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

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Outline

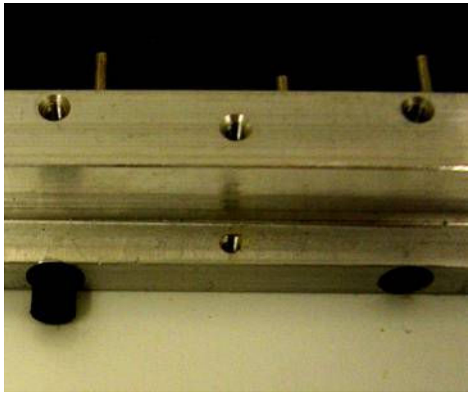
- **The CALICE Tail-Catcher Muon-Tracker**
  - **Goals:**
    - **Prototype ILC muon detector using SiPMs**
    - **Correct for leakage due to thin calorimeters**
  - **Test Beam needed to:**
    - **Study end of hadronic shower & validate simulations**
    - **Understand & address impact of coil**
    - **Understand TCMT in PFA framework**
    - **Achieve good μ ID and control fake rates**
- **Preliminary Results from CERN**
- **Energy resolution as a function of calorimeter depth and improvements due to post coil sampling.**

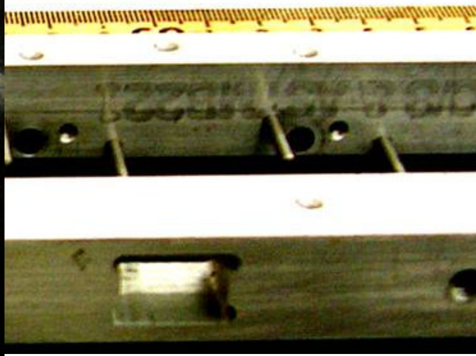
CALICE Tail-Catcher Muon-Tracker Prototype

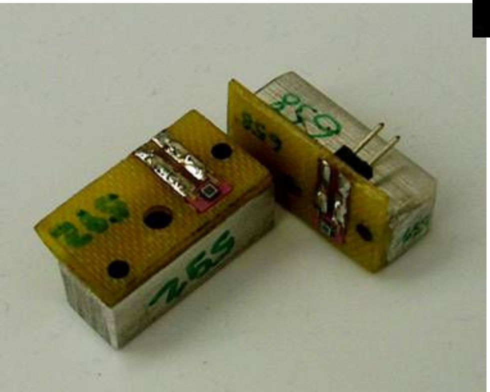
- **Mechanical Structure/Absorber**
  - "Fine" section (8 layers)
    - ~2 cm thick steel
  - "Coarse" section (8 layers)
    - ~10 cm thick steel
  - Engineered and assembled by Fermilab PPD
- **16 Cassettes:**
  - Extruded Scintillator Strips
    - 5mm thick
    - 5cm wide strips
    - Tyvek/VM2000 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)

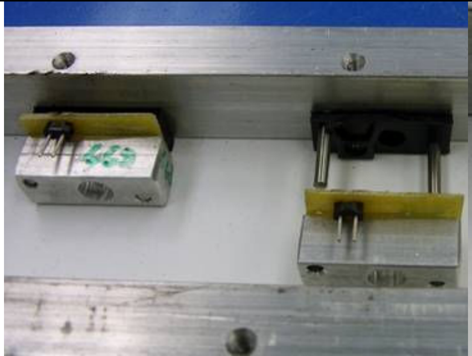
- **Dimensions:**
  - Length (along beam) - 142 cm
  - Height - 109 cm
- **Weight ~10 tons**

