

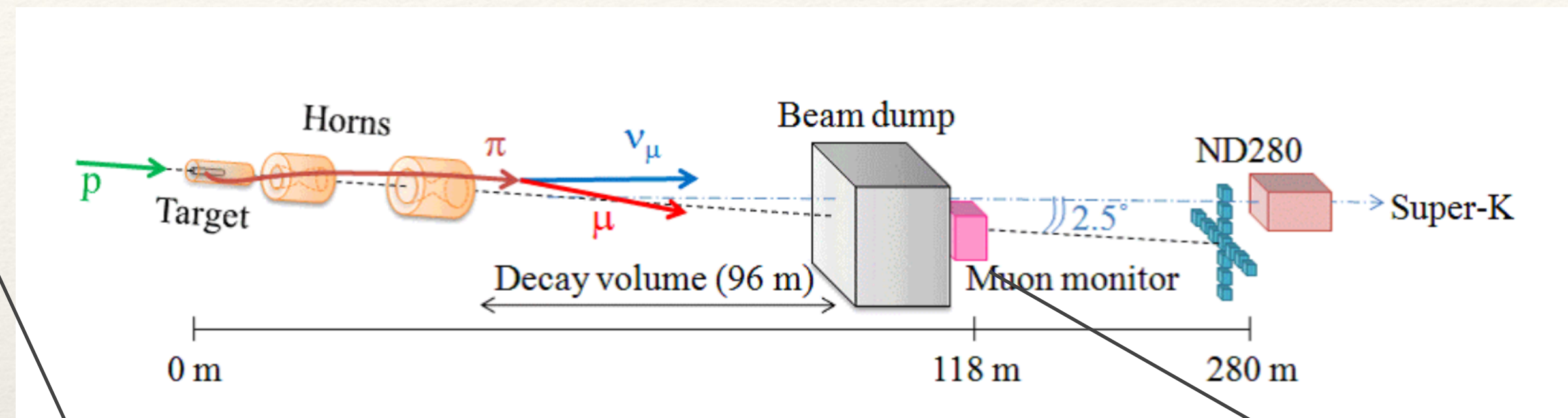
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# T2K Notebook

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Nov 5th 2024

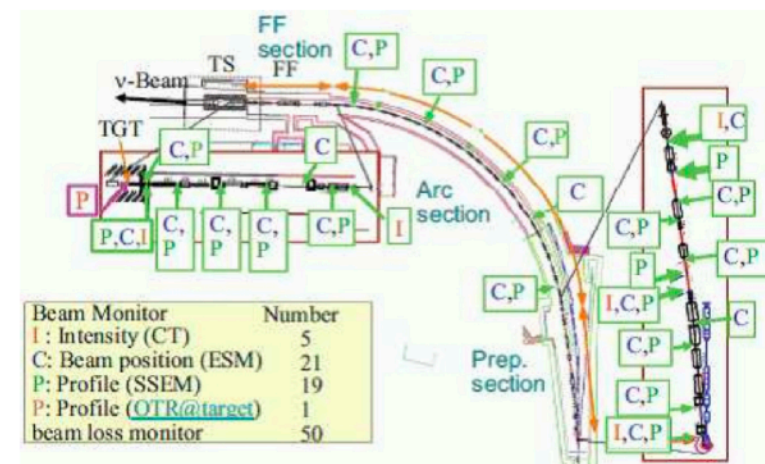
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# T2K Primary Beam & Muon Monitors



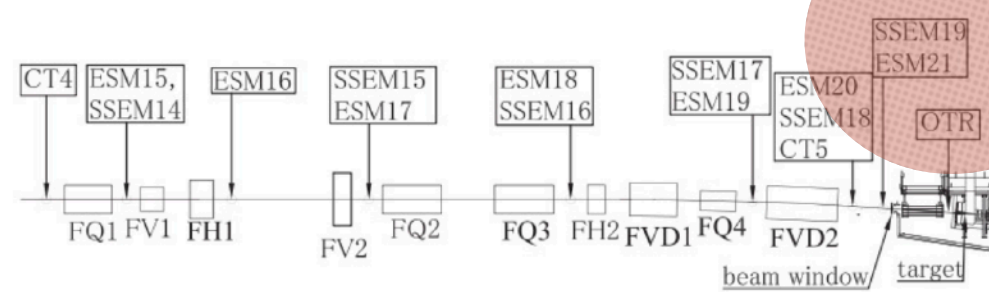
## T2K Primary Beam Monitors

### Primary Beamline Monitors



### Final Focusing Section (these are used for flux simulation inputs)

### Beam Direction →



- 19 SSEMs (Segmented Secondary Emission Monitors) – monitor beam profile
- 21 ESMs (Electrostatic Monitors) – monitor beam position
- 50 BLMs (Beam Loss Monitors) – monitor beam loss
- 5 CTs (Current Transformers) – monitor beam current
- 1 OTR (Optical Transition Radiation) Monitor – monitors beam profile at target
- MUMON (Muon Monitor) – monitors muon flux/profile after target

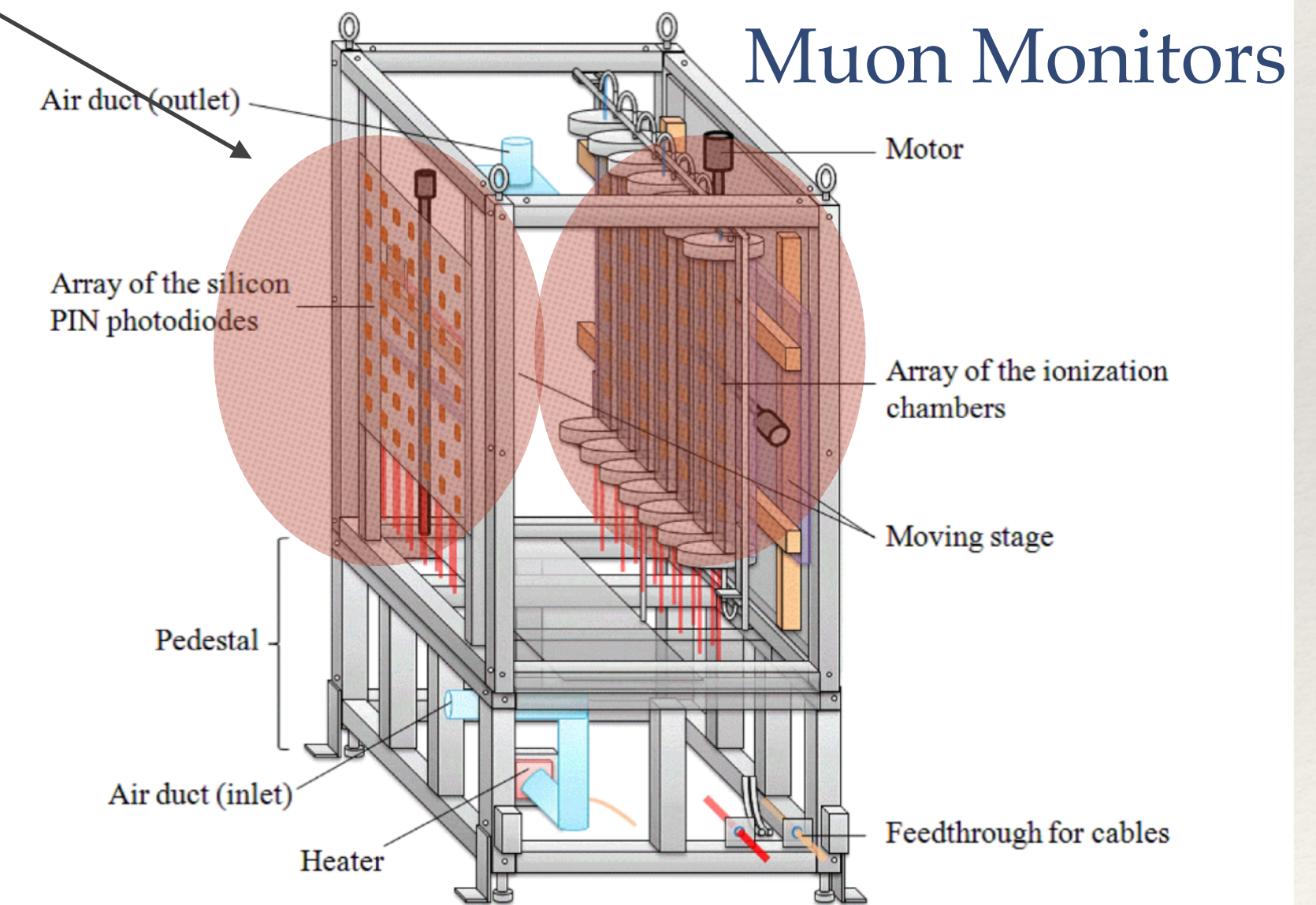


Fig. 3. Schematic view of the muon monitor. The beam enters from the left side. On the upstream side, 49 silicon PIN photodiodes are placed on the support enclosure. On the downstream side, the large moving stage holds seven ionization chambers, each of which contains seven sensors. The whole structure is covered with aluminum insulation panels, which are not drawn in the figure.

