Early Tail-Catcher Muon-Tracker MTBF & CERN Results for Calorimetry & Muon Detection using SiPMs

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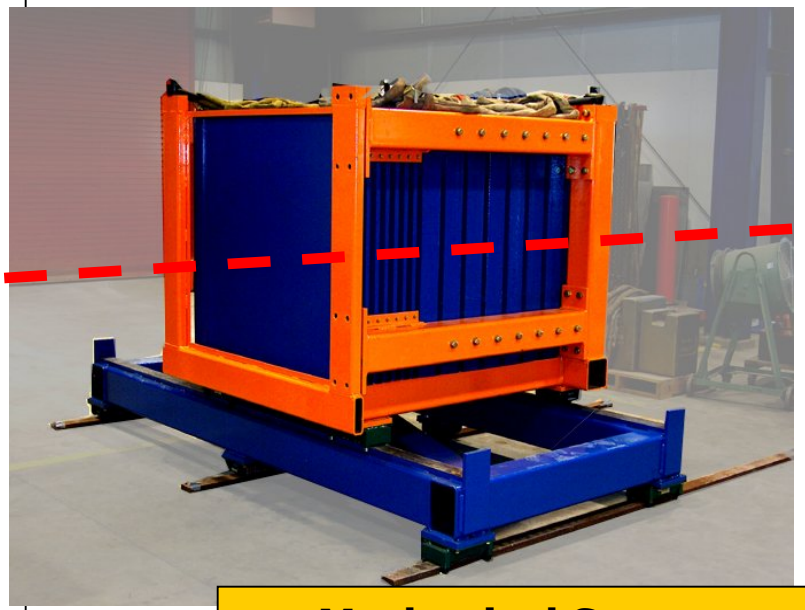
Outline

- The CALICE Tail-Catcher Muon-Tracker
  - Study end of hadronic shower & validate simulations available
  - Prototype ILC detector
    - Correct for leakage
    - Understand & address impact of coil
    - Promote PFA
    - Good μ ID and control fake rates
- Results from MTBF
- Results from CERN
- Plans for the Future
- Comments on the use of scintillator and SiPM for muon detection

CALICE Tail-Catcher Muon-Tracker Prototype

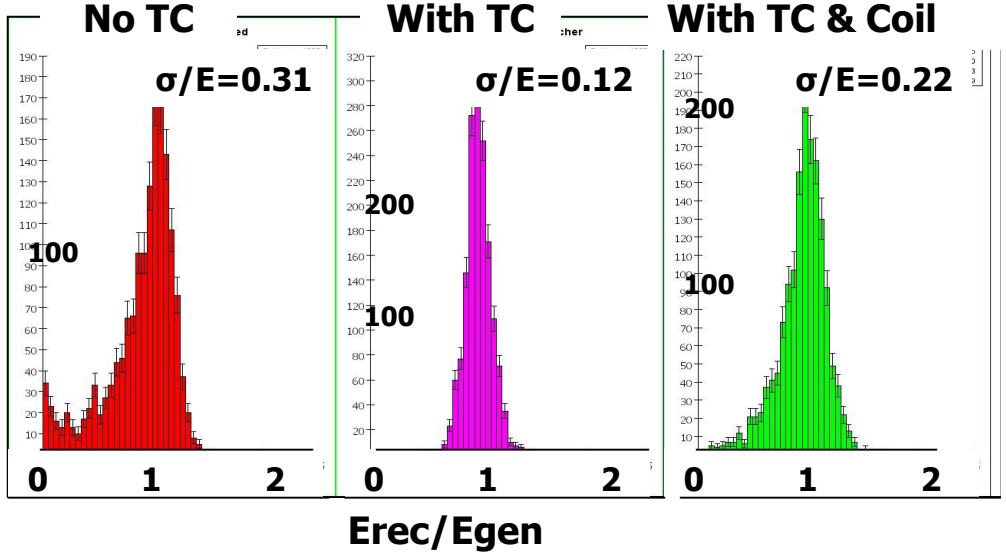
- **Mechanical Structure/Absorber**
  - "Fine" section (8 layers)
    - 2 cm thick steel
  - "Coarse" section (8 layers)
    - 10 cm thick steel
- **16 Cassettes:**
  - Extruded Scintillator Strips
    - 5mm thick
    - 5cm wide strips
    - Tyvek/VM2000 wrapping
    - Alternating x-y orientation
  - Readout
    - WLS Fiber
    - SiPM photo detection
    - Common readout with CALICE HCAL
- **Dimensions:**
  - Length (along beam) - 142 cm
  - Height - 109 cm
- **Weight ~10 tons**

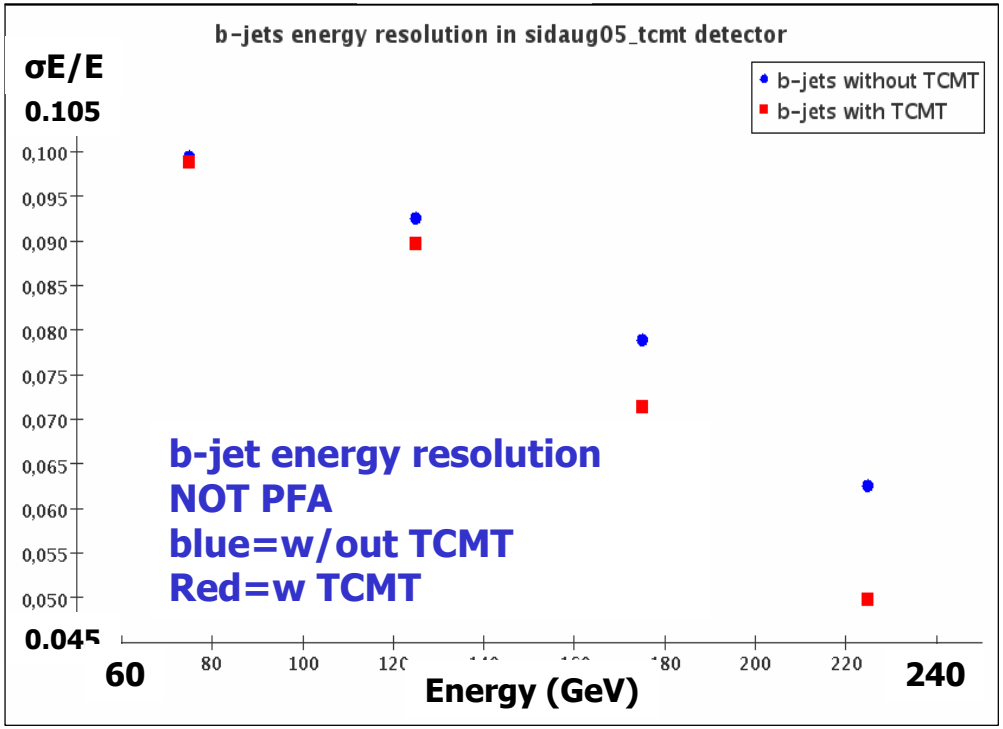


Mechanical Structure Engineered and Assembled by Fermilab PPD

Design considerations: Depth for Calorimetry

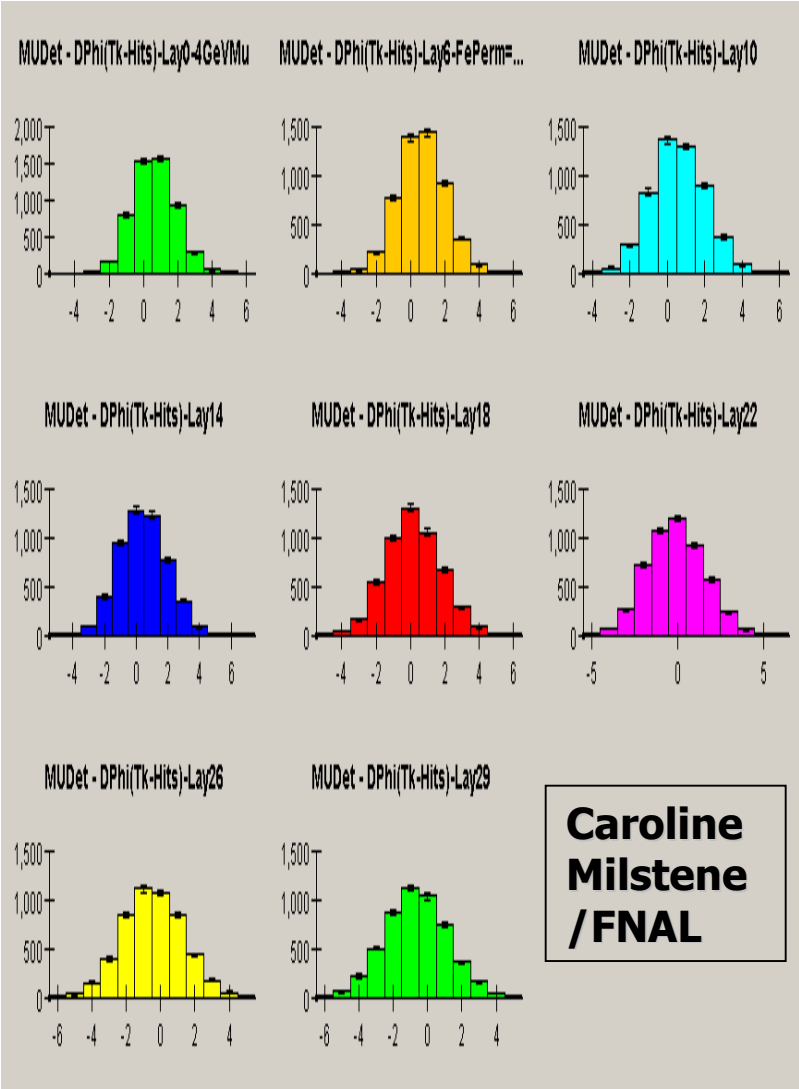
- TCMT required for sufficient depth to contain hadronic showers and validate Monte Carlos for PFA studies.
- For many ILC concepts calorimetry is thin and inside the coils. The outer solenoid flux return is composed of layers of Fe plates with gaps: consideration of a tail catcher is natural.
- Used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



