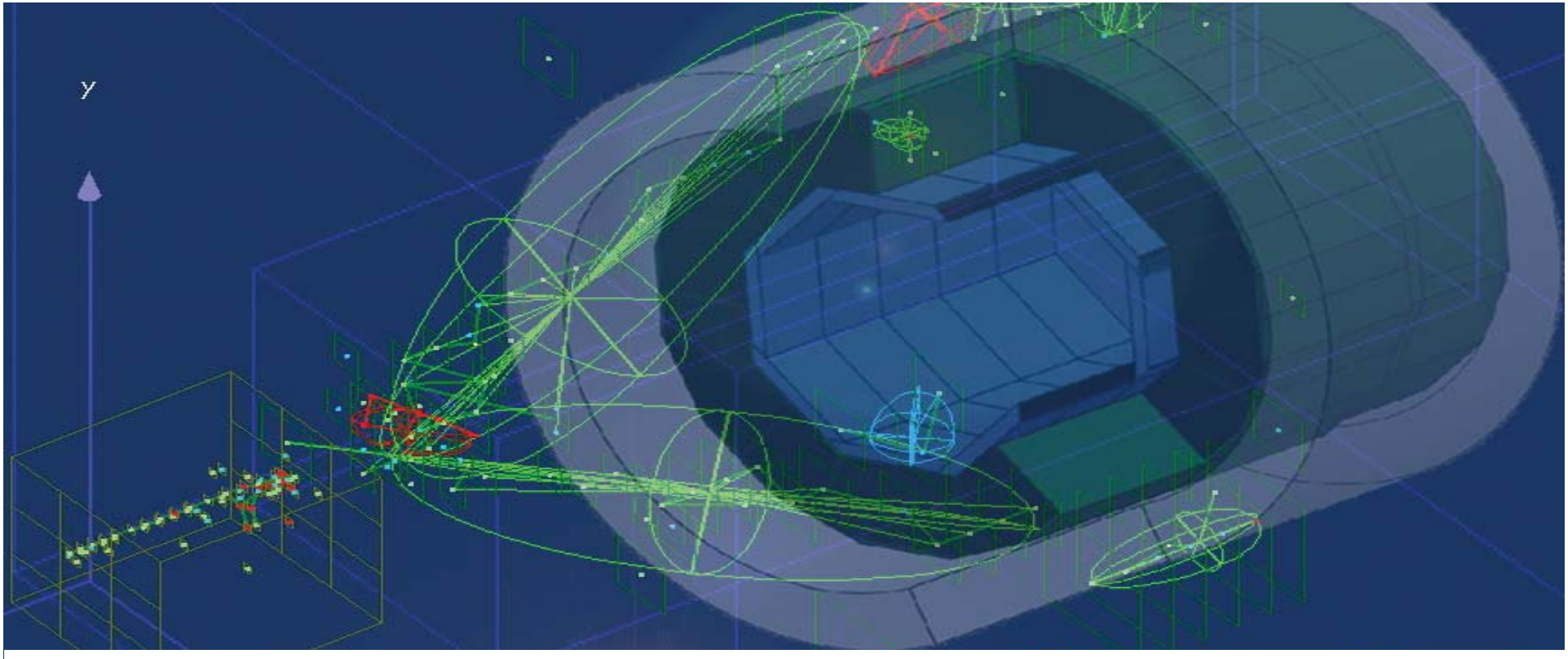
HCAL analysis

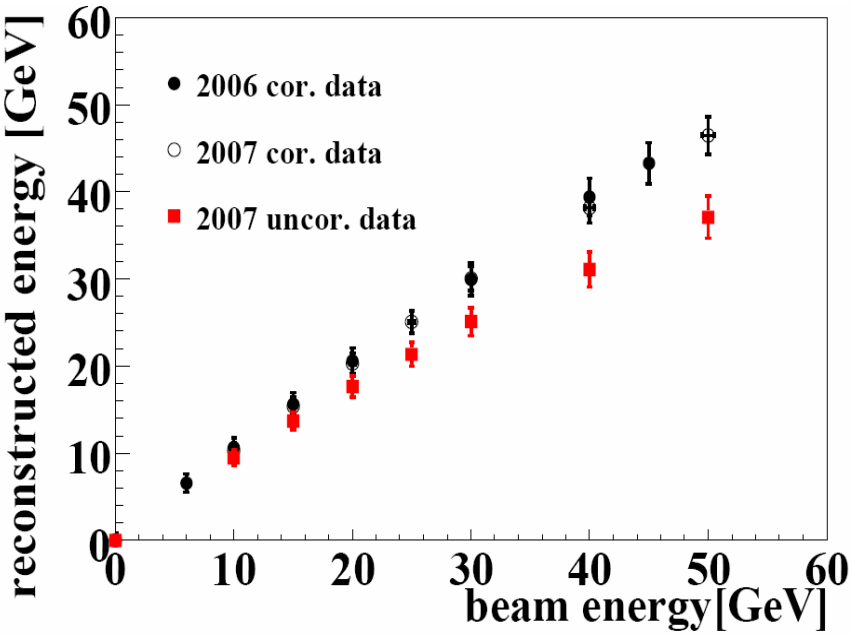
Erika Garutti

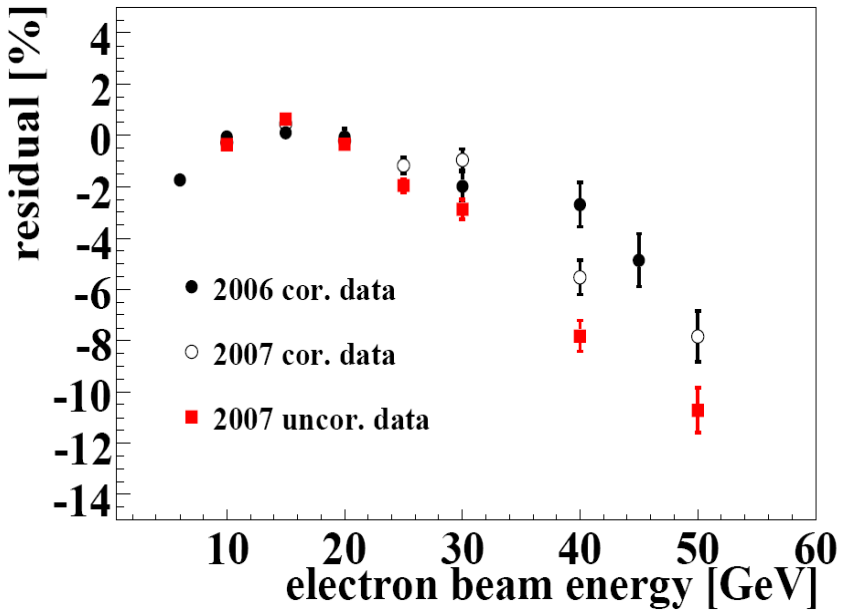


Overview of analysis status:

- EM analysis from Nanda Wattimena (Sebastian Richter, Sergey Morozov)
- Pion analysis from Oliver Wendt
- Showers separation Jörgen Samson

EM analysis (NW)



