A preliminary analysis of the CALICE test beam data

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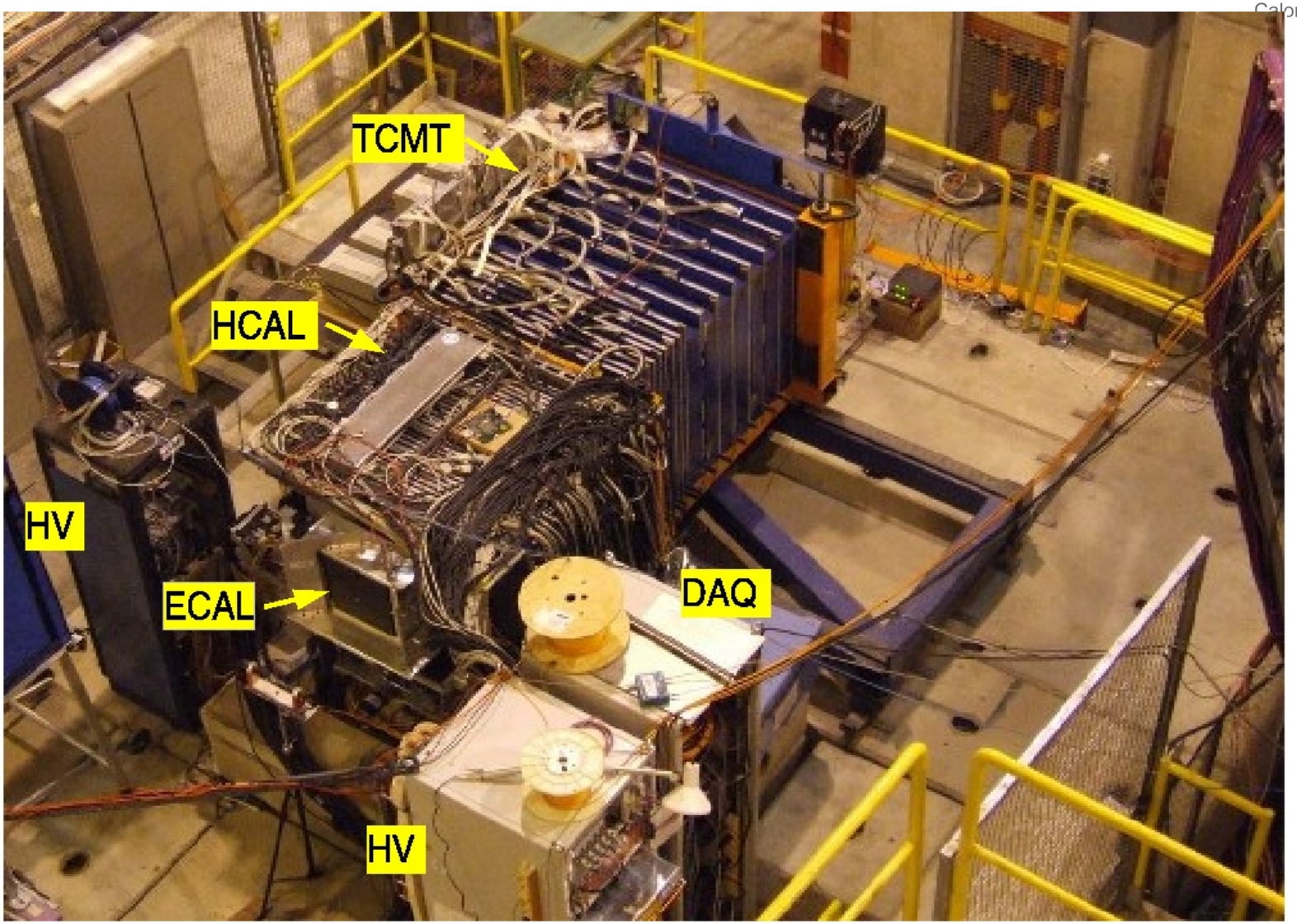
Talk outline

- Test beam apparatus
- Data analysis
  - Overview
  - Hit selection, background rejection
  - Correlations among and combination of ECal, HCal, & TCMT energies.
- Results
  - Linearity
  - Energy resolution
- Summary

Layout of beam test area during 10/06 run



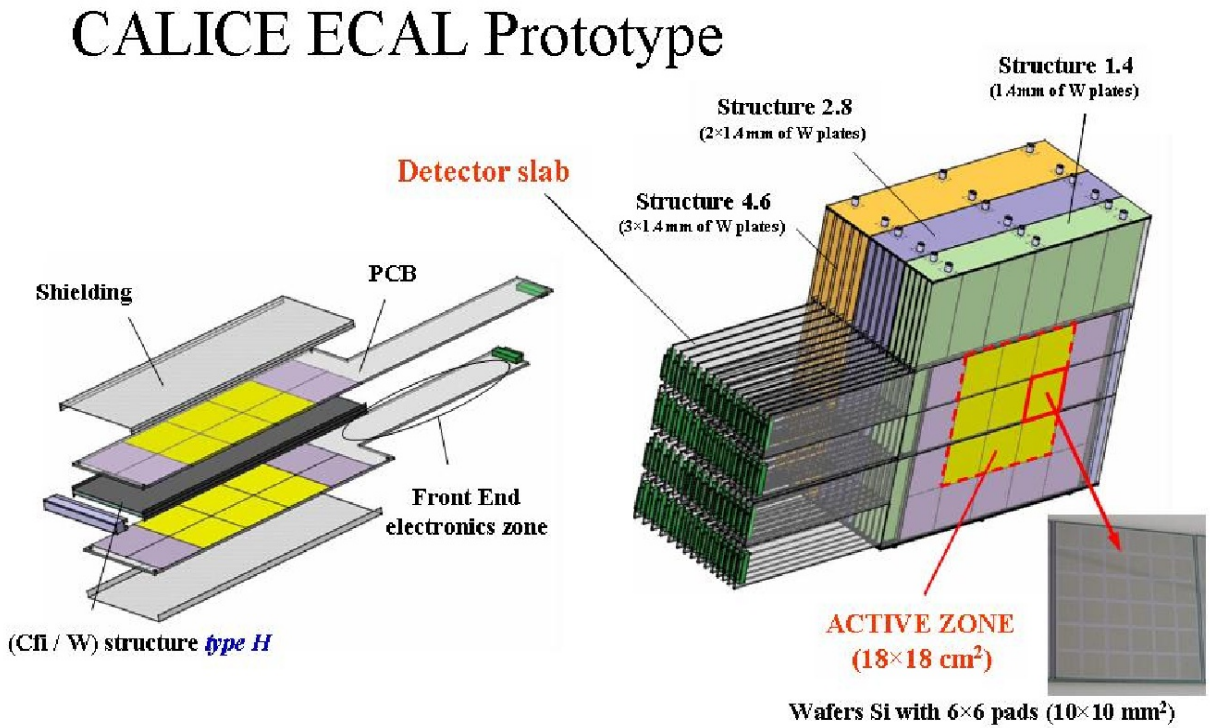
The CALICE ECal prototype

Czech Rep., France, Korea, UK

Design: 30 Si-W layers x 9 wafers x 6x6 1cm x 1cm cells. Three modules, each with different W thicknesses:

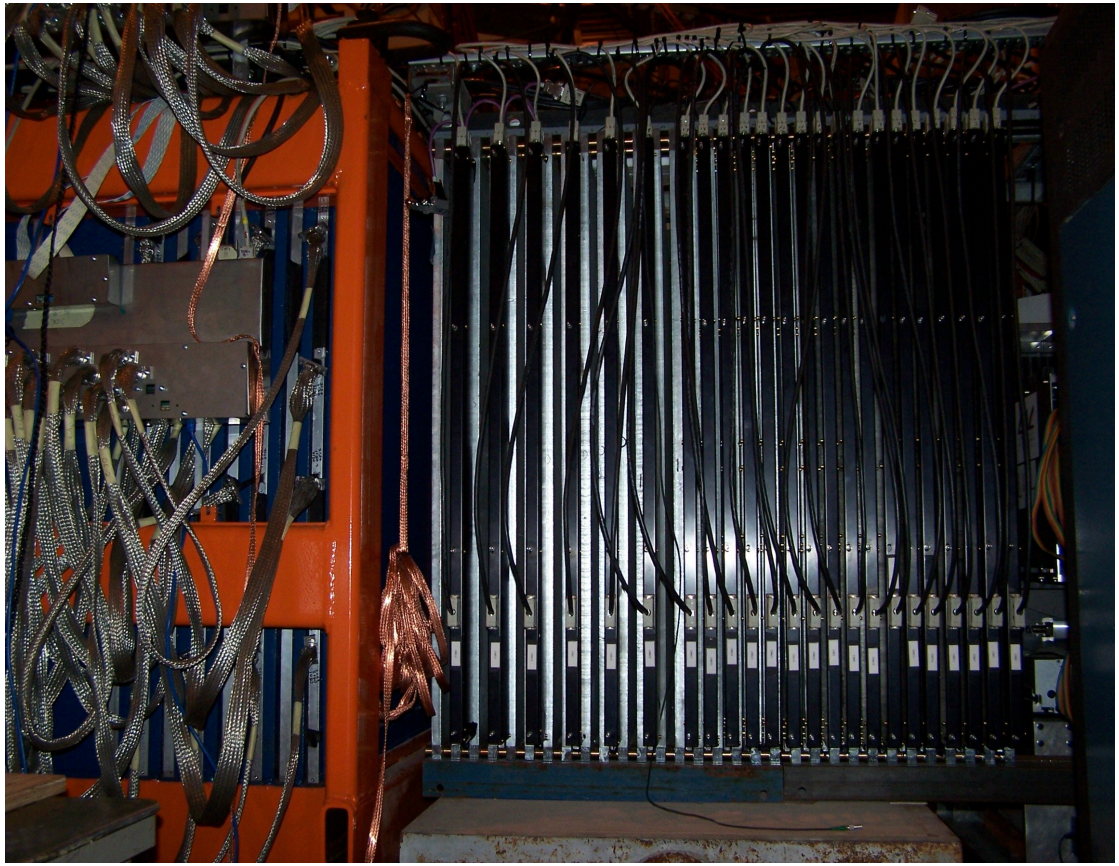
- layers 1-10 - 1.4mm
- layers 11-20 - 2.8mm
- layers 21-30 - 4.2mm

Oct/2006 run: all 30 layers are partially instrumented (6 out of 9 wafers / layer). Total of 30 x 6 x 36 = 6480 channels.



