

# SNS 2020 Fitting Update

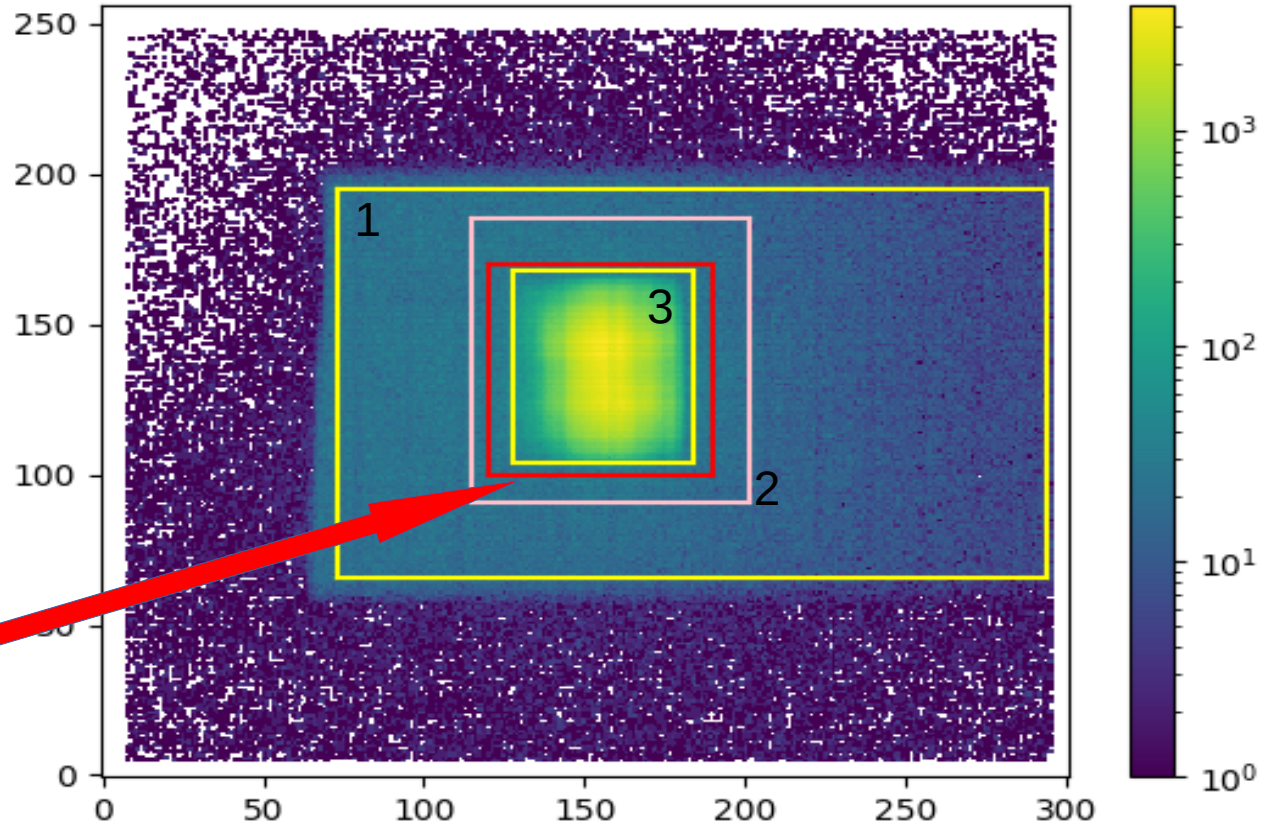
UT/ORNL n → n' Group

5/25/2023

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



# Description of Fit Methods

- 1) 6-Fit: A plane and a gaussian fit at the same time
- 2) PLANE\*: Just the plane
- 3) PLANE\* - GAUSS: Fit the plane in the BR first (same as in fit #2), then fit the gaussian
- 4) "4-Fit": Plane & gaussian amplitude are free parameters,  $\sigma_x$  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  $F_0, \eta$  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.
- 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  $\sigma_x$  and  $K = \sigma_y / \sigma_x$ , then fit 3 plane parameters and 1 gaussian amplitude like in Fit 2. Motivated by simulations.

# Fit Histogram Contribution – 6-Fit

Background Region

Background Region

FROI

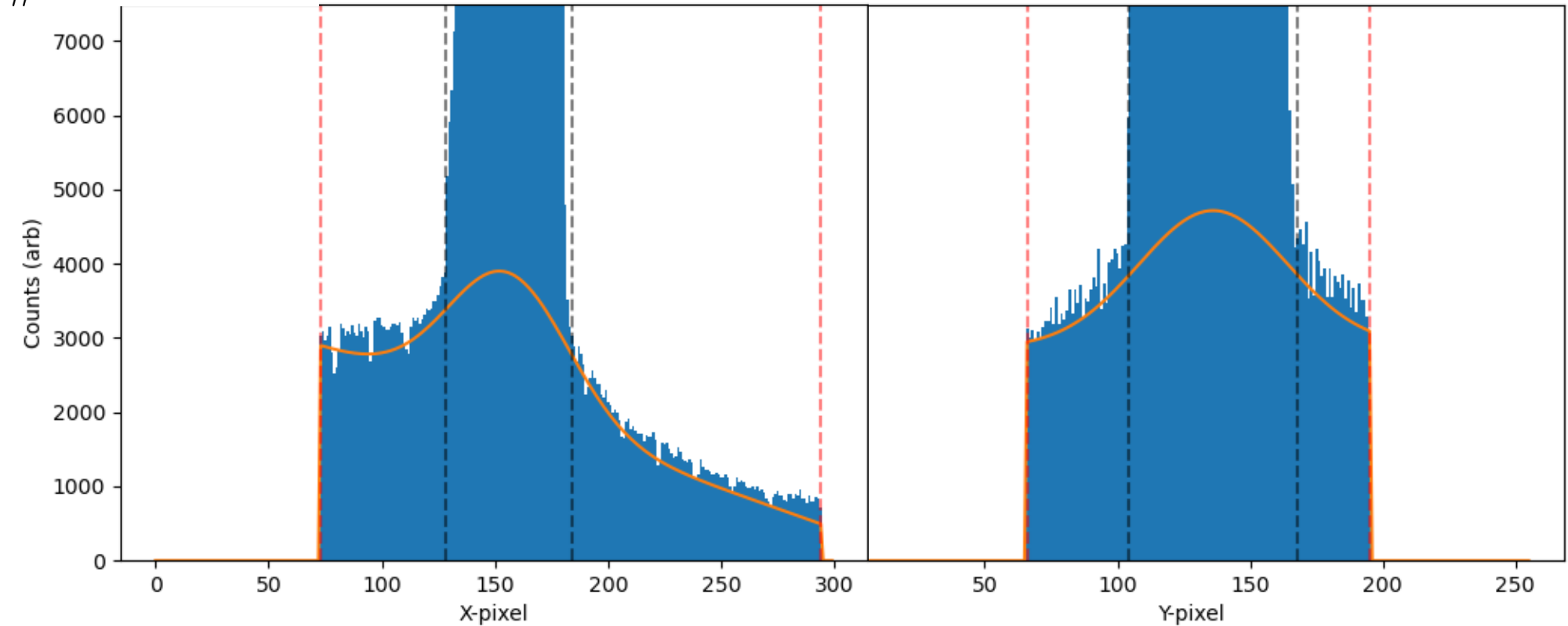
FROI

$$\chi^2/\text{DoF} = 1.46$$

# DoF = 20247 Whole Detector (X-Proj'n.)

18 PC plates

Whole Detector (Y-Proj'n.)



# Fit Histogram Contribution – PLANE\* Only

$$\chi^2/\text{DoF} = 1.60$$

Background Region

FROI

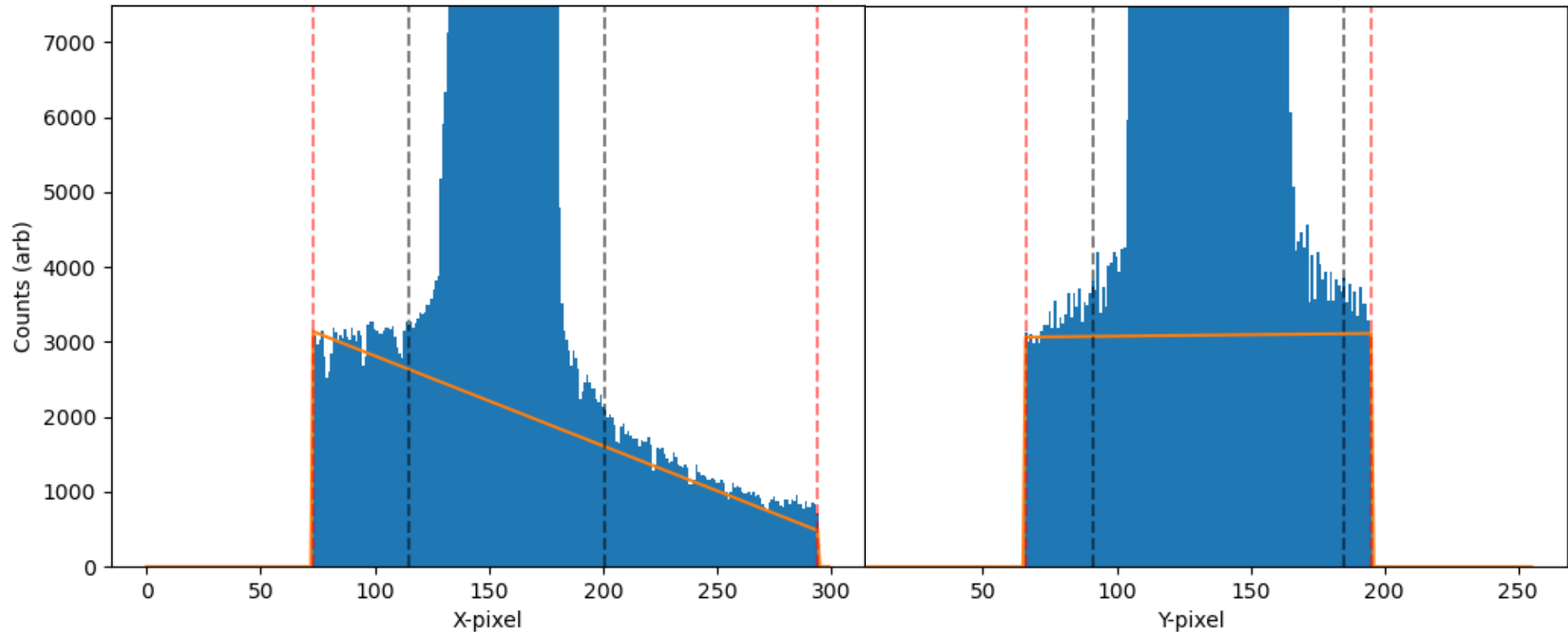
Whole Detector (X-Proj'n.)

