First look at Photon ID methods

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Calorimeter for ILC

Photon ID

- Investigate particle ID capabilites

  – distinguish photons from other (neutral) particles (e.g. neutrons, pions)
  – method developed / studied @ Clermont: M.Benyamna, P.Gay, Z.Yang
  – test method with CALICE test beam data / MC

- A first look in this presentation:

  – define outline of analysis steps
  – very preliminary plots
  – would like to have some feedback

The method

- Based on longitudinal shower shape for 1-100 GeV

$$f(E,t)=\frac{(bt)^{a-1}e^{-bt}}{\Gamma(a)}$$

normalised shape
t depth in rad. length

$$\langle t^n\rangle=\int_0^\infty t^n f(E,t)\,dt$$

$$\langle t\rangle=\frac{a}{b} \qquad \langle t^2\rangle=\frac{a^2+a}{b^2}$$

- a,b can be expressed by moments of t
- use combination of energy dependent a,b as statistical estimators for photon ID
- possibly include more variables later

The algorithm

- Clusterisation to define photon signal hits
- Calculate shower axis
- Compute estimators a and b
- Compare calculated estimators with expectation

A first look

- Clusterisation to define photon signal hits
  include all hits in the calorimeter prototype

- Calculate shower axis
  normally incident beam only / test tensor of inertia

- Compute estimators a and b
  use 1:2:3 sampling fractions to determine energies
  radiation depth calculation includes only tungsten

- Compare calculated estimators with expectation
  extract expectation from data (use electron samples)
  and simulation

Data / MC sets

- Use data from 2006 electron runs:

  Energies {6,10,12,15,20,30,40,45} GeV

  normally incident beam only

- Electron MC:

  (for 2006 electron analysis, not most recent version)

  Energies {6,10,12,20,30,40} GeV

  normally incident beam only

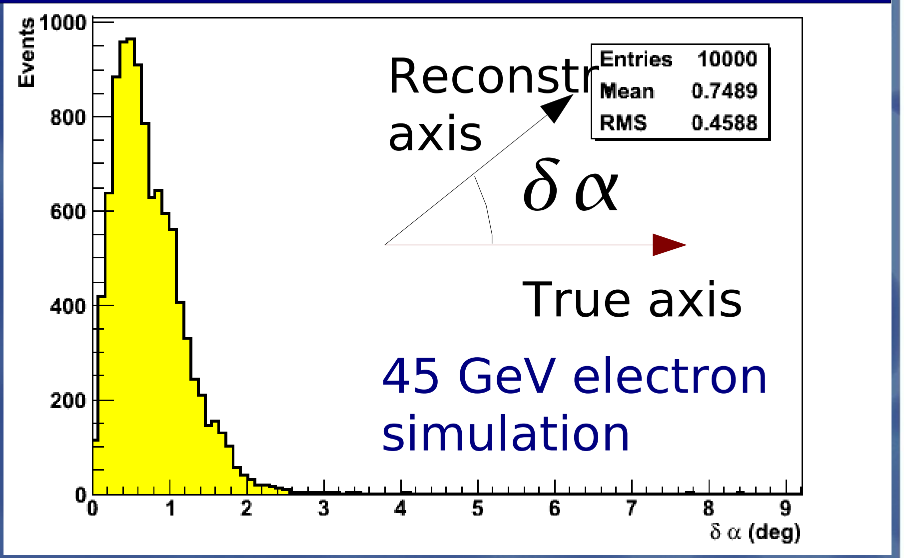
Shower axis / tensor of inertia

- Compute and diagonalise tensor of inertia
- Eigenvector with smallest eigenvalue yields shower axis

Tensor of inertia

$$I = \sum m_k \begin{pmatrix} y_k^2 + z_k^2 & -x_k y_k & -x_k z_k \\ -x_k y_k & x_k^2 + z_k^2 & -y_k z_k \\ -x_k z_k & -y_k z_k & x_k^2 + y_k^2 \end{pmatrix}$$