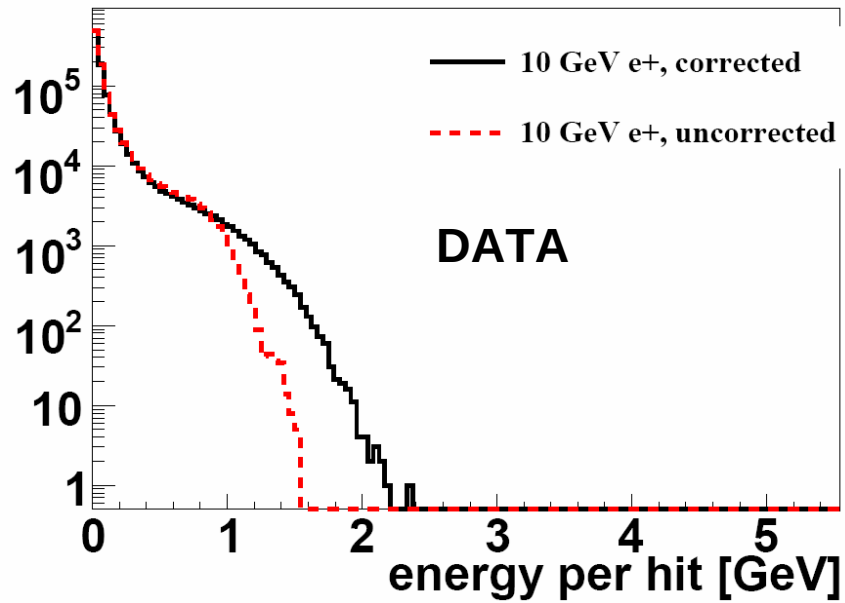


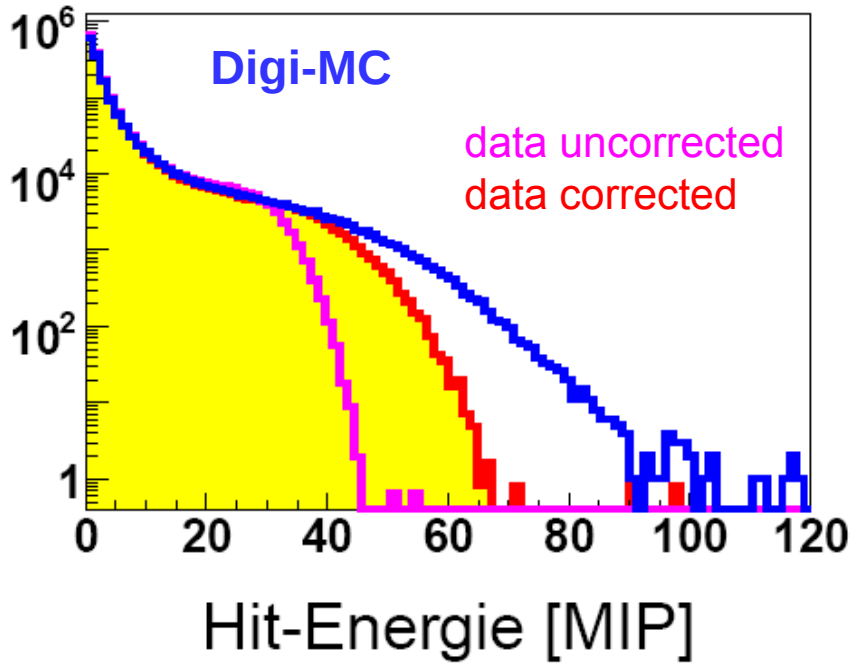
status already presented at last CALICE meeting

6 < E < 30 GeV linearity ~2%

E > 30 GeV linearity ~8% ➔ saturation correction to be improved

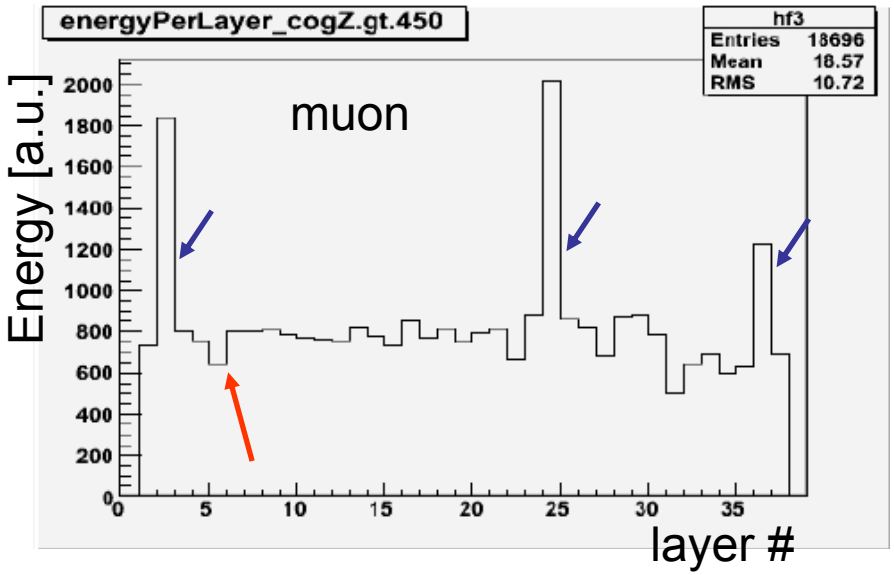
Hit energy distribution

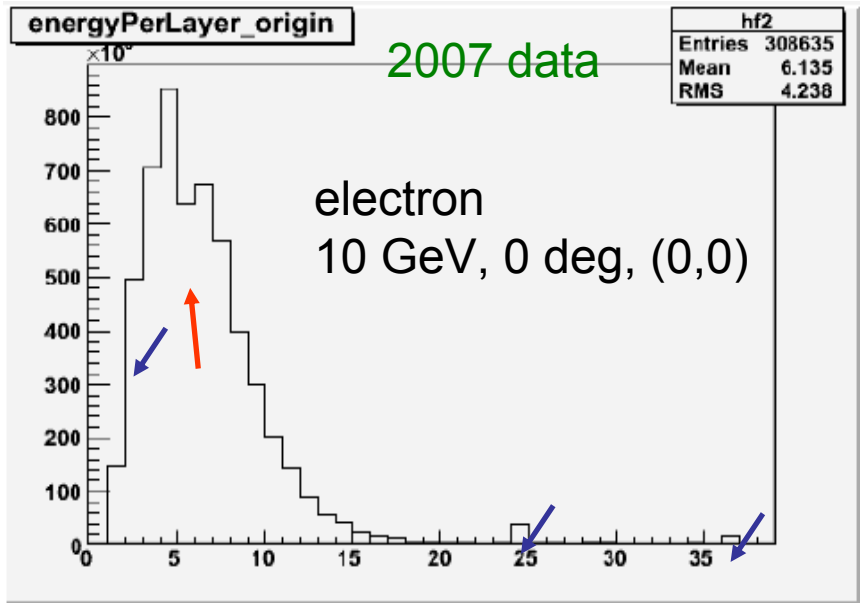




ongoing work to understand the effects of saturation on digitized MC (SR)