The CALICE HCal prototype

TCMT HCAL



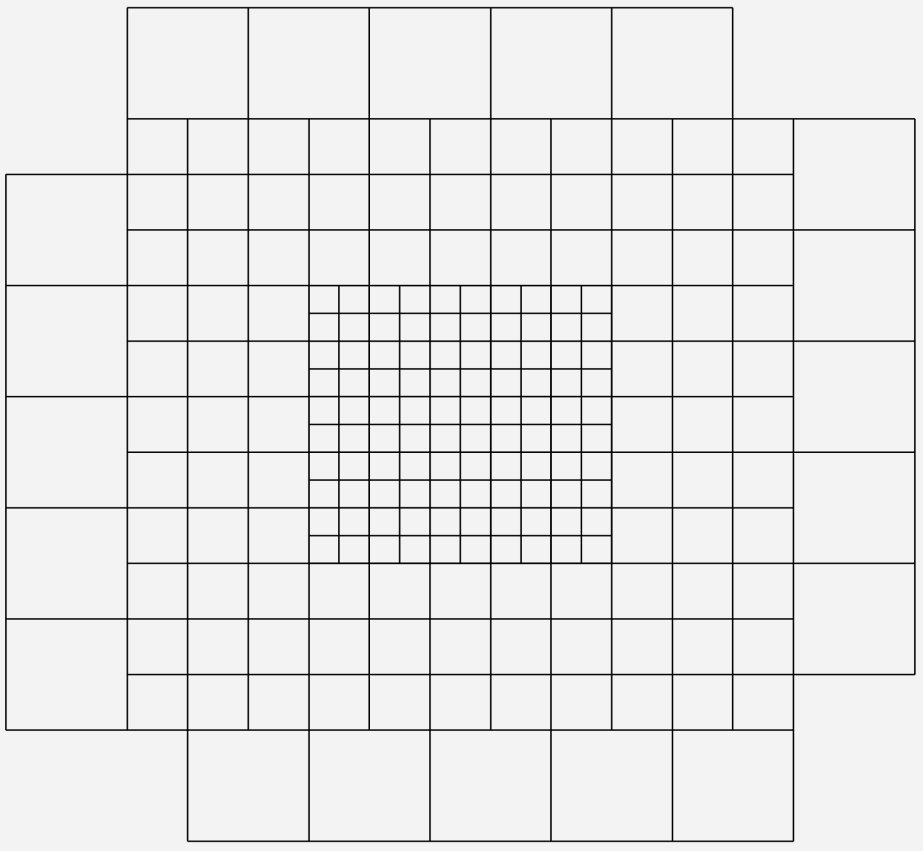
Czech Rep., France, Germany, Russia, UK, USA

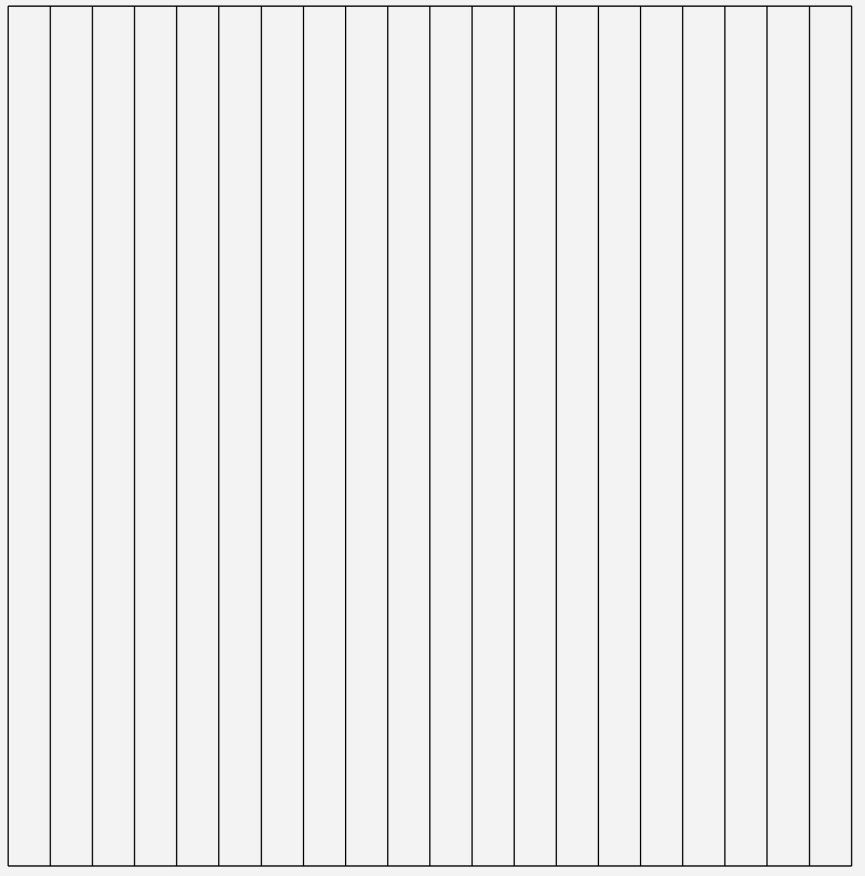
Design: 38 scintillator-steel layers, with SiPM readout.
Layering: 0.5cm active / 2.0cm steel.
Three granularity regions per layer:
3x3 , 6x6 and 12x12 cm^2

Oct/2006 run: 23/38 layers in place:
Layers 1-17 – all instrumented
Layers 19-29 – every other layer instrumented

23 layers x 216 channels / layer
= 4968 channels

HCal and TCMT segmentation





The CALICE TCMT prototype

Designed and built at NICADD/NIU, in partnership with DESY, and with engineering help from Fermilab.

Design: 16 Scint-steel layers with alternate x,y orientations, with SiPM-readout scintillator strips.

