ASNR Autorité de sûreté nucléaire et de radioprotection

INTERCOMPARISON OF NUCLEAR DATA PROCESSING

Vaibhav JAISWAL, Abdoul-Aziz ZAKARI
PSN-RES/SNC/LN

THE FUNDAMENTAL QUESTION

The Reality

- Neutronics simulations rely on evaluated nuclear data (ENDF format)
- ENDF files cannot be used directly by Monte Carlo codes
- Must be "**processed**" into usable formats (ACE files)

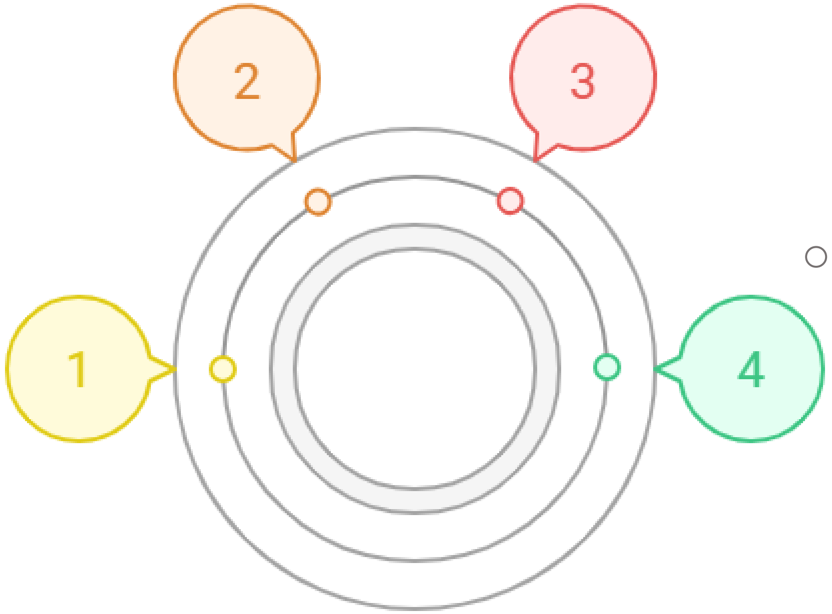
The Problem

Multiple nuclear data processing codes (using somewhat different algorithms):

- NJOY (LANL, US)
- FUDGE (LLNL, US)
- GAIA (ASNR, France)
- AMPX (ORNL, US)

Nuclear Data Processing

A Hidden Variable in Criticality Safety

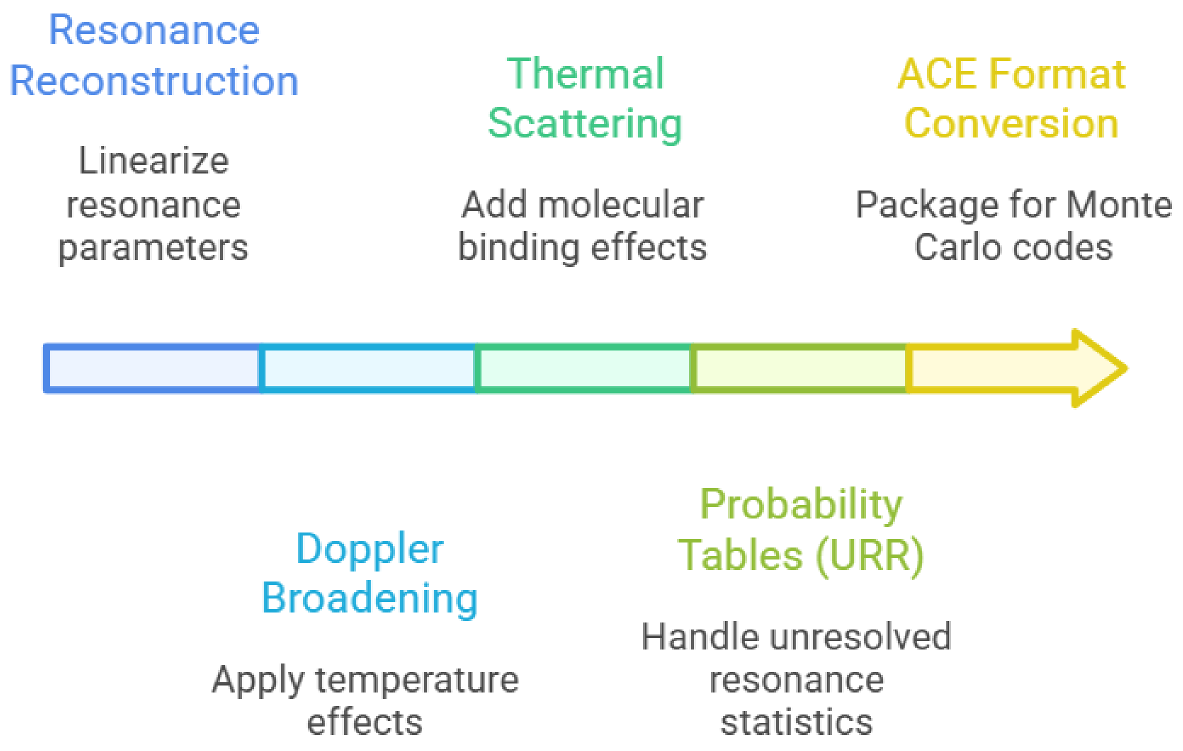


The Question

- Do these processing differences matter for criticality safety?
- Or do they all produce equivalent results?

