

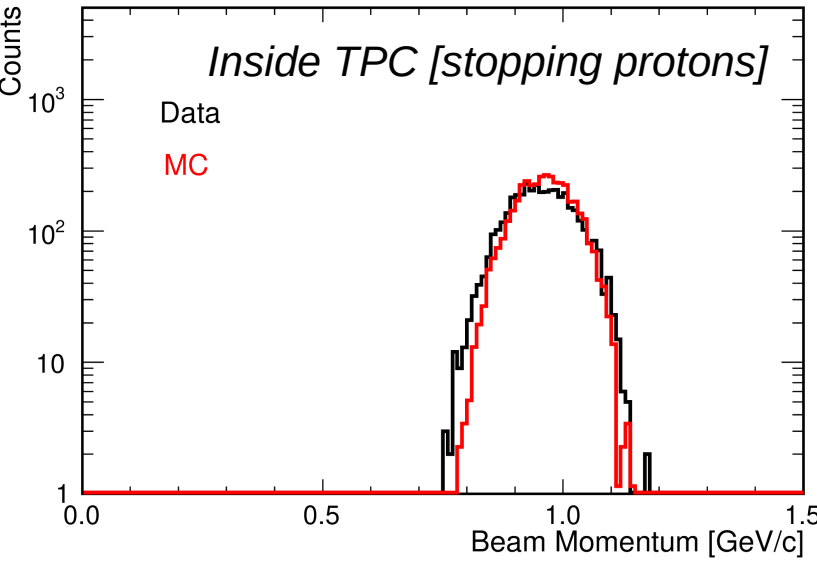
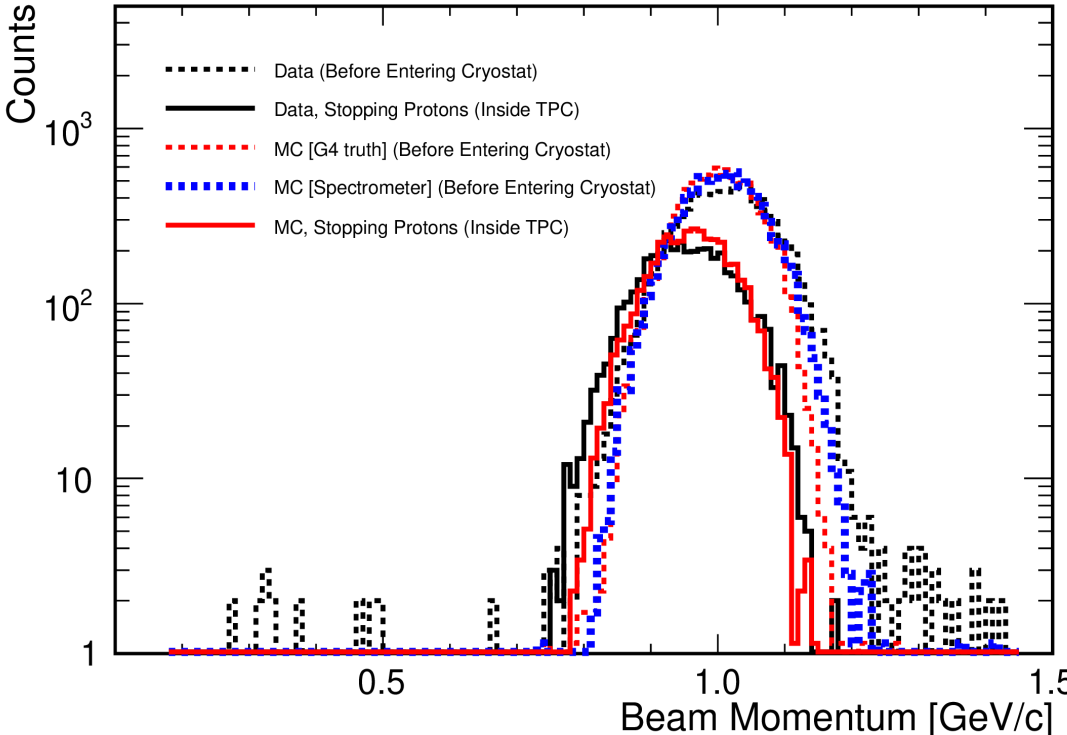
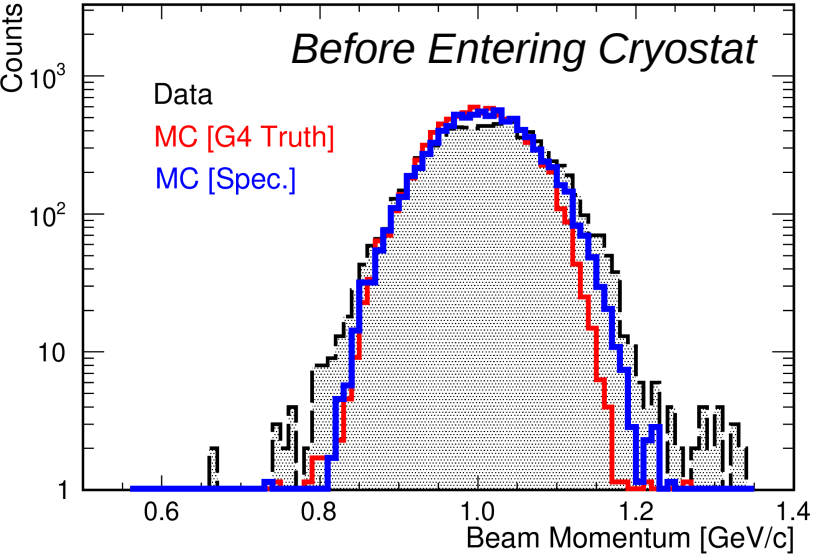
Proton Beam Momentum Reweighting

