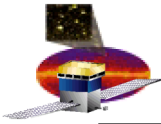


GLAST Large Area Telescope: TKR TOT/Threshold Calibrations

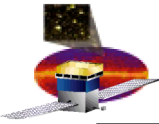
Hiro Tajima (SLAC)

TKR



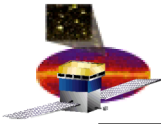
TKR Parameters Relevant to TOT Calib

- **TACK timing.**
 - TOT is initiated by TACK (trigger acknowledge), not TREQ (trigger request).
 - TACK is ~2 us later than TREQ.
 - Different between GASU and non-GASU system.
- **GTFE charge injection scale.**
 - GTFE calibration DAC determines charge for charge injection tests.
 - Affect threshold calibration.
 - Use muon TOT peak for absolute calibration.
 - Requires correct GTFE threshold and tot parameters.
- **GTFE Threshold.**
 - Higher threshold, shorter TOT.
- **TOT gain parameter.**
 - Correlate input charge and TOT.
 - Requires correct TACK timing and GTFE threshold.
- **Above parameters are cross-dependent.**
 - Requires interactive process to optimize the parameters.



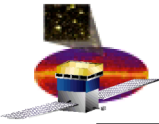
TOT Calibration Sequence

- **Determine TACK timing for charge injection test.**
- **TOT calibration procedure.**
 - **GTFE Threshold calibration assuming calibration DAC scale is correct.**
 - **TOT-charge calibration.**
 - **Measure TOT vs. input charge and fit to 2nd order polynomial to obtain TOT “gain” parameter.**
 - **Pretend input charge (calibration DAC scale) is correct.**
 - **Factor out channel dependence.**
 - **Charge scale calibration.**
 - **Use TOT gain parameters to convert TOT to charge.**
 - **Muon MIP peak to calibrate input charge (calibration DAC) scale.**
 - **Second iteration of Threshold DAC calibration.**
 - **Use the calibration DAC scale obtained above.**
 - **Second iteration of TOT-charge calibration.**



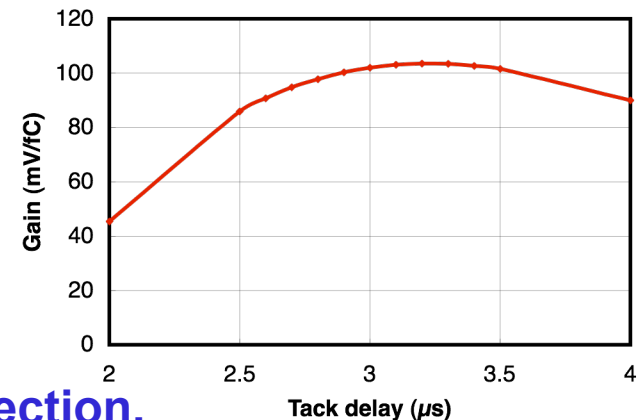
End-to-End TOT Calibration Summary

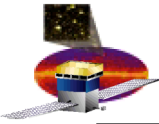
- TACK timing.
 - done.
- GTFE charge injection scale.
 - done.
- GTFE Threshold.
 - done.
- TOT gain parameter.
 - Correct thresholds were not used due to a bug in the TKR script
 - Fixed before 8-tower tests.
 - Column and row number were swapped due to a bug in LATTE tower mapping.
 - Fixed before 8-tower tests.
- TKR recon.
 - Wrong scale was used for “charge per MIP” parameter.