WHAT ACTUALLY HAPPENS DURING PROCESSING

Five Critical Processing Steps:



Even small algorithmic differences can propagate through all five steps

WHAT ACTUALLY HAPPENS DURING PROCESSING

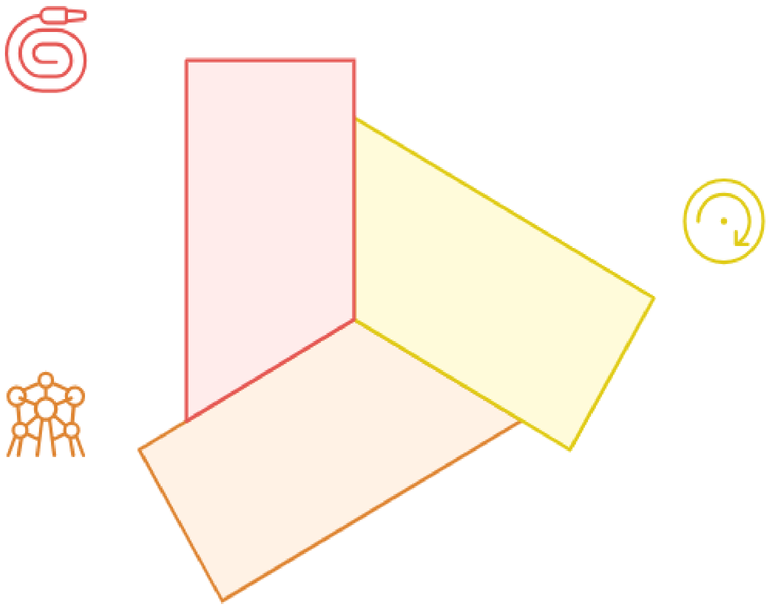
Five Critical Processing Steps:

FUDGE

Python-based code allowing flexible processing order.

GAIA

Integrated workflow where DOP combines steps 1 and 2.



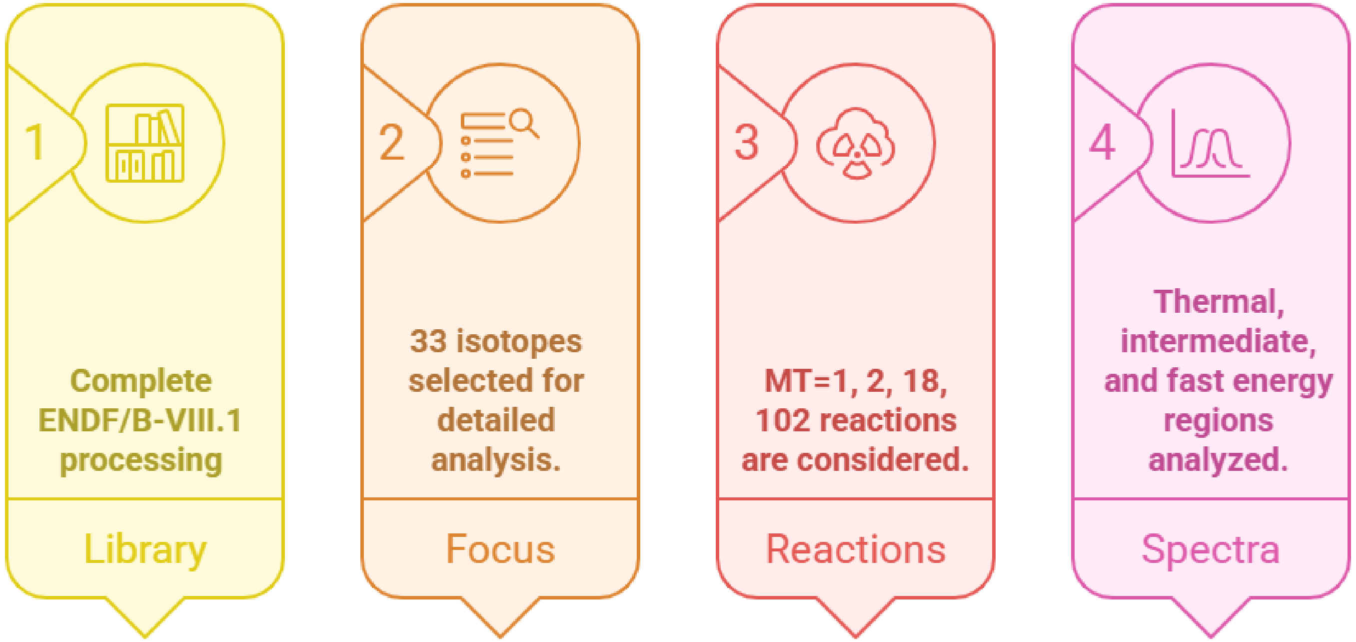
NJOY

Modular Fortran code using sequential processing.

Even small algorithmic differences can propagate through all five steps

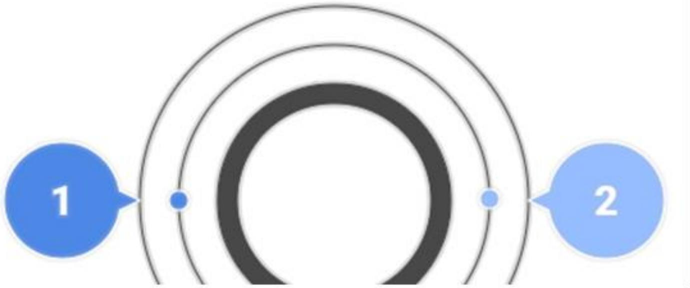
OUR INVESTIGATION STRATEGY

Quantify how processing methodology affects neutronics simulations



Cross Section Differences

- Direct ACE/PENDF file comparison
- Energy-dependent relative differences
- Identify where codes disagree

