$b \to s\ell\ell$: angular analyses and studies with muons

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on behalf of the LHCb collaboration

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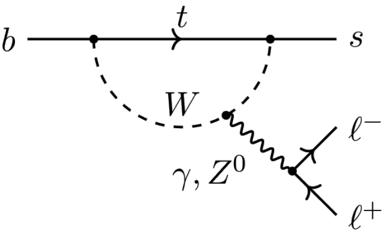
Why rare $b \to s\ell\ell$ decays?

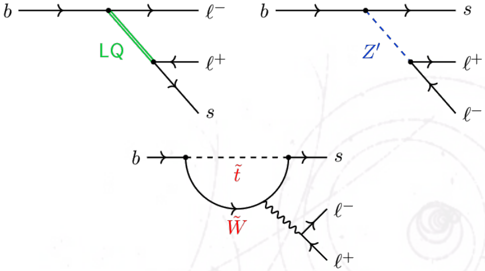
NB: this talk covers $b \to s\mu\mu$ decays at LHCb, for $b \to see$ decays (including LFU results) see Albert Puig's talk (up next!)

- $b \to s\ell\ell$ transitions are forbidden at tree level $\to$ suppressed decays in the SM maybe be more sensitive to new physics (NP) effects.
- Virtual new physics particles $\to$ high mass reach.

$b \to s\ell\ell$ in the SM

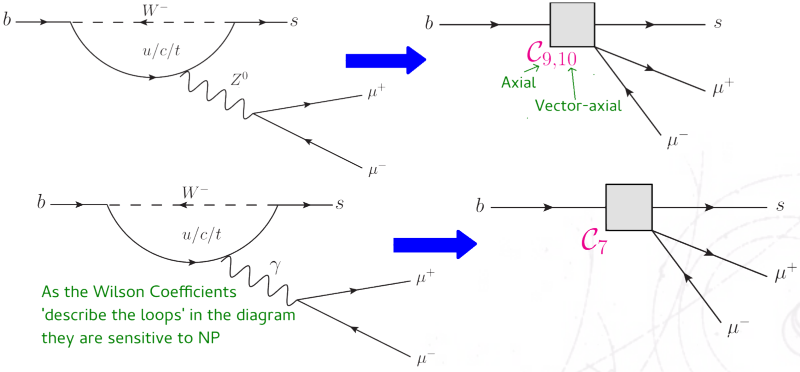


Possible contributions from NP



Use of effective theories in $b \rightarrow s\ell\ell$ SM predictions

- The heavy physics in $b \rightarrow s\ell\ell$ decays can be integrated out to give effective couplings, parameterised by the Wilson Coefficients (C_i).
- $b \rightarrow s\ell\ell$ transitions are most sensitive to the coefficients $C_{9/10}$

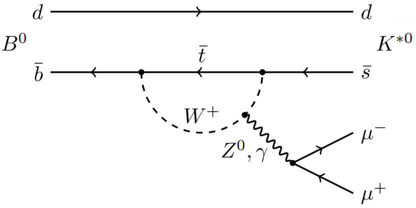


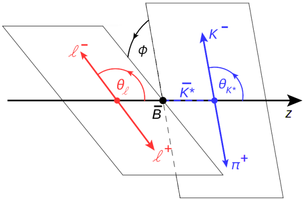
Measuring $b \to s\ell\ell$ transitions

- Angular analyses and branching fraction measurements

$B^0 \to K^{*0} [\to K^+\pi^-] \mu^+\mu^-$ angular analysis $[\mathcal{C}_7, \mathcal{C}_9, \mathcal{C}_{10}]$

Angular decay fully described by the dilepton mass (q^2) and the angles $\cos(\theta_l)$ $\cos(\theta_K)$ and ϕ:





$$\frac{1}{\mathrm{d}(\Gamma+\bar{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}^3(\Gamma+\bar{\Gamma})}{\mathrm{d}\vec{\Omega}} = \frac{9}{32\pi}\Big[\tfrac{3}{4}(1-\boxed{F_{\mathrm{L}}})\sin^2\theta_K + \boxed{F_{\mathrm{L}}}\cos^2\theta_K + \tfrac{1}{4}(1-\boxed{F_{\mathrm{L}}})\sin^2\theta_K\cos 2\theta_\ell$$

$$- \boxed{F_{\mathrm{L}}}\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi$$

$$+ S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi + P'_5\sqrt{F_L(1-F_L)}\sin 2\theta_K\sin\theta_\ell\cos\phi$$

$$+ \tfrac{4}{3}\boxed{A_{\mathrm{FB}}}\sin^2\theta_K\cos\theta_\ell + S_7\sin 2\theta_K\sin\theta_\ell\sin\phi$$

$$+ S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi + S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big]$$

