EMCAL Uniformity Studies Summary for Position Scans in 2017 and 2018 Test Beam Runs

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Analysis Status

- Analysis notes (33 pages) with all position scan data (all test beam runs in2017 and 2018 test beams) have been analyzed and compiled

- Analysis codes are available on github: https://github.com/MYOMAO/SPHENIX/tree/master/FullyAuto

T1044-2017 and 2018 sPHENIX Test Beam EMCal Position Scan Analysis

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Abstract

sPHENIX Collaboration conducted test beam experiment at Fermilab Test Beam Facilities in 2017 and 2018 to study the performance of the sPHENIX calorimeter systems. The sPHENIX calorimeter system consists of electromagnetic calorimeter (EMCal) and inner and outer hadronic calorimeter (HCAL). We have conducted energy and position scan to study the uniformity, energy linearity, and energy resolution of the calorimeter systems. In this paper, we will present our detailed analysis on the 2017 and 2018 EMCal position scans to study its uniformity and discuss the possible methods to improve the EMCal uniformity.

Contents

Datasets Used

2017 test beam run (η = 1):

- Second position scan: 0° tilted 8 GeV electrons (recalib)
- Third position scan: 10° tilted 8 GeV electrons (recalib)

2018 test beam run (η = 1):

- Third position scan: sPHENIX position 5 GeV electrons (recalib)
- Four position scan: dual channeling 5 GeV electrons (recalib)
- Fifth position scan: dual channeling 8 GeV electrons (prod)
- Sixth position scan: sPHENIX+5 8 GeV electrons (prod)
- Seventh position scan: sPHENIX position 8 GeV electrons (prod)

Analysis Techniques

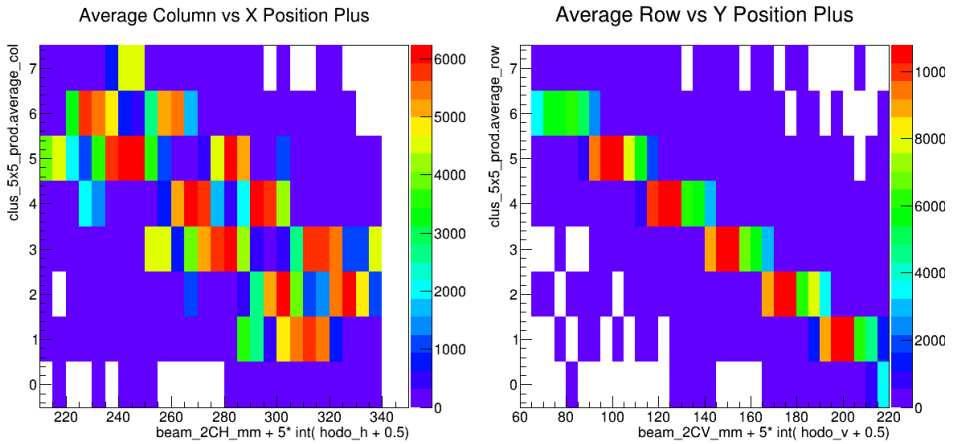
Basic Analysis:

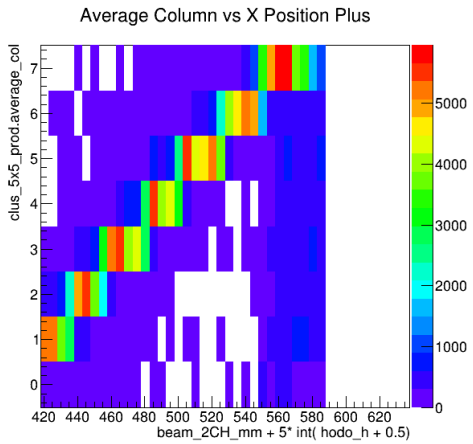
- Step 1: hodoscope corrections
- Step 2: preliminary data assessment (position corrections: prdf vs root files disagreements, 2018 data only and statistics distributions)
- Step 3: mean energy extraction (mean and fits methods)
- Step 4: Interpolation (2017 data only due to non uniformity)

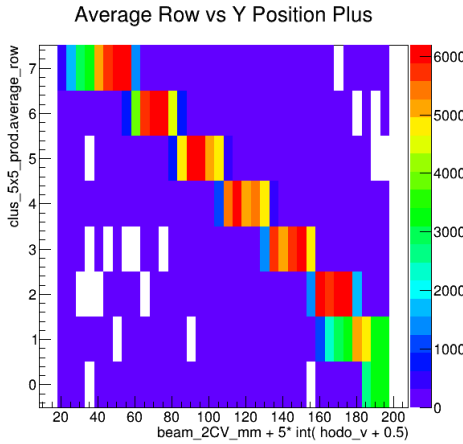
Further Analysis:

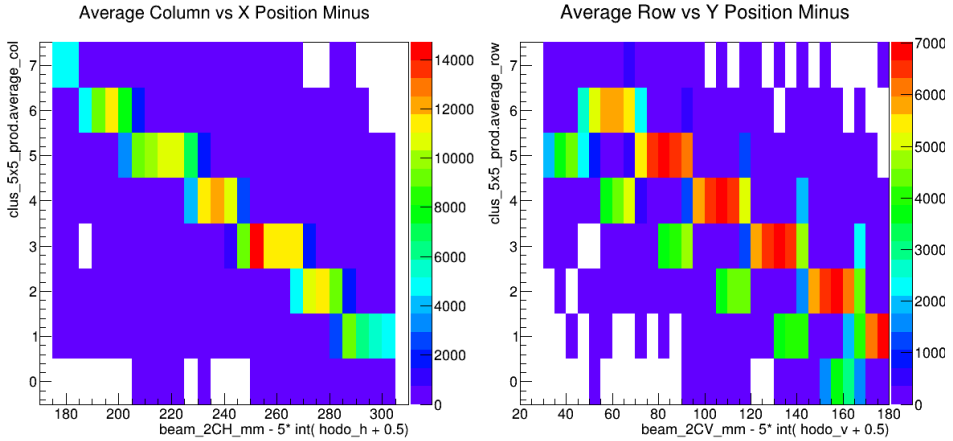
- 1 D Projections and comparisons
- Central 4 × 4 tower comparisons to study uniformity

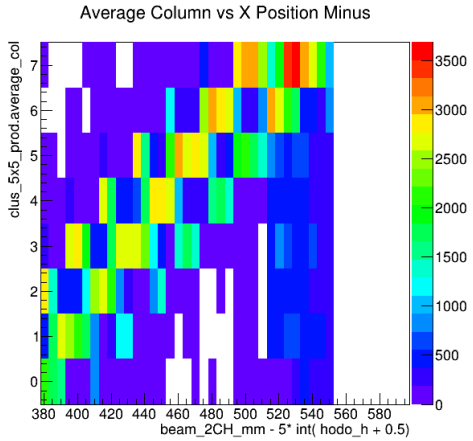
Hodoscope Corrections

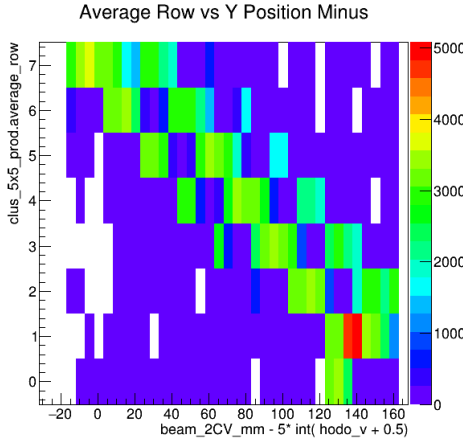












2017 2nd Position Scan

2018 7th Position Scan

All position scans have the same signs for hodoscope corrections (horizontal – and vertical +) except the 2018 7th position scan, which has horizontal + and vertical +.

Position Corrections

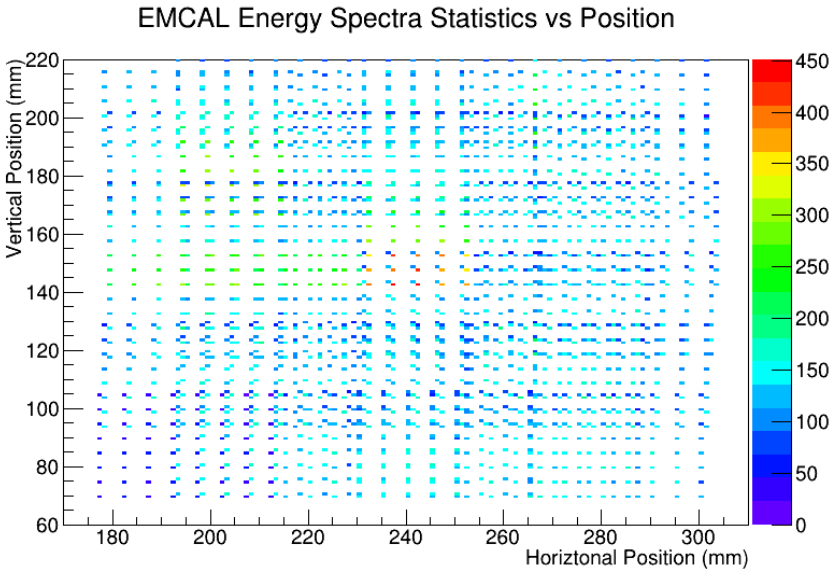
- Disagreement between prdf files and root files for x and y positions in the same run in 2018 test beam runs:

Run Number	prdf file x (mm)	prdf file y (mm)	root file x (mm)	root file y (mm)
901	431.1	98.87	431.1	98.9
902	450.9	98.87	431	98.89
903	471.1	98.87	450.9	98.87
904	491.2	98.86	471.1	98.87
905	510.9	98.9	491.2	98.86
906	531	98.9	510.9	98.9
907	551	98.89	531	98.9
908	570.9	98.92	551	98.89
909	0	98.93	570.9	98.92
910	0	119	0	109.9

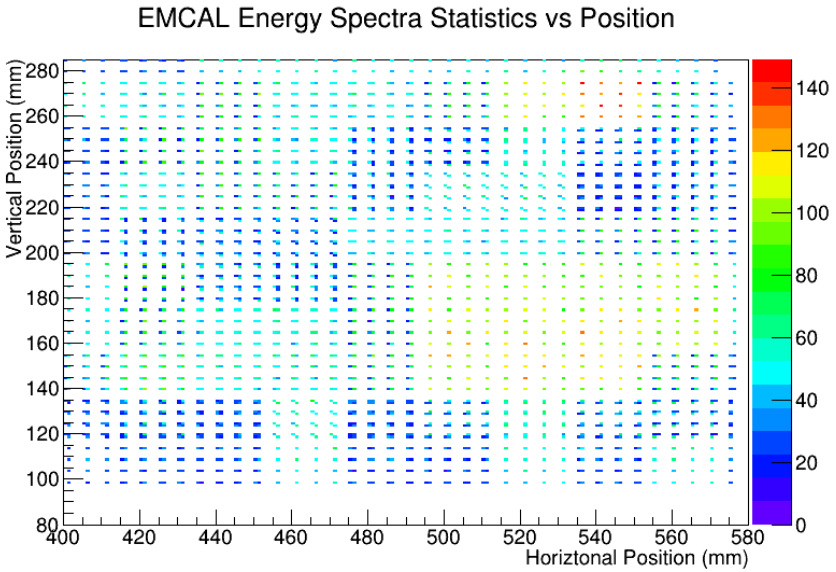
Table 4.1: Horizontal and vertical position prdf files and root files for 10 runs in the fourth position scan in the 2018 test beam run.

- Analysis code correct positions of the root file, which are incorrect, back to the positions of the prdf files positions, which are correct

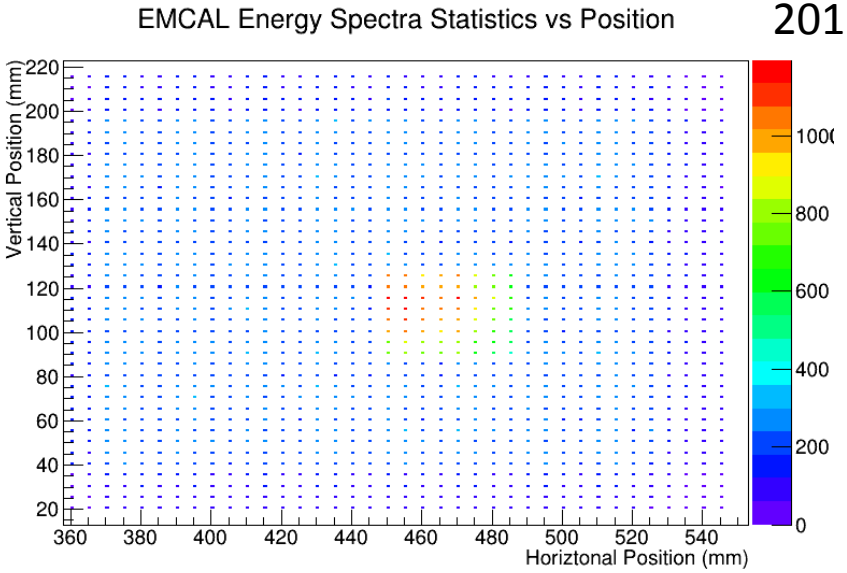
Statistics Distributions



2017 2nd Scan



2018 4th Scan (First Run)



2018 6th Scan (Second Run)

Statistics: second run in 2018 test beam > 2017 test beam > first run in the 2018 test beam

Mean Energy Extraction

Analysis strategies:
1. Collect the position corrected TH3 histogram energy, x, y distribution from the "\.EMCalCalib.root" files with "good_e" (good electrons) selections.

