A preliminary analysis of the CALICE test beam data

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Talk outline

- Test beam apparatus
- CALICE software environment
- Data analysis
  - Sanity checks
  - Hit selection, background rejection
  - Ecal x Hcal x Tcmt energy correlations
- Things to do next
- Summary

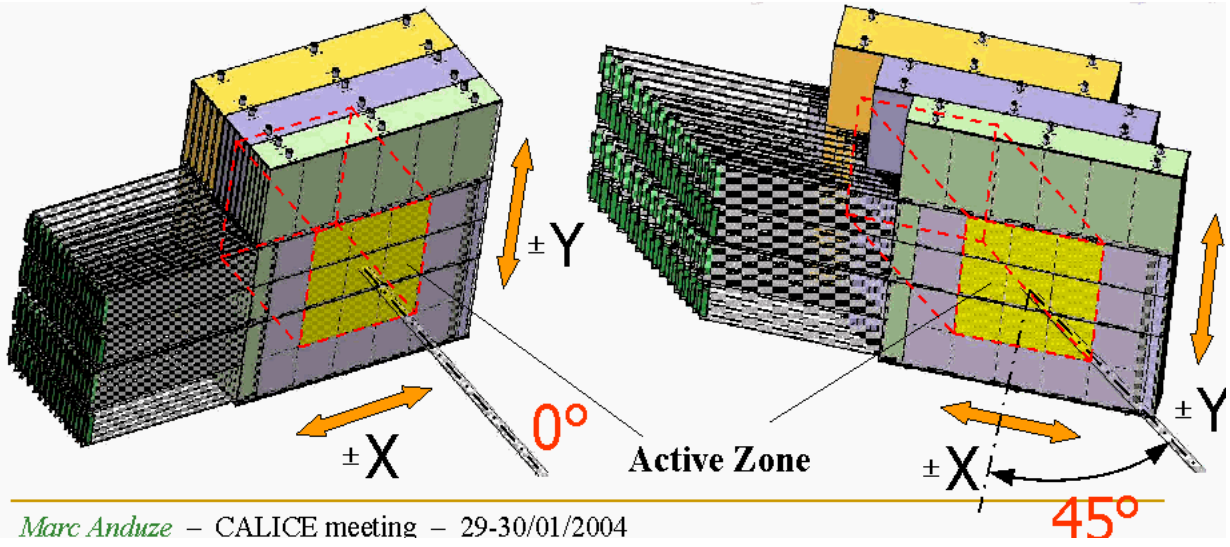
The CALICE ECal prototype

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:

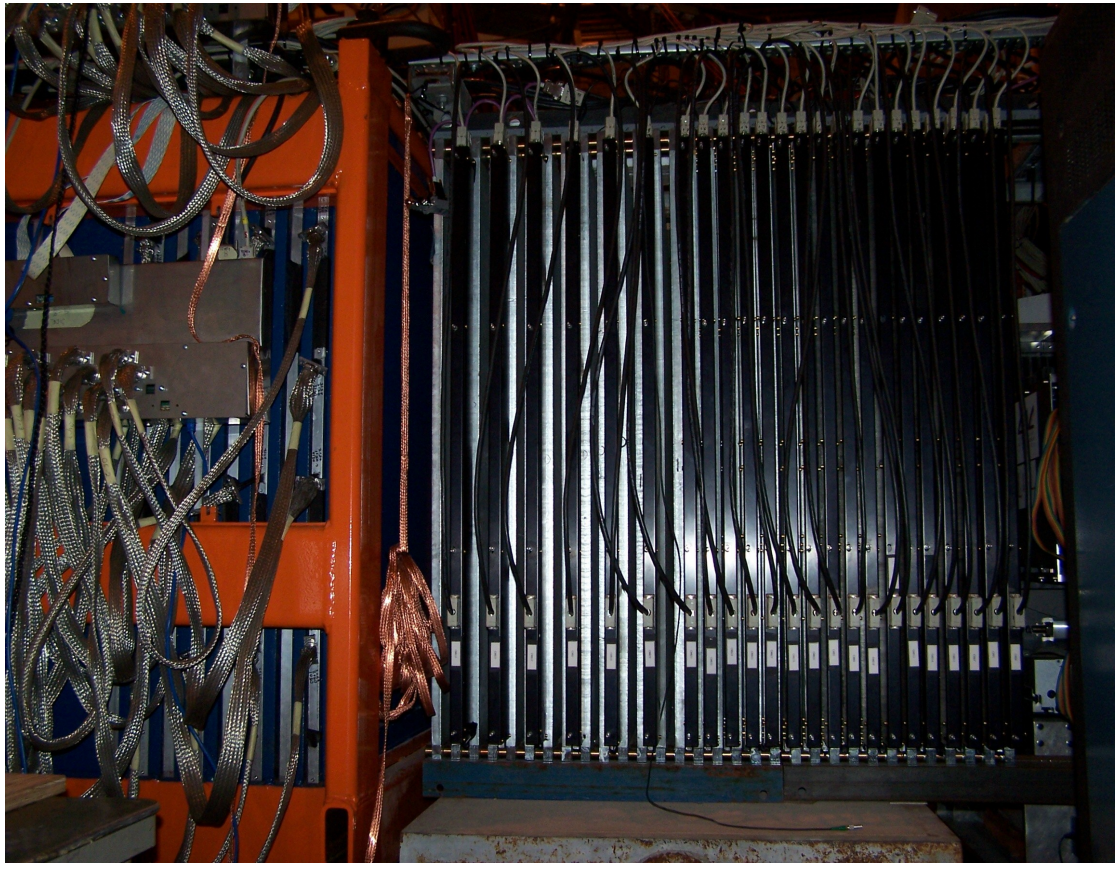
- layers 1-10 - 1.4mm
- layers 11-20 - 2.8mm
- layers 21-30 - 4.2mm

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: 30/38 layers in place:
Layers 1-17 – all instrumented
Layers 19-29 – every other layer instrumented

23 layers x 216 channels / layer
= 4968 channels

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.

