Calorimeter energy calibration using the energy conservation law

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The copy of this talk one can find at the http://www.desy.de/˜morgunov

How to get calorimeter energy conversion coeffs?

Easy:

One should run muons in Monte–Carlo, take whole energy in absorber and scintillator, and divide it by energy in the scintillator.

The reason for this is: if one particle crosses one sampling layer it should deposit the whole energy, but we can measure the scintillator energy only.

But: the cascade in matter consists of not only pure particles (track–like) but rather dense electromagnetic showers and a mixture of the photoeffect's and compton scattered electrons together with pure track–like energy deposition.

This leads to the co–called e/π **ratio for the calorimeter response for different types of particles.**

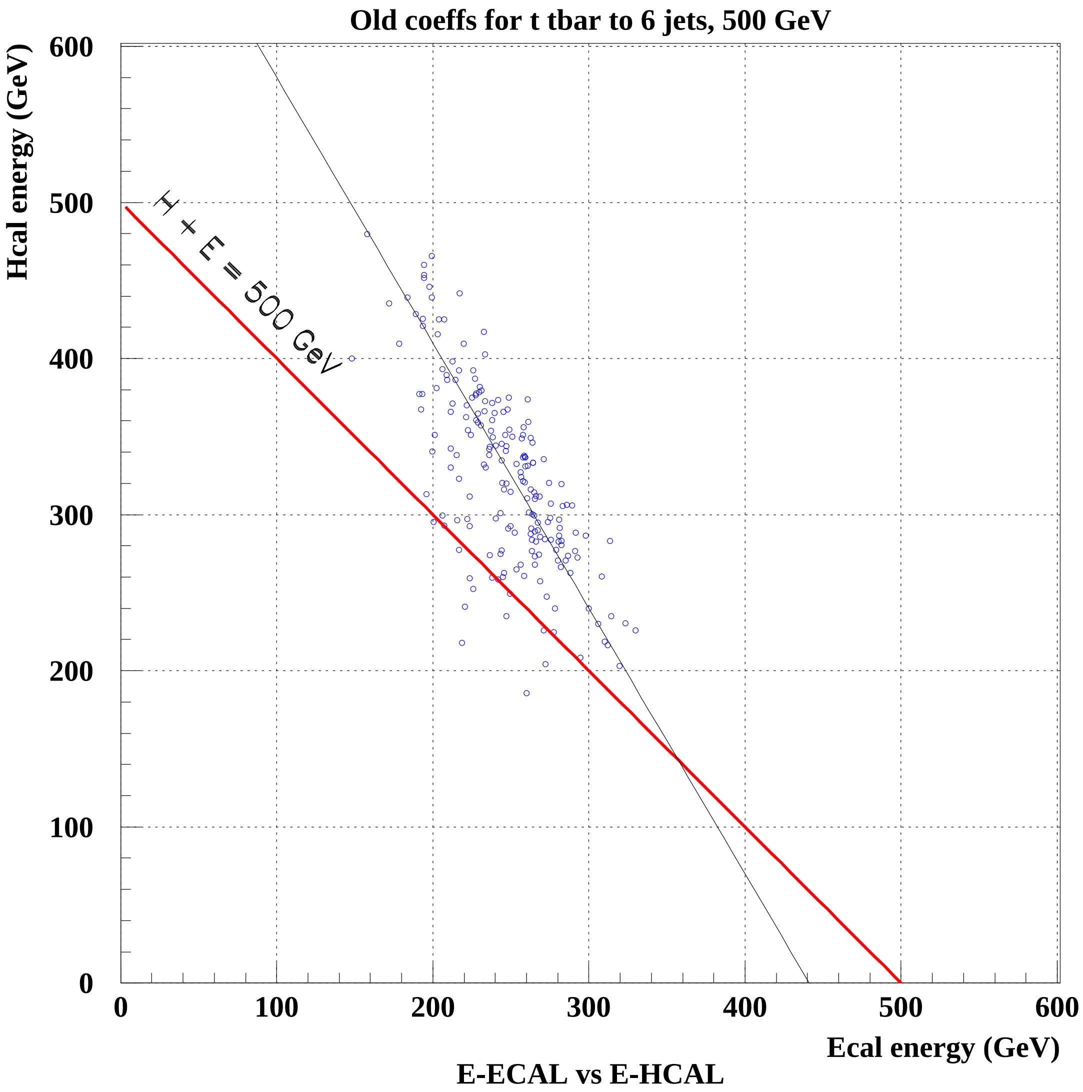
The using of the complex calorimeter, which we have in LDC detector, leads to even more tricky procedure for the calibration, because it needs to define the coeffs for each part of the calorimeter with different samplings and then choose the correct ratio between that coeffs to get a correct whole measured energy.

So, let us start from the coeffs defined by muon run in the simulation.

$$\mathcal{C} = \mathbf{E_{whole}}/\mathbf{E_{visible}}$$

for each sampling structures, that are three of them in our case.

How to get a whole event energy conservation?



The simple formula should give us an answer

$$E_{Ecal} + E_{Hcal} = E_{CM}$$

but, we have no this – see a picture.

