

Muon Energy Loss Comparison

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Purpose

- Compare muon energy loss in TileCal
 - Testbeam data
 - 2008 Cosmic Data
 - Monte Carlo
 - 2009 Cosmic Data
- Compare ID and MuSpec measurements to TileCal

Cosmic Data

2008

- Run: 91900
- Reprocessing: r653
 - 14.5.2.4
- IDCosmic stream
- 242,800 events

Monte Carlo

- 978,000 events
- Reprocessing: 14.5.2.12

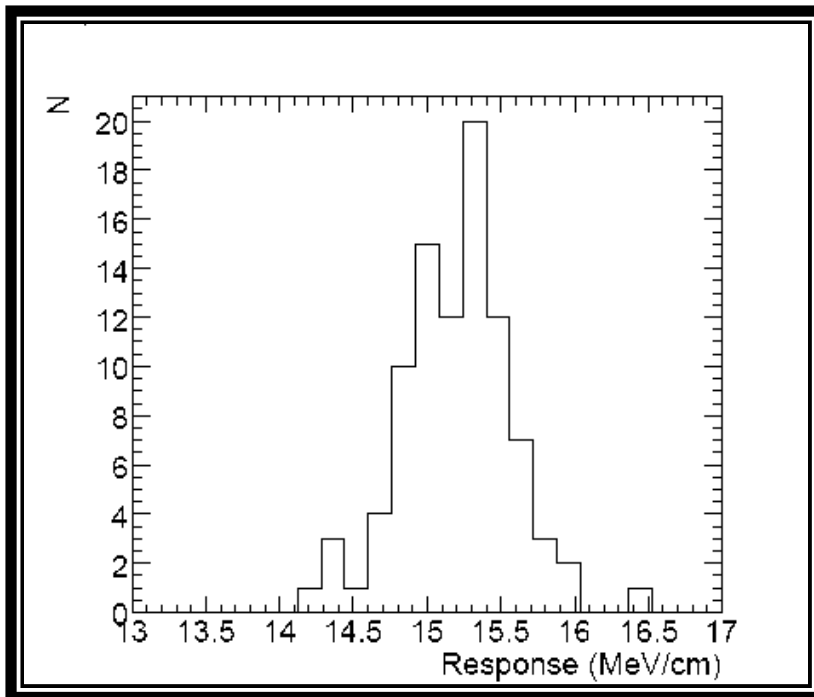
2009

- Run: 121630
- Reprocessing: r733
 - 15.2.0.11
- IDCosmic stream
- 388,400 events

TileMuonFitter Tag

- 2008/MC
 - TileCosmicAlgs-00-02-05
- 2009:
 - TileCosmicAlgs-00-02-11

Test Beam E/mm



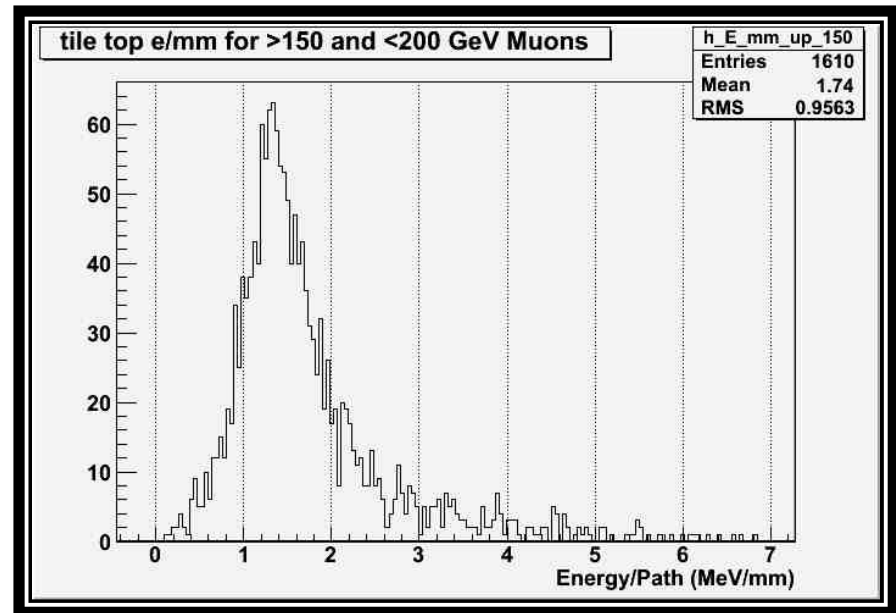
- Truncated Mean:
1.52 MeV/mm
- 180 GeV muons

Cuts in Data

- 150 to 200 GeV Muon Momentum
- Spectrometer perigee “y” > 0
- Tile Path > 0 and < 8000 mm
- Tile Top Path < 6000 mm
- Tile Energy Top and Bottom > 20 MeV
- Tile, ID, MuSpec track amount > 0

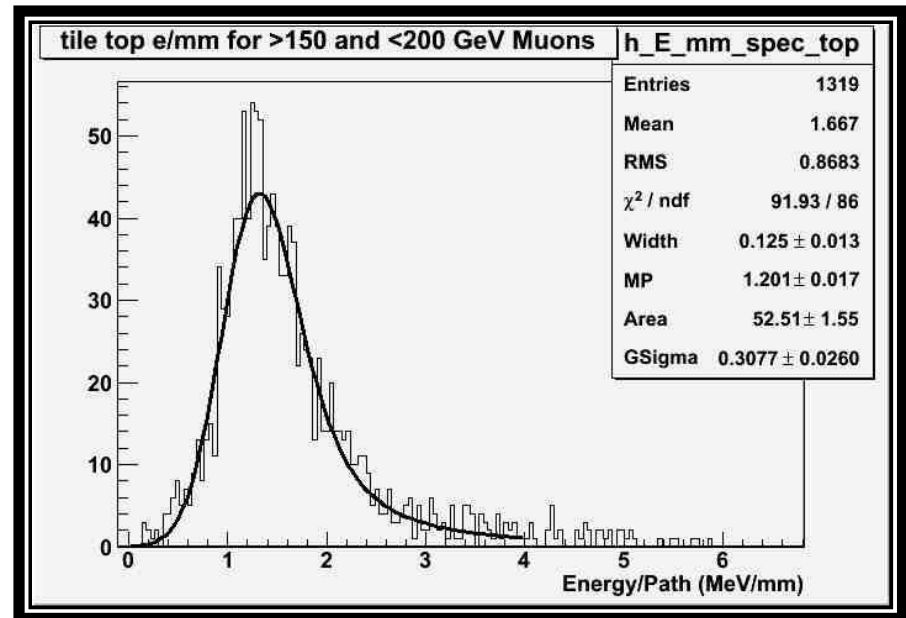
2008 Cosmic Data E/mm

- Muons measured in Inner Detector
 - 150 to 200 GeV Muons
 - E/mu of 0.91 applied
 - Truncated 97.5%
-
- Mean: 1.74 MeV/mm
 - 14.5% higher
 - 18% expected from Cs



