CALICE Tail-Catcher Muon-Tracker(TCMT) Preliminary Test Beam Results

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CALICE Collaboration

SID MEETING
Fermilab
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Outline

- **The CALICE Tail-Catcher Muon-Tracker**
  - **Goals:**
    - **Prototype ILC muon detector using SiPMs**
    - **Correct for leakage due to thin calorimeters**
  - **Test Beam needed to:**
    - **Study end of hadronic shower & validate simulations available**
    - **Understand & address impact of coil**
    - **Understand TCMT in PFA framework**
    - **Achieve good μ ID and control fake rates**
- **Very Preliminary Results from CERN**
- **Plans for the Future**

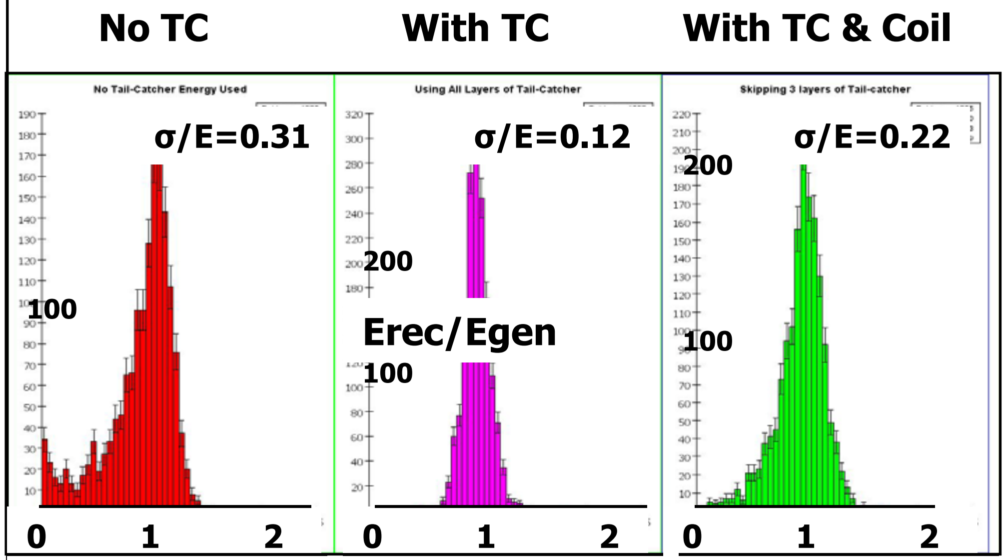
CALICE Tail-Catcher Muon-Tracker Prototype

- **Mechanical Structure/Absorber**
  - **"Fine" section (8 layers)**
    - **2 cm thick steel**
  - **"Coarse" section (8 layers)**
    - **10 cm thick steel**
  - **Engineered as assembled by Fermilab PPD**
- **16 Cassettes:**
  - **Extruded Scintillator Strips**
    - **5mm thick**
    - **5cm wide strips**
    - **Tyvek/VM2000 wrapping**
    - **Alternating x-y orientation**
  - **Readout**
    - **WLS Fiber**
    - **SiPM photo detection**
    - **Uses common electronics (DESY) readout with CALICE HCAL**
    - **Uses common CALICE DAQ (Imperial college)**

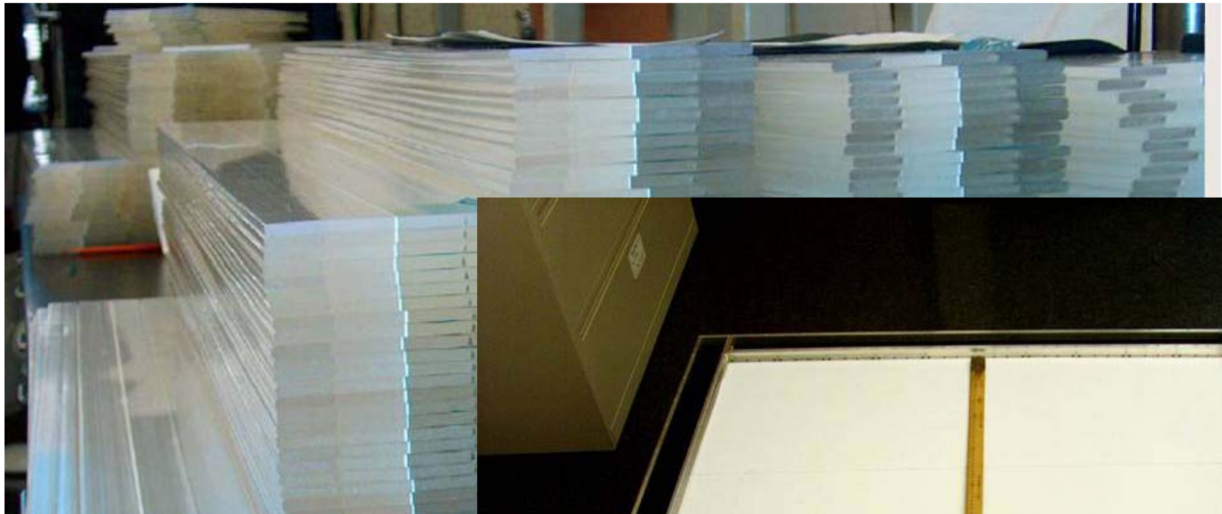
- **Dimensions:**
  - **Length (along beam) - 142 cm**
  - **Height - 109 cm**
- **Weight ~10 tons**

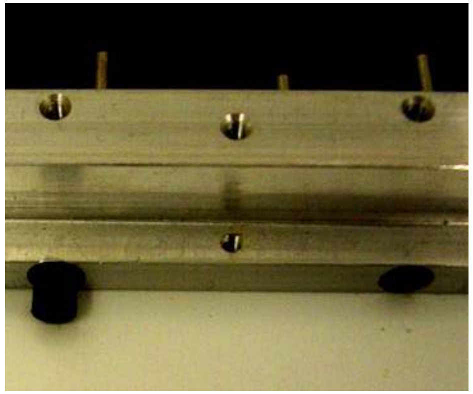
Design Motivations

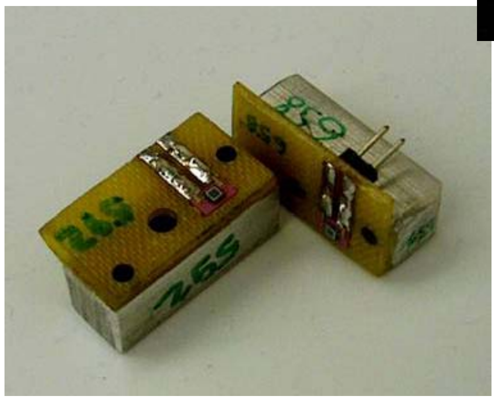
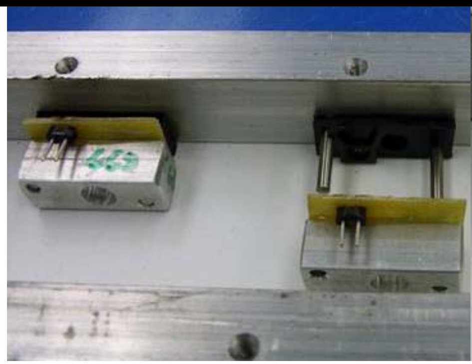
- TCMT required for sufficient depth to contain hadronic showers and validate Monte Carlos for PFA studies.
- For many ILC concepts calorimetry is thin and inside the coils. The outer solenoid flux return is composed of layers of Fe plates with gaps: consideration of a tail catcher is natural.
- Used SiD ECAL/HCAL simulation to understand effects:
  - 4.6 nuclear λ
  - 5T solenoid coil + cryostat 1.27λ.
  - HCAL outer radius is 2.37 m.
  - The muon system outside solenoid and cryostat at radius ~3.50 m.



