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

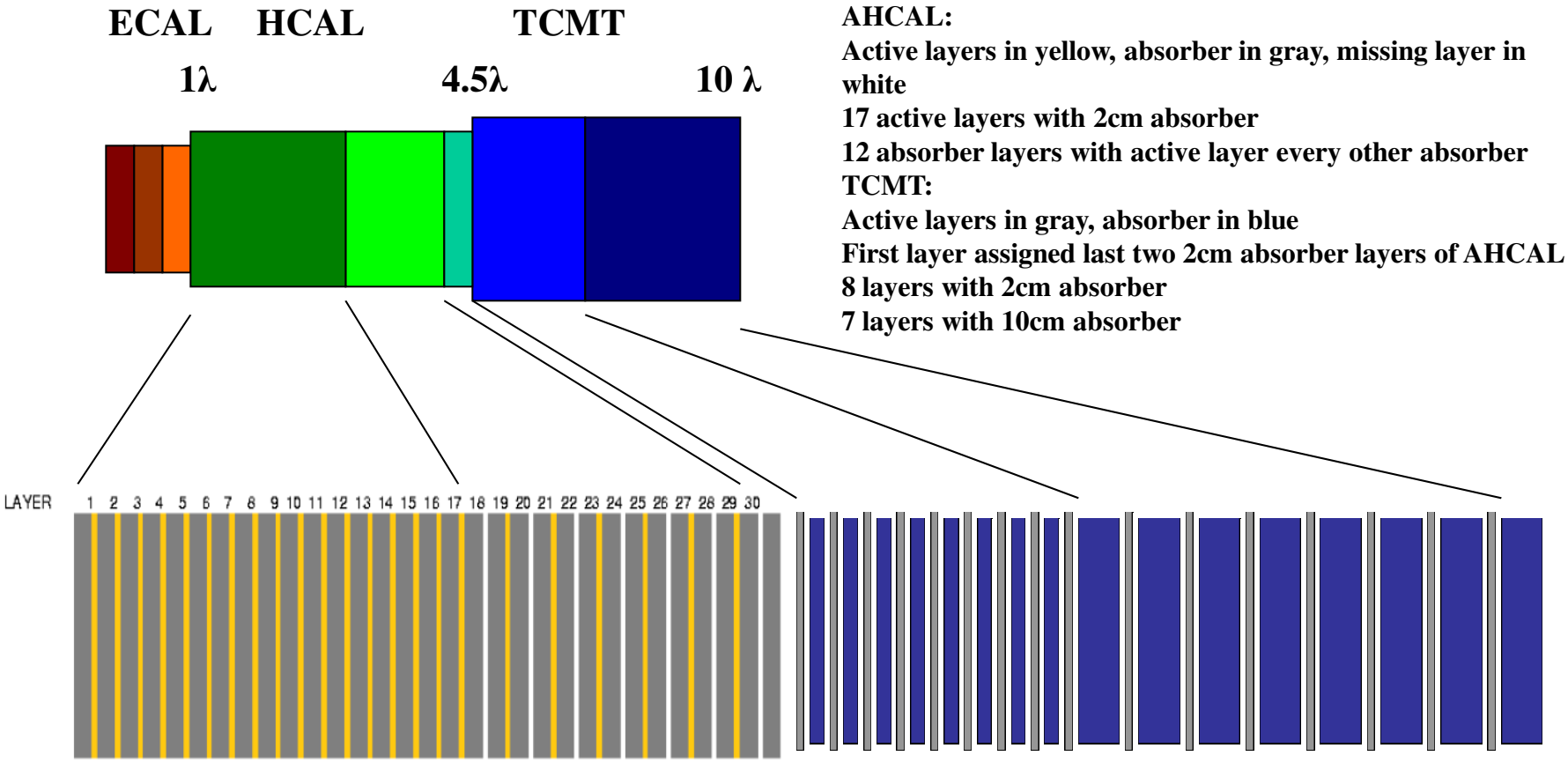
Kurt Francis
NICADD/Northern Illinois University
For
CALICE Collaboration

AHCAL MAIN MEETING
DESY, Hamburg
December 10, 2009

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



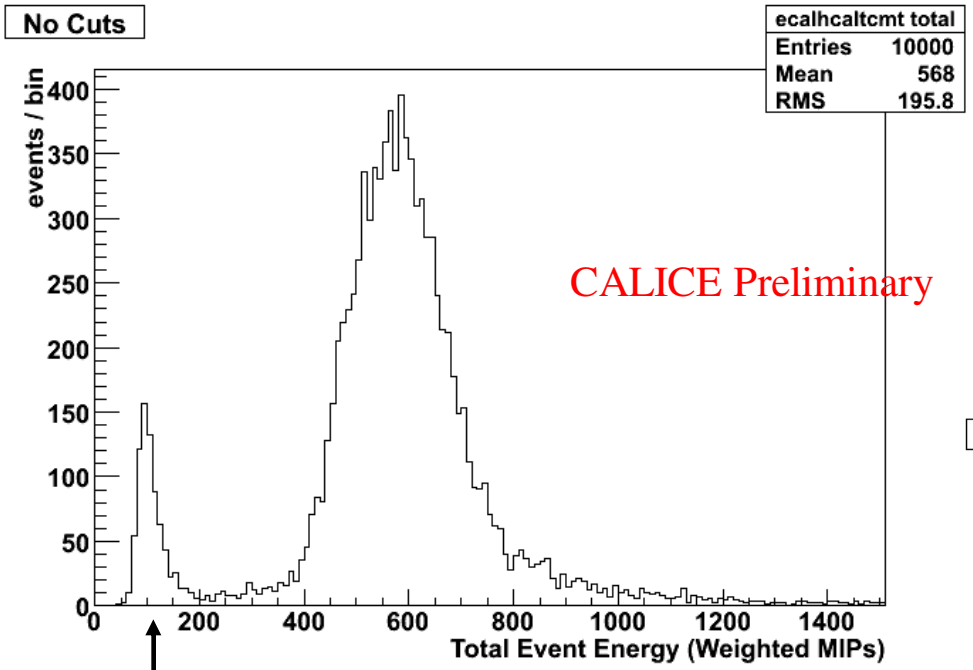
AHCAL:
Active layers in yellow, absorber in gray, missing layer in white
17 active layers with 2cm absorber
12 absorber layers with active layer every other absorber
TCMT:
Active layers in gray, absorber in blue
First layer assigned last two 2cm absorber layers of AHCAL
8 layers with 2cm absorber
7 layers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

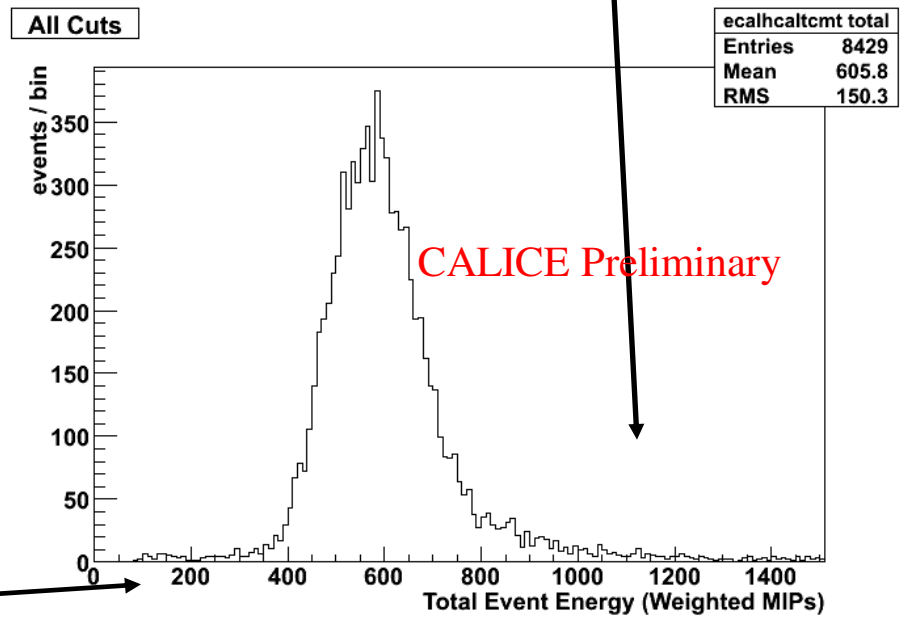
- **Conditions**
  - Saturation correction applied to correct for non-linear nature of Silicon photomultipliers
  - No temperature correction
  - Pion beams
  - Sampling weights
    - Derived using least squares minimization procedure for the resolution
    - Five to eight weights used depending on the 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)
      - pion detection efficiency of approximately 95% and a muon rejection of approximately 80%.
    - Cut based on Low end tail -> MIP