So, let us "rotate" the black line to the position of the red one by rescaling the coefficient of energy conversion (see previous slide). **"Rotation" actually means of the affine transformation of this 2–D space. (see next slide)**

These "rotated" coeffs consist of all the "properties" of the whole LDC calorimeters as well as the flavor's containment of the jets!

How to "rotate"?

The black line equation is:

$$a_0 E_{Ecal} + E_{Hcal} = a_0(c_1 E_{vis1} + c_2 E_{vis2}) + c_3 H_{vis} = E_0$$

where: c_1, c_2 **and** c_3 **is an initial energy conversion coeffs,** a_0 **is the slope which give us the minimal energy width.** E_0 **is some constant – the line should come through the most probable value of the initial energy sum.**

By the way; if the initial coeffs were bad fitted to the intrinsic mutual calorimeter properties (bad inter–calibration), one will never get the sharp top right edge of the energy distribution as well as the most probable "line"!

The red line equation is: $E^{calib}_{ECAL} + E^{calib}_{HCAL} = E_{CM}$ **– energy conservation law.**

Let us require $E_0 = E_{CM}$ **and** $a_0 = 1$ **exactly.**

Then we got the new coeffs:

$$c_1^{calib} = f a_0 c_1, \;\; c_2^{calib} = f a_0 c_2 \;\; and \;\; c_3^{calib} = f c_3;$$

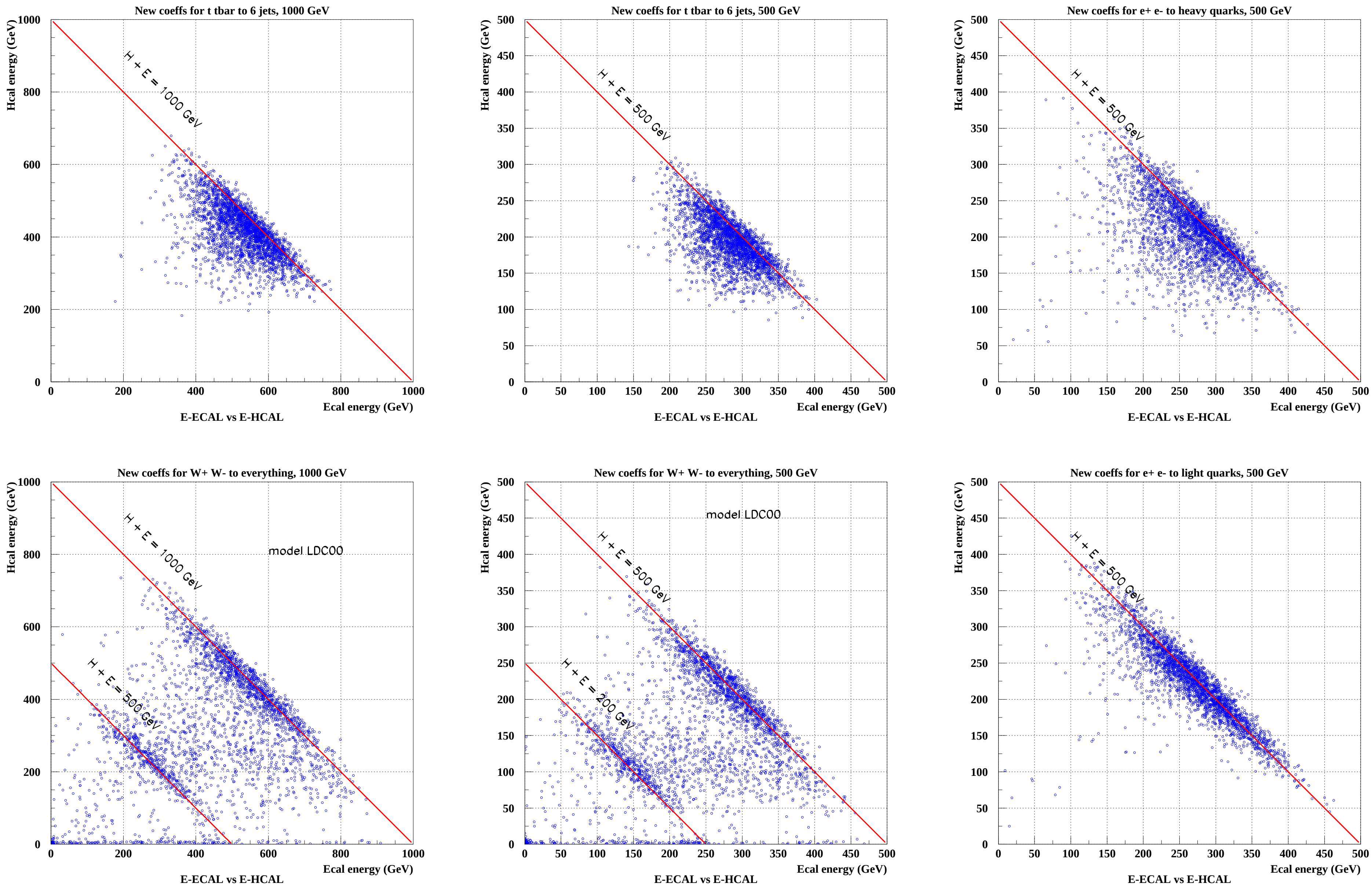
where: $f = E_{CM}/E_0$ **; and**

$$c_1^{calib} E_{vis1} + c_2^{calib} E_{vis2} + c_3^{calib} H_{vis} = E_{CM} \quad \textbf{along the most probable line}$$

