Calibration to improve calorimeter performance

- Quantities on cluster level
- Weights and weighting
- Identification of EM clusters
- Status of students in Bratislava

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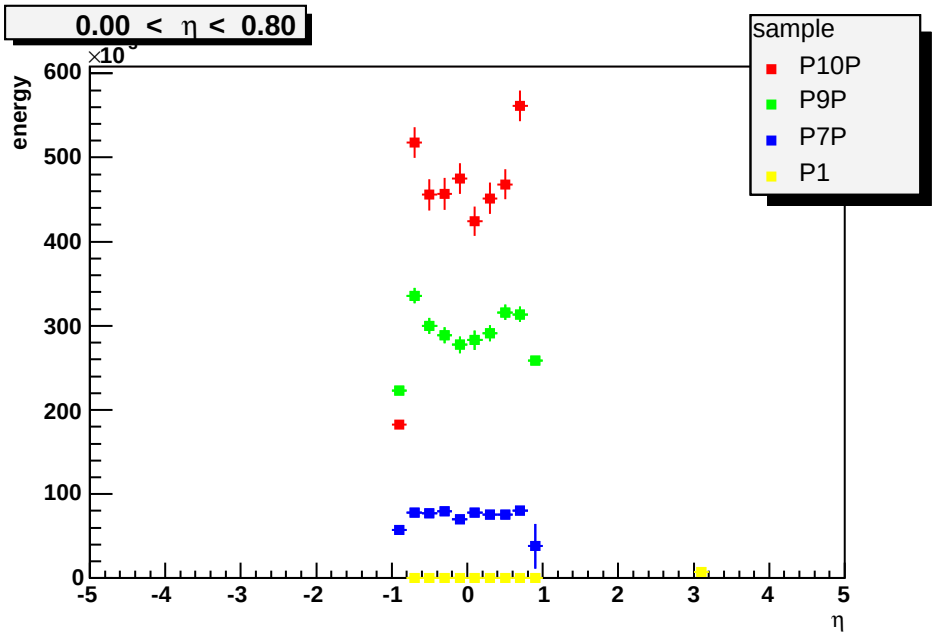
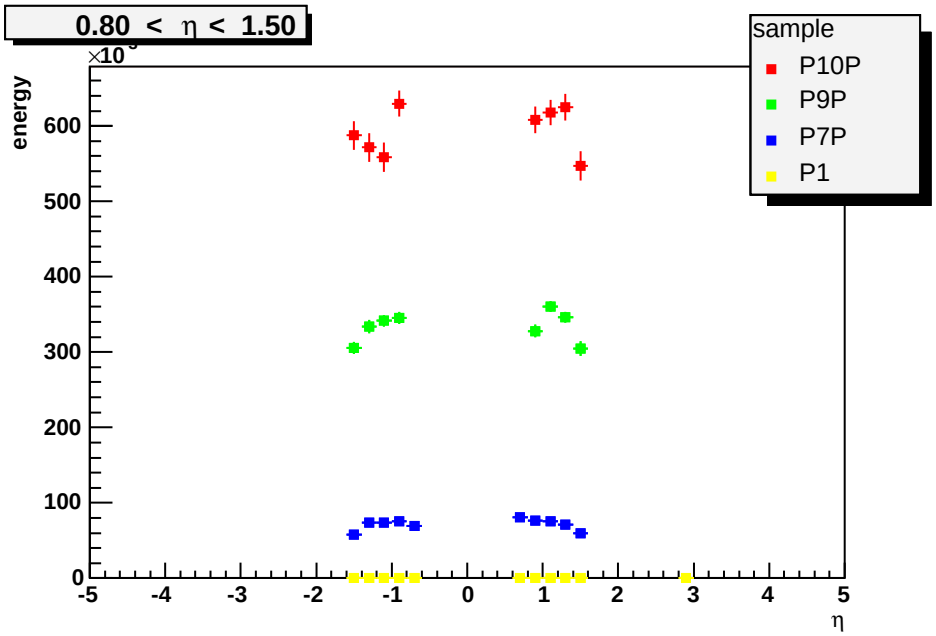
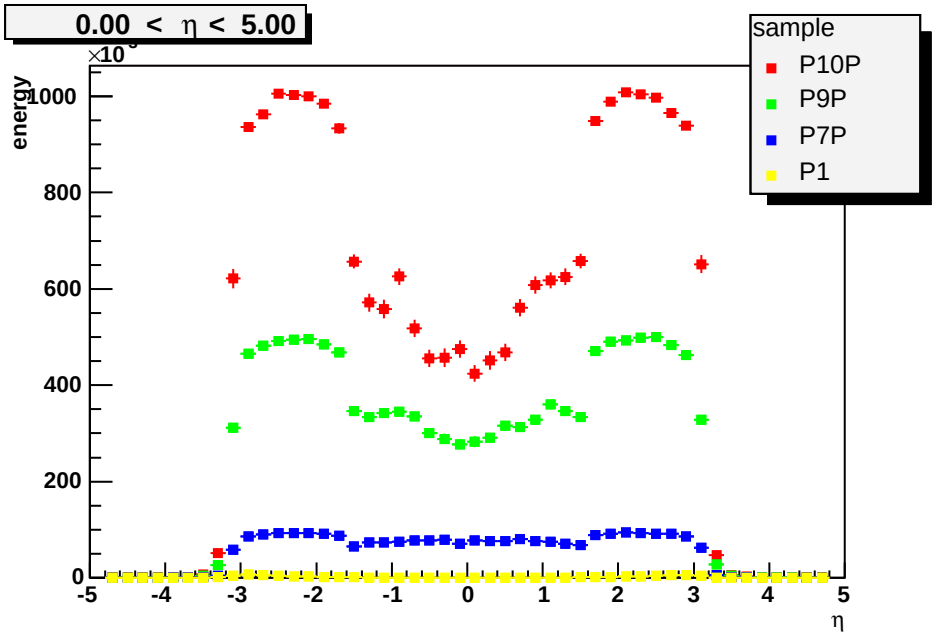
Unfortunately, available simulated data of Rome production are buggy... only region which is not influenced much by the bug is ENDCAP

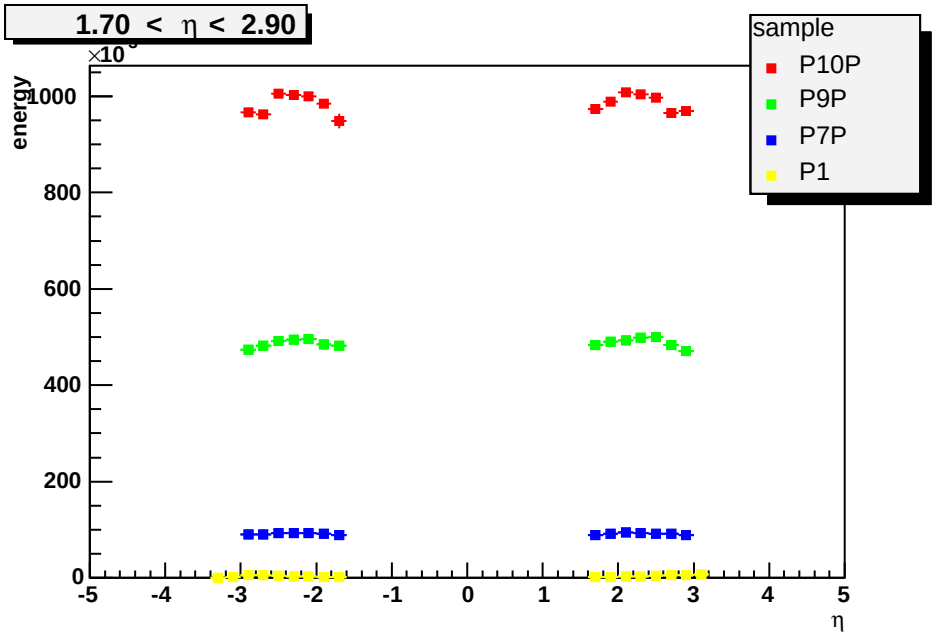
$$1.7 < \eta < 2.9$$

TileCal is problematic and FCAL calibration hits not available.


0.00 < η < 0.80
sample
P10P
P9P
P7P
P1
energy
η


0.80 < η < 1.50
sample
P10P
P9P
P7P
P1
energy
η


0.00 < η < 5.00
sample
P10P
P9P
P7P
P1
energy
η


1.70 < η < 2.90
sample
P10P
P9P
P7P
P1
energy
η

Moments and other quantities on cluster level

- Some moments were implemented into athena. The following list contains moments and cluster information important for our investigation
  - SECOND_R -second radial moment (shower effective radius)
  - SECOND_LAMBDA -second longitudinal moment (shower effective length)
  - DELTA_ALPHA - full angle between IP axis and shower axis
  - cl_nc - number of cells in cluster
  - CENTER_LAMBDA

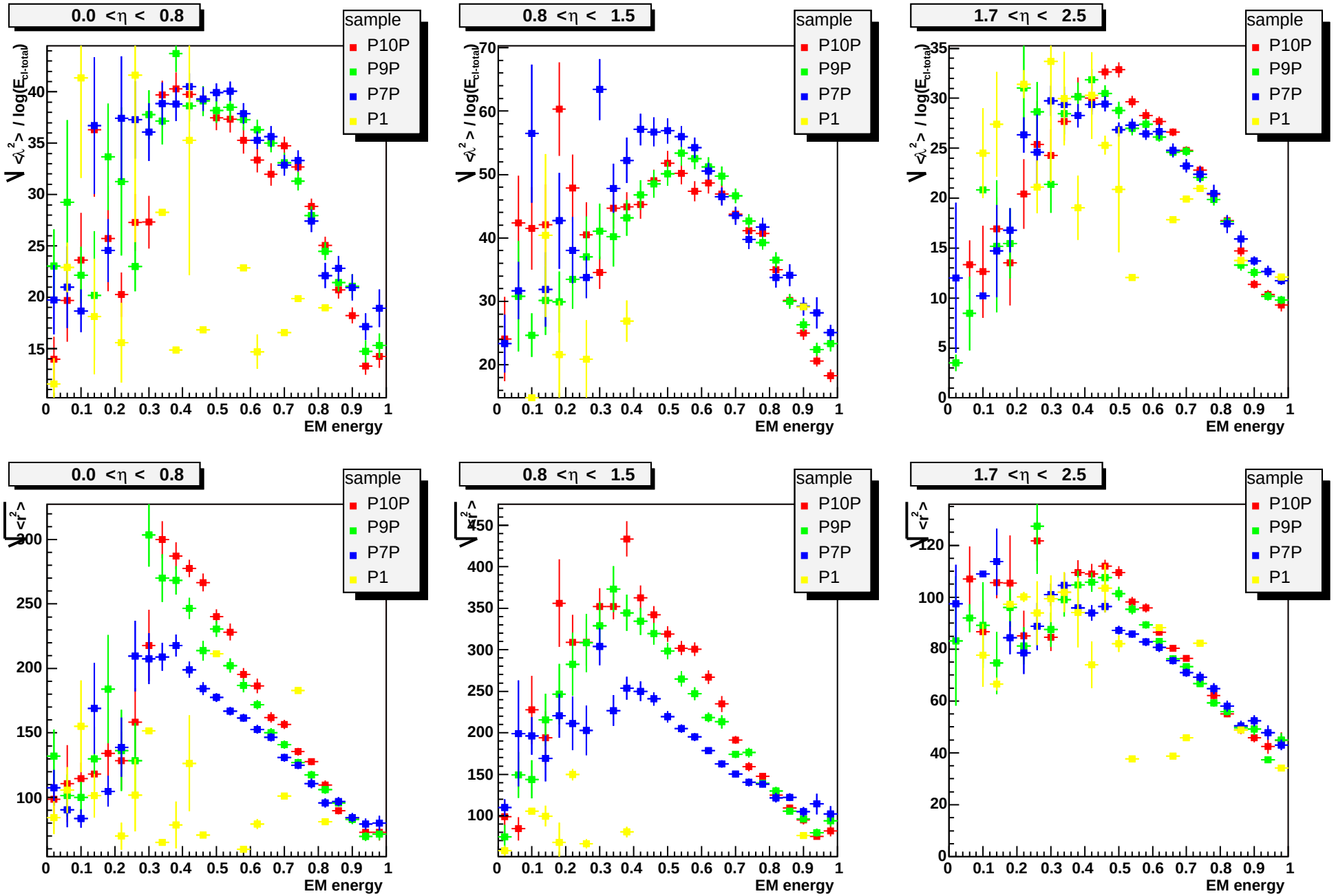
Second moments definition:

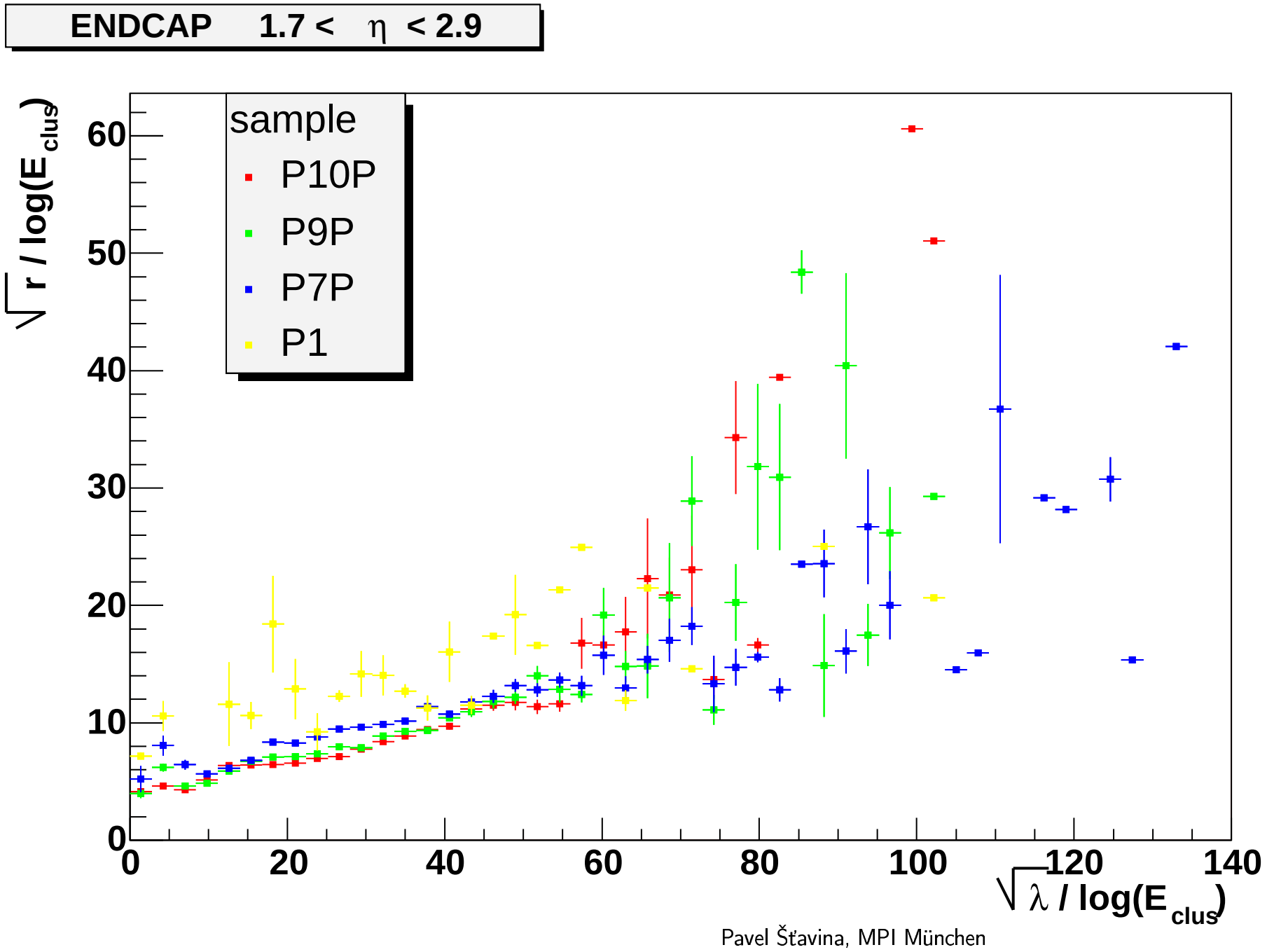
$$\lambda = \frac{\sum_{i=1}^{n} \lambda_i^2 \cdot E_i}{\sum_{i=1}^{nl} E_i}$$

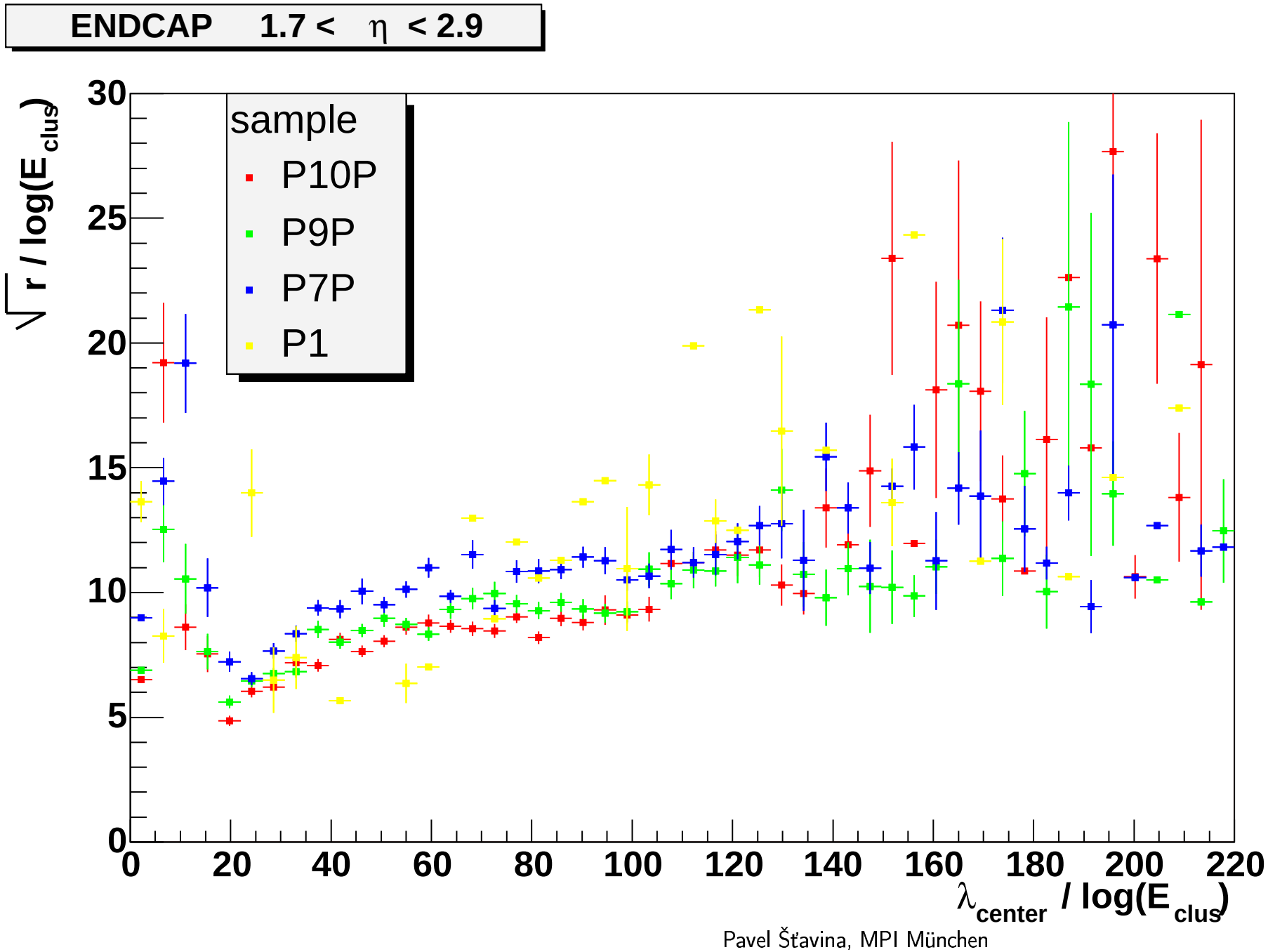
$$r = \frac{\sum_{i=1}^{n} r_i^2 \cdot E_i}{\sum_{i=1}^{n} E_i}$$

