SNS 2020 Fitting Update

UT/ORNL n → n’ Group
06/01/2023
Cary Rock

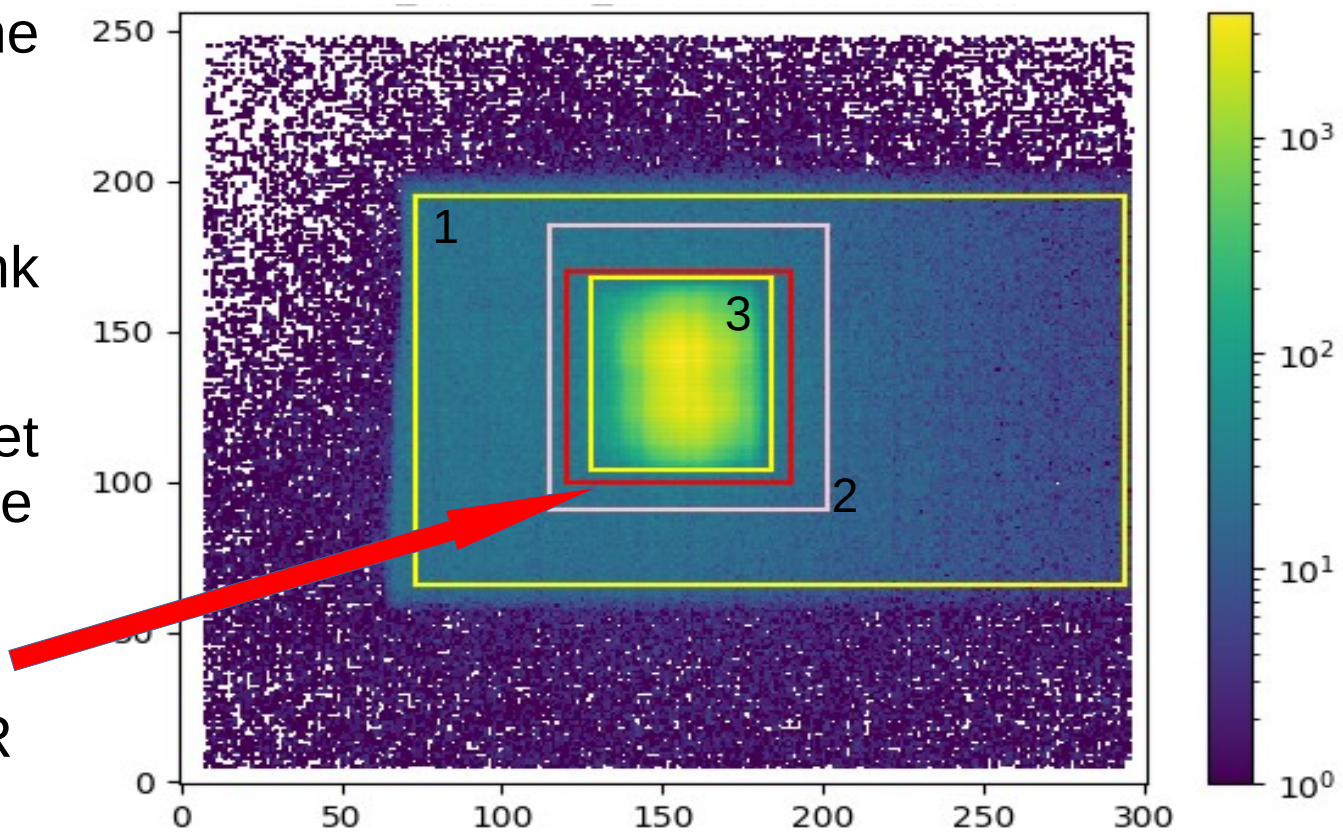
Definition of Regions

1) Background Region (BR): the set of points only in the outer yellow box

2) Scattering Region (SR): the set of points in the pink box, excluding ROI.

3) Peak Region (PR): the set of points of the peak of the beam

4) Dr. Gonzalez' (F)ROI is slightly larger than the PR



Fits are made over regions 1, 2, and 3, but the results are computed over FROI

Description of Fit Methods

A) 6-Fit: A plane and a gaussian fit at the same time

B) PLANE*: Just the plane

C) PLANE* + GAUSS: Fit the plane in the BR first (same as in fit #2), then fit the gaussian

D) "4-Fit": Plane & gaussian amplitude are free parameters, σ_x and ratio of $K = \sigma_y / \sigma_x$ are constant determined from global 4-parameter fit (by hand). Motivated by simulations.

Methods of Fitting the Background

All methods integrate over FROI for determining F_0, η except for Fit 1

1) 6-Fit: Fit 3 plane and 3 gaussian parameters over BR + SR. Integrated over the whole of the effective detector region. Includes most of the background.

2) 6-Fit: Fit 3 plane and 3 gaussian. Considered the “baseline”.

3) Plane: 3 plane parameters over BR only.

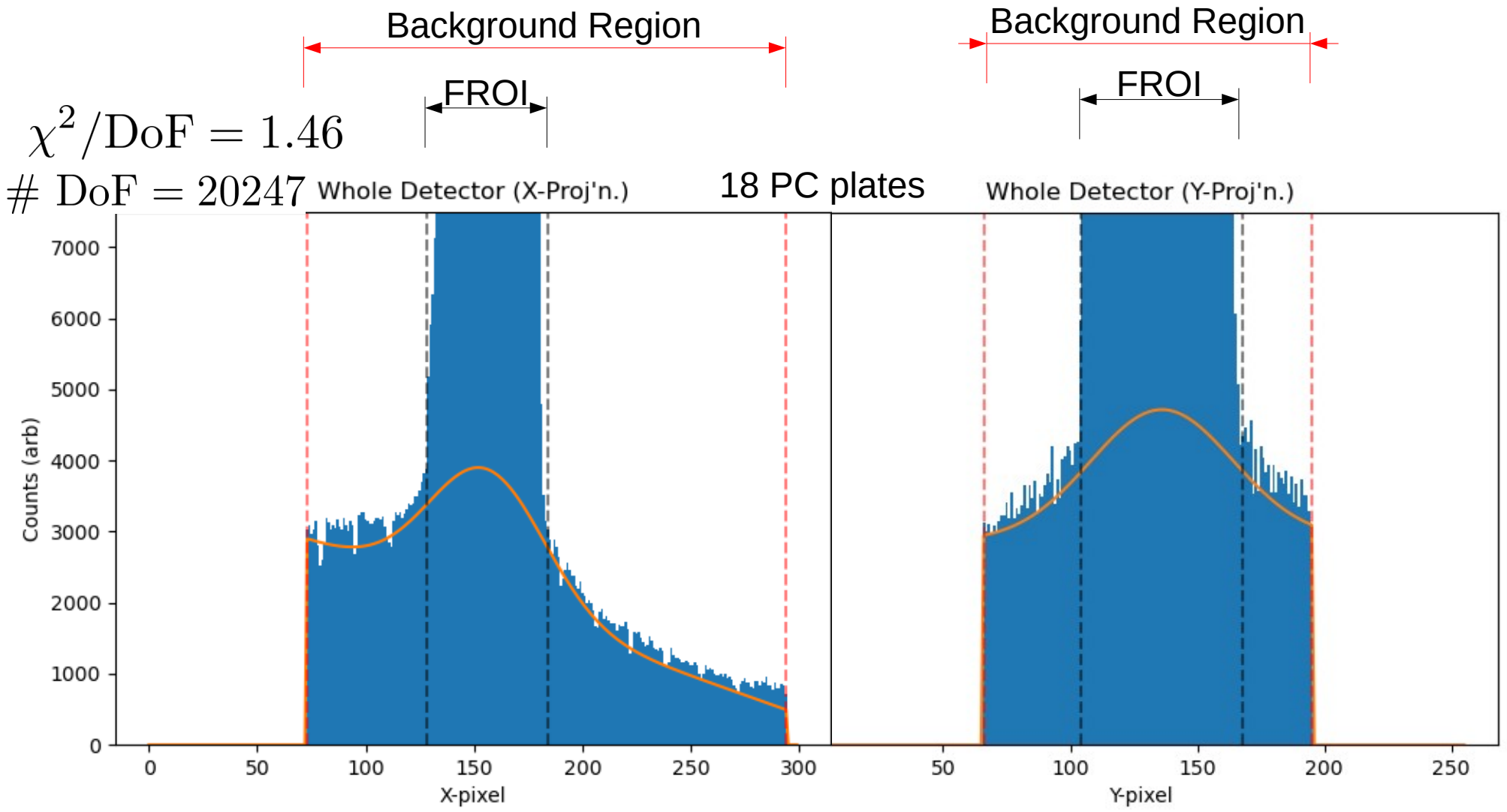
4) Plane + Gauss: Fit 3 plane parameters over BR, then separately fit 3 gaussian parameters over BR + SR.

5) “BR/2”: Like Fit 2, but BR reduced by half.

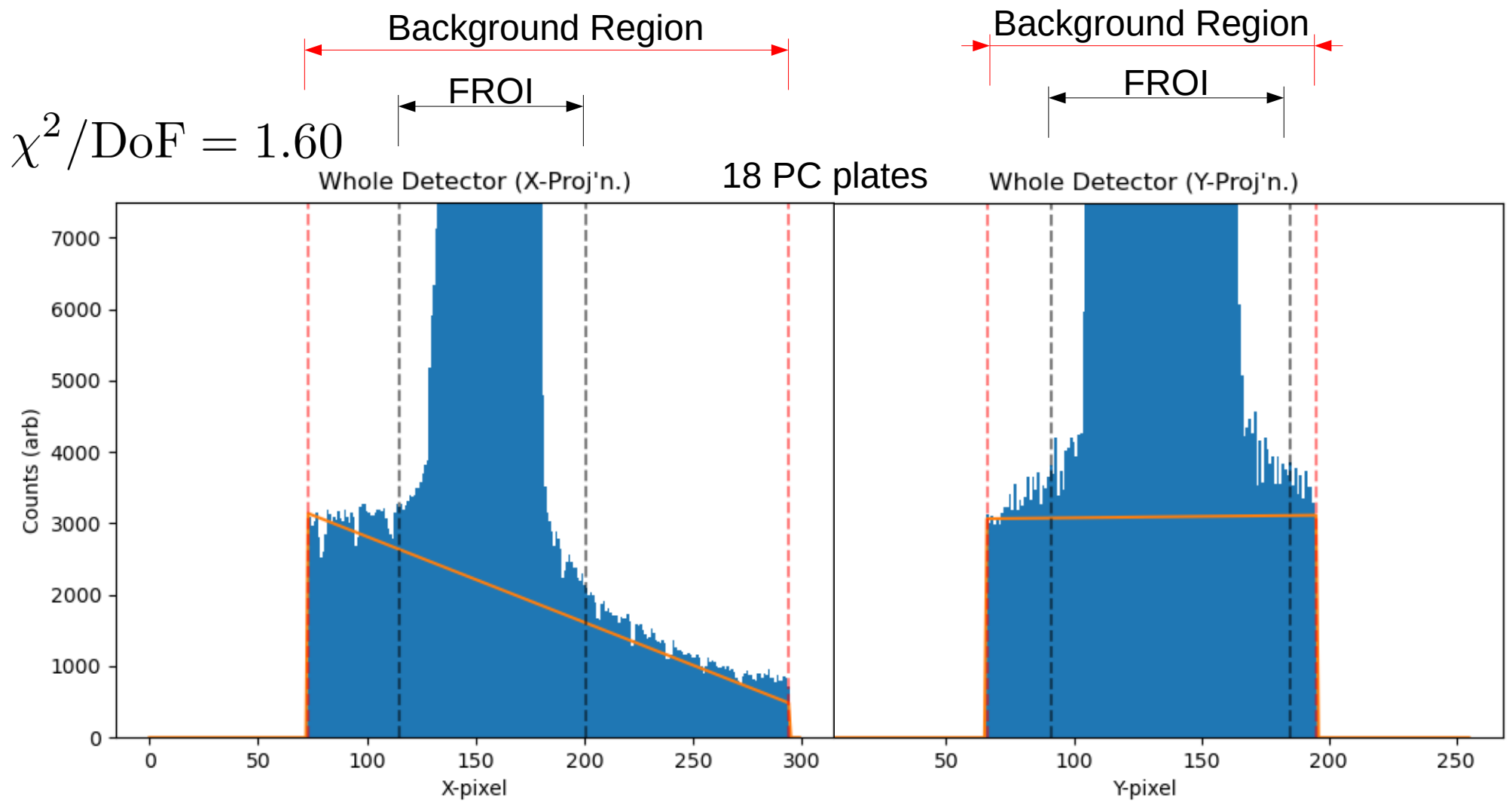
6) SR+20: Like Fit 2, but BR set to SR + 20 pixels.