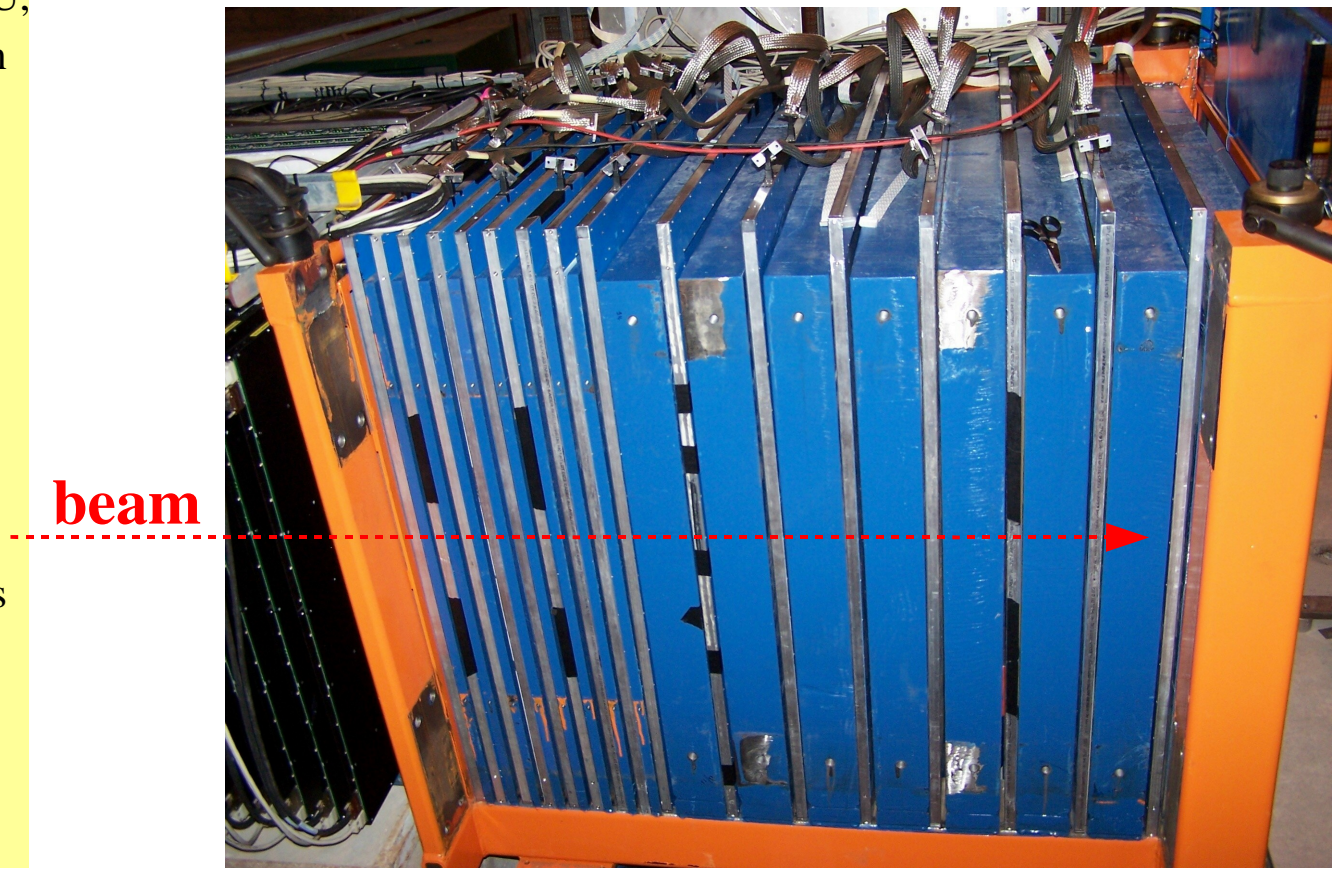
Each strip is 100 x 5 x 0.5 cm^3

Layers 1-8: ~2cm absorber

Layers 9-16: ~10cm absorber

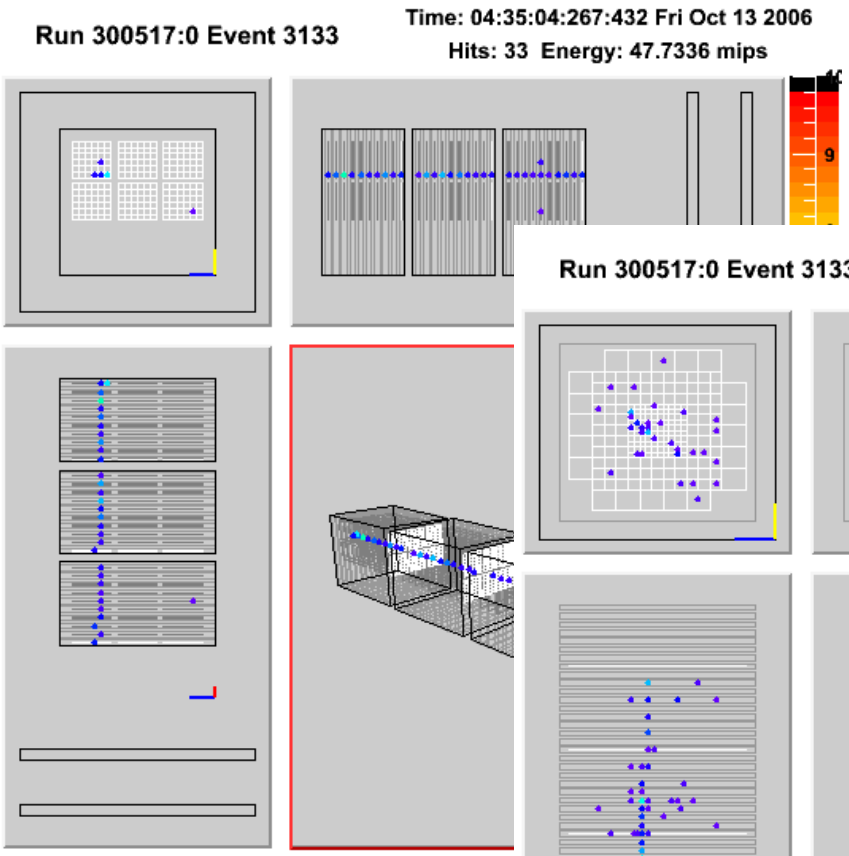
16 layers x 20 strips = 320 channels

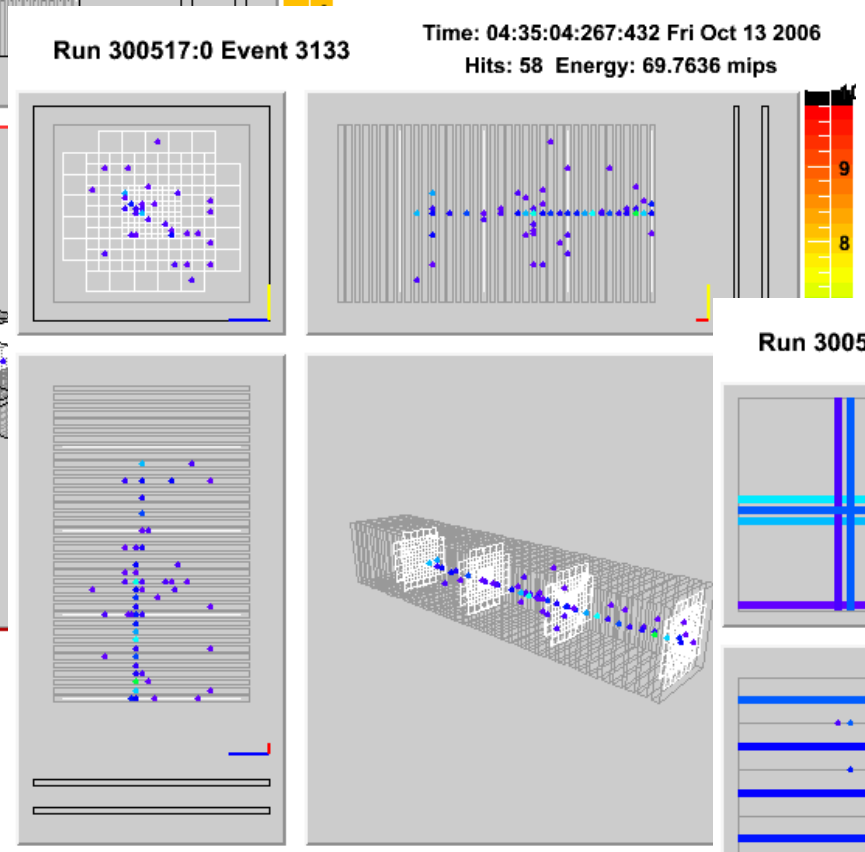
Oct/2006 run: All 16 layers fully instrumented, according to design.

