Getter Radon Emanation Measurement

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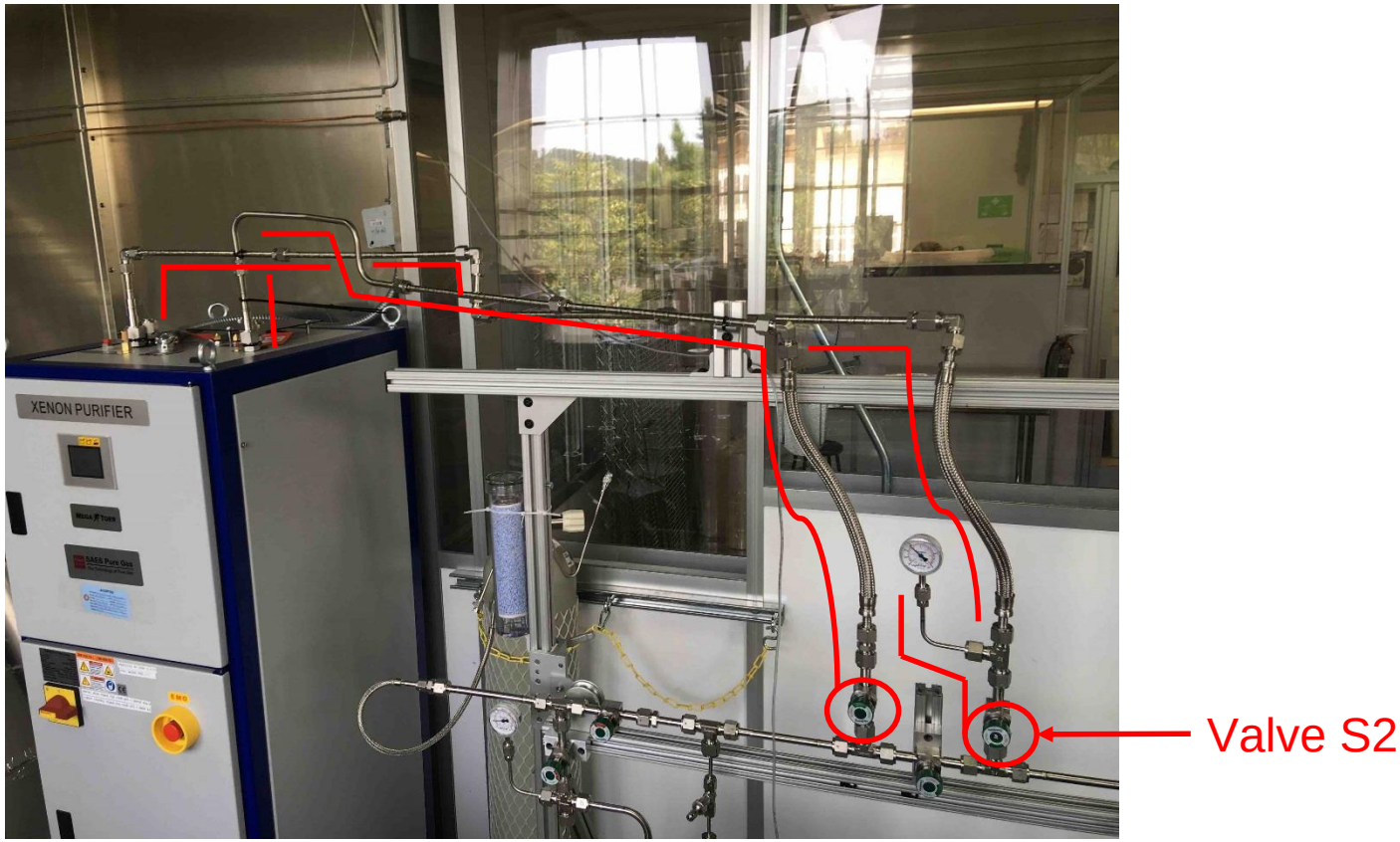
Sample



Getter Cabinet with Portable Panel

Getter cabinet does not heat up unless internal valves are open, so during emanation getter interior was open to the transfer lines, marked in red (up to the valves circled in red). Parts of the transfer lines have been emanated and have emanation rates negligible compared to the Getter. At the end of the second transfer a small seat leak was measured at valve S2 (see slide 11 for details).

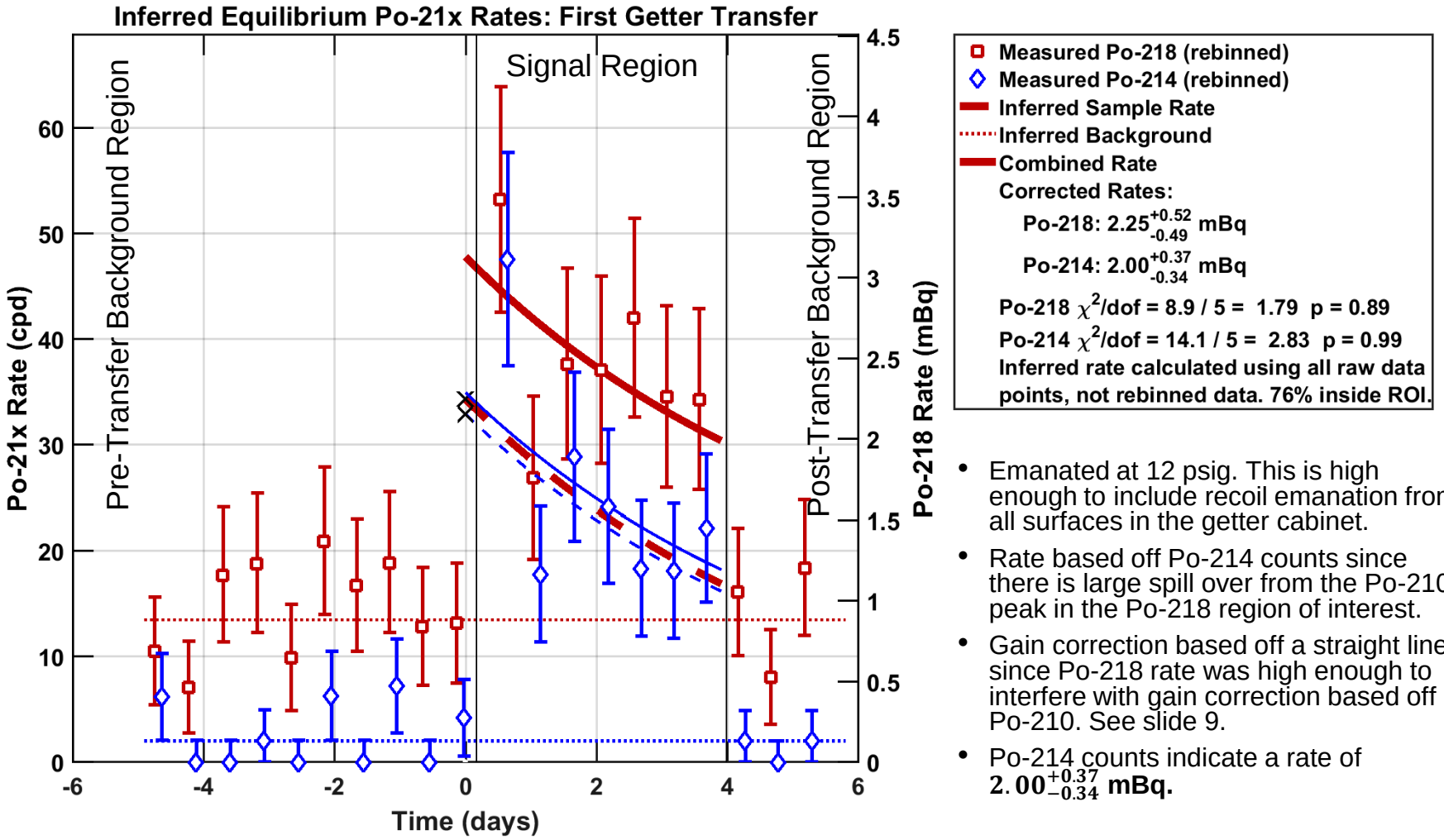
Emanated at about 420°C, and with a pressure of 12 psig (roughly 1400 Torr).

Total volume of the transfer lines is 0.6 liters (calculated by inner diameter and length), total internal volume of the getter is 6.8 liters (calculated by volume sharing and associated change in pressure). For volume calculation details see slide 12.

Overview

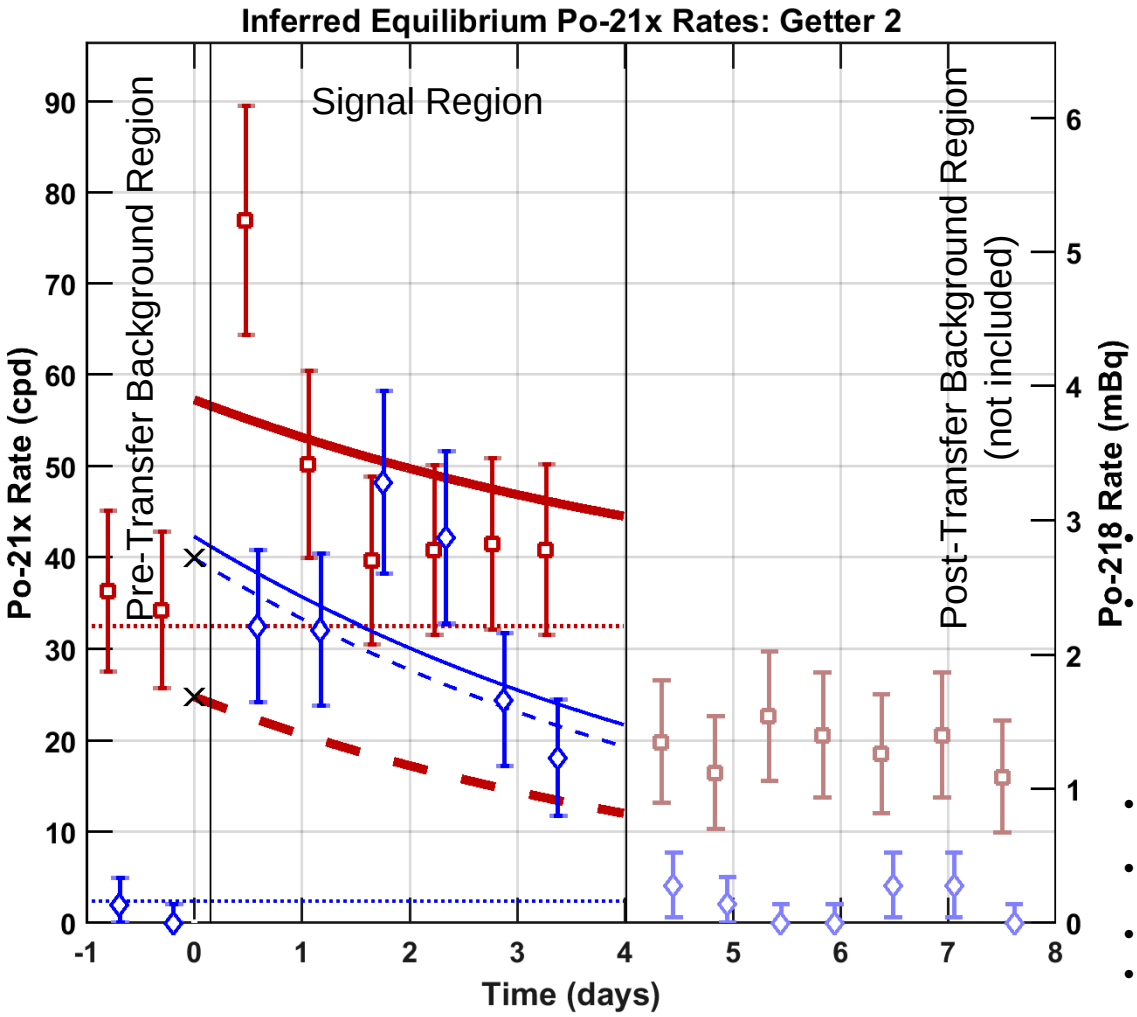
- Emanated the getter 2 times between August and October, 2018.
- Cabinet and portable panel used for transfer leak-checked using helium leak checker. There were no detectable (external) leaks anywhere in the setup.
- During second transfer pressure dropped by 4.5%. Some portion of this could be lost sample through a valve seat leak (see slide 11 for details).
- Measurements indicated an emanation rate of $\mathbf{2.26^{+0.28}_{-0.27}}$ **mBq** for all the getter and the cabinet.
  - This is consistent with the preassay assumptions of $\mathbf{4.69^{+0.35}_{-3.79}}$ **mBq** which was based on Xenon1T radon emanation measurements of two different getters.
    - LZ is estimated to use 3.5x as much getter as Xenon1T.
    - First getter had a rate of 1.34 mBq, resulting in a prediction of 4.7 mBq for LZ.
    - Second getter had a rate of 0.26 mBq, resulting in a prediction of 0.9 mBq for LZ.
    - Higher rate was assumed for central value to be conservative.
- Post-assay background of second transfer was not useable (it was done with a different filter box which turned out to not be functioning correctly).

