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Shower Models for Calorimeter

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In this proceeding, I aim to summarise the status of the study of shower modela in GLD simulation group, including models of electronetic and hadronic.

1. INTRODUCTION

The work can be separated into two categories: electromagnetic (EM) related and hadronic (HD) related. This document follows this categorization.

2. EM RELATED

Simulations of EM processes provided in **GEANT4** [1] are called **standard EM process** (**physics_lists/electromagnetic/standard/**). Some added models written by Stanford team are called **LCPhysics** [2] (**LCIonPhysics, LCBosonPhysics, LCLeptonPhysics, and LCDecayPhysics**). The source codes of both **standard EM process** and **LCPhysics** are available and free of charge.

A sandwiched calorimeter is made in the compose of 8-mm-thick lead plates and 2-mm-thick scintillator plates with a transverse size of 1 m $\times$ 1 m and total layers of 18. By summing up the total energy deposited in the scintillator (dE/dx) and fitting the distributions by the Gaussian function, we then obtain the single e^- beam caused energy resolution. The comparsion of energy resolution between data [3] and MC results is given in Figure 1 (Left). It shows a good agreement between data and MC. With the extra models in **LCPhysics**, MC results will be a bit closer to the data.

In summary, the energy resolution results of the single e^- beam could simulate our prototype data well (Table I).

3. HD RELATED

There are no standard HD processes in **GEANT4**, we therefore test four suggested models by CMS team: **QGSP, LHEP, FTFP, and QGSC**. Extra HD models provided by Stanford team, **LCHadronPhysics**, will let our programs crashed down sometimes. We then give up to use it.

Similarly, we make a sandwiched calorimeter in the compose of 8-mm-thick lead plates and 2-mm-thick scintillator plates with a transverse size of 1 m $\times$ 1 m and total layers of 136. The 1st to 18th layers are treated as ECAL (EM calorimeter) and the 19th to 136th layers are HCAL (HD calorimeter). A 50-mm-thick iron block is placed in front of the ECAL to reject electrons while the π^- beam energy higher than 10 GeV. This special treatment is because of rebuilding the setup of the real data taking envirnment.

The comparsion of energy resolution between data [3] and MC results is given in Figure 1 (Right). Arguments of the best HD shower models are the one which provides the most close energy resolutions to data (Table I). We therefore conclude the **QGSP** is the best among them.

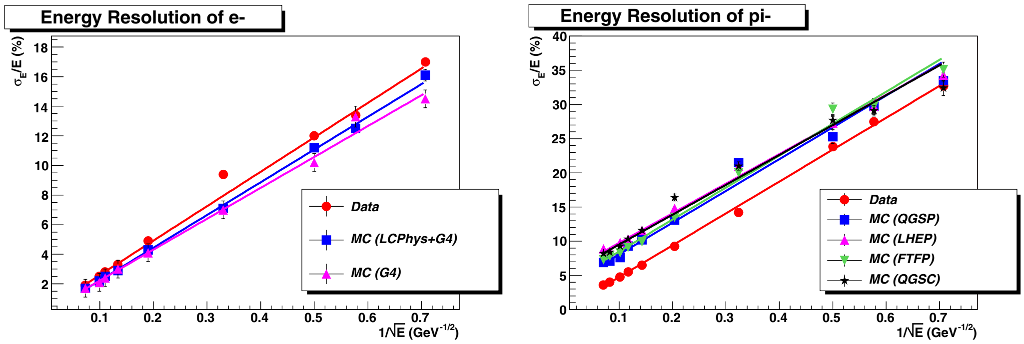

Figure 1: Comparsion of energy resolution of e^- (left) and π^- (right) between data and MC.

4. ENERGY CALIBRATION AND COMPENSATION

While there have been numerous designs of the calorimeter, it is important to realise that the same goal among them is to get the best jet energy resolution in the ILC envirnment. To reach this goal, the energy calibration and compensation studies need to be considered more seriously.

Calibration factor of e^- beam is obtained by scaling the mean value of total energy deposited in ECAL to its incident beam energy. In the π^- beam case, we first separate the absorbed energy in ECAL and HCAL. Then, sum up the energy as $\mathbf{E} = \mathbf{a} \times (\mathbf{E_{ECAL}} + \mathbf{b} \times \mathbf{E_{HCAL}})$. The factor $\mathbf{b}$ is determined by the minimum energy resolution of $\mathbf{E}$. We calibrate the mean value of the $\mathbf{E}$ to its incident beam energy by timing the other factor $\mathbf{a}$. Details of the energy calibration study are reported in another proceeding [4].

After energy is calibrated, we continue to compare the energy compensation between data [3] and MC. Energy compensation means the responsed EM and HD showers of the same energy are identical. In another word, if the e^- energy distribution in ECAL is equal to that of π^- in HCAL (e/π ratio equals to 1), we can conclude the "hardware compensation" idea to be succeeded. In Figure 2, data results show a good compensation, however, MC results don't match very well. The difference between data and MC is 10 to 30%, it may come from the non-perfect HD shower models and the calibration factors.

