CM Prague August 2024

Alpha Spectroscopy

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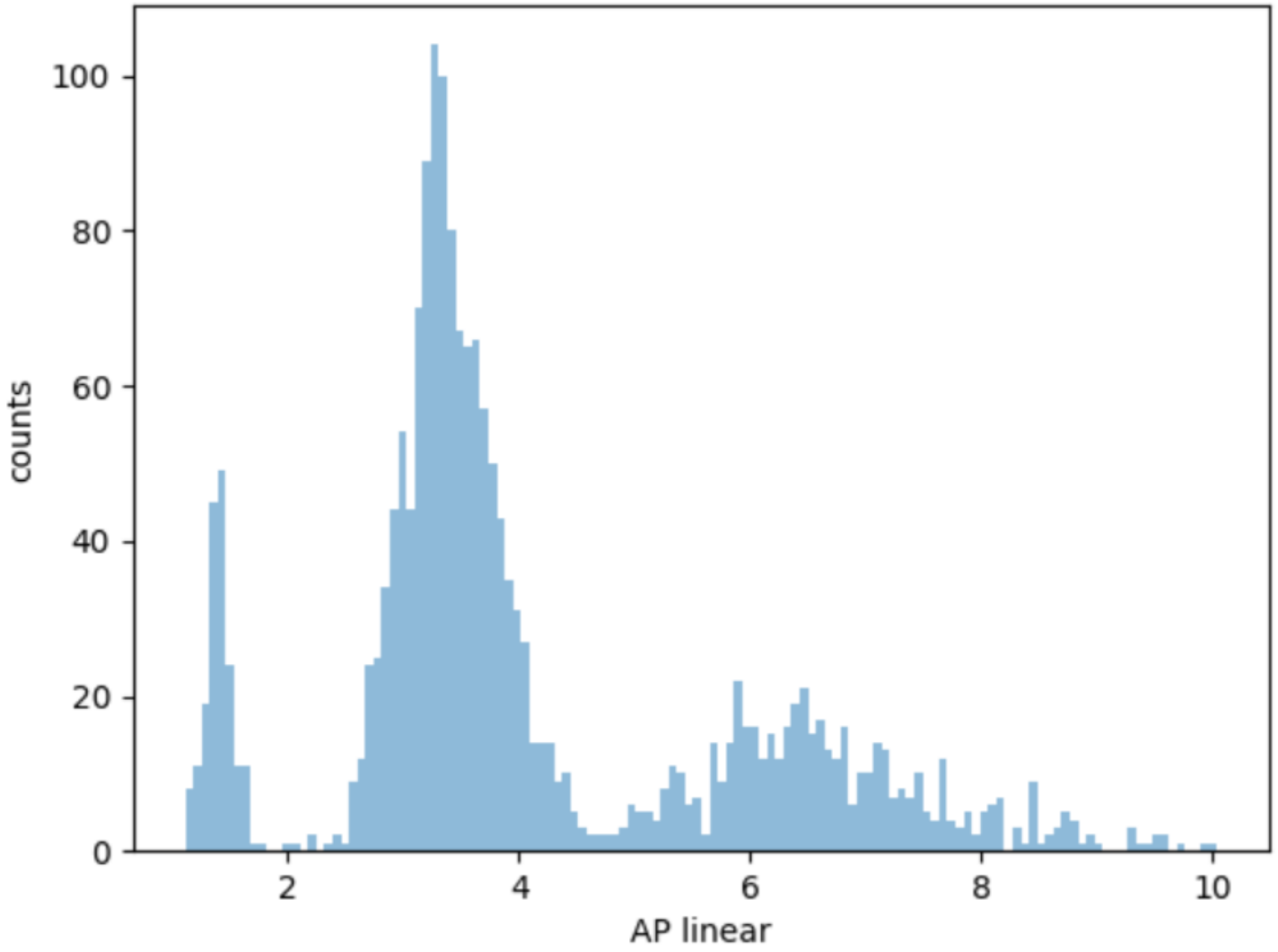
Agenda

- Position corrections for AP (alpha focus)
- Piezo, band selection resolution
- Alpha pair tagging
- Alpha pair tracking
- Gaussian fits for thorium decay chain analysis

AP plot generated from current recon file



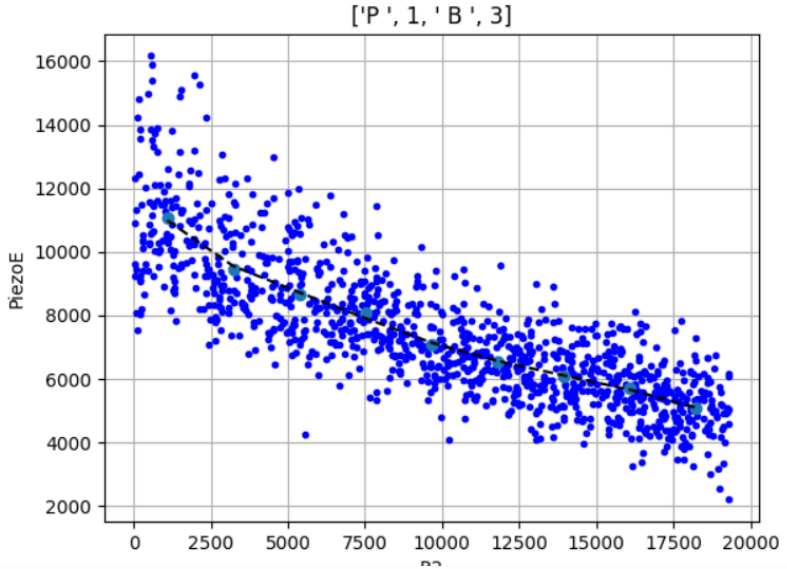
Piezo energy distribution corrected using neutron recoil data

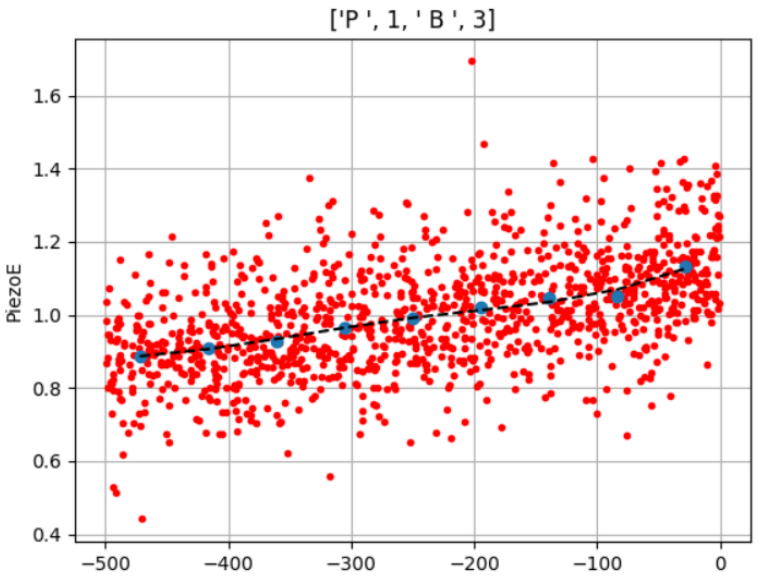
Linear AP scale

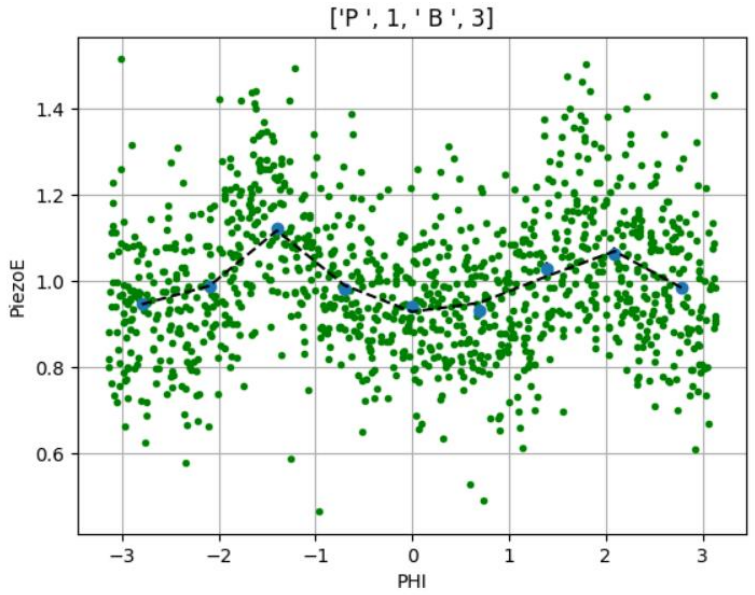
Features

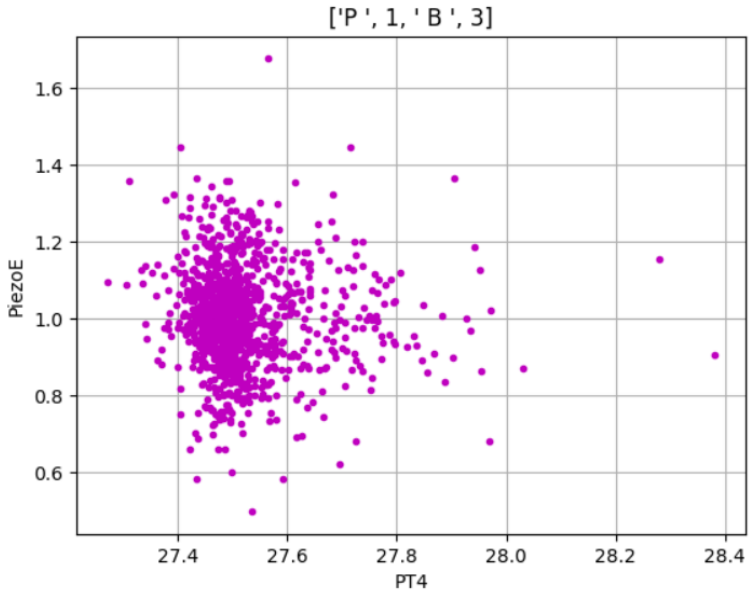
- Nice ROI resolution
- No alpha peak separation

