LA-UR-11-03933

Approved for public release;
distribution is unlimited.

Title:	Polyethylene Reflected Pu Multiplication Inference Simulations
Author(s):	Clell J. (CJ) Solomon
Intended for:	Nuclear Criticality Safety Program (NCSP) Subcritical Measurement Workshop, Los Alamos National Laboratory, 14 July 2011

Form 836 (7/06)

Polyethylene Reflected Pu Multiplication Inference Simulations

Clell J. (CJ) Solomon, Jr.

Los Alamos National Laboratory

14 July 2011

LA–UR–11–03933

Abstract

Calculated and measured Feynman distributions of a polyethylene reflected plutonium sphere are compared for two different sets of experimental data. The results indicate a systematic bias in the computed results that consistently over predicts the moments of the Feynman distributions. Work by Mattingly et. al. (one of the authors of the experimental data) has shown that modeling uncertainties alone are unable to account for the systematic discrepancies and that erroneous plutonium $\overline{\nu}$ data in the ENDF/B-VII evaluation may be culpable. This work investigates Mattingly et. al.'s claim based on the ENDF/B-VII experimental and evaluated data and finds the claim reasonable. Moreover, further critical and subcritical benchmark experiments are needed to investigate correction of data parameters such as $\overline{\nu}$, σ_f, and $\chi(E)$.

Outline

Introduction

Polyethylene Reflected Pu Simulations

Results

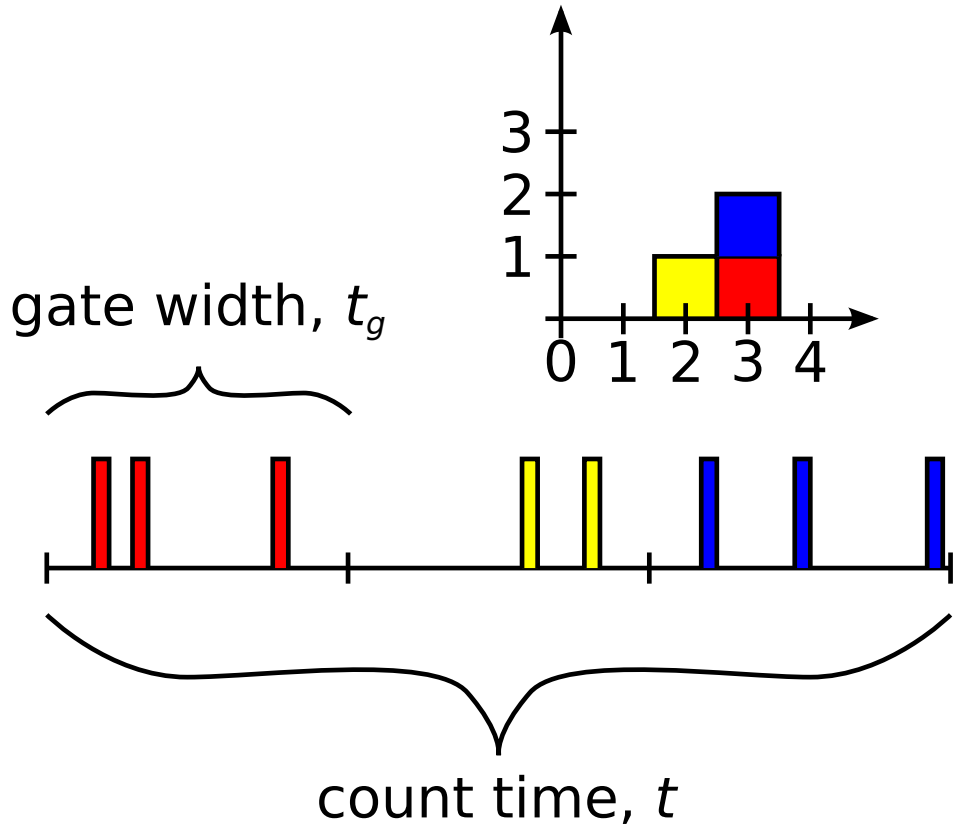
Discussion

Conclusions

Outline

Feynman Distributions

- Probability that a given number of counts is obtained in a given count time from a random source is Poisson distributed
- Correlated sources (e.g. multiplying media) are not Poisson distributed
- Feynman distributions are constructed and the deviation of the distribution from a Poisson gives us information about the multiplication of the system



New MCNP5 "Multiplication Patch"

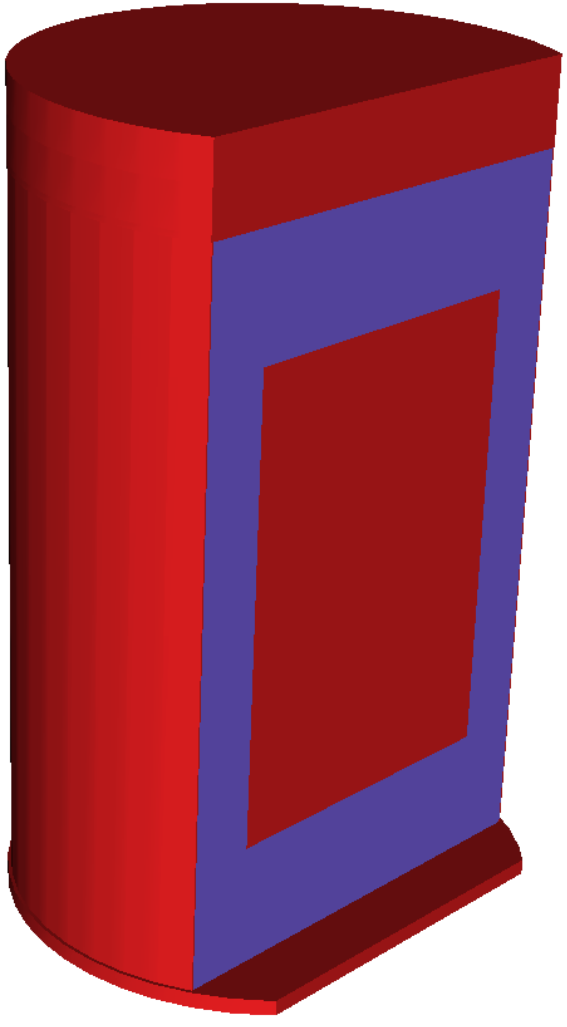
- simulates physics necessary for constructing Feynman distributions
- no longer a patch–implemented via the user defined SOURCE and TALLYX routines
- sources spontaneous fission reactions (creating multiple particles) or single particles
- tally uses the FU modifier on a cell-flux tally to create a list of neutron absorption times and the cell in which it is absorbed
- resulting tally output can be post processed to construct Feynman distributions

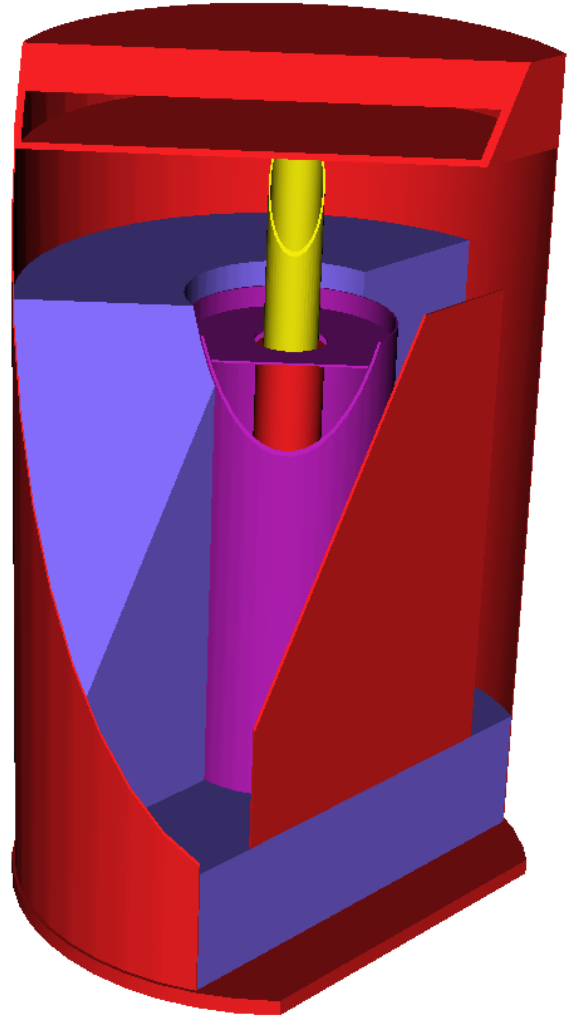
Outline

Measurement Configurations

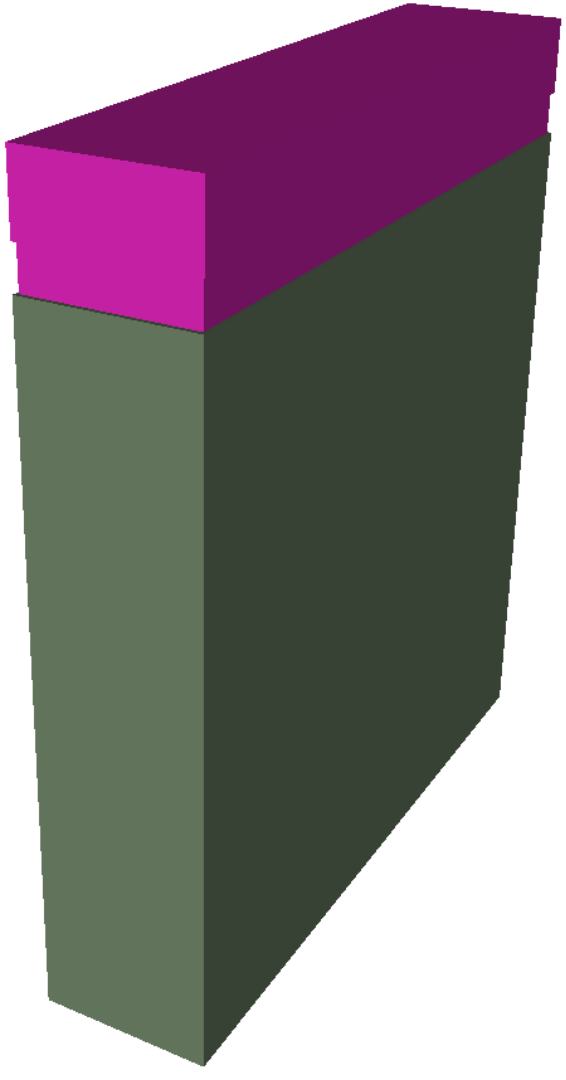
- Two different measurement configurations
  1. LANL-N2 (2007)
  2. SNL-Mattingly (2009)
- a solid sphere of plutonium is the source (BeRP ball)
- different thicknesses of polyethylene shells are placed around the BeRP ball (0–6" of radial reflection)
- measurements are made with SNAP and NPOD detectors

