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Pu9(n,f) cross section covariances including USU components

Georg Schnabel

Nuclear Data Section
Division of Physical and Chemical Sciences NAPC
Department for Nuclear Sciences and Applications
IAEA, Vienna

Mini-CSEWG meeting

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GMA database
(maintained within neutron standards project)

- **Includes cross sections**

  ^{6}Li(n,a), ^{6}Li(n,n), ^{10}B(n,a$_0$), ^{10}B(n,a$_1$), ^{10}B(n,n), ^{197}Au(n,g), U8(n,g), U5(n,f), **Pu9(n,f)**, U8(n,f)

  + thermal neutron constants and SACS (in ^{252}Cf(sf) PFNS)

- **Measurement types**

  absolute, shape, ratio, shape ratio, sum of xs, SACS, shape of sums, etc.

1) A.D. Carlson et al, “Evaluation of the Neutron Data Standards”, Nuclear Data Sheets 148 (2018)

2) D. Neudecker et al, “Applying a Template of Expected Uncertainties to Updating ^{239}Pu(n,f) Cross-section Covariances in the Neutron Data Standards Database”, Nuclear Data Sheets 163 (2020)

3) D. Neudecker, V.G. Pronyaev and L. Snyder, “Including ^{238U}(n,f) /^{235}U(n,f) and ^{239}Pu(n,f) / ^{235}U(n,f) NIFFTE fission TPC Cross-sections into the Neutron Data Standards Database”, Technical report, LA-UR-21-24093 (2022)

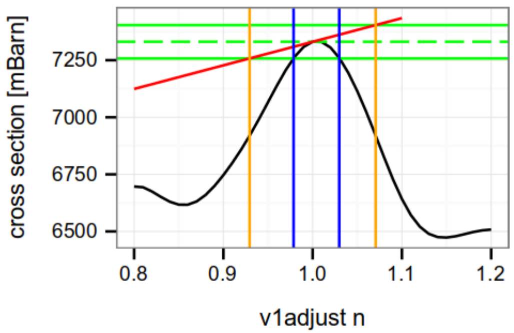
GMA code
(Generalized Least Squares code)

$$\pi(\vec{p}_{\text{true}} \,|\, \vec{\sigma}_{\text{exp}}, M) \propto f(\vec{\sigma}_{\text{exp}} \,|\, \vec{p}_{\text{true}}, M)\,\pi(\vec{p}_{\text{true}} \,|\, M)$$

Experimental info:
multivariate normal

Linear “model”

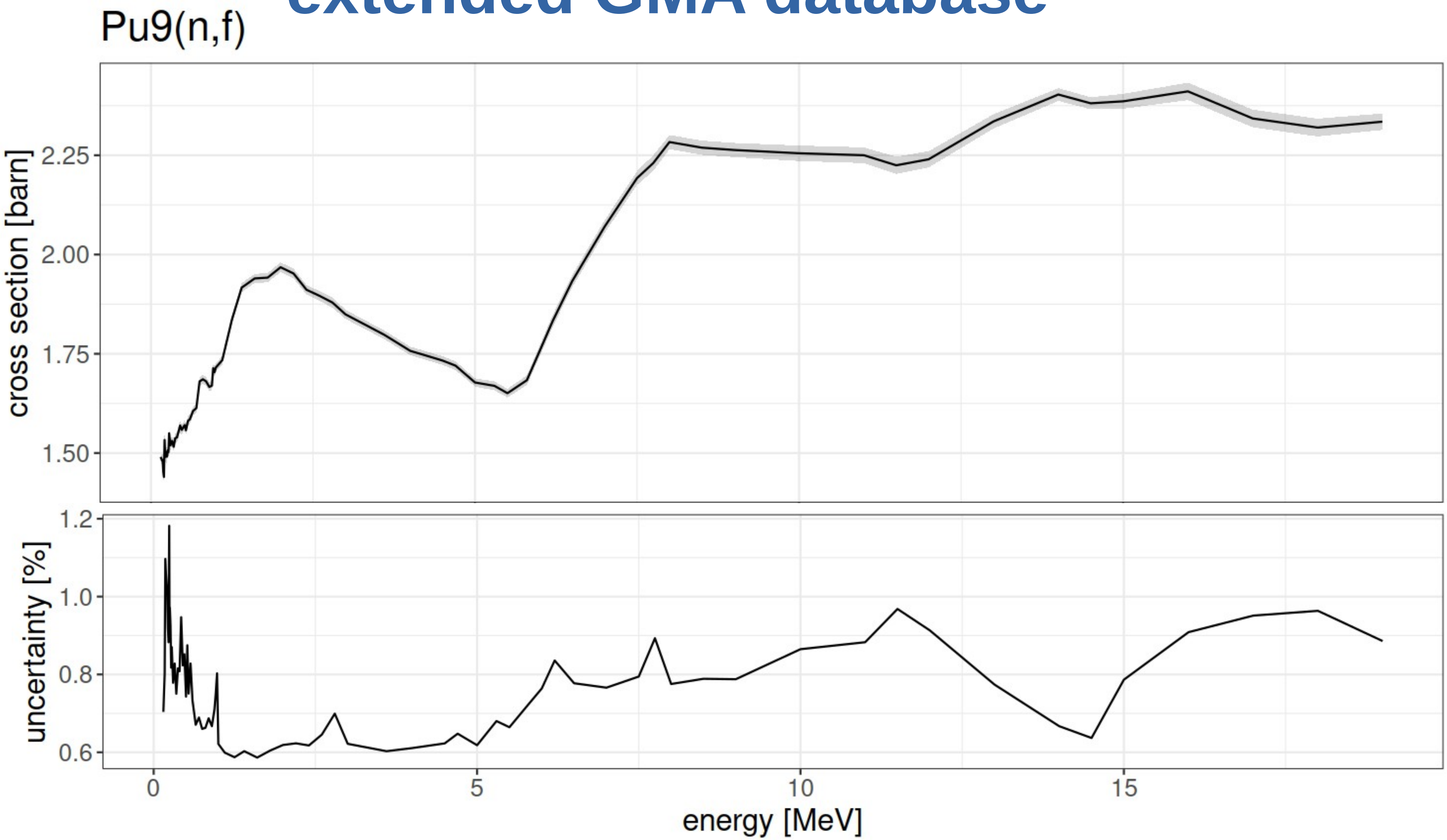
Prior:
multivariate normal



Optimization
(Iterative GLS)

Ref: W.P. Poenitz, “Data interpretation, objective evaluation procedures and mathematical techniques for the evaluation of energy-dependent ratio, shape and cross section data”, Proc. of the Conf. on Nuclear Data Evaluation and Procedures (1981)