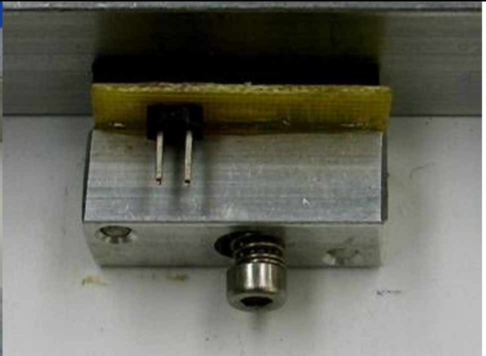
TCMT Cassette Components

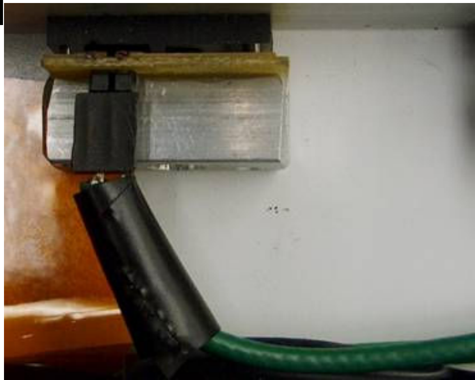








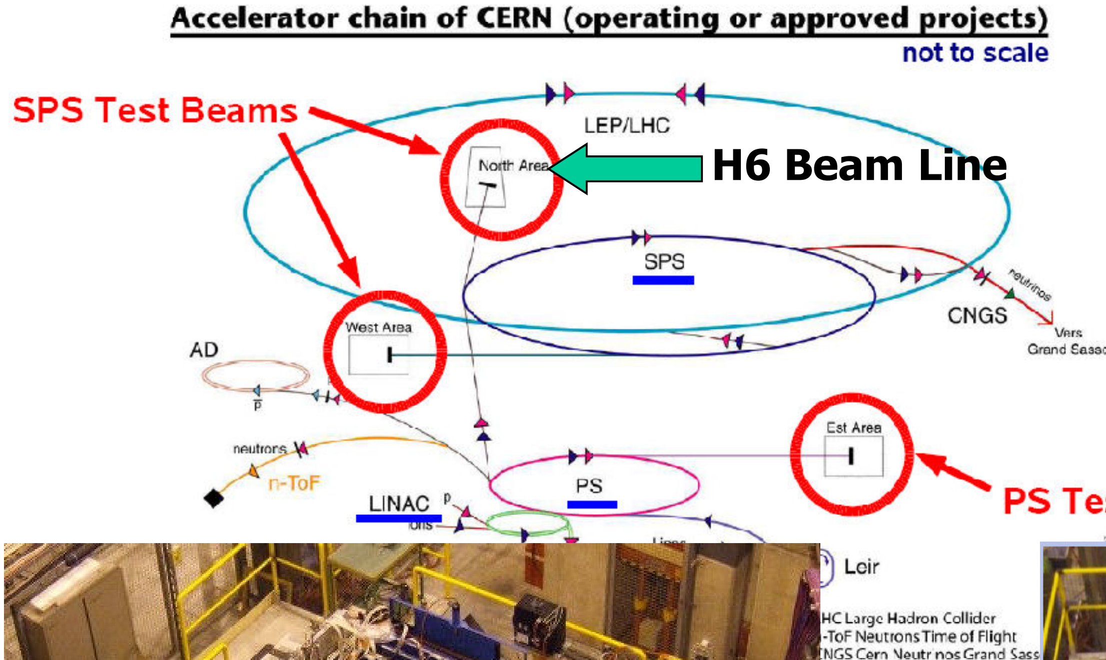




CALICE Calorimeters at Test Beam

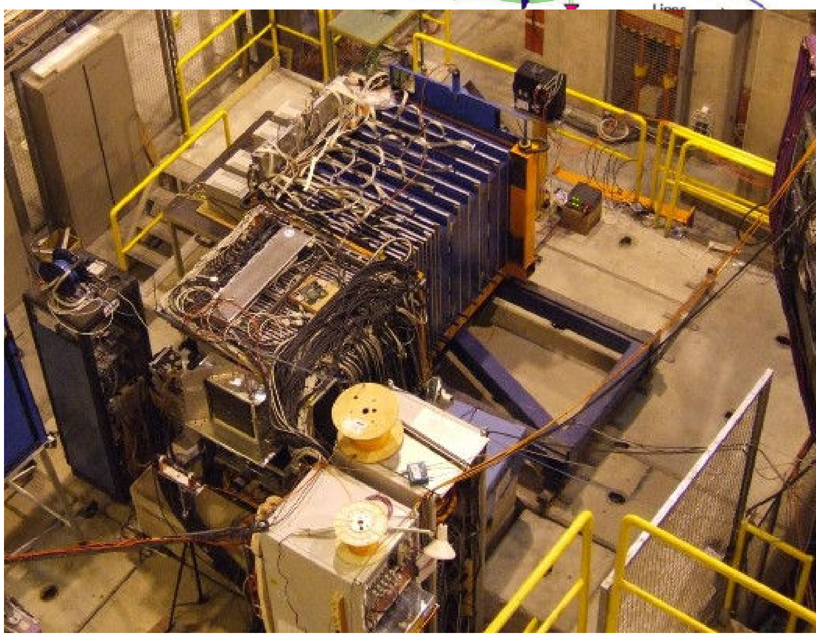
- **ECAL**
  - 30 active layers of silicon diode pad detectors with ~10,000 channels
  - tungsten absorbers with thickness of 1.4mm to 4.2mm
  - total thickness $24X_0$ radiation length
- **HCAL**
  - Up to 38 absorbers (30 used in 2006) – 2cm thick steel
  - Gaps instrumented with 0.4mm thick modules with high granularity core (3x3cm^2)
  - 4.5 interaction lengths
  - Rotating stage used for position and angle scans in 2007 run
  - 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
    - 3.5 Interaction lengths
    - No movable stage
- **CERN Test Beam Runs**
  - 2006 August/September and October/November (discussed here)
  - 2007 June to August (still under analysis)
- **FNAL Test Beam Runs**
  - 2008 April/May with SiW ECAL and September with Scintillator ECAL at Fermilab
  - 2009 May with Scintillator ECAL at Fermilab