7) 4-Fit: Determine iteratively the optimal value of σ_x and $K = \sigma_y / \sigma_x$, then fit 3 plane parameters and 1 gaussian amplitude like in Fit 2. Motivated by simulations.

Fit Histrogram Contribution – 6-Fit (#2)



Fit Histrogram Contribution – PLANE* Only (#3)



Fit Histrogram Contribution – 4-Fit (#7)

Background Region

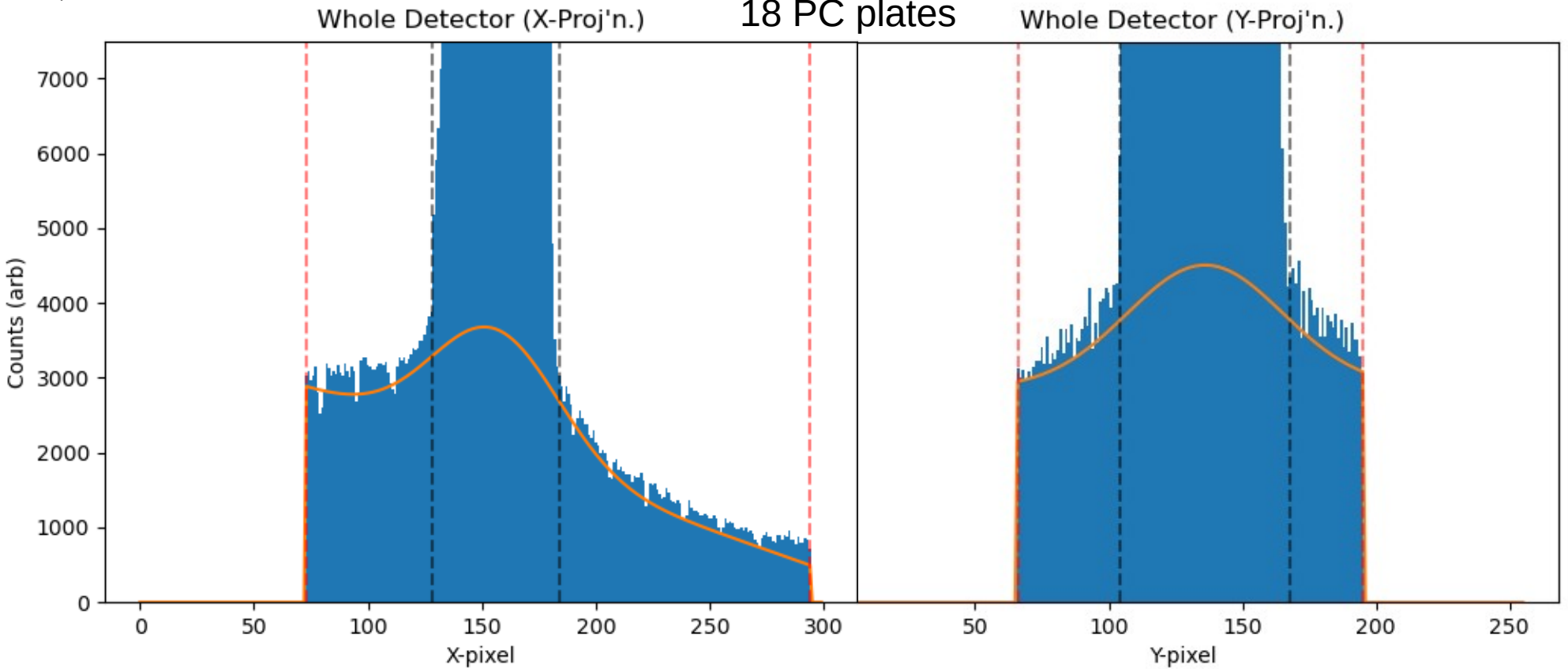
FROI

Background Region

FROI

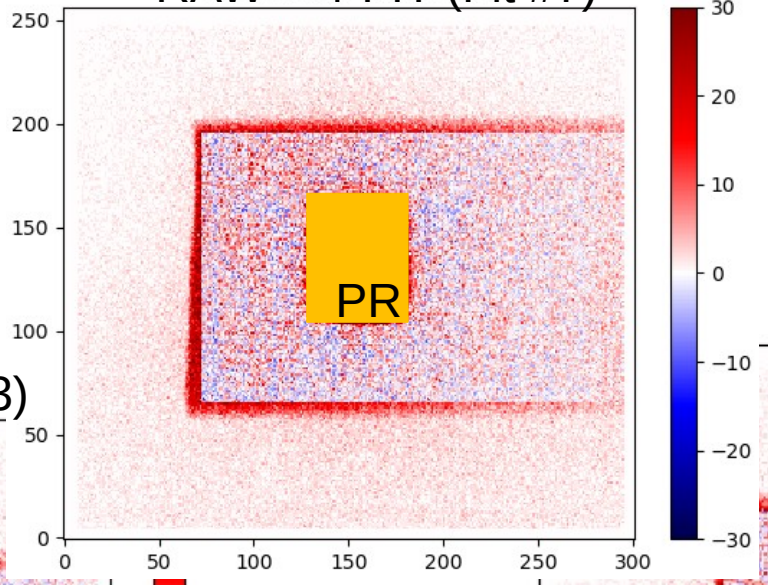
$\chi^2/\mathrm{DoF} = 1.48$

18 PC plates

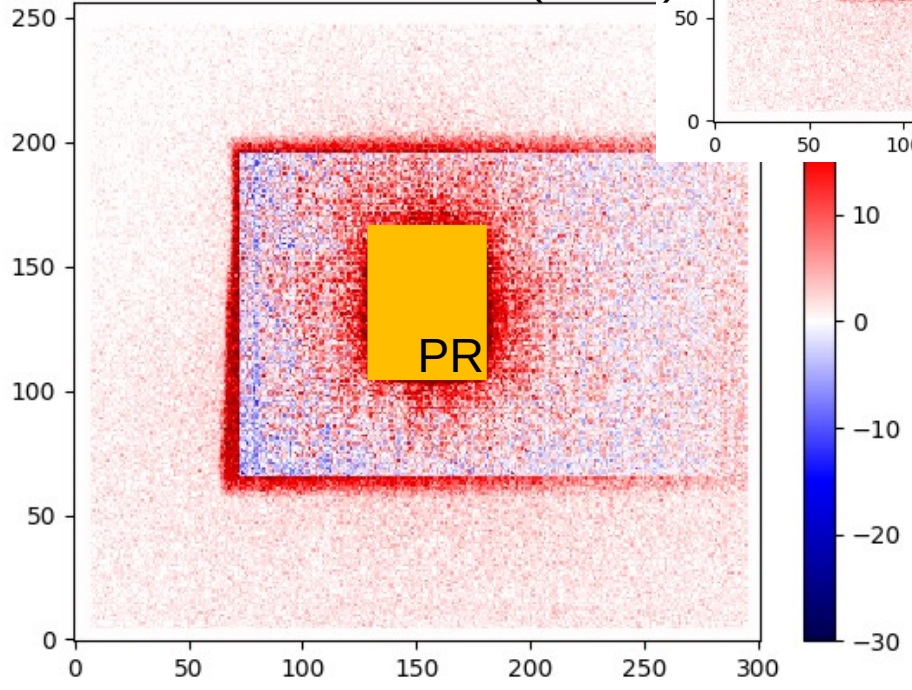


18 PC Fit Residuals

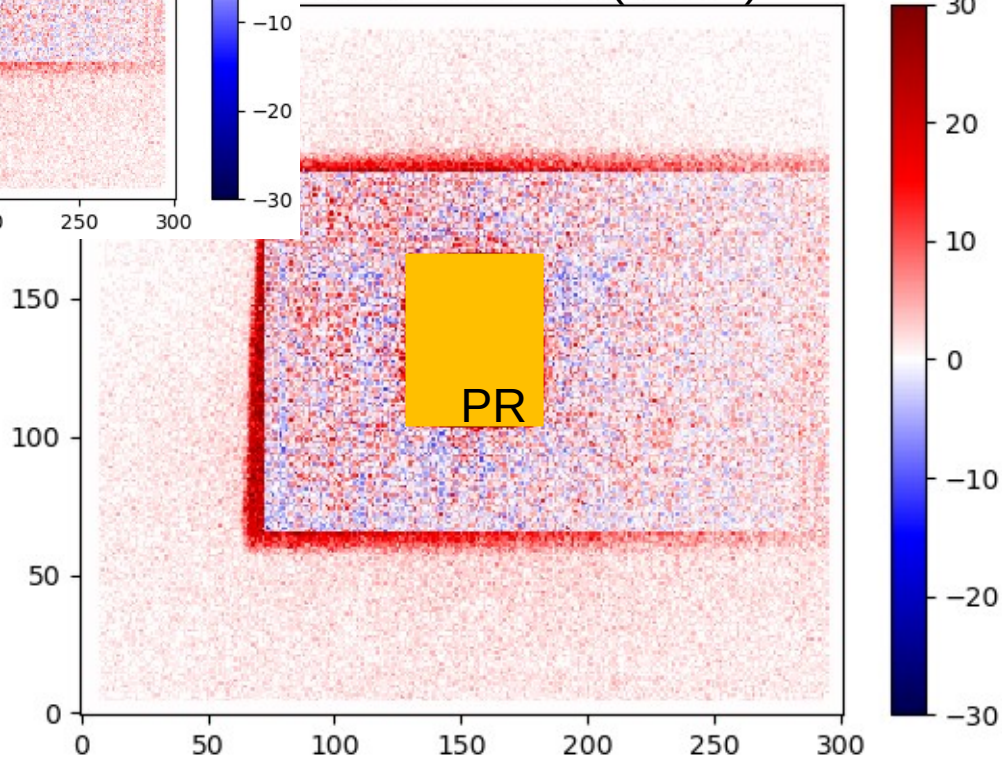
RAW – 4-FIT (Fit #7)