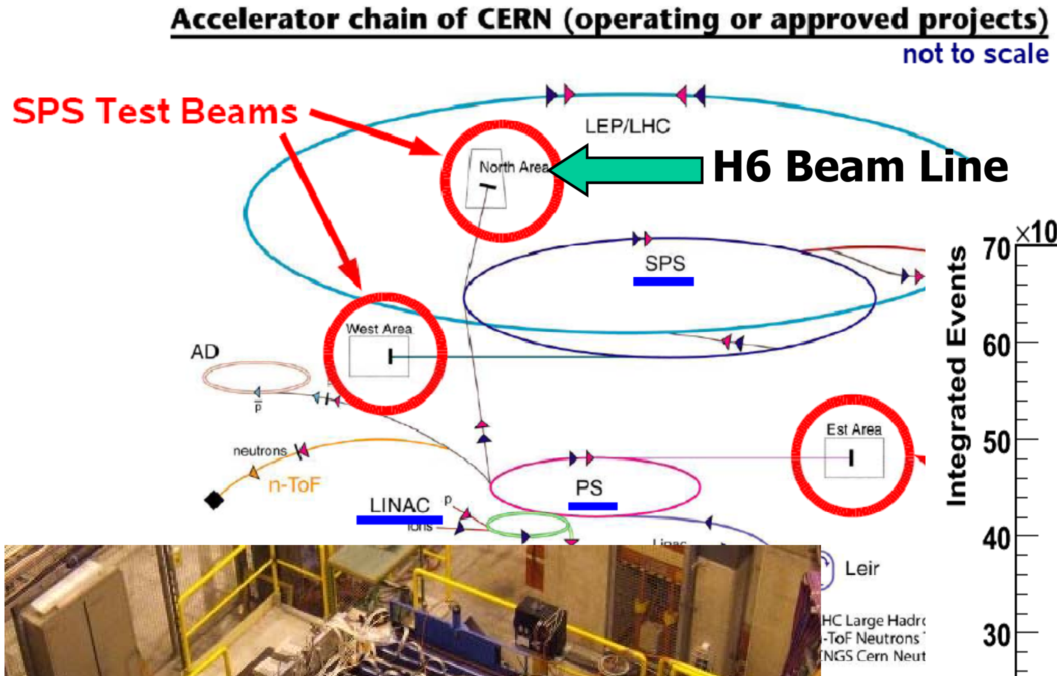
TCMT Cassette Components

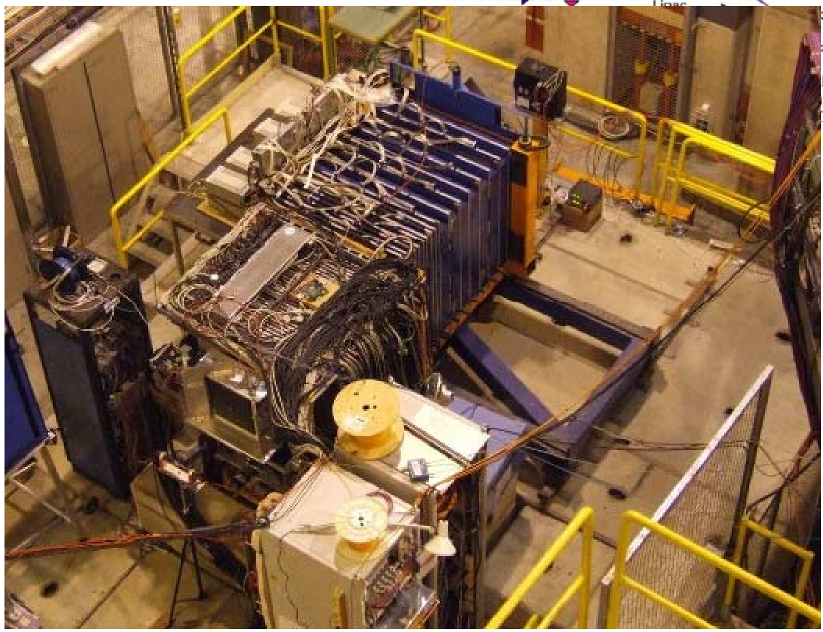




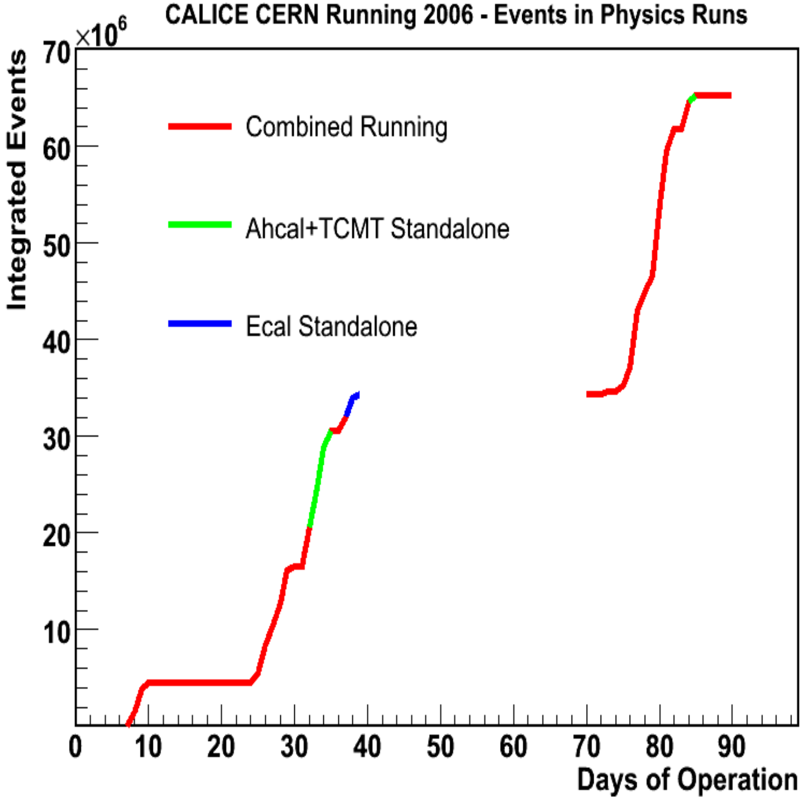



CALICE @ CERN Test Beam





This slide thanks to
Erika Garutti and R. Pöschl



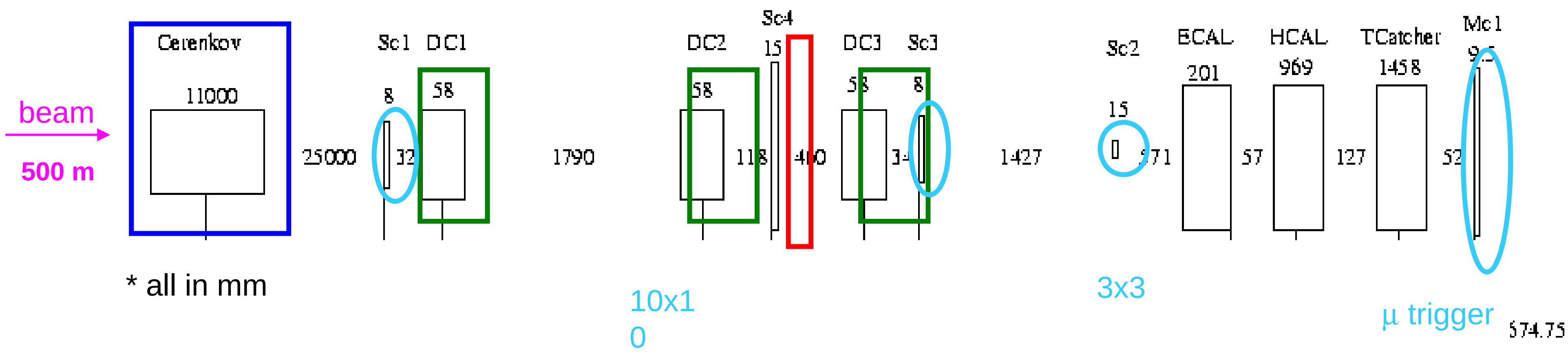
CALICE Calorimeters at Test Beam

- **ECAL**
  - 30 active layers of silicon diode pad detectors with ~10,000 channels
  - tungsten absorbers with thickness of 1.4mm to 4.2mm
  - total thickness $24X_0$

- **HCAL**
  - 30 out of 38 absorbers in place – 1.6cm thick steels
  - Gaps instrumented with 0.4mm thick modules with high granularity core (3x3cm^2)
    - Layers 1-17 - all instrumented
    - Layers 19-29 - every other layer instrumented
    - Total of 23 layers x 216 chan/layer = 4968 channels
  - 4.5 interaction lengths

The CERN setup

…much more than "just" 3 calorimeters



Steps towards a clean physics data sample:

1) Optimize beam ➔ tune magnets, collimators, secondary trg, abs
2) Separate e/π ➔ Cherenkov detector (for E_{beam} < 40 GeV)
3) Itentify beam impact point on ECAL ➔ 3 x/y pairs of MWPC with double readout
4) Tag multi-particle events ➔ amplitude r/o of 1cm thick scint. counter (veto)
5) trigger physics with high efficiency ➔ trigger system

➔ Store event by event info from 2) 3) 4) 5) in the common DAQ

This slide thanks to Erika Garutti

Details of data taken

Combined data taking

E [GeV]	e +	e -	h + (π, p)	h - (π)
	number of events collected [k ev]			
6	~200	~130	~450	~1800
8	~200			~1800
10	~150	~170	~700	~1800
12	~200			~1500
15	~470	~120	~700	~1600
18	~300	~230		~1300
20	~390	~210	~800	~1500
30	~400		~2500	
40			~1700	
50	~300		~1800	
80			~1800	

AHCAL+TCMT alone

E [GeV]	e +	e -	h + (π, p)	h - (π)
	number of events collected [k ev]			
10	~600			
15	~600			
20	~600			
30	~600			
40			~50	
50	~600			
80			~300	