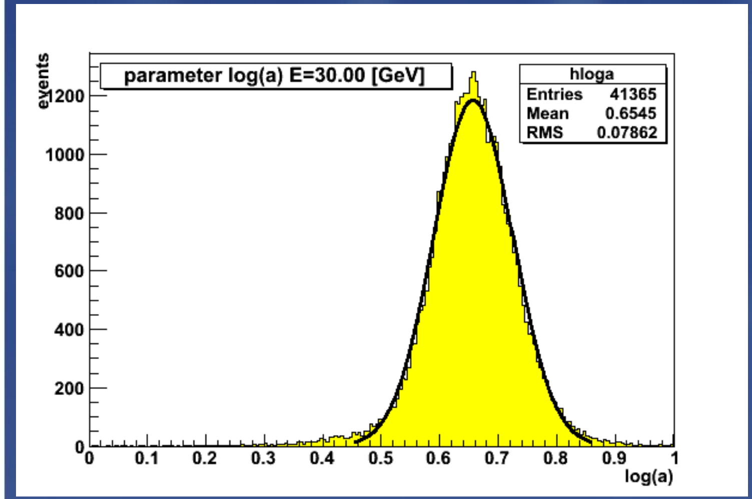
Space angle between reconstructed and true shower direction

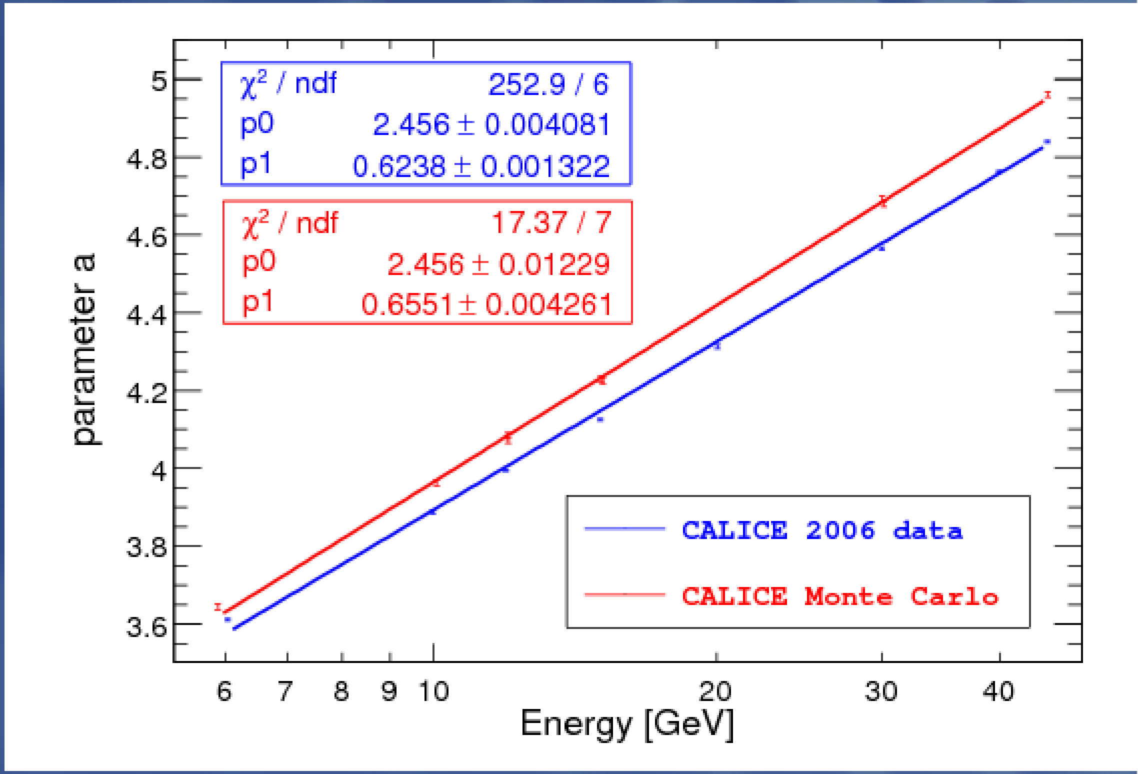


- Not gaussian: $f(\theta, \phi)\, d\Omega$
- Results do look quite good

Profile parameters: a

- Extract mean and variance from data / MC
- Fit: p0 + p1 log(E)