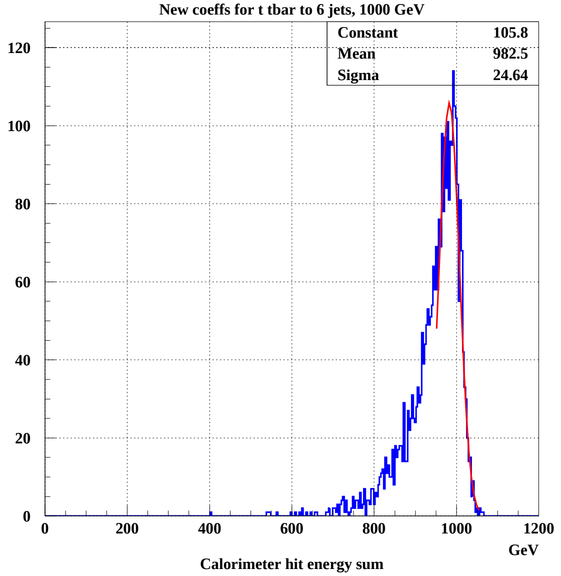
These three coeffs will be applied latter on to each hit in the particular sampling regions of the calorimeter.

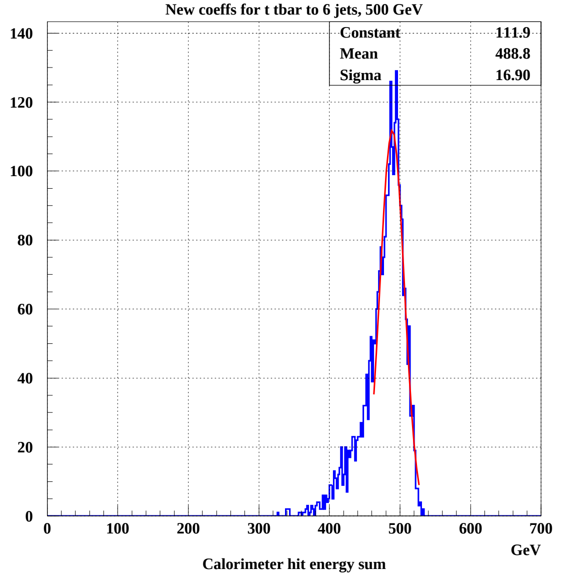
For any events you will see below.