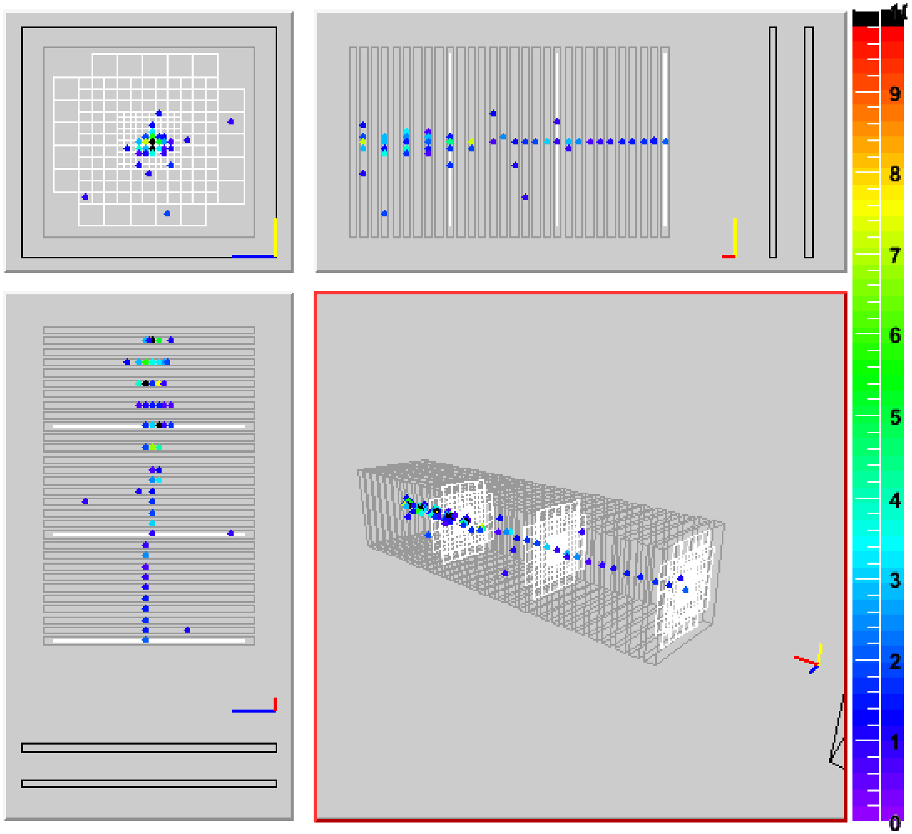
In addition: **42 M muons for calibration**
14 M calibration (pedestal, SiPM gain, SiPM saturation scans …)

In Total: **Greater than 5 Tbyte data on DESY dCache / GRID ready to be analyzed**

