SBU JLab Group Meeting
July 13, 2018

GEM Alignment Progress

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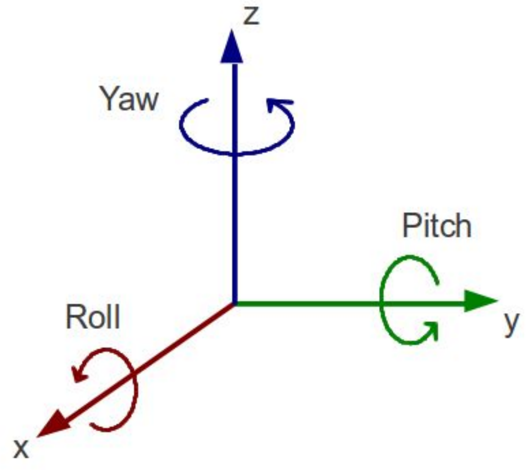
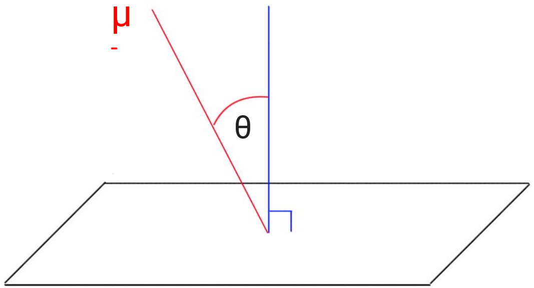
Problems

- Offsets in x and y translations and in yaw, pitch, and roll rotations, as well as the GEM resolution, produce changes in the fitted muon angle with respect to the normal
- Must align middle and bottom GEM with top GEM
- 10 total parameters (5 in each GEM except top)
- We also need an estimate on the maximum possible offset a GEM can have





Solutions

- χ^2 Minimization can be used to solve for rotational offsets, however
  1. It is insensitive to translational offsets
  2. More parameters = More unreliable and higher uncertainty (as confirmed by Daniel's regression script)
  3. Pitch and roll rotations require z-coordinate inputs

∴ **χ^2 Minimization should only be used to solve for yaw (z-axis) rotational offsets**

- Translational offsets can be determined by selecting vertical muons, then measuring the differences in GEM coordinates

How Well Should the GEMs be Aligned? Can We Ignore Pitch and Roll Rotations?

Aim: If we apply reasonable offsets, but do not correct for them, what is the difference between the truth and fitted GEM angle?

Monte Carlo Simulation of Stand- Steps:

1. Truth coordinates generated in GEM 1 and GEM 3
2. Truth coordinates calculated in GEM 2 using a linear regression
3. Add offsets to GEM 2 and 3’s truth coordinates to get GEM coordinates (GEM 1 is considered the lab frame)
4. Factor in GEM resolution to the GEM coordinates
5. Fit truth and shifted GEM coordinates to linear functions
6. Calculate slopes of both
7. Slopes used to calculate truth and shifted GEM angles

How to Fit Muon Angle

$$\tan(\alpha) = \frac{R\cos(\theta)}{R\sin(\theta)\cos(\phi)}$$

$$k_x = \tan(\alpha) = \frac{1}{\tan(\theta)\cos(\phi)}$$

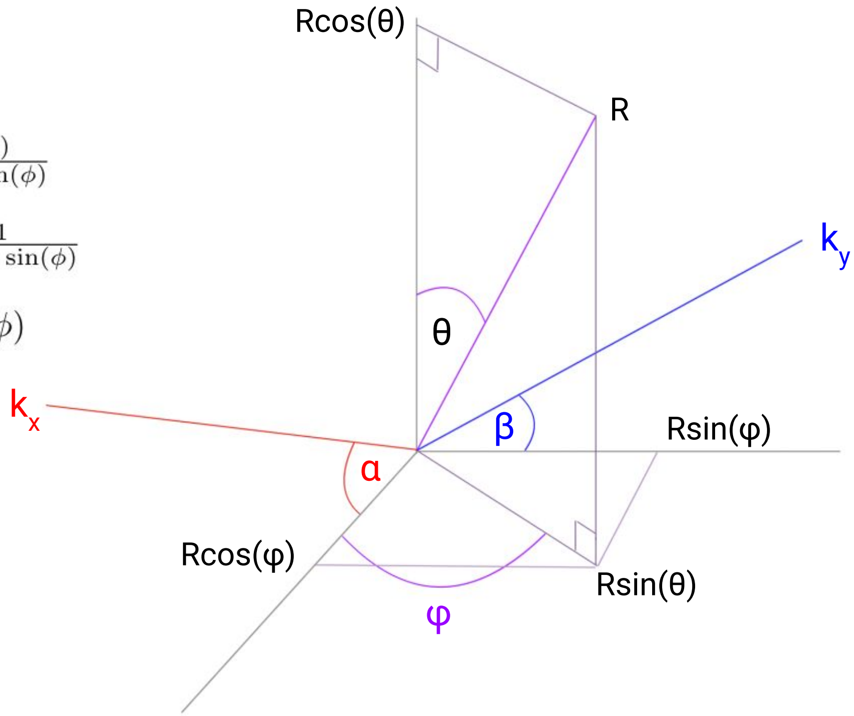
$$\frac{1}{k_x} = \tan(\theta)\cos(\phi)$$

