W-DHCal simulation and digitisation

CALICE Meeting

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Samir Arfaoui [CERN/PH-LCD]
samir.arfaoui@cern.ch

on behalf of the CLIC Detector and Physics Study
and
William Nash [Boston University]

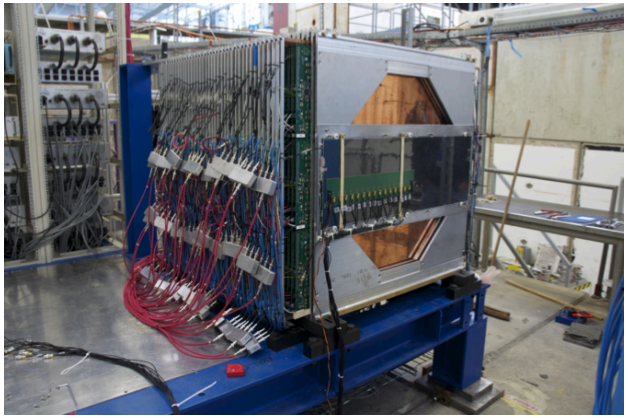
Outline

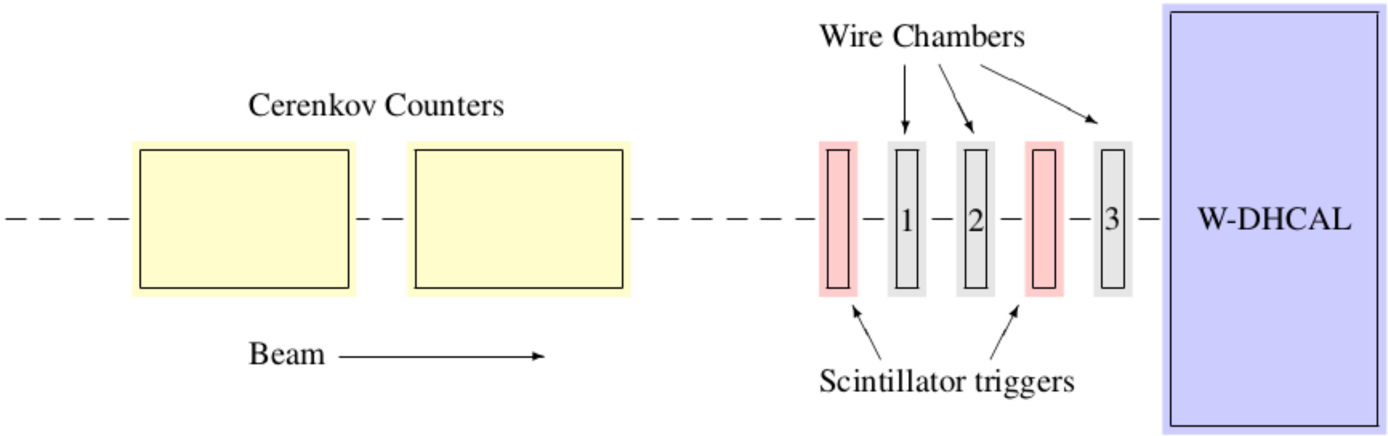
- Introduction
  - Detector Descritption
  - Mokka model
- Calibration and Particle Identification
  - RPC Inefficiency rescaling
  - Muon Identification
- RPC Digitisation Optimisation
  - Parameter scans and comparisons
- Results
  - nHits distributions
  - <nHits> vs. Energy
- Conclusion and Perspectives

Detector description

- 54 RPC Layers
  - Main stack: 39 layers with W absorber
  - TailCatcher: 15 layers with Steel absorber
- Readout: 96x96 1cm^2 cells / layer
  - Total: ~500000 readout channels (WR!)