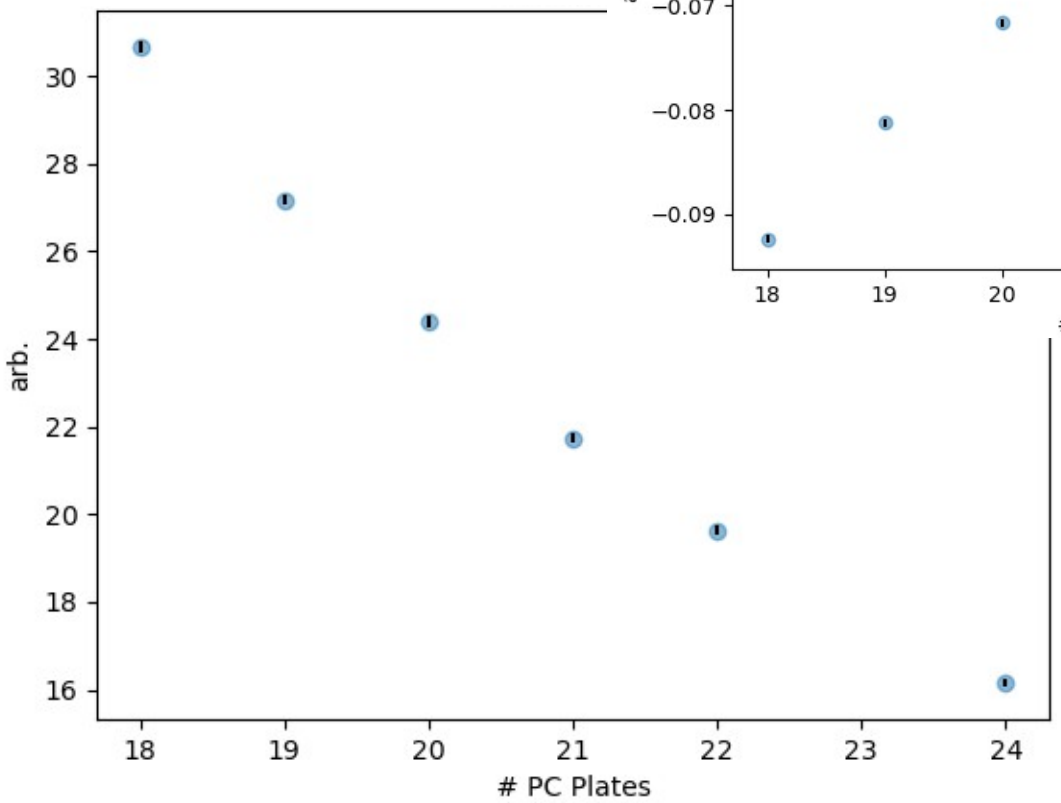
RAW – PLANE* (Fit #3)

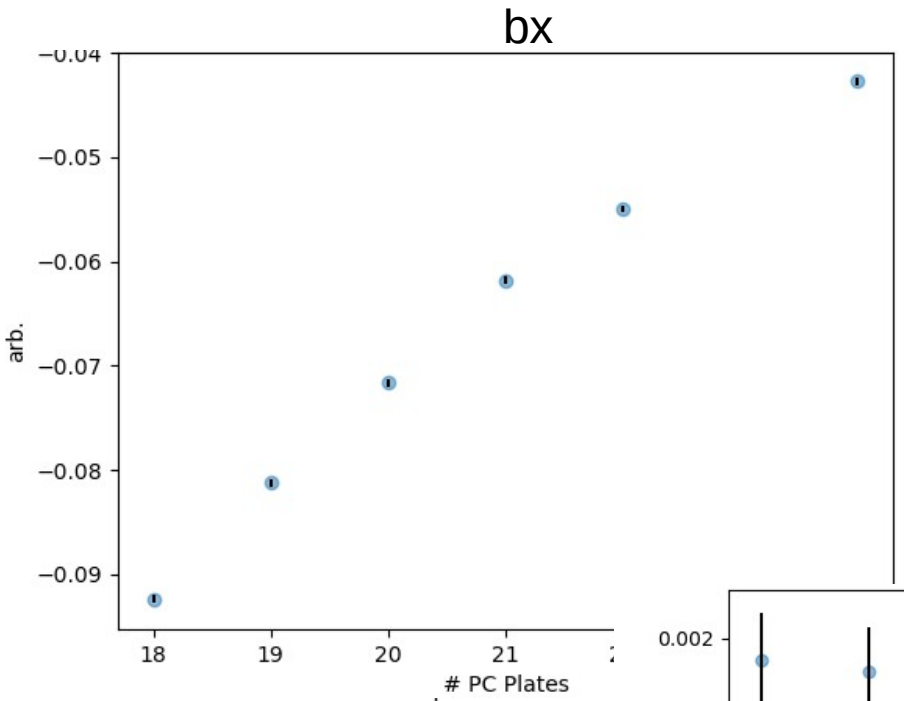


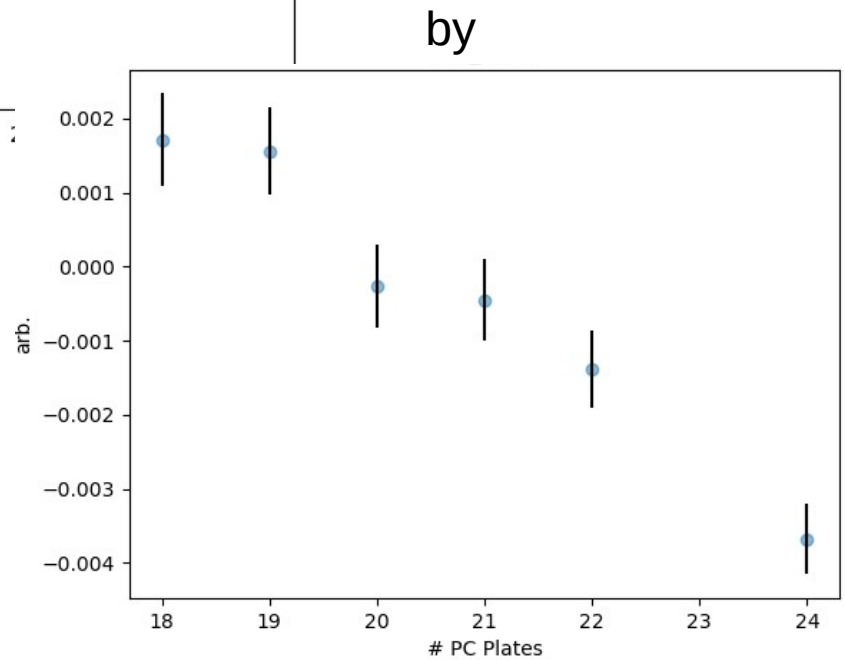
RAW – 6-FIT (Fit #2)



