

Development of a Precise 4d Emittance Meter Using Differential Slit Image Processing

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4D emittance & Differential Slit method

x-y coupling beam: 4D phase space $(x-x', x-y', y-x', y-y')$

- Dual Slit method, Pepper pot

New
Method

Virtual Pepper Pot method

- image processing slit position x and y slit image \Rightarrow 1D scan \rightarrow 2D Scan

G. Z. Georgiev and M. Krasilnikov, IBIC 19'

One
More
Step

- Uncertainty from Slit width \rightarrow Differential slit method

- **Differential Slit method:**

- Using Slit position x and x+slit width slit image

\rightarrow narrower than slit moving step size \rightarrow precise measurement

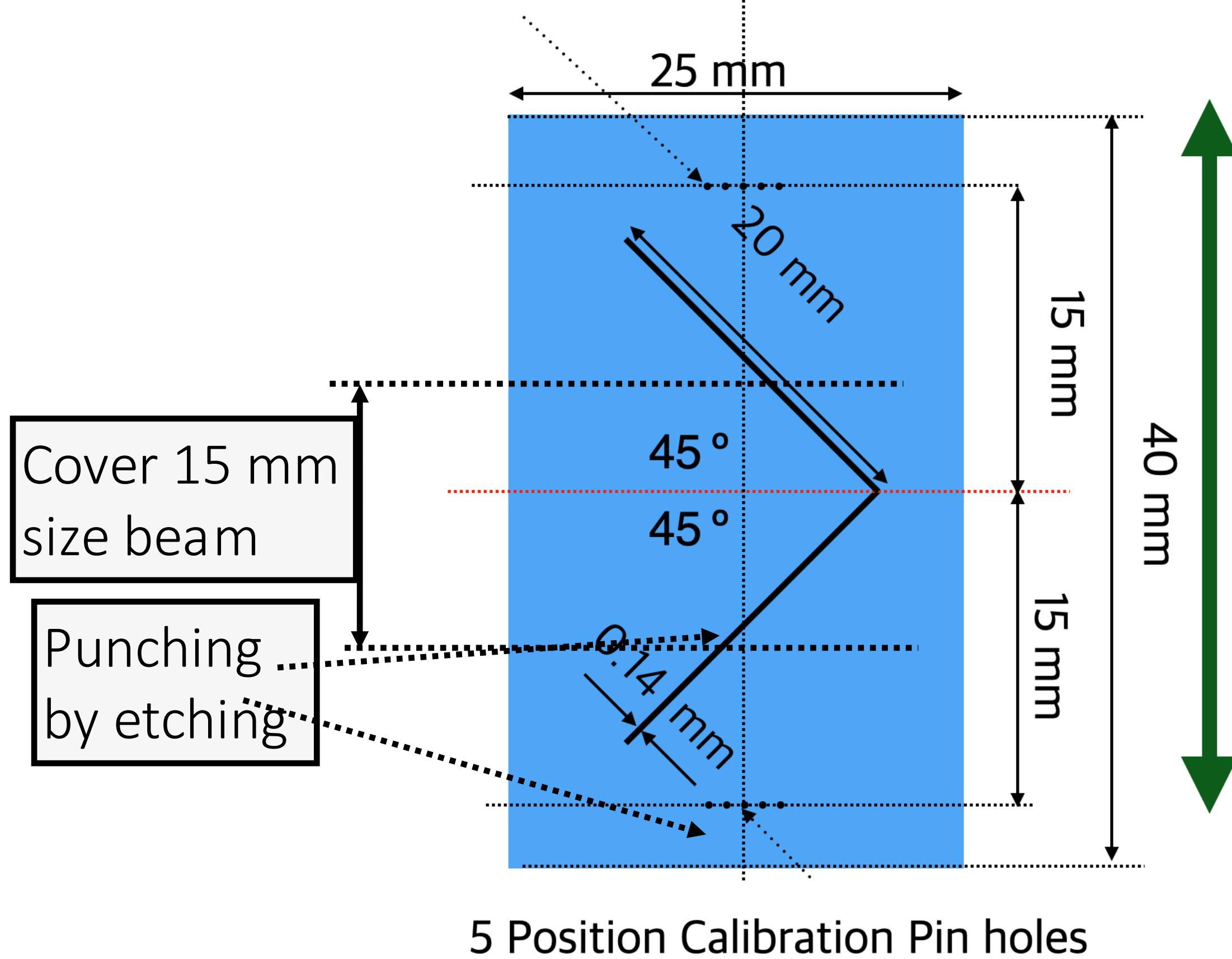
2

We introduce our differential slit method with simulation data analysis

Slit Design

Target Beam Line: PAL-eLABs (or ITF) $E_{\text{beam}} = 70 \text{ MeV}$, Korea 4GSR LINAC $E_{\text{beam}} = 200 \text{ MeV}$

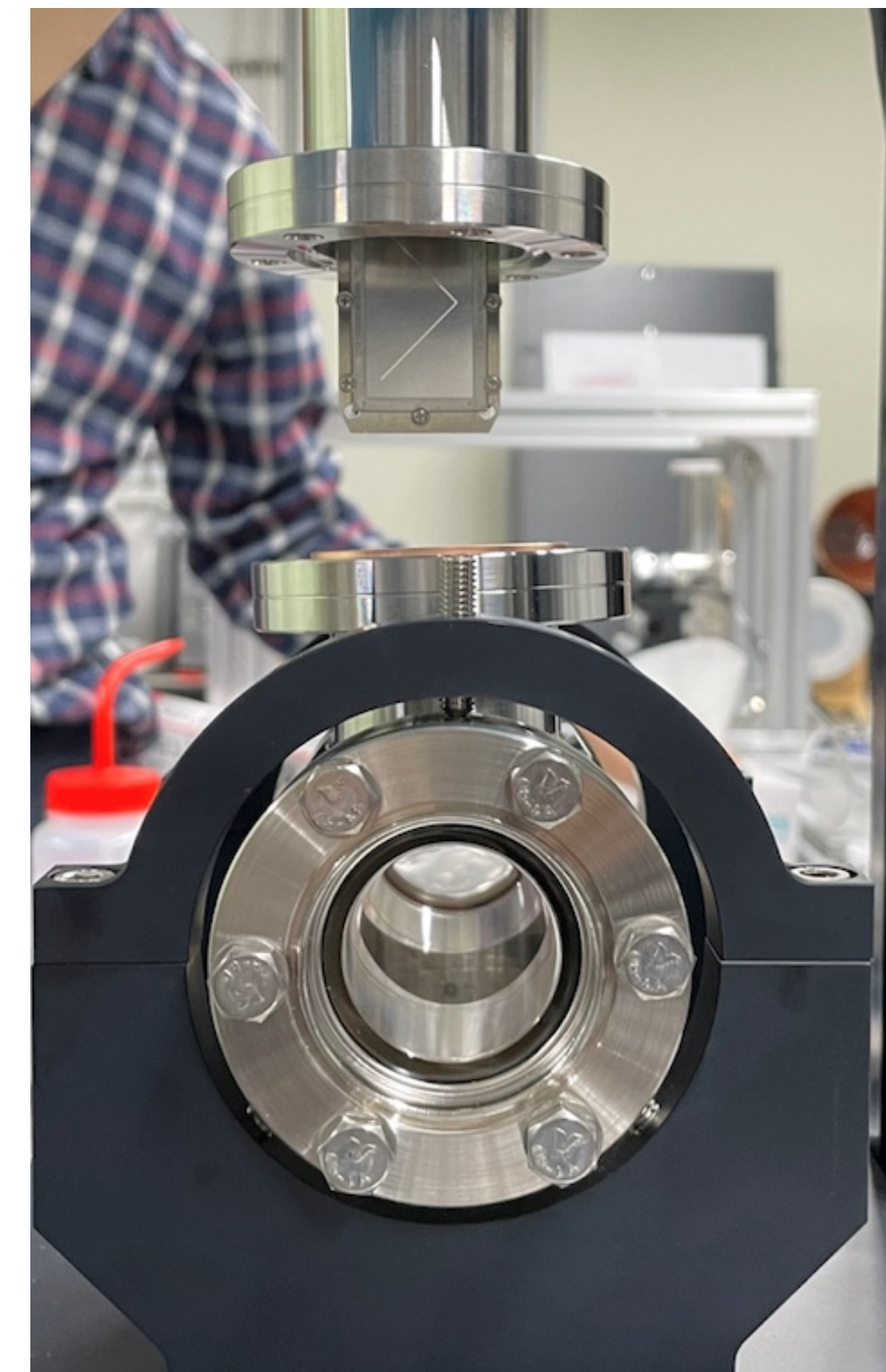
5 Position Calibration Pin holes



5 Position Calibration Pin holes



50 μm Stainless steel
- etching Manufacturing
- BKG by beam scattering



Simulation

- Beam Condition: PAL-eLABs (or ITF)
 - 70 MeV, 10~20 nm · rad w/ artificially rotate
 - Slit-Screen Dist.: 3.5 m
 - Slit moving every 20 μm \Rightarrow 10 Hz with 200 $\mu\text{m/s}$

