Uniform Beam Simulation Compared with Nominal Beam Simulation for NuMI

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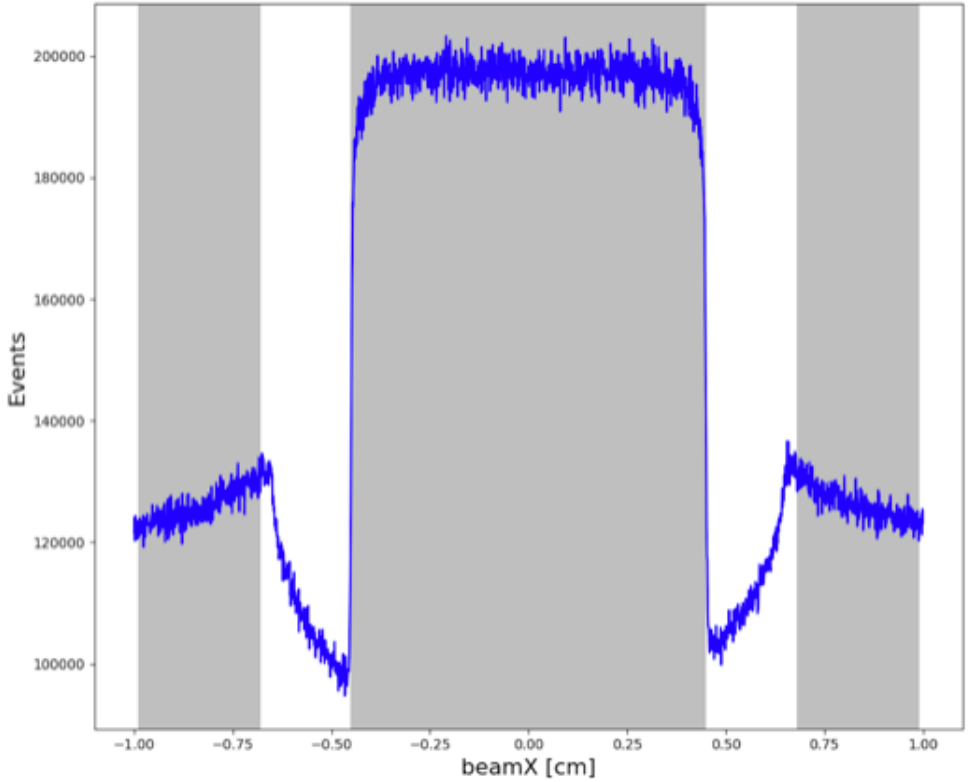
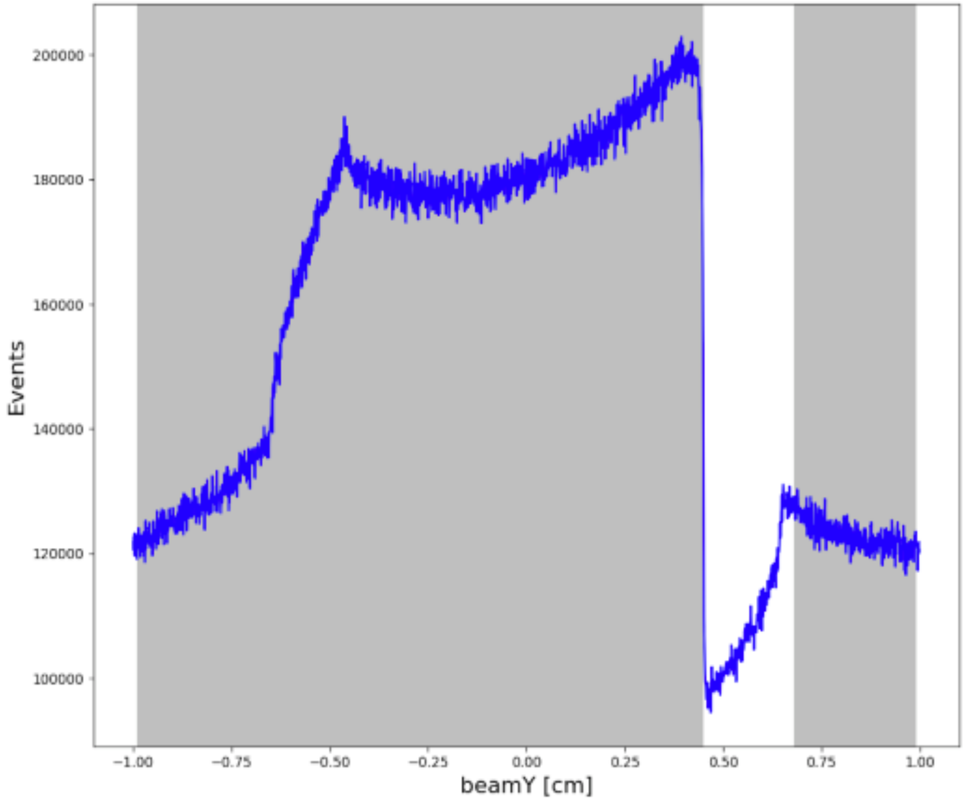
Uniform Beam Simulation

- Uniform proton beam position generated by random throws along horizontal dir. & vertical dir.

Horizontal proton beam position for recorded beam interactions which has a neutrino candidate at downstream neutrino detectors



Vertical proton beam position



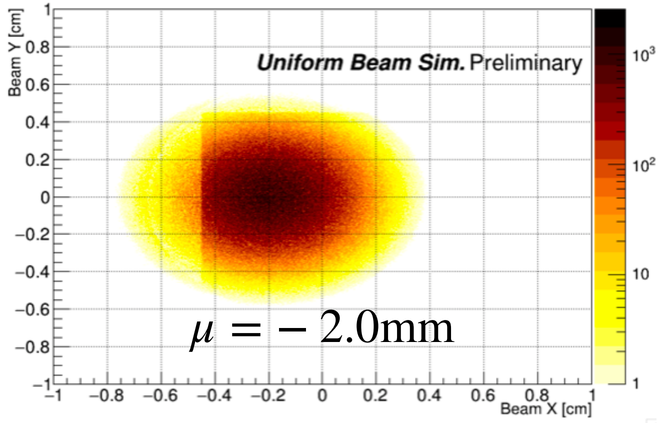
Generate Gaussian Beam for a given beam width & beam position

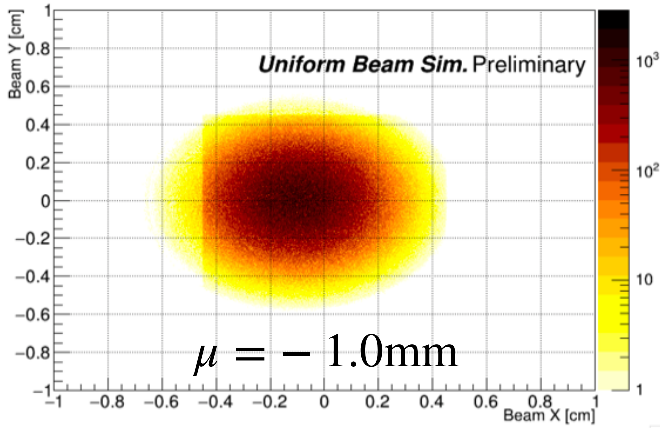
Gaussian weight: $w_i = \frac{1}{\sqrt{2\pi}\sigma} \cdot e^{-\frac{(x_i-\mu)^2}{2\sigma^2}}$

