Differential Branching ratio and angular analysis of $B^+ \to K^+\mu^+\mu^-$ at LHCb

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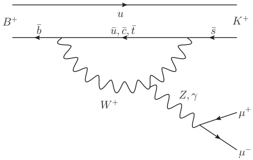
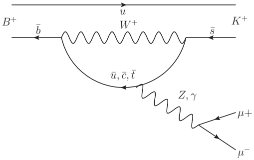
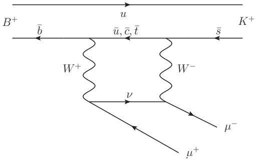
Outline

Theory - Introduction

- $B^+ \to K^+\mu^+\mu^-$ is a flavour-changing-neutral-current (FCNC) decay.
- Proceeds via a $b \to s$ transition.
- FCNC decays forbidden at tree level, must occur through higher order loop diagrams (suppressed).
- May probe New Physics such as yet unobserved particles and processes.







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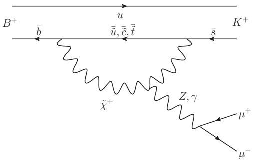
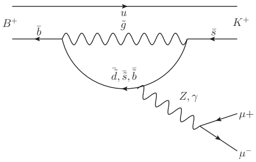
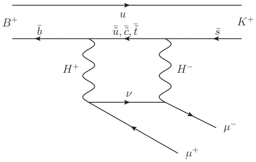
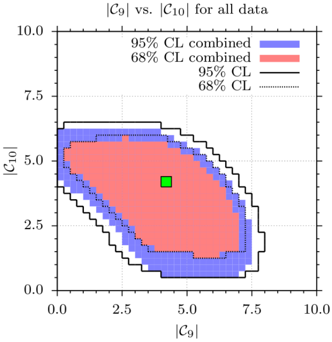






Theory - Interest

- Measurement of branching ratio can help to further constrain the Wilson coefficient relation $|C_9| - |C_{10}|$ when combined with measurements from other channels such as $B^0 \rightarrow K^{*0}\mu^+\mu^-$[1].



- F_H and A_{FB} both sensitive to scalar and pseudoscalar operators.
- F_H and A_{FB} expected to be negligible in SM.
- Significant deviation from expectation would indicate New Physics.

Strategy - Branching Fraction Measurement

- The differential branching fraction is given by:

$$\frac{BR(B^+ \to K^+\mu^+\mu^-)}{BR(B^+ \to J/\psi K^+)} = \frac{N_{K^+\mu^+\mu^-}}{N_{J/\psi K^+}} \times \frac{\epsilon_{J/\psi K^+}}{\epsilon_{K^+\mu^+\mu^-}} \times BR(J/\psi \to \mu^+\mu^-)$$

- $N_{K^+\mu^+\mu^-}$ and $N_{J/\psi K^+}$ are the measured yields of $K^+\mu^+\mu^-$ and $J/\psi K^+$ respectively, extracted from an unbinned maximum likelihood fit to the $m_{K^+\mu^+\mu^-}$ distribution.
- $\epsilon_{J/\psi K^+}/\epsilon_{K^+\mu^+\mu^-}$ is the total relative efficiency between the two channels and is calculated using simulated data.
- The values for $BR(B^+ \to J/\psi K^+)$ and $BR(J/\psi \to \mu^+\mu^-)$ are taken from the PDG.
- The branching fraction is calculated in each of the 7 q^2-bins (dimuon invariant mass) used in this analysis.

Strategy - Angular analysis

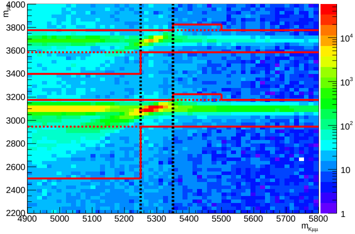
- The angular distribution is given by:

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_l} = \frac{3}{4}(1 - F_H)(1 - \cos^2\theta_l) + \frac{F_H}{2} + A_{FB}\cos\theta_l$$

- The angle θ_l is defined as the angle between the direction of the dimuon pair in the B^+ (B^-) rest-frame and the direction of the μ^+ ($\mu-$) in the dimuon rest-frame.
- A_{FB} is the forward-backward asymmetry and F_H is a flat parameter.
- A_{FB} and F_H are extracted with a simultaneous fit to the $m_{K^+\mu^+\mu^-}$ and $cos\theta_l$ distributions in each of the 7 q^2-bins used in this analysis.

