



cLFV searches at LHCb

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on behalf of LHCb Collaboration



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- The LHCb experiment
- Motivation for search for cLFV
- The search for $B_{(s)}^0 \rightarrow e^\pm \mu^\mp$ decays
- The search for $D^0 \rightarrow e^\pm \mu^\mp$ decays
- The search for $\tau^+ \rightarrow \mu^+ \mu^- \mu^+$ decay
- Other analyses
- Summary

The LHCb experiment

- Single-arm spectrometer covering the forward $2 < \eta < 5$ region
- Dedicated to heavy flavour physics
- Looks for indirect evidence of new physics in CP violation and rare decays

Momentum resolution:

$$\delta p/p = 0.4 \% \text{ at } 5 \text{ GeV to } 0.6 \% \text{ at } 100 \text{ GeV}$$

Impact parameter resolution:

$$\sigma_{\text{IP}} \sim 20 \mu\text{m}$$

(high momentum particles)

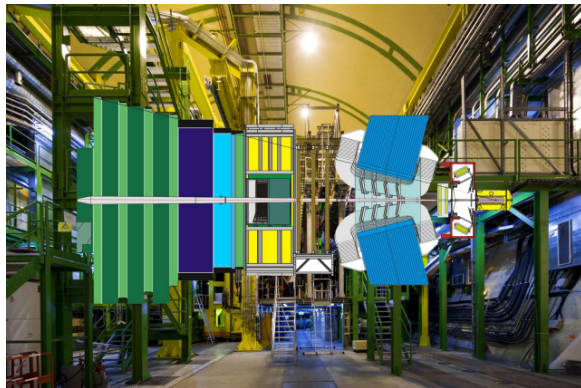
Primary vertex resolution:

$13 \mu\text{m}$ in x and y , and $71 \mu\text{m}$ in z

Decay time resolution:

$$\sigma_{\tau} \sim 50 \text{ fs}$$

Excellent particle identification



Int.J.Mod.Phys.A30,1530022(2015),
JINST3(2008)S08005

Hints on lepton flavour non-universality:

PRL 113 (2014) 151601

$$R_K = \frac{\mathcal{B}(B^+ \rightarrow K^+ \mu\mu)}{\mathcal{B}(B^+ \rightarrow K^+ ee)} = 0.745_{-0.074}^{+0.090}(\text{stat}) \pm 0.036(\text{syst}) \quad 1.0 < q^2 < 6.0 \text{ GeV}^2/c^4$$

JHEP 08 (2017) 055

$$R_{K^{*0}} = \frac{\mathcal{B}(B^0 \rightarrow K^{*0} \mu\mu)}{\mathcal{B}(B^0 \rightarrow K^{*0} ee)} = \begin{cases} 0.66_{-0.07}^{+0.11}(\text{stat}) \pm 0.03(\text{syst}) & 0.045 < q^2 < 1.1 \text{ GeV}^2/c^4 \\ 0.069_{-0.07}^{+0.11}(\text{stat}) \pm 0.05(\text{syst}) & 1.1 < q^2 < 6.0 \text{ GeV}^2/c^4 \end{cases}$$

PRL 115, 111803 (2015)

$$R_{D^*} = \frac{\mathcal{B}(\bar{B}^0 \rightarrow D^{*+} \tau^- \nu_\tau)}{\mathcal{B}(\bar{B}^0 \rightarrow D^{*+} \mu^- \nu_\mu)} = 0.336 \pm 0.027(\text{stat}) \pm 0.030(\text{syst})$$

$$R_K^{\text{exp}} < R_K^{\text{SM}}$$

$$R_{K^*}^{\text{exp}} < R_{K^*}^{\text{SM}}$$

$$R_{D^*}^{\text{exp}} > R_{D^*}^{\text{SM}}$$

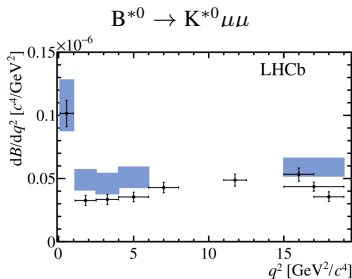
LUV in the lepton flavour conserving decay channels may imply the existence of a charged lepton flavour violation.

