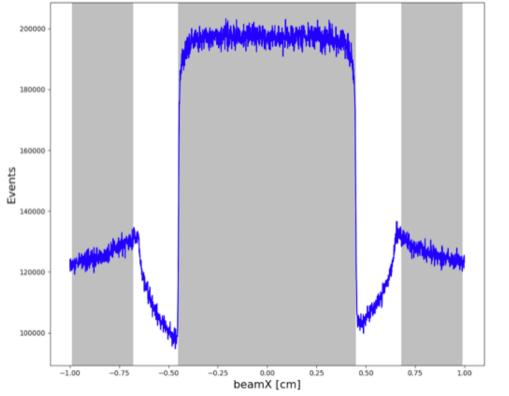
Uniform Beam Simulation Compared with Nominal Beam Simulation for NuMI

Athula, Sudeshna 10/26/2022

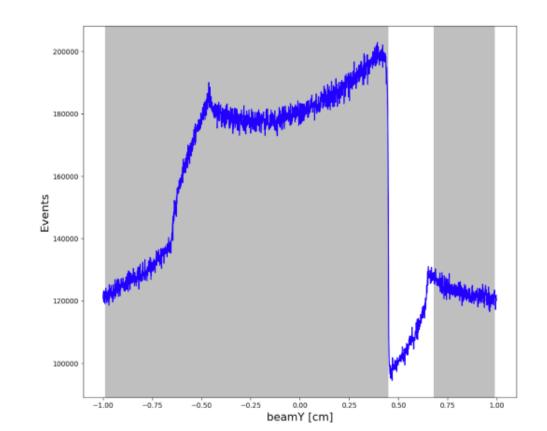
Uniform Beam Simulation

• 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

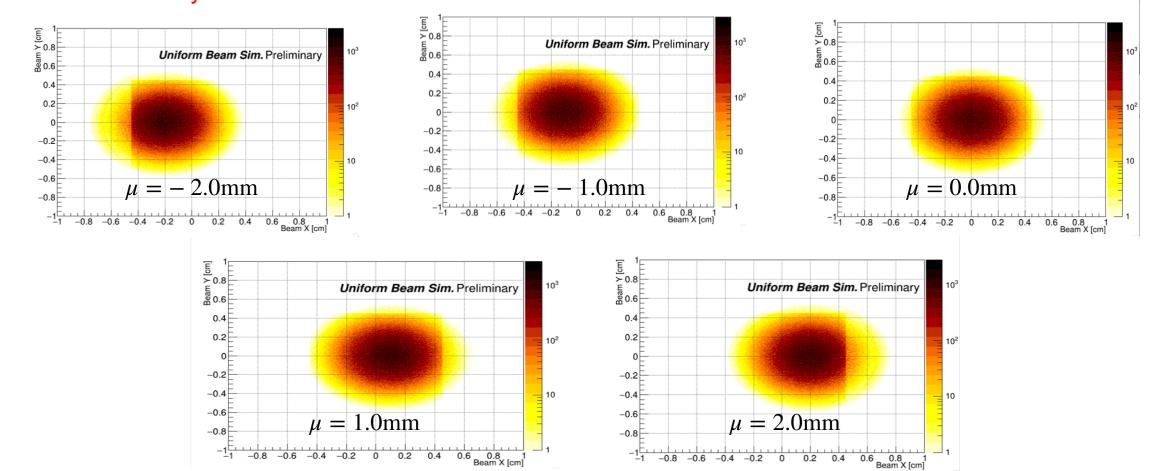
. . .

