New reconstruction technique developed for CALICE HCAL prototype

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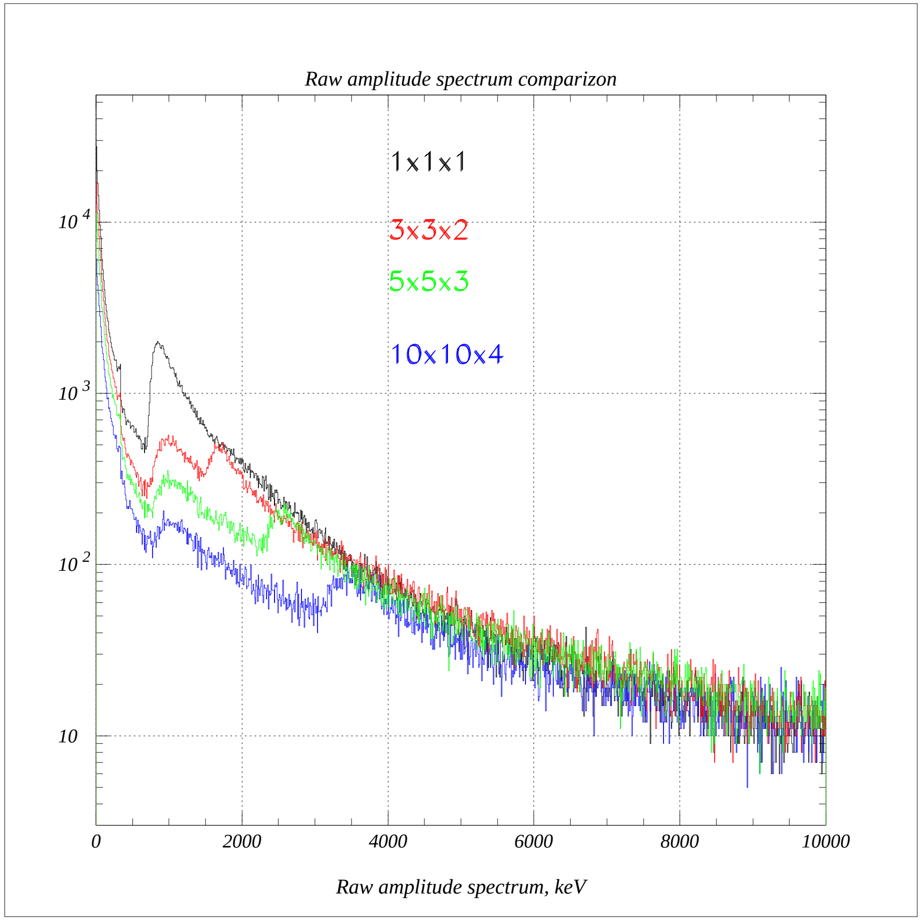
The copy of this talk one can find at the http://www.desy.de/˜morgunov

Reconstruction method – 1

1. Hits are separated at the very beginning at tree groups by its energy. As the thickness of the scintillator the same for all tiles such a separation has a meaning of the hit density separation.

Latter on hit can be reassigned to the other type, it depends on the final cluster identification.



. π^+ 10 GeV. Different colors show different cell sizes

MIP $\sim$ 1000 keV

Hit energy boundaries are:

I. from half of a MIP to 1.7 MIP

II. from of a 1.7 MIP to 3.5 MIP

III. from of a 3.5 MIP to the largest energy

The hits with energy less than a half of a MIP do not use in the event analysis; that is more or less usual noise cut.

Reconstruction method – 2

2. The 3–D clustering is made separately for each group of hits. (3–D clustering is the imaging self–adaptive algorithm)

Special technique is used for the III–d group of hits – that is primary suppose to be the electromagnetic clusters; so, for this group after 3-D clustering surrounding hit collection is applied in addition.

3. Merging close clusters of the same type into one cluster.

4. For each cluster few properties are calculated:

   a. center position

   b. eccentricity of "inertia tensor" with hit energy as mass role.

   c. "inertia tensor" ellipsoid volume, and spatial density E/V.

   d. average hit density E/N.

   e. fi rst and last hit positions.

The list of the most signifi cant properties is presented here.

Actually there are many others cluster properties calculated and used for further analysis.

Reconstruction method – 3

5. All clusters separated into four classes by its properties:

The separation of clusters into classes is made by taking into account

the primary separation by hit density,

topological/imaging properties of clusters,

its inter relations and

its positioning in the calorimeter volume.

The main properties of clusters are:

I. Track–like $\Rightarrow$ has small eccentricity and hit density

II. Hadron–like $\Rightarrow$ has small hit density

III. Electromagnetic–like $\Rightarrow$ has large hit density and small eccentricity.

IV. Neutron–like $\Rightarrow$ separated hits in calorimeter volume which were not catched into any cluster.

Result 1

As the result of this procedure all hits in events become to belong to four different types.

The whole event energy is separated into three types:

Hadron–like and Track–like $\Rightarrow$ tracks and group of tracks that cannot be separated into tracks;
$\Rightarrow$ both are hadronic activity in the hadronic shower.

Electromagnetic–like $\Rightarrow$ energy created by π^0 $\Rightarrow$ electromagnetic activity in hadronic shower.

Neutron–like $\Rightarrow$ energy created by neutrons in hadronic shower

(registered in scintillator by protons from elastic scattering and gammas from n–γ reactions).

The number of hits of each type is also known.

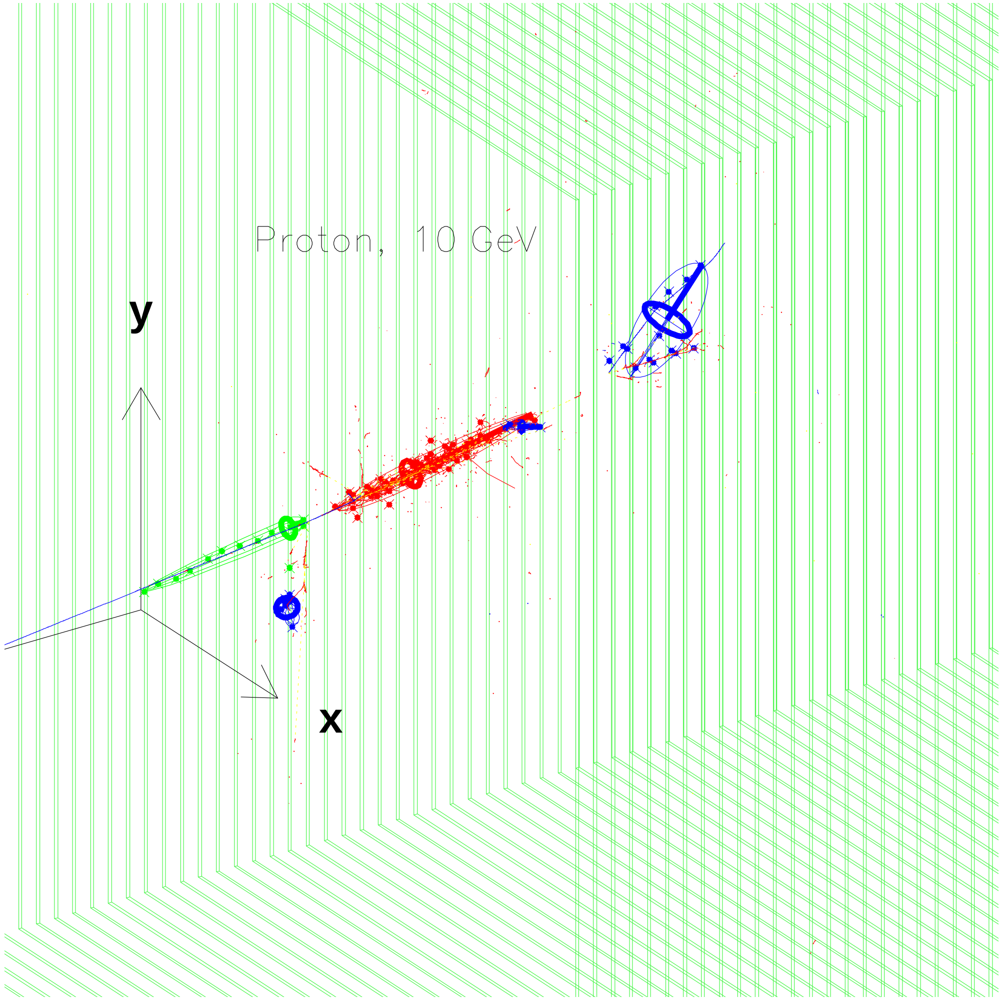
So, each event/shower has eight characteristics numbers:

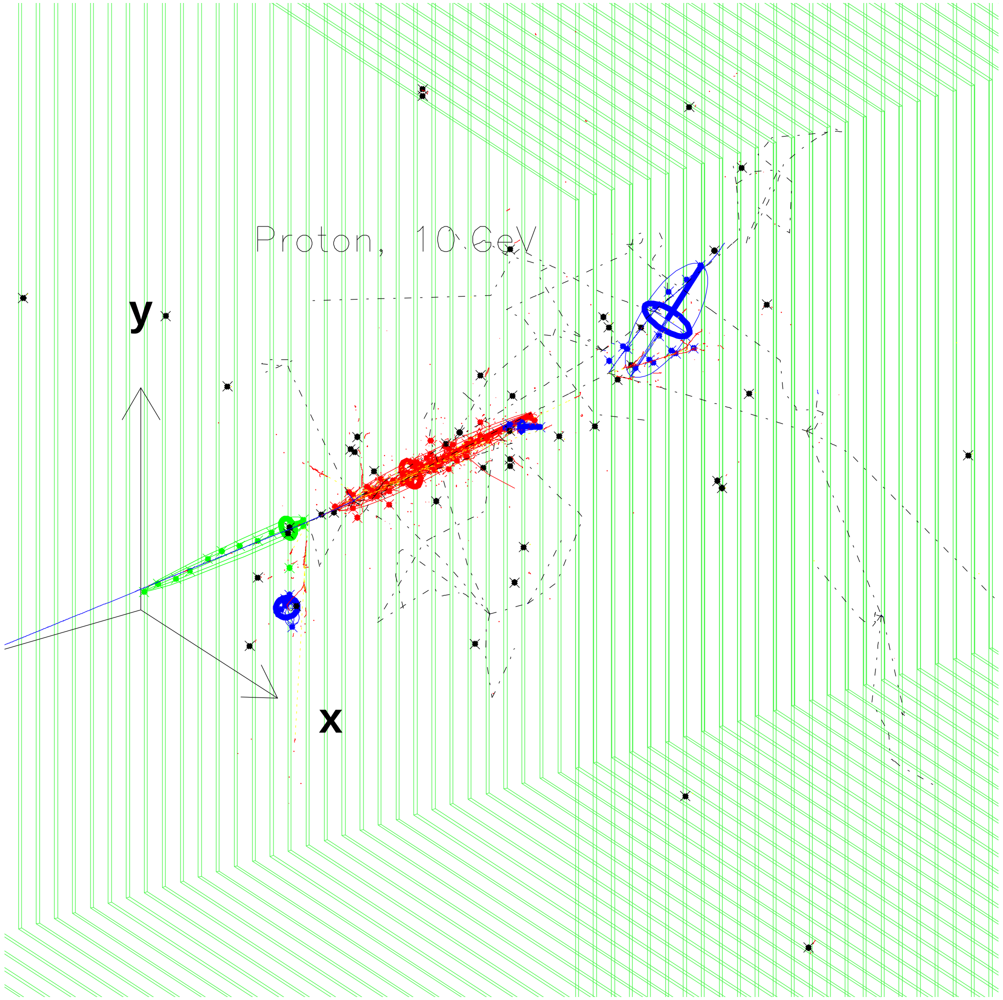
Track–like	–	$N_{TRK\ hits}$	and	E_{TRK}
Hadron–Like	–	$N_{HAD\ hits}$	and	E_{HAD}
Electromagnetic–like	–	$N_{EM\ hits}$	and	E_{EM}
Neutron–like	–	$N_{NEU\ hits}$	and	E_{NEU}

This information can be applied for shower reconstructed energy correction.

Latter on these colors will be used for the cluster and hit presentation in events