► Outline

- Beam momentum reweighting
- Data/MC comparison using new data-driven beam MC

Heng-Ye Liao,
ProtoDUNE sim/reco meeting
Aug 19, 2020

Beam Momentum – Outside/Inside TPC



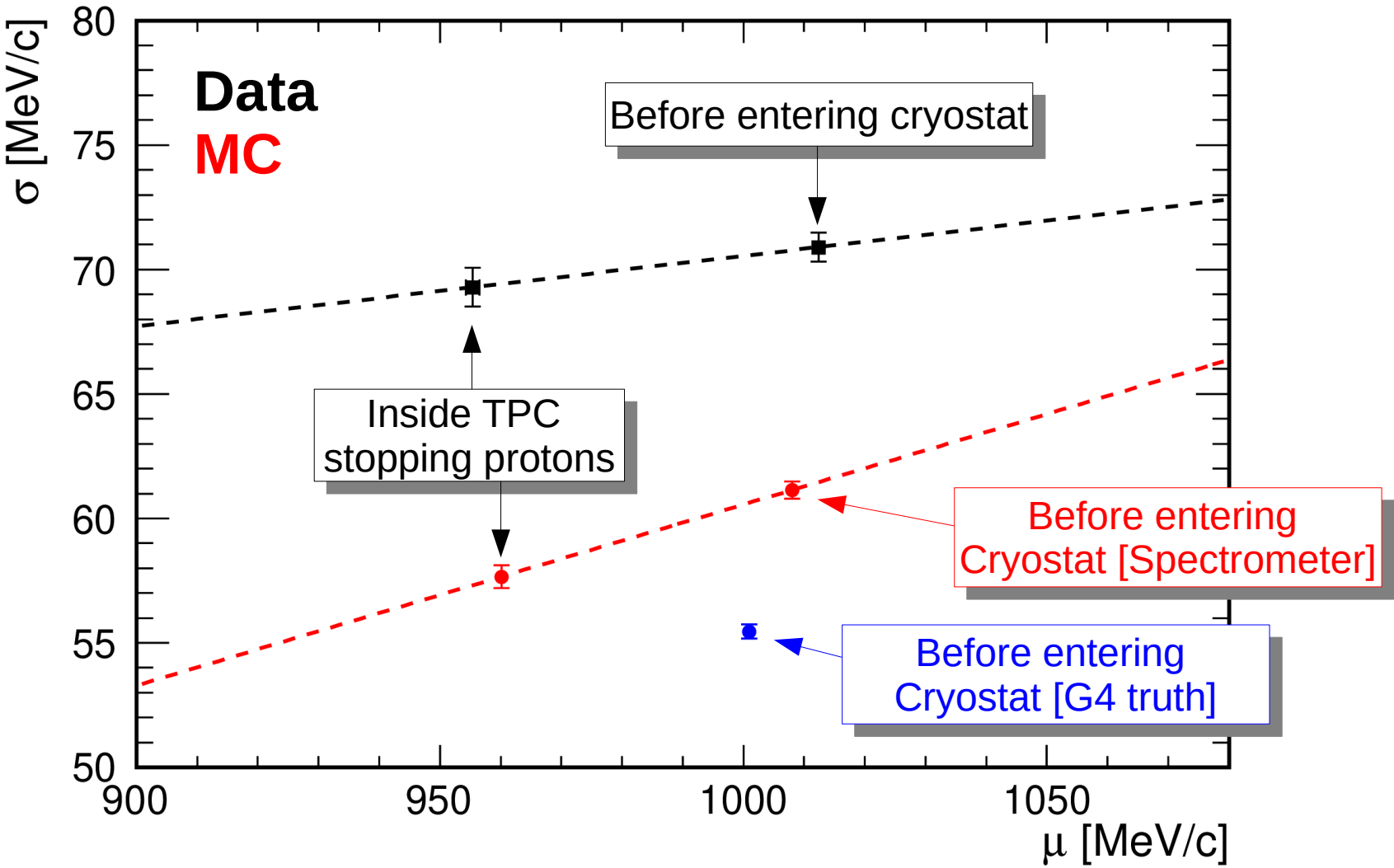
- ▶ Prod.3 MC sample (*RITM0986948*) [*pandoracali*]
- ▶ MC Beam momentum from spectrometer (spec.) output has a wider width (w.r.t G4 truth)

Beam Momentum – Summary Table

	Mean (sigma) of Peak [MeV/c]		
	Data	MC	
		Prod. 3	Prod. 3 [Spec]
Before entering cryostat	1012.4* (70.9)	1000.9 (55.5)	1008.0 (61.1)
Stopping protons inside TPC	955.4 (69.3)		960.1 (57.7)
Momentum loss	56.9	40.8	47.9
Momentum loss fraction	5.6 %	4.1 %	4.7 %
Energy loss	41.2 MeV	29.5 MeV	34.6 MeV
Energy loss fraction	9.3 %	6.8 %	7.9 %

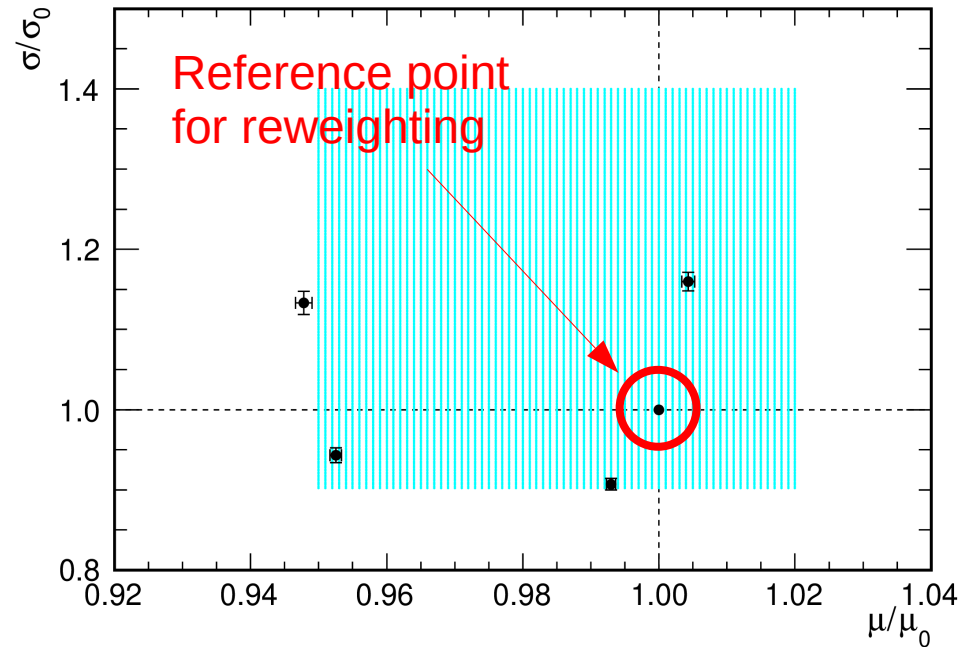
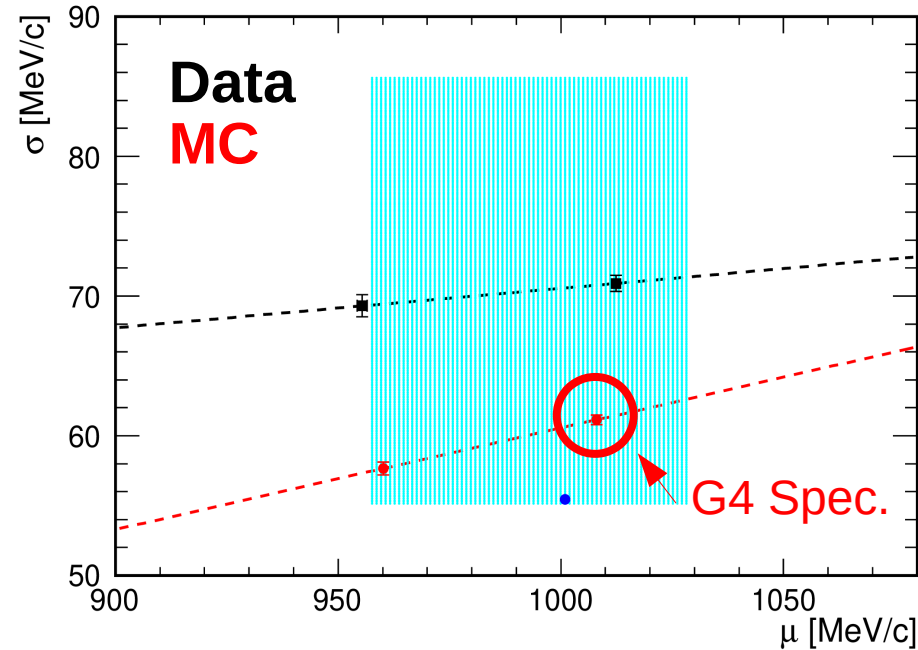
* Mean & sigma of fitted Gaussian