Alpha position corrections: R^2 ϕ Z P



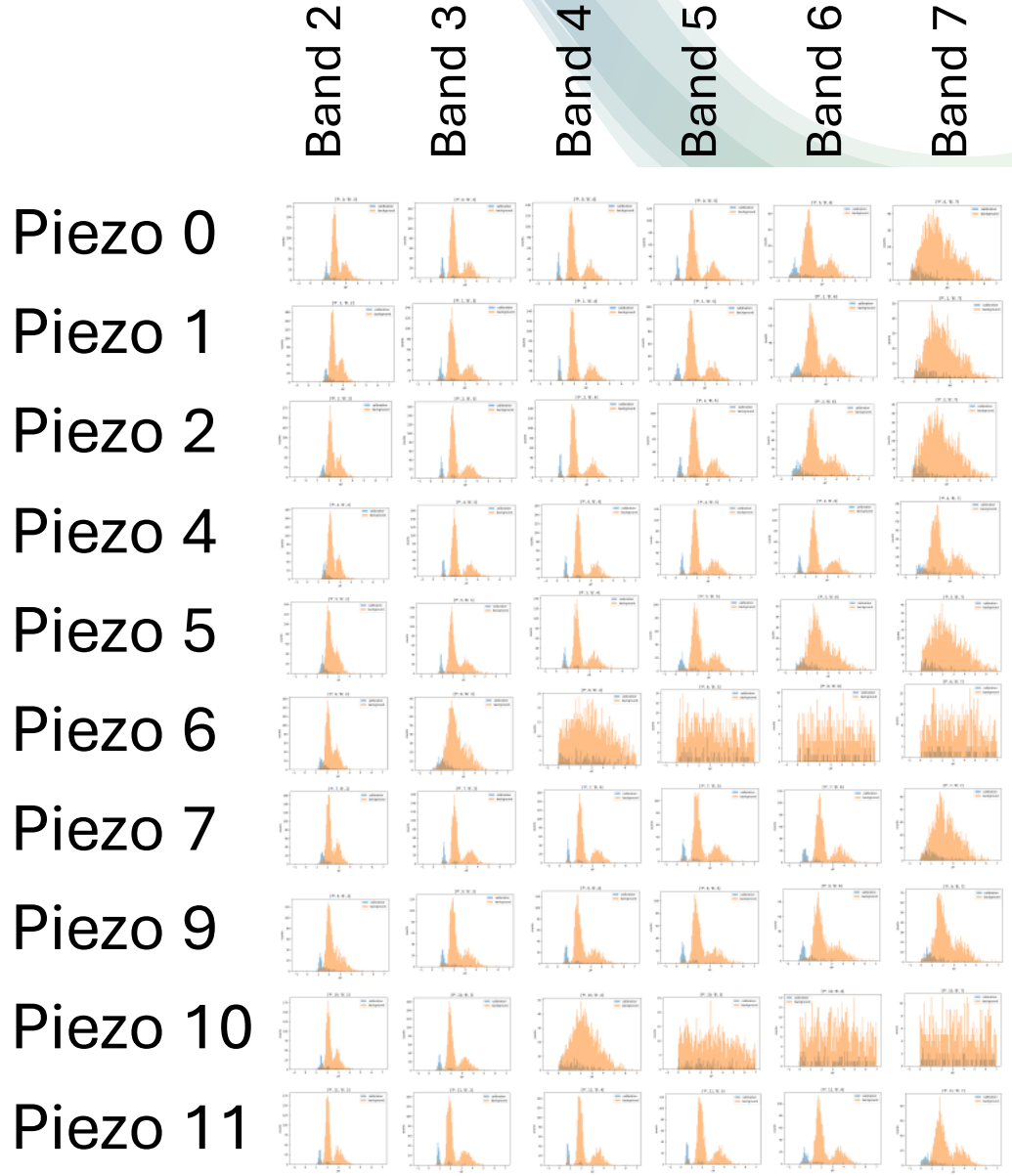






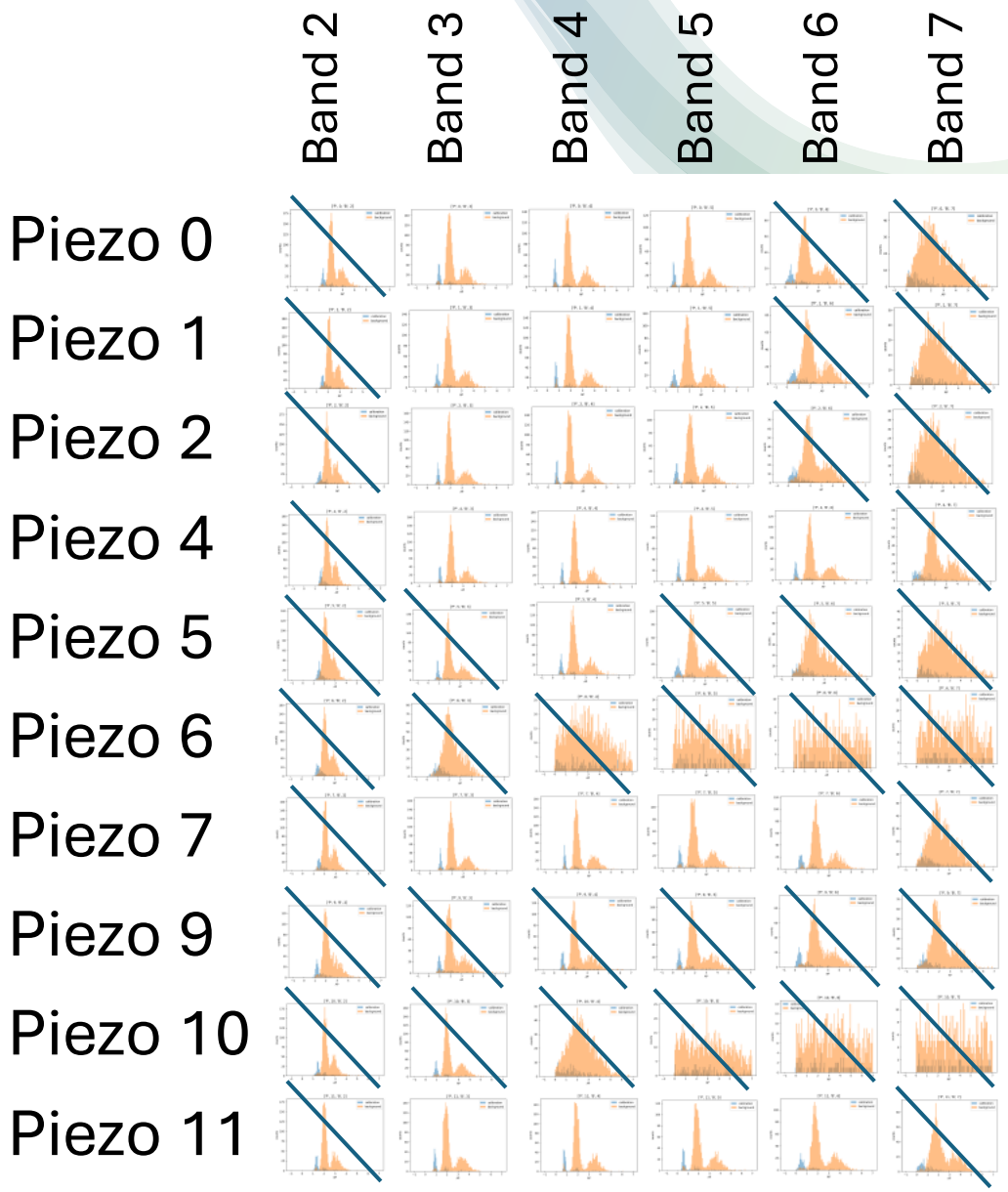
- Plot a histogram of corrected energy for each piezo, each band

- Plot a histogram of corrected energy for each piezo, each band
- Some bands cleaner than others



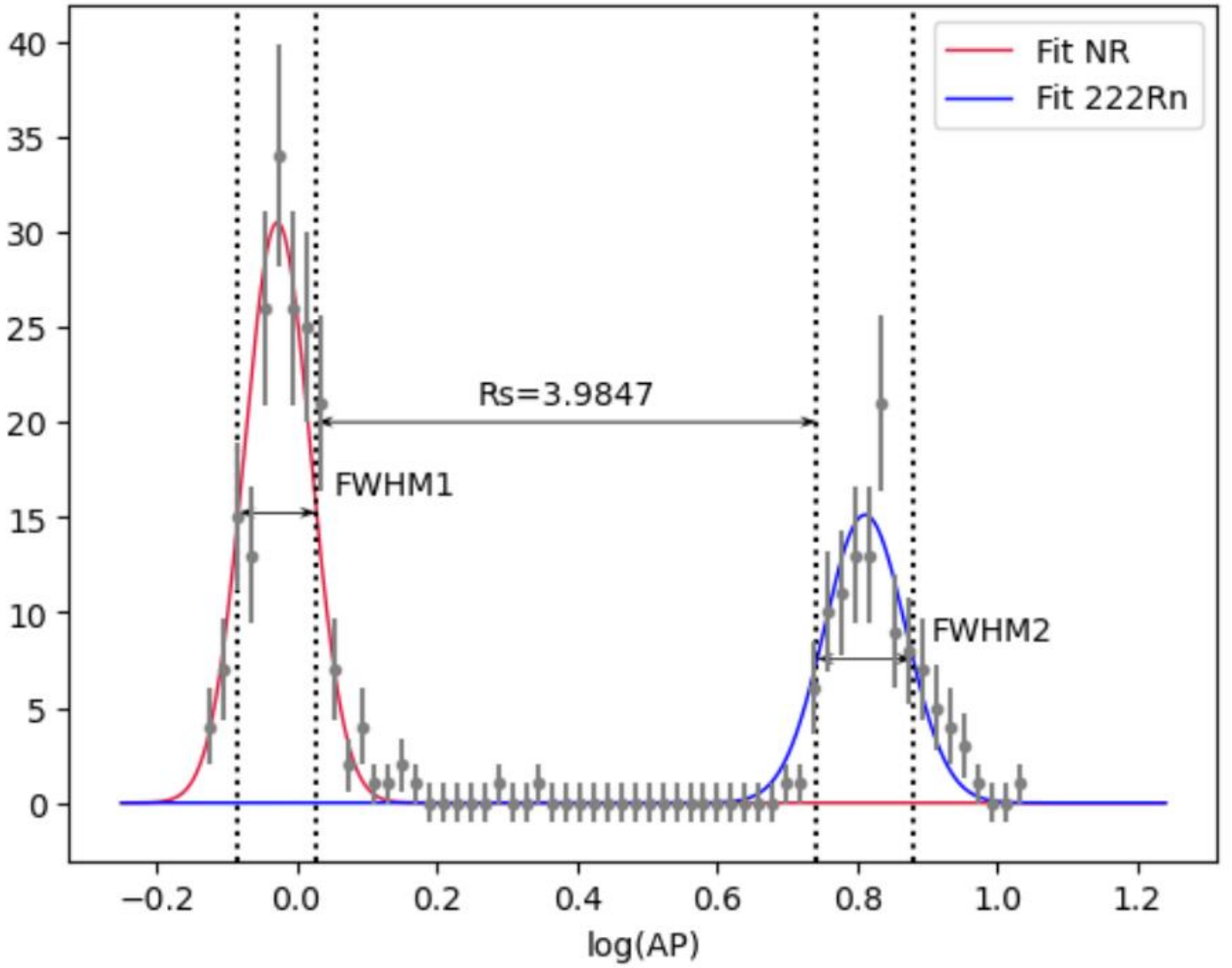
Selecting p, b by eye

Piezo	Bands used
0	3, 4, 5
1	3, 4, 5
2	3, 4, 5
4	3, 4, 5, 6
5	4
6	-
7	3, 4, 5, 6
9	-
10	-
11	3, 4, 5, 6

