COMPARISONS OF HADRONIC SHOWER PACKAGES

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We report on simulation studies comparing various hadronic shower packages. Results show that predictions from different models vary significantly, illustrating the necessity of testbeam data to resolve the situation.

1 Introduction

The high precision measurements needed to exploit the physics potential of an e^+e^- Future Linear Collider with 0.5 - 1 TeV center-of-mass energy range set strict requirements on performance of vertex, tracking and calorimetric detectors. The CALICE Collaboration [1] has been formed to conduct the research and development effort needed to bring initial conceptual designs for the calorimetry to a final proposal suitable for an experiment at the Future Linear Collider. Software development and simulation studies play a key role in this effort. Some such studies are reported here.

2 Comparisons of hadronic shower models

The CALICE Collaboration proposes that both electromagnetic and hadronic calorimeters should be highly granular to allow very efficient pattern recognition for excellent shower separation and particle identification within jets and subsequently to provide excellent jet reconstruction efficiency [1,2]. Prototypes are being constructed and simulation studies are under way to support and guide the forthcoming testbeam program. Such studies will help to identify regions where testbeams should focus to give answers, resolve discrepancies and finally lead to a simulation code with validated and reliable predicting power.

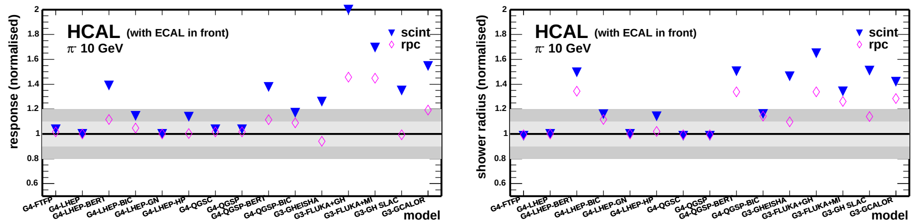
In the following we report briefly on systematic comparisons of different hadronic shower models. A plethora of models are available within GEANT3 [3] and GEANT4 [4] simulation frameworks. In table 1 we give a short description of those we have studied. In GEANT3 several GHEISHA and FLUKA based models are implemented. In GEANT4 all models involve GHEISHA; low and high energy extensions with intranuclear cascade models and quark-gluon string models respectively can be added. We simulated an electromagnetic calorimeter longitudinally segmented into 30 layers of W of varying thickness as absorber (the first 10 layers at 1.4 mm thick each, 2.8 mm in the next 10 and 4.2 mm in the final 10) interleaved with 0.5 mm Si pads as sensitive material.

model tag	brief description
G3-GHEISHA	GHEISHA, parametrized hadronic shower development
G3-FLUKA-GH	FLUKA, for neutrons with $E < 20$ MeV GHEISHA
G3-FLUKA-MI	FLUKA, for neutrons with $E < 20$ MeV MICAP
G3-GH SLAC	GHEISHA with some bug fixes from SLAC
G3-GCALOR	$E < 3$ GeV Bertini cascade, $3 < E < 10$ GeV hybrid Bertini/FLUKA, $E > 10$ GeV FLUKA, for neutrons with $E < 20$ MeV MICAP
G4-LHEP	GHEISHA ported from GEANT3
G4-LHEP-BERT	$E < 3$ GeV Bertini cascade, $E > 3$ GeV GHEISHA
G4-LHEP-BIC	$E < 3$ GeV Binary cascade, $E > 3$ GeV GHEISHA
G4-LHEP-GN	GHEISHA + gamma nuclear processes
G4-LHEP-HP	as G4-LHEP, for neutrons with $E < 20$ MeV use evaluated cross-section data
G4-QGSP	$E < 25$ GeV GHEISHA, $E > 25$ GeV quark-gluon string model
G4-QGSP-BERT	$E < 3$ GeV Bertini cascade, $3 < E < 25$ GeV GHEISHA, $E > 25$ GeV quark-gluon string model
G4-QGSP-BIC	$E < 3$ GeV Binary cascade, $3 < E < 25$ GeV GHEISHA, $E > 25$ GeV quark-gluon string model
G4-FTFP	$E < 25$ GeV GHEISHA, $E > 25$ GeV quark-gluon string model with fragmentation ala FRITJOF
G4-QGSC	$E < 25$ GeV GHEISHA, $E > 25$ GeV quark-gluon string model

Table 1: a brief line of description per studied model.

It is read out in 1 cm^2 cells. The hadronic calorimeter consists of 40 layers of Fe absorber, each 18 mm thick, equipped with scintillator tiles or resistive plate chambers (rpc). For the latter version digital readout is envisaged. Both versions are simulated as being read out in 1 cm^2 cells. Detector geometry and material definition were implemented identically in both frameworks and their corresponding physics control parameters were tuned to produce the same mip peak value for muons. Several experimentally accessible parameters predicted by the different models were studied, such as total response, response per detector cell, transverse and longitudinal development of showers *etc.* An example, corresponding to incident π^- at 10 GeV, is shown in Fig. 1. Different models predict significantly different HCAL response, Fig. 1(a), and similarly different shower size, Fig. 1(b). Results for both versions of HCAL are shown.

In general, our observations from such studies can be summarised by the following: 1) predictions of FLUKA based models are definitely different from those of GHEISHA ones. 2) The treatment of low energy neutrons is important especially for the scintillator HCAL and as expected has little effect on a gaseous detector (HCAL rpc). 3) Intranuclear cascade models also play a crucial role. 4) ECAL standalone with total depth of about 1 λ_I may have some discriminating power with low energy incident hadrons, as can be seen in Fig. 2. Further detailed studies are under way, waiting to be confronted with



(a) (b)

Figure 1: (a) hadronic calorimeter response, in terms of total number of cells hit, vs hadronic model, (b) average shower radius vs model. Results are normalised to the G4-LHEP case, $\pm 10\%, \pm 20\%$ bands shown to guide the eye.

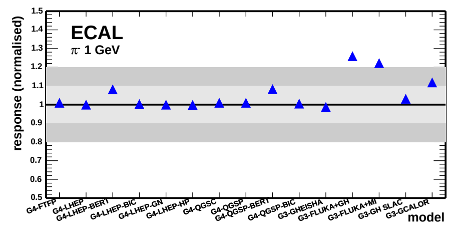


Figure 2: electromagnetic calorimeter response (total number of cells hit) to incident π^- at 1 GeV vs hadronic model.

testbeam data.

3 Conclusion

Simulation studies reveal significant discrepancies among packages, thus preventing model independent predictions on calorimeter performance and reliable detector design optimization. This underlines the necessity and the importance of an extensive testbeam program to resolve the situation and reduce the current large uncertainty factors.

References

1. CALICE Collaboration `http://polywww.in2p3.fr/flc/calice.html`
2. talks on calorimetry *these proceedings*.
3. R. Brun *et al.* GEANT3.21, CERN Program Library W5013 and references therein for GHEISHA and FLUKA models.
4. S. Agostinelli *et al.* (GEANT4 Collaboration) *Nucl. Instrum. Methods* A**506** (2003) 250, `http://geant4.web.cern.ch/geant4/` and references therein for the various models implemented.