Effect of Pulse Shape on Hcal Resolution

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Outline

1) processing of GEANT “Hits” in ORCA
   (Hit -> “Digi”)
2) Jet Energy Resolution with default ORCA settings, no noise, no pileup, no poisson fluctuations on light output
3) add poisson fluctuations
4) replace HCAL pulse shape with ECAL pulse shape

Basic Flow in ORCA 3 (and vocabulary)

“timesamples” exists for each calorimeter cell. These time samples are arrays of length 10, and are supposed to represent the pulse height from the amplifier at 10 different times. The time of the “current” beam crossing is element 5 in this array. The other elements represent times of the previous and later beam crossings, and thus have a 25 ns spacing.

At the start of an ORCA run, the “shape” of a pulse from each part of the Calorimeter is calculated and stored. Then, for each event, the “Hits” from GEANT for the hard scattering are fetched. The elements of the timesample are then filled with the product of the shape at the time for that element times the hit energy

Basic Flow...

Then, Hits from the overlapping events are fetched for the crossing of interest, and for previous and later crossings. Timesamples are created from these Hits and are added to those from the hard scattering.

Then, noise is added to each element of the timesamples.

The energy for the cell is then extracted as a sum of the elements of the timesample times weights. Crossings prior to the current crossing tend to have negative weights, and thus result in a pedistal subtraction. For the HCAL, the results are also multiplied by a factor which converts from energy in the active medium to total energy in the cell (approx 100 for HB, HE, about 1 for HF)

How timesamples are filled

amplitude for each time sample is calculated as

amp = shape (bintime) * geant_hit_energy

bintime = 25ns (bin number-5) + 32.0 - jitter + crossing_offset (hcal)

=-93,-68,-43,-18,7,32,57,82,107,132 ns

=25 ns (bin number-5) + 47.6683 -jitter + crossing_offset (ecal)

crossing_offset is for energy from previous/later crossings (occurs in 25 ns steps). =0 for hard scatter.

jitter should be geant_hit_time - estimated_hit_time, but for now is set to zero for hcal. Previous studies show this is not a big effect.

Same for HCAL and VCAL

ECAL shape

$$\frac{1}{0.115855} \bullet (x - 1.3924x^2 + 0.34451x^3) \bullet$$

$$\exp(-x - 2.1681x^2 + 0.67193x^3)$$

$$x = time / 182.64$$

HCAL shape

From Dan Green….

// unit height in GeV and time constants in ns
const float a = 0.0269257;   // pulse height normalization for 1 GeV of energy
const int ts = 11;   // scintillation time constant
const int thpd = 10;   // HPD current collection drift time
const int tpre = 25;   // preamp time constant (should this be 3ns? Tully was unsure)

$$f(t) = \frac{C\int_0^t n_{td}(t_d)\int_0^t n_{th}(t_h - t_d)n_{tp}(t - t_h)dt_h dt_d}{\int_0^\infty n_{td}(t_d)dt_d \int_0^\infty n_{th}(t_h)dt_h \int_0^\infty n_{tp}(t_p)dt_p}$$

