JEFF-3.3 covariance application to ICSBEP using SANDY and NDaST

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WONDER 2018 : 5th International Workshop On Nuclear Data Evaluation for Reactor applications
Oct 8, 2018 – Oct 12, 2018

Outline

- Comparison of two state-of-the art tools for nuclear data uncertainty propagation
  - NDaST
  - SANDY
- JEFF-3.3 covariance propagation
- Comparison of results for ICSBEP criticality benchmarks
  - Effect of angular distribution covariance data
  - Effect of energy distribution covariance data

NDaST

- Java-based software
- NEA sensitivity tool
- Linear perturbation theory
- User friendly GUI

$$COV_{keff} = S\,COV_{ND}\;S^T$$

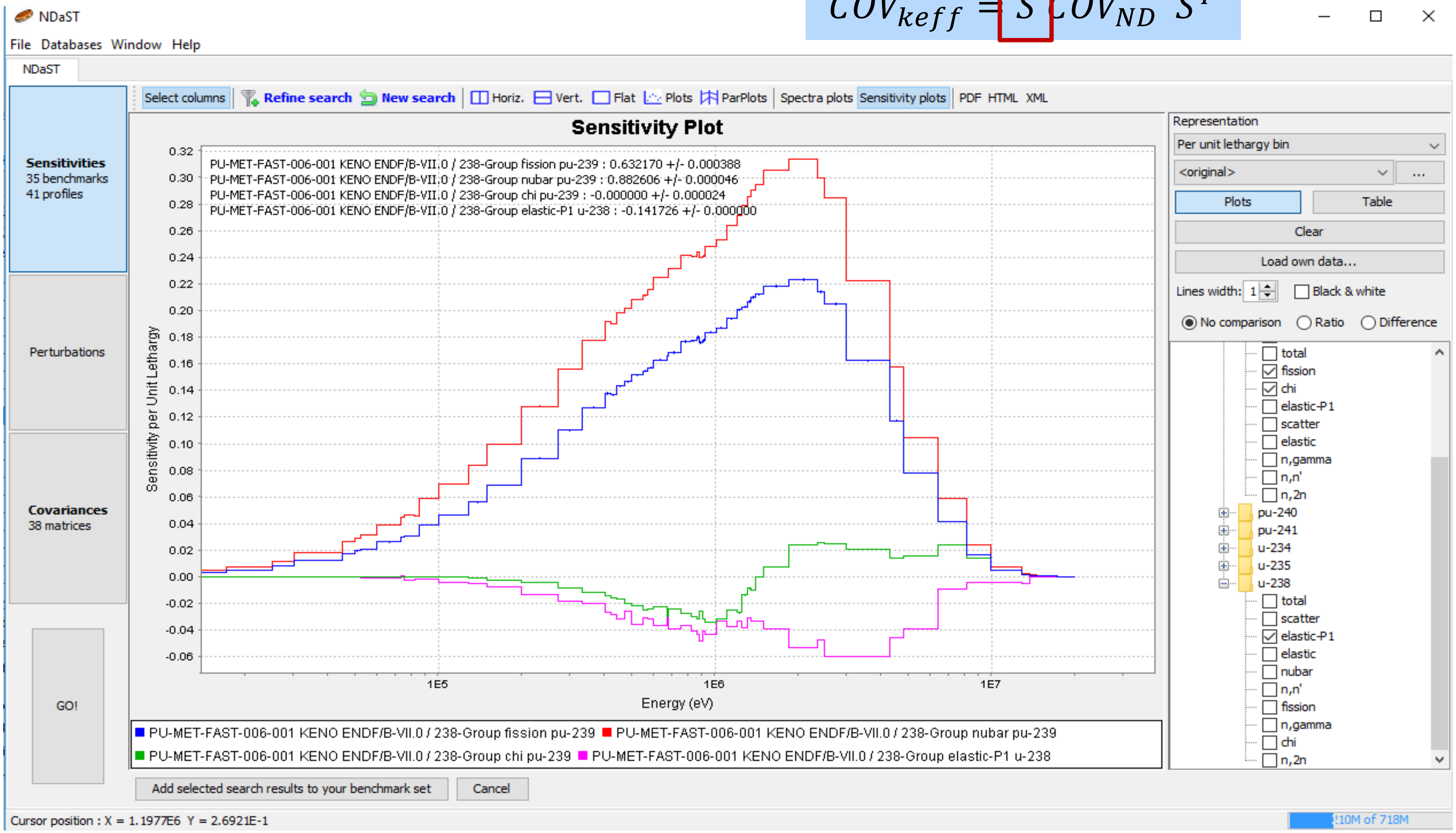
SANDY

- Python3 package
- Sampling of nuclear data
- Whole phase-space of the problem
- Production of *perturbed* files for brute force uncertainty propagation

$$\left.\begin{array}{lll} x_1^{(1)}, x_2^{(1)}, \dots, x_3^{(1)} \longrightarrow & f(x_1^{(1)}, x_2^{(1)}, \dots, x_3^{(1)}) \longrightarrow & y^{(1)} \\ x_1^{(2)}, x_2^{(2)}, \dots, x_3^{(2)} \longrightarrow & f(x_1^{(2)}, x_2^{(2)}, \dots, x_3^{(2)}) \longrightarrow & y^{(2)} \\ x_1^{(N)}, x_2^{(N)}, \dots, x_3^{(N)} \longrightarrow & f(x_1^{(N)}, x_2^{(N)}, \dots, x_3^{(N)}) \longrightarrow & y^{(N)} \end{array}\right\} COV_y$$

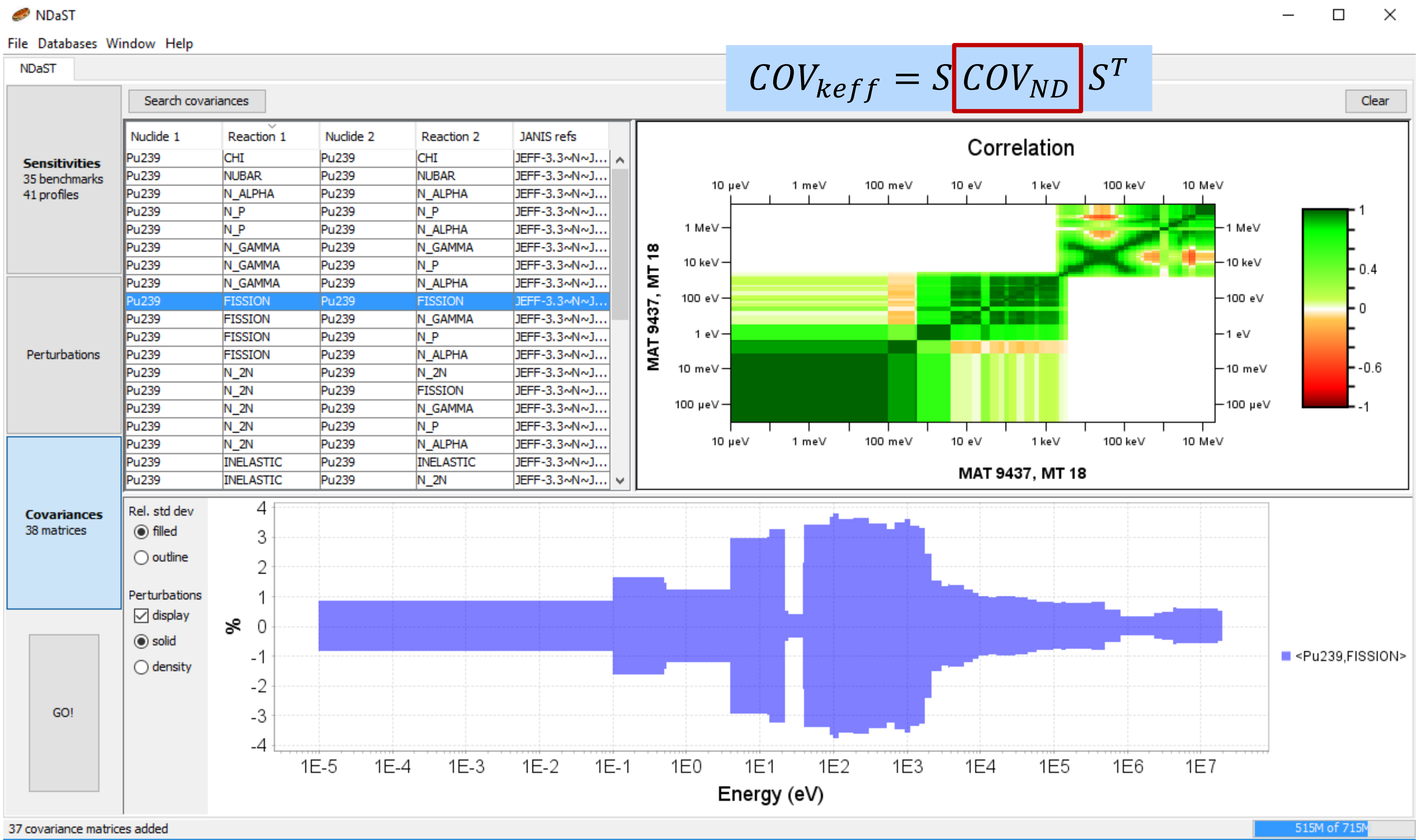
Sensitivities from DICE

$$COV_{keff} = \boxed{S}\, COV_{ND}\ S^T$$



Covariances from JANIS

$$COV_{keff} = S\, \boxed{COV_{ND}}\, S^T$$



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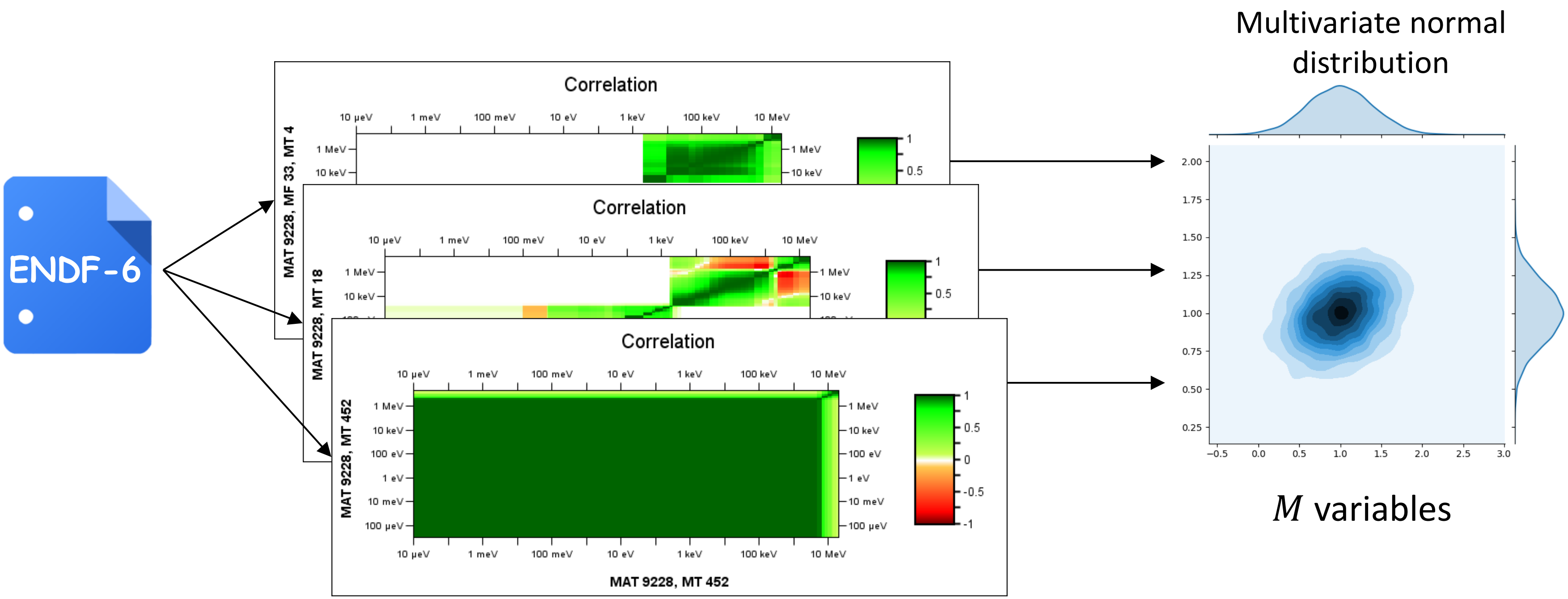
Why SANDY?