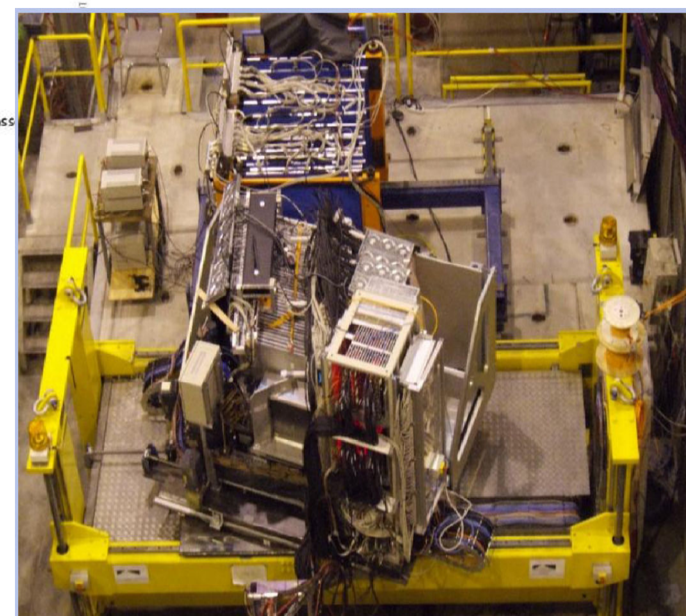
CALICE @ CERN Test Beam



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

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

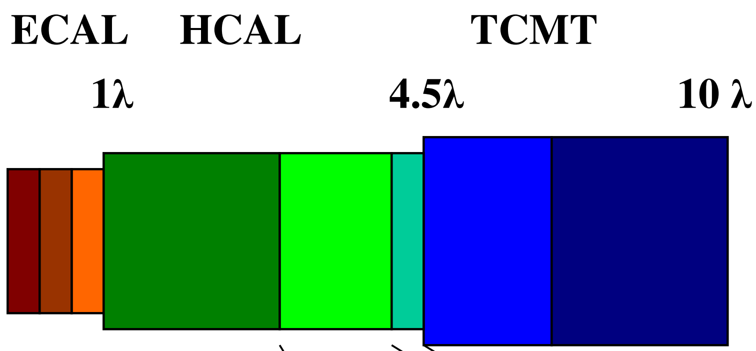




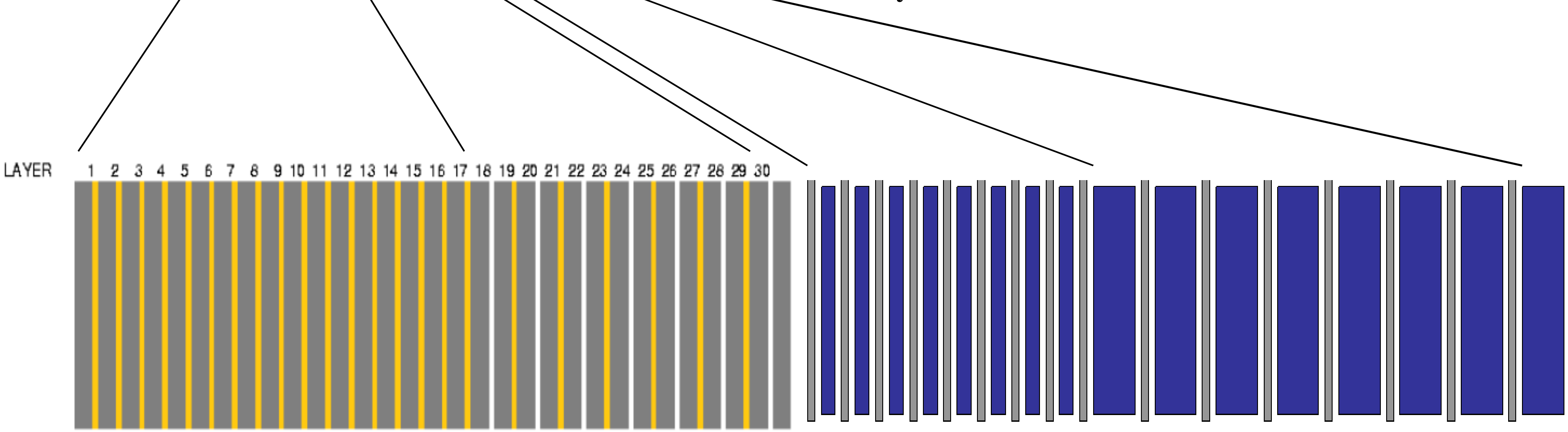
Current Analysis

- **The effect of TCMT and coil on leakage was studied**
- **Compared resolution of a calorimeter with a system with calorimeter, coil, and post coil sampling**
- **Used a subset of TCMT layers, leaving a gap equivalent to ~1.8 lambda to simulate magnetic coil**
- **Used CALICE October 2006 CERN data**

CALICE Configuration, Oct. 2006



AHCAL:
Active layers in yellow, absorber in gray, missing layer in white
17 active layers with 2cm absorber
12 absorber layers with active layer every other absorber
TCMT:
Active layers in gray, absorber in blue
First layer assigned last two 2cm absorber layers of AHCAL
8 layers with 2cm absorber
7 layers with 10cm absorber