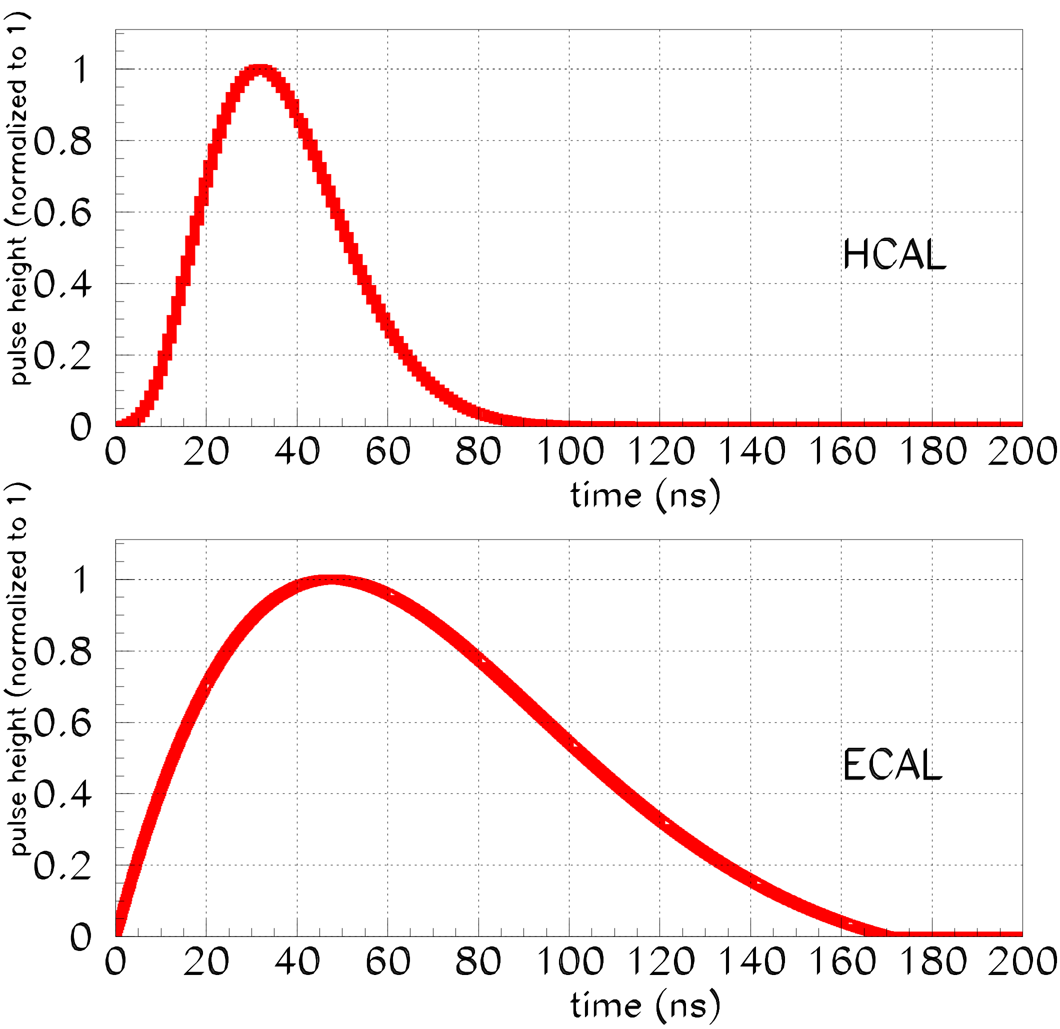
$$n_{td}(t) = \exp(-t/\tau_s)$$

$$n_{th}(t) = 1.0 + (t/\tau_{hpd})$$

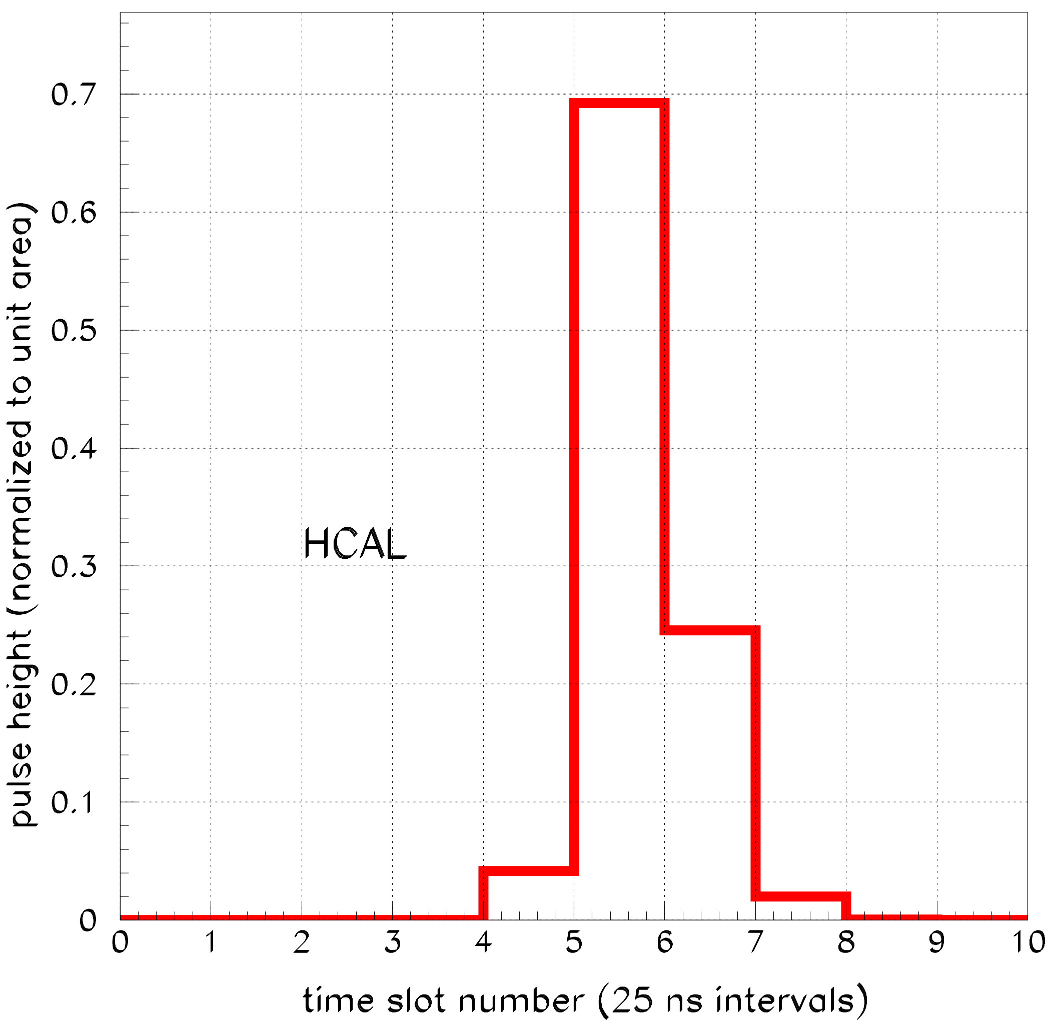
$$n_{tp}(t) = t \bullet \exp(-(t/\tau_{pre})^2)$$

Used both in HCAL and VCAL

shape


pulse height (normalized to 1)
1
0.8
0.6
0.4
0.2
0
0 20 40 60 80 100 120 140 160 180 200
time (ns)
HCAL
pulse height (normalized to 1)
1
0.8
0.6
0.4
0.2
0
0 20 40 60 80 100 120 140 160 180 200
time (ns)
ECAL

Example: single 30 GeV pions, eta=0.4, no noise, no pileup



10 time samples
Code arranges it so max pulse height should occur in bin 5

How the energy is calculated

Basicially energy = sum(w_I * timesample(I))

	Weights	
bin number	HCAL/VCAL	ECAL
0	0	0
1	-0.208	-0.361
2	-0.208	-0.361
3	-0.208	-0.361
4	-0.138	0.271
5	0.942	0.467
6	0.201	0.347
7	-0.174	0.111
8	-0.207	-0.112
9	0	0

Hcal calculation basically uses bins 5 and 6
negative weights do the pedistal subtraction

How the Energy is Calculated

Results are scaled by the sampling correction factors

```
// From Shuichi Kunori
//HB  depth-1     72.
//          2    147.
//          3    147.
//          4    200.
//HE  depth 1    108.
//          2    237.
//          3    237.
//HF  depth 1    2.07
//          2    1.40
//          3    0.00
//   (Note- Ring variation in HF is ignored.)
```

note, HB depths 2+3 are actually ganged in hardware. they are not separate readouts. same for HE depths 2 and 3.

Jet Energy Resolution

Data sample: QCD dijets with Pt between 120 and 170

Use cone jet finder (cone 0.5) to find jets using generator particles

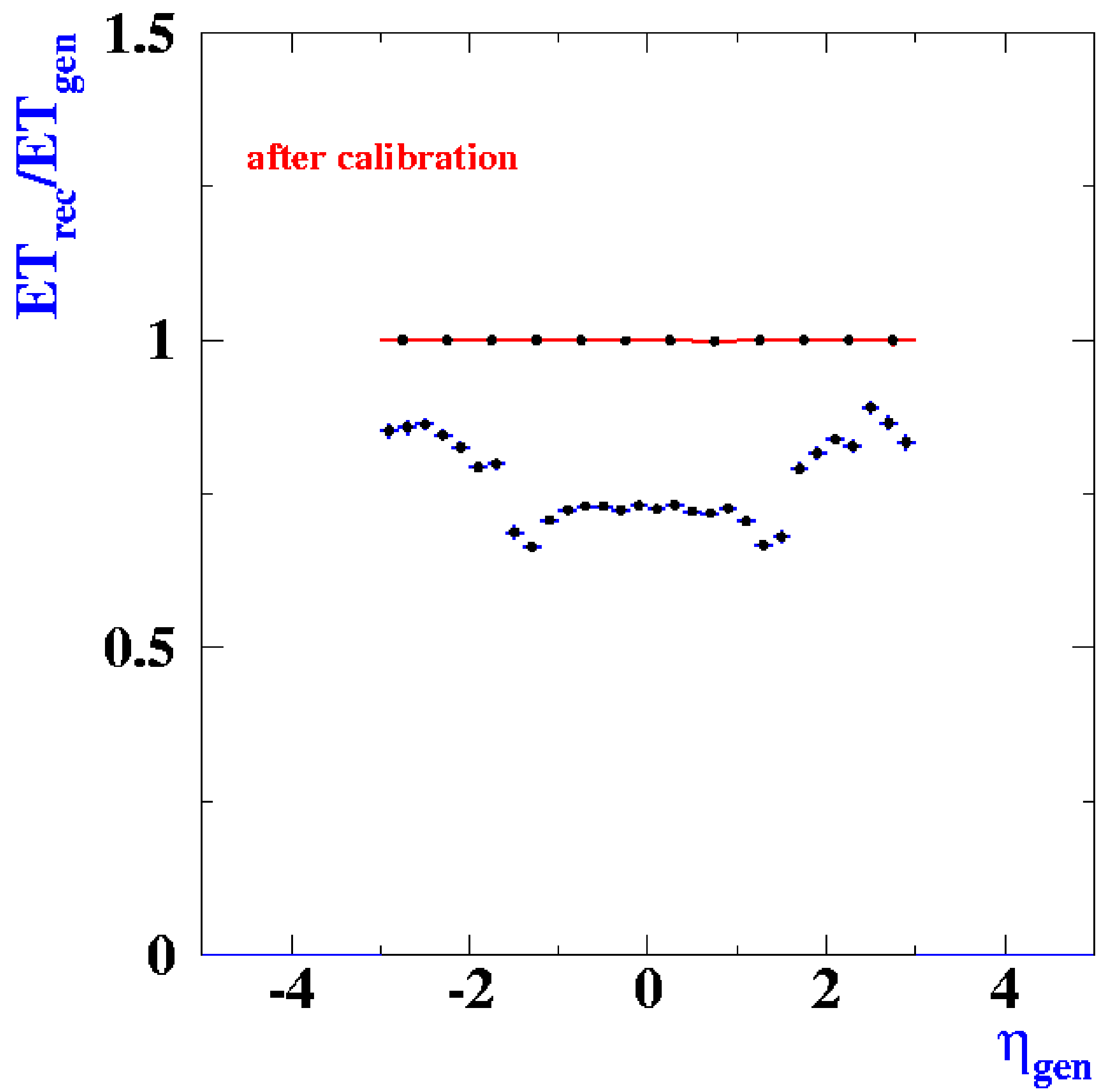
ditto using calorimeter “towers”

find closest offline jet to each generator jet

use if ΔR between offline jet, generator jet is less than 0.2 and eta of generator jet is less than 1.1