6-FIT: Plane Parameters vs # PC Plates



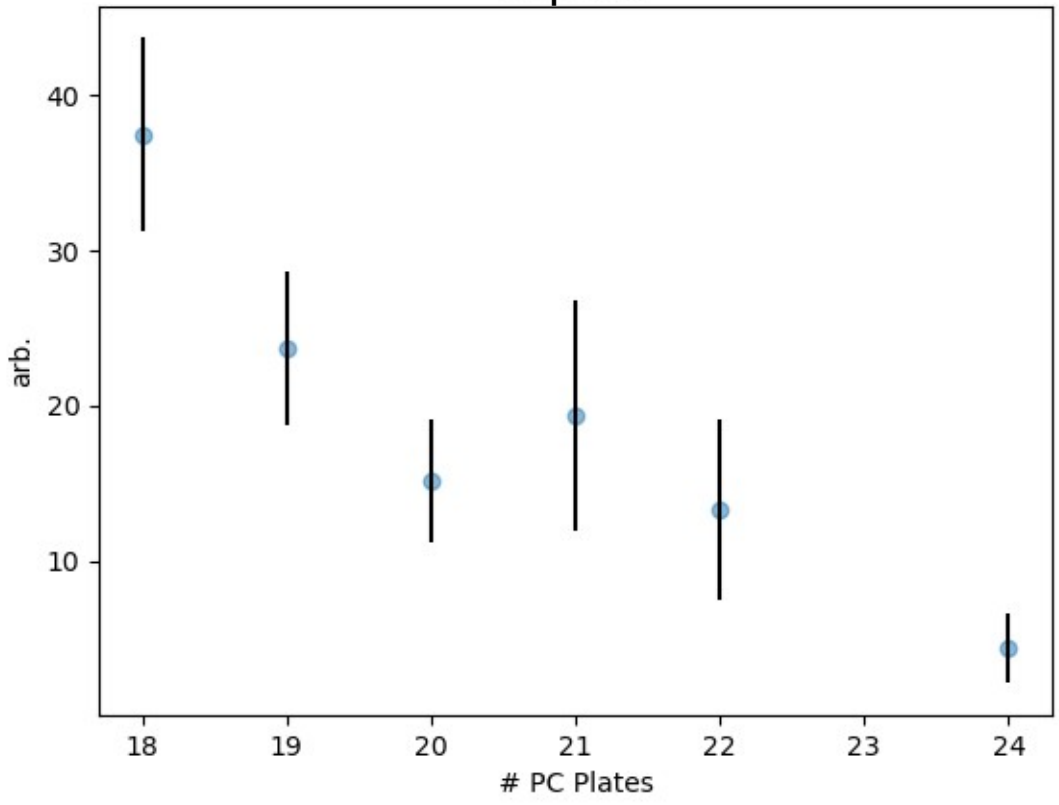




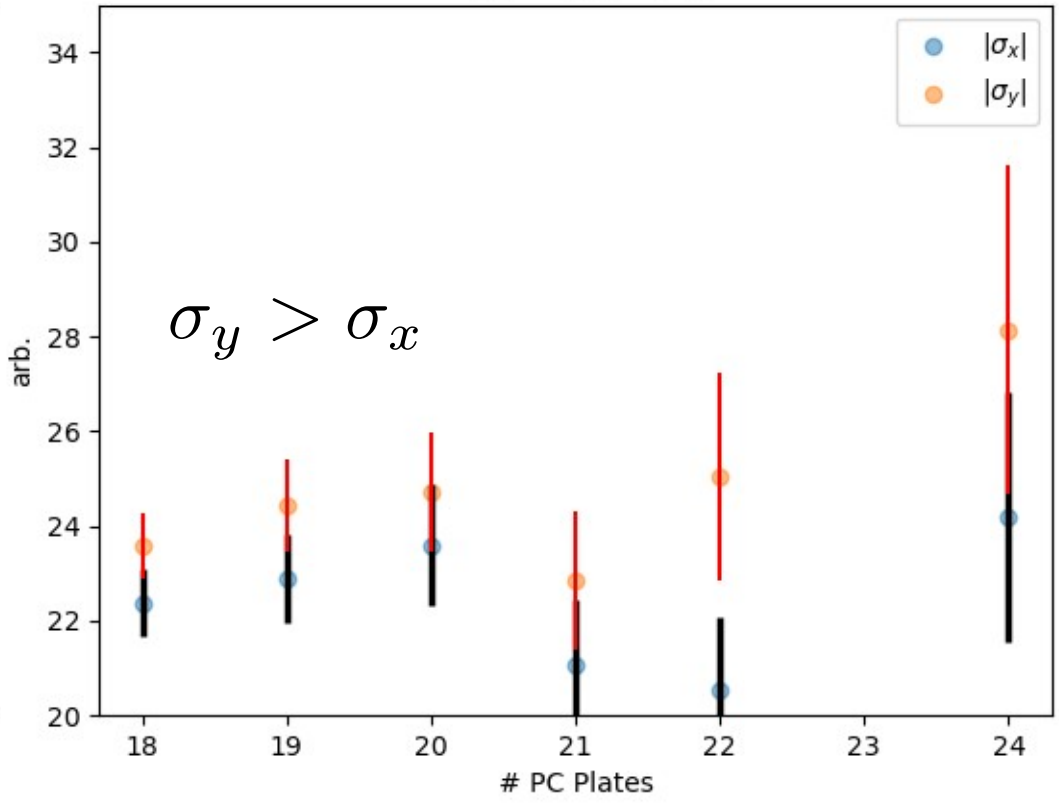
6-FIT: Gaussian Parameters vs # PC Plates

Note: σ_x and σ_y are in units of pixels

Amplitude

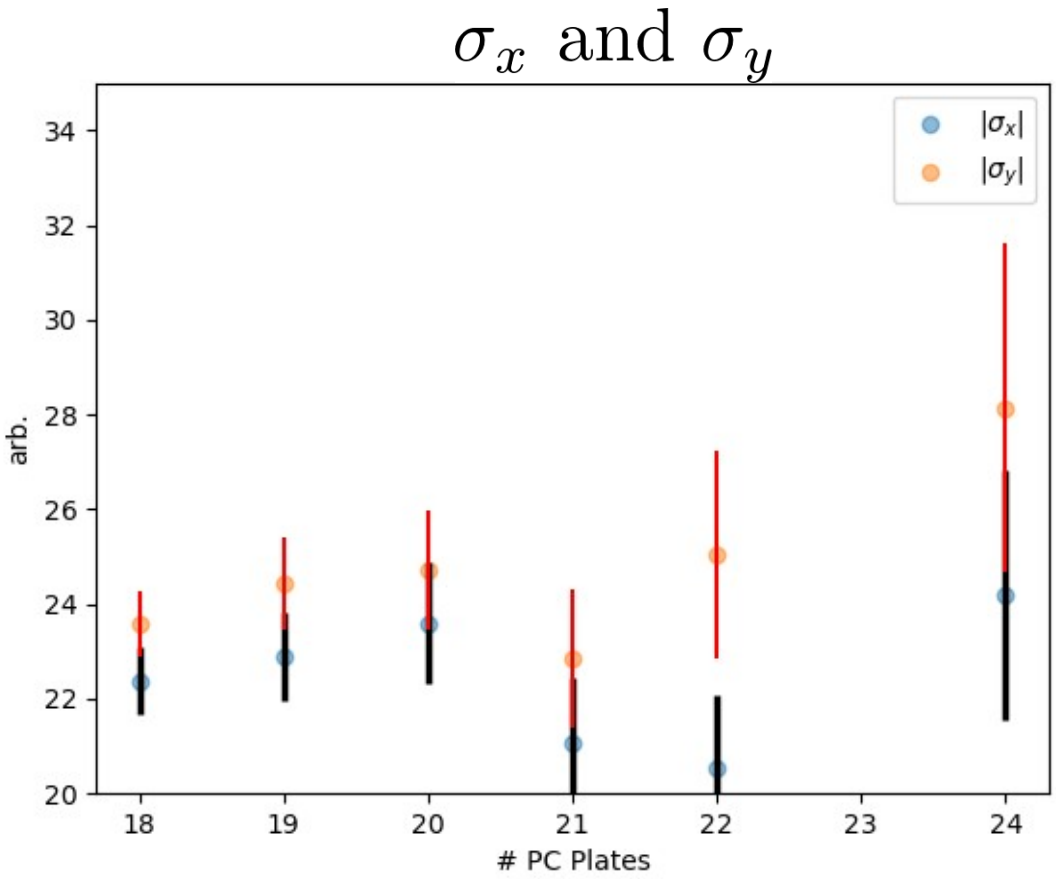


σ_x and σ_y



σ_x and σ_y

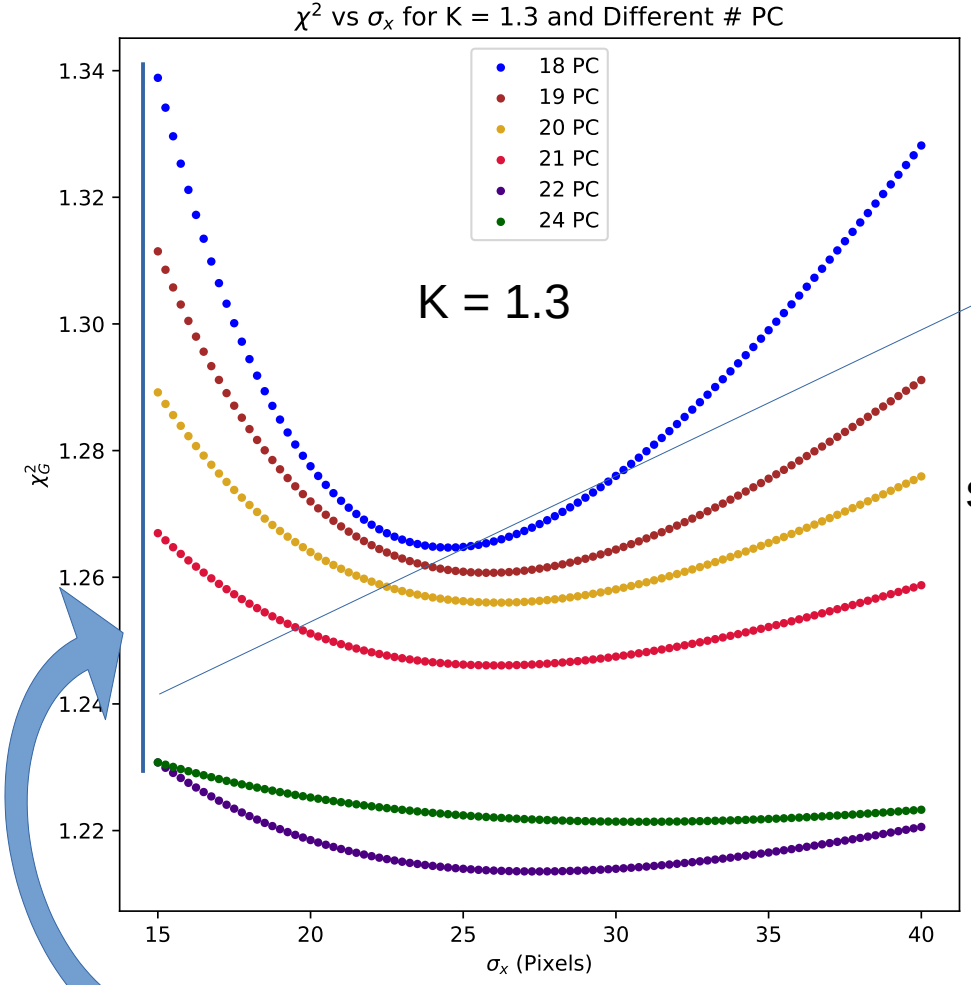
- σ_x and σ_y are free parameters in the 6-FIT
- Monte Carlo suggests that σ_x, σ_y, and σ_y / σ_x are constant.
- Experiment indicates that $\sigma_y > \sigma_x$.
- A fit using these constraints was performed → “4-FIT” (Fit #7)



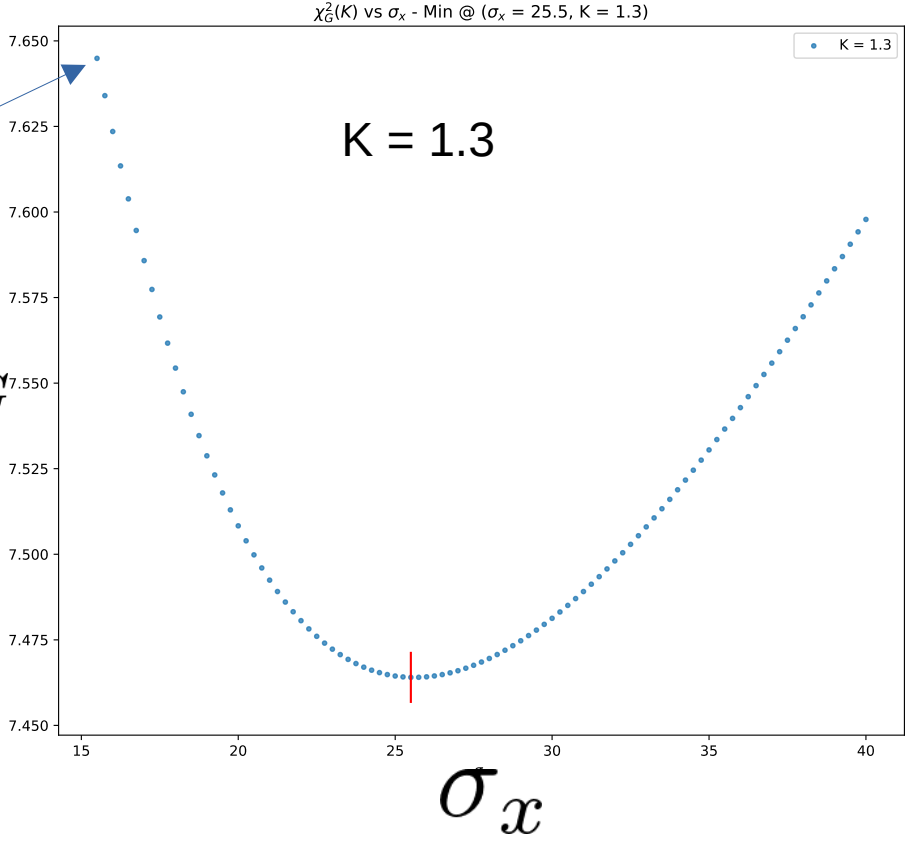
4-Fit: Varying Parameters (#7): Fixing σ_x & σ_y

- Constraining σ_x and σ_y/σ_x to investigate influence on final results.
- **Method:** σ_x is iterated over, the relevant fit parameters are determined, and the global χ^2 is computed at each iteration to check the effect on results. The parameters of the "best" values of χ^2 are used to perform a 6-FIT (Fit #2) with σ_x and σ_y fixed (4-FIT - Fit #3).