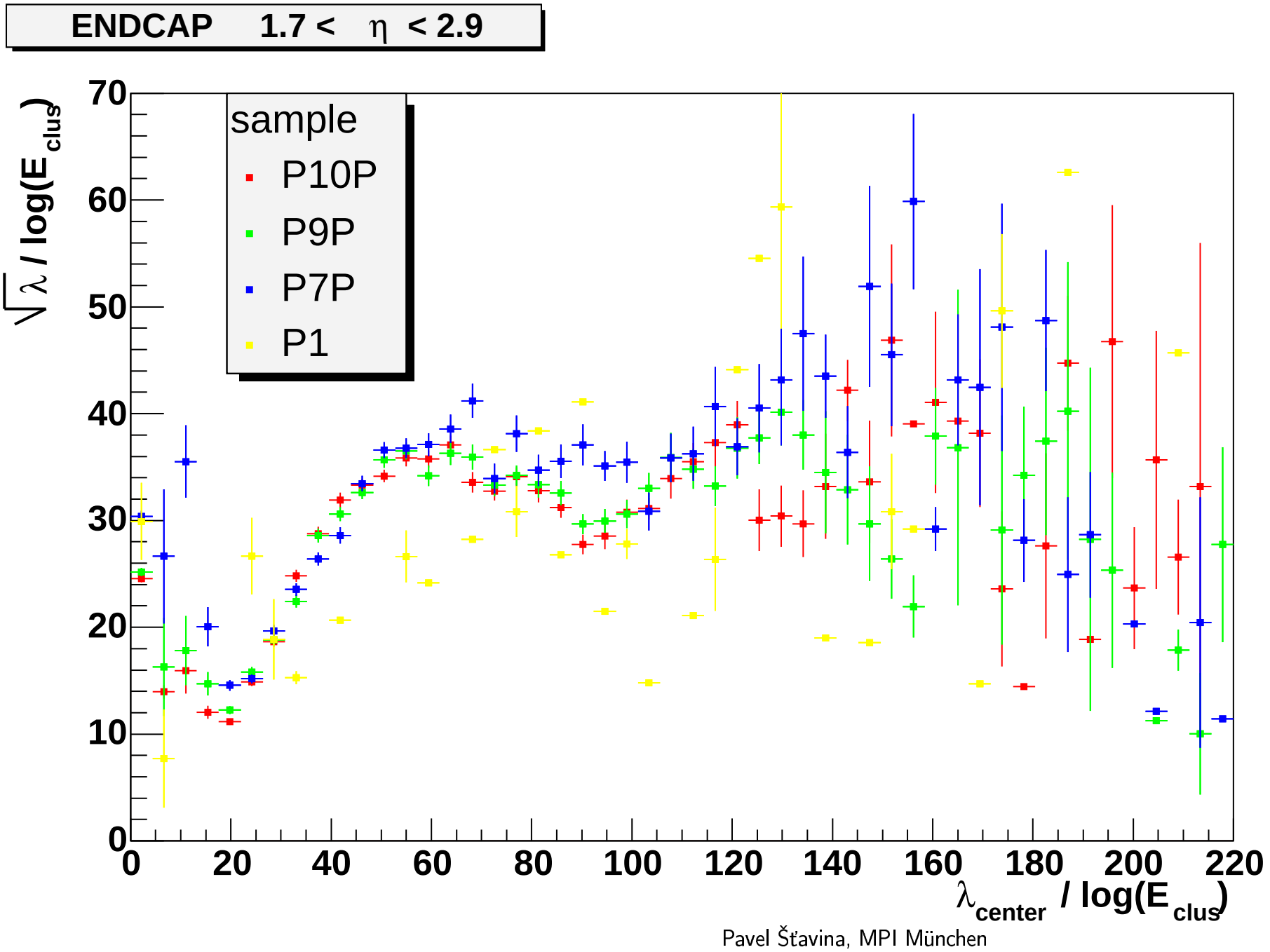
where

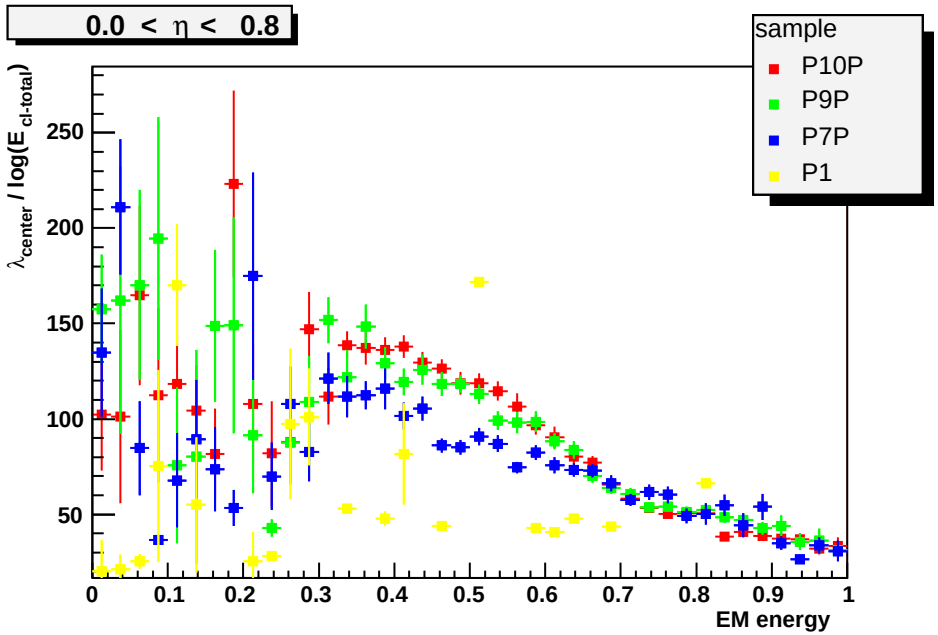
- r_i - radial distance of i-th cell from shower axis
- λ - longitudinal distance of i-th cell from shower center
- E_i - energy deposited at i-th cell
- n - number of cells in cluster

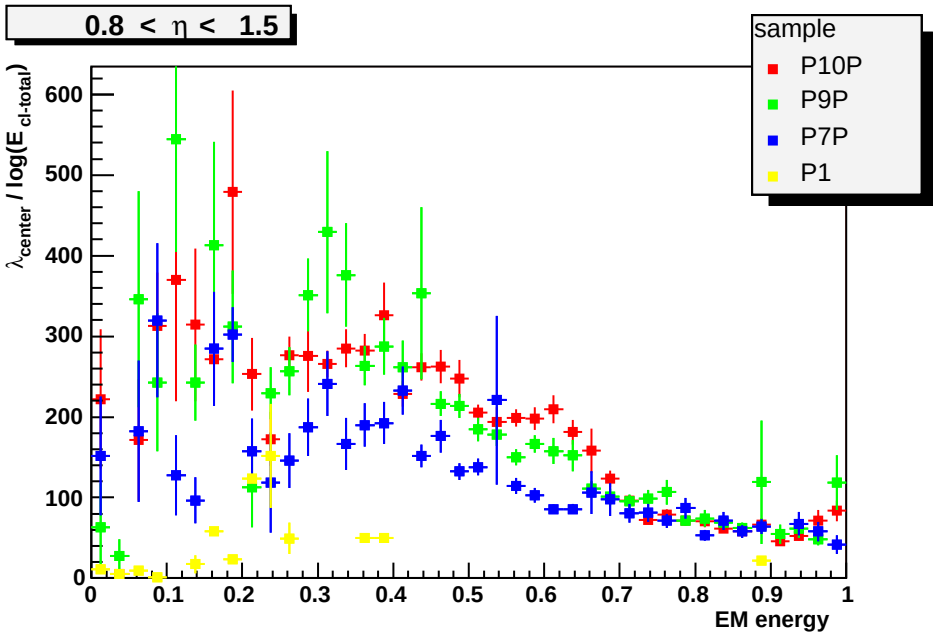

0.0 <η < 0.8
0.8 <η < 1.5
1.7 <η < 2.5
sample
P10P
P9P
P7P
P1
EM energy

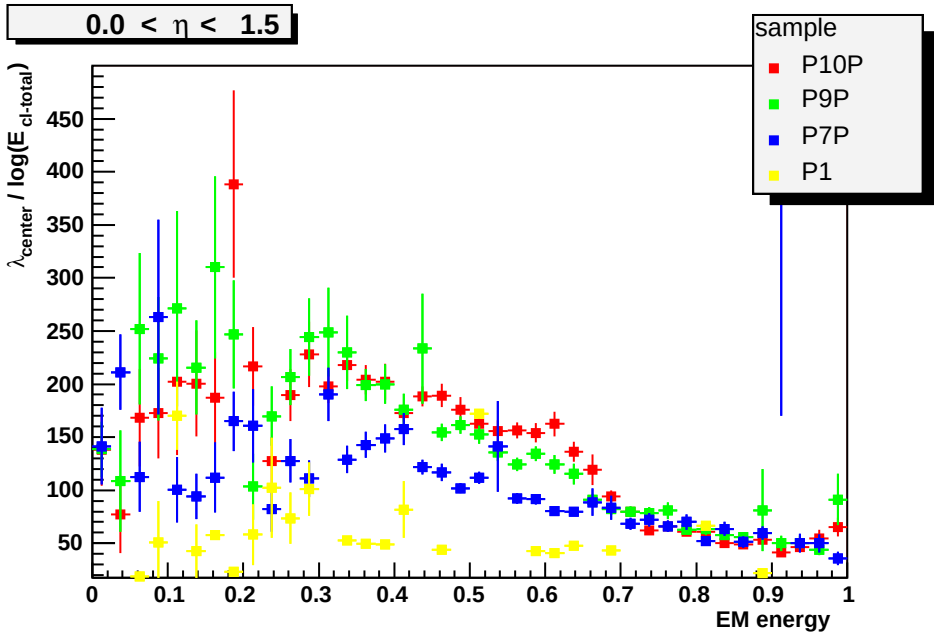

ENDCAP 1.7 < η < 2.9
sample
P10P
P9P
P7P
P1
√ r / log(E clus)
√ λ / log(E clus)
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140

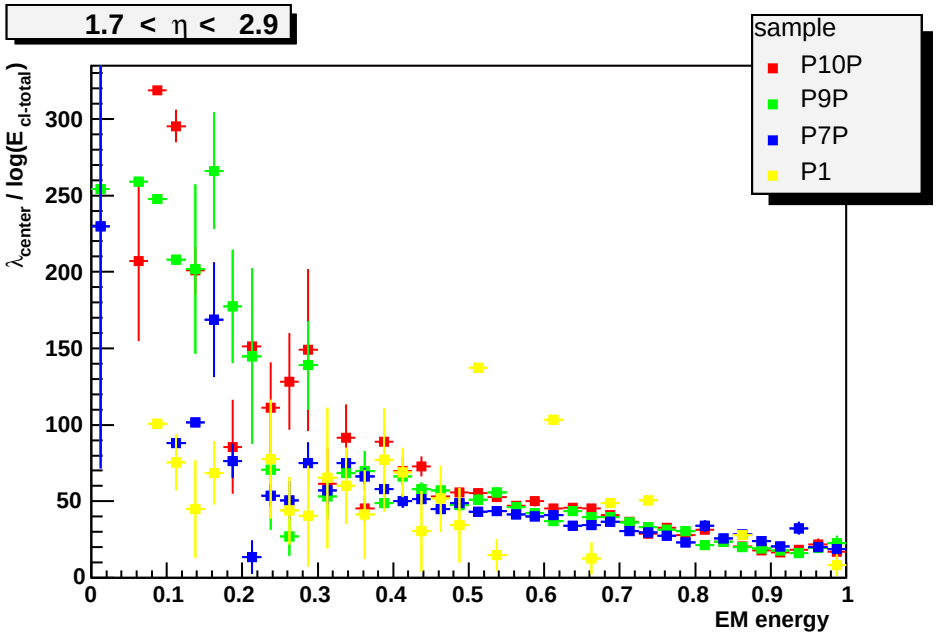

ENDCAP 1.7 < η < 2.9
sample
P10P
P9P
P7P
P1
√r / log(E_clus)
λ_center / log(E_clus)
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140
160
180
200
220

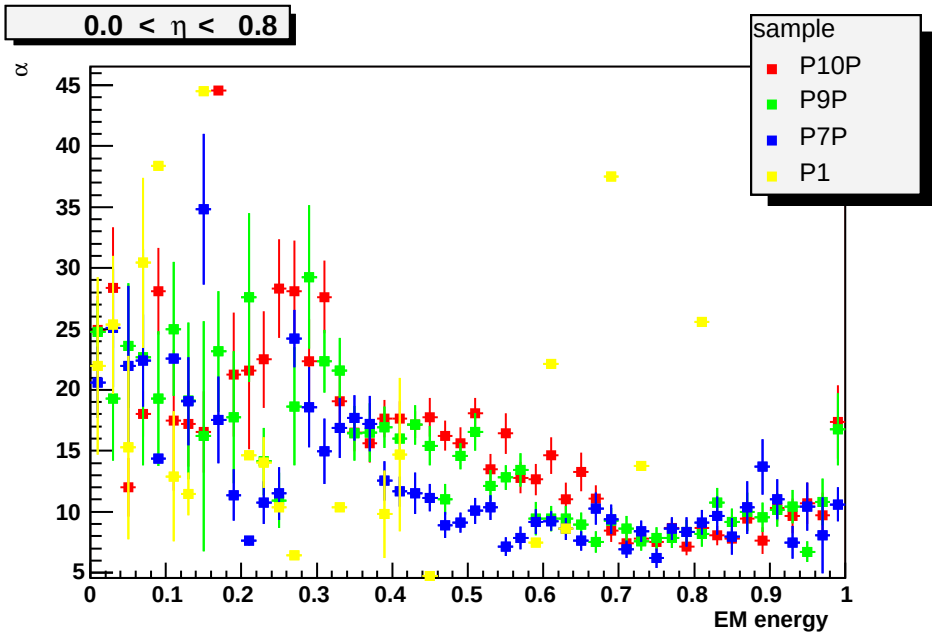

ENDCAP 1.7 < η < 2.9
sample
P10P
P9P
P7P
P1
√λ / log(E_clus)
λ_center / log(E_clus)
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120
140
160
180
200
220

