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

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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**

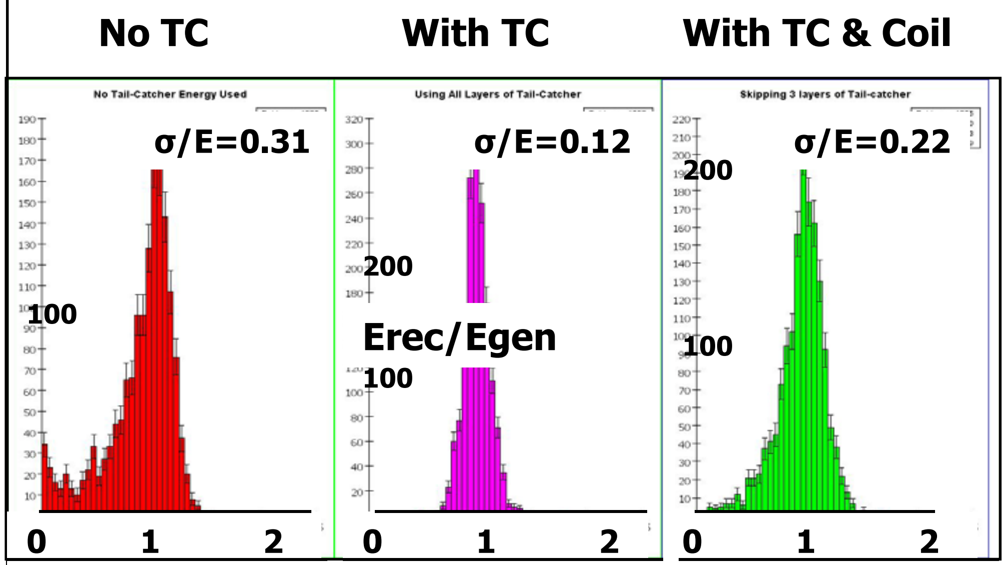
CALICE Tail-Catcher Muon-Tracker Prototype

- **Mechanical Structure/Absorber**
  - **"Fine" section (8 layers)**
    - **2 cm thick steel**
  - **"Coarse" section (8 layers)**
    - **10 cm thick steel**
  - **Engineered and 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)**

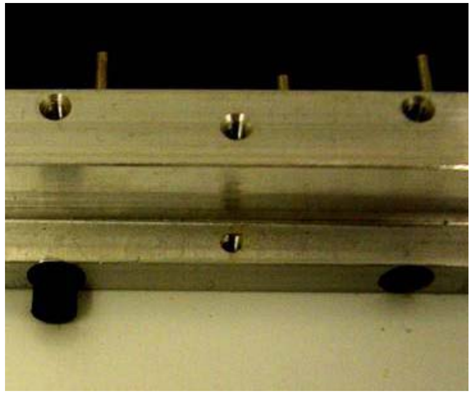
- **Dimensions:**
  - **Length (along beam) - 142 cm**
  - **Height - 109 cm**
- **Weight ~10 tons**

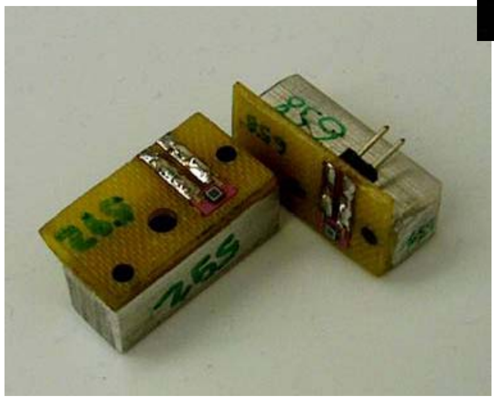
Design Motivations

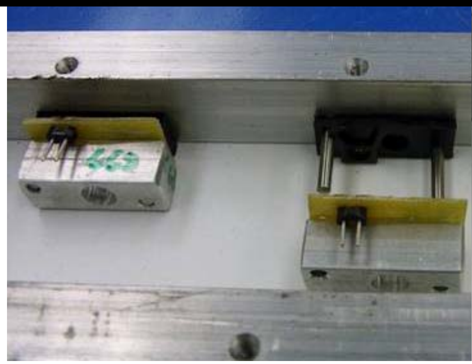
- TCMT required for sufficient depth to contain hadronic showers and validate Monte Carlos for PFA studies.
- For many ILC concepts calorimetry is thin and inside the coils. The outer solenoid flux return is composed of layers of Fe plates with gaps: consideration of a tail catcher is natural.
- Used 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.



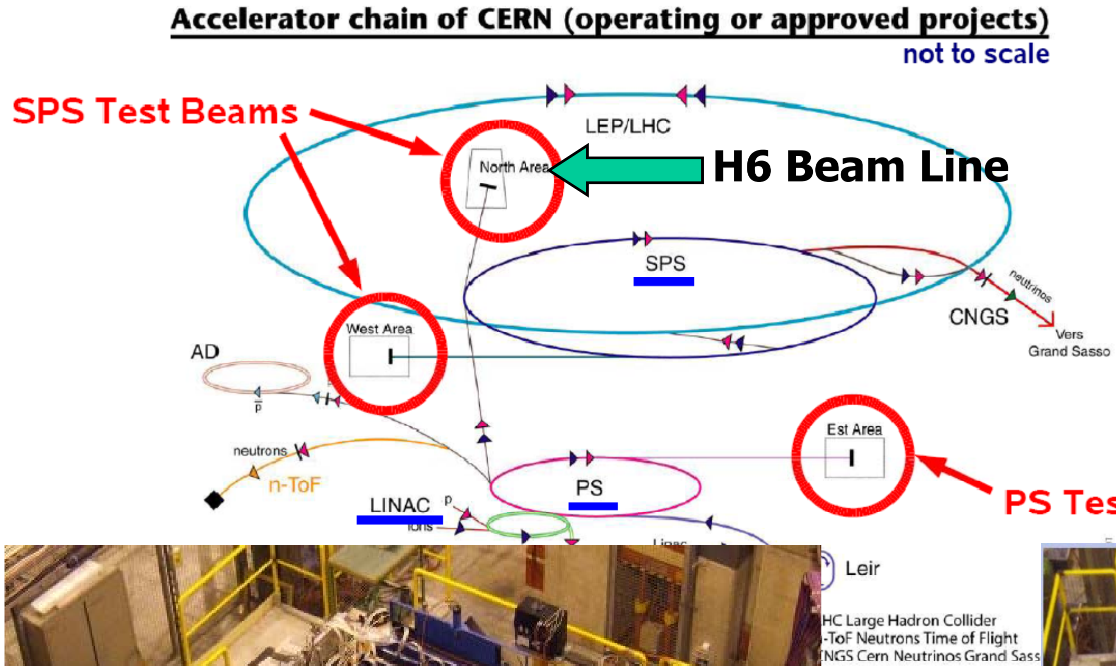
TCMT Cassette Components





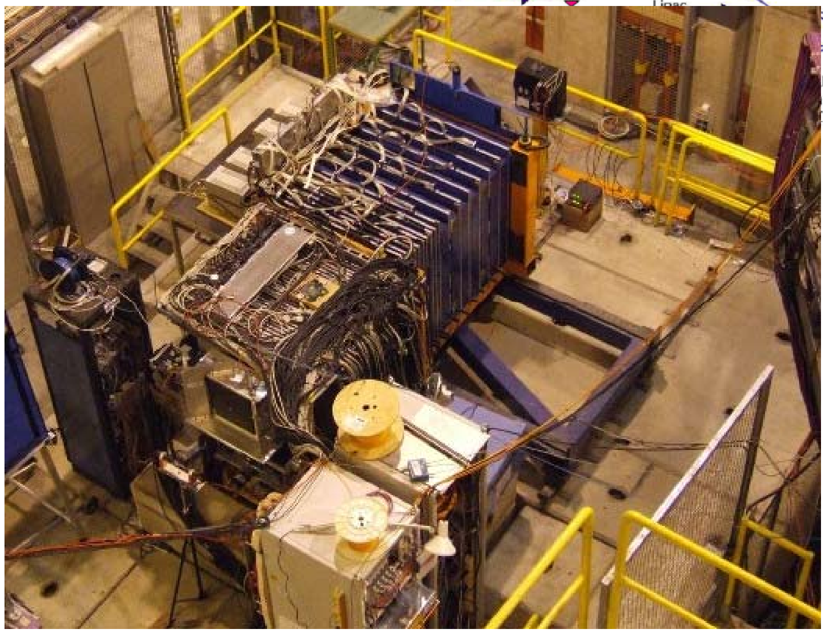


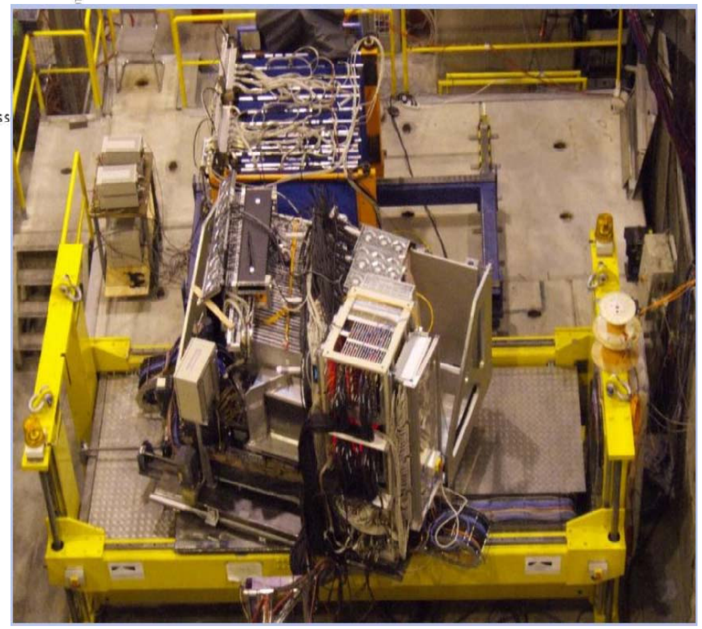
CALICE @ CERN Test Beam



Portions of this slide thanks to Erika Garutti and R. Pöschl

- **>5Tbyte 2006 data**
- **>14Tbyte 2007 data**
- **Available on Grid for analysis**



