Search for $B^0 \to K^{*0}\tau^+\tau^-$ via an unbinned analysis of $B^0 \to K^{*0}\mu^+\mu^-$

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Flavour anomalies

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- Pattern of deviations from SM predictions observed in $b \to c\ell\nu$ and $b \to s\ell\ell$ transitions

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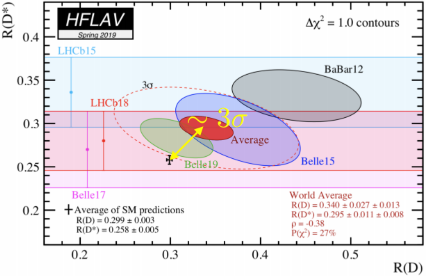
$$\underline{b \to c\ell^- \bar{\nu}_\ell}$$

- μ vs e consistent with SM at current precision
- τ vs $(\mu,\ e)$ at $\sim 3\sigma$



$$R(D^{(*)}) = \frac{\mathcal{B}(\bar{B} \to D^{(*)} \tau^- \bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D^{(*)} \mu^- \bar{\nu}_\mu)}$$

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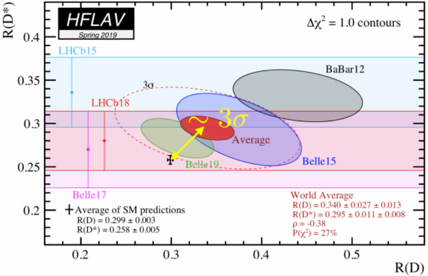

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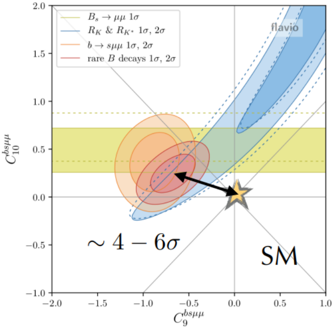
$$\underline{b \to s\ell^-\ell^+}$$

- μ vs e at 3σ (combined $> 4\sigma$)
- τ vs $(\mu,\ e)$ promising
- Loop-suppressed



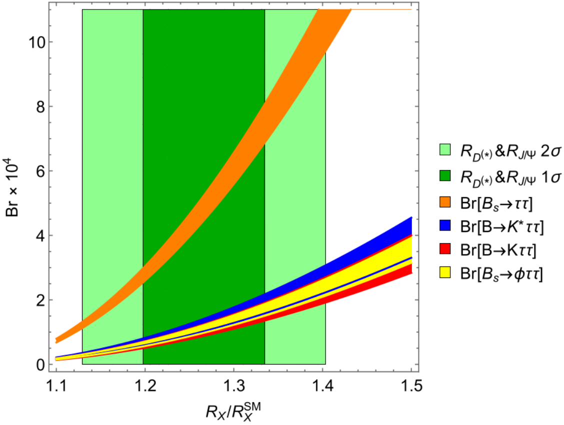
arXiv:2103.13370

$b \to s\tau^-\tau^+$ decays

- To explain both $R_{D^{(*)}}$ and $b \to s\ell\ell$ results, large enhancements are needed in tauon decay modes

- $b \to s\tau\tau$ very interesting
  - ▷ Loop-suppressed and 3^{rd} generation

- SM prediction of $\mathcal{O}(10^{-7})$ compared to NP prediction of up to $\mathcal{O}(10^{-4})$



PRL 120 (2018) 181802

Direct searches

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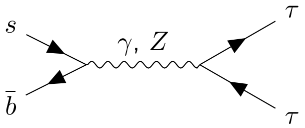
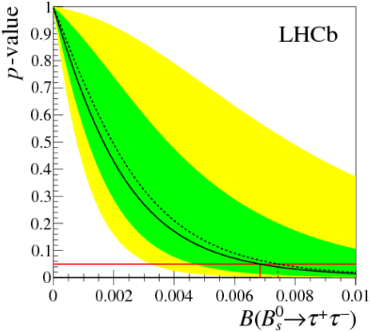
- Fully leptonic decay $B_s^0 \to \tau^+\tau^-$