Effect of Cuts to Clean Pion Sample
Full Detector



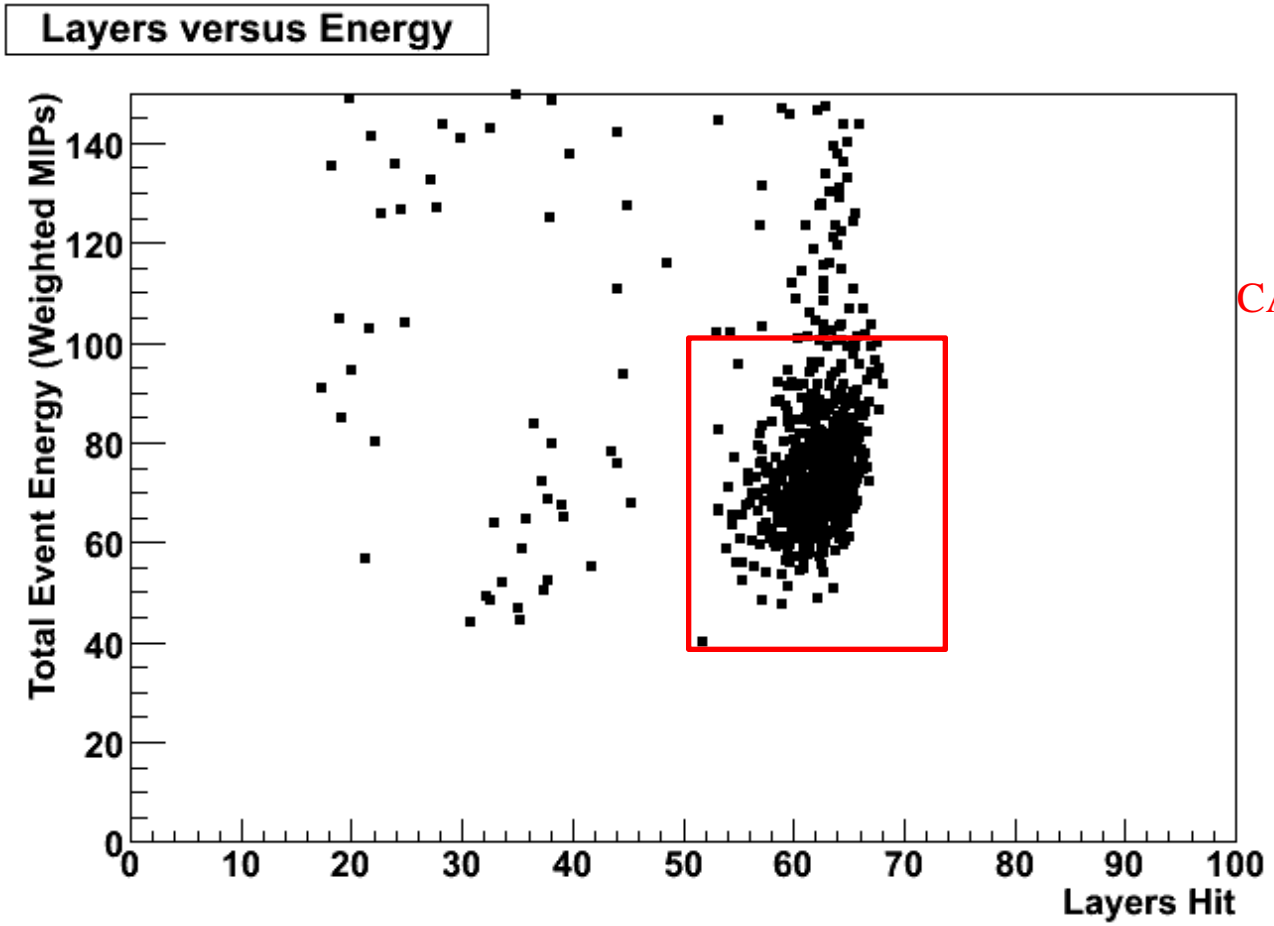
High energy tail due to non-optimized weights (used physical sf's)

Low energy tail due to electrons and muons



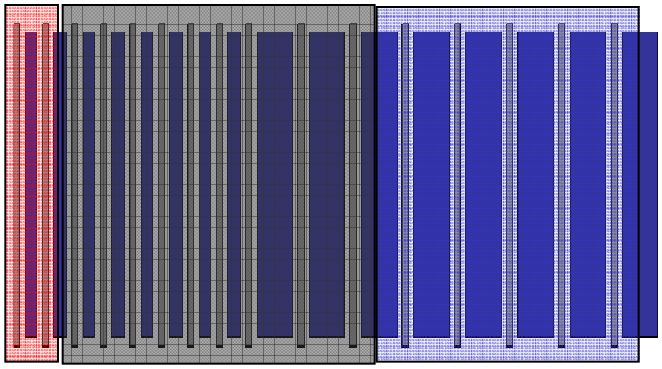
Cleaned up by using cherenkov and muon ID cuts

Cut Based on Number of Layers and Event Energy to Indentify Muons



CALICE Preliminary

Allocation of TCMT Layers



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

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

# TCMT Layers Added to Calorimeter (Thickness, λ)	Sim. Coil Thickness (cm)	Sim. Coil Thickness (λ)	End of coil/ First Layer Post-coil Sample	Layers in Post-coil Sample
0 (4.54)	29.2	1.78	10	6 (3.74)
1 (4.79)	26.0	1.59	10	6 (3.74)
2 (4.90)	34.0	2.08	11	5 (3.12)
3 (5.02)	32.0	1.96	11	5 (3.12)
4 (5.14)	30.0	1.83	11	5 (3.12)
5 (5.25)	28.0	1.71	11	5 (3.12)
6 (5.37)	26.0	1.59	11	5 (3.12)
7 (5.49)	34.0	2.08	12	4 (2.49)
8 (5.60)	32.0	1.96	12	4 (2.49)
9 (5.72)	30.0	1.83	12	4 (2.49)
10 (6.34)	30.0	1.83	13	3 (1.87)
11 (6.96)	30.0	1.83	14	2 (1.25)
12 (7.59)	30.0	1.83	15	1 (0.62)

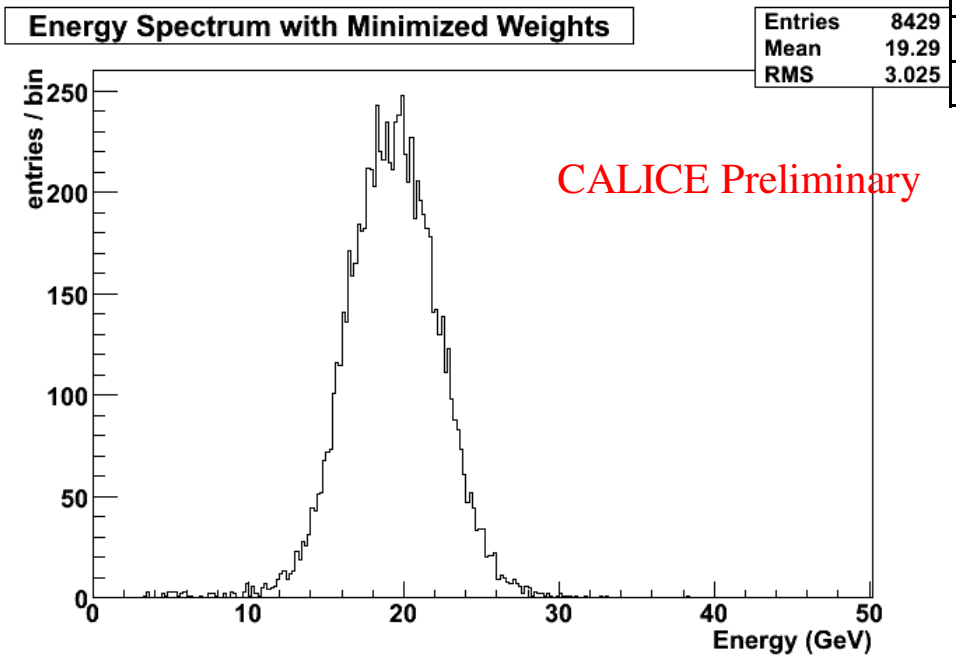
Minimization of Weights

Resolution was minimized such that:

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

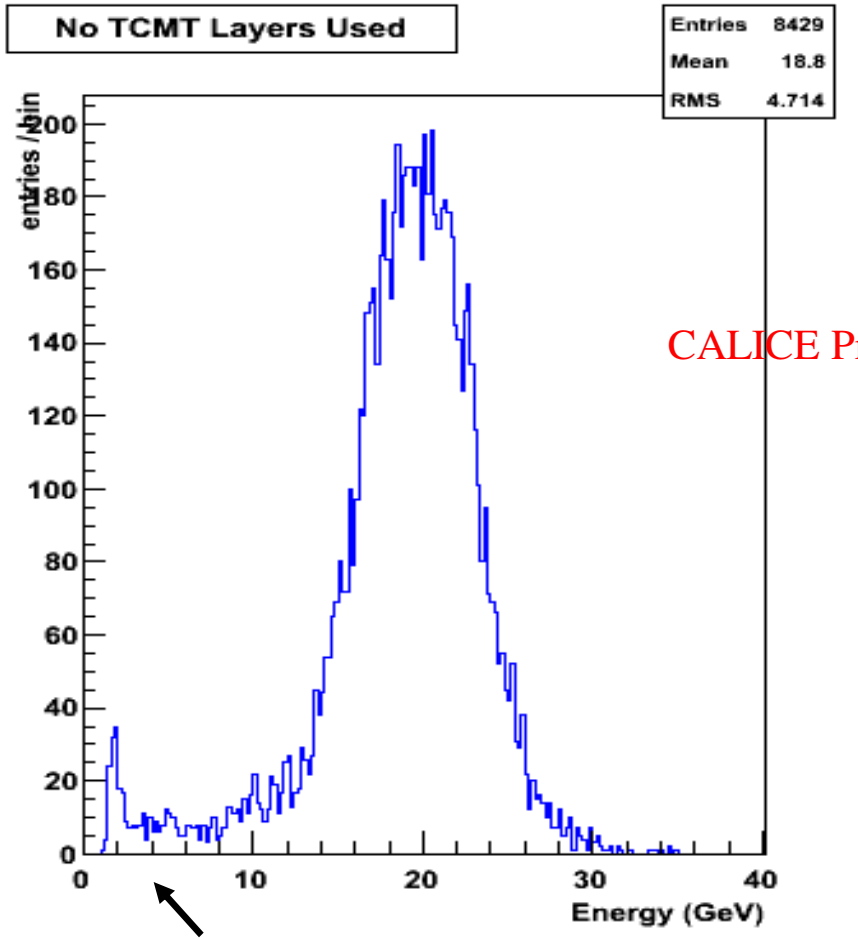
A unique set of weights was determined for each configuration.

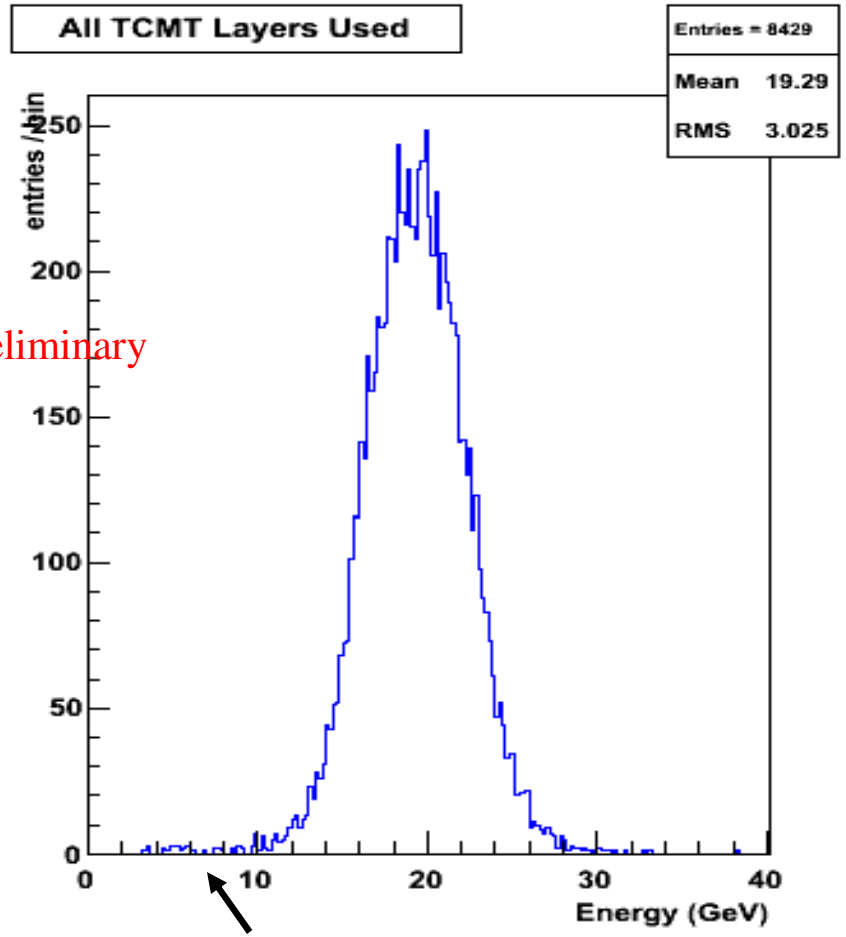
coil						TCMT	TCMT	TCMT
	ECAL	ECAL	ECAL	HCAL	HCAL	Thin	Thick	post-
Config.	1	2	3	1	2	XCAL	XCAL	coil
0	0.0089	0.0091	0.0133	0.0335	0.0811	0.0000	0.0000	0.2057
1	0.0090	0.0091	0.0132	0.0334	0.0655	0.1604	0.0000	0.1810
2	0.0089	0.0091	0.0132	0.0334	0.0631	0.1088	0.0000	0.2521
3	0.0089	0.0091	0.0132	0.0334	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