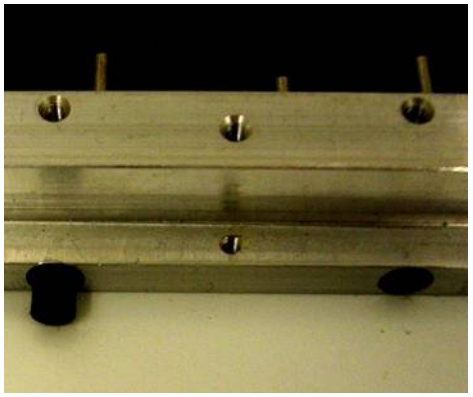


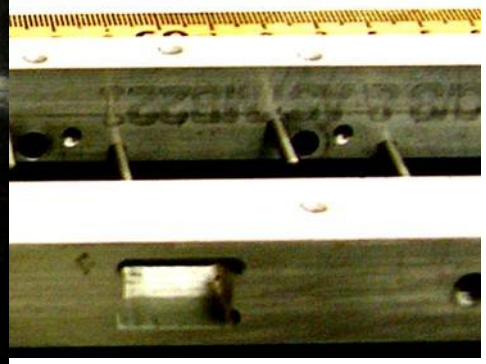
Design Considerations: Segmentation for Muon Detection

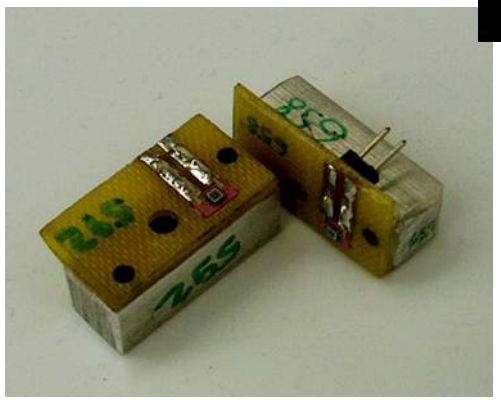
- **Width of strips driven by**
  - **Channel Number → $**
  - **Multiple Scattering & Radial position**
  - **Availability**
- **Monte Carlo's studies with SiD detector suggest ~4 cm for a detector just outside coil.**
  - **5cm Fe abs, 1.5 cm gaps**
  - **4 GeV muons**
  - **Calculate $\Delta\phi$ @ layers 0, 6…**
  - **At Layer 6 : $\Delta\phi_{rms}$ = 27 mr**
  - **Accordingly Δx_{rms} = 1.1 cm**
  - **1.1cm x sqrt (12) → 4 cm**
- **Most appropriate FNAL - NICADD extruder die was 5cm**