Back to calibration quality

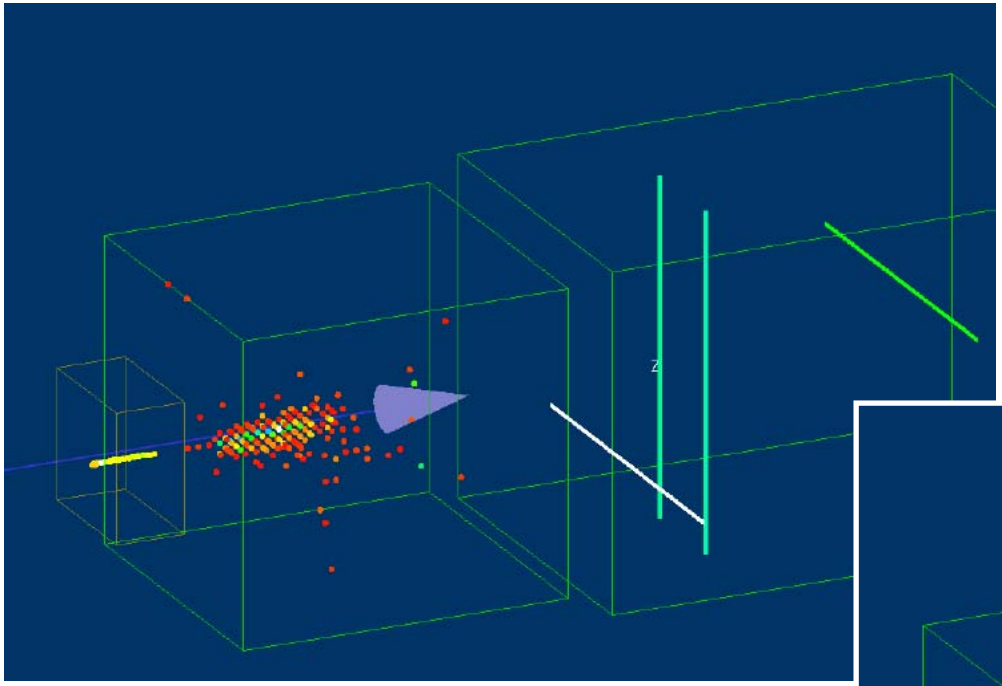


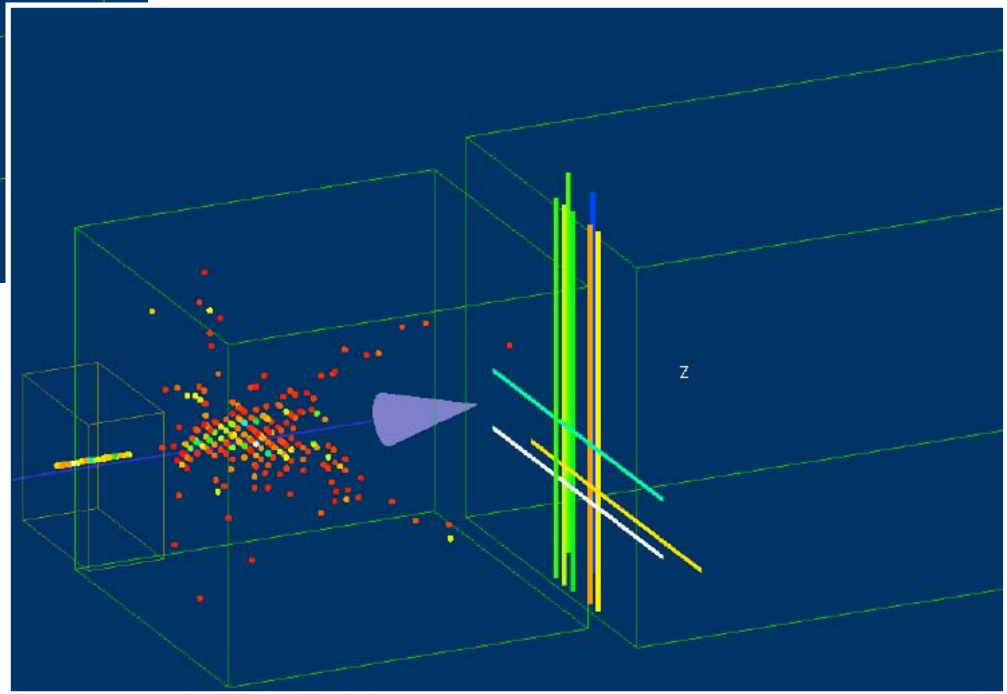


new issues in calibration identified (SM)
now investigating:
-deep in layer 5
-3 layers with too large reconstructed energy

for 2006 the muon energy per layer looks flat as it should be

Pion analysis





Comparison of phys. lists

from a publication of the G4 group:
CERN-LCGAPP-2007-02

- G4 version 8.2
- range cut 0.7 mm
- pi- 30,100,300 GeV
- Cu-LAr sampling calorimeter (25mm Cu : 8.5 mm LAr)
- length = 10 λ, width = 150 cm
- simplified geometry:

  the calorimeter is divided in 4 longitudinal blocks (L1 – L4) 2.5 λ each

  and 3 concentric cylinders (R1 – R3) with R1<0.3 λ, 0.3 < R2 < 0.6 λ and R3>0.6 λ

Observable	LHEP	QGSP	QGSC	QGSP_BIC	QGSP_BERT	QGSP_BERT_HP

the two main opponents

QGS + CHIPS

combine only theoretical models with each other, parameterization is used to fill the gaps

Integral quantities

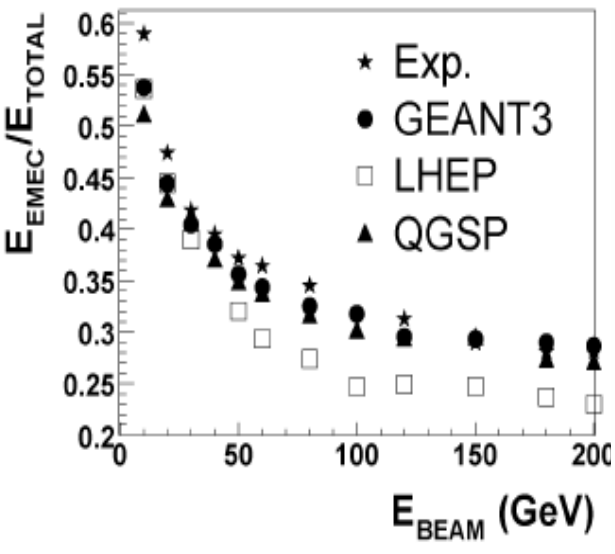
Observable	LHEP	QGSP	QGSC	QGSP_BIC	QGSP_BERT	QGSP_BERT_HP
E_{vis}	1113 ± 2 MeV	1183	1160	1225	1277	1292
σ_E/E	13.6%	12.3%	13.8%	11.0%	9.5%	9.6%
e/π	1.30	1.22	1.24	1.18	1.13	1.12

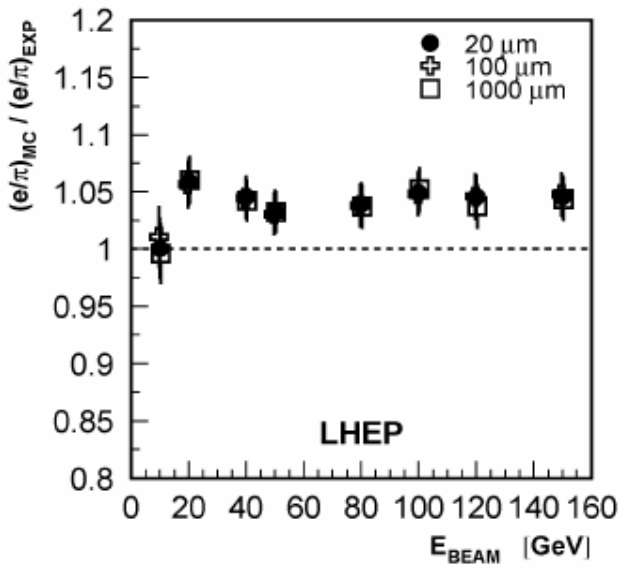
lowest E vis
worse E resolution
largest e/pi

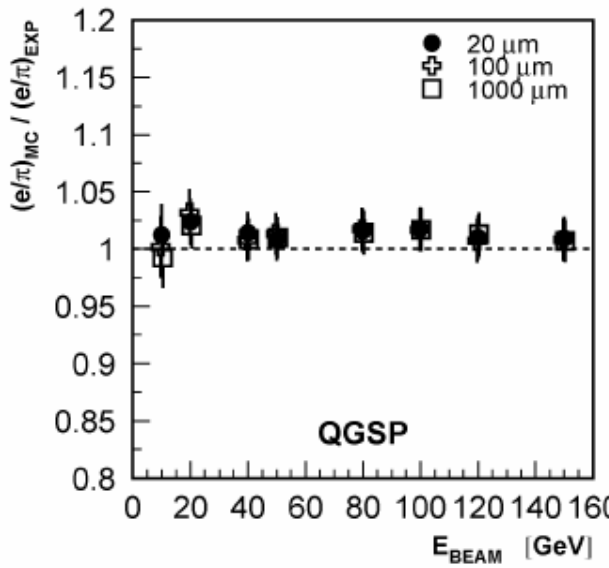
largest E vis
best E resolution
lowest e/pi