2008 Cosmic Data E/mm

- Muons measured in Spectrometer
 - 150 to 200 GeV muons
 - E/mu of 0.91 applied
 - Truncated 97.5%
-
- Mean: 1.667 MeV/mm
 - 9.7% > testbeam
 - 18% expected from Cs



Sources of Uncertainty

- TileMuonFitter
- ID and MuSpec resolution
- Range of energies
 - 150 TO 200 GeV – not 180 GeV
- Large spectrum of angles
 - Phi
 - Eta – less than testbeam

ID and MuSpec P_T Resolution

\approx Resolution	100 GeV	150 GeV	200 GeV	250 GeV
Inner Detector [*]	4%	6%	8%	10%
Muon Spectrometer [†]	2.5%	2.7%	3%	3.5%

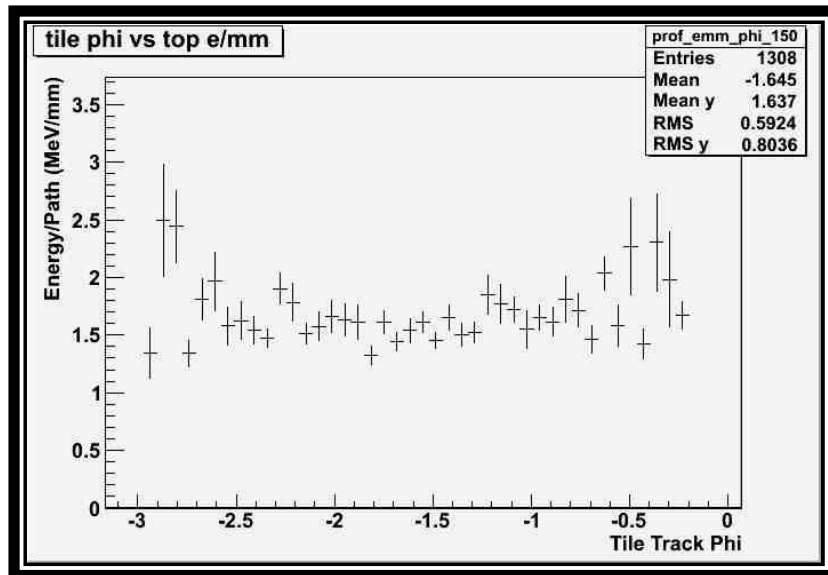
* Calculated from: $\sigma(1/P_T) \approx 0.4 \text{ TeV}^{-1}$ given in LHCC presentation June 5, 1997 – also, ID TDR pg 106

† Taken from spectrometer TDR plot, pg.398

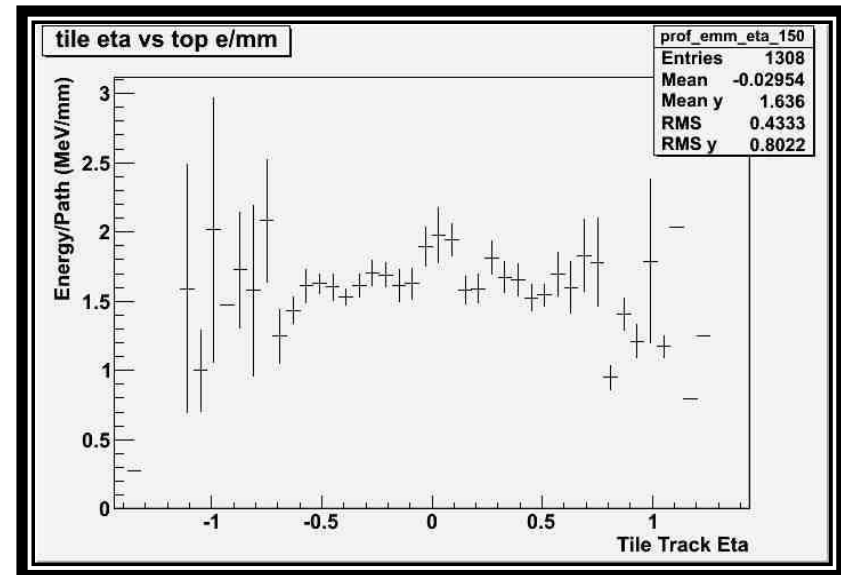
TMF Phi and Eta vs. E/mm

- Eta ranges from about -1.3 to 1.3
- Testbeam eta was -1.5 to 1.5
- E/mm shows little dependence on either

Phi vs. E/mm



Eta vs. E/mm

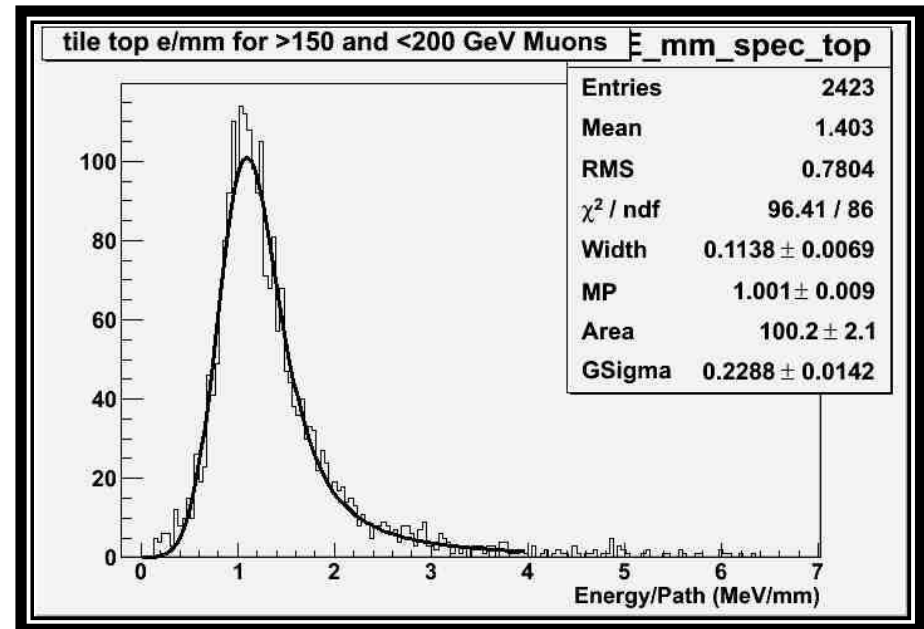


Re: Sources of Uncertainty

- TileMuonFitter - Primary
- ID and MuSpec resolution - Minimal
- Range of energies
 - 150 TO 200 GeV – not 180 GeV
- Large spectrum of angles - Minimal