18 PC plates

Background Region

FROI

Whole Detector (Y-Proj'n.)



# Fit Histogram Contribution – 4-Fit

Background Region

FROI

Background Region

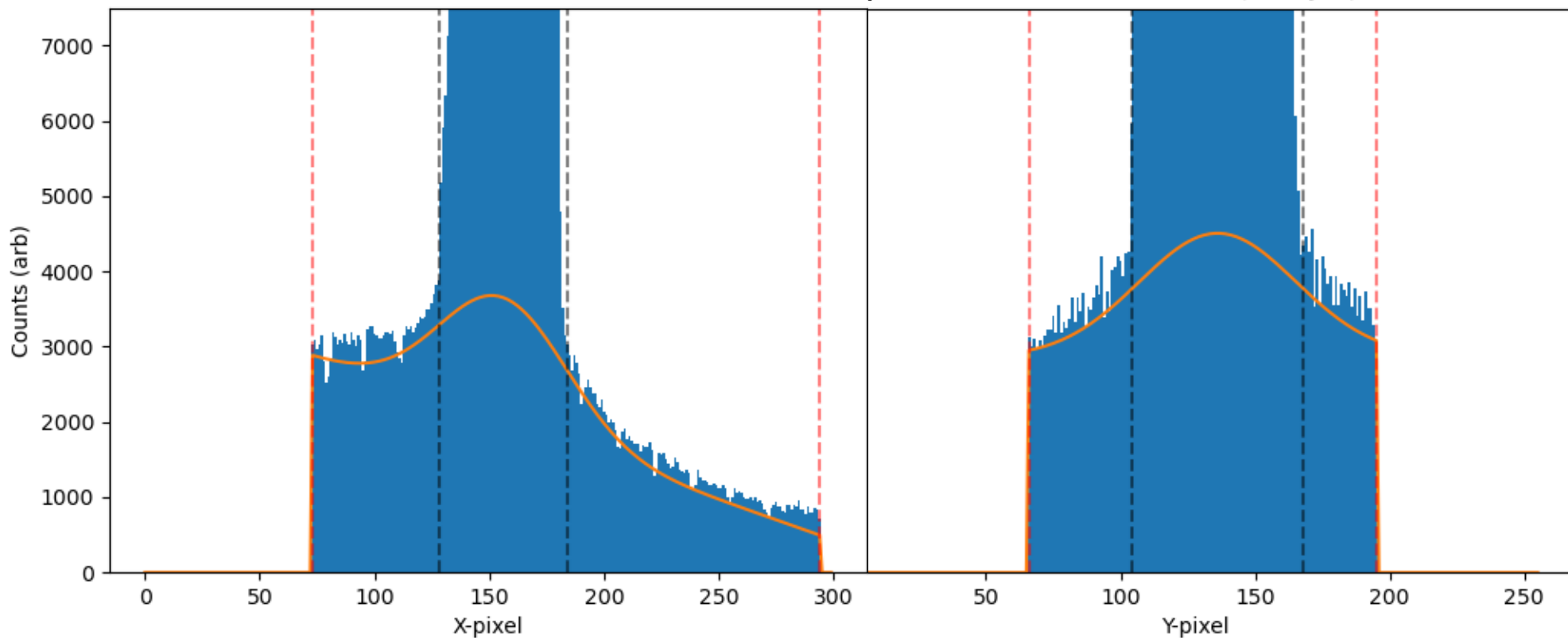
FROI

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

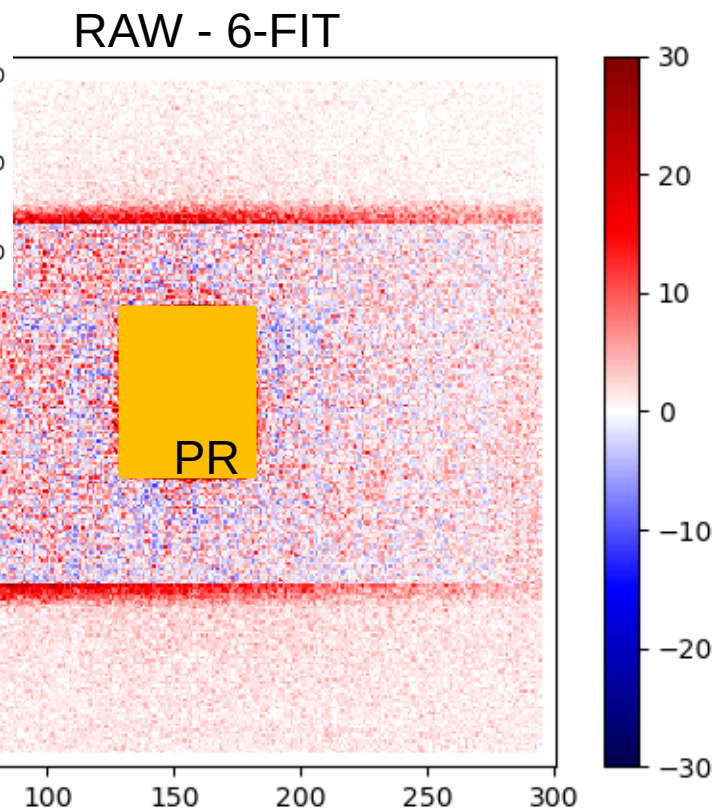
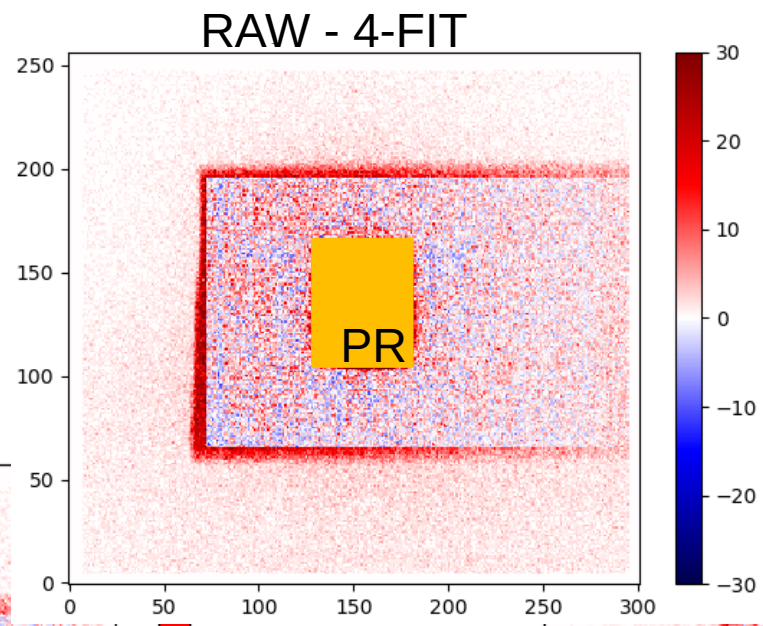
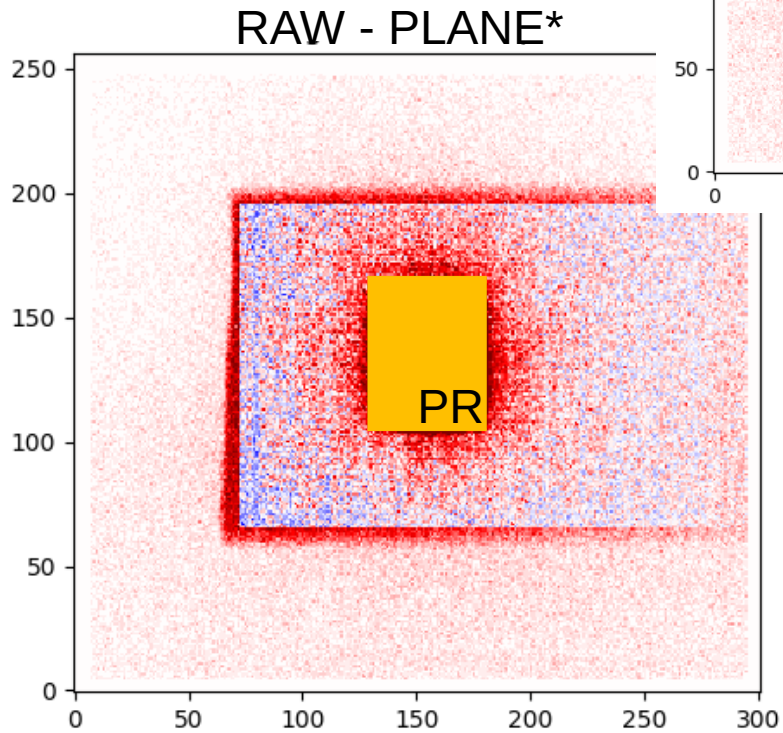
Whole Detector (X-Proj'n.)

