Uncertainties for criticality-safety benchmarks and consequences for nuclear data measurements

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Contents

① Motivations for a change:

$\Longrightarrow$ *a roadmap to consistent and state-of-the-art evaluations*

② Concept:

$\Longrightarrow$ *Monte Carlo from nuclear data evaluations to large-scale systems*

③ How does it work ?

$\Longrightarrow$ *TALYS + Monte Carlo*

④ Examples with ^{235,238}U, ^{238,242}Pu and ^{244}Cm isotopes:

$\Longrightarrow$ *k_{eff} uncertainties and feedback to differential data for ^{238,242}Pu and ^{244}Cm*

⑤ Conclusions

Motivations: How to produce consistent (and reproductible) evaluations ?

Usual procedures in evaluations imply

- First, there were measurements,
- Then nuclear reaction codes (TALYS, GNASH, EMPIRE...),
- Format the output semi-manually to ENDF file,
- Compare with experimental cross sections,
- Modify manually the ENDF file,
- Compare with integral tests,
- Modify manually the ENDF file, ENDF file ready,
- At last, ”Industry can use evaluations”, but...

➳ How include propagation of nuclear data uncertainties with a minimum number of approximation ?

Concept: No more delocalization

Experiments

(integral, differential)

Evaluation 1

(basic quantities)

Evaluation 2

(uncertainties)

Formatting

Checking

Library

Processing

(NJOY)

Benchmarks

(MCNP, Perturbation)

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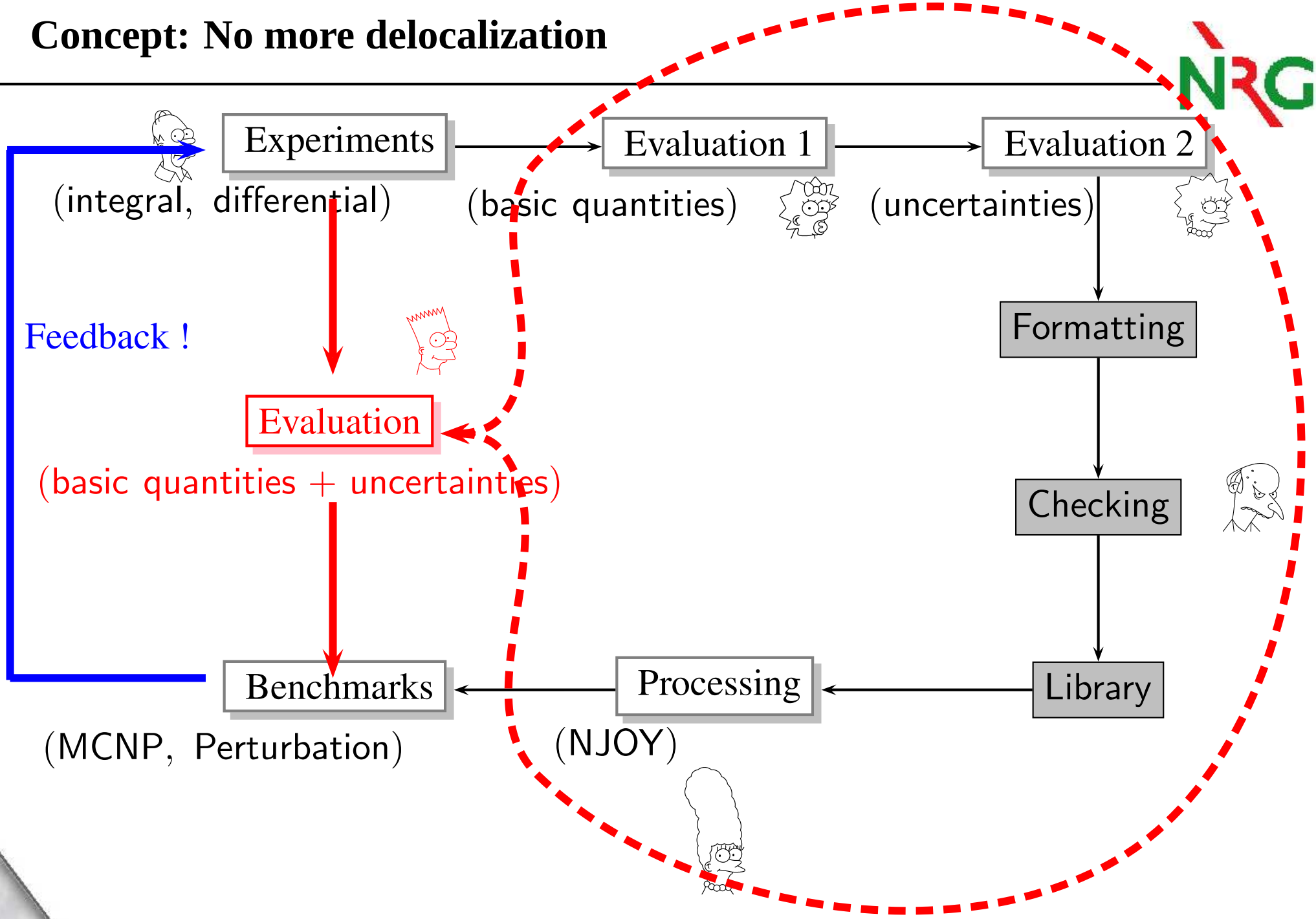
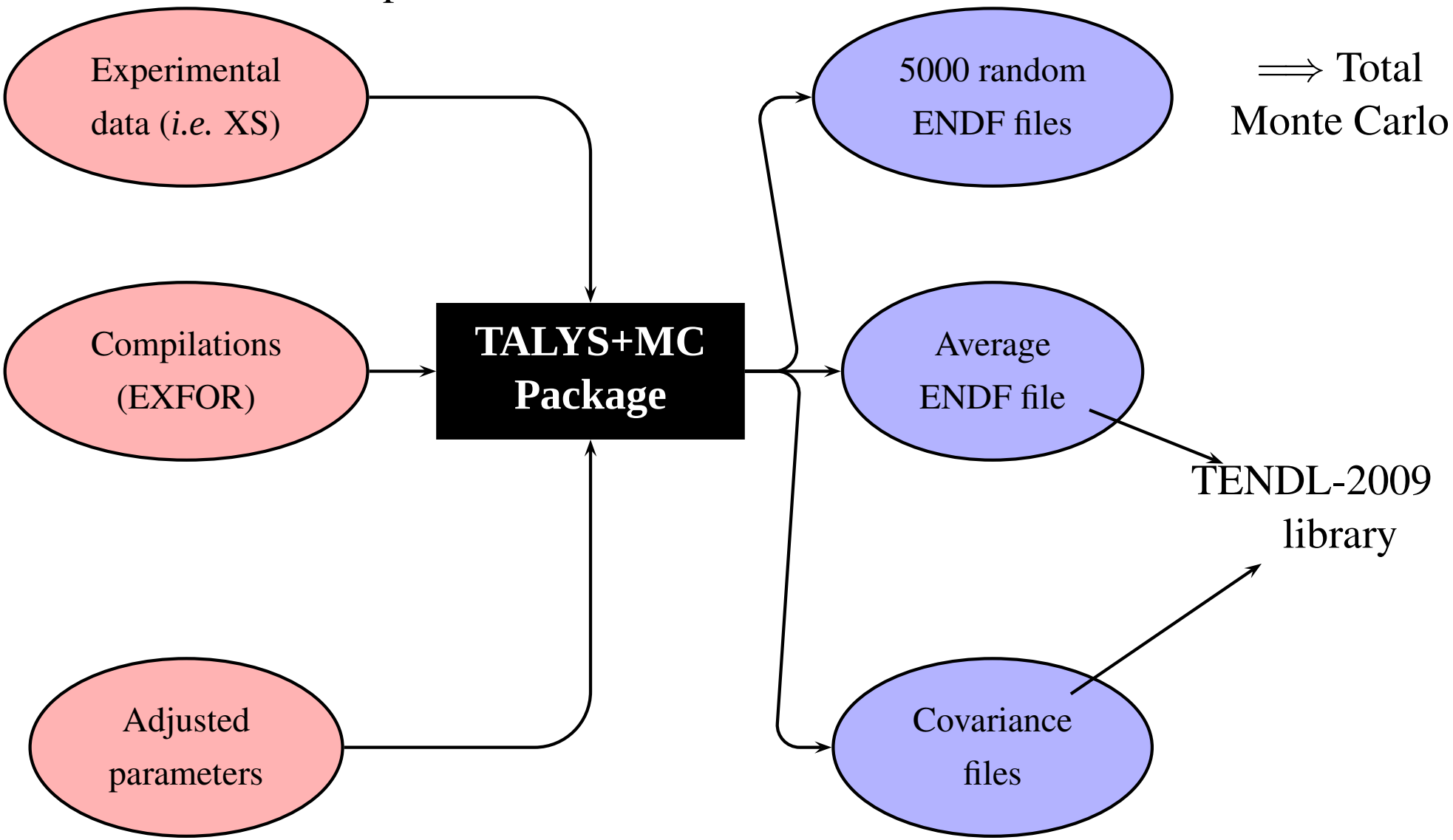


Concept: TALYS + Monte Carlo

Possible answer to this problem: Maximization of automation



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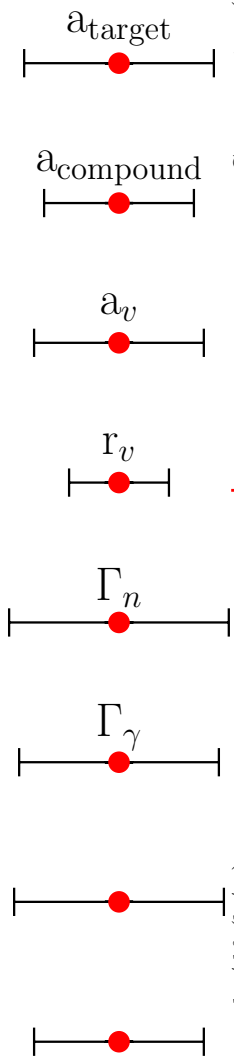

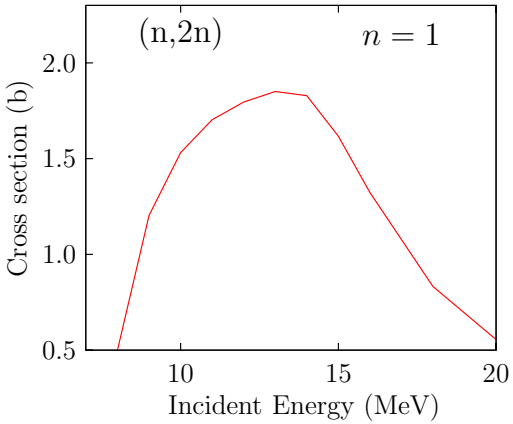

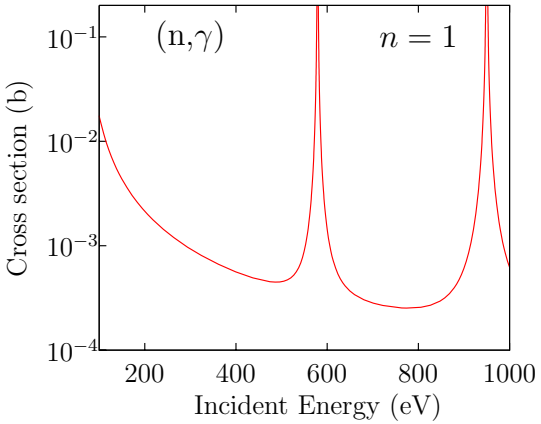

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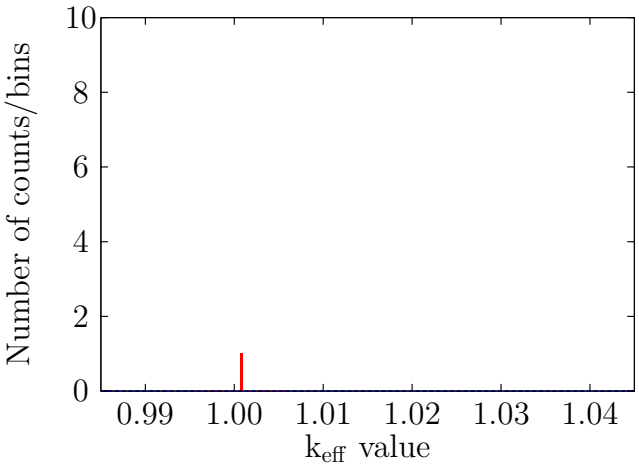

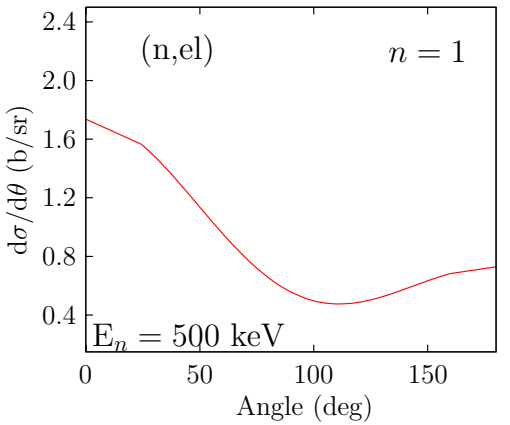

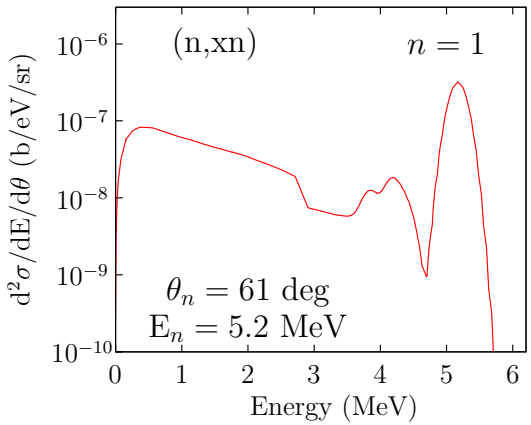

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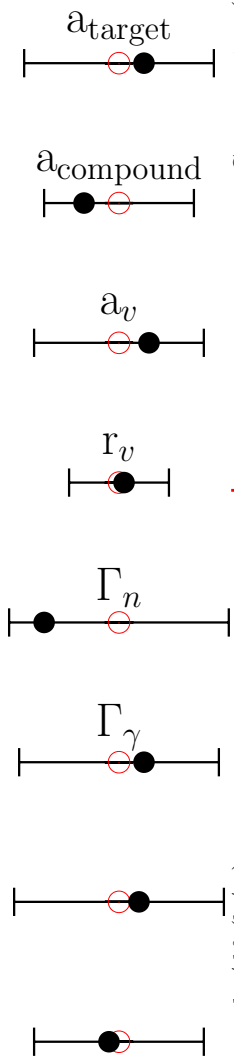

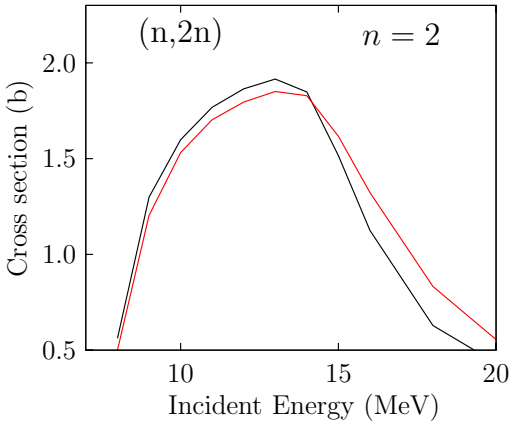

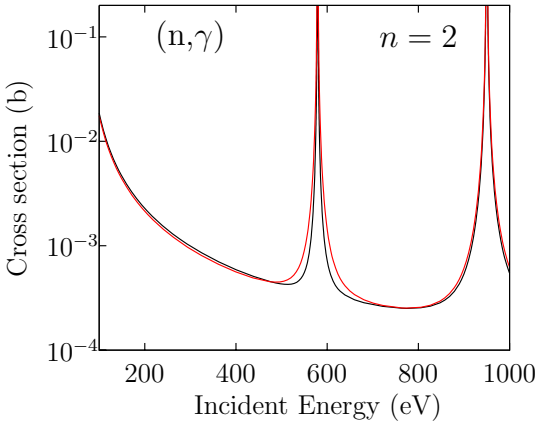

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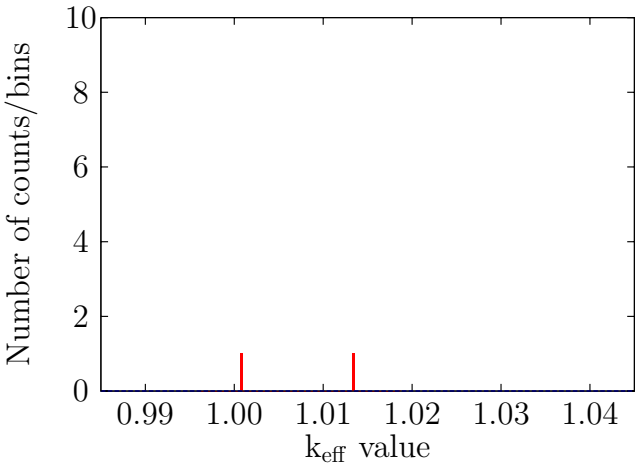

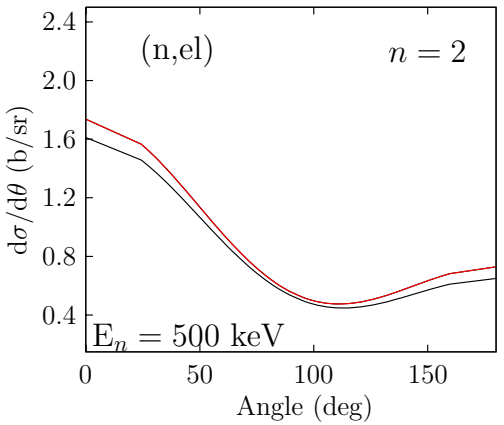

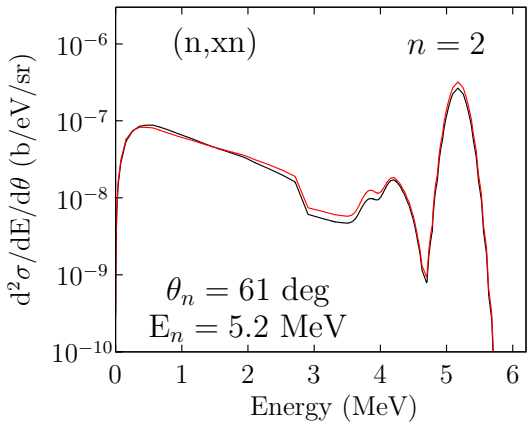

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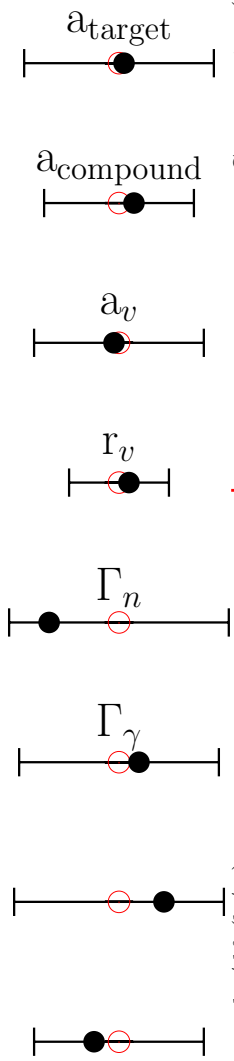

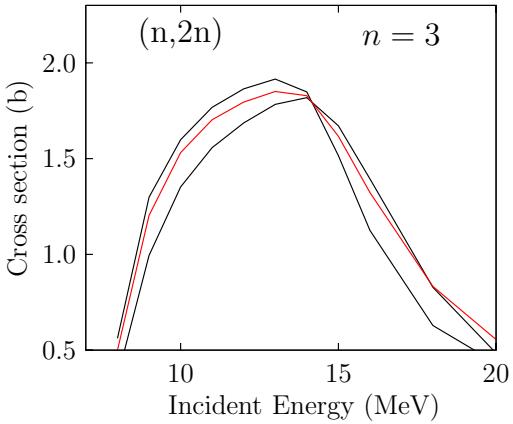

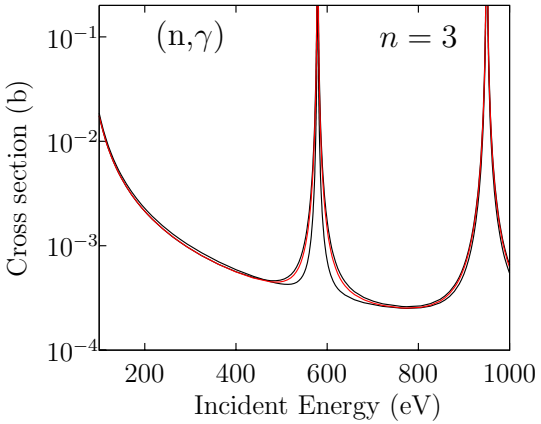

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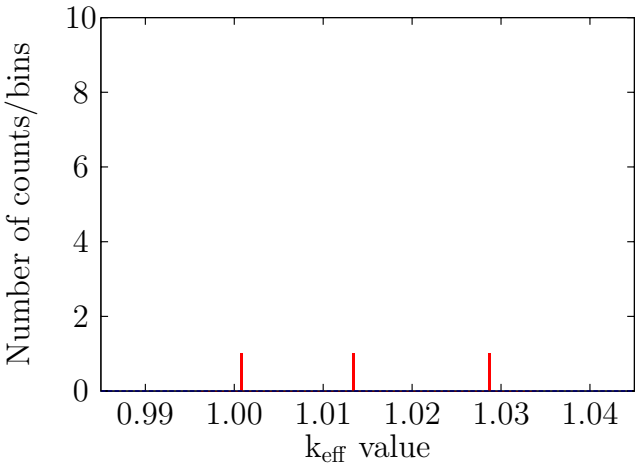

