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

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Joint Annual Meeting of SPS and ÖPG

31 August 2021

Flavour anomalies

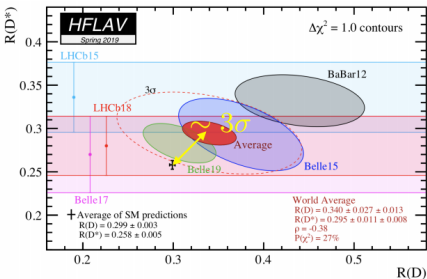


- Pattern of deviations from SM predictions observed in $b \rightarrow cl\nu$ and $b \rightarrow sl\ell$ transitions

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

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

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

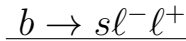


$$R(D^{(*)}) = \frac{B(\bar{B} \rightarrow D^{(*)} \tau^- \bar{\nu}_\tau)}{B(\bar{B} \rightarrow D^{(*)} \mu^- \bar{\nu}_\mu)}$$

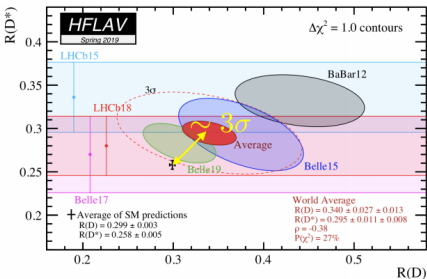
Flavour anomalies



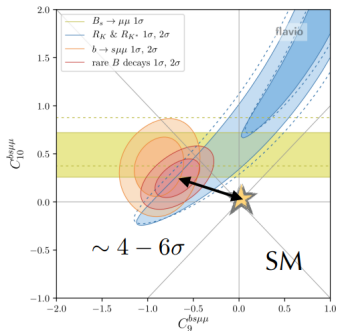
- Pattern of deviations from SM predictions observed in $b \rightarrow cl\nu$ and $b \rightarrow sl\ell$ transitions



- μ vs e consistent with SM at current precision
- τ vs (μ, e) at $\sim 3\sigma$
- μ vs e at 3σ (combined $> 4\sigma$)
- τ vs (μ, e) promising
- Loop-suppressed



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

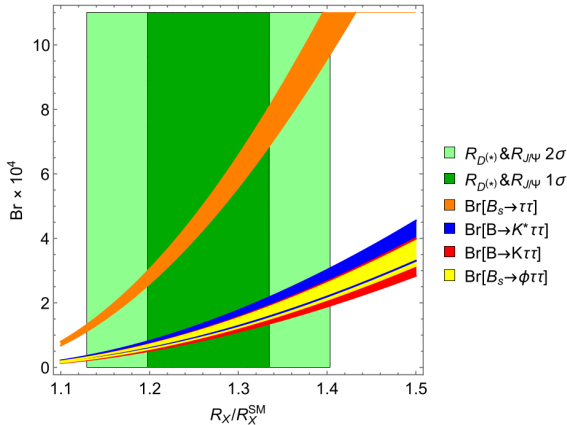


[arXiv:2103.13370](https://arxiv.org/abs/2103.13370)

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



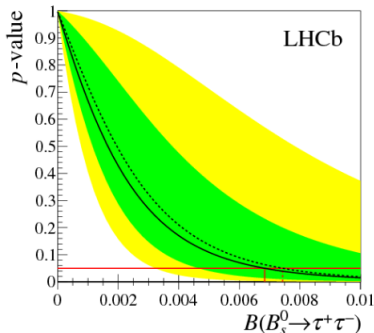
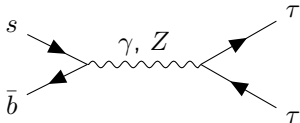
- To explain both $R_{D^{(*)}}$ and $b \rightarrow s\ell\ell$ results, large enhancements are needed in tauon decay modes
- $b \rightarrow s\tau\tau$ very interesting
 - ▷ Loop-suppressed and 3^{rd} generation
- SM prediction of $\mathcal{O}(10^{-7})$ compared to NP prediction of up to $\mathcal{O}(10^{-4})$



Direct searches



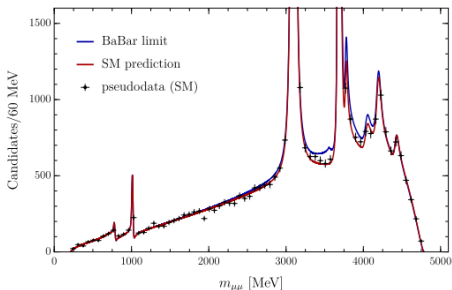
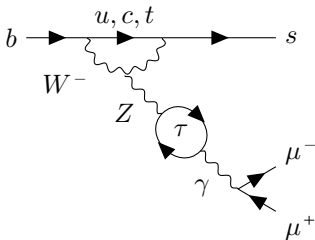
- Fully leptonic decay $B_s^0 \rightarrow \tau^+ \tau^-$
- Current experimental constraints on $\mathcal{B}(B_s^0 \rightarrow \tau^+ \tau^-)$ and $\mathcal{B}(B^+ \rightarrow K^+ \tau^+ \tau^-)$ of $\mathcal{O}(10^{-3})$
- Direct measurements of tauons via $\tau^+ \rightarrow \mu^+ \nu_\mu \bar{\nu}_\tau$ or $\tau^+ \rightarrow \pi^- \pi^+ \pi^+ \bar{\nu}_\tau$
 - ▷ Difficult reconstruction of the final state particles, combined with small branching fractions