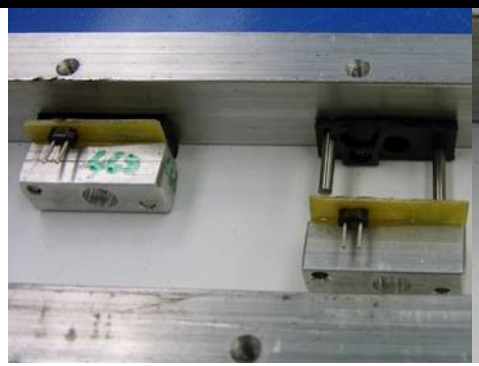


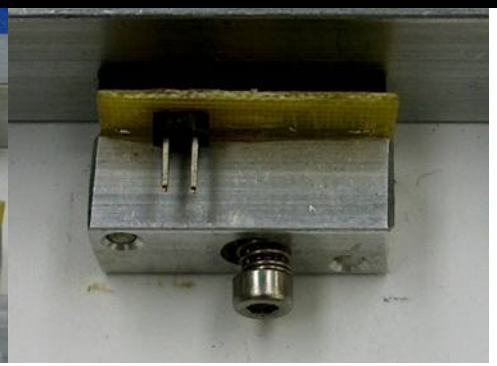
TCMT Cassette Components

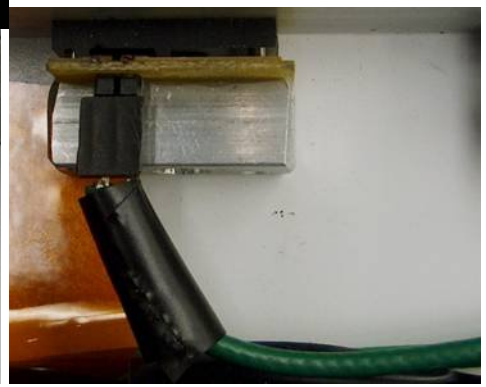






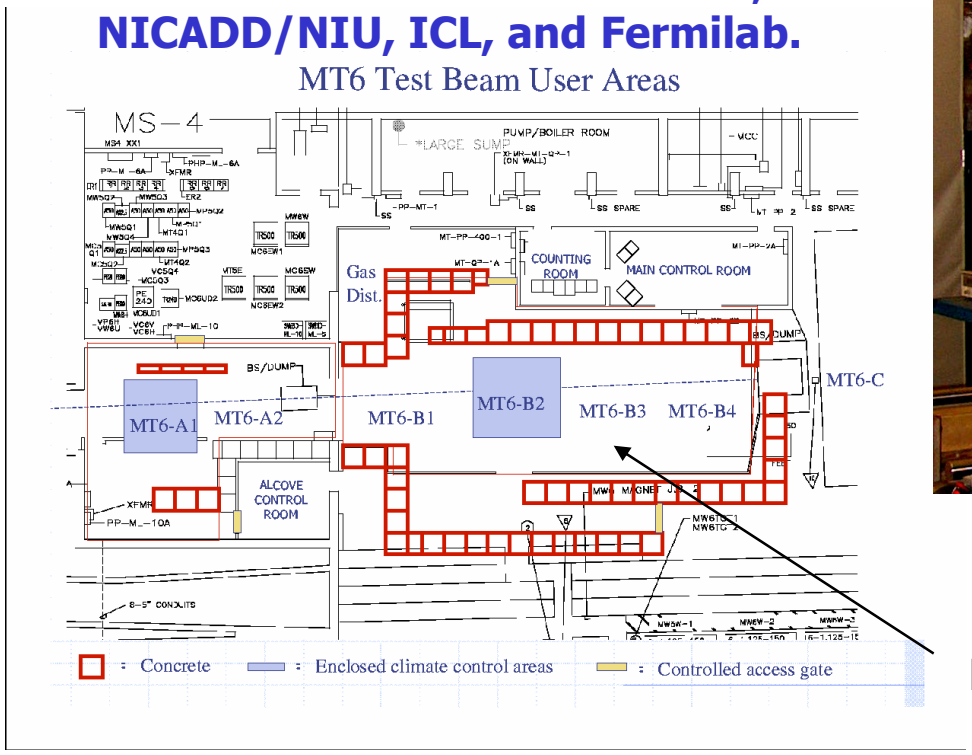


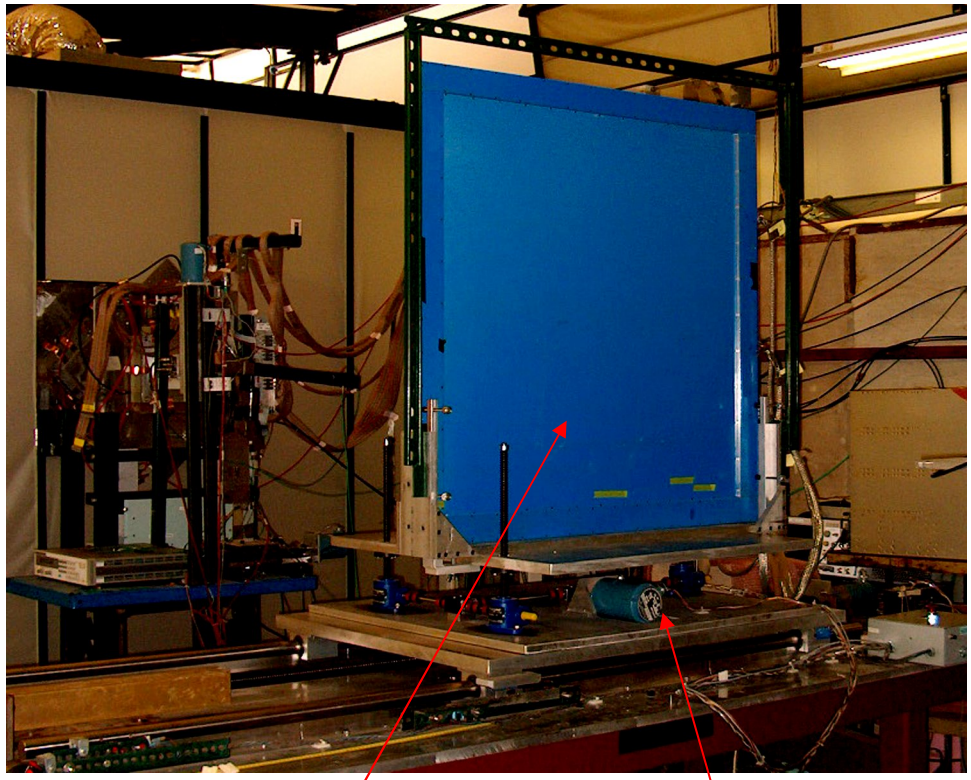




February 2006 MTBF Beam

- Took beam in the last week of Feb. for ~ 5 days w/ one cassette and no absorber.
- Took 120 GeV/c protons, 16 GeV/c (mostly pions) and some beam dump muon runs
- ~ 1M events collected
- CALICE DAQ Electronics chain reproduced and tested
- Involved Personnel from DESY, NICADD/NIU, ICL, and Fermilab.

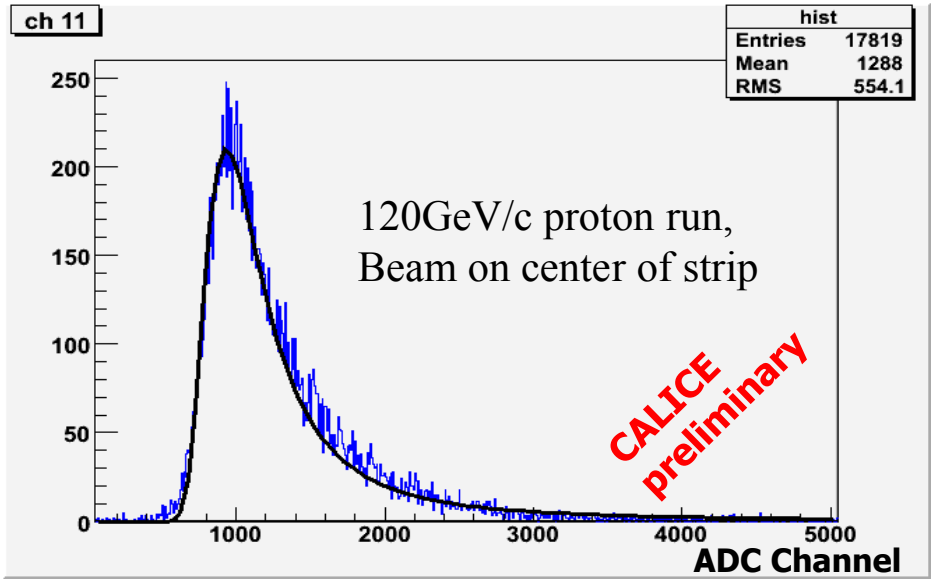


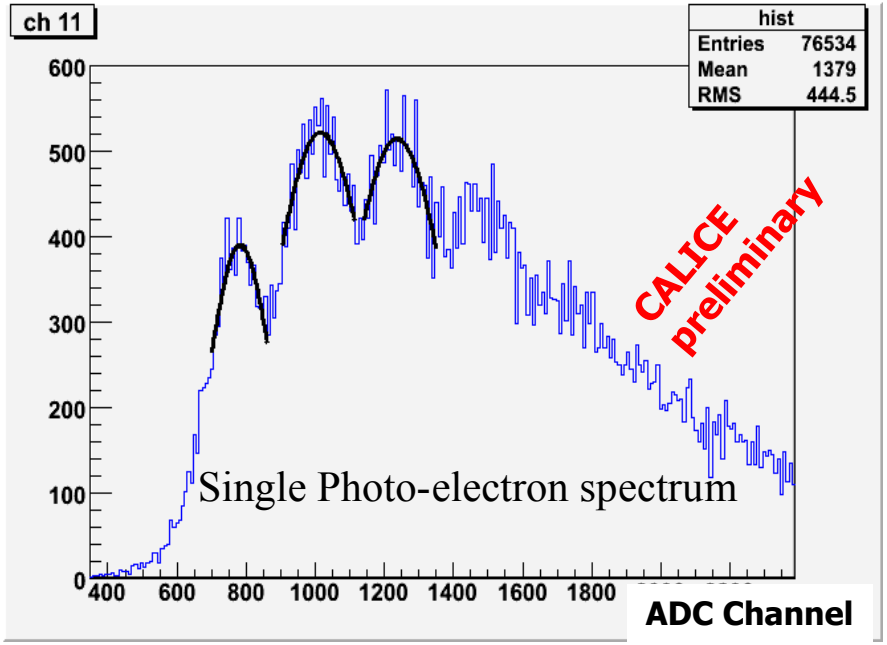


MT6-B3 Area

MTBF Beam Results

- Motion table allowed for directing beam at several points along strip
- Preliminary Light Yield data for several channels measured
- Detailed analysis underway to be compared with CERN results
- Plenty of light for MIP detection

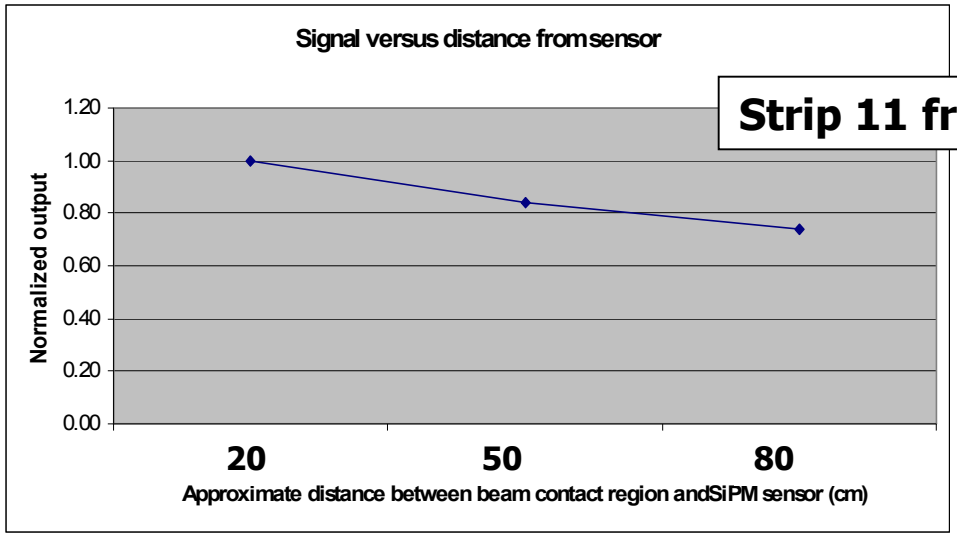




Preliminary Light Yield Data for Three Channels

120 GeV/c proton runs	CHANNEL		
	11	16	17
pedestal mean	692	875	876
calibration mode to physics mode ratio	7.0	6.9	7.2
gain of channel	231	256	190
data run number	210171	210190	210186
landau MPV - pedestal	270	326	277
.NP.E .in cal mode	77.0	63.0	62.6
ADC channels for 1 PE in physics mode	33.1	36.9	26.5
Light Yield (in Photoelectrons)	**8.2**	**8.8**	**10.2**