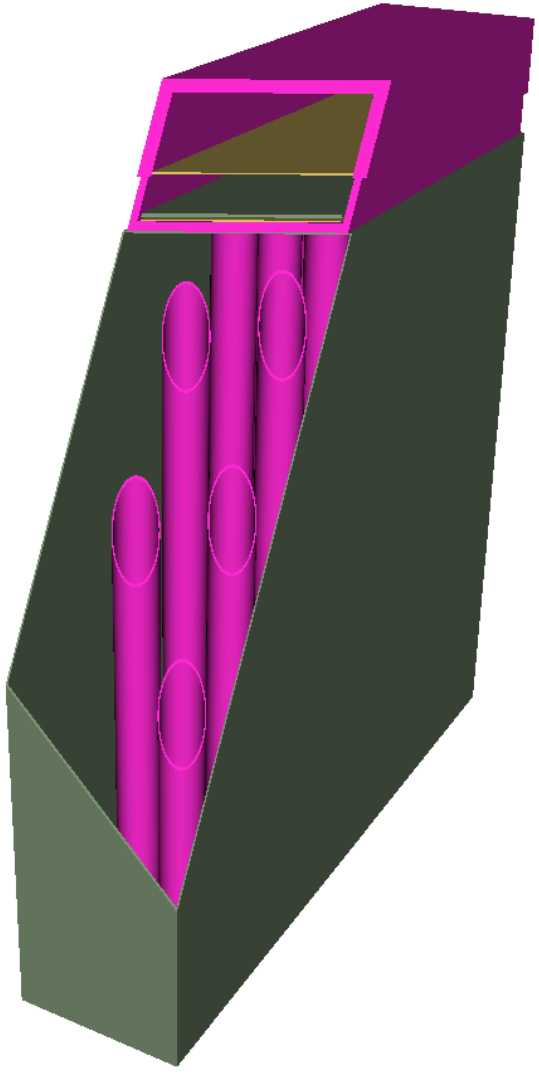
SNAP Detector Model





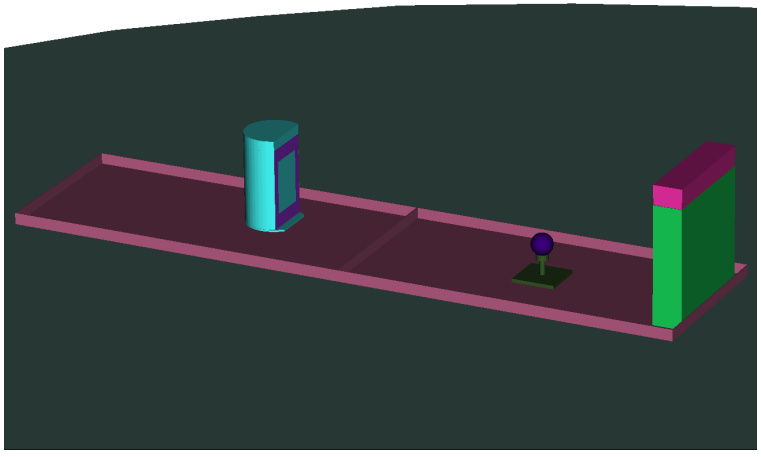
NPOD Detector Model

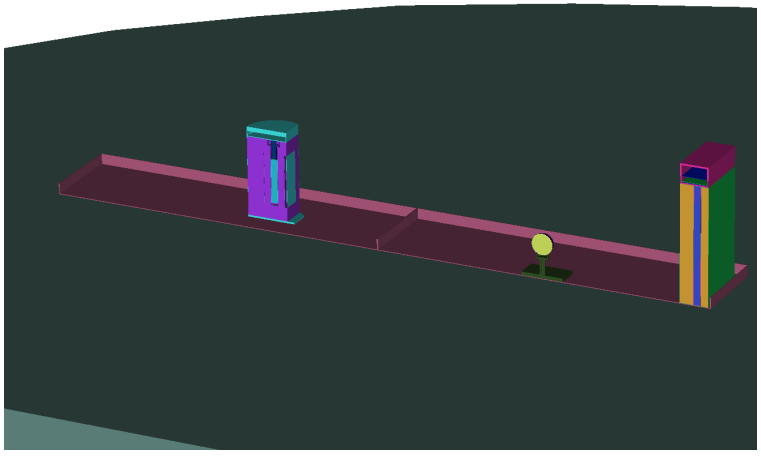




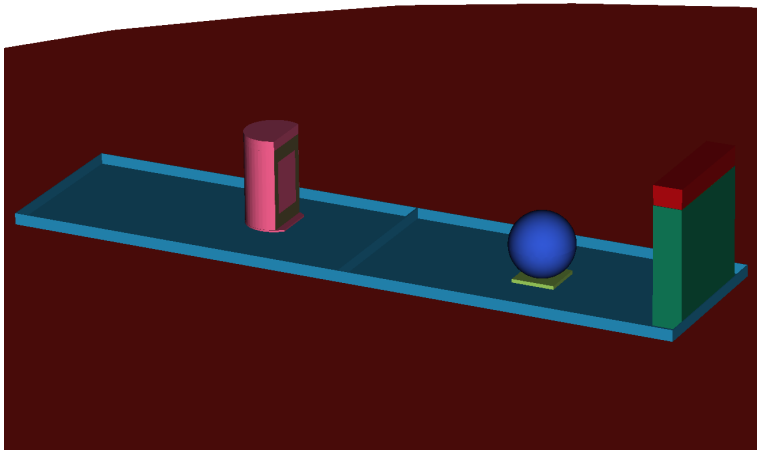
LANL-N2 Measurement Geometry

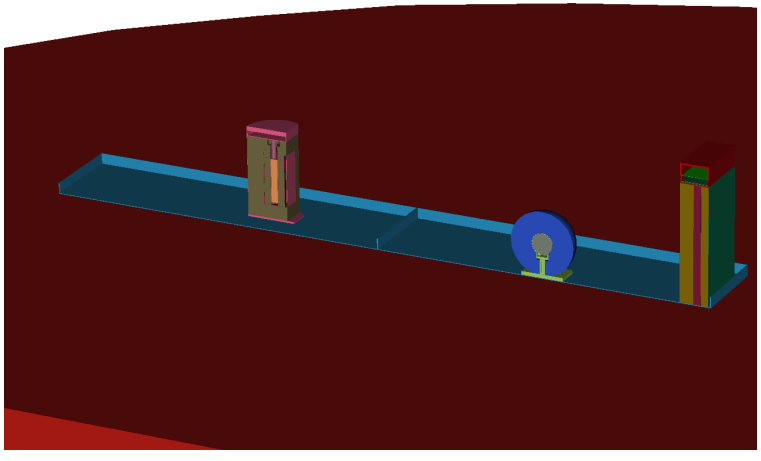
Bare





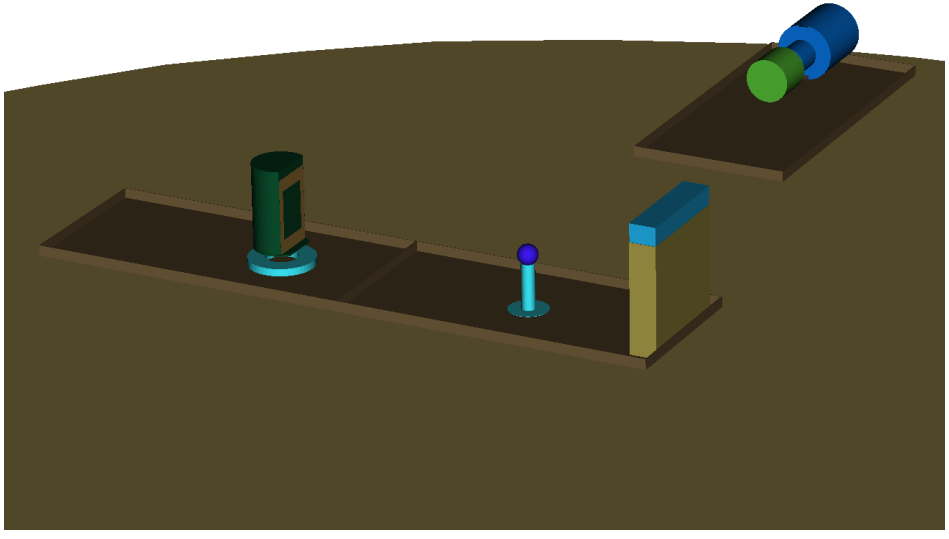
3 in Poly



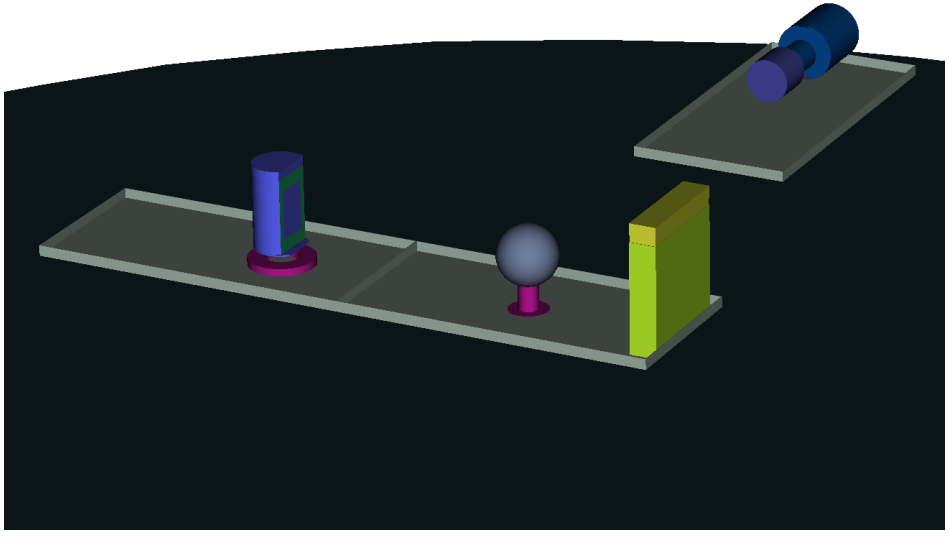


SNL-Mattingly Measurement Geometry

Bare

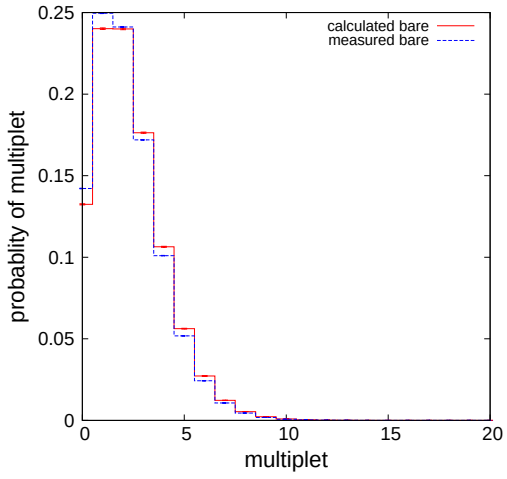


