A Study on Leakage and Energy Resolution

Ivan Marchesini , CALICE Collaboration Meeting, 2010-09-22

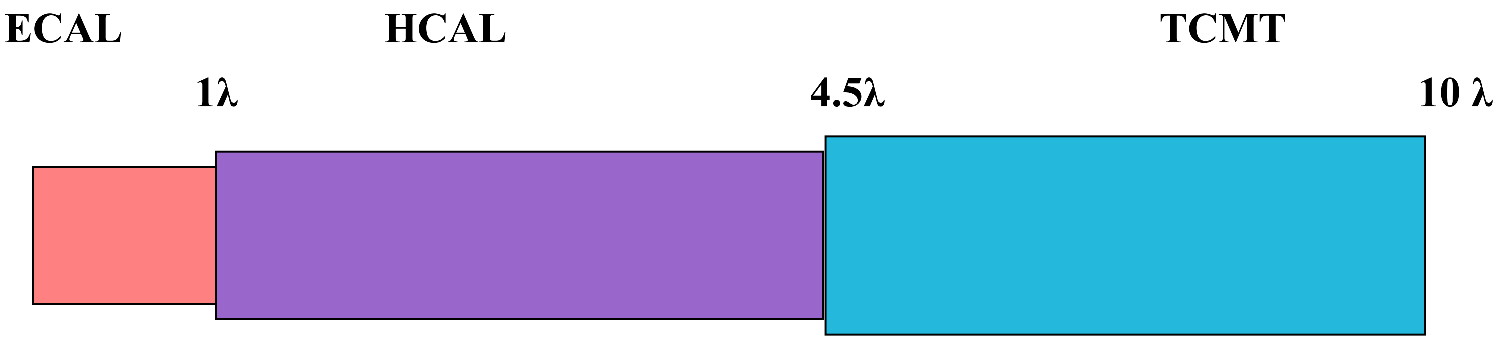
Outlook

- Introduction.
- Pion event selection.
- Variables sensitive to the leakage:
  - Shower Start;
  - End-Fraction.
- A correction to the leakage.
- Comments and next steps.

Introduction

Cern 2007 Prototype

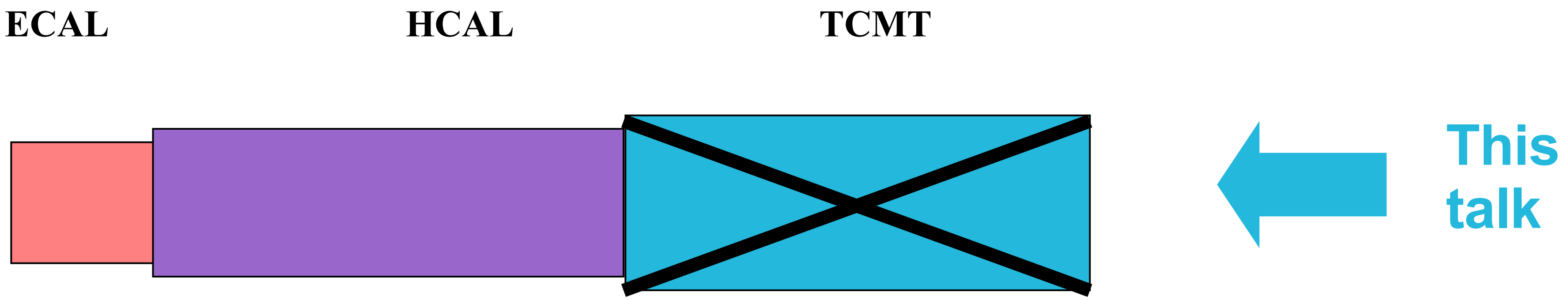
- This study uses **pion** data collected in 2007 at CERN by the CALICE prototype.



- ECAL+HCAL+TMCT: leakage from the complete set-up very small, in the energy region of interest of ILD.

Tasks of the Study - 1

1) Study a correction to the leakage from the HCAL, using the **HCAL alone**, without TCMT information.



- In an ILD/Particle Flow perspective a correction to the leakage essentially matters for the **neutrals** (study on the pions easily transferable).

Tasks of the Study – 1

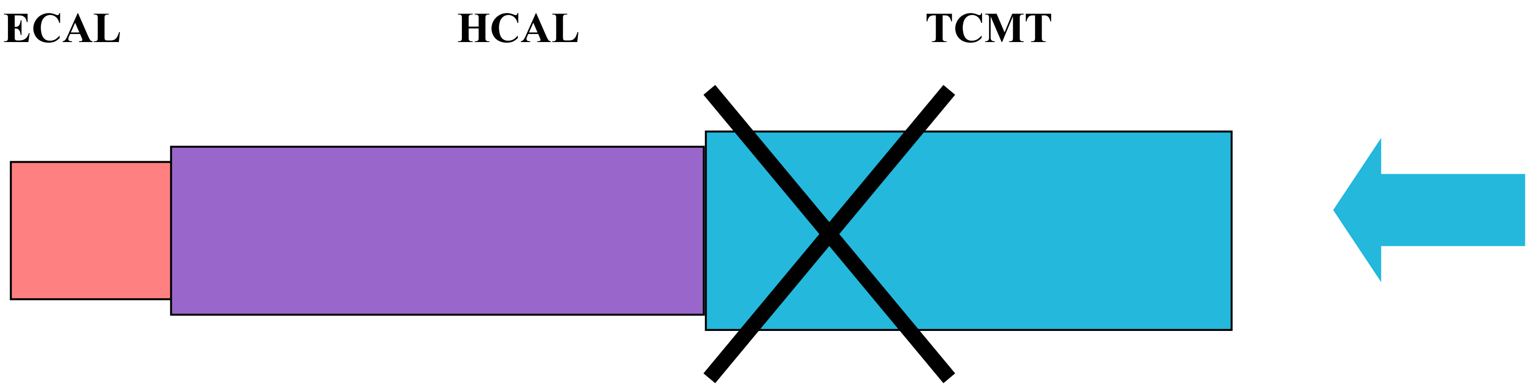
- This part of the study does not consider the **punchthrough** pions, that start showering in the TCMT (~1%).

- Studies of corrections to the leakage, so far:
  - developed in an **idealistic** case: using the a-priori knowledge of the beam energy.
  - power: **14%** sigma/mean **relative** improvement at 80 GeV (B.Lutz PhD Thesis).

- Main task of the study is to develop a **realistic** correction: no a-priori knowledge of the beam energy.

Tasks of the Study - 2

2) In ILD **non-instrumented coil** between HCAL and TMCT. Can be simulated removing information from the first TCMT layers. See the benefit of having additionally a **TCMT** in such an ILD-like configuration:



Not in this talk

Single Pion Event Selection

Event Selection

- **CERN 2007** pion$^-$ runs. Examples for **80 GeV** run 330962.

- Cuts:
  - 0.5 MIP threshold.
  - TRIGGER:
    - BeamBit==1;
    - b100x100Bit==0 no muons.
    - CherenkowBit==0 no electrons.
  - **Shower start in the HCAL**:
    - Marina processor: shower start after HCAL layer 2.
    - Currently excluding also layers 37, 38, since the processor puts the punchthrough at the end of the HCAL.
    - Triangle cut included: E TCMT vs E HCAL+ECAL for muon rejection.
  - Further muon rejection. Frac-10 cut: E hits > 10 MIPs / total E > 0.01 (for ECAL + HCAL + TCMT).

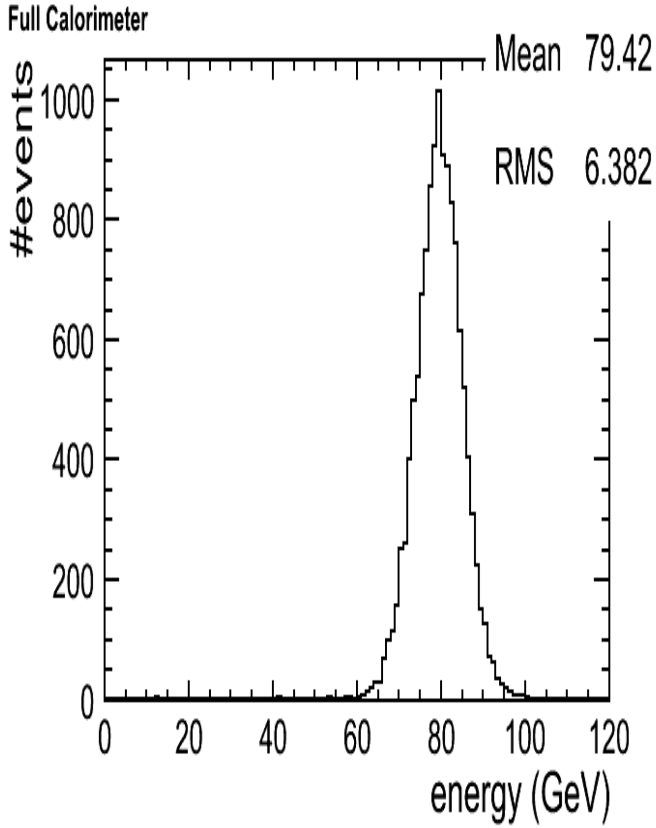
Note

- Selecting a **subsample** of the full sample, with **more leakage** from the HCAL in average, than the full-sample:
  - → Using the ECAL only as a tracker reduces systematics and simplifies selection and analysis.
  - → Negligible amount of events with leakage excluded.