Fraction of longitudanal polaristion of the K*

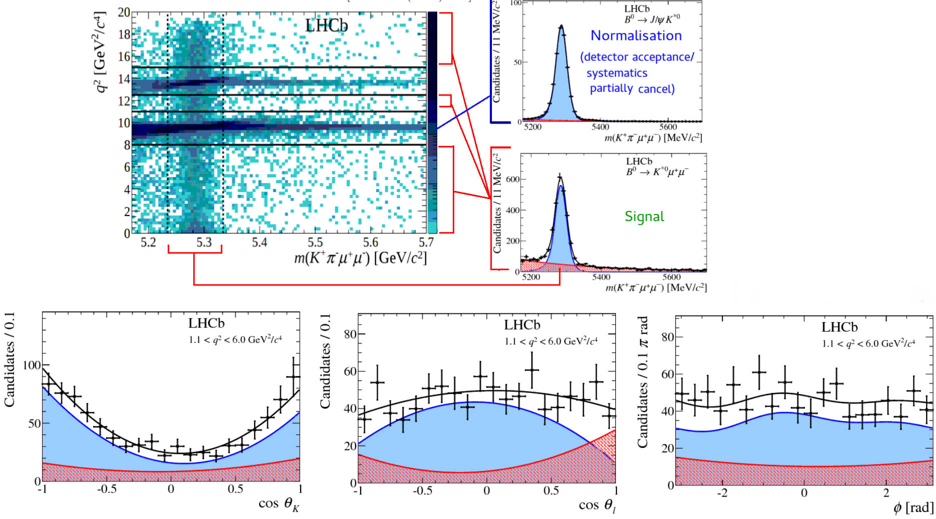
Forward-backward asymmetry of the dilepton system

All angular coefficients depend on Wilson coefficients and hadronic form factors

3D fit to all three angles (in q^2 bins), exploiting the correlations between the S_i, F_L and A_{FB} terms to obtain their respective values (+ swave - see back-up).

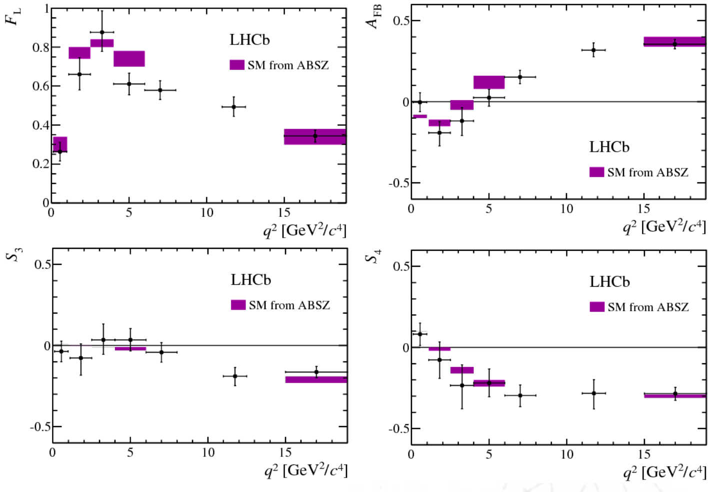
$B^0 \to K^{*0}\,[\to K^+\pi^-\,]\mu^+\mu^-$ angular analysis: Results

[JHEP 02 (2016) 104]



$B^0 \to K^{*0} [\to K^+\pi^-]\mu^+\mu^-$ angular analysis: Results

Generally very good agreement with the Standard Model



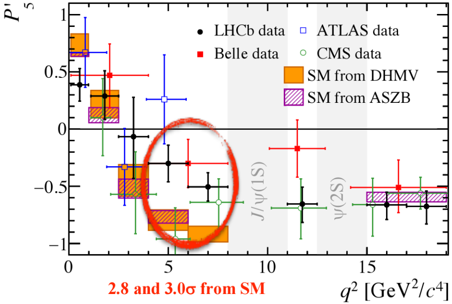
[JHEP 02 (2016) 104]

$B^0 \to K^{*0} [\to K^+\pi^-] \mu^+\mu^-$ angular analysis: Results

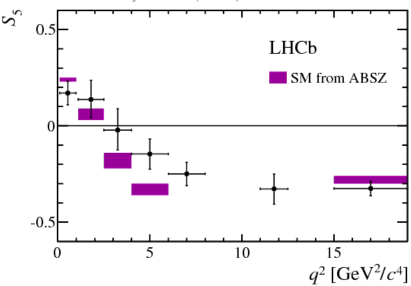
Reduce form factor dependence

Can construct ratios of angular observables where form-factors cancel at leading order: $P_5' = S_5/\sqrt{F_L(1-F_L)}$

P_5' plot: Bins 4/5 = local SM tension of 2.8 and 3.0σ. Global tension= 3.4σ, assuming tension due to shift in Wilson coeff. $\mathcal{R}e(C_9)$ (LHCb only)

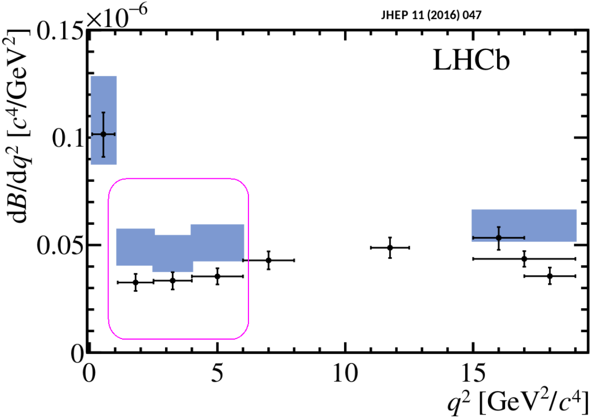


LHCb: JHEP 02 (2016) 104 ATLAS-CONF-2017-023
Belle: PRL 118 (2017) CMS: PLB 781 (2018) 517541



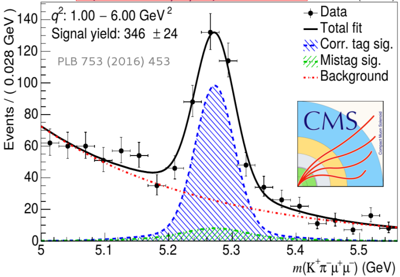
$B^0 \to K^{*0} [\to K^+\pi^-]\mu^+\mu^-$ branching fraction