TACK Timing Determination

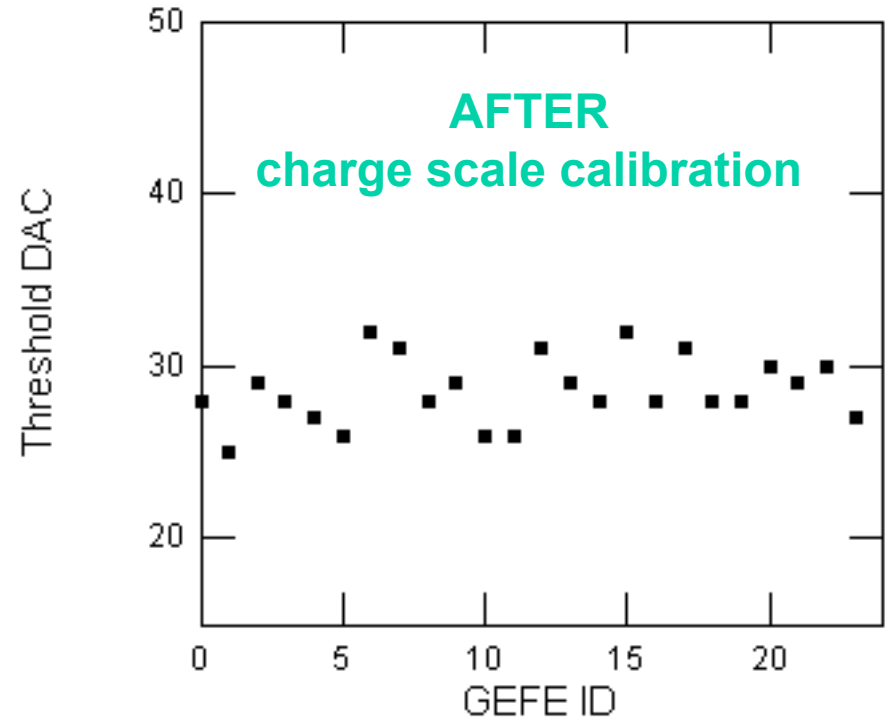
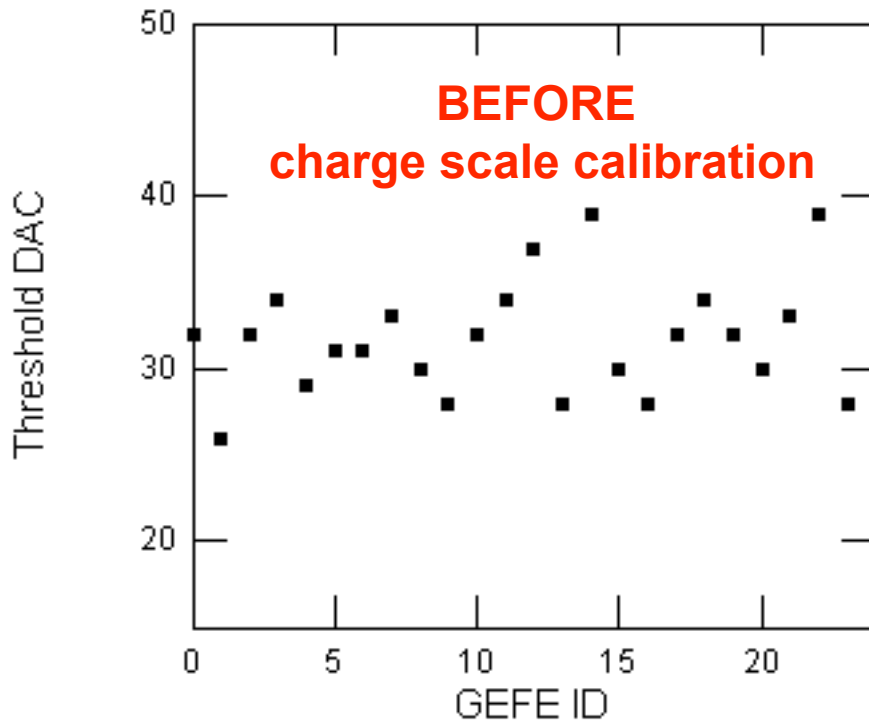
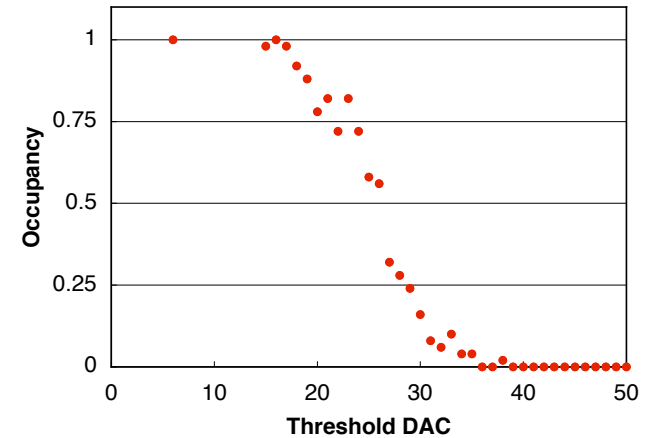
- **TACK timing for charge injection needs to be determined.**
 - **Peak TACK timing for charge injection.**
 - TACK timing at TKR pulse peak.
 - Obtain from TACK scan.
 - **Data capture TACK timing for charge injection.**
 - TACK timing corresponding to data capture with TKR trigger.
 - Determine data capture timing with respect to the peak timing for TKR trigger.
 - TACK scan with external scintillator trigger peaks at $0.25 \mu\text{s}$ with trigger window width=1.
 - This corresponds to $-0.25 \mu\text{s}$ for TKR trigger. (TKR trigger is $0.5 \mu\text{s}$ later than the external scintillator trigger.)
 - In the real data taking, the data is captured at $0.55 \mu\text{s}$ (trigger window width = 12).
 - The distance between the peak and the data capture is $0.8 \mu\text{s}$ ($0.55 + 0.25 \mu\text{s}$).