Illustration



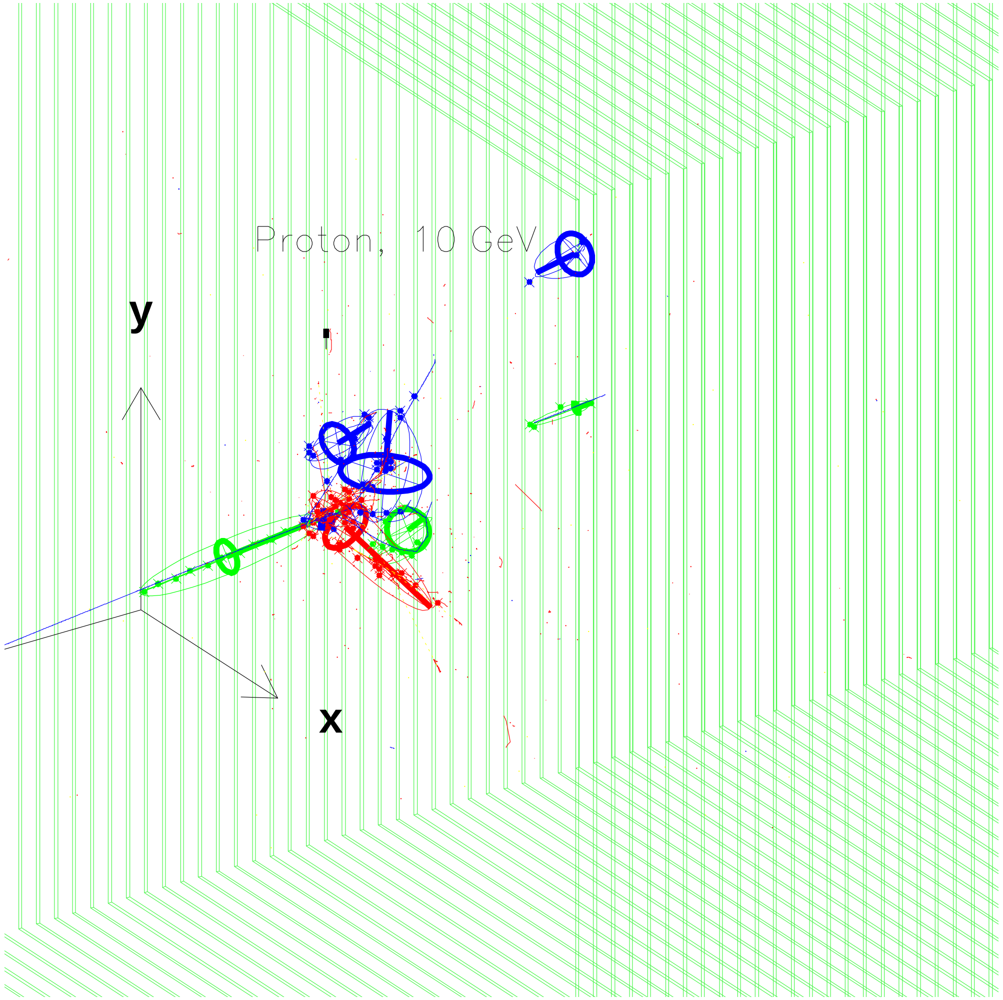


Here are presented three type of clusters

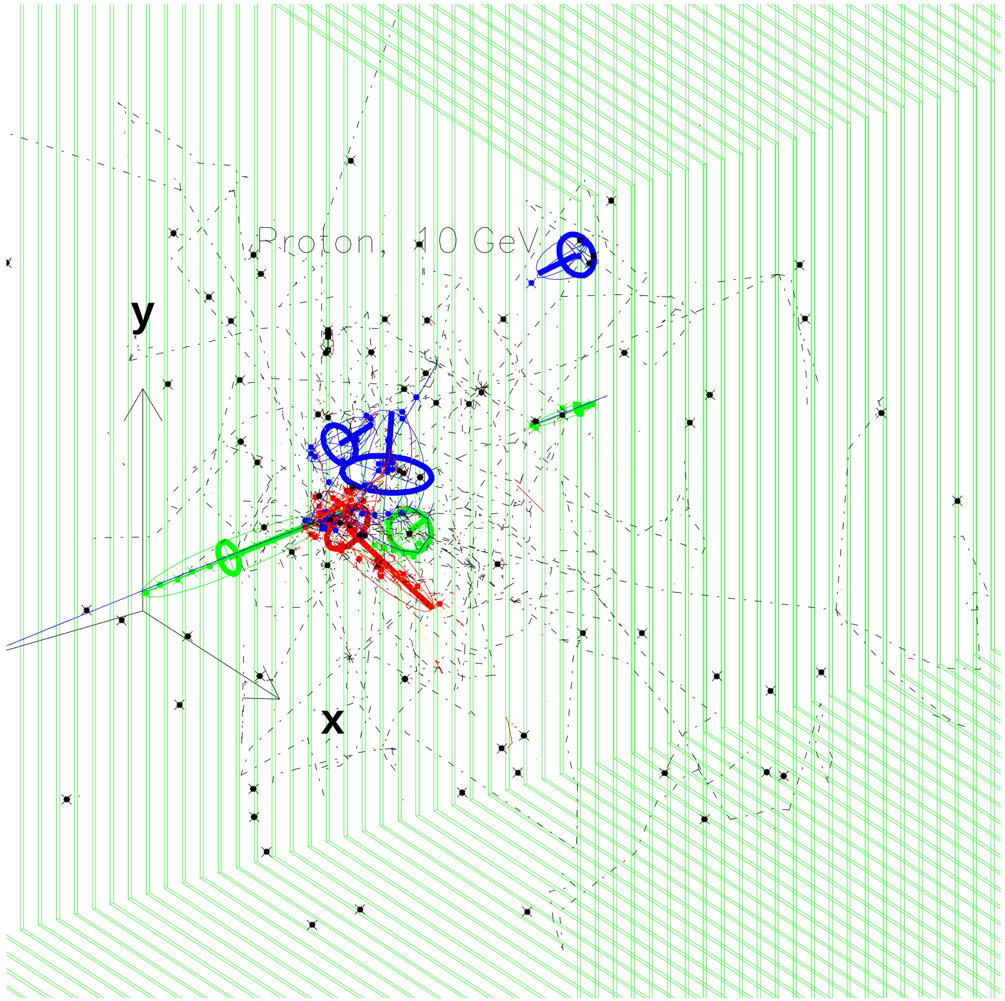
Add neutron hits and tracks

Axis arrow size is 33 cm. Scintillator plates are visible. GEANT3 with FLUKA and MICAP was used for event simulation