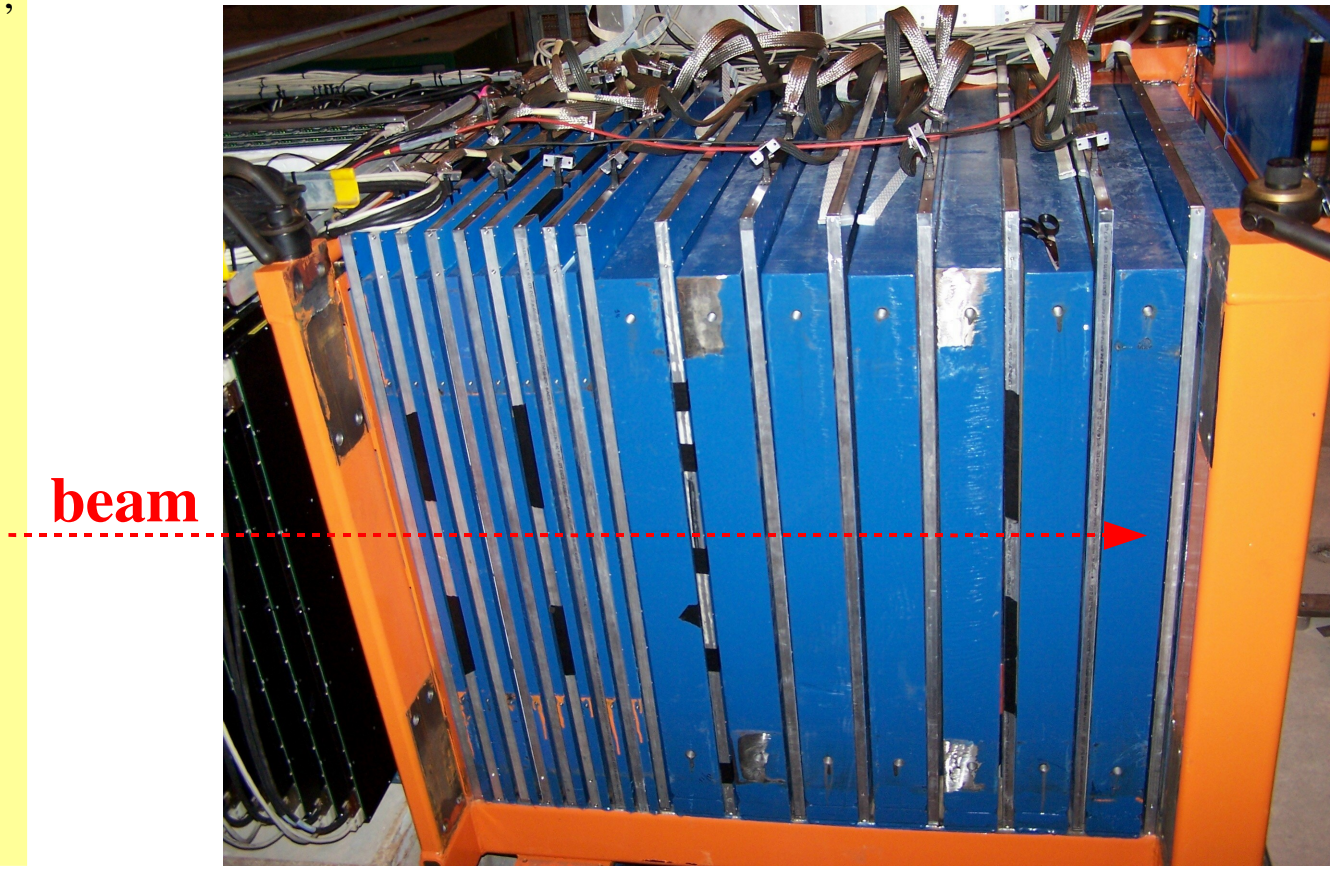
Each strip is 100 x 5 x 0.5 cm^3

Layers 1-8: ~2cm absorber

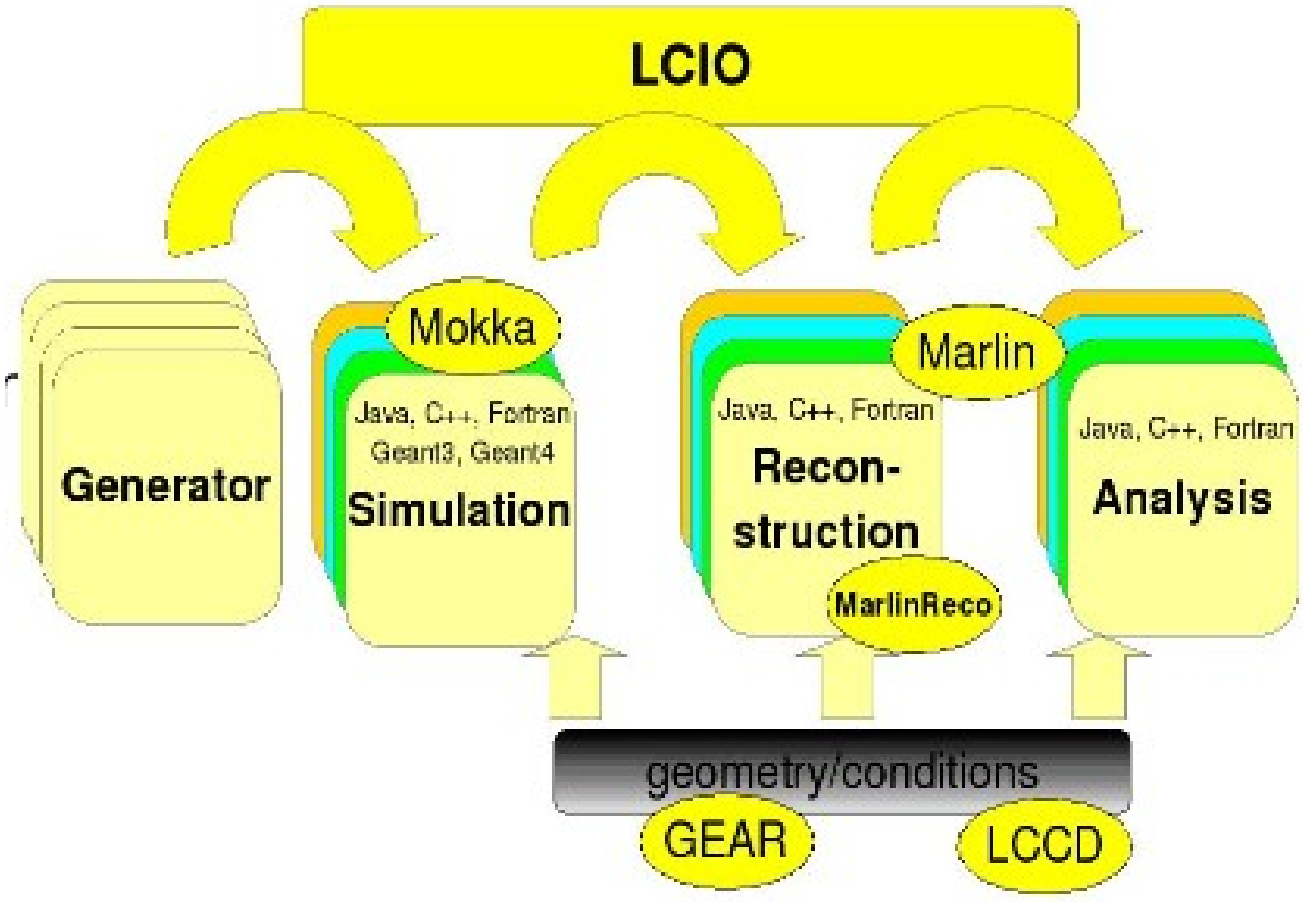
Layers 9-16: ~10cm absorber

16 layers x 20 strips = 320 channels

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



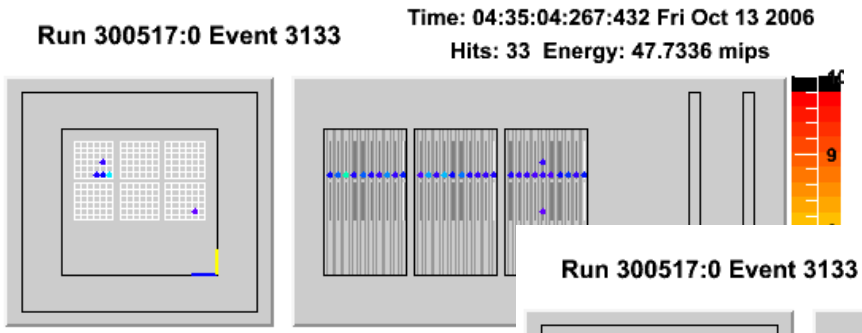
CALICE software environment

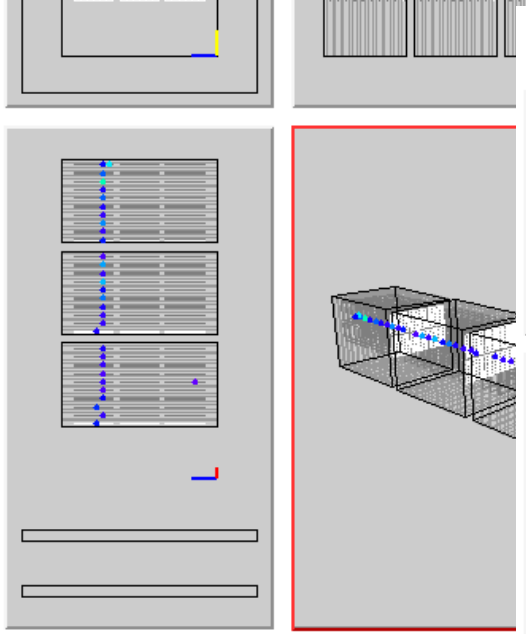


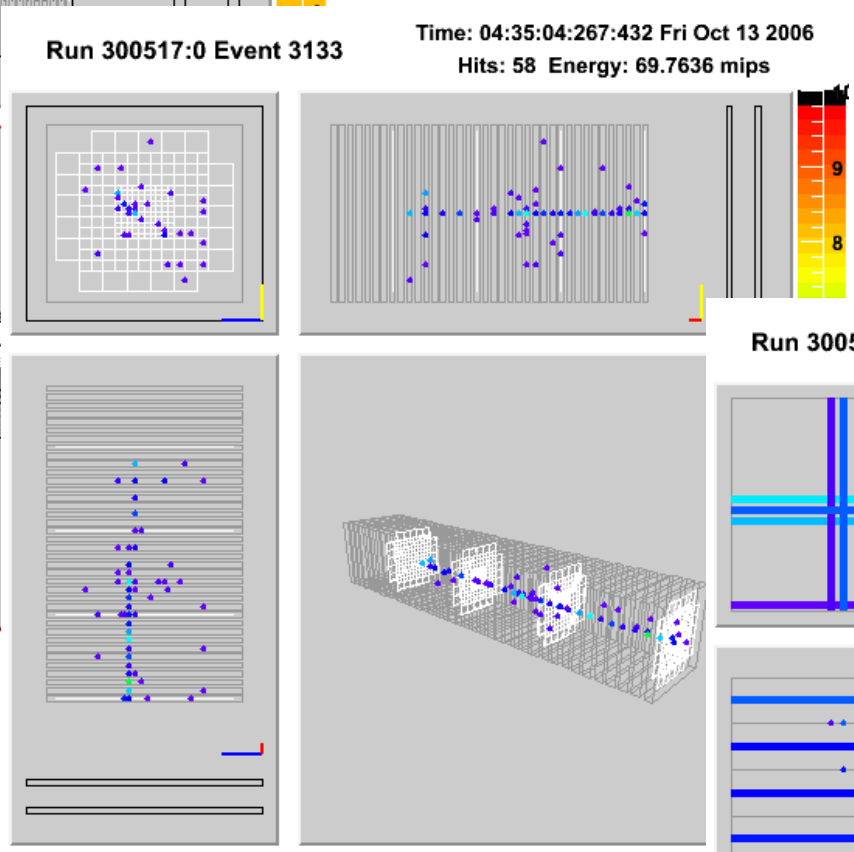
Test beam: software processing chain

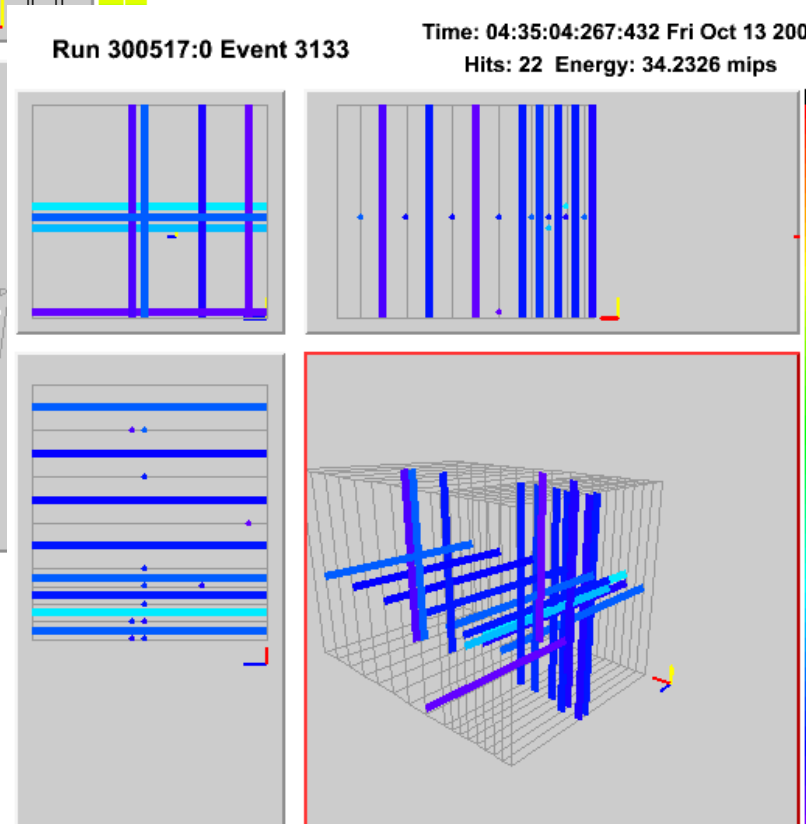
- Real data processing:
  - LCIO converter: raw data structures in LCIO format (data is grid-available)
  - Official reco framework: Marlin + LCCD/CondDBMySQL + Calice libs
    - Pedestal subtraction, calibrations (gain, intercalib, saturation, mip)
    - Output: calibrated hits, zero suppressed, global hit position
- Monte Carlo processing:
  - Mokka (Geant4): latest version (6.3.p01) with TBCern1006_01 geometry model
  - DigiSim: energy threshold, MIP calibration. No x-talk or noise simulated yet!
    - Output: calibrated hits, zero suppressed, global hit position
- Data analysis: Marlin processors, ntuple fillers, root scripts (org.lcsim + JAS3?)