Geant4: beam interaction

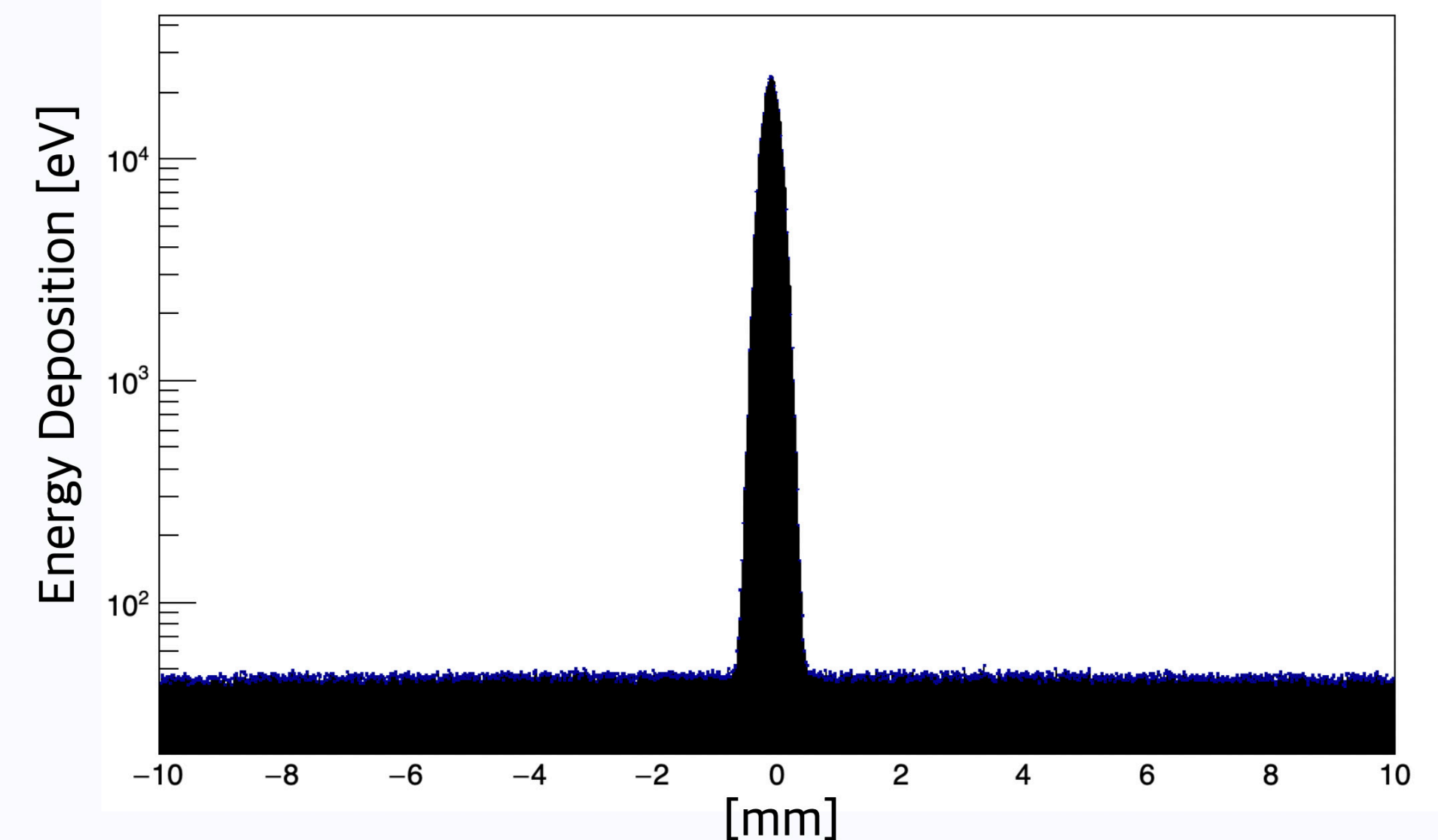
- 50 μm thickness Slit
- 100 μm thickness YAG

\rightarrow E_{dep} in YAG Screen

openCV: Image processing

- $E_{\text{dep}} \rightarrow$ px count
- px res: 20 μm x 20 μm
- resol.: 1000 x 1000
- 12 Bit image

\rightarrow 16 bit scaled movie format

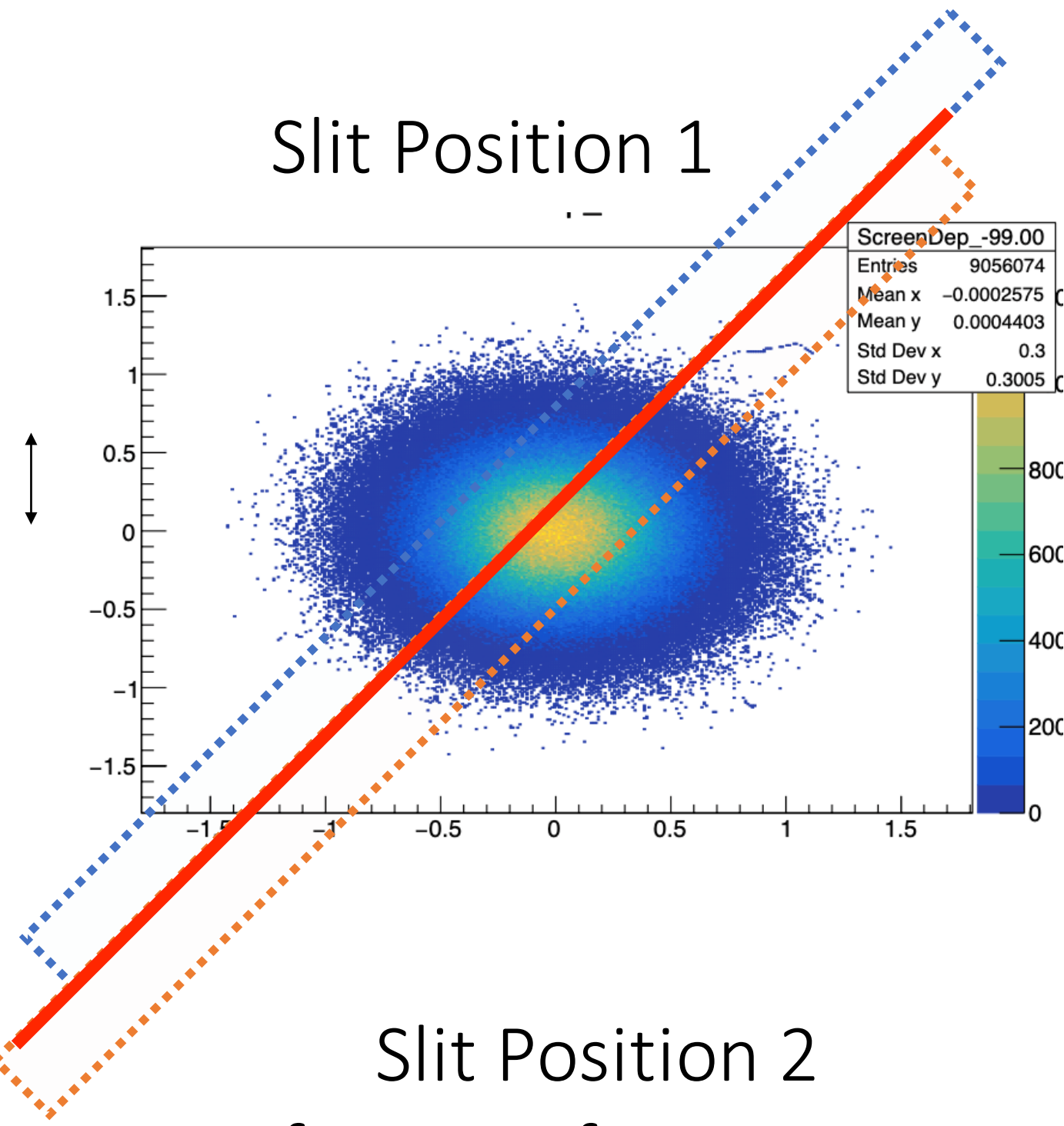


Background Beam Scattering by 50 μm Stainless plate is negligible

"Differential Slit Method" (This Topic)