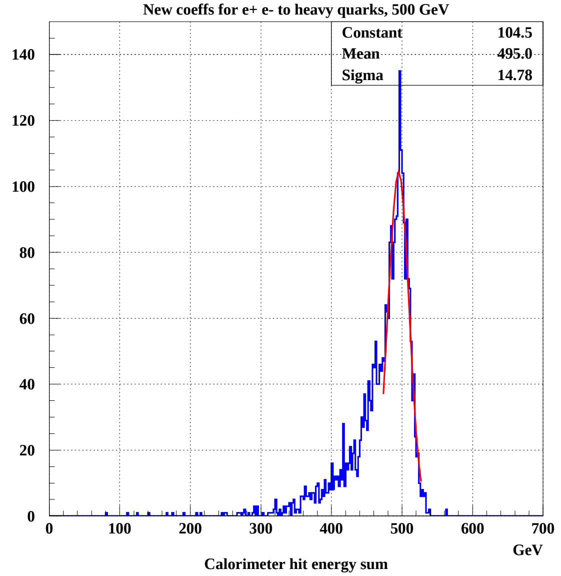
The results of “rotation/rescaling” are

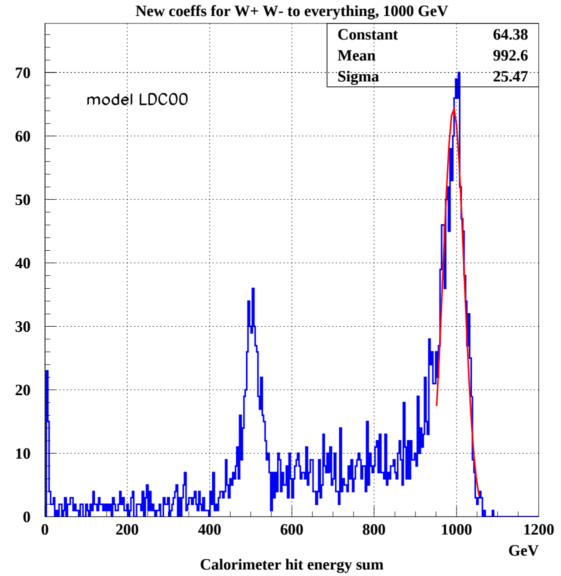


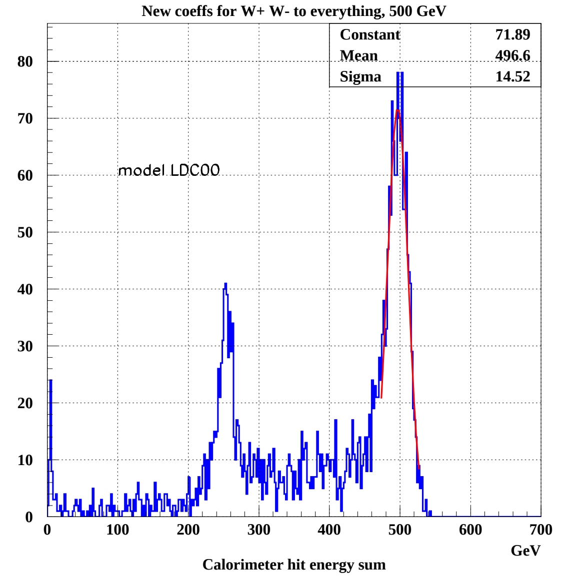
Calorimeter energy sum

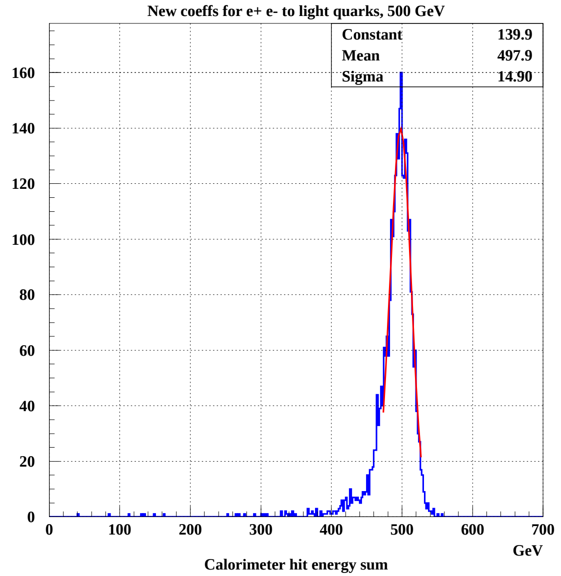












about Available Energy

Events for all these plots were generated without luminosity curve and without ISR,

so, the whole sum of energy in HEP record is equal of the center mass energy exactly.

To calculate available energy for calorimeters one should subtract

the neutrino energies, as well as the

energy of particles which go to the "beam–tube" (acceptance – detector inefficiency); and also subtract