Illustration

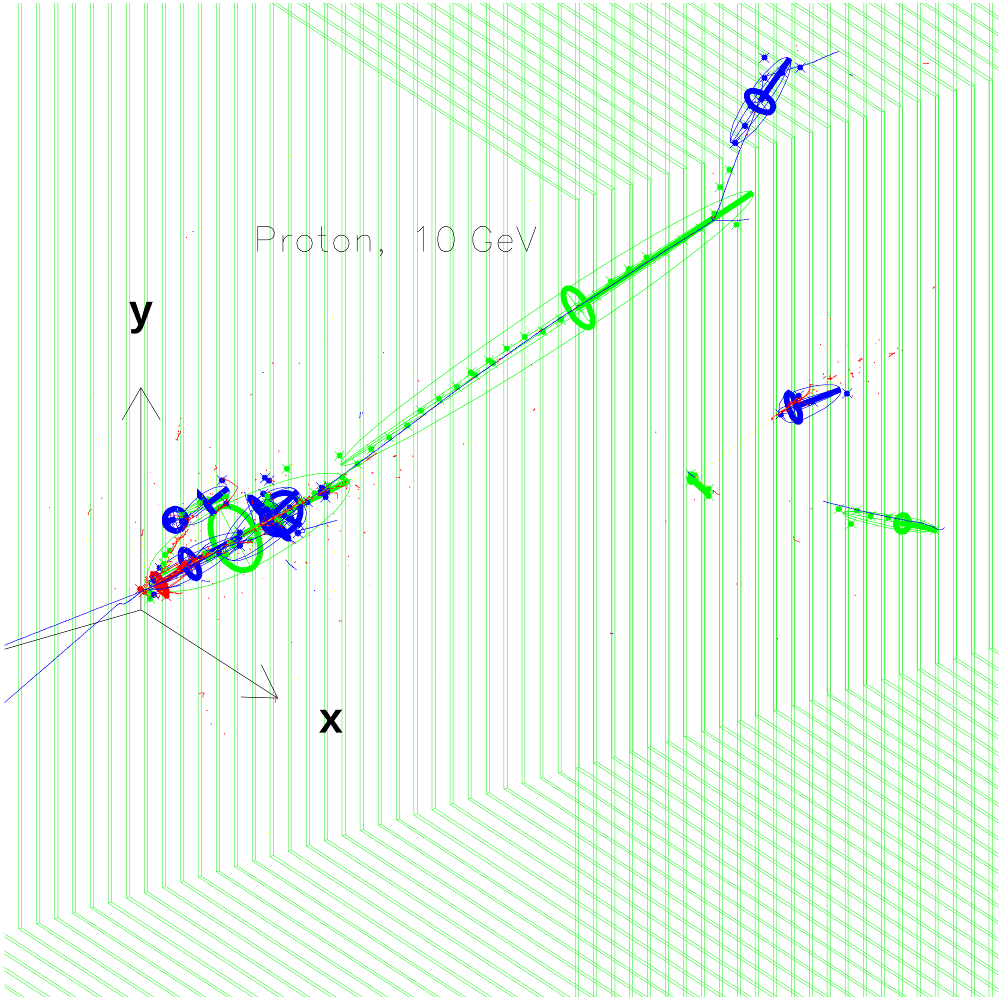


Here are presented three type of clusters



Add neutron hits and tracks

Illustration



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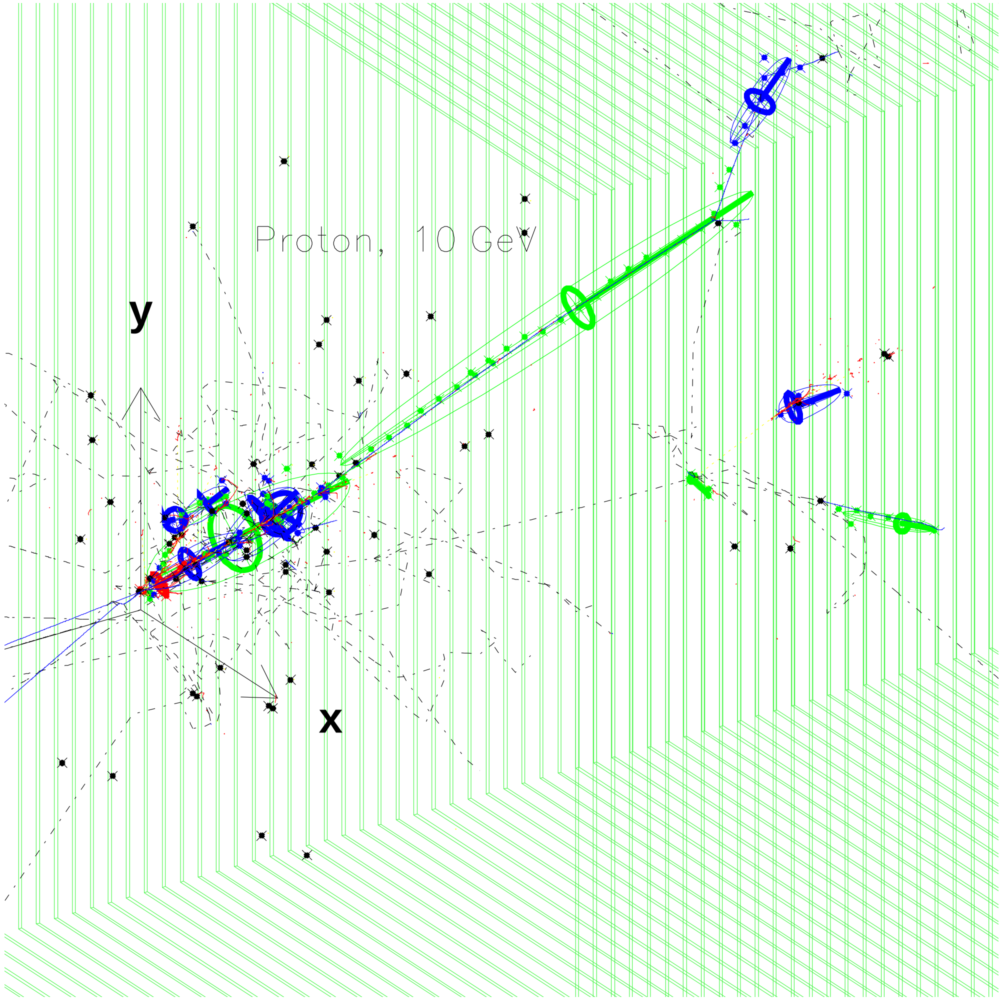
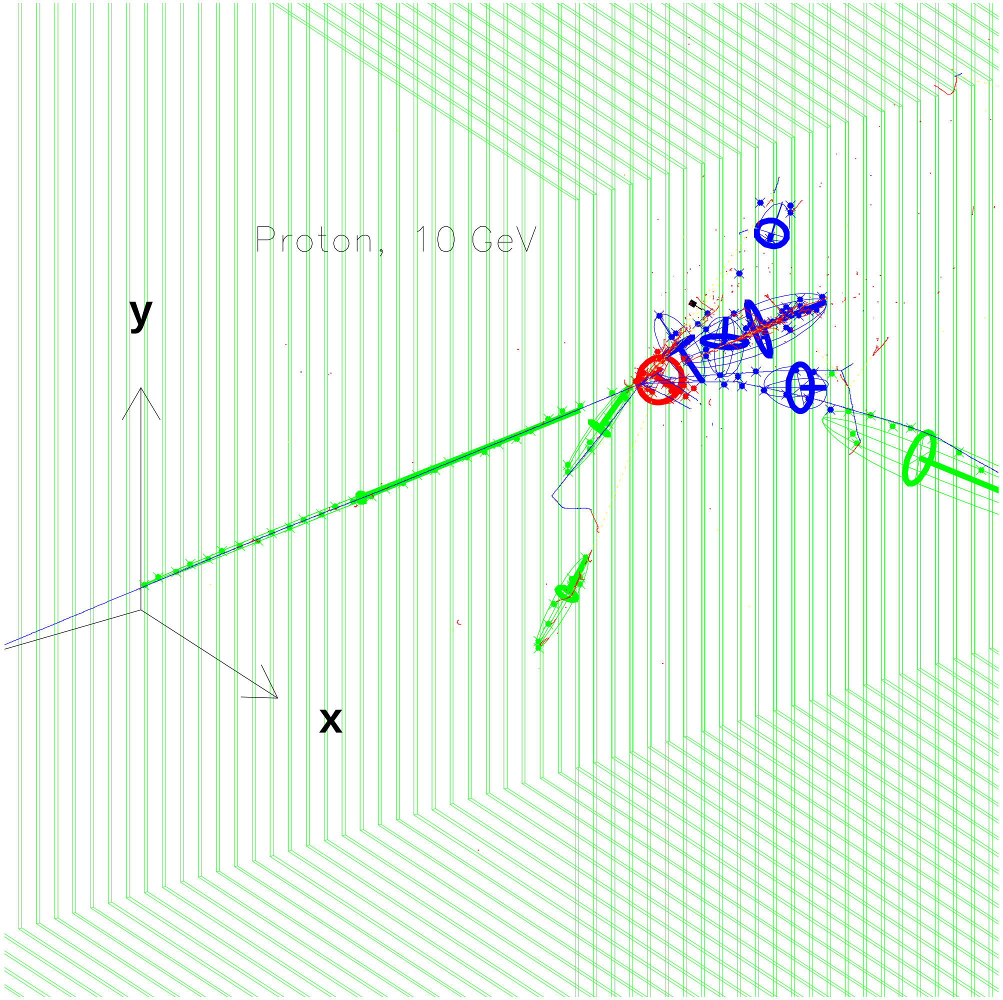


