IER:121 Updates on the NeSO Benchmark

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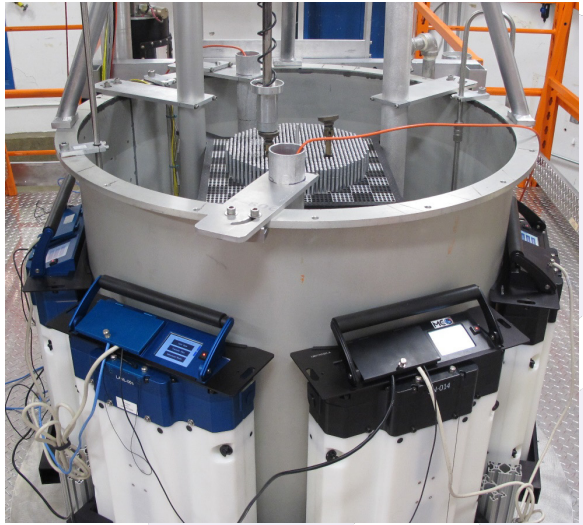
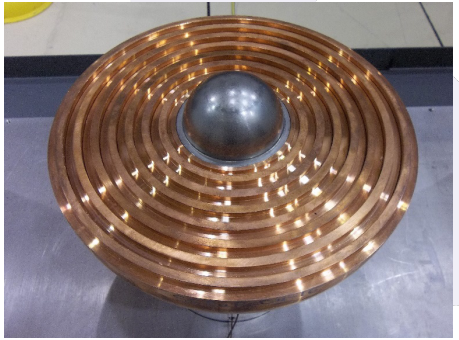
2/22/2023

LA-UR-23-21612

Subcritical Experiments at NCERC

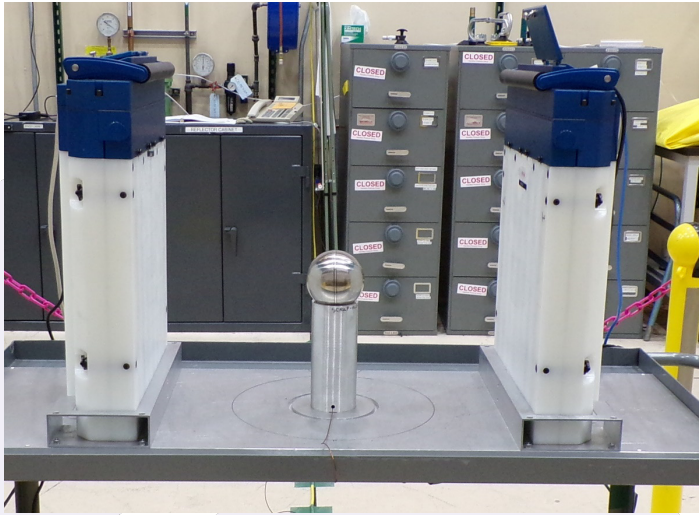
- BeRP-Ni, BeRP-W, SCRαP
- MUSIC
- EUCLID
- IER-518 (Performed at Sandia)
- And NeSO!