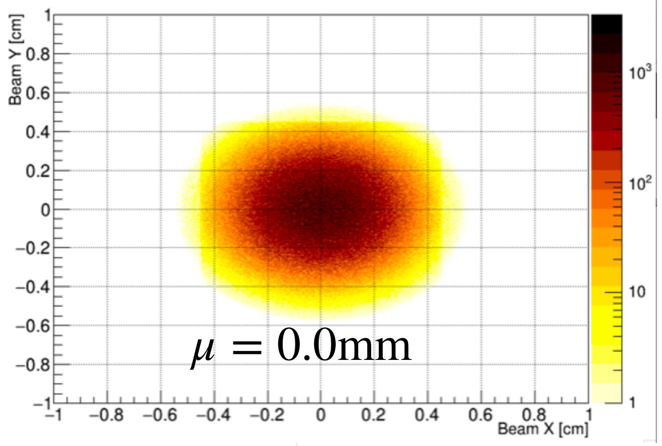
Gaussian width:
$\sigma = $ 1.5 mm
$\mu = -2\ mm,\ -1\ mm,\ 0\ mm,\ 1\ mm,\ 2\ mm$

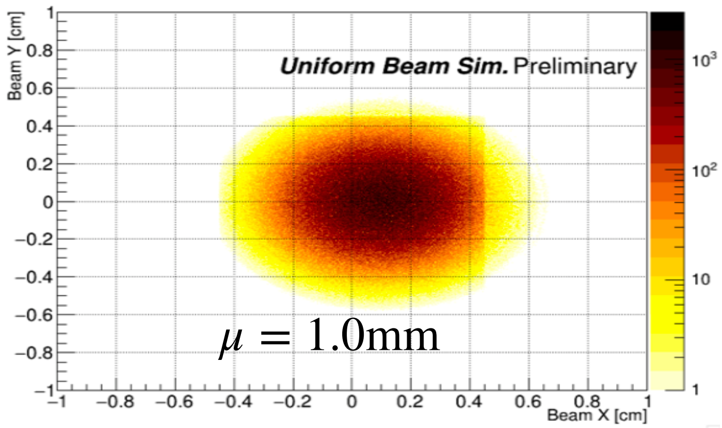
Gaussian slices, beam X centroid changes as $\mu = -2\ mm,\ -1\ mm,\ 0\ mm,\ 1\ mm,\ 2\ mm$