← favorite by data

ATLAS End-cap hadronic calorimeter





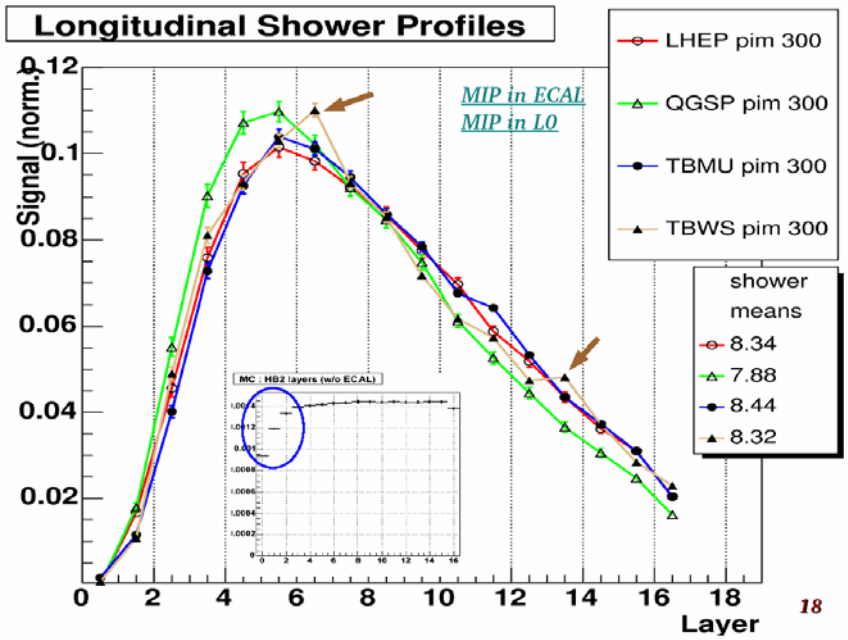


longitudinal shower shape in data

CMS HCAL (brass/scintillator sampling)

LHEP predicts longest and wider showers

➔ better agreement to data



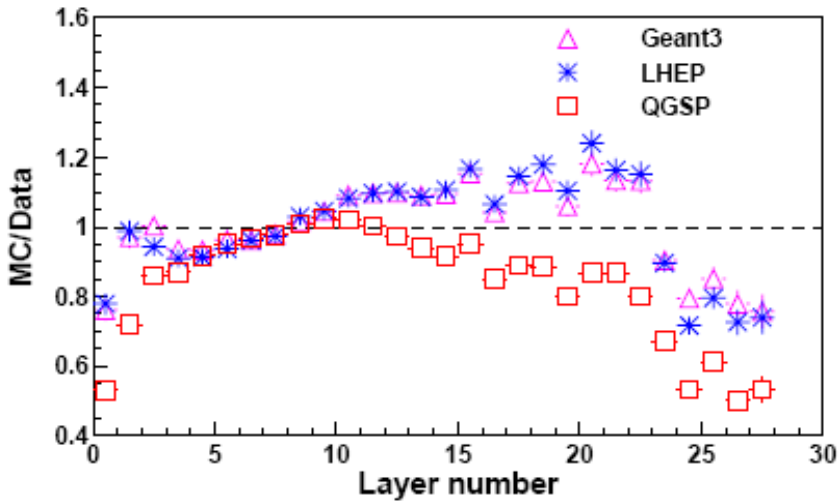


Figure 9: Ratio between simulations and data for longitudinal shower profile of 100 GeV π in the HCAL standalone test-beam set-up.

Shower shape

Observable	LHEP	QGSP	QGSC	QGSP_BIC	QGSP_BERT	QGSP_BERT_HP
f_{L1}	67.8 ± 0.5 %	66.3%	67.3%	65.3%	62.1%	61.6%
f_{L2}	26.3 ± 0.3 %	26.9%	26.3%	27.5%	29.5%	29.4%
f_{L3}	5.1 ± 0.1 %	5.8%	5.6%	5.9%	7.1%	7.4%
f_{L4}	0.8 ± 0.04 %	1.0%	0.9%	1.2%	1.4%	1.5%
f_{R1}	72.8 ± 0.3 %	76.1%	76.2%	72.7%	67.5%	66.7%
f_{R2}	23.7 ± 0.1 %	21.1%	21.0%	22.6%	25.8%	25.6%
f_{R3}	3.6 ± 0.04 %	2.8%	2.8%	4.7%	6.7%	7.7%

same shower shape when exchanging pre-compound and CHIPS. BUT, they are the same for E<10 GeV
➔ one alternative: QGSC_EFLOW

inter-nuclear cascade models make showers longer and weider
RIGHT direction!
but they change E res and e/pi
WRONG direction ➔ to be checked

Bertini stronger effect than Binary:
pi/k E<10 GeV Bertini
pi E<3 GeV Binary

Favorite
by data:
longer and wider showers

HP has small effect on shape

shower composition

Observable	LHEP	QGSP	QGSC	QGSP_BIC	QGSP_BERT	QGSP_BERT_HP
$\#EM$	25,931 ± 120	29,720	28,377	35,182	37,470	38,034
$\#\pi$	48 ± 0.1	39	39	41	37	37
π^0/π	38%	38%	38%	37%	32%	32%
$\#p$	140 ± 0.7	129	147	121	151	144
$\#n$	244 ± 1.1	247	272	445	807	647

LHEP has the smallest EM fraction

smallest fraction of pi0 due to Bertini instead of LEP for pi E<10GeV

electrons give the largest contribution to visible energy (followed by p, pi+/-, and ions. K and mu are negligible)

electron contribution to shower shape is shortest and narrowest

➔LHEP describes had. shower profiles well at high energies
➔too high EM component in QGS, maybe due to overproduction of pi0

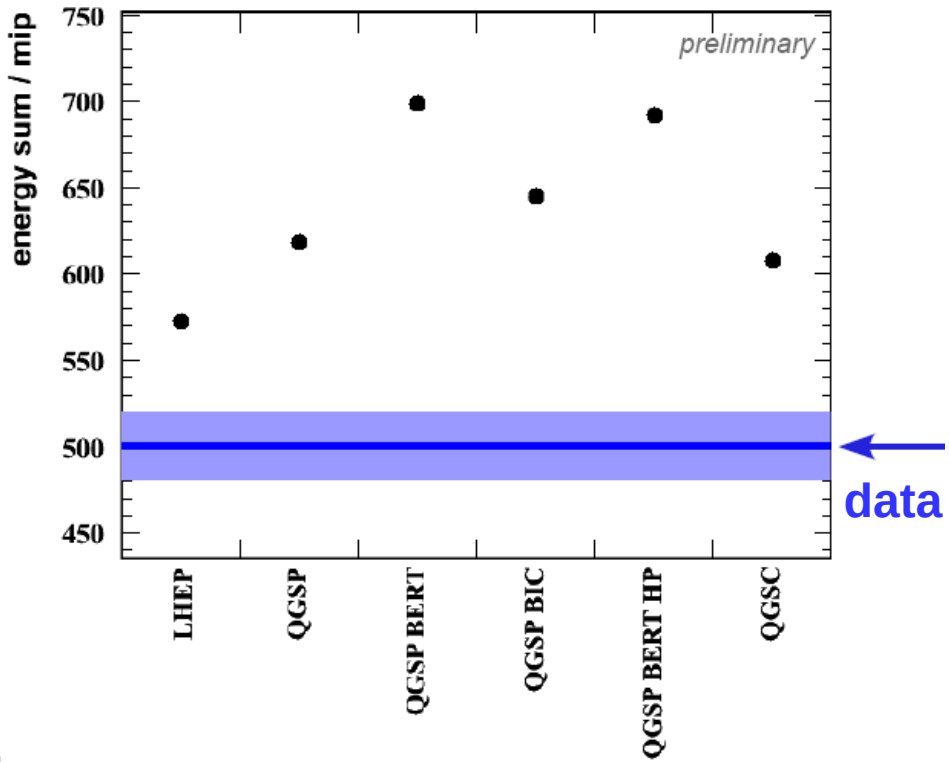
LEP under-production of pi0 is compensated in high energy shower by over-production in HEP when used alone LEP does a bad job