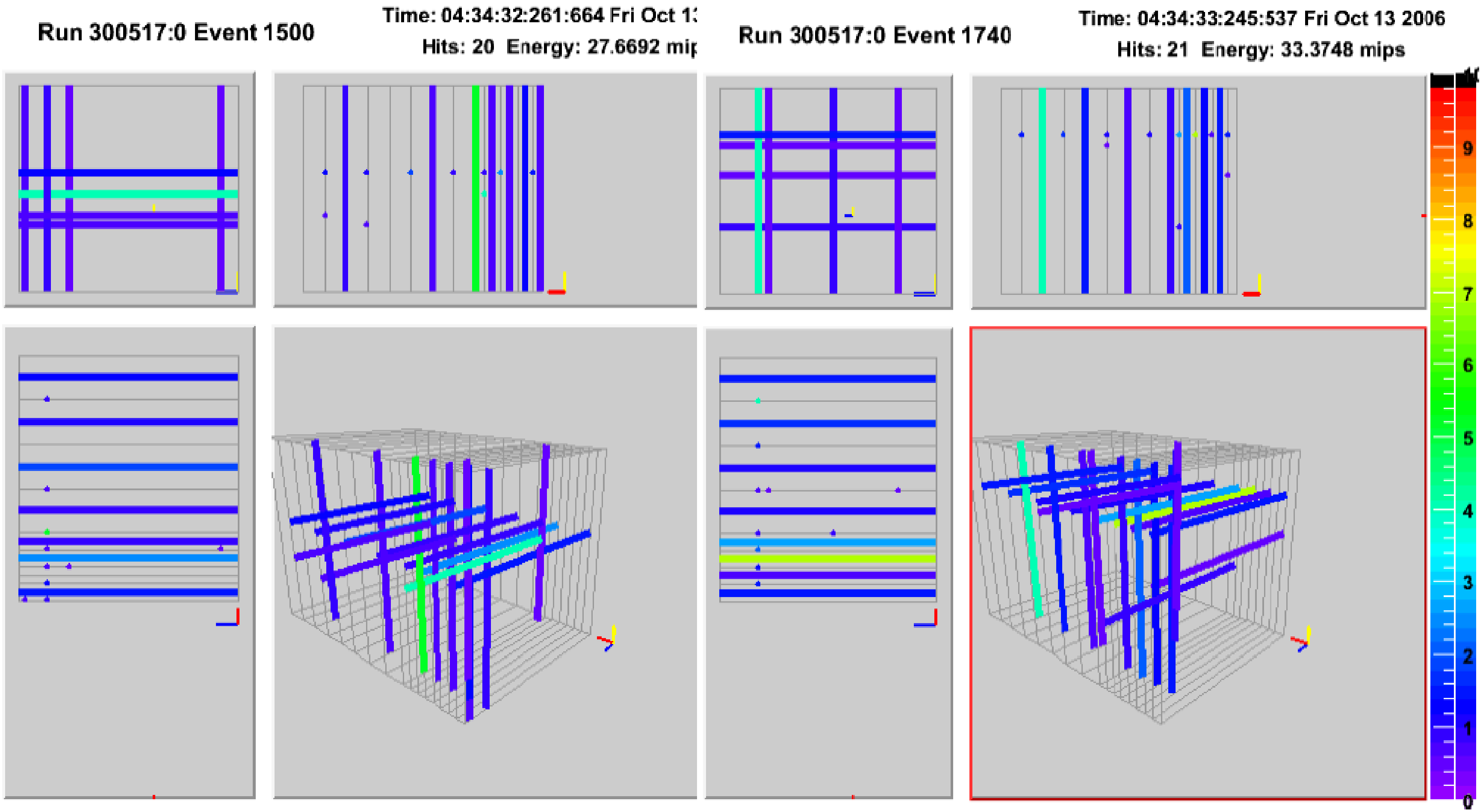


CALICE Calorimeters at Test Beam

- **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 $24X_0$ radiation length
- **HCAL**
  - Up to 38 absorbers (30 used in 2006) – 1.6cm thick steels
  - Gaps instrumented with 0.4mm thick modules with high granularity core (3x3cm^2)
    - During 2006 Run
      - Layers 1-17 - all instrumented
      - Layers 19-29 - every other layer instrumented
      - Total of 23 layers x 216 chan/layer = 4968 channels
    - During 2007 Run
      - Layers 1- 30 – all instrumented
      - Layers 31 – 38 without high granularity core scintillators
      - > 7500 channels
  - 4.5 interaction lengths
  - Rotating stage used for position and angle scans in 2007 run
- **Test Beam Runs**
  - 2006 August/September and October/November (discussed here)
  - 2007 June to August (still under analysis)

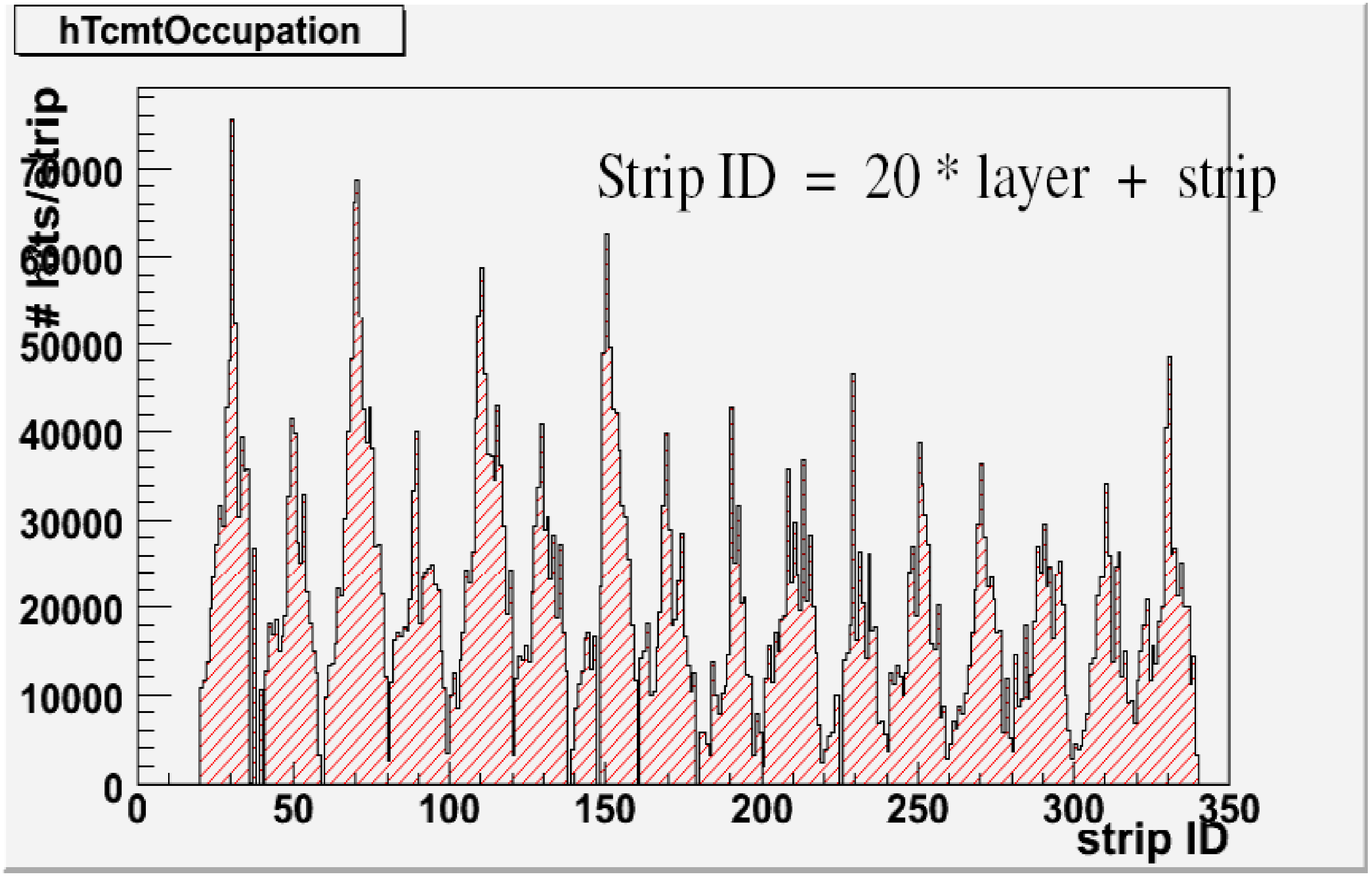
TCMT at CERN (2007)