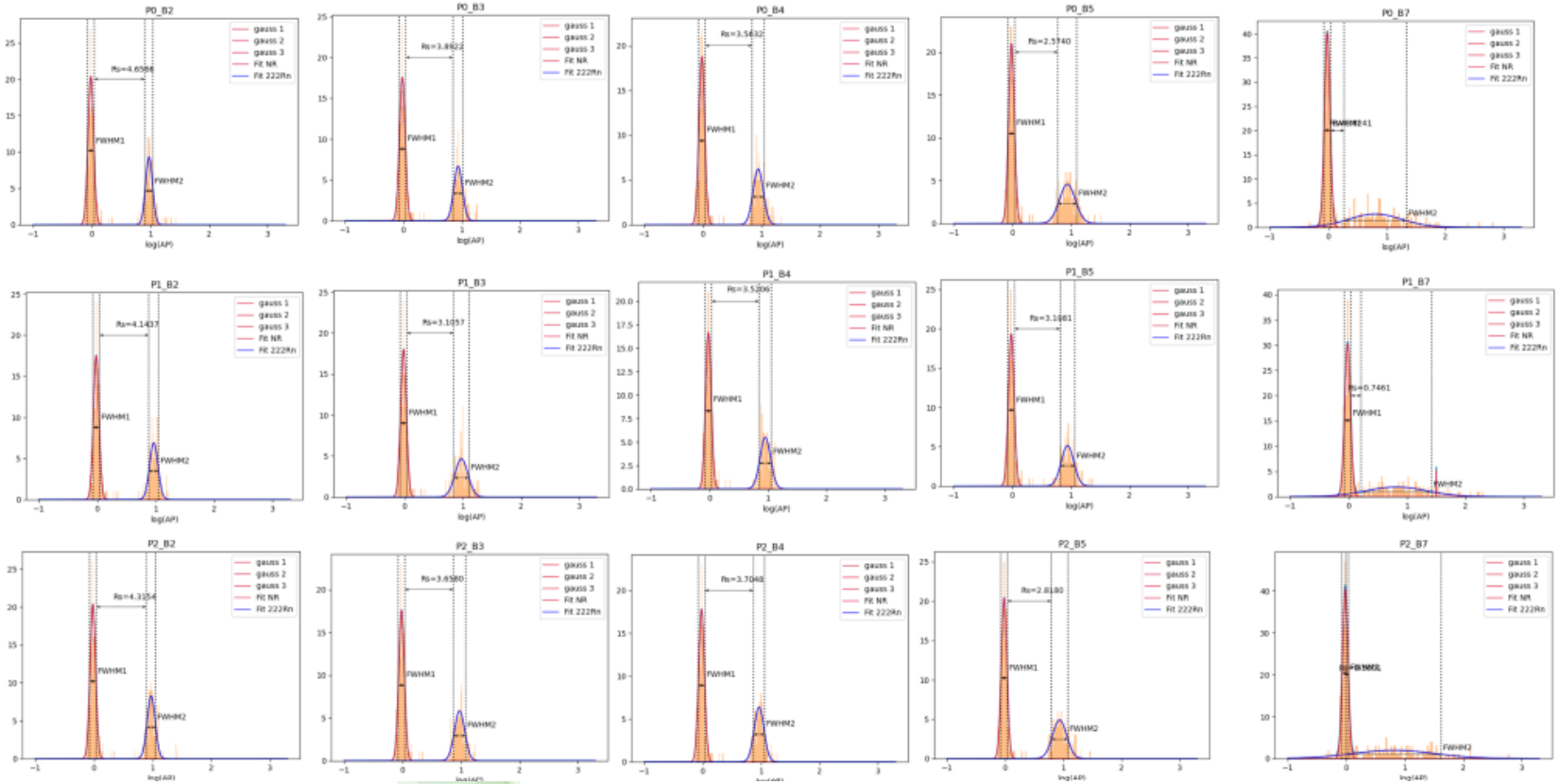


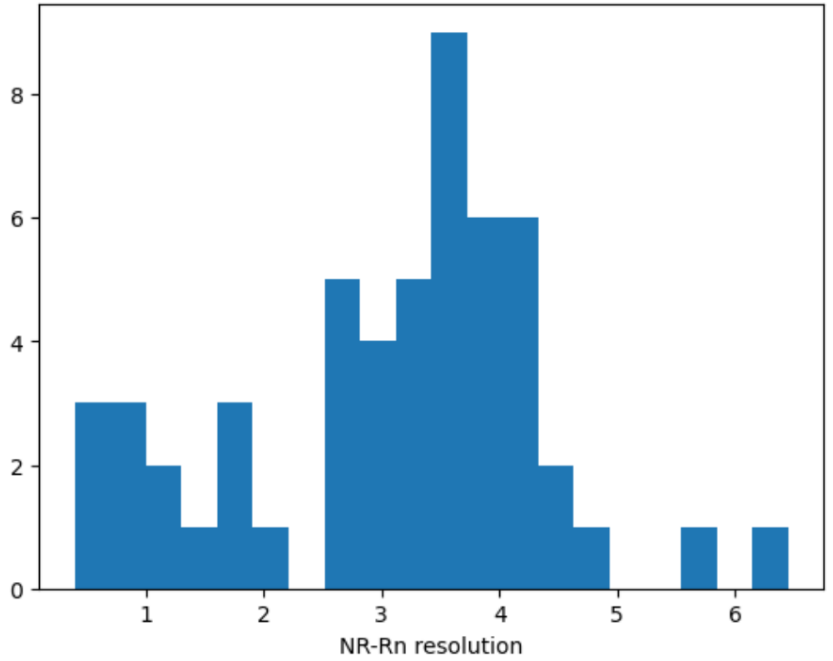
Selecting p, b with resolution metric

$$Rs = 1.18 * \left(\frac{(\mu_2 - \mu_1)}{(FWHM2 + FWHM1)}\right)$$



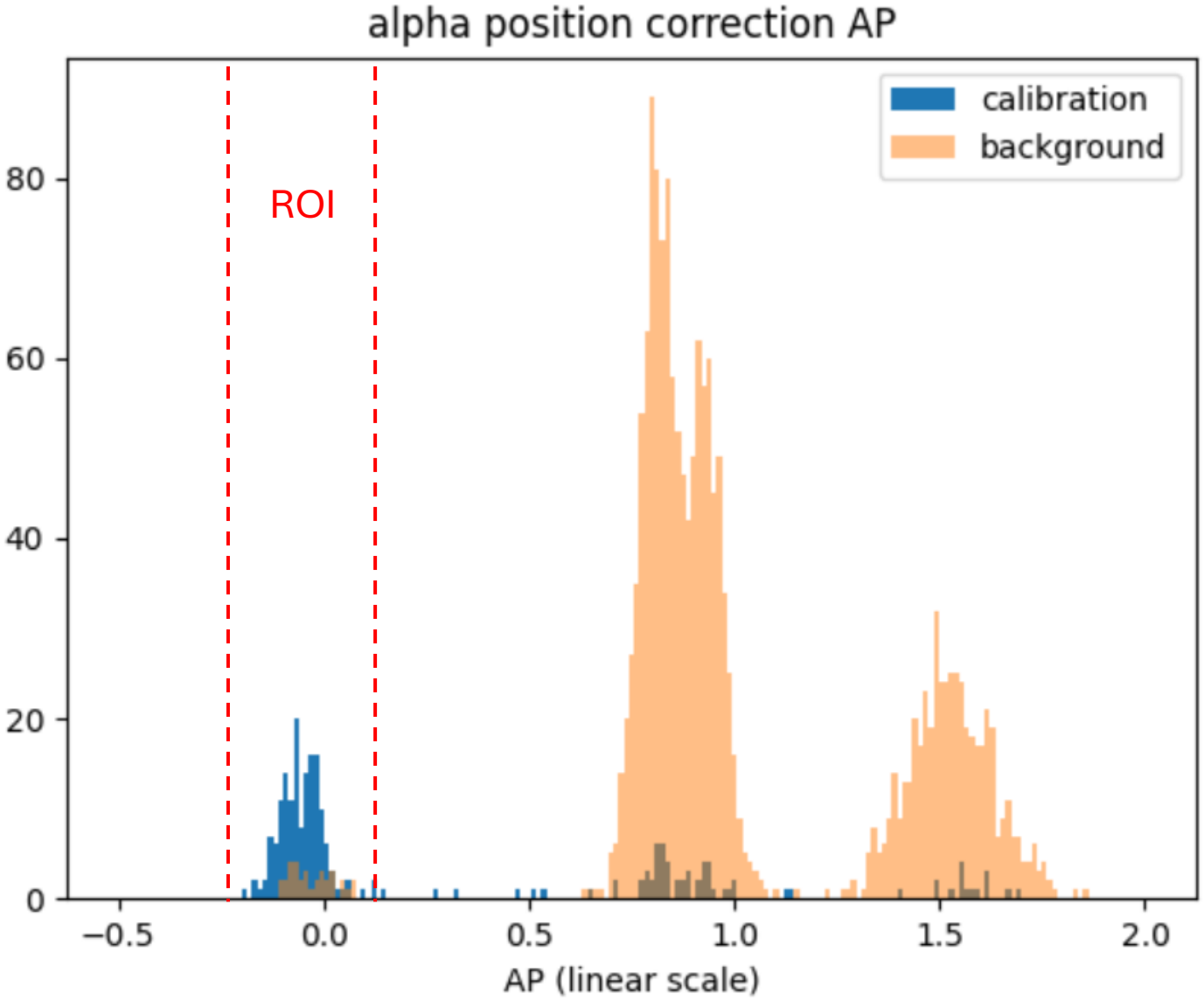
Select best resolutions for AP mean





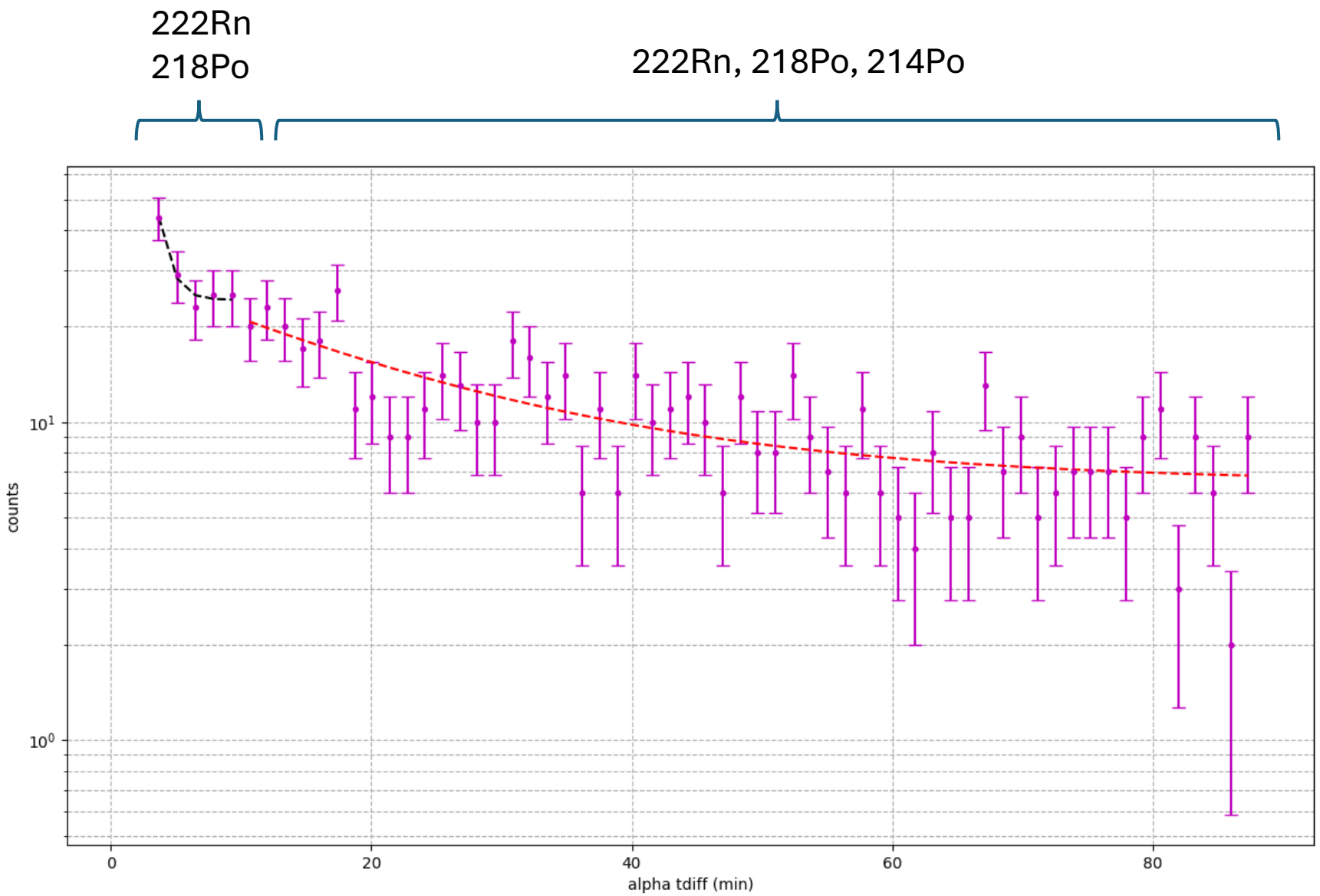
↳ Histogram of each resolution per piezo, per band

Log(AP) plot



- Position corrections with alpha data
- Less resolution in ROI
- Improved resolution in alpha regime

Alpha timing



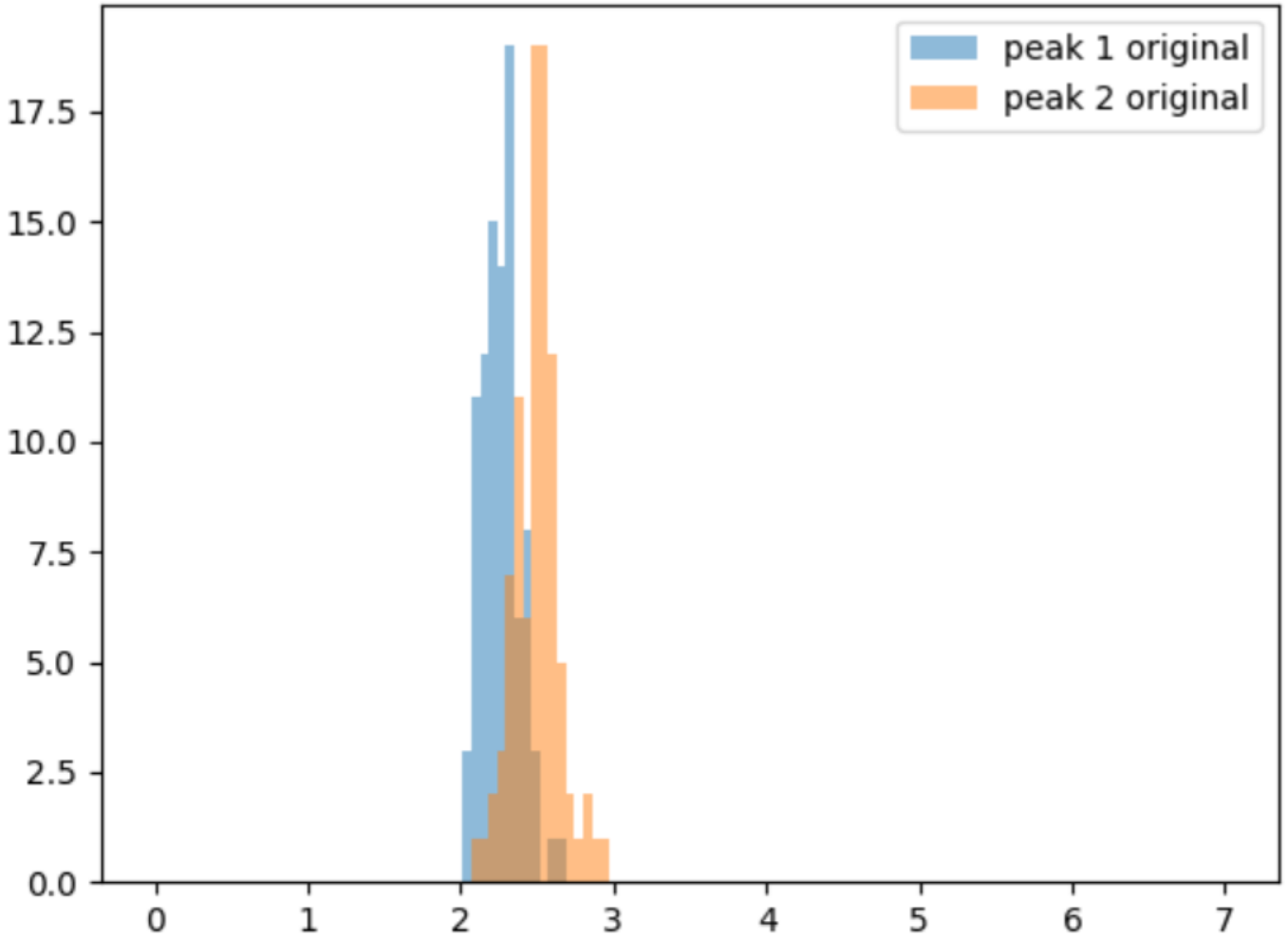
Data

$$t_2 - t_1$$

Fit

$$y = a * \exp(b(-x) - d) + c$$

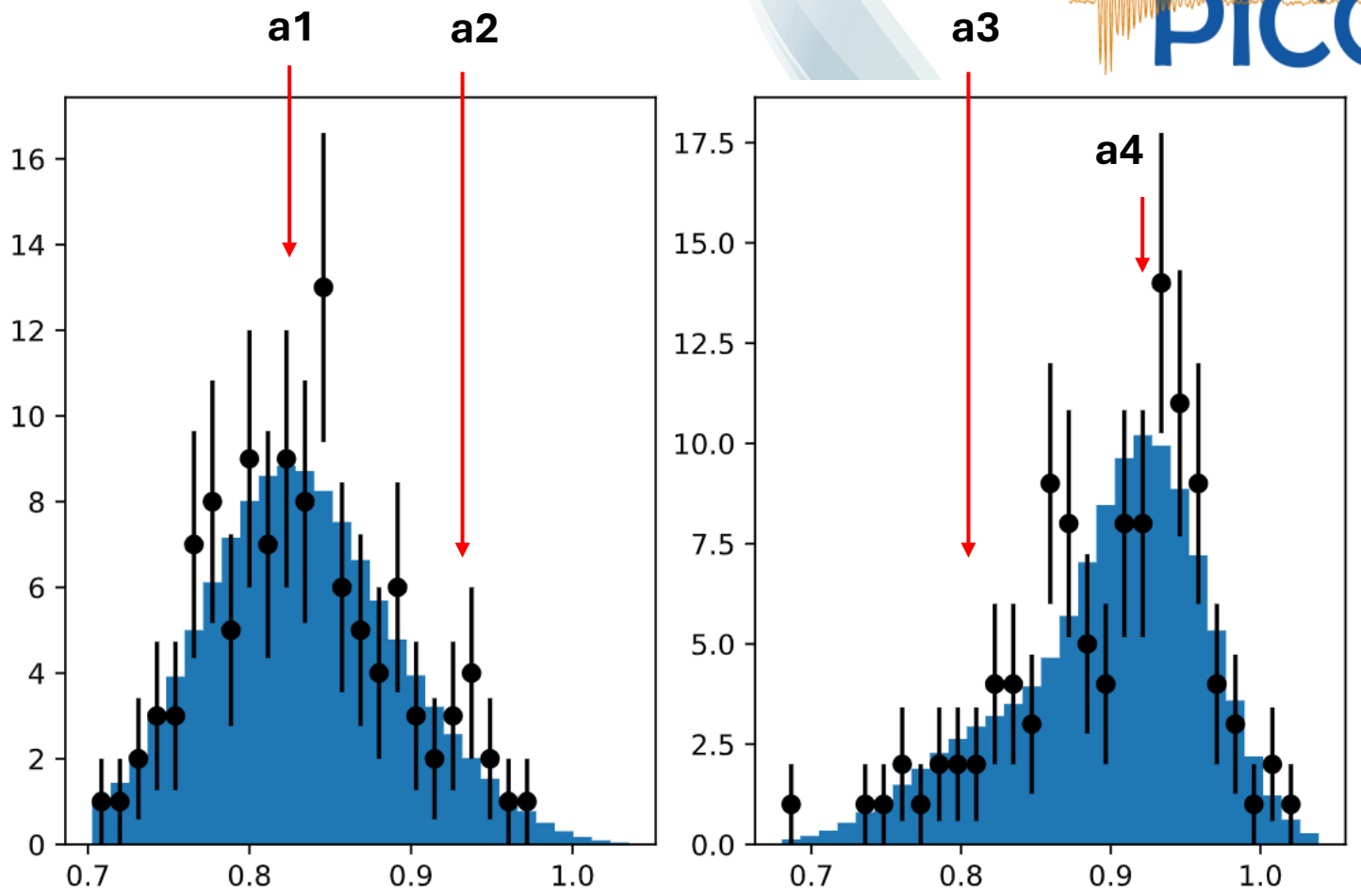
Pair separation



- Identify pairs of alpha events with time separation of 10 min or less
- Constraint that the events are consecutive