Add neutron hits and tracks

Illustration



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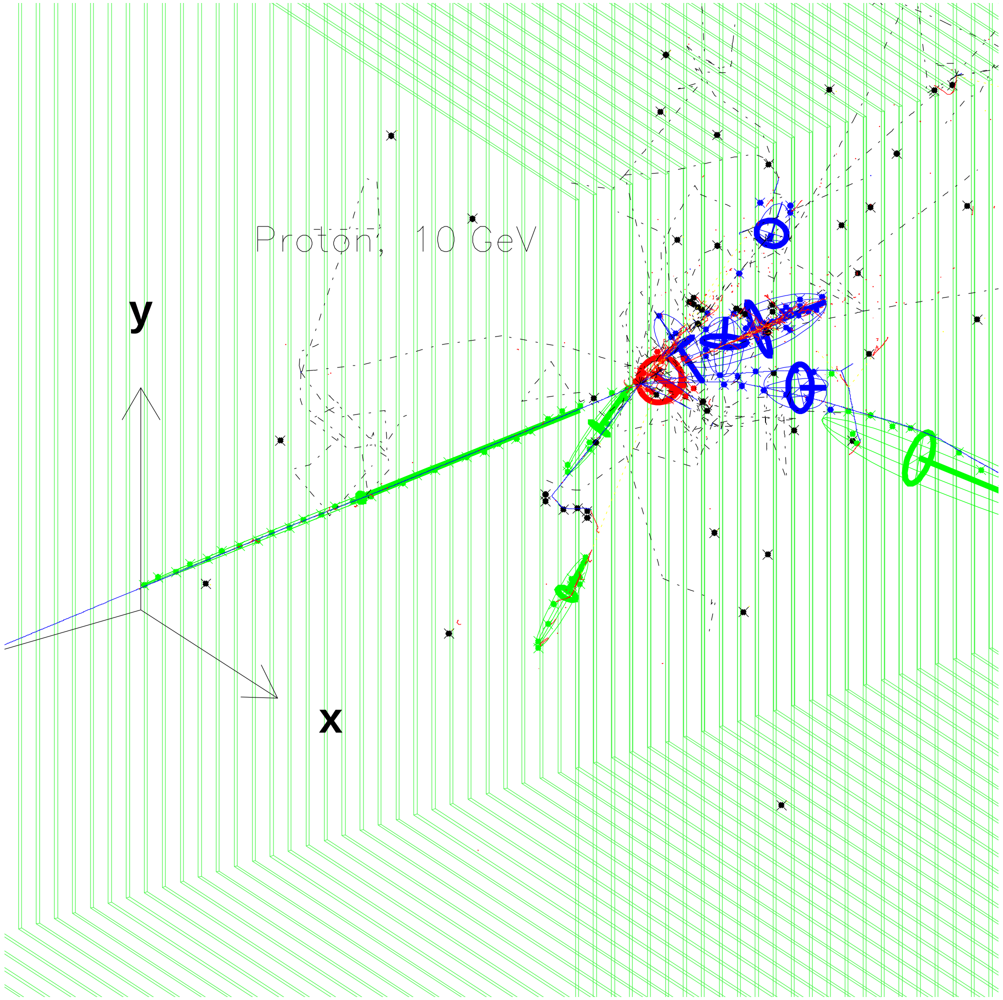
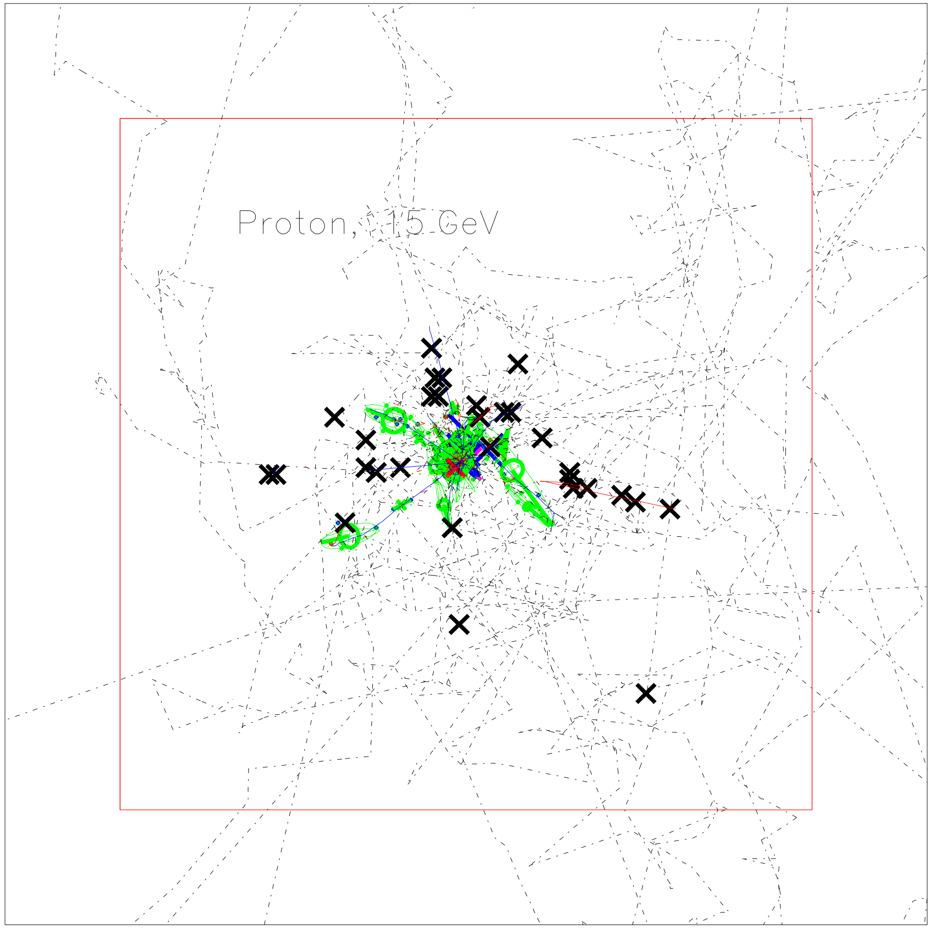


