Studies of $e^+e^- \to b\bar{b}$ channel at the International Linear Collider

A fresh look at the LEP $A_{FB}^b$ anomaly

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Abstract

The heavy-quark doublet plays a central role in the quest for new physics. The complementarity between studies of electroweak top-quark production and bottom-quark production is therefore naturally clear and pointed out in this paper. The tension between the LEPI measurement and the Standard Model prediction of the forward-backward asymmetry $A_{FB}^b$ is still one of the unresolved questions in the field and may be interpreted as a hint of new phenomena in the heavy quark sector. The process $e^+e^- \to b\bar{b}$ at the ILC offers a unique opportunity for a final word on the tension. Polarized beams allow for a large dismantling of the coupling constants or form factors that govern the $Z^0\gamma b\bar{b}$ vertex.

Introduction

• So far, LEPI has determined the $b$-quark couplings to the $Z^0$ boson by measuring the $b$ partial width and the forward-backward asymmetry called $A_{FB}^b$.
• It turns out that this value is at about three standard deviation away from the very precise value from SLD using beam polarisation [1].
• Reducing precisely the $b$-quark electroweak coupling measurement is therefore a priority for future $e^+e^-$ colliders.
• In this study, we intend to prove that the International Linear Collider (ILC) [2], with polarized beams and high luminosity, offers a unique opportunity for precise measurements well above the resonance, where both $b\bar{b}$ and photon exchanges are present.
• The $e^+e^- \to b\bar{b}$ channel is studied at $\sqrt{s} = 250$ GeV using full simulation of the ILC experiment at the ILC.
• The high-granularity of the ILC subdetectors allows for an individual particle reconstruction using the Particle Flow approach.

B-quark charge measurement

The $b$-quark polar angle reconstruction requires an accurate $b$-quark charge measurement. The $b$-quark charge is identified using two basic signatures:

• Vertex charge is a sum of all reconstructed particles charges, which are associated to the $b$-hadron vertices.
• Kaon charge is a charge of kaons found in $b$-hadron vertices.

The developed Vertex Charge Recovery procedure enhances the vertex charge purity by adding the missing particles back to the reconstructed vertices. The kaon identification is possible using the TPC $dE/dx$ information. After equalizing the $dE/dx$ in angular spectrum, the kaons from $b$-hadron vertices can be identified with 97.6% purity and 87% efficiency.

Interpretation

The ILC precision on the $e^+e^- \to b\bar{b}$ coupling is enough to fully confirm or discard the New Physics influence on the $b$-quark electroweak couplings.

Conclusions

• The developed procedure of the $b$-quark charge reconstruction allows for measuring the $b$-quark polar angle. The residual impurity is corrected by a data-driven procedure.
• The $b$-quark polar angle fit allows for an independent determination of four electroweak couplings of the $b$-quark. The fit can be extended to include also a term proportional to $\sin^2\theta_W$, giving access to an independent determination of the tensorial couplings.
• The relative precision on the right-handed coupling $g_{LL}^b = g_{RR}^b \approx 2\%$ at the ILC is sufficient to confirm at $> 5 \sigma$ or to discard the LEPI effect, which is at the 25% level.
• A reach of $5 \%$ at 1 TeV is achievable for indirect New Physics searches.

Forthcoming Research

The kaon charge method can be extended on the $c$-quark polar angle analysis, where one can improve the LEPI results on the $c$-quark couplings precision. Hence, at the ILC one can measure the top, bottom and charm quark electroweak couplings with an excellent sensitivity to New Physics effects.

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References