Pu9(n,f) evaluation by GMA fit on extended GMA database



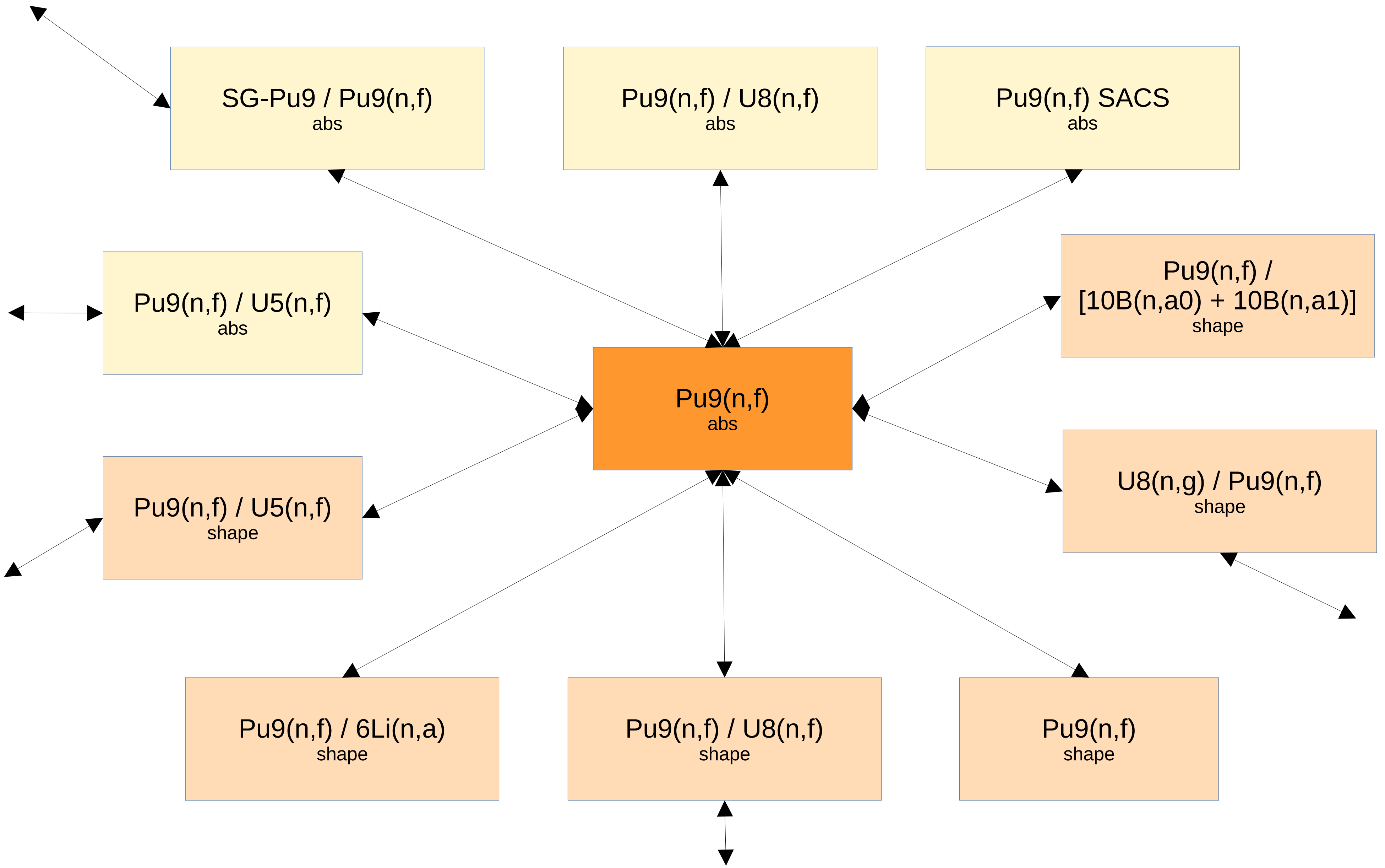
low evaluated uncertainties => introduction of 1.2% USU for NDS 2017

Related refs:

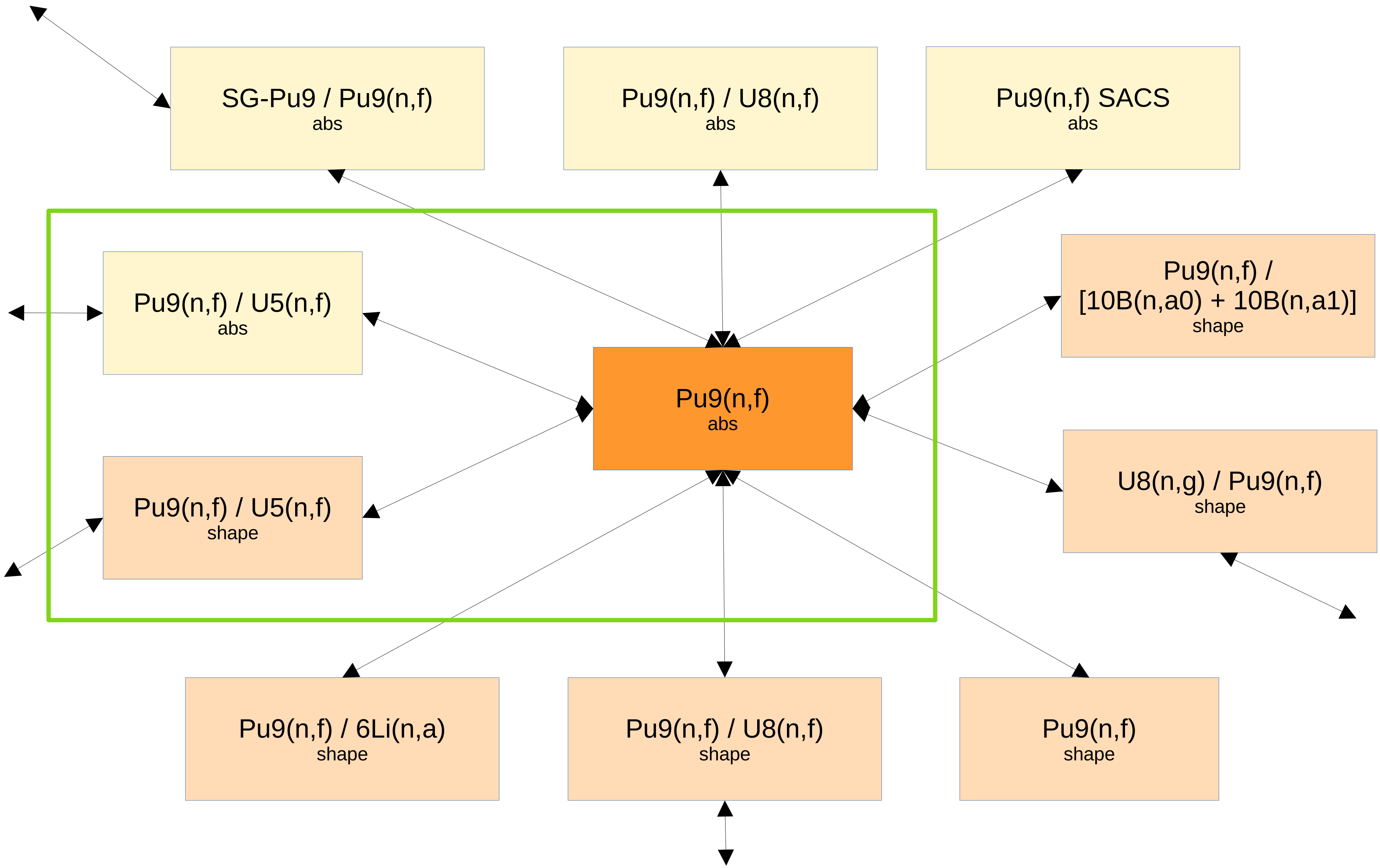
1) R. Capote and D. Neudecker, “How accurately we know the standard $^{252}Cf(sf)$ neutron multiplicity”, arXiv:1908.00272 (2019)

2) R. Capote et al, “Unrecognized Sources of Uncertainties (USU) in Experimental Nuclear Data”, Nuclear Data Sheets 163 (2020)