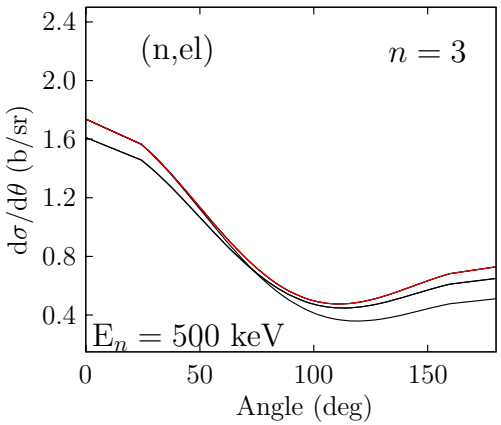

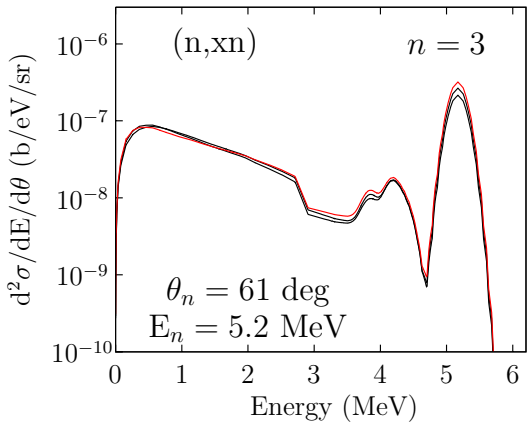

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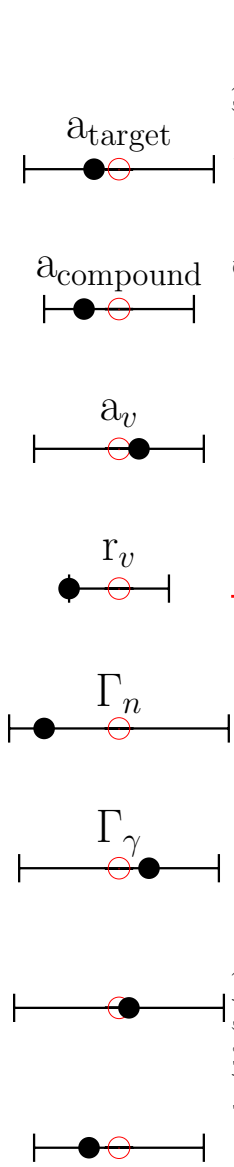

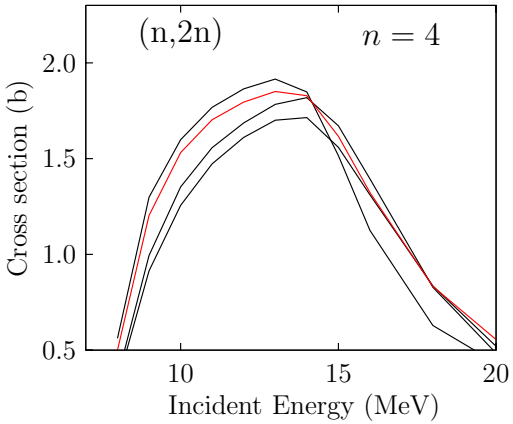

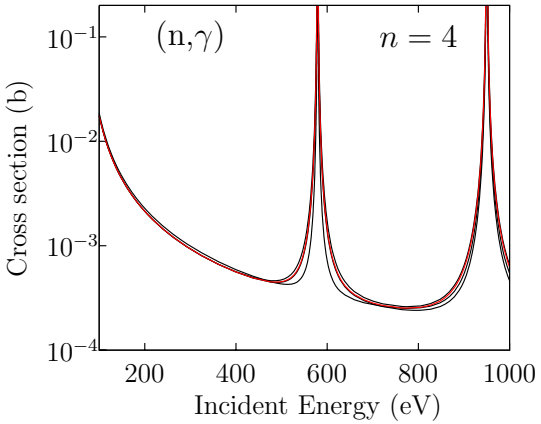

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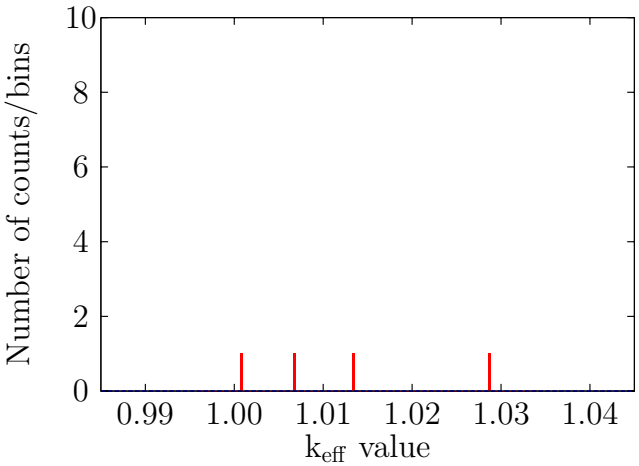

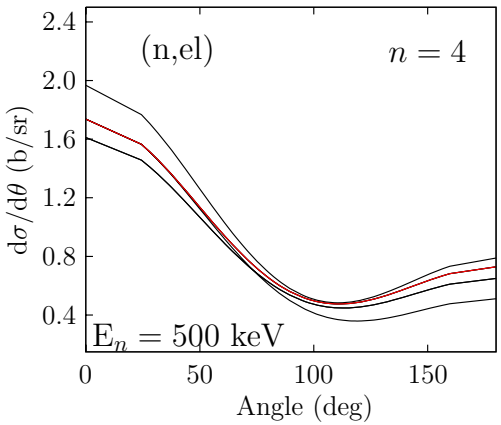

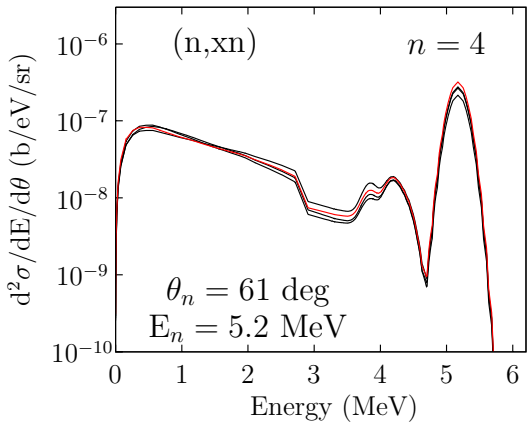

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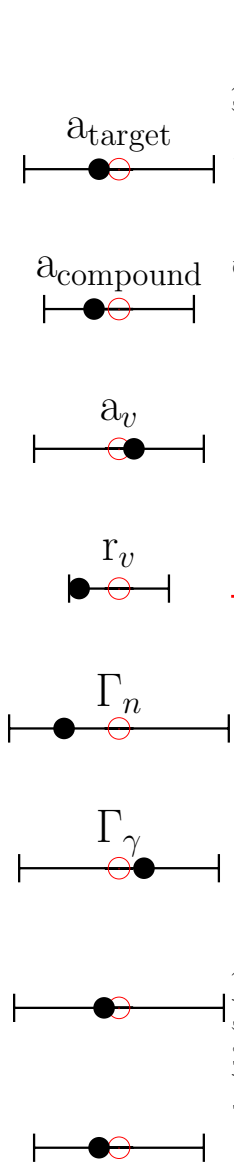

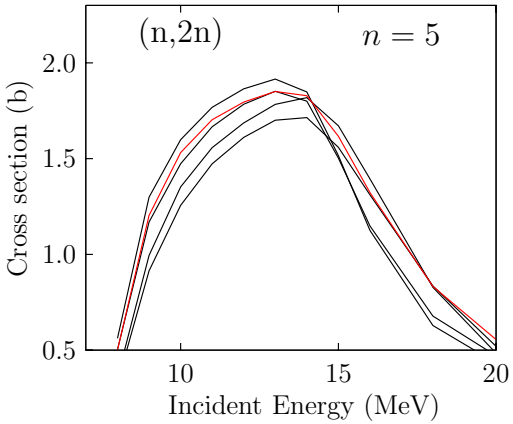

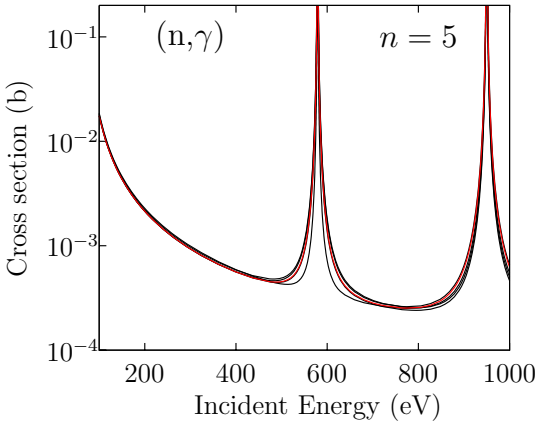

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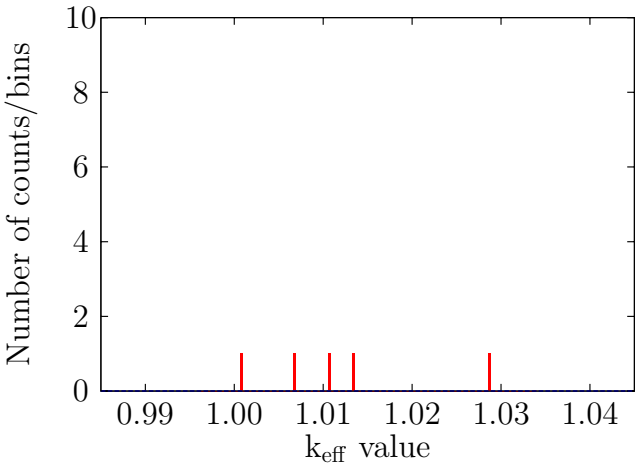

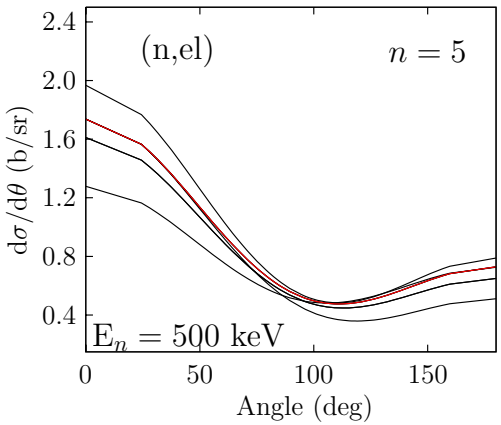

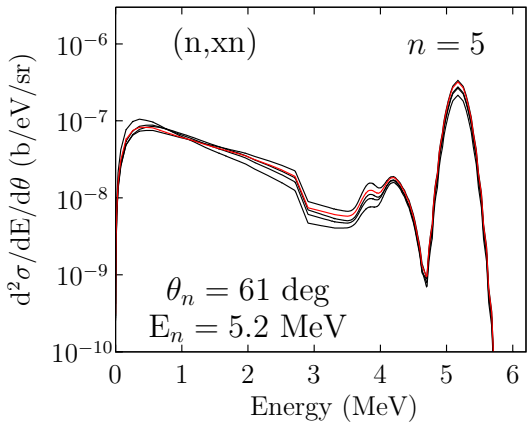

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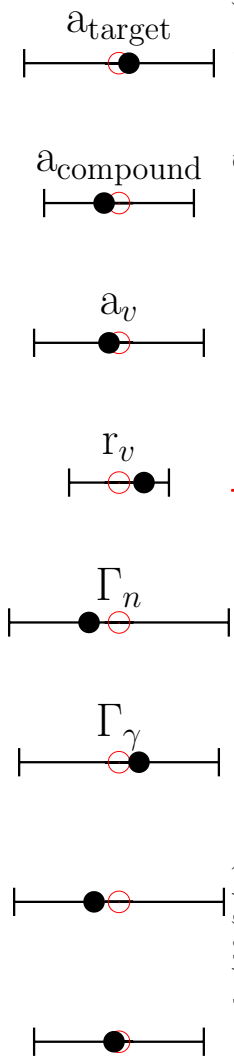

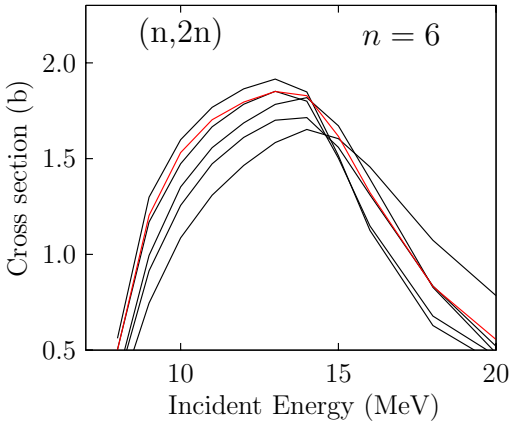

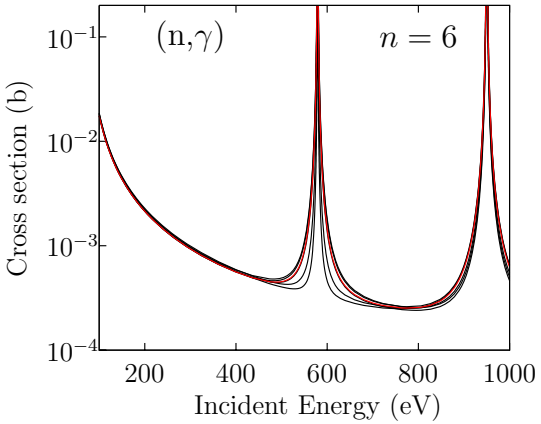

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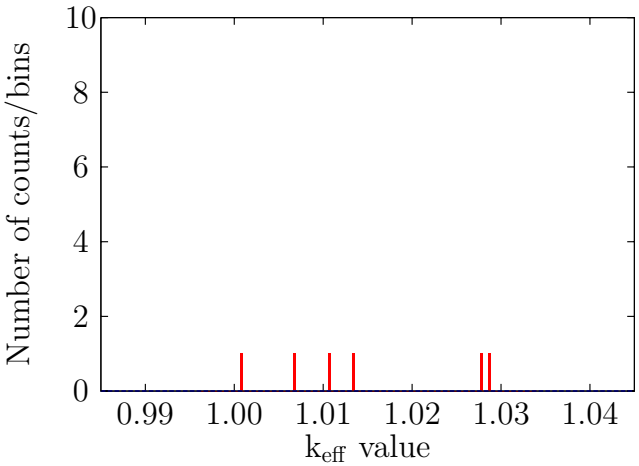

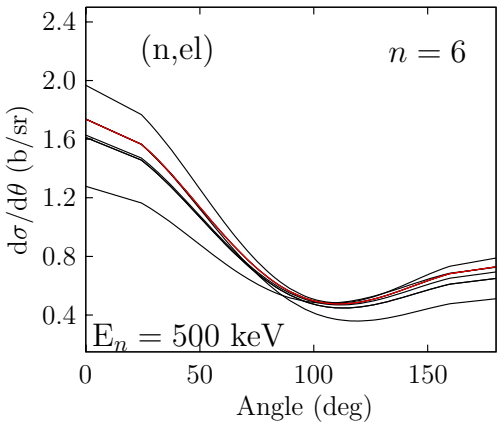

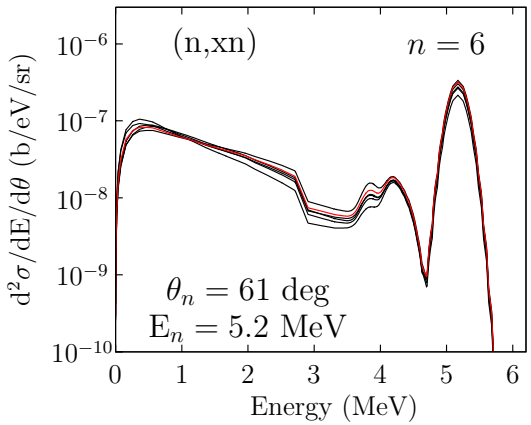

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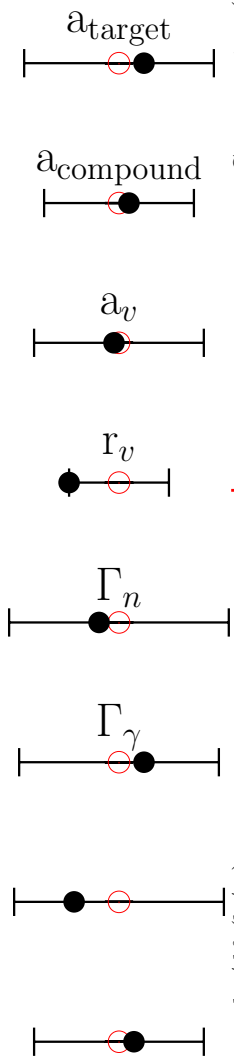

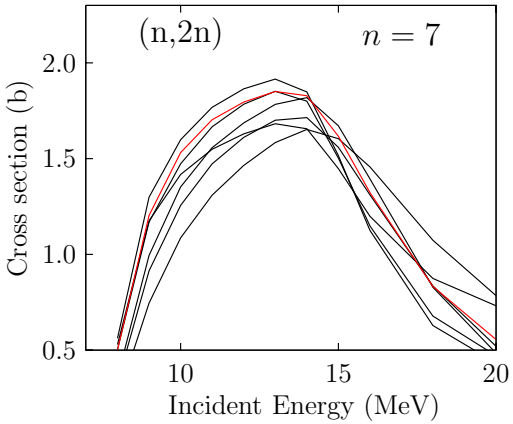

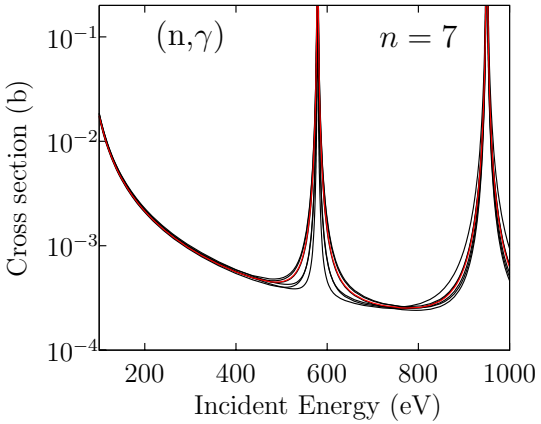

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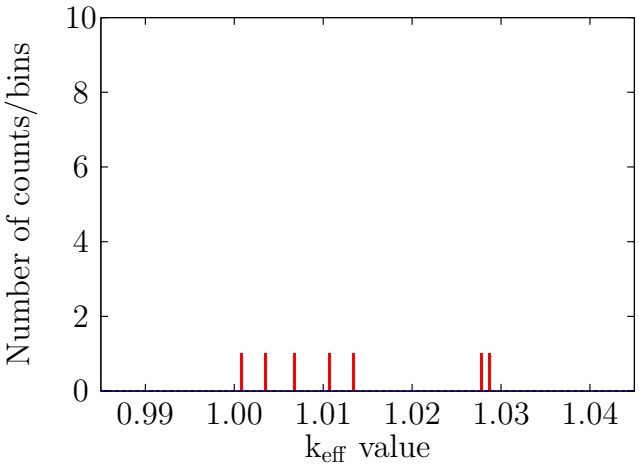

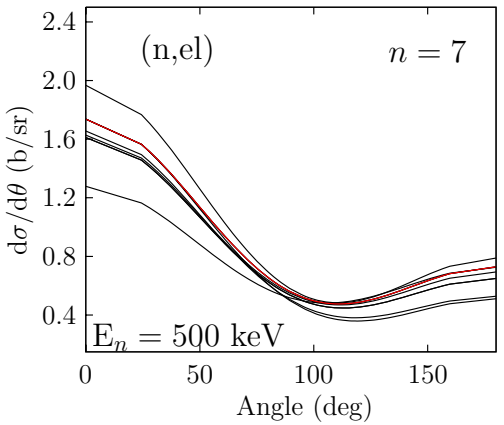

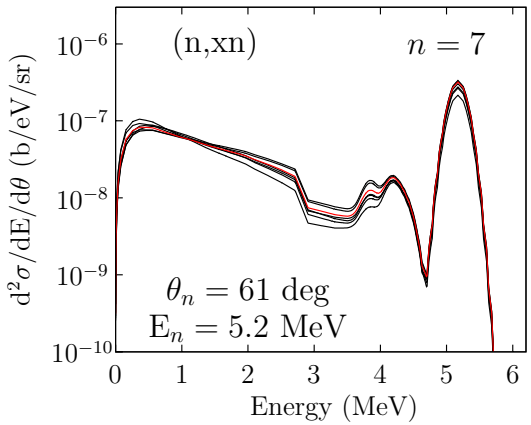

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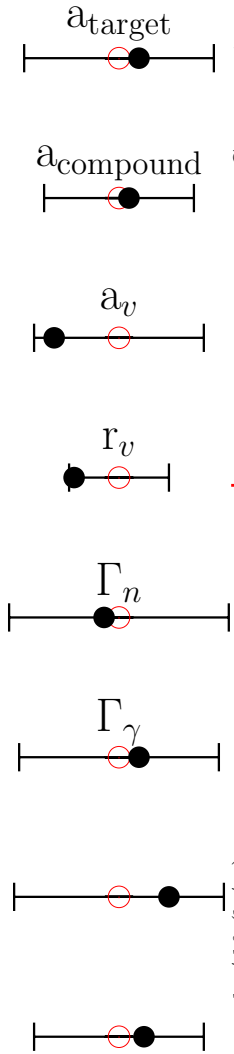