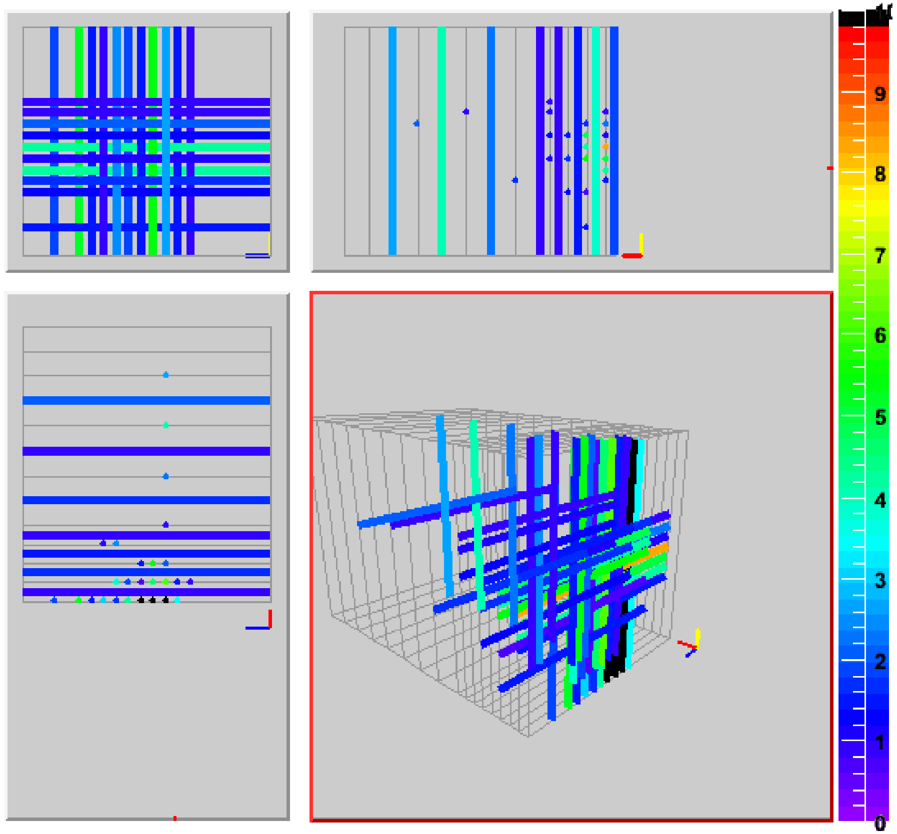
Example pion event display

40GeV/c pion
with CALICE online analysis software

HCAL



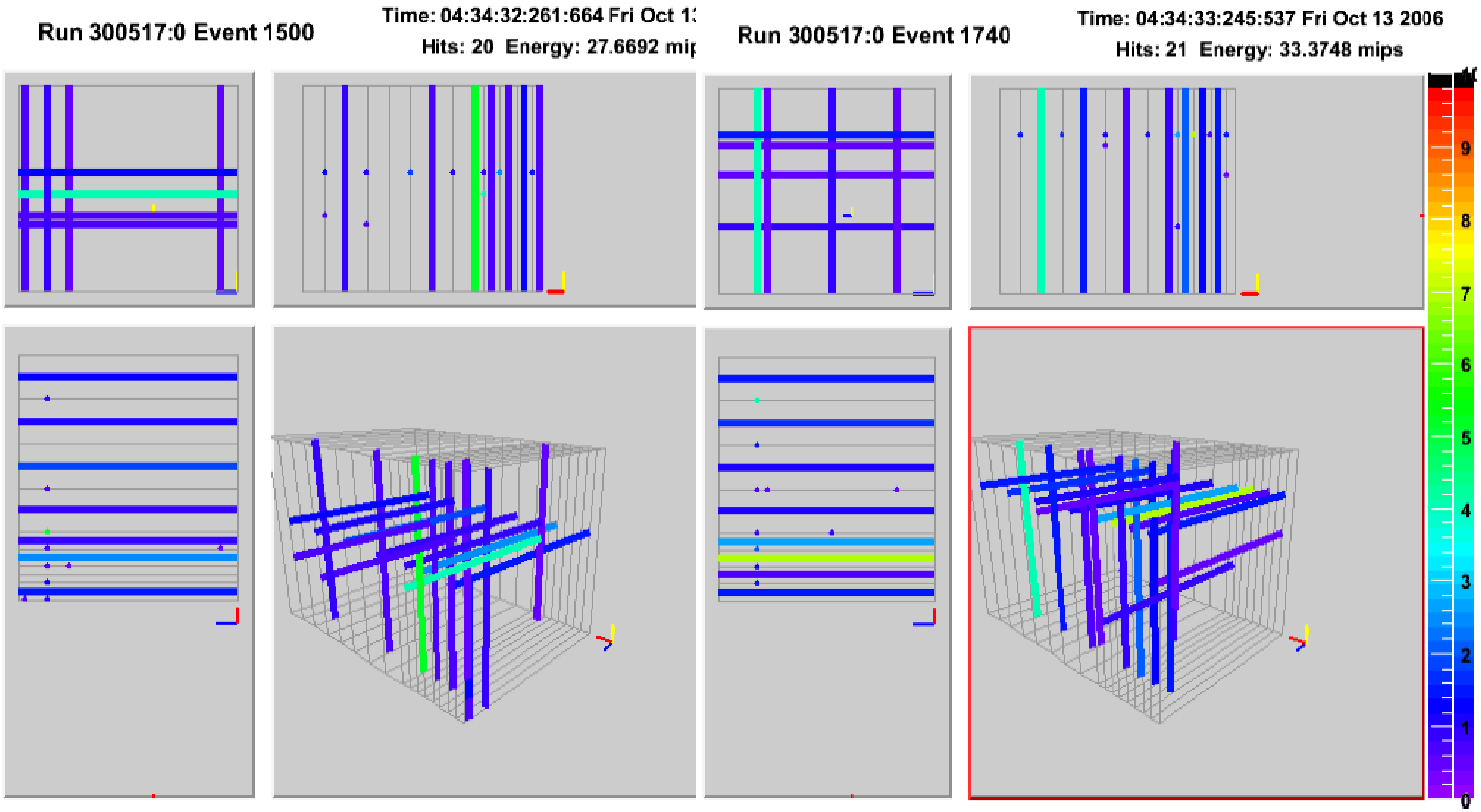
TCMT



Late shower in HCAL

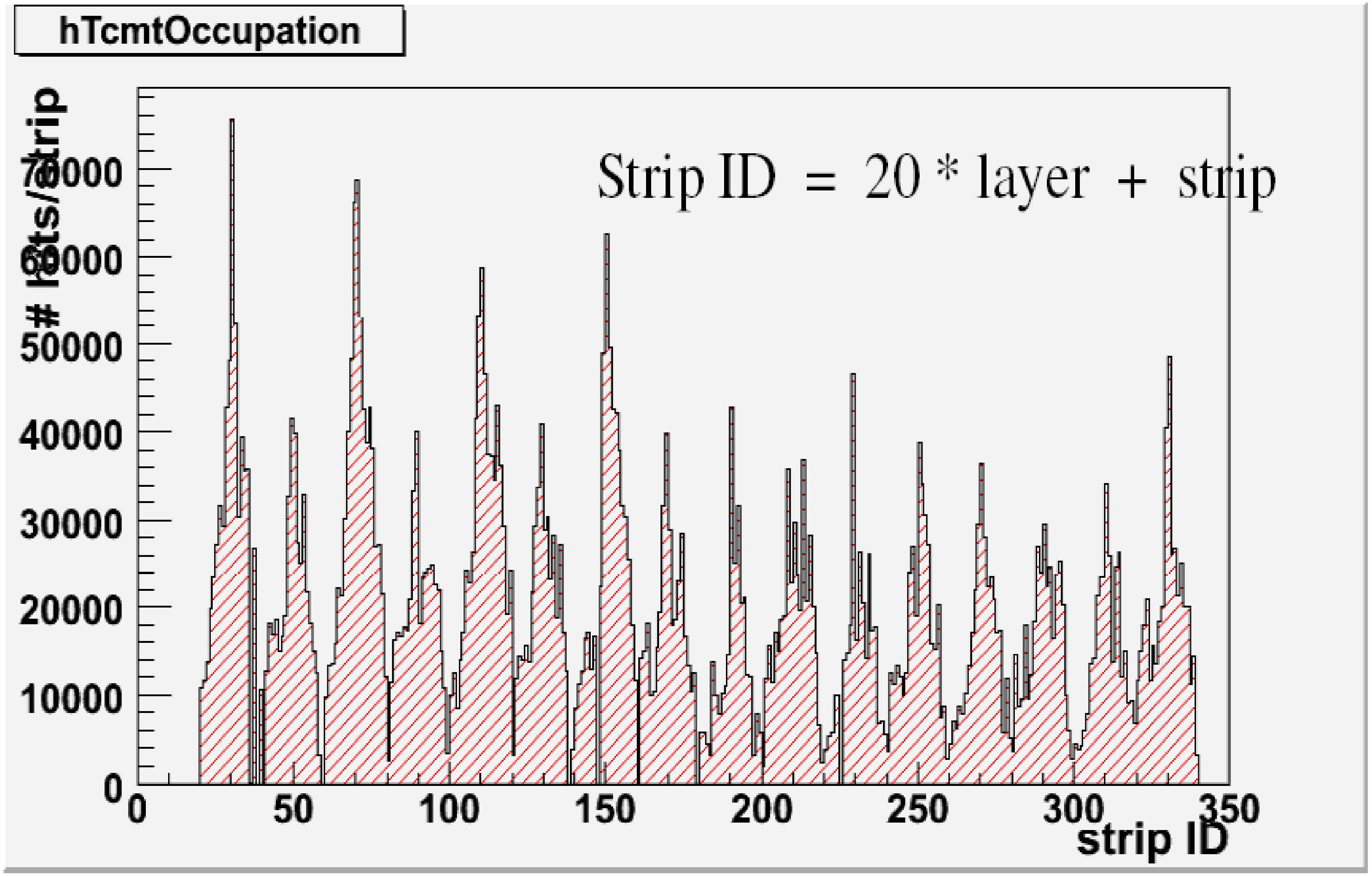
TCMT clearly needed to contain shower

Event Displays - Muons

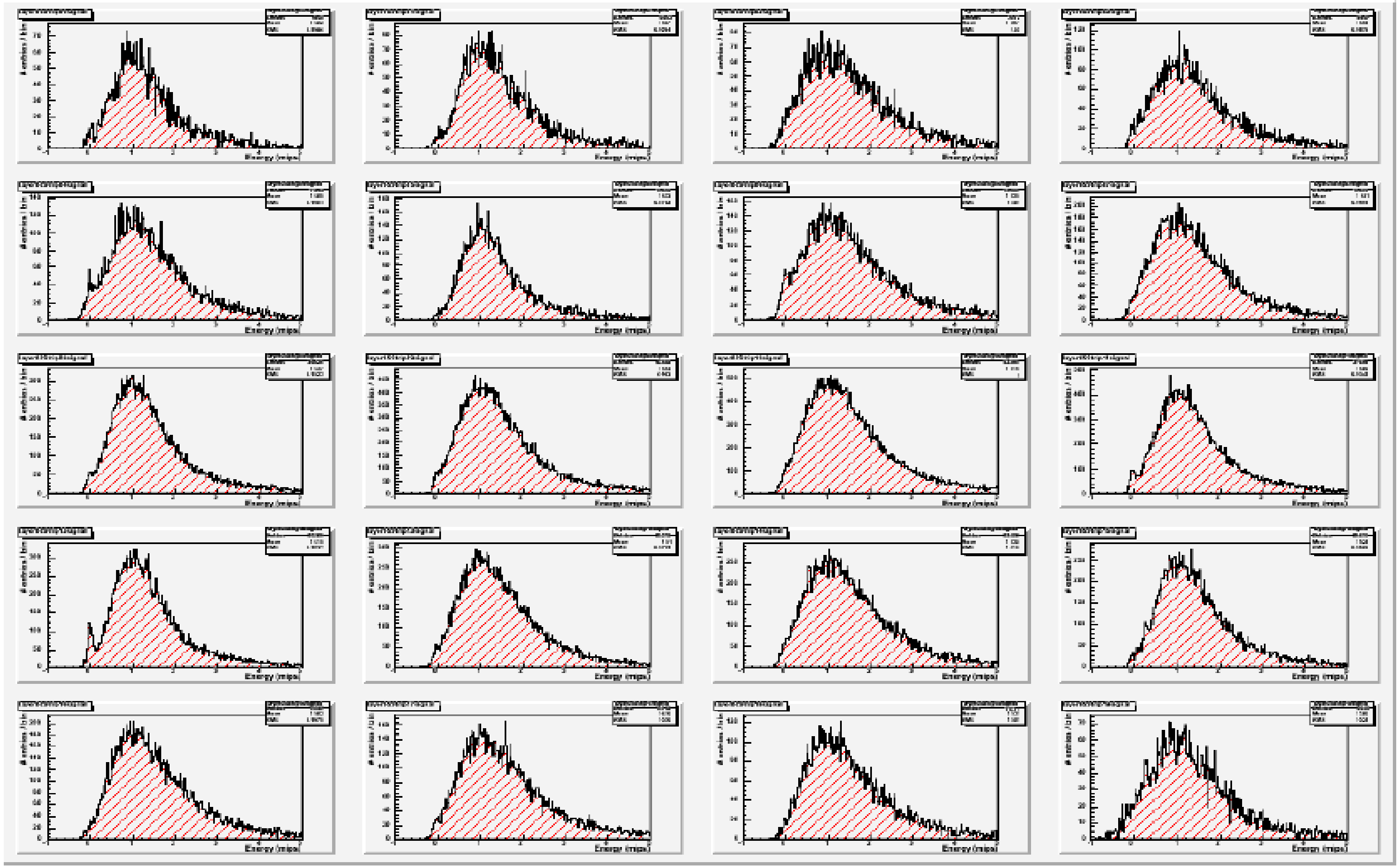