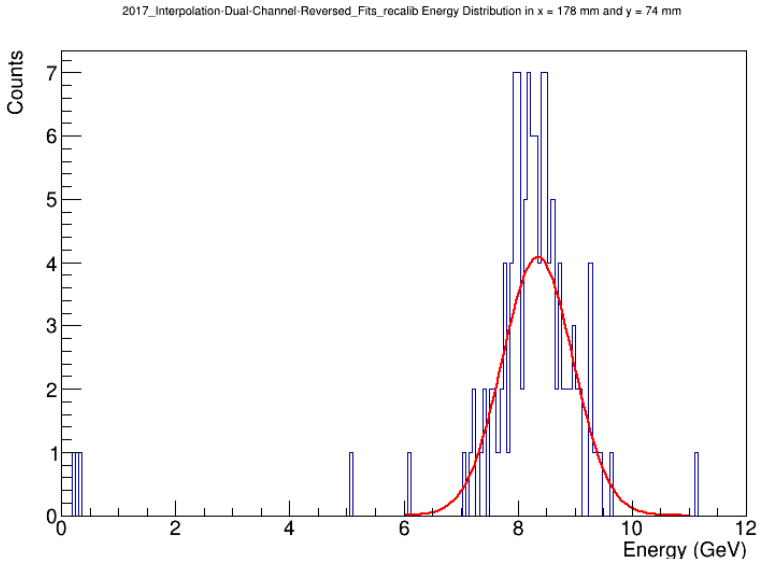
2. Project the TH3 histogram to the 1 mm × 1 mm bins to obtain the energy spectra

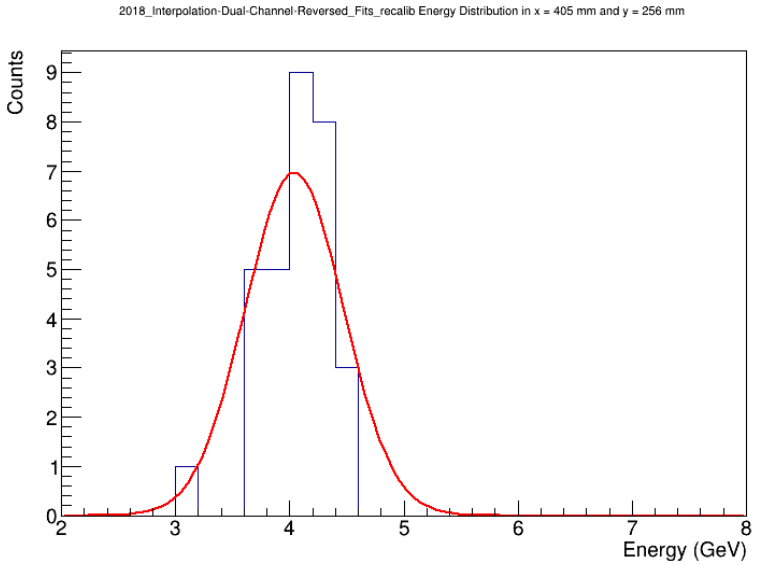
3. Extract the mean from the distribution with mean and Gaussian fits method

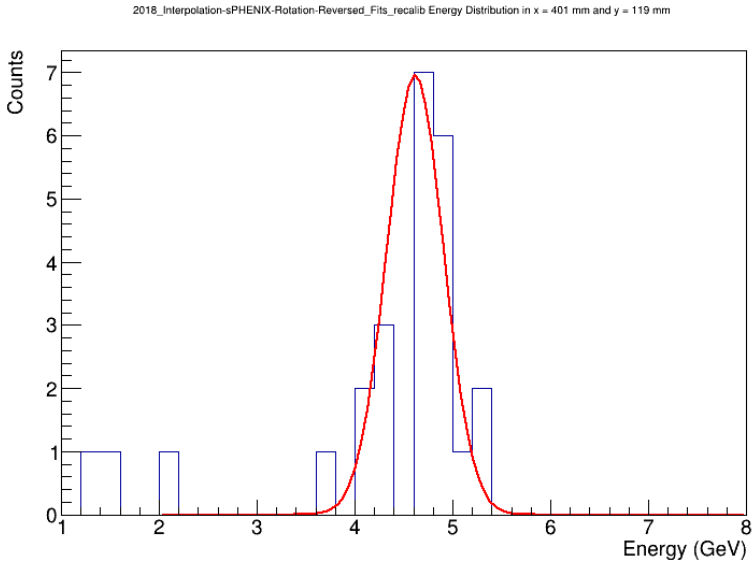
Mean method: take the mean directly from the spectrum. Applicable when the statistics is low but the precision is not as good as the mean method

Fits method: perform a Gaussian fits with certain range near the electron beam energies. Applicable when we have sufficient statistics. It is better to represent the mean energy than the mean method.

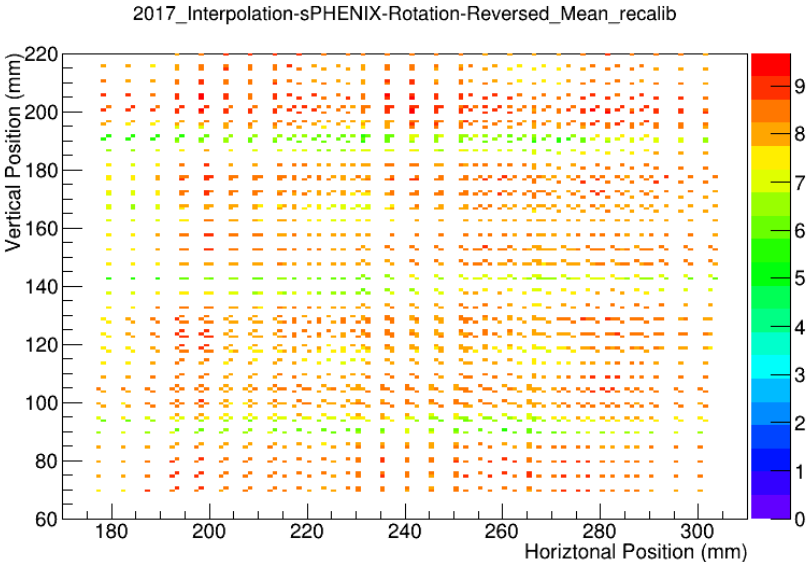
Energy Spectra and Gaussian Fits

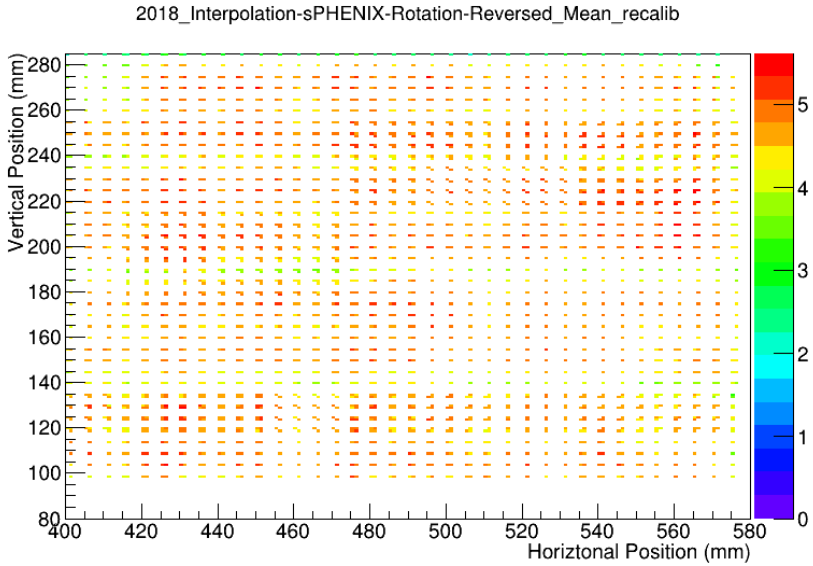


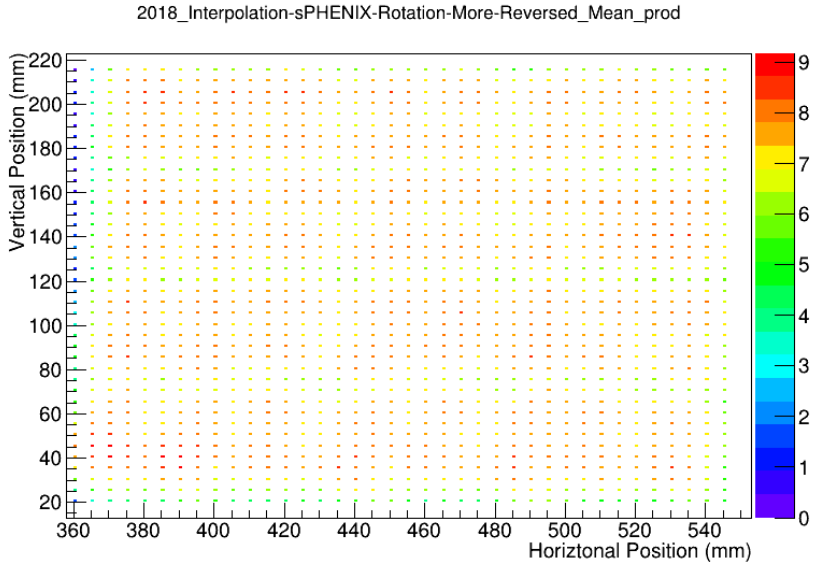




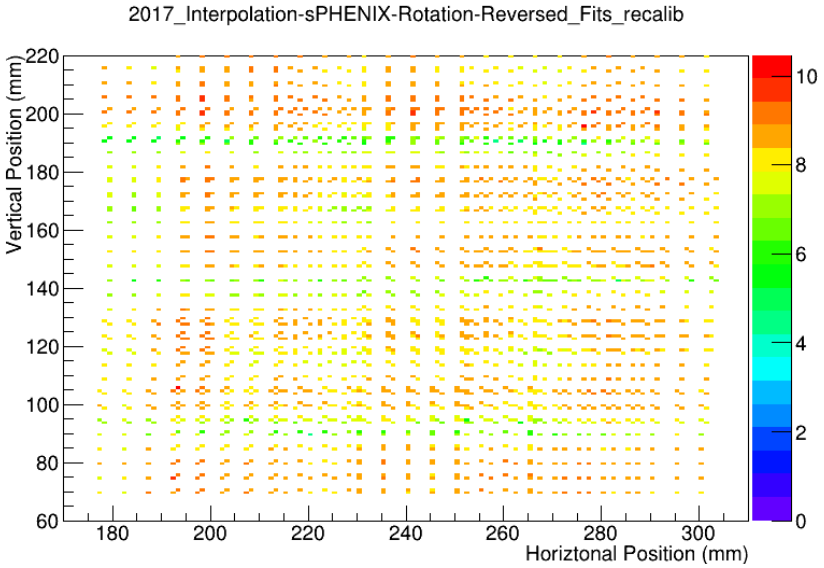
1 mm × 1mm Mean Energy Distributions (Mean Method)

