Updates: Top Tracker Prototype & Calibration

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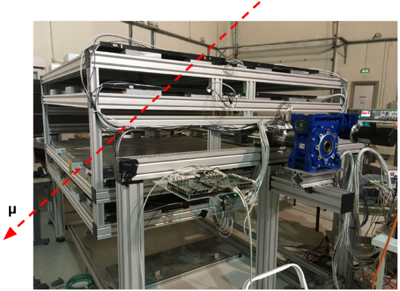
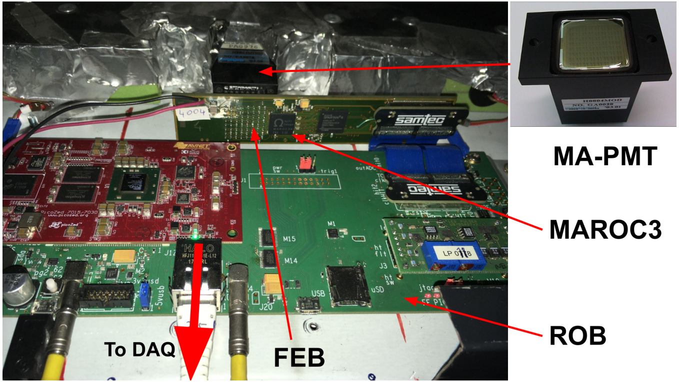
The Top Tracker Prototype and the Top Tracker Electronics



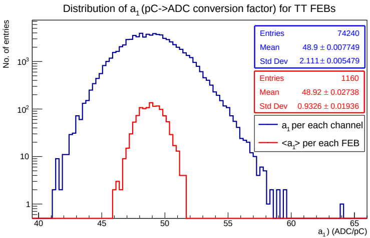
The Muon telescope: The Top Tracker prototype

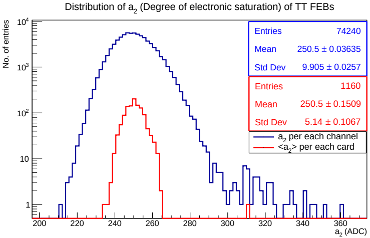
- Built with same materials as Top Tracker
- 64 strips along x and y-directions per sub-layer
- 8 end-caps (512 channels)

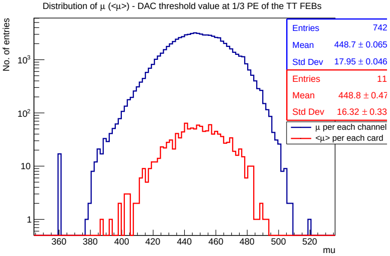


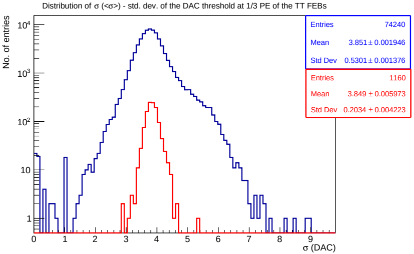
- Front-End Board (FEB): PMT digitization and gain correction, noise level control
- Read-Out Board (ROB): High voltage supply to MA-PMTs, control of the calibration LEDs

FEB Charge & Electronics calibration



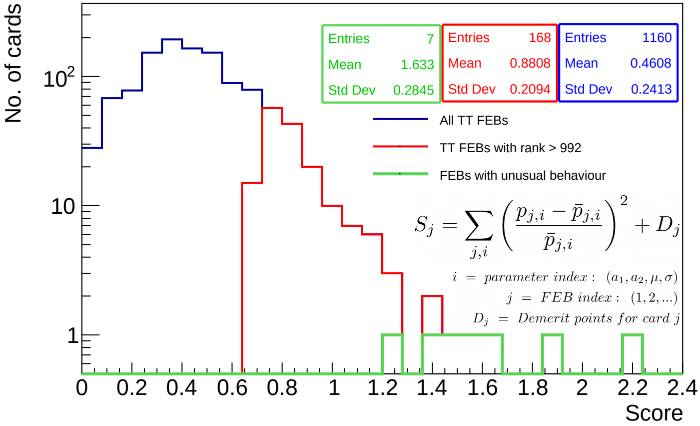






- TT FEB mass testing:
  - Goal: select 992/1160 FEBs for TT installation
  - charge injected using a calibrated injection system
  - tested for charge linearity & saturation, DAC threshold etc. using dedicated functions
    - ★ improved fit quality
  - Result: Consistent performance among TT FEBs
    - ★ No channel dependencies observed

