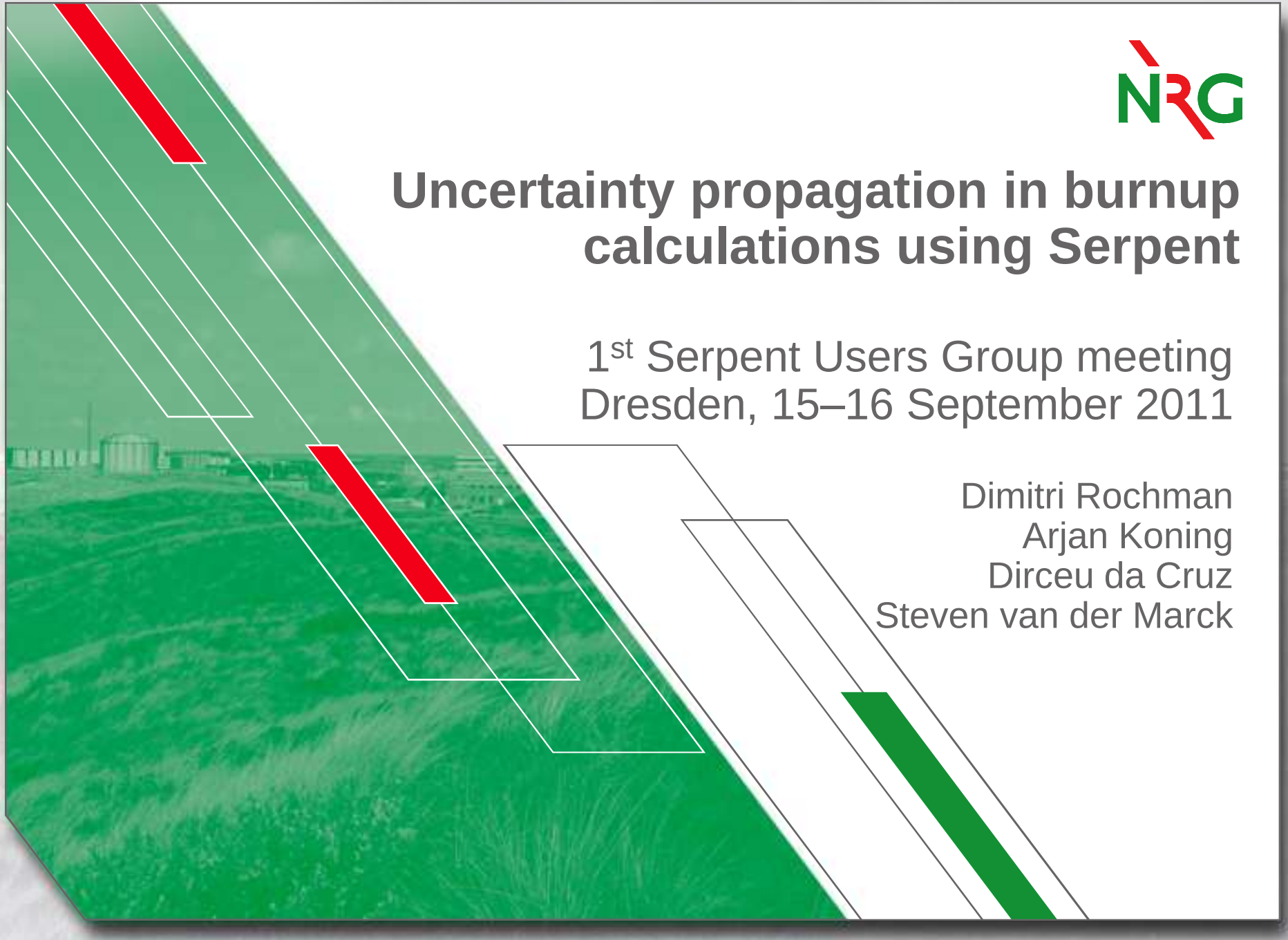


Uncertainty propagation in burnup calculations using Serpent

1st Serpent Users Group meeting
Dresden, 15–16 September 2011

Dimitri Rochman
Arjan Koning
Dirceu da Cruz
Steven van der Marck

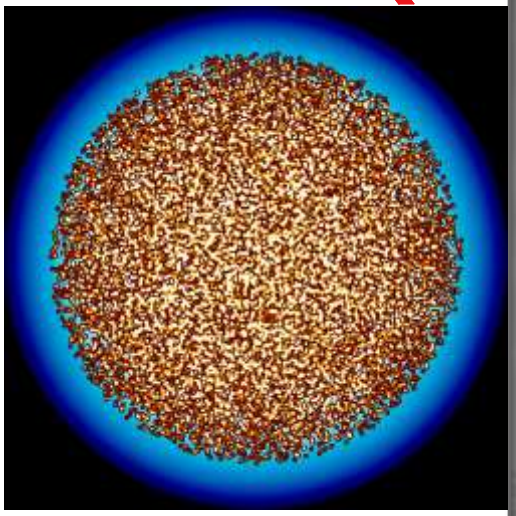
Outline

- Uncertainty? Nuclear data?
- Code & system selection
- Methodology
- Results
- Conclusions

Nuclear data uncertainty calculation

- Increasing interest in uncertainties in calculated quantities
  Uncertainties in nuclear data contribute to overall uncertainty
- Traditionally, uncertainty calculated as:
  difference between e.g. ENDF/B-VII.0 and JEFF-3.1
- Better approach these days: use covariance data …, but:
  - Not all quantities have covariance data
  - Not all isotopes have covariance data
  - No code system prepared for fully consistent calculation
- Most rigorous approach: perform ‘Monte Carlo’ over all realistically possible nuclear data evaluations
  - This is possible because of TALYS and associated programs (TEFAL, TASMAN, …)