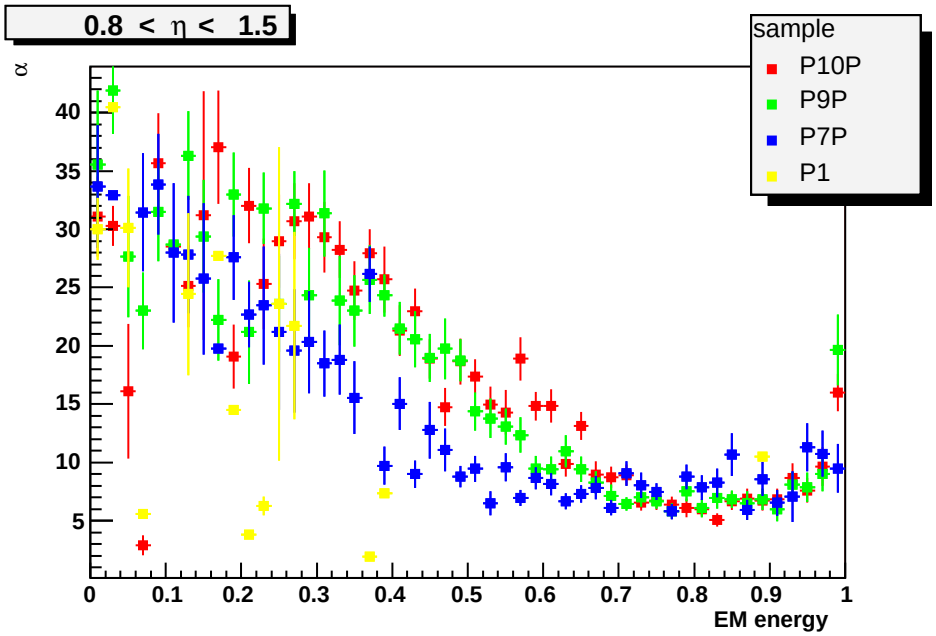

0.0 < η < 0.8
sample
P10P
P9P
P7P
P1
λcenter / log(Ecl-total)
EM energy

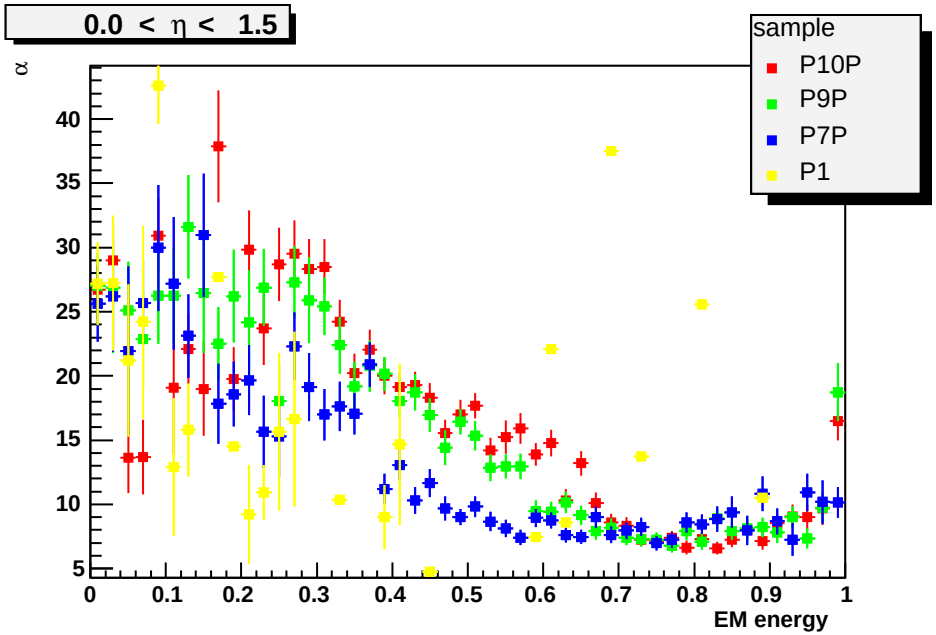

0.8 < η < 1.5
sample
P10P
P9P
P7P
P1
λcenter / log(Ecl-total)
EM energy

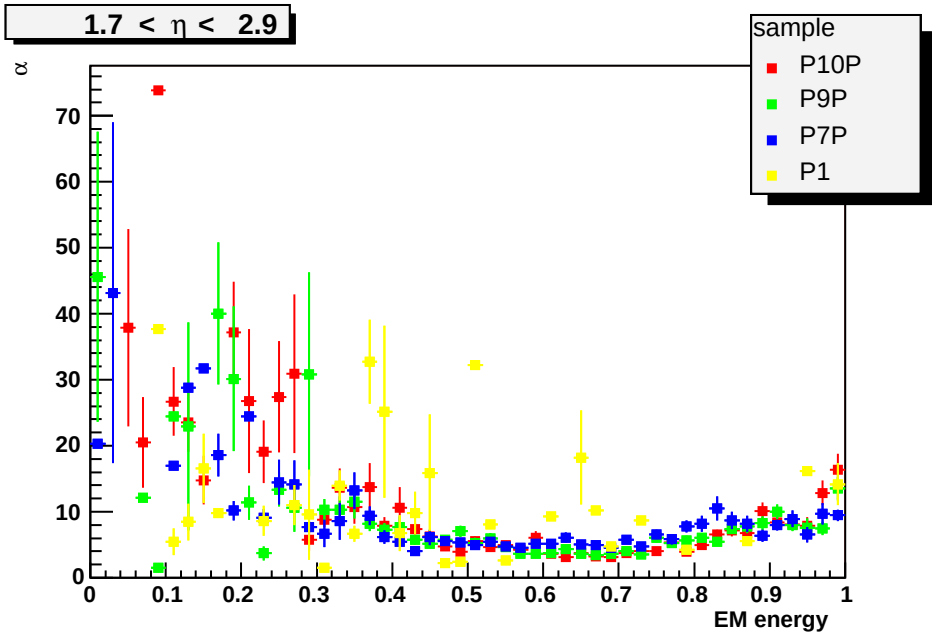

0.0 < η < 1.5
sample
P10P
P9P
P7P
P1
λcenter / log(Ecl-total)
EM energy

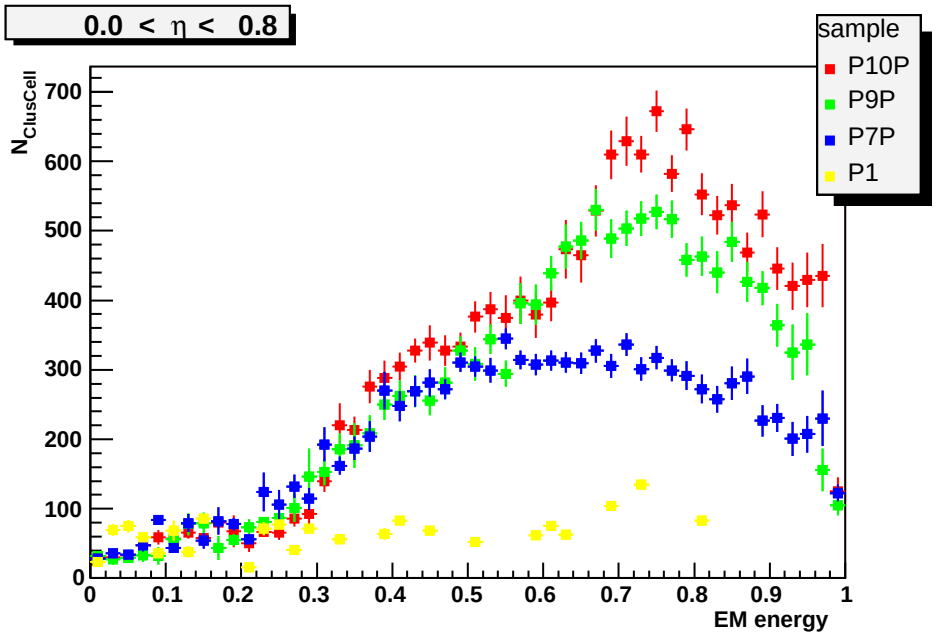

1.7 < η < 2.9
sample
P10P
P9P
P7P
P1
λcenter / log(Ecl-total)
EM energy

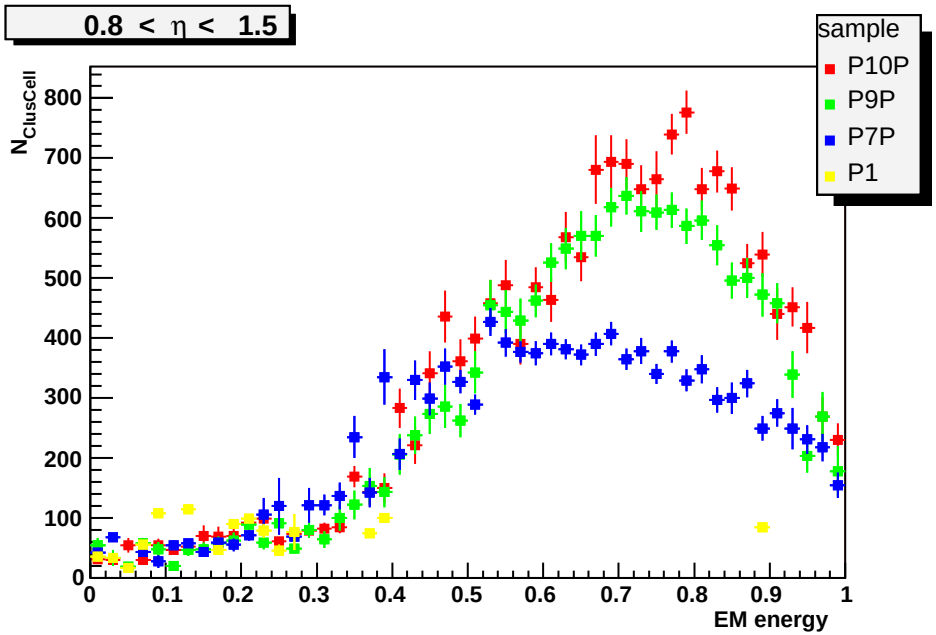

0.0 < η < 0.8
sample
P10P
P9P
P7P
P1
α
EM energy

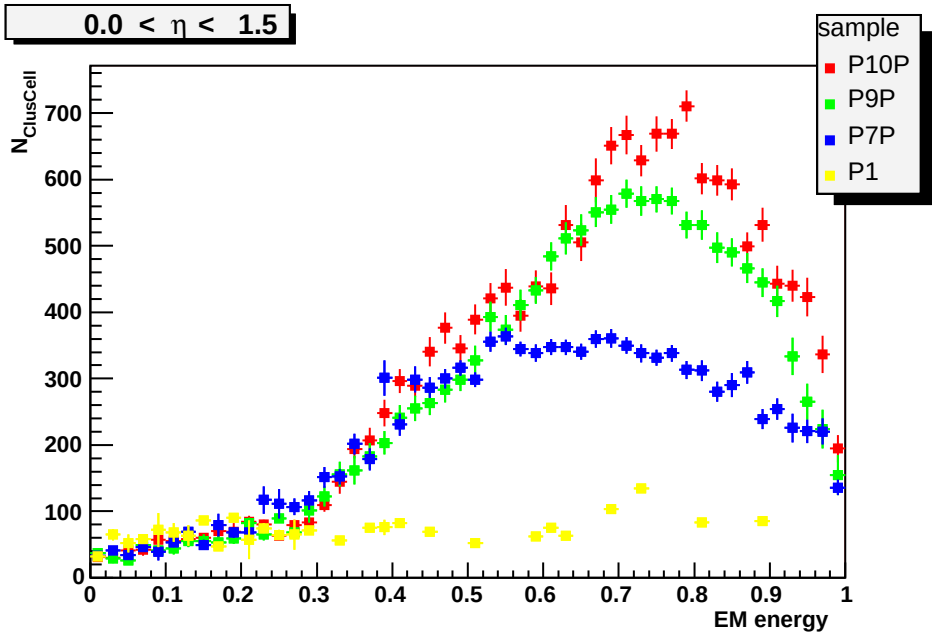

0.8 < η < 1.5
sample
P10P
P9P
P7P
P1
α
EM energy

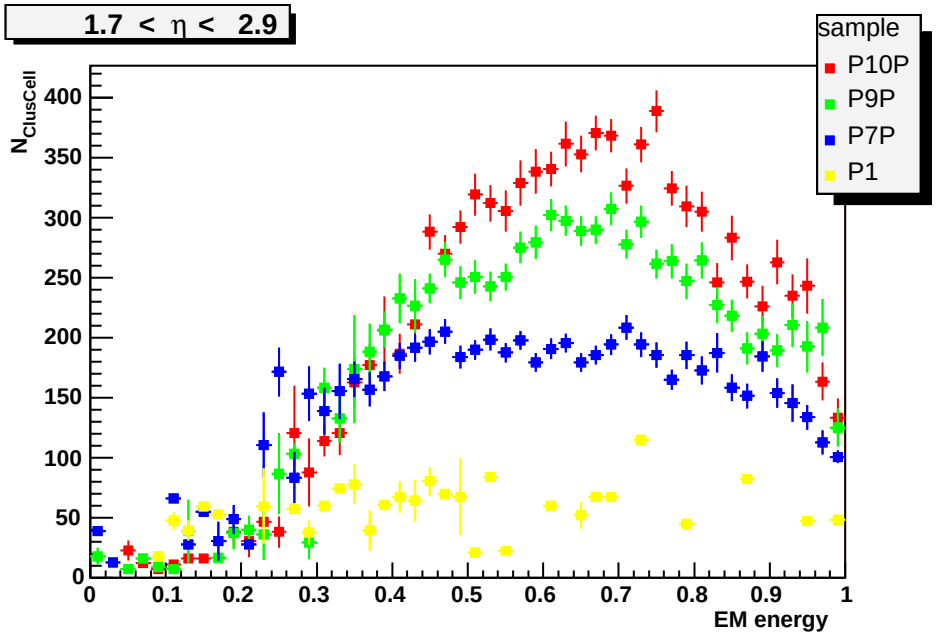

0.0 < η < 1.5
sample
P10P
P9P
P7P
P1
α
EM energy


1.7 < η < 2.9
sample
P10P
P9P
P7P
P1
α
EM energy


0.0 < η < 0.8
sample
P10P
P9P
P7P
P1
N_ClusCell
EM energy


0.8 < η < 1.5
sample
P10P
P9P
P7P
P1
N_ClusCell
EM energy


0.0 < η < 1.5
sample
P10P
P9P
P7P
P1
N_ClusCell
EM energy


1.7 < η < 2.9
sample
P10P
P9P
P7P
P1
N_ClusCell
EM energy

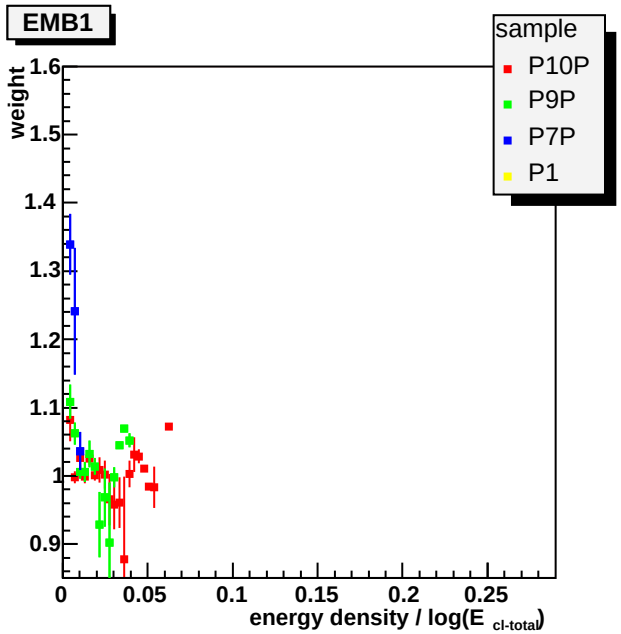
WEIGHTS

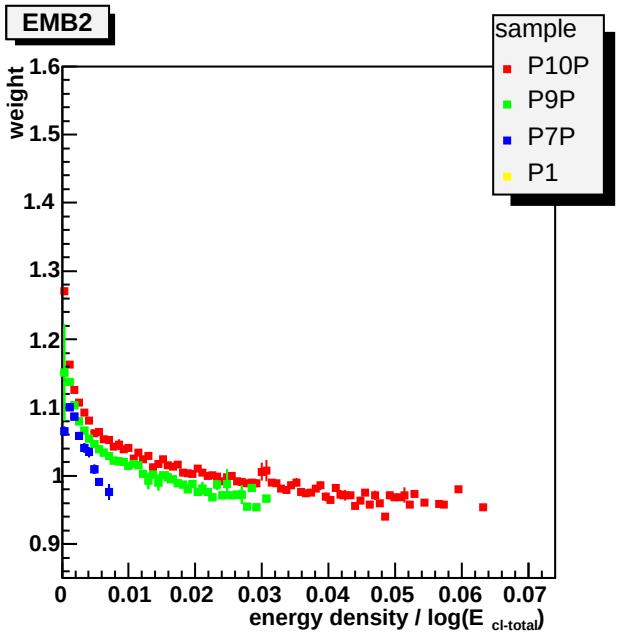
- Weighting coefficient:

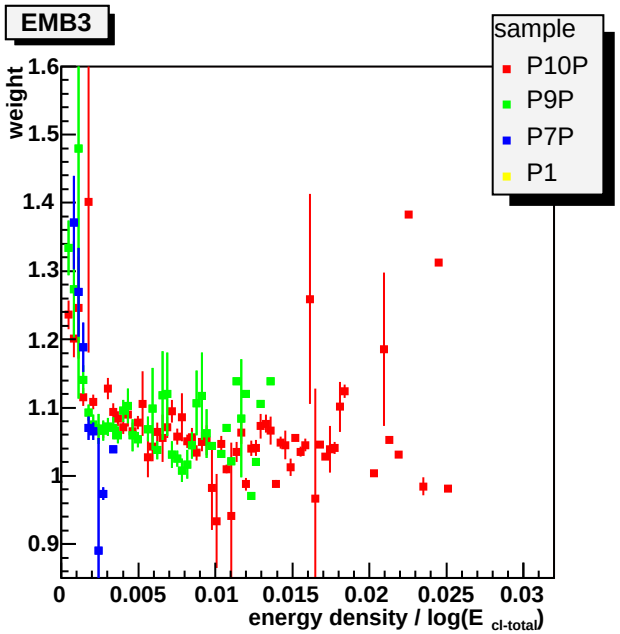
$$W_{cell} = \frac{E_{EM} + E_{NonEM} + E_{Invis} + E_{Esc}}{E_{reconstructed}}$$

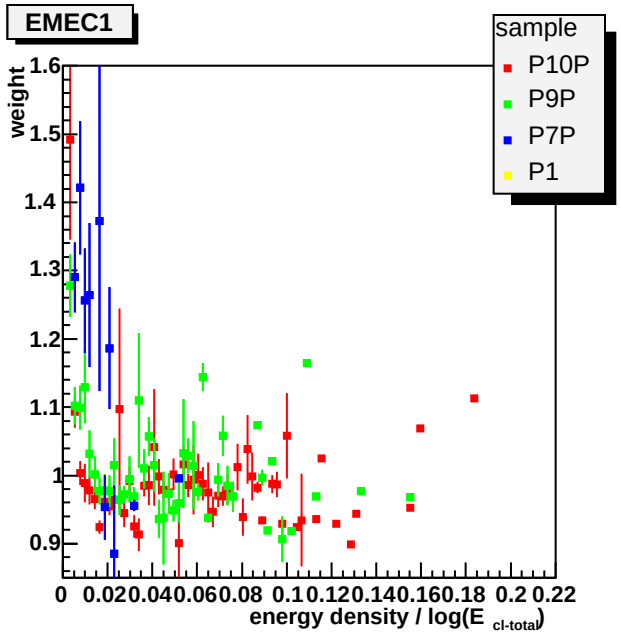
- Density:

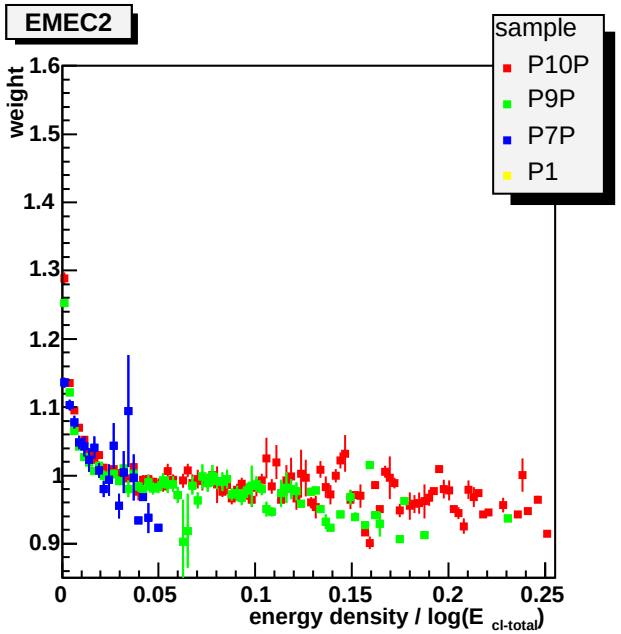
$$q_{cell} = \frac{E_{EM} + E_{NonEM} + E_{Invis} + E_{Esc}}{V_{cell}}$$

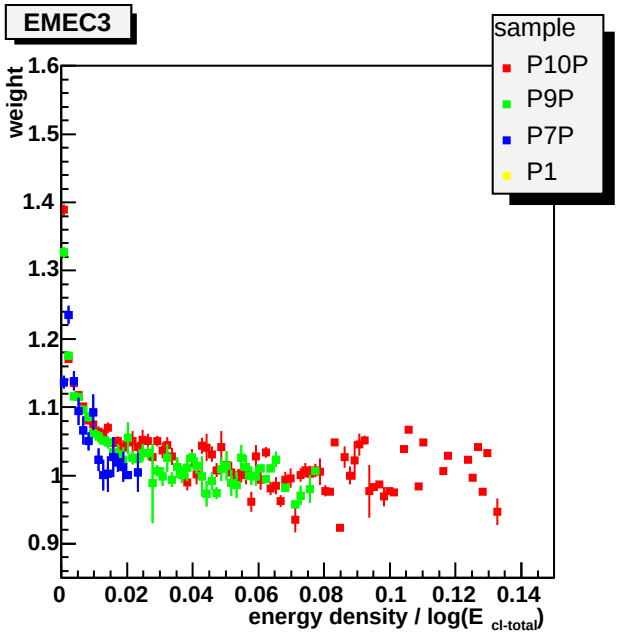

EMB1
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)

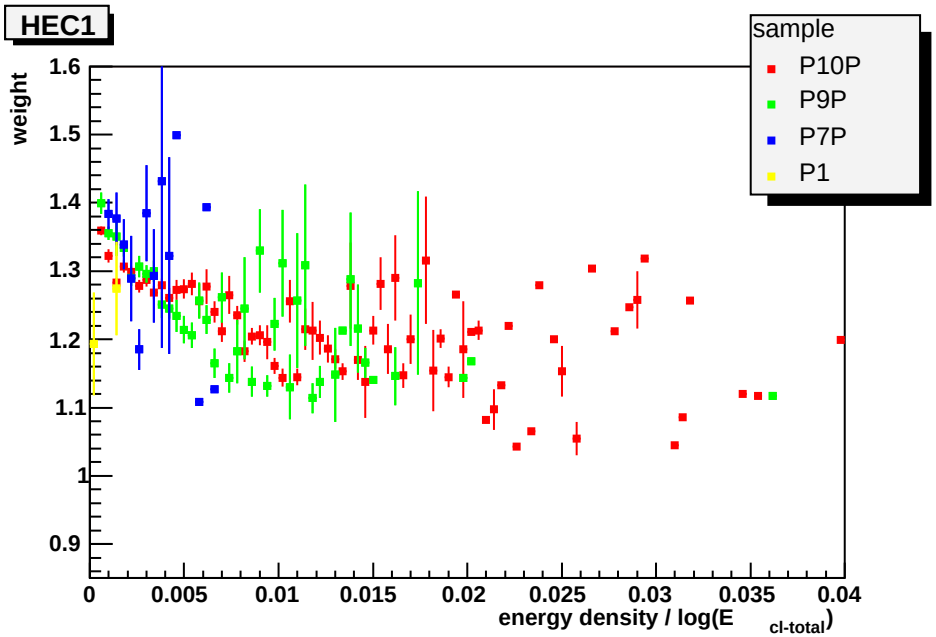

EMB2
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)

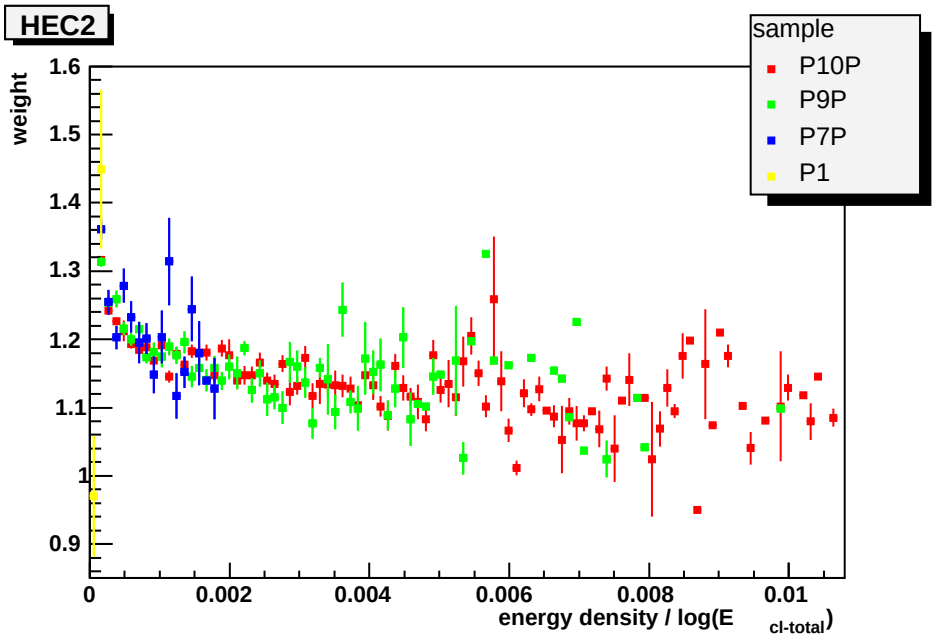

EMB3
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)

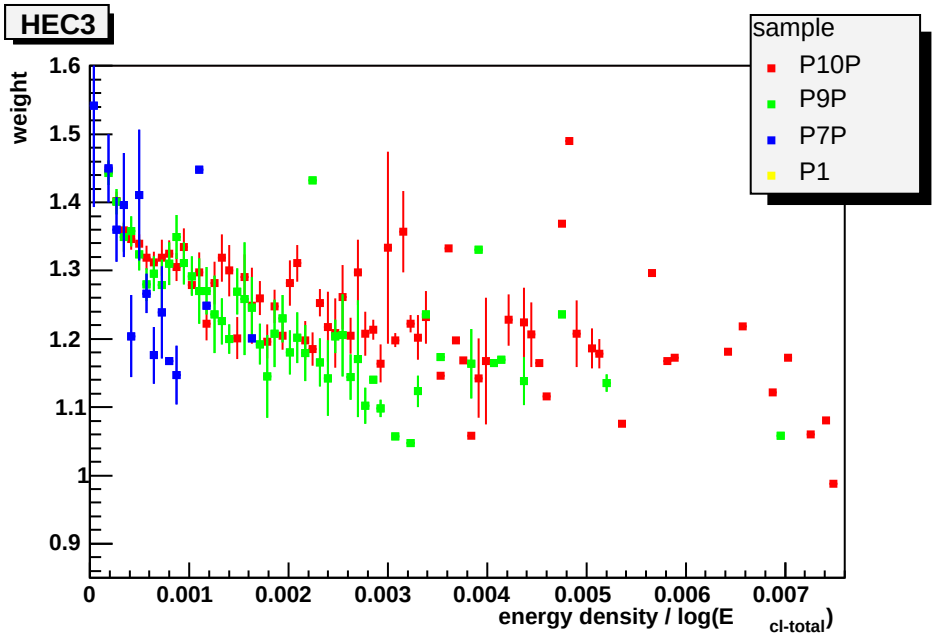

EMEC1
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)

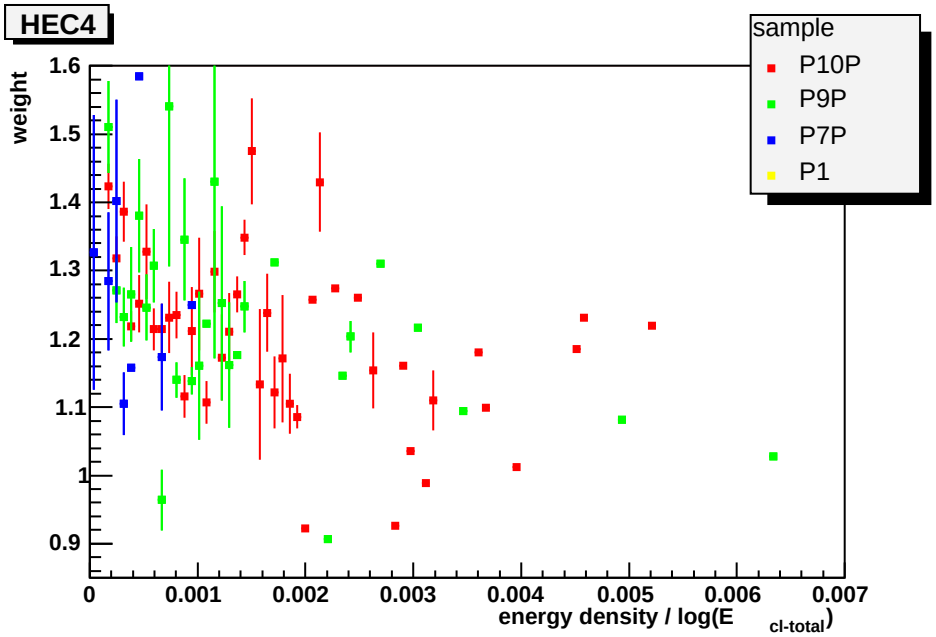

EMEC2
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)


EMEC3
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)

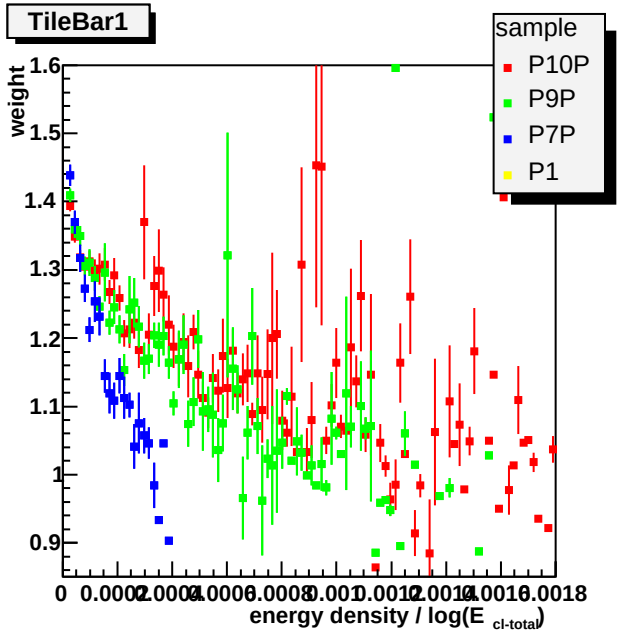

HEC1
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)

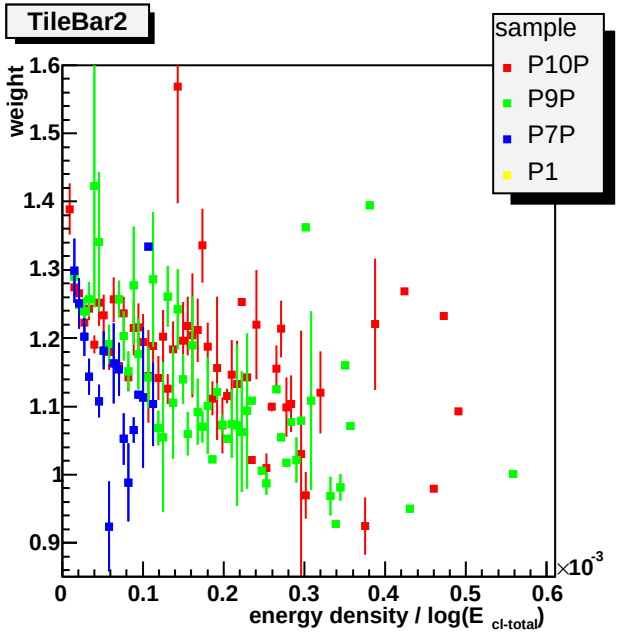

HEC2
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)