The differential branching fraction also shows some tension at low q^2

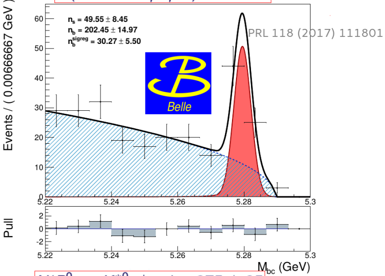


Performance comparison: $B^0 \to K^{*0}\mu^+\mu^-$

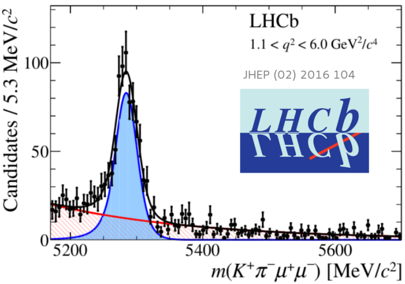
$N(B^0 \to K^{*0}\mu^+\mu^-) = 346 \pm 24$



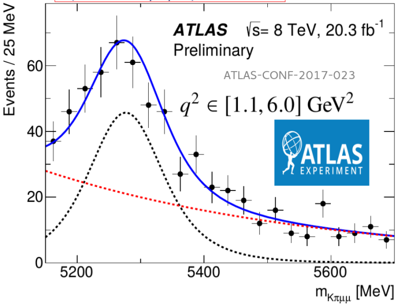
$N(B^0 \to K^{*0}\mu^+\mu^-) = 50 \pm 8$



$N(B^0 \to K^{*0}\mu^+\mu^-) = 624 \pm 30$



$N(B^0 \to K^{*0}\mu^+\mu^-) = 275 \pm 35$

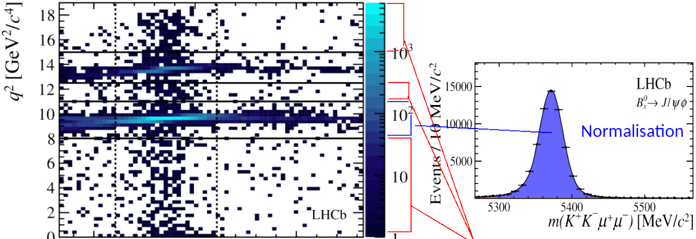


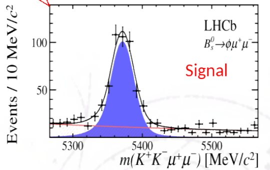
$B_s^0 \to \phi[\to K^+K^-]\mu^+\mu^-$ $[\mathcal{C}_7, \mathcal{C}_9, \mathcal{C}_{10}]$

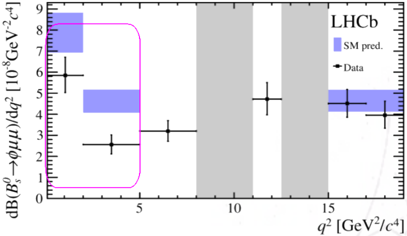
Equivalent process of $B^0 \to K^{*0}\mu^+\mu^-$ for B_s^0 mesons.

Angular variables consistent with the SM. P_5' cannot be measured as $B_s^0 \to \phi\mu^+\mu^-$ not self-tagging.

In bin $1 < q^2 < 6$ GeV/c^2 the data is 3.3σ from the SM prediction.



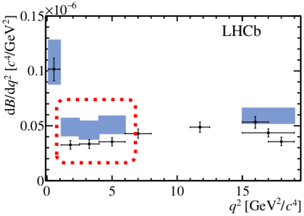




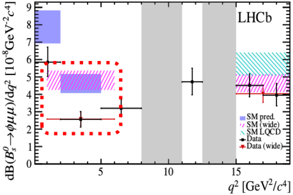
[JHEP 09 (2015) 179]

Further $b \to s\ell\ell$ branching fractions

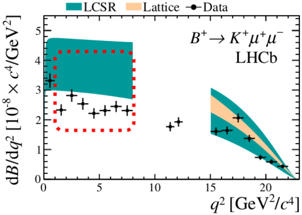
LHCb $B^0 \to K^{*0}\mu^+\mu^-$ [JHEP 11 (2016) 047]



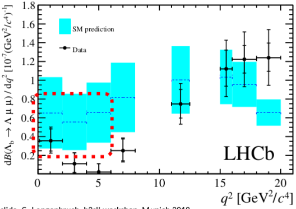
LHCb $B_s^0 \to \phi\mu^+\mu^-$ [JHEP 09 (2015) 179]