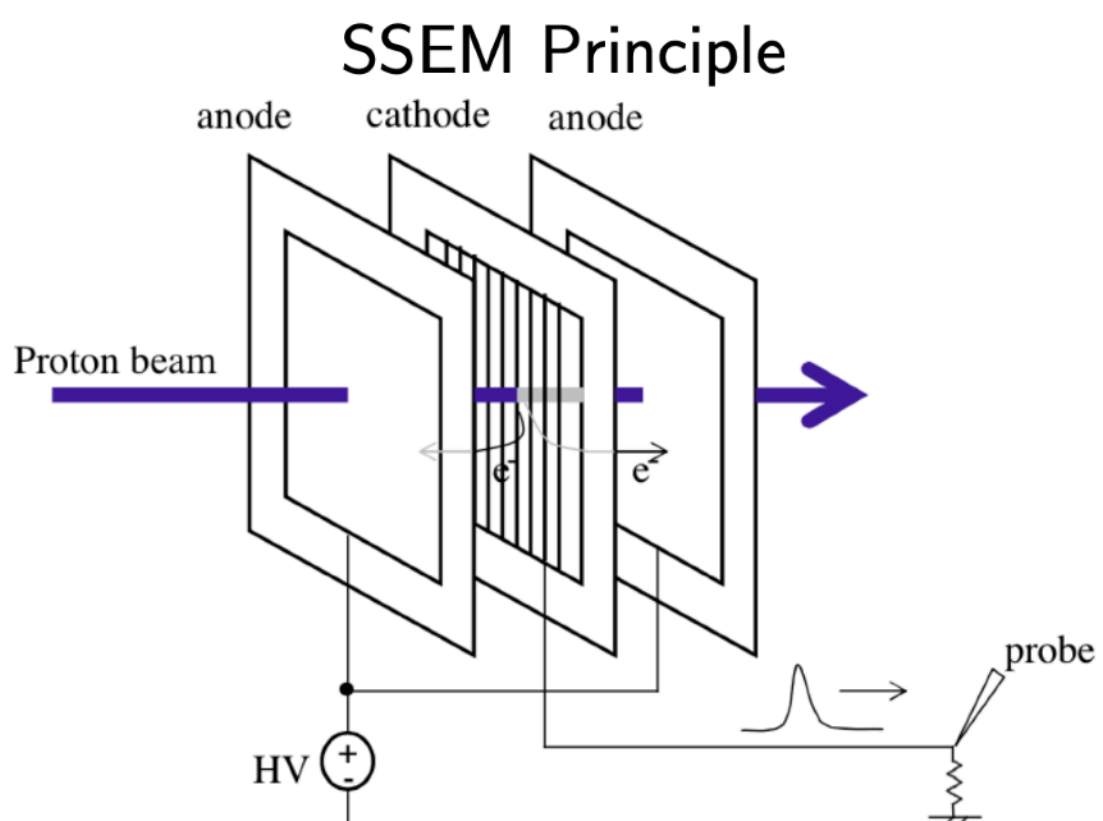
# Beam Monitors

## ❖ BEAM PROFILE MONITORS

### ❖ SSEM ( Segmented Secondary Emission Monitors)

**J-PARC NU SSEM Principle and Design**

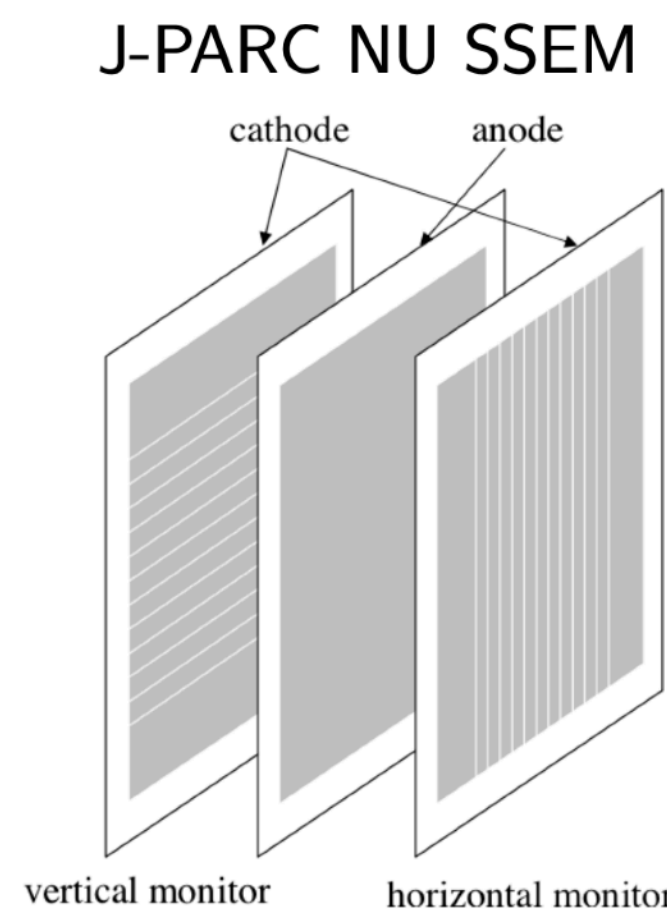
**SSEM Principle**



The diagram shows a proton beam entering from the left, passing through an anode, a cathode, and another anode. The cathode is segmented into vertical strips. Secondary electrons (e-) are emitted from the cathode and collected by the anodes. A high voltage (HV) source is connected to the anodes. A probe is connected to the anodes to measure the signal.

- Protons interact with foils
- Secondary electrons are emitted from segmented cathode plane and collected on anode planes
- Compensating charge in each cathode strip is read out as positive polarity signal

**J-PARC NU SSEM**



The diagram shows a vertical monitor and a horizontal monitor. Each monitor consists of a cathode and an anode. The cathode is segmented into vertical strips. The anode is a single plane between two stripped cathode planes. The foils are 5 μm thick Ti.

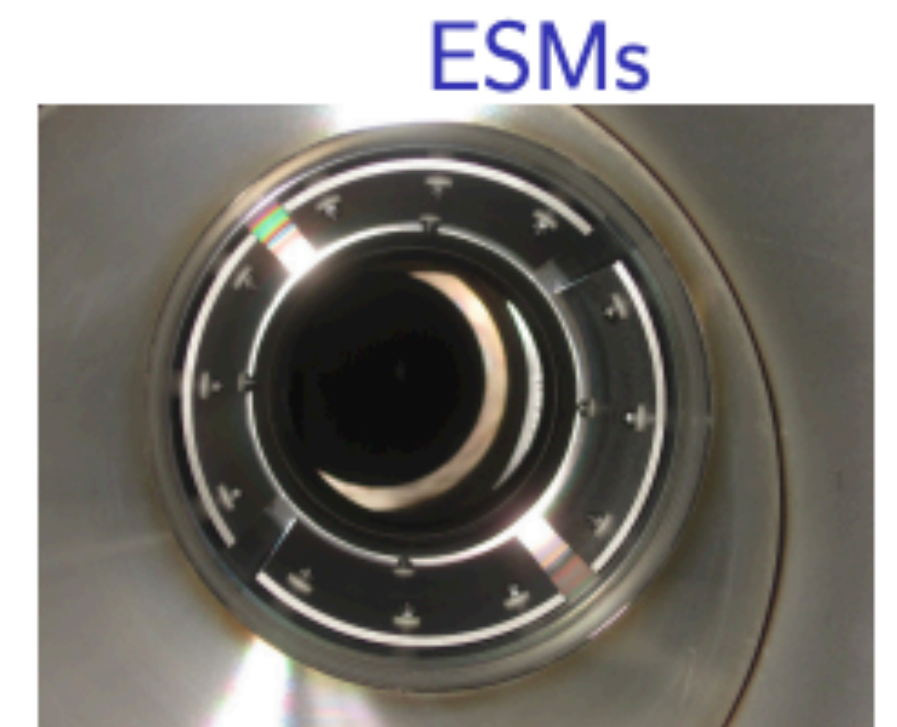
- Single anode plane between two stripped cathode planes
- 5 μm thick Ti foils

## ❖ BEAM POSITION MONITORS

### ❖ ESM (Electrostatic Monitors)

#### 21 ESMs (Electrostatic Monitor)

- Four segmented cylindrical electrodes surrounding the proton beam orbit (80° coverage)
- Non-destructively, continuously monitor the proton beam position using a top-bottom and left-right asymmetry of the beam-induced current on each electrode
  - 4 ESMs were rotated by 45° last year
- Precision on the beam position is better than 450 μm
- However, ESMs are used for monitoring stability of beam position, rather than for calculating absolute beam position
  - ESM19, 20, 21 monitor the beam position nearest the target and are used in determining the proton beam parameters for the flux prediction (when SSEMs are OUT)



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# What I could dig out from the data

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- ❖ two different beam intensities
  - ❖ muana\_run0910178\_00.root is at 600kW beam power,
  - ❖ muana\_run0910086\_00.root is at 400 kW beam power

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# Muon Monitors Data Structure

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- ❖ music (silicon sensors)/ muic (ionization chamber sensors):
  - ❖ sum[9]: adc sum
  - ❖ Q[7][7][9]: integrated charge for each sensor
  - ❖ fit[5][9]: gaus fit parameters ([0]: const, [1]: x center, [2]: x sigma, [3]: y center, [4]: y sigma)
  - ❖ wmeanx / y[9]: im not sure
  - ❖ ped[7][7]: pedestal values for each sensor
  - ❖ pedrms[7][7]: pedestal rms values
  - ❖ fitF[9]: fit fitness? not sure

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# Beam Monitors Data Structure

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#SSEM (beam profile monitor), only SSEM19 (array value [18] is available during continuous operation)