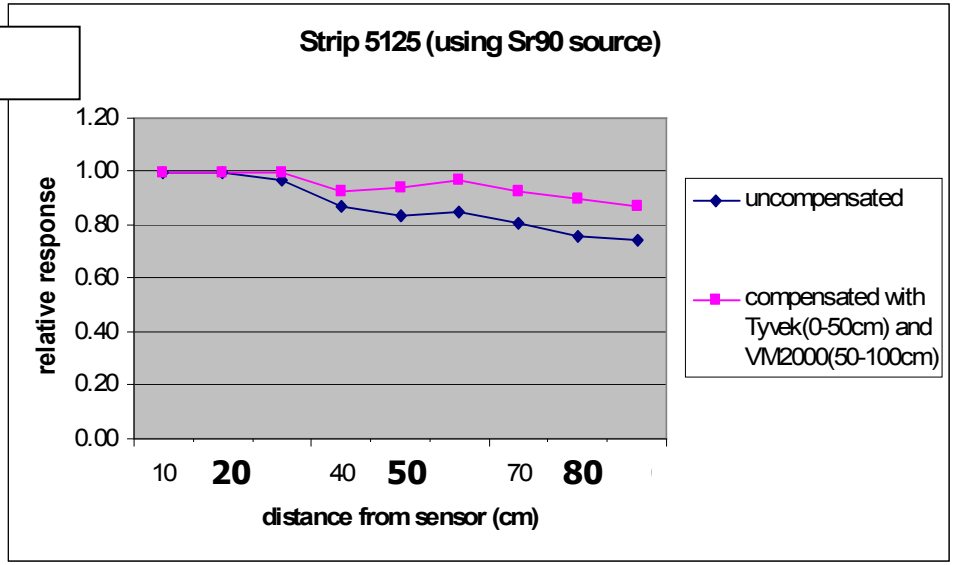
Response along a Strip (120 GeV)



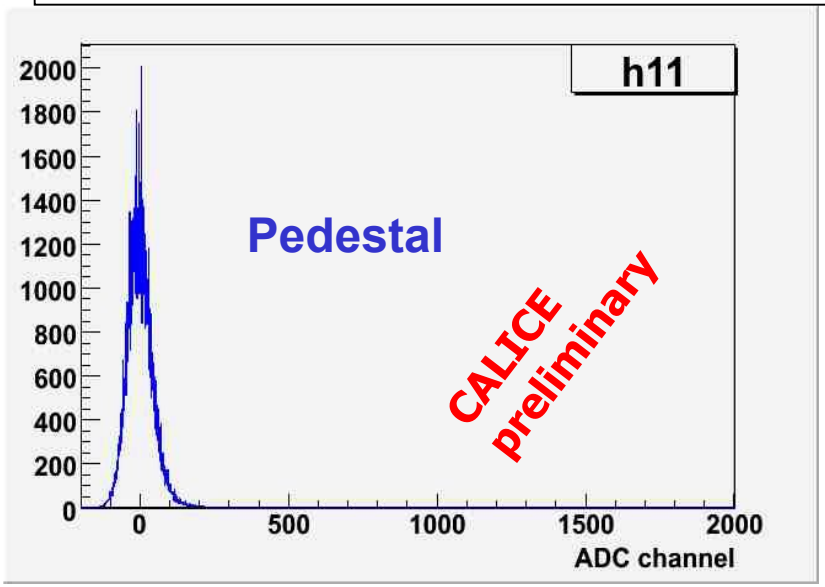
Strip 11 from MTBF

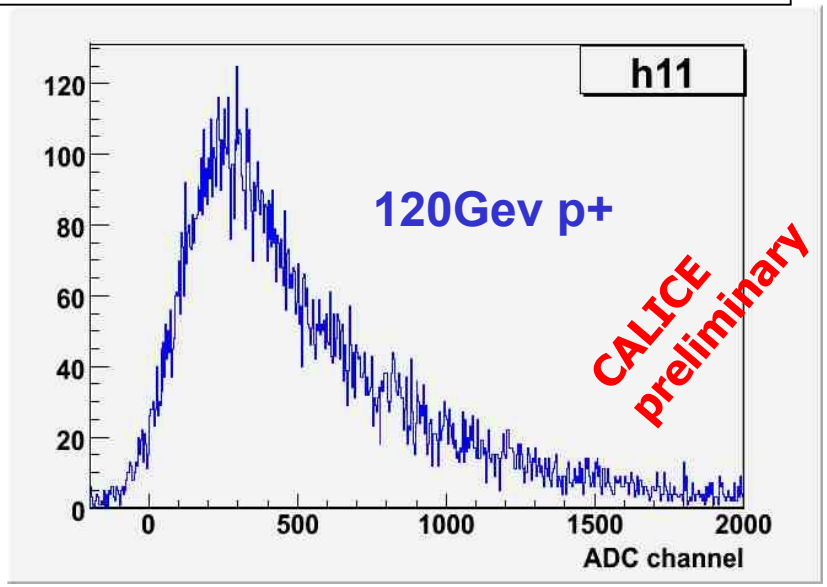
Lab test with source

- **Attenuation of approximately 25%**
- **Can be compensated for by selection of reflective materials**

