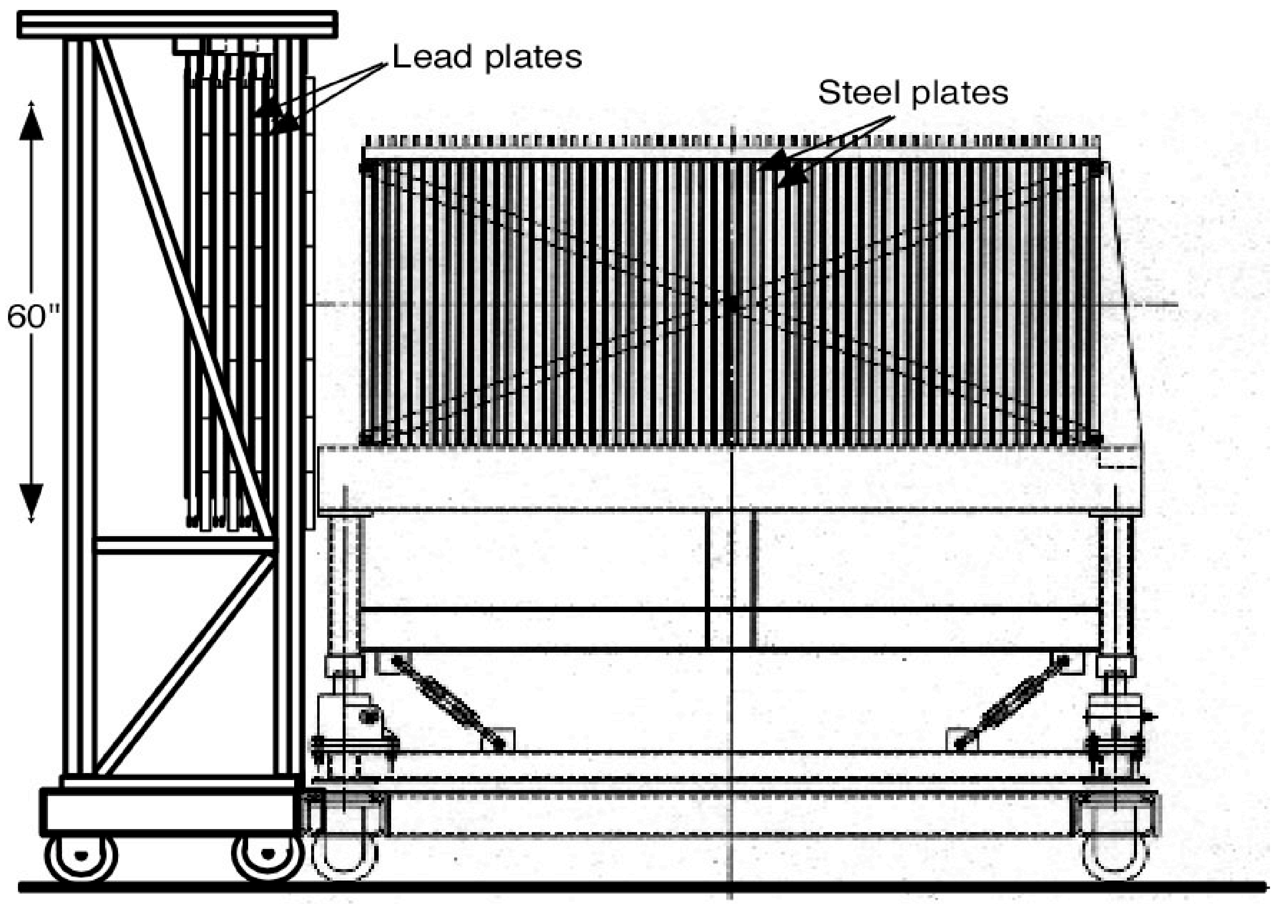
EMCAL/HCAL Status Report



M. Longo 4/8/2006

Personnel Matters

- New postdoc Turgun Nigmanov has been doing a very nice job on data analysis.
- Durga Rajaram is back in action.
- Hyangkyu Park is gone.

The purpose of the HCAL in MIPP is to measure the production of forward-going neutrons. The purpose of the EMCAL is to measure the production of forward high-energy photons.

For "engineering" applications, the inclusive cross sections for photons are most useful because that's what is propagating in the various media.

However, for "physics", the inclusive production cross sections for π^0's are needed. These can be determined by reconstructing the π^0 mass from pairs of gammas in the EMCAL. This requires a very careful energy calibration. The acceptance for two gammas is rather small. However, the cross sections for forward π^0 production are very large, so that the accuracy of the results is likely to be limited by systematics. rather than statistics. We also believe that once the backgrounds and calibration are understood, it will be possible to infer the π^0 yield from single high-energy gammas.