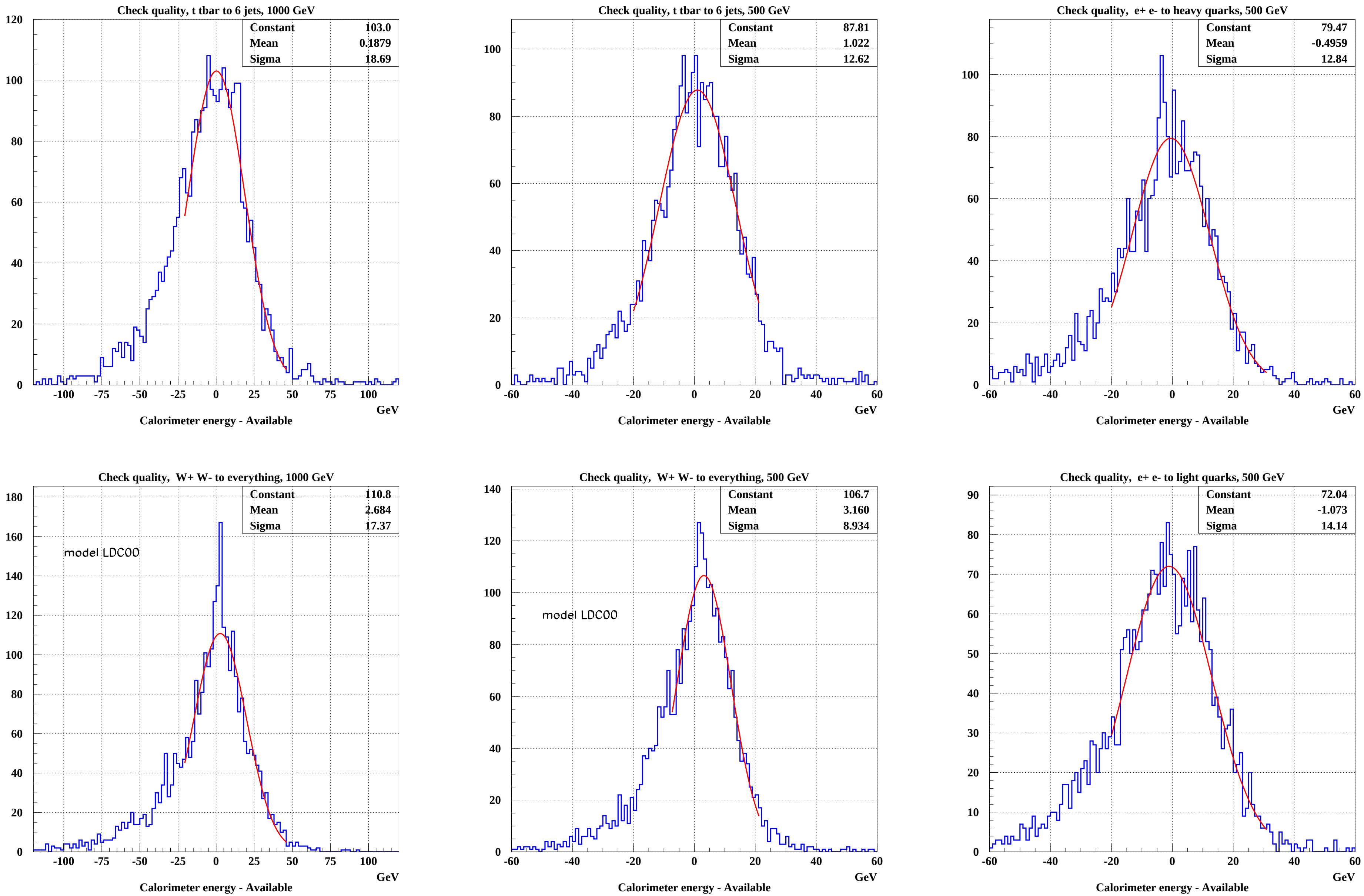
the muons energies

but with leaving of the energy which deposited by any muon in the calorimeter, which is about 1.6 GeV per muon.

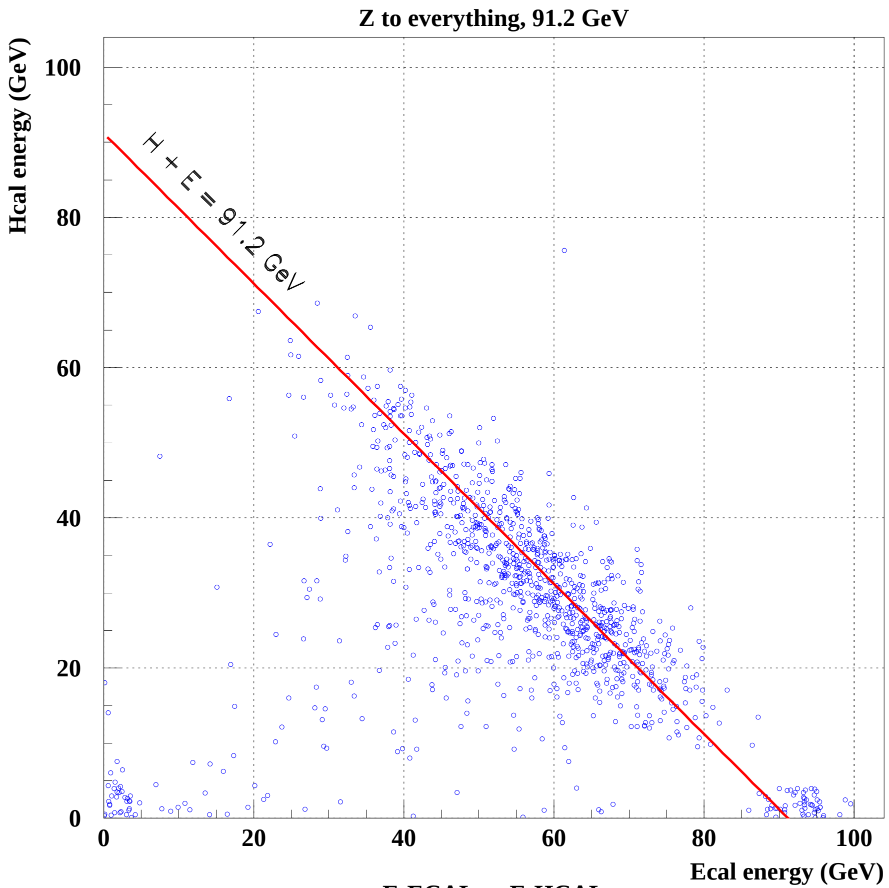
So, the estimated energy to be measured by calorimeters for each event is:

$$E_{available} = E_{CM} - E_{neutrinos} - E_{to\ tube} - E_{muons} + N_{muons} \times 1.6\ GeV$$