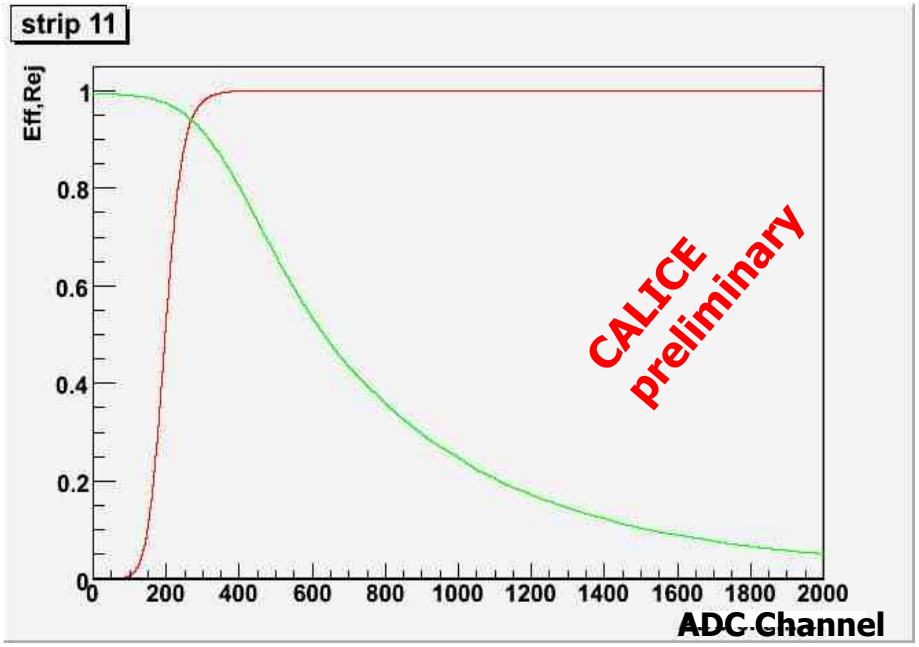


Response to Protons on Strip 11



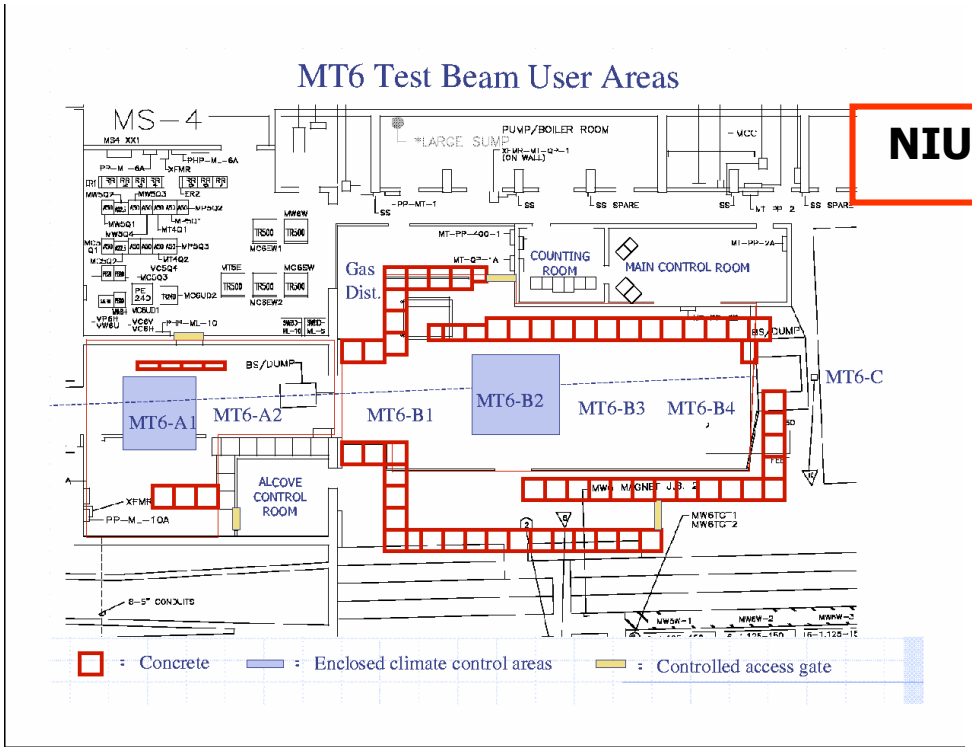


Preliminary: at ~95% efficiency we have ~95% rejection

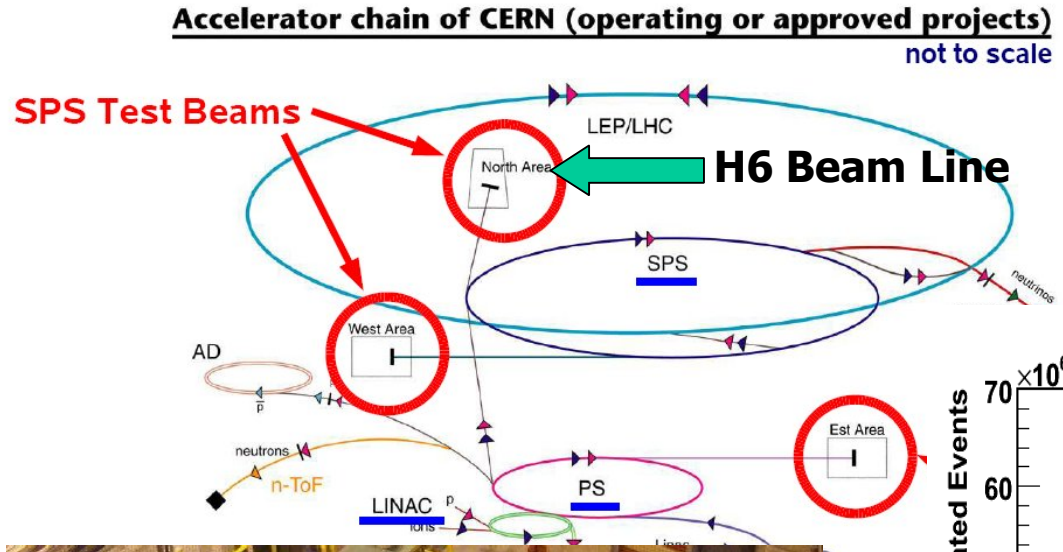


Pre-commissioning at MTBF

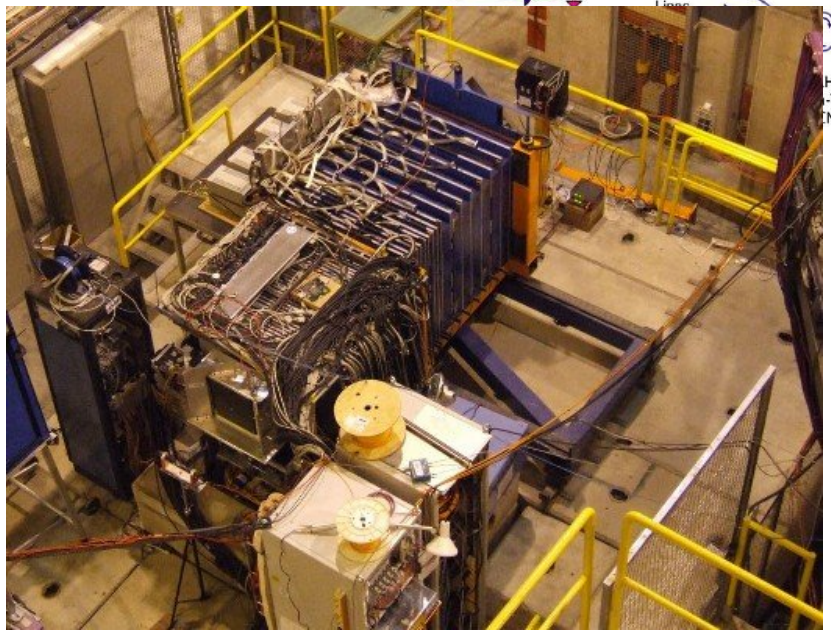
- During 2006 shutdown we continued to use the MTBF facilities for development and pre-commissioning of the cassettes, including:
  - Characterization of SiPMs
  - Development of LED calibration system designed by Fermilab EED
  - Testing, final assembly and pre-calibration of cassettes before shipment to CERN in August
- Very important: it allowed us to get TCMT up and running quickly at CERN