Event Displays - Muons

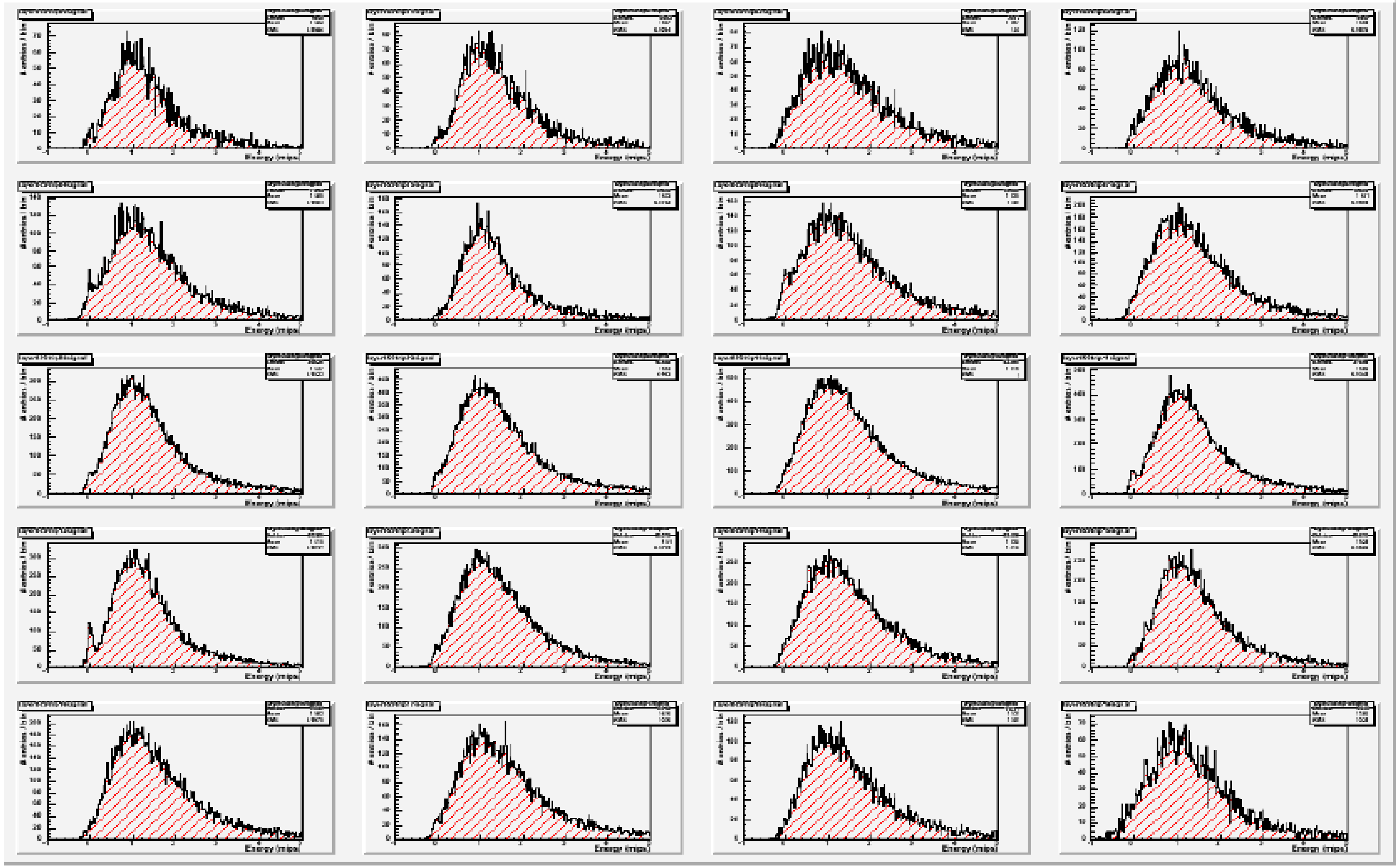


Muon Run Beam Profile and Occupation

Run300517 Beam Dump with no defined energy

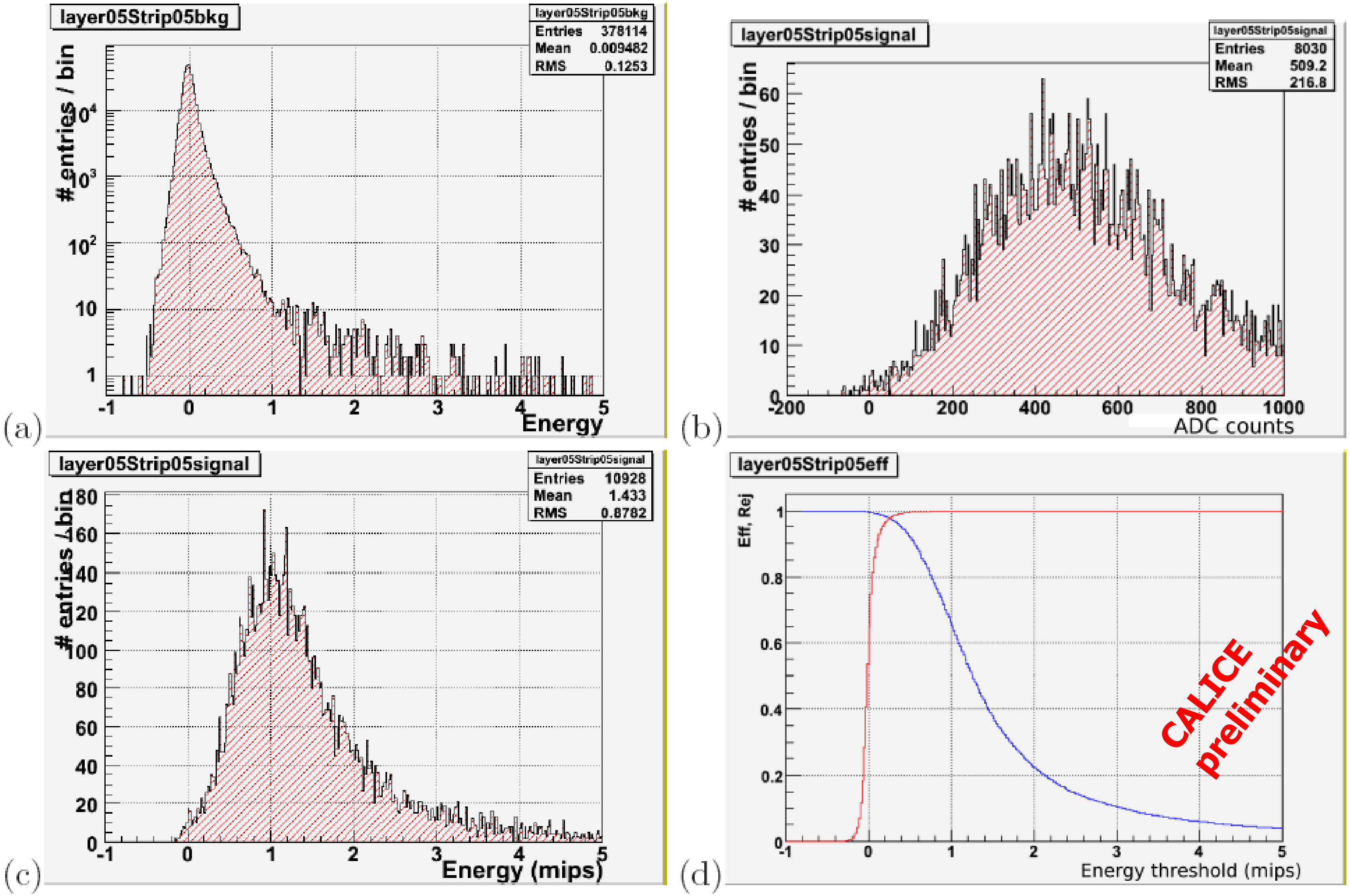


Muon Run Layer 5 Example



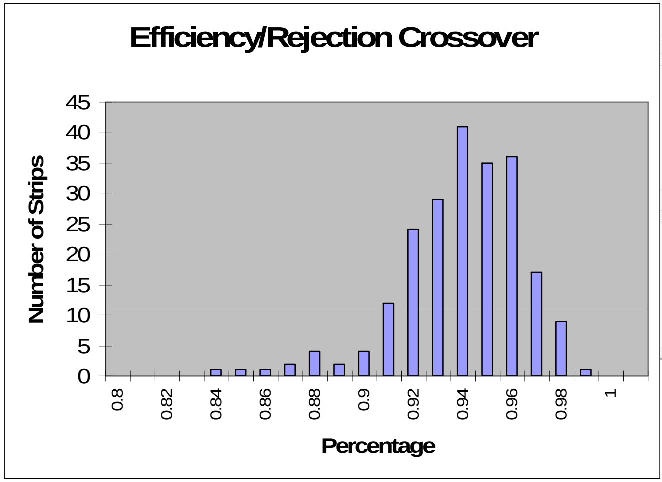
Software triggered on 4/5 closest parallel strips

