Measurement of $B \to \ell^+\ell^-$ decays at LHCb

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on behalf of the LHCb collaboration

‘Impact of B →μμ on New Physics Searches’ Workshop,
PSI, 18-19 December 2017

Outline

- Measurement of $B^0_{(s)} \to \mu^+\mu^-$ BF and effective lifetime [PRL 118, 191801 (2017)]
- Search for $B^0_{(s)} \to \tau^+\tau^-$ [PRL 118, 251802 (2017)]
- Search for $B^0_{(s)} \to e^\pm\mu^\mp$ [LHCb-PAPER-2017-031]

$B^0_{(s)} \to \mu^+\mu^-$ @ LHC before 2017

- CMS-LHCb combined analysis with Run 1 data
  - Observation of $B^0_s \to \mu\mu$

    $BF(B^0_s \to \mu^+\mu^-) = 2.8^{+0.7}_{-0.6} \times 10^{-9}$

    6.2σ significance observed

    compatible with SM @ 1.2σ
  - Evidence of $B^0 \to \mu\mu$

    $BF(B^0 \to \mu^+\mu^-) = 3.9^{+1.6}_{-1.4} \times 10^{-10}$

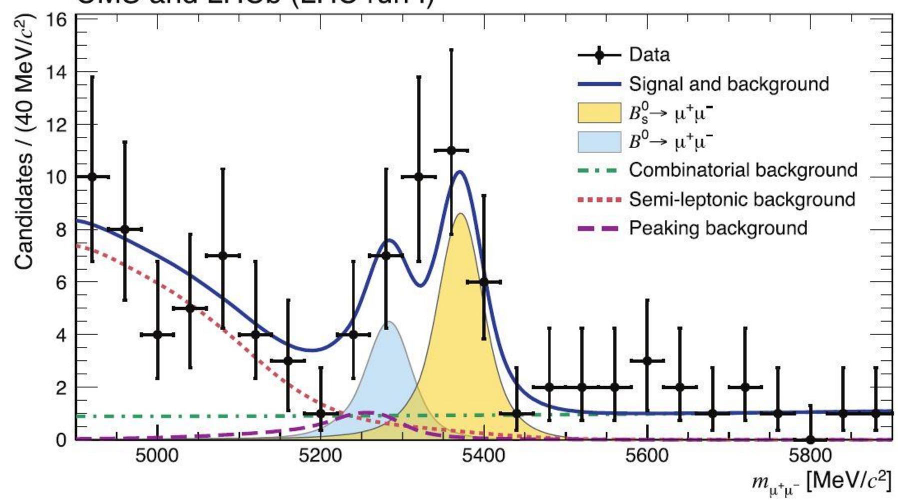
    3.0σ significance observed

    compatible with SM @ 2.2σ
- ATLAS with Run 1 data

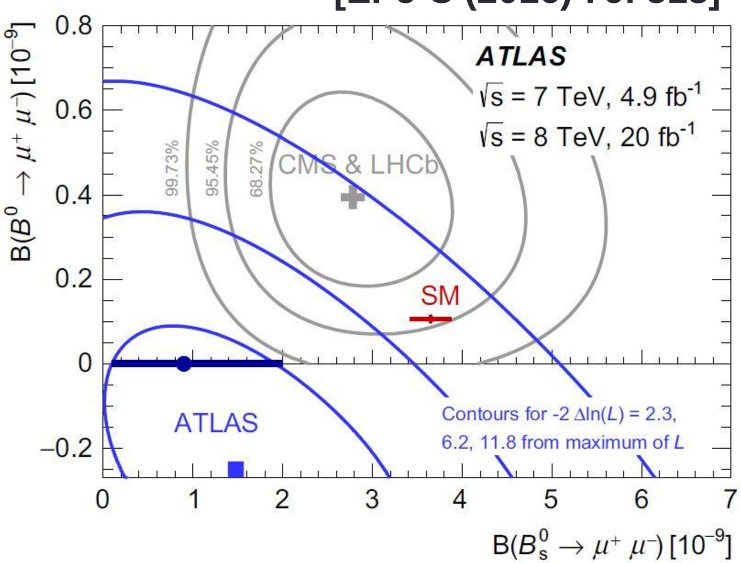
  $BF(B^0_s \to \mu^+\mu^-) = 0.9^{+1.1}_{-0.8} \times 10^{-9}$

  $BF(B^0 \to \mu^+\mu^-) = 4.2 \times 10^{-10}$ @95 CL

[Nature 522, 68]



[EPJ C (2016) 76: 513]



New LHCb BF measurement in 2017

Analysis procedure similar to that of previous round but with some significant improvements

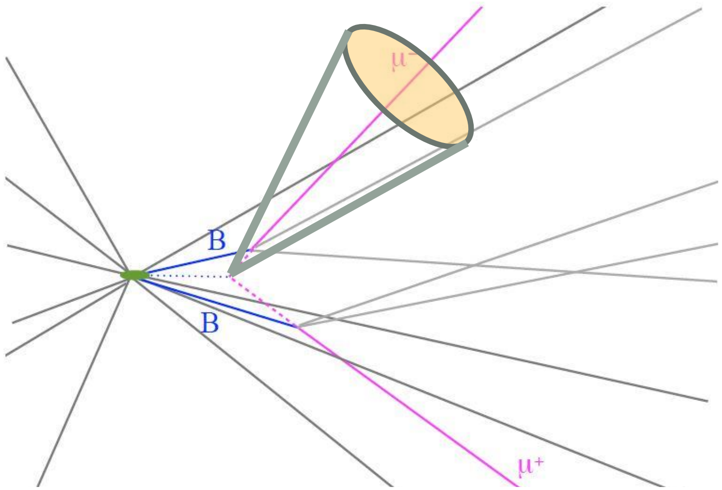
Analysis strategy:

- Pairs of opposite-charge muons selected with $m_{\mu\mu} \in [4900{,}6000] MeV/c^2$
- After pre-selection, the sample is split in bins of a Boosted Decision Tree (BDT) output. BDT based on kinematic and geometrical variables. Signal BDT shape calibrated on data with $B_s^0 \to h^+ h'^-$ decays.
- BFs extracted from fit to $m_{\mu\mu}$ in bins of BDT, using $B^+ \to J/\psi K^+$ and $B^0 \to K^+\pi^-$ as normalisation channels.

Main analysis improvements:

- New isolation variables, also exploiting ‘VELO’ tracks in addition to ‘long’ tracks. Much better BDT performance in rejecting the comb. background
- Tighter PID selection to reject ‘exclusive backgrounds’ (optimized for B^0)
- Improved estimate of exclusive background yields