Muon Run Beam Profile and Occupation

Run300517 Beam Dump with no defined energy

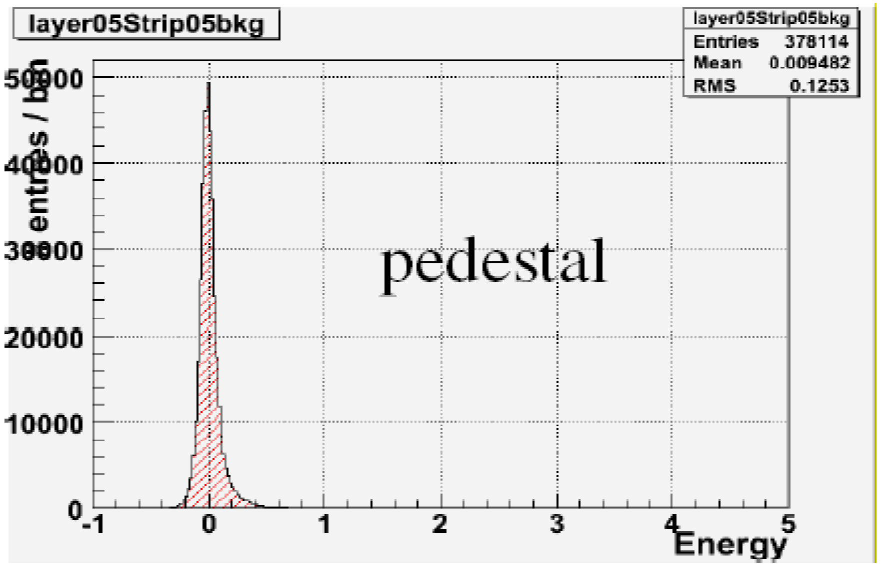


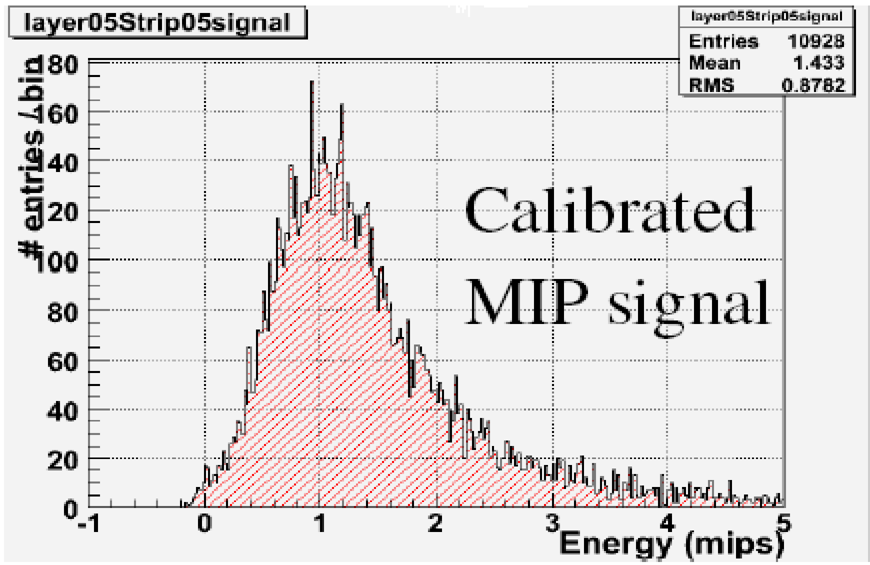
Muon Run Layer 5 Example

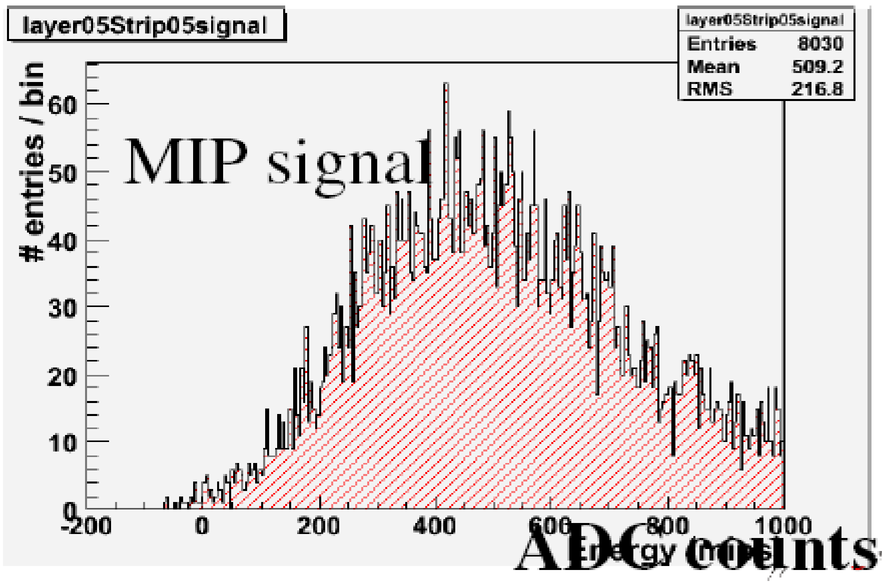


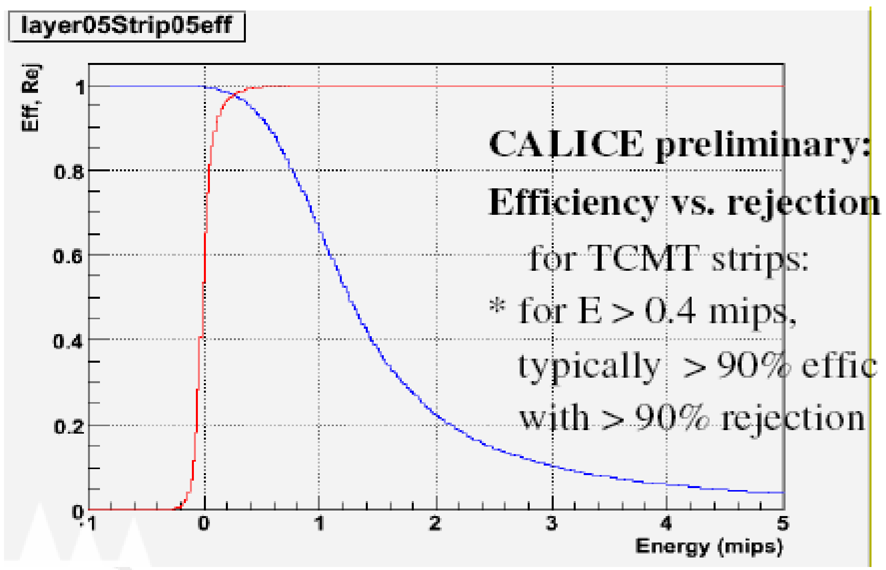
Software triggered on 4/5 closest parallel strips

