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Analysis of hadronic showers in the physics prototype of the CALICE silicon tungsten electromagnetic calorimeter - Si-W ECAL

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Introduction

The physics at future high-energy lepton colliders requires jet energy reconstruction with unprecedented precision. Detector concepts for the International Linear Collider (ILC) and the Compact Linear Collider (CLIC) rely on Particle Flow Algorithms to achieve the necessary precision. This event reconstruction technique requires highly granular calorimeters to deliver optimal performance. Such calorimeters are developed and studied by the CALICE collaboration.

To develop realistic Particle Flow Algorithms, the interactions of hadrons must be modelled reliably in Monte Carlo simulations and the detector response to hadrons must be well-understood.
Highly granular calorimeter prototypes provide a unique means to test and to further develop models of hadronic cascades.
The response of the CALICE silicon-tungsten electromagnetic calorimeter prototype (Si-W ECAL) is used to test hadronic shower models at low energies. The depth of the Si-W ECAL corresponds to approximately one interaction length (λ_I), which means that, although the complete shower is not recorded, the first hadronic interaction can be studied in great detail because of the fine longitudinal and transversal sampling.
The Si-W ECAL was operated in a test beam at the Fermi National Accelerator Laboratory (FNAL) with negatively charged pions (π^-) in the energy of range $2-10$ GeV.
The majority of charged pions and other hadrons within high energy jets have energies in this range and therefore it is of considerable interest to validate the performance of Monte Carlo simulations at these energies.

Studying the structure of the first hadronic interaction

The results of the study of global observables such as radial and longitudinal hit and energy distributions of hadronic showers, that has been published in *Nucl.Instrum.Meth. A794 (2015) 240-254* will be briefly recapitulated. As an extension of this analysis the contribution will present new results that become available due to the high granularity of the Si-W ECAL
An algorithm has been developed to measure tracks in the Si-W ECAL, while permitting at the same time to characterise the interaction zone in terms of energy deposition and spatial extension. All observables studied in the analysis are thus very detailed probes of hadronic shower models.

The entire set of the results of this innovative study will be presented for the first time at the CALOR conference.

The analysis will compare the energy deposited in the interaction zone and the number of tracks that emerge from the interaction zone for different energies of the primary pion. Preliminary results show that, as expected, the deposited energy and the number of tracks increase with the energy of the primary pion. However, the tested Monte Carlo models contained in GEANT4 are not able to reproduce the energy deposited in the first hard interaction. On the other hand track based observables are surprisingly well reproduced by the Monte Carlo Models.

The secondaries that lead to measurable tracks interact in the Si-W ECAL in form of MIPs. As will be shown, the analysis is also a first step towards an in-situ calibration of the Si-W ECAL. In-situ calibration will be extremely useful to monitor the response of a full size Si-W ECAL in a Linear Collider experiment.

Precise tracking in the Si-W ECAL is an indispensable premise for the application of Particle Flow algorithms to highly granular calorimeters. The successful seed of secondary tracks in the Si-W ECAL facilitates the reconstruction of tracks throughout the calorimeter system that will be completed by a hadronic calorimeter with depth of several interaction lengths. The comparatively simple tracking algorithm, as presented in this contribution, will allow to judge on the performance of more involved algorithms such as PandoraPFA or ARBOR.

Summary

A detailed study of hadronic interactions is presented using data recorded with the highly granular CALICE silicon-tungsten electromagnetic calorimeter. The predictions of several Monte Carlo GEANT4 models are compared with experimental data, taken at FNAL in 2008.
The contribution recaps results published in 2015 and a set of new results available since the beginning of 2016.
The published results present a detailed analysis of hadronic showers in terms of radial and longitudinal hit and energy distributions.For the most recent analysis a simple track-finding algorithm was developed to study tracks left by secondary particles, emerging from hadronic interactions in the highly granular electromagnetic calorimeter prototype.

Present Monte Carlo simulations provide a good description of the experimental data in terms of new observables, available through the detailed analysis of secondary particles; the Monte Carlo predictions are within 20% of the data, and for many observables much closer.

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