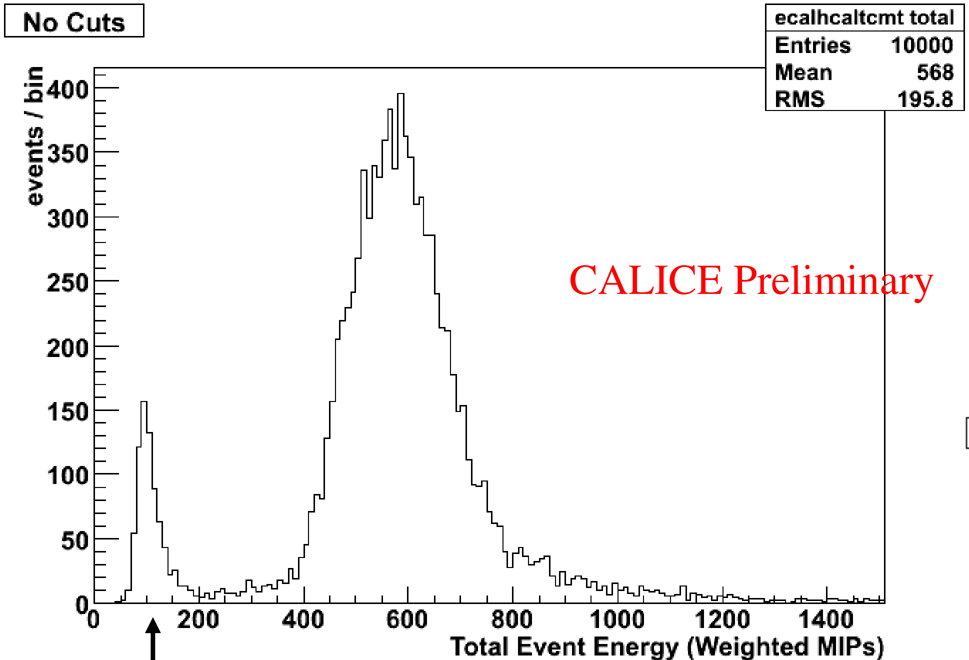


Would like to compare Energy Resolution of :
[ECAL + HCAL + n TCMT Layers]
Extended to:
[ECAL + HCAL + n TCMT Layers] + 1.8 λ gap + remaining layers of TCMT
(or same calorimeter configuration but post magnet gap sampled)

Conditions & Cuts

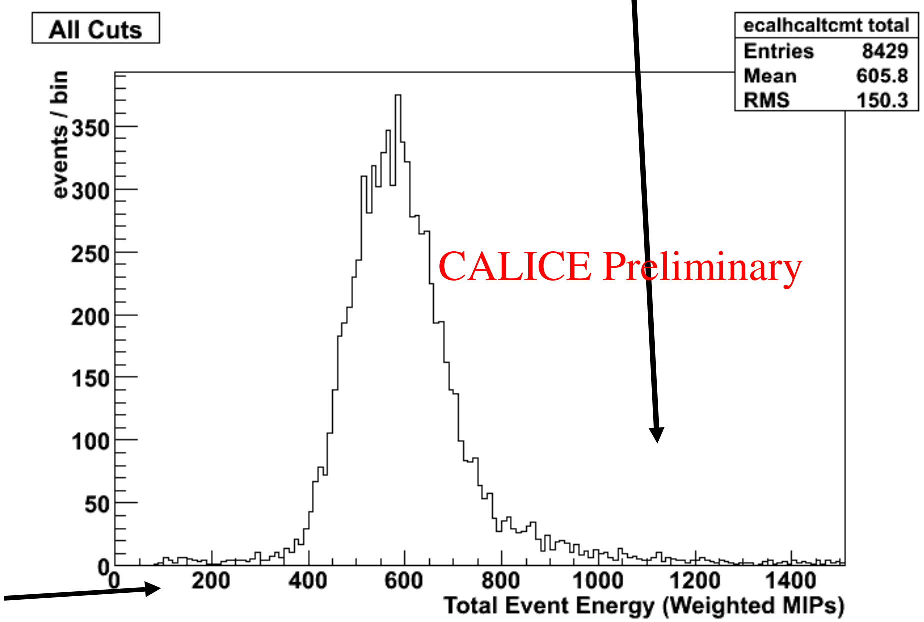
- **Conditions**
  - Saturation correction applied to correct for non-linear nature of Silicon photomultipliers
  - No temperature correction
  - Pion beams
  - Sampling weights
    - Derived using least squares minimization procedure for the resolution
    - Five to eight weights used depending on the configuration
- **Cuts**
  - 0.5 MIP threshold
  - electrons rejected with Cherenkov
  - Double particle events rejected
  - Muons rejected by:
    - 1m x 1m veto counter behind TCMT
    - Energy sum cut (E of hits>10MIPs/total E < 0.02)
    - Cut based on Low end tail -> MIP

Effect of Cuts to Clean Pion Sample
Full Detector



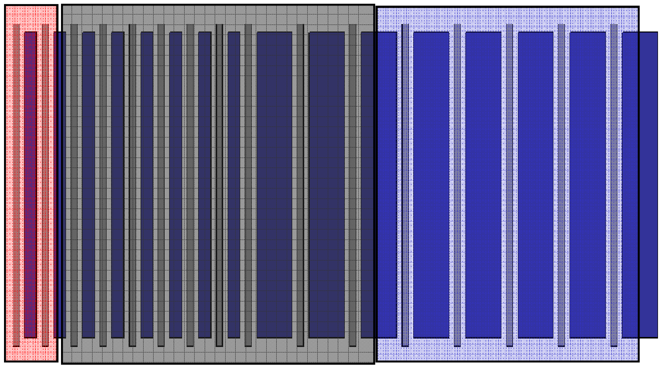
High energy tail due to non-optimized weights (used physical sf's)

Low energy tail due to electrons and muons



Cleaned up by using cherenkov and muon ID cuts

Allocation of TCMT Layers



Example Configuration 2:
2 layers to calorimeter
9 layers for coil
5 layers post coil sampling

Example Configuration 8:
Closest to SiD depth
8 layers to calorimeter
4 layers for coil
4 layers post coil sampling

