Shower Energy Calibration

Nathaniel Tagg
on behalf of the Calibration Group:
Lisa, Jeff, Pat, Peter, Simona, Tingyun,
Pedro, Caius, Justin, Minsuk, Jiajie,
Phil, Phil, and sometimes Phil

- It is our job to prove:
  - ND/MC calorimetric energy scale is correct to x%
  - FD/MC calorimetric energy scale is correct y%
  - Absolute calorimetric energy scale is correct to z%
  - The resolution of the shower energy is similar in data and MC at each detector

The Purpose

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Caveats

- We are proving this only for total pulse height.
  - Andy's, Niki's, etc shower energy estimators are NOT covered.... we make no promises.
  - This is because they depend on 'number of hits', which requires a calibration of channel thresholds and gains, which is NOT done by anyone at the current time.
- We assume that relative calibration is done ND→MC and FD→MC, not ND→FD
  - Subtleties in sparsification, xtalk can only be taken out by the Monte Carlo.
- This analysis is not our best...it's what was possible for this time scale. (See Lisa's talk.)

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Calibration	Detector	Data	MC
Drift	Far	Not calibrated	Perfect
	Near	Not calibrated	Perfect
Linearity	Far	Not calibrated	Not calibrated
	Near	Not calibrated	Not calibrated
Strip-to-Strip	Far	3 month data set	Perfect
	Near	3 day data set	Perfect
Attenuation	Far	Mapper fits	Perfect
	Near	Mapper fits (fixed)	Perfect
Stop-μ	Far	Jul/Aug 2005	Perfect (tuned)
	Near	Jul/Aug 2005	Perfect (tuned)

What's in Carrot?

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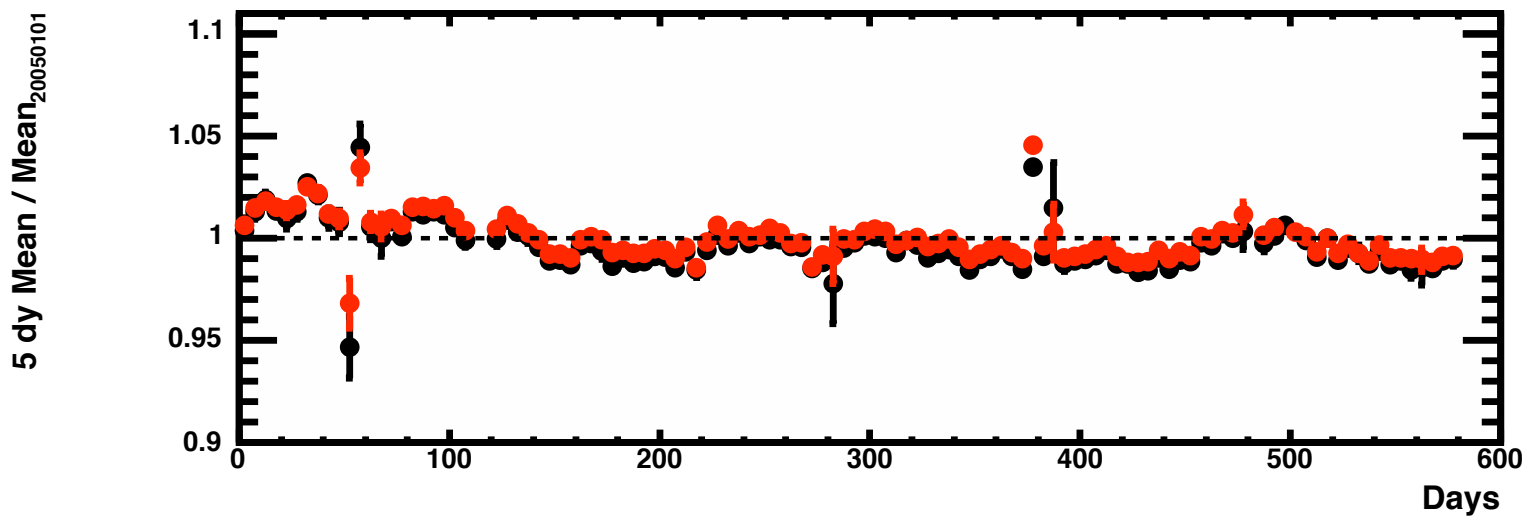
- Studies of FD PMTs show the gain is slowly increasing, at ~2%/year
- Studies of FD muons imply the scintillator is slowly degrading, at ~2%/year
- The net drift of ADC/year we estimate to be less than 2% over the Box exposure.
- Preliminary estimates show the ND to be even more stable; to be conservative we choose
  - 2% uncertainty ND
  - 2% uncertainty FD



