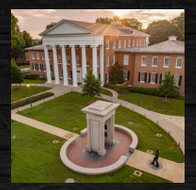
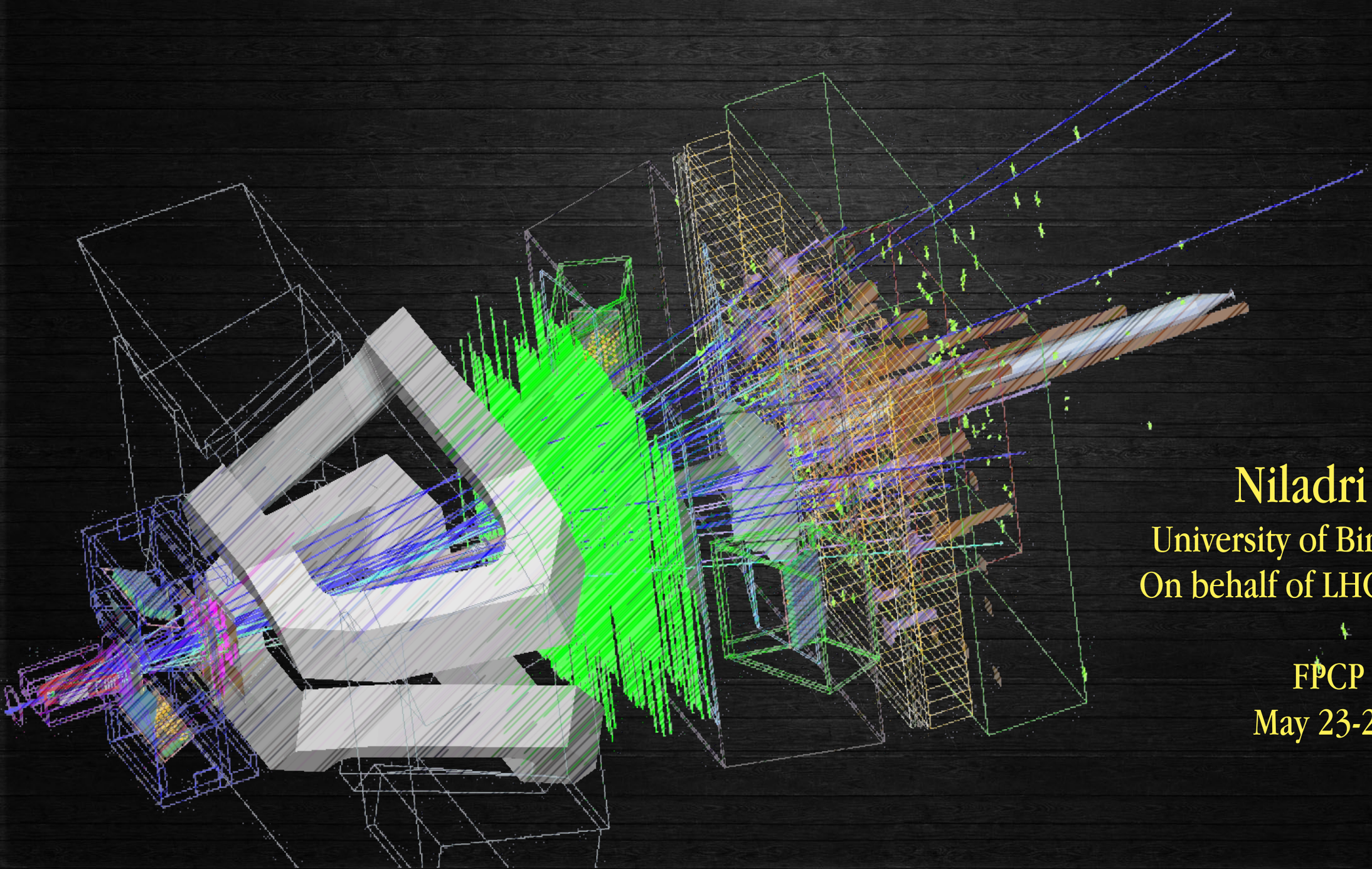


LFV in B decays in LHCb



Niladri Sahoo

University of Birmingham (UK)

On behalf of LHCb collaboration

FPCP 2022

May 23-27, 2022

Outline

- Motivation
- Lepton Flavor Violating (LFV) decays in LHCb
  - $B^0 \to K^{*0}\mu^{\pm}e^{\mp}$ and $B_s \to \phi\mu^{\pm}e^{\mp}$ NEW
  - $B^+ \to K^+\mu^-\tau^+$
  - $B^+ \to K^+\mu^{\pm}e^{\mp}$
  - $B^0_{(s)} \to \tau^{\pm}\mu^{\mp}$
- Summary

Motivation

- Lepton Flavor Violation (LFV) occurs in SM via neutrino oscillation
- Very low decay rates $< 10^{-40}$, in charge lepton sector $< 10^{-54}$
- These decays are effectively forbidden in SM
- Interests in LFV grown up lately because of anomalies reported recently in
  - $b \to sll$ neutral currents (e vs μ)
  - $b \to cl\nu$ charged currents (τ vs e, μ)
- Lepton Flavor Non-Universality implies LFV Glashow, Guadagnoli, Lane (2015)
- Several BSM models predict rates close to experimental reach, e.g, Leptoquark models Hiller, Loose, Schönwald (2016)

$B^0 \to K^{*0}\mu^{\pm}e^{\mp}$ and $B_s \to \phi\mu^{\pm}e^{\mp}$

NEW

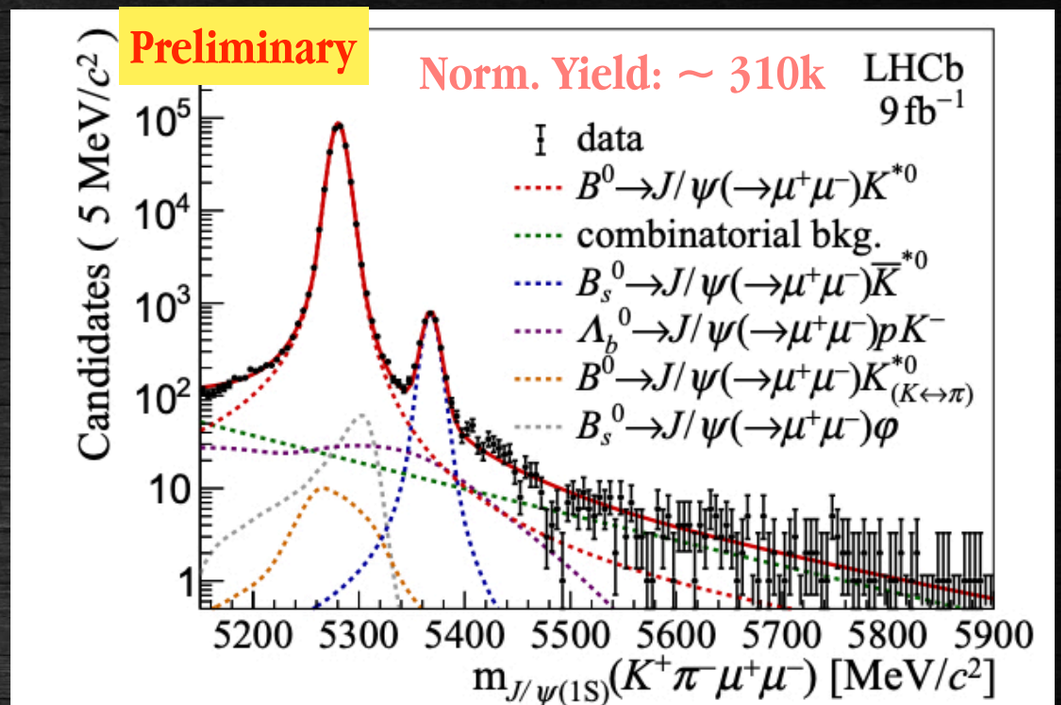
LHCb-PAPER-2022-008 [in prep]