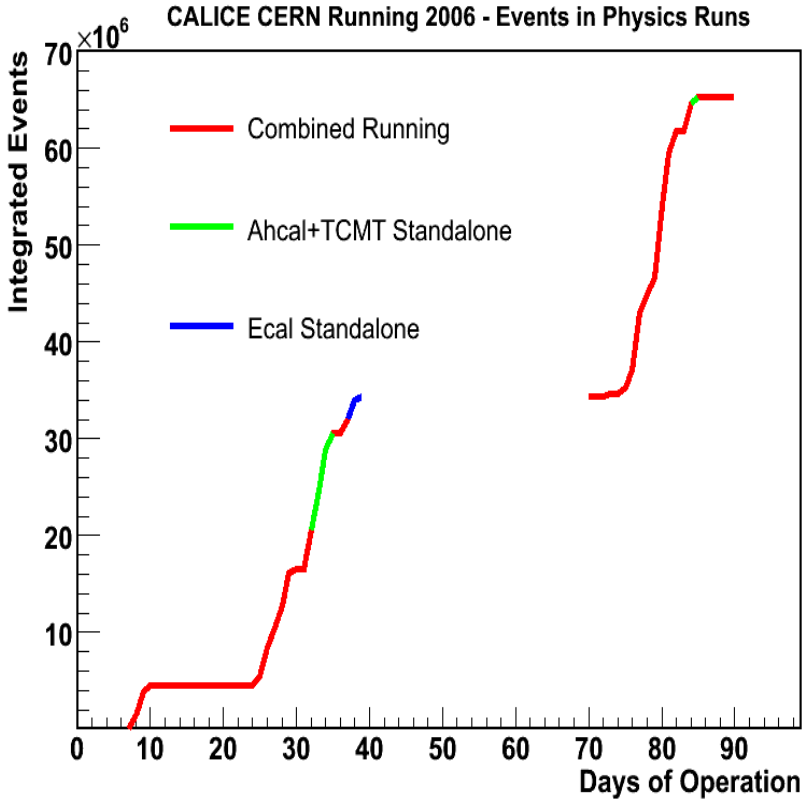


CALICE @ CERN Test Beam



This slide and next: thanks to Erika Garutti and R. Pöschl

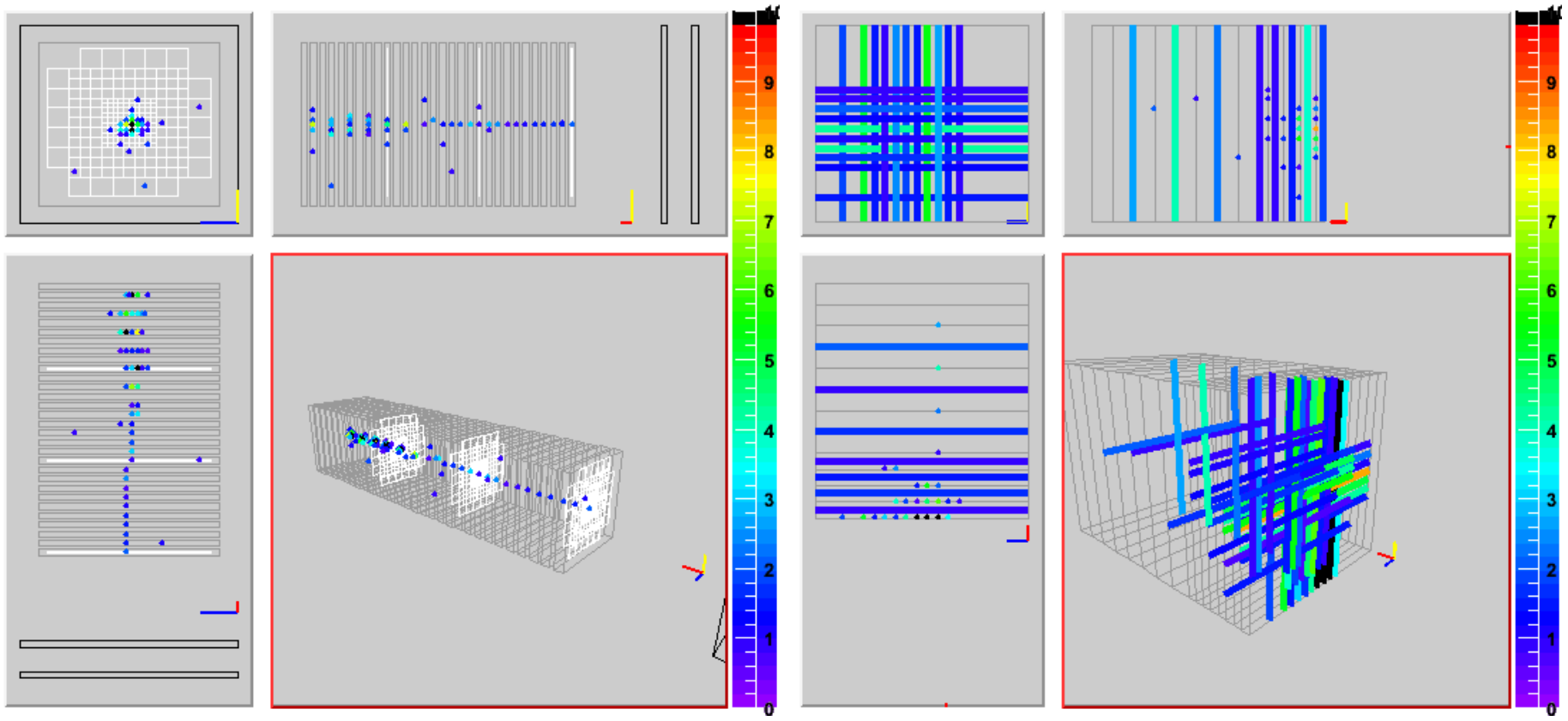




Example pion event display

40GeV/c pion
with CALICE online analysis software

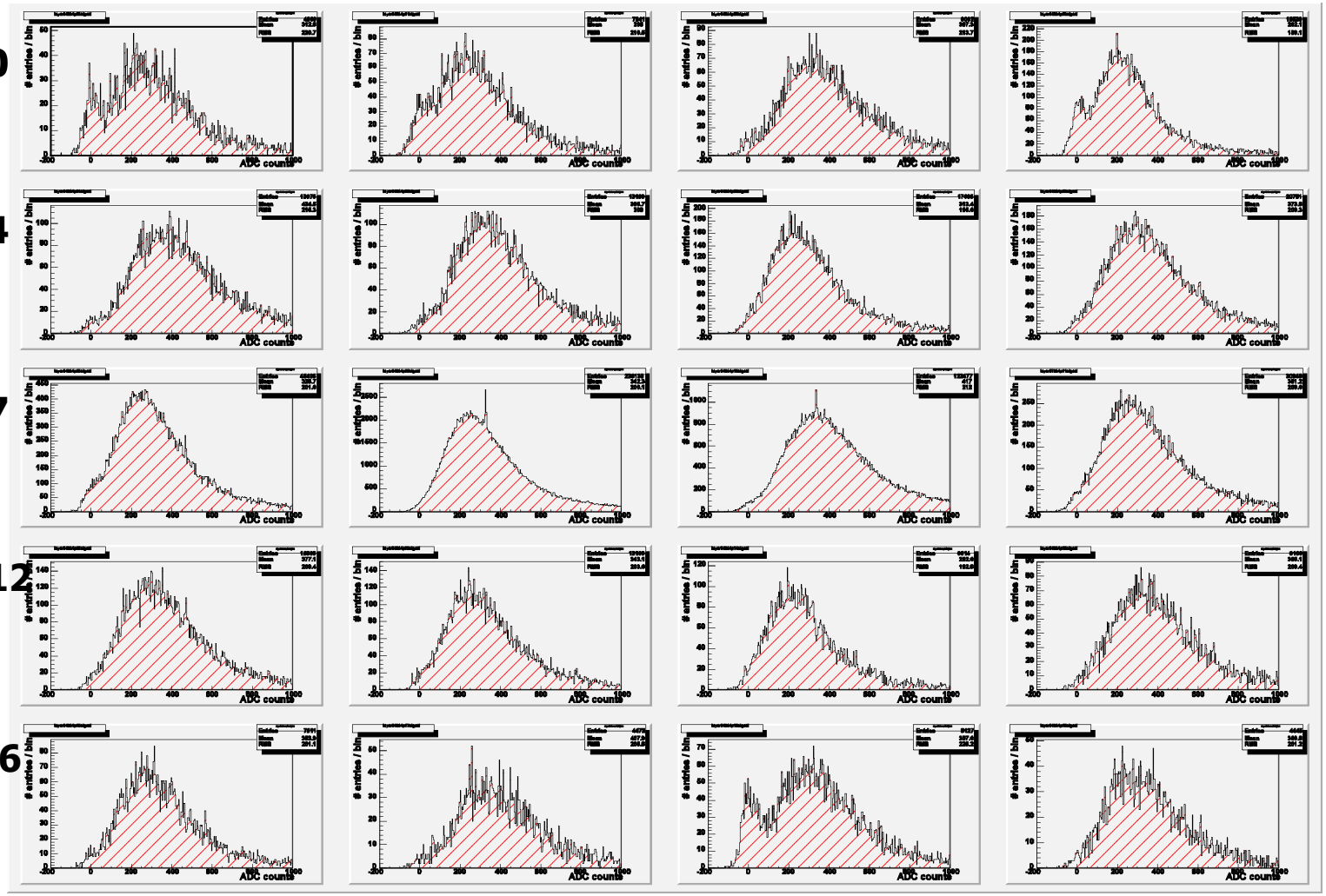
HCAL **TCMT**



Late shower in HCAL

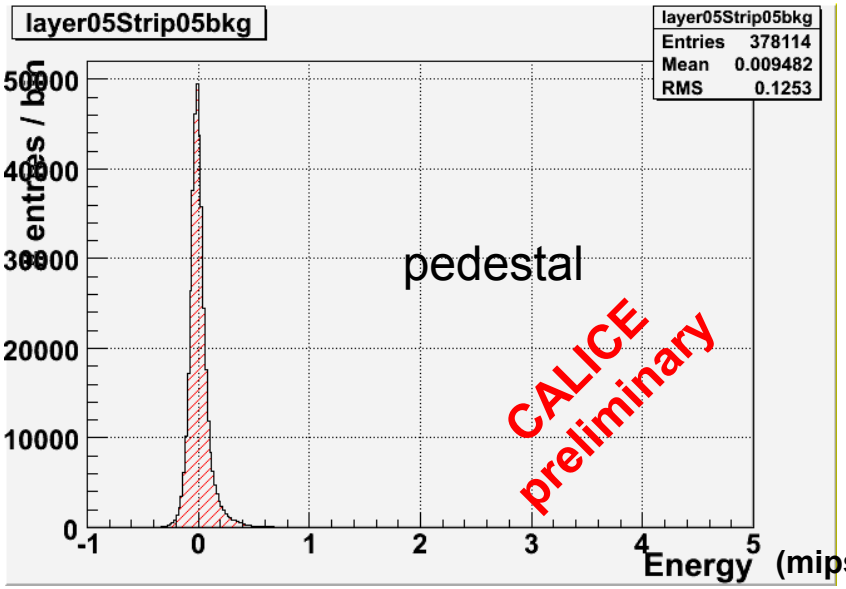
TCMT clearly needed to contain shower

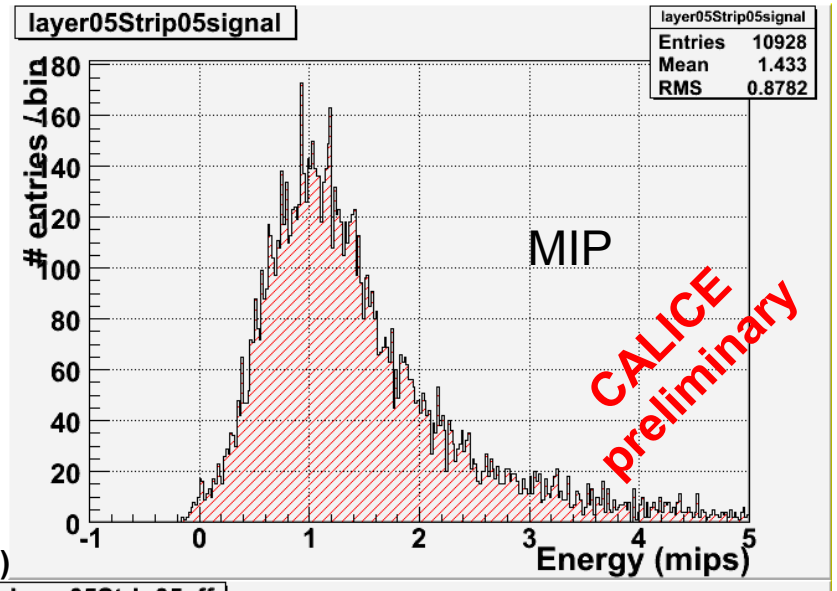
Cassette Response to Muons



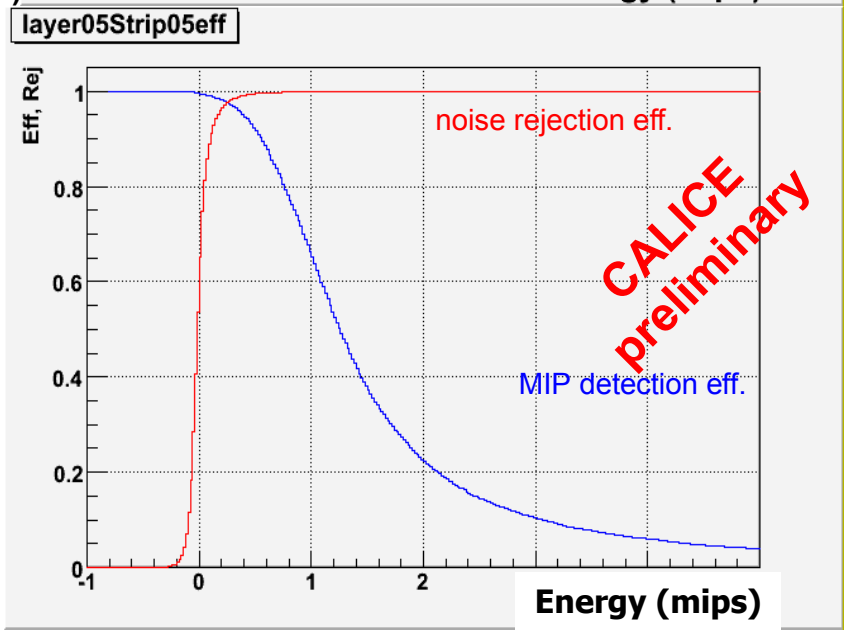
Profile more intense in center strips. Using 1m x 1m trigger plane.