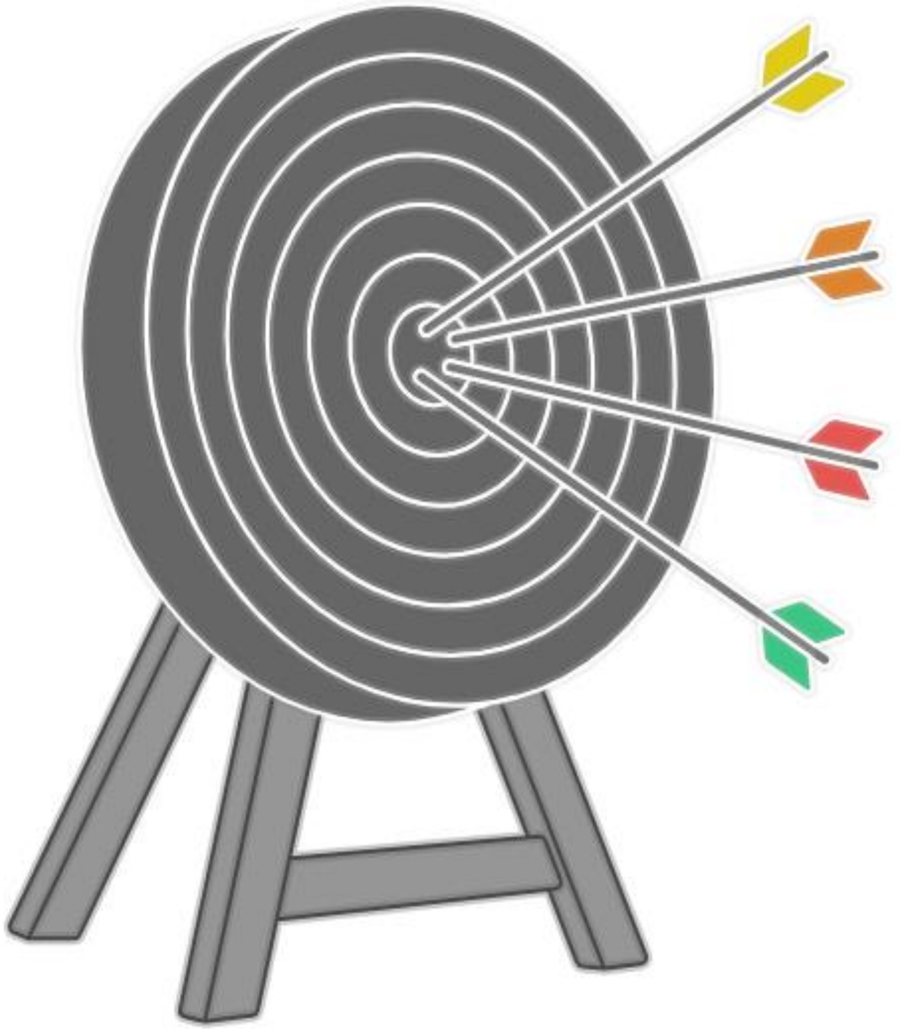


Two-Level Analysis

Impact on Criticality

- ICSBEP benchmark calculations
- k_eff variations between codes
- Correlation: cross sections → reactivity effects

METHODOLOGICAL RIGOR



Phase 1: Baseline Establishment (This Work)

✓ All codes use default (user-defined) processing parameters
✓ Same ENDF/B-VIII.1 source data
✓ Identical temperature grids

Phase 2: Parameter Sensitivity (Planned)

- Systematic variation of reconstruction tolerances
- Different thermal scattering treatments
- Variation of several other processing parameters

Quantitative Metrics

- $\Delta\sigma/\sigma$
- Energy-integrated differences by region
- Statistical distribution analysis

Validation Approach

- CALINS tool → sensitive benchmark selection
- 5 benchmarks per isotope covering different neutron spectra
- Correlate cross sections with k_eff variations

ANALYSIS WORKFLOW

Strategic Selection Covering Key Nuclear Applications

Actinides (12):

- Uranium: ^{234}U, ^{235}U, ^{236}U, ^{238}U
- Plutonium: ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu
- Minor Actinides: ^{237}Np, ^{241}Am, ^{243}Am

Fission Products (15):

- Neutron Poisons: ^{103}Rh, ^{133}Cs, ^{149}Sm, ^{152}Sm, ^{155}Gd
- Other FP: ^{95}Mo, ^{99}Tc, ^{101}Ru, ^{109}Ag, ^{143}Nd, ^{145}Nd, ^{147}Sm, ^{150}Sm, ^{151}Sm, ^{153}Eu

Structural Materials (6):

- Iron: ^{54}Fe, ^{56}Fe, ^{57}Fe, ^{58}Fe
- Copper: ^{63}Cu, ^{65}Cu

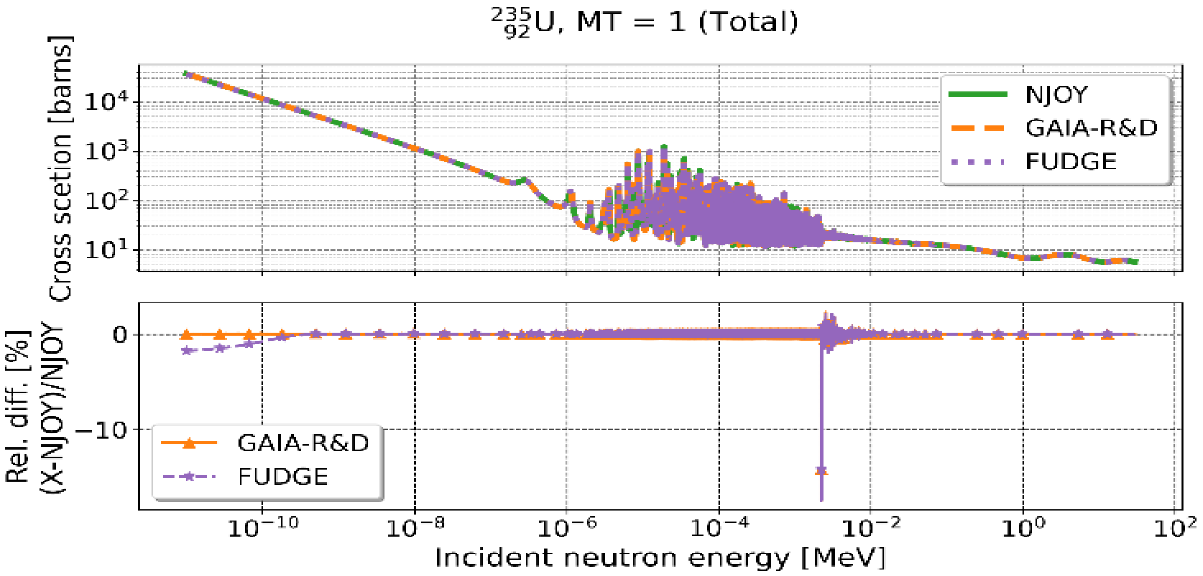
Selection Rationale:

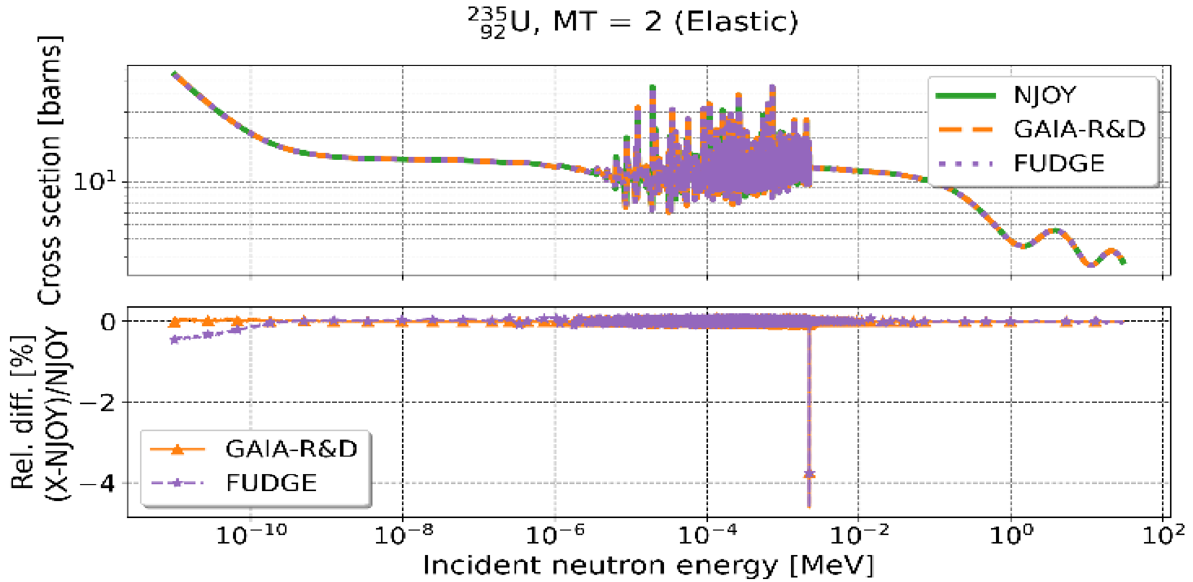
- Criticality safety relevance across all spectra
- Diverse nuclear properties (fissile, fertile, absorbers)
- Representative of reactor fuel and structural compositions

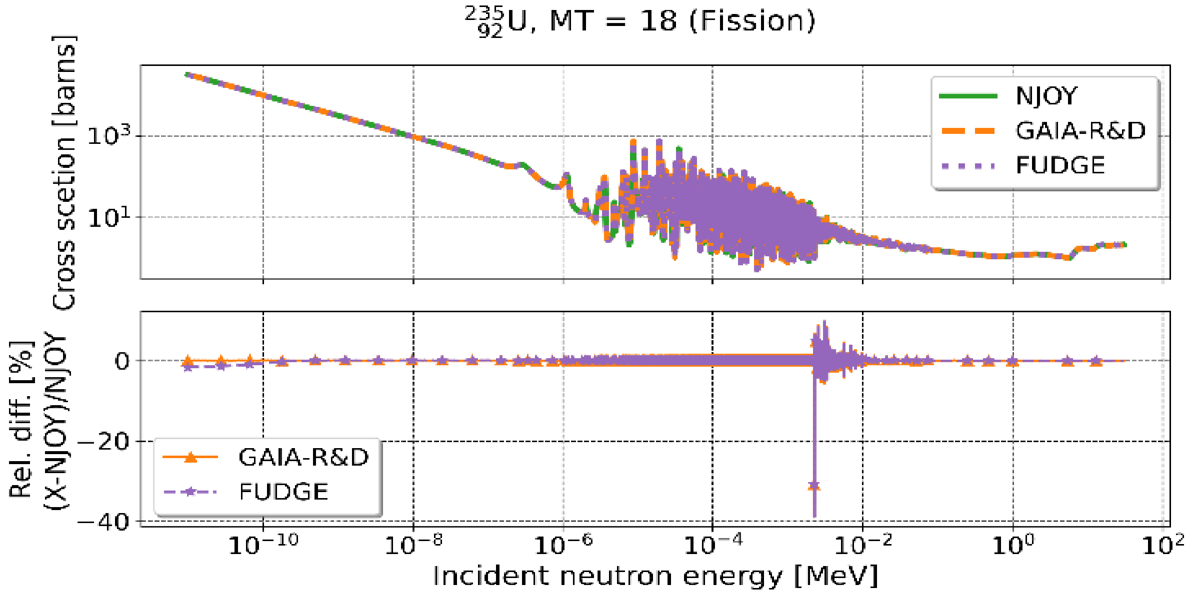
Study Approach:

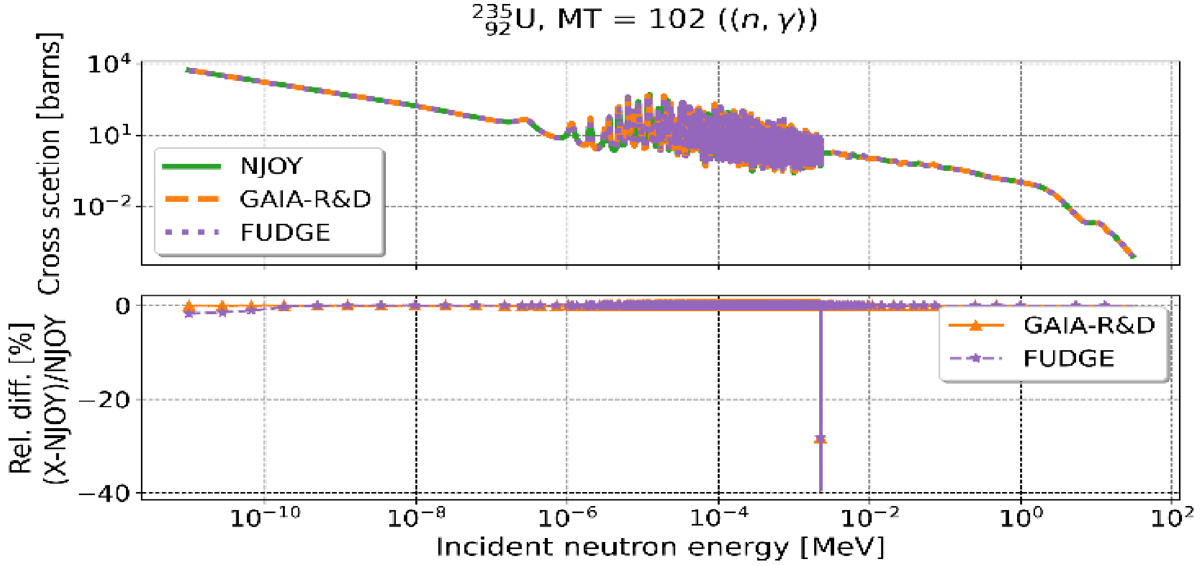
- **Phase 1 (This Presentation):** Default parameters used for FUDGE, NJOY, and GAIA → Establishes baseline comparison → Identifies inherent code methodology differences
- **Phase 2 (Planned):** Systematic parameter variation study → Quantifies parameter sensitivity → Separates parameter effects from methodology differences → *AMPX processing to be included in future phase*

