Status of the LAr Shower Parameterisation

Anthony Waugh
University of Sydney

Elisabetta Barberio
University of Melbourne

LAr Simulation Meeting

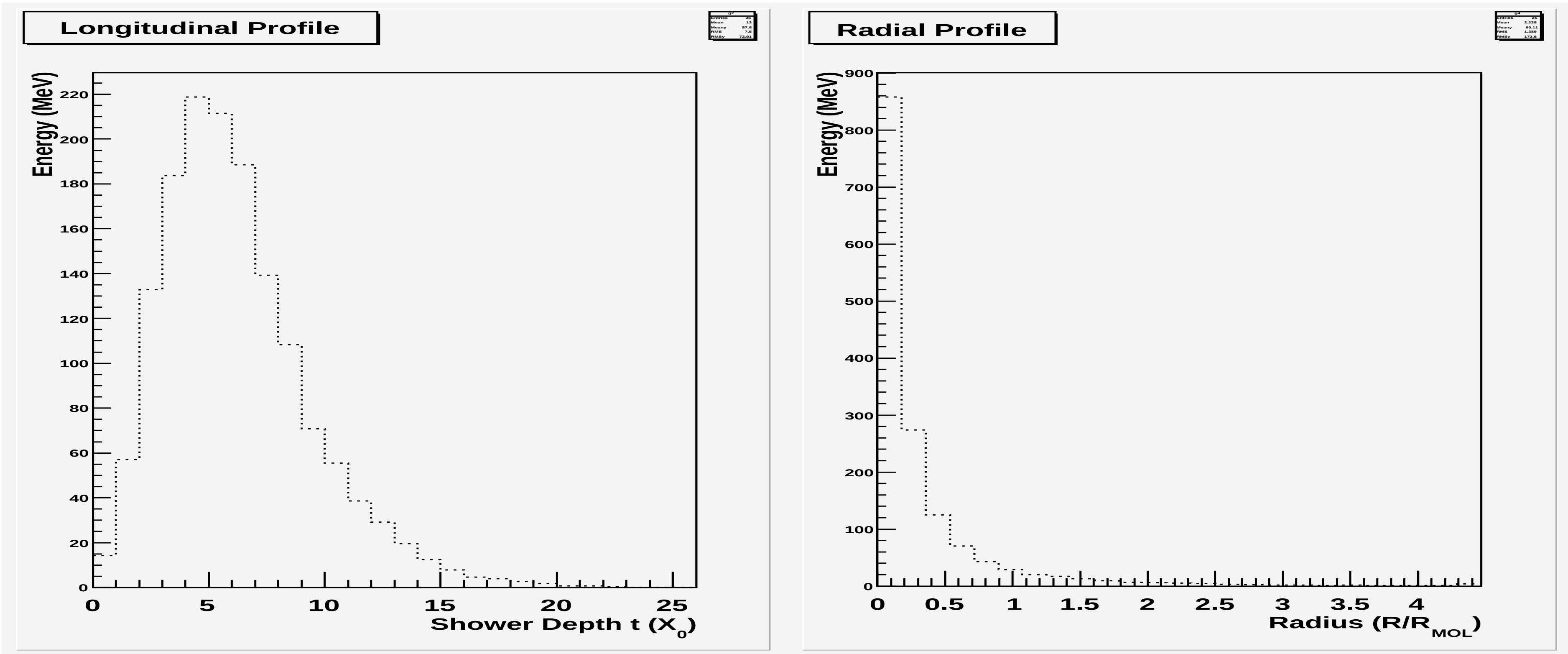
19/6/06

Motivation for Shower Paramaterisation

- For Geant4 simulation, one of the biggest users of CPU time is electromagnetic showers.
- One proton - proton event can contain many high energy photons and electrons
- To estimate background for rare interactions we require millions of simulated events
- We wish to find a set of equations which describe the shape of the shower, given only the 4 vector of the incoming electron
- Parameterisation used is based on Grindhammer & Peters

  arXive:hep-ex/0001020v1

Energy Profiles



Longitudinal and radial profiles of a single 10 GeV electron shower in the EM barrel.