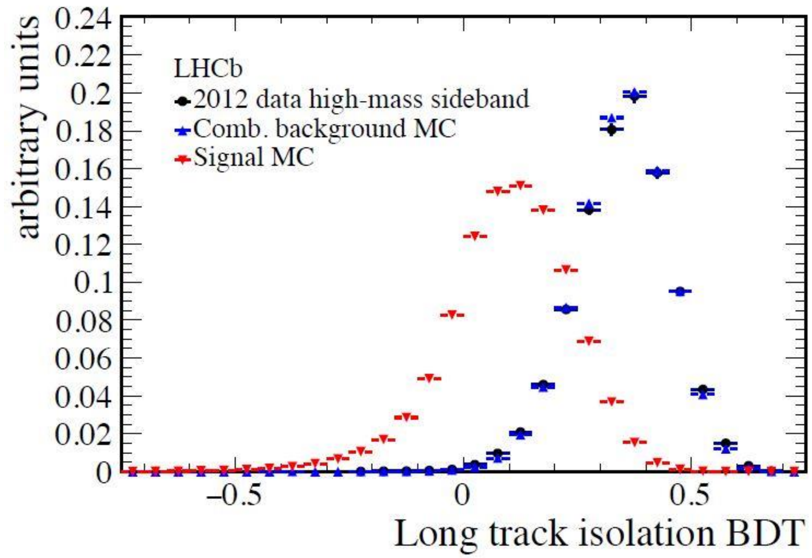
New track isolation

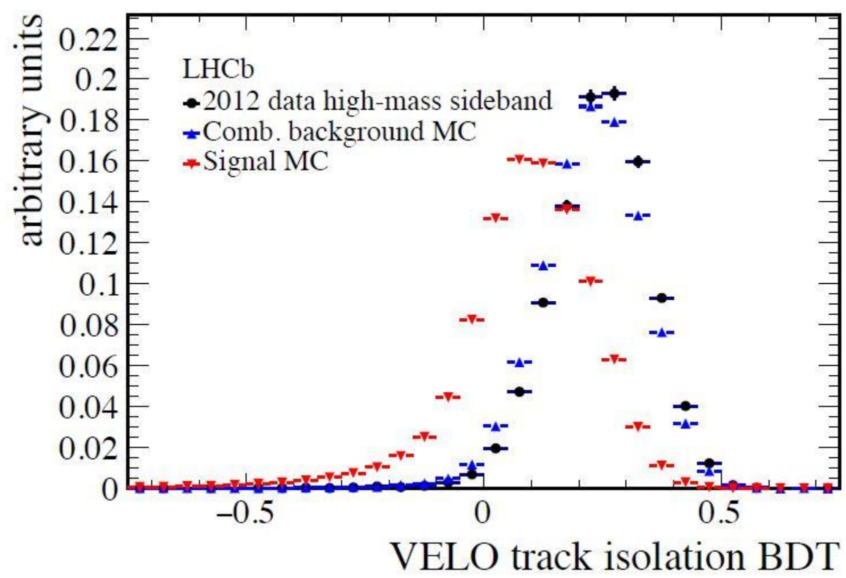


typical combinatorial background event with two muons from different b decays

- Previous muon isolation based on rectangular cuts on variables related to the neighbour tracks information
- Two multivariate classifiers used now, one based on “long tracks”[1], the other with tracks reconstructed only in the VELO detector

[1] tracks passing through all tracking stations

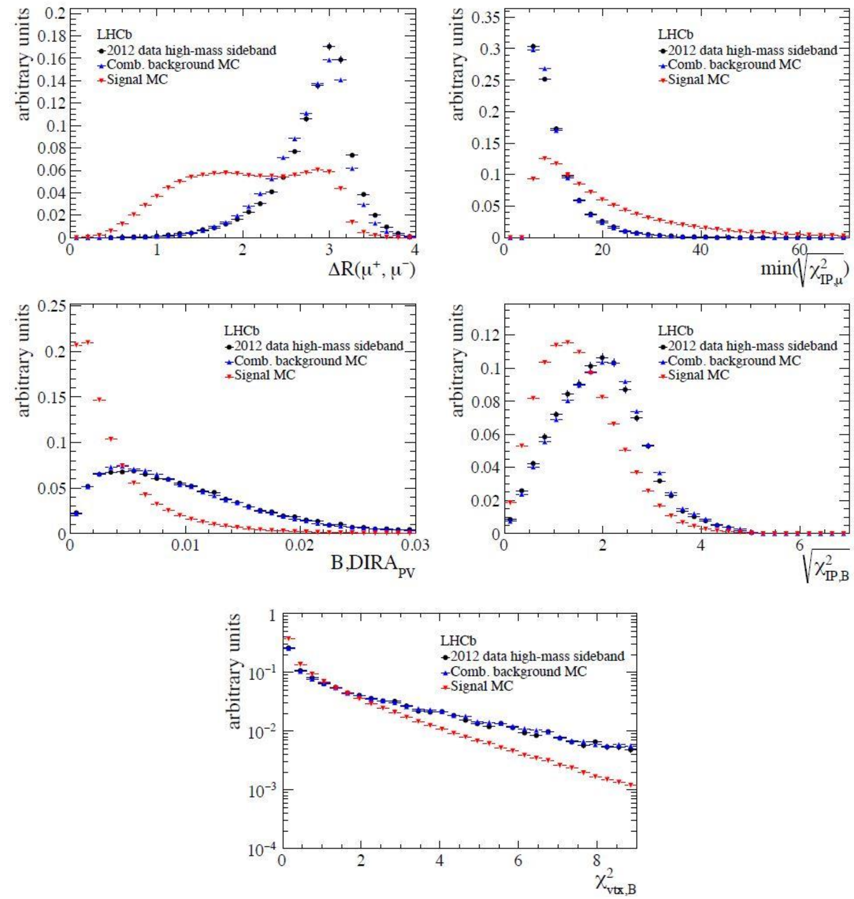


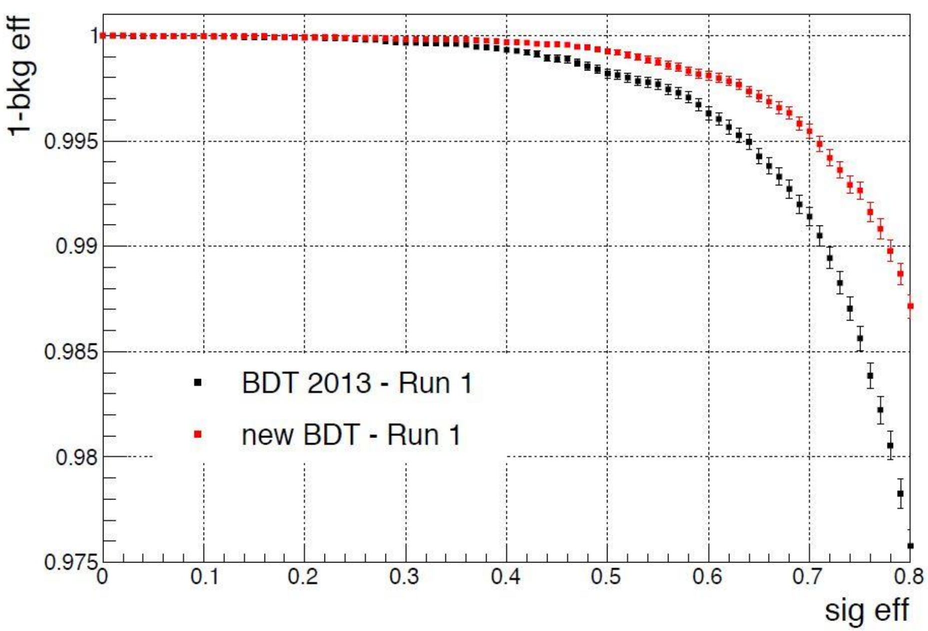


Multivariate classifier (BDT)

- Long track isolation used as starting point to build the global BDT classifier
- Optimisation and training on MC
- Correlation with $m_{\mu\mu}$ below 5%
- Compared to prev analysis: -50% comb background with same signal efficiency