$$\tan(\beta) = \frac{R\cos(\theta)}{R\sin(\theta)\sin(\phi)}$$

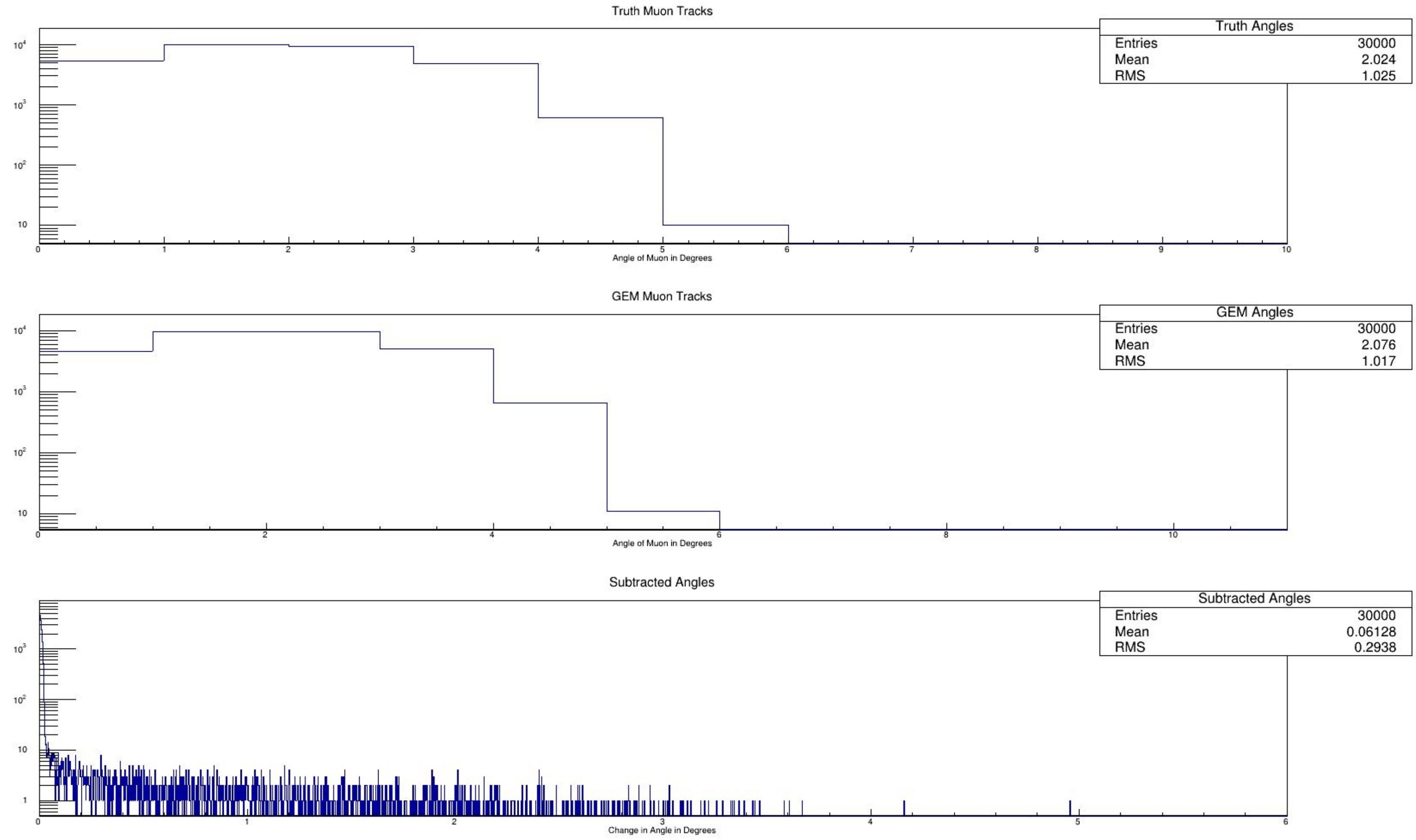
$$k_y = \tan(\beta) = \frac{1}{\tan(\theta)\sin(\phi)}$$

$$\frac{1}{k_y} = \tan(\theta)\sin(\phi)$$

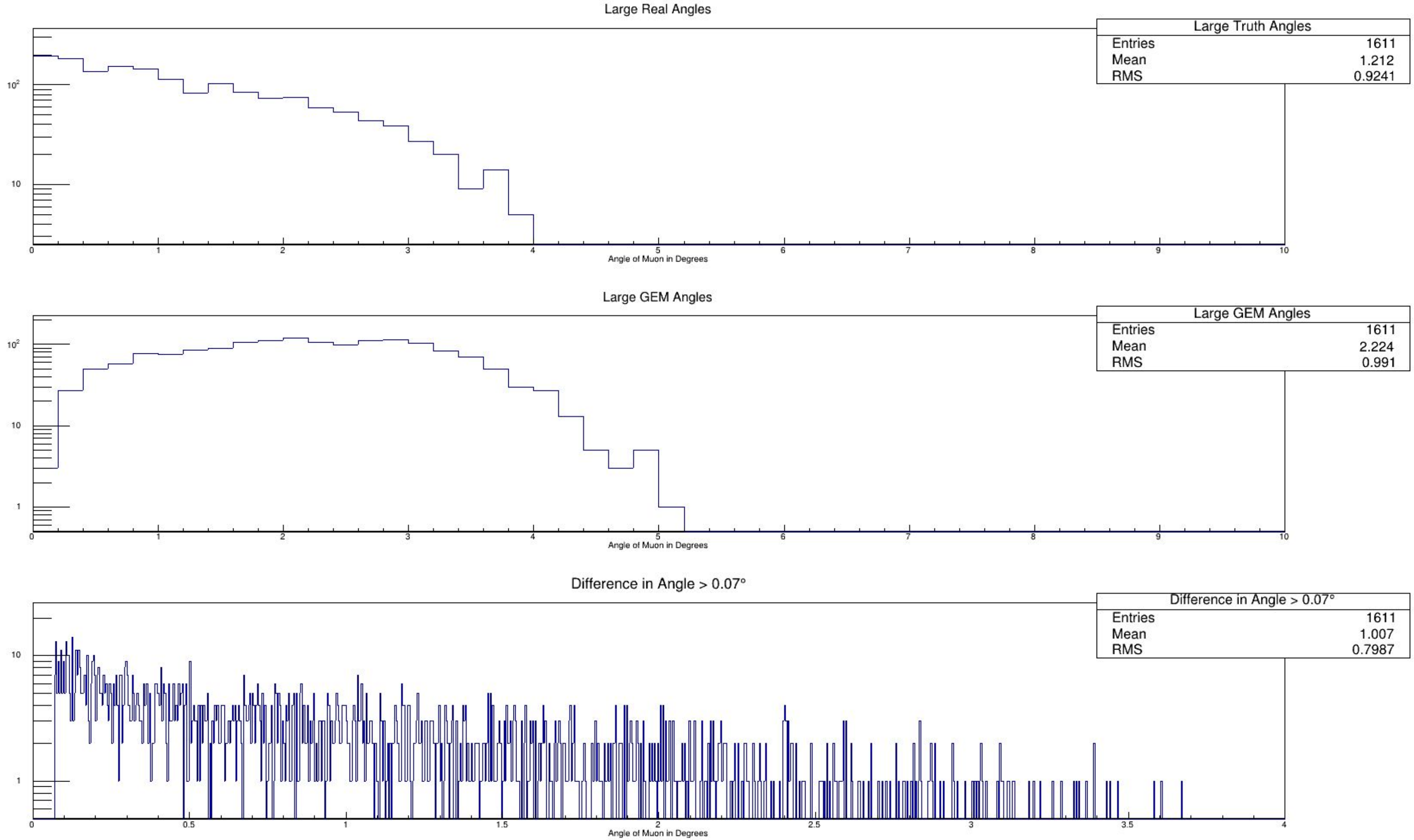
$$\tan(\theta) = \sqrt{\left(\frac{1}{k_x}\right)^2 + \left(\frac{1}{k_y}\right)^2}$$