5. THICKNESS OF CALORIMETER

The calorimeter will cover about 70% of the GLD detector, therefore, to decide the volume of it is very important. To make sure the high energy jets, up to 200 GeV, will not escape from the end of the calorimeter, we sum up the whole energy absorbed in both Pb and Scintillator plates and compare to its incident energy (absorbed ratio). In Figure 3, the beam energy higher than 50 GeV points are more or less stable which indicates the enough thickness for high energy jets (6.37 λ_I). The low energy points, lower than 50 GeV cases, are 10% lower than expected. That may due to the non-perfect HD shower models or the bugs in **GEANT4**.

References

[1] http://geant4.web.cern.ch/geant4/. The version 7.0.p1 is used.

[2] http://www.slac.stanford.edu/comp/physics/geant4/slac_physics_lists/ilc/physlistdoc.html

[3] S. Uozumi, et al., Nucl. Instr. and Meth. A 487 (2002) 291-307.

[4] M.-C. Chang, "Calibration Factors", ALCPG1111.

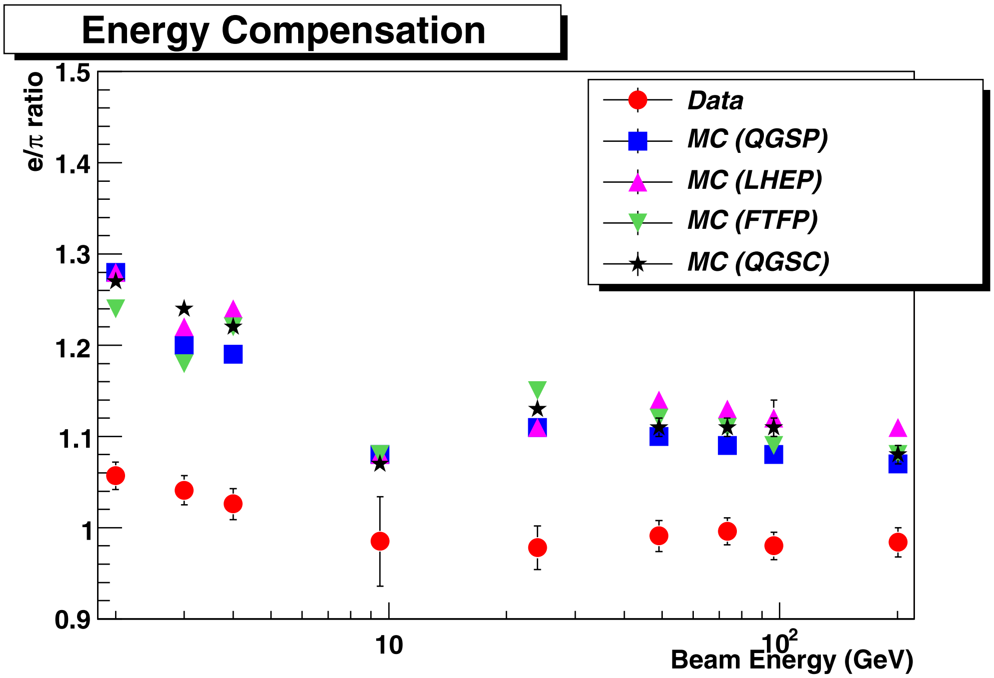

Figure 2: Comparsion of e^-/π^- ratio between data and MC.

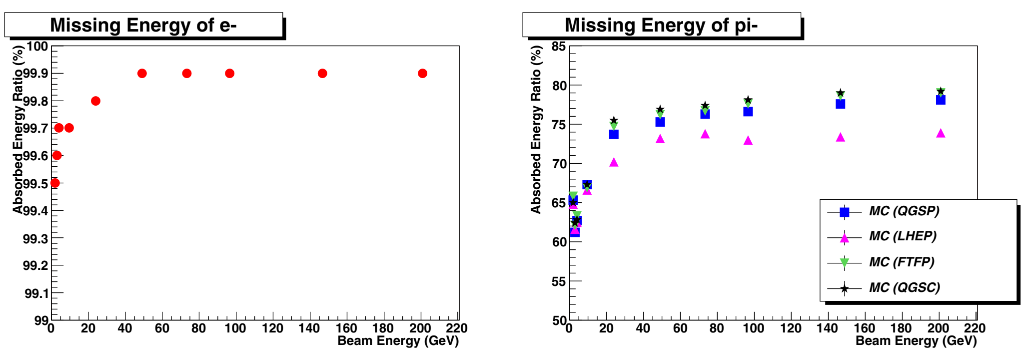

Figure 3: Absorbed energy ratio of e^- (left) and π^- (right) in MC.

Table I: Summary of energy resolution results in Figure 1. In the table, we use A and B for the fitting slope and constant term of the energy resolution results, where $\sigma_E/E = \mathrm{A}\%/\sqrt{E} \oplus \mathrm{B}\%$.

	A	**B**
e^- (Data)	22.1 ± 0.4	0.0 ± 0.1
e^- (MC, G4)	20.9 ± 0.9	0.1 ± 0.3
e^- (MC, G4+LCPhysics)	20.9 ± 0.9	0.1 ± 0.3
π^- (Data)	46.6 ± 0.4	0.1 ± 0.1
π^- (MC, QGSP)	46.5 ± 1.0	3.4 ± 0.2
π^- (MC, FTFP)	46.8 ± 1.0	3.8 ± 0.2
π^- (MC, QGSC)	43.7 ± 1.0	5.1 ± 0.2
π^- (MC, LHEP)	43.3 ± 1.0	5.4 ± 0.2