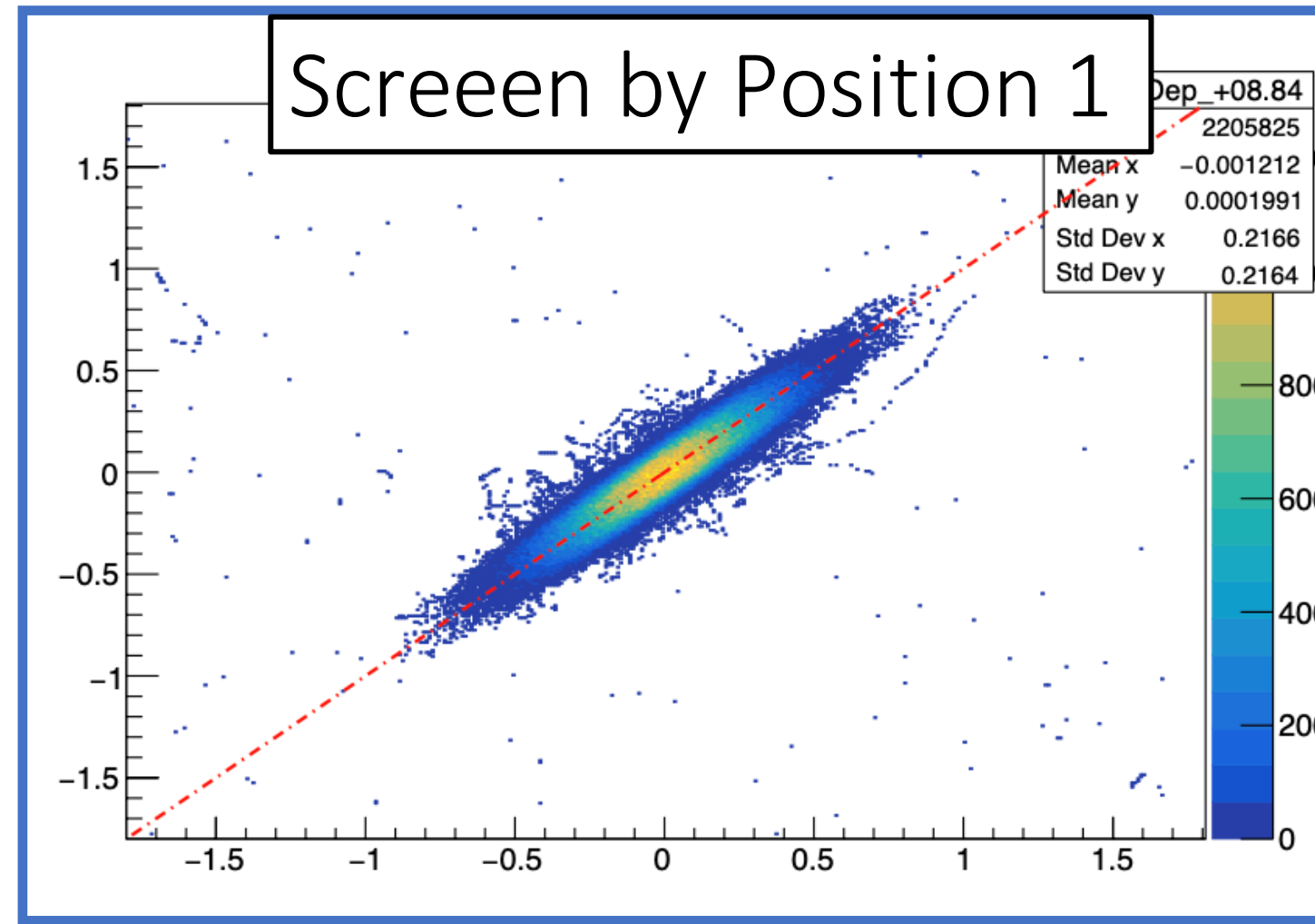
Slit

Slit Position 1

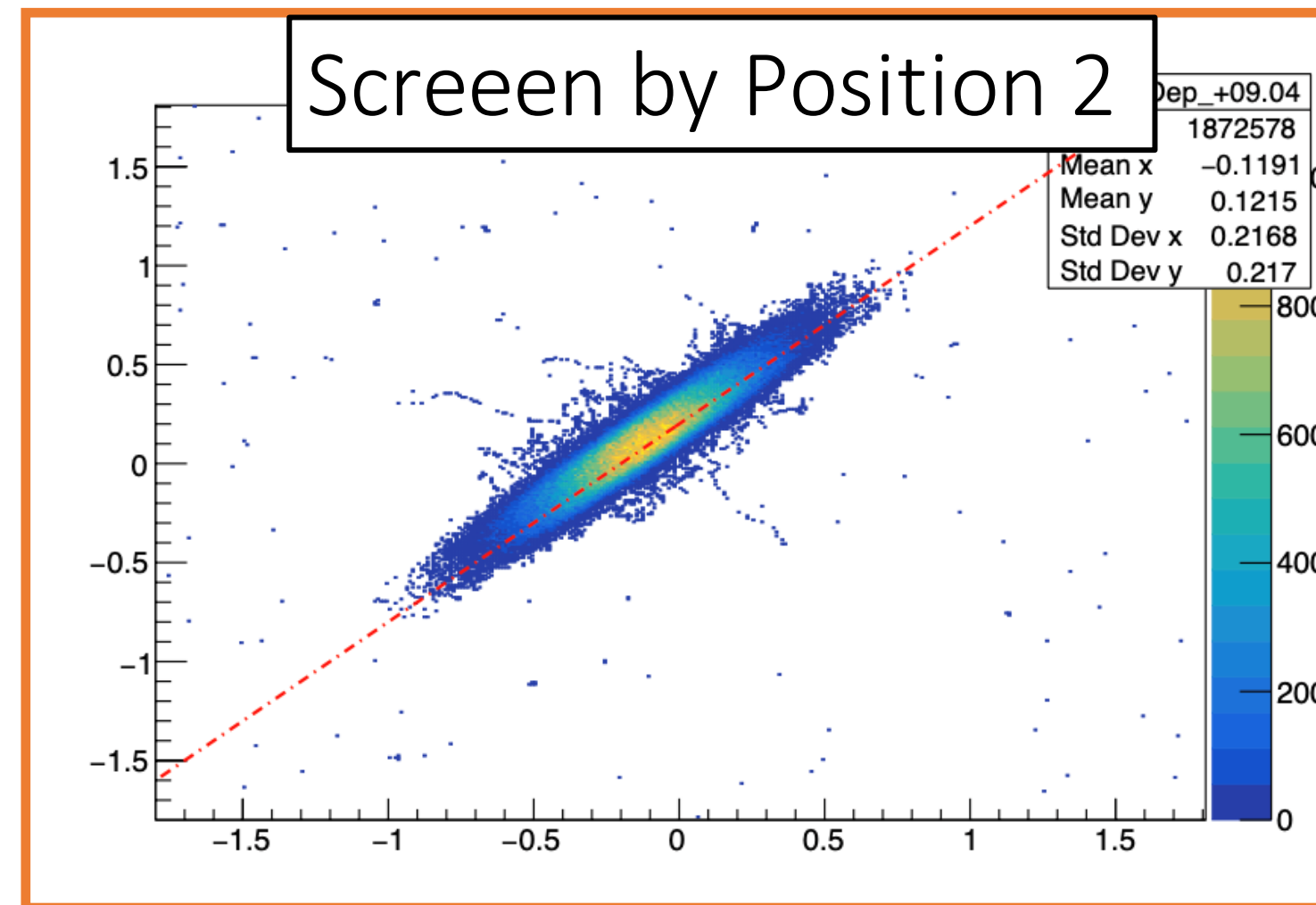


Slit Position 2
10 frames after position 1

Screen by Position 1



Screen by Position 2

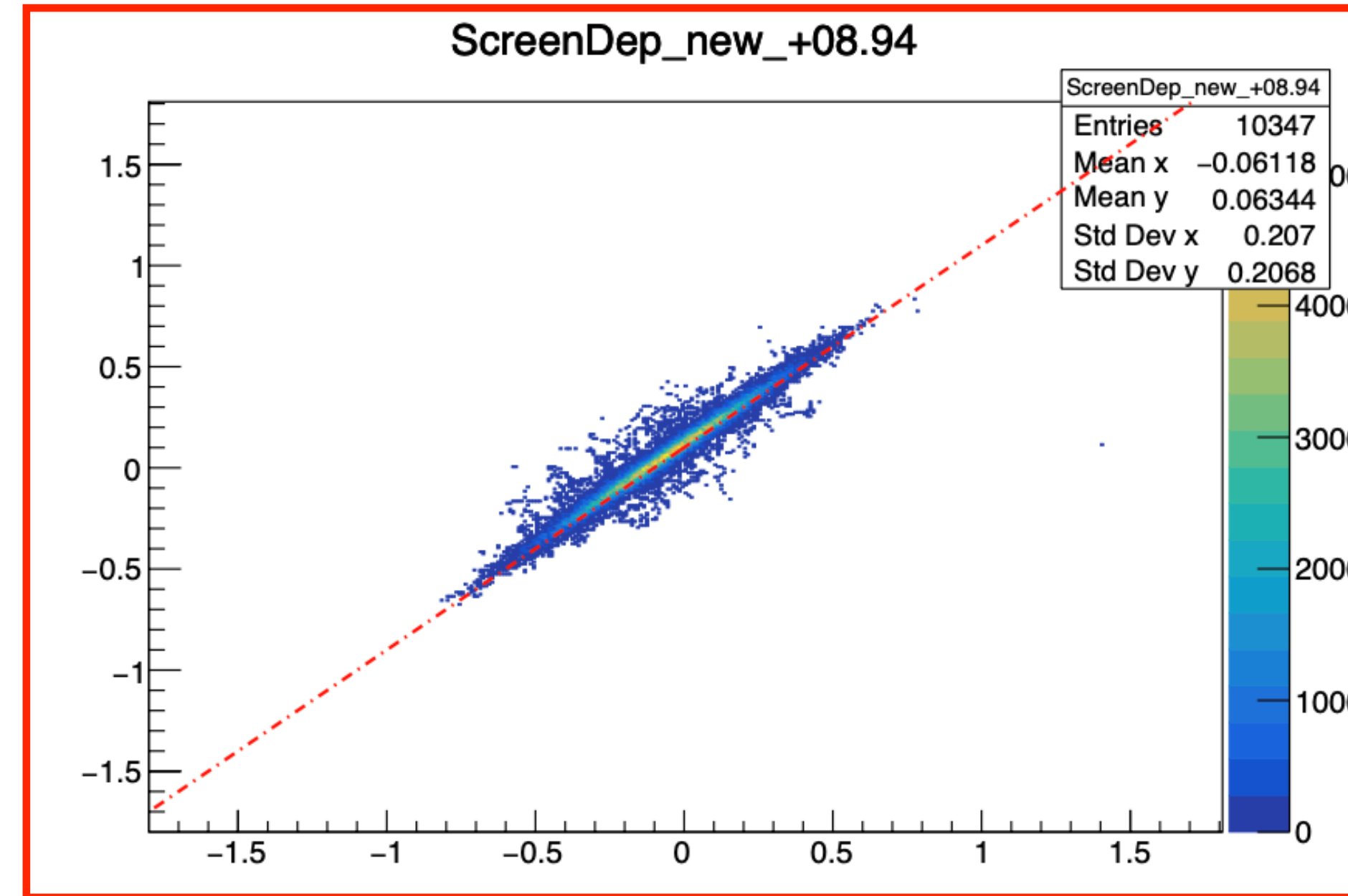