7 input variables: 2 track isolations + the 5 quantities shown below

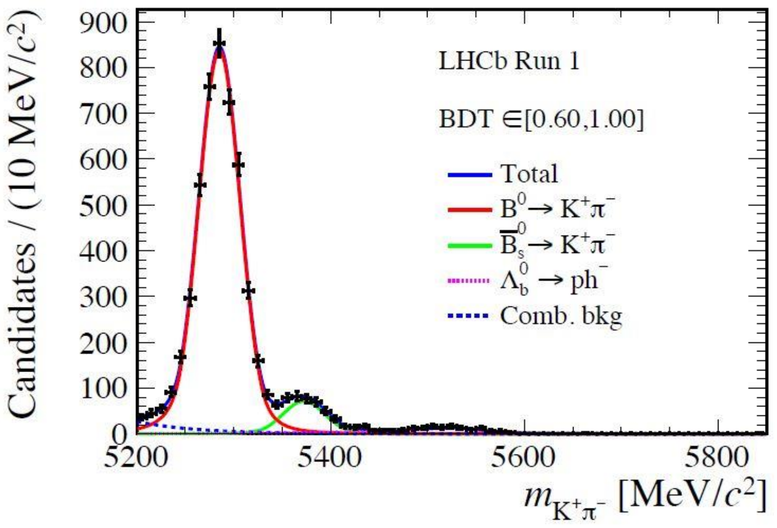


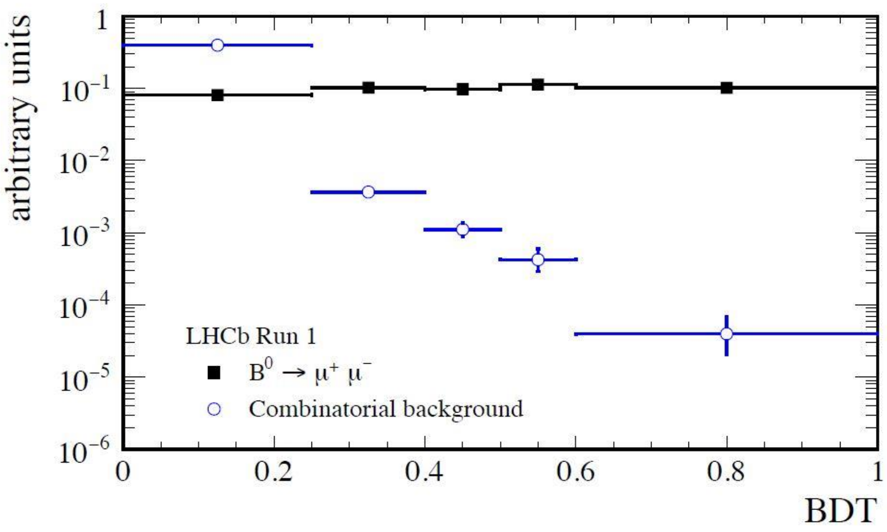


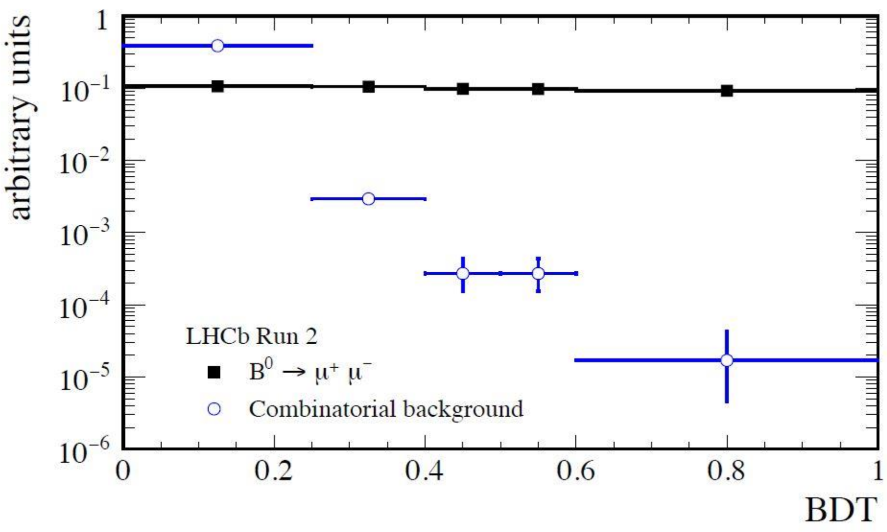
BDT calibration

- BDT output defined to be flat for B^0 signal and peaking at zero for combinatorial background
- $B^0 \to \mu^+\mu^-$ BDT shape derived from $B^0 \to K^+\pi^-$ in data corrected for trigger and PID selection. Additional lifetime-related correction for $B_s^0 \to \mu^+\mu^-$

$B^0 \to K^+\pi^-$ selection in data, BDT>0.6



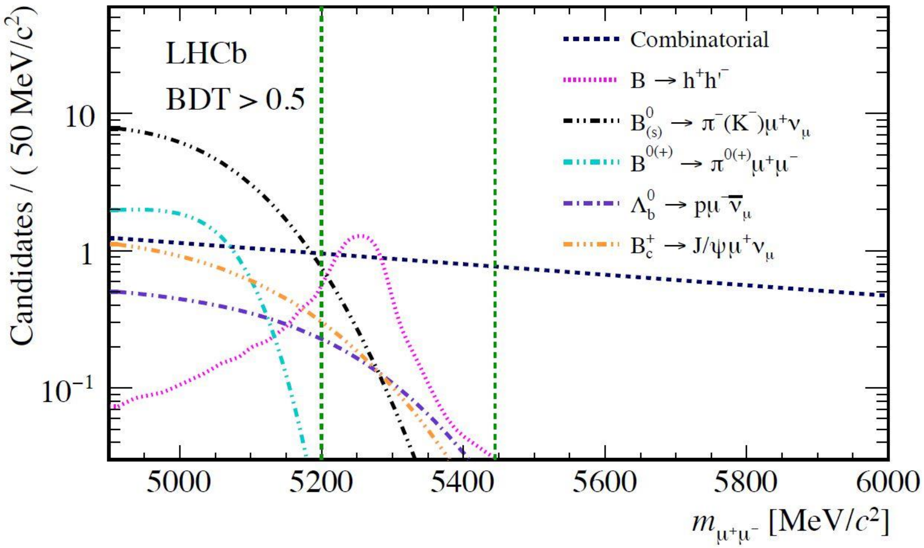




Backgrounds

Yields of main exclusive backgrounds *in signal region* with BDT>0.5:

$B \to h^+h'^-$	2.9 ± 0.3
$B_c^+ \to J/\psi\mu^+\nu_\mu$	1.2 ± 0.2
$B^0_{(s)} \to h^-\mu^+\nu_\mu$	0.80 ± 0.06
$\Lambda_b^0 \to p\mu^-\bar{\nu}_\mu$	0.7 ± 0.2
$B^{0(+)} \to \pi^{0(+)}\mu^+\mu^-$	negligible



- Above decays taken into account in the fit. Mass and BDT shapes determined from simulated samples with misID prob calibrated on data
- $B \to h^+h'^-$ efficiency reduced by $\sim$ 2 w.r.t. previous analysis thanks to tighter PID requirements, to optimize sensitivity to $B^0 \to \mu^+\mu^-$ (-10% signal eff.)
- Independent $B^0_{(s)} \to h^-\mu^+\nu_\mu$ and $B \to h^+h'^-$ estimates from $h\mu$ mass spectra
- $B^0_s \to \mu^+\mu^-\gamma$ has negligible impact on fit result
- Comb. bkg: -20% due to tighter PID ➔ -60% total reduction from BDT + PID

Normalisation

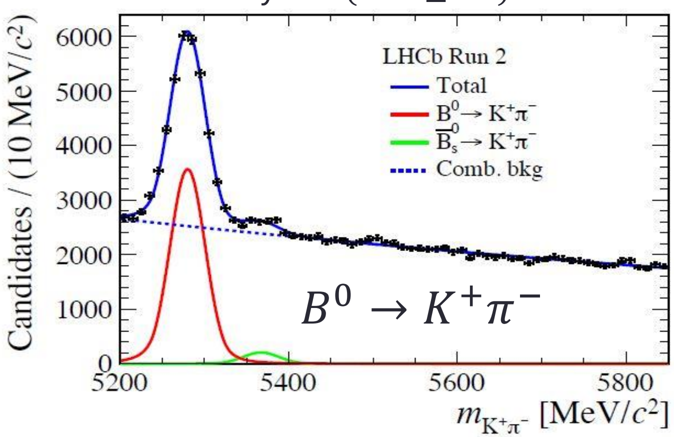
$$BF(B^0_{(s)} \to \mu\mu) = \frac{BF_{norm}}{N_{norm}} \times \frac{\epsilon^{Acc}_{norm}}{\epsilon^{Acc}_{sig}} \times \frac{\epsilon^{RecSel|Acc}_{norm}}{\epsilon^{RecSel|Acc}_{sig}} \times \frac{\epsilon^{Trig|RecSel}_{norm}}{\epsilon^{Trig|RecSel}_{sig}} \frac{f_d}{f_{d(s)}} N_{B^0_{(s)}\to\mu\mu} = \alpha_{(s)} \times N_{B^0_{(s)}\to\mu\mu}$$

