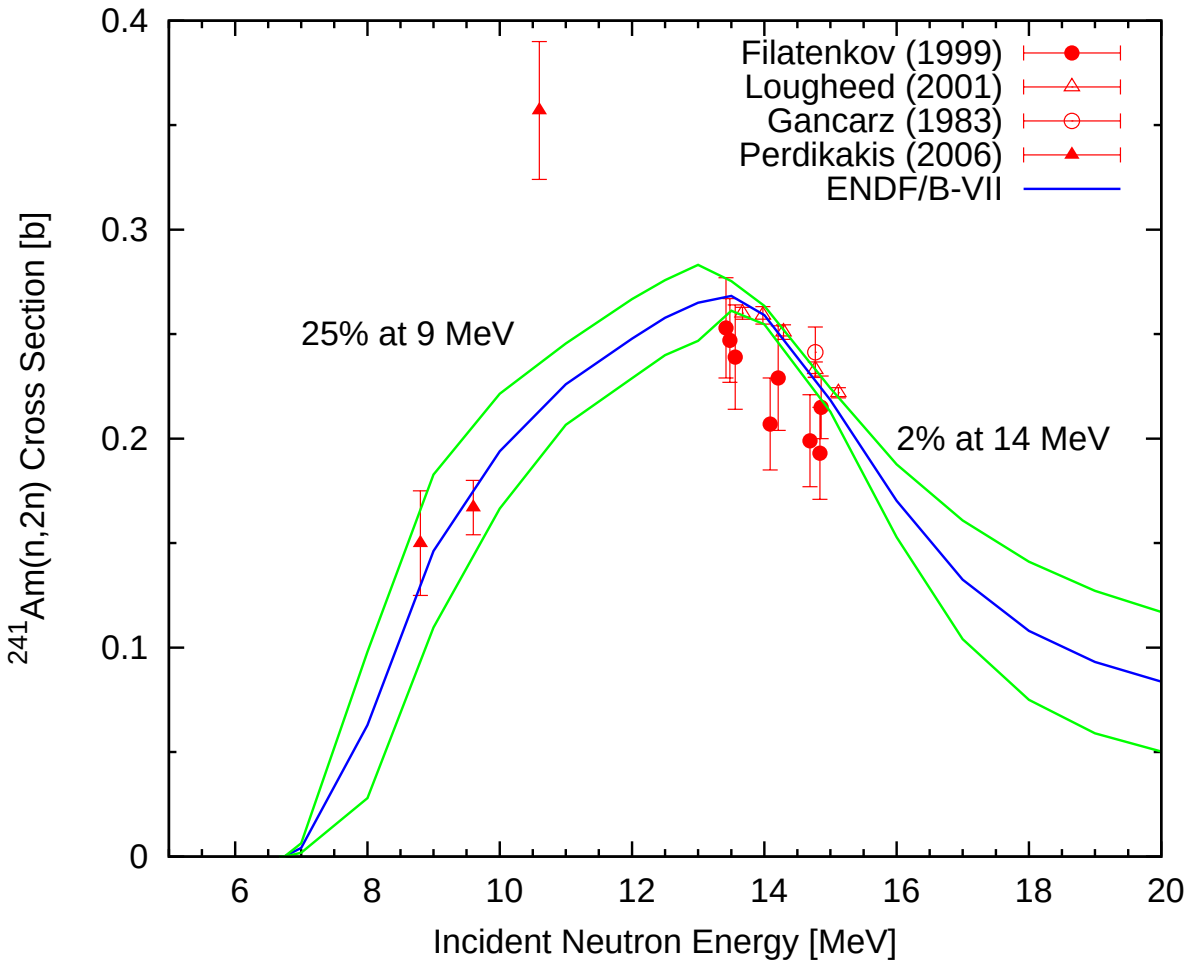
# (n,2n) Reaction Cross Section - Am-241




With the Bayesian method, the covariance data of evaluated cross section are obtained. The covariance data include information of both experimental and theoretical uncertainties.

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# Concluding Remarks

## New Evaluation for ENDF/B-VII

- The nuclear data for americium isotopes were upgraded. The new evaluation took advantage of recent measurements and advances in calculational modeling methods. The statistical Hauser-Feshbach theory was widely used for our evaluations.

## Future work for AFCI Data Needs

- The same technique can be used for cross section evaluations of other minor actinides. However, development of a better nuclear reaction model must be indispensable.
- Once the model codes are developed, and those parameters are well tuned to experimental data available, one can generate a covariance matrix by using the Bayesian technique.