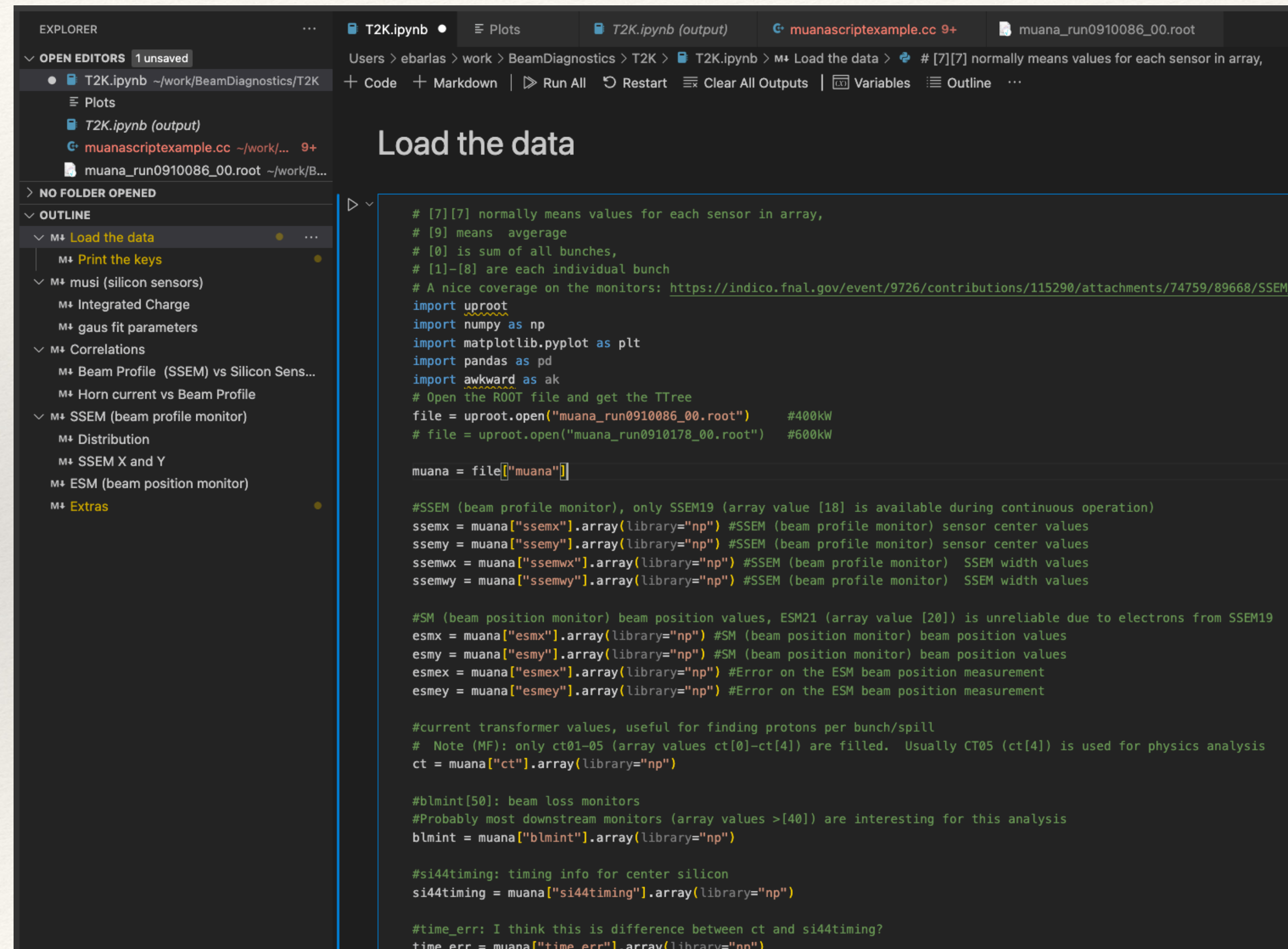
- #SSEM (beam profile monitor) sensor x center values
- #SSEM (beam profile monitor) sensor y center values
- #SSEM (beam profile monitor) SSEM x width values
- #SSEM (beam profile monitor) SSEM ywidth values

#SM (beam position monitor) beam position values, ESM21 (array value [20]) is unreliable due to electrons from SSEM19

- #SM (beam position monitor) beam position values
- #SM (beam position monitor) beam position values
- #Error on the ESM beam position measurement
- #Error on the ESM beam position measurement

# What I could dig out from the data

- ❖ Implemented the data structure into a Jupyter notebook
- ❖ Loaded all the necessary parts which is relevant to us. It's very straightforward to check these parts and their correlation now



The screenshot shows a Jupyter Notebook interface with a dark theme. The left sidebar contains an Explorer and Outline view. The main area displays a code cell titled "Load the data" with the following Python code:

```
Users > ebarlas > work > BeamDiagnostics > T2K > T2K.ipynb > m+ Load the data > # [7][7] normally means values for each sensor in array,
+ Code + Markdown | ▶ Run All ↺ Restart ≡ Clear All Outputs | 📄 Variables ≡ Outline ...

Load the data

# [7][7] normally means values for each sensor in array,
# [9] means average
# [0] is sum of all bunches,
# [1]-[8] are each individual bunch
# A nice coverage on the monitors: https://indico.fnal.gov/event/9726/contributions/115290/attachments/74759/89668/SSEM\_t
import uproot
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
import awkward as ak
# Open the ROOT file and get the TTree
file = uproot.open("muana_run0910086_00.root") #400kW
# file = uproot.open("muana_run0910178_00.root") #600kW

muana = file["muana"]

#SSEM (beam profile monitor), only SSEM19 (array value [18] is available during continuous operation)
ssemx = muana["ssemx"].array(library="np") #SSEM (beam profile monitor) sensor center values
ssemy = muana["ssemy"].array(library="np") #SSEM (beam profile monitor) sensor center values
ssemwx = muana["ssemwx"].array(library="np") #SSEM (beam profile monitor) SSEM width values
ssemwy = muana["ssemwy"].array(library="np") #SSEM (beam profile monitor) SSEM width values

#SM (beam position monitor) beam position values, ESM21 (array value [20]) is unreliable due to electrons from SSEM19
esmx = muana["esmx"].array(library="np") #SM (beam position monitor) beam position values
esmy = muana["esmy"].array(library="np") #SM (beam position monitor) beam position values
esmex = muana["esmex"].array(library="np") #Error on the ESM beam position measurement
esmey = muana["esmey"].array(library="np") #Error on the ESM beam position measurement

#current transformer values, useful for finding protons per bunch/spill
# Note (MF): only ct01-05 (array values ct[0]-ct[4]) are filled. Usually CT05 (ct[4]) is used for physics analysis
ct = muana["ct"].array(library="np")

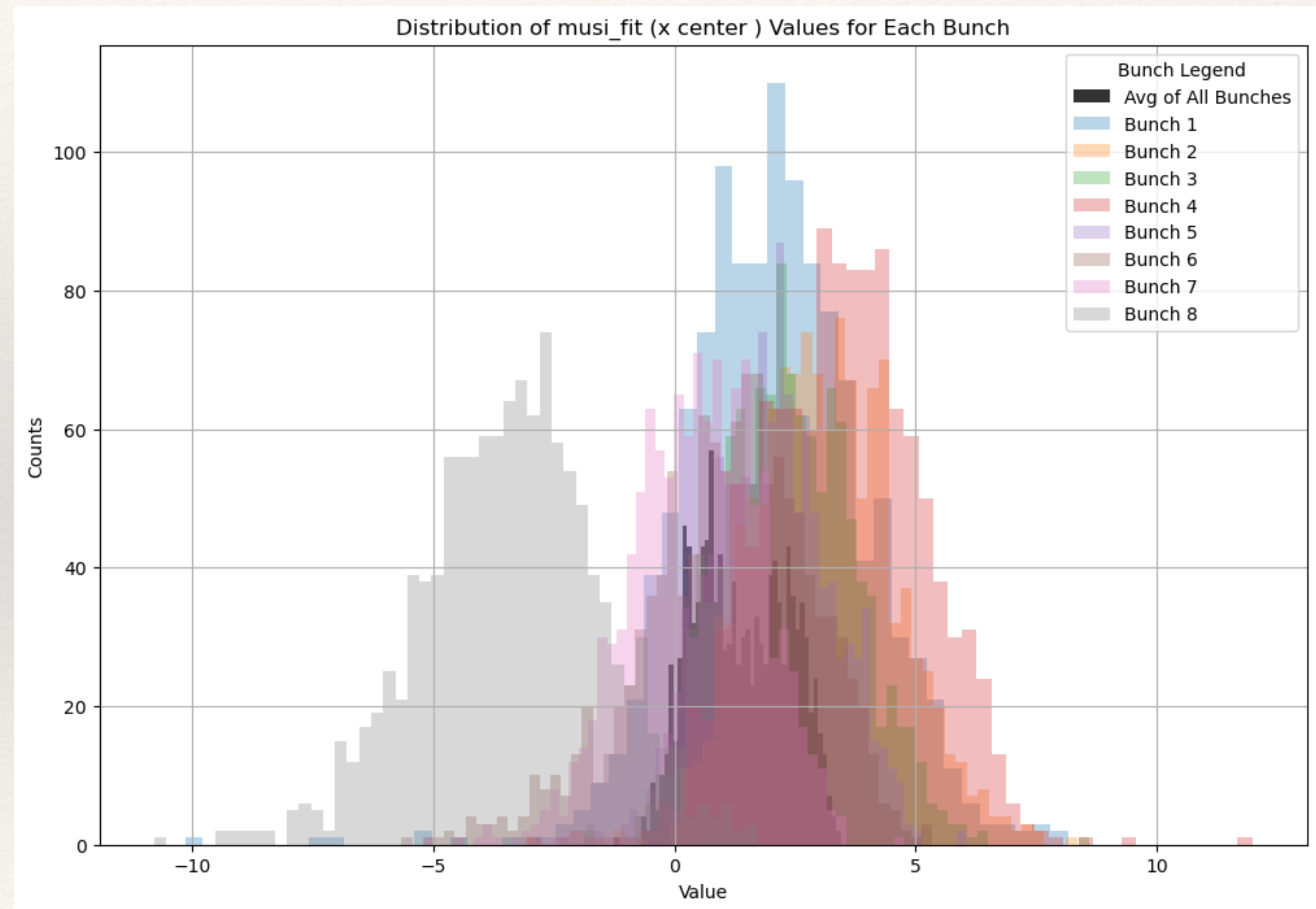
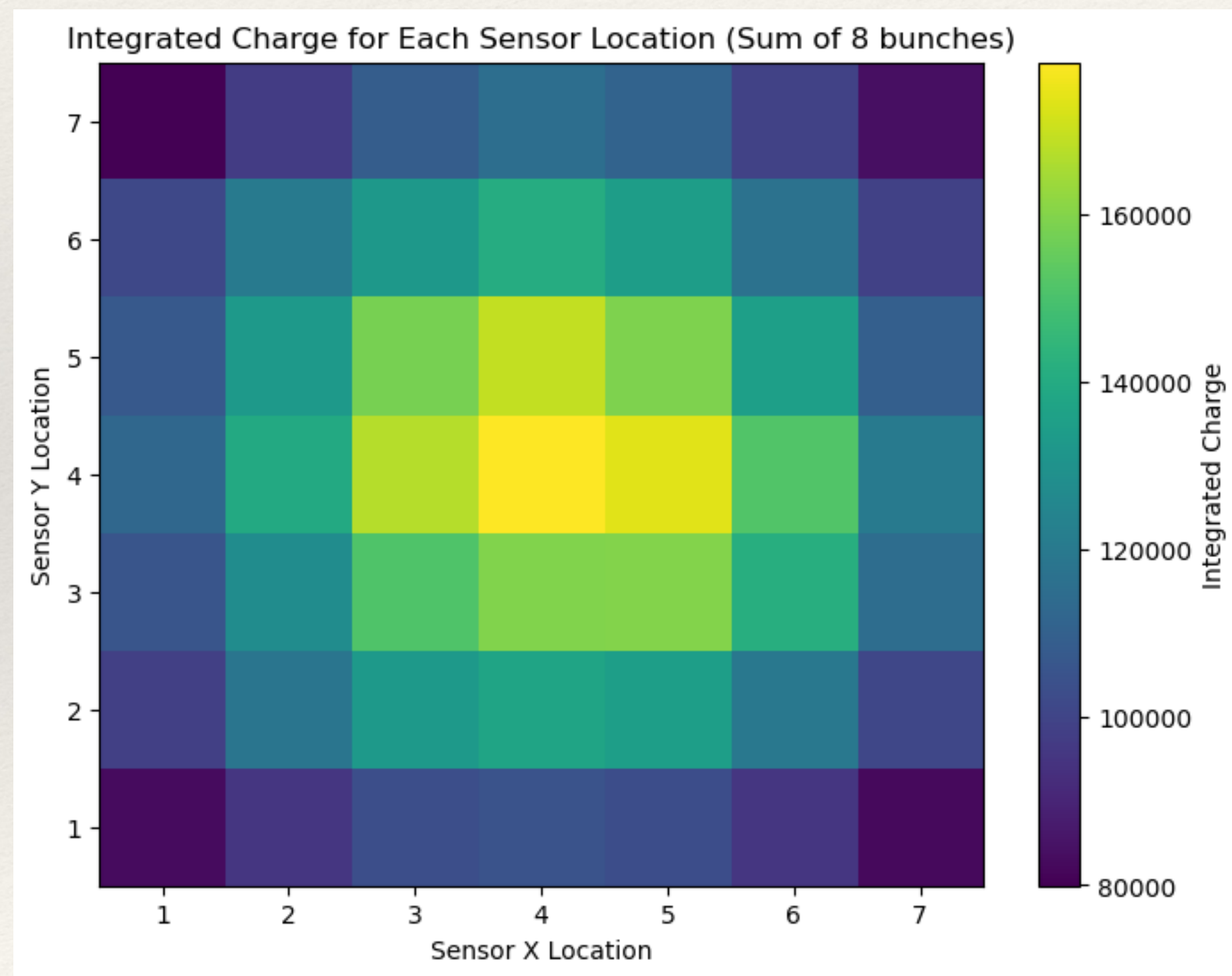
#blmint[50]: beam loss monitors
#Probably most downstream monitors (array values >[40]) are interesting for this analysis
blmint = muana["blmint"].array(library="np")

#si44timing: timing info for center silicon
si44timing = muana["si44timing"].array(library="np")

#time_err: I think this is difference between ct and si44timing?
time_err = muana["time_err"].array(library="np")
```