- $\alpha_s = (5.7 \pm 0.4) \times 10^{-11}$; $\alpha = (1.60 \pm 0.04) \times 10^{-11}$
  Weighted averages from $B^+ \to J/\psi K^+$ and $B^0 \to K^+\pi^-$
- $\epsilon^{Acc}_{norm}/\epsilon^{Acc}_{sig}$ and $\epsilon^{RecSel|Acc}_{norm}/\epsilon^{RecSel|Acc}_{sig}$ evaluated with MC + corrections from data
- $\epsilon^{Trig|RecSel}_{norm}/\epsilon^{Trig|RecSel}_{sig}$ evaluated with data-driven technique
- $f_s/f_d = 0.259 \pm 0.015$ measured by LHCb at 7 TeV

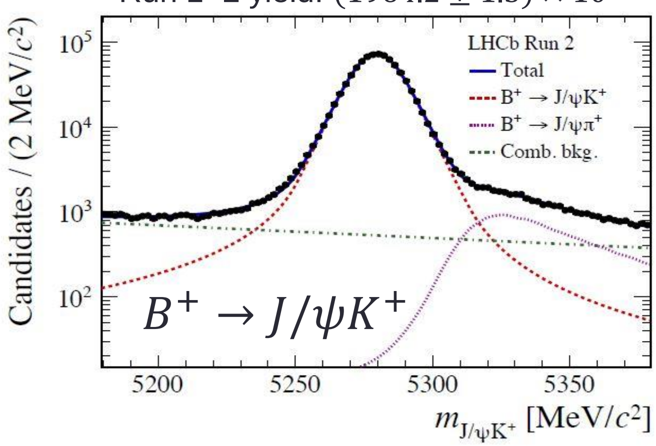
Main source of $BF(B_s \to \mu\mu)$ systematic error

- $BF(B^0 \to K\pi)/BF(B^+ \to J/\psi\, K^+)$ and $BF(B_s \to J/\psi\, \phi)/BF(B^+ \to J/\psi\, K^+)$ used as validation tool

Run 1+2 yield: $(31.3 \pm 0.4) \times 10^3$

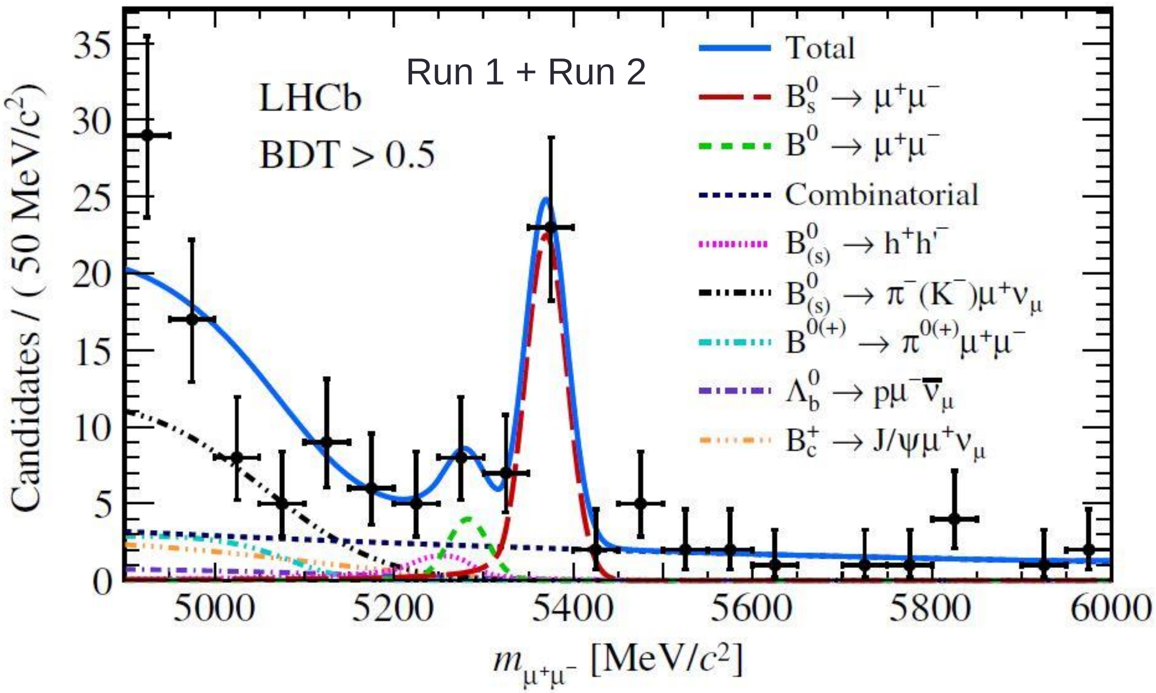


Run 1+2 yield: $(1964.2 \pm 1.5) \times 10^3$



BF fit

- Unbinned maximum likelihood fit of $m_{\mu\mu}$ in bins of BDT
  - 5 BDT bins for each Run 1 and Run 2 dataset
- Free parameters: $BF(B^0 \to \mu\mu), BF(B_S^0 \to \mu\mu)$, combinatorial background
- Exclusive bkg yields and other nuisance parameters are constrained according to their expected values and uncertainties



Results

PRL118, 191801 (2017)
arXiv:1703.05747

- Fit results:

$$BF(B_s^0 \to \mu^+\mu^-) = (3.0 \pm 0.6^{+0.3}_{-0.2}) \times 10^{-9} \quad \mathbf{7.8\,\sigma}$$

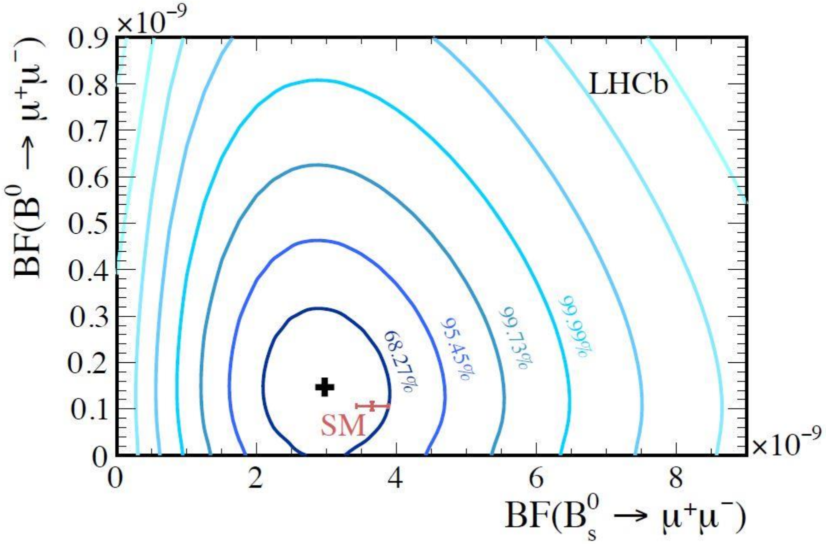
compatible with SM

$$BF(B^0 \to \mu^+\mu^-) = (1.5^{+1.2}_{-1.0}{}^{+0.2}_{-0.1}) \times 10^{-10} \quad 1.6\,\sigma$$

$$< 3.4 \times 10^{-10} \text{ at 95\% CL}$$

The fit assumes $\tau(B_s^0 \to \mu\mu) = \tau_{B_s}/(1 - y_s)$ (i.e. $A_{\Delta\Gamma} = 1$)
The measured $B_s^0 \to \mu\mu$ BF increases by 4.6% (10.9%) if $A_{\Delta\Gamma} = 0\ (-1)$ is assumed (the efficiency decreases)

Main source of systematic uncertainty:
$BF(B_s^0 \to \mu^+\mu^-)$: knowledge of f_s/f_d
$BF(B^0 \to \mu^+\mu^-)$: exclusive backgrounds