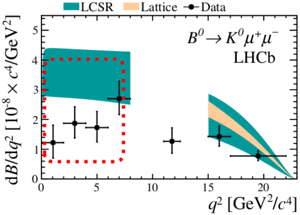
LHCb $B^+ \to K^+\mu^+\mu^-$ [JHEP 06 (2014) 133]



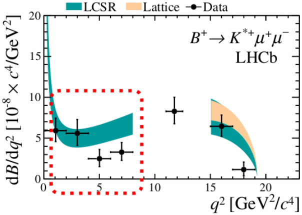
$\Lambda_b^0 \to \Lambda\mu^+\mu^-$ [JHEP 06 (2015) 115]



LHCb $B^0 \to K^0\mu^+\mu^-$ [JHEP 06 (2014) 133]



$B^+ \to K^{*+}\mu^+\mu^-$ [JHEP 06 (2014) 133]



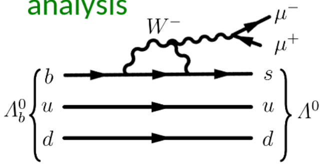
slide: C. Langenbruch, b2sll workshop, Munich 2018

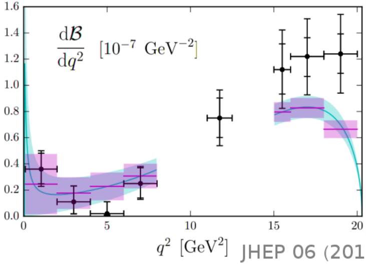
$b \to s\ell\ell$ transitions in baryons

- Baryon sector still relatively unexplored compared to mesons
- Measurements can complement those from meson sector

The decays $\Lambda_b^0 \to \Lambda^0\mu^+\mu^-$ and $\Lambda_b^0 \to pK\mu^+\mu^-$

Differential branching fraction and angular analysis





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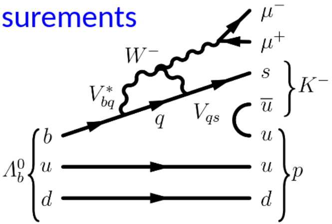
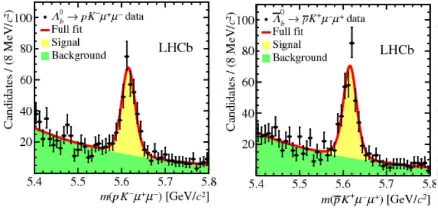
First observation and CPV measurements





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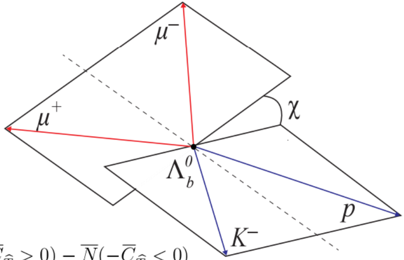
CPV in $\Lambda_b^0 \to pK\mu^+\mu^-$

Baryon production asymmetries not well known: use $\Delta\ A_{cp}$ and triple products

proportional to sin χ

$$\boxed{\begin{aligned} C_{\widehat{T}} &\equiv \vec{p}_{\mu^+} \cdot (\vec{p}_p \times \vec{p}_{K^-}), \\ \overline{C}_{\widehat{T}} &\equiv \vec{p}_{\mu^-} \cdot (\vec{p}_{\overline{p}} \times \vec{p}_{K^+}), \end{aligned}}$$



$$A_{\widehat{T}} \equiv \frac{N(C_{\widehat{T}} > 0) - N(C_{\widehat{T}} < 0)}{N(C_{\widehat{T}} > 0) + N(C_{\widehat{T}} < 0)}, \qquad \overline{A}_{\widehat{T}} \equiv \frac{\overline{N}(-\overline{C}_{\widehat{T}} > 0) - \overline{N}(-\overline{C}_{\widehat{T}} < 0)}{\overline{N}(-\overline{C}_{\widehat{T}} > 0) + \overline{N}(-\overline{C}_{\widehat{T}} < 0)},$$

$$\boxed{a_{CP}^{\widehat{T}\text{-odd}} \equiv \frac{1}{2}\left(A_{\widehat{T}} - \overline{A}_{\widehat{T}}\right), \qquad a_{P}^{\widehat{T}\text{-odd}} \equiv \frac{1}{2}\left(A_{\widehat{T}} + \overline{A}_{\widehat{T}}\right),}$$

$a_{CP}^{\hat{T}-odd} = (1.2 \pm 5.0(\mathrm{stat}) \pm 0.7(\mathrm{syst})) \times 10^{-2} \to$ no significant CPV

- Measure $\Delta\mathcal{A}_{\mathcal{CP}} = \mathcal{A}_{\mathcal{CP}}(\Lambda_b^0 \to pK^-\mu^+\mu^-) - \mathcal{A}_{\mathcal{CP}}(\Lambda_b^0 \to J/\psi\, pK^-)$

$\Delta\mathcal{A}_{\mathcal{CP}}$ = (-3.5 $\pm$ 5.0 (stat) $\pm$ 0.2 (syst)) $\times 10^{-2} \to$ no significant CPV