Differential Slit image

Equivalent 2.1 μm slit

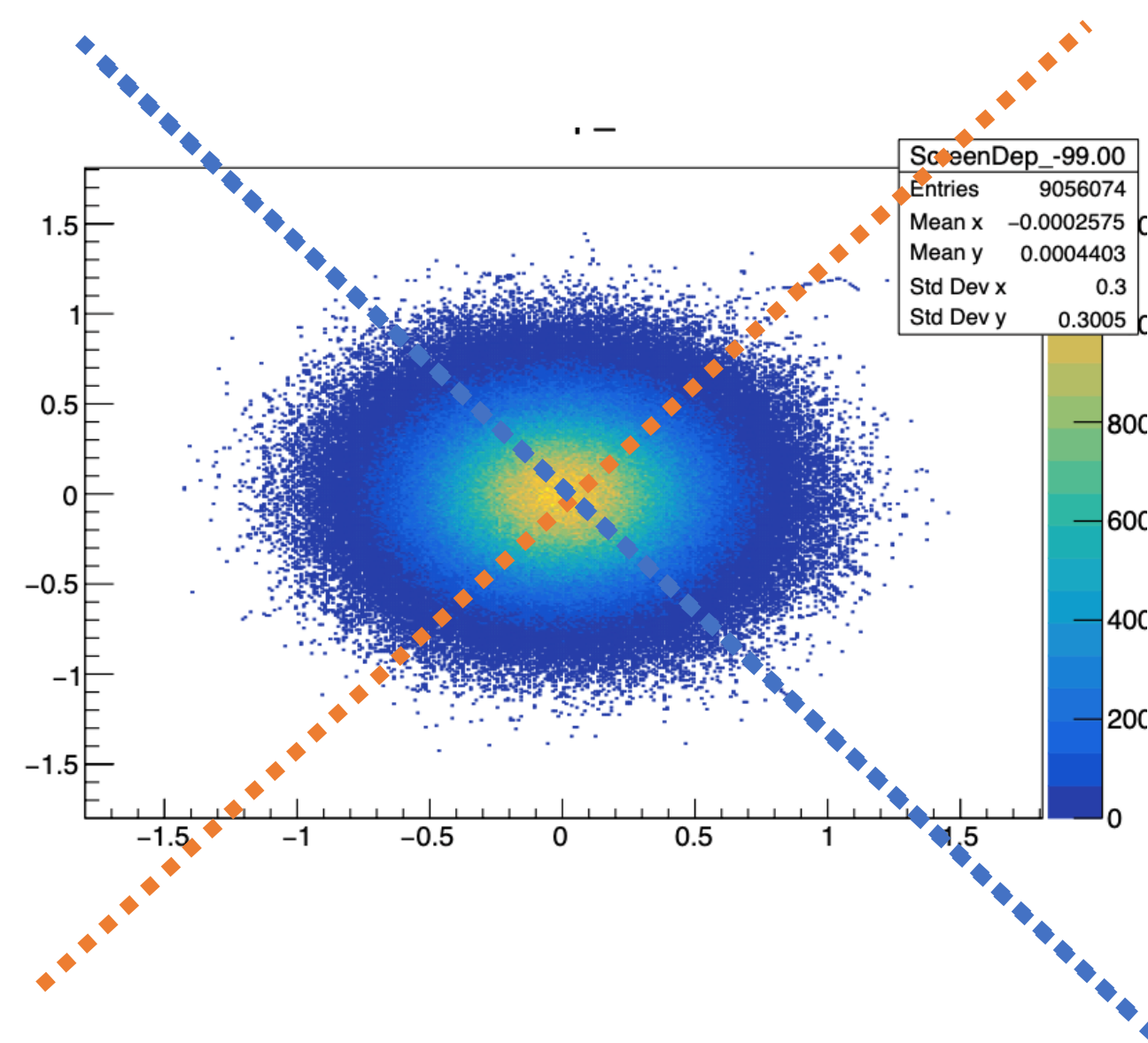
Minimum px count pick up

ScreenDep_new_+08.94

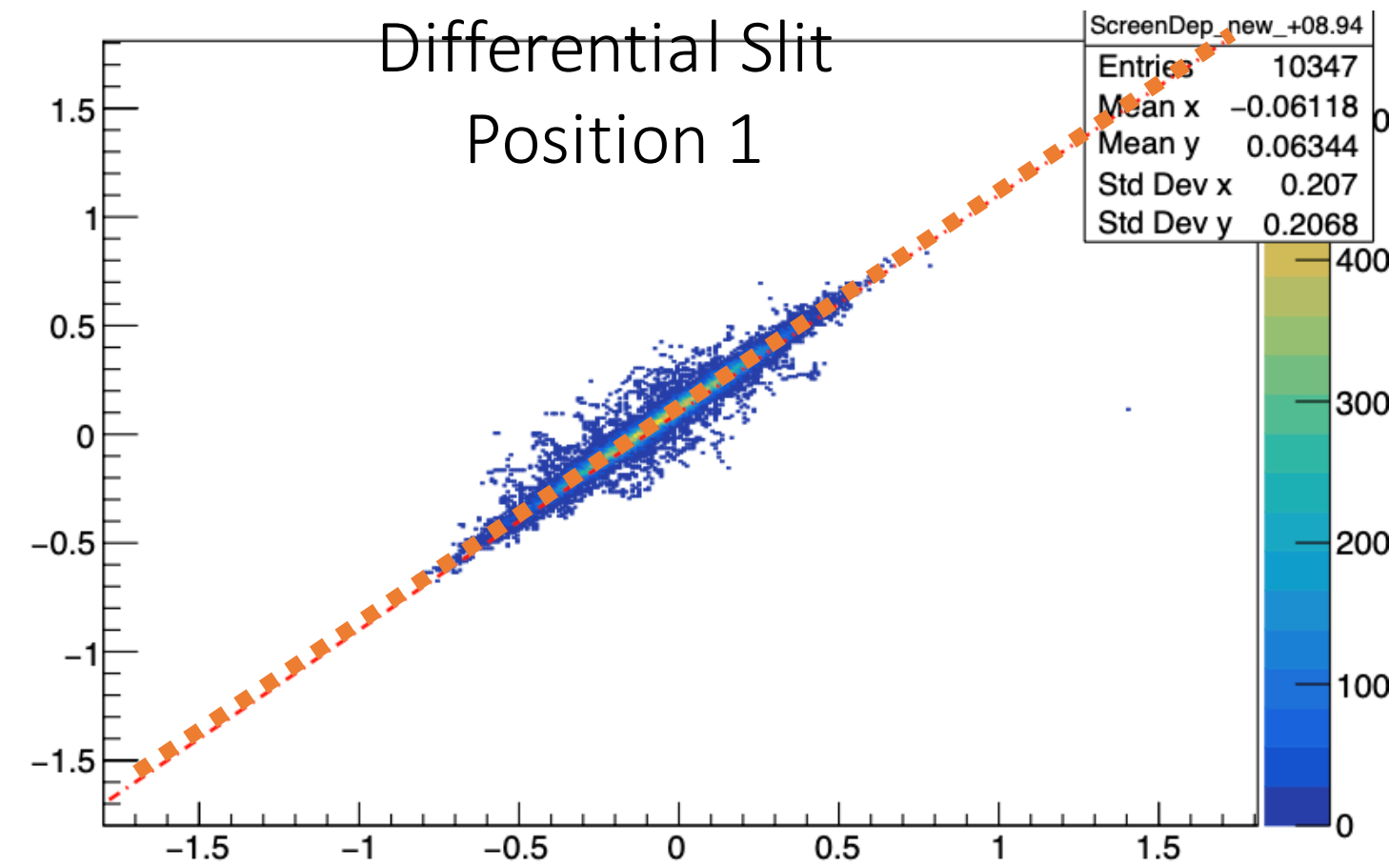


Analysis: Virtual Pepper Pot

