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WORLDWIDE LINEAR COLLIDER CALORIMETER R&D TEST BEAM EFFORT[a]

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The talk summarizes the goals of the calorimeter R&D and the requirements for a test beam programme. It gives an overview on past and present activities and describes the ongoing preparations for a collaborative effort towards combined tests with electromagnetic and hadronic prototypes.

1 Introduction: Calorimeter R&D challenges

The excellent physics potential of a linear collider must be matched by an adequate detector performance [1,2]. The need to reconstruct heavy boson (W,Z,H) hadronic decays in multi-jet events and to separate them by means of the dijet invariant mass represents a formidable challenge for the detector, namely the calorimeter: one aims at a jet energy resolution of $30\%/\sqrt{E}$, a factor of 2 better than obtained in present experiments. Simulations show that this can be achieved in the so-called "particle flow" approach which optimizes the overall resolution of tracking and calorimetric systems together by measuring each particle separately. In this approach the spatial resolution and the particle separation power of the calorimeters are at least as important as the single particle energy resolution.

These requirements translate into a very compact (dense) electromagnetic calorimeter (ECAL) design with small effective Moliere radius. Most ECAL R&D efforts favor a Silicon Tungsten concept with a technologically very challenging thin (~ 2 mm) readout gap. With about 3000 m^2 of Si sensors needed, the ECAL cost amounts to almost half of the total detector budget. Therefore, since particle separation requires large radius and length, the ECAL geometry and compactness, but also the reconstruction algorithms have to be very carefully optimized.

The hadron calorimeter (HCAL) must be imaging as well. Two different readout options are being followed, one based on scintillator, but with fine granularity, using novel types of photo-detectors. The other is based on large area gaseous detectors and digital readout, i.e. recording hit information only, on pads as small as 1 cm^2. Innovative pattern recognition programs for the

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reconstruction of the tree structure of the hadronic cascade are being created in parallel.

The R&D effort has a strong emphasis on software, since fully developed, separately optimized particle flow algorithms are needed to evaluate the different design concepts. However, these algorithms make use of details of the simulations to which existing (coarser) calorimeters are insensitive.

The goal of the test beam effort [4] is to demonstrate the feasibility of the advanced technologies, to further develop the algorithms and to validate the simulations, i.e. to confront the particle flow approach with real data and to lay a solid ground for basic detector choices.

2 Test beam and detector requirements

Mean single particle energies in linear collider events are typically 6 to 12 GeV, but the spectra extend to 100 GeV and beyond. Test beams should thus cover an energy range starting in the GeV regime, but reach up to 50 GeV at least. Electrons and hadrons are needed; muons would be valuable in addition for calorimeter tracking studies and calibration. Test-beam facilities which meet these basic requirements are presently offered by FNAL (USA) and IHEP (Russia).

To ensure reasonable containment, the HCAL prototypes are of roughly cubic meter size. For the granularities under consideration, this implies of the order of 10'000 electronic channels for the analogue HCAL and 10 times more for the digital version. The range of particle incidence angles is also large and suggests for realistic particle reconstruction development a flexible test set-up allowing for wide angular scans.

The beam must be well defined: the energy spread should stay within 1 - 2 %, particle identification devices should allow to select types with high purity, and tracking devices must define the impact for single events to 1 mm precision. Magnetic fields are required only for technology tests of small devices, not necessarily with beam.

In order to estimate the sensitivities required to validate simulations, Monte Carlo studies using different hadron shower codes have been performed[3]. Examples are shown in Fig. 1. Considerable differences are observed in both ECAL and HCAL, and they vary with energy, particle type, and active detector material. Thus both pions and protons are needed, and the the proposed HCAL technologies must be tested separately.

The number of different detector, particle type, energy and angular configurations to be tested is of the order of 10^2. Large data samples of 10^6 events per configuration are needed, not only to allow tighter beam selection

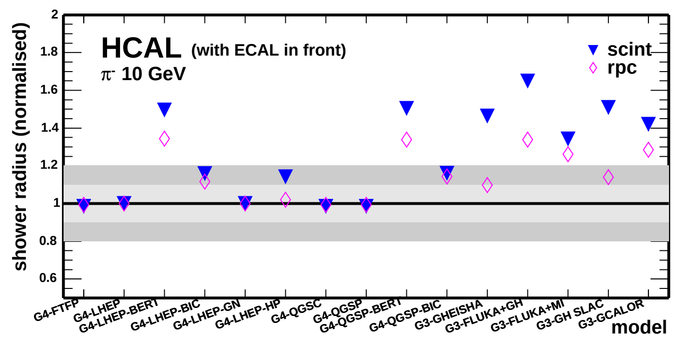

Figure 1: Normalized shower radius in a hadron calorimeter as predicted by different hadron shower models.