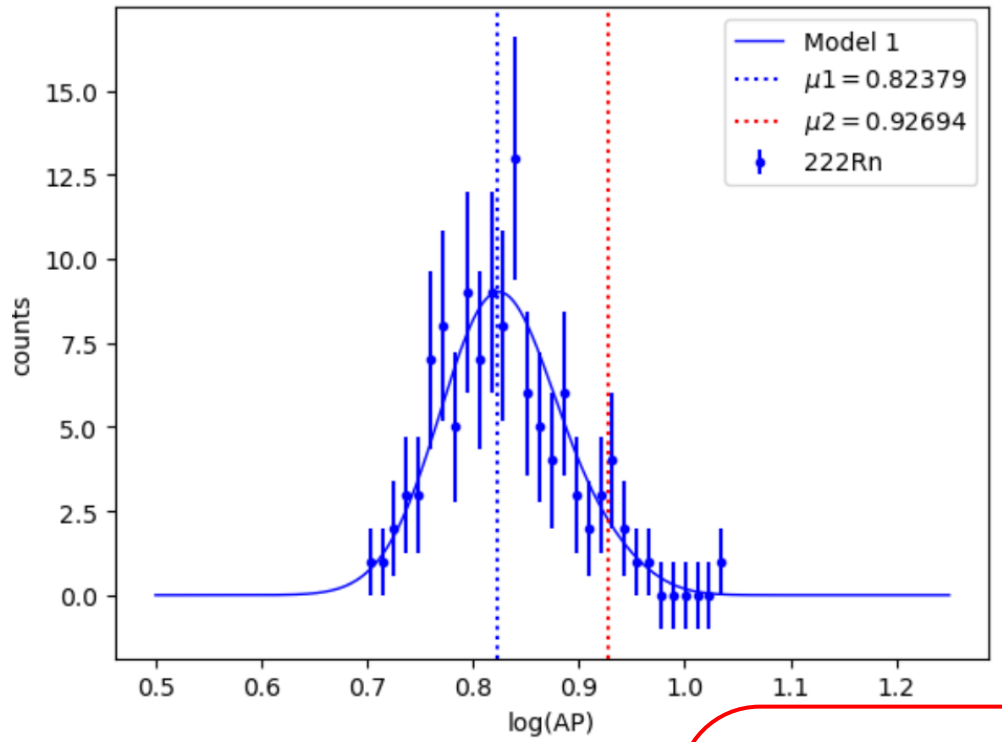
Peak purity

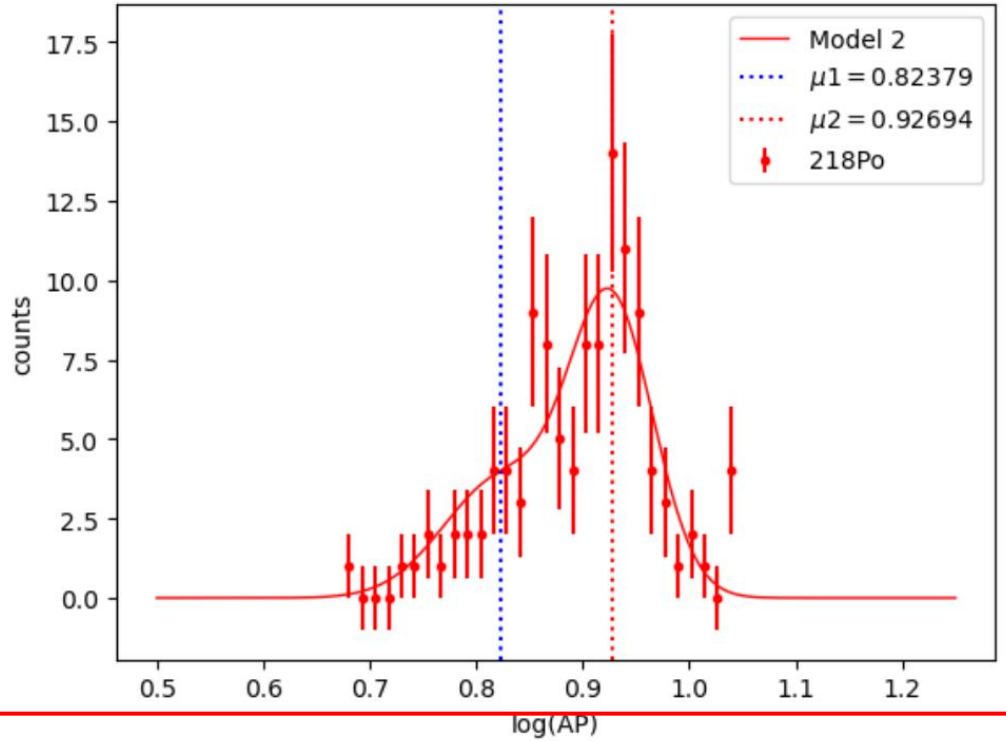
	Name	Value	Hesse Error	
0	a1	105	>	14
1	a2	9	<	10
2	mu1	0.824		0.010
3	sig1	0.055		0.007
4	mu2	0.927		0.008
5	sig2	0.040		0.006
6	a3	32	>	11
7	a4	78	>	13



- No ^{218}Po present in ^{222}Rn peak (counts=0 within error)
- Some leakage of ^{222}Rn into the ^{218}Po peak

Sum under peaks





	Name	Value	Hesse Err	Minos Err-	Minos Err+
0	a1	105	14	-13	16
1	a2	9	10	-11	10
2	mu1	0.824	0.010	-0.009	0.011
3	sig1	0.055	0.007	-0.007	0.008
4	mu2	0.927	0.008	-0.008	0.008
5	sig2	0.040	0.006	-0.006	0.006
6	a3	32	11	-10	12
7	a4	78	13	-13	13

222Rn:

$\mu - 3\sigma = 0.82379 - 3(0.055) =$

$\mu + 3\sigma = 0.82379 - 3(0.055) =$

218Po:

$\mu - 3\sigma = 0.92694 - 3(0.040) =$

$\mu + 3\sigma = 0.92694 - 3(0.040) =$

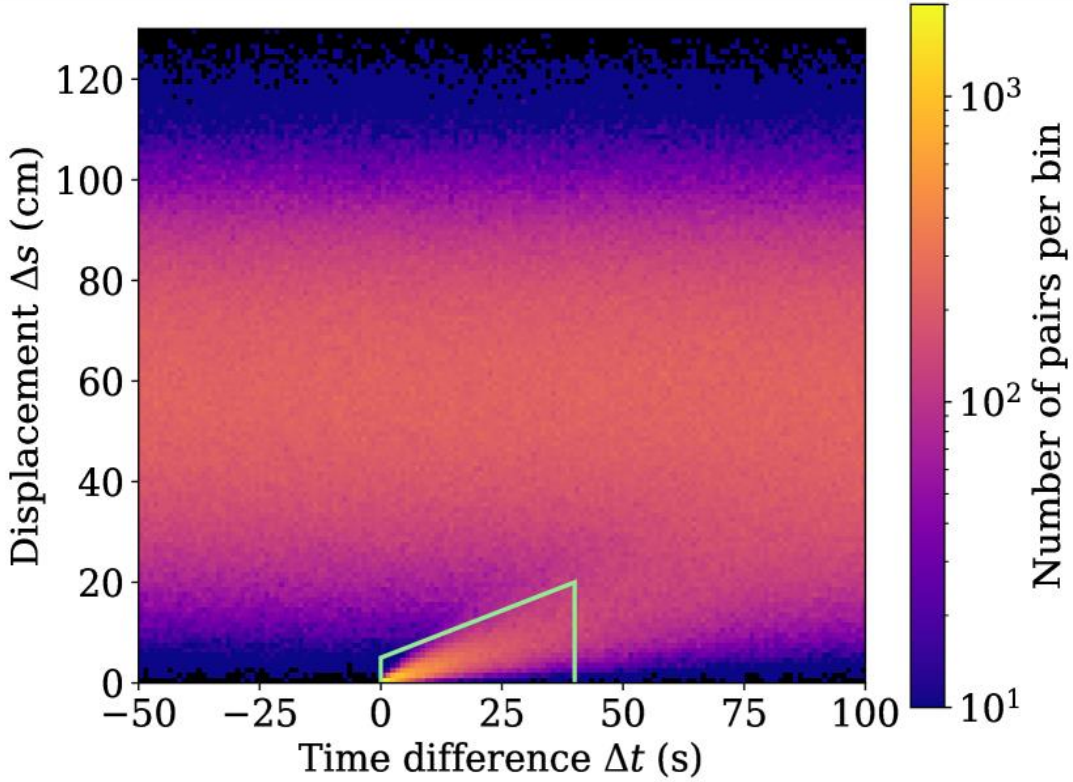
$$\int_{\mu-3\sigma}^{\mu+3\sigma} \left(\frac{[A + err]}{\sigma\sqrt{2\pi}} \right) \exp\left(-\left(\frac{1}{2} \frac{(x-\mu)^2}{\sigma^2} \right) \right)$$