Global fits

- Global fits performed by theorists to a range of results from $b \to s\ell\ell$ measurements
- Will also discuss interpretations of global fits

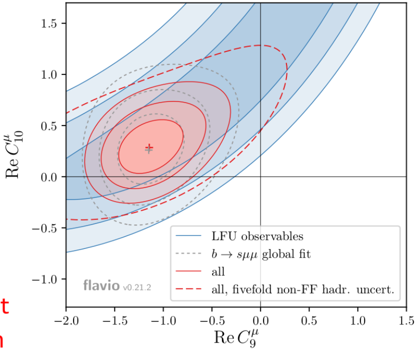
Global fits

- Sub-divide between ‘clean’ observables (LFU measurements - see next talk) and ‘dirty’ observables (e.g. angular analyses)
- Just LFU $\rightarrow \sim 4\ \sigma$ deviations
- Combining all measurements $\rightarrow$ over 5 σ deviations

Non-exhaustive list of global fit examples: arXiv:1704.05438, arXiv:1703.09189, arXiv:1603.00865, arXiv:1702.02234

one example of a global fit, many others out there (!)

Coeff.	best fit	1σ	2σ	$\boxed{\text{pull}}$
C_9^μ	-1.56	$[-2.12, -1.10]$	$[-2.87, -0.71]$	4.1σ
C_{10}^μ	$+1.20$	$[+0.88, +1.57]$	$[+0.58, +2.00]$	4.2σ
C_9^e	$+1.54$	$[+1.13, +1.98]$	$[+0.76, +2.48]$	4.3σ
C_{10}^e	-1.27	$[-1.65, -0.92]$	$[-2.08, -0.61]$	4.3σ
$C_9^\mu = -C_{10}^\mu$	-0.63	$[-0.80, -0.47]$	$[-0.98, -0.32]$	4.2σ
$C_9^e = -C_{10}^e$	$+0.76$	$[+0.55, +1.00]$	$[+0.36, +1.27]$	4.3σ
$C_9^e = C_{10}^e$	-1.91	$[-2.30, -1.51]$	$[-2.71, -1.10]$	3.9σ

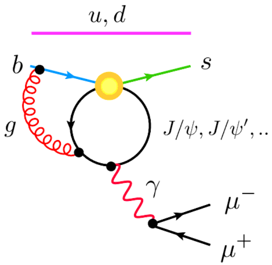


Pull assuming 1D variation only and just LFU measurements -> increased tension when including angular analyses

arXiv:1704.05435

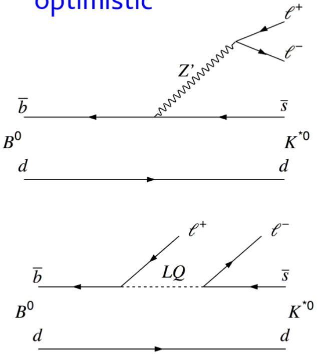
What could be causing this anomaly?

pessimistic



long distance SM effects

optimistic



short distance NP effects

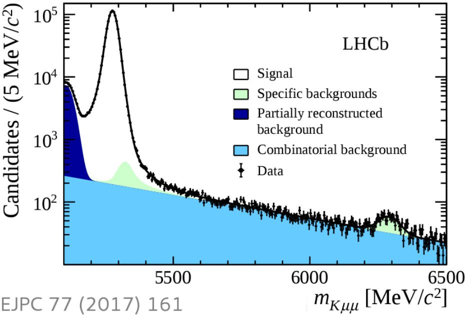
Data driven measurements of short and long distance interference

- Due to the difficulty of modelling Charmonium resonances, the J/ψ and $\psi(2S)$ are generally removed from data when looking at just the short-distance contributions.
- Vector resonances producing dimuon pairs could mimic a contribution to C_9 allowing C_9 to be expressed as

$$C_{9\mathrm{eff}} = C_9 + Y(q^2)$$

- Possible that the deficiency in muons could be due to destructive interference from such Charmonium resonances.

Data driven measurements of short and long distance interference



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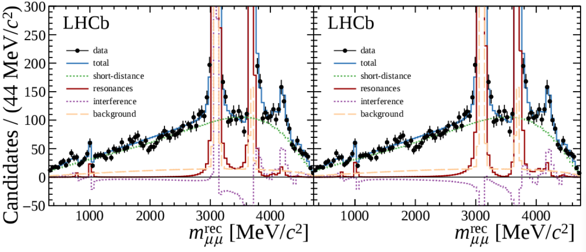
- Data driven approach $\rightarrow$ fit to unbinned data in q^2 for the data $B^+ \rightarrow K^+\mu^+\mu^-$
- Express $Y(q^2)$ in terms of the sum of the magnitude and phases of the vector meson resonances $(\rho, \omega, \phi, J/\psi, \psi(2S), \psi(X))$ $\rightarrow$ model these contributions as a sum of Breit Wigners with individual width and phase.