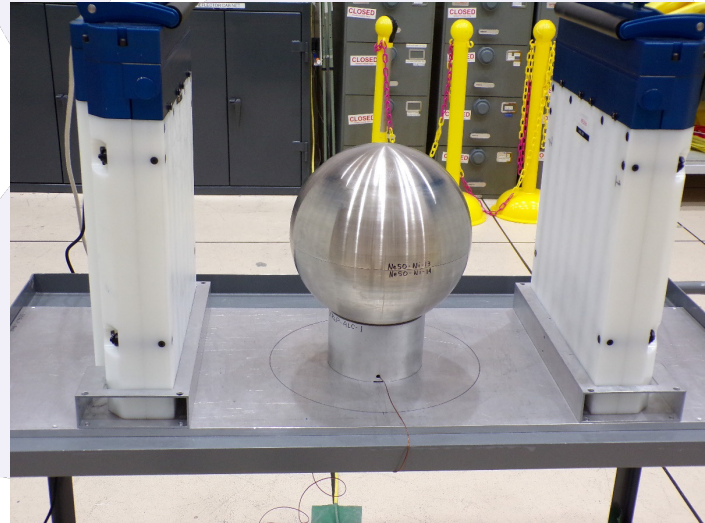




NeSO Overview

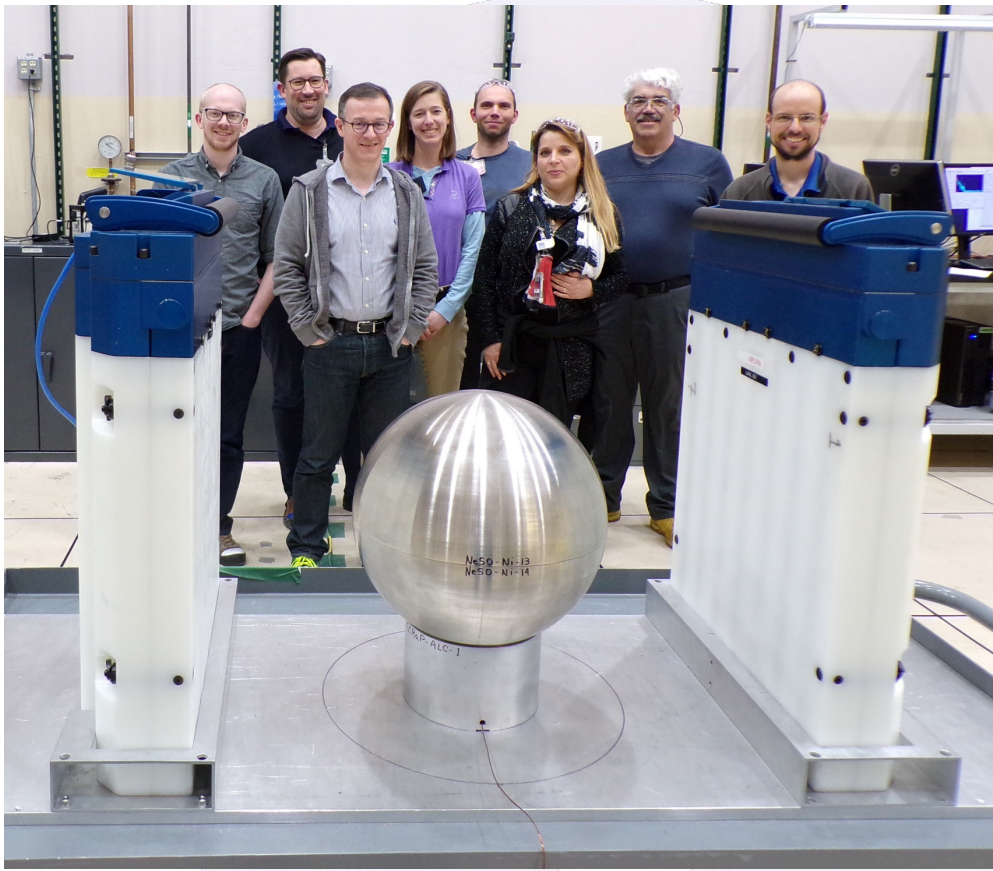
- **Ne**ptunium **S**ubcritical **O**bservation
- Neptunium sphere reflected with nickel shells
- Many cases:
  - Bare and reflected by 0.6, 1.1, 1.6, 2.1, 2.6, 3.1, and 3.6 inches of nickel
  - Also Cf-252 source measurements for detector efficiency
- Purpose:
  - Better understand Np Sphere
  - Np data at high multiplication