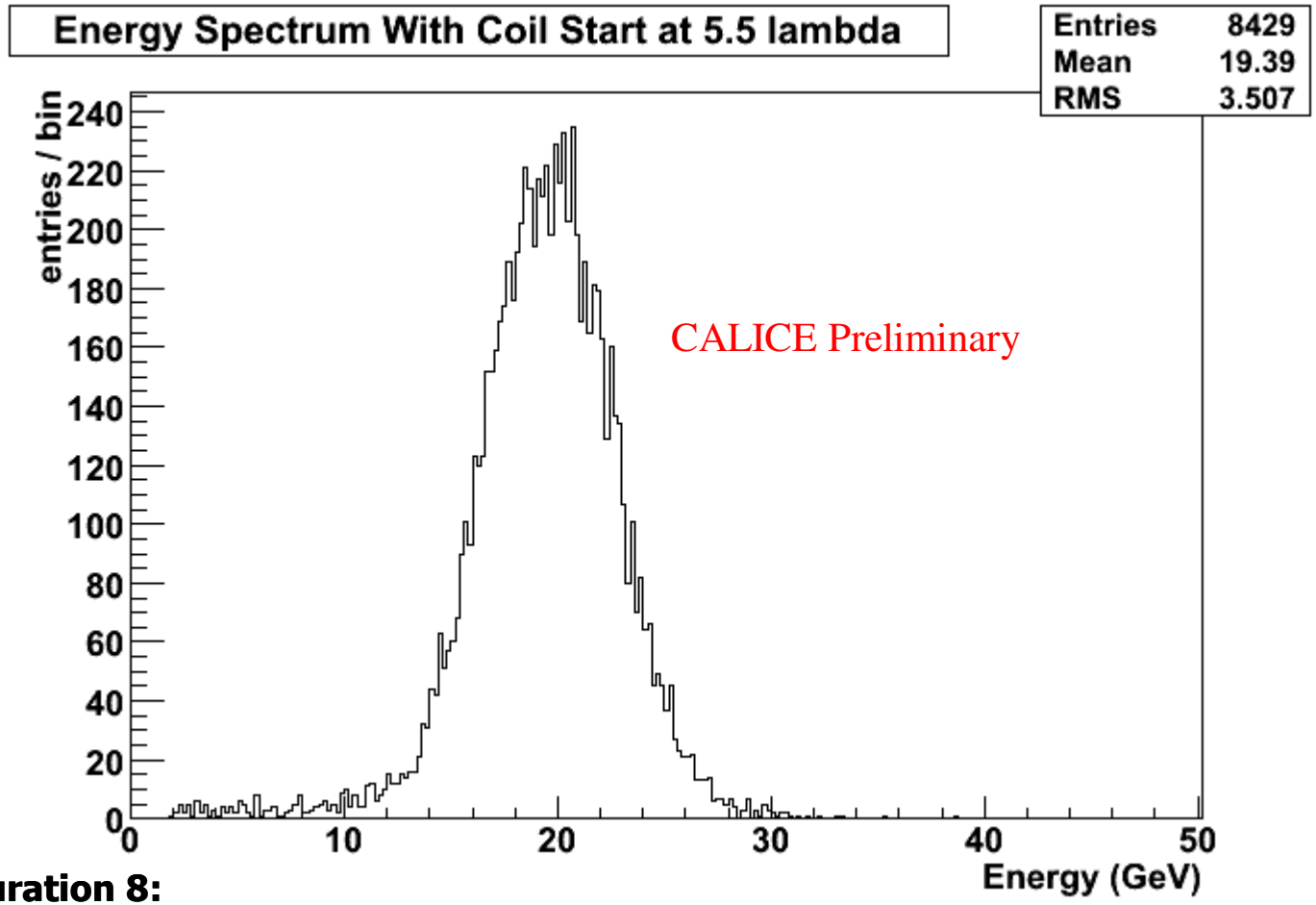
CALICE Preliminary

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

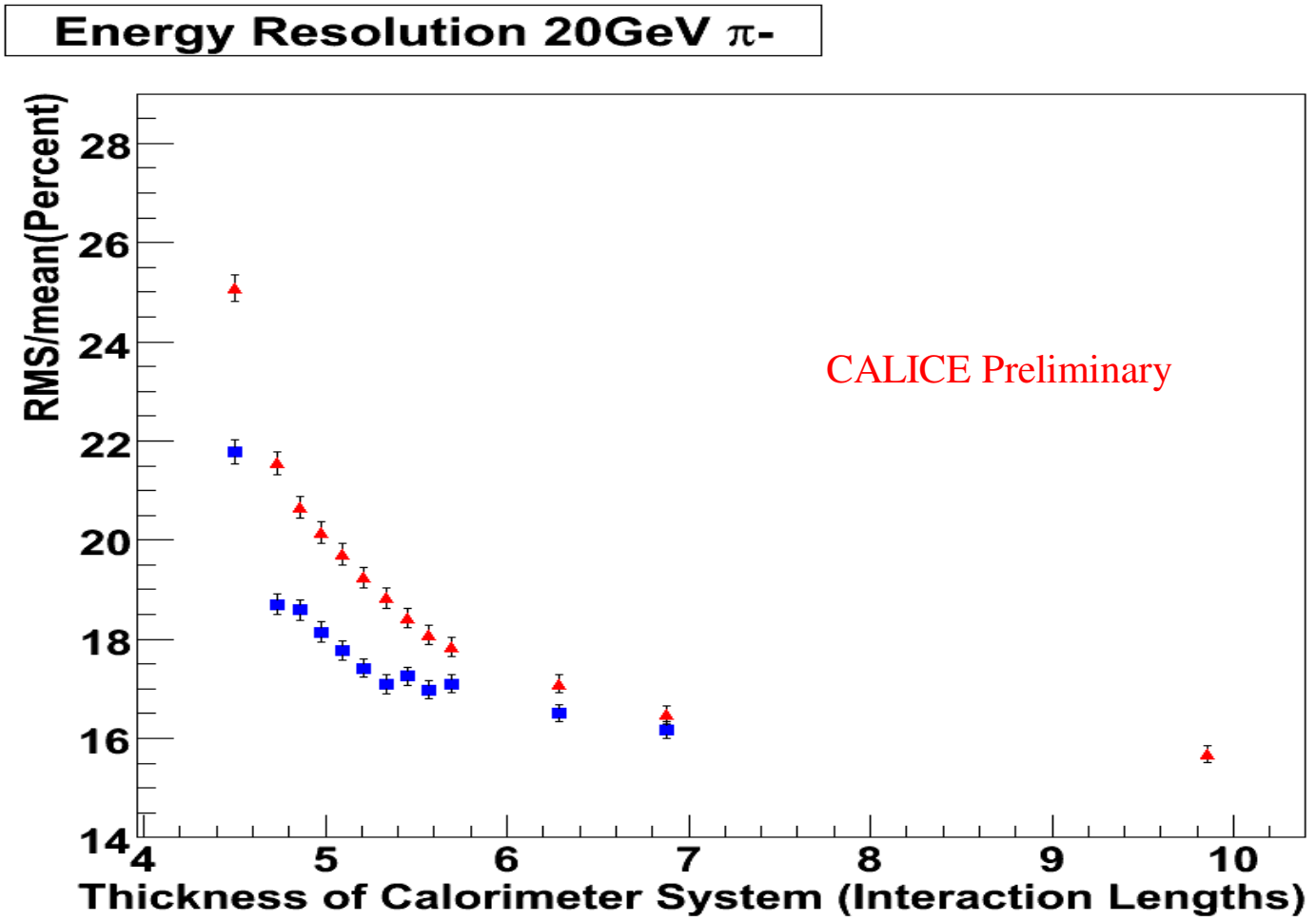
Energy Spectrum With Coil and Post Coil Sampling