Beam Momentum – Parametrization



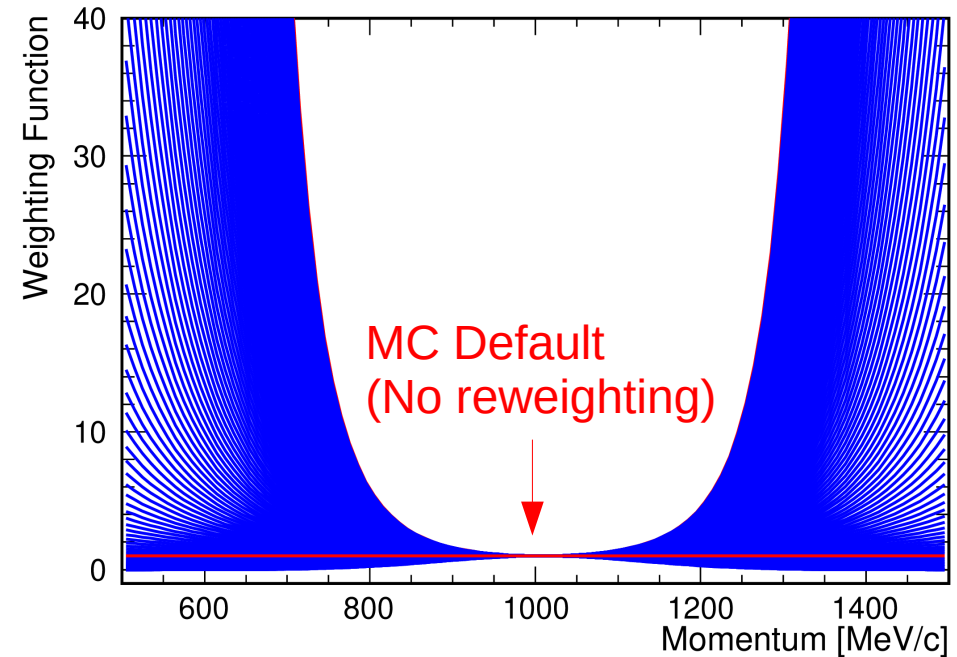
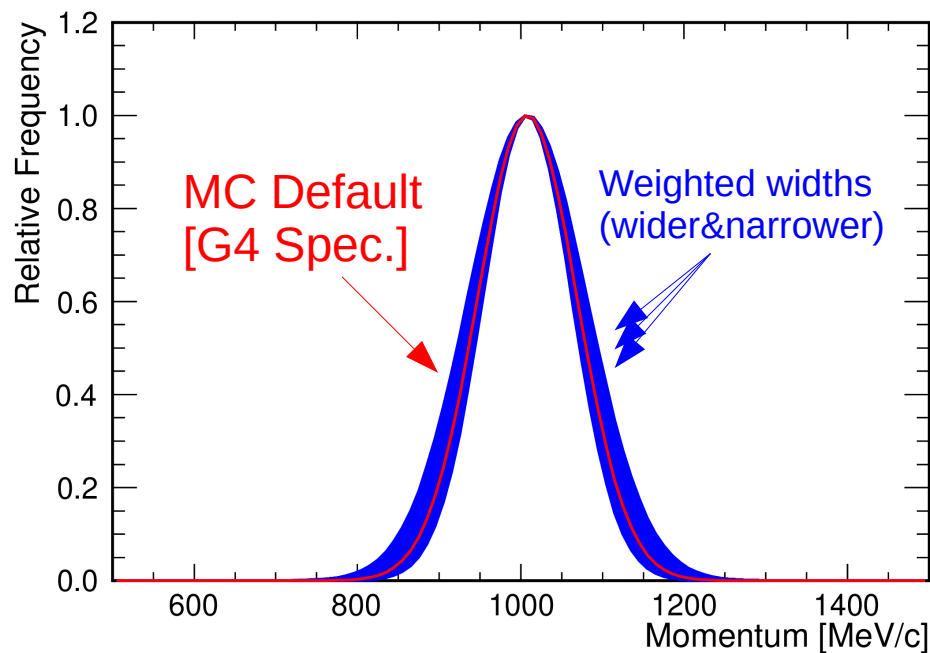
* Mean (μ) & sigma(σ) of fitted Gaussian

Beam Momentum – Reweighting



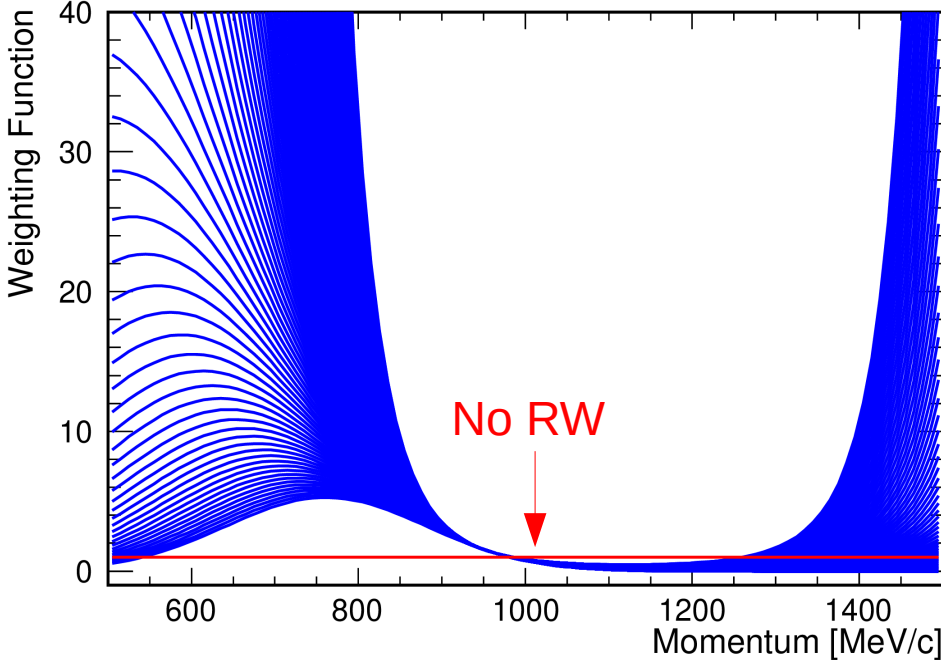
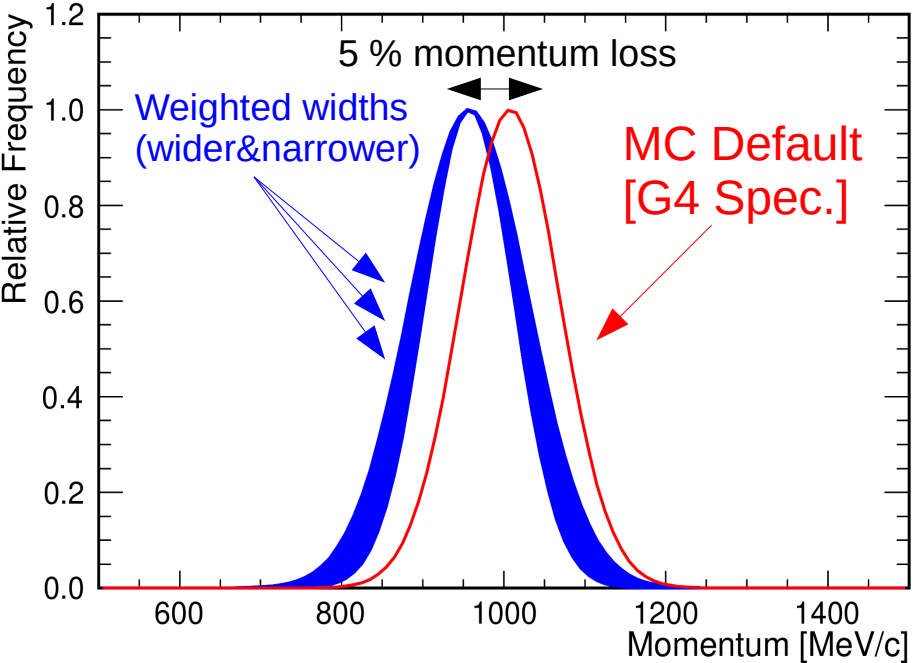
- ▶ Use μ & σ for reweighting
- ▶ Grid search in (μ, σ) space
 - μ : 0.95 – 1.02, $\Delta\mu=0.001$
 - σ : 0.90 – 1.40, $\Delta\sigma=0.002$(each light blue dot represents one grid point for reweighting)
- ▶ Reference point (no reweighting)
 - { μ_0 : Mean of beam momentum [G4 Spec.]
 - { σ_0 : Sigma of beam momentum [G4 Spec.]