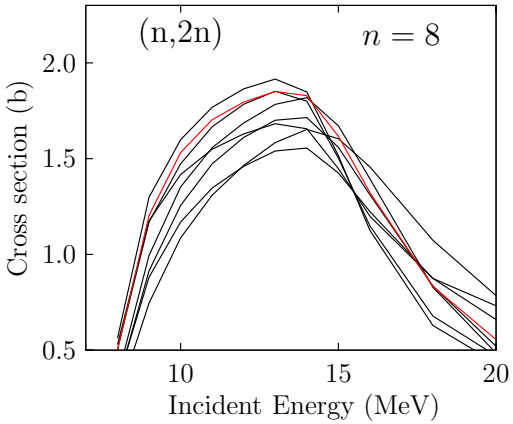

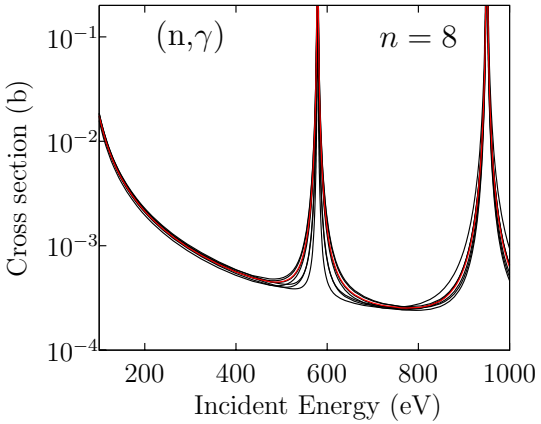

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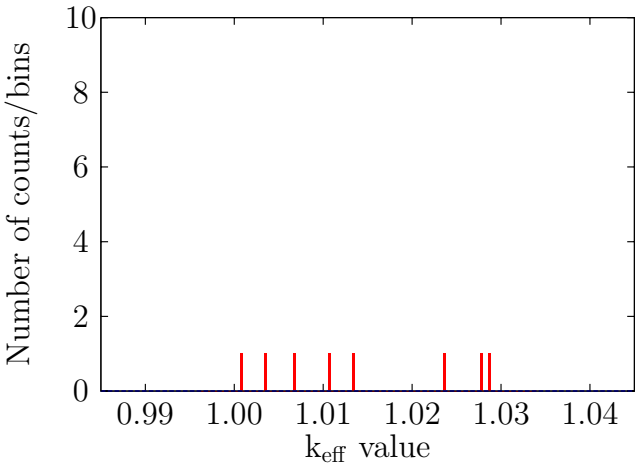

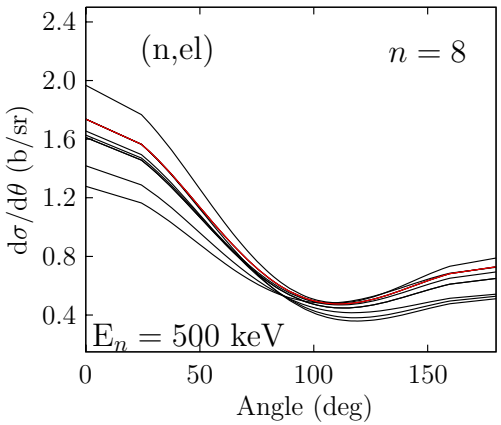

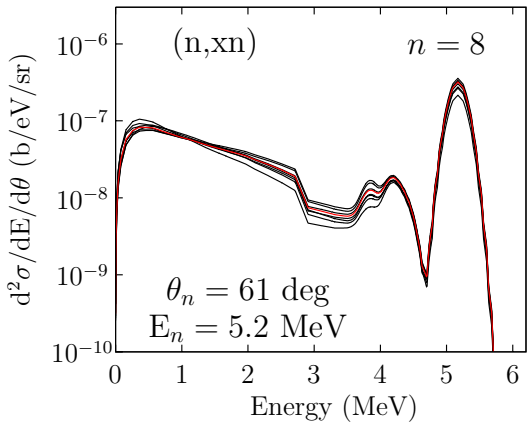

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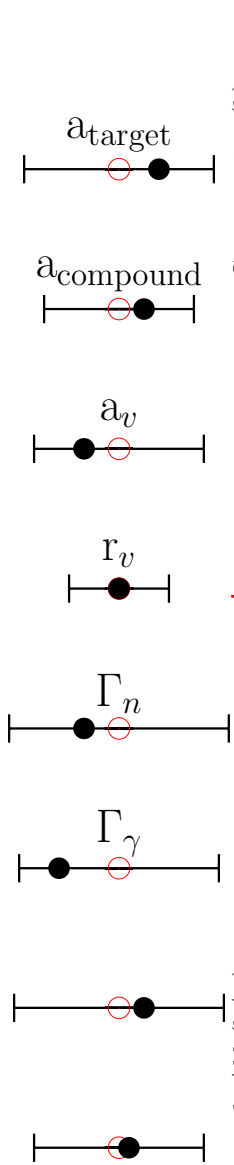

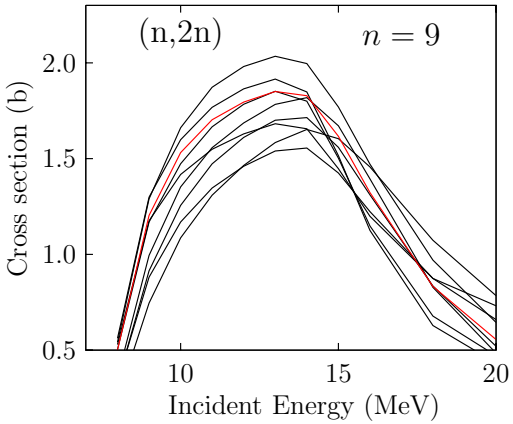

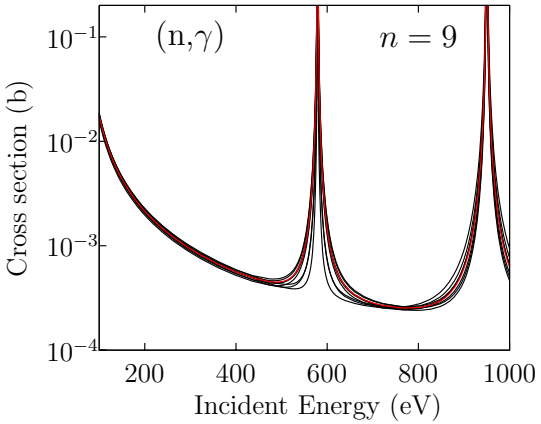

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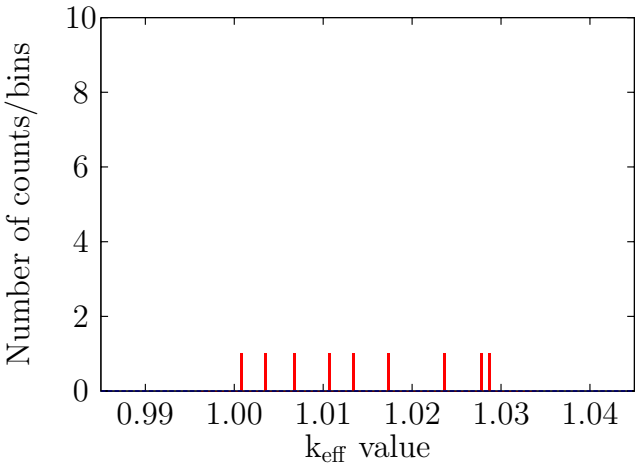
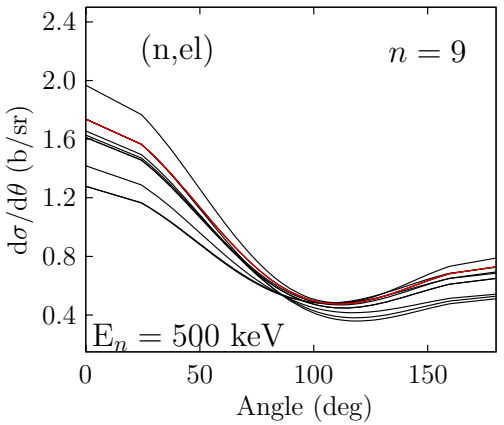
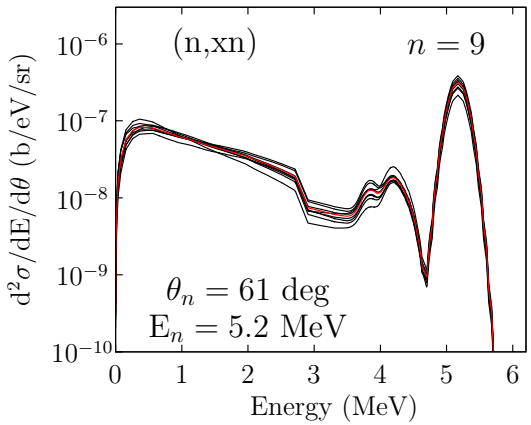
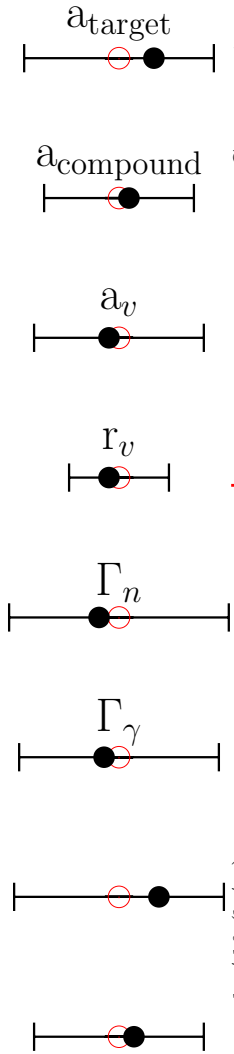
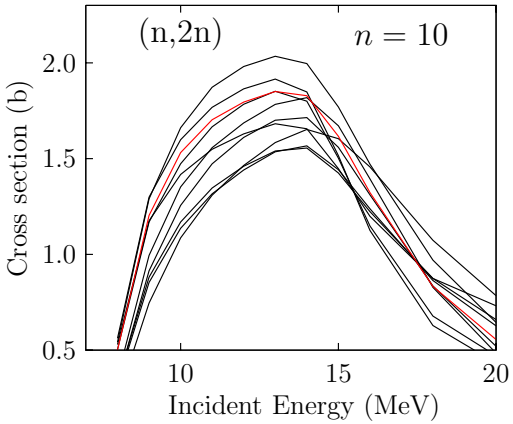


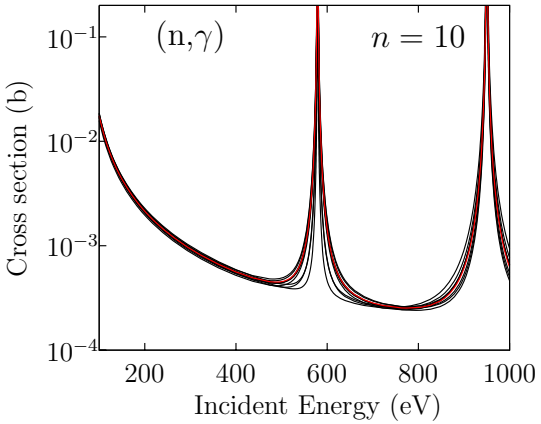




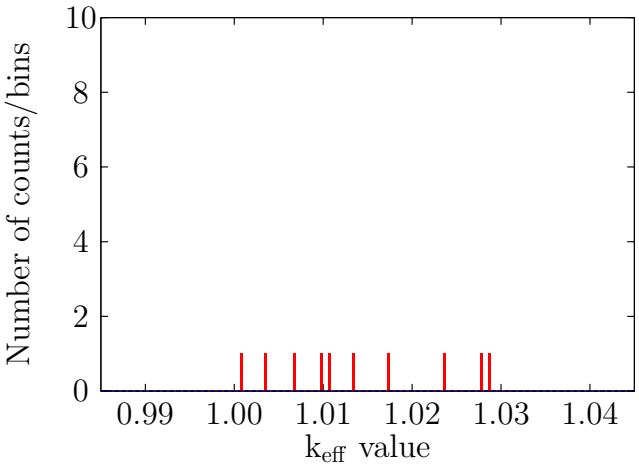
Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”

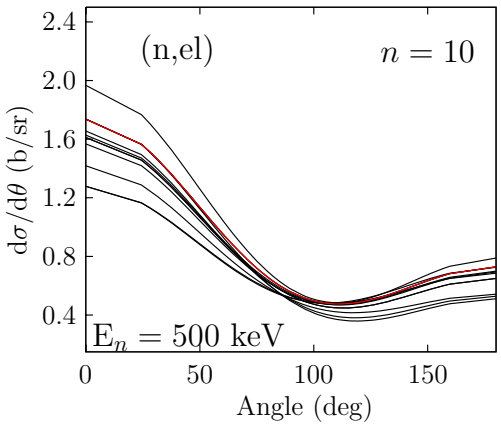


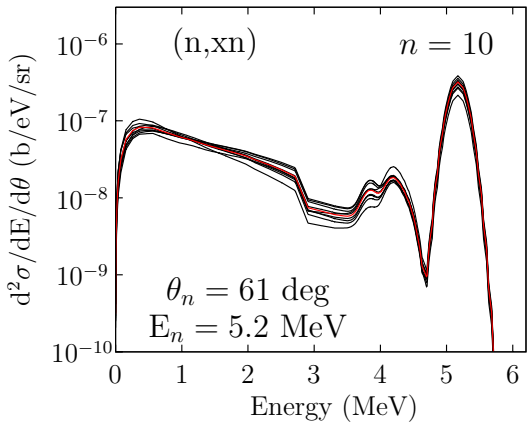




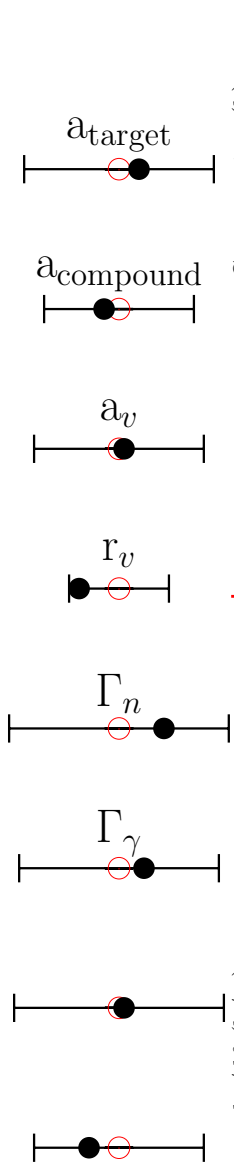
TALYS MCNP

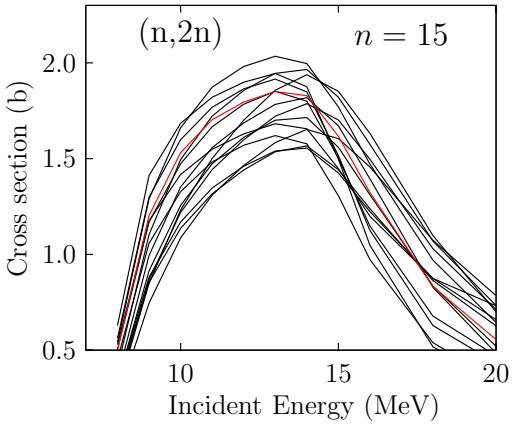


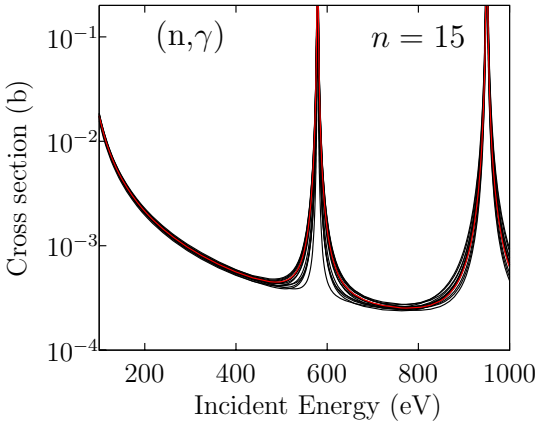




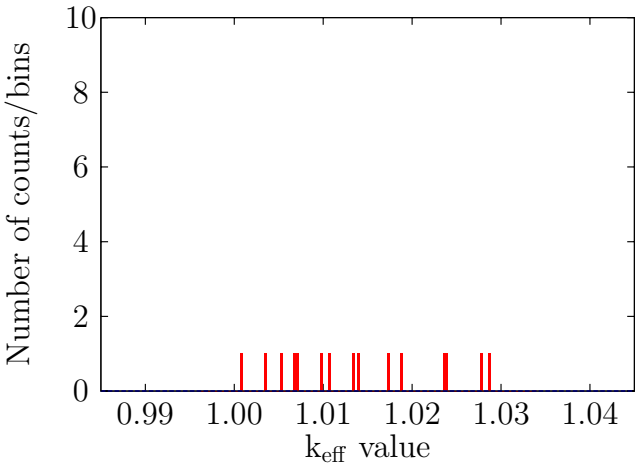
Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”