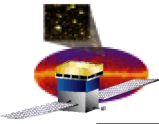




Threshold DAC Calibration

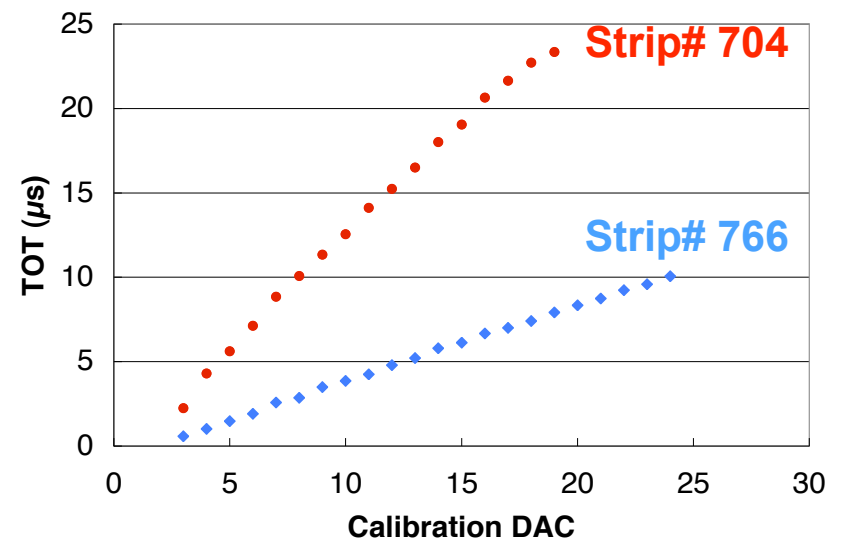
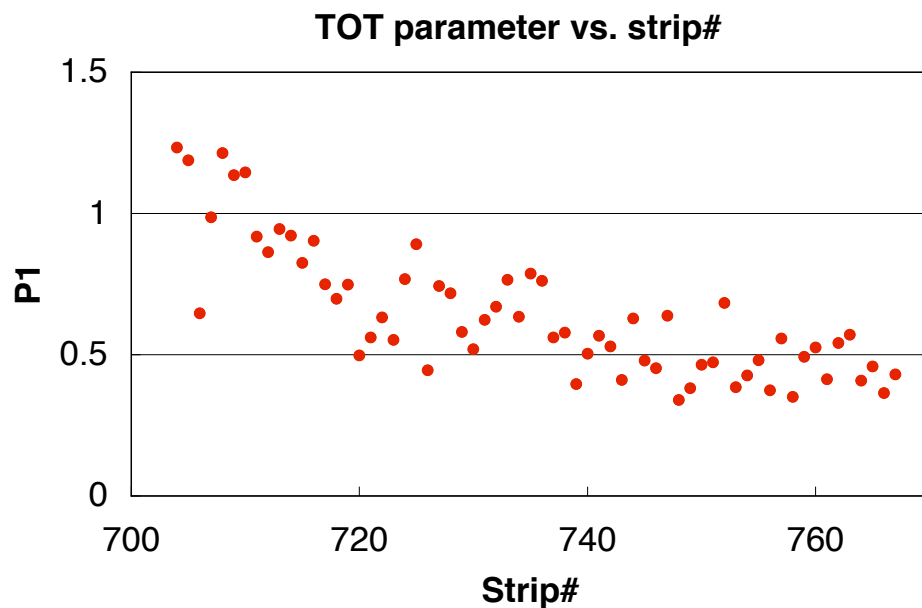
- Scan threshold DAC for a given input charge (1.4 fC ~ 0.27 MIP)
- Fit to error function.