Long Stand
Translation Analysis

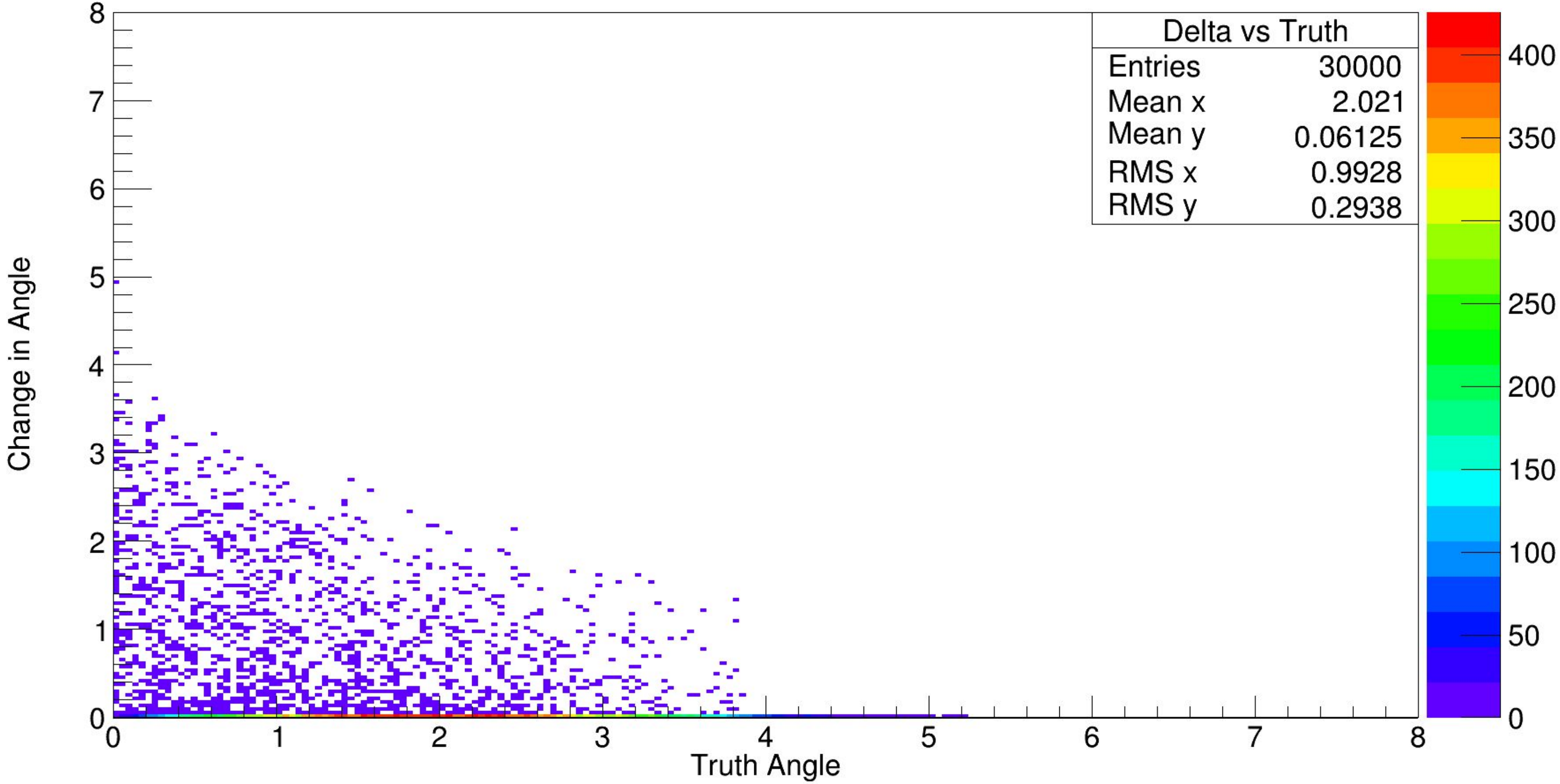


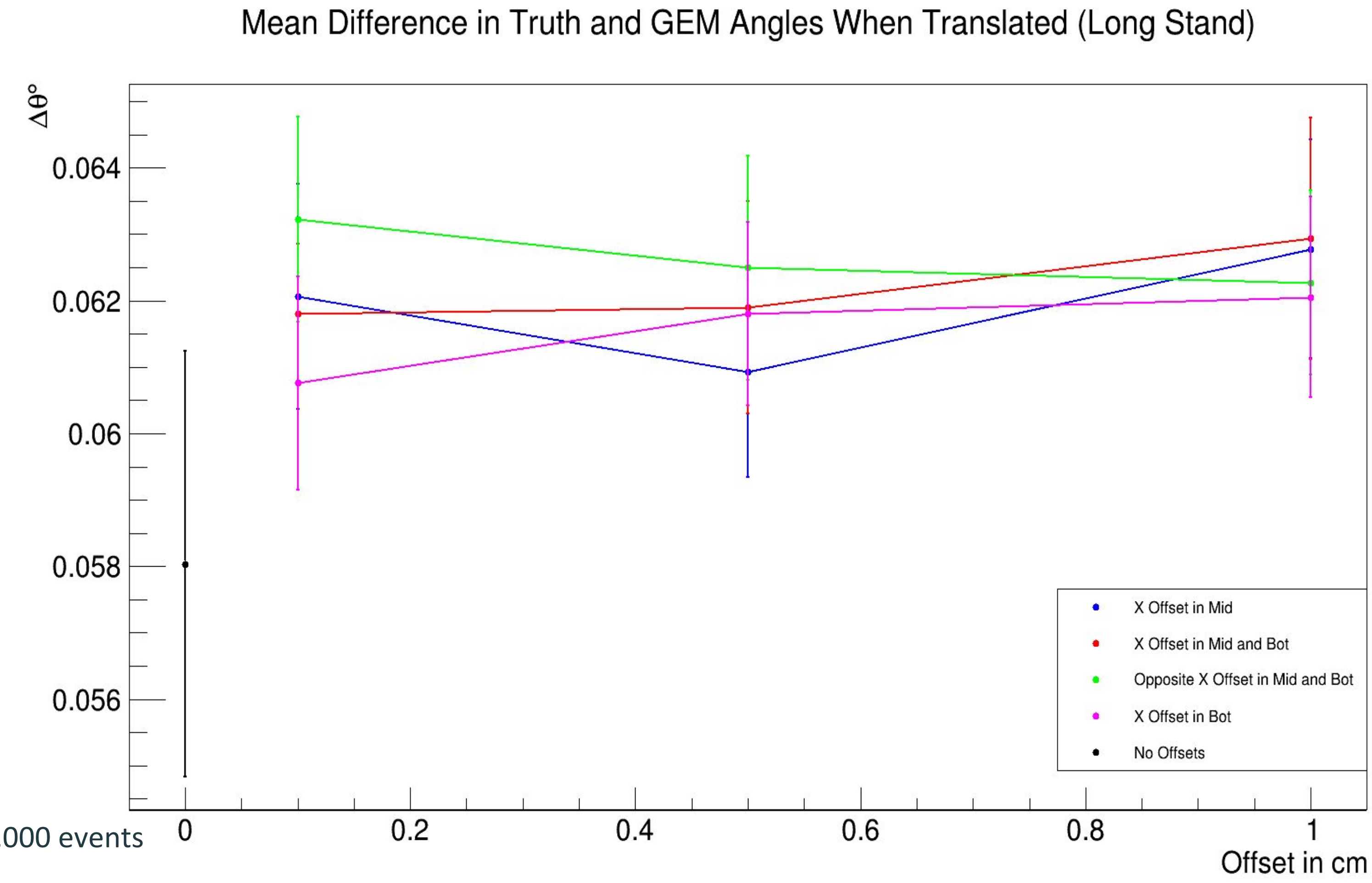
Truth Muon Tracks
Truth Angles
Entries 30000
Mean 2.024
RMS 1.025
Angle of Muon in Degrees
GEM Muon Tracks
GEM Angles
Entries 30000
Mean 2.076
RMS 1.017
Angle of Muon in Degrees
Subtracted Angles
Subtracted Angles
Entries 30000
Mean 0.06128
RMS 0.2938