but also to analyze the hadron shower data as a function of observables which cannot be pre-configured, like the electromagnetic energy fraction, the number of hadronic interaction vertices, or the longitudinal and lateral containment. Such studies are needed for the optimization of both the single particle energy reconstruction using weighting methods, as well as for particle flow algorithm development. Beam intensities and data acquisition systems must thus allow for mean rates of about 100 Hz, in oder to complete such a programme in several weeks of running time.

3 Past and present test-beam activities

An overview on the worldwide linear collider calorimetry R&D activities can be found in [2,4]. Test-beam studies with pre-prototypes have already been performed and results are reported to this conference. Japanese groups [5] have finished this spring a series of beam tests which started already on 1996 and included a joint test of scintillator based ECAL shower maximum prototype together with the CALICE scintillator steel HCAL pre-prototype ("minical") in the DESY low energy electron test beam. The CALICE minical has undergone a series of tests with different types of photodetectors [6] and established a novel photodetector technology, the "silicon photo-multiplier" on a 100 channel basis. A scintillator silicon hybrid ECAL prototype was constructed and delivered the expected performance in a test-beam programme carried out by the Italian LCCAL group [7].

4 Preparations for a worldwide test beam programme

The Asian, American and European groups are all intending to use the time period 2005-2008 for beam tests. The plans of the CALICE collaboration, discussed here, comprise a world-wide efforts of 170 physicists from 28 institutions located in all three regions. The groups are actively pursuing the construction of prototypes for a silicon tungsten ECAL and for different HCAL options, based on scintillator or gaseous detector readout. The collaborative nature of the programme is underlined by a high degree of task sharing in the prototype construction on one hand, and commonly used hardware, software and infrastructure on the other. A versatile mechanical structure is foreseen to allow insertion of active modules with different readout technologies, and the ECAL and analog HCAL – with almost 10k channels each – are using a unified DAQ system. Test-beam simulation and reconstruction software is being developed in a common framework. Fig. 2 shows a simulated event [8] in the combined set-up, which includes a scintillator steel tail catcher and muon tracker.

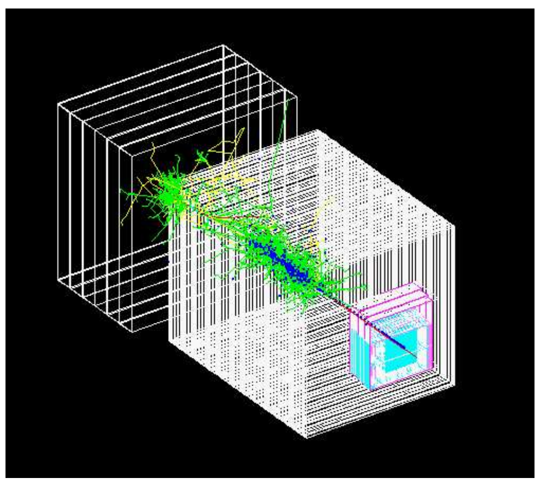

Figure 2: Simulated test-beam event: a π^- with 40 GeV energy enters the setup of Si W ECAL, scintillator steel HCAl and tail catcher as being prepared by CALICE.

CALICE test-beam data taking will start with the first ECAL modules in the DESY electron beam in the end of this year 2004. The goal is to then integrate the scintillator HCAL and move both into a hadron beam in 2005. Other HCAL options will follow in 2006, and combinations with ECAL options being prepared by other groups are also being discussed.

References

1. J.A.Aguilar-Saavedra *et al.,* TESLA Technical Design Report, Part III, Physics at an e^+e^- Linear Collider, DESY 2001-011, hep-ph/010631.

2. J.Brau *et al.,* Linear Collider Detector R&D, http://blueox.uoregon.edu/ lc/randd.html

3. G. Mavromanolakis and D. Ward, this conference.

4. Worldwide LC Test Beam Working Group, http://www-lc.fnal.gov/lc_testbeams/wwlctb_working_group.pdf

5. H. Miyata, this conference, K. Kawagoe, *ibid.,* T. Takeshita, *ibid.*

6. E. Garutti, this conference, J. Cvach, *ibid.*

7. P. Checchia, this conference.

8. R. Poeschl, this conference.