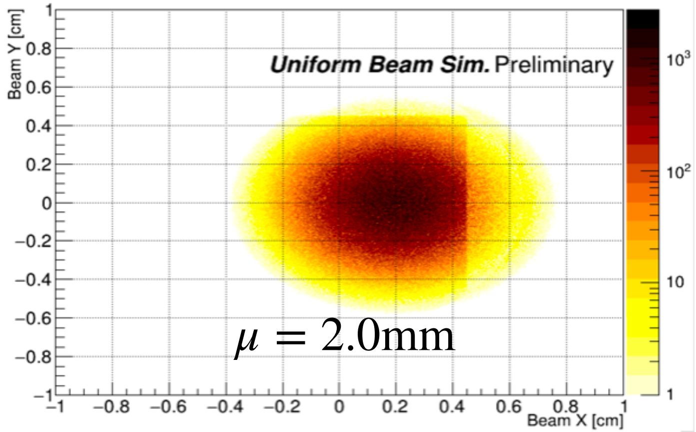
Beam Y centroid stays fixed at 0 mm



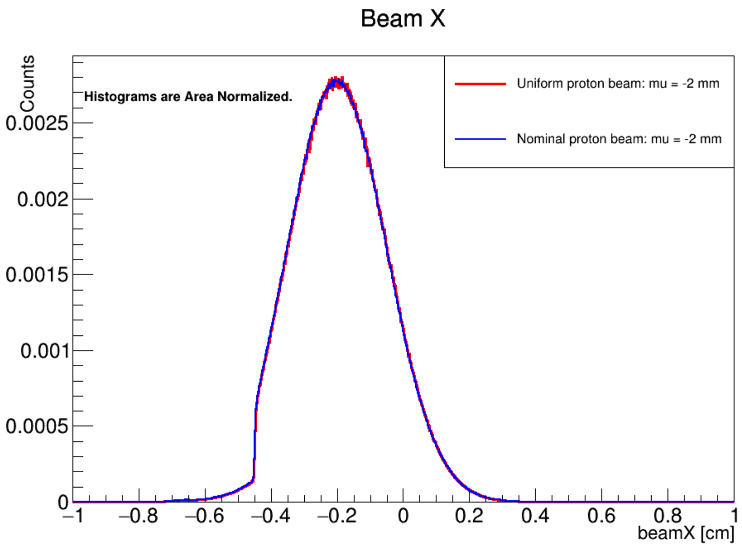


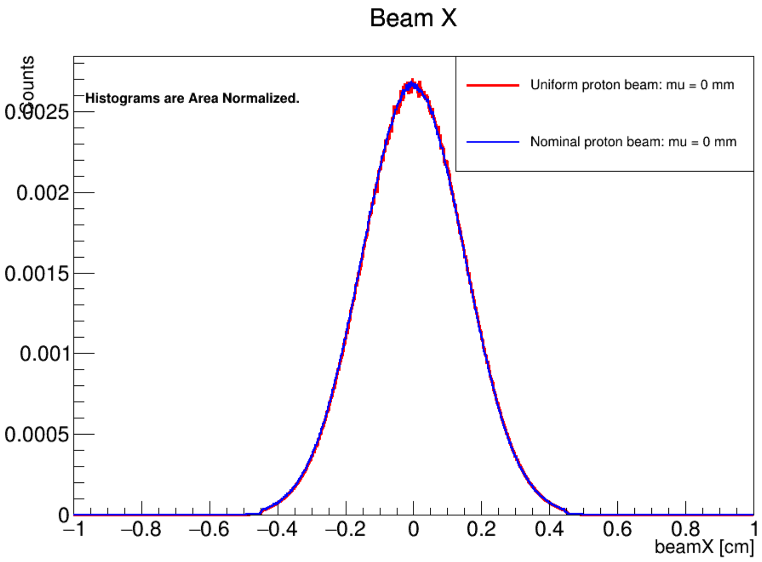


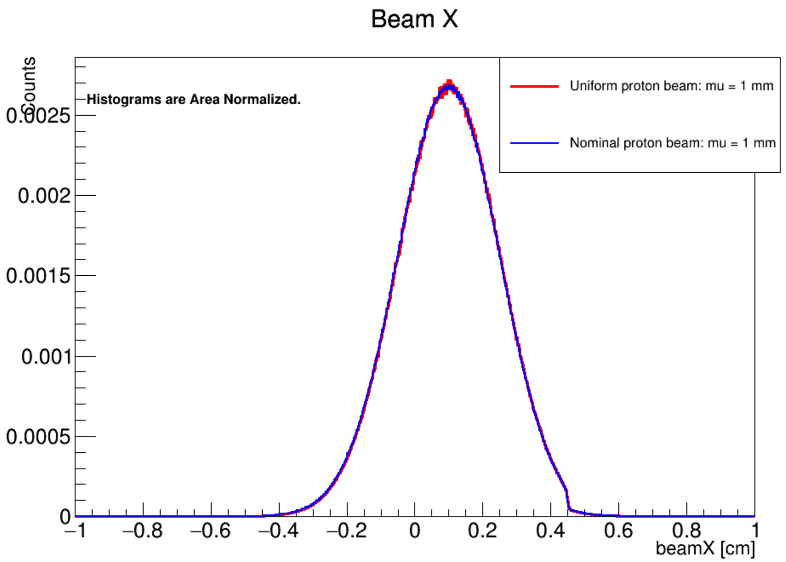


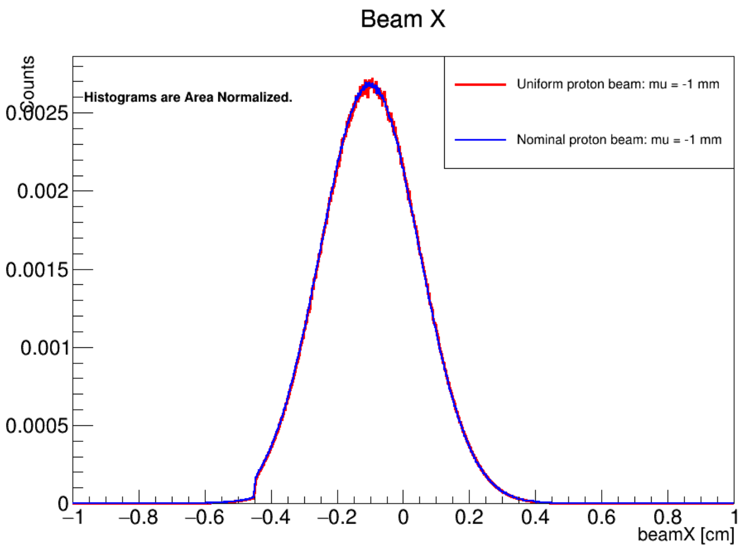


Proton beam profile comparisons



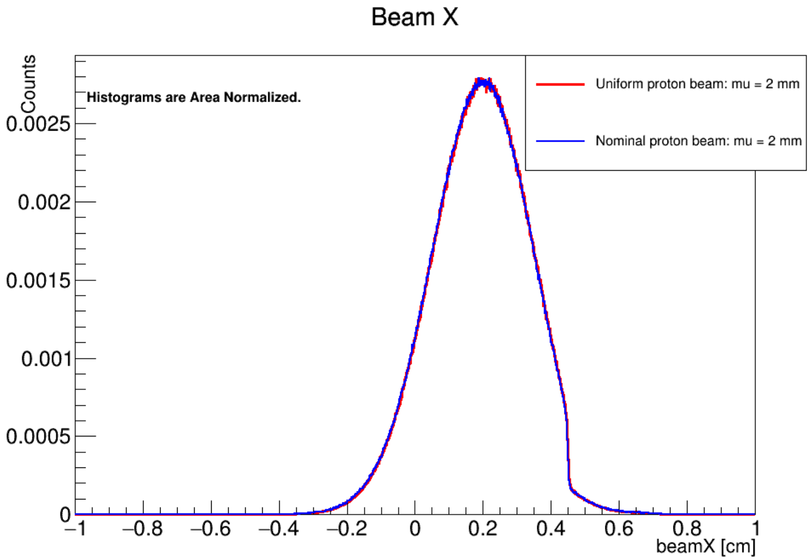




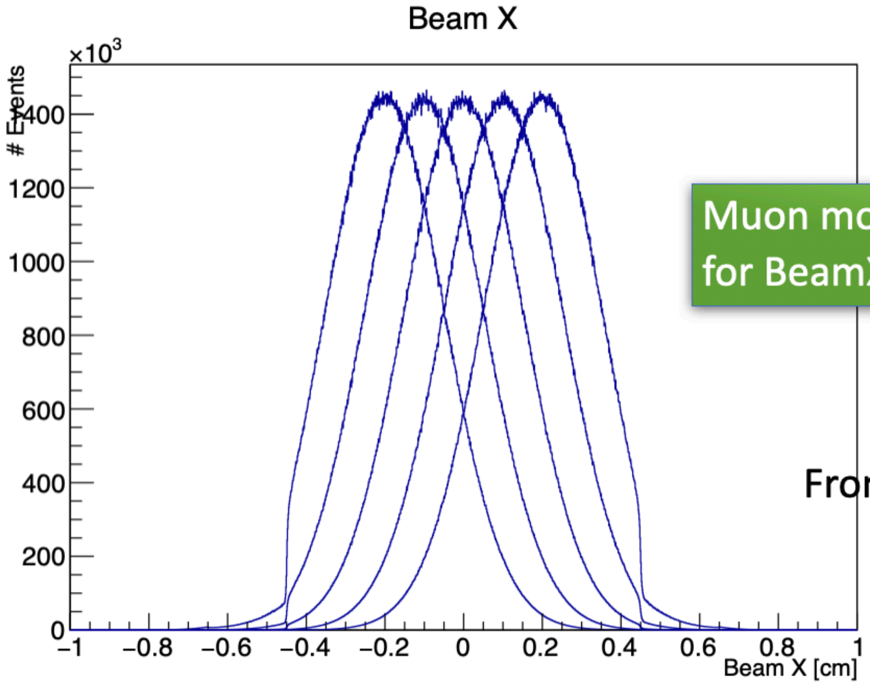


Comparison of uniform beam profile shows a same beam profile as nominal

We have done a separate study of narrow beams with sigma = 0.8 mm and the results shows a very good matching