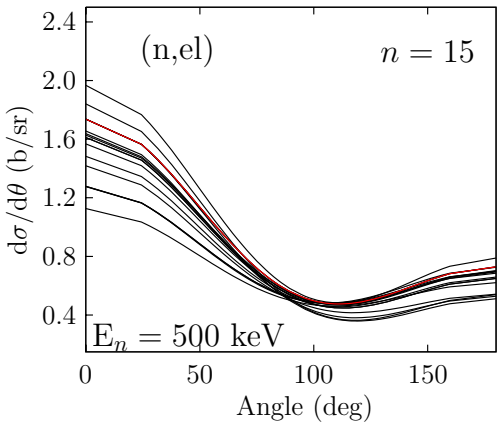


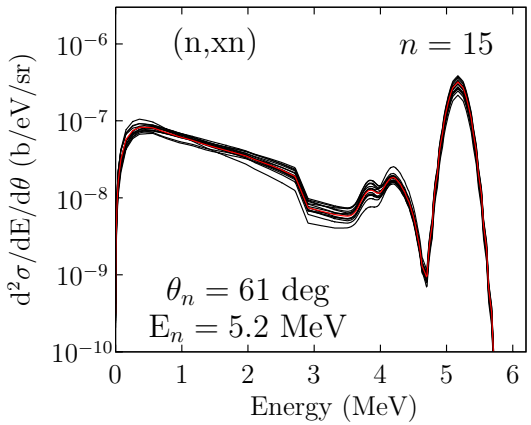




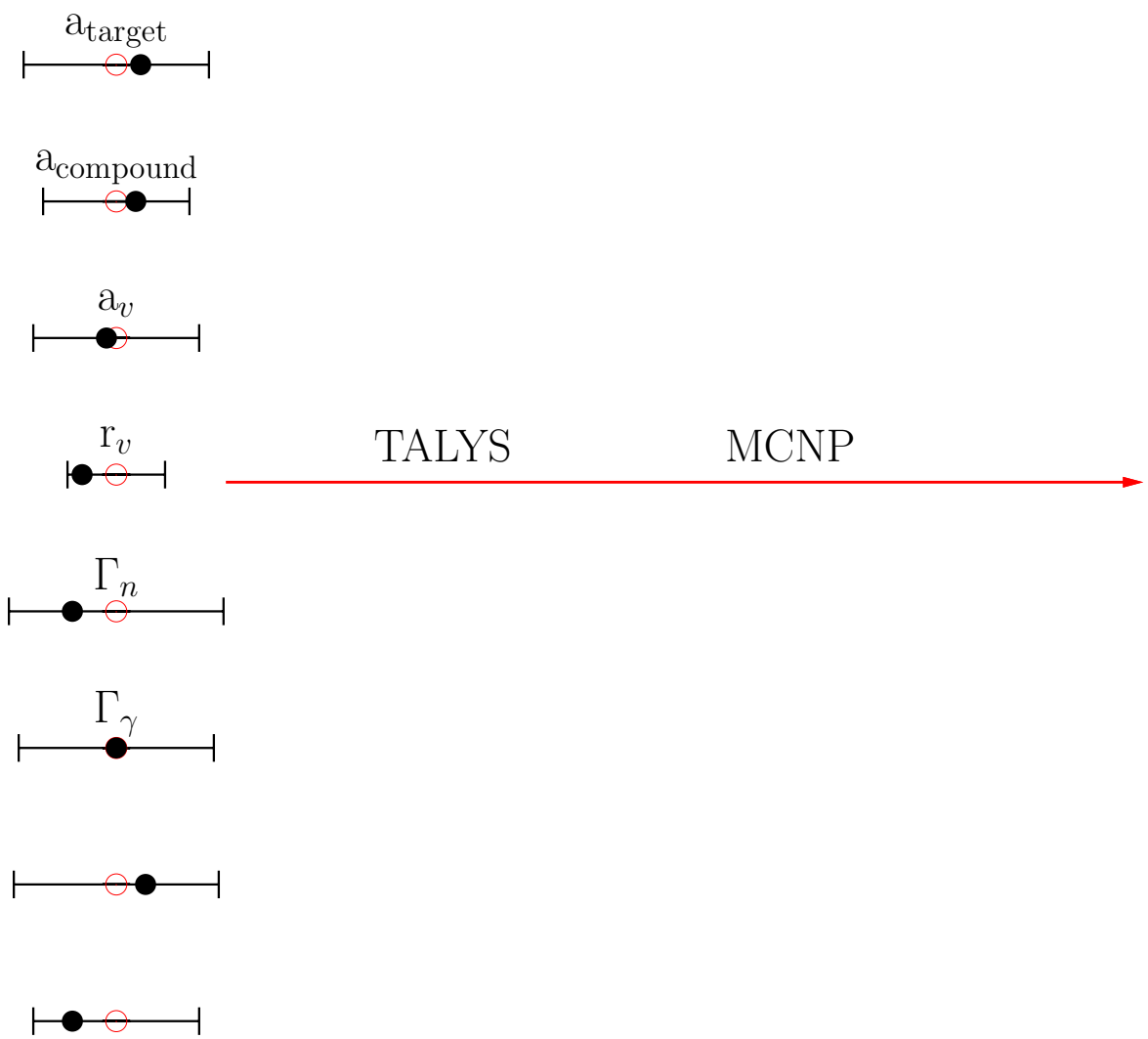
TALYS MCNP

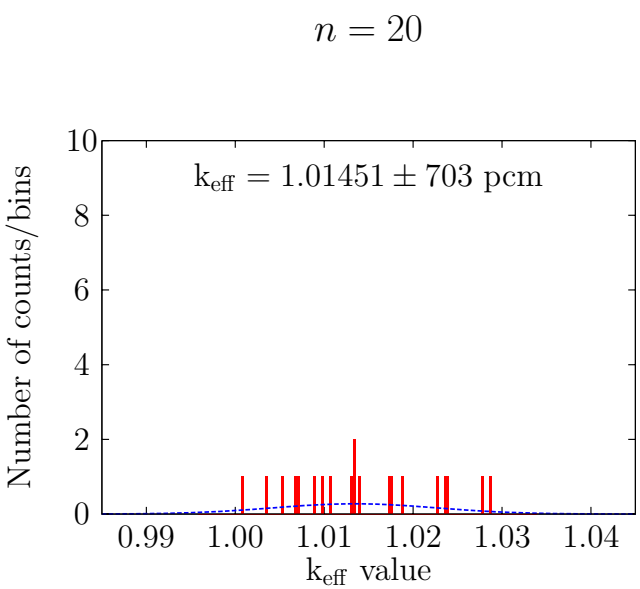




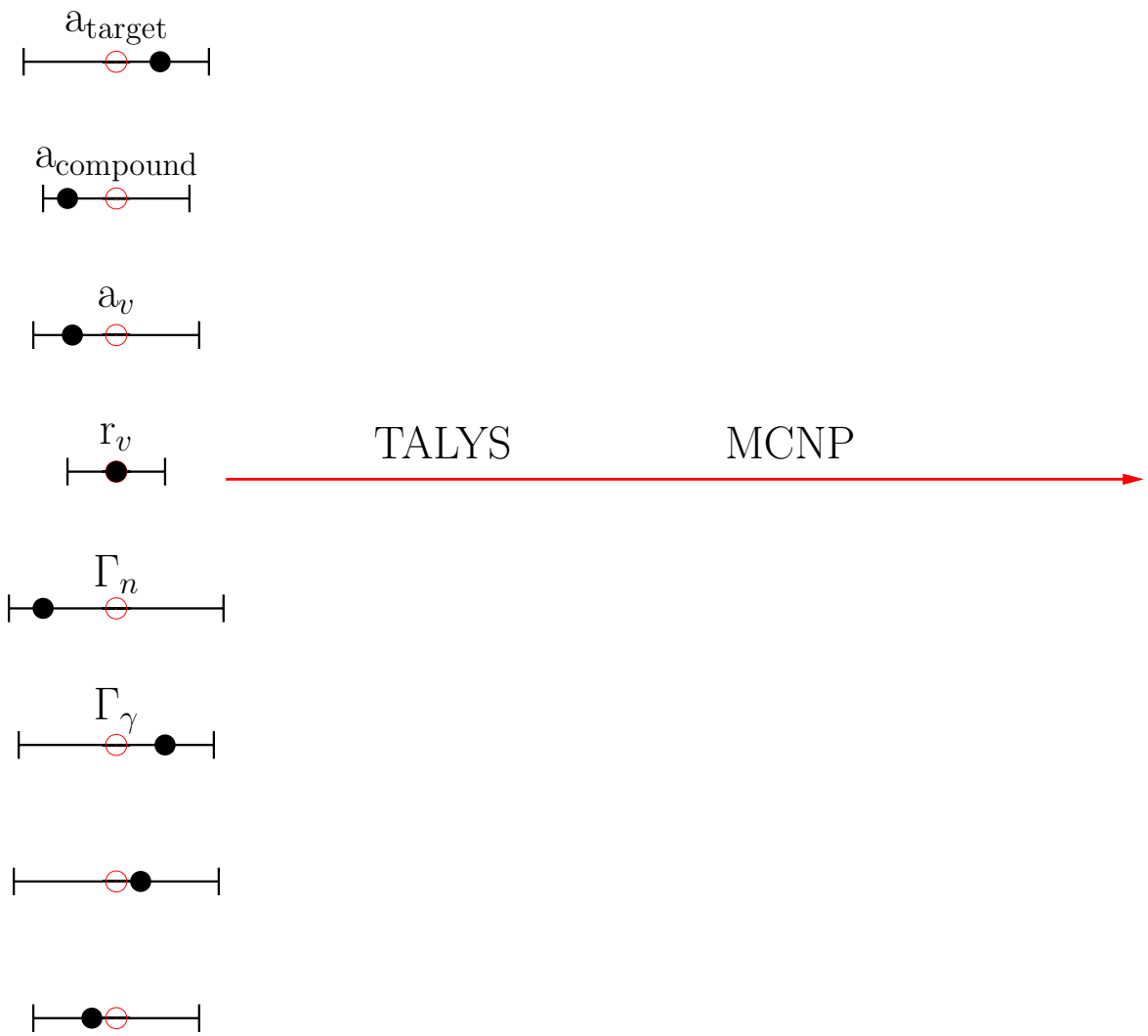


Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”

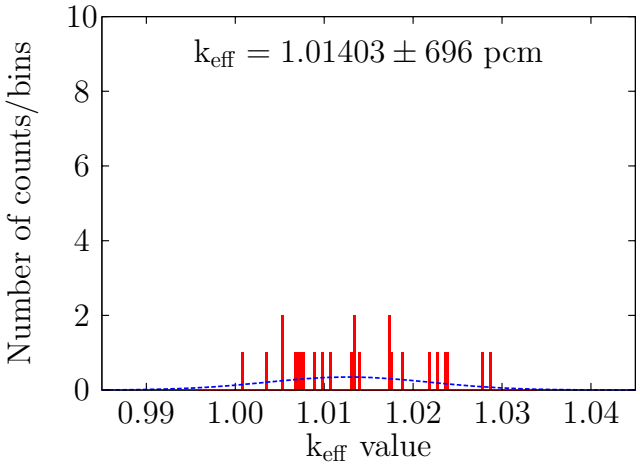




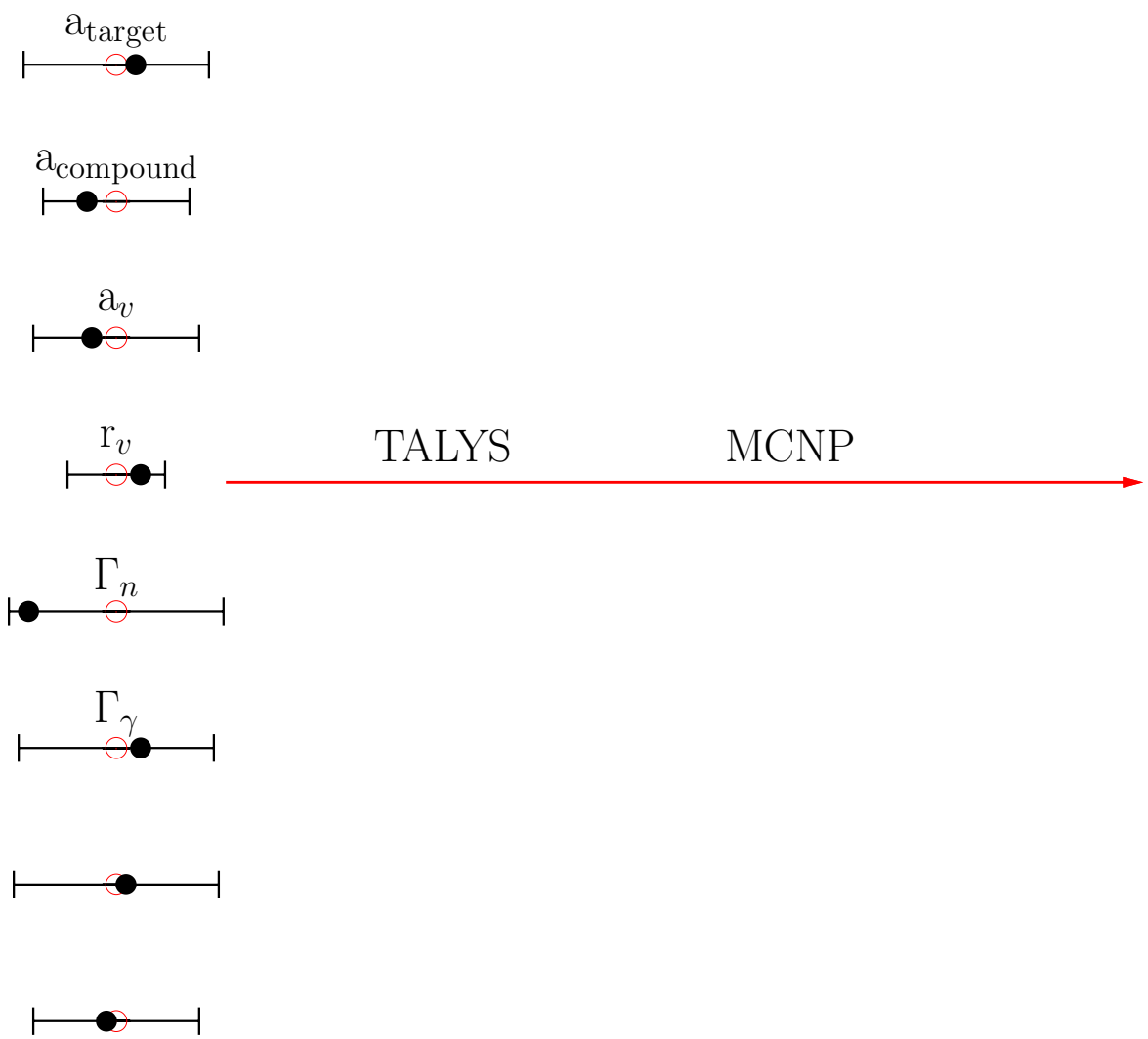
Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”



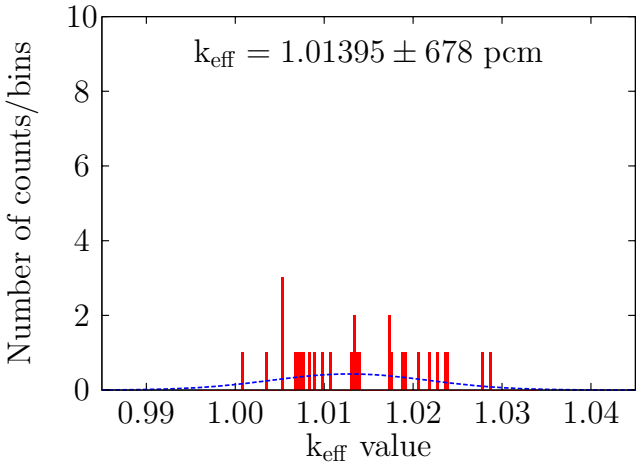
$n = 25$



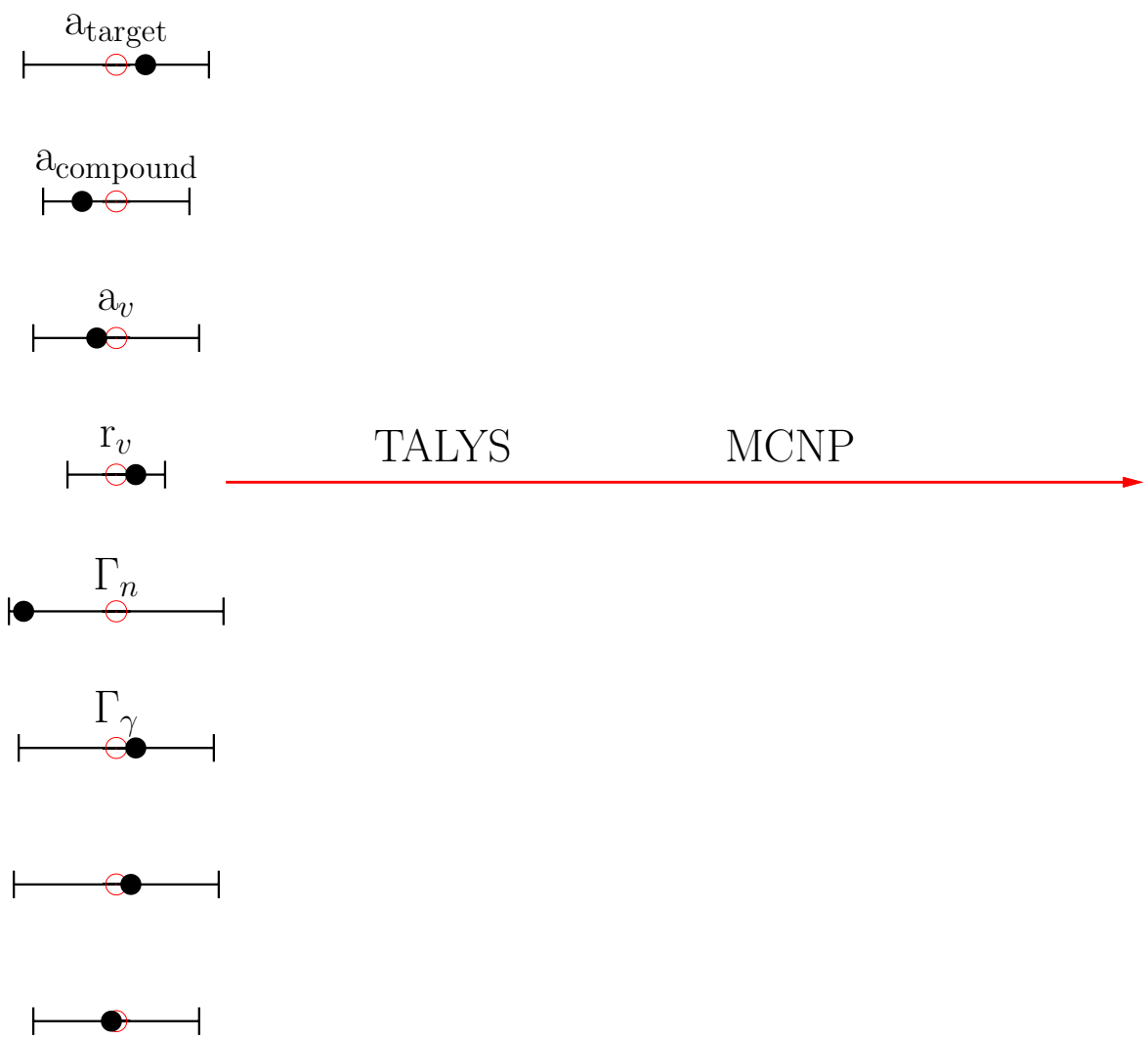
Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”



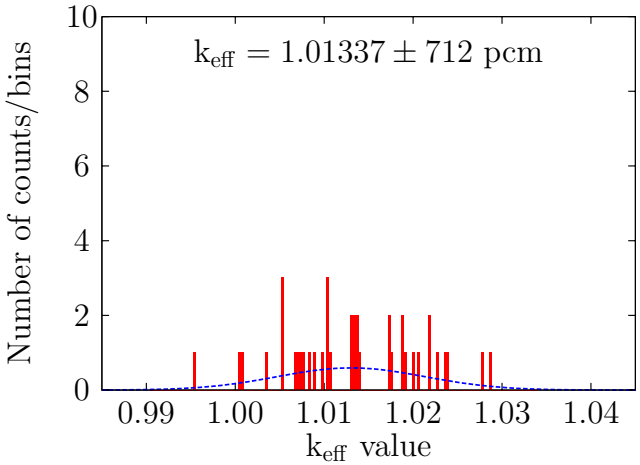
$n = 30$



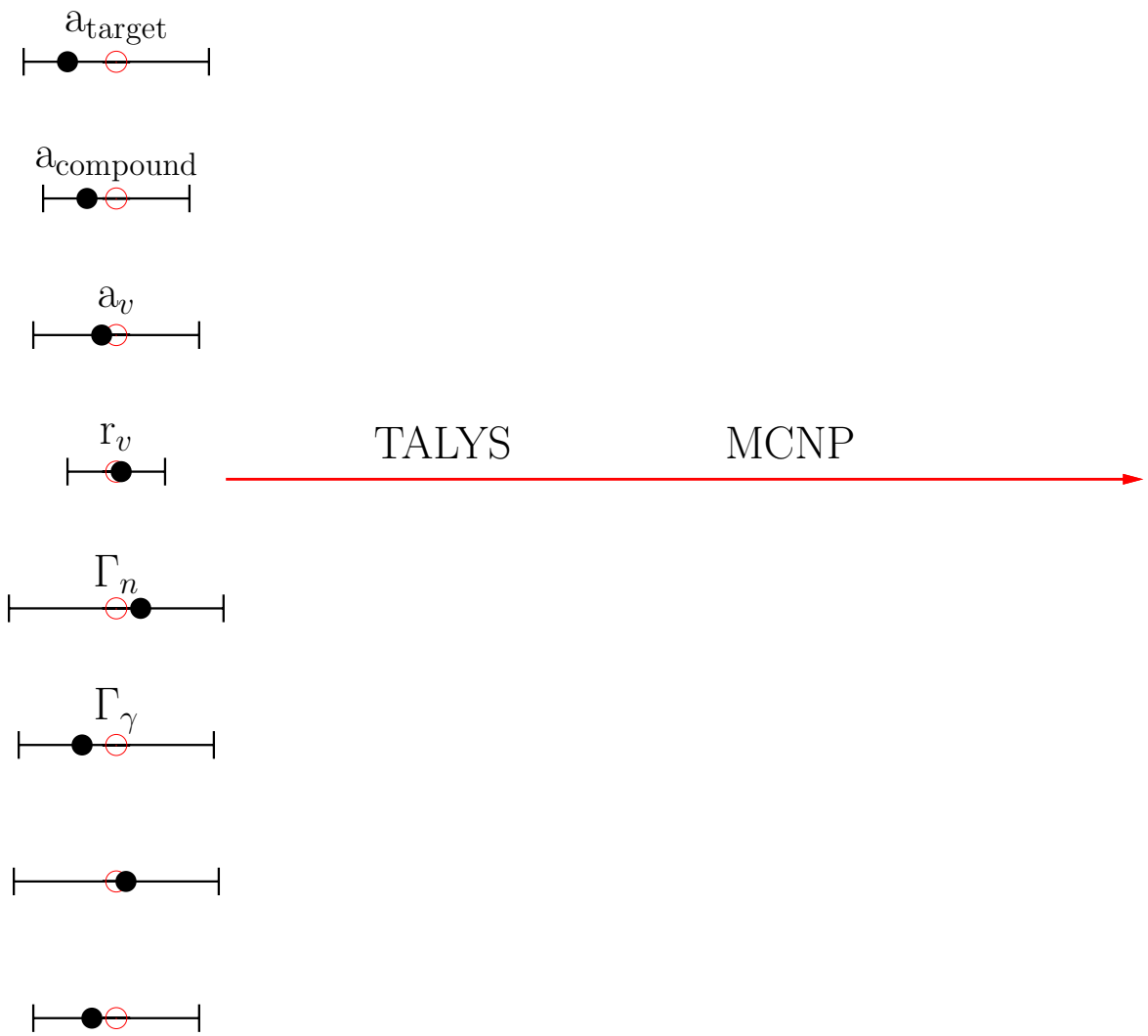
Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”