Motivation for search for cLFV

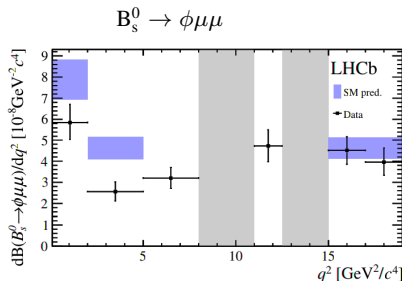
Anomalies in $b \rightarrow sll$ transitions:

→ measurements go to the same direction!

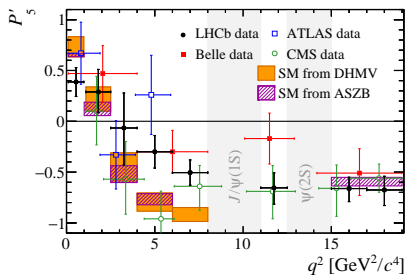
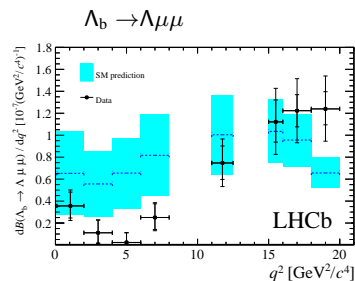
JHEP04(2017)142



JHEP09(2015)179



JHEP06(2015)115



$B^{*0} \rightarrow K^{*0} \mu\mu$

JHEP02(2016)104

PhysRevLett.118.111801

arXiv:hep-ex/1710.02846

ATLAS-CONF-2017-023

Observation of the lepton flavour violating decay would be a clear sign of new physics.

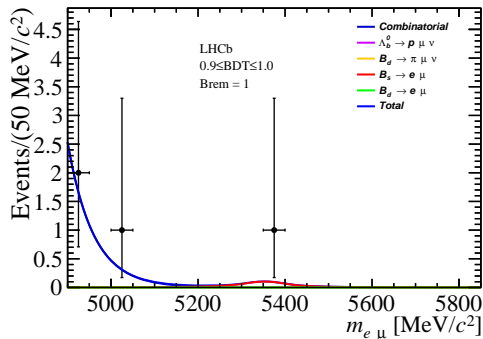
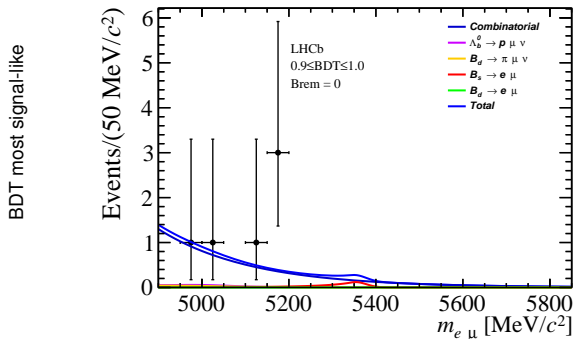
Decays searched: $B^0 \rightarrow e^\pm \mu^\mp$, $B_s \rightarrow e^\pm \mu^\mp$