$B_s^0 \to \mu^+\mu^-$ effective lifetime

- Effective lifetime:

$$\tau_{\mu^+\mu^-} \equiv \frac{\int_0^\infty t\langle\Gamma(B_s^0(t) \to \mu^+\mu^-)\rangle dt}{\int_0^\infty \langle\Gamma(B_s^0(t) \to \mu^+\mu^-)\rangle dt}$$

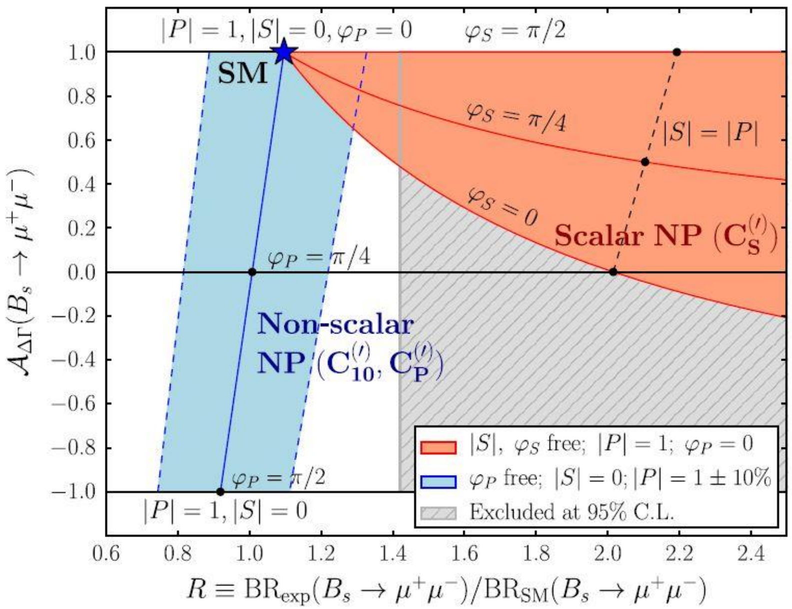
- The following holds:

$$\tau_{\mu^+\mu^-} = \frac{\tau_{B_s^0}}{1-y_s^2}\left(\frac{1+2A_{\Delta\Gamma}^{\mu^+\mu^-}y_s+y_s^2}{1+A_{\Delta\Gamma}^{\mu^+\mu^-}y_s}\right)$$

$$y_s \equiv \tau_{B_s}\Delta\Gamma/2 = 0.062 \pm 0.006\ \mathrm{ps}^{-1}$$

$$A_{\Delta\Gamma}^{\mu^+\mu^-} = -2Re(\lambda)/(1+|\lambda|^2) \quad \text{with} \quad \lambda = q/p\, A(\bar{B}_s^0 \to \mu^+\mu^-)/A(B_s^0 \to \mu^+\mu^-)$$

PRL 109, 041801 (2012)



- $A_{\Delta\Gamma}^{\mu^+\mu^-} = 1$ in SM, can be in $[-1,1)$ if NP occurs

  ➔ additional probe for NP, complementary to the branching ratio

$\tau_{\mu^+\mu^-}$ never measured so far

Analysis strategy

- Very similar selection as for the BF measurement. Same BDT but simplified BDT>0.55 requirement.
- Fit performed in 2 stages:
  - Fit on $m_{\mu\mu}$ in $[5320,6000] MeV/c^2$ to evaluate weights with the sPlot technique
  - Fit to the weighted decay-time distribution to determine $\tau_{\mu\mu}$
- Decay-time acceptance function modeled on simulated $B_s^0 \to \mu^+\mu^-$ events

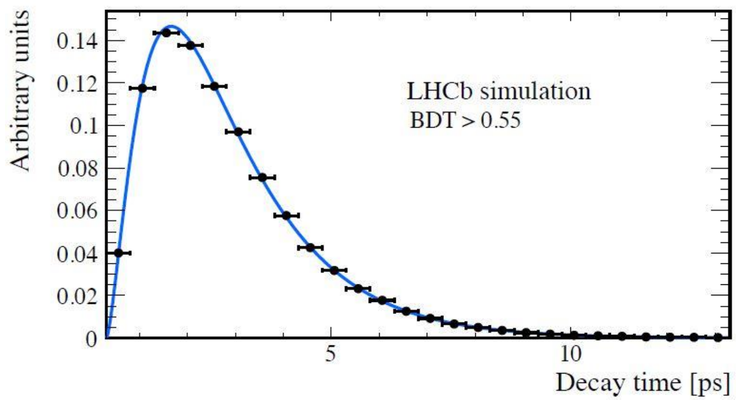
$$\epsilon(t) = \frac{[a(t-t_0)]^n}{1+[a(t-t_0)]^n}$$

- Acceptance function (and overall procedure) validated by measuring $\tau(B^0 \to K^+\pi^-)$

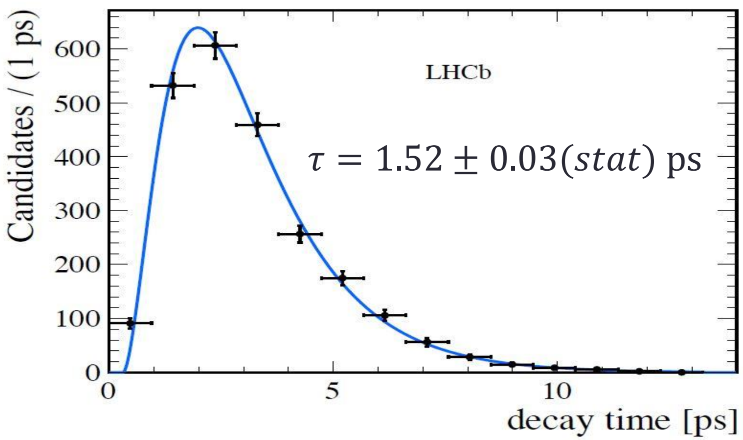
$$\tau(B^0 \to K^+\pi^-) = 1.52 \pm 0.03(stat) \text{ ps}$$