18 PC plates

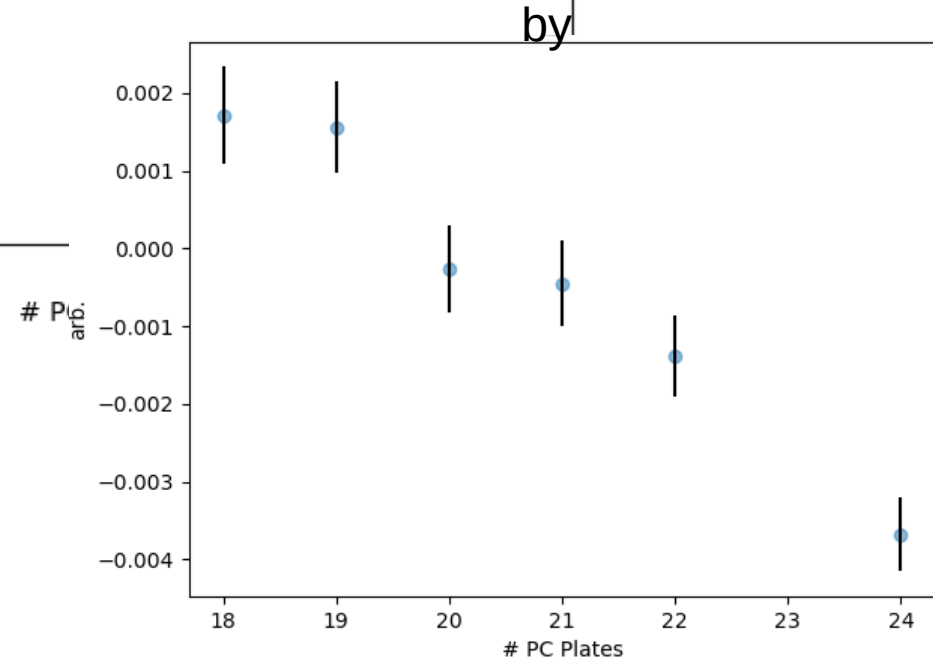
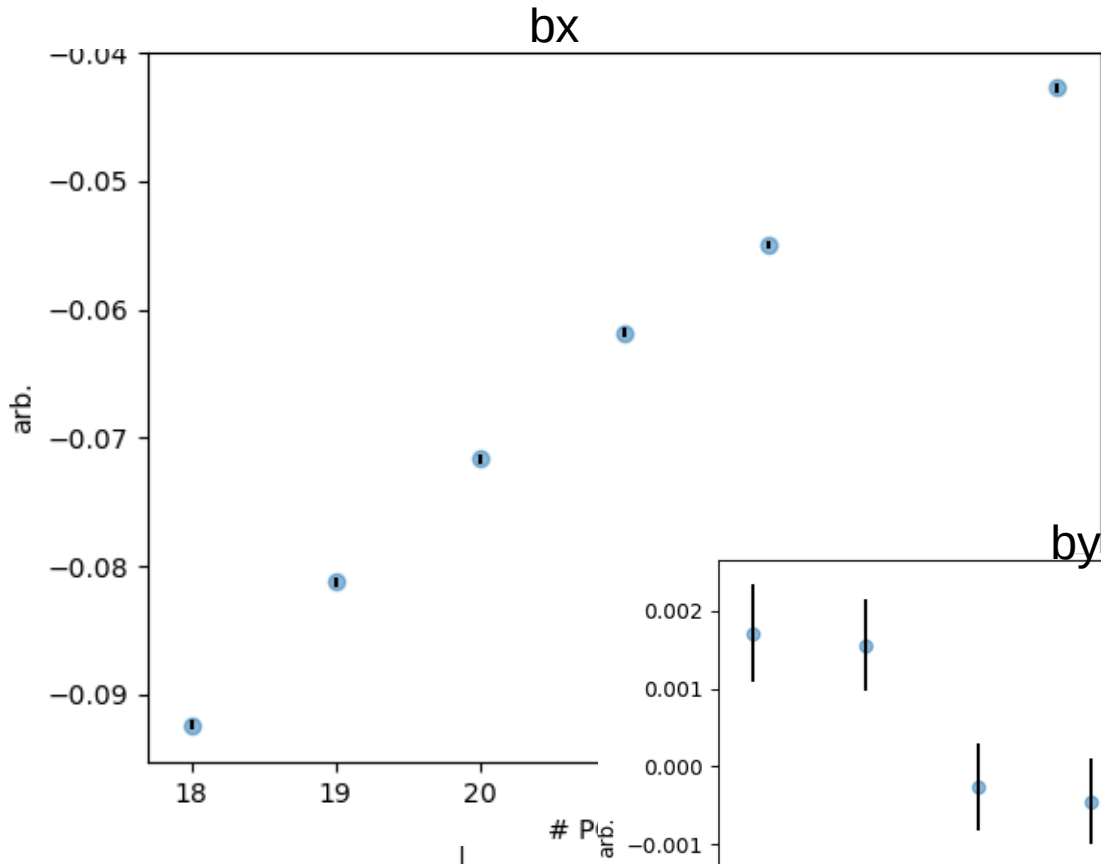
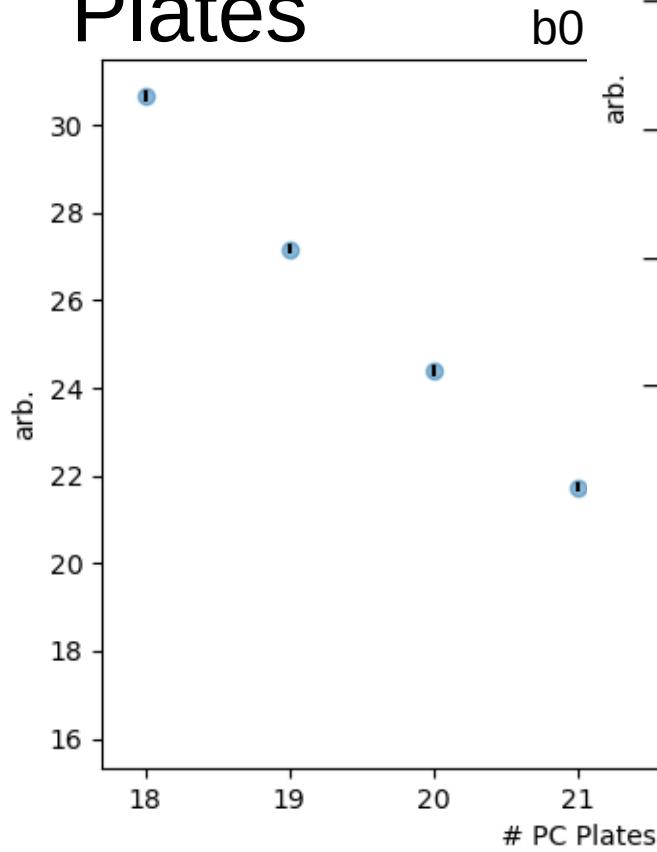
Whole Detector (Y-Proj'n.)



# 18 PC Fit Residuals



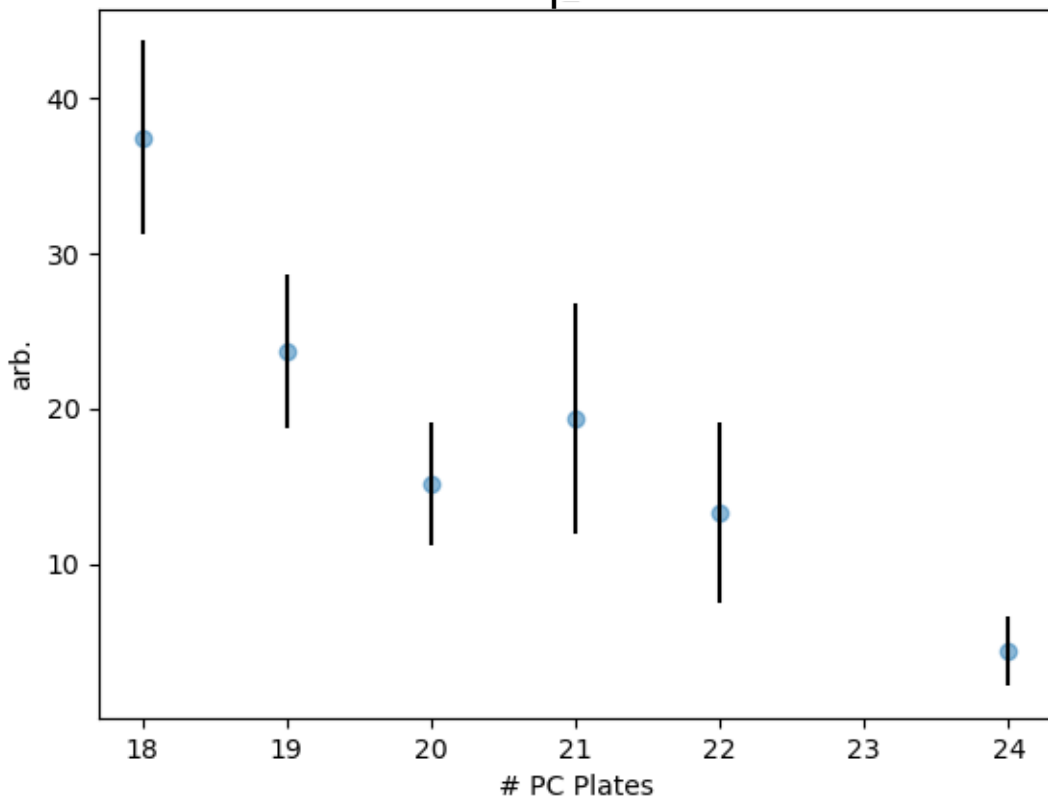
# 6-FIT: Plane Parameters vs # PC Plates