- It samples from the covariances in the file
- It can perturb all nuclear data for which covariances are given
- It can be used with any code (provided that you can process the perturbed files)
- It is open-source

Sampling method

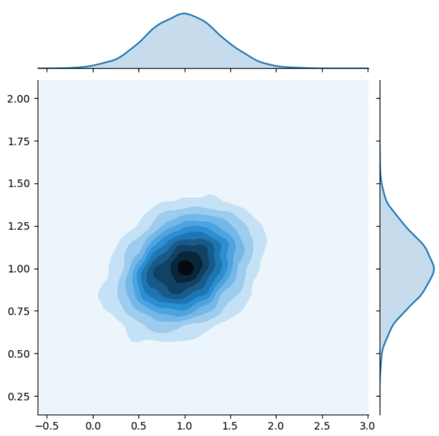
Extract covariances from ENDF-6 evaluated file



Sampling method

Draw N sets of perturbations

Multivariate normal distribution



$$(p_1 \quad p_2 \quad \cdots \quad p_M)^{(1)}$$

$$(p_1 \quad p_2 \quad \cdots \quad p_M)^{(2)}$$

$$\vdots$$

$$(p_1 \quad p_2 \quad \cdots \quad p_M)^{(N)}$$

Sampling method

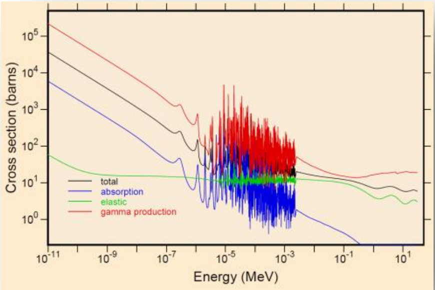
- ❑ Apply perturbations to original data

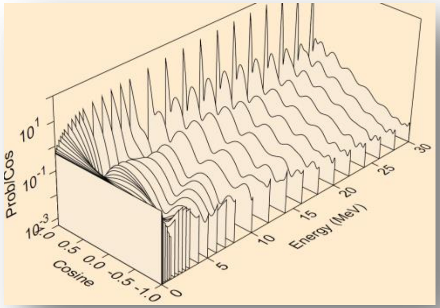
$$(p_1 \quad p_2 \quad \cdots \quad p_M)^{(1)} \longrightarrow$$