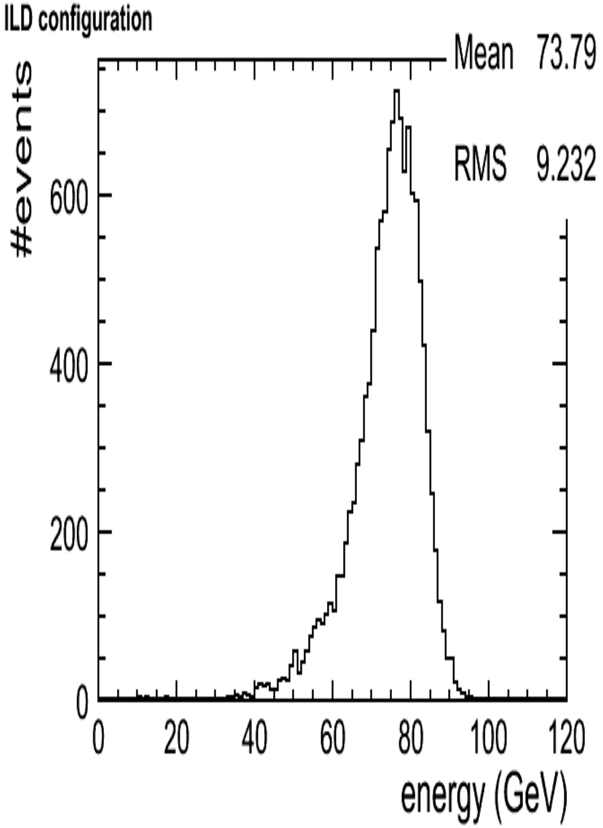
- Study is not biased, but one needs to remember that the effect of the leakage from the HCAL, on the energy resolution, is **amplified**, when comparing with the full sample.

Total Energy

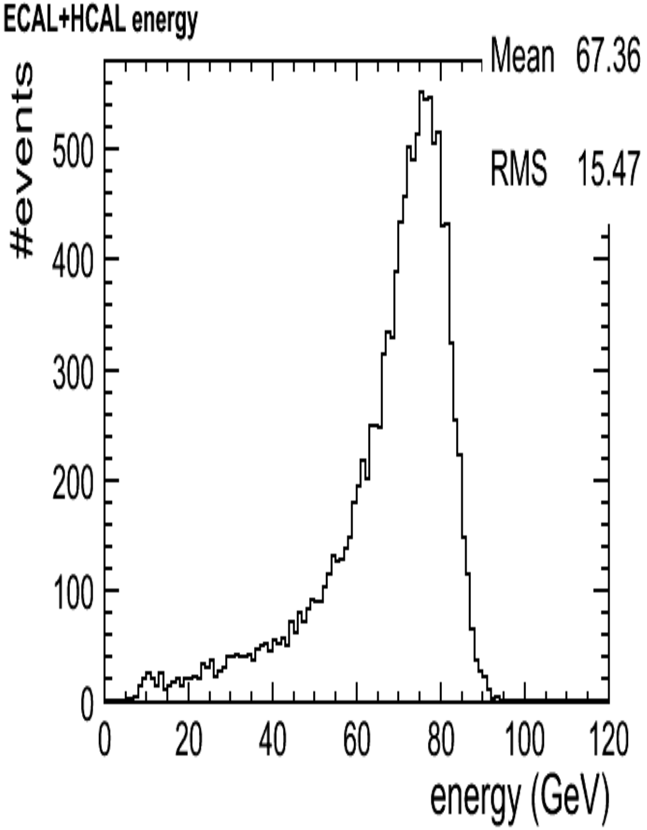
All



ECAL+HCAL+~~COIL~~ +TCMT = ILD



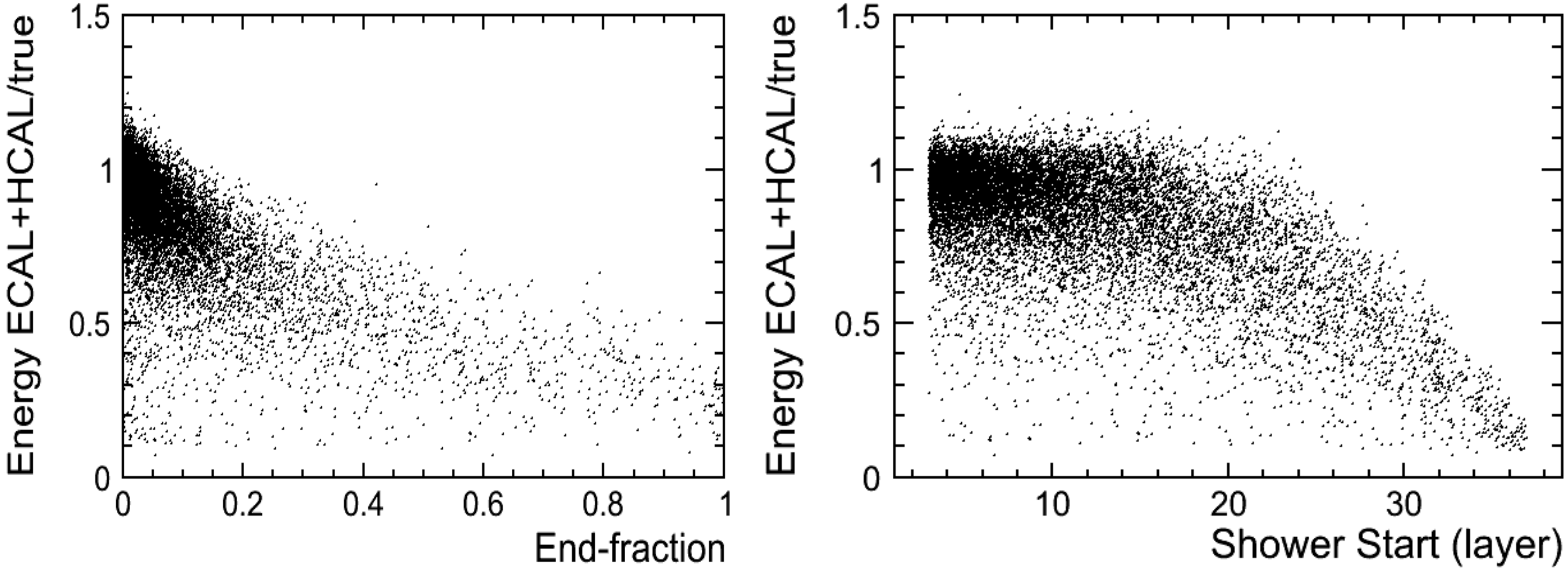
ECAL+HCAL



Variables Sensitive to Leakage

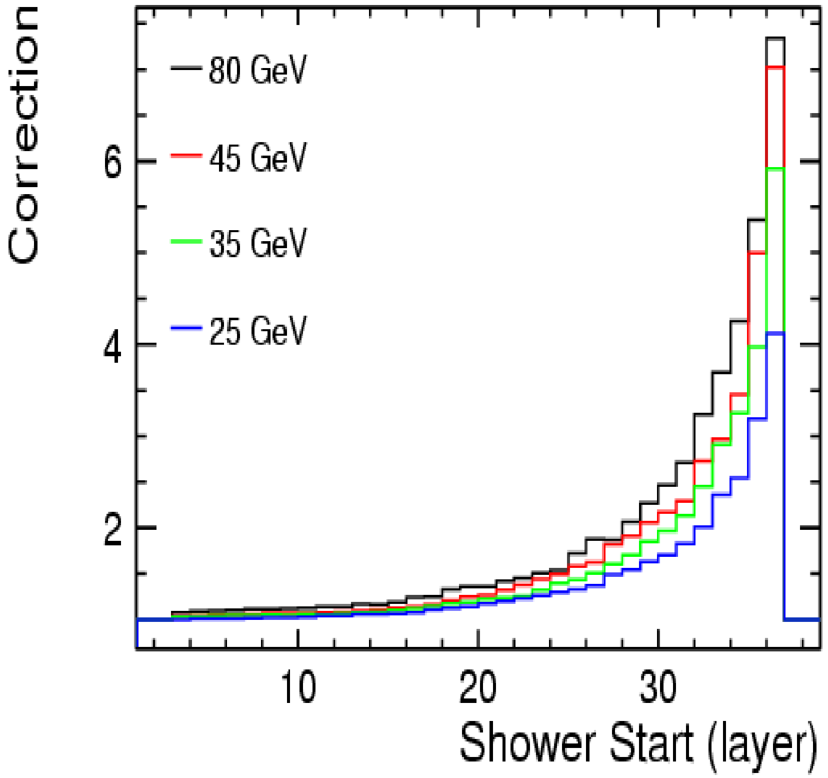
End-fraction & Shower Start

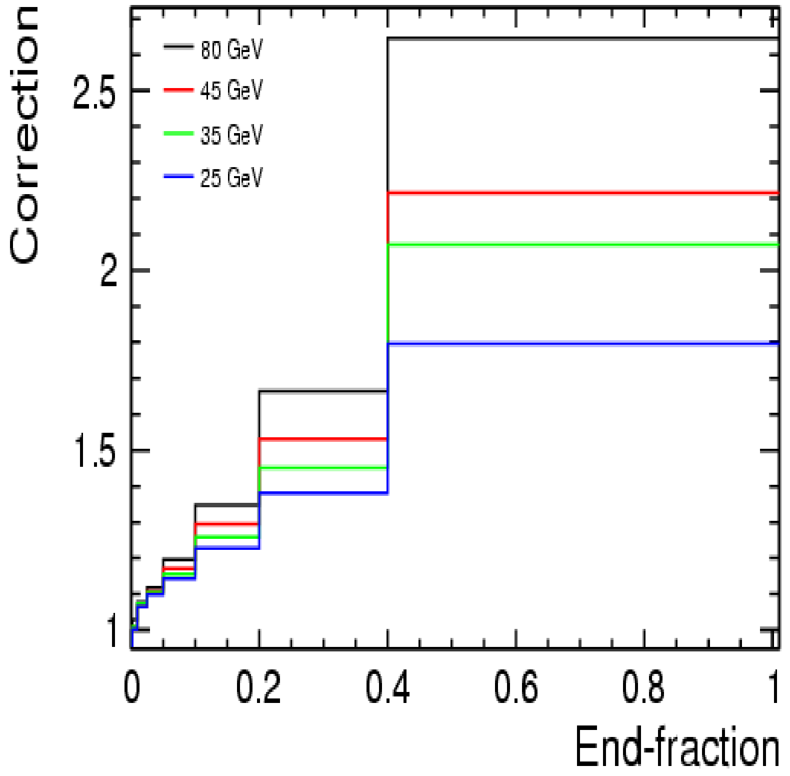
- End-fraction: fraction of measured energy from the shower start deposited in the end (**last 4 layers**) of the HCAL:
  - High End-fraction -> shower not concluded -> high leakage;
  - Low End-fraction -> shower almost concluded -> low leakage.