Dataset: full Run1

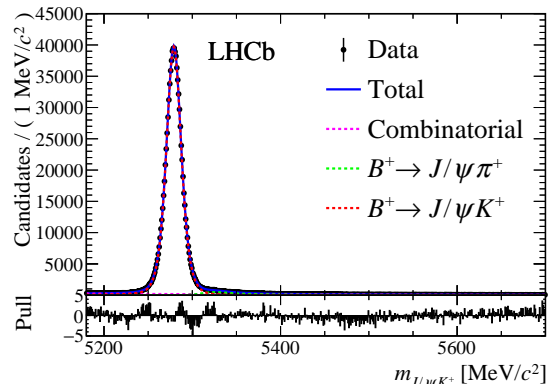
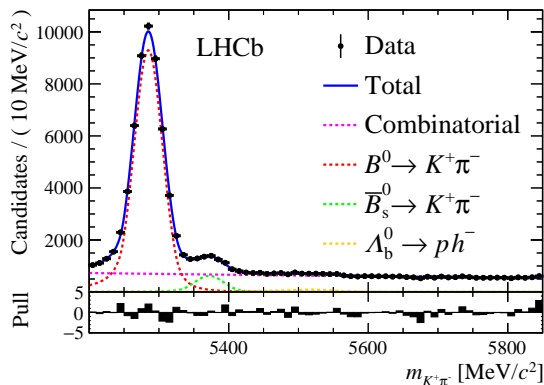
Normalisation channels: $B^+ \rightarrow K^+ J/\psi (\rightarrow \mu^+ \mu^-)$ and $B^0 \rightarrow K^+ \pi^-$

Background sources: misidentification of $B^0 \rightarrow h^+ h'^-$ decays, partially reconstructed decays with misidentified particles

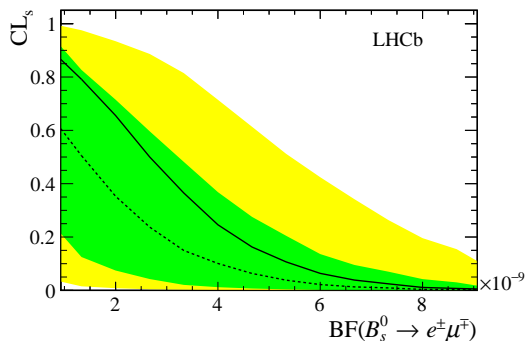
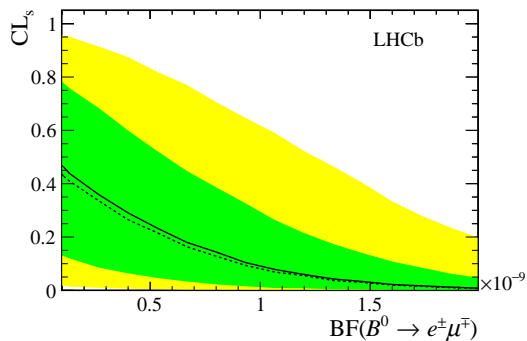
Fit to invariant mass: performed, in two bremsstrahlung categories in BDT bins, showed no excess



Fits to normalisation channels:



Results:



$$\mathcal{B}(B^0 \rightarrow e^\pm \mu^\mp) < 1.0 \text{ (1.3)} \times 10^{-9}$$

$$\mathcal{B}(B_s^0 \rightarrow e^\pm \mu^\mp) < 5.4 \text{ (6.3)} \times 10^{-9}$$

at 90% (95%) CL

The search for $D^0 \rightarrow e^\pm \mu^\mp$ decays

PLB754(2016)167

Decay searched: tagged $D^{*+} \rightarrow D^0(\rightarrow e^\pm \mu^\mp) \pi^+$

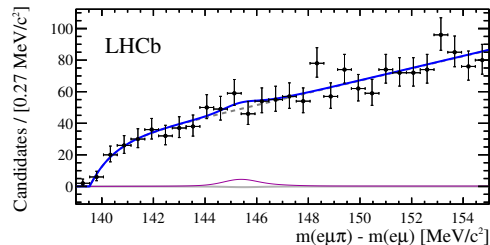
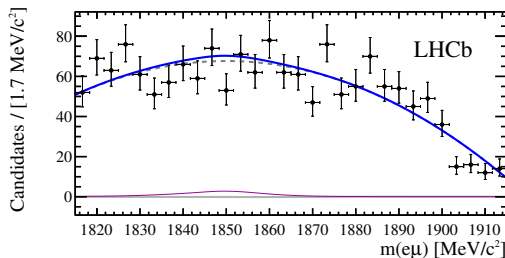
Dataset: full Run1