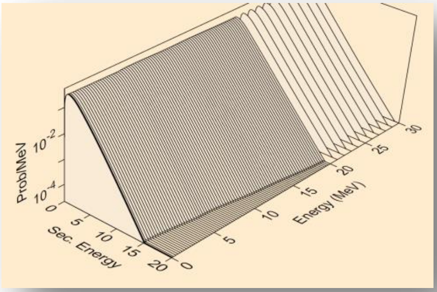
$\longrightarrow$

perturbed file

- xs
- nubar
- PFNS
- ang. distr.
- …

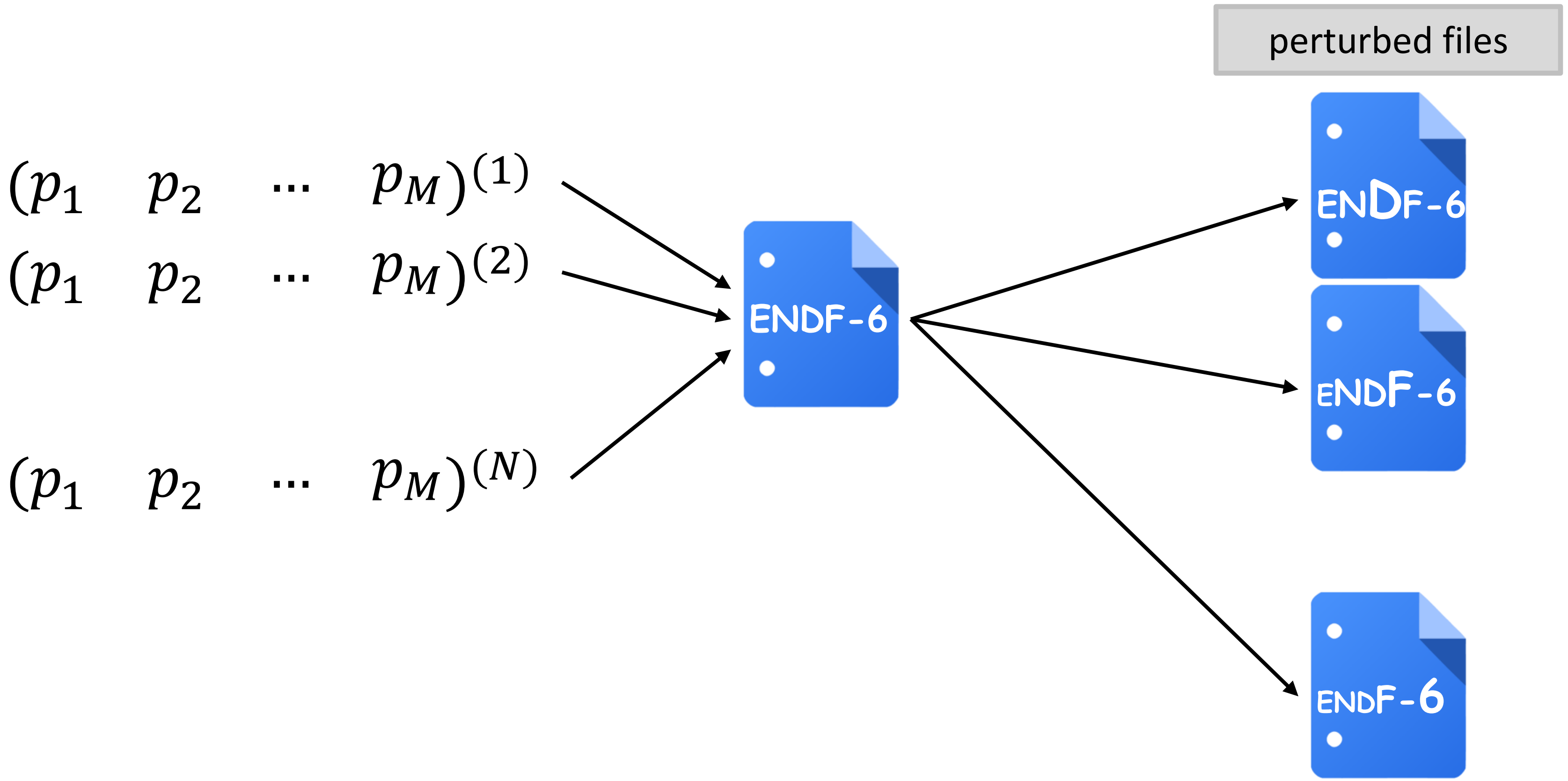




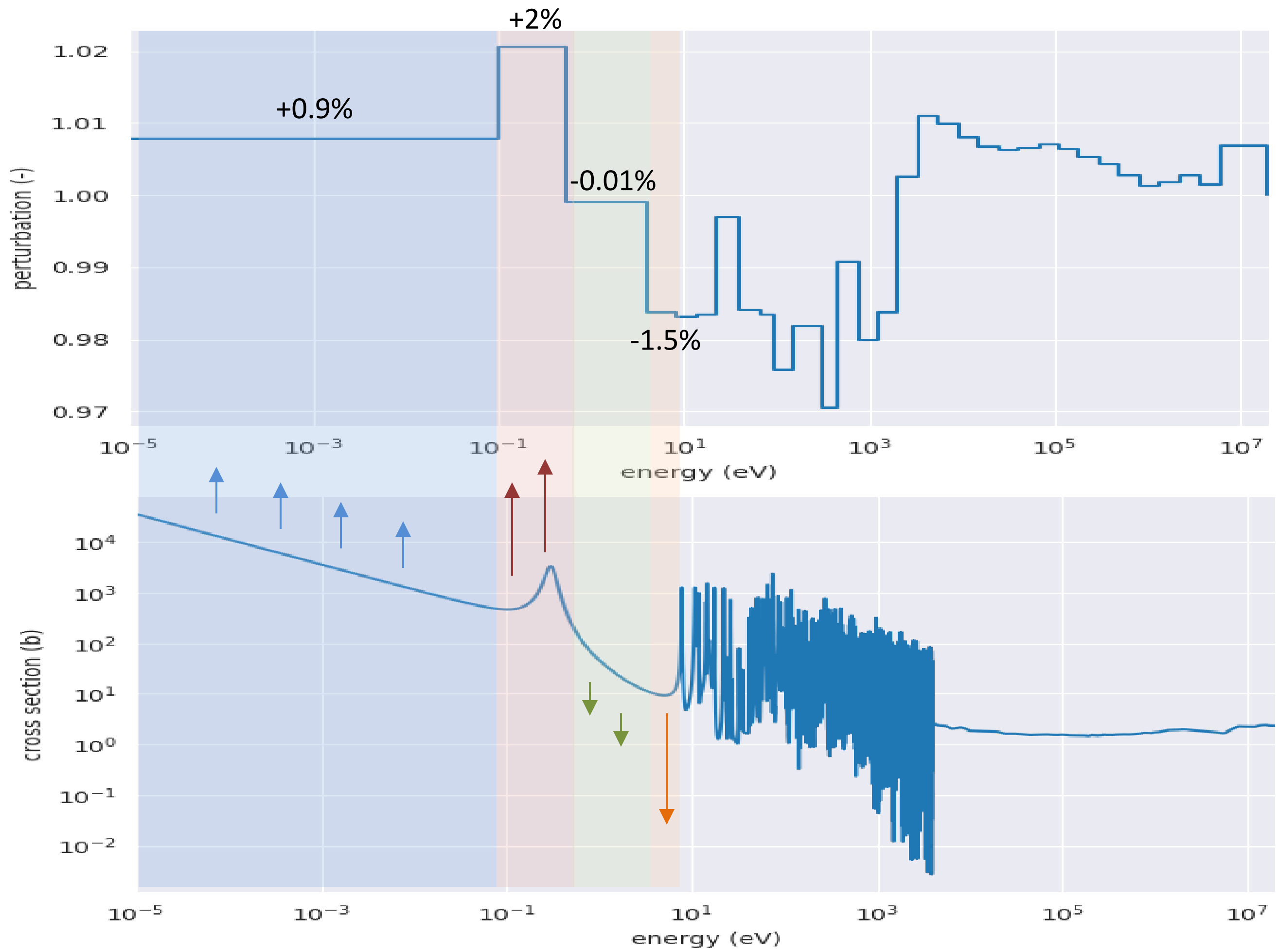


Sampling method

- Apply perturbations to original data



Multigroup perturbations



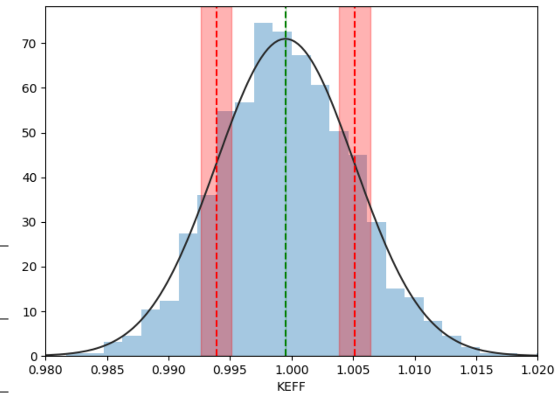
Comparison NDaST / SANDY

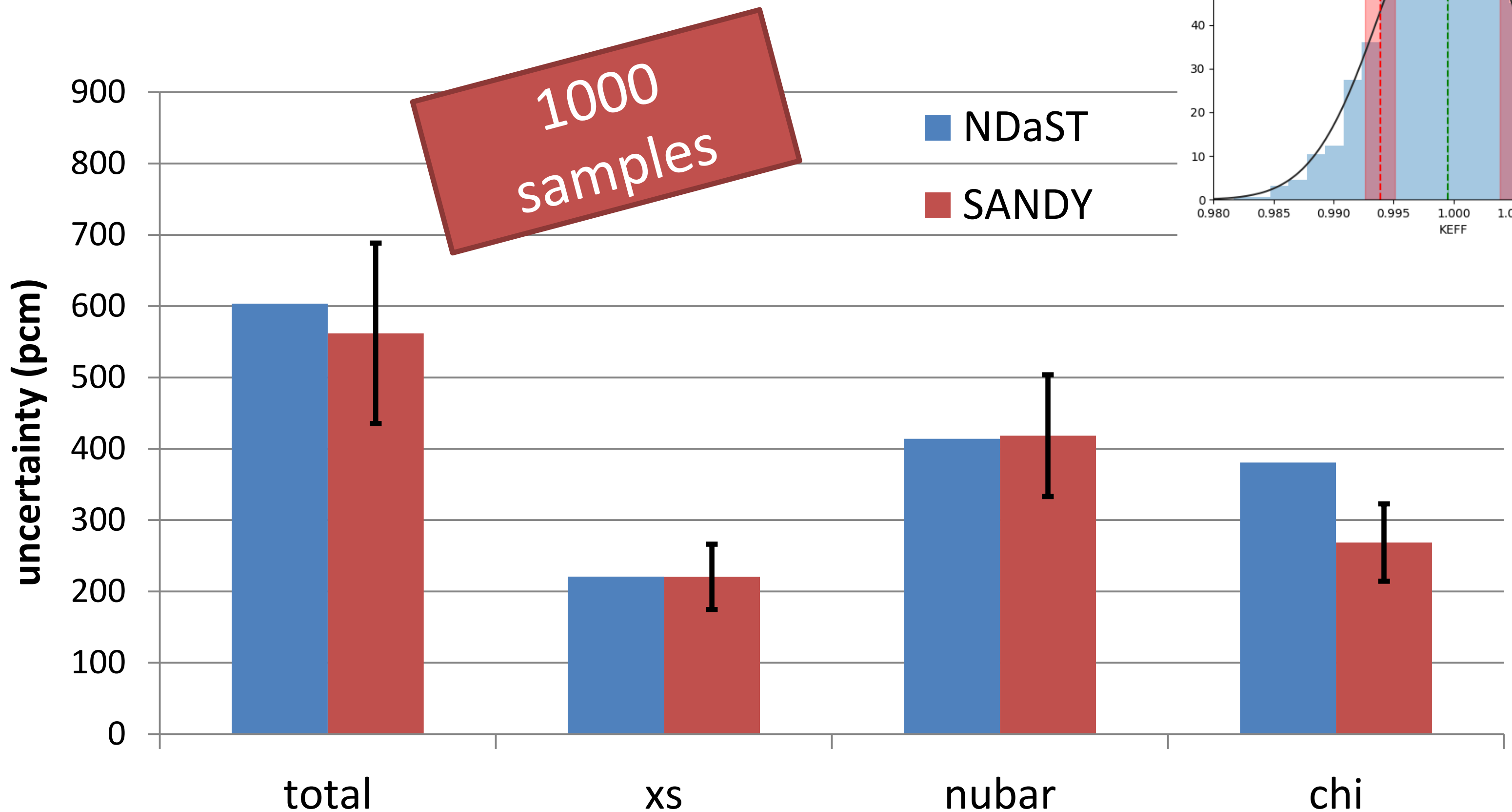
Covariance type	JEFF-3.3	JEFF-3.2	ENDF/B-VIII.0
MF31 – fission multiplicities	50	17	73
MF32 – resonance parameters	352	181	118
MF33 – cross sections	442	218	220
MF34 – angular distributions	359	158	108
MF35 – energy distributions	36	3	65

- Mosteller's suite
  - Jezebel
  - Plutonium benchmarks
  - PMF6

Jezebel

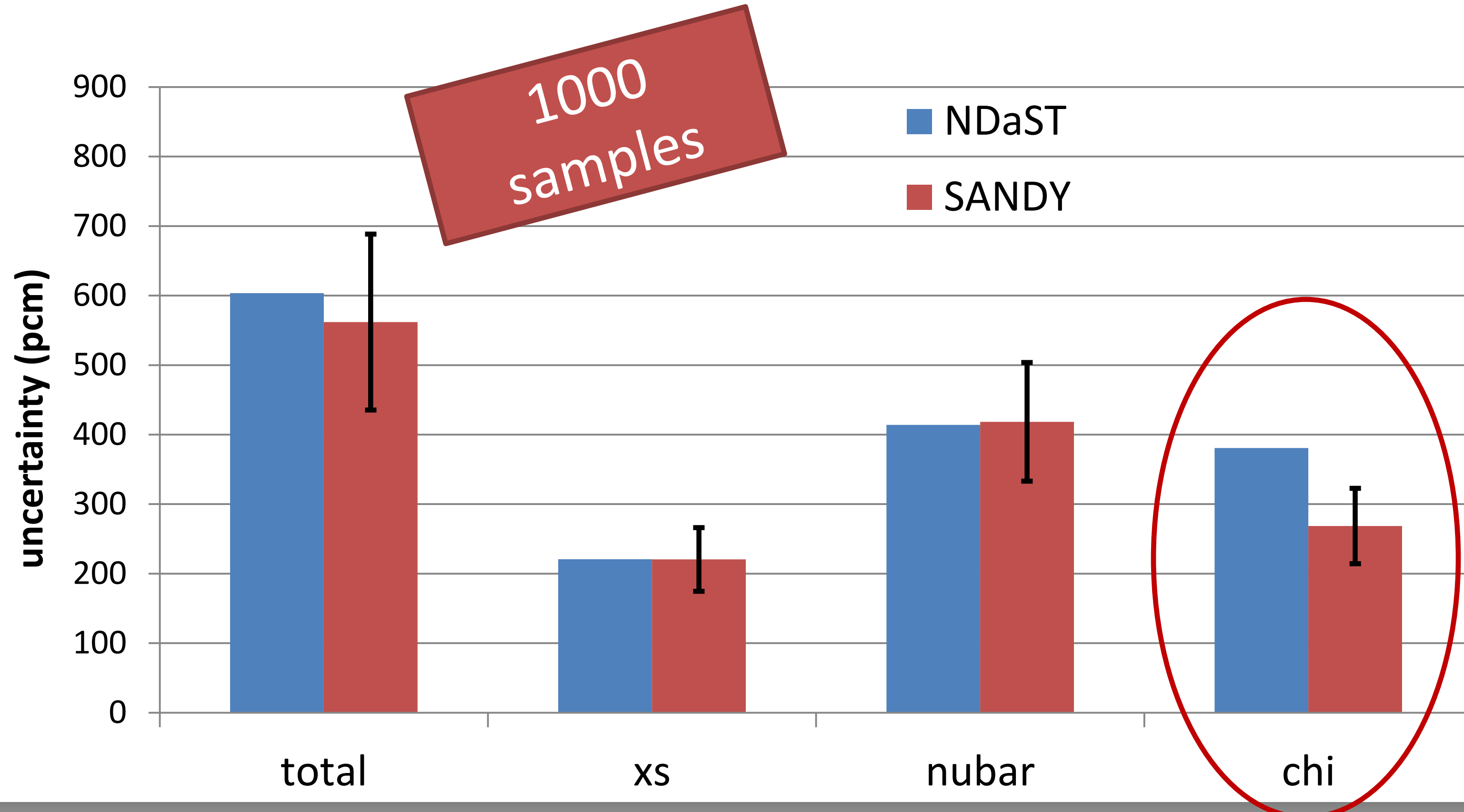
- Comparison NDaST / SANDY for Pu239
- No covariances for angular distributions