PRELIMINARY RESULTS - CROSS SECTIONS: U235

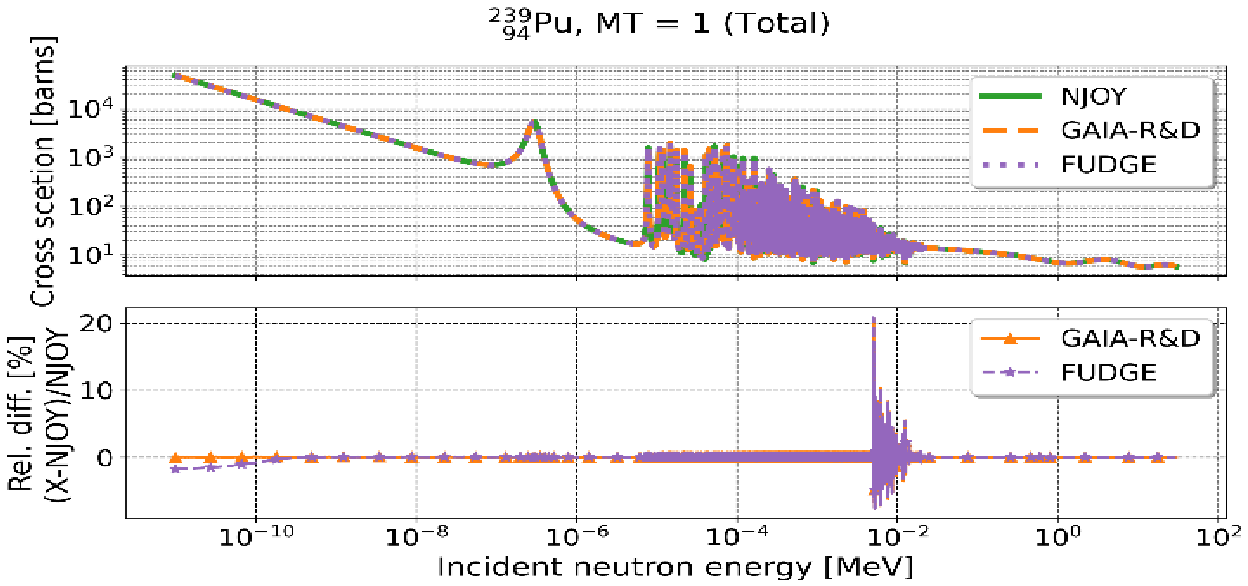


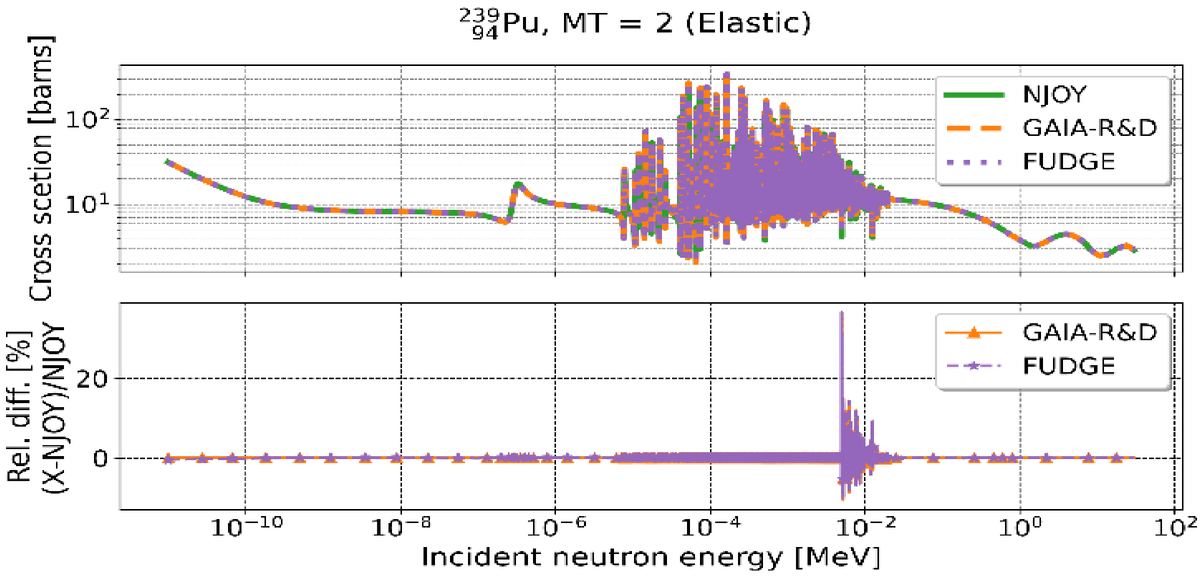


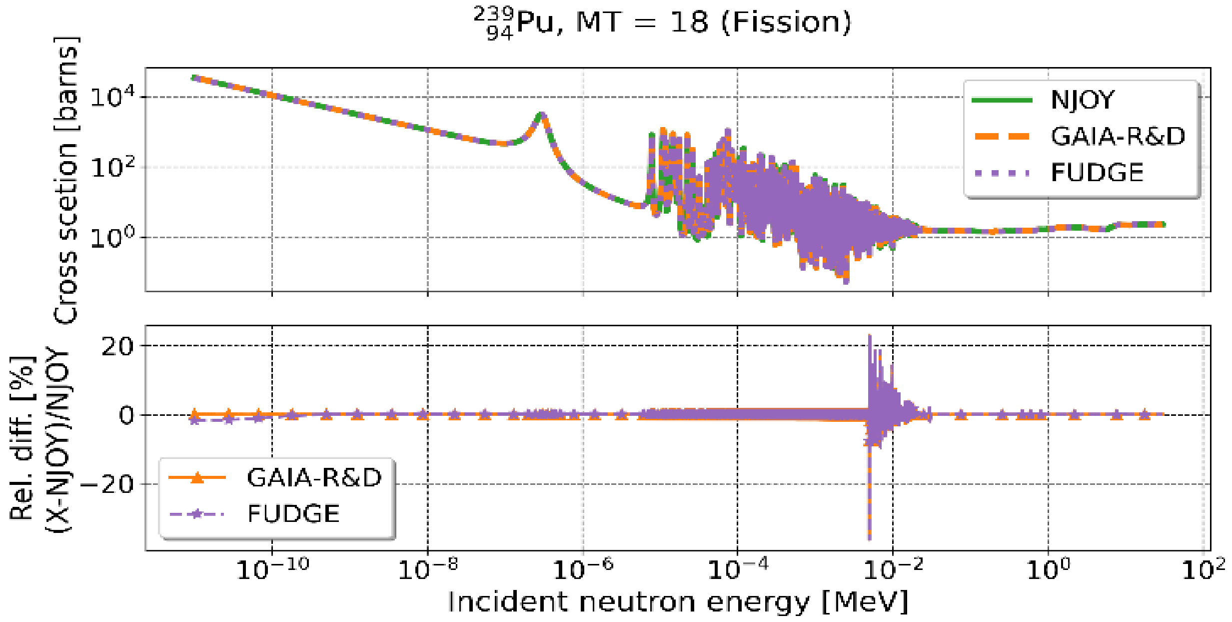


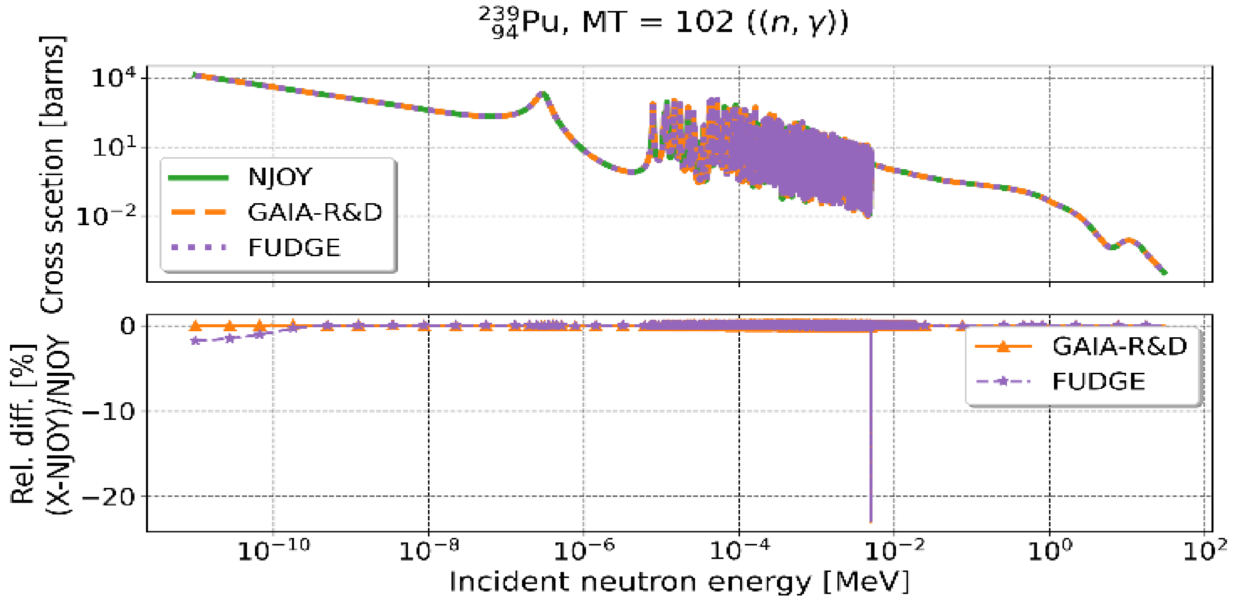


PRELIMINARY RESULTS - CROSS SECTIONS: PU239

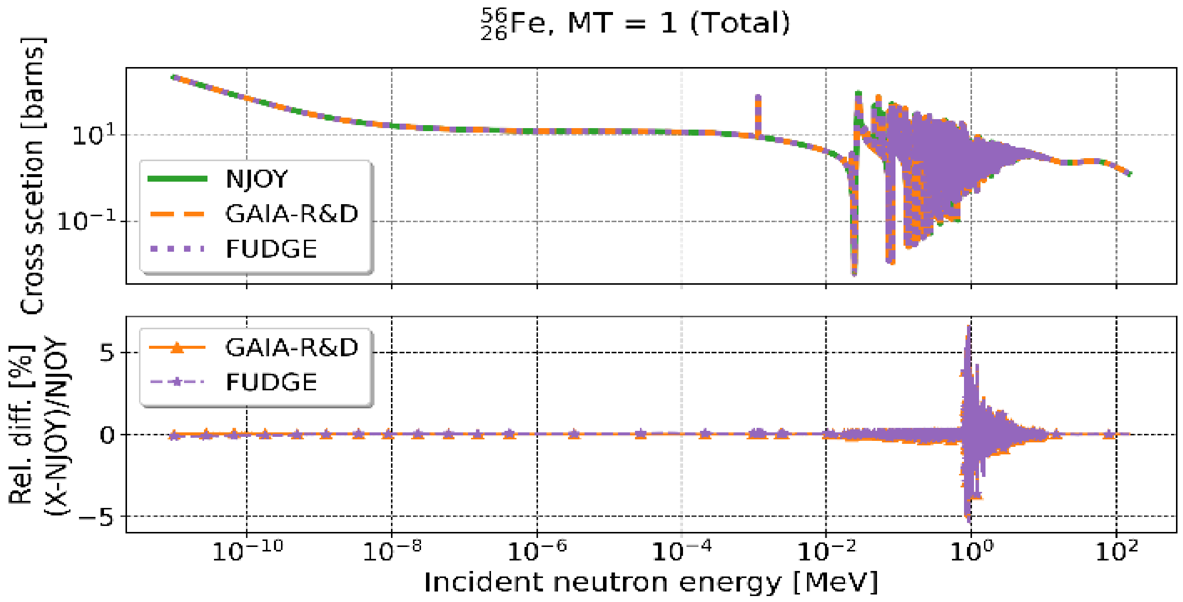


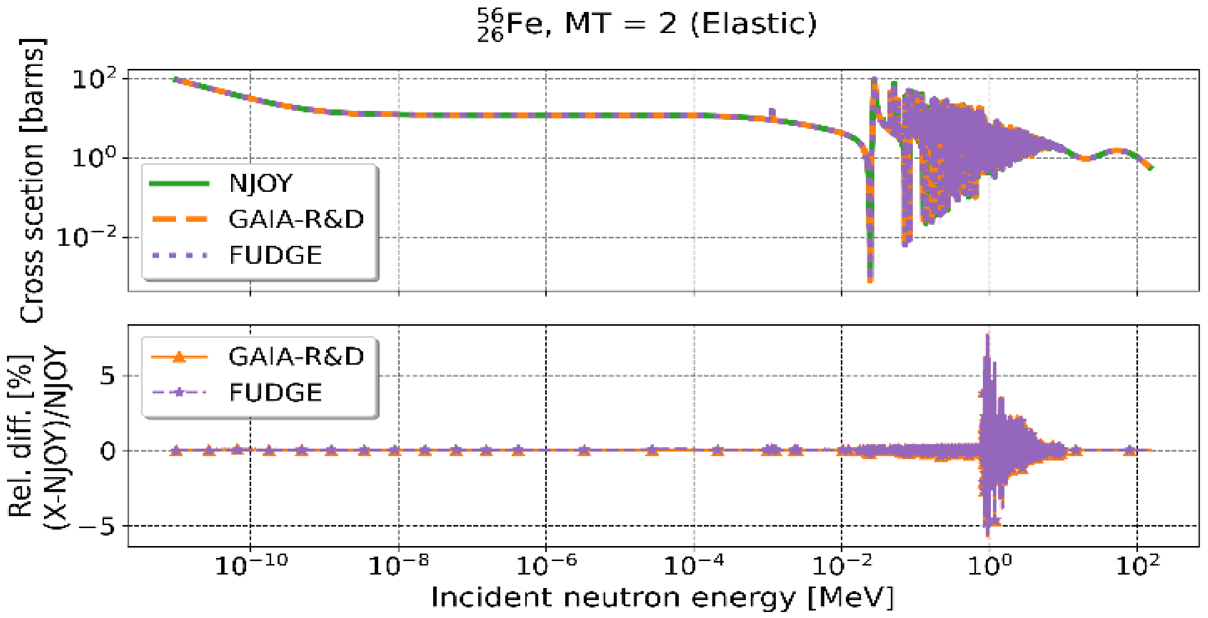


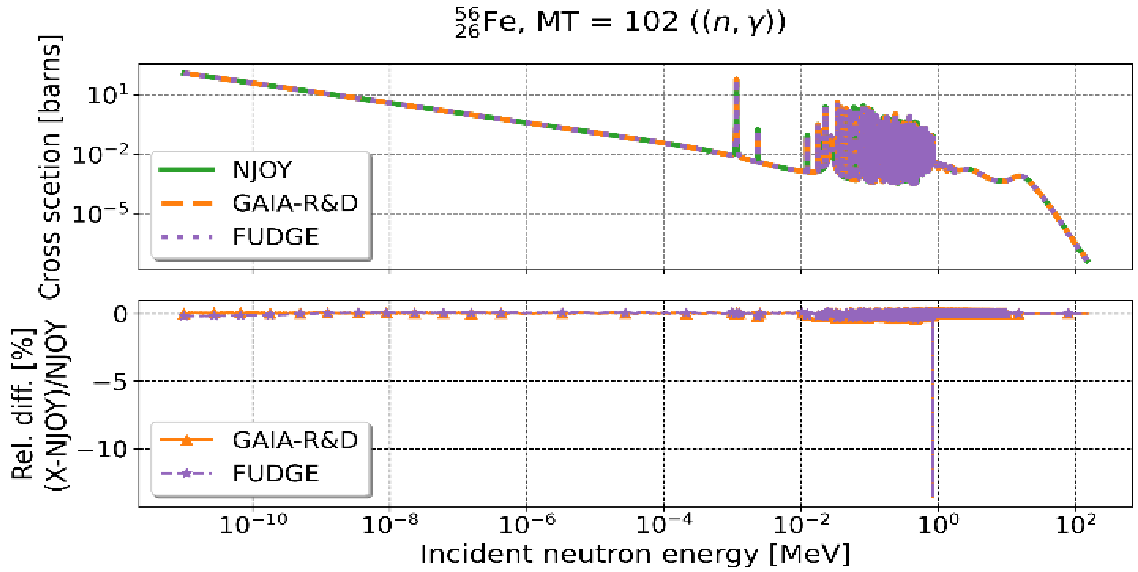




PRELIMINARY RESULTS - CROSS SECTIONS: FE56







BENCHMARK IMPACT

DICE Database: 4,259 ICSBEP Benchmarks

Sensitivity data in .sdf format

↓

Sensitivity Criterion

$$\left|\sum_{i=X}^{i=Y} S_i\right| > \theta$$

θ = user-defined threshold

↓

Three Spectral Regions

Thermal: 1e-5 eV → 0.605 eV

Intermediate: 0.605 eV → 100 keV

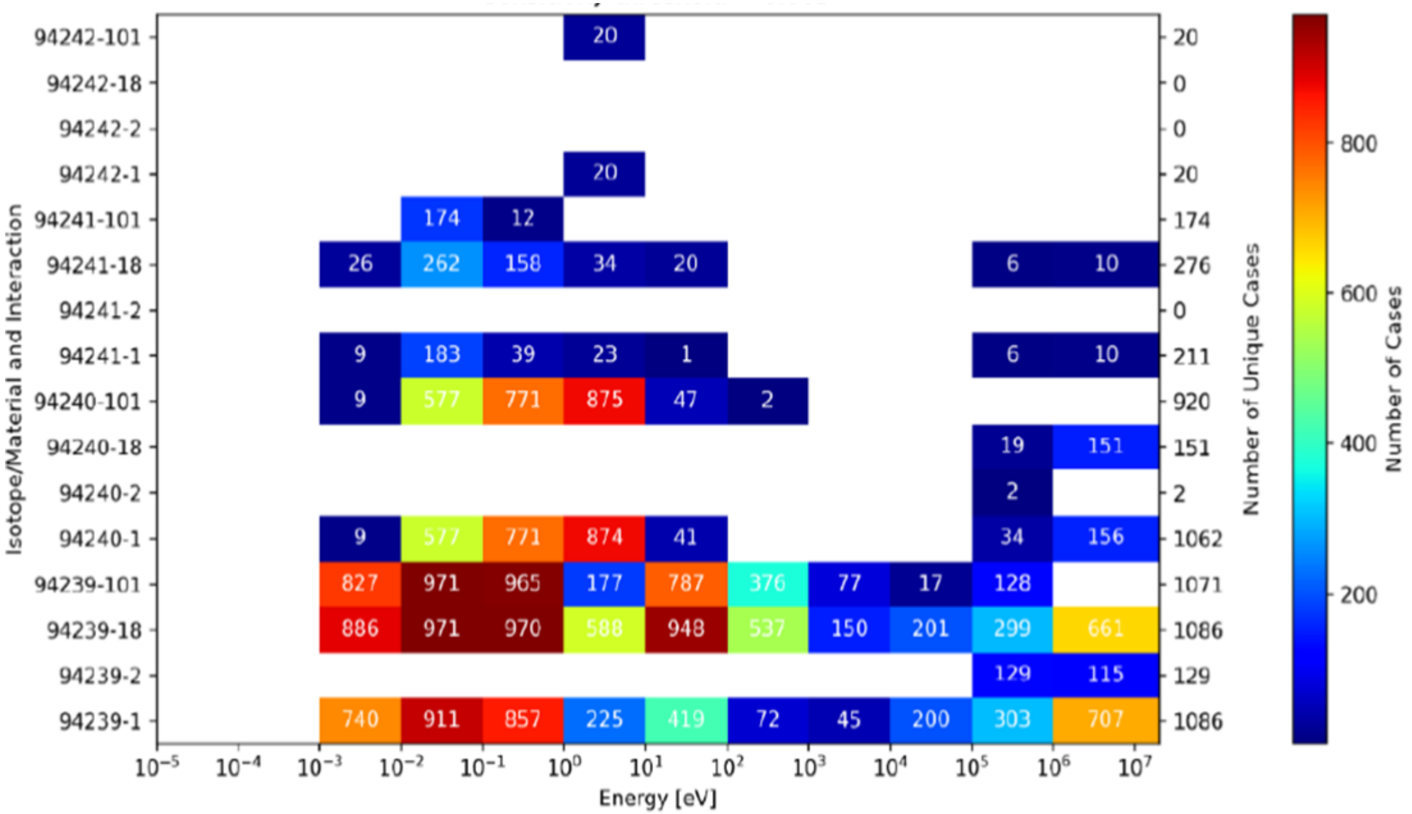
Fast: 100 keV → 20 MeV

↓

Selected Benchmarks

5 benchmarks per isotope covering all spectra

165 total benchmarks for 33 isotopes