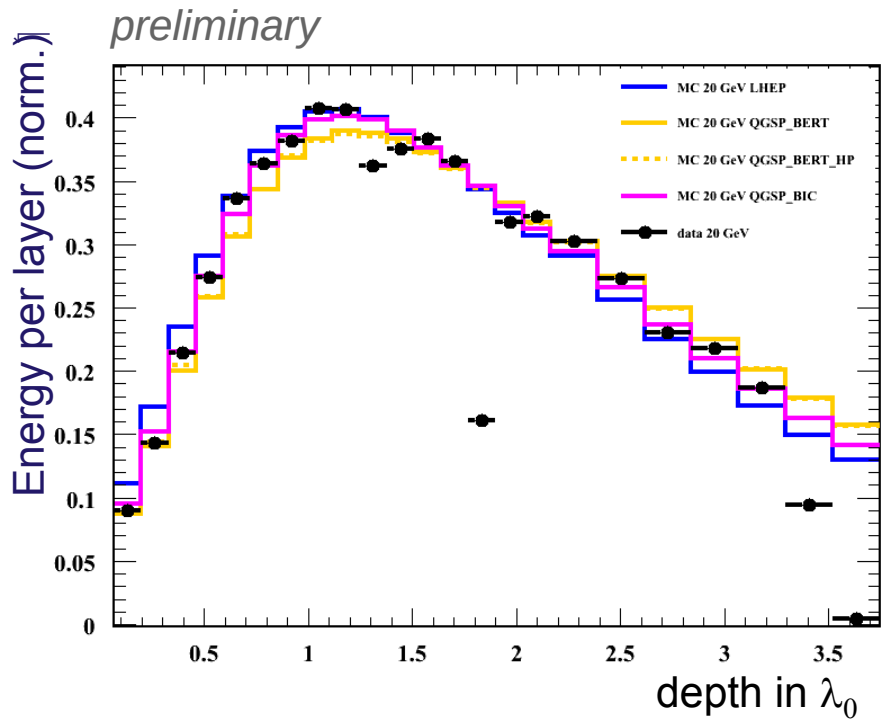
from G4: we need to replace LEP with a better model for pions ➔ !!!
no LHEP_Bert mentioned

HCAL pion analysis (OW)

20 GeV pion shower, HCAL 2006 is used, track in ECAL required

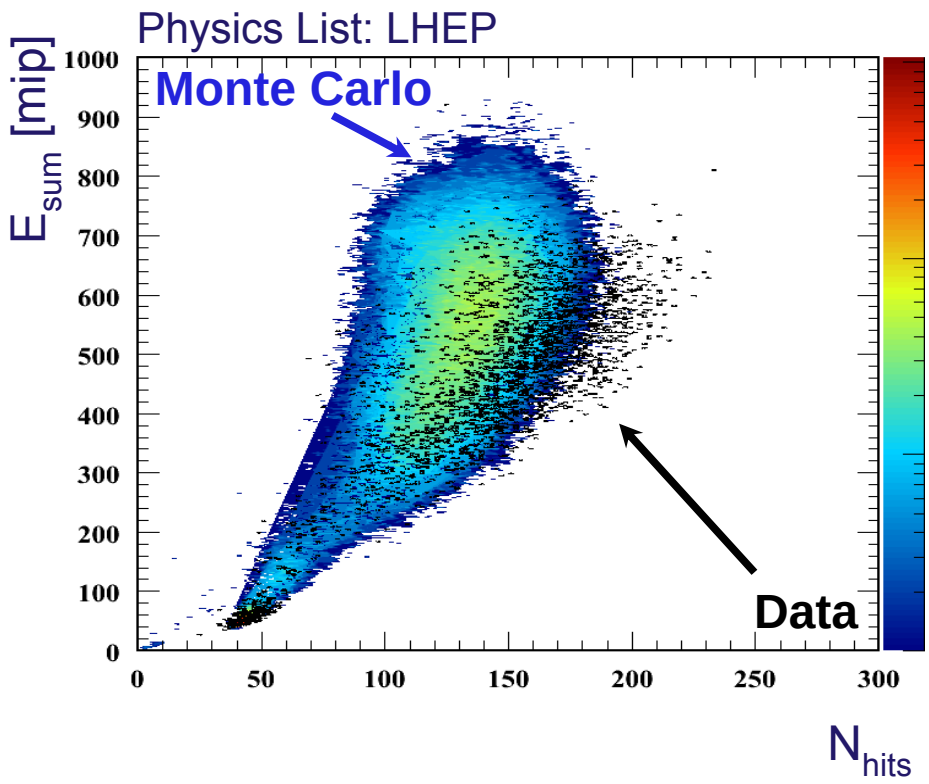
no threshold / no digitalization in MC !!

