LFU Tests at the Z Pole

Measurement of bsττ and beyond

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LHCP2021

Introduction

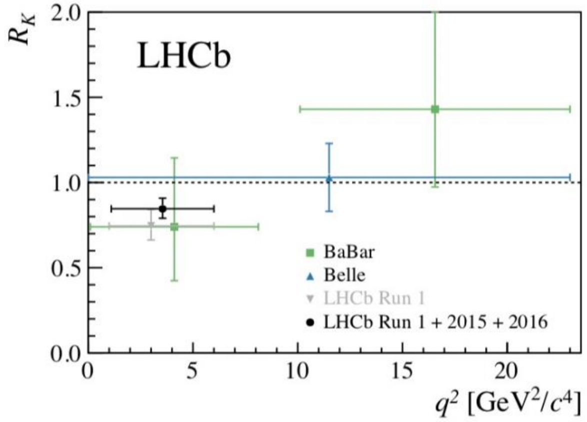
KLOE BESIII Belle II

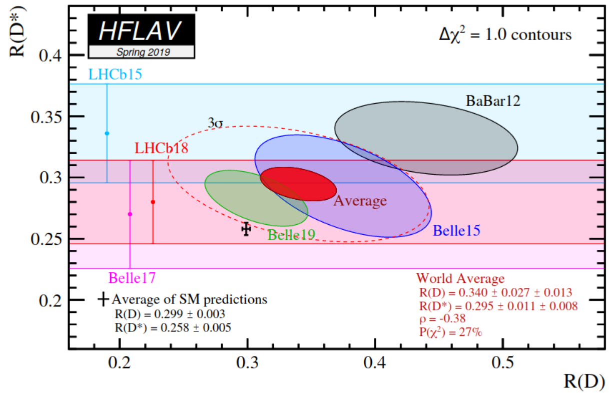
Tera–Z W–Factory Higgs–Factory Top–Factory

m_K m_ϕ $m_{J/\Psi}$ $m_{\Upsilon 4S}$ m_Z m_{H+Z} **Scale**

L E P ATLAS/CMS LHCb

Z-Factory of ee-colliders, e.g. FCC-ee, CEPC and ILC. Up to $O(10^{13})$ Z-bosons will be produced.





Channel	Belle II	LHCb	Giga-Z	Tera-Z	10×Tera-Z
B^0, $\bar{B}^0$	5.3×10^{10}	$\sim 6\times10^{13}$	1.2×10^{8}	1.2×10^{11}	1.2×10^{12}
$B^\pm$	5.6×10^{10}	$\sim 6\times10^{13}$	1.2×10^{8}	1.2×10^{11}	1.2×10^{12}
B_s, $\bar{B}_s$	5.7×10^{8}	$\sim 2\times10^{13}$	3.2×10^{7}	3.2×10^{10}	3.2×10^{11}
$B_c^\pm$	-	$\sim 4\times10^{11}$	2.2×10^{5}	2.2×10^{8}	2.2×10^{9}
Λ_b, $\bar{\Lambda}_b$	-	$\sim 2\times10^{13}$	1.0×10^{7}	1.0×10^{10}	1.0×10^{11}

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 (τ vs. μ/e): R_D, R_{D*}, $R_{J/\Psi}$.
- Neutral current anomalies (μ 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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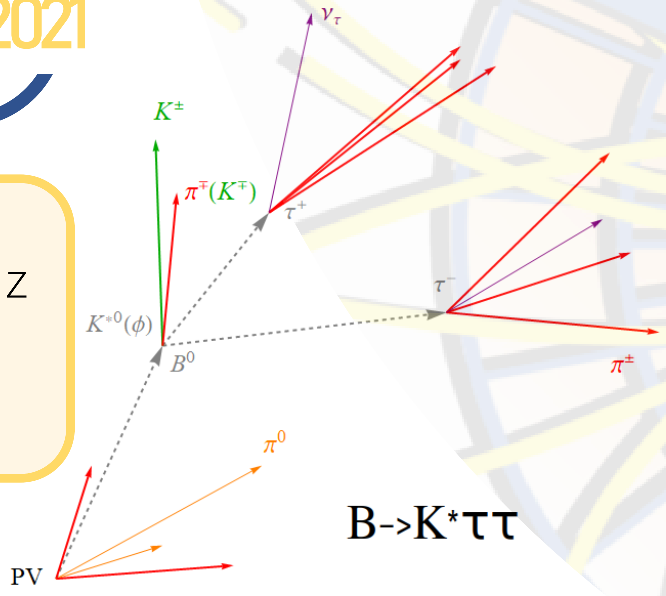
Simulation & Analysis