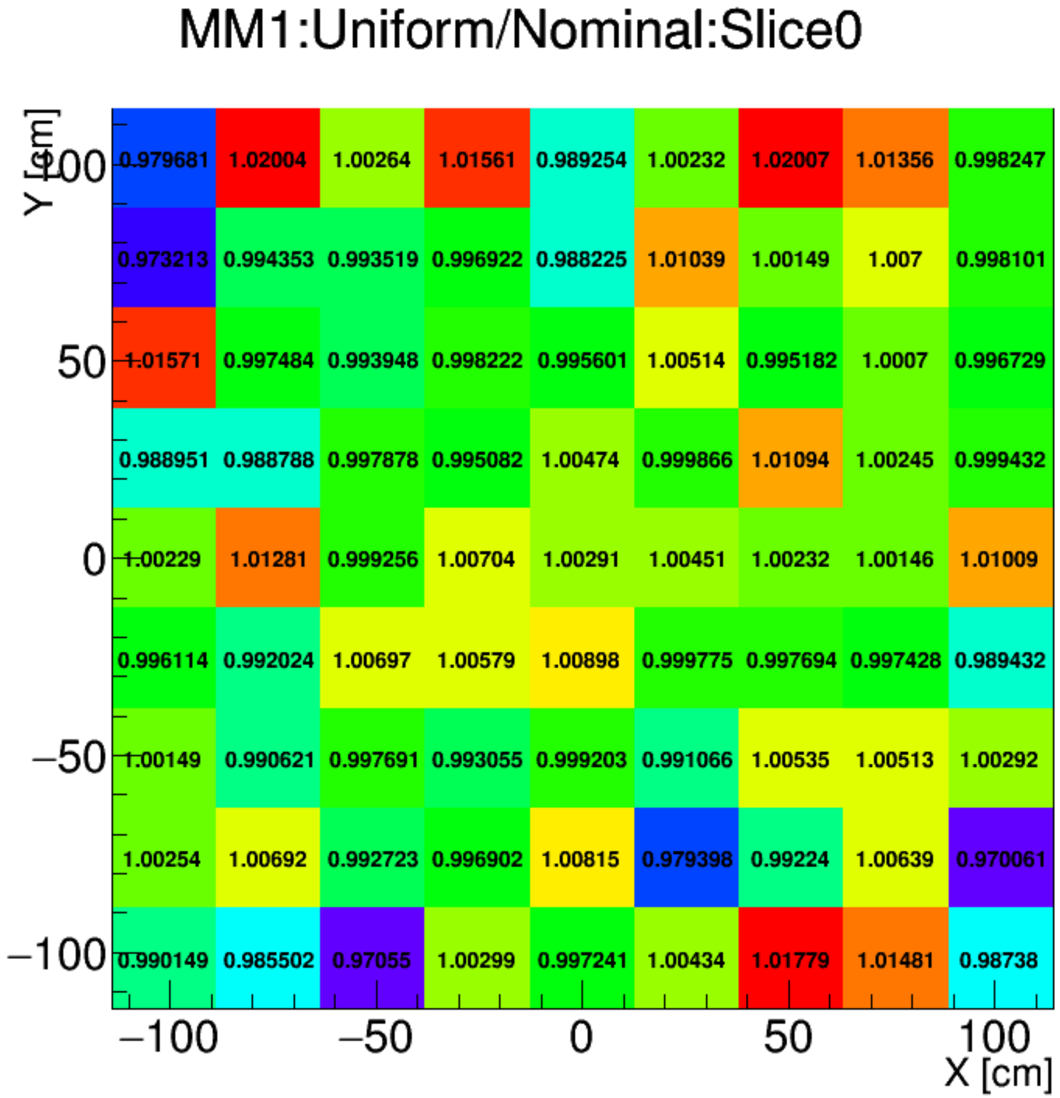


Response on Muon Monitor 1 for each gaussian slice with $\mu = -2\ mm,\ -1\ mm,\ 0\ mm,\ 1\ mm,\ 2\ mm$



Muon monitor response plotted for BeamX : -1 cm to 1 cm

From slice 0 to slice 4

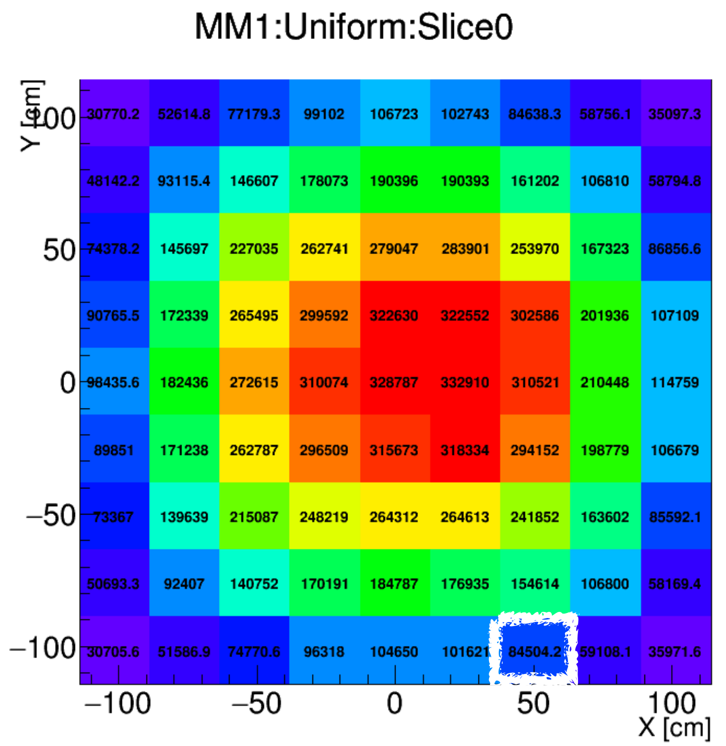


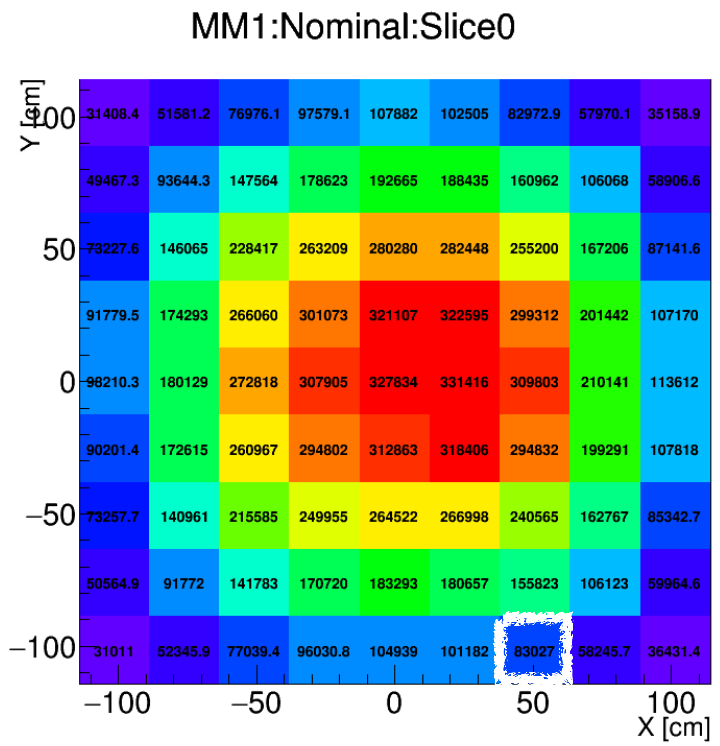
(S.f) = $\frac{\Sigma Evts_{nominal}}{\Sigma Evts_{uniform}}$

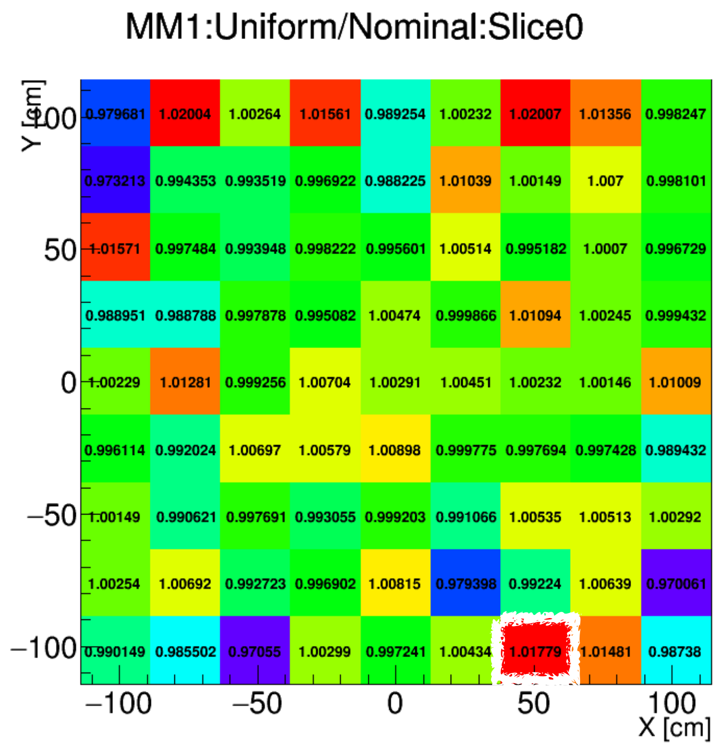
Area normalized #Evts in each pixel from Uniform = #Evts in each pixel from Uniform* S.f

Ratio = **Area normalized #Evts** in each pixel from uniform / #Evts in each pixel from Nominal