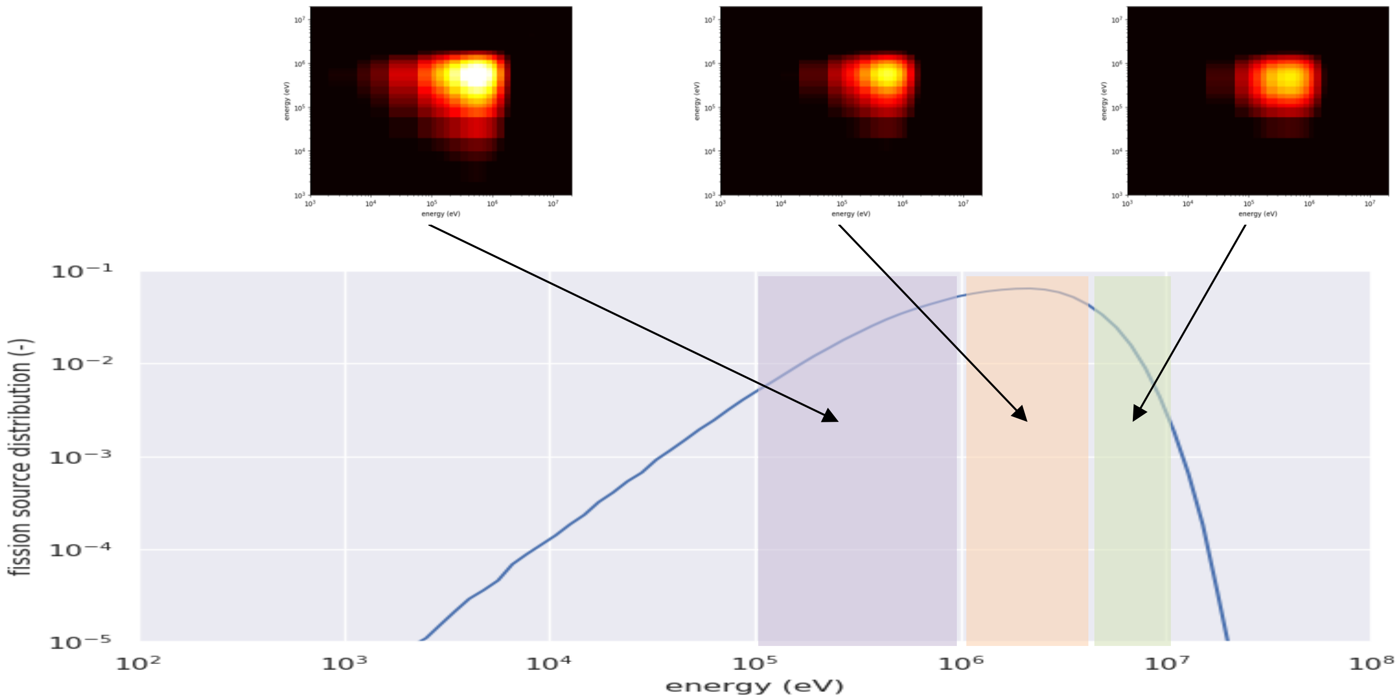
Jezebel

- Comparison NDaST / SANDY
- Discrepancy for PFNS



Energy distributions

- Covariances for PFNS are given in blocks for few incident energy ranges



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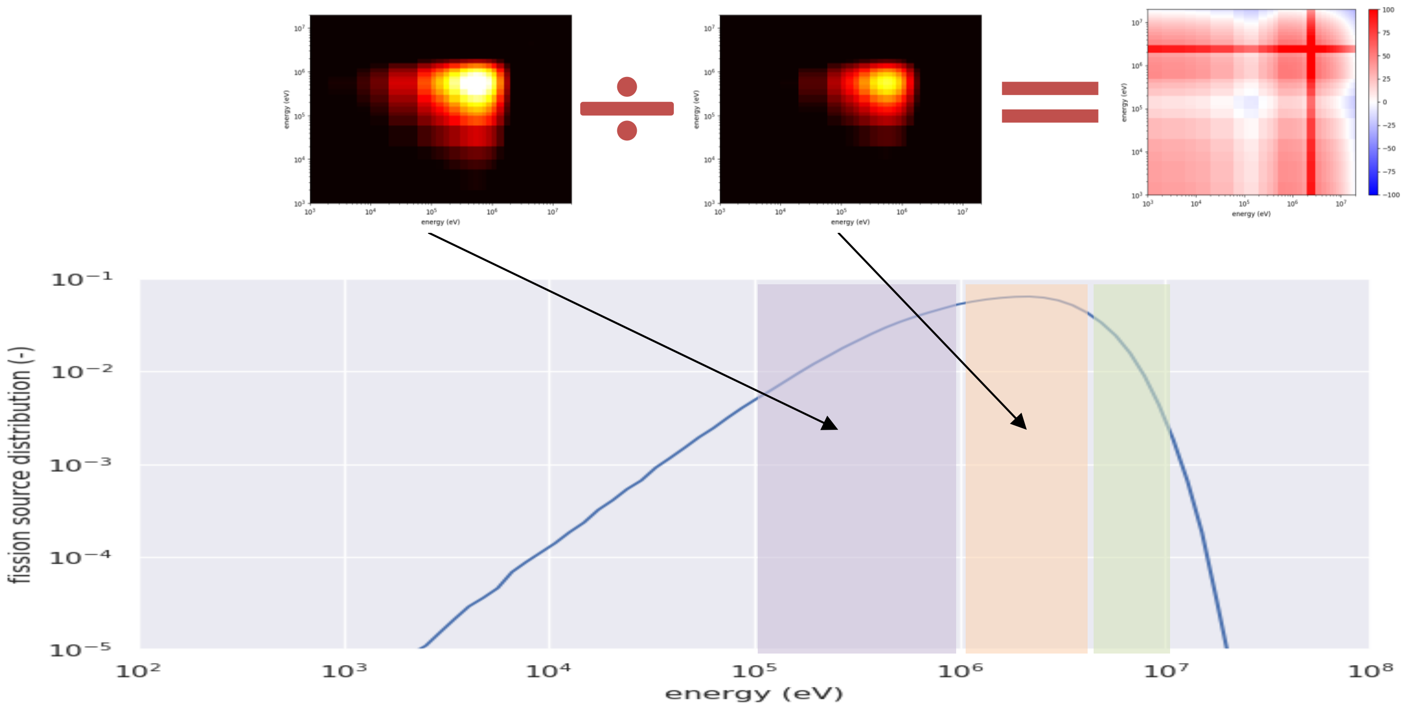

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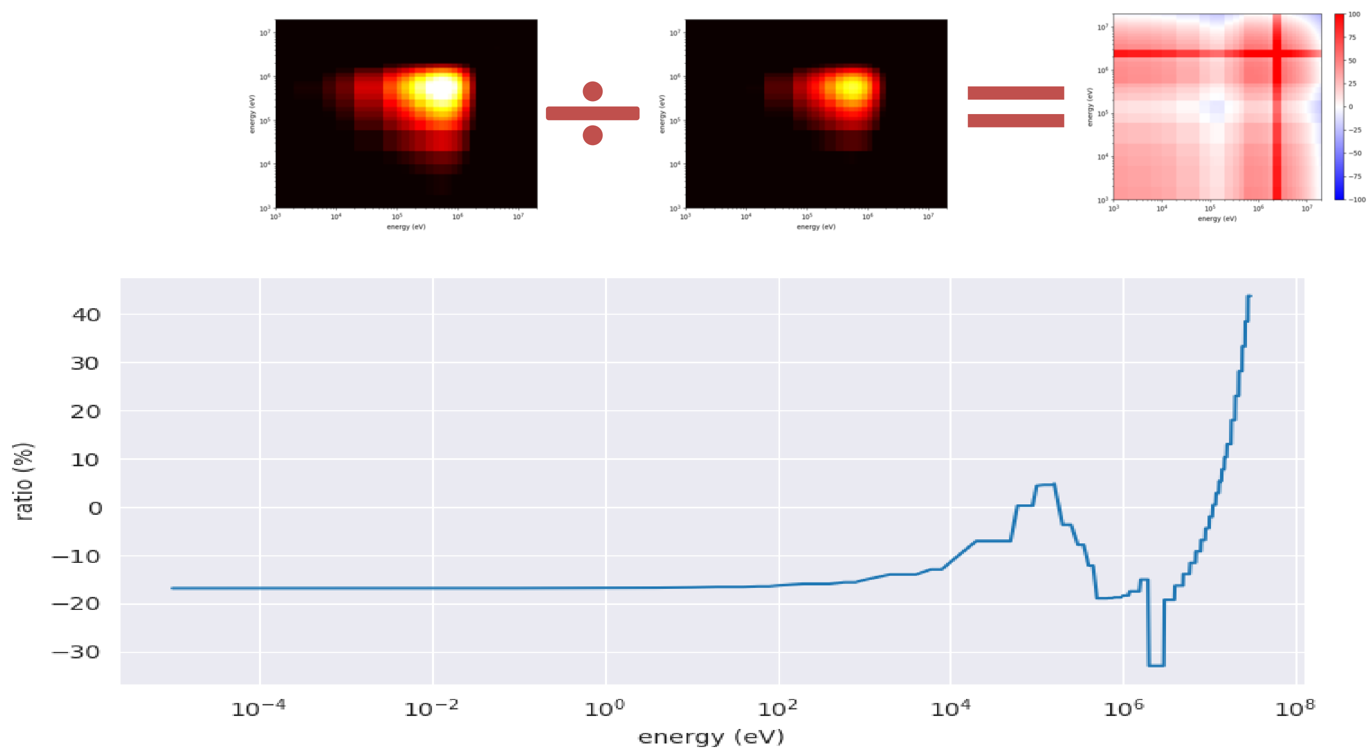
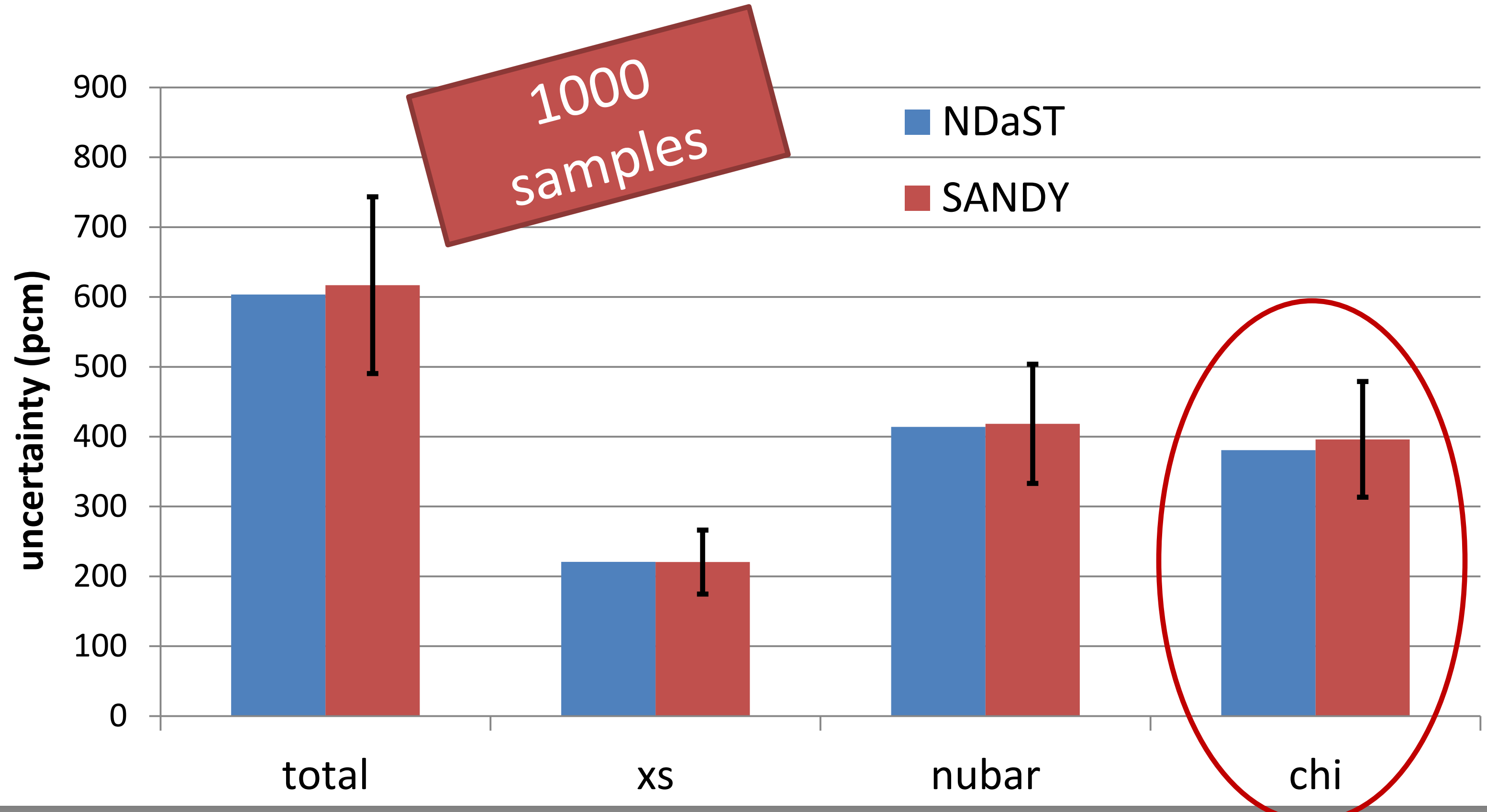
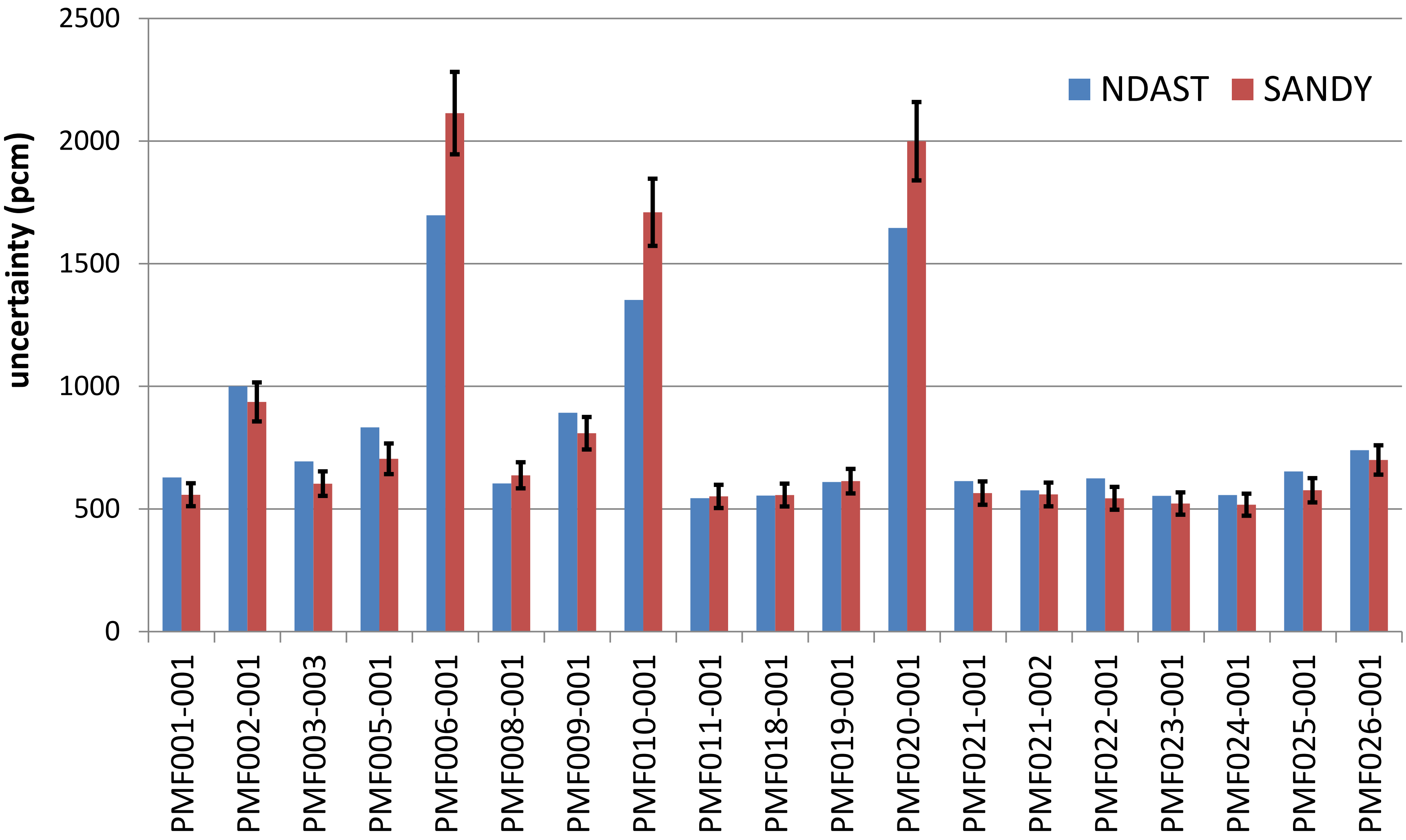


