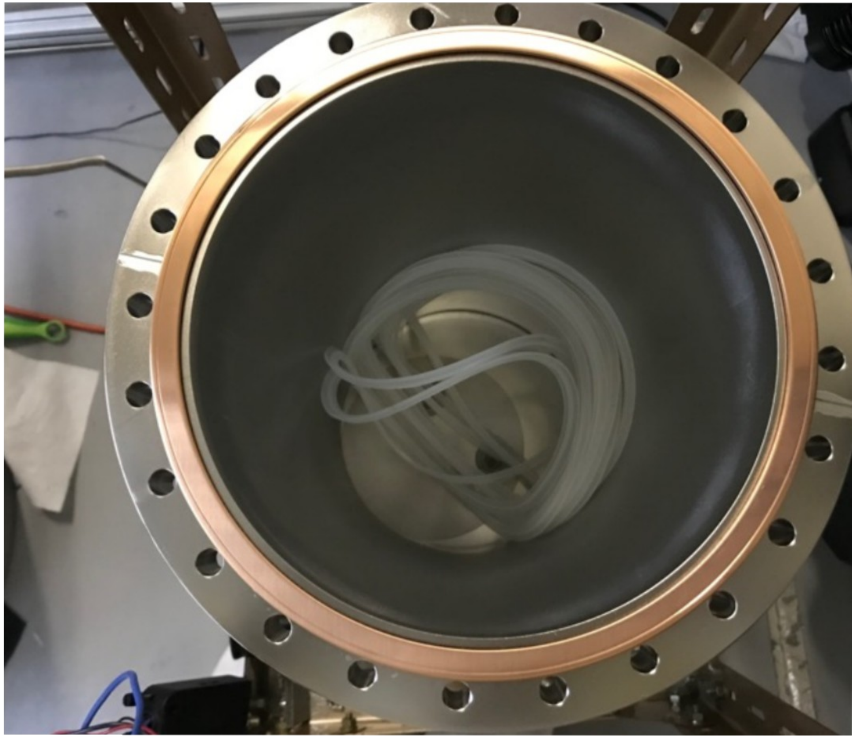
8” Silicone Gasket Radon Emanation Measurement

H. Ryott Glayzer
SDSMT Research Assistant
September 2023

Sample Photos



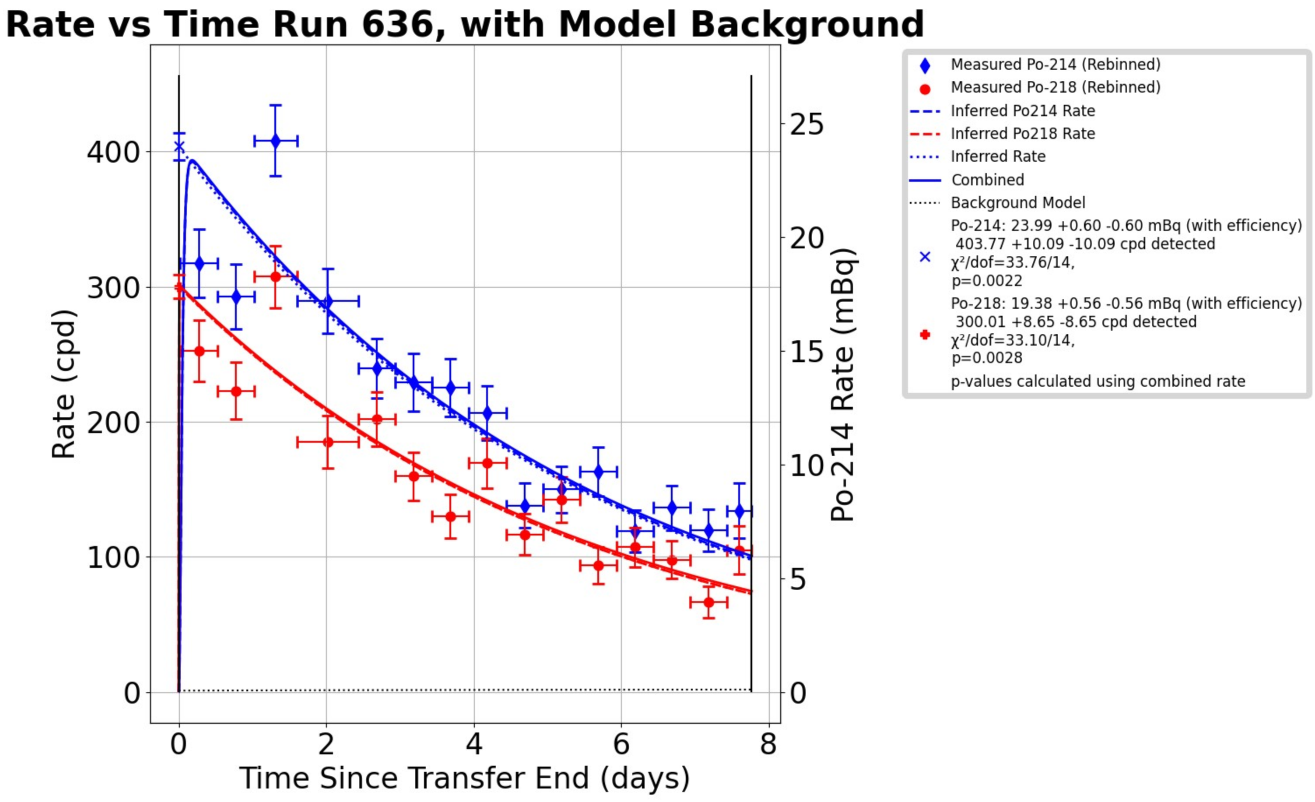
Picture of sample placement (10 Gaskets) in small emanation chamber at SD Mines in September 2020.
Photo Credit: Nic Chott/SD Mines

Picture of SuperCDMS Tower Shipping/Storage Containers at SNOLAB in May 2023. Sample is used as the gasket to seal the shippng/storage containers.
Photo Credit: Vijay Iver/University of Toronto

Overview

- Gasket Material for Tower Storage/Shipping Containers
- Emanation of Bulk Material: September – October 2020
  - Ten Silicone Gaskets were emanated three times in the Small Emanation Chamber at SDSMT
  - Original analysis, performed by Nic Chott, indicated a total emanation rate of 35 ± ? mBq
  - Current analysis of these same runs indicate a total emanation rate of 23.99 ± 0.60 mBq
  - Assuming all gaskets are equally “hot”, this would indicate a single gasket emanation rate of 2.40 ± 0.06 mBq
  - Data indicates that gaskets are not equally “hot”.
- December 2020: four gaskets were sent to SLAC, chosen at random
  - Gaskets were confirmed to fit the storage container, and were used for Towers 1-4 storage
  - Assuming that these four gaskets are equally ‘hot’, it can be inferred that each gasket has a ^{222}Rn emanation rate of **1.44 ± 0.22 mBq** and a ^{210}Pb plate-out rate of 2.45 ± 0.37 nBq/cm^{2}yr (conservative estimate) or 0.32 ± 0.05 nBq/cm^{2}yr (likely more accurate estimate)
- Additional assays were performed on the remaining six gaskets
  - They were determined to be hotter than the four sent to SLAC, so they were kept at SD Mines

Emanation Rate, Run 636 (10 Gaskets) 2020-10-02 → 2020-10-13

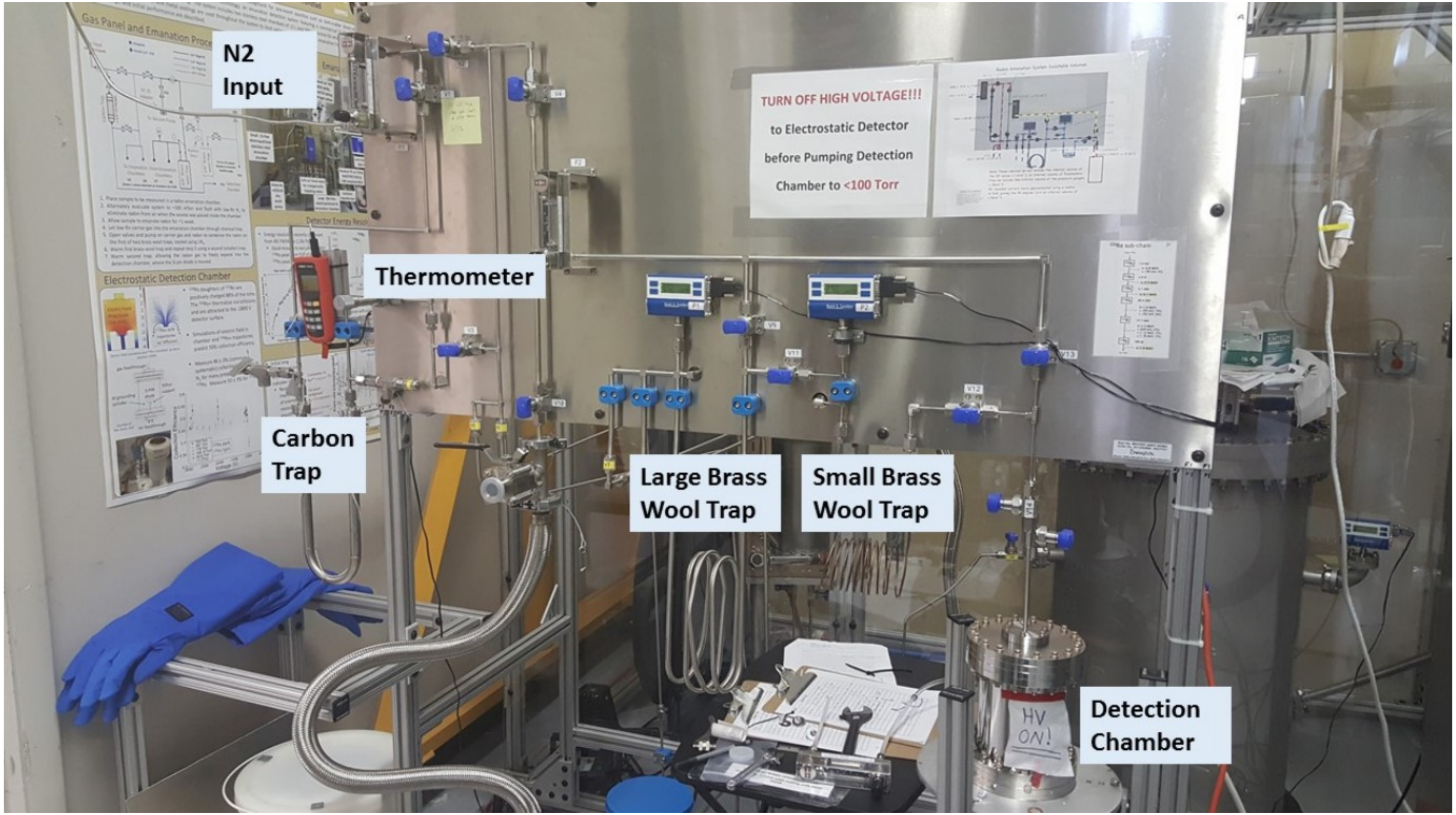


- Emanation Rate for Run 636:
  - **23.99 ± 0.60 mBq**, based on the ^{214}Po sample rate
  - The sole ^{214}Po sample rate was chosen rather than a weighted average of ^{218}Po and ^{214}Po due to poor resolution between the ^{210}Po and ^{218}Po ROIs, which likely led to a number of ^{210}Po events being counted as ^{218}Po events
- High Chi-Squared value indicates a poor fit to the data
  - Upon analysis of the ^{214}Po residuals, a single time bin was identified as the main contributor to the bad fit
  - However, upon analysis of the raw and gain-corrected data for the same time bin, no inconsistencies or systematic errors were identified. (p. 45-54)

Ten Silicone Gasket Emanation Summary

- Estimated emanation rate of the ten gaskets: **23.99 ± 0.60 mBq**
  - This is based on the ^{214}Po rate from Run 636
  - This indicates a single-gasket emanation rate of **2.40 ± 0.06 mBq**
- Run 634 suffered from a partial sample loss
  - During the sample transfer, the small Brass Wool Trap appeared to be clogged (see next slide)
  - A portion of the sample was likely lost when the trap was subsequently isolated and unclogged
- Run 631 contained no useful data
  - The system gain was so low that any radon daughter events were obscured by low-energy noise
  - Nic Chott attempted to fix this by rebiasing the detector and increasing gain on the amplifier to no avail
- Original analysis vs. Current analysis
  - Nic Chott’s original analysis proposed a ten-gasket emanation rate of ~35 mBq
  - There was a bug in the code that plotted the data wrong and led to the assumption that the fit was wrong.
  - Nic fit a rate of 35 mBq to this bugged data. The bug has since been fixed.

Experimental Setup

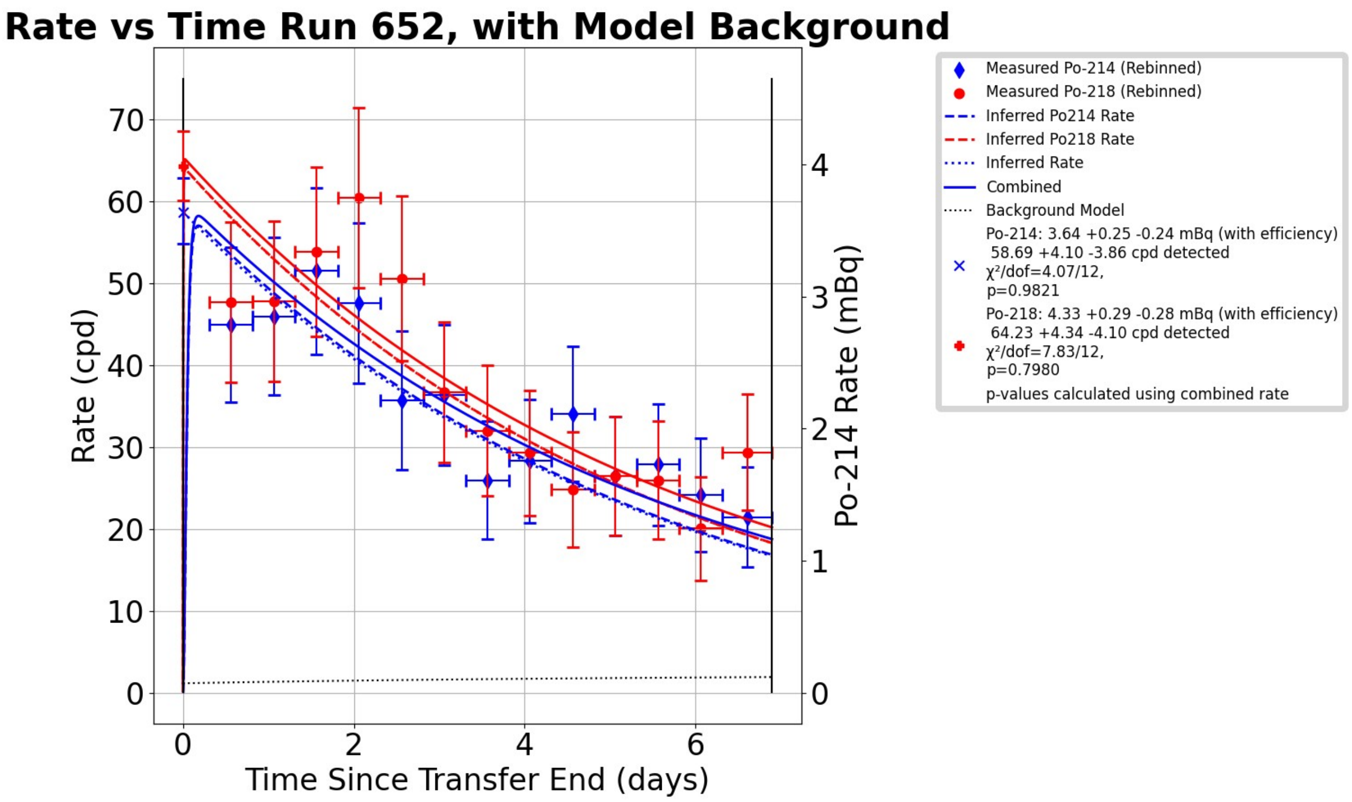


- Sample is emanated in emanation chambers (behind panel in Class 1000 clean room)
- Emanation Sample is transferred from emanation chamber to brass wool traps (BWT)
- BWTs cooled with LN_2 to cryogenically trap ^{222}Rn from sample and condense it
- Emanation Sample is then transferred to HV Detection Chamber and the run is started.
- Gaseous N_2 is flowed through ^{12}C trap cooled with IPA and dry ice to trap any ^{222}Rn and progeny before being used to move sample

Overview of Six Gaskets Emanation

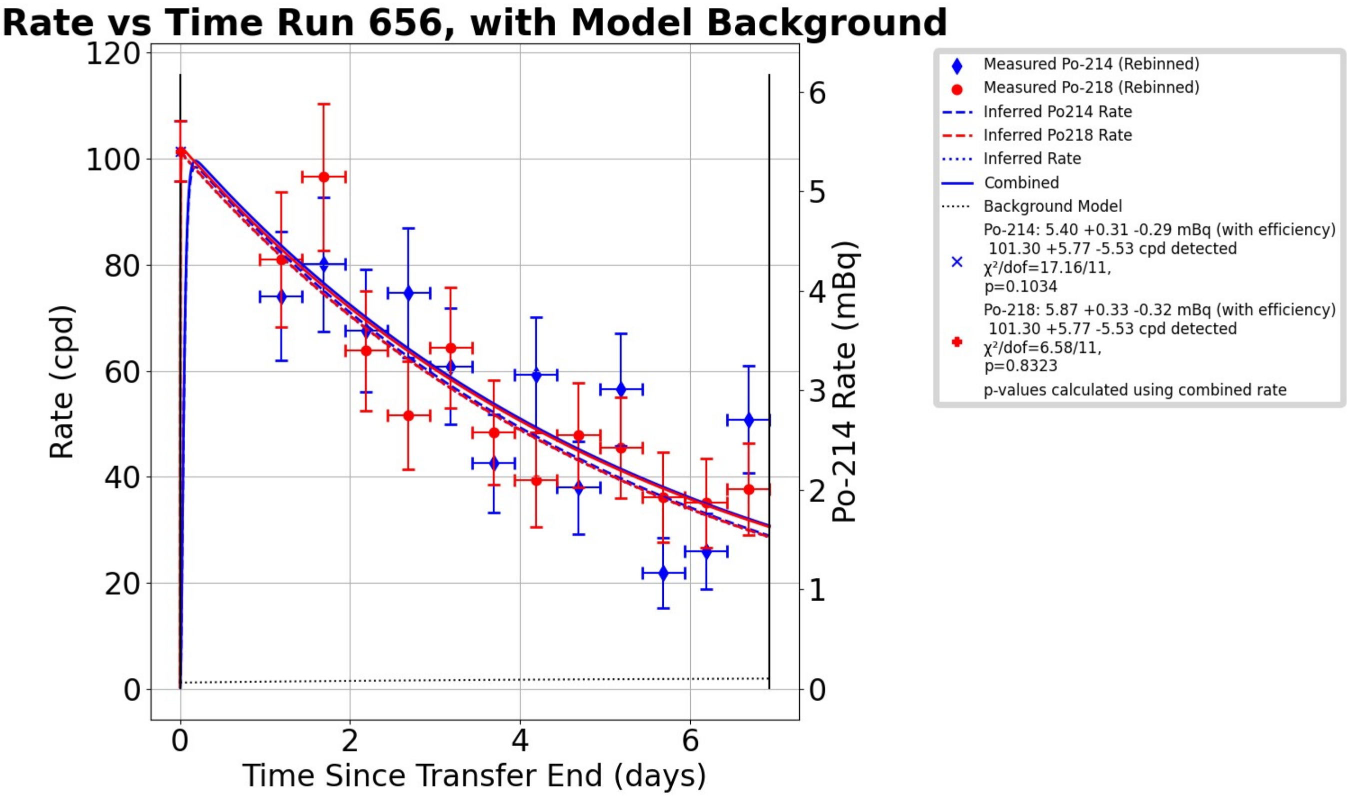
- February to March 2021:
  - Single Silicone Gasket was emanated four times
  - Single Gasket emanation rate: 4.30 ± 0.16 mBq
  - If all gasket are equally ‘hot’, this is significantly higher than the predicted 2.40 ± 0.06 mBq (over 11σ signifcance)
- April – May 2021:
  - Two Silicone Gaskets were emanated two times.
  - Two gasket emanation rate: 6.43 ± 0.23 mBq
  - Rate per gasket: 3.21 ± 0.12 mBq
  - If all gaskets are equally ‘hot’, this is significantly higher than the predicted 2.40 ± 0.06 mBq
- July – September 2021
  - Three remaining Silicone gaskets were emanated four times
  - Three Gasket emanation rate: 7.51 ± 0.16 mBq
  - Single Gasket emanation rate: 2.50 ± 0.05 mBq
- Total Six Gaskets Rate = **18.75 ± 0.64 mBq**

Emanation Rate, Run 652 (1 Gasket) 2021-02-10 → 2021-02-23



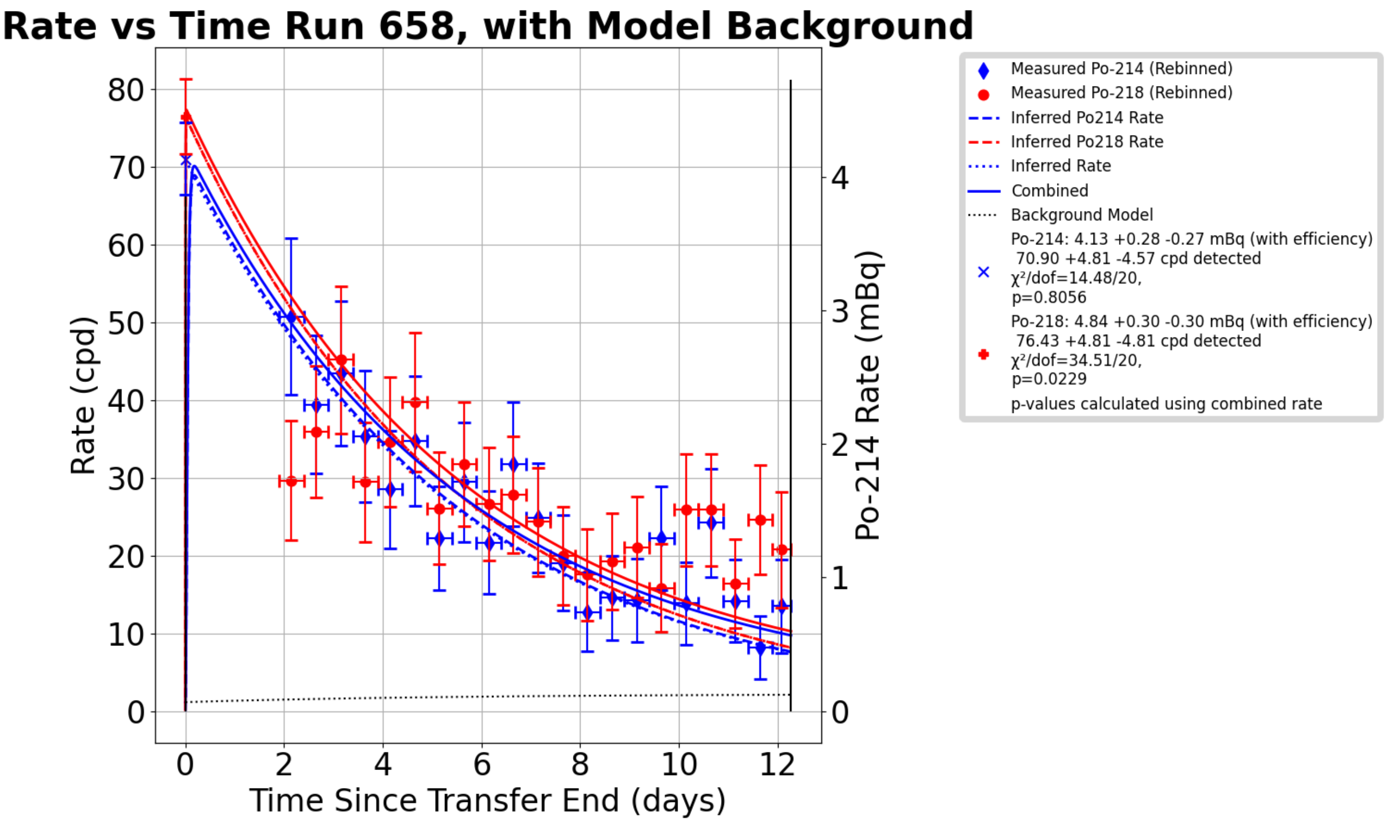
- Emanation Rate for Run 652:
  - **3.64 ± 0.25 mBq**, based on the ^{214}Po rate
  - The sole ^{214}Po sample rate was chosen rather than a weighted average of ^{218}Po and ^{214}Po due to poor resolution between the ^{210}Po and ^{218}Po ROIs, which likely led to a number of ^{210}Po events being counted as ^{218}Po events

Emanation Rate, Run 656 (1 Gasket) 2021-02-23 → 2021-02-25



- Emanation Rate for Run 656:
  - **5.40 ± 0.30 mBq**, based on the ^{214}Po rate
  - The sole ^{214}Po sample rate was chosen rather than a weighted average of ^{218}Po and ^{214}Po due to poor resolution between the ^{210}Po and ^{218}Po ROIs, which likely led to a number of ^{210}Po events being counted as ^{218}Po events

Emanation Rate, Run 658 (1 Gasket) 2021-03-19 → 2021-03-30

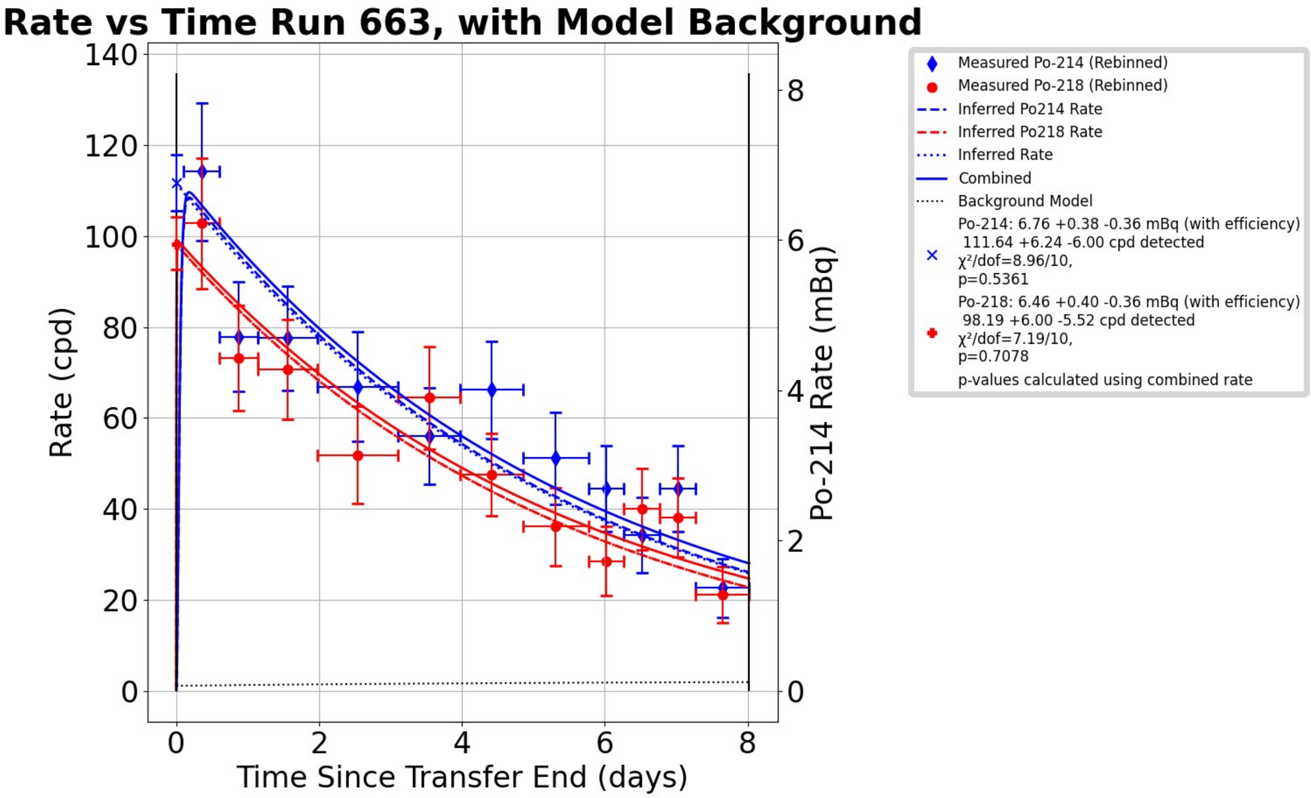


- Emanation Rate for Run 658:
  - **4.13 ± 0.28 mBq**, based on the ^{214}Po rate
  - The sole ^{214}Po sample rate was chosen rather than a weighted average of ^{218}Po and ^{214}Po due to poor resolution between the ^{210}Po and ^{218}Po ROIs, which likely led to a number of ^{210}Po events being counted as ^{218}Po events

Single Gasket Emanation Summary

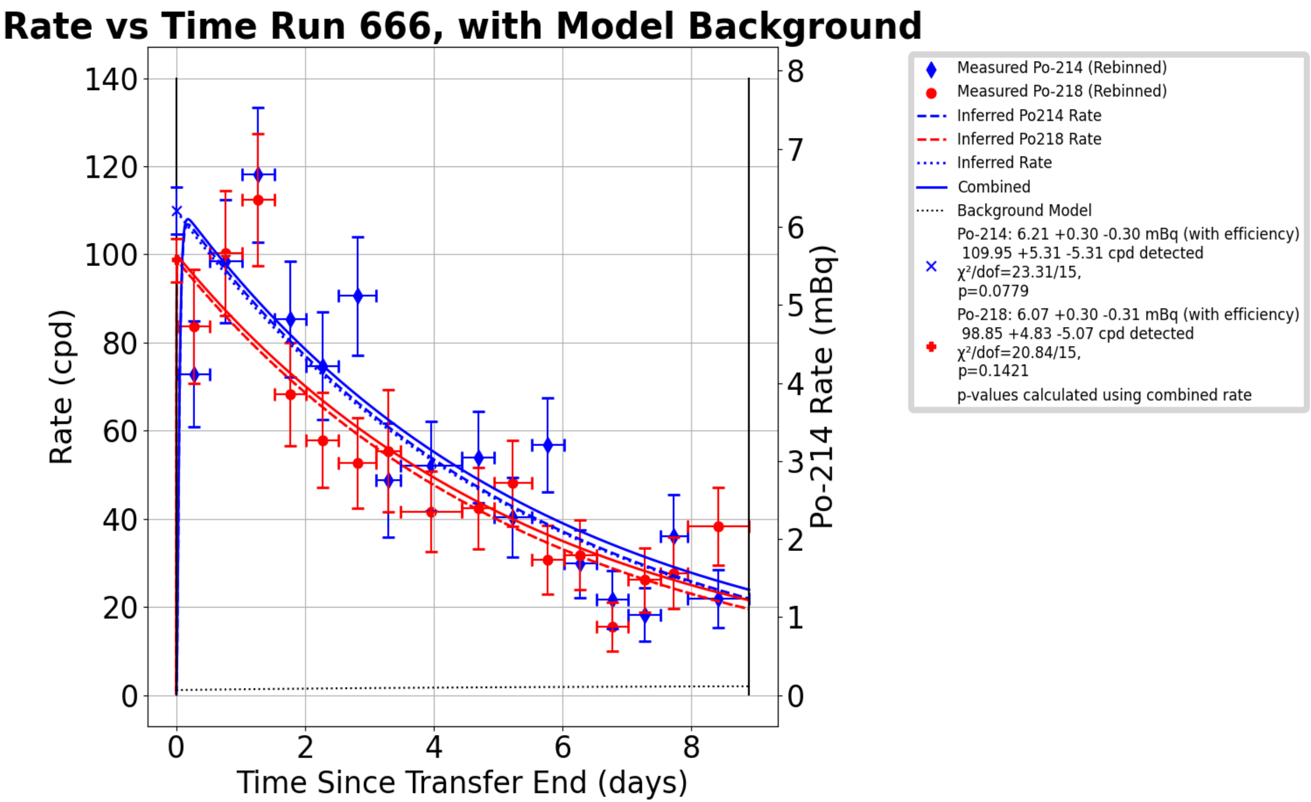
- Single Silicone Gasket was emanated four times throughout February and March 2021
  - Single Silicone Gasket Emanation Rate: **4.30 ± 0.74 mBq**
- Run 660 was excluded from the analysis
  - Run 660 exhibited a level of gain variance too extreme to correct
  - No useful data could be acquired from this run
- This measurement is 11 σ higher than the predicted 2.40 ± 0.06 mBq
  - This indicates that the gaskets were not equally “hot”
- These are at SD Mines

Emanation Rate, Run 663 (2 Gaskets) 2021-04-29 → 2021-05-18



- Emanation Rate for Run 663:
  - **6.76 ± 0.37 mBq**, based on the ^{214}Po rate
  - The sole ^{214}Po sample rate was chosen rather than a weighted average of ^{218}Po and ^{214}Po due to poor resolution between the ^{210}Po and ^{218}Po ROIs, which likely led to a number of ^{210}Po events being counted as ^{218}Po events

Emanation Rate, Run 666 (2 Gaskets) 2021-05-18 → 2021-06-15

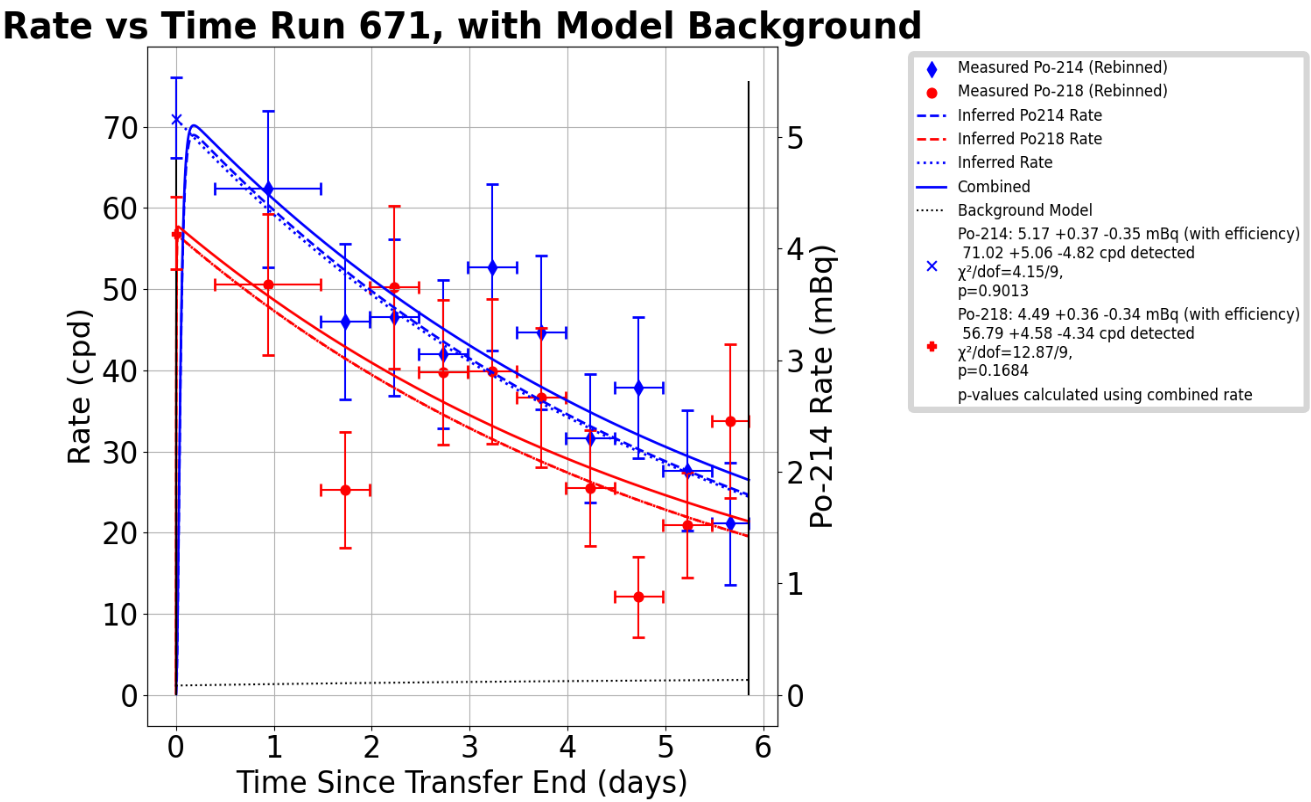


- Emanation Rate for Run 666:
- **6.21 ± 0.30 mBq**, based on the ^{214}Po rate
- The sole ^{214}Po sample rate was chosen rather than a weighted average of ^{218}Po and ^{214}Po due to poor resolution between the ^{210}Po and ^{218}Po ROIs, which likely led to a number of ^{210}Po events being counted as ^{218}Po events

Two Gaskets Emanation Summary

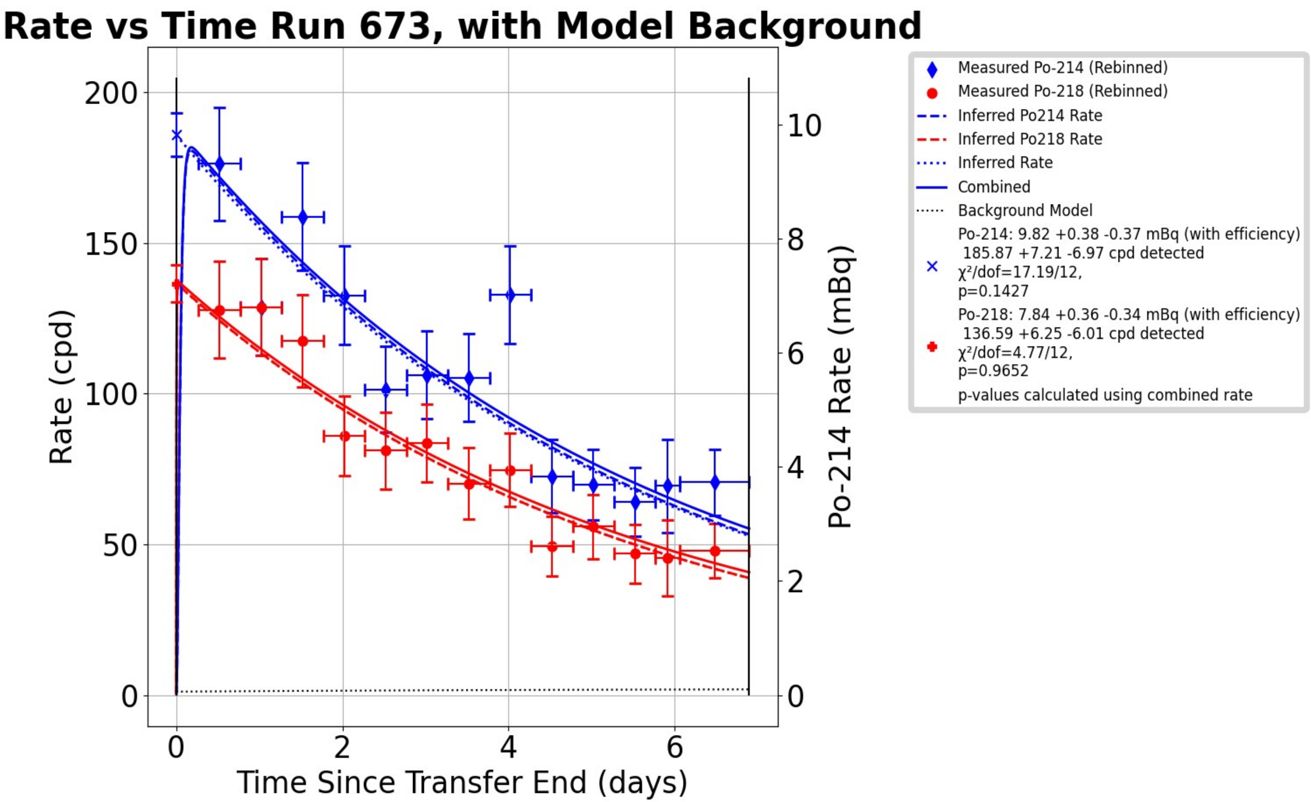
- Two Silicone Gaskets were emanated two times From April to June 2021
  - Two silicone gaskets emanation rate: **6.43 ± 0.23 mBq**
  - Inferred single gasket emanation rate: **3.21 ± 0.12 mBq**
- This measurement is 6 σ higher than the predicted 2.40 ± 0.06 mBq
  - This indicates that the ten gaskets were not equally “hot”
- These are currently at SD Mines

Emanation Rate, Run 671 (3 Gaskets) 2021-07-29 → 2021-08-06



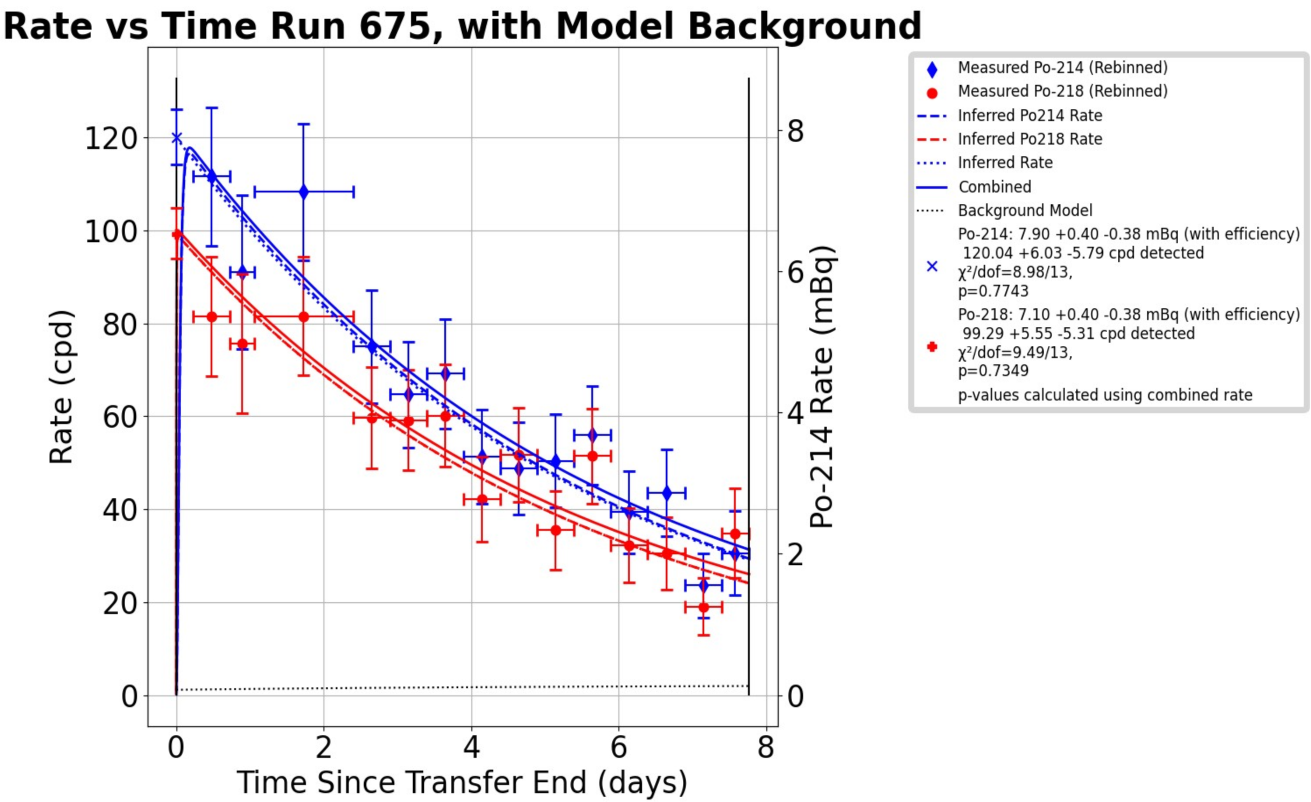
- Emanation Rate for Run 671:
  - **5.17 ± 0.36 mBq**, based on the ^{214}Po rate
  - The sole ^{214}Po sample rate was chosen rather than a weighted average of ^{218}Po and ^{214}Po due to poor resolution between the ^{210}Po and ^{218}Po ROIs, which likely led to a number of ^{210}Po events being counted as ^{218}Po events

Emanation Rate, Run 673 (3 Gaskets) 2021-08-06 → 2021-08-20



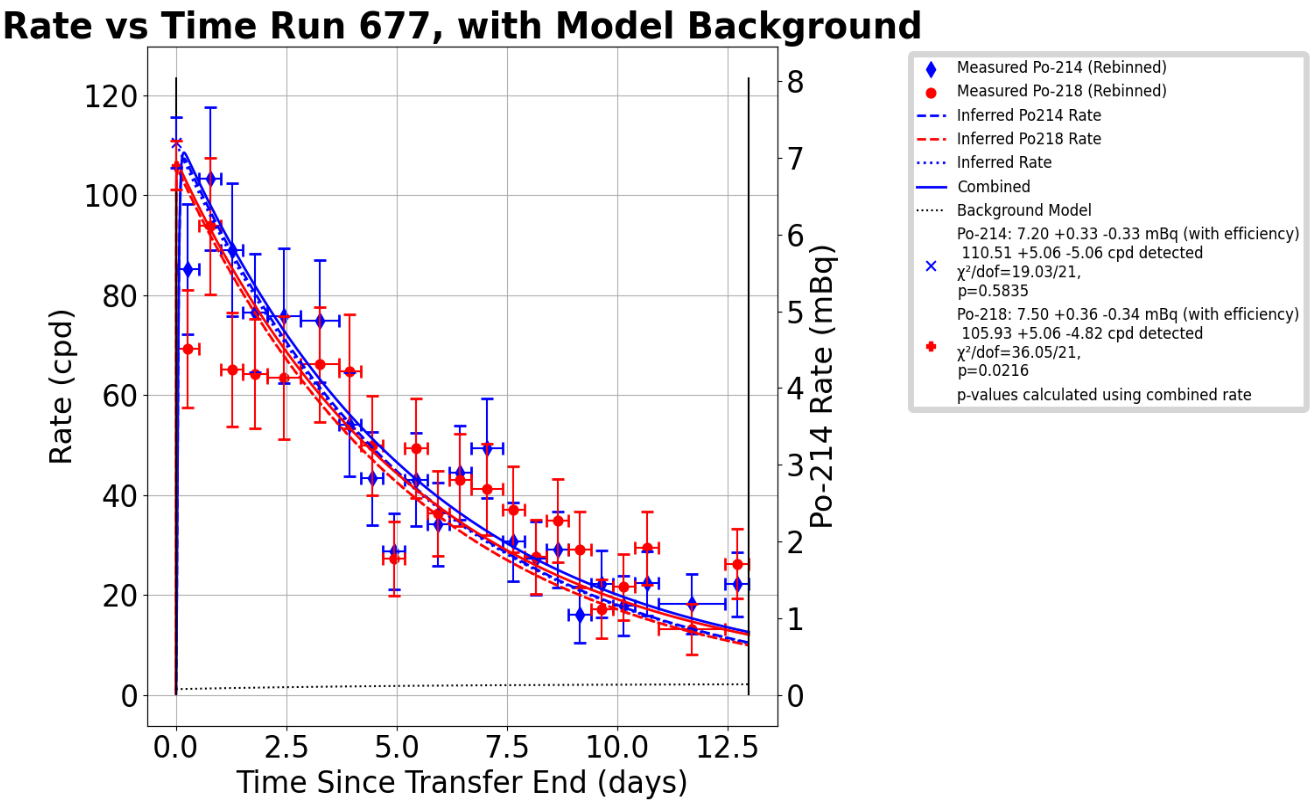
- Emanation Rate for Run 673:
  - **8.76 ± 0.26 mBq**, based on the ^{214}Po rate
  - This was based on a weighted average of the ^{214}Po and ^{218}Po rates.

Emanation Rate, Run 675 (3 Gaskets) 2021-08-20 → 2021-09-01



- Emanation Rate for Run 675:
  - **7.90 ± 0.39 mBq**, based on the ^{214}Po rate
  - The sole ^{214}Po sample rate was chosen rather than a weighted average of ^{218}Po and ^{214}Po due to poor resolution between the ^{210}Po and ^{218}Po ROIs, which likely led to a number of ^{210}Po events being counted as ^{218}Po events

Emanation Rate, Run 677 (3 Gaskets) 2021-09-01 → 2021-09-17



- Emanation Rate for Run 677:
  - **7.20 ± 0.33 mBq**, based on the ^{214}Po rate
  - The sole ^{214}Po sample rate was chosen rather than a weighted average of ^{218}Po and ^{214}Po due to poor resolution between the ^{210}Po and ^{218}Po ROIs, which likely led to a number of ^{210}Po events being counted as ^{218}Po events

Three Gaskets Emanation Summary

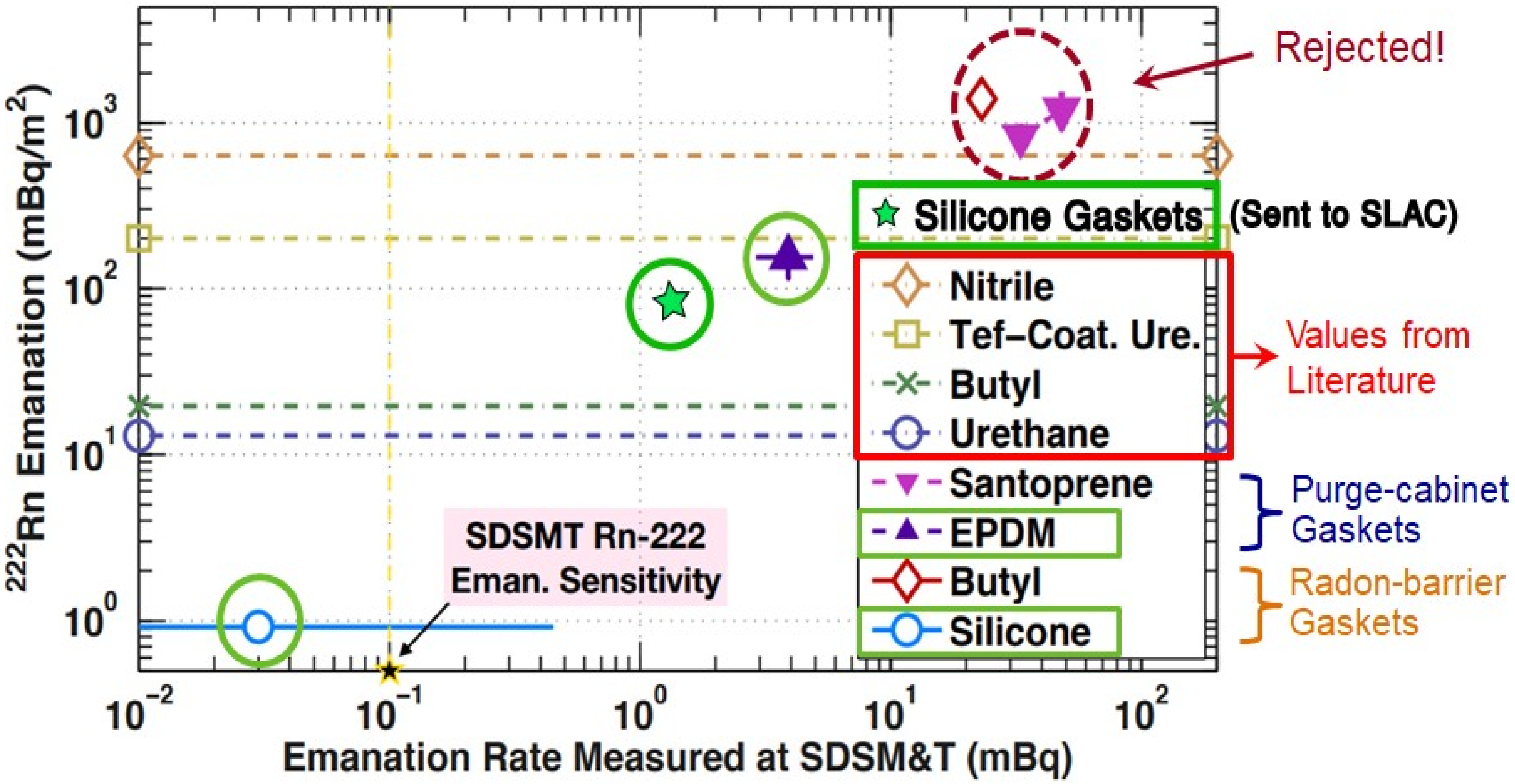
- Three Silicone Gaskets were emanated four times From July to September 2021
  - Three silicone gaskets emanation rate: **7.51 ± 1.33 mBq**
  - Inferred single gasket emanation rate: **2.50 ± 0.44 mBq**
- This measurement is within 2 σ of the predicted 2.40 ± 0.06 mBq
  - This doesn’t indicate that the ten gaskets were equally “hot”
- These gaskets are currently at SD Mines

Current Emanation Summary

- Total emanation of 6 gaskets: **18.24 ± 0.74 mBq**
  - This indicates that the four gaskets sent to SLAC had a total emanation rate: **5.75 ± 1.16 mBq**
    - And an estimated single emanation rate: **1.44 ± 0.22 mBq**
    - This estimation is based off of the assumption that all gaskets are equally “hot”, which we know to be untrue. However, this assumption is the only way we can estimate the emanation rate per gasket

Batch	Measured Rate	Rate/Gasket	Rate/m^2
Ten Gaskets	23.99 ± 0.60 mBq	2.40 ± 0.06 mBq	132.38 ± 3.31 mBq/m^2
Four Gaskets (SLAC)	5.75 ± 1.16 mBq	1.44 ± 0.22 mBq	79.43 ± 12.13 mBq/m^2
Single Gasket (SD Mines)	4.30 ± 0.16 mBq	4.30 ± 0.16 mBq	237.18 ± 8.83 mBq/m^2
Two Gaskets (SD Mines)	6.42 ± 0.23 mBq	3.21 ± 0.12 mBq	177.05 ± 6.62 mBq/m^2
Three Gasket (SD Mines)	7.51 ± 0.16 mBq	2.50 ± 0.05 mBq	137.89 ± 2.76 mBq/m^2

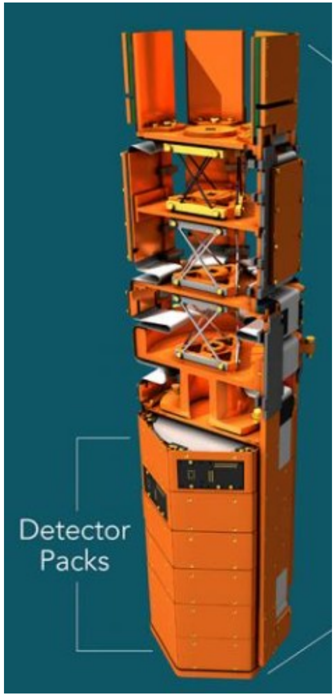
Emanation of Various Materials



Sample Considerations

- In 2020, Nic Chott measured the dimensions of a single silicone gasket with calipers
  - Single gasket suface area measured to be **181.3 cm^2**
    - Width of gasket measured to be 0.400”, which agrees with dimensions given by vendor (7.78” inner diam. And 8.57” outer diam.)

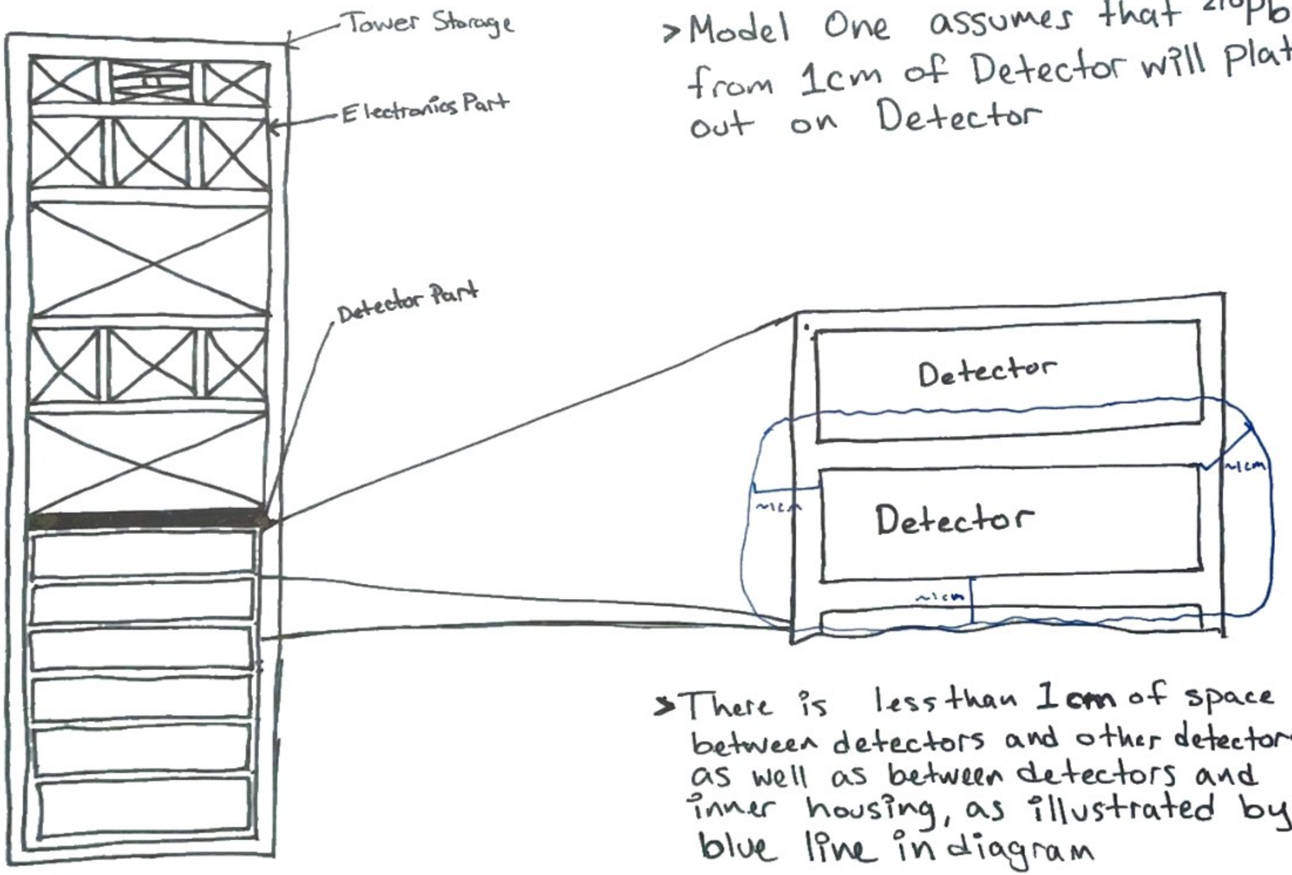
^{210}Pb Background Estimation Overview



- This is an illustration of one of the SuperCDMS Towers. The Storage Container is a cylinder that fits around the tower.
  - Model 1 assumes that all ^{222}Rn within 1cm of the detector surface will deposit ^{210}Pb onto the detector
    - This is a conservative overestimate
  - Model 2 assumes that the ^{210}Pb will plate out evenly across all surfaces.
    - This is likely the most conservative estimate
  - Model 3 assumes that only the ^{222}Rn near the detectors will plate out ^{210}Pb onto the detector, and it will plate out proportionally to all surfaces in that area
    - This is likely the most accurate estimate

Batch	Eman. Rate	Model 1	Model 2	Model 3
Single Gasket	1.44 ± 0.22 mBq	1.25 ± 0.19 nBq/cm^{2}yr	2.45 ± 0.37 nBq/cm^{2}yr	0.32 ± 0.05 nBq/cm^{2}yr

^{210}Pb Plate-Out Background Estimation, Model One



- Model One assumes that ^{210}Pb from 1cm of Detector will plate out on Detector
- There is less than 1 cm of space between detectors and other detectors, as well as between detectors and inner housing, as illustrated by blue line in diagram
- Thus, Model 1 is a conservative overestimate

^{210}Pb Background Estimation, Model One

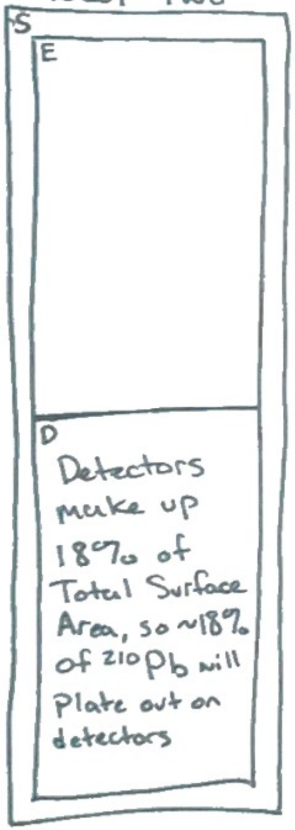
- **Model One: Plate-Out Height**
  - Approximate ^{222}Rn concentration inside storage container based on internal volume and ^{222}Rn level
  - Estimate amount of ^{210}Pb using an effective plate-out height
    - Estimated Internal Volume: ~0.017m^3 (conservative overestimate)
    - Assume a 1cm plate-out height (conservative overestimate)

^{210}Pb = (^{222}Rn Emanation Rate from Gasket) * (Plate-Out Height) / [(^{210}Pb Mean-Life) * (Volume of Storage Container)] = nBq/cm^2 of ^{210}Pb per year of storage

^{210}Pb Plate-Out Estimation, Model 1: 1.25 ± 0.19 nBq/cm^2 per year of storage

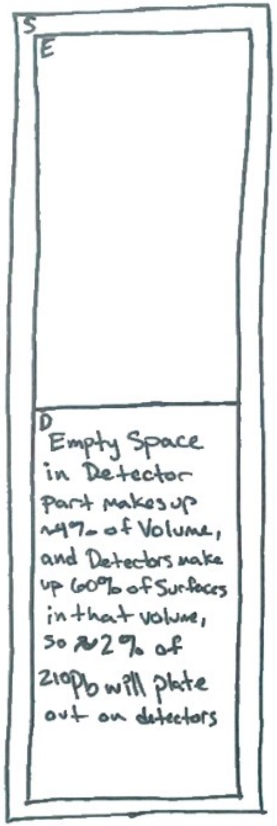
^{210}Pb Plate-Out Background Estimation, Models 2 & 3

Model Two



Model 2 assumes ^{210}Pb will Plate out Evenly on all Surfaces.