Correction (Idealistic Case)

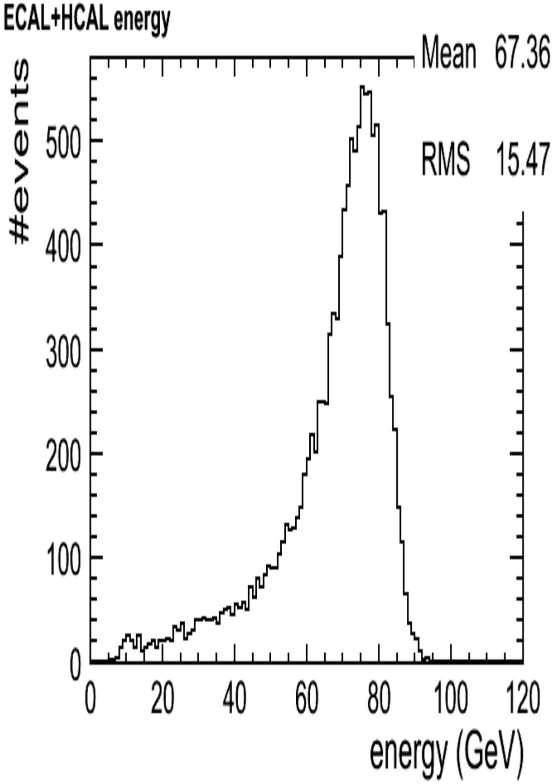
- Correction can be obtained, strongly **energy dependent**.
- Here applied in the idealist case (correction chosen depending on beam energy information).



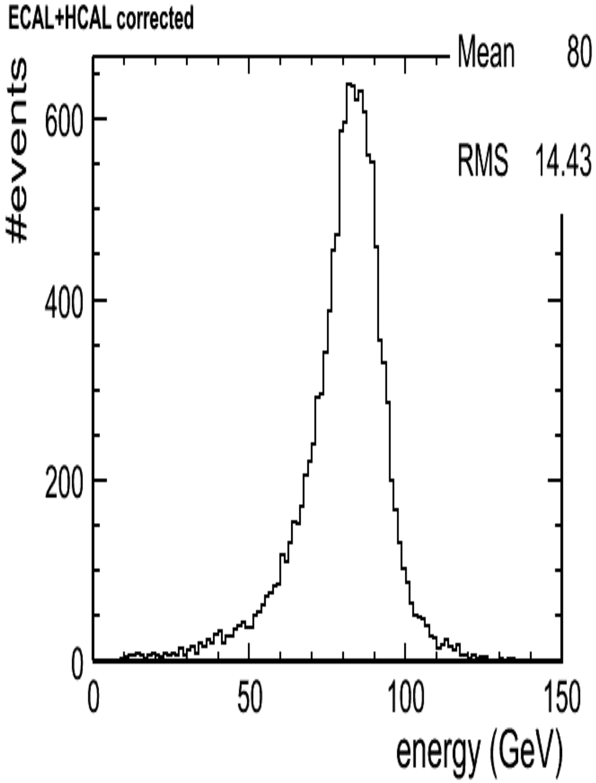


Result

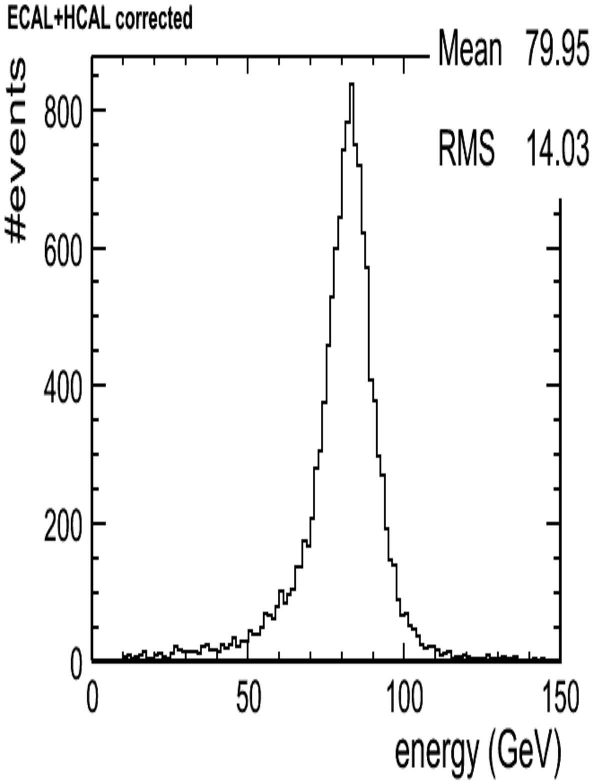
- Mean value recovered and RMS reduced.
- Power of the two corrections comparable: RMS/Mean relative improvement ~ 20%.



Uncorrected



Shower Start Corr



End-Fraction Corr

Correction to the Leakage

Content

- Shower start and End-fraction: sensitive to the leakage but corrections are energy dependent.

- Idea: add **measured energy** observable to obtain an energy independent correction.

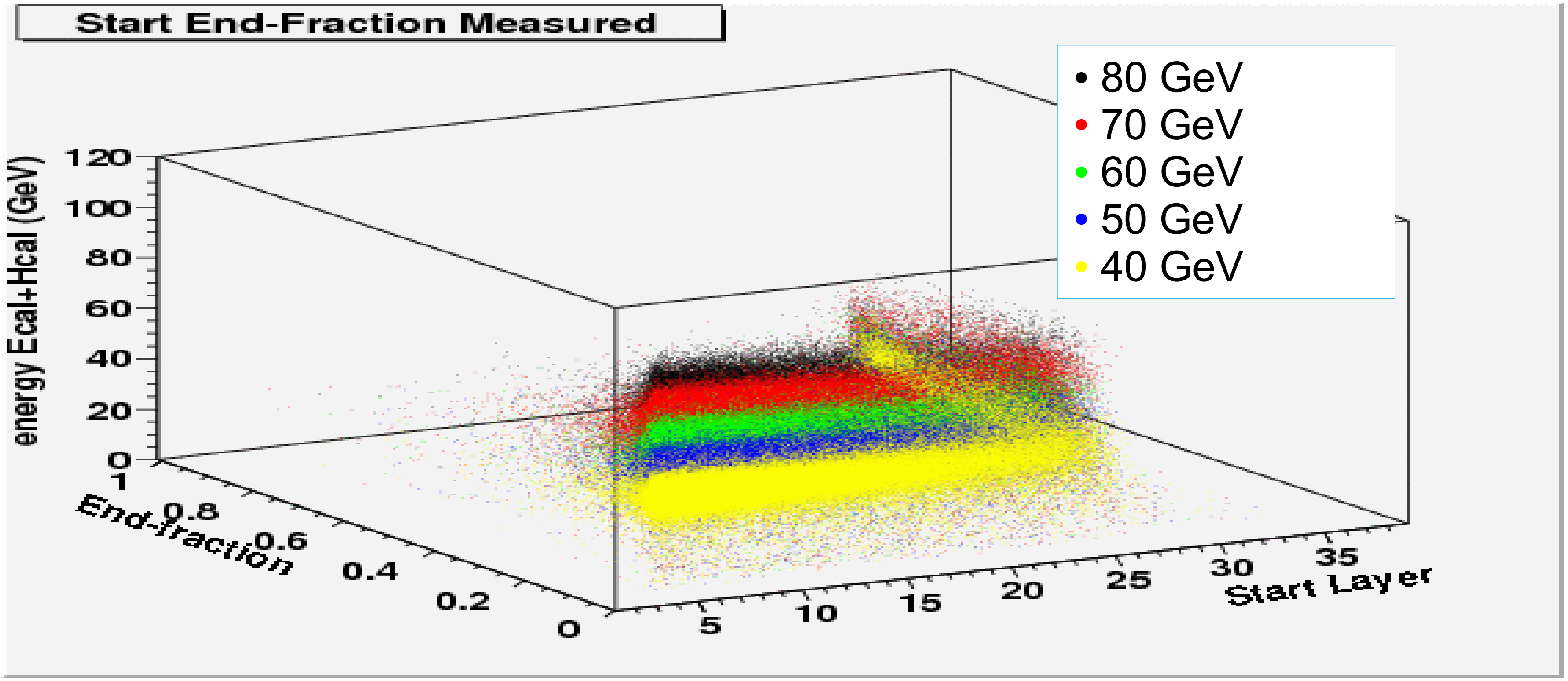
- I present here a **Monte Carlo study**.

- Monte Carlo files:
  - physics list: FTFP_BERT;
  - detector model: TBCern0707_p0709.

- Correction studied over the full energy range [2.5, 100] GeV.

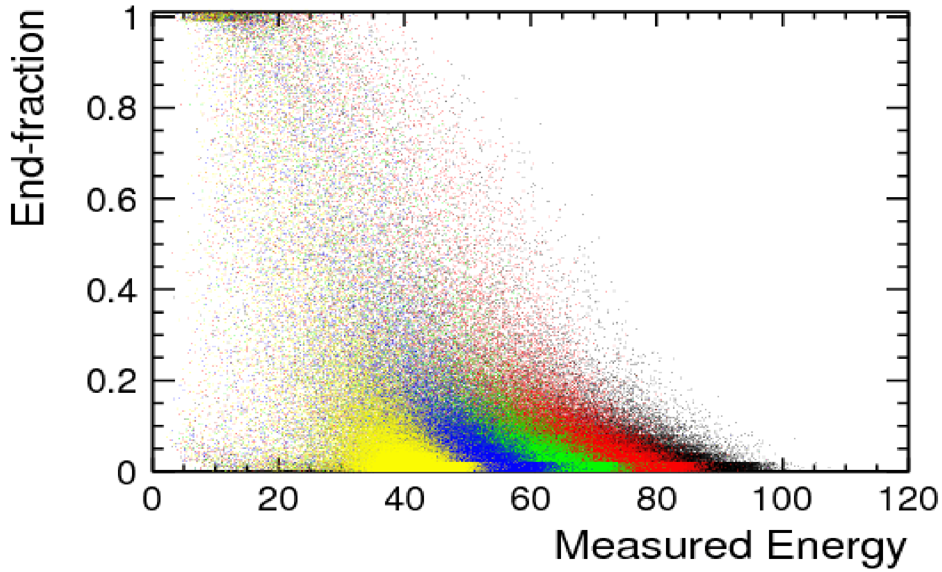
3D Distribution

- X: shower start layer;
- Y: End-fraction;
- Z: measured energy (Ecal+Hcal).