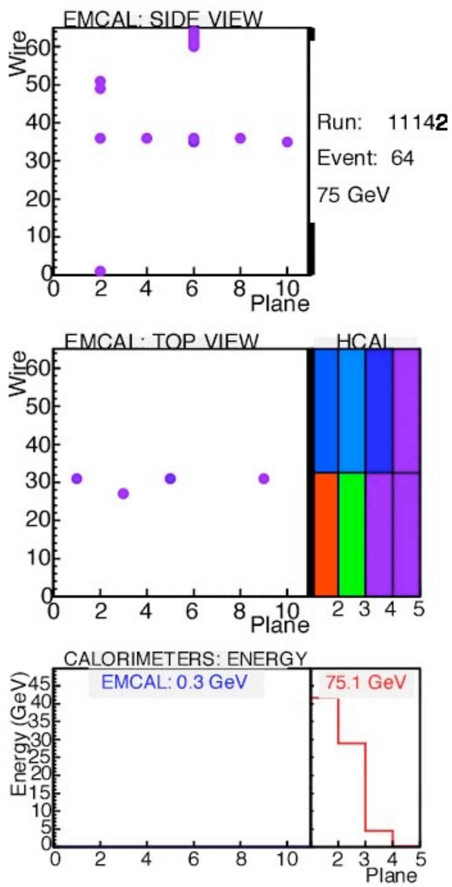
Note that the original motivation and ongoing funding for the calorimeters is for proton radiography.

EMCAL data sample

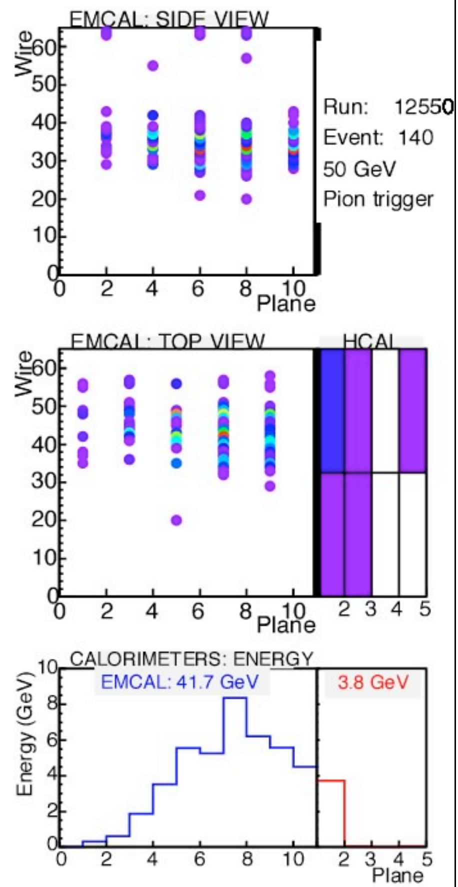
Total evts. $=14 \times 10^6$

TARGET	MOMENTUM(GeV)	EVENTS(K)
Aluminum	−59	19
Aluminum	±35	102
Beryllium	±59	560
Beryllium	±35	96
Beryllium	120	1080
Bismuth	±59	1260
Bismuth	120	1050
Carbon	±59	207
Carbon	35	77
Carbon	47	75
Carbon	120	16
2% Carbon	20	387
2% Carbon	59	256
2% Carbon	120	474
Copper	59	83
LH2	±5	213
LH2	±20	1474
LH2	±59	1975
LH2	±85	1731
NuMI	120	1850
Silver	47	66
Uranium	±59	1177