Layers of TCMT Added to Calorimeter	Sim. Coil Thickness (cm)	Sim. Coil Thickness (interaction lengths)	End of coil/ First Layer Post-coil Sample	Layers in Post-coil Sample
0	29.2	1.78	10	6
1	26.0	1.59	10	6
2	34.0	2.08	11	5
3	32.0	1.96	11	5
4	30.0	1.83	11	5
5	28.0	1.71	11	5
6	26.0	1.59	11	5
7	34.0	2.08	12	4
8	32.0	1.96	12	4
9	30.0	1.83	12	4
10	30.0	1.83	13	3
11	30.0	1.83	14	2
12	30.0	1.83	15	1

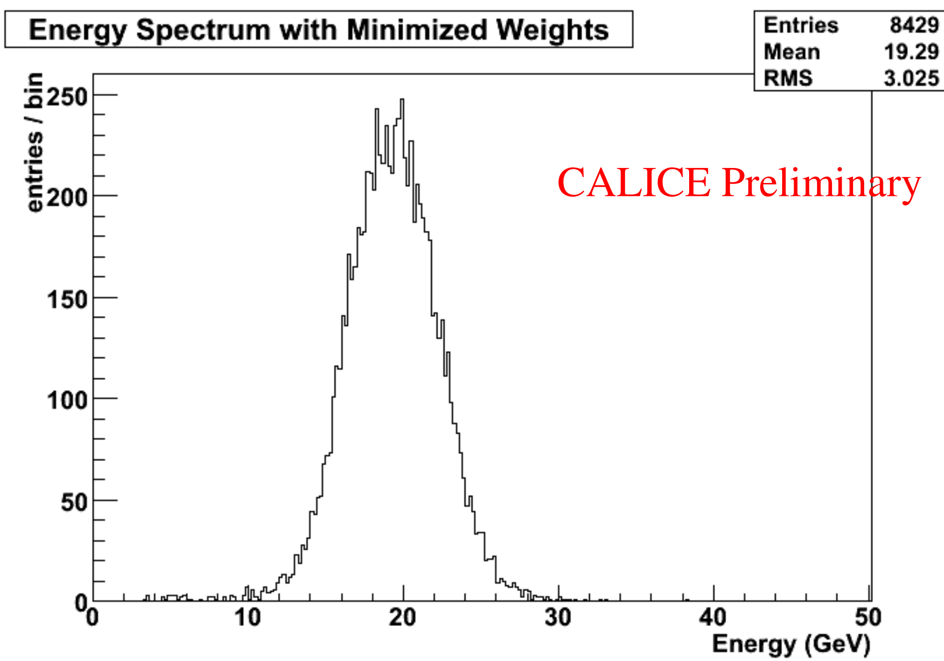
Minimization of Weights

Resolution was minimized such that:

$$\chi^2 = (E_{beam} - \sum_{i=1}^{N} \alpha_i E_i)^2$$

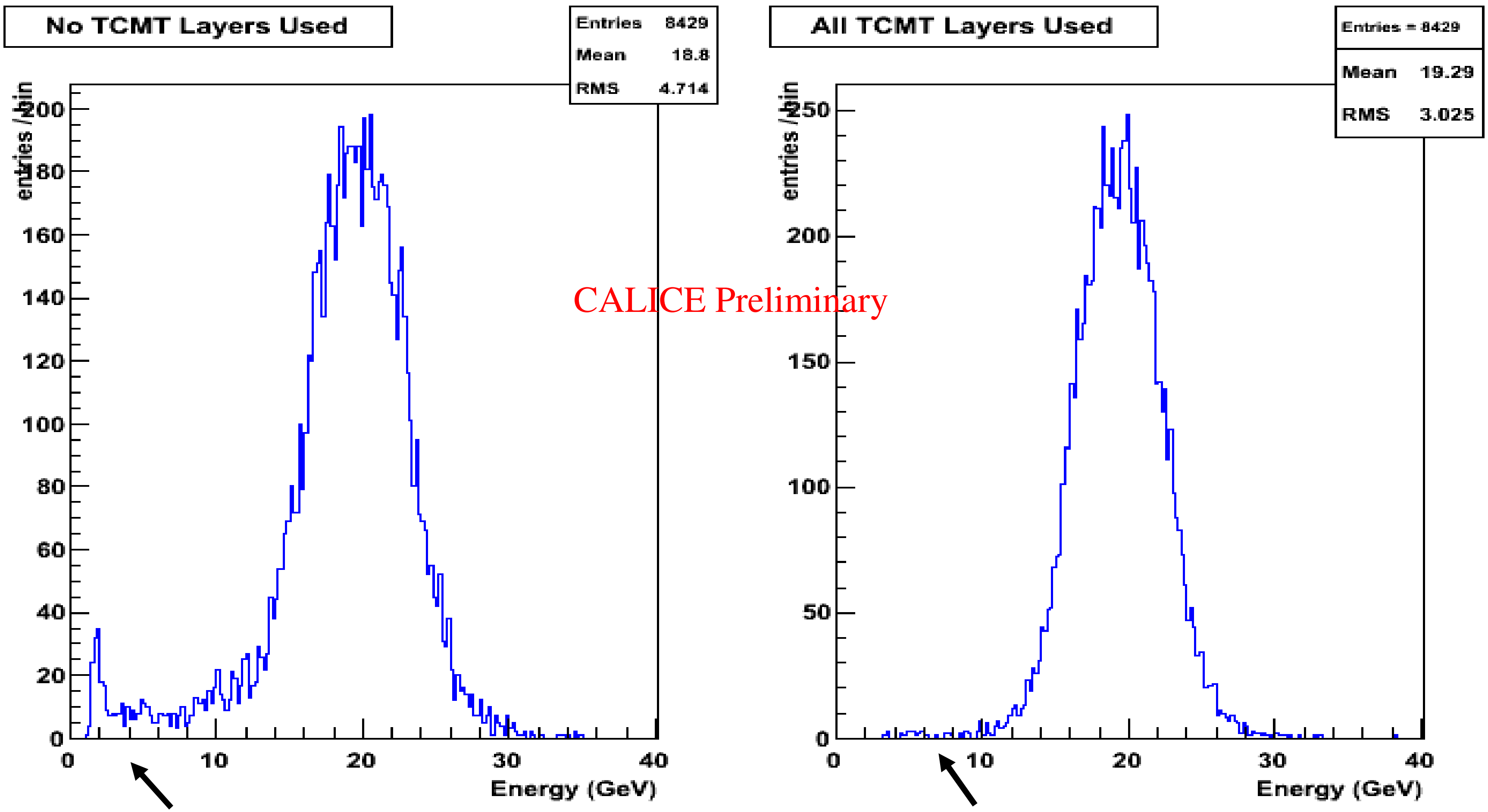
A unique set of weights was determined for each configuration.