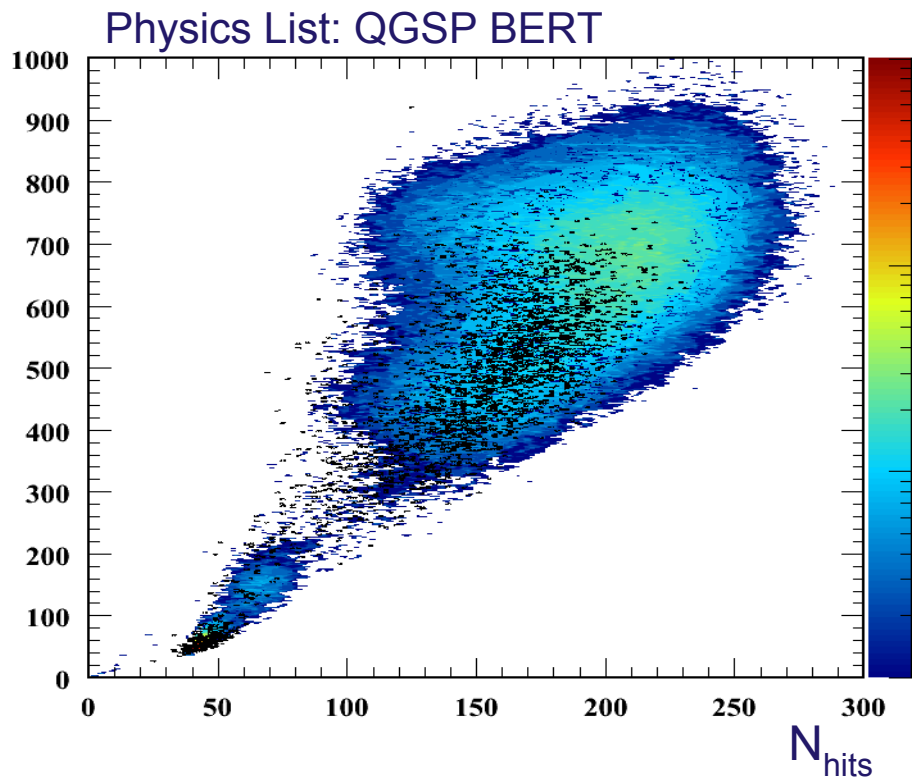




too early to draw conclusion on which phys. list is favored by the data

more power on MC models discrimination

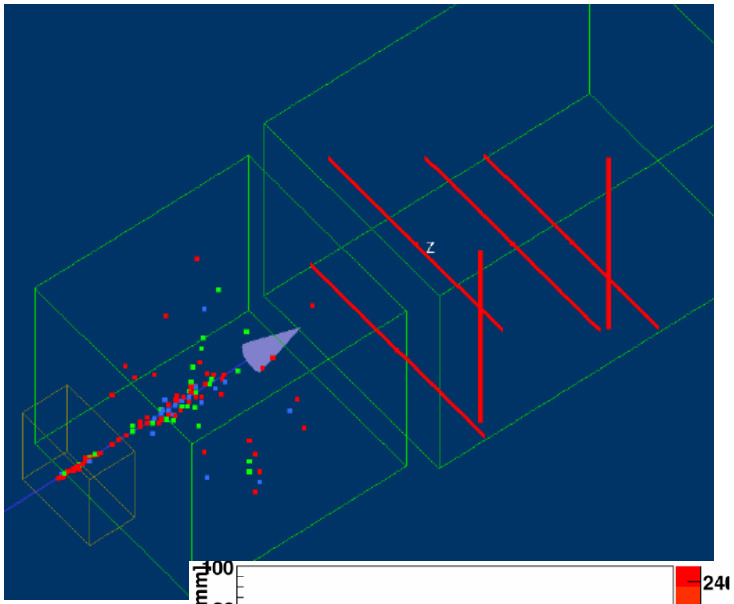


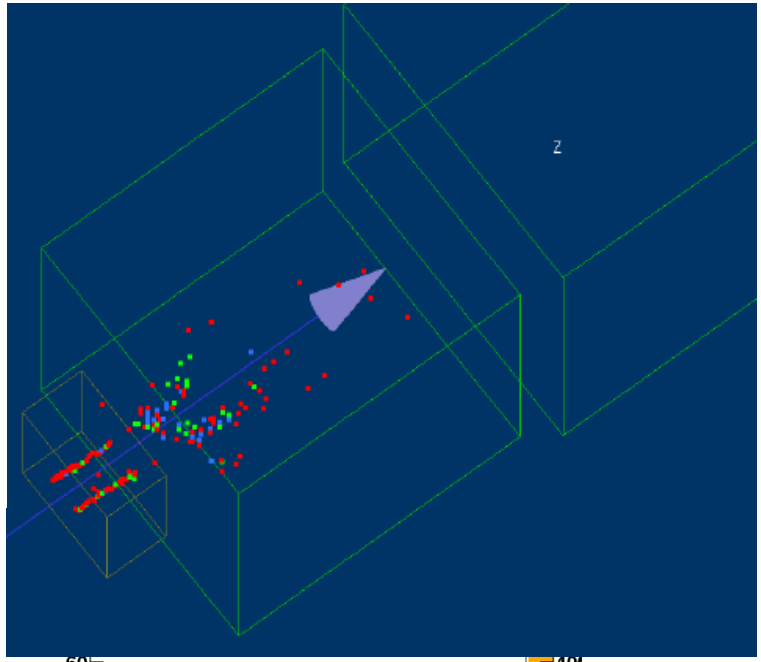


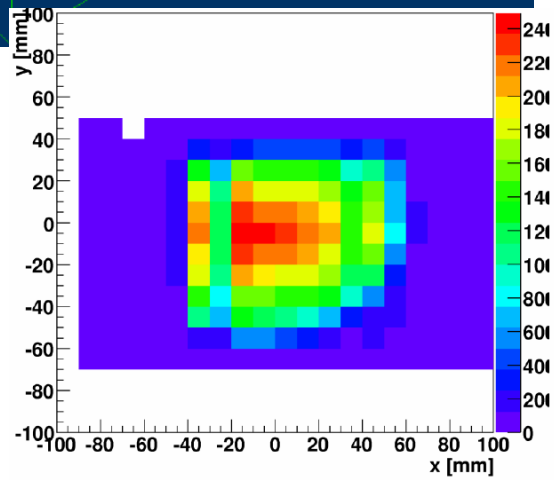
different correlations can be used to better discriminate between MC models

… after correct calibration and proper threshold cut in MC

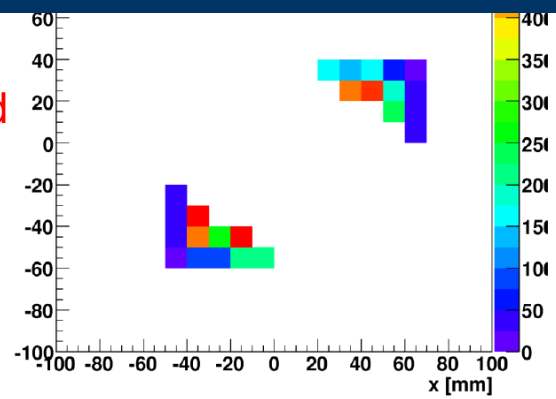
Overlay of showers







select events
with distance >d

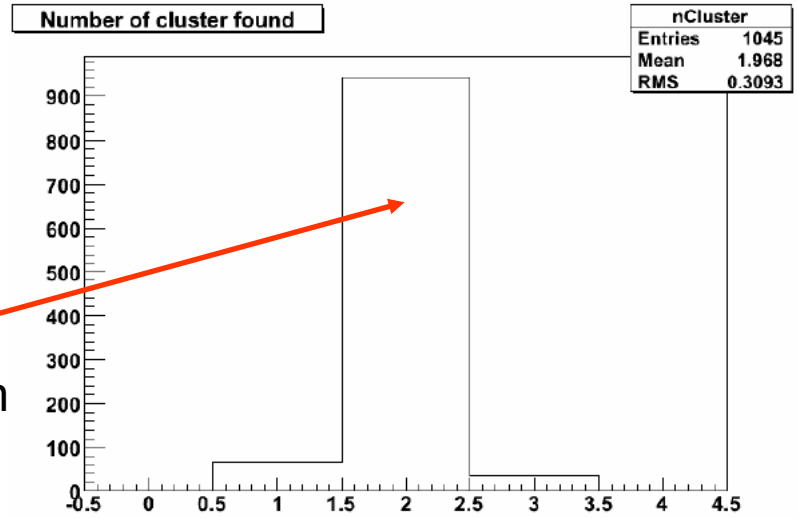


Shower clustering

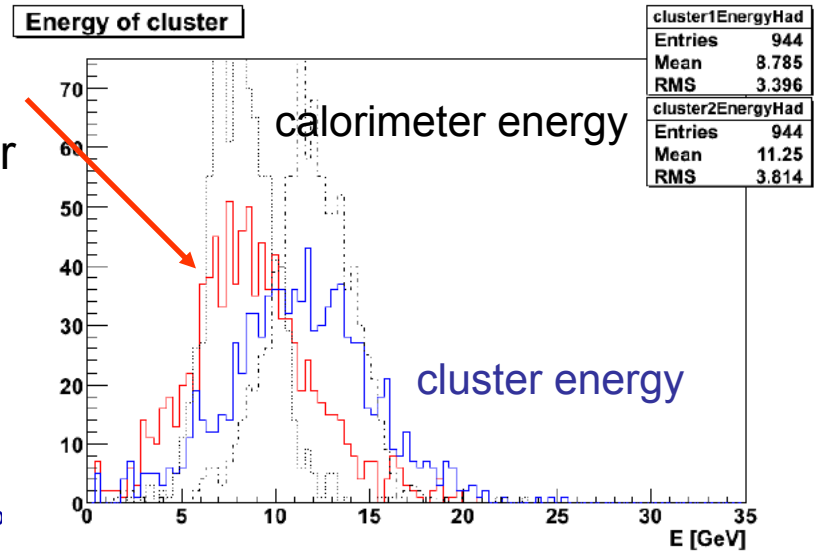
Track-wise clustering algorithm applied to overlaid showers

example for 8 GeV and 12 GeV pions

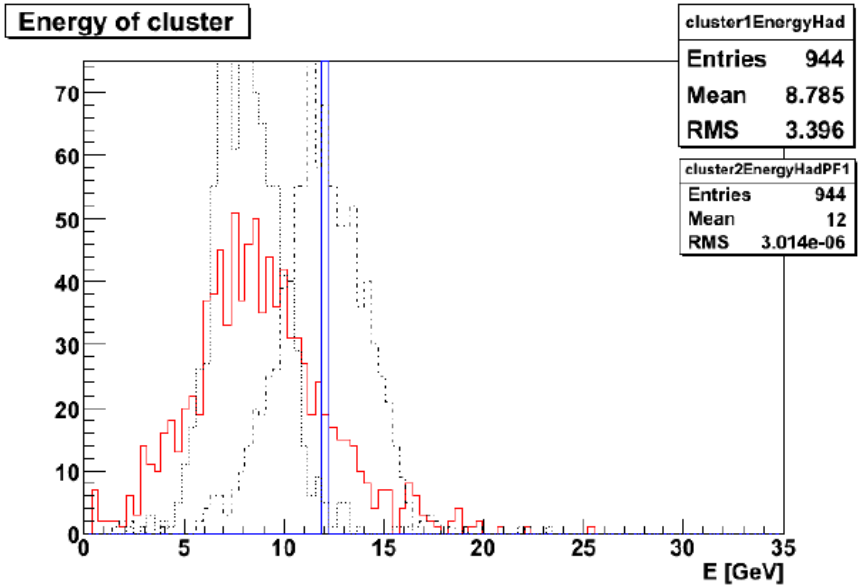
➔efficiency of 2 cluster found > 90% for 10 cm distance between clusters