Beam Momentum Reweighting - Example



- ▶ The same μ with different σ
- ▶ Weighting function
 - Wider width \rightarrow U-shape curve above the red line
 - Narrower width \rightarrow curve below the red line

Beam Momentum Reweighting - Example

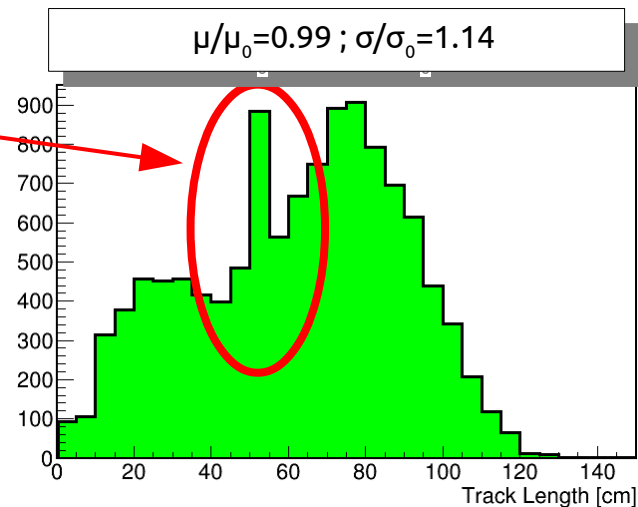
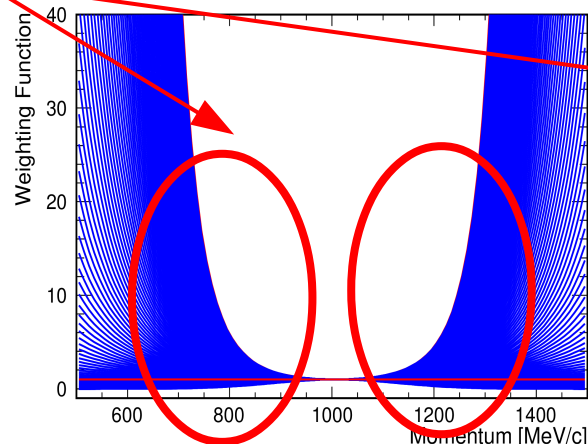
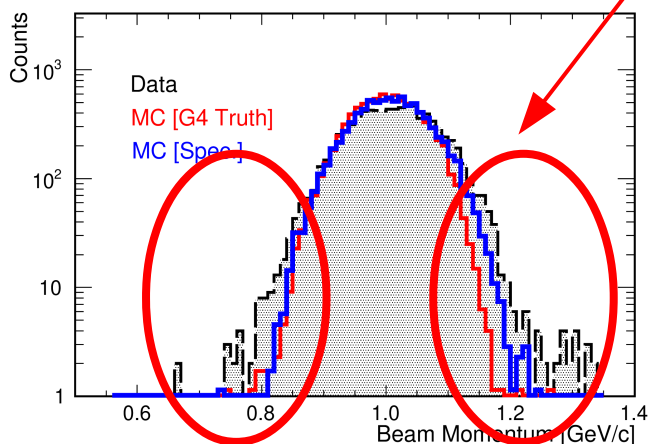


► Different μ with different σ

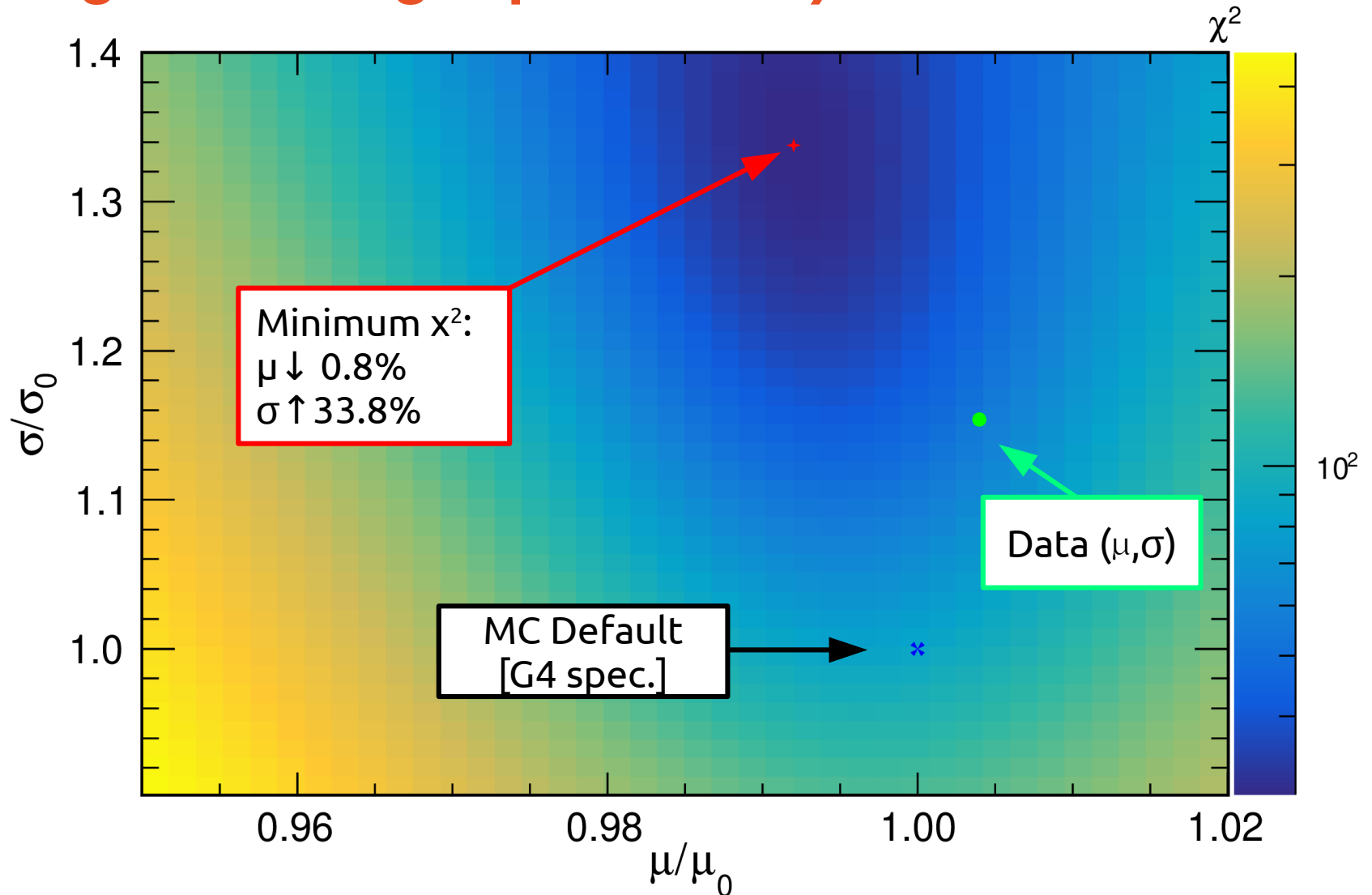
One More Data Quality Cut

- ▶ Except for XY cut*, one more cut has applied
- ▶ **Beam momentum cut**
 - Apply $(\mu \pm 3\sigma)$ on both data & MC
 - Help to improve agreement between data & MC
 - Reduce the number of events on the low & high tails that have higher weights for reweighting (“spikes” after beam momentum reweighting)