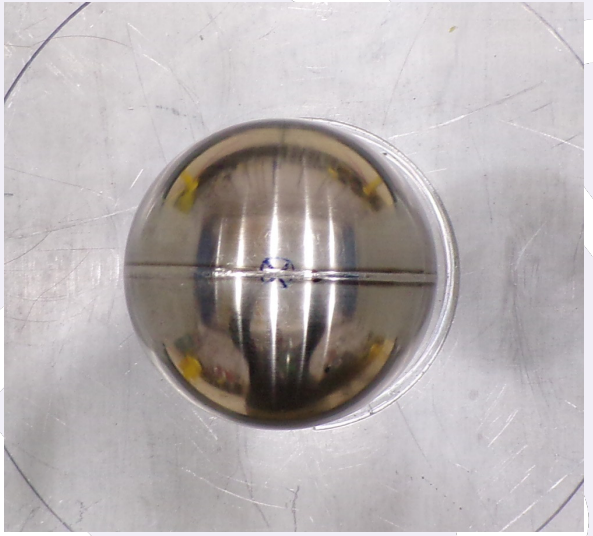
NeSO Overview

- Measurements performed in 2019
- Collaboration with IRSN



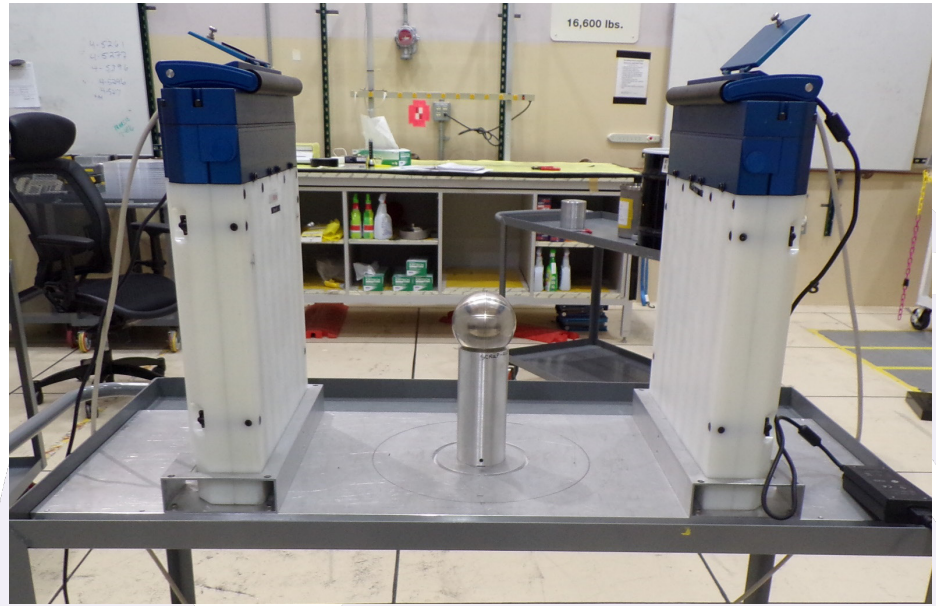
Np Sphere Composition

- Originally 8 kg of $^{237}NpO_2$ from Savannah River, Purex reprocessing of DOE reactor fuels.
- One issue – when the Np sphere was made, there was not enough Np for the casting.
- Impurities which would have floated out of the cast became stuck in the sphere
  - Top of the sphere has more impurities than the rest of the sphere
- This makes it difficult to model correctly



Np Sphere Composition

- Multiple methods for determining the composition:
  - Gamma measurements of each side
  - Neutron measurements at different intervals to measure decay (2019, 2021, 2022)
  - New composition analysis of shavings
- Due to the interesting nature of the Np composition, the Nuclear and Radiochemistry Group (C-NR) at LANL is preparing a paper for an analytic chemistry journal.



Np Sphere Composition

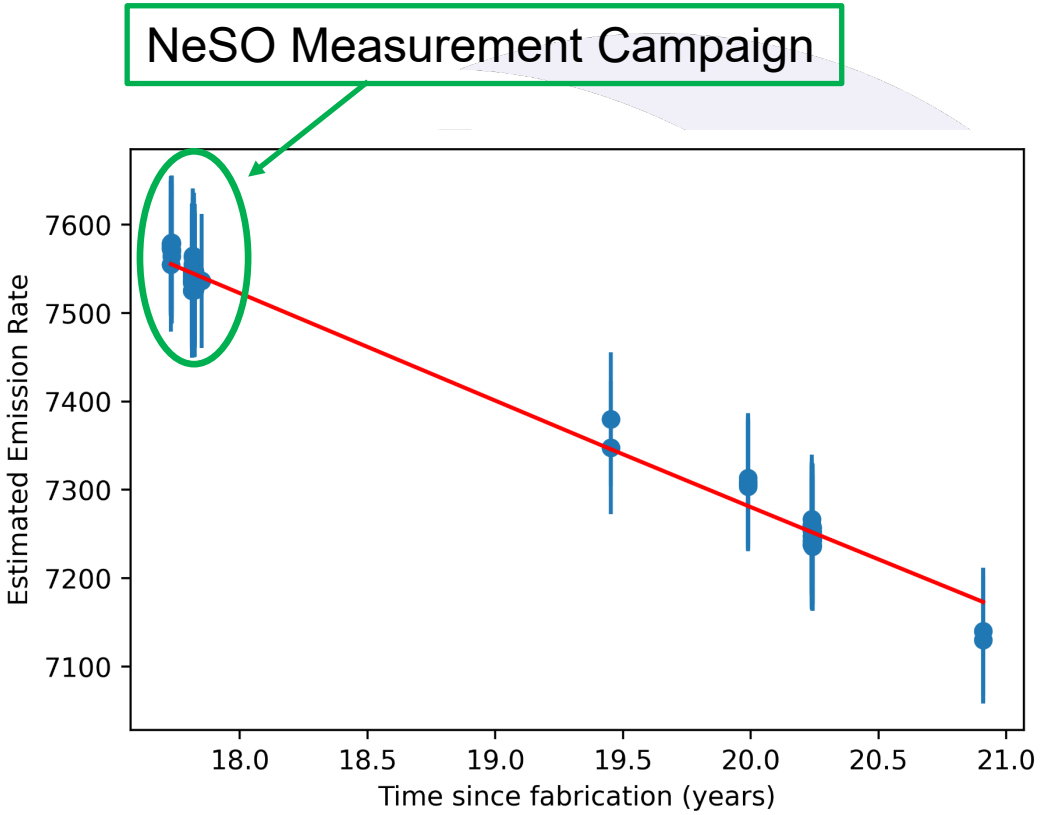
From the C-NR report (LA-UR-22-29909):