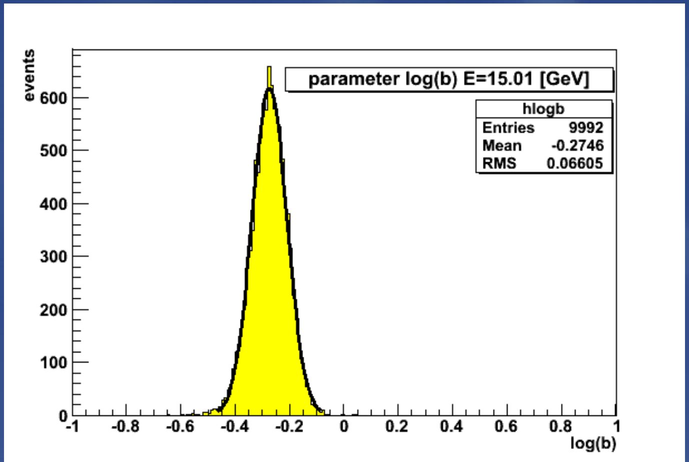


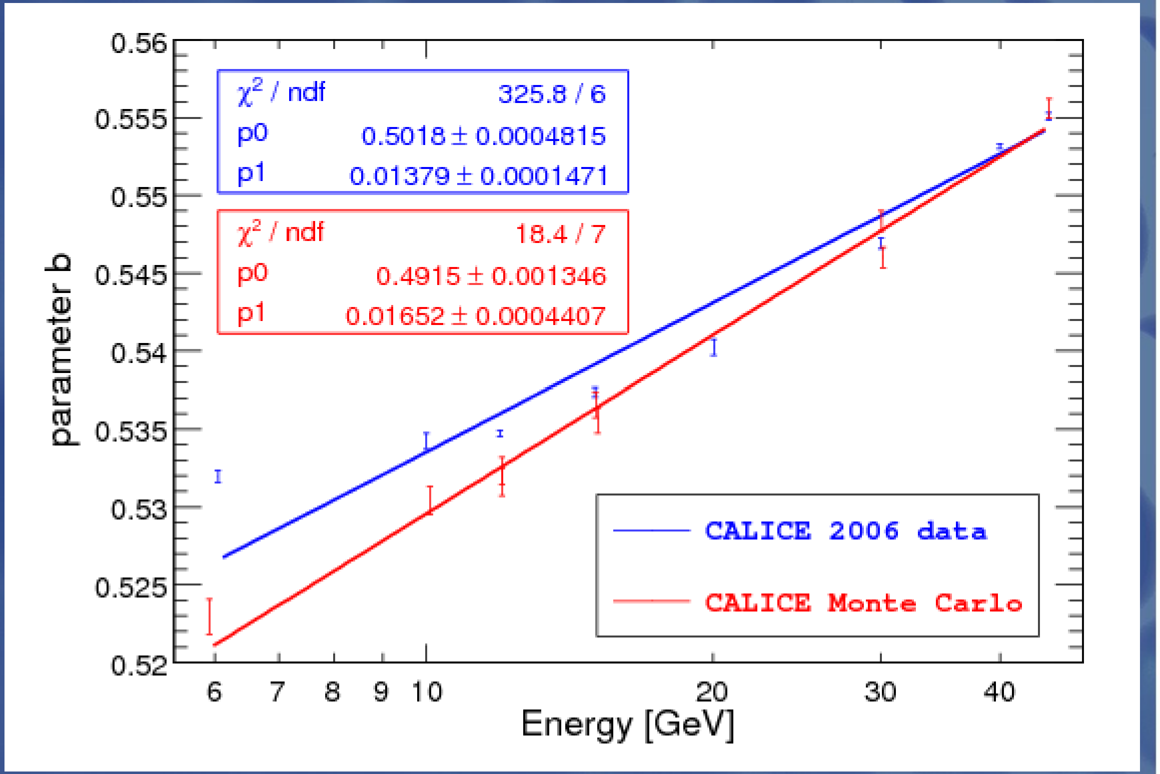


- Small difference in p1

Profile parameters: b

- Extract mean and variance from data / MC
- Fit: p0 + p1 log(E)