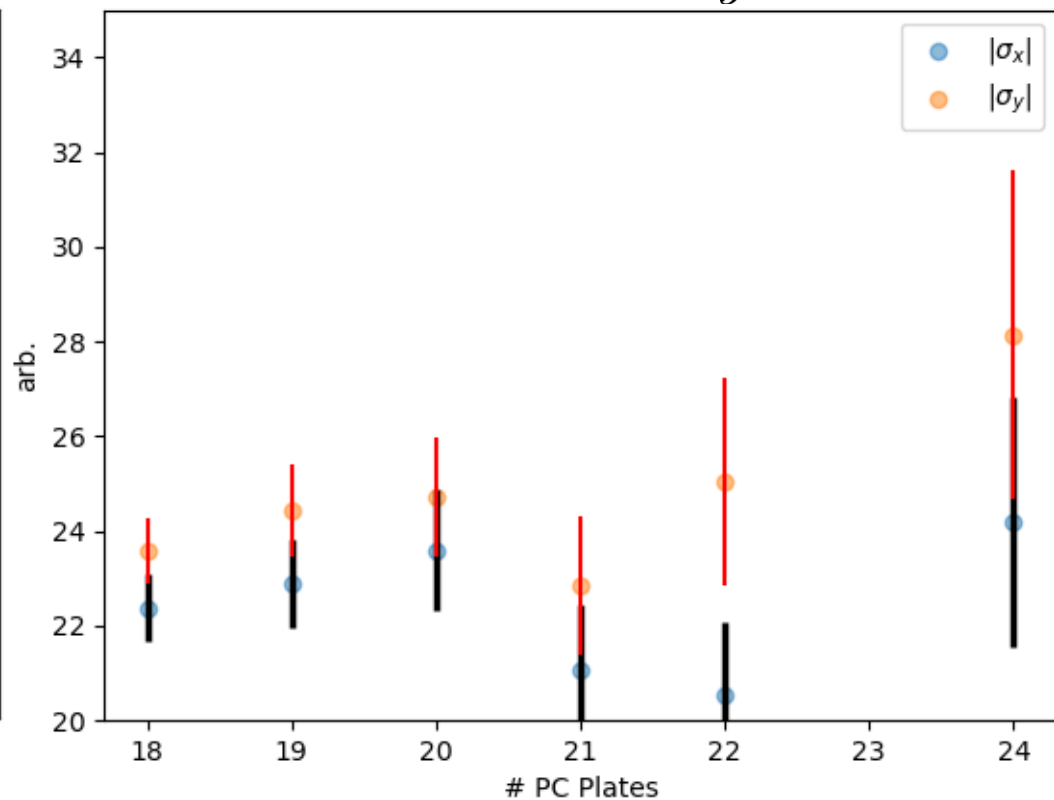
# 6-FIT: Gaussian Parameters vs # PC Plates