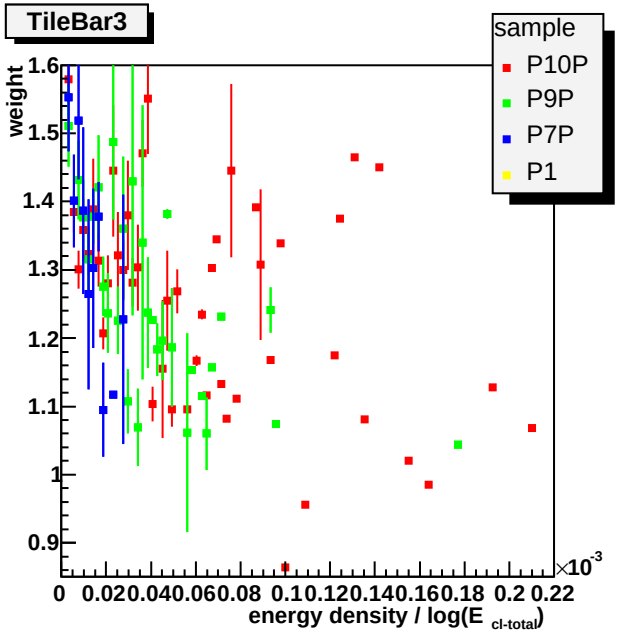

HEC3
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)

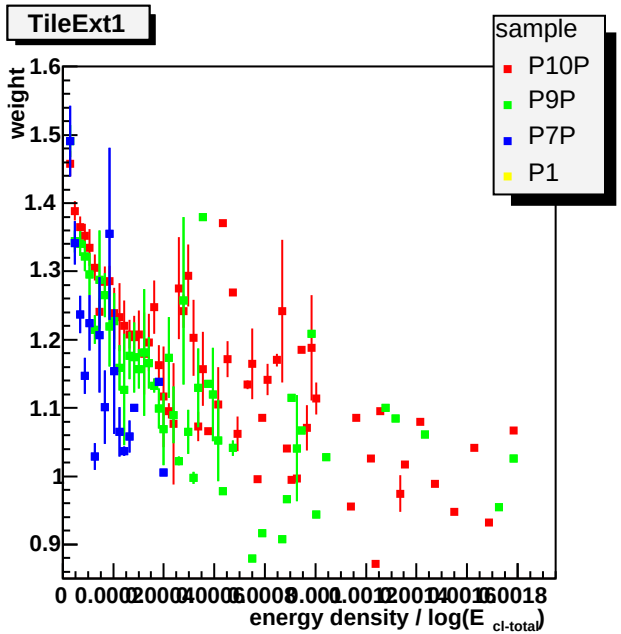

HEC4
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)

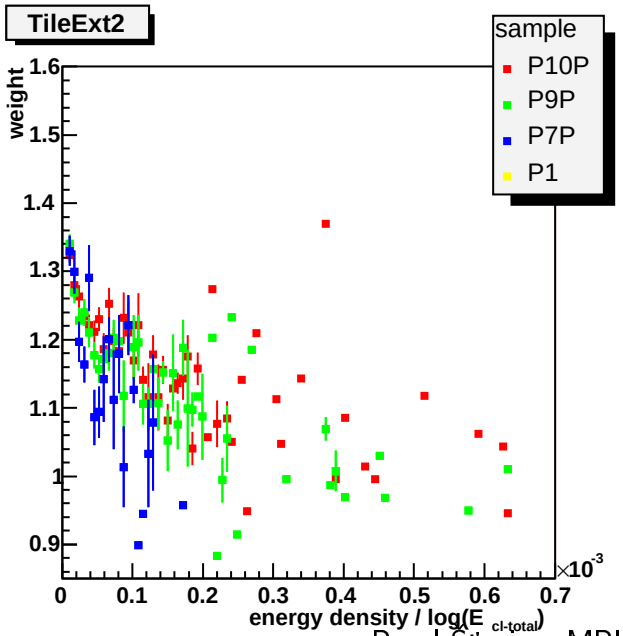
BAD DATA !

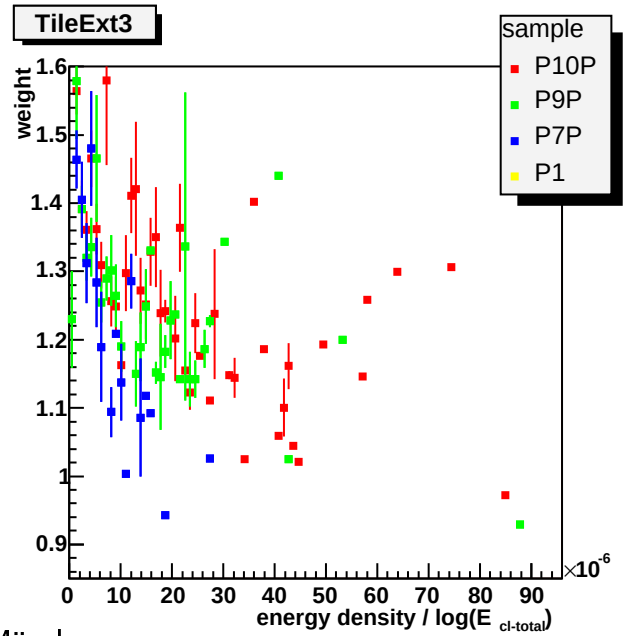

TileBar1
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)


TileBar2
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)


TileBar3
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)


TileExt1
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)

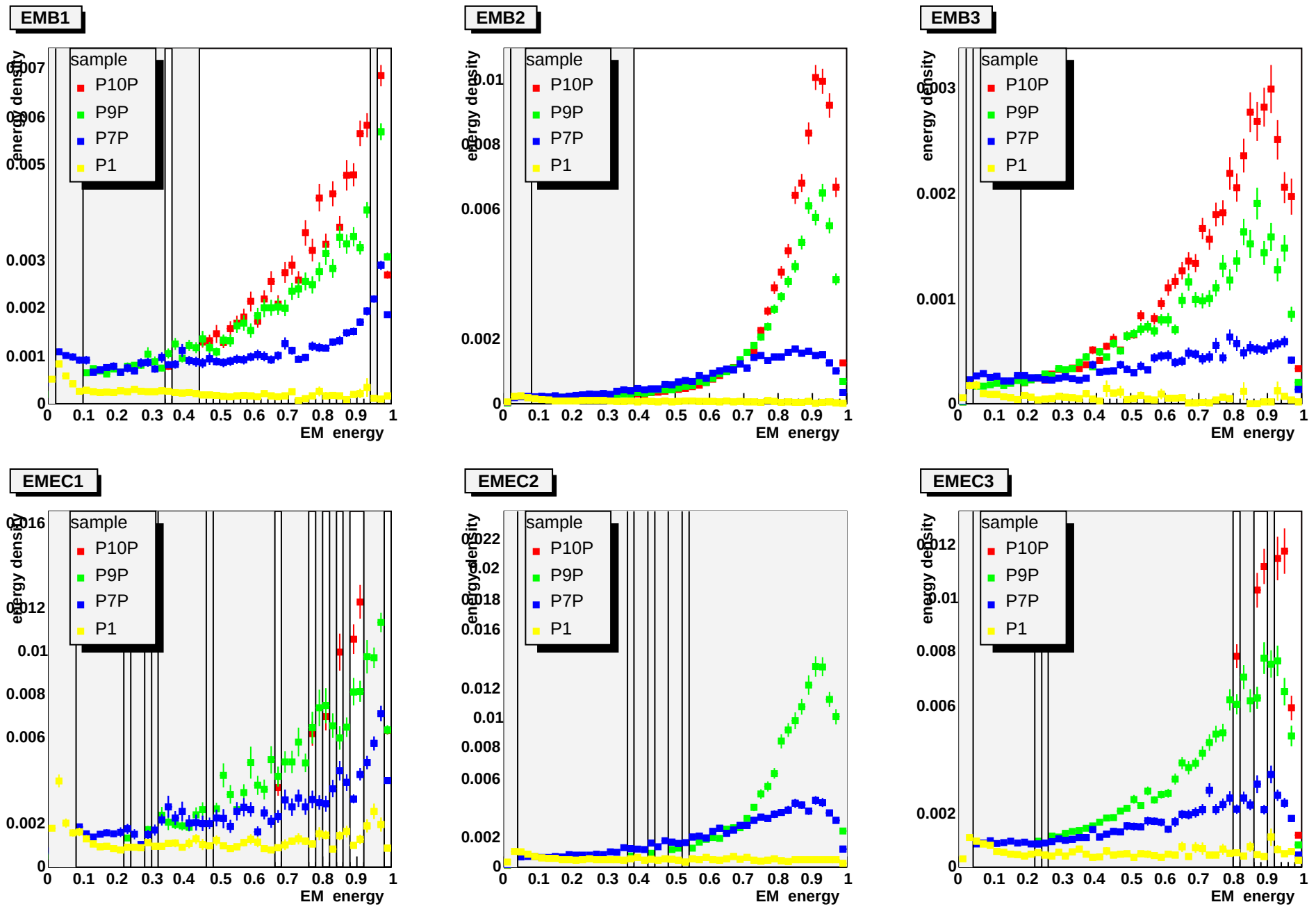

TileExt2
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)

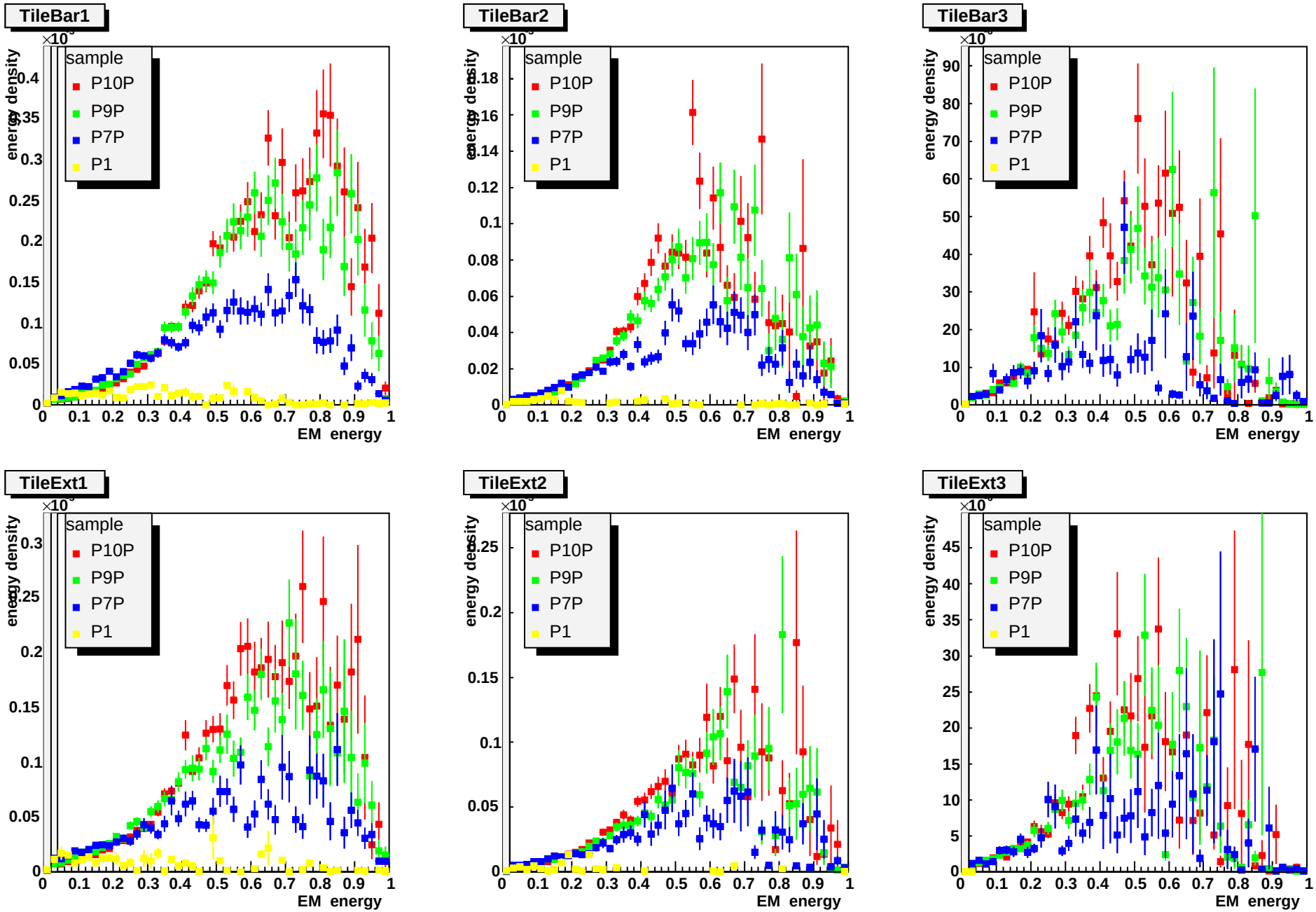

TileExt3
sample
P10P
P9P
P7P
P1
weight
energy density / log(E cl-total)

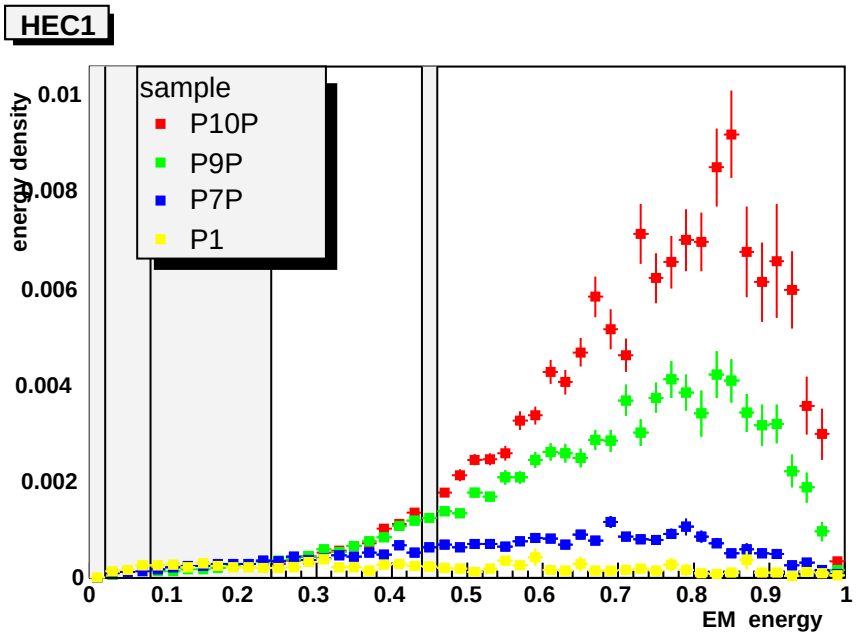
The energy density

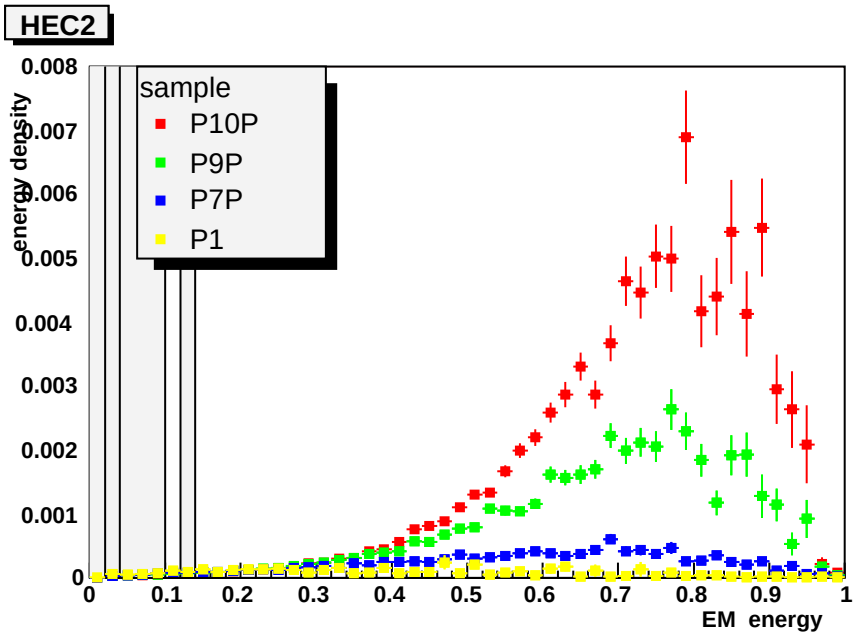
- The energy density defined above is the only additional information which we have at cell level. It is linked to the electromagnetic component of the deposited energy.

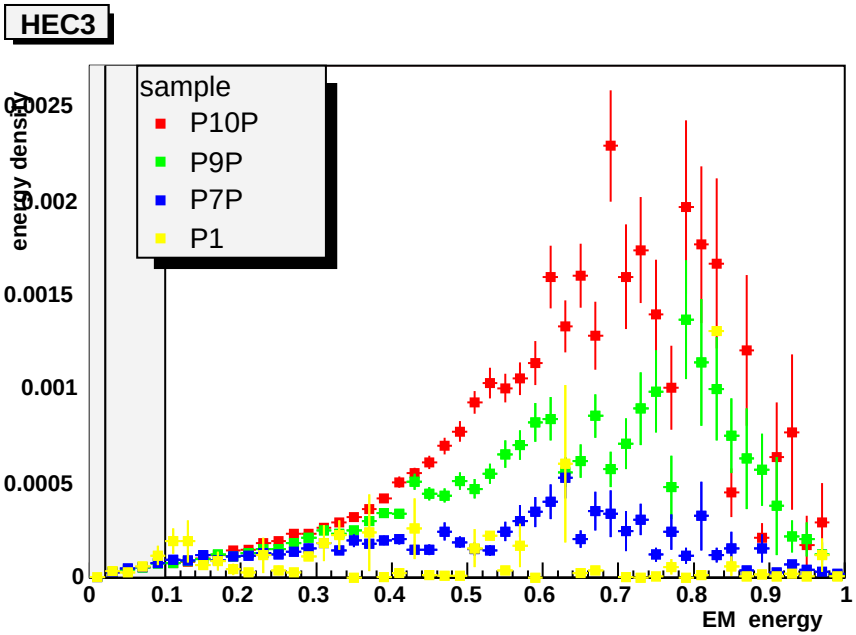
- The following plots show this relation

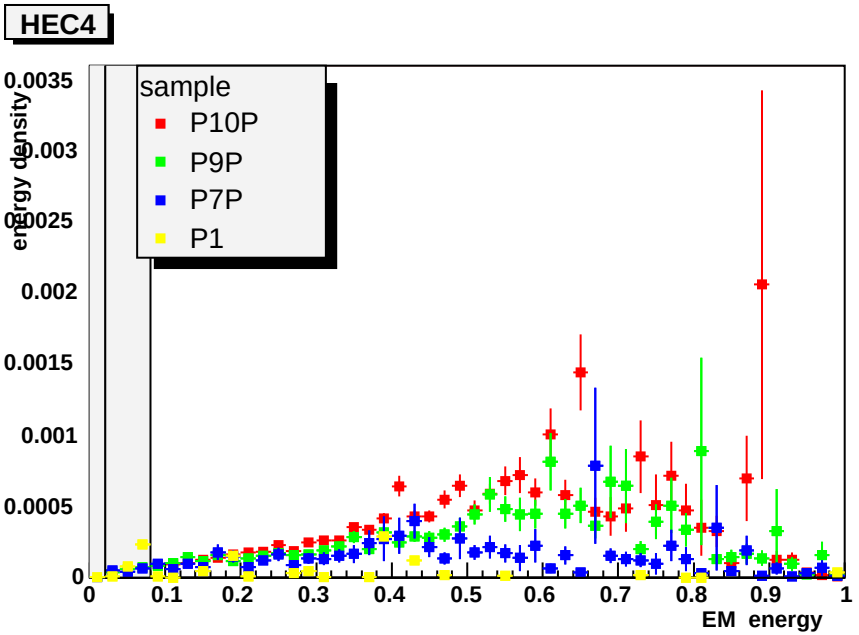

EMB1
EMB2
EMB3
EMEC1
EMEC2
EMEC3
sample
P10P
P9P
P7P
P1
energy density
EM energy


TileBar1
TileBar2
TileBar3
TileExt1
TileExt2
TileExt3
sample
P10P
P9P
P7P
P1
energy density
EM energy


HEC1
sample
P10P
P9P
P7P
P1
energy density
EM energy


HEC2
sample
P10P
P9P
P7P
P1
energy density
EM energy


HEC3
sample
P10P
P9P
P7P
P1
energy density
EM energy


HEC4
sample
P10P
P9P
P7P
P1
energy density
EM energy

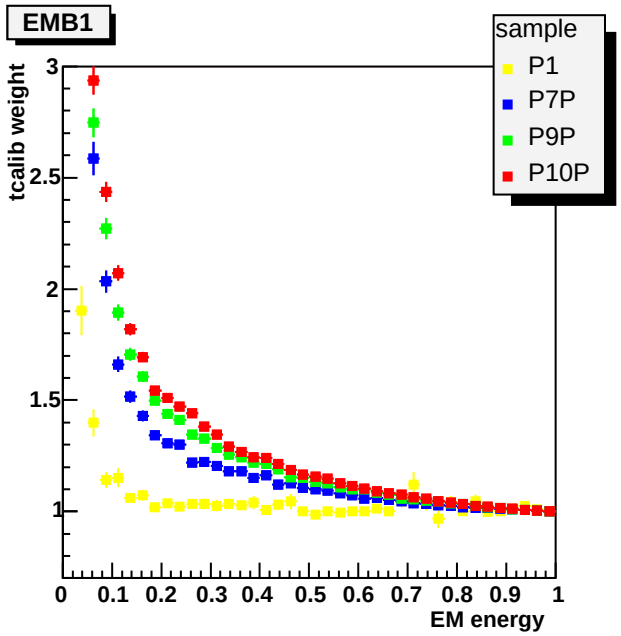
Theoretical weights

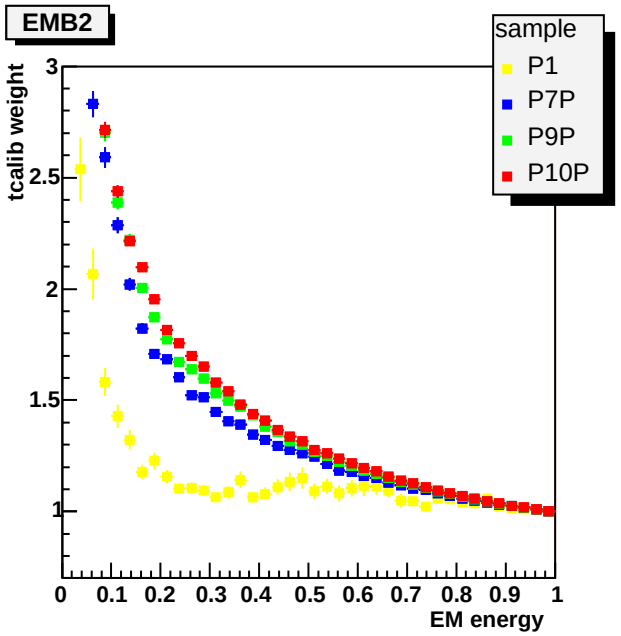
- We can define other weighting coefficient as follows:

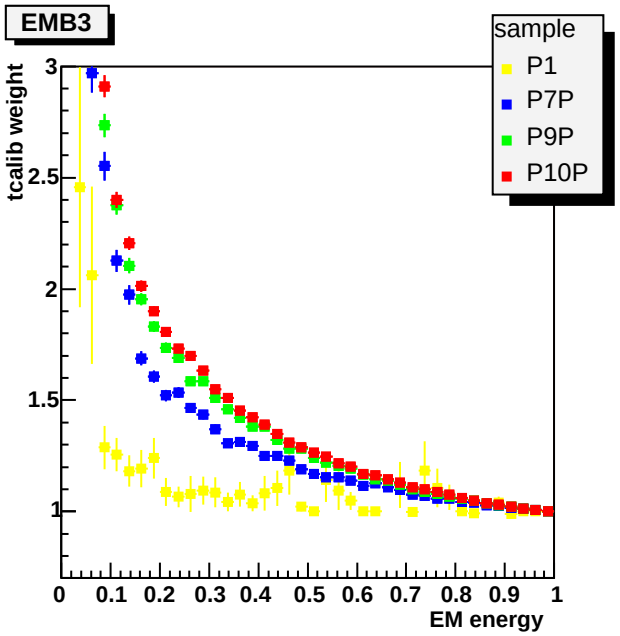
$$W_{cell} = \frac{E_{EM} + E_{NonEM} + E_{Invis} + E_{Esc}}{E_{E_{EM}+E_{NonEM}}}$$

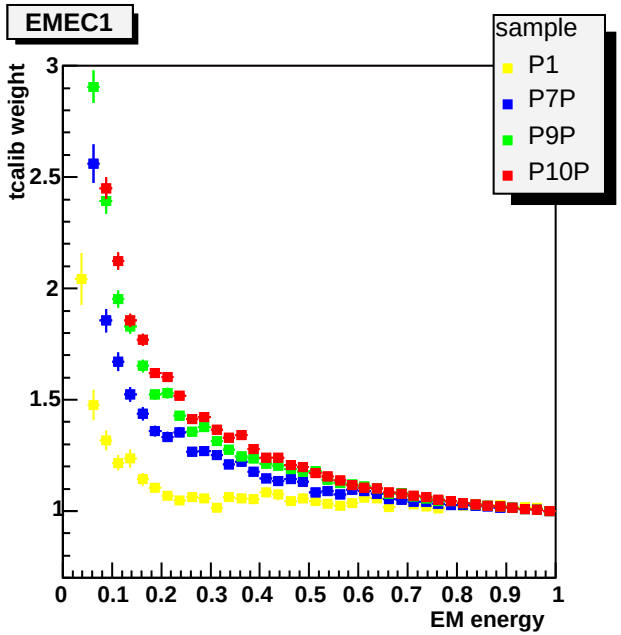
- These are the "TRUE" weights based on electromagnetic component of the deposited energy as it comes from MC. It is not influenced by noise or anything else. It seems to be energy independent. The only problem of this quantity is that in the following plots it is a function of the mentioned

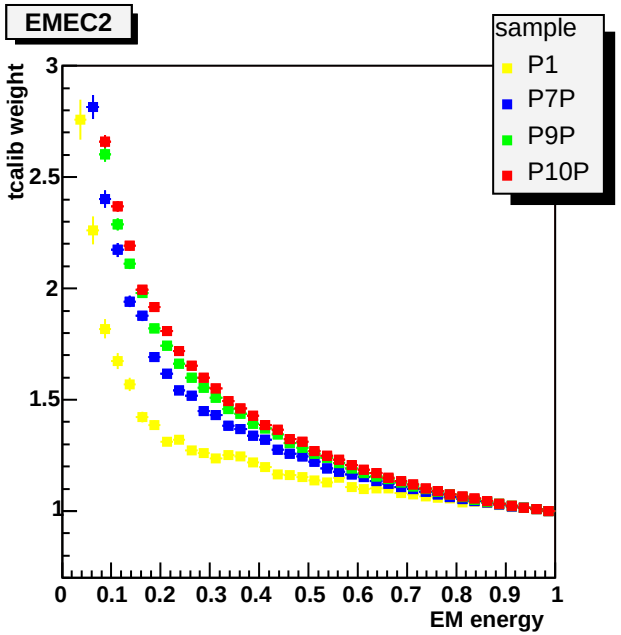
electromagnetic component of the deposited energy which is not directly measured quantity. Nevertheless it is not bad to know the behaviour of this quantity once it is available in MC data.

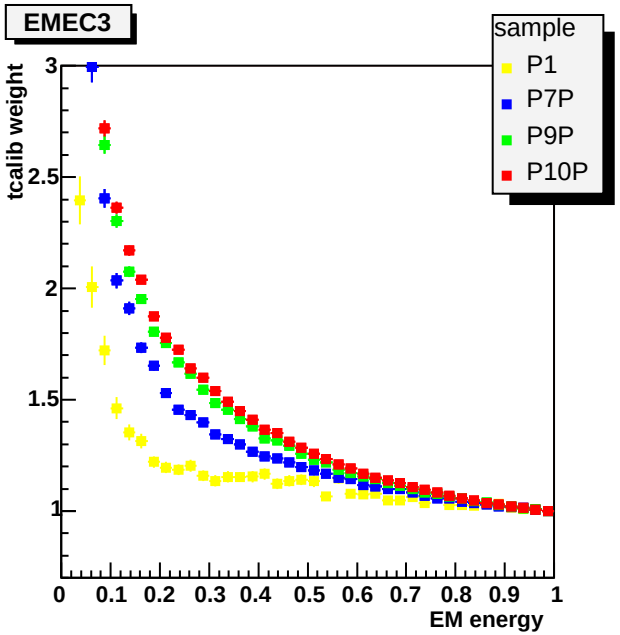

EMB1
sample
P1
P7P
P9P
P10P
tcalib weight
EM energy

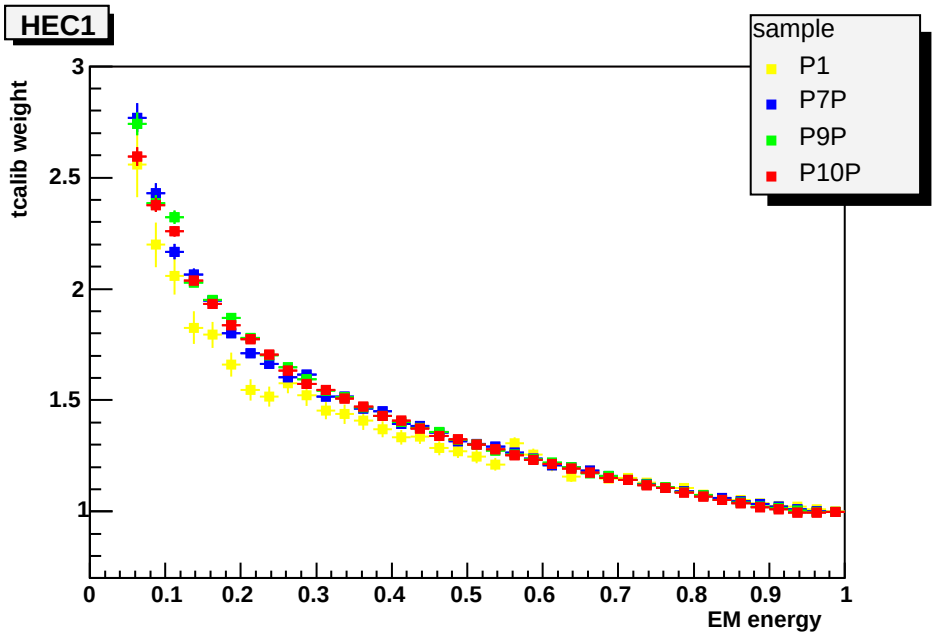

EMB2
sample
P1
P7P
P9P
P10P
tcalib weight
EM energy

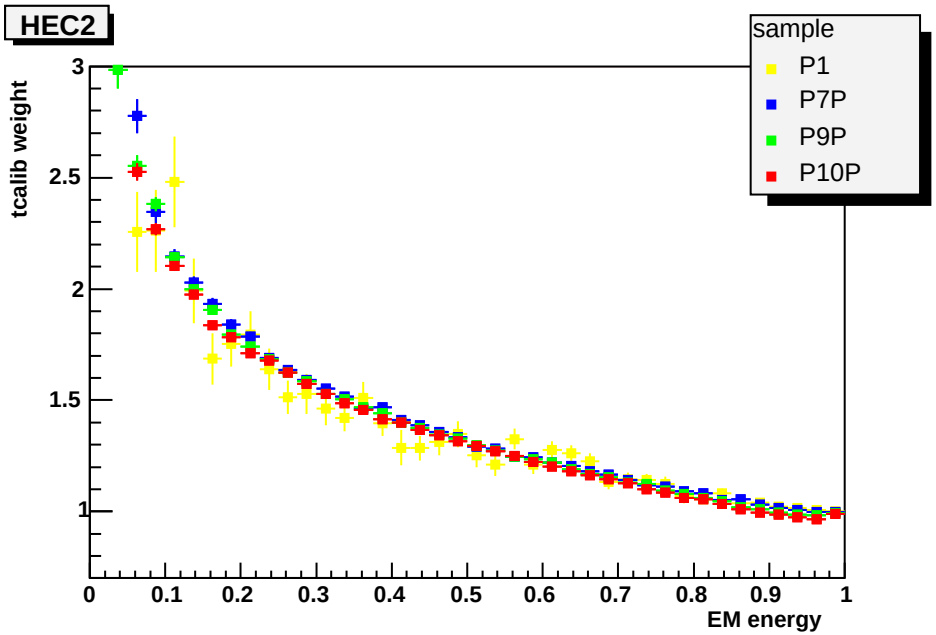

EMB3
sample
P1
P7P
P9P
P10P
tcalib weight
EM energy

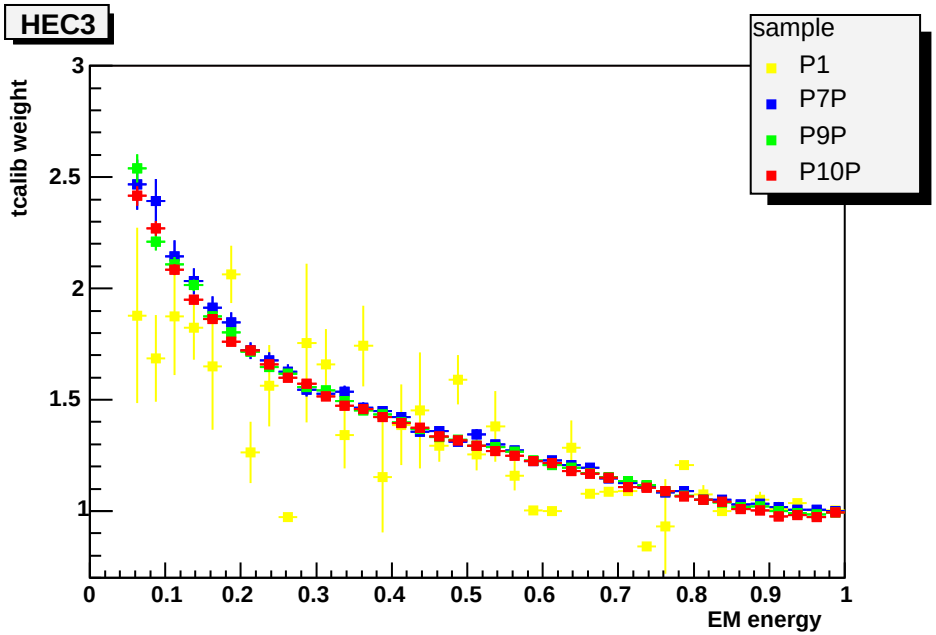

EMEC1
sample
P1
P7P
P9P
P10P
tcalib weight
EM energy

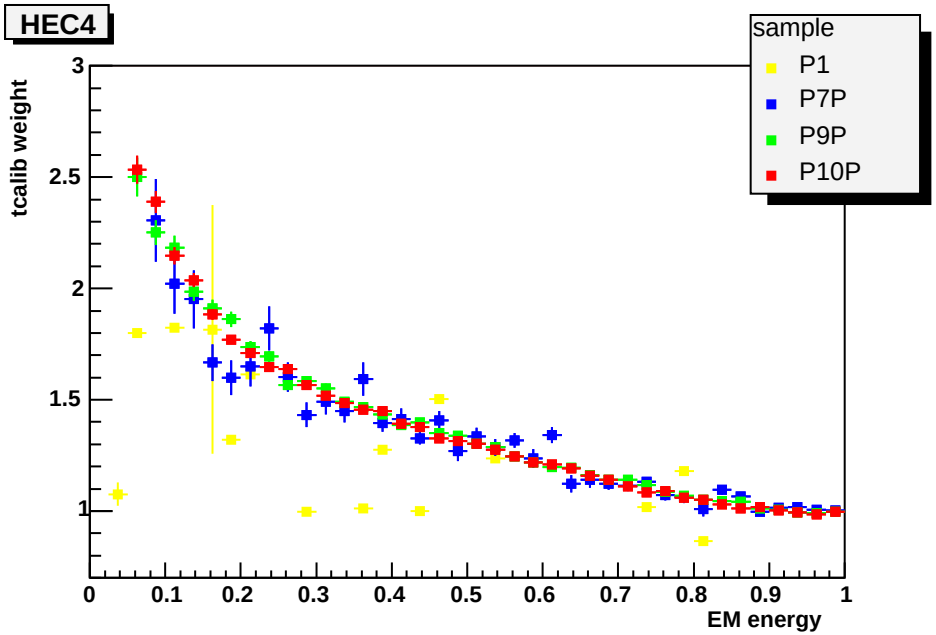

EMEC2
sample
P1
P7P
P9P
P10P
tcalib weight
EM energy


EMEC3
sample
P1
P7P
P9P
P10P
tcalib weight
EM energy

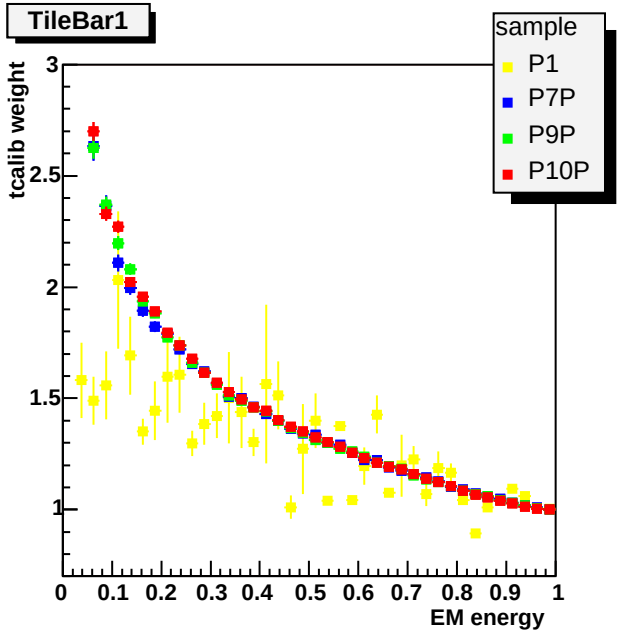

HEC1
sample
P1
P7P
P9P
P10P
tcalib weight
EM energy

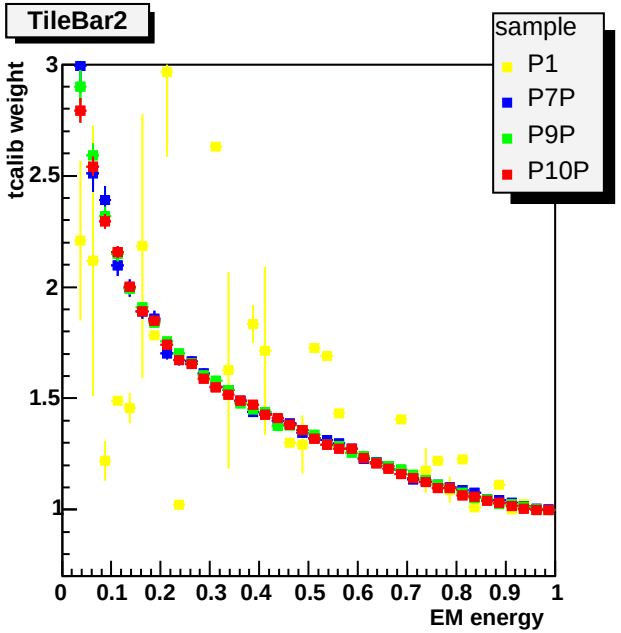

HEC2
sample
P1
P7P
P9P
P10P
tcalib weight
EM energy

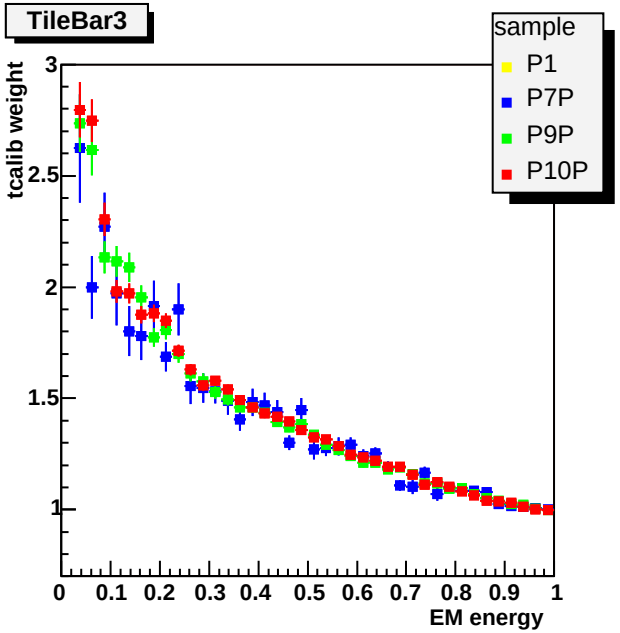

HEC3
sample
P1
P7P
P9P
P10P
tcalib weight
EM energy

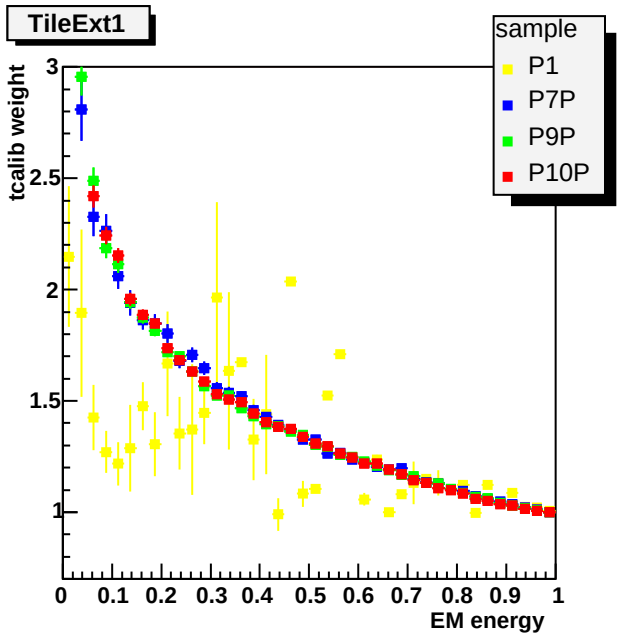

HEC4
sample
P1
P7P
P9P
P10P
tcalib weight
EM energy

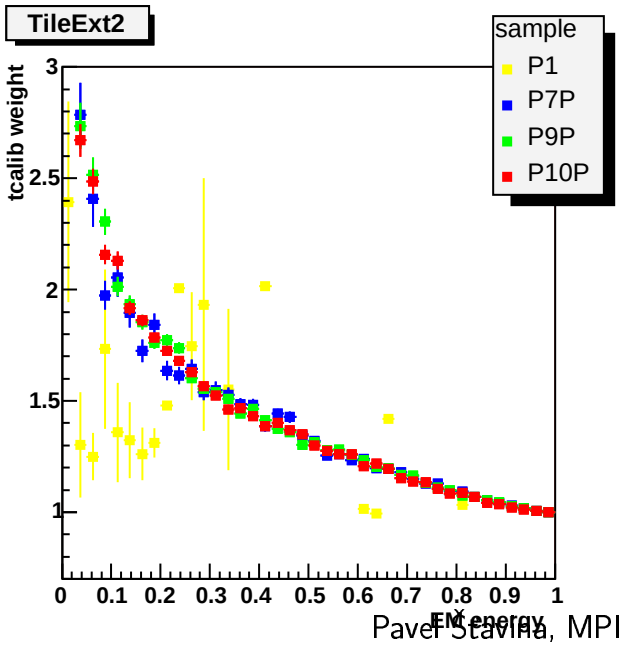
Only part of the energy present !