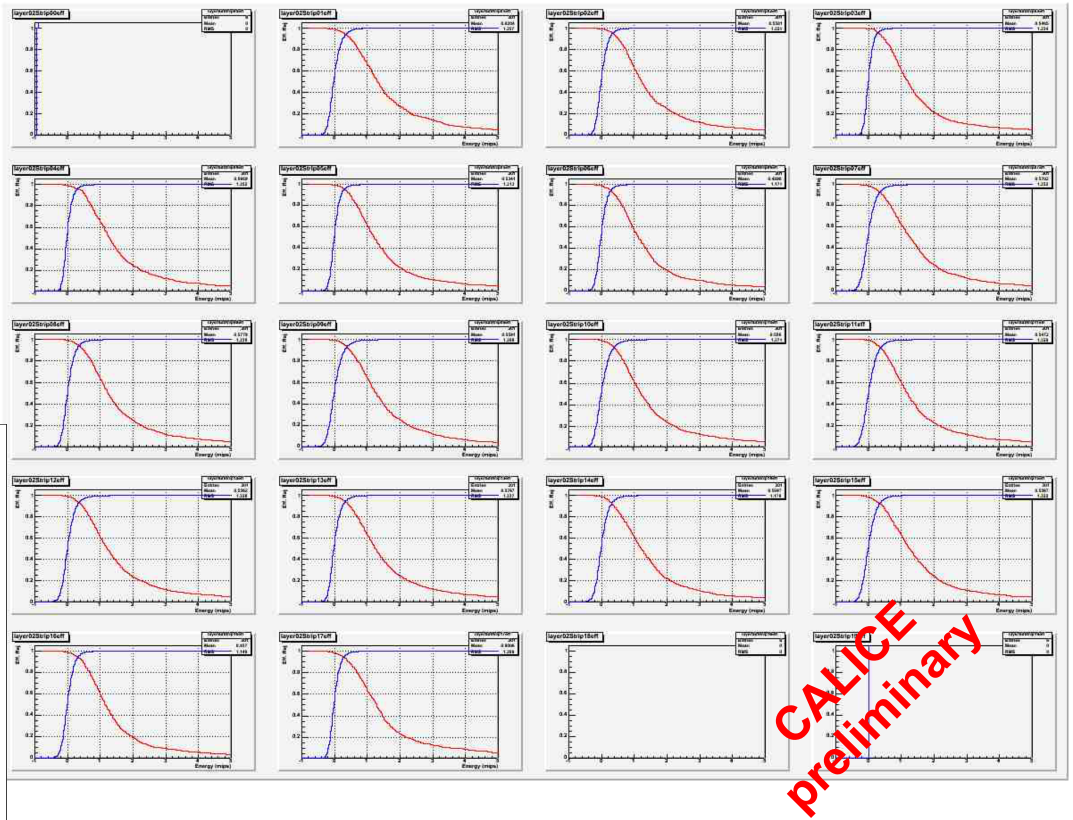
Efficiency Rejection Calculations



Efficiency/Rejection Plots

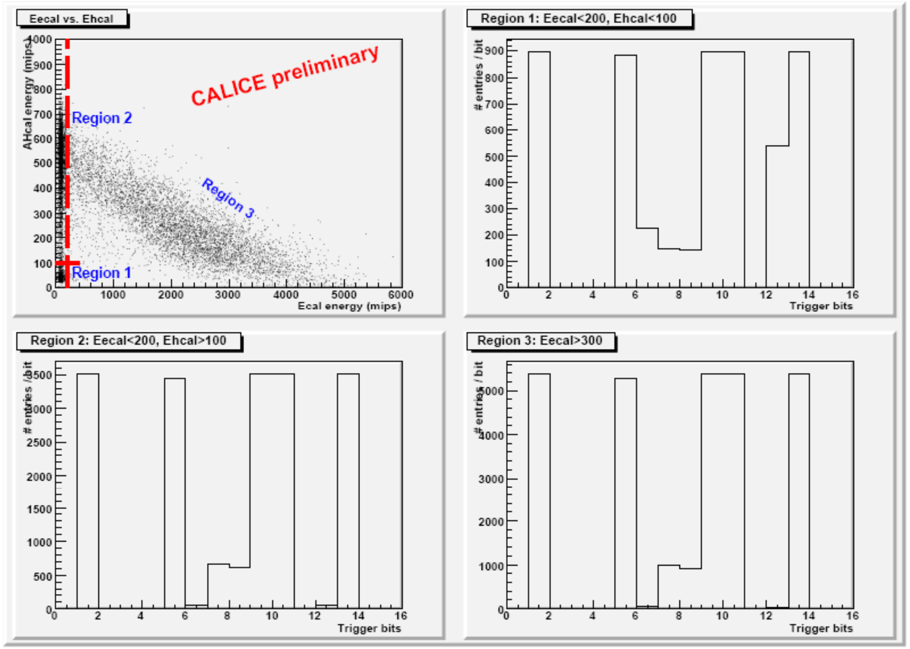
- Layer 2 example
- Efficiency in red, Rejection in blue
- Missing channels due to faulty sensor in parallel strips
- At crossover average efficiency and rejection~ 95%