Normalisation channel: $D^0 \rightarrow K^\pm \pi^\mp$

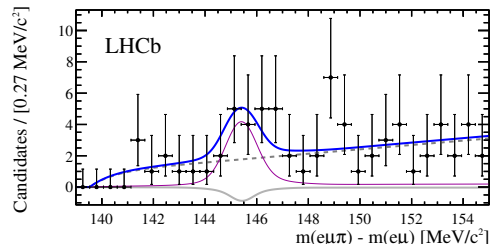
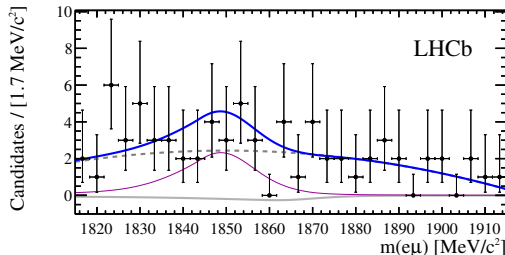
Background sources: from misidentified $D^0 \rightarrow \pi^+ \pi^-$, $D^0 \rightarrow K^- \pi^+$, semileptonic D^0

Fit to invariant mass: in two variables, in BDT bins, showed no excess

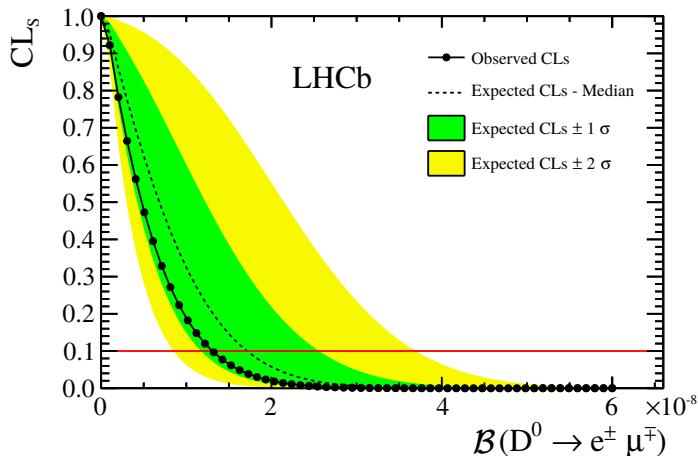
BDT most background-like



BDT most signal-like



Results:



$$\mathcal{B}(D^0 \rightarrow e\mu) < 1.3 \times 10^{-8}$$

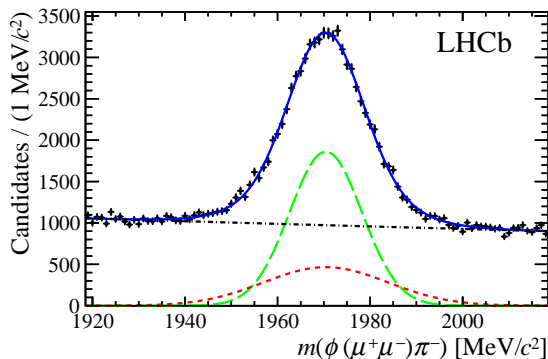
Decay searched: $\tau^- \rightarrow \mu^+ \mu^- \mu^-$