This is a conservative overestimate.



Model 3 assumes ^{210}Pb will plate out proportionally to Volume, on the surfaces it has access to.

This is likely the most accurate estimation

^{210}Pb Background Estimation, Model Two

- **Model Two: Plate-Out Fraction**
  - Model one is likely not accurate for SuperCDMS purposes
  - A better approach: estimate fractional surface area represented by detector surfaces
  - Assume that ^{222}Rn decays will plate-out ^{210}Pb evenly across all surfaces
    - Detector Surfaces make up approximately 3% of the surface area (Conservative Overestimate)

^{210}Pb = (^{222}Rn Decay Rate from Gasket) * (Plate-Out Fraction) / [(Detector Surface Area) * (^{210}Pb Mean-Life)] = nBq/cm^2 of ^{210}Pb per year of storage

^{210}Pb Plate-Out Estimation, Model 2: 2.45 ± 0.37 nBq/cm^2 per year of storage

^{210}Pb Background Estimation, Model Three

- **Model Three: Plate-Out Fraction (Better)**
  - This is a combination of Model One and Two
  - Plate-Out fraction based only on detector and inner-housing surface areas
    - Detector Surfaces make up approximately 10% of the surface area (Conservative Overestimate)
    - [(Housing Inner Volume) – (6 * (Detector Volume))] / (Total Volume inside Container) = (2214-(6*259))/(17000cc) = ~3.9% of ^{222}Rn near detectors
    - (Detector Surface) / (6 * Detector Surface + Housing Inner Area) = 260/((6*260)+995) = ~10% of total available surface area for deposition

^{210}Pb = (^{222}Rn Emanation Rate from Gasket) * (Fraction of Rn near Detector) * (Plate-Out Fraction) / [(Detector Surface Area) * (^{210}Pb Mean-Life)] = nBq/cm^2 of ^{210}Pb per yr of storage

^{210}Pb Plate-Out Estimation, Model 3: 0.32 ± 0.05 nBq/cm^2 per year of storage

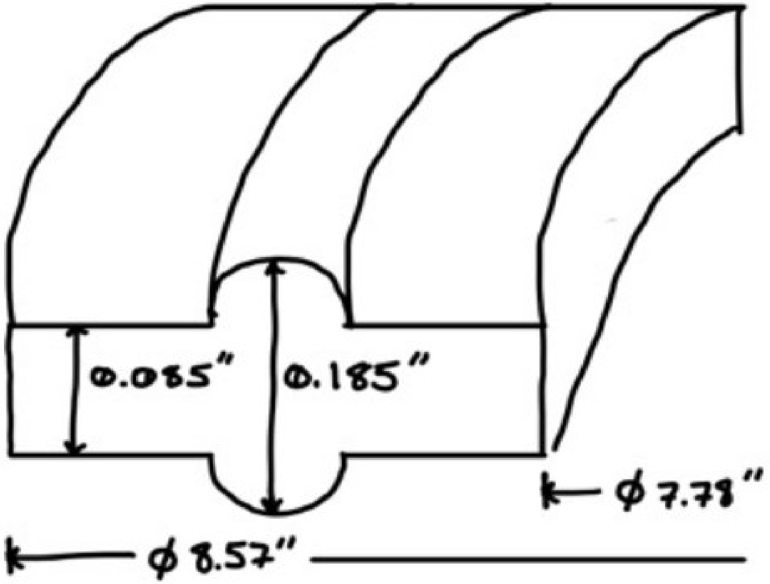
Backup Slides

Gasket Surface Area Calculation

******Calculations performed by Nic Chott in his 2022 report on the SuperCDMS Silicone Gaskets***

SuperCDMS Silicone Gasket

8" Silicone tri-clamp gasket, for SuperCDMS shipping/storage Container



Gasket width (specs)

$$\frac{8.57'' - 7.78''}{2} = \frac{0.79''}{2} \approx \frac{0.8''}{2}$$

Measured width = 0.400"

Height, gland to gland: 0.185"

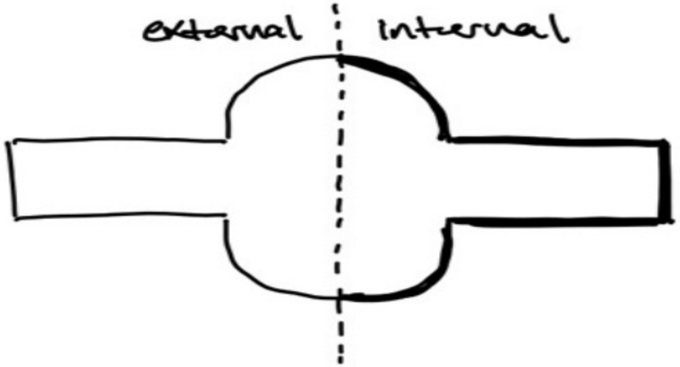
Height, w/o glands: 0.085"

top/bottom look symmetric

Gland height: 0.050"

Gasket Surface Area Calculation cont.

Gasket dimensions in 1/1000"



Gasket Sections

1. Toroid of $r = 0.050"$
   Centered @ $R = 7.78"/2 + 0.145" + 0.045" = 4.08"$
2. Ring of height $h = 0.085"$
   Centered @ $R = 7.78"/2 = 3.89"$
3. Ring of height $h = 0.085"$
   Centered @ $R = 8.57"/2 = 4.285"$
4. Ring of inner radius $R_1 = 3.89"$
   Ring of outer radius $R_2 = 3.89" + 0.145" = 4.035"$
5. Ring of inner radius $R_1 = 3.89" + 0.145 + 0.09 = 4.125"$
   Ring of outer radius $R_2 = 4.285"$

Gasket Surface Area Calculation cont.

$$A_1 = 4\pi^2 Rr = 4\pi^2(4.08'')(0.050'')(2.54\,cm/in)^2 = 51.959\ cm^2$$

$$A_2 = 2\pi Rh = 2\pi(3.89'')(0.085'')(2.54\,cm/in)^2 = 13.403\ cm^2$$

$$A_3 = 2\pi Rh = 2\pi(4.285'')(0.085'')(2.54\,cm/in)^2 = 14.764\ cm^2$$

$$A_4 = \pi(R_2^2 - R_1^2) = \pi[(4.035'')^2 - (3.89'')^2](2.54\,cm/in)^2 = 23.291\ cm^2$$

$$A_5 = \pi(R_2^2 - R_1^2) = \pi[(4.285'')^2 - (4.125'')^2](2.54\,cm/in)^2 = 27.273\ cm^2$$

Internal Surface Area:

$\frac{1}{2}A_1 + A_2 + 2A_4 = 86.0\ cm^2$

Fraction of gasket exposed to inner volume: 0.474

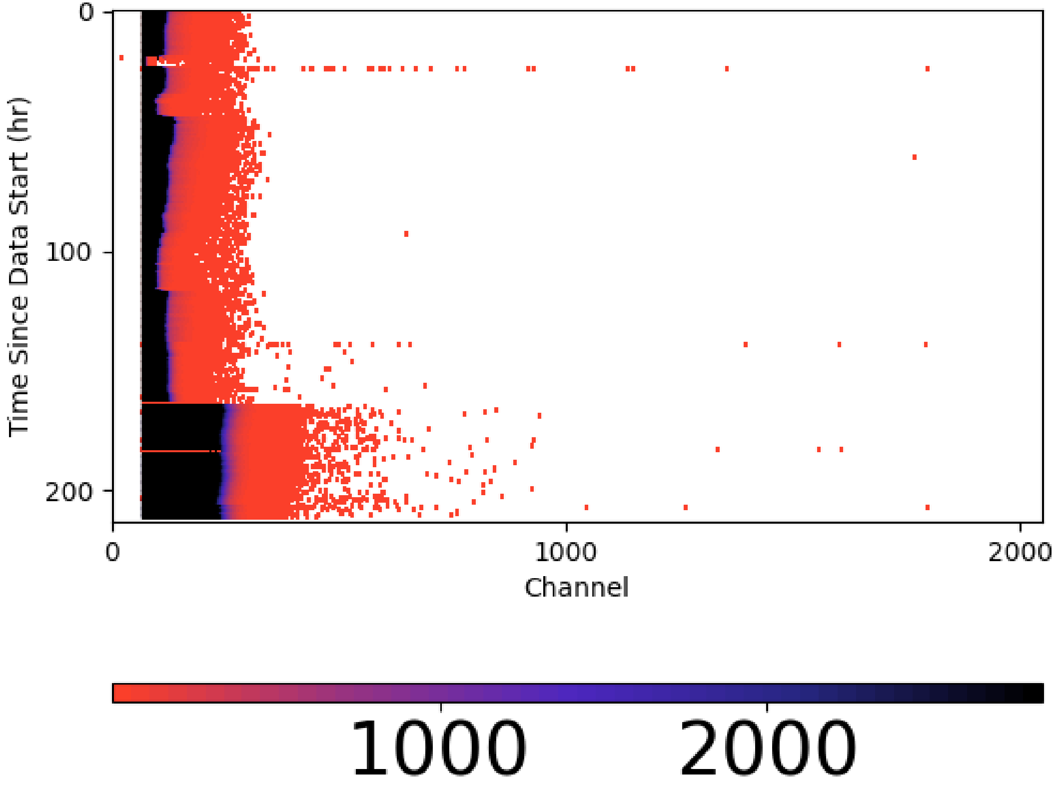
Total Surface Area:

$A_1 + A_2 + A_3 + 2A_4 + 2A_5 = 181.3\ cm^2$

Run Data Plots

Run 631 Plots

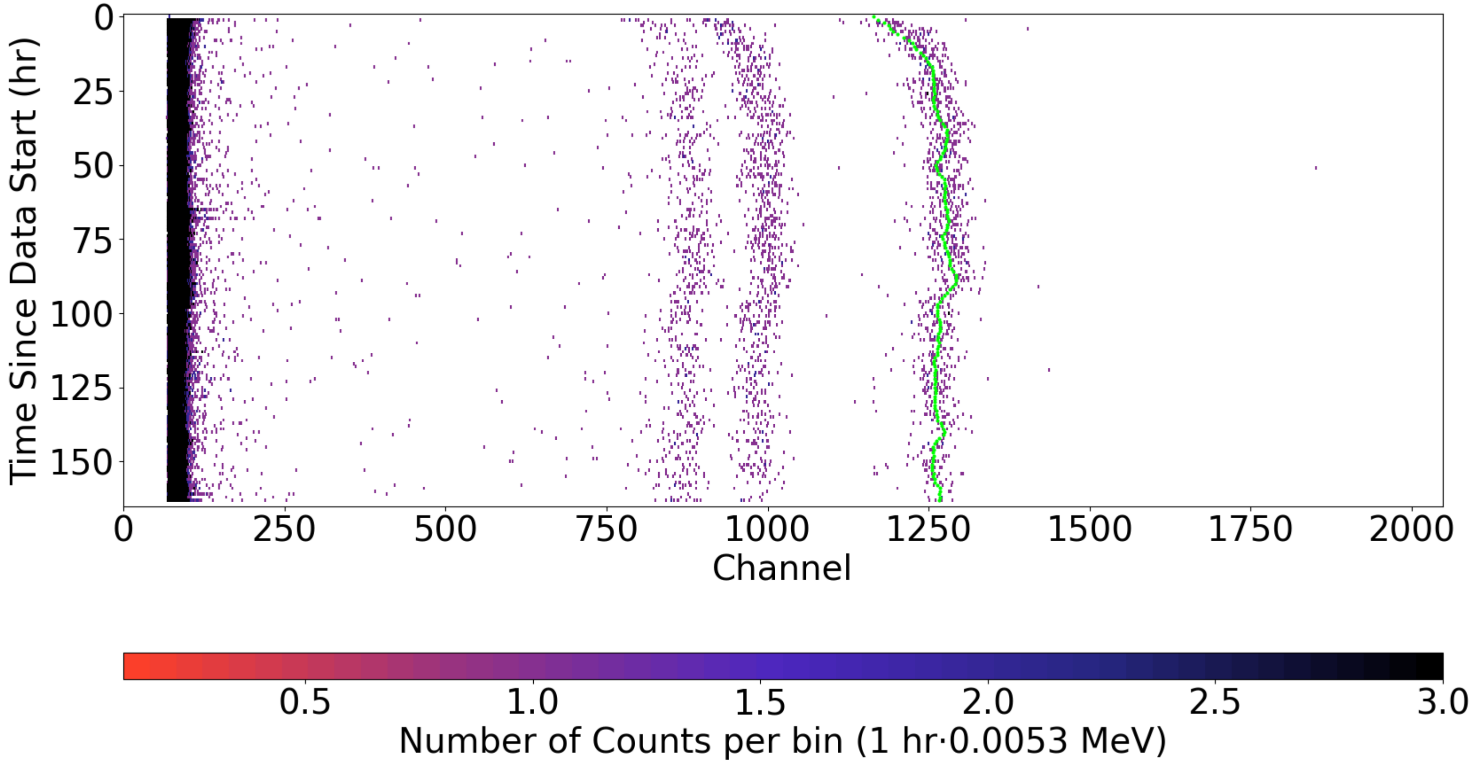
Run 631 Raw Data



- No ^{21x}Po lines are visible in the raw data
- Data is unusable for any analysis
- Nic Chott attempted to fix gain issue by rebiasing the detector and raising the gain on the amplifier
  - This did not fix the issue.
- Detector has an issue with gain variance, but usually it can be corrected for. Sometimes it affects the resolution between $^{210 \& 218}$Po peak lines.

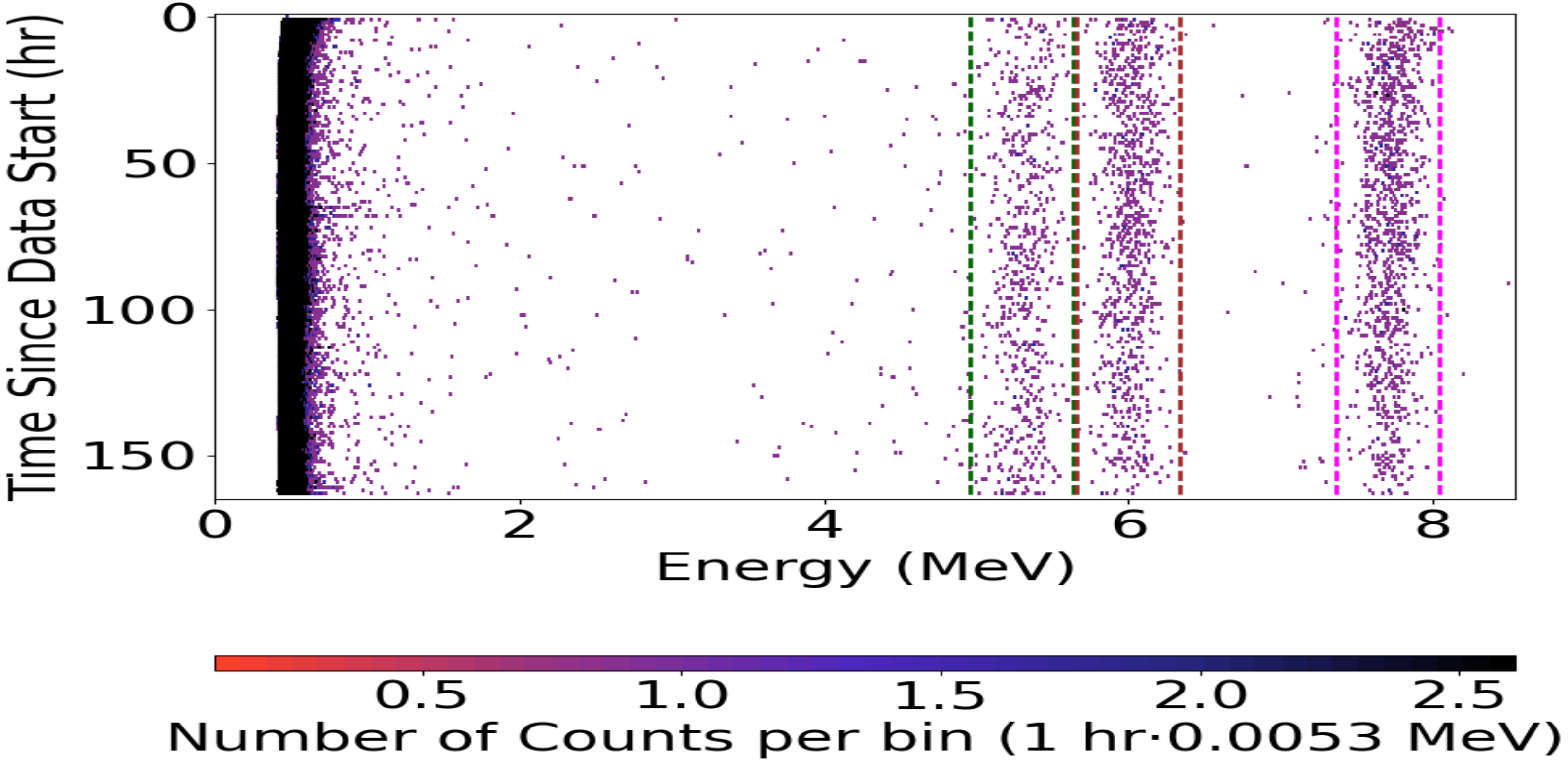
Run 634 Plots

Run 634 Raw Data



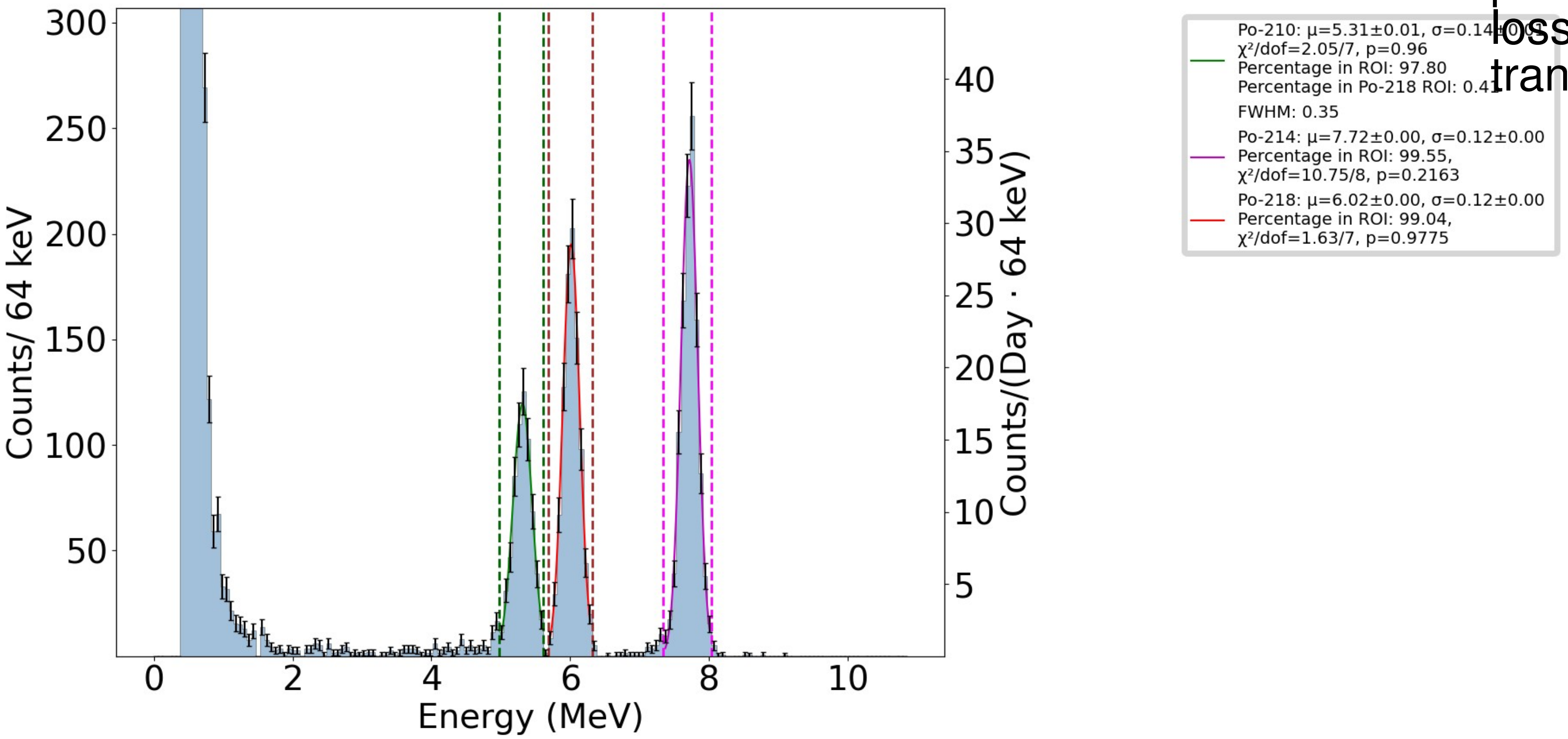
There was a partial sample loss during transfer

Run 634 Gain Corrected Data



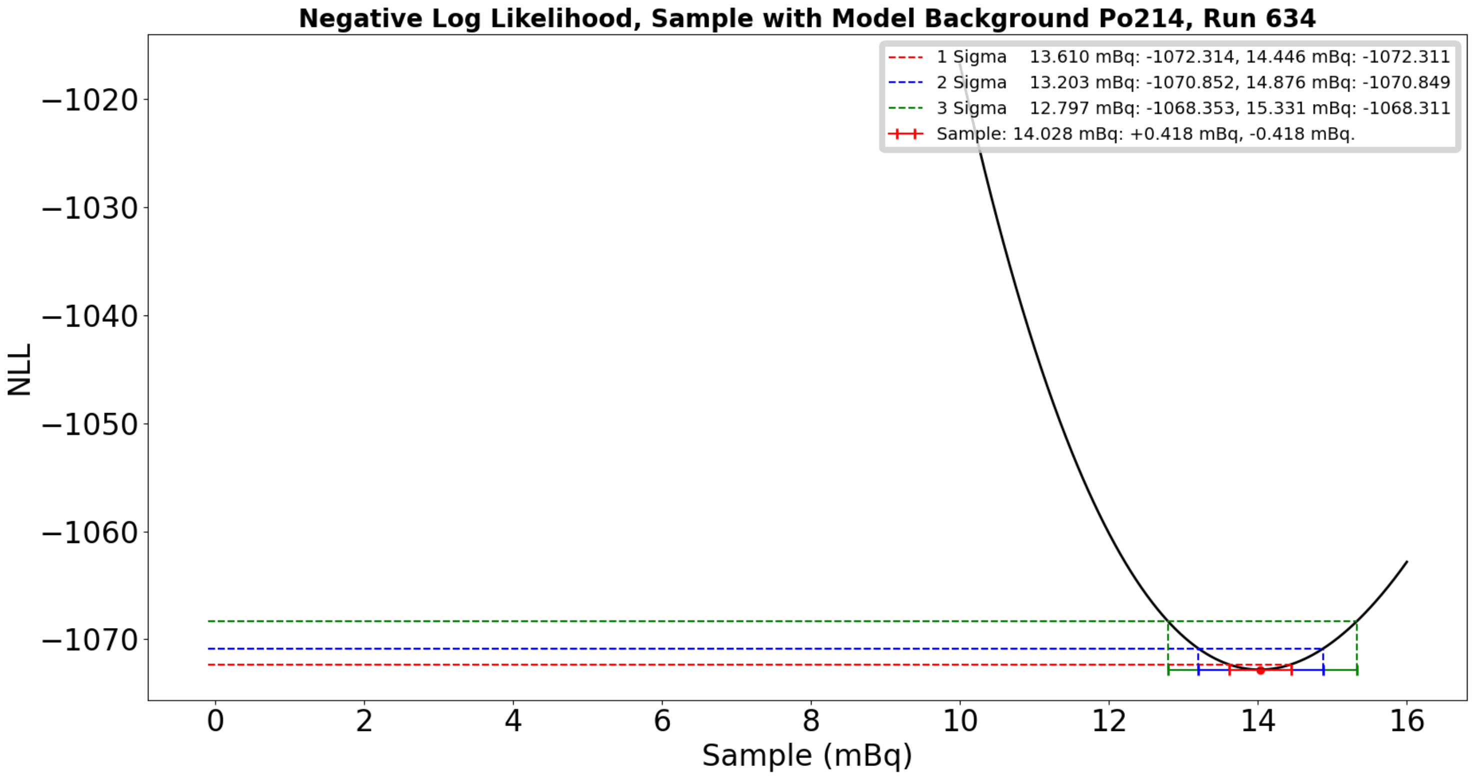
There was a partial sample loss during transfer

Run 634 Counts vs Energy



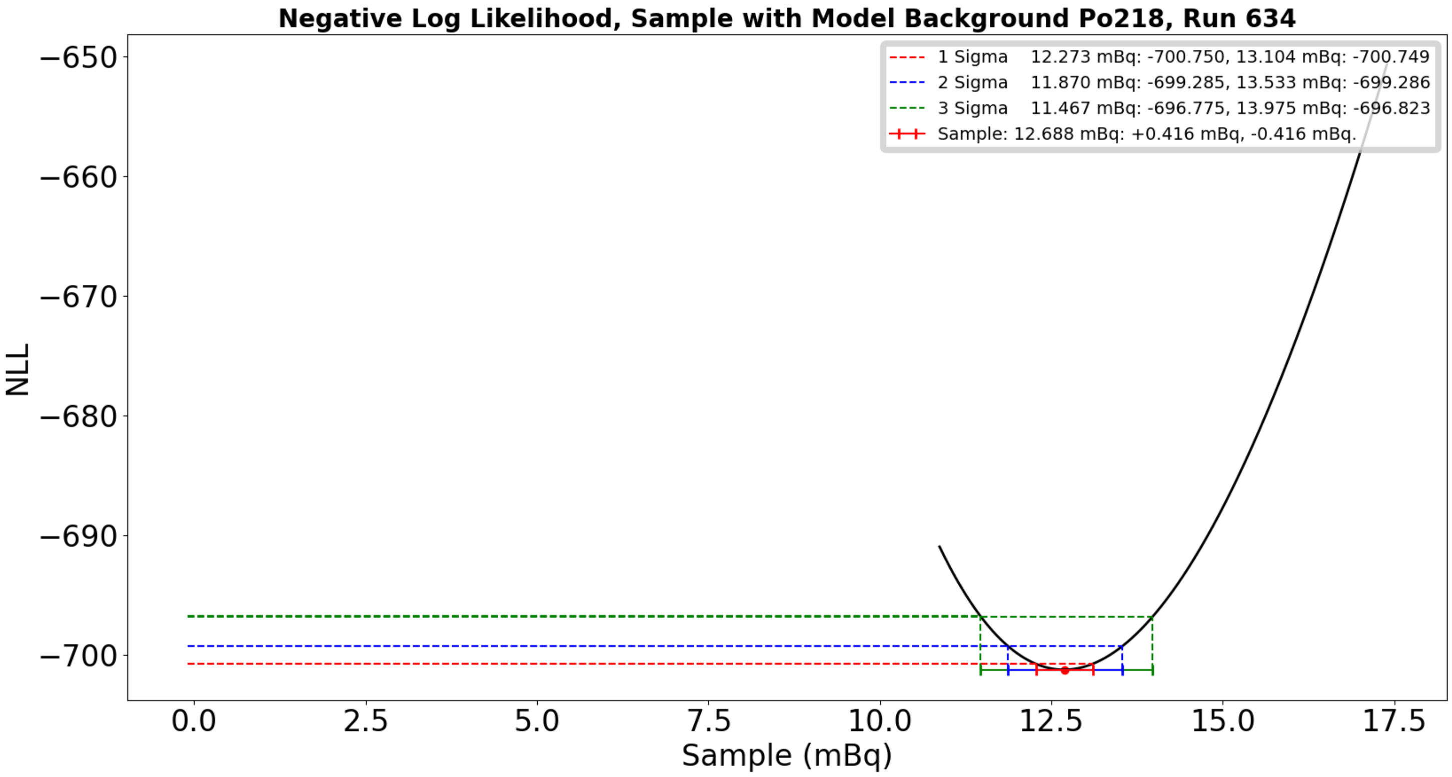
There was a partial sample loss during transfer

Run 634 Po-214 NLL



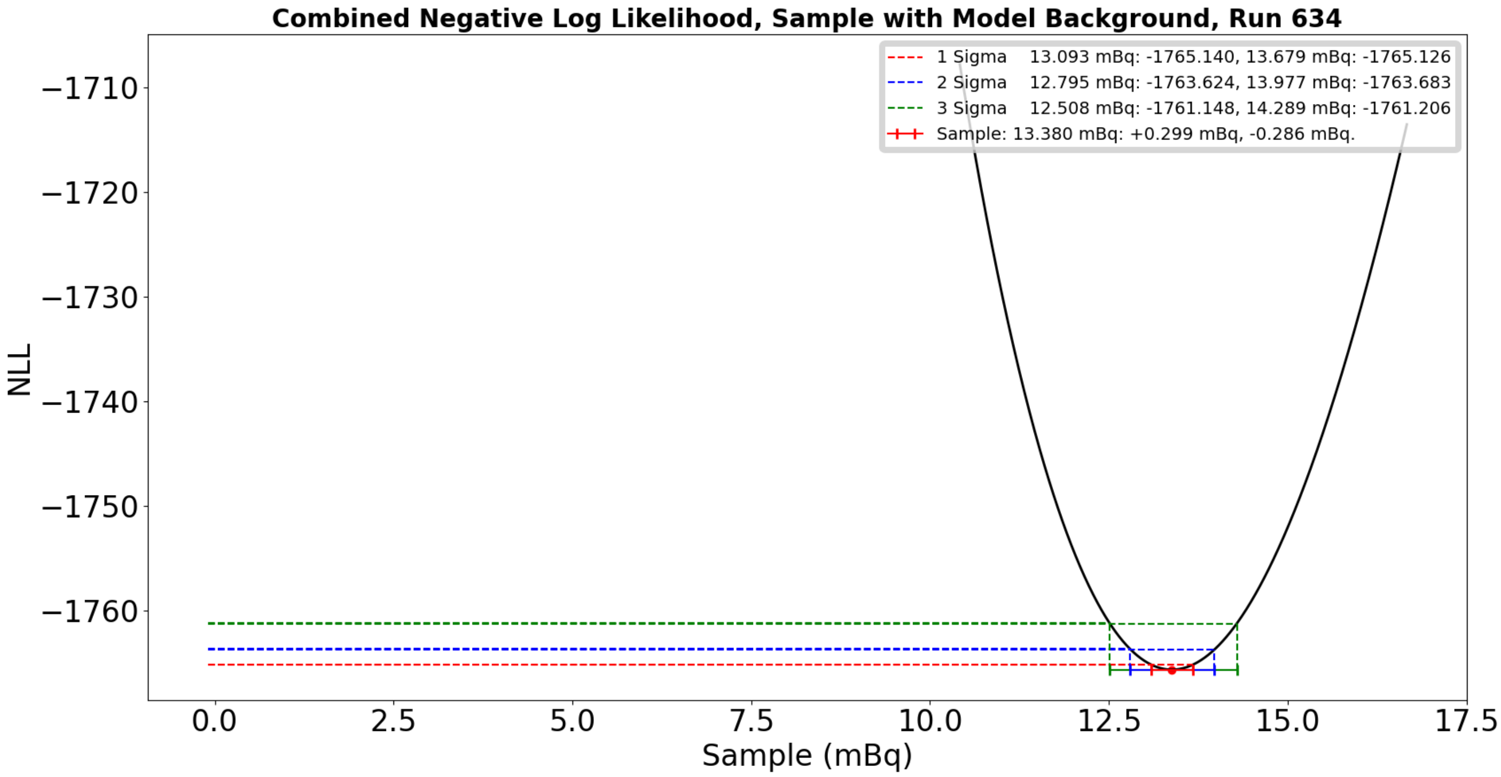
There was a partial sample loss during transfer

Run 634 Po-218 NLL



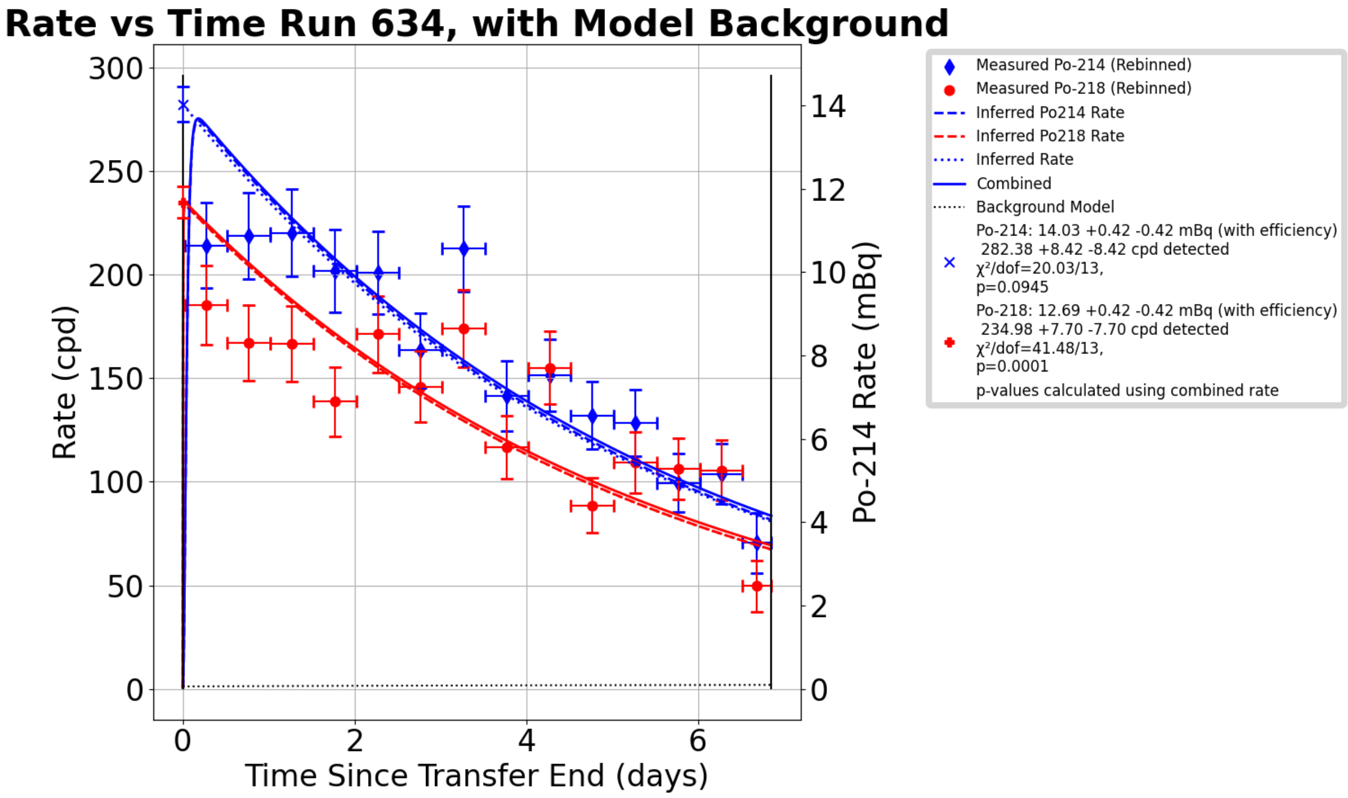
There was a partial sample loss during transfer

Run 634 Combined NLL



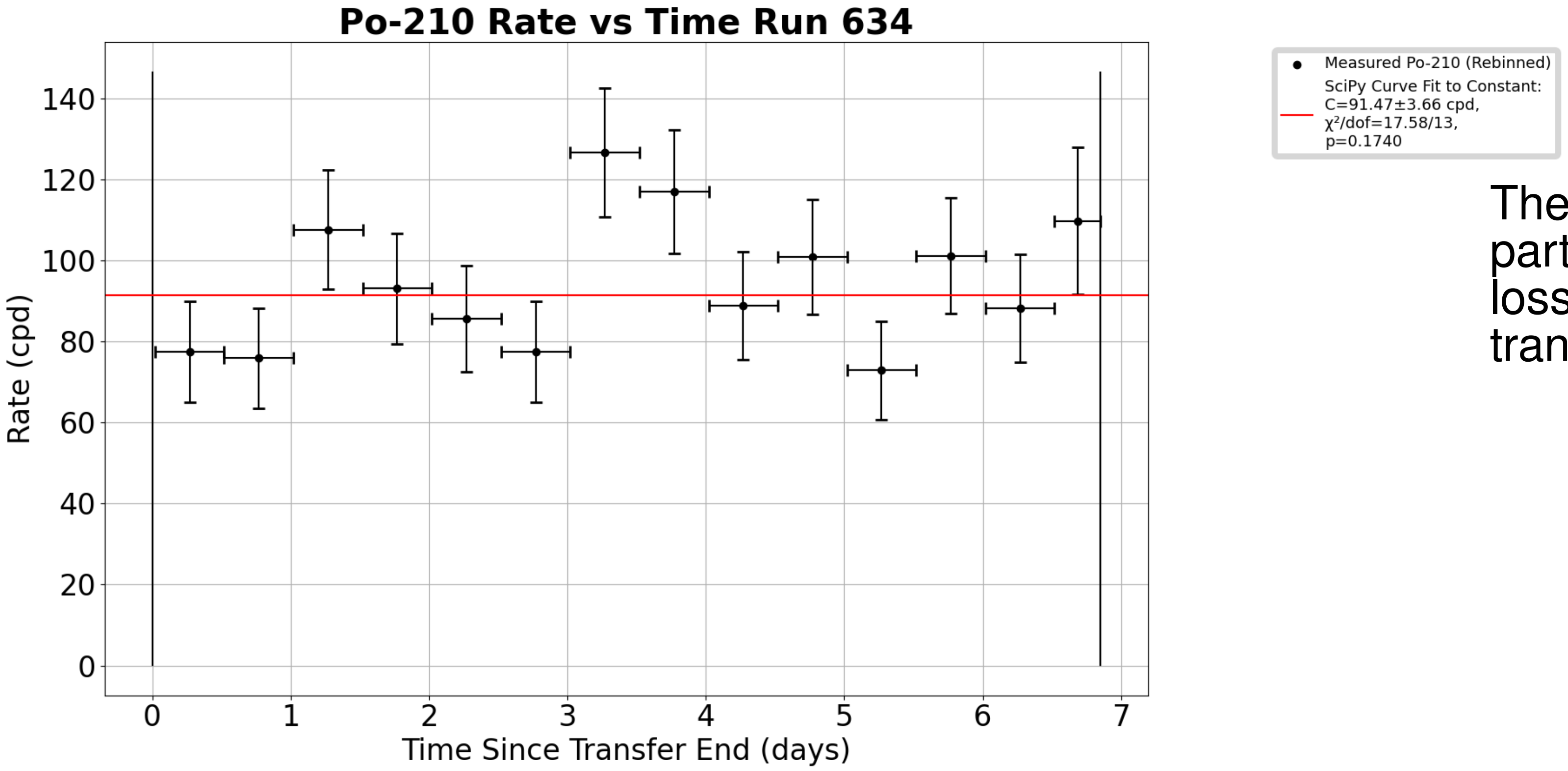
There was a partial sample loss during transfer

Emanation Rate, Run 634 (10 Gaskets) 2020-09-09 → 2020-10-02



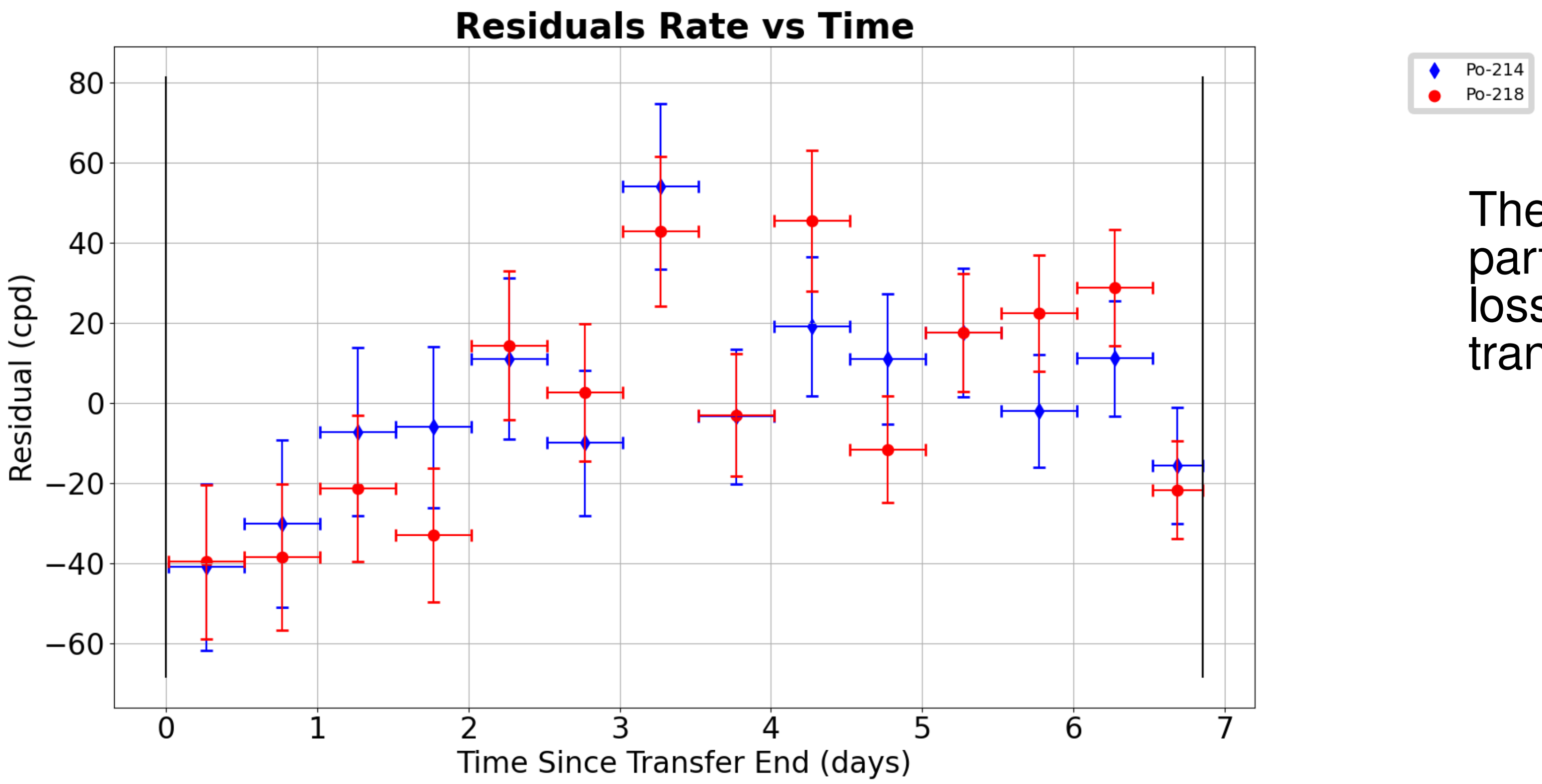
- Emanation rate for Run 634:
  - **13.36 ± 0.30 mBq** based on a weighted average of Po-218 and Po-214 rates
- It is likely that a loss of the radon sample occurred during transfer
  - Nic Chott, who performed the transfer, noted that the small Brass Wool Trap (BWT) appeared to be clogged.
  - A portion of the sample was likely lost while an attempt was made to flow through the clogged BWT, which escaped when the small BWT was isolated and unclogged.
  - Thus, Run 634 is not included in the analysis of the ten silicone gaskets.

Run 634 Po-210 Rate vs Time



There was a partial sample loss during transfer

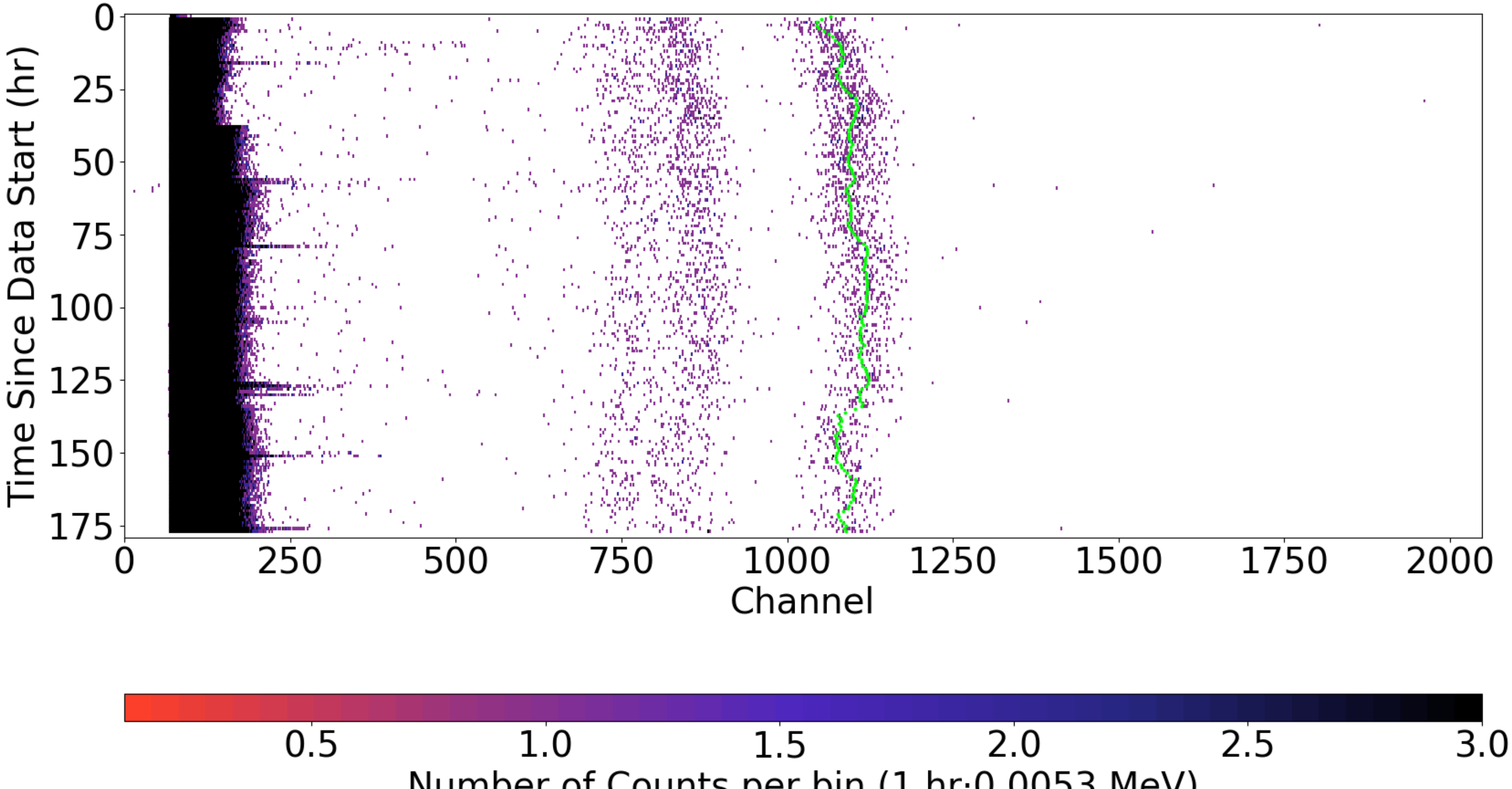
Run 634 Residuals



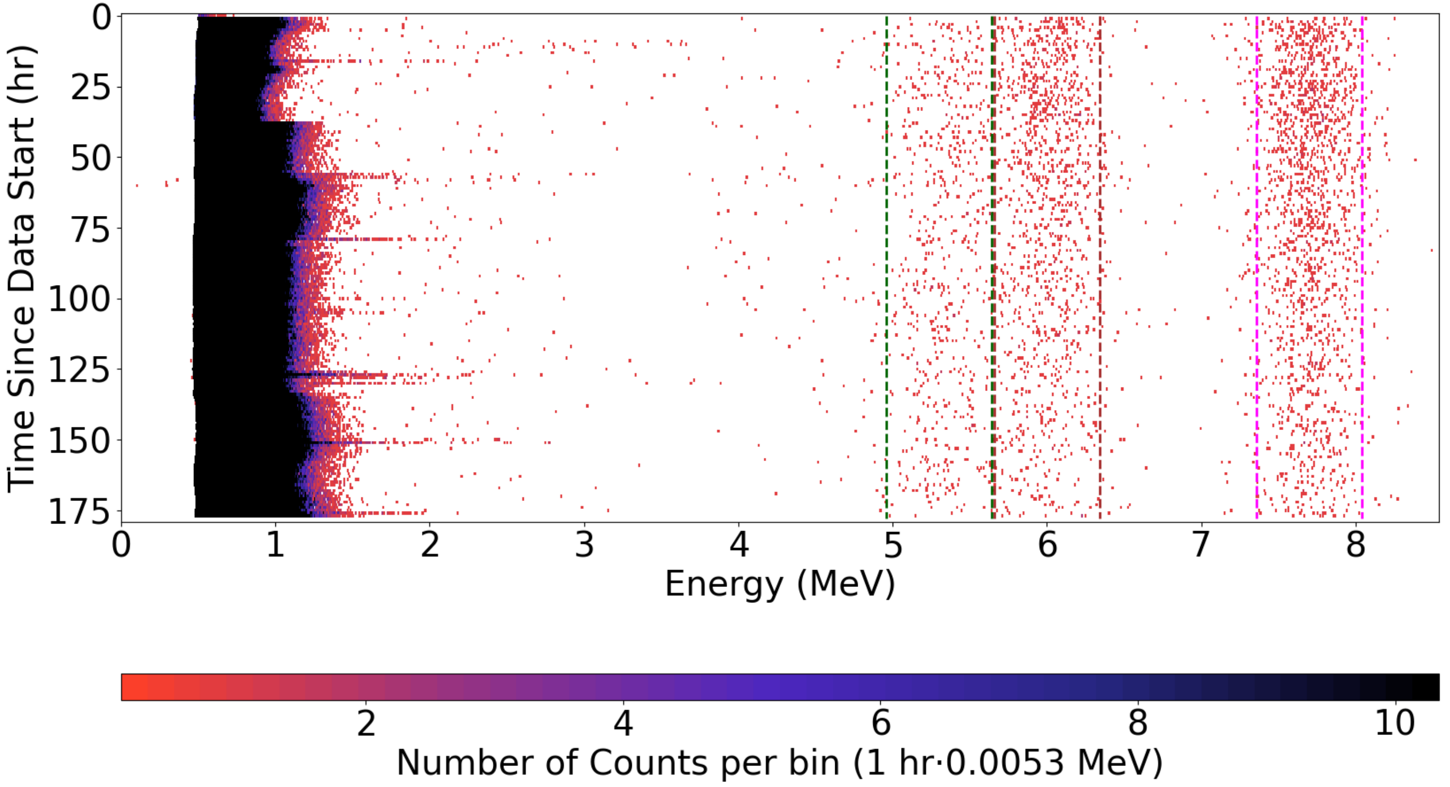
There was a partial sample loss during transfer