Code selection: PSG2 / Serpent



- Requirements
  - Flux and burnup calculation
  - Access to nuclear data
  - Speed & ease of use

- Serpent
  - One integrated code (no need to couple two codes)
  - Full access to nuclear data in public format
  - Fast & easy

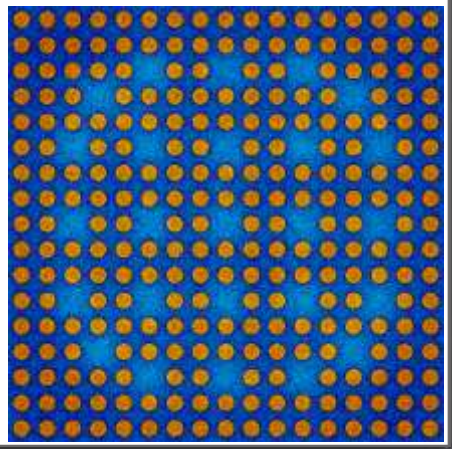
PSG2 / Serpent

a Continuous-energy Monte Carlo Reactor Physics Burnup Calculation Code

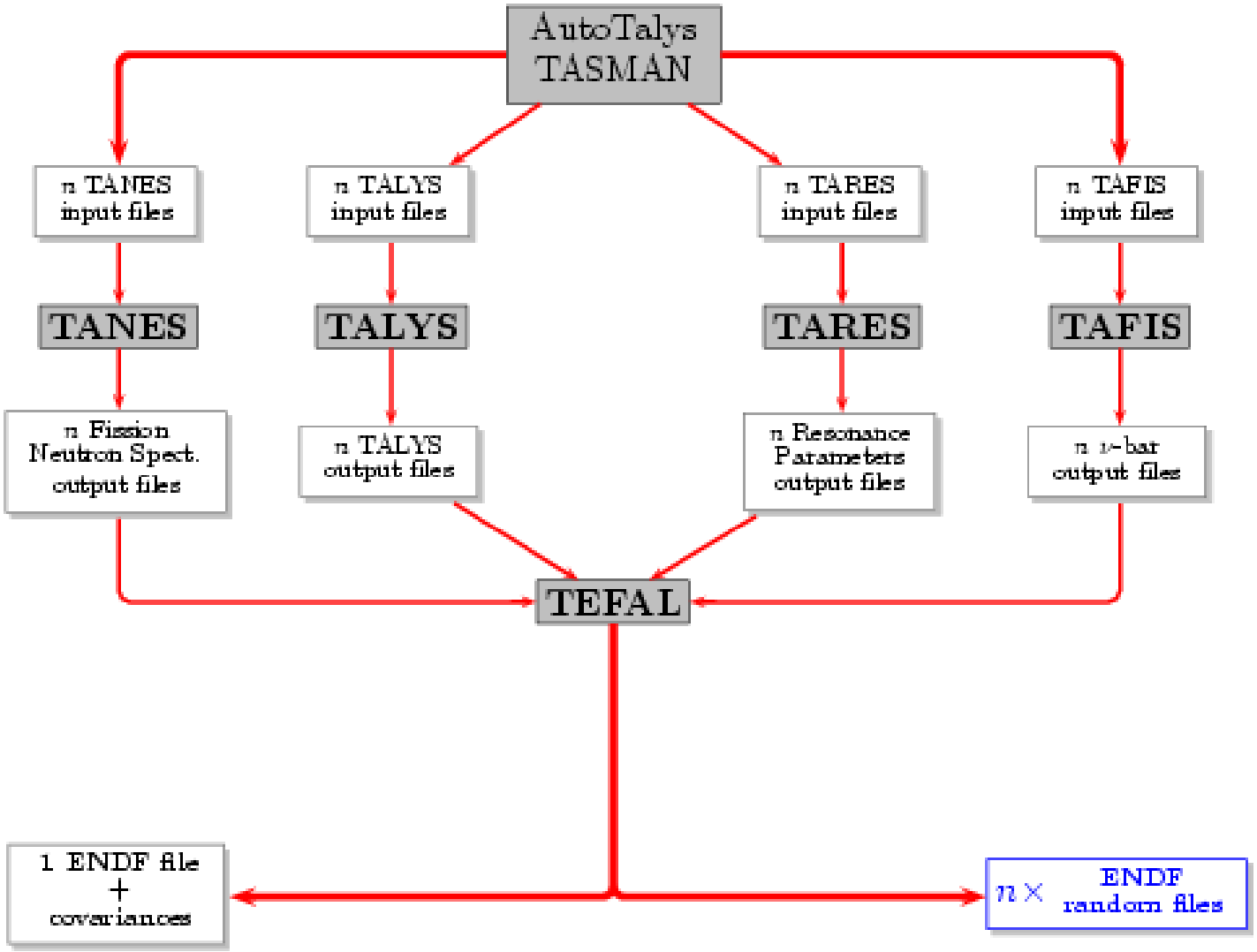
System selection: PWR

- Requirement
  - Current system
  - Simplified model or benchmark available
  - Availability of measured or calculated data

- PWR Westinghouse
  - 85 reactors ‘Westinghouse PWR’ in WNA database
  - Textbook stuff, e.g. described in Duderstadt & Hamilton
  - 17×17 fuel element, U(4.8wt%)O_2
  - Comparisons possible?



