Angular Analysis of $B_d^0 \longrightarrow K^*\mu\mu$ Decays at ATLAS

Run-1 Analysis JHEP 10 (2018) 47

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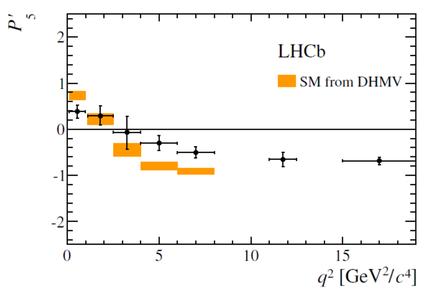
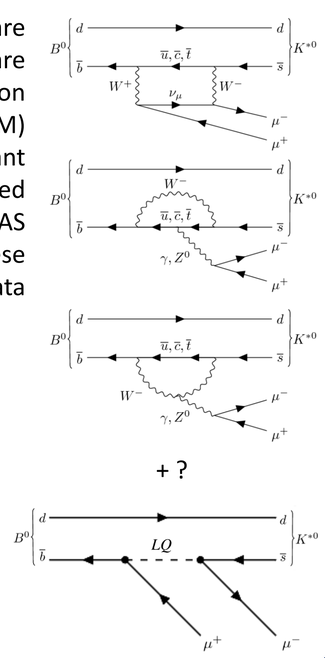
Motivation

Flavour-changing neutral currents are forbidden at tree level and thus they are very sensitive to New Physics. A deviation up to 3.4σ from the Standard Model (SM) prediction in several q^2 (di-muon invariant mass squared) regions has been reported by the LHCb experiment. The ATLAS measurement is performed in these regions using 20.3 fb^{-1} of pp collisions data at 8 TeV.

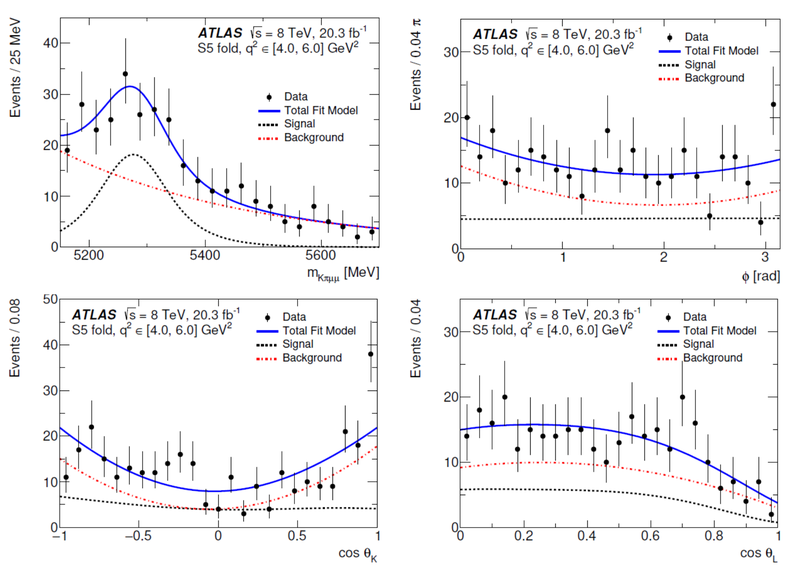


Angular observables derermined from a maximum likelihood fit [2].



Fitting Method

An extended unbinned maximum-likelihood fit is performed in each bin of q^2. The first per-candidate Gaussian pre-fit fixes the B-mass parameters, while the consequent full mass-angular fit focuses on helicity angles. The detector sculpting of angular distributions is compensated by factorized polynomial acceptance functions extracted from signal MC simulation. A combinatorial background component is included in the fit, while peaking backgrounds (B^+, B_s, B_d, Λ_b) are treated as systematic uncertainties.



B-mass and angular fits of S5 folding scheme for q^2 range of 4.0 – 6.0 GeV^2 [1].

Conclusion and Outlook

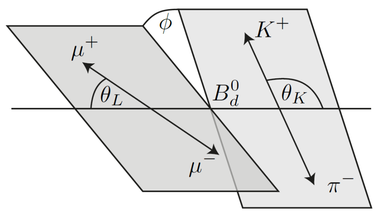
The Run-1 ATLAS measurement of the angular parameters in the $B_d^0 \longrightarrow K^*\mu\mu$ decay is consistent within the limited statistical precision with SM, although the largest deviation in P_5' follows the direction of LHCb observation. The analysis of much larger Run-2 dataset is ongoing. Better b-hadron decay time resolution is expected due to the installation of an additional pixel layer (IBL). Furthermore studies of full q^2 range are planned.