222Rn	222Rn in peak 2	218Po	218Po in peak 1

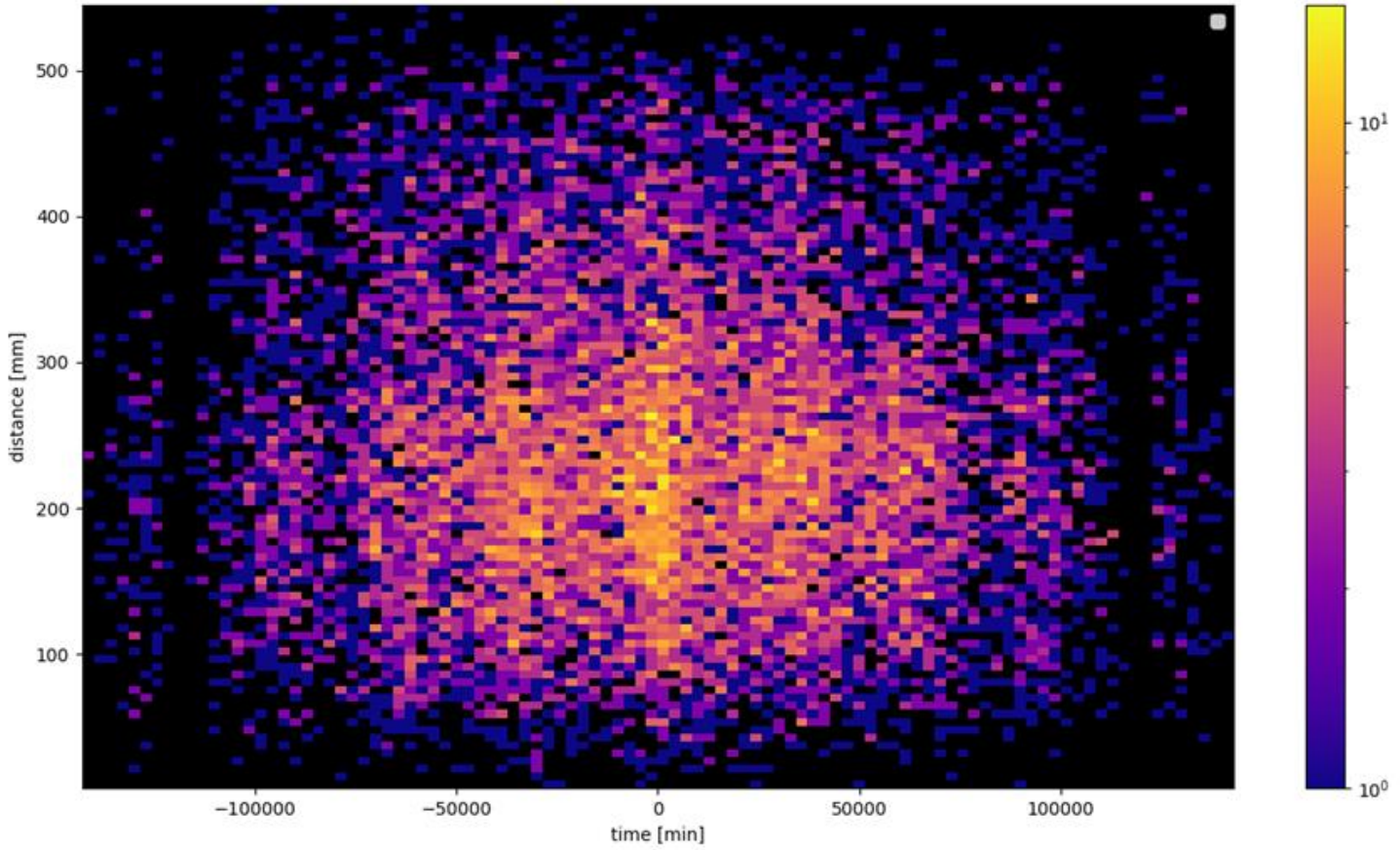
2d histogram: Δs vs Δt

Xenon1T

Excess Δs<20cm
0s<Δt<40s



PICO-40L



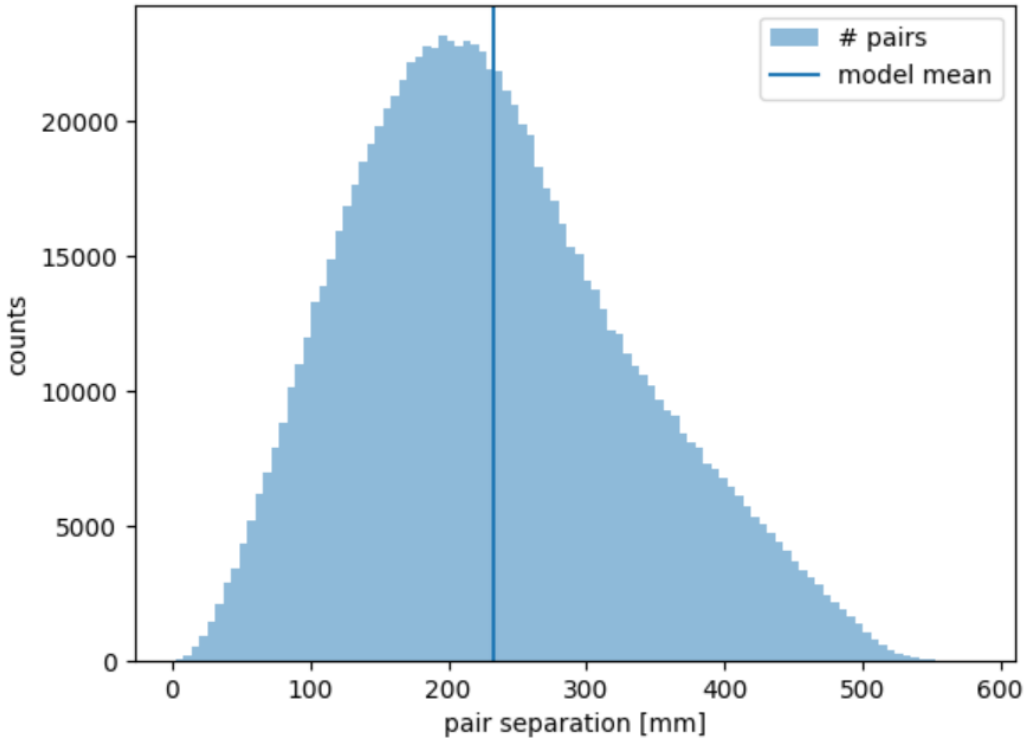
https://arxiv.org/html/2403.14878v1

KS test: are the distributions the same?

→ Yes

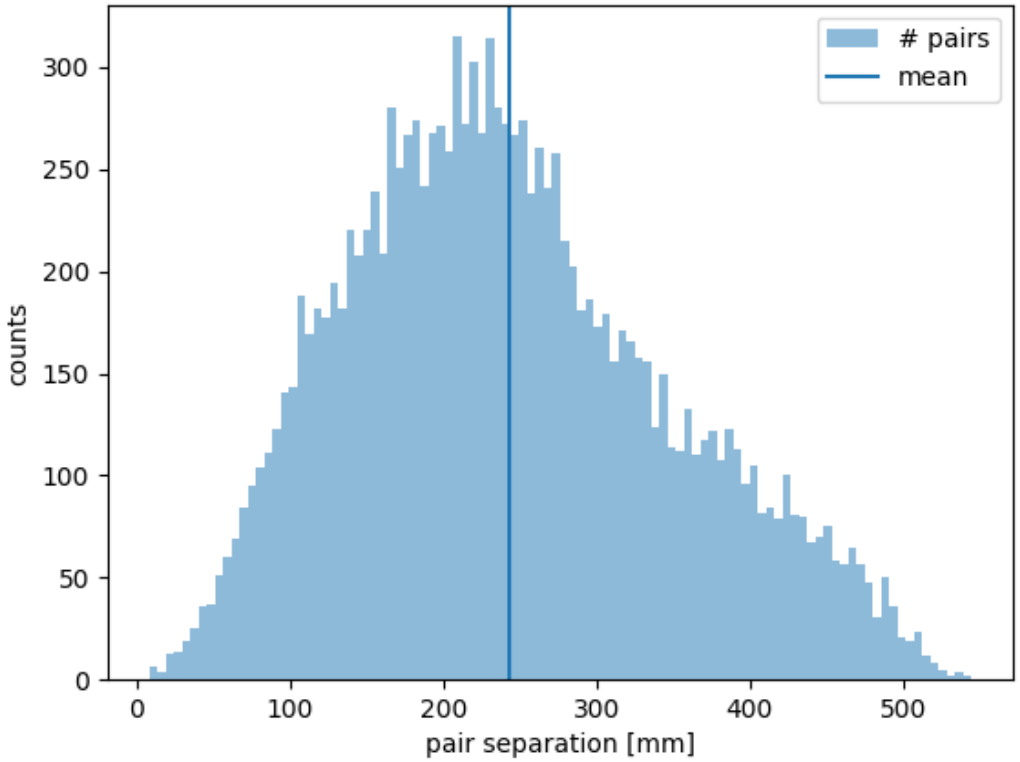
- Random pairs

$\Delta S_{avg} = 232.3mm \pm 0.2mm$

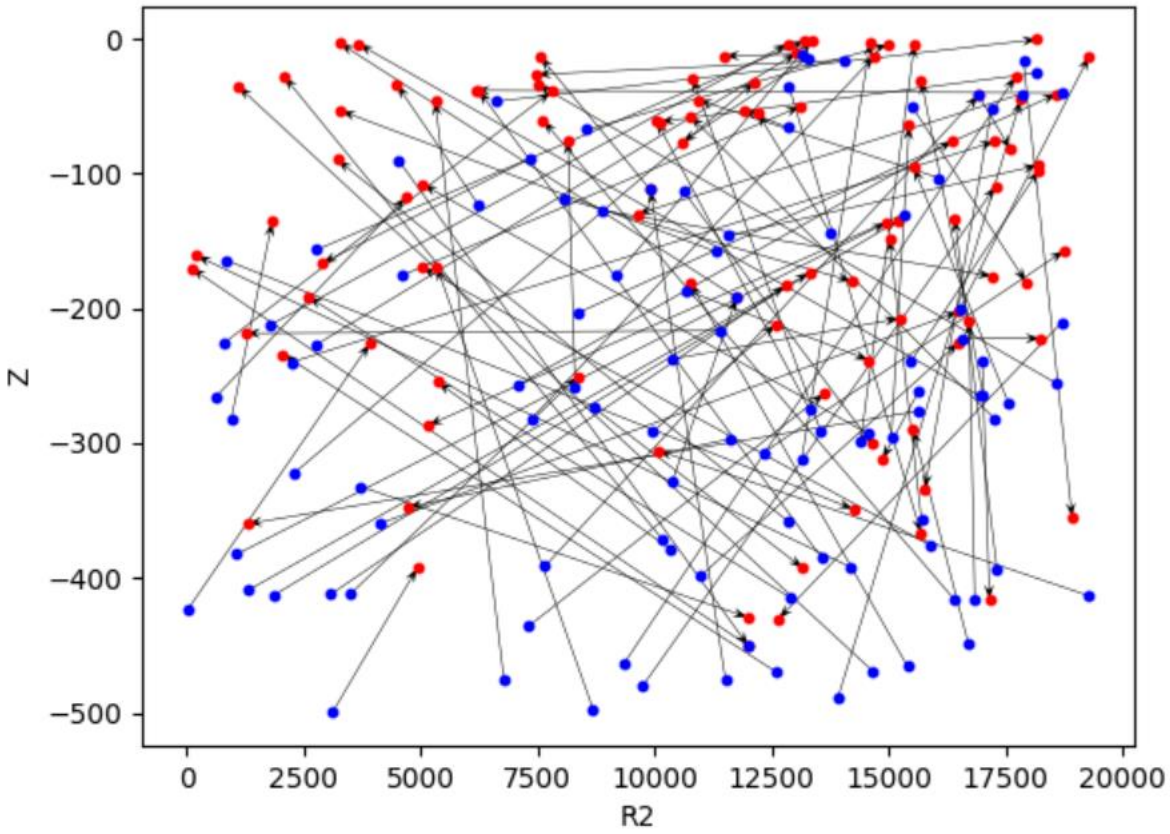


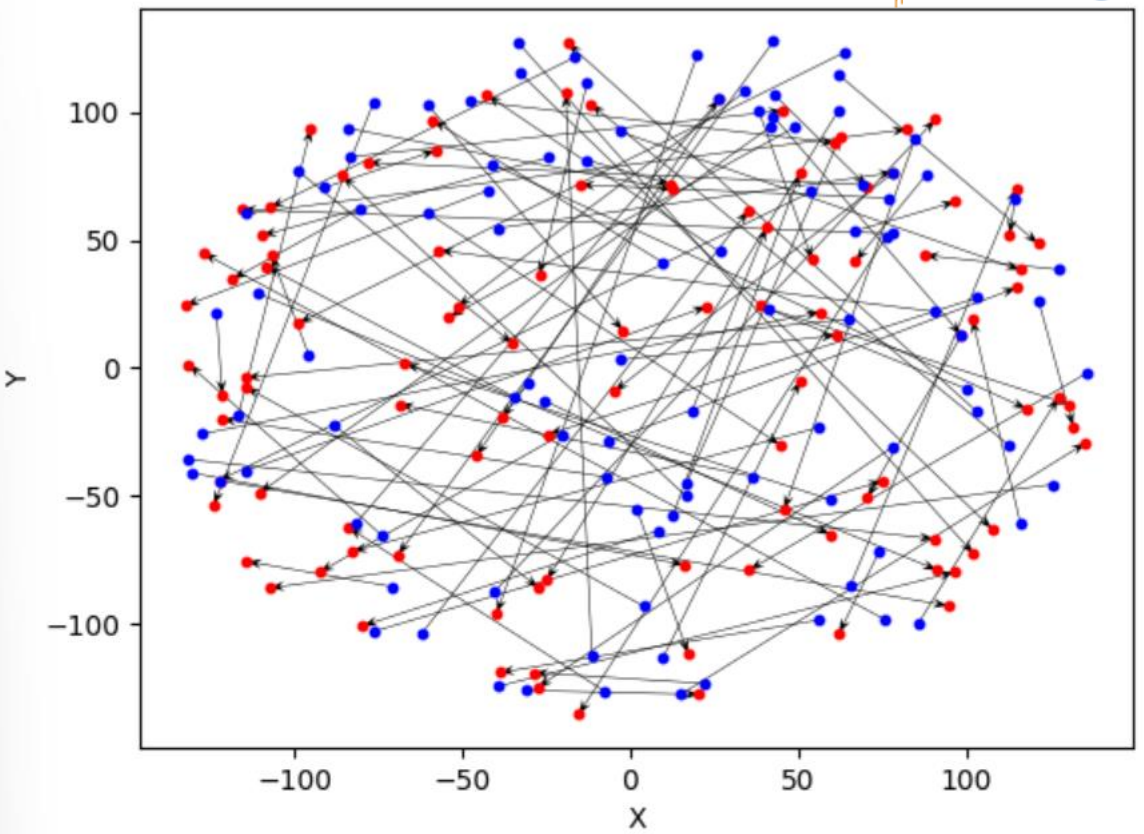
- Alpha peak1, peak 2 pairs

$\Delta S_{avg} = 243.6mm$



Pair tracking, binomial probability

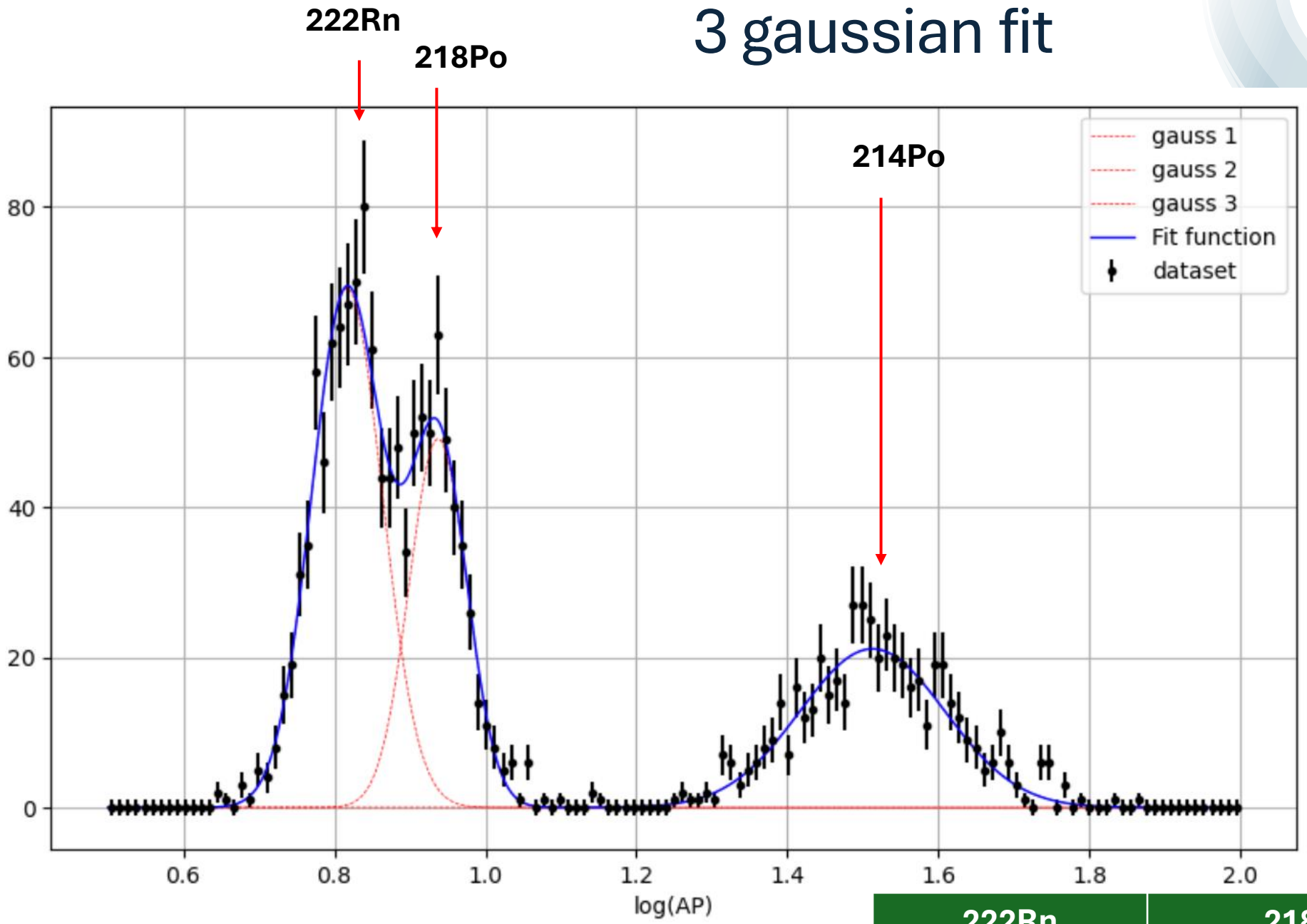




	Z	R2	X	Y	ϕ
n	104	104	104	104	104
k	78	53	48	46	50
p	0.5	0.5	0.5	0.5	0.5
P(at least k)	**0.0000164%**	**46.1%**	**81.1%**	**89.9%**	**68.8%**