Jezebel

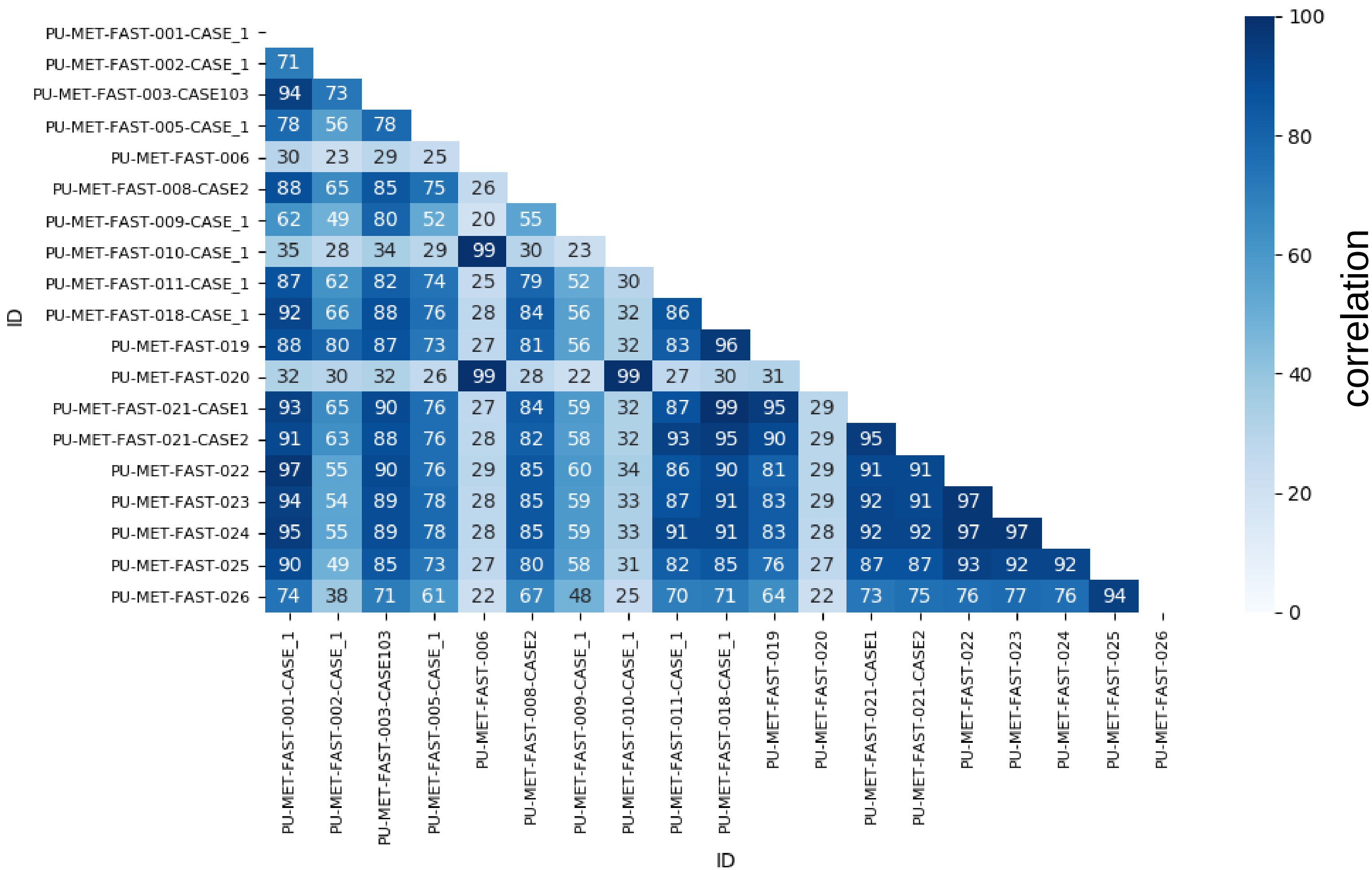
- NDaST results can be reproduced by SANDY sampling from only one covariance matrix



PU-MET-FAST (uncertainties)



PU-MET-FAST (correlations)



PU-MET-FAST (correlations)

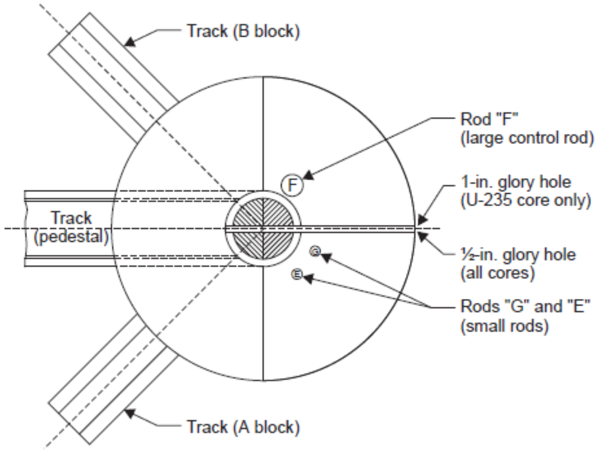
U238 reflector

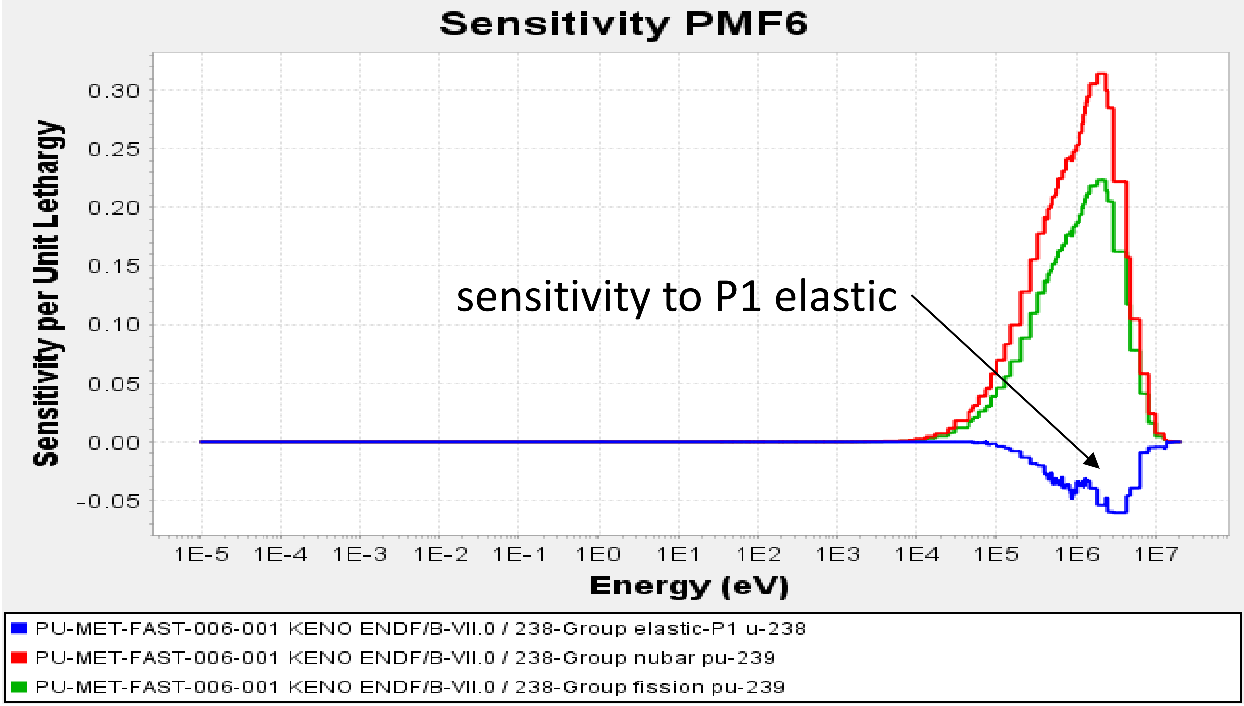
ID	PU-MET-FAST-001-CASE_1	PU-MET-FAST-002-CASE_1	PU-MET-FAST-003-CASE103	PU-MET-FAST-005-CASE_1	PU-MET-FAST-006	PU-MET-FAST-008-CASE2	PU-MET-FAST-009-CASE_1	PU-MET-FAST-010-CASE_1	PU-MET-FAST-011-CASE_1	PU-MET-FAST-018-CASE_1	PU-MET-FAST-019	PU-MET-FAST-020	PU-MET-FAST-021-CASE1	PU-MET-FAST-021-CASE2	PU-MET-FAST-022	PU-MET-FAST-023	PU-MET-FAST-024	PU-MET-FAST-025	PU-MET-FAST-026
PU-MET-FAST-001-CASE_1																			
PU-MET-FAST-002-CASE_1	71																		
PU-MET-FAST-003-CASE103	94	73																	
PU-MET-FAST-005-CASE_1	78	56	78																
PU-MET-FAST-006	30	23	29	25															
PU-MET-FAST-008-CASE2	88	65	85	75	26														
PU-MET-FAST-009-CASE_1	62	49	80	52	20	55													
PU-MET-FAST-010-CASE_1	35	28	34	29	99	30	23												
PU-MET-FAST-011-CASE_1	87	62	82	74	25	79	52	30											
PU-MET-FAST-018-CASE_1	92	66	88	76	28	84	56	32	86										
PU-MET-FAST-019	88	80	87	73	27	81	56	32	83	96									
PU-MET-FAST-020	32	30	32	26	99	28	22	99	27	30	31								
PU-MET-FAST-021-CASE1	93	65	90	76	27	84	59	32	87	99	95	29							
PU-MET-FAST-021-CASE2	91	63	88	76	28	82	58	32	93	95	90	29	95						
PU-MET-FAST-022	97	55	90	76	29	85	60	34	86	90	81	29	91	91					
PU-MET-FAST-023	94	54	89	78	28	85	59	33	87	91	83	29	92	91	97				
PU-MET-FAST-024	95	55	89	78	28	85	59	33	91	91	83	28	92	92	97	97			
PU-MET-FAST-025	90	49	85	73	27	80	58	31	82	85	76	27	87	87	93	92	92		
PU-MET-FAST-026	74	38	71	61	22	67	48	25	70	71	64	22	73	75	76	77	76	94	