3 in Poly

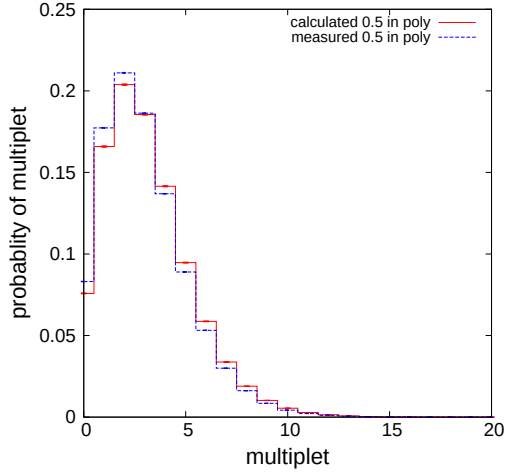


Outline

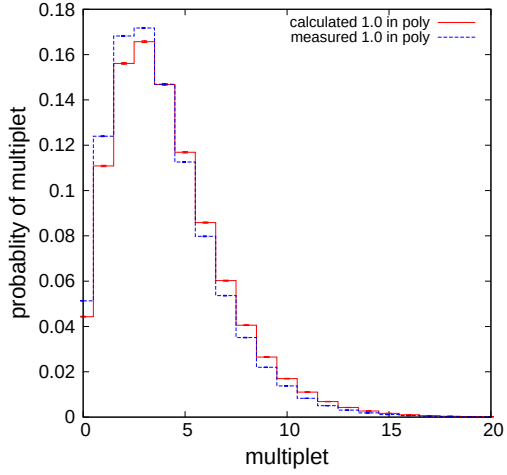
LANL-N2 Multiplicity Distributions (260 μs gate)



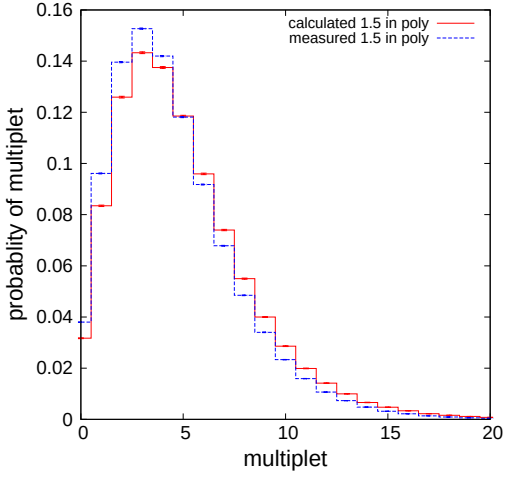
Bare



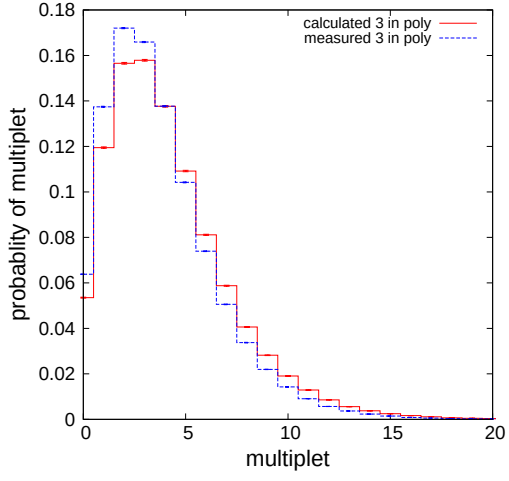
0.5" Poly



1.0" Poly

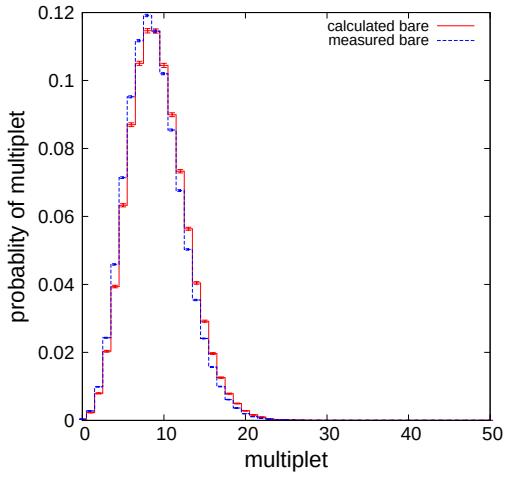


1.5" Poly

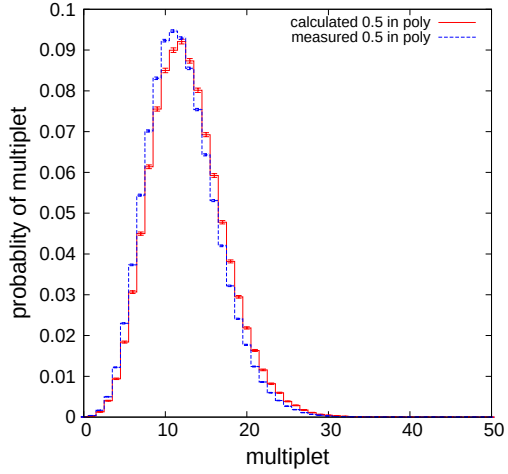


3.0" Poly

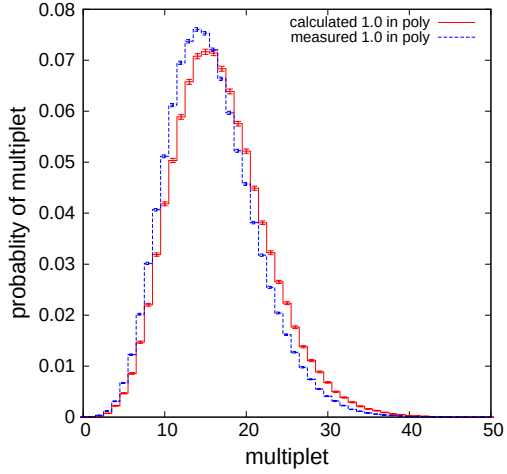
LANL-N2 Multiplicity Distributions (1060 μs gate)