- Latest test beam periods at CERN
  - 2 weeks at PS: 1-10 GeV
  - 4 weeks at SPS: 10-300 GeV
  - Total: >30 million events recorded





Mokka model

- Octogonal tungsten absorbers + support from W-AHCal driver
- RPC cassette contents, layout, and sensitive detector description from Steel DHCal (Kurt Francis et al.)
- Beam instrumentation (scintillators, Cerenkov counters, and Wire Chambers) from W-AHCal simualtion ingredients
- At the moment, all the simulation has been done only with the main stack

- Output of simulation
  - Geant4 hits containing individual energy deposits (a.k.a “hit contributions”, a.k.a “points”)
  - These “points” then have to be digitised in order to fold in the RPC response

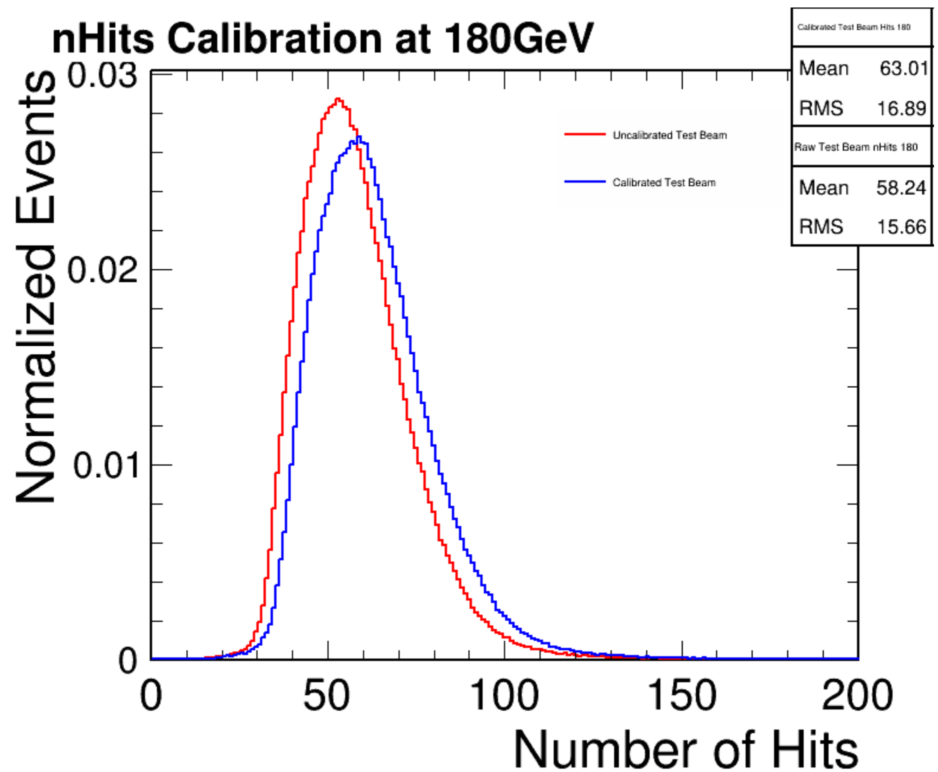
Note: Simulated beam profile is Gaussian with 5 cm width, no angular spread

Efficiency correction

- Goal: correct for RPC inefficency in data before comparing to simulation
- For each individual RPC in each run, efficiency is determined in data by dedicated Marlin processor

Procedure

- check RPC efficiency
- if < 20%, remove RPC in data and Monte Carlo
- else, rescale <nHits>



Muon identification

- Muon selection is performed by looking at consecutive small clusters that form a straight line
- Procedure
  - In each layer, look for a cluster of size < 5, if none in first 8 layers or in 3 or more consecutive layers, throw event
  - Perform straight line fit, select good fits with chi2/ndf < 5
  - Additional cut: <nClusters>/layer < 1.2

Energy (GeV)	Percentage of Muons	Run Number
5	32.69%	660095
10	12.38%	660177
30	16.65%	660217
50	11.86%	660229
80	49.50%	660254
Pure Muon 180	87.23%	660525
300	47.06%	660507