- "significant quantities and unusual isotope profiles of americium and curium contaminants"
  - "The amount of americium relative to neptunium in the material is relatively high, with measured atom ratios of $^{243}Am/^{237}Np$ and $^{241}Am/^{237}Np$ of $1.07(2)\times10^{-3}$ and $4.23(7)\times10^{-6}$, respectively."
  - "The isotopic composition of the americium is also unusual; the material we studied had a $^{241}Am/^{243}Am$ atom ratio of 0.00395(5) and no detectible ^{242m}Am"

isotope	measured atoms/g A solution	% unc.	Neutrons/s
^{237}Np	1.87E+18	1.35	0.68
^{238}Pu	2.37E+13	0.98	196.61
^{239}Pu	5.33E+14	0.90	0.04
^{240}Pu	3.84E+13	0.95	125.45
^{241}Pu	3.78E+11	4.90	0.00
^{242}Pu	5.48E+12	1.20	30.19
^{244}Pu	L_D = 9.1E+09		0.00
^{241}Am	7.90E+12	0.91	0.03
^{242m}Am	L_D = 9.0E+09		0.00
^{243}Am	2.00E+15	0.90	0.00
^{244}Cm	3.05E+11	1.42	20515.15
^{233}U	7.79E+13	0.37	0.00
^{234}U	1.42E+13	0.41	0.00
^{235}U	4.95E+14	0.38	0.00
^{236}U	2.80E+12	0.41	0.00
^{238}U	5.05E+13	1.94	0.00

