Reconstruction of Semileptonic Decays and
Search for $B^0_s \rightarrow K^{*+}\mu^+\nu_\mu$ at the LHCb Experiment

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Abstract

A search for the semileptonic decay $B^0_s \rightarrow K^{*+}\mu^+\nu_\mu$ is performed on the data collected by the LHCb experiment in proton-proton collisions at the centre-of-mass energy of 8 TeV corresponding to an integrated luminosity of 2.08 fb⁻¹. This decay is induced by a $b \rightarrow u$ transition at quark level which allows to determine the Cabibbo-Kobayashi-Maskawa (CKM) matrix element $|V_{ub}|$. A novel technique using neural networks for the reconstruction of $B^0_s$ mesons is presented. By applying this technique, the invariant mass of the $\mu^+\nu_\mu$ system can be determined. This approach is applicable for studies with non-fully reconstructed semileptonic decays.

The Cabibbo-Kobayashi-Maskawa matrix $(V_{CKM})$ is a unitary matrix which contains information on the strength of the quark flavour mixing through the exchange of a $W^\pm$ boson [1]. The interaction results in transitions between up-type and down-type left-handed chiral quark states.

![Diagram of the Cabibbo-Kobayashi-Maskawa (CKM) matrix element $|V_{ub}|$.](Image)

The quark flavour mixing parameter of $u$ and $b$ quarks $(|V_{ub}|)$ is one of the least well-known parameters in the CKM matrix. Measurements of this quantity show a discrepancy between inclusive and exclusive semileptonic decays of $b$-mesons as shown in Figure 2. This provides a strong motivation for studies of other exclusive semileptonic decays of the $b$-hadron.

We present here a search for the decay $B^0_s \rightarrow K^{*+}\mu^+\nu_\mu$ at the LHCb experiment. This decay provides access to $|V_{ub}|$. The use of a vector meson allows for testing the structure of the weak current in the $W$-boson exchange by performing an angular analysis.

The LHCb Detector

The LHCb detector is a single-arm forward spectrometer dedicated to search for indirect evidence of new physics in the decay of particles composed of a beauty or charm quark. The coverage of the detector is in the range $2 < \eta < 5$ of pseudorapidity ($\eta$) which is optimal for $b$-hadron production at the Large Hadron Collider (LHC).

The detector is mainly composed of a vertex locator, a tracking system, Cherenkov detectors, calorimeters, and muon chambers as shown in Figure 3 [3].

Reconstruction of Semileptonic Decays

There is missing information from the neutrino in the decay, the invariant mass of the $B^0_s$ meson cannot be reconstructed. The momentum of the $B^0_s$ meson can be obtained analytically as follows:

$P_{B^0_s} = P_{\pi^0} + P_{\mu^+\nu_\mu}$, where $P_{\pi^0}$ and $P_{\mu^+\nu_\mu}$ are the momenta of the $\pi^0$ and $\mu^+\nu_\mu$ daughters. In addition, a Recurrent neural network (RNN) is also optimised for $b$-hadron production at the Large Hadron Collider (LHC).

Conclusions

In conclusion, we propose and compare various models of neural networks and linear regression models to estimate the momentum of a $B^0_s$ meson decaying semileptonically to resolve the ambiguity of two solutions from the quadratic equation.

References