Software Compensation in PandoraPFANew

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Outline

Idea of Software Compensation

Non-compensating calorimeters in ILD

$\Downarrow$

Try to reach $\frac{e}{\pi} = 1$ with software compensation

$\Downarrow$

Distinguish between electromagnetic and hadronic shower parts

- Electromagnetic showers tend to be denser than hadronic ones
- The higher the energy density, the higher the propability to be an electromagnetic shower component
- Electromagnetic shower hits get lower weights in overall energy sum than hadronic ones
- Weights depend on detector (ECAL, HCAL), hit energy density and hadronic cluster energy (ILD00)

General extraction / parameterization on of weights

Extraction of weights:

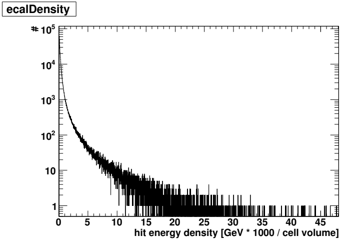
- Deviation of hit energy density (ED) in several bins for ECAL and HCAL
- One weight ω per energy density bin
- $E_{rec} = \sum_{hit,\textbf{ecal}} E_{hit,\textbf{ecal}} \cdot \omega_{\textbf{ecal}} + \sum E_{hit,\textbf{hcal}} \cdot \omega_{\textbf{hcal}}$
  - Lower weight for higher energy density:
    $\omega_{ecal} = p_{0,ecal} \cdot ED + p_{1,ecal}$
    $\omega_{hcal} = p_{0,hcal} \cdot exp(p_{1,hcal} \cdot ED) + p_{2,hcal}$
- Weights need to be energy dependent:
  - Energy dependence of $p_{0,ecal}, p_{1,ecal}, p_{0,hcal}, p_{1,hcal}, p_{2,hcal}$
- Weights are found using the true energy of the clusters
- Minimization procedure to extract the appropriate weights

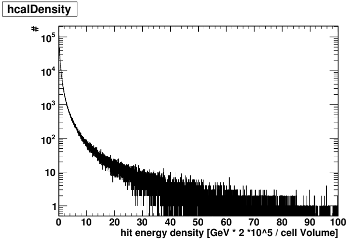
Application of software compensation:

- Input: hit energy density, hadronic cluster energy
- No deviation in energy density bins
- No use of true cluster energy

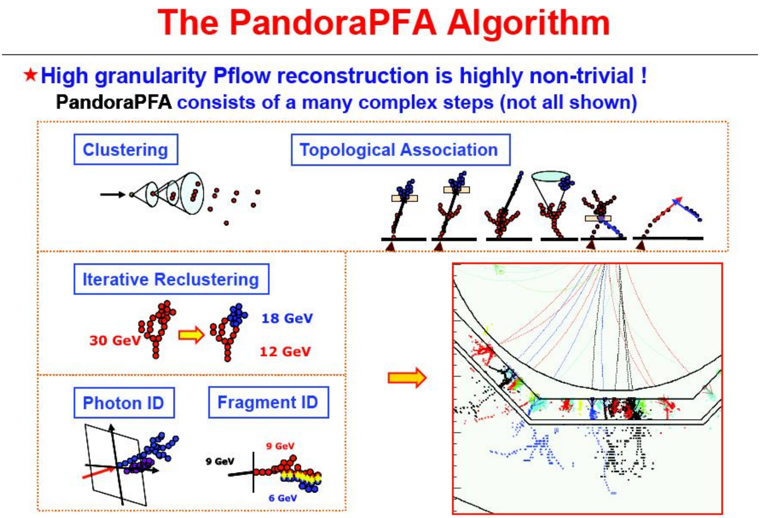
Development of weights

- Use events with defined cluster/ pfo energy $\Rightarrow K_L^0$ events (Thanks to Angela!), simulated with physics list: LCPhys
  - no tracks
  - one cluster/particle flow object per event
  - look at hit energy density of neutral hadronic clusters





Energy density for cluster hits in ECAL and HCAL (100 GeV).