Run 636 Plots

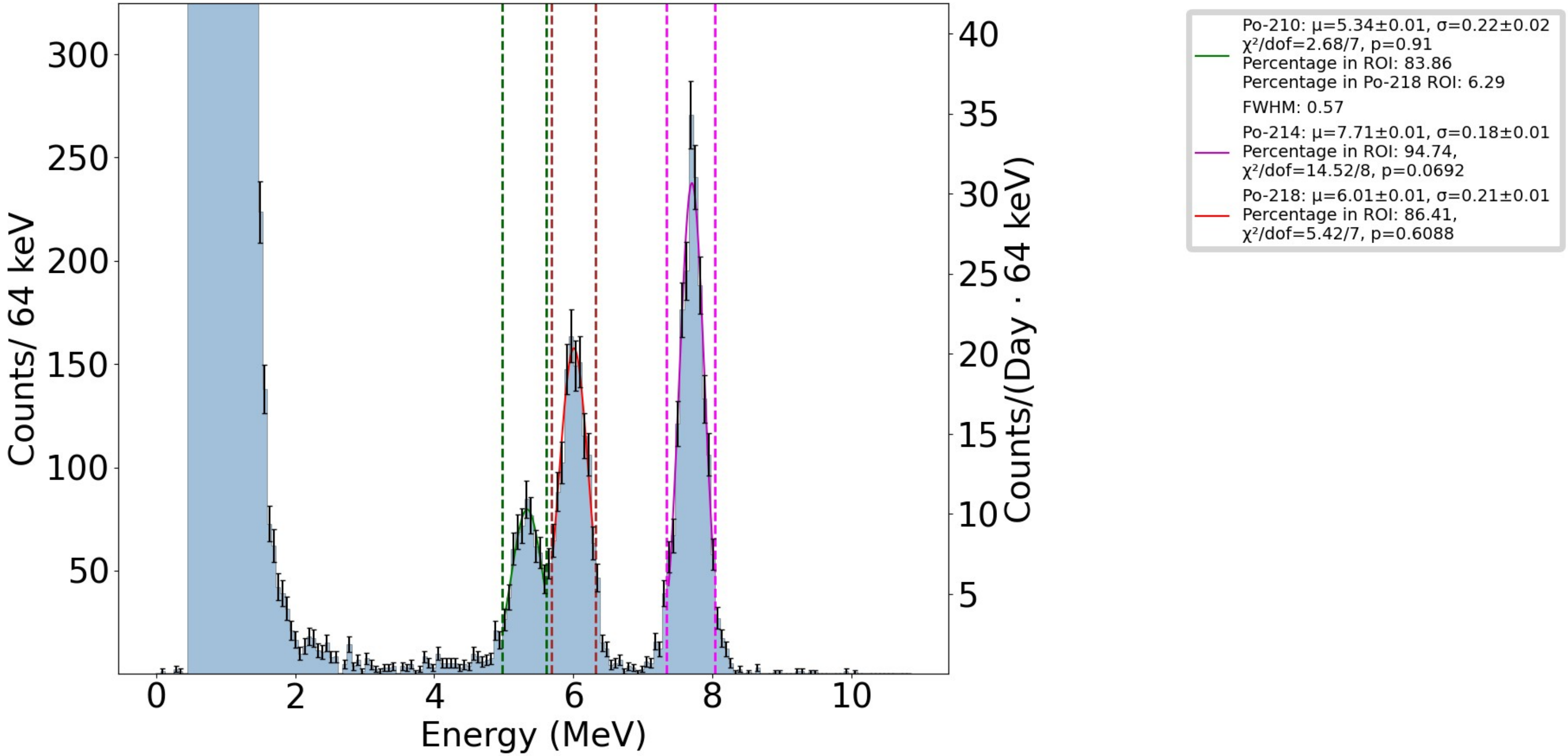
Run 636 Raw Data



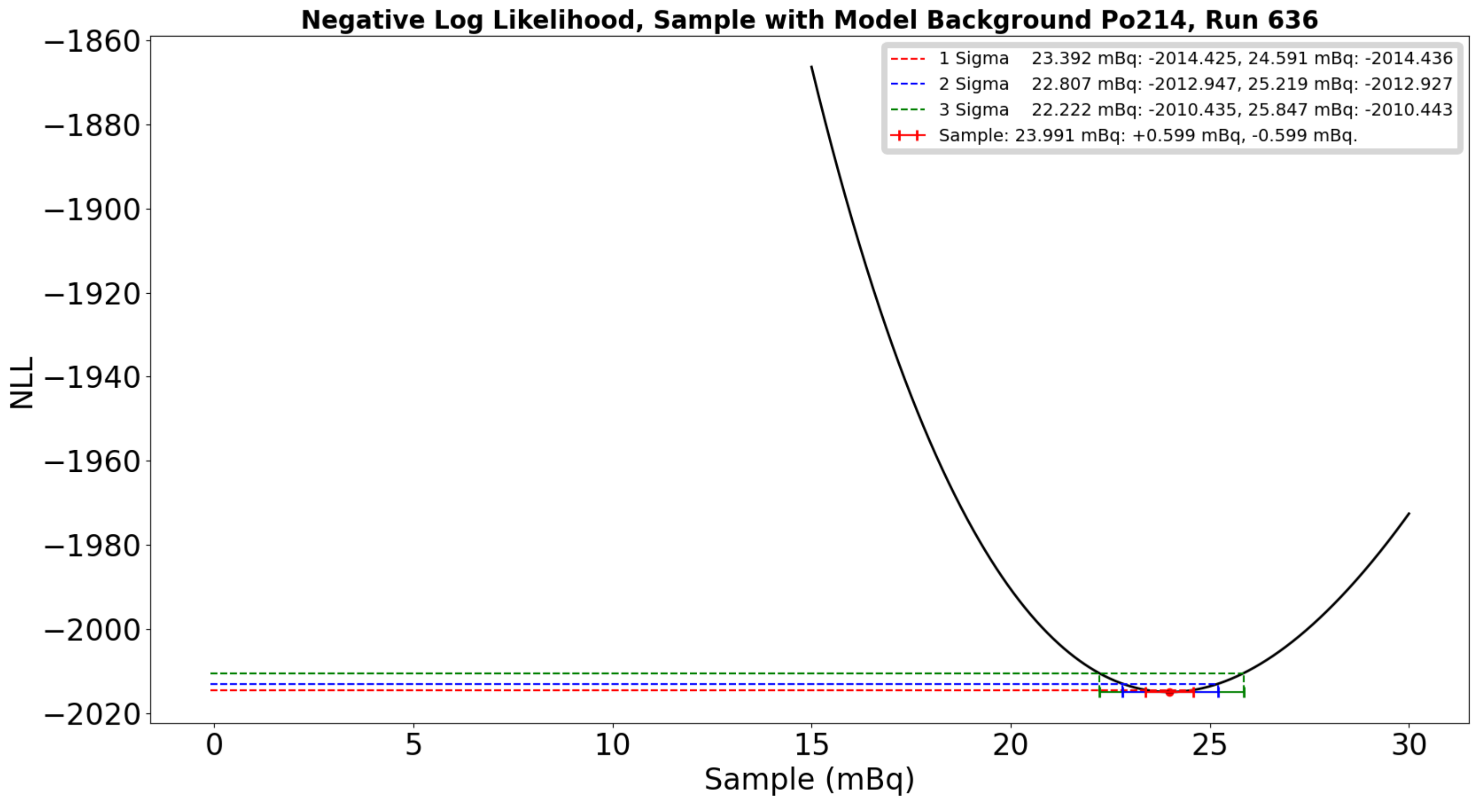
Run 636 Gain Corrected Data



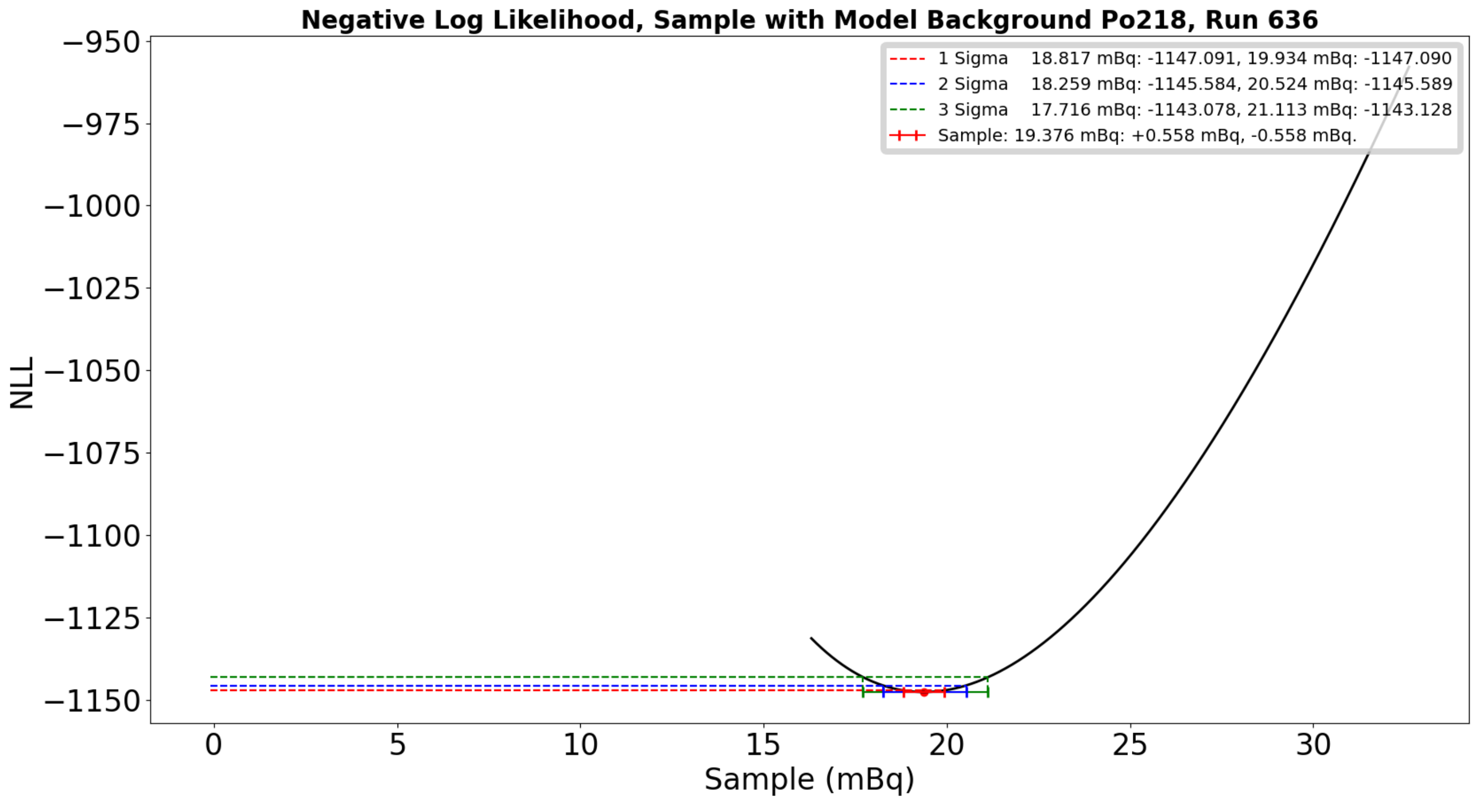
Run 636 Counts vs Energy



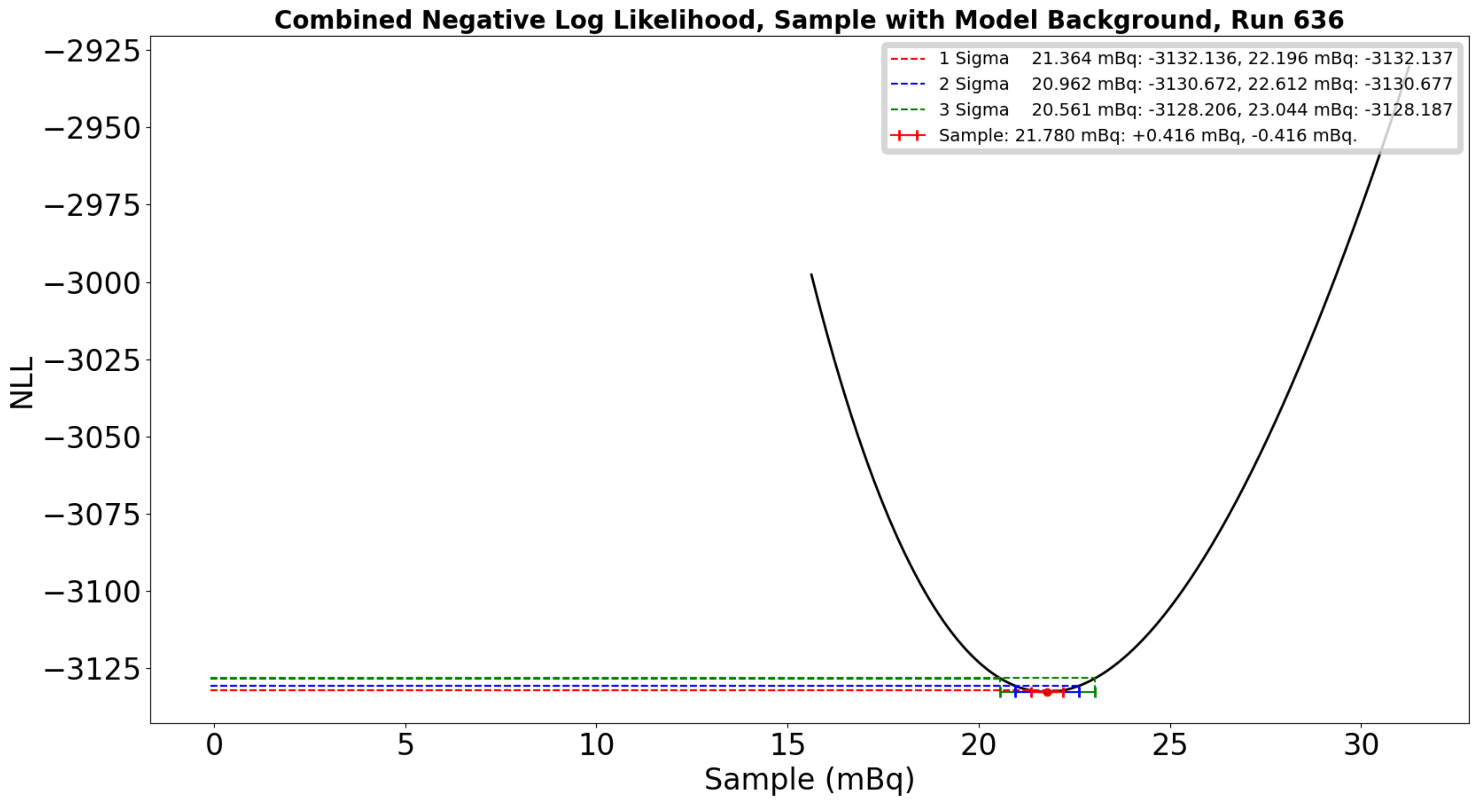
Run 636 Po-214 NLL



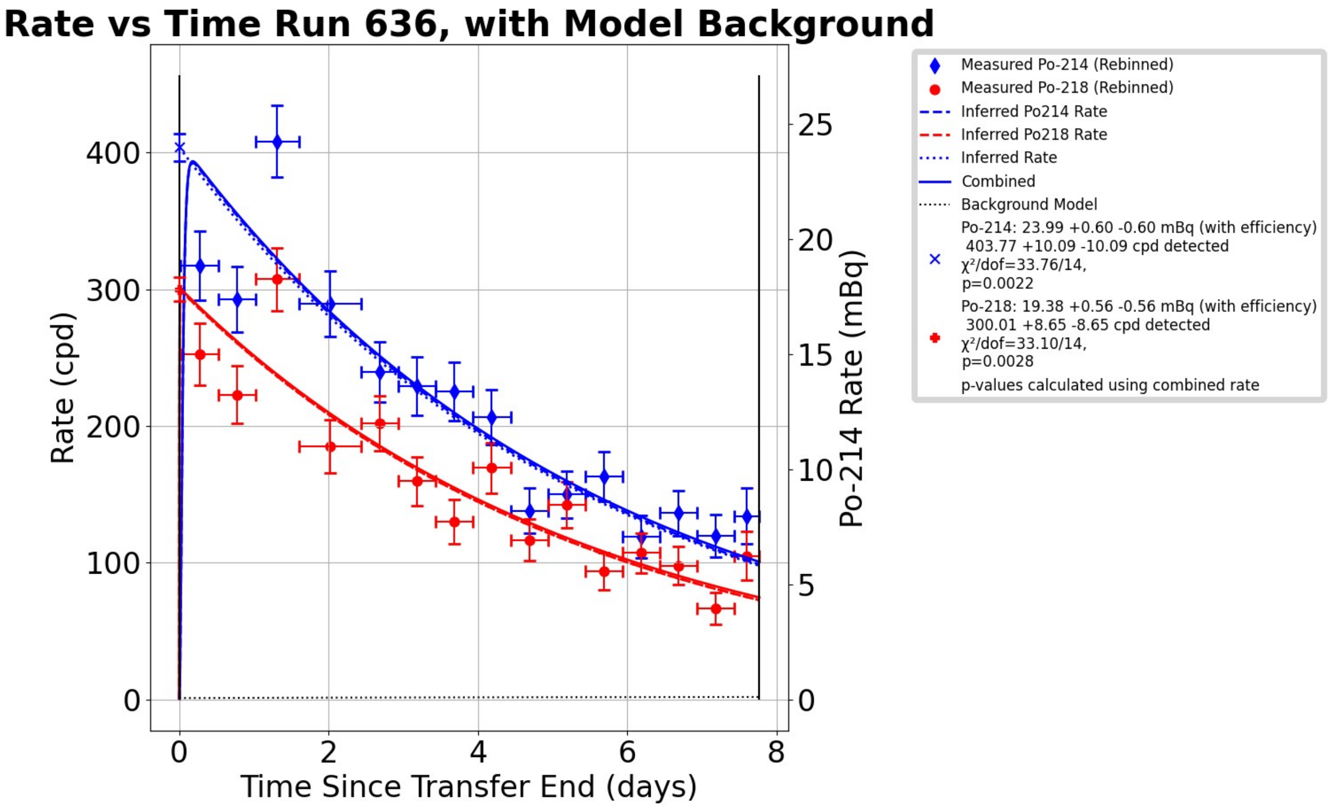
Run 636 Gain Po-218 NLL



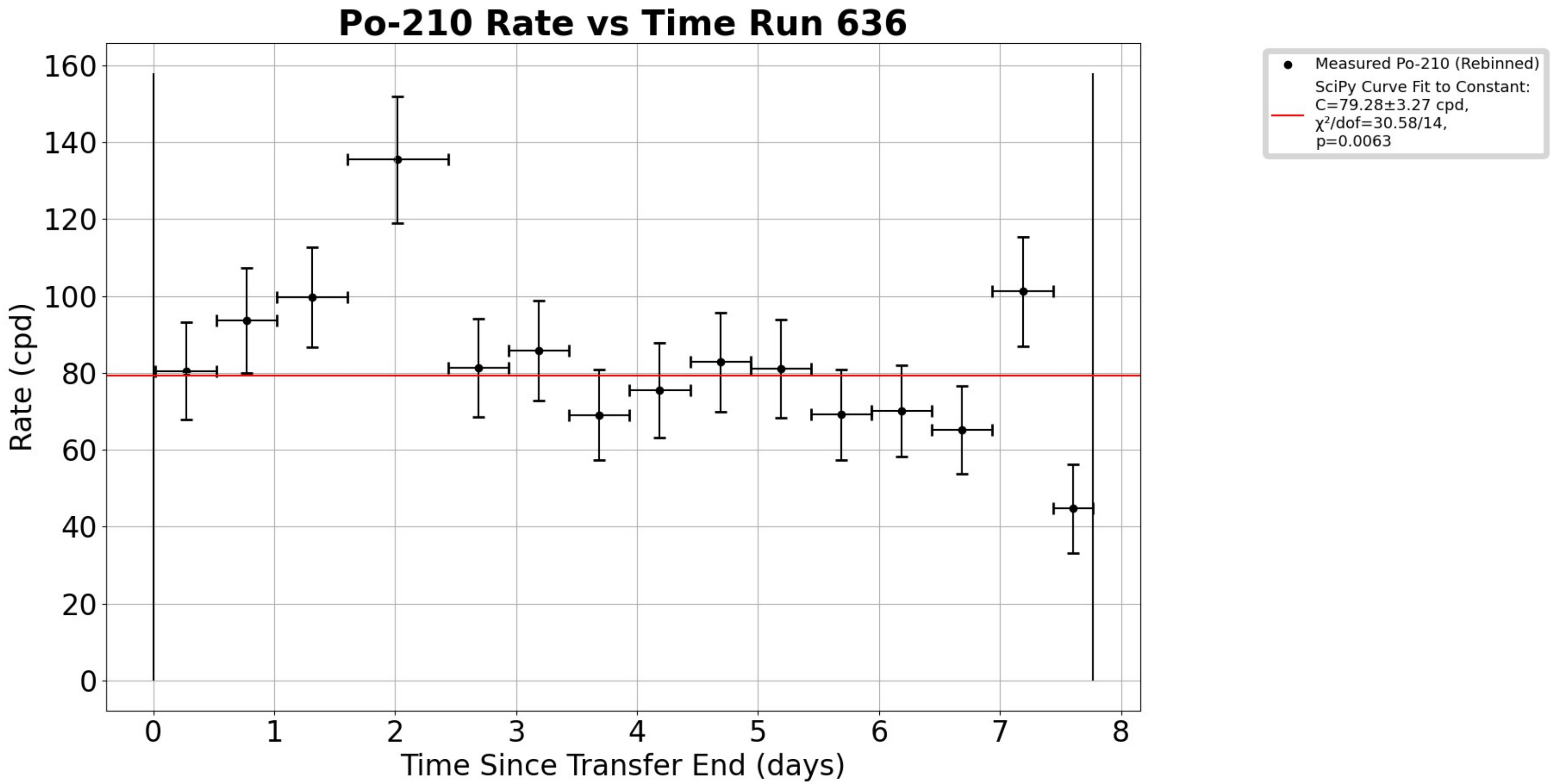
Run 636 Combined NLL



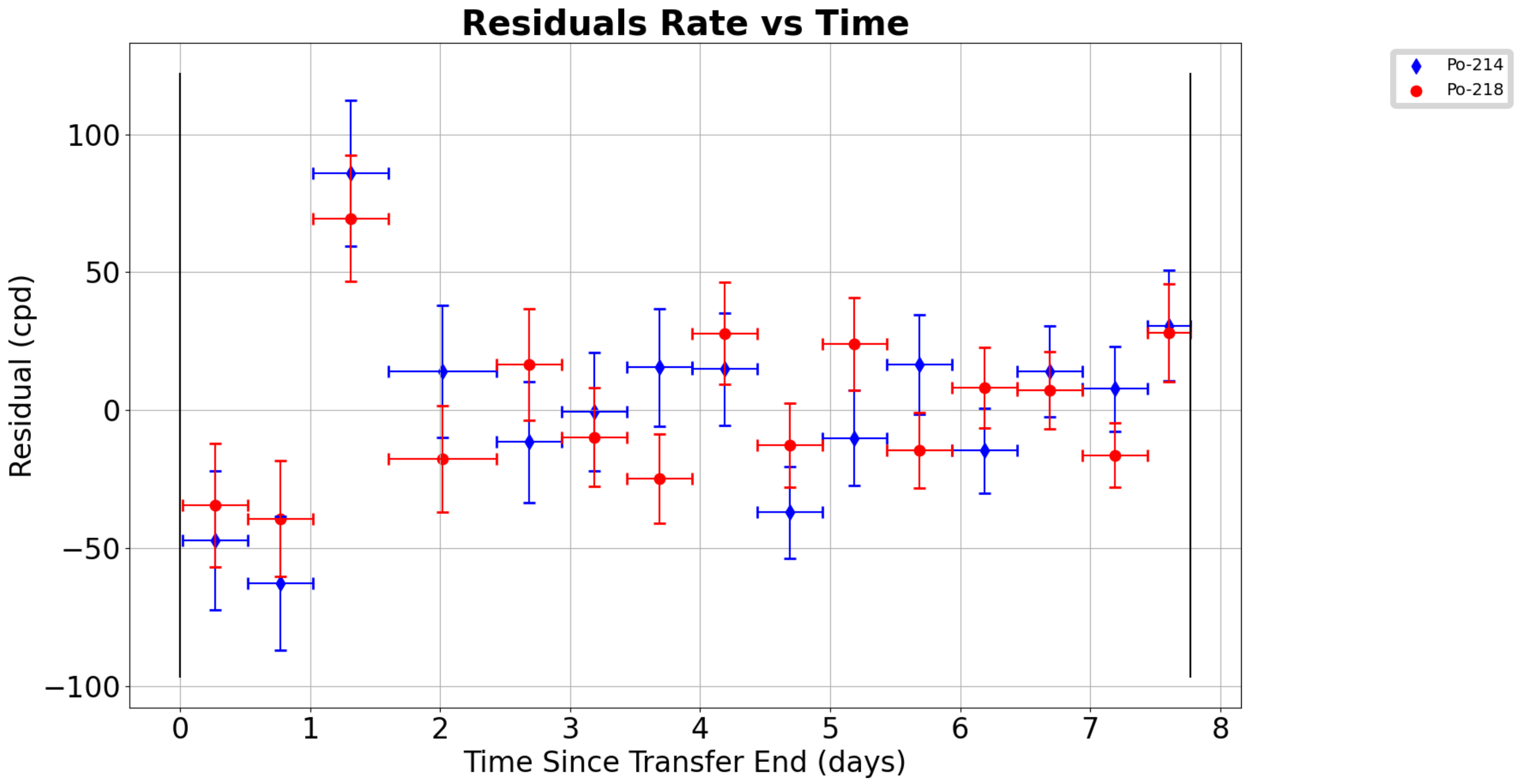
Run 636 Rate vs Time



Run 636 Po-210 Rate vs Time

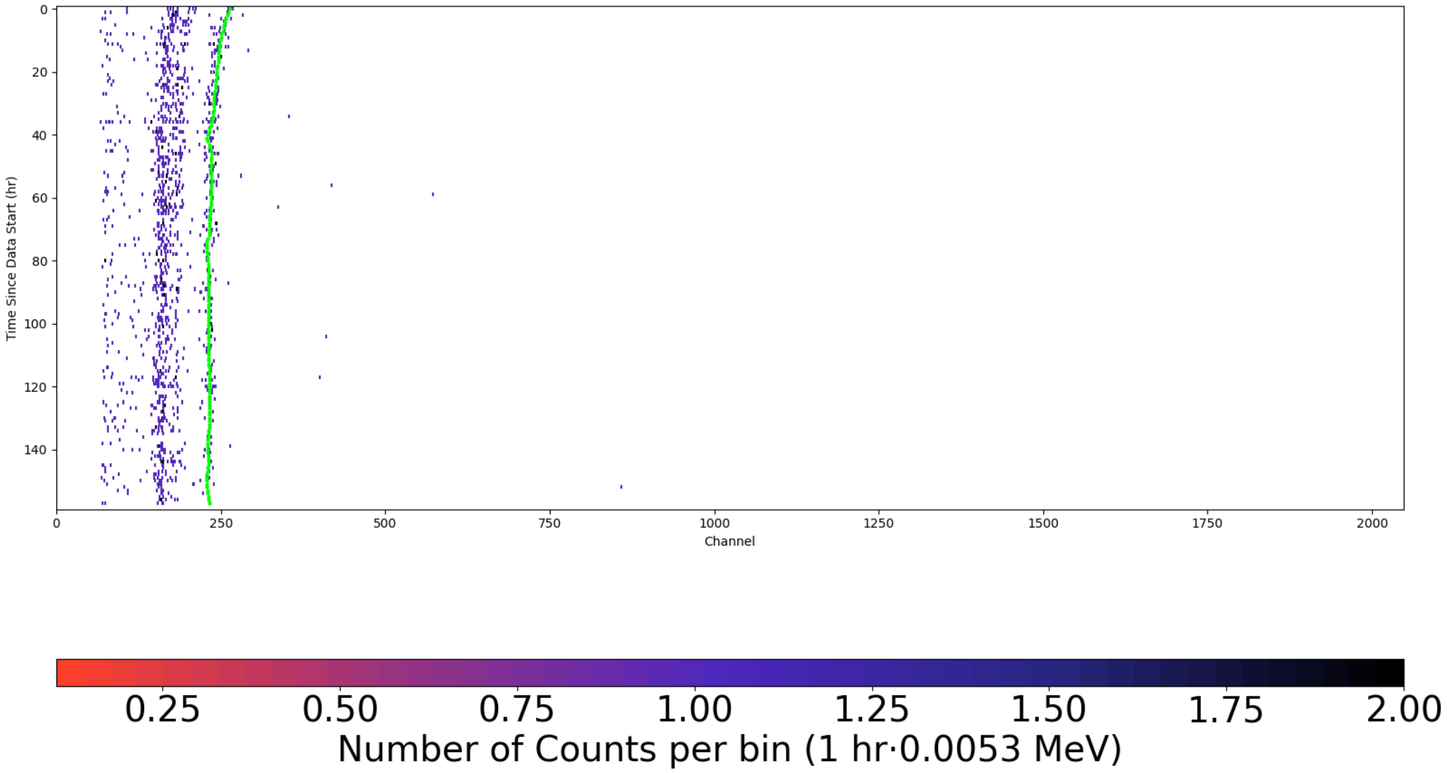


Run 636 Residuals

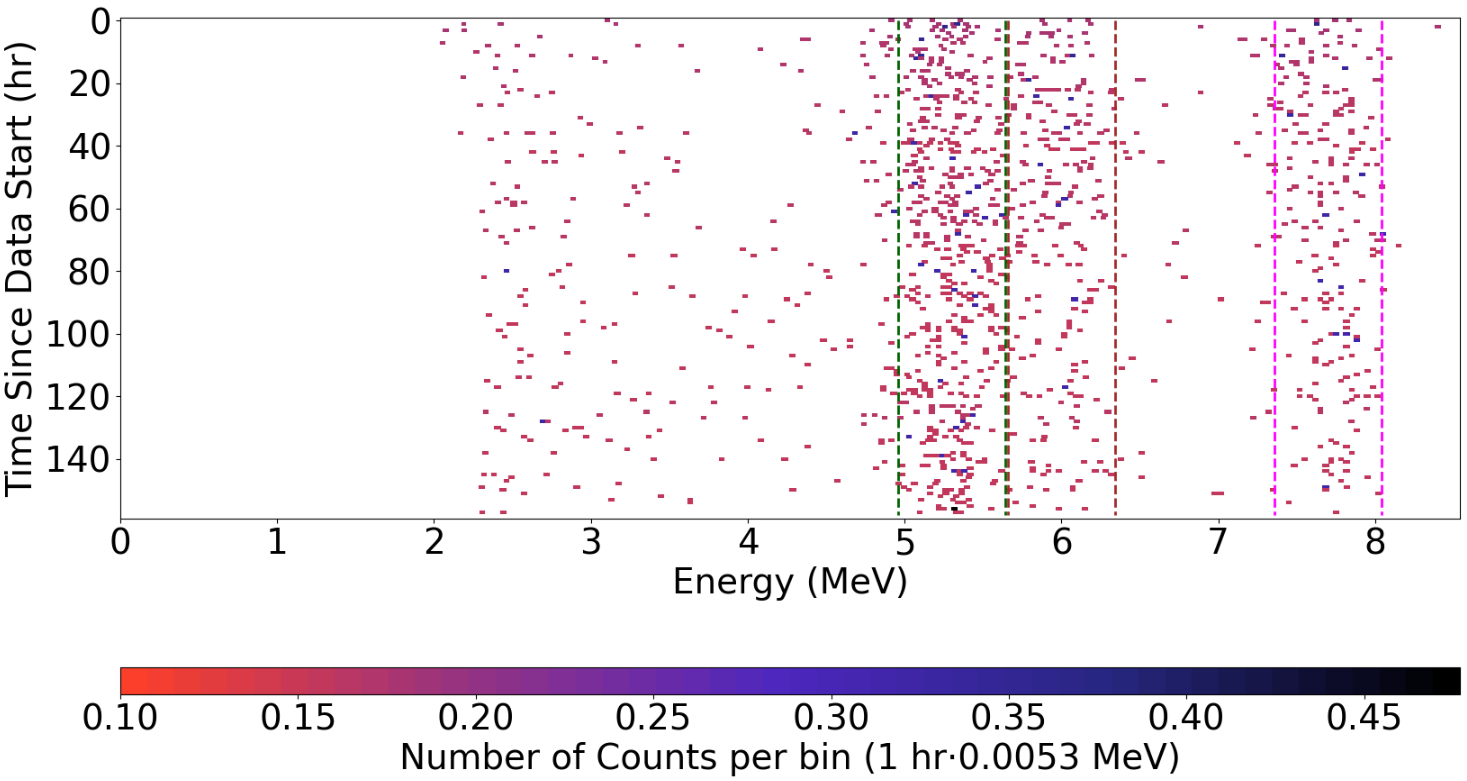


Run 652 Plots

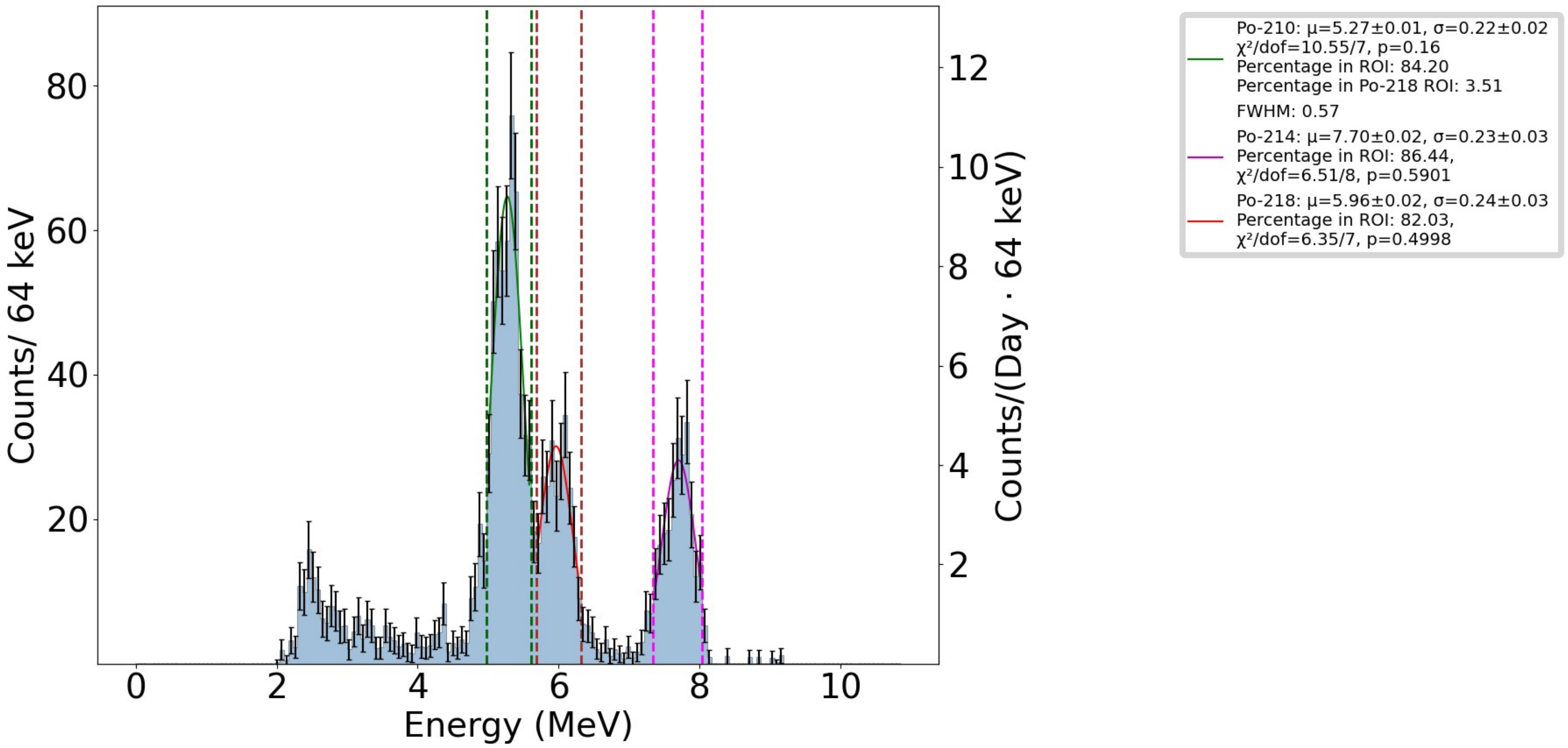
Run 652 Raw Data



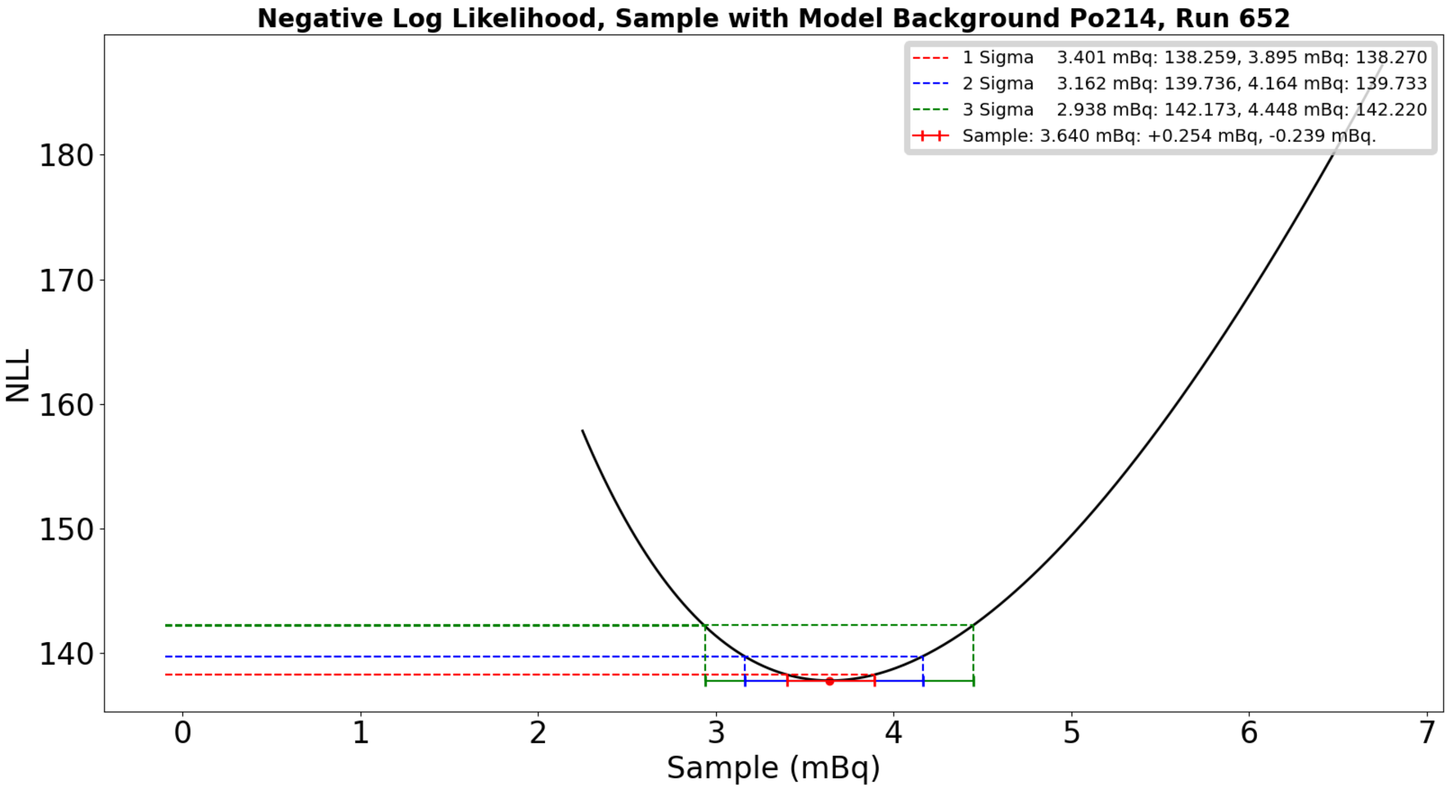
Run 652 Gain Corrected Data



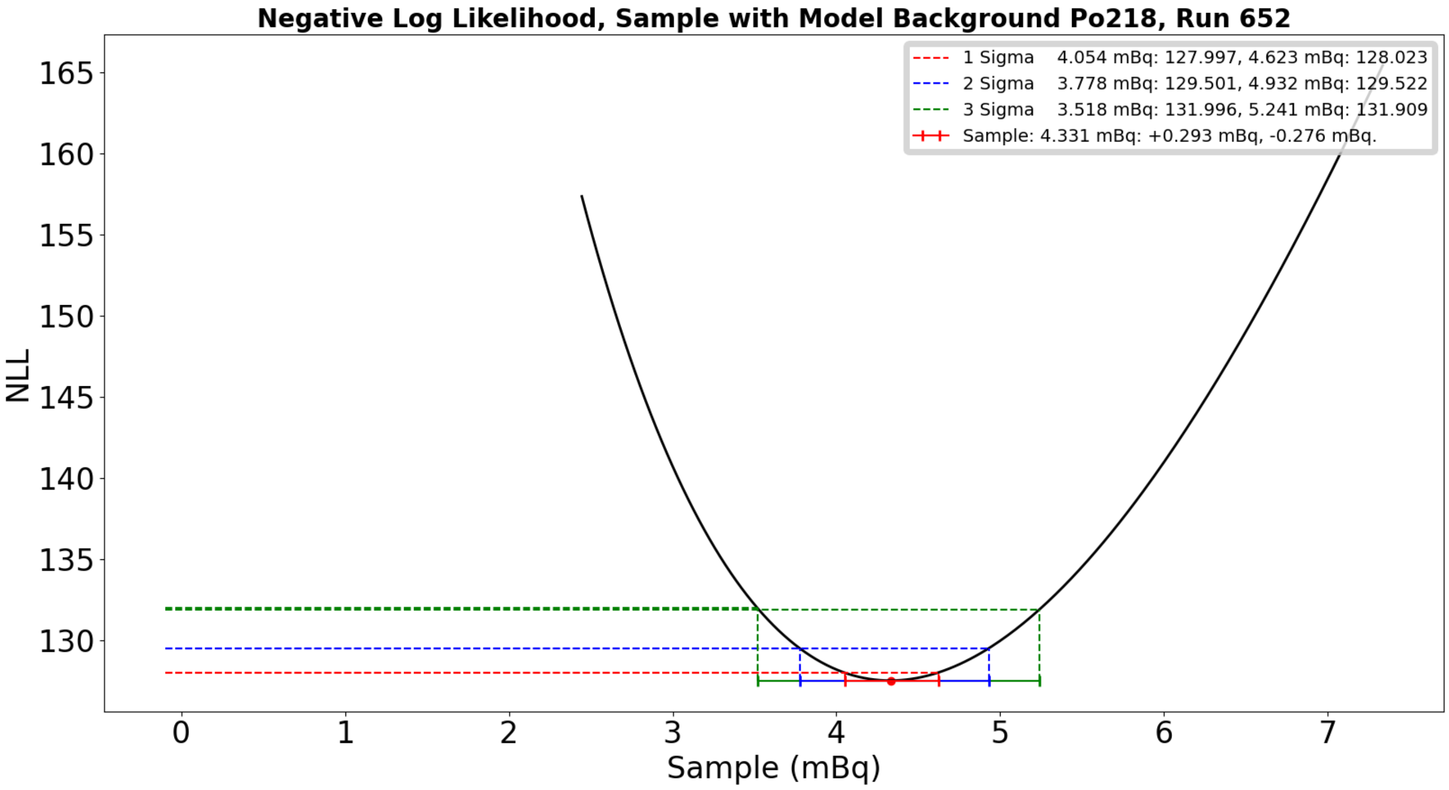
Run 652 Counts vs Energy



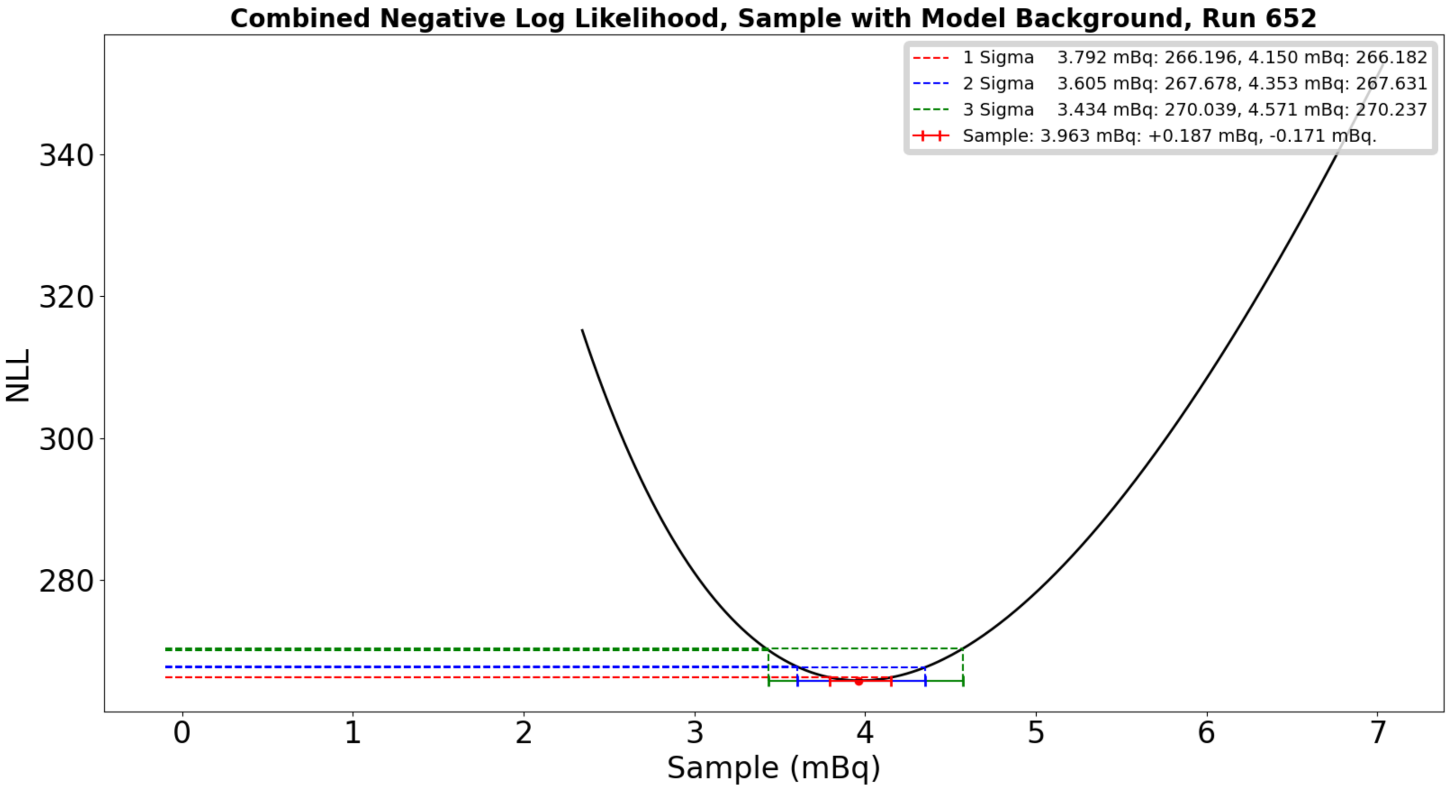
Run 652 Po-214 NLL



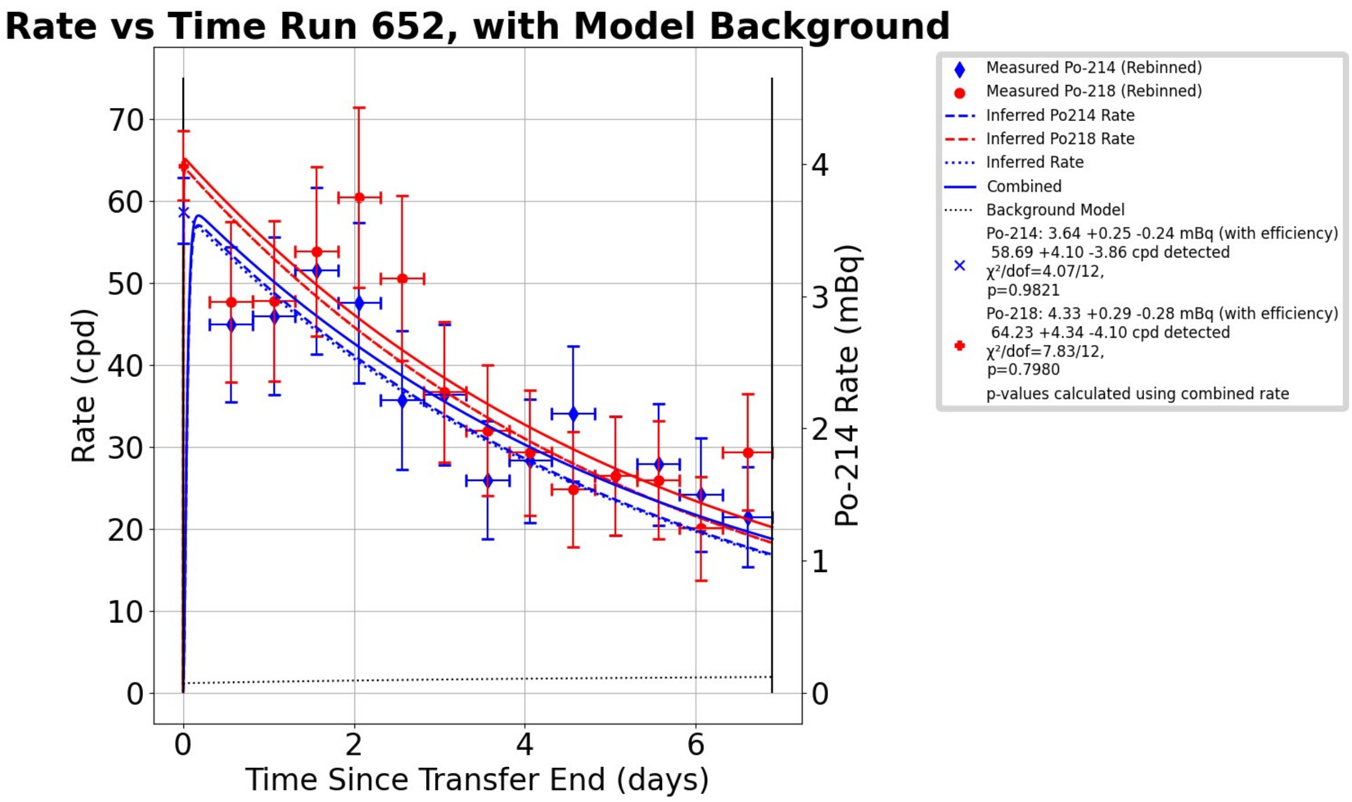
Run 652 Po-218 NLL



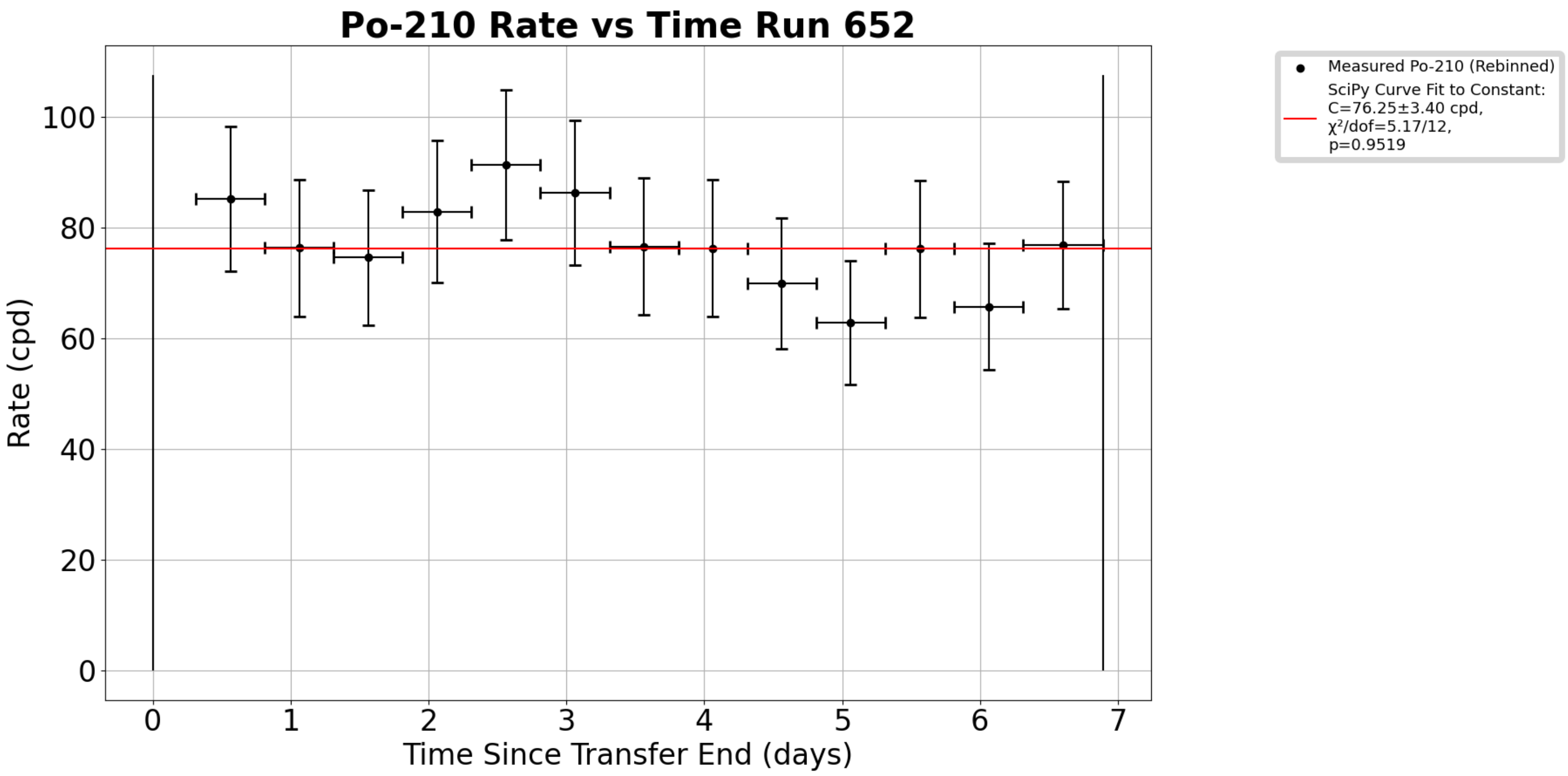
Run 652 Combined NLL



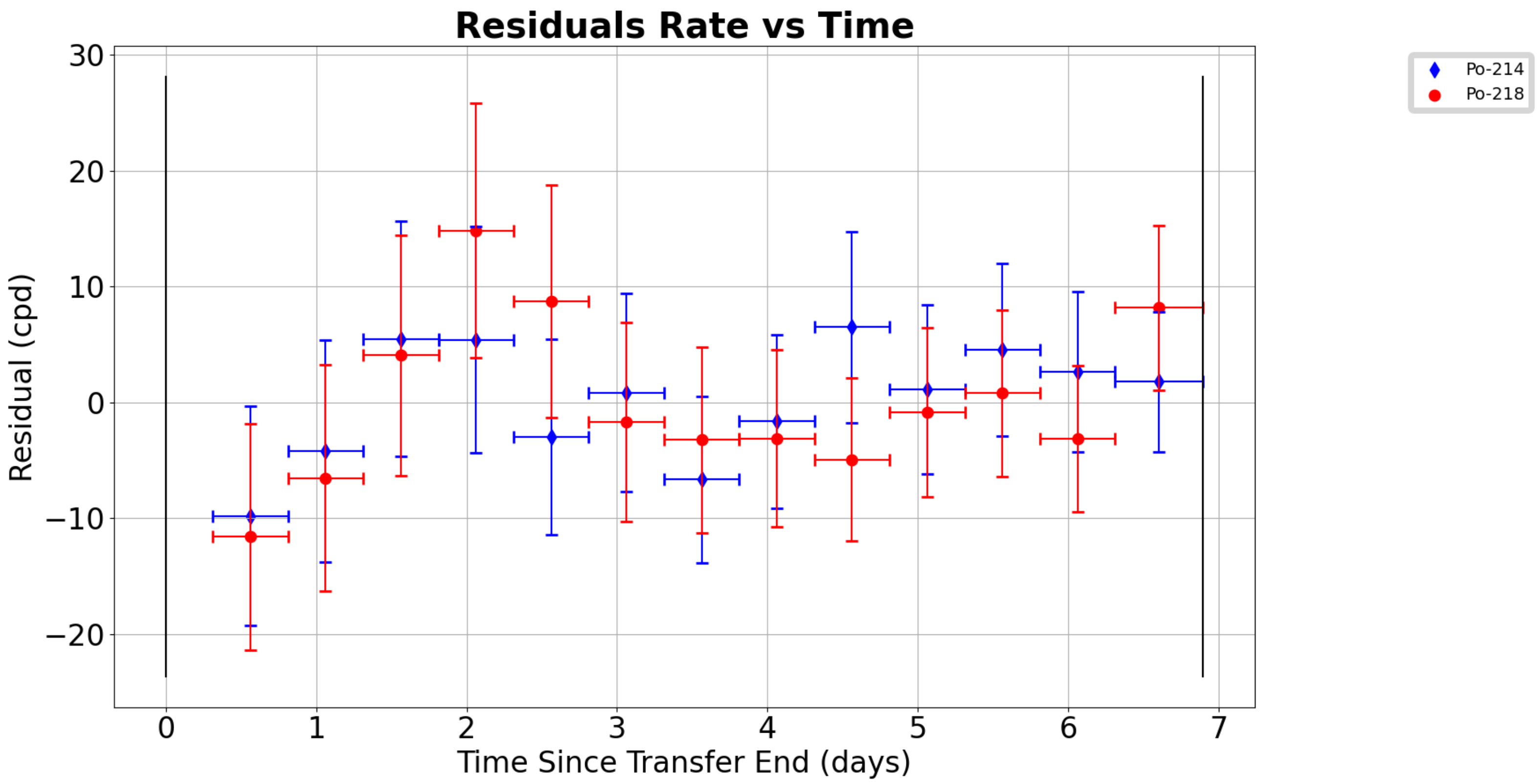
Run 652 Rate vs Time



Run 652 Po-210 Rate vs Time

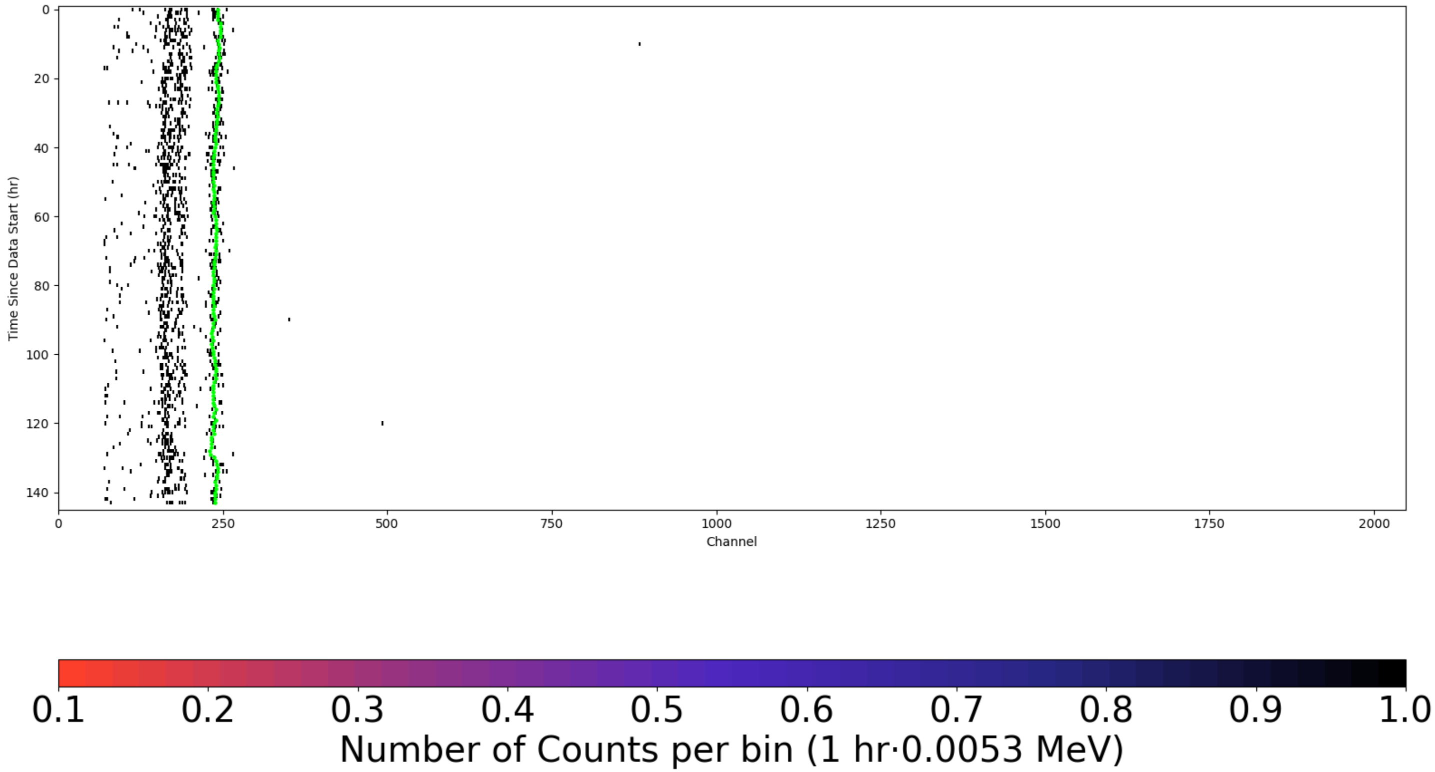


Run 652 Residuals

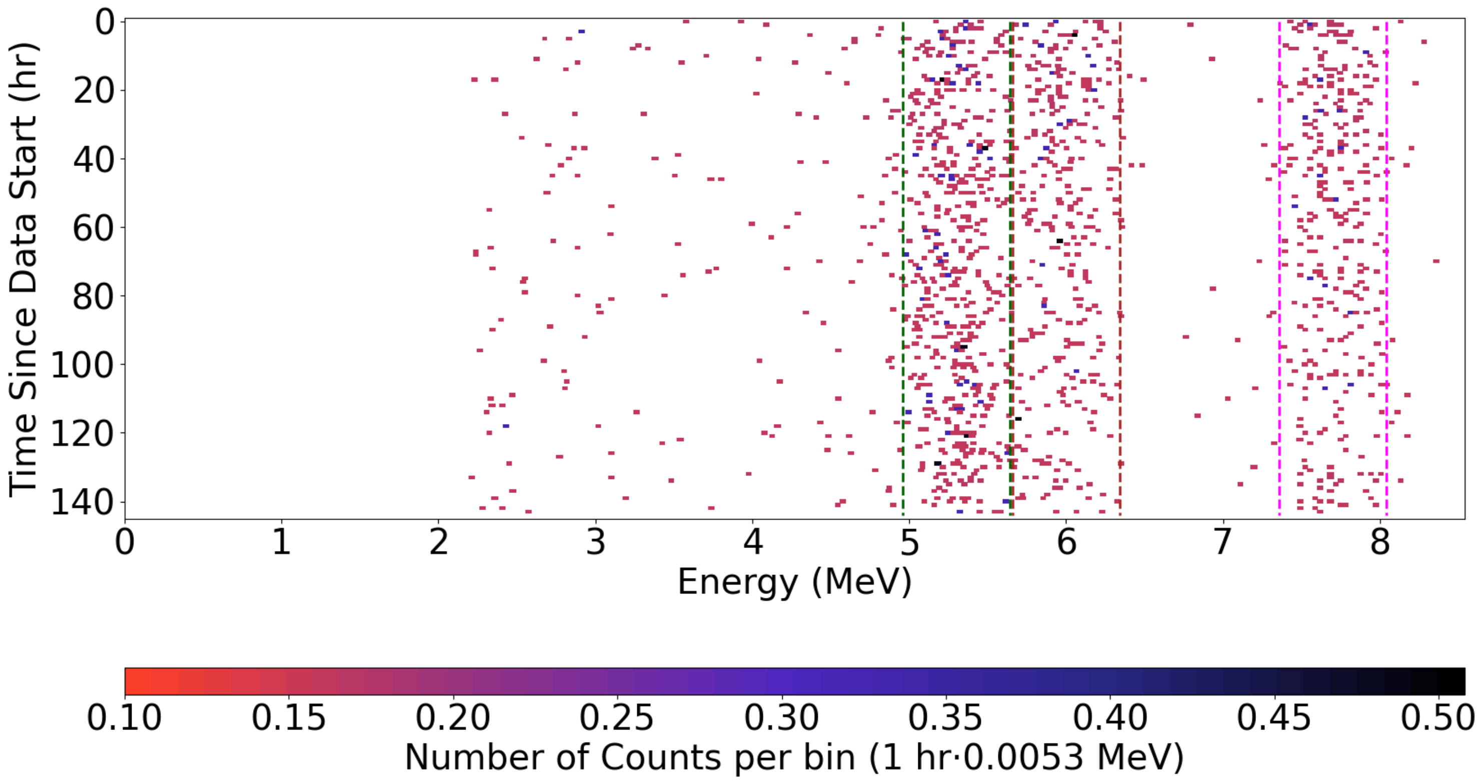


Run 656 Plots

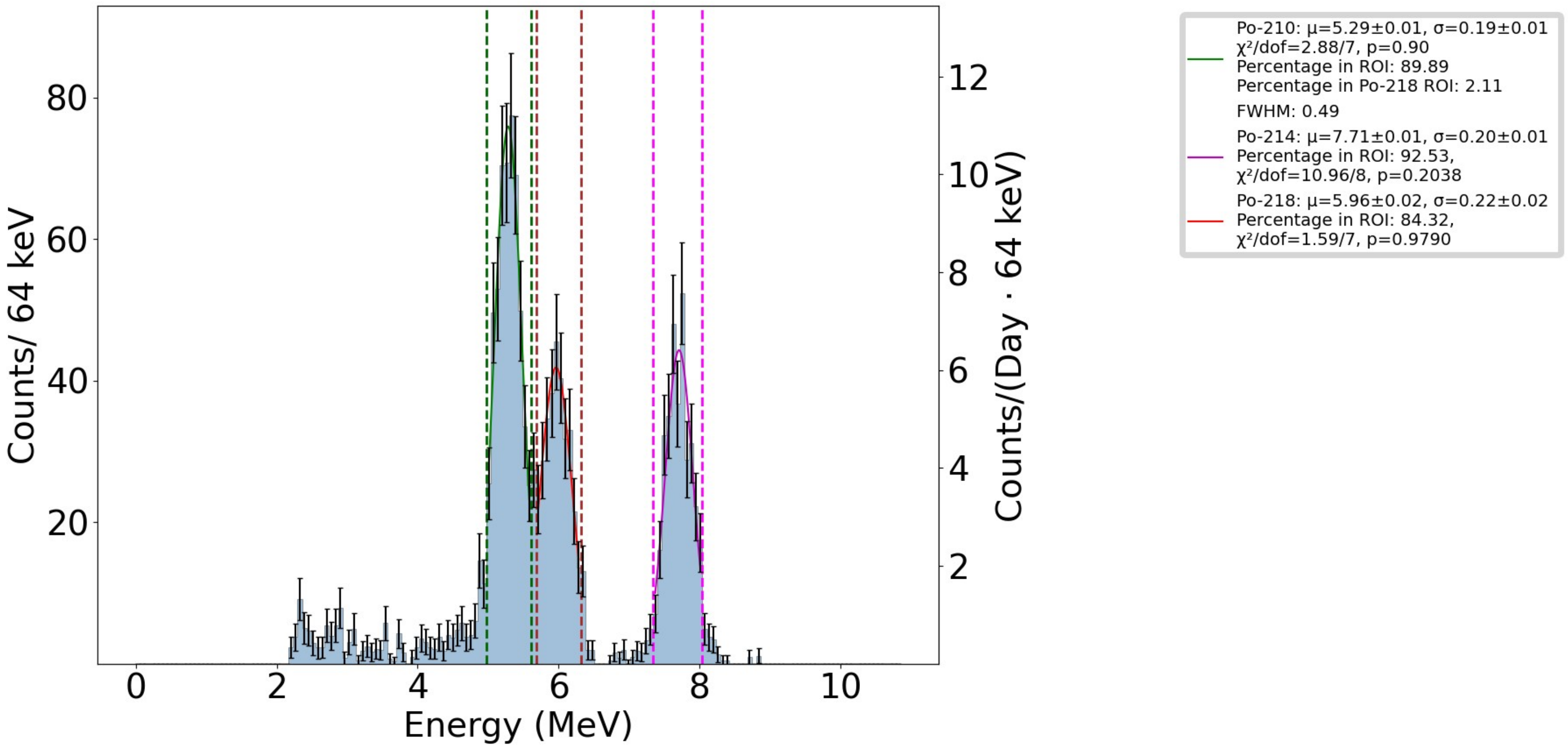
Run 656 Raw Data



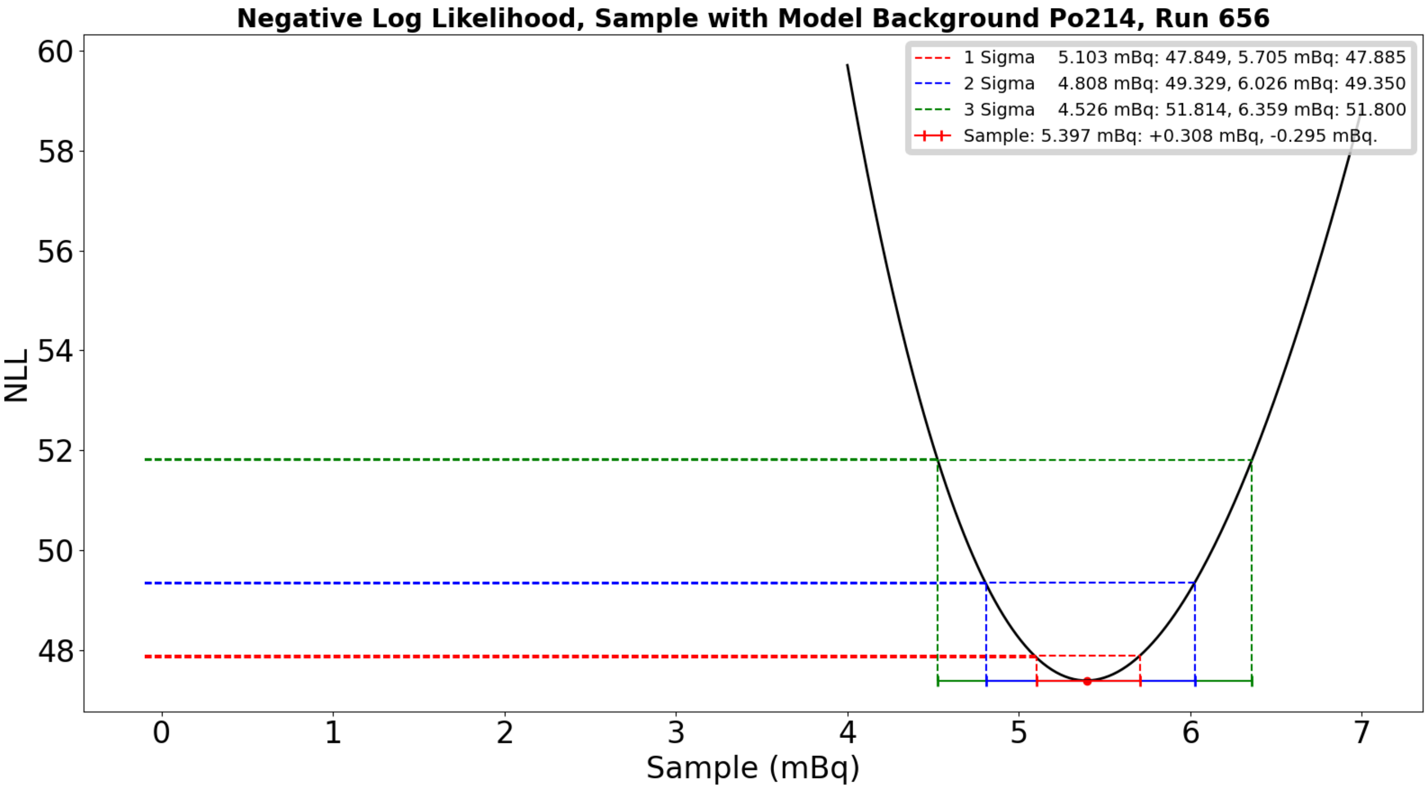