Digitisation parameters

There are 6 parameters used to tune RPCSim, each with a different physical significance. Q is the full charge produced by a single energy deposit

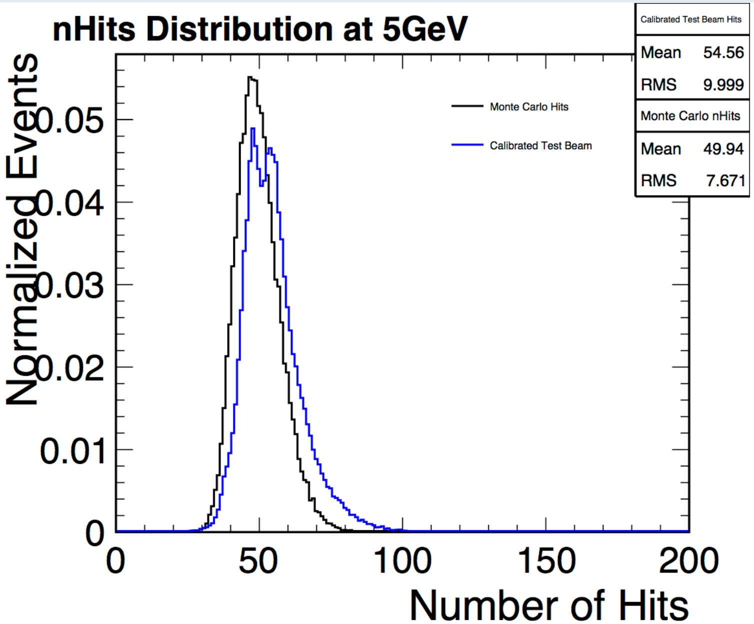
- **DistCut** - Closest lateral distance between two energy deposits which will still form a full shower
- $\mathbf{Q}_0$ - Charge correction factor $(Q_{eff} = Q - \mathbf{Q}_0)$
- **Slope1** - Exponential slope of the lateral spread of charge ($e^{\frac{-\sqrt{x^2+y^2}}{\mathbf{Slope1}}}$), dies faster than Slope2
- **Slope2** - Exponential slope of the lateral spread of charge ($e^{\frac{-\sqrt{x^2+y^2}}{\mathbf{Slope2}}}$), dies slower than Slope1
- **Ratio** - The charge produced by the lateral spread is split so that $Q_{pad} \approx \sum_{i=1}^{deps} \int_0^{Q_{eff}} \mathrm{d}Q' ((1-\mathbf{Ratio}) \cdot e^{\frac{-\sqrt{\Delta x_i^2+\Delta y_i^2}}{\mathbf{Slope1}}} + \mathbf{Ratio} \cdot e^{\frac{-\sqrt{\Delta x_i^2+\Delta y_i^2}}{\mathbf{Slope2}}})$
- **T** - Energy threshold for a cell to be on

Digitisation tuning

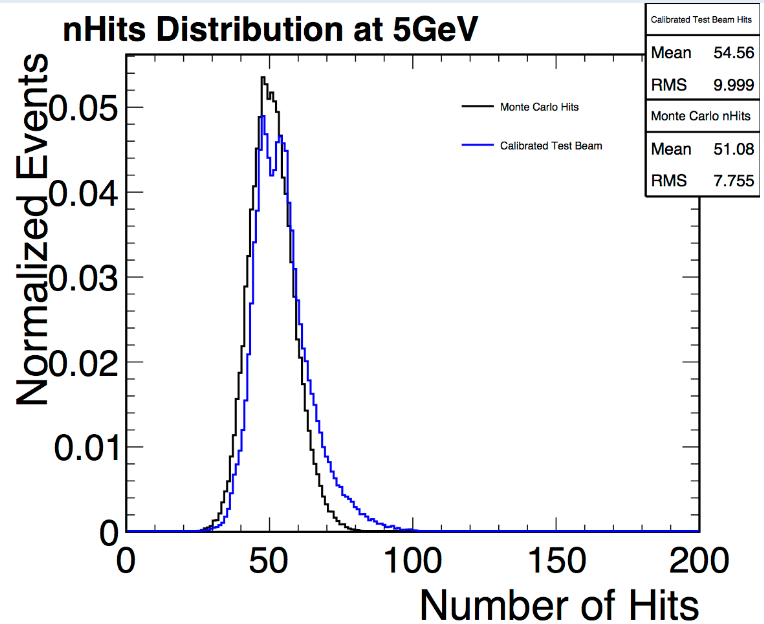
- What goes in
  - Muon-rich, efficiency-corrected data sample at given energy
  - Pure muon Mokka simulation sample at same energy
- Procedure
  - Randomly vary the 6 digitisation parameters
  - Run RPCSim Marlin processor on Mokka sample
  - Compare <nHits> distributions for data+MC in form of bin-by-bin difference squared (Λ, kind of a chi-square)
  - Iterate until Λ is sufficiently small

