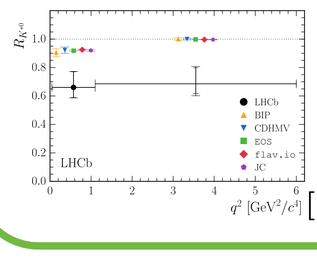
Search for the lepton-flavour-violating decays $B^+ \to K^+ e^\pm \mu^\mp$

Gerwin Meier on behalf of the LHCb collaboration

Introduction

Charged lepton flavour violation

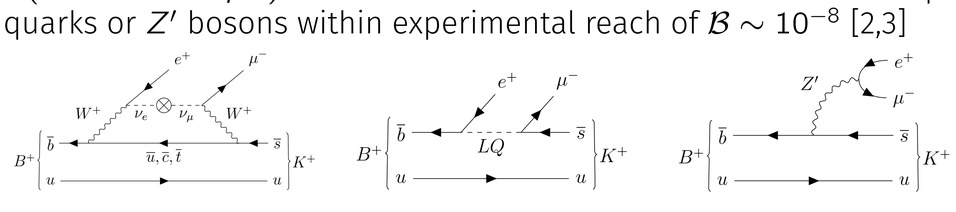


[1]

Motivated by lepton flavour violations in neutrino oscillations and hints of lepton flavour non-universality in $R_{K^{(*)}}$.

Standard model and New Physics models

$\mathcal{B}(B^+ \to K^+ e^\pm \mu^\mp) \sim 10^{-40}$ in extended SM. NP models with lepto-quarks or Z' bosons within experimental reach of $\mathcal{B} \sim 10^{-8}$ [2,3]



Current limit

Best limit from BaBar with 90% CL [4]

$\mathcal{B}(B^+ \to K^+ e^+ \mu^-) < 9.1 \times 10^{-8}$

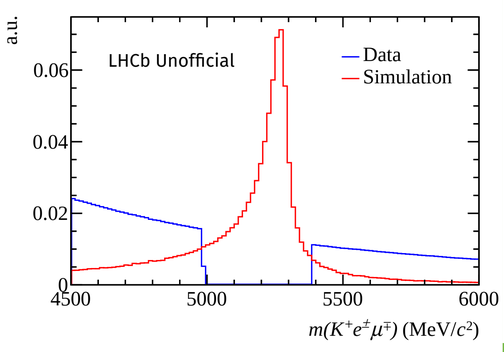
$\mathcal{B}(B^+ \to K^+ e^- \mu^+) < 13 \times 10^{-8}$

Dataset and analysis strategy

Data taken by the LHCb experiment during Run 1 corresponding to an integrated luminosities of $1\,\text{fb}^{-1}$ at 7 TeV and $2\,\text{fb}^{-1}$ at 8 TeV.

- Loose preselection and trigger requirements
- Data-MC corrections in kinematic and particle identification variables
- Selection with two multivariate classifiers

After central LHCb preselection



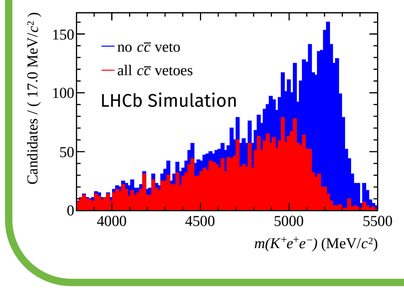
- Tight particle identification requirements
- Upper limit relative to $B^+ \to K^+ J/\psi\,(\to \mu^+\mu^-)$ with CLs method [5] using GammaCombo framework [6]

Suppress peaking backgrounds

- Veto $m_{\ell\ell}$ for charmonium resonances, where $\ell \to \ell'$ and $K \to \ell$ misidentification is considered
- Veto decays including D^0 with $m_{K\ell} > 1885$ MeV/c^2
- Veto misidentified backgrounds with particle identification requirements

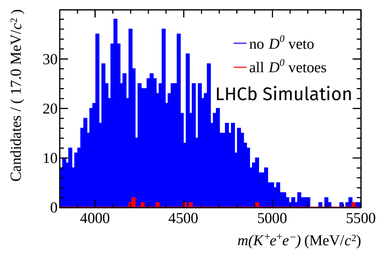
With and without charmonium resonance veto in

$B^+ \to K^+ J/\psi\,(\to e^+e^-)$



With and without D^0 veto in

$B^+ \to e^+ \nu_e \bar{D}^0 (\to \pi^- K^+)$

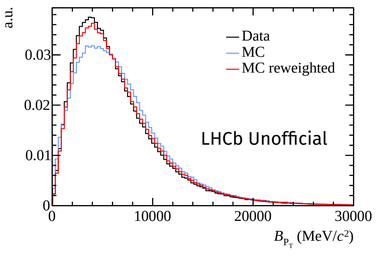


Data-MC corrections

Correction of the simulation to reproduce kinematics and PID variables accurately

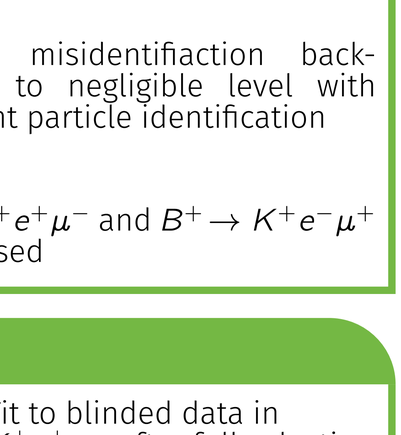
Kinematic reweighting

- Iterative calculation of weights in bins of
  - track multiplicity
  - B transverse momentum
  - B meson vertex quality



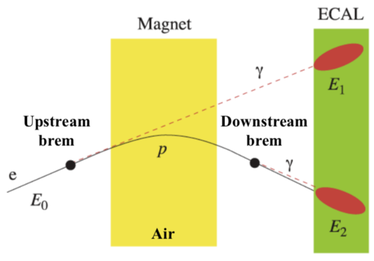
Resampling of particle identification variables

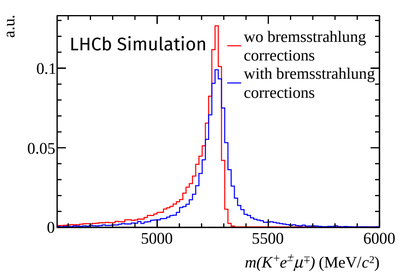
- Correction of simulated particle identification variables with calibration datasets.



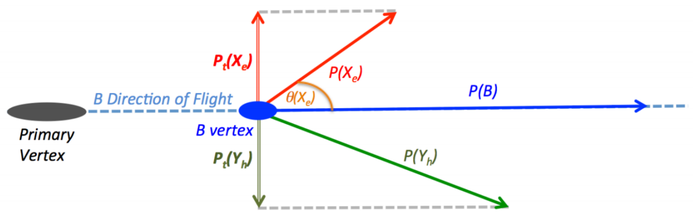
Bremsstrahlung

- Energy loss due to bremsstrahlung radiation by electrons → momentum corrections
- Describe the mass distribution in two categories, whether bremsstrahlung corrections are applied or not





HOP variable



[8]

- $P_t(X_e)$, $P_t(Y_h)$: transverse momentum wrt. B meson flight direction of the electron, all other particles
- $P_t(X_e) = P_t(Y_h)$ for perfect reconstruction
- $\alpha_{\text{HOP}} = \frac{P_t(Y_h)}{P_t(X_e)} \neq 1$ for partial reconstructed decays
- Helpful to reduce partially reconstructed backgrounds

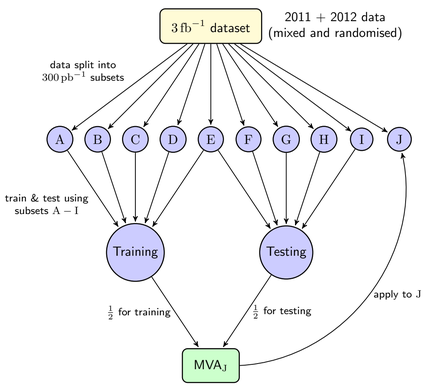
Selection

BDT

- BDT with GradientBoost algorithm [7]
- k-folding with $k = 10$
- Signal: reweighted simulation of $B^+ \to K^+ e^\pm \mu^\mp$
- Background: upper mass sideband from data of $B^+ \to K^+ e^\pm \mu^\mp$
- Features: kinematic, vertex quality and track isolation variables
- Greatly reduces combinatorial background

BDT HOP

- 2nd BDT after applying 1st BDT requirements
- The same technique as 1st BDT
- Signal: reweighted simulation of $B^+ \to K^+ e^\pm \mu^\mp$
- Different background sample: lower mass sideband from data
- Add α_{HOP} to feature set
- Strongly reduces partial reconstructed backgrounds



Particle identification cuts

Reduce misidentifiaction background to negligible level with excellent particle identification

Optimisation of selection cuts

- Based on expected upper limit with the CLs method
- Split samples in $B^+ \to K^+ e^+ \mu^-$ and $B^+ \to K^+ e^- \mu^+$ to find optimal cut unbiased

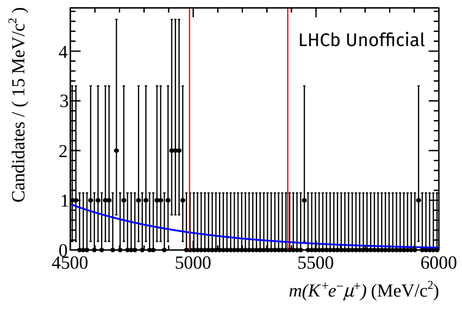
Analysis status and outlook

The physical background found to be negligible. The expected background yield in the signal region is

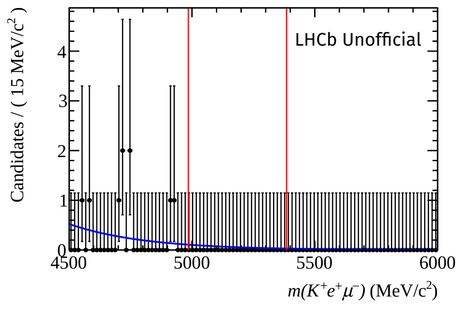
$$N_{\text{phys bkg}} < \mathcal{O}(1),$$
$$N_{\text{comb bkg}} < \mathcal{O}(10).$$

This analysis is still blind but in review. The expected upper limit is $\mathcal{O}(10^{-8})$.

Fit to blinded data in $B^+ \to K^+ e^- \mu^+$ after full selection



Fit to blinded data in $B^+ \to K^+ e^+ \mu^-$ after full selection



References

[1] LHCb Collaboration, R. Aaij et. al., Test of lepton universality with $B^+ \to K^{*0}\ell^+\ell^-$ decays, JHEP 08 (2017) 055

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[3] A. Crivellin et. al., Correlating lepton flavour universality violation in B decays with $\mu \to e\gamma$ using leptoquarks, Phys. Re. D97 (2018) 015019

[4] BaBar collaboration, B. Aubert et al., Measurements of branching fractions, rate asymmetries, and angular distributions in the rare decays $B^+ \to K\ell^+\ell^-$ and $B^+ \to K^*\ell^+\ell^-$, Phys. Rev. D73 (2006) 092001

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[6] M. Kenzie et. al., GammaCombo - A statistical analysis framework for combining measurements, fitting datasets and producing confidence intervals, https://gammacombo.github.io/index.html

[7] A. Hocker et. al., TMVA - Toolkit for Multivariate Data Analysis, PoS ACAT (2007) 040

[8] LHCb Collaboration, R. Aaij et. al., Test of lepton universality with $B^0 \to K^{*0}\ell^+\ell^-$ decays, JHEP. 08 (2017) 055