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Response of the CALICE Si-W electromagnetic calorimeter physics prototype to electrons

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ABSTRACT

A prototype silicon–tungsten electromagnetic calorimeter (ECAL) for an international linear collider (ILC) detector was installed and tested during summer and autumn 2006 at CERN. The detector had 6480 silicon pads of dimension $1 \times 1\,\text{cm}^2$. Data were collected with electron beams in the energy range 6–45 GeV. The analysis described in this paper focuses on electromagnetic shower reconstruction and characterises the ECAL response to electrons in terms of energy resolution and linearity. The detector is linear to within approximately the 1% level and has a relative energy resolution of $(16.53 \pm 0.14(\text{stat}) \pm 0.4(\text{syst}))/\sqrt{E(\text{GeV})} \oplus (1.07 \pm 0.07(\text{stat}) \pm 0.1(\text{syst}))$ (%). The spatial uniformity and the time stability of the ECAL are also addressed.

1. Introduction

The CALICE Collaboration is conducting R&D into calorimetric systems for the ILC [1]—a proposed e^+e^- linear collider intended to operate at a centre of mass energy ranging up to the TeV scale. The physics scope at the ILC includes precise measurements of the triple- and quartic-gauge bosons interactions, as well as the complete characterisation of the Higgs-boson and top-quark sectors. In addition, searches for physics beyond the Standard Model could most often be addressed in a model-independent way.

The final states are typically multiple hadronic jets, accompanied frequently by low-momentum leptons and/or missing energy. The signature of the final states of interest often relies on the identification of Z or/and W bosons in their decay modes into two jets. In order to distinguish them efficiently, a jet energy resolution close to $30\%/\sqrt{E/\text{GeV}}$ has to be achieved [1]. A precise reconstruction of the jet direction (few mrad$/\sqrt{E/\text{GeV}}$) is also required. These are among the main requirements driving the detector design in general at the ILC and the calorimetry design in particular.

The target jet energy resolution represents an improvement by a factor close to two over the best obtained in previous detectors. Moreover the detection environment becomes more complex with increasing centre-of-mass energy. A promising way to achieve this increase in resolution is through designing a detector system optimised for the so called "*particle flow*" approach [2], which relies on the separate reconstruction of as many particles in the jet as possible, using the most suitable detector systems.

The success of such an algorithm depends on the quality of the pattern recognition in the calorimeters. For particle flow, a high spatial granularity is therefore as important as the intrinsic energy resolution for single particles. Furthermore, the overall design of the detector (tracking, electromagnetic and hadronic calorimetry) needs to be considered in a coherent way.

The design of the ILC detectors can be optimised using Monte Carlo simulations, but in order to do this, it is crucial to validate the Monte Carlo tools with data. Therefore, the R&D of the CALICE Collaboration has two broad aims. The first is to construct realistic calorimeter prototypes, and learn about their operation and behaviour in beam-tests. The second objective is to compare the data with Monte Carlo simulations using the same tools as those used for the full detector. This is especially important in the case of hadronic showers, for which many models are available, with differing predictions for the calorimeter response. The CALICE plan is to expose complete calorimeter systems (electromagnetic and hadronic, using various technologies) to test beams of electrons, muons and hadrons. To this end, a first round of beam-tests was performed at DESY and CERN in summer 2006, using a silicon–tungsten sampling electromagnetic calorimeter [3], followed by a hadron calorimeter composed of iron and scintillator tiles [4], and then a tail catcher and muon counter (TCMT) of iron instrumented with scintillator strips [5].

In this paper, the results of exposure of the prototype to electron beams in the energy range 6–45 GeV at the CERN H6 beam line [6] are reported. The layout of the beam-tests is outlined in Section 2. The ECAL is briefly described in Section 3 and some key technical aspects of its performance are highlighted. Section 4 summarises the Monte Carlo simulation. Features of the electron beam data are reviewed in Section 5 and the uniformity across the detector is addressed. The results of the energy measurements together with some of their systematic uncertainties are presented in Section 6 for the detector areas of uniform response.

Several other studies of the prototype are ongoing, exploiting its unprecedentedly fine segmentation and capacity to observe shower development in detail. These studies will be reported in subsequent publications.

2. Experimental setup

A sketch of the CERN H6 [6] test-beam setup is presented in Fig. 1 and a detailed description of the detectors can be found in Ref. [3]. The beam trigger was defined by the coincidence signal of two of the three scintillator counters (referred to as Sc2, Sc3 and

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