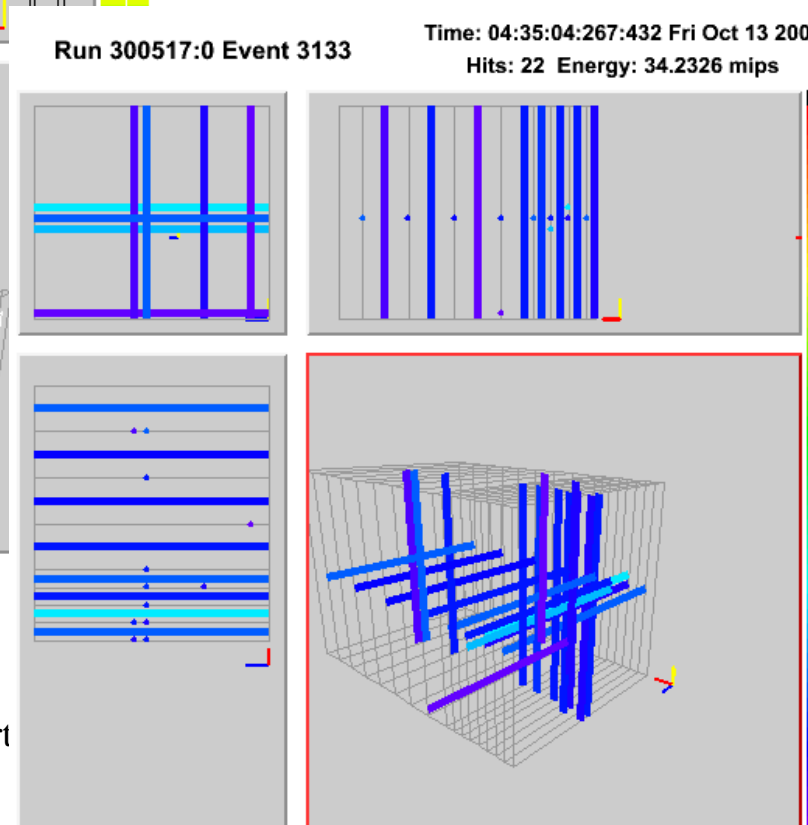


HCAL TCMT

A typical muon event



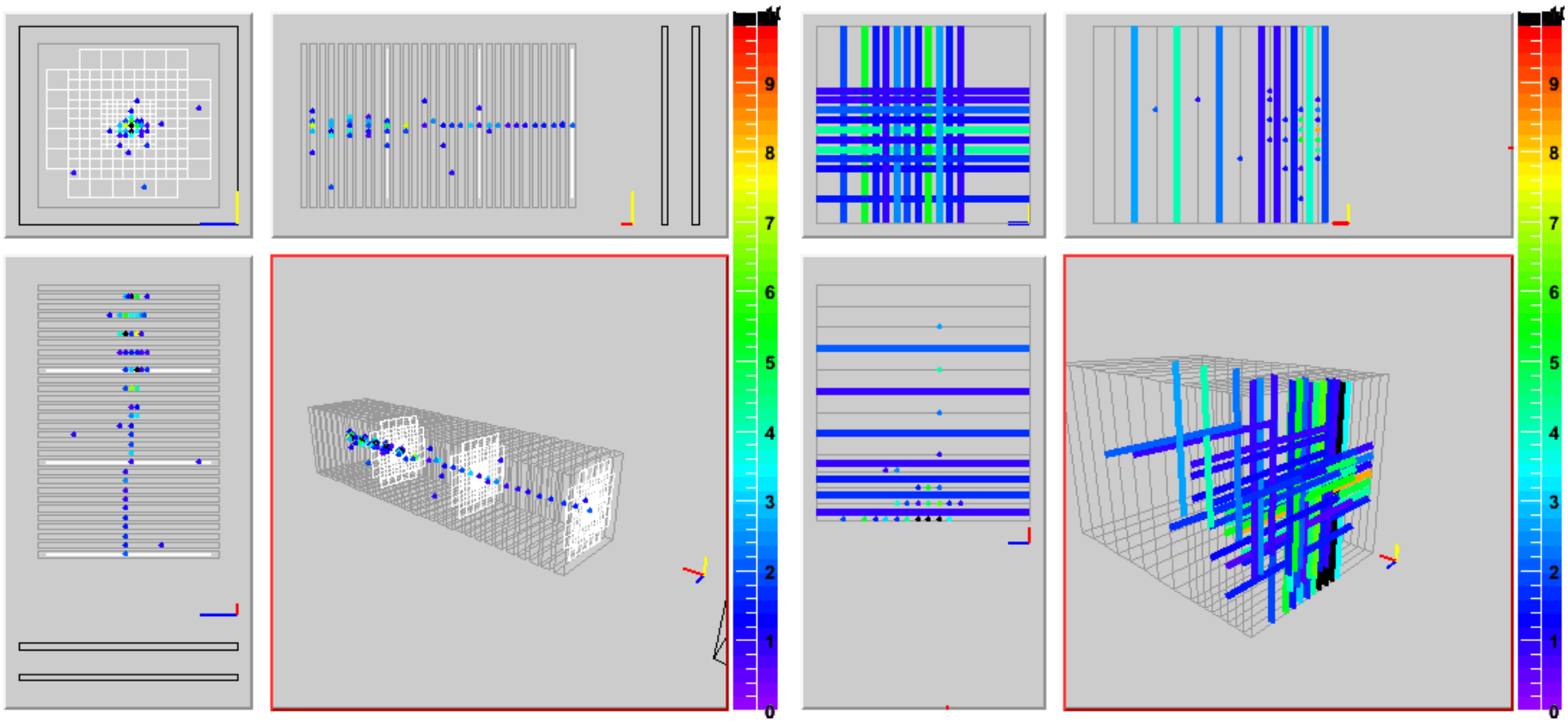




Example pion event display

40GeV/c pion
with CALICE online analysis software

HCAL **TCMT**



Late shower in HCAL

TCMT clearly needed to contain shower

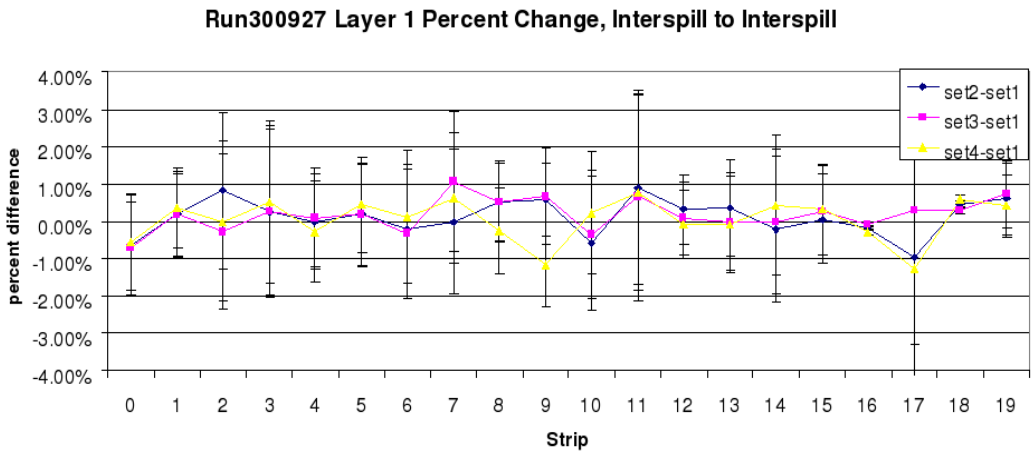
Slide from K.Francis' talk

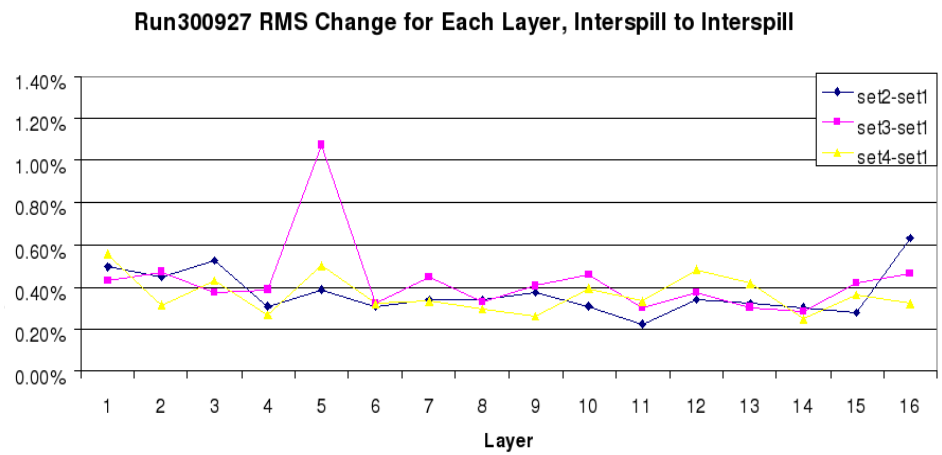
Analysis overview

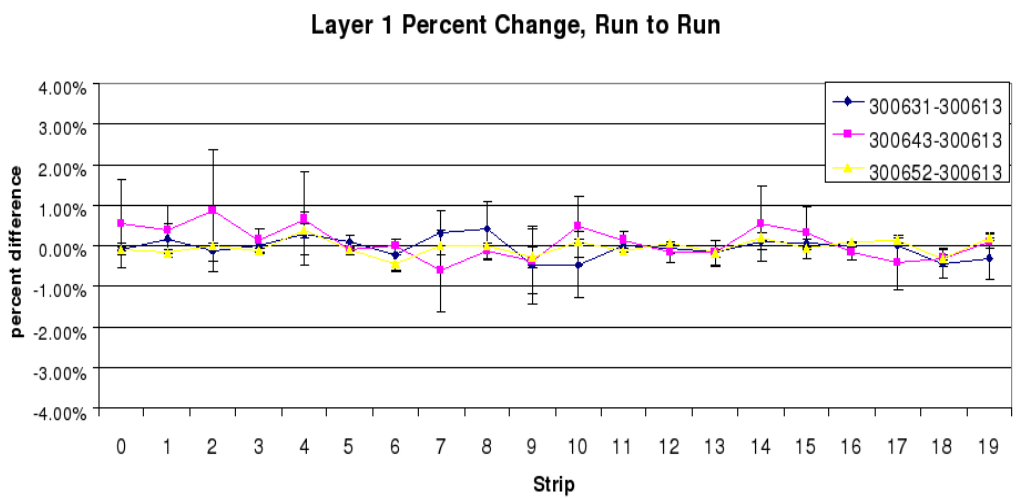
- Data collected with pion beams at 6-80 GeV. This analysis focuses on 10-20 GeV.
- Official CALICE software packages and conditions database used for pedestal subtraction, calibration, and zero-suppression.
- Processing of ECal hits is done by a single processor.
- Processing of AHCal hits is modularized into several processors.
- TCMT hit processing is modelled after AHCal.
  - Pedestal is stable within 1%, MIP within 1.5%.
- Difference at low end of AHCal response between MC and data is thought be due to inadequate modeling of photosensor noise and cross-talk.
- Hit selection requirement: Ehit > 0.5 Emip .and. Ehit > 2 $\sigma_{pedestal}$