Efficiency Rejection Calculations



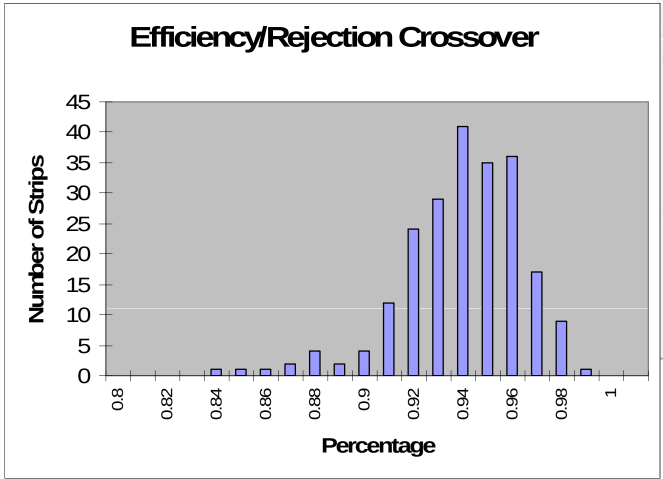


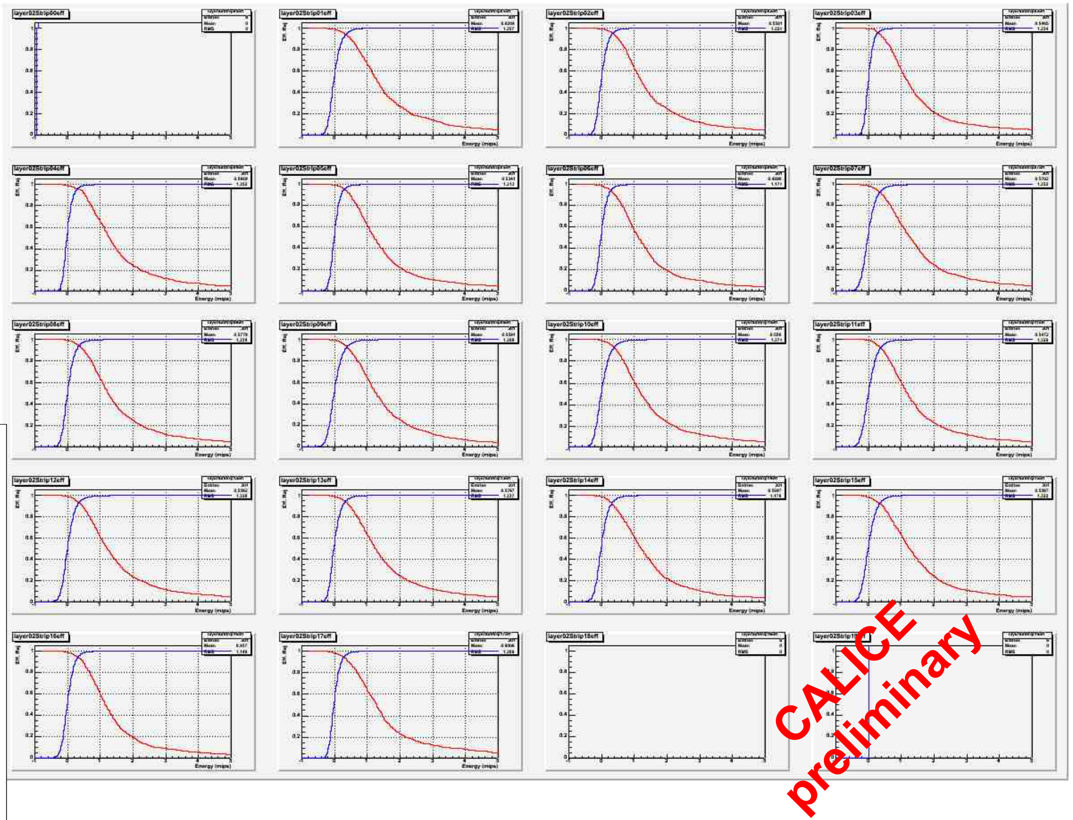




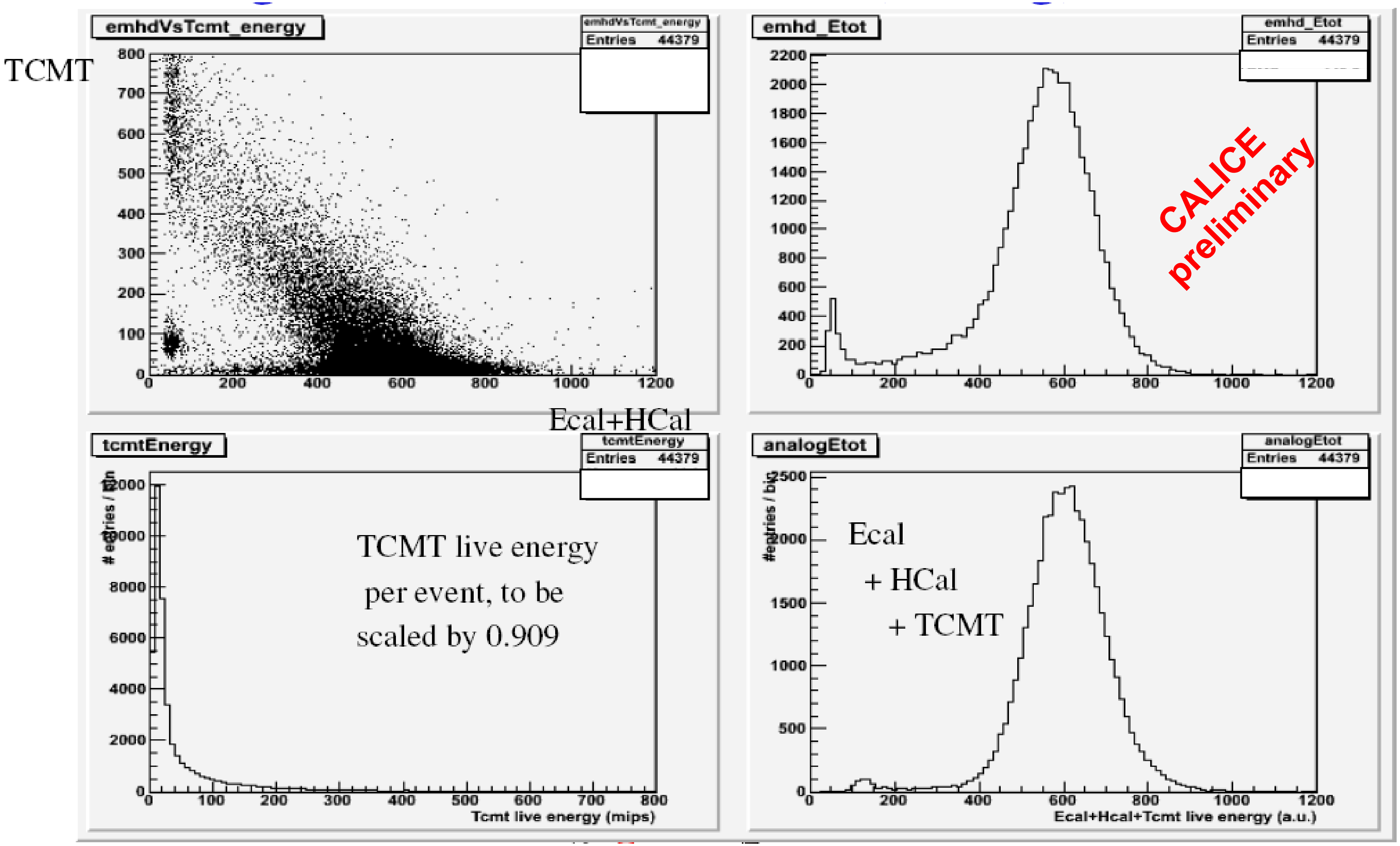
Efficiency/Rejection Plots

- Layer 2 example
- Efficiency in red, Rejection in blue
- Missing channels due to faulty sensor in parallel strips
- At crossover average efficiency and rejection~ 95%