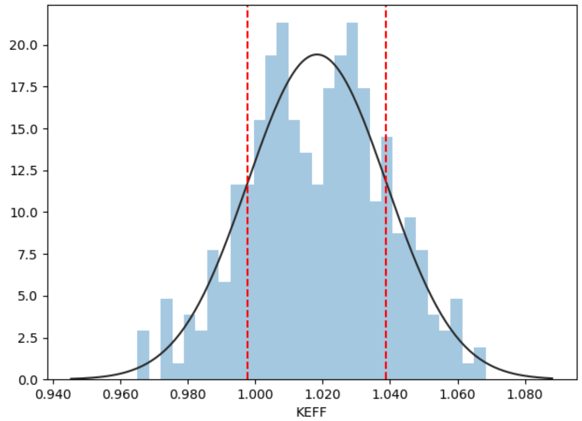
correlation (scale 0 – 20 – 40 – 60 – 80 – 100)

Pu-Met-Fast-006

U238-reflected Pu sphere



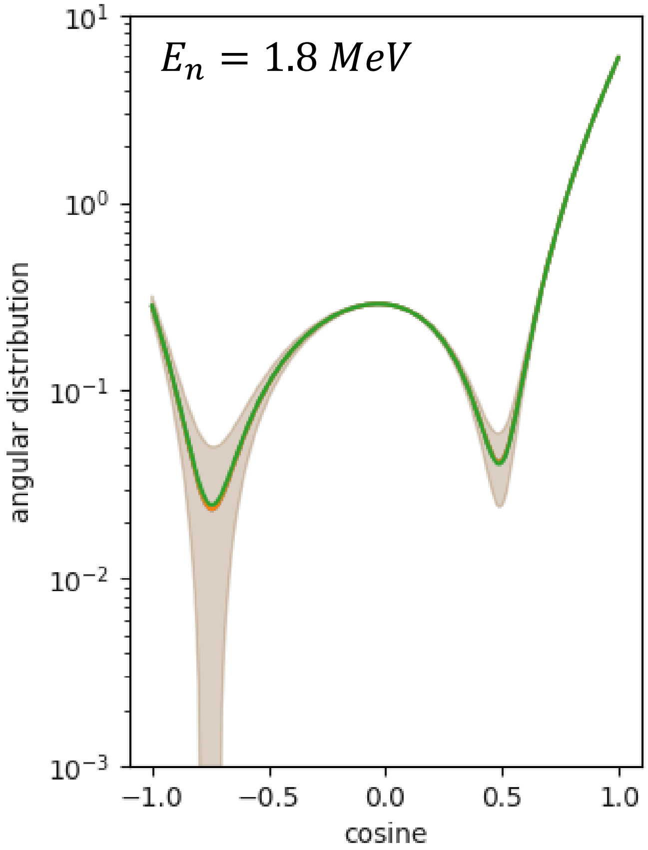


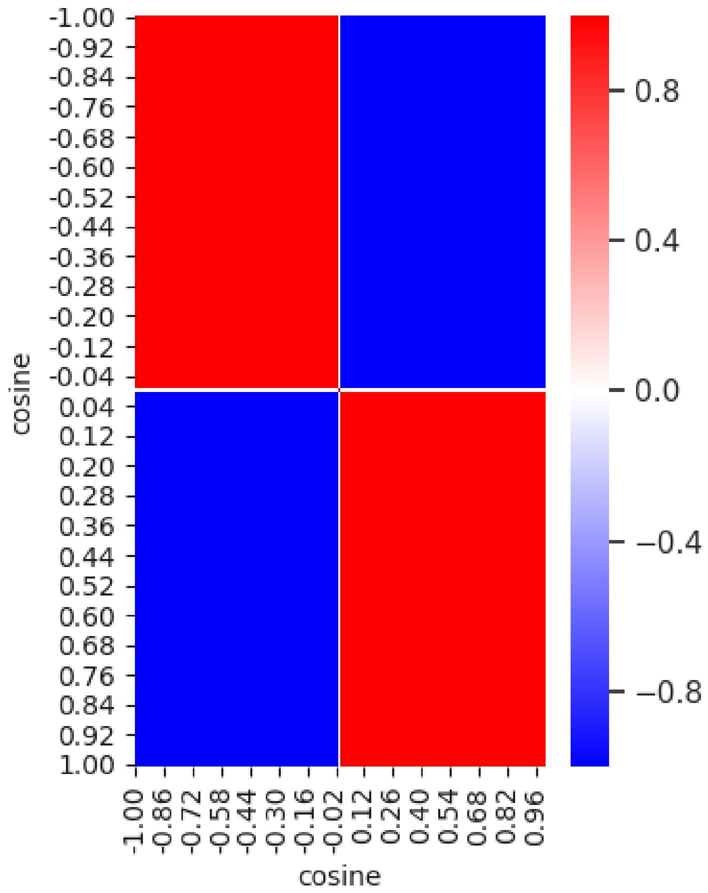


stdev SANDY = 2056 ± 555 pcm

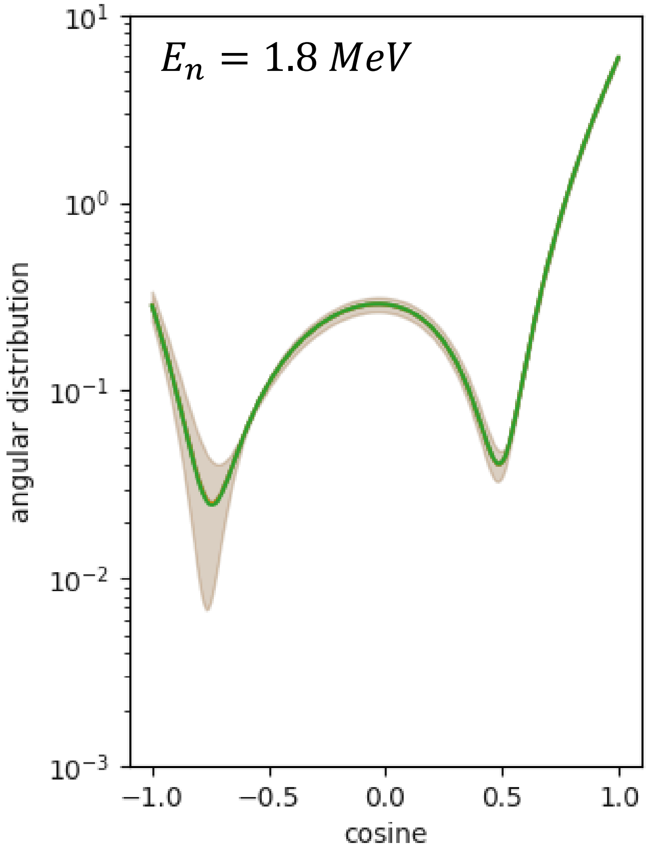
stdev NDaST = 1382 pcm

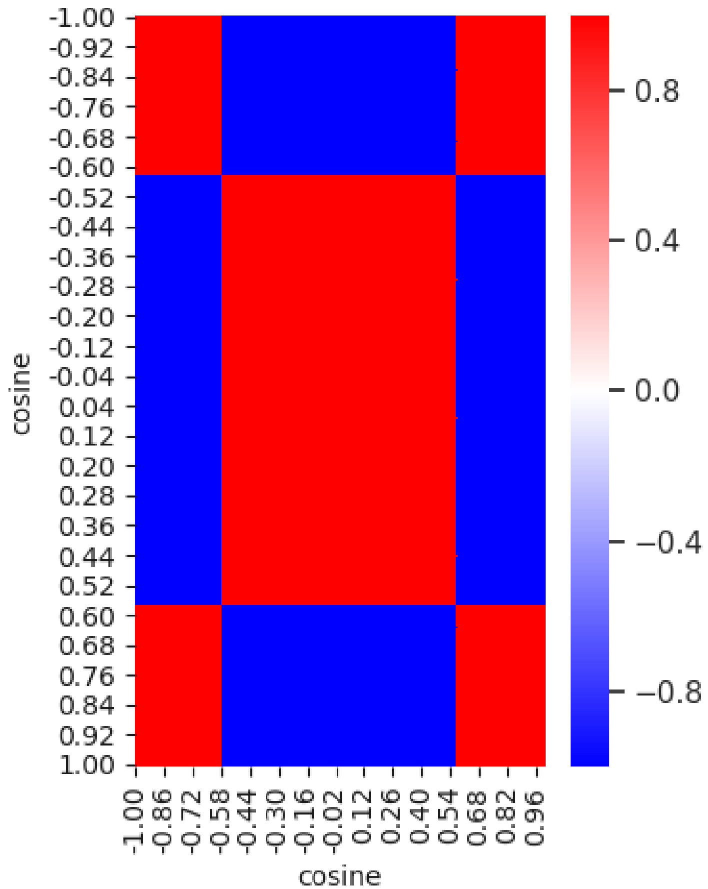
P1 covariance



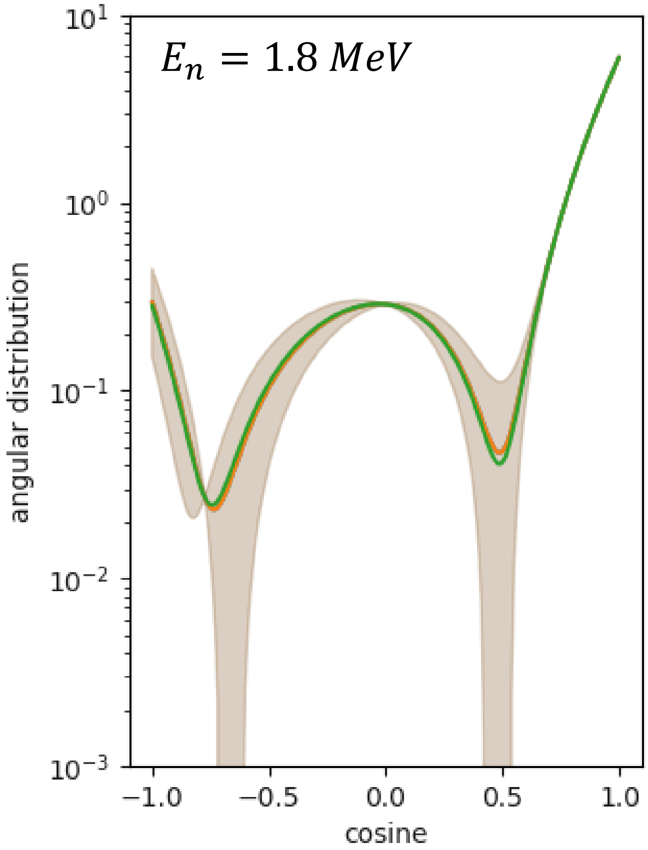


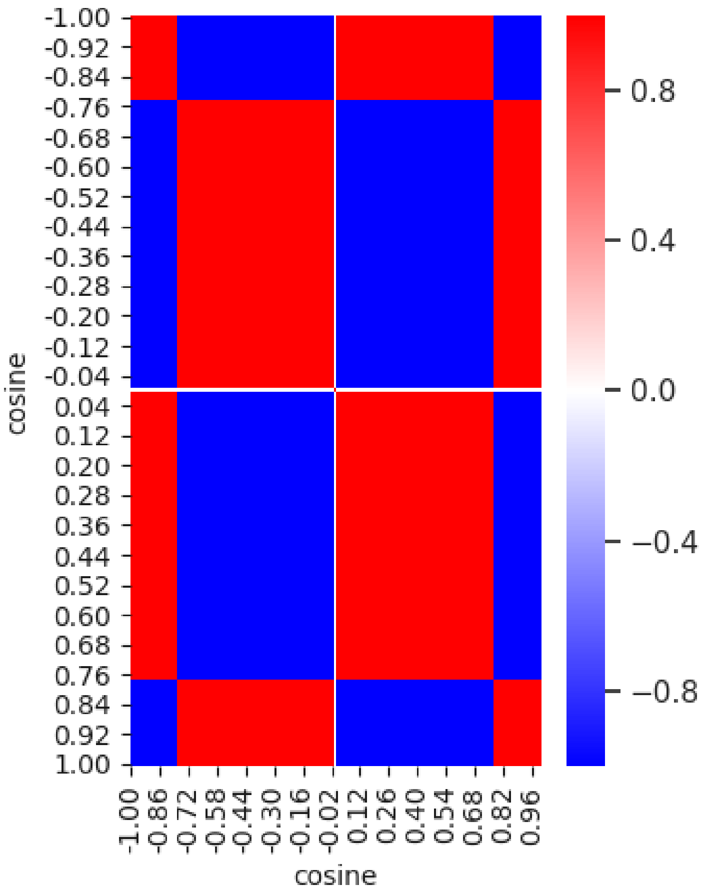
P2 covariance



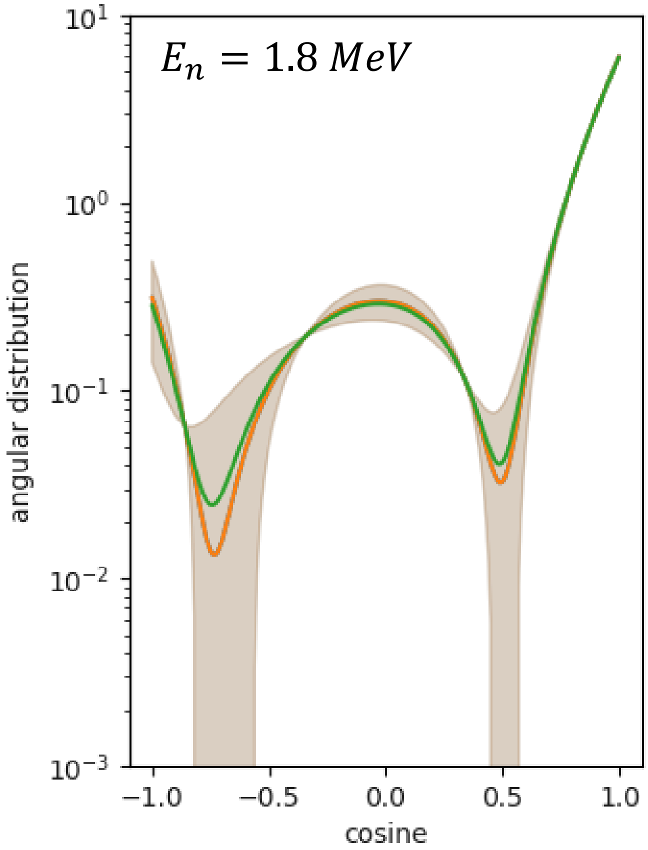


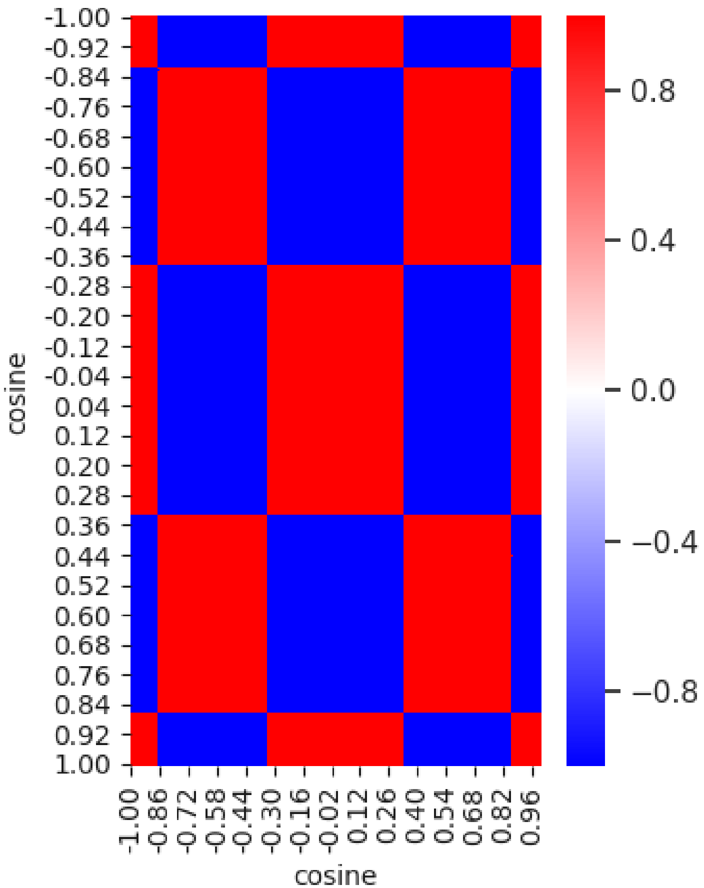
P3 covariance