Run 656 Gain Corrected Data



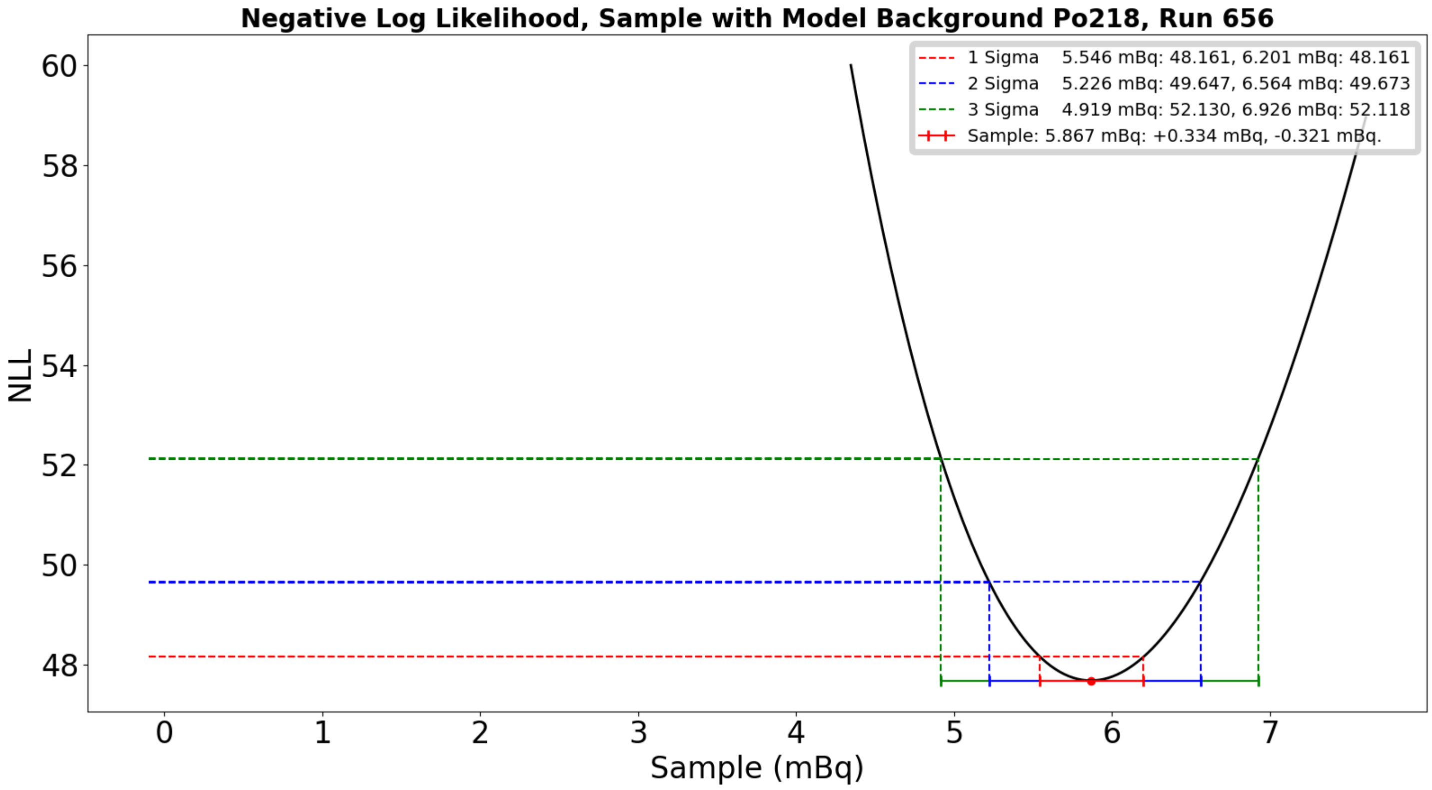
Run 656 Counts vs Energy



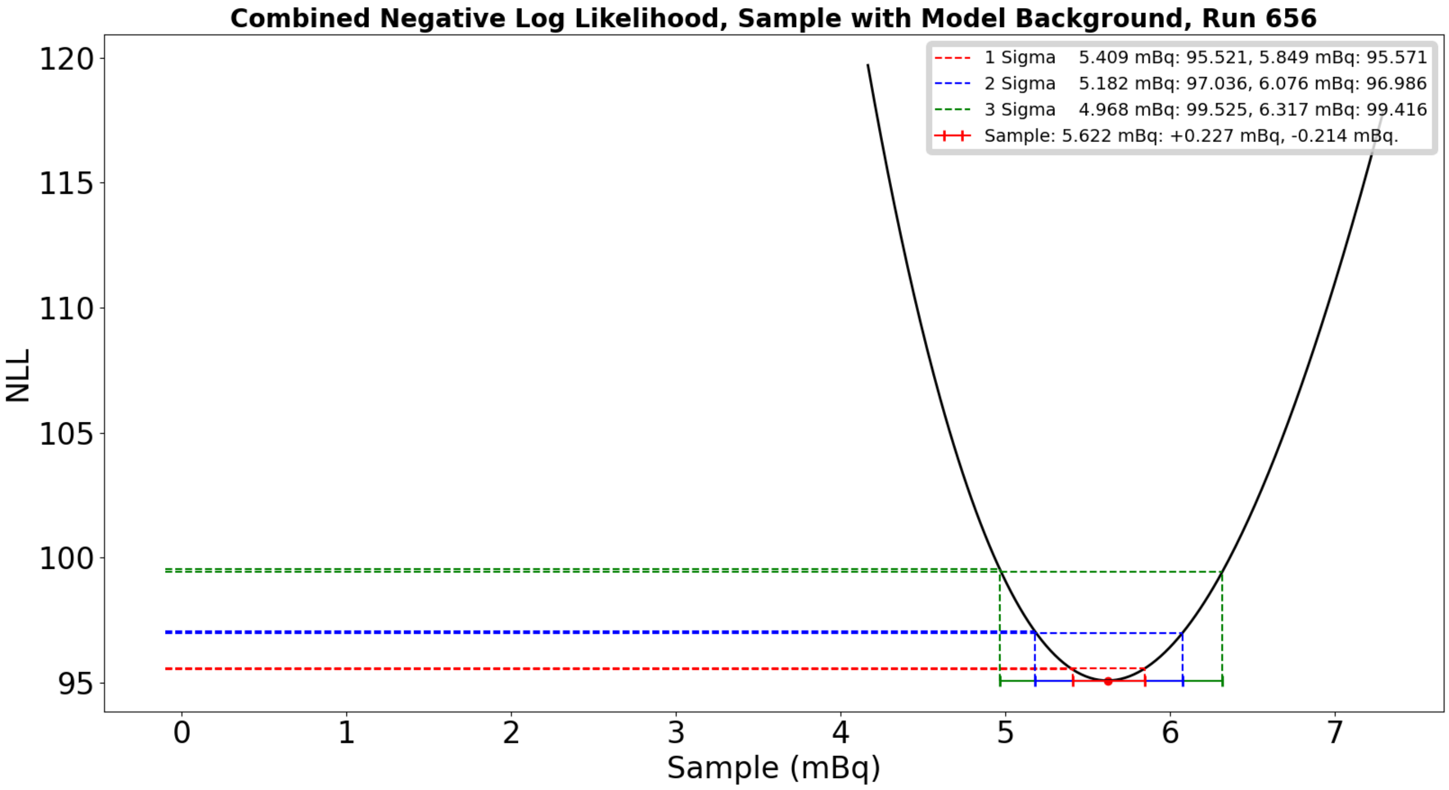
Run 656 Po-214 NLL



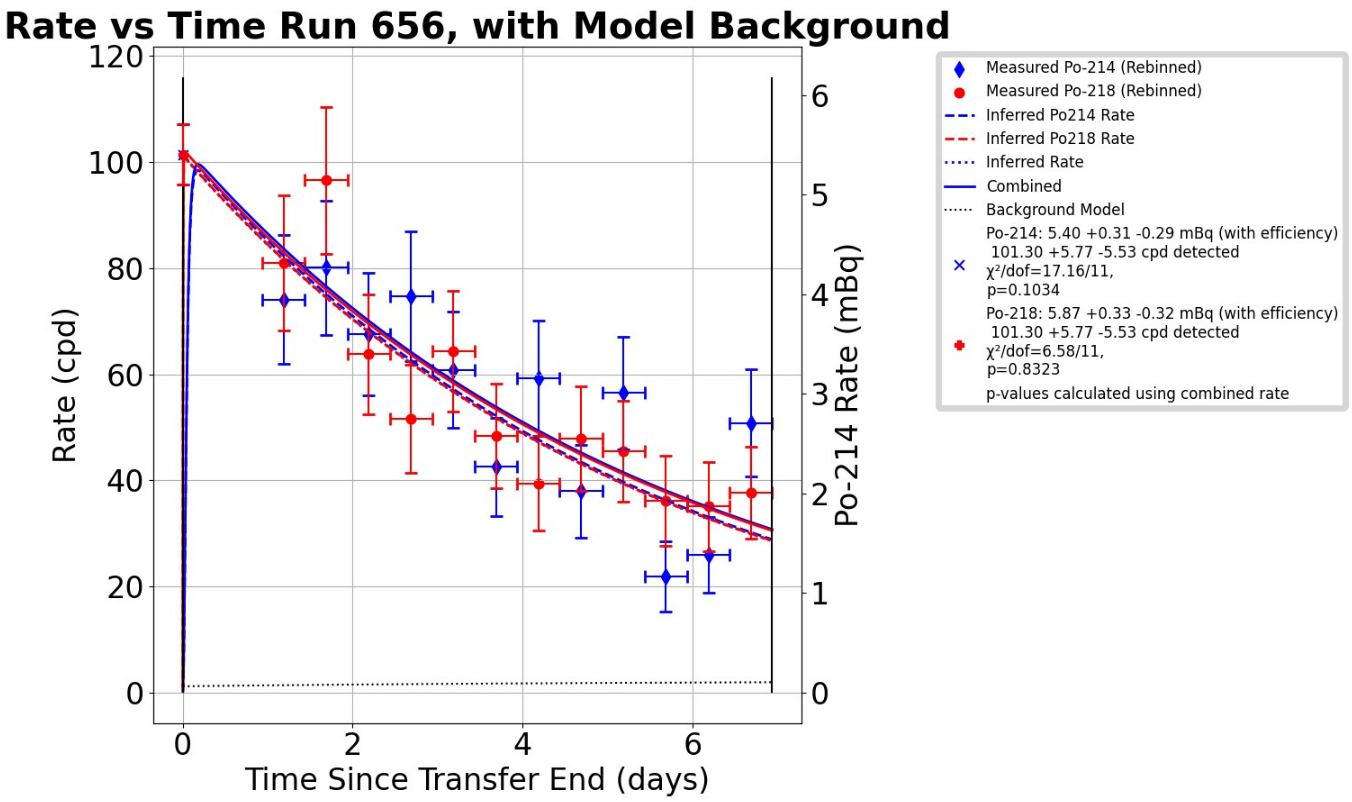
Run 656 Po-218 NLL



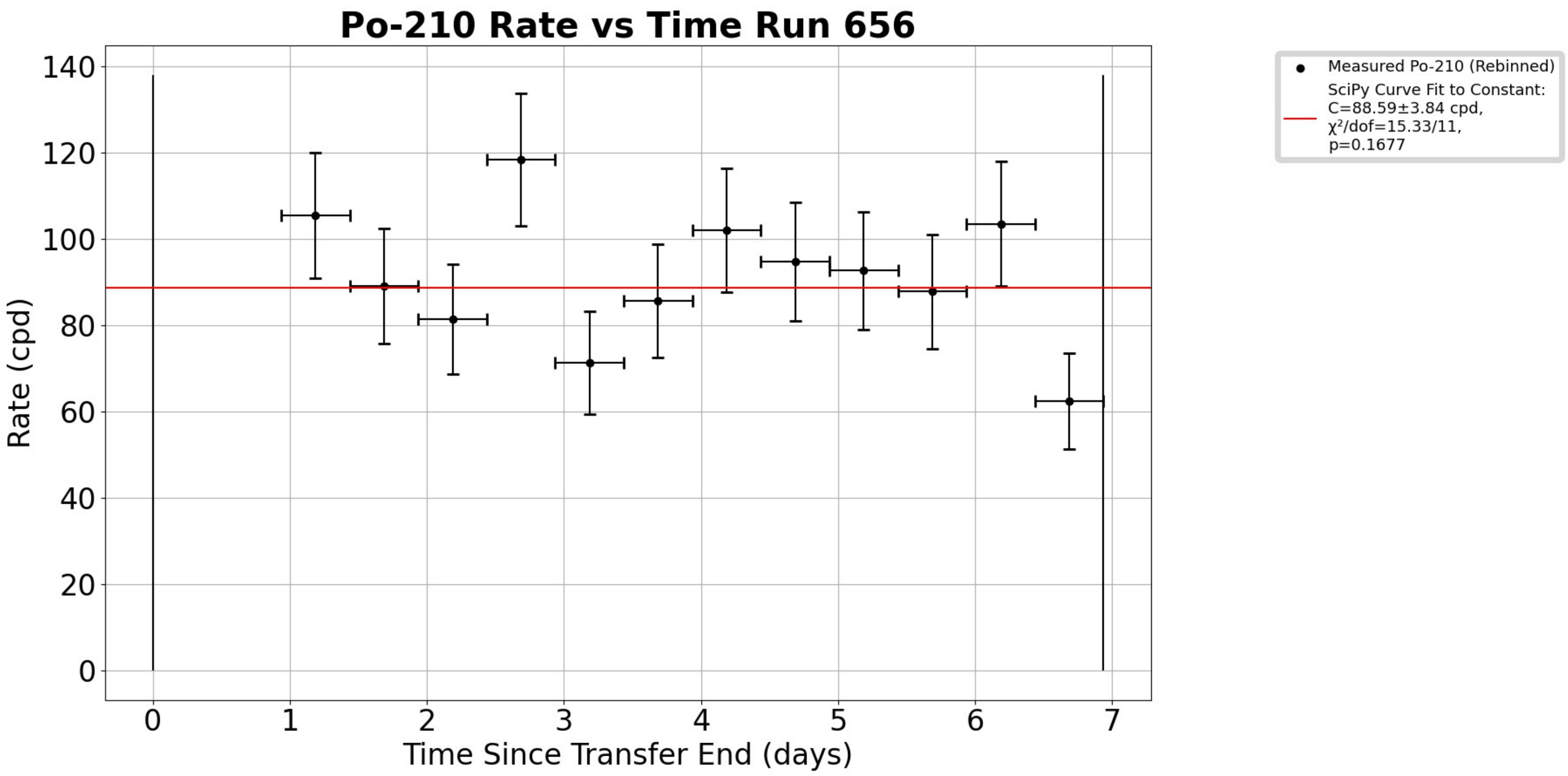
Run 656 Combined NLL



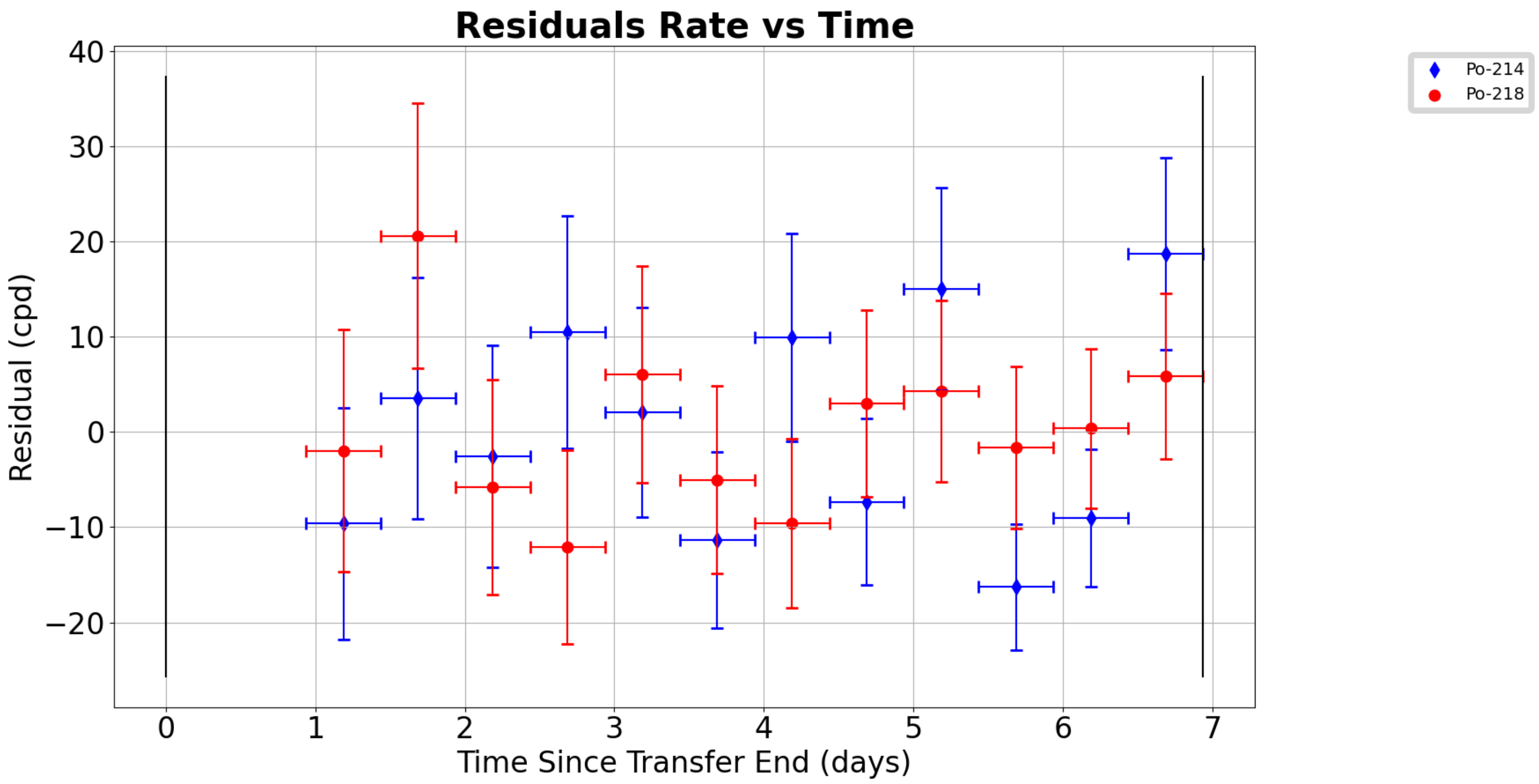
Run 656 Rate vs Time



Run 656 Po-210 Rate vs Time

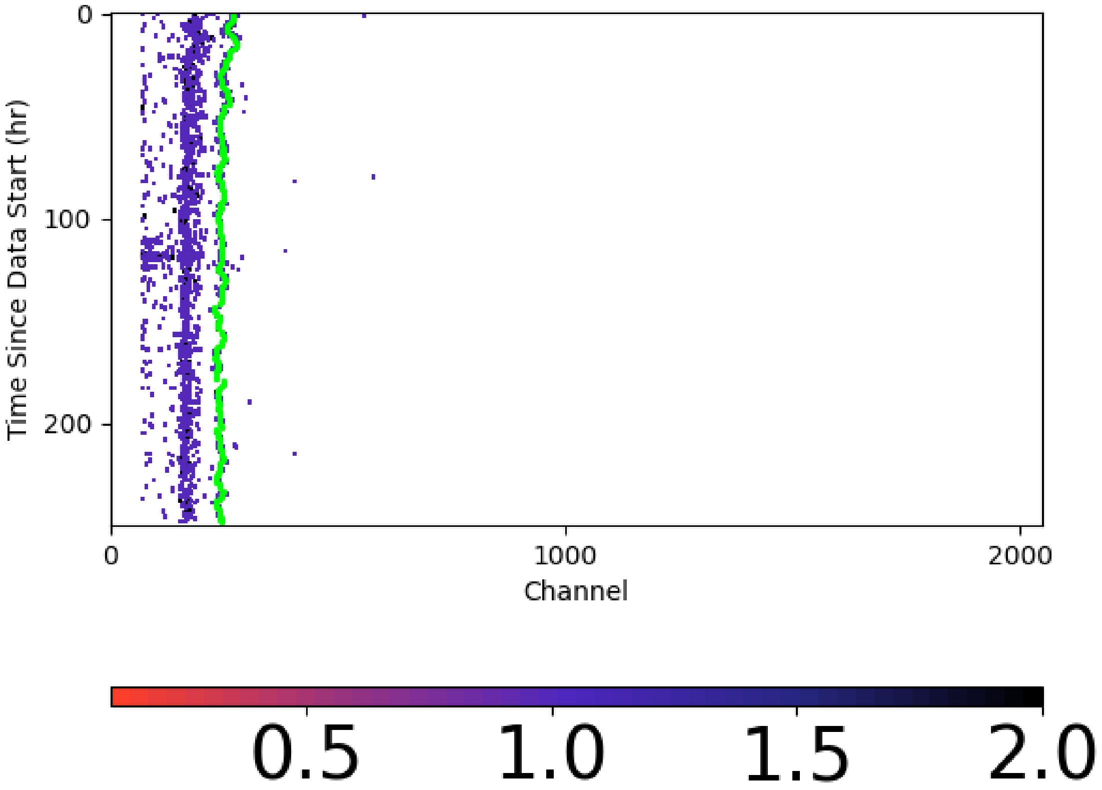


Run 656 Residuals

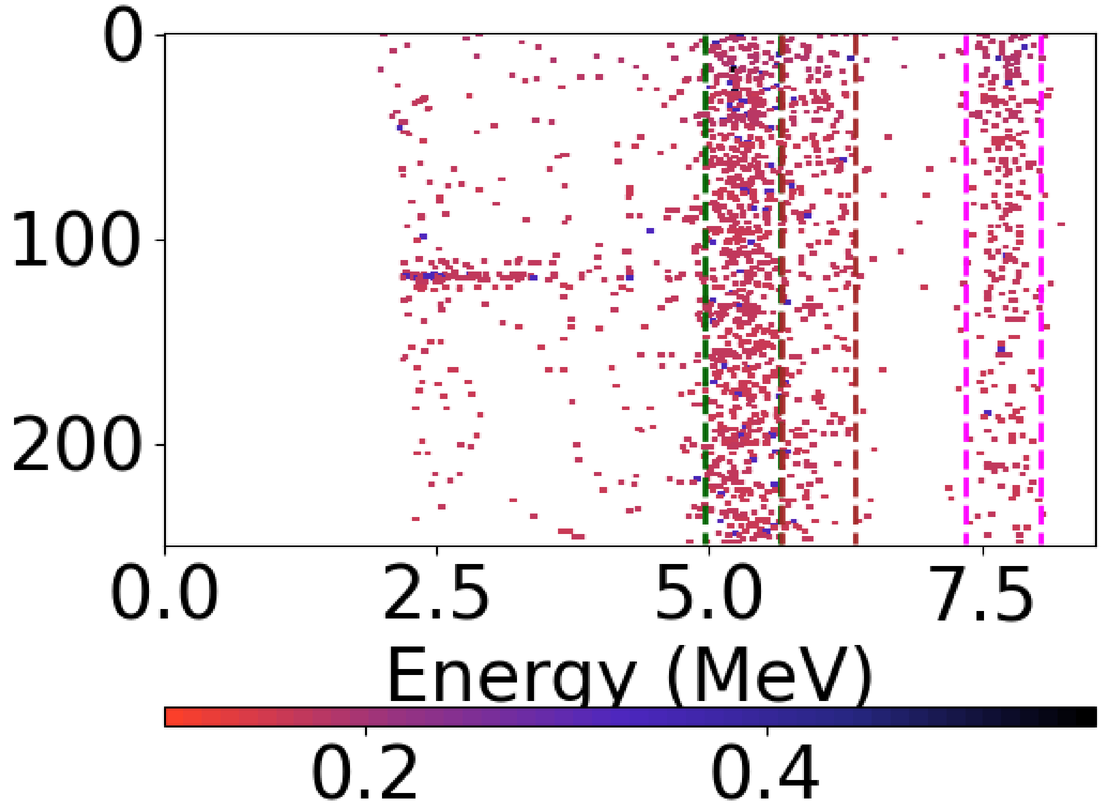


Run 658 Plots

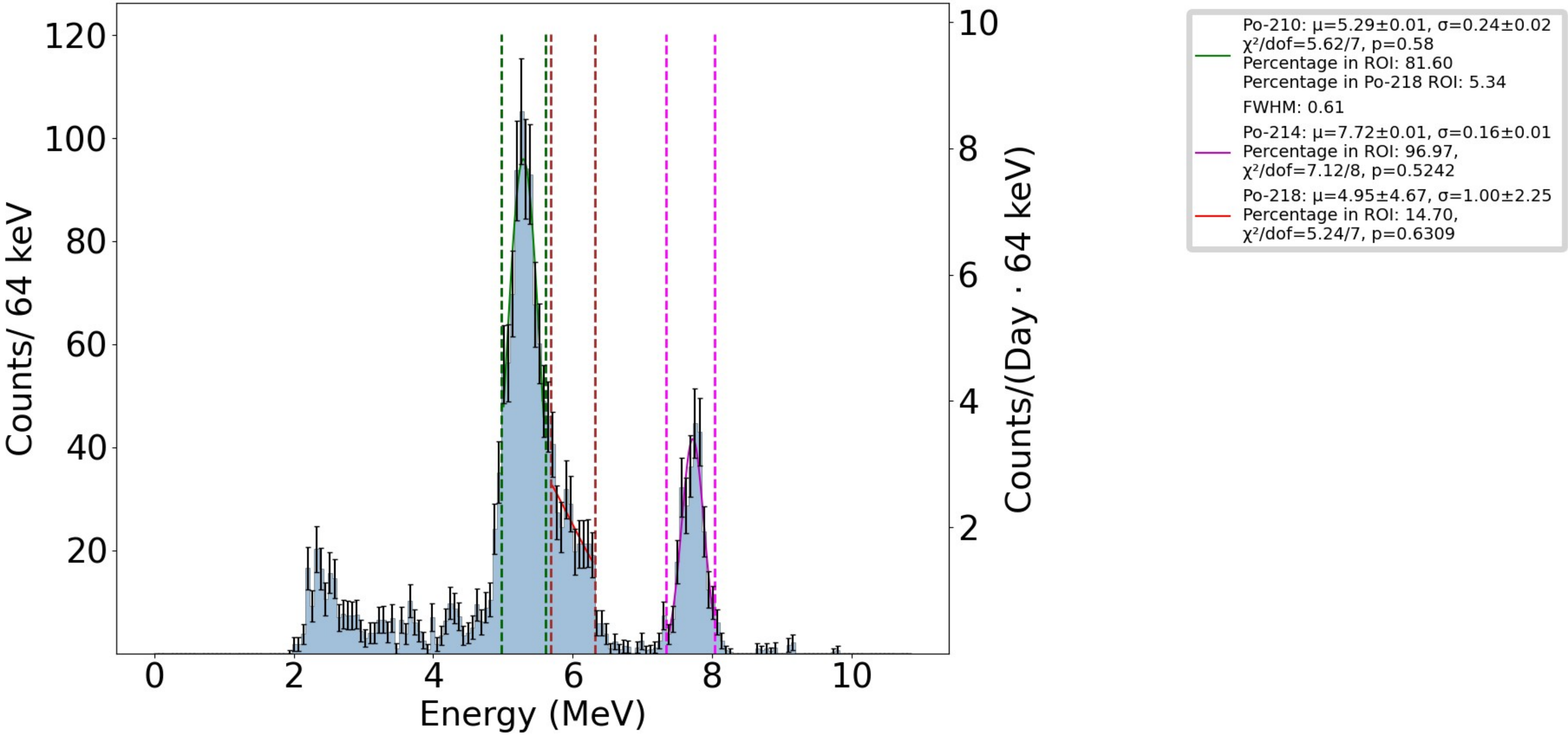
Run 658 Raw Data



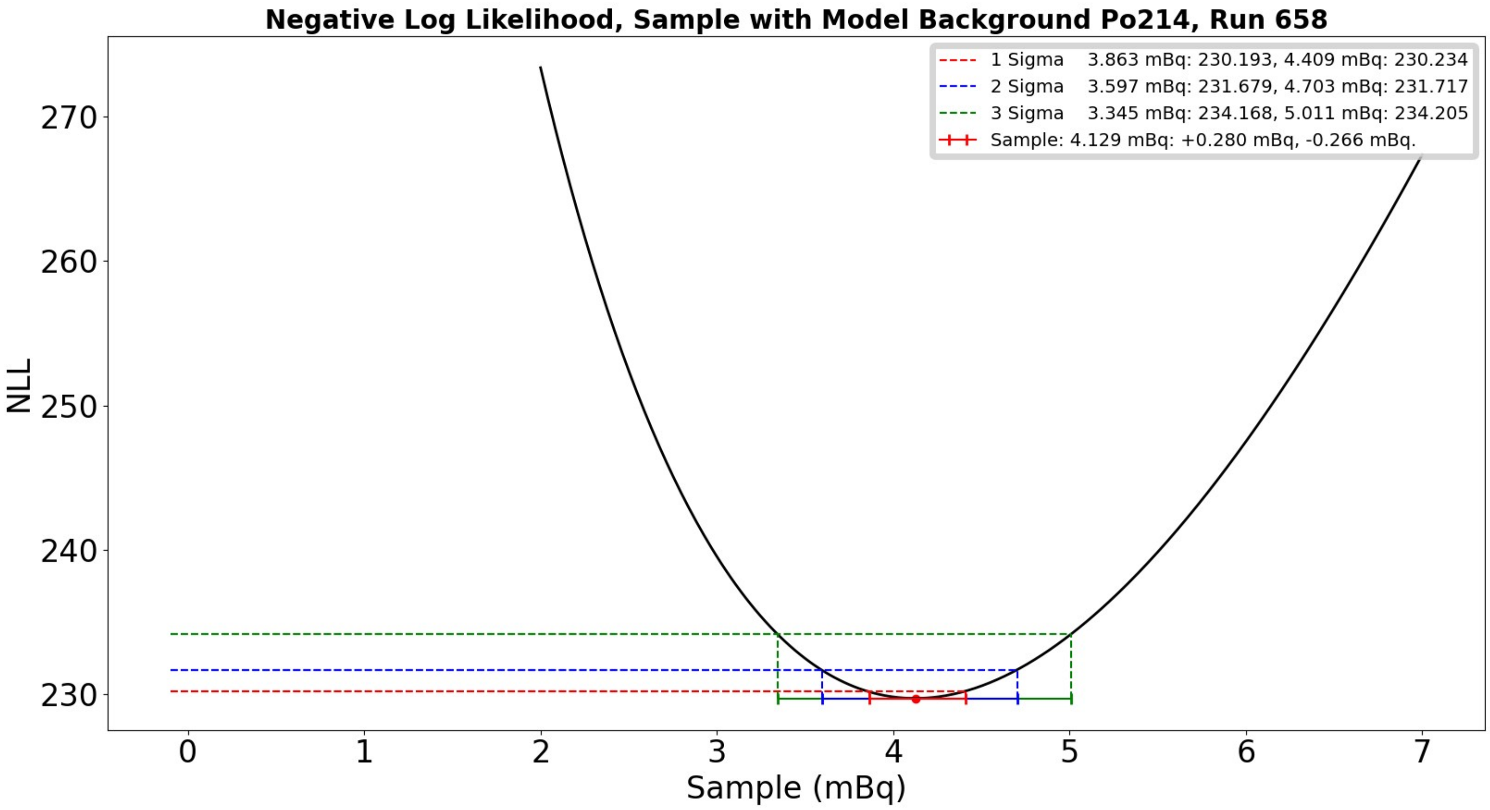
Run 658 Gain Corrected Data



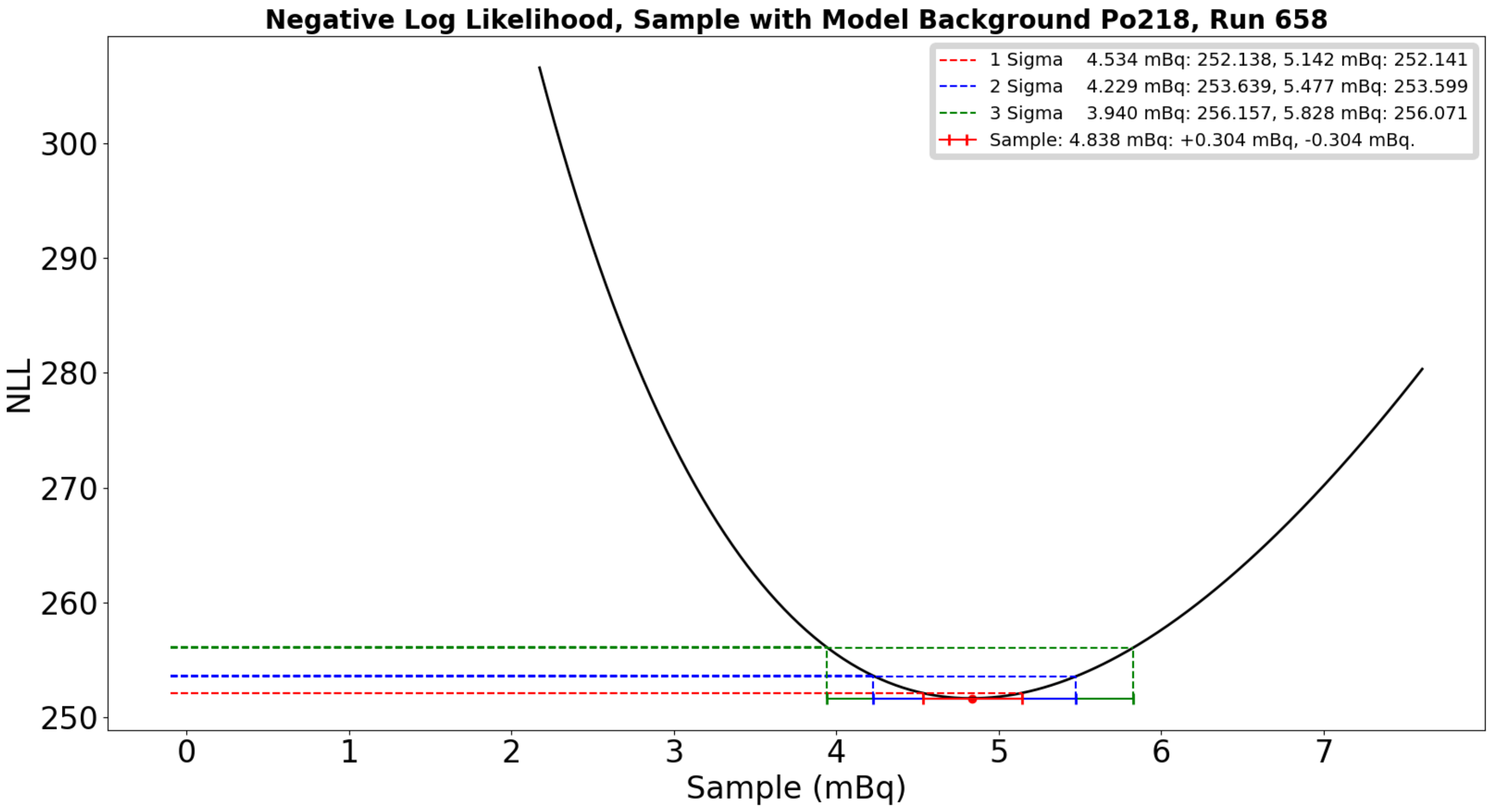
Run 658 Counts vs Energy



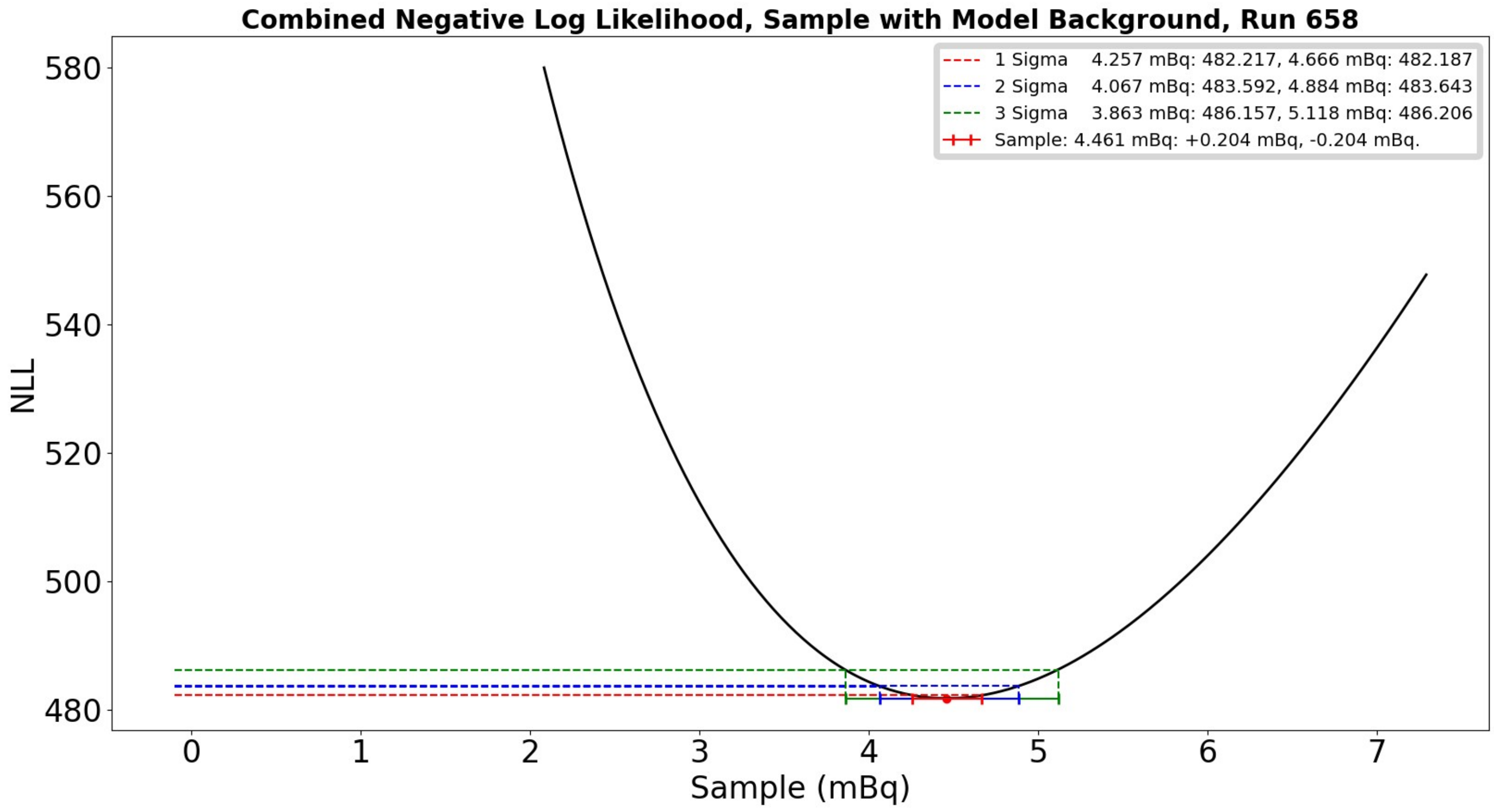
Run 658 Po-214 NLL



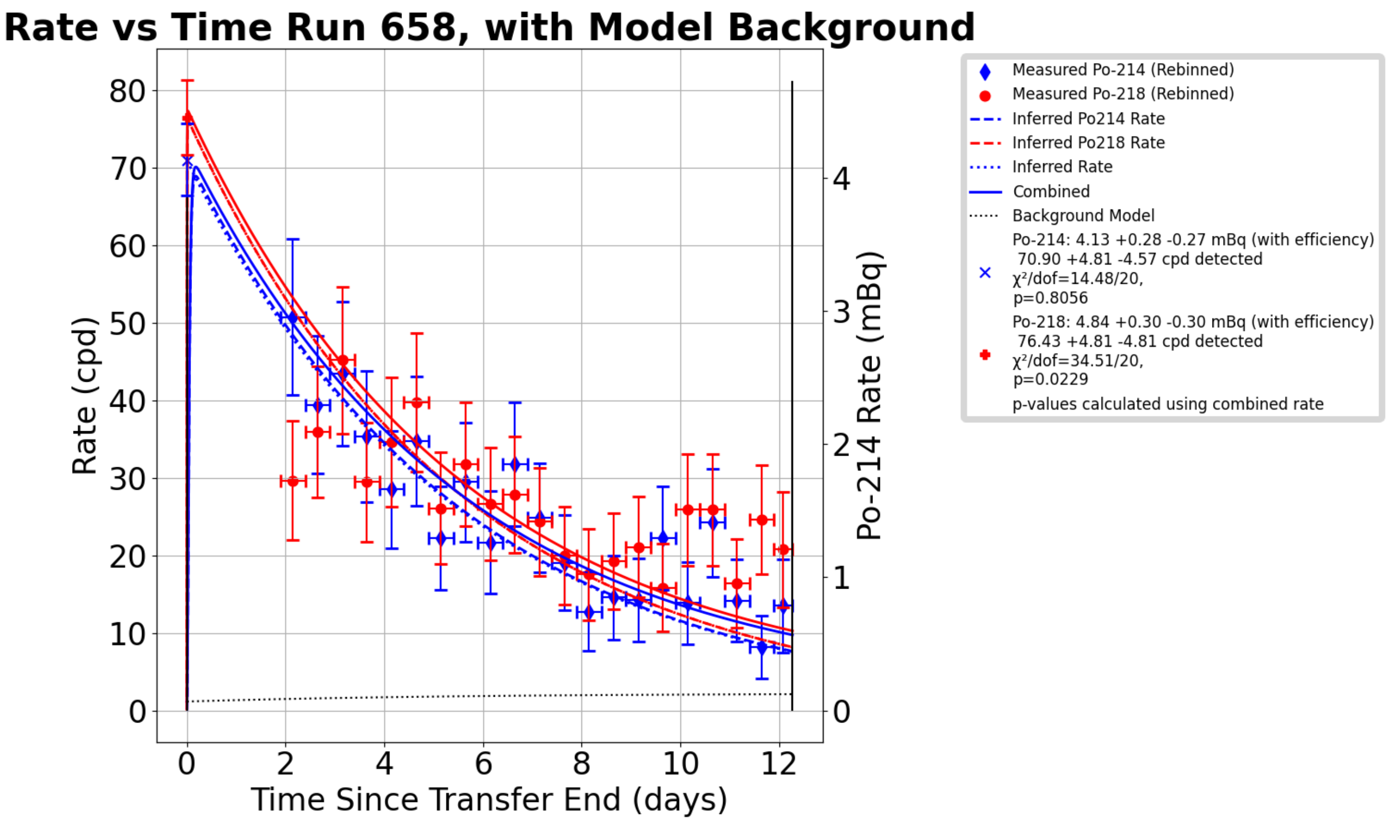
Run 658 Po-218 NLL



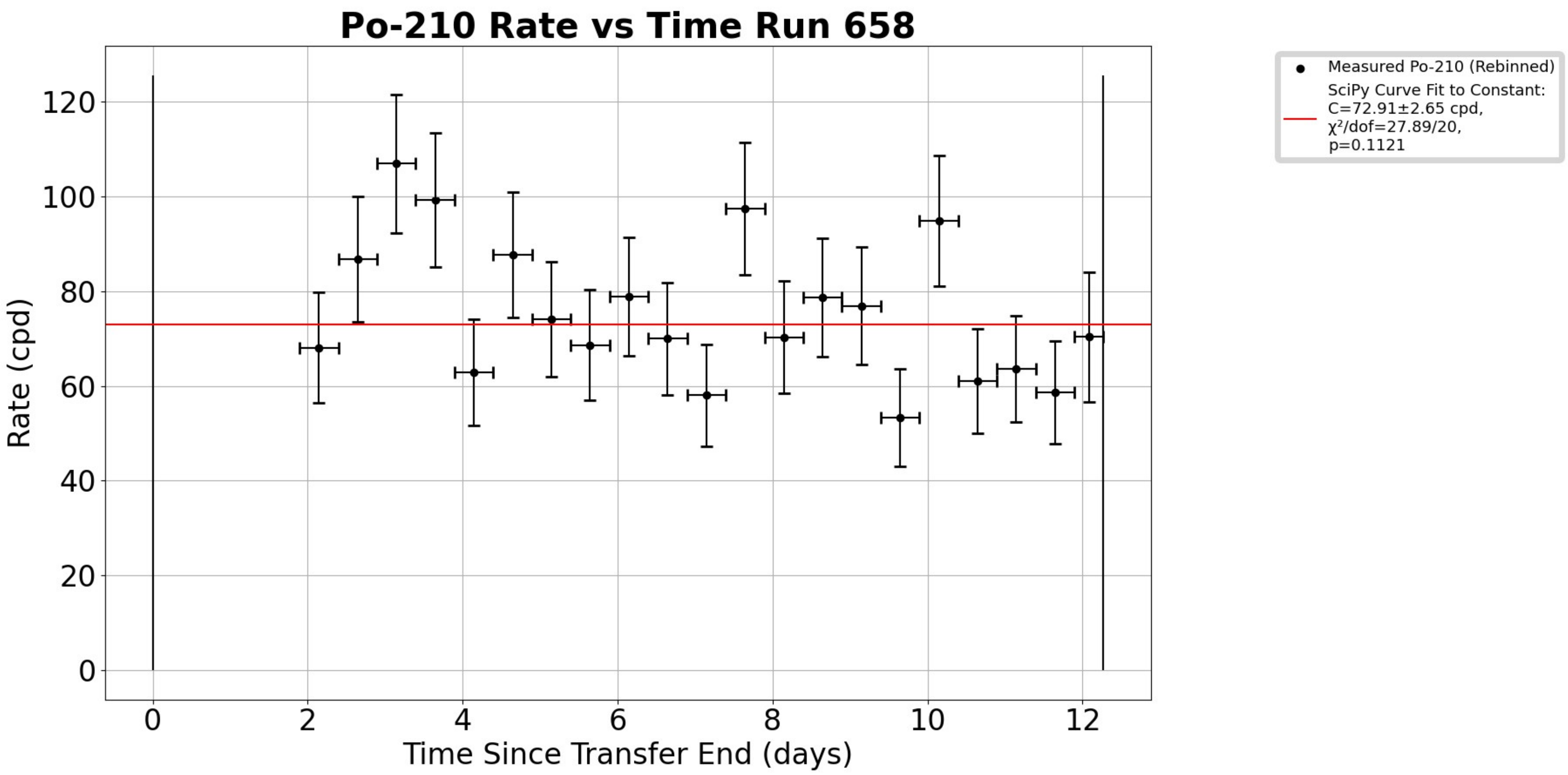
Run 658 Combined NLL



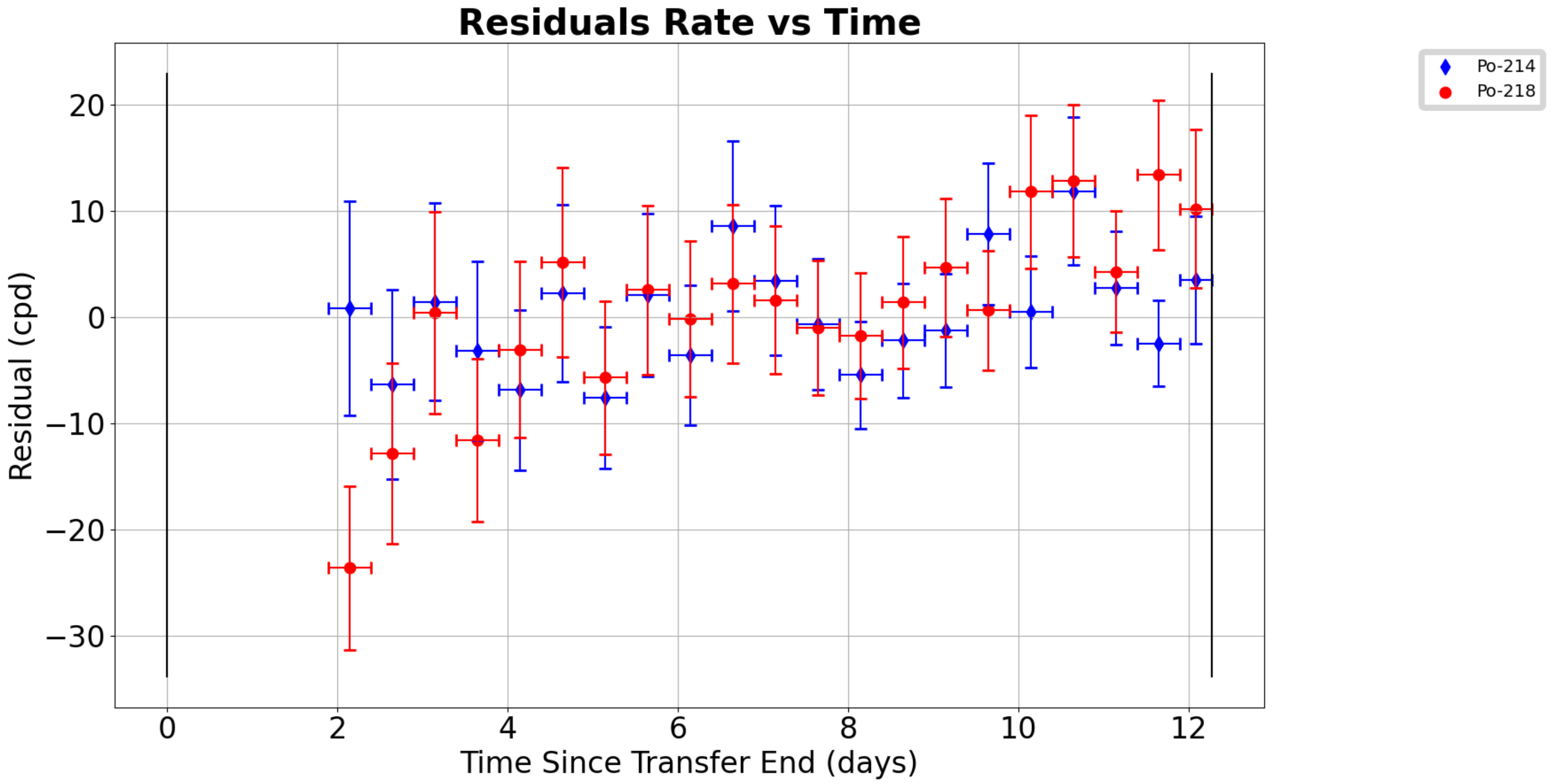
Run 658 Rate vs Time



Run 658 Po-210 Rate vs Time

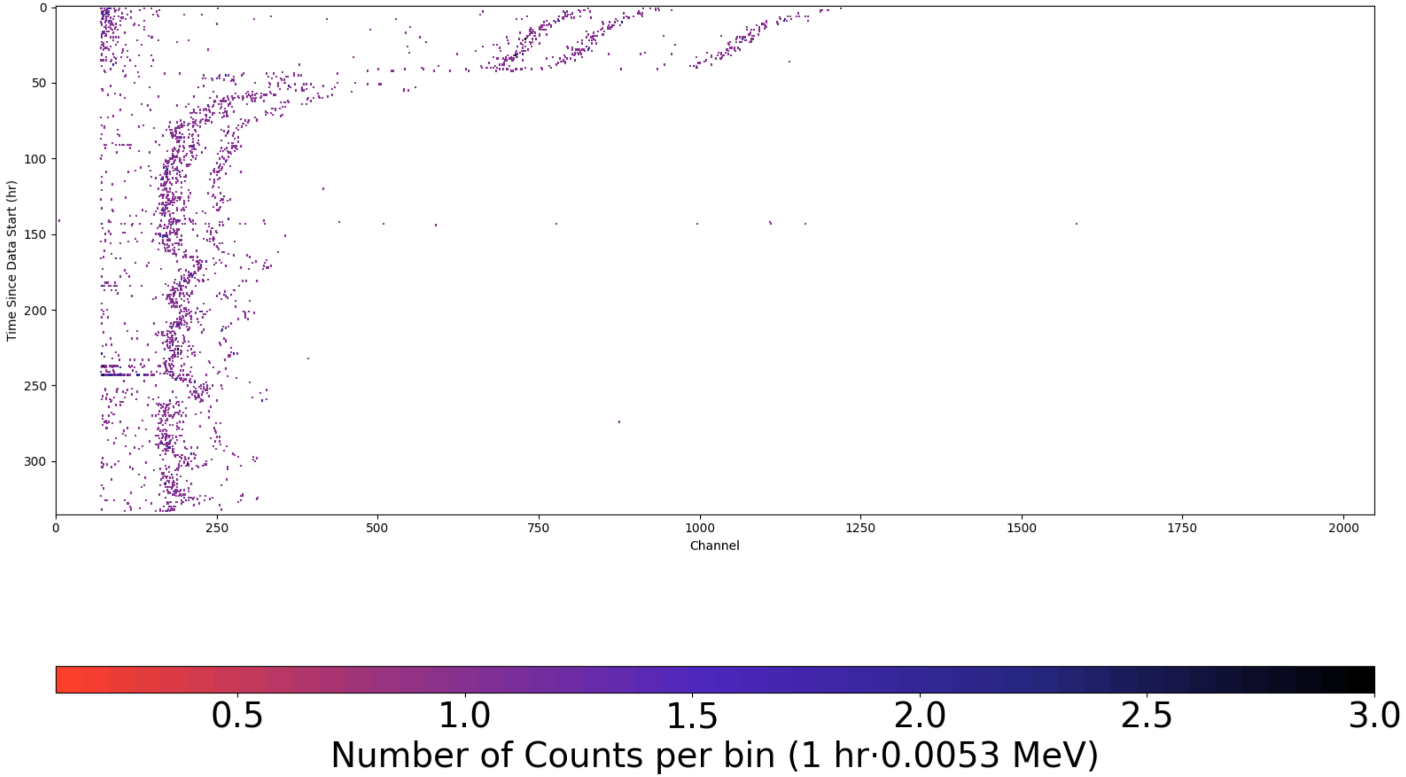


Run 658 Residuals

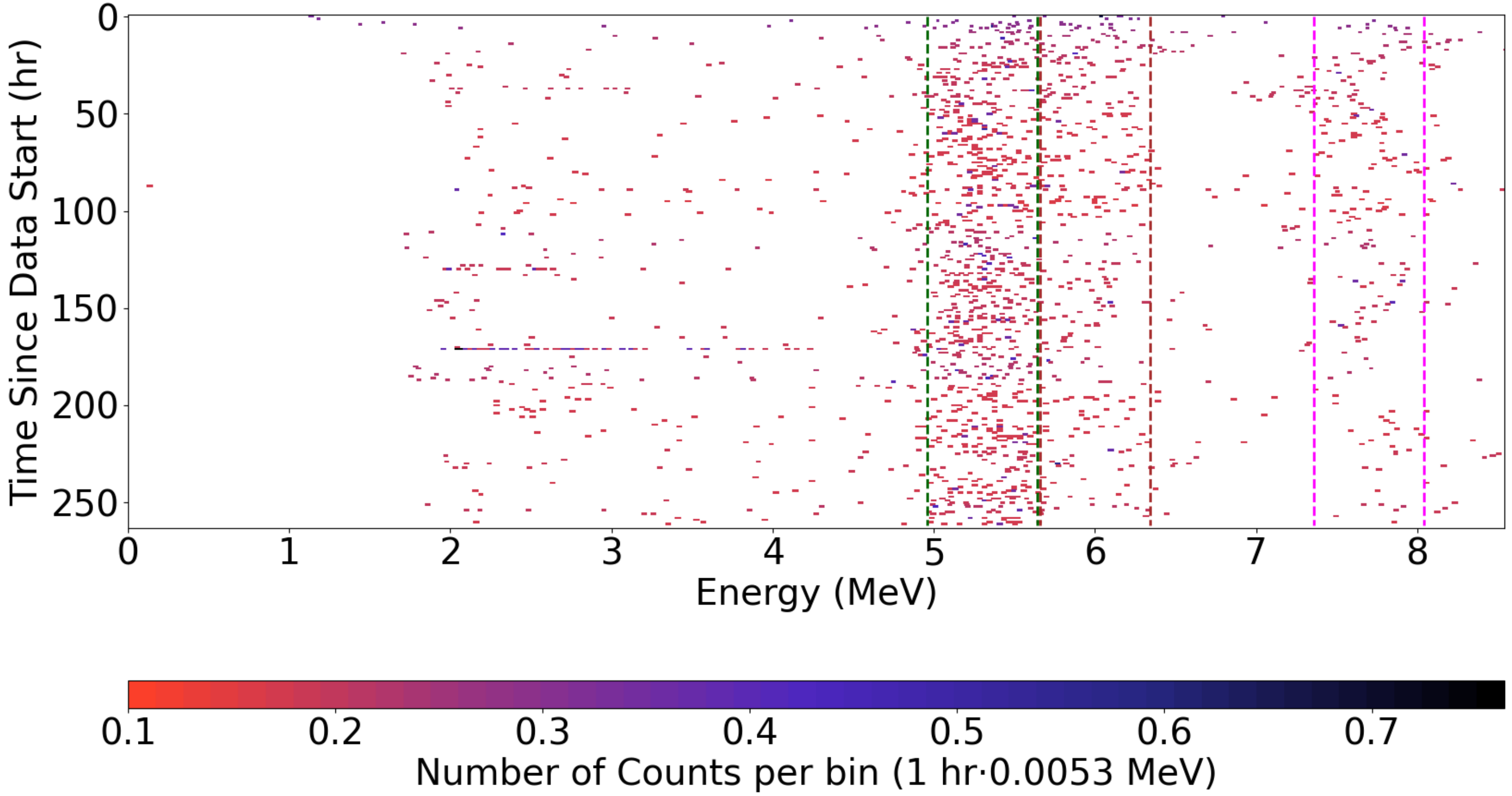


Run 660 Plots

Run 660 Raw Data

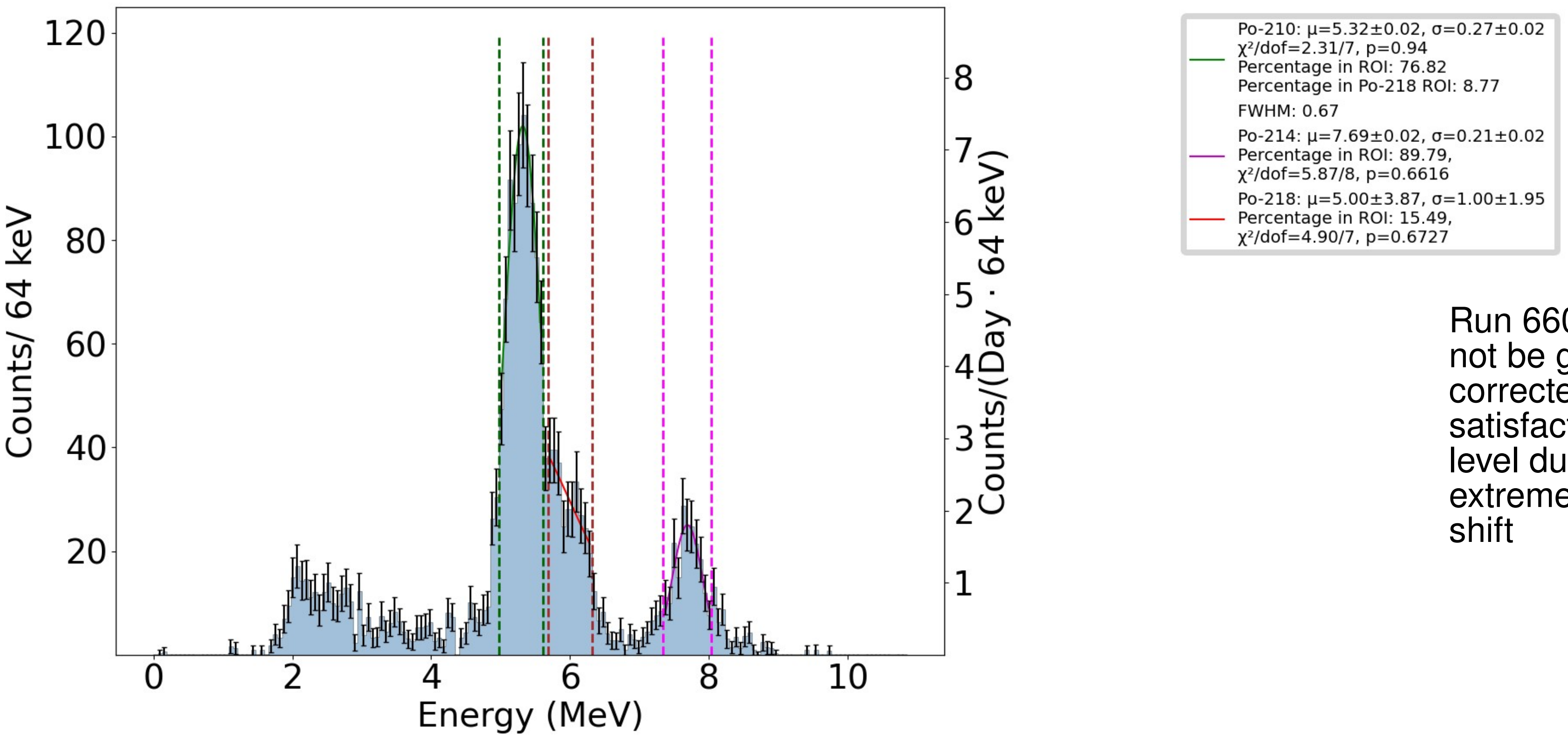


Run 660 Gain Corrected Data



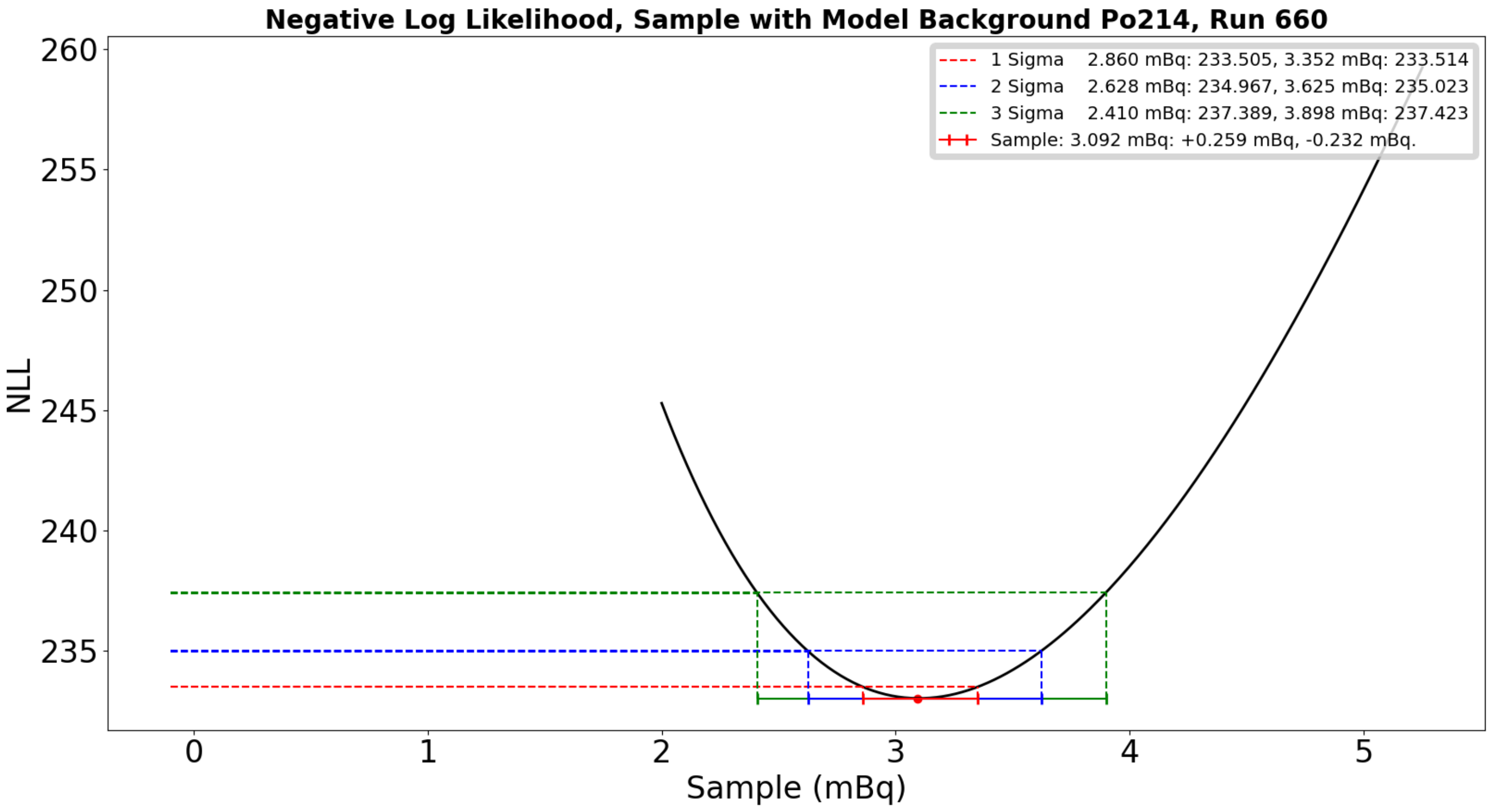
Run 660 could not be gain corrected to a satisfactory level due to extreme gain shift