consistent with PDG average

decay-time distribution of MC $B_s^0 \to \mu^+\mu^-$

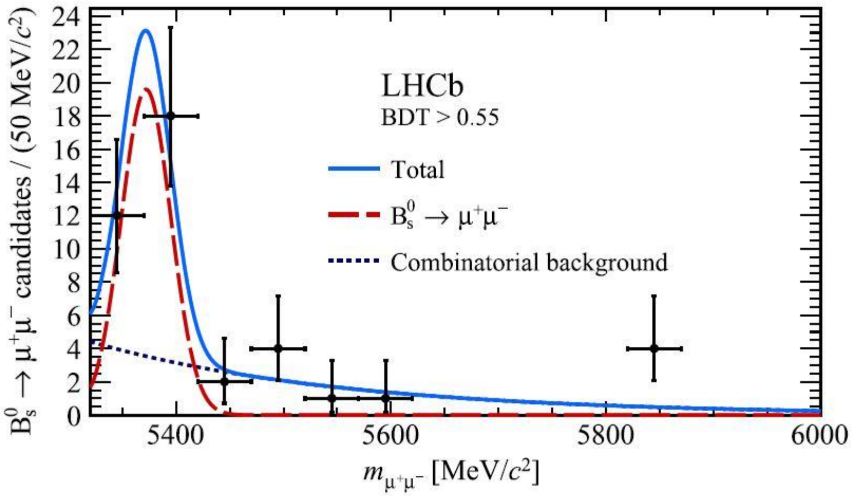


decay-time distribution of $B^0 \to K^+\pi^-$ on data

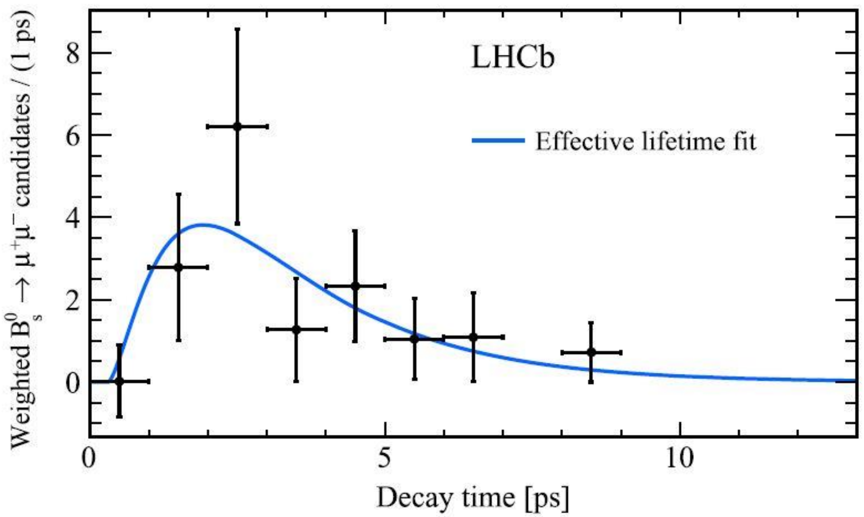


Results

PRL118, 191801 (2017)
arXiv:1703.05747



- The mass fit includes $B_s^0 \to \mu^+\mu^-$ and combinatorial background
  - Contamination from $B^0 \to \mu^+\mu^-$ and other backgrounds treated as systematic
  - Fit procedure validated with simulated events and $B^0 \to K^+\pi^-$



- Fit result:

$$\tau(B_s^0 \to \mu^+\mu^-) = 2.04 \pm 0.44 \pm 0.05 \text{ ps}$$

Measurement consistent with $A_{\Delta\Gamma}^{\mu^+\mu^-} = 1(-1)$ hypothesis at $1.0(1.4)\ \sigma$

Prospects

LHC era			HL-LHC era	
Run1 (2010-12)	Run2 (2015-18)	Run3 (2021-23)	Run4 (2026-29)	Run5+ (2032+)
$3fb^{-1}$	$8fb^{-1}$	→	$50fb^{-1}$	$*300fb^{-1}$

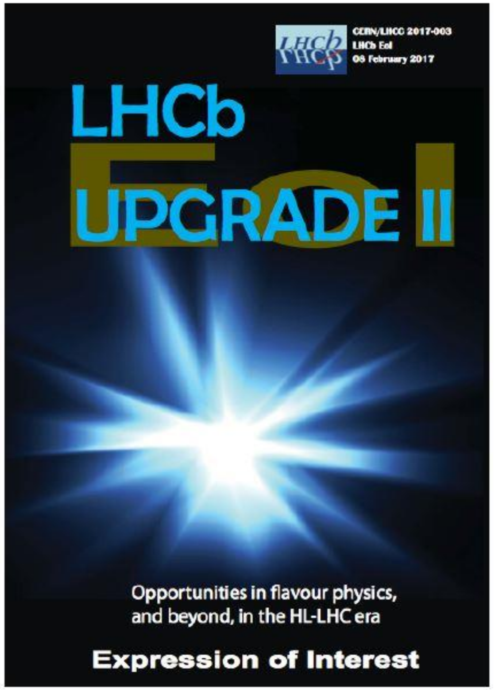
* assumes Phase-II upgrade runs with $L = 2 \times 10^{34} cm^{-2} s^{-1}$

$$R \equiv \frac{BF(B^0 \to \mu\mu)}{BF(B_s^0 \to \mu\mu)}$$

By the end of Run 4 (50 fb^{-1}):
$\sigma(R) \sim 40\%$
$\sigma(\tau_{B_s \to \mu\mu}) \sim 0.08$ ps

After hypothetical phase-II (300 fb^{-1}):
$\sigma(R) \sim 20\%$
$\sigma(\tau_{B_s \to \mu\mu}) \sim 0.03$ ps

NB: estimates for R are based on Run 1 analysis → the performance improvement of the latest measurement is not taken into account



https:/cds.cern.ch/record/2244311/

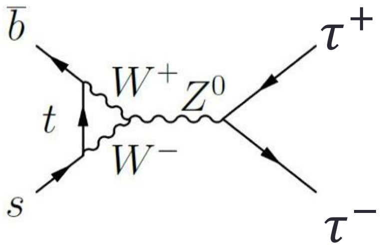
submitted to LHCC this year

Search for $B^0_{(s)} \to \tau^+\tau^-$ decays

- FCNC processes analogous to $B^0_{(s)} \to \mu^+\mu^-$ but much less suppressed

$$\frac{\mathcal{B}(\mathrm{B}^0_{(s)} \to \tau^+\tau^-)}{\mathcal{B}(\mathrm{B}^0_{(s)} \to \mu^+\mu^-)} = \frac{m_\tau^2}{m_\mu^2} \times \sqrt{\frac{m_\mathrm{B}^2 - 4m_\tau^2}{m_\mathrm{B}^2 - 4m_\mu^2}}$$

$$283 \times 0.74 \sim \mathbf{210}$$

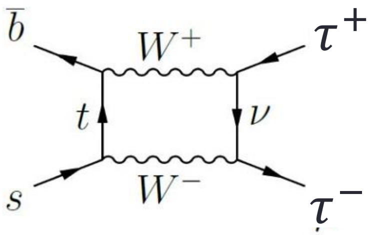


- With $B^0_{(s)} \to \mu^+\mu^-$ they can test lepton flavor universality
- SM time-integrated BF:

$$BF(B^0_s \to \tau^+\tau^-) = (7.73 \pm 0.49) \times 10^{-7}$$

$$BF(B^0 \to \tau^+\tau^-) = (2.22 \pm 0.19) \times 10^{-8}$$

[Bobeth et al, PRL 112 (2014), 101801]



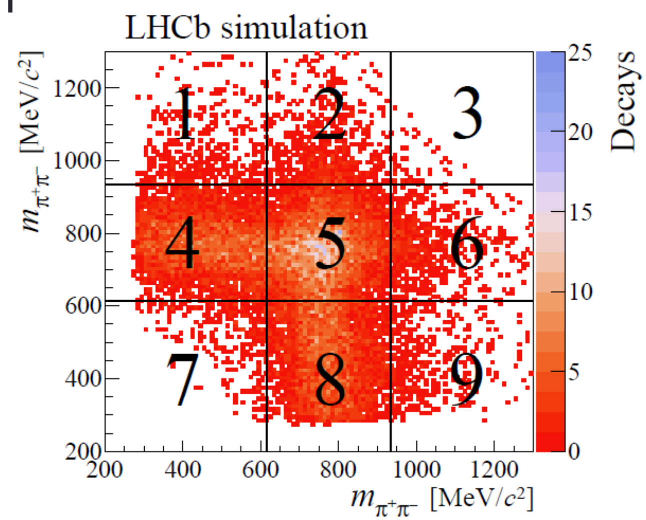
- τ leptons selected in $\tau^+ \to \pi^+\pi^-\pi^+\bar{\nu}_\tau$. τ decay model tuned on BaBar data
- Experimentally VERY challenging due to two neutrinos in final state
- B^0_s and B^0 cannot be separated: assumption on one decay needed to extract limit on the other

Search for $B^0_{(s)} \to \tau^+\tau^-$ decays

[PRL 118 (2017) 251802]