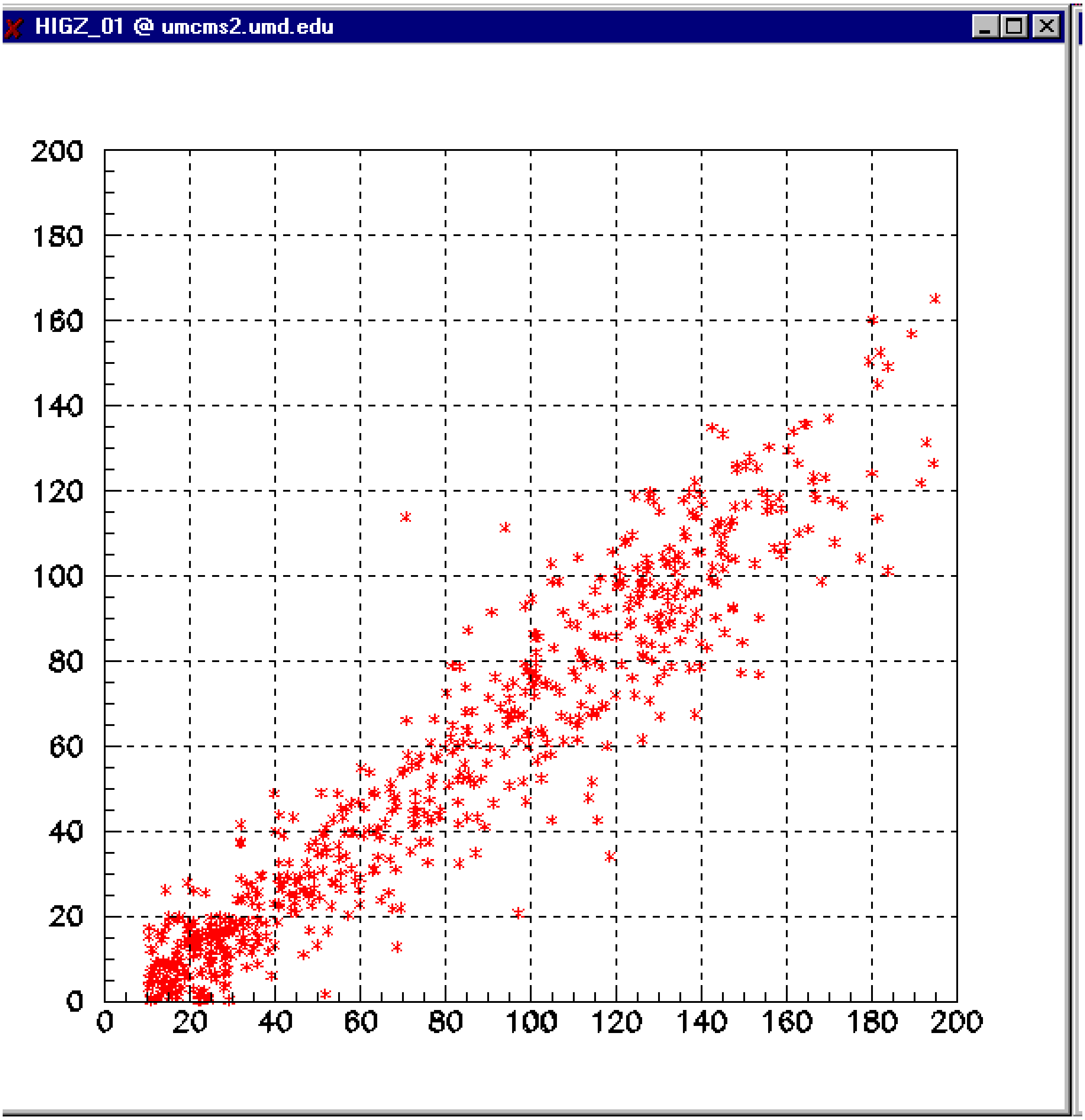
Eta cut

Require eta<1.1 so can ignore eta-dependent calibration issues...