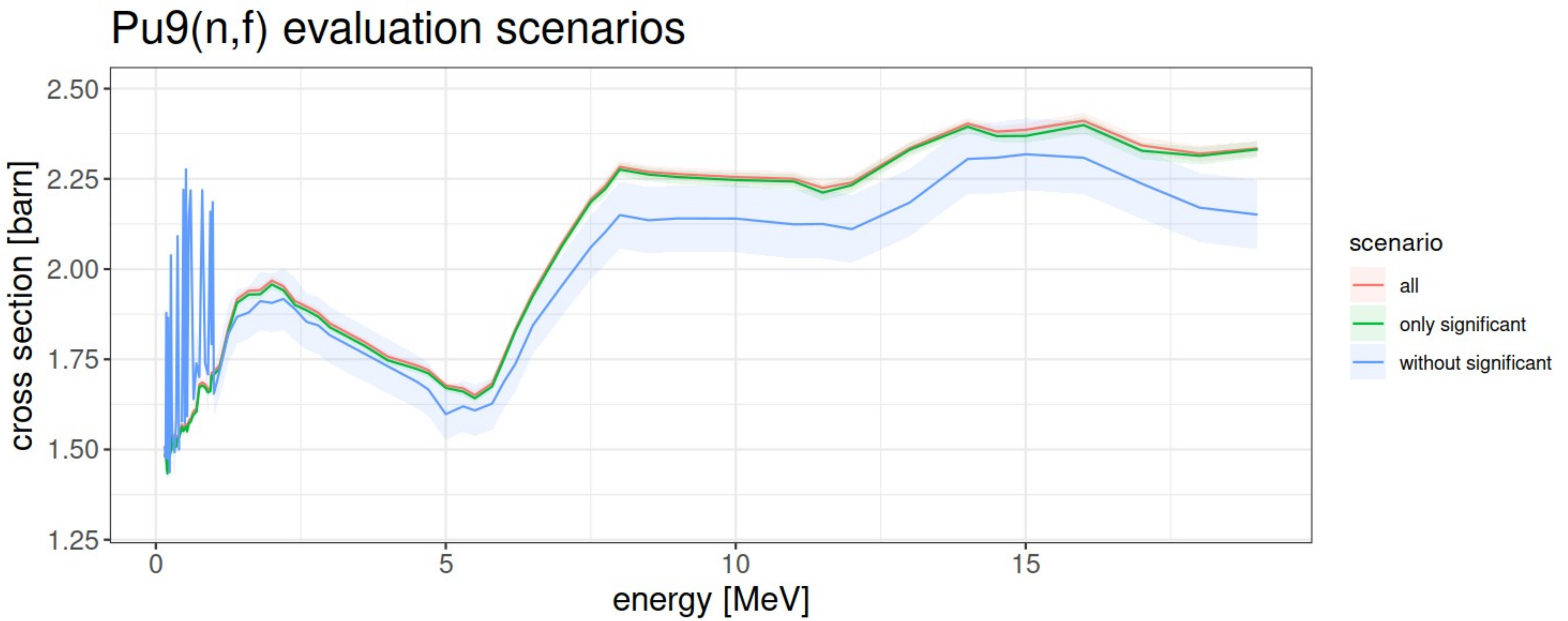
Information flow

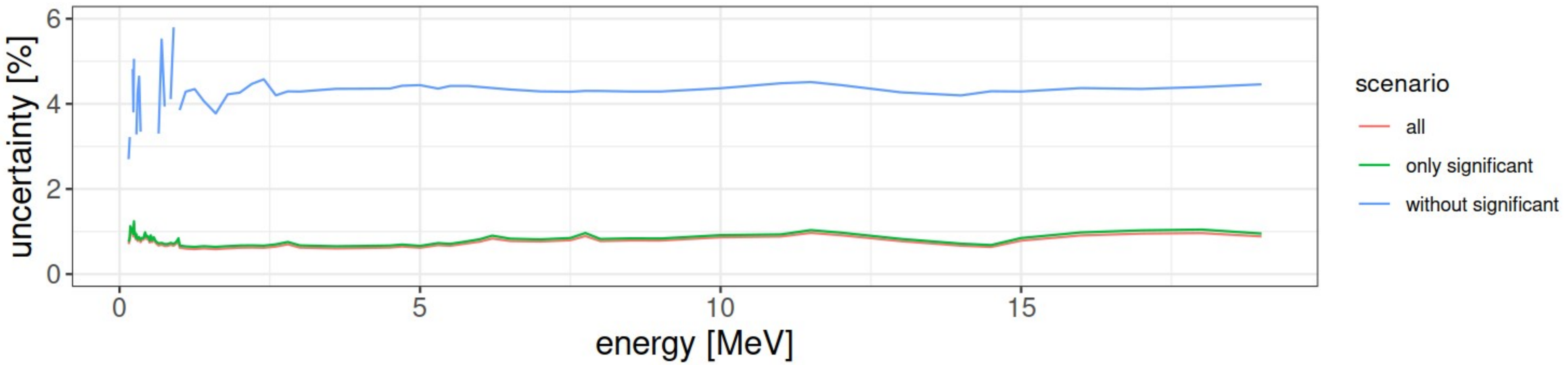


Information flow



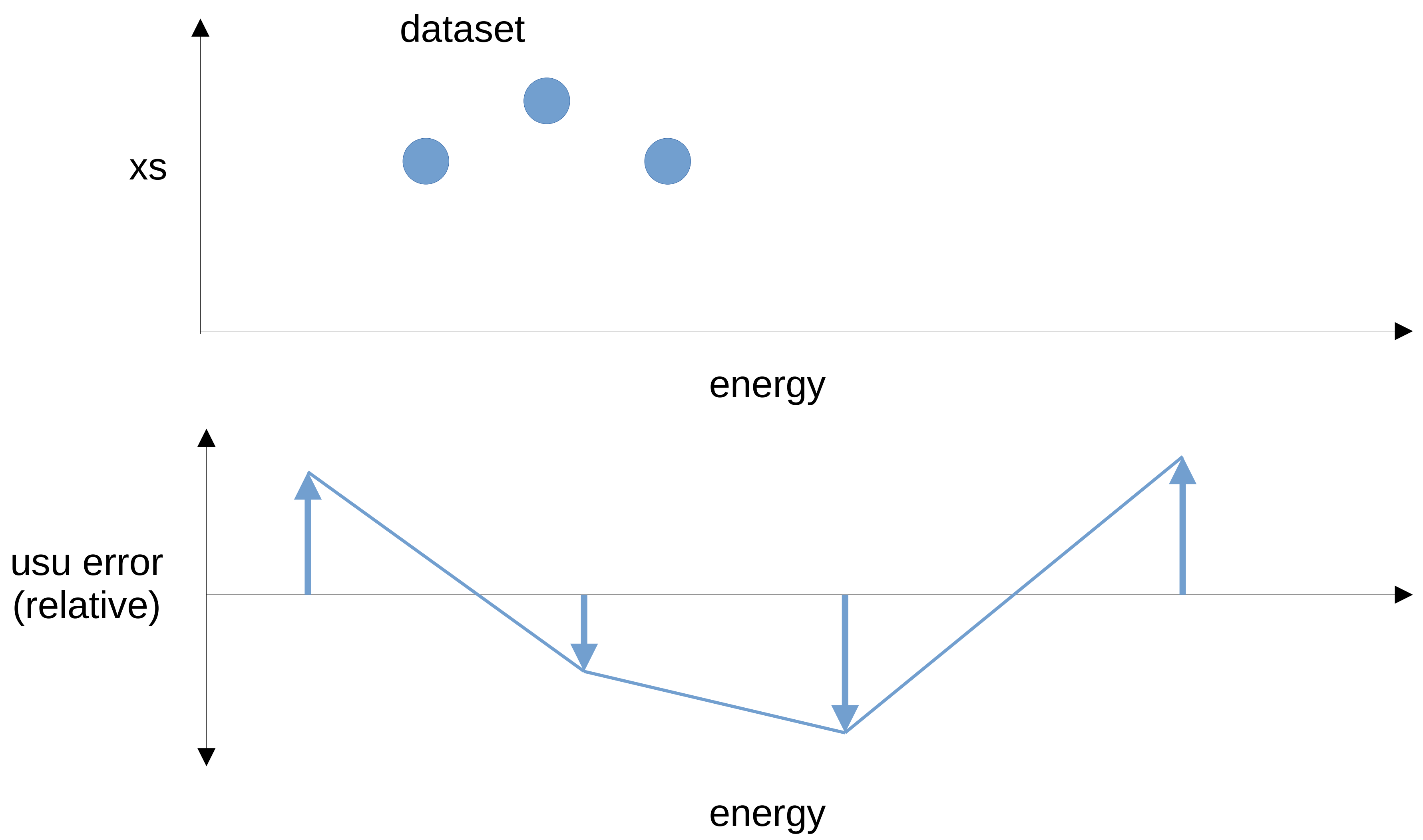
Evaluation scenarios



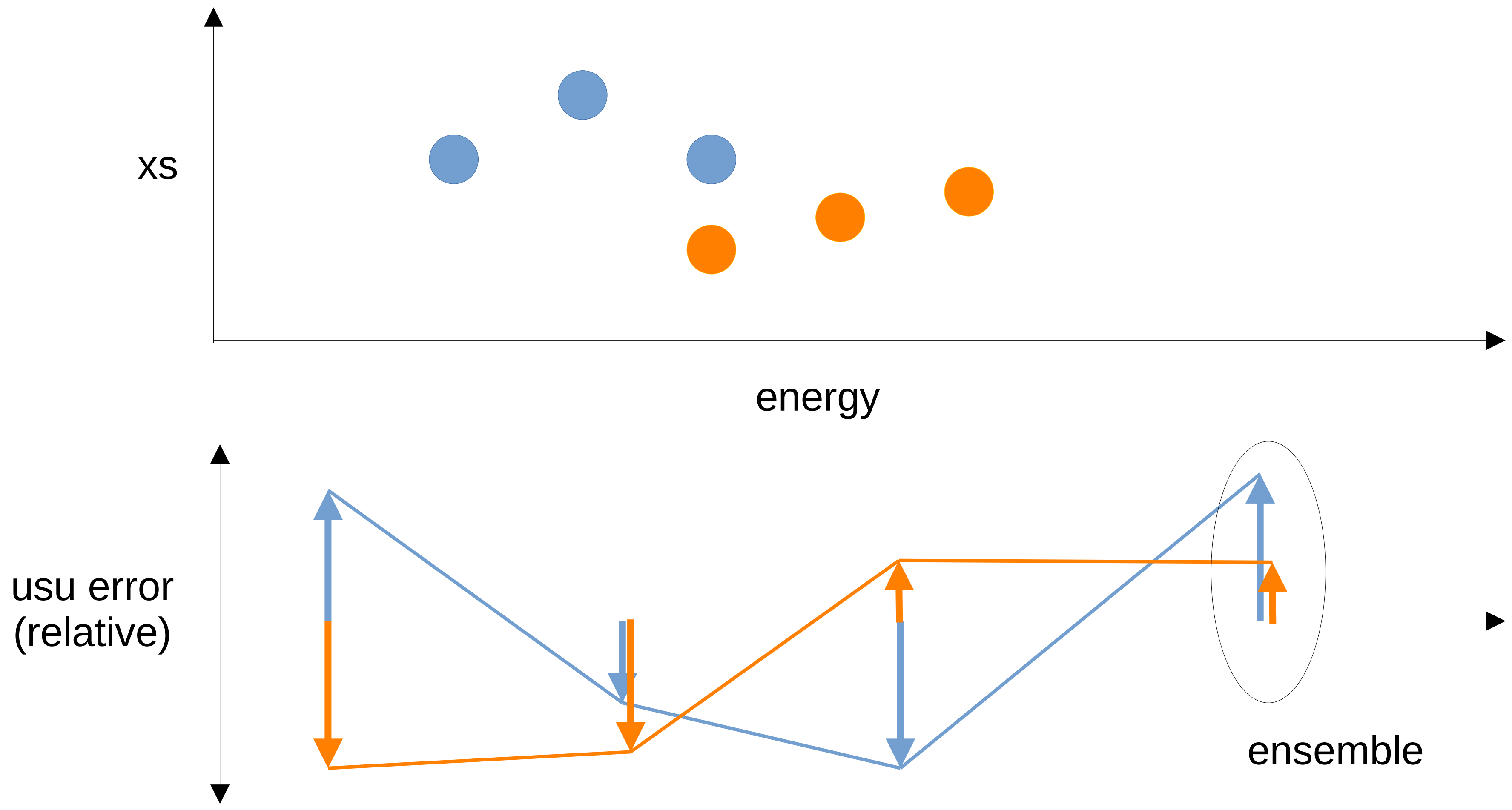


=> Focus for determination of USU on (absolute) Pu9(n,f) and (absolute and shape) Pu9(n,f) / U5(n,f)

Definition of energy dependent USU (in a nutshell)



Definition of energy dependent USU (in a nutshell)



Per energy USU uncertainty can be estimated
