Update on the ν_μ Systematics

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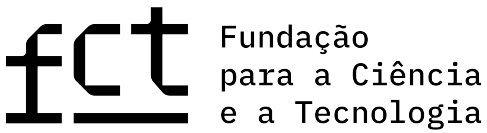

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Estimating Systematic ν_μ Errors

ν_μ event selection goes through the following cuts :

- **Fiducial Volume**
  - Scifi : Vertical [+200 ;-336] ; Horizontal [+300 ;-200] ($^{+4.8\%}_{-6.6\%}$)
  - DS : Horizontal Bars 70-105 and Vertical 10-50 ($^{+8.3\%}_{-15.0\%}$)
- Track requires intercepting the first Scifi plane
- Sum of DOCA between track and hits < 3 cm
- **> 35 Scifi Hits**
- **QDC for Upstream Muon System > 600**
- Maximum of 10 hits in the Downstream Muon System

Used partition 0 through 50 from */eos/experiment/sndlhc/MonteCarlo/Neutrinos/Genie/sndlhc_13TeV_down_volTarget_20fb-1_SNDG18_02a_01_000/*, with a total of 40272 ν events

Plan and Common Event Selection

Use 2023 Testbeam data to select events with showers that fulfill each other criteria :

- To analyze the US QDC select events with $>$ 35 Scifi Hits
- To analyze the minimum Scifi hits select events with US QDC > 600 a.u.

Produce distribution plots and find reasonable criteria to vary

MC data comes from 2×10^5 MC π^- events with 180 GeV/c^2
Applied event filter :

- Only consider Scifi hits within 26 ns of event start
- At least 10 Scifi hits
- At least 1 hit per station on X and Y projection each up to 3rd plane

For events that pass the initial filter :

- Scifi hits around for [-0.5 ;+1.2] clk cycles around t_{ref} for each plane and orientation
- Only consider US hits when $t_{hit} < t_{ref1H} + 3$clk cycle

  Doing it individually for each SiPM instead of for the average timestamp of the hit for simplicity purposes, and not removing small SiPM responses ($QDC_S = QDC_I$) which may lead to a factor of 4/3 between MC and Testbeam data

Additional Testbeam data cuts :

- No event during previous 150ns

US QDC Requirement

US QDC distributions have similar shapes

Find a scale factor based on reference points

Apply scale factor on MC QDC response and check ν_μ selection efficiency influence

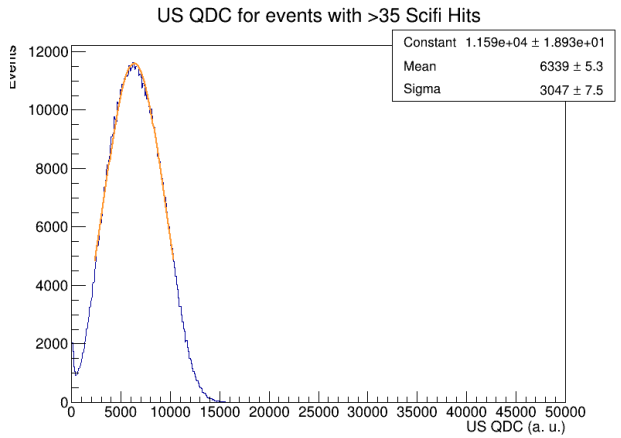
Perform a Gaussian fit to peak of the distribution

Refine fit to a range of $\mu \pm 1.5\sigma$ to isolate maximum of the distribution

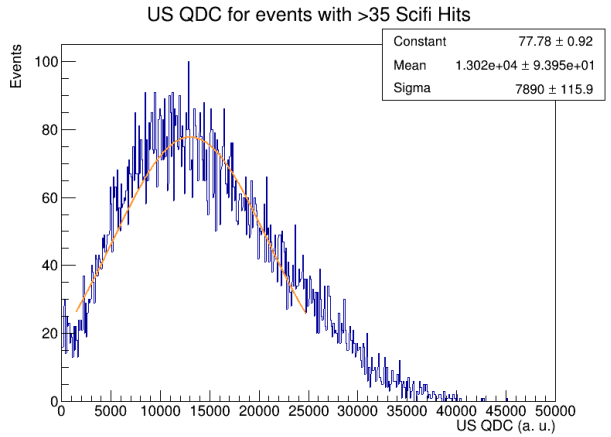
Get cumulative distribution for QDC > μ and define 3 more points