Add neutron hits and tracks

Illustration

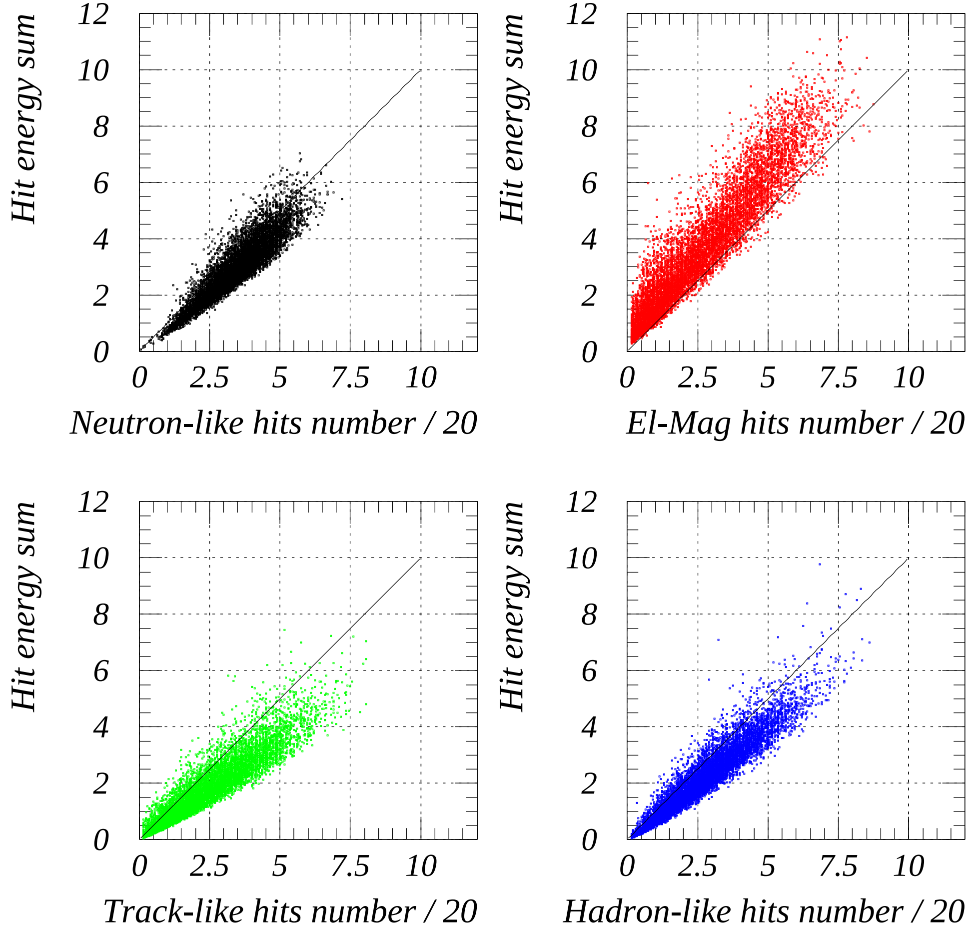


Front view of the calorimeter; neutron–like hits are shown in black; neutron tracks as dashed lines.

Red line is one square meter.

Application 1

Strong correlation between number of hits and sum of hit energy of hadronic type can be applied for the Landau fluctuation suppression in each event.



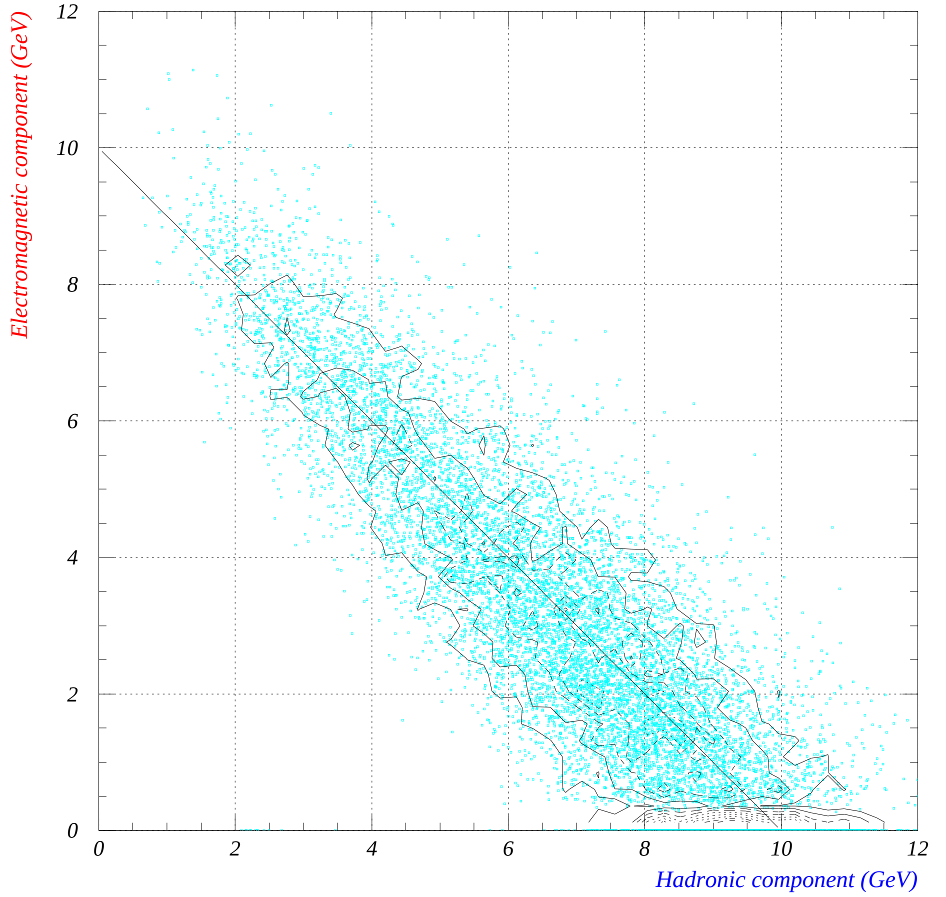
The shape of these distributions and slope of the correlations depends on the hadronic model and neutron transport quality in the simulation programs.

Real numbers will be taken at the test–beam time.

Application 2

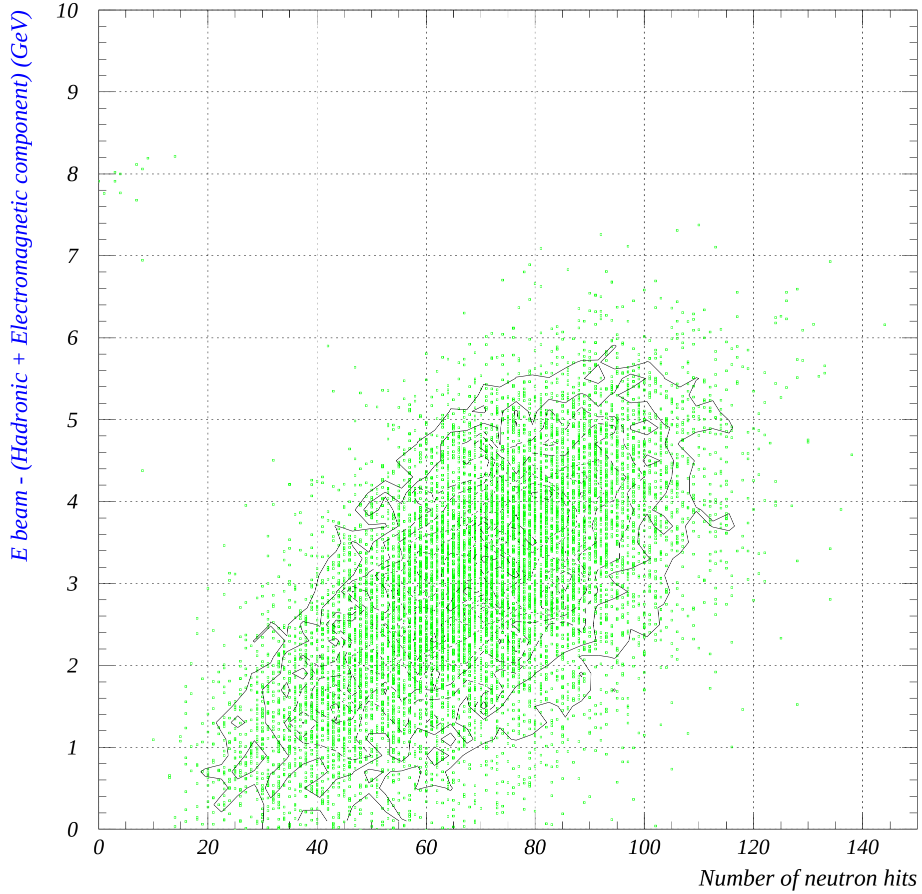
Event energy subdivision into EM and HAD gives possibility to apply different coeffi cient for visible to physical energy conversion.

$$\pi^+ \quad 10GeV$$



Application 3

Binding/invisible energy can be calculated if one takes into account weak correlation between number of neutron hits in event and binding energy.