The 3πν decay of τ 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

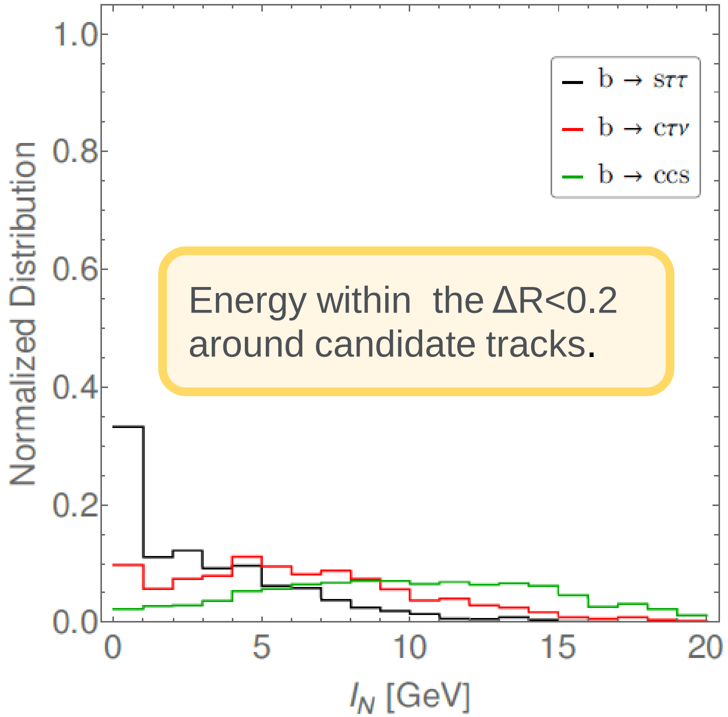


B->K*ττ

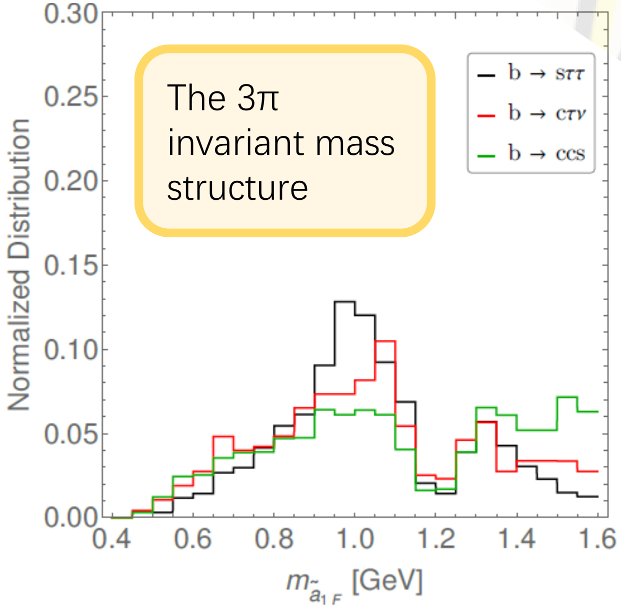
In SM, large backgrounds from D mesons faking τ: 3π+X decays of D mesons is common!

- Conservative bkgs estimation using data.

	Properties	Decay Mode	BR
$\tau^\pm$	$m = 1.777$GeV	$\pi^\pm\pi^\pm\pi^\mp\nu$	9.3%
	$L = 87.0\mu$m	$\pi^\pm\pi^\pm\pi^\mp\pi^0\nu$	4.6%
$D_s^\pm$	$m = 1.968$GeV	$\tau^\pm\nu$	5.5%
	$L = 151\mu$m	$\pi^\pm\pi^\pm\pi^\mp$	1.1%
		$\pi^\pm\pi^\pm\pi^\mp\pi^0$	0.6%
		$\pi^\pm\pi^\pm\pi^\mp 2\pi^0$	4.6%
		$\pi^\pm\pi^\pm\pi^\mp K_S^0$	0.3%
		$\pi^\pm\pi^\pm\pi^\mp\phi$	1.2%
$D^\pm$	$m = 1.870$GeV	$\tau^\pm\nu$	$< 0.12\%$
	$L = 311\mu$m	$\pi^\pm\pi^\pm\pi^\mp$	0.31%
		$\pi^\pm\pi^\pm\pi^\mp\pi^0$	1.1%
		$\pi^\pm\pi^\pm\pi^\mp K_S^0$	3.0%