Longitudinal Profile

$$< \frac{1}{E}\frac{dE(t)}{dt} >= \frac{(\beta t)^{\alpha-1}\beta exp(-\beta t)}{\Gamma(\alpha)}$$

t =longitudinal depth into shower

α =shape parameter

β =scaling parameter

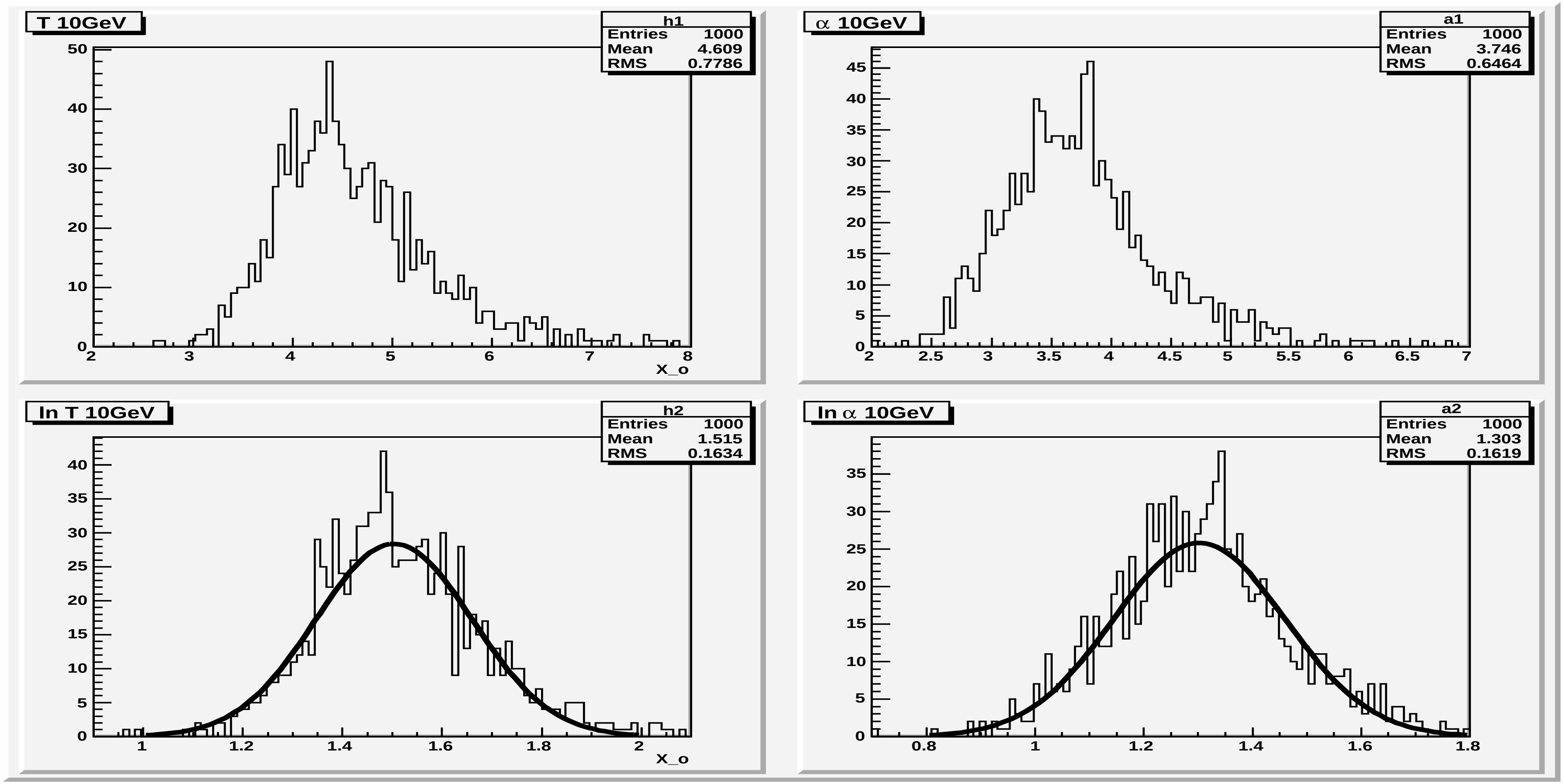
$T = \frac{\alpha-1}{\beta}$ =depth of shower energy maximum