Perform linear regression to get the **Scale Factor**

2023 Testbeam

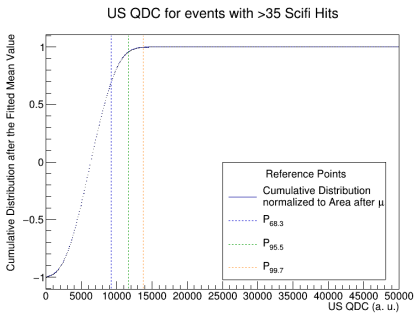


Monte Carlo

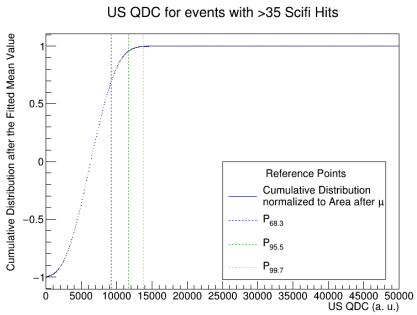


Cumulative Distributions and Reference Points

2023 Testbeam

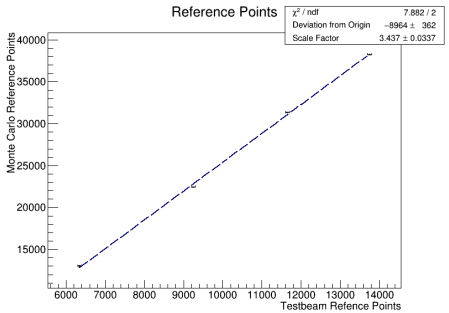


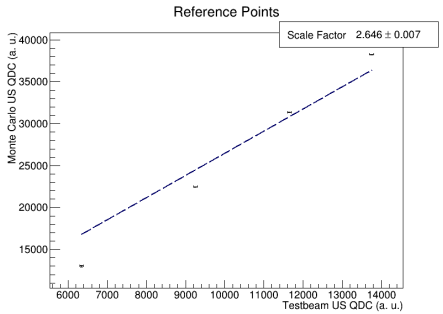
Monte Carlo



Sample	Max	66.3 %	95.5 %	99.7 %
Testbeam	6339	9250	11650	13750
Monte Carlo	13020	22450	31350	38250

Reference Point Regressions





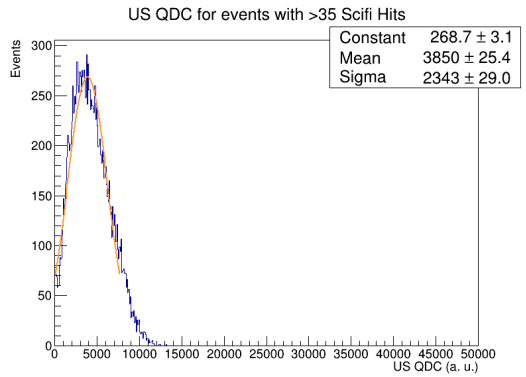
Scale Factor
$= (3.44 \pm 0.03)^{-1}$

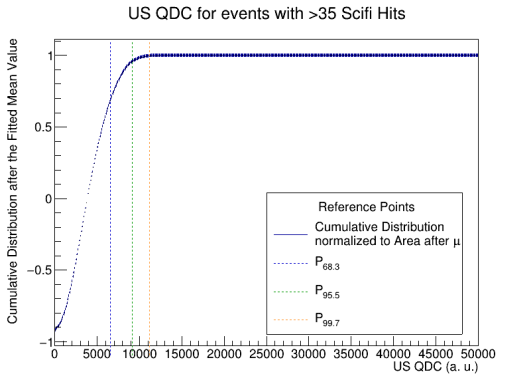
Scale Factor
$= (2.646 \pm 0.007)^{-1}$

Cut Set		Surviving Events	Selection Efficiency (%)	Relative Baseline Error (%)
Baseline		1251	3.11	-
Scale Factor	3.44	931	2.31	-25.7
	2.64	999	2.48	-20.3