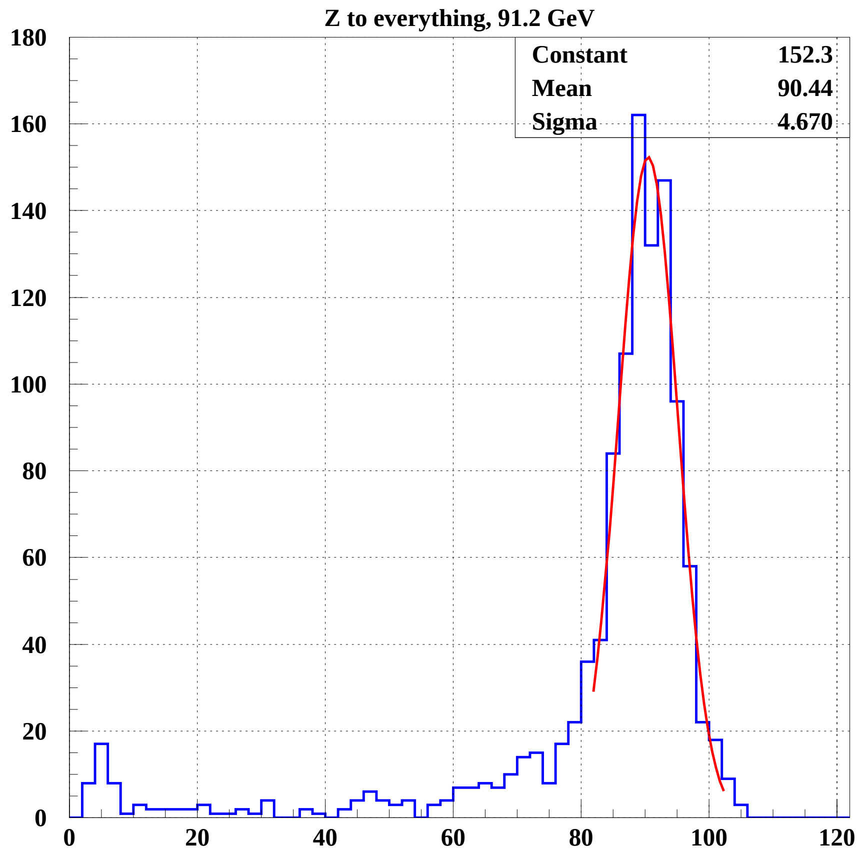
Check plots


Check quality, t tbar to 6 jets, 1000 GeV
Constant 103.0
Mean 0.1879
Sigma 18.69
Calorimeter energy - Available
GeV
Check quality, t tbar to 6 jets, 500 GeV
Constant 87.81
Mean 1.022
Sigma 12.62
Calorimeter energy - Available
GeV
Check quality, e+ e- to heavy quarks, 500 GeV
Constant 79.47
Mean -0.4959
Sigma 12.84
Calorimeter energy - Available
GeV
Check quality, W+ W- to everything, 1000 GeV
Constant 110.8
Mean 2.684
Sigma 17.37
model LDC00
Calorimeter energy - Available
GeV
Check quality, W+ W- to everything, 500 GeV
Constant 106.7
Mean 3.160
Sigma 8.934
model LDC00
Calorimeter energy - Available
GeV
Check quality, e+ e- to light quarks, 500 GeV
Constant 72.04
Mean -1.073
Sigma 14.14
Calorimeter energy - Available
GeV