$$T_i = \frac{2Z_1^2 - Z_2}{Z_1}$$

$$\alpha_i = \frac{Z_1^2}{Z_2 - Z_1^2}$$

$$Z_n = \int_0^\infty t^n f_L(t)\,dt$$

Fitting the Longitudinal Profile



Gaussian fits for log T and log α at $E = 10GeV$

Fitting the Longitudinal Profile

$$< lnT >= ln(c_1 + lny)$$

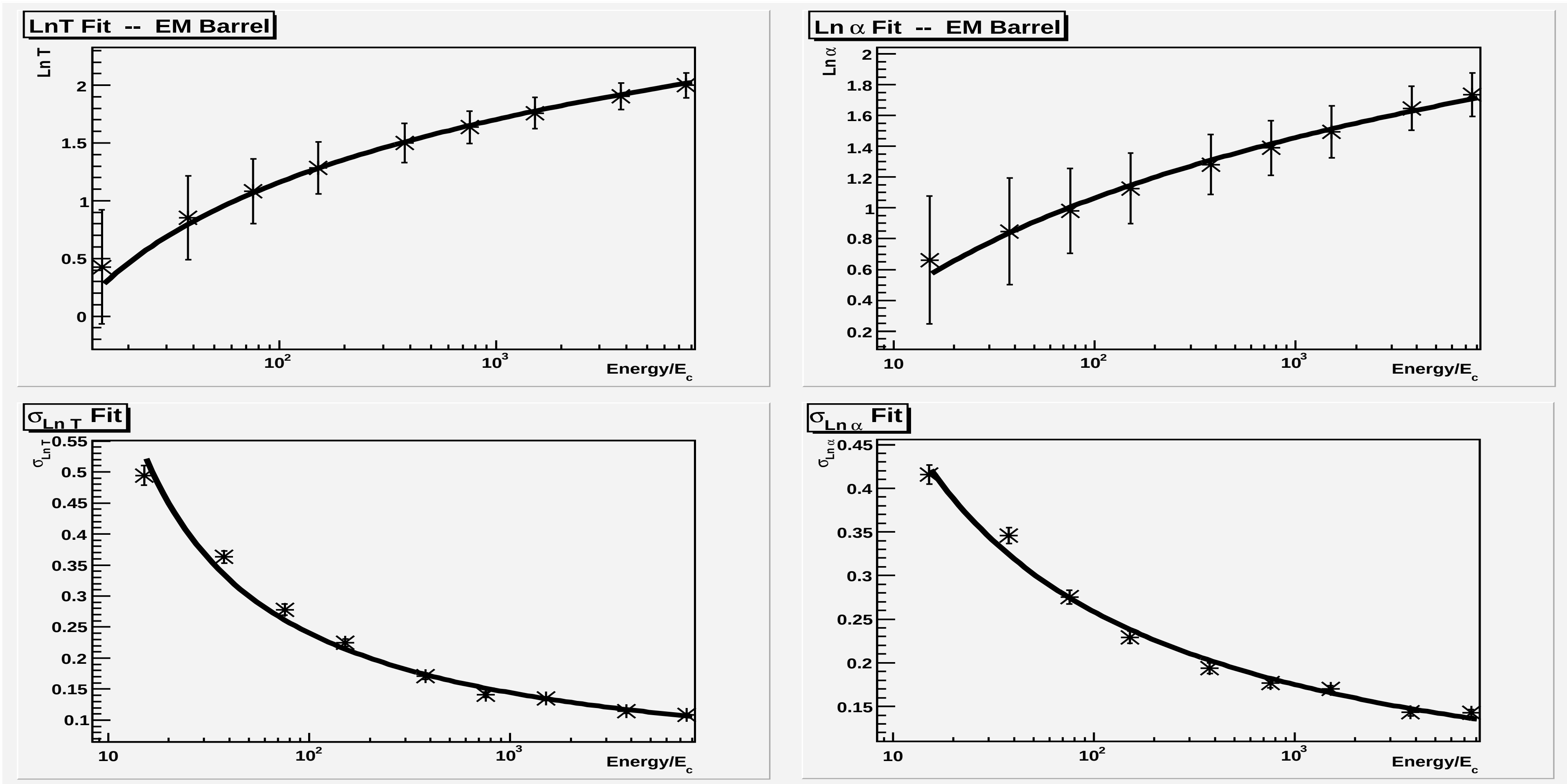
$$< ln\alpha >= ln(c_2 + c_3 lny)$$

$$\sigma_{lnT} = (c_4 + c_5 lny)^{-1}$$

$$\sigma_{ln\alpha} = (c_6 + c_7 lny)^{-1}$$

$$y = E/E_{critical}$$

Fitting the Longitudinal Profile



Longitudinal profile fits for the EM barrel

Radial Profile

- Divide shower in length in units of X_0
- Fit radial energy profile for each length

$$< \frac{1}{E(t)} \frac{dE(t,r)}{dt} >= p \frac{2rR_C^2}{(r^2+R_C^2)^2} + (1-p) \frac{2rR_T^2}{(r^2+R_T^2)^2}$$