- Current experimental constraints on $\mathcal{B}(B_s^0 \to \tau^+\tau^-)$ and $\mathcal{B}(B^+ \to K^+\tau^+\tau^-)$ of $\mathcal{O}(10^{-3})$

- Direct measurements of tauons via $\tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau$ or $\tau^+ \to \pi^-\pi^+\pi^+\bar{\nu}_\tau$
  - ▷ Difficult reconstruction of the final state particles, combined with small branching fractions

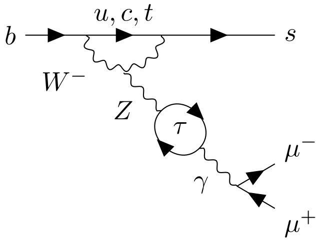


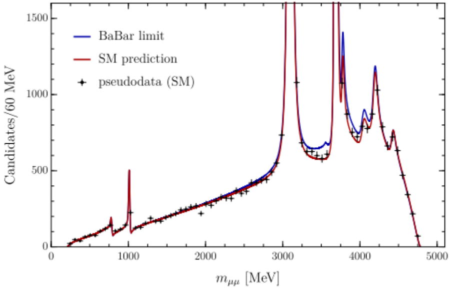


PRL 118, 251802 (2017), PRL 118, 031802 (2017)

The $B^0 \to K^{*0}\tau^+\tau^- \to K^{*0}\mu^+\mu$ decay

- Inspired by arXiv:2001.04470, measure the re-scattering process $B^0 \to K^{*0}\tau^+\tau^- \to K^{*0}\mu^+\mu$
  - ▷ Muons are well reconstructed and understood at LHCb
  - ▷ Experimental challenges are orthogonal to direct searches
- No current limit on $\mathcal{B}(B^0 \to K^{*0}\tau^+\tau^-)$, on-going direct searches at LHCb
- SM prediction compared to BaBar limit on $\mathcal{B}(B^+ \to K^+\tau^+\tau^-)$

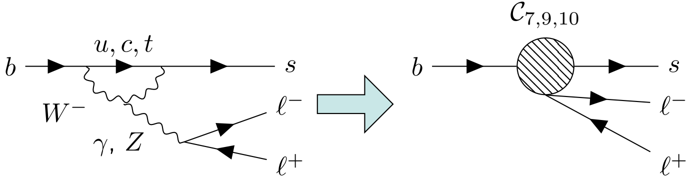




arXiv:2001.04470

Effective Hamiltonian and Wilson Coefficients

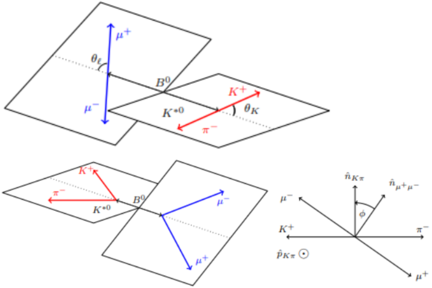
- $\mathcal{A}(i \rightarrow f) = < f|\mathcal{H}_{eff}|i >$

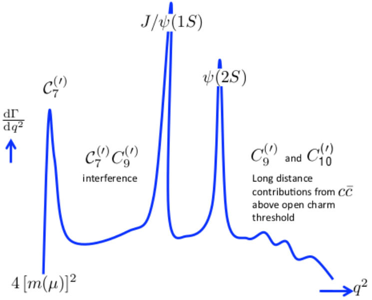


- $\mathcal{H}_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i \mathcal{C}_i \mathcal{O}_i$
- Wilson Coefficients contains the integrated out heavy fields
  - ▷ Effective couplings, analogous to Fermi's constant
  - ▷ Heavy New Physics would cause deviations from well known SM $\mathcal{C}_i$ values
- Local Operators containing light fields $< m_W$
- Goal: Set a limit on $\mathcal{B}(B^0 \rightarrow K^{*0}\tau^+\tau^-)$ and the effective coupling C_9^τ

Model parameterisation

- More difficult than $B^+ \to K^+\tau^+\tau^-$, similar approach to talk by Michele Atzeni