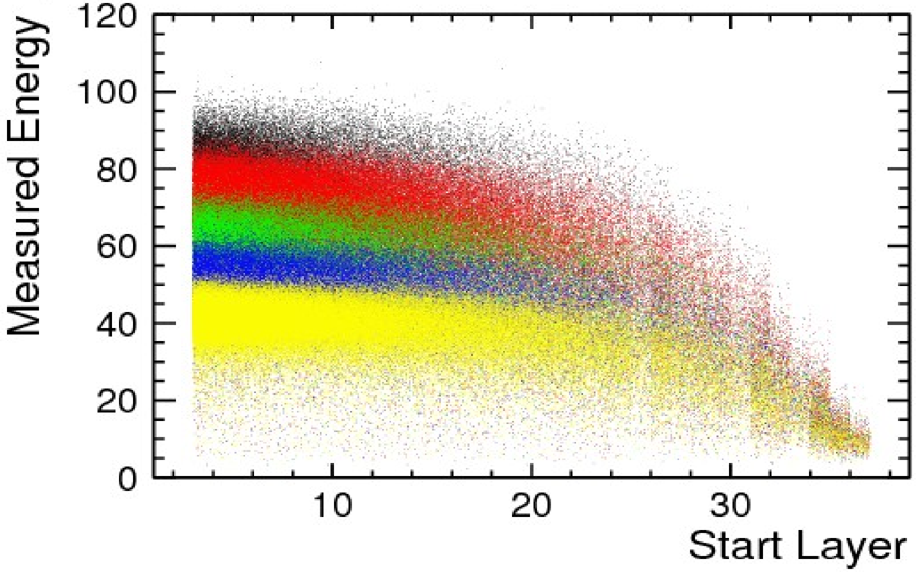


2D Projections

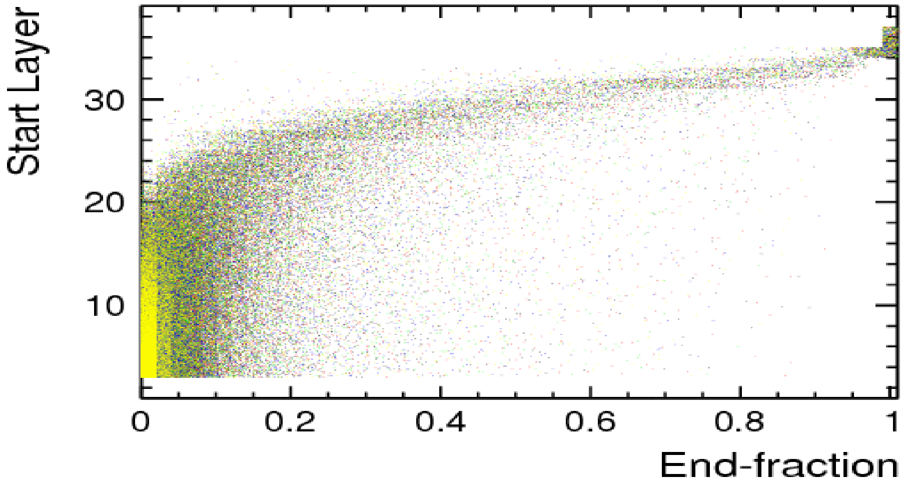
2D projection



2D projection



2D projection



- ● 80 GeV
- ● 70 GeV
- ● 60 GeV
- ● 50 GeV
- ● 40 GeV

Correction Structure

- Different energies cover different regions of the 3D space, though with overlaps.

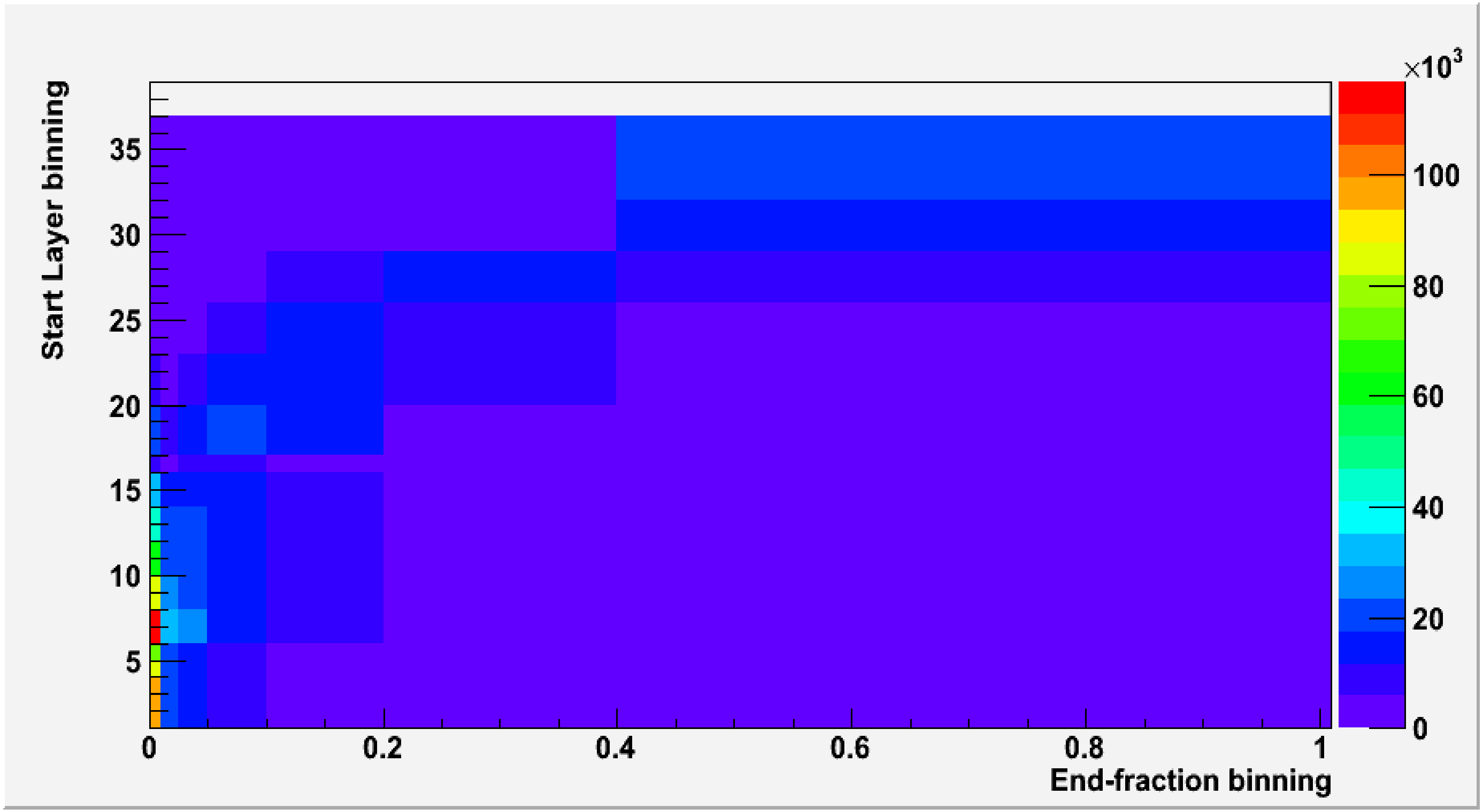
- Idea: use the **position in the 3D space** to replace the beam energy information use.

- Note: shower start finder uses the beam energy information, but a new version which uses the measured energy already implemented (Alex and Marina) and included in the new software release of last week.

- Build a template using energies from [2.5,100] GeV. Apply the correction to energies not used to build the template, to assure statistical independence.

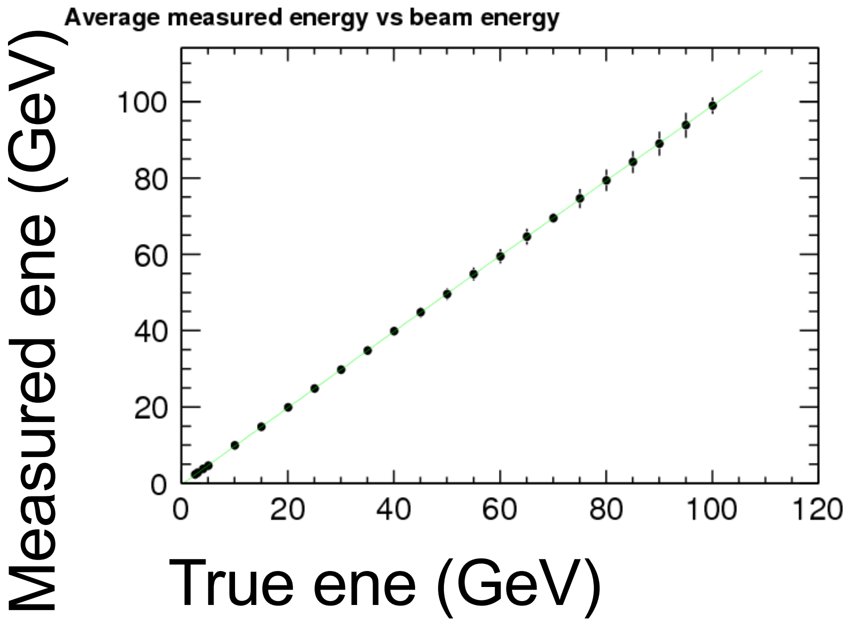
Fit: Step 1

- Shower start/ End-fraction 2D distributions.