Note:  $\sigma_x$  and  $\sigma_y$  are in units of pixels

## Amplitude

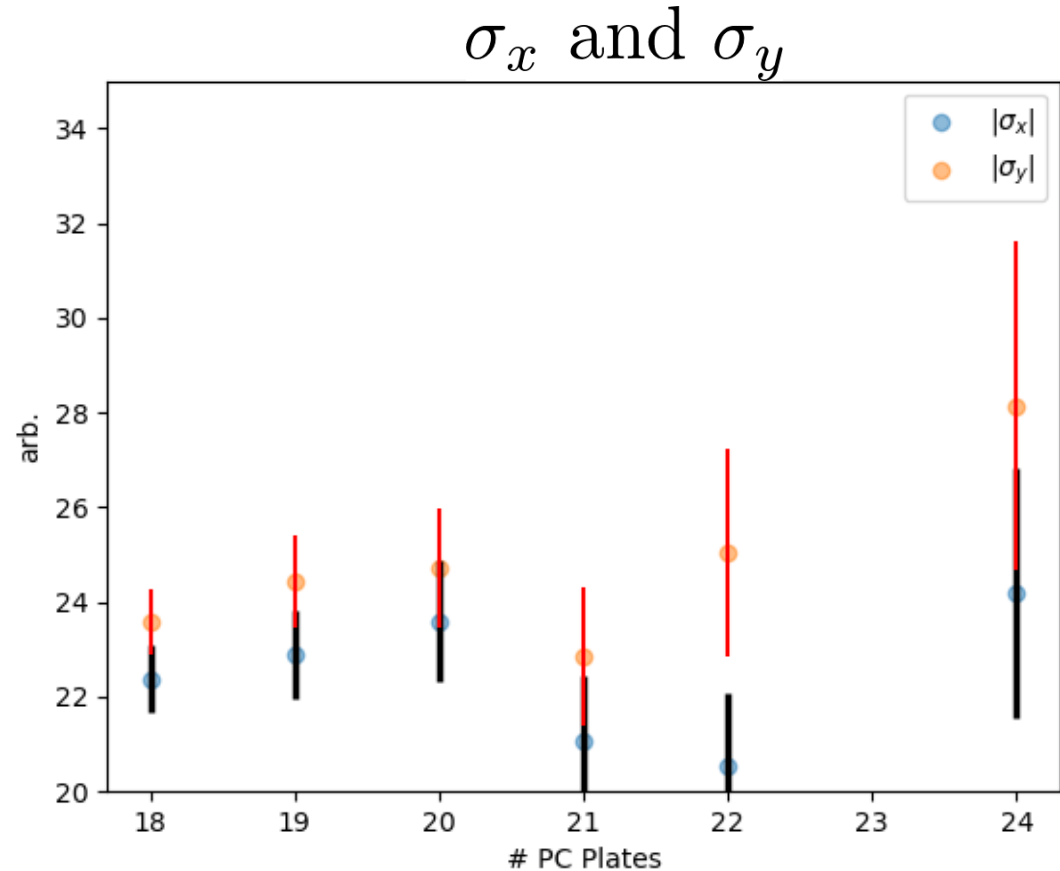


## $\sigma_x$ and $\sigma_y$



# $\sigma_x$ and $\sigma_y$

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

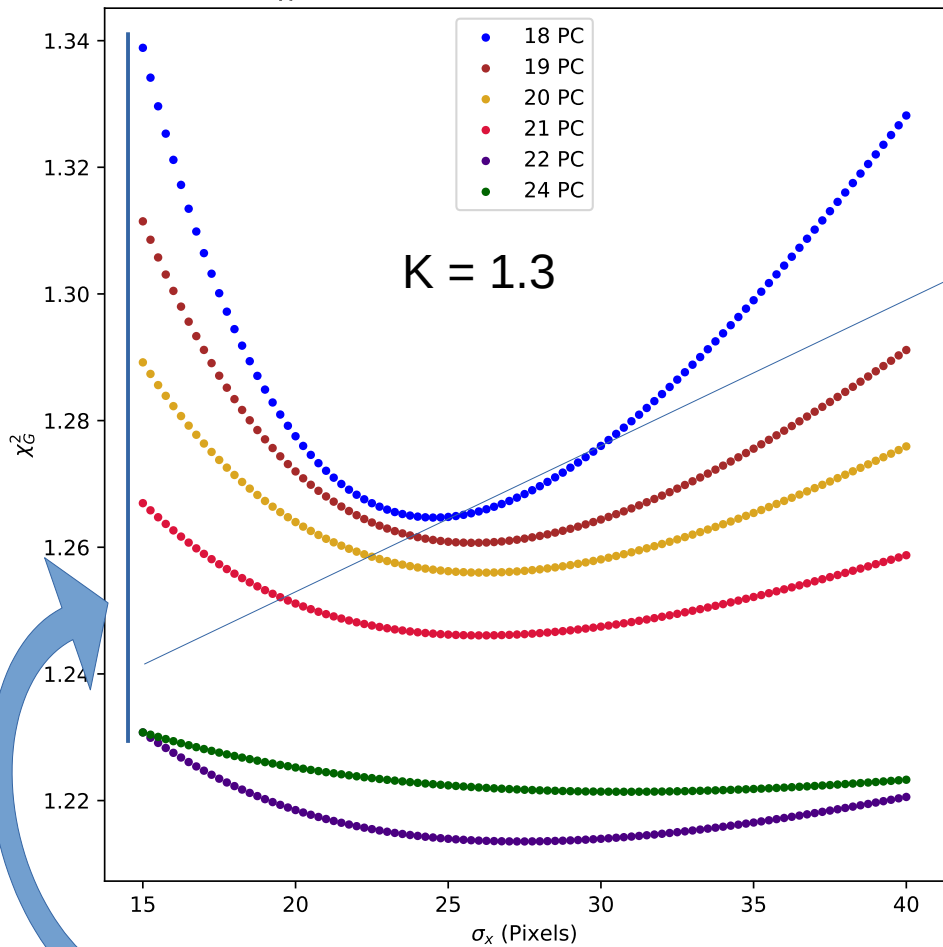


# 4-Fit: Varying Parameters: Fixing

$$\sigma_x \text{ \& \ } \sigma_y$$

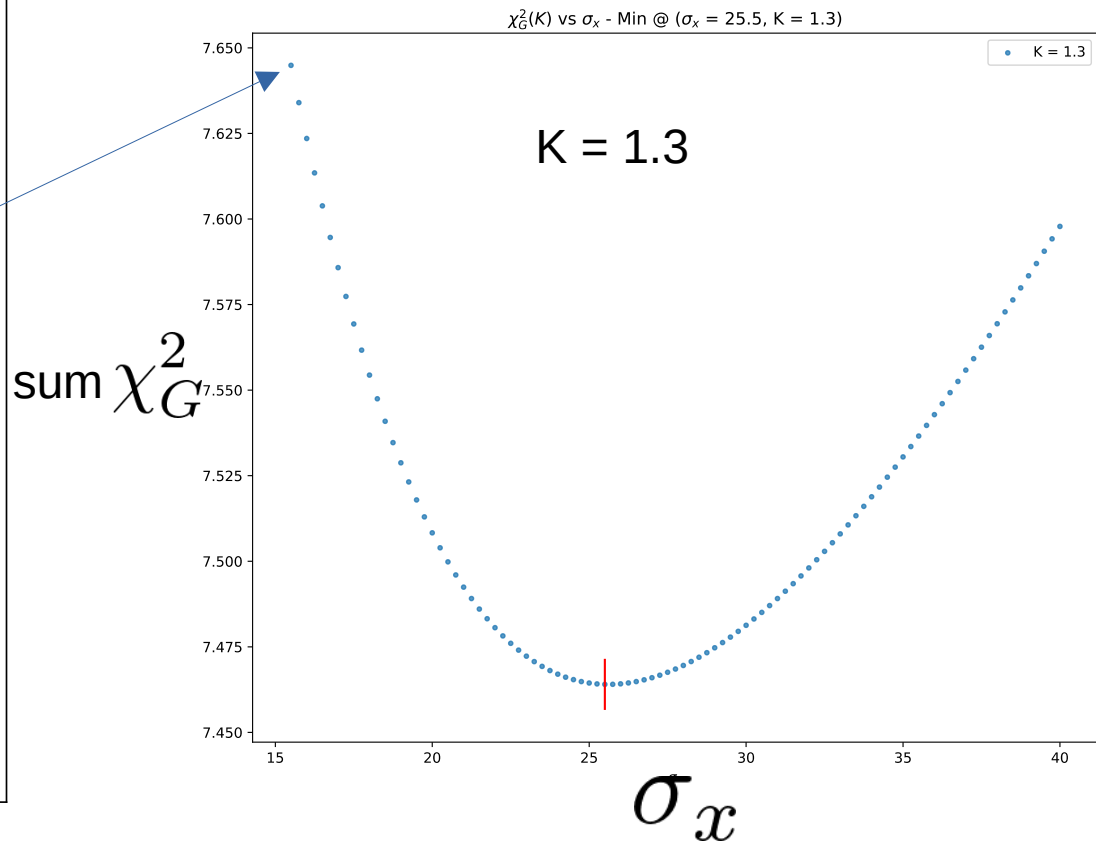
- Constraining  $\sigma_x$  and  $\sigma_y/\sigma_x$  to investigate influence on final results.
- **Method**:  $\sigma_x$  is iterated over, the relevant fit parameters are determined, and the global  $\chi^2$  is computed at each iteration to check the effect on results. The parameters of the “best” values of  $\chi^2$  are used to perform a 6-FIT with  $\sigma_x$  and  $\sigma_y$  fixed (4-FIT).

$\chi^2$  vs  $\sigma_x$  for  $K = 1.3$  and Different # PC



$$\text{sum } \chi_G^2 = \sum \chi^2 (\text{PC}(\sigma_x))$$

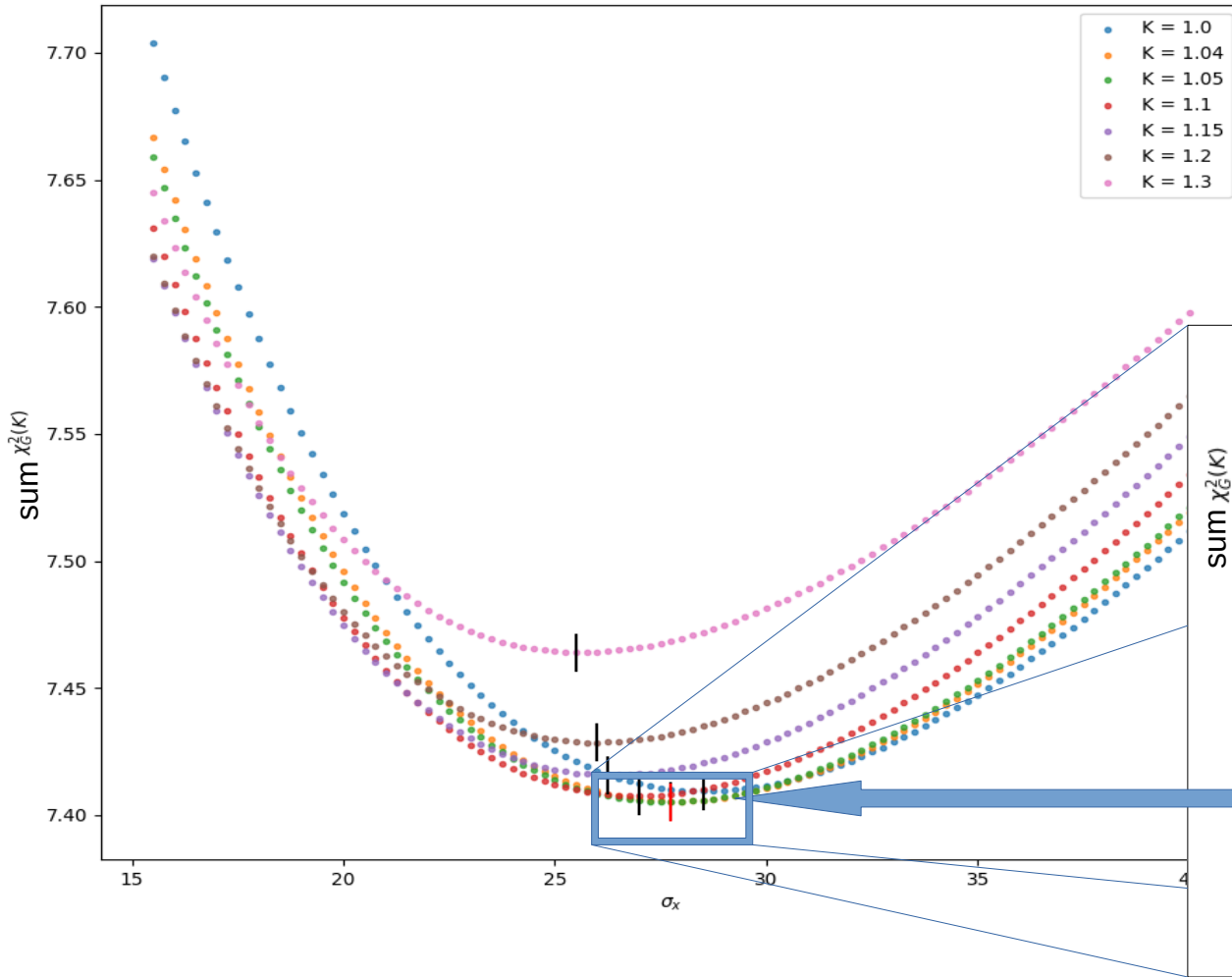
# Plotting for a given $K$



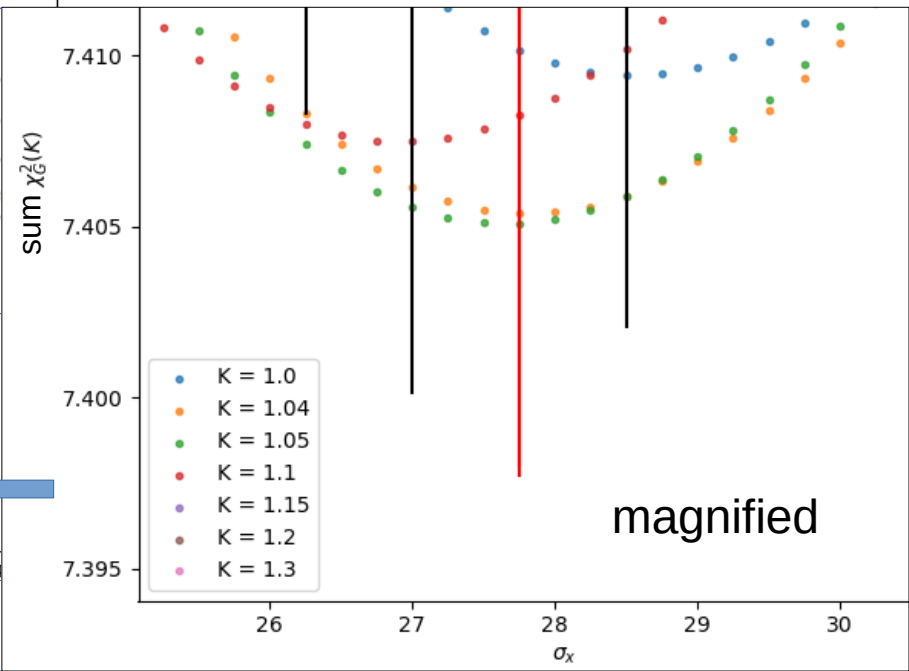
The vertical line denotes the minimum of a curve for a given  $K$

# Varying Value of K

$\chi_G^2(K)$  vs  $\sigma_x$  - Min @ ( $\sigma_x = 27.75$ ,  $K = 1.05$ )



Each point is the sum of the column of points at every value of  $\sigma_x$ .



magnified

# Fit Results

All data points after this account for proton charge normalization and  
deadtime corrections.