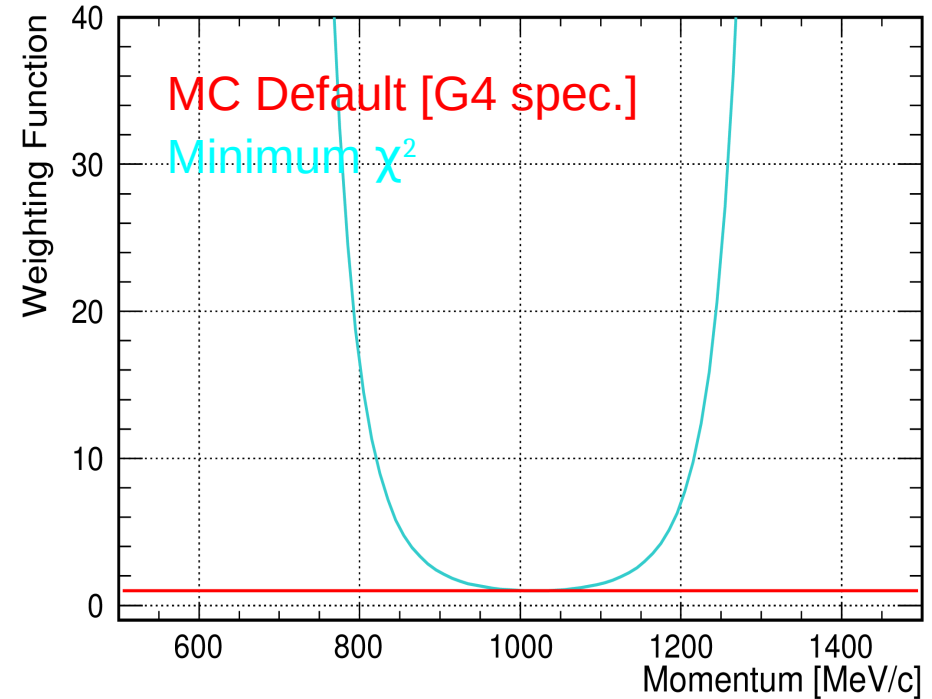
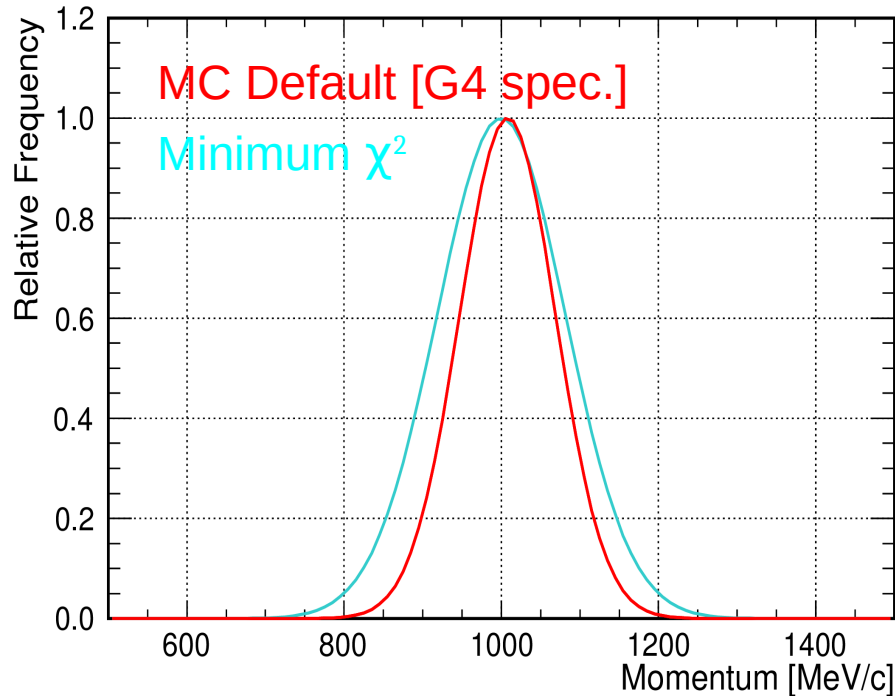
“Tail events” have high weights \rightarrow “spikes”



χ^2 Distribution after Beam Momentum Reweighting (using track length parameter)

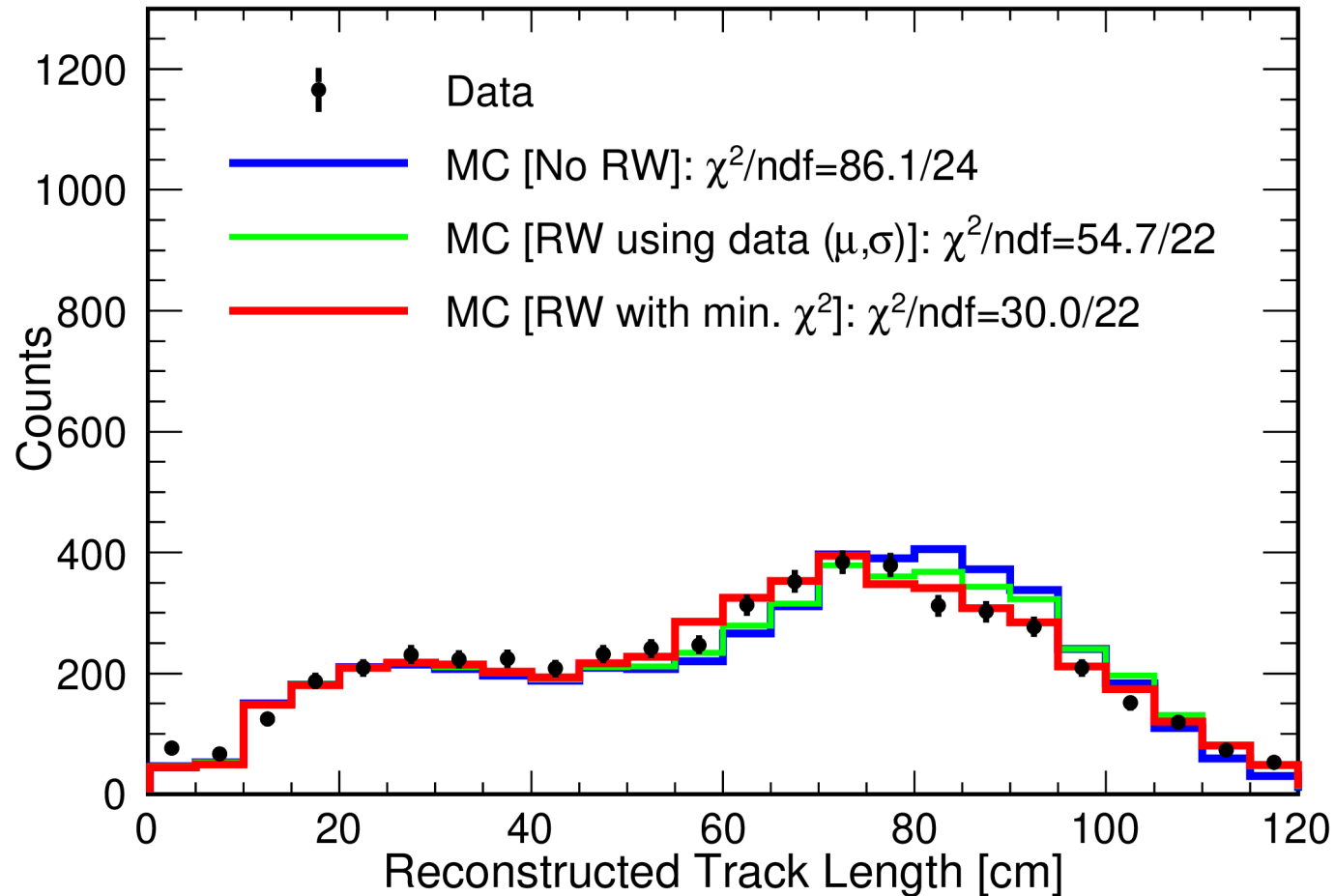


Beam Momentum Profile & Weighting Function with Minimum χ^2



- ▶ MC Default: $(\mu, \sigma) = (1008.0, 61.1)$ [MeV/c]
- ▶ Minimum χ^2 : $\mu \downarrow 0.8\%$ & $\sigma \uparrow 33.8\%$