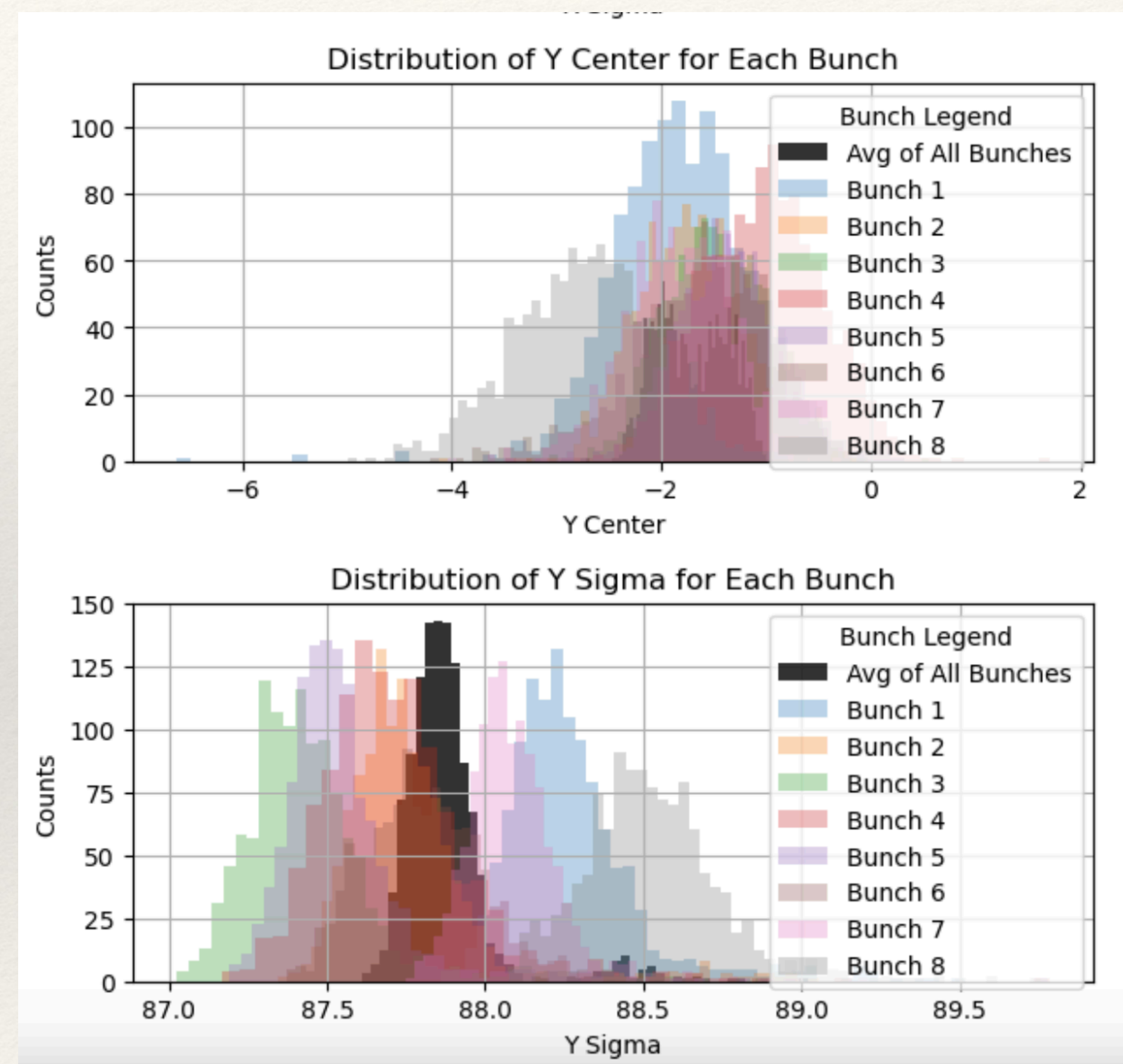
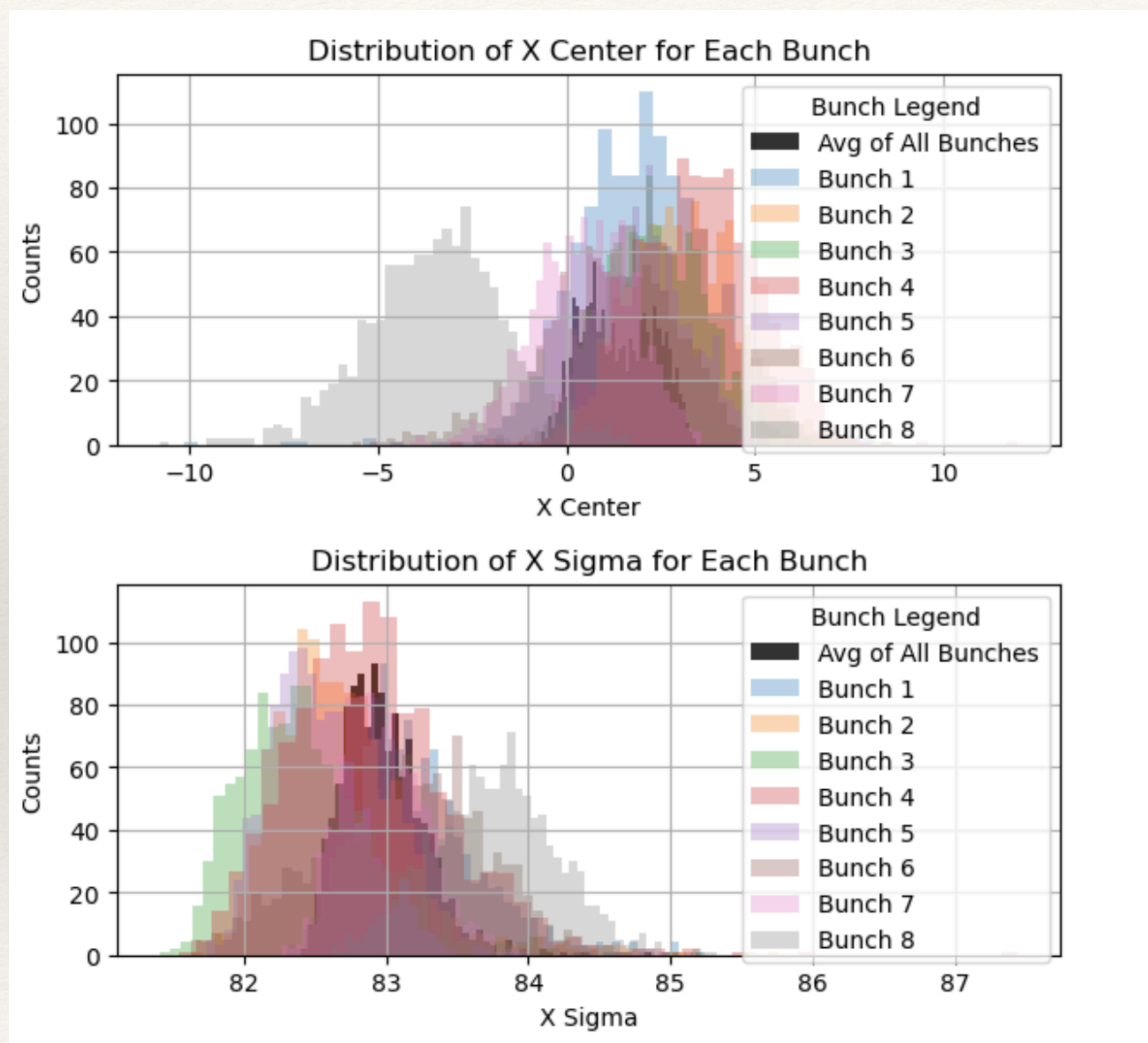
# What I could dig out from the data (Musi-Silicon Sensors)