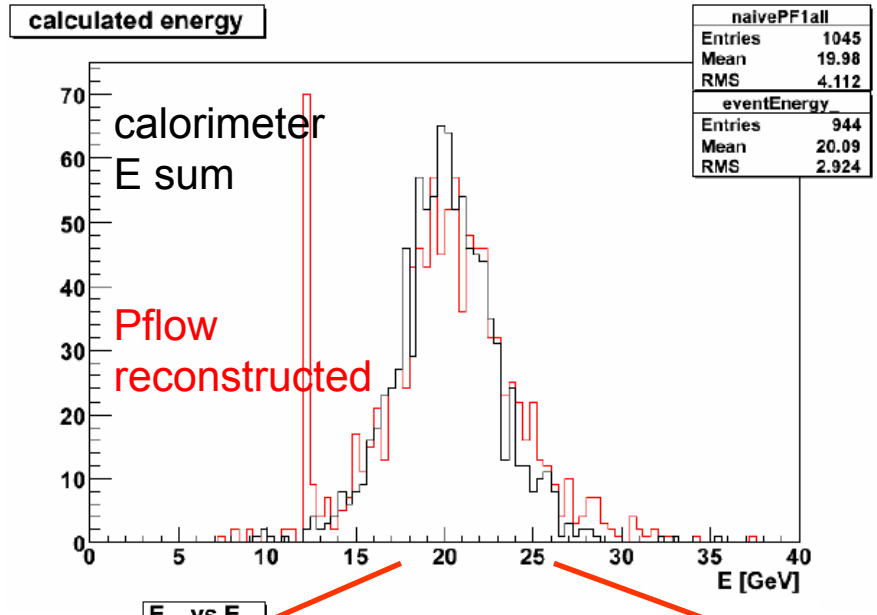


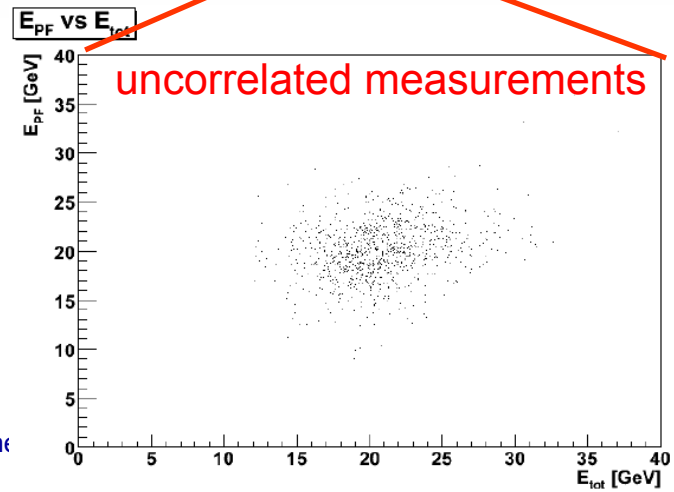
➔cluster energy has a broader distribution than reconstructed particle energy in calorimeter



Naïve particle flow



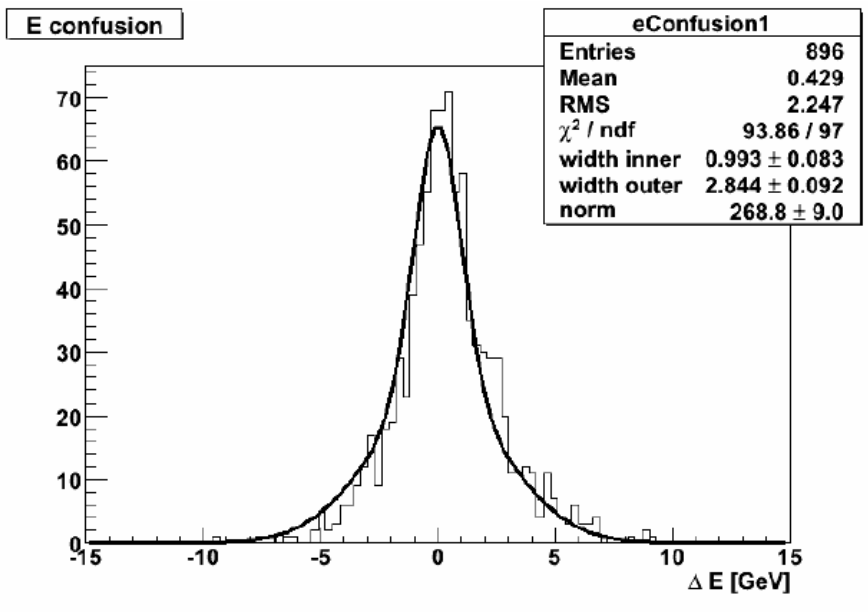




from reconstructed clusters
- assume one to belong to a charge particle
- substitute energy with known momentum
- sum clusters to a Pflow reconstructed object

compare to E sum in the calorimeter

Figure of Merit



knowing the true energy in the calorimeter Figure of Merit of this technique is

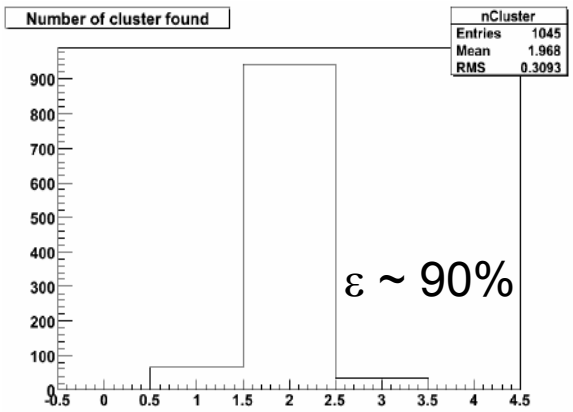
$\Delta E = E\_Pflow - E\_calo$

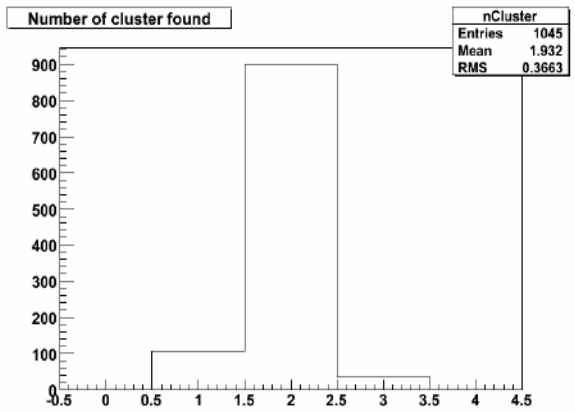
double Gaussian fit with fix amplitude ratio

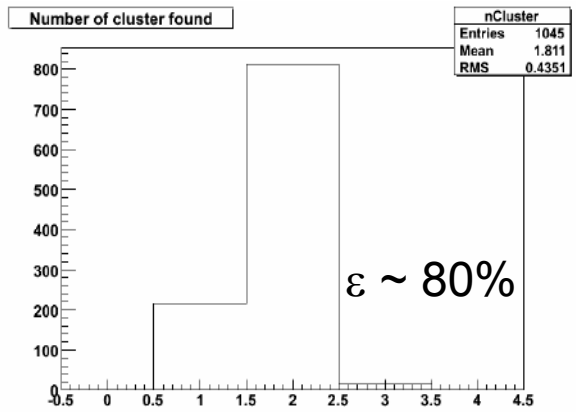
inner Gaussian width proportional to confusion term

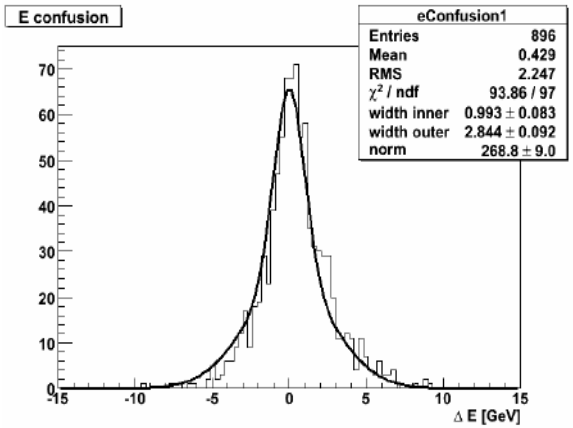
indication from this study:
for a 20 GeV “jet” made of two particles at a distance of 10 cm
the energy reconstructed in the HCAL using a Naïve Pflow method has
~1 GeV confusion term
at this point confusion eats up the advantages of the Pflow approach (in this ex.)