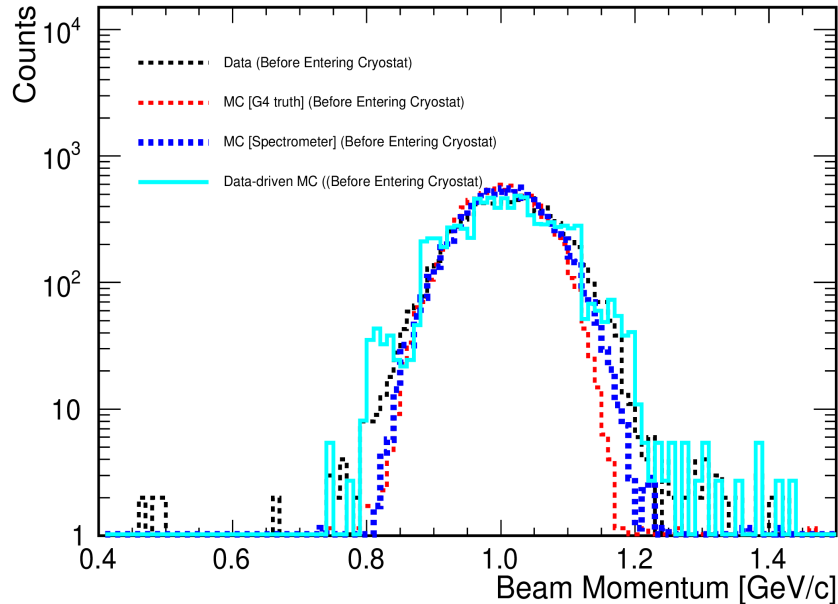
Track Length Distribution after B.M. Reweighting



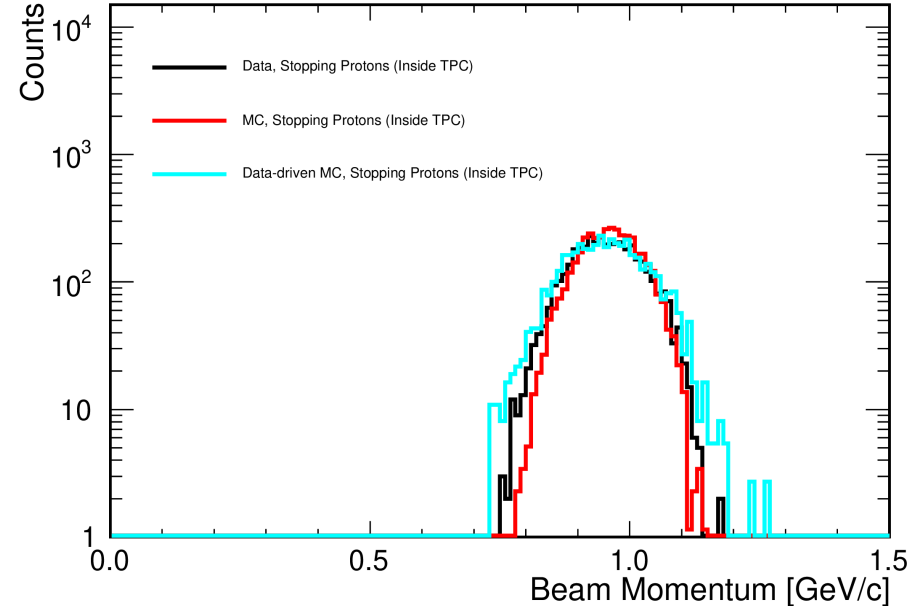
- ▶ Before beam momentum cut: $\chi^2/\text{ndf}=88.1/24$ → after cut: 86.1/24
- ▶ Good agreement between data & MC after B.M. reweighting
 $\chi^2/\text{ndf}=30.0/22$ (p-value: 0.1185)

Data-driven Beam MC

Before Entering Cryostat



Inside TPC, Stopping Protons



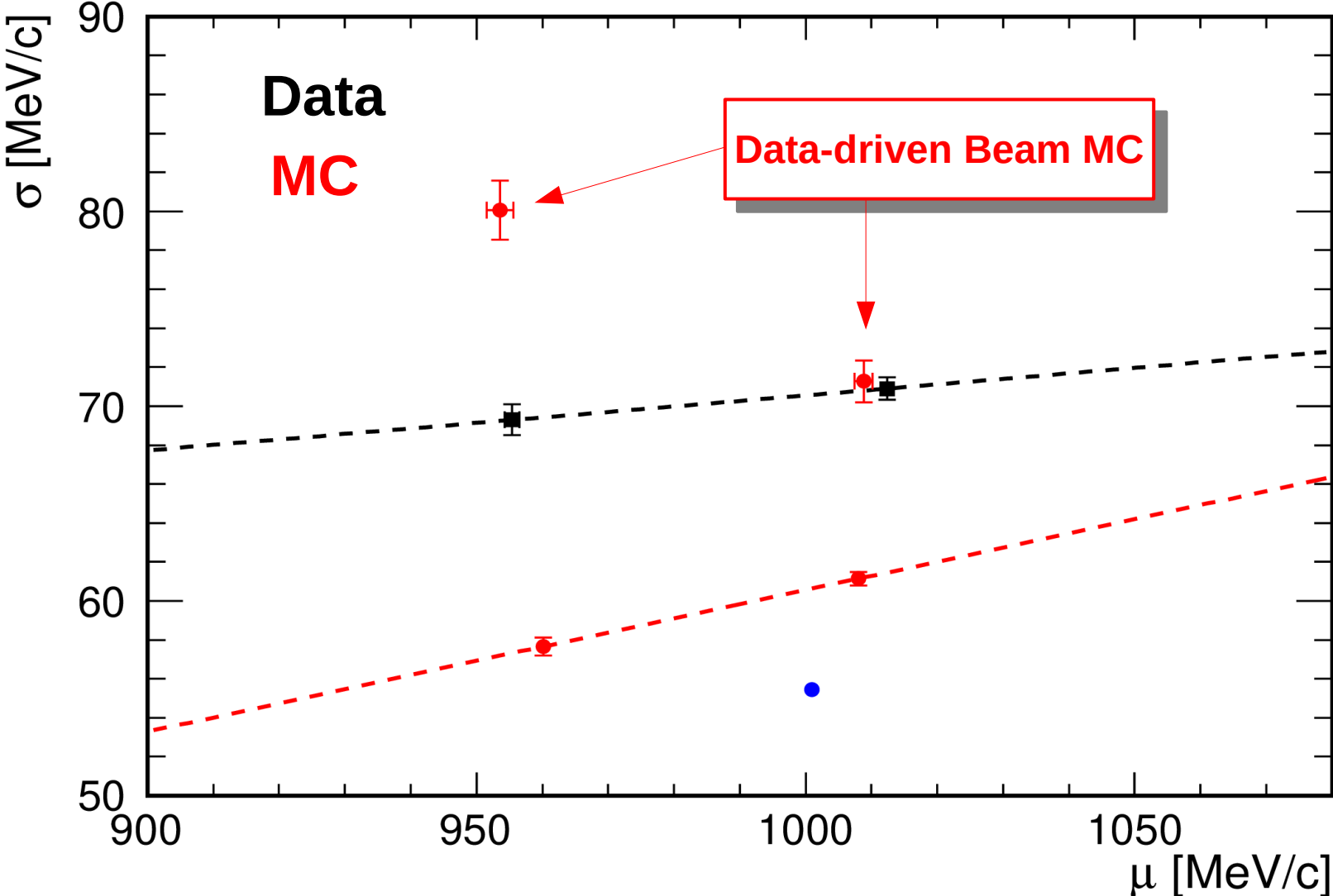
- ▶ Use Jake's new data-driven beam MC sample
Definition name: *calcuttj_pdsp_datadriven_reco_1GeV_v08_60_00*
- ▶ Data-driven beam MC has similar width of data beam (before entering cryostat)
- ▶ Wider width of stopping protons of data-driven beam MC