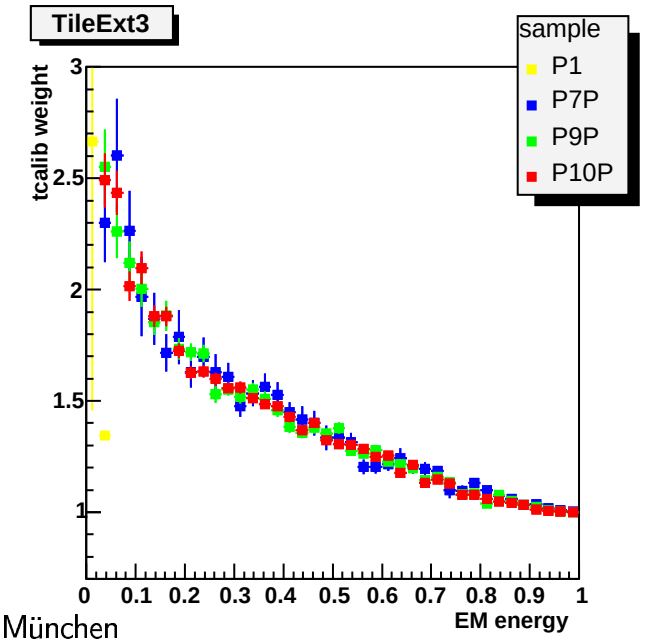






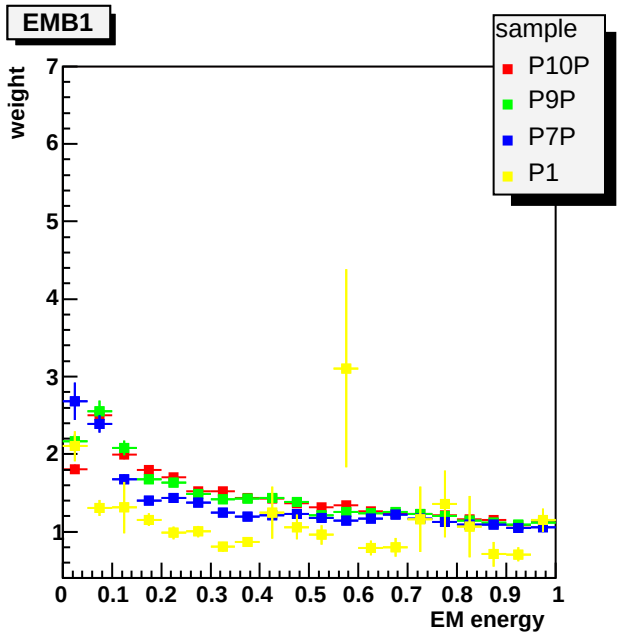


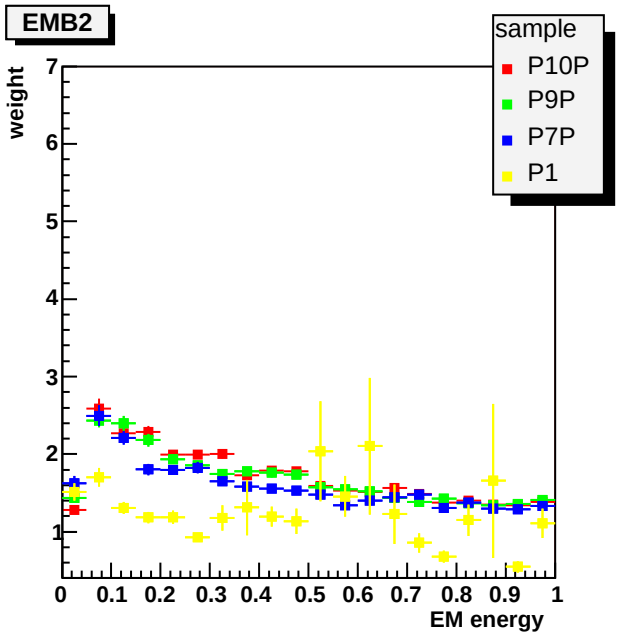


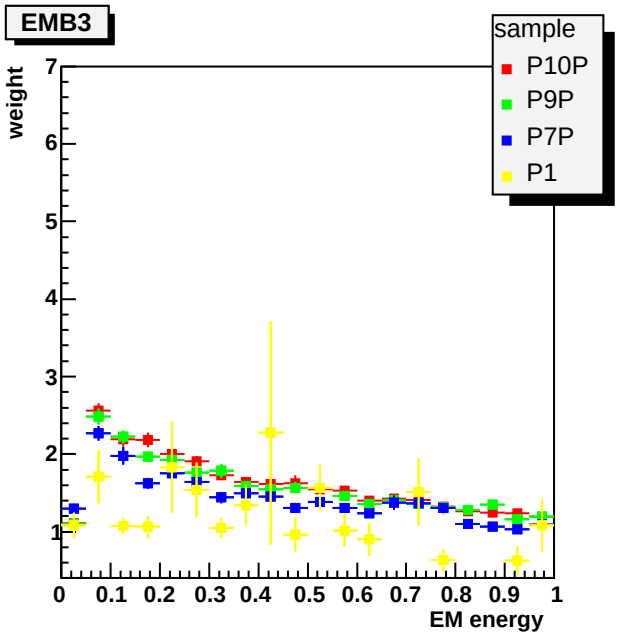


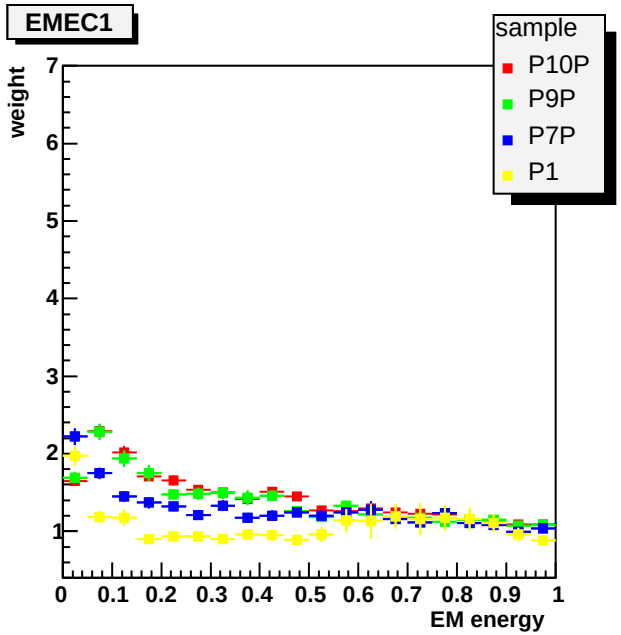
Weights as a function of electromagnetic component of the deposited energy

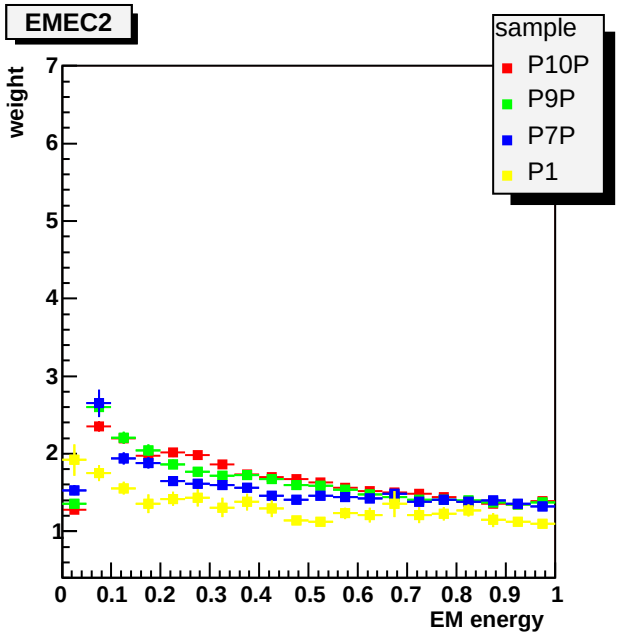
- The following plots show the above defined weights as a function of electromagnetic component of the deposited energy

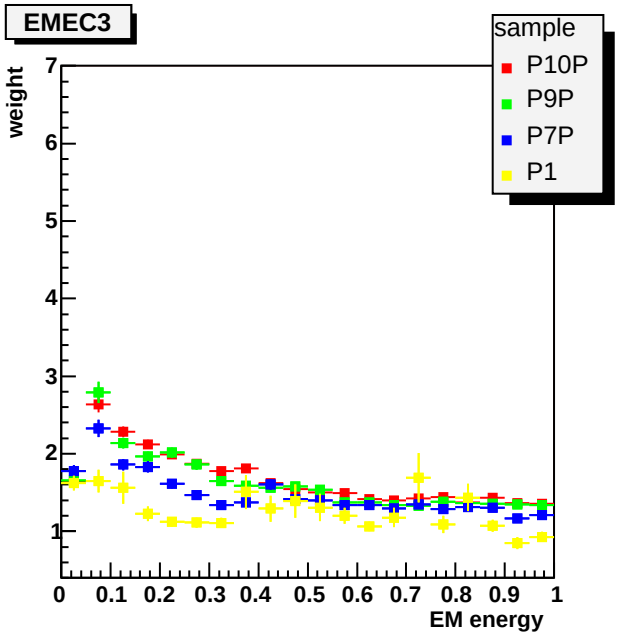

EMB1
sample
P10P
P9P
P7P
P1
weight
EM energy

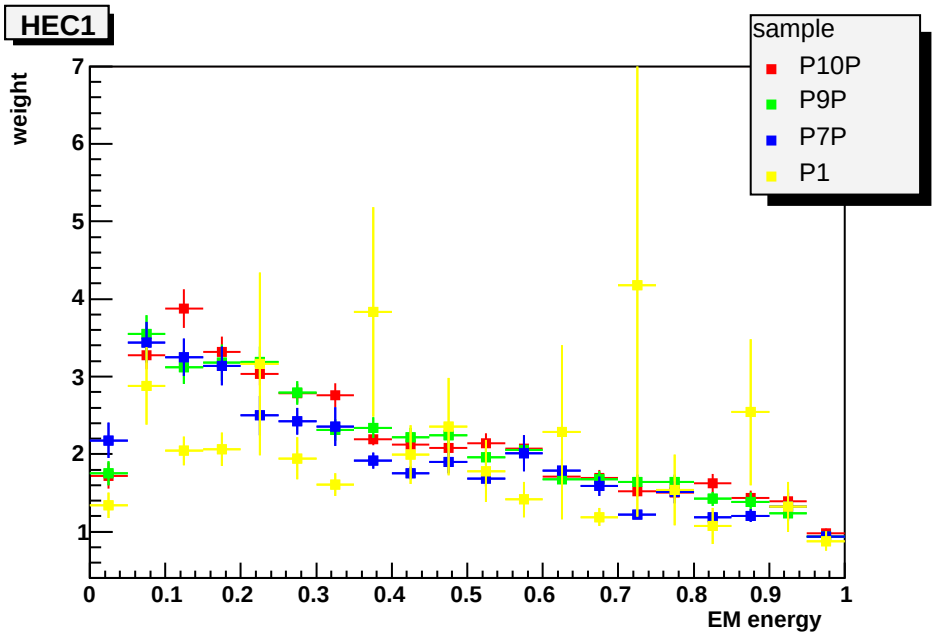

EMB2
sample
P10P
P9P
P7P
P1
weight
EM energy

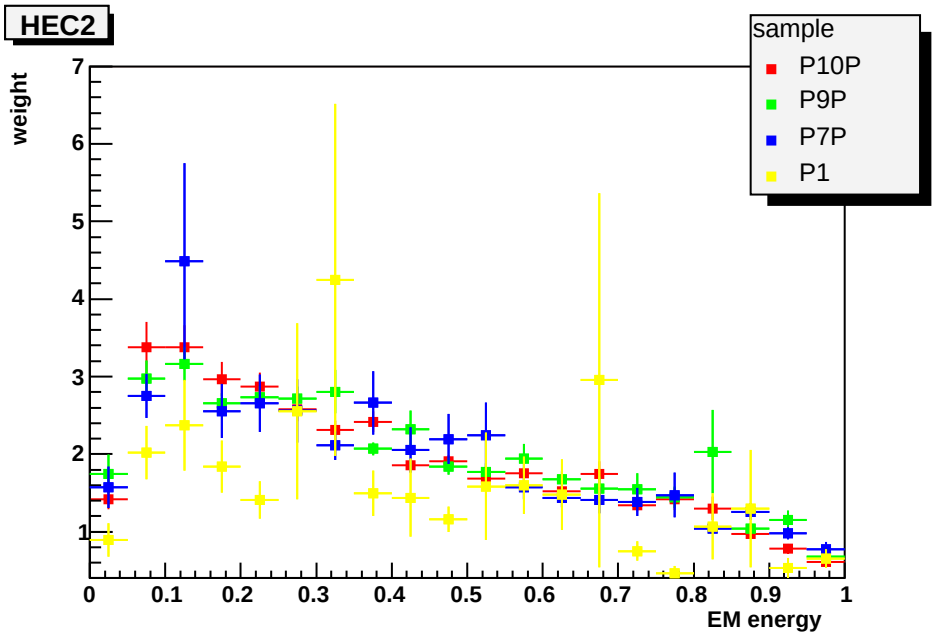

EMB3
sample
P10P
P9P
P7P
P1
weight
EM energy

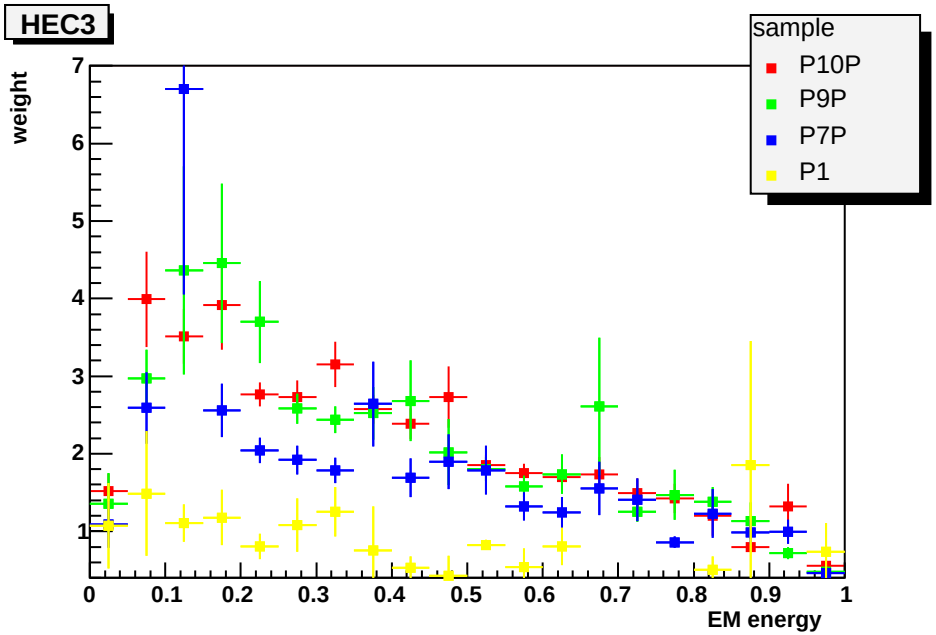

EMEC1
sample
P10P
P9P
P7P
P1
weight
EM energy

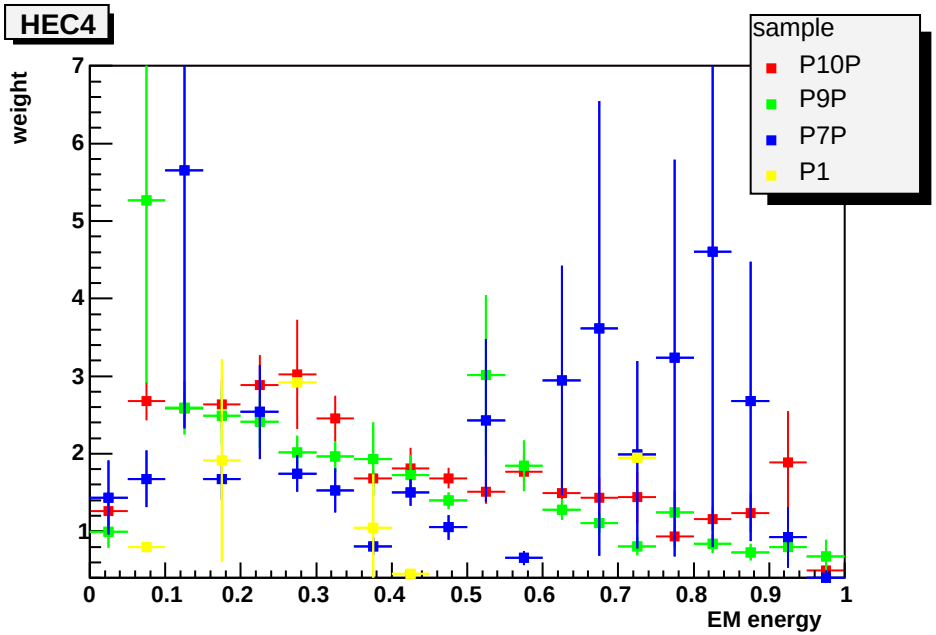

EMEC2
sample
P10P
P9P
P7P
P1
weight
EM energy


EMEC3
sample
P10P
P9P
P7P
P1
weight
EM energy

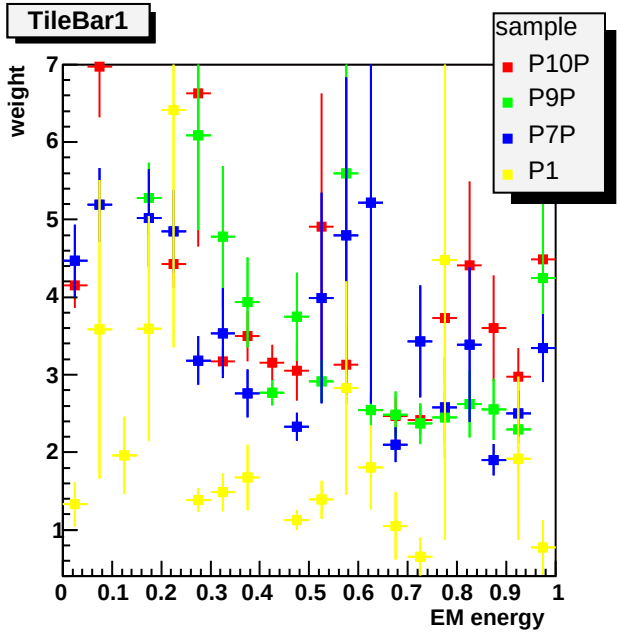

HEC1
sample
P10P
P9P
P7P
P1
weight
EM energy

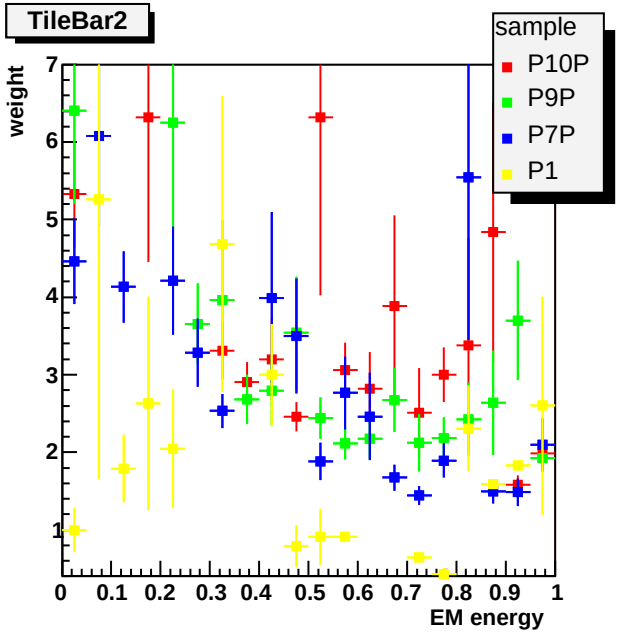

HEC2
sample
P10P
P9P
P7P
P1
weight
EM energy

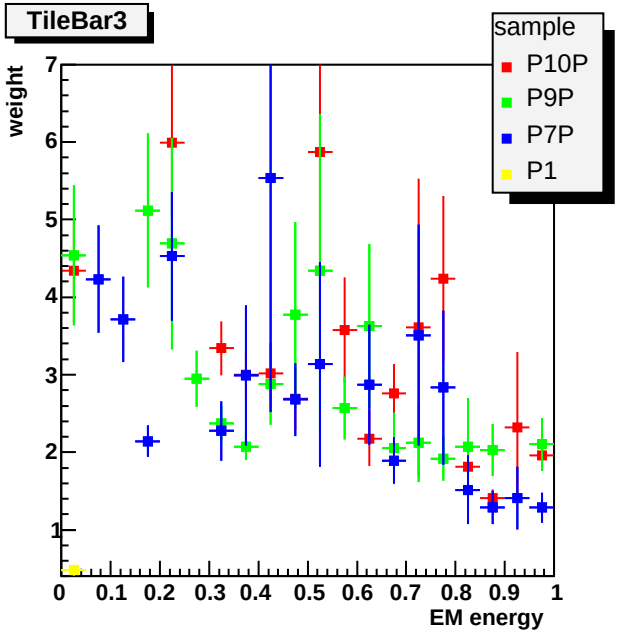

HEC3
sample
P10P
P9P
P7P
P1
weight
EM energy

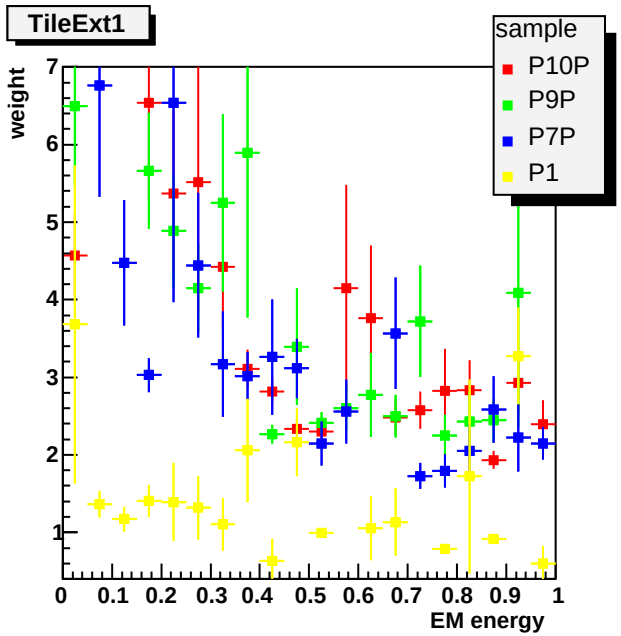

HEC4
sample
P10P
P9P
P7P
P1
weight
EM energy

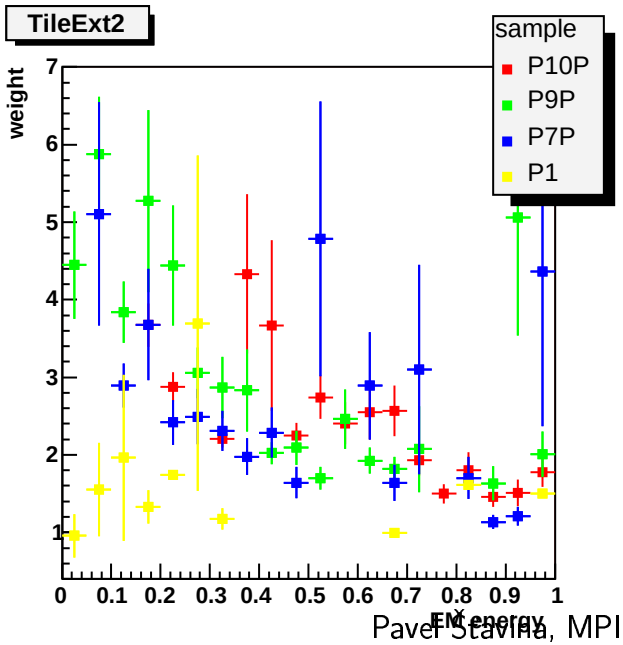
Only part of the energy present !

