Study of charm production by neutrinos in nuclear emulsion
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Summary

The neutrino is one of the known fundamental particles. It is only very weakly interacting with matter, hence it is difficult to detect. Since decades, in experiments all around the world, neutrinos are used as a probe and they are subject of research to reveal their properties.

The CHORUS experiment at CERN has been designed to search for neutrino oscillation of the type $\nu_\mu \rightarrow \nu_\tau$. It uses 720 kg of nuclear emulsion simultaneously as a target and as a tracker in three dimensions with sub-μm resolution. The emulsion information is combined with electronic detector information, e.g. energy and momentum measurements.

In this thesis charm production by neutrinos is studied. Although not directly concerned with the main purpose of the CHORUS experiment, this work could be included in the CHORUS programme. It could make use of—and possibly contribute to—the measurements and techniques developed for the neutrino oscillation search. CHORUS and E531 at Fermilab (USA) are the only experiments where charmed particles can be directly observed in the emulsion, both at the production and at the decay vertex.

Two different production mechanisms of charmed particles by neutrinos are analyzed: deep-inelastic and diffractive charm production.

To suppress any background, the deep-inelastic charm production study concentrates on the muonic decay channels of the charmed hadrons. This results in a data sample of 132 observed charm decays. With this sample the fractional charm production (with muonic decay) per charged-current interaction is measured to be $(4.6 \pm 0.4 \pm 0.7) \times 10^{-3}$. This charm production as a function of the neutrino energy is in agreement with other experiments. The cross section ratio of neutral and charged charmed hadrons as a function of the neutrino energy shows at low energies a tendency of enhanced production of charged with respect to the neutral charmed hadrons.

Describing the charm production cross section with the slow rescaling model,
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results in a charm quark mass of $m_c = (1.6 \pm 0.8)$ GeV. Parameterizing the charm hadronization with the Peterson fragmentation model gives for the fragmentation parameter $\epsilon_P = 0.12 \pm 0.02 \pm 0.06$. The integrated strangeness-down ratio in the nucleon is measured to be $s/d = 0.024 \pm 0.011 \pm 0.008$. Combining information of charged charm production from E531 with our observed neutral over charged charm ratio leads to a weak mixing angle value $V_{cd} = 0.247 \pm 0.028$.

The diffractive production search focuses on $D_s^*$ mesons with subsequent decays $D_s^* \to D_s \to \tau \to \mu$. In this thesis we present the first observation of a neutrino induced charged-current charm production event showing this unique decay signature. A complete analysis of this single event is possible thanks to the exceptional tracking capabilities of the CHORUS hybrid emulsion detector. At the primary vertex no nuclear break-up is observed. The structure of the whole event, the measured $Q^2 = (0.8 \pm 0.1)$ GeV$^2$ and $|t| = (1.1 \pm 0.4)$ GeV$^2$ point to diffractive $D_s^*$ production on a nucleon. The observation of one event is expressed in an upper limit of the cross section per charged-current interaction of $4.6 \times 10^{-3}$ at 90% CL.

Our results show that the CHORUS data can contribute significantly to the knowledge of charm production by neutrinos. They motivate a dedicated charm study, including the hadronic decay channels. This can lead to a ten times bigger charm sample using the emulsion data from the Phase II CHORUS emulsion scanning and analysis. For the first time, it then may also become possible to study simultaneously deep-inelastic and diffractive charm production by neutrinos in detail.