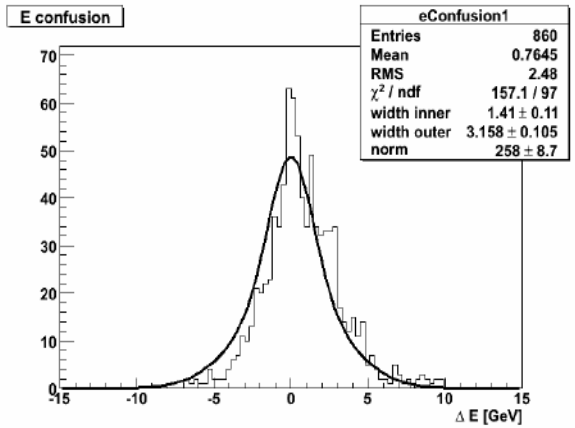
Dependence on particle distance

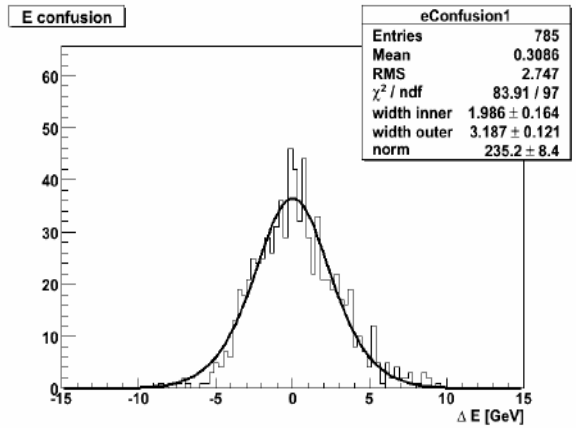












10 cm

σ_G = 1 GeV

7.5 cm

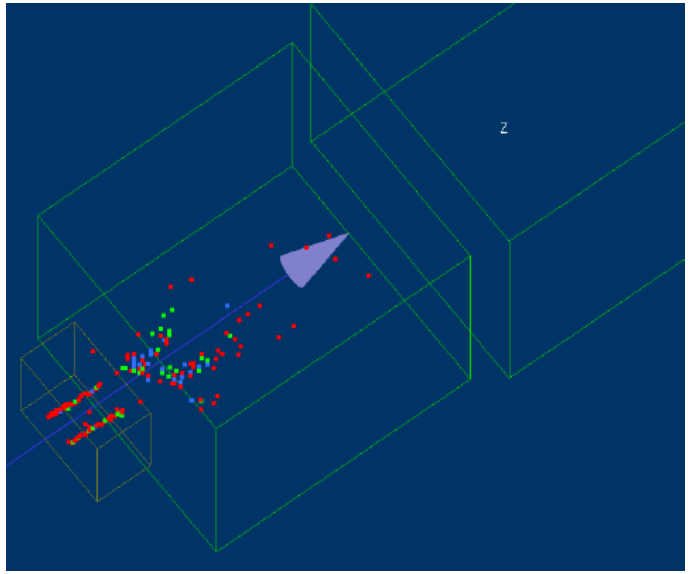
σ_G = 1.4 GeV

5 cm

σ_G = 2 GeV

Warnings & disclaims

- the selection of pion shower fully contained in the HCAL might bias the result
- the fact that both particles have mip-like stubs helps the clustering algorithm
- only one clustering algorithm tested (Track-wise clustering)
  ➔ this method can be used to compare various clustering algorithms



- a real jet is much more complex then two particles
- a real Pflow algorithm is also more complex, more screws to turn!

- no magnetic field in this studies

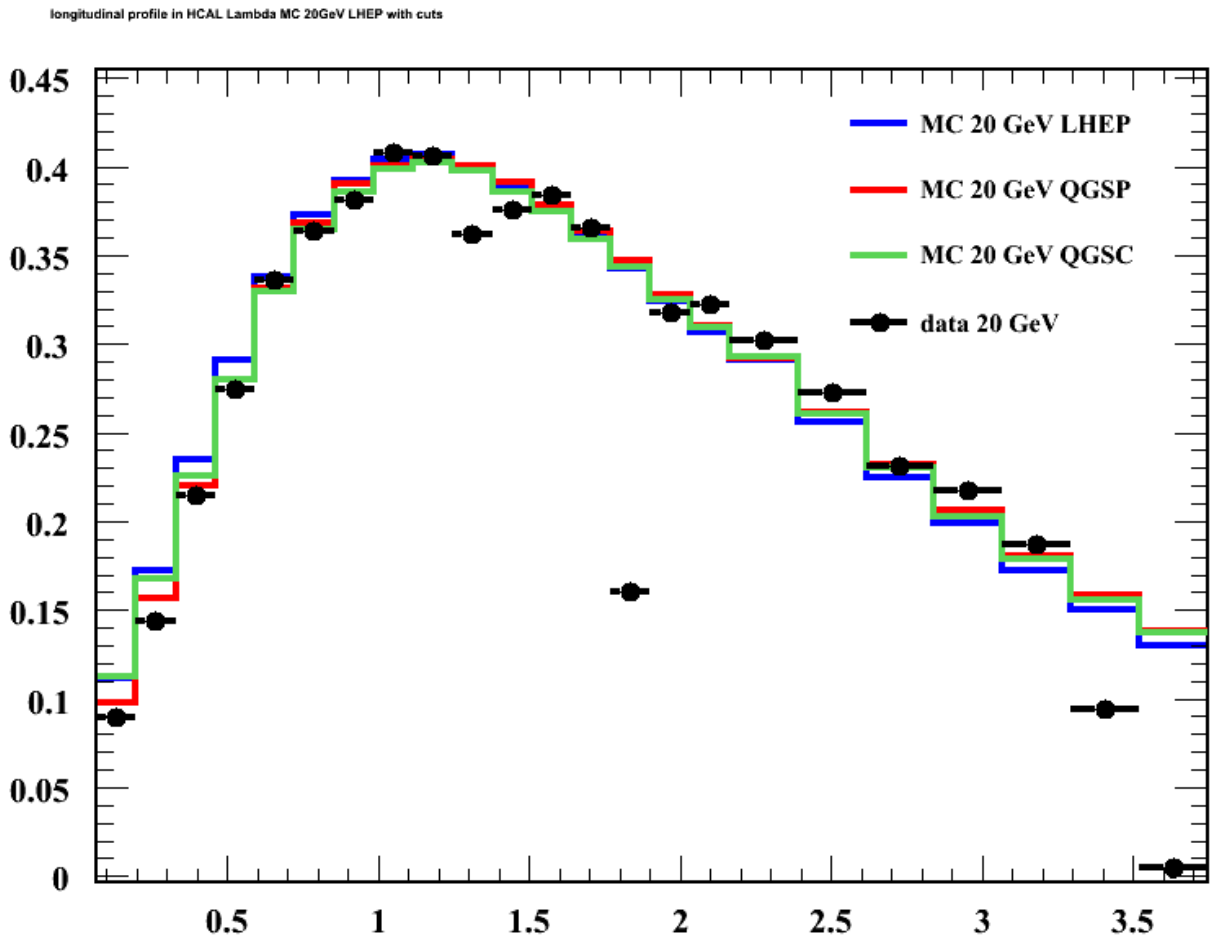
Conclusions

- serious analysis has started (also thanks to improved software)
- still lot of work to establish HCAL calibration procedure to the % level

- pion analysis is progressing in parallel with EM validation
- we can reach good discrimination power between various MC
- but first calibration has to be solid

- the data collected at the CERN test beam are used to test the particle flow with real hadronic showers
- the test is at present still naïve but with comparison to simulation can provide important insight for particle flow development

Backup


longitudinal profile in HCAL Lambda MC 20GeV LHEP with cuts
MC 20 GeV LHEP
MC 20 GeV QGSP
MC 20 GeV QGSC
data 20 GeV
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.5
1
1.5
2
2.5
3
3.5