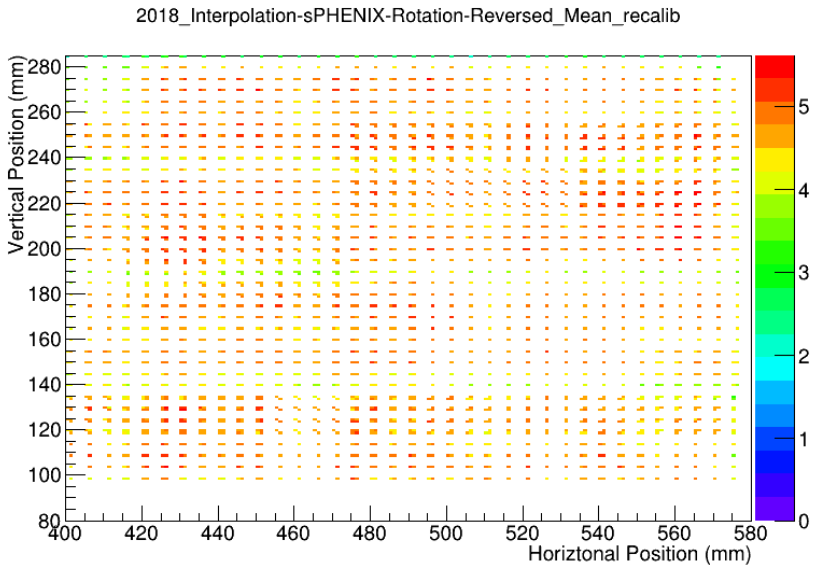


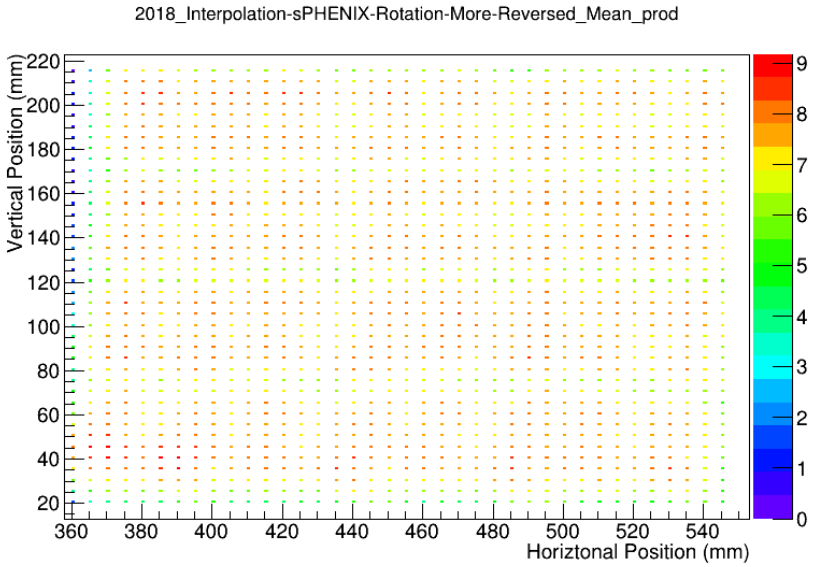




1 mm × 1mm Mean Energy Distributions (Fits Method)







Mean Energy vs Position Interpolation

Analysis strategies:

1. Input the 1 mm × 1 mm energy vs position distribution plots and loop through all positions

2. For zero-value bins, we search the nearby forward, backward, leftward, and rightward 2 mm bins. If we get non-zero values, we add them up and average them. The averaged value will become the energy of the zero-value bins.

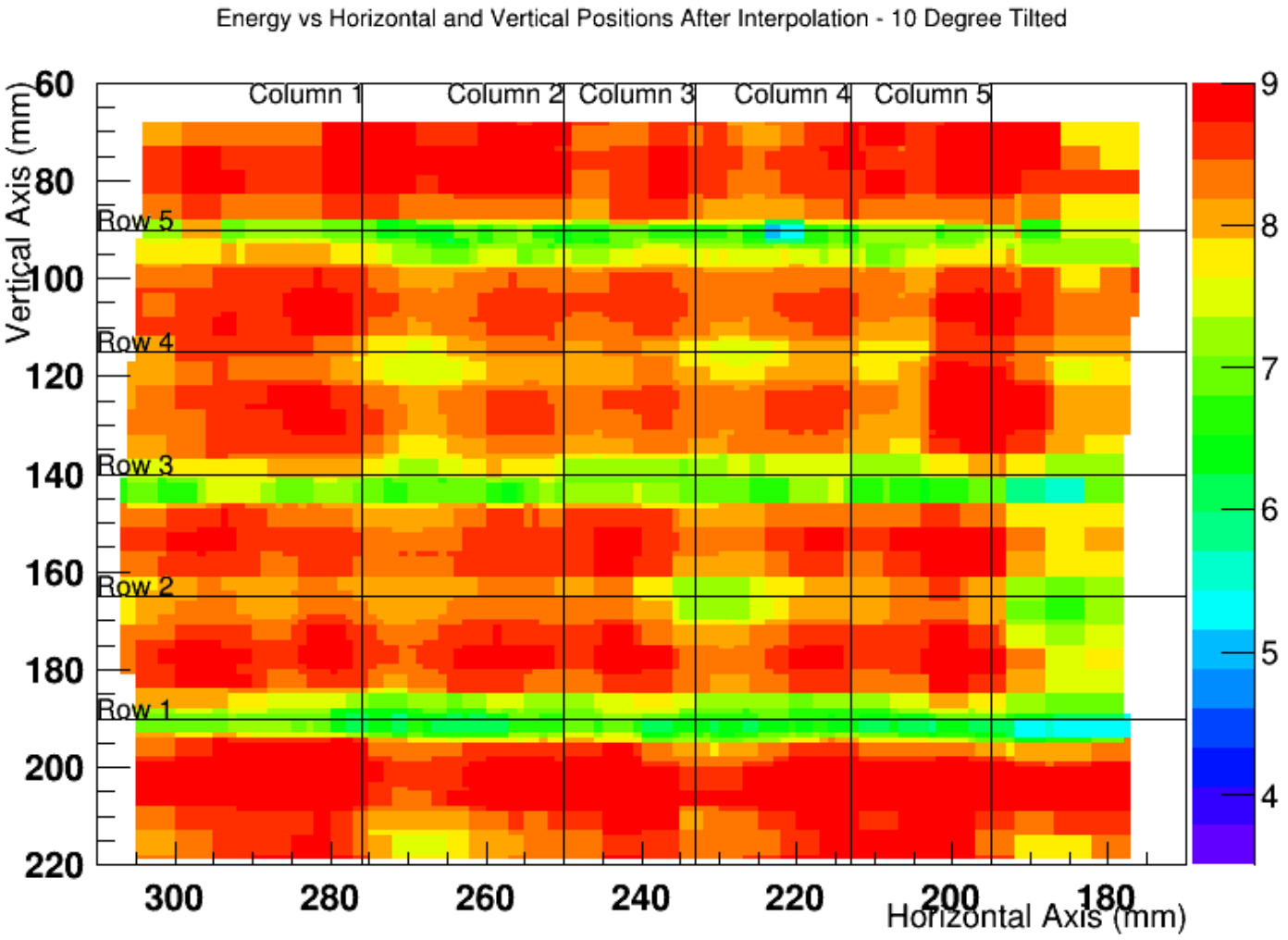
3. After interpolating, we will be able to get the continuous mean energy vs position distribution

4. We add the tower boundaries to the plots determined from the hodoscope corrections plots

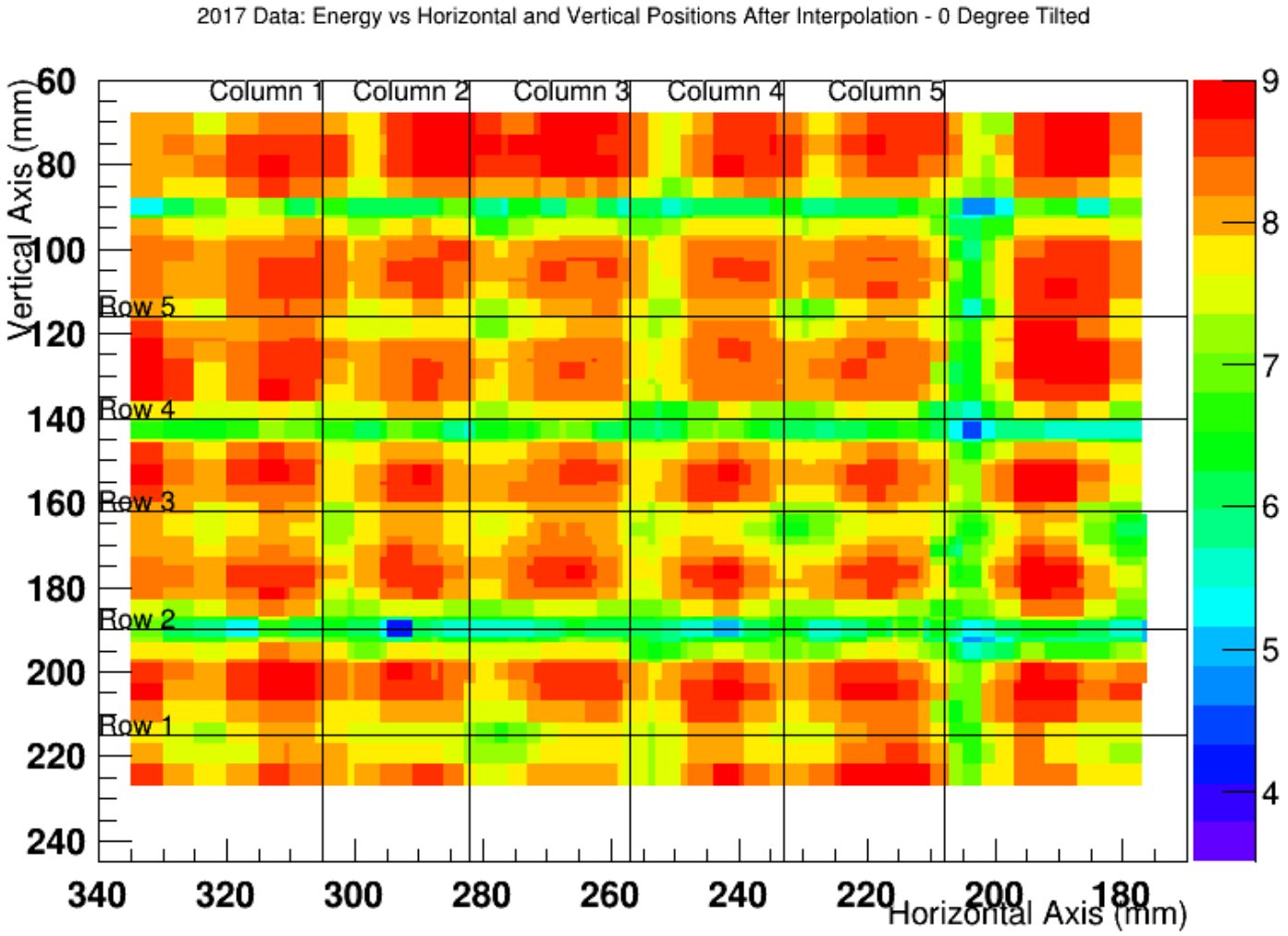
Since the position scan in the 2018 test beam is uniformly spaced, we can skip the interpolation steps and directly perform 5 mm × 5 mm projection to obtain the continuous mean energy vs position distribution plots.

From now on, I will only present the fits method.

2017 2nd Position Scan (10° Tilted)

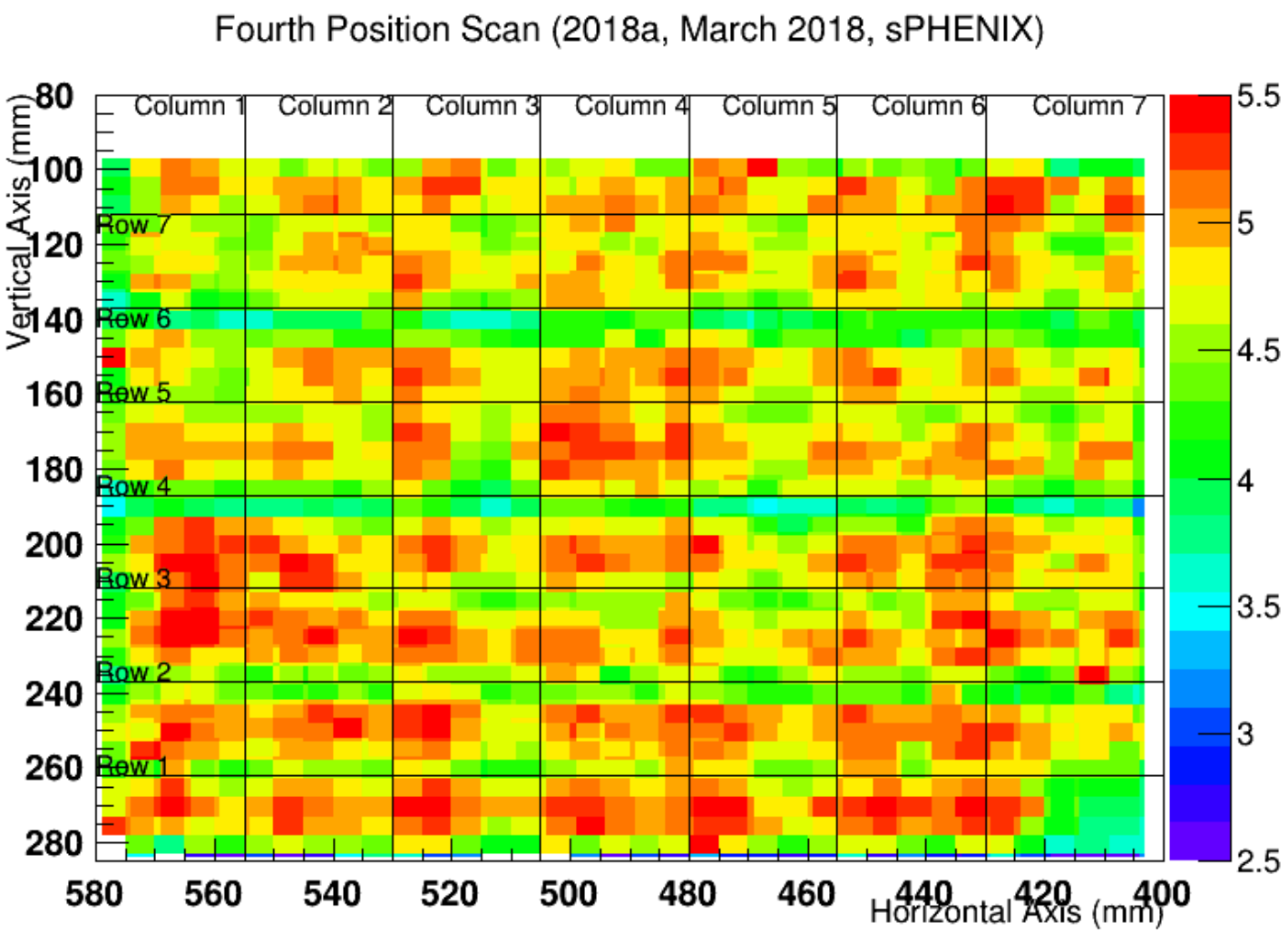


2017 3rd Position Scan (0° Tilted)