First Emanation (August 29 – September 17)



- Emanated at 12 psig. This is high enough to include recoil emanation from all surfaces in the getter cabinet.
- Rate based off Po-214 counts since there is large spill over from the Po-210 peak in the Po-218 region of interest.
- Gain correction based off a straight line since Po-218 rate was high enough to interfere with gain correction based off Po-210. See slide 9.
- Po-214 counts indicate a rate of $\mathbf{2.00^{+0.37}_{-0.34}}$ **mBq.**

Second Emanation (September 17–October 16)



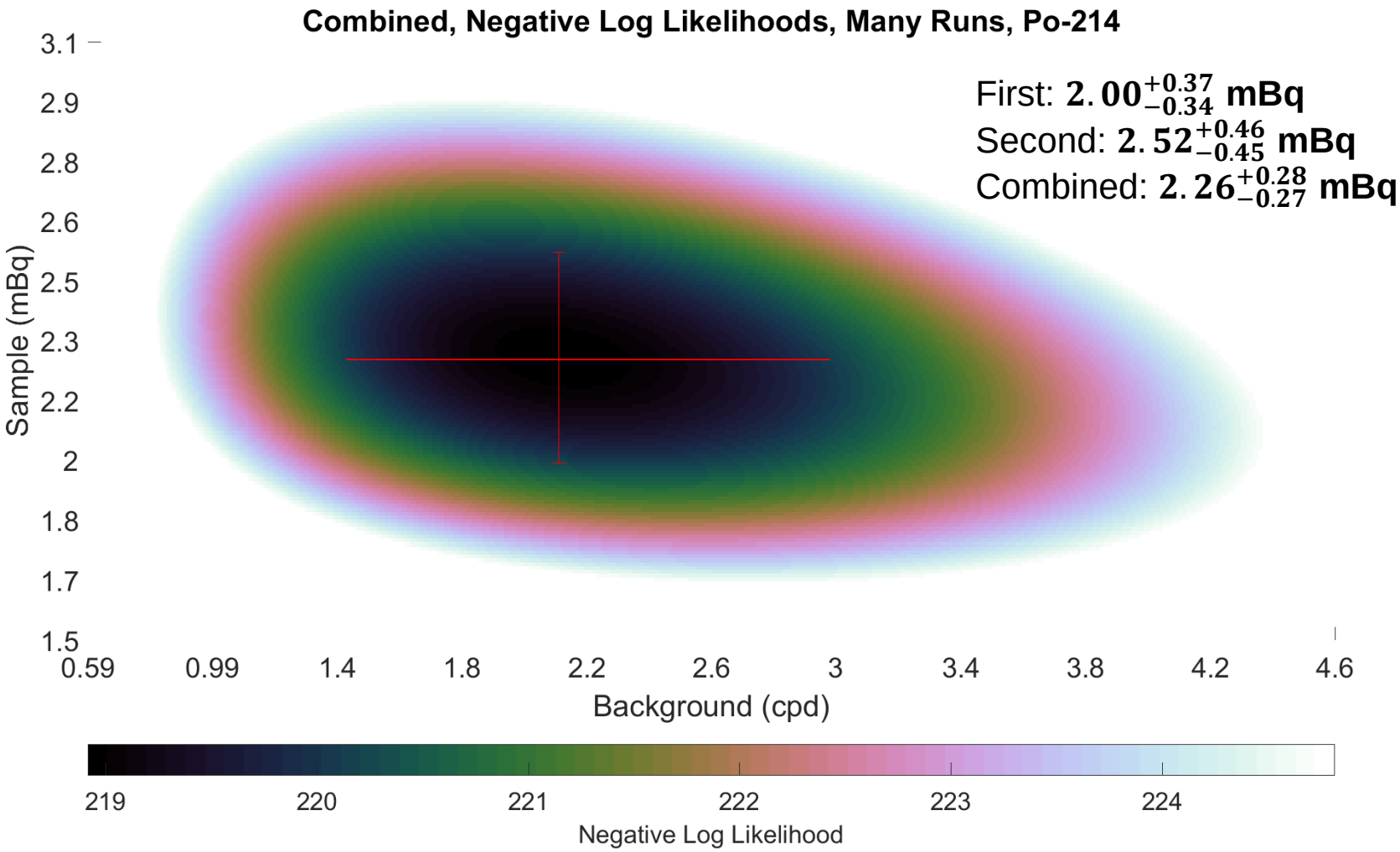
Emanated at 12 psig. This is high enough to include recoil emanation from all surfaces in the getter cabinet.

Rates based off of Po-214 counts since too many counts from the Po-210 peak spilled into the region of interest, particularly in the background run which had significantly worse resolution than the sample run (see slides 24 and 25).

- Spill over in the background run is equivalent to 2 mBq, i.e. nearly as many counts as the sample.

- Up to 4.5% of the sample could have leaked out (probably less actually did, see slide 11).
- Post background used a different filter box which was not functioning correctly, and so that run is not used here.
- Po-214 counts indicate a rate of $\mathbf{2.52^{+0.46}_{-0.45}}$ **mBq.**
- If post transfer background is included there would be almost no change in Po-214 counts. See slide 10 for details.

Combined Likelihoods

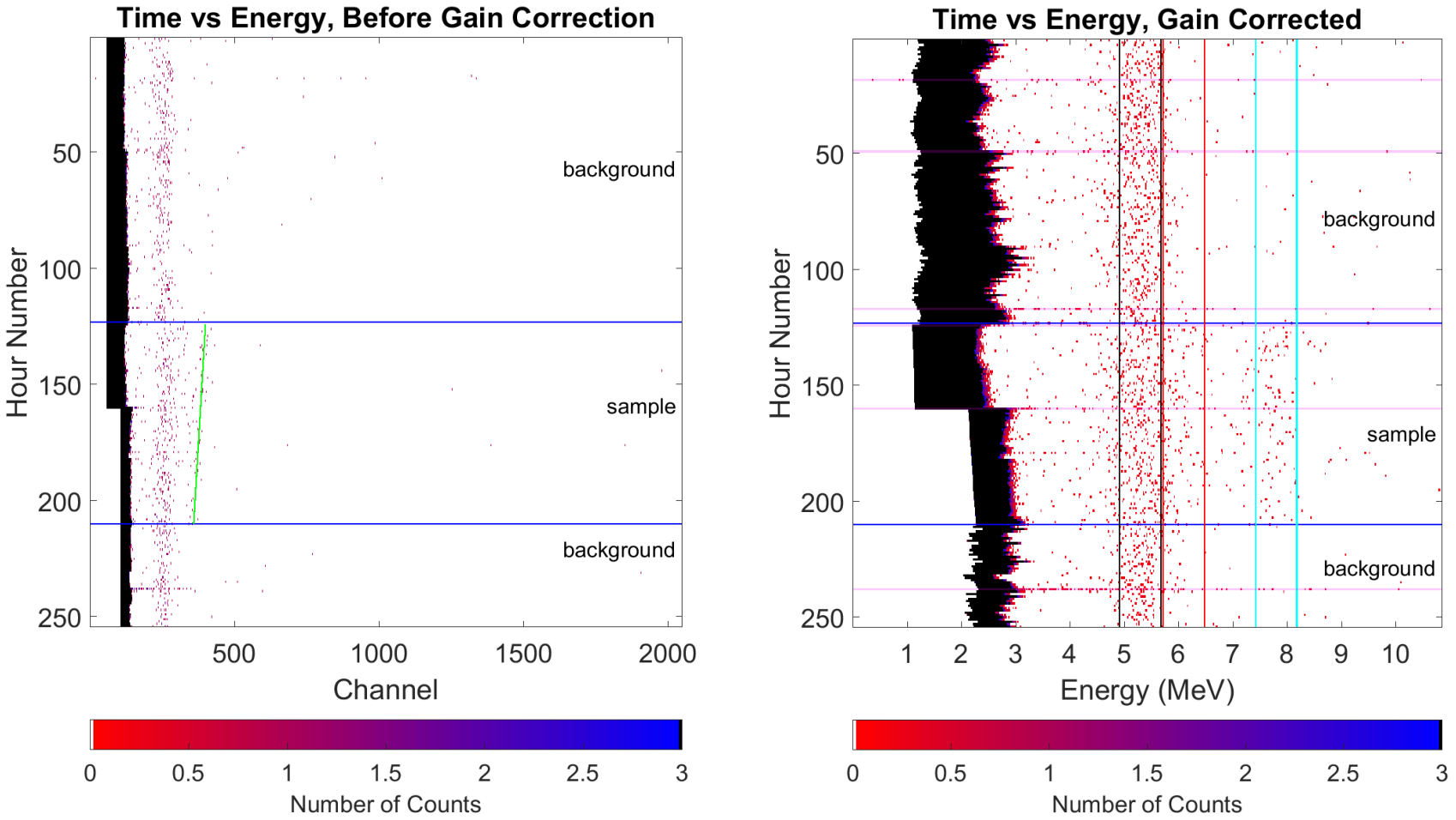


Conclusion

- Getter emanates at $\mathbf{2.26^{+0.28}_{-0.27}}$ **mBq**.
  - This includes the getter itself and all components exposed to the flow path in the getter cabinet at operating temperature and 12 psig, as well as the transfer lines connecting it to the portable emanation panel.
  - This is consistent with the preassay assumptions, $\mathbf{4.69^{+0.35}_{-3.79}}$ **mBq**.

