The decay $B \to D^* \tau^- \bar{\nu}_\tau$ is predicted to be sensitive to new physics including a non-universal coupling over the three generations. We report the first measurement of the $\tau$ polarization $P_\tau(D^*)$ and a new measurement of the ratio of the branching fractions $R(D^*) = BF(B \to D^* \tau^- \bar{\nu}_\tau) / BF(B \to D^* \tau^- \bar{\nu}_\tau)$ using the full data sample containing $(7.72 \pm 0.11) \times 10^8 B \bar{B}$ pairs accumulated at the Belle Experiment. We reconstruct signal events from $\tau^- \to \pi^- \nu_\tau$ and $\rho^- \nu_\tau$. Our measurement results in $P_\tau(D^*) = -0.38 \pm 0.51 (\text{stat.}) \pm 0.12 (\text{syst.})$ and $R(D^*) = 0.270 \pm 0.035 (\text{stat.}) \pm 0.017 (\text{syst.})$. These are consistent with the SM prediction.

**Belle Experiment**

**B-factory at the $e^+e^-$ Collider KEKB**

- $e^+e^-$ collision at 10.58 GeV, where $B$ mesons are produced through $Y(4S) \to B B$
- Clean environment as there is no particle except for two $B$ mesons
- Belle has recorded data containing $(7.72 \pm 0.11) \times 10^8 B \bar{B}$

**$\tau$ Polarization Analysis Method**

**Principle of the Measurement**

We need to measure $\cos \theta_{\text{hel}}$, but cannot obtain the complete $\tau$ momentum due to insufficient constraint

- Use $W$ rest frame

**Signal Extraction**

- $E_{\text{CL}}$ is a linear energy sum of the remaining clusters in ECL
- This is the best variable in terms of:
  - Good background discrimination
  - Very small correlation to $P_\tau(D^*)$

**Hadronic B Background Calibration**

- Important background component:
  - Similar event topology to the signal
  - Huge uncertainty due to low energy hadronization process
- Strategy for the yield determination:
  - Calibrate composition of hadronic $B$ decays modes using data
  - Determine the yield in the final fit

**Calibration Method**

- Fully reconstruct seven specific $B$ decay modes
- Compare the yields between the MC and the data
- Take the yield ratio
- The ratio is used as a calibration factor for the yield in the MC

**Summary**

Using hadronic $\tau$ decays $\tau^- \to \pi^- \nu_\tau$ and $\rho^- \nu_\tau$, we measured $P_\tau(D^*)$ as well as $R(D^*)$. One of the difficulties in the $P_\tau(D^*)$ measurement was that the full $\tau$ momentum could not be obtained. We have established the $P_\tau(D^*)$ measurement method using the rest frame of $W$ and the symmetry in the decay kinematics. To cope with background from hadronic $B$ decays, we have calibrated the composition of the decay modes using the calibration data samples. Our measurement results in $P_\tau(D^*) = -0.38 \pm 0.51 (\text{stat.}) \pm 0.12 (\text{syst.})$, $R(D^*) = 0.270 \pm 0.035 (\text{stat.}) \pm 0.017 (\text{syst.})$, consistent with the SM prediction. Our study has demonstrated the polarization measurement in $B \to D^* \tau^- \bar{\nu}_\tau$, that gives an additional dimension in the NP searches with the semitauonic $B$ meson decays.