Run 660 Counts vs Energy



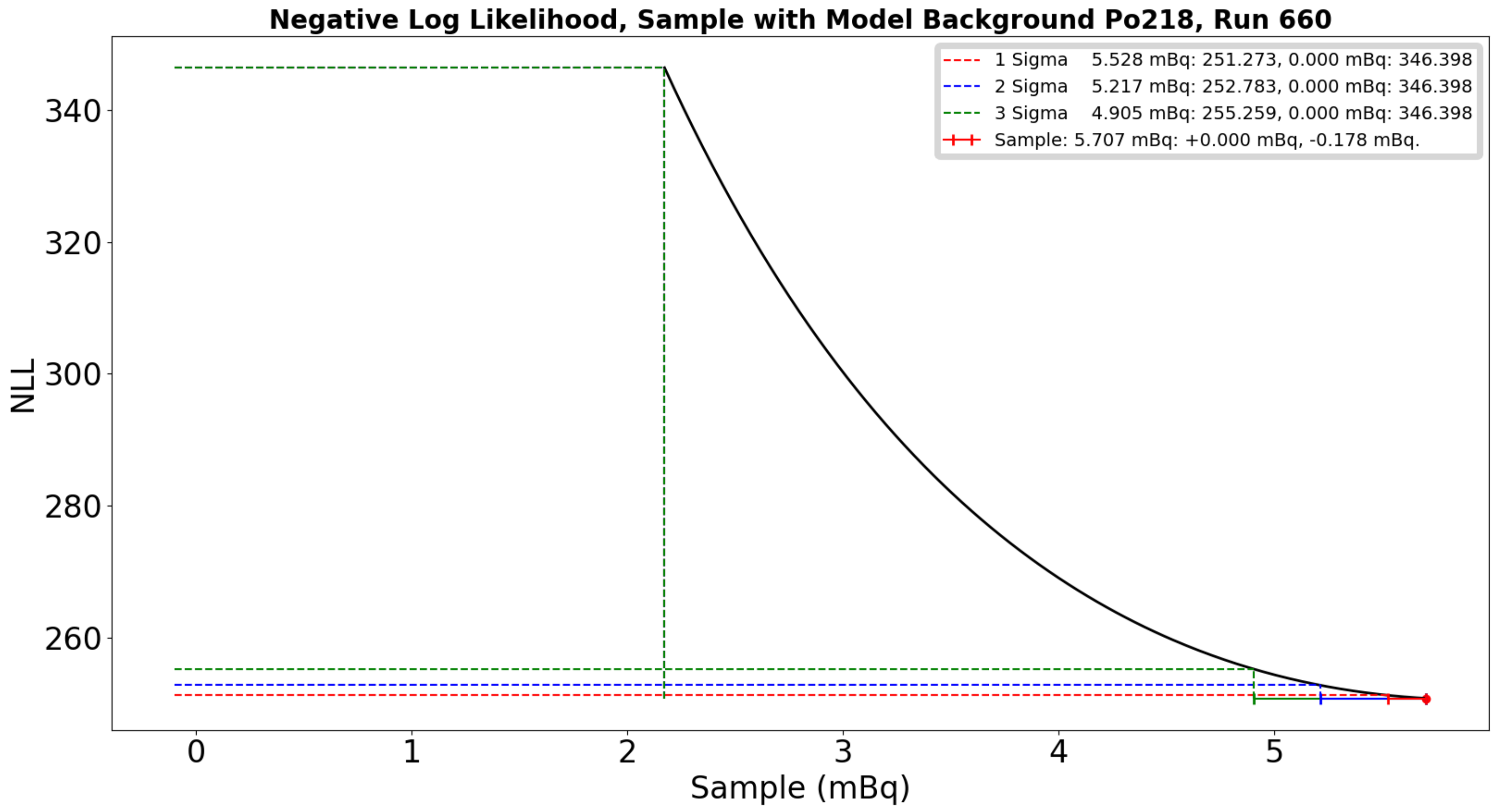
Run 660 could not be gain corrected to a satisfactory level due to extreme gain shift

Run 660 Po-214 NLL



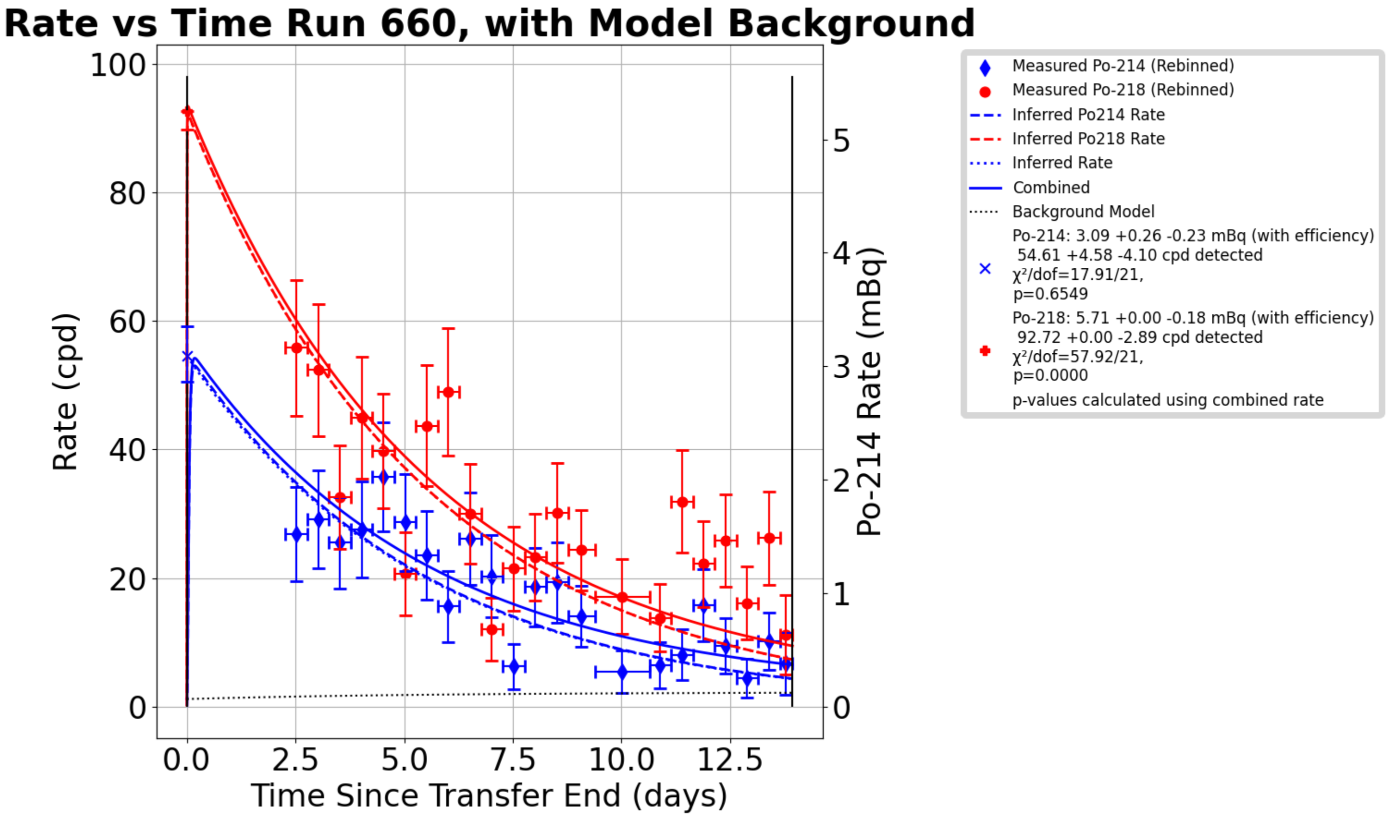
Run 660 could not be gain corrected to a satisfactory level due to extreme gain shift

Run 660 Po-218 NLL



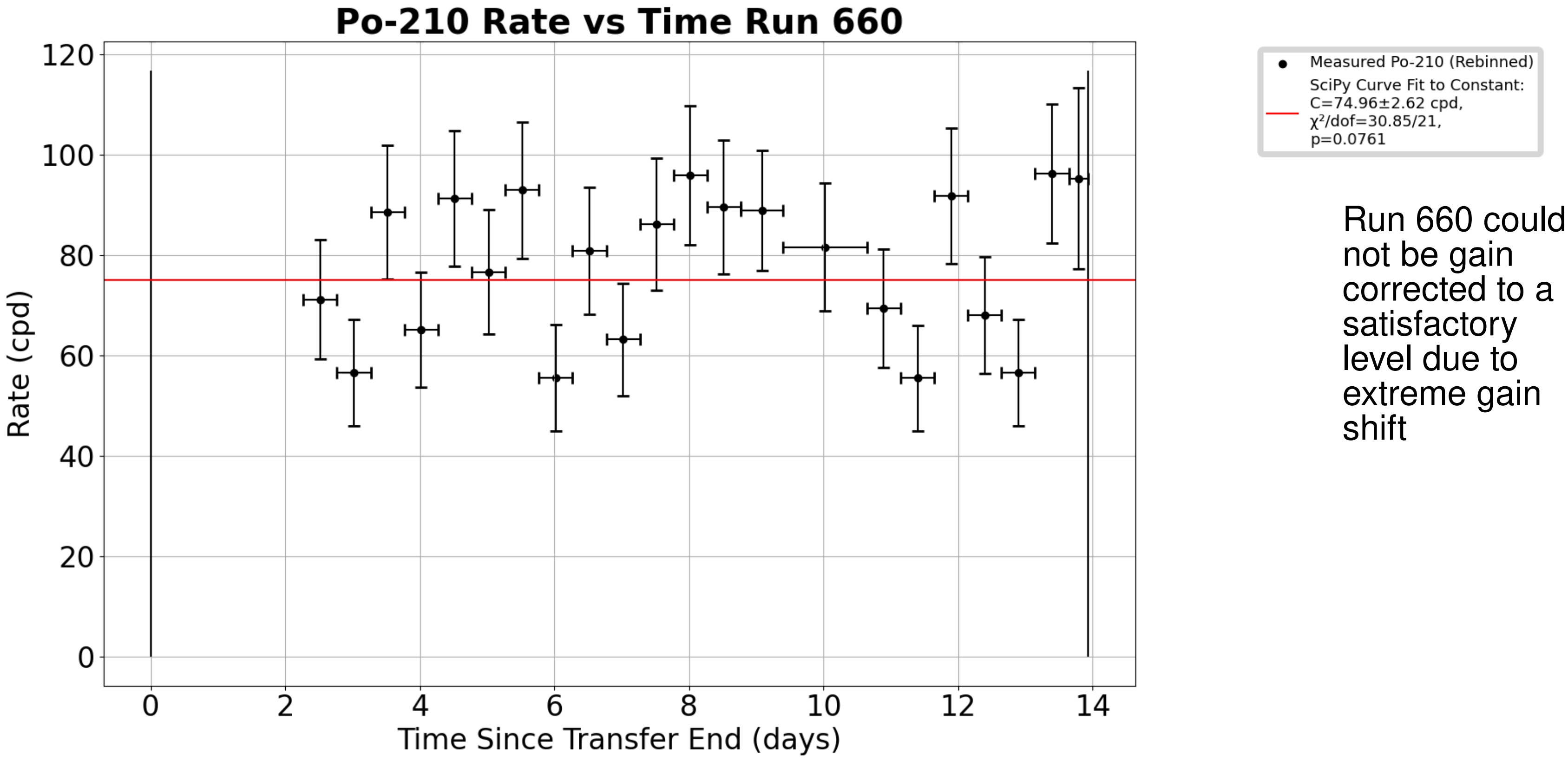
Run 660 could not be gain corrected to a satisfactory level due to extreme gain shift

Run 660 Rate vs Time



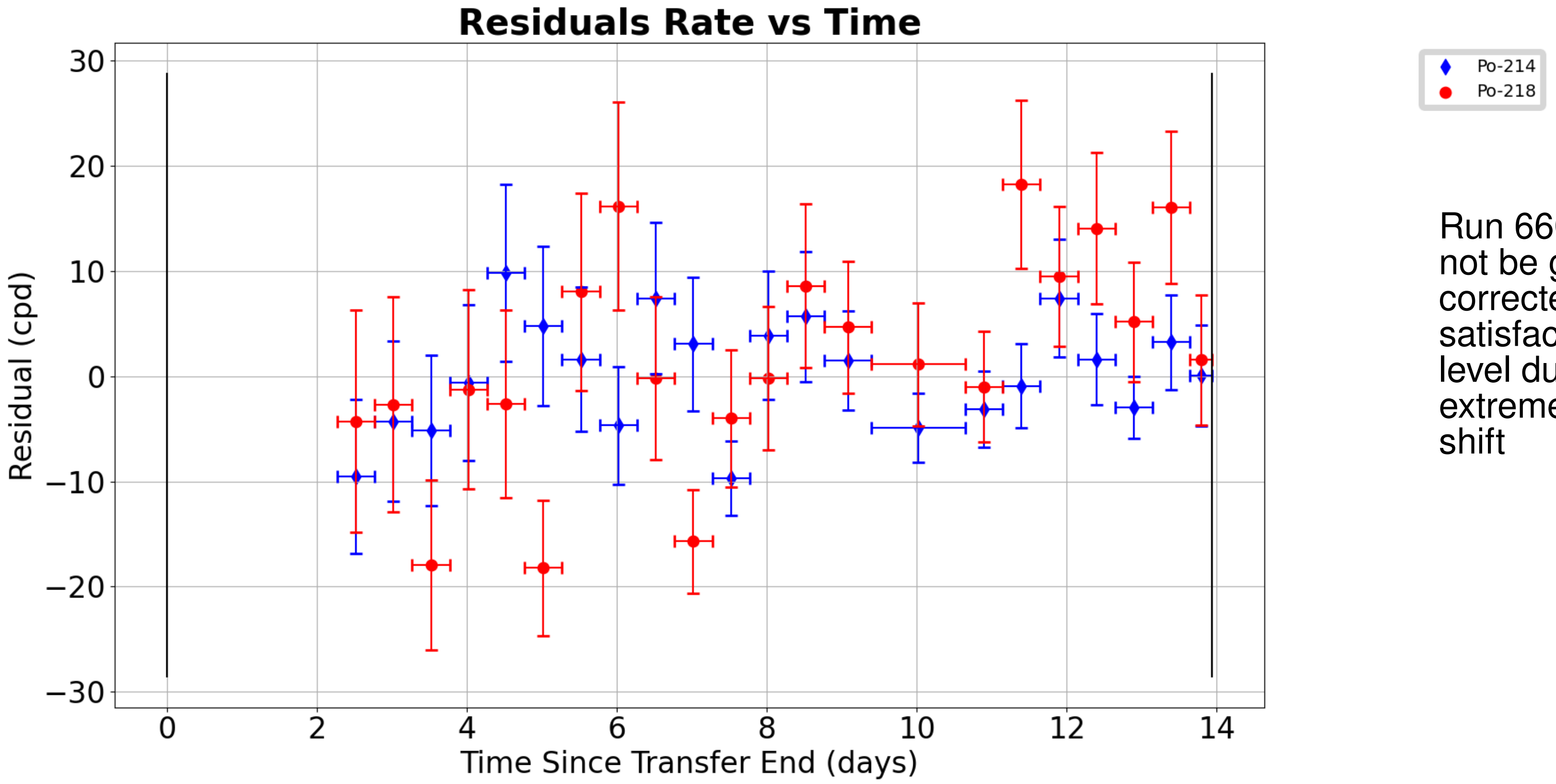
Run 660 could not be gain corrected to a satisfactory level due to extreme gain shift

Run 660 Po-210 Rate vs Time



Run 660 could not be gain corrected to a satisfactory level due to extreme gain shift

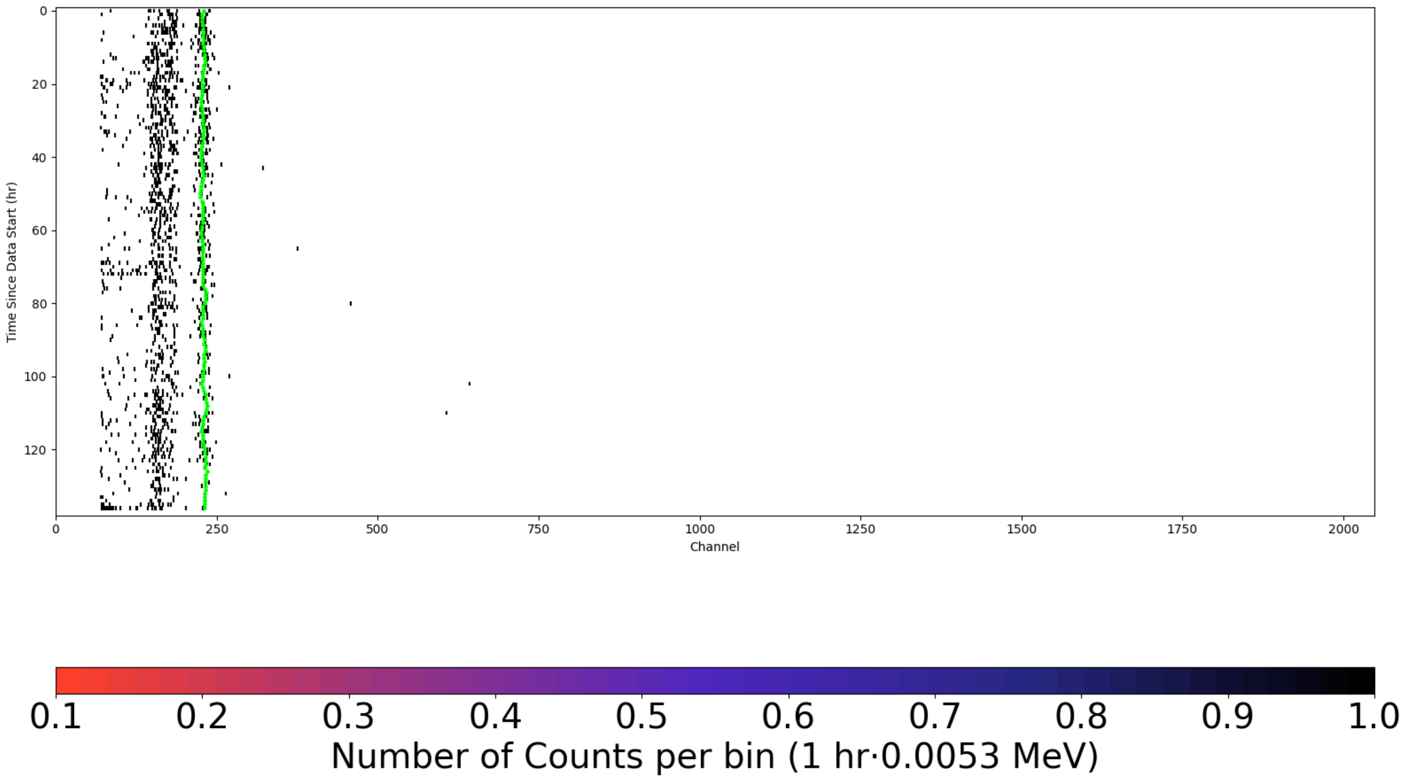
Run 660 Residuals



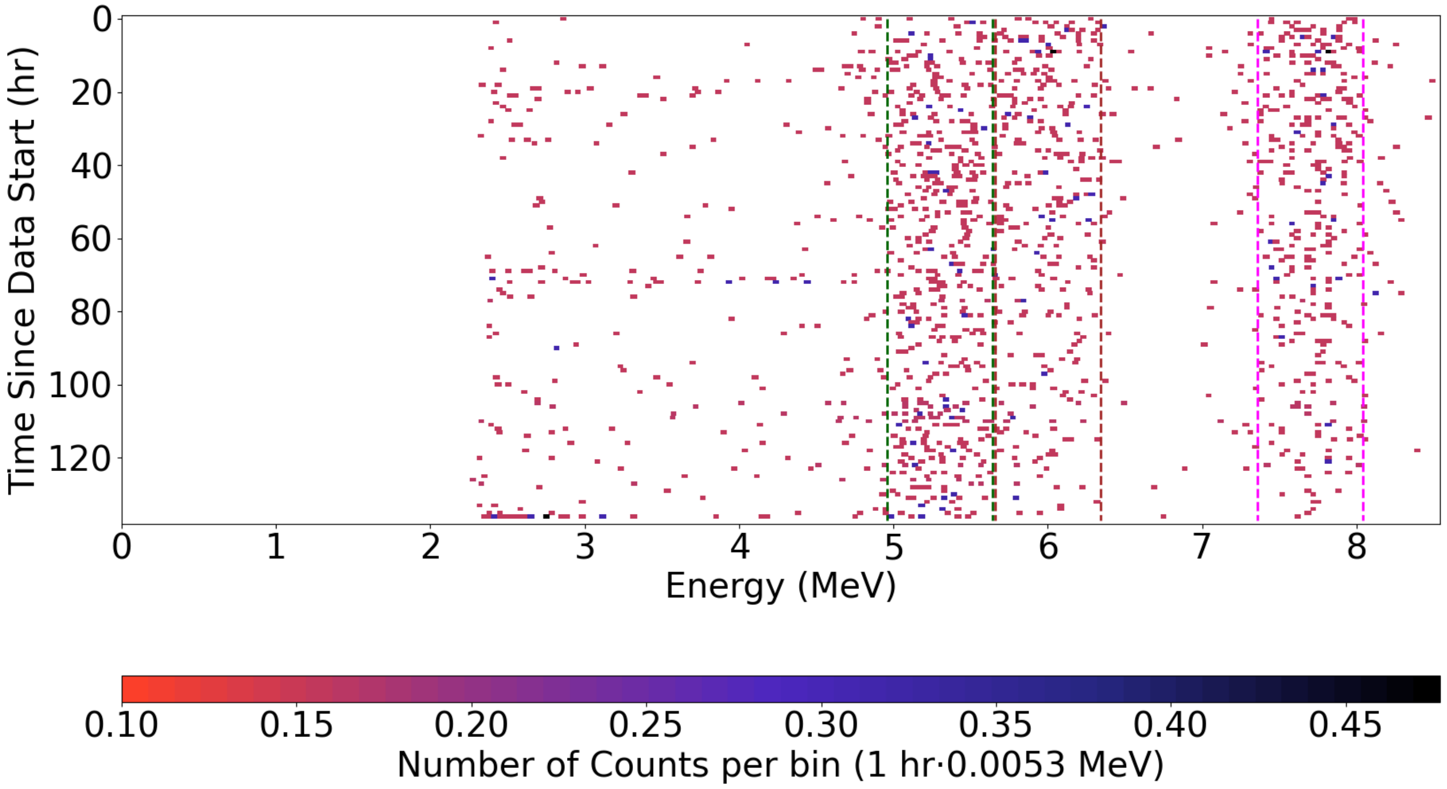
Run 660 could not be gain corrected to a satisfactory level due to extreme gain shift