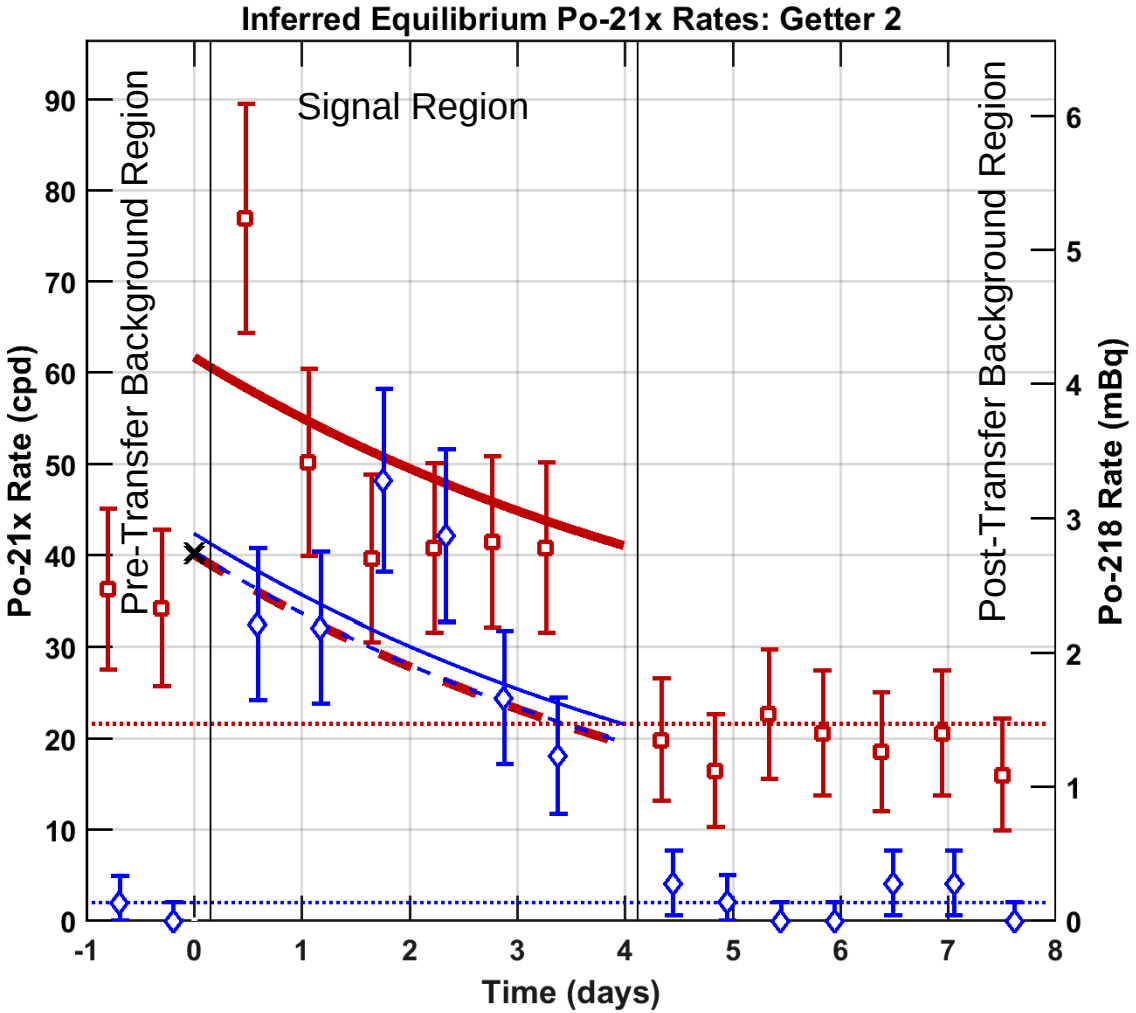
Backup Slides

Gain Correction Line for First Emanation



- Line used for gain correction shown in green, after gain correction shown on the right.
- Sample run could not be gain corrected based off of Po-210 since the Po-218 signal was large enough to interfere with gain correction.

Second Emanation with post background run (March 27 – April 9)



- Emanated at 12 psig. This is high enough to include recoil emanation from all surfaces in the getter cabinet.
- Post background used a different filter box which was not functioning correctly.
- Up to 4.5% of the sample could have leaked out (probably less actually did).
- Po-214 counts indicate a rate of $\mathbf{2.55^{+0.44}_{-0.39}}$ **mBq.**
- Note that this is almost identical (central values are within 0.03 mBq of each other) to the Po-214 rate indicated if the post background is taken out.
- Also note that because of the Po-210 spill over in the prebackground run the Po-218 rate changes significantly if the post background is left in ($\mathbf{2.73^{+0.66}_{-0.63}}$ mBq) vs if it is taken out ($\mathbf{1.69^{+0.90}_{-0.92}}$ mBq).

Second Emanation Potentially Lost Sample

- During the second emanation, pressure dropped by **4.5%** (from 12 psig to 10.8 psig).
  - This could be due to a combination of a leak and temperature changes in the heated getter and lab air, and/or some interaction with the getter components (adsorption may effect how pressure responds to temperature changes in the getter for example).
  - A seat leak through one of the valves was measured with the helium leak checker at the end of the second emanation, with a rate of about 1 x 10^{-8} Torr*liters/sec. If this reading is accurate and constant throughout the emanation the pressure drop due to it should've only been 0.01%.
- If the pressure change is due to temperature rather than a leak, either both the getter cabinet pressure and the room temperature would have to change, or a temperature change more than 4.5% would be needed in one of them. For example:
  - If both changed by the same percent, then getter temperature dropped by roughly 31°C, and room temperature by 13°C.
  - If Getter temperature was constant, then room temperature dropped by roughly 62°C.
  - If room temperature was constant getter temperature would have to have dropped by roughly 37°C
- Since temperature changes this extreme were not noticed, temperature alone does not seem like a good explanation.
- Gas lost early in the emanation would have a smaller effect on emanation efficiency since it would carry less radon out.

Volume Calculations

- Volume of transfer lines and internal getter bypass plumbing calculated based on measured length and internal radius.
- Measurements:
  - Inlet connection length is 105 in, OD is ½ in, ID is 0.375 in.
  - Outlet connection length is 82 in, OD is ½ in, ID is 0.375 in.
  - Getter bypass plumbing is 57 in, OD is ¾ in, ID is 0.625 in.
- Volume in the transfer lines and bypass plumbing (which is open to gas when the valves are opened):

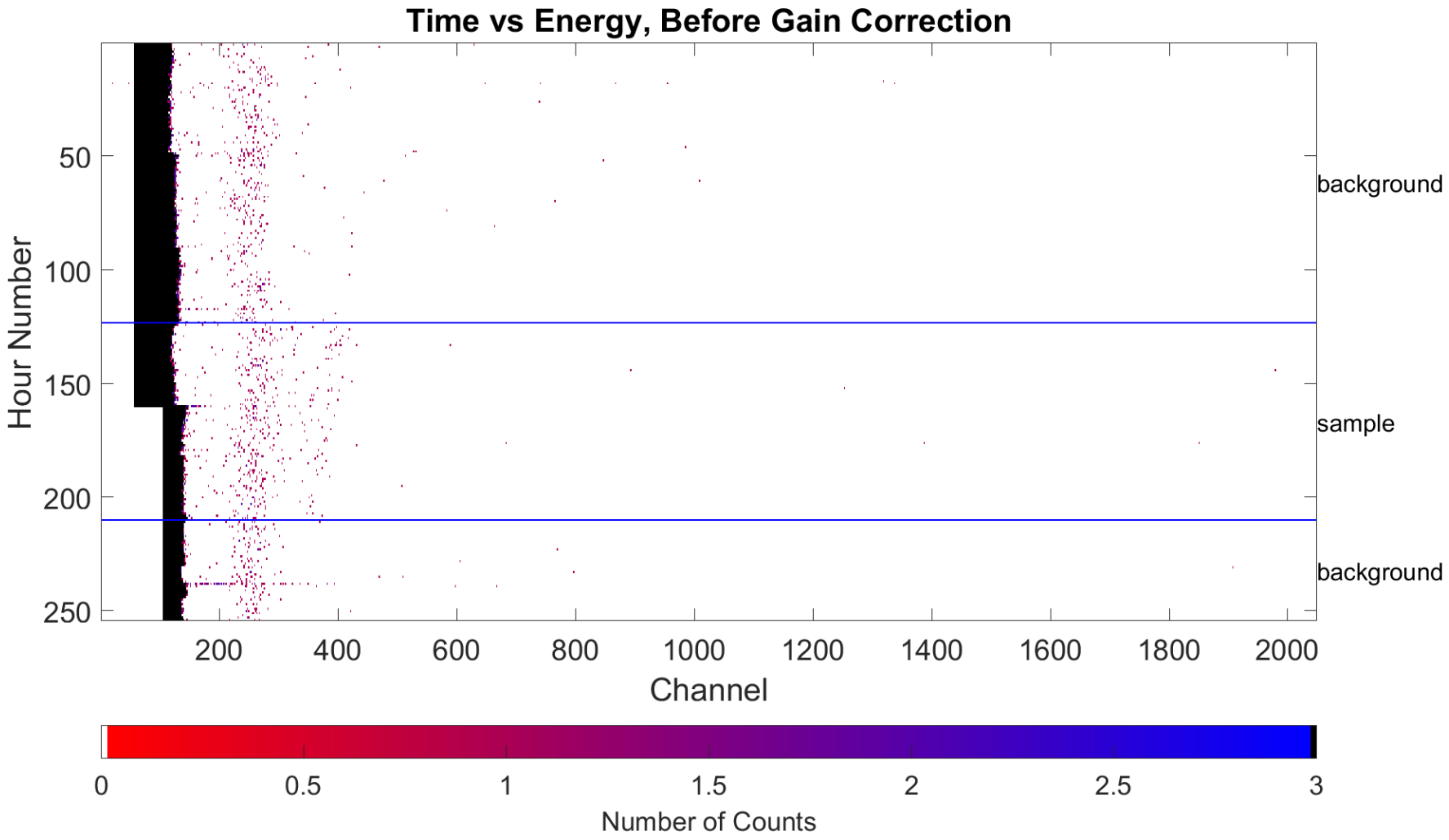
$$\left(105in * pi\left(\frac{0.375in}{2}\right)^2 + 82in * pi\left(\frac{0.375in}{2}\right)^2 + 57in * pi\left(\frac{0.625in}{2}\right)^2\right) * \frac{1\ liter}{61.02\ in^3} = 0.625\ liters$$