- First alpha
- Second alpha

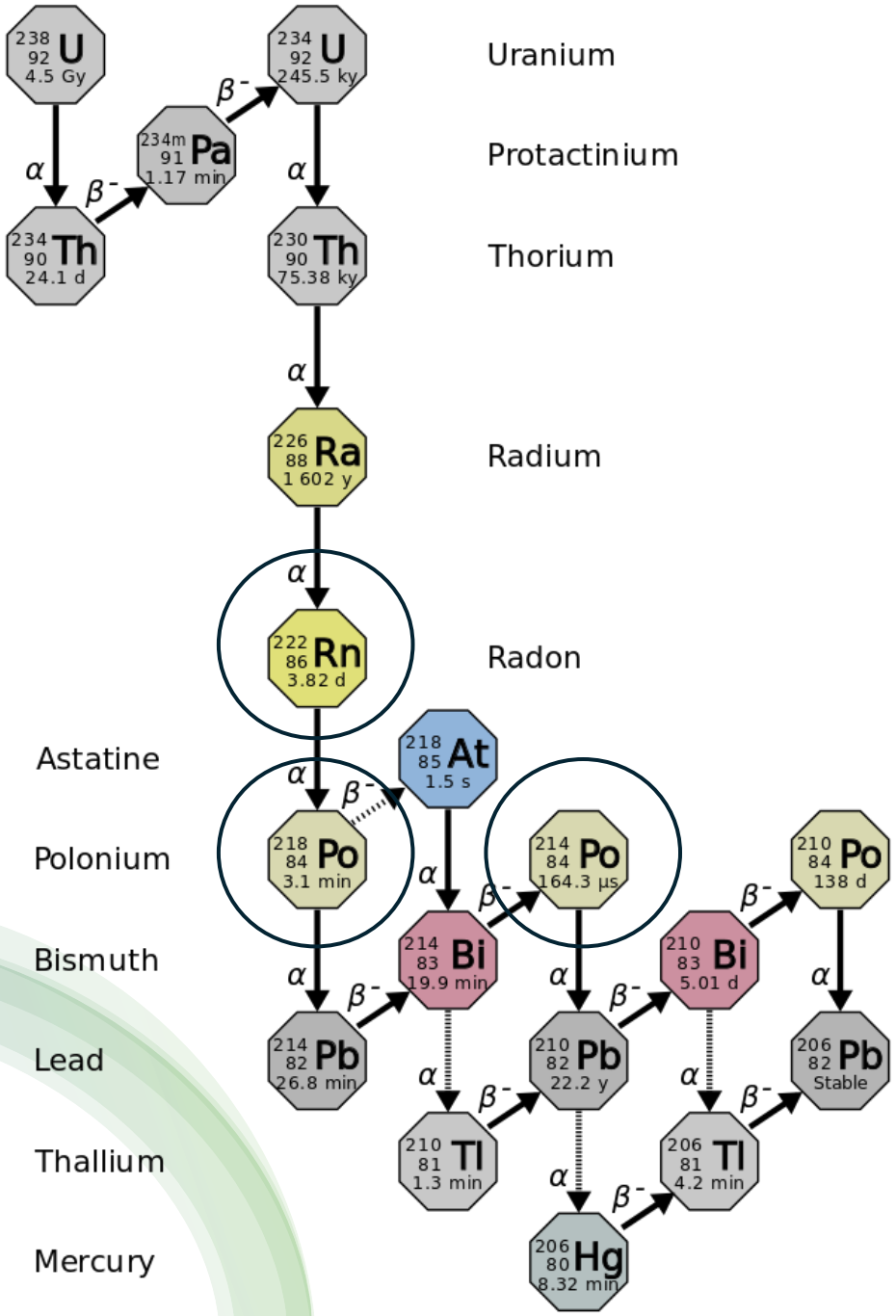
3 gaussian fit

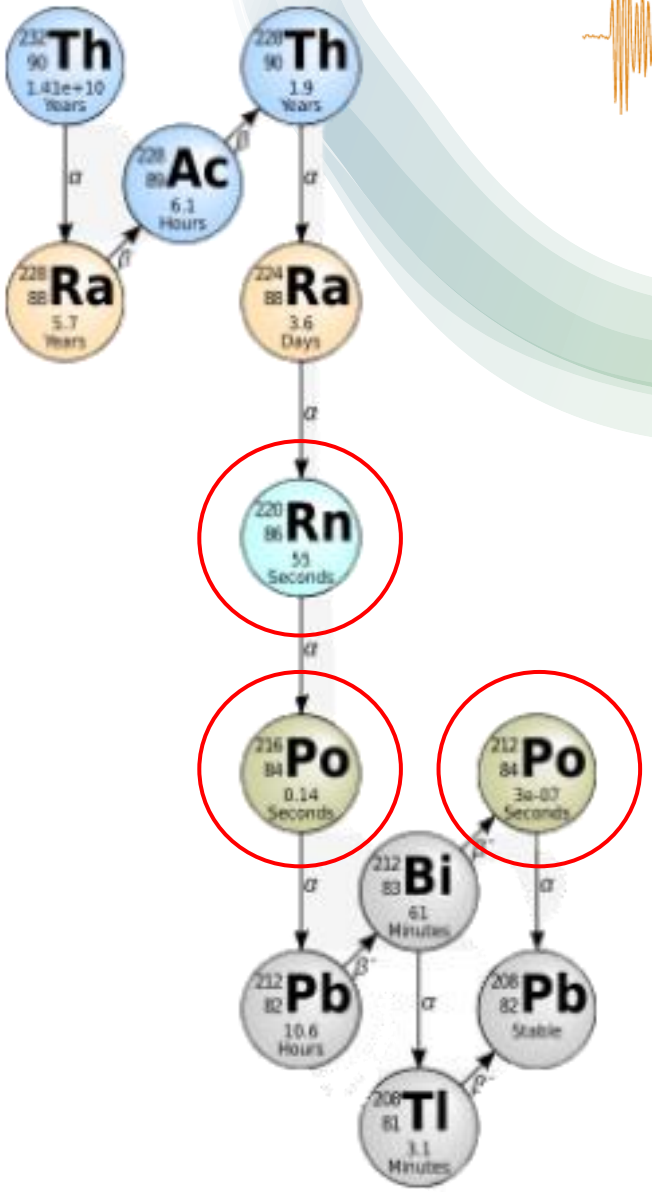


- Uranium decay chain

Error bars $= \sqrt{N}$

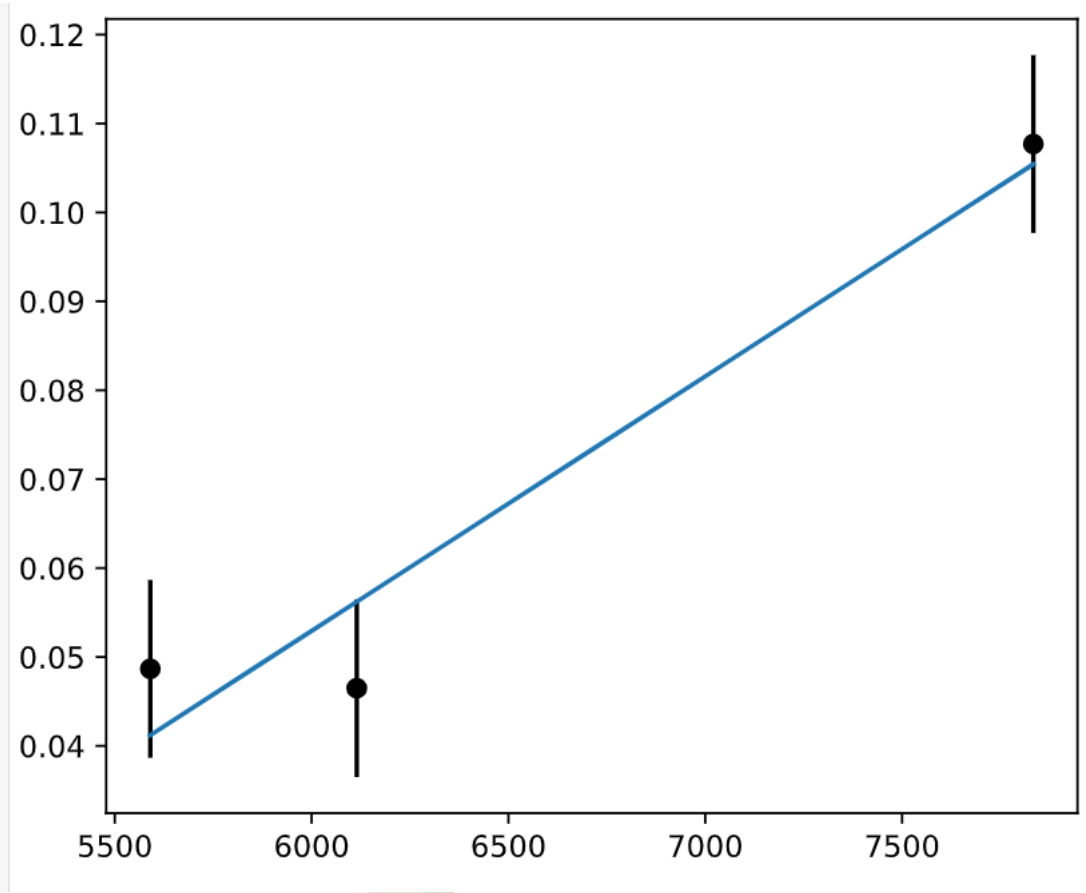
222Rn	218Po	214Po
8.664 ± 0.173	$4.220 (\pm 0.149)$	$5.516 (\pm 0.036)$


238 92 U 4.5 Gy
234 92 U 245.5 ky
234m 91 Pa 1.17 min
234 90 Th 24.1 d
230 90 Th 75.38 ky
226 88 Ra 1 602 y
222 86 Rn 3.82 d
218 85 At 1.5 s
218 84 Po 3.1 min
214 84 Po 164.3 µs
210 84 Po 138 d
214 83 Bi 19.9 min
210 83 Bi 5.01 d
214 82 Pb 26.8 min
210 82 Pb 22.2 y
206 82 Pb Stable
210 81 Tl 1.3 min
206 81 Tl 4.2 min
206 80 Hg 8.32 min
α
β-
Uranium
Protactinium
Thorium
Radium
Radon
Astatine
Polonium
Bismuth
Lead
Thallium
Mercury