- $\frac{d\Gamma[B^0 \to K^{*0}\mu^+\mu^-]}{dq^2 d\vec{\Omega}} = \frac{9}{32\pi}\sum_i J_i(q^2) f_i(\cos\theta_\ell, \cos\theta_K, \phi)$
  - f_i introduces the angular dependence through spherical harmonics
  - Angular observables J_i are combinations of complex transversity amplitudes $\mathcal{A}$
  - E.g. $J_{6s} = 2\sqrt{1 - \frac{4m_\ell^2}{q^2}}[\mathcal{A}_\parallel^L \mathcal{A}_\perp^{L*} - \mathcal{A}_\parallel^R \mathcal{A}_\perp^{R*}]$

Model parameterisation

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  - The decay rate in K^{*0} P-wave configuration is fully described by six amplitudes $\mathcal{A}^{L,R}_{0,\|,\perp}$ (two more needed to include the S-wave)

form factors

$$\mathcal{A}_0^{L,R}(q^2) = -8N\frac{m_B m_{K^*}}{\sqrt{q^2}}\left\{(C_9 \mp C_{10})A_{12}(q^2) + \frac{m_b}{m_B + m_{K^*}}C_7 T_{23}(q^2) + \mathcal{G}_0(q^2)\right\}$$

Penguin contribution

non-local contribution

arXiv:2001.04470

Non-local contributions

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- Contains long-distance contributions which effect C_9 in a q^2 dependent way

$$\mathcal{G}_0(q^2) = \frac{m_b}{m_B + m_{K^*}} T_{23}(q^2)\zeta^0 e^{i\omega^0} + A_{12}(q^2)\Bigg\{ \sum_j \eta_j^0 e^{i\theta_j^0} A_j^{res}(q^2)$$

$$+ \eta^0_{D_{avg}} e^{i\delta^0_{D_{avg}}} h_S(q^2, m) + \sum_{k=D,D^*} \eta_k^0 e^{i\delta_k^0} h_P(q^2, m_k) + Y_{c\bar{c}}^{(0)0}$$

$$+ C_9^\tau \frac{-\alpha_{EM}}{2\pi}\left(h_S(q^2, m_\tau) - \frac{1}{3} h_P(q^2, m_\tau)\right)\Bigg\}$$

- 1P intermediate states: Photon pole, charmonium and light quark resonances, e.g. ρ_{770}, J/ψ, $\psi(2S)$
- open-charm contributions DD, D^*D, D^*D^*
- $\tau\tau$ contribution
- lineshape parameterisations: 1P Breit-Wigner and 2P dispersion relations

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arXiv:2001.04470

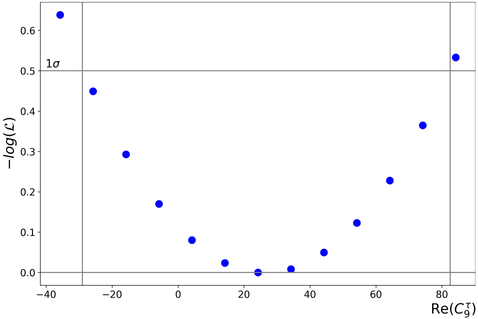
Fit strategy and expected sensitivity

- Model including the $\tau\tau$ contribution is implemented and validation with pseudodata is on-going

- Physics parameters extracted from data via an unbinned maximum-likelihood fit

- Expected sensitivity to C_9^τ determined using pseudodata
  - ▷ Considering only the signal component, statistical uncertainty on $Re(C_9^\tau)$: ± 60

- Current best limit is $C_9^\tau < 910$ at 95% CL (BaBar)



Summary

- Combination of $b \to c\ell\nu$ and $b \to s\ell\ell$ results motivate theories with $b \to s\tau\tau$ enhancements

- Direct searches are experimentally challenging

- New approach searching for $K^{*0}\tau\tau$ via its imprint on the $K^{*0}\mu\mu$ spectrum is implemented

- Orthogonal experimental challenges compared to direct searches, alignment in results would further our confidence

- Promising early stage results

Thank you for listening!
Questions?