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



Type	Channel	Color	$s\bar{s}$	τ	BR
$b \to c\bar{c}s$	$B^0 \to K^{*0}D^{(*)+}D^{(*)-}$				1.2×10^{-2}
	$B_s \to K^{*0}D^{(*)+}D_s^{(*)-}$				1.2×10^{-2}
	$B_s \to \bar{K}^{*0}D_s^{(*)+}D^{(*)-}$				1.2×10^{-2}
	$B^0 \to K^{*0}D_s^{(*)+}D_s^{(*)-}$		✓		1.6×10^{-3}
$b \to c\tau\nu$	$B^0 \to K^{*0}D_s^{(*)-}\tau^+\nu$		✓	✓	3.0×10^{-5}
	$B_s \to \bar{K}^{*0}D^{(*)-}\tau^+\nu$			✓	4.6×10^{-4}

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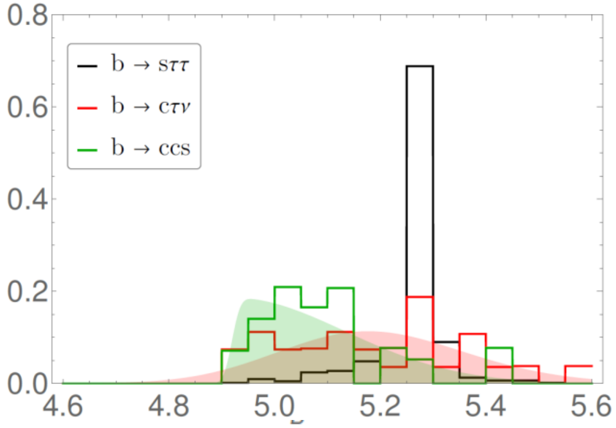
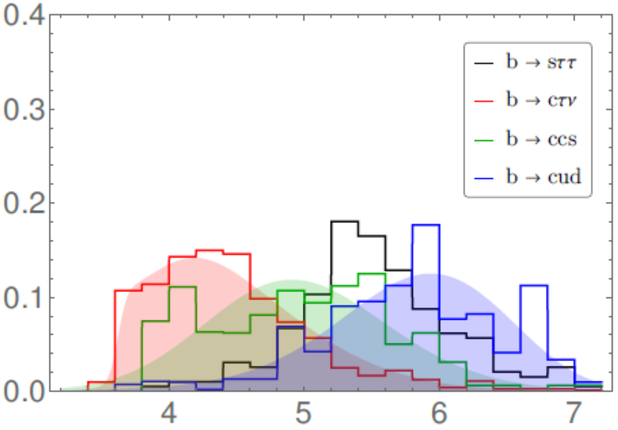
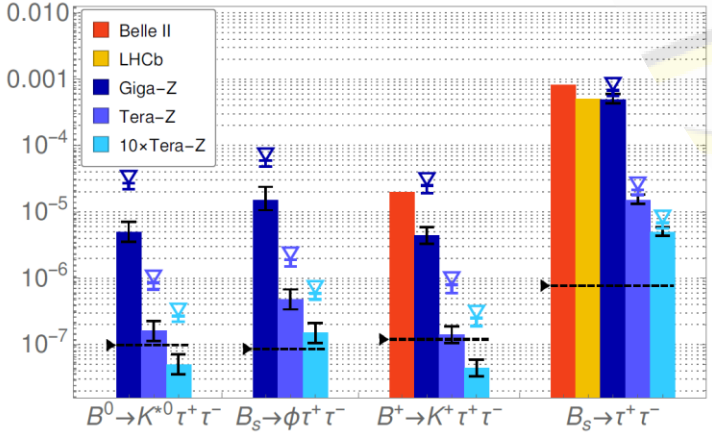
Results & Interpretation

Up: Mass peak of $B^0 \to K^* \tau\tau$
Down: Mass peak of $B_s \to \tau\tau$
Final S/B ratio ~1-10%