Nuclear data production

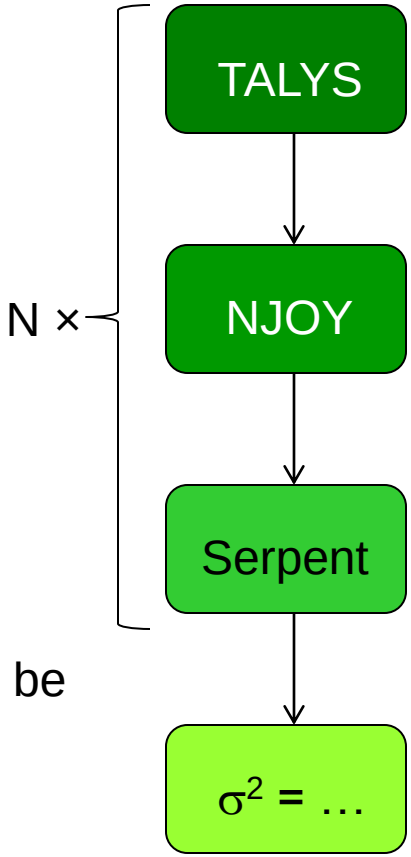


Methodology

- In TALYS input, 20–30 parameters randomized (varied within pre-determined ranges)
- Random resonance parameters generated (varied within pre-determined ranges)
- NJOY-99.336 for processing nuclear data files
- SERPENT used throughout

- Total variance at the end is the sum of
  ‘transport statistics’ + ‘nuclear data variance’

- To disentangle these two, the transport statistics should be well under control
  (convergence is always an issue …)

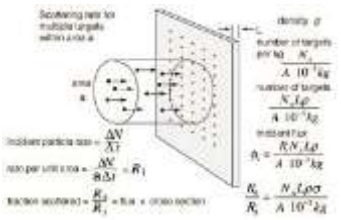


Limitations

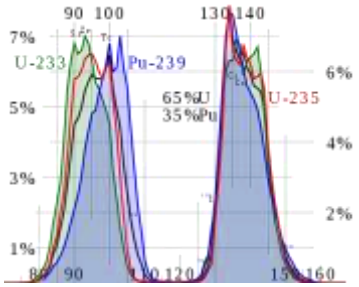
- Only isotopes: $^{235, 236, 238}U$, ^{239}Pu
- No variations in thermal scattering data
- Only nuclear data
  (no geometry, material composition, enrichment variations)

Types of nuclear data

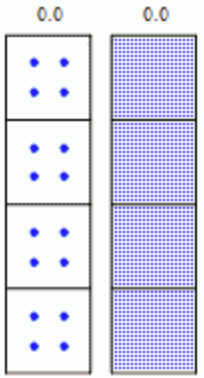
- Transport data
  - ✓ Cross sections
  - ✓ Angular distributions
  - ✓ Double differential data
  - ✓ Emission spectra
- Fission yields
  - ✓ Fission product yields
- Decay data
  - ✓ Half lives
  - ✓ Decay schemes



'Cross section'