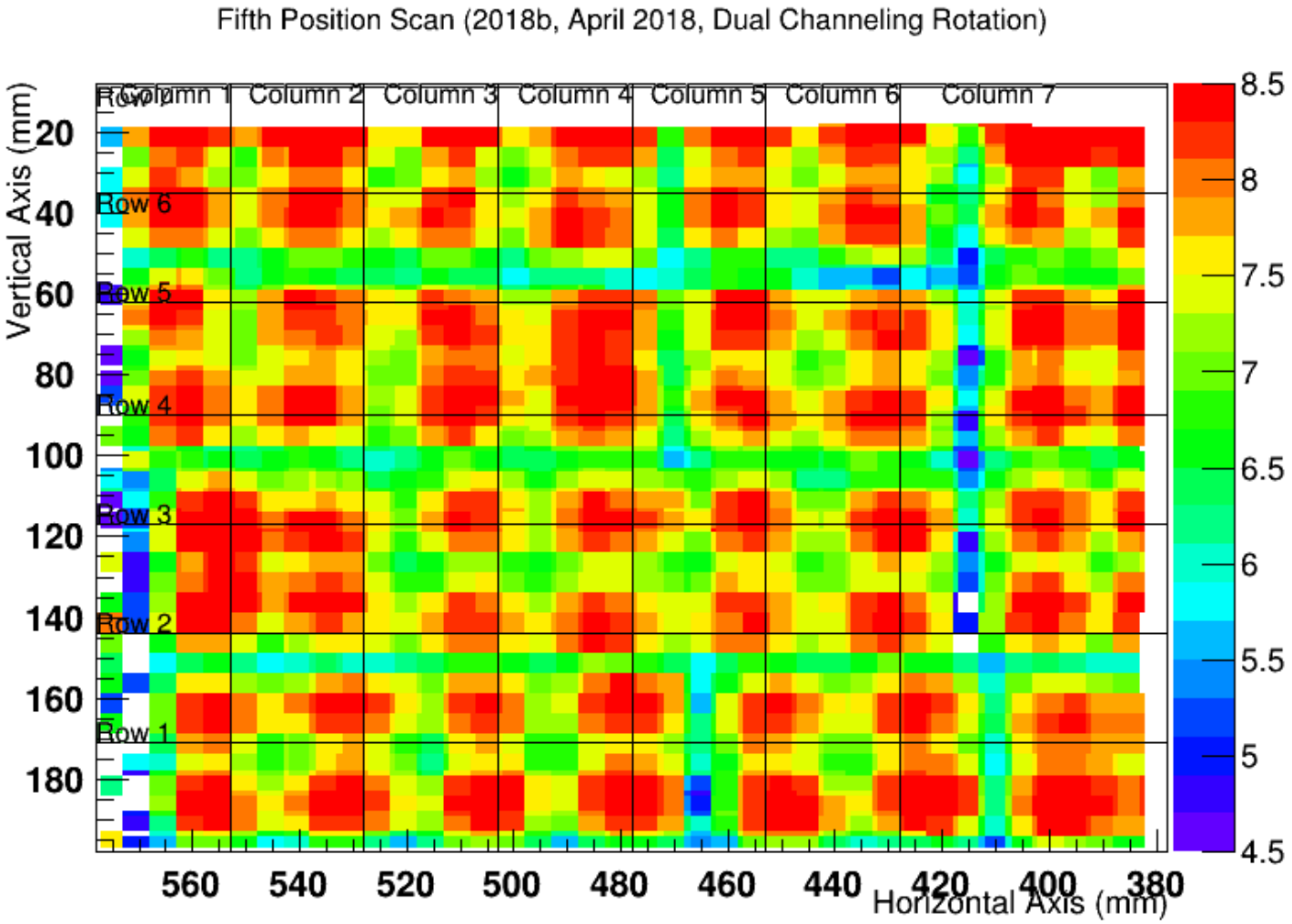


2018 3rd Position Scan (Dual Channeling)

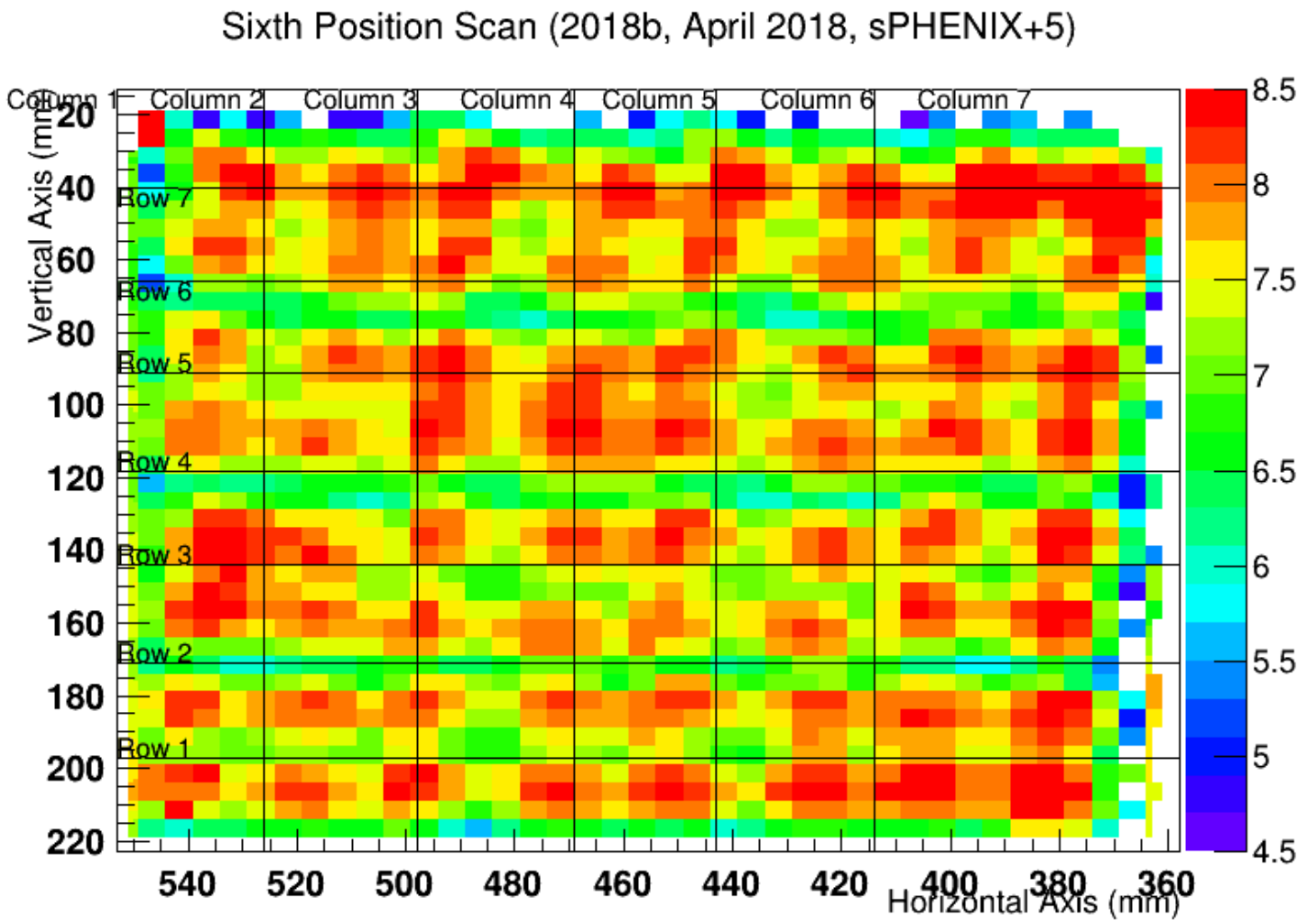
2018 4th Position Scan (sPHENIX Rotation)



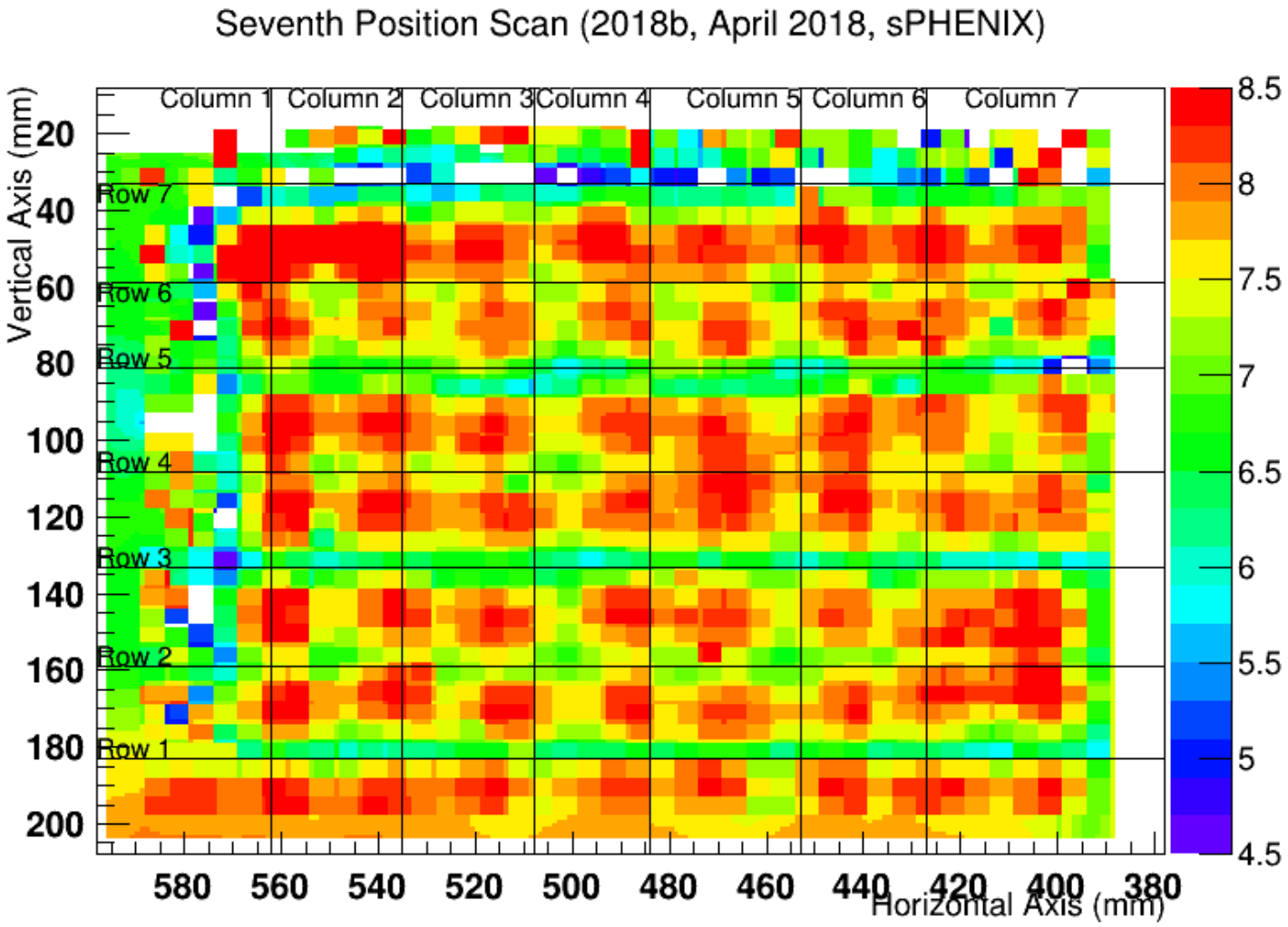
2018 5th Position Scan (Dual Channeling)