Gaussian width:
Gaussian width:

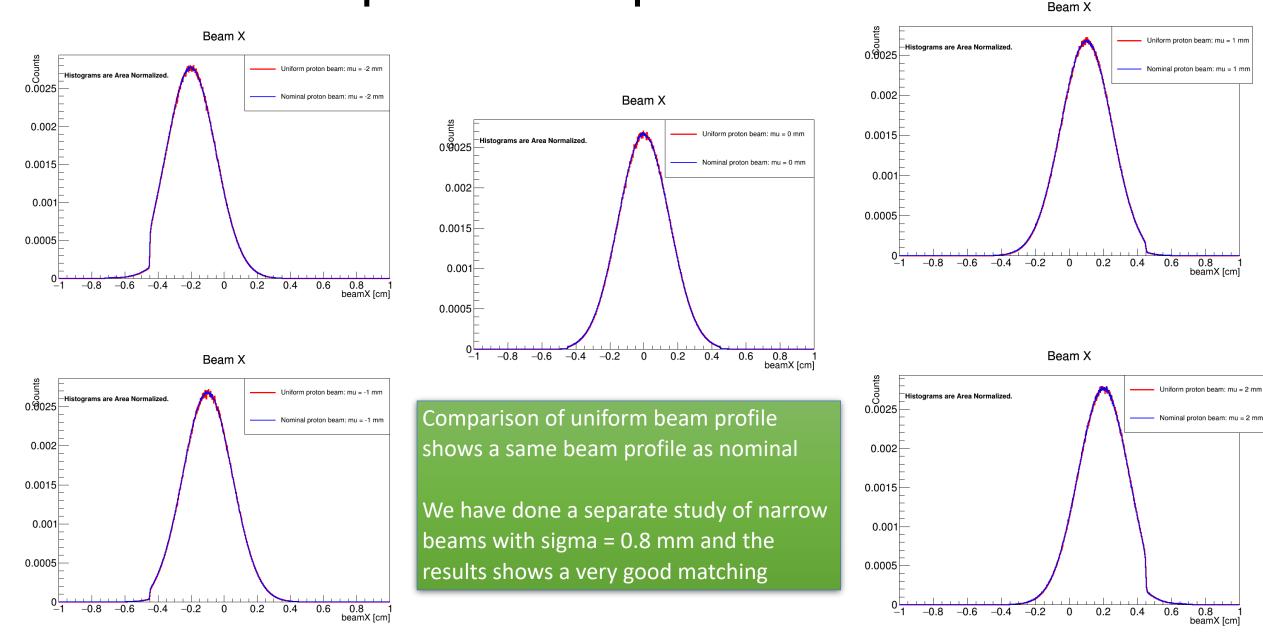
$$\sigma = 1.5 \text{ mm}$$

 $\mu = -2 \text{ mm}, -1 \text{ mm}, 0 \text{ mm}, 1 \text{ mm}, 2 \text{ mm}$

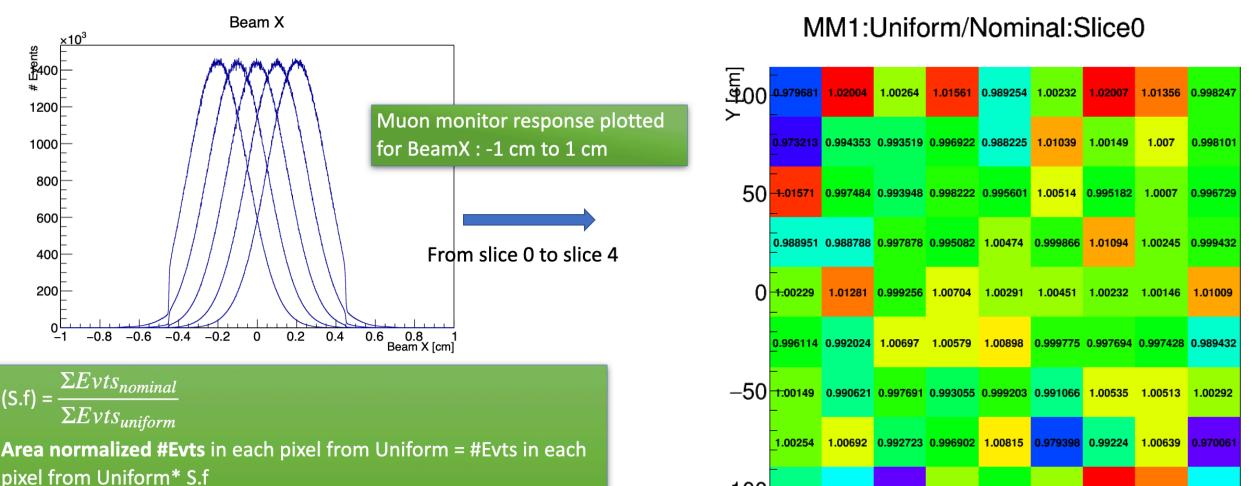
Gaussian slices, beam X centroid changes as $\mu = -2 mm$, -1 mm, 0 mm, 1 mm, 2 mmBeam Y centroid stays fixed at 0 mm