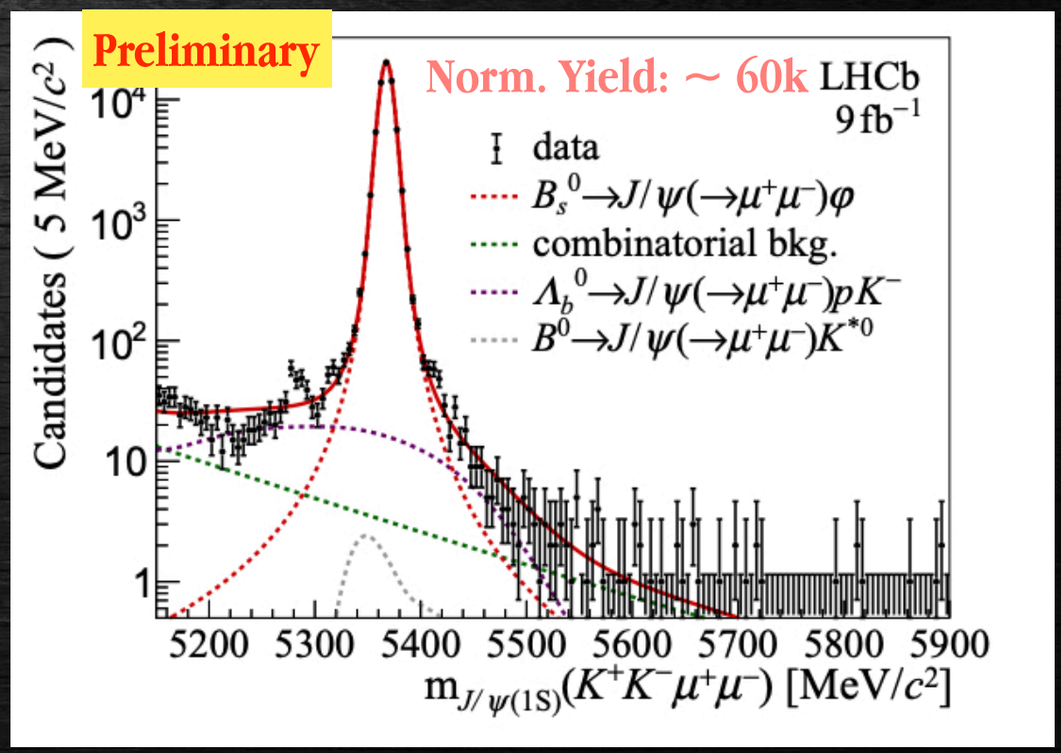
- Full LHCb dataset: 9 fb^{-1}
- Final states: $K^+\pi^-\mu^{\pm}e^{\mp}$ and $K^+K^-\mu^{\pm}e^{\mp}$
- Invariant mass of $K^+\pi^-$ (K^+K^-) required to be within 100 MeV (12 MeV) of K^* (ϕ) mass
- Normalisation modes:

  $B^0 \to J/\psi(\to \mu^+\mu^-)K^{*0}$ and $B_s \to J/\psi(\to \mu^+\mu^-)\phi$
- Signal Branching fraction:

$$\mathcal{B}_{\rm sig} = \frac{\mathcal{B}_{\rm norm}}{N_{\rm norm}} \times \frac{\epsilon_{\rm norm}}{\epsilon_{\rm sig}} \times N_{\rm sig}$$