A typical muon event





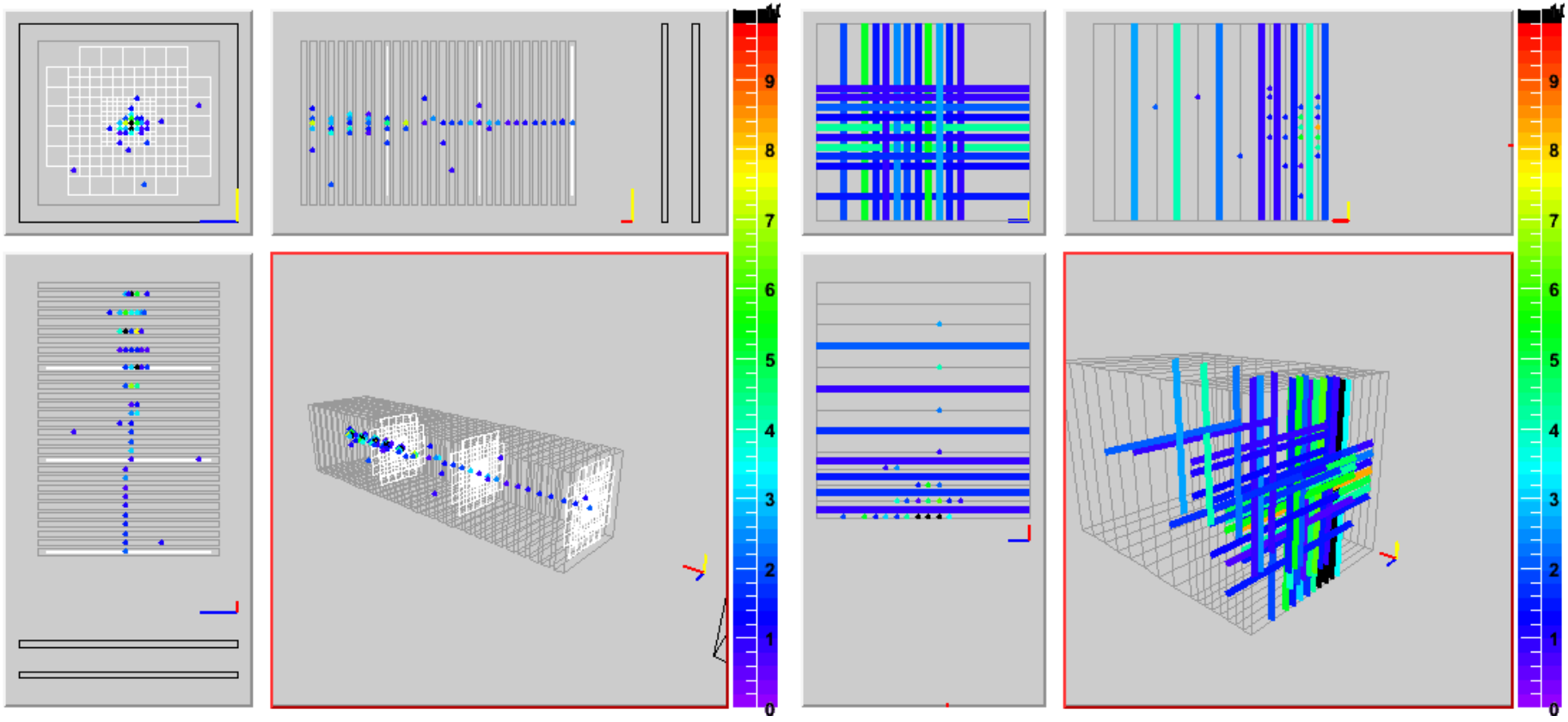




Example pion event display

40GeV/c pion
with CALICE online analysis software

HCAL **TCMT**



Late shower in HCAL

TCMT clearly needed to contain shower

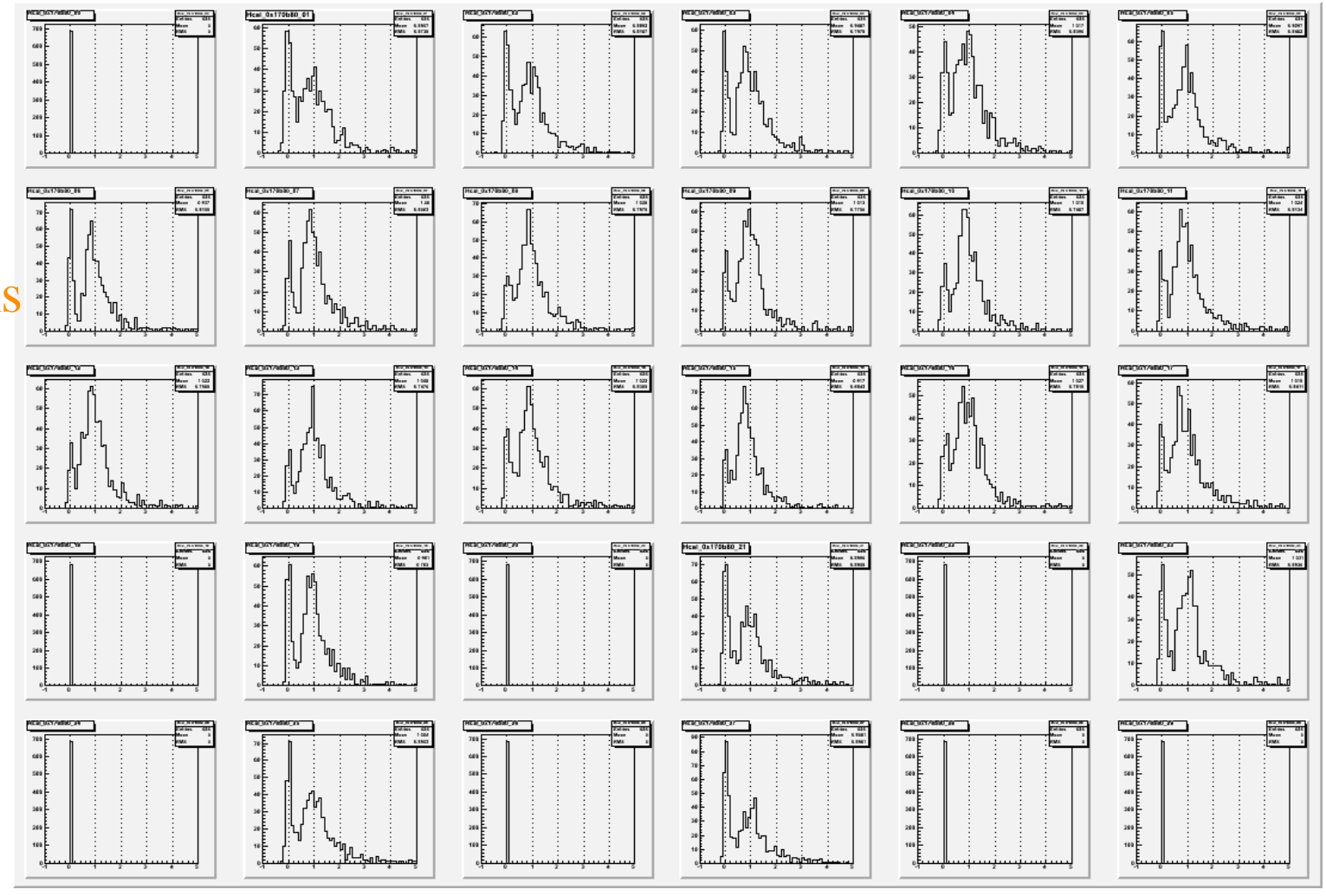
Slide from K.Francis' talk

Overview of our test beam data analysis

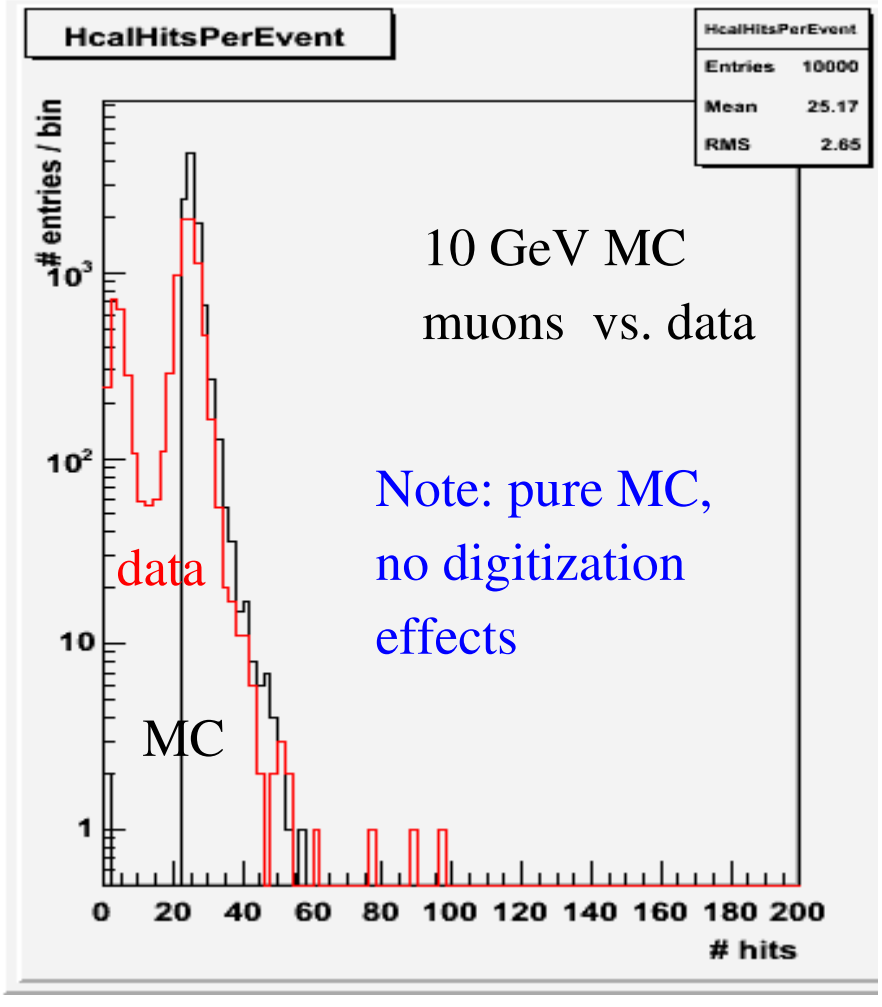
- Recent developments (since last presentations at SiD phone meetings):
  - Use of official reconstruction framework + calibration constants from conditions DB
  - Better background rejection (trigger bits and veto counter amplitude)
  - Account for different detector thicknesses (7 distinct hit weights)
  - Simple-minded procedure for finding sampling fractions
- Hit selection requirements: Ehit > 0.5 Emip .and. Ehit > 2 $\sigma_{pedestal}$
- Compare test beam MC vs. real data taken at Cern (focus on Hcal/Tcmt response)
  - MC samples of muons (6, 10 GeV) and pions (6, 8, 10, 12, 15, 18, 20, 30, 40, 50, 80 GeV)
- Basic sanity checks, energy correlations, combined live energies, etc.
- Preliminary look at pion samples at several different energies

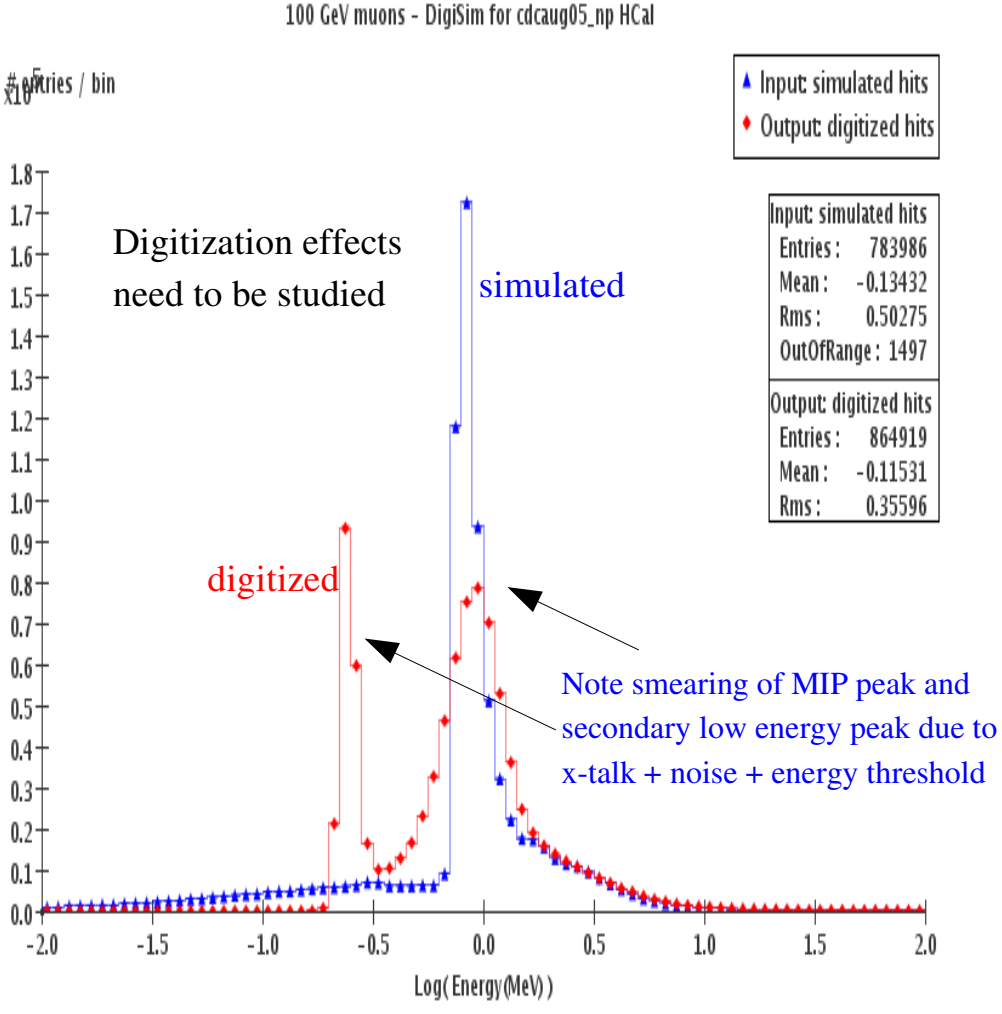
Checking mip calibration in Hcal

Use software triggering to select mip tracks (8 aligned hits), then plot response of every cell.