- $R_C(t)$ =the median of the energy distribution of the core of the shower
- $R_T(t)$ =the median of the energy distribution of the tail of the shower
- p is a weighting function

$$p(t) = E_{core}(t)/E_{tail}(t)$$

- Core is the radial interval containing 90% of the total energy
- Tail is the radial interval between Core and the radius containing 99% of the energy

Fitting the Radial Profile

$$R_C(y,\tau) = (c_{10} + c_{11} lny + c_{12}\tau)$$

$$R_C(y,\tau) = (c_{12}(exp(c_{13}(\tau - c_{14}) + exp(c_{15} - c_{16} lny)(\tau - c_{14}))$$

$$p(y,\tau) = c_{17} exp(\frac{c_{18}-\tau}{c_{19}-c_{20} lny} exp(\frac{c_{18}-\tau}{c_{19}-c_{20} lny}))$$

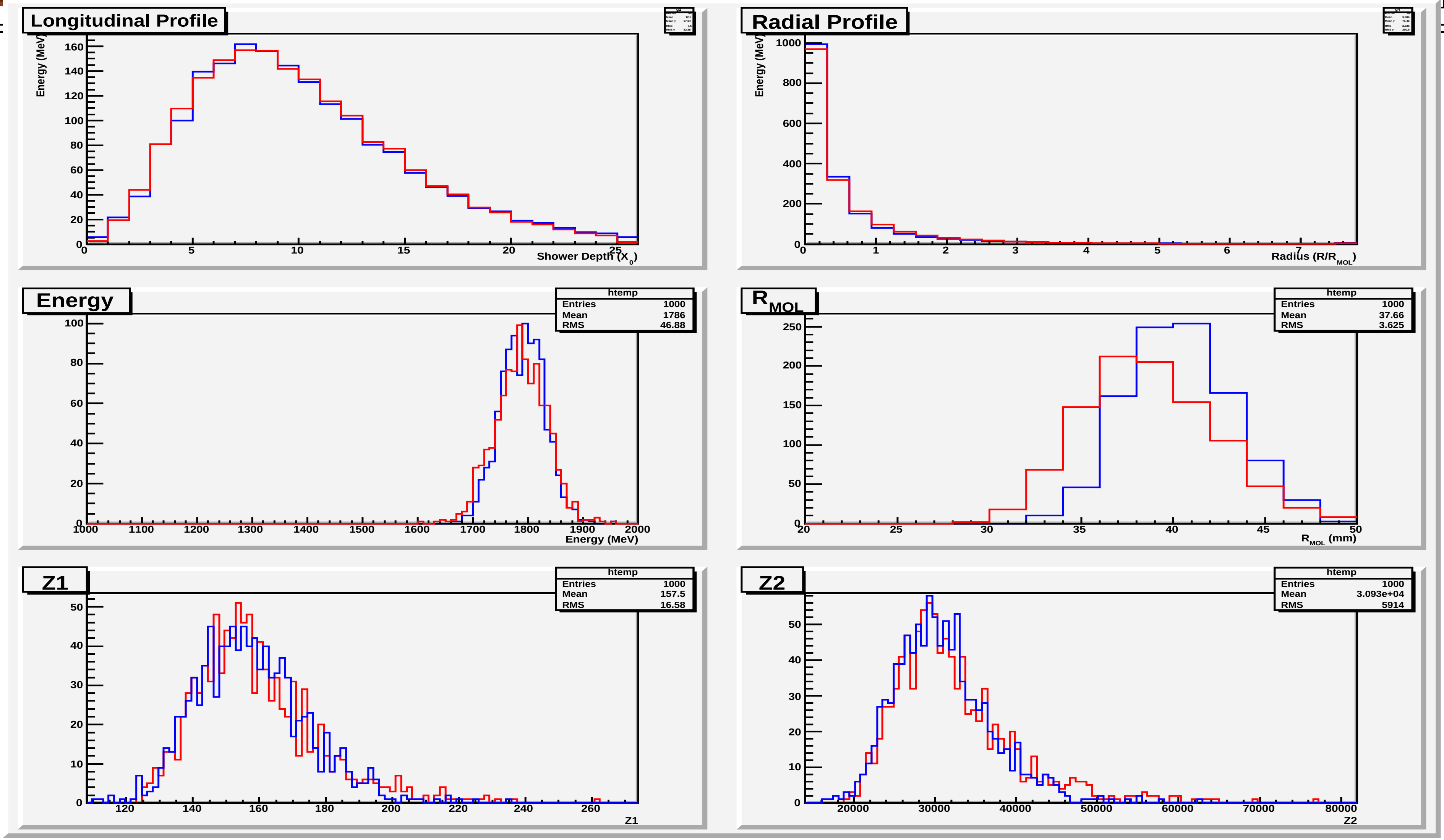
$$\tau = R/R_{MOLIERE}$$