For “reference” Z–pole reaction



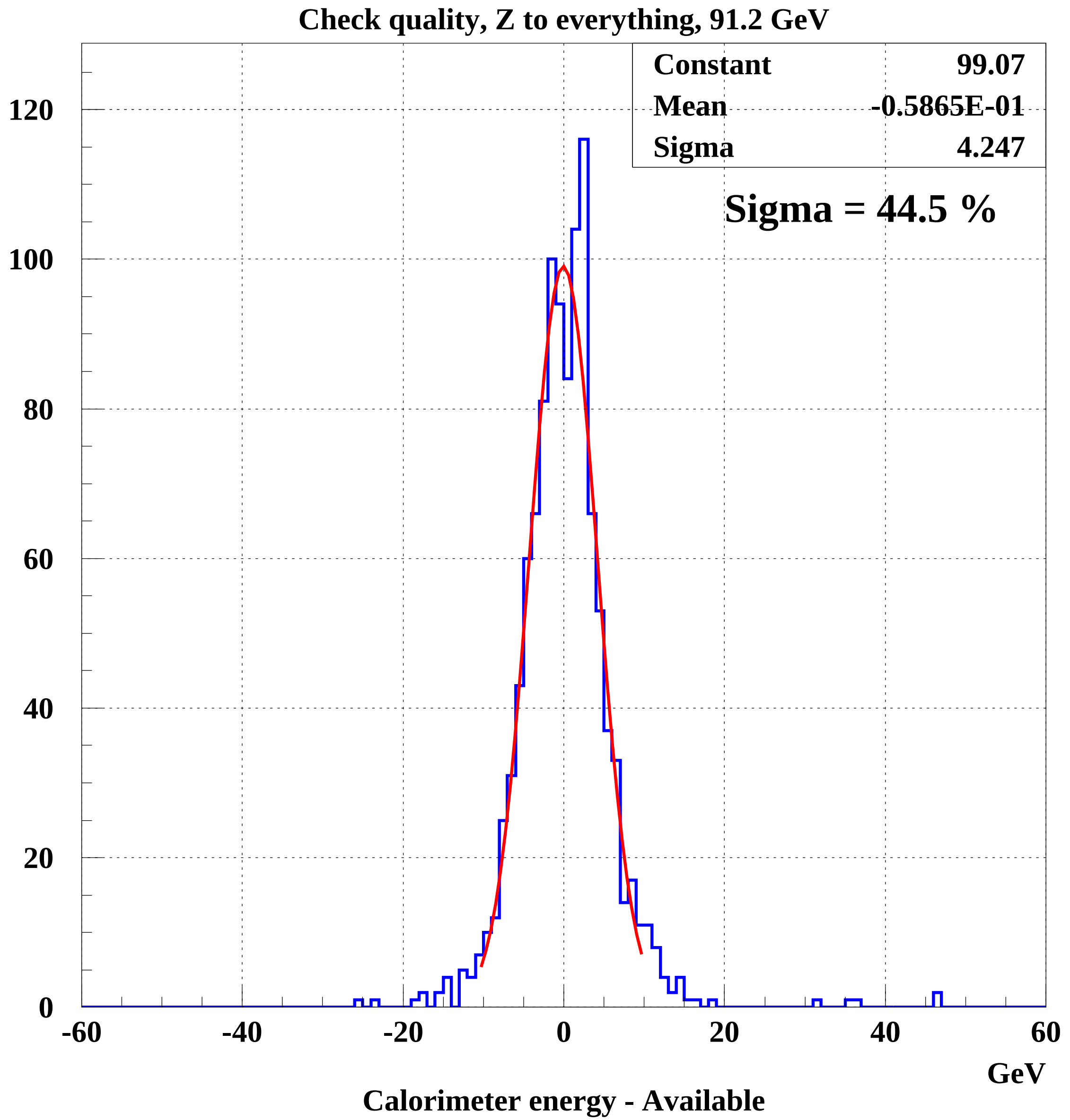
E-ECAL vs E-HCAL



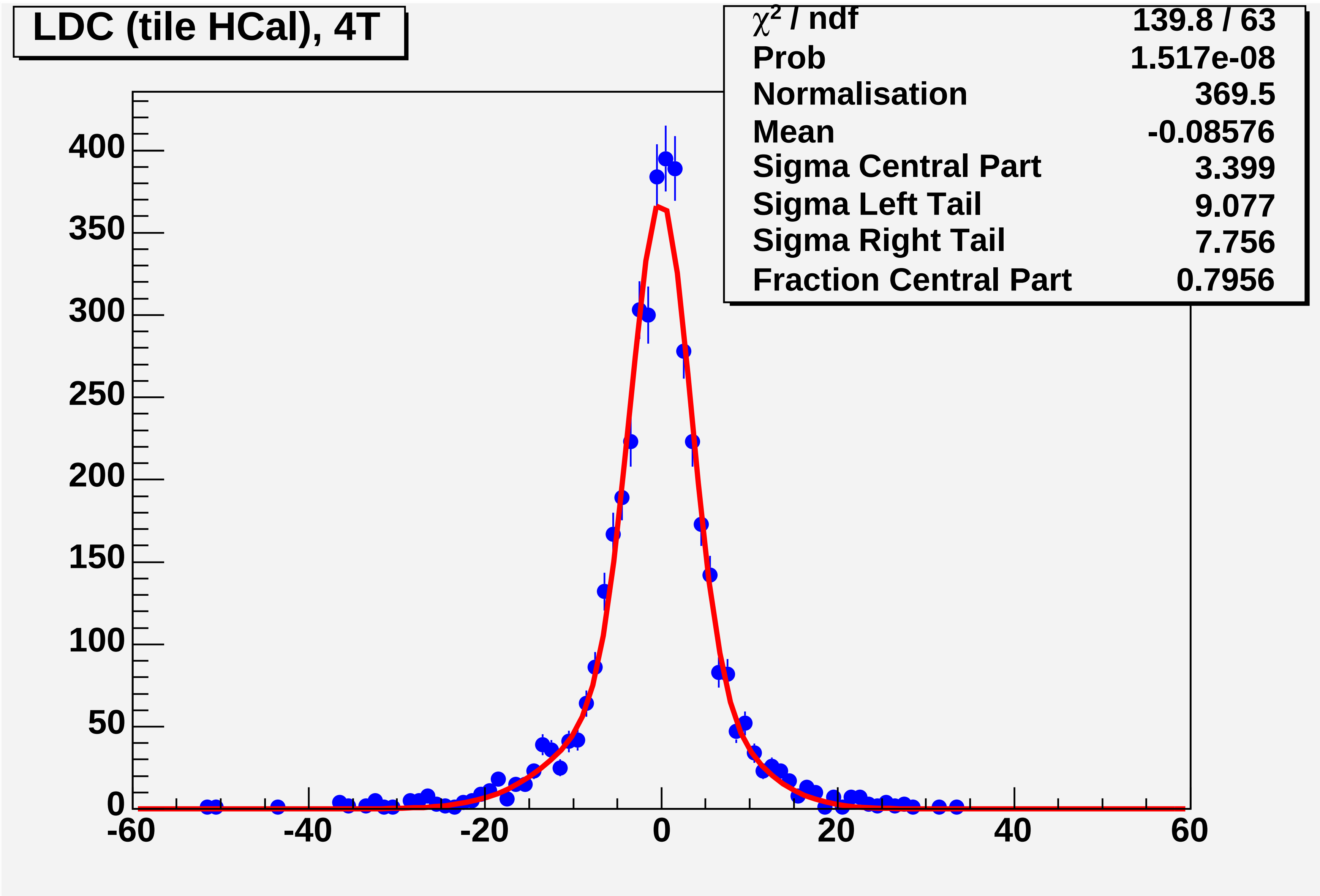
Calorimeter hit energy sum

All decay channels are allowed.