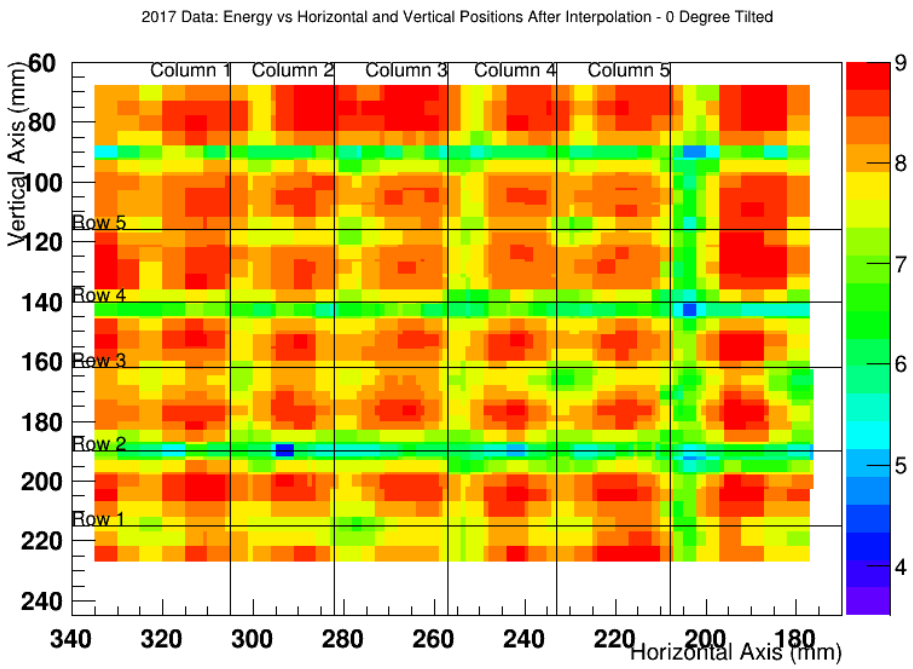
2018 6th Position Scan (sPHENIX + 5)

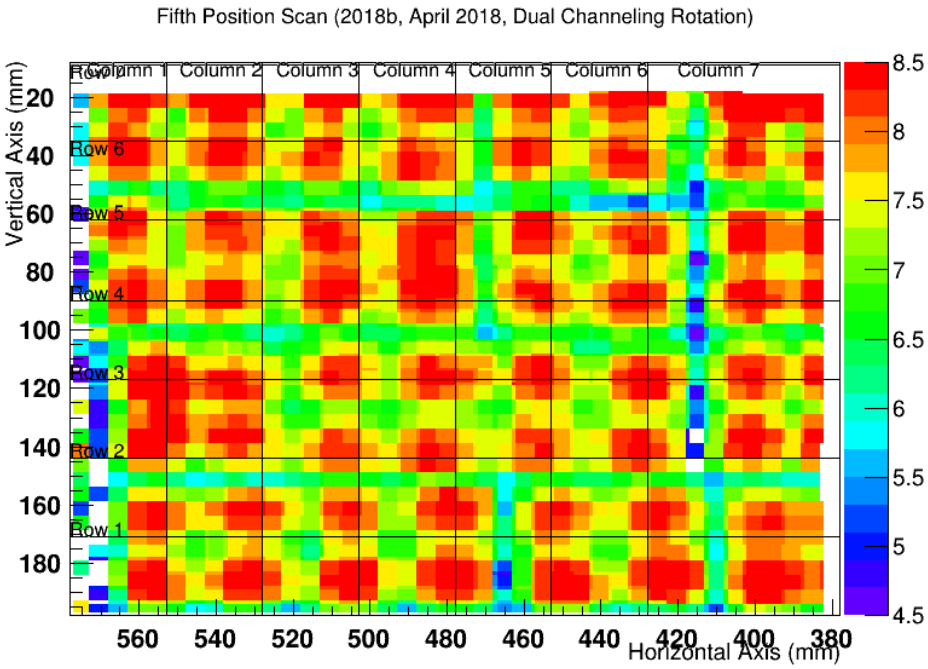


2018 7th Position Scan (sPHENIX Rotation)



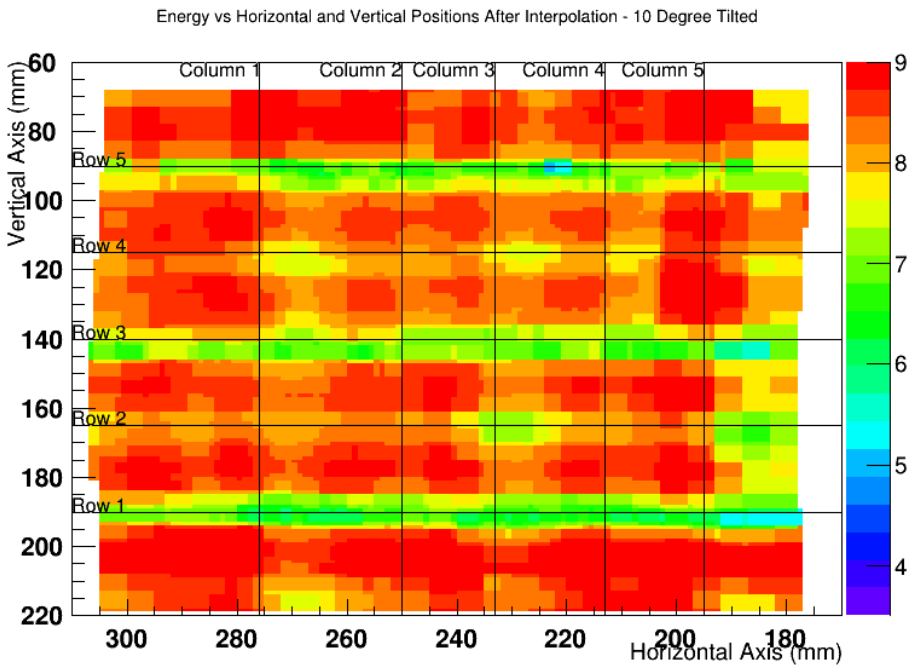
Qualitative Comparisons (0° Tilted vs Dual Channeling)

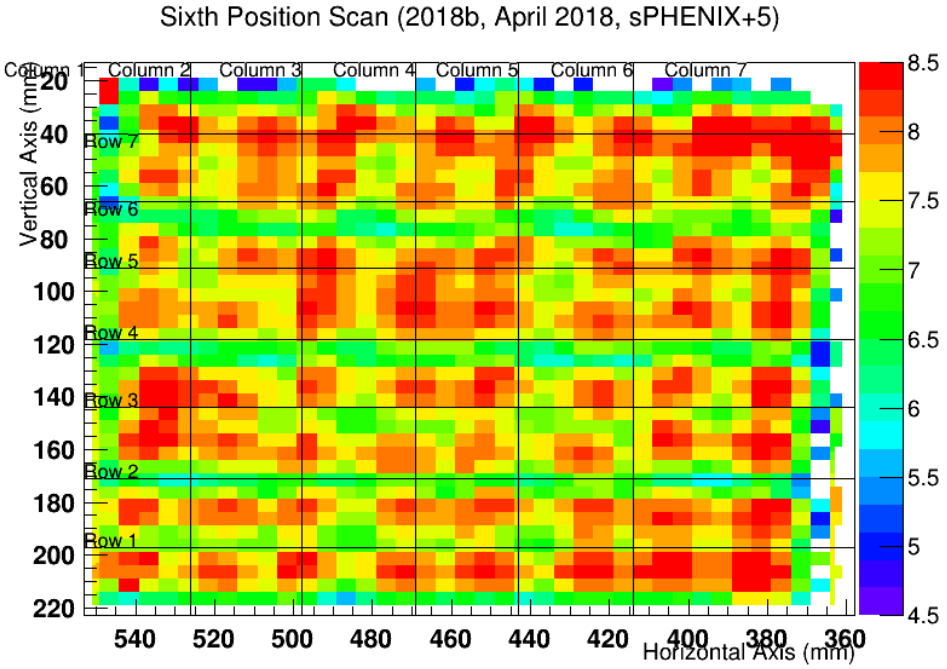




Qualitatively, it appears that the 2017 0° has better uniformity than the 2018 dual channeling. We need to perform more quantitative studies to draw a conclusion.

Qualitative Comparisons (10° Tilted vs sPHENIX+5)





Qualitatively, it appears that the 2017 10° has better uniformity than the 2018 sPHENIX + 5 horizontally and has worse uniformity vertically. We need to perform more quantitative studies to draw a conclusion.

Further Analysis: 1D Projection

Analysis strategies:

1. Input the mean energy vs position distribution plots

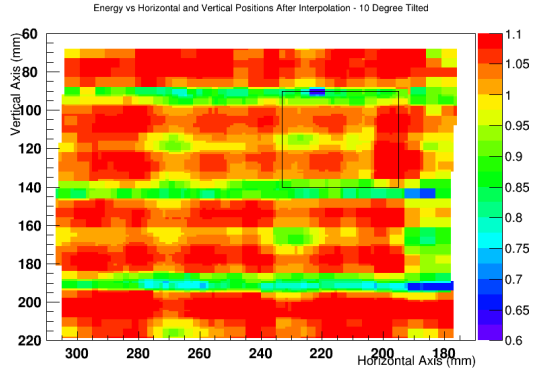
2. Normalized all the mean energy vs position plots by the average energies of the central 2 × 2 towers

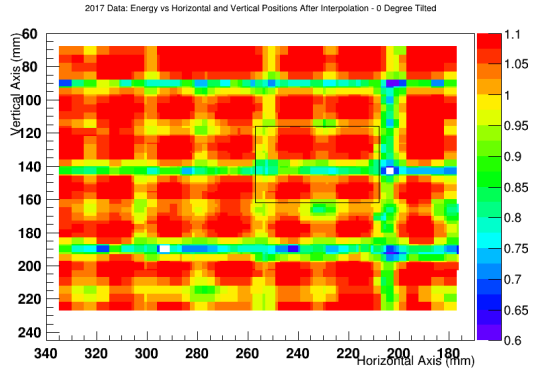
3. Perform 10 bins (10 mm) 1D projections on the tower boundary and central of the towers horizontally and vertically on the plots of the same scales

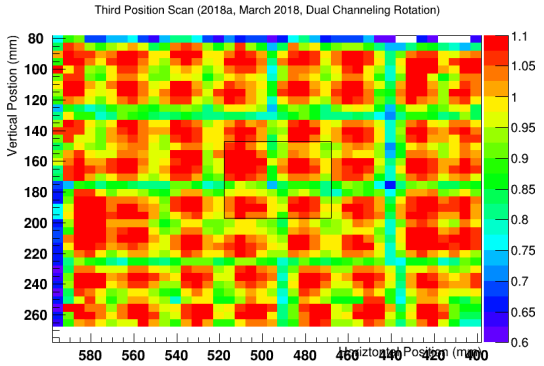
4. Compare the 1D distributions of the 2018 test beam results with the 2017 test beam results

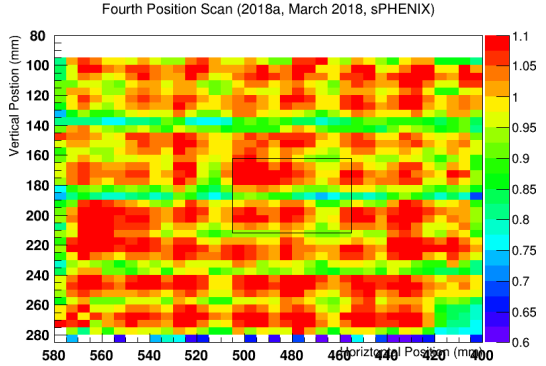
From now on, we will only compare the results of the central towers since this is where the uniformity we really care about .