- Getter internal volume calculated by filling the getter vessel pressure to 15.2 psig and then pumping on the transfer lines until they are approximately at vacuum, and then volume sharing between the getter and transfer lines to get a new pressure of 12.7 psig:

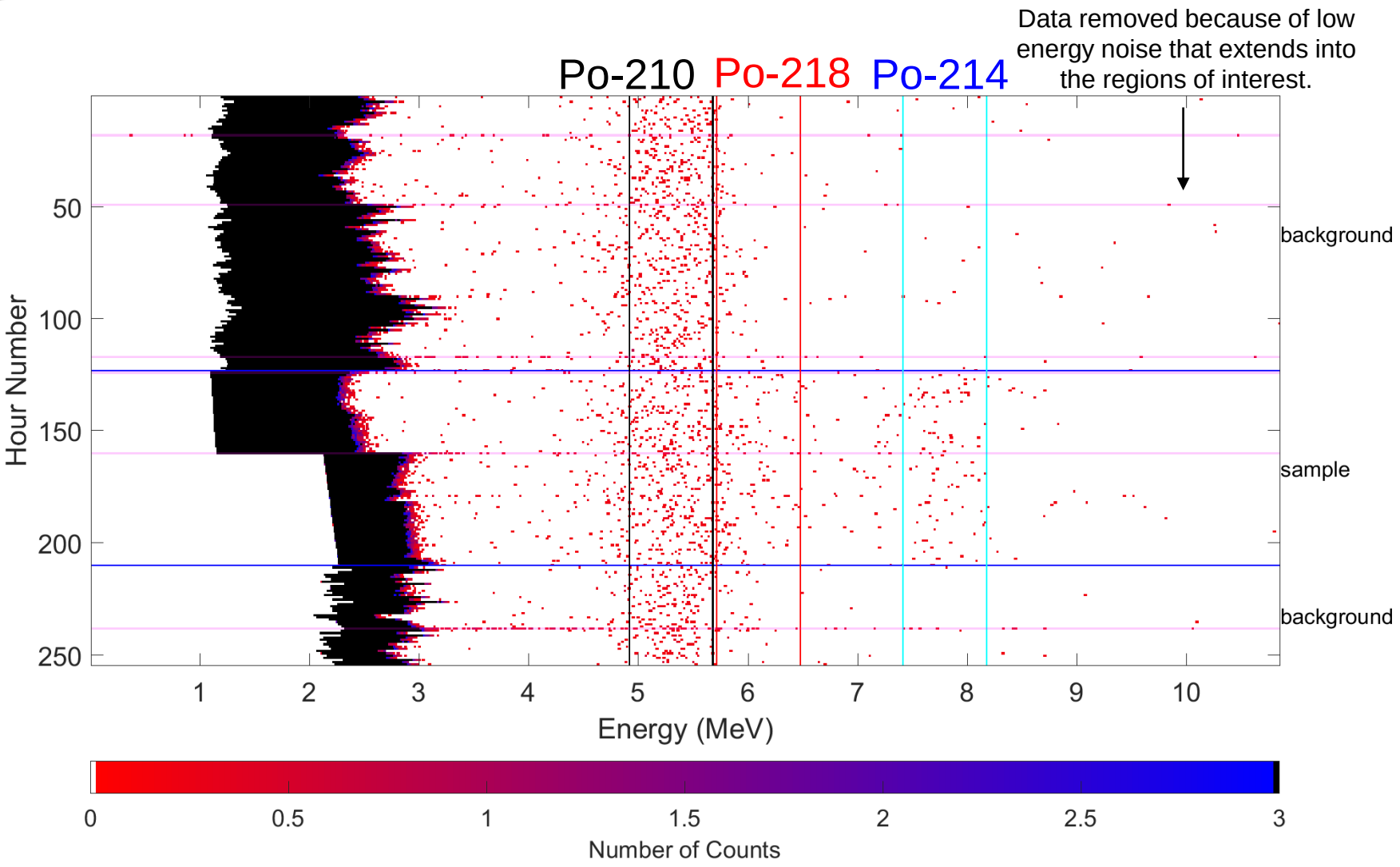
$$\left(15.2psig + 14.7\frac{psi}{atm}\right) * V_{Getter} = \left(12.7psig + 14.7\frac{psi}{atm}\right) * (V_{Getter} + 0.625\ liters)$$

$$V_{Getter} = \frac{\left(12.7psig + 14.7\frac{psi}{atm}\right) * 0.625\ liters}{15.2psi - 12.7psi} = 6.85\ liters$$