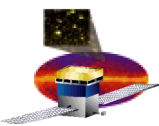




TOT-Charge Calibration

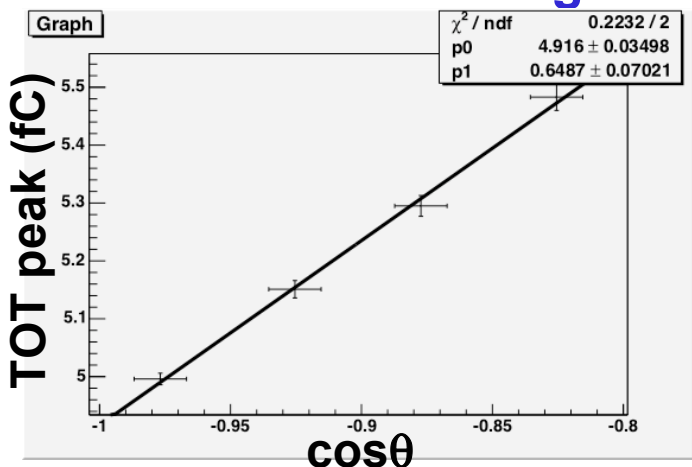
- **Charge injection test.**
 - Measure TOT as a function of input charge.
 - Fit to second order polynomial.
 - $\text{Charge} = p_0 + p_1 \cdot \text{TOT} + p_2 \cdot \text{TOT}^2$
 - Large dispersion of conversion parameters within GTFE.
 - Due to shaper circuitry limitation.





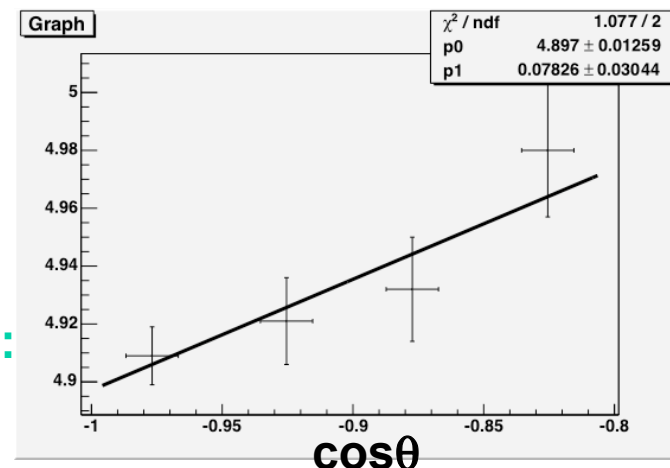
TOT Peak for Charge Scale Calibration

- MC studies on incident angle dependence and bias.
 - Incident angle dependence.