Cosmic Monte Carlo E/mm

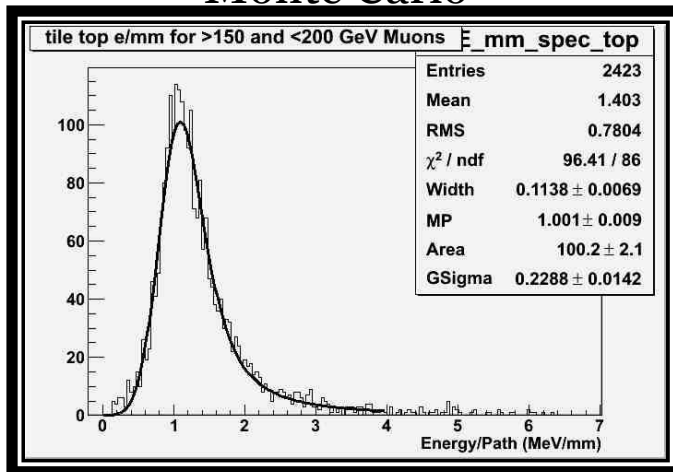
- Muons measured in Spectrometer
- 150 to 200 GeV muons
- E/mu of 0.91 applied
- Truncated 97.5%
- Mean: 1.403 MeV/mm
- 15.8% < 2008 data
- 7.7% < testbeam



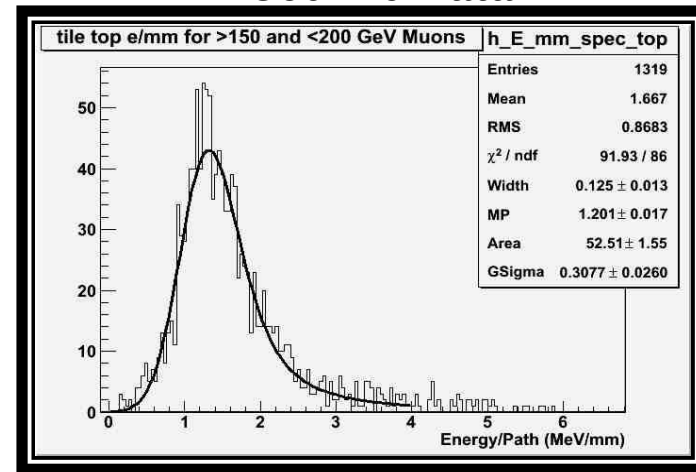
Most Probable Values:

- Monte Carlo: 1.001 MeV/mm
- 2008 Cosmic Data: 1.201 MeV/mm
 - 2008/MC = 20%

Monte Carlo



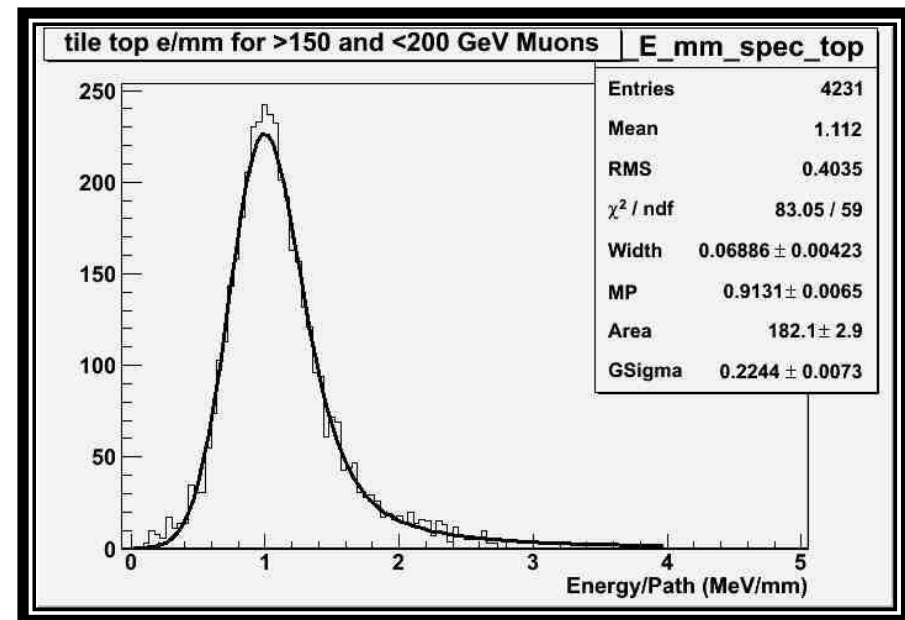
Cosmic Data



2009 Cosmic Data E/mm

- Muons measured in Spectrometer
- 150 to 200 GeV muons
- E/mu of 0.91 applied
- Truncated 97.5%

- Mean: 1.112 MeV/mm



All E/mm Values

Energy/Path	Truncated Mean (MeV/mm)	%Difference From Testbeam*	Most Probable Value (MeV/mm)
Testbeam	1.52	-----	-----
2008 Cosmic: Inner Detector	1.74	14.5	-----
2008 Cosmic: MuSpec	1.667	9.7	1.201
Monte Carlo	1.403	-7.7	1.001
2009 Cosmic: MuSpec	1.112	-26.8	0.9131

* %Diff is $(\text{mean A} - \text{testbeam})/(\text{testbeam})$

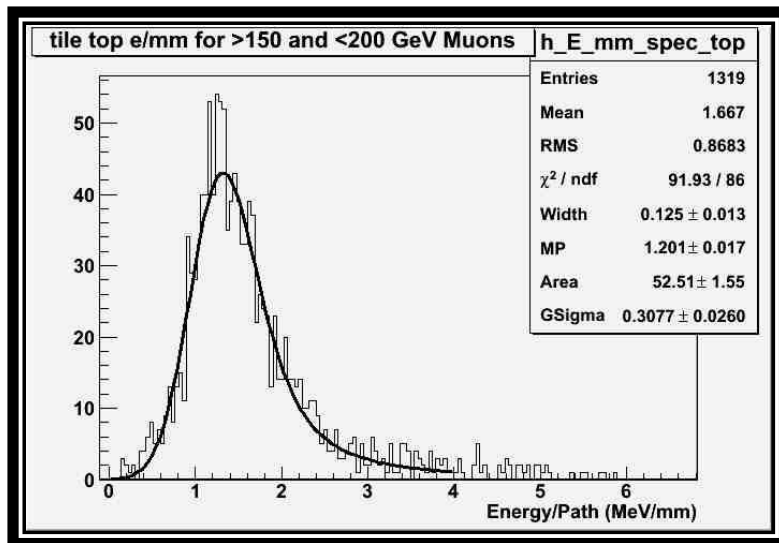
Expected 2008 difference is $\approx 22\%$ on this scale