Plotting for a given *K*



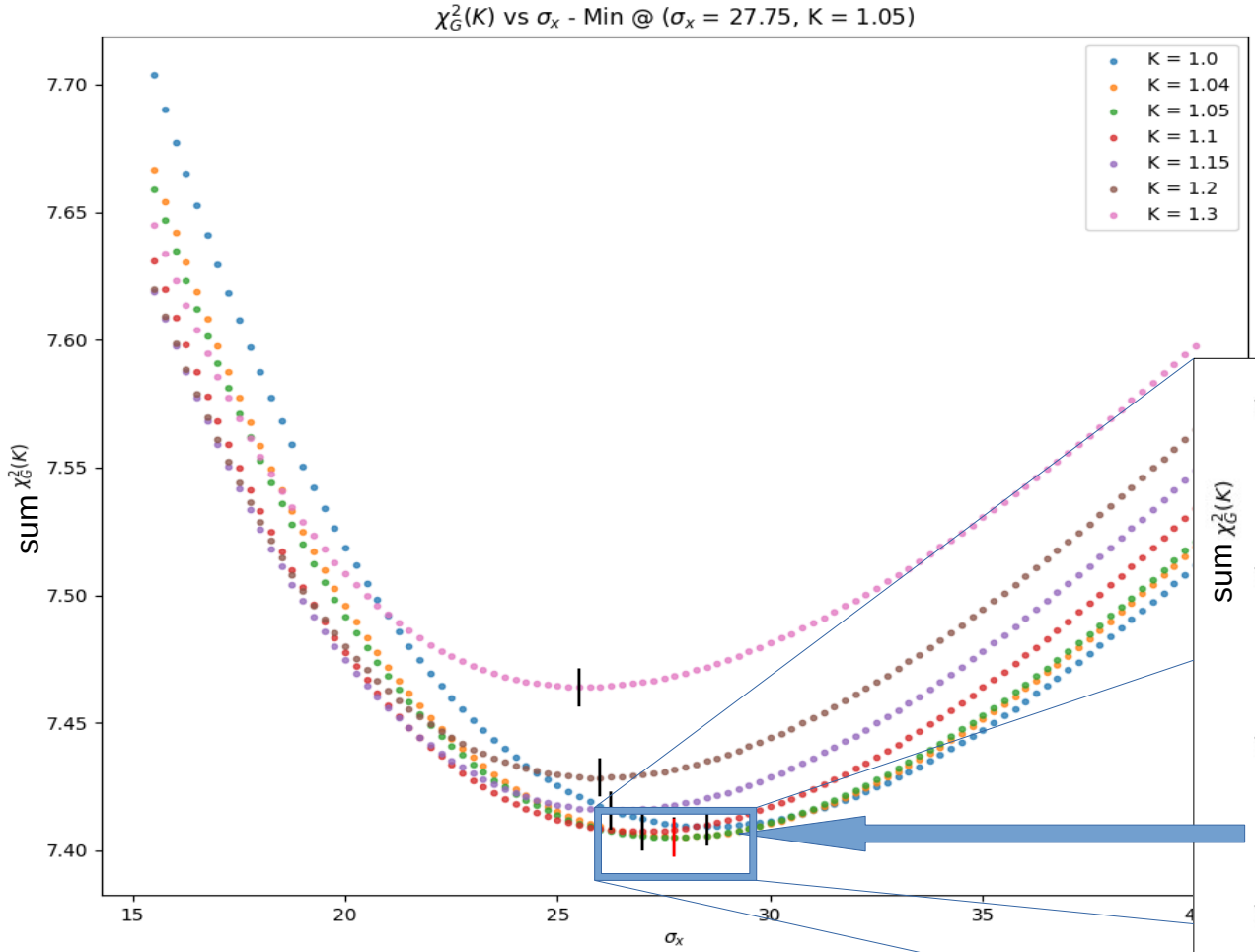
sum χ^2_G



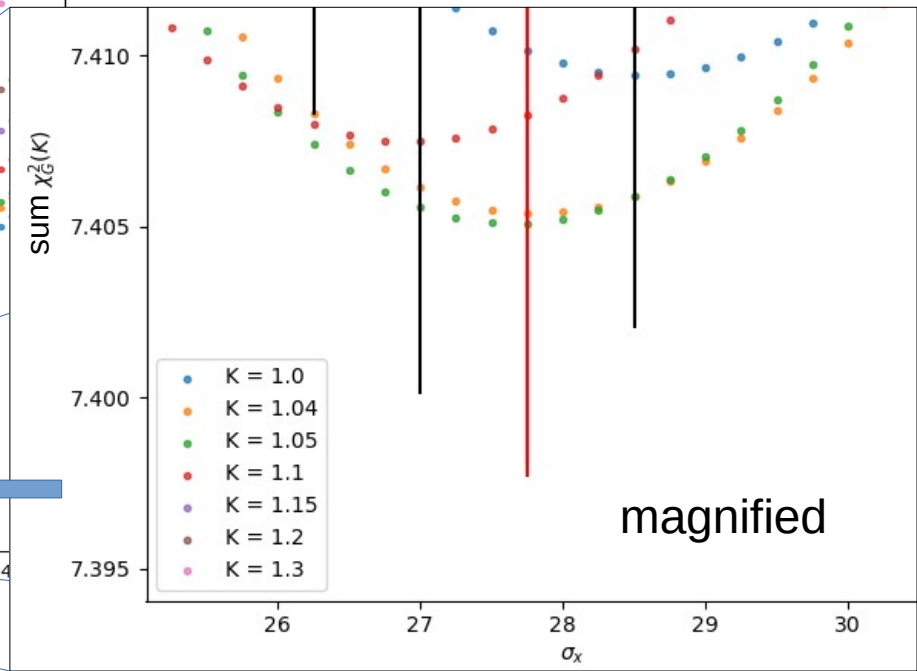
sum $\chi^2_G = \sum \chi^2 \left(\mathrm{PC}(\sigma_x)\right)$

The vertical line denotes the minimum of a curve for a given *K*

Varying Value of K



Each point is the sum of the column of points at every value of σ_x.



Fit Results

All data points after this slide account for proton charge normalization and dead time corrections.

Conclusion for 4-Fit

$$\sigma_x \approx 27.75$$

$$K = \sigma_y / \sigma_x \approx 1.05$$

Average over # PC: $\bar{\chi}^2 = 1.56$

Integrated Background Counts (all but Fit 1 in FROI)

Fit #:	1	2	3	4	5	6	7
PC	RoB (over whole BR)	6-Fit (“Baseline”)	PLANE* (3 param)	PLANE* + GAUSS (3* + 3 param)	Red. BR 1	Red. BR 2	4-Fit (sigx, sigy fixed)
18	5.01E+05	1.61E+05	8.35E+04	1.79E+05	1.61E+05	1.62E+05	1.51E+05
19	4.27E+05	1.26E+05	7.46E+04	1.37E+05	1.25E+05	1.25E+05	1.25E+05
20	3.74E+05	1.06E+05	6.69E+04	1.08E+05	1.26E+05	1.01E+05	1.04E+05
21	3.35E+05	8.92E+04	6.10E+04	1.08E+05	8.62E+04	8.52E+05	8.75E+04
22	2.96E+05	7.46E+04	5.51E+04	8.83E+04	7.24E+04	7.20E+04	7.66E+04
24	2.40E+05	5.61E+04	4.55E+04	5.81E+04	5.37E+04	5.26E+04	6.03E+04

“Red. BR 1”: Half of the right side of the BR is excluded
“Red. BR 2”: Right side of BR set to SR + 20
All performed in FROI except Fit 7 which was over whole BR

Integrated Counts of 6-FIT in ROI

PC	RAW in FROI	RAW – 6-Fit (Effect of Att'n'd. Beam)	Systematic Error (James)	Total Error
18	2.98E+06	2.82E+06	1549	2320.2
19	1.98E+06	1.85E+06	1307	1919.4
20	1.36E+06	1.25E+06	2177	2469.2
21	9.20E+05	8.26E+05	1374	1674.2
22	6.37E+05	5.63E+05	963	1250.8
24	3.14E+05	2.58E+05	2007	2083.9

This table (including James' statistical errors) could be made for all seven of the fits.