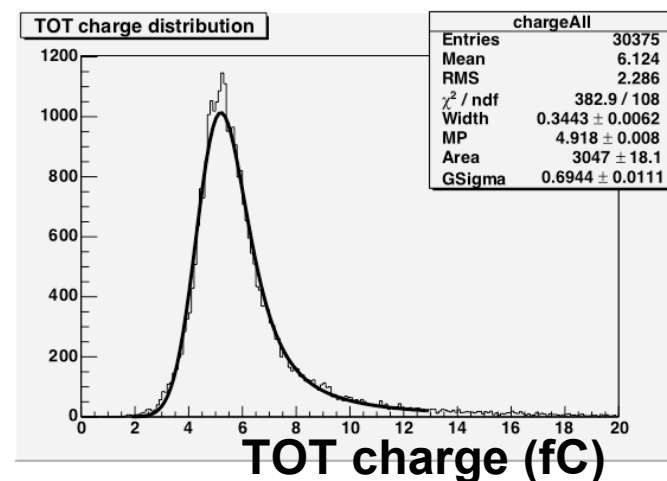
Before angle correction: 10% effect

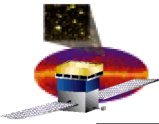
After angle correction: 1% effect



- Bias due to fit, charge sharing and angle correction

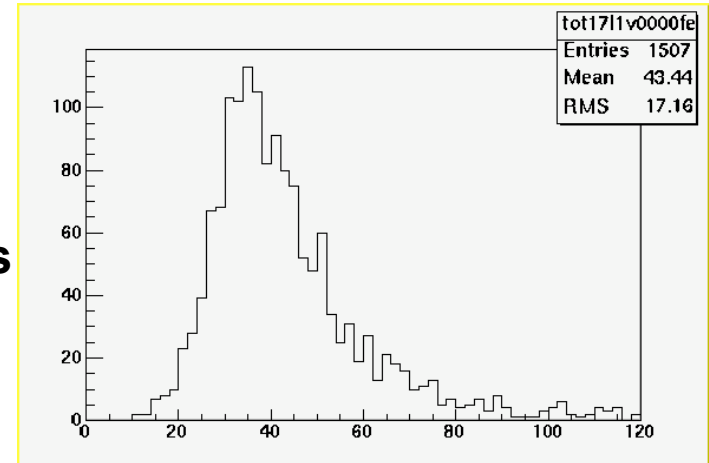
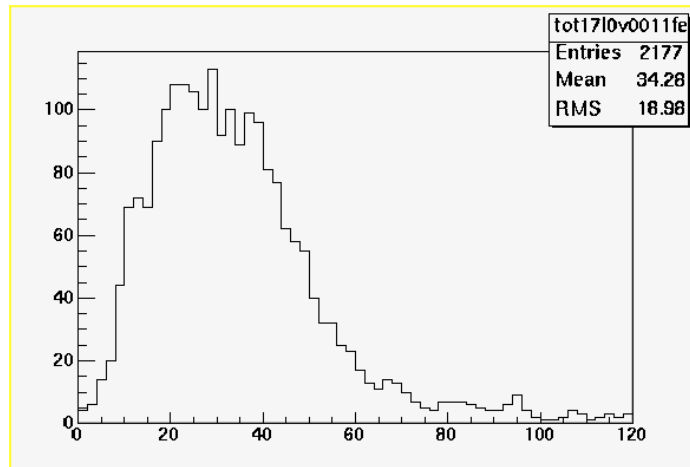
- Peak at 4.92 fC
- This bias is taken into account in charge scale calibration
- Muon energy distribution could affect the peak.



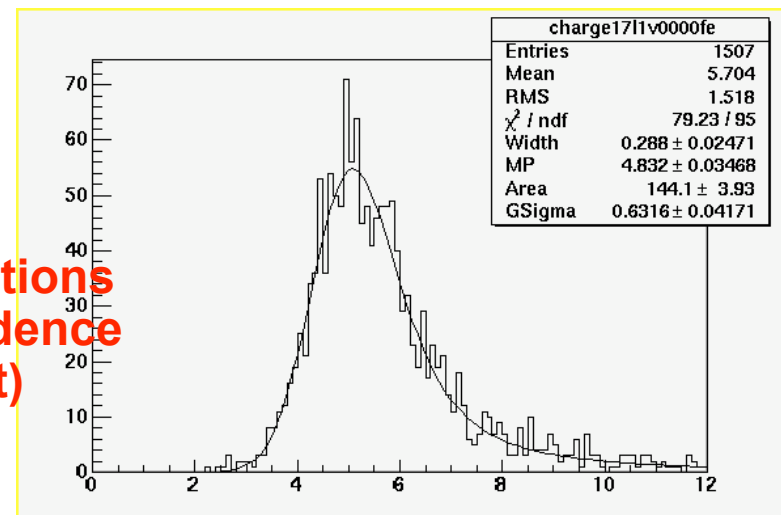
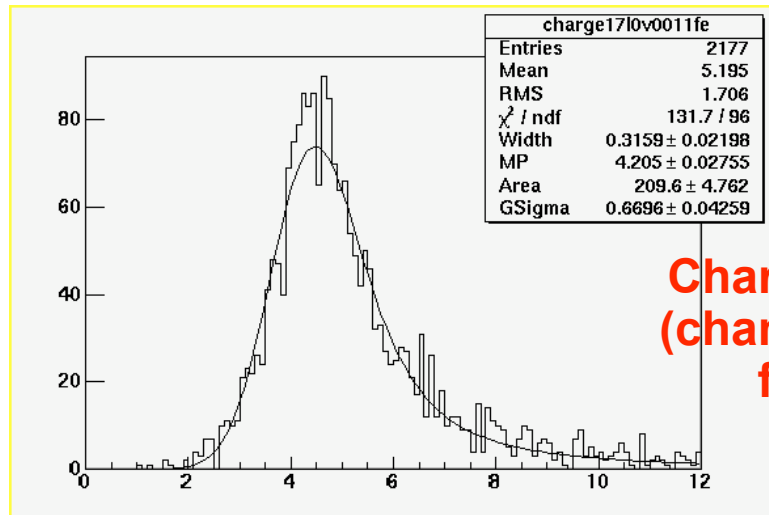