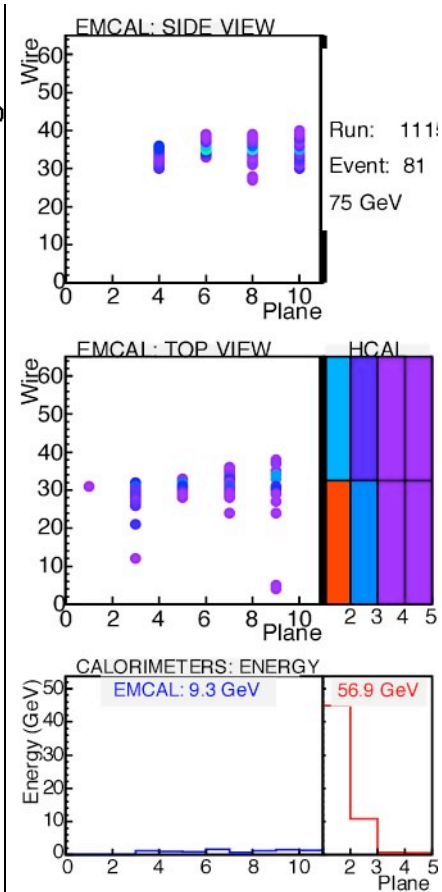
“Typical” Events



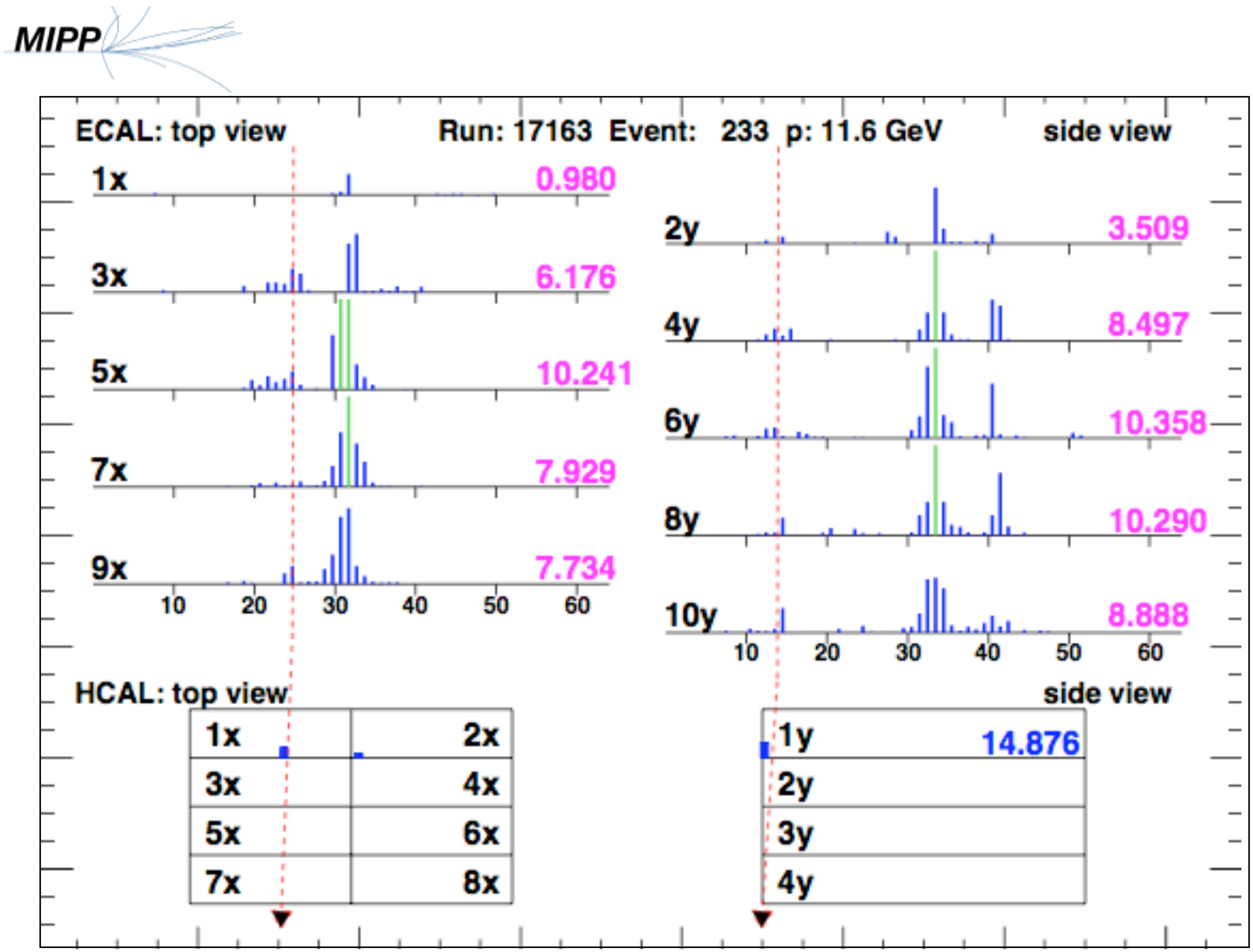
A high-energy “neutron” that deposits most of its energy in the HCAL. The leading neutron carries most of the energy of the beam proton.



An electromagnetic shower that leaves most of its energy in the EMCAL. This may be a photon that converts in material upstream.



A shower that starts in the EMCAL but leaves the bulk of its energy in the HCAL.



Turgun has written a more elegant event display.

Charged track + π^0(?) from 59 GeV Uranium

M. Longo 4/8/2006

CALIBRATION OF THE CALORIMETERS

The MIPP EMCAL contains about 10 radiation lengths of lead plates, so that an electron or photon will deposit much of its energy in the EMCAL, while a hadron will typically deposit <10%. Generally the response of a calorimeter is expected to be a linear function of the incoming particle's energy. Thus for incoming hadrons we can write

$$E_0 = c_{hE}\sum EMCAL + c_{hH}\sum HCAL \qquad (1)$$

where E_0 is the beam energy, $\sum EMCAL$ and $\sum HCAL$ are the summed ADC counts in the EMCAL and HCAL, and the c_h's are proportionality constants for the EMCAL and HCAL. The c's are expected to be almost independent of energy if the ADC counts in the EMCAL and HCAL readouts are proportional to energy.