Selection - Charmonium vetoes

- $B^+ \to J/\psi K^+$ and $B^+ \to \psi(2S)K^+$ have BFs ~100 and ~10 times larger than $B^+ \to K^+\mu^+\mu^-$.
- $B^+ \to K^+\mu^+\mu^-$ is isolated by vetoing their contributions.
- Veto is extended in low mass sideband to remove the radiative tail of the J/ψ and $\psi(2S)$.
- Also extended in the upper mass sideband to the (non-Gaussian) tails of poorly reconstructed J/ψ and $\psi(2S)$.

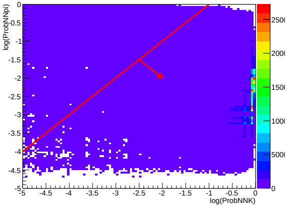


- Multivariate selection using a Boosted Decision Tree (BDT).
- Variables are chosen that provide the greatest seperating power while not biasing the q^2 and $cos\theta_l$ distributions.

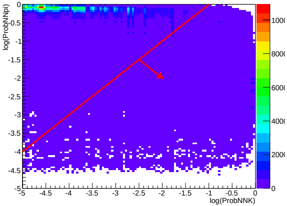
Particle	Variables
B^+	DIRA
B^+	τ
B^+	IP χ^2
B^+	End Vertex χ^2
B^+	p_T
K^+	Track χ^2/DOF
$\mu^\pm$	p_T
$\mu^\pm$	IP χ^2

Selection - PID requirements

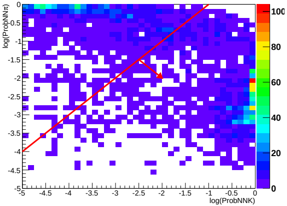
- PID requirements applied to select ‘genuine’ kaons.
- PID variables used are output of a Neurobayes neural network.
- ’Pure’ samples obtained from $D^{*+} \rightarrow D^0\{\rightarrow K^+\pi^-\}\pi^+$ and $D^{*+} \rightarrow D^0\{\rightarrow K^+\pi^-\}K^+$ calibration samples.



(a) Pure kaon sample



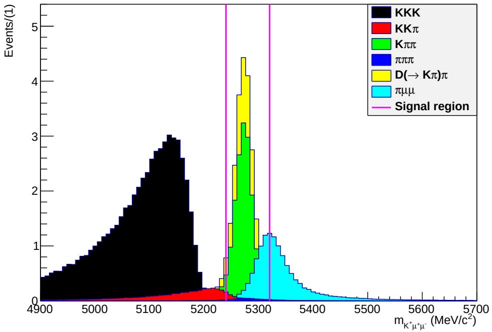
(b) Pure pion sample



(c) $B^+ \rightarrow K^+\mu^+\mu^-$ sample

Selection - Peaking background study

- An extensive peaking background study has been performed.
- Four types of peaking background were investigated:
  - Hadronic B^+ decays.
  - $B^+ \to J/\psi K^+$ with a $K^+ \leftrightarrow \mu^+$ swap.
  - Semileptonic $B \to D$ decays.
  - $B^+ \to \pi^+\mu^+\mu^-$.

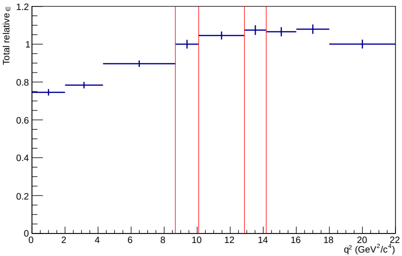


Total relative efficiency

- The total relative efficiency is given by:

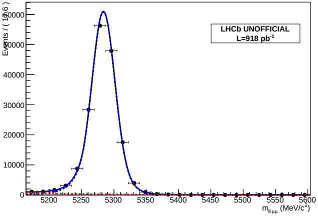
$$\frac{\epsilon_{J/\psi K^+}}{\epsilon_{K^+\mu^+\mu^-}} = \frac{\epsilon^{acc}_{J/\psi K^+}}{\epsilon^{acc}_{K^+\mu^+\mu^-}} \times \frac{\epsilon^{rec\&sel}_{J/\psi K^+}}{\epsilon^{rec\&sel}_{K^+\mu^+\mu^-}} \times \frac{\epsilon^{trigger}_{J/\psi K^+}}{\epsilon^{trigger}_{K^+\mu^+\mu^-}}$$

- ϵ_{acc} is the geometric acceptance of LHCb.
- $\epsilon_{reco\&sel}$ is the combined detection, reconstruction and selection efficiency.
- $\epsilon_{trigger}$ is the trigger efficiency.