coil						TCMT	TCMT	TCMT
	ECAL	ECAL	ECAL	HCAL	HCAL	Thin	Thick	post-
Config.	1	2	3	1	2	XCAL	XCAL	coil
0	0.0089	0.0091	0.0133	0.0335	0.0811	0.0000	0.0000	0.2057
1	0.0090	0.0091	0.0132	0.0334	0.0655	0.1604	0.0000	0.1810
2	0.0089	0.0091	0.0132	0.0334	0.0631	0.1088	0.0000	0.2521
3	0.0089	0.0091	0.0132	0.0334	0.0622	0.0809	0.0000	0.2421
4	0.0089	0.0091	0.0132	0.0334	0.0615	0.0709	0.0000	0.2369
5	0.0088	0.0091	0.0132	0.0333	0.0616	0.0624	0.0000	0.2306
6	0.0088	0.0091	0.0132	0.0333	0.0613	0.0575	0.0000	0.2238
7	0.0088	0.0091	0.0132	0.0332	0.0615	0.0547	0.0000	0.2981
8	0.0088	0.0091	0.0132	0.0331	0.0613	0.0516	0.0000	0.2903
9	0.0090	0.0092	0.0134	0.0335	0.0628	0.0466	0.0000	0.1070
10	0.0089	0.0091	0.0133	0.0331	0.0613	0.0428	0.0980	0.2993
11	0.0089	0.0091	0.0133	0.0332	0.0614	0.0410	0.1042	0.3242
12	0.0089	0.0091	0.0133	0.0333	0.0616	0.0409	0.1021	0.4918