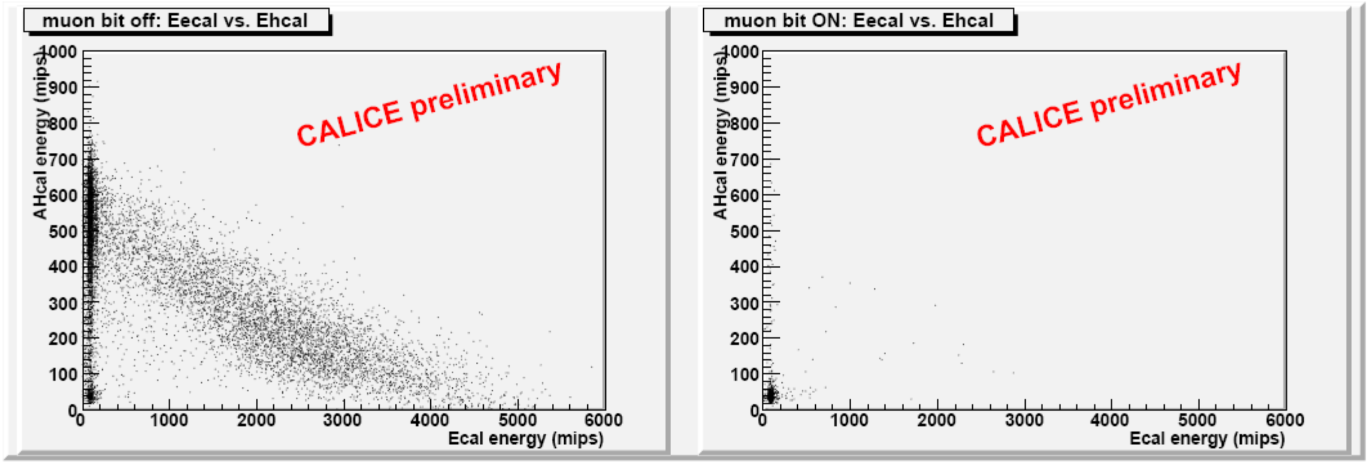




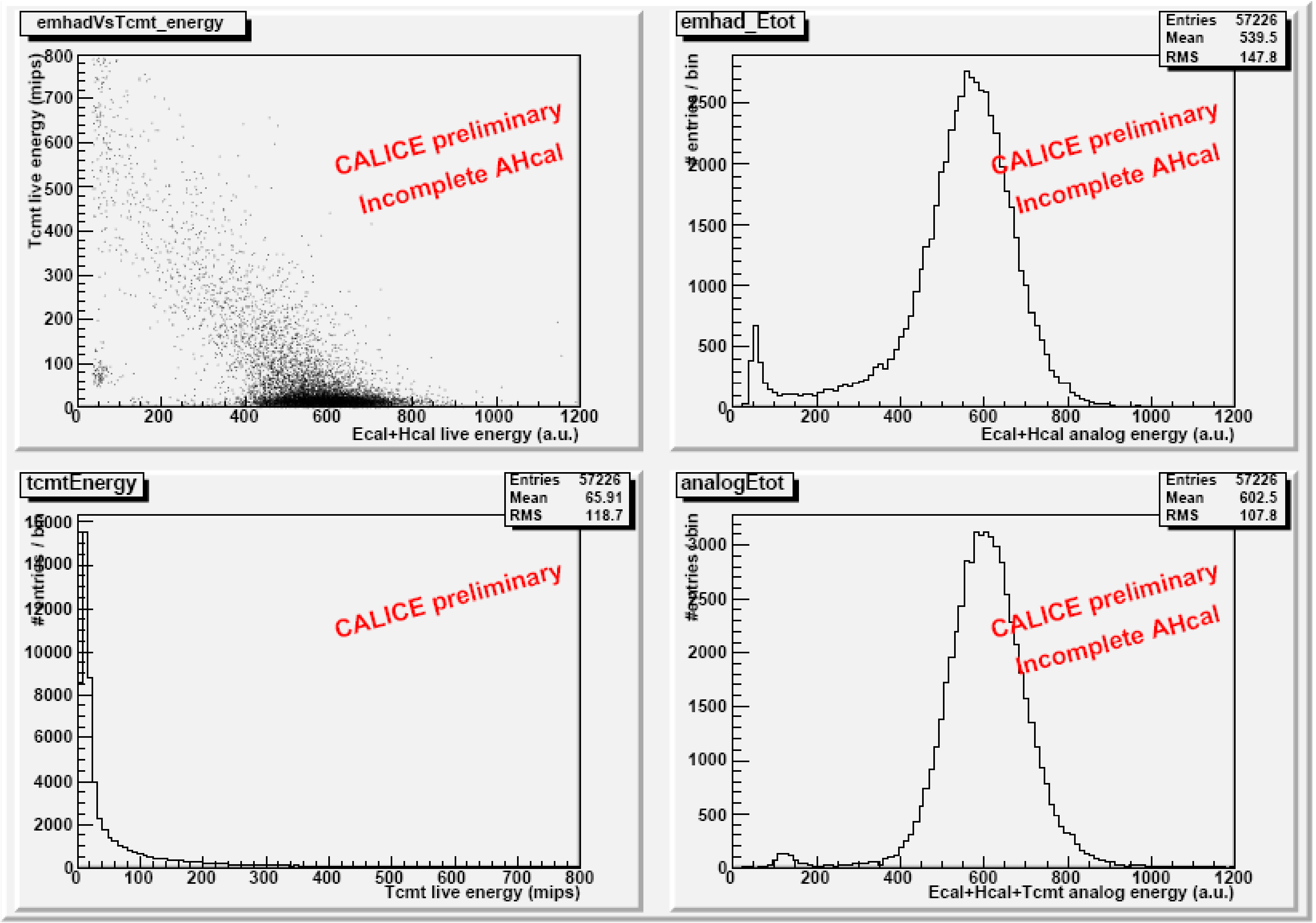
Event Selection

- **ECAL vs HCAL**
  - **Region 1 - MIPs**
  - **Region 2 - pions traverse ECAL without showering**
  - **Region 3 - Anti-correlation region, pions shower in e-cal**

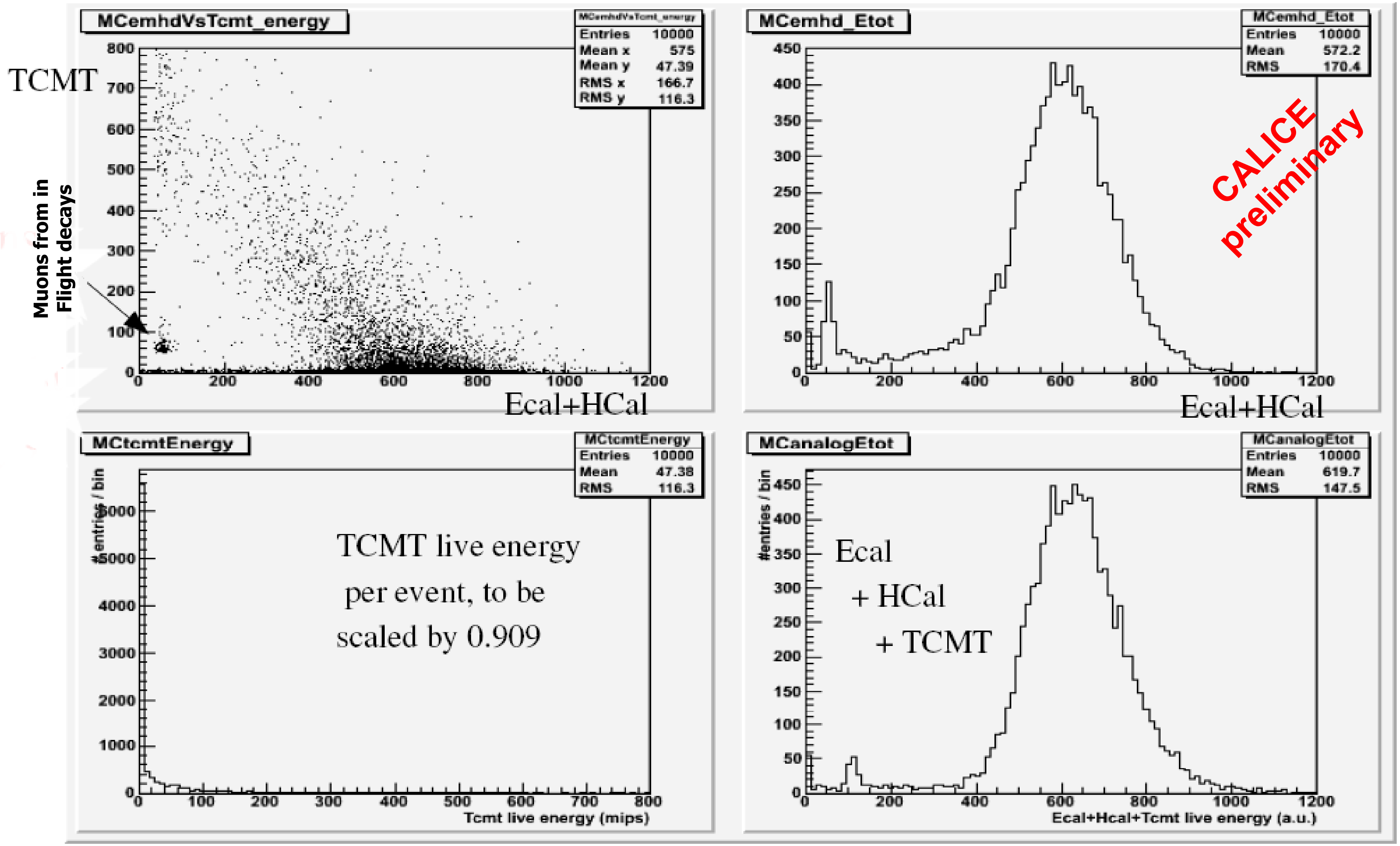




Analog Energy Response – 20Gev pi-

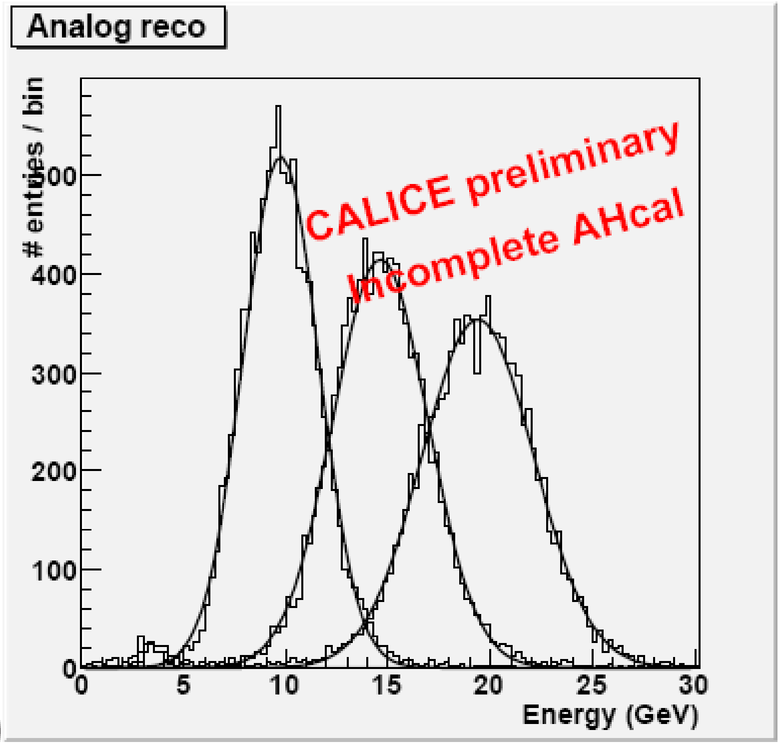


Analog Energy Response - MC

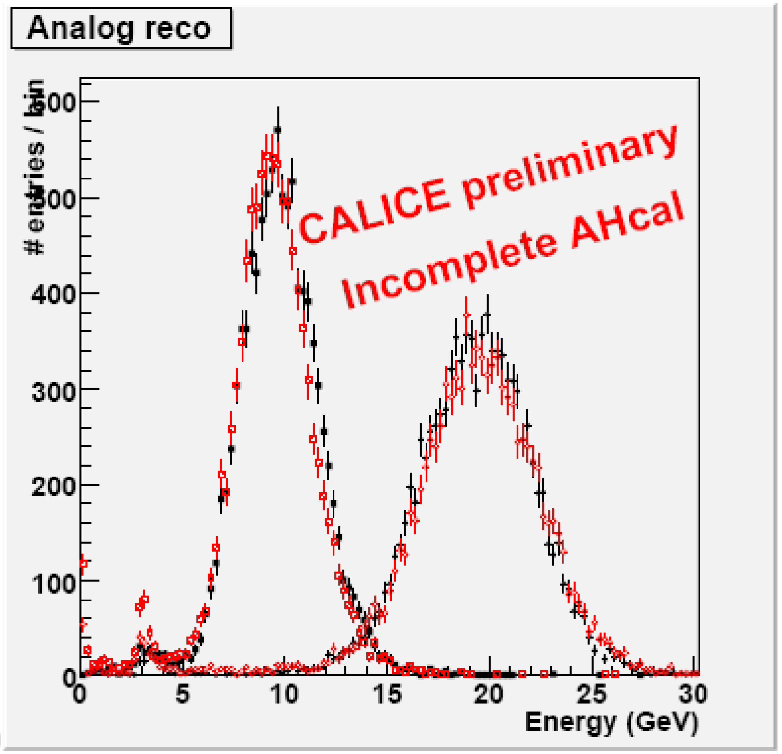


Energy Reconstruction

- **Energy Reconstruction using analog readout**
  - **(a) for pion beams with different energies 10,15,20 GeV**
  - **(b) comparison between test beam and Monte Carlo 10,20 GeV**