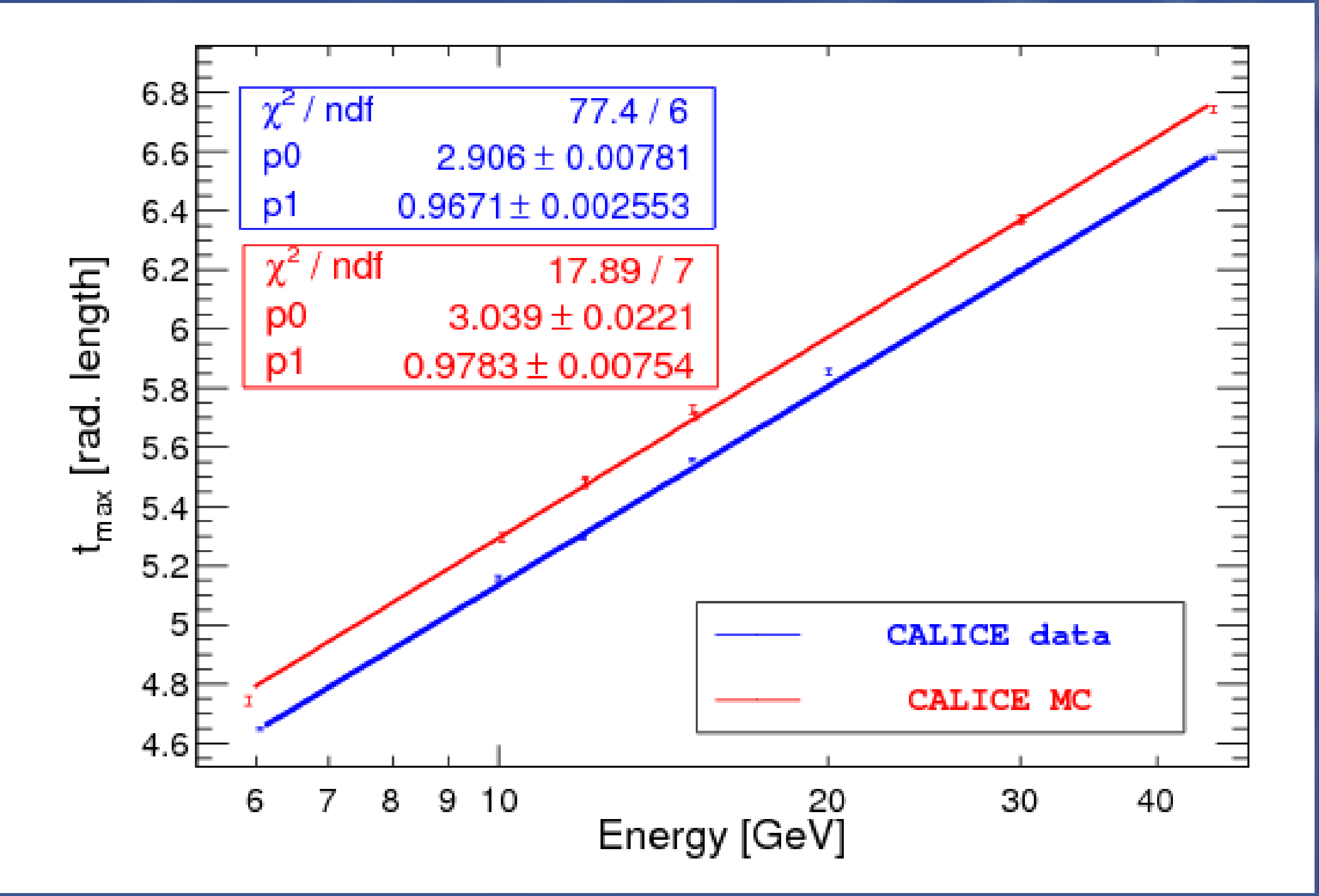


- Problem: errors (for data) are underestimated

Shower maximum

Comparision data / simulation

$$t_{max} = \frac{a-1}{b}$$



5% difference between data and simulation

simulated shower maximum occurs later

have to redo analysis with newest simulation

Summary / next steps

- Use shower profile parameters (mean and variance) for photon ID
- Shower axis calculated using tensor of inertia
- TODOs:
  - understand differences MC / data (use latest MC)
  - use detailed / energy dep. sampling fraction
  - use more exact values for radiation depth
  - possibly generalise methods to include more estimators
  - characterise method by looking at background processes (e.g. neutrons), determine efficiency vs. purity curves