by considering ensembles of USU errors
associated with different datasets

Python package gmapy (modernized GMA)

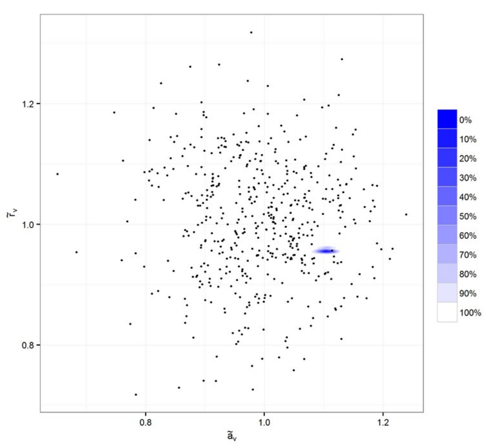
uniform prior

$$\pi(\vec{p}_{\mathrm{true}} \,|\, \vec{\sigma}_{\mathrm{exp}}, M) \propto f(\vec{\sigma}_{\mathrm{exp}} \,|\, \vec{p}_{\mathrm{true}}, M)\pi(\vec{p}_{\mathrm{true}} \,|\, M)\ \pi(\textit{USU uncertainties})$$

Experimental info:
multivariate normal

Exact (non-linear) “model”
(e.g. ratios)