Change in Angle in Degrees



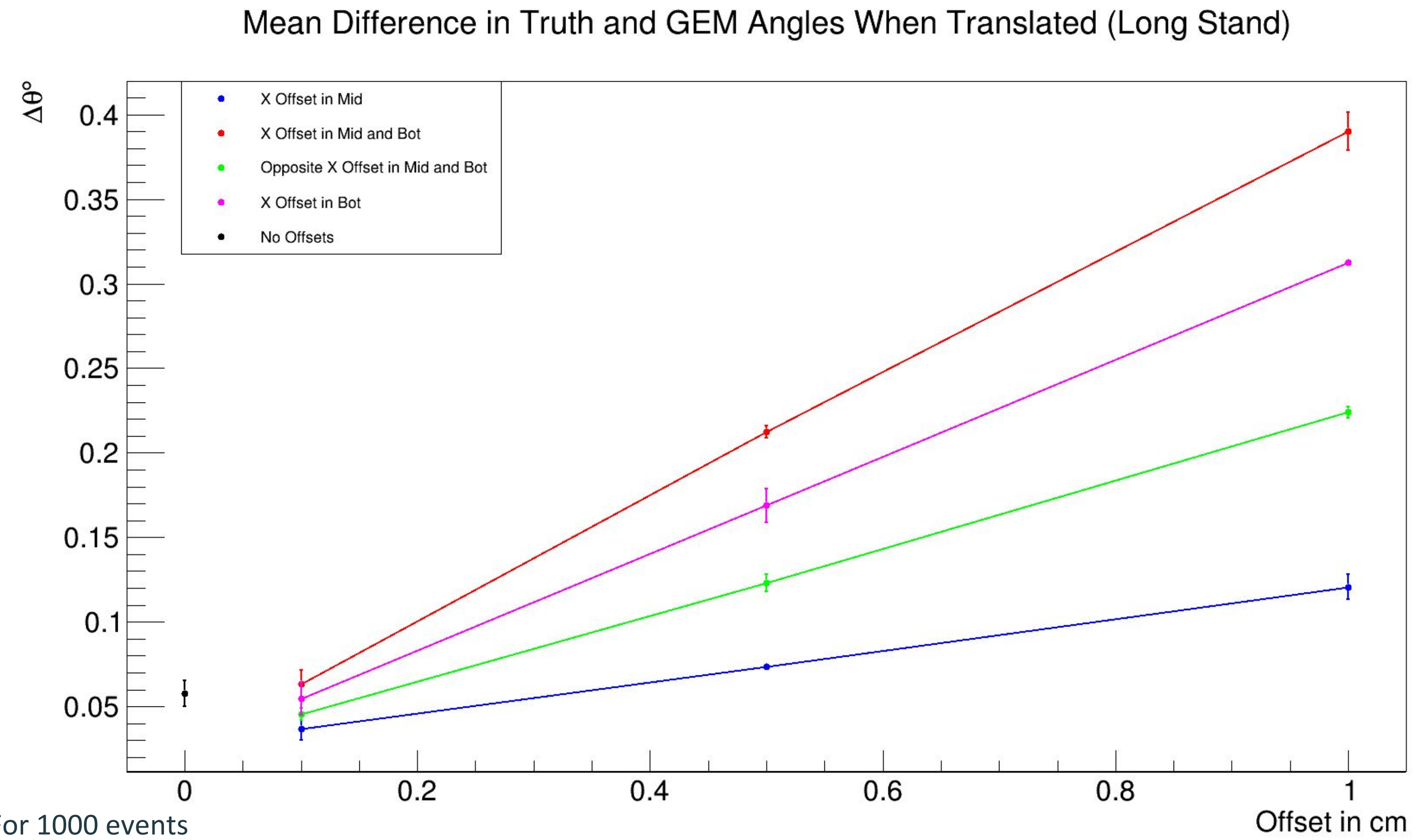
Large Real Angles
Large Truth Angles
Entries 1611
Mean 1.212
RMS 0.9241
Angle of Muon in Degrees
Large GEM Angles
Large GEM Angles
Entries 1611
Mean 2.224
RMS 0.991
Angle of Muon in Degrees
Difference in Angle > 0.07°
Difference in Angle > 0.07°
Entries 1611
Mean 1.007
RMS 0.7987
Angle of Muon in Degrees