Similarly, for incoming electrons or photons we can write

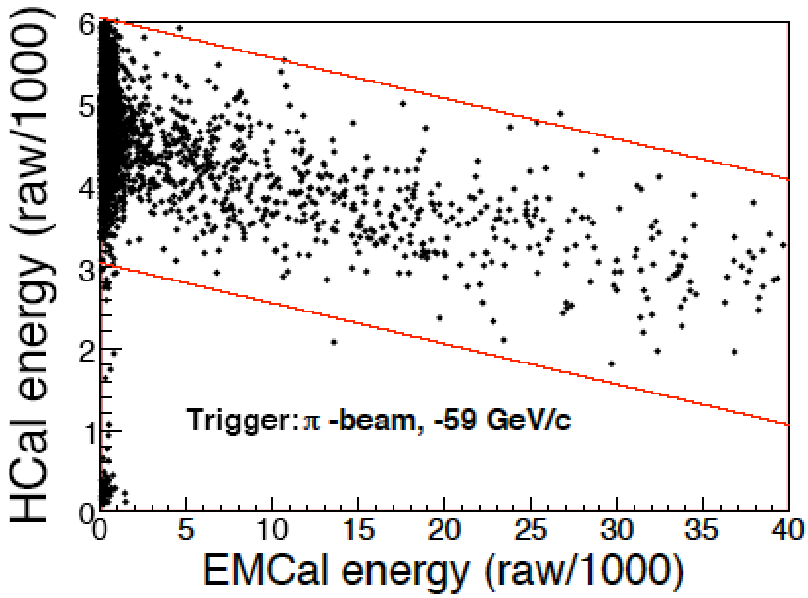
$$E_0 = c_{eE}\sum EMCAL + c_{eH}\sum HCAL \qquad (2)$$

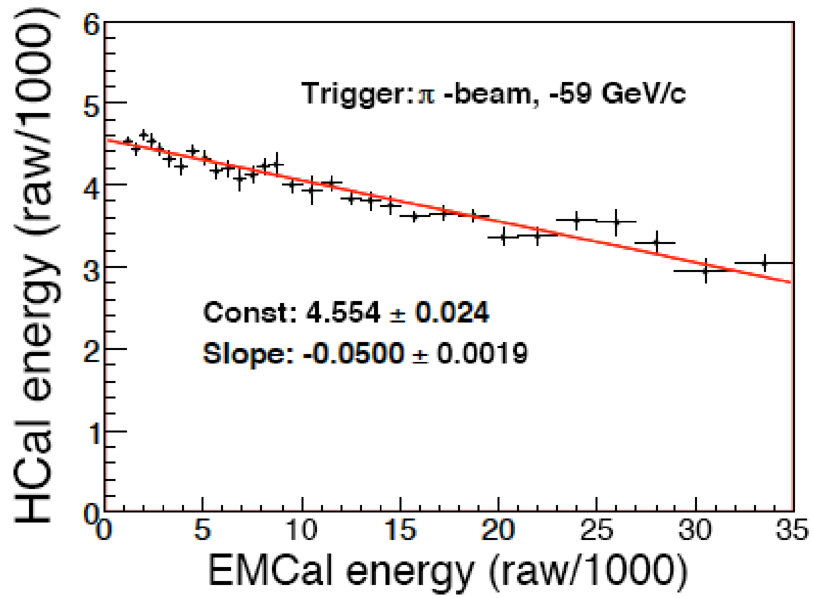
Thus, to first order at least, the energy calibrations of the EMCAL and HCAL are determined by the four c's. The ratios c_{eE}/c_{hE} and c_{eH}/c_{hH} are the e/π ratios for the EMCAL and HCAL respectively.

Note that the 10 planes in the EMCAL should have very consistent gains, so that it is not necessary to do a plane-by-plane calibration.

As is well known, the energy response of calorimeters is significantly different for electrons(or photons) compared to hadrons because hadrons produce more energy in the form of highly ionizing tracks that are not efficiently seen by the active medium. Also some of the energy from hadrons is carried out of the calorimeter by muons and neutrinos. This effect is embodied in the famous "e/π" ratio. This ratio generally determines the energy resolution of hadron calorimeters because of the large fluctuations in the fraction of the energy carried off by π^0s in a hadron-induced shower. For optimal energy resolution e/π should be **1.0**. This has led to the use of rather exotic materials such as uranium for hadron calorimeters. For uranium, e/π is typically ~1.0; for lead (as in the EMCAL) it is expected to be slightly larger than 1; and for iron plates it is usually ~1.3.


The first-order calibration of the HCAL is relatively straightforward since we have lots of data for hadrons with known momentum. The c_h's can be extracted from a scatter plot of $\sum HCAL$ *vs.* $\sum EMCAL$ as illustrated below. We see that, as expected, a large fraction of the pions deposit most of their energy in the HCAL. [See also Raja's talk.]