Run 663 Plots

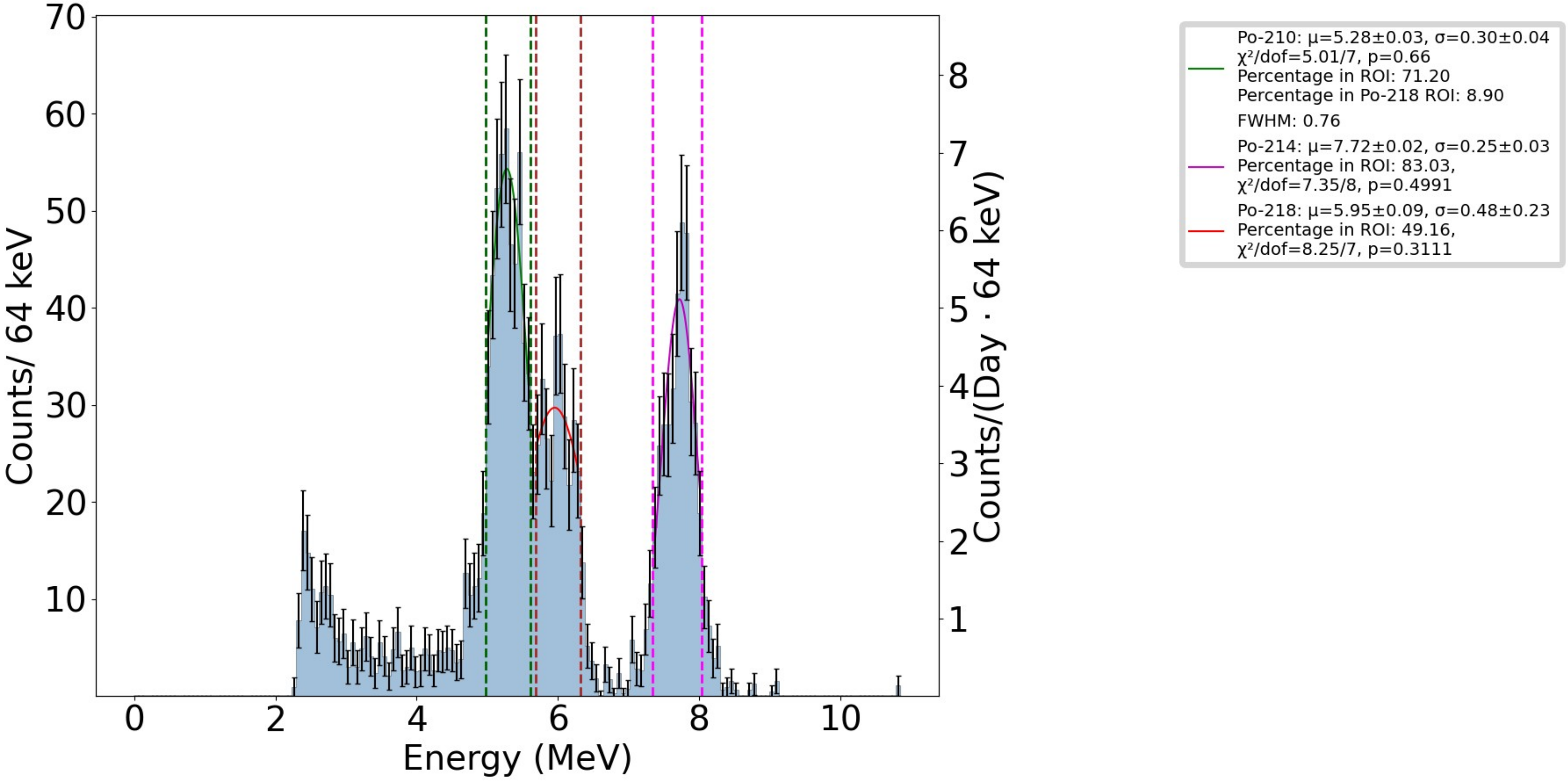
Run 663 Raw Data



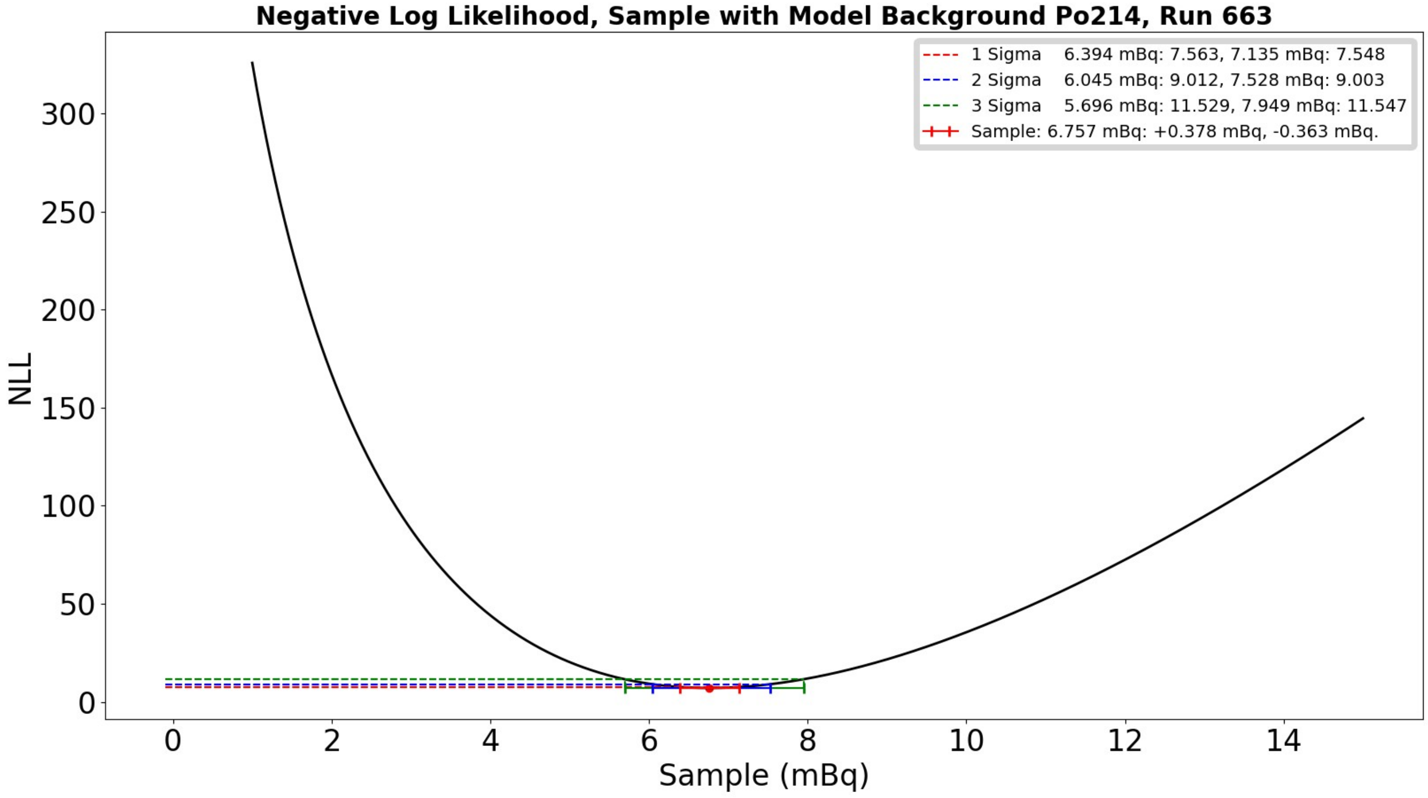
Run 663 Gain Corrected Data



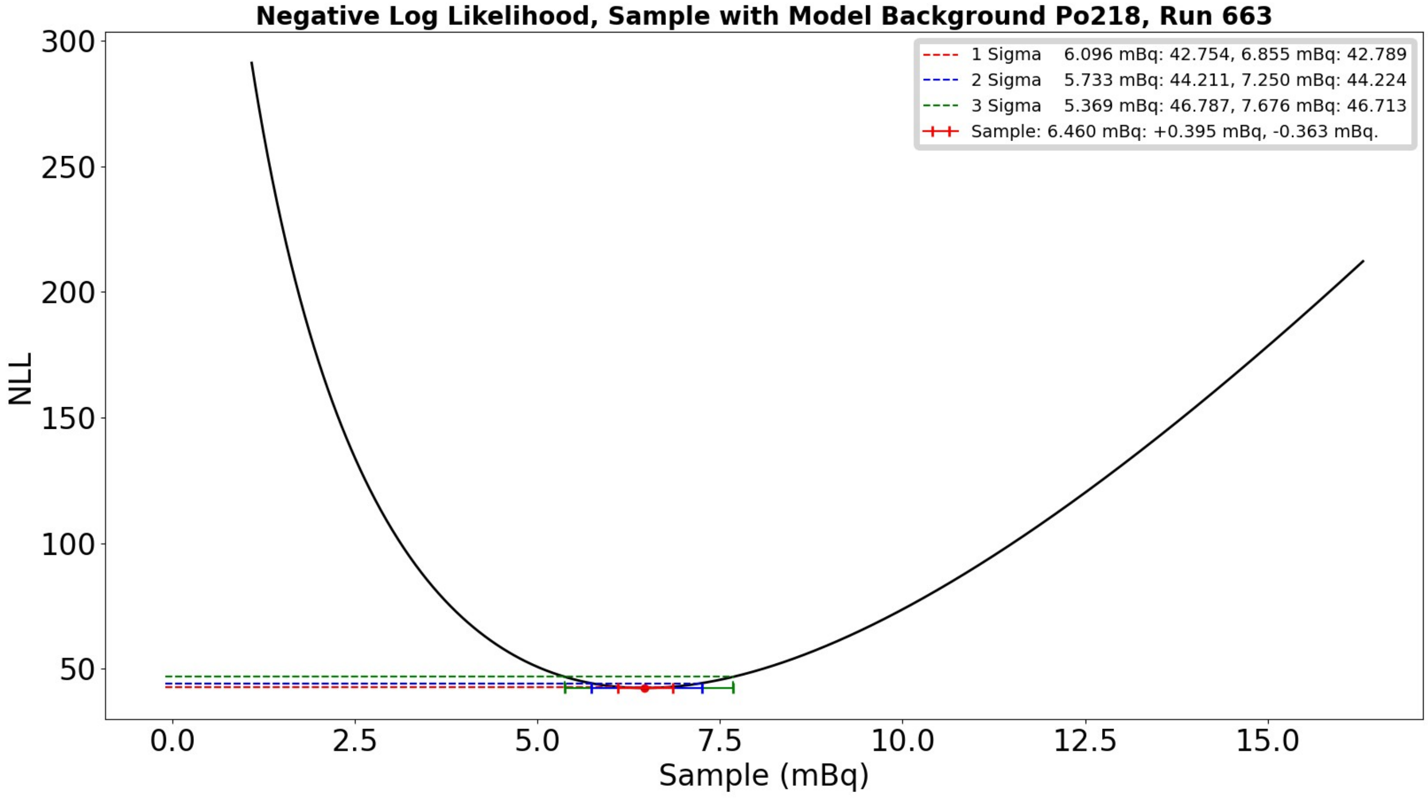
Run 663 Counts vs Energy



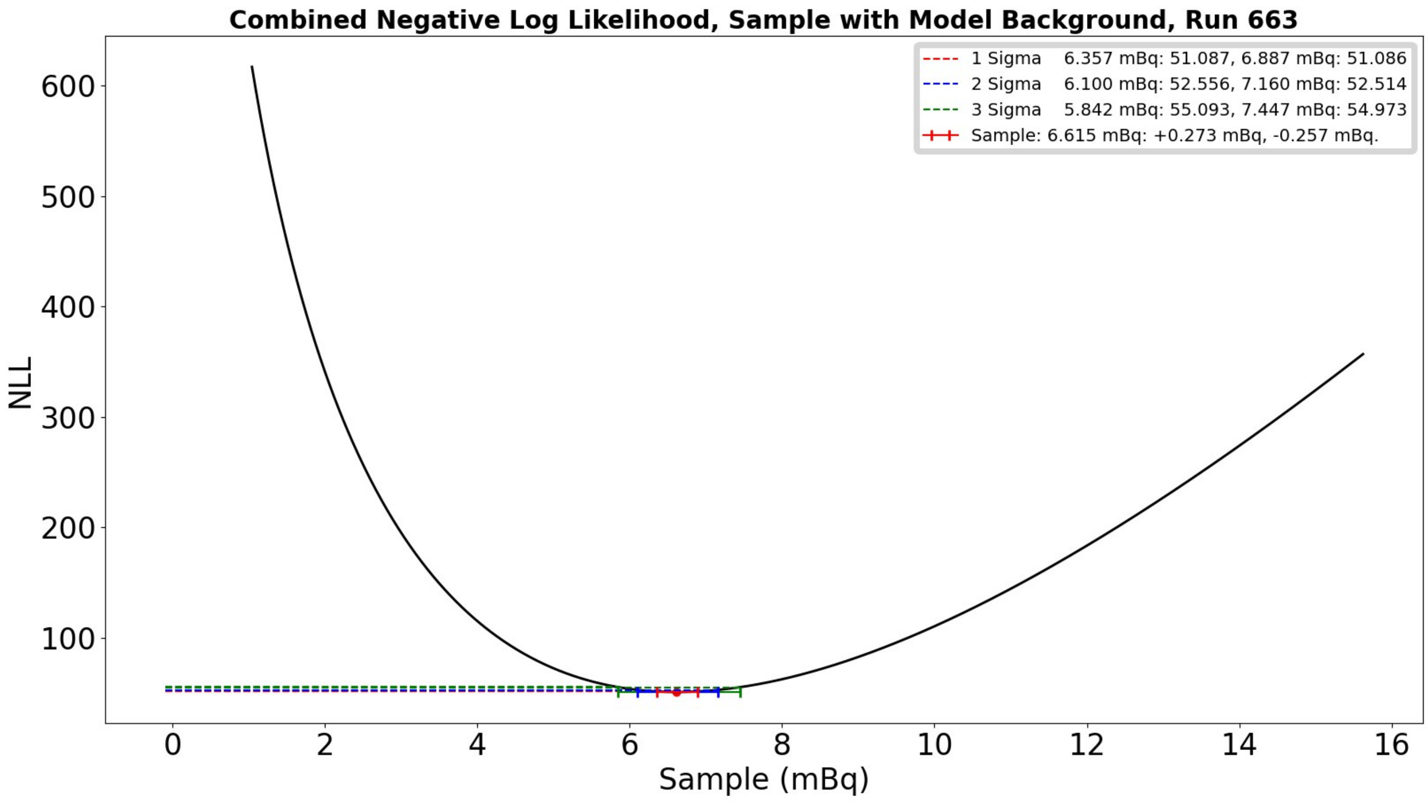
Run 663 Po-214 NLL



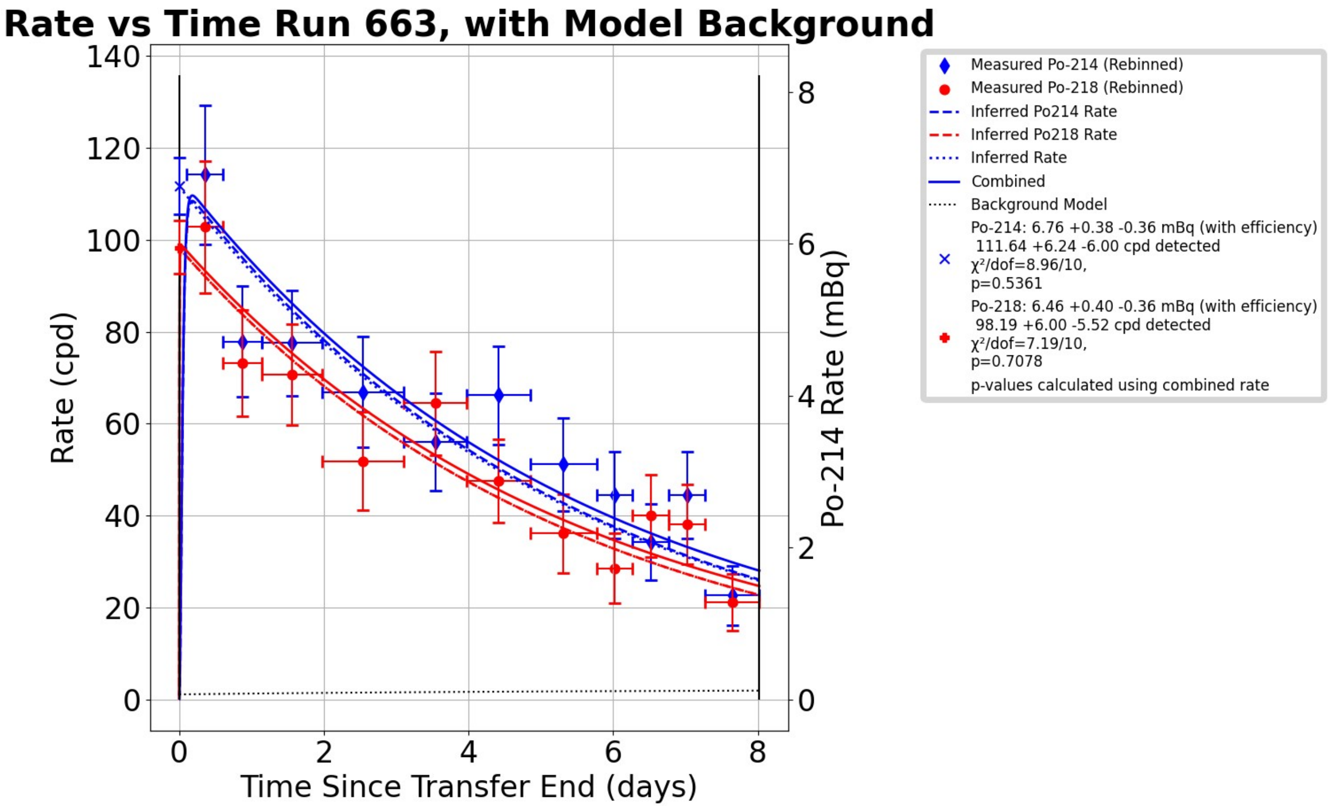
Run 663 Po-218 NLL



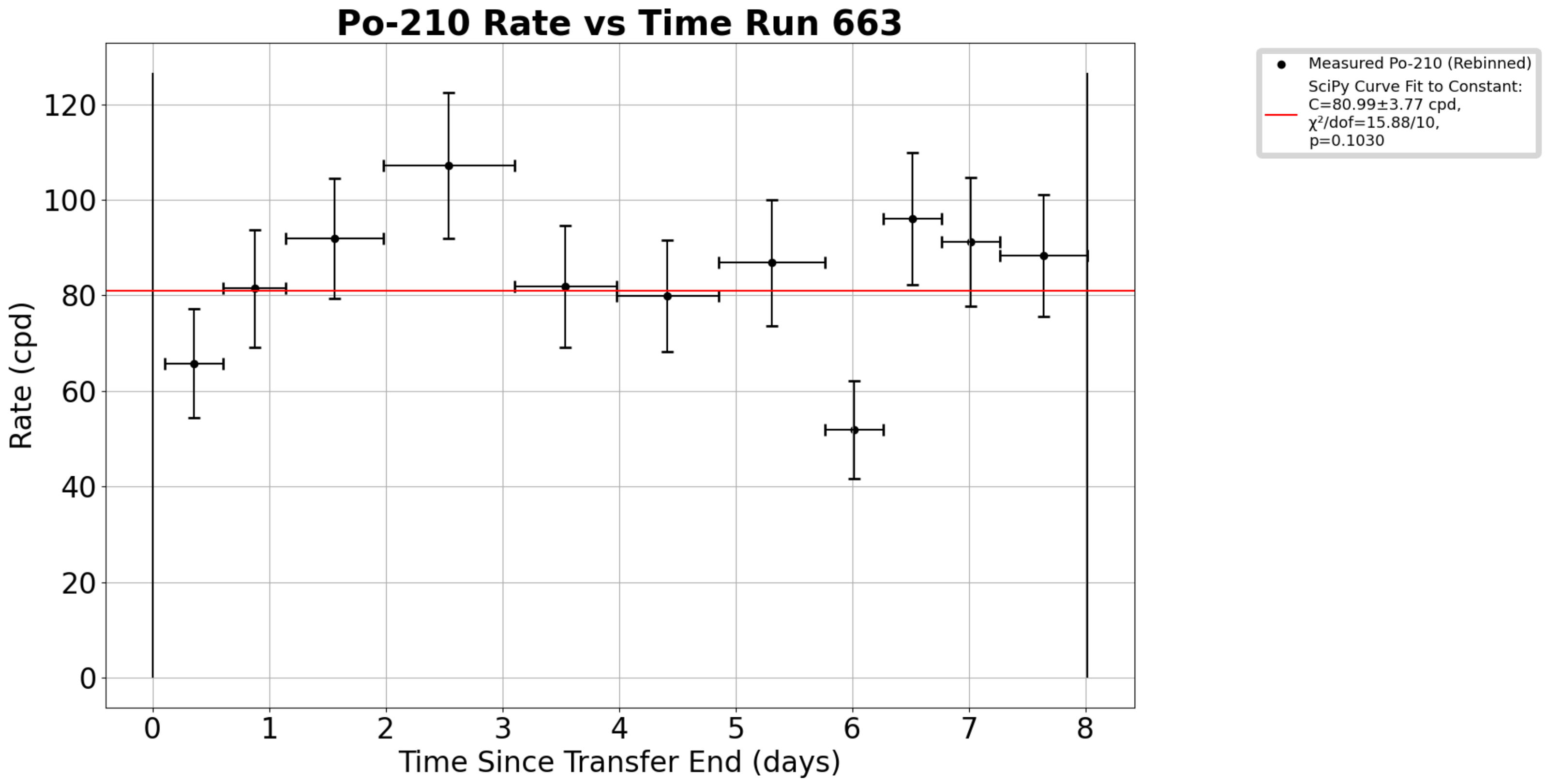
Run 663 Combined NLL



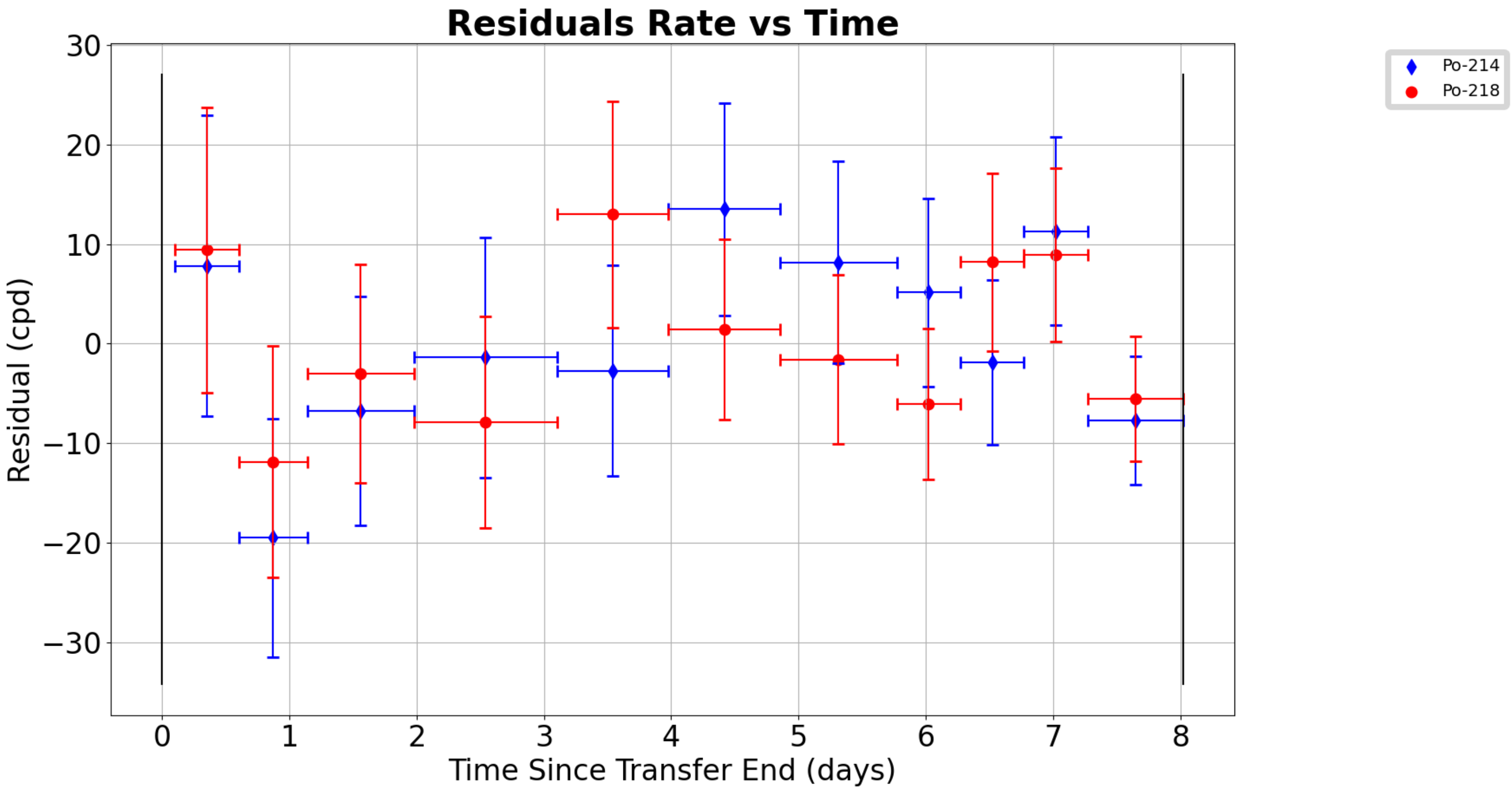
Run 663 Rate vs Time



Run 663 Po-210 Rate vs Time

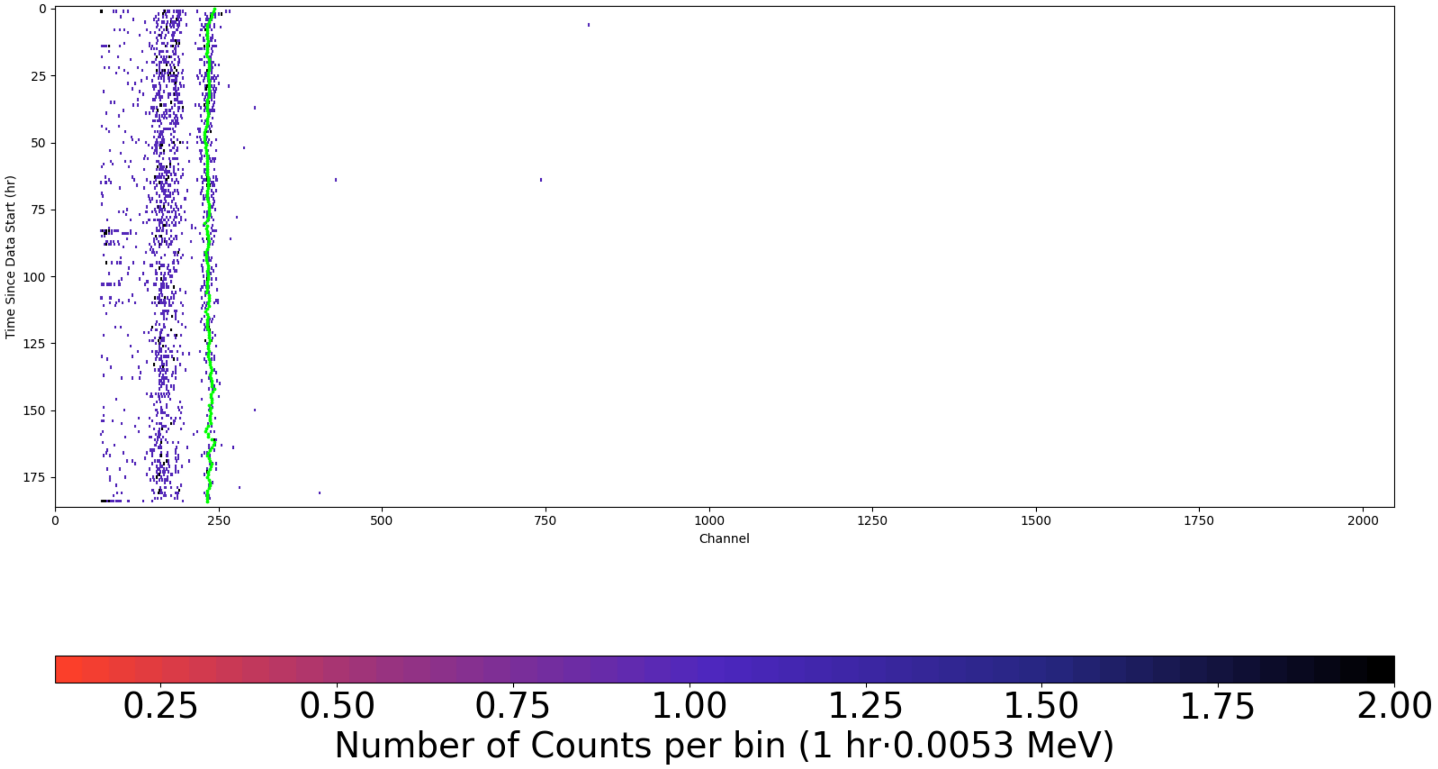


Run 663 Residuals

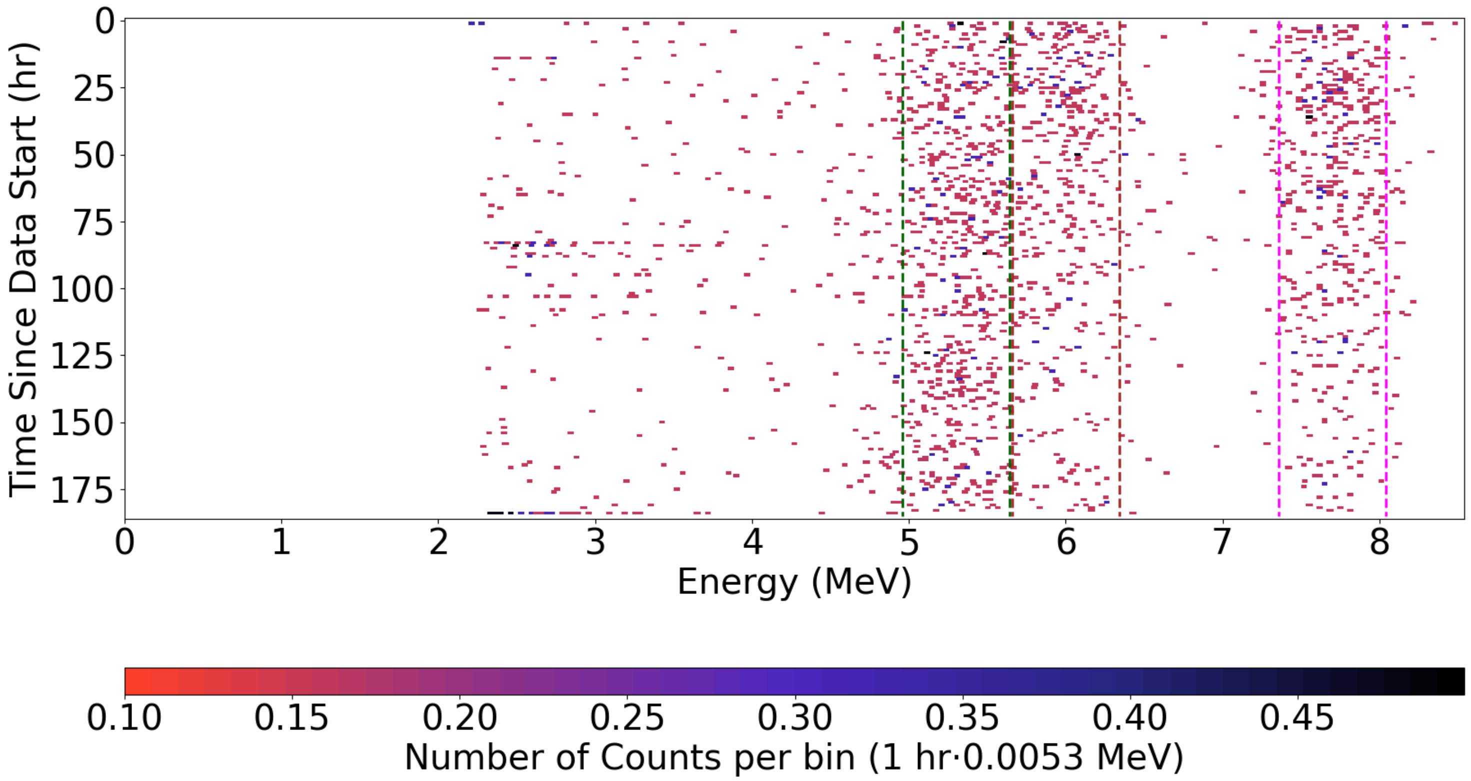


Run 666 Plots

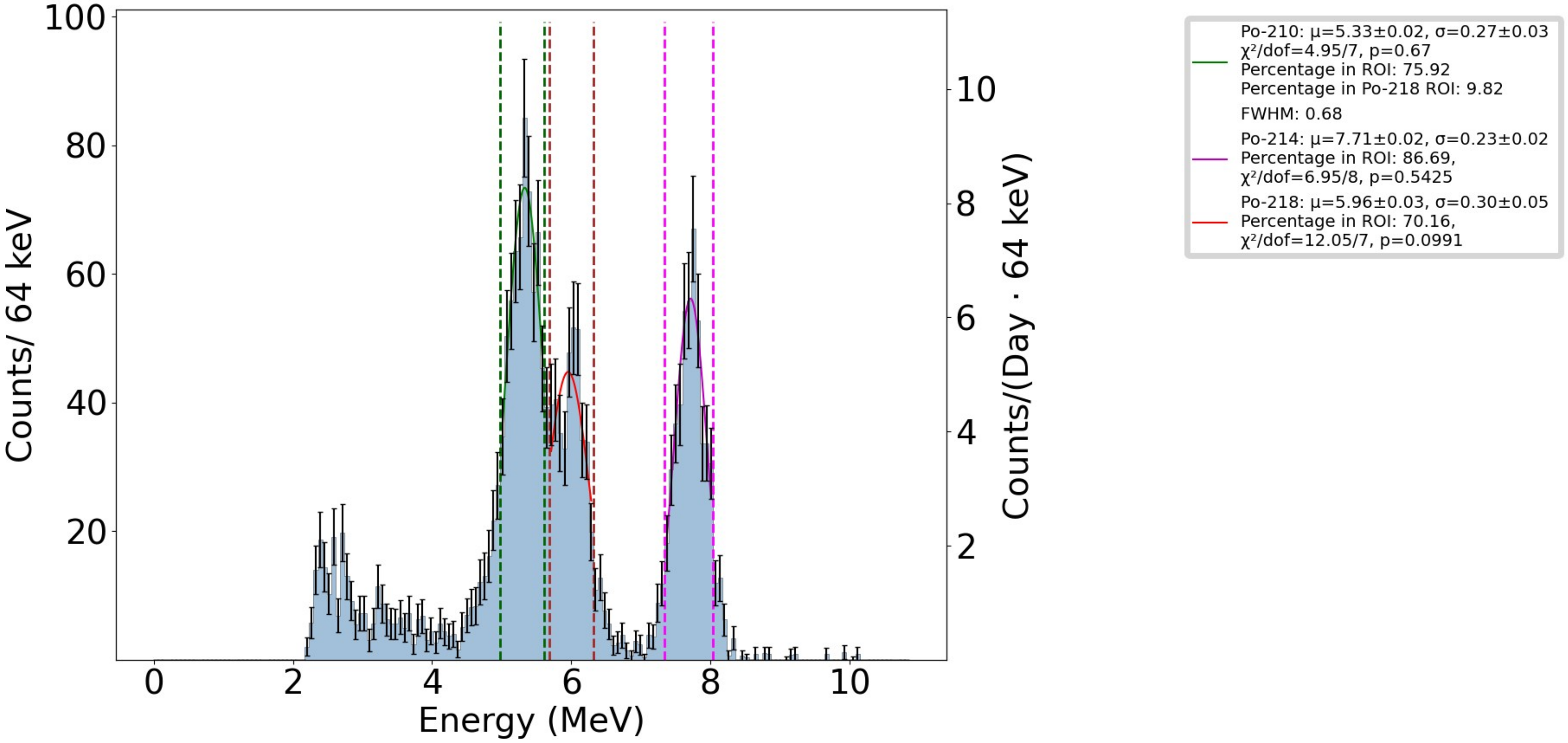
Run 666 Raw Data



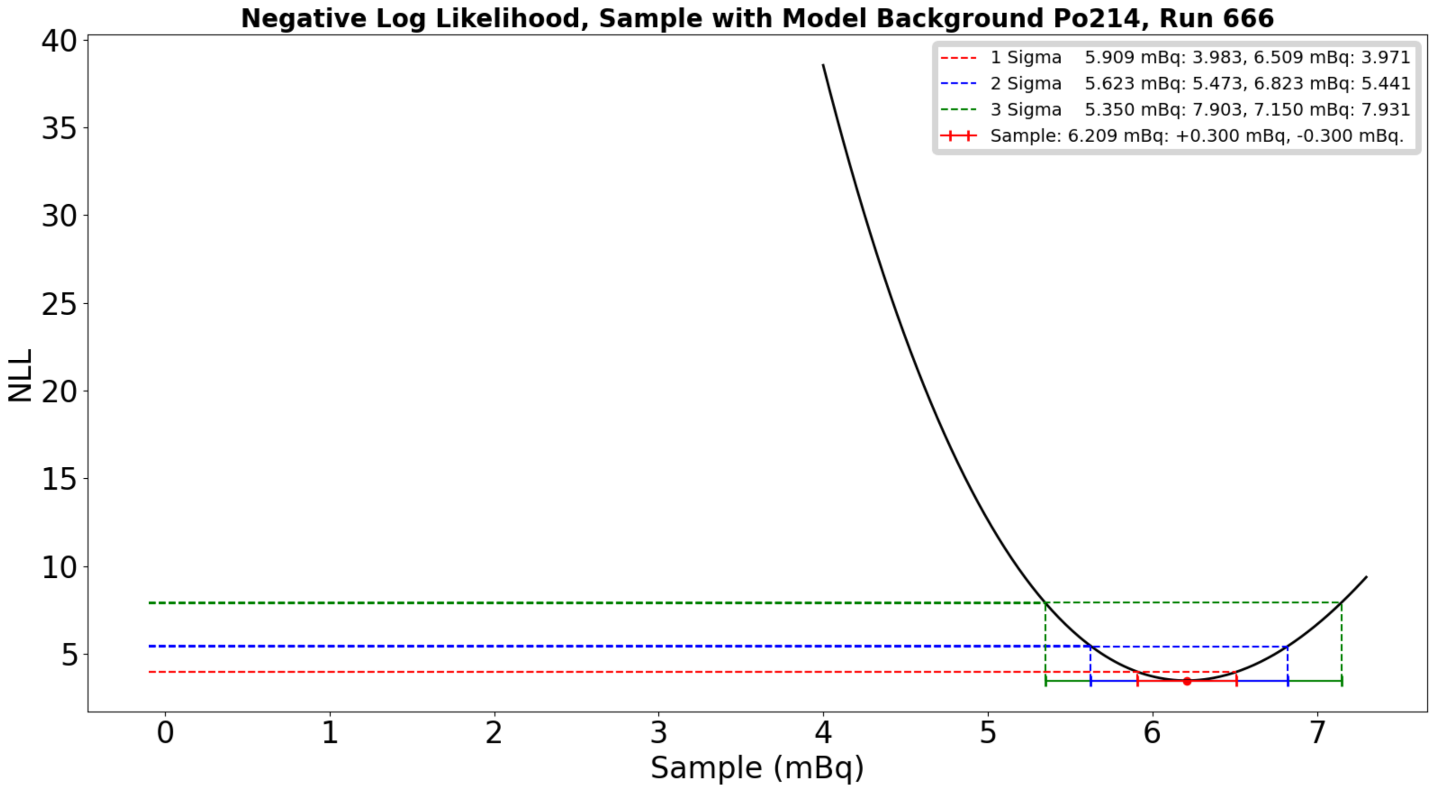
Run 666 Gain Corrected Data



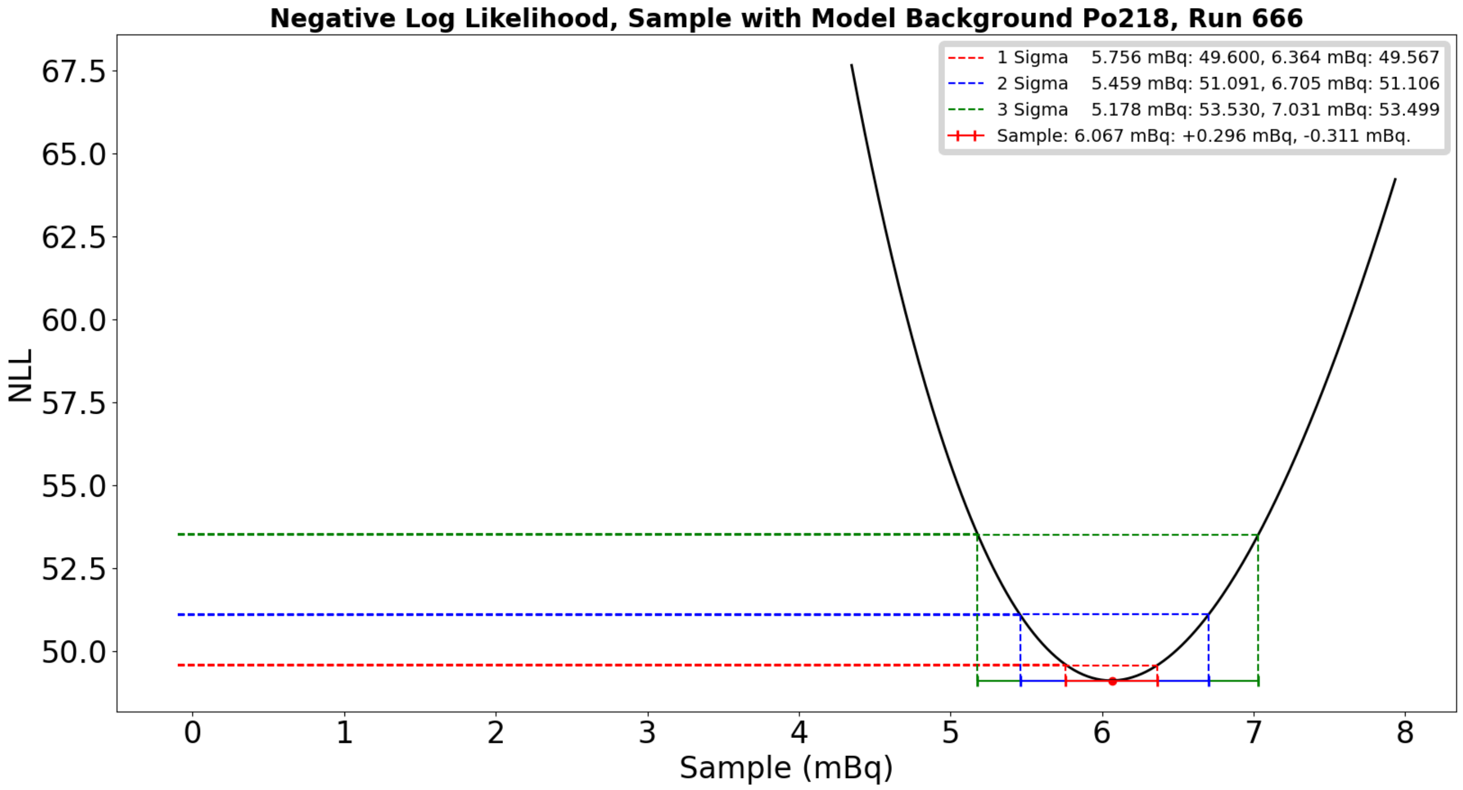
Run 666 Counts vs Energy



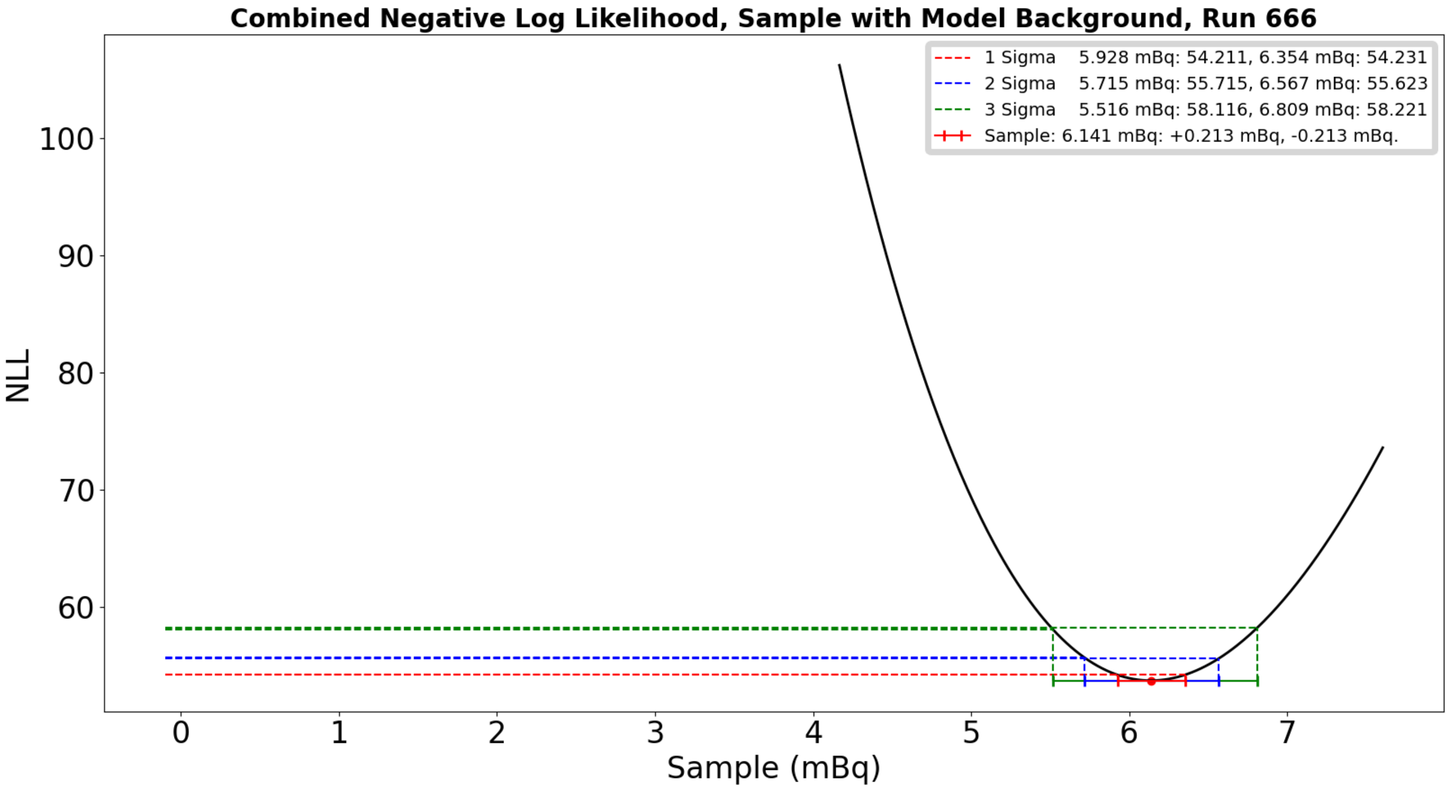
Run 666 Po-214 NLL



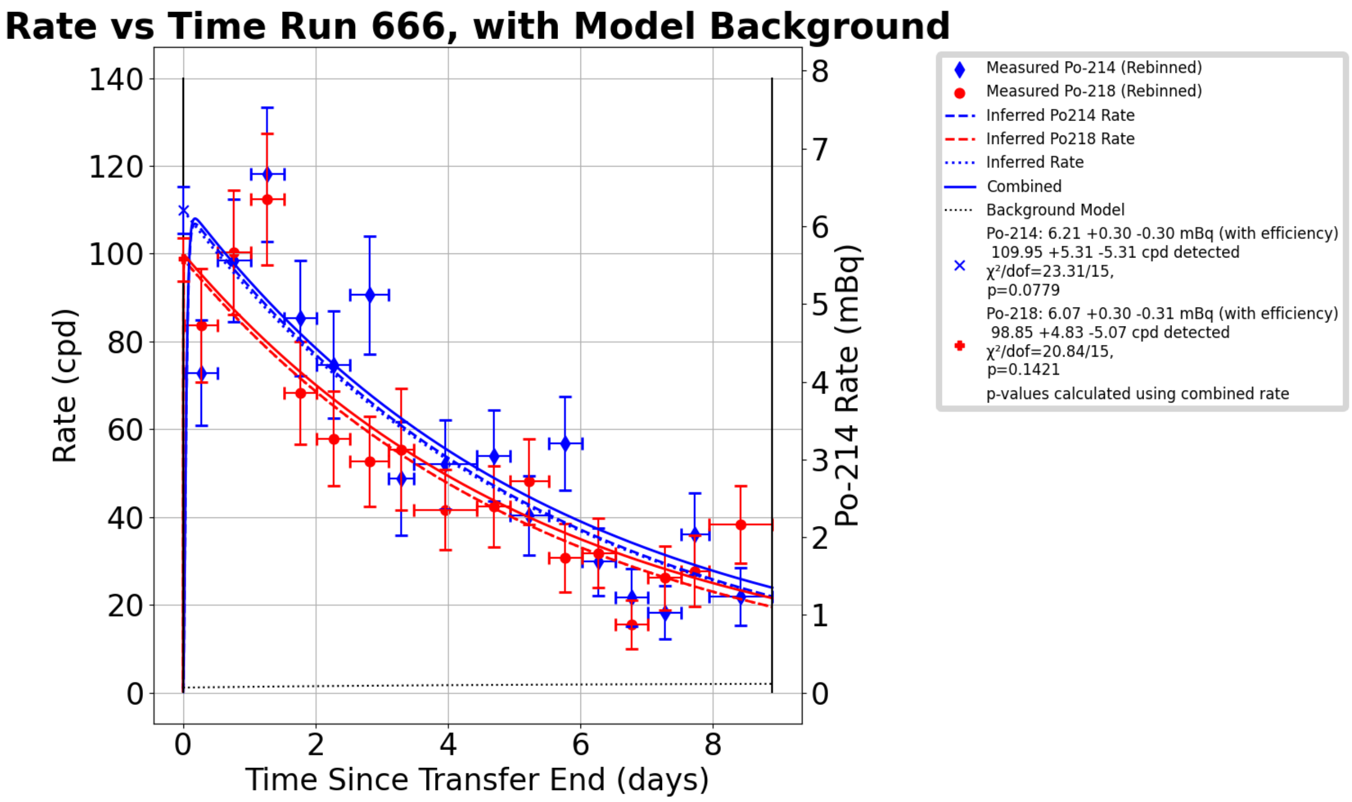
Run 666 Po-218 NLL



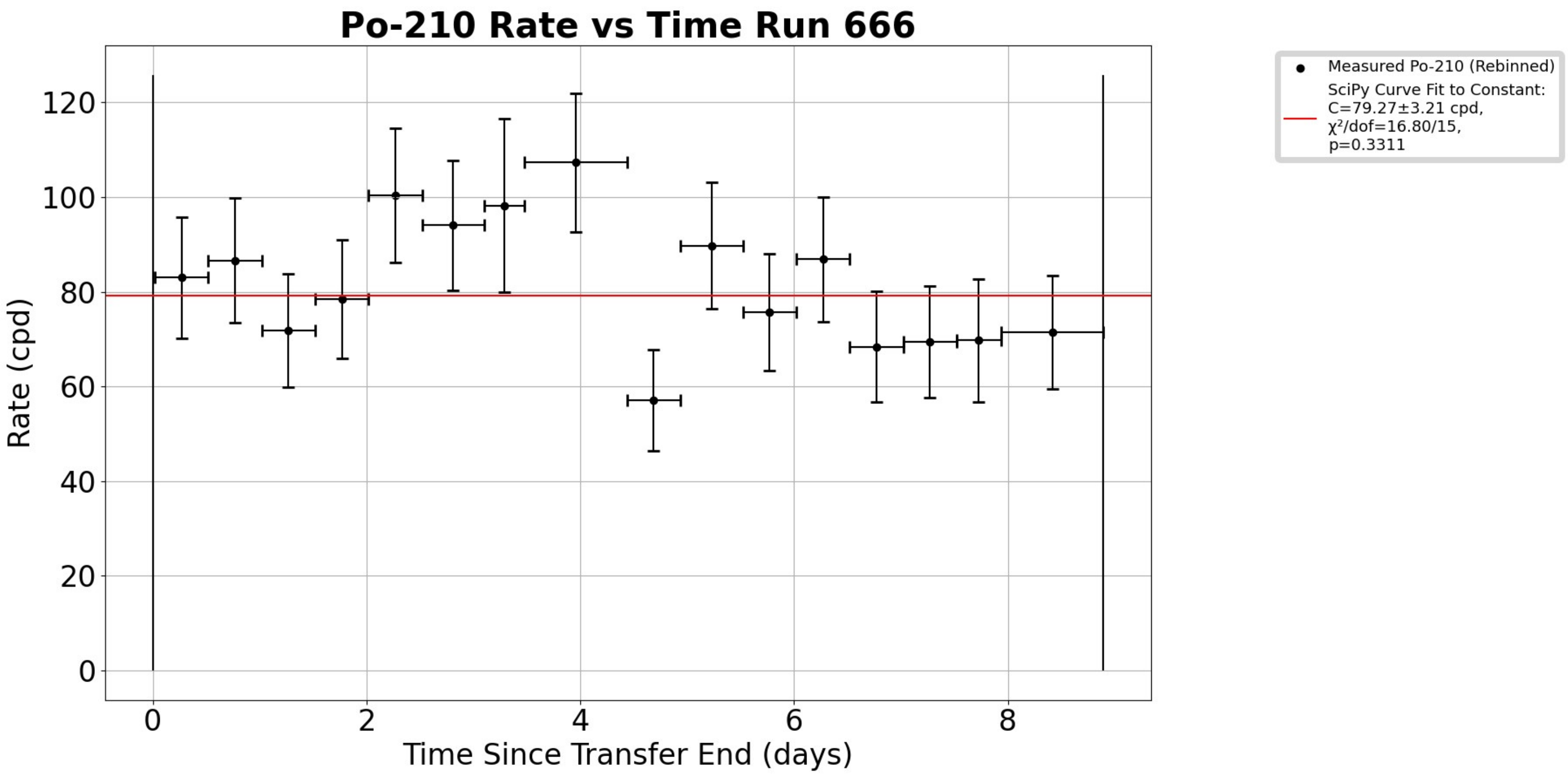
Run 666 Combined NLL



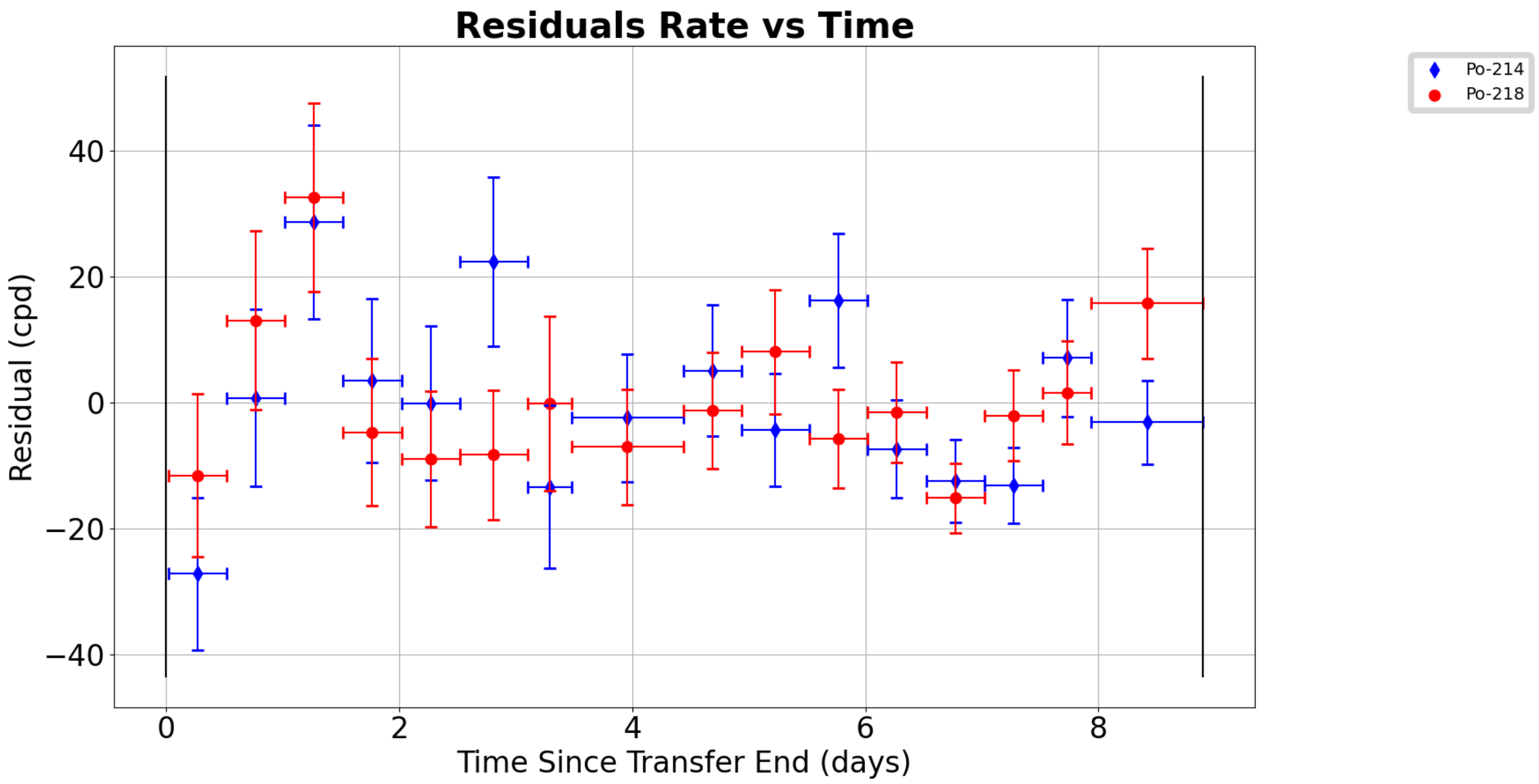
Run 666 Rate vs Time



Run 666 Po-210 Rate vs Time

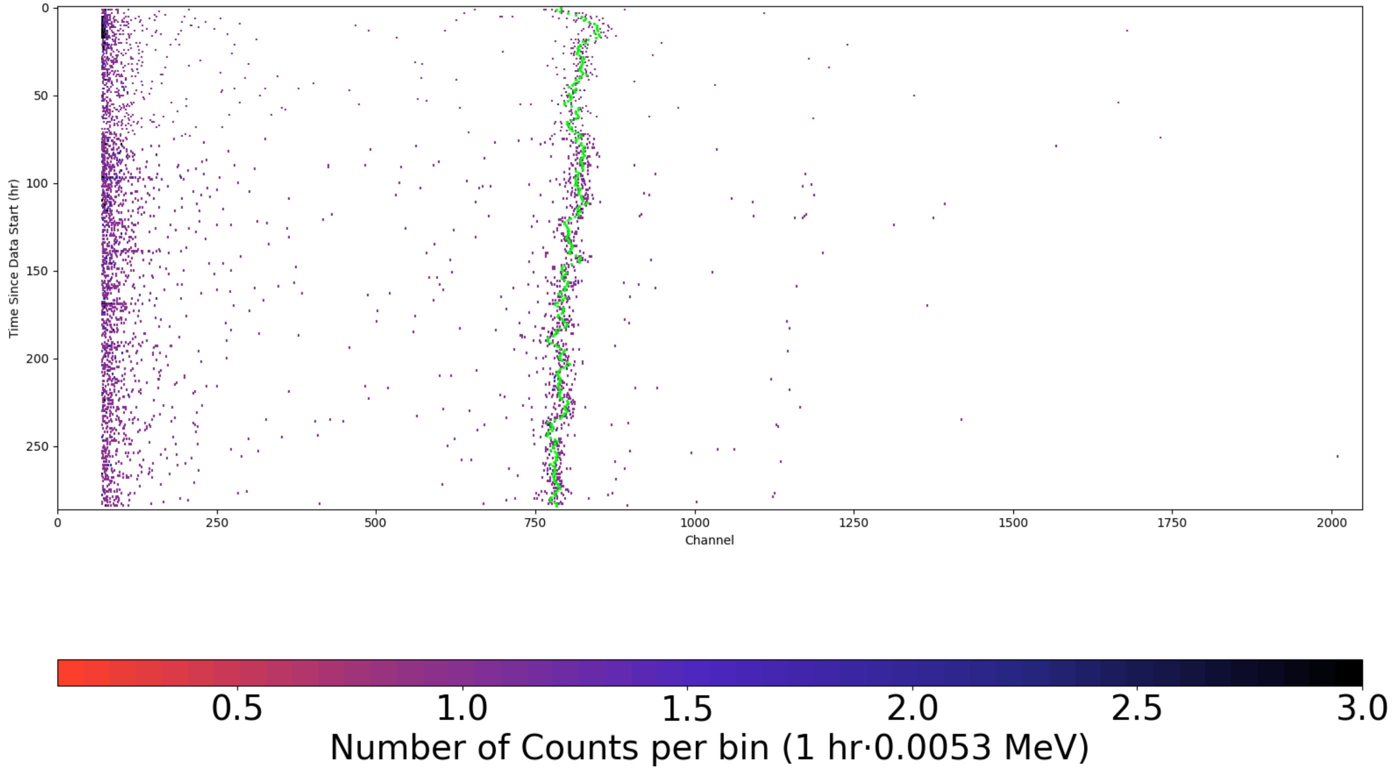


Run 666 Residuals



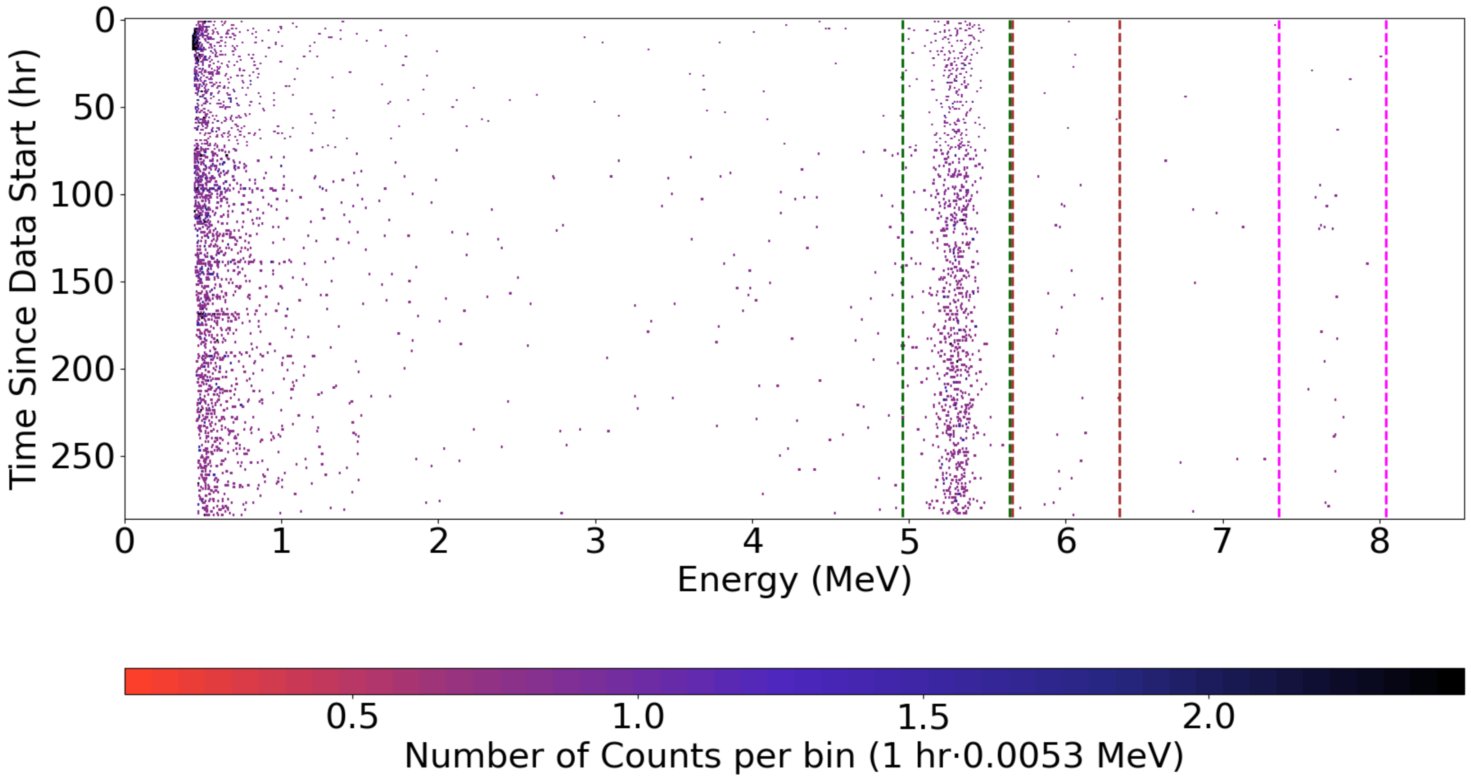
Run 668 Plots

Run 668 Raw Data

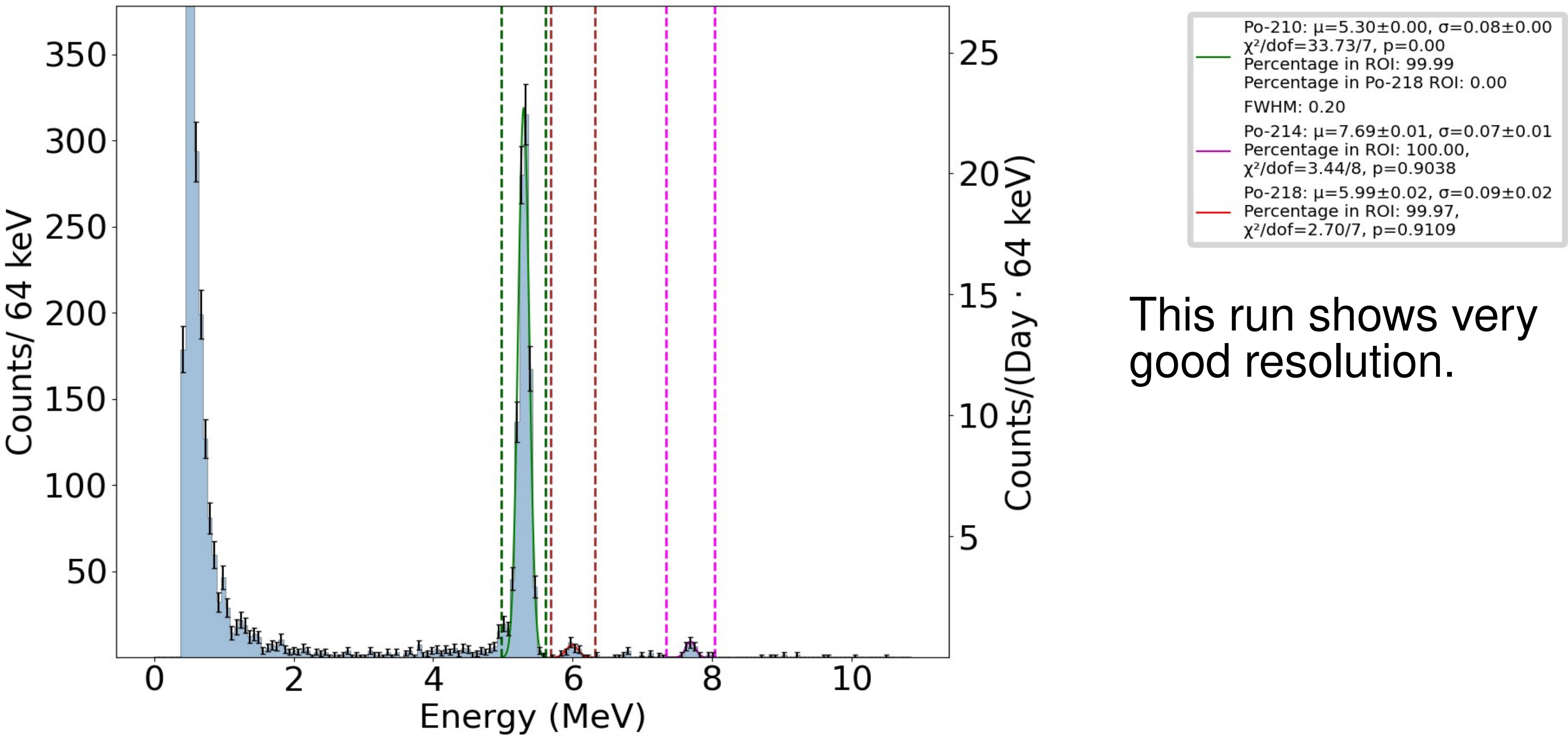


- This is a Small Emanation Chamber Blank run, which helps us identify any possible leaks or other systemic issues.

Run 668 Gain Corrected Data

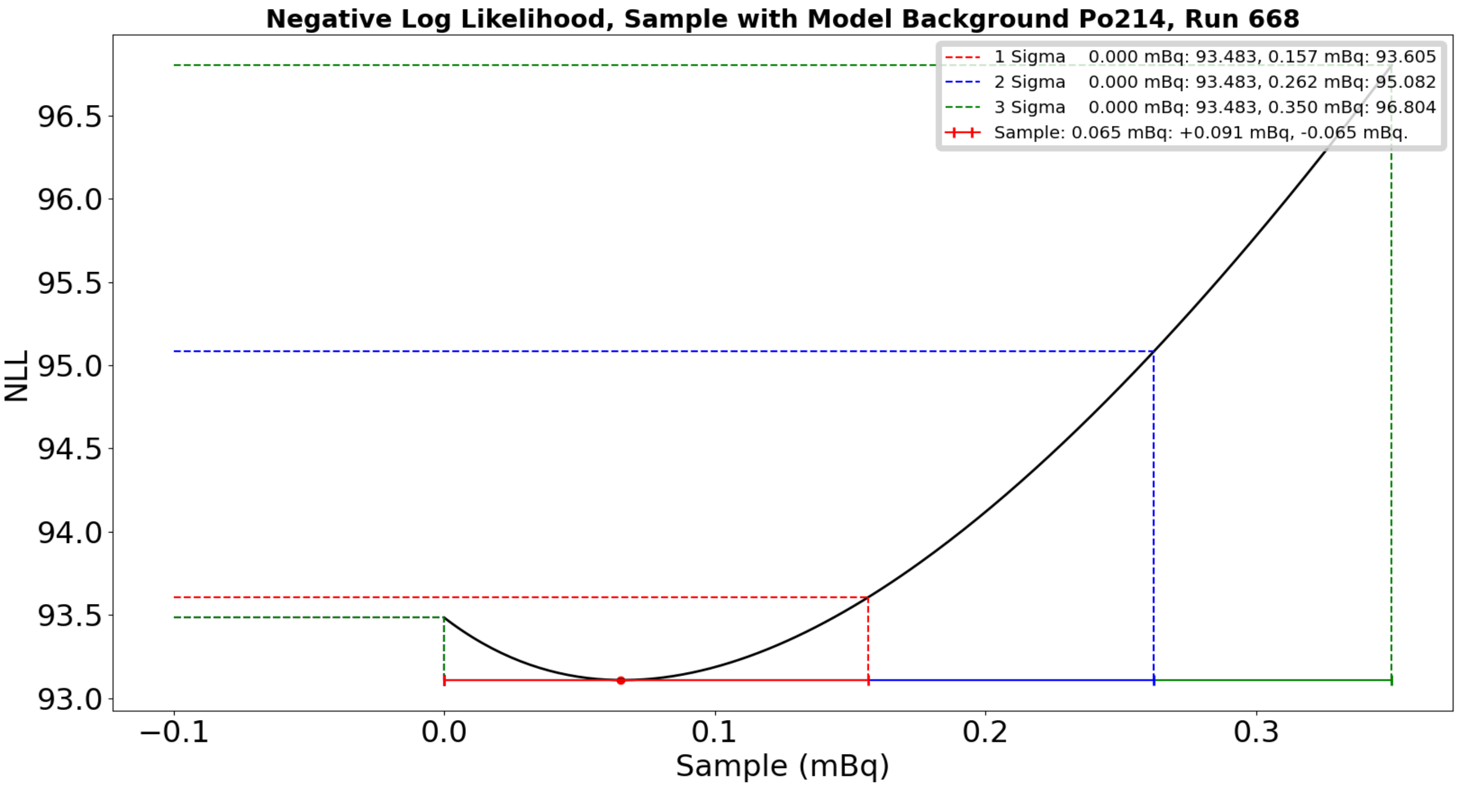


Run 668 Counts vs Energy

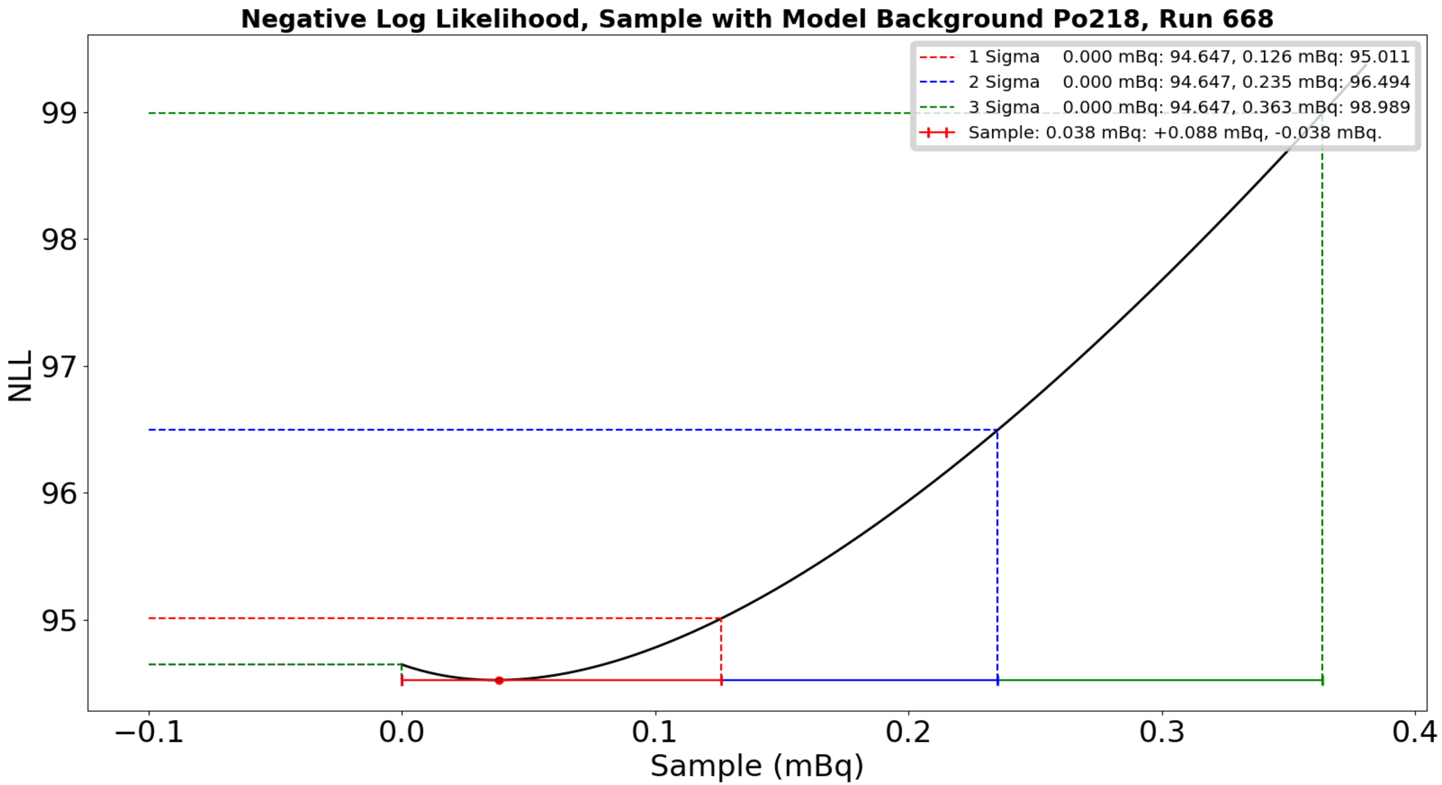


This run shows very good resolution.