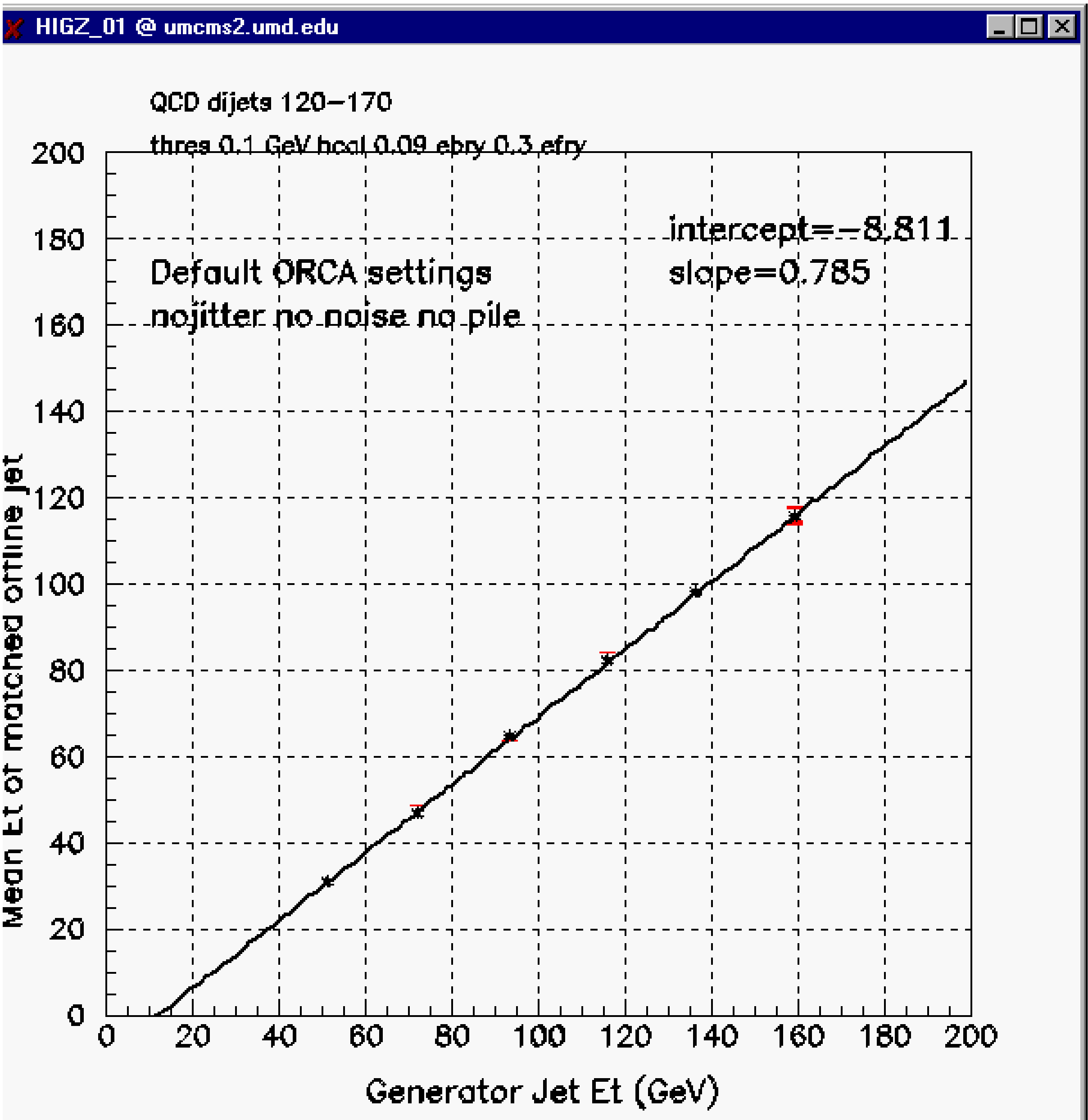


Silvia Arcelli, MD

Jet Energy Scale

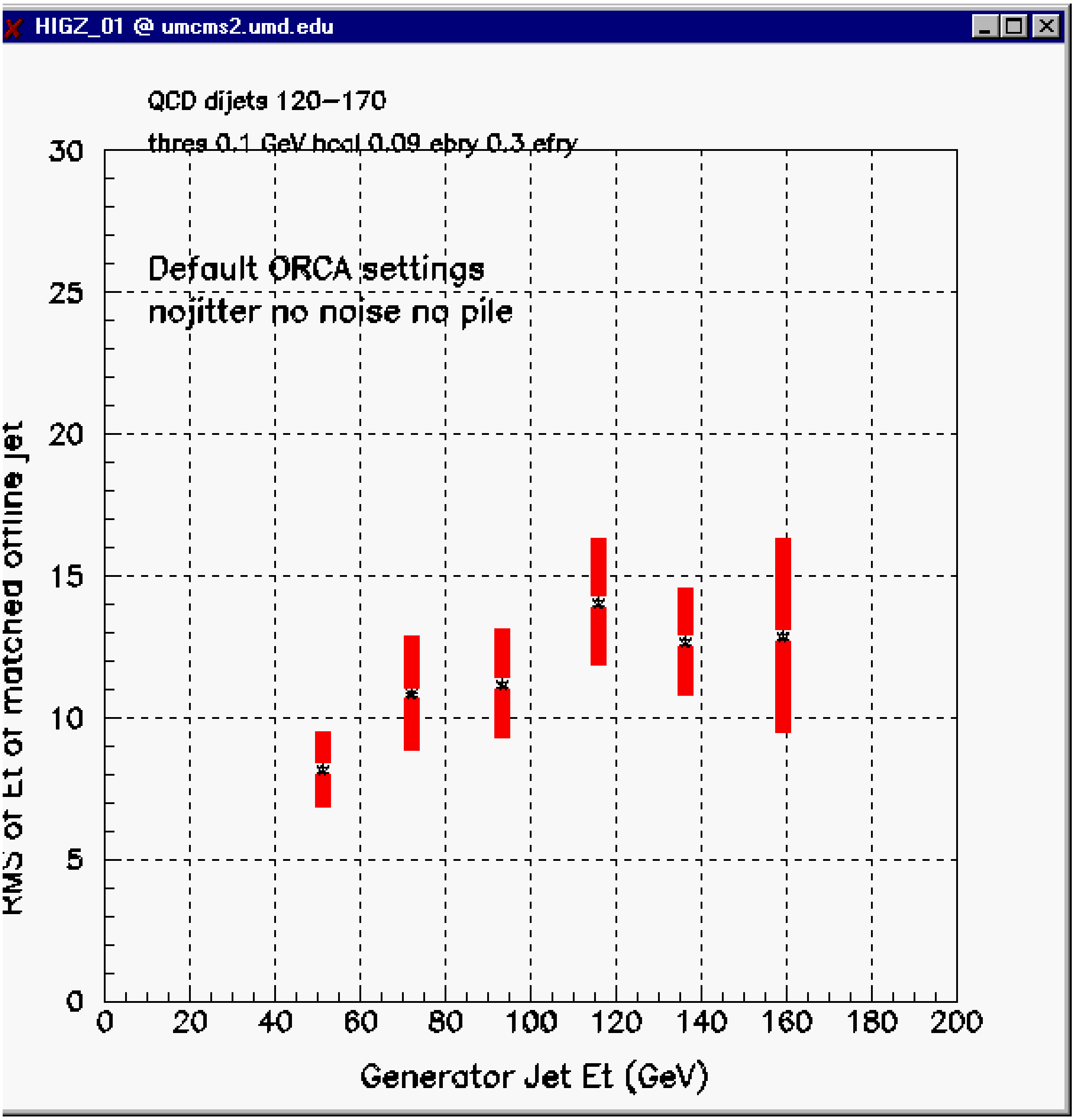


Jet Energy Scale



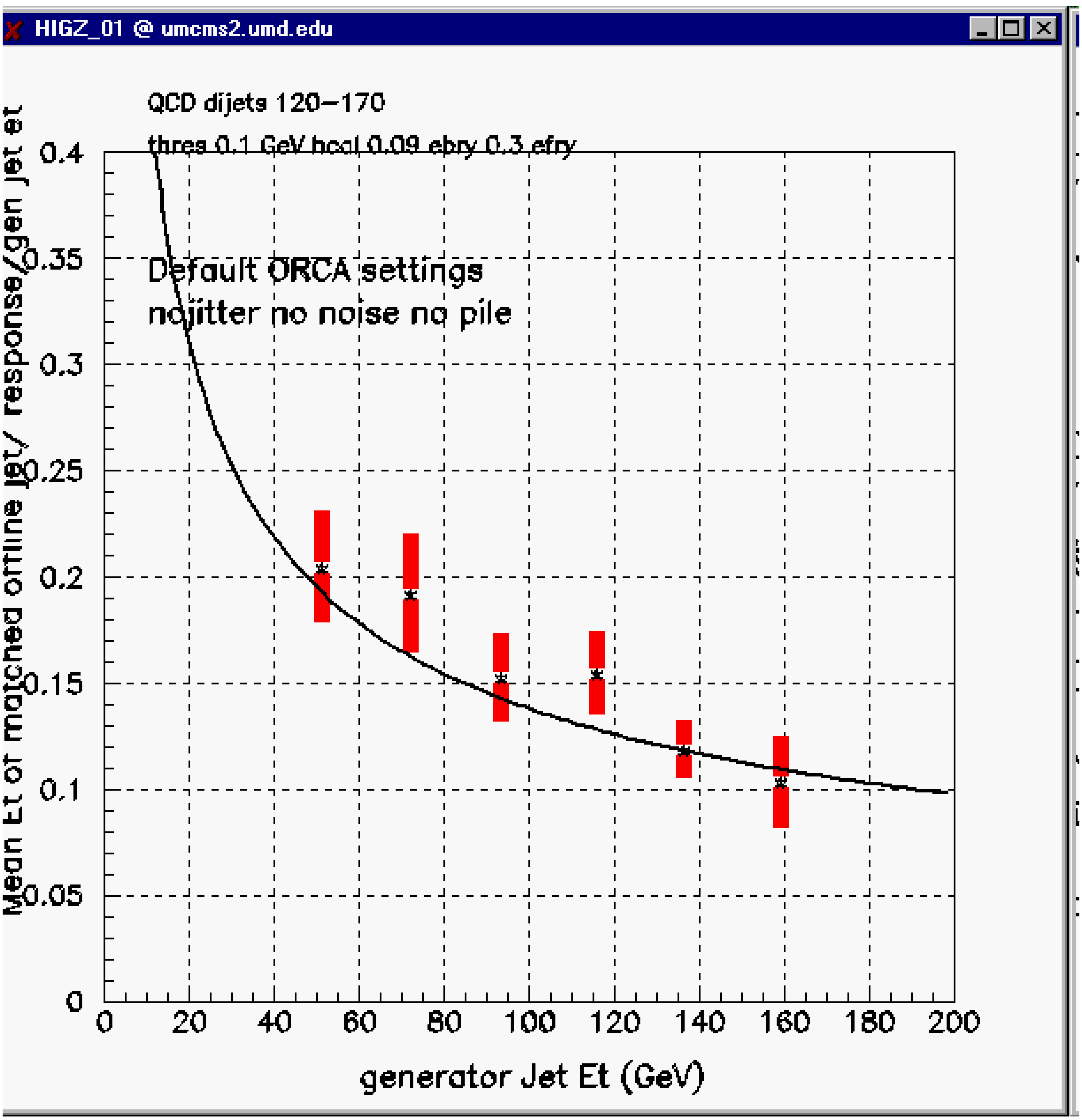
Why negative intercept????