## Integrated Charge



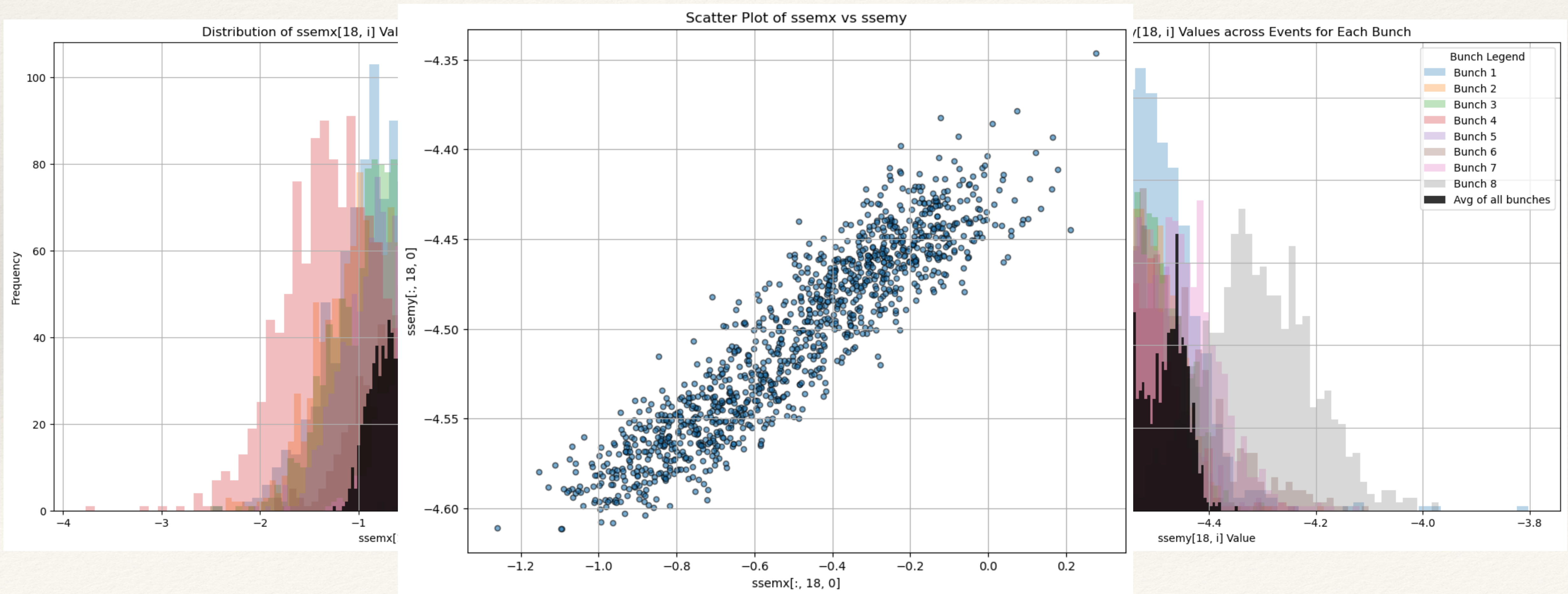


# What I could dig out from the data (Musi-Silicon Sensors)

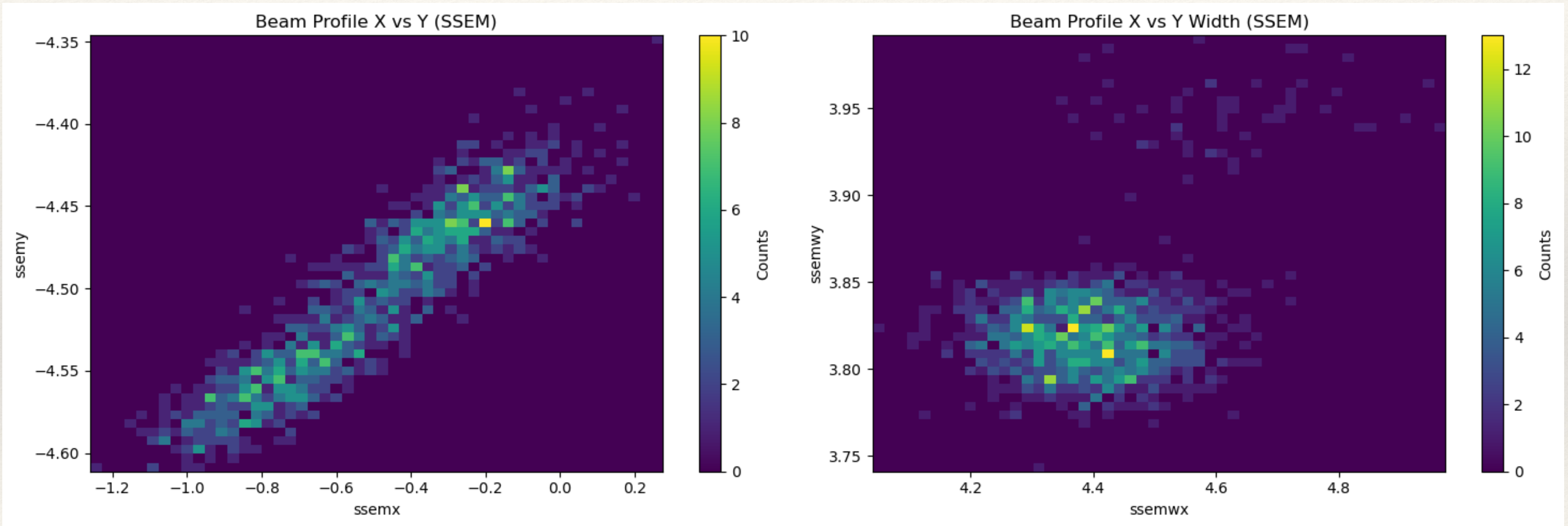


# What I could dig out from the data (SSEM Beam Profile)

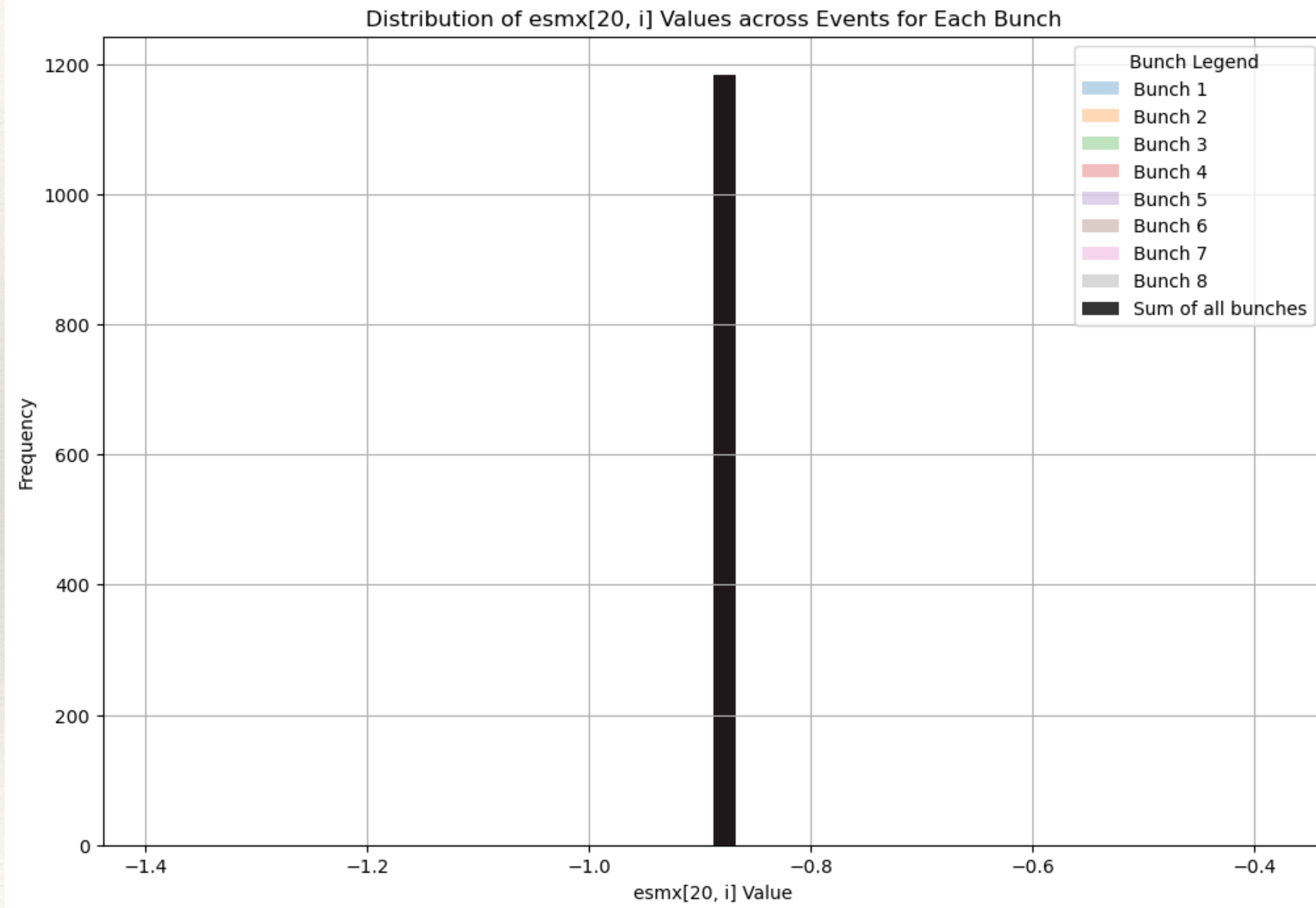
*Distributions of SSEM (beam profile monitor) sensor center values for Different Bunches*