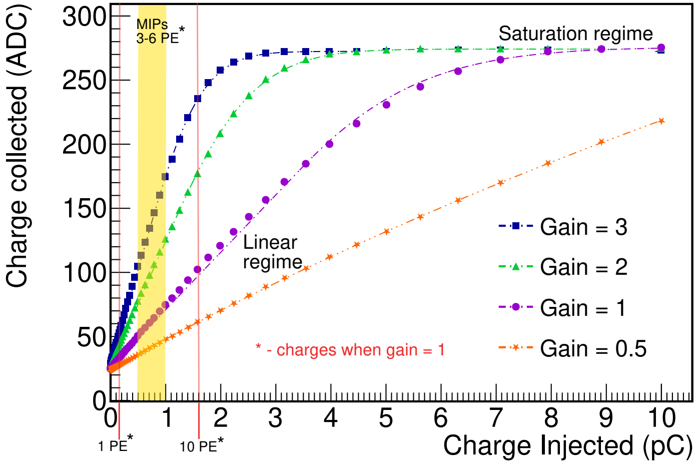
Grading the TT FEBs based on parameter distributions



- Grades based on 4 parameters
  - a_1, a_2, σ, μ
- award demerit points for failed plots/outlier cards
- low (high) score $\leftrightarrow$ small (large) deviation from mean $\leftrightarrow$ good (bad) rank

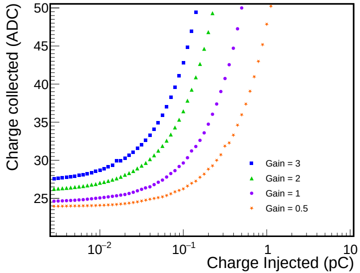
- Note : all these TT FEBs are tested good. In this analysis the best ones are chosen (the rest will be kept as good spares).

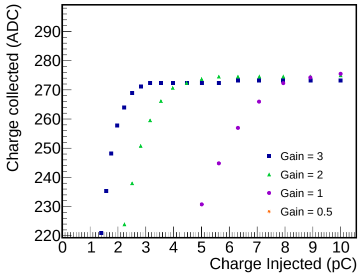
FEB performance at variable channel gain



- Goal: Measurement of calibration curves and testing performance at variable gains
- All the channels of a FEB can only be set with a given High voltage & a given DAC threshold at a given instance.
- The MAROC3 pre-amplifier correction factors can be tuned to adjust fluctuations so that every PMT channel will have similar response to incoming signals.

FEB performance at variable channel gain

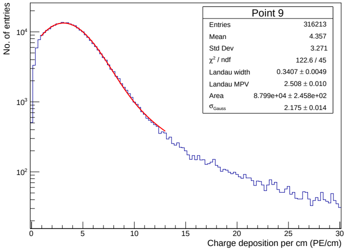


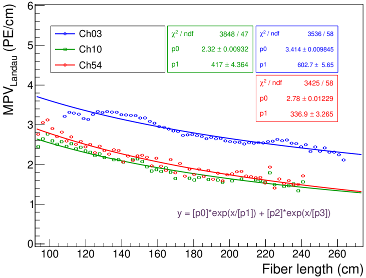


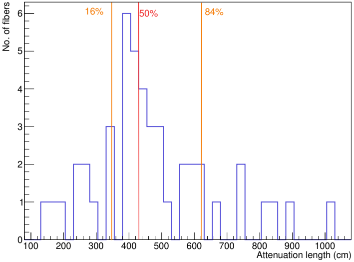
- Across different gains,
  - The pedestal & saturation are stable,
  - the ratios between slopes are similar to the ratios between gains.