Parameter	Default	Best Fit
DistCut	0.092 cm	0.075 cm
$\mathbf{Q_0}$	0.201 pC	0.189 pC
Slope1	0.0678 cm	-
Slope2	0.671 cm	0.247 cm
Ratio	0.345	1
T	0.3645 pC	0.6818 pC
Λ	1.3×10^{-3}	1.5×10^{-4}

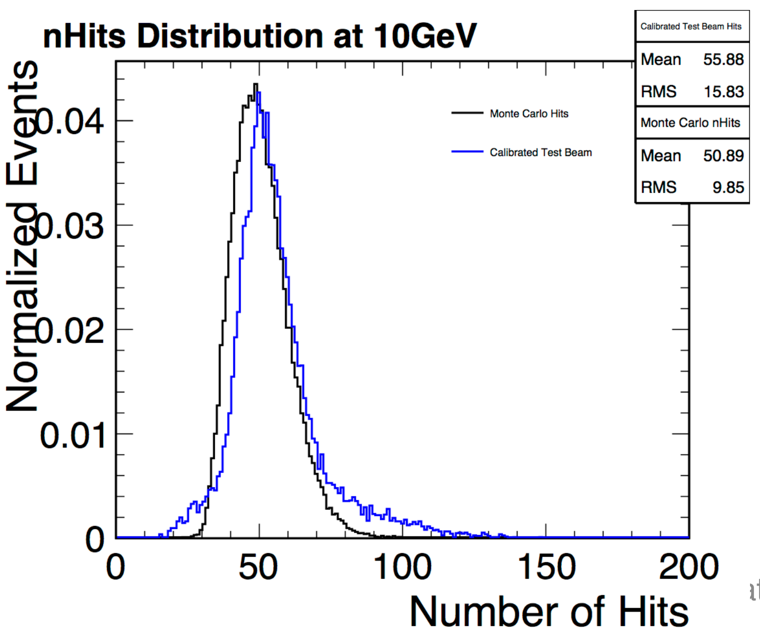
Low energy



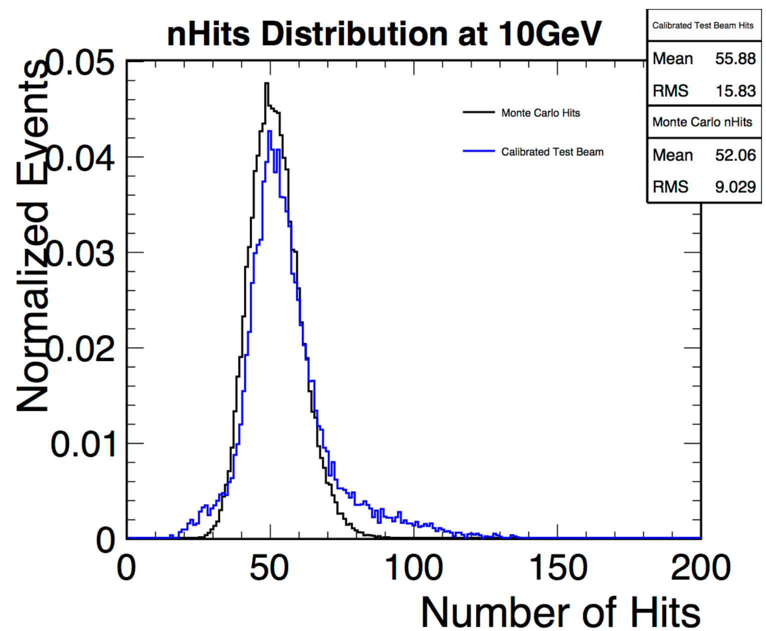
nHits Distribution at 5GeV
Calibrated Test Beam Hits
Mean 54.56
RMS 9.999
Monte Carlo nHits
Mean 49.94
RMS 7.671
Monte Carlo Hits
Calibrated Test Beam
Normalized Events
0
0.01
0.02
0.03
0.04
0.05
0
50
100
150
200
Number of Hits



nHits Distribution at 5GeV
Calibrated Test Beam Hits
Mean 54.56
RMS 9.999
Monte Carlo nHits
Mean 51.08
RMS 7.755
Monte Carlo Hits
Calibrated Test Beam
Normalized Events
0
0.01
0.02
0.03
0.04
0.05
0
50
100
150
200
Number of Hits