# What I could dig out from the data (SSEM Beam Profile)

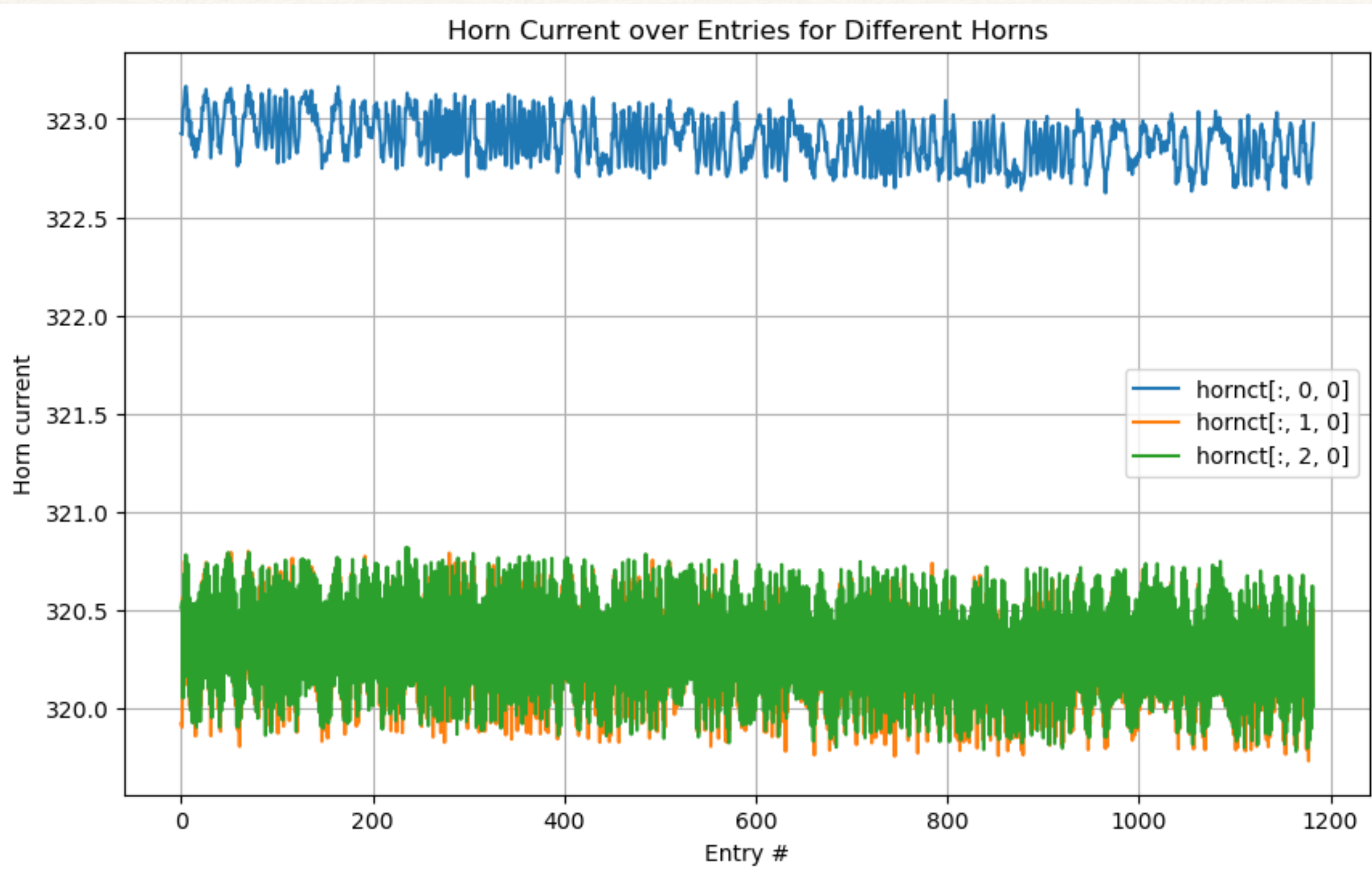


# What I could dig out from the data (ESM Beam Position)



ESM data is empty

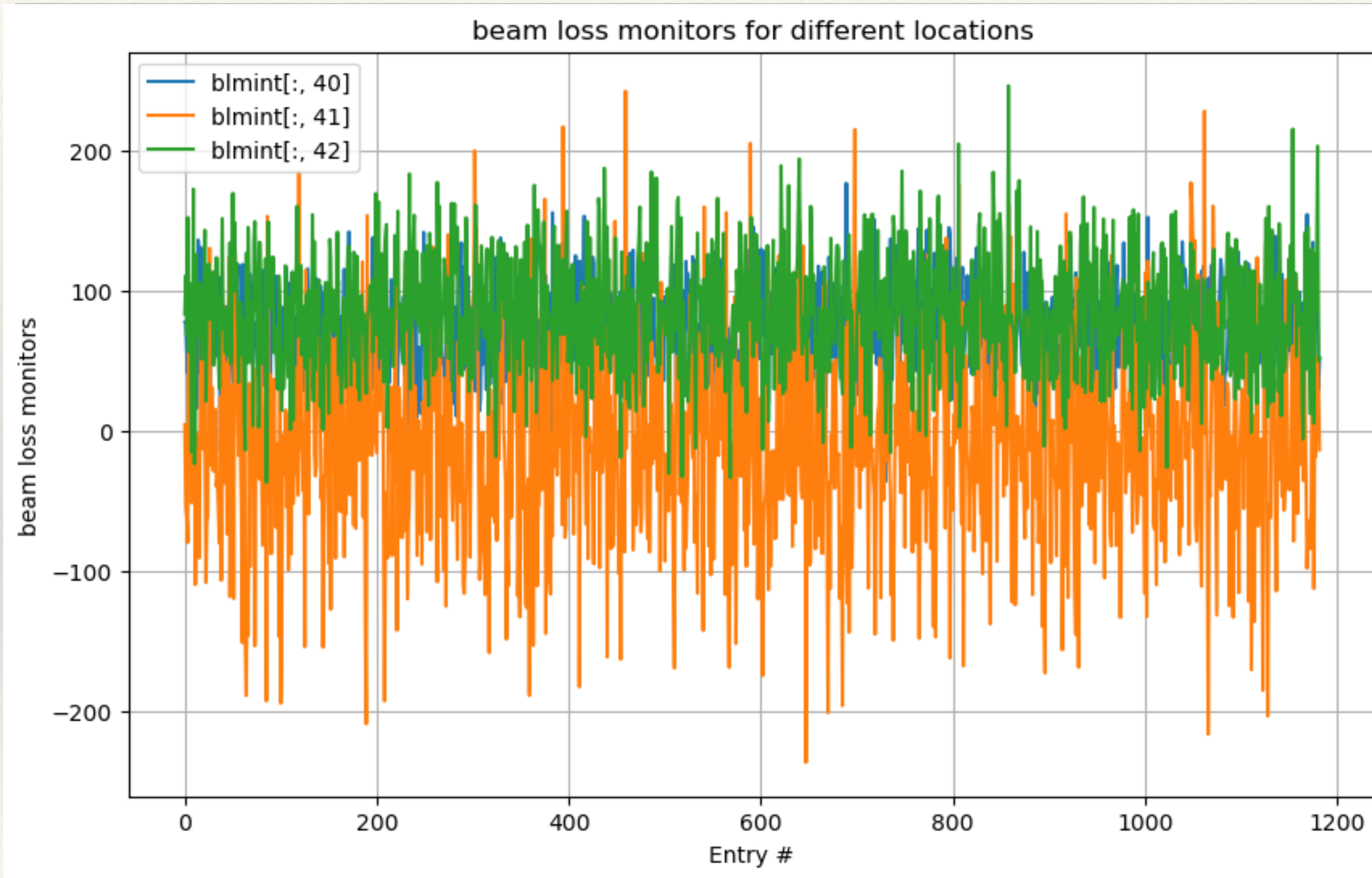
# What I could dig out from the data (Horn Current)



We have 3 entries.

I think they correspond to  
3 different horns?