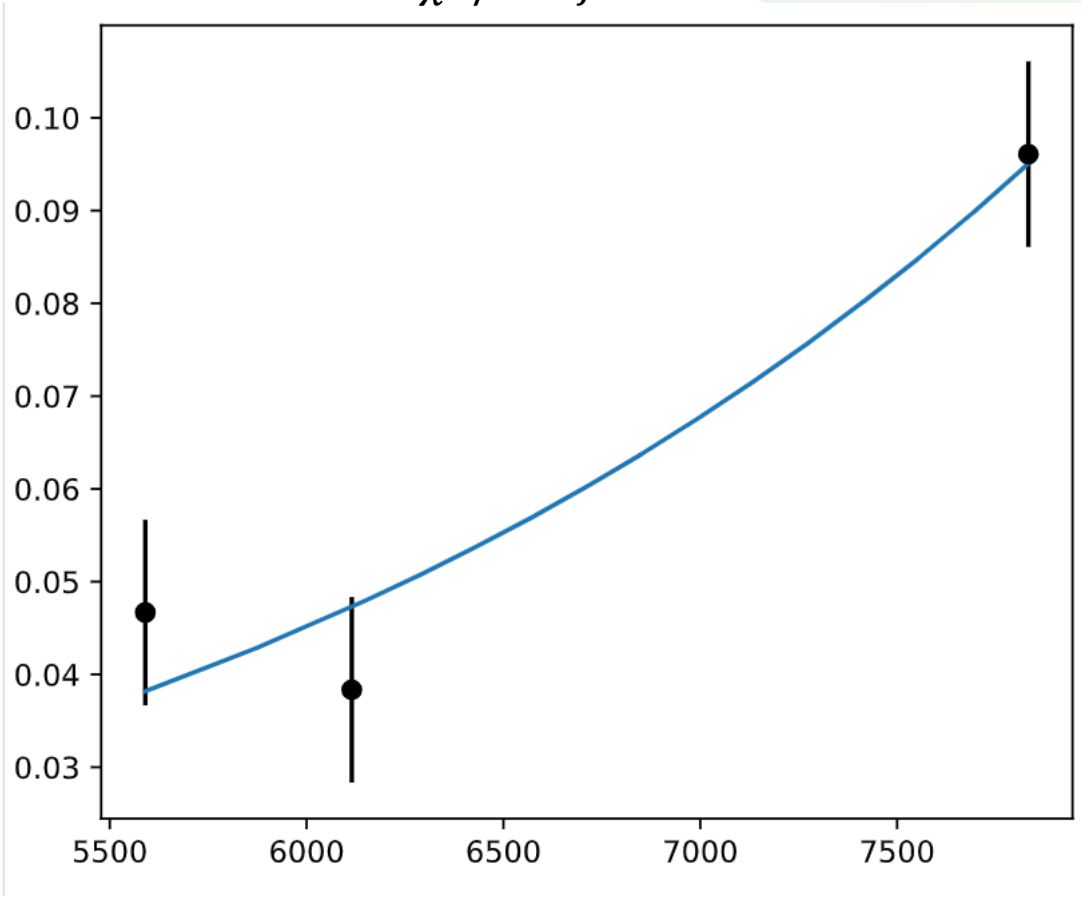

232 90 Th 1.41e+10 Years
228 89 Ac 6.1 Hours
228 88 Ra 5.7 Years
228 90 Th 1.9 Years
224 88 Ra 3.6 Days
220 86 Rn 55 Seconds
216 84 Po 0.14 Seconds
212 84 Po 3e-07 Seconds
212 83 Bi 61 Minutes
212 82 Pb 10.6 Hours
208 82 Pb Stable
208 81 Tl 3.1 Minutes
α
β-