Check plot


Check quality, Z to everything, 91.2 GeV
Constant 99.07
Mean -0.5865E-01
Sigma 4.247
Sigma = 44.5 %
120
100
80
60
40
20
0
-60
-40
-20
0
20
40
60
GeV
Calorimeter energy - Available

Marlin Reco also knows about this



Summary Table, model LDC00

	Whole calorimeter sum		Check plots	
e+ e- into , at energy	Mean [GeV]	Sigma [GeV]	Mean [GeV]	Estimated energy resolution [GeV]
t tbar, 1000 GeV	982.3	24.6	0.19	18.7
W+ W-, 1000 GeV	992.6	25.5	2.7	17.4
t tbar, 500 GeV	488.8	16.9	1.8	12.6
W+ W-, 500 GeV	496.6	14.5	1.6	10.9
heavy quarks, 500 GeV	495.0	14.8	-0.5	12.8
light quarks, 500 GeV	497.9	14.9	-1.1	14.3
t tbar, 360 GeV	356.4	14.0	5.5	10.0
Z pole, 91.2 GeV	90.4	4.67	-0.06	4.25

Any reconstruction program should give us these resolutions, at least.

Attempt of Optimization

Shift of the most probable peak of energy from the center of mass energy.

	3 Tesla				4 Tesla			
	LDC01		LDC00		LDC01		LDC00	
e+ e- into , at energy	-20 -20	+00 +00	+00 00	+20 +20	-20-20	+00 +00	+00 +00	+20 +20
W+ W-, 500 GeV	-3.4	-2.1	+3.1	+2.4	-0.8	-0.4	+4.2	+3.1
t tbar, 500 GeV	-6.9	-7.0	-3.1	-4.6	-6.2	-5.0	-1.9	-3.0
t tbar, 360 GeV	-6.7	-6.3	-3.6	-4.6	-5.8	-6.5	-3.2	-5.0

Tendency is visible, BUT, to make any decision on these numbers is too hard,

they are around one percent of whole energy.

All detector models are good from the point of view of the energy consistence

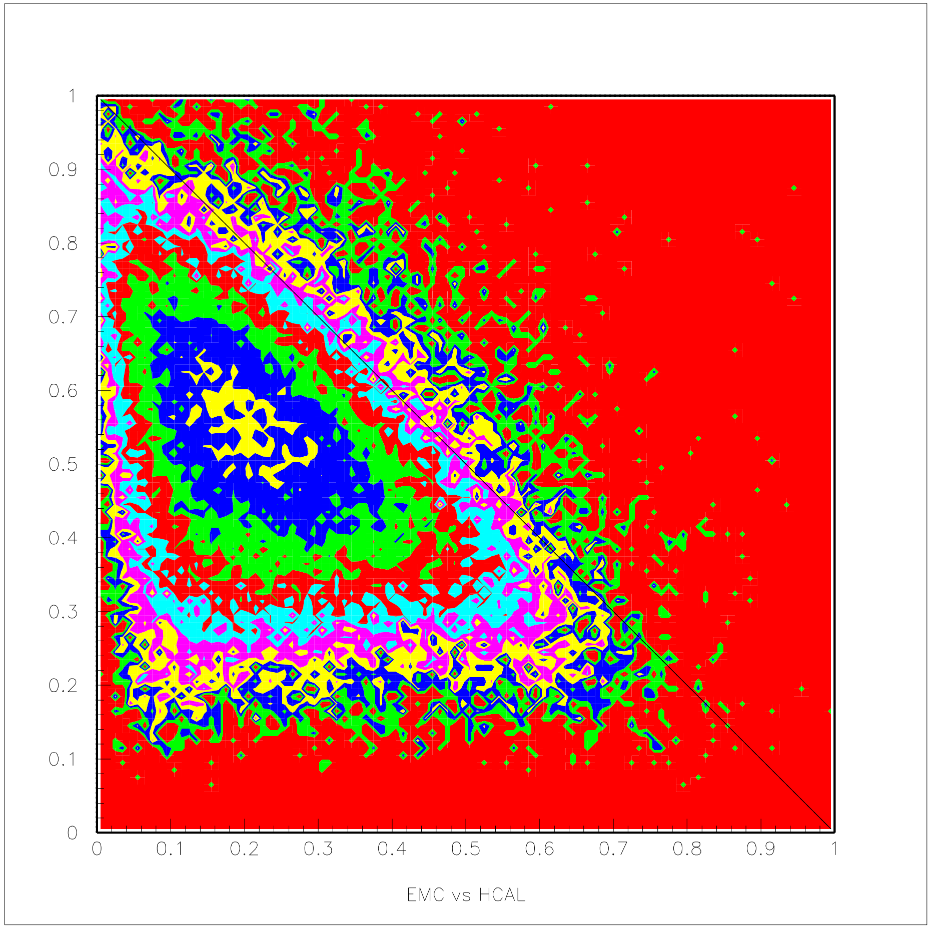
in the calorimeter.

Conclusion

Let us use the energy conservation law

with its full power.

After the conclusion



(ZEUS data)

For HERA experiments this feature also can be used but at the more complex way.

The relative calibration can be done using $E - P_z = 2 \times E_{e\ beam}$ equation.