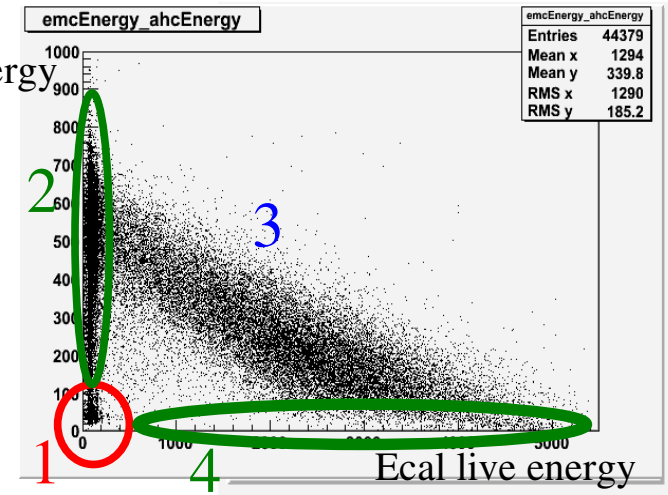
MC comparisons: # Hcal hits per event

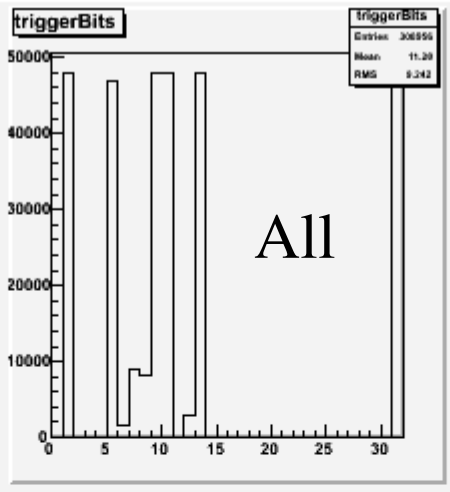


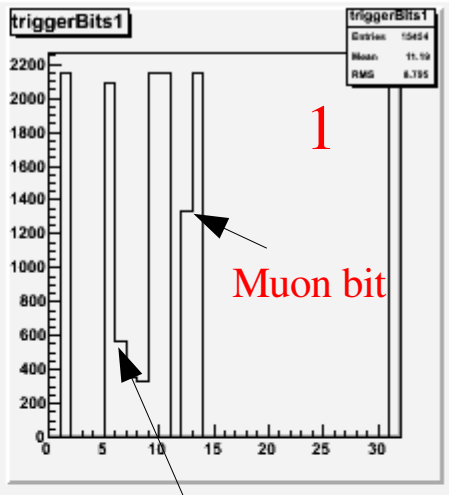


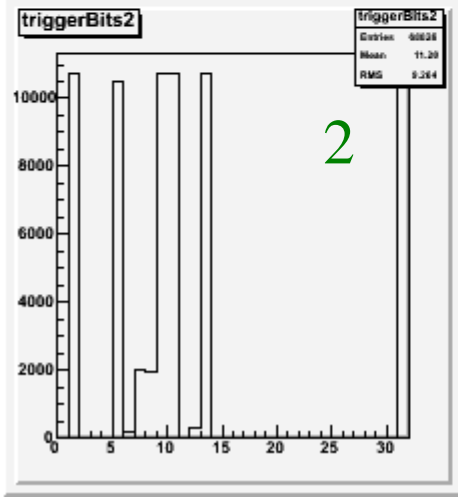
Background rejection: muons in pion samples

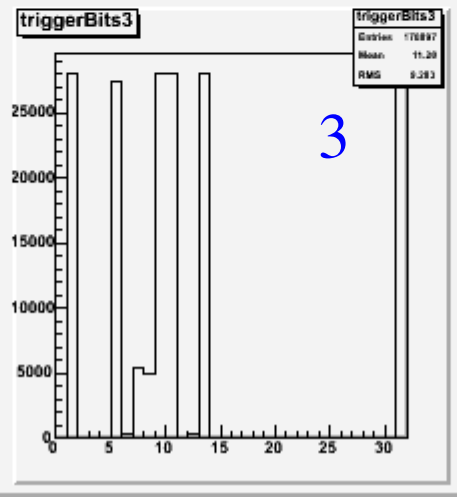
Hcal live energy

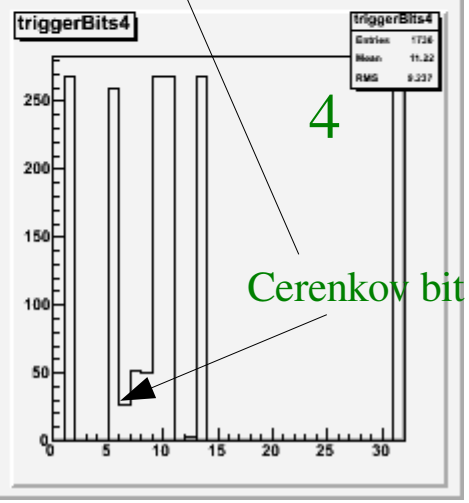










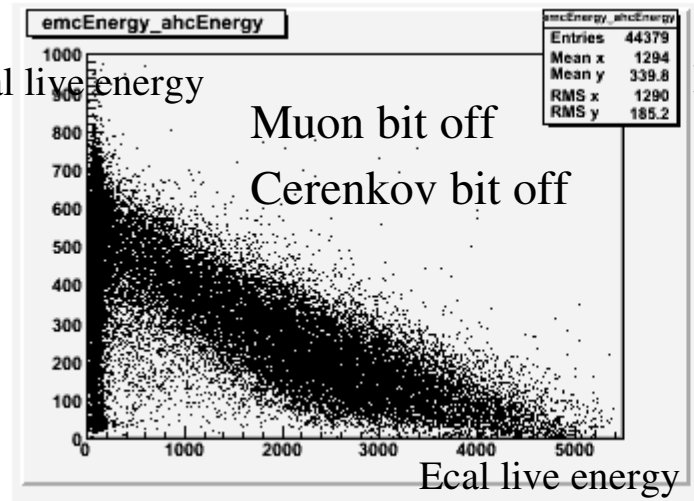


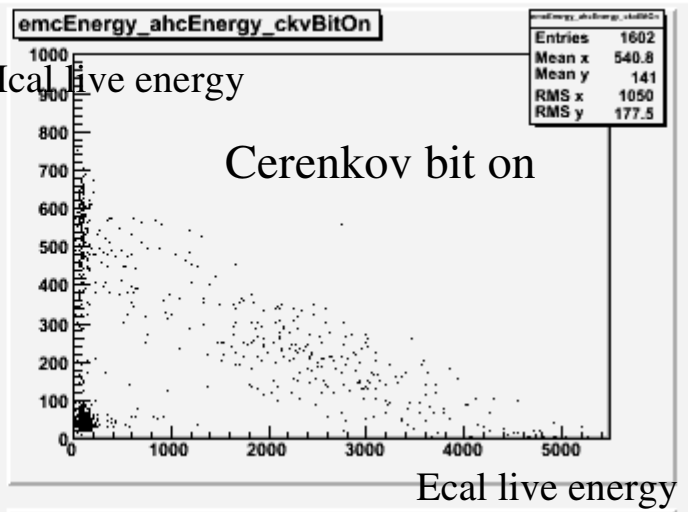
Trigger bits:

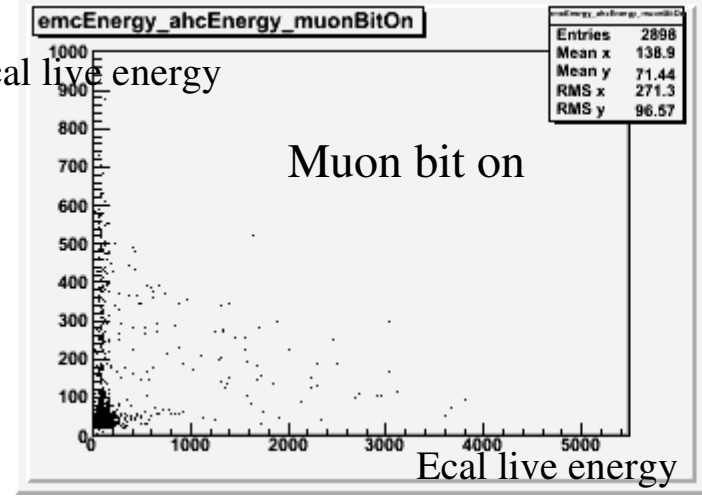
12: muon counters

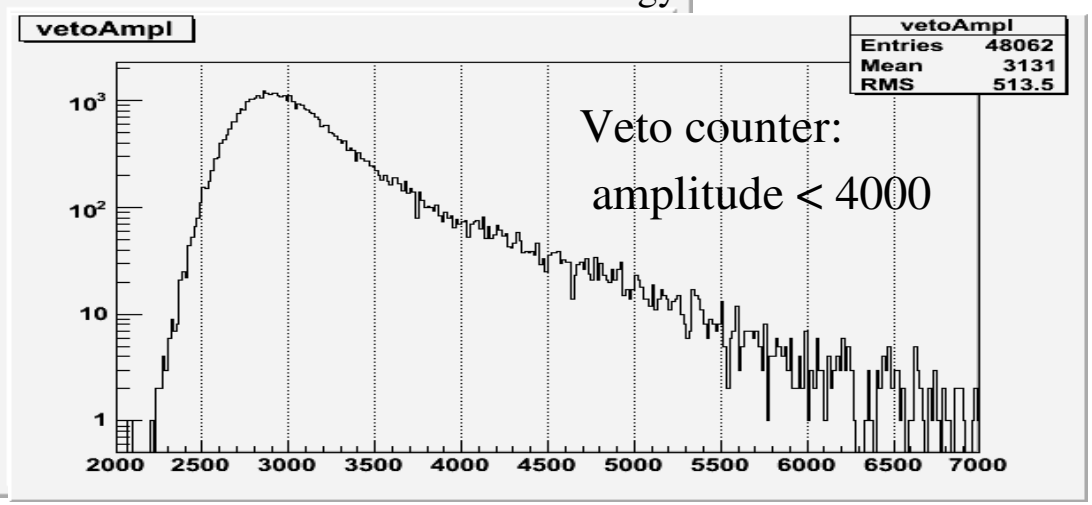
6: Cerenkov

Background rejection handles







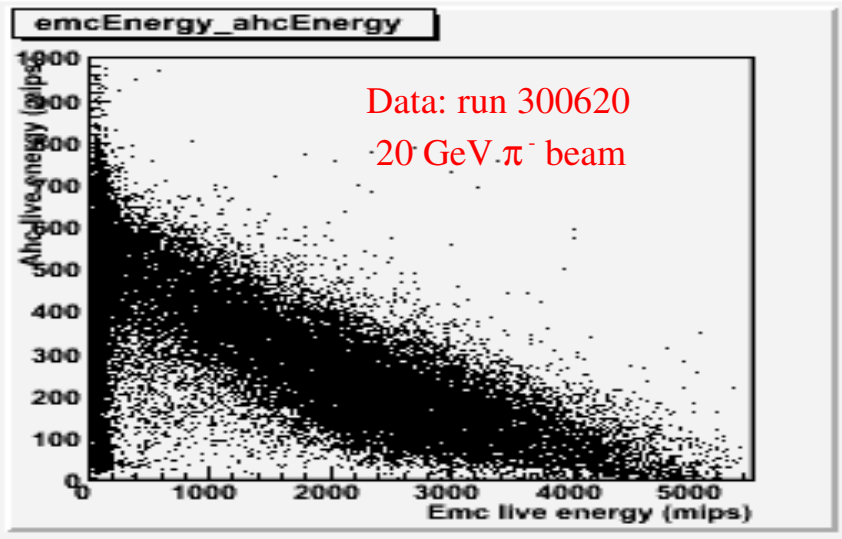


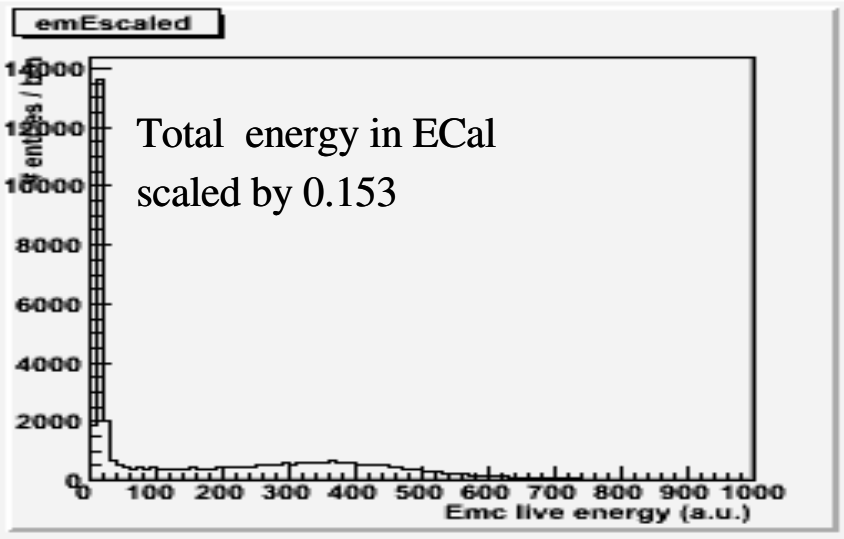
Energy correlations in a sample of 20 GeV π^-

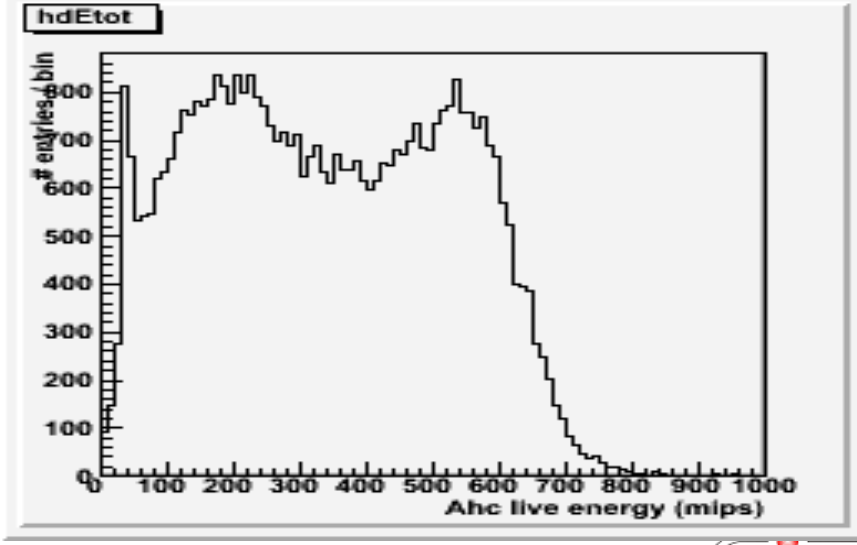
- Energy combination accounts for relative intra-component absorber thicknesses (Rel.Abs.Th.) and for inter-component sampling fractions (ICF)
- SW_analog = (Rel.Abs.Thickness) * (ICF_analog) and similar for digital
- Simple-minded ICF factors: angular coefficient of a line representing the anti-correlation scatter-plots.

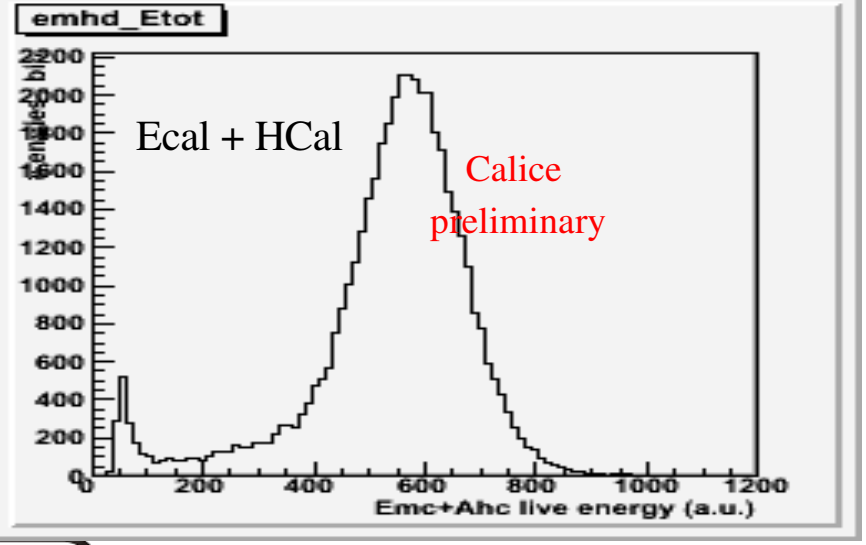
	Rel.Abs.Th	ICF_ana	ICF_digi	SW_ana	SW_digi
Ecal1	1	0.153	0.292	0.1526	0.292
Ecal2	2	0.153	0.292	0.3052	0.584
Ecal3	3	0.153	0.292	0.4578	0.876
Hcal1	1	1.000	1.000	1.0000	1.000
Hcal2	2	1.000	1.000	2.0000	2.000
Tcmt1	1	0.909	0.257	0.9091	0.257
Tcmt2	4.92	0.909	0.257	4.4728	1.264