- Phase space model used for signal simulation



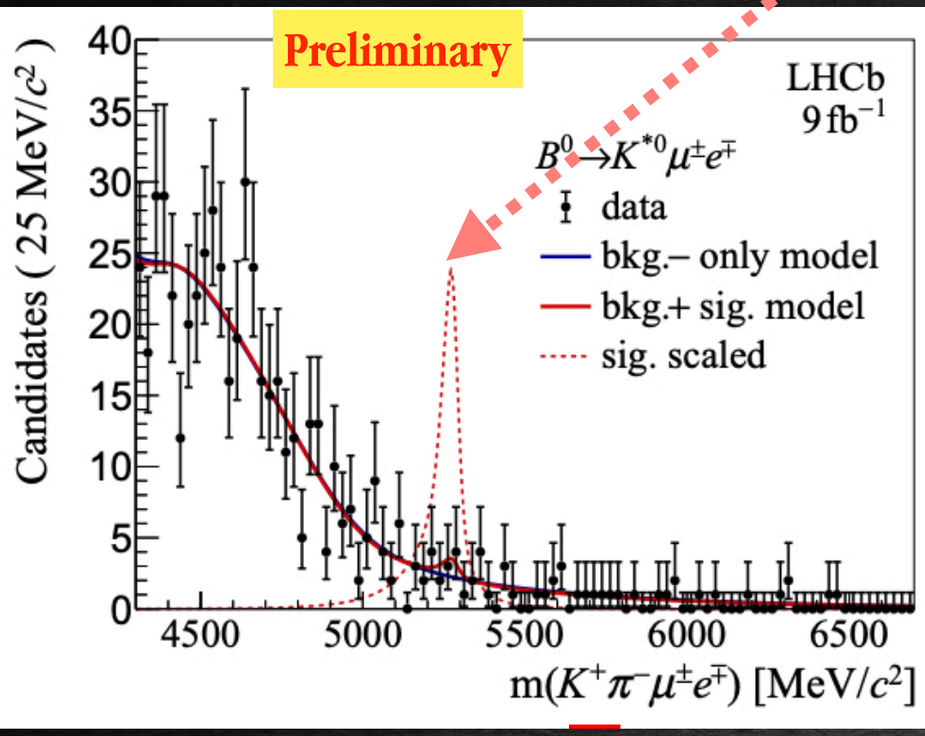


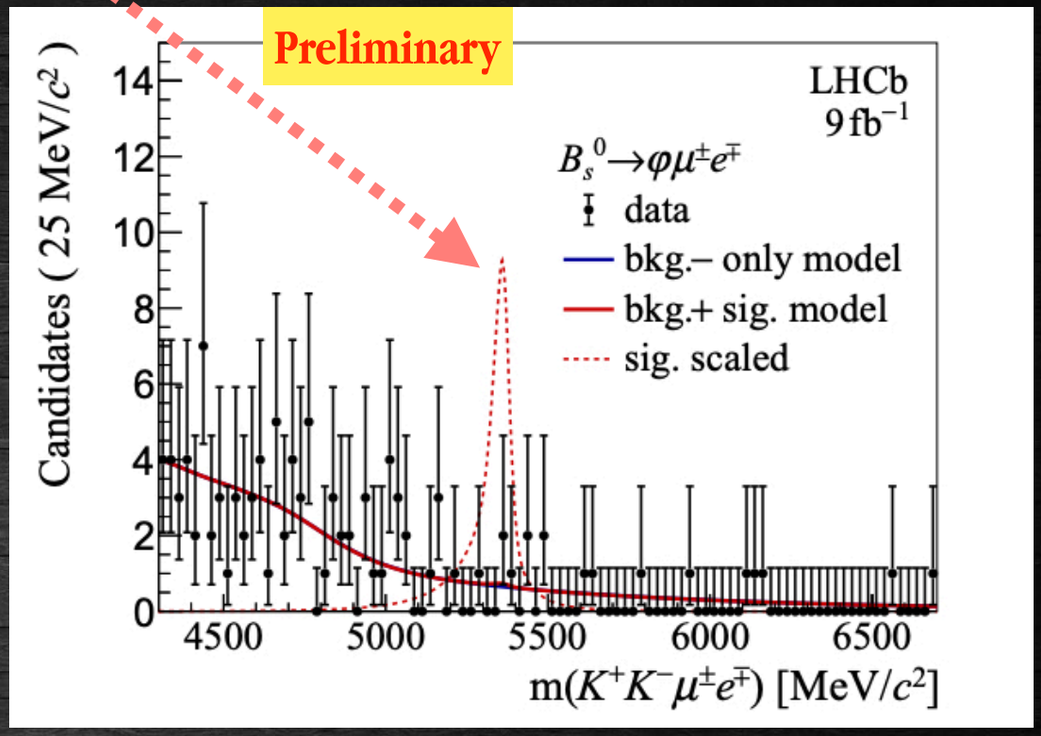
$B^0 \to K^{*0}\mu^{\pm}e^{\mp}$ and $B_s \to \phi\mu^{\pm}e^{\mp}$ [results]

NEW

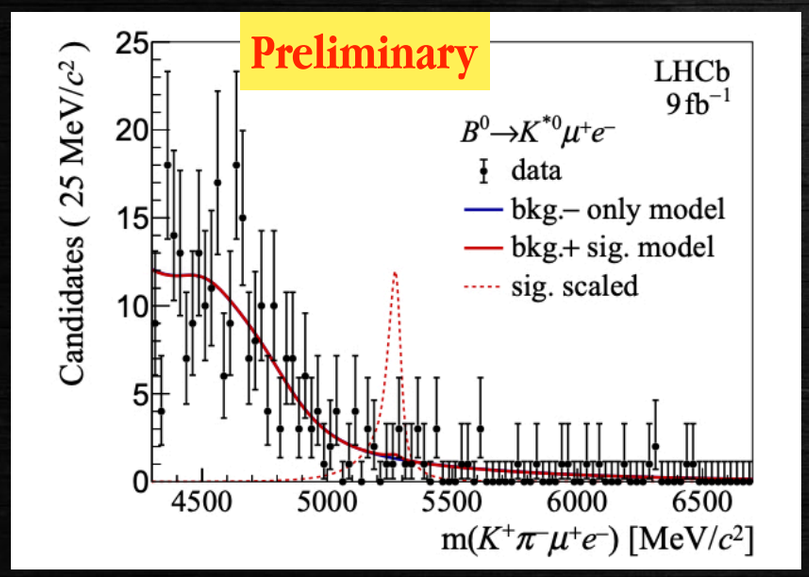
LHCb-PAPER-2022-008 [in prep]

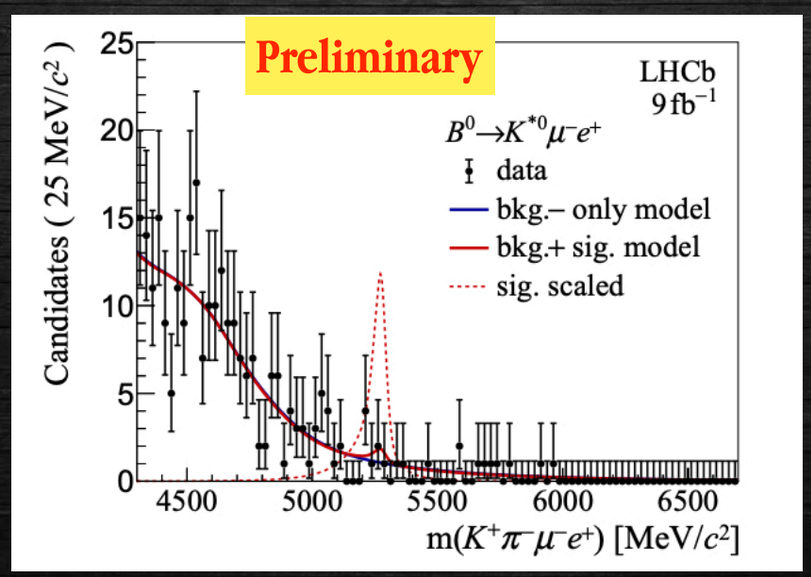
Signal arbitrarily scaled





Charge splitting for K^* mode





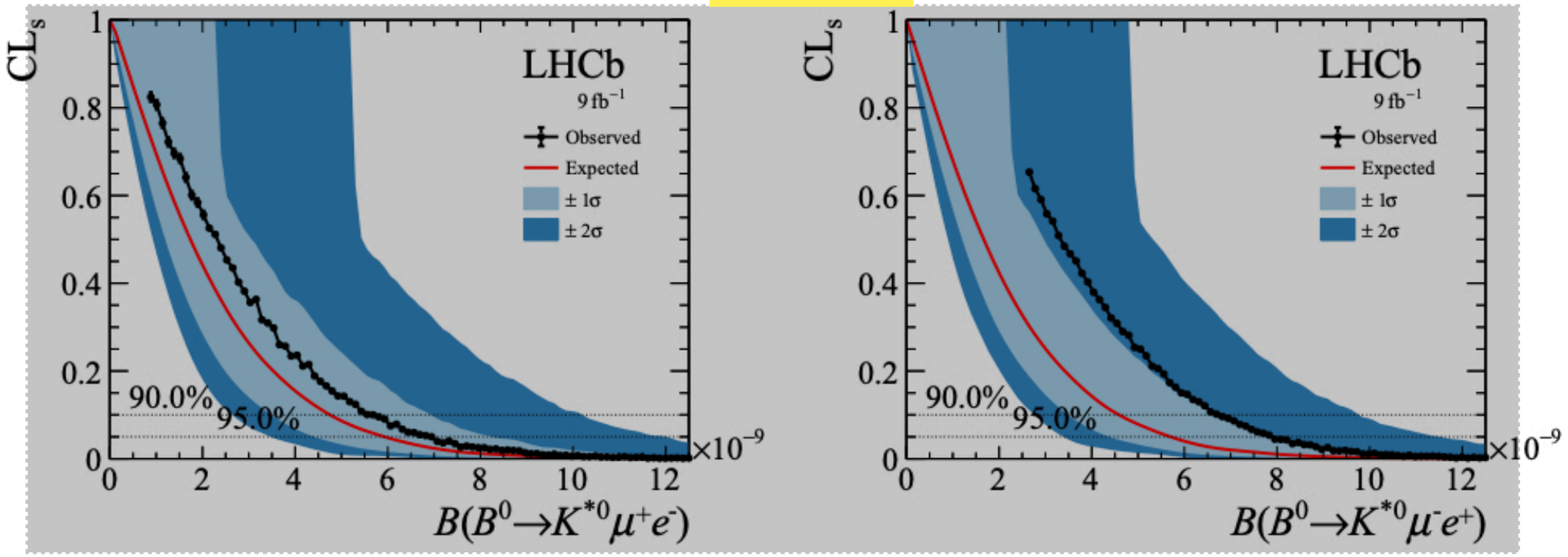
$B^0 \to K^{*0}\mu^{\pm}e^{\mp}$ and $B_s \to \phi\mu^{\pm}e^{\mp}$ [results]