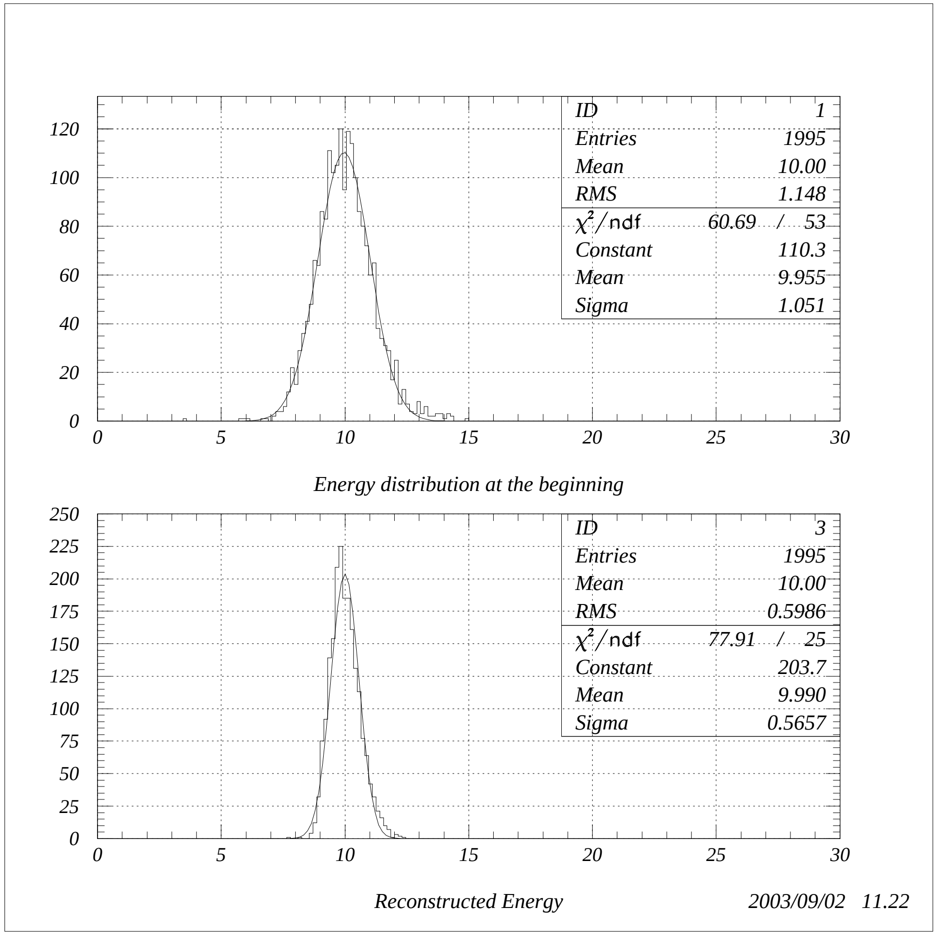
GEANT3 and GEANT4 give different shape of these distributions; in particular different slopes.

Real numbers will be taken at the test–beam time.

"Result" 2

Hadron "energy resolution" with Bayesian approach about beam energy.

$\pi^+ \quad 10GeV$



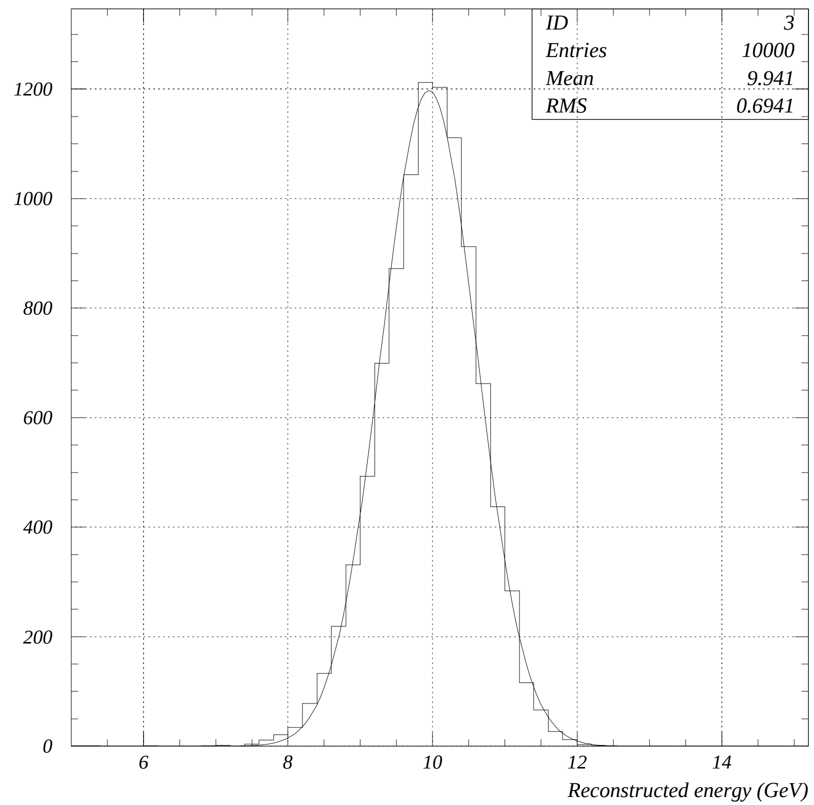
Having in hands tree components of shower energy
it is easy to get a "DREAM–like" distribution.

The left–hand side bottom distribution
that indicates 17.8% over square root of E,
has no deal with the calorimeter resolution,
it shows the degree of correlation
between measured numbers
which sum to be a beam energy.

"Result" 3

Using all described applications for energy corrections one can get 21% over square root of E.

BUT and again for the one beam energy. (none–evidently Bayesian approach)



The dependence of the coeffi cients used for the corrections on the beam energy and its stability/reliability are under investigation.