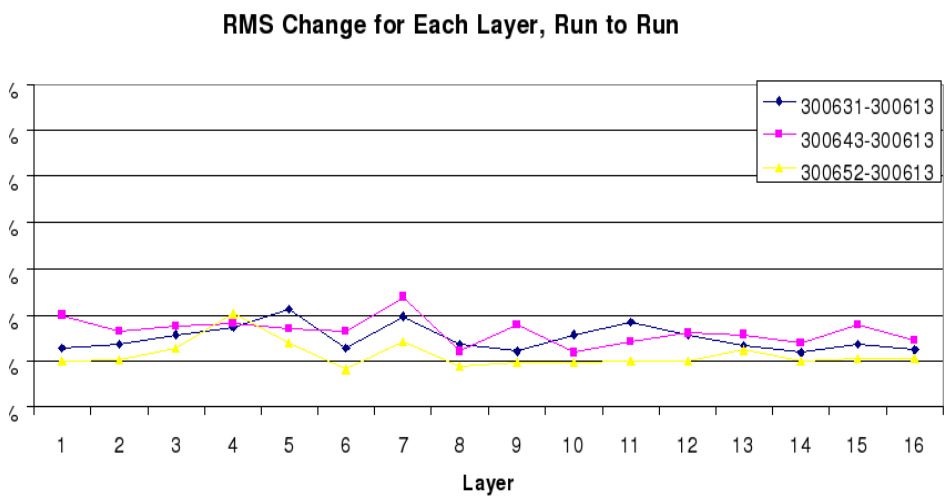
Pedestal stability in the TCMT

10 GeV pions

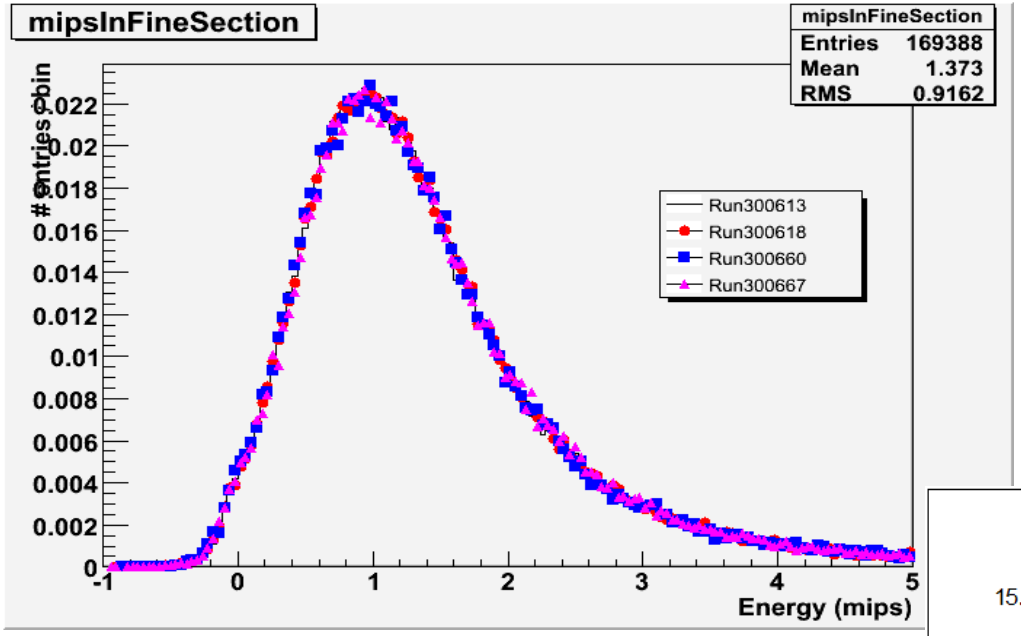




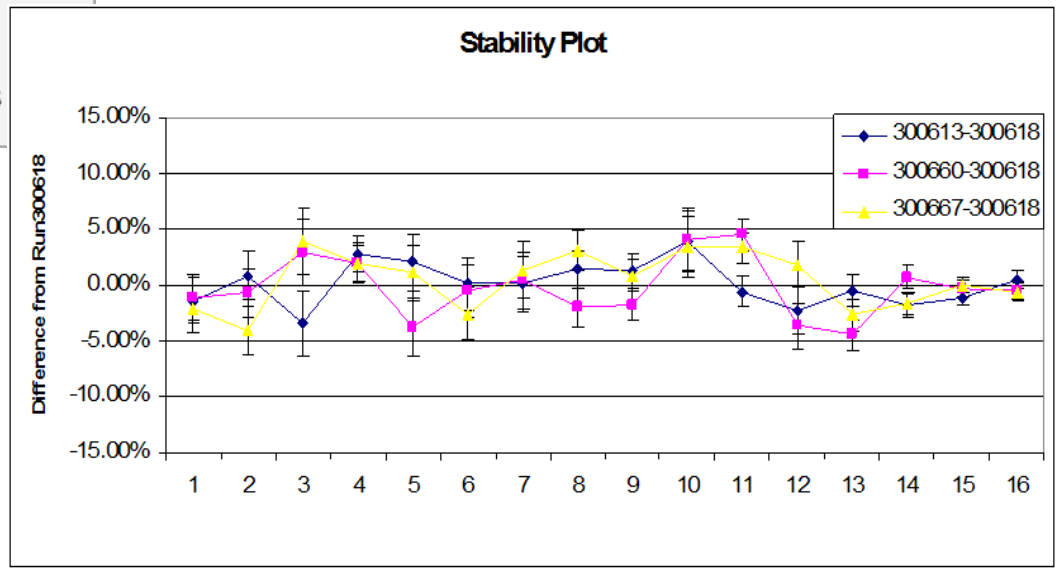




MIP calibration and response stability of the TCMT



10 GeV pions

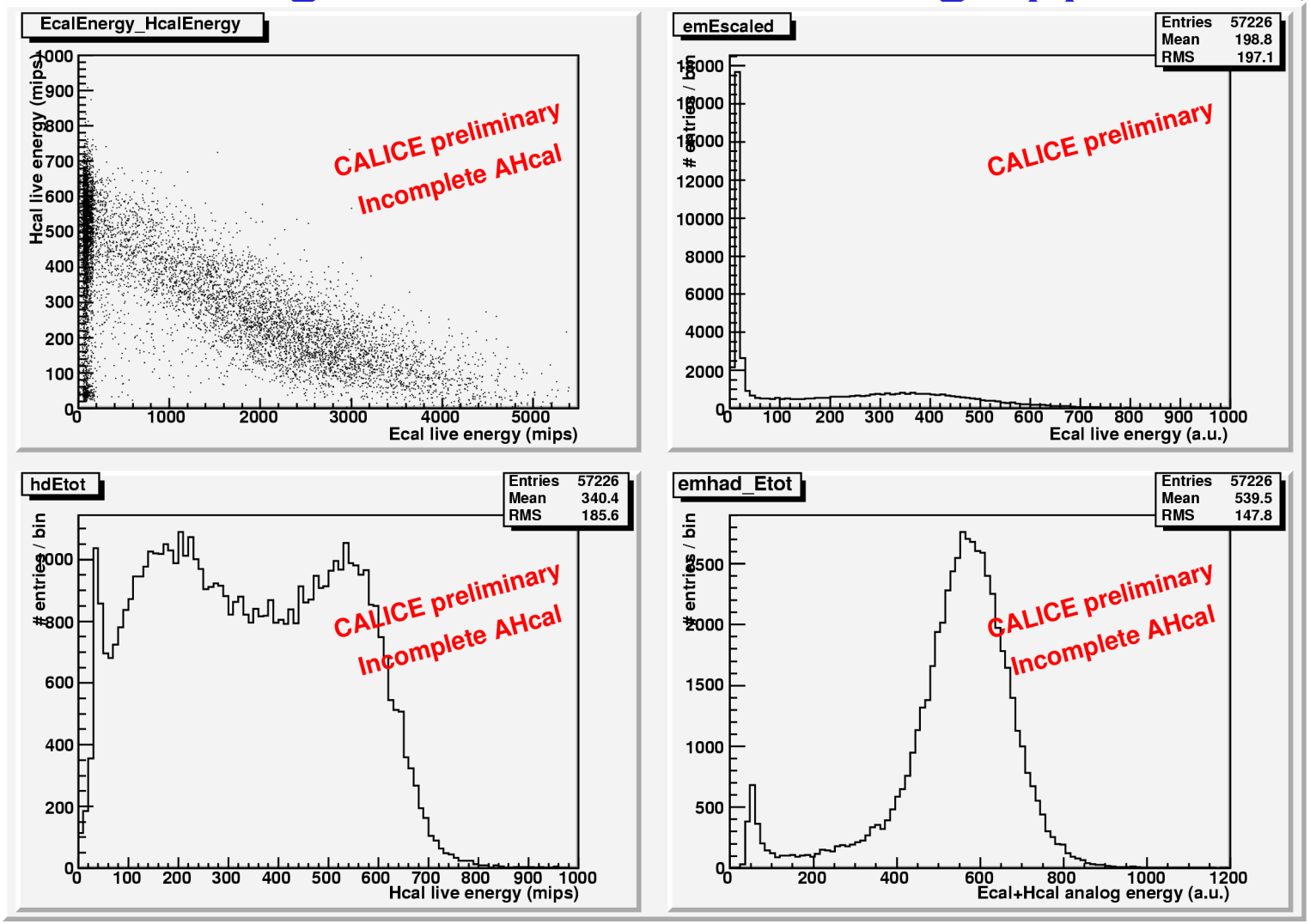


Combination of ECal, HCal, & TCMT energies

- Analog as well as semi-digital (2-bit weighted hit counting) measurements tried.
- 7 regions defined, each with its own sampling weight = the subdetector's inter-component factor times intra-component thickness.

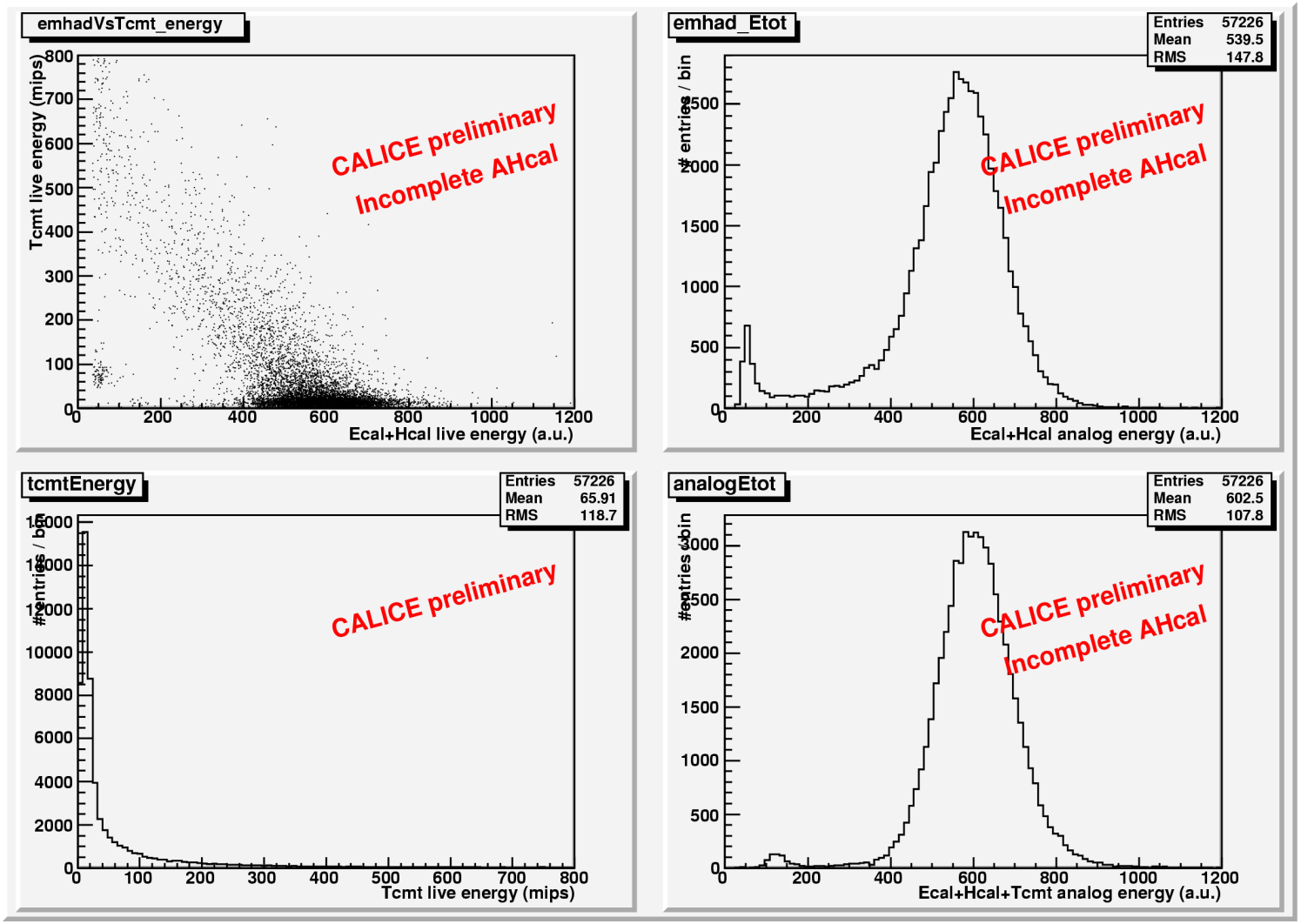
Region	Rel. thickness	ICF		Relative sampling weight	
		Analog	Digital	Analog	Digital
ECAL 1	1	0.153	0.292	0.153	0.292
ECAL 2	2	0.153	0.292	0.306	0.584
ECAL 3	3	0.153	0.292	0.459	0.876
AHCAL 1	1	1.000	1.000	1.000	1.000
AHCAL 2	2	1.000	1.000	2.000	2.000
TCMT 1	1	0.909	0.257	0.909	0.257
TCMT 2	4.92	0.909	0.257	4.472	1.264