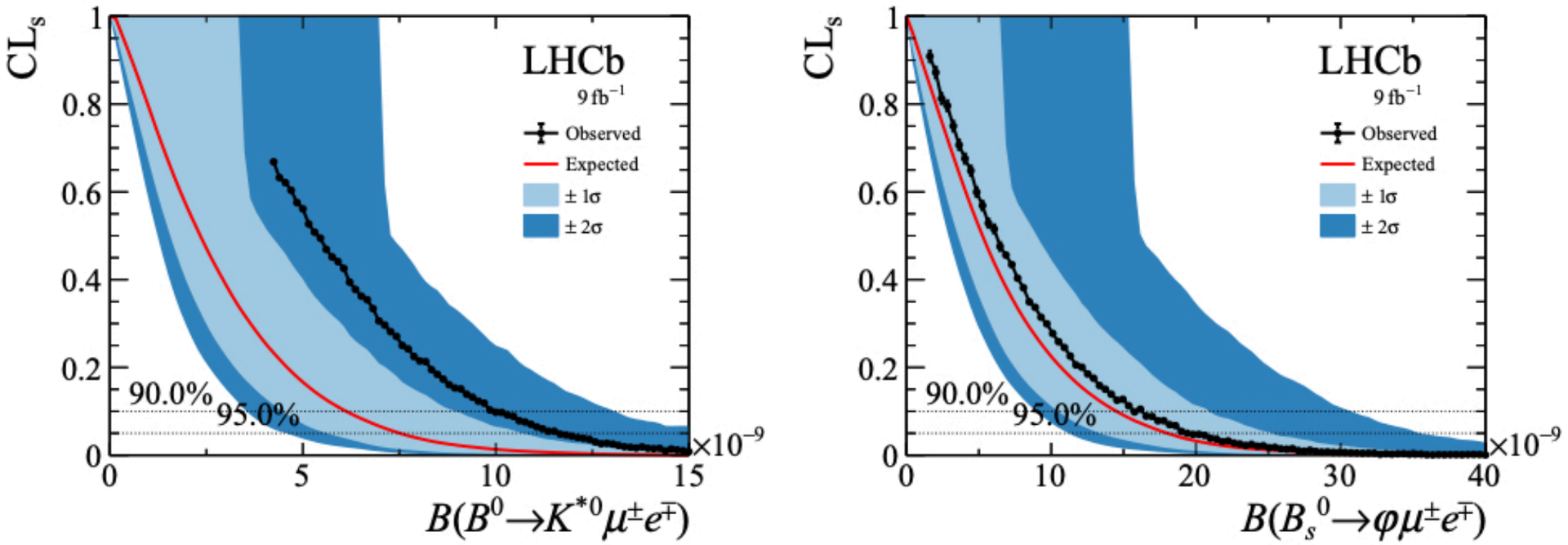
NEW

LHCb-PAPER-2022-008 [in prep]

Charge splitting for K^* mode

Preliminary





$B^0 \to K^{*0}\mu^{\pm}e^{\mp}$ and $B_s \to \phi\mu^{\pm}e^{\mp}$ [results]

NEW

LHCb-PAPER-2022-008 [in prep]

- Most stringent upper limits till date @ 90% (95%) CL

$$\mathcal{B}(B^0 \to K^{*0}\mu^+e^-) < 5.7 \times 10^{-9}\ (7.0 \times 10^{-9}),$$
$$\mathcal{B}(B^0 \to K^{*0}\mu^-e^+) < 6.7 \times 10^{-9}\ (7.9 \times 10^{-9}),$$
$$\mathcal{B}(B^0 \to K^{*0}\mu^{\pm}e^{\mp}) < 9.9 \times 10^{-9}\ (11.6 \times 10^{-9}),$$
$$\mathcal{B}(B_s^0 \to \phi\mu^{\pm}e^{\mp}) < 15.9 \times 10^{-9}\ (19.4 \times 10^{-9})$$

- $\sim$ One order of magnitude improvement w.r.t Belle results [PRD 98 (2018) 071101]