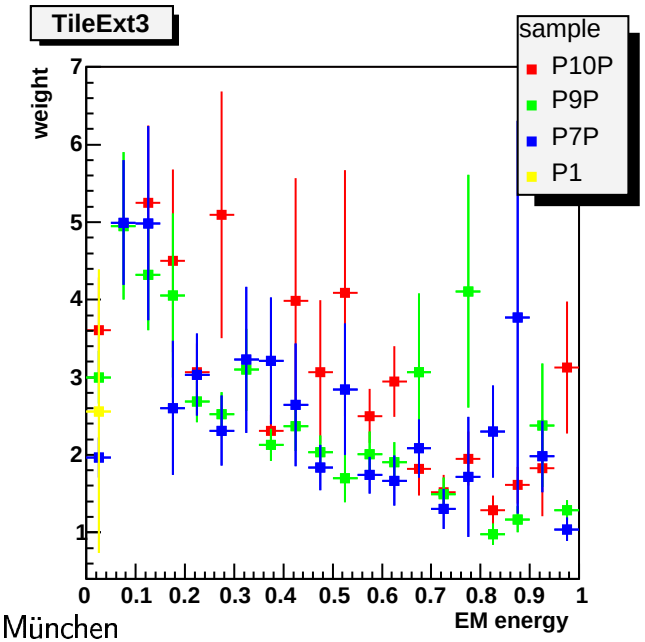










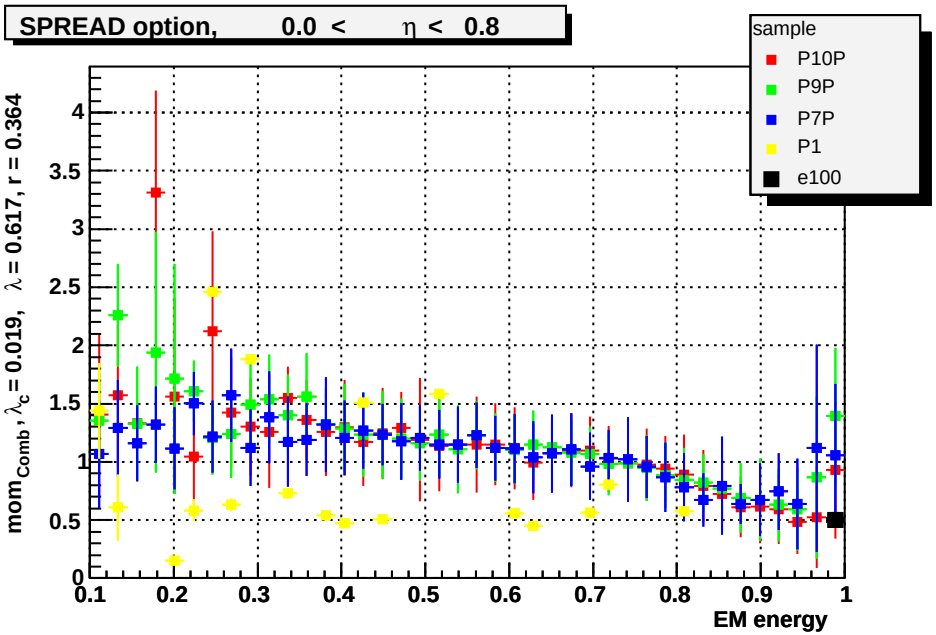


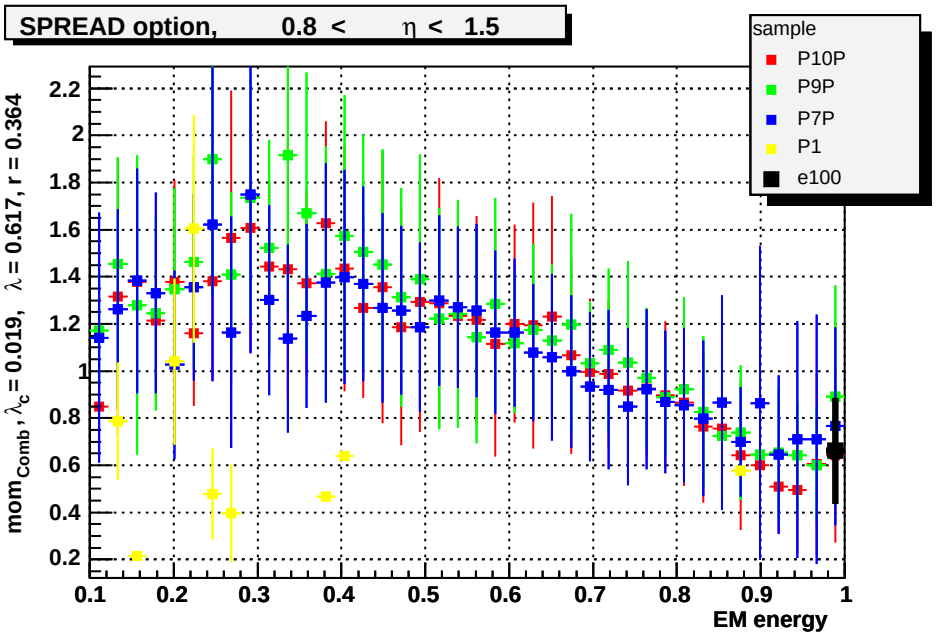
The more sophisticated quantities

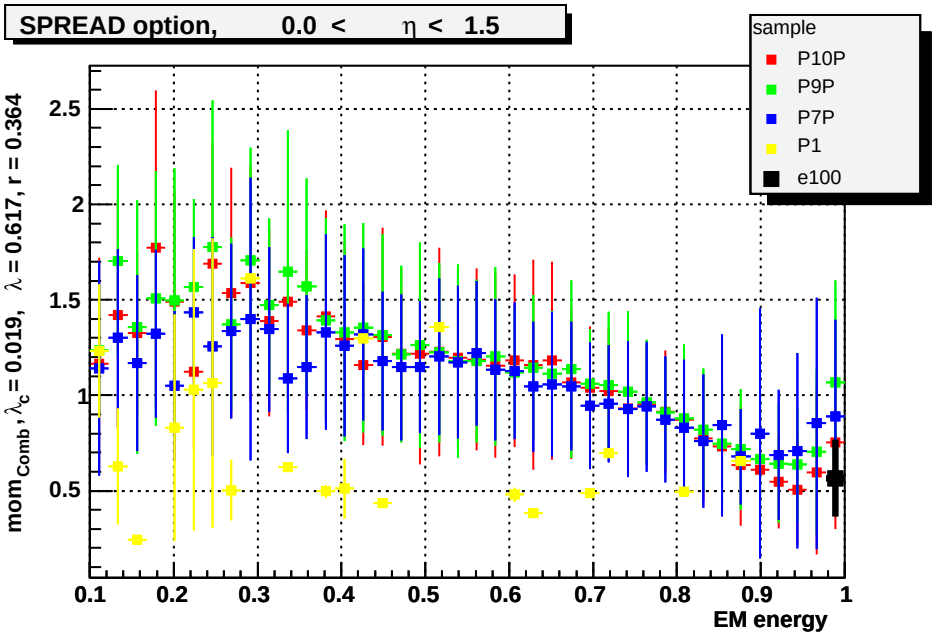
- The first aim is to identify EM clusters and exclude them from the weighting.
- Many quantities are related to the electromagnetic component of the deposited energy
- Let's try to define some quantities which from the statistical point of view are able to estimate the electromagnetic component of the deposited energy

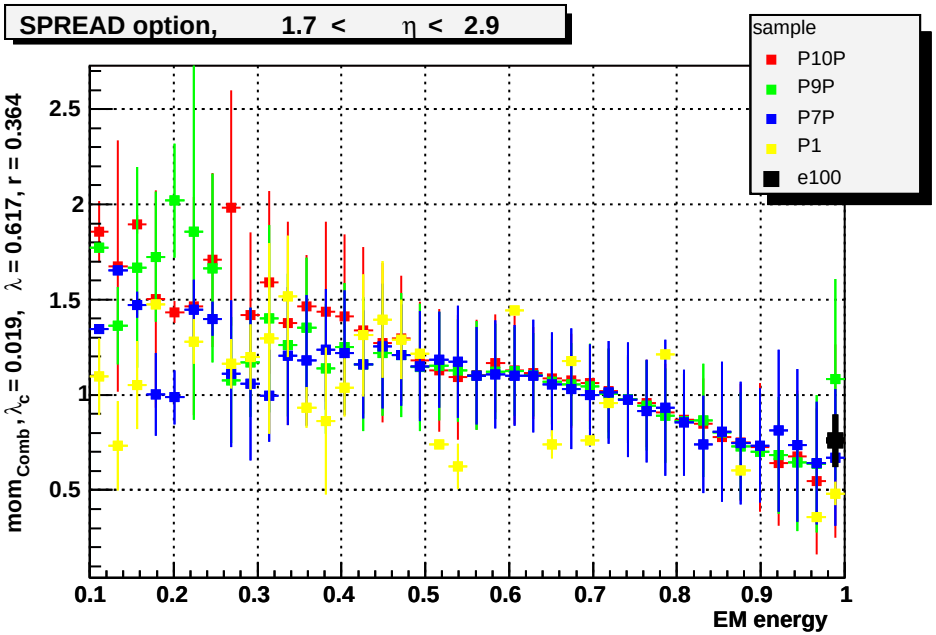
The first shot - generalised moment

- All the topological moments are functions of electromagnetic component of the deposited energy
- The most simple option is, of course, linear combination
- To be able to calculate any mean value of some generalised moment we have to normalize them first just to be able to make summation
- The next step is to find sort of weighted mean value
- We use MINUIT with the aim to minimize spread over the profile bins


SPREAD option, 0.0 < η < 0.8
sample
P10P
P9P
P7P
P1
e100
mom_Comb, λ_c = 0.019, λ = 0.617, r = 0.364
EM energy


SPREAD option, 0.8 < η < 1.5
sample
P10P
P9P
P7P
P1
e100
mom_Comb, λ_c = 0.019, λ = 0.617, r = 0.364
EM energy


SPREAD option, 0.0 < η < 1.5
sample
P10P
P9P
P7P
P1
e100
mom_Comb, λ_c = 0.019, λ = 0.617, r = 0.364
EM energy


SPREAD option, 1.7 < η < 2.9
sample
P10P
P9P
P7P
P1
e100
mom_Comb, λ_c = 0.019, λ = 0.617, r = 0.364
EM energy

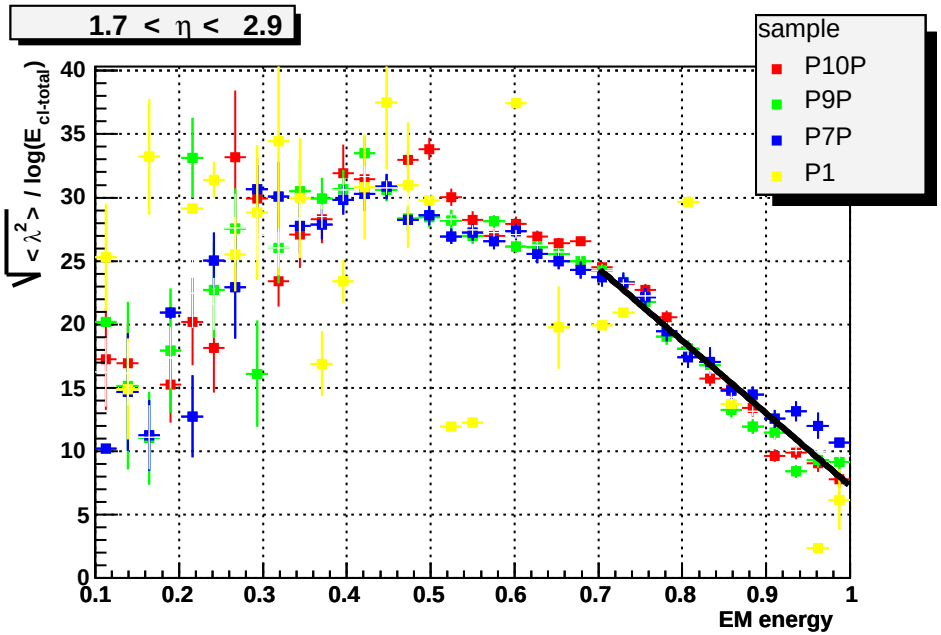
Calculating the electromagnetic component of the deposited energy from cluster parameters

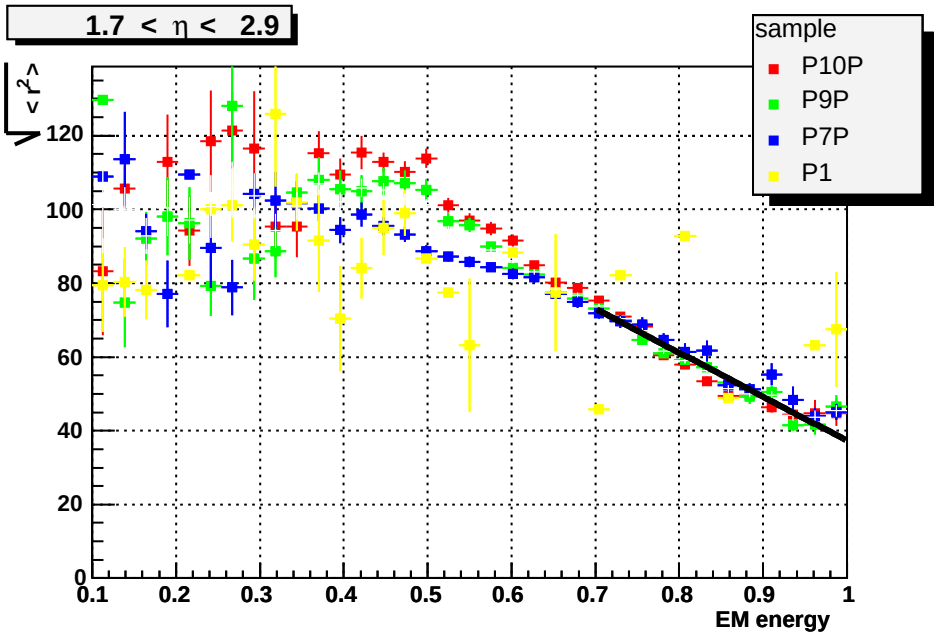
- Maybe the idea to calculate directly the electromagnetic component of the deposited energy from cluster parameters as a description of "TRUE" electromagnetic component of the deposited energy is the worth to be investigated as well... ;-)

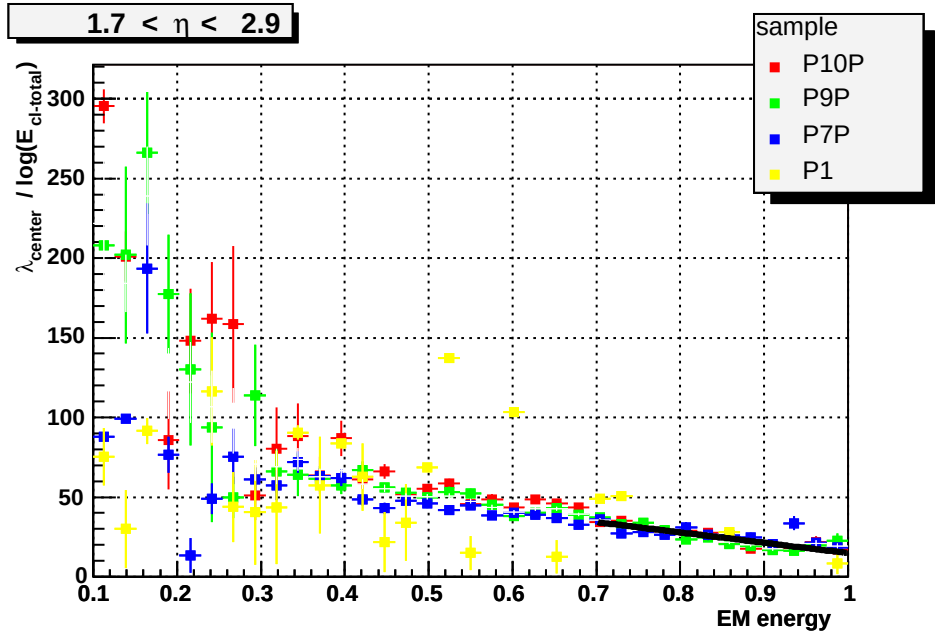
- We use simple linear fit to calculate the electromagnetic component of the deposited energy from cluster moments

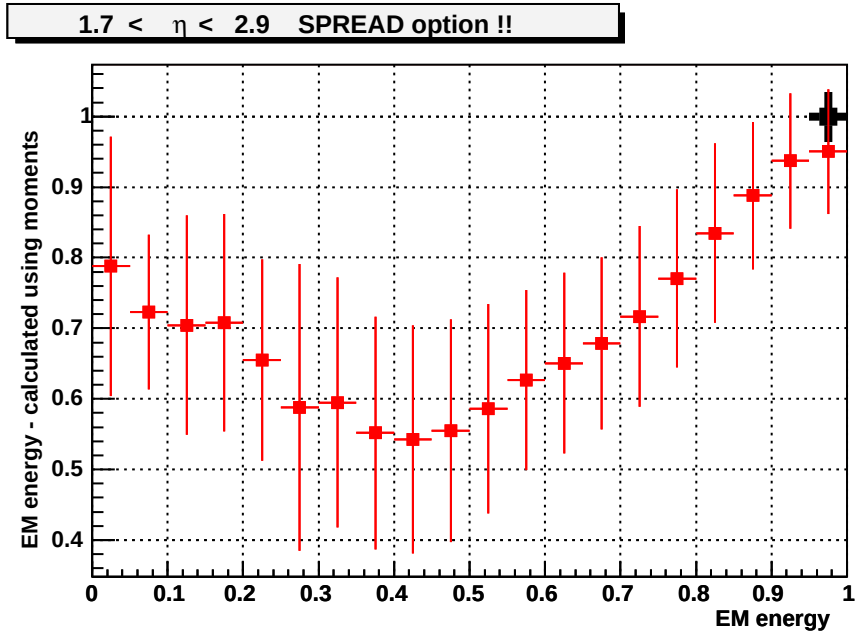
- The next step is to find sort of weighted mean value again

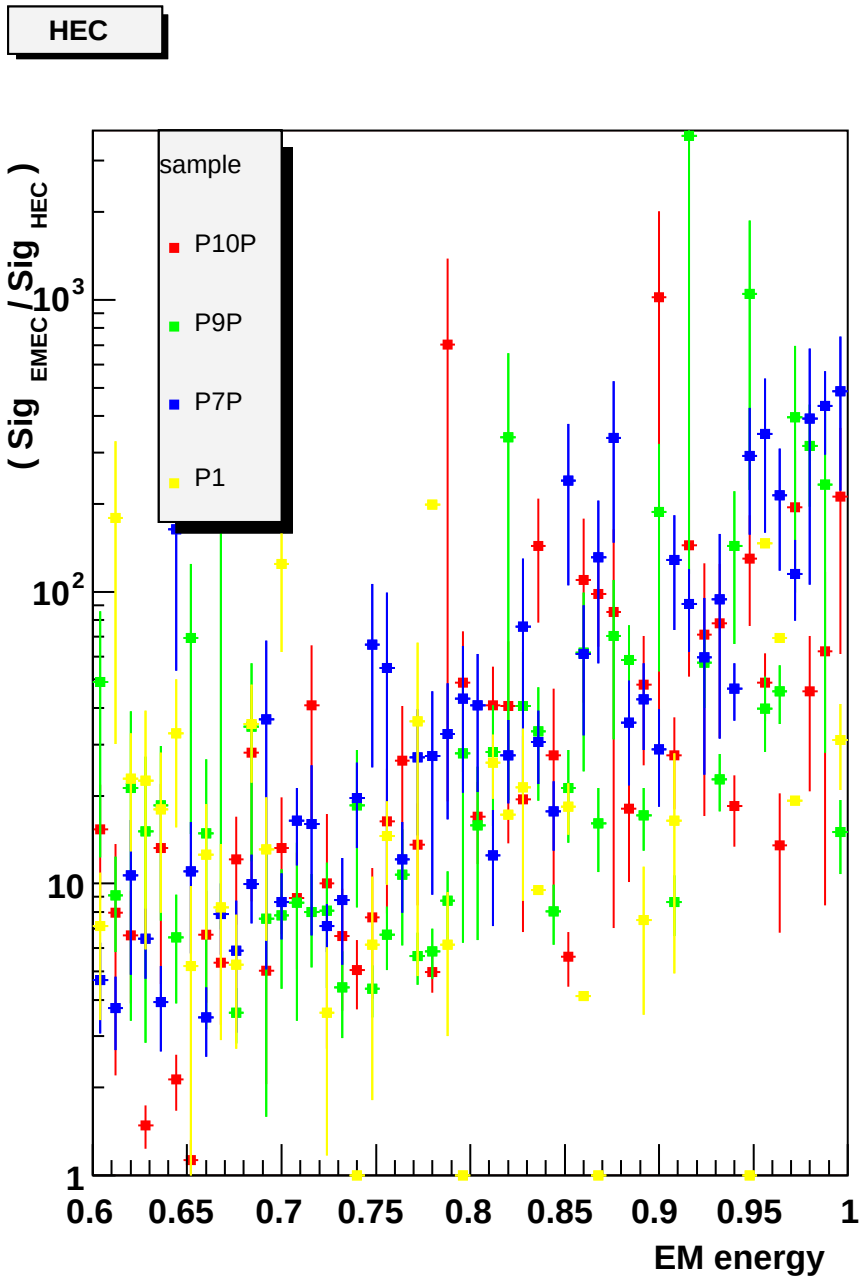
- And obviously we use MINUIT to minimize the spread again