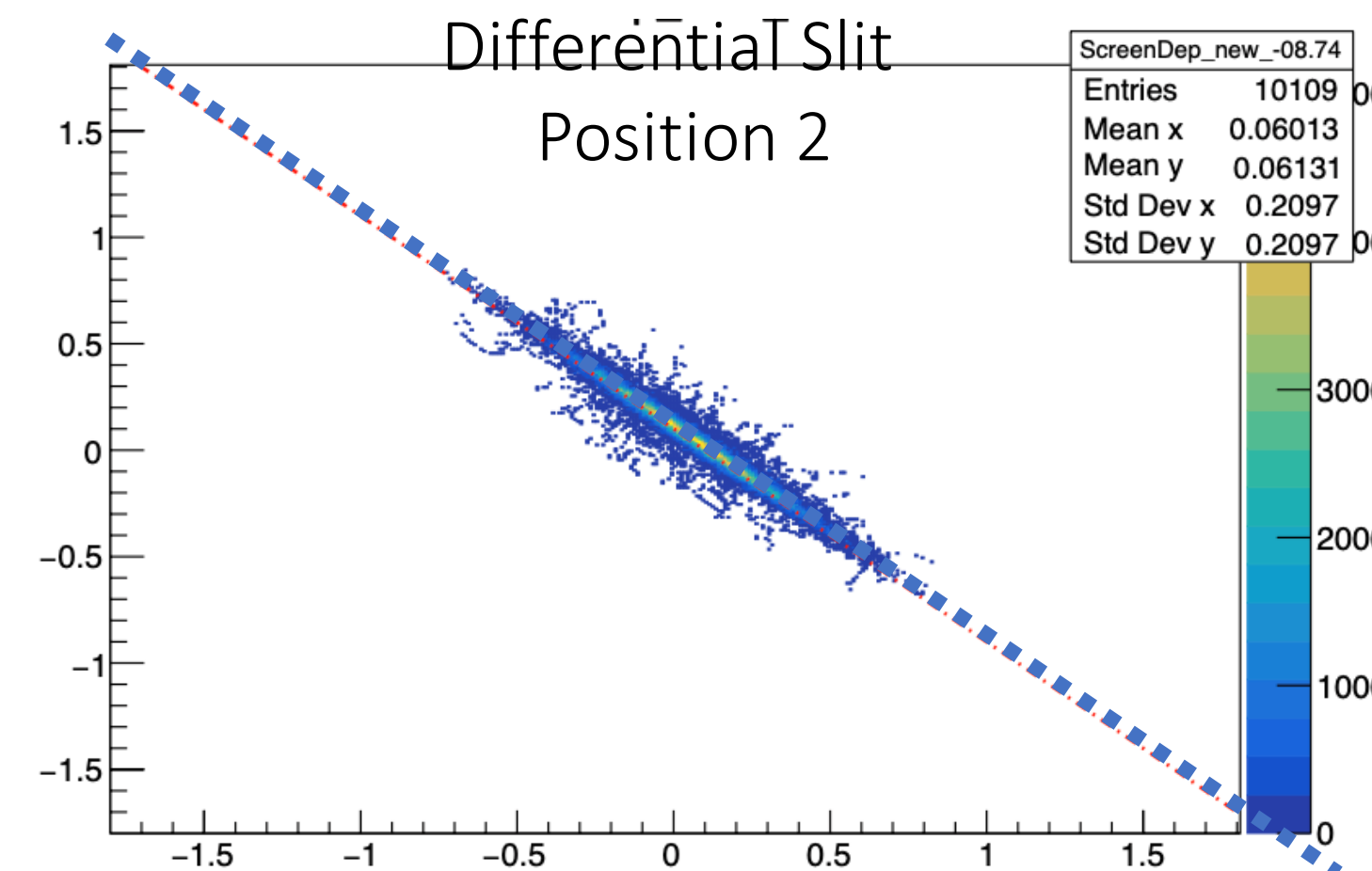
Differential Slit
Position 2



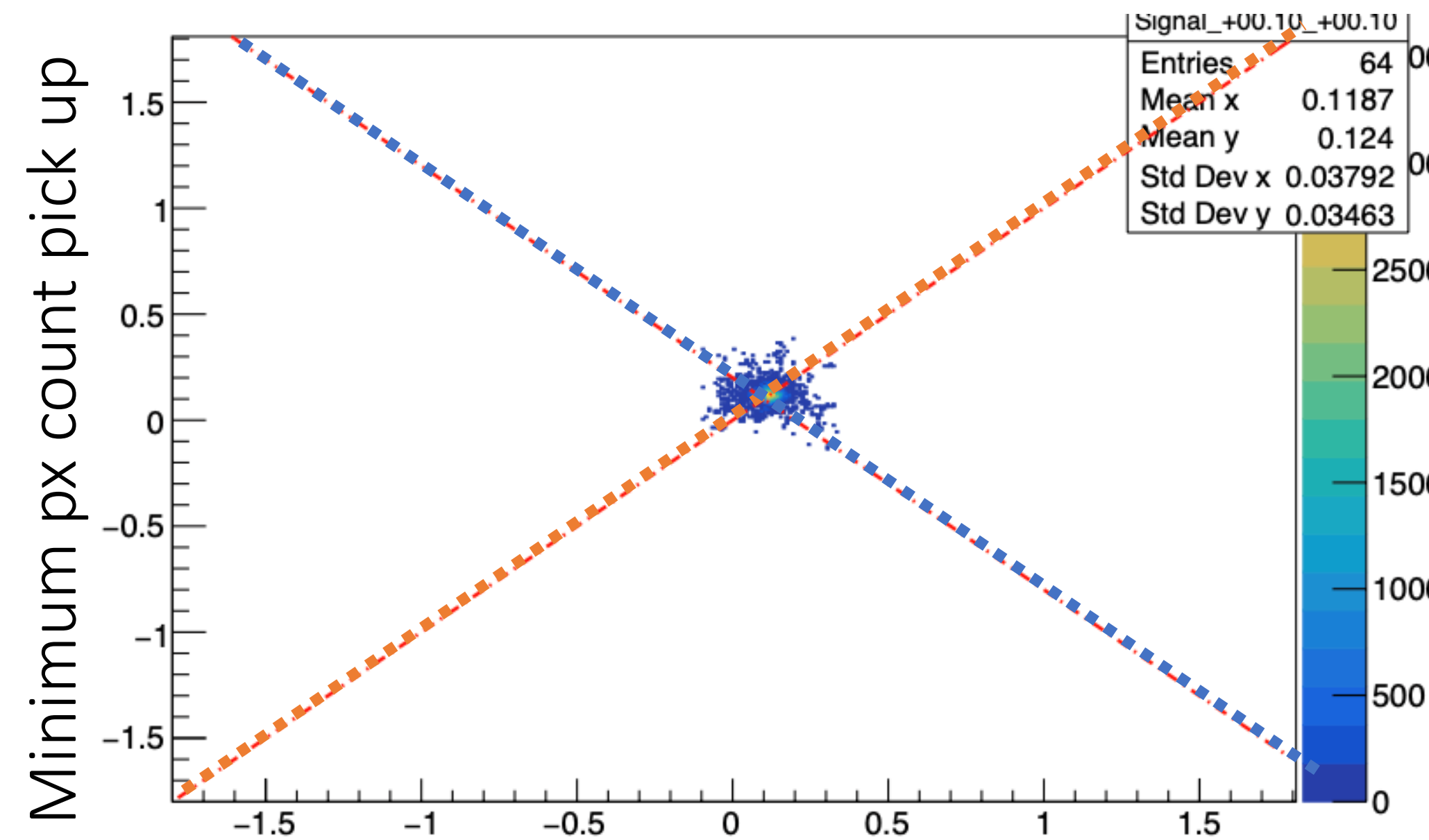
Differential Slit
Position 1



Differential Slit
Position 2

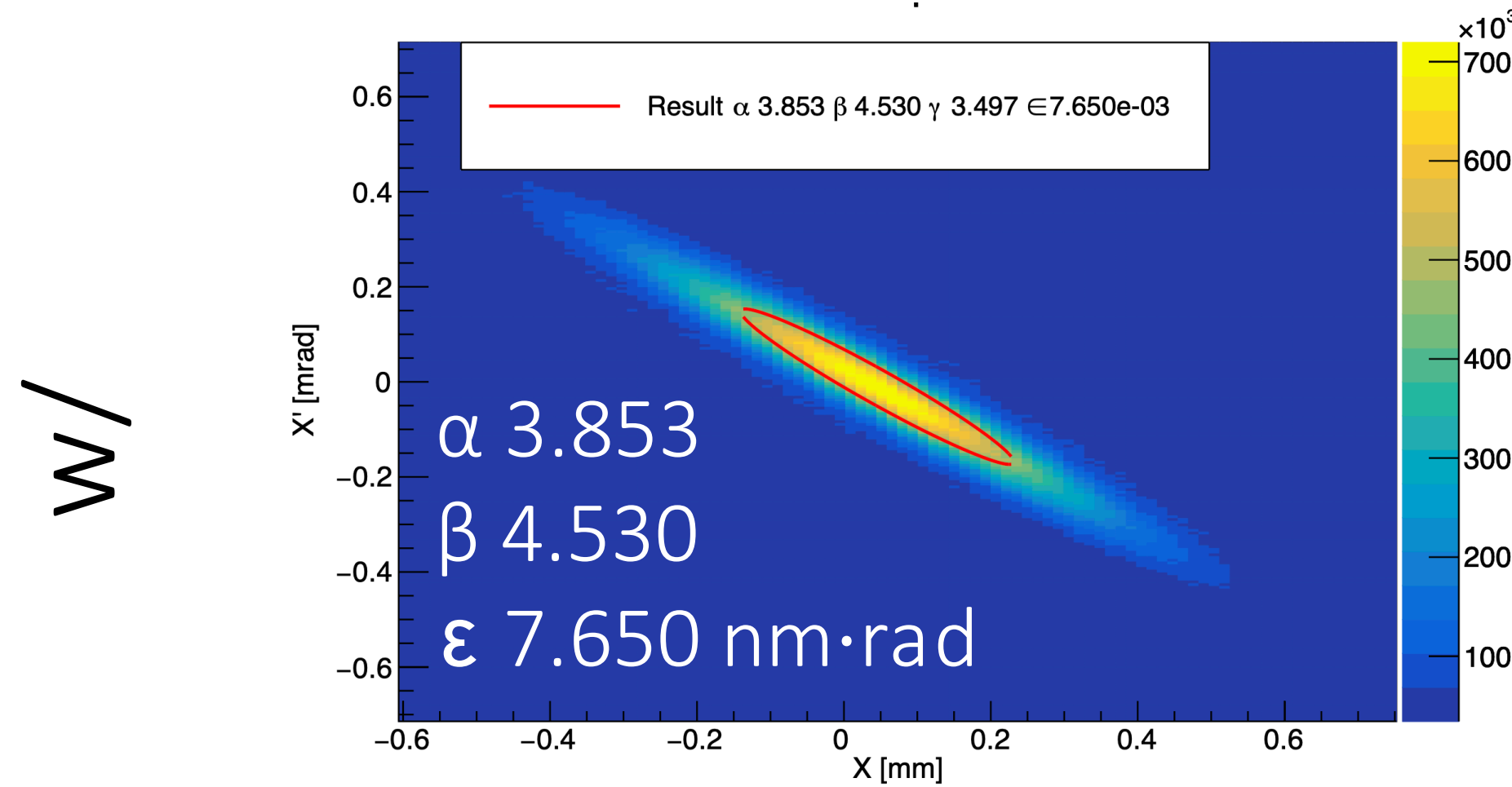