Jet Energy Resolution

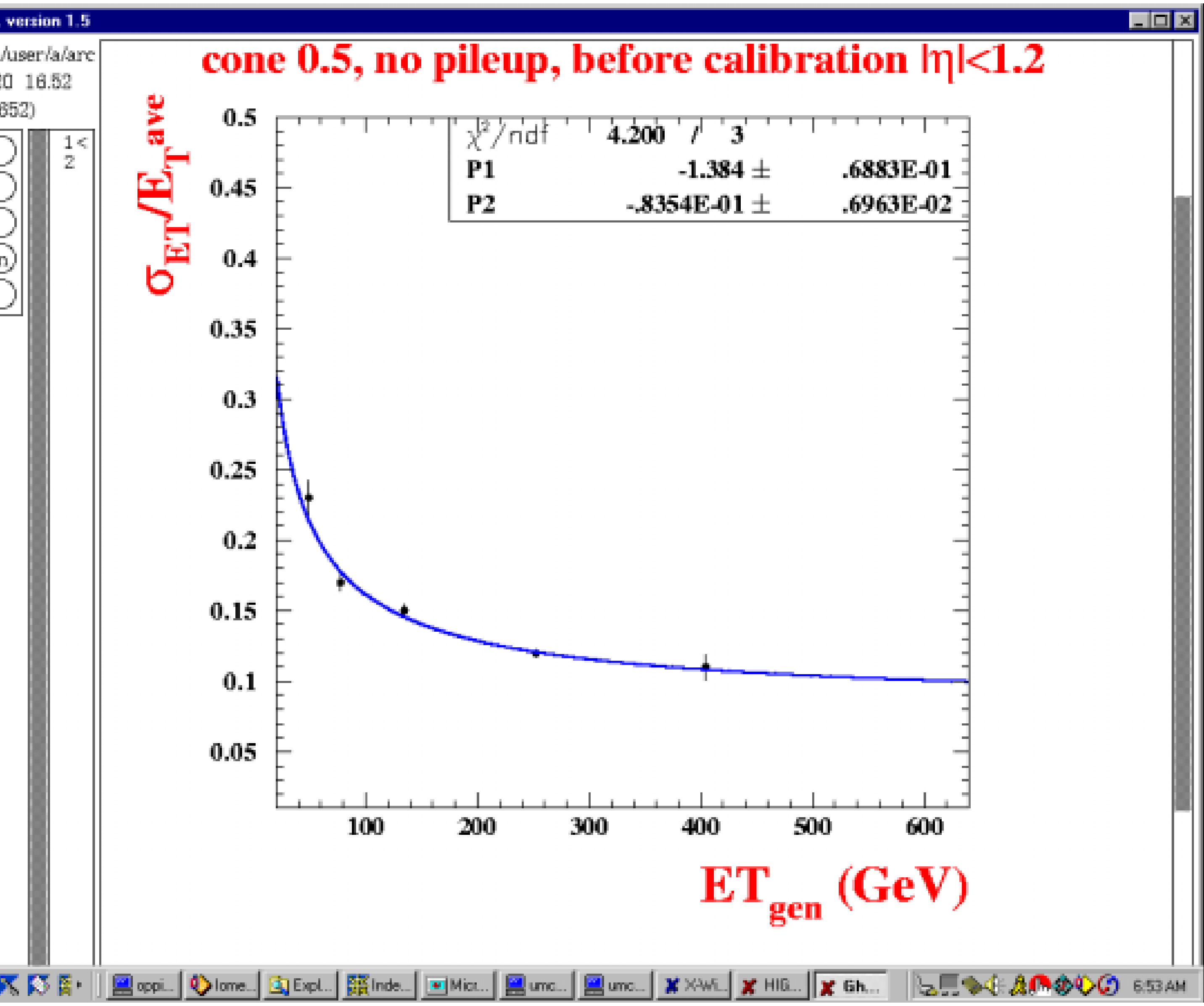


Jet Energy Resolution

Response is slope of offline et vs generator ET. Divide RMS by response to correct for energy scale. Then, divide by generator jet et to get % resolution. Expect 1.38/sqrt(measured_jet_et) (solid line)