Prior:
multivariate normal

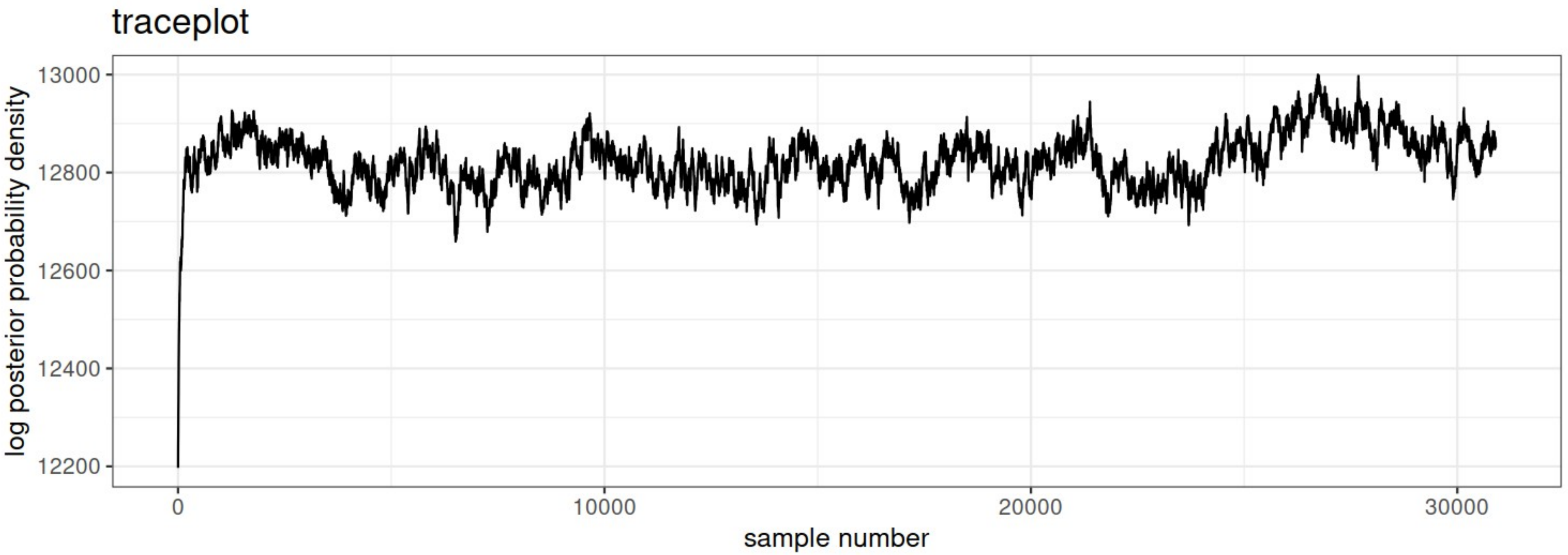


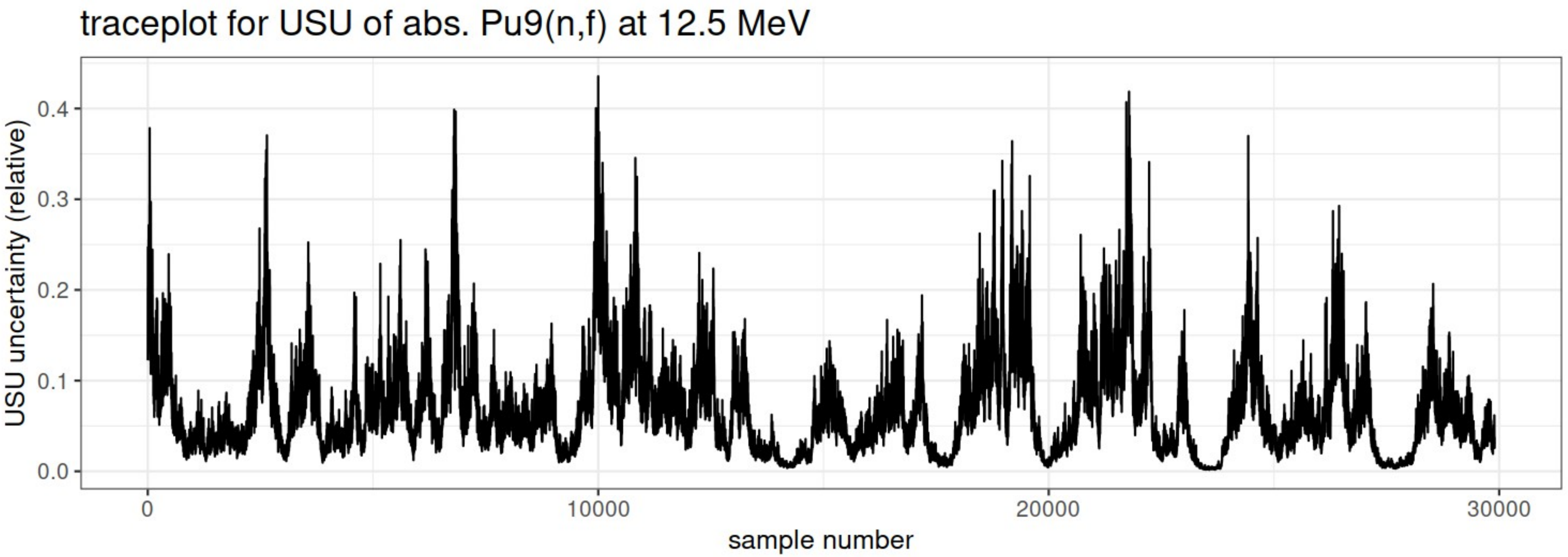
Monte Carlo (Metropolis-Hastings)

Related ref: G. Schnabel, “Fitting and Analysis Technique for inconsistent nuclear data”, Proc. of M&C, (2017)

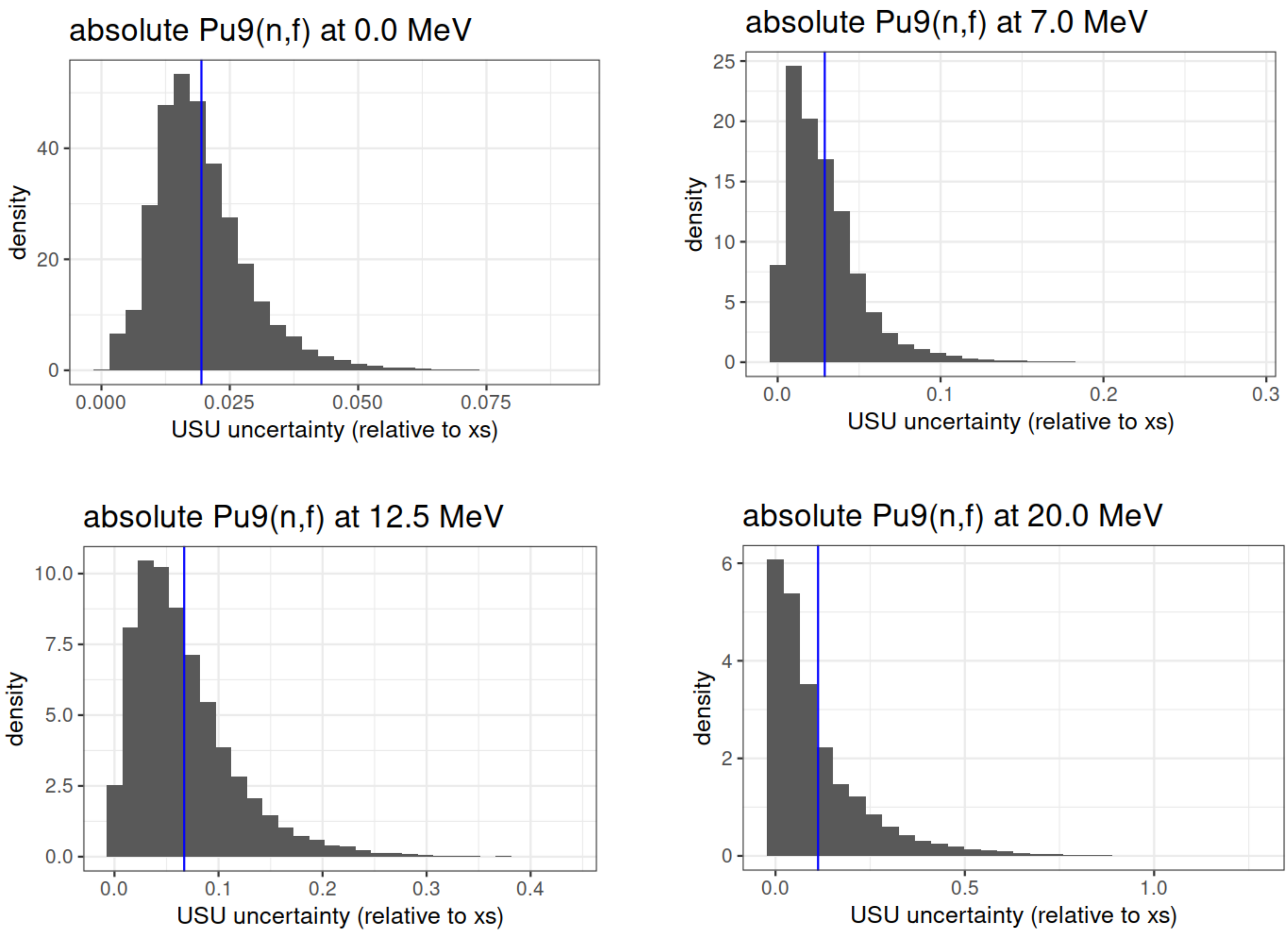
But here: Monte Carlo treatment extended to non-linear model