Result VPP Image

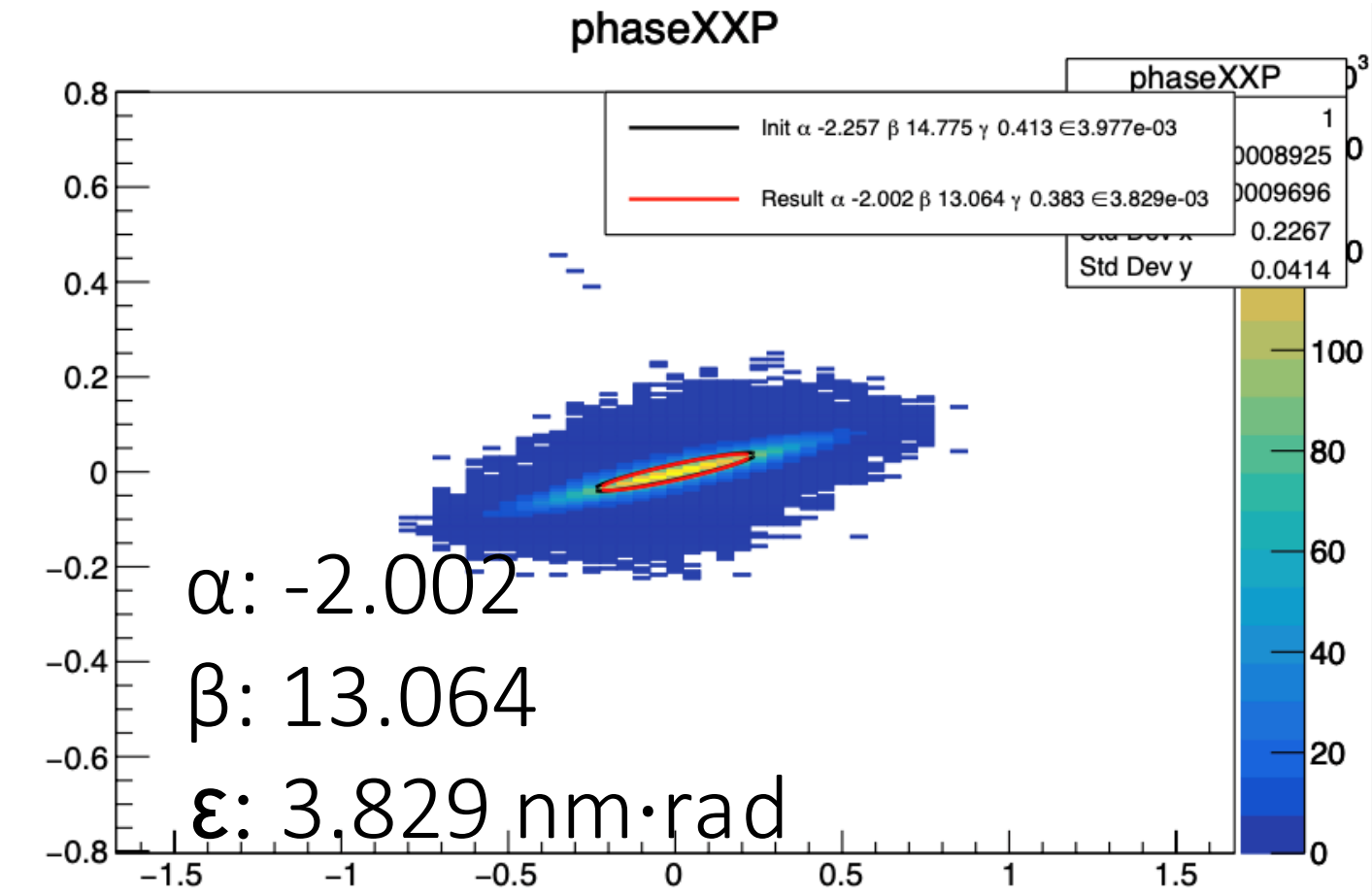


w/ w/o Differential Slit

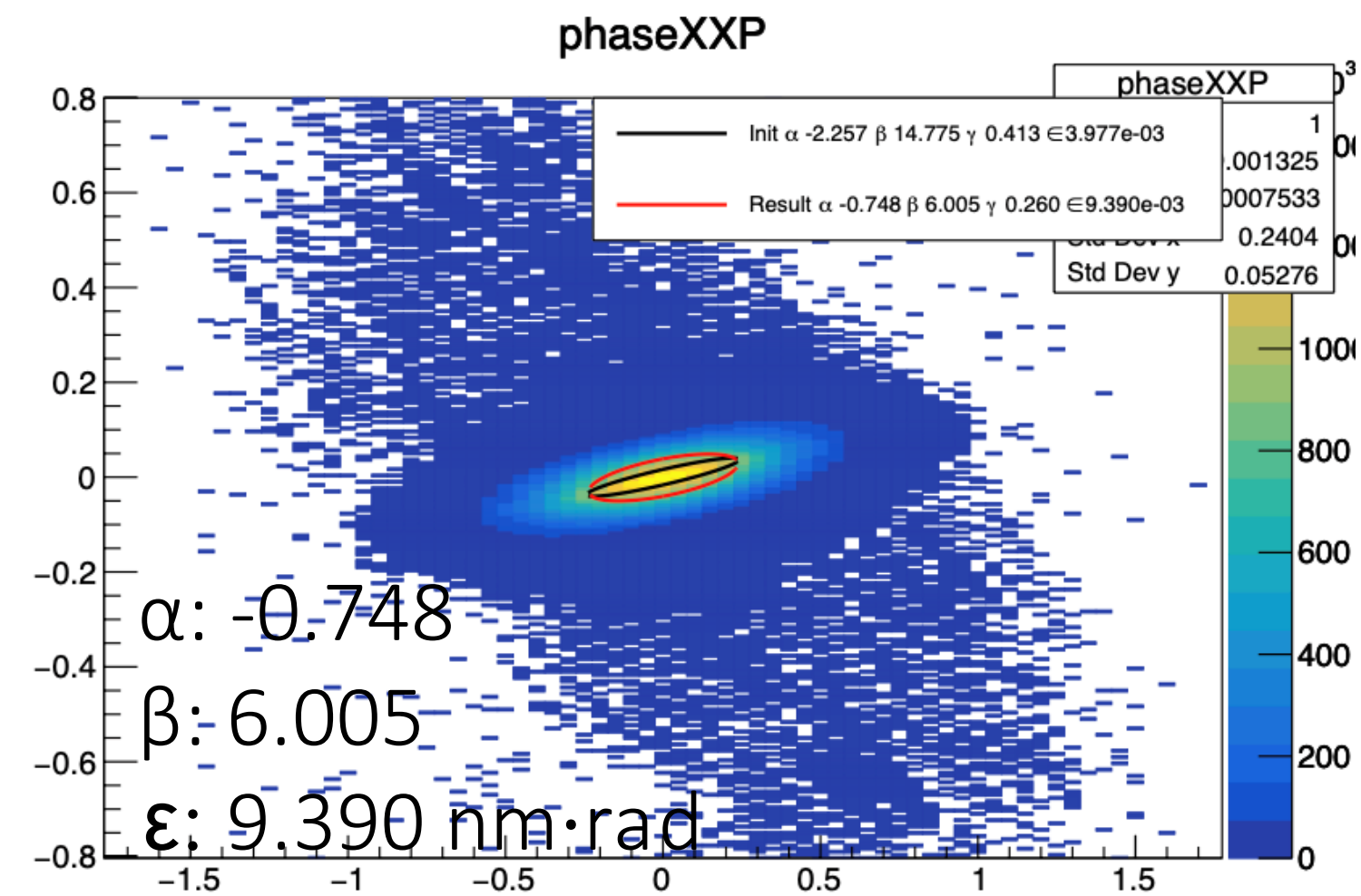
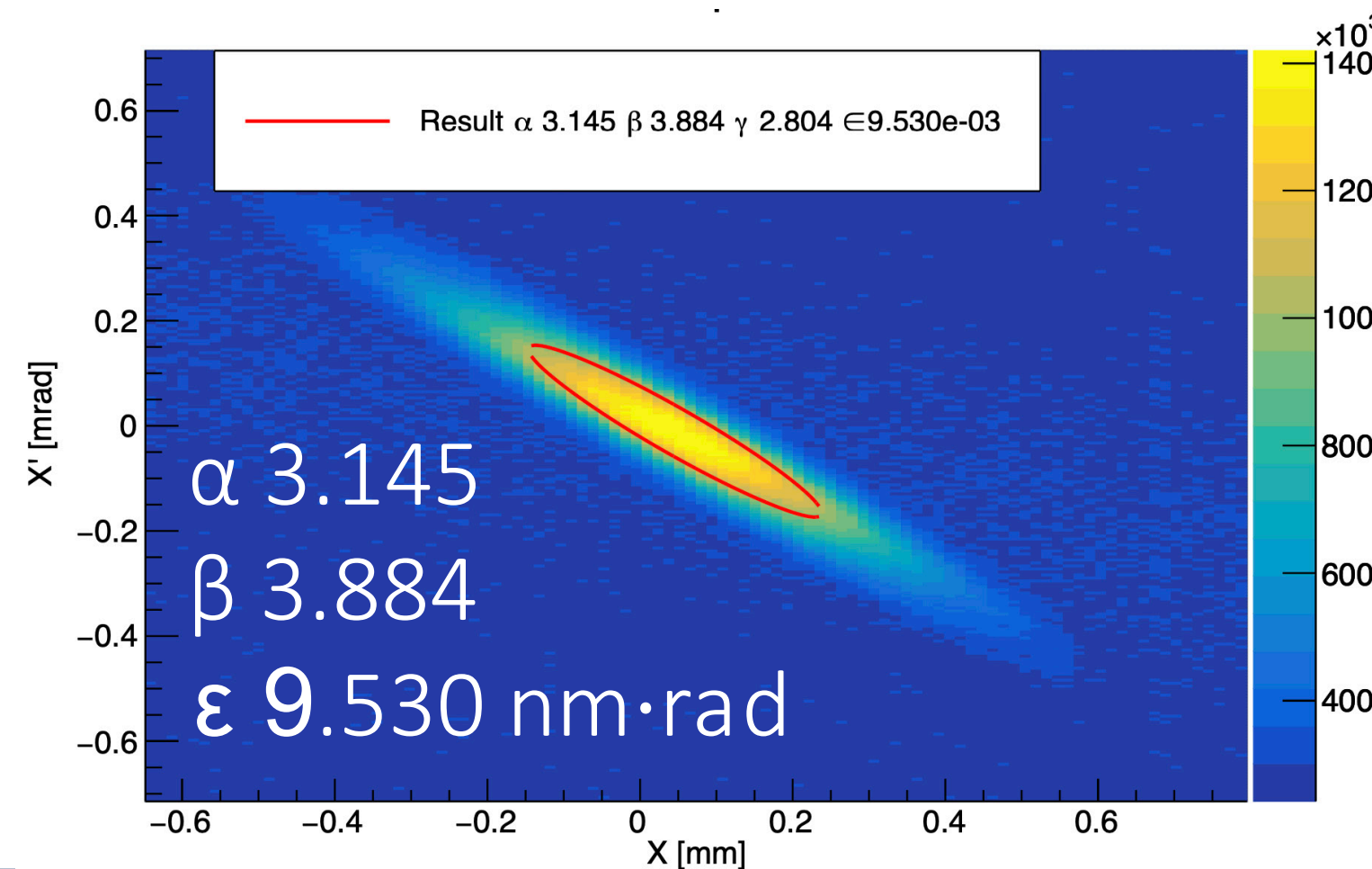
Input α 4.467 β 4.390 ϵ 7.449 nm rad