Charge Scale Calibration

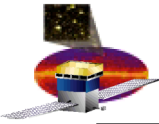
- Fit muon charge distribution for each GTFE.
 - Gaussian convolved Landau distribution.



Raw TOT Distributions



Charge Distributions (channel dependence factored out)

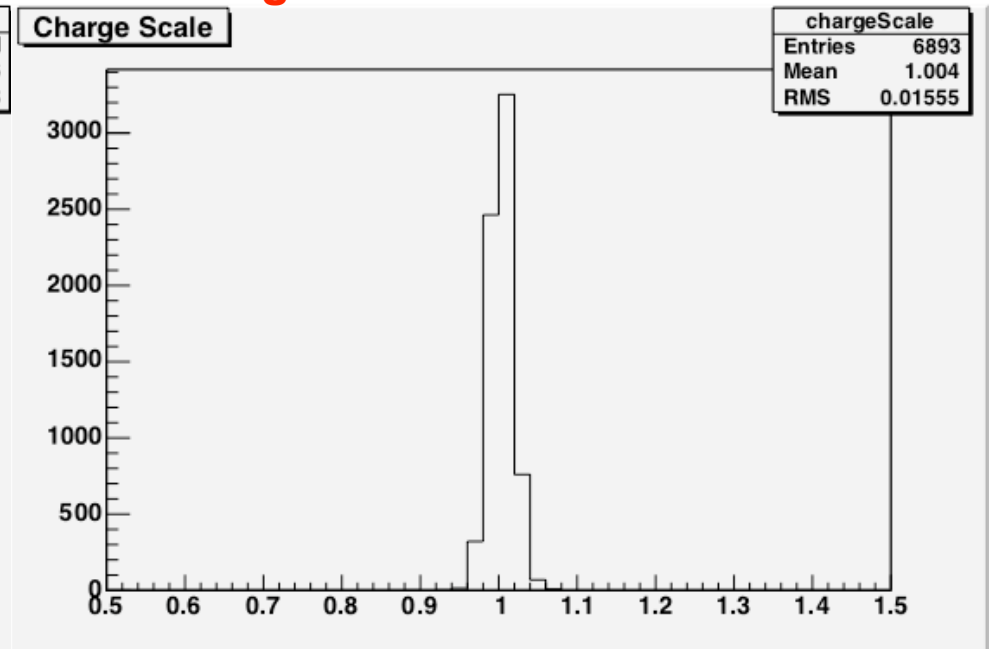
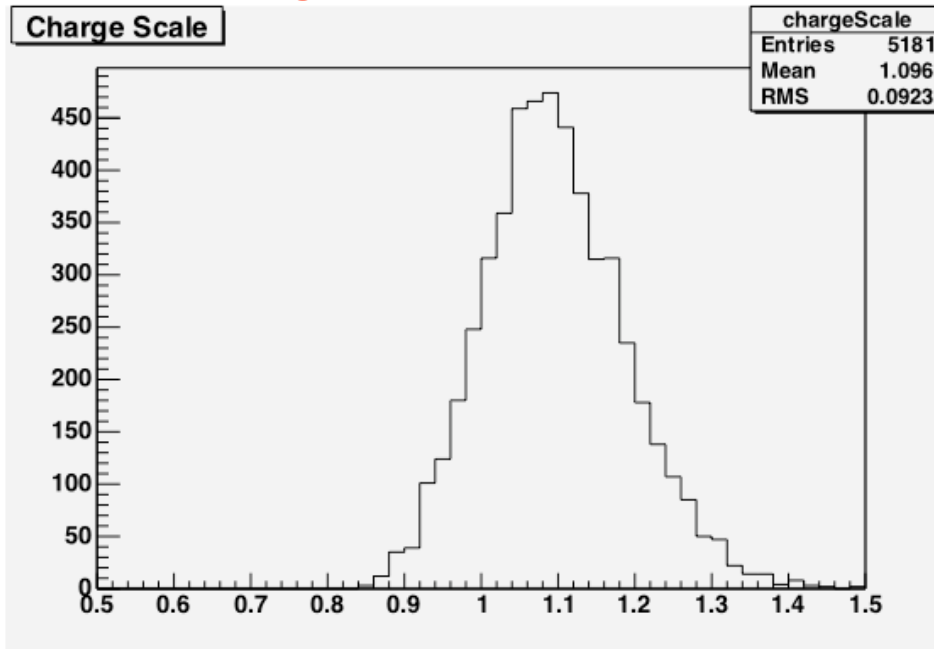