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

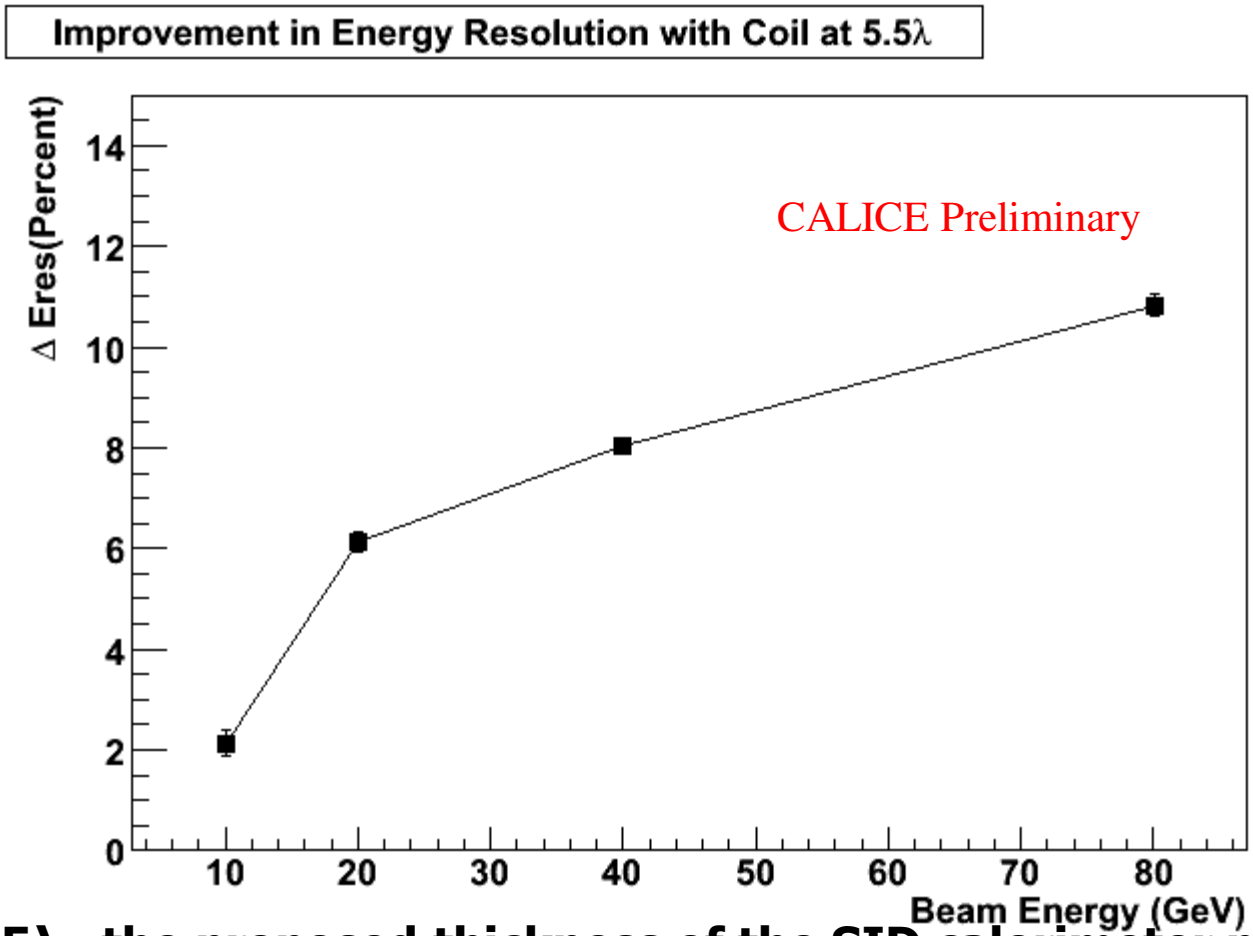
12 out of 16 TCMT layers used

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

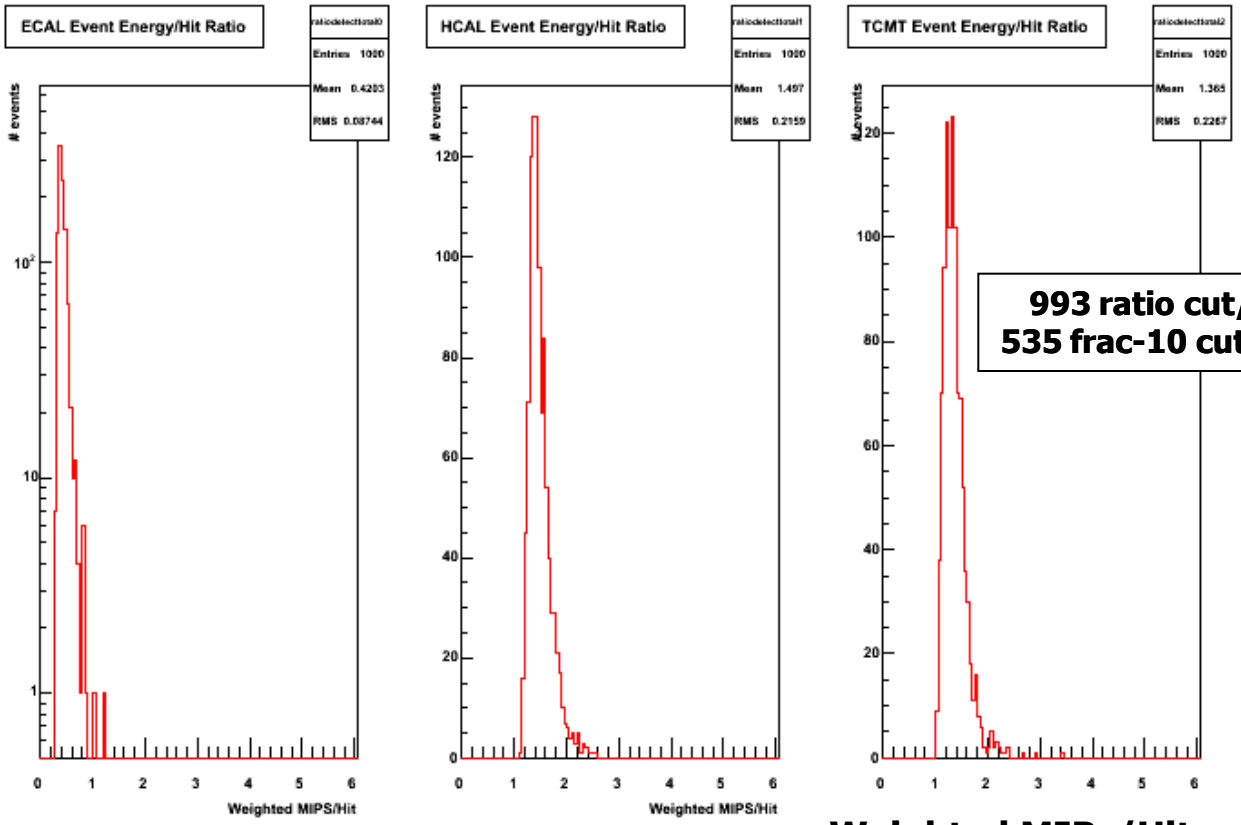


Coil at 5.5λ , the proposed thickness of the SID calorimeter plus post-coil sampling

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

Studies of Energy/#Hits Ratio

Monte Carlo Muons - 6Gev



These suggest ratio cuts of:
ECAL ratio = 1.0
HCAL ratio = 2.5
TCMT ratio = 2.5

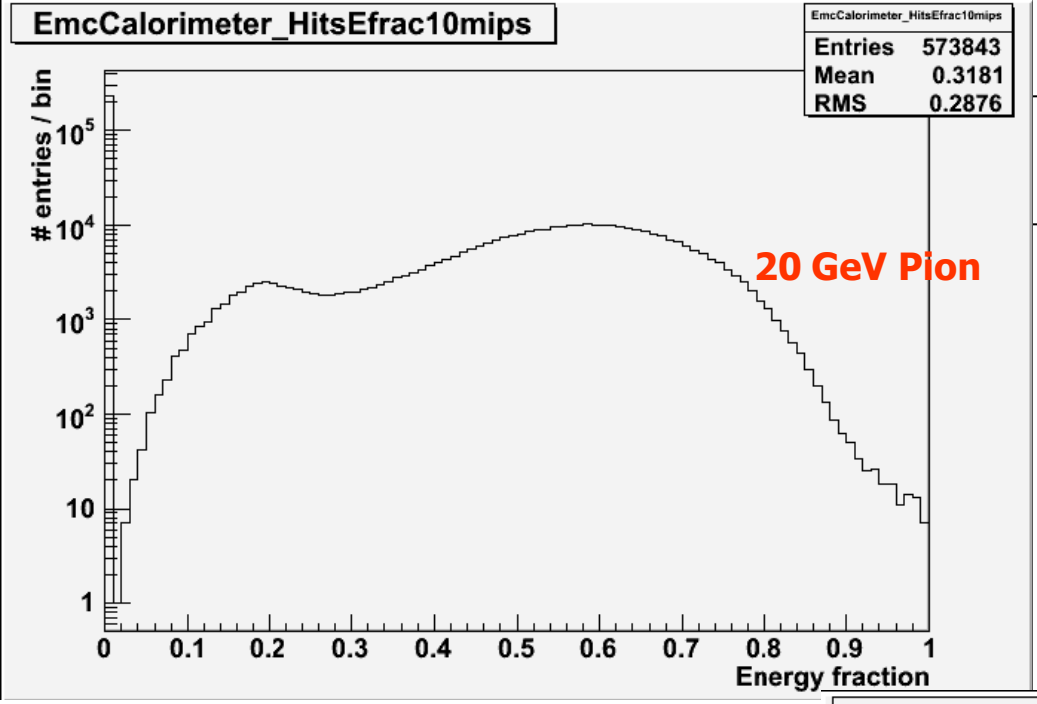
993 ratio cut/1000 total muons = 0.99
535 frac-10 cuts/1000 total muons = 0.54

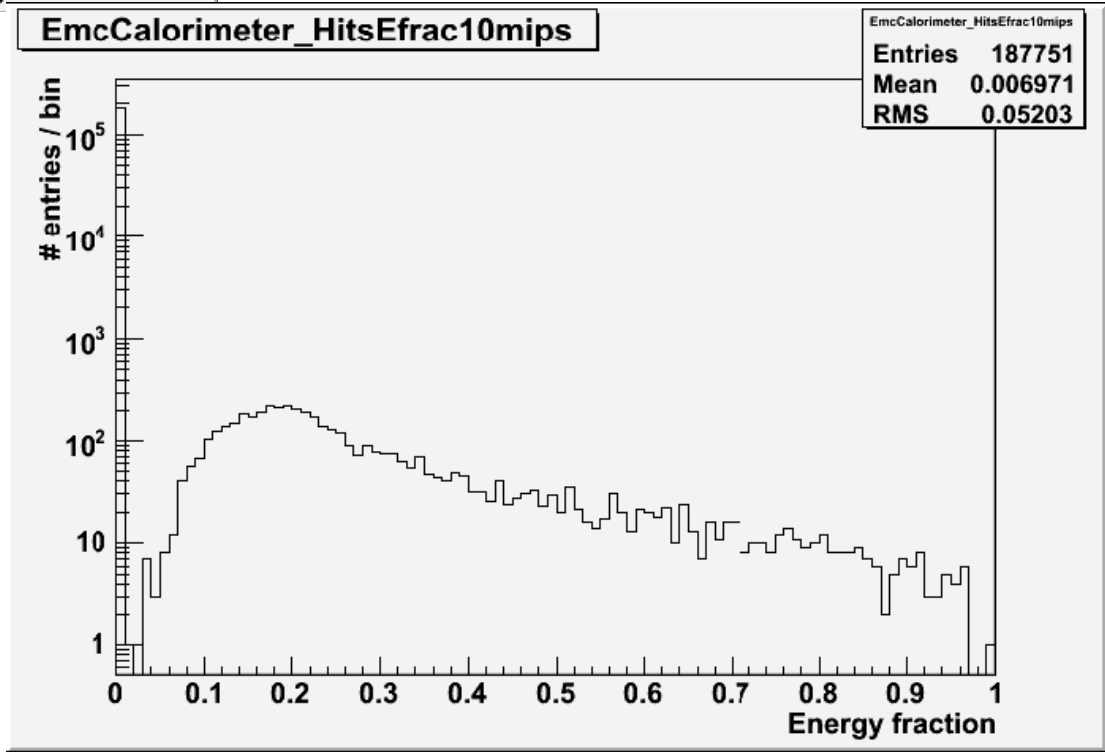
Plan to switch to a cut derived from studying distribution of muons from in flight decay of pions in Monte Carlo runs (with truth information).
This is going slow because of technical difficulties.