Used 20GeV weights for all runs
They do not vary much for 10-80 GeV

Energy Spectrum without and with TCMT

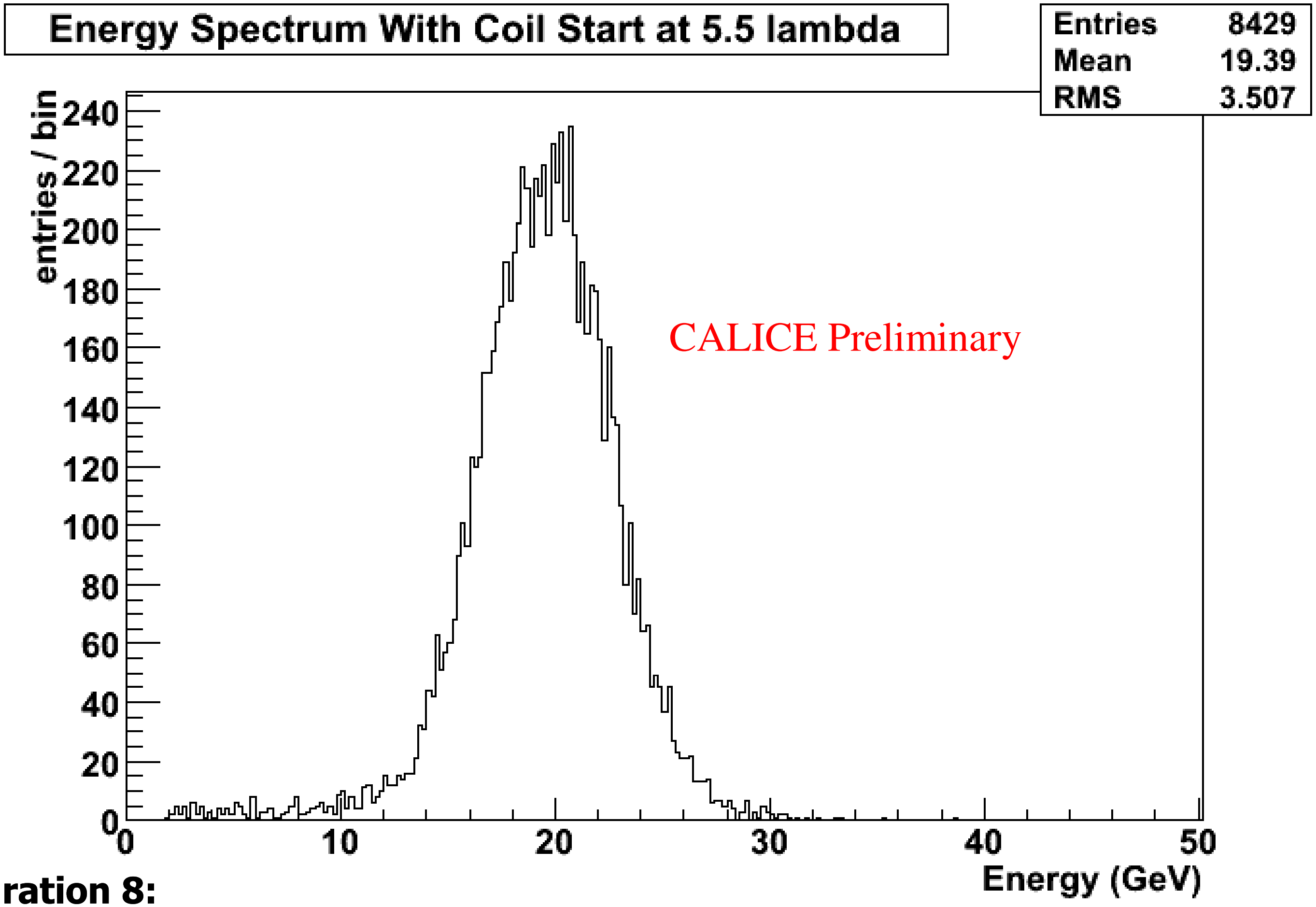


Low energy tail due to uncontained events

Tail greatly reduced when using full TCMT

Energy resolution calculated with Eres = statistical RMS/statistical Mean
This is necessary to take into account the low end tail

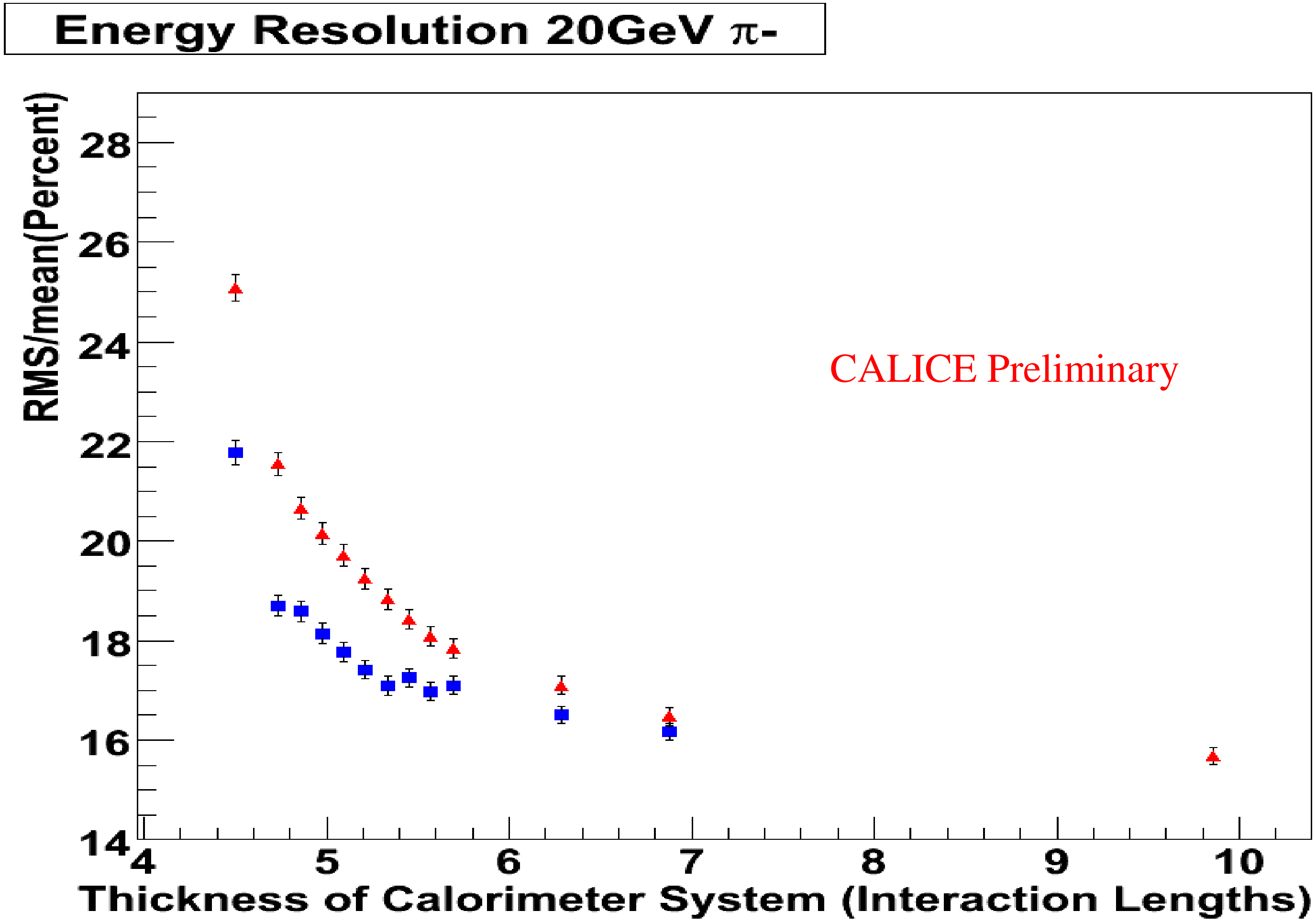
Energy Spectrum With Coil and Post Coil Sampling