Drift

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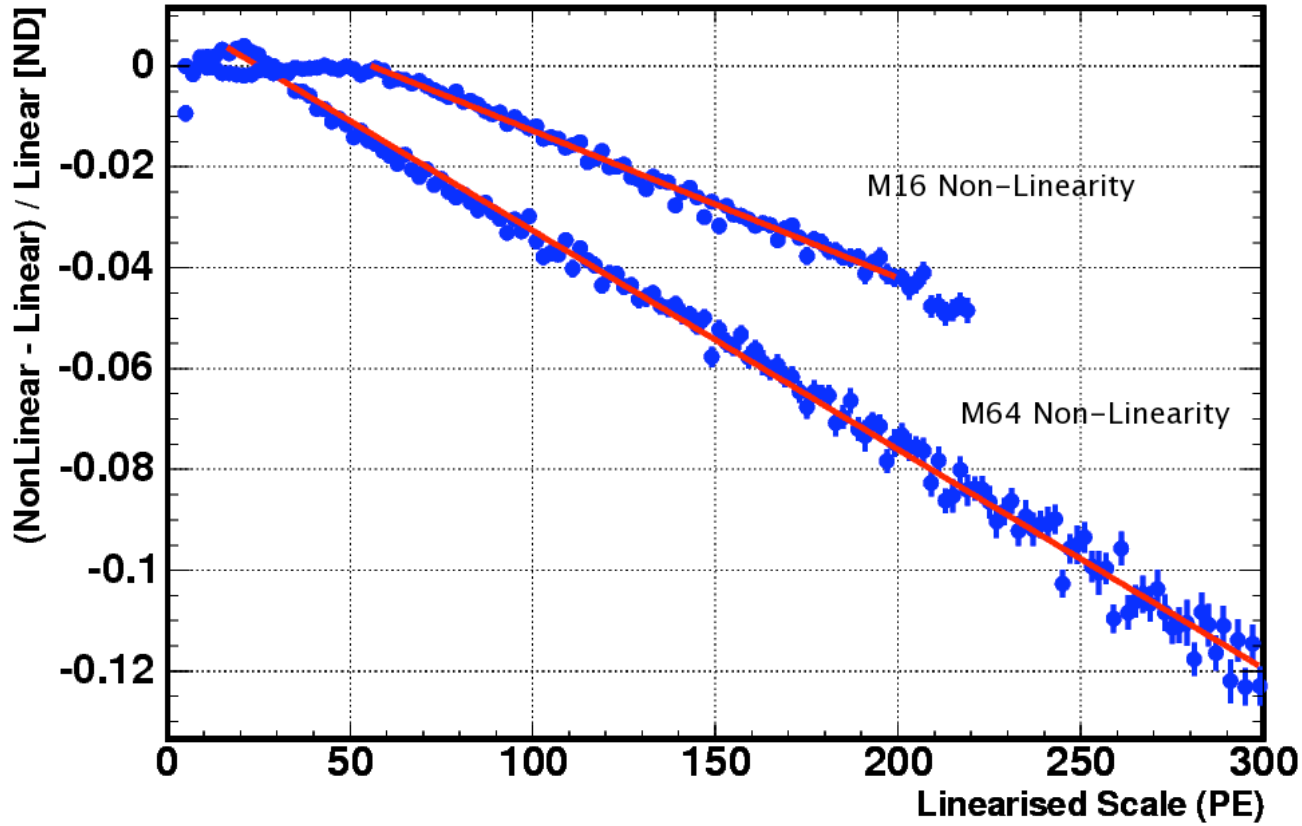
- The MC has a nonlinearity simulation.
- Neither the MC nor data has a linearity correction.
- Getting the nonlinearity wrong in the simulation would cause us to get the energy scale wrong.
  - If the nonlinearity was wrong by a factor of 2, this would cause a scale shift of 1.5% at 3 GeV.