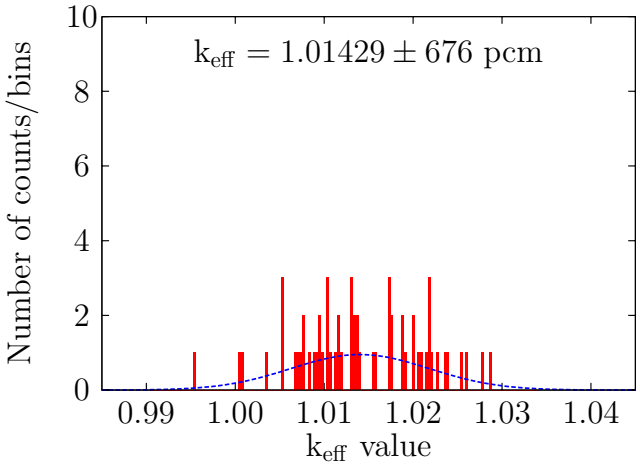
$n = 40$



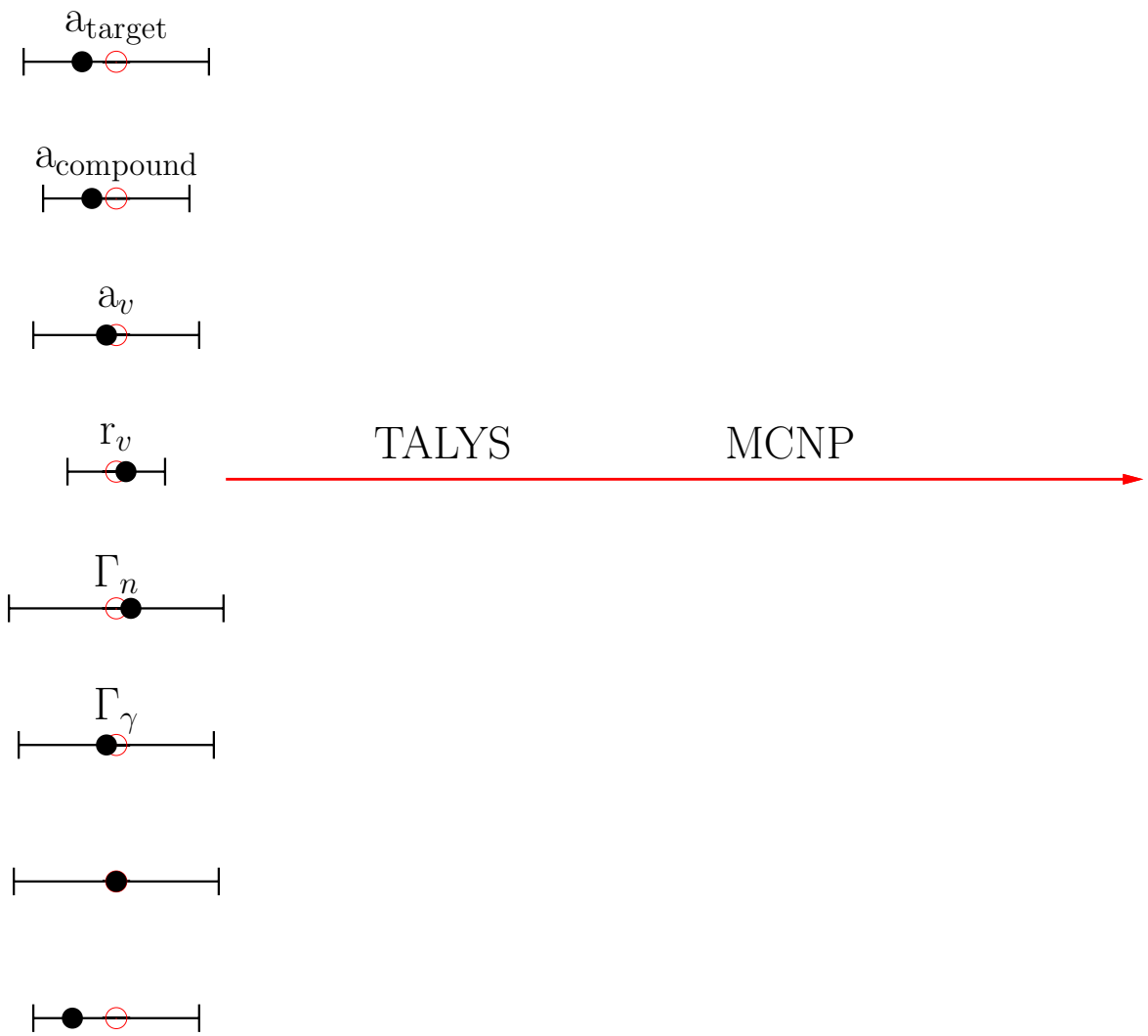
Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”



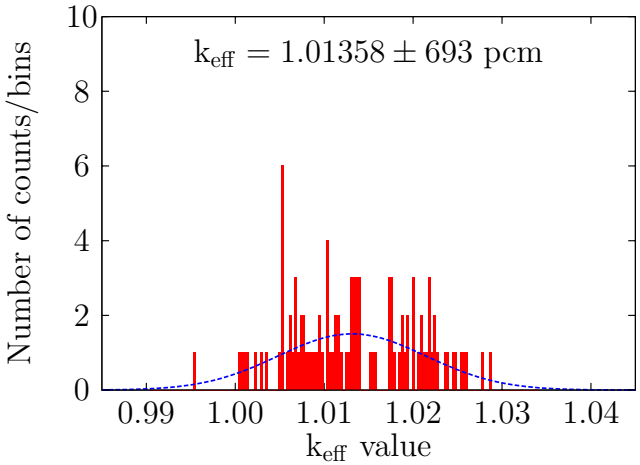
$n = 60$



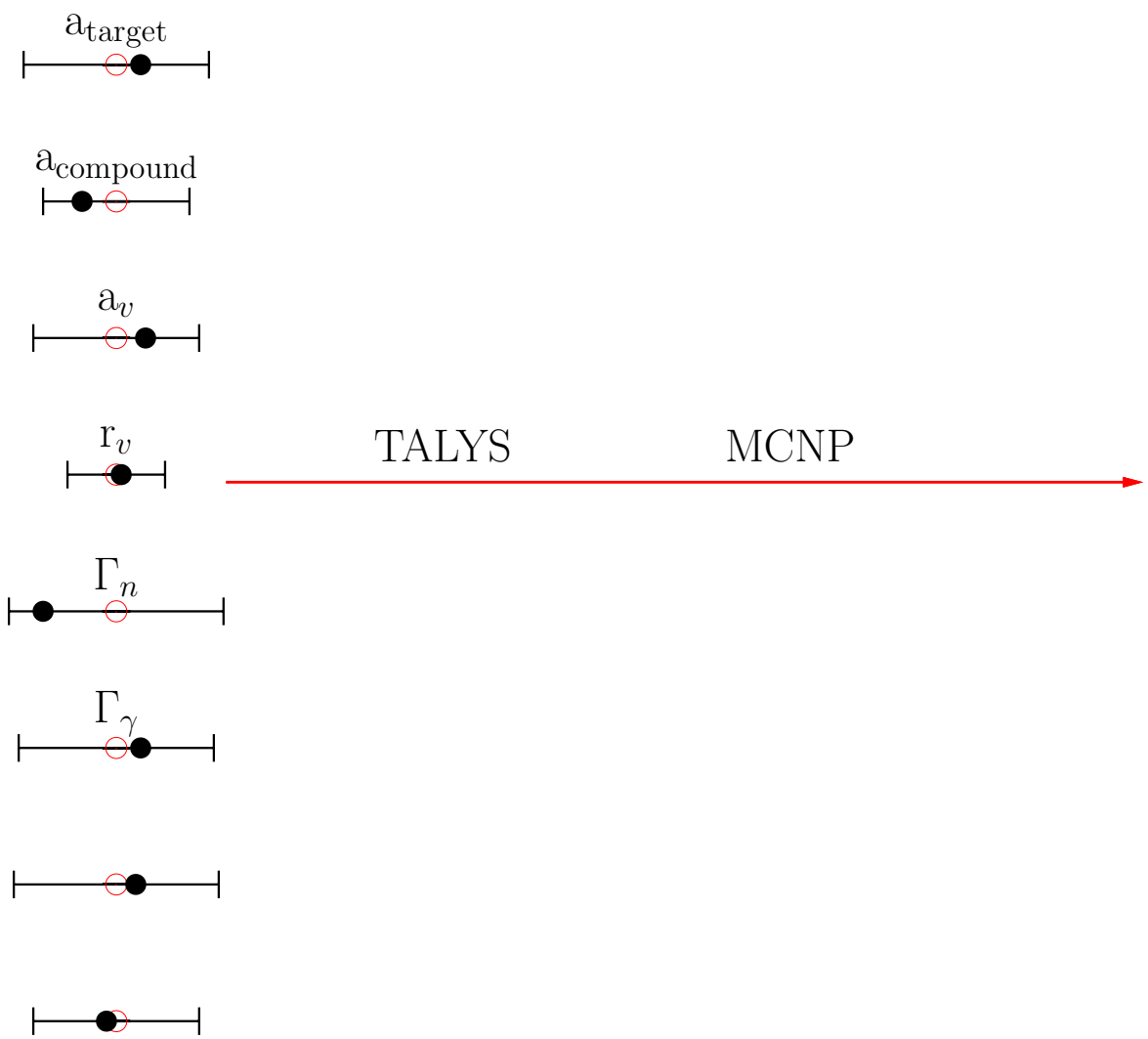
Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”



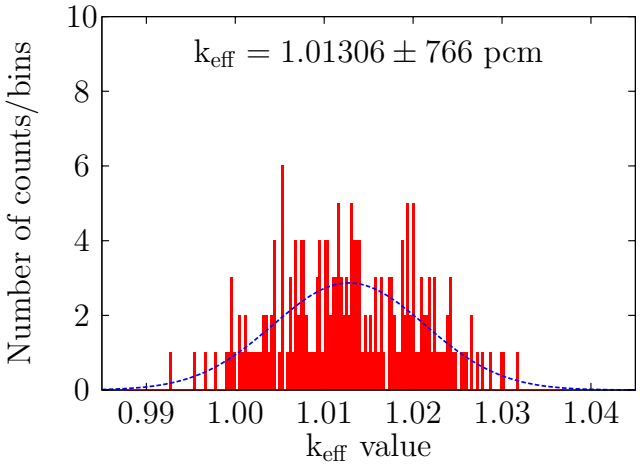
$n = 100$



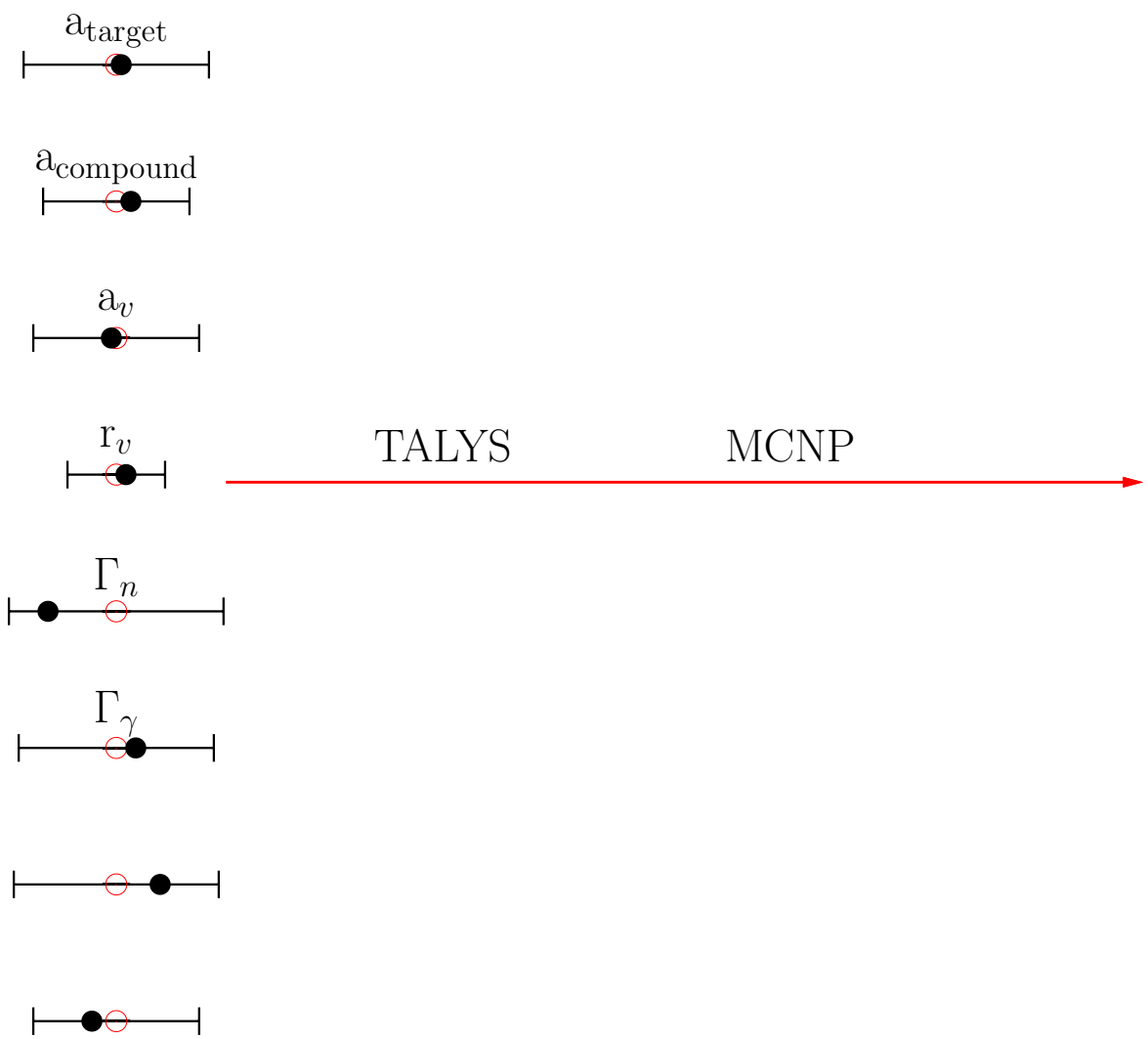
Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”

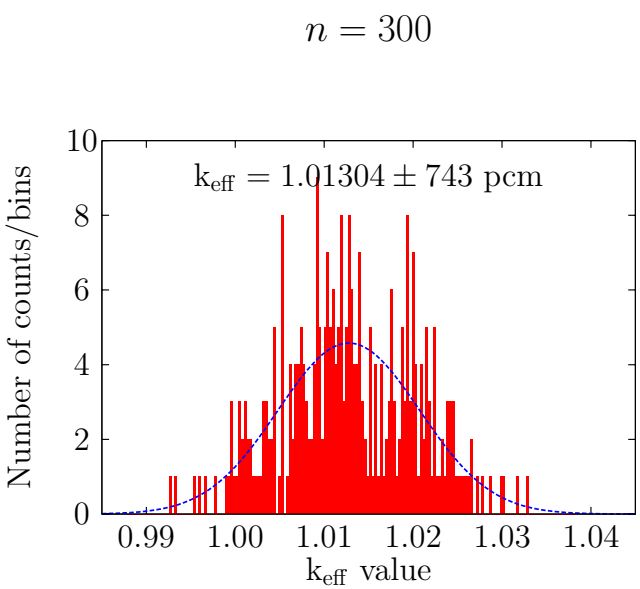


$n = 200$

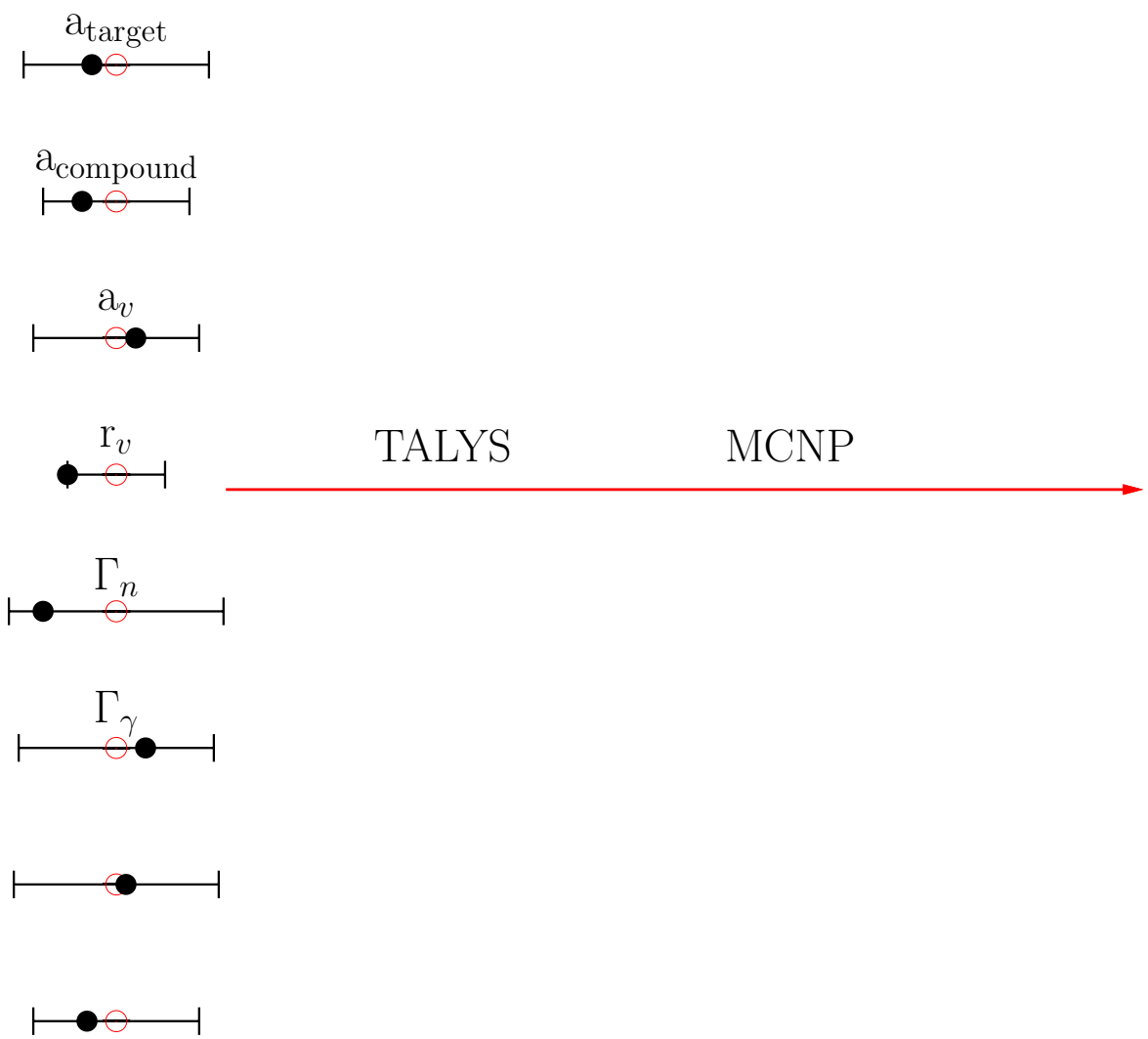


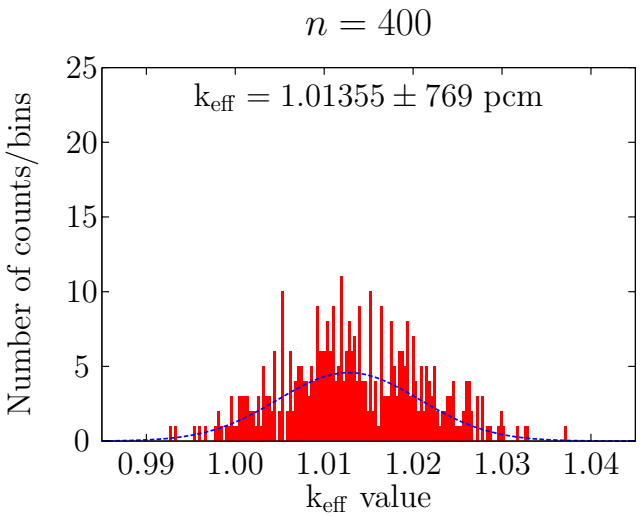
Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”



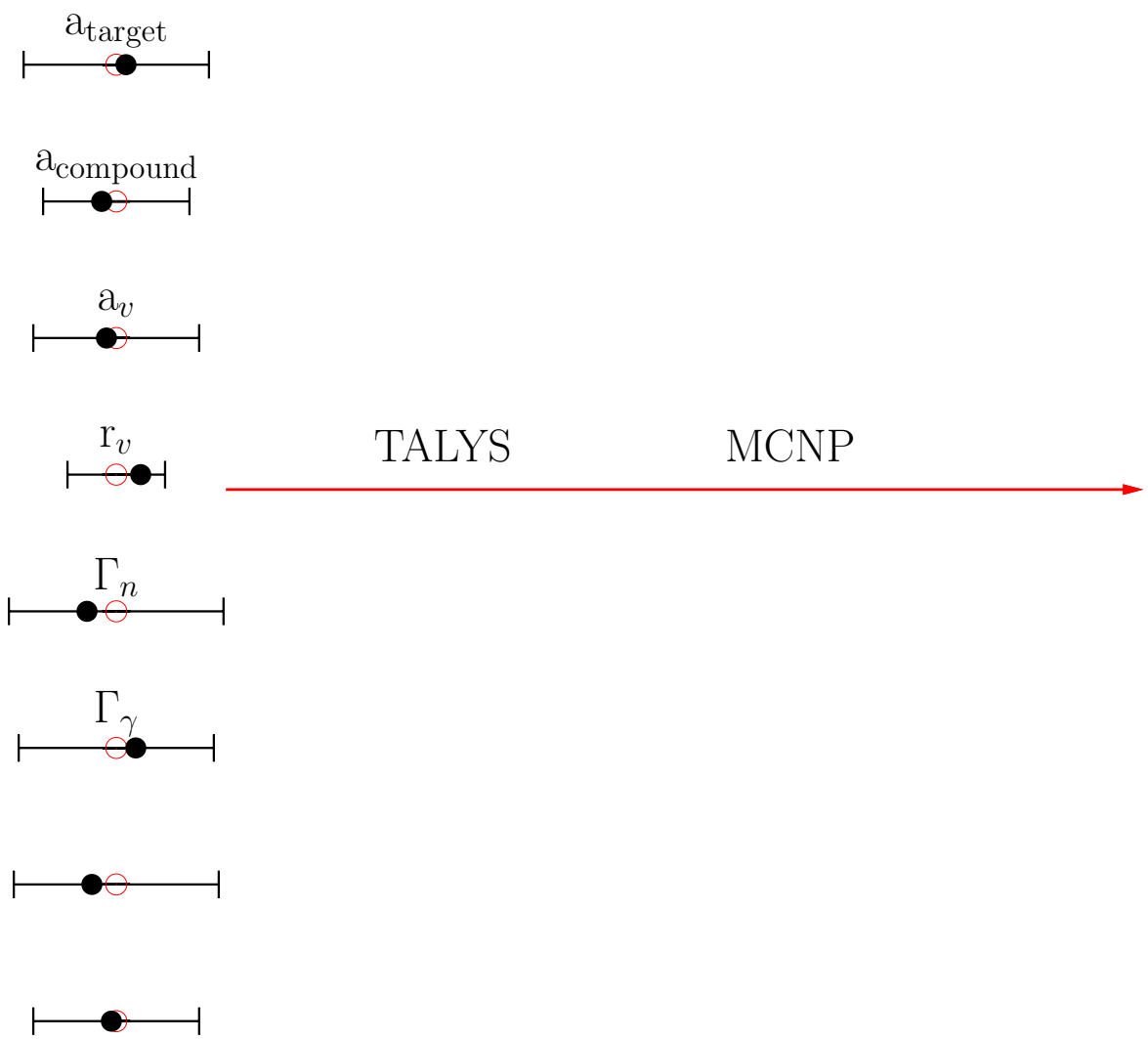


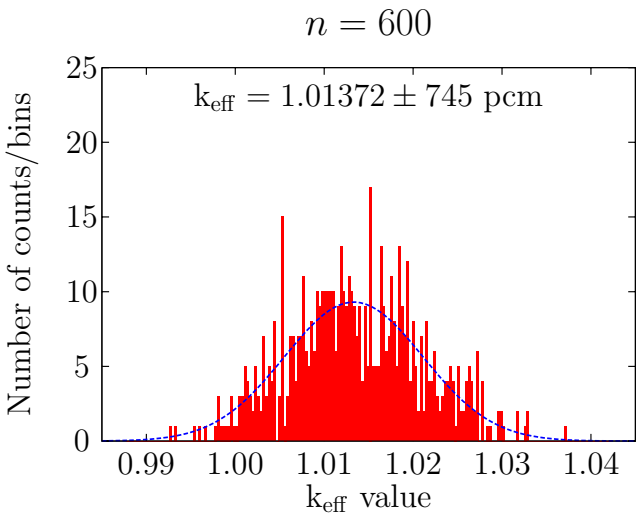
Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”



