Thesis Abstract Yuichi Okugawa

"Analysis of test beam data using a technological prototype of a highly granular calorimeter and study of light quark production at a future linear collider"

One of the physics goals at future linear colliders, particularly at the International Linear Collider (ILC), is the precision measurement of the electroweak couplings between the Z/gamma and fermion pair which might be altered by the presence of new particles in the propagator. These electroweak couplings depend on the fermion helicity. Therefore this measurement is greatly supported by the polarization of electron and positron beams. One way to extract these couplings is by measuring the differential cross-section as a function of the polar angle of the fermion. From this, the forward-backward asymmetry can be derived. This observable is defined as the difference between the cross-section in the forward and backward hemispheres with respect to the polar angle of the scattered fermion, divided by the total cross-section. Previously, heavy flavor pair production (t, b, c) was investigated. This analysis extends this study to light quark pair production at the ILC with a 250 GeV center-of-mass energy, using the full detector simulation of the International Large Detector (ILD) concept. In previous years, we have elaborated widely recognized results for the heavy quarks (t and b). The extension to lighter quarks (u, d, and s) perfectly complements this research program. In contrast to the heavy quark pair production analysis, it is not possible to extract the original hard process using the vertex charge information, as was the case for the t, b, and c jets. In the context of light quark jets, we select the hardest charged Particle Flow Object (PFO) within a jet, which is supposed to be the imprint of the hard process. To accomplish this, a precise particle identification method is required, which is achieved by the utilization of the dE/dx information provided by the Time Projection Chamber (TPC) of ILD. The obtained results will underline the discovery potential of linear colliders by measuring a pattern of deviations with respect to the Standard Model of particle physics.

The second part of this thesis is the analysis of data recorded with the electromagnetic calorimeter prototype. Highly granular calorimeters are part of all detector concepts of current and future particle physics projects, particularly for those of future e+e-colliders. At IJCLab, we are working intensively on R&D for an electromagnetic calorimeter that uses silicon as an active part and tungsten as the absorber material. Since the end of 2021, three individual test beam campaigns have been conducted dedicated to investigating the performance of these prototypes. The first two experiments took place at DESY, which used 1-5 GeV electron beams, while the third one was at CERN SPS, where we had access to three different types of beams (electron, muon, pion) with energies ranging from 10-200 GeV. In all three experiments, we were able to combine 15 layers of the SiW-ECAL, which makes the number of operating calorimetric cells over 15,000. With this quantity of cells, careful commissioning and control of the detector had to be conducted. The analysis of the result requires event building, which relates all hits registered in the detector with the same or nearby Bunch-Crossing-ID. Once the event reconstruction is processed, event selections are applied to purify the data samples. The event display was developed to verify the shapes of the shower profile. The final result of this thesis compares data to GEANT4 simulations, into which the test beam environment has been implemented.

English (for general public)

At the International Linear Collider (ILC), researchers aim for precision measurements of the Higgs Boson and of the electroweak coupling between particles. They achieve this by adjusting the beam polarization to increase pair production and calculate couplings using differential cross-sections. While heavy quarks have been studied, this analysis explores lighter quarks (u, d, s) at the ILC, requiring precise particle identification. The final state of the process under study comprises particle jets. Therefore, the second part of the thesis focuses on an electromagnetic calorimeter prototype with silicon and tungsten components. Three test beam experiments, conducted at DESY and CERN SPS, assessed the prototype's performance. With over 15,000 operating cells, careful commissioning and control were necessary. The final analysis compared experimental results to GEANT4 simulations.