Expected 2009 and MC difference is $\approx 0\%$

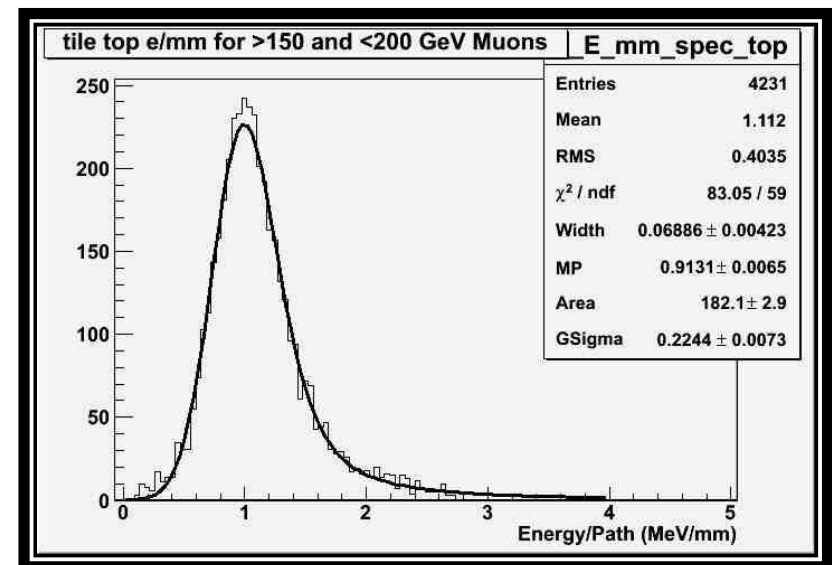
E/mm Plot Width

- 2009: 0.06886
- MC: 0.1138
- 2008: 0.125
- 2009 distribution shape has changed

2008



2009

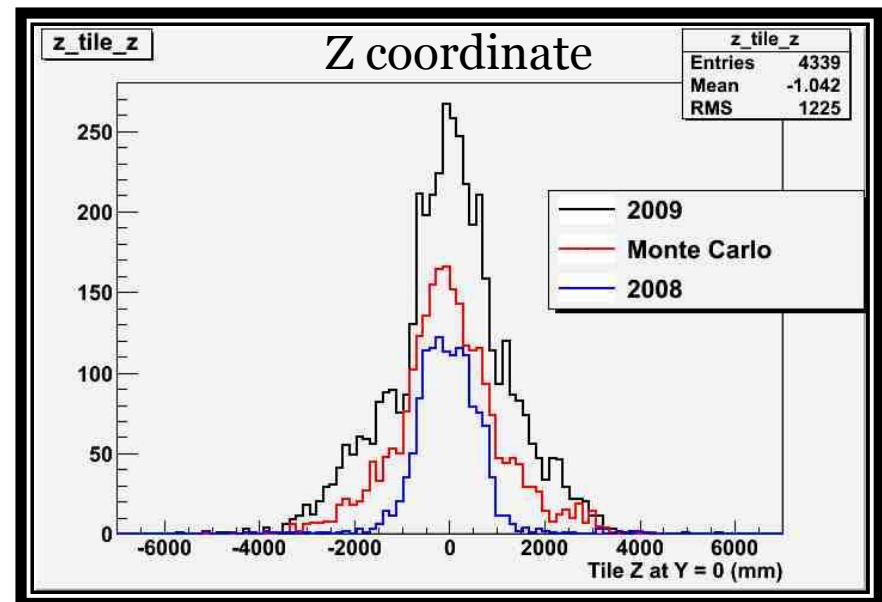
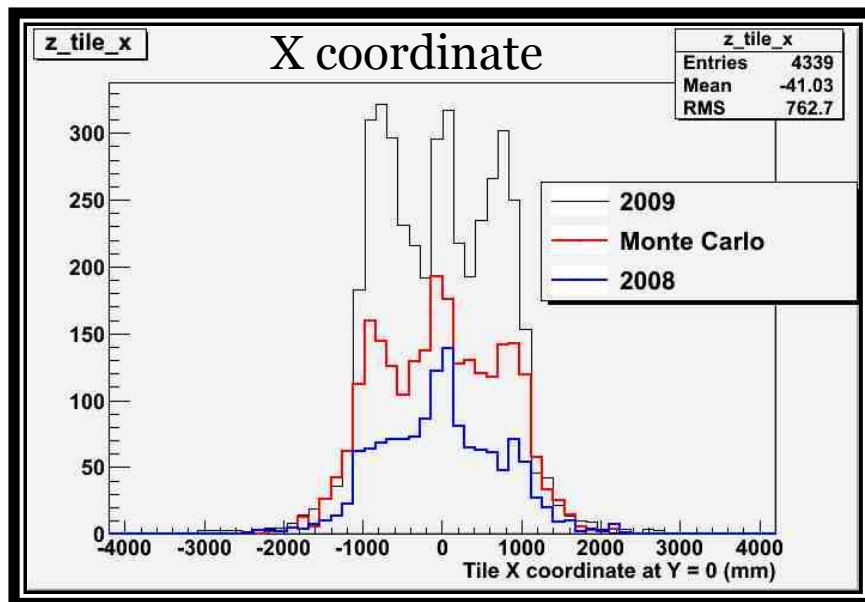


Data Comparison for 150 to 200 GeV Muons

- What changes between 2008, Monte Carlo, and 2009 Data?
- Do these changes affect E/mm ?