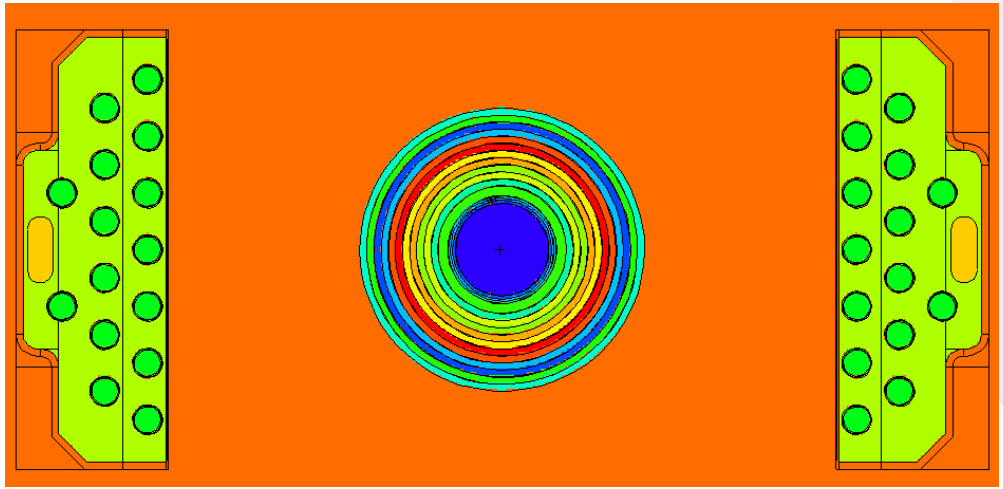
Np Sphere Decay Data

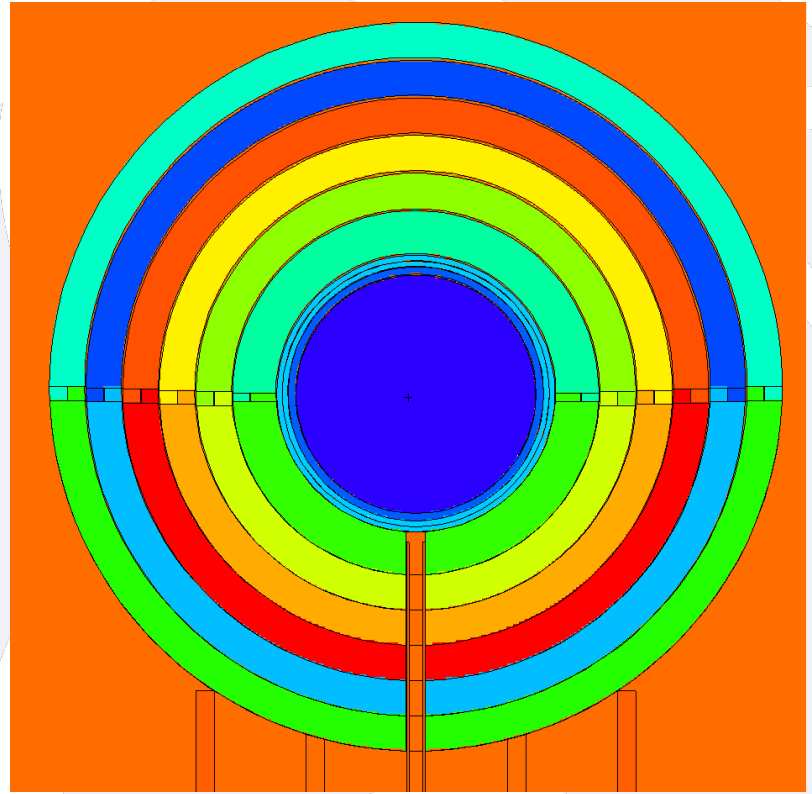
- ^{244}Cm half-life: 18.11 years
- ^{243}Am half-life: 7370 years
  - Decays into ^{239}Np (2.36 days half-life)
- Current data:
  - 40-42 year half-life
  - More work to be done to understand this



NeSO Modeling for ICSBEP Benchmark

- Working model in MCNP
- Python script to make and modify the model
- Uncertainty analysis underway