Input α -2.257 β 14.775 ϵ : 3.977E-03



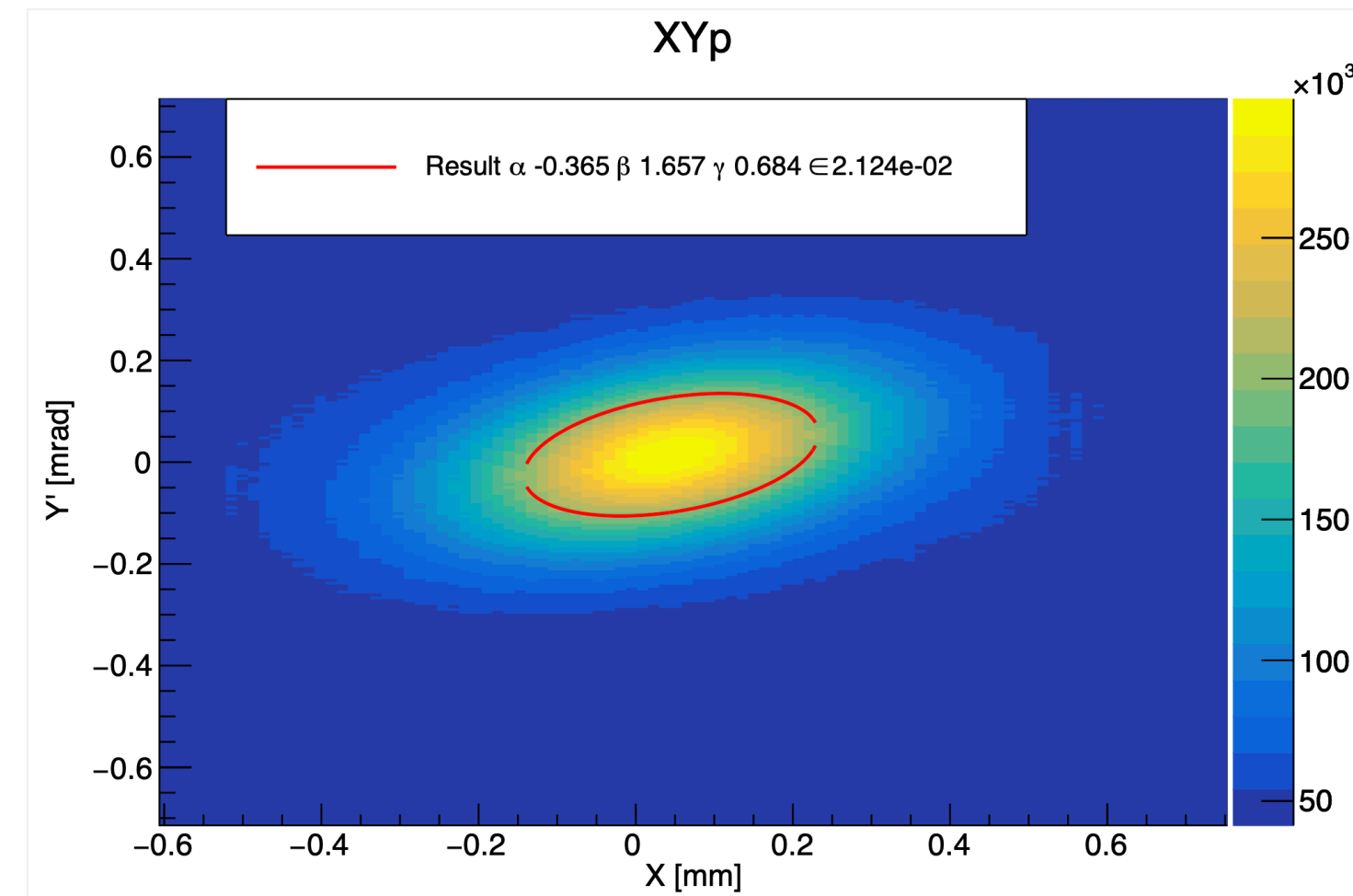
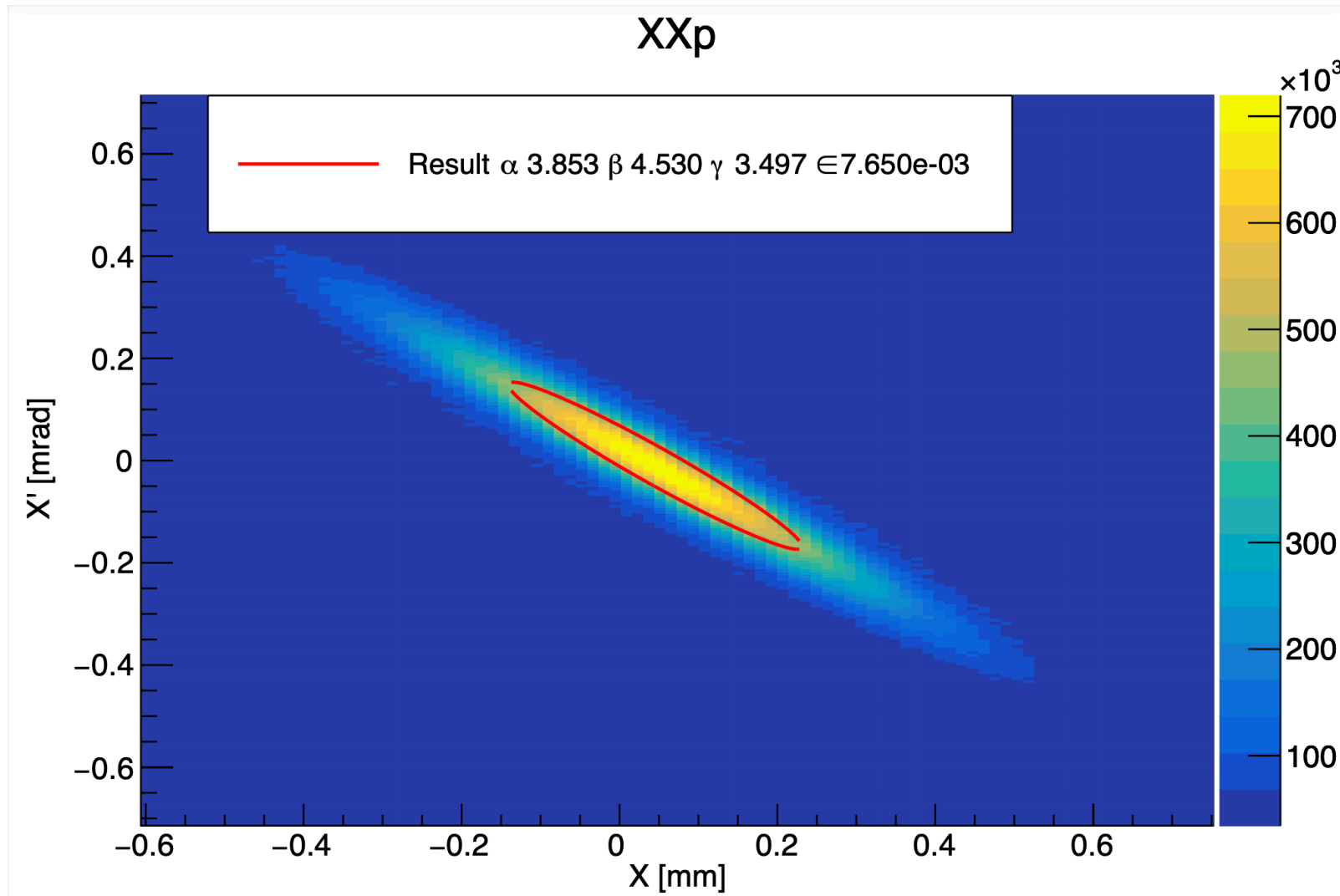
w/o



4D Emittance Result

	INPUT	RECON.
α	4.467	3.871
β	4.390	4.549
ϵ (nm rad)	7.449	7.650

3%

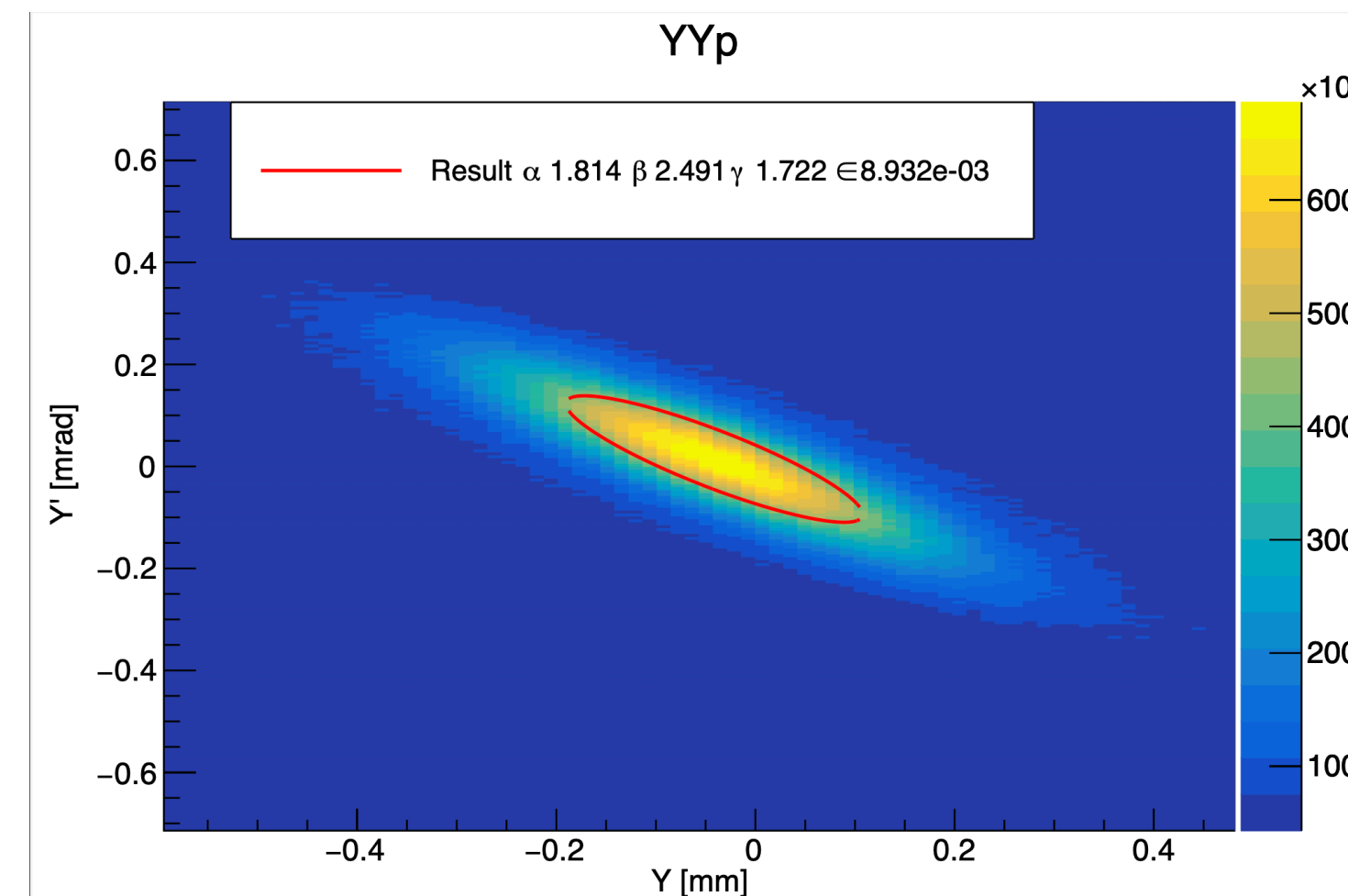
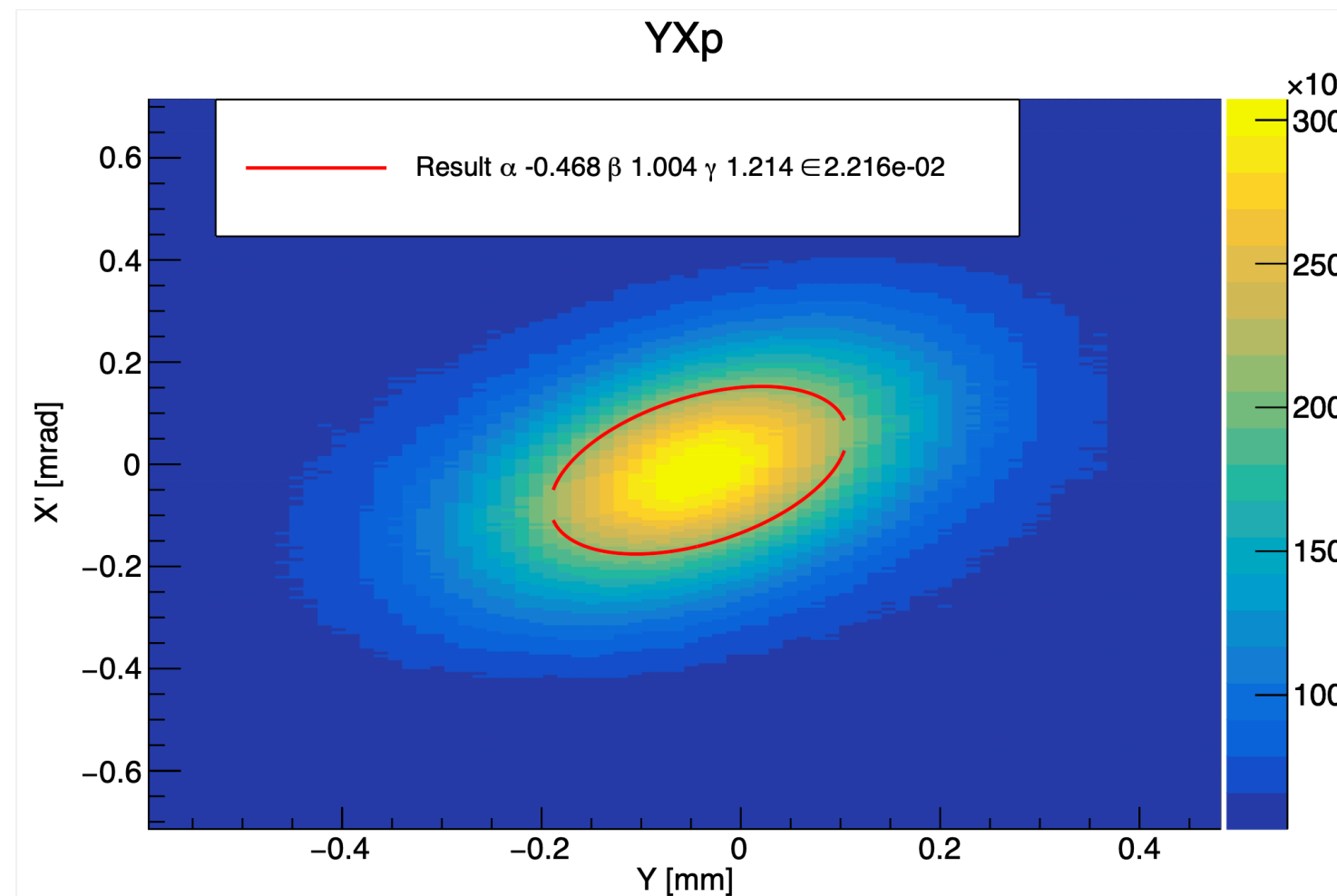