Data driven measurements of short and long distance interference



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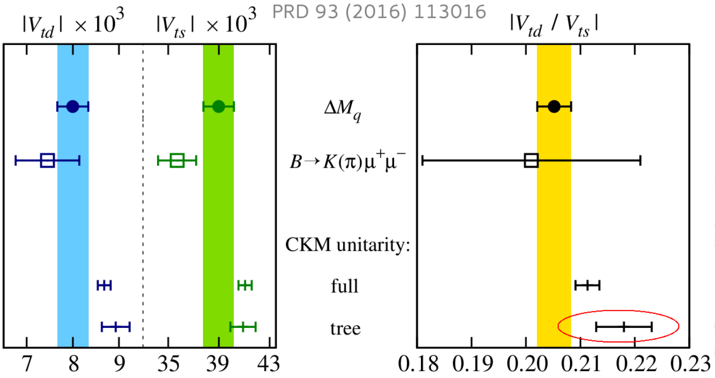
- Four solutions fit data well reflecting the unknown sign of the J/ψ and $\psi(2S)$ phases (NB resolution dominants these resonances widths)
- The phases that are measured suggest a small contribution to the short-distance component in the dimuon mass regions far from the J/ψ and $\psi(2S)$ masses, given the assumptions made in model.

$b \to d\ell\ell$ transitions

- The increased data collected at the LHCb detector means that the Cabibbo-suppressed $b \to d\ell\ell$ modes are becoming more of interest

Why $b \to d\ell\ell$ transitions?

- Combining $b \to s\ell\ell$ with their Cabibbo-suppressed partner allows a measurement of V_{td}/V_{ts} and thus a test of Minimal Flavour Violation.
- Expect branching fractions to be ~ 25 times smaller than s quark partner



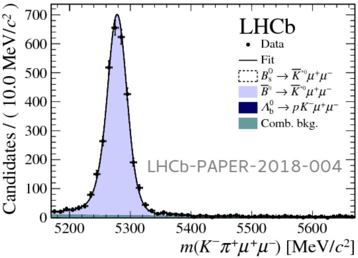
Examples of $b \to d\ell\ell$ transitions

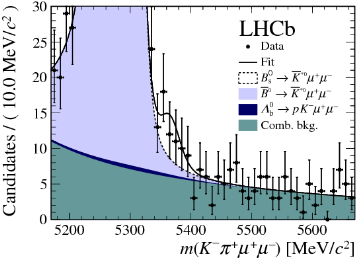
$\mathcal{B}(B_s^0 \to \overline{K^{*0}}\mu^+\mu^-)$ — $B^0 \to K^{*0}\mu^+\mu^-$ equivilent

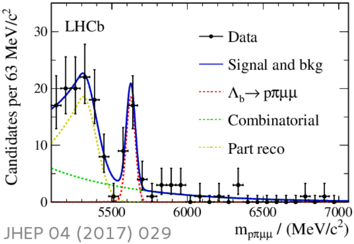
$= (2.9 \pm 1.0 \pm 0.2 \pm 0.3) \times 10^{-8}$

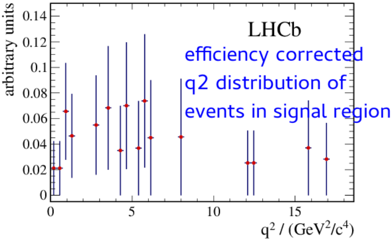
$\mathcal{B}(\Lambda_b^0 \to p\pi^-\mu^+\mu^-)$ — $\Lambda_b^0 \to pK^-\mu^+\mu^-$ equivilent

$= (6.9 \pm 1.9 \pm 1.1^{+1.3}_{-1.0}) \times 10^{-8}$



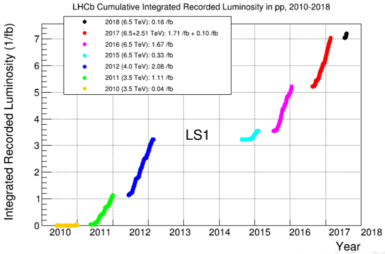






Conclusions and outlook

- Number of anomalies in $b \to s\ell\ell$ transitions, consistent with a deficit in the muon channel
- Could be theoretical limitations or new physics
- More data necessary to further qualify this, as well as development in theory
- Advent of Belle 2 and further runs at the LHC will yield interesting results



Back-up slides

Data driven measurements of short and long distance interference

Following the notation of Ref. [40], the CP-averaged differential decay rate of $B^+ \to K^+\mu^+\mu^-$ decays as a function of the dimuon mass squared, $q^2 \equiv m^2_{\mu\mu}$, is given by

$$\frac{\mathrm{d}\Gamma}{\mathrm{d}q^2} = \frac{G_F^2\alpha^2|V_{tb}V_{ts}^*|^2}{128\pi^5}|\boldsymbol{k}|\beta \left\{ \frac{2}{3}|\boldsymbol{k}|^2\beta^2 \left|\mathcal{C}_{10}f_+(q^2)\right|^2 + \frac{4m_\mu^2(m_B^2 - m_K^2)^2}{q^2m_B^2} \left|\mathcal{C}_{10}f_0(q^2)\right|^2 \right.$$
$$\left. + |\boldsymbol{k}|^2\left[1 - \frac{1}{3}\beta^2\right] \left|\mathcal{C}_9 f_+(q^2) + 2\mathcal{C}_7\frac{m_b + m_s}{m_B + m_K}f_T(q^2)\right|^2 \right\}, \qquad (1)$$

where $|\boldsymbol{k}|$ is the kaon momentum in the B^+ meson rest frame.
The parameters $f_{0,+,T}$ denote the scalar, vector and tensor $B \to K$ form factors.