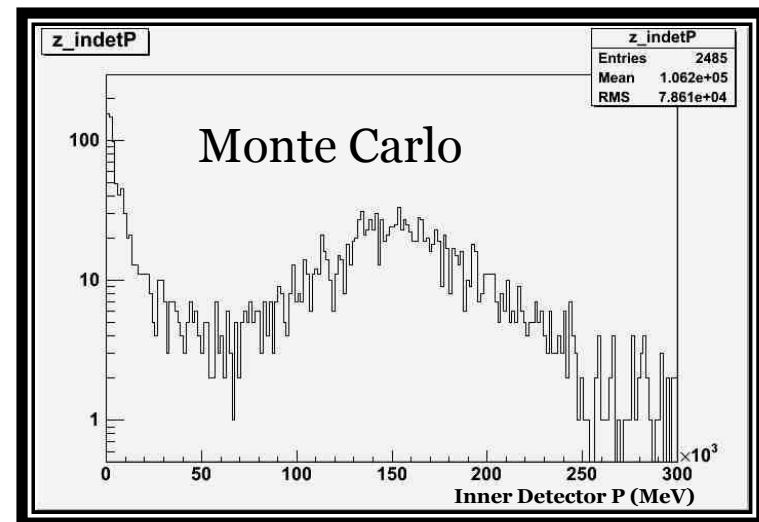
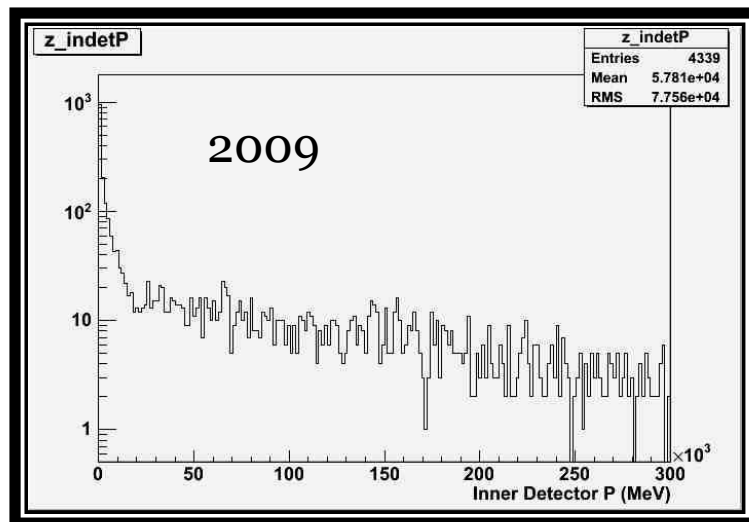
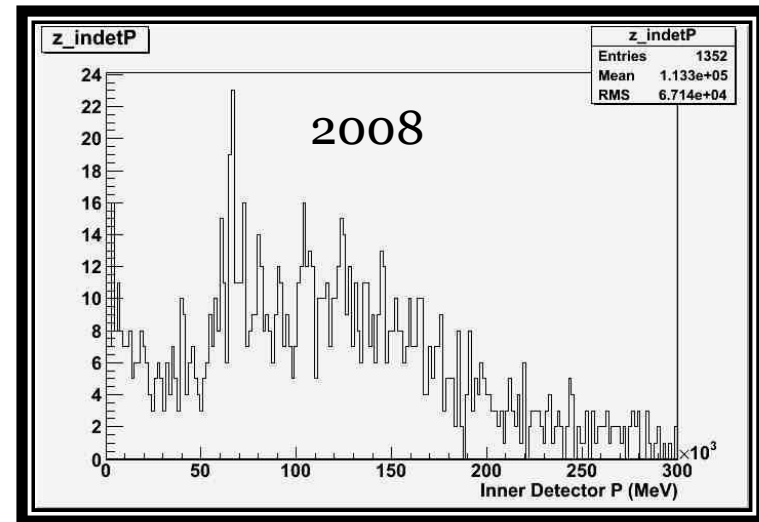
TMF Z, X Values at $Y = 0$

- 2009 data – wider Z distribution
- Spikes in X distribution – not in 2008
- E/mm showed no dependence



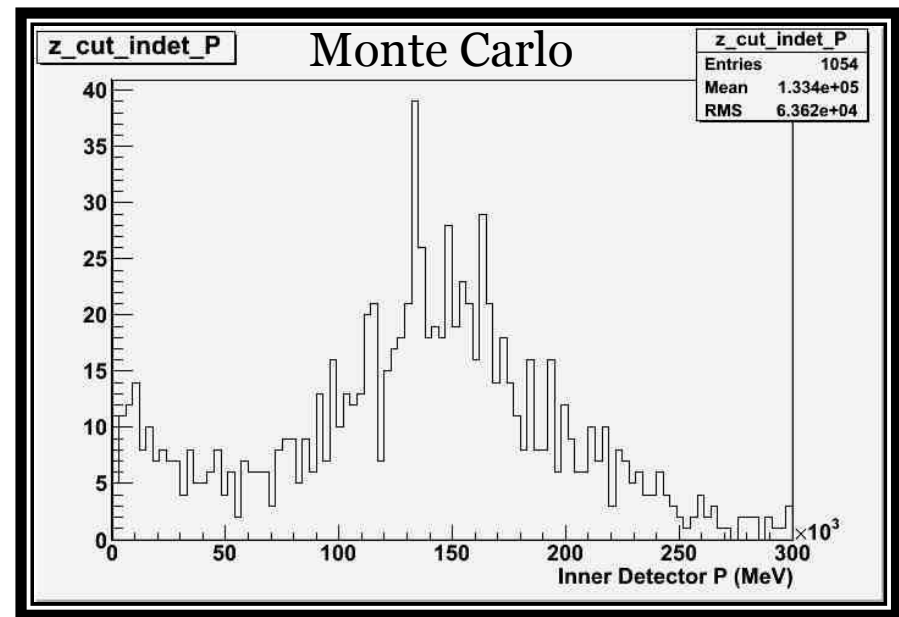
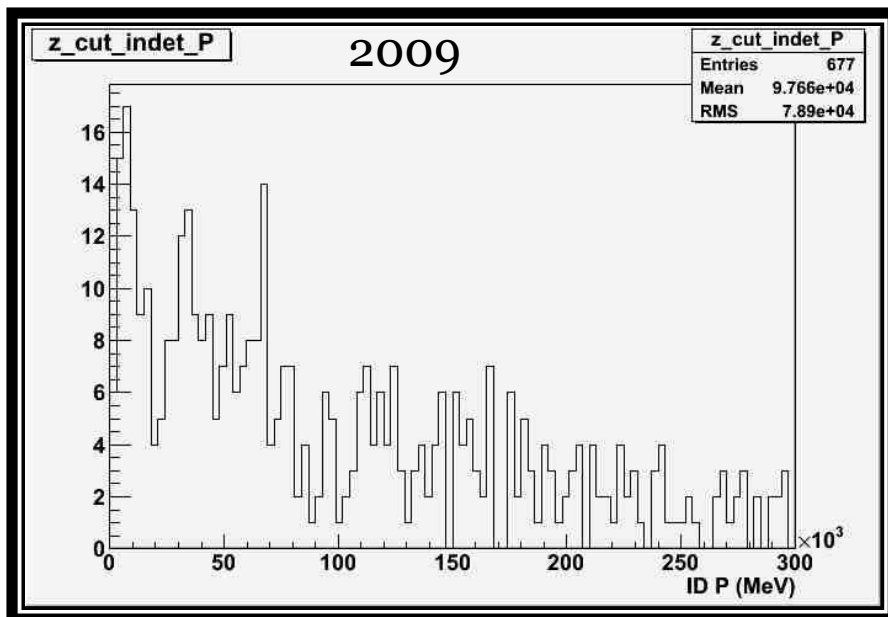
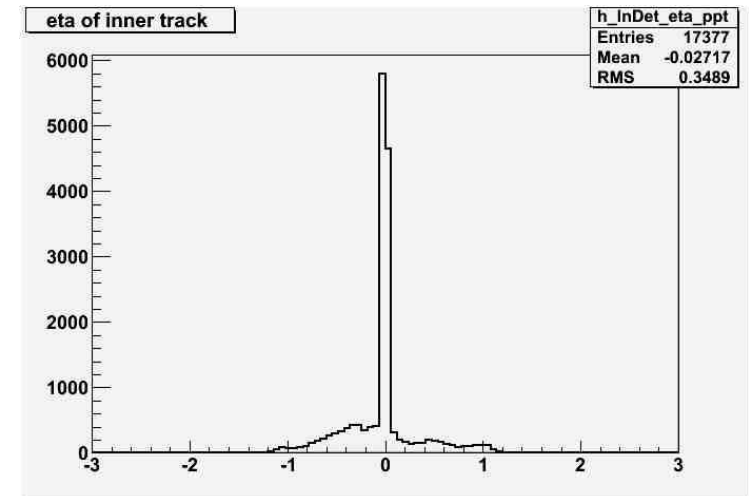
ID Track Momentum