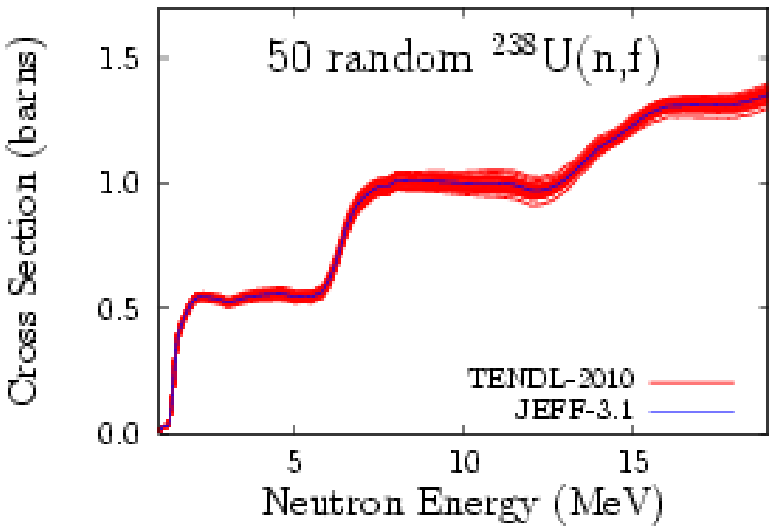


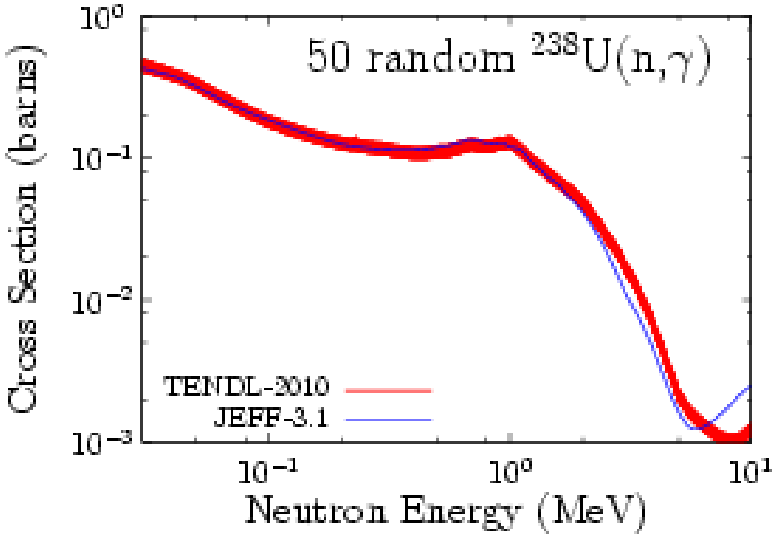
Fission product yields

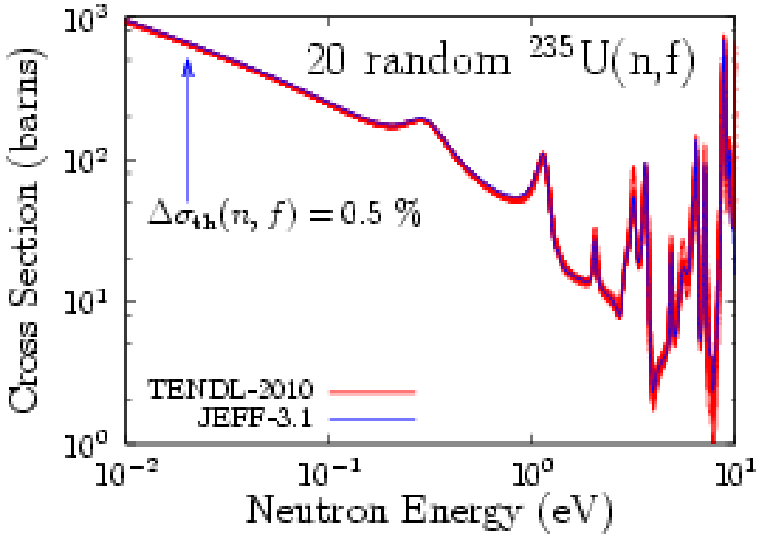


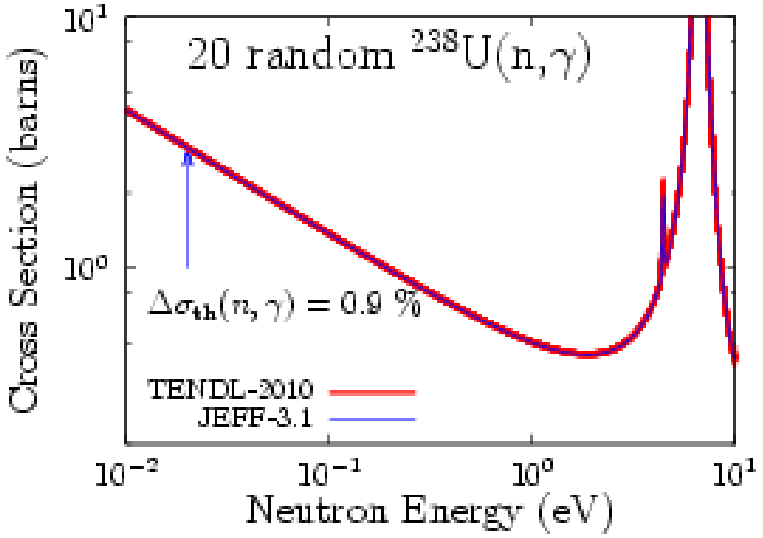
'decay'