Evolution of MCMC chain

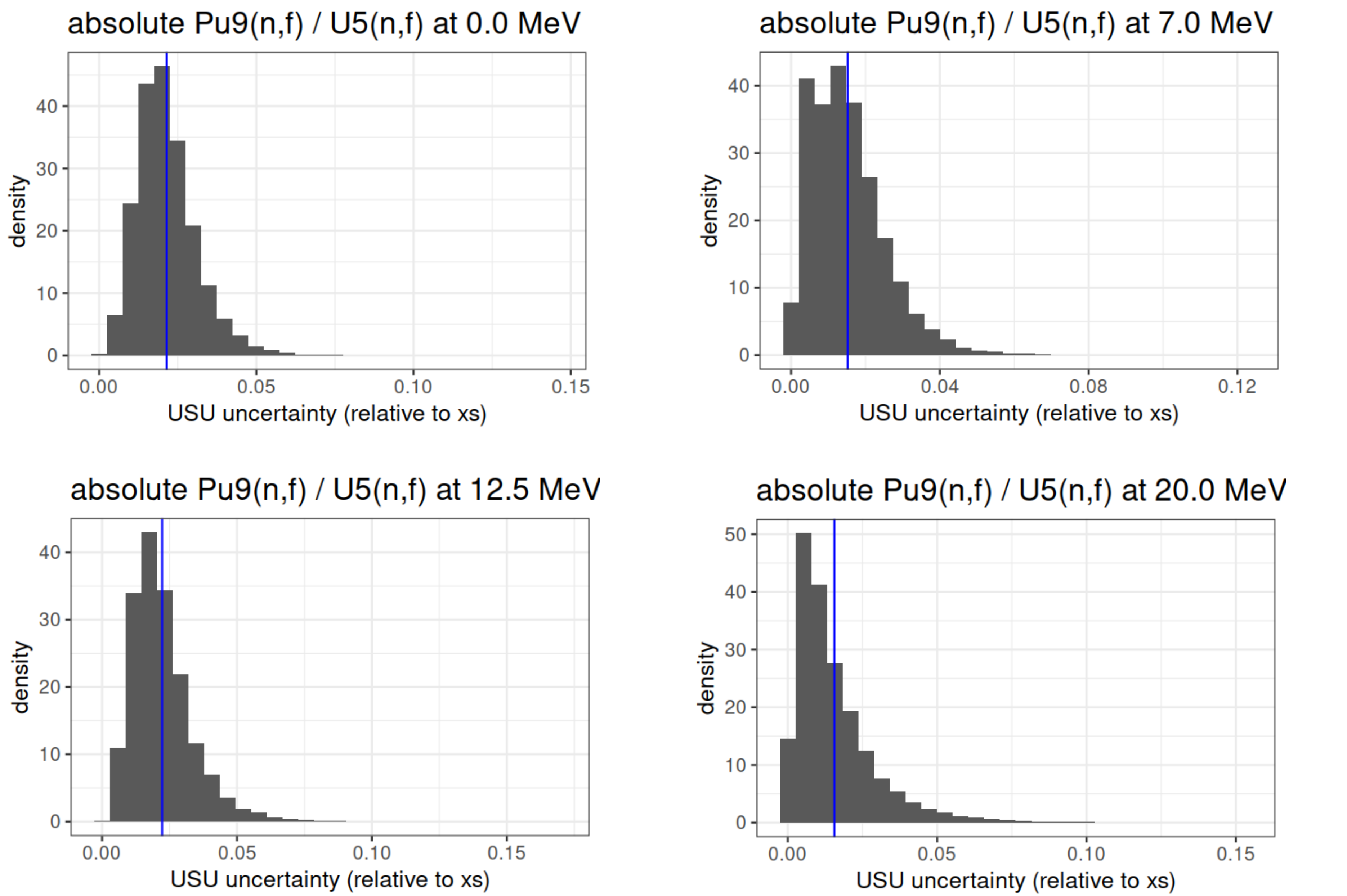




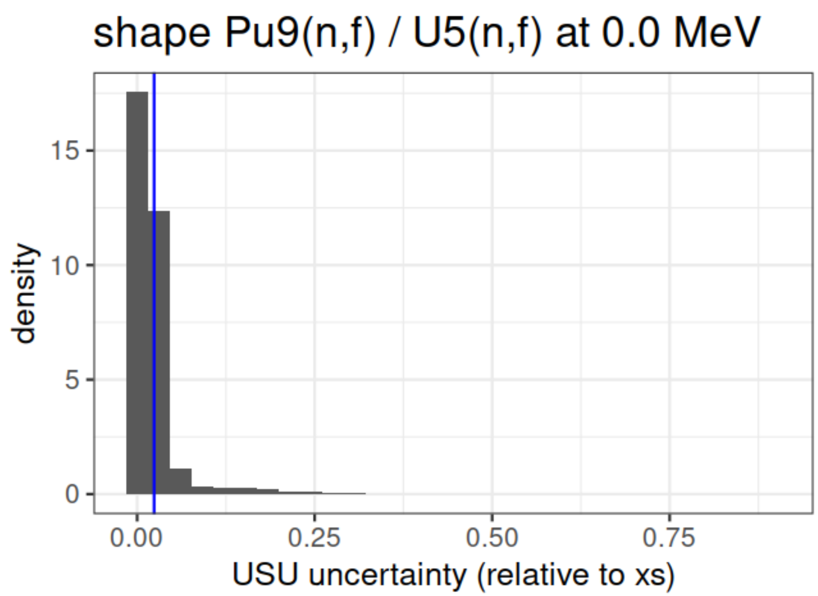
Examples of USU posterior histograms

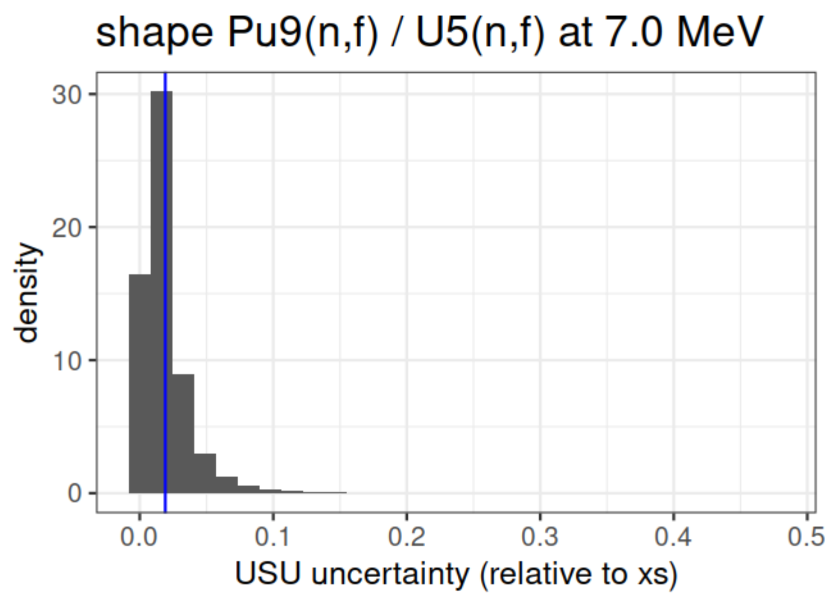


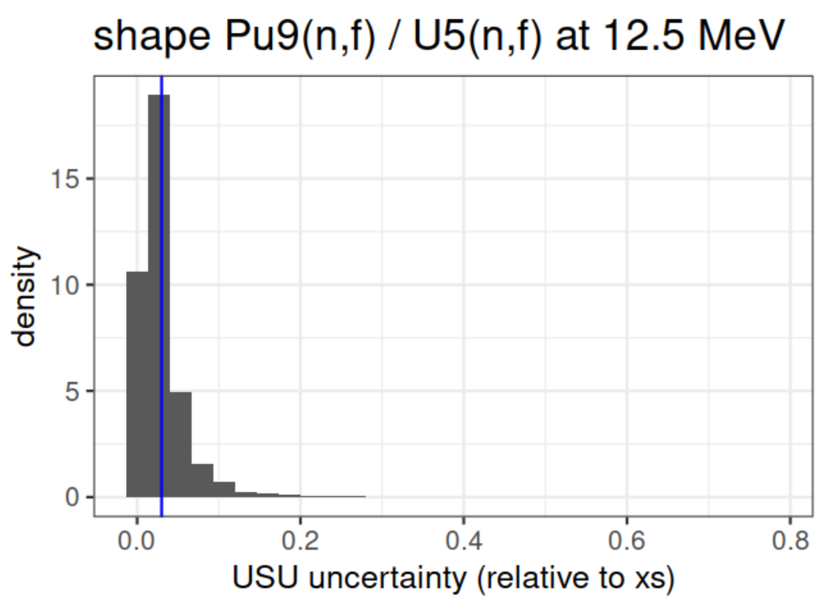
Examples of USU uncertainty posterior histograms