## Conclusion for 4-Fit

$$\sigma_x \approx 27.75$$

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

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

# Integrated Background Counts (2-7 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

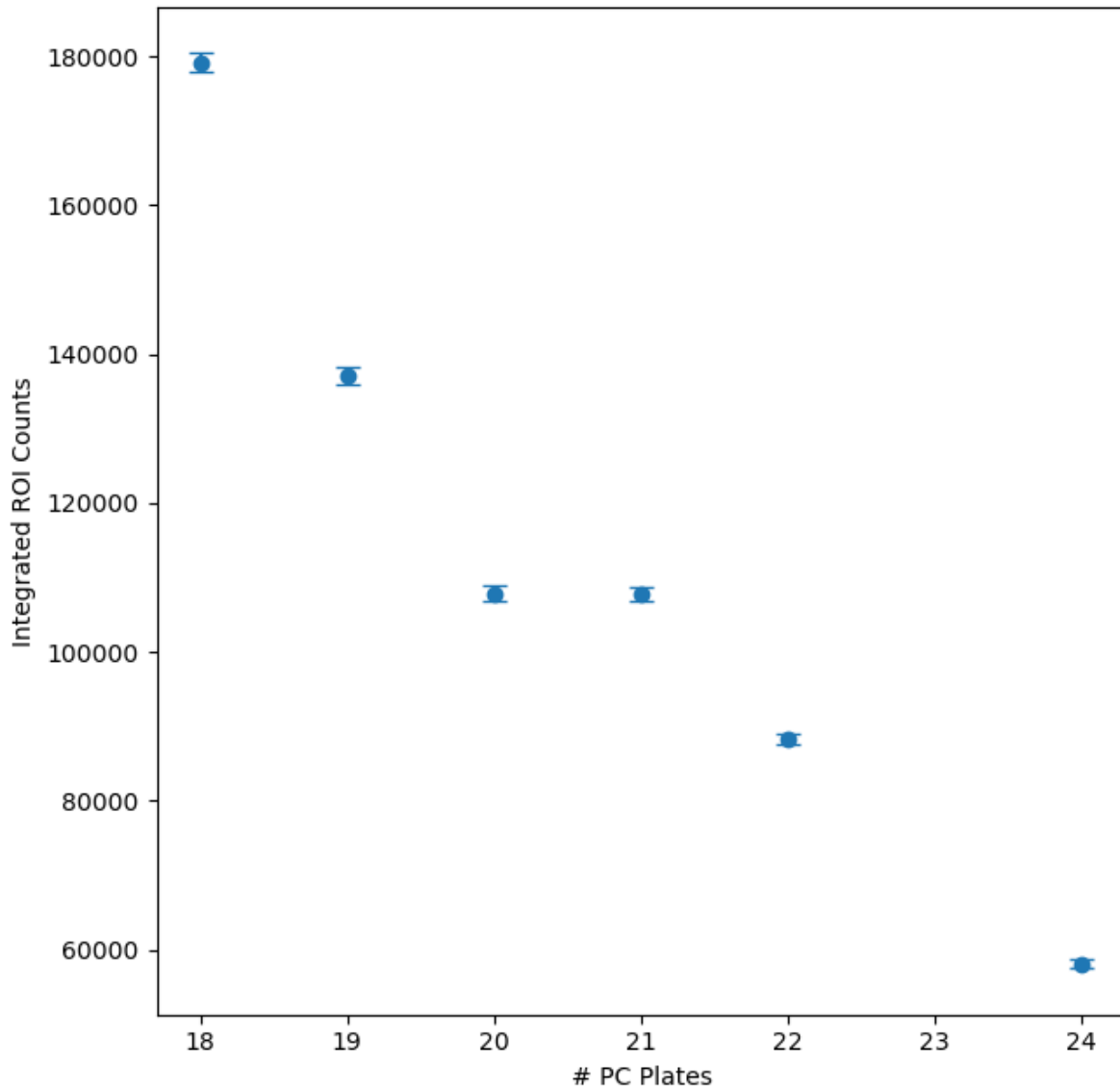
This table could be made for all seven of the fits.

# Integrated Results of All Background Subtractions

Inputs for the two-parameter exponential fit,  $F = F_0 \eta^k$

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

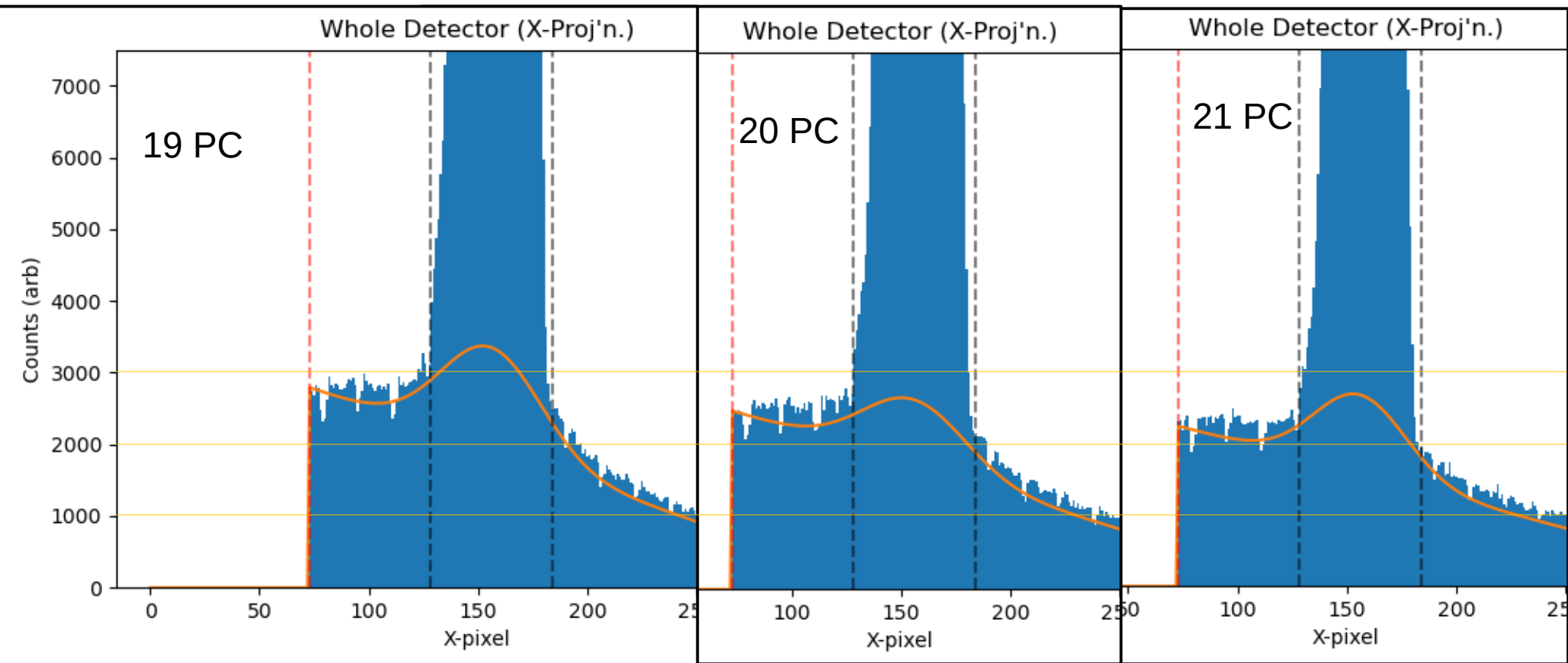
PLANE\* + GAUSS ROI vs PC Plates



# PLANE\* + GAUSS BKGD only

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

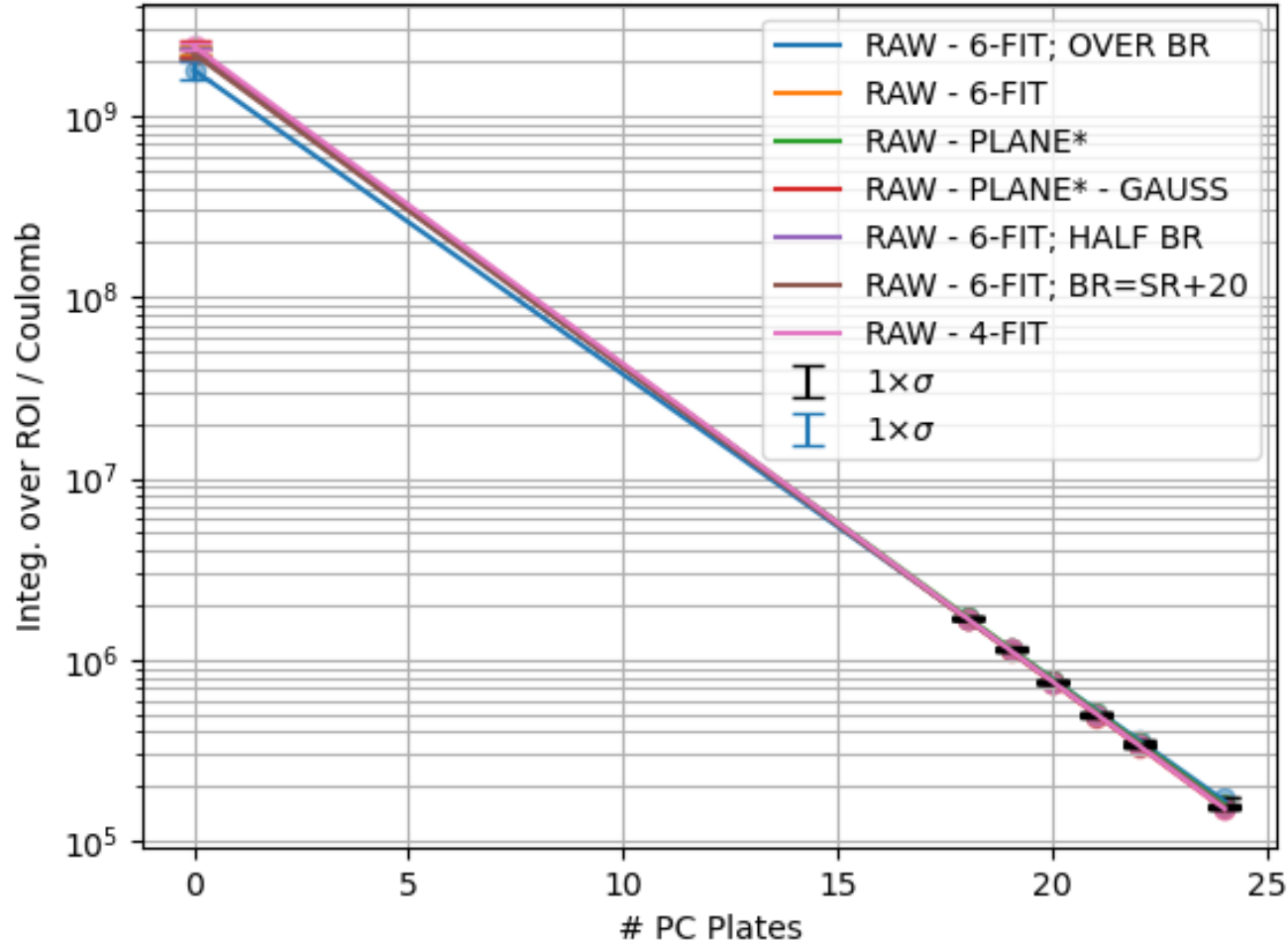
# What's Going On in the PLANE\* + GAUSS Fit?