Analysis Method

Differential Decay Rate

- described in helicity basis amplitudes (F_L ... fraction of longitudinally polarised K^*, S_i ... angular parameters)

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



theory uncertainty reduction → $A_{FB} = \frac{3}{4}S_6$

$$P_1 = \frac{2S_3}{1-F_L} \qquad P_2 = \frac{2}{3}\frac{A_{FB}}{1-F_L} \qquad P_3 = -\frac{S_9}{1-F_L} \qquad P'_{j=4,5,6,8} = \frac{S_{i=4,5,7,8}}{\sqrt{F_L(1-F_L)}}$$

In total 342 ± 39 signal events in the q^2 range (0.04 - 6) GeV^2 was observed, which is too low for full angular distribution using candidates in the dataset.

→ trigonometric folding scheme

$$F_L, S_3, S_4, P'_4: \begin{cases} \phi \to -\phi & \text{for } \phi < 0 \\ \phi \to \pi - \phi & \text{for } \theta_L > \frac{\pi}{2} \\ \theta_L \to \pi - \theta_L & \text{for } \theta_L > \frac{\pi}{2} \end{cases} \quad \cos\theta_L \in [0,1], \cos\theta_K \in [-1,1] \text{ and } \phi \in [0,\pi]$$

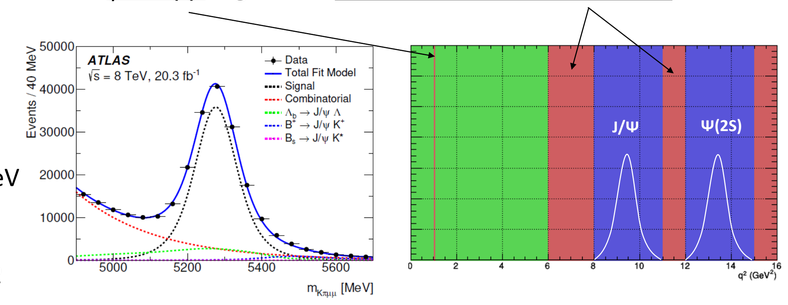
$$F_L, S_3, S_7, P'_6: \begin{cases} \phi \to \pi - \phi & \text{for } \phi > \frac{\pi}{2} \\ \phi \to -\pi - \phi & \text{for } \phi < -\frac{\pi}{2} \\ \theta_L \to \pi - \theta_L & \text{for } \theta_L > \frac{\pi}{2} \end{cases} \quad \cos\theta_L \in [0,1], \cos\theta_K \in [-1,1] \text{ and } \phi \in [-\pi/2,\pi/2]$$

$$F_L, S_3, S_5, P'_5: \begin{cases} \phi \to -\phi & \text{for } \phi < 0 \\ \theta_L \to \pi - \theta_L & \text{for } \theta_L > \frac{\pi}{2} \end{cases} \quad \cos\theta_L \in [0,1], \cos\theta_K \in [-1,1] \text{ and } \phi \in [0,\pi]$$

$$F_L, S_3, S_8, P'_8: \begin{cases} \phi \to \pi - \phi & \text{for } \phi > \frac{\pi}{2} \\ \phi \to -\pi - \phi & \text{for } \phi < -\frac{\pi}{2} \\ \theta_L \to \pi - \theta_L & \text{for } \theta_L > \frac{\pi}{2} \\ \theta_K \to \pi - \theta_K & \text{for } \theta_L > \frac{\pi}{2} \end{cases} \quad \cos\theta_L \in [0,1], \cos\theta_K \in [-1,1] \text{ and } \phi \in [-\pi/2,\pi/2]$$