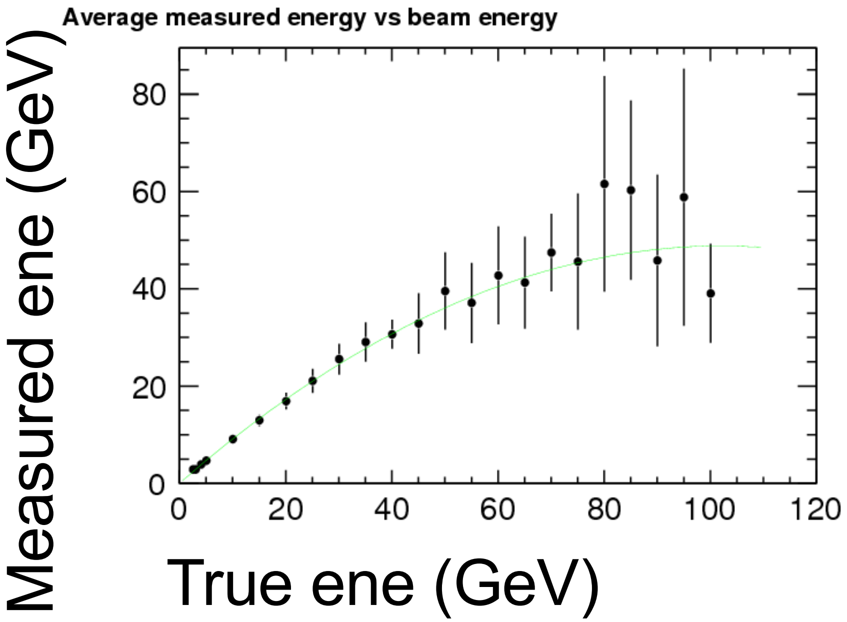


Fit: Step 2

- For each bin Shower start/ End-fraction 2D distributions correction based on the plot: average measured energy vs true beam energy.



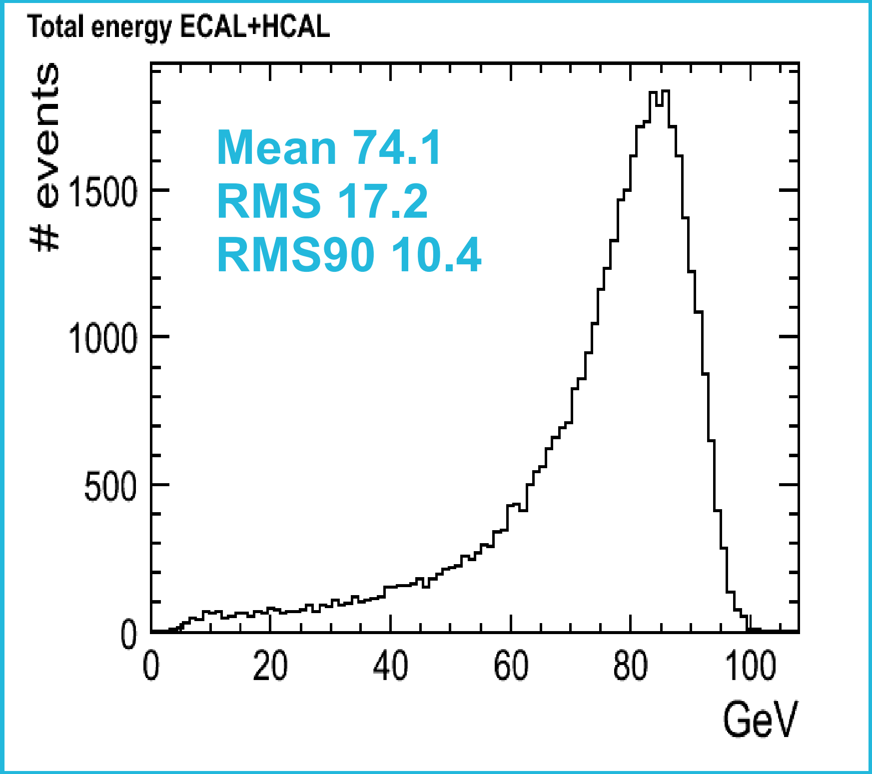
Bin : early start/low End-fraction => no leakage



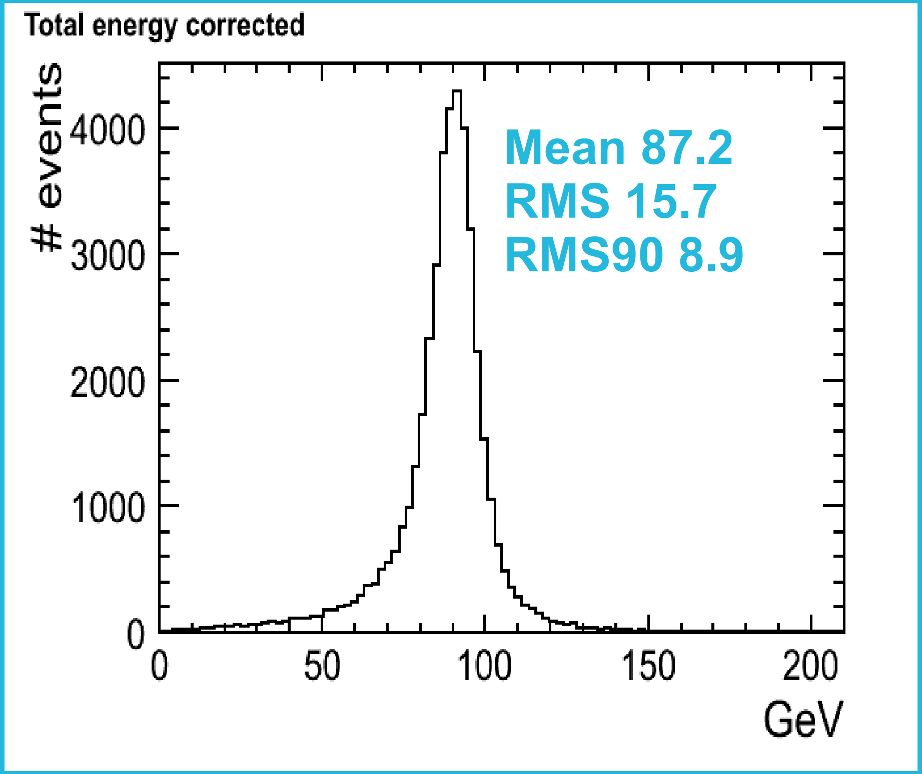
Bin : advanced start/higher End-fraction => leakage for high energies

Application: 87.5 GeV

- Correction is able to identify proper energy.
- RMS$_{90}$/Mean % **improvement 27%**: effect comparable to the individual energy-tuned corrections.



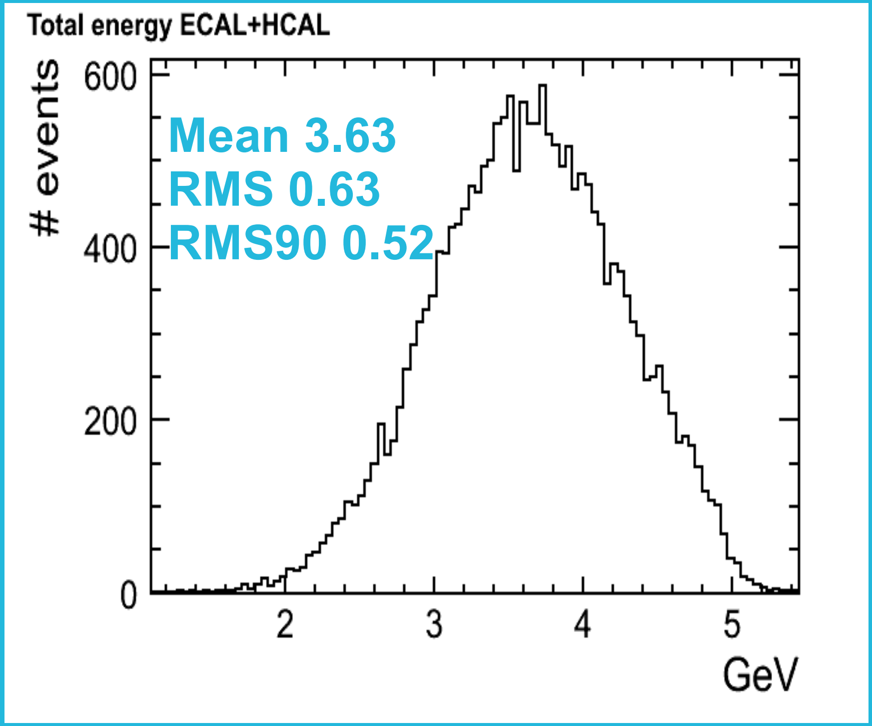
Uncorrected



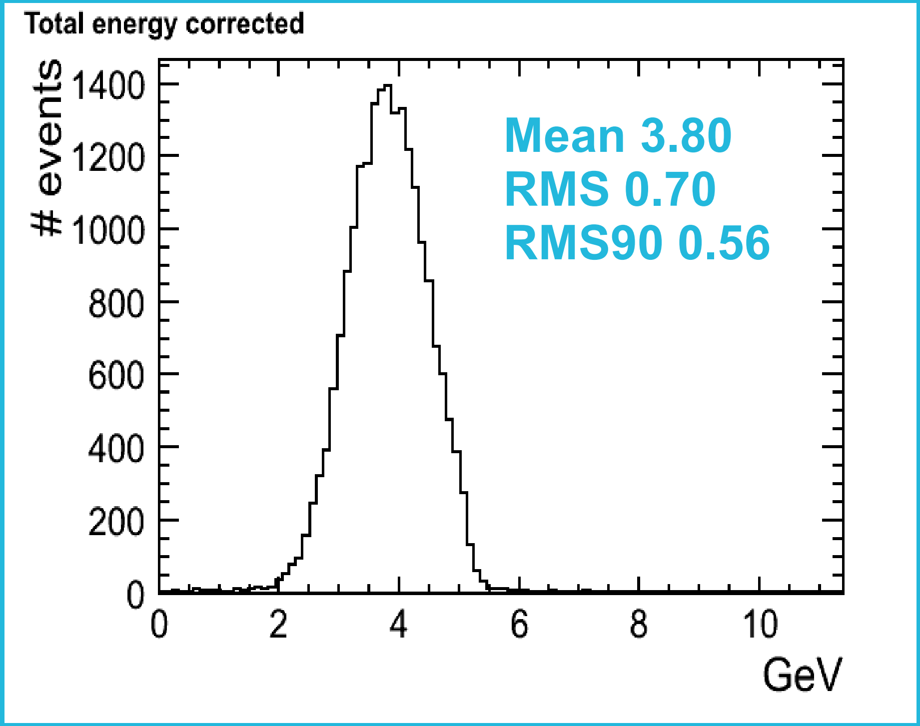
Corrected

Application: 3.75 GeV

- Ideal correction should leave untouched the low energies.
- Correction does not spoil significantly the low energies.