Proton beam profile comparisons



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



-100 0.990149 0.985502 0.97055

-100

1.00299

-50

0.997241 1.00434

0

1.01779 1.01481

50

0.98738

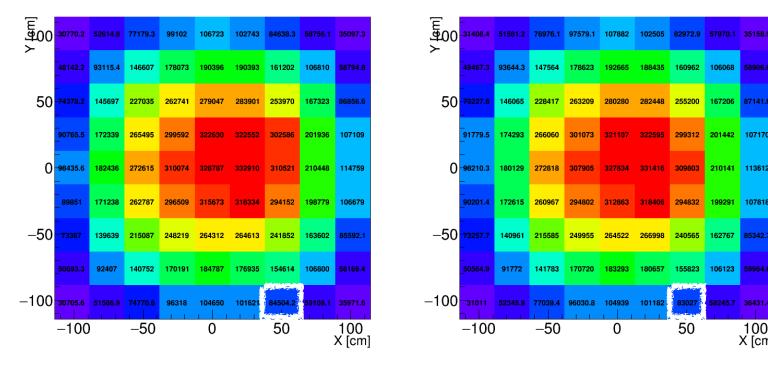
100

X [cm]

. 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

MM1:Uniform:Slice0



MM1:Nominal:Slice0

87141.6

113612

10781

167206

210141

100201

162767

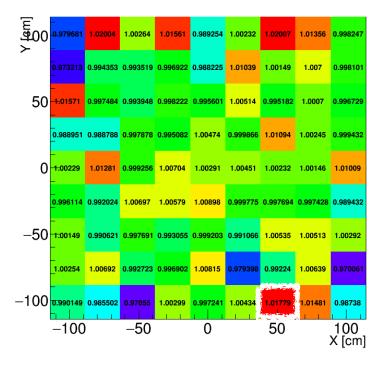
106123 59964.6

8245.7 36431.4

100 X [cm]

201442 107170

MM1:Uniform/Nominal:Slice0



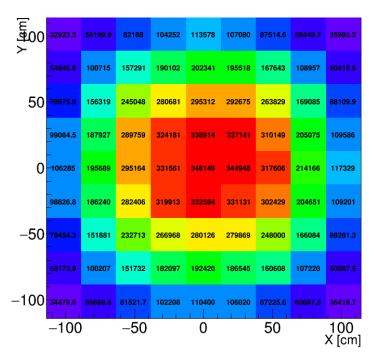
• There is a ~3% difference between the two simulations in some of the edge pixels

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

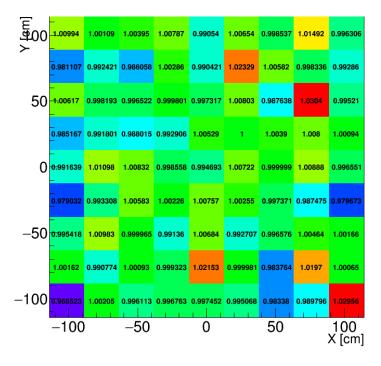
MM1:Uniform:Slice2

≻ ≣00	_ _33250.5 _	56261	82512.8	105073	112504	107780	87386.6	59321.5	35860.2
ŗ	53809.4	99951.8	155098	190646	200403	200071	168619	108775	59984.3
50	 - 8 0469.6 	156036	244195	280625	294520	295025	260567	174224	87687.9
		186386	286286	321881	340706	337141	311357	206715	109689
0	 1 05396 	197837	297620	331083	346301	347439	317606	216069	116925
		184994	284051	320637	335102	331975	301634	202087	106982
-50		153374	232705	264661	282043	277828	247150	166855	88427.8
	55263.1	99282.2	151872	181974	196564	186542	158000	109331	60126.5
-100	33394.1	56805.9	81204.9	101878	110119	105497	85775.9	60048.5	37496.2
	-100		-50		0		50		100 X [cm]