Gain	Relative slope (with respect to Gain = 1 case)
0.5	0.54
1	1
2	2.18
3	3.33

Measurement of TT optical fiber attenuation using cosmic muons







- Measured the charge deposition per cm by muons through each section of strips
  - for strips with detection efficiency $> 95\%$ (excluding edge strips)
  - via x-y coincidence measurements + reconstruction
- Fit: Landau-Gauss convolution
  - Landau: ionizing particle through thin strips, Gauss: detector effects
  - choose Landau MPV as probe to measure fiber attenuation & help identify problematic strips
- Fit MPVs with double exponential (fast component fixed to 80cm - OPERA results)

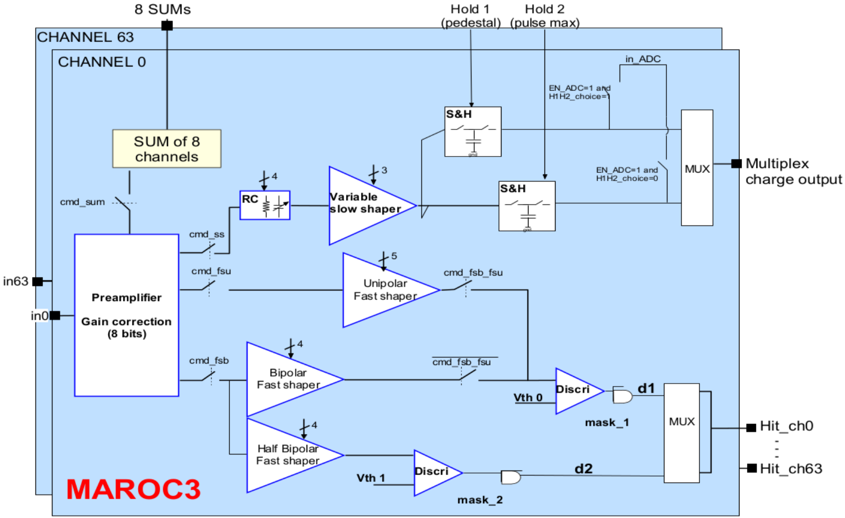
Conclusion

- The TT Prototype at IPHC Strasbourg is used to conduct various TT calibrations:
  - Charge calibration — Electronics calibration — Gain calibration
- TT FEBs were characterized using the test bench
  - Developed a grading system and ranked the cards based on their parameters
- The FEB performance at variable gains was tested
  - stable pedestal and saturation, proportional slopes as expected
- An estimate for the fiber attenuation length was measured
  - applied corrections for gain fluctuations, charge non-linearity, distance the signal travelled along fiber

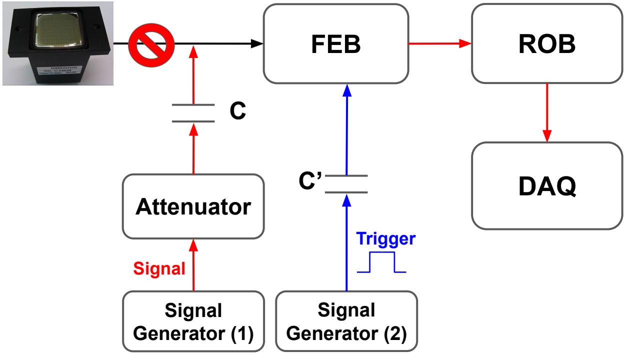
Thank you!

Backup

Multi-Anode Readout Chip v.3 (MAROC3)