We estimate that the simulation is correct to 50%, so the energy scale uncertainty is 0.75%(ND and FD)

Linearity

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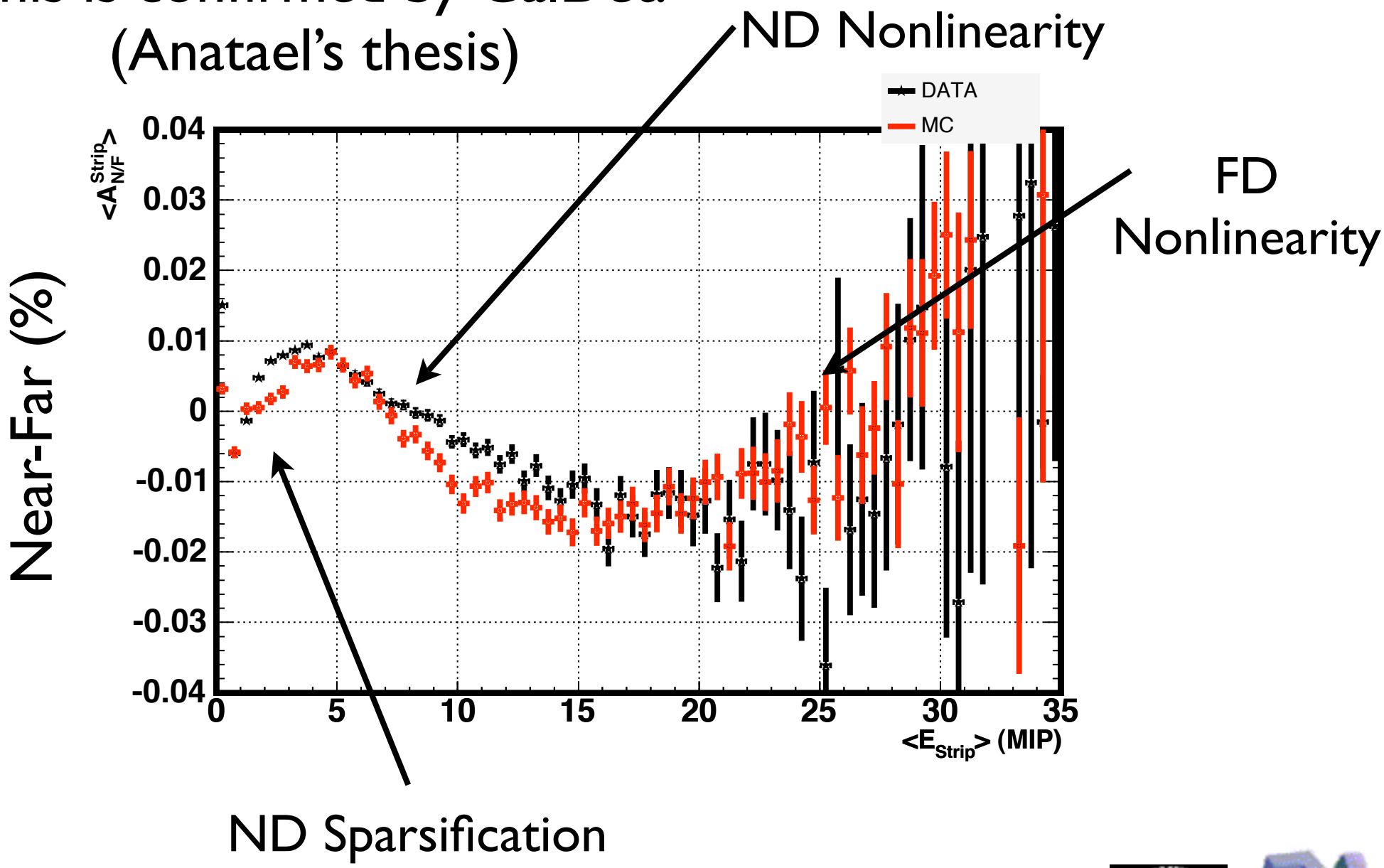
This is confirmed by CalDet:
(Anatael's thesis)