Fast Simulation Scheme

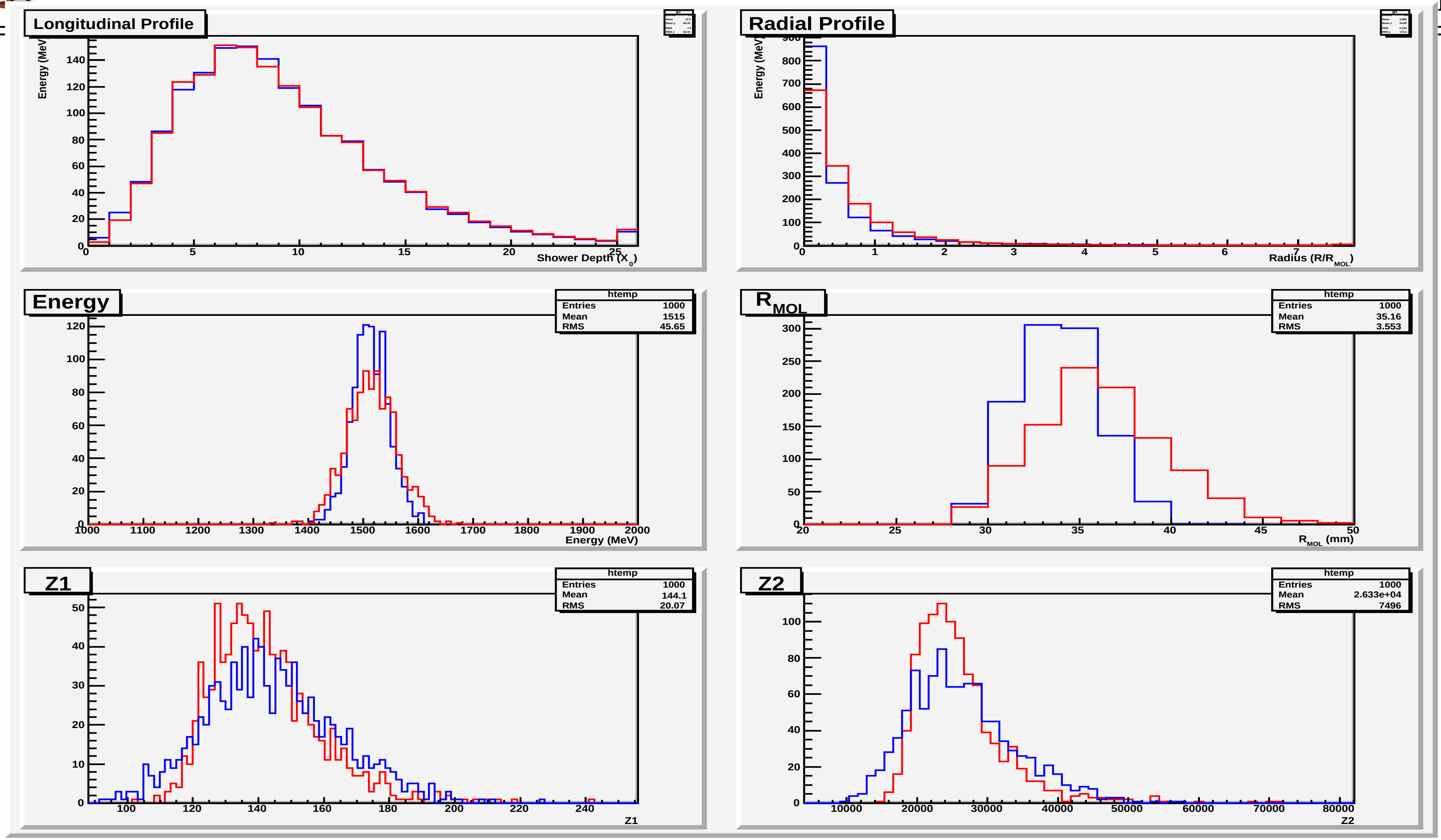
- Conditions for parameterisation
  - Only electrons/positrons are parameterized.
    Photons are returned to full sim and the first electron produced is parameterised.
  - Particle must be within allowable energy range, if not it is returned to full simulation
  - Shower must be contained within the calorimeter, checked at Z(95%) and R(95%).
- Handling of Leakage
  - If shower not contained, returned to full simulation; when the shower produces a fully contain electron, it is parameterised
- Showers starting before the calo
  - Particles are tracked using full simulation until they enter the calo, then each is parameterised separately

Fast Simulation Scheme cont...

