# ILD Software and Analysis Meeting

## SDHCAL energy reconstruction

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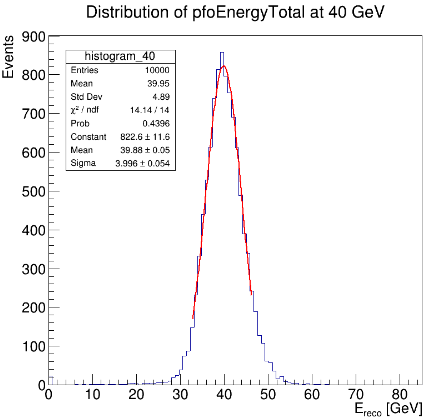
September 25, 2024

# Context

- Currently working on SDHCAL energy reconstruction and its corrections
- Using `ILD_l2_v02` (Videau geometry)
- Samples of single KLong with energy from 5 GeV to 90 GeV
- **Goals** : compare different methods of SDHCAL energy reconstruction and try to find the best one

# Procedure

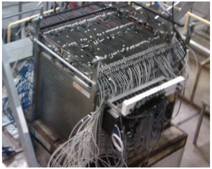
- Simulate and reconstruct samples of KLong going straight into the barrel ($\theta = \varphi = \frac{\pi}{2}$)
- For each energy, we look at the `pfoEnergyTotal` distribution
- Distributions fitted with Gaussian function in a RMS90 range (smallest interval with $\geq$ 90% of the events)
- Mean value and standard deviation of the Gaussian function treated as the reconstructed energy and its resolution

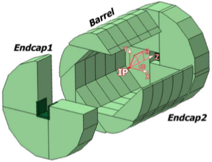


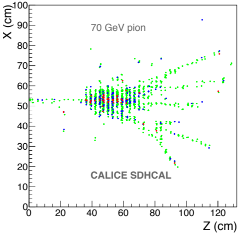
# Semi-Digital HCAL

## SDHCAL reconstructed energy

$$E_{reco} = \alpha_1 N_1 + \alpha_2 N_2 + \alpha_3 N_3$$





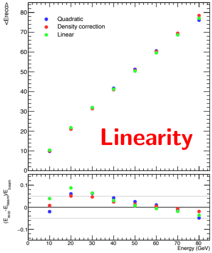

### Options for $E_{reco}$

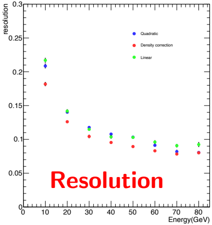
Thresholds(pC): 0.11, 5, 15

**Quadratic** $\alpha_i = a_i N_{hit}^2 + b_i N_{hit} + c_i$ (TB default)

**Linear** $\alpha_i$ constant (Pandora default).

**Density** $\alpha_i$ = above $\times$ f(N neighbour hits)



# $\alpha_i$ parameters computation

- Different methods tried
  - Classical method : $\chi^2$ minimization
  - Solving system of equations with GSL
  - New reconstruction method
- For quadratic : $\alpha_i = a_i N_{hit}^2 + b_i N_{hit} + c_i$ with $N_{hit} = N_1 + N_2 + N_3$

## Classical method : $\chi^2$ minimization

- $\chi^2 = \sum_{i=1}^{N} \frac{(E_{\text{mc,i}} - E_{\text{reco,i}})^2}{E_{\text{mc,i}}}$, $N$ : Number of events used
- Minimization with TMinuit and MIGRAD (ROOT)

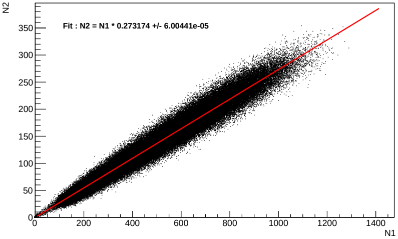
## Solving system of equations with GSL

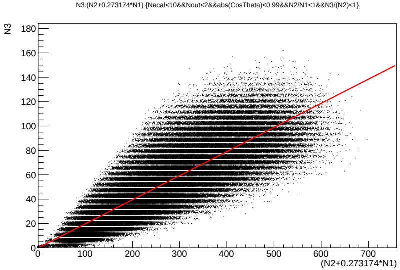
- 9 equations with 9 unknowns and $E_{\text{reco}}$ known
- Compute the $N$ means for each of the 9 energies : $< N_1 >, < N_{hit} N_1 >, ...$
- Solving with GSL (GNU Scientific Library)

- Cons :
  - A lot of parameters to adjust (9 for the quadratic formula)
  - Difficult to constrain the parameters

# New reconstruction method

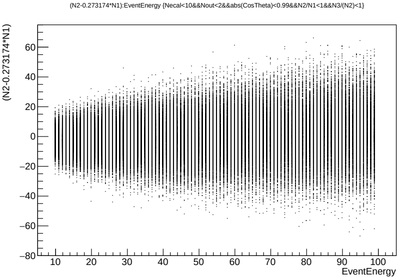
- Initial observation : $N_2$ behaves approximately as a fraction of $N_1$, and $N_3$ behaves approximately as a fraction of the combination of $N_1$ and $N_2$
- $N_2 = 0.273174 \times N_1$
- $N_3 = 0.197756 \times (0.273174 \times N_1 + N_2)$

