Study of Michel parameters in $\tau$ decays at Belle

Denis Epifanov on behalf of Belle collaboration
Novosibirsk State University, Budker Institute of Nuclear Physics, Novosibirsk Russia

1. Introduction. Michel parameters

In the SM charged weak interaction is described by the exchange of $W^\pm$ with a pure vector coupling to only left-handed fermions ("V-A" Lorentz structure). Deviations from "V-A" indicate New Physics.

$e^- \rightarrow e^- e^+\nu\bar{\nu}$

$\tau \rightarrow \tau^- e^+\nu\bar{\nu}$

$\mu^- \rightarrow \mu^- e^+\nu\bar{\nu}$

These provide clean laboratory to probe electroweak couplings.

The most general, Lorentz invariant four-lepton matrix element:

$$M_{\ell\ell\ell\ell} = \frac{4G_F}{\sqrt{2}} \rho \bar{\nu}_e (\bar{\nu}_e \gamma) \ell^- (\ell^+ \gamma) \nu_{\ell'}$$

Ten couplings $\rho_{\ell\ell\ell\ell}$ in the SM the only non-zero constant is $\rho_{\ell\ell\ell\ell} = 1$

Four bilinear couplings $\rho_{\ell\ell\ell\ell}$ which are called as Michel parameters (MP) $\rho$, $\eta$, $\xi$ and $\delta$ appear in the energy spectrum of the outgoing leptons.

The ratio $\rho_{\ell\ell\ell\ell}$ is $\frac{1}{2}G_F(1 + \frac{1}{2} + \gamma)$

We take events with two oppositely charged tracks, one of them is identified as lepton $\ell^\pm$.

$\ell^- \rightarrow e^- e^+\nu\bar{\nu}$

$\ell^- \rightarrow \tau^- e^+\nu\bar{\nu}$

$\ell^- \rightarrow \mu^- e^+\nu\bar{\nu}$

We can extract $\rho$, $\eta$, $\xi$, and $\delta$ from the $\ell^\pm$ energy and angular resolution.

We use Belle data for $\tau \rightarrow \tau^- e^+\nu\bar{\nu}$ and $\mu^- e^+\nu\bar{\nu}$ events.

2. Belle Experiment

Belle Detector

KEKB

3. Method of study of $(\ell\ell\ell\ell)$ and $(\ell\ell\ell\ell\ell\ell)$ events

Effect of $\tau$ spin-spin correlation is used to measure $\rho$ and $\eta$ MP. Events of $(\ell^+ \tau^- \rightarrow \ell^+ e^+\nu\bar{\nu})$ topology are used to measure $\rho$, $\eta$, $\xi$, and $\delta$ also.

4. Selection criteria

- After the standard preselections we take events with two oppositely charged tracks, one of them is identified as lepton (e, $\mu$, d > 0.9) and the other one as pion (PID$\rho$/K$\rho$/K' < 0.4).

- $p^+$ is calculated from the pair of pions ($K^+ + K^-$) (80 MeV)$^2 < M_{\ell\ell\ell\ell}^2 < \frac{160 MeV}{c^2}$.

- $p^+$ is calculated from the four-momentum sum of the four leptons.

- Detection efficiency $\epsilon_{\ell\ell\ell\ell}$ is $\sim 12\%$.

5. Physical corrections, detector effects

- Physical corrections: All $\ell\ell\ell\ell$ QED and electroweak higher order corrections to $e^+ e^- \rightarrow \ell^+ \ell^-$ ($\tau\tau$) are included.

- Radiative lepton decay $\tau^- \rightarrow e^- e^+\nu\bar{\nu}$

- Detector effects:

- Track momentum resolution

- $\gamma$ energy and angular resolution

- Effect of external internalization for $e^- e^+$ events

- Beam energy spread

- Data MC efficiency corrections

6. Description of background

$B_{\ell\ell\ell\ell} = \frac{1}{1 + \frac{1}{2} + \gamma}$

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7. Validation of the fitter

For each configuration SM MC sample is fitted. The other statistically independent SM MC sample was used to calculate normalizations.

8. Data/MC efficiency corrections

- We found that the Data/MC trigger efficiency correction, $R_{data}$, is the dominant one. Two independent subtriggers (energy trigger and track trigger) are used to evaluate it.

- 2D correlation $\epsilon_{\ell\ell\ell\ell}(x, y)$ is $\sim 20\%$.

- The reconstruction efficiencies are different for the energy and track triggers, the combined procedure is under development.

9. Fit of the data, systematic uncertainties

- Helicity sensitive variable $x = p_{\ell^+} + p_{\ell^-} + p_{\ell^+} + p_{\ell^-}$

- Spin correlation is seen in the momentum-momentum correlations of the final lepton and pions

10. Summary

- The procedure to measure 4 Michel parameters (MP) $(\rho, \eta, \xi, \delta)$ in leptonic $\tau$ decays at B factory has been developed and tested. It is based on the analysis of the $(\ell^+ e^- \rightarrow \ell^+ e^-)$ events and utilizes spin correlation of tau leptons.

- We confirmed that with the whole Belle data sample the statistical accuracy of MP is by one order of magnitude better than in the previous best measurements (CLEO, ALEPH).

- The main background components $(\ell\ell\ell\ell)$, $(\ell\ell\ell\ell\ell\ell)$ are described analytically in the fit, the remaining background (with the fraction of about 20%) is described with help of the MC-based method. We reached acceptable description of the backgrounds in the PDF.

- Various Data/MC efficiency corrections provide the dominant contribution to the systematic uncertainties of MP.

- The largest contribution comes from the trigger efficiency correction $(1-3\%)$. We are working to improve this uncertainty.