Combining Ecal and Hcal (analog) – TB data

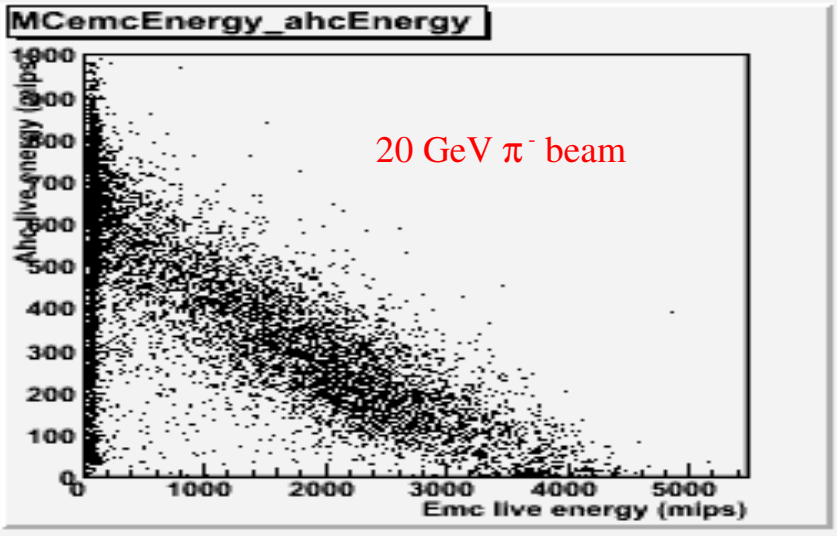


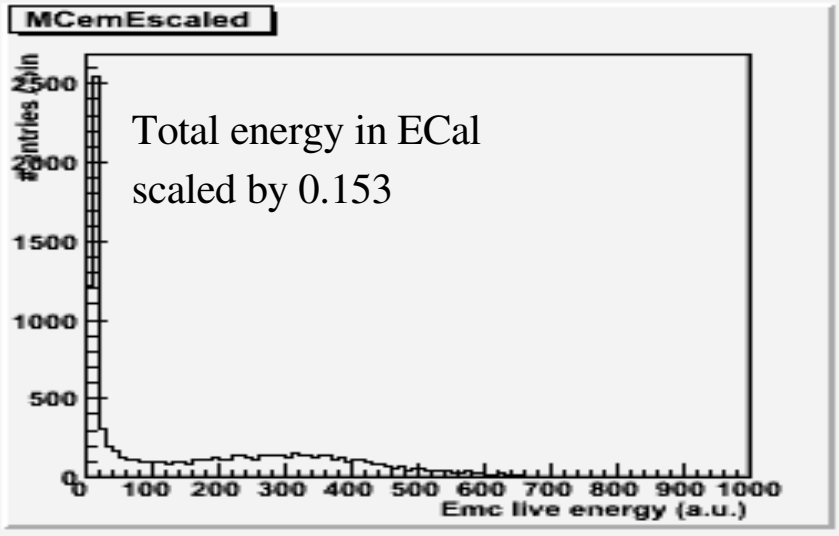


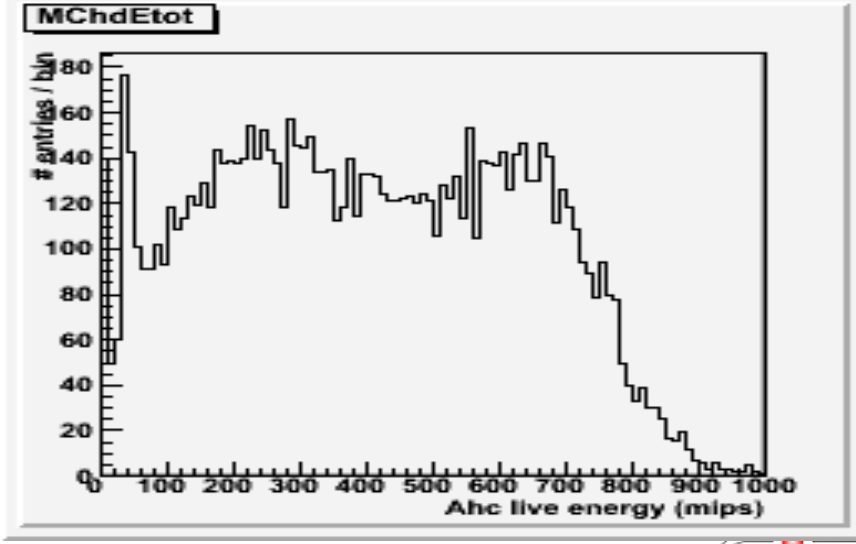


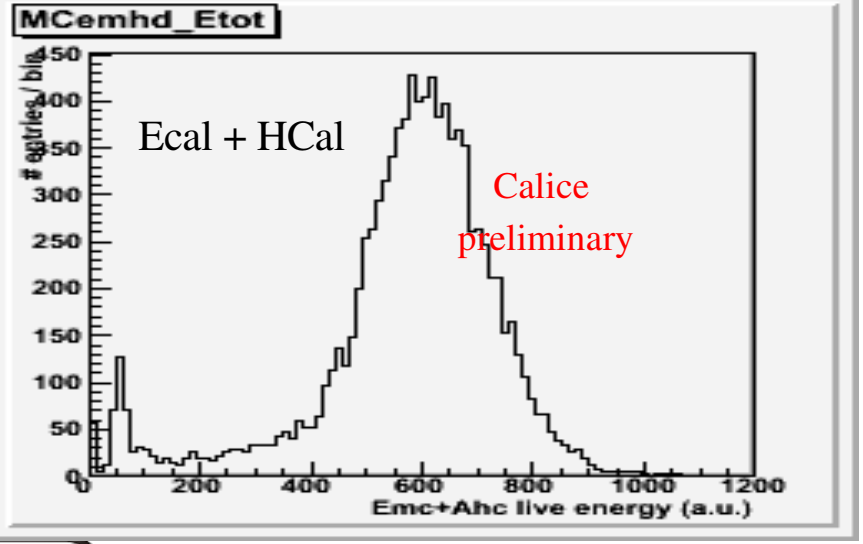


Combining Ecal and Hcal (analog) - MC



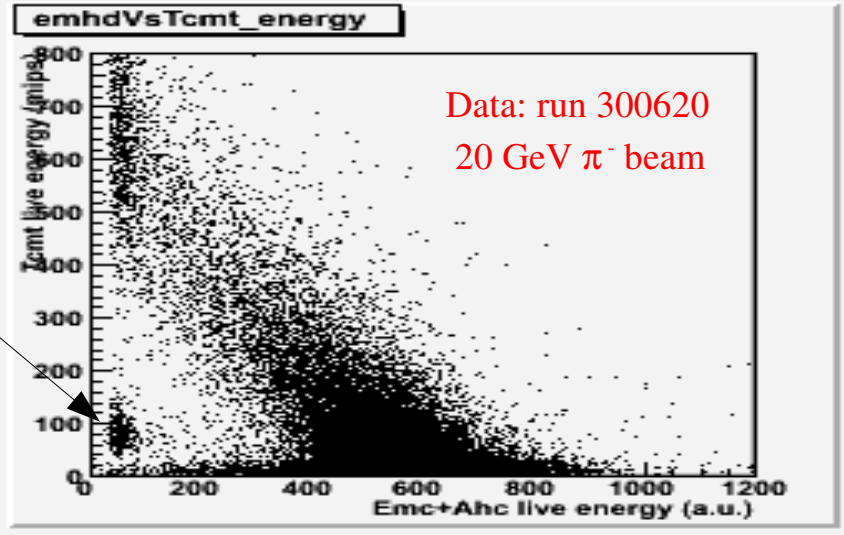


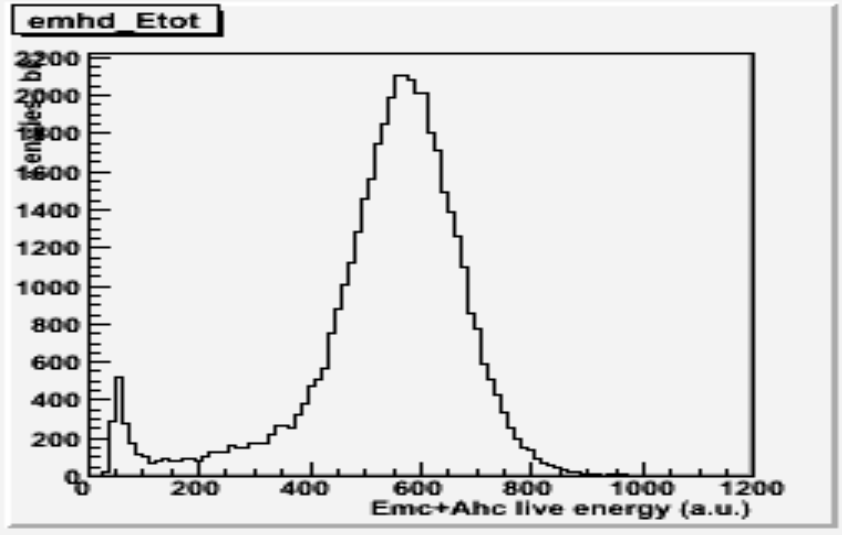


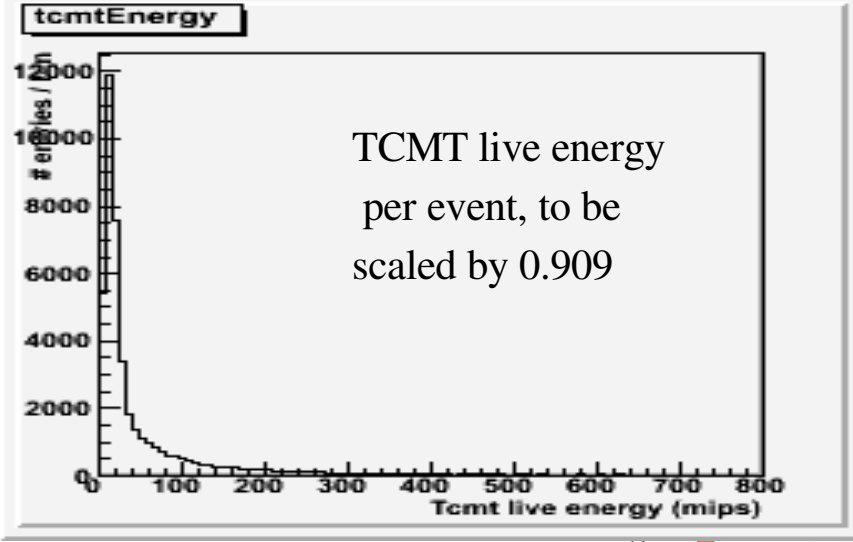


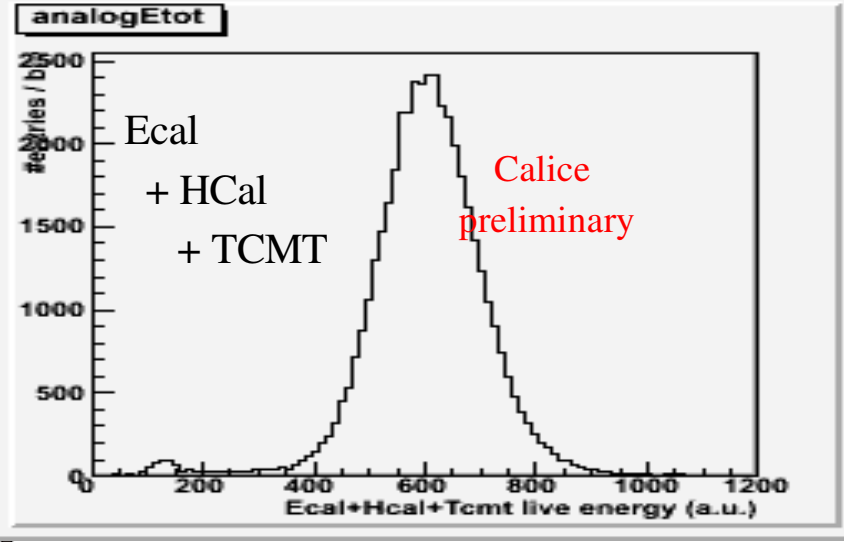
Combining EM+HD and TCMT (analog) – TB data

Muons from in-flight decays









Combining EM+HD and TCMT (analog) - MC

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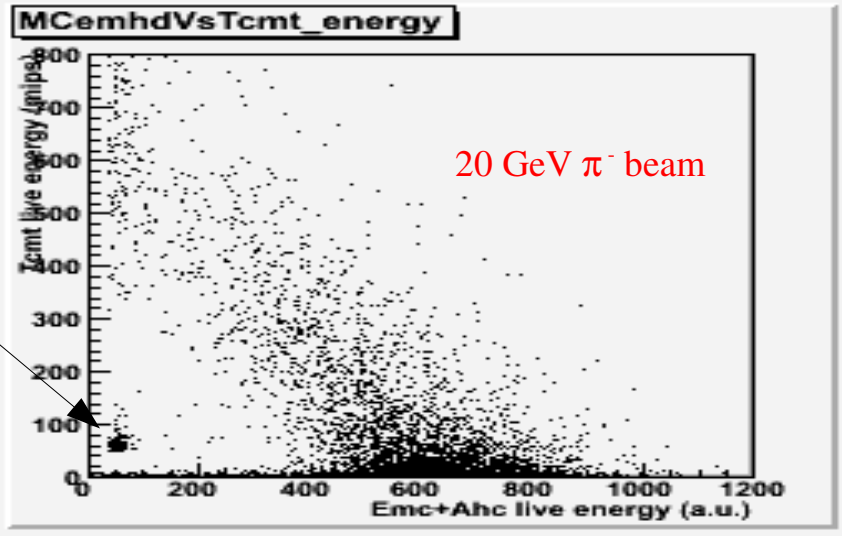
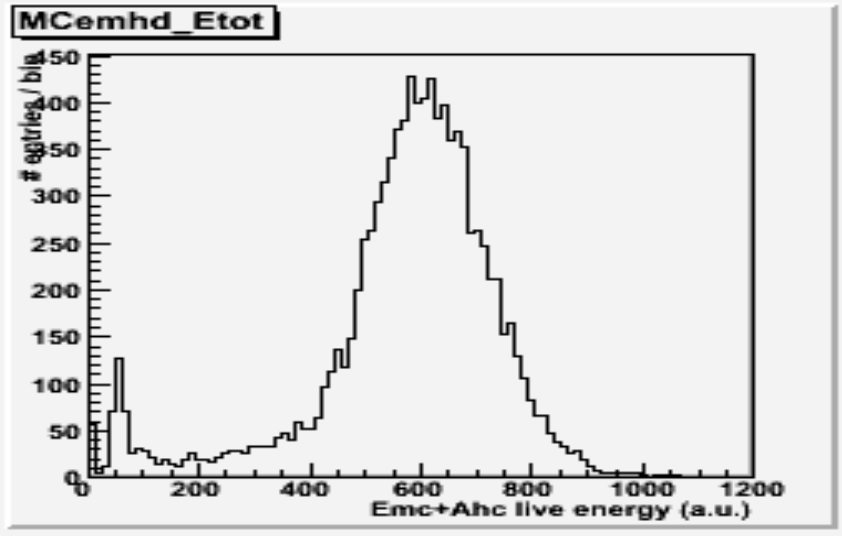
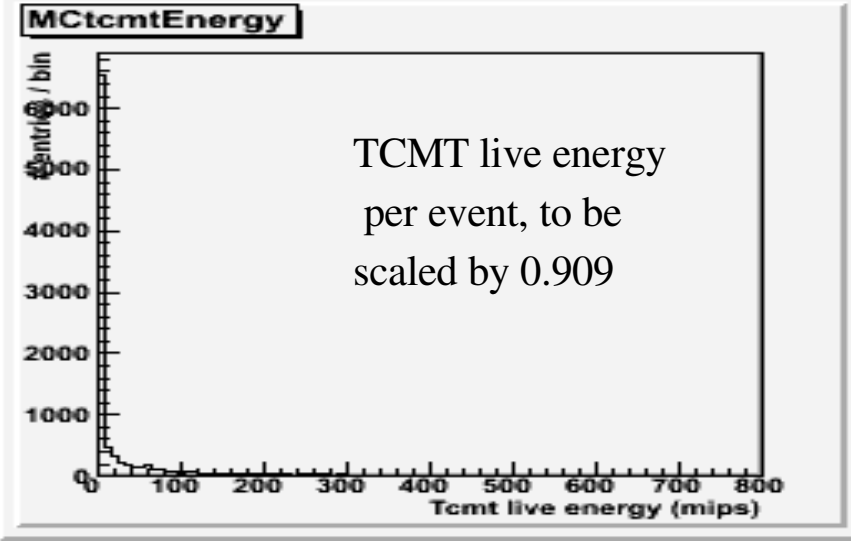
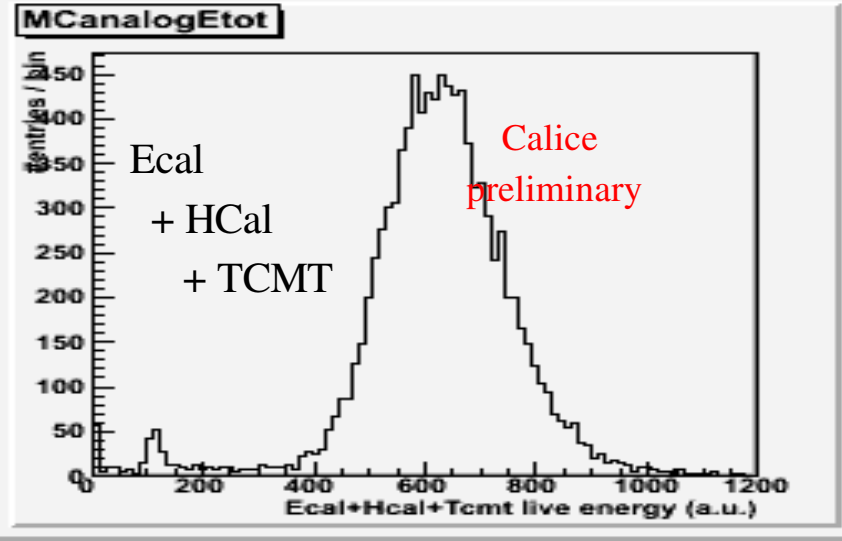
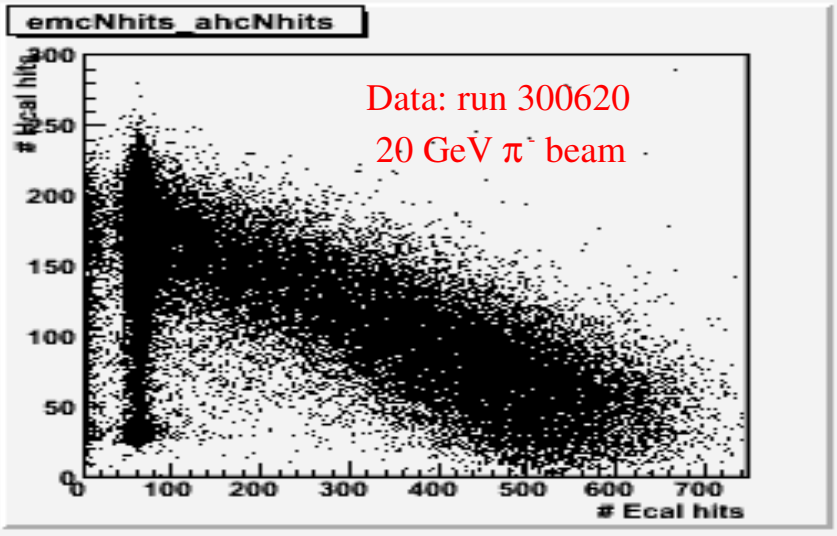