Uniform beam POT = 1E9 protons
Nominal beam POT = 2.5 E8 protons

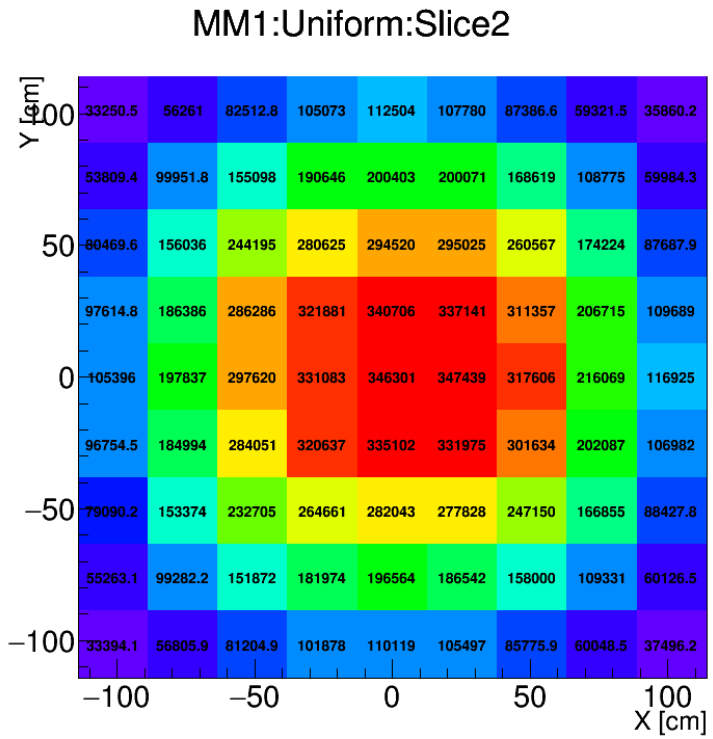


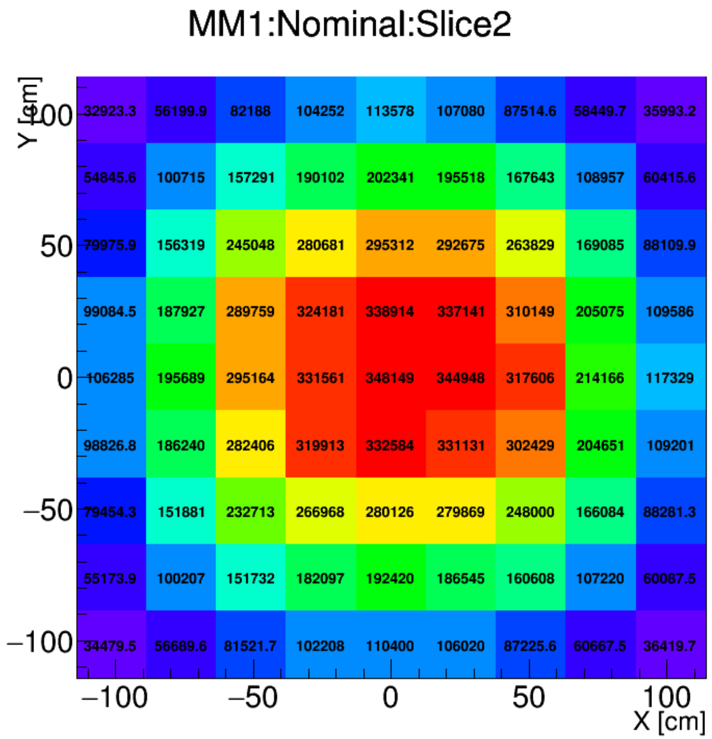


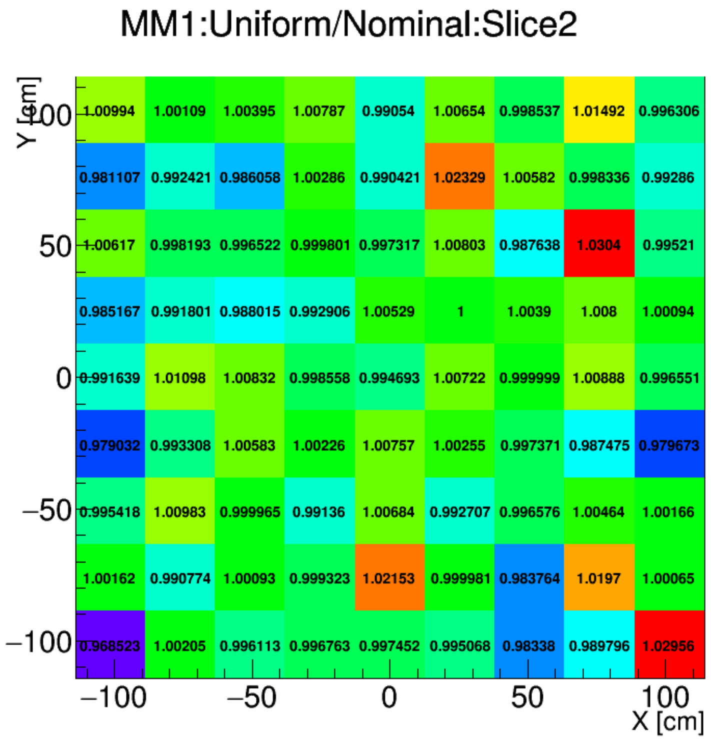


- There is a ~3% difference between the two simulations in some of the edge pixels