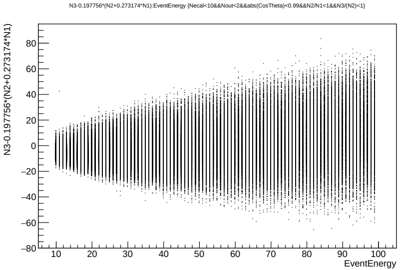


# Checking the coefficients

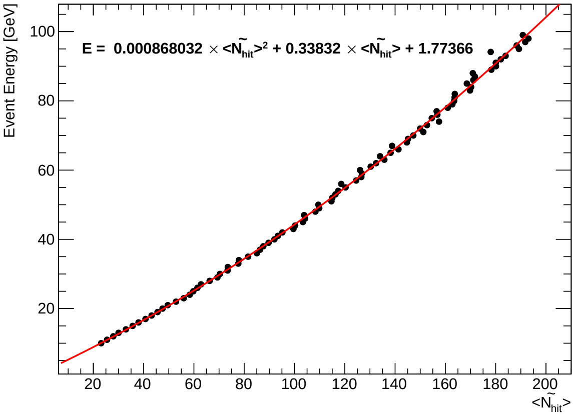
- Averages around zero when we look at the difference between the different terms as a function of energy
- Relations remain correct no matter what the energy is



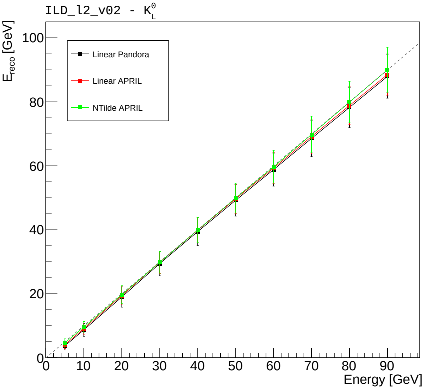
# New formula

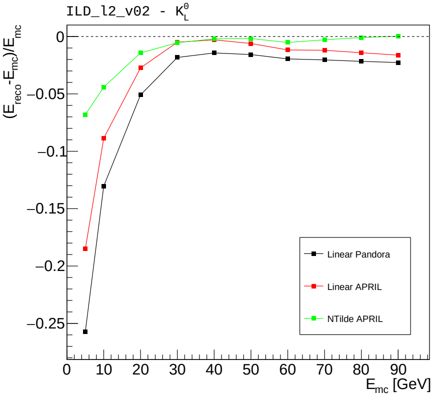
- We define : $\tilde{N_{hit}} = N_3 + 0.197756 \times (0.273174 \times N_1 + N_2)$
- We plot $E = f(< \tilde{N_{hit}} >)$
- Best results for $f(< \tilde{N_{hit}} >)$ as quadratic



# Results

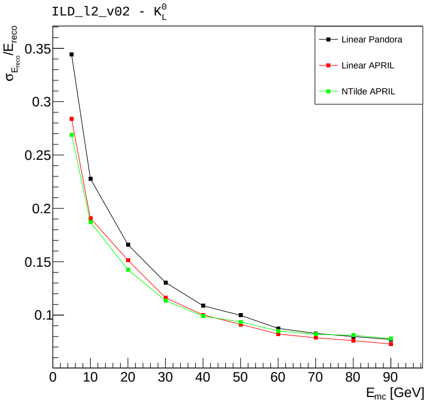
- Achieve good linearity with the different methods for $E \geq 20$ GeV
- New method gives the best linearity

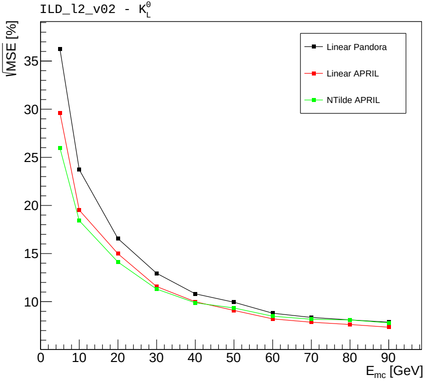


# Results

- $\text{MSE} = \left(\frac{\sigma_{E_{\text{reco}}}}{E_{\text{reco}}}\right)^2 + \left(\frac{E_{\text{reco}} - E_{\text{mc}}}{E_{\text{mc}}}\right)^2$
- Best resolution and MSE with new method for $E \leq 40$ GeV
- All methods tend to converge for higher energies



# Summary and outlook

**Summary**

- A new way of computing the SDHCAL energy has been found
- Gives encouraging results on samples of single KLong

**Outlook**

- Currently preparing a poster including these results for the incoming ECFA workshop in Paris
- Working on the SDHCAL calibration for `ILD_l5_o2_v02` (Tesla geometry)
- Reconstruct jet events to compare the different methods
- Longer term : possibly try machine learning for reconstruction