Beam Momentum – Summary Table

	Mean (sigma) of Peak [MeV/c]			
	Data	MC		
		Prod. 3 [G4 truth]	Prod. 3 [Spec]	Data-driven Beam MC
Before entering cryostat	1012.4* (70.9)	1000.9 (55.5)	1008.0 (61.1)	1008.8 (71.3)
Stopping protons inside TPC	955.4 (69.3)		960.1 (57.7)	953.6 (80.1)
Momentum loss	56.9	40.8	47.9	55.3
Momentum loss fraction	5.6 %	4.1 %	4.7 %	5.5 %
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Energy loss fraction	9.3 %	6.8 %	7.9 %	9.0 %

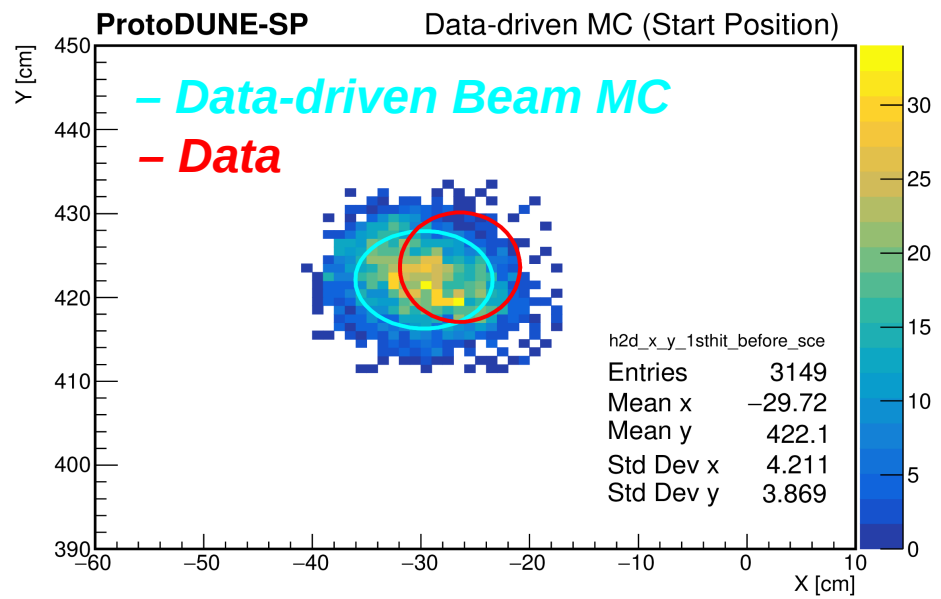
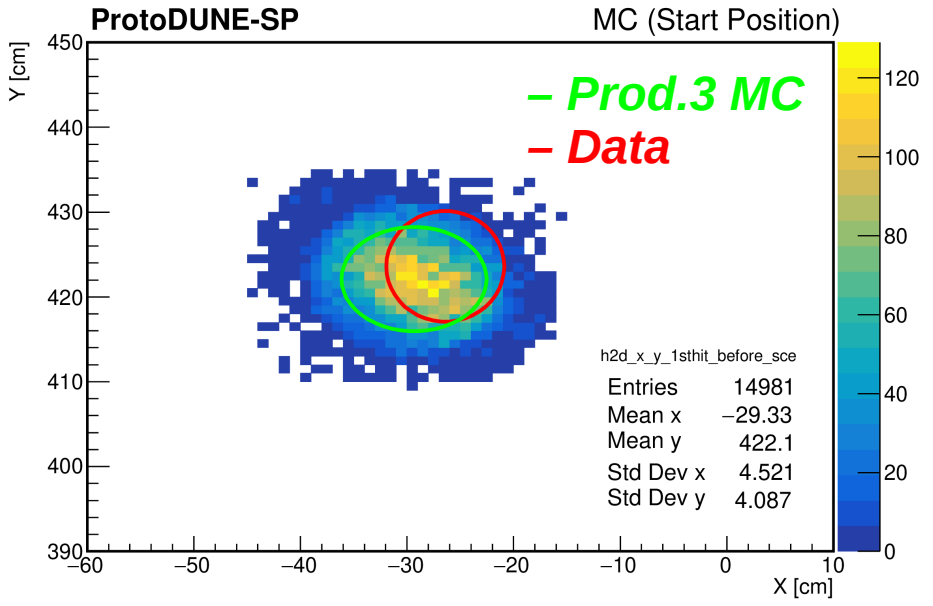
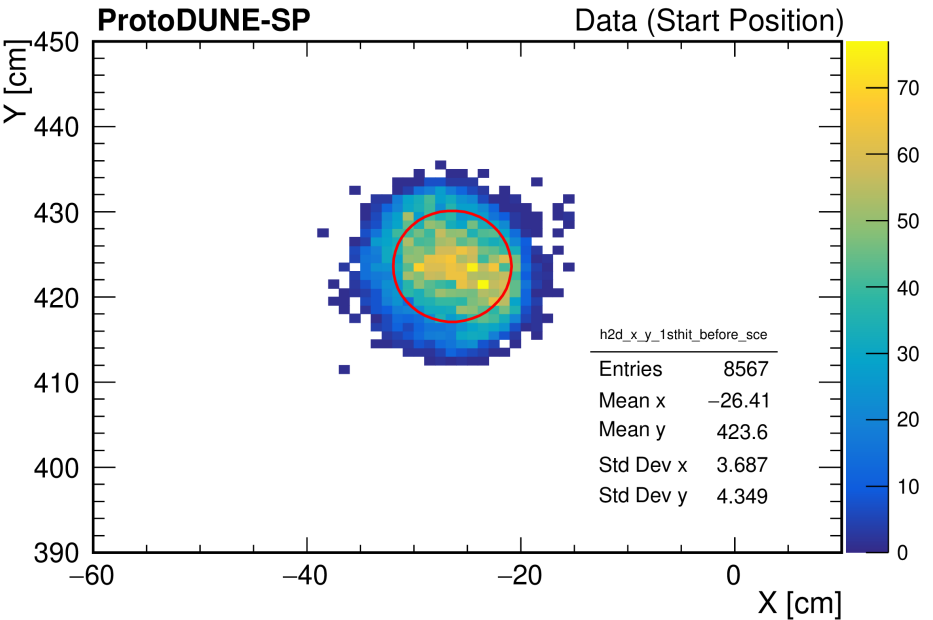
* Mean & sigma of fitted Gaussian