Signal Selection

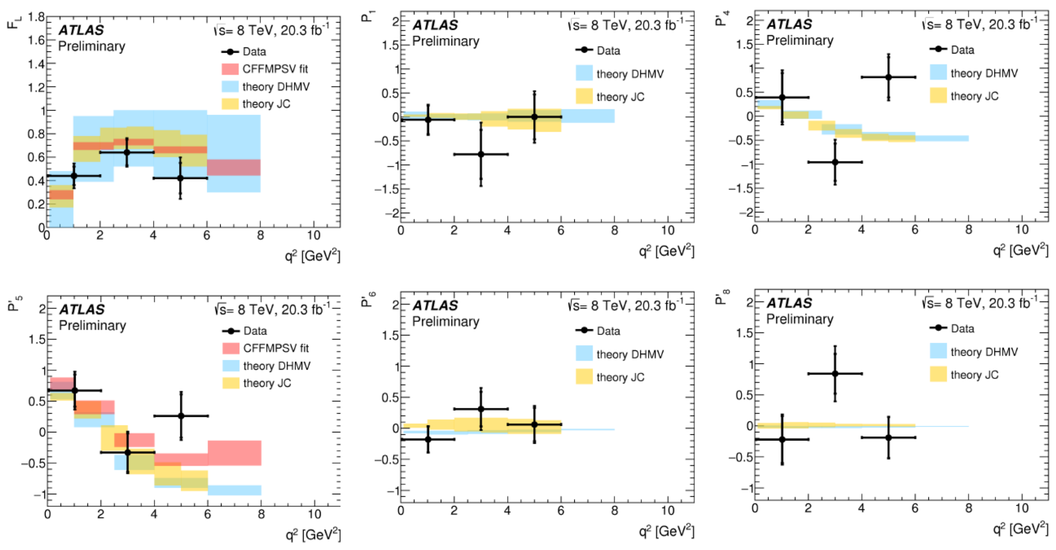
- range limited to 0.04 < q^2 < 6 GeV^2, exclusion of $\varphi \to \mu\mu$ region and radiative tails of $c\bar{c}$ resonances
- 19 trigger chains
- dominated by di-muon request
- $p_T(\mu_1) > 4$ GeV $\wedge$ $p_T(\mu_2) > 6$ GeV
- $|\eta| < 2.5$, $p_T(\mu, \pi, K) > (3.5, 0.5, 0.5)$ GeV
- $\tau/\sigma_\tau > 12.75$, B-vertex cos(ϑ) > 0.999
- secondary vertex fit quality χ^2/NDF < 2



As a control channel $B \to J/\Psi K^*$ is used [2]. Analyzed regions of q^2 (in green) and control regions (in blue).

Results

- results consistent with SM predictions and other experiments, largest deviation 2.7σ (P_5') from DHMV



Measured F_L and P_j' parameters compared with the SM predictions [1] from the theoretical approches CFFMPSV [JHEP 06 (2016) 116], DHMV [JHEP 12 (2014) 125] and JC [JHEP 05 (2013) 043].

- statistical uncertainties more than twice as high as systematics
- fit feasibility validated with toy-MC (low statistics)
- the largest systematic uncertainty comes from the background description

Source	F_L	S_3	S_4	S_5	S_7	S_8
Combinatoric $K\pi$ (fake K^*) background	0.03	0.03	0.05	0.04	0.06	0.16
D and B^+ veto	0.11	0.04	0.05	0.04	0.01	0.06
Background pdf shape	0.04	0.04	0.03	0.03	0.03	0.01
Acceptance function	0.01	0.01	0.07	0.01	0.01	0.01
Partially reconstructed decay background	0.03	0.05	0.02	0.08	0.05	0.06
Alignment and B field calibration	0.02	0.04	0.05	0.04	0.04	0.04
Fit bias	0.01	0.01	0.02	0.03	0.01	0.05
Data/MC differences for p_T	0.02	0.02	0.01	0.01	0.01	0.01
S-wave	0.01	0.01	0.01	0.01	0.01	0.03
Nuisance parameters	0.01	0.01	0.01	0.01	0.01	0.01
Λ_b, B^+ and B_s background	0.01	0.01	0.01	0.01	0.01	0.01
Misreconstructed signal	0.01	0.01	0.01	0.01	0.01	0.01
Dilution	–	–	-	< 0.01	–	< 0.01

References

[1] The ATLAS collaboration, *Angular analysis of $B_d^0 \to K^*\mu^+\mu^-$ decays in pp collisions at √s=8 TeV with the ATLAS detector*, JHEP 10 (2018) 47

[2] LHCb collaboration, *Angular analysis of the $B^0 \to K^{*0}\mu^+\mu^-$ decay using 3 fb^{-1} of integrated luminosity*, JHEP 02 (2016) 104 [arXiv:1512.04442]

Acknoledgements

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