Combining ECal & HCal: analog approach (A)



20 GeV pions

Adding TCMT to ECal & HCal : analog approach



20 GeV pions

Semi-digital approach (D): weighted (2-bit) hit-counting in ECal, HCal, and TCMT

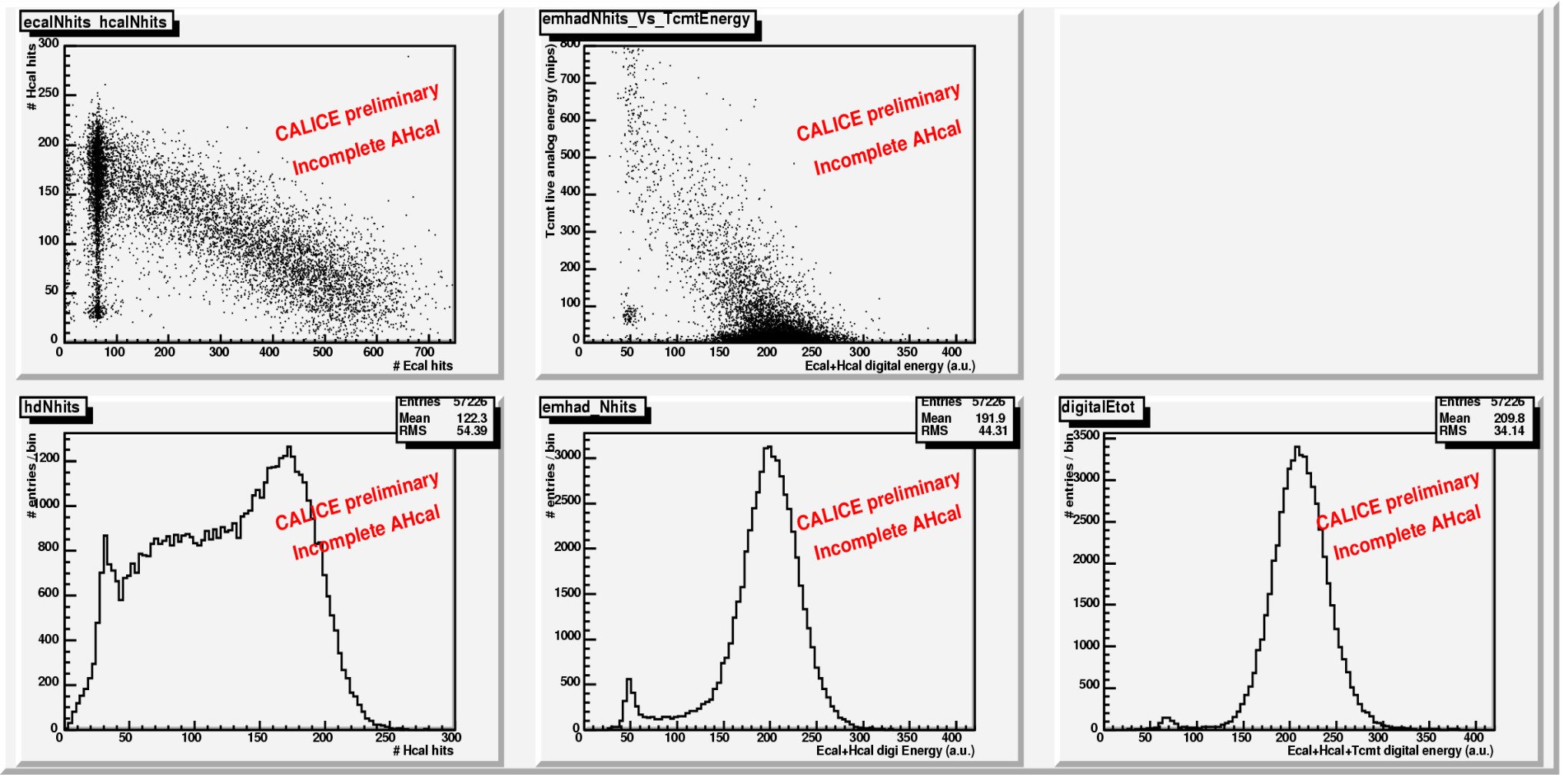
- Four energy bins used, each with its own weight:

Energy (MIP)	Weight
0-0.5	0
0.5-5.0	1
5.0-10.0	4
>10.0	8

- Same for all 3 detectors.
- The thresholds and weights have not been fine-tuned. Optimal combinations are quite possibly multiple and/or broad.

Semi-digital approach (D)

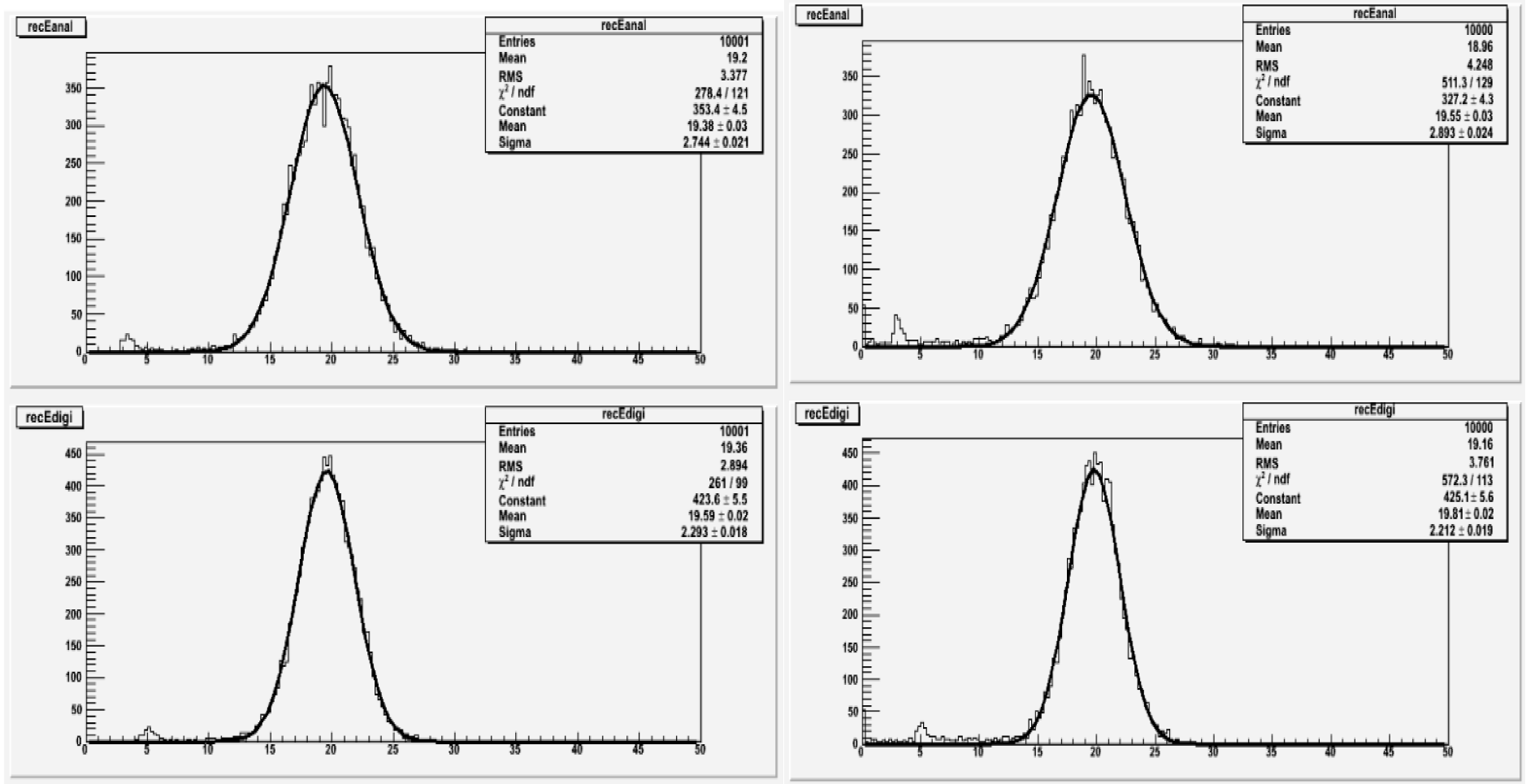
20 GeV pions



Comparison between data (L) and MC (R)