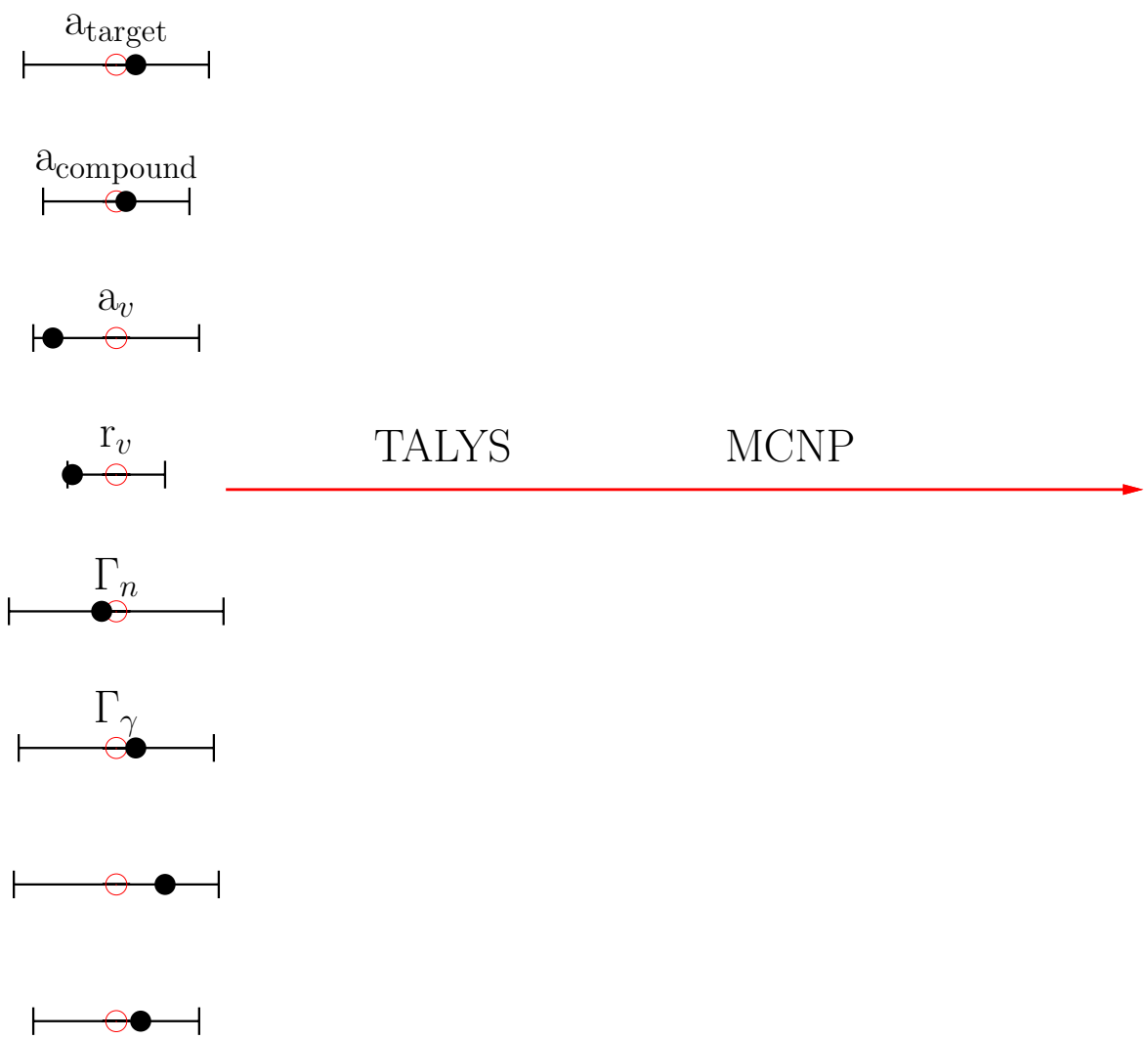


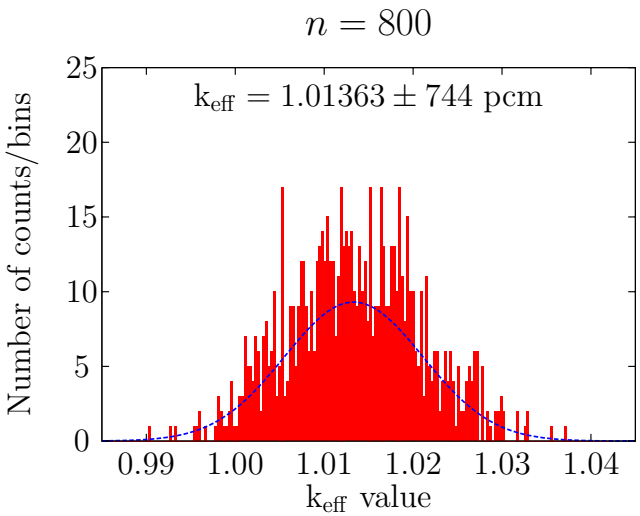
Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”



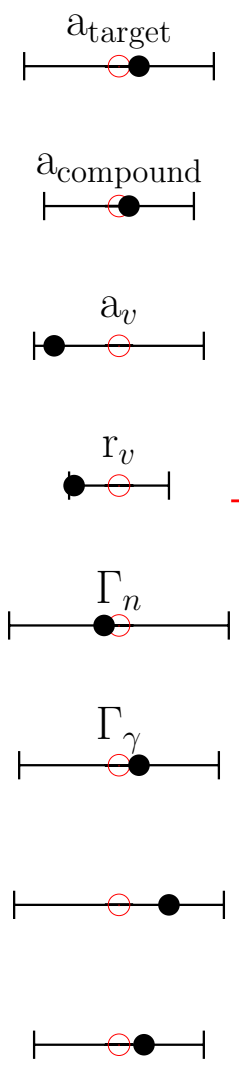


Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”

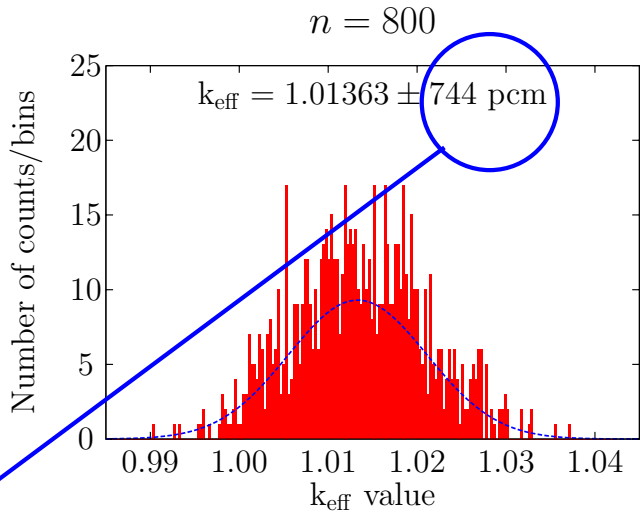




Hands on “1000 ×(Talys + ENDF + NJOY + MCNP) calculations”



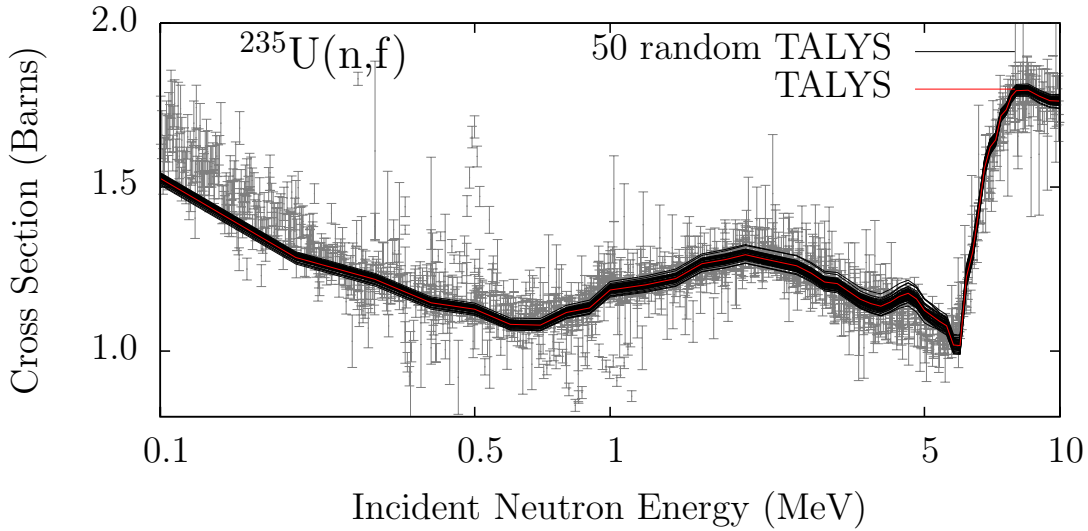
TALYS MCNP

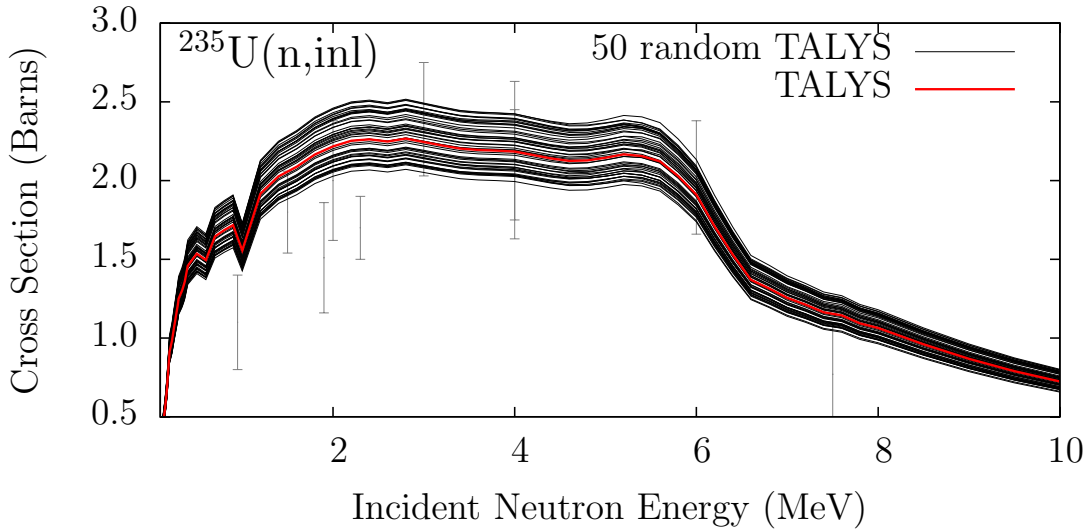


Statistical uncertainty $\simeq$ 68 pcm

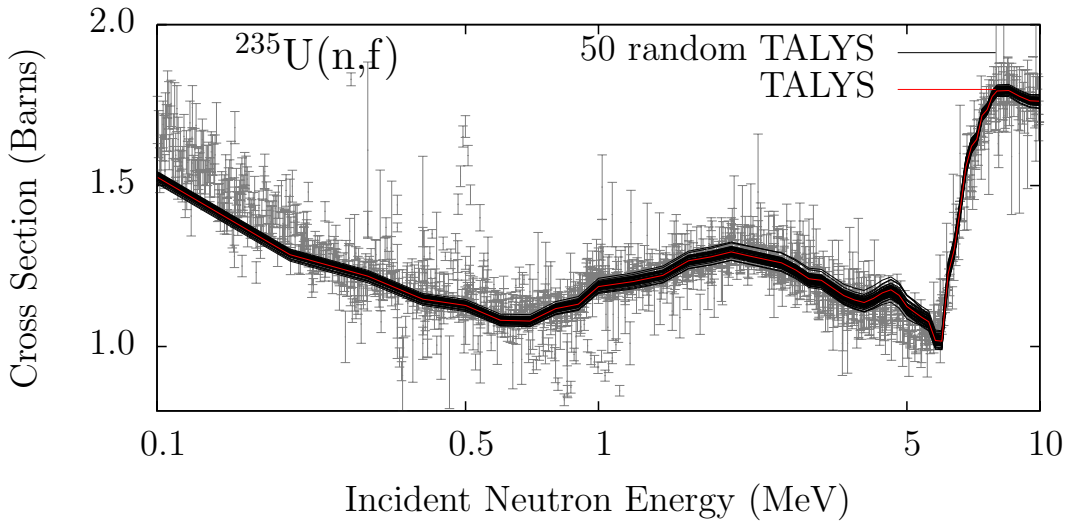
$\Longrightarrow$ uncertainty due to nuclear data $\simeq$ 740 pcm

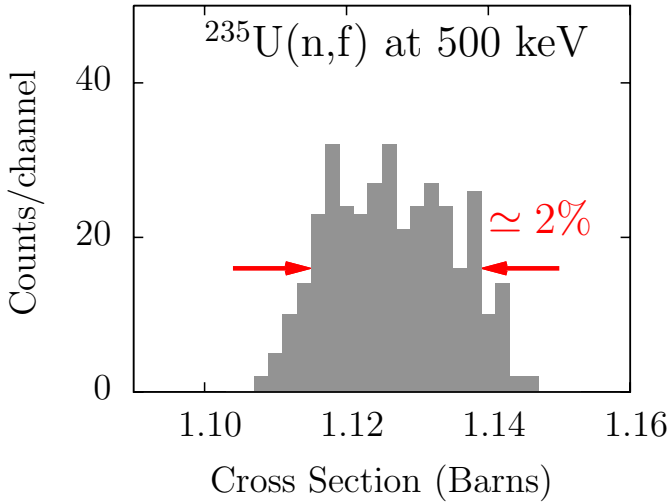
Example with ^{235}U: Monte Carlo calculations