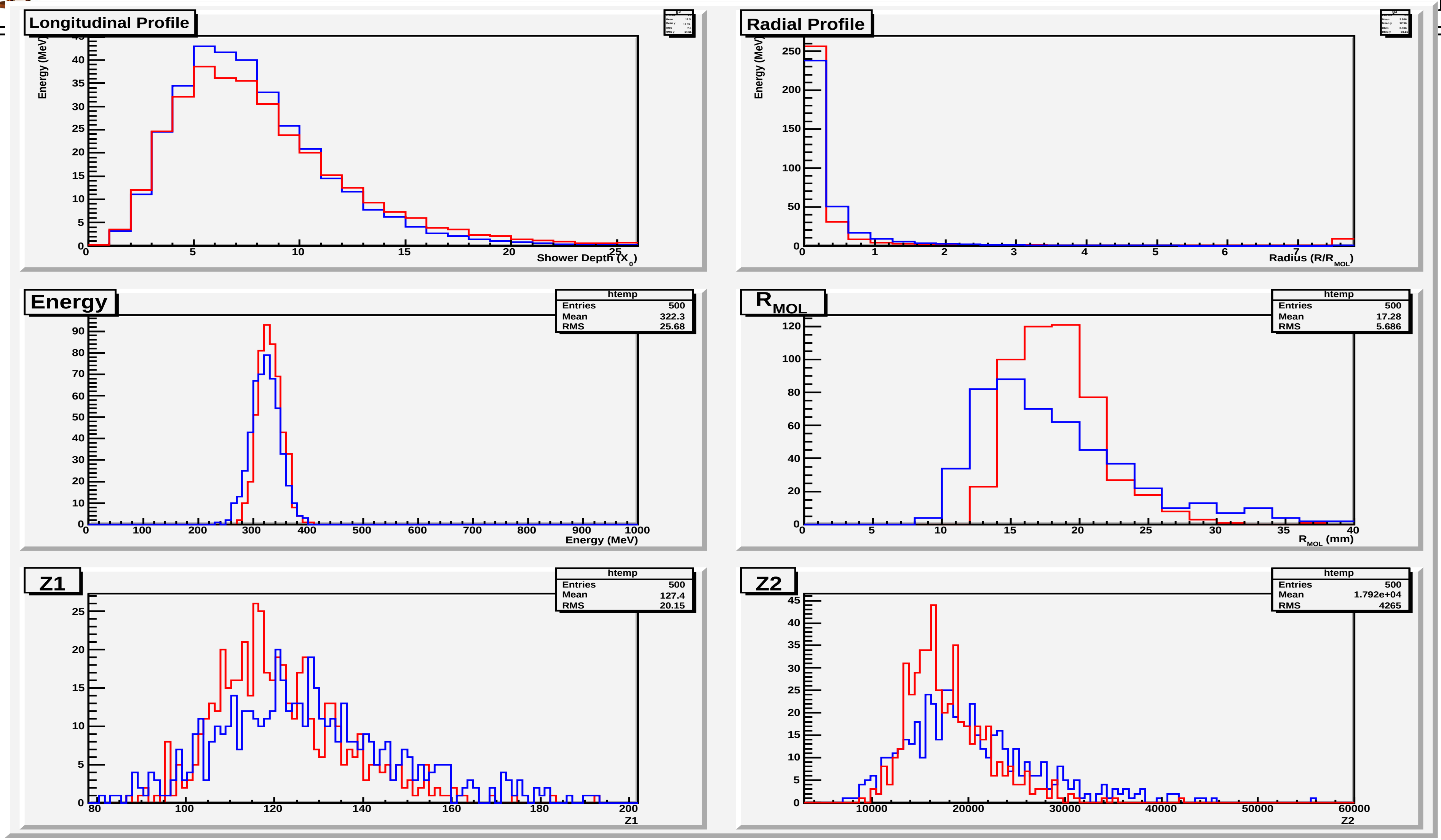
- If the conditions are satisfied
  - the track is killed
  - generate fake steps of a chosen length ($10\mu m$)along the initial electron trajectory; calculate energy deposited and number of spots for each step
  - applying sampling fluctuation, taking into account the calorimeter resolution
  - calculate energy and position of each spot
  - generate hits and fill fake step to feed the sensitive detector
  - follow the full simulation chain to process the hits
  - loop until the total shower energy is deposited