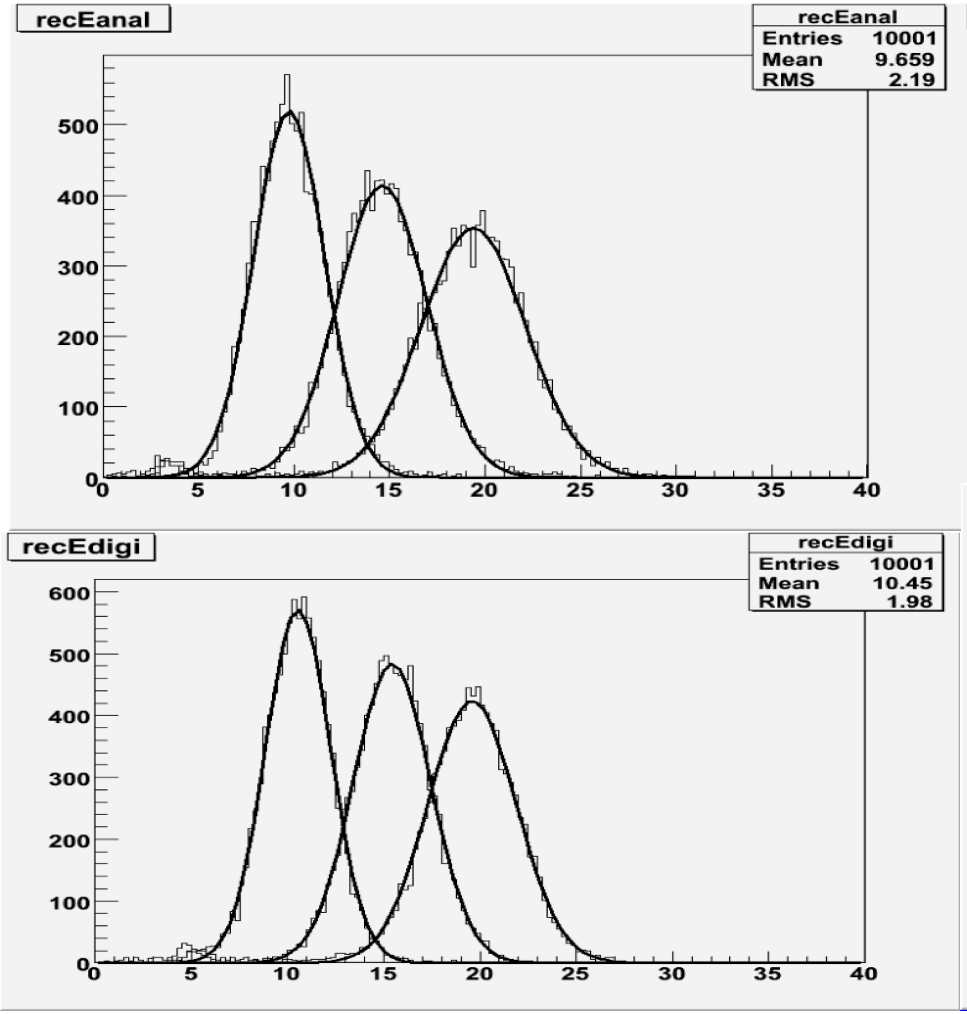
20 GeV pions

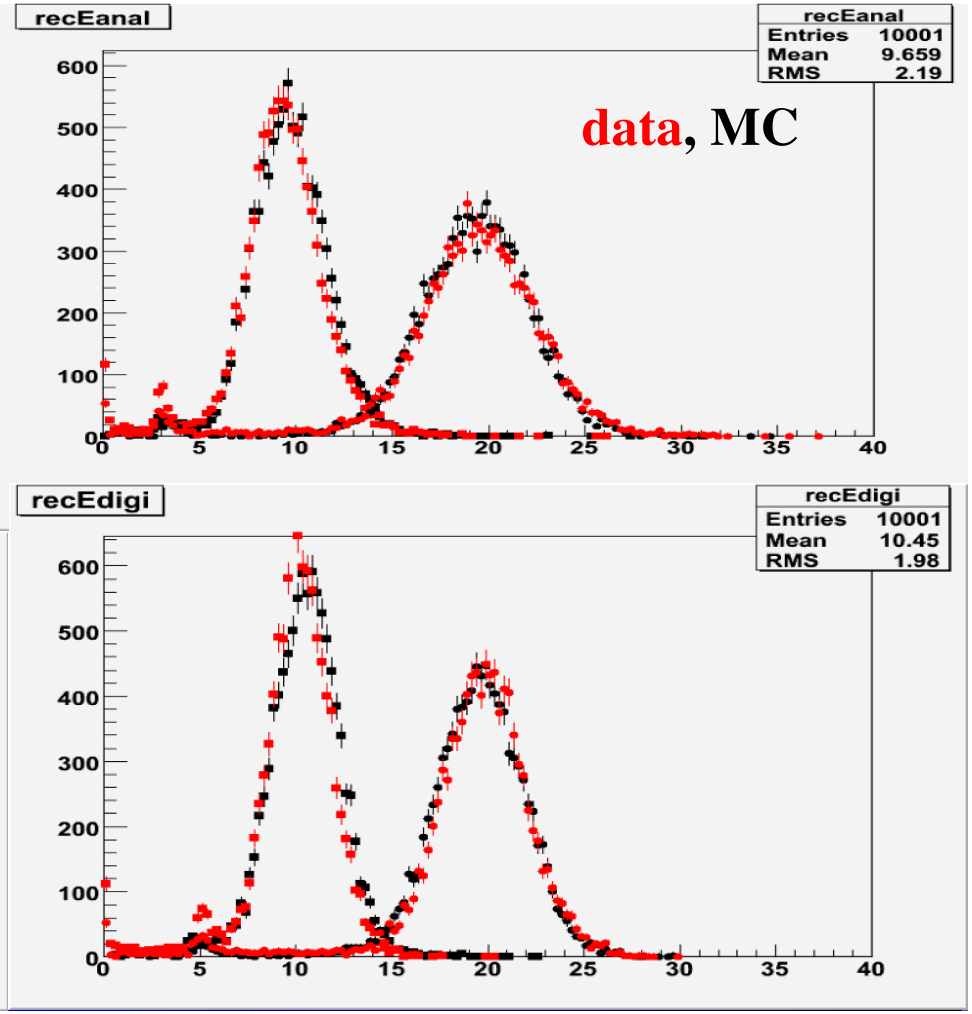
MC = Mokka v06-03-p01, with LHEP physics list & TBCern1006_01 eometry



Reconstruction at different energies and comparison with MC

10, 15, 20 GeV pions





A

D

Linearity and energy resolution ratios (preliminary)

- Chisquare-based method for finding sampling factors.
- Only 23 out of 38 HCal layers were instrumented.

	Scheme	Analog	Semi-digital	Analog	Semi-digital	Analog	Semi-digital
Linearity: E_{reco}/E_{beam}	Data	1.004	1.05	1.003	1.03	1.0	1.0
	MC	0.972	1.04			1.0	1.0
Resolution: $_E/E$	Data	0.19	0.16	0.16	0.13	0.14	0.12
	MC	0.19	0.16			0.15	0.11

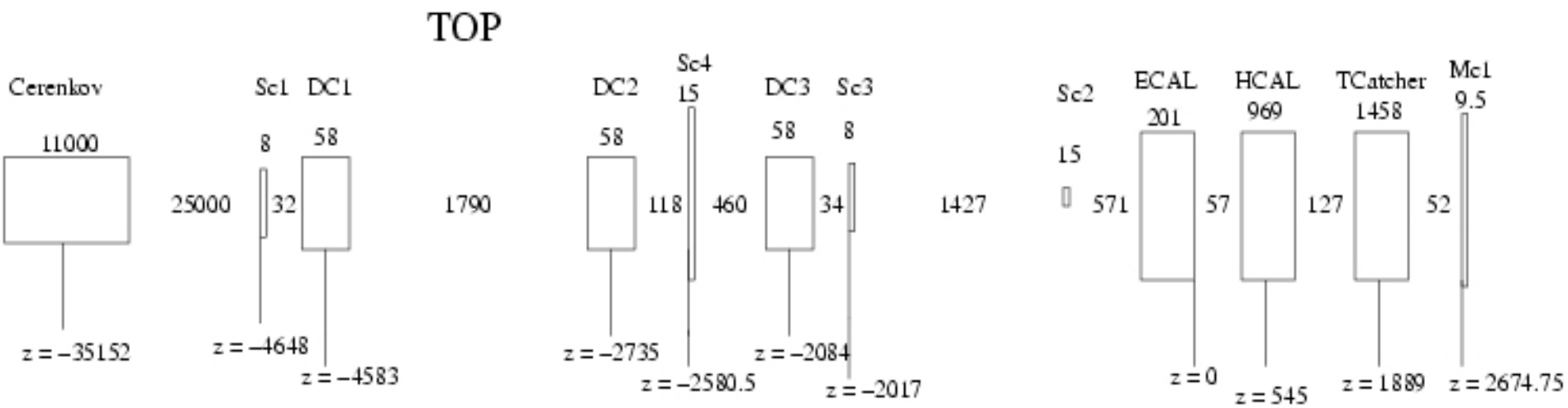
- Semi-digital measurement has better resolution.

Summary

- Preliminary results are most promising.
  - Excellent agreement in the limited comparisons with MC done so far.
  - Still more data to come (Jul/Aug '07 @ CERN, late 2007 @ MTBF/FNAL).
- SiPM readout for high-granularity scintillator -based hadron calorimetry is successful.
- TCMT clearly improves energy resolution.
- Semi-digital calorimetry gives better resolution for single hadrons around 10-20 GeV.
- More detailed analysis, incl. shower shape and better weight-tuning coming soon.
  - The prototype's high granularity allows a detailed study of shower shapes: validation of hadronic shower simulation models.
  - evaluation (and developments) of clustering and particle flow algorithms in future, high-granularity calorimeters.