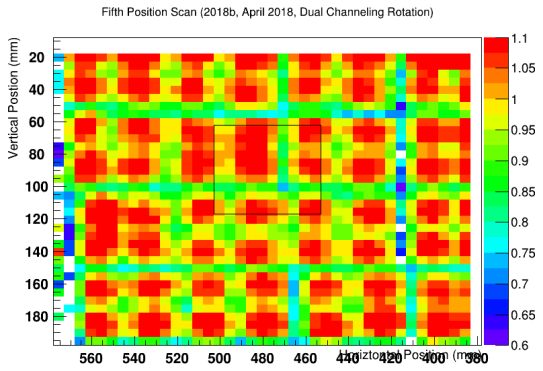
1D Projection Normalization Range

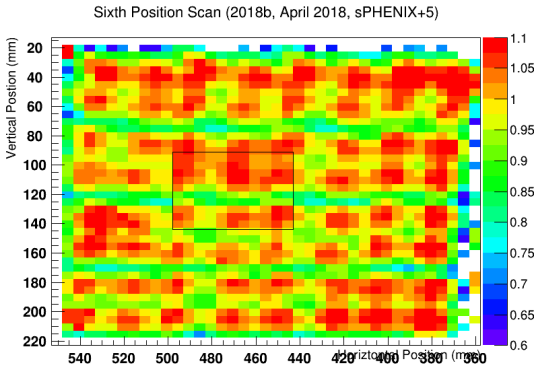


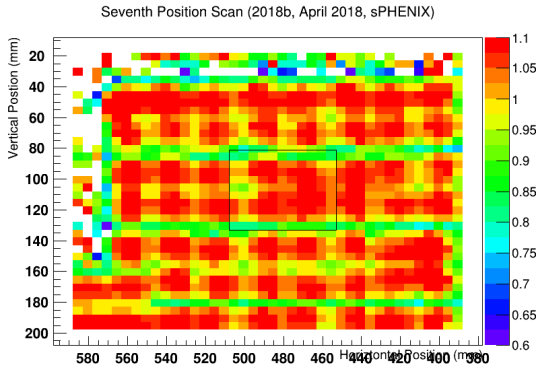




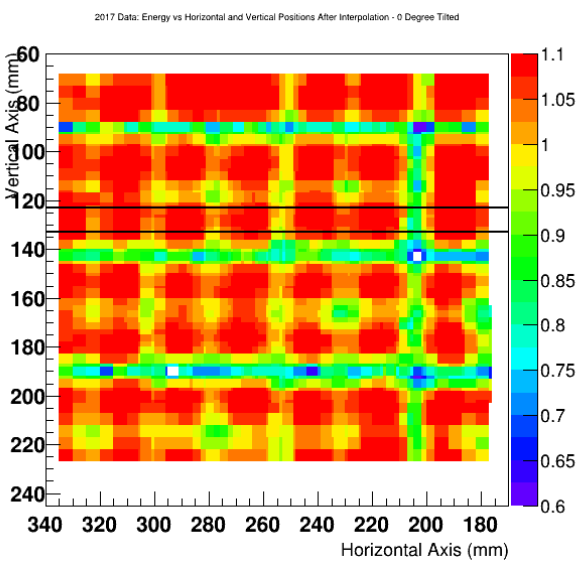


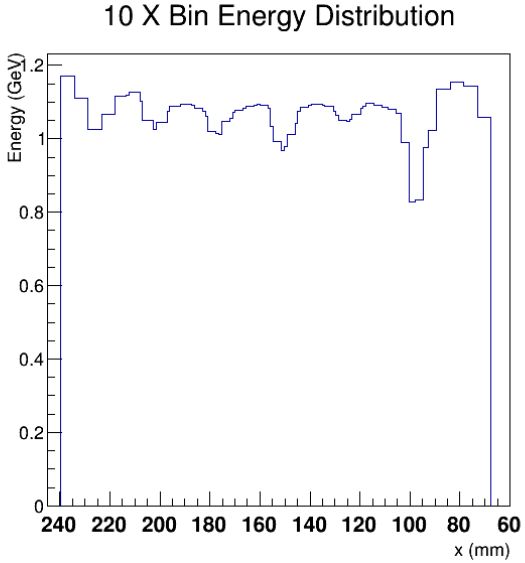




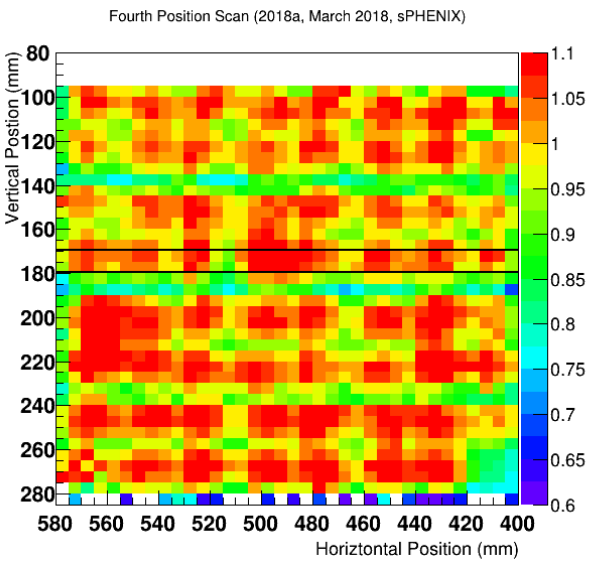


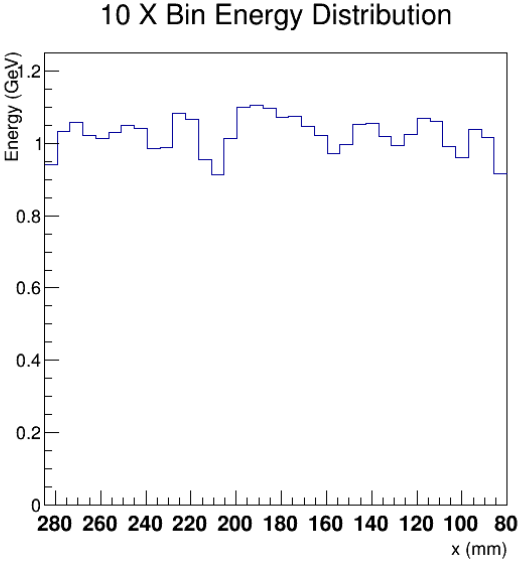
1D Horizontal Projection Comparison of 2017 0° tilted with 2018 Dual Channeling





2017 0° tilted

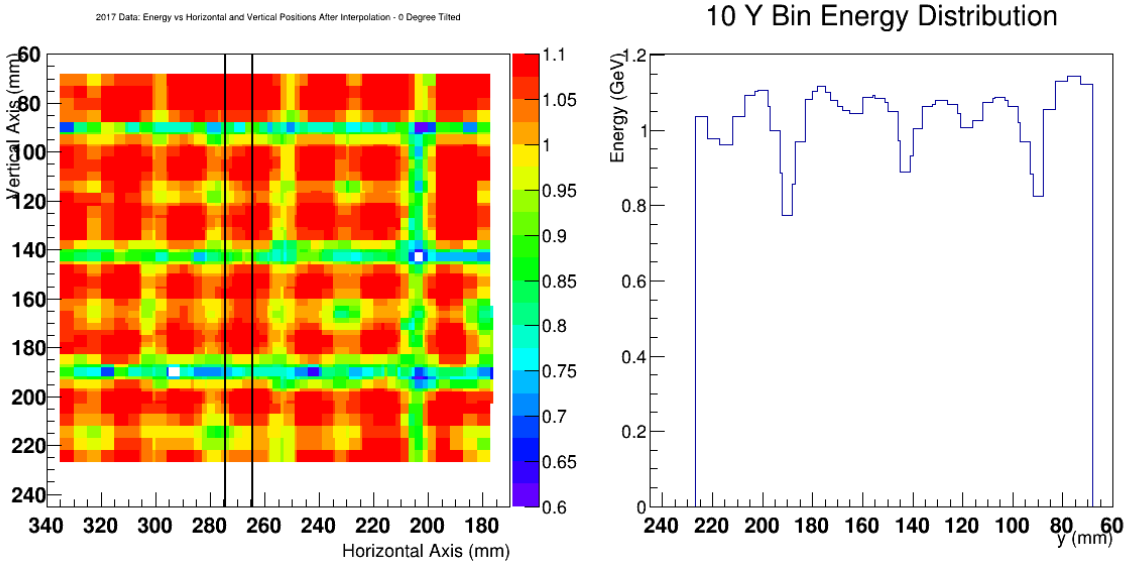




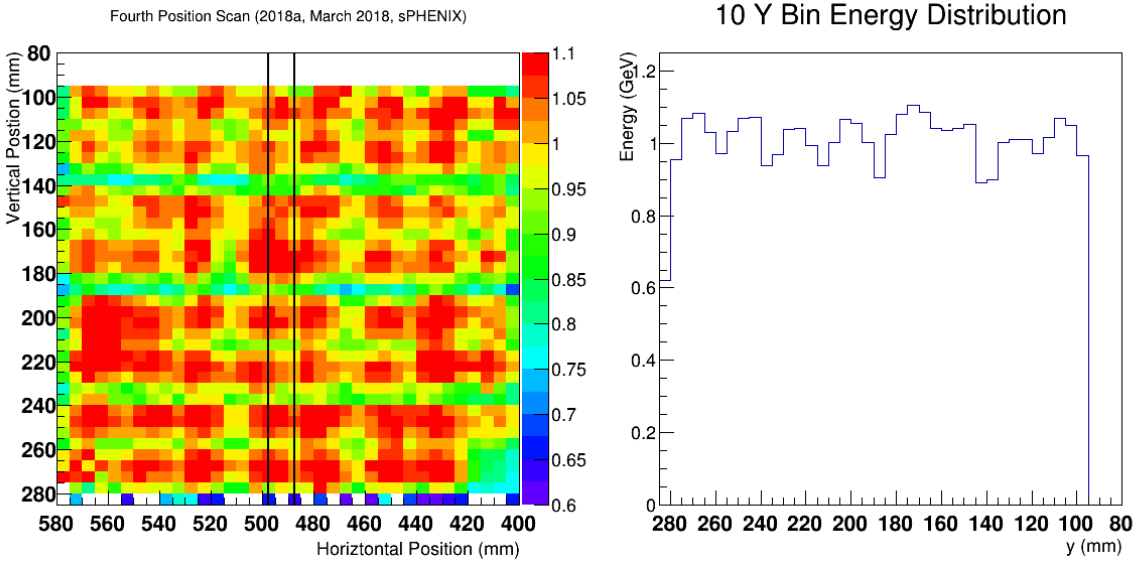
2018 dual channeling

Here, we can see that the 2018 EMCAL prototype has better uniformity vertically than the 2017 EMCAL prototype

1D Vertical Projection Comparison of 2017 0° tilted with 2018 Dual Channeling



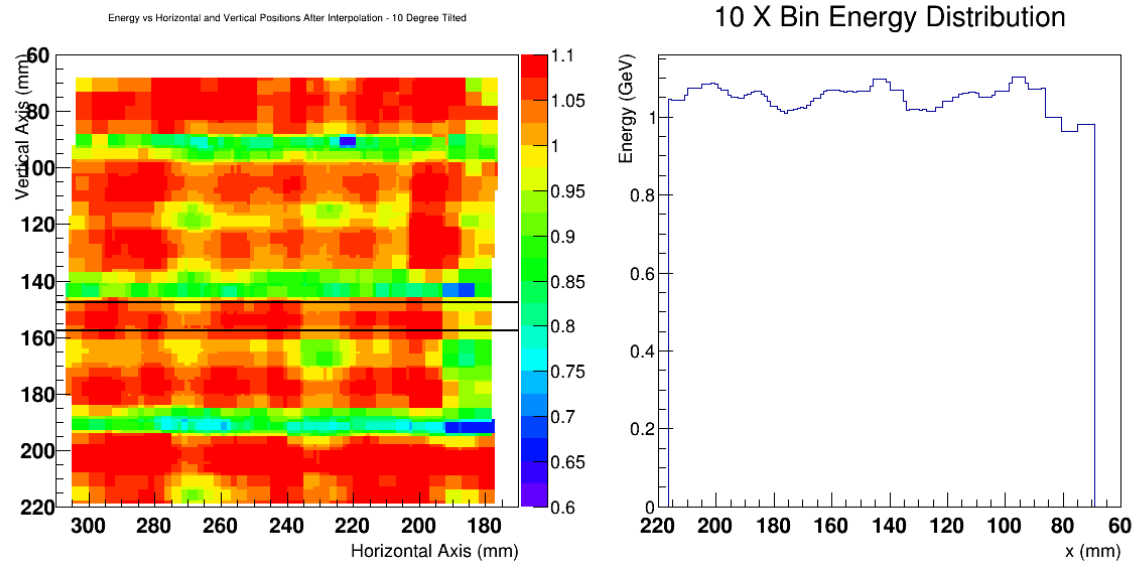
2017 0° tilted



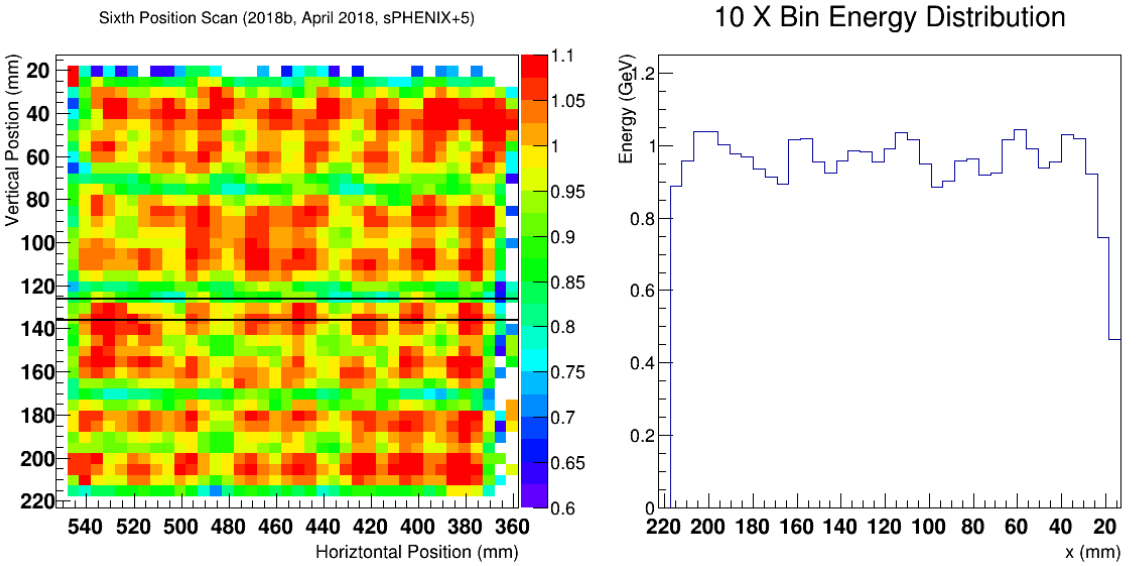
2018 dual channeling

Here, we can see that the 2018 EMCAL prototype has better uniformity vertically than the 2017 EMCAL prototype