Jet energy res

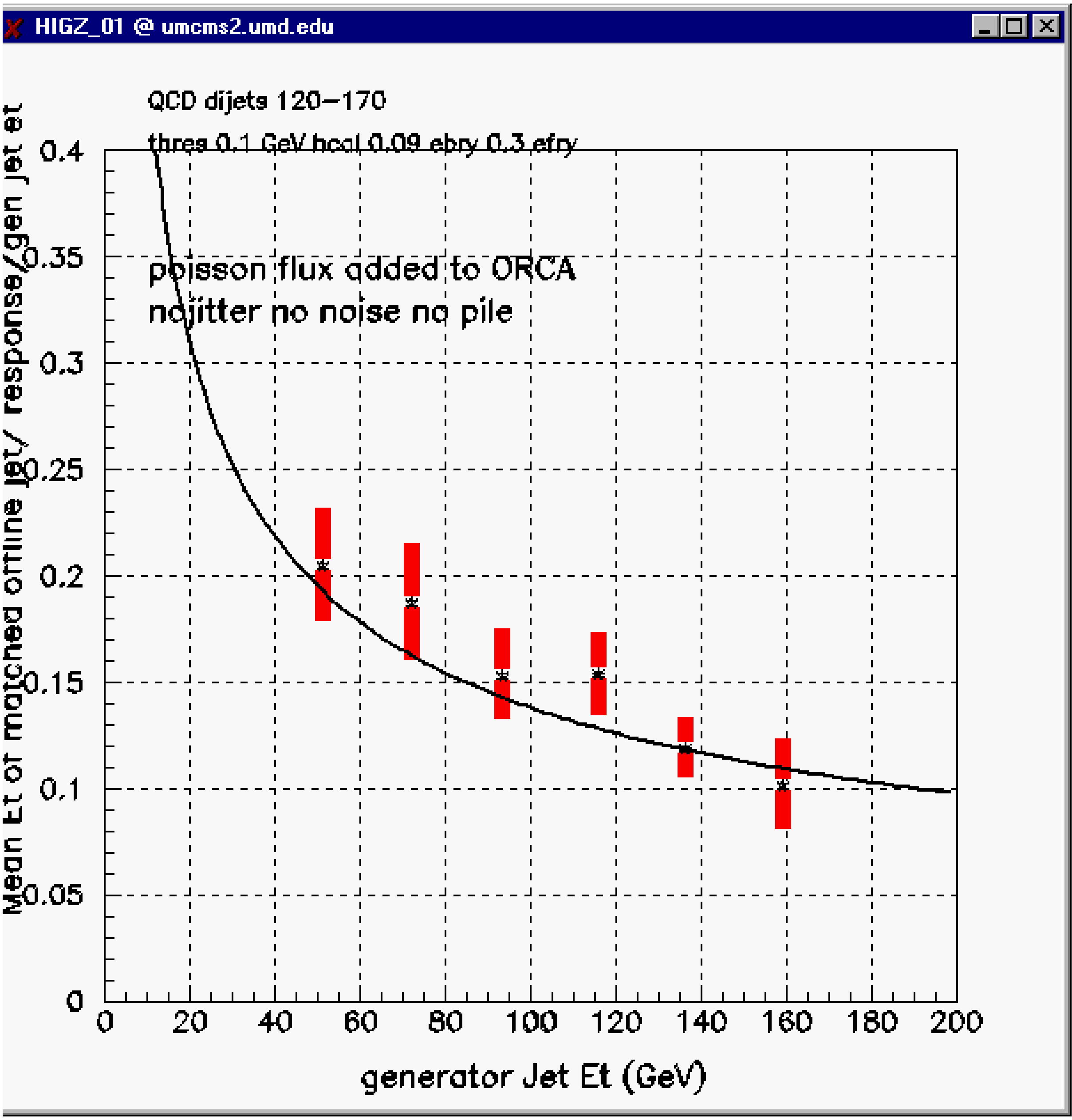


Poisson Flux

Alter ORCA so that we fluctuate hit energy using poisson stats before timesamples are formed.

Take hit energy
divide by hit energy -># photons conversion (from Shuichi)
    HB1 0.0004486 gev/pe
    HB2 0.0006803 hit = 0.1 gev/pe digi
    HE1 0.0004491
    HE2 0.0000679
use this as input to Poisson random number gen
multiple output by conversion factor

Jet Energy Resolution



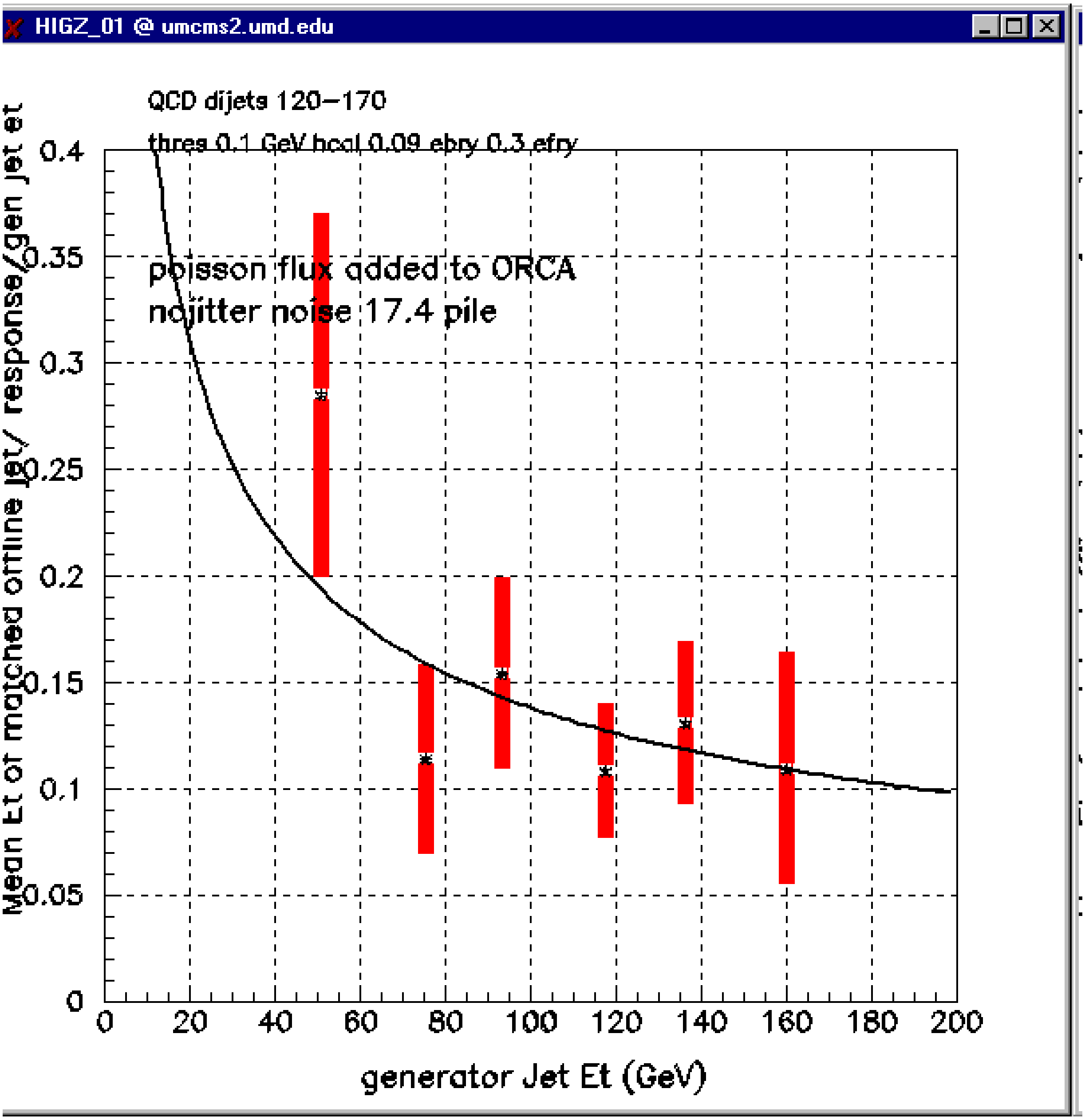
Ecal Pulse Shape

Note that if there is no noise, no jitter, and no pileup, then the algorithm to extract the energy from the time samples returns the poisson-fluctuated energy exactly, regardless of the pulse shape. So, the pulse shape in HCAL will not affect…