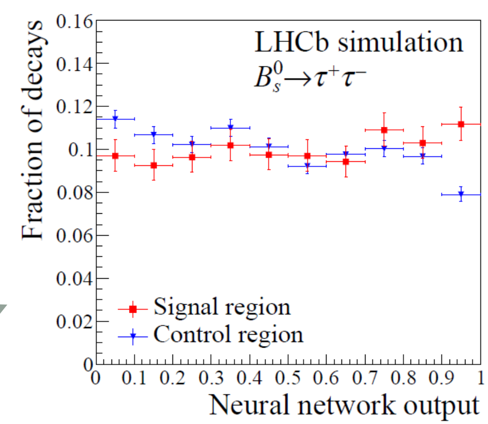
- Approximate reconstruction of $B \to \tau^+\tau^-$ decay chain by exploiting geometrical and mass constraints
- Definition of *signal*, *control* and *NN training* samples based on $(m_{\pi_1^\pm\pi_2^\mp}, m_{\pi_3^\pm\pi_2^\mp})$ of $\tau^\pm \to \pi_1^\pm\pi_2^\mp\pi_3^\pm\nu_\tau$ decays
  - signal region: both $\tau^\pm$ in 5
  - background control region: one τ in 4 or 8, the other in 4, 5 or 8
  - background NN training region: at least one τ in 1, 3, 7 or 9

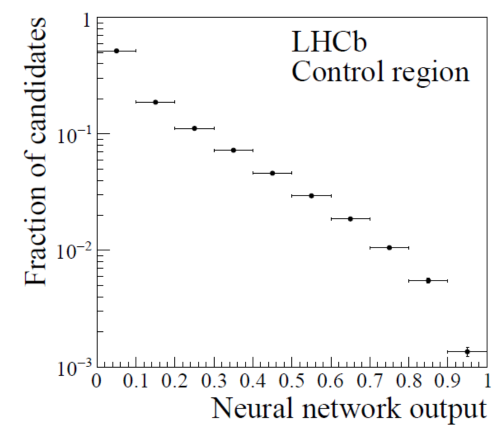
$B_s^0 \to \tau^+\tau^-$ signal MC



- After pre-selection, NN built with geometric, kinematic and isolation variables to separate signal and background

signal NN distribution uniform in [0,1], background peaks at 0





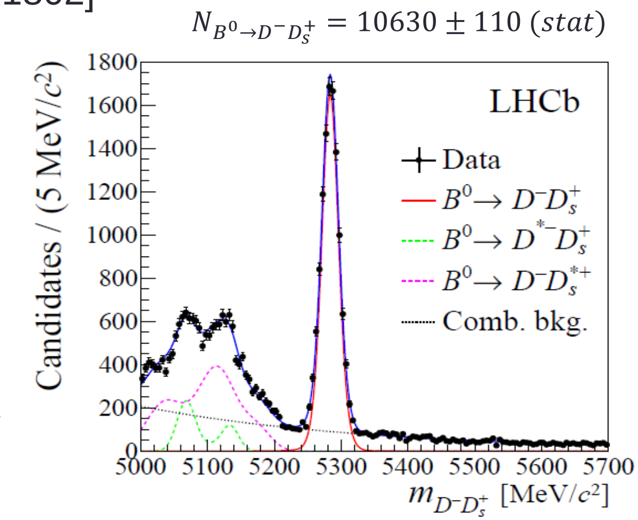
Search for $B^0_{(s)} \to \tau^+\tau^-$ decays

[PRL 118 (2017) 251802]

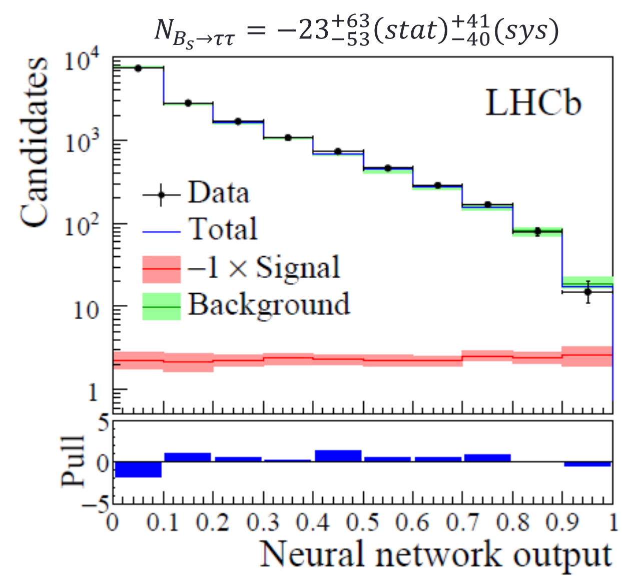
- $B^0 \to D^+[K^-\pi^+\pi^+]D_s^-[K^+K^-\pi^-]$ used as calibration and normalisation channel
- Signal extracted from fit to NN in signal region:

$$\mathcal{B}(B_s^0 \to \tau^+\tau^-) = \alpha^s \times N_{B_s\to\tau\tau}$$

$$\alpha^s \equiv \frac{\epsilon^{D^-D_s^+} \times \mathcal{B}(B^0 \to D^-D_s^+) \times \mathcal{B}(D^+ \to K^-\pi^+\pi^+) \times \mathcal{B}(D_s^+ \to K^+K^-\pi^+)}{N^{\mathrm{obs}}_{D^-D_s^+} \times \epsilon^{\tau^+\tau^-} \times [\mathcal{B}(\tau^- \to \pi^-\pi^+\pi^-\nu_\tau)]^2} \times \frac{f_d}{f_s}$$



$BF(B_s^0 \to \tau^+\tau^-) < 5.2(6.8) \times 10^{-3}$ at 90(95)% CL



Assuming signal fully dominated by B^0:

$BF(B^0 \to \tau^+\tau^-) < 1.6(2.1) \times 10^{-3}$ at 90 (95%) CL

x 2.6 improvement w.r.t. previous result from BaBar
[PRL 96 (2006) 241802]

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

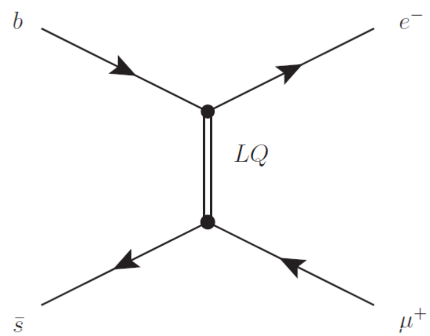
- Lepton flavour violating process
- Decay allowed in several New Physics scenarios including e.g. models with Z' boson, heavy singlet Dirac neutrinos, SUSY and the Pati-Salam model
- Complementary probe to direct searches of NP particles at ATLAS and CMS
- Previous best limits by LHCb based on 1 fb^{-1} Run1 data

$$BF\left(B^0_s \to e^{\pm}\mu^{\mp}\right) < 1.1(1.4)\ 10^{-8} \ @\ 90(95)\%\ \text{CL}$$
$$BF\left(B^0 \to e^{\pm}\mu^{\mp}\right) < 2.8(3.7)\ 10^{-9} \ @\ 90(95)\%\ \text{CL}$$

[PRL 111 (2013) 141801]

- Measurement recently updated with
  - full Run 1 dataset (3 fb^{-1})
  - improved signal selection

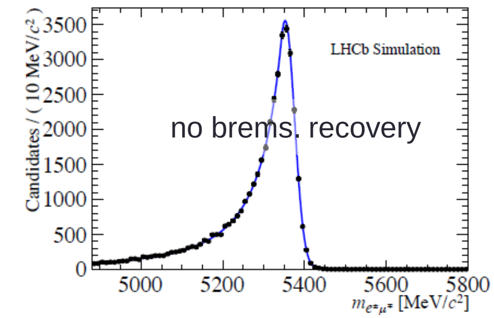
LQ coupling to leptons and quarks of different generations

