

# Update on the $\nu_\mu$ Systematics

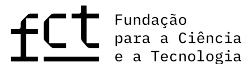
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29<sup>th</sup> May



Scattering and Neutrino Detector  
at the LHC



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## 1 $\nu_\mu$ Error Estimation

## 2 Activity Cuts

- US QDC
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# Estimating Systematic $\nu_\mu$ Errors

$\nu_\mu$  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  $\nu$  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  $2 \times 10^5$  MC  $\pi^-$  events with  $180 \text{ GeV}/c^2$

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 3<sup>rd</sup> 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  $t_{hit} < t_{ref1H} + 3\text{clk cycle}$

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  $\nu_\mu$  selection efficiency influence

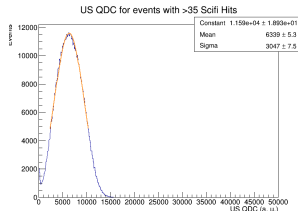
Perform a Gaussian fit to peak of the distribution

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

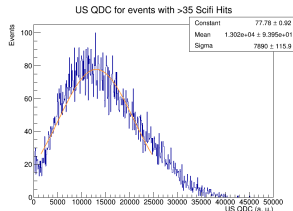
Get cumulative distribution for QDC  $> \mu$  and define 3 more points

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

## 2023 Testbeam

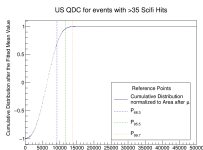


## Monte Carlo



# Cumulative Distributions and Reference Points

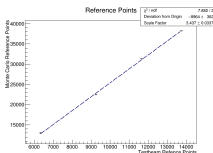
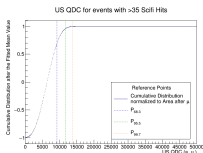
## 2023 Testbeam



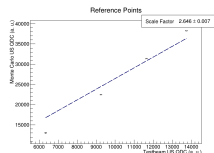
Sample	Max	66.3 %	95.5 %	99.7 %
Testbeam	6339	9250	11650	13750
Monte Carlo	13020	22450	31350	38250

## Reference Point Regressions

## Monte Carlo



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

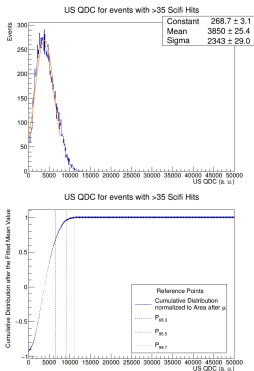


**Scale Factor**  
 $= (2.646 \pm 0.007)^{-1}$

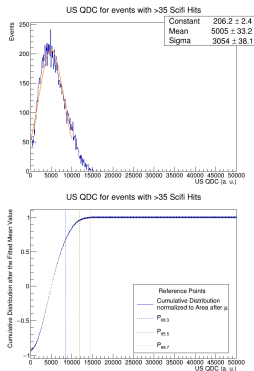
Cut Set		Surviving Events	Selection Efficiency (%)	Relative Baseline Error (%)
Baseline		1251	3.11	-
Scale Factor	3.44	931	2.31	-25.7
	2.64	999	2.48	-20.3

# 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

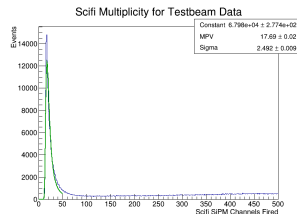
Scifi Hit multiplicity distributions has an early peak that is removed by the  $>35$  hits criterion

## Fit peak with a Landau Distribution

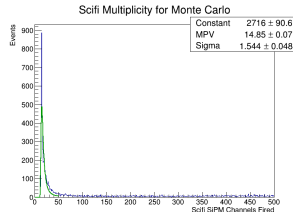
Retrieve variation from difference in  $\sigma$  or a combination of MPV and  $\sigma$

Sample	MPV	$\sigma$
Testbeam	$17.69 \pm 0.02$	$2.49 \pm 0.01$
Monte Carlo	$14.85 \pm 0.07$	$1.54 \pm 0.05$
$\Delta$	$3.74 \pm 0.07$	$0.95 \pm 0.05$

## 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 T118 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<sup>rd</sup> wall. Although no DS track can be reconstructed, the number of hits on the 1<sup>st</sup> 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