Linearity

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- Strip-to-strip constants:
  - 3-Month FD set from summer 2005
  - 3-day ND set from July 2005
- Attenuation constants:
  - Mapper fits
  - Includes Jiajie's refits for ND.

➡ Systematic impact is evaluated using stopping muons

Intra-detector

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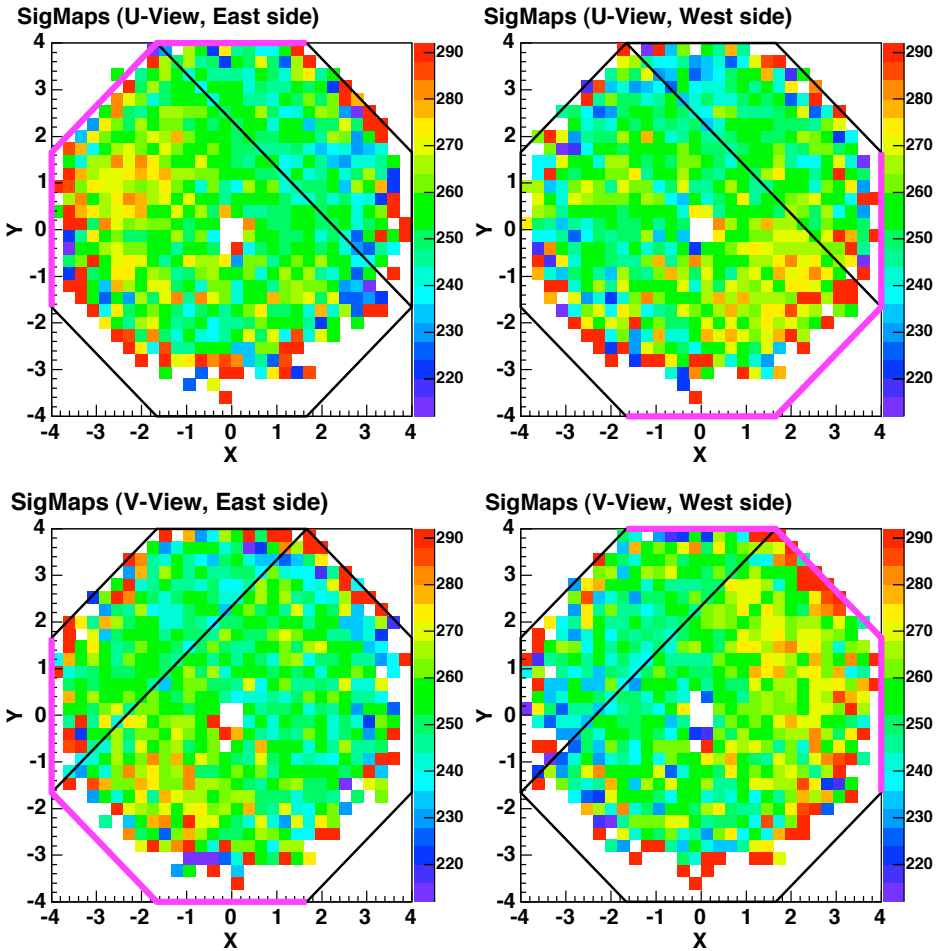
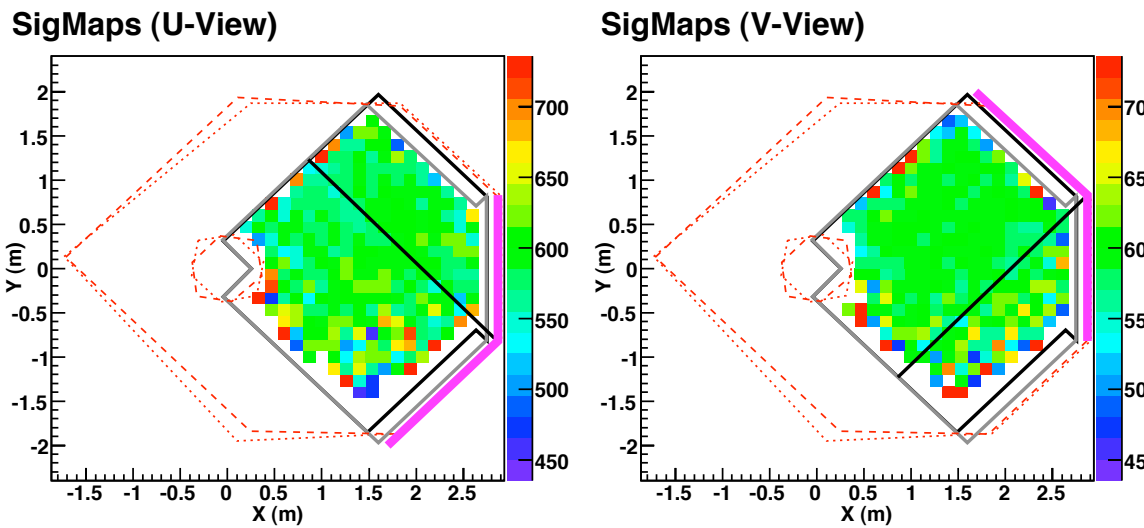