so, add noise, <17.4> pileup events

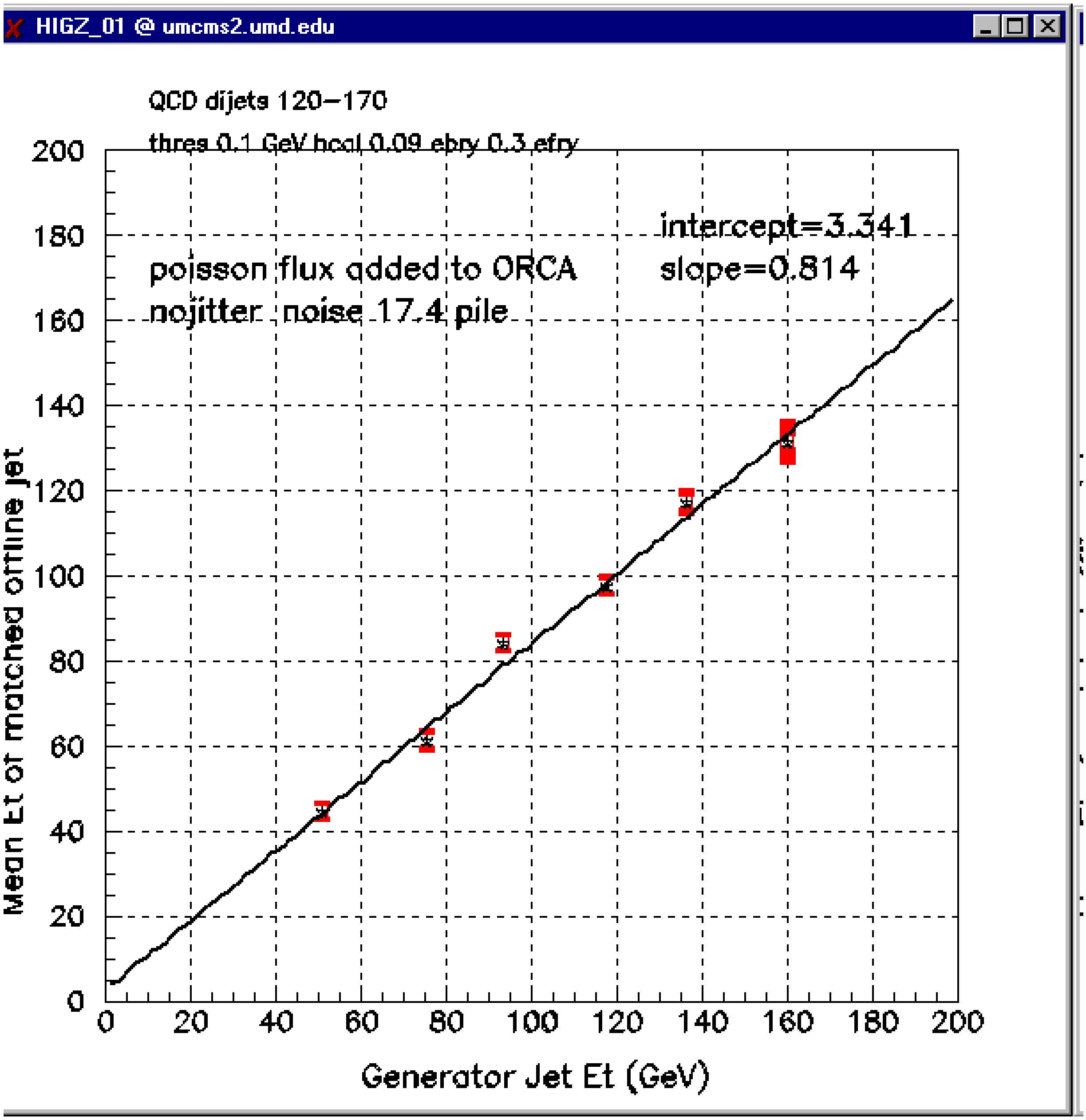
HB1: 7.2 MeV   rms noise to digi
HB2: 14.7 MeV
HB3: 14.7 MeV
HB4: 20.0 MeV
HE1: 10.8 MeV
HE2: 23.7 MeV
HE3: 23.7 MeV
VCAL1: 0.207 MeV
VCAL2: 0.140 MeV
VCAL3: 0.0

Jet Energy Resolution: HCAL pulse shape



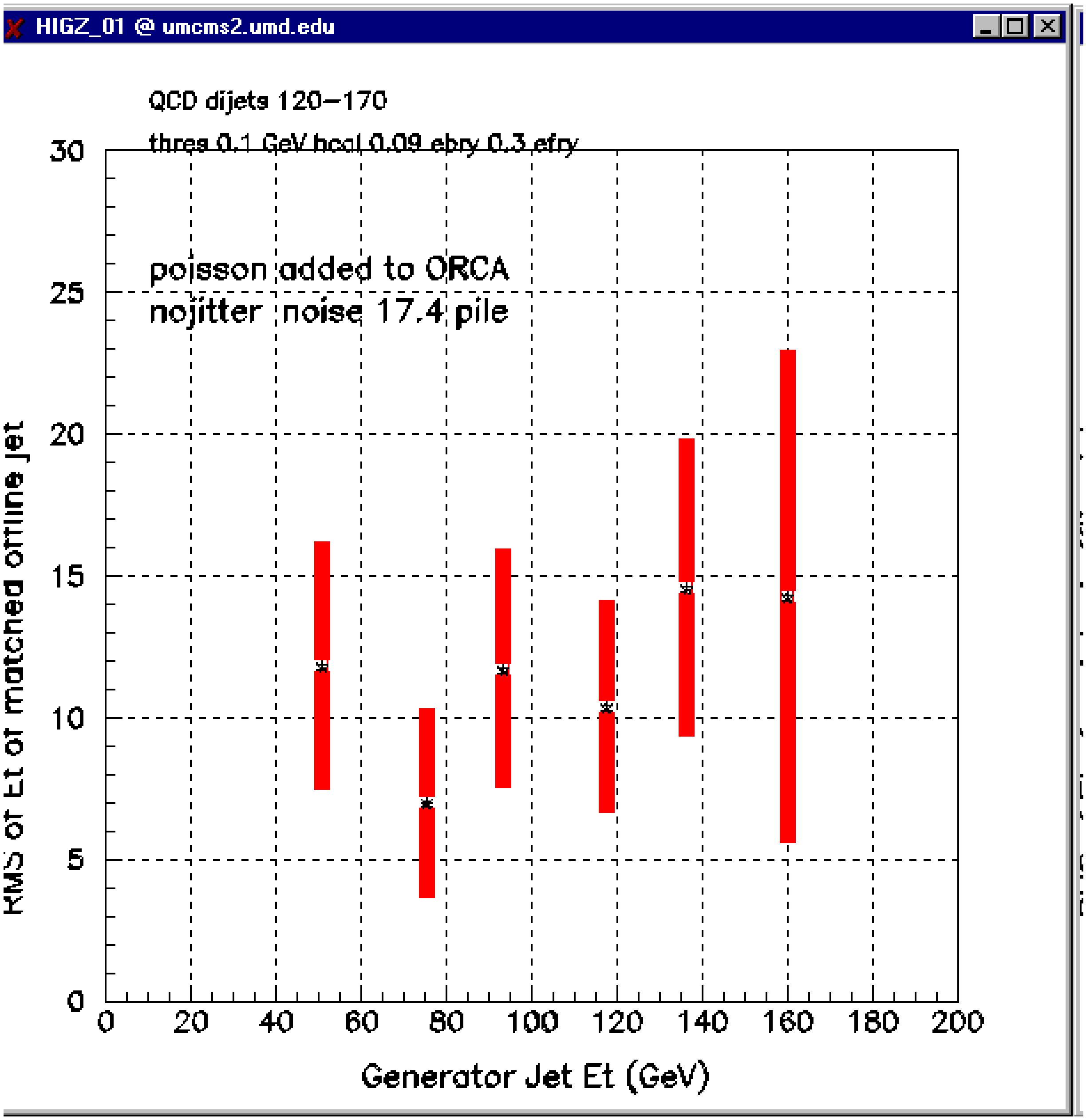
(fewer events… these guys are a pain to process… 10 crossings x 17 events per crossing...