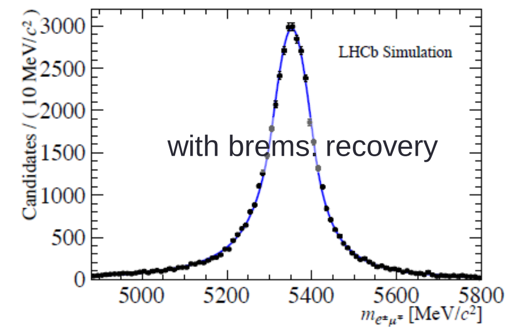


Updated search for $B^0_{(s)} \to e^{\pm}\mu^{\mp}$ decays

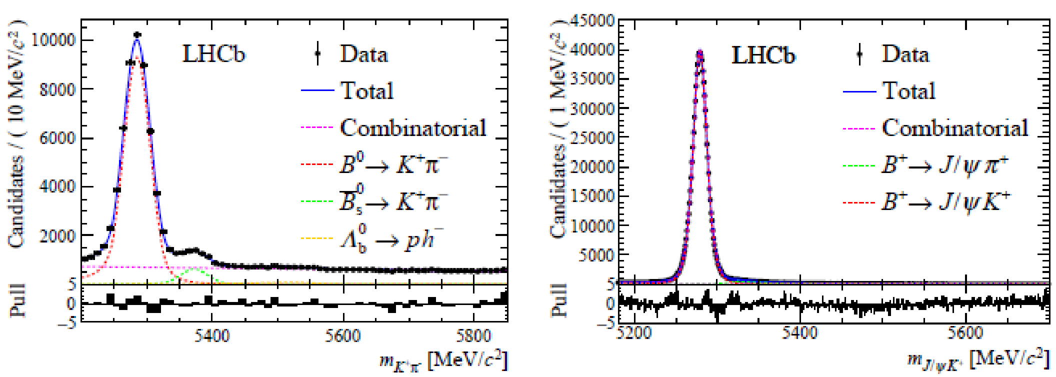
[LHCb-PAPER-2017-031, arXiv:1710.04111]

- Preselection similar to that of $B_{(s)} \to \mu^+\mu^-$ (except for trigger and PID)
- Sample split in two categories: with/without bremsstrahlung recovery
- Final signal/background discrimination through BDT (multivariate classifier) and $m_{e\mu}$
- Main background from $b\bar{b} \to e^{\pm}\mu^{\mp}X$ decays
- $B^0 \to K^+\pi^-$ and $B^+ \to J/\psi\ K^+$ used as normalisation channels
- $B^0 \to K^+\pi^-$ also used to calibrate the signal BDT shape

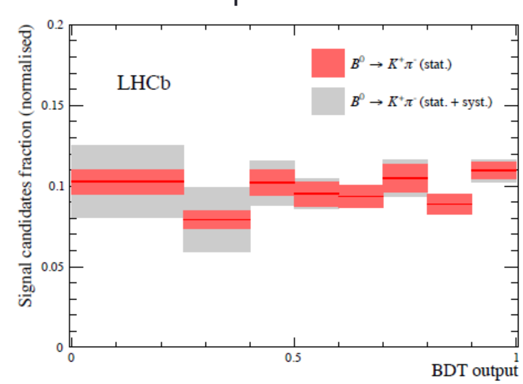




Selected normalisation decays $B^0 \to K^+\pi^-$ and $B^+ \to J/\psi K^+$



BDT shape of $B^0 \to K^+\pi^-$



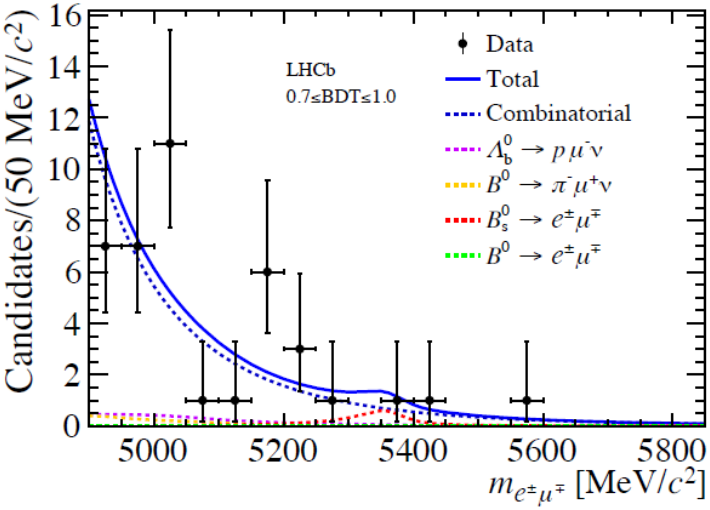
Updated search for $B^0_{(s)} \to e^{\pm}\mu^{\mp}$ decays

[LHCb-PAPER-2017-031, arXiv:1710.04111]

$i = B^0 \to K^+\pi^-, B^+ \to J/\psi K^+$

$$\mathcal{B}(B^0_{(s)} \to e^{\pm}\mu^{\mp}) = \sum_i w^i \frac{\mathcal{B}^i_{\rm norm}}{N^i_{\rm norm}} \frac{\varepsilon^i_{\rm norm}}{\varepsilon_{\rm sig}} \frac{f_q}{f_{d(s)}} \times N_{B^0_{(s)} \to e^{\pm}\mu^{\mp}}$$
$$= \alpha_{B^0_{(s)}} \times N_{B^0_{(s)} \to e^{\pm}\mu^{\mp}},$$

events summed over the 3 most sensitive BDT bins and the 2 brem. categories



- No signal found. Events in signal region consistent with the expected background
- Upper limit on $BF(B^0_{(s)} \to e^{\pm}\mu^{\mp})$ evaluated with the CLs method:

$$BF\left(B^0_s \to e^{\pm}\mu^{\mp}\right) < 5.4(6.3)\ 10^{-9} \text{ @ } 90(95)\% \text{ CL}$$
$$BF\left(B^0 \to e^{\pm}\mu^{\mp}\right) < 1.0(1.3)\ 10^{-9} \text{ @ } 90(95)\% \text{ CL}$$

Best UL to date, improved by factor 2-3 since previous LHCb measurement

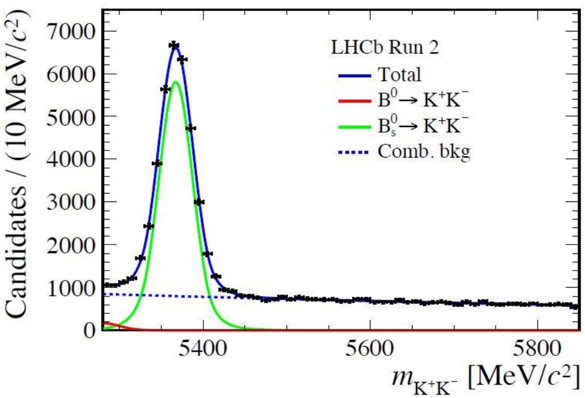
Summary

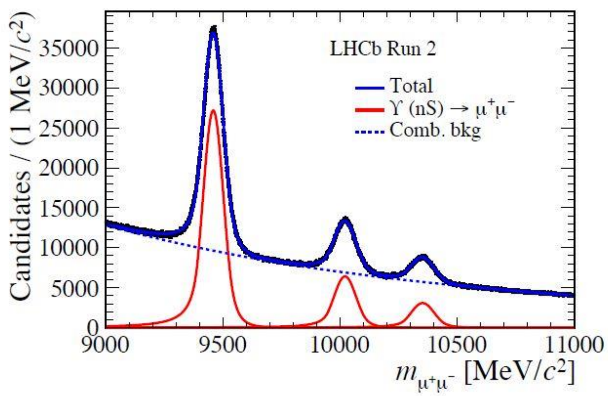
- Updated LHCb measurement of $B^0_{(s)} \to \mu^+\mu^-$ decays combining Run 1 with 2015+2016 data
  - Improved analysis and increased dataset have led to first single-experiment observation of $B^0_s \to \mu^+\mu^-$ decay with 7.8 σ significance
    $BF(B^0_s \to \mu^+\mu^-) = (3.0 \pm 0.6^{+0.3}_{-0.2}) \times 10^{-9}$
  - No evidence of $B^0 \to \mu^+\mu^-$ in this dataset
    $BF(B^0 \to \mu^+\mu^-) < 3.4 \times 10^{-10}$@ 95% CL
  - First measurement of $B^0_s \to \mu^+\mu^-$ effective lifetime
    $\tau(B^0_s \to \mu^+\mu^-) = 2.04 \pm 0.44 \pm 0.05$ ps
- First search