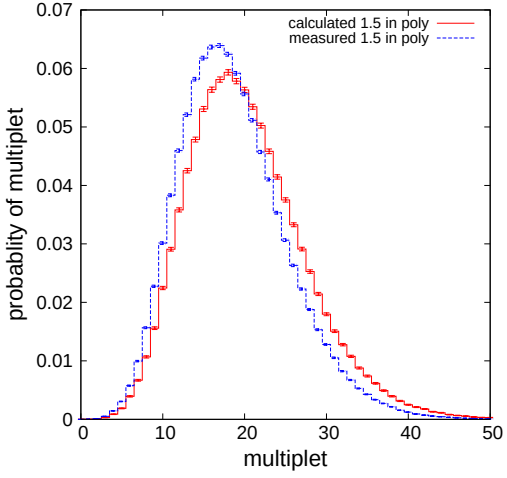
Bare



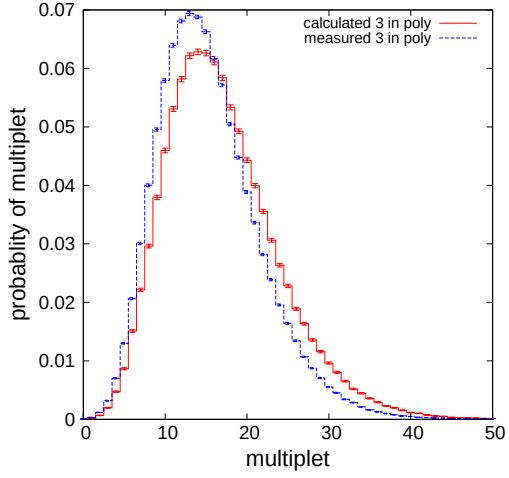
0.5" Poly



1.0" Poly

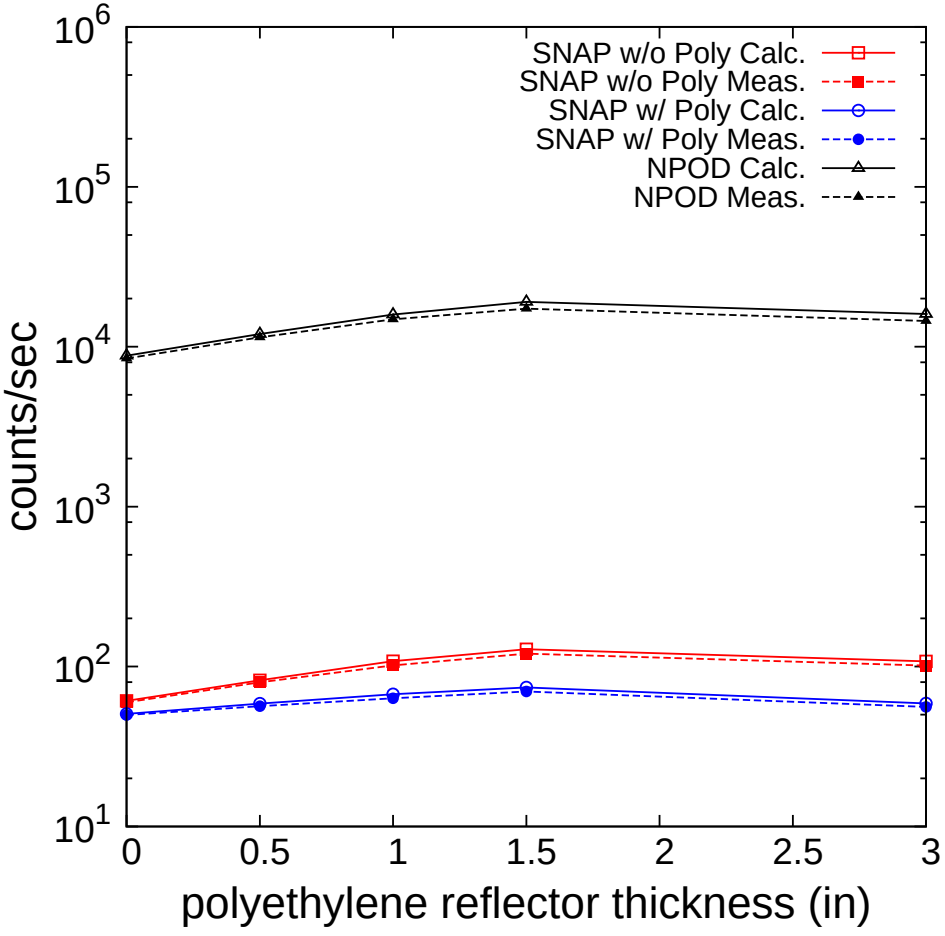


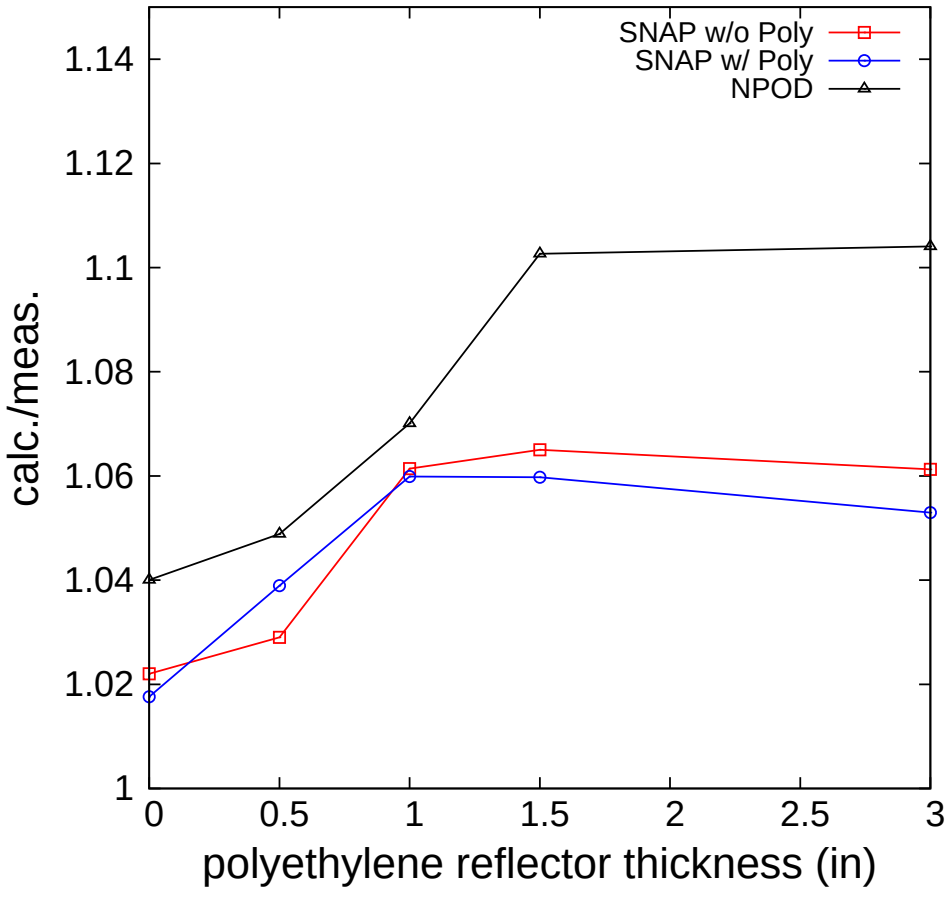
1.5" Poly



3.0" Poly

LANL-N2 Count Rate Comparisons





LANL-N2 Multiplicity Distribution Moment Comparisons

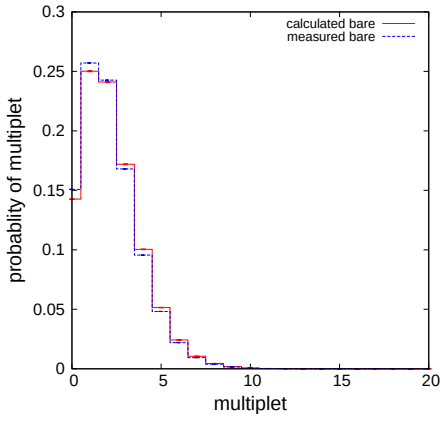
- 260 μs gate

Poly. Thick.	First Moment					Second Moment				
	Calc.	Rel. Err.	Meas.	Rel. Err	C/M	Calc.	Rel. Err.	Meas.	Rel. Err.	C/M
Bare	2.28	0.0012	2.20	0.0006	1.04	8.17	0.0016	7.63	0.0008	1.07
0.5"	3.12	0.0011	2.98	0.0006	1.05	14.47	0.0016	13.26	0.0009	1.09
1.0"	4.13	0.0011	3.86	0.0007	1.07	24.75	0.0016	21.77	0.0011	1.14
1.5"	4.96	0.0011	4.57	0.0008	1.09	35.87	0.0016	30.45	0.0011	1.18
3.0"	4.16	0.0011	3.77	0.0007	1.10	26.28	0.0017	21.70	0.0011	1.21

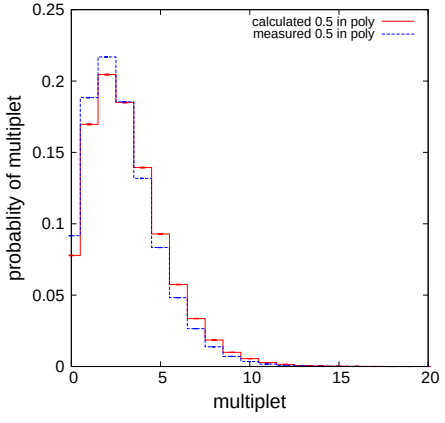
- 1060 μs gate

Poly. Thick.	First Moment					Second Moment				
	Calc.	Rel Err.	Meas.	Rel. Err	C/M	Calc.	Rel. Err.	Meas.	Rel. Err.	C/M
Bare	9.31	0.0020	8.95	0.0010	1.04	99.13	0.0023	91.94	0.0012	1.08
0.5"	12.74	0.0020	12.15	0.0011	1.05	182.40	0.0023	166.24	0.0013	1.10
1.0"	16.84	0.0020	15.73	0.0013	1.07	317.08	0.0023	277.38	0.0015	1.14
1.5"	20.24	0.0020	18.63	0.0014	1.09	461.07	0.0023	390.29	0.0016	1.18
3.0"	16.97	0.0020	15.37	0.0013	1.10	335.87	0.0025	274.78	0.0016	1.22