Integrated Results of All Background Subtractions

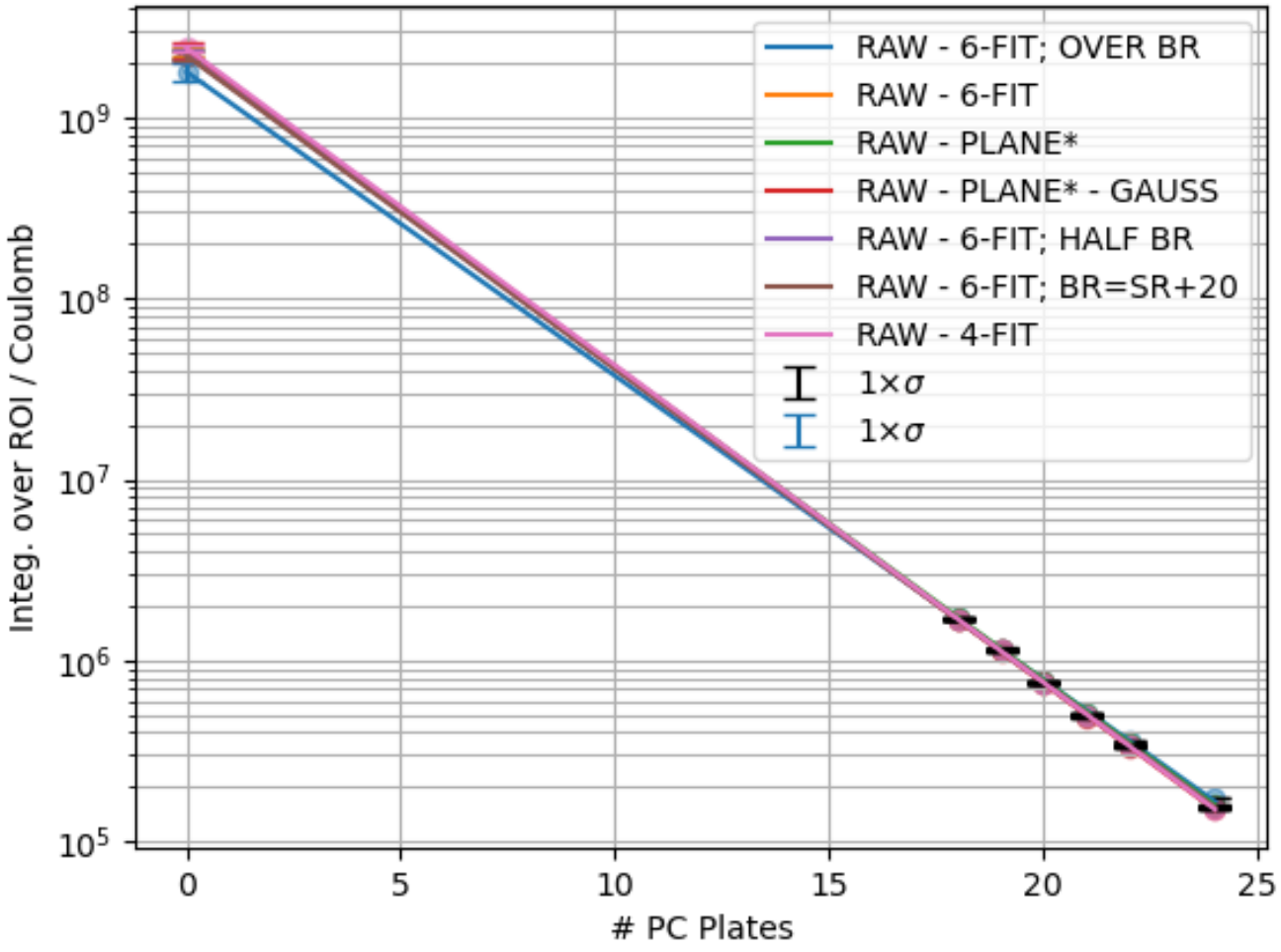
Inputs for the two-parameter exponential fit, $\mathrm{F} = \mathrm{F}_0 \eta^k$

PC	FIT 1 RoB	Fit 2 6-Fit	Fit 3 PLANE*	Fit 4 P* + G	Fit 5 BR/2	Fit 6 SR+20	Fit 7 4-Fit
18	5.01+05 +/- 0.017E+05	1.61E+05 +/- 0.015E+05	8.35E+04 +/- 0.021E+04	1.80E+05 +/- 0.013E+05	1.61E+05 +/- 0.013E+05	1.62E+05 +/- 0.013E+05	1.51E+05 +/- 0.019E+05
19	4.27E+05 +/- 0.14E+04	1.26E+05 +/- 0.013E+05	7.46E+04 +/- 0.20E+04	1.37E+05 +/- 0.011E+05	1.25E+05 +/- 0.011E+05	1.25E+05 +/- 0.011E+05	1.25E+05 +/- 0.018E+05
20	3.74E+05 +/- 0.22E+04	1.06E+05 +/- 0.022E+05	6.69E+04 +/- 0.019E+04	1.08E+05 +/- 0.010E+05	1.26E+05 +/- 0.010E+05	1.01E+05 +/- 0.010E+05	1.04E+05 +/- 0.017E+05
21	3.35E+05 +/- 0.14E+04	8.92E+04 +/- 0.13E+04	6.10E+04 +/- 0.018E+04	1.08E+05 +/- 0.0086E+05	8.62E+04 +/- 0.086E+04	8.52E+05 +/- 0.086E+04	8.75E+04 +/- 0.16E+04
22	2.96E+05 +/- 0.11E+04	7.46E+04 +/- 0.094E+04	5.51E+04 +/- 0.016E+04	8.83E+04 +/- 0.0076E+04	7.24E+04 +/- 0.076E+04	7.20E+04 +/- 0.076E+04	7.66E+04 +/- 0.15E+04
24	2.40E+05 +/- 0.20E+04	5.61E+04 +/- 0.19E+04	4.55E+04 +/- 0.015E+04	5.81E+04 +/- 0.0064E+04	5.37E+04 +/- 0.064E+04	5.26E+04 +/- 0.064E+04	6.03E+04 +/- 0.13E+04

These are the inputs to the exponential fitting for F_0 and include James' statistical errors.

Comparison of Integ. over ROI

Fits integrated over Dr. Gonzalez' ROI (per coulomb)

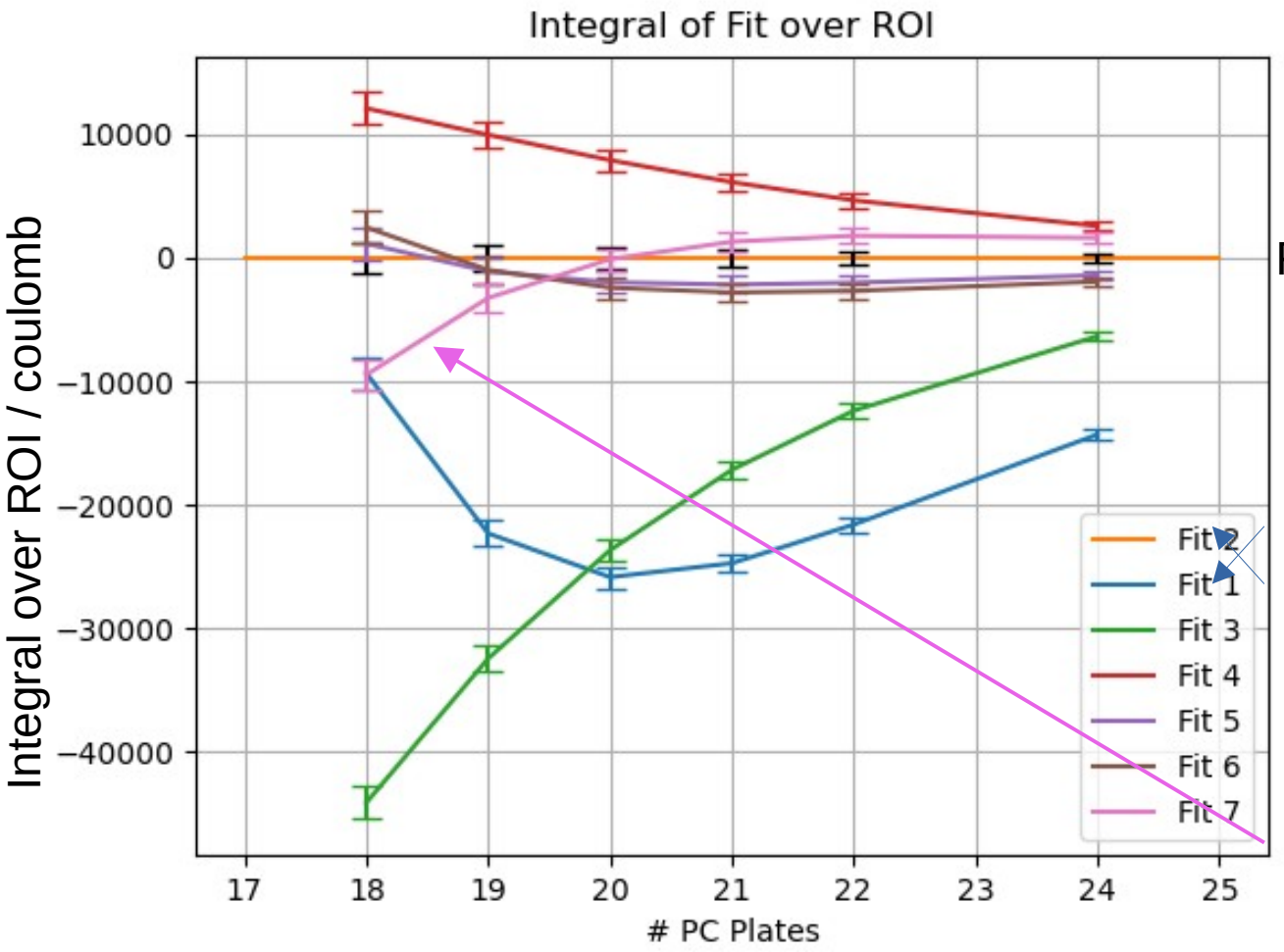


FIT #1
FIT #2
FIT #3
FIT #4
FIT #5
FIT #6
FIT #7

After the subtraction of the background, the slope of the neutron beam fitted line increases.

Background fits have a different slope than the neutron beam data.

Residuals of All Fits from (RAW - 6-FIT)

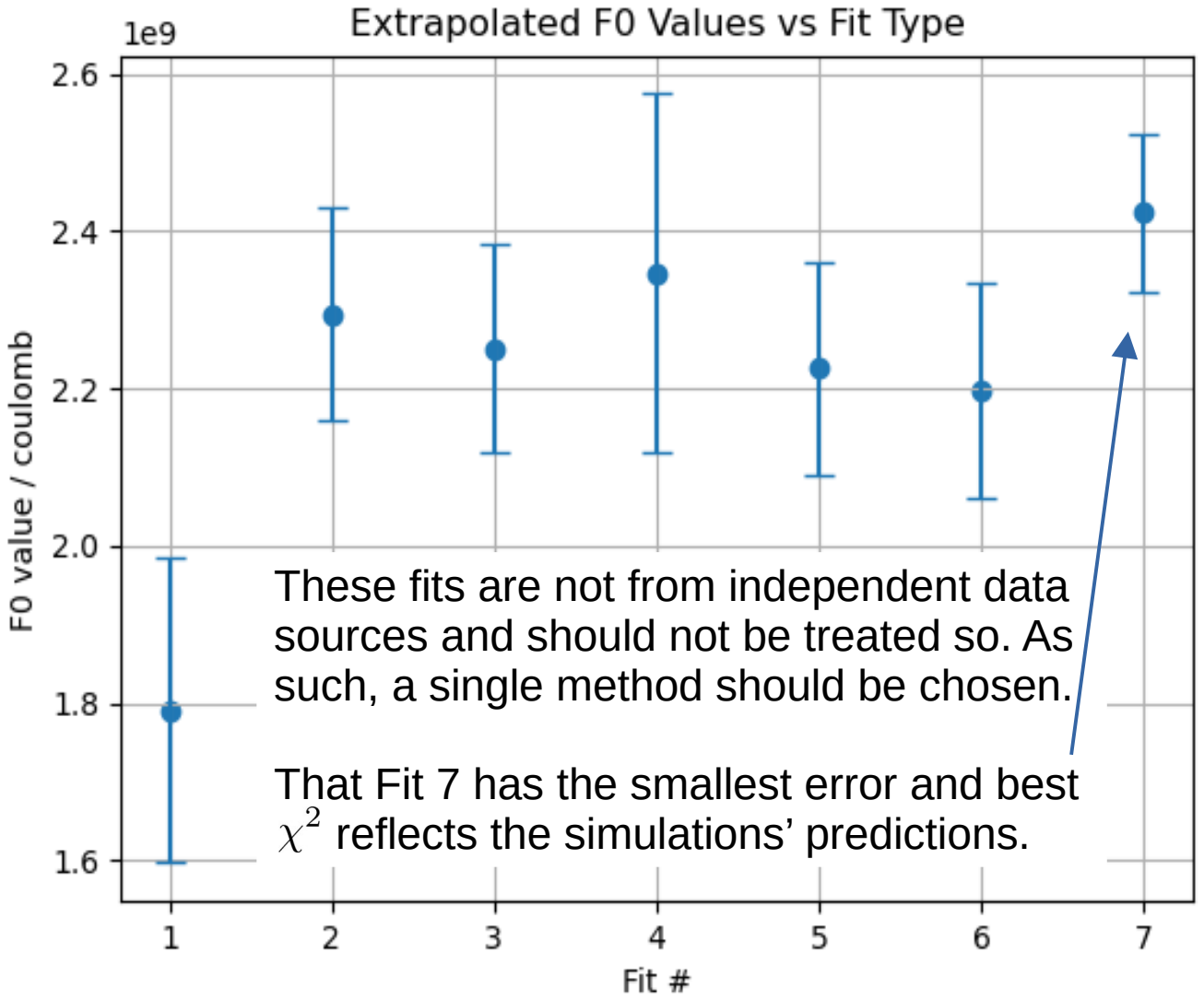


Fit 2: 6-Fit used as “baseline”