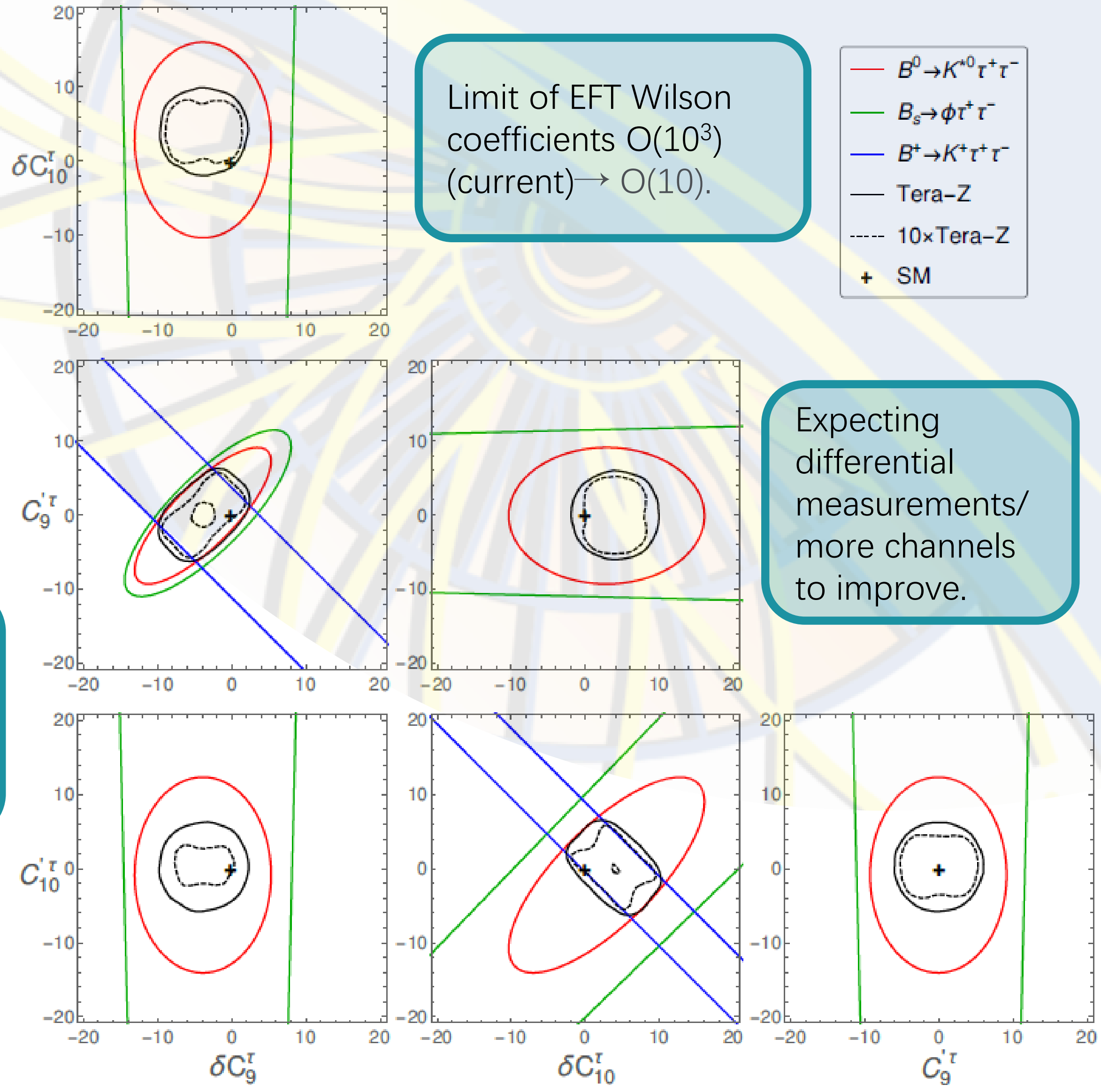
At Tera-Z., able to see O(1) deviations from the SM.

UNIQUE chance at the Z pole!

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

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

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



Expecting differential measurements/ more channels to improve.

