University of Victoria | Graduate Studies

Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

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MSc (University of Victoria, 2015)
BEng (McMaster University, 2013)

"First Application of CsI(Tl) Pulse Shape Discrimination at an e^+e^- Collider to Improve Particle Identification at the Belle II Experiment"

Department of Physics and Astronomy

Monday, October 7, 2019
2:00 P.M.
David Strong Building
Room C130

Supervisory Committee:
Dr. J. Michael Roney, Department of Physics and Astronomy, University of Victoria (Supervisor)
Dr. Robert Kowalewski, Department of Physics and Astronomy, UVic (Member)
Dr. Michel Lefebvre, Department of Physics and Astronomy, UVic (Member)
Dr. Alexandre Brolo, Department of Chemistry, UVic (Non-Unit Member)

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Dr. Hirohisa A. Tanaka, SLAC National Laboratory, Stanford University

Chair of Oral Examination:
Dr. Mantis Cheng, Department of Computer Science, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

This dissertation investigates CsI(Tl) pulse shape discrimination (PSD) as a novel experimental technique to improve challenging areas of particle identification at high energy e^+e^- colliders using CsI(Tl) calorimeters. In this work CsI(Tl) PSD is implemented and studied at the Belle II experiment operating at the SuperKEKB e^+e^- collider, representing the first application of CsI(Tl) PSD at a B factory experiment.

Results are presented from Belle II as well as a testbeam completed at the TRIUMF proton and neutron irradiation facility. From the analysis of the testbeam data, energy deposits from highly ionizing particles are shown to produce a CsI(Tl) scintillation component with decay time of 630±10 ns, referred to as the hadron scintillation component, and not present in energy deposits from electromagnetic showers or minimum ionizing particles. By measuring the fraction of hadron scintillation emission relative to the total scintillation emission, a new method for CsI(Tl) pulse shape characterization is developed and implemented at the Belle II experiment's electromagnetic calorimeter, constructed from 8736 CsI(Tl) crystals.

A theoretical model is formulated to allow for simulations of the particle dependent CsI(Tl) scintillation response. This model is incorporated into GEANT4 simulations of the testbeam apparatus and the Belle II detector, allowing for accurate simulations of the observed particle dependent scintillation response of CsI(Tl). With $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, $K^{\pm}$ and $p/\bar{p}$ control samples selected from Belle II collision data the performance of this new simulation technique is evaluated. In addition the performance of hadronic interaction modelling by GEANT4 particle interactions in matter simulation libraries is studied and using PSD potential sources of data vs. simulation disagreement are identified.

A PSD-based multivariate classifier trained for K_L^0 vs. photon identification is also presented. With K_L^0 and photon control samples selected from Belle II collision data, pulse shape discrimination is shown to allow for high efficiency K_L^0 identification with low photon backgrounds as well as improved π^0 identification compared to shower-shape based methods.