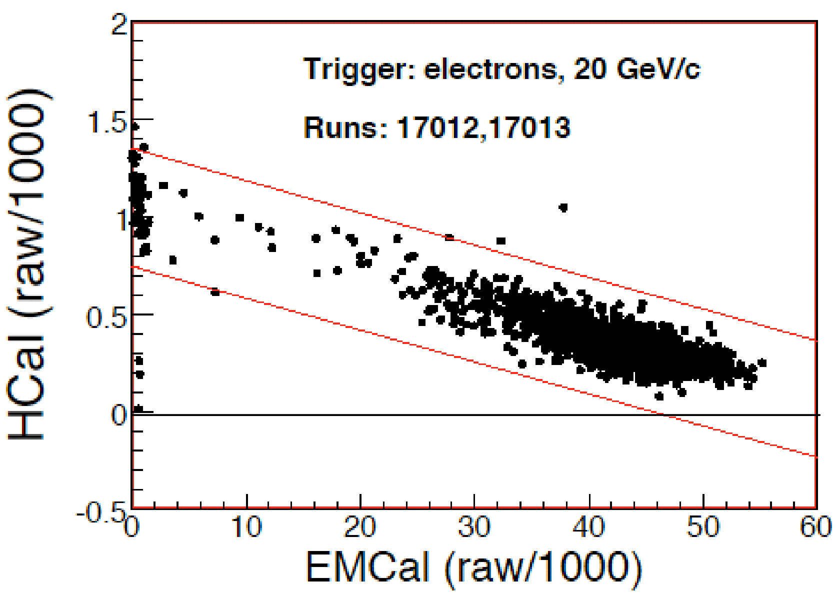


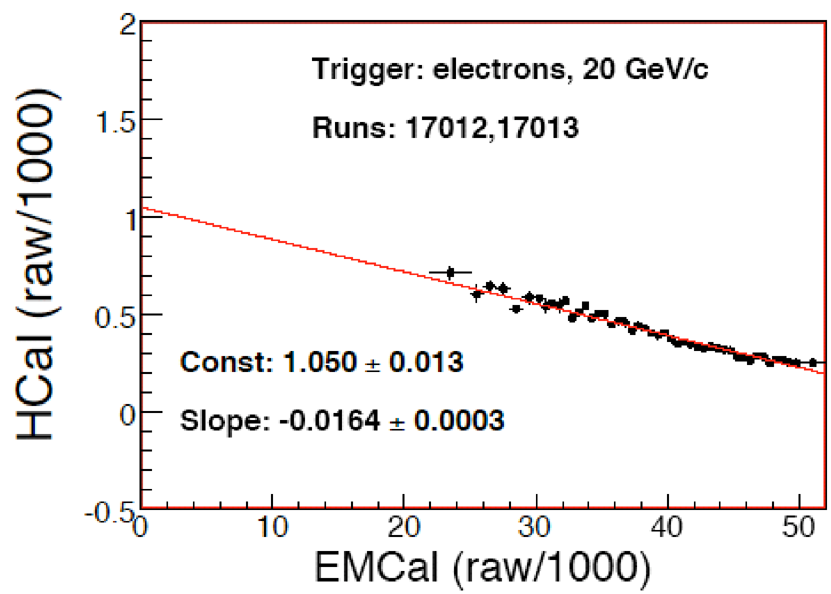


(Left) Scatter plot of HCAL sum *vs.* EMCAL sum for 59 GeV/c pions. The clump of events near EMCAL=0 is due to pions that deposit essentially all their energy in the HCAL.
(Right) Histogram and fit to the events within the parallel roads.

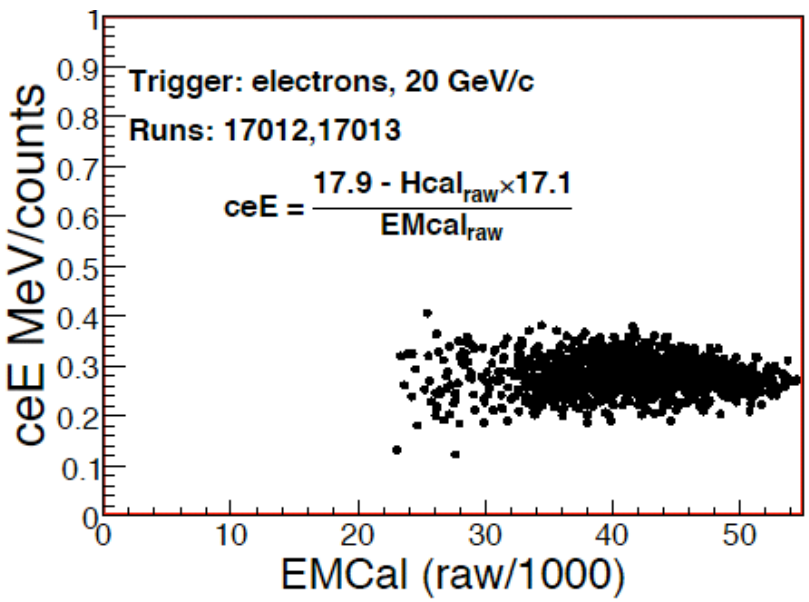
The situation with the EMCAL is quite different. Since its purpose is to measure photon energies, it must be calibrated with electrons (or tagged photons). We have a limited sample of tagged electron data, and we have only been able to identify electrons below 20 GeV.

The figure below shows the same plots for 20 GeV electrons. As expected, the electrons deposit most of their energy in the EMCAL. Note, however, the large clump of events near $\sum EMCAL \sim 0$; these are presumably due to pion contamination in the "electron" sample.