Muon: Efficiency versus Noise

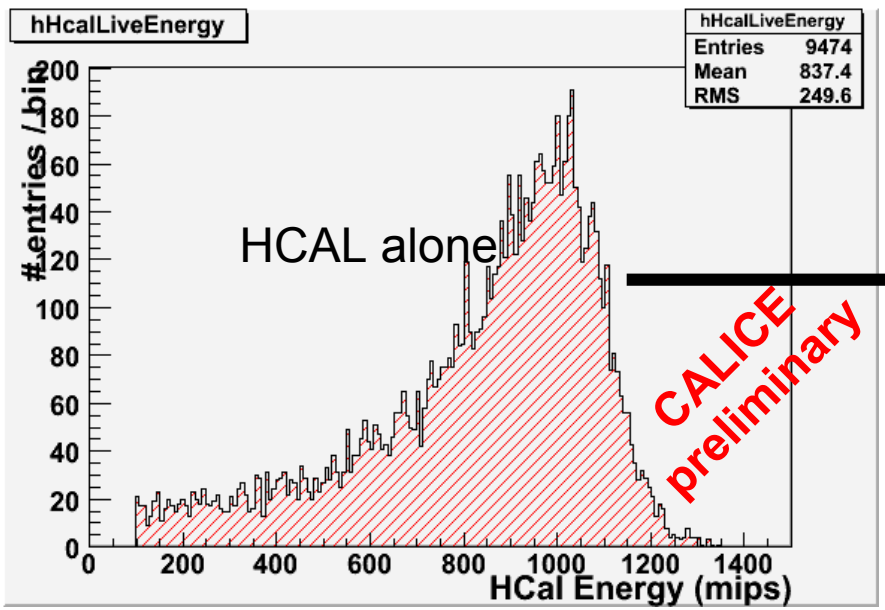


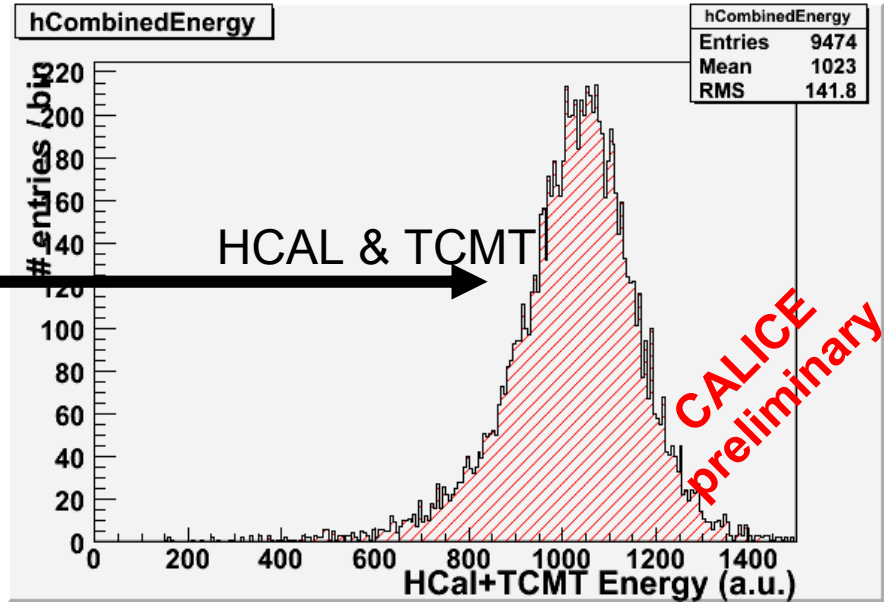


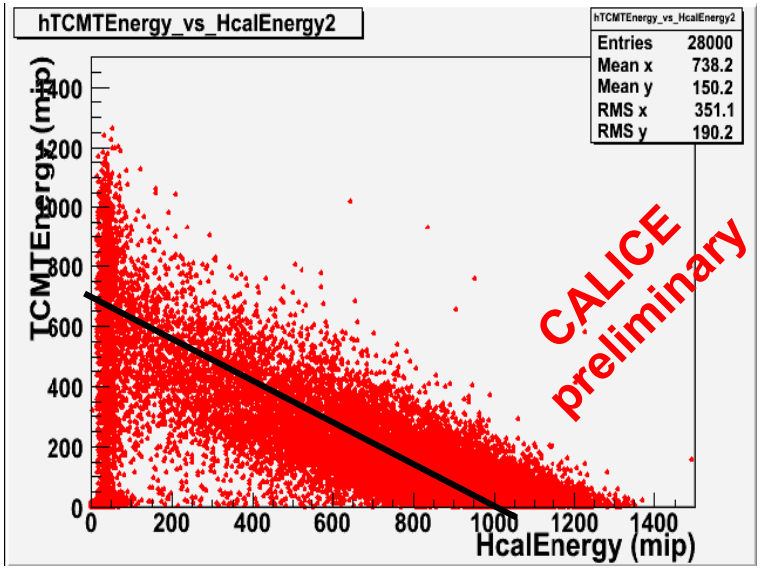
Preliminary:
With a threshold of ~ 0.25 mip
Efficiency ~ 97%
Rejection ~ 97%



Energy Response to 80GeV Pion Beam







- Different sampling fractions corrected with constant factor between HCAL and TCMT.
- The MIP-calibrated energy is summed on event-basis.
- Resolution improves by a factor of 2
- Very preliminary, done with online analysis package

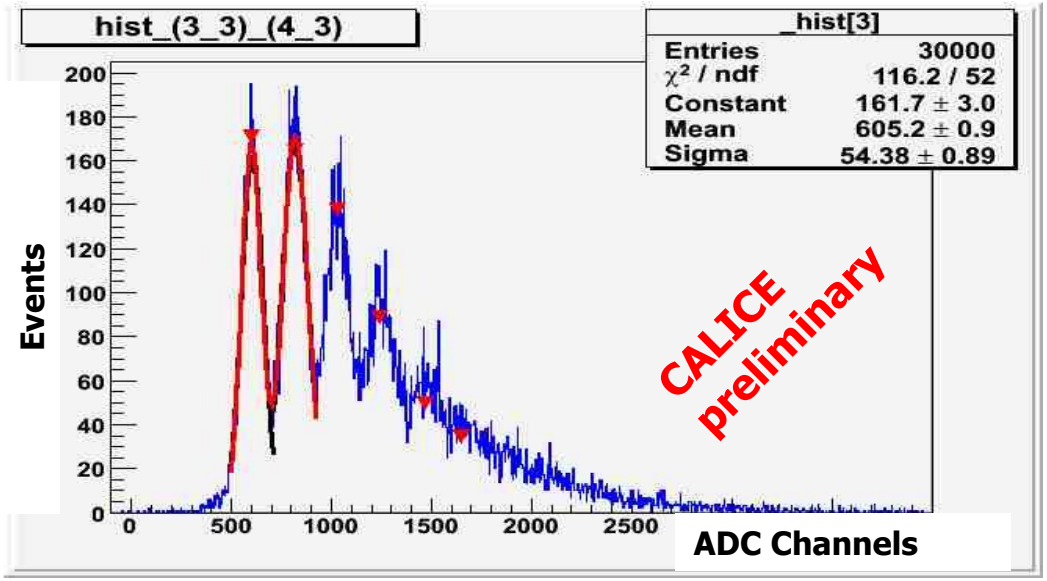
Plans for MTBF and CERN, possible improvements for MTBF