MM1:Nominal:Slice2



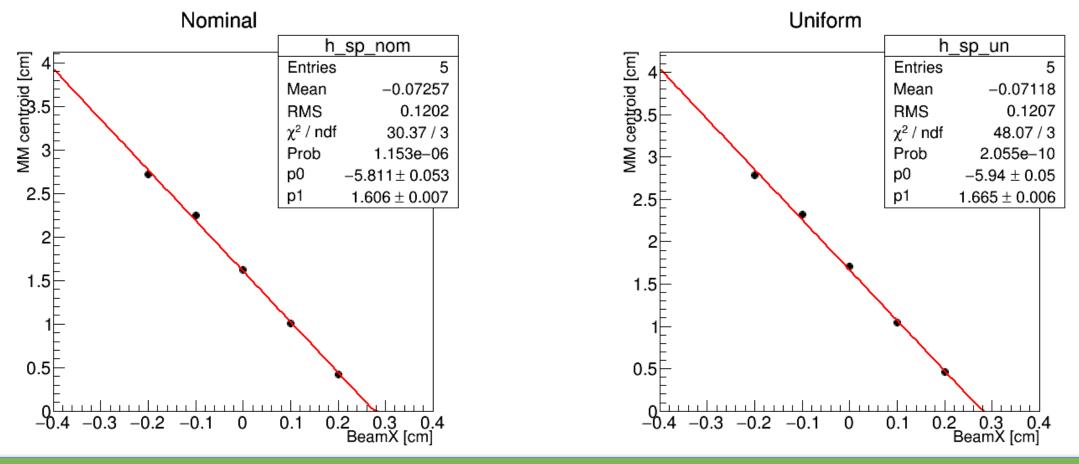
MM1:Uniform/Nominal:Slice2



• 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

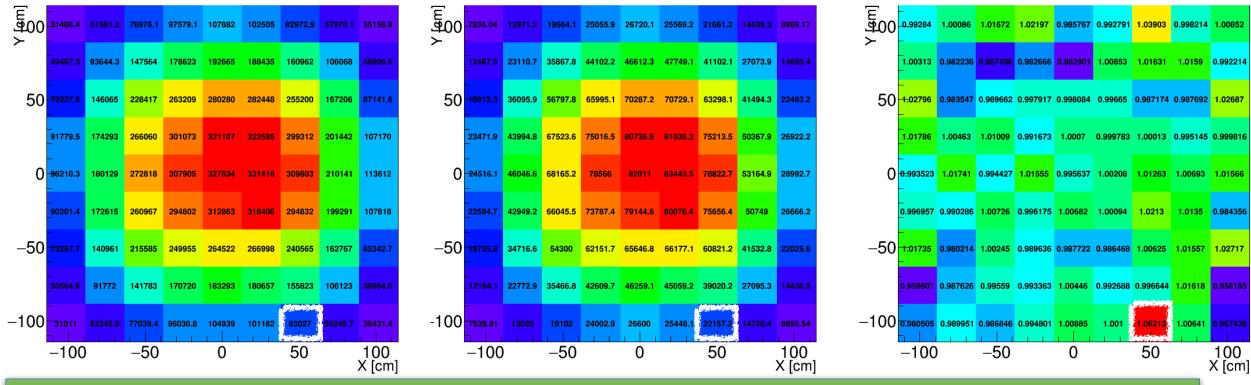


• The difference in the slope is ~ 2.2 %

Statistical effects on MM1 pixels Uniform beam POT = 2.5 E8 protons Nominal beam POT = 2.5 E8 protons