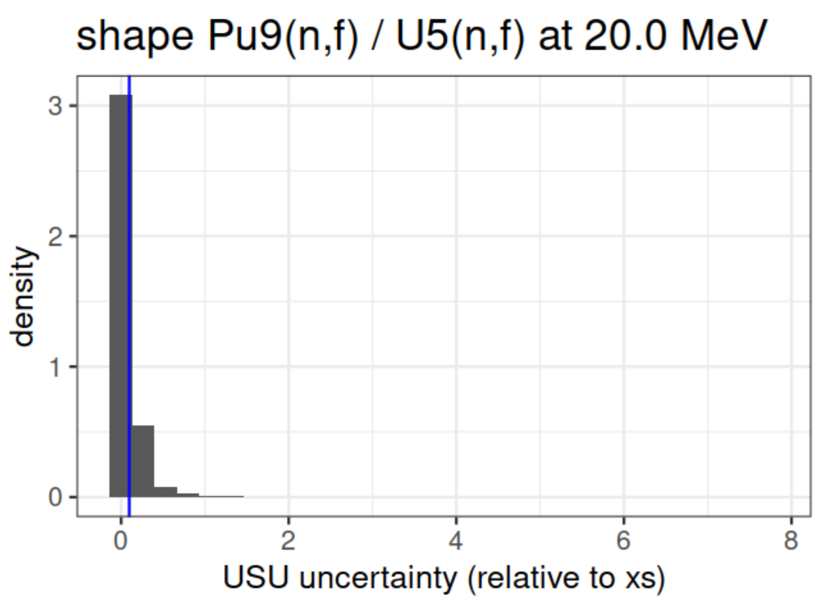


Examples of USU posterior histograms

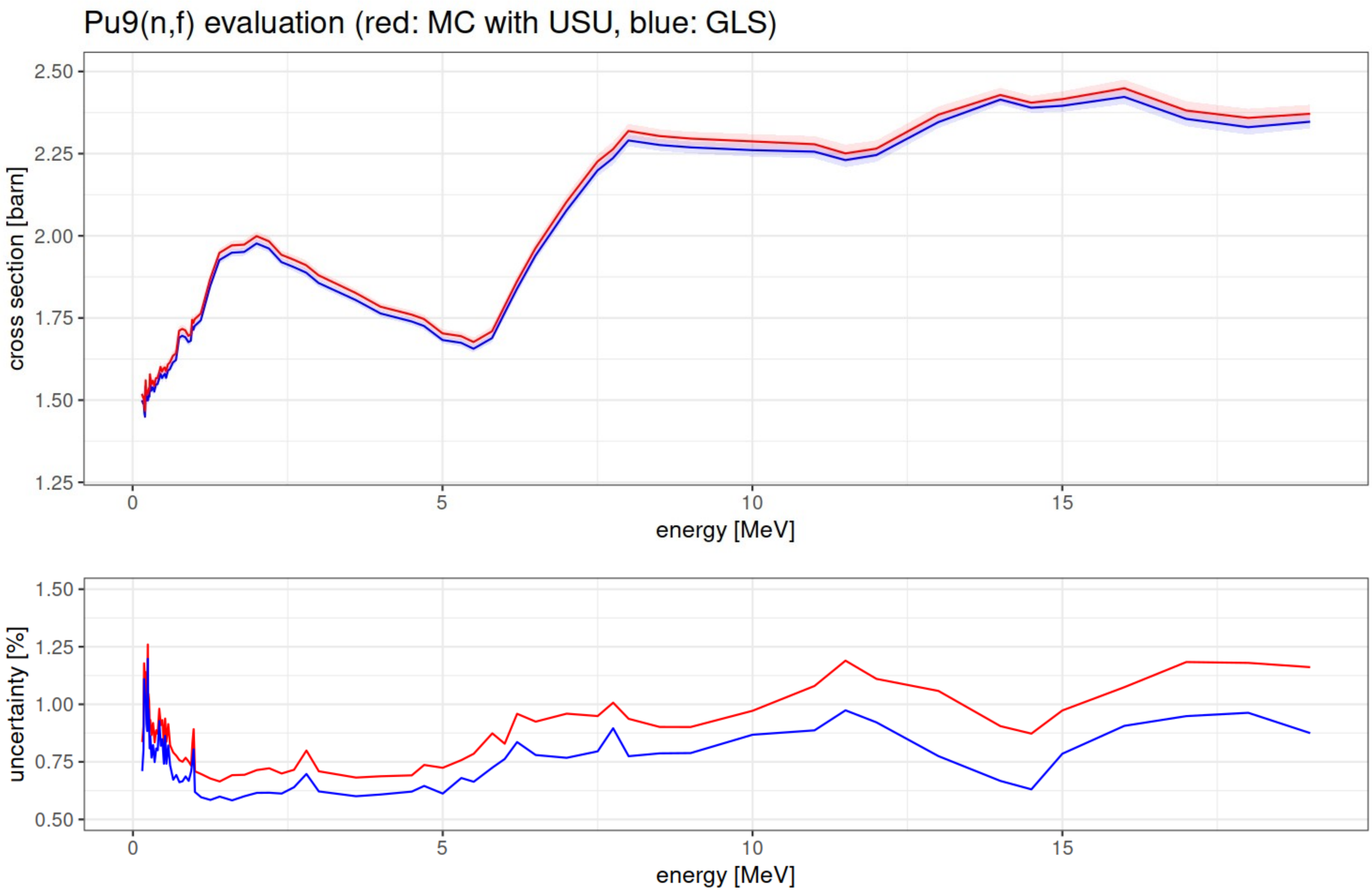




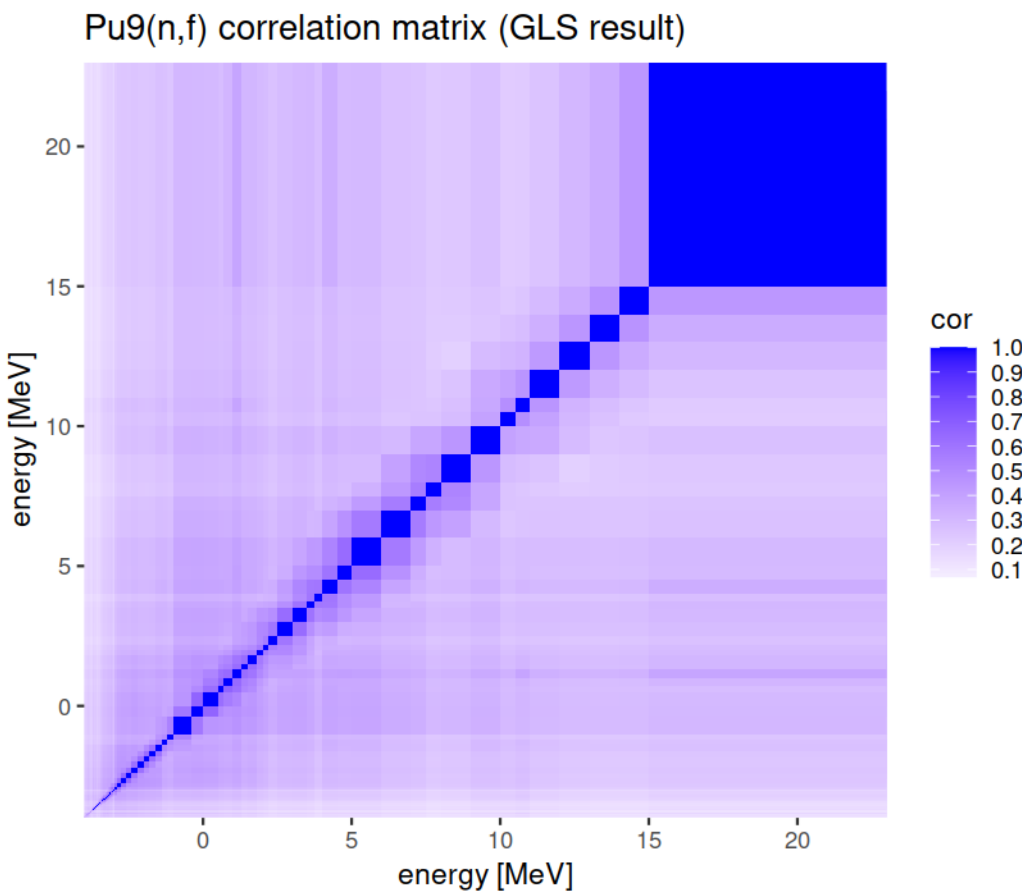


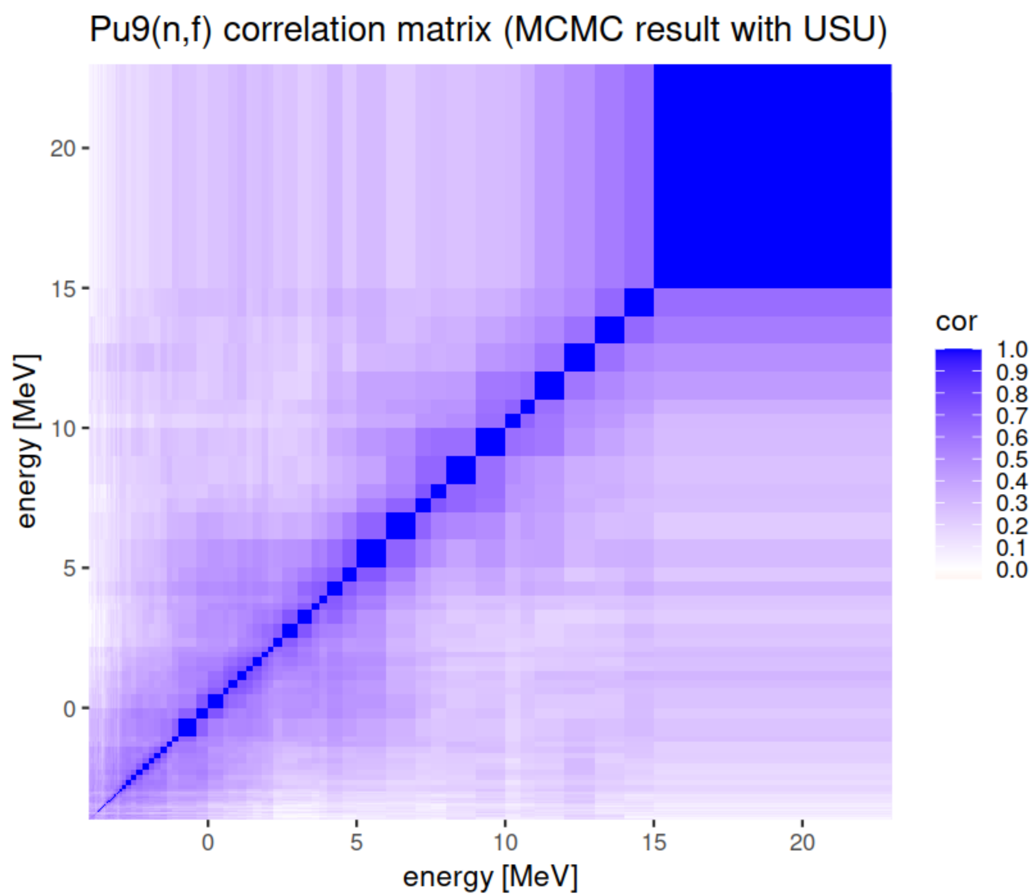


MCMC evaluation including USU components



Correlation plots





Summary

- Estimation of Pu9(n,f) covariance matrix using MCMC and incorporating the assumption of unknown USU uncertainties
- Importantly, USU estimation accounts for all uncertainty specifications in the GMA database
- Evaluation performed with Python package gmapy, which is a modernized (yet backward-compatible) version of GMA
- This approach may be used to update the covariance matrices of U5(n,f), U8(n,f), Pu9 (n,f) in the GMA standards database