Change in Angle vs Truth Angle in Degrees





For 30,000 events

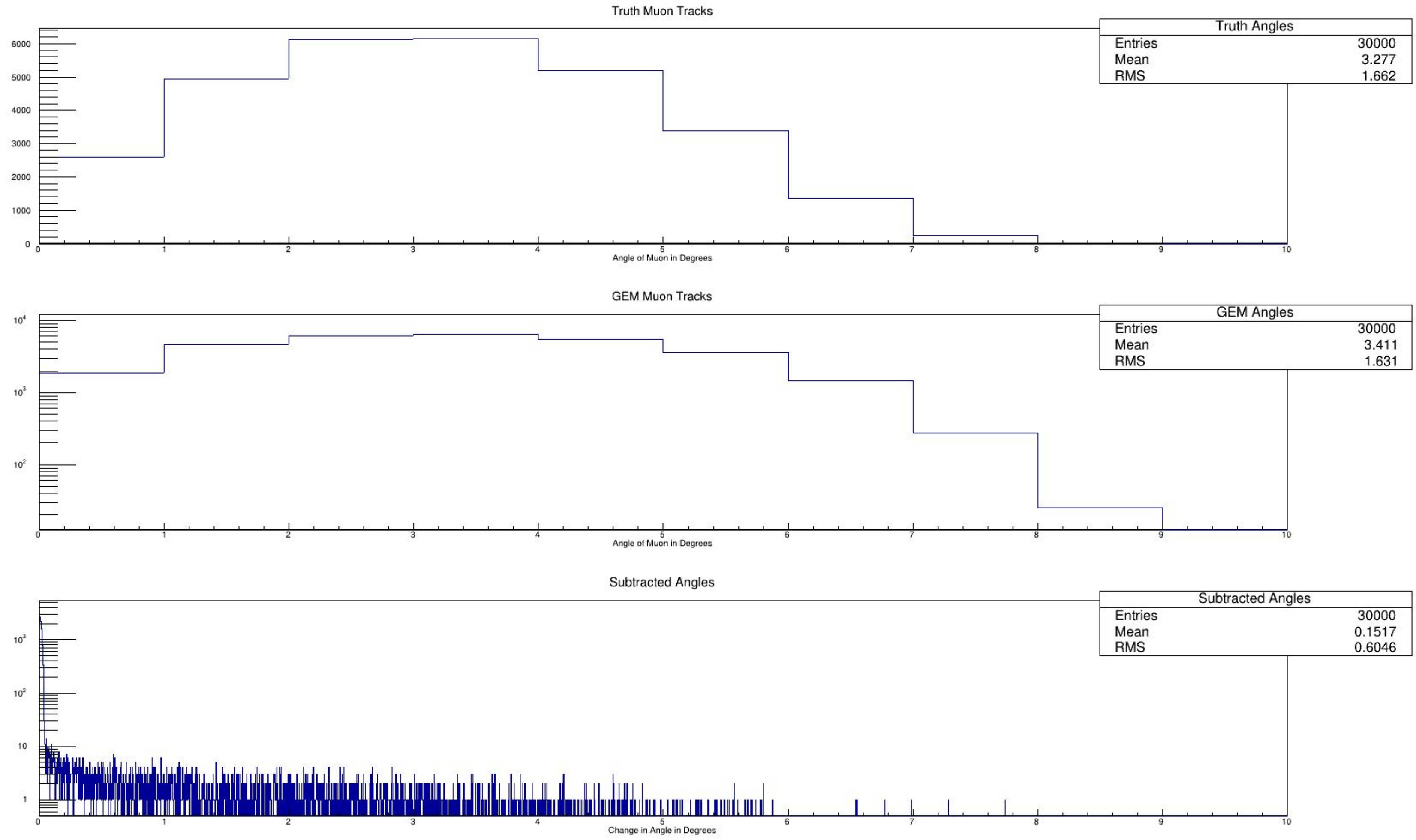


For 1000 events

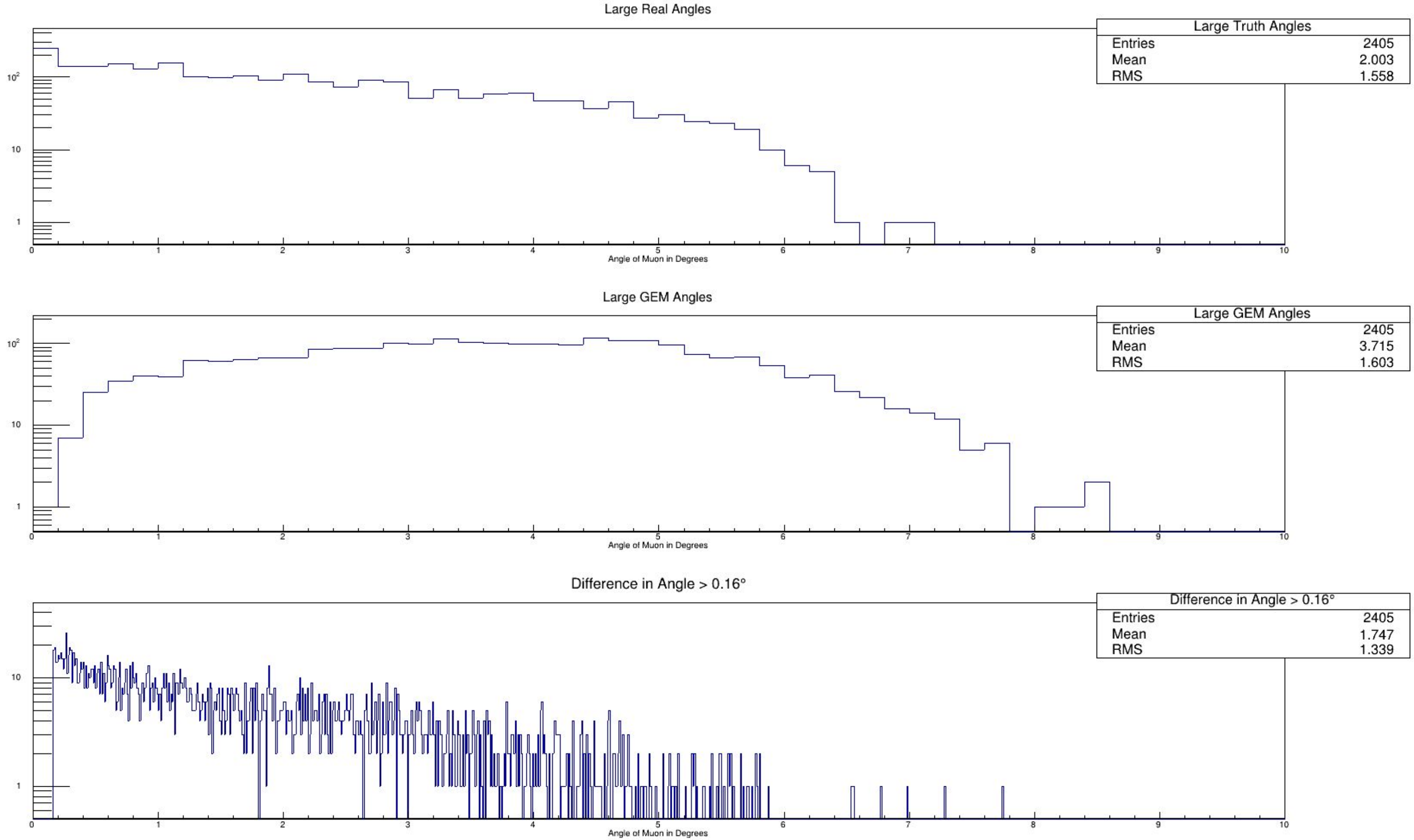
Long Stand Analysis

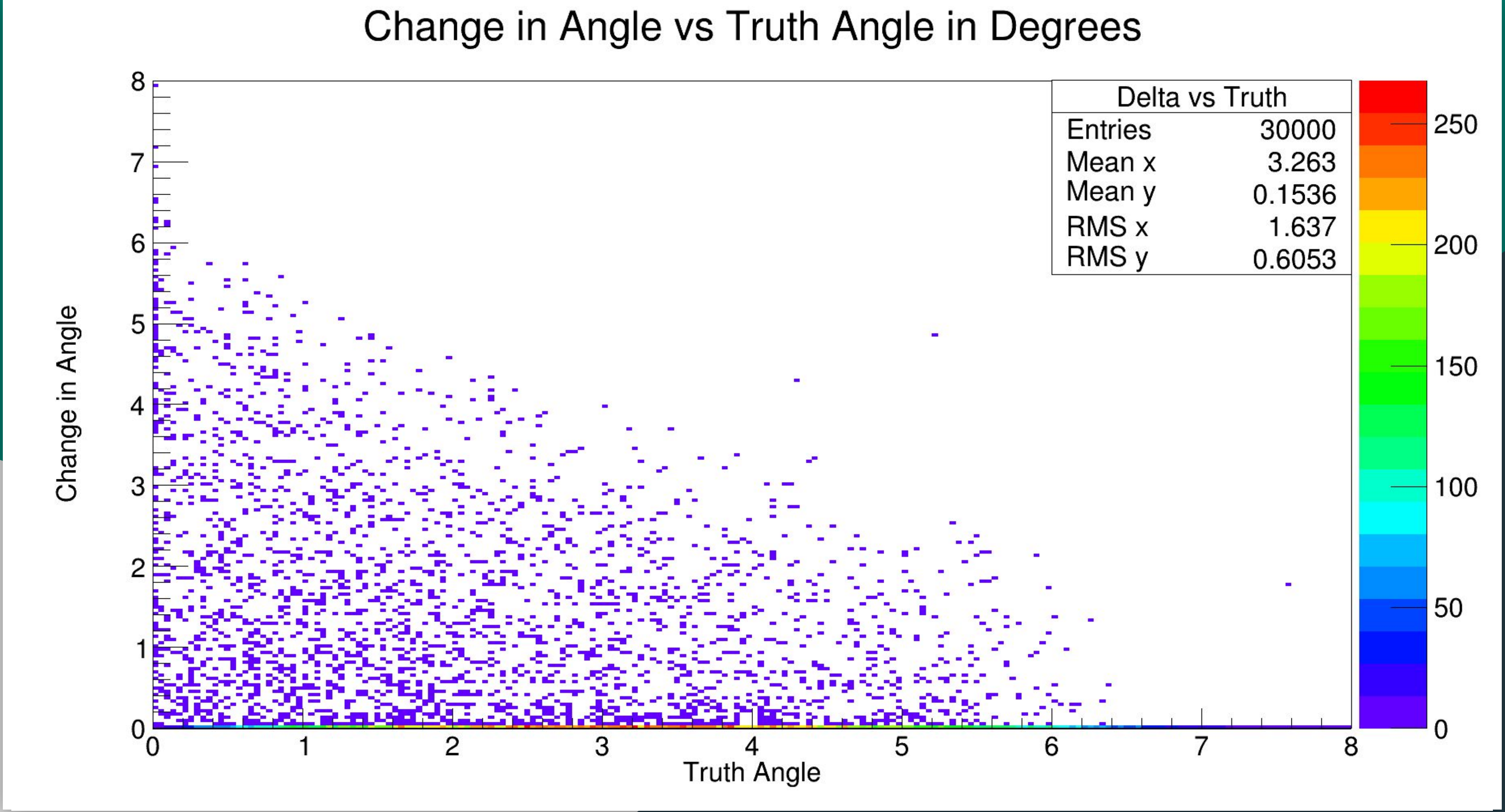
- No correlation between angle magnitude and $\Delta\theta$
- ~5.65% of muon tracks had a $\Delta\theta > 0.07°$ during all translations
- ~5.98% of muon tracks had a $\Delta\theta > 0.05°$during all rotations
- Note: No resolution yields $\Delta\theta = 0°$