Example Configuration 8:
<u>Closest to SiD depth</u>
8 TCMT layers added to calorimeter
4 layers for coil
4 layers post coil sampling

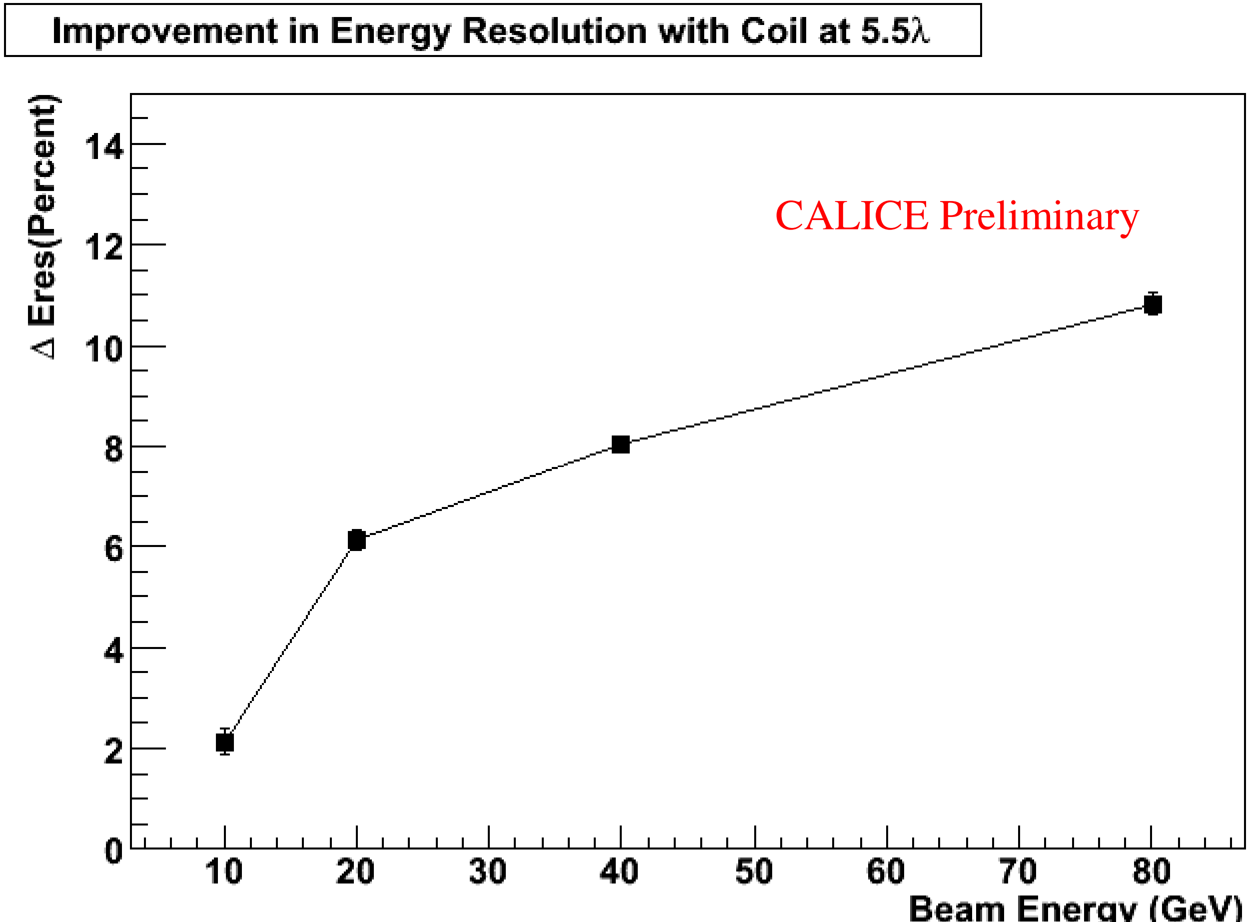
12 out of 16 TCMT layers used

Energy Resolution as a Function of Calorimeter Depth



Red Triangles: Calorimeter
Blue Squares: Calorimeter+coil+post coil sample

Improvement in Energy Resolution as a Function of Beam Energy



Coil at 5.5λ , the proposed thickness of the SID calorimeter plus post-coil sampling

*** Δ Eres= [Eres(w/coil) – Eres(cal. only)] / Eres(cal. only)**

Summary

- Detector performed well
- Analysis is underway and progressing
- Post coil sampling improves resolution for coil position from 4.5 to 6 λ.
- At a depth of 5.5λ (the design thickness of the SID calorimeter), a tail-catcher improves energy resolution by about 6% for 20 GeV pions and 10% for 80 GeV pions.
- SiPMs show good potential for calorimetry