# What I could dig out from the data (Beam Loss Monitors)

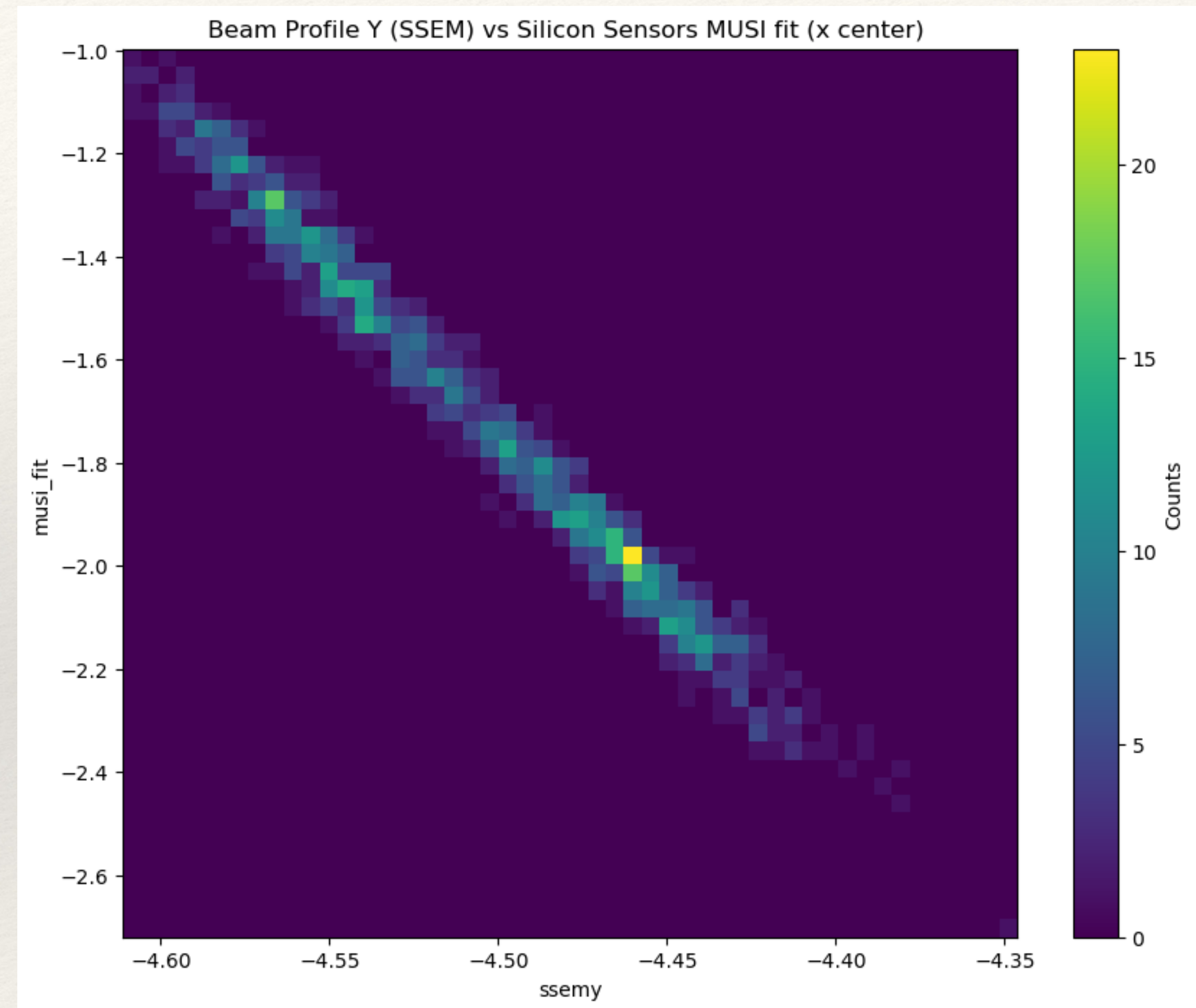
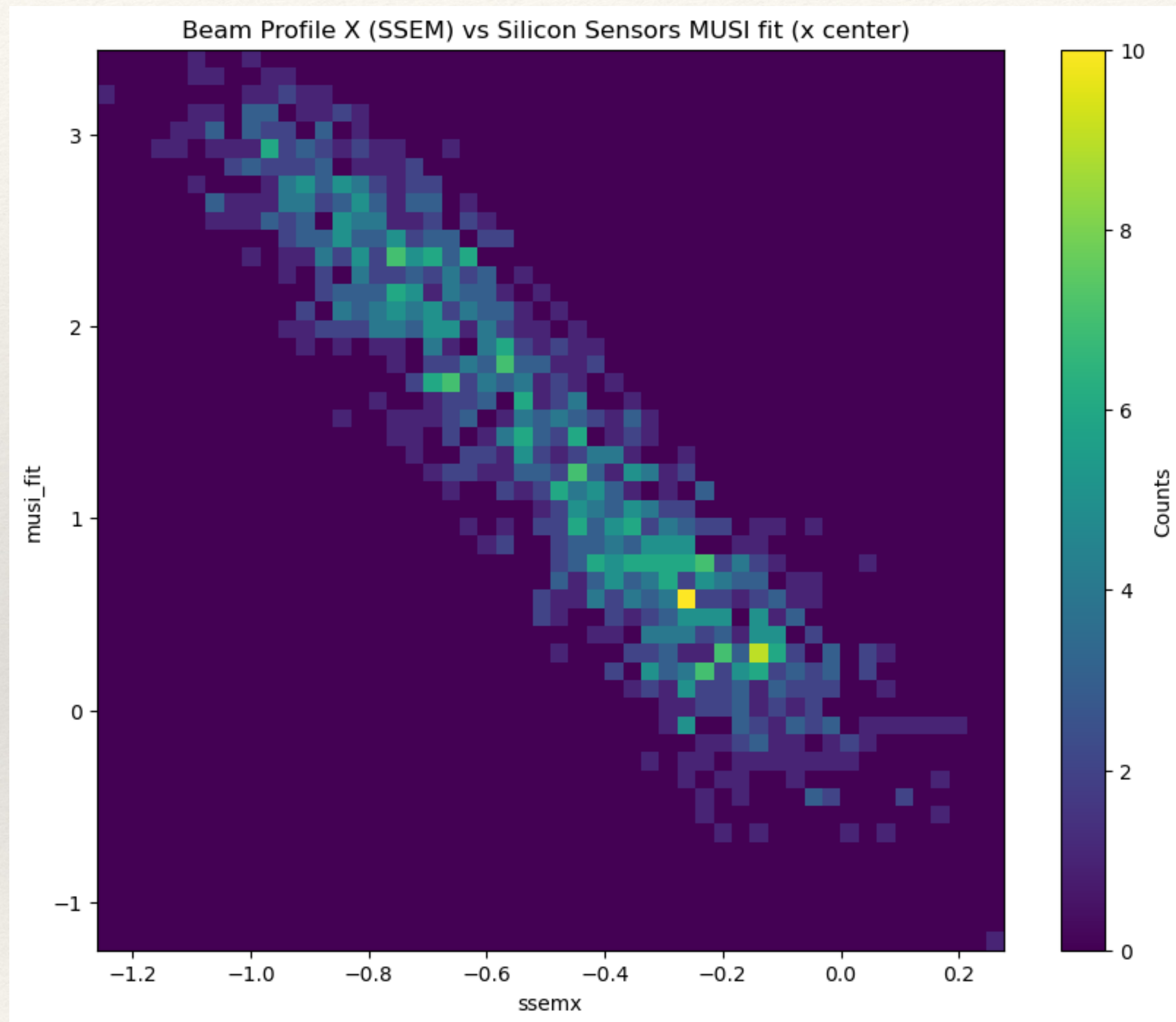


50 monitors.

>40 is related?

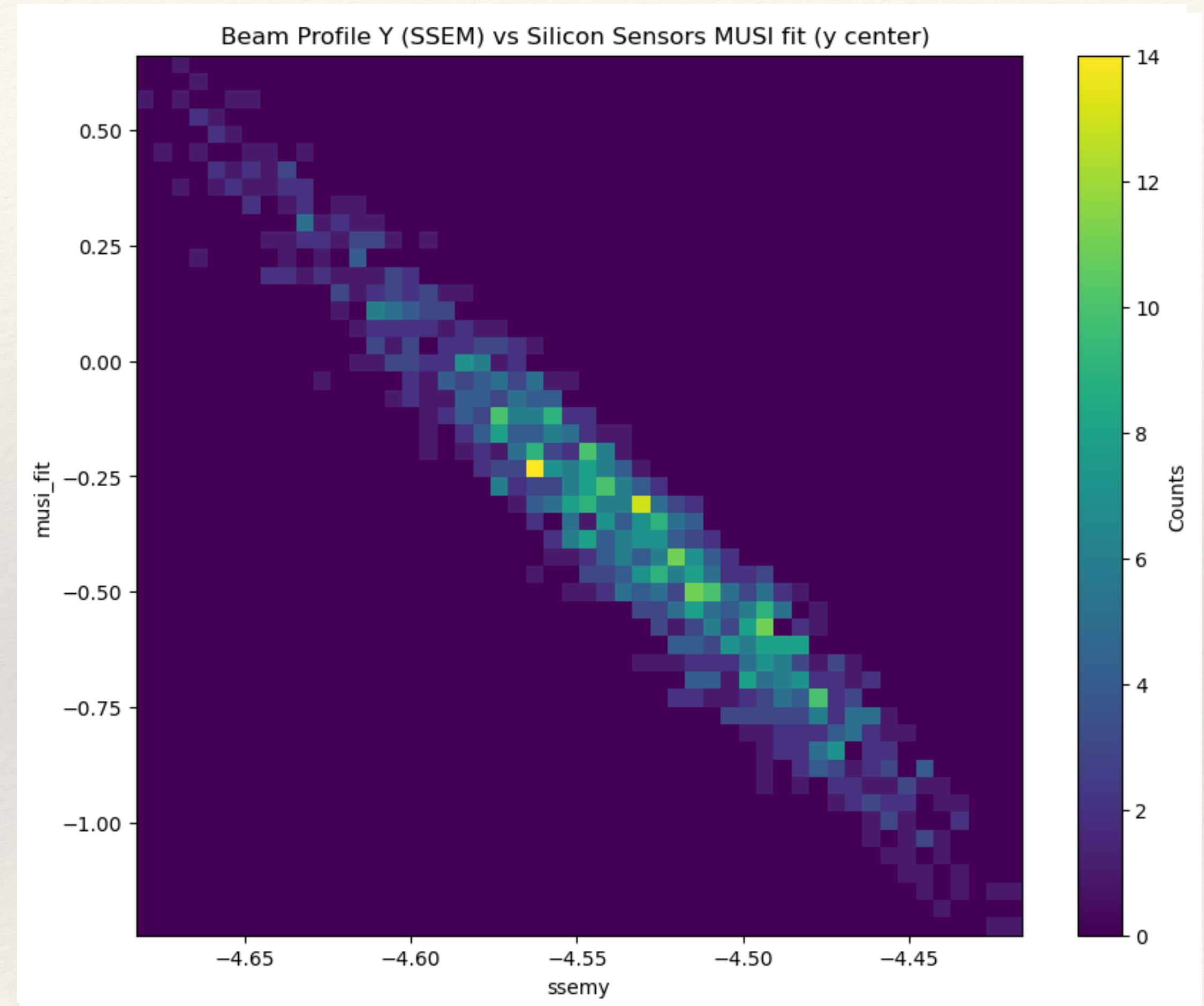
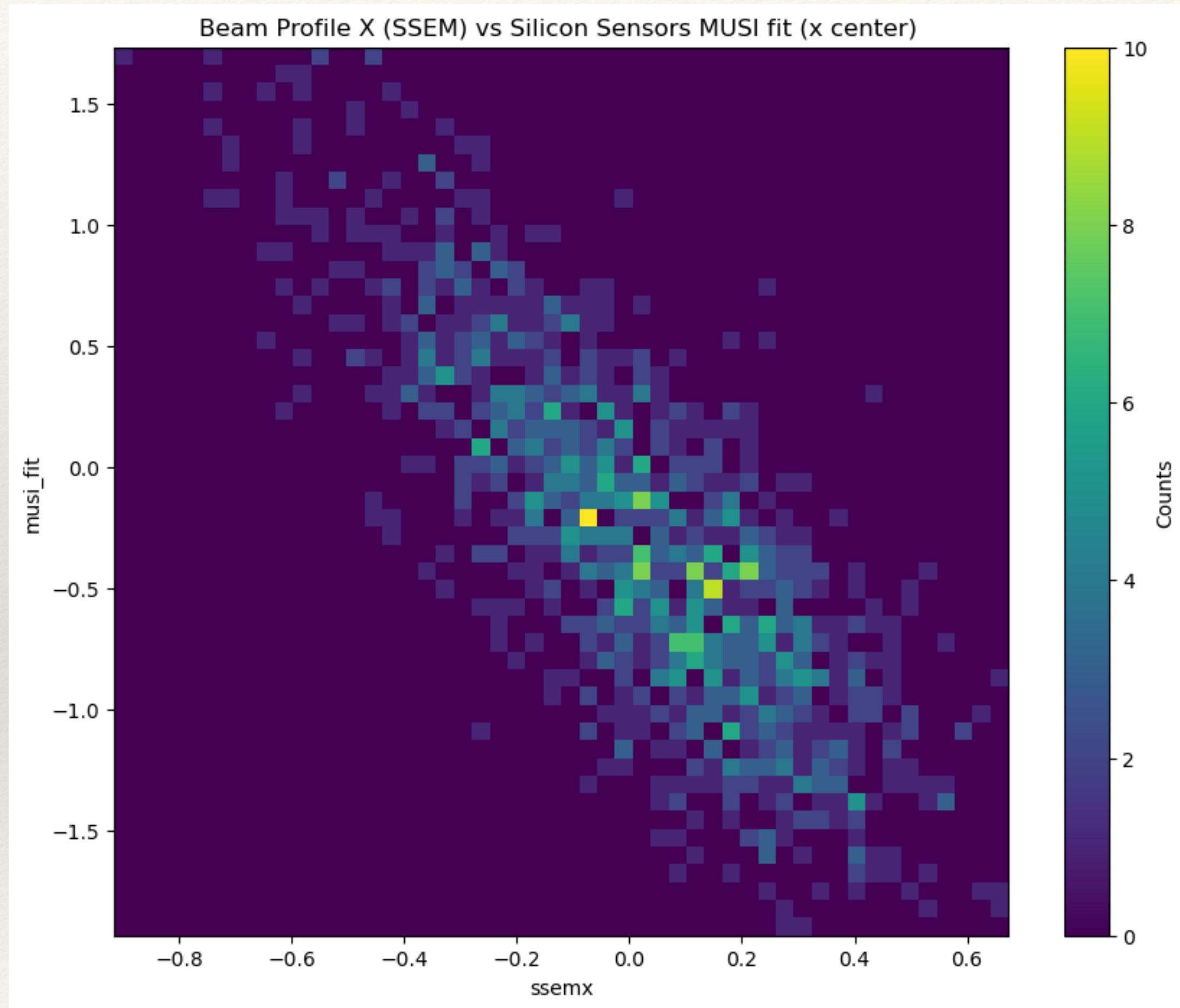
# What I could dig out from the data (Correlations)