Dataset: full Run1

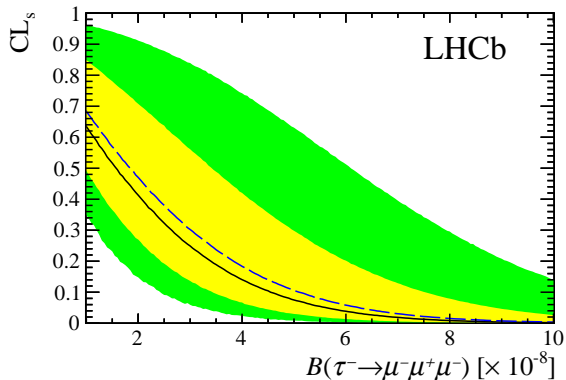
Normalisation channel: $D_s^- \rightarrow \phi(\rightarrow \mu^- \mu^+) \pi^-$

Background sources: decays with three muons of total charge ± 1 (such as $D_s^+ \rightarrow \eta(\rightarrow \mu^+ \mu^- \gamma) \mu^+ \nu_\mu$), misidentified decays ($D^+ \rightarrow K^- \pi^+ \pi^-$, $D^{*+} \rightarrow D^0(\rightarrow K^- \pi^+ \pi^0) \pi^+$)

Fit to invariant mass: showed no excess



Results:



$$\mathcal{B}(\tau^- \rightarrow \mu^+ \mu^- \mu^+) < 4.6 \text{ (5.6)} \times 10^{-8} \text{ at 90\% (95\%) CL}$$

$$B_s \rightarrow \tau\mu \text{ and } B^0 \rightarrow \tau\mu$$

It is the first search in the B_s channel.

Predictions:

$$\mathcal{B}(B_s \rightarrow \tau\mu) \sim 10^{-9} \quad \text{arXiv:hep-ph/9806359}$$

$$\mathcal{B}(B_s \rightarrow \tau\mu) \sim 10^{-7} \quad \text{arXiv:hep-ph/1504.07928}$$

$$\mathcal{B}(B_s \rightarrow \tau\mu) \sim 10^{-6} \quad \text{arXiv:hep-ph/1211.5168}$$

The experimental upper limit for the B^0 channel set by the *BaBar* collaboration:

$$\mathcal{B}(B^0 \rightarrow \tau\mu) < 2.2 \times 10^{-5} \text{ at 90 \% CL}$$

Phys.Rev.D77:091104,2008

$B \rightarrow Ke\mu$

The experimental upper limits set by the *BaBar* collaboration:

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

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

Phys.Rev.D73:092001,2006

Predictions:

$$\mathcal{B}(B^+ \rightarrow K^+ e^+ \mu^-) \in [4.2, 6.2] \times 10^{-10}$$

PL B750 (2015) 367

$$\mathcal{B}(B^+ \rightarrow K^+ e^+ \mu^-) \sim 3 \times 10^{-8} \left(\frac{1-R_K}{0.23} \right)^2$$


with $R_K = 0.745$ gives:

$$\mathcal{B}(B^+ \rightarrow K^+ e^+ \mu^-) \sim 3.7 \times 10^{-8}$$

arXiv:hep-ph/1609.08895

Possible lepton flavour violation searches in Λ_b decays.