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

# Comparison of Integ. over ROI

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

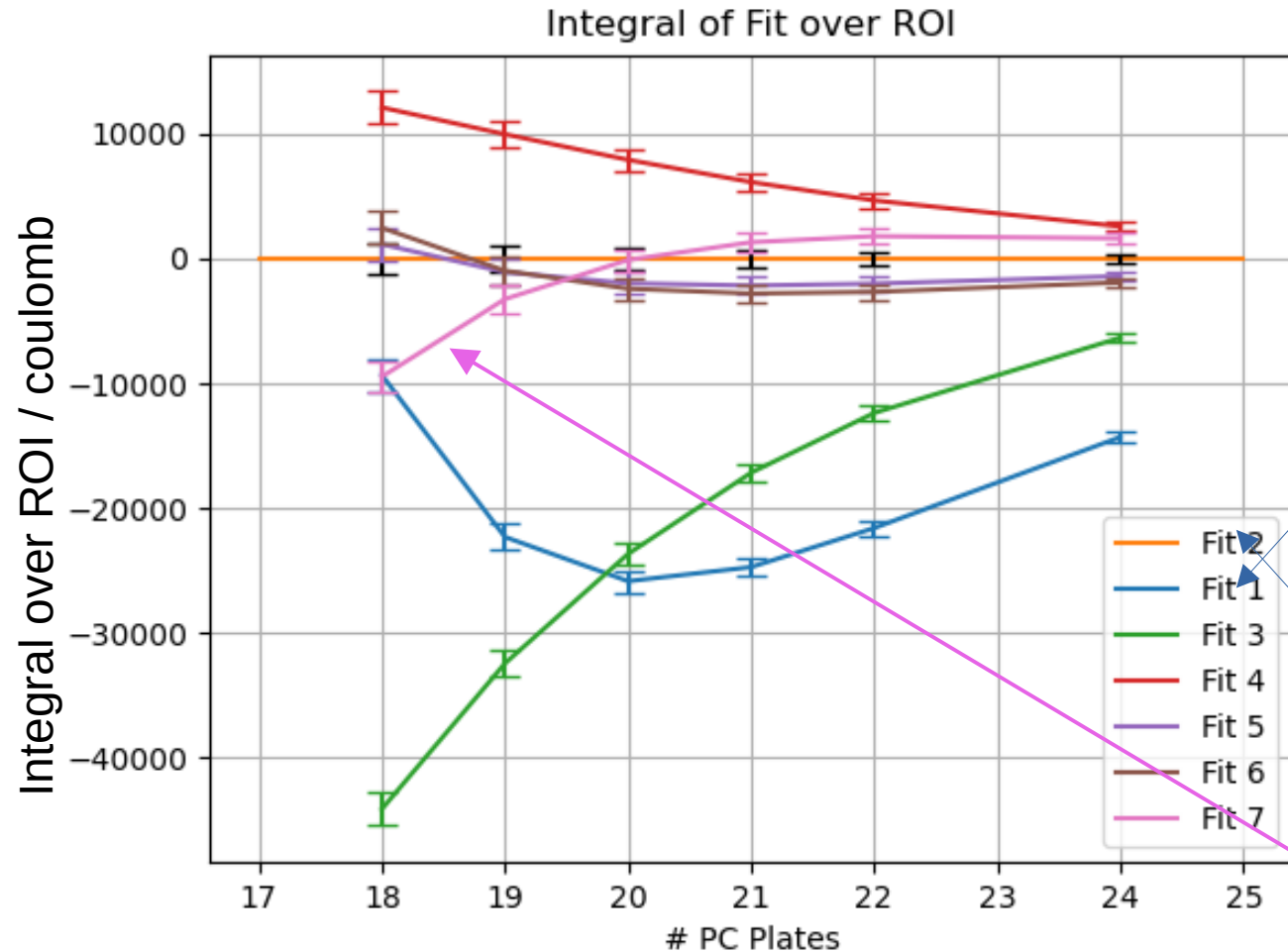


FIT #1  
FIT #2  
FIT #3  
FIT #4  
FIT #5  
FIT #6  
FIT #7

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)



Convert these to splines,  
then fit error bars on top

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)

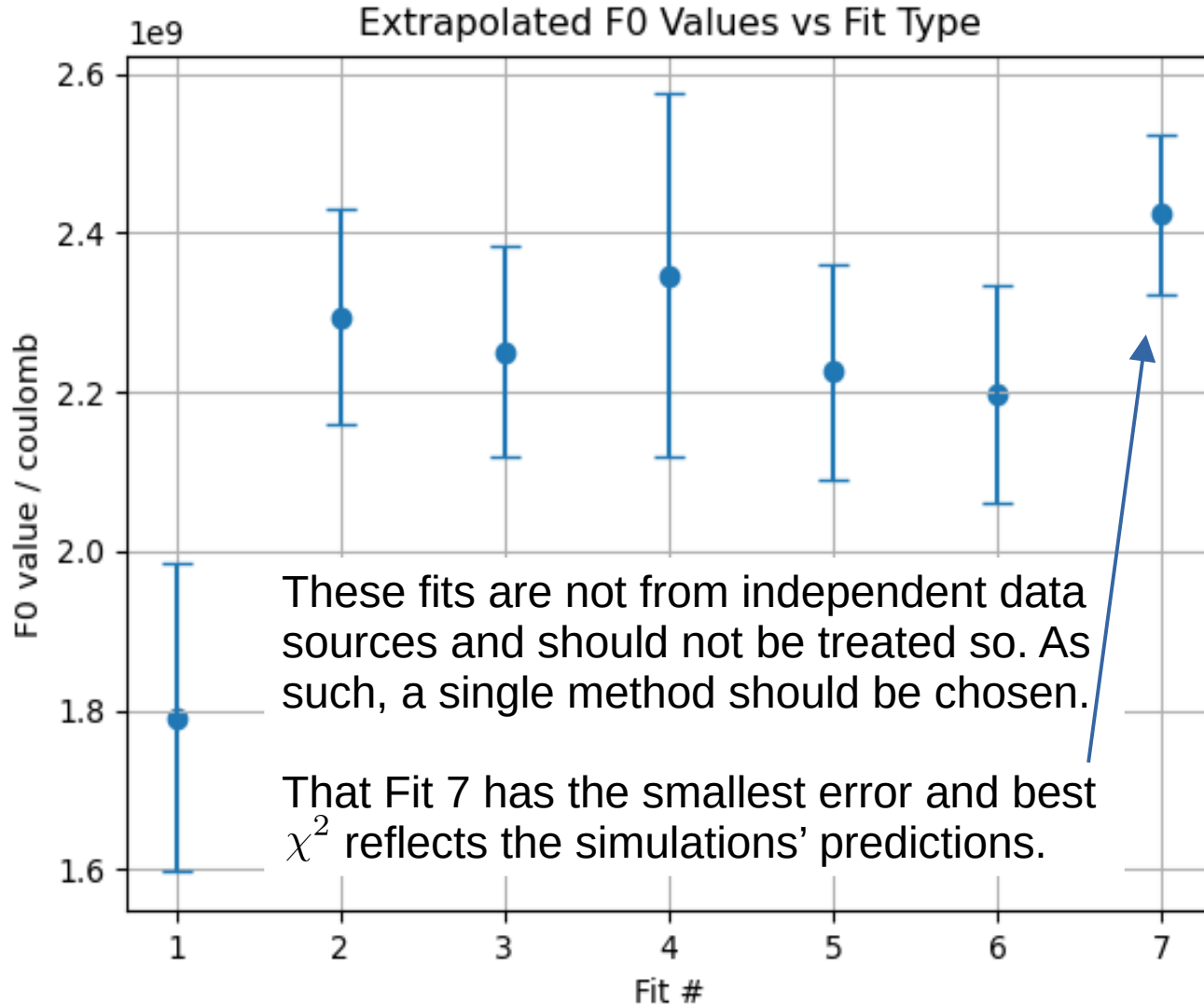
Fit 5: 6-Fit; fit on BR/2

Fit 6: 6-Fit; fit on SR+20

Fit 7: 4-Fit

Keep an eye on this 4-Fit

# F0



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.