Uniform beam POT = 1E9 protons
Nominal beam POT = 2.5 E8 protons



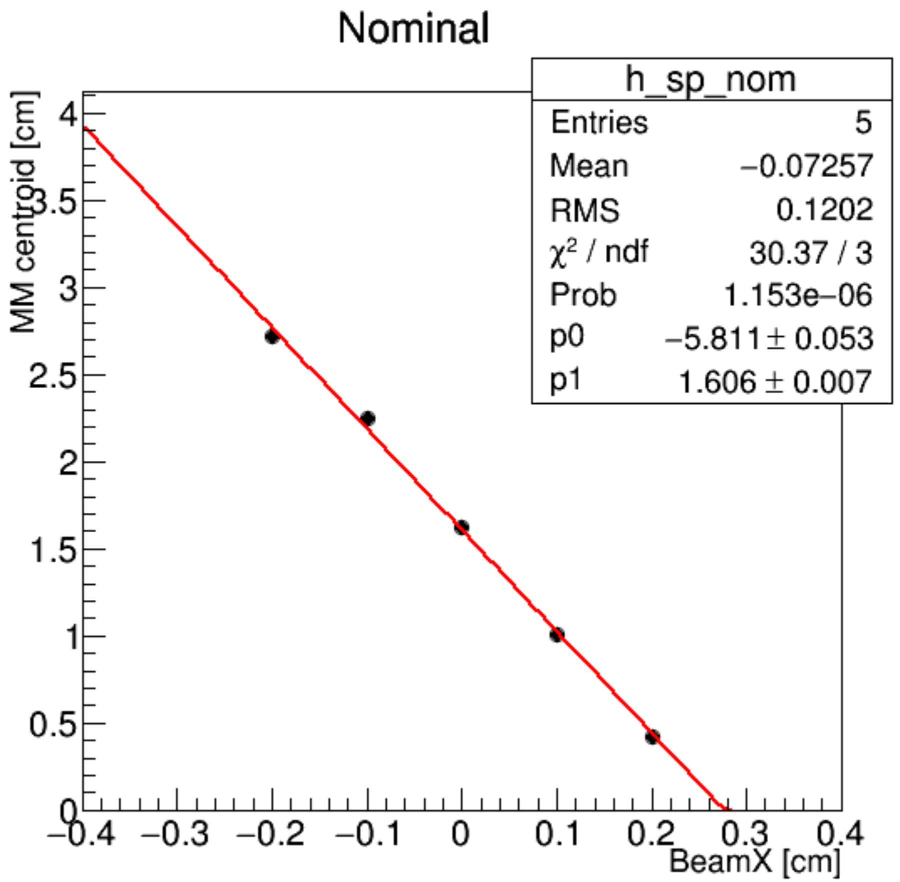


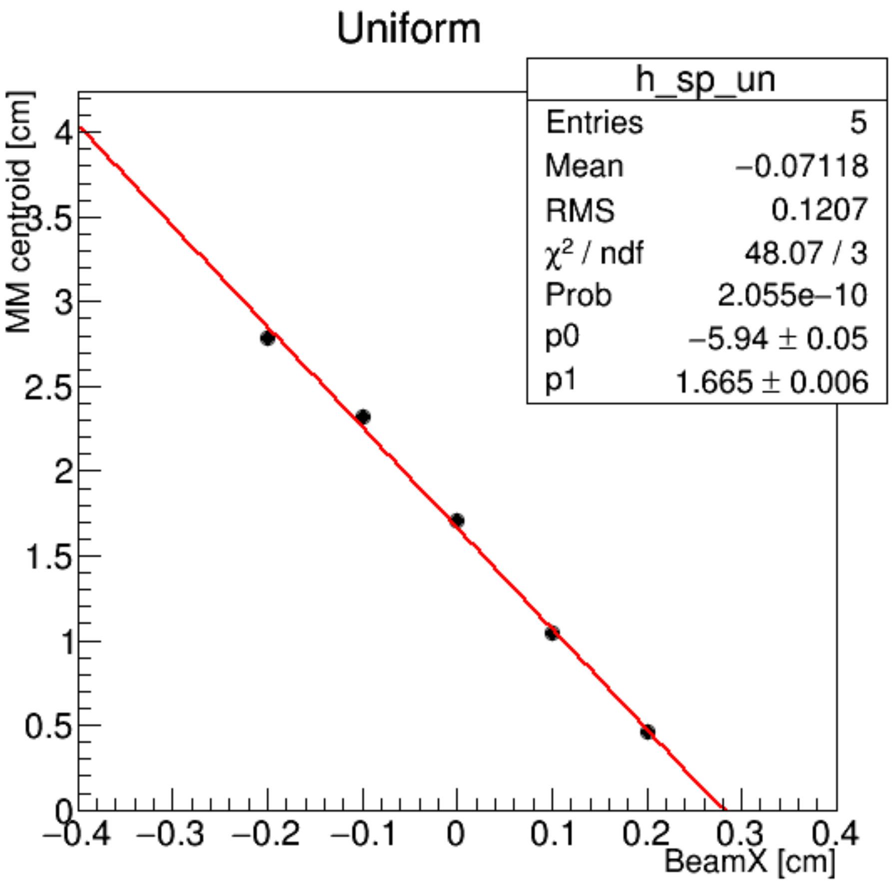


- There is a ~3% difference between the two simulations in some of the edge pixels