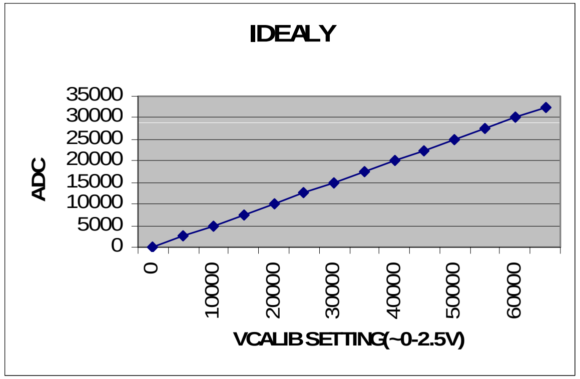
(a)

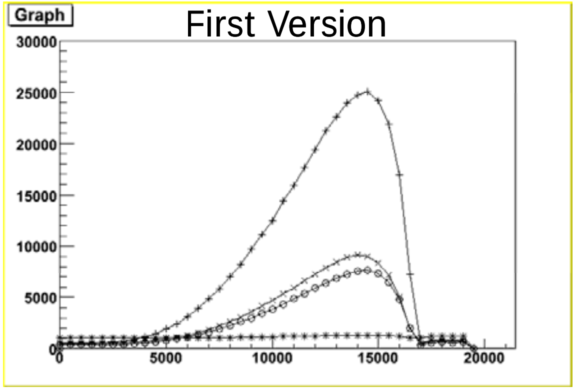


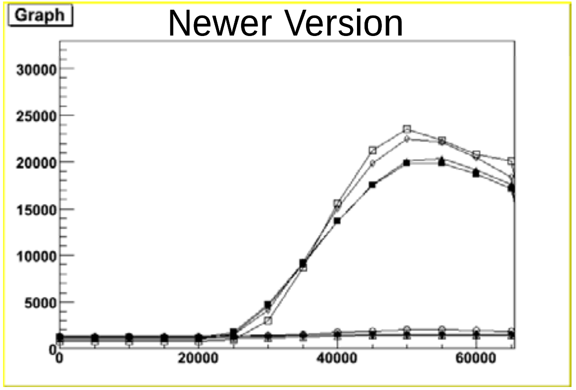
(b)

Calibration LED Driver Development

- LED Calibration system:
  - Blue/UV LED for each strip
  - CALICE DAQ puts out a VCALIB setting in range of 0-65000 for calibration
    - in low end range for single photo-electron spectra gain measurements
    - In a higher range for light yield and stability measurements
  - Custom 'driver' board was designed to adjust output of each LED so they are equal
- Ideally multiple channels response will be linear with VCALIB and all channels would have same slope
- First iteration of design
  - Channels had wide range of slopes – hard to find a good VCALIB setting that would give good SPE for all channels
- New design has several potentiometers for each channel to linear region for

