10 FCC Tau Polarization

Authors: Swagato Banerjee and Zbigniew Was
Corresponding Author: Zbigniew Was [z.was@cern.ch]

SM parameters, such as the τ polarization can be measured very precisely in τ decays. The phenomenology is quite similar to that of measurement of the A_{FB} parameter of the SM [21]. Details of τ decay spectrum as well a good understanding of associated uncertainty play an important role in this measurement of polarization, because the spin of the τ lepton is not measured directly.

The distribution of hadronic final state products in decays of a τ lepton needs to be evaluated to understand the sub-structure of the vertex. One of the important effect is related to bremsstrahlung, because signature of every decay mode needs to take into account the final state configurations with accompanying photons. Corresponding virtual corrections cancel the bulk of these effects and specialized programs such as PHOTOS [1, 2] are useful.

Corresponding effects can be sizable, and even during early step of LEP preparations it was found [3] that the corresponding corrections affect the slope of π spectrum in $\tau^- \to \pi^-\nu$, for example. That translates to 0.013 effect on τ idealized observable A_{pol}. For more discussion and essential experimental context see [4].

However, not all of final state photons can be associated with bremsstrahlung. For example, in the cascade decay $\tau^- \to \pi^-\omega\nu$, a subsequent decay of $\omega \to \pi^0\gamma$ contributes to the final state $\tau^- \to \pi^-\pi^0\gamma\nu$ coincides with the radiative corrections to final state of the $\tau^- \to \rho^-\nu$ decay channel. In this case, the photon originates from the $\omega \to \pi^0\gamma$ decay and is of non-QED bremsstrahlung origin.

The branching fractions for the $\tau^- \to \pi^-\omega\nu$ decay, and for the $\omega \to \pi^0\gamma$ decay are 0.02 and 0.08, respectively [5]. Thus, the resulting decay channel $\tau^- \to \pi^-\pi^0\gamma\nu$ contributes 0.0015 of all τ decays.

Such contributions and subsequent changes of the hadronic decay energy spectrum in τ decays need to be understood for each spin sensitive channel. Resulting deformation of $\tau^- \to \rho^-\nu$ decay spectra may mimic the contribution of the τ polarization can be obtained from a future high precision data analysis at the Belle II experiment.

This is the case when one of the τ decay channels mimic bremsstrahlung correction for the other one. The dynamics of the low energy strong interactions is difficult to obtain from a perturbative calculation.

Another hint of non-point-like nature of the τ vertex was explained in the corrections to the π energy spectra in the $\tau^- \to \pi^-\nu$ decay channel [6, 7]. Although at the lowest order, the spectrum is fully determined by the Lorentz structure of the vertex, the real and virtual photonic corrections play an important role in the level of precision under discussion. The dominant part of the effects of the QED bremsstrahlung from point-like sources can be seen in the Fig. 3 of [7], where the effects induced by hadronic resonances also play an important role.

The Belle II experiment is expected to collect 10^{11} τ lepton decays with 50 ab^{-1} of data, and the detector is extremely well-suited to study τ lepton physics. The backgrounds can be well controlled in an electron-positron collider environment. We can expect that the τ decay spectra can be measured without large degradation due to a highly granular electromagnetic calorimeter with large fiducial coverage, as explained in the Belle II technical design report [8].

References

[1] E. Barberio, Z. Was, PHOTOS: A Universal Monte Carlo for QED radiative corrections. Version 2.0, Comput. Phys. Commun. 79 (1994) 291–308. doi:10.1016/0010-4655(94)90074-4.

[2] N. Davidson, T. Przedzinski, Z. Was, PHOTOS interface in C++: Technical and Physics Documentation, Comput. Phys. Commun. 199 (2016) 86–101. arXiv:1011.0937, doi:10.1016/j.cpc.2015.09.013.

[3] F. Boillot, Z. Was, Uncertainties in τ Polarization Measurement at SLC/LEP and QED/-Electroweak Radiative Corrections, Z. Phys. C43 (1989) 109. doi:10.1007/BF02430616.

[4] LEP Electroweak Working Group, Precision Electroweak Measurements and Constraints on the Standard Model, arXiv:1012.2367.

[5] M. Tanabashi, et al., Review of Particle Physics, Phys. Rev. D98 (3) (2018) 030001. doi:10.1103/PhysRevD.98.030001.

[6] R. Decker, M. Finkemeier, Radiative corrections to the decay tau $\to$ pi (K) tau-neutrino, Phys. Lett. B316 (1993) 403–406. arXiv:hep-ph/9307372, doi:10.1016/0370-2693(93)90345-I.

[7] R. Decker, M. Finkemeier, Radiative corrections to the decay tau $\to$ pi tau-neutrino, Nucl. Phys. Proc. Suppl. 40 (1995) 453–461. arXiv:hep-ph/9411316, doi:10.1016/0920-5632(95)00170-E.

[8] T. Abe, et al., Belle II Technical Design Report, arXiv:1011.0352.