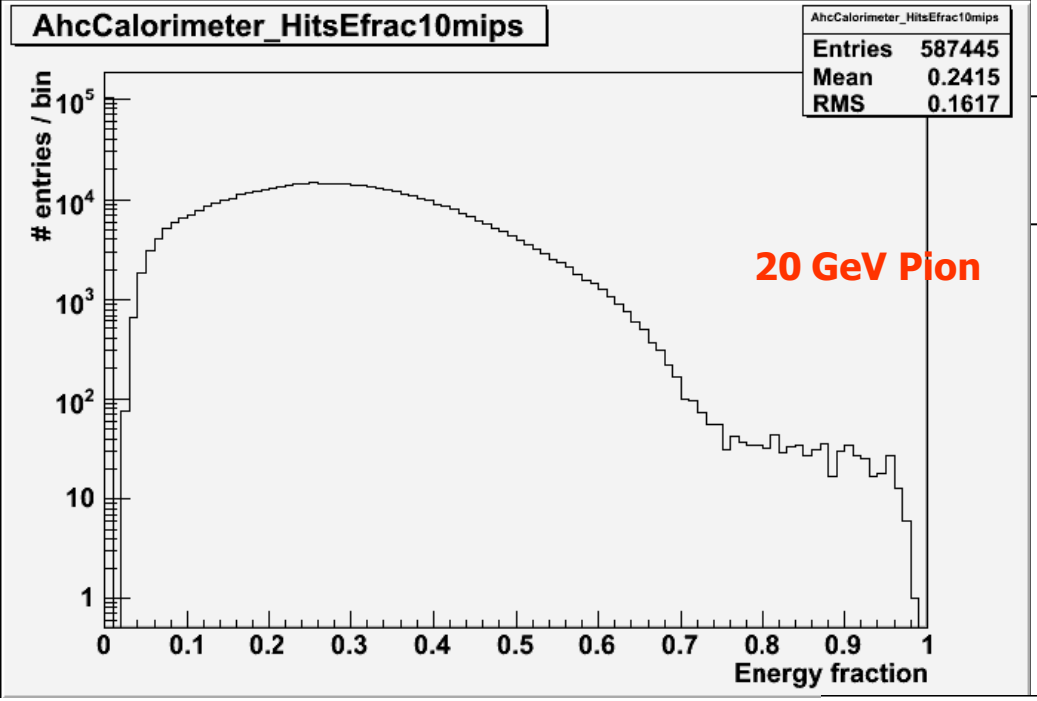
Summary

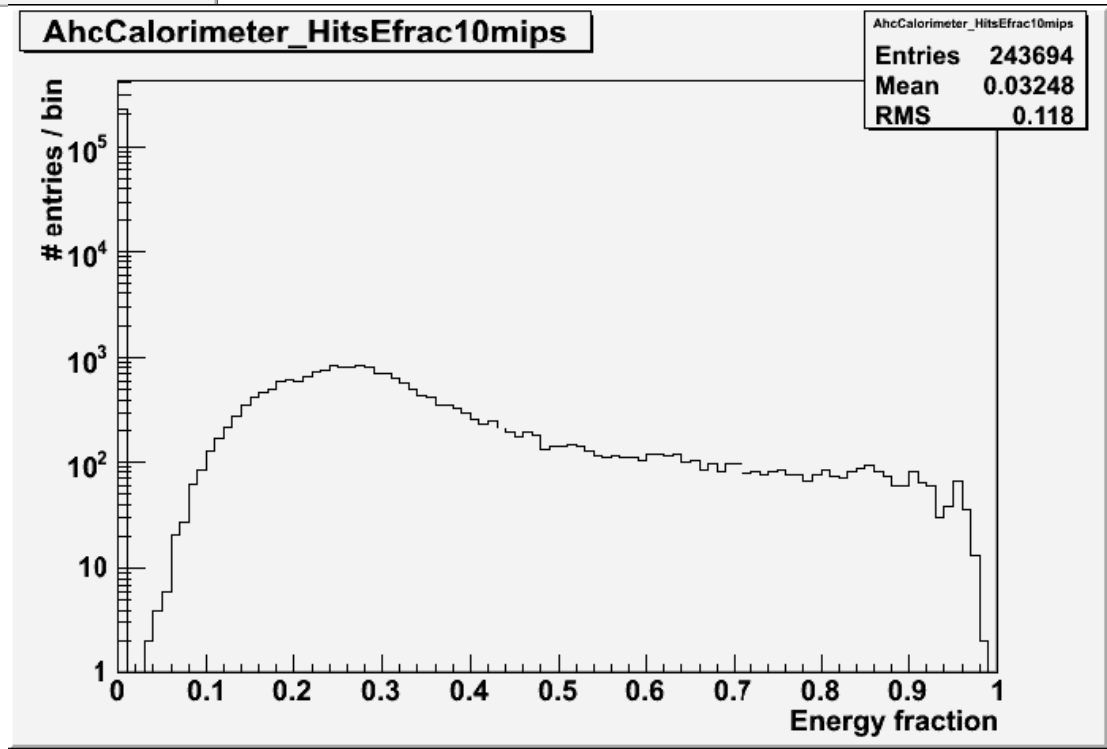
- Detector performed well
- Analysis is underway and progressing
- Post coil sampling improves resolution for coil position from 4.5 to 6 λ.
- At a depth of 5.5λ (the design thickness of the SID calorimeter), a tail-catcher improves energy resolution by about 6% for 20 GeV pions and 10% for 80 GeV pions.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

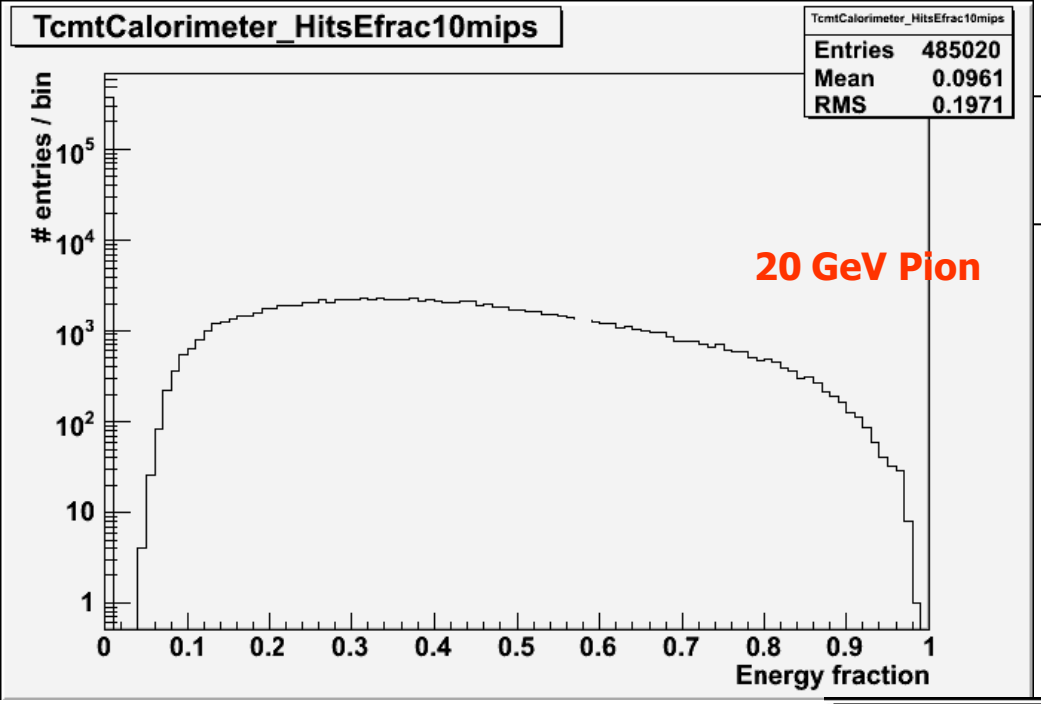
Additional Slides


EmcCalorimeter_HitsEfrac10mips
EmcCalorimeter_HitsEfrac10mips
Entries 573843
Mean 0.3181
RMS 0.2876
entries / bin
Energy fraction
20 GeV Pion

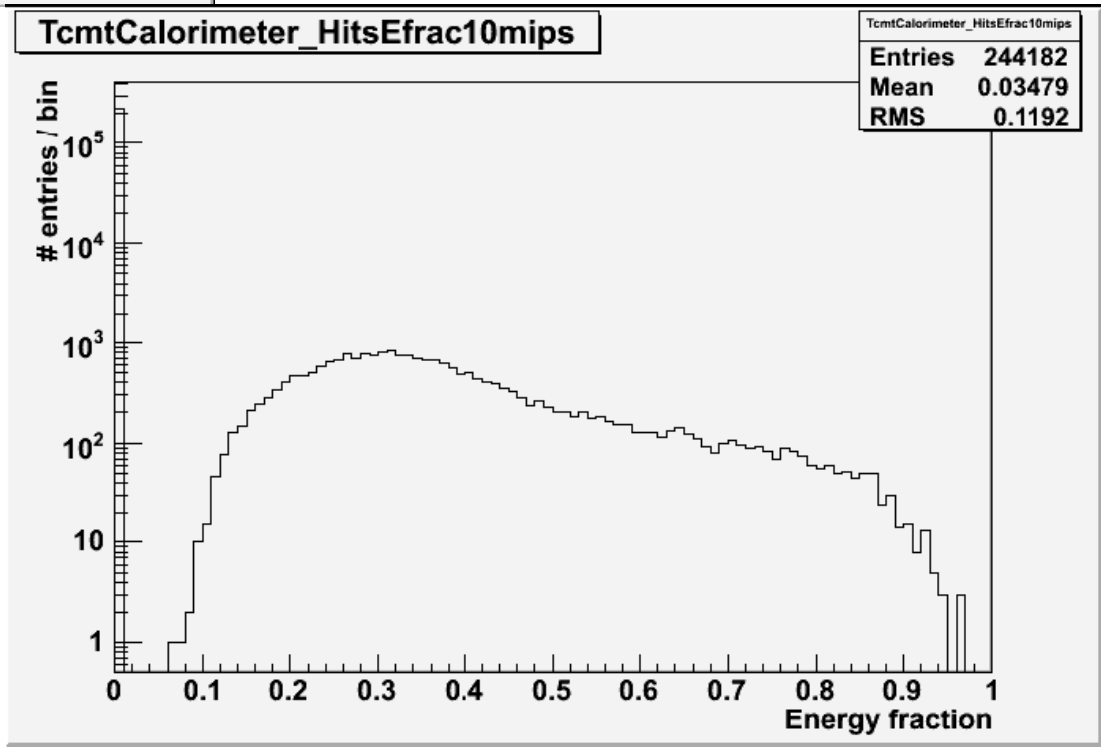

EmcCalorimeter_HitsEfrac10mips
EmcCalorimeter_HitsEfrac10mips
Entries 187751
Mean 0.006971
RMS 0.05203
entries / bin
Energy fraction