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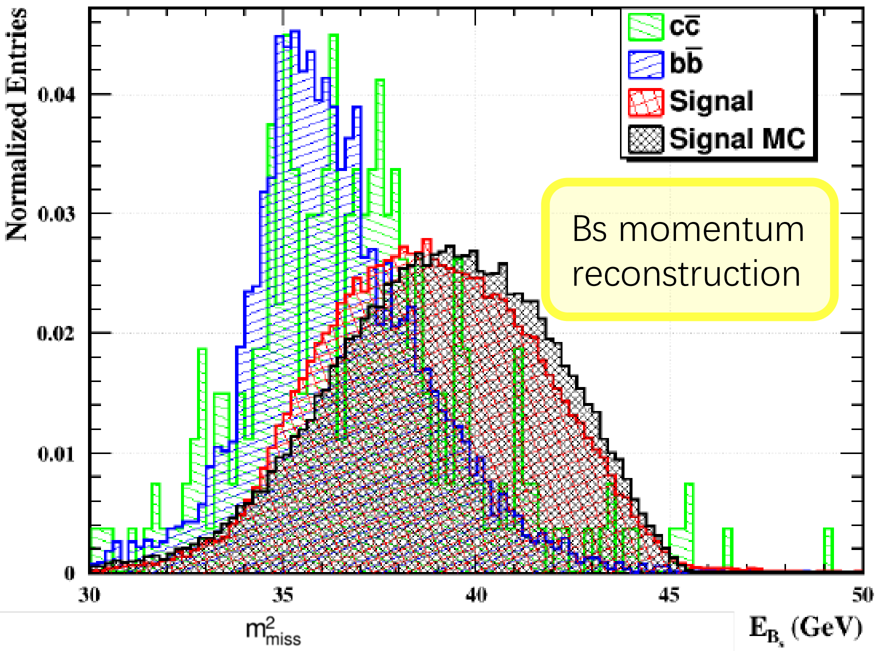
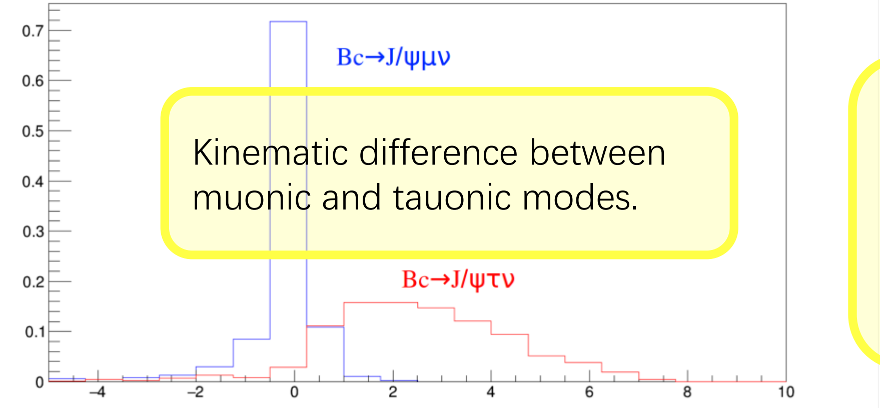
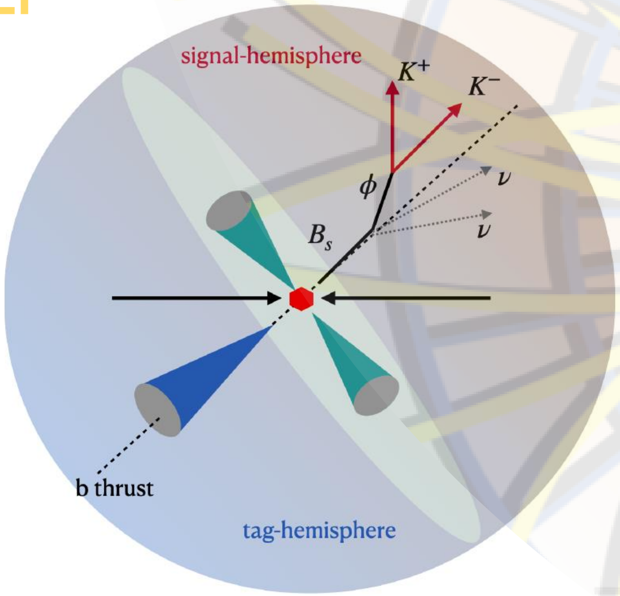
Future Prospects



Bs momentum reconstruction



Kinematic difference between muonic and tauonic modes.



Multiple searches using FCCC b → cτν decays are in preparation

- $R_{J/\psi}$, R_{Ds}, R_{Ds*}, and $R_{\Lambda c}$!
- Good reconstruction quality ensuring S/B~1.

Projection of $B_s \to \phi\nu\nu$ 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

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