- Should peak around ≈ 160 GeV
- 2009 and MC: Spike at 0



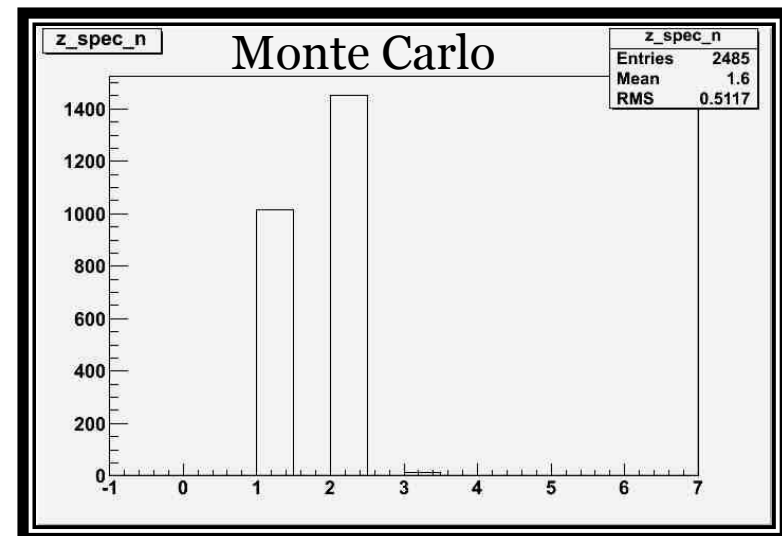
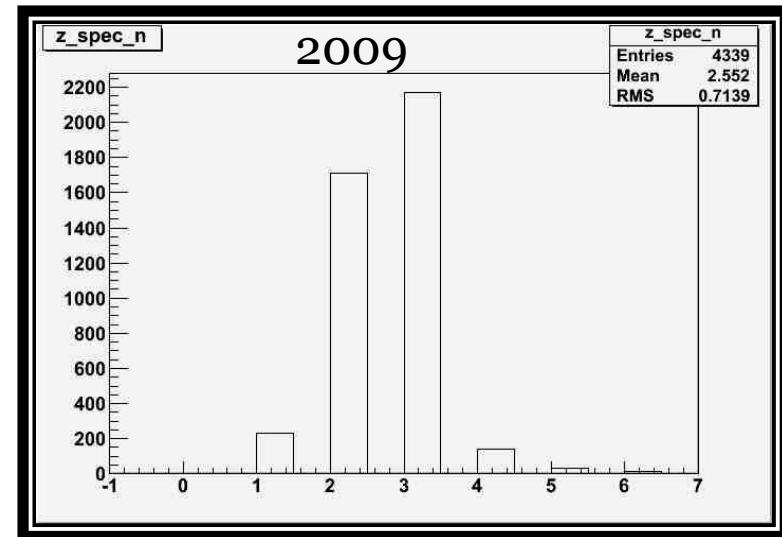
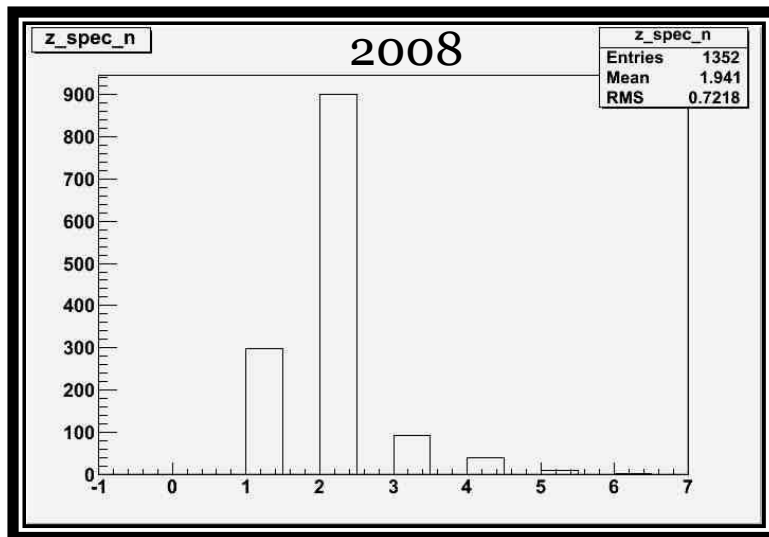
InDet P with Eta cut

- InDet Eta = 0 cut out
- MC: InDet P spike removed
- TRT does not measure P?