(scale from previous)

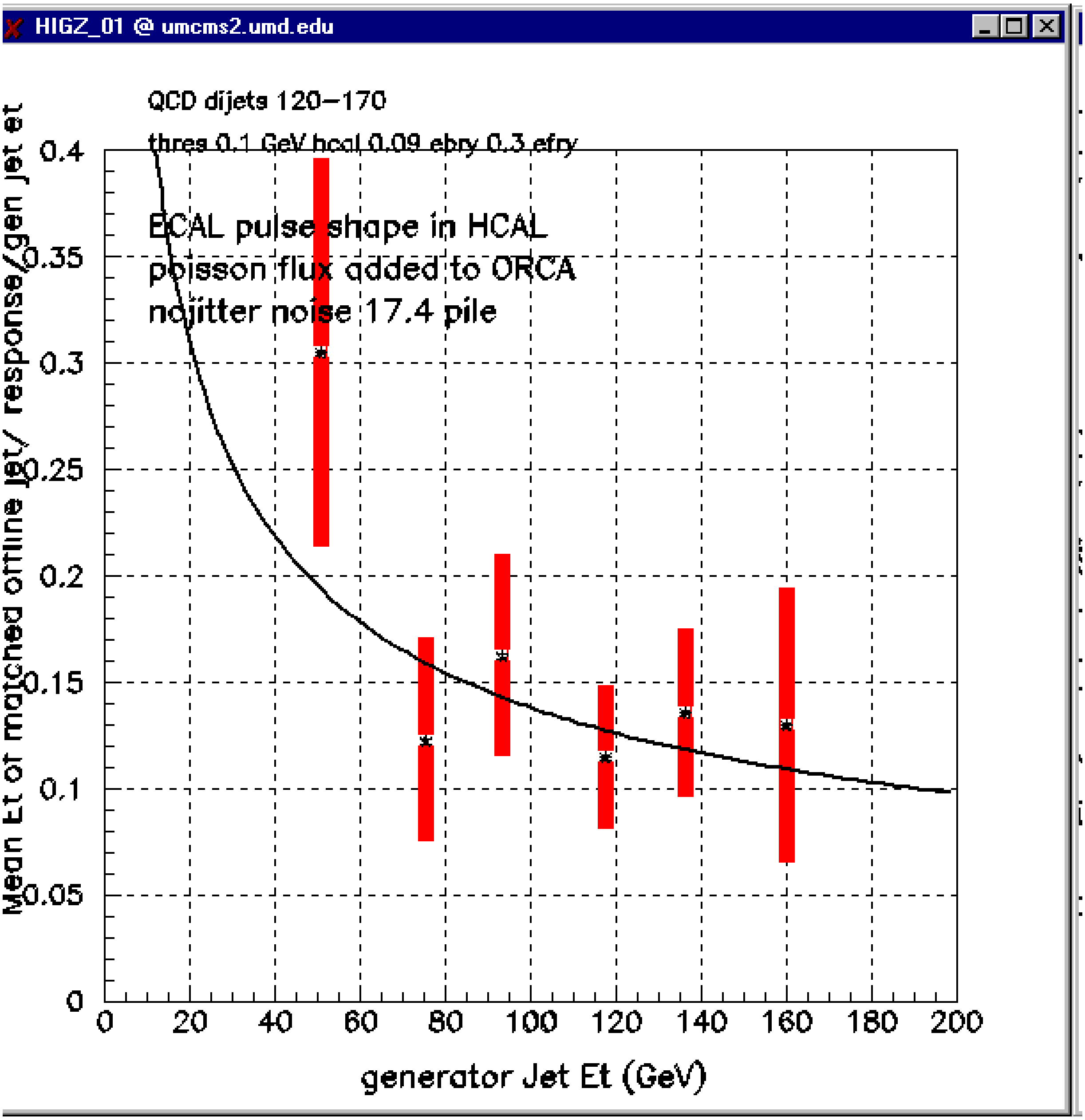


(note change in offset)

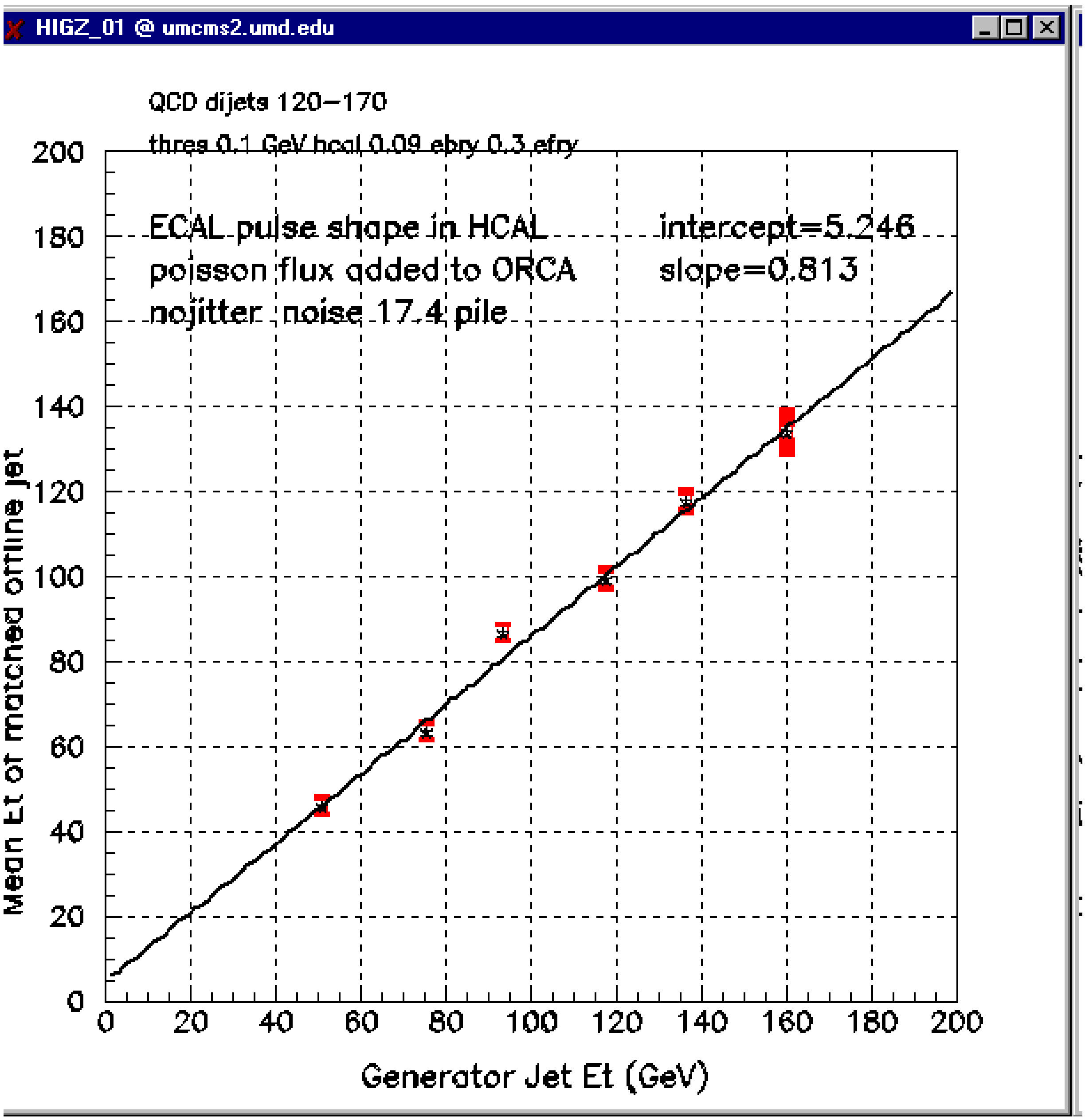
(raw RMS from prev)



Ecal pulse shape



(scale from previous)



(intercept even bigger….)

(raw RMS from prev)