FD



ND

Intra-detector

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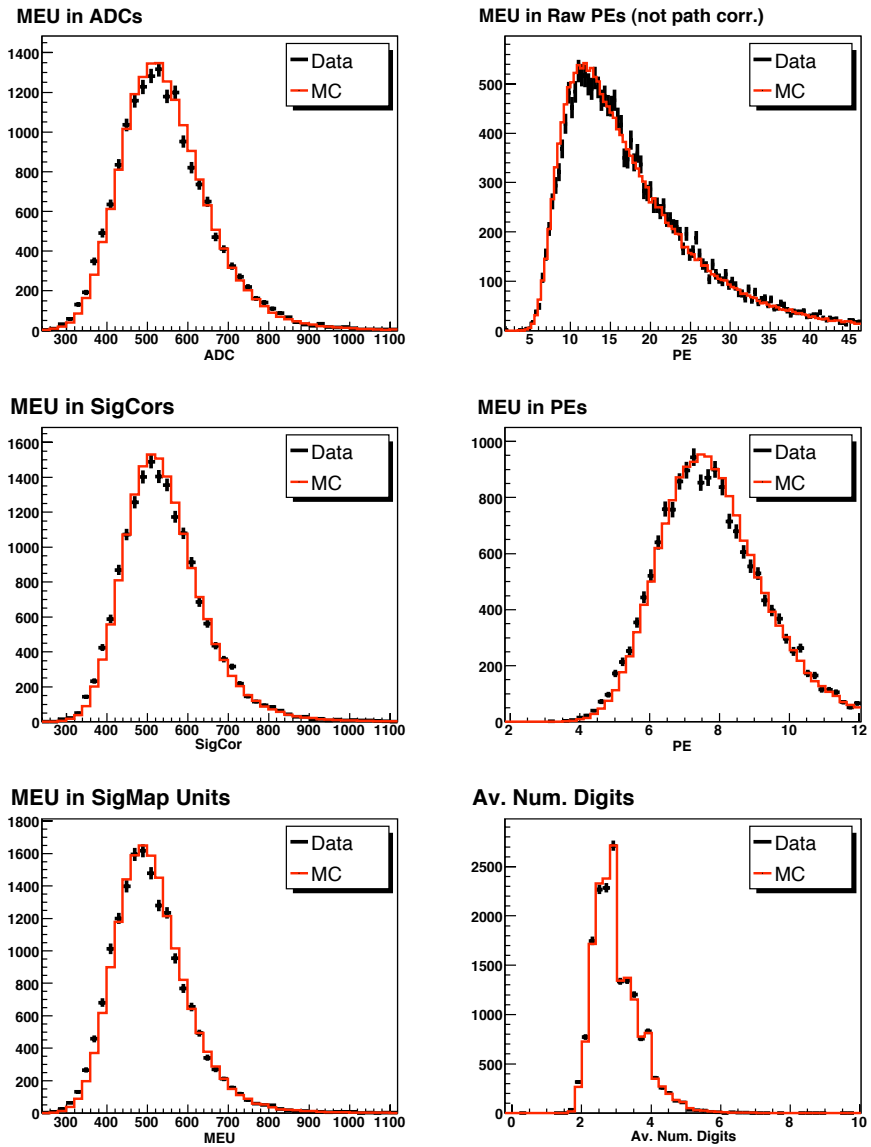
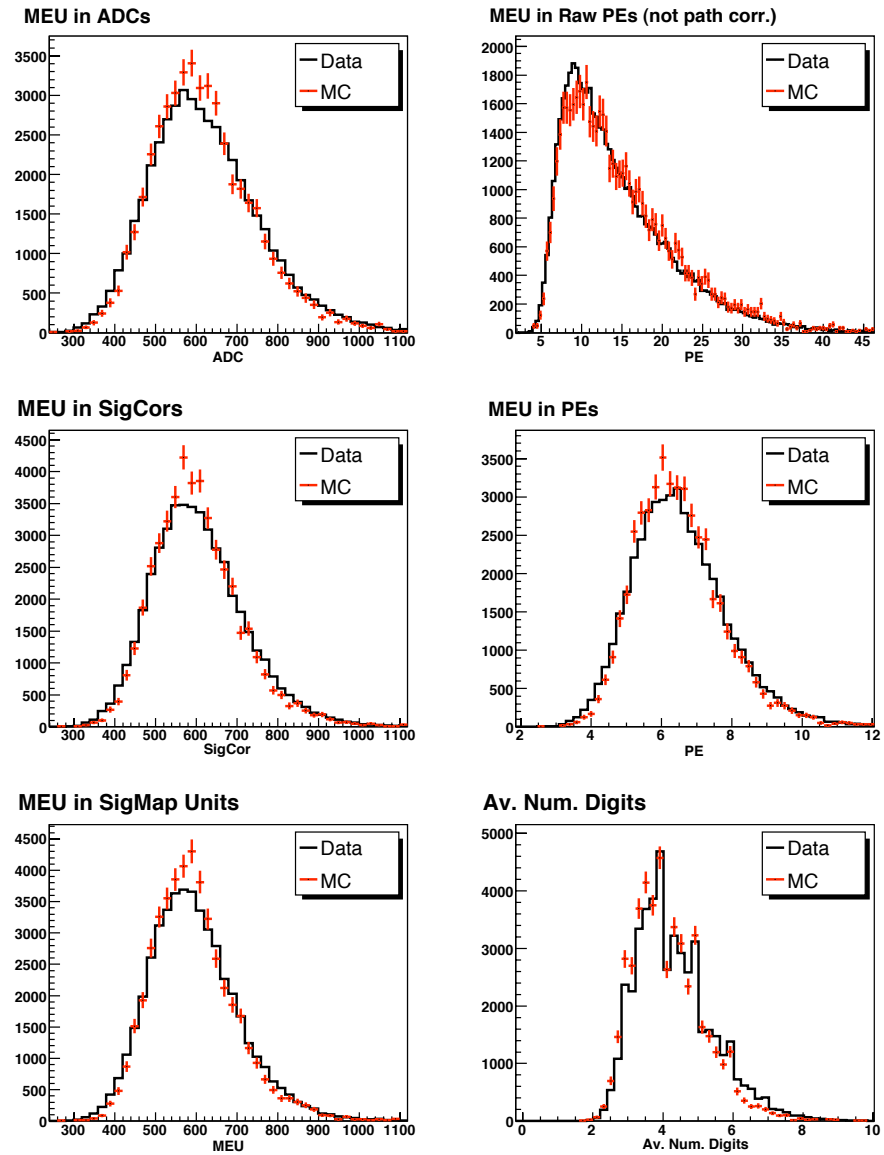