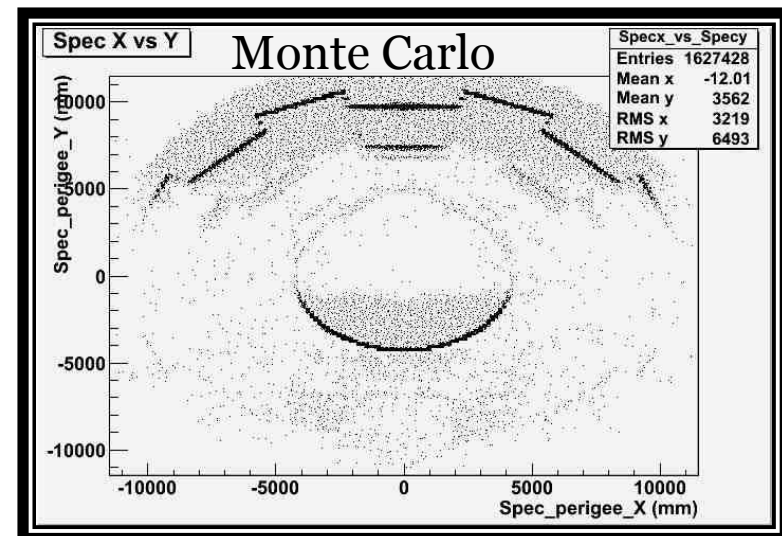
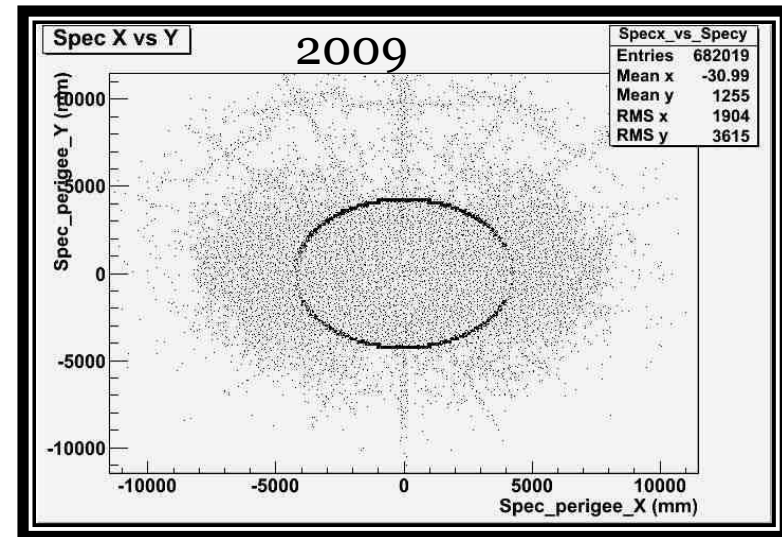
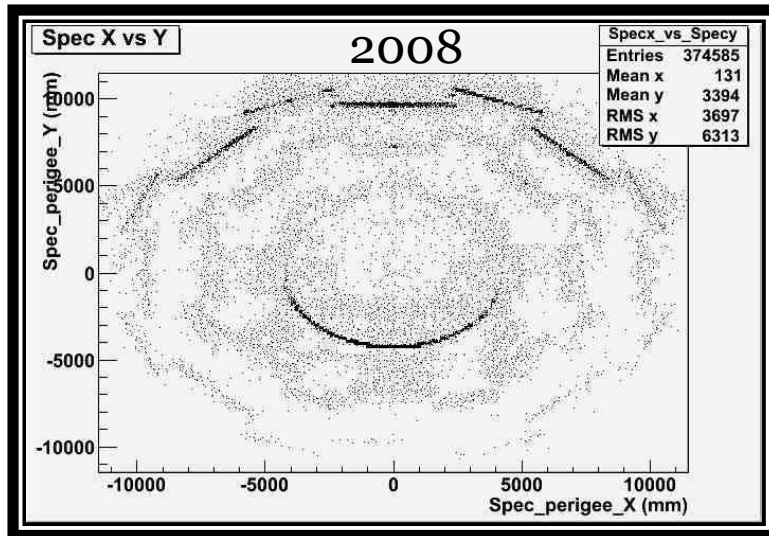
MuSpec Tracks

- 2008: Usually 2 tracks
- 2009: Often 3 Tracks
- MC: Usually 2 tracks
- 1 muon has 2 tracks



MuSpec “Perigee”

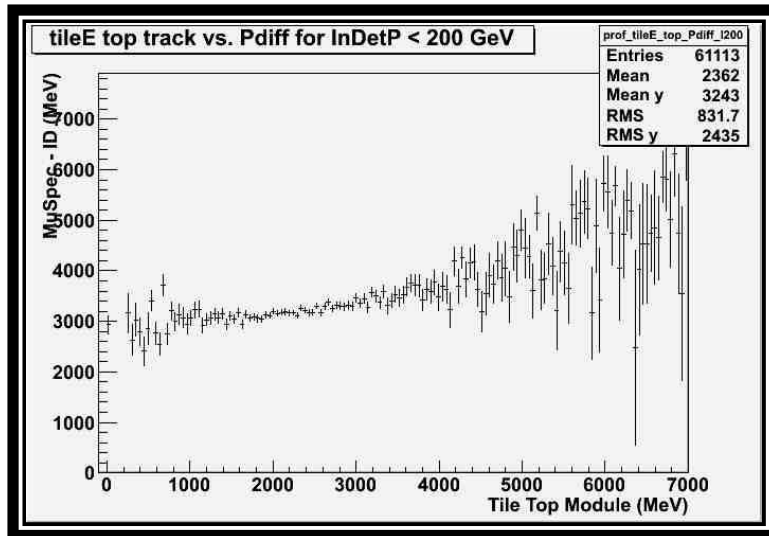
- 2008: Detection point in MuSpec
- 2009: Inner MuSpec Surface, 4.3m
- Why the change?