Back-up slides

Layout of beam test area during 08/06 run



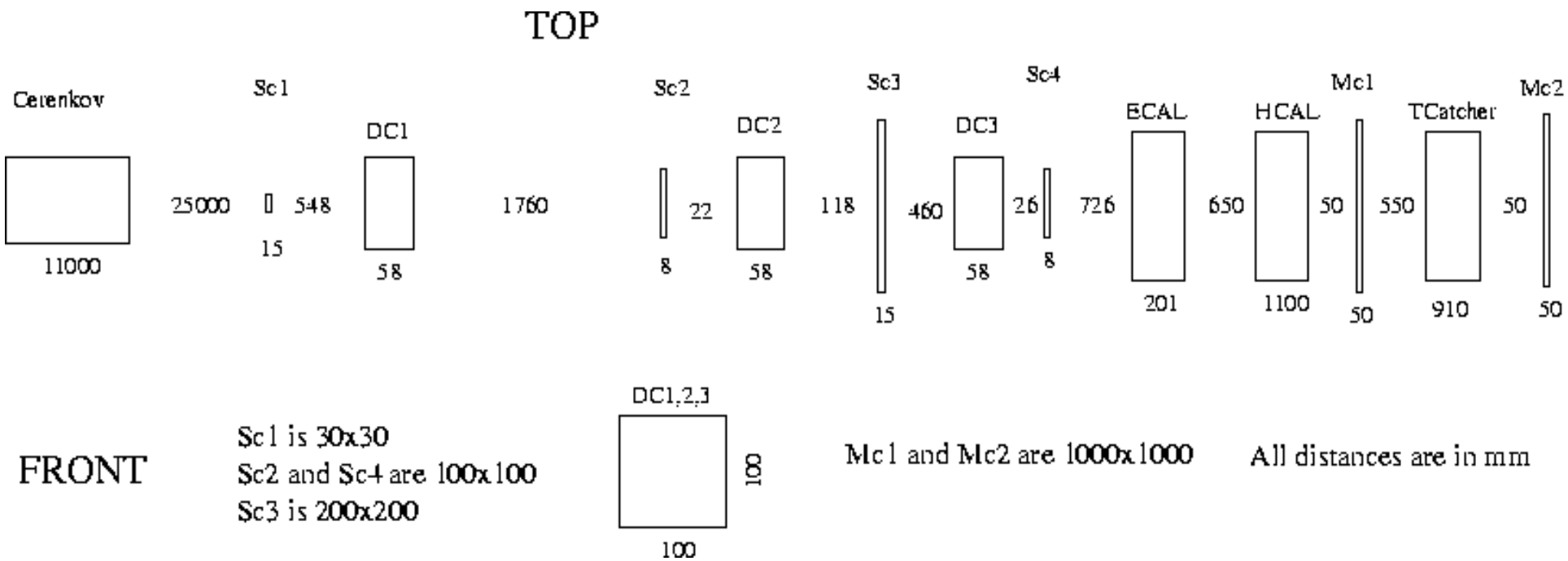
FRONT

Sc2 is 30x30
Sc1 and Sc3 are 100x100
Sc4 is 200x200

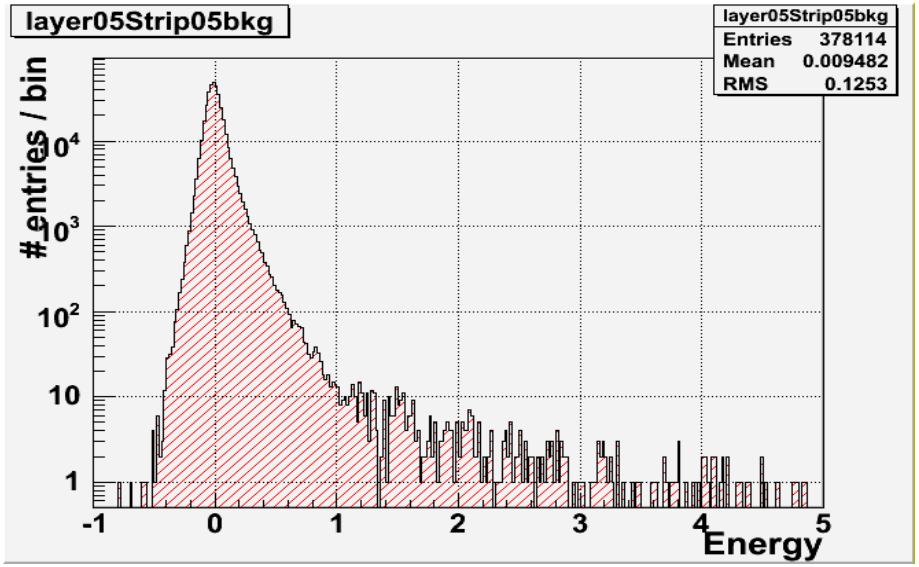
Mc1 is 1000x1000

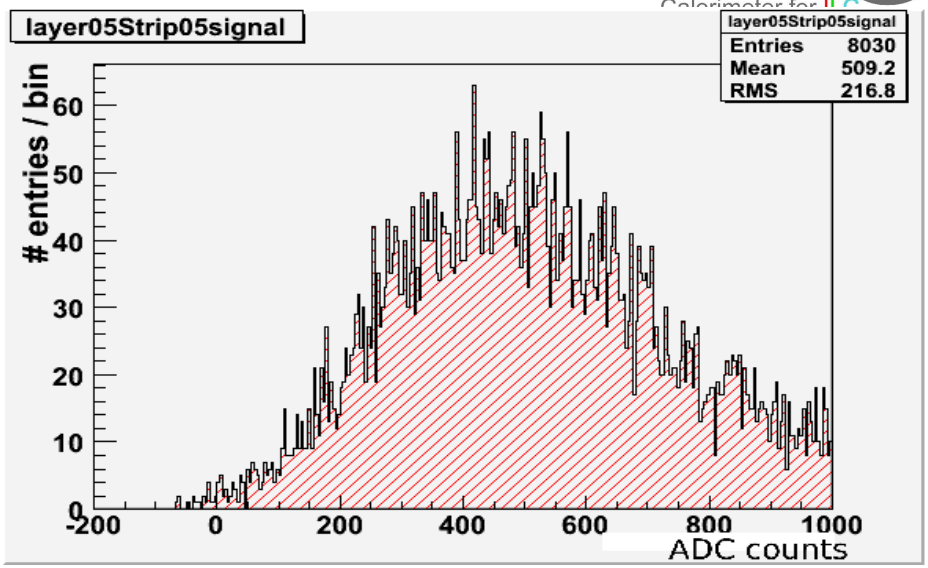
All distances are in mm

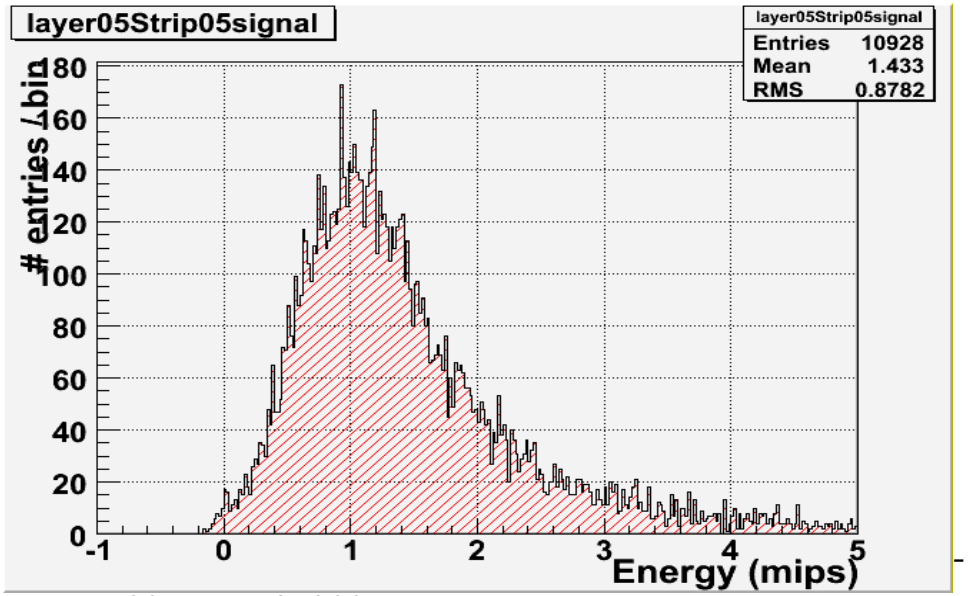
Layout of beam test area during 10/06 run

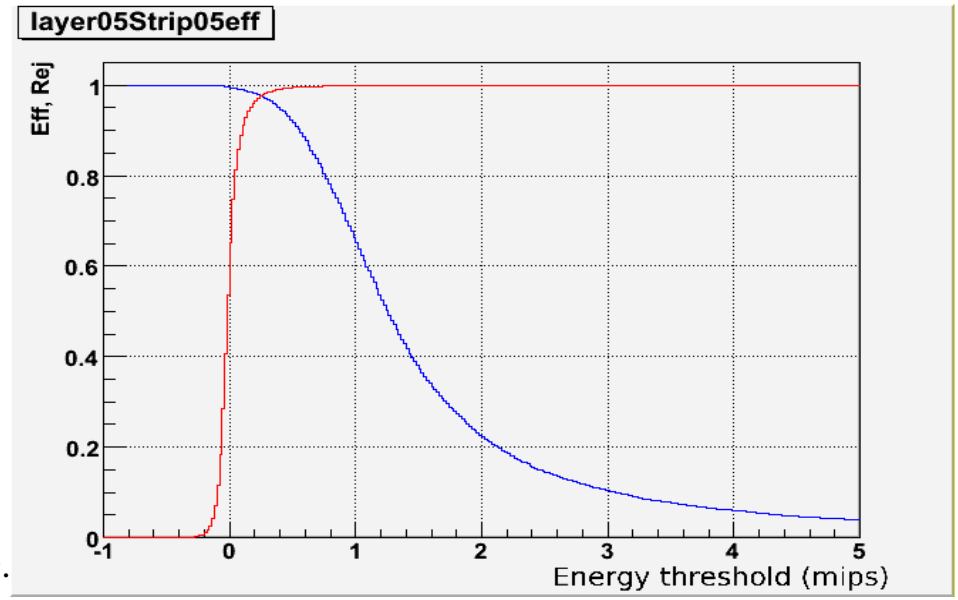


Calibration of a TCMT strip









AHCAL response: data-MC comparison