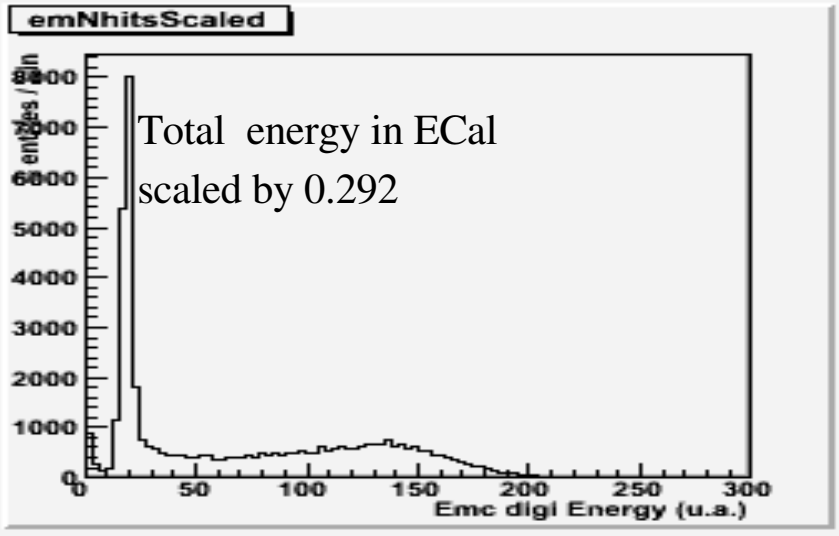


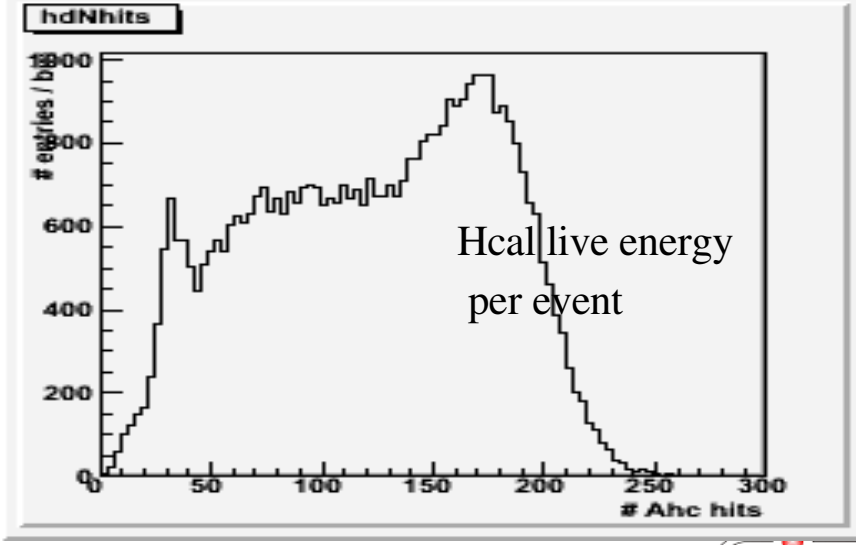


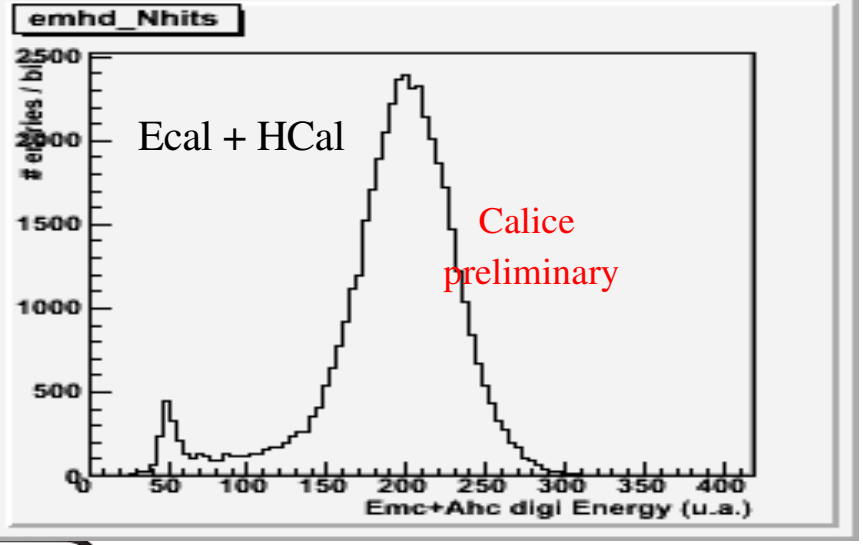


Combining Ecal and Hcal (hit counting) – TB data









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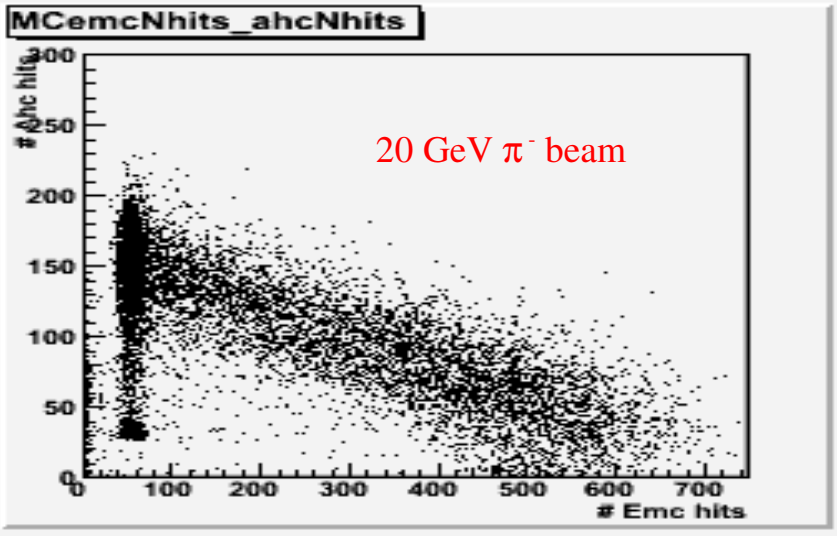
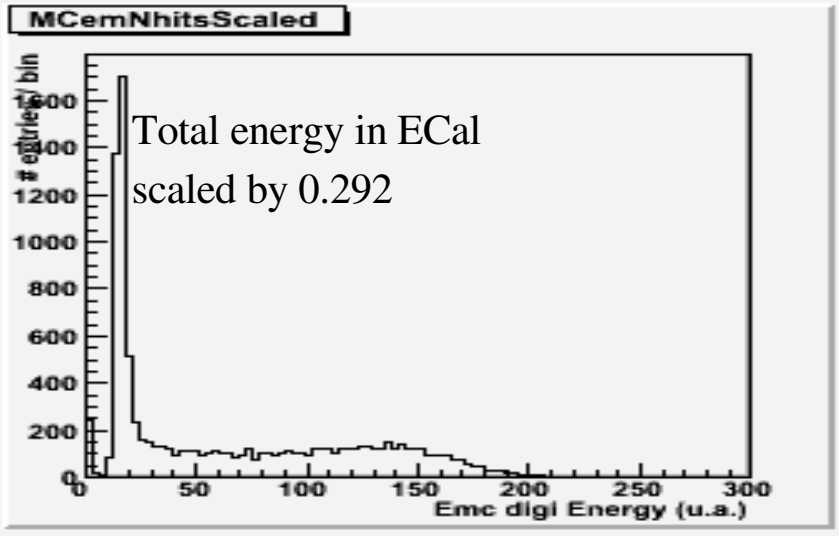
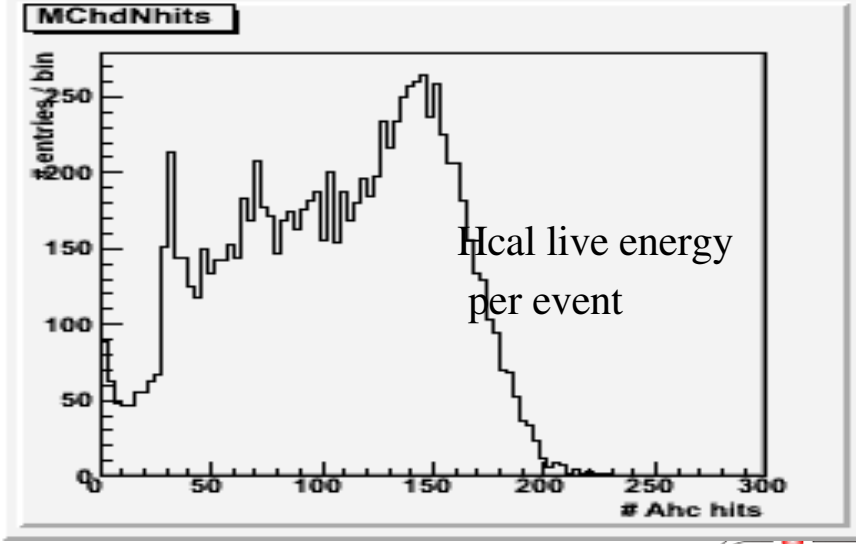
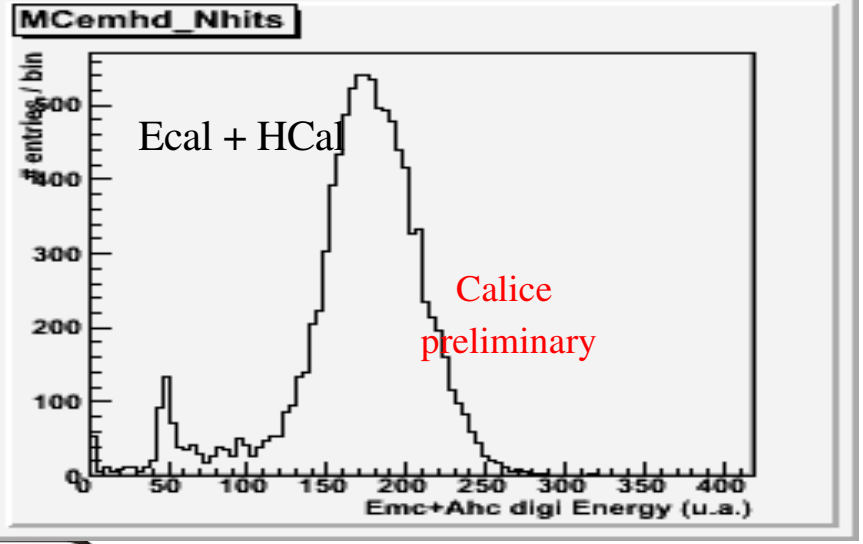
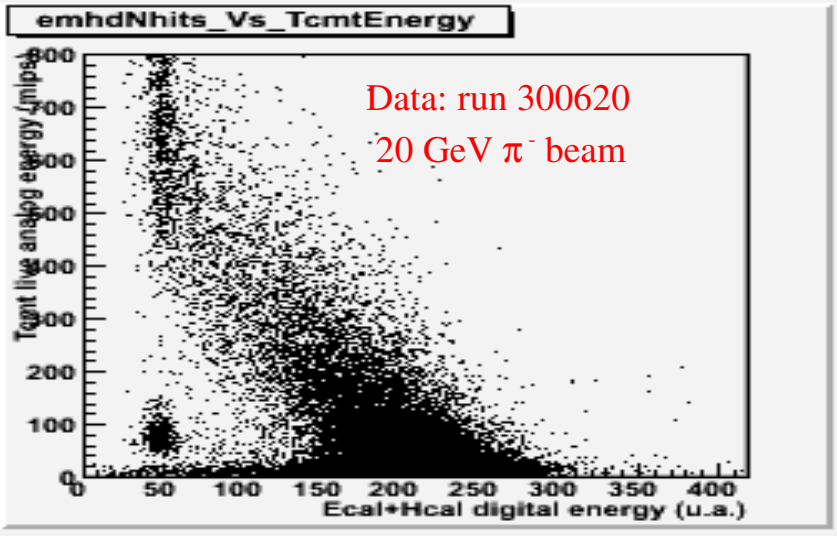