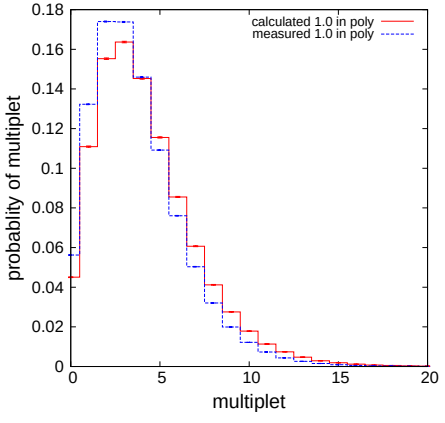
SNL-Mattingly Multiplicity Distributions (256 μs gate)



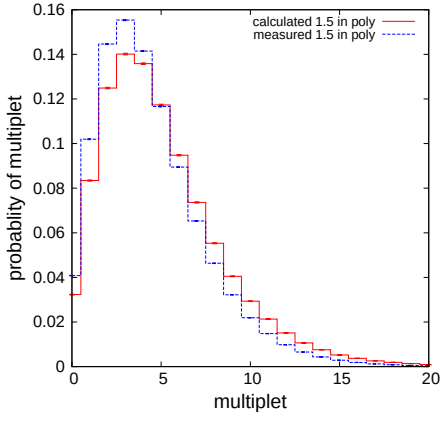
Bare



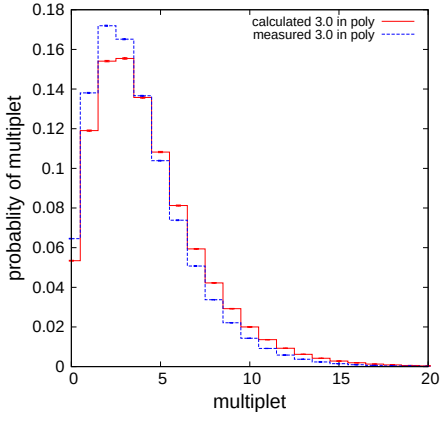
0.5" Poly



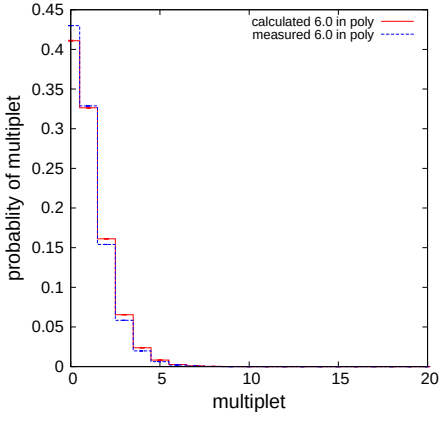
1.0" Poly



1.5" Poly

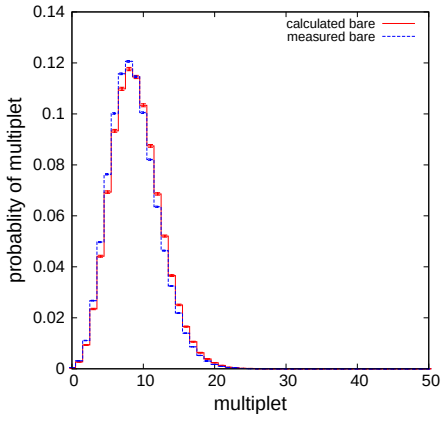


3.0" Poly

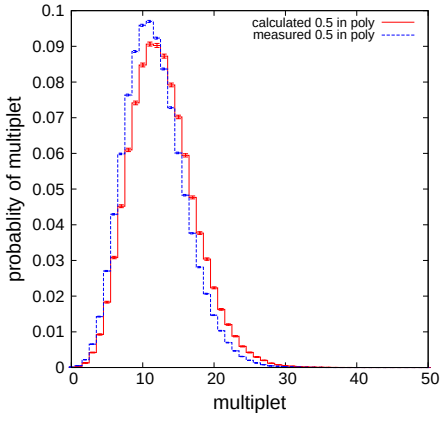


6.0" Poly

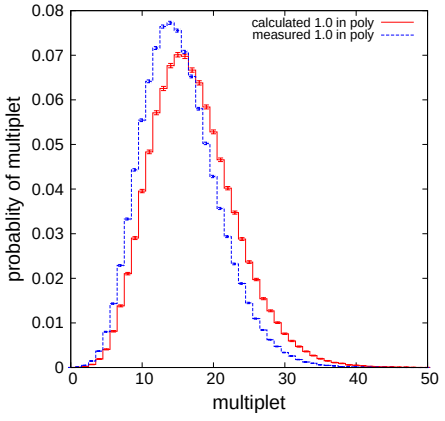
SNL-Mattingly Multiplicity Distributions (1056 μs gate)