Sensitivity heatmap of ICSBEP benchmarks for the total, capture, elastic, and fission for Pu

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		NJOY	GAIA	Delta
	Thermal energy region			
1	PU-SOL-THERM-012-004	1.00219	1.00154	**-64**
2	PU-SOL-THERM-012-003	1.00093	1.00112	**20**
3	PU-SOL-THERM-012-002	1.00018	1.00005	**-12**
	Intermediate energy region			
1	MIX-MET-INTER-004-001	0.97992	0.97973	**-18**
2	MIX-MET-INTER-003-001	0.97053	0.96981	**-71**
3	PU-MET-INTER-002-001	1.00391	1.00375	**-15**
4	MIX-MISC-MIXED-001-004	1.00654	1.00666	**13**
	Fast energy region			
1	PU-MET-FAST-022-001	0.99784	0.99824	**41**
2	PU-MET-FAST-001-001	1.00100	1.00040	**-59**
3	PU-MET-FAST-025-001	0.99977	0.99984	**8**
4	PU-MET-FAST-035-001	0.99714	0.99708	**-5**
5	PU-MET-FAST-040-001	0.99362	0.99341	**-20**

A preliminary result of GAIA and NJOY processing effect on benchmarks sensitive to Pu239

PRELIMINARY CONCLUSIONS

Status

- This is a kick-off study demonstrating feasibility.