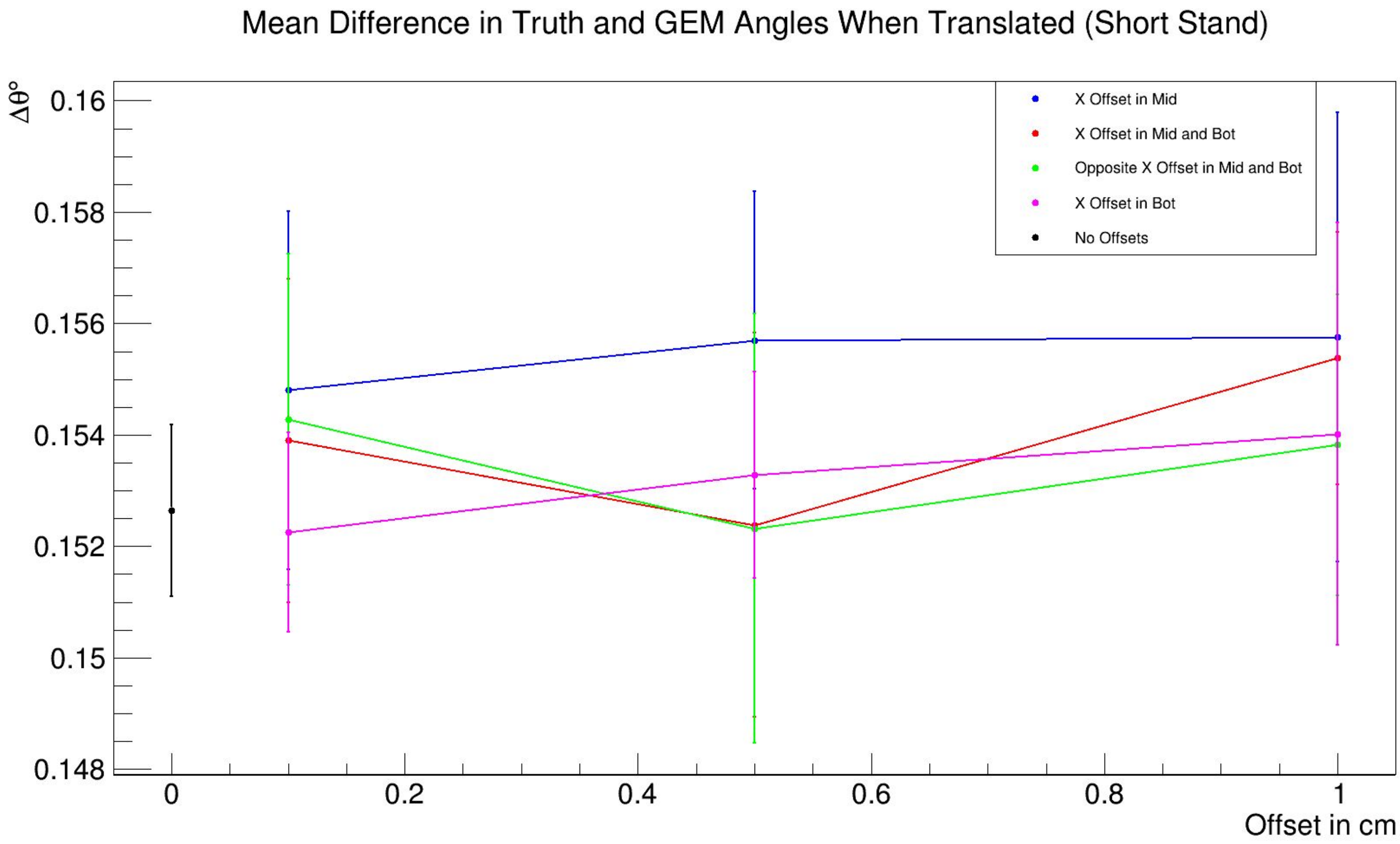
Short Stand
Translation Analysis



Truth Muon Tracks
Truth Angles
Entries 30000
Mean 3.277
RMS 1.662
Angle of Muon in Degrees
GEM Muon Tracks
GEM Angles
Entries 30000
Mean 3.411
RMS 1.631
Angle of Muon in Degrees
Subtracted Angles
Subtracted Angles
Entries 30000
Mean 0.1517
RMS 0.6046
Change in Angle in Degrees