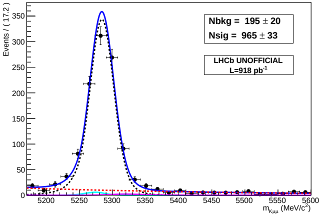


Fits to $m_{K^+\mu^+\mu^-}$ for $B^+ \to J/\psi K^+$ and $B^+ \to K^+\mu^+\mu^-$

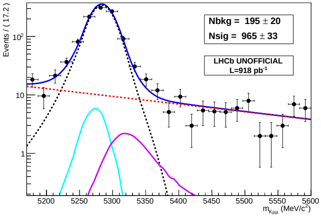
$B^+ \to J/\psi K^+$



$B^+ \to K^+\mu^+\mu^-$

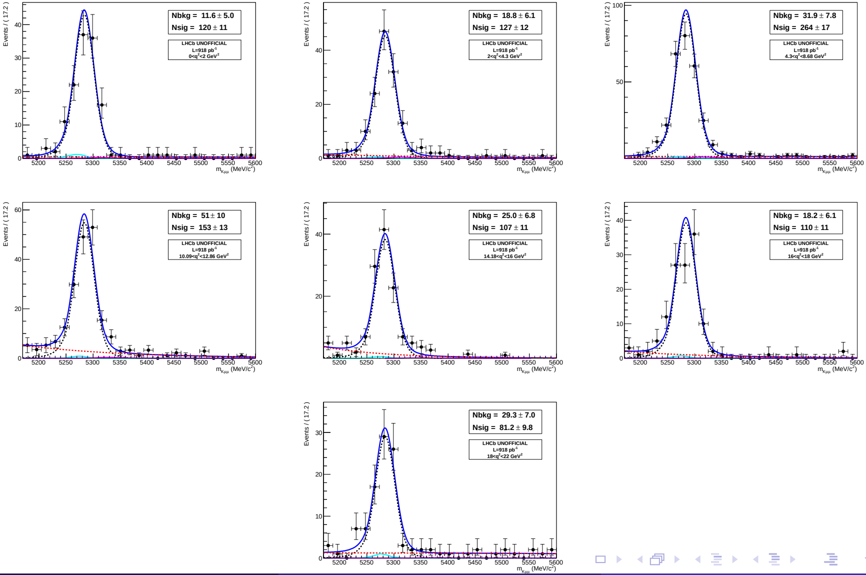


$B^+ \to K^+\mu^+\mu^-$



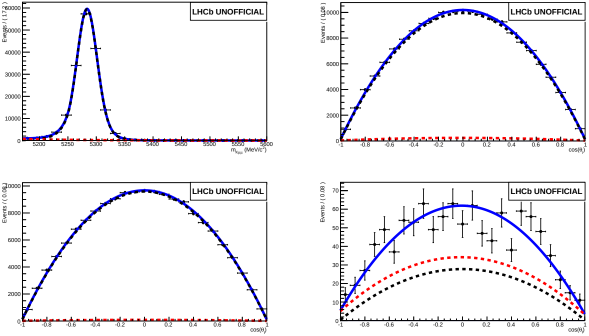
- Peaking background visible on log scale.
  - $B^+ \to K^+\pi^+\pi^-$
  - $B^+ \to \pi^+\mu^+\mu^-$

Mass fits - $B^+ \to K^+\mu^+\mu^-$ in bins of q^2



Angular fits - $B^+ \to J/\psi K^+$

- Simultaneous fit to the $m_{K^+\mu^+\mu^-}$ and $cos\theta_l$ distributions for $B^+ \to J/\psi K^+$.



- Everything can be seen to be working.

Conclusion

- Analysis is in an advanced stage.
- Currently undergoing internal review within LHCb.
- Hope to publish results for A_{FB} and F_H in the near future.