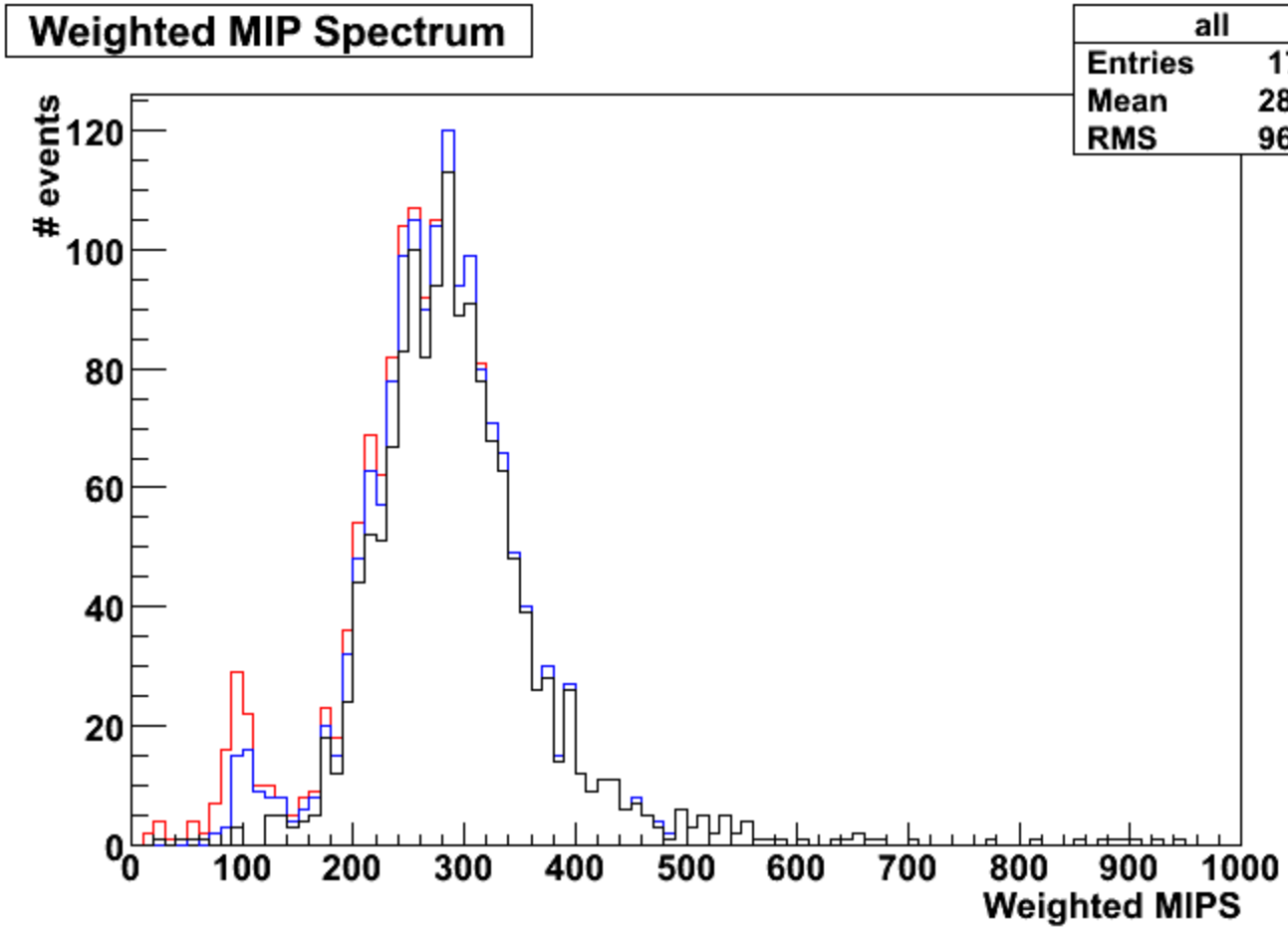

AhcCalorimeter_HitsEfrac10mips
AhcCalorimeter_HitsEfrac10mips
Entries 587445
Mean 0.2415
RMS 0.1617
entries / bin
Energy fraction
20 GeV Pion


AhcCalorimeter_HitsEfrac10mips
AhcCalorimeter_HitsEfrac10mips
Entries 243694
Mean 0.03248
RMS 0.118
entries / bin
Energy fraction