The PandoraPFA Algorithm
★High granularity Pflow reconstruction is highly non-trivial !
PandoraPFA consists of a many complex steps (not all shown)
Clustering
Topological Association
Iterative Reclustering
30 GeV
18 GeV
12 GeV
Photon ID
Fragment ID
9 GeV
9 GeV
6 GeV

Application of Software Compensation

Inside PandoraPFA:

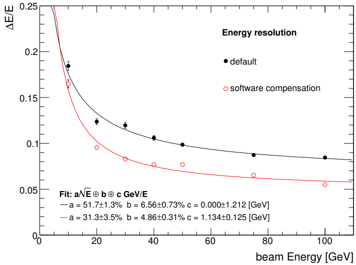
- Used during reclustering and during pfo creation
- Tested: software compensation as the only energy correction function and with the default energy correction functions
- Result: Improvement comparable with default energy correction functions

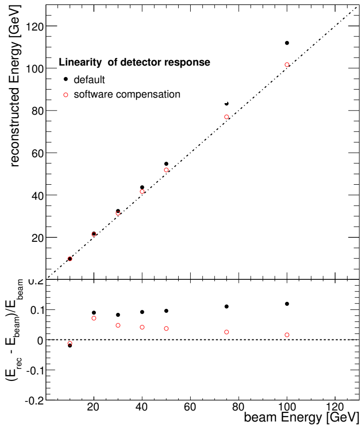
After PandoraPFA:

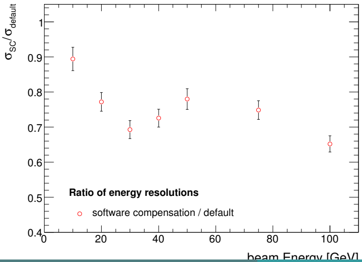
- Final step after PFO creation
- Only applied on neutral hadrons
- Default energy correction fucntions still used
- Results: Improvement better than default energy correction functions
  $\Rightarrow$ This is used for all following results

Improvement:

Software Compensation applied on the K_L^0 events simulated with physics list: LCPhys







Z $\rightarrow$ uds at 200 GeV - without Tracks

- Test on independent data set Z $\rightarrow$ uds at 200 GeV
- Simulation of Z $\rightarrow$ uds with physics list QGSP_BERT
- **Dropped all track collections!**
- Resolution given by the calorimeters only
- Gaussian fit of reconstructed energy

	default PandoraPFA	PandoraPFA + software compensation
E_{cm} [GeV]	200	200
E_{rec} [GeV]	205.4 $\pm$ 0.1	204.9 $\pm$ 0.1
σ_{rec} [GeV]	9.09 $\pm$ 0.09	8.65 $\pm$ 0.08

- Energy resolution improvement 4.61 %

Z $\rightarrow$ uds with Tracks

- Z $\rightarrow$ uds at various energies
- Events simulated with physics list QGSP_BERT
- Full particle flow performance (kept all track collections)
- Gaussian fit for E_{rec}
- RMS90 for width

Energy[GeV]	91	200	360	500
Default				
Default E_{rec} [GeV]	91.48±0.04	202.29±0.08	367.09±0.13	512.66±0.19
RMS90 [GeV]	2.58±0.05	5.03±0.08	9.58±0.12	14.42±0.19
RMS90/E_{rec} [%]	2.82±0.02	2.49±0.02	2.61±0.02	2.81±0.02
Software Compensation				
E_{rec} [GeV]	91.63±0.04	201.97±0.07	365.25±0.12	508.92±0.18
RMS90 [GeV]	2.56±0.03	4.81±0.09	9.15±0.12	13.74±0.17
RMS90/E_{rec} [%]	2.79±0.02	2.38±0.02	2.51±0.02	2.70±0.02
Improvement [%]	1.06	4.42	3.83	3.91

Comments (for experts):

- Changed MaxHCalHitHadronicEnergy in PandoraPFA from 1. to 100. (GeV)