Sigma vs Alpha energy for U chain

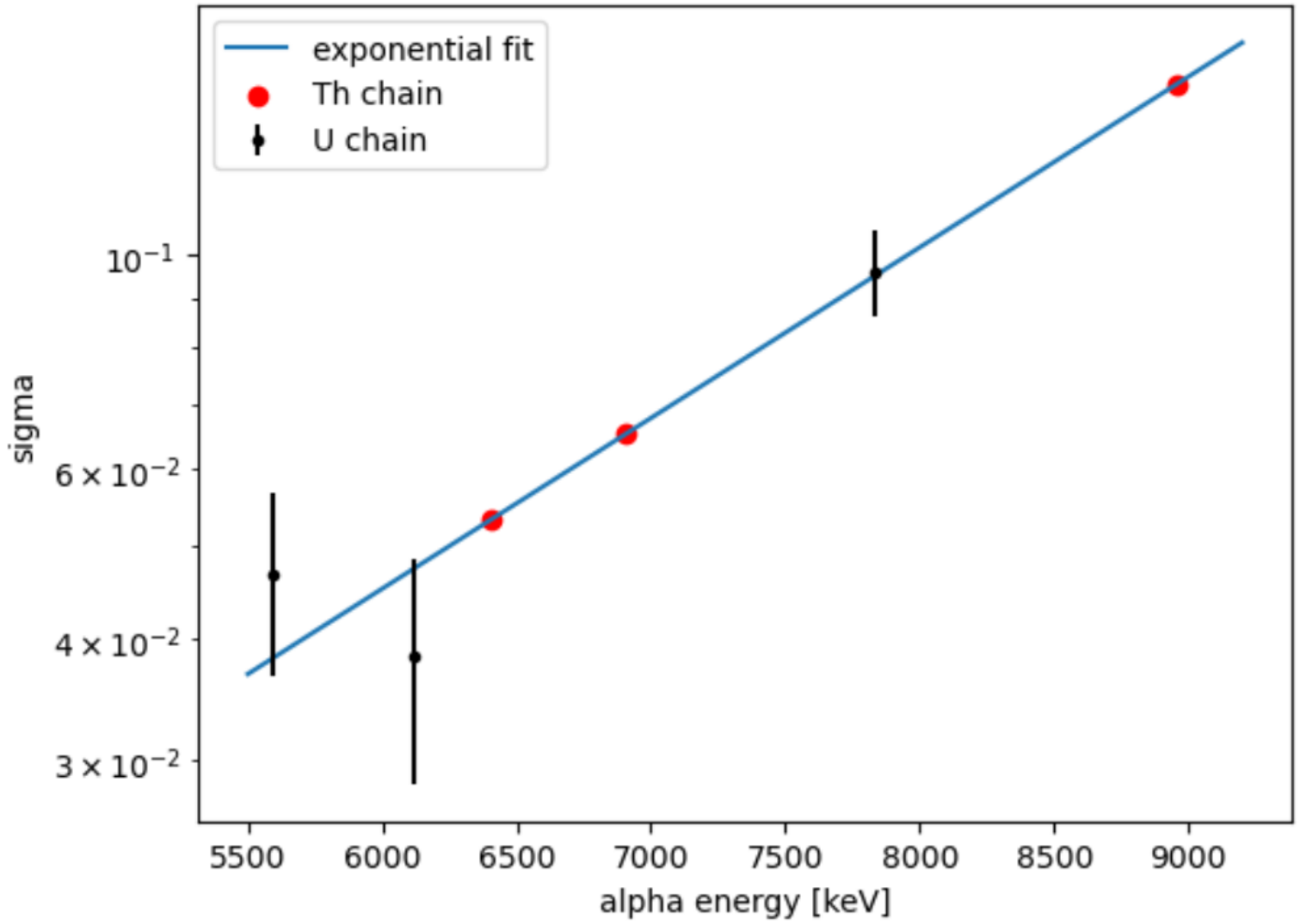
$\chi^2/ndof = 1.6$



$\chi^2/ndof = 1.525$

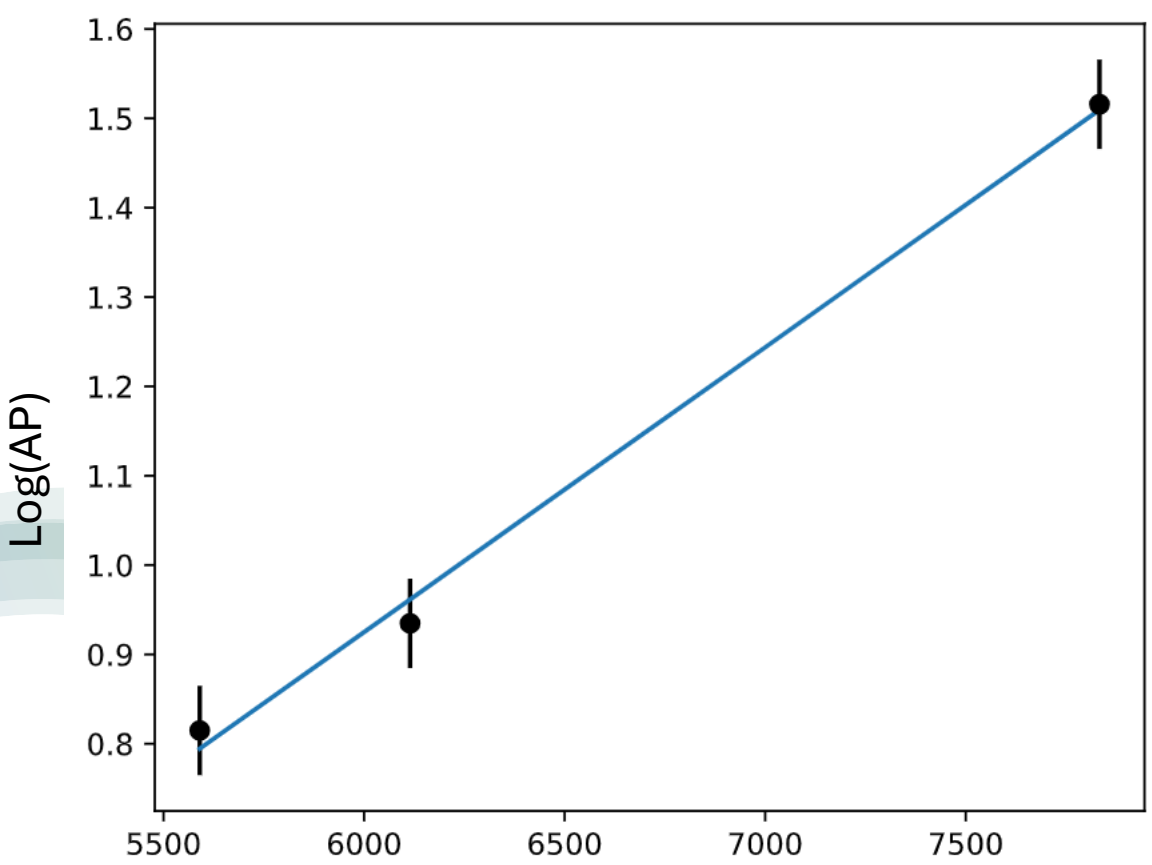


Propagate to approximate Th chain sigmas

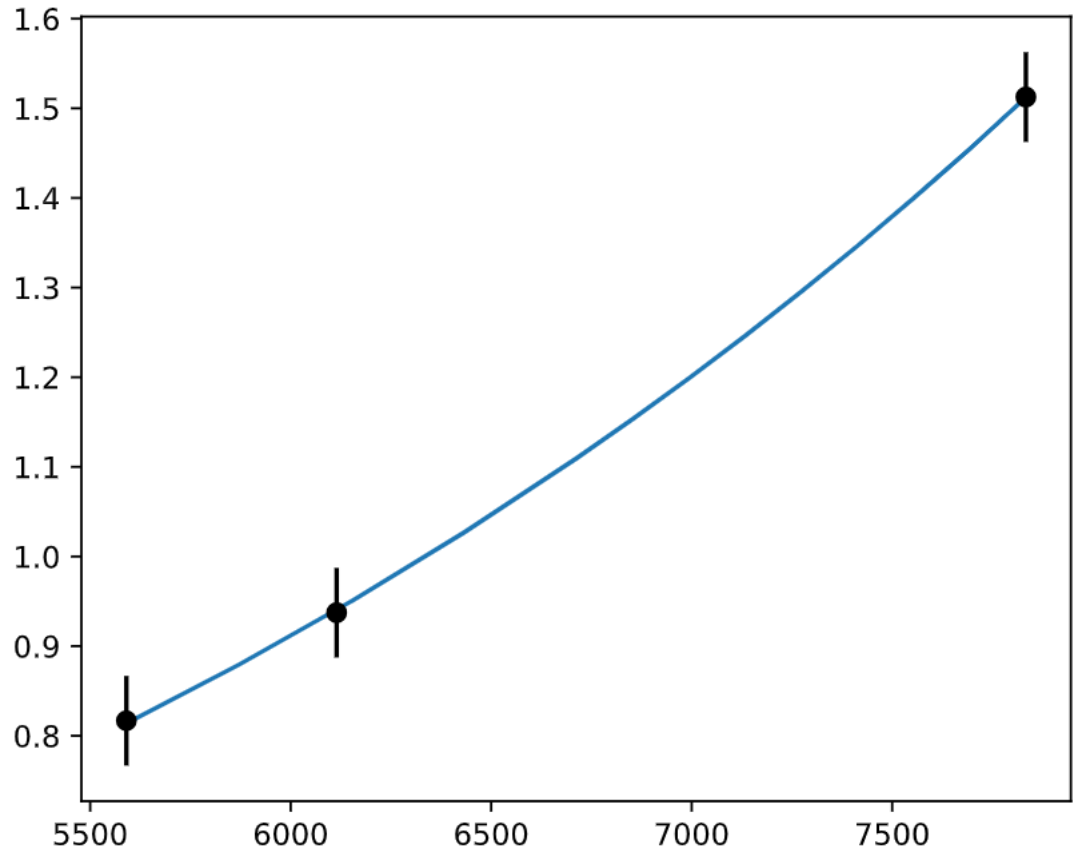


Same process to find Th chain mean AP

$\chi^2/ndof = 0.5$

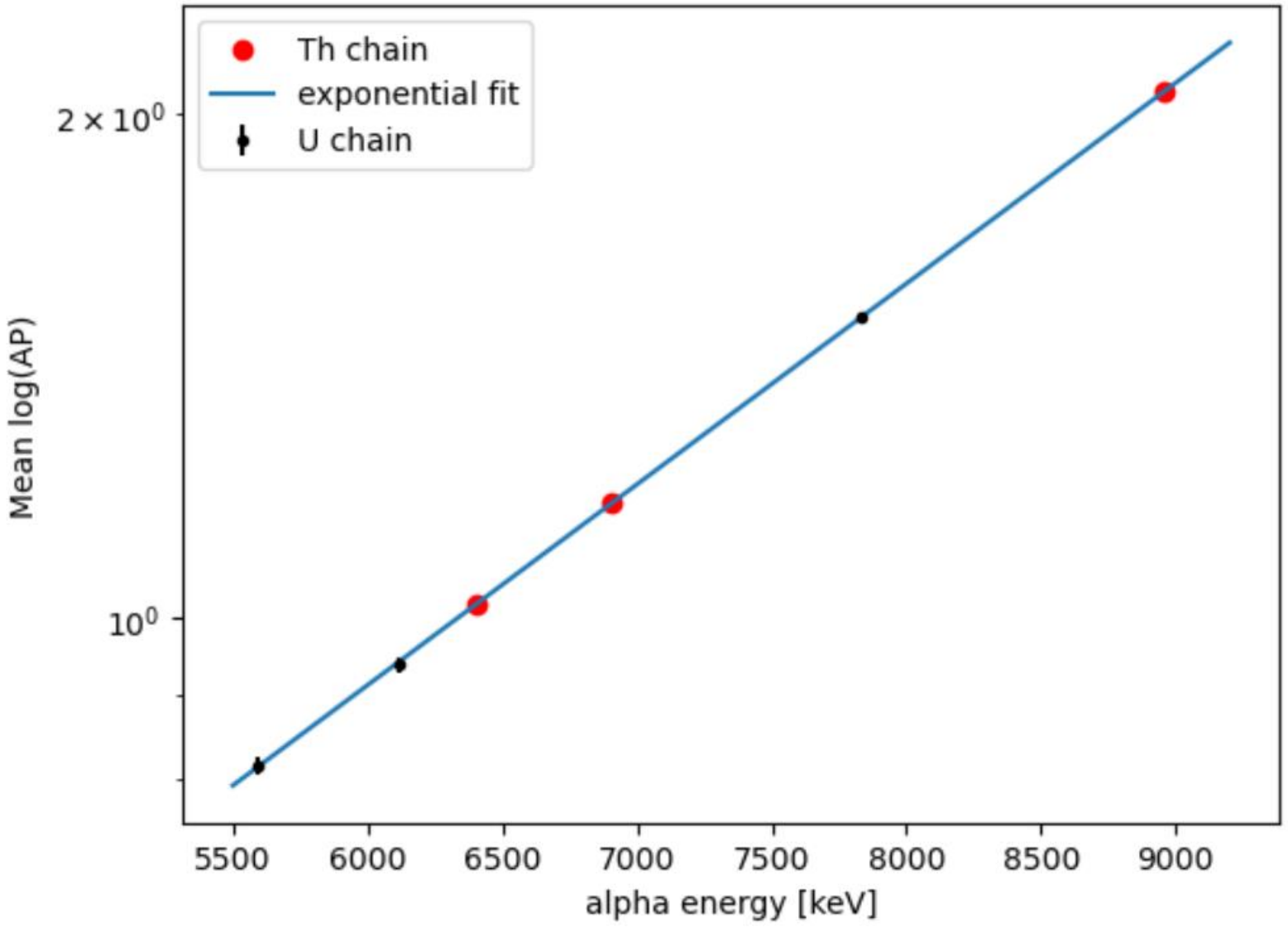


$\chi^2/ndof = 0.4$

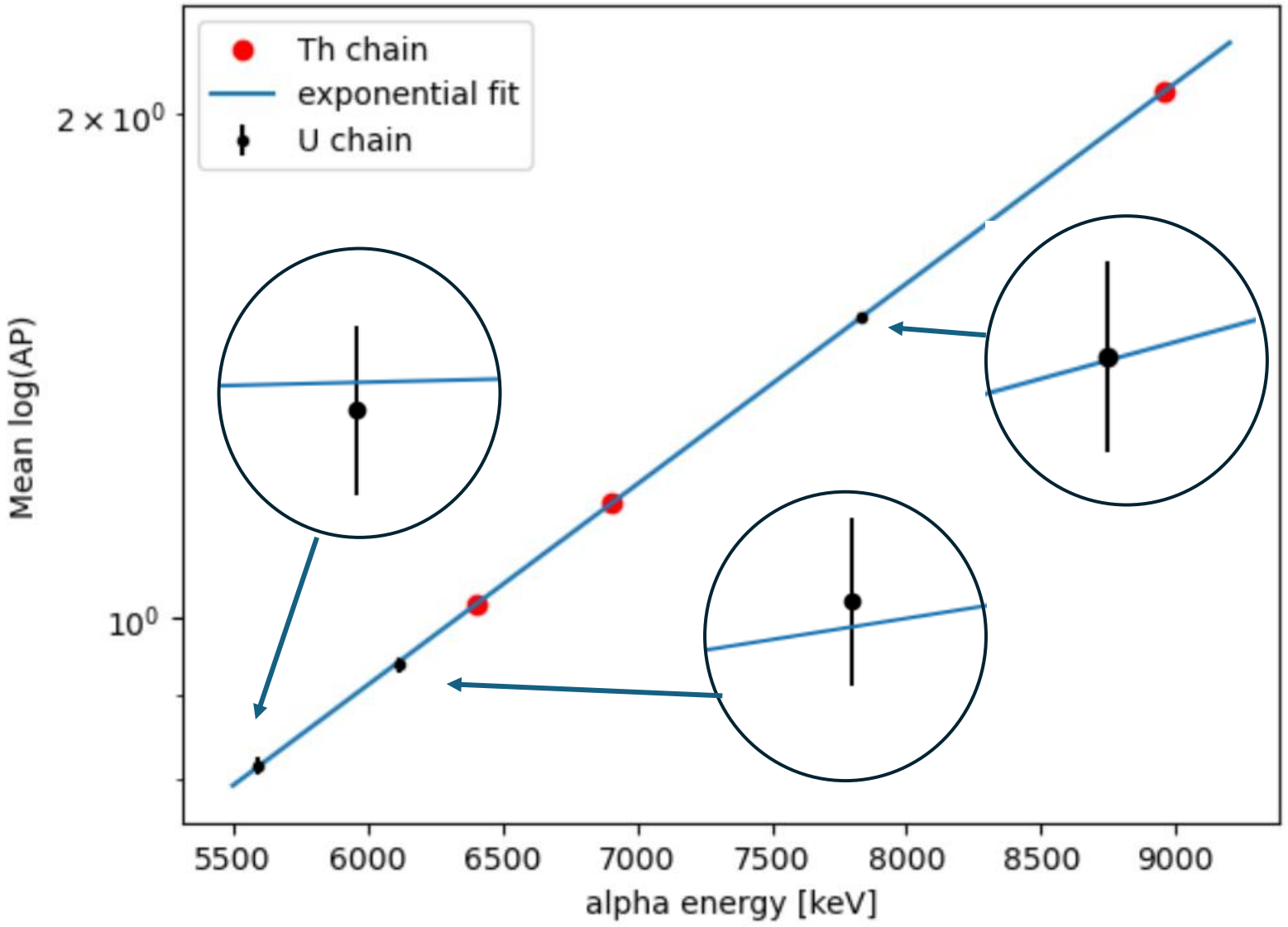


Alpha energy [keV]

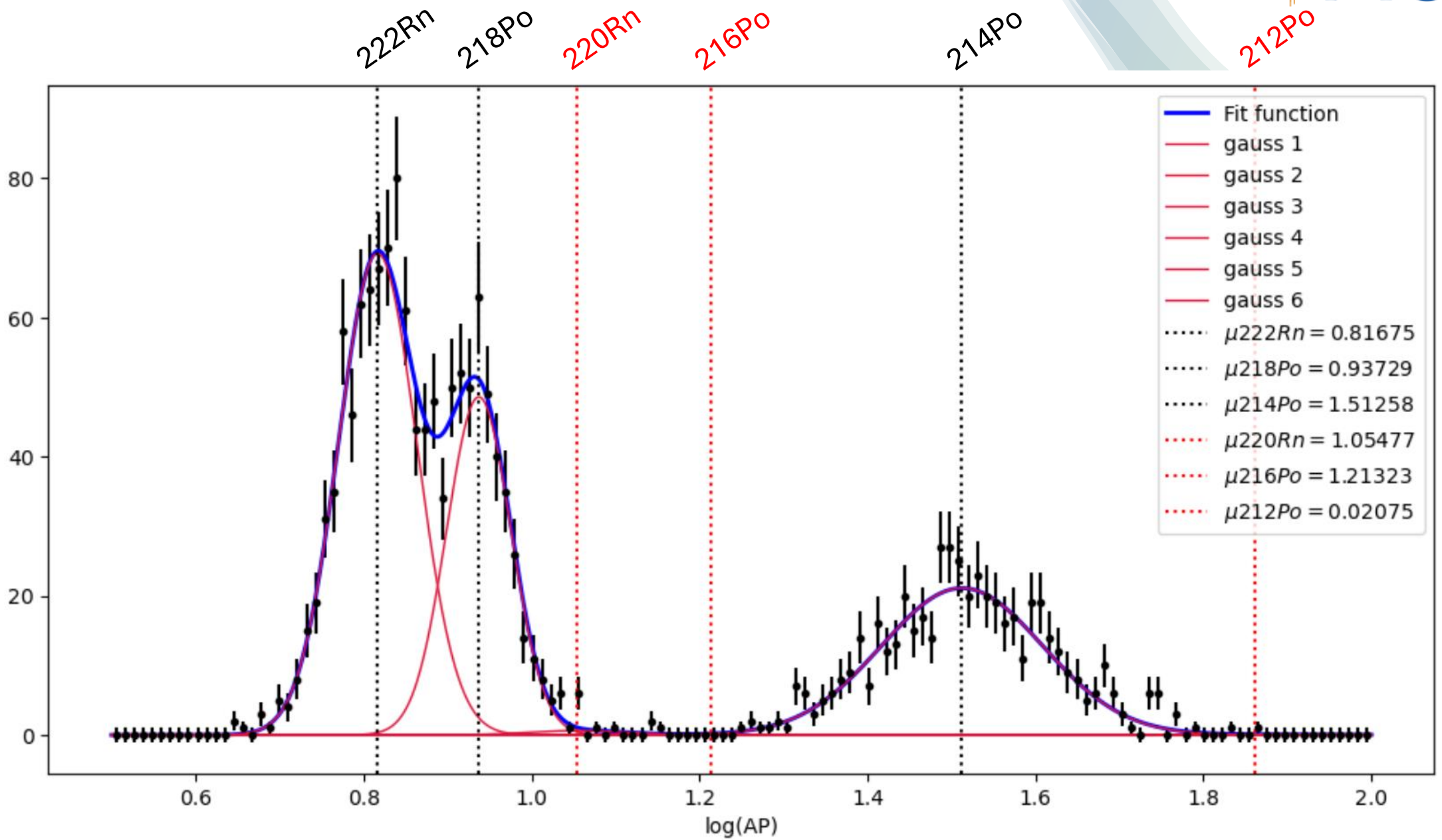
Propagate this line to get mean AP for Th chain



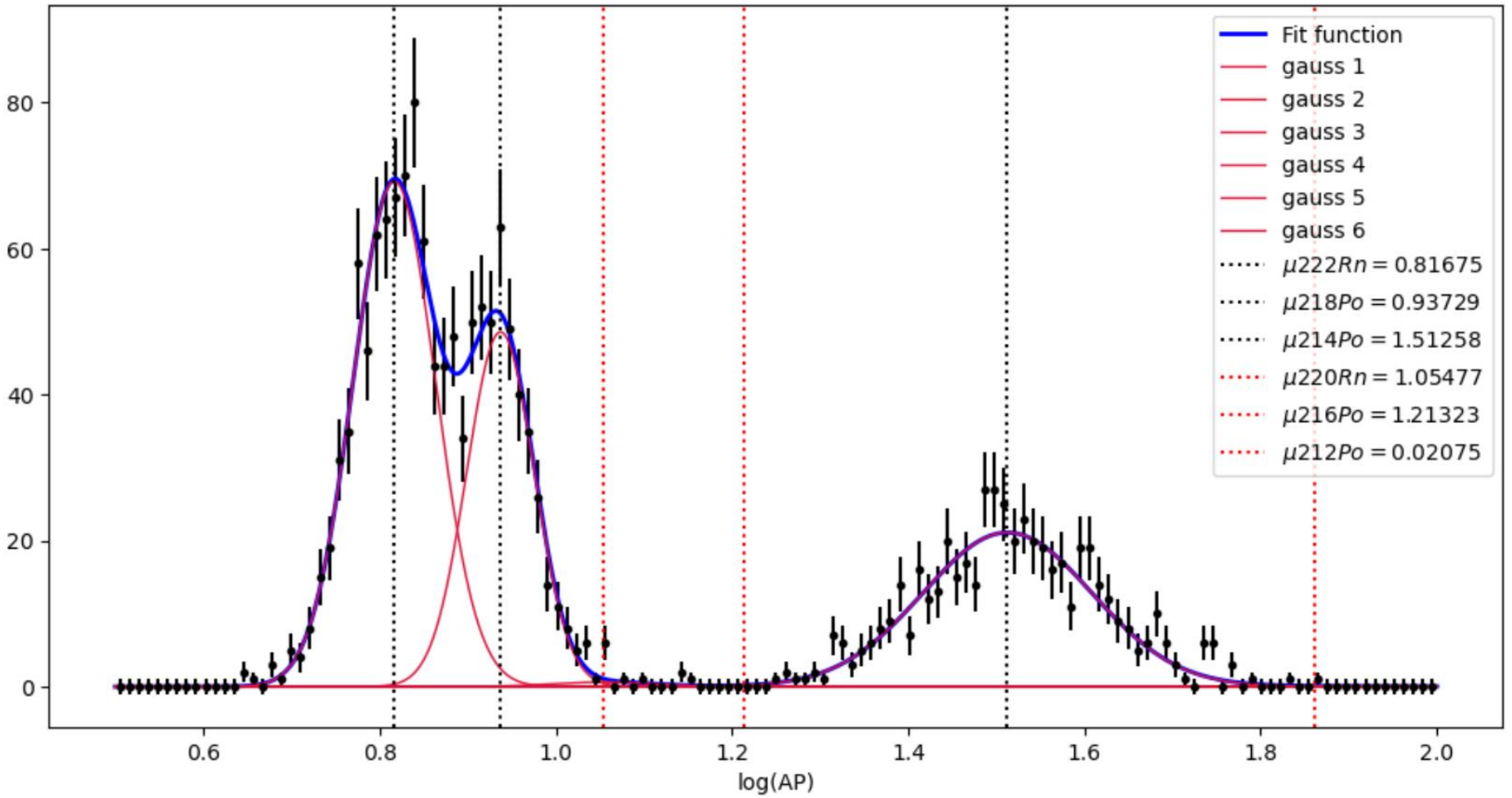
Error agrees with exponential fit



6 gaussian fit



6 gaussian fit amplitudes



Error not included
(want to be sure before concluding we are free of thorium)

222Rn	218Po	220Rn	216Po	214Po	212Po
8.103	4.632	0.106	0.022	5.089	0.029

PICO

Thank You!

Questions, Comments?