$$\boxed{\mathcal{C}_9^{\text{eff}} = \mathcal{C}_9 + Y(q^2),}$$

Insert term into eq. above

where the term $Y(q^2)$ describes the sum of resonant and continuum hadronic states appearing in the dimuon mass spectrum. In this analysis $Y(q^2)$ is replaced by the sum of vector meson resonances j such that

If n*pi/2 term disappears in eq.1

$$\mathcal{C}_9^{\text{eff}} = \mathcal{C}_9 + \sum_j \eta_j e^{i\boxed{\delta_j}} A_j^{\text{res}}(q^2), \qquad (3)$$

assumes no continuum hadronic states (e.g. no DDbar)

where η_j is the magnitude of the resonance amplitude and δ_j its phase relative to C_9.

CPV in $\Lambda_b^0 \rightarrow pK\mu^+\mu^-$

Baryon production asymmetries not well known: use $\Delta\, A_{cp}$ and triple products
Sensitivity of methods may differ depending on strong phase interference

$\hat{T}_{even}$, $\hat{T}_{odd}$ amplitudes

$$a_{CP}^{\hat{T}-odd} \propto cos(\delta_{even} - \delta_{odd}) sin(\phi_{even} - \phi_{odd})$$

not sensitive if $\delta_{even} - \delta_{odd} = \pi/2$ or $3\pi/2$

A_1, A_2 amplitudes

$$\mathcal{A}_{CP} \propto sin(\delta_1 - \delta_2) sin(\phi_1 - \phi_2)$$

not sensitive if $\delta_1 - \delta_2 = 0$ or π

δ = strong phase, ϕ = weak phase

- Measure $\Delta\mathcal{A}_{\mathcal{CP}} = \mathcal{A}_{\mathcal{CP}}(\Lambda_b^0 \rightarrow pK^-\mu^+\mu^-) - \mathcal{A}_{\mathcal{CP}}(\Lambda_b^0 \rightarrow J/\psi\, pK^-)$
- $\Delta\mathcal{A}_{\mathcal{CP}}$ = (-3.5 $\pm$ 5.0 (stat) $\pm$ 0.2 (syst)) $\times 10^{-2}$ $\rightarrow$ no significant CPV

$B^0 \to K^{*0}\mu^+\mu^-$: S-wave pollution

- S wave: $K^+\pi^-$ doesn't come from K^{*0} (P-wave) but from spin 0 configuration
- Introduces additional terms in decay amplitude

$$\frac{1}{\mathrm{d}(\Gamma+\bar{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}^3(\Gamma+\bar{\Gamma})}{\mathrm{d}\vec{\Omega}}\bigg|_{\mathrm{S+P}} = (1-F_{\mathrm{S}})\frac{1}{\mathrm{d}(\Gamma+\bar{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}^3(\Gamma+\bar{\Gamma})}{\mathrm{d}\vec{\Omega}}\bigg|_{\mathrm{P}} + \frac{3}{16\pi}F_{\mathrm{S}}\sin^2\theta_\ell + \text{S-P interference}$$

$$\frac{1}{\mathrm{d}(\Gamma+\bar{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}(\Gamma+\bar{\Gamma})}{\mathrm{dcos}\theta_l\,\mathrm{dcos}\theta_K\,\mathrm{d}\phi}\bigg|_{\mathrm{S+P}} = (1-F_S)\frac{1}{\mathrm{d}(\Gamma+\bar{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}(\Gamma+\bar{\Gamma})}{\mathrm{dcos}\theta_l\,\mathrm{dcos}\theta_K\,\mathrm{d}\phi}\bigg|_{\mathrm{P}}$$

Expanding S-P interference terms:

$$+\tfrac{3}{16\pi}\big[F_S\sin^2\theta_l + S_{S1}\sin^2\theta_l\cos\theta_K + S_{S2}\sin 2\theta_l\sin\theta_K\cos\phi + S_{S3}\sin\theta_l\sin\theta_K\cos\phi + S_{S4}\sin\theta_l\sin\theta_K\sin\phi + S_{S5}\sin 2\theta_l\sin\theta_K\sin\phi\big].$$

- To determine F_s more precisely, exploit difference in $m_{K^+\pi^-}$ mass shape between P-, S-wave and fit simultaneously to $m_{K^+\pi^-}$
- $m_{K^+\pi^-}$ line shape in S-wave: LASS model (Nucl. Phys. B296 (1988) 493), P-wave, Breit-Wigner

$B^0 \to K^{*0}\mu^+\mu^-$: systematics

- Analysis statistically dominated (and still will be in Run 2)