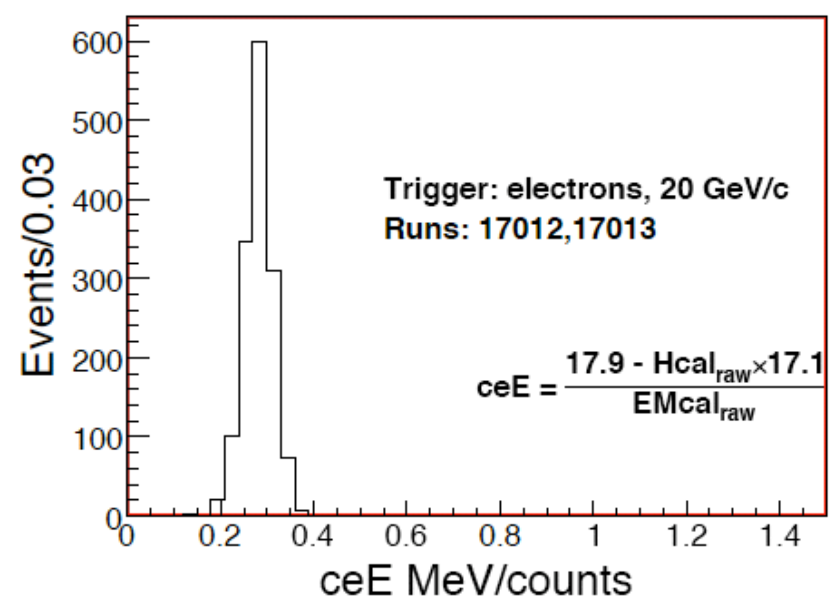




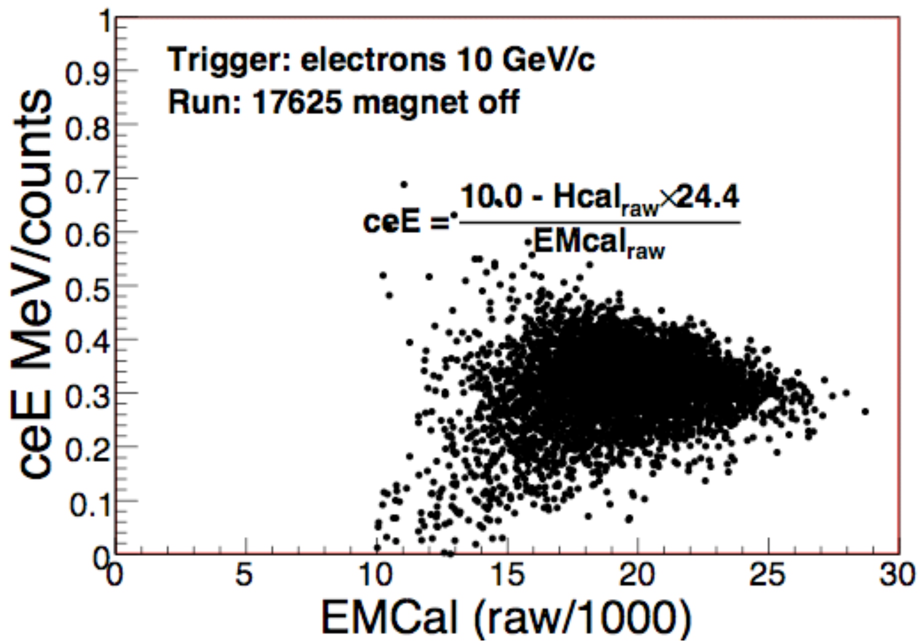
(Left) Scatter plot of HCAL sum *vs*. EMCAL sum for 20 GeV/c electrons. The electrons deposit most of their energy in the EMCAL. (Right) Histogram and fit to the events within the parallel roads.