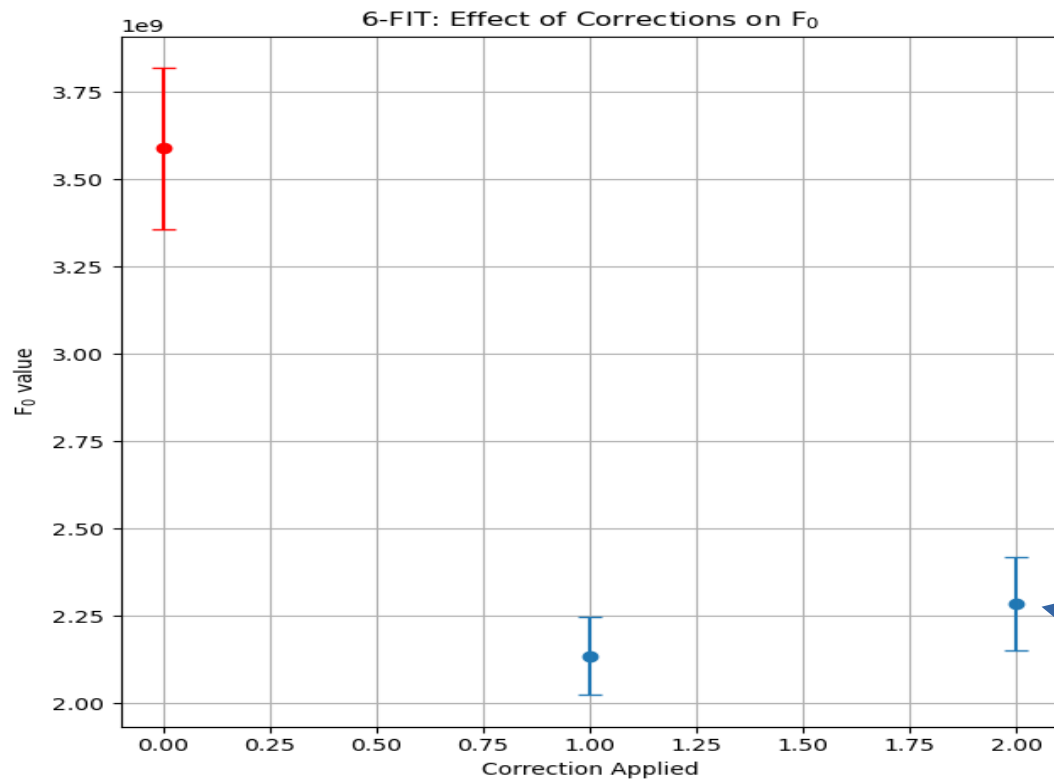
Fits 2 – 7 are consistent for  $F_0$ .

# Results of the Different Fits in “FROI”

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

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

# Consideration: Effect of Corrections on F<sub>0</sub> and eta



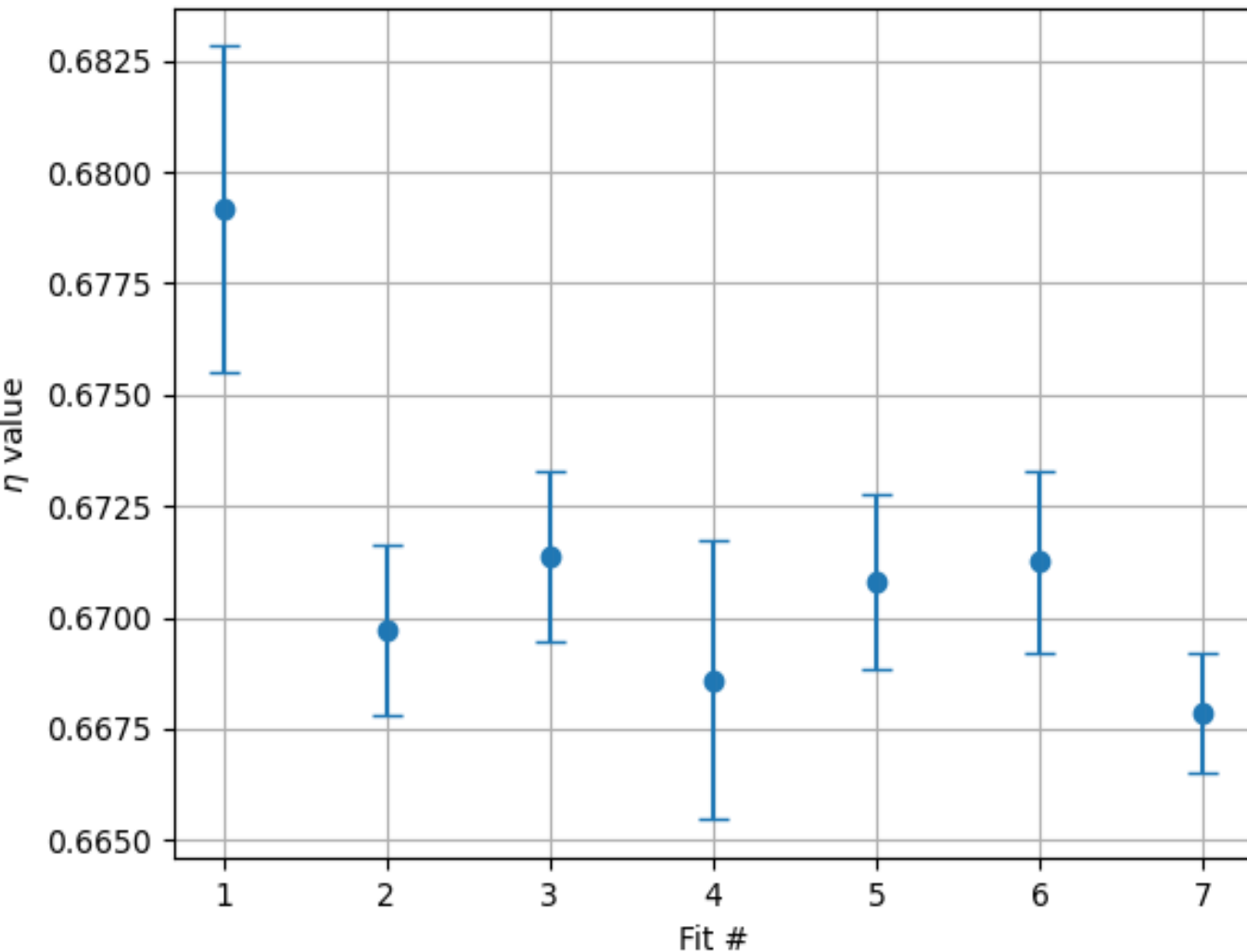
6-FIT Corrected F<sub>0</sub>:  
2.29 +/- 0.135

The proton charge correction is  
very important!

Uncorrected  
(invalid)

Proton Q  
correction  
only  
(required)

+ Detector  
deadtime  
corrected

$\eta$ Extrapolated  $\eta$  vs Fit Type

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

$\eta$  is within  $\sim 0.669 \pm 0.002$  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	$F_0 \pm dF_0$	$\eta \pm d(\eta)$	chi2/DOF (sig)	Comment
INTENSITY RECONSTRUCTION – Charge “Normalized” + Deadtime-Corrected				
0. RAW	$(1.79 \pm 0.159) \times 10^9$	$0.6811 \pm 0.0031$	0.6700	Stat'l.
1. 6-FIT over BR	$(1.79 \pm 0.114) \times 10^9$	$0.6792 \pm 0.0016$	0.9279	Stat'l. + Sys.
2. 6-FIT	$(2.29 \pm 0.135) \times 10^9$	$0.6697 \pm 0.0019$	0.4979	Stat'l. + Sys.
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7. 4-FIT	$(2.42 \pm 0.100) \times 10^9$	$0.6679 \pm 0.0013$	0.3291	Stat'l. + Sys.
WEIGHTED MEAN VALUE (excluding RAW and 6-FIT over BR)			Reminder: the fits are not independent.	
	$(2.30 \pm 0.05) \times 10^9$	$0.6691 \pm 0.0007$		

# Proposed Final Answer: RAW – 4-FIT

The result of the fit for  $\chi^2$  of the  $(F_0, \eta, \text{DoF}=4)$

$F_0, \delta F_0$ :

$$F_0 = 2.42 \times 10^9$$

$$\delta F_0 = 0.100 \times 10^9$$

4-Fit:

$$\chi^2 / \text{DoF} = 0.3291$$

The result for  $\eta, \delta\eta$ :

$$\eta = 0.6679$$

$$\delta\eta = 0.0013$$

Optimal  $\sigma_x$ , K Value for  
determining  $\sigma_y$ :

$$\sigma_x = 27.75$$

$$K = 1.05$$

# Comparison with M. Kline 2021 Analysis

M. Kline considered the effect of ToF on  $F_0$  and  $\eta$ .

2<sup>nd</sup> Smallest pinhole:

$$F_0 = 2.6 \times 10^9 \quad \eta = 0.67 \quad \chi^2/\text{DoF} = 38$$

Smallest pinhole (w/ simple background subtraction):

$$F_0 = (2.68 \pm ?) \times 10^9 \quad \eta = 0.67 \quad \chi^2/\text{DoF} = 25$$

This 4-Fit:

$$F_0 = (2.42 \pm 0.100) \times 10^9 \quad \eta = 0.6679 \pm 0.0013 \quad \chi^2/\text{DoF} = 0.3291$$

END