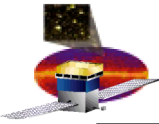
Charge Scale after TOT Calibrations

- Definition of charge scale.
 - Plot ratio 4.92/peak. (4.92 fC is expected for MIP)
(should be 1.0 if calibration is correctly applied.)

Before charge scale calibration

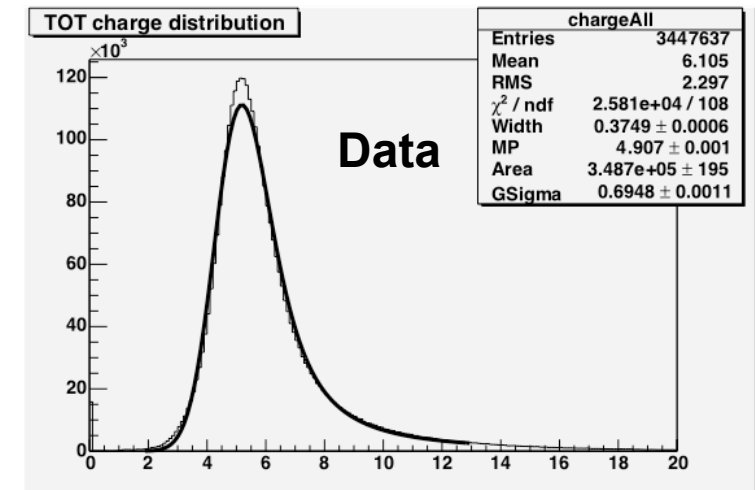
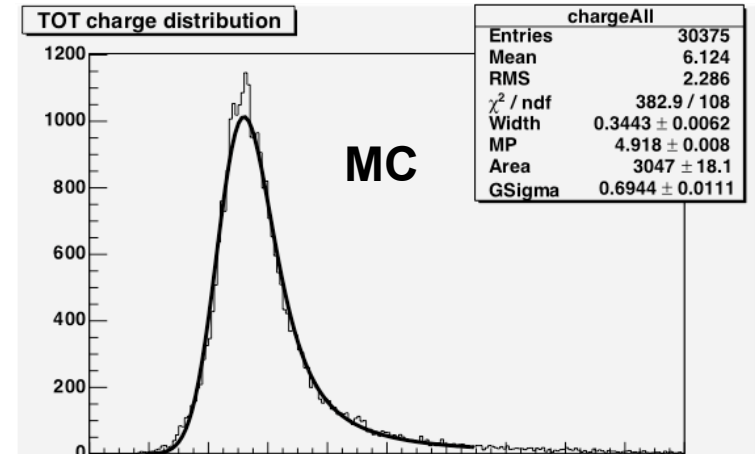
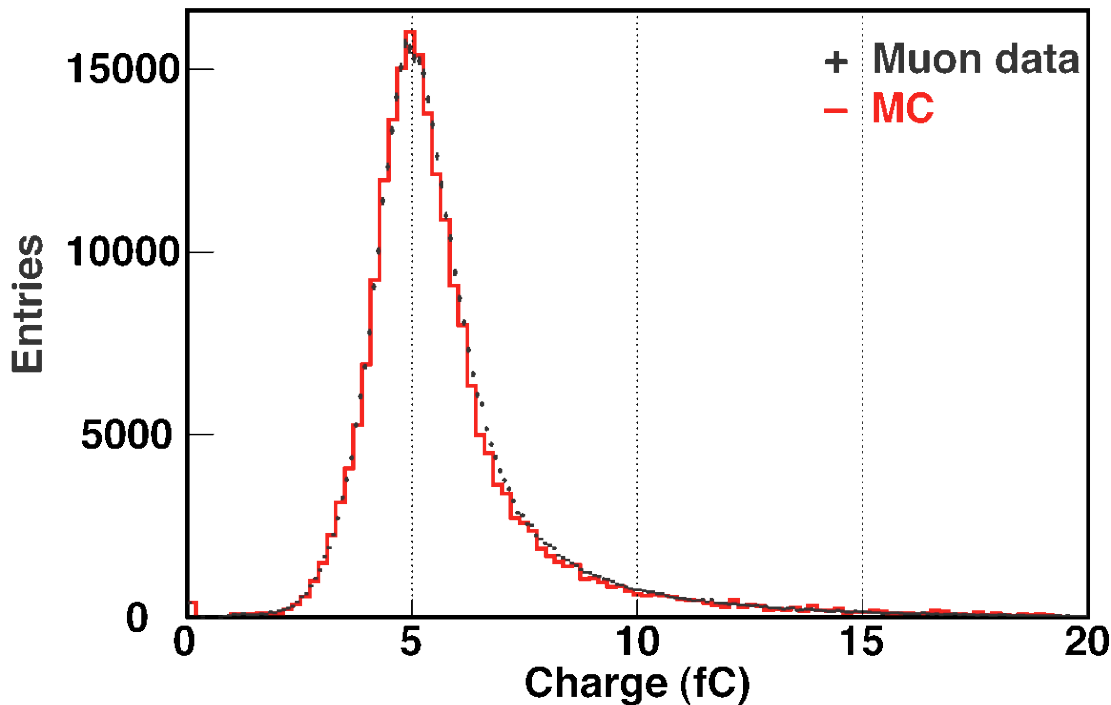
After charge scale calibration