Beam Momentum – Parametrization

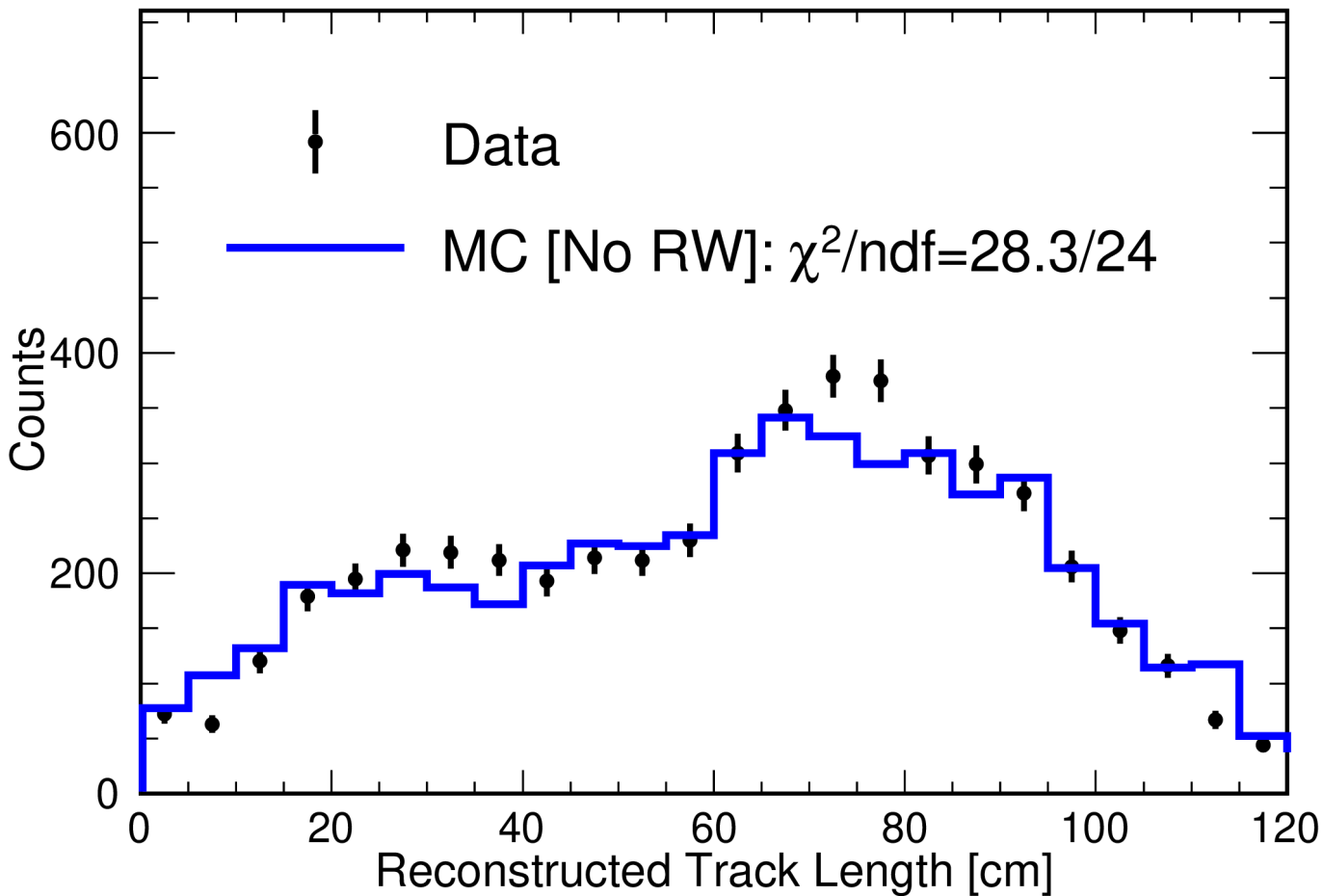


* Mean (μ) & sigma(σ) of fitted Gaussian

XY Distribution



Track Length Distribution [Data-driven Beam MC]



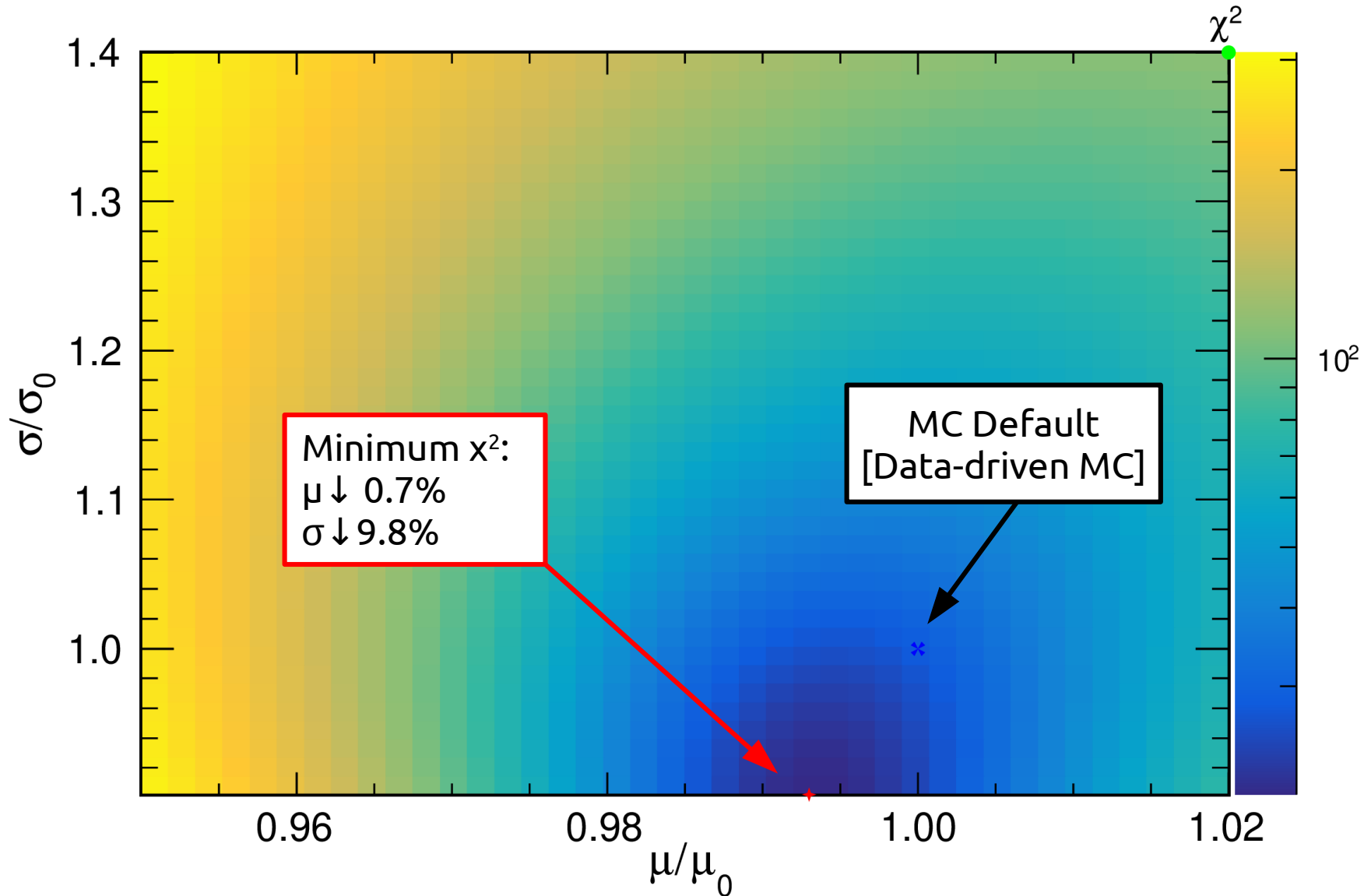
- ▶ Better agreement using data-driven beam MC!
 - $\chi^2/\text{ndf}=28.3/24$ (p-value: 0.2476)
 - Official Prod.3 $\chi^2/\text{ndf}=86.1/24$

Summary & Outlook

- ▶ Profile of beam momentum matters
 - Mean & sigma of beam momentum are all important
- ▶ Beam momentum reweighting helps to improve data/MC agreement
 - $\mu \downarrow 0.8\%$ & $\sigma \uparrow 33.8\%$ (w.r.t. G4 spec. MC)
- ▶ Jake's new data-driven beam MC has better agreement with data (w.r.t. official Prod. 3 MC)
- ▶ Next:
 - Performances using other parameters:
Normalized track length distribution, z_2-z_0 , impact parameter
 - Model-dependent XS measurement
 - Systematic uncertainties

Backup

χ^2 Distribution (using track length parameter)



Track Length Distributions after B. M. Reweighting

