Parallel session *Antimatter* Summary

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Conveners: Carsten Niebuhr (DESY Hamburg), Ulrich Nierste (KIT), Hans Ströher (FZ Jülich), Jochen Walz (HI Mainz)

Our program:

Antimatter: Cross Topic Parallel Session - (14:30-17:00)

time	[id] title	presenter
14:30	[28] Relating EDM to fundamental CP-violating parameters	WIRZBA, Andreas
15:15	[29] Analysis of B -> K tau tau at Belle	WEHLE, Simon
15:45	[30] Analysis of Tauonic B Decays	HECK, Martin
16:15	[31] Discussion forum on new physics in B->X tau tau decays	BLANKE, Monika NIERSTE, Ulrich NIEBUHR, Carsten

Change: talk by Andreas Wirzba (FZJ) cancelled.

Parallel session Antimatter

Attendance: 6 people,
thereof 2 from DESY and 4 from KIT,
or 3 theorists and 3 experimentlists

Apparently a small number . . .

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Apparently a small number …

…which might be the remnant of
$\sim 6 \cdot 10^{10}$ physicist-antiphysicist annihilations.

Topic: Angular analysis of

$$B \to K^* \ell^+ \ell^-, \qquad \ell = e, \mu$$

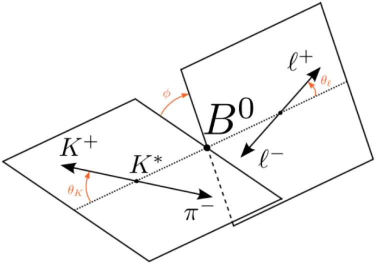
with Belle data. q^2 is the invariant mass^2 of the $\ell^+\ell^-$ pair.

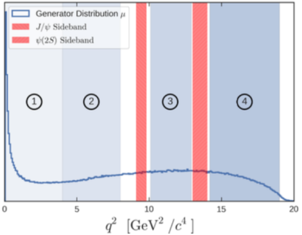
This decay is triggered by $b \to s\ell^+\ell^-$. Related observables show persistent deviations from the SM prediction:

- angular-analysis observables in $B \to K^* \ell^+ \ell^-$ at LHCb
- $B(B \to \phi\mu^+\mu^-)$ too small
- $\dfrac{B(B \to K\mu^+\mu^-)}{B(B \to Ke^+e^-)}$ deviates from 1

Combined significance of this anomaly: $\sim 4.5\sigma$.

Full Angular Analysis



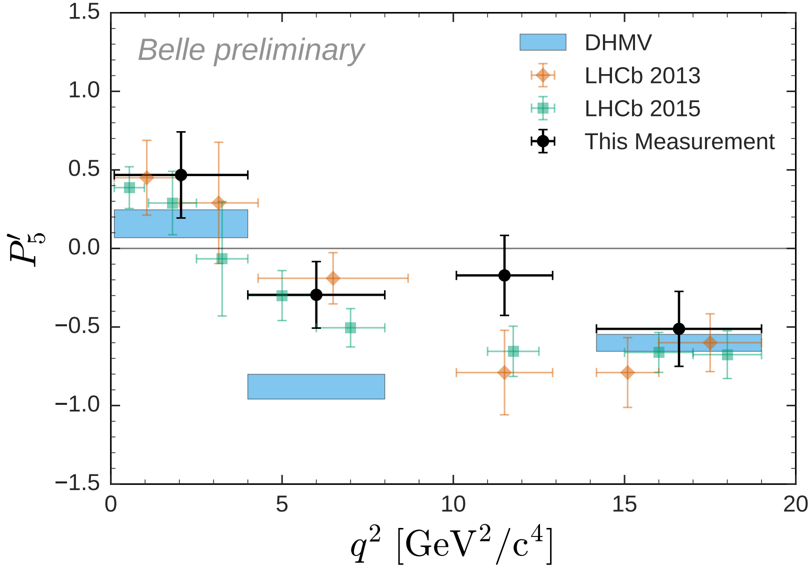


The observables are depended on $q^2 = M^2_{\ell^+\ell^-}$

The differential decay rate for $B \to K^* \ell^+ \ell^-$ can be written as

$$
\begin{aligned}
\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2} \frac{\mathrm{d}^4\Gamma}{\mathrm{d}\cos\theta_L\, \mathrm{d}\cos\theta_K\, \mathrm{d}\phi\, \mathrm{d}q^2} = \frac{9}{32\pi} \Big[& \frac{3}{4}(1 - F_L)\sin^2\theta_K + F_L \cos^2\theta_K \\
& + \frac{1}{4}(1 - F_L)\sin^2\theta_K \cos 2\theta_L \\
& - F_L \cos^2\theta_K \cos 2\theta_L + S_3 \sin^2\theta_K \sin^2\theta_L \cos 2\phi \\
& + S_4 \sin 2\theta_K \sin 2\theta_L \cos\phi + S_5 \sin 2\theta_K \sin\theta_L \cos\phi \\
& + S_6 \sin^2\theta_K \cos\theta_L + S_7 \sin 2\theta_K \sin\theta_L \sin\phi \\
& + S_8 \sin 2\theta_K \sin 2\theta_L \sin\phi + S_9 \sin^2\theta_K \sin^2\theta_L \sin 2\phi \Big],
\end{aligned}
$$

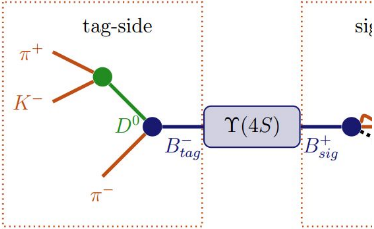
Does Belle confirm the LHCb anomaly?