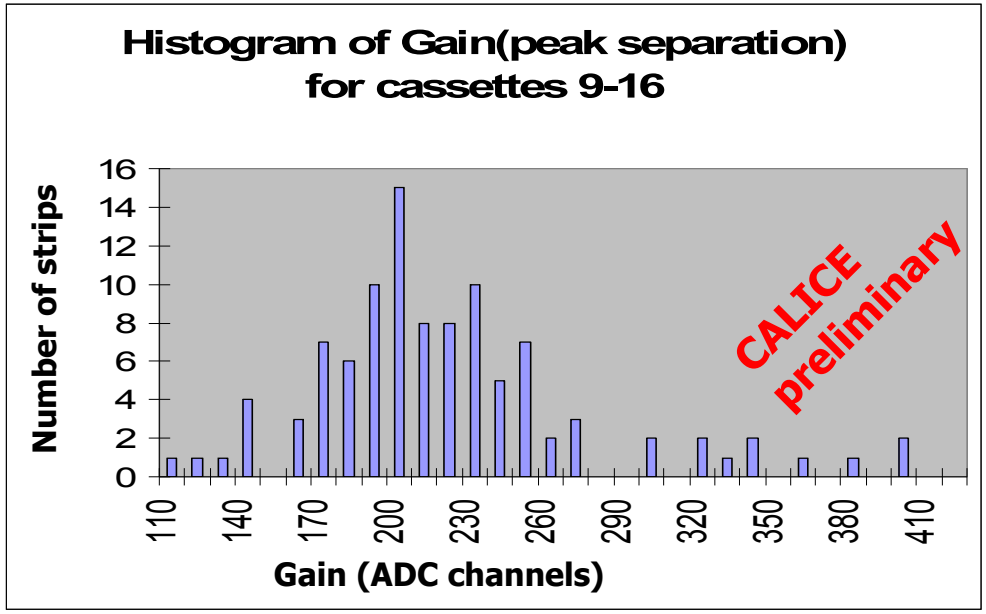
- **Plans for CERN:**
  - Calibrate with improved LED calibration system
  - More strip to strip uniformity data with muons
  - Combine data with fully instrumented HCAL and ECAL
  - Collect more statistics

- **Hoped for improvements at MTBF:**
  - Finish fixing the leaky roof
  - Higher rate for Muons
  - "Cleaner" power supply
  - Better Environmental Control

CALICE TCMT Plans

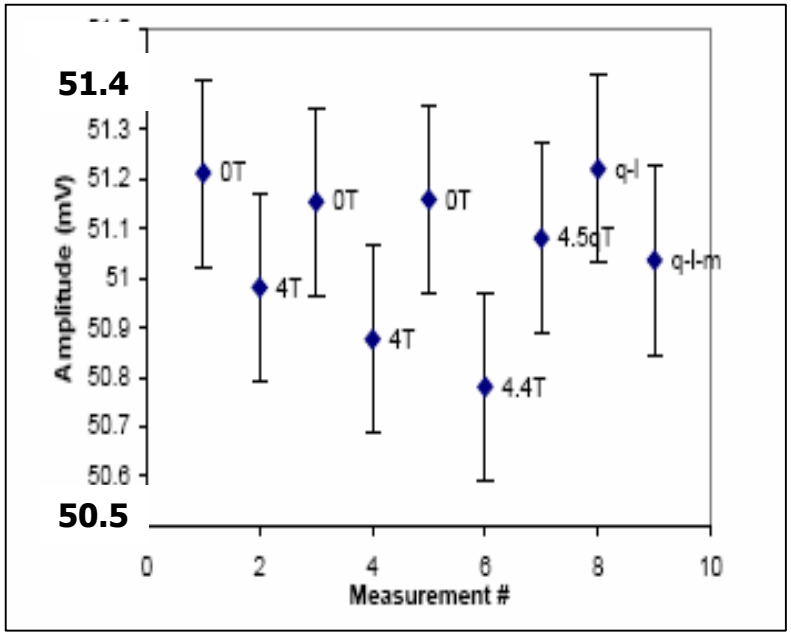
- **Continue Data Analysis**
  - Currently focusing on stability of peds/gains
  - Calibrate in terms of mips & PEs
  - Ultimately: study shower shape in terms of hits & energy
- **Additional CALICE running**
  - Proposal for summer 2007 run at CERN
  - MTBF thereafter
  - HCAL & TCMT infrastructure available to test other technologies
- **Cassettes at SiDet for Calibration LED Upgrade**





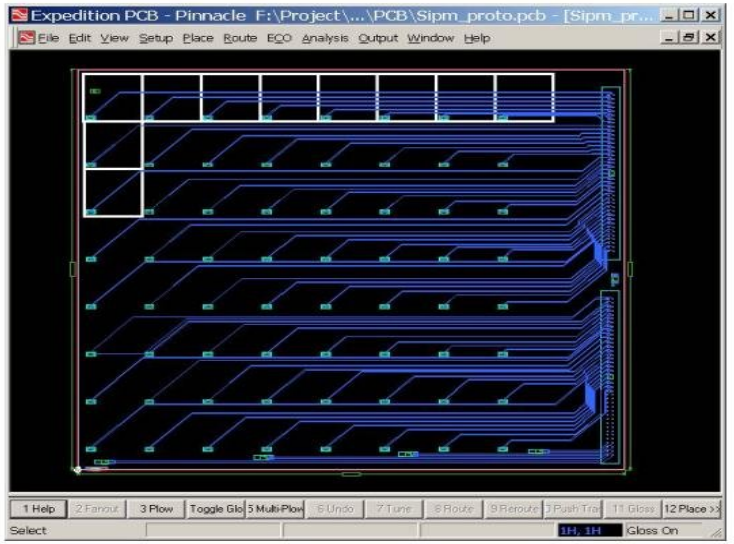
Comments on Scintillator/SiPM for muon detection

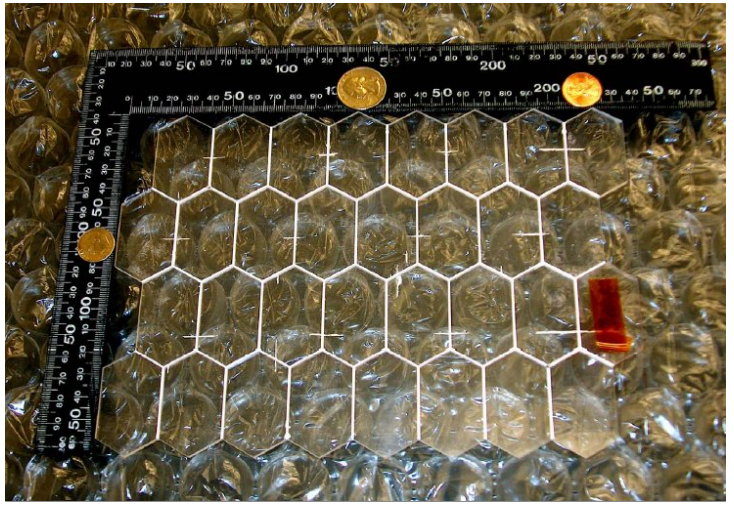
- **Scintillator**
  - **Extruded scintillator offers great deal of flexibility wrt size and length.**
  - **NICADD/Fermilab extrusion facility**
    - **Excellent R&D capabilities**
    - **Production capabilities**
  - **Uniformity of response along strip acceptable and can be "tuned"**
- **Insensitivity of SiPM to magnetic field eases construction**
- **Beam data at MTBF and CERN show**
  - **Good Efficiency**
  - **Good Rejection**
- **All-in-all a technology worth investigating**



Plans for SiPM based muon and calorimeter detector development

- **Continue Scintillator/SiPM Prototyping**
  - Integration of scintillator/SiPM/ASIC with direct coupling
  - LCDRD proposal submitted: NIU/Colorado & Fermilab as collaborator
- **Initiate Muon Prototype with SiPM**
  - Construction of muon prototype plane using extruded scintillator and SiPMs
  - LCDRD Proposal submitted: Wayne State/Indiana/Notre Dame/NIU & Fermilab as collaborator
  - To be tested at MTBF





Summary

- The CALICE TCMT behaves as expected, analysis underway
- SiPMs show good potential for calorimetry and muon detection
- Looking forward to more data at CERN and MTBF

Details of TCMT Simulation

- **Sidaug05-tcmt has**
  - **Non-projective 5x5 mm² ECAL**
  - **20 mm SS and 10x10 mm² Scintillator HCAL**
  - **SS and 30x30 mm² Scintillator TCMT (G. Lima)**
- **The tail catcher has:**
  - **48 layers of 20 mm SS, the thickness of SS in the TCMT is the same as the HCAL**
  - **5 mm scintillator**
  - **3 mm G10**

MTBF Pion and Muon Runs