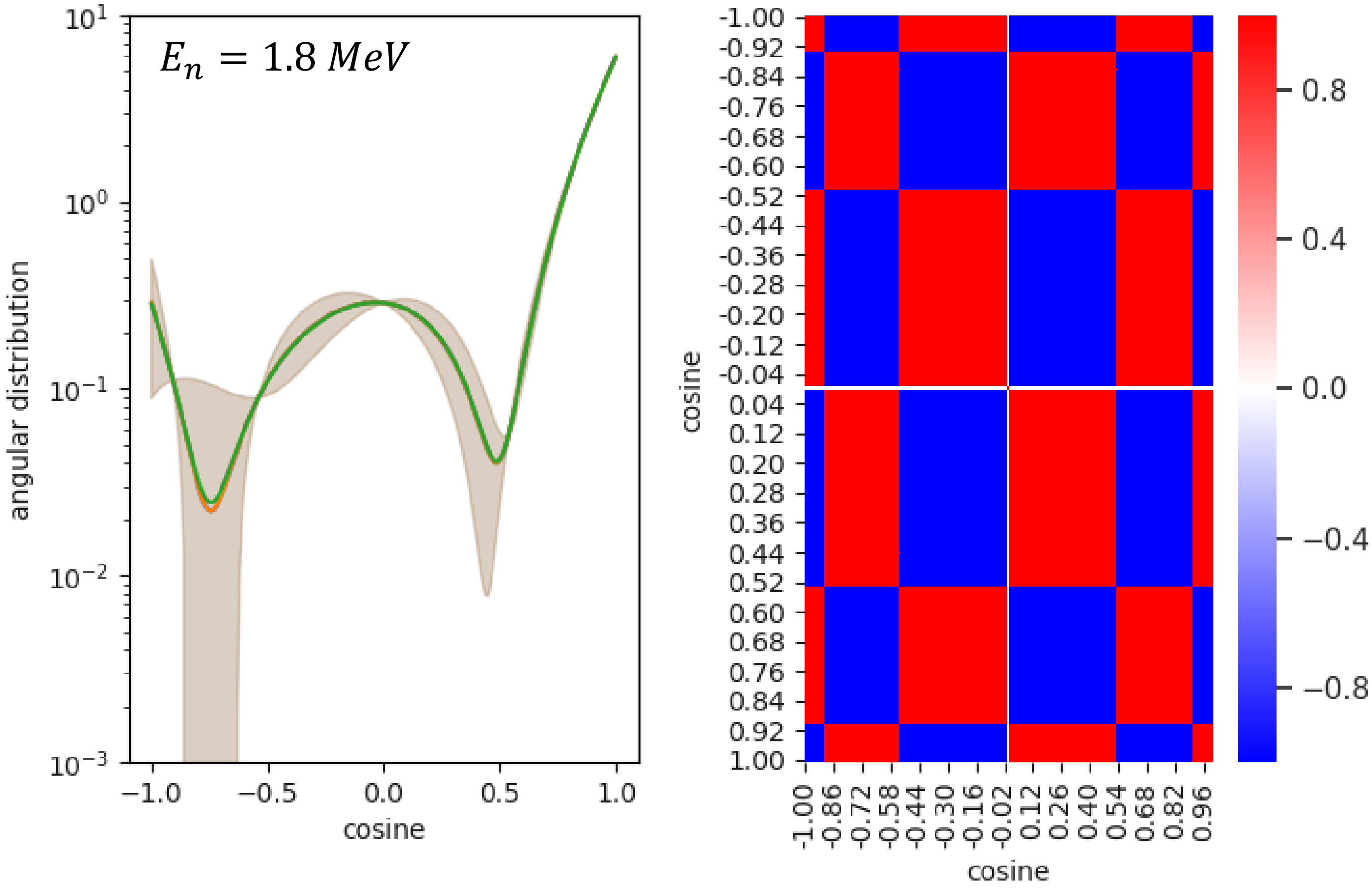


P4 covariance

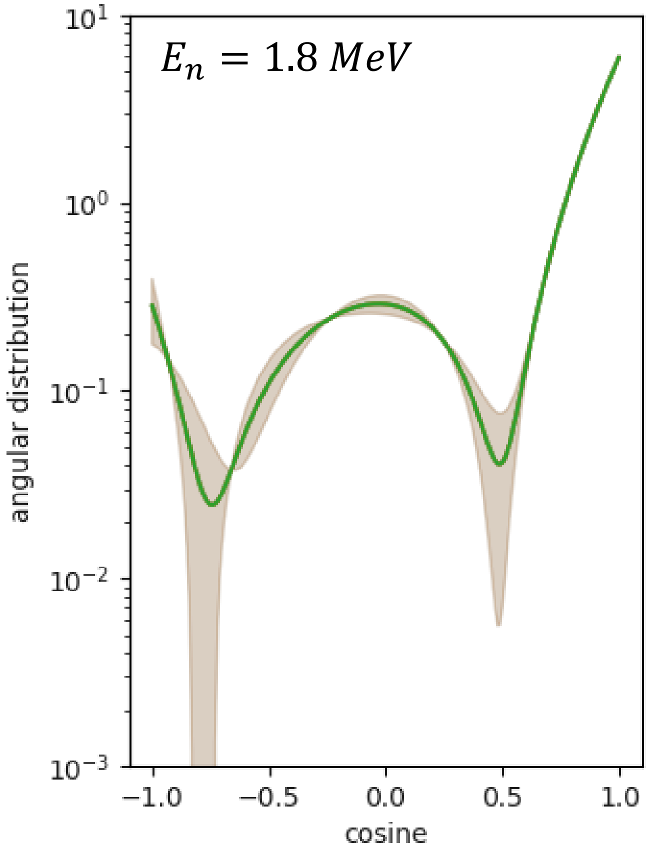


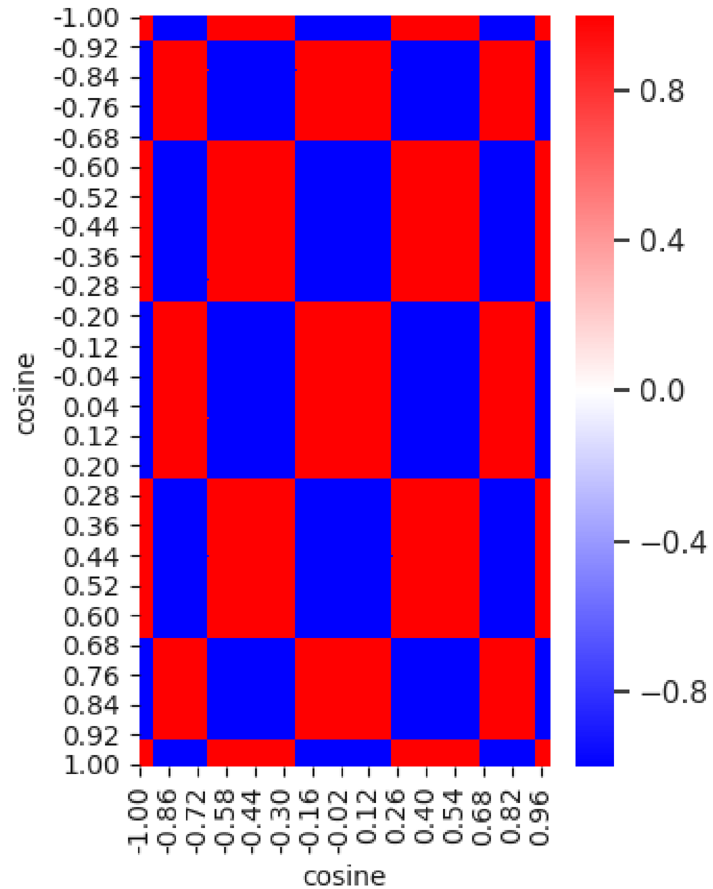


P5 covariance



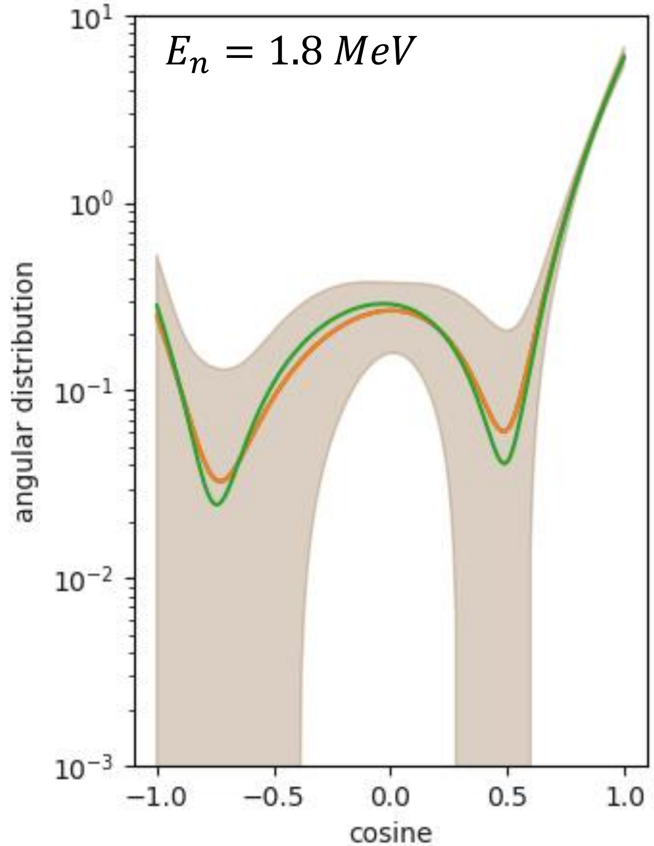
P6 covariance

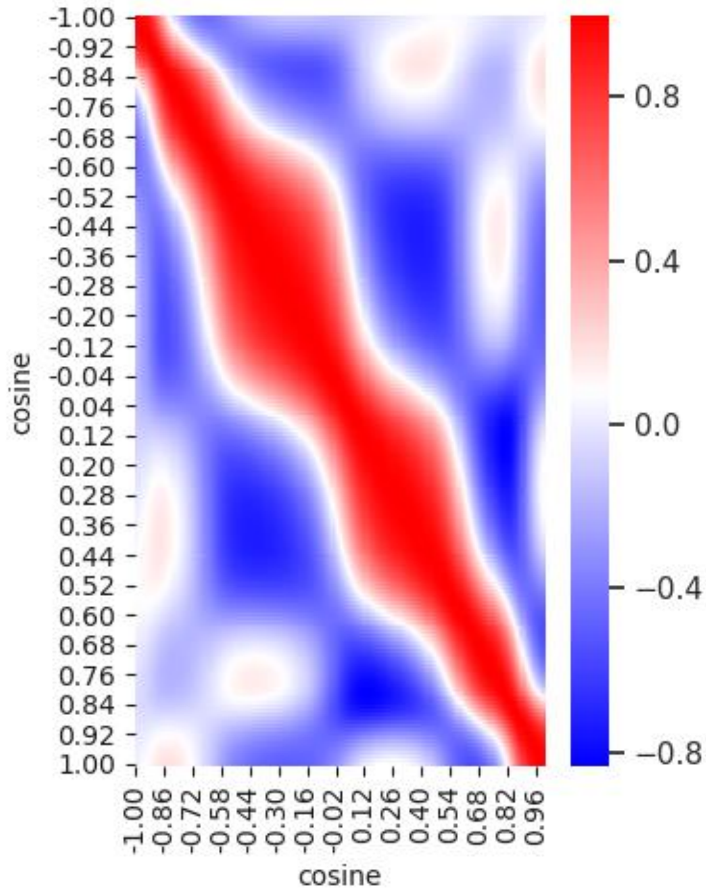




All P covariances

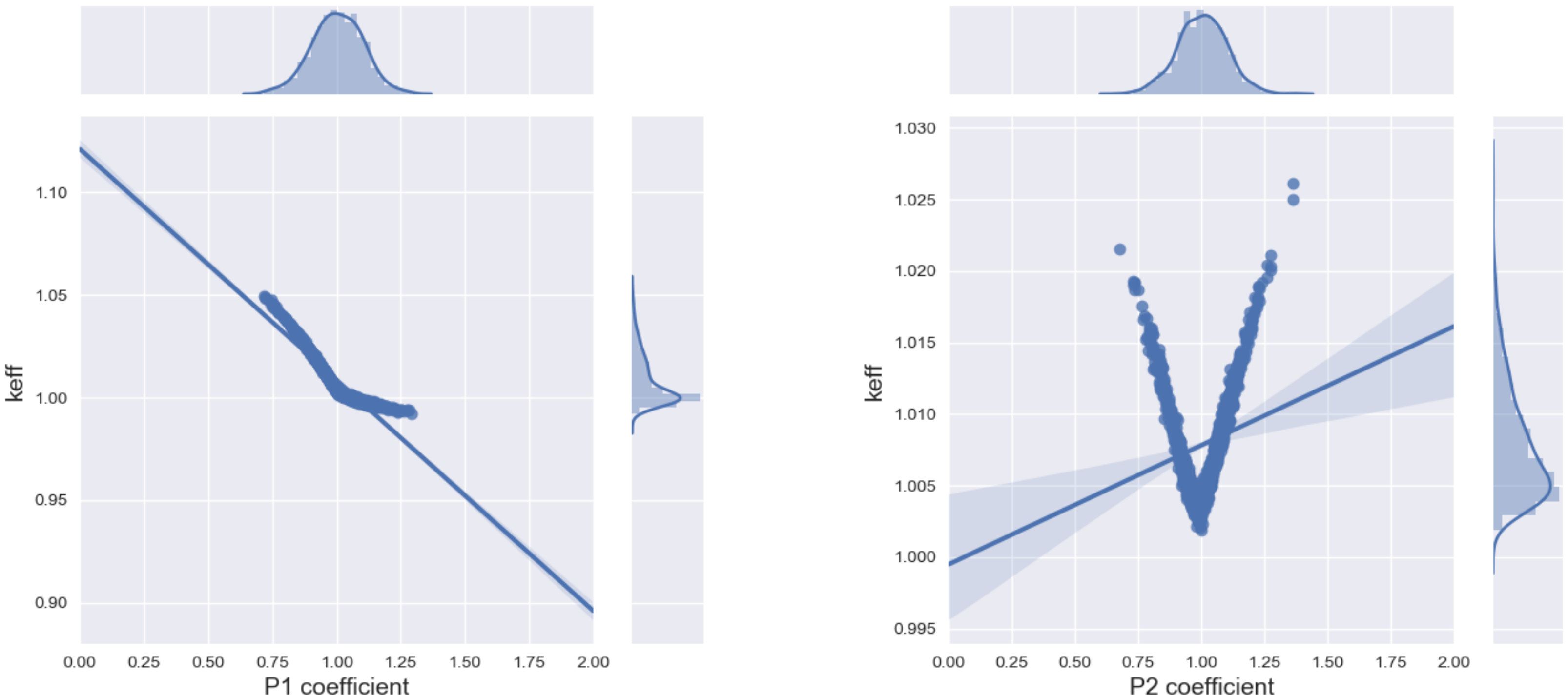
- NDaST results can be reproduced by SANDY sampling from only P1





Sensitivity to P1-P2 coefficients

- 10% std dev over all neutron energies
- Strong non-linearity (mean shift, non-Normal PDF)
- Null-hypothesis of Normal distribution is rejected