The Belle data support the LHCb anomaly!
Moreover the deviation is driven by $B \to K^* \mu^+ \mu^-$, not $B \to K^* e^+ e^-$.

The $b \to s \ell^+ \ell^-$ amplitude is generated by a quantum loop in the SM and therefore highly sensitive to new physics.

Upcoming: Belle analysis of $B \to K^* \tau^+ \tau^-$ by Simon Wehle.



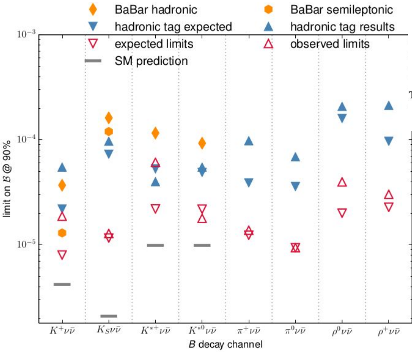
Preselection

- Use hadronic tag side reconstruction;
- Require $o_{tag} > 0.05$, $|\Delta E_{tag}| < 0.05$ GeV , and $M_{BC,tag} > 5.27$ Gev/c^2 on the tag side;
- Reconstruct tau into two charged tracks, divide sample into PID subsamples;
- Veto on good tracks, pi^0, K_S, K_L;
- Cut on angular variable in the pionic final states, see later...

Systematic uncertainty currently under investigation.

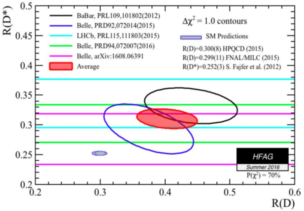
with $h = \pi, K, \rho \ldots$

Logarithmic Scale



New physics in $B \to D^{(*)}\tau\nu$

CKM 2016



HFAG average:
4.0σ deviation from SM

full set of 4-fermion operators

$$(\bar{b}_L\gamma_\mu c_L)(\bar{\nu}_{\tau L}\gamma^\mu\tau_L)$$
$$(\bar{b}_L c_R)(\bar{\nu}_{\tau L}\tau_R)$$
$$(\bar{b}_R c_L)(\bar{\nu}_{\tau L}\tau_R)$$
$$(\bar{b}_R\sigma_{\mu\nu} c_L)(\bar{\nu}_{\tau L}\sigma^{\mu\nu}\tau_R)$$
$$(\bar{b}_R\gamma_\mu c_R)(\bar{\nu}_{\tau L}\gamma^\mu\tau_L)$$

➢ restoring $SU(2)_L$ invariance

$$(\bar{Q}^i_L\gamma_\mu\sigma^a Q^j_L)(\bar{L}_L\gamma^\mu\sigma_a L_L)$$
$$(\bar{Q}^i_L c_R)i\sigma^2(\bar{L}_L\tau_R)$$
$$(\bar{b}_R Q^j_L)(\bar{L}_L\tau_R)$$
$$(\bar{b}_R\sigma_{\mu\nu} Q^j_L)(\bar{L}_L\sigma^{\mu\nu}\tau_R)$$

➢ **also induce $(\bar{b}q)(\bar{\tau}\tau)$**

Flavour structure – example: $(\bar{b}_R Q_L^j)(\bar{L}_L \tau_R)$

2. flavour alignment in the down-sector

- alignment with d_L:

$$Q_L^j = \begin{pmatrix} V_{ud}^* u_L + V_{cd}^* c_L + V_{td}^* t_L \\ d_L \end{pmatrix}$$

  ➢ too large contribution to $B \to \tau\nu$ and $B_d \to \tau\tau$

- alignment with s_L:

$$Q_L^j = \begin{pmatrix} V_{us}^* u_L + V_{cs}^* c_L + V_{ts}^* t_L \\ s_L \end{pmatrix}$$

  ➢ again trouble with $B_s \to \tau\tau$ and τ_{B_s}

- alignment with b_L:

$$Q_L^j = \begin{pmatrix} V_{ub}^* u_L + V_{cb}^* c_L + V_{tb}^* t_L \\ b_L \end{pmatrix}$$

  ➢ no $B_{s,d} \to \tau\tau$ generated

  ➢ strongest constraints from $b\bar{b} \to \tau\bar{\tau}$ at the LHC

Faroughy, Greljo, Kamenik (2016)

Summary

- $B \to K^{(*)}\ell^+\ell^-$ decays are a hot topic. The DESY Belle analysis of $B \to K^*\ell^+\ell^-$ confirms the LHCb anomaly.
- $B \to K^{(*)}\tau^+\tau^-$ and $B \to \tau^+\tau^-$ are studied at DESY and KIT.
- KIT theorists are on the case.
- A KIT Belle analysis lead to improved bounds on $B \to h\nu\overline{\nu}$ branching fractions.