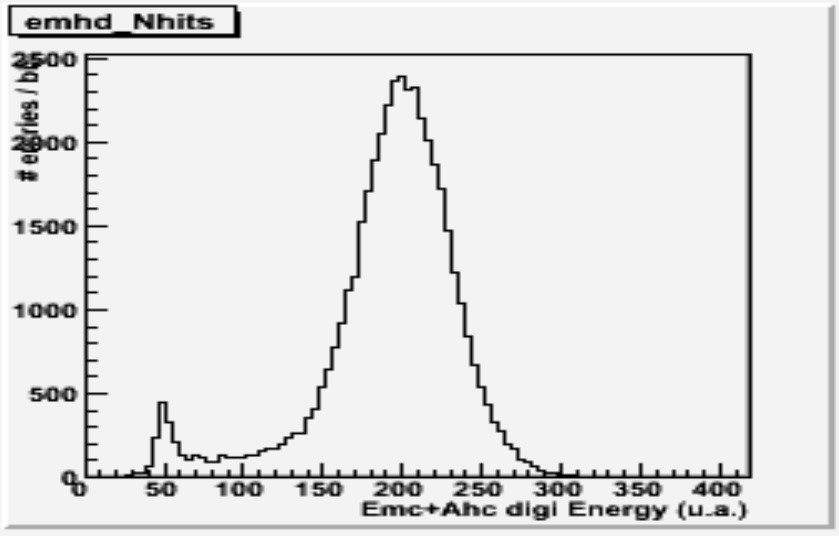


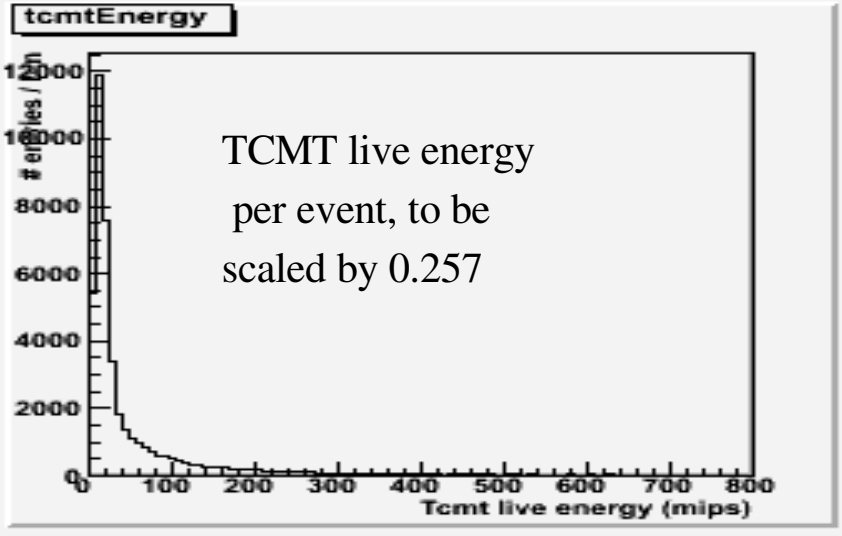


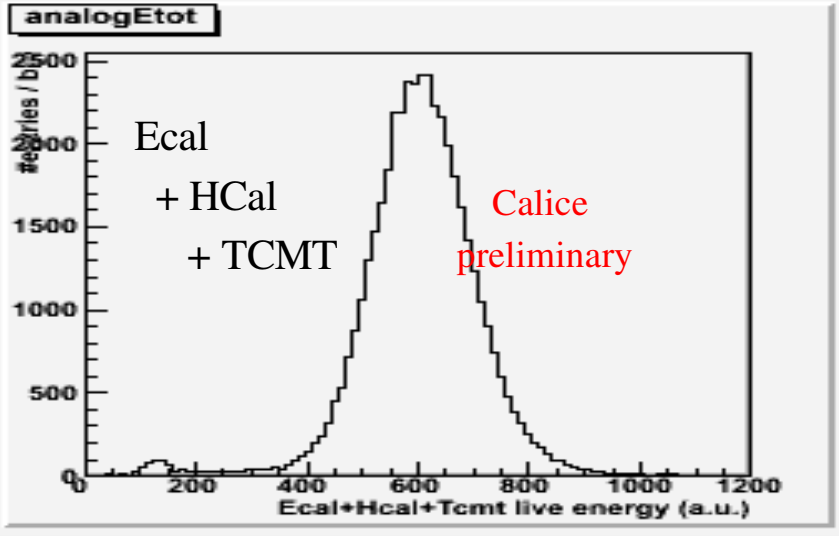


Combining EM+HD and TCMT (hit counting) – TB data









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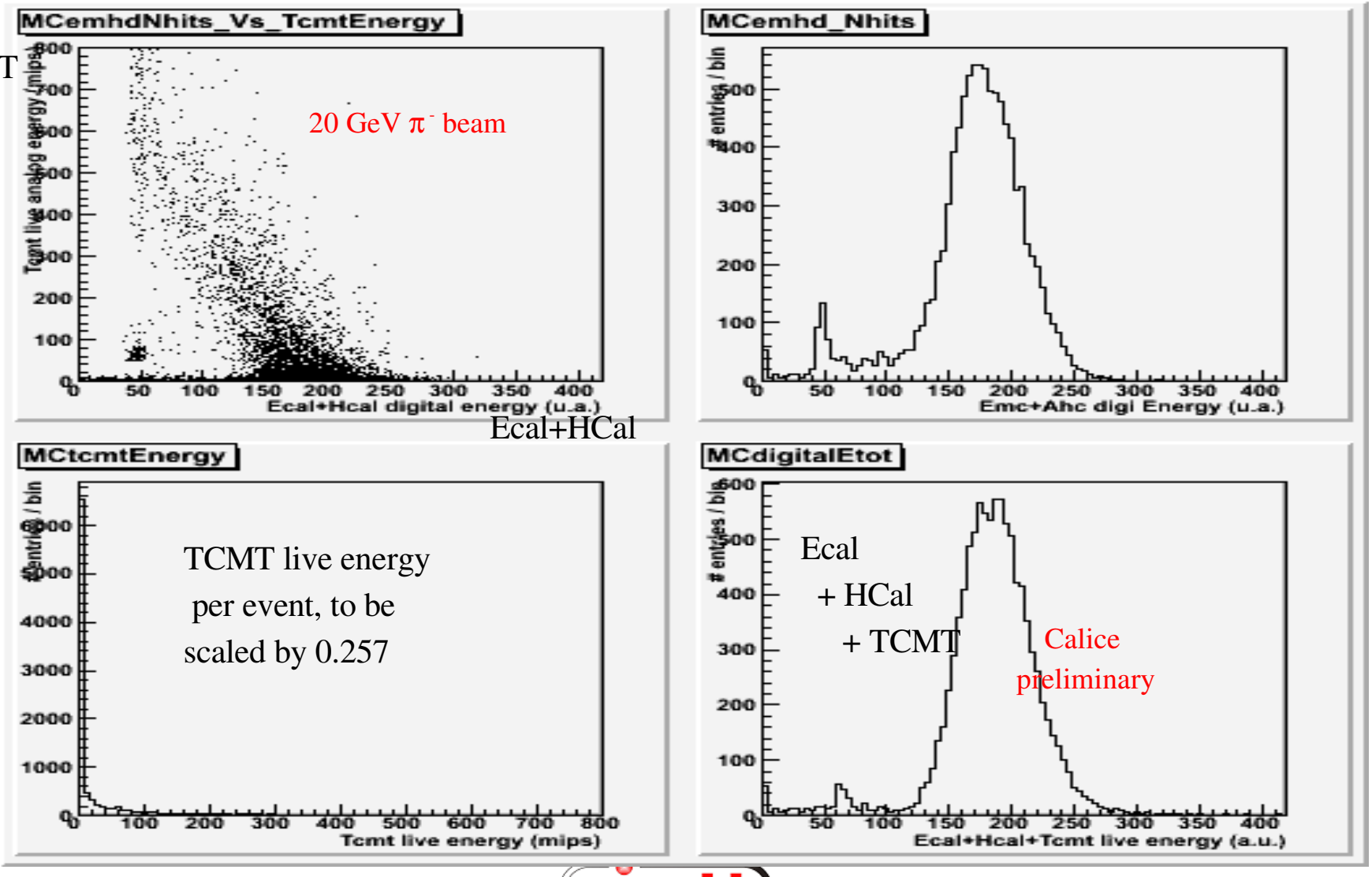

Things to do next

- Chisquare-based method for finding sampling factors
  - First pass is done, but plots not yet shown today
- More sophisticated hit weighting schemes on real data, for better energy resolution
- Hcal/TCMT alignment ---> look at transverse shower shapes
- Exercise directed tree clustering in test beam data (plans to use org.lcsim + JAS3)
- Introduce corrections for SiPM saturation effects in TCMT
- Energy resolution studies

Summary

- Lots of test beam data already available, detailed analysis is just starting
  - Still more data to come (Jul/Aug '07 @ CERN, late 2007 @ MTBF/FNAL)
- Results will show the performance of SiPM readout for high-granularity calorimetry
- 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
- Preliminary results look very encouraging!