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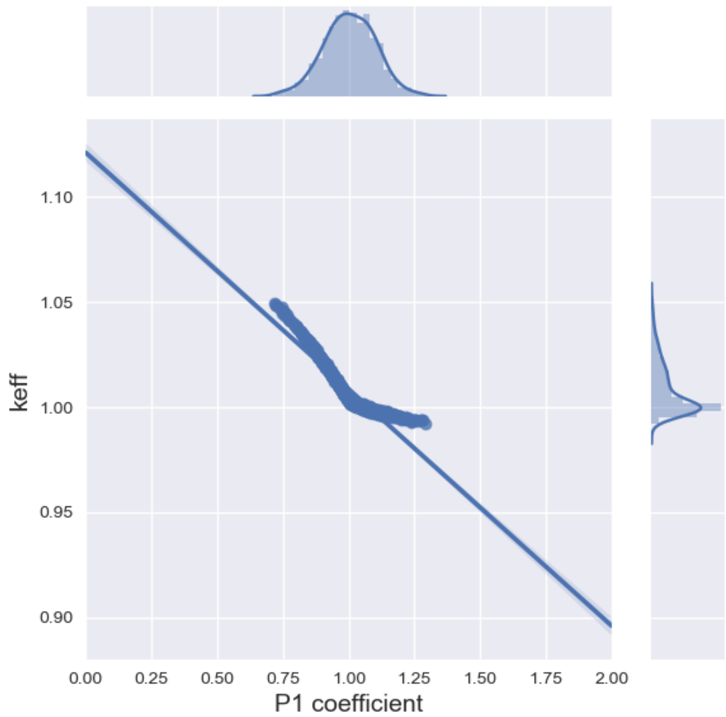

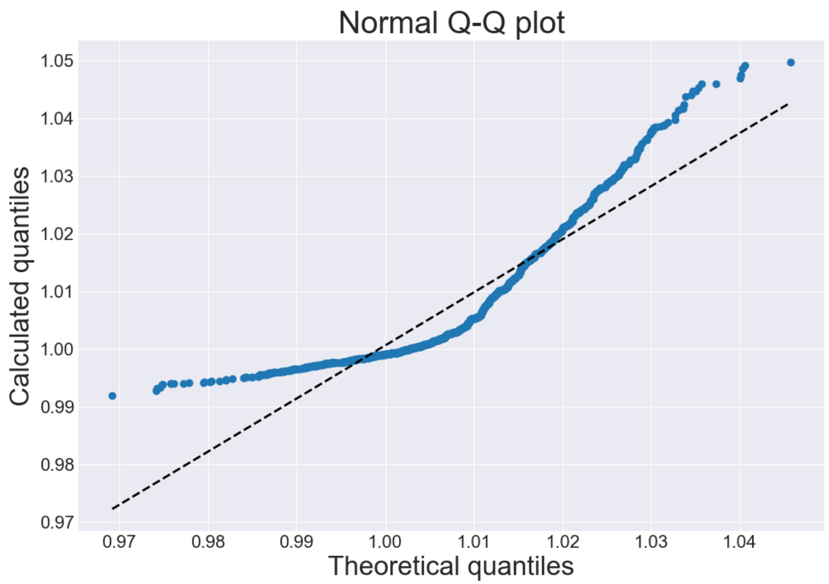

Conclusions

- JEFF-3.3 covariances were processed and included into JANIS
- 300 perturbed suites were created for JEFF-3.3 in ACE format (293.6 K) for criticality studies
- SANDY validates NDAST results for PMF
- Energy distribution covariances should be weighed on the fission rate
- Covariances for P>1 can be significant for systems such as PMF6
- The format for angular distribution covariances should be addressed to avoid non-physical correlations