FD



ND

MC/Data agreement with Stopping Muons

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- Jeff has done the analysis on both Beam and Cosmic muons on the ND
- We are using the Cosmic number for consistency with the FD.
- Answer comes out the same to 0.5%, which is within systematic errors.
- The beam answer changed by 2% going from R1.18 to R1.18.2. Was this expected?
- There is some confusion about dE/dx model. The facts:
  Cosmic MC agrees with cosmic data.
  Beam MC agrees with beam data.
  Beam and cosmic data agree with each other.
  Cosmic MC had Mike's 2% dE/dx correction. (Steel and scint.)
  Beam MC did not.
  This does not make sense.

Good

Bad

What the ...?

Notes on Stopping-μ

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Error description	Percentage error
Spatial variations in detector response	±0.6
Angular dependence	±0.5
Shape differences between data/MC	±0.2

Table 9: Systematic errors on the Far detector MEU value.

FD

Error description	Percentage Error
Angular Dependence	±0.5
Spatial variations in detector response	±1.0
Shape differences between data/MC	±1.0

Table 6: Systematic errors on the Near detector MEU value.

ND

Stopping-μ Errors

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Final Results I:
Energy Resolution

- The energy resolution of the data will be worse than the MC
  - The MC has perfect calibration
  - The data has imperfect calibration
- This is probably a small effect for hadronic showers, which have a poor resolution anyway.

Source	Detector	Resolution Degradation
Drift	Far	2% overall
	Near	2% overall
Intra-detector resolution	Far	6% per plane
	Near	9% per plane

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Final Results II: Relative Calibration

Calibration	Detector	Data	MC	Energy Scale Sys. Err.
Drift	Far	Not calibrated	Perfect	2%
	Near	Not calibrated	Perfect	2%
Linearity	Far	Not calibrated	Not calibrated	0.75%
	Near	Not calibrated	Not calibrated	0.75%
Strip-to-Strip	Far	3 month data set	Perfect	(in Stop Mu)
	Near	3 day data set	Perfect	(in Stop Mu)
Attenuation	Far	Mapper fits	Perfect	(in Stop Mu)
	Near	Mapper fits (fixed)	Perfect	(in Stop Mu)
Stop-μ	Far	Jul/Aug 2005	Perfect (tuned)	0.9%
	Near	Jul/Aug 2005	Perfect (tuned)	1.5%

Energy scale uncertainty

ND to MC: ±2.6%

FD to MC: ±2.3%

ND to FD: ±3.5%

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Final Results III: Absolute Calibration

Source	Energy Scale Uncertainty
Tuning hadron (pion) MC to CalDet data	2.5 to 5% (energy dependent)
CalDet beam energy uncertainty	2%
CalDet stopping-muon calibration uncertainty	1.4%
Tuning stopping-muon MC to CalDet, ND, and FD data	1.2%

Table 3: Absolute Energy Scale Systematic Errors.

Absolute Energy Scale Uncertainty

of MC:	±5.7%
of ND:	±6.3%
of FD:	±6.1%

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- Relative error is dominated by lack of drift.. this is a focus for future work.
- The large error on the absolute calibration is dominated by the CalDet analysis. Improvements must come from the CalDet group.
- The ND plots do not match the MC as well as I would hope, but the FD is in good shape. Cause for concern?
- Andy's shower energy method uses 'number of hits'. This measure is NOT properly calibrated, Great care must be taken to compare this quantity in MC and Data to make sure it matches.