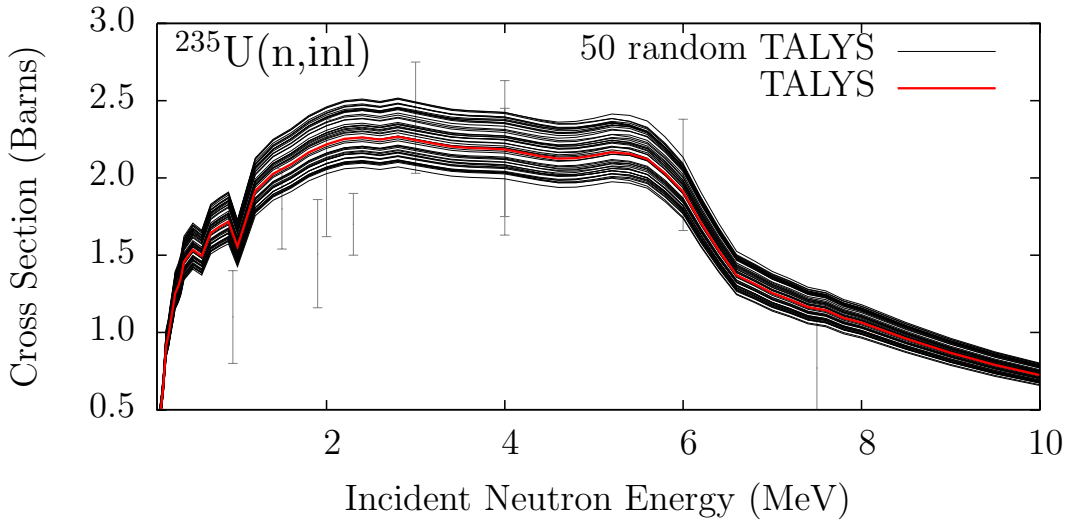


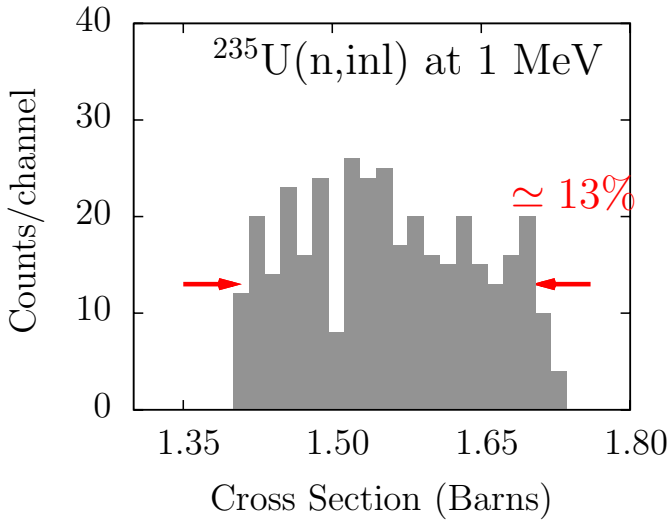


Example with ^{235}U: Monte Carlo calculations

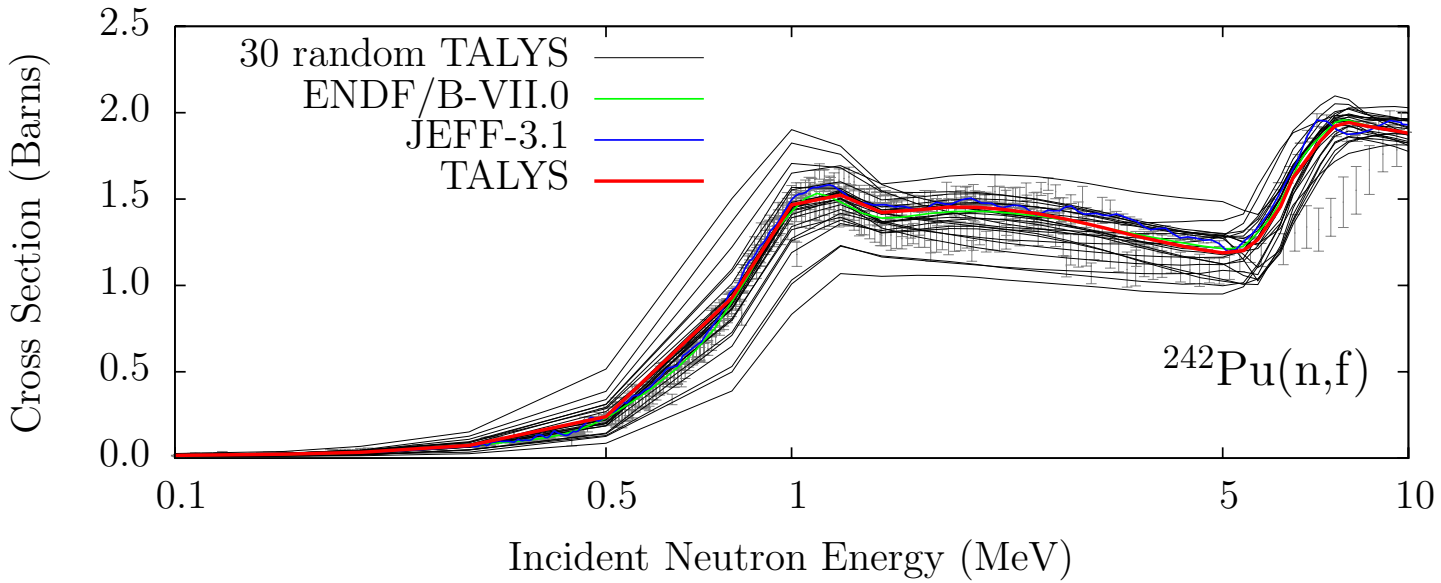


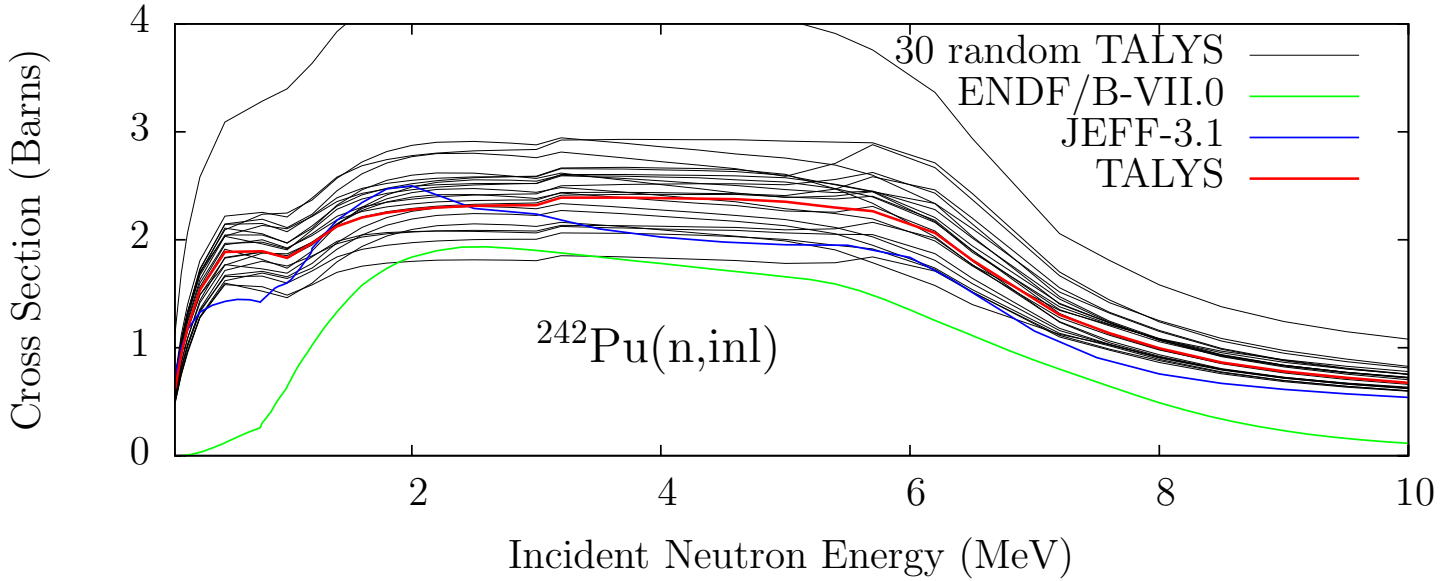




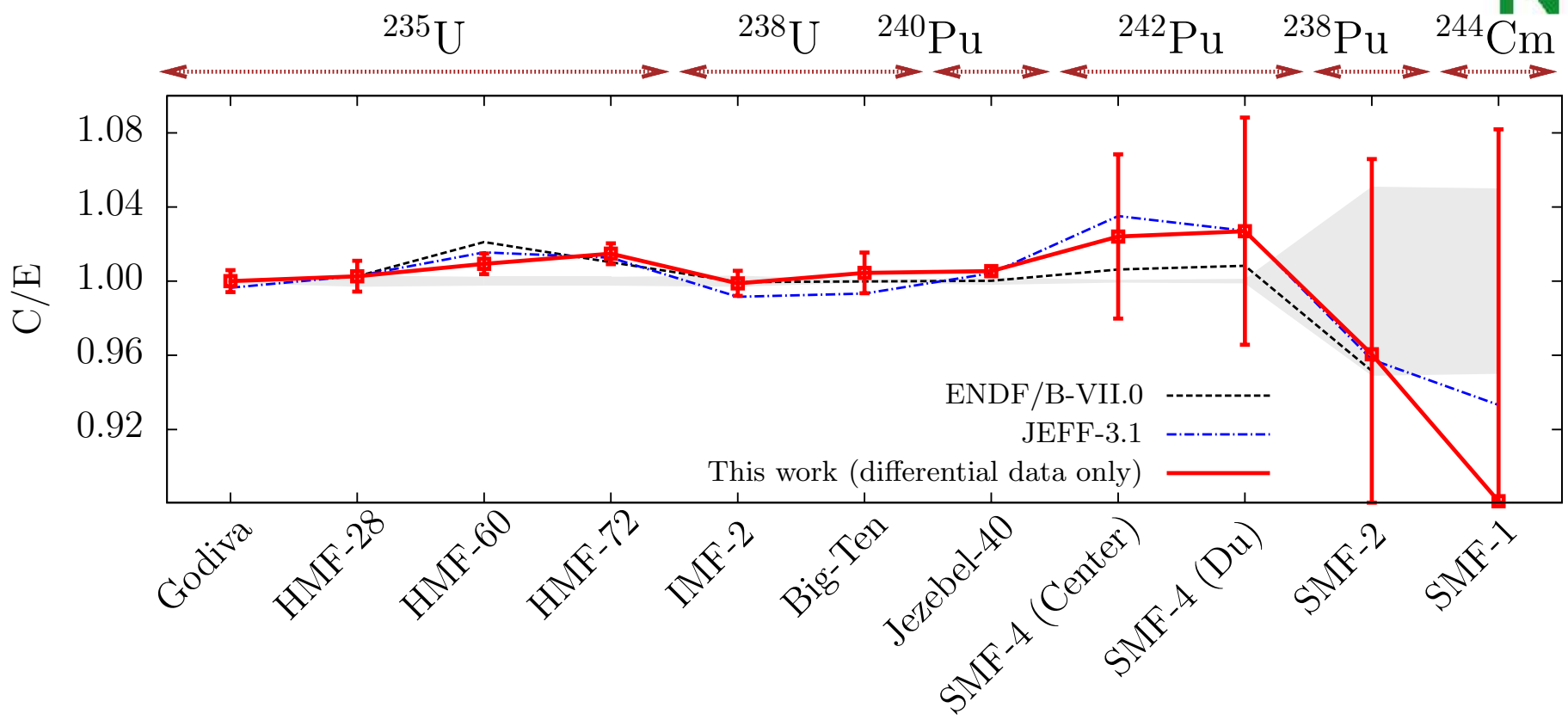


Example with ^{242}Pu: Monte Carlo calculations



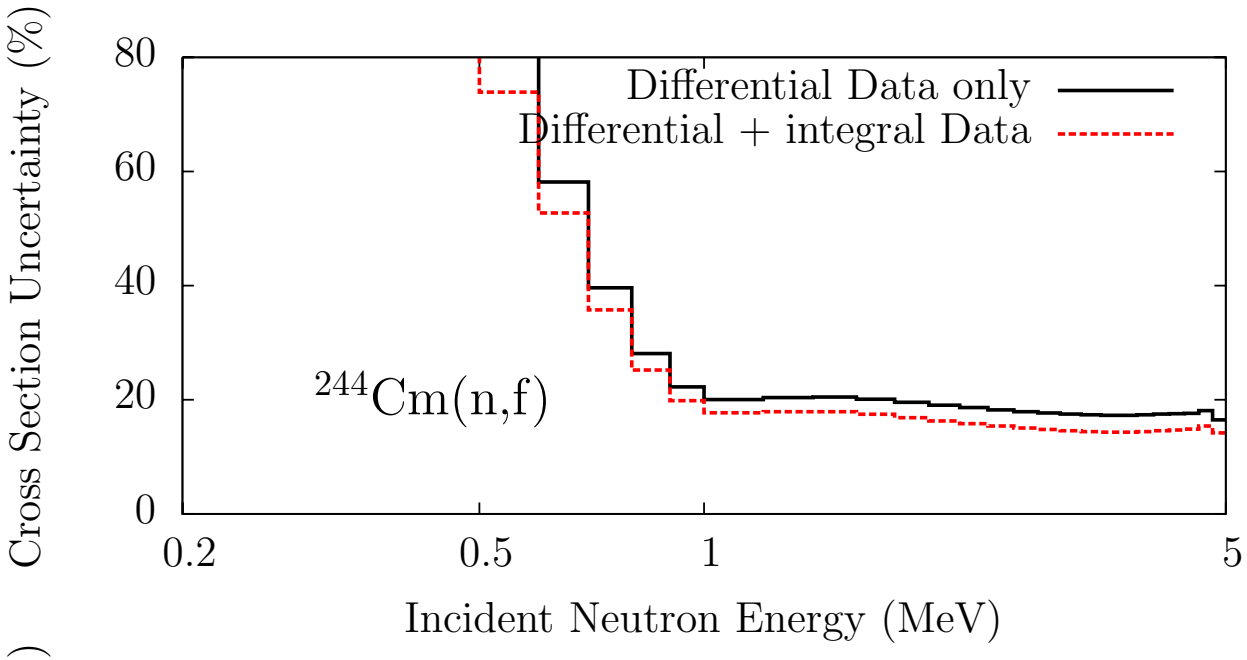


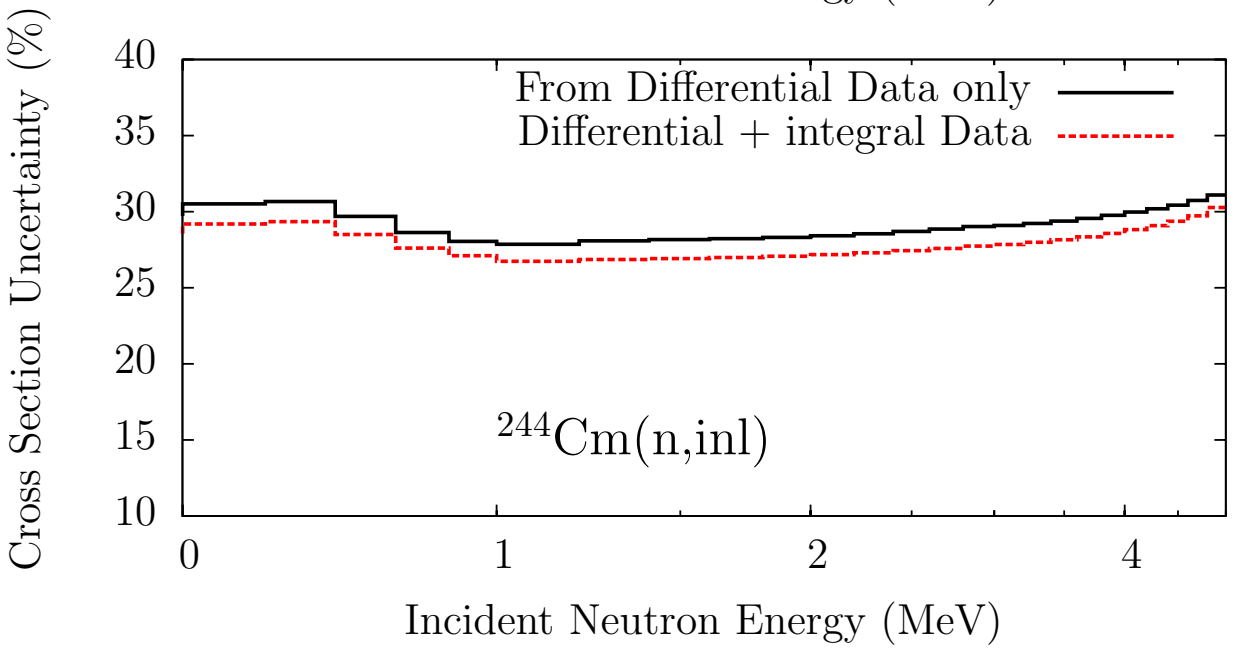
Benchmark results using differential data only



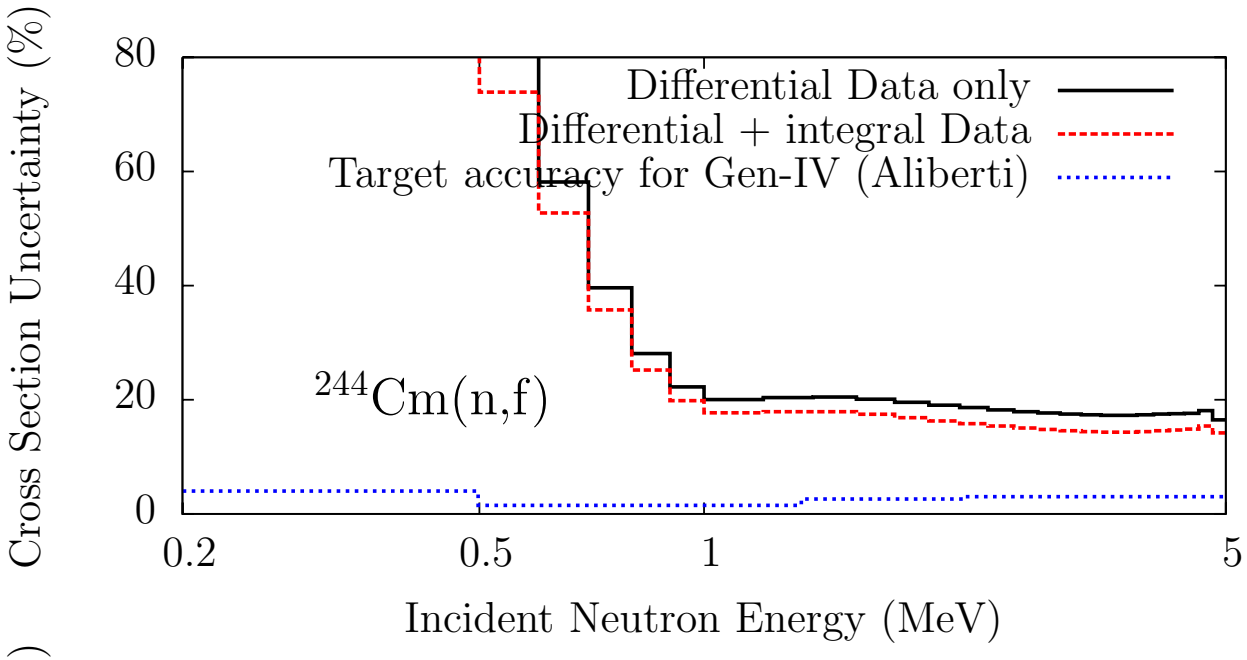
- Fast benchmarks
- SMF-1, -2 and -4: dedicated to minor actinides (^{238,242}Pu and ^{244}Cm)
- SMF-1 and -2: Replacement measurements using Jezebel
- SMF-4: Plates of ^{242}Pu

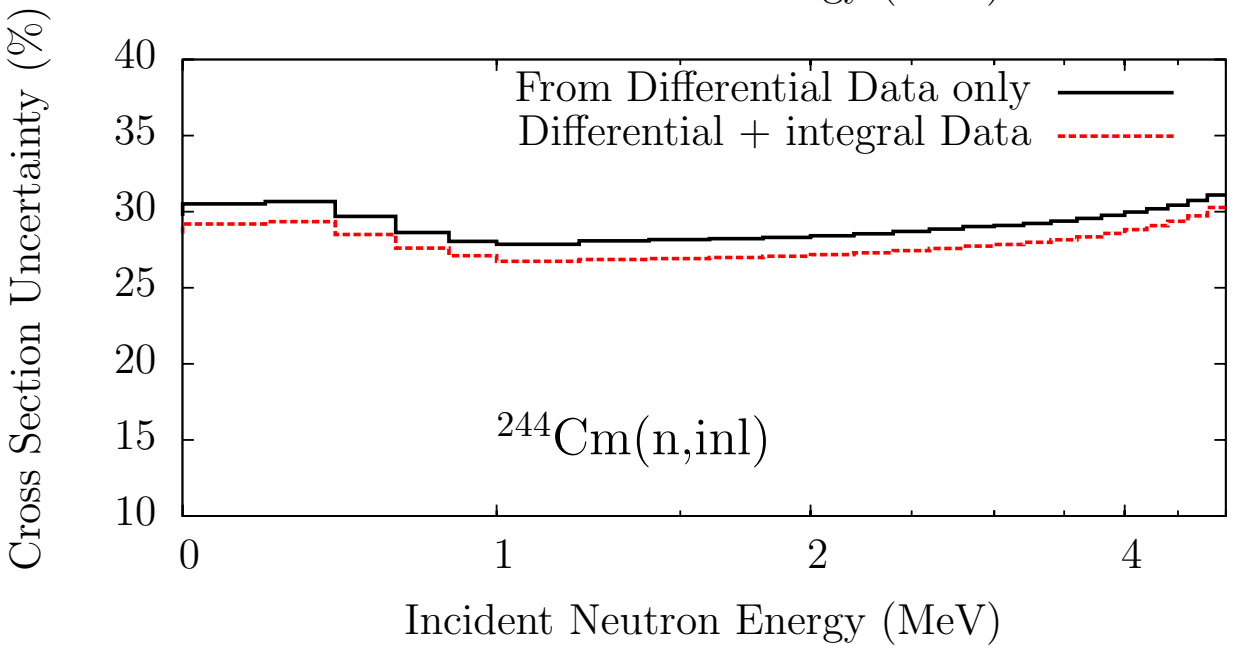
Impact on ^{244}Cm(n,f) and ^{244}Cm(n,inl) uncertainties



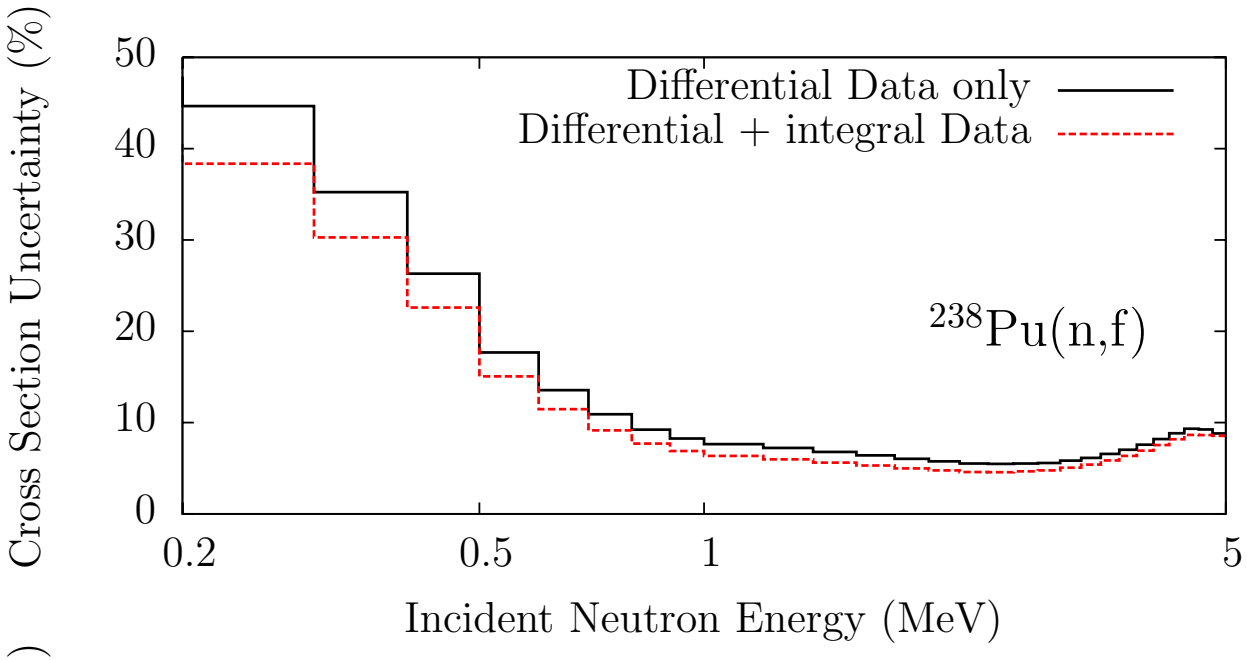


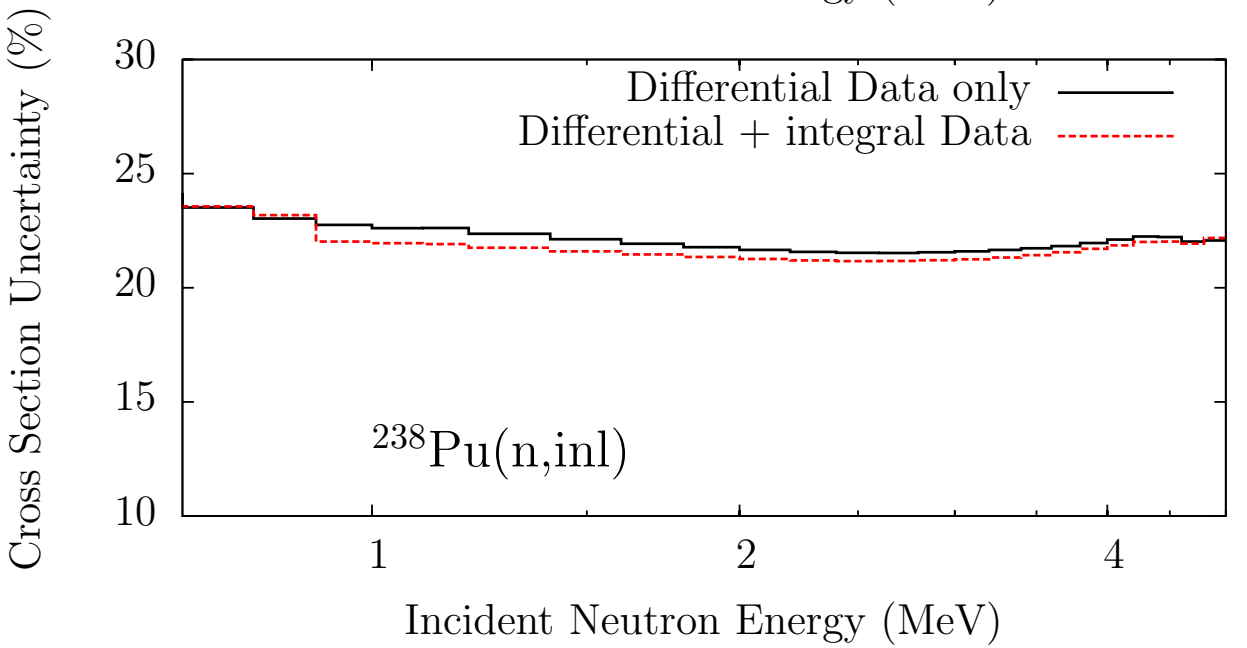
Impact on ^{244}Cm(n,f) and ^{244}Cm(n,inl) uncertainties