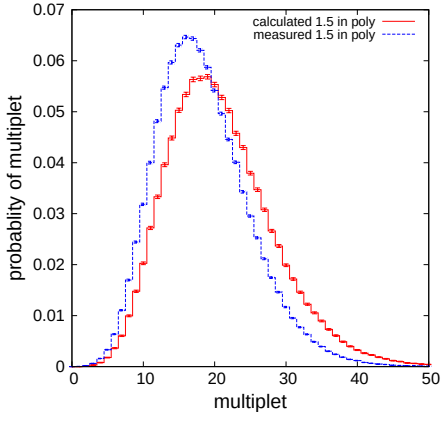
Bare



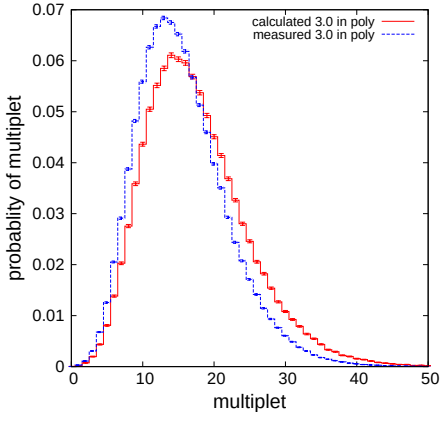
0.5" Poly



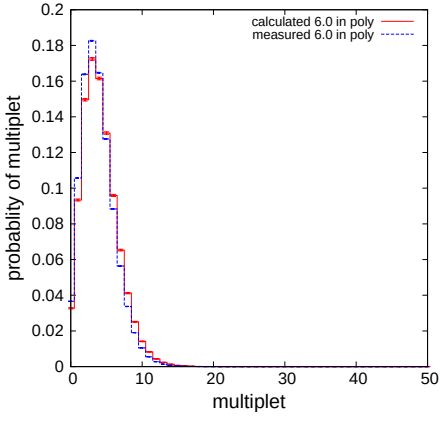
1.0" Poly



1.5" Poly

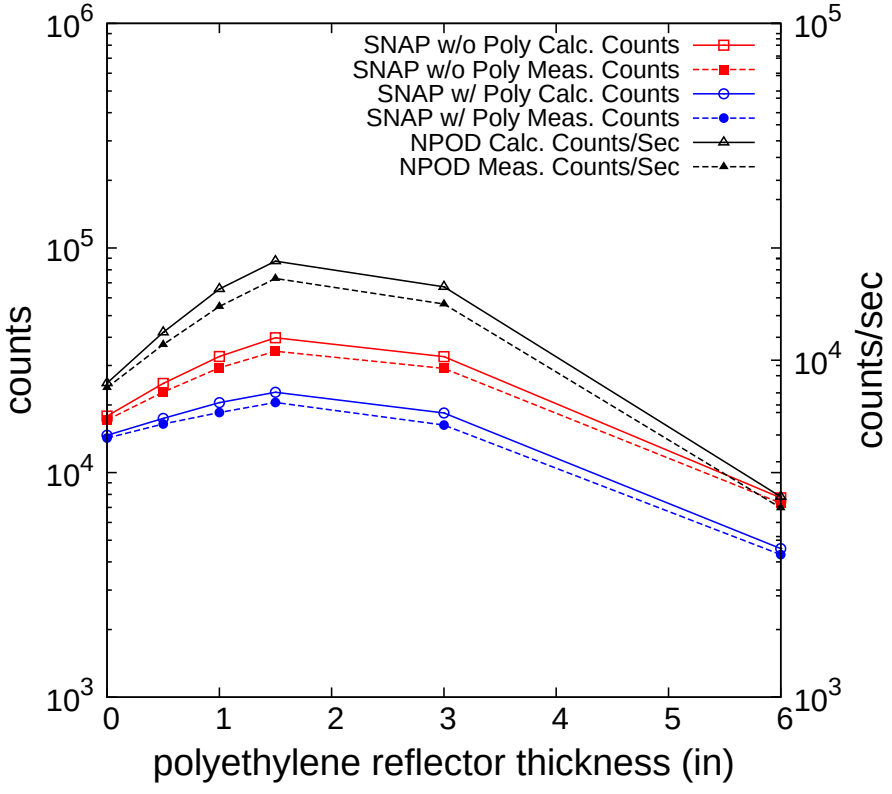


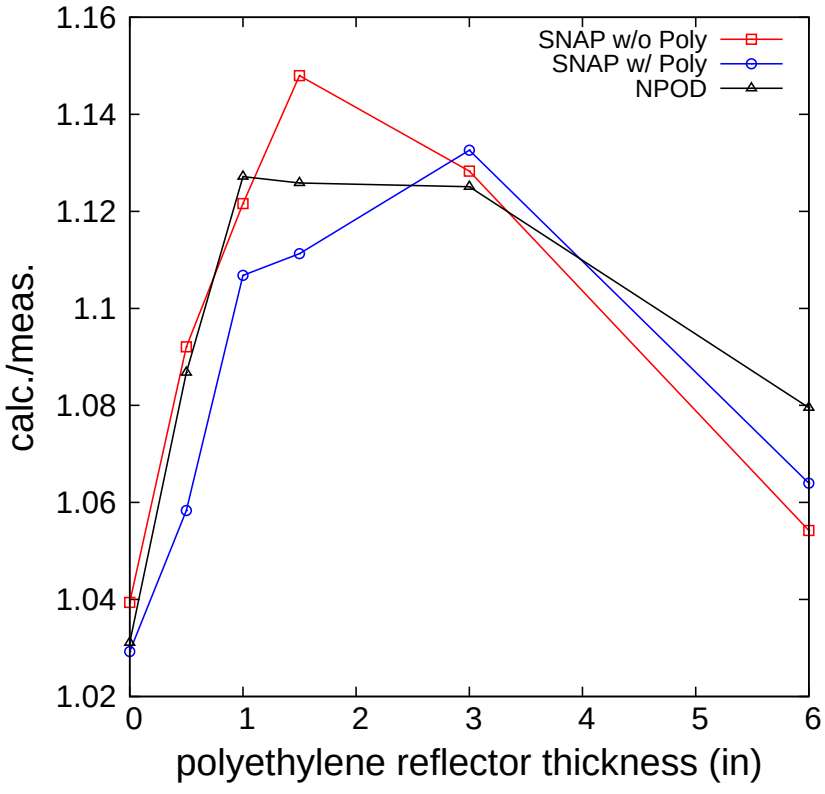
3.0" Poly



6.0" Poly

SNL-Mattingly Count Rate Comparisons





SNL-Mattingly Multiplicity Distribution Moment Comparisons

- 256 μs gate

Poly. Thick.	First Moment					Second Moment				
	Calc.	Rel Err.	Meas.	Rel. Err	C/M	Calc.	Rel. Err.	Meas.	Rel. Err.	C/M
Bare	2.19	0.0012	2.12	0.0006	1.03	7.61	0.0016	7.20	0.0008	1.06
0.5"	3.10	0.0011	2.85	0.0006	1.09	14.31	0.0016	12.24	0.0008	1.17
1.0"	4.17	0.0011	3.72	0.0008	1.12	25.39	0.0016	20.41	0.0011	1.24
1.5"	5.04	0.0011	4.45	0.0008	1.13	37.36	0.0016	29.06	0.0011	1.29
3.0"	4.23	0.0011	3.77	0.0008	1.12	27.35	0.0017	21.80	0.0012	1.25
6.0"	1.01	0.0014	0.94	0.0005	1.07	2.32	0.0021	2.06	0.0007	1.13

- 1056 μs gate

Poly. Thick.	First Moment					Second Moment				
	Calc.	Rel Err.	Meas.	Rel. Err	C/M	Calc.	Rel. Err.	Meas.	Rel. Err.	C/M
Bare	9.04	0.0020	8.75	0.0010	1.03	93.63	0.0023	88.07	0.0012	1.06
0.5"	12.78	0.0020	11.74	0.0010	1.09	183.67	0.0023	155.76	0.0011	1.18
1.0"	17.19	0.0020	15.35	0.0013	1.12	331.00	0.0023	264.58	0.0015	1.25
1.5"	20.79	0.0020	18.35	0.0014	1.13	488.41	0.0023	379.32	0.0016	1.29
3.0"	17.45	0.0020	15.56	0.0014	1.12	356.41	0.0025	281.87	0.0017	1.26
6.0"	4.16	0.0022	3.88	0.0008	1.07	23.51	0.0029	20.51	0.0010	1.15

Outline

What is Wrong Here?

- consistently over calculating the count rates and moments of the Feynman histograms
- two independently developed MCNP modifications give essentially the same results
- Mattingly et. al. have eliminated many possible sources of modeling error
- Not $S(\alpha, \beta)$ or ^{3}He issues, Mattingly et. al.'s ^{252}Cf results look good

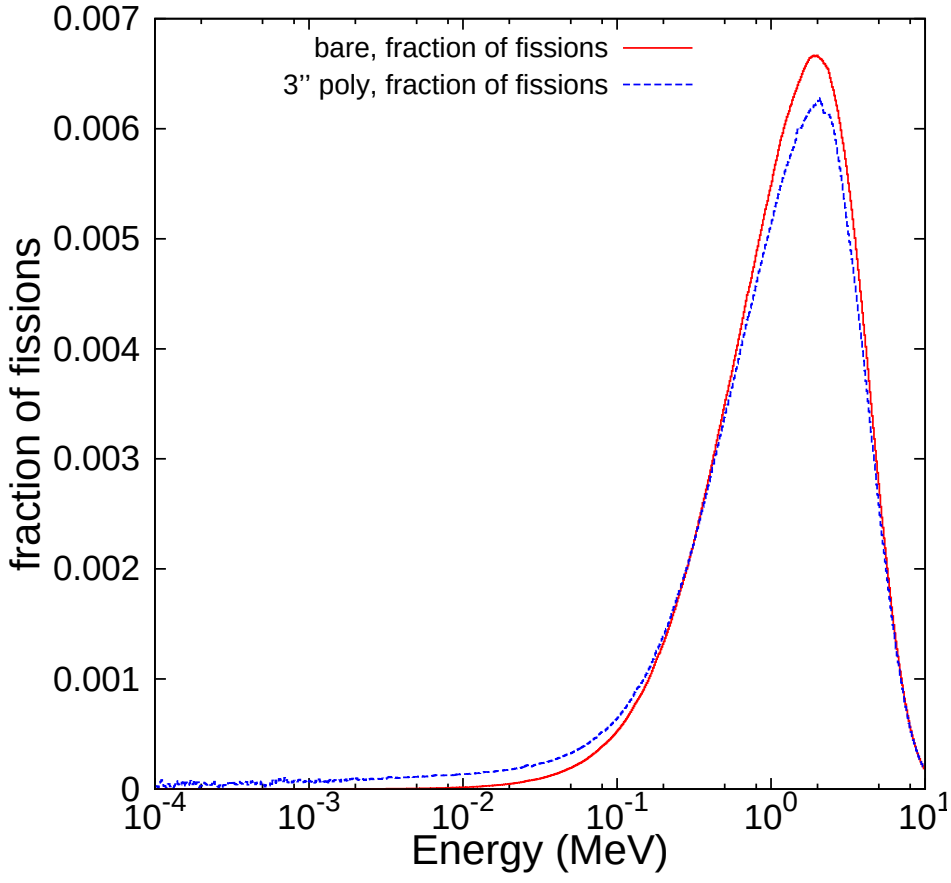
What is Wrong Here?

- consistently over calculating the count rates and moments of the Feynman histograms
- two independently developed MCNP modifications give essentially the same results
- Mattingly et. al. have eliminated many possible sources of modeling error
- Not $S(\alpha, \beta)$ or ^{3}He issues, Mattingly et. al.'s ^{252}Cf results look good

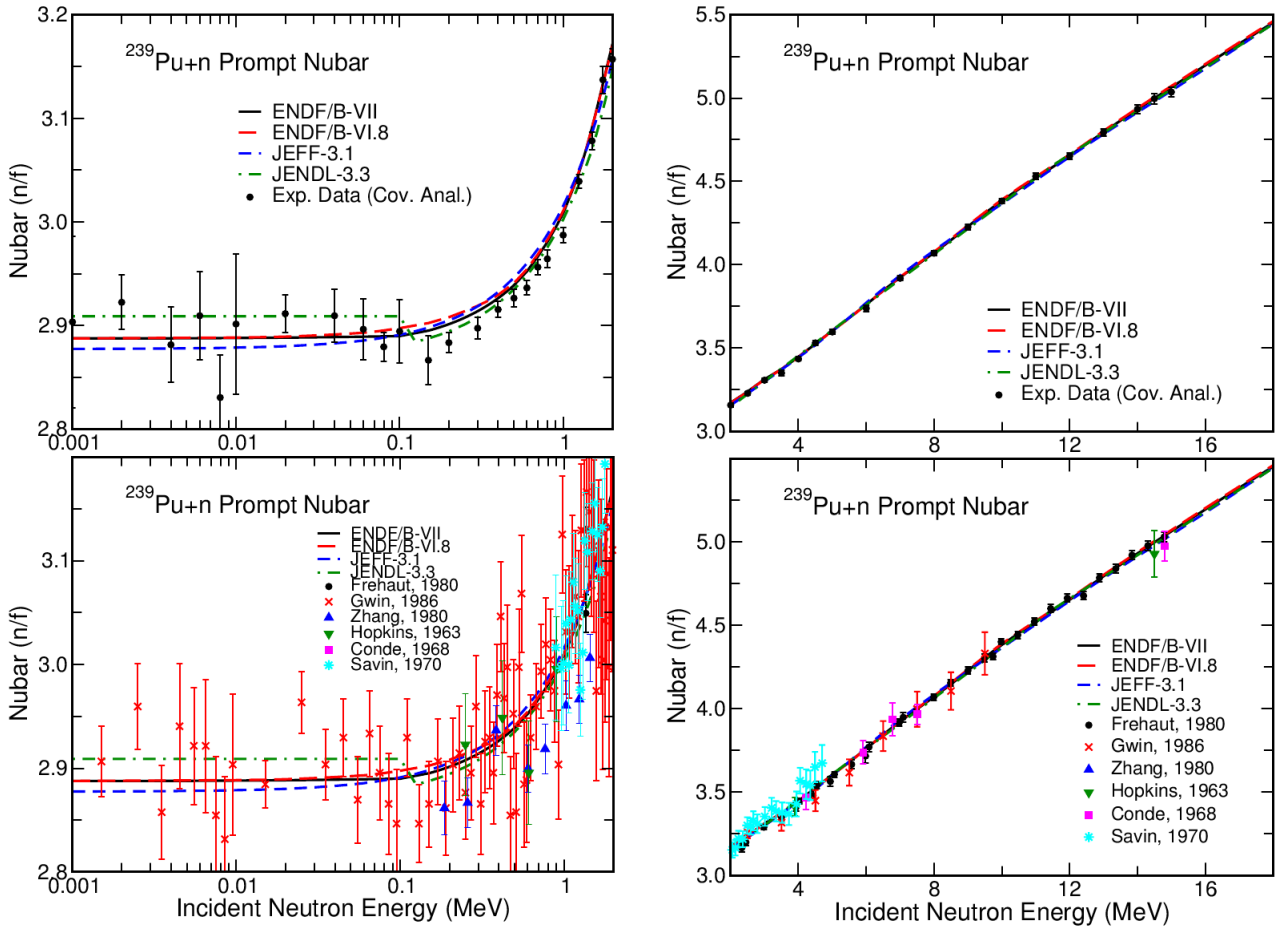
Is Mattingly et. al.'s proposed reduction to $\overline{\nu}$ reasonable?