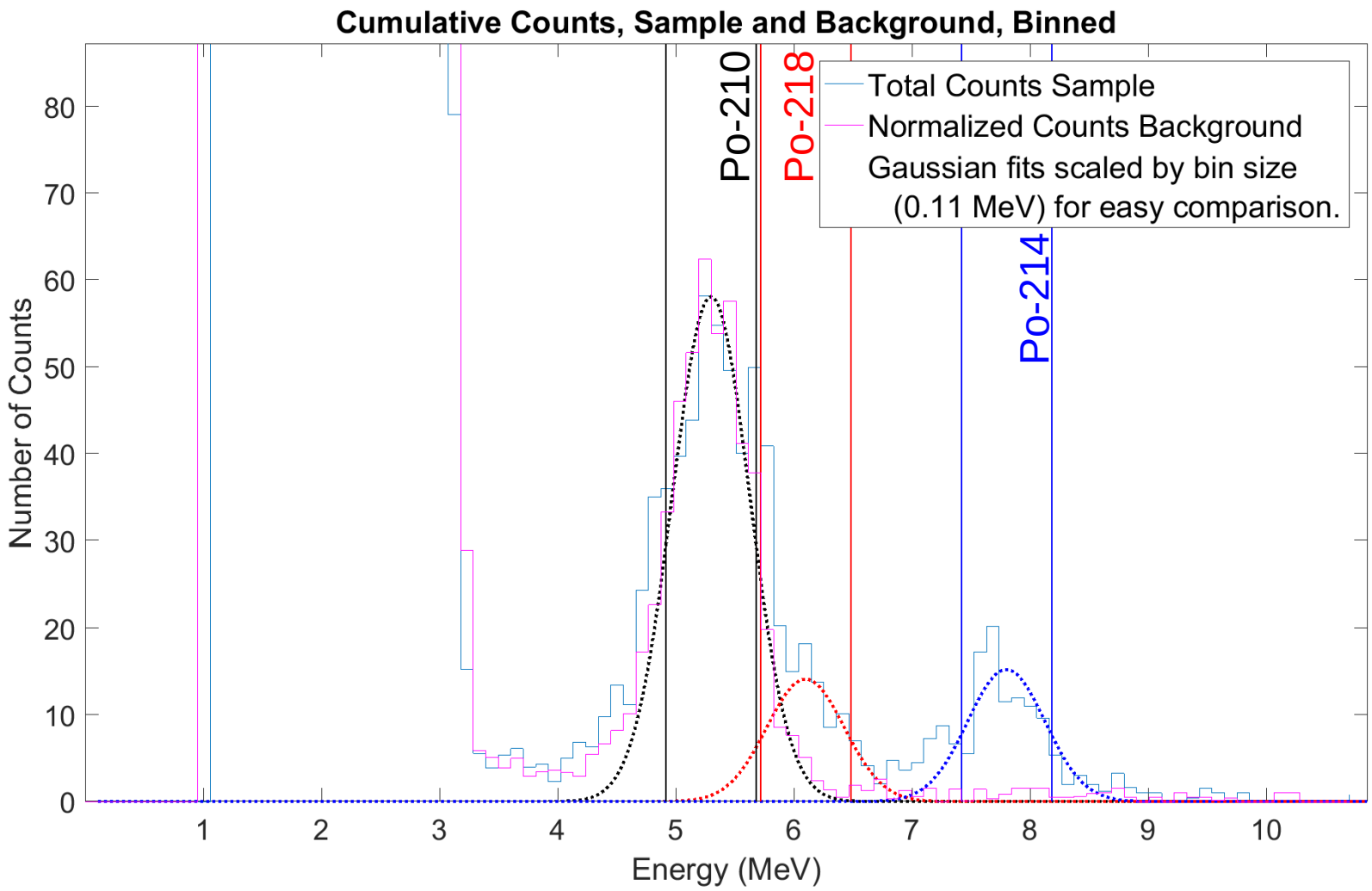
First Transfer



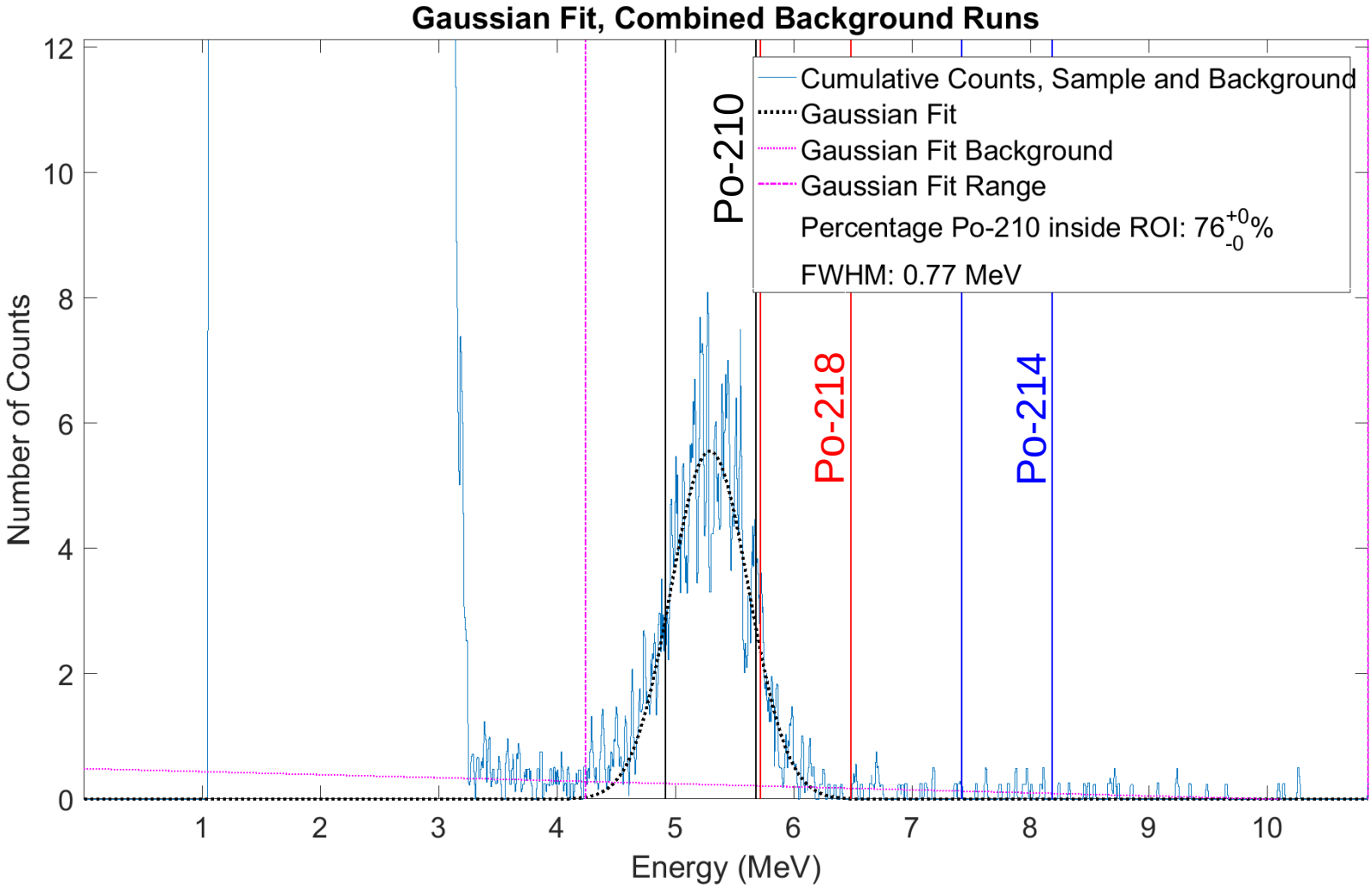
First Transfer



Cumulative Counts First Transfer

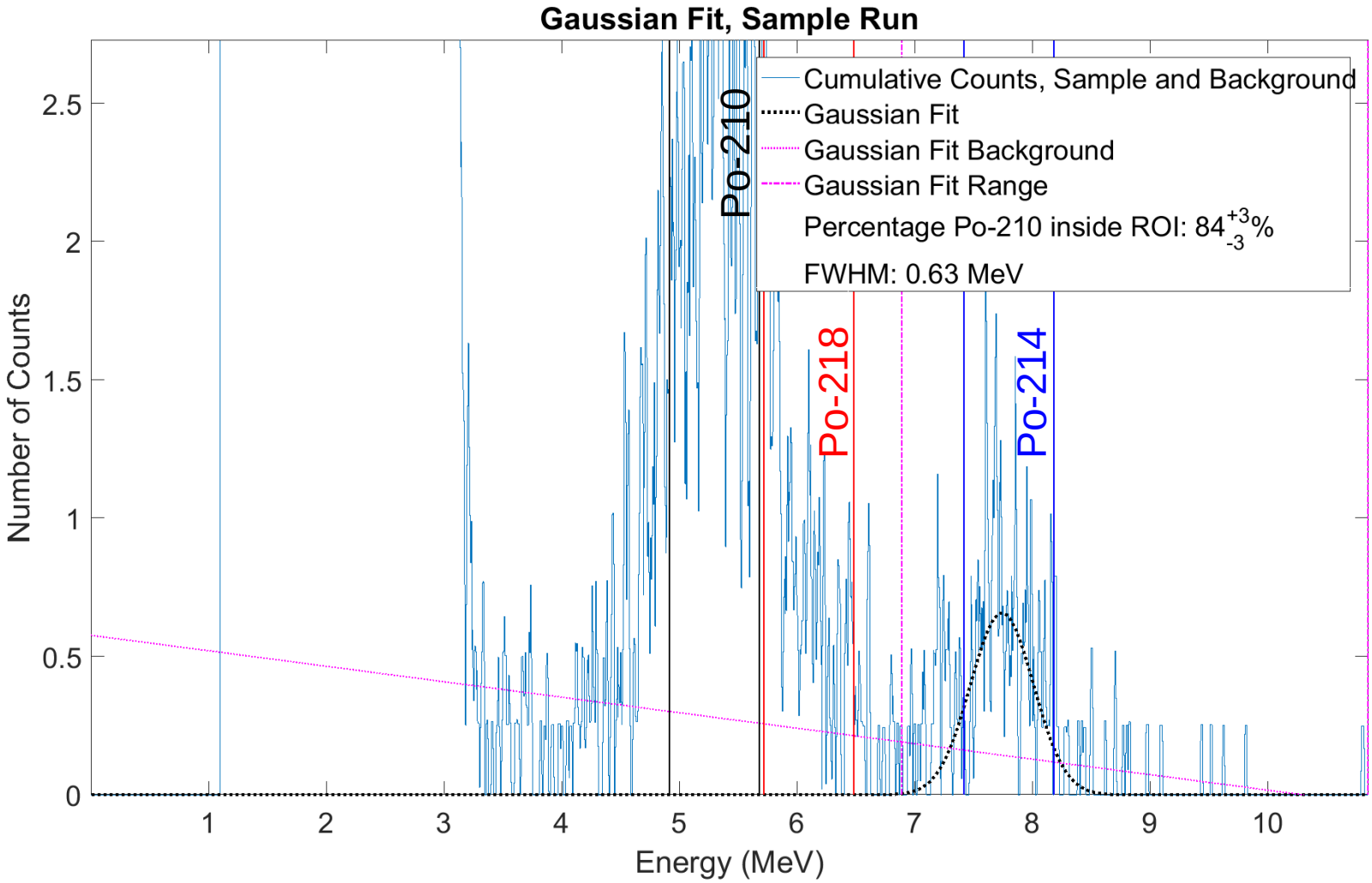


Resolution First Transfer Backgrounds



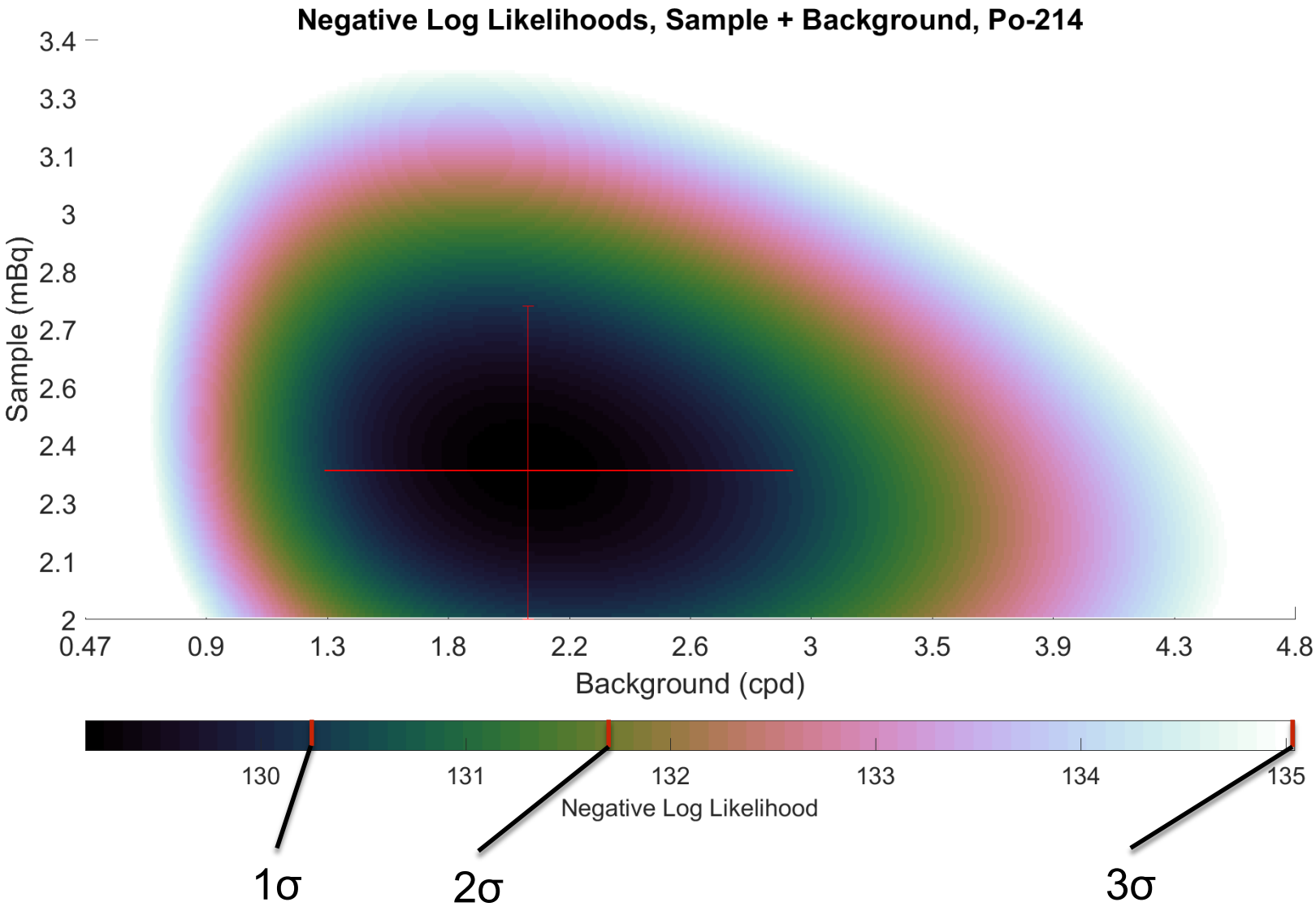
ROI efficiency is based on this fit rather than a fit to the sample run since there are more counts and no interference from the Po-218 and Po-214 signals.