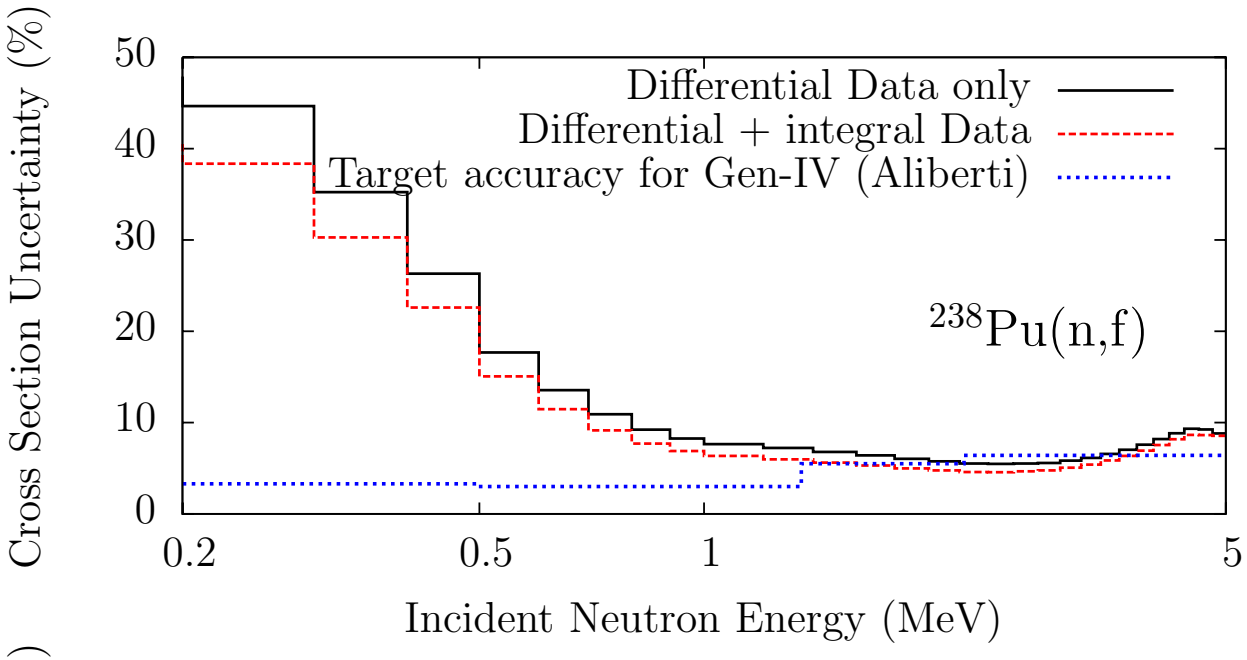


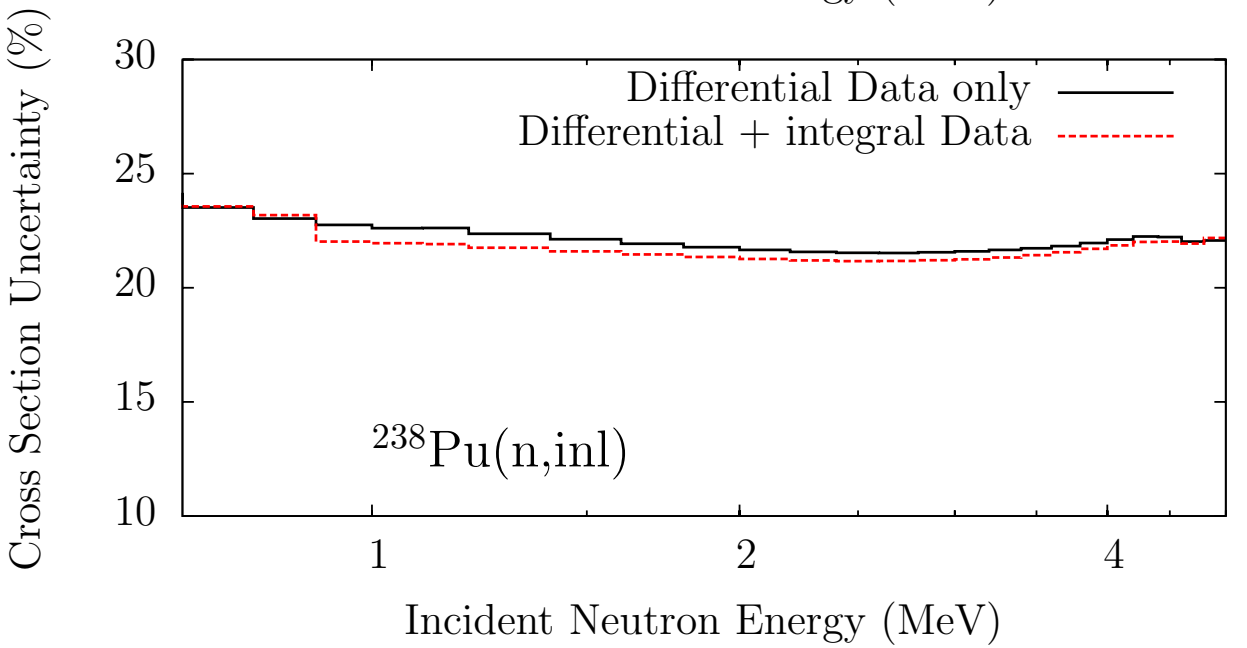
Impact on ^{238}Pu(n,f) and ^{238}Pu(n,inl) uncertainties



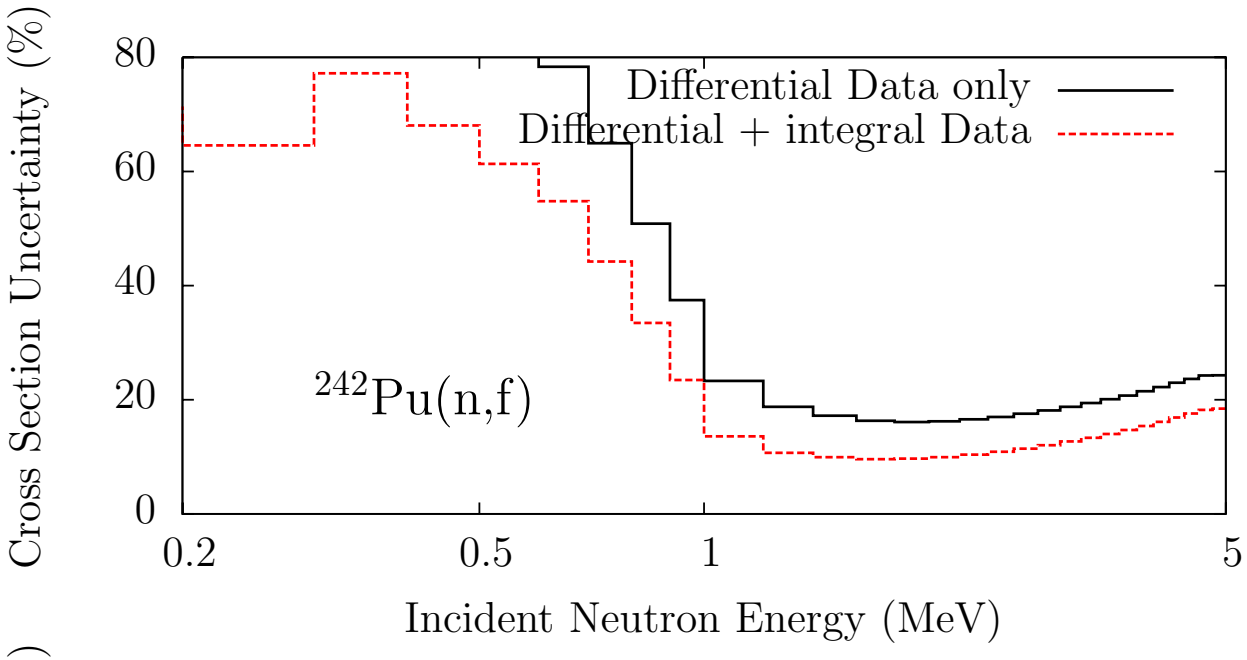


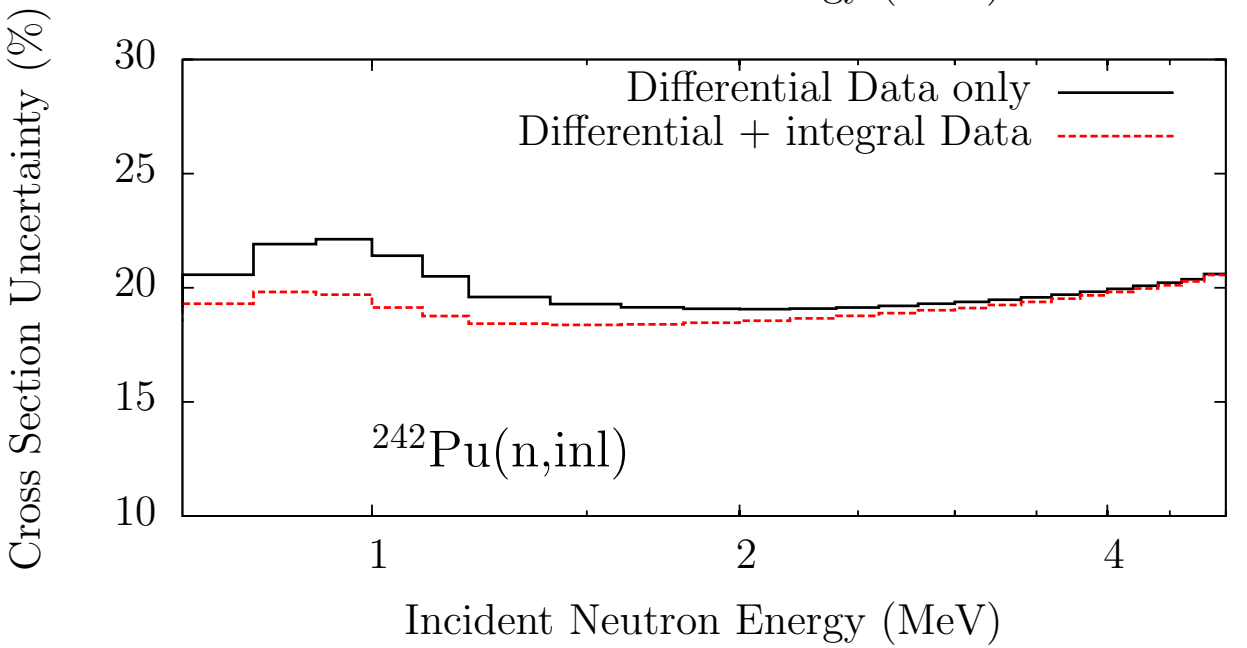
Impact on ^{238}Pu(n,f) and ^{238}Pu(n,inl) uncertainties





Impact on ^{242}Pu(n,f) and ^{242}Pu(n,inl) uncertainties





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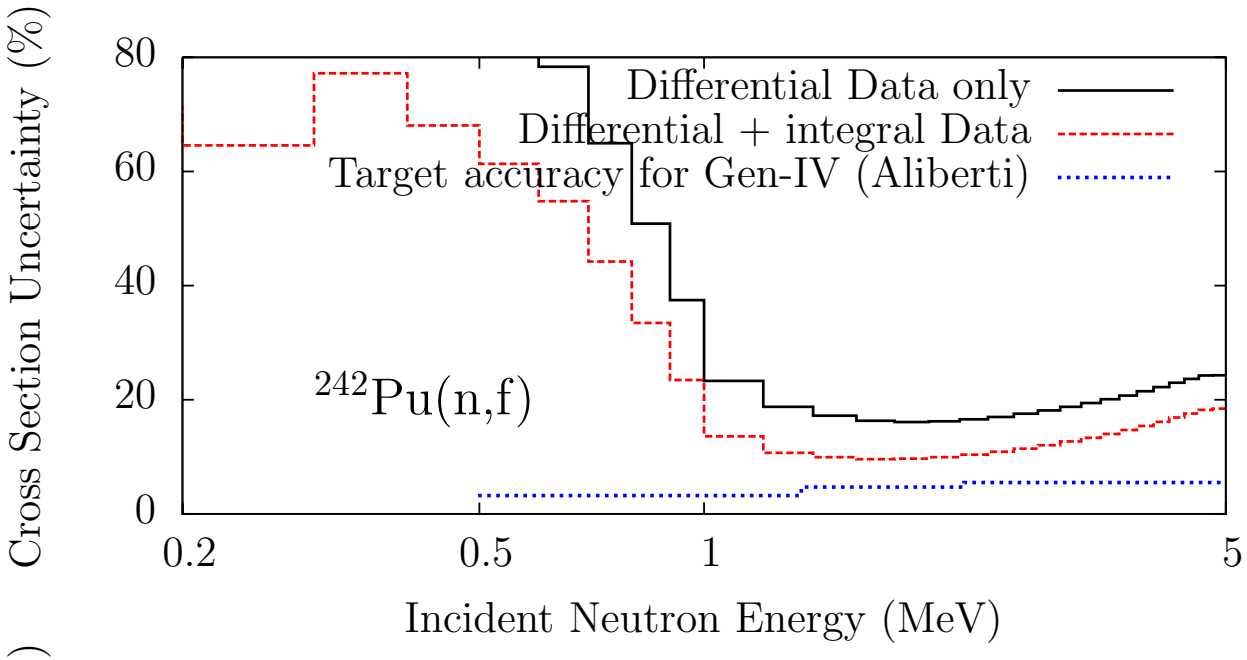
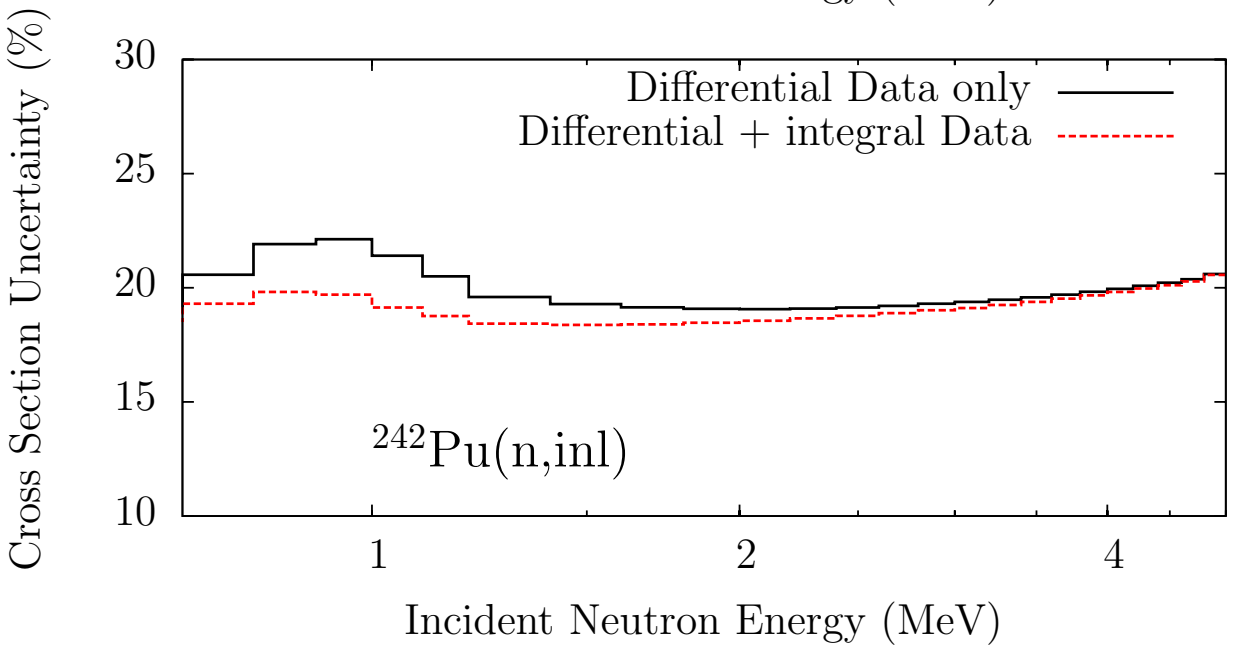
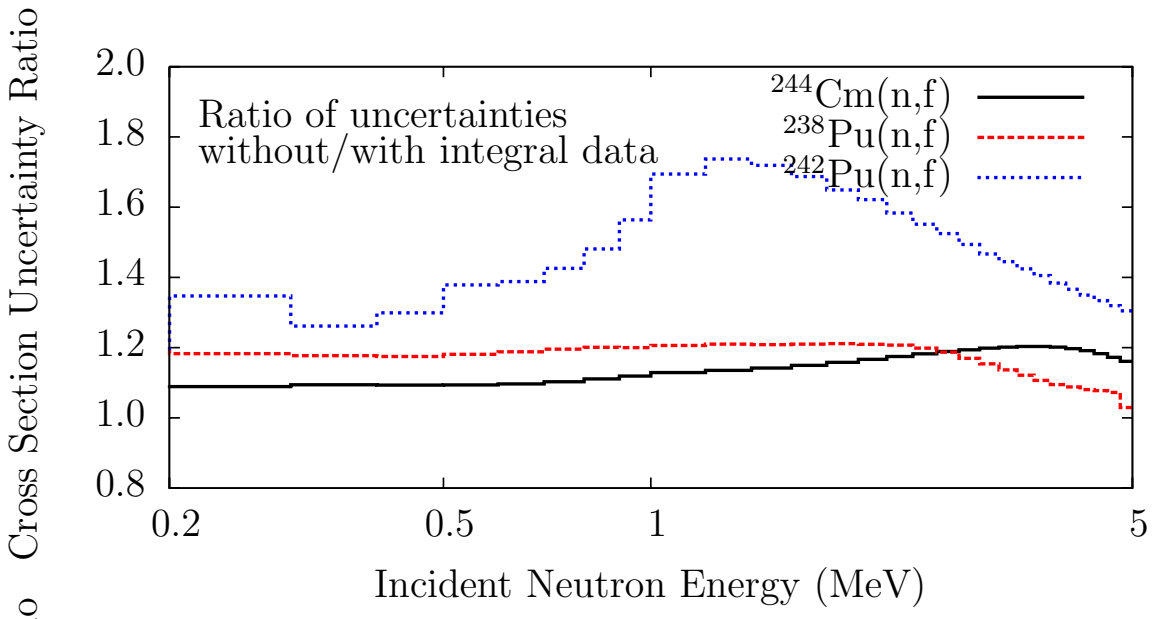
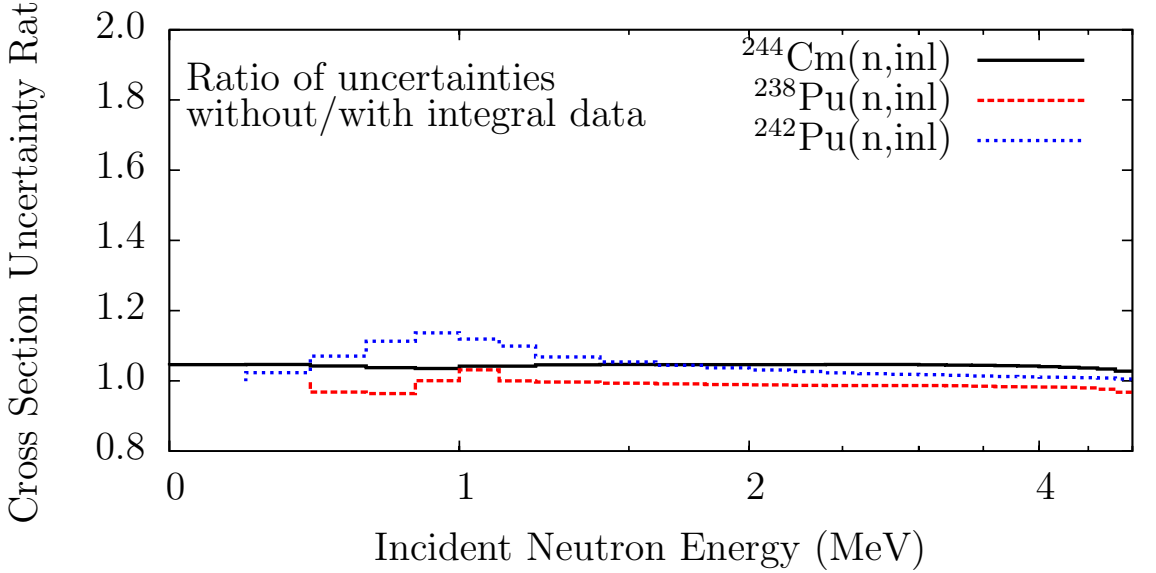




Summary of the impact





Conclusions and future improvements

- ☒ New methodology to propagate nuclear data uncertainty to integral quantities (k_{eff} benchmarks, shielding benchmarks, reactivity swing, neutron flux for commercial reactor) via Monte Carlo
- ☒ Blending differential measurements, evaluations, and validation in one approach
- ☒ Proof of principle with minor actinides (and other isotopes)
- ☒ Mass production tested (new library TENDL-2008 and TENDL-2009 (see JEFF meeting in June))

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- ☒ Mass production tested (new library TENDL-2008 and TENDL-2009 (see JEFF meeting in June))
- ☐ Needs to develop best central-value evaluations (non-fissile and fissile) ?
- ☐ Compare with more benchmarks and more reaction channels (*e.g.* (n,γ))
- ☐ Need more clever sampling,
- ☐ At the end, experimentalists can tell about the feasibility of reaching smaller uncertainties.