Spectrum of Neutrons Causing Fissions

- average neutron energy causing fission is $\approx$ 1.5 MeV, regardless of reflector thickness
- fraction of fissions below 100 keV:
  - $\approx$ 2% for bare
  - $\approx$ 5% for 3" poly

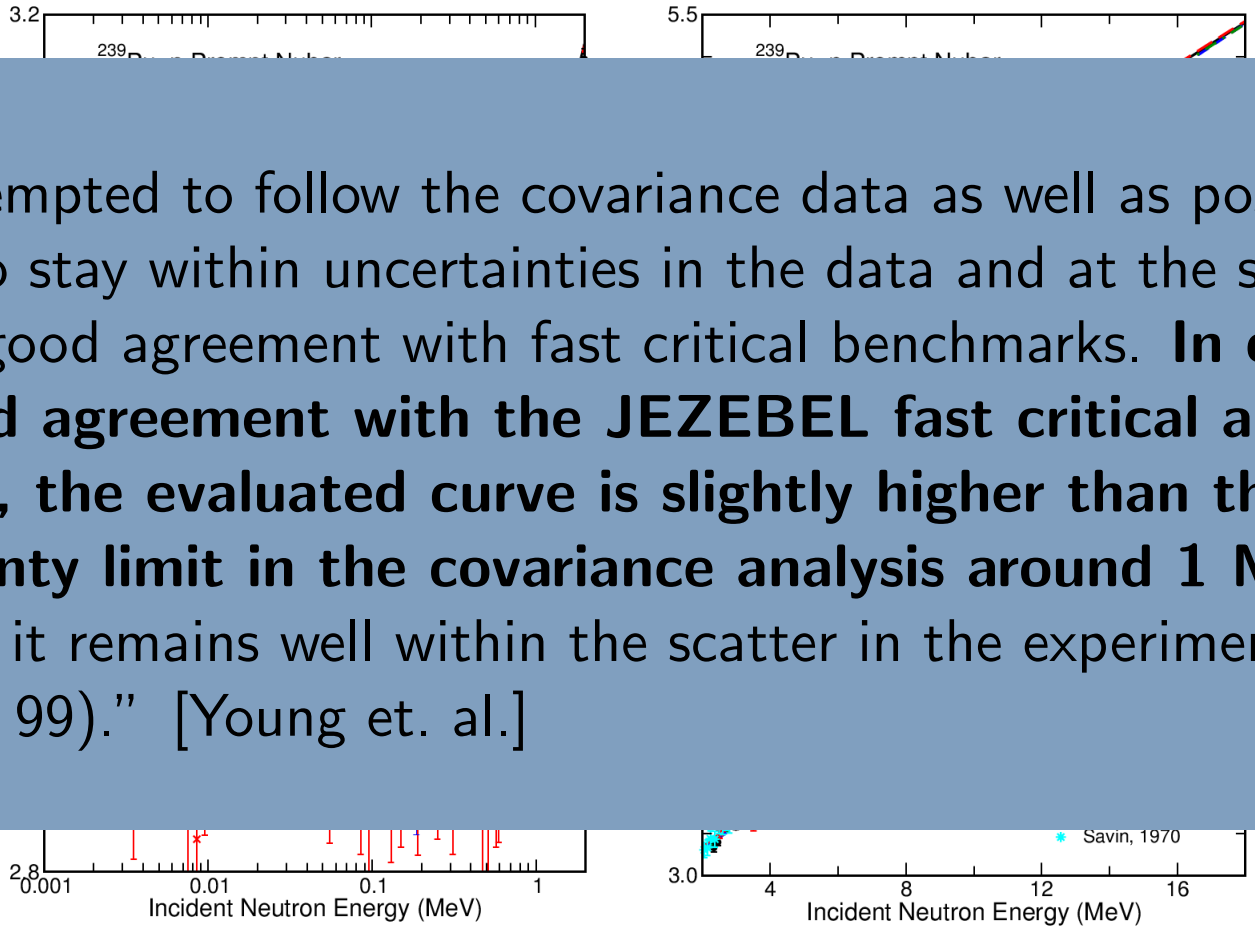


How good is the ^{239}Pu $\overline{\nu}$?



P.G. Young et. al. Evaluation of Neutron reactions for ENDF/B-VII: $^{232-241}$U and ^{239}Pu. *Nuclear Data Sheets*:108, number 12, 2007.

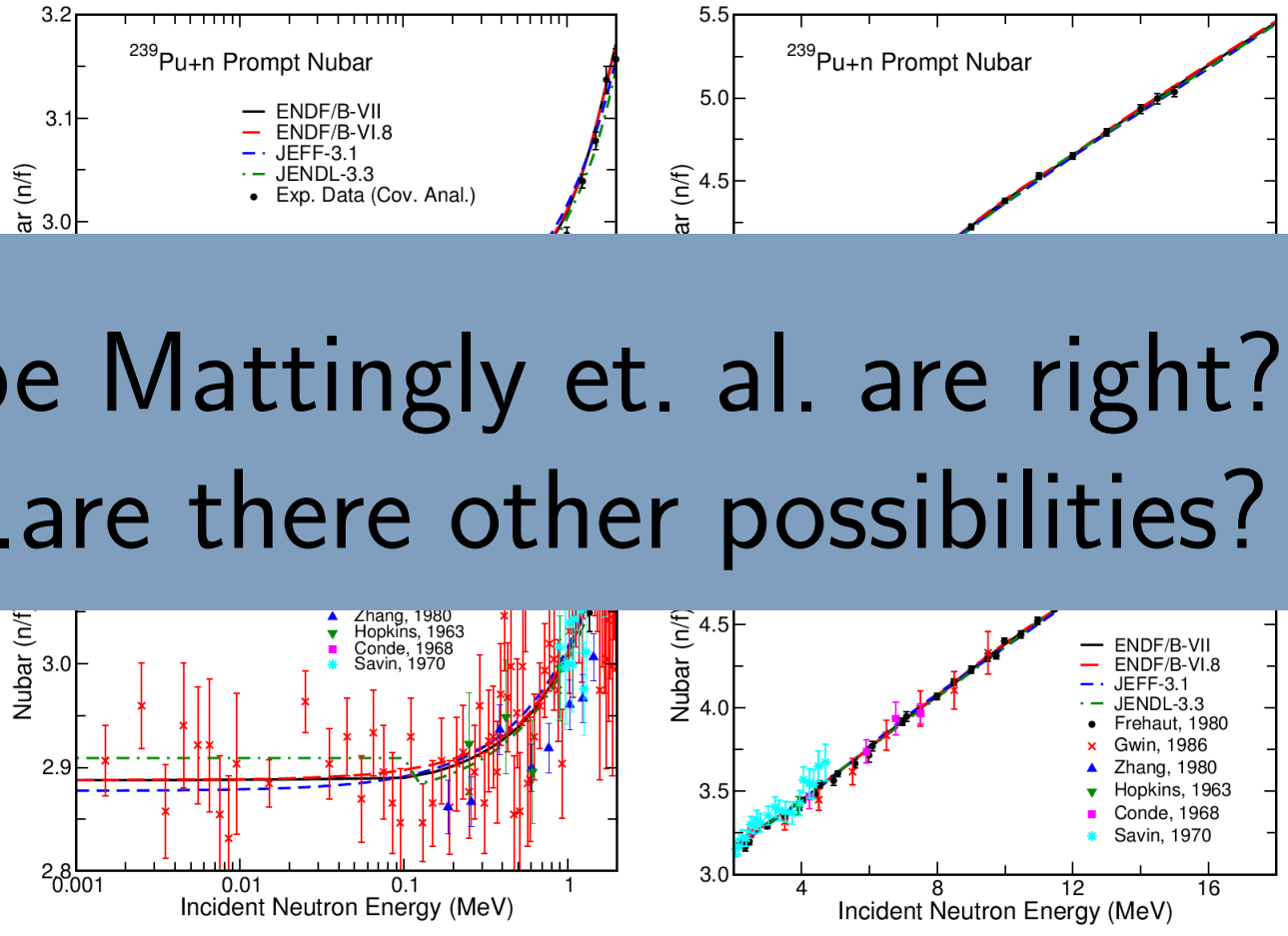
How good is the ^{239}Pu $\overline{\nu}$?



"We attempted to follow the covariance data as well as possible but mainly to stay within uncertainties in the data and at the same time to keep good agreement with fast critical benchmarks. **In order to get good agreement with the JEZEBEL fast critical assembly, however, the evaluated curve is slightly higher than the uncertainty limit in the covariance analysis around 1 MeV**, although it remains well within the scatter in the experimental data (see Fig. 99)." [Young et. al.]

P.G. Young et. al. Evaluation of Neutron reactions for ENDF/B-VII: $^{232-241}$U and ^{239}Pu. *Nuclear Data Sheets*:108, number 12, 2007.