Resolution First Transfer Sample

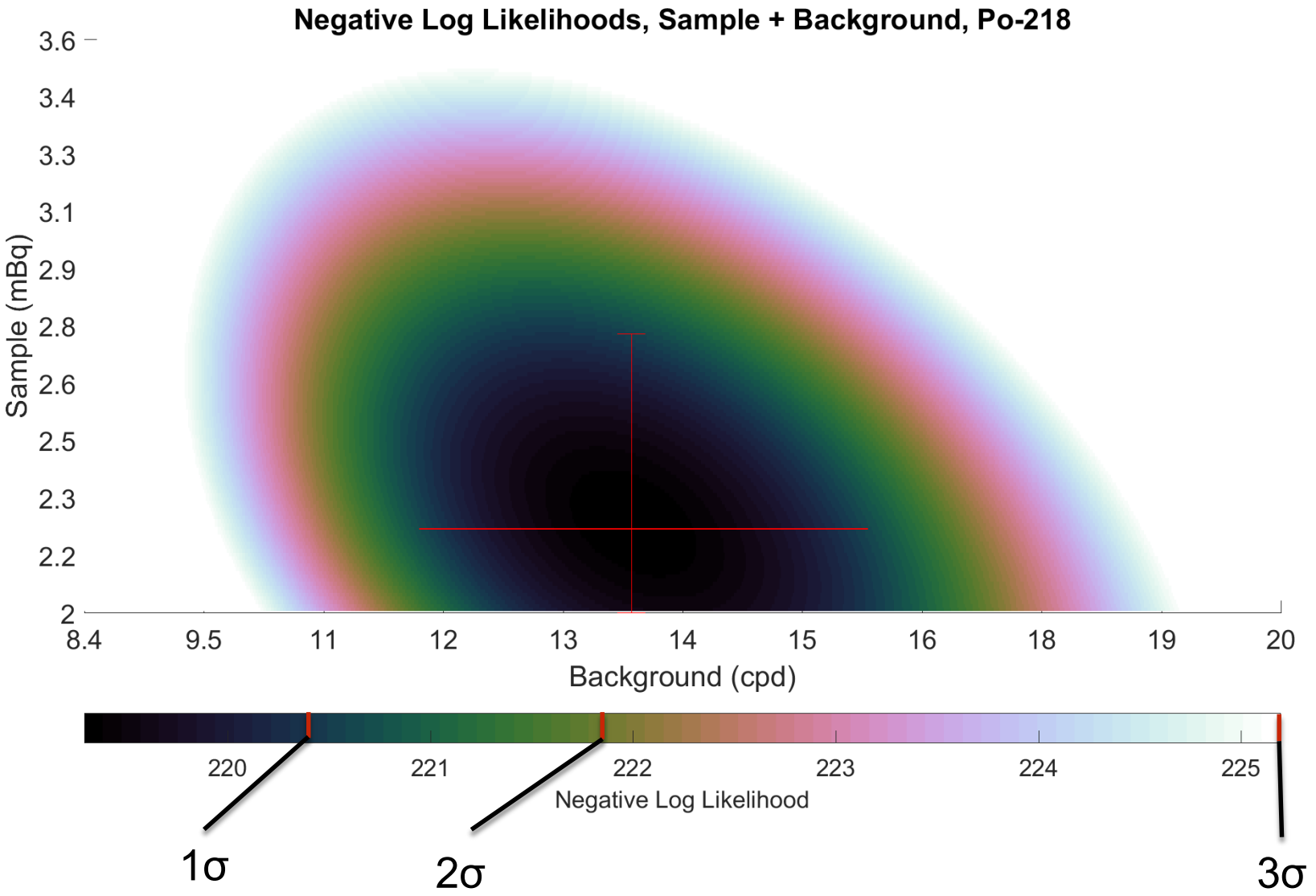


Resolution shown here is from the Po-214 signal since the Po-218 overlap makes it harder to get resolution from the Po-210 signal.

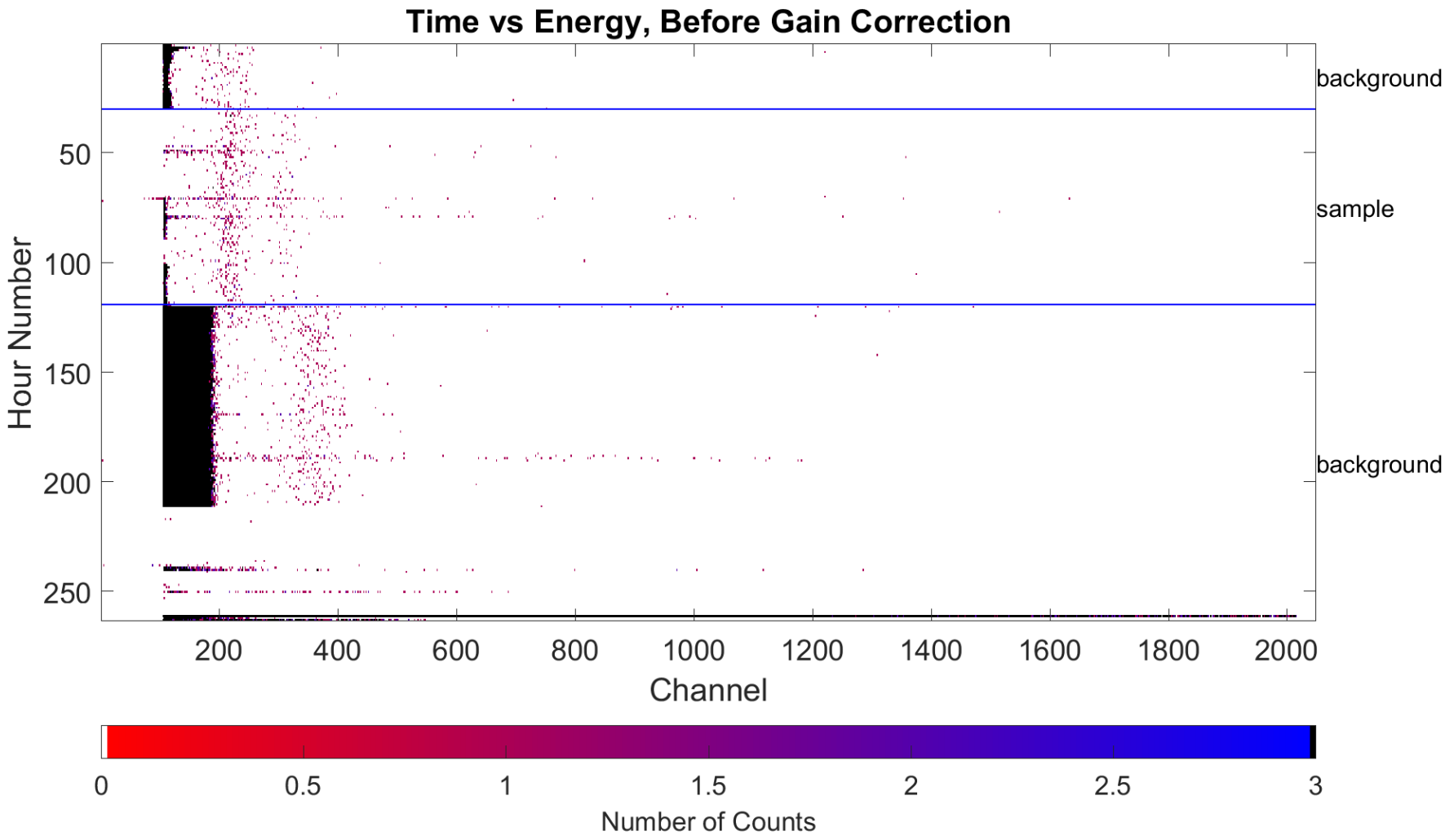
Negative Log Likelihoods for First Transfer, Po-214



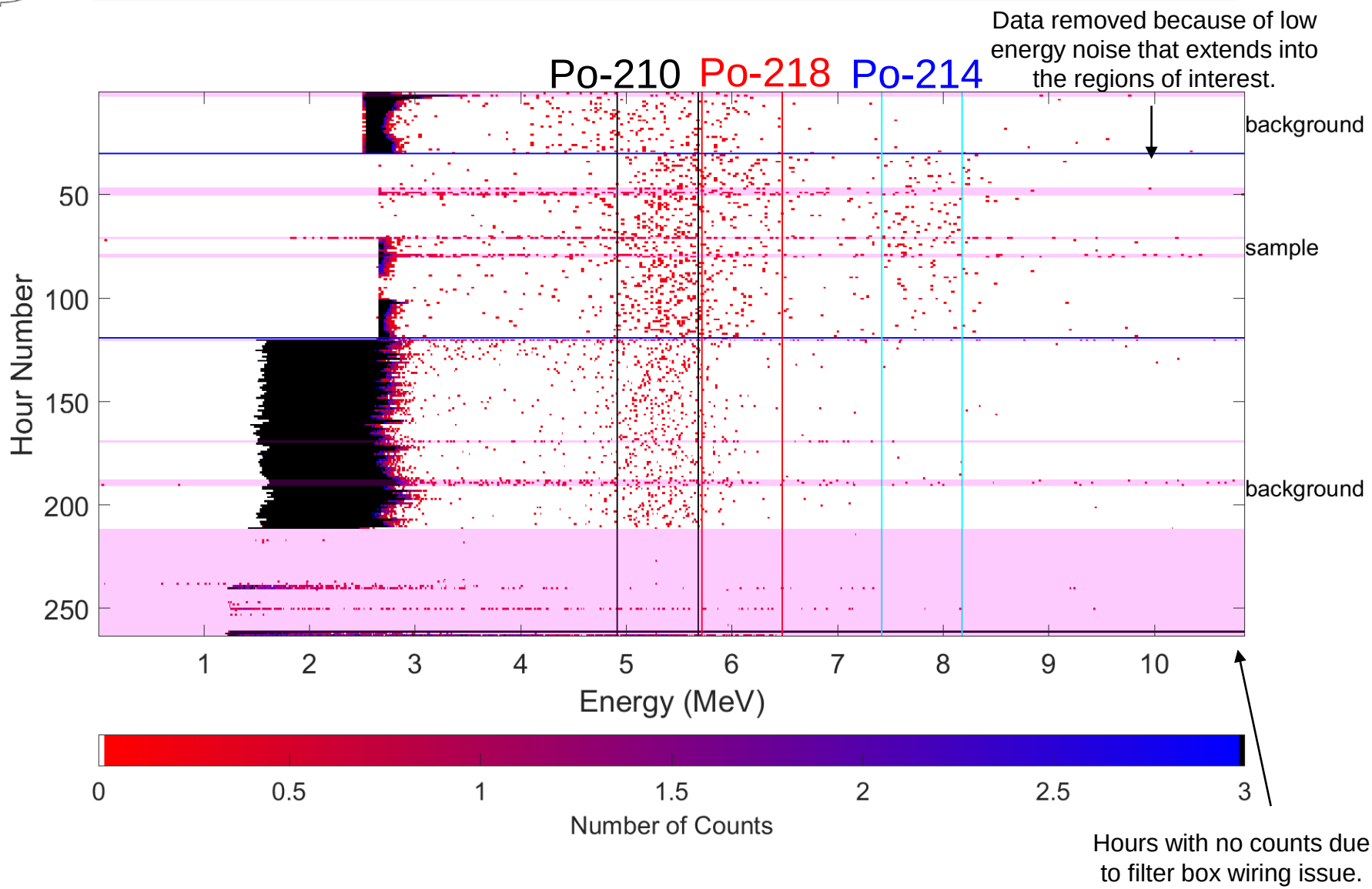
Negative Log Likelihoods for First Transfer, Po-218