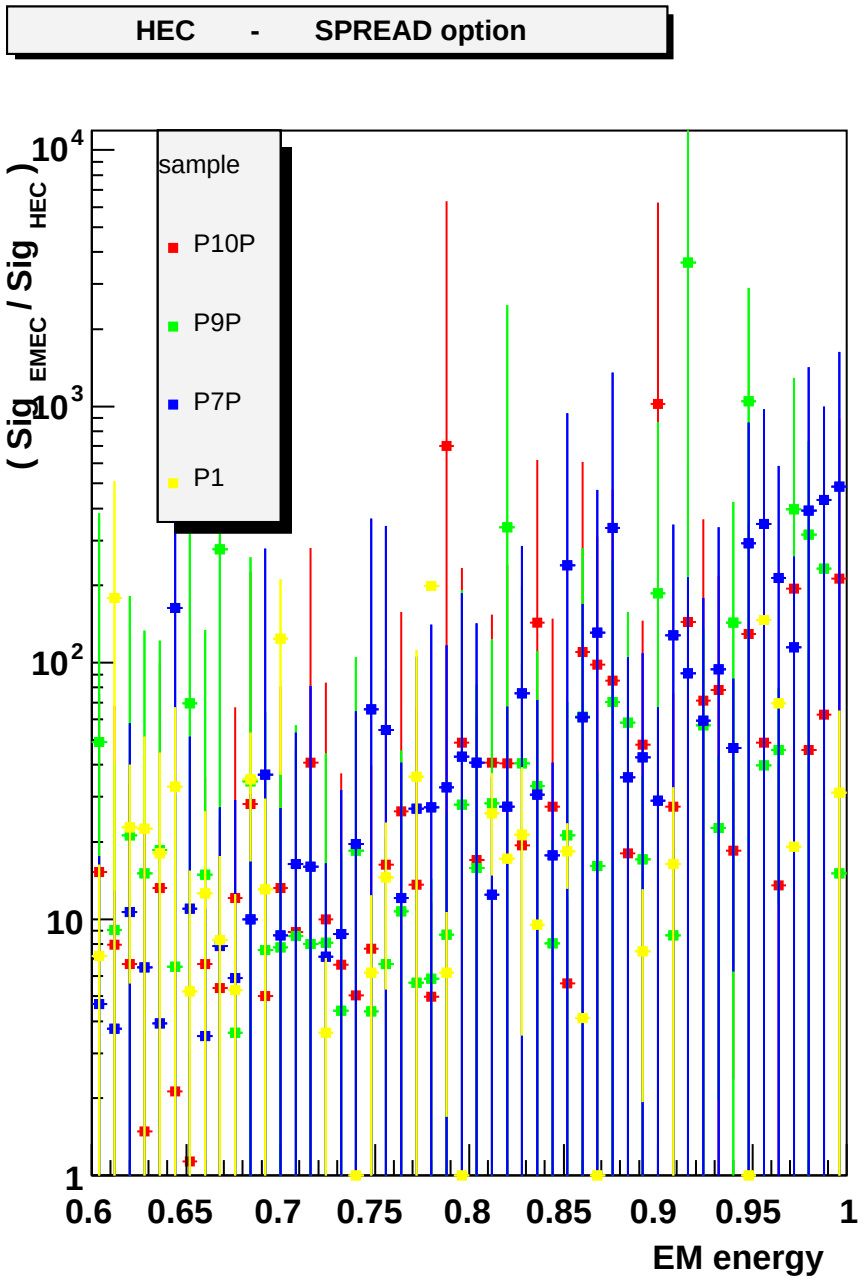

1.7 < η < 2.9
sample
P10P
P9P
P7P
P1
$\sqrt{<\lambda^2>}$ / log($E_{cl\text{-}total}$)
EM energy

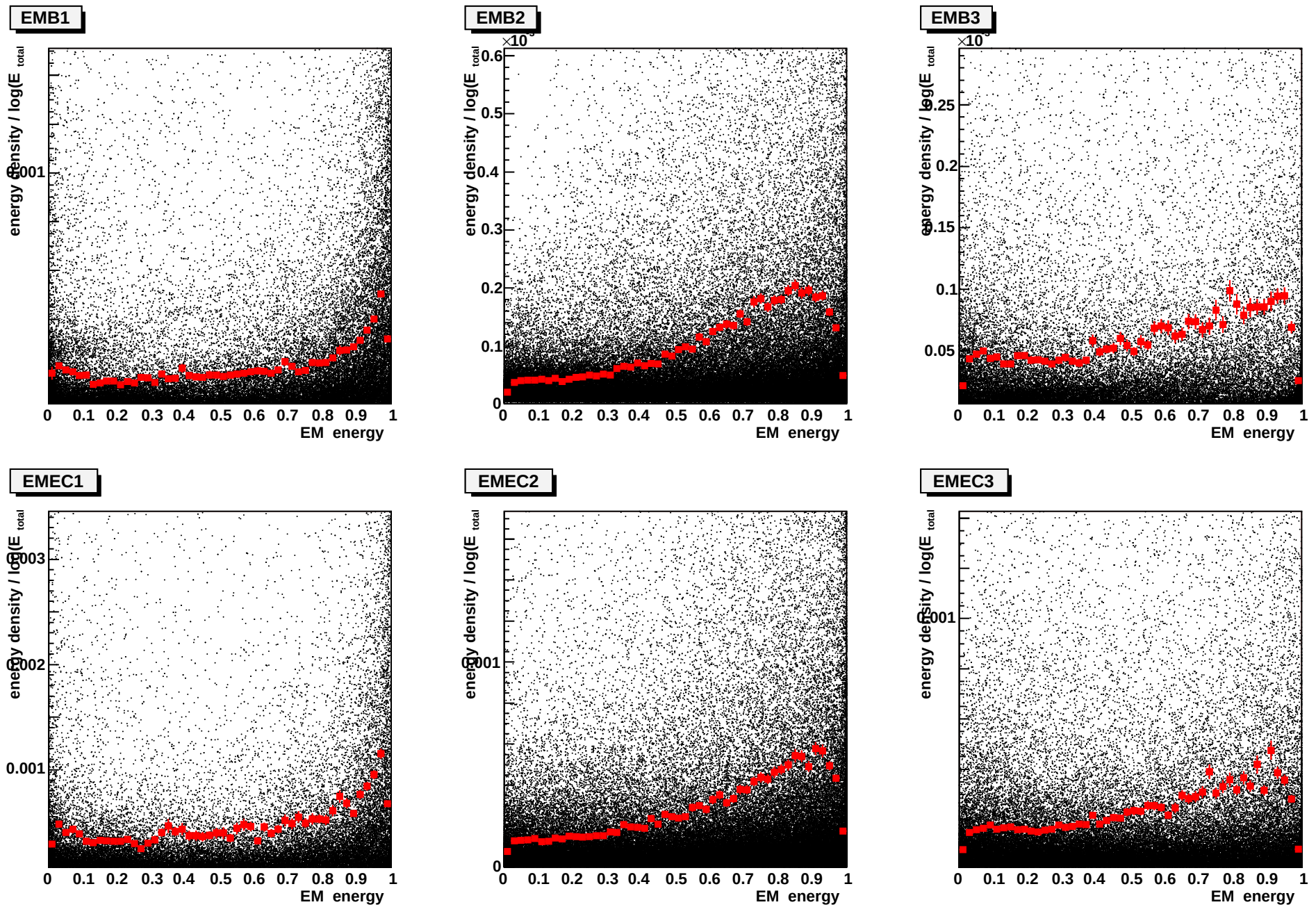

1.7 < η < 2.9
sample
P10P
P9P
P7P
P1
$\sqrt{<r^2>}$
EM energy

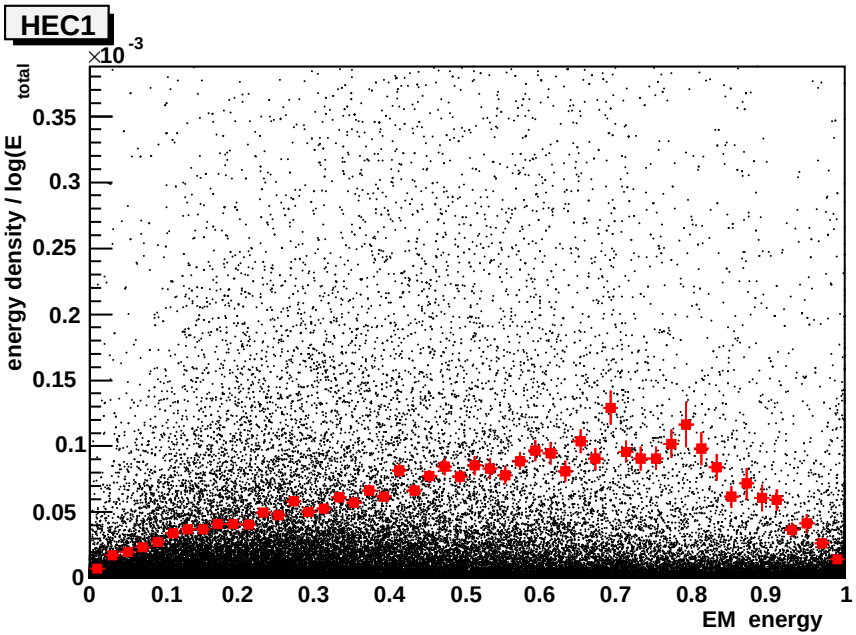

1.7 < η < 2.9
sample
P10P
P9P
P7P
P1
λ_{center} / log($E_{cl\text{-}total}$)
EM energy

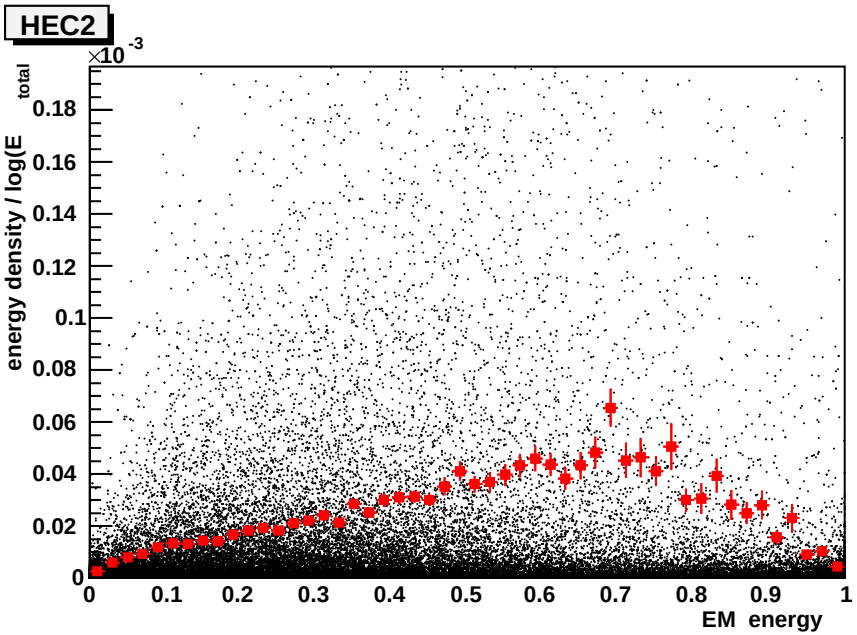

1.7 < η < 2.9 SPREAD option !!
EM energy - calculated using moments
EM energy

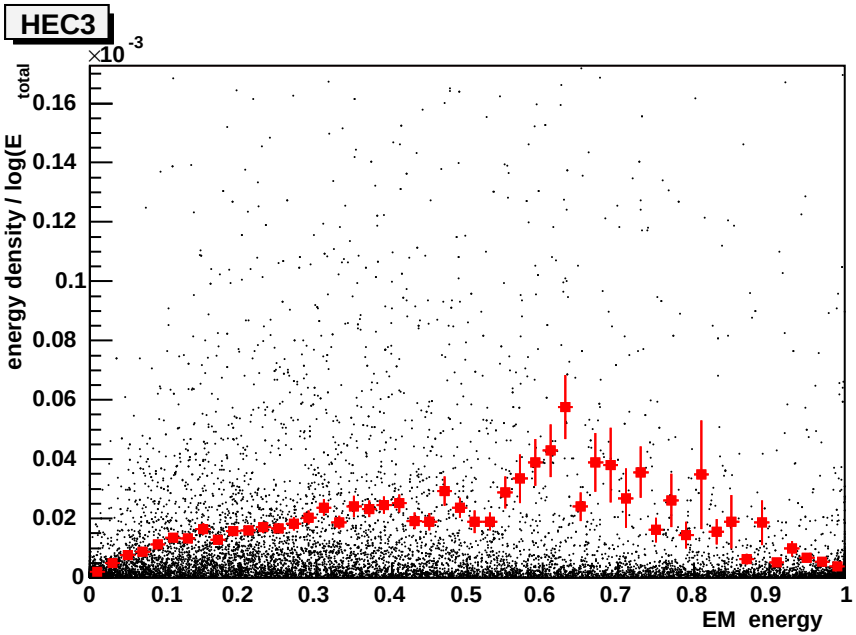

HEC
sample
P10P
P9P
P7P
P1
(Sig EMEC / Sig HEC)
10^3
10^2
10
1
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
EM energy

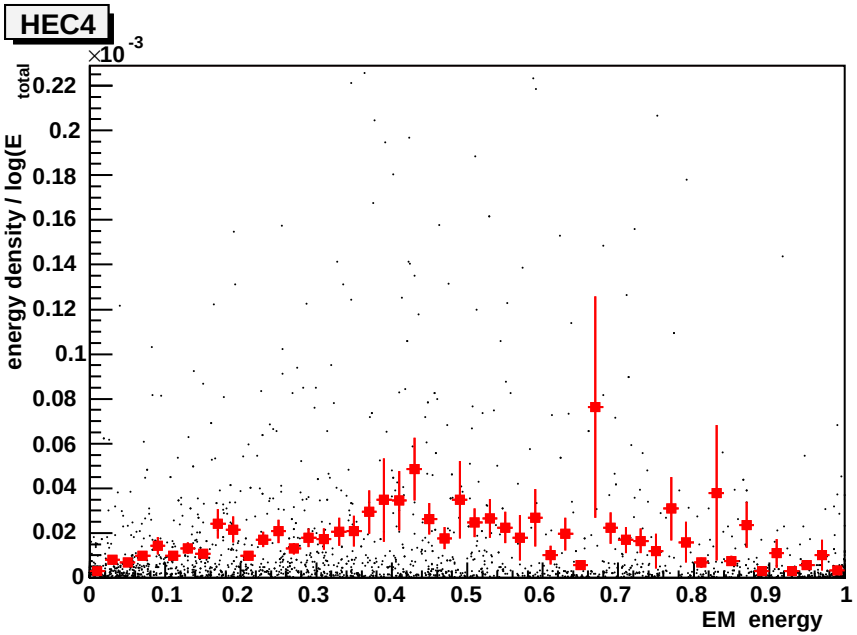

HEC - SPREAD option
sample
P10P
P9P
P7P
P1
(Sig EMEC / Sig HEC)
10^4
10^3
10^2
10
1
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
EM energy

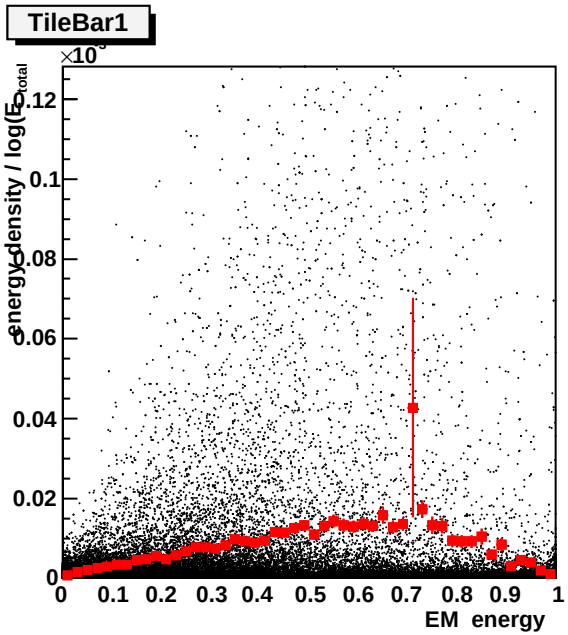

EMB1
EMB2
EMB3
EMEC1
EMEC2
EMEC3
energy density / log(E total)
EM energy
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.001
0.002
0.003
0.05
0.15
0.25
×10⁻³

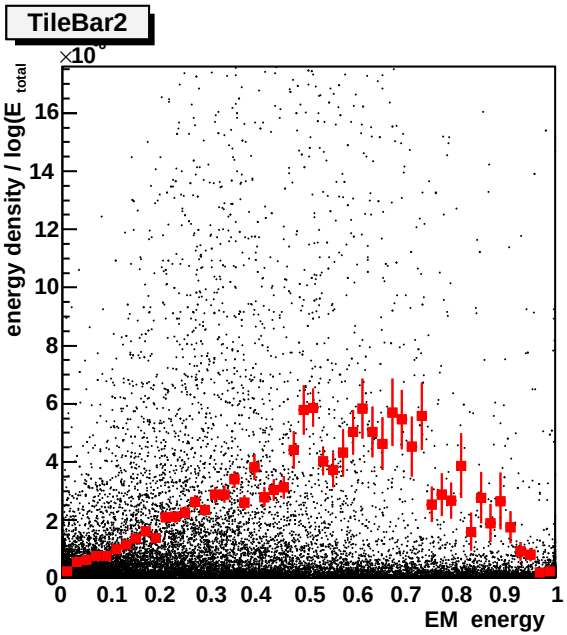

HEC1
×10 -3
energy density / log(E total
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
EM energy

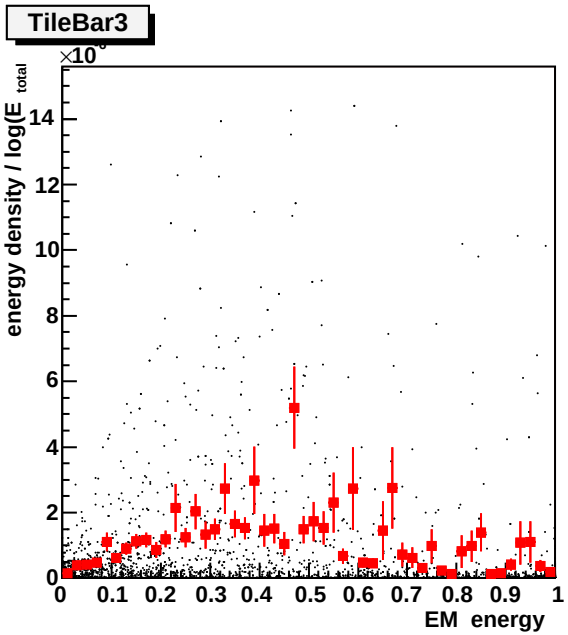

HEC2
×10 -3
energy density / log(E total
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
EM energy

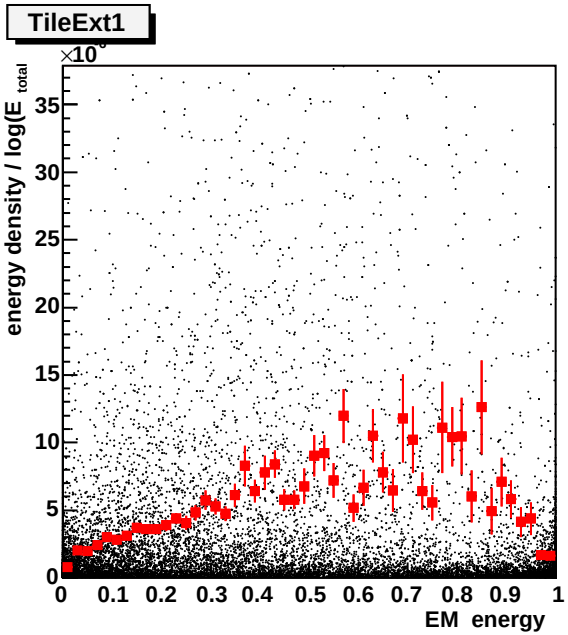

HEC3
×10 -3
energy density / log(E total
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
EM energy

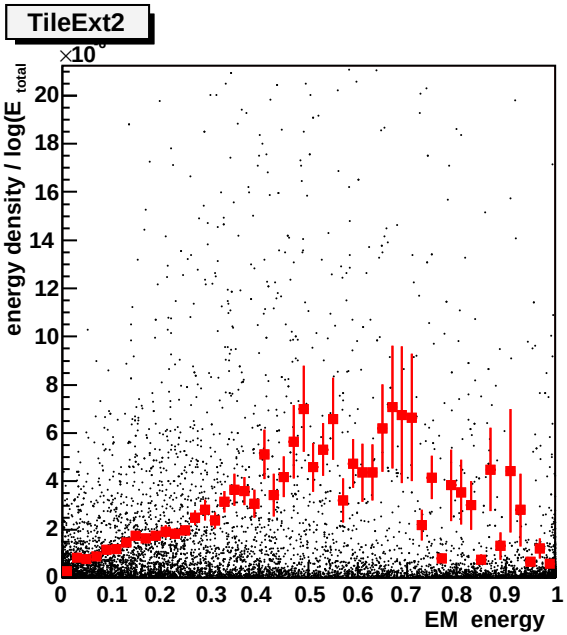

HEC4
×10 -3
energy density / log(E total
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
EM energy

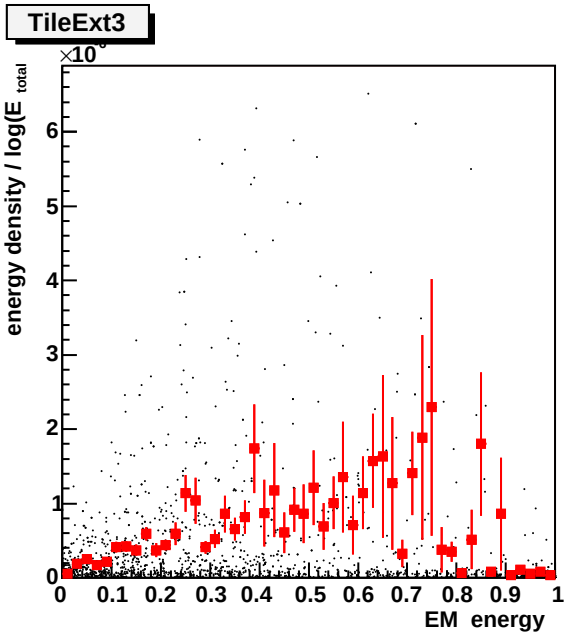

TileBar1
energy density / log(E total)
EM energy


TileBar2
energy density / log(E total)
EM energy


TileBar3
energy density / log(E total)
EM energy


TileExt1
energy density / log(E total)
EM energy


TileExt2
energy density / log(E total)
EM energy


TileExt3
energy density / log(E total)
EM energy

Conclusions

- Using the calibration hits is useful and powerful tool to improve the calorimeter performance
- WE NEED NORMAL DATA !!
- The moments were investigated and some criteria how to define the cuts to exclude the EM clusters from weighting were found
- The results of analysis will be probably useful for classification of clusters and cells
- Lots and lots of work to be done.....

Status of students in Bratislava

- Vladimir Fekete - he is expected to finish his diploma work in one year. At present he is at CERN as a summer student. Good C++ programmer. The code to read calibration hits is the mostly his work.

- Pavol Federič and Matrin Pécsy they are expected to finish their diploma works in two years. In July they will participate the summer training program for students in Dubna.

- Students Scientific Conference - in Slovakia it is a possibility for students to present their works. All above mentioned students participated there. The Students

Scientific Conference consists of two rounds - the first one is within the institute and the best works pass to the Slovak conference. This year (just two days ago) Matrin Pécsy becomes the absolute winner of the "Nuclear and Particle Physics" section. Congratulations !