Fit 1: 6-Fit; integ. Over all BR
Fit 2: 6-Fit
Fit 3: Plane*
Fit 4: (Plane* + Gauss)
Fit 5: 6-Fit; fit on BR/2
Fit 6: 6-Fit; fit on SR+20
Fit 7: 4-Fit

Keep an eye on this 4-Fit

F0



These fits are not from independent data sources and should not be treated so. As such, a single method should be chosen.

That Fit 7 has the smallest error and best χ^2 reflects the simulations' predictions.

All points account for proton charge "normalization" and deadtime corrections.

Fit 1: 6-Fit; integ. Over all BR
Fit 2: 6-Fit
Fit 3: Plane*
Fit 4: (Plane* + Gauss)
Fit 5: 6-Fit; fit on BR/2
Fit 6: 6-Fit; fit on SR+20
Fit 7: 4-Fit

Fit 1 is an outlier due to including values from outside the ROI. It will be excluded.

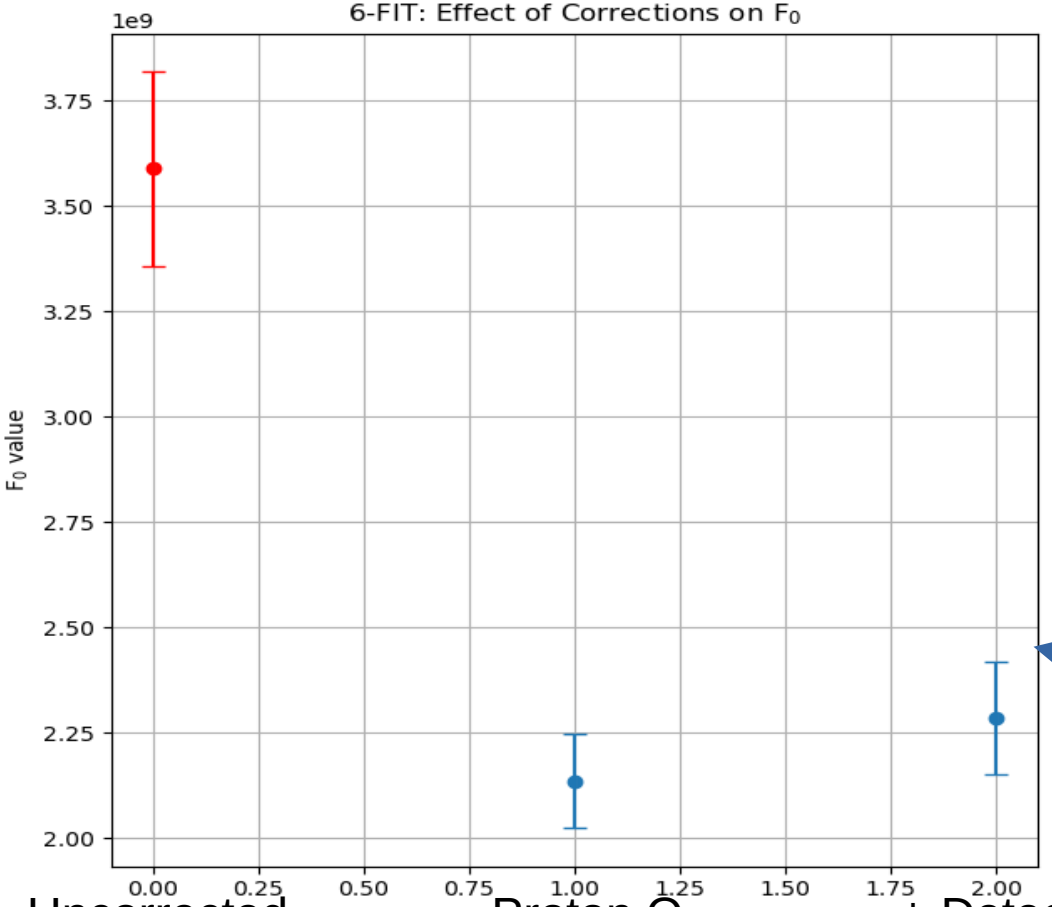
Fits 2 – 7 are consistent for F_0.

Results of the Different Fits in “FROI”

FIT	F_0 +/- dF_0	eta +/- d(eta)	chi2/DOF	Comment
INTENSITY RECONSTRUCTION – Charge “Normalized” + Deadtime-Corrected				
0. RAW (no sub’n.)	(1.79 +/- 0.159) x 10^9	0.6811 +/- 0.0031	0.6700	Stat’l.
1. 6-FIT over BR	(1.79 +/- 0.114) x 10^9	0.6792 +/- 0.0016	0.9279	Stat’l. + Sys.
2. 6-FIT	(2.29 +/- 0.135) x 10^9	0.6697 +/- 0.0019	0.4979	Stat’l. + Sys.
3. PLANE*	(2.25 +/- 0.131) x 10^9	0.6714 +/- 0.0019	0.6021	Stat’l. + Sys.
4. (PLANE*+GAUSS)	(2.35 +/- 0.227) x 10^9	0.6686 +/- 0.0031	0.6152	Stat’l. + Sys.
5. “BR/2”	(2.23 +/- 0.135) x 10^9	0.6689 +/- 0.0018	0.5614	Stat’l. + Sys.
6. “SR+20”	(2.20 +/- 0.138) x 10^9	0.6693 +/- 0.0018	0.5770	Stat’l. + Sys.
7. 4-FIT	(2.42 +/- 0.100) x 10^9	0.6679 +/- 0.0013	0.3291	Stat’l. + Sys.

Note: $\chi^2 < 1$ due to inclusion of systematic errors in the fit analysis.

Consideration: Effect of Corrections on F0 and eta



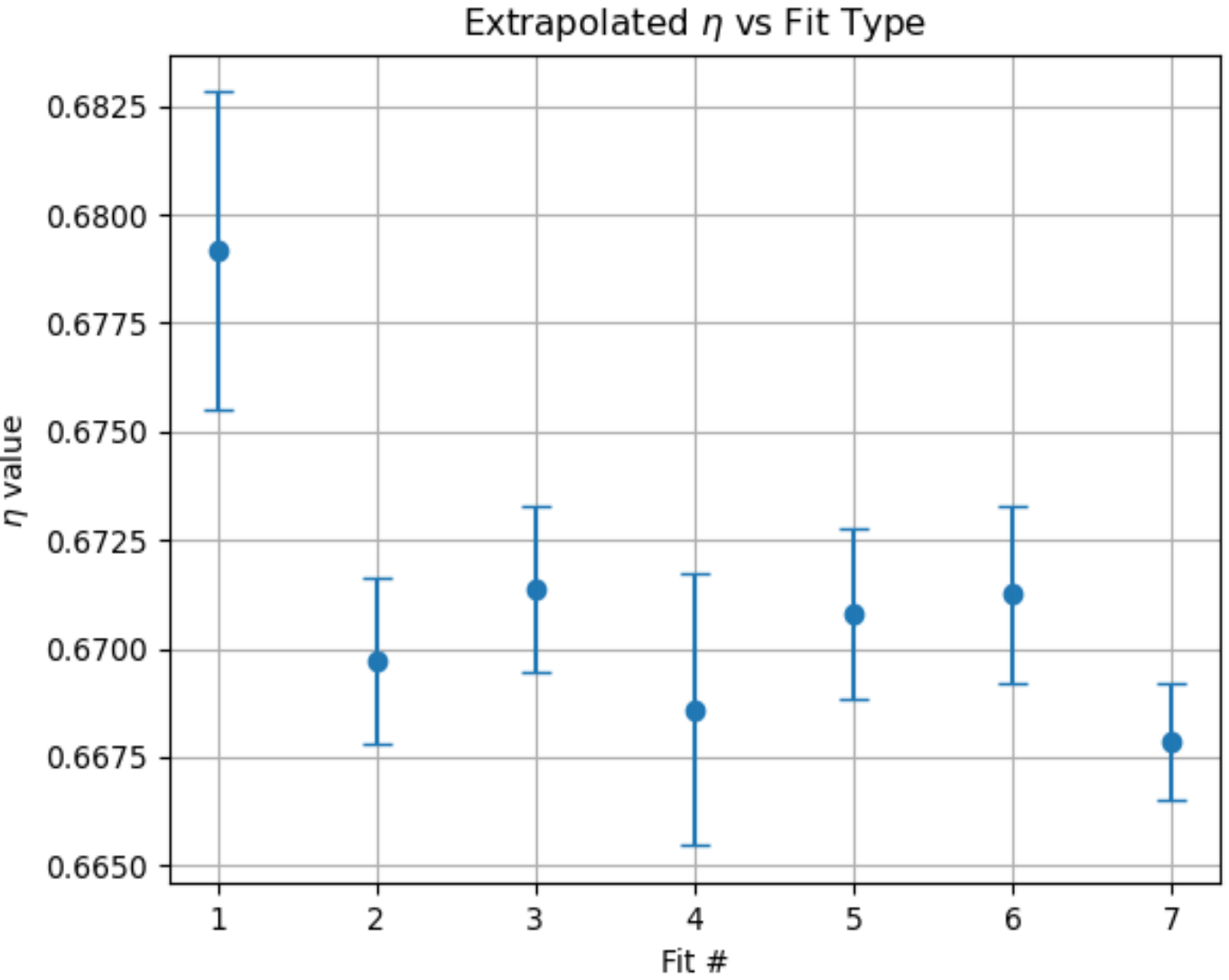
6-FIT Corrected F_0:
2.29 +/- 0.135

The proton charge correction is very important!