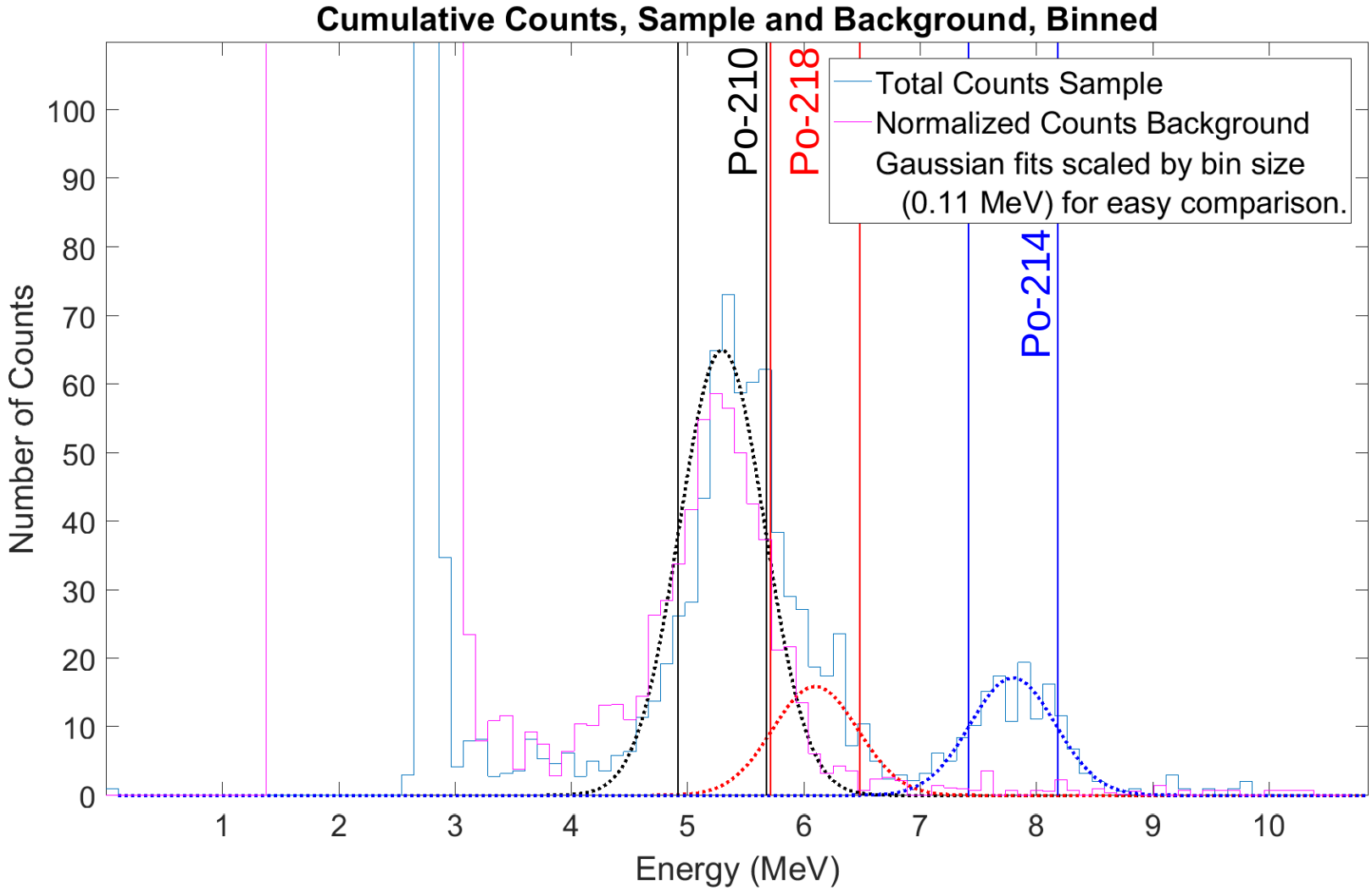
Second Transfer with post background



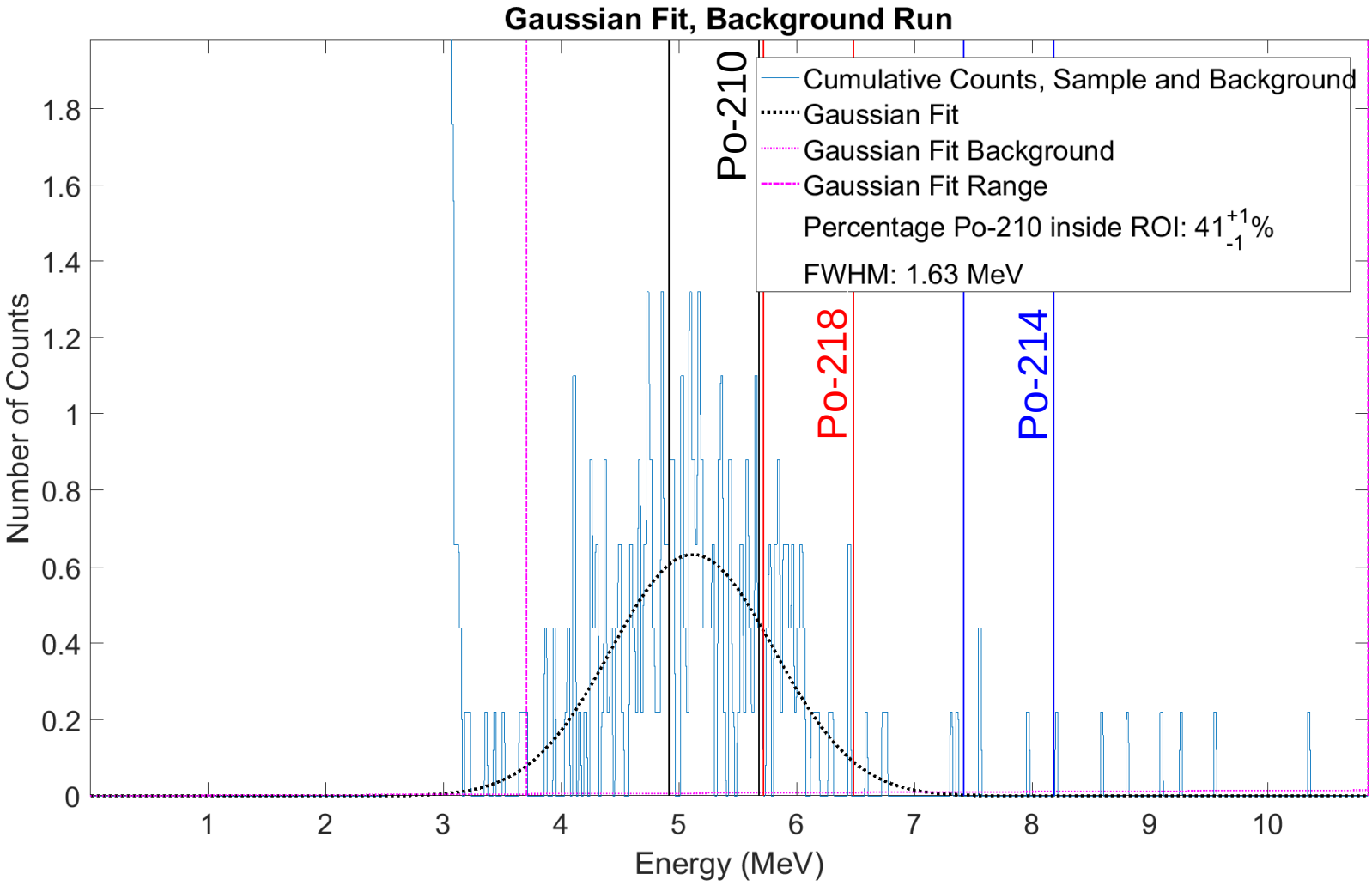
Second Transfer with post background



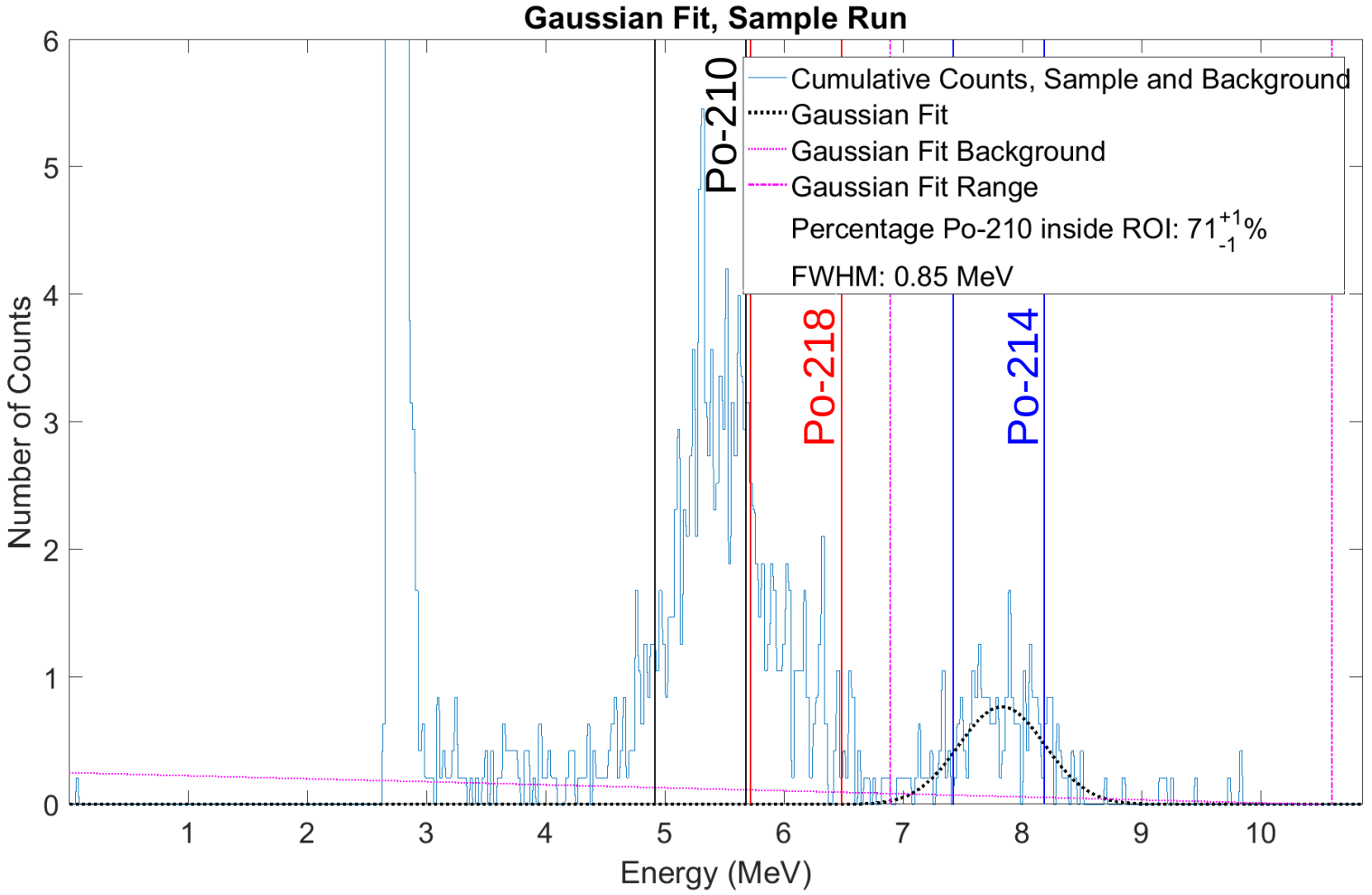
Cumulative Counts, Second Transfer with post background