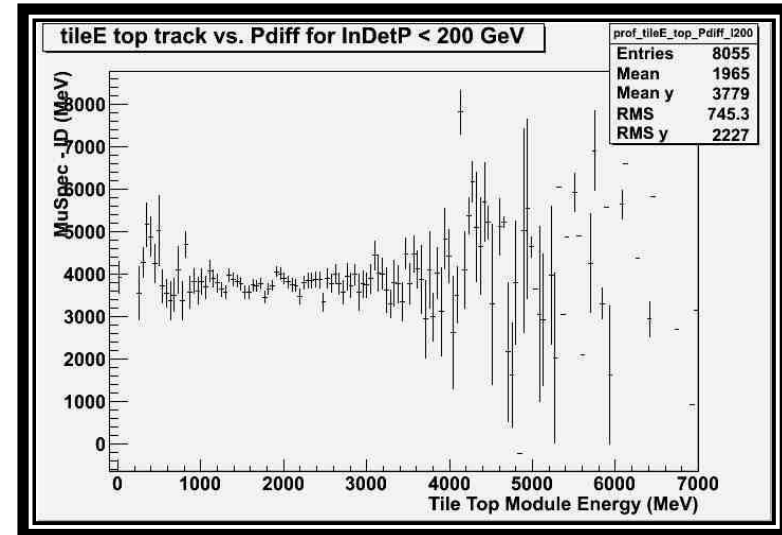
Lost Correlation

Top Tile Module Energy vs. Momentum Difference

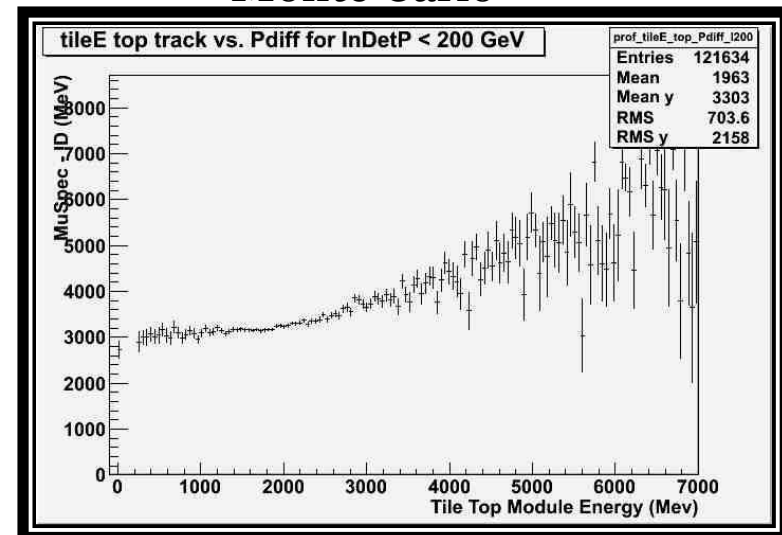
2008



2009



Monte Carlo



TileMuonFitter Changes

(From 2008+MC to 2009)

4/09/09

- Remove masking of bad cells, optimized loop over CaloCellContainer to read only TileCells
- Bug fixed for dE/dx analysis in TileCosmicsAlgs-00-02-08*
- Bug fixed in TMF::CntCells (count # cells inside a line between 2 cells)
- Fix path calc. for tracks crossing LB/EB gap

6/17/09

- Bug fix in cell selection – Do cells were rejected

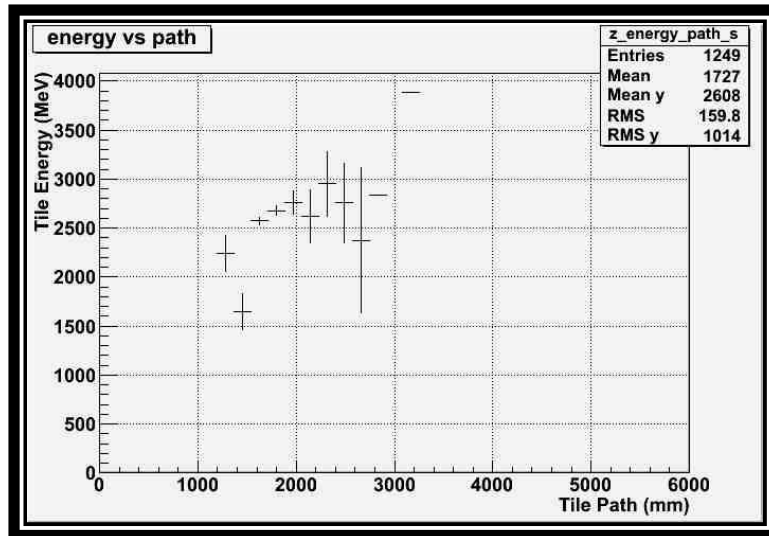
*See talk by Jose Maneira:

<http://indico.cern.ch/getFile.py/access?contribId=11&sessionId=1&resId=0&materialId=0&confId=59714>

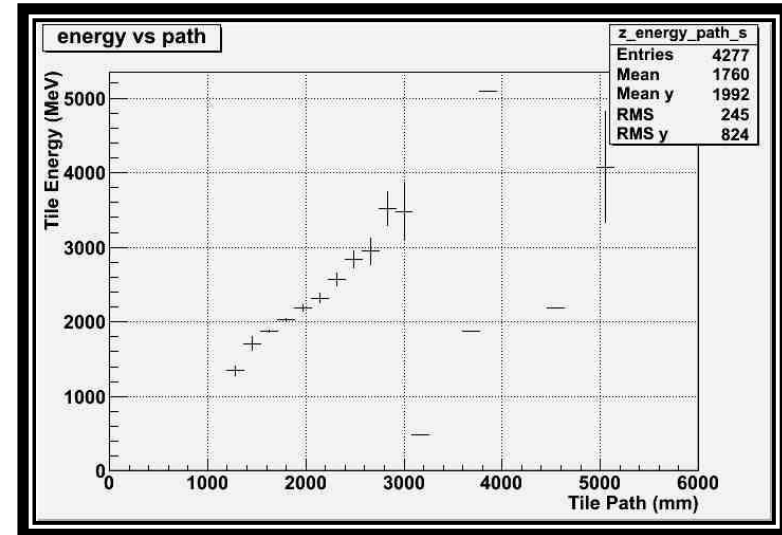
Energy Vs. Path

- Energy and Path seem correlated in both TMF versions for 150 to 200 GeV muons
- 2008 data has low entries

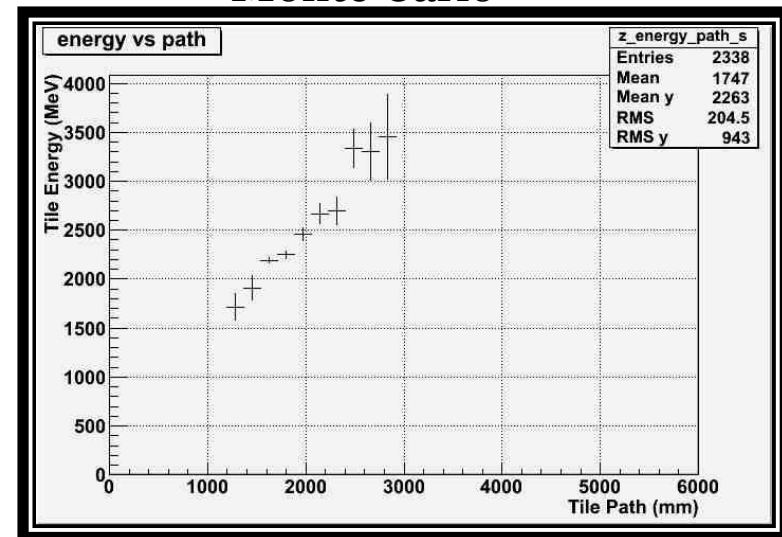
2008



2009



Monte Carlo



Conclusion

- All data points towards TileMuonFitter returning low energy values
- Many changes from 2008 to 2009 data makes it hard to find the cause of low E/mm values
- 2009 E/mm distribution is not exactly comparable due change in shape, width
- 2009 EM gain is low or TMF severely changed

Future?

- My position at Argonne is over
- Need studies with multiple runs from 08 and 09
- Use tile cell data with spectrometer muon extrapolation to compute energy and compare with TMF
- Include liquid argon data
- Investigate other trigger streams
- Understand path length dependance of E/mm values
- Measure e/μ ratio with real data and apply the correct ratio to correct energy muons

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