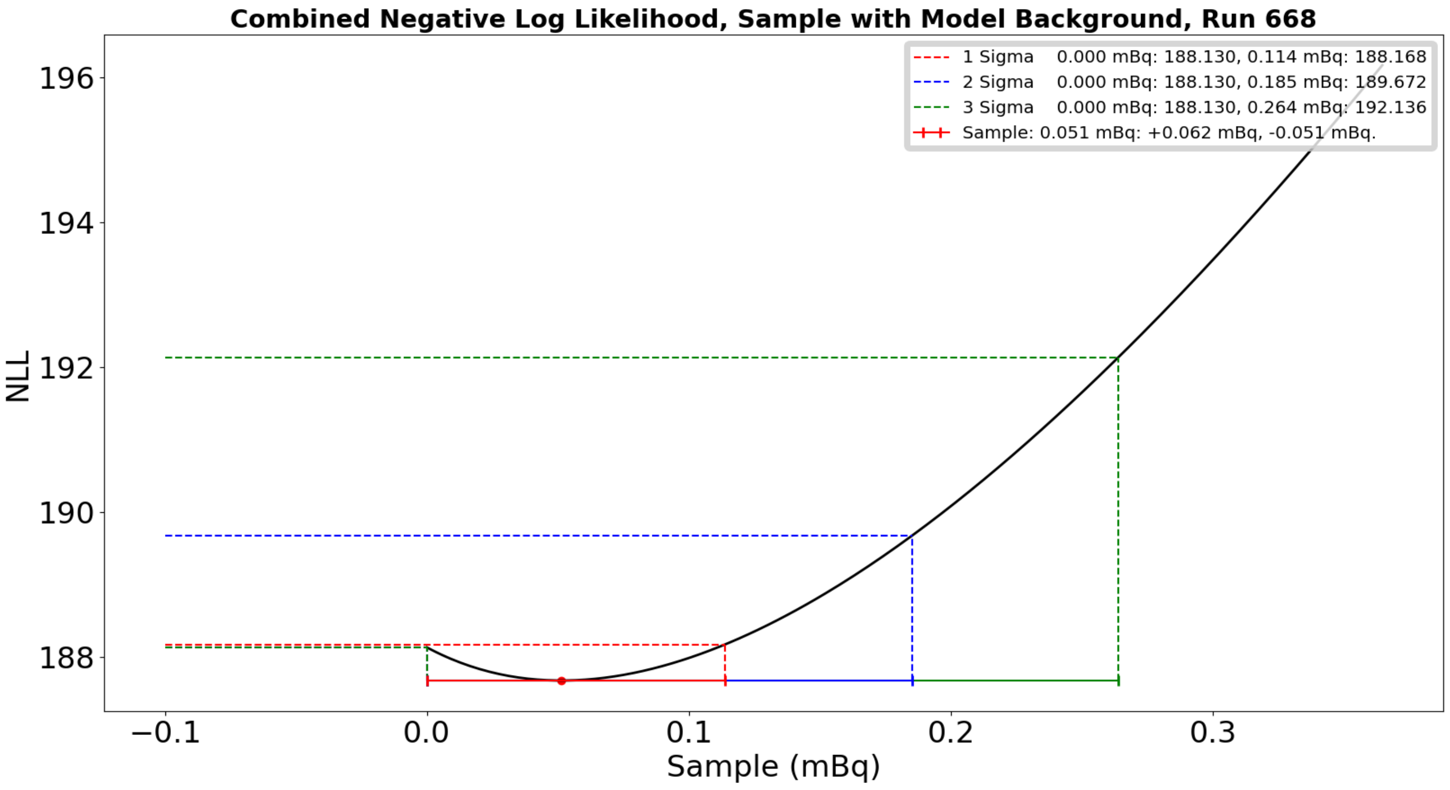
Run 668 Po-214 NLL



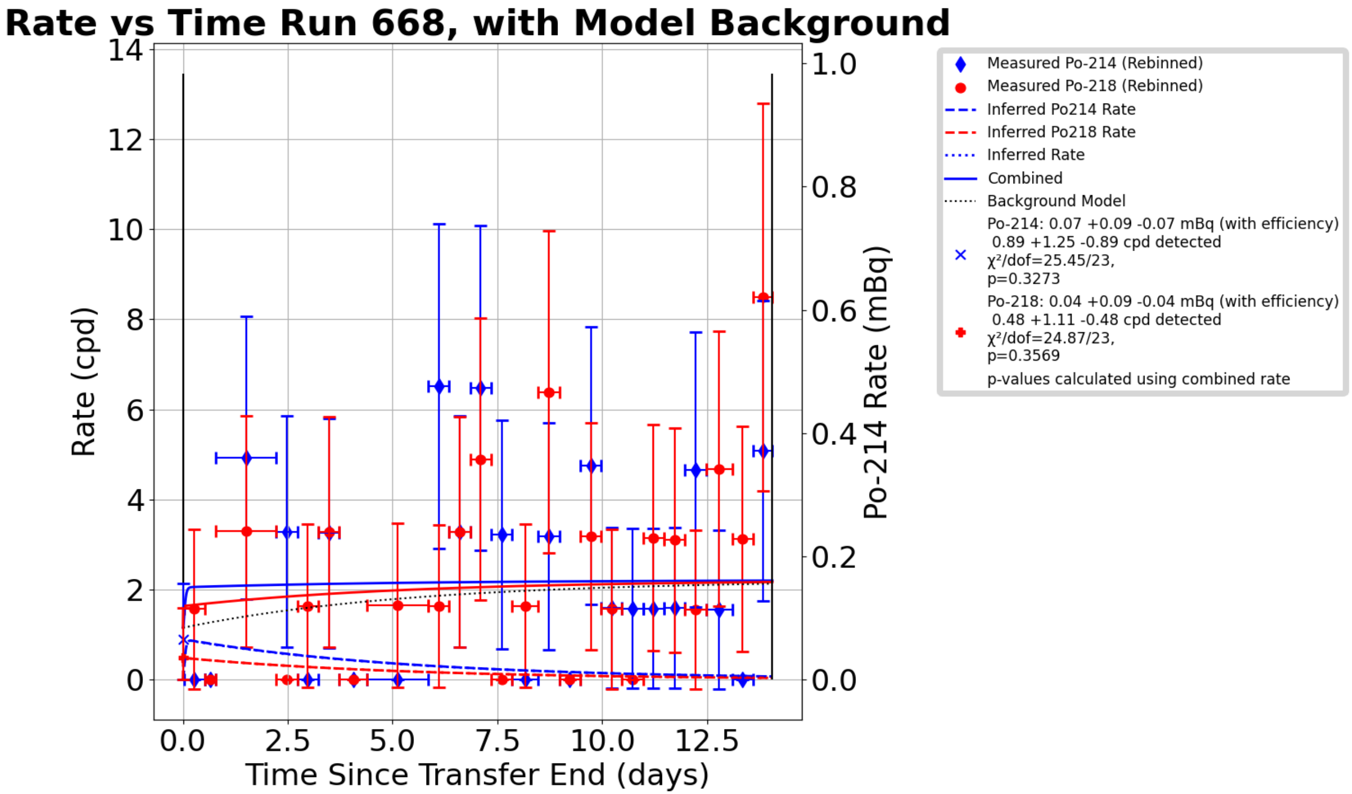
Run 668 Po-218 NLL



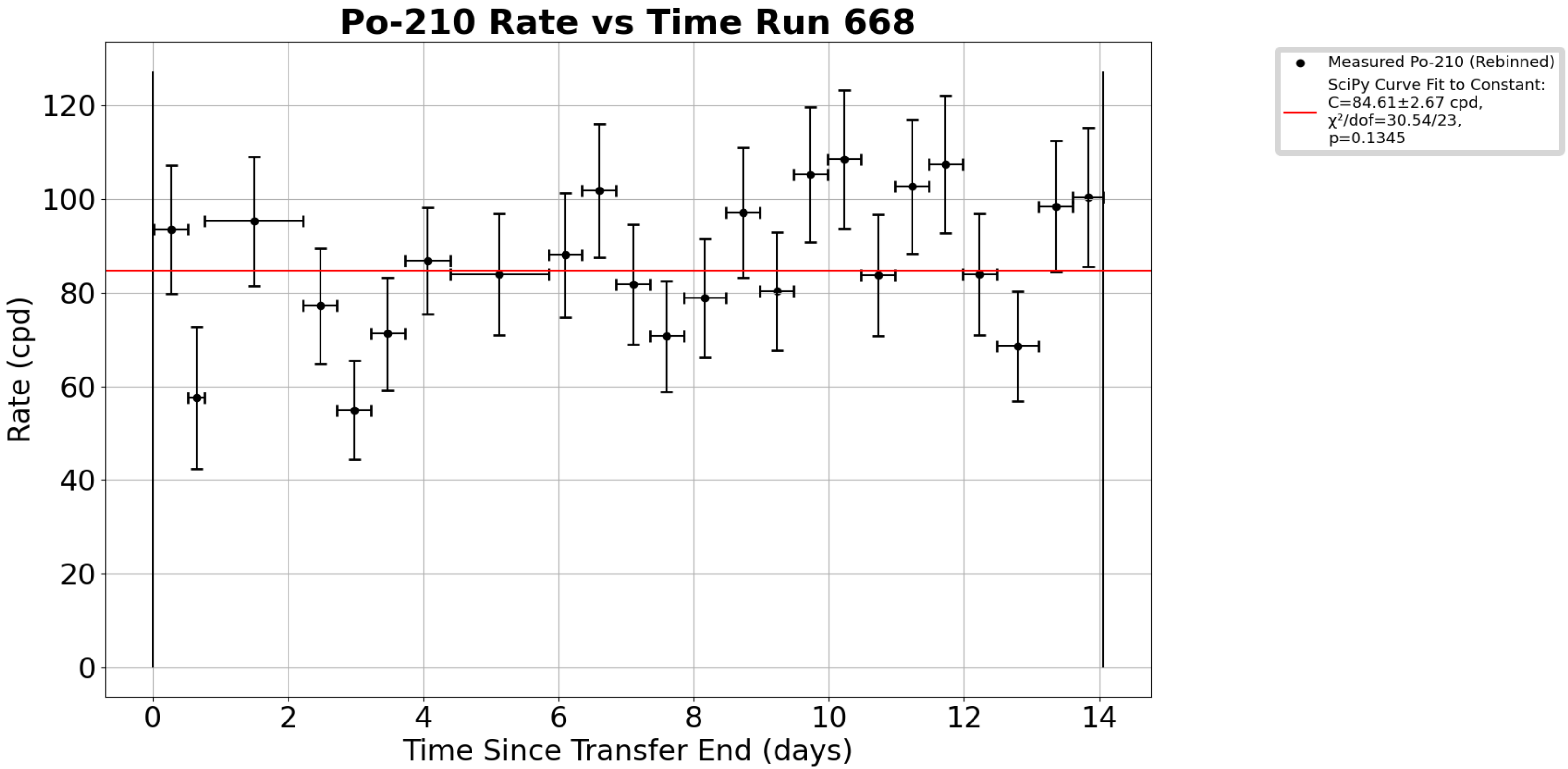
Run 666 Combined NLL



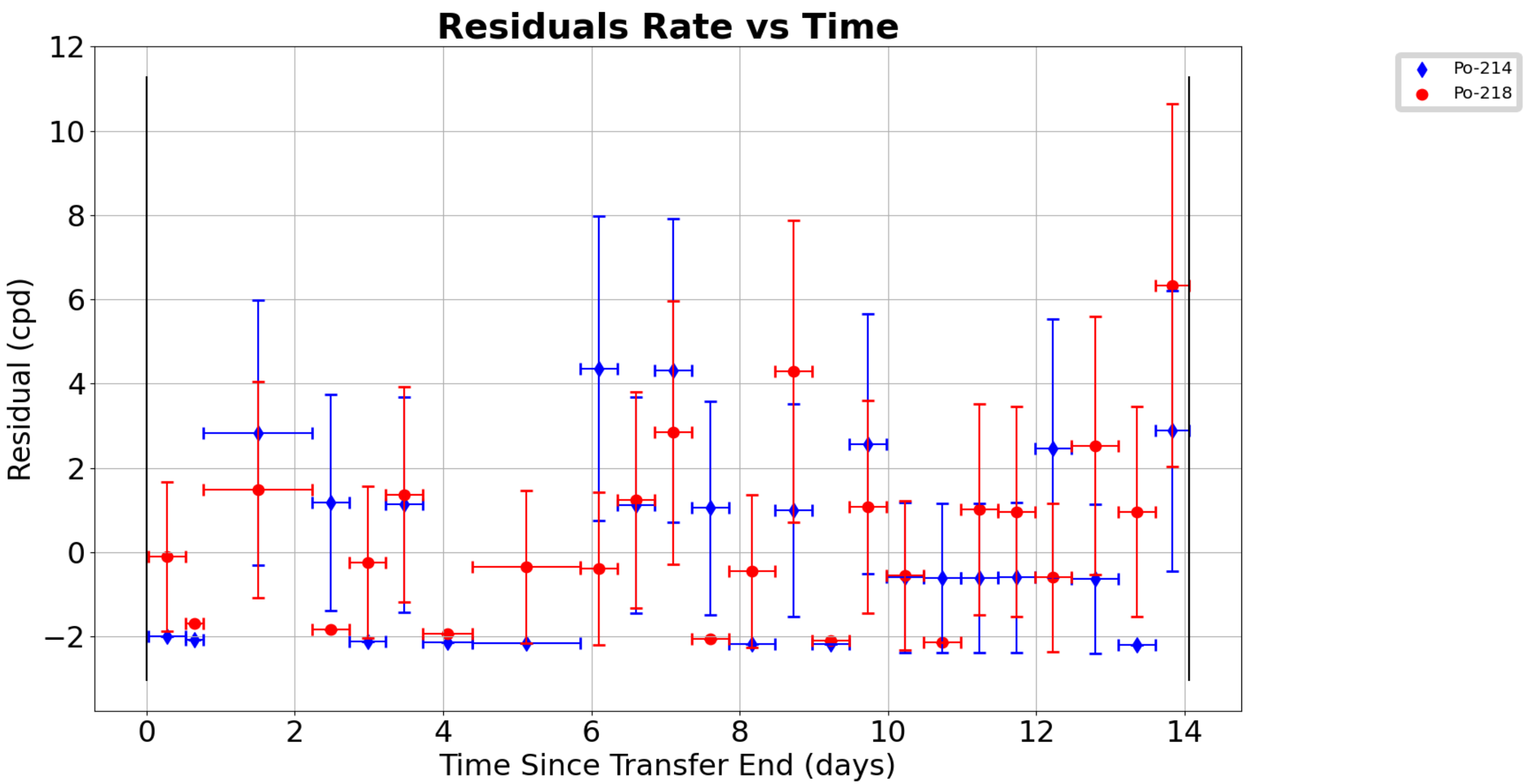
Run 666 Rate vs Time



Run 668 Po-210 Rate vs Time

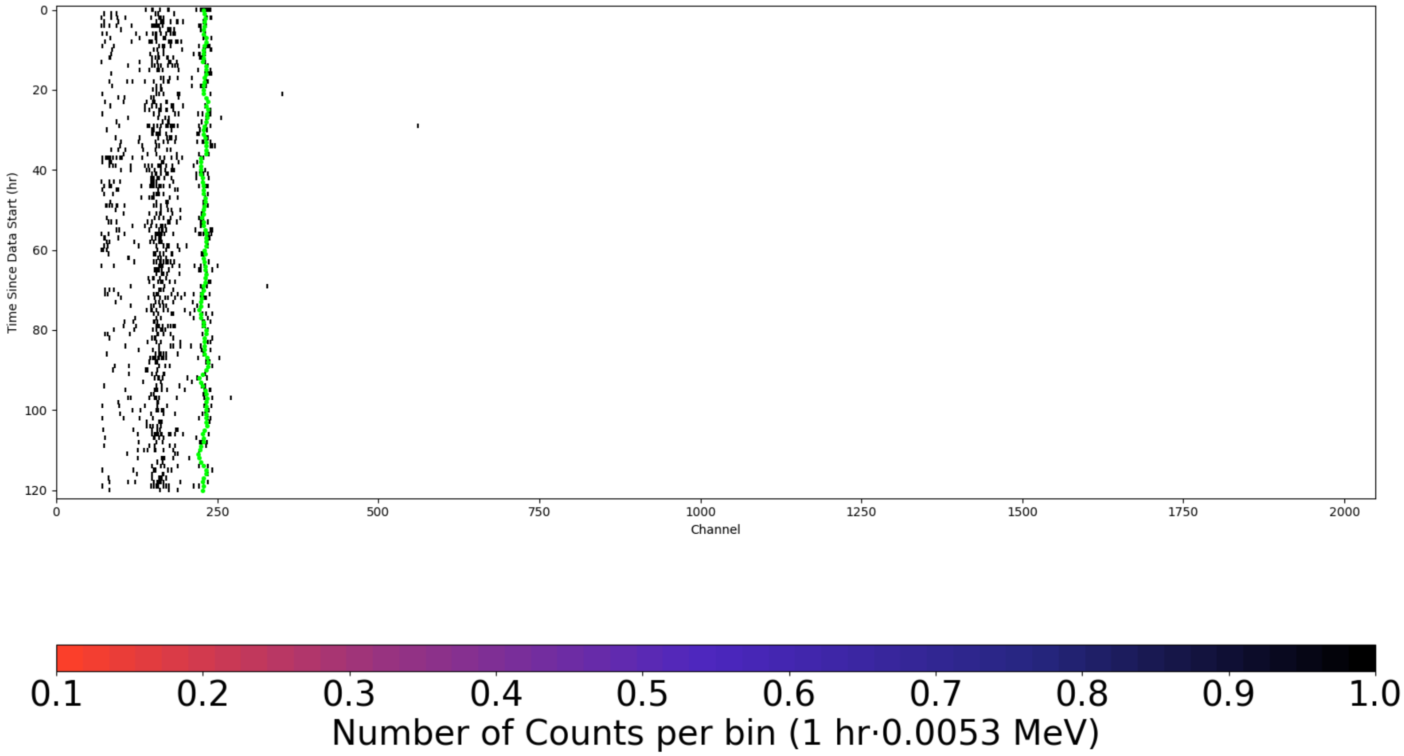


Run 668 Residuals

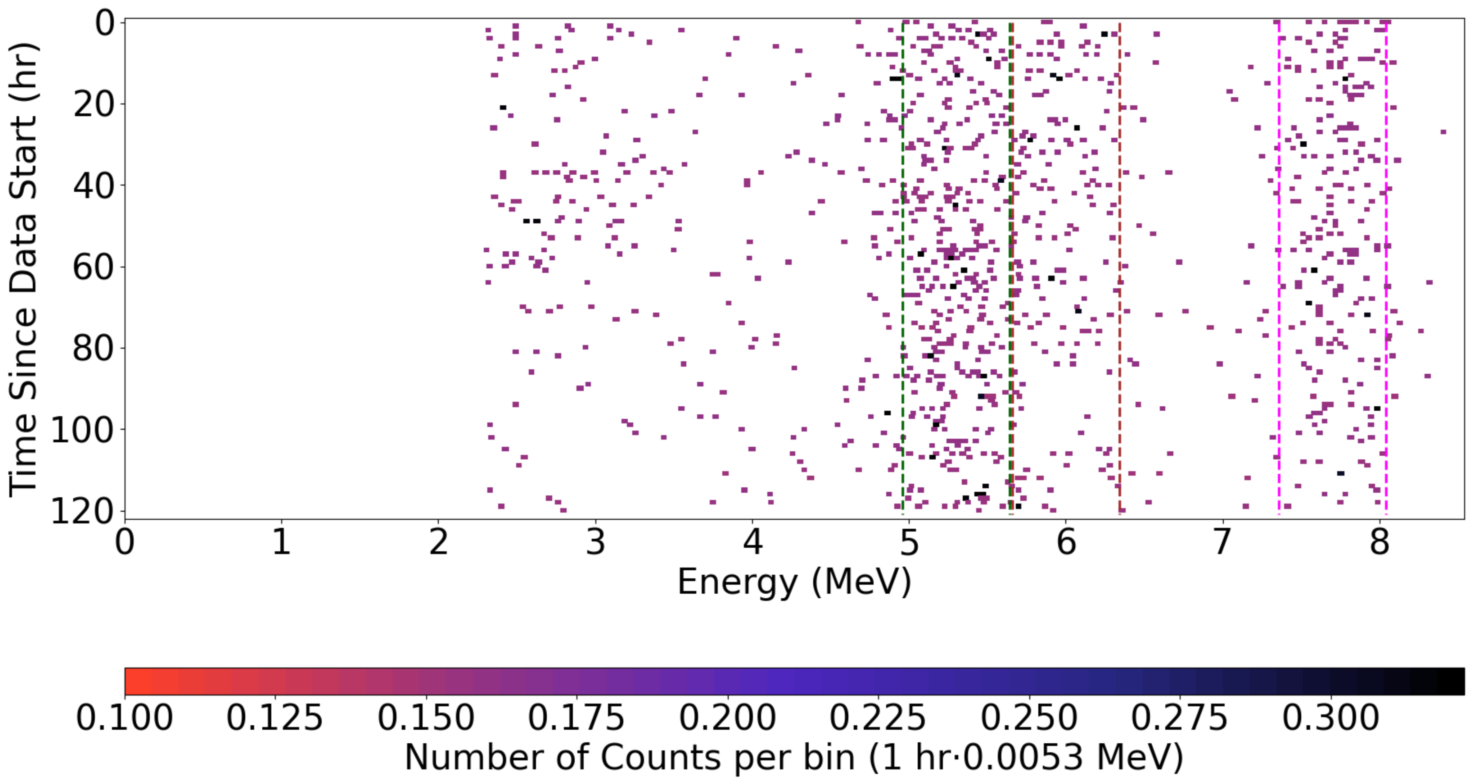


Run 671 Plots

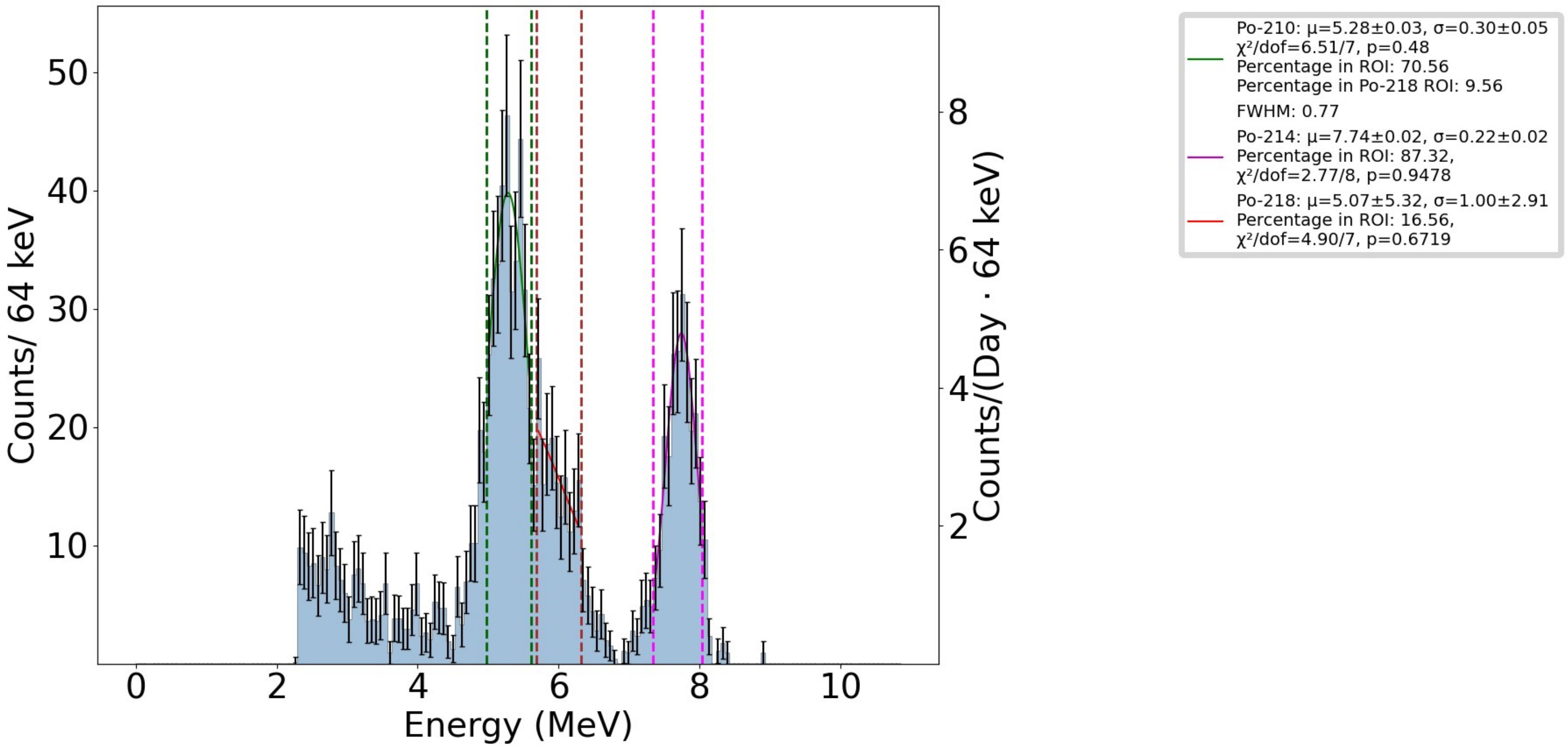
Run 671 Raw Data



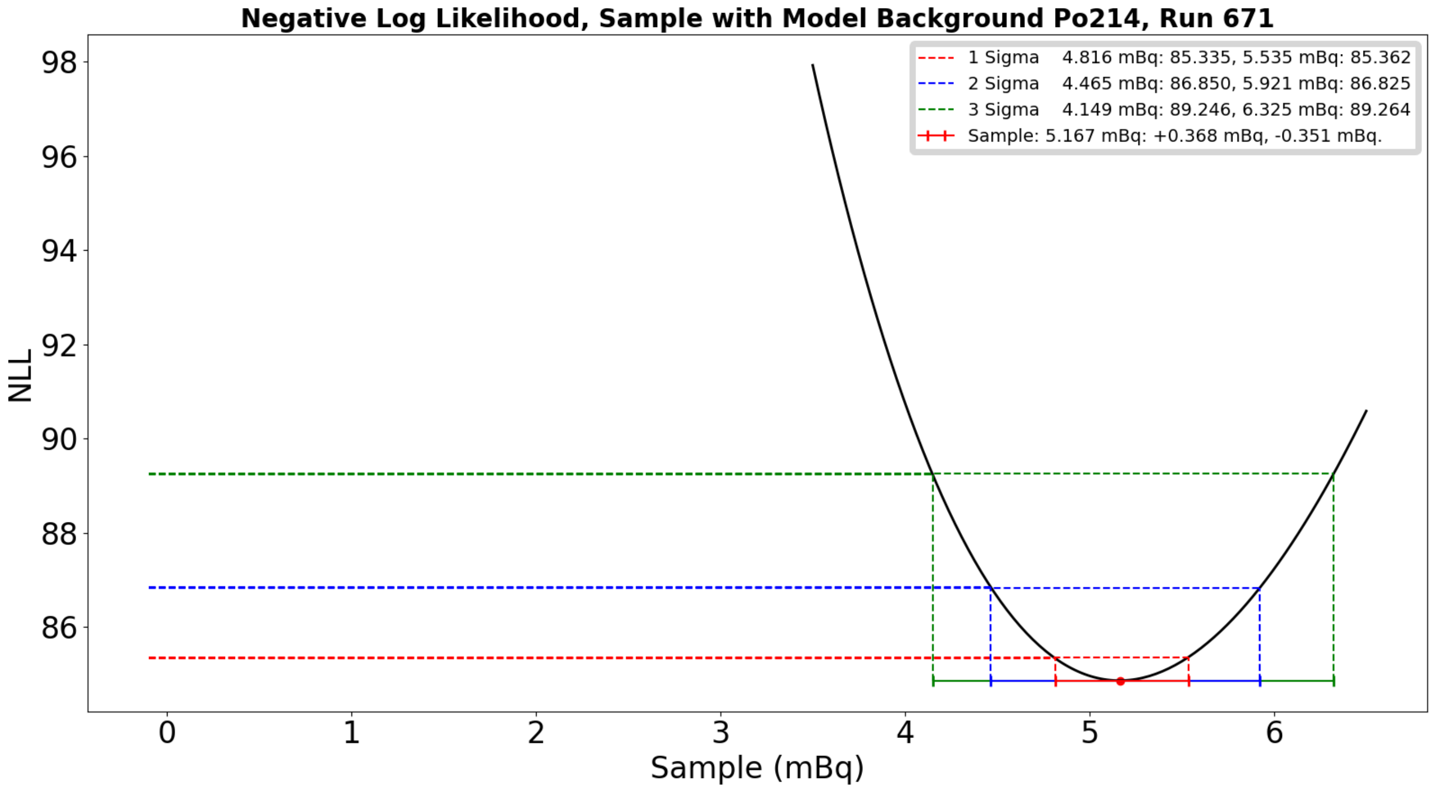
Run 671 Gain Corrected Data



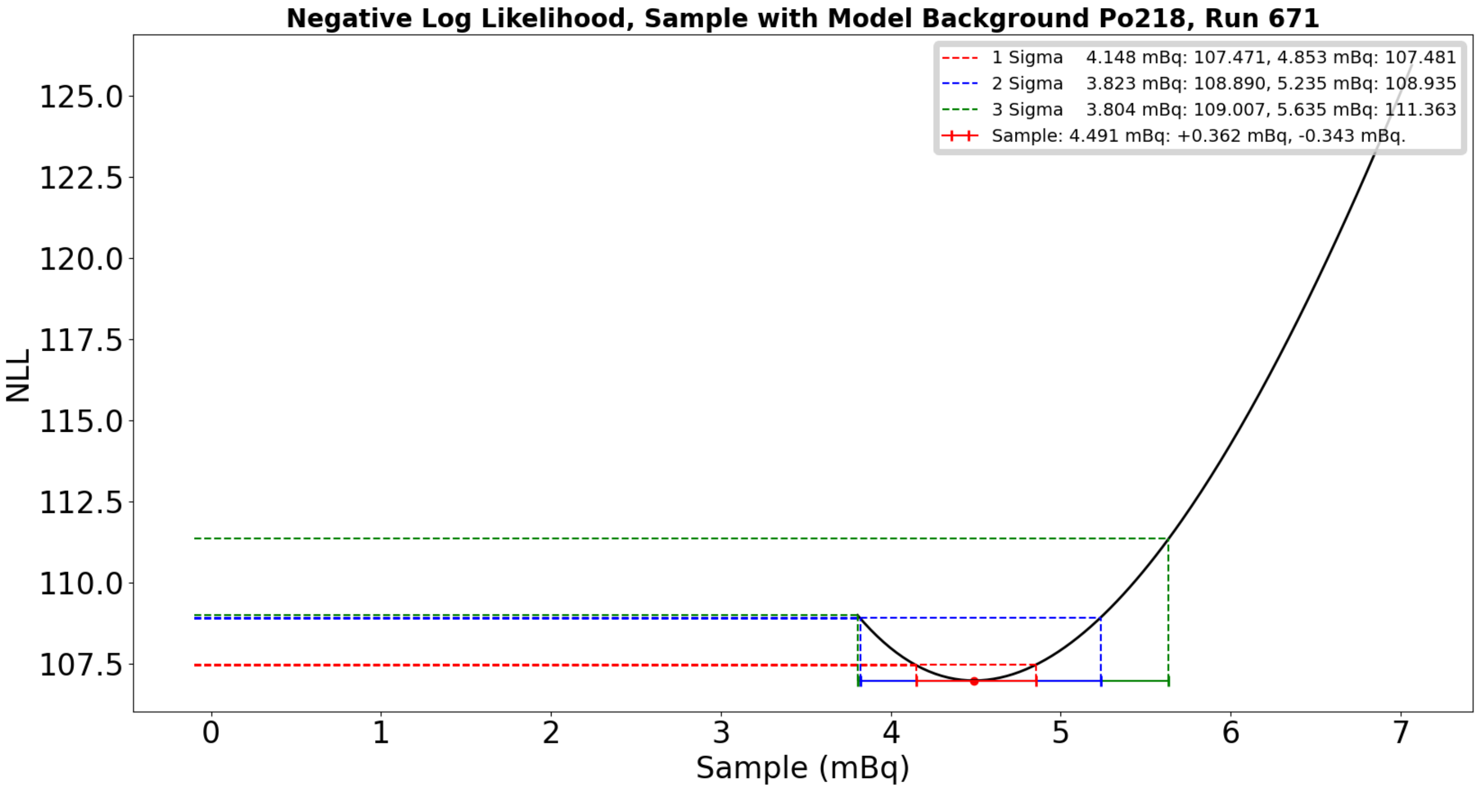
Run 671 Counts vs Energy



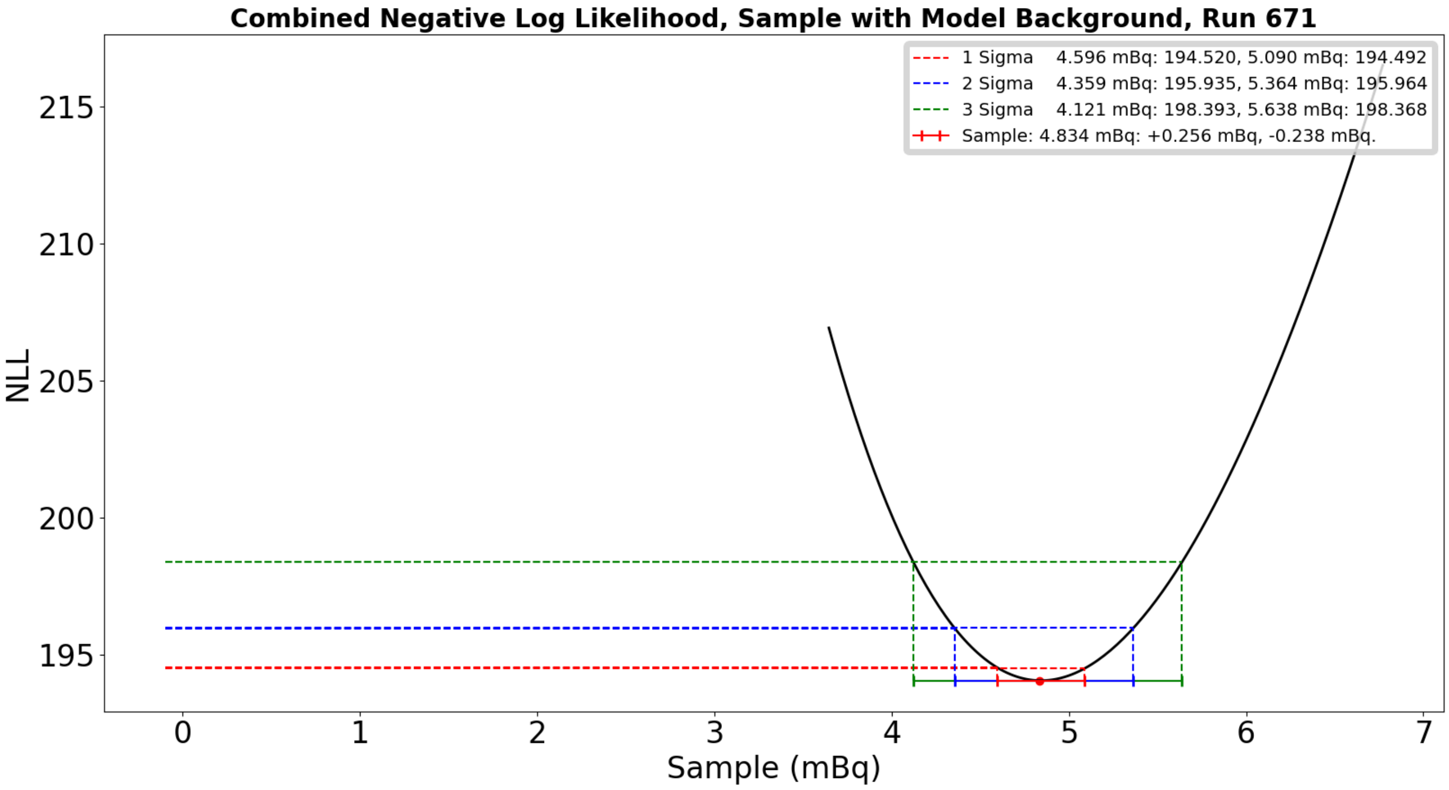
Run 671 Po-214 NLL



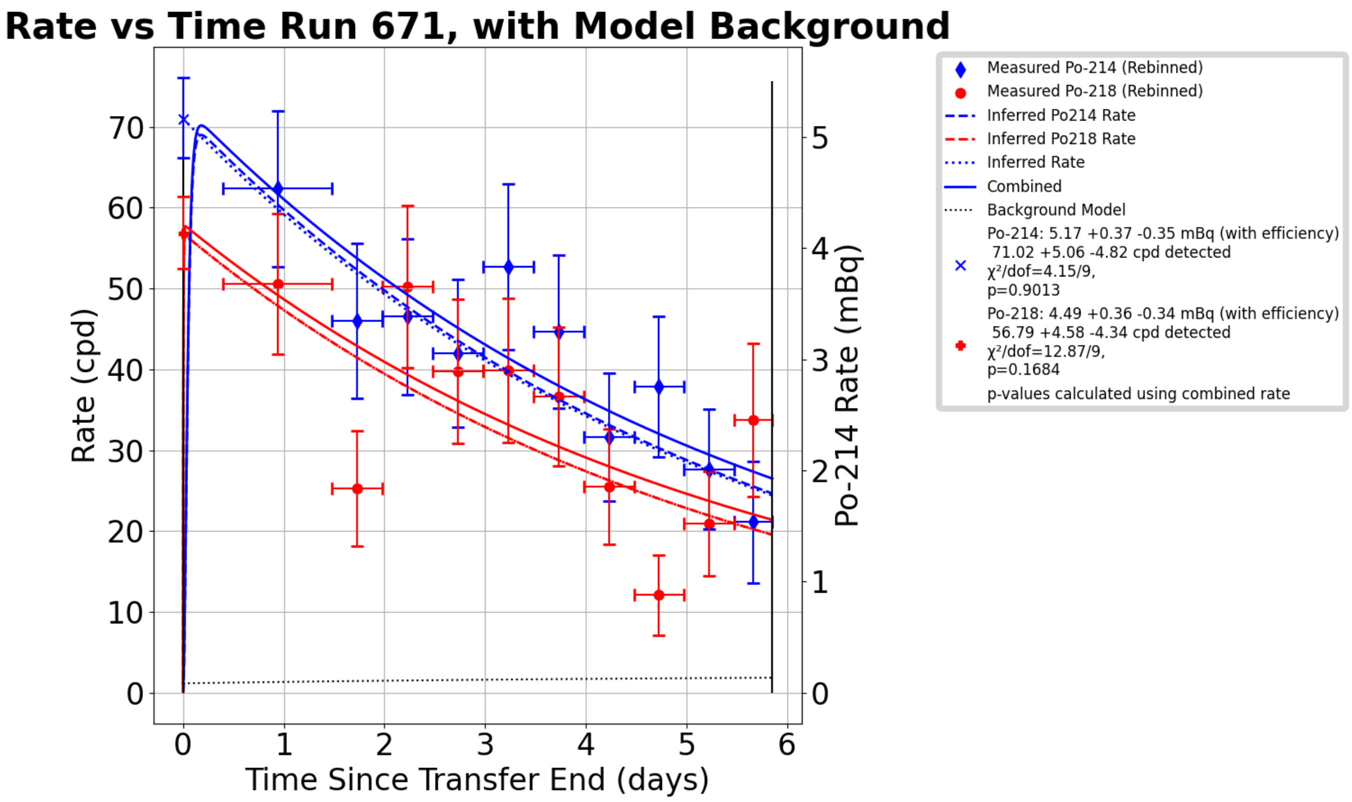
Run 671 Po-218 NLL



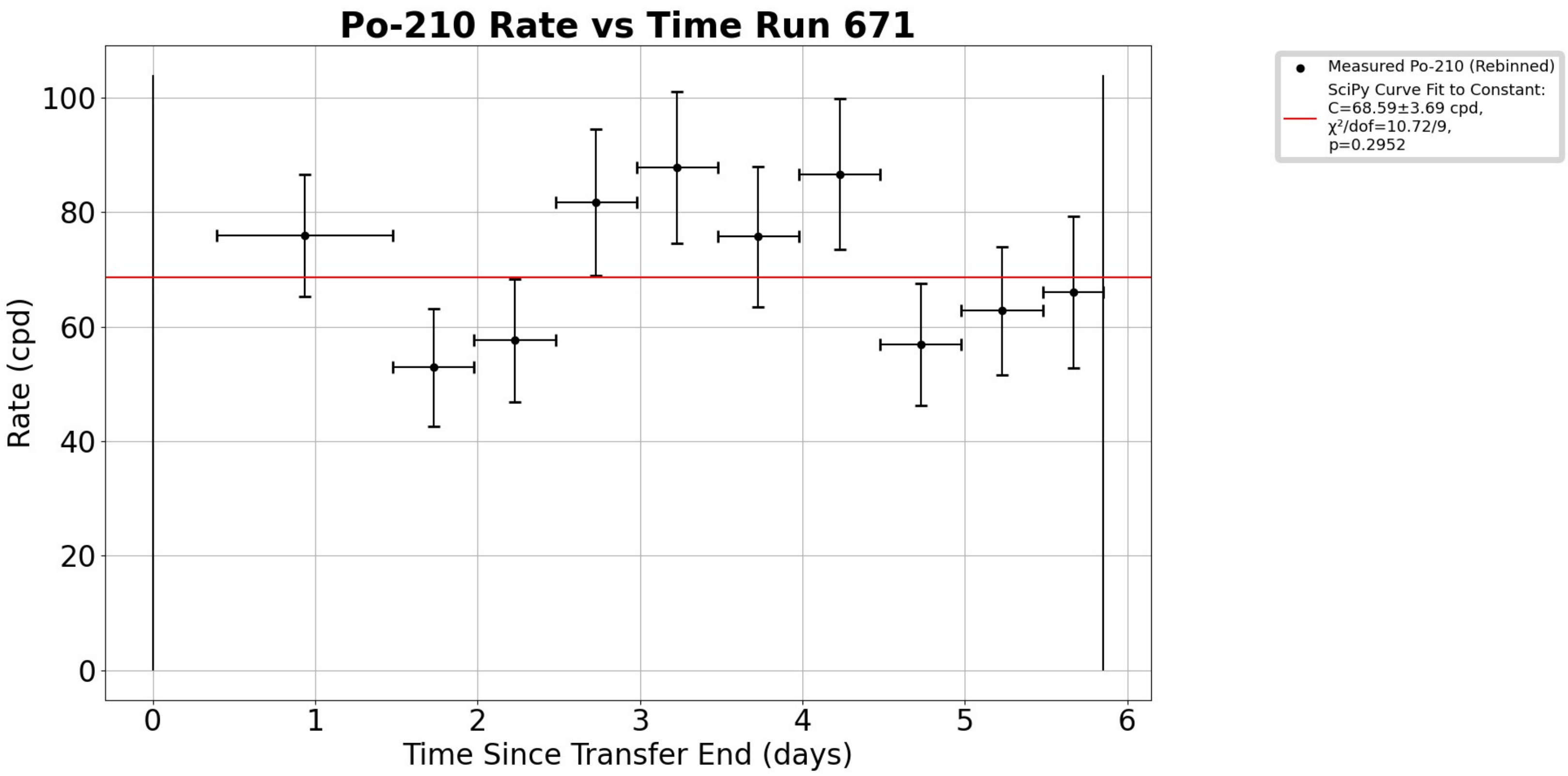
Run 671 Combined NLL



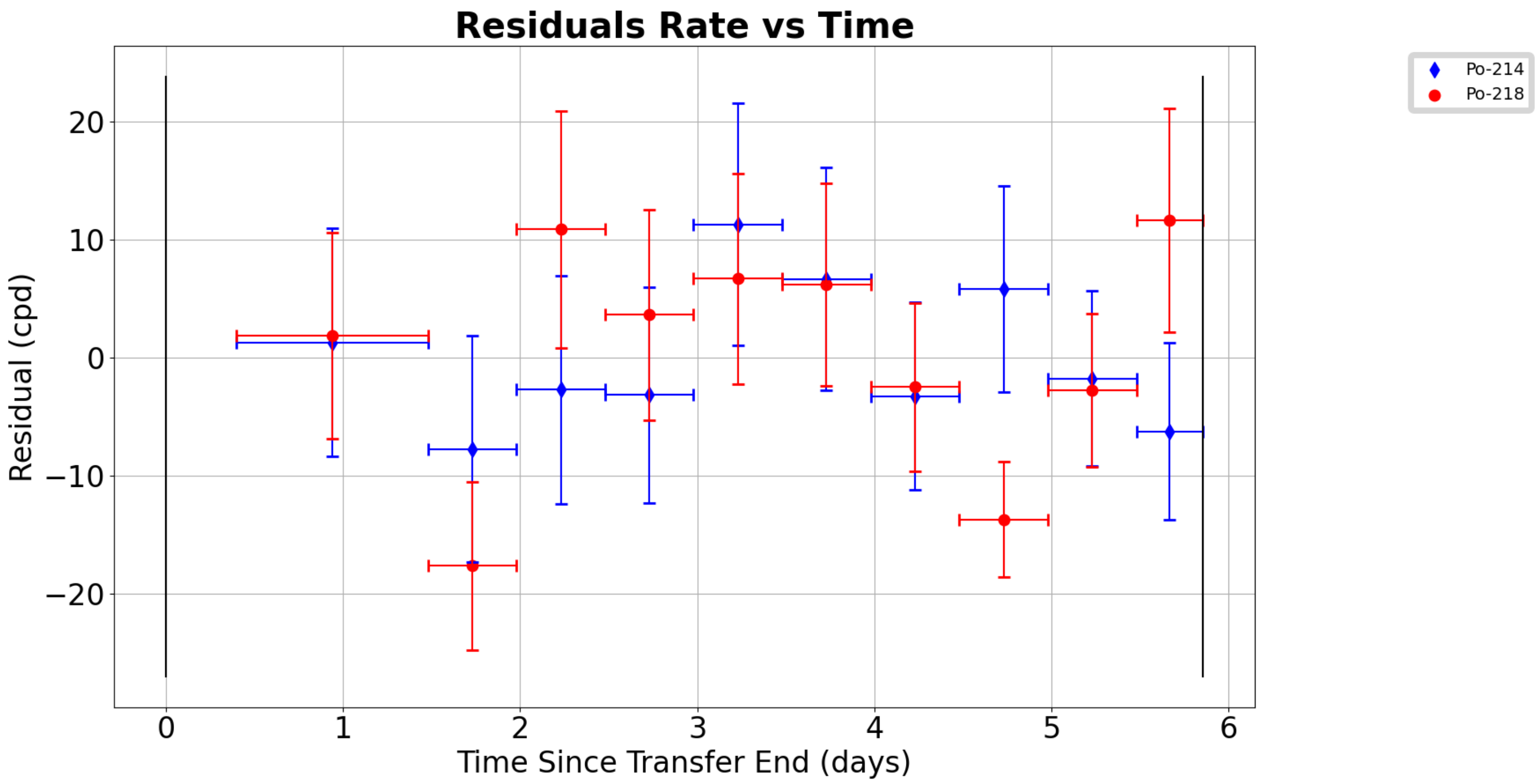
Run 671 Rate vs Time



Run 671 Po-210 Rate vs Time

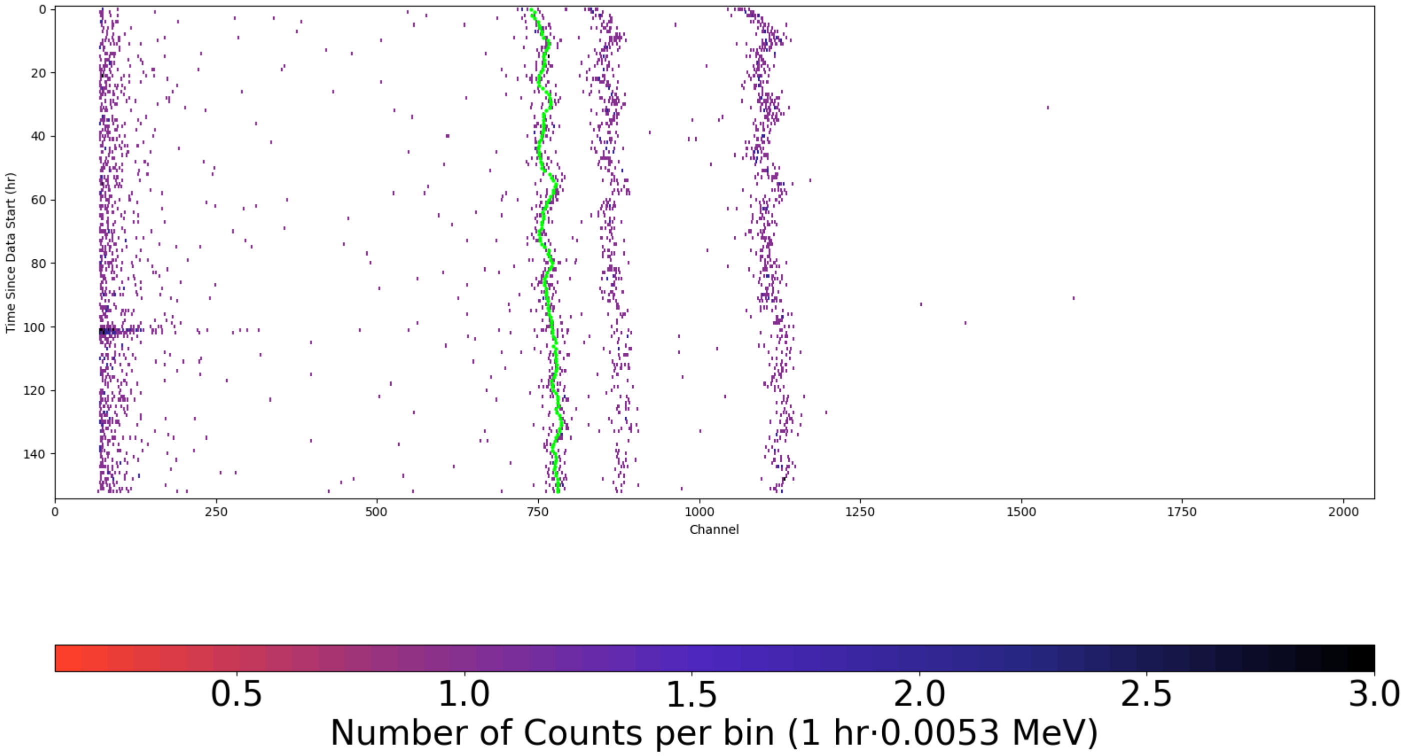


Run 671 Residuals

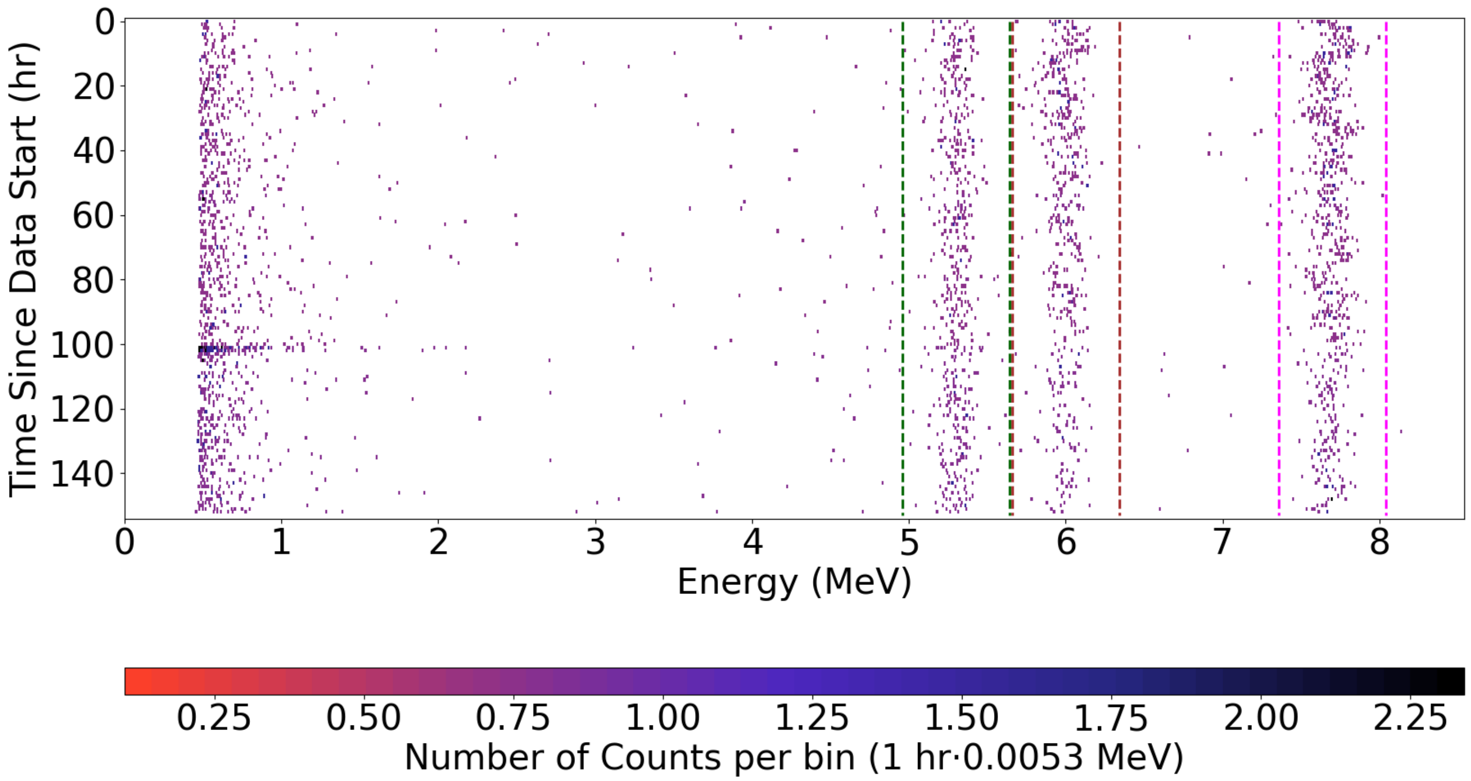


Run 673 Plots

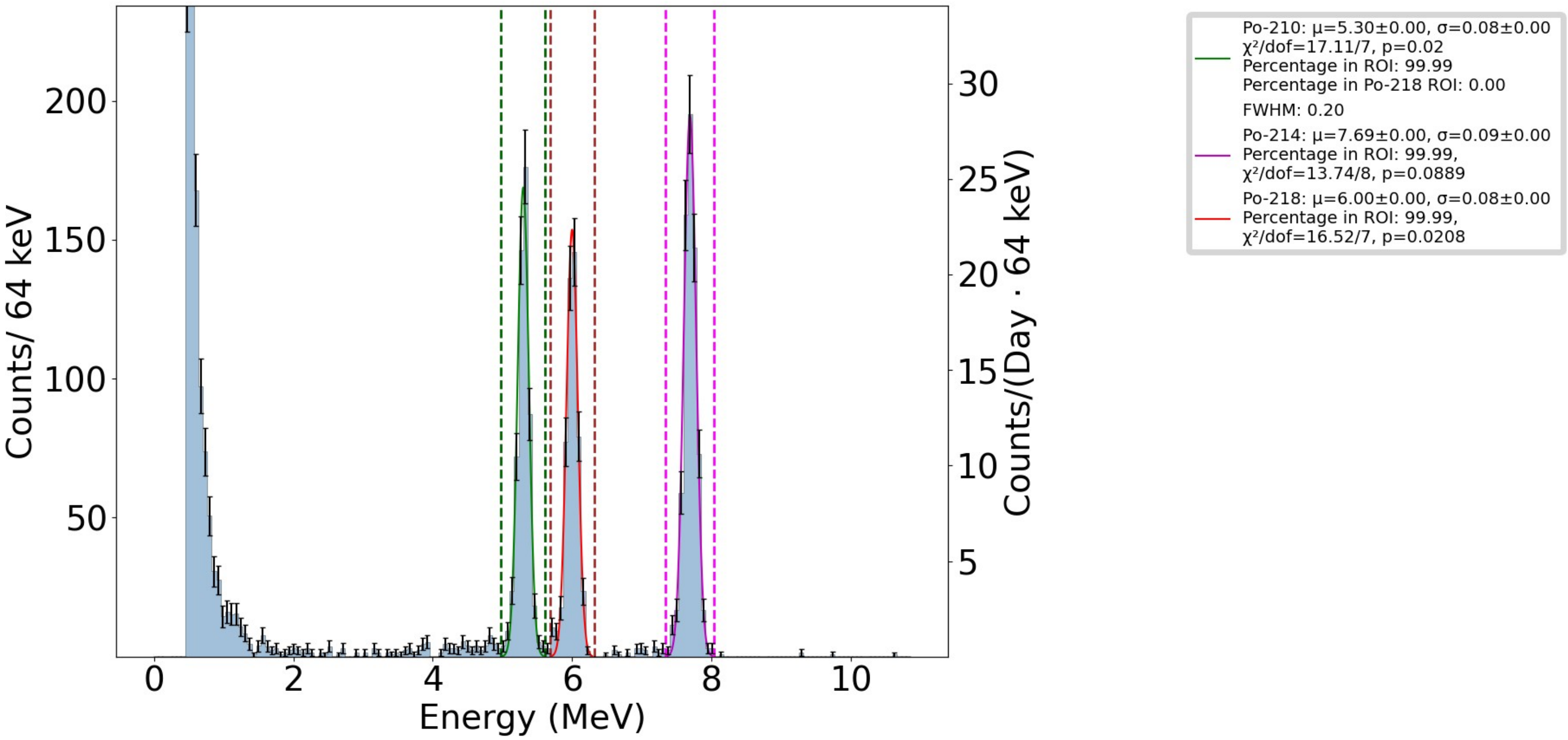
Run 673 Raw Data



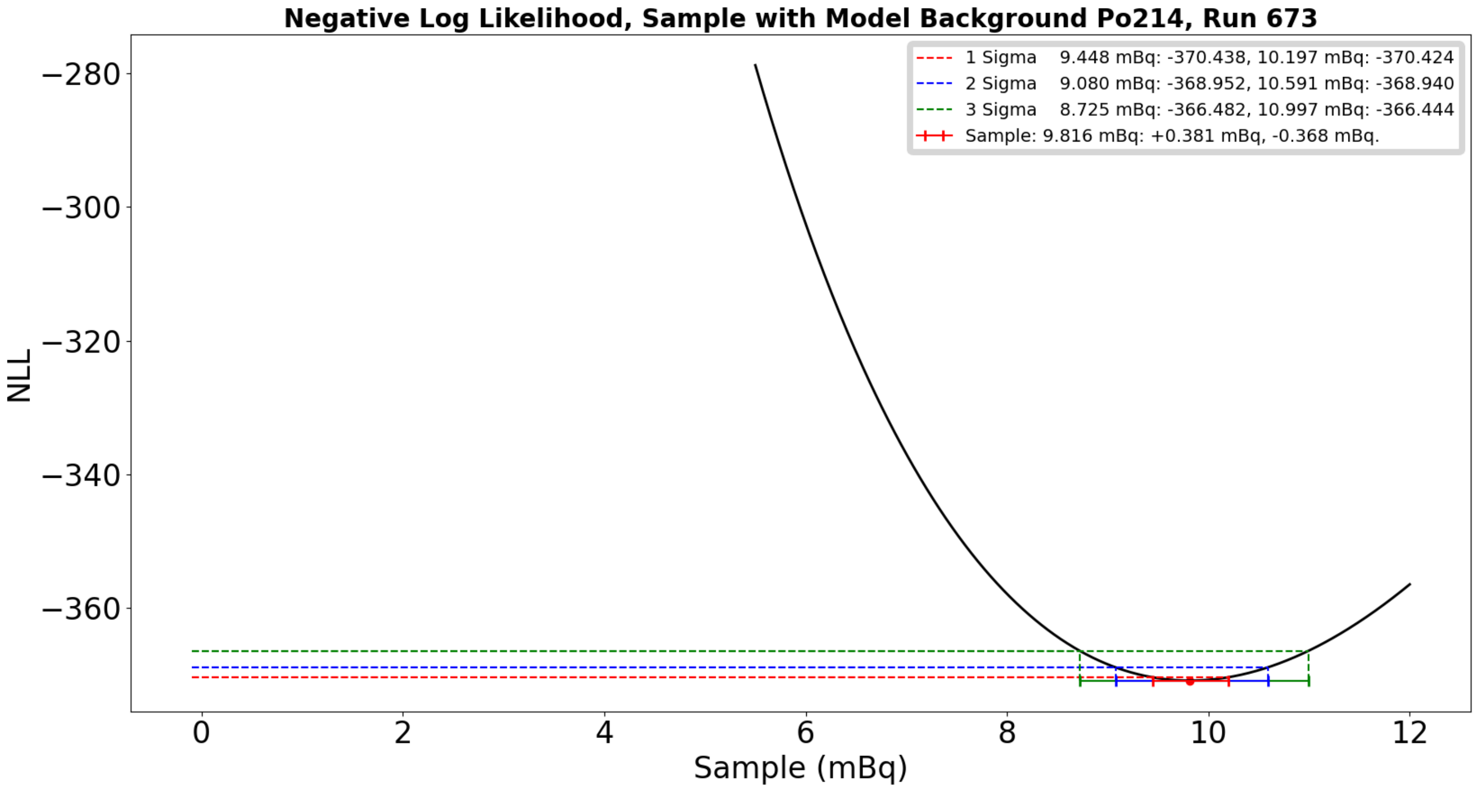
Run 673 Gain Corrected Data



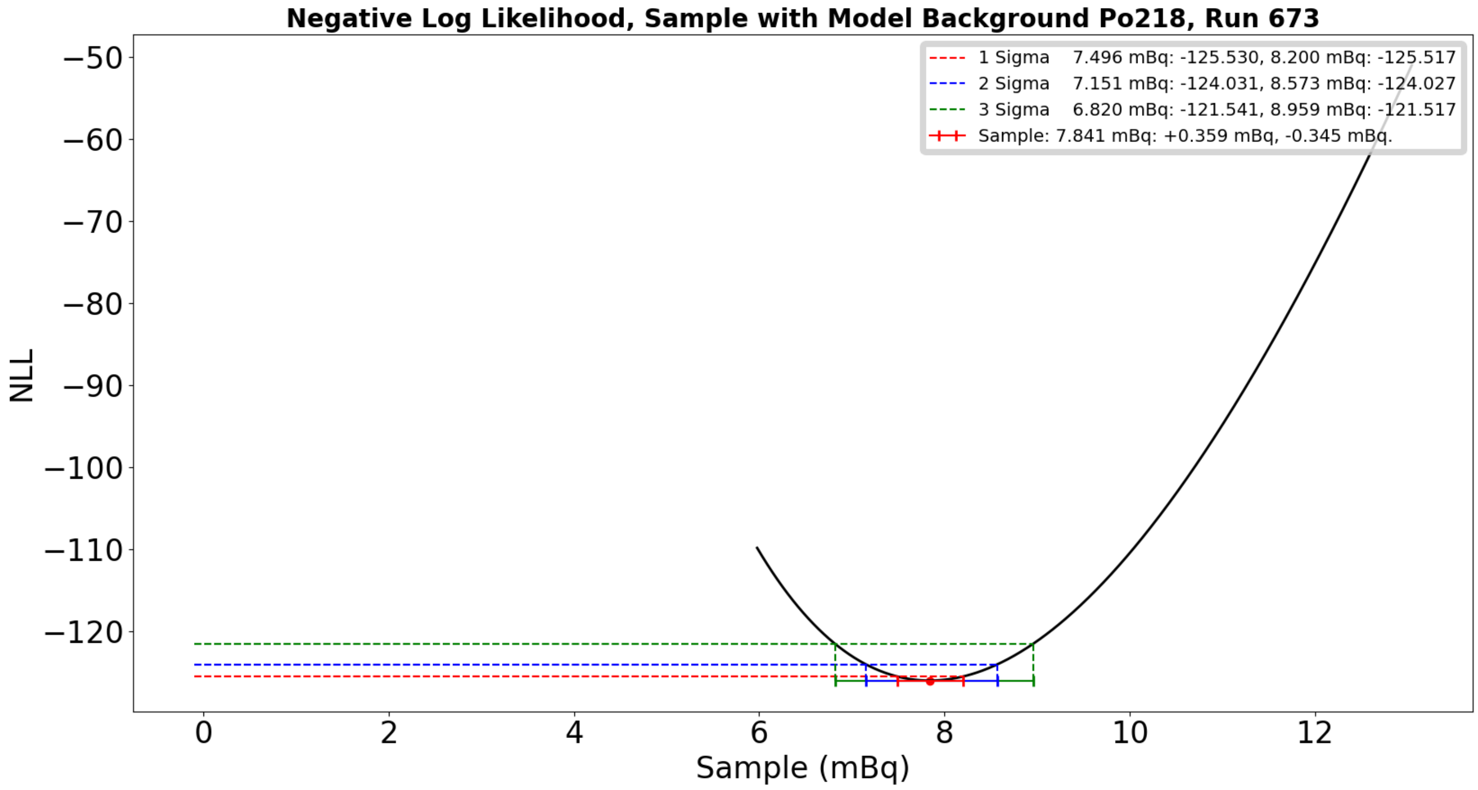
Run 673 Counts vs Energy



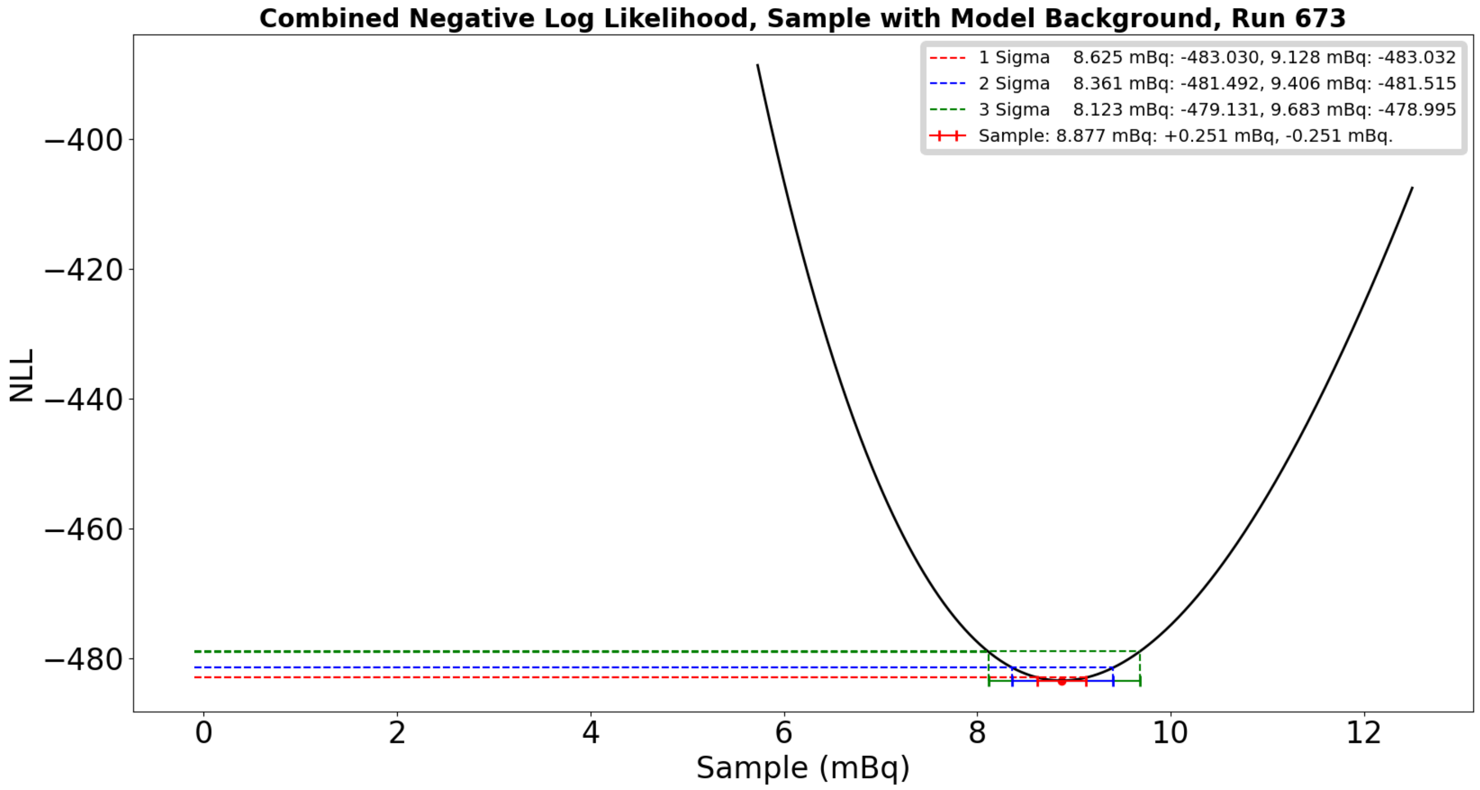
Run 673 Po-214 NLL



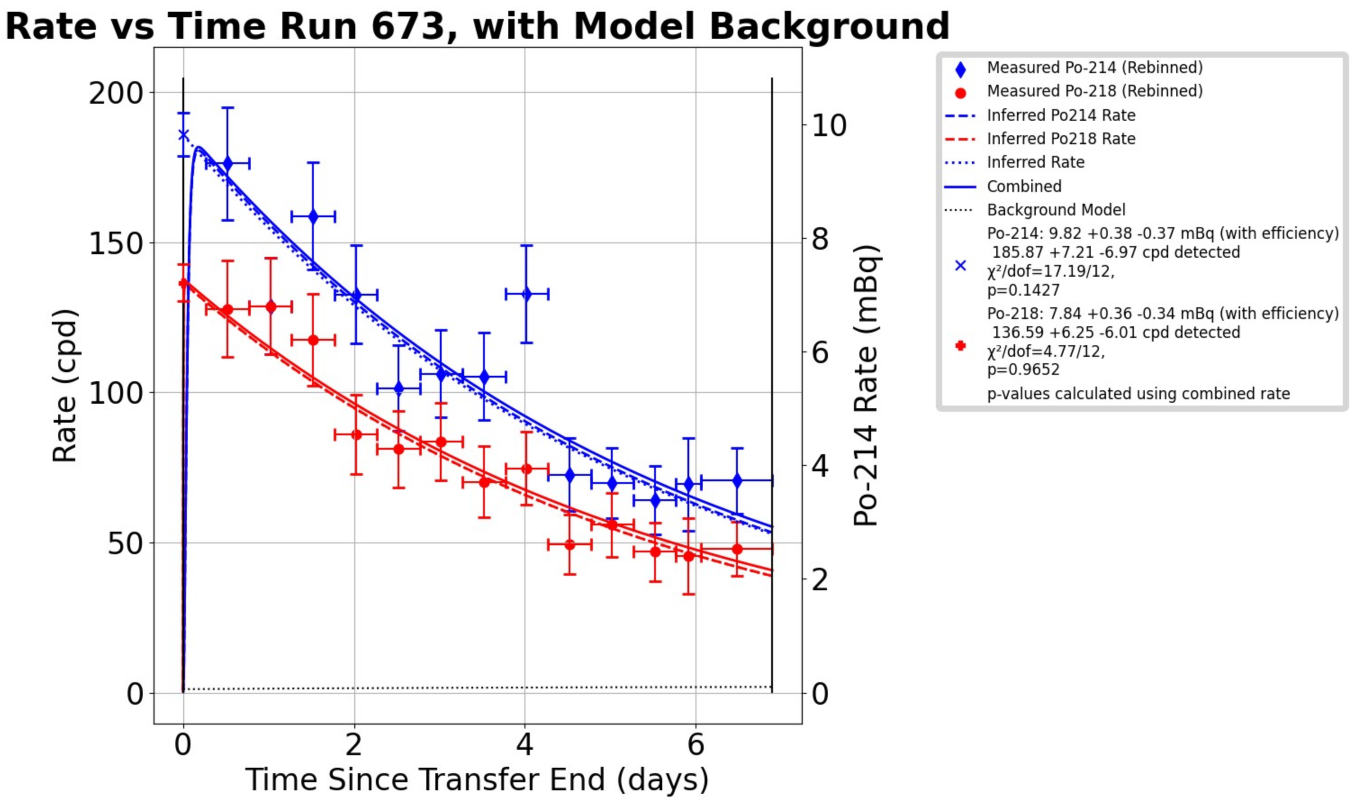
Run 673 Po-218 NLL