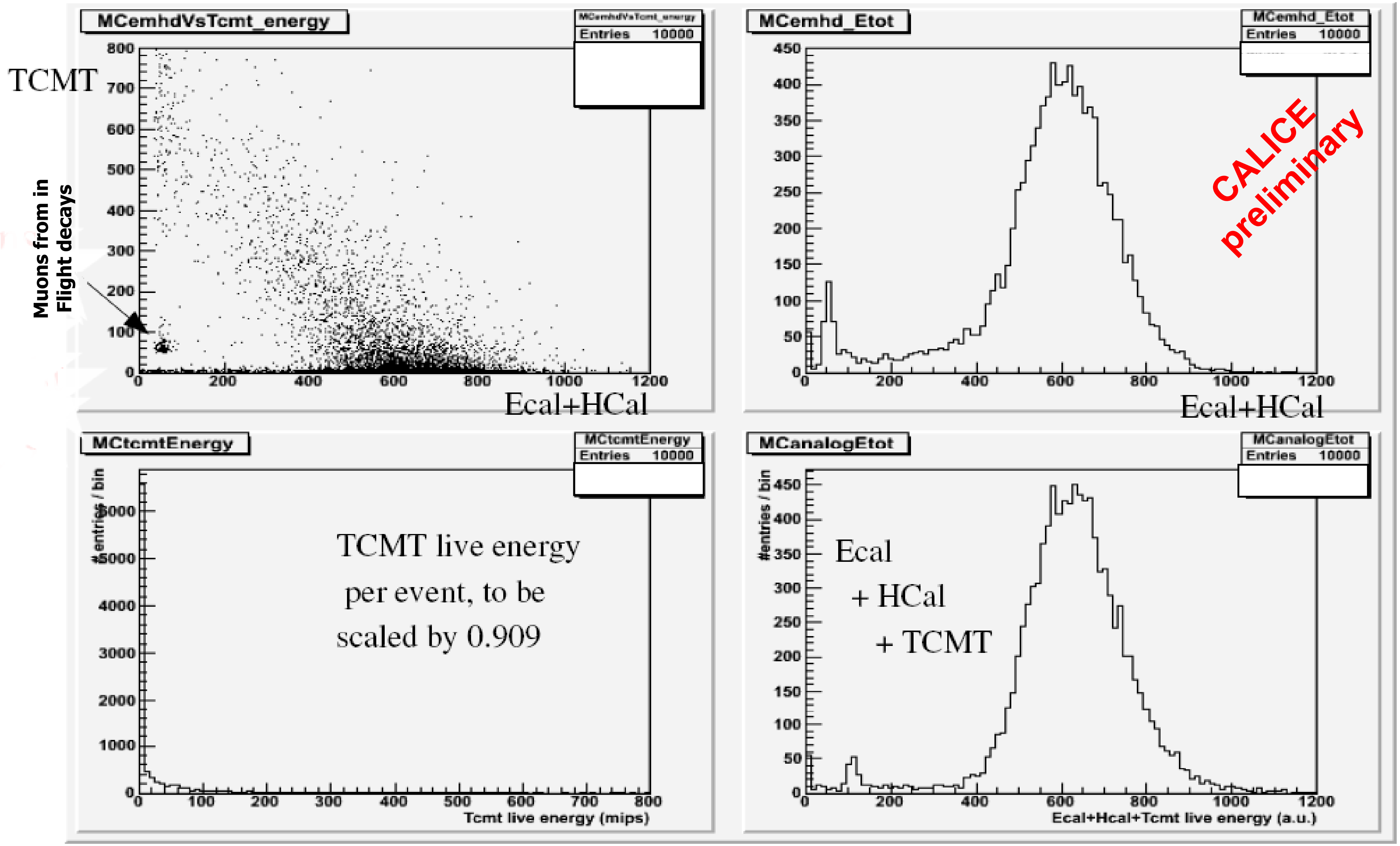




Analog Energy Response – 20Gev pi-

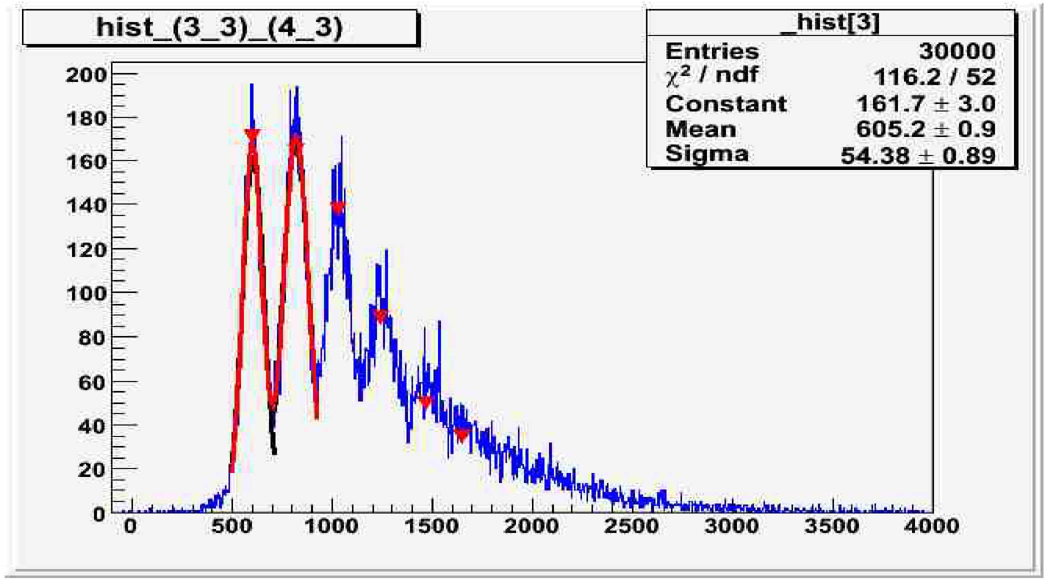


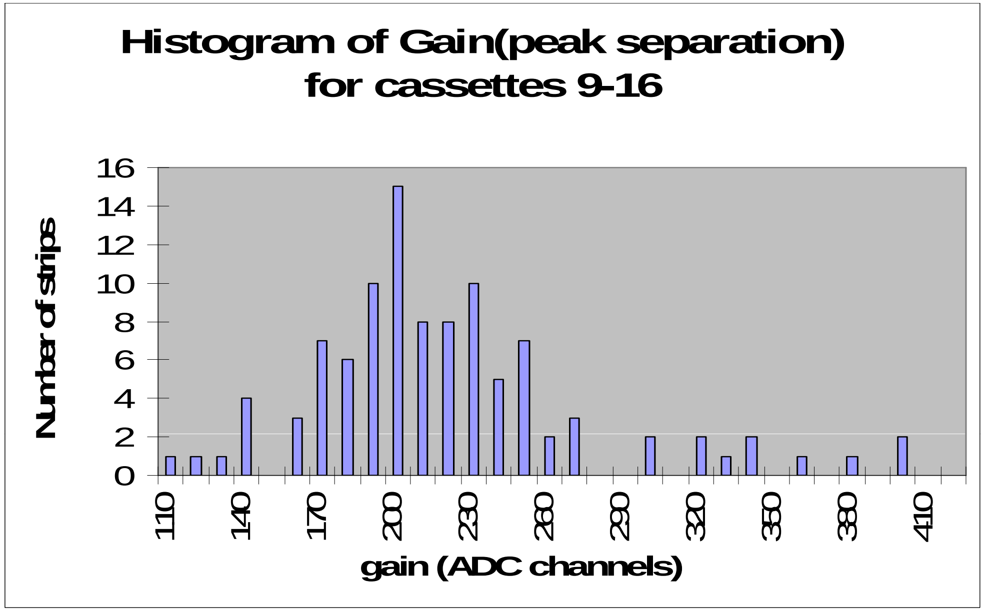
Analog Energy Response - MC



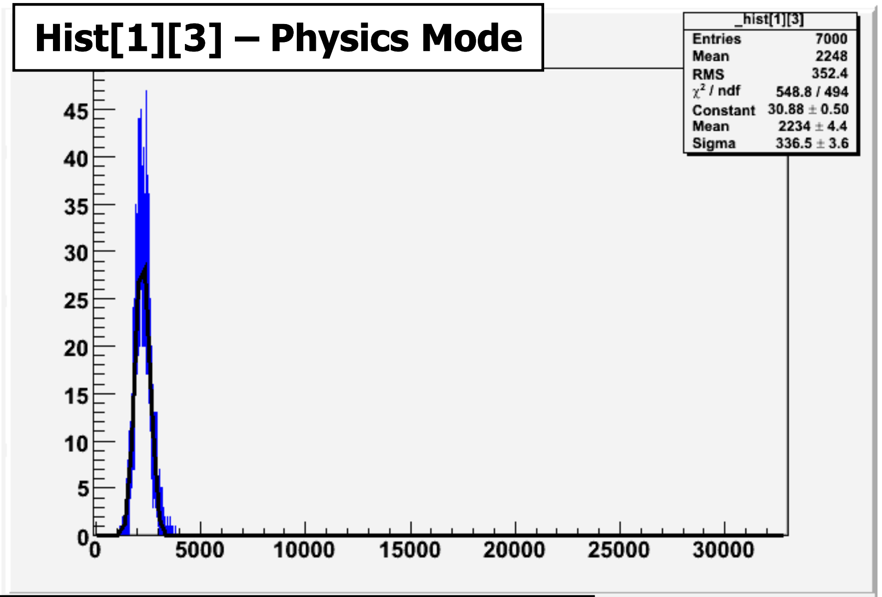
Gain Measurements

- **LED Calibration system:**
  - **Blue/UV LED for each strip**
  - **Amplitude controlled by DAQ software**
  - **Fine adjustments for each channel with TrimDAC**
  - **Low amplitude setting used to acquire S.P.E. spectra for each strip to calculate gain**
  - **High amplitude setting for mode to mode intercalibration measurements and long term stability studies**
  - **Note: DAQ systems operates in a high gain cal. mode and a wider range physics mode (ratio of 7 to 12 times depending on ASIC)**
- **Automated software finds peaks in spectra and fits first two peaks to find gain in terms of ADC channels**
- **Average gain ~ 200 ADC channels/P.E.**





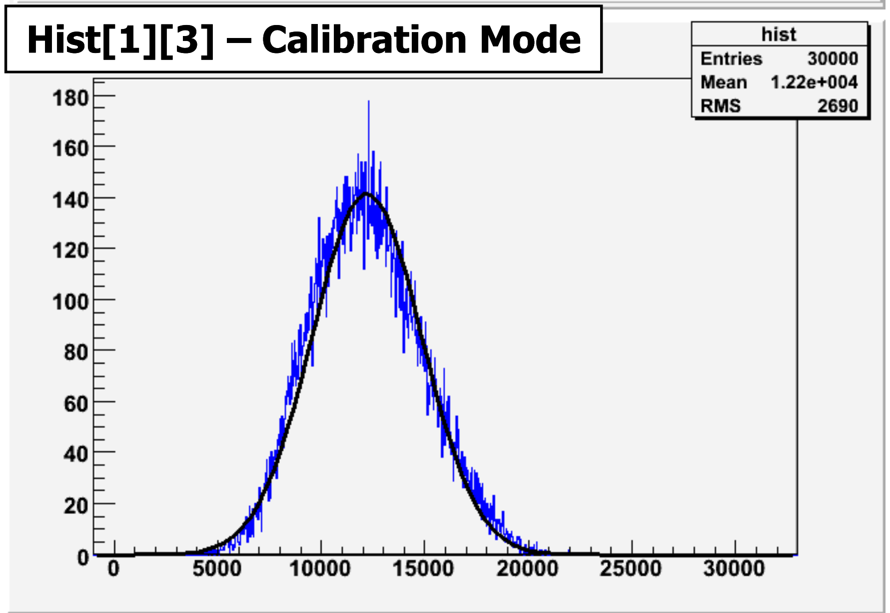
Light Yield

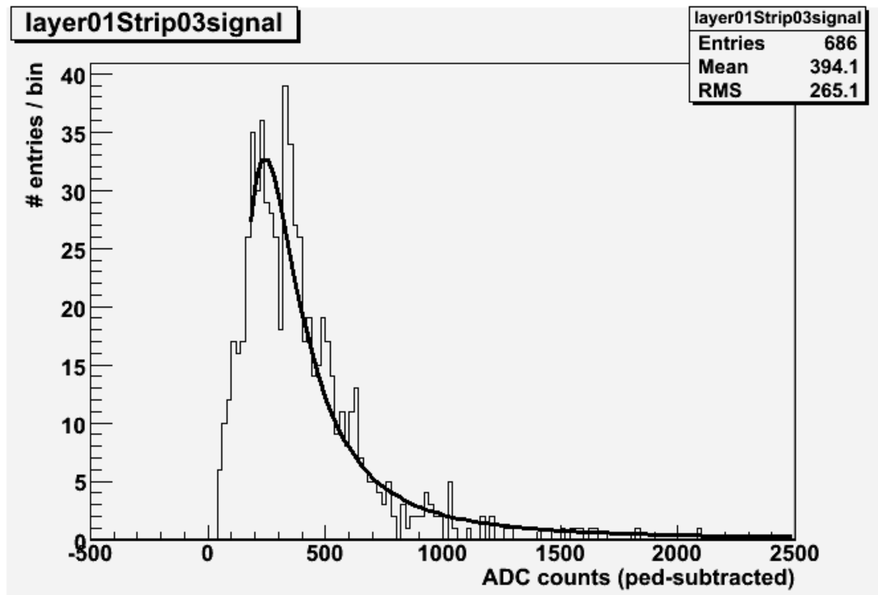


Calculation Requires

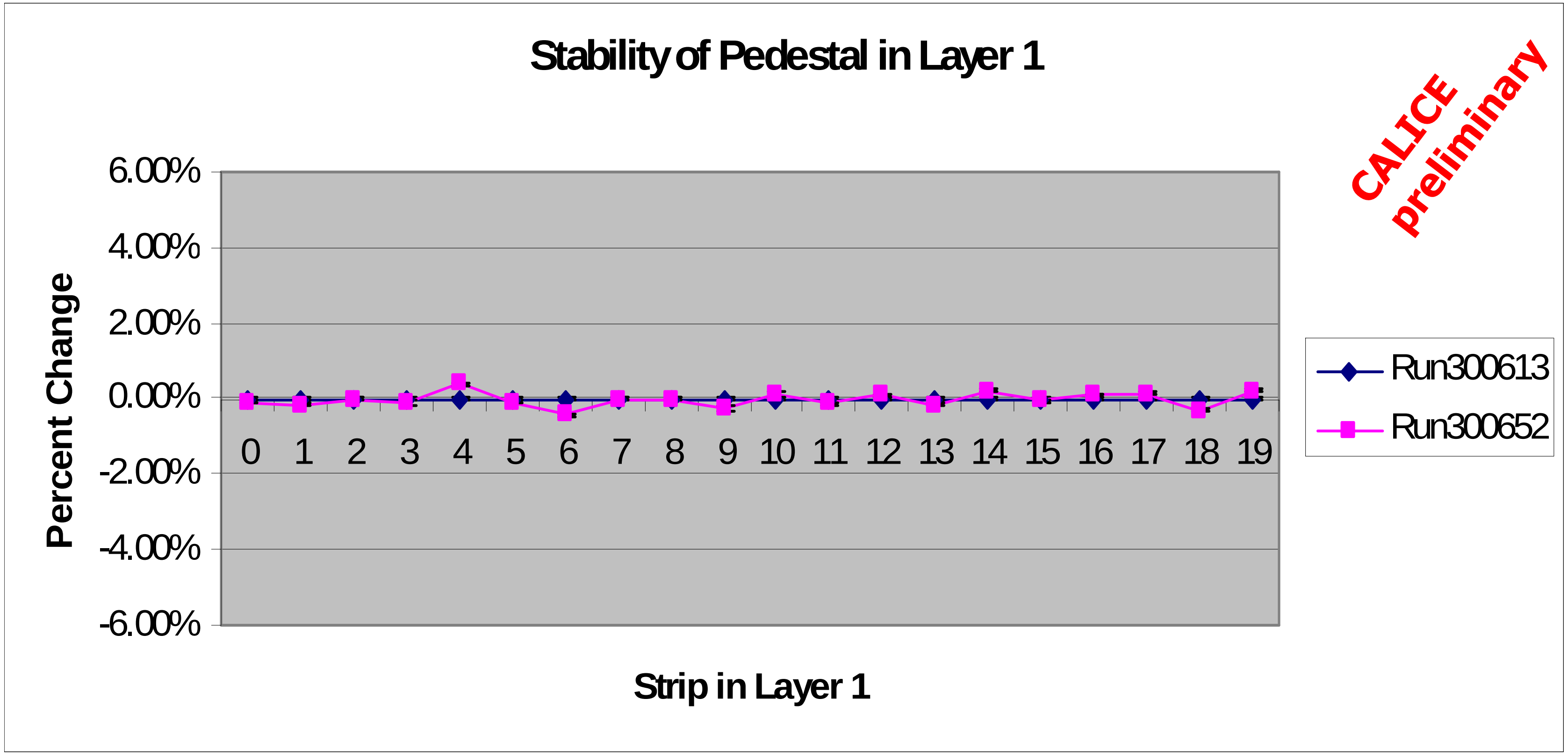
- Pedestal run
- LED calibration run in cal. mode to get gain in ADC channels
- LED calibration run in physics mode
- Intercalibration run in calibration mode
- Muon calibration run