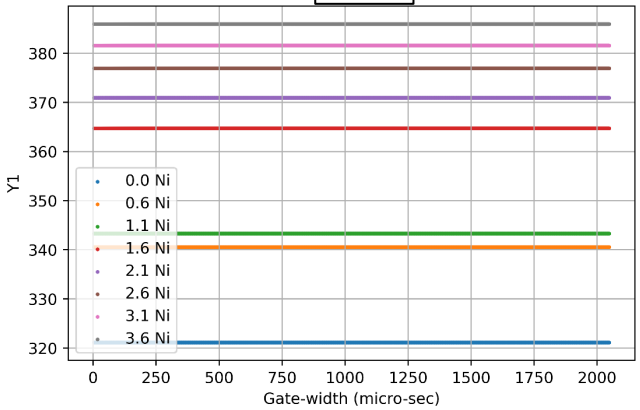




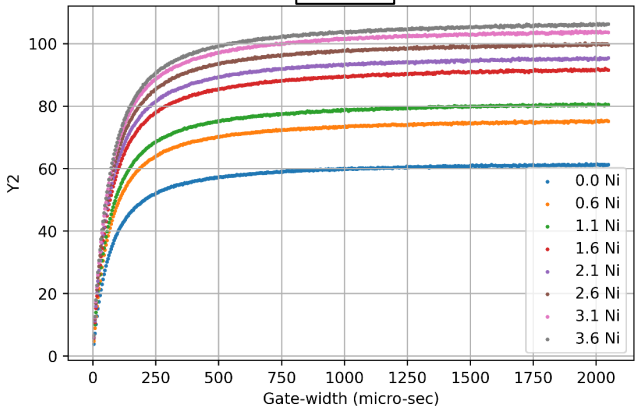
NeSO initial results

- Feynman moments
- Y1 – count rate
- Y2 – proportional to doubles rate

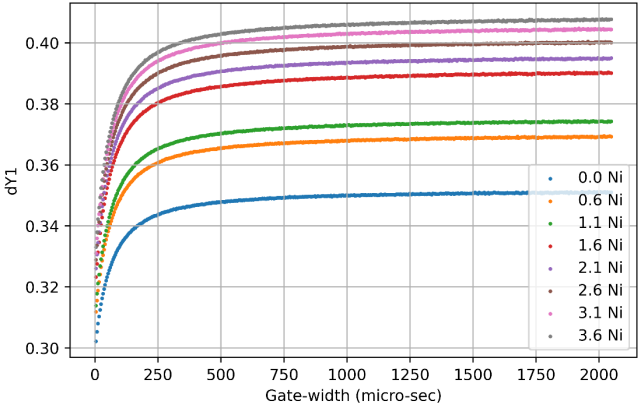
Y1



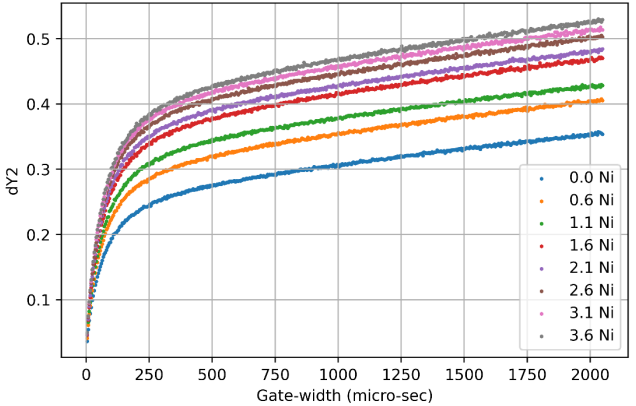
Y2



Y1 uncertainty



Y2 uncertainty



Results

- New isotopics from new rad-chem measurement of composition
- Performing MCNP uncertainty analysis
  - Python tools developed to help speed up process
- Performing data analysis
  - Data looks very good

Acknowledgements

- This work was supported by the DOE Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the Department of Energy. This measurement was done in collaboration with IRSN.

Backup

NeSO Initial Results

- Y2 can be fit:

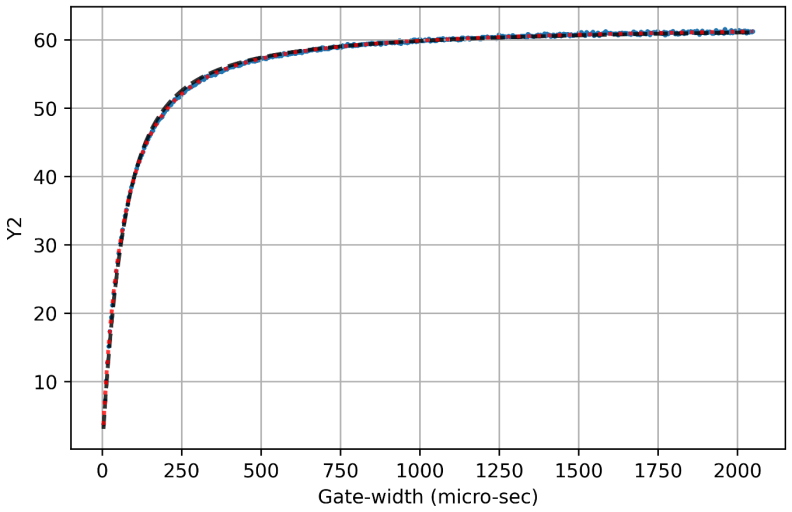
$$Y_2 = A\left(1 - \frac{1 - e^{-\lambda\tau}}{\lambda\tau}\right)$$

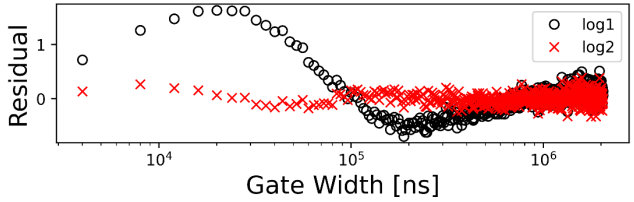
  - Fit solves for A and λ.

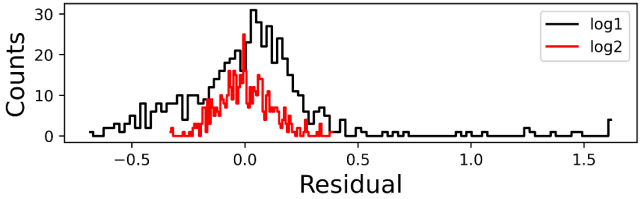
- Can also perform a fit with two terms:

$$Y_2 = A\left(1 - \frac{1-e^{-\lambda_1\tau}}{\lambda_1\tau}\right) + C\left(1 - \frac{1-e^{-\lambda_2\tau}}{\lambda_2\tau}\right)$$

Bare Np







Black: single term fit.
Red: two term fit.