Types of nuclear data: cross section

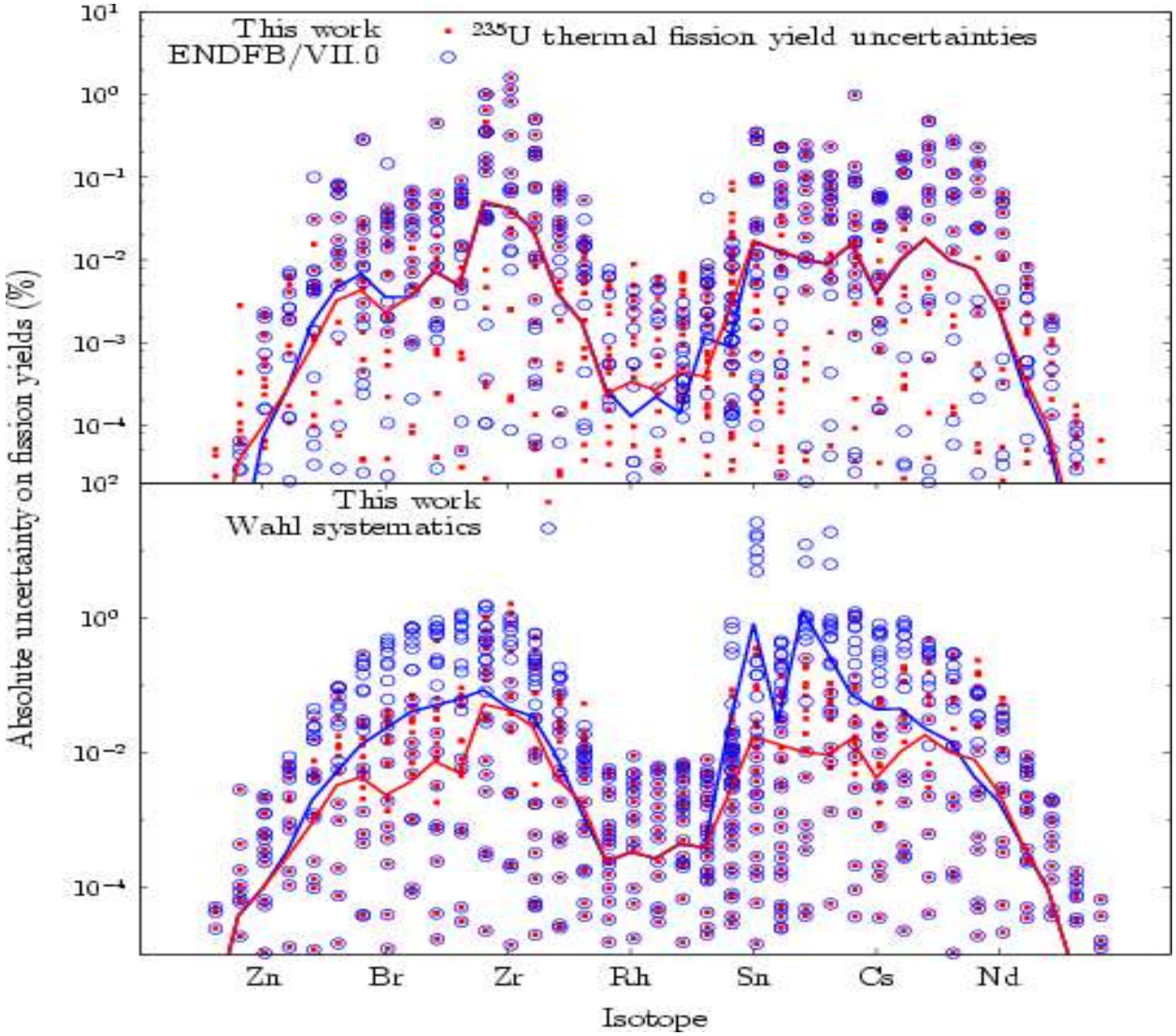






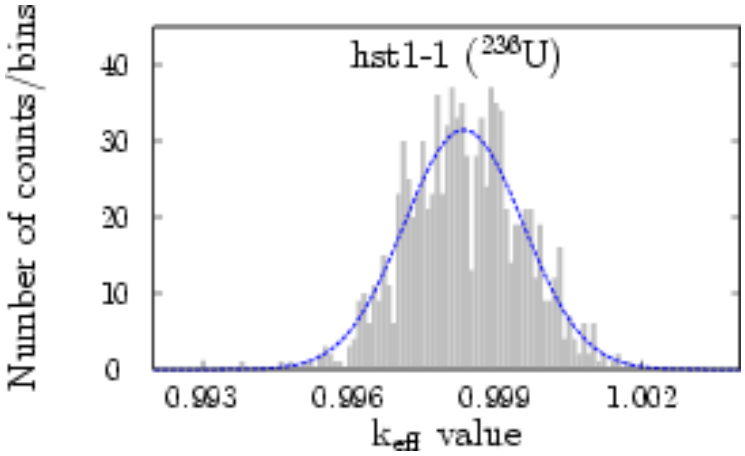


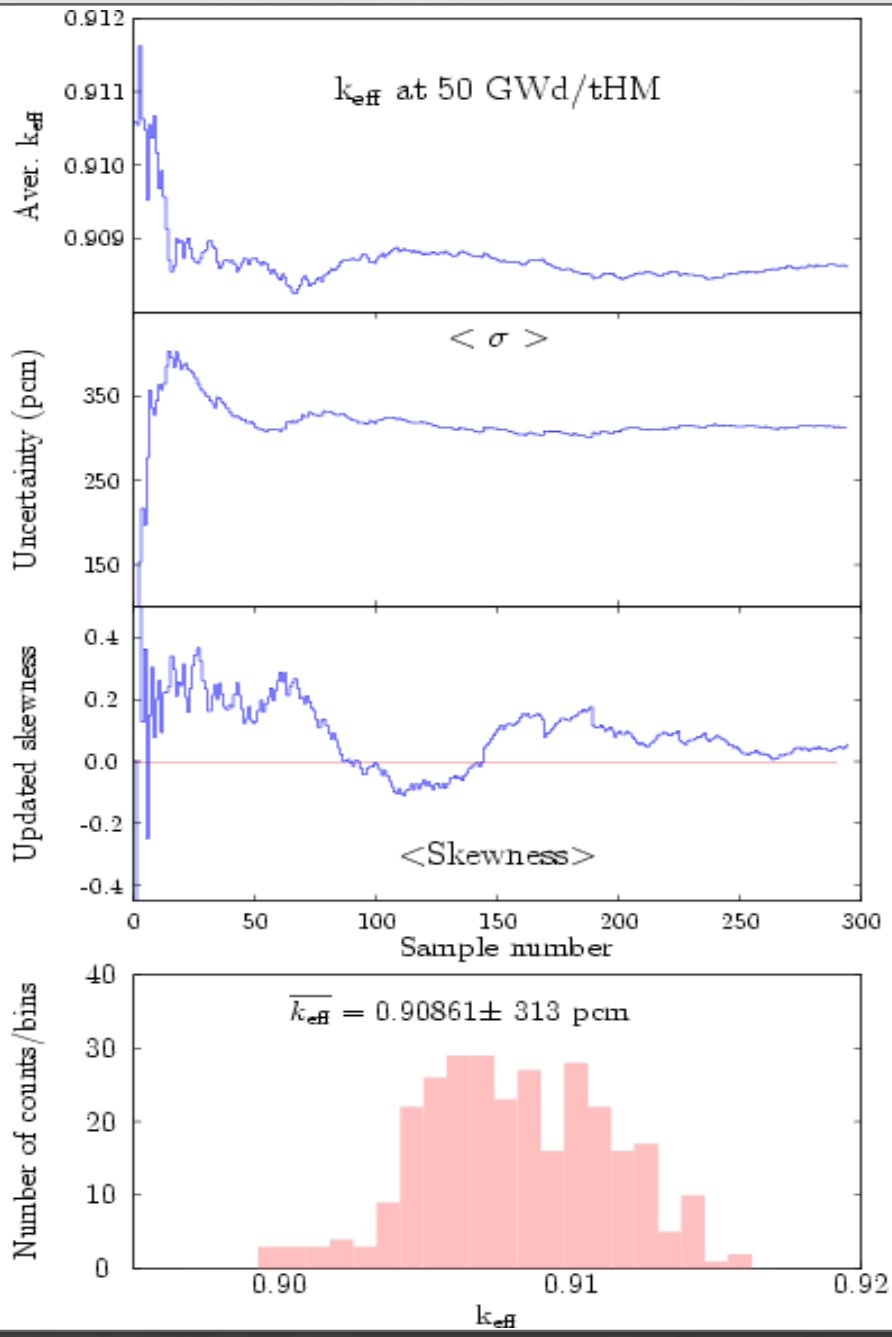
Types of nuclear data: fission yields