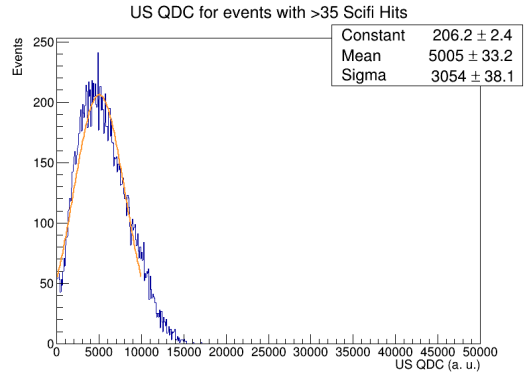
US QDC after Scale Factors

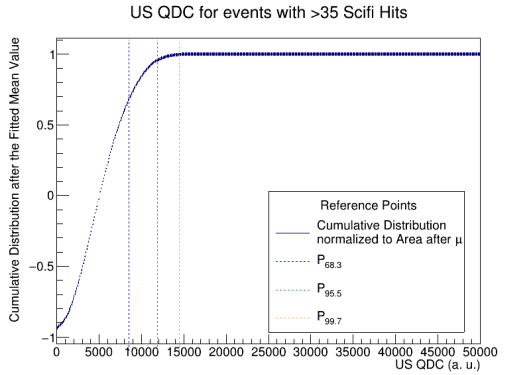
Scale Factor = 3.44^{-1}





Scale Factor = 2.64^{-1}





Sample		Max	66.3 %	95.5 %	99.7 %
Testbeam		6339	9250	11650	13750
Monte Carlo	Baseline	13020	22450	31350	38250
	SF = 3.44	3850	6550	9150	11150
	SF = 2.64	5005	8550	11850	14450

Scifi Multiplicity

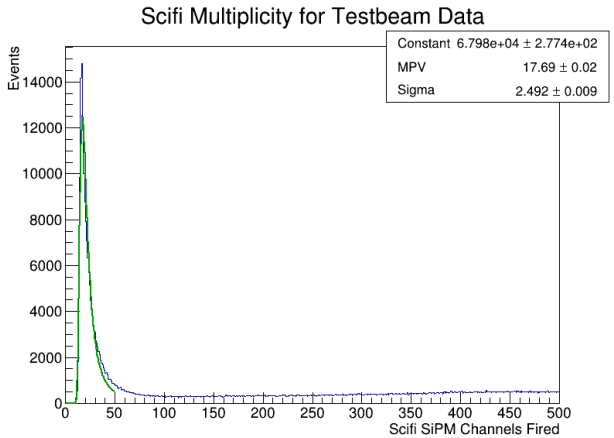
Scifi Hit multiplicity distributions has an early peak that is removed by the >35 hits criterion

Fit peak with a Landau Distribution

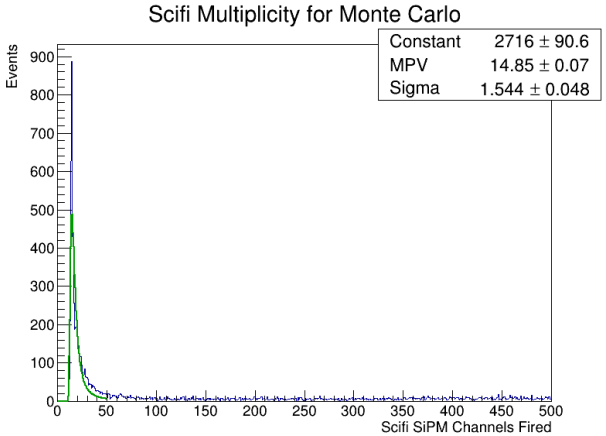
Retrieve variation from difference in σ or a combination of MPV and σ

Sample	MPV	σ
Testbeam	17.69 ± 0.02	2.49 ± 0.01
Monte Carlo	14.85 ± 0.07	1.54 ± 0.05
Δ	3.74 ± 0.07	0.95 ± 0.05

2023 Testbeam



Monte Carlo



Scifi Activity Systematic Errors

Minimum Scifi Hits Required		Surviving Events	Selection Efficiency (%)	Relative Baseline Error (%)
Baseline	35	1251	3.11	-
$\pm\Delta_\sigma$	34	1261	3.13	+0.6
	36	1243	3.09	-0.6
$\pm(\Delta_\sigma + \Delta_{\text{MPV}})$	30	1284	3.19	+2.6
	40	1218	3.02	-2.9

Follow Up

- Scifi Hit filter was updated to work properly with Monte Carlo
- Need to check filter influence in the selection efficiency of the Monte Carlo samples
- Currently redoing the Scifi Fiducial volume systematic error analysis with updated 2023 Testbeam geometry
- DS Fiducial volume error estimation will be aprimorated using a sample of TI18 muon events with Scifi tracks that generate showers and can be extrapolated to the DS system
- Sum of DOCA will also use shower generating muons, but with DS tracks that can be extrapolated to the Scifi
- Will check shower influence on the DS through Testbeam events that produce showers on the 3^{rd} wall. Although no DS track can be reconstructed, the number of hits on the 1^{st} DS plane should be a good proxy for how much the hit variation should be
- **Scifi Activity Systematic Uncertainties are** $^{+2.6\%}_{-2.9\%}$
- US QDC selection looks like the biggest contribution to Systematic Uncertainties