MM1:Uniform:Slice0

MM1:Nominal:Slice0

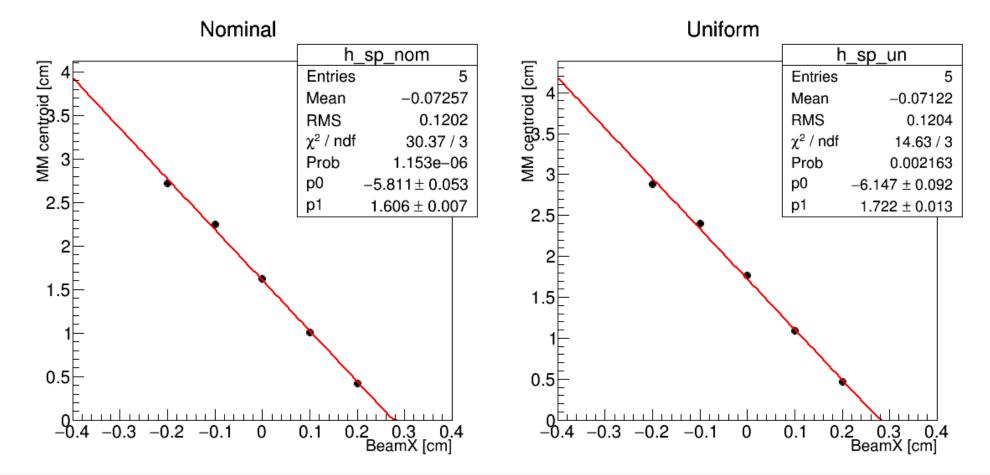


• There is a > 4% difference between the two simulations in some of the edge pixels

MM1:Uniform/Nominal:Slice0

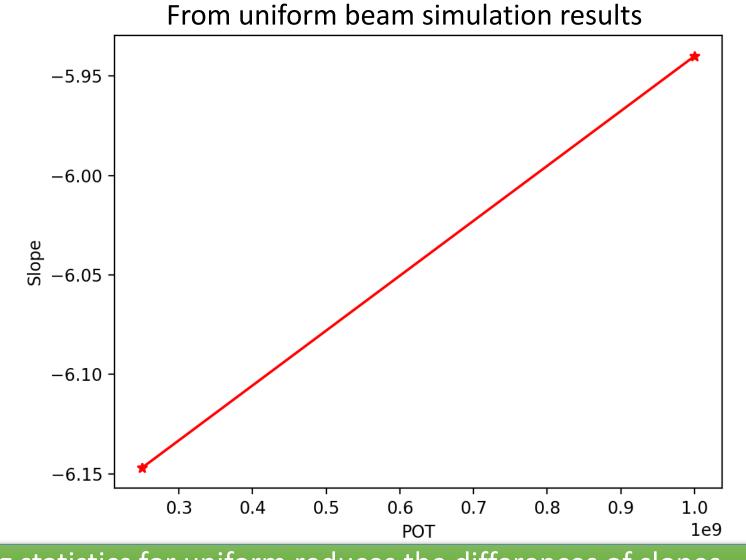
Statistical effects on slope

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

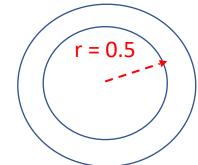


• Increasing statistics for uniform reduces the differences of slopes

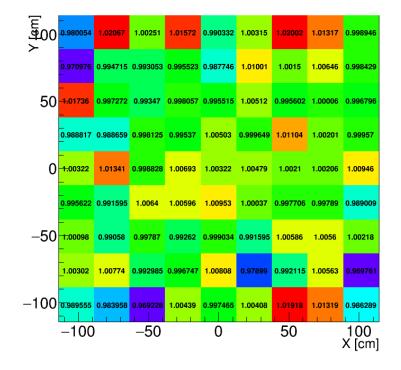
Studying effects of the gaussian tail

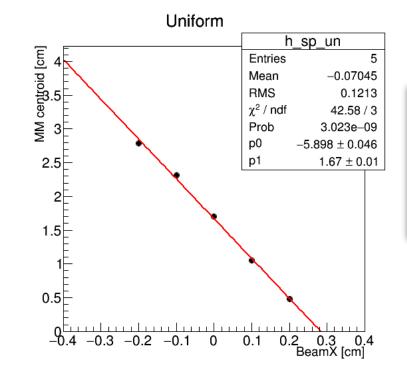
Understanding the effects of the gaussian tails from the uniform beam simulation on the edge pixels on MM1

- 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



MM1:Uniform/Nominal:Slice0





- 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