Uncorrected for proton Q and dead time

Proton Q correction only (required)

+ Detector dead time corrected



η

Fit 1: 6-Fit; integ. Over all BR
Fit 2: 6-Fit
Fit 3: Plane*
Fit 4: (Plane* + Gauss)
Fit 5: 6-Fit; fit on BR/2
Fit 6: 6-Fit; fit on SR+20
Fit 7: 4-Fit

η is within ~0.669 +/- 0.002 and are consistent with each other.

Fit 1 is an outlier due to including values from outside the ROI. It will be excluded.

Results of the Different Fits in “FROI”

FIT	F_0 +/- dF_0	eta +/- d(eta)	chi2/DOF (sig)	Comment
INTENSITY RECONSTRUCTION – Charge “Normalized” + Deadtime-Corrected				
0. RAW	(1.79 +/- 0.159) x 10^9	0.6811 +/- 0.0031	0.6700	Stat’l.
1. 6-FIT over BR	(1.79 +/- 0.114) x 10^9	0.6792 +/- 0.0016	0.9279	Stat’l. + Sys.
2. 6-FIT	(2.29 +/- 0.135) x 10^9	0.6697 +/- 0.0019	0.4979	Stat’l. + Sys.
3. PLANE*	(2.25 +/- 0.131) x 10^9	0.6714 +/- 0.0019	0.6021	Stat’l. + Sys.
4. (PLANE*+GAUSS)	(2.35 +/- 0.227) x 10^9	0.6686 +/- 0.0031	0.6152	Stat’l. + Sys.
5. “BR/2”	(2.23 +/- 0.135) x 10^9	0.6689 +/- 0.0018	0.5614	Stat’l. + Sys.
6. “SR+20”	(2.20 +/- 0.138) x 10^9	0.6693 +/- 0.0018	0.5770	Stat’l. + Sys.
7. 4-FIT	(2.42 +/- 0.100) x 10^9	0.6679 +/- 0.0013	0.3291	Stat’l. + Sys.
WEIGHTED MEAN VALUE (excluding RAW and 6-FIT over BR)			Reminder: the fits are not independent.	
	(2.30 +/- 0.05) x 10^9	0.6691 +/- 0.0007		

Proposed Final Answer: RAW – 4-FIT

The result of the fit for F_0, $\delta\mathrm{F}_0$:

F_0= 2.42 x 10^9

$\delta\mathrm{F}_0$= 0.100 x 10^9

χ^2 of the (F_0, η,DoF=4) 4-Fit:

χ^2/DoF = 0.3291

The result for η, $\delta\eta$:

η = 0.6679

$\delta\eta$ = 0.0013

Optimal σ_x, *K* Value for determining σ_y :

σ_x = 27.75

K = 1.05

Comparison with M. Kline 2021 Analysis

M. Kline considered the effect of ToF on F_0 and η.

2nd Smallest pinhole:

$$\mathrm{F}_0 = 2.6 \times 10^9 \quad \eta = 0.67 \quad \chi^2/\mathrm{DoF} = 38$$

Smallest pinhole (w/ simple background subtraction):

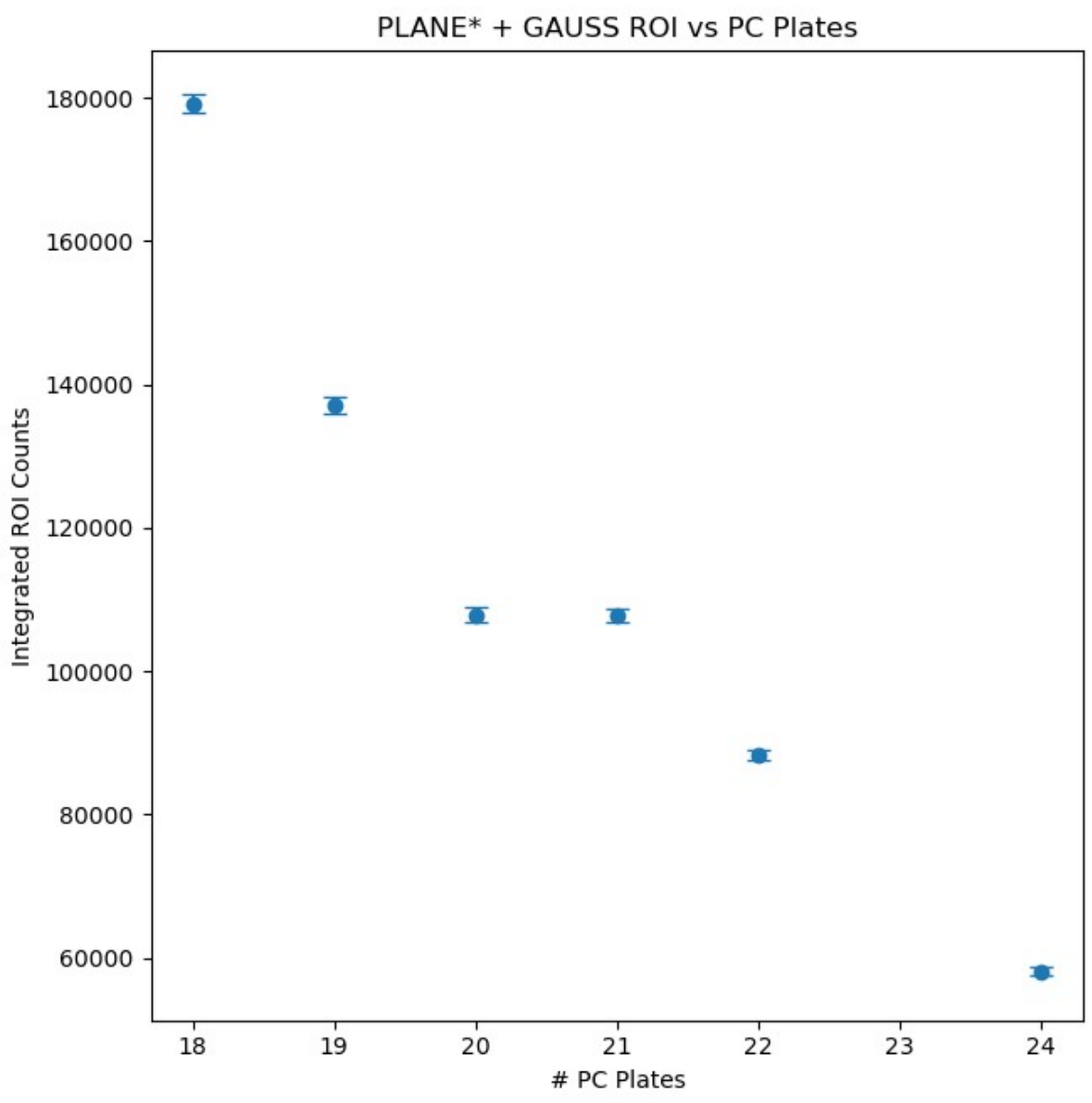
$$\mathrm{F}_0 = (2.68 \pm ?) \times 10^9 \quad \eta = 0.67 \quad \chi^2/\mathrm{DoF} = 25$$

This 4-Fit (#7):

$$\mathrm{F}_0 = (2.42 \pm 0.100) \times 10^9 \quad \eta = 0.6679 \pm 0.0013 \quad \chi^2/\mathrm{DoF} = 0.3291$$

Note: MK does not take into account the gaussian-like background

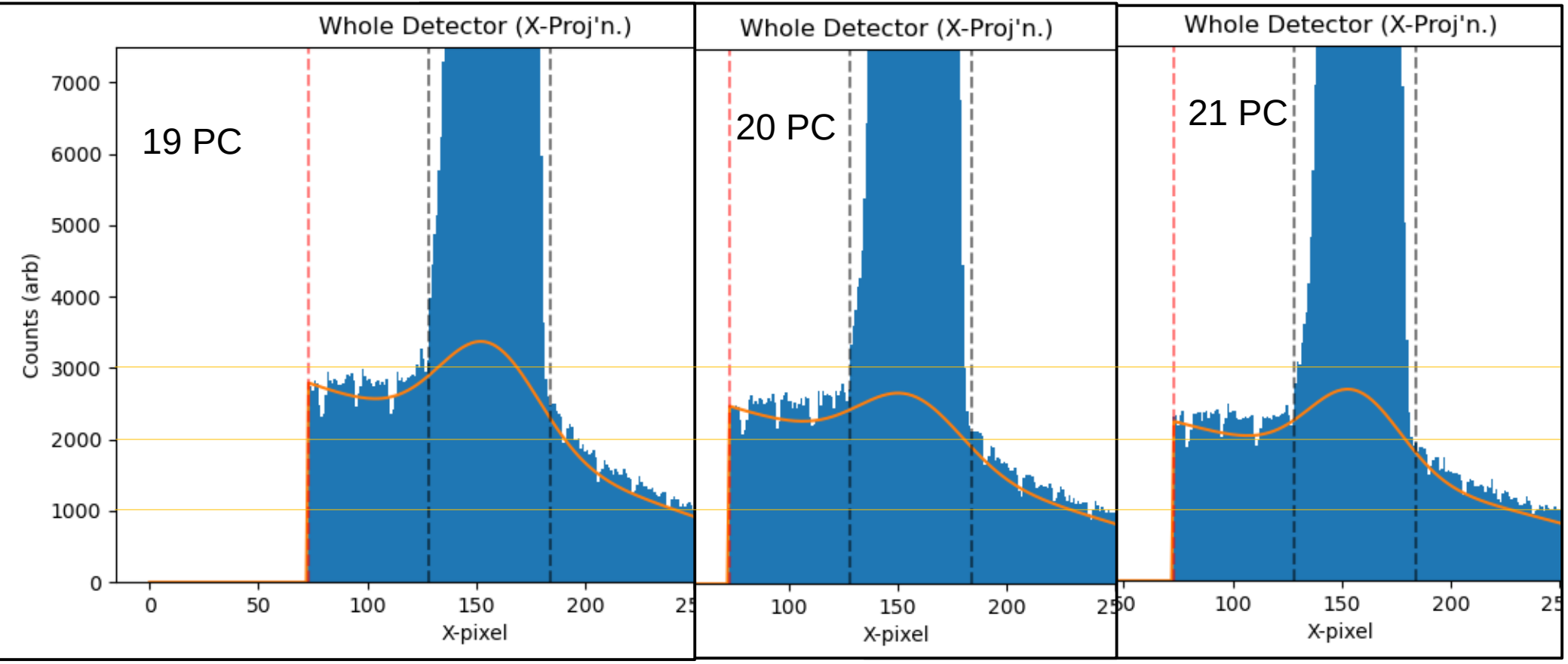
END



PLANE* + GAUSS BKGD only

The points for this fit were suspicious – why were # PC = 20 and # PC = 21 the same?

What's Going On in the PLANE* + GAUSS Fit?



Background is decreasing slightly, but gaussian peak is slightly more pronounced, "skewing" the results.