Slope Comparisons

Uniform beam POT = 1E9 protons
Nominal beam POT = 2.5 E8 protons

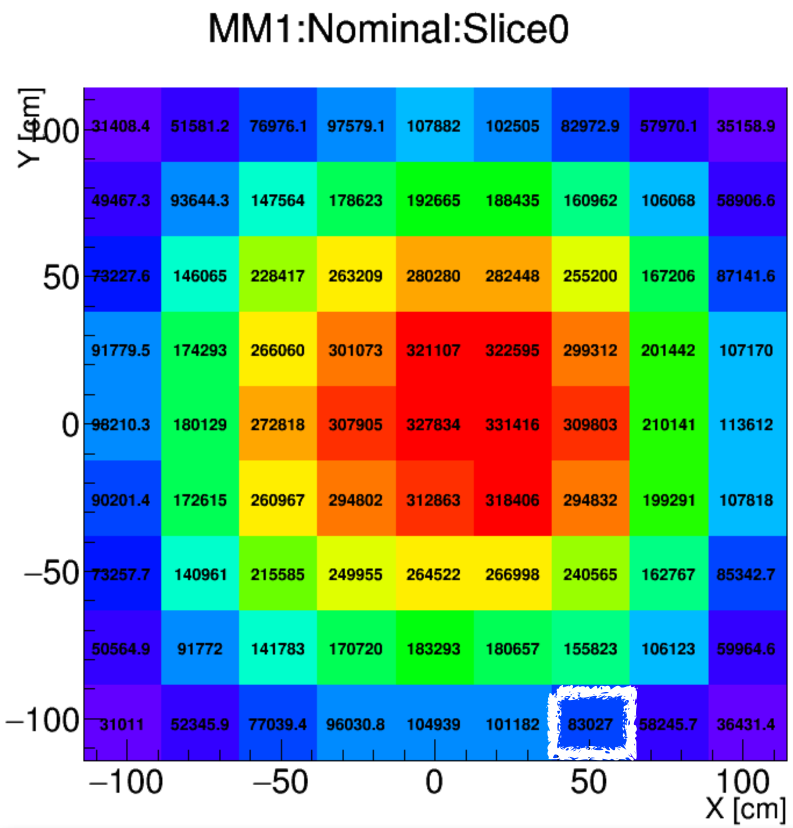


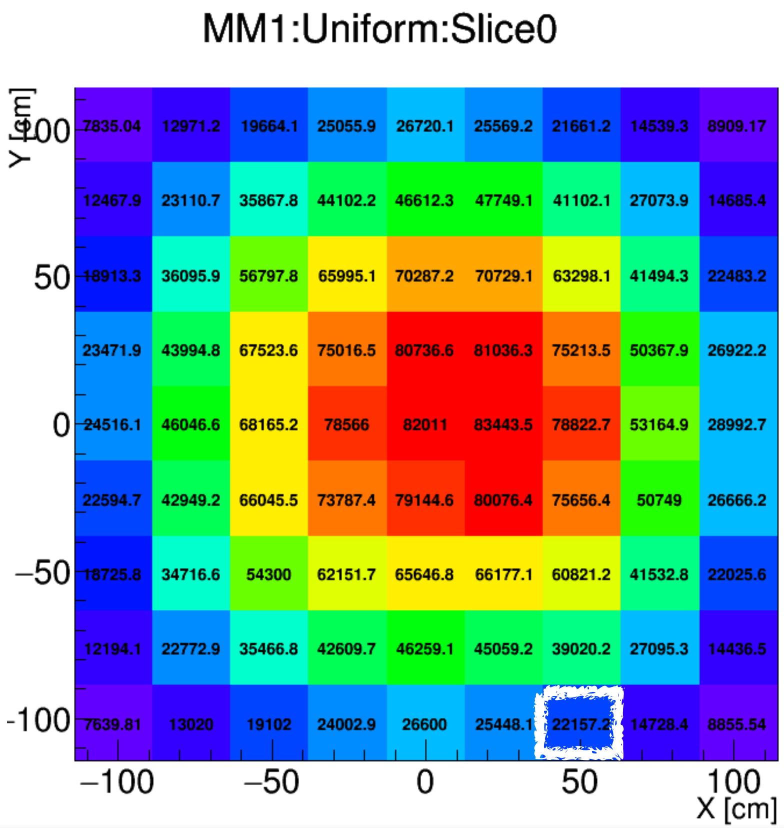


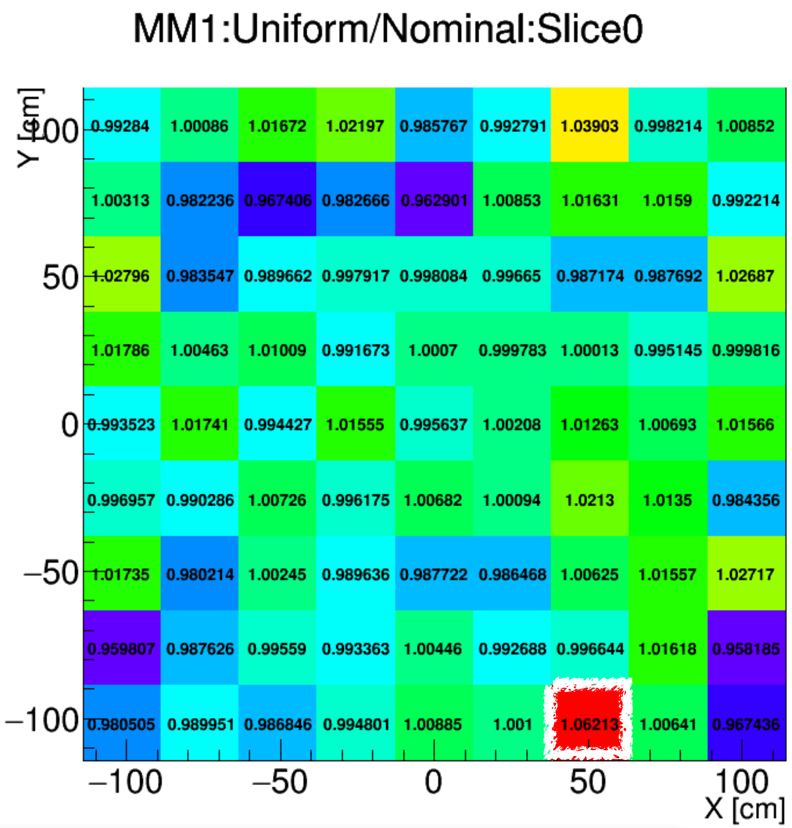
- The difference in the slope is ~ 2.2 %

Statistical effects on MM1 pixels

Uniform beam POT = 2.5 E8 protons
Nominal beam POT = 2.5 E8 protons



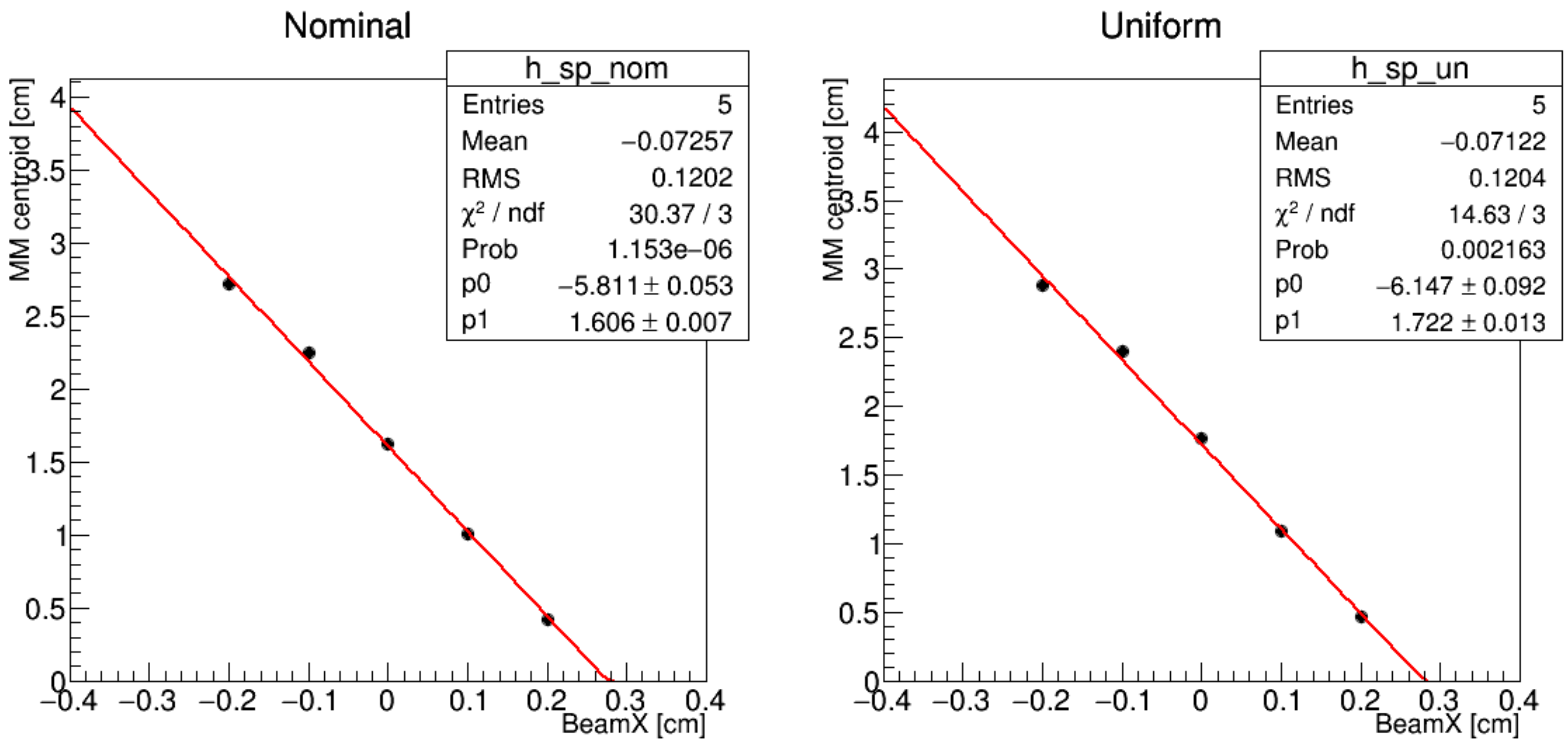




- There is a > 4% difference between the two simulations in some of the edge pixels