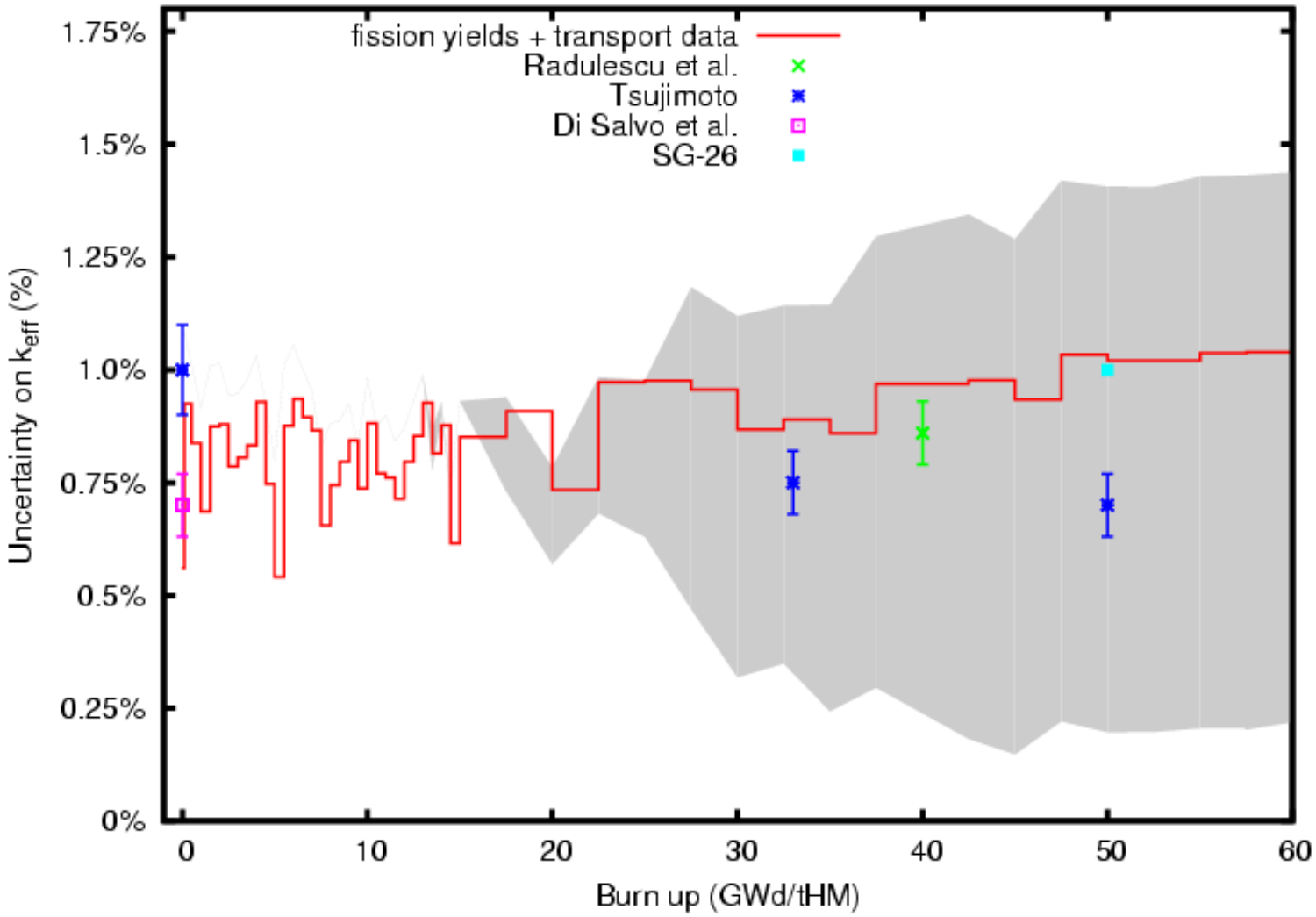
Results

- Calculated quantities
  - First: convergence …
  - Reactivity swing
  - Inventory after 50 GWd/tU
  - Radiotoxicity curve