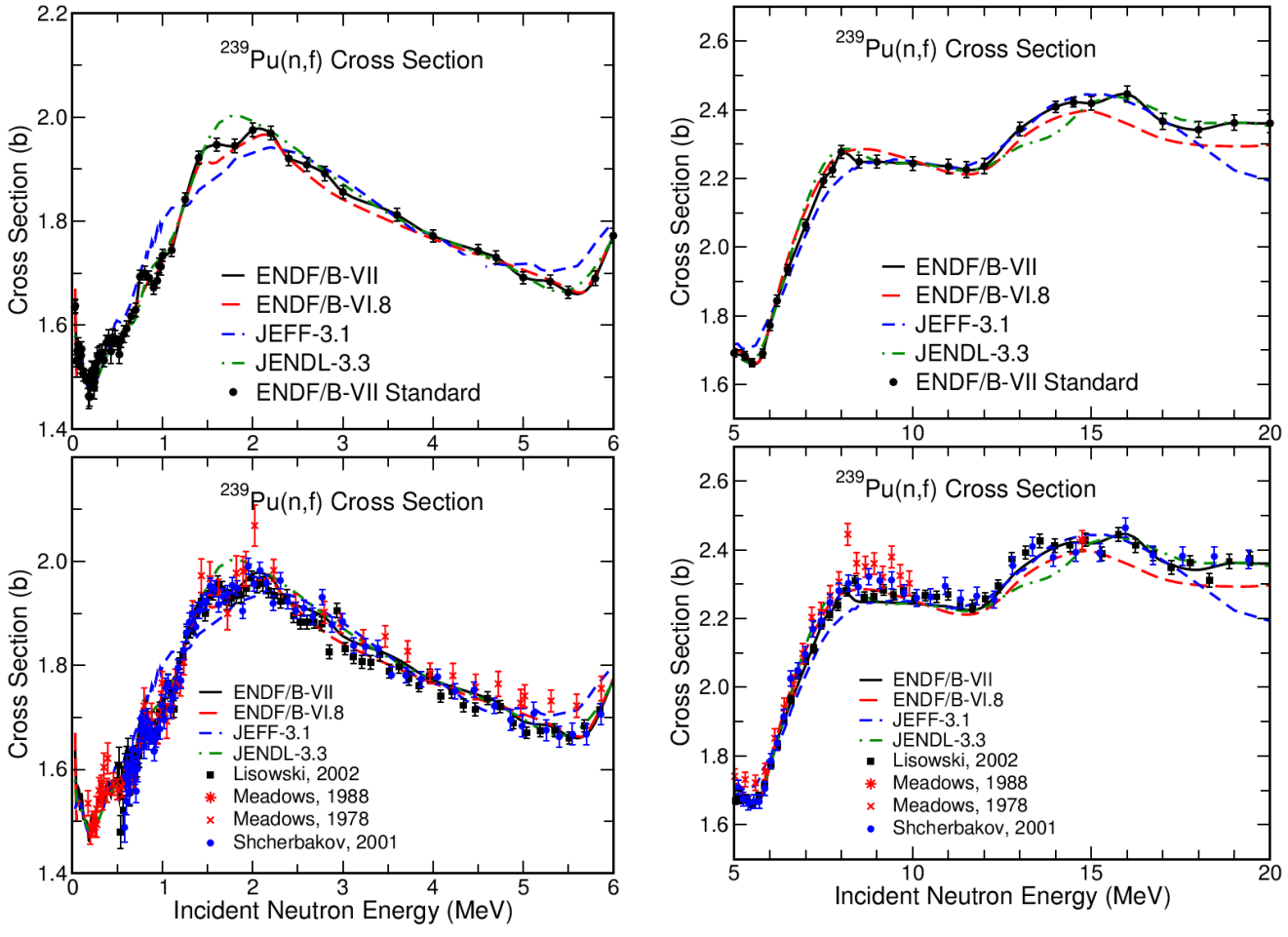
How good is the ^{239}Pu $\overline{\nu}$?



Maybe Mattingly et. al. are right?
But...are there other possibilities?

P.G. Young et. al. Evaluation of Neutron reactions for ENDF/B-VII: $^{232-241}$U and ^{239}Pu. *Nuclear Data Sheets*:108, number 12, 2007.

How Good is the ^{239}Pu σ_f?



P.G. Young et. al. Evaluation of Neutron reactions for ENDF/B-VII: $^{232-241}$U and ^{239}Pu. *Nuclear Data Sheets*:108, number 12, 2007.

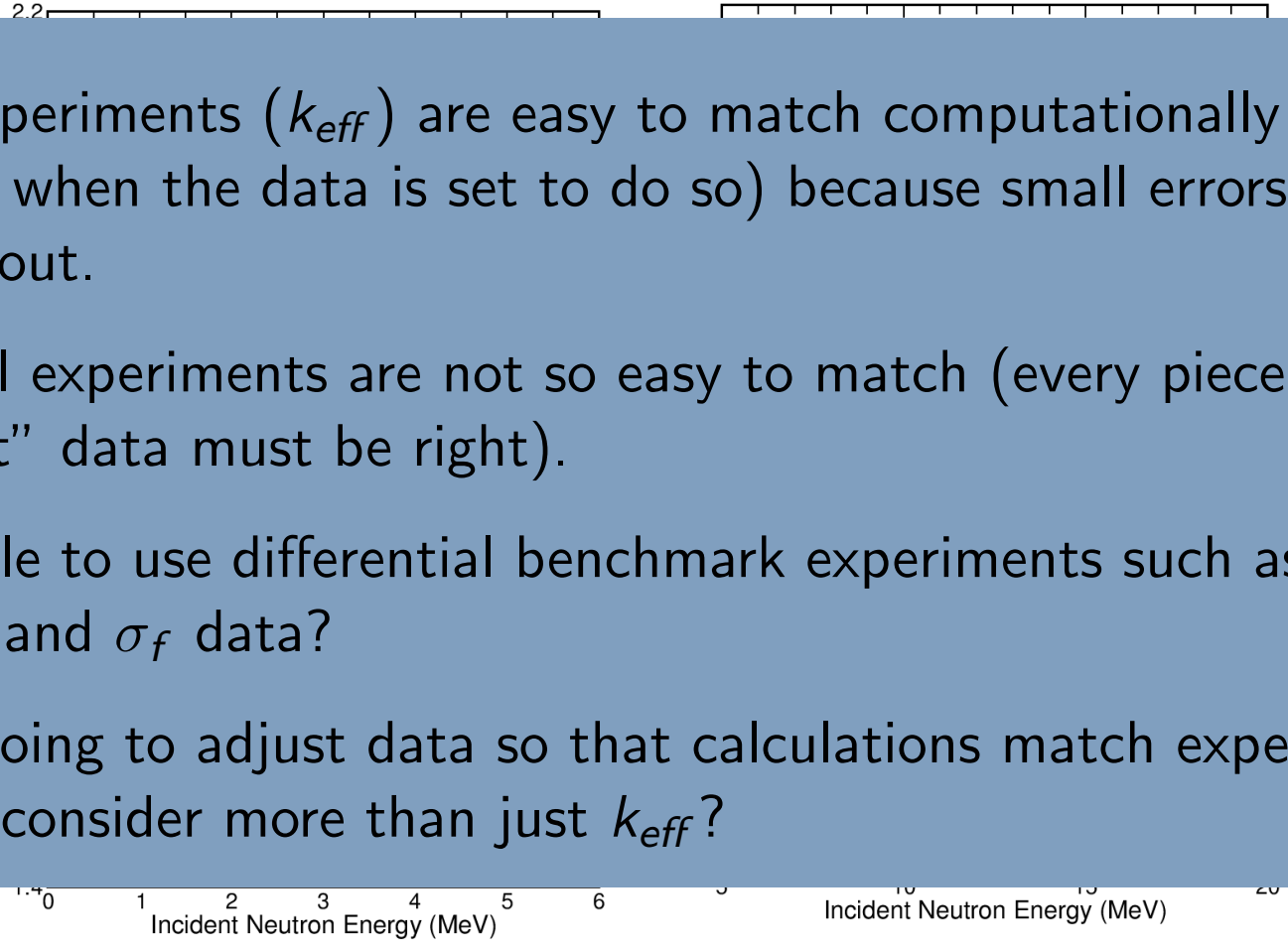
How Good is the ^{239}Pu σ_f?

Integral experiments (k_{eff}) are easy to match computationally (especially when the data is set to do so) because small errors are smoothed out.

Differential experiments are not so easy to match (every piece of "important" data must be right).

May be able to use differential benchmark experiments such as these to improve $\overline{\nu}$ and σ_f data?

If we are going to adjust data so that calculations match experiment, should we consider more than just k_{eff}?



P.G. Young et. al. Evaluation of Neutron reactions for ENDF/B-VII: $^{232-241}$U and ^{239}Pu. *Nuclear Data Sheets*:108, number 12, 2007.

Outline

Conclusions

- simulation of two different polyethylene reflected plutonium experiments exhibit the same erroneous systematic trend
- two independent modifications to MCNP produce the same erroneous systematic trend
- most modeling errors have been investigated (Mattingly et. al.)
- ^{239}Pu $\overline{\nu}$, σ_f, and possibly χ may be the source of the error
- these subcritical differential experiments are highly sensitive (correlated counts on 100s–1000s μs) to input data
- subcritical experiment and critical experiment data, including but not limited to k_{eff}, should be used for data regression

Thanks to

- Avneet Sood (LANL)
- Guy Estes (LANL)
- Mark Chadwick (LANL)
- Morgan White (LANL)
- John Mattingly (NC State)
- Jesson Hutchinson (LANL)
- Bill Myers (LANL)