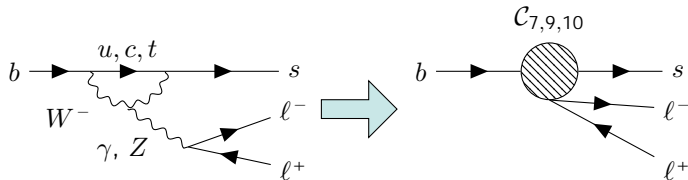
The $B^0 \rightarrow K^{*0} \tau^+ \tau^- \rightarrow K^{*0} \mu^+ \mu^-$ decay



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

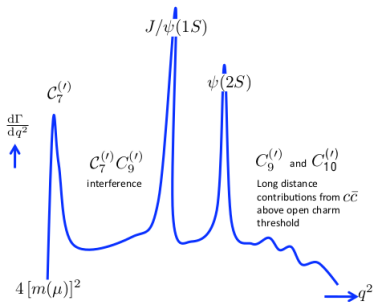
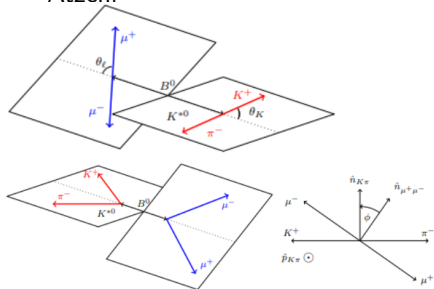


- $\mathcal{A}(i \rightarrow f) = \langle f | \mathcal{H}_{eff} | i \rangle$



- $\mathcal{H}_{eff} = -\frac{4G_F}{2} V_{tb} V_{ts} \sum_i \mathcal{C}_i \mathcal{O}_i$
- **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

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



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

Model parameterisation

- $\frac{d [B^0 \rightarrow K^0 \mu^+ \mu^-]}{dq^2 d\Omega} = \frac{9}{32\pi} \sum_i J_i(q^2) f_i(\cos \theta_\ell, \cos \theta_K, \phi)$
 - ▷ The decay rate in K^0 P-wave configuration is fully described by six amplitudes $\mathcal{A}_0^{L,R}$, (two more needed to include the S-wave)

$$\mathcal{A}_0^{L,R}(q^2) = -8N \frac{m_B m_K}{\sqrt{q^2}} \left\{ \underbrace{(C_9 \mp C_{10}) A_{12}(q^2)}_{\text{Penguin contribution}} + \frac{m_b}{m_B + m_K} \underbrace{C_7 T_{23}(q^2)}_{\text{non-local contribution}} + \underbrace{\mathcal{G}_0(q^2)}_{\text{form factors}} \right\}$$

Diagram illustrating the parameterisation of the decay amplitude $\mathcal{A}_0^{L,R}(q^2)$. The amplitude is expressed as a sum of three terms, each associated with a specific contribution:

- Penguin contribution:** $(C_9 \mp C_{10}) A_{12}(q^2)$
- non-local contribution:** $\frac{m_b}{m_B + m_K} C_7 T_{23}(q^2)$
- form factors:** $\mathcal{G}_0(q^2)$

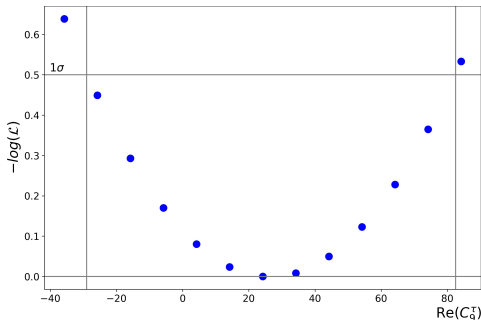
- Contains long-distance contributions which effect C_9 in a q^2 dependent way

$$\begin{aligned} \mathcal{G}_0(q^2) = & \frac{m_b}{m_B + m_K} T_{23}(q^2) \zeta^0 e^{i\omega^0} + A_{12}(q^2) \left\{ \sum_j \eta_j^0 e^{i\theta_j^0} A_j^{res}(q^2) \right. \\ & + \eta_{D_{avg}}^0 e^{i\delta_{D_{avg}}^0} h_S(q^2, m) + \sum_{k=D, D} \eta_k^0 e^{i\delta_k^0} h_P(q^2, m_k) + Y_{c\bar{c}}^{(0)0} \\ & \left. + C_9^\tau \frac{-\alpha_{EM}}{2\pi} \left(h_S(q^2, m_\tau) - \frac{1}{3} h_P(q^2, m_\tau) \right) \right\} \end{aligned}$$

- 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

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)



- Combination of $b \rightarrow cl\nu$ and $b \rightarrow sll$ results motivate theories with $b \rightarrow s\tau\tau$ 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?