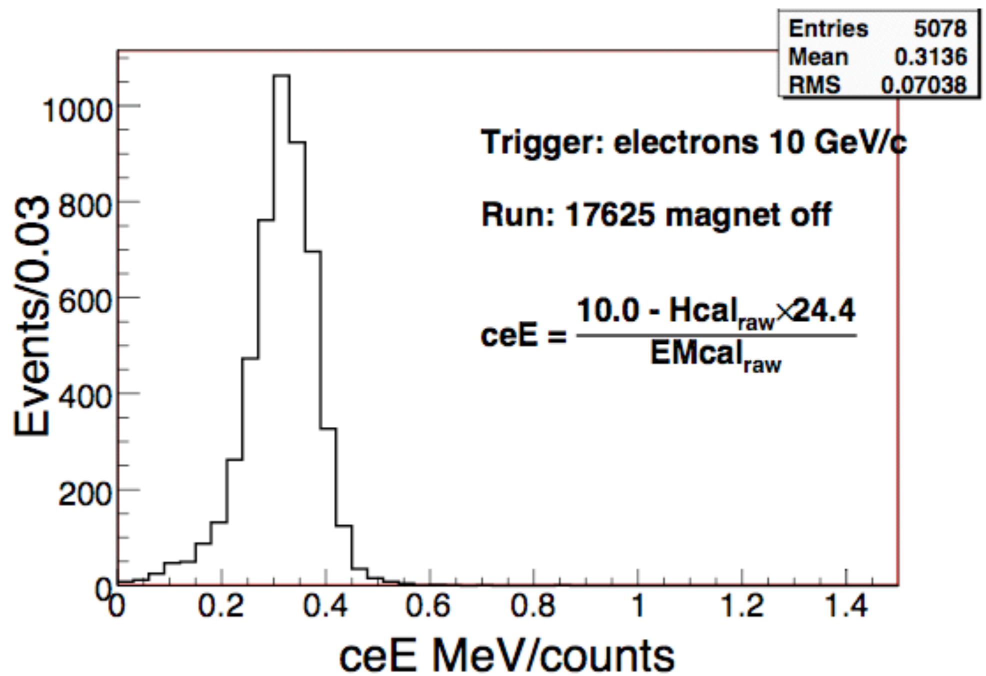


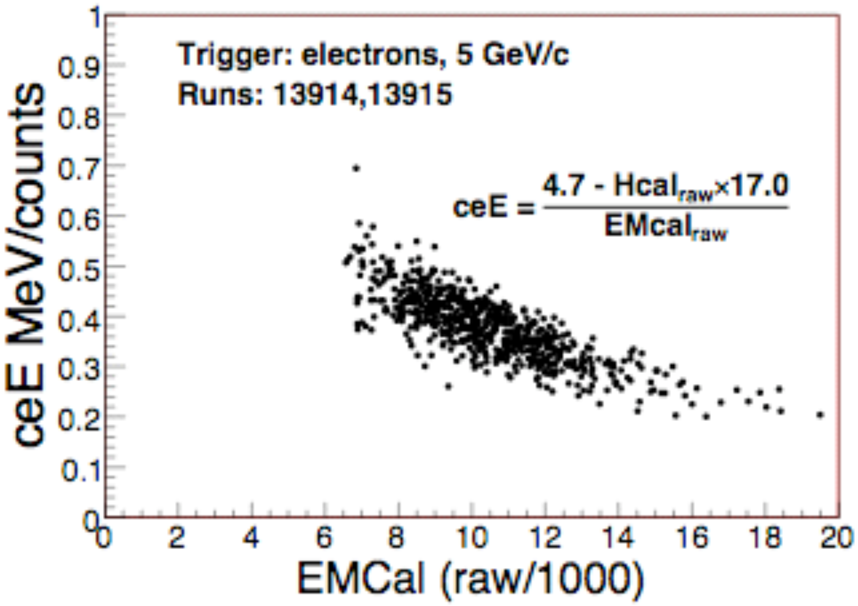
c_{eE}

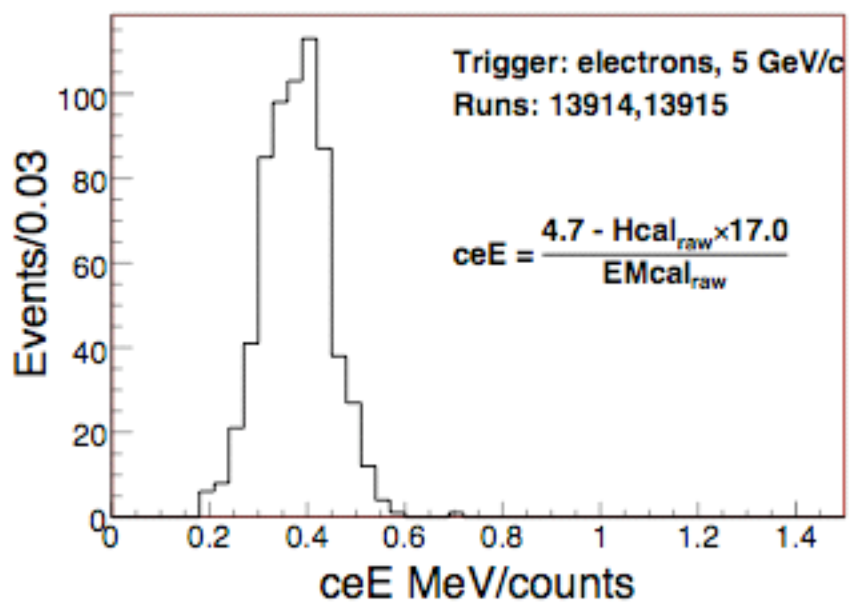


M. Longo 4/8/2006


Trigger: electrons 10 GeV/c
Run: 17625 magnet off
ceE = (10.0 - Hcal_raw×24.4) / EMcal_raw
ceE MeV/counts
EMCal (raw/1000)


Entries 5078
Mean 0.3136
RMS 0.07038
Trigger: electrons 10 GeV/c
Run: 17625 magnet off
ceE = (10.0 - Hcal_raw×24.4) / EMcal_raw
Events/0.03
ceE MeV/counts





Here are the same plots for 5 GeV electrons. However, the procedure doesn't work because there is no significant energy in the HCAL much of the time. We think we know how to fix this.

This technique for extracting calibration constants for the EMCAL seems to be working, at least at 10 and 20 GeV. However, when we look at the e/π ratios ….

Least Square Binning	c_{eE}	$c_{\pi E}$	c_{eH}	$c_{\pi H}$	$e/\pi(EMCAL)$	$e/\pi(HCAL)$
20 GeV	0.28	0.52	17.1	12.9	0.54 (!)	1.33
10 GeV	0.31	0.55	24.4	15.7	0.56 (!)	1.55
5 GeV	0.28	0.33	37.9	28.0	0.85(?)	1.35

Max. Likelihood	c_{eE}	$c_{\pi E}$	c_{eH}	$c_{\pi H}$	$e/\pi(EMCAL)$	$e/\pi(HCAL)$
20 GeV	0.31	0.52	13.3	12.9	0.60 (!)	1.03
10 GeV	0.41	0.66	12.8	13.9	0.62 (!)	1.09
5 GeV	0.43	0.66	12.8	14.5	0.65 (!)	1.13

e/π ratio does decrease as the thickness of the active medium decreases relative to the absorber.