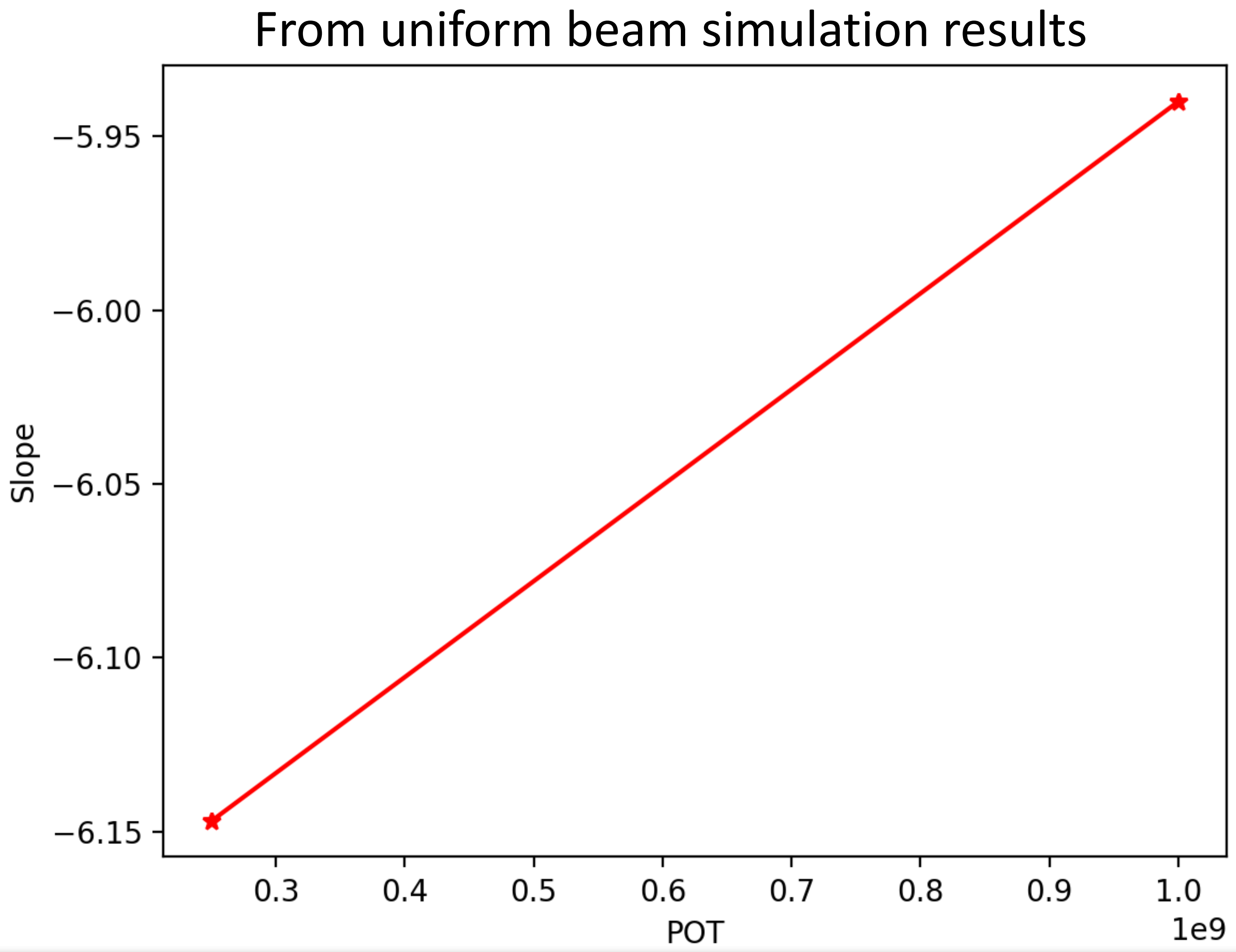
Statistical effects on slope

Uniform beam POT = 2.5 E8 protons
Nominal beam POT = 2.5 E8 protons



- The difference in the slope is ~ 5.6 %

Slope vs Statistics

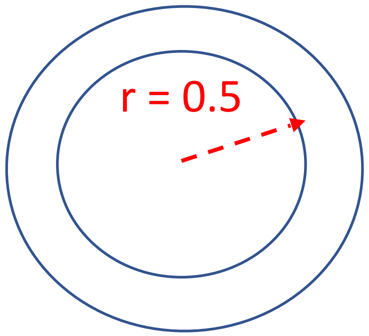


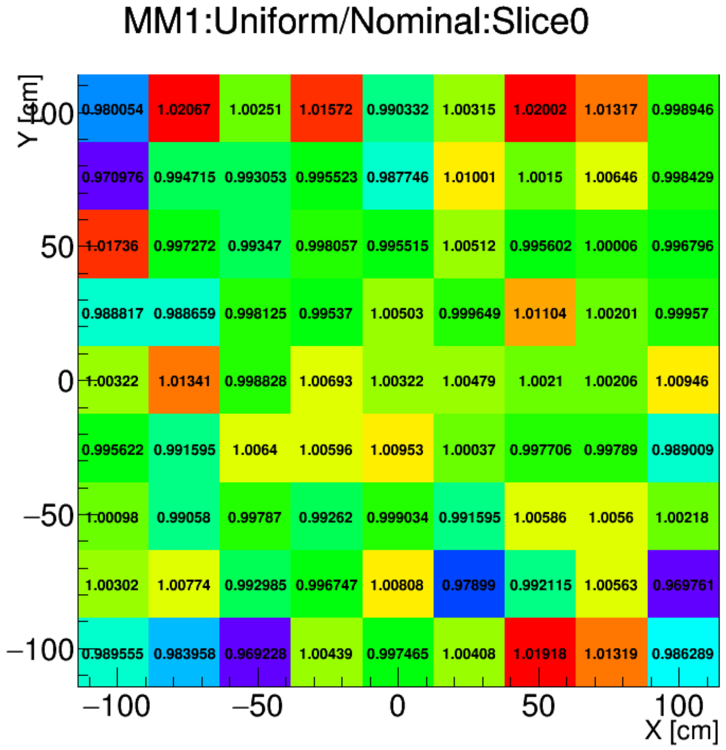
- Increasing statistics for uniform reduces the differences of slopes

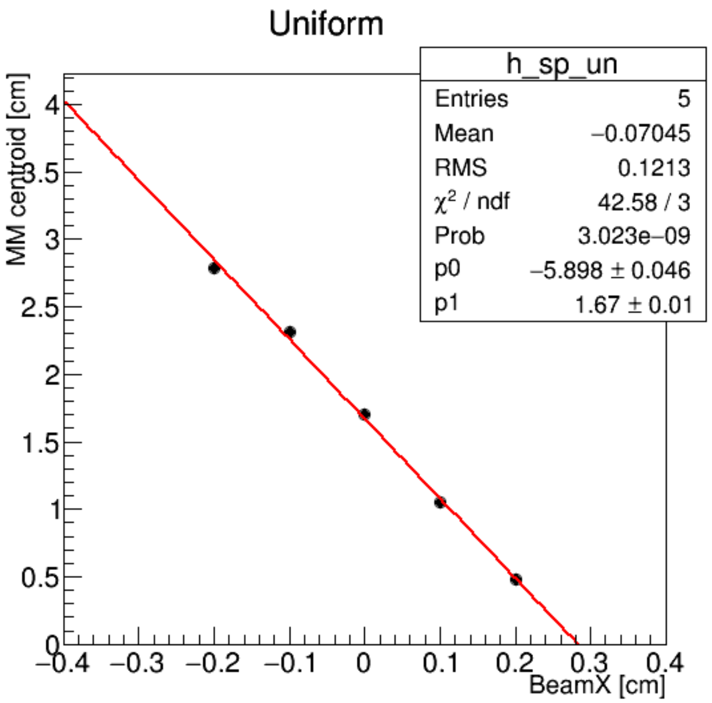
Studying effects of the gaussian tail

Understanding the effects of the gaussian tails from the uniform beam simulation on the edge pixels on MM1

1. Calculate r = $\sqrt{(proton\ X)2 + (proton Y)2}$
2. Look at MM pixel response for r < 0.5
3. Calculate slope for r < 0.5







- R<0.5 cut consistent with no radius cut
- The gaussian tail doesn't have any effect on the edge pixels

Summary

- Motivated to track down the ~6% slope difference between uniform and nominal
- Increasing statistics for uniform reduces the differences of slopes
- Uniform beam profile has been validated against the nominal beam profile
- Gaussian tail from the uniform beam simulation doesn’t affect the muon monitor response