- Robust, large-scale work is needed next.

Initial Findings

- Processing codes produce generally good agreement (~1% typical)
- Local differences in certain energy regions (resonances, URR)
- Differences arise from algorithmic choices, not errors

Key Insight

- Cross section variations are quantifiable
- But their impact on criticality safety needs comprehensive investigation

Methodology Established

- Systematic framework for comparing processing codes
- Automated workflows and analysis tools Quasi-operational

THE BROADER VISION

The Real Work Begins Now

Comprehensive Baseline Processing Campaign

Process ENDF/B-VIII.1 library using major codes

- FUDGE
- NJOY
- GAIA
- AMPX
- Any other ?

Develop a common standard

- All isotopes, all temperatures, all reaction channels
- Standardized comparison methodology

Why This Matters

Current work demonstrates how to compare an entire nuclear data library (processing effect) needed for meaningful criticality safety conclusions.

International Collaboration

We envision working on this exercise with participants from: ORNL, LLNL, LANL, NNL

CALL TO ACTION

Finalize Current Study

- ❖ Carry out ICSBEP benchmark calculations with NJOY, GAIA, FUDGE and AMPX with baseline parameters for all 33 isotopes

Launch Full-Scale Campaign (FY 2026)

- ❖ Coordinate with ORNL, LLNL, LANL, NNL
- ❖ Collect/share processed nuclear data libraries
- ❖ Establish common quality metrics

Systematic Parameter Studies

- ❖ Processing parameter sensitivity
- ❖ Temperature effects
- ❖ Thermal scattering treatment variations

Our Ask to Collaborators:

- ❖ Active participation in processing efforts
- ❖ Joint analysis of results

Timeline:

- ❖ Ready to start working robustly—we need your involvement to make it comprehensive and credible.

- ❖ This presentation demonstrates the methodology and invites collaboration for the real work ahead.