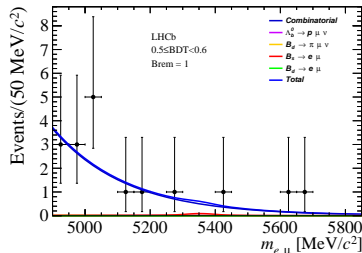
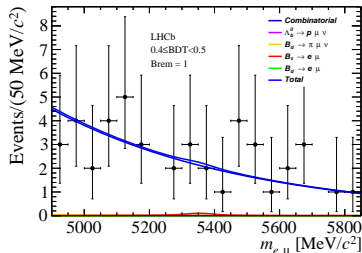
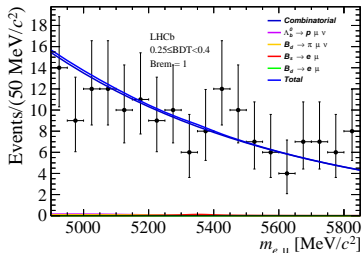
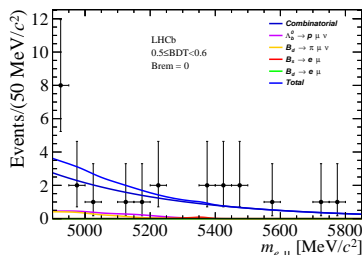
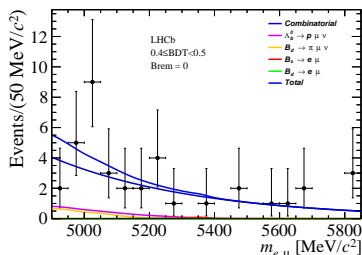
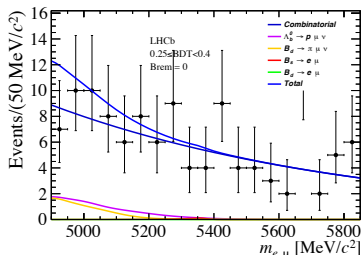
- No observation of the lepton flavour violation in the charged lepton sector
- Any evidence would point directly to new physics
- Many other cLFV searches ongoing in LHCb, some will be out soon

The background of the slide is a complex visualization of particle detector data, likely from the LHCb experiment. It features a central point from which numerous tracks radiate outwards, forming a starburst pattern. The tracks are composed of small, semi-transparent grey dots, and some are connected by thin lines. The overall appearance is that of a high-energy particle collision event being reconstructed. A semi-transparent blue horizontal bar is overlaid across the center of the image, containing the text 'Thank you for your attention :)'.

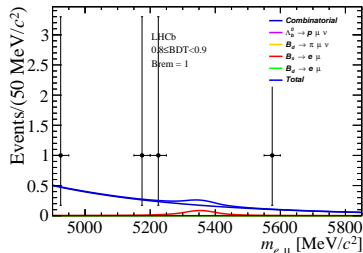
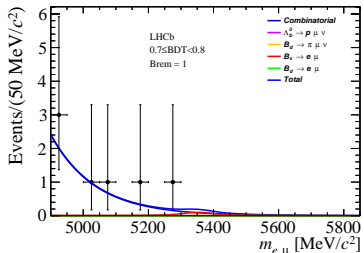
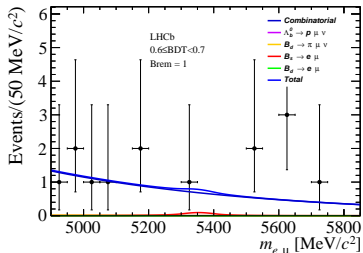
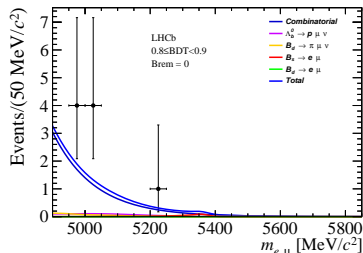
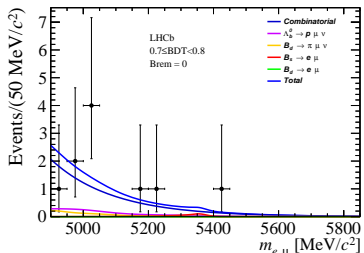
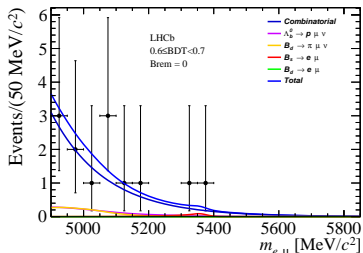
Thank you for your attention :)

Backup

$B_{(s)}^0 \rightarrow e^\pm \mu^\mp$ - fits in all BDT bins



$B_{(s)}^0 \rightarrow e^\pm \mu^\mp$ - fits in all BDT bins



$D^0 \rightarrow e^\pm \mu^\mp$ - fits in all BDT bins