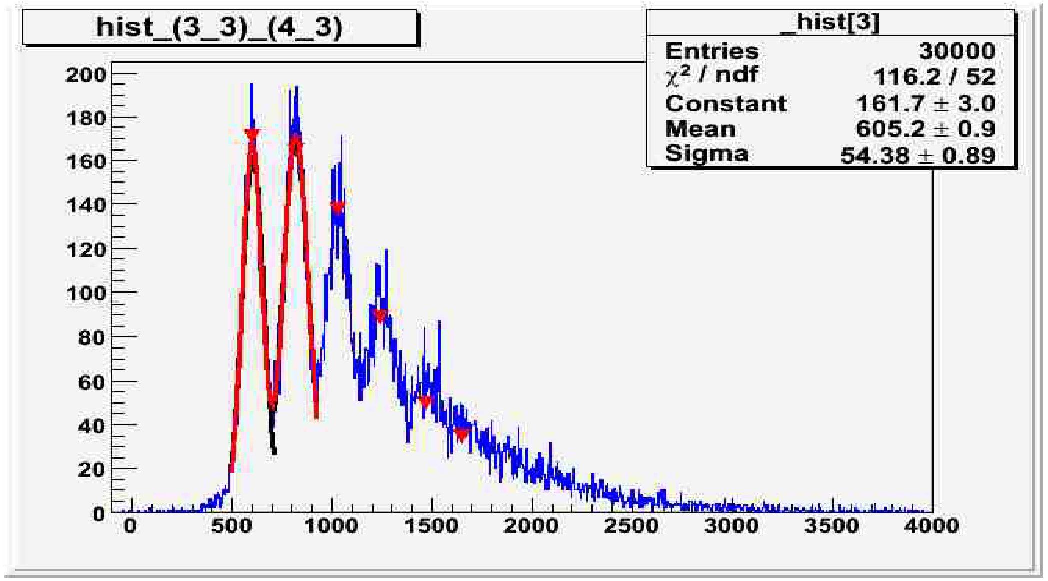


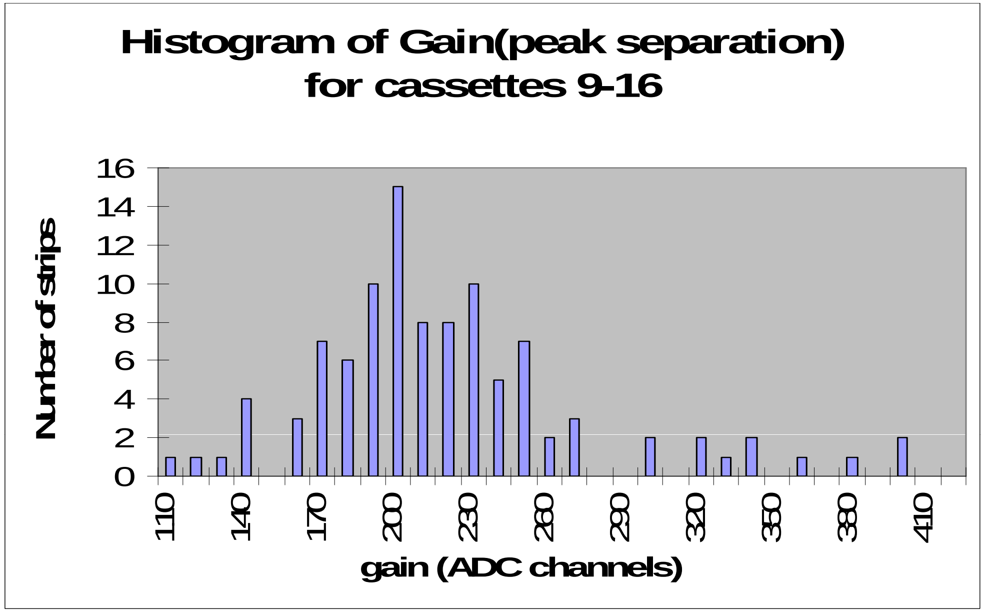




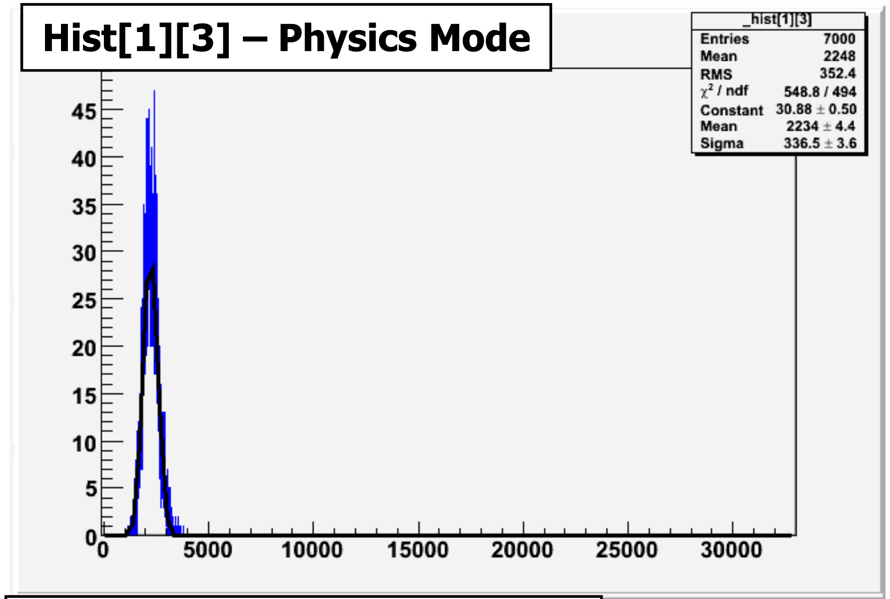
Gain Measurements

- **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.**





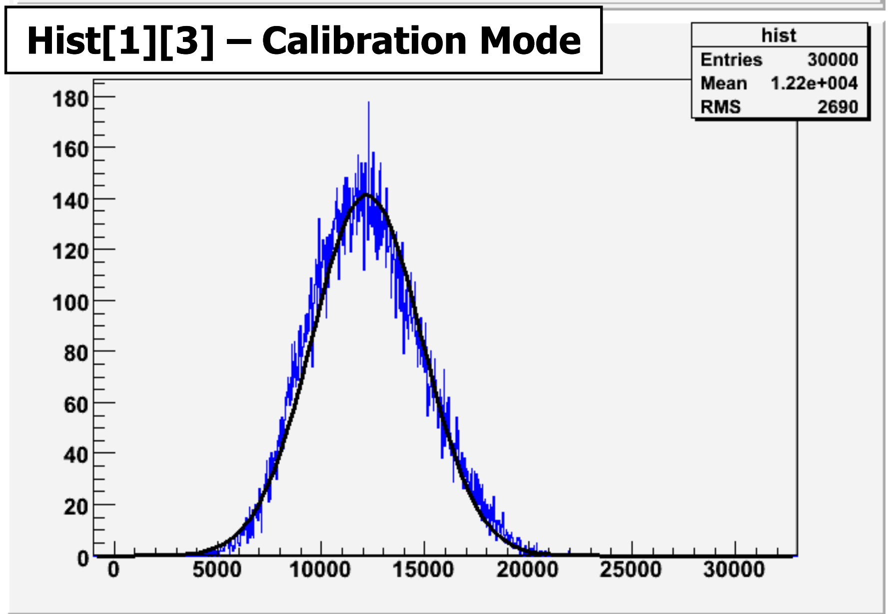
Light Yield

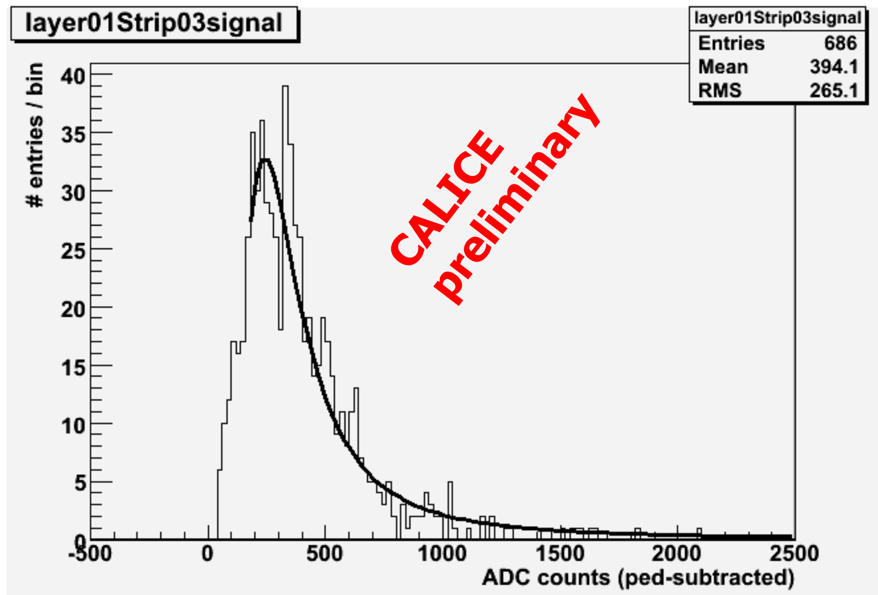


Calculation Requires

- 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

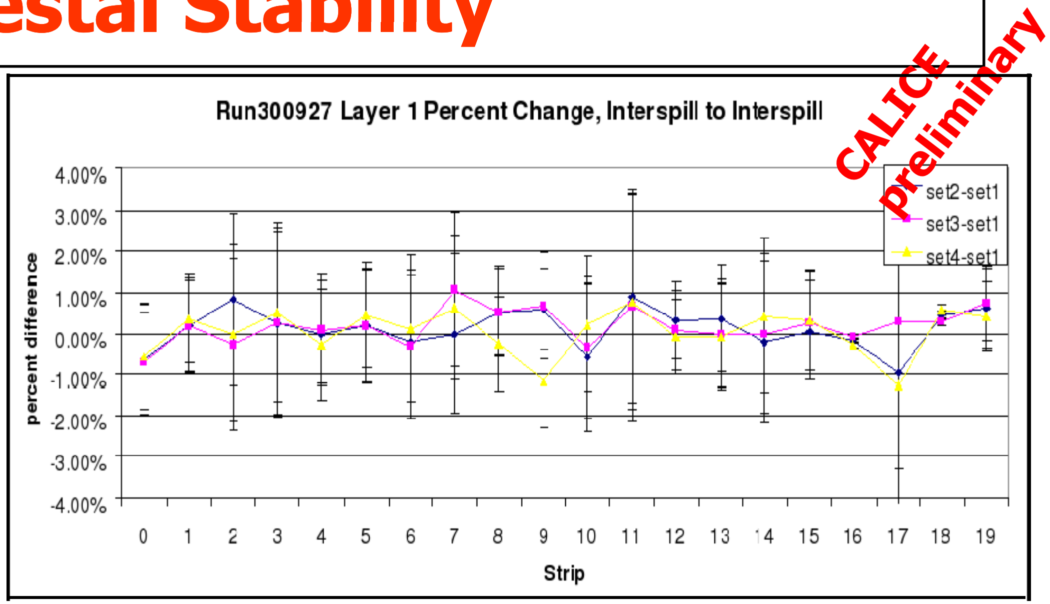
- **Average L.Y. ~= 10 P.E.**

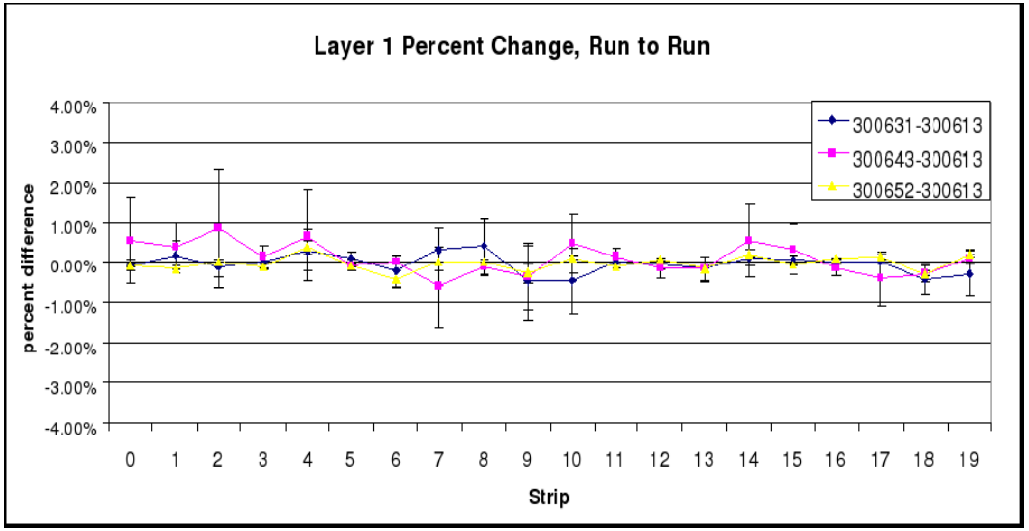




Pedestal Stability

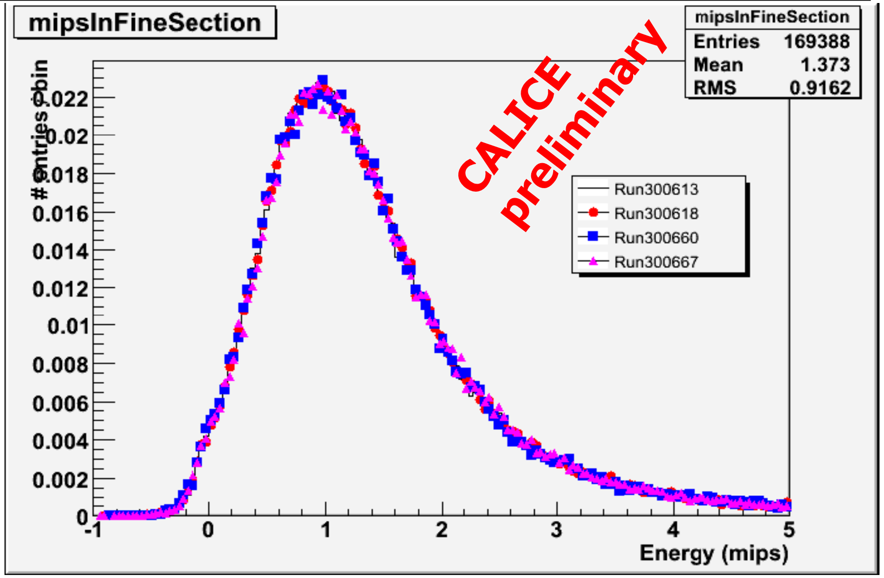
- **Typical Pedestal Variations in Example Layer**
  - **"Interspill" are groups of 500 pedestal events between beam spill**
  - **Usually separated by 10minutes**
  - **Within run they vary by ~1%**
  - **Percent Change between runs also acceptable ~1%**
- **RMS changes (not shown)**
  - **Average < 1% for both interspill and Run to Run comparisons**