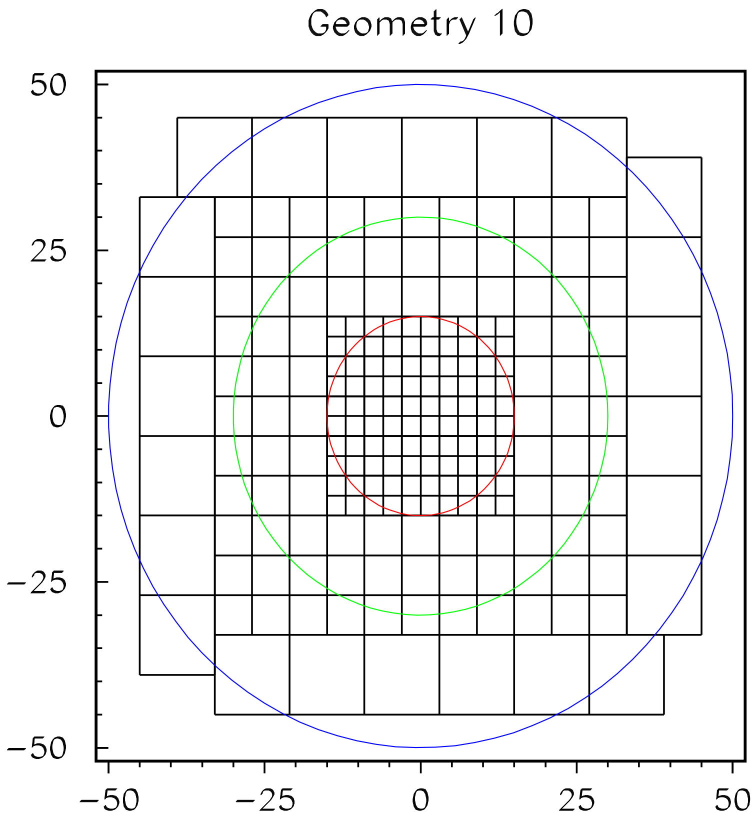
Reality

All previous pictures and numbers were shown for the highly granulated calorimeter
with cell size 1x1 cm^2 in 2x2x2 m^3 calorimeter volume
to show the principal ability of this reconstruction method,

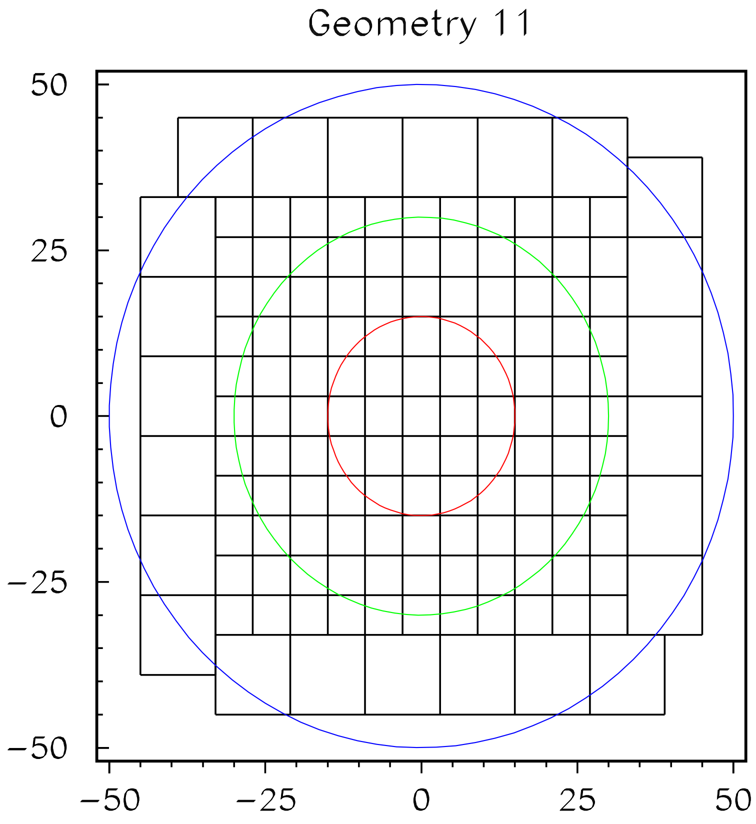
But what about the realistic calorimeter?

Short description of HCAL prototype

Tile layout for one cubic meter HCAL prototype:



100 - 3x3 cm, 96 - 6x6 cm, 24 - 12x12 cm



121 - 6x6 cm, 24 - 12x12 cm

First 30 sampling layers

Last 8 sampling layers

Detector – 5 mm plastic scintillator; Absorber – 2 cm stainless–steel.

About 8000 channels to read in common.

Energy correction methods

1. Simplest sum:

$E_{corr} = \sum_{i=1}^{4} c_i E_i$ where i is index of shower component (NEU, EM, MIP, TRK)

where: c_i are taken from energy resolution minimization around the beam energy value.

2. Projection method:

For each type of component knowing E_i and N_i and making a projection to the average hit density (see Application 1) and after that apply the simplest sum (see above).

3. Iterative FLC correction method: based on the V. Shekelyan proposal (H1-10/89-121).

$E_i^{corr} = c_6(N_i c_i(1 - W_i))$; then: $E_{tot} = \sum_{i=1}^{4} c_i E_i^{corr}$

where: $W_i = c_5 \ln(c_i/E_{tot})\sqrt{E_{tot}}$ and i is index of shower component (NEU, EM, MIP, TRK);

the meaning of c_i here is the average hit density and weight the same time;

all coeffi cients are taken from energy resolution minimization around the beam energy value.

Result 4

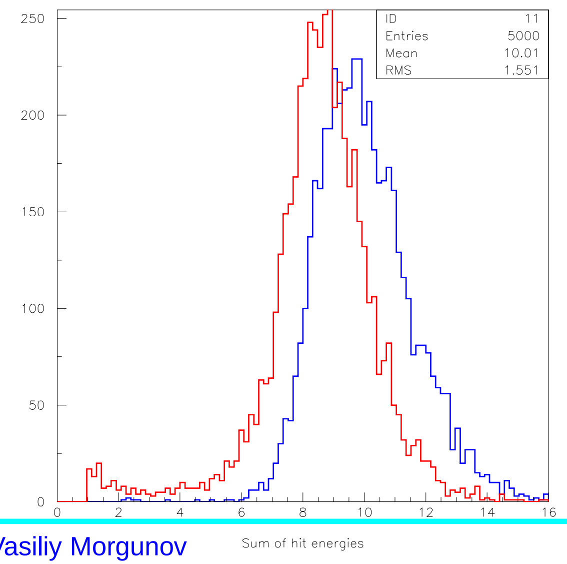
Difference between 1x1 and 3x3 cm cell size in 2x2x2 m^3 calorimeter volume;

and realistic HCAL prototype 1x1x1 m^3 geometry

Gaussian width of energy distribution in GeV

Corr. method	Simplest			Projection			FLC		
Tile size	1x1x1	3x3x1	Prototype	1x1x1	3x3x1	Prototype	1x1x1	3x3x1	Prototype
5 GeV	0.90	0.90	1.00	0.80	0.81	0.86	0.45	0.47	0.48
10 GeV	1.26	1.23	1.50	1.01	1.14	1.35	0.67	0.81	0.91
15 GeV	1.56	1.52	2.02	1.41	1.44	1.91	0.94	1.21	1.58

Worse correction of the resolution for protoptype is due to the leakage and the bigger tile sizes.



Energy distribution without corrections: blue 2x2x2 m^3 and 1x1x1 m^3

Conclusion

1. New imaging hadron shower analysis method was developed for highly granulated hadron calorimeter.
2. Method allows to distinguish clusters on its physical origins in hadronic shower.
3. Application allows to reconstruct hadronic shower energy with better accuracy than usual energy reconstruction methods.
4. Visible cluster sources will allow to tune simulation programs at the real test–beam events.
5. New energy correction methods are under development.