Source	F_L	S_3–S_9	A_3–A_9	P_1–P'_8
Acceptance stat. uncertainty	< 0.01	< 0.01	< 0.01	< 0.01
Acceptance polynomial order	< 0.01	< 0.02	< 0.02	< 0.04
Data-simulation differences	0.01–0.02	< 0.01	< 0.01	< 0.01
Acceptance variation with q^2	< 0.01	< 0.01	< 0.01	< 0.01
$m(K^+\pi^-)$ model	< 0.01	< 0.01	< 0.01	< 0.03
Background model	< 0.01	< 0.01	< 0.01	< 0.02
Peaking backgrounds	< 0.01	< 0.01	< 0.01	< 0.01
$m(K^+\pi^-\mu^+\mu^-)$ model	< 0.01	< 0.01	< 0.01	< 0.02
Det. and prod. asymmetries	–	–	< 0.01	< 0.02

$B^0 \to K^{*0}\mu^+\mu^-$: J terms

Definition of J_i terms in decay rate (the complex amplitudes are the terms which are sensitive to the Wilson coefficients):

$$J_1^s = \frac{(2+\beta_\mu^2)}{4}\left[|A_\perp^L|^2 + |A_\parallel^L|^2 + (L\to R)\right] + \frac{4m_\mu^2}{q^2}\Re e(A_\perp^L A_\perp^{R*} + A_\parallel^L A_\parallel^{R*})$$

$$J_1^c = |A_0^L|^2 + |A_0^R|^2 + \frac{4m_\mu^2}{q^2}\left[|A_t|^2 + 2\Re e(A_0^L A_0^{R*})\right]$$

$$J_2^s = \frac{\beta_\mu^2}{4}\left[|A_\perp^L|^2 + |A_\parallel^L|^2 + (L\to R)\right]$$

$$J_2^c = -\beta_\mu^2\left[|A_0^L|^2 + (L\to R)\right]$$

$$J_3 = \frac{\beta_\mu^2}{2}\left[|A_\perp^L|^2 - |A_\parallel^L|^2 + (L\to R)\right]$$

$$J_4 = \frac{\beta_\mu^2}{\sqrt{2}}\left[\Re e(A_0^L A_\parallel^{L*}) + (L\to R)\right]$$

$$J_5 = \sqrt{2}\beta_\mu\left[\Re e(A_0^L A_\perp^{L*}) - (L\to R)\right]$$

$$J_6^s = 2\beta_\mu\left[\Re e(A_\parallel^L A_\perp^{L*}) - (L\to R)\right]$$

$$J_7 = \sqrt{2}\beta_\mu\left[\Im m(A_0^L A_\parallel^{L*}) - (L\to R)\right]$$

$$J_8 = \frac{\beta_\mu^2}{\sqrt{2}}\left[\Im m(A_0^L A_\perp^{L*}) + (L\to R)\right]$$

$$J_9 = \beta_\mu^2\left[\Im m(A_\parallel^{L*} A_\perp^L) + (L\to R)\right]$$

define CP-averaged observables S_i and CP-violating observables A_i according to

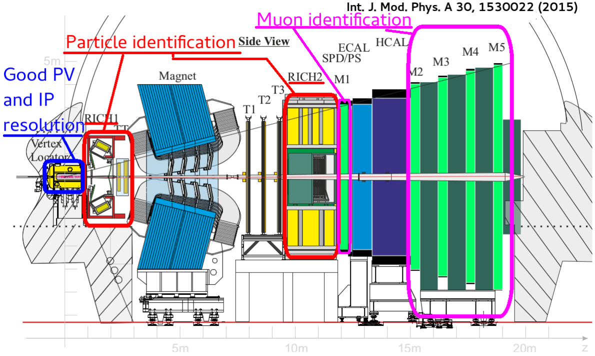
$$S_i = \frac{J_i + \bar{J}_i}{(\mathrm{d}\Gamma + \mathrm{d}\bar{\Gamma})/\mathrm{d}q^2}$$

$$A_i = \frac{J_i - \bar{J}_i}{(\mathrm{d}\Gamma + \mathrm{d}\bar{\Gamma})/\mathrm{d}q^2}.$$

with $\beta_\mu^2 = (1 - 4m(\mu)^2/q^2)$. The angular distribution therefore depends on 7 q^2 dependent complex amplitudes ($A_0^{L,R}$, $A_\parallel^{L,R}$, $A_\perp^{L,R}$ and A_t) corresponding to different polarisation states of the $B \to K^* V^*$ decay.

The LHCb detector

The LHCb detector is a single arm spectrometer which covers the forward region at LHC.



$\Delta p/p \sim 0.4\%$ at $5\,\mathrm{GeV}$, $\sigma_{IP} = 20\ \mu\mathrm{m}$ for high p_T tracks.

π/K separation: ϵ_K ~90%, 5% $\pi \rightarrow K$ mis-id.

π/μ separation: ϵ_μ ~97%, 1-3% $\pi \rightarrow K$ mis-id.

The minimal flavour violation hypothesis

- The excellent agreement with theory of flavour measurements places stringent constraints on the mass scale, Λ, of new physics $\rightarrow$ if new physics is assumed to have a generic flavour structure of $\mathcal{O}(1) \rightarrow \Lambda$ as high as 10^4 TeV (Ann.Rev.Nucl.Part.Sci.60:355, 2010)
- The MFV hypothesis offers solution to this flavour problem:

  Assume NP flavour structure = SM flavour structure
- Comparing the CKM elements obtained via loop and tree level processes tests the MFV hypothesis.