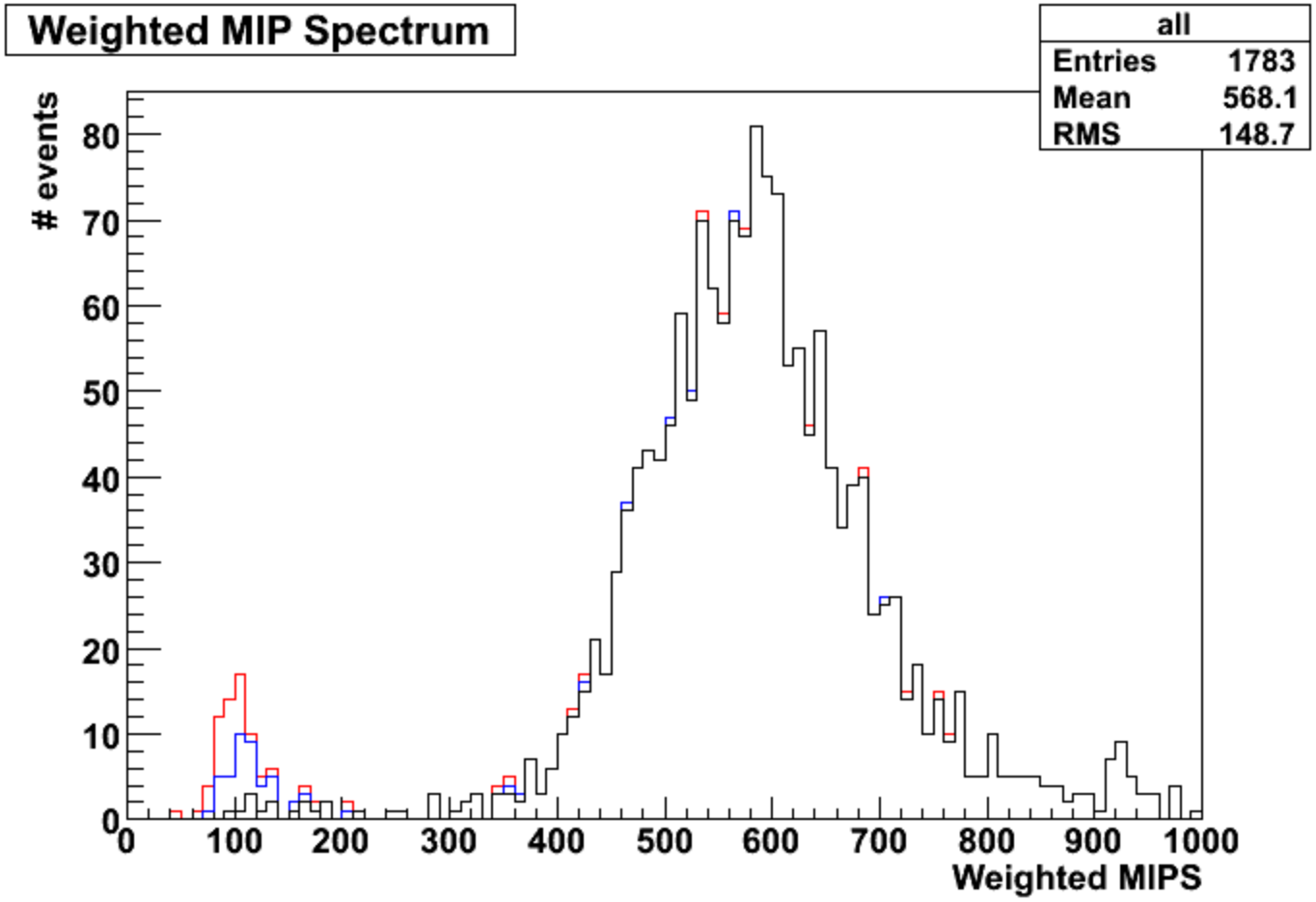
Beam Dump
Muon





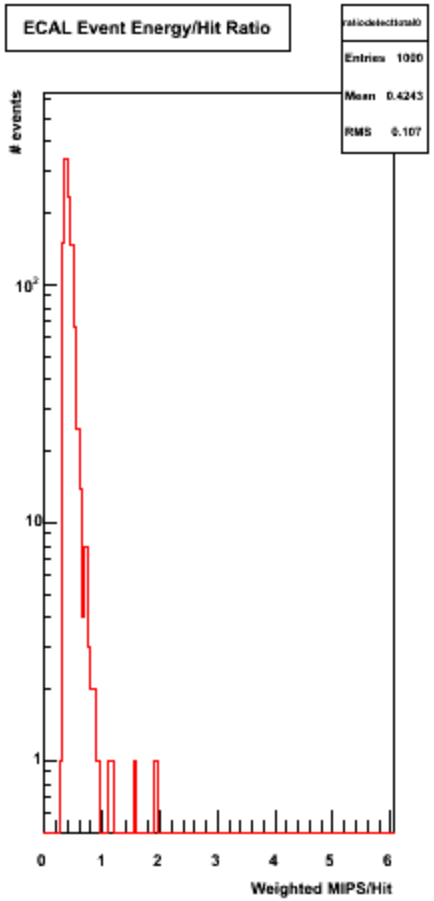
10GeV Pion Run

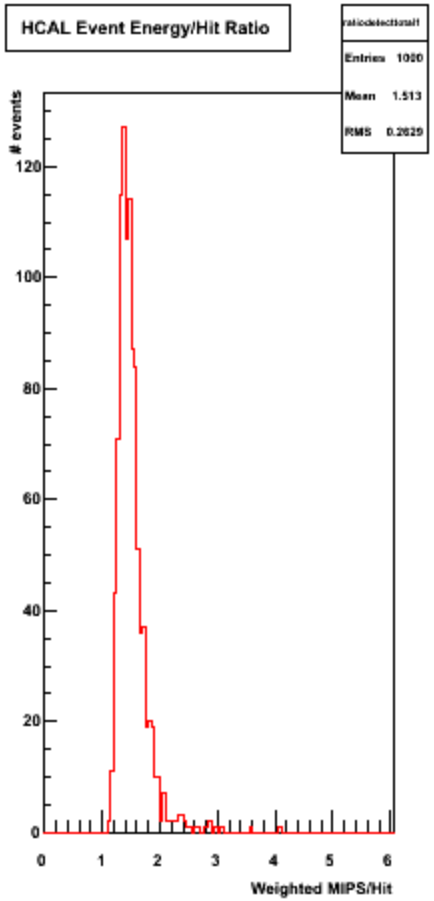
Red: No muon cuts RMS=97 MEAN=281 RESOLUTION=0.34
Blue: After Frac-10 and Counter RMS=91 MEAN=289 RESOLUTION=0.32
Black: After Ratio cut and Counter RMS=88 MEAN=298 RESOLUTION=0.30

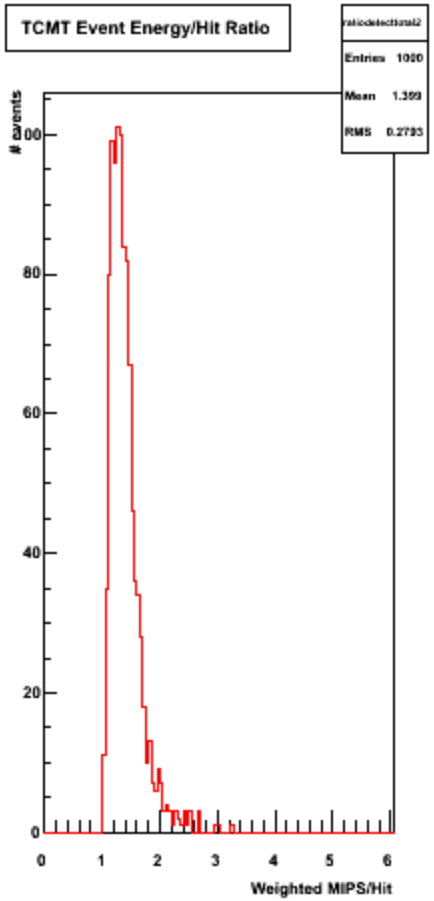


20GeV Pion Run

Red: No muon cuts RMS=149 MEAN=568 RESOLUTION=0.26
Blue: After Frac-10 and Counter RMS=134 MEAN=578 RESOLUTION=0.23
Black: After Ratio cut and Counter RMS=117 MEAN=588 RESOLUTION=0.20



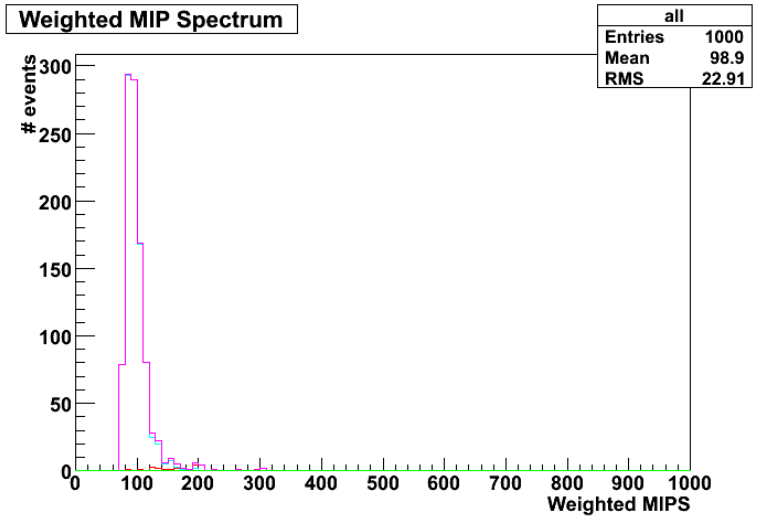


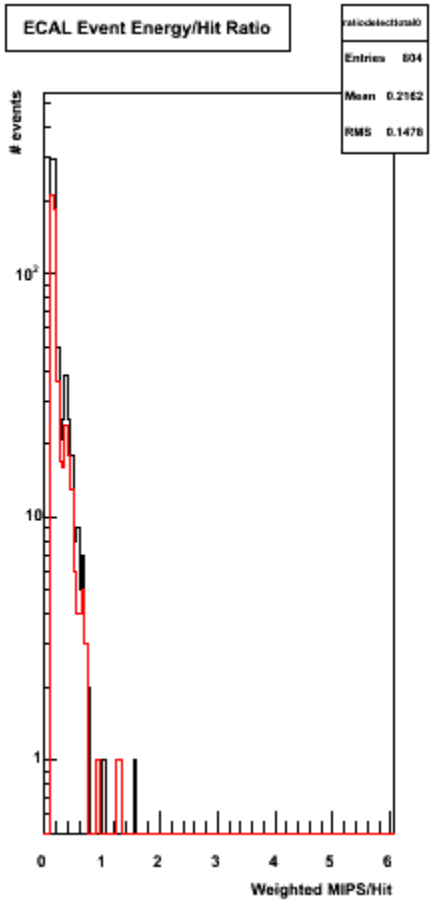


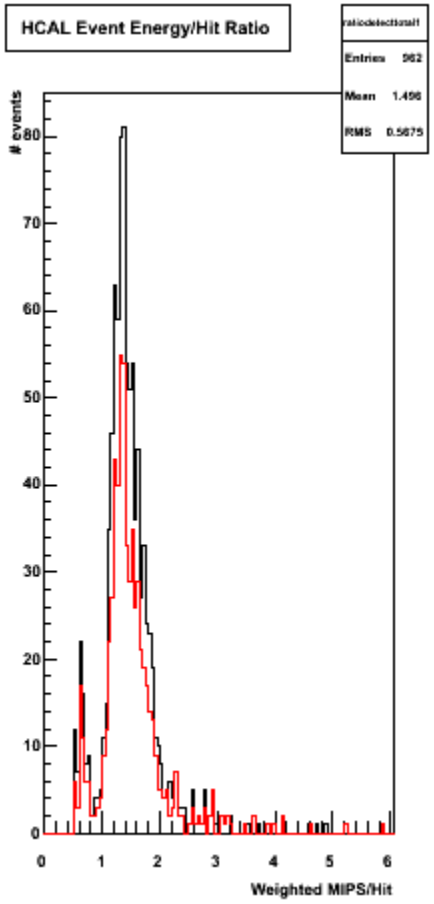
Monte Carlo Muons - 10GeV

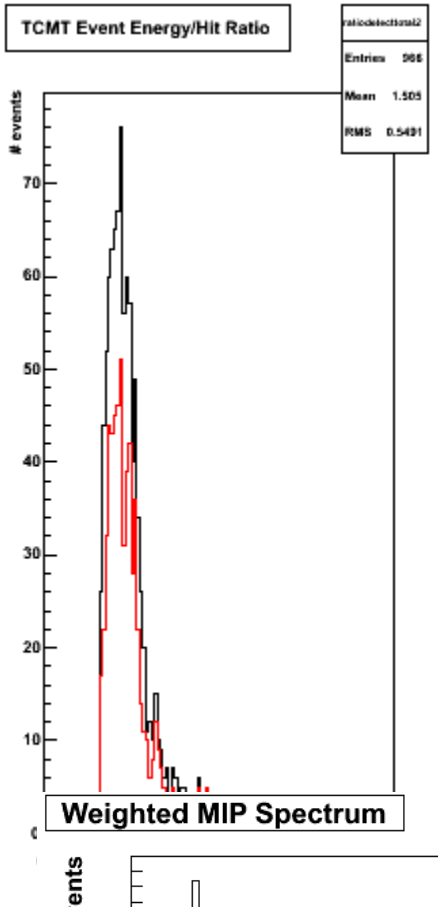
10GeV

975 ratio cut/1000 total muons = 0.98
565 frac-10 cuts/1000 total muons = 0.57









Run300778 Beam Muons

484 ratio cut/543 total muons = 0.89
324 frac-10 cuts/543 total muons = 0.60

Events that don't pass through ECAL are ignored