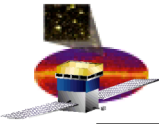




Data/MC Comparison: TOT Distribution

- Fit parameters for data and MC are very similar
 - Gaussian convolved Landau distribution function
 - Peak at 4.91 : 4.92 fC
 - Landau width at 0.375 : 0.344
 - Gaussian sigma at 0.69 : 0.69

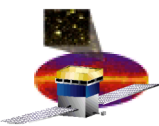




Effect of Calibration

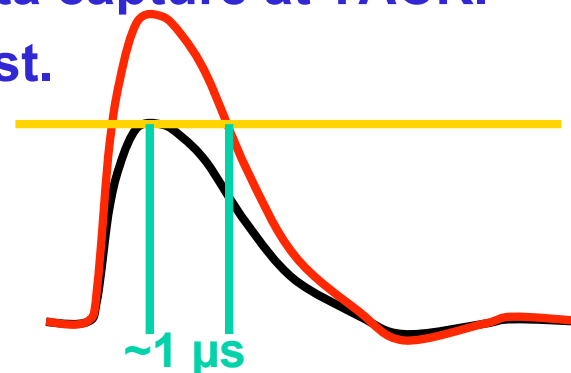
- Threshold dispersion improves in the second iteration.
 - Order of 10% change due to charge scale.
- Change of TOT offset, gain and charge scale is minimal.
 - Stable against 10% level change of threshold.

Parameter	First Iteration		Second Iteration		Ratio, $X_i(2nd)/X_i(1st)$	
	Mean	RMS	Mean	RMS	Mean	RMS
Threshold	28.4	2.3	26.5	2.1	0.93	0.04
TOT offset (fC)	1.23	0.21	1.23	0.21	1.01	0.08
TOT gain (fC/ μ s)	0.59	0.14	0.59	0.14	1.00	0.04
Charge scale	1.11	0.09	1.10	0.10	1.01	0.02



Effective Data Threshold

- Effective data threshold is higher than the trigger threshold.
 - Trigger threshold: charge required to trigger at pulse peak.
 - Data threshold: charge required for data capture at TACK.
 - TACK: $\sim 1 \mu\text{s}$ after the trigger request.



Trigger threshold
Mean: 1.43 fC
RMS(channel): 5.2%
RMS(GTFE): 2.7%

Data threshold
Mean: 1.58 fC
RMS(channel): 8%
RMS(GTFE): 7%