1D Horizontal Projection Comparison of 2017 10° tilted with2018 sPHENIX + 5



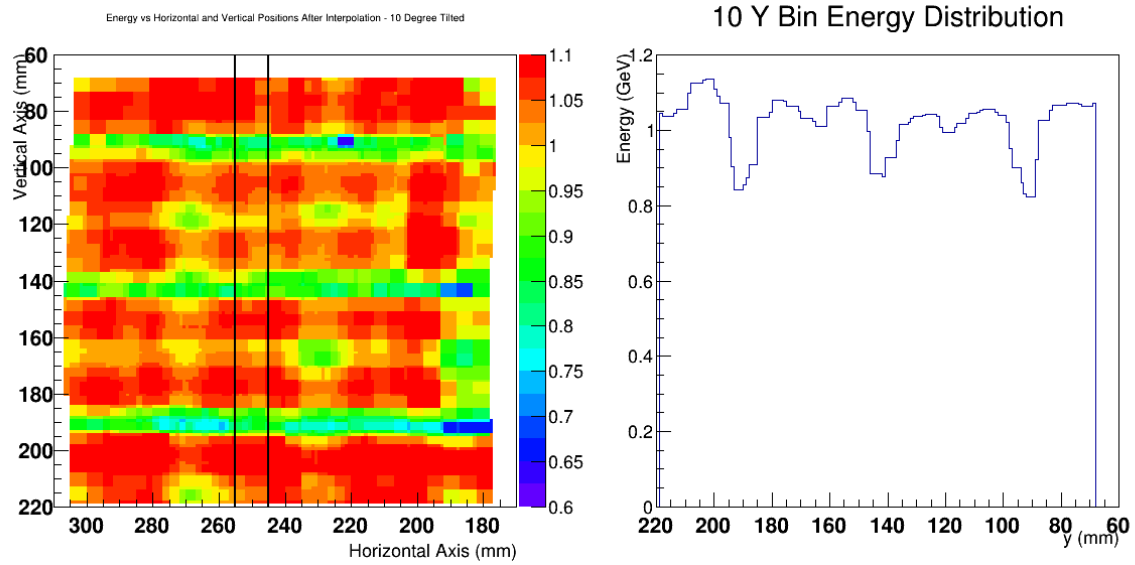
2017 10° tilted



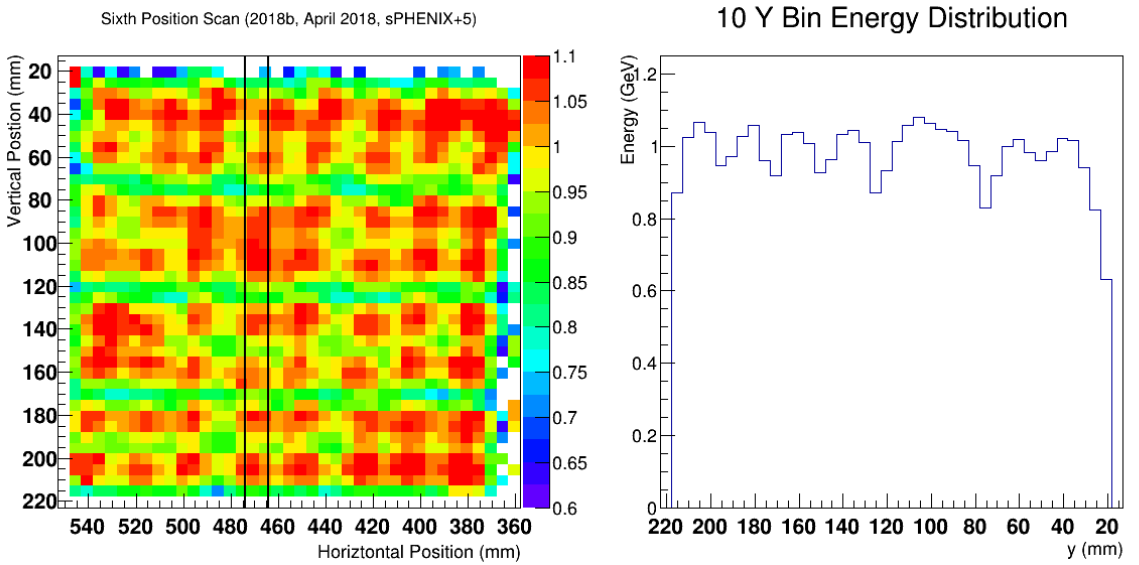
2018 sPHENIX+5

Here, we can see that the 2018 EMCAL prototype has similar uniformity vertically that the 2017 EMCAL prototype

1D Vertical Projection Comparison of 2017 0° tilted and 2018 Dual Channeling



2017 10° tilted



2018 sPHENIX +5

Here, we can see that the 2018 EMCAL prototype has better uniformity vertically that the 2017 EMCAL prototype

Further Analysis: Mean Energy Comparison for Central 4 × 4 towers

Analysis strategies:

1. Input the mean energy vs position distribution plots

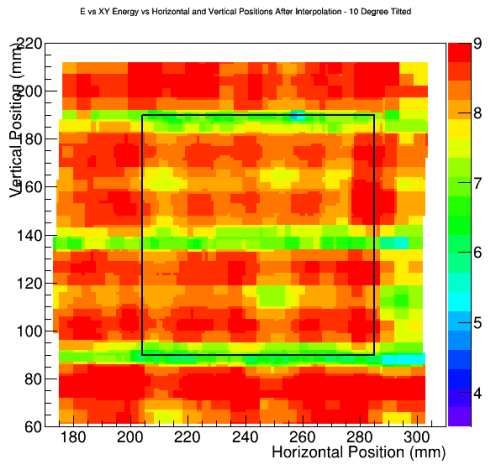
2. Normalized all the mean energy vs position plots by the average energies of the central 4 × 4 towers

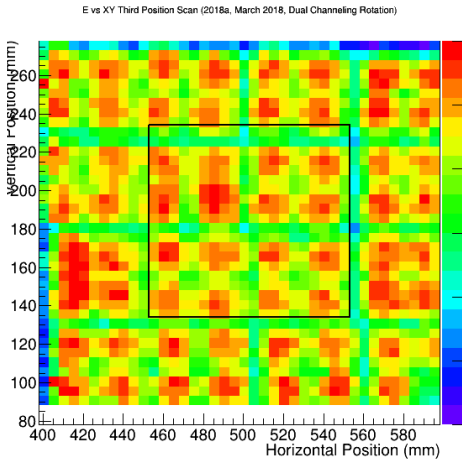
3. Fill the TH1 histogram with energy values within the 4 × 4 towers

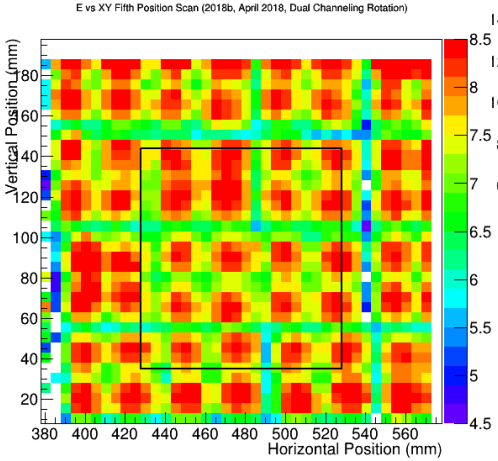
4. Perform direct RMS and mean calculations and fit the distribution with single Gaussian function. Take the RMS/mean ratio for these two method

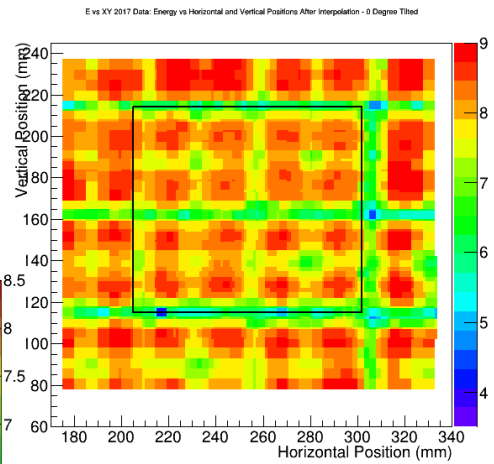
5. Rescale all plots to make their energy peaks locate right at 1, plot them together in the same plots, look at their widths, and compare their uniformity

