**LFU Tests at the Z Pole**

**Introduction**

Many new physics scenarios plausible: (leptoquarks, new bosons, SUSY…)

- Models resolving the FCCC $b \to c\tau\nu$ anomaly introduce $O(0.1)$ correction to SM coupling at tree level.
- Enhancing $b \to s\tau\tau$ rates by ~3 orders: more than a smoking gun!
- Still compatible with stringent FCNC $b \to s\nu\nu$ limits ($O(10^{-5})$)

Recent hints of lepton flavor universality (LFU) violation:

- Charged current anomalies ($\tau$ vs. $\mu/e$): $R_D$, $R_{D^*}$, $R_{J/\Psi}$.
- Neutral current anomalies ($\mu$ vs. $e$): $R_K$, $R_{K^*}$.
- Typical $b \to s\tau\tau$ rate in SM: $10^{-7}$, current limit ~ $10^{-2}$

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**Scale**

<table>
<thead>
<tr>
<th>Channel</th>
<th>Belle II</th>
<th>LHCb</th>
<th>Giga-Z</th>
<th>Tera-Z</th>
<th>$10\times$ Tera-Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^0, \bar{B}^0$</td>
<td>$5.3 \times 10^{10}$</td>
<td>$6 \times 10^{13}$</td>
<td>$1.2 \times 10^{8}$</td>
<td>$1.2 \times 10^{11}$</td>
<td>$1.2 \times 10^{12}$</td>
</tr>
<tr>
<td>$B^\pm$</td>
<td>$5.6 \times 10^{10}$</td>
<td>$6 \times 10^{13}$</td>
<td>$1.2 \times 10^{8}$</td>
<td>$1.2 \times 10^{11}$</td>
<td>$1.2 \times 10^{12}$</td>
</tr>
<tr>
<td>$B_s, \bar{B}_s$</td>
<td>$5.7 \times 10^{8}$</td>
<td>$2 \times 10^{13}$</td>
<td>$3.2 \times 10^{7}$</td>
<td>$3.2 \times 10^{10}$</td>
<td>$3.2 \times 10^{11}$</td>
</tr>
<tr>
<td>$B_c^\pm$</td>
<td>$-\quad$</td>
<td>$4 \times 10^{11}$</td>
<td>$2.2 \times 10^{5}$</td>
<td>$2.2 \times 10^{8}$</td>
<td>$2.2 \times 10^{9}$</td>
</tr>
<tr>
<td>$\Lambda_b, \bar{\Lambda}_b$</td>
<td>$-\quad$</td>
<td>$2 \times 10^{13}$</td>
<td>$1.0 \times 10^{7}$</td>
<td>$1.0 \times 10^{10}$</td>
<td>$1.0 \times 10^{11}$</td>
</tr>
</tbody>
</table>
The $3\pi\nu$ decay of $\tau$ provides information of each decay vertex, given the high boost and tracking precision at the Z pole. 

- 6 kinetic constraints + 2 mass-shell conditions,
- Fully reconstruct $m_B$

In SM, large backgrounds from D mesons faking $\tau$: 3$\pi$+X decays of D mesons is common!

- Conservative bkgs estimation using data.

Energy within the $\Delta R<0.2$ around candidate tracks.

Quiet $ee$ collider + boosted tracks: Large D meson veto.

The $3\pi$ invariant mass structure
Measurement of $b \tau \tau$ and beyond

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Hong Kong U. of Sci. and Tech.

LFU Tests at the Z Pole
Results & Interpretation

Up: Mass peak of $B^0 \rightarrow K^\* \tau \tau$
Down: Mass peak of $B_s \rightarrow \tau \tau$
Final S/B ratio $\sim 1 \text{-} 10\%$

At Tera-Z, able to see $O(1)$ deviations from the SM.

UNIQUE chance at the Z pole!

$$O^\tau_{9(10)} = \frac{\alpha}{4\pi} \left[ \bar{s} \gamma^\mu P_L b \right] \left[ \bar{\tau} \gamma^\mu (\gamma^5) \tau \right]$$

$$O^\tau_{9(10)} = \frac{\alpha}{4\pi} \left[ \bar{s} \gamma^\mu P_R b \right] \left[ \bar{\tau} \gamma^\mu (\gamma^5) \tau \right]$$

Limit of EFT Wilson coefficients $O(10^3)$ (current) $\rightarrow O(10)$.

Expecting differential measurements/more channels to improve.
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Measurement of $b\tau\tau$ and beyond
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Multiple searches using FCCC $b \rightarrow c\tau\nu$ decays are in preparation
• $R_{J/\psi}$, $R_{D_s}$, $R_{D_{s*}}$, and $R_{\Lambda_c}$
• Good reconstruction quality ensuring $S/B \sim 1$.

Kinematic difference between muonic and tauonic modes.

Projection of $B_s \rightarrow \phi \nu \nu$ process, using full simulation data from the CEPC group.
• Differential measurements included
• $S/B > 1$ to avoid large systematics.
• Motivation for detector R&D

References
Lingfeng Li and Tao Liu, [arXiv:2012.00665].
CEPC Study Group Collaboration, M. Dong et al., [arXiv:1811.10545].