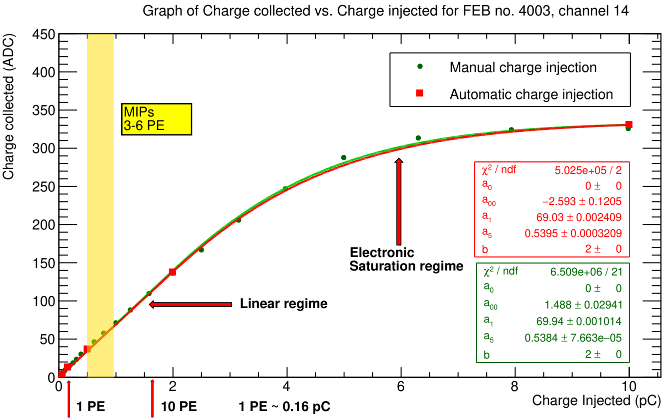


Charge Calibration: injection technique



- Inject charge using a calibrated charge injection system
- New technique: External trigger applied by injecting to a geometrically well-separated channel
  - avoid bias when measuring small injected charges

Charge Calibration: accounting the electronics saturation



- Only 5 data points taken per FEB during mass testing of 1160 FEBs

- The fit function:

$$f(x) = \begin{cases} a_0 + a_1 x & , x \le b \\ a_{00} + a_2\left(1 - e^{-a_3 x^{a_4}}\right) & , x > b \end{cases}$$

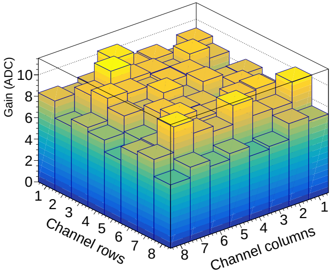
$a_5 = a_3 b^{a_4}$

  - Continuity and differentiability of f(x) imposed
- no. of free parameters reduced
- a_0 fixed to 0 and b fixed to 2

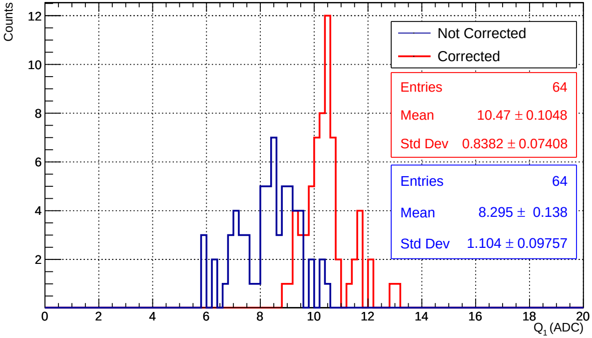
Gain Calibration

- Goal: Testing the gain tuning of the FEB channels
- Gain calibration: 2 steps
  - Determination of PMT High Voltage - 1 value across all PMT channels
  - Calculation of pre-amplifier correction factors (with respect to the highest gain channel)
- the percentage spread of the gain across channels decrease from 13% to 8% upon the calibration (performed on the TT prototype)

MA-PMT Gain Distribution

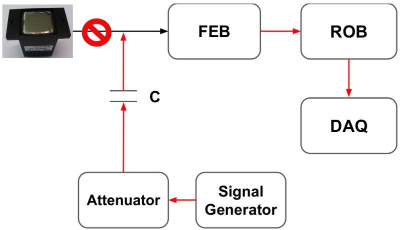


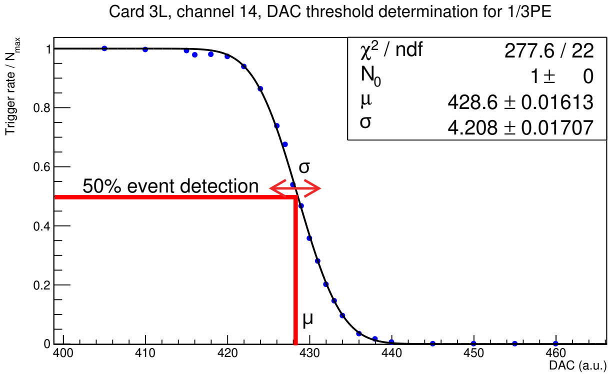
PMT channel gain distribution (uncorrected)



Electronics Calibration

Determination of Digital-to-Analog Converter (DAC) threshold:





- We need to tune the electronics to measure very small charges as low as 1/3 PE (0.056pC) while keeping noise levels as low as possible
  - Goal: Need to find the electronic DAC threshold value corresponding to 1/3 PE charge
- Expected charge deposition for a muon: 3-6 PE