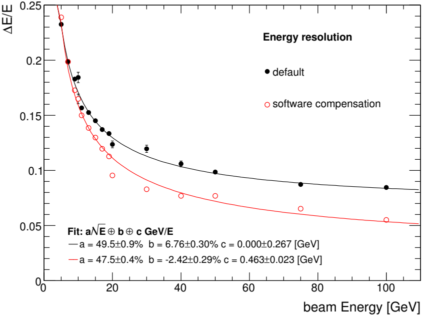
- No KinkFinder used so far
- Parametrization of weights for software compensation extracted with physcis list LCPhys
  Application to events simulated with physics list: QGSP_BERT
  ⇒ Same physics list should improve results

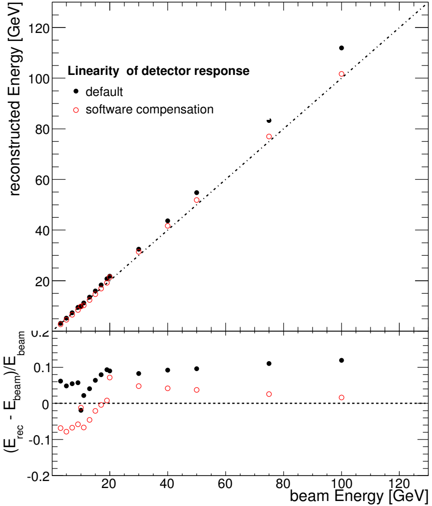
- At the moment: Software Compensation included in MarlinPandora
  Future: Software Compensation as an own Pandora algorithm, after PFO creation

- More energy set for extraction of weights could lead to a further improvement, specially at small energies ⇒ closer look at the dip between 10 GeV and 20 GeV

K_L^0 events with physics list QGSP_BERT at low energies

Dip at 10 GeV. Most likely due to physics list composition





Summary and Outlook

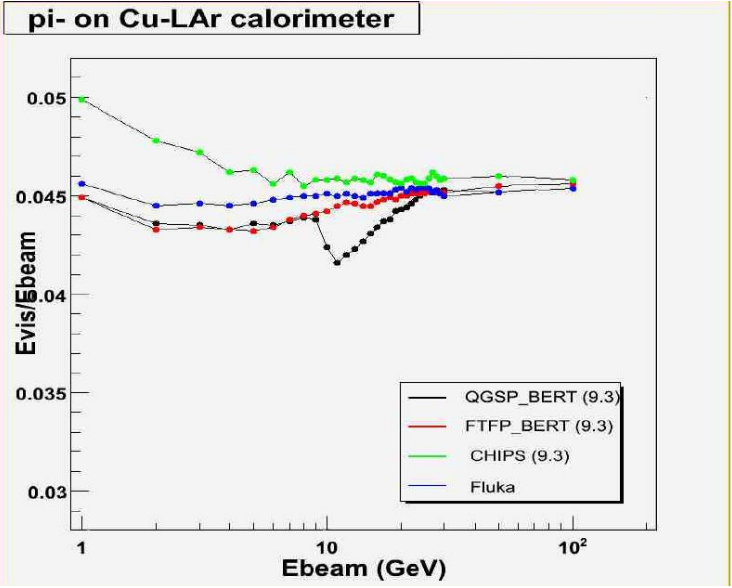
Summary:

- Development of Software Compensation technique for neutral hadronic clusters in ILD00
- Software Compensation improves energy resolution up to 4 %

Outlook:

- Improve technique for PandoraPFA
- Use of different physics list
- Use of other particles for extraction of weights:
  π^- Events with no tracks (drop track collections) $\Rightarrow$ Application of software compensation for all clusters in the reclustering phase. Improvement of energy resolution with software compensation during the reclustering ?

Phyiscs List behavior



Physics Lists:

LCPhys

- K_L^0**:** hadron inelastic scattering
  Bertini cascade : 0 - 13 GeV
  Quark-gluon String with Precompound : 12 GeV - 100 TeV

- π^-**:** hadron inelastic scattering
  Bertini cascade : 0 - 9.9 GeV
  Low Energy Parameterized : 9.5 - 25 GeV
  Quark-gluon String with Precompound : 12 GeV - 100 TeV

QGSP_BERT

- same for K_L^0 ??
- same for π^-