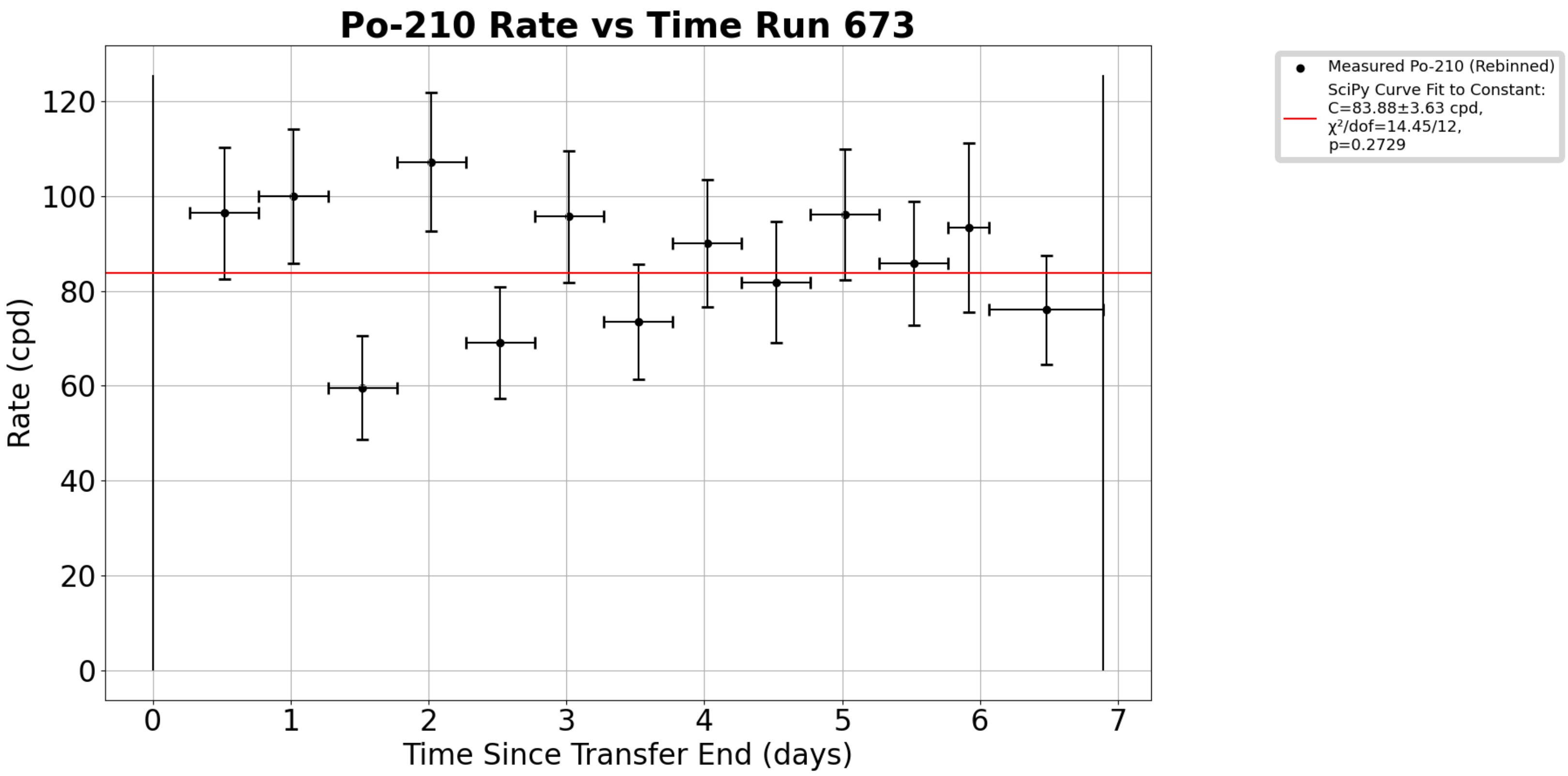
Run 673 Combined NLL



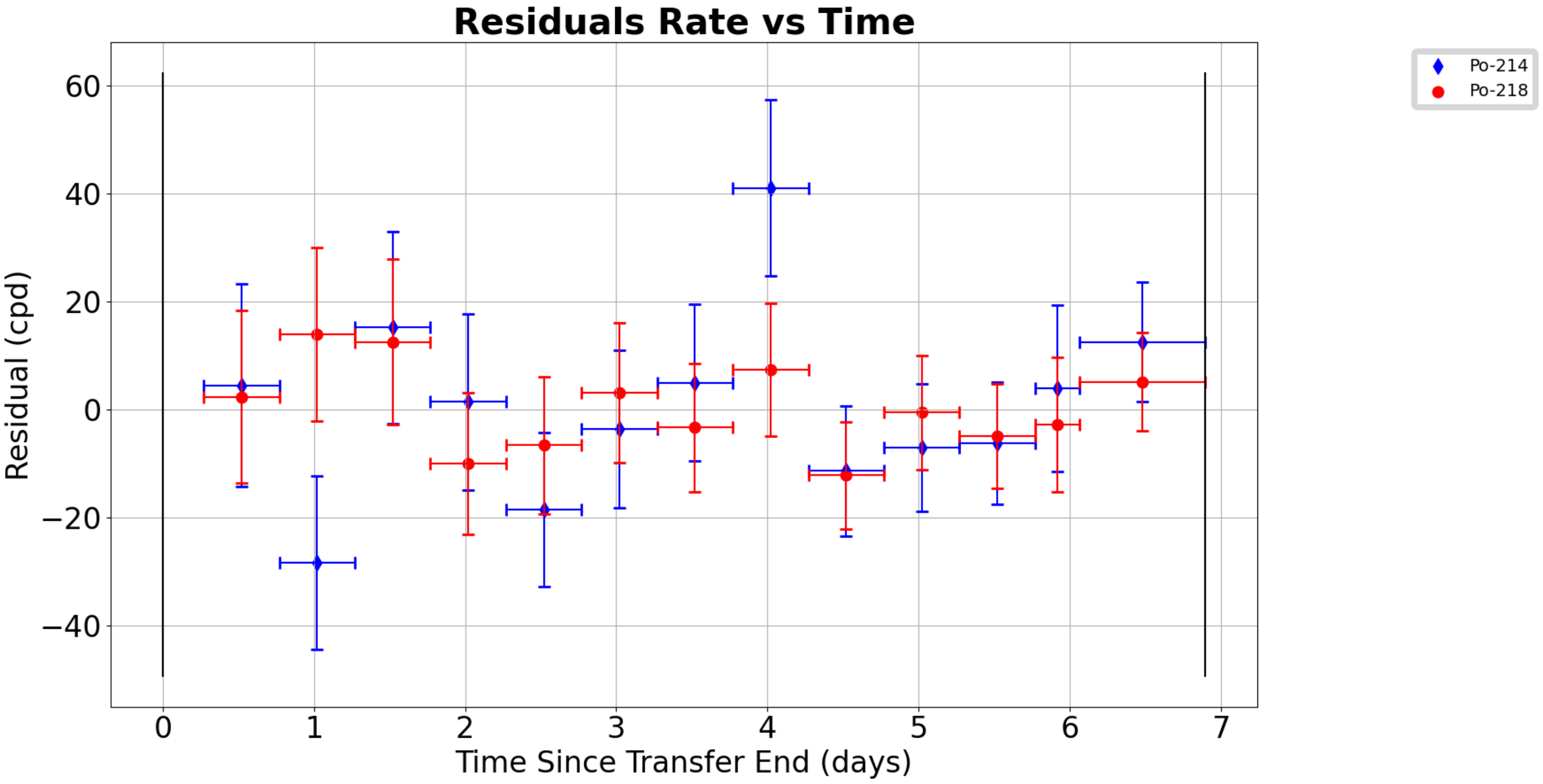
Run 673 Rate vs Time



Run 673 Po-210 Rate vs Time

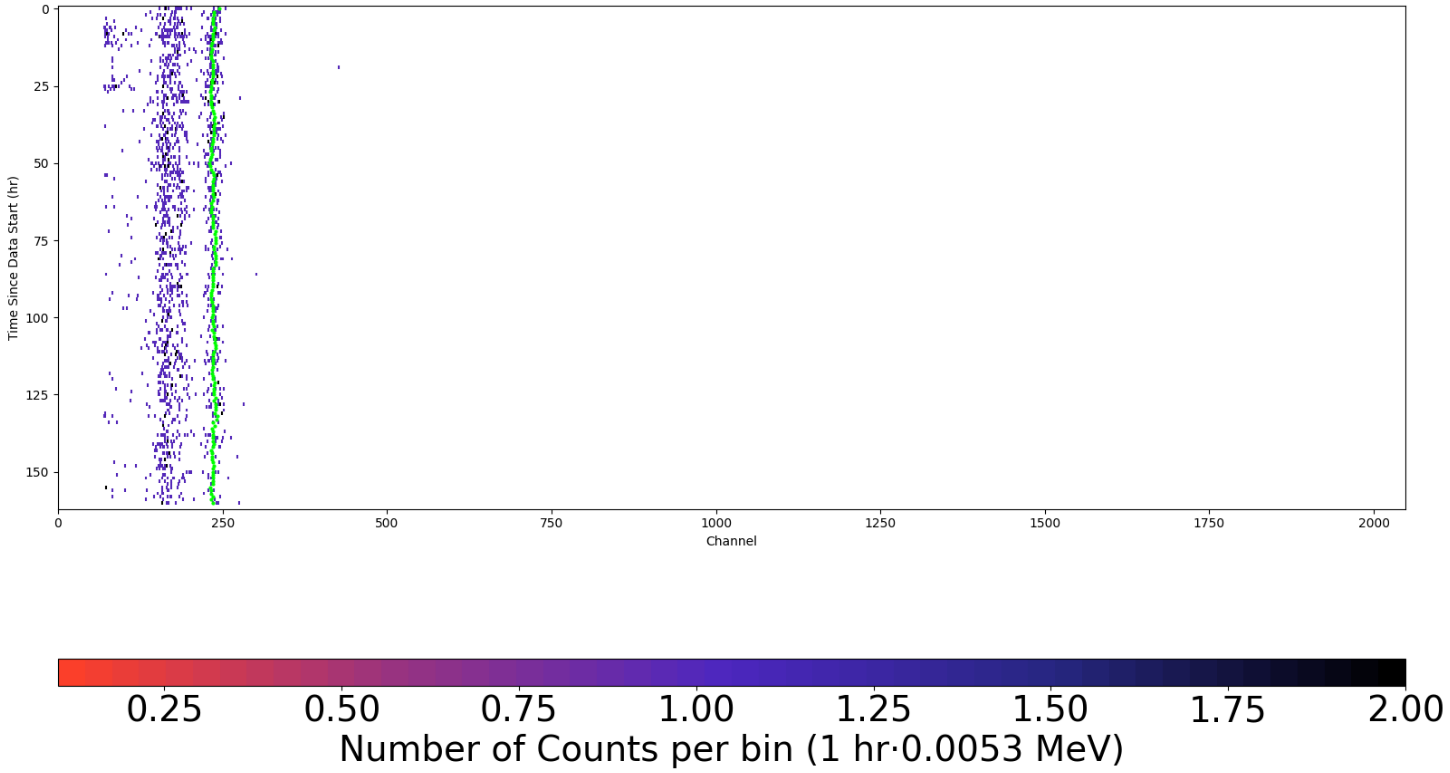


Run 673 Residuals

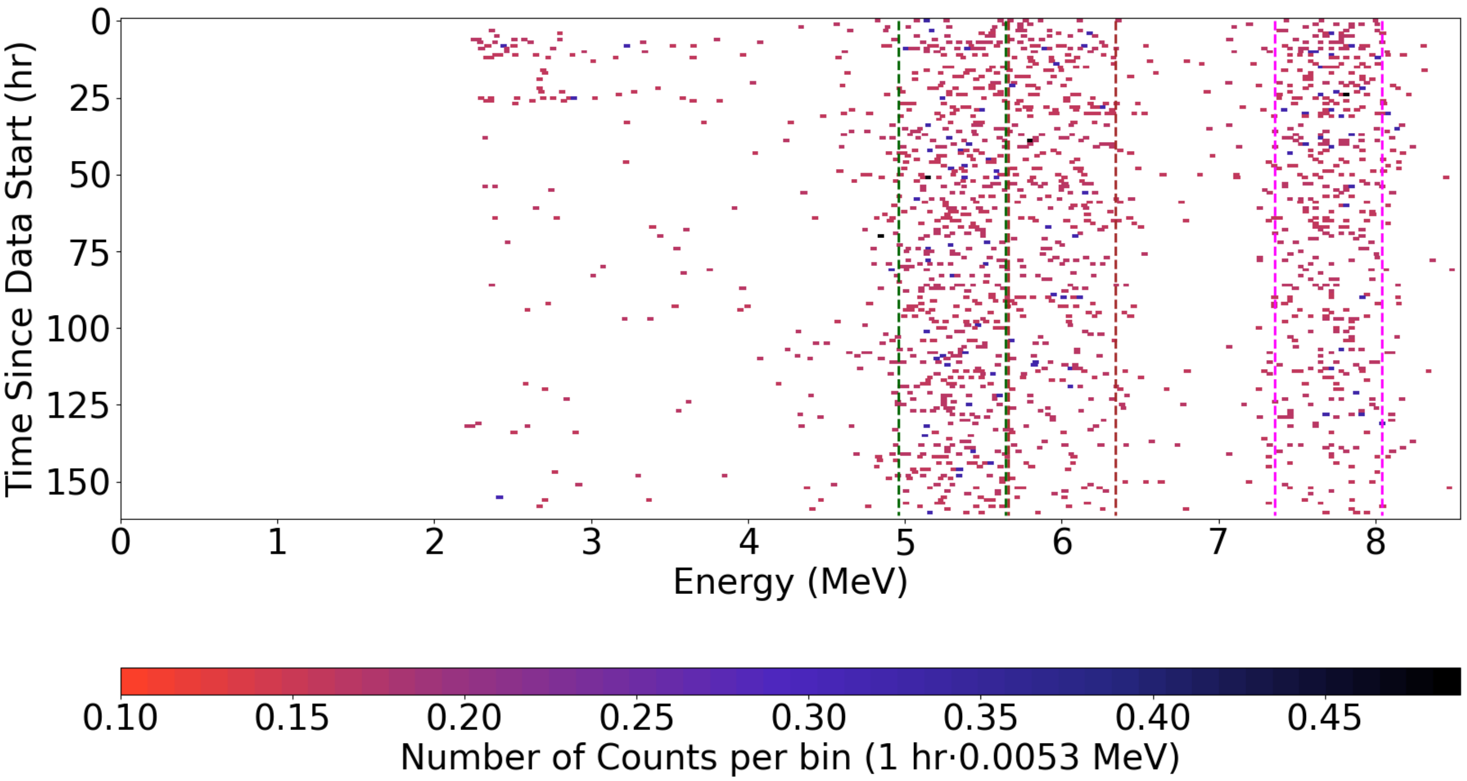


Run 675 Plots

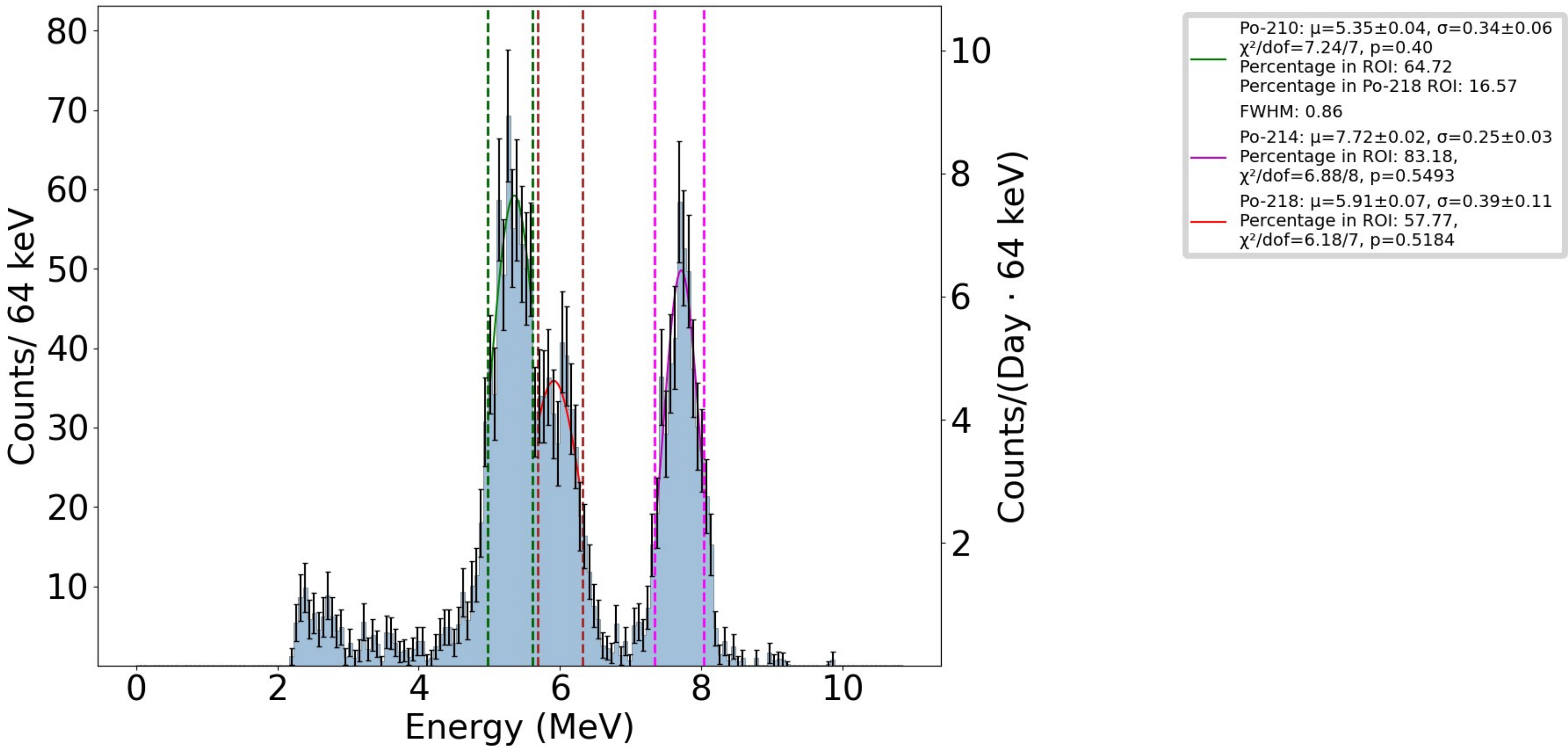
Run 675 Raw Data



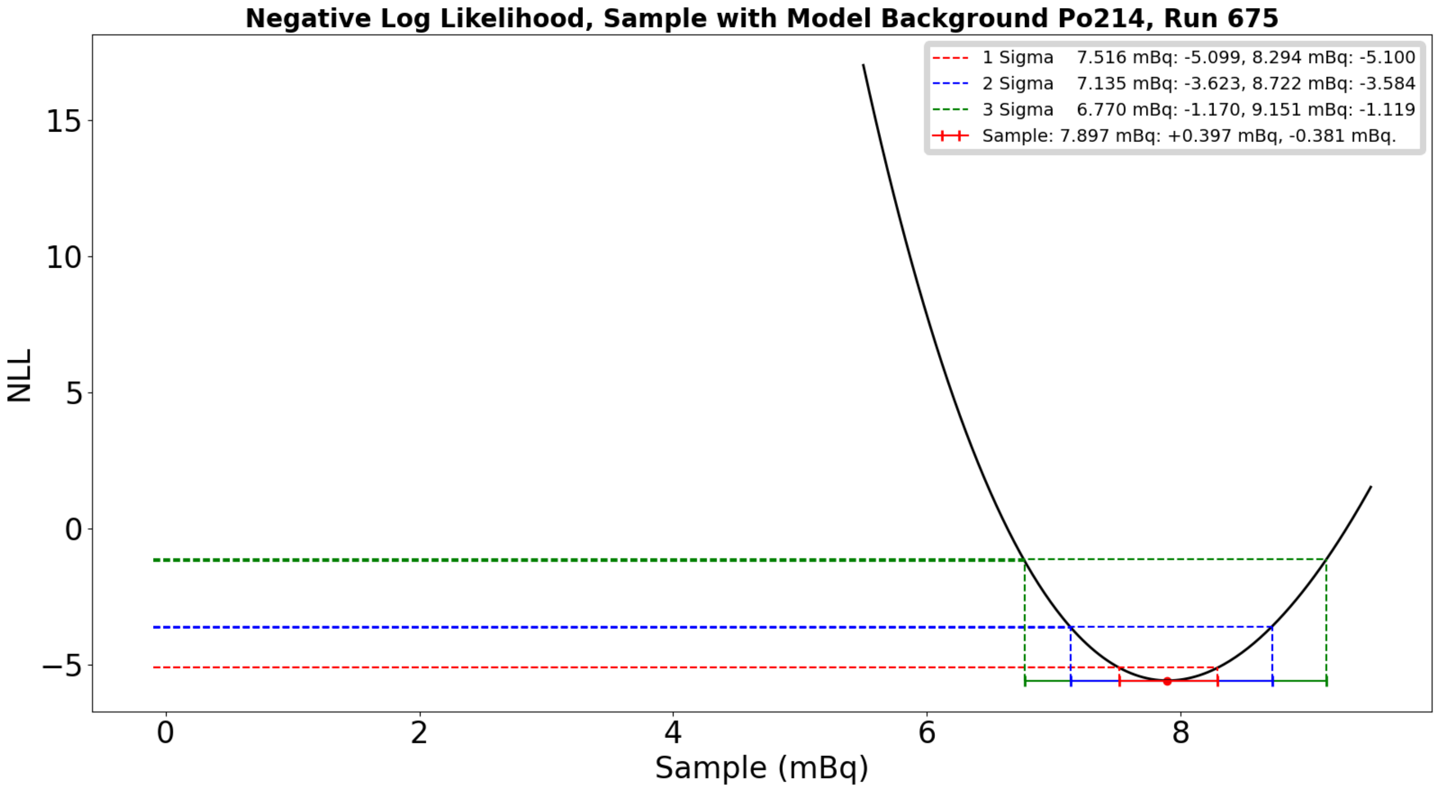
Run 675 Gain Corrected Data



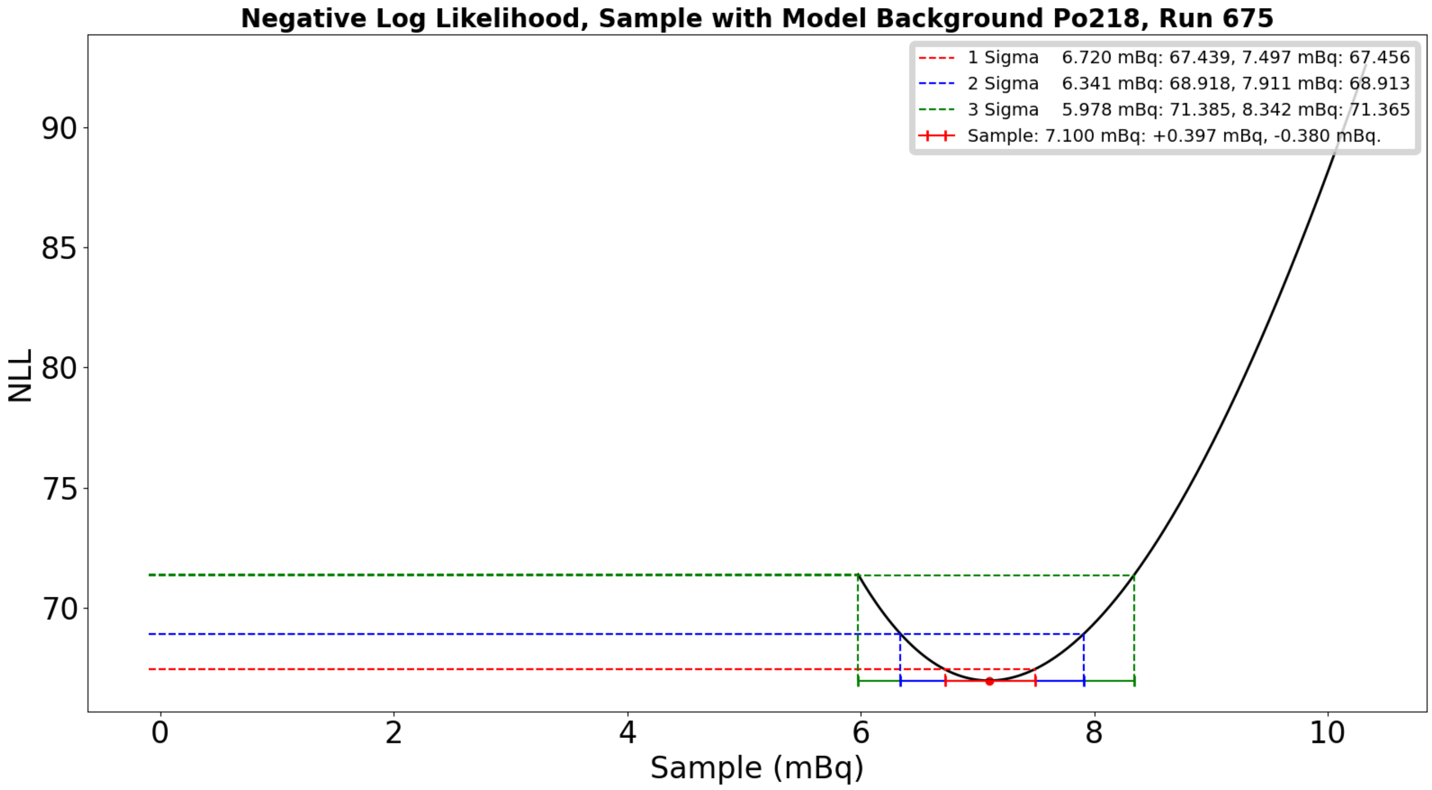
Run 675 Counts vs Energy



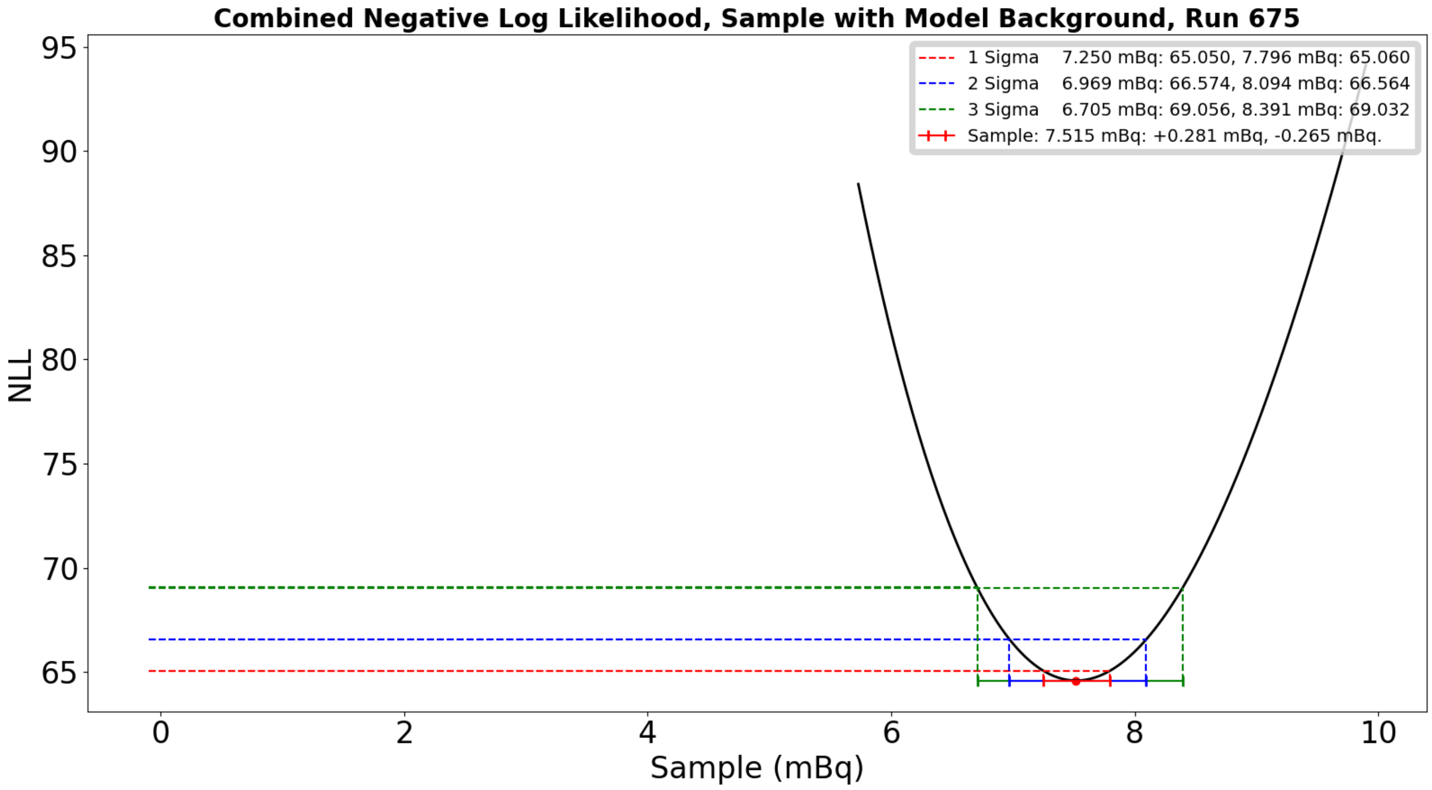
Run 675 Po-214 NLL



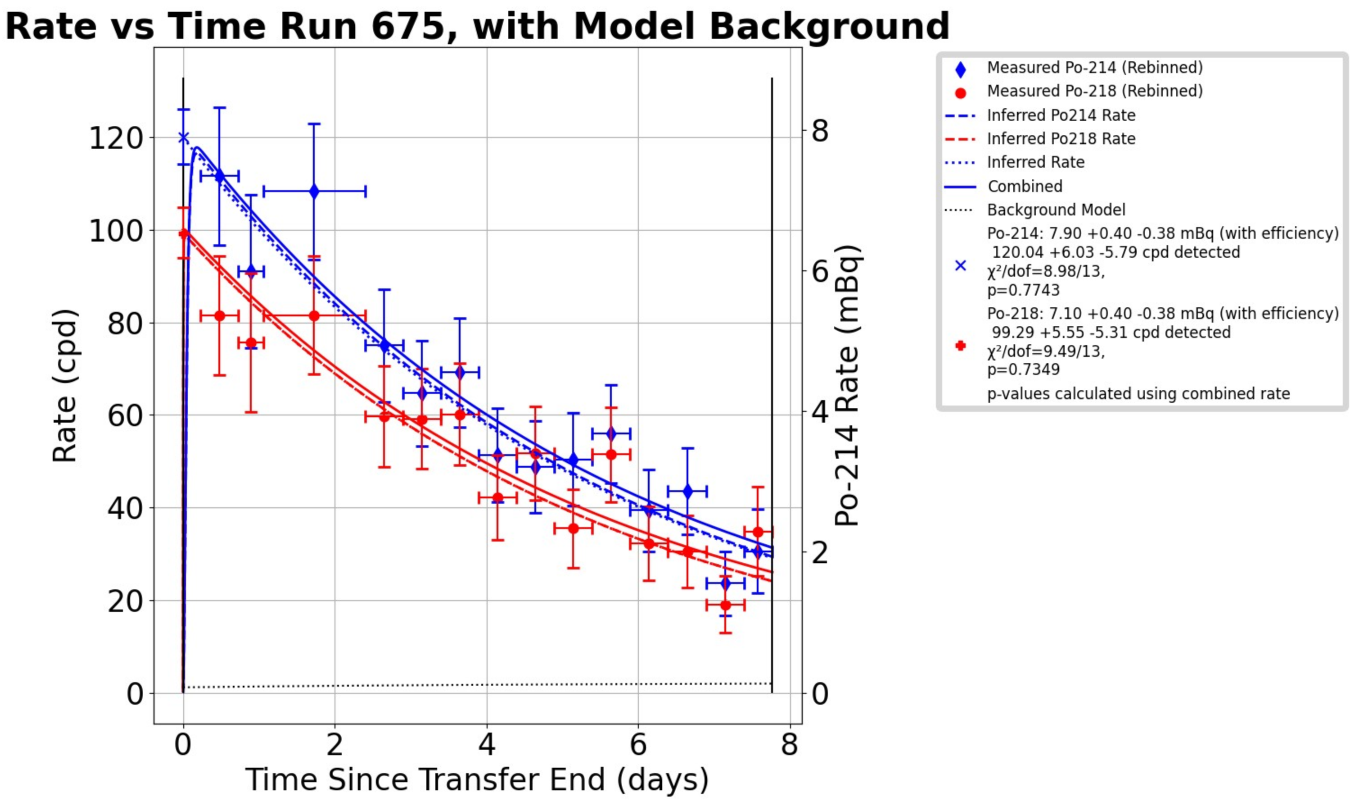
Run 675 Po-218 NLL



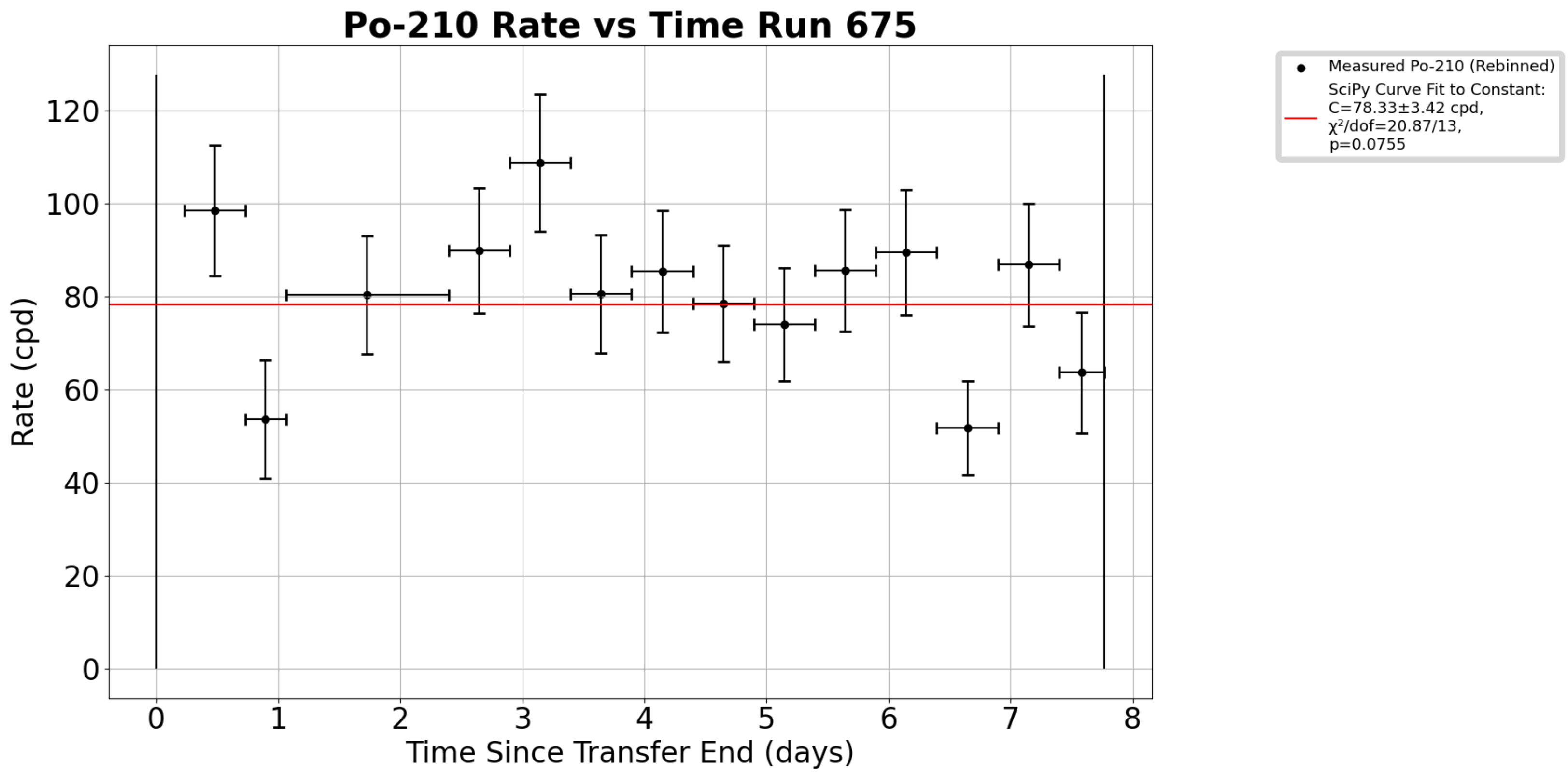
Run 675 Combined NLL



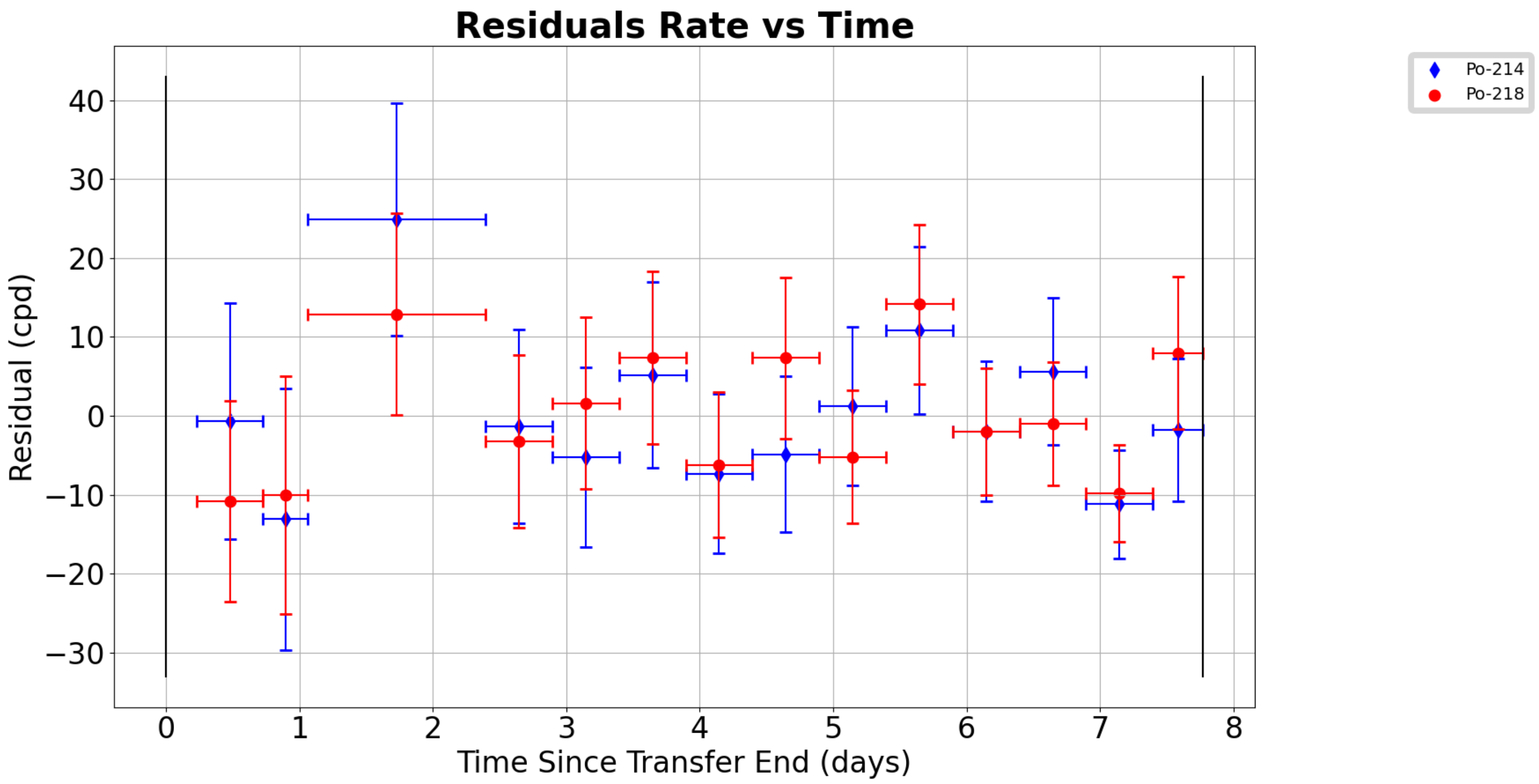
Run 675 Rate vs Time



Run 675 Po-210 Rate vs Time

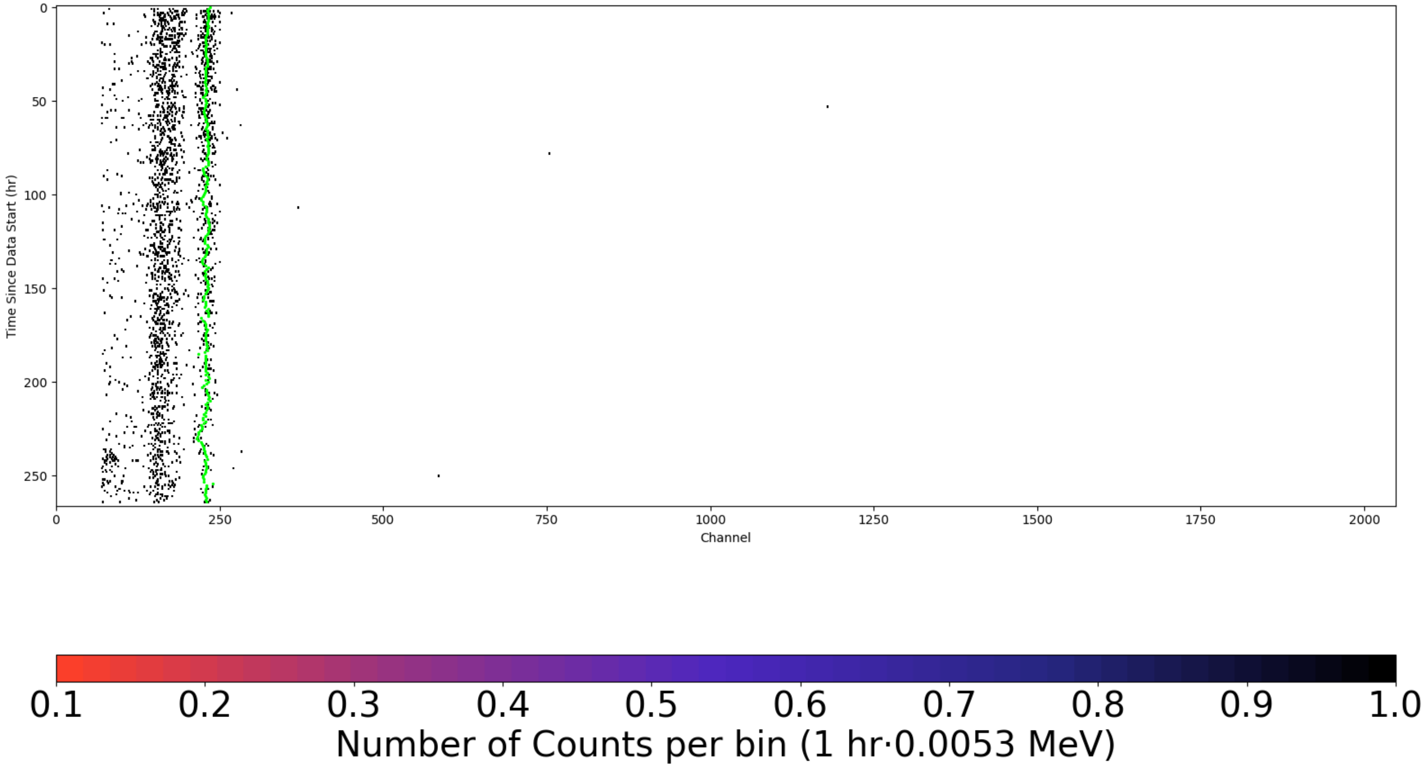


Run 675 Residuals

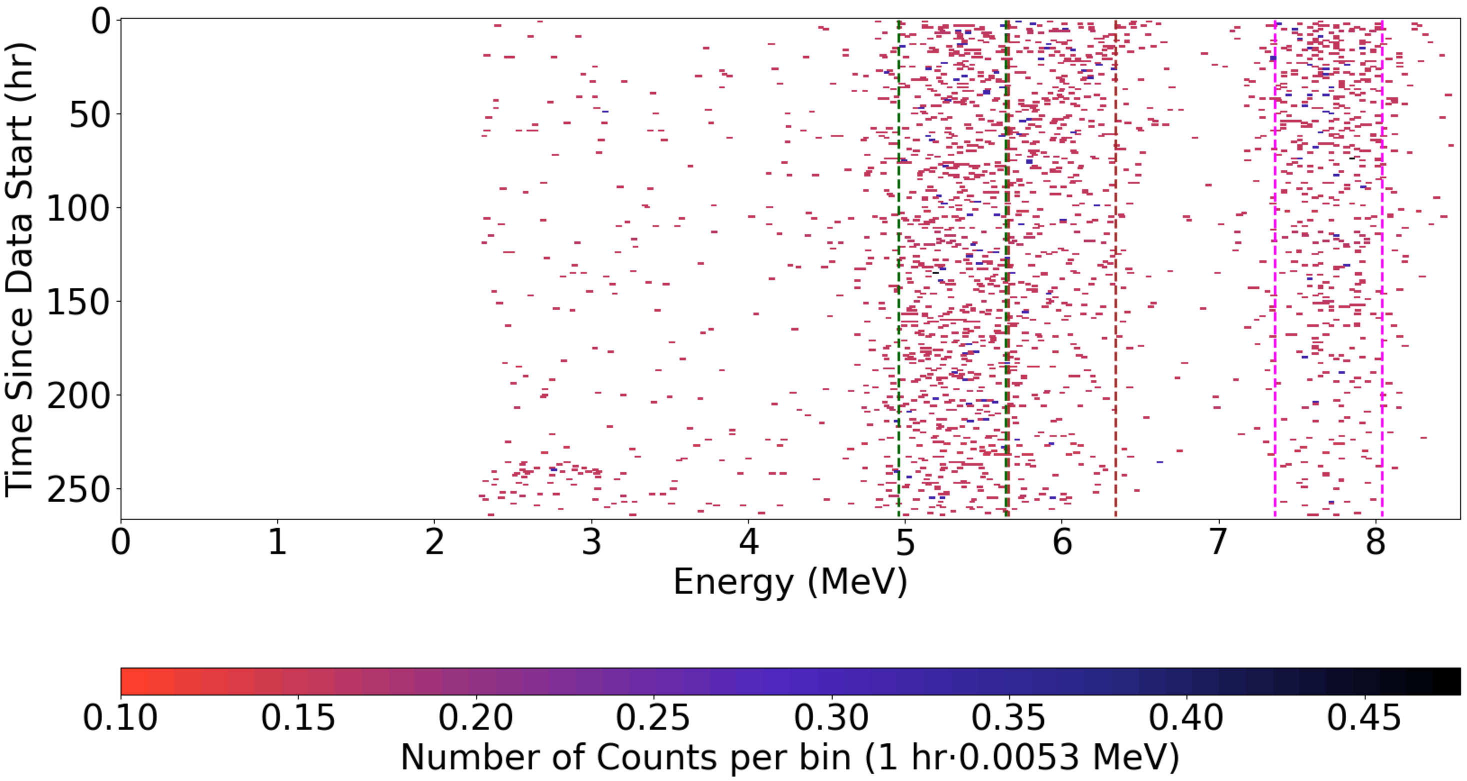


Run 677 Plots

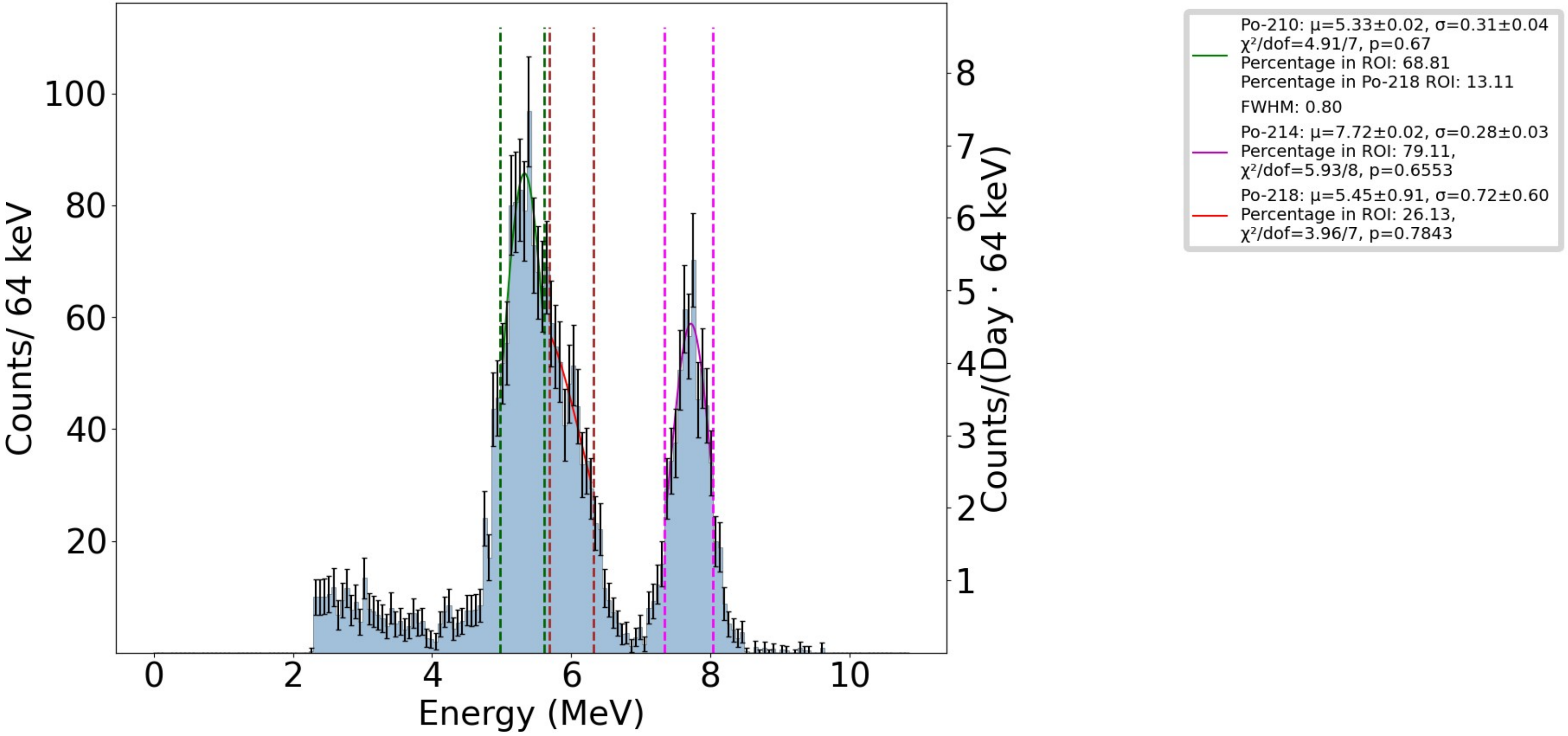
Run 677 Raw Data



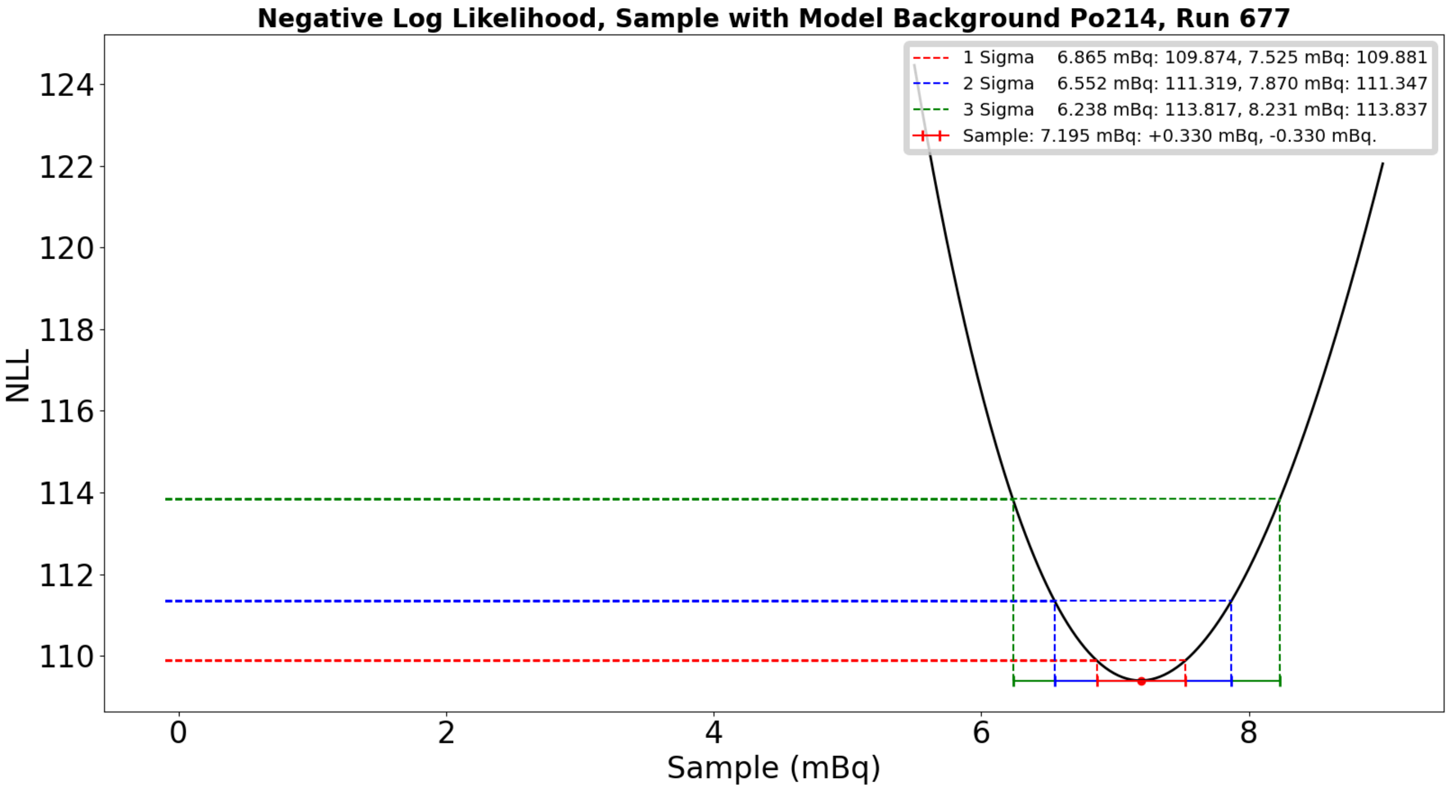
Run 677 Gain Corrected Data



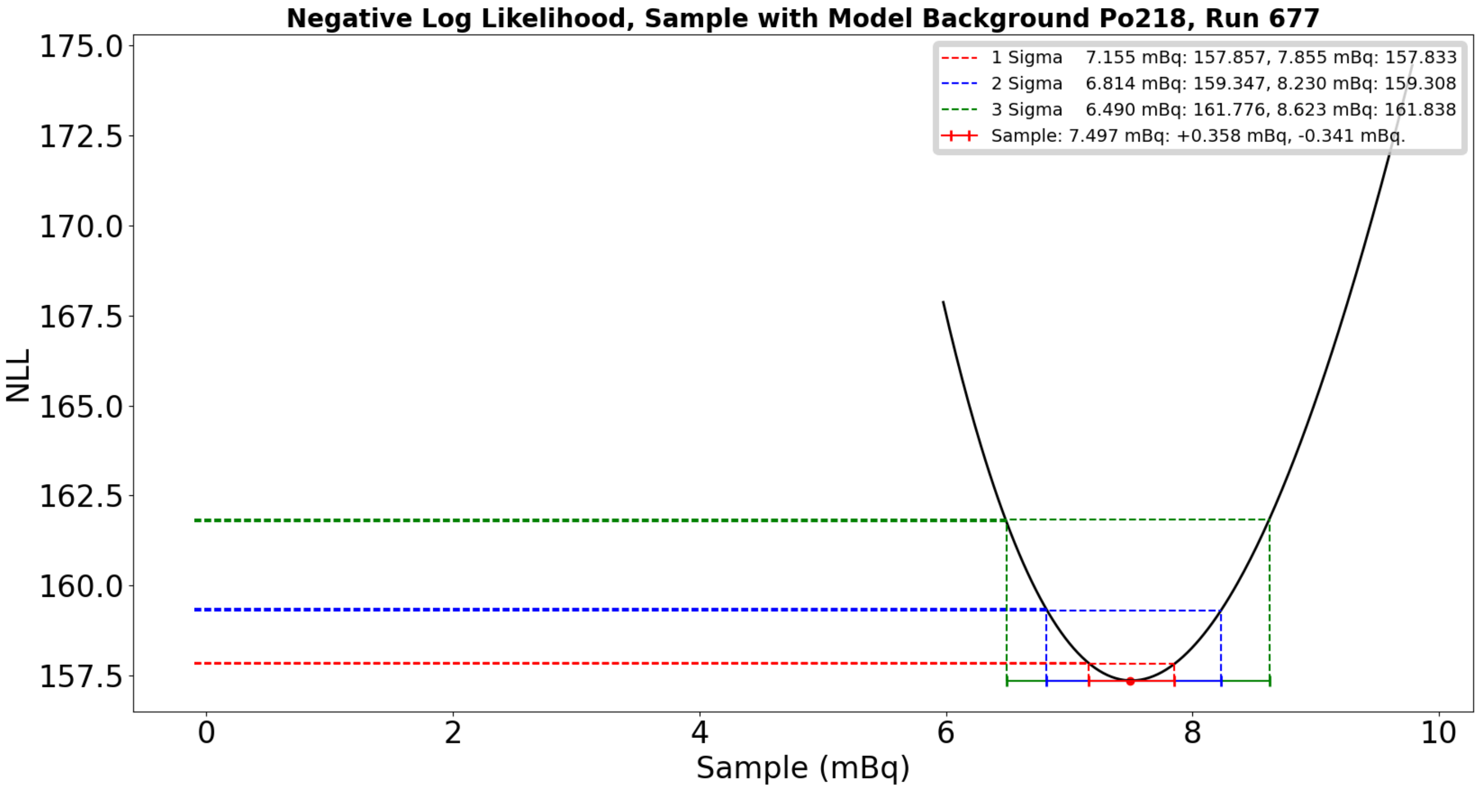
Run 677 Counts vs Energy



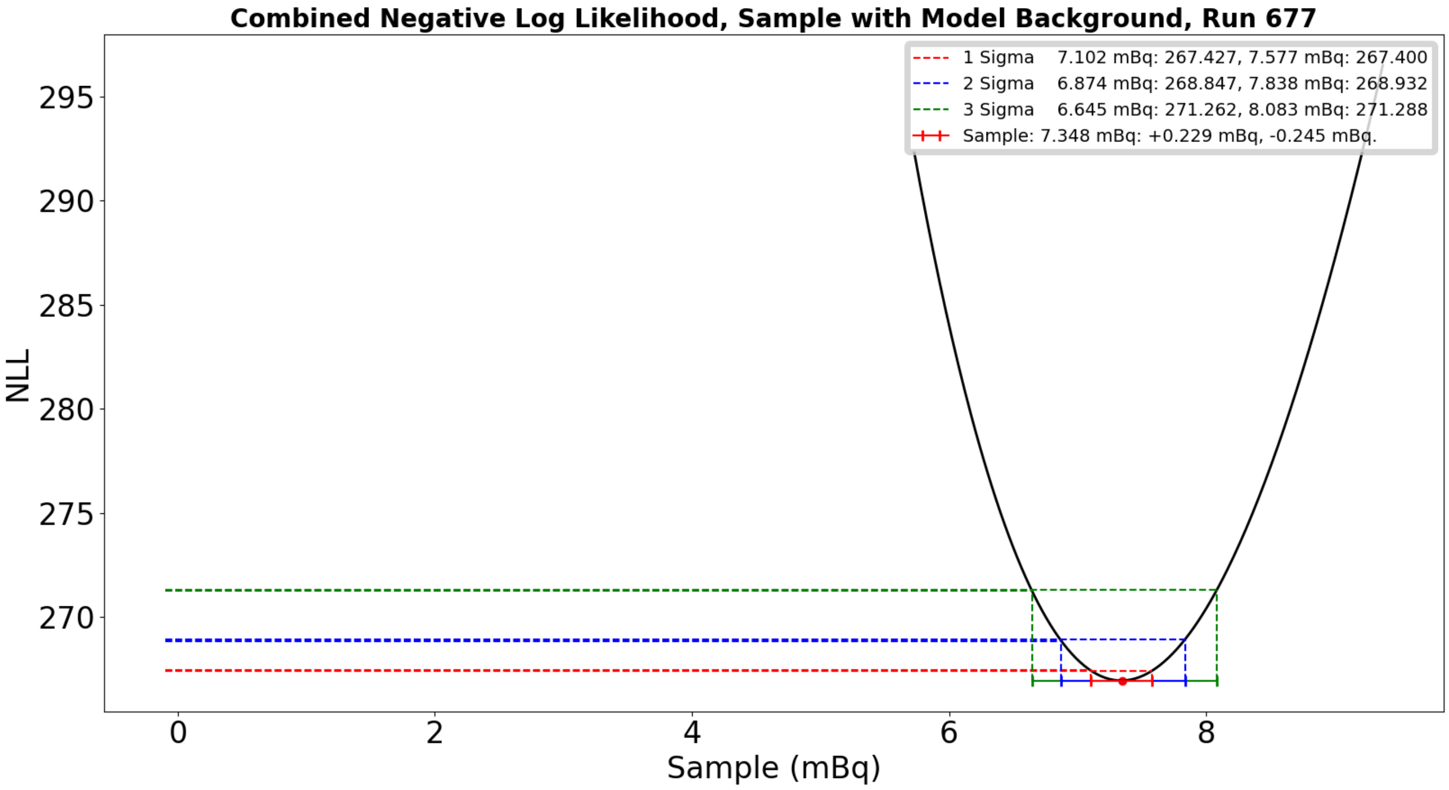
Run 677 Po-214 NLL



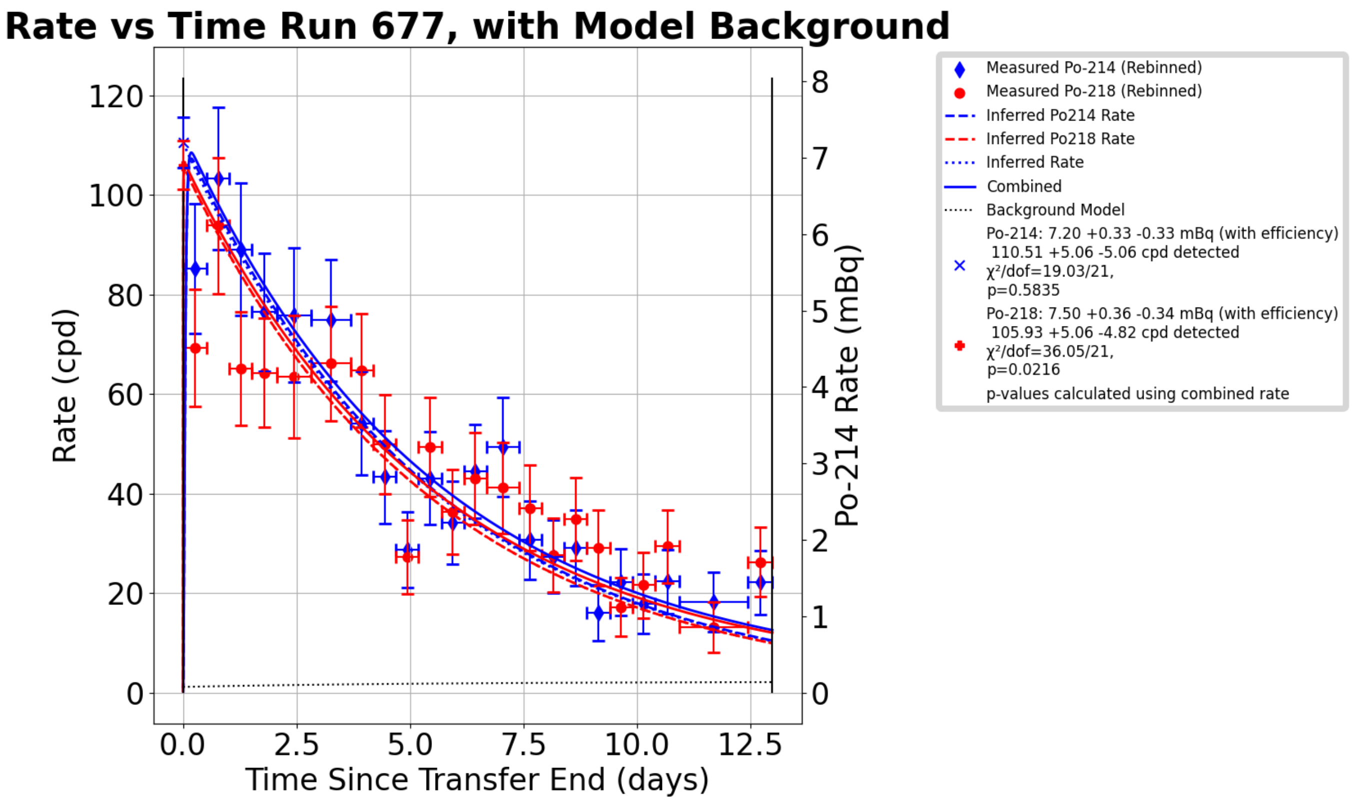
Run 677 Po-218 NLL



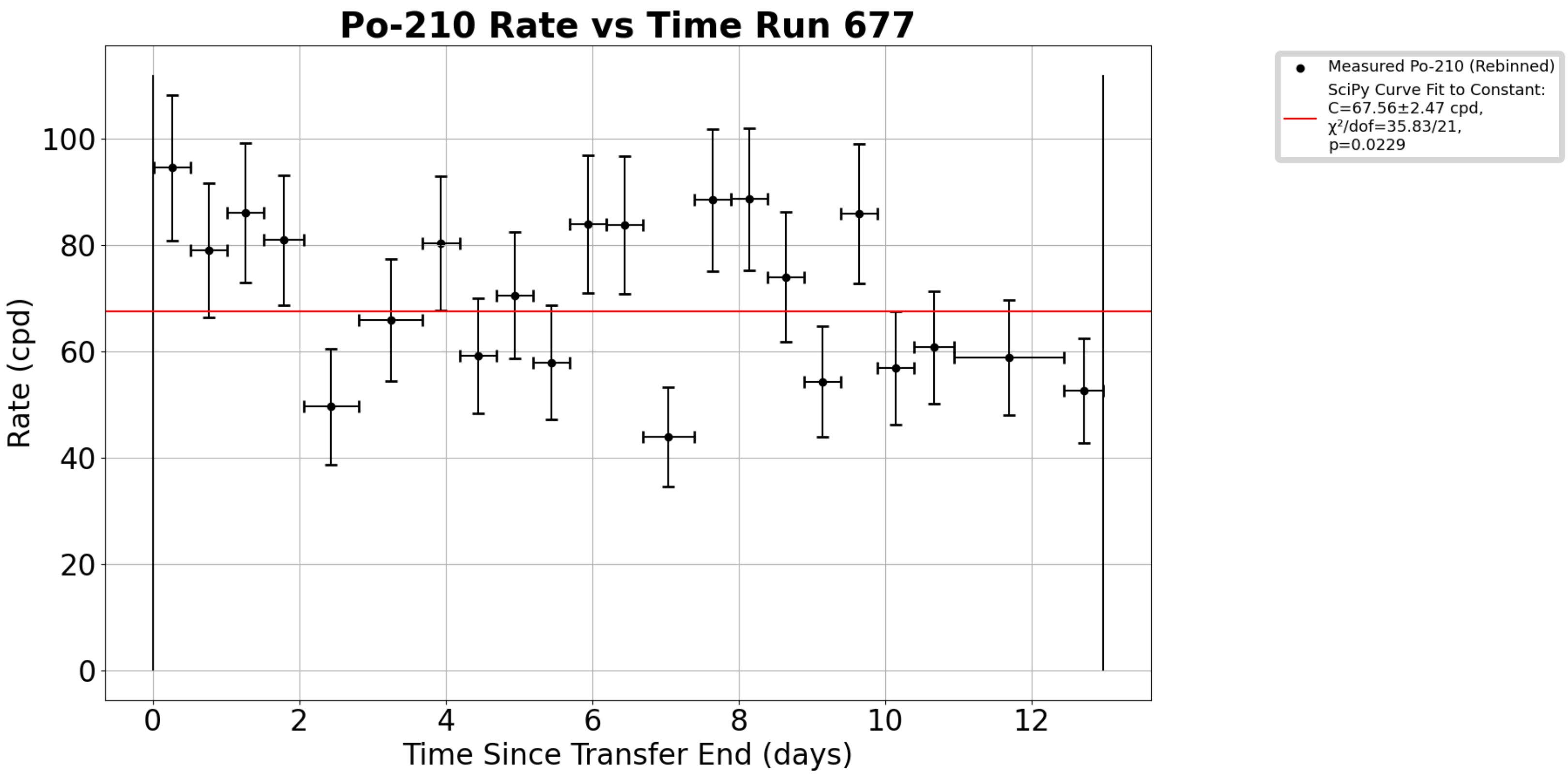
Run 677 Combined NLL



Run 677 Rate vs Time



Run 677 Po-210 Rate vs Time



Run 677 Residuals