• **Average L.Y. ~= 10 P.E.**



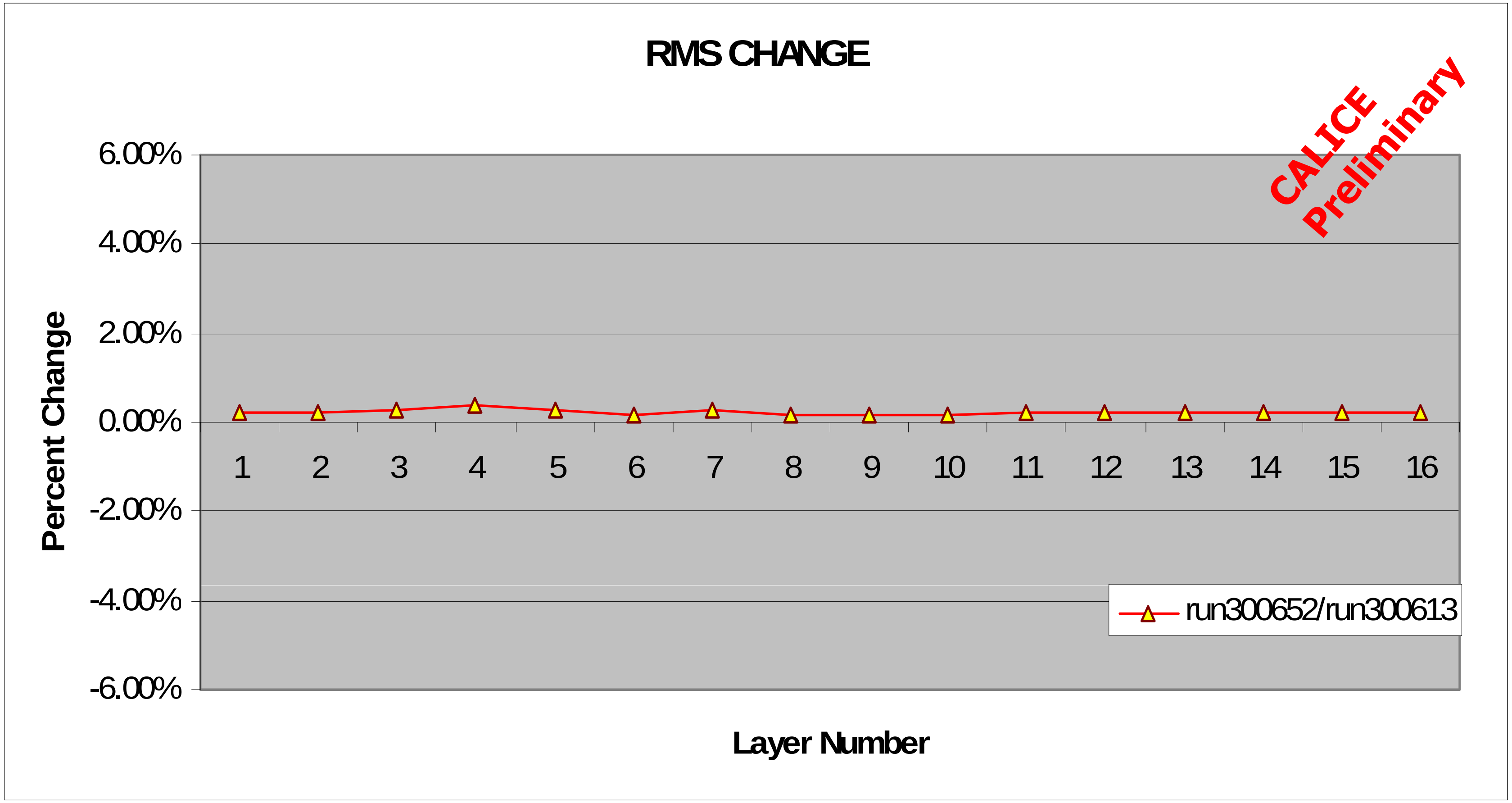


Pedestal Stability



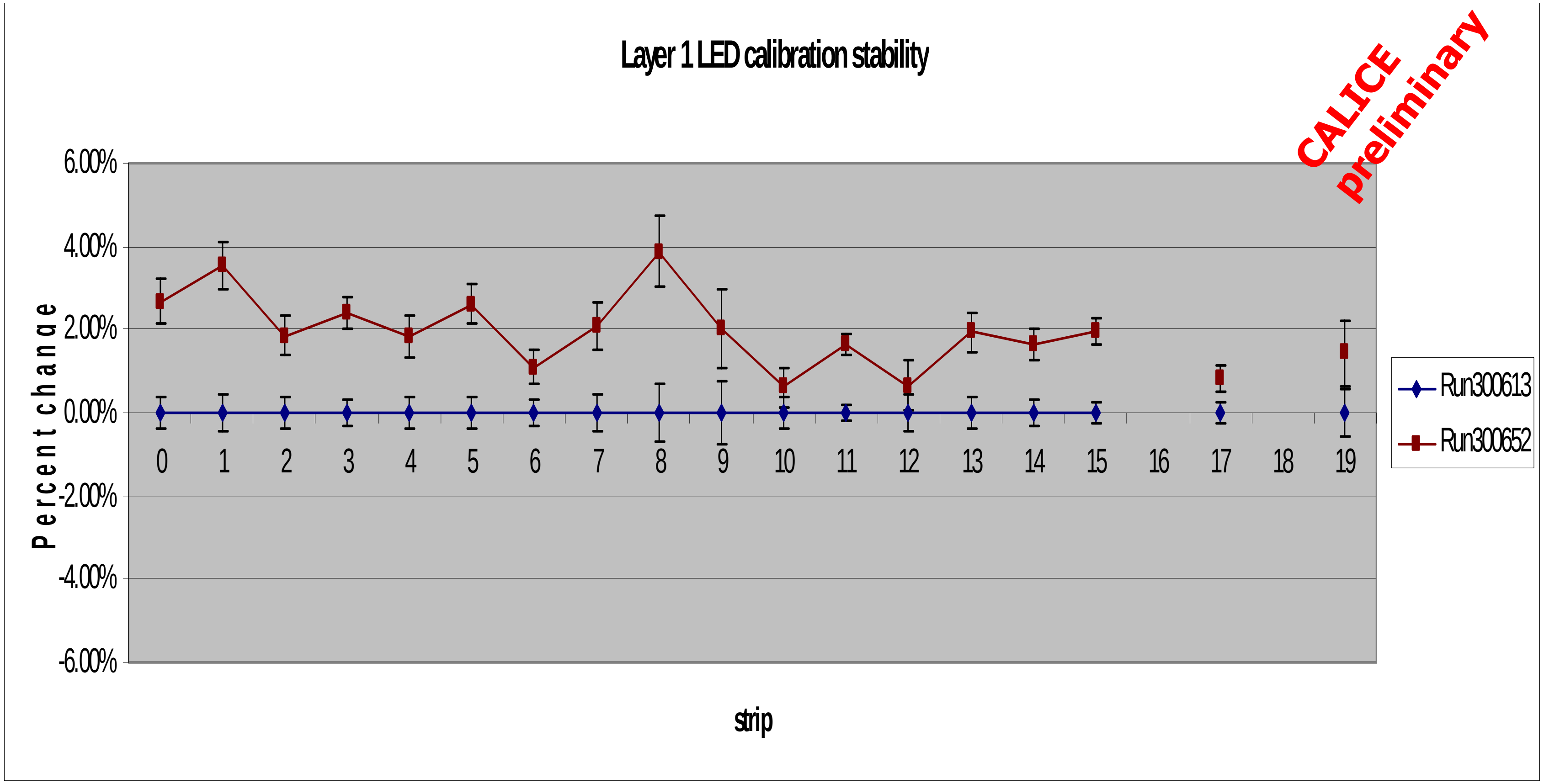
Example of 20 strips from one cassette.
Pedestal data taken from interspill events from each run.
Runs approximately 26 hours apart.

Pedestal Stability



Plots Standard deviation of all 20 strips in each layer
Average RMS change over 16 layers ~ .23%

LED Calibration Stability



CALICE TCMT Plans

- Continue Data Analysis
  - Currently focusing on stability of peds/gains
  - Ultimately: study shower shape in terms of hits & energy
- Additional CALICE running
  - Summer 2007 run at CERN
    - Calibrate with improved LED calibration system
    - Combine data with fully instrumented HCAL and ECAL
    - Collect more statistics
  - Move to MTBF at FNAL thereafter
  - HCAL & TCMT infrastructure available to test other technologies
- Cassettes at SiDet facility at Fermilab for Calibration LED Upgrade

Summary

- The CALICE TCMT behaves as expected to track muons and capture HCAL tail
- Analysis is underway and progressing well
- SiPMs show good potential for calorimetry and muon detection
- Looking forward to more data at CERN and MTBF