  → We have NOT analyzed systematic errors for Andy's method, or any other shower energy estimator other than total pulse height. This may be a concern.

Personal Comments

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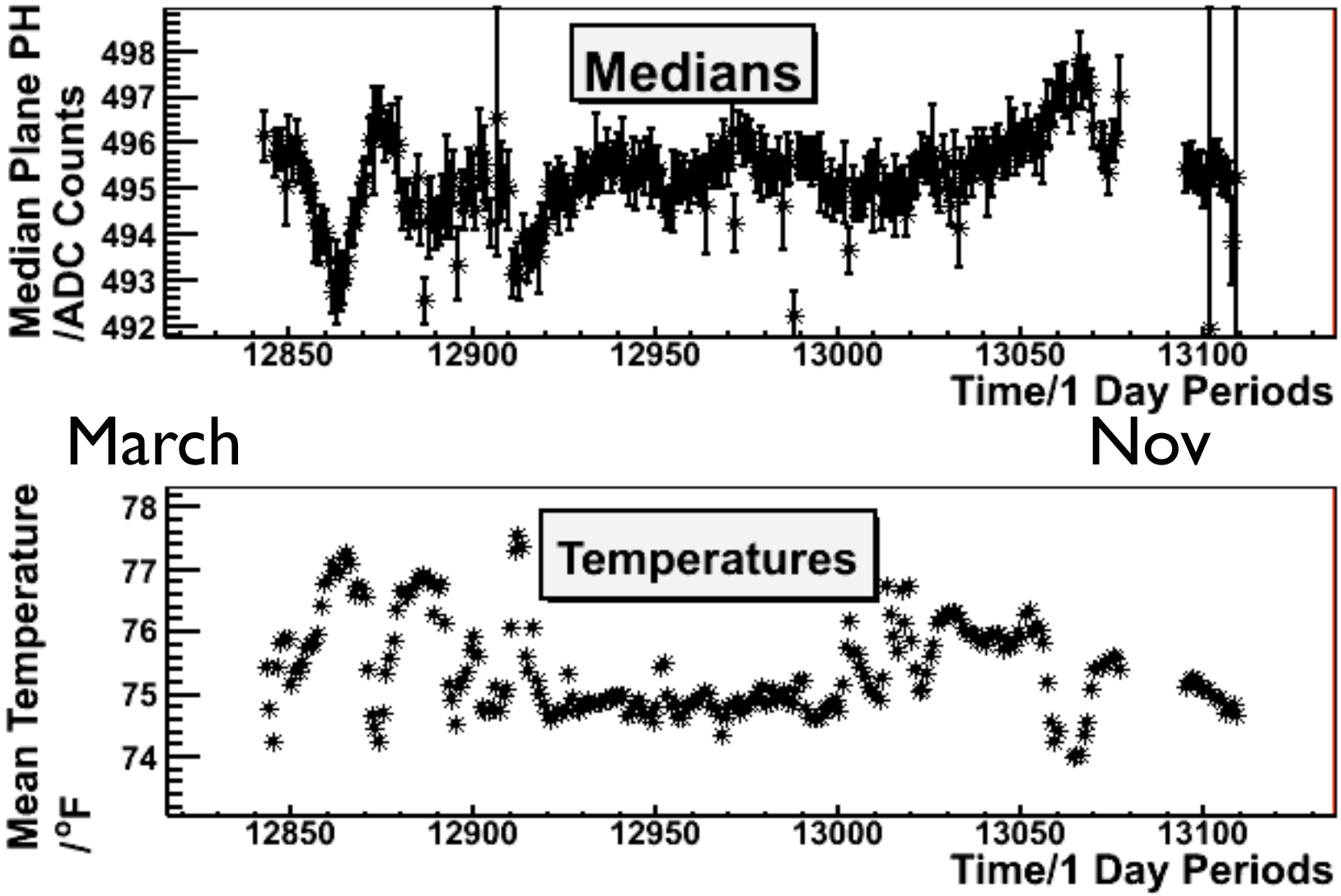

ND Drift

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