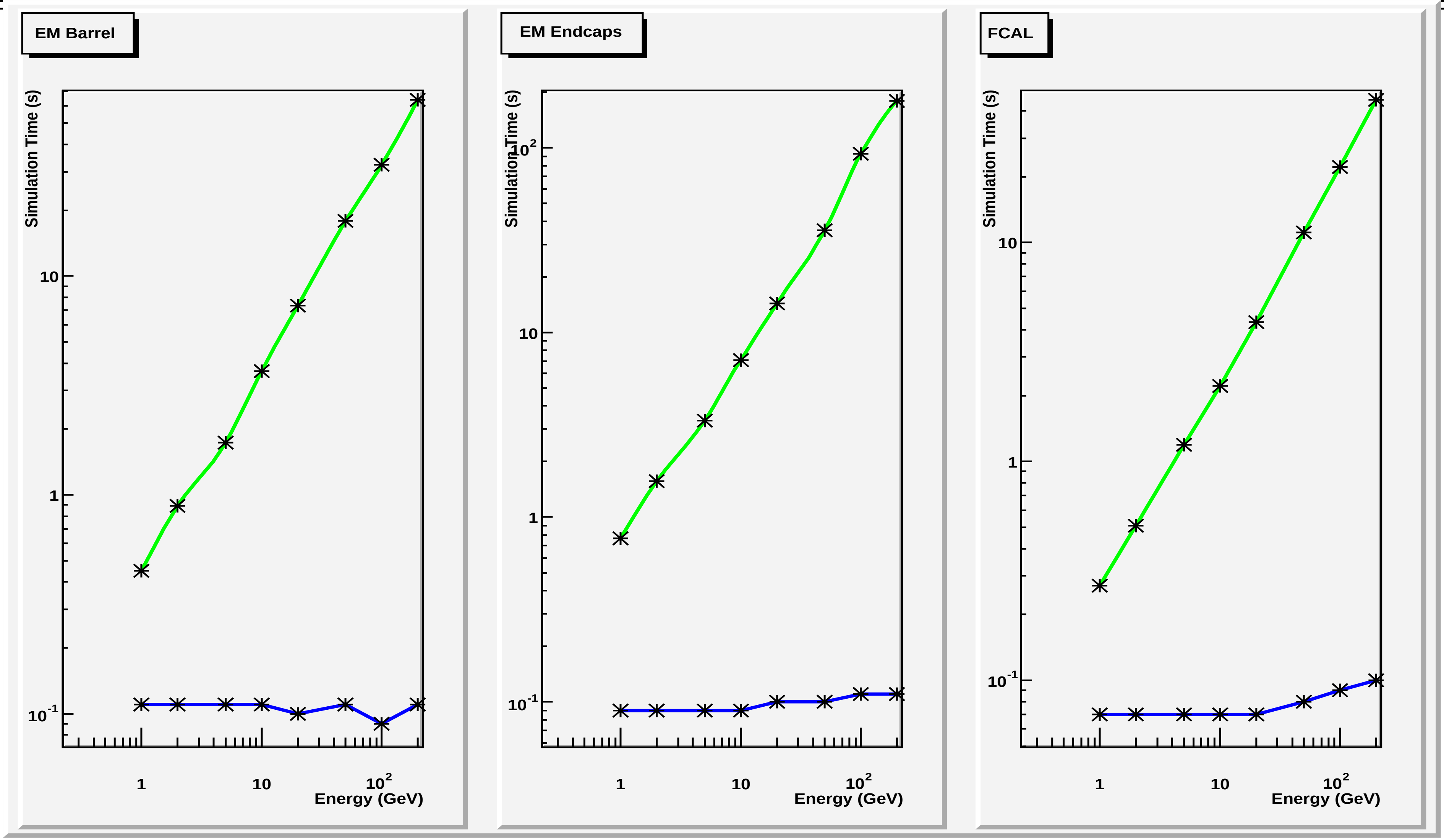
- Shower profiles for EMBarrel (1000 10GeV electrons) - using GEANT4 hits
- BLUE — Full simulation RED — Fast simulation