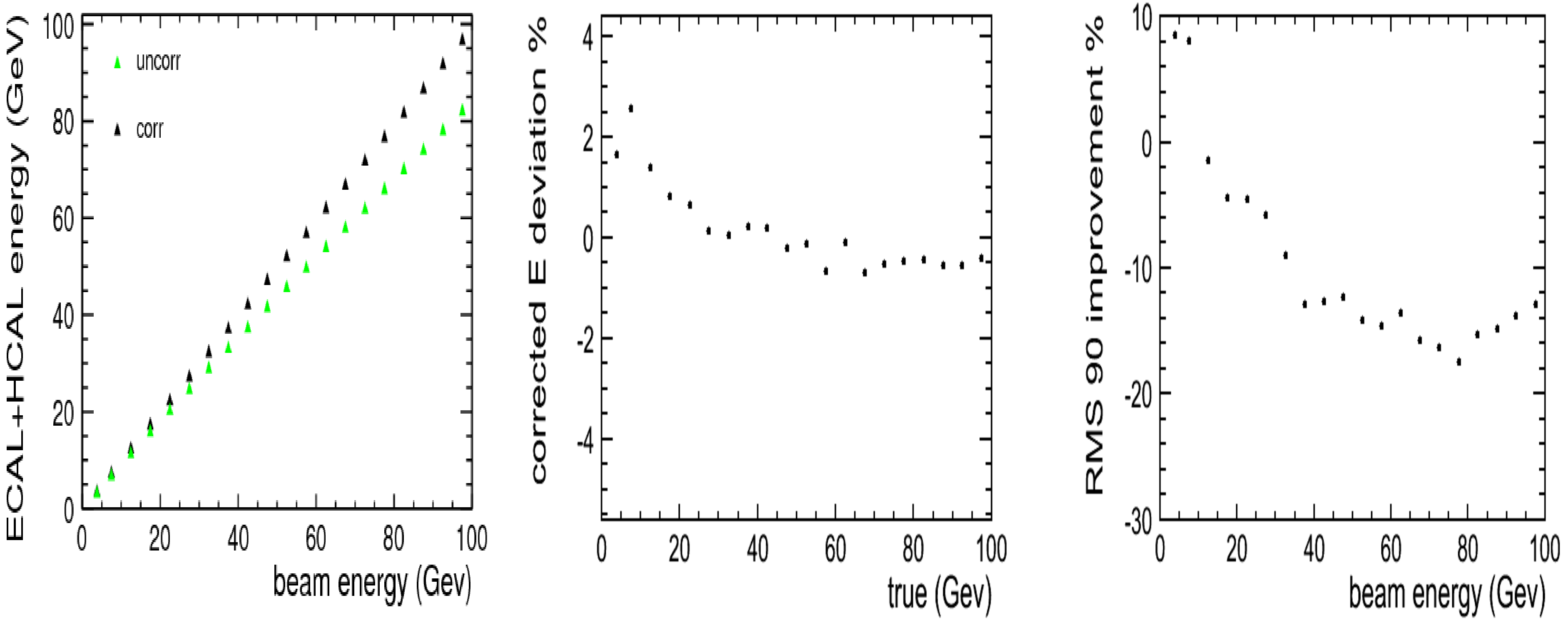


Uncorrected



Corrected

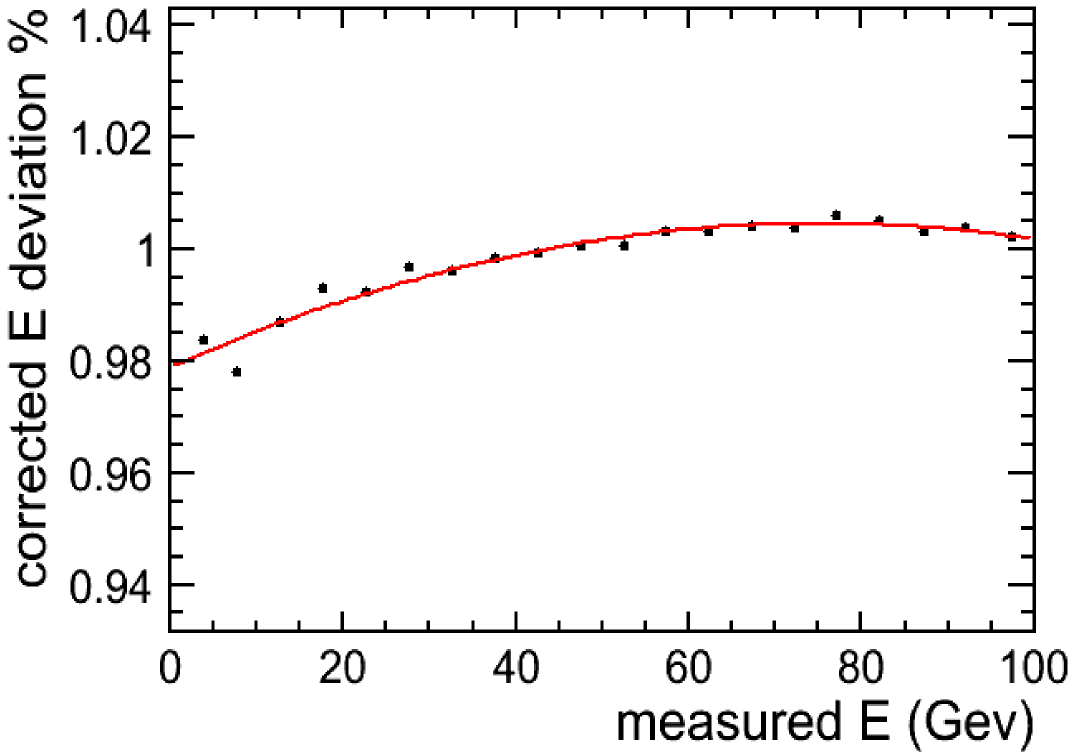
Correction Response (Partial)



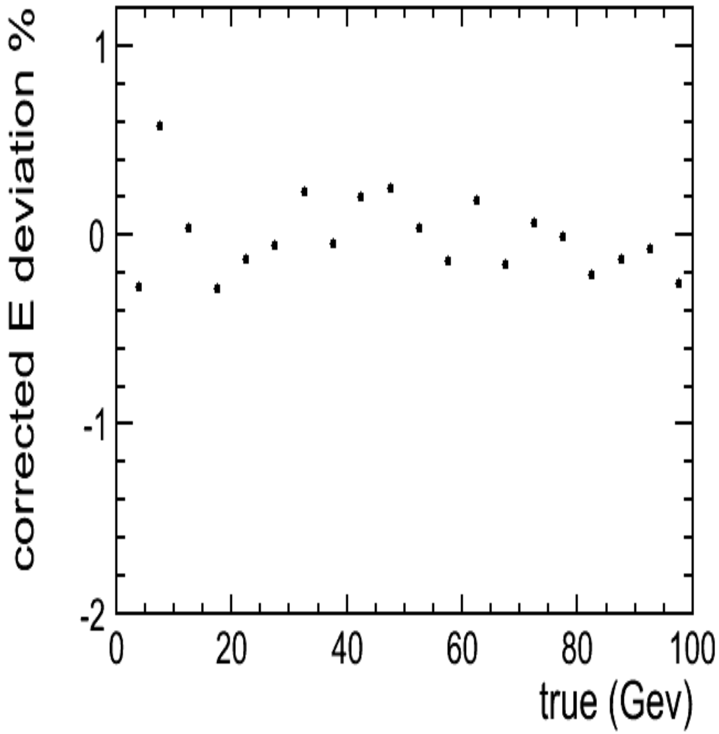
- Good recovery of the leakage.
- Mean recovery better than 1% over the full range from 10 GeV. Under control even at very low energies < 10 GeV (2.5%).
- RMS$_{90}$ % improvement 15% at high energies.

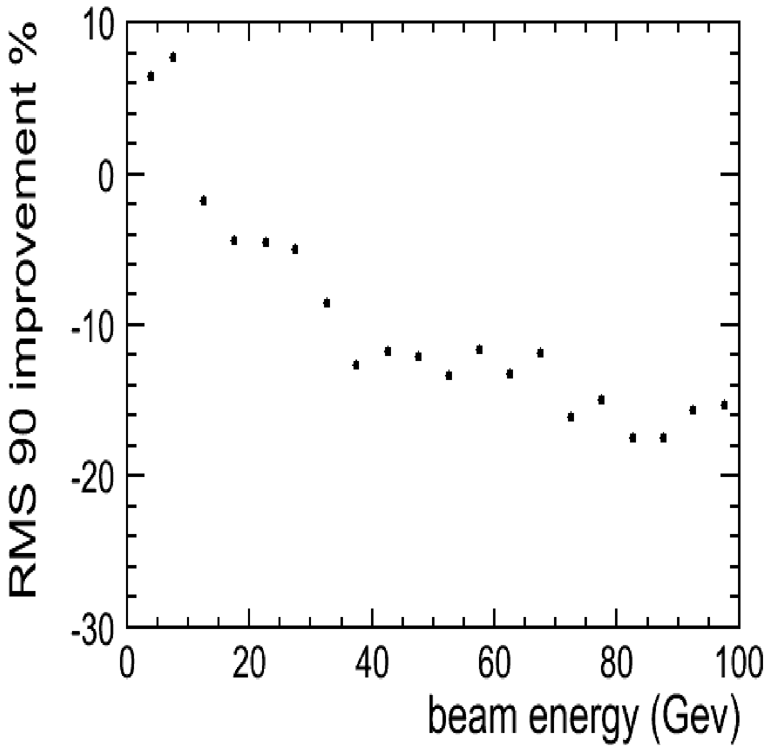
Fit: Step 3

- Possible to further improve the fit response, adding on top a correction to the events depending on the measured energy corrected, using the average deviation of the fit response as a function of the measured energy.