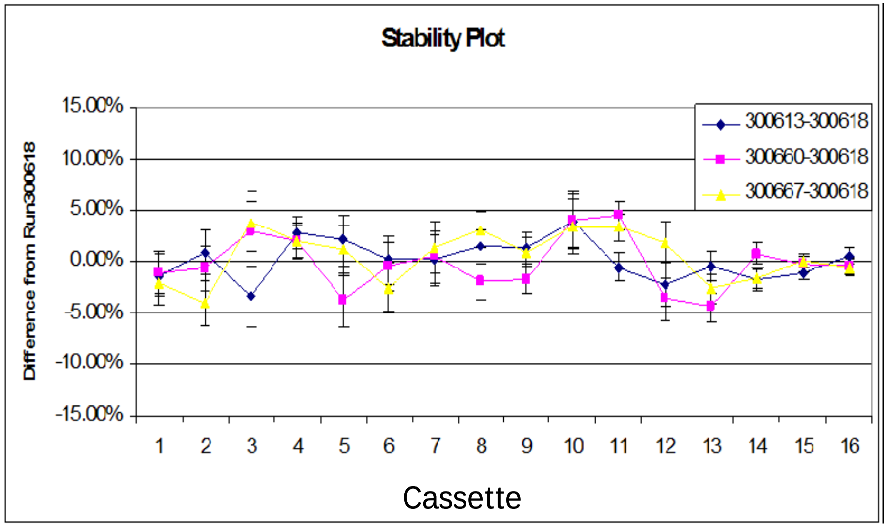




MIP Stability

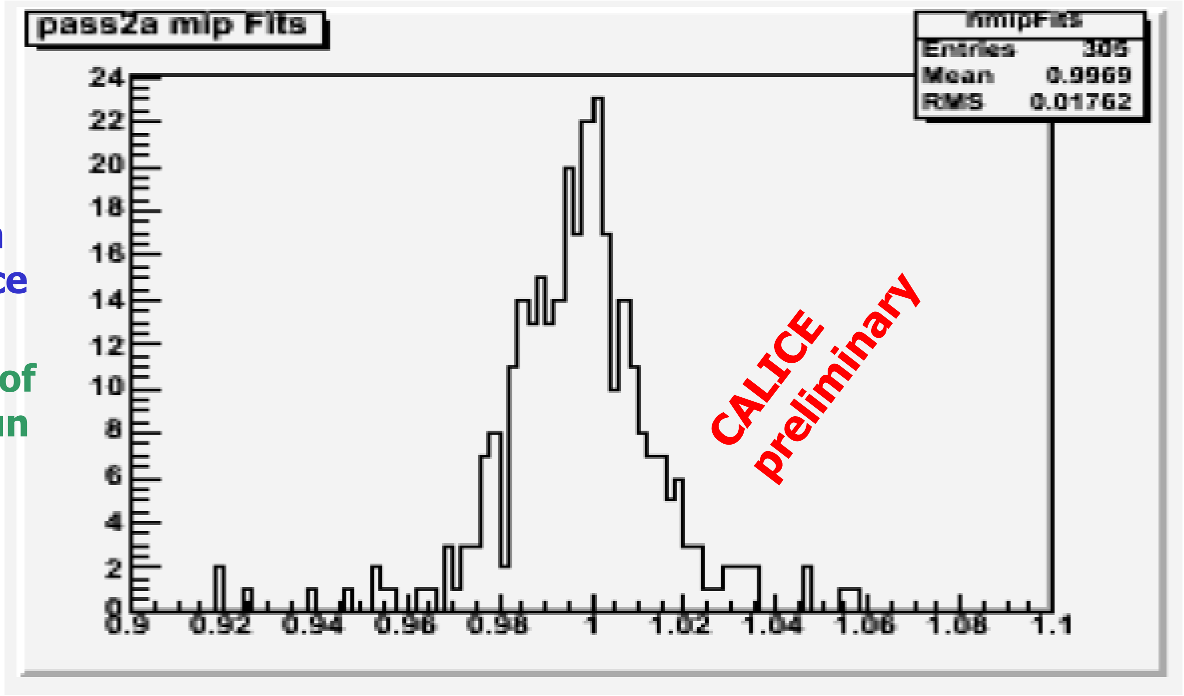
- To Study Calibration Stability During pion runs:
  - Triggered on muons created from pion decay
  - Plot shows overlay of MIPs in fine section in four 10Gev pion runs over a 34 hour period
  - Percent Change between runs is very good ~2%
- TCMT response stability
  - Used 10 GeV pion beams, in several runs spanning the time range under study.
  - Looked at the hit distributions for each layer for hits above 0.5 Emip.
  - Stability Plot shows the relative variations in the mean values of the distributions of hit energies in each layer .
  - Results consistent within the statistical uncertainties.





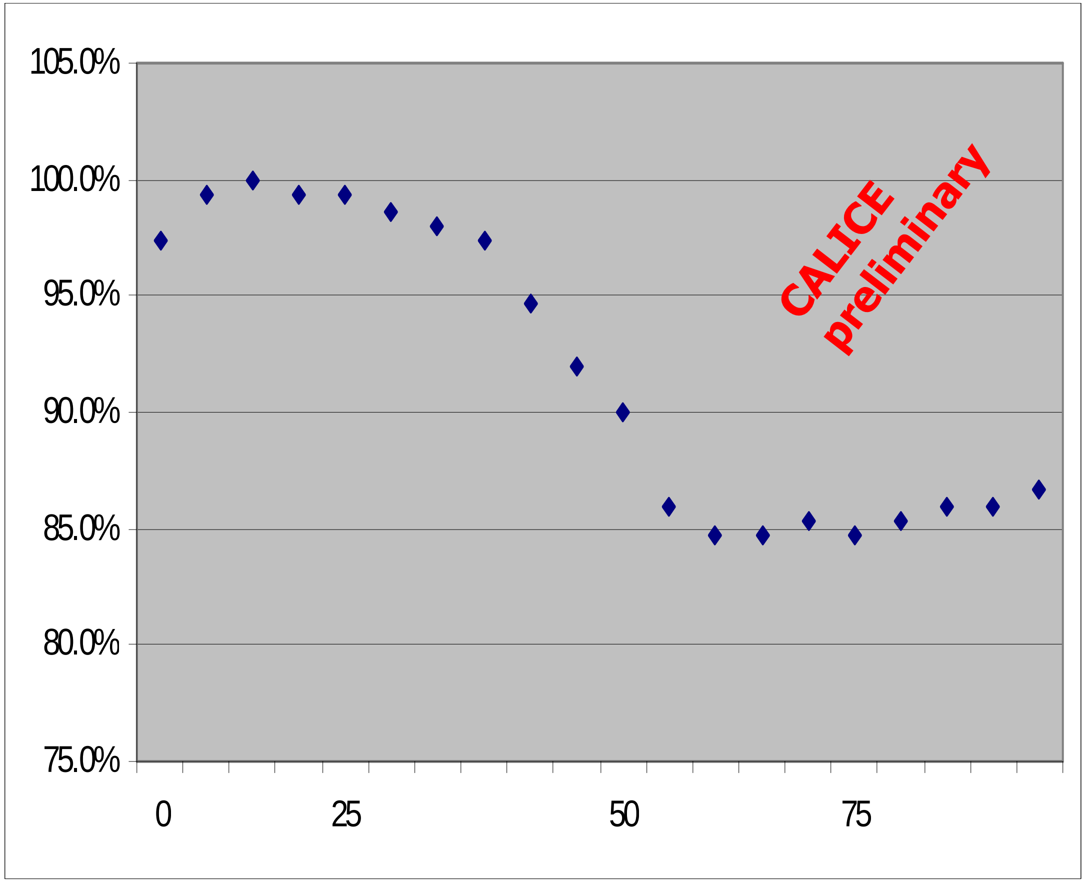
MIP Calibration Summary

- Another look at stability
- Comparing MIP fits from a Muon run to a reference Muon run
  - Standard Deviation of 1.7% from run to run



Response Along Strip

- Example is one strip in one cassette
- Response decreases with distance from SiPM
- Correctable by selecting different reflective coverings in different regions of the strip
- Not yet used to tune calibration



CALICE TCMT Plans

- **Additional CALICE running**
  - **Upgrade LED Calibration system of the TCMT**
  - **Move to MTBF at FNAL**
  - **HCAL & TCMT infrastructure available to test other technologies**
- **Continue Data Analysis**
  - **Include analysis of staggered strips in 2007 data**
  - **Including correction for SiPM saturation**
  - **Further studies of light yield**
  - **Ultimately: study shower shape in terms of hits & energy**

Summary

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