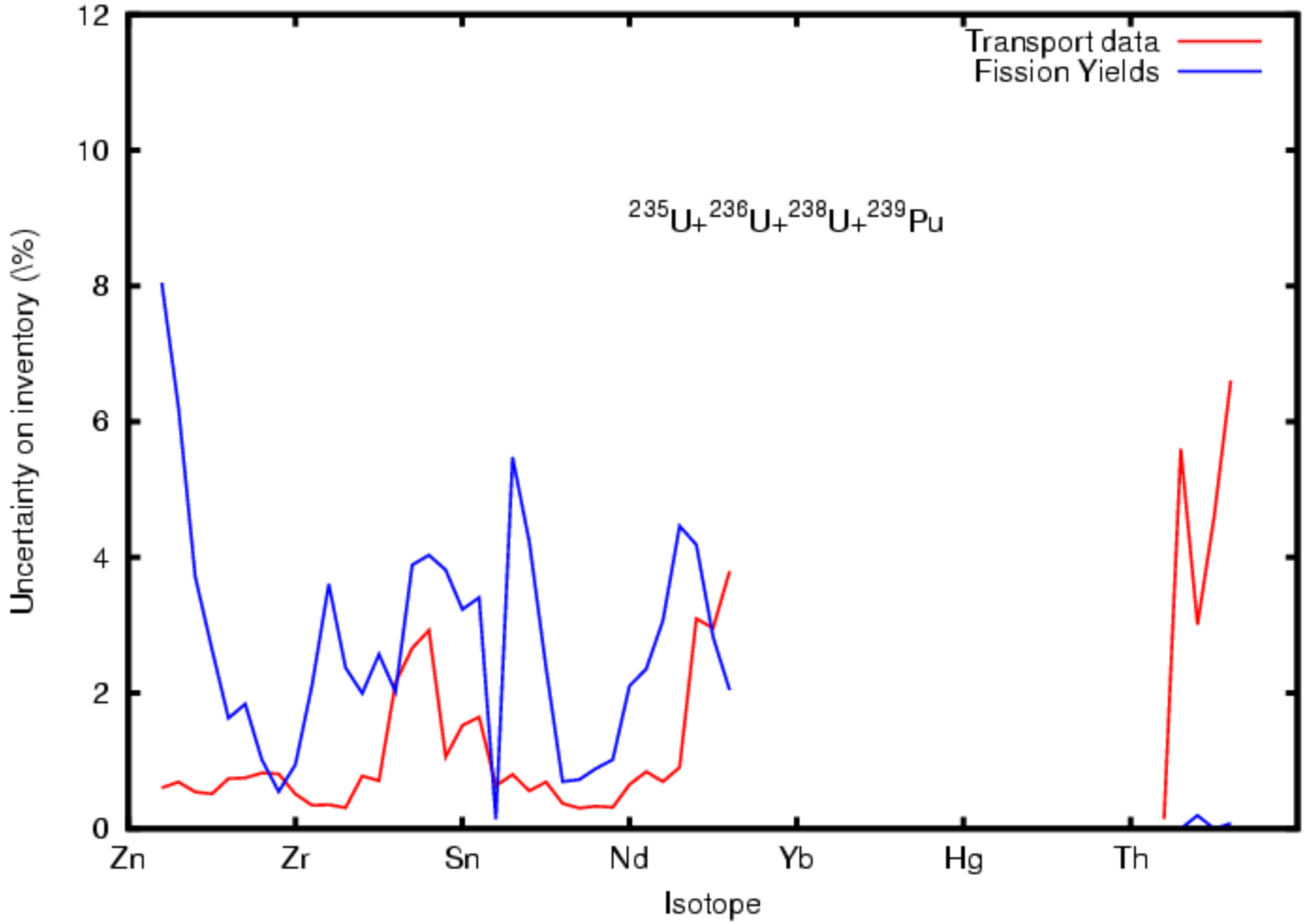




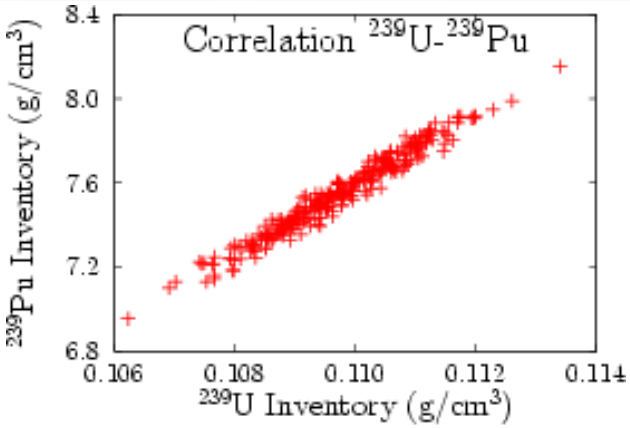
Results: Reactivity swing

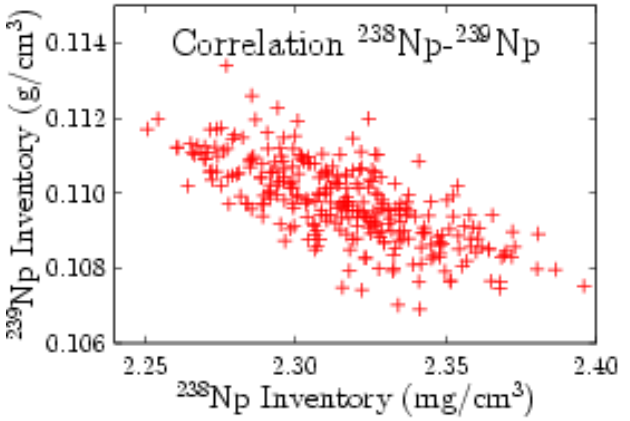


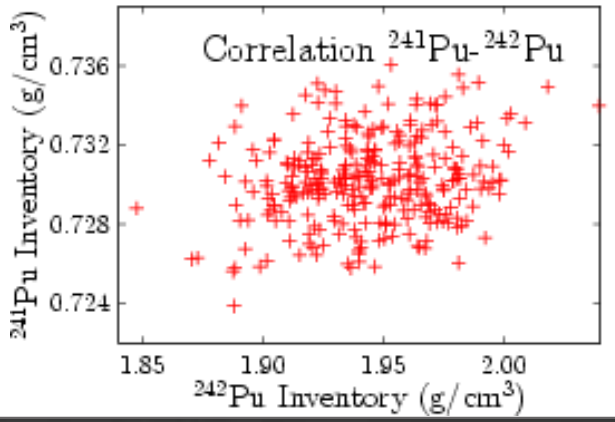
Results: Inventory



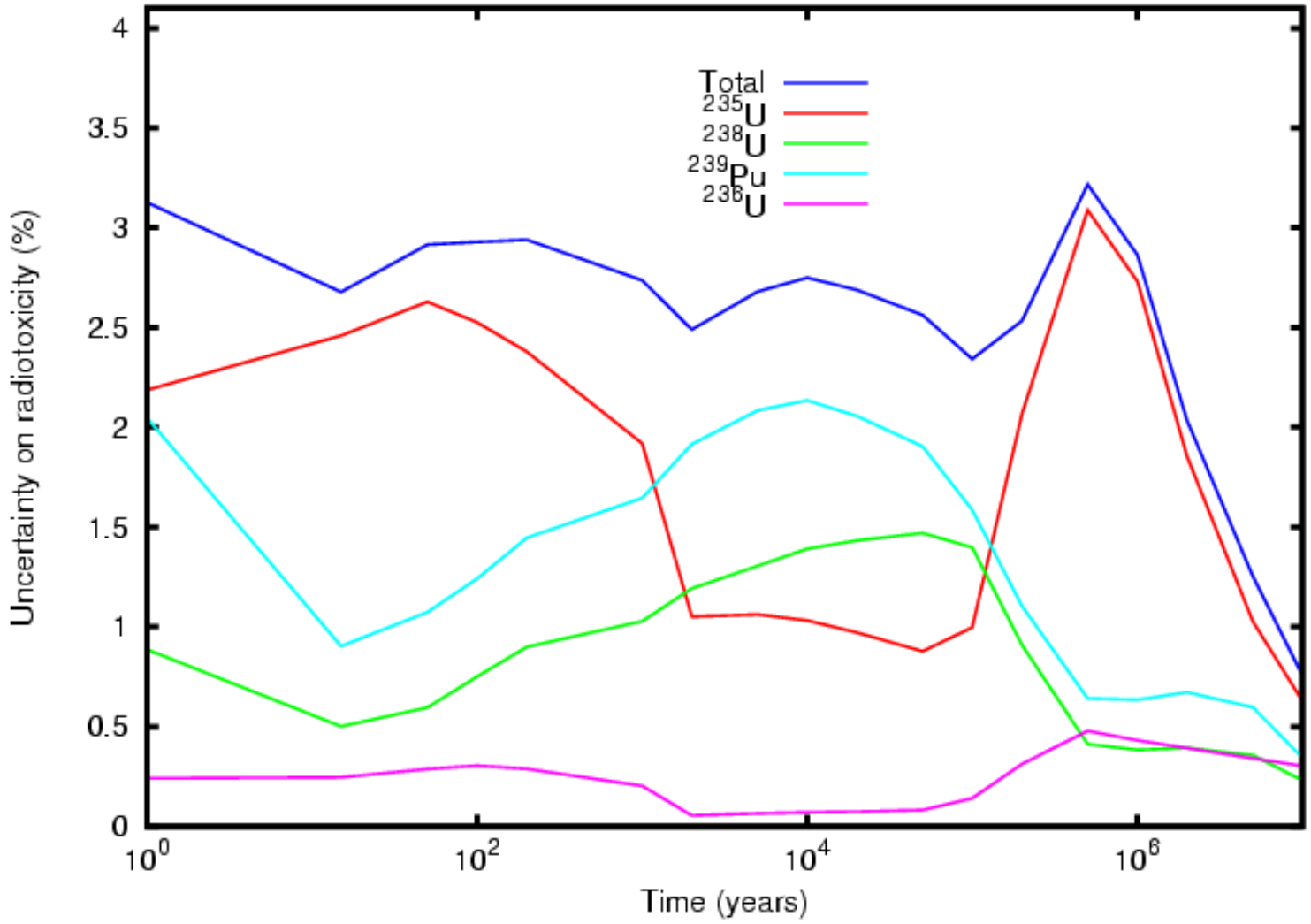
Results: Inventory (2)







Results: Radiotoxicity



Conclusions

- Rigorous approach to nuclear data uncertainty is feasible
- Input uncertainties in this study:
  - ✓ $^{235,236,238}U$, ^{239}Pu
  - ✓ Transport data, fission yield data, decay data
- Output uncertainties in this study:

	Transport	Fiss. yields	Sum
Reactivity	≅ 1 %	0 – 0.7 %	≅ 1 %
Inventory	1 – 7 %	1 – 8 %	1 – 8 %
Radiotoxicity	0.3 – 3 %	0.3 – 3%	1 – 3%

- Fission yields can also contribute to fuel cycle uncertainties