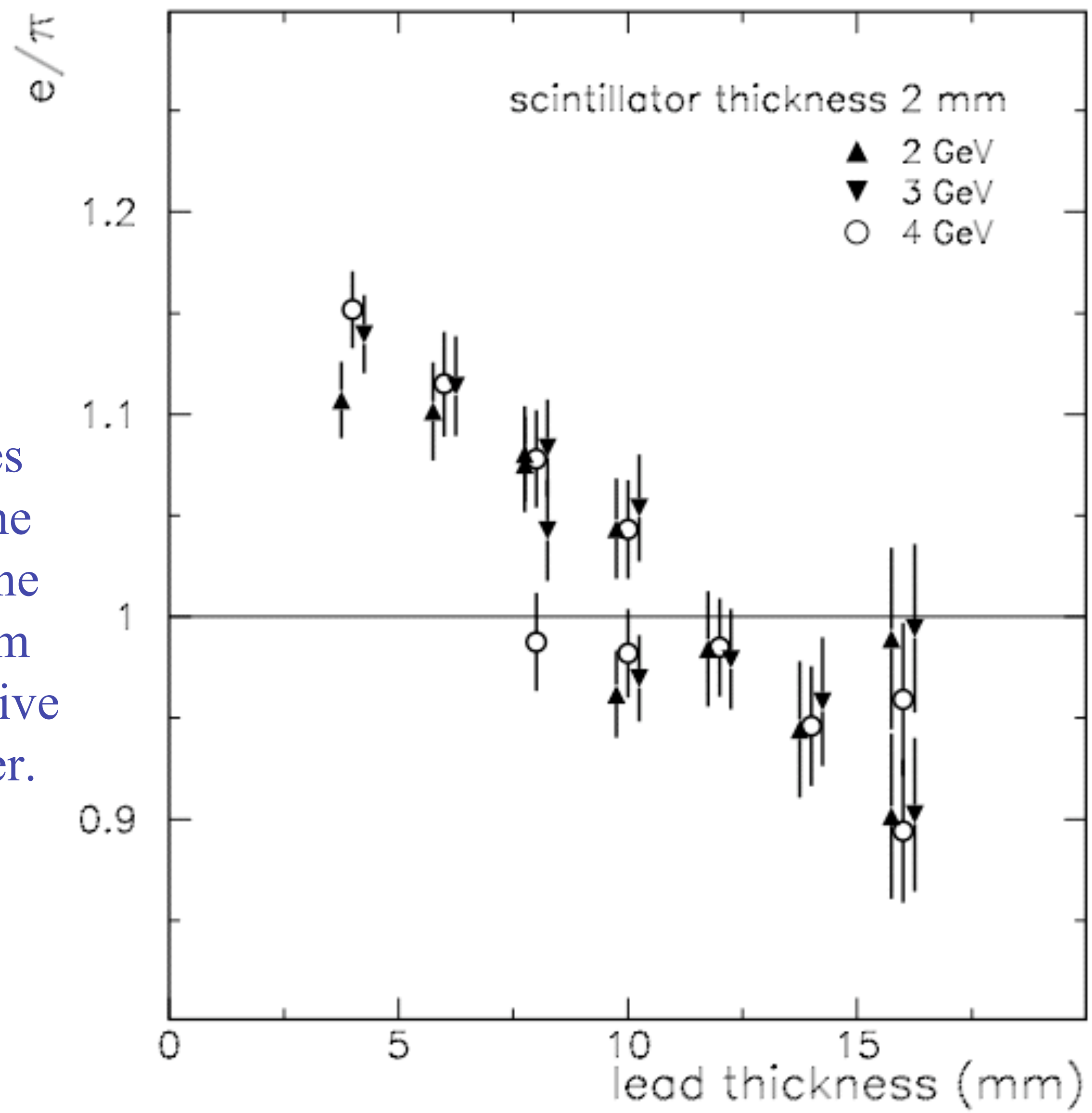


Fig. 22. The e/π ratio (uncorrected) vs. Pb thickness. The error is dominated by systematic uncertainties introduced when the lead thickness is changed. Therefore the errors are correlated for the data in the same configuration, this irreducible by combining data of same configuration.

CONCERNS

- The hadron calorimeter was built ~10 years ago for the Hyper*CP* experiment. It is literally a "black box". We don't know the condition of the optical fibers and scintillators. If they have deteriorated significantly, there could be a serious position dependence of the calibration constants. It is not clear if we have any way of looking at this.
- EMCAL calibration is complicated by the small size of the HCAL.
- We still have a lot of work to do to understand the calibration, especially at low energies.
- We're still not sure if the calibration constants have significant energy dependence.
- We haven't yet tried to reconstruct π^0's from 2-photon events.

MIPP

University of Michigan

We are interested in calibrating the individual PWCs in the EMCAL with ^{83}Kr. We can cover some of the costs for the ^{83}Rb source.