Large Real Angles
Large Truth Angles
Entries 2405
Mean 2.003
RMS 1.558
Angle of Muon in Degrees
Large GEM Angles
Large GEM Angles
Entries 2405
Mean 3.715
RMS 1.603
Angle of Muon in Degrees
Difference in Angle > 0.16°
Difference in Angle > 0.16°
Entries 2405
Mean 1.747
RMS 1.339
Angle of Muon in Degrees


Change in Angle vs Truth Angle in Degrees
Delta vs Truth
Entries 30000
Mean x 3.263
Mean y 0.1536
RMS x 1.637
RMS y 0.6053
Change in Angle
Truth Angle
0
1
2
3
4
5
6
7
8
0
50
100
150
200
250


Mean Difference in Truth and GEM Angles When Translated (Short Stand)
Δθ°
0.16
0.158
0.156
0.154
0.152
0.15
0.148
0
0.2
0.4
0.6
0.8
1
Offset in cm
X Offset in Mid
X Offset in Mid and Bot
Opposite X Offset in Mid and Bot
X Offset in Bot
No Offsets

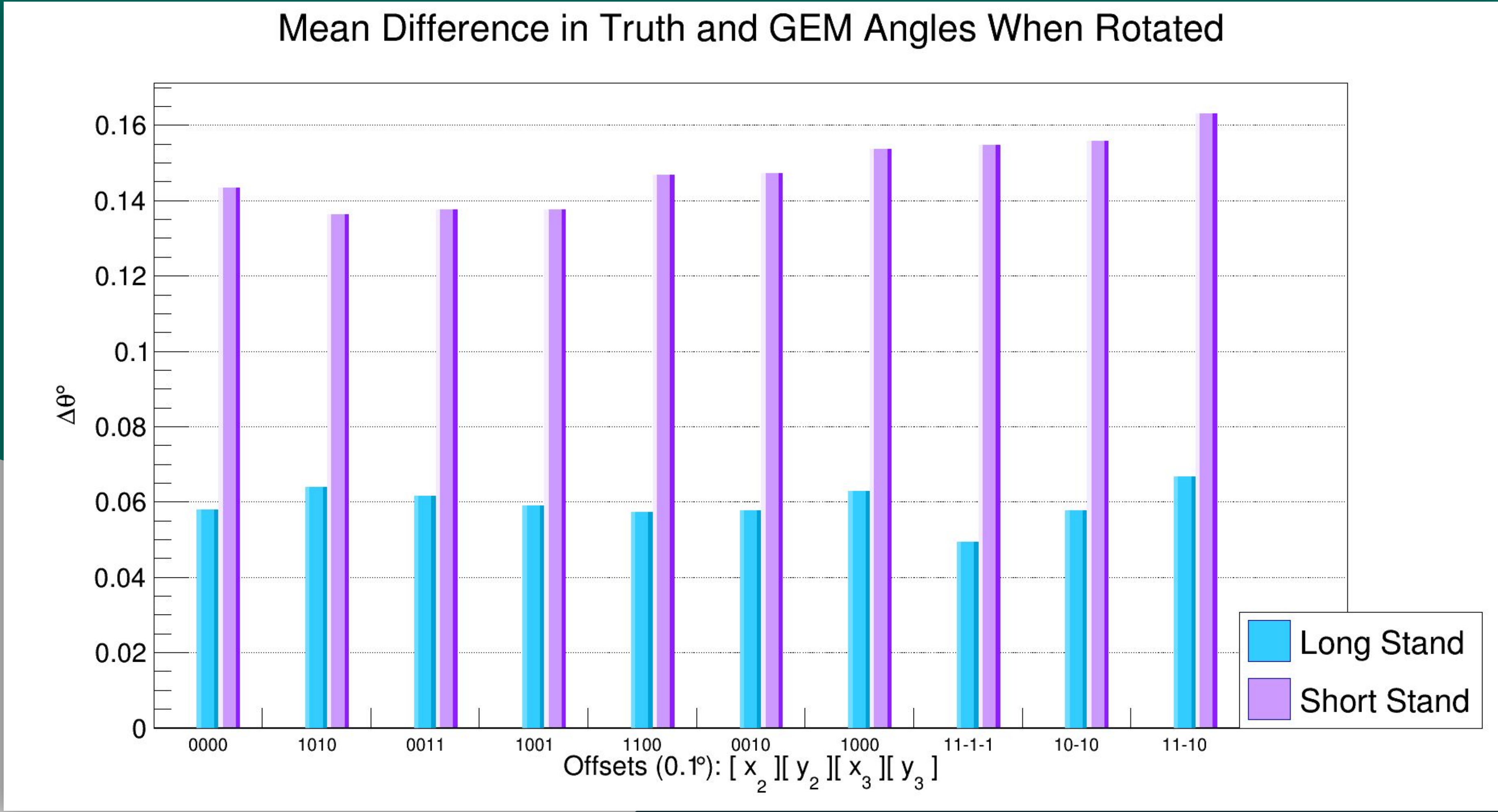
Short Stand Analysis

- No correlation between angle magnitude and $\Delta\theta$
- ~5.65% of muon tracks had a $\Delta\theta > 0.07°$ during all translations
- ~5.98% of muon tracks had a $\Delta\theta > 0.05°$during all rotations
- GEM resolution seems to dominate angular deviations (but why only for the short stand?)

Rotation Analysis

Rotation Analysis

- Using the level, we can get the GEMs aligned within 0.1° around the x and y axis
- Test whether rotations this small make a major difference in fitted GEM angle
- This is important because it is impossible to accurately develop a χ^2 minimization model without z-coordinates (which we cannot measure with GEMs)



Mean Difference in Truth and GEM Angles When Rotated
Δθ°
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0000
1010
0011
1001
1100
0010
1000
11-1-1
10-10
11-10
Offsets (0.1°): [x2][y2][x3][y3]
Long Stand
Short Stand

Rotation Analysis

- For 0.1° rotations, GEM resolution dominates
- Pitch and roll rotational offsets do not need to be precisely measured

Moving Forward

- Investigate why higher event rate results in no correlation between offset and mean angle difference
- Complete χ^2 minimization regression code to measure yaw rotational offsets with uncertainties