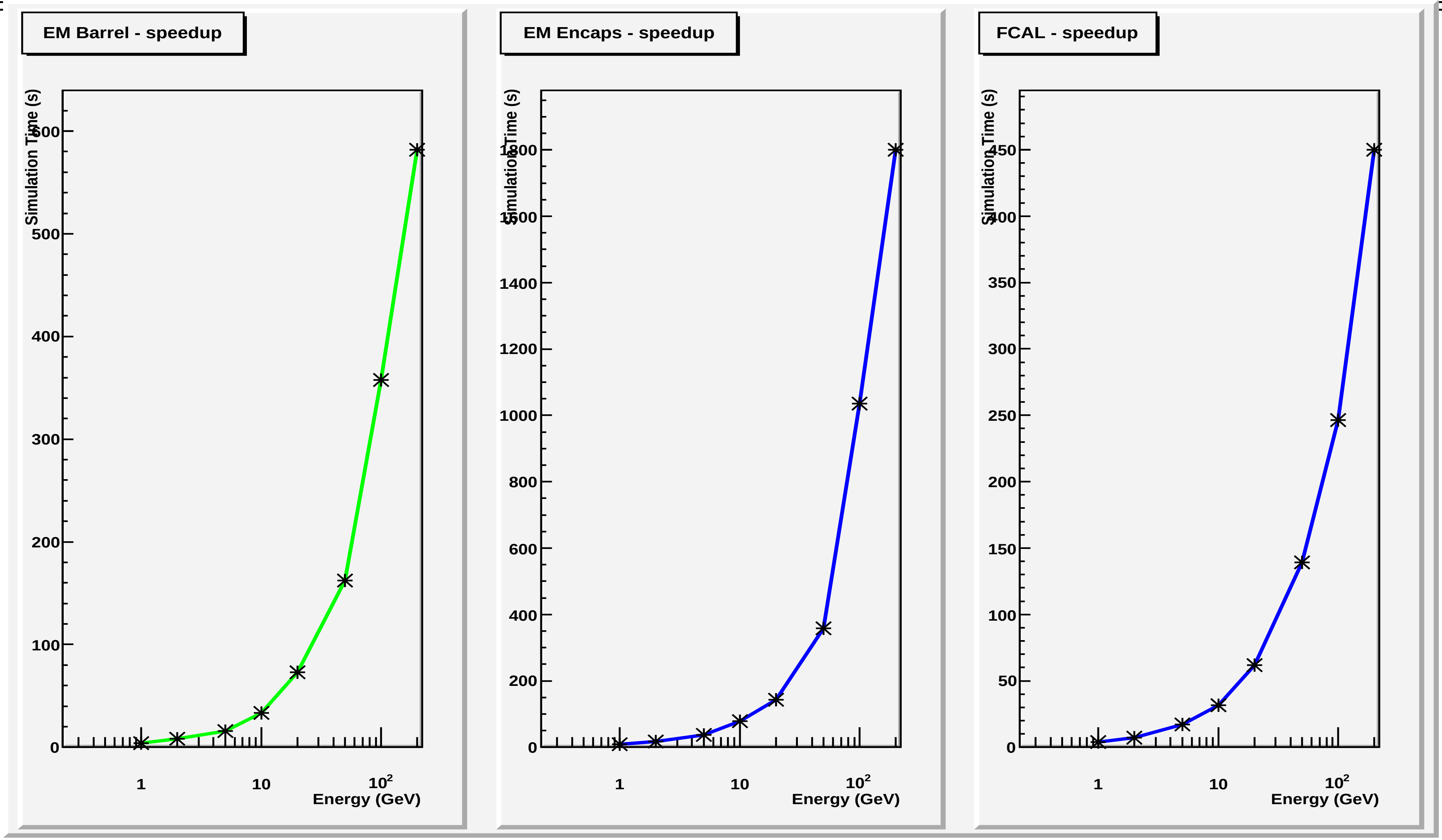
- Shower profiles for EM Endcap (1000 10GeV electrons) - using GEANT4 hits
- BLUE — Full simulation RED — Fast simulation



- Shower profiles for FCAL (500 10GeV electrons) - - using GEANT4 hits
- BLUE — Full simulation RED — Fast simulation



- electron shower simulation time (EM calorimeter only) for fast simulation and full simulation



- electron shower speedup (EM calorimeter only) for full simulation vs fast simulation

Validation

- Parallel production with athena 12.0.1
- To be validated by e-gamma person - blind analysis?
- Initially: single electrons, Z and W events.
- Down the track: jets, minimum bias events, susy

Current/Future Work

- Maintenance of code; significant changes to geometry or athena require refit
- Extend paramaterisation to hadron calorimeter and modules 2 and 3 of fcal to speed up simulation of EM component of hadron showers
- Feasibility of parameterising pion showers
- GEANT4.8

Conclusion

- EM calorimeter has been parameterised and fast simulation implemented
- Comparisons show reasonable agreement between full and fast simulations
- Timing is significantly improved
- Small production for validation using 12.0.1