Final Correction Response

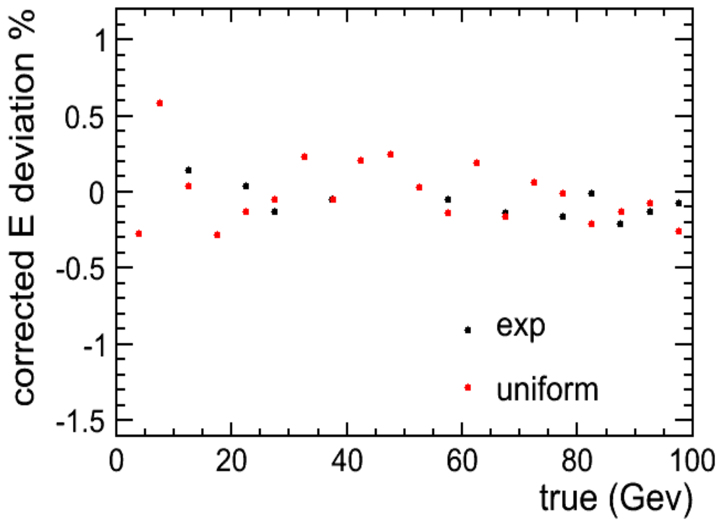


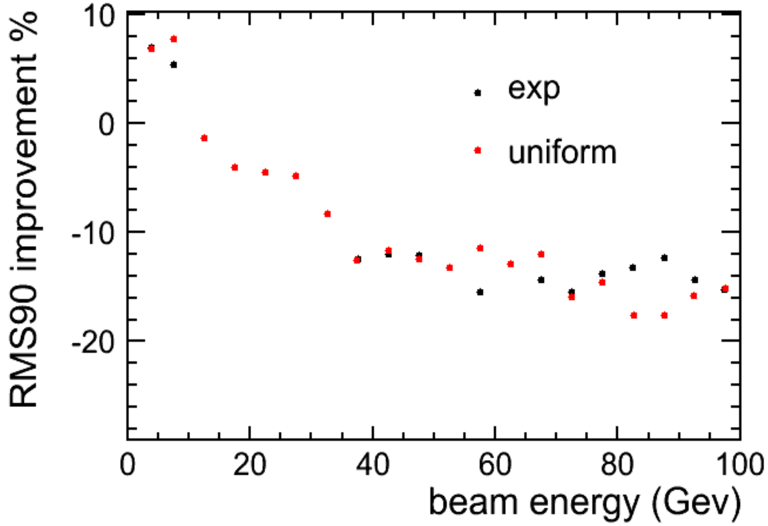


- Mean improvement further improved, without spoiling the RMS improvement.
- Fit response better than **~0.5% over the full range**, including low energies.

About Energy Distributions

- This fit structure not influenced by the chosen energy distribution. Ex: flat vs exponential peaking at low energies (exp(-0.05*Energy)). Results are compatible.

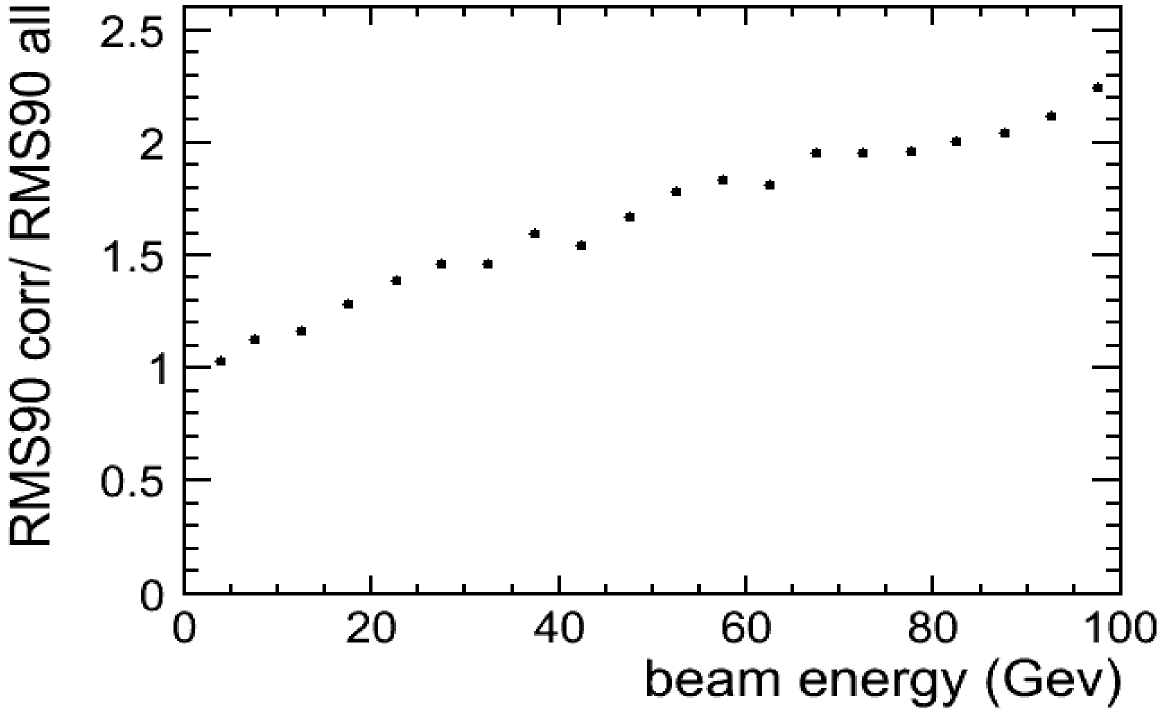




- On the other side. The correction is event-wise, therefore assumptions on the energy distribution of the sample to be corrected is not relevant.

Importance of the Calorimeter Depth

- MC fit works perfectly but does not replace a deeper calorimeter.
- Using the TCMT information still gives a better resolution with respect to the HCAL only + correction response.



Next Steps & Conclusions

Next Steps & Conclusions

- The high granular calorimeter promising for a correction to the leakage.

- Correction powerful in restoring the mean of the total energy, and reduces the RMS, but does not replace the calorimeter depth.

- Application to data is being finalized.

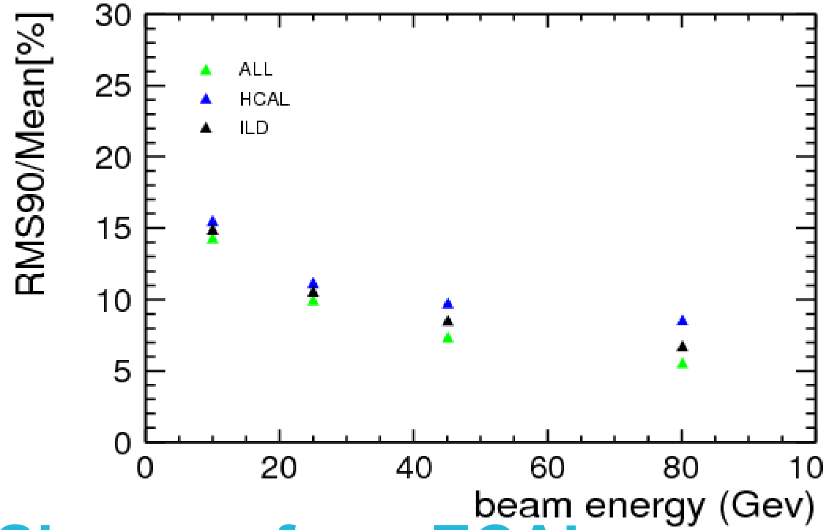
- Possible improvement: apply the correction on top the energy density re-weighting. The re-weighting should increase the correlation between the leakage and the observables used for the correction.

End

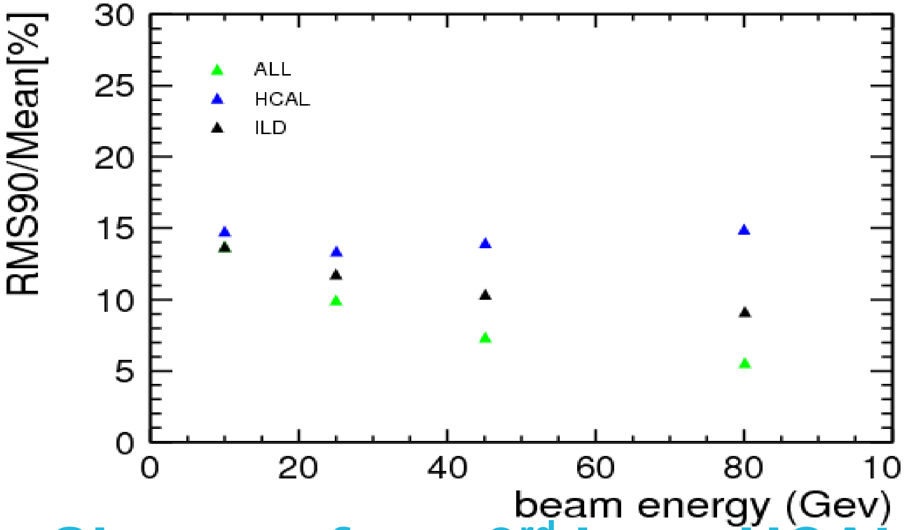
Additional Slides

Resolution

- Compare resolution for the full-sample and pion showers after the 2nd HCAL layer:
  - weights optimized for individual energies with E_{beam} constraint.
  - Selection of showers starting in the ECAL not optimized (purpose is only this plot).
  - Leakage effect is more evident for the second subsample.



Showers from ECAL



Showers from 3rd layer HCAL

Note: Monte Carlo Linearity

- Relevant for the study to check the proper response of the correction to different energies.