	INPUT	RECON.
α	-0.379	-0.365
β	1.377	1.657
ϵ (nm rad)	23.73	21.24

11%

	INPUT	RECON.
α	-0.479	-0.468
β	0.826	1.004
ϵ (nm rad)	23.87	22.16

7%



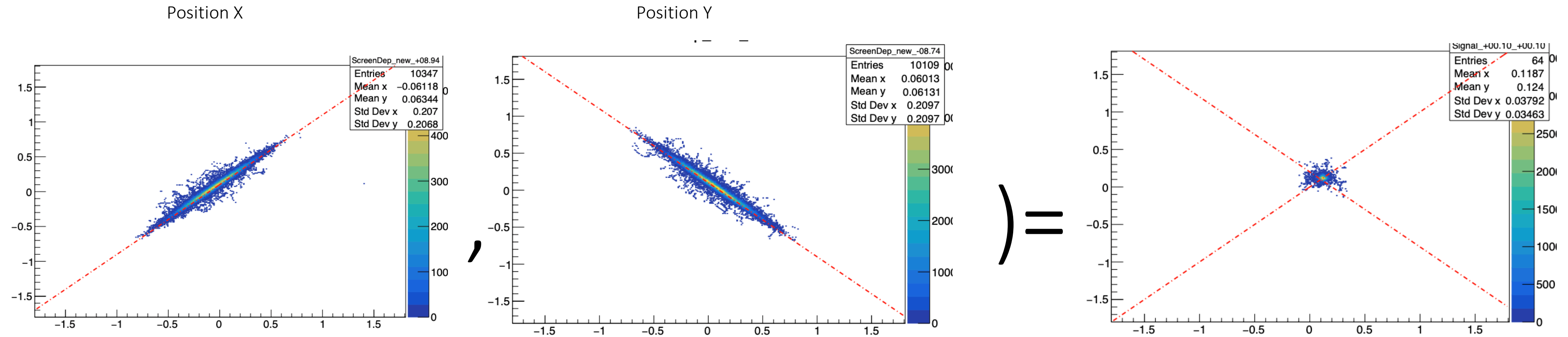
	INPUT	RECON.
α	1.914	1.821
β	2.161	2.496
ϵ (nm rad)	9.137	8.932

2%

Comparison

VPP

Min (

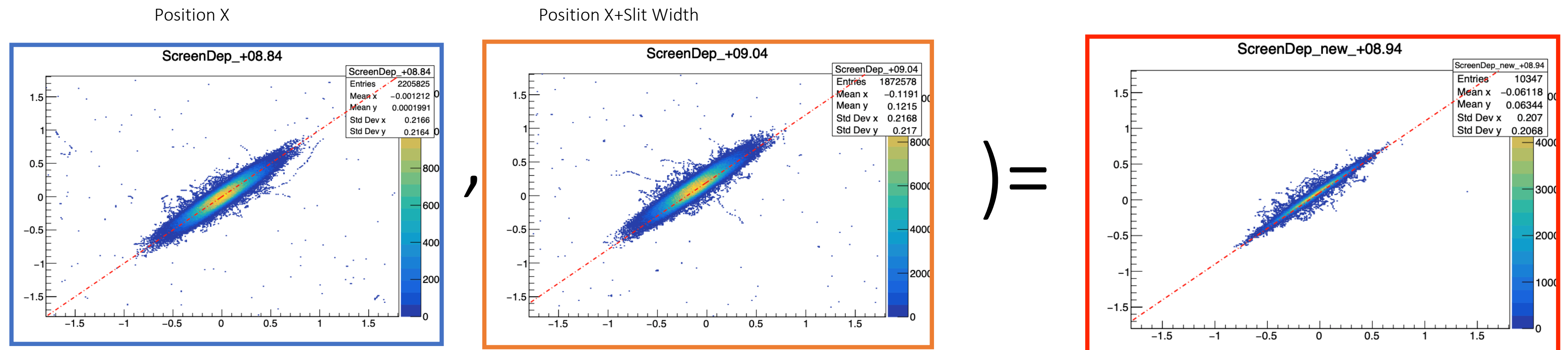


) =

Differential

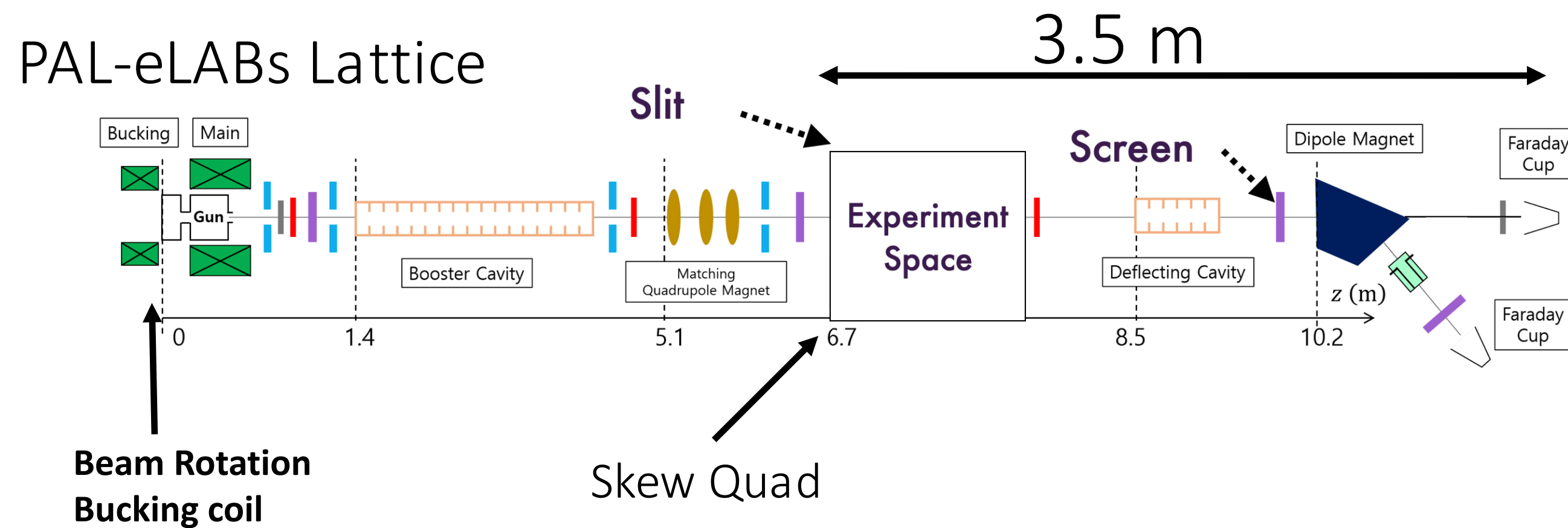
Slit

Min (



) =

Experiment Plan & Summary



by End of this Year

Summary

- **Differential Slit: solve Slit width uncertainty with simple technique**
 - ⇒ **Apply all slit-screen method**
 - ⇒ **VPP with Differential Slit: precise 4D emittance analyzer**