400kW



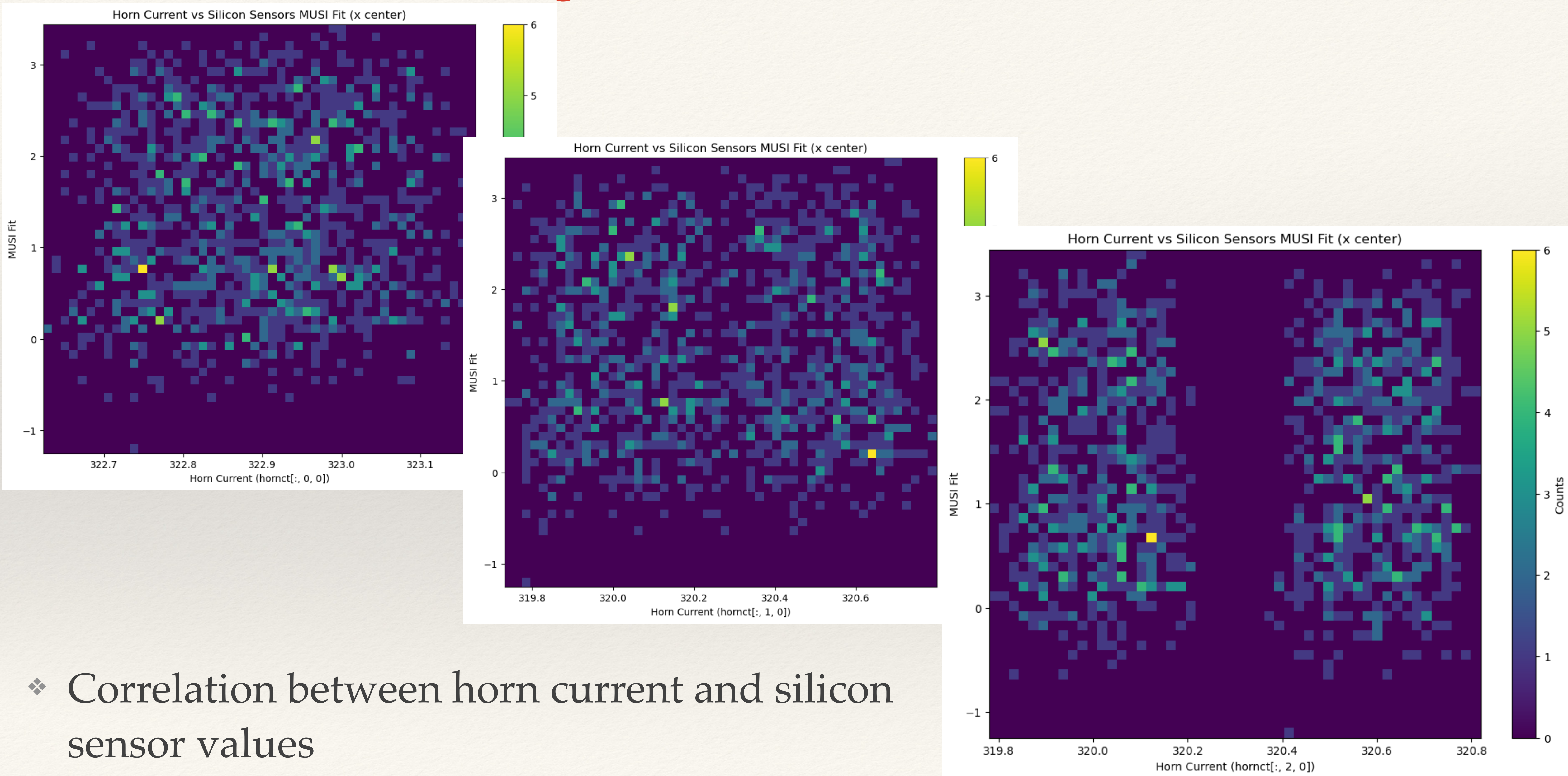
# What I could dig out from the data (Correlations)

600kW





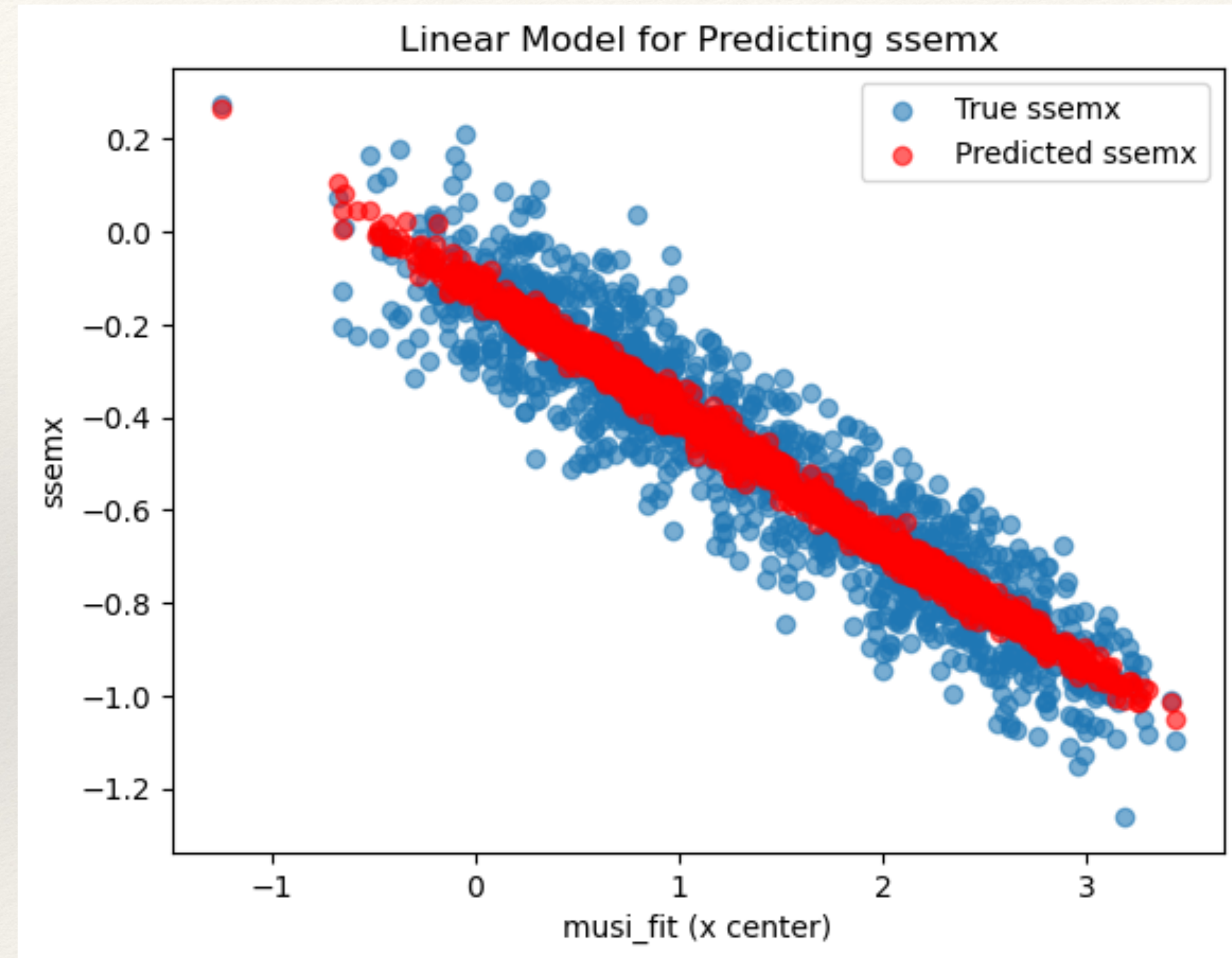
# What I could dig out from the data (Correlations)



- ❖ Correlation between horn current and silicon sensor values

# Linear Regression

- ❖ A simple example of how linear regression can estimate beam profile from muon monitors



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# Questions

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- ❖ Beam positions:
  - ❖ SSEM (beam profile monitor): we have this data
  - ❖ ESM (beam position monitor) beam position values: we don't have this data, is unreliable due to electrons from SSEM19.
  - ❖ pbeamx / y[5] shows fit beam position but not been being filled?