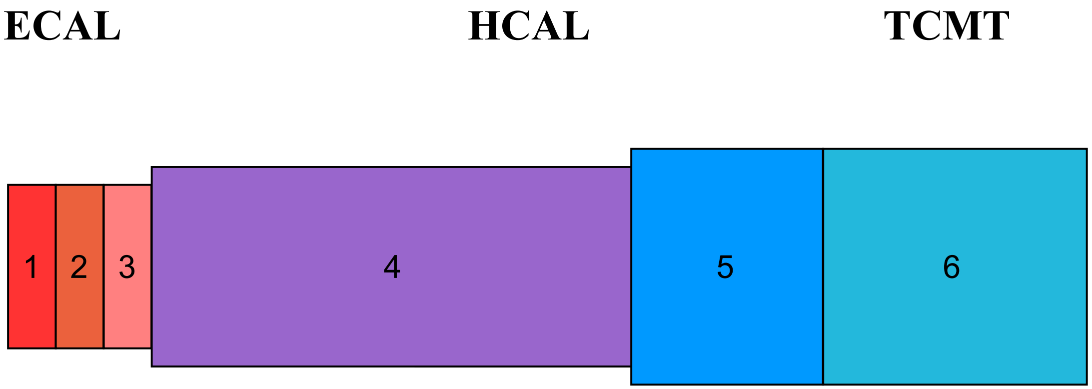
- Important to start with a good **Monte Carlo linearity** in terms of energy.

- Linearity depends on a proper choice of:
  - Sampling weights, which express the fraction of visible energy and are energy-dependent.
  - Mip to GeV conversion.

- For the purpose of the study Monte Carlo produced **without noise** and without **zero-suppression**: at low energies noise creates relevant deviation from linearity. Difficult to disentangle from correction effects.

Sampling Weights Optimization

- **6 weights** for different sections.

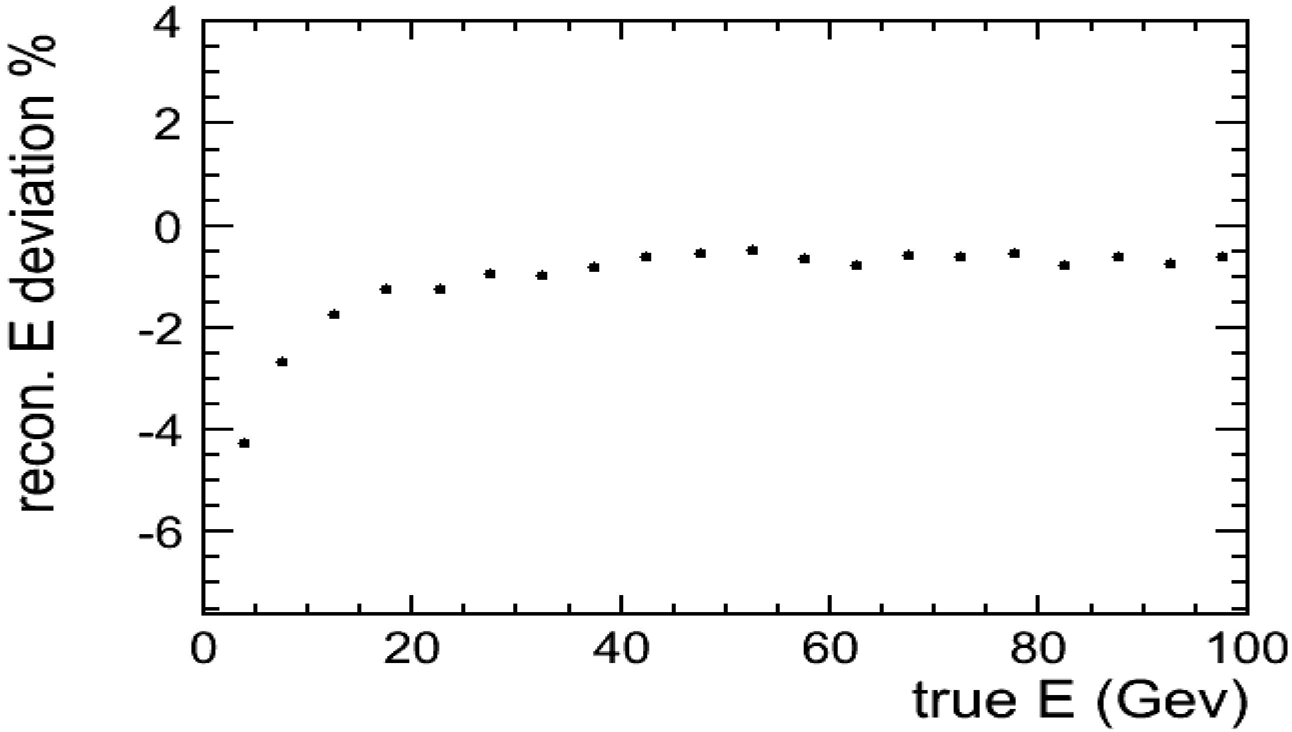


- SW by a χ^2 **minimization** on the total energy:

$$\chi^2 = \sum_{\text{events}} \left(E_{\text{beam}} - \left(E_{\text{ECAL1}} \cdot w_1 + E_{\text{ECAL2}} \cdot w_2 + E_{\text{ECAL3}} \cdot w_3 + E_{\text{HCAL}} \cdot w_4 + E_{\text{TCMT1}} \cdot w_5 + E_{\text{TCMT2}} \cdot w_6\right)\right)$$

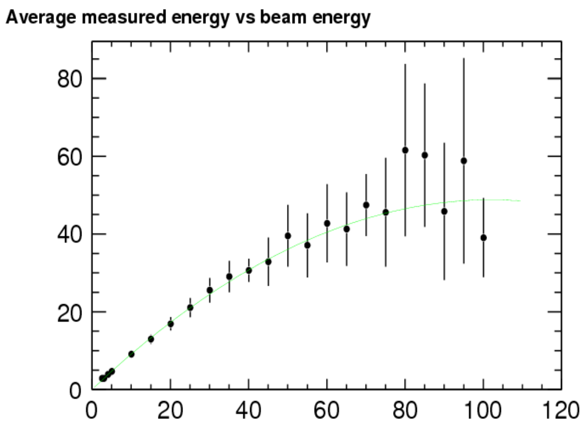
- We use pions starting in the HCAL, no sensitivity ECAL weights: ratios between w1, w2, w3 fixed to those given by the literature.

Monte Carlo Linearity



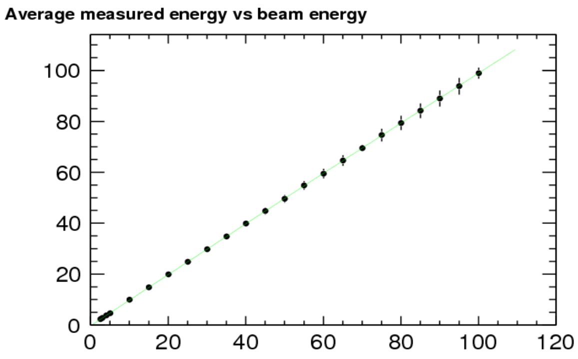
- Still deviation, due to some uncertainty in the sampling weights optimization, but not big.

Fit: Details - 1



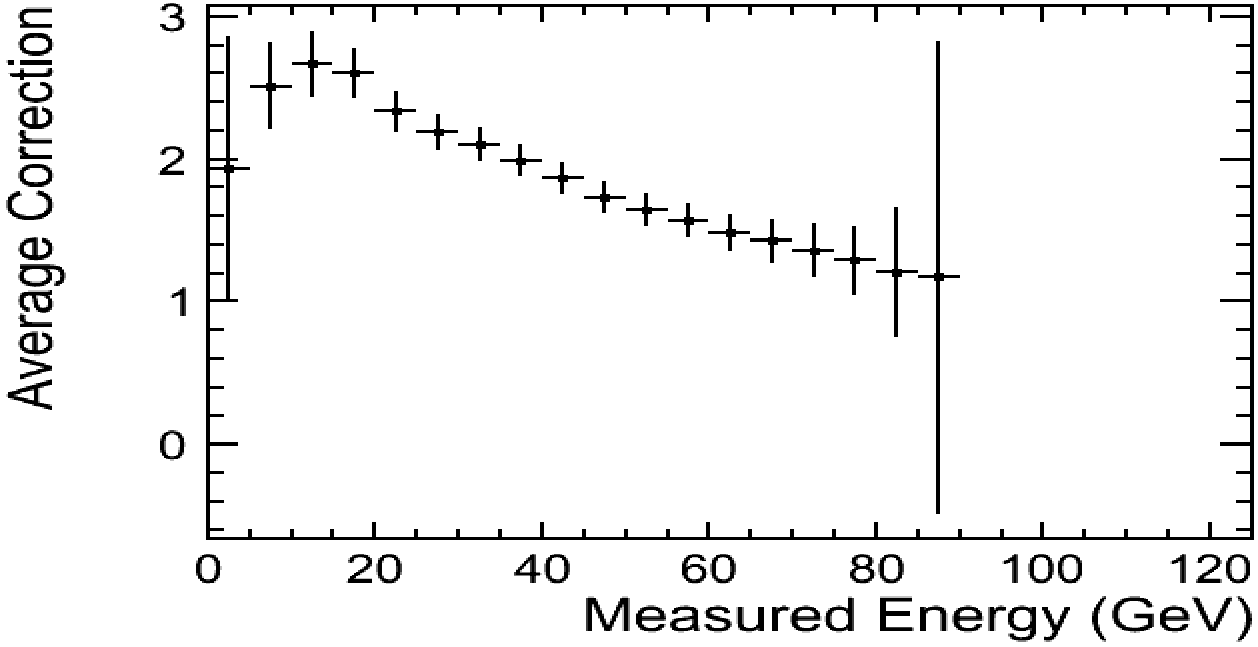
Fit a pol2 to the distribution.

In case the curvature of the pol2 is too small (0.0001), fit a pol1.



Inverse of the fitting function gives the correction to be applied to the measured energy.

Fit: Details - 2



In case for a certain event solution of the inverse pol2 fit should not exist, or correction for small energies should give a negative value, using the average correction for the measured energy in that bin (~1% of the events get this correction).