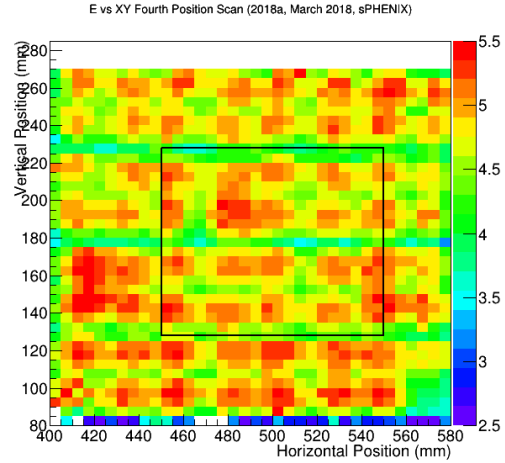
RMS-Mean Analysis Projection Range

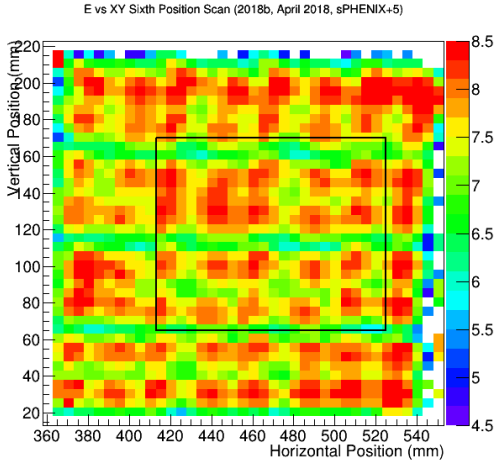


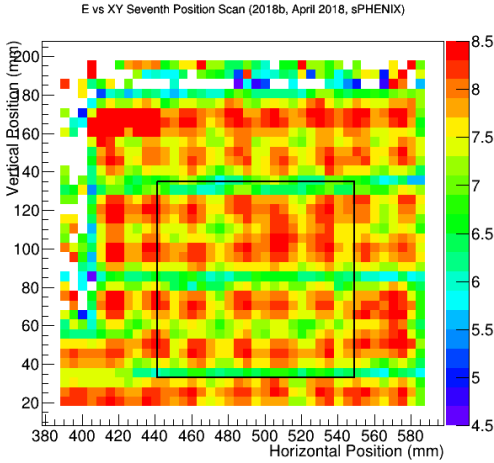




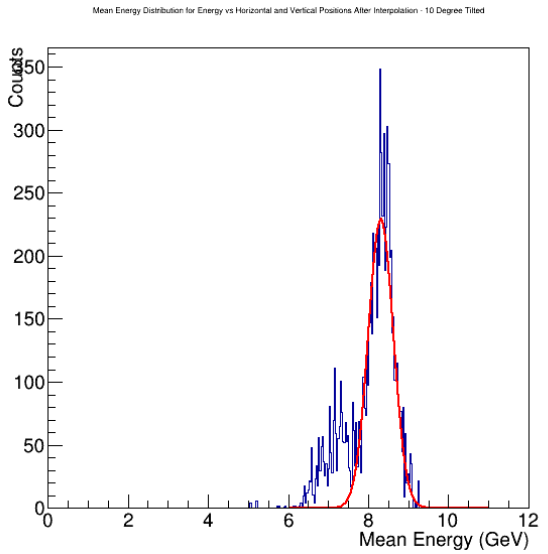


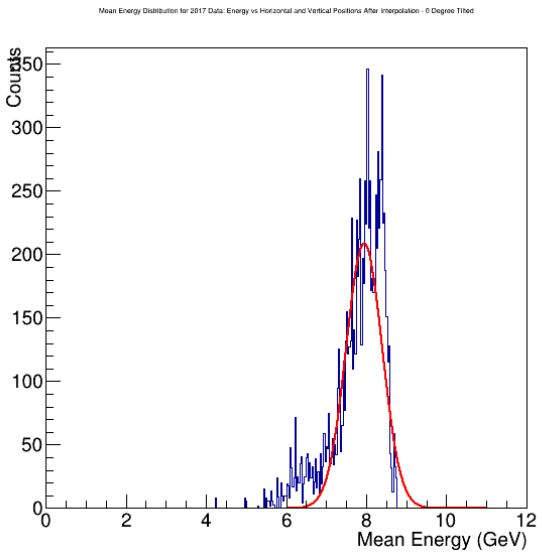


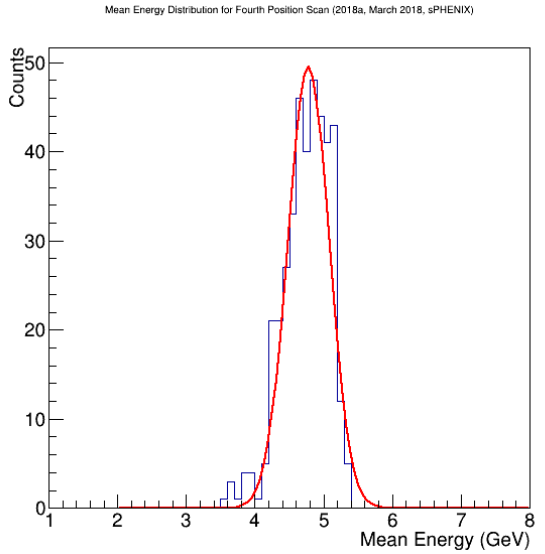


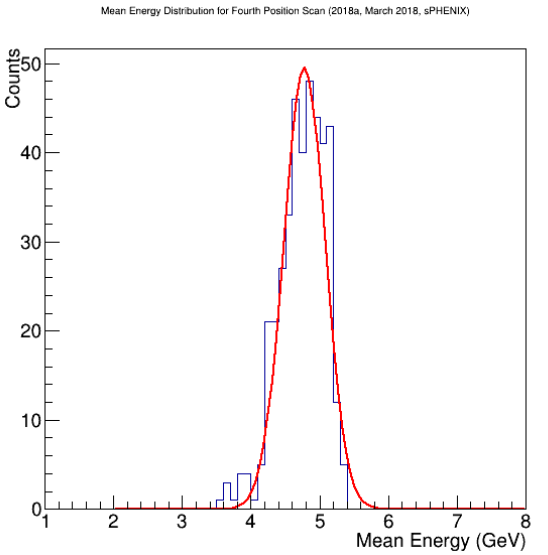


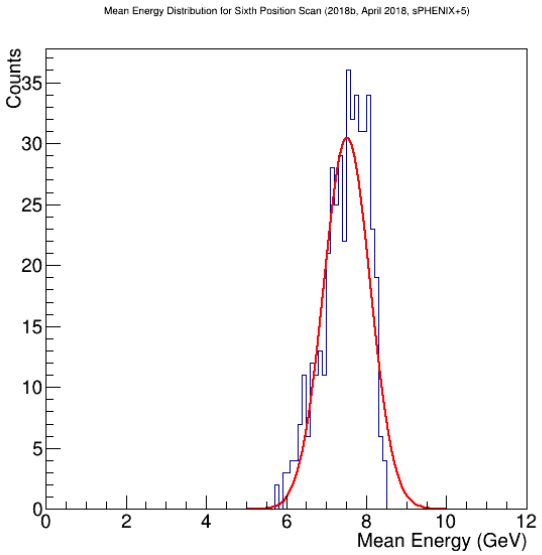
Mean Energy Distribution in the Central 4 × 4 Tower

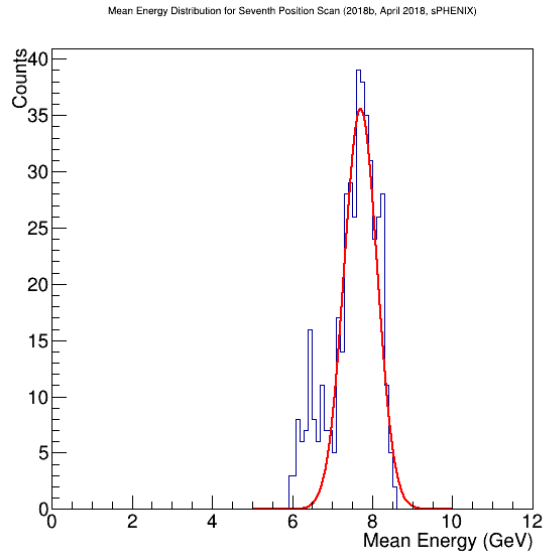










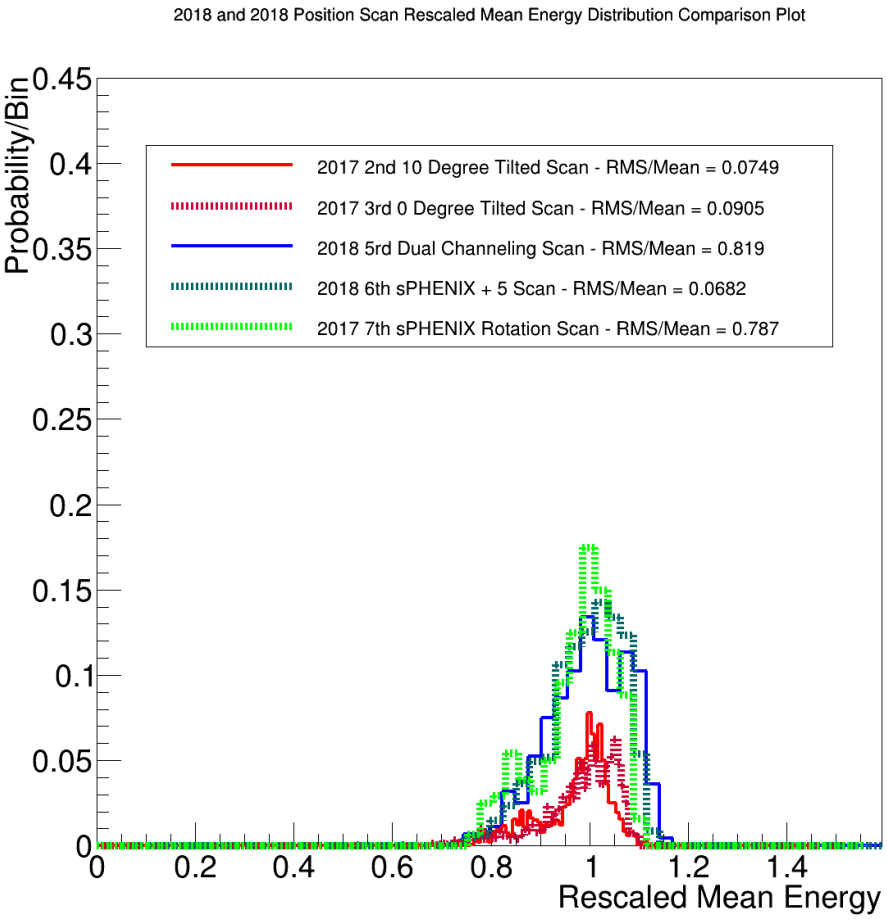


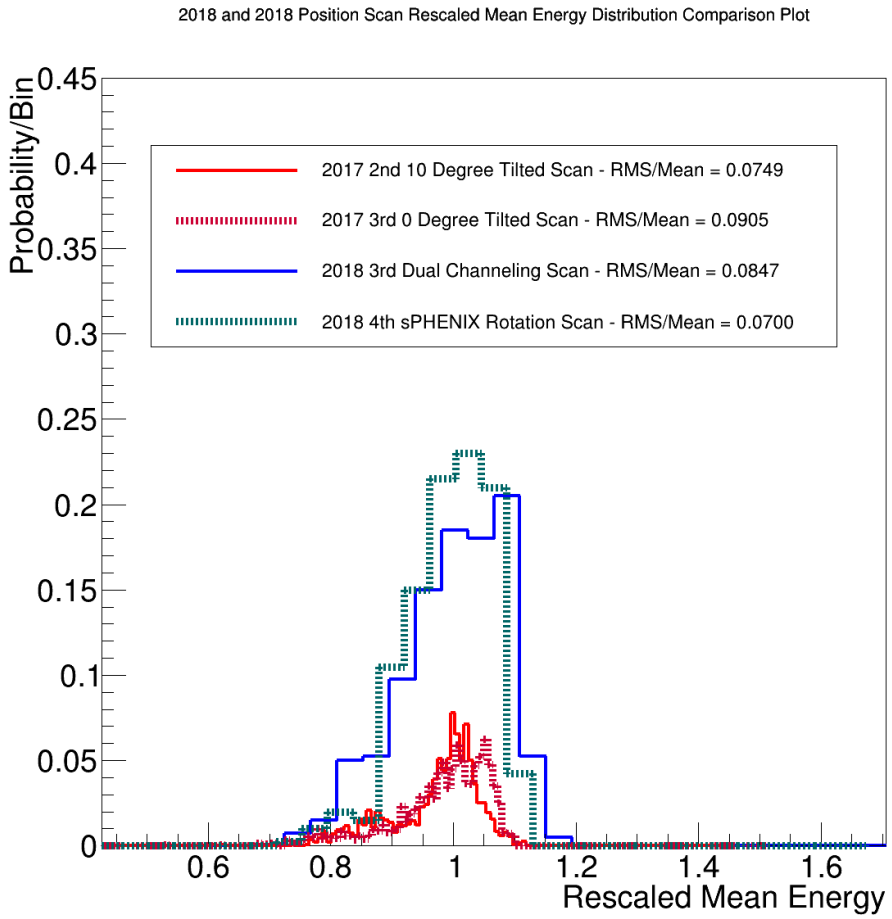
Numerical Values of the Analysis

Scan	Description	Method	Mean Energy (GeV)	RMS Energy (GeV)	Ratio
2017 2nd	10° Tilted	Gaussian Fits	8.31391	0.309854	0.0372693
2017 2nd	10° Tilted	Direct Mean	8.06557	0.604261	0.0749186
2017 3rd	0° Tilted	Gaussian Fits	7.95036	0.446548	0.056167
2017 3rd	0° Tilted	Direct Mean	7.79044	0.648128	0.0831953
2018 3rd	Duel Channeling	Gaussian Fits	4.68995	0.383474	0.0817651
2018 3rd	Duel Channeling	Direct Mean	4.68438	0.396932	0.0847351
2018 4th	sPHENIX Rotation	Gaussian Fits	4.78303	0.30055	0.0628368
2018 4th	sPHENIX Rotation	Direct Mean	4.74758	0.332545	0.0700452
2018 5th	Duel Channeling	Gaussian Fits	7.53188	0.622385	0.0826334
2018 5th	Duel Channeling	Direct Mean	7.50998	0.614703	0.0818514
2018 6th	sPHENIX + 5	Gaussian Fits	7.5257	0.576267	0.0765731
2018 6th	sPHENIX + 5	Direct Mean	7.46732	0.559328	0.0749034
2018 7th	sPHENIX	Gaussian Fits	7.71524	0.407703	0.0528438
2018 7th	sPHENIX	Direct Mean	7.52643	0.592596	0.0787353

- Direct Method better describe the data since 2 peak structures is observed in 2017 data
- RMS Energy: 2017 0° Tilted > 2018 Dual Channeling > 2017 10° Tilted > 2018 sPHENIX Rotation > 2018 sPHENIX +5
- RMS/Mean Energy: 2017 0° Tilted > 2018 Dual Channeling > 2018 sPHENIX Rotation > 2017 10° Tilted ≈ 2018 sPHENIX +5

Rescaled Energy Distribution Plots





Summary and Conclusion

- The sPHENIX EMCAl analysis has been carried out

- The uniformity of 2018 prototype has improved, particularly in the vertical direction, compared to the 2017 prototype

- According to our analysis, we estimate the energy uncertainties of the 2018 EMCAL prototype due to the non-uniformity as follows:

- Dual Channeling: 8.2%
- sPHENIX Rotation: 7.8%
- sPHENIX + 5: 7.5%