Resolution Second Transfer Background

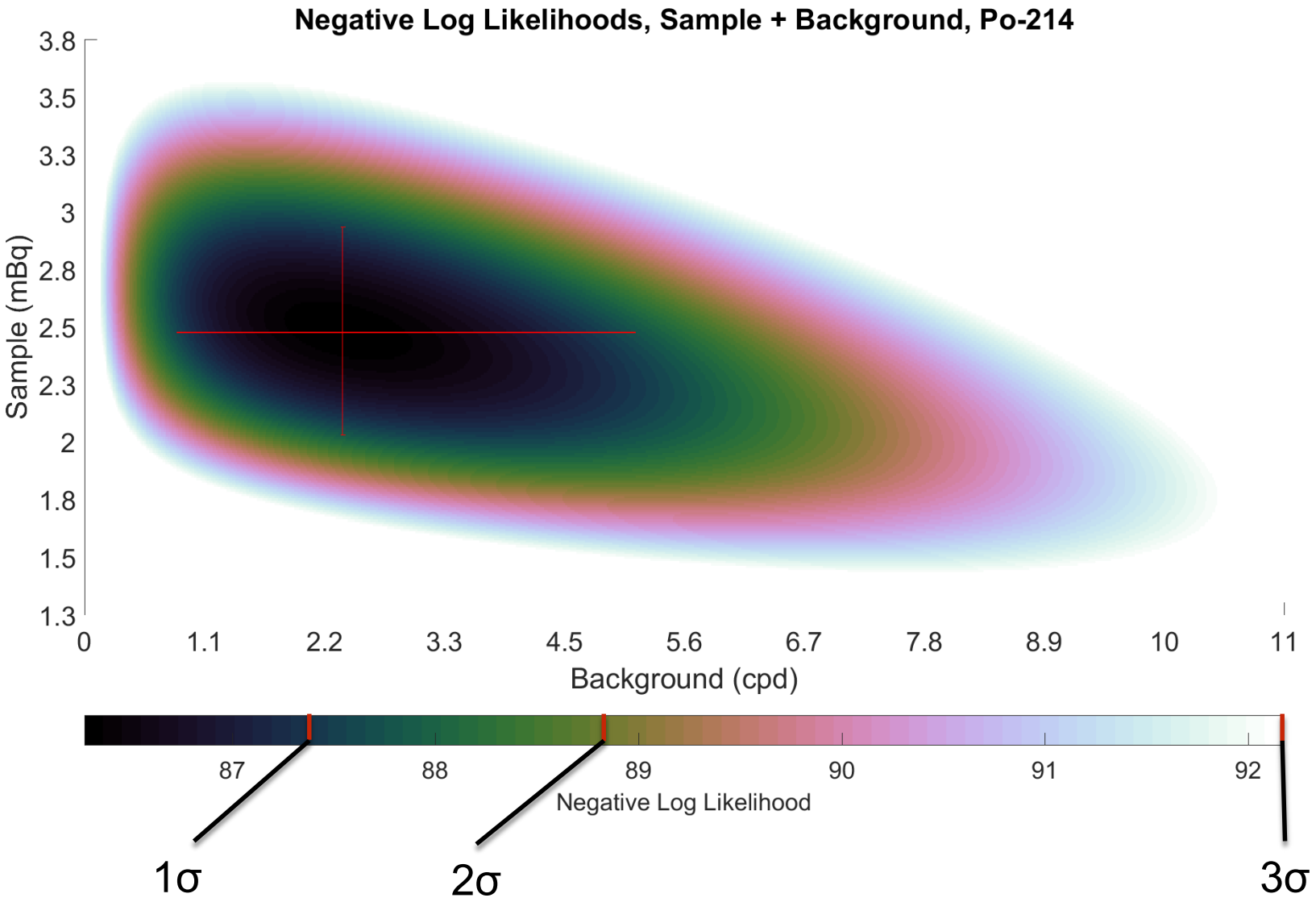


Resolution Second Transfer Sample

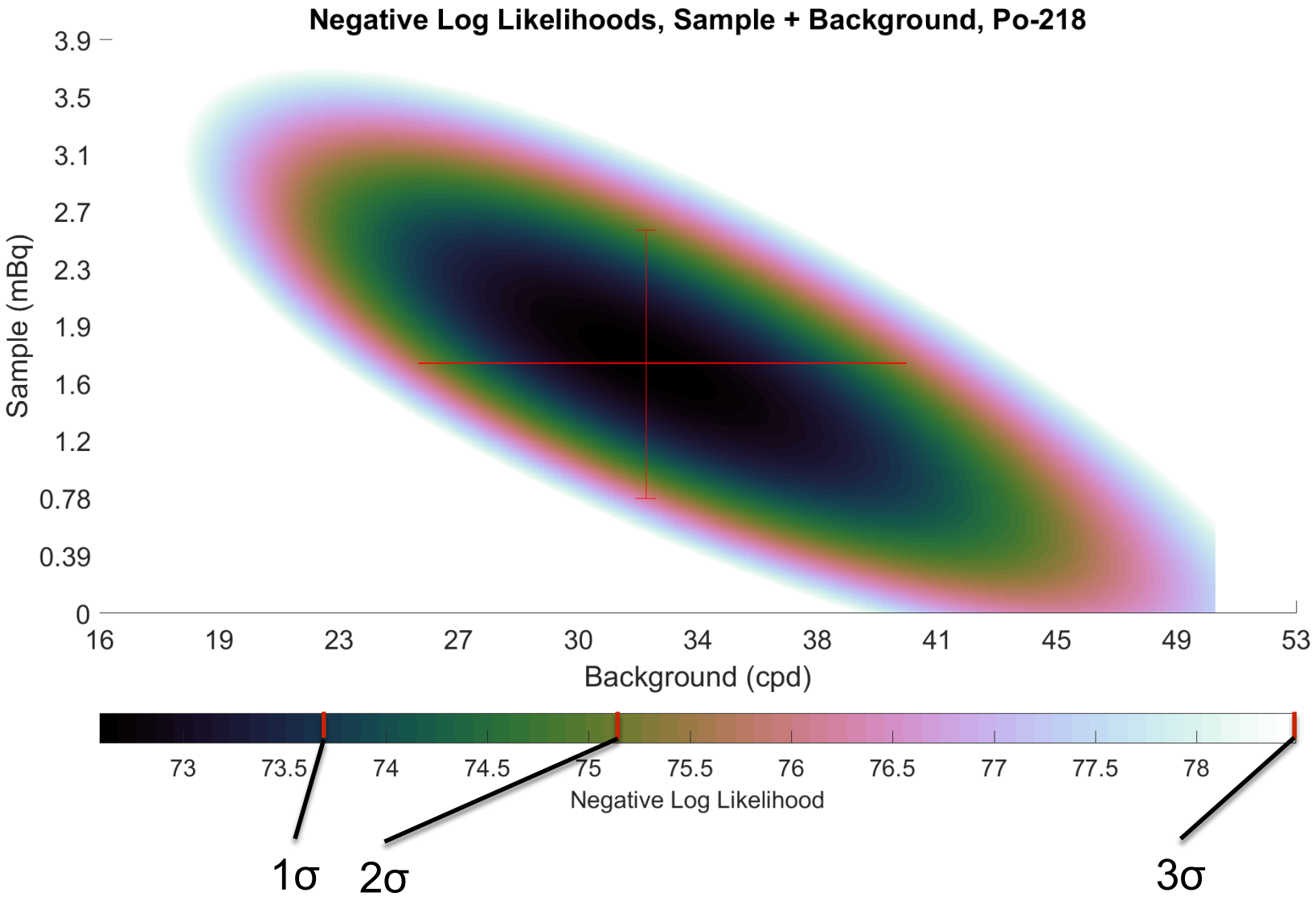


ROI efficiency is based on this fit instead of the background even though there are fewer counts, since the resolution is significantly worse in the background run.

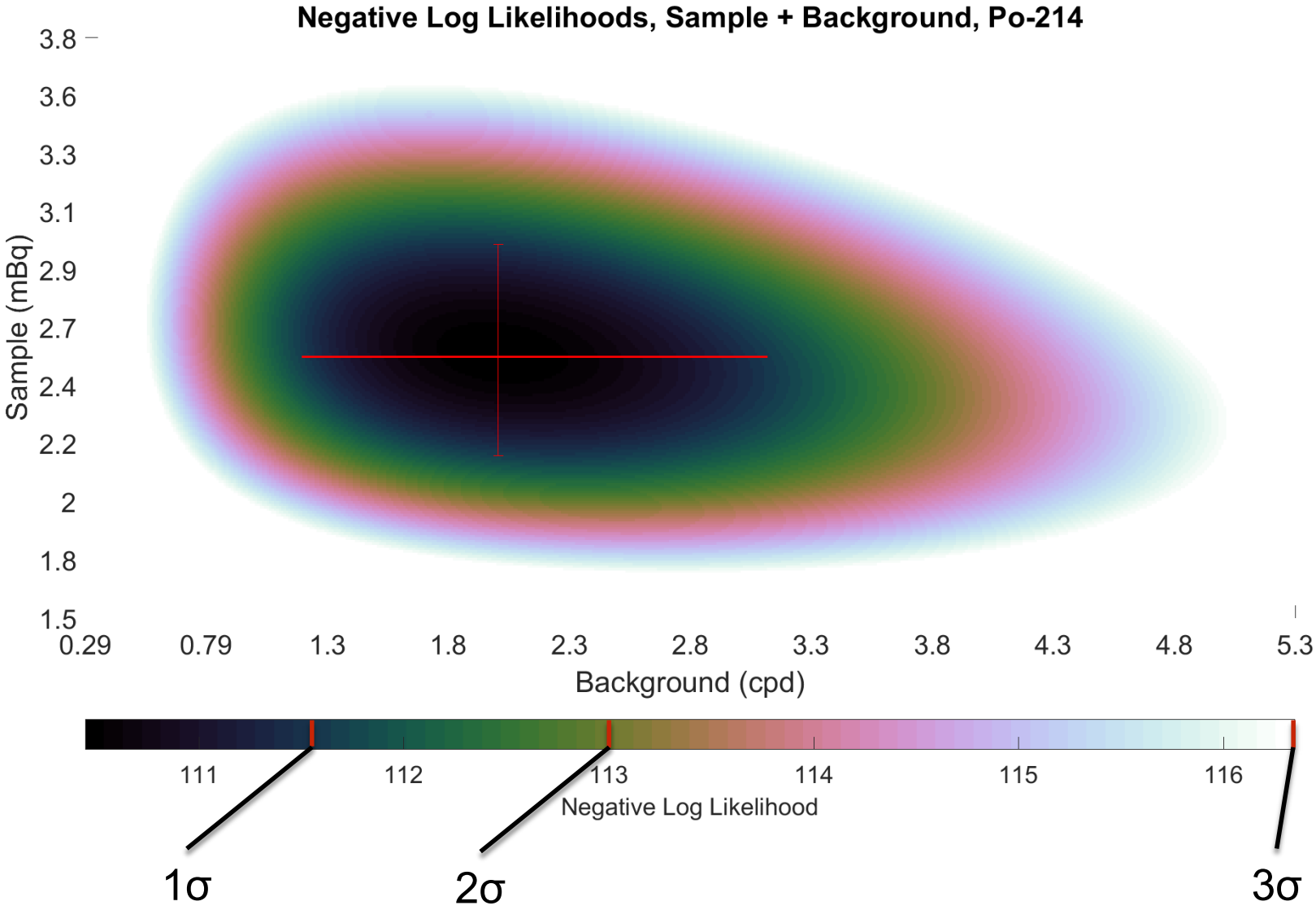
Negative Log Likelihoods for Second Transfer no post background, Po-214



Negative Log Likelihoods for Second Transfer no post background, Po-218



Negative Log Likelihoods for Second Transfer with post background, Po-214



Negative Log Likelihoods for Second Transfer with post background, Po-218