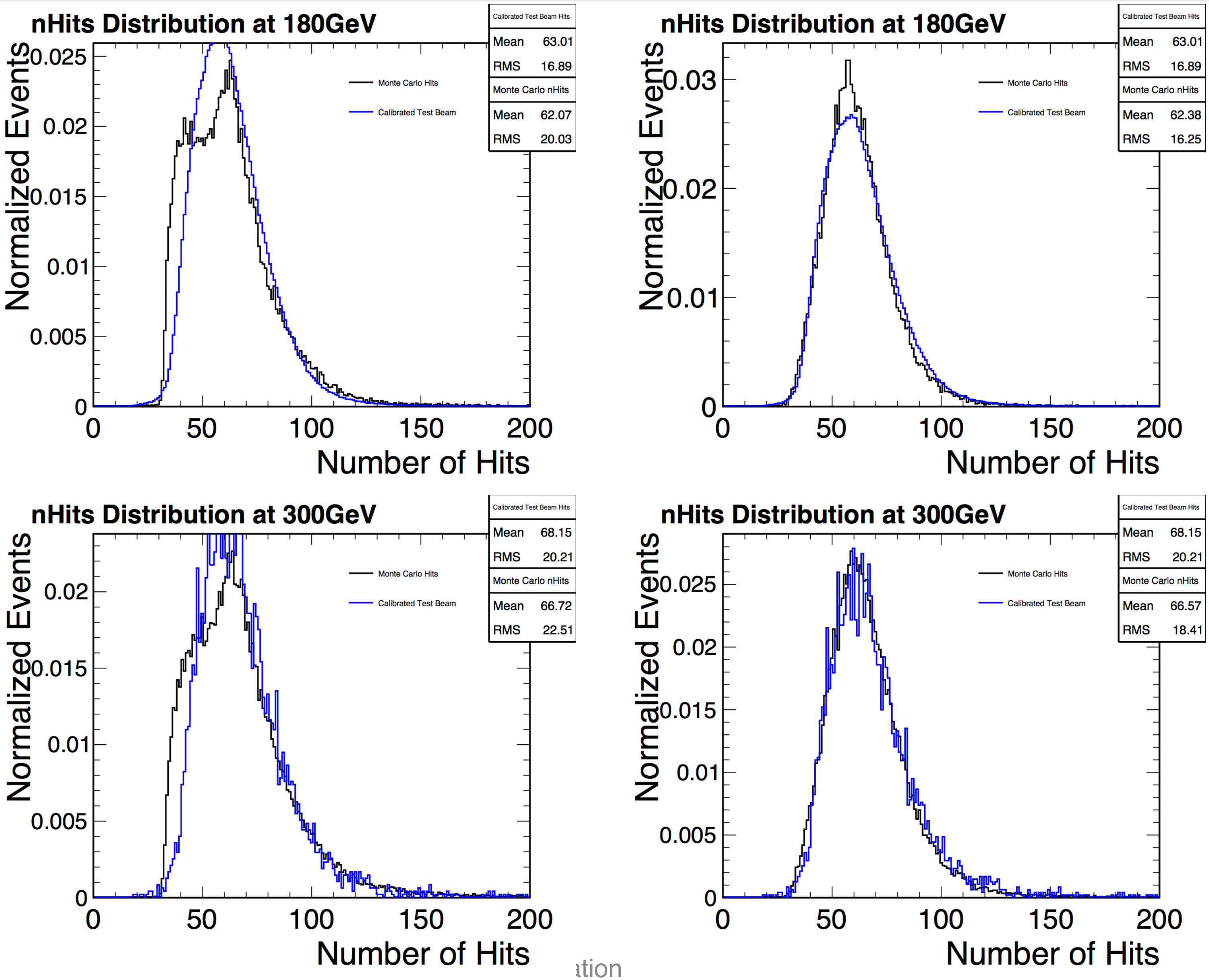


nHits Distribution at 10GeV
Calibrated Test Beam Hits
Mean 55.88
RMS 15.83
Monte Carlo nHits
Mean 50.89
RMS 9.85
Monte Carlo Hits
Calibrated Test Beam
Normalized Events
0
0.01
0.02
0.03
0.04
0
50
100
150
200
Number of Hits

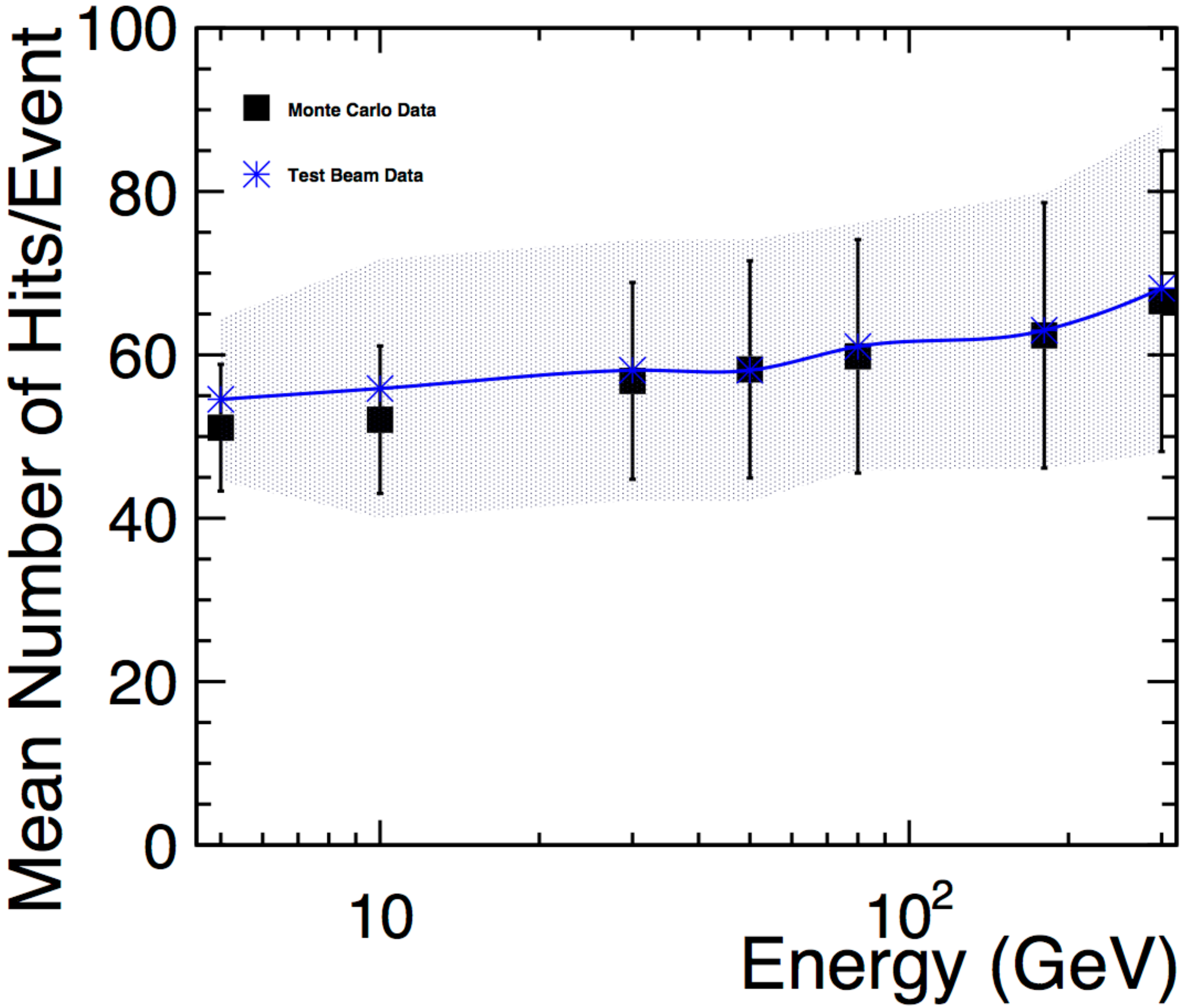


nHits Distribution at 10GeV
Calibrated Test Beam Hits
Mean 55.88
RMS 15.83
Monte Carlo nHits
Mean 52.06
RMS 9.029
Monte Carlo Hits
Calibrated Test Beam
Normalized Events
0
0.01
0.02
0.03
0.04
0.05
0
50
100
150
200
Number of Hits

High energy


nHits Distribution at 180GeV
Normalized Events
Number of Hits
Monte Carlo Hits
Calibrated Test Beam
Calibrated Test Beam Hits
Mean 63.01
RMS 16.89
Monte Carlo nHits
Mean 62.07
RMS 20.03
nHits Distribution at 180GeV
Normalized Events
Number of Hits
Monte Carlo Hits
Calibrated Test Beam
Calibrated Test Beam Hits
Mean 63.01
RMS 16.89
Monte Carlo nHits
Mean 62.38
RMS 16.25
nHits Distribution at 300GeV
Normalized Events
Number of Hits
Monte Carlo Hits
Calibrated Test Beam
Calibrated Test Beam Hits
Mean 68.15
RMS 20.21
Monte Carlo nHits
Mean 66.72
RMS 22.51
nHits Distribution at 300GeV
Normalized Events
Number of Hits
Monte Carlo Hits
Calibrated Test Beam
Calibrated Test Beam Hits
Mean 68.15
RMS 20.21
Monte Carlo nHits
Mean 66.57
RMS 18.41

nHits vs. energy



Summary and outlook

- Mokka
  - Main stack driver complete and functionnal
  - To do
    - Implement Tail Catcher and Beam Instrumentation
    - Add angular spread in beam profile, or better: use realistic beam profile from Wire Chamber data
    - Officialise drivers, consolidate database information
- In the data
  - Review efficiency correction, should we do it before comparing to MC?
  - Is this muon selection the best we can do?
- RPC digitisation
  - CPP version of dual-exponential model implemented as Marlin processor
  - Parameter scan and optimisation procedure in place
    - Better discriminator? Should we keep comparing <nHits>?
  - Should we try other digitisation models?
- Outlook
  - When the procedure has been reviewed and the digitisation parameters satisfactory with muons
    - Optimise DistCut with electrons
    - Look at how well pion showers at digitised
  - Write paper!