- World's first constraint of a semileptonic LFV B_s decay

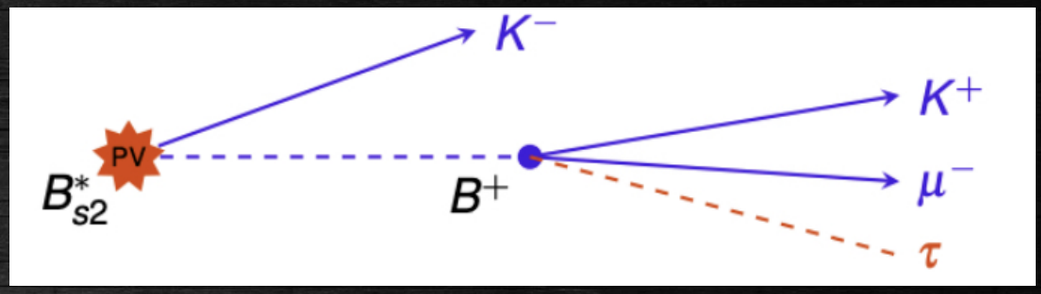
$B^+ \to K^+\mu^-\tau^+$

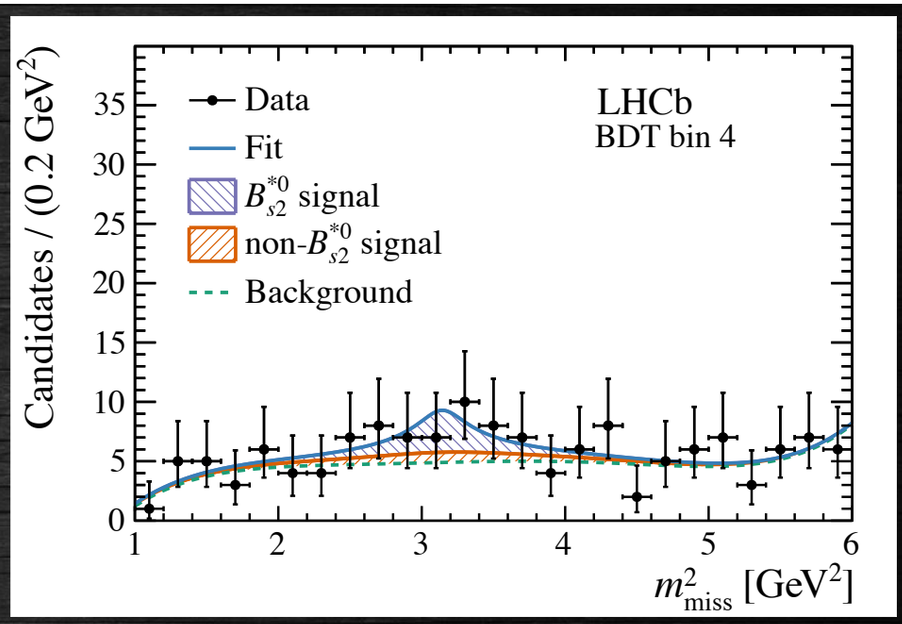
JHEP 06 (2020) 129

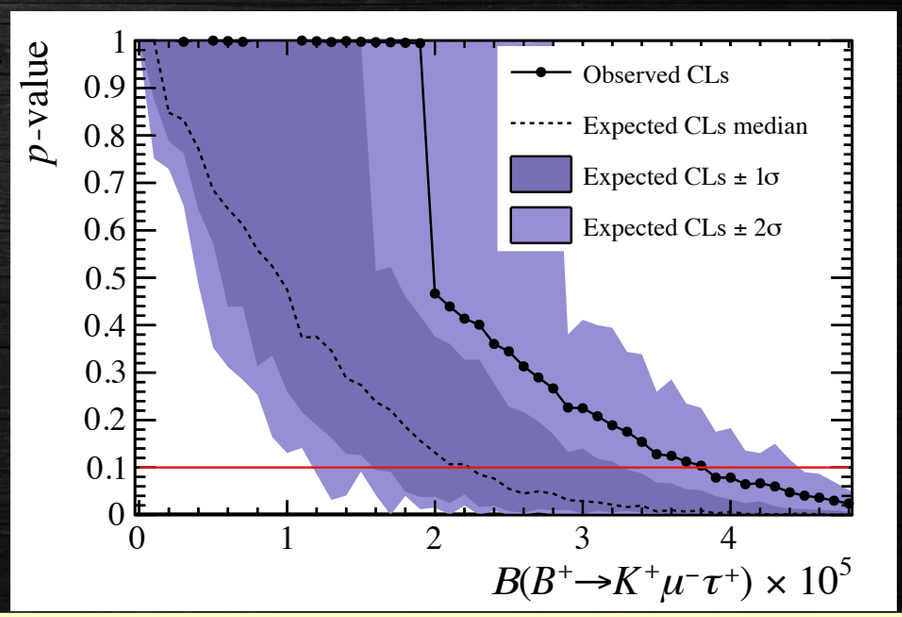
- Full LHCb dataset: 9 fb^{-1}
- Normalisation mode: $B^+ \to J/\psi(\to \mu^+\mu^-)K^+$
- τ indirectly reconstructed by using B^+ from prompt $B^*_{s2} \to B^+K^-$: $P_{miss} = P_B - P_{K\mu}$
- Combinatorial background suppression: BDT
- Final fit to m^2_{miss} in 4 BDT bins
- Upper Limits:

$$\mathcal{B}(B^+ \to K^+\mu^-\tau^+) < 3.9 \times 10^{-5} \text{ at } 90\% \text{ CL},$$
$$< 4.5 \times 10^{-5} \text{ at } 95\% \text{ CL}.$$

☞ Search for $B^+ \to K^+\mu^\mp\tau^\pm$ with 3-prong τ decay ongoing







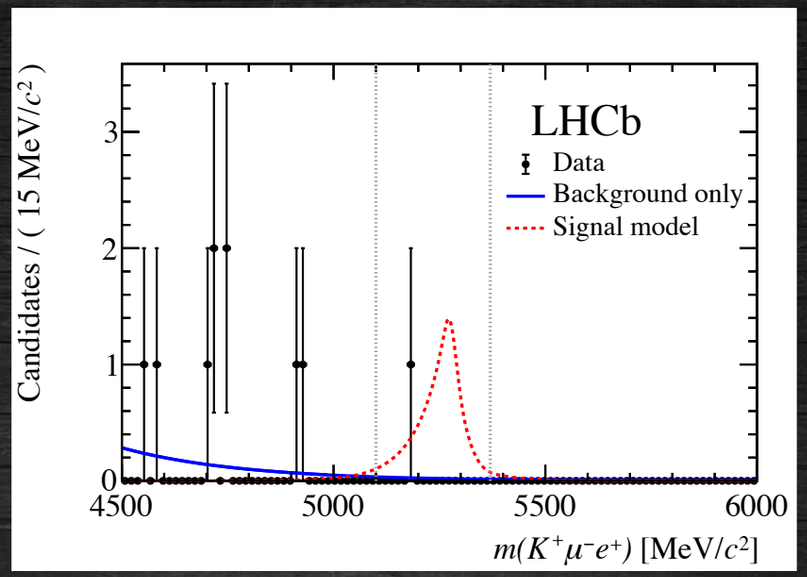
$B^+ \to K^+\mu^\pm e^\mp$

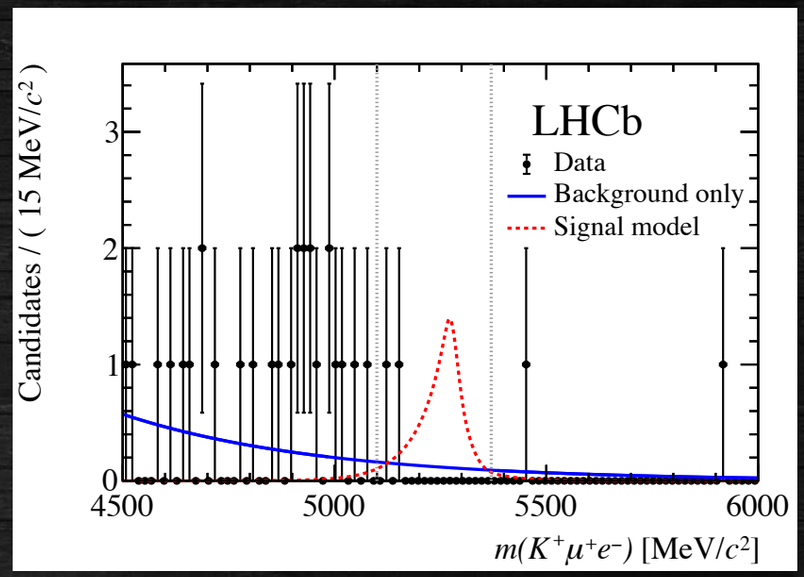
PRL 123 (2019) 241802

- Run 1 LHCb dataset: 3 fb^{-1}
- Normalisation mode:

  $B^+ \to J/\psi(\to \mu^+\mu^-)K^+$
- Control mode:

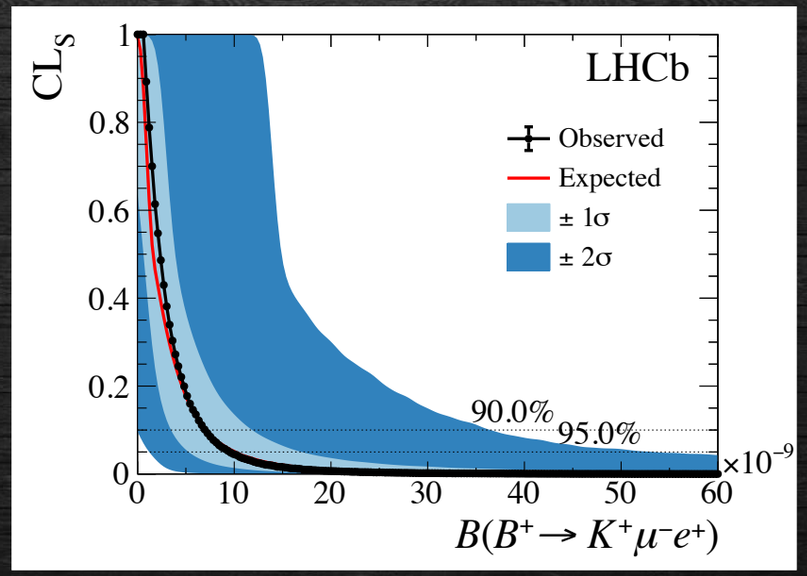
  $B^+ \to J/\psi(\to e^+e^-)K^+$

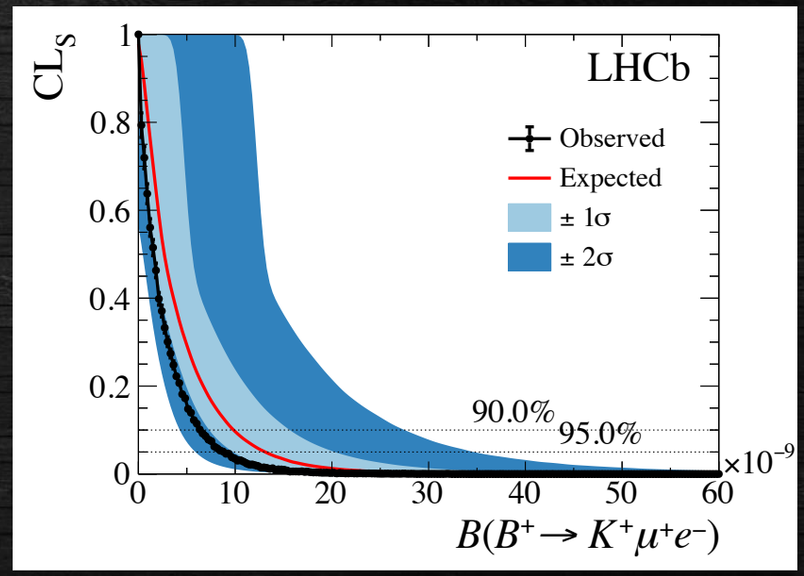




- Charge split Upper Limits

	90% C.L.	95% C.L.
$\mathcal{B}(B^+ \to K^+\mu^-e^+)/10^{-9}$	7.0	9.5
$\mathcal{B}(B^+ \to K^+\mu^+e^-)/10^{-9}$	6.4	8.8





- One order of magnitude improvement w.r.t previous world average

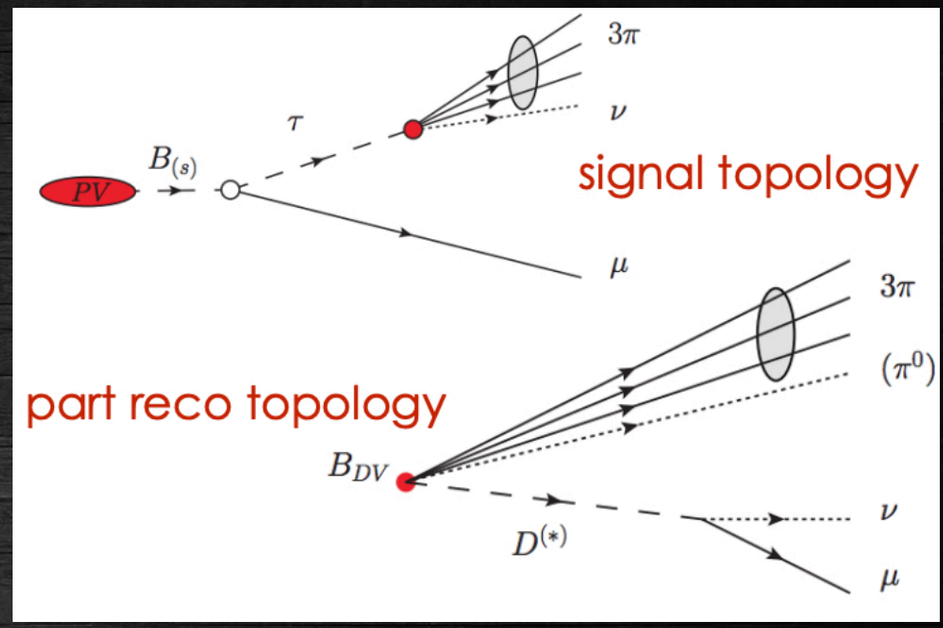
☞ Search with Run 2 data ongoing

$B^0_{(s)} \to \tau^{\pm}\mu^{\mp}$

PRL 123 (2019) 211801

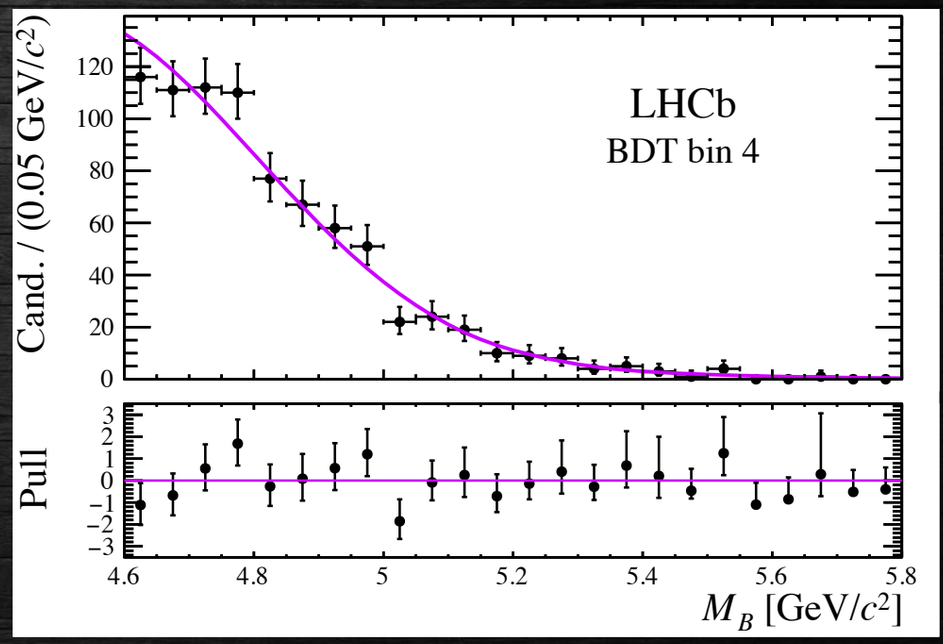
- Run 1 LHCb dataset: 3 fb^{-1}
- Normalisation mode: $B^0 \to D^-(\to K^-\pi^+\pi^-)\pi^+$
- τ reconstructed with 3-prong decays:

  $\tau \to \pi^+\pi^-\pi^+(\pi^0)\bar{\nu}_\tau$
- B mass from kinematical constraints
- BDT used for combinatorial background suppression



- background modelled with same sign $\tau\mu$ decays
- Decay time cut to reduce part. reco. backgrounds
- Simultaneous fit in bins of BDT and B mass
- Upper Limits:

Mode	Limit	90% CL	95% CL
$B^0_s \to \tau^{\pm}\mu^{\mp}$	Observed	3.4×10^{-5}	4.2×10^{-5}
	Expected	3.9×10^{-5}	4.7×10^{-5}
$B^0 \to \tau^{\pm}\mu^{\mp}$	Observed	1.2×10^{-5}	1.4×10^{-5}
	Expected	1.6×10^{-5}	1.9×10^{-5}



☞ First limit on $B^0_s \to \tau^{\pm}\mu^{\mp}$

Summary

- LFV is very interesting to probe for BSM, along with ongoing LFU tests.
- LHCb provides excellent environment for searching these kind of LFV decays.
- No evidence for LFV till date, the stringent limits are set on BFs.
- More analyses with full Run 1 and 2 data ongoing, more results to come soon.
- Looking forward to more data (in Run 3 and beyond) to be collected in coming years.

Decay modes	Data analysed	Upper Limit @ 90% CL	Upper Limit @ 95% CL
$B^0 \to K^{*0}\mu^{\pm}e^{\mp}$	9 fb^{-1}	9.9 x 10^{-9}	11.6 x 10^{-9}
$B_s \to \phi\mu^{\pm}e^{\mp}$	9 fb^{-1}	15.9 x 10^{-9}	19.4 x 10^{-9}
$B^+ \to K^+\mu^-\tau^+$	9 fb^{-1}	3.9 x 10^{-5}	4.5 x 10^{-5}
$B^+ \to K^+\mu^-e^+$	3 fb^{-1}	7.0 x 10^{-9}	9.5 x 10^{-9}
$B^+ \to K^+\mu^+e^-$	3 fb^{-1}	6.4 x 10^{-9}	8.8 x 10^{-9}
$B_s^0 \to \tau^{\pm}\mu^{\mp}$	3 fb^{-1}	3.4 x 10^{-5}	4.2 x 10^{-5}
$B^0 \to \tau^{\pm}\mu^{\mp}$	3 fb^{-1}	1.2 x 10^{-5}	1.4 x 10^{-5}
$B_s^0 \to e^{\pm}\mu^{\mp}$	3 fb^{-1}	5.4 x 10^{-9}	6.3 x 10^{-9}
$B^0 \to e^{\pm}\mu^{\mp}$	3 fb^{-1}	1.0 x 10^{-9}	1.3 x 10^{-9}
$\tau^- \to \mu^-\mu^+\mu^-$	3 fb^{-1}	4.6 x 10^{-8}	5.6 x 10^{-8}

Back Up Slides

$B^0_{(s)} \to e^{\pm}\mu^{\mp}$

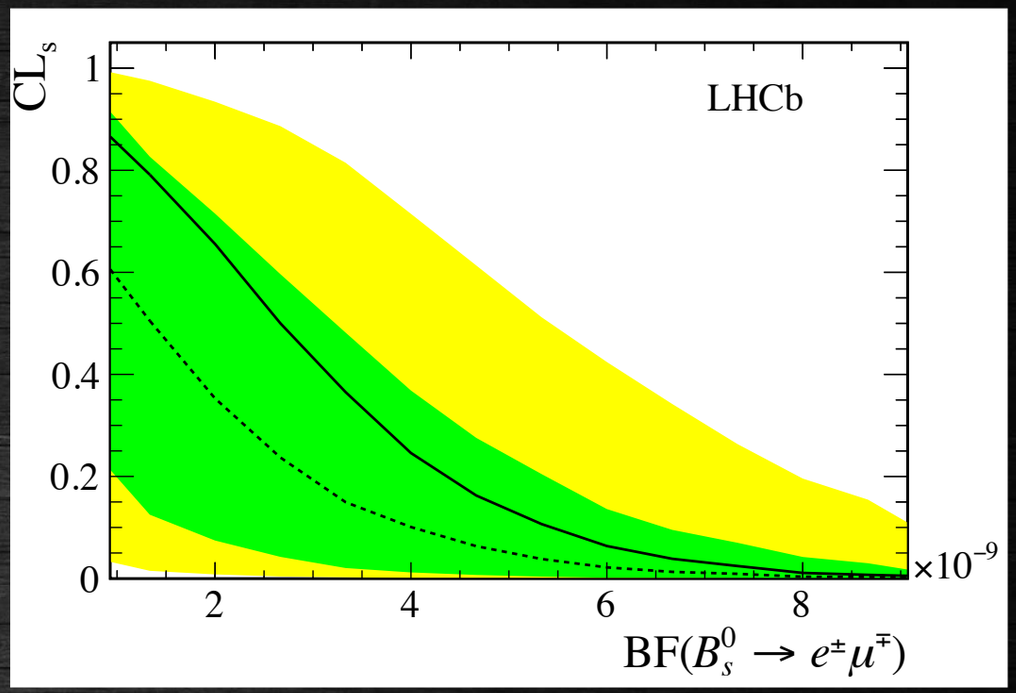
JHEP 03 (2018) 078

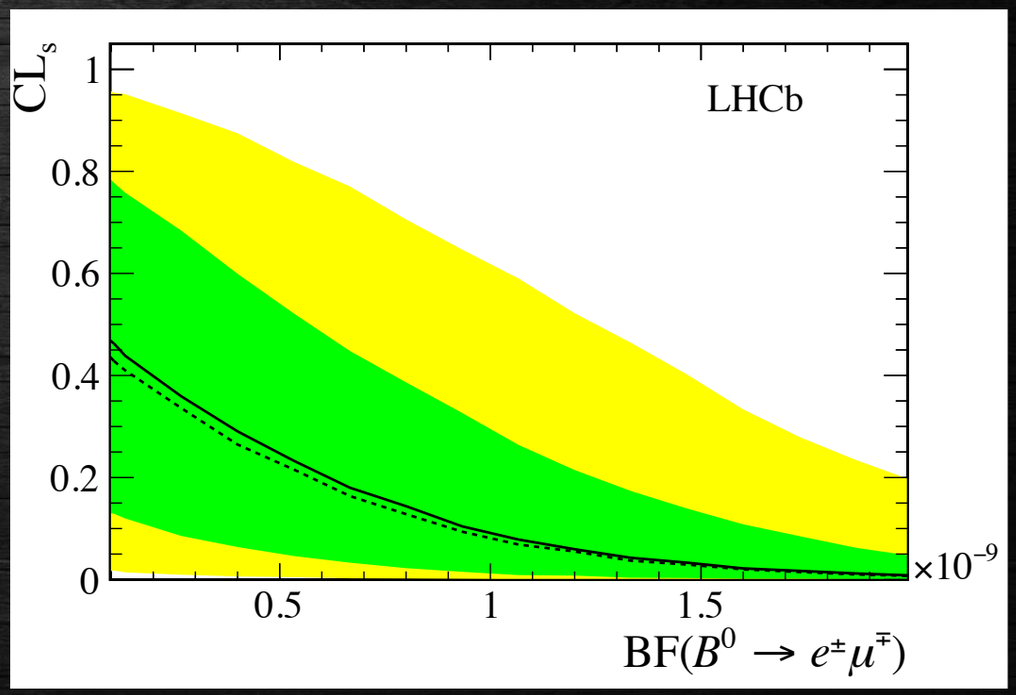
- Run 1 LHCb dataset: 3 fb^{-1}
- Normalisation modes:

  $B^0 \to K^+\pi^-$, $B^+ \to J/\psi(\to \mu^+\mu^-)K^+$
- BDT used for combinatorial background suppression
- Simultaneous fit in bins of BDT and B mass
- Upper Limits:

channel	expected	observed
$\mathcal{B}(B^0_s \to e^{\pm}\mu^{\mp})$	$5.0\,(3.9) \times 10^{-9}$	$6.3\,(5.4) \times 10^{-9}$
$\mathcal{B}(B^0 \to e^{\pm}\mu^{\mp})$	$1.2\,(0.9) \times 10^{-9}$	$1.3\,(1.0) \times 10^{-9}$

- All results are most stringent to date





$\tau^- \to \mu^-\mu^+\mu^-$

JHEP 02 (2015) 121

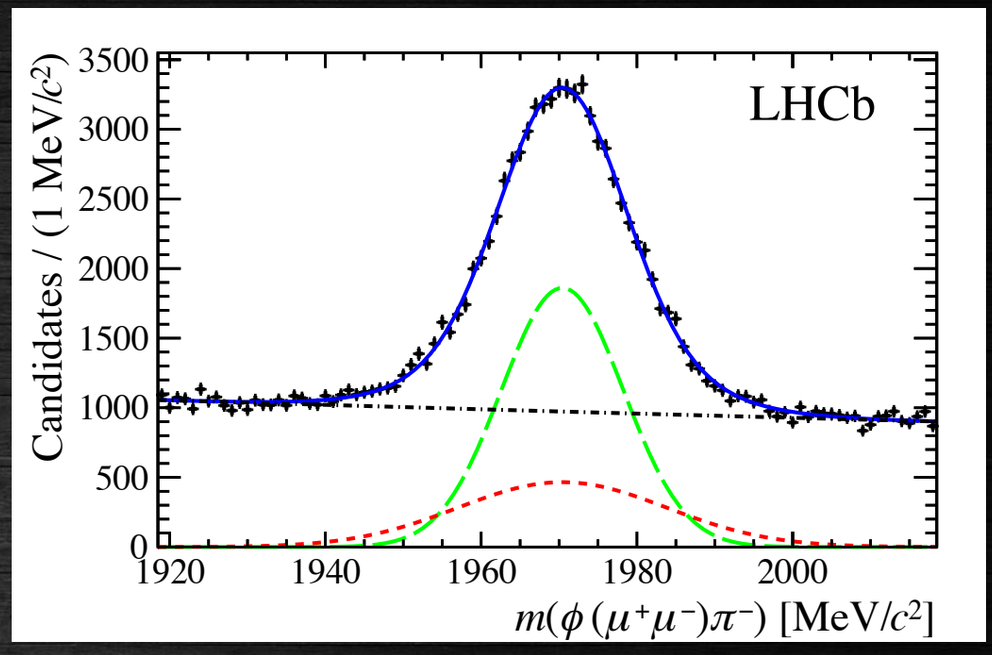
- Run 1 LHCb dataset: 3 fb^{-1}
- Normalisation modes:

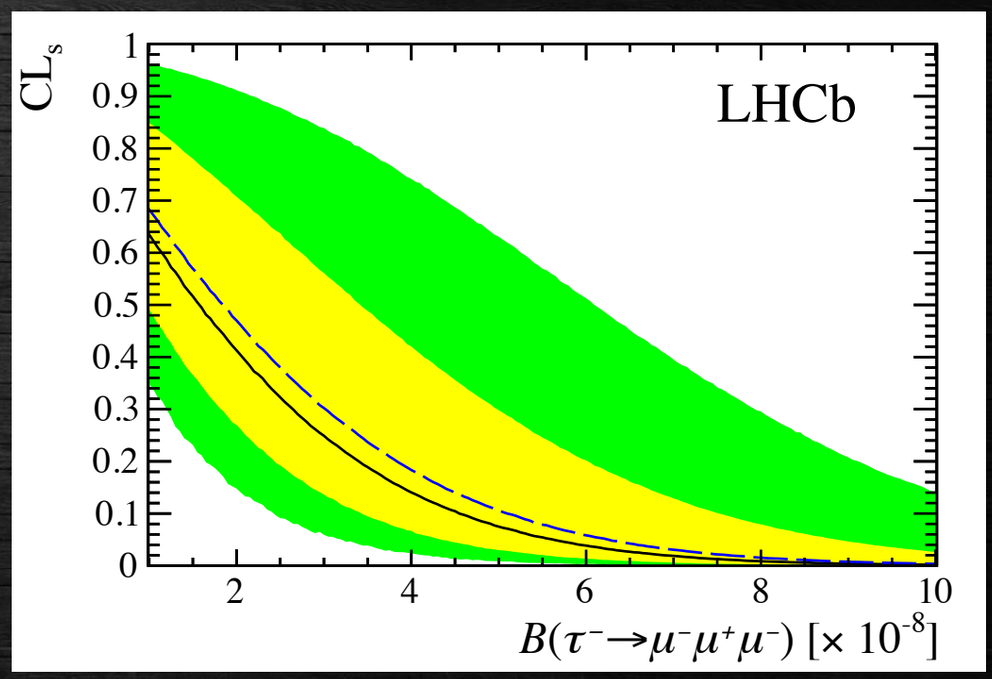
  $D_s^+ \to \phi(\to \mu^+\mu^-)\pi^+$
- Two multivariate classifiers used for:

  - combinatorial background rejection

  - mis-identified decays
- Unbinned maximum likelihood fit in τ invariant mass
- Upper Limits @ 90% (95%) CL:

$$\mathcal{B}\left(\tau^- \to \mu^-\mu^+\mu^-\right) < 4.6\ (5.6) \times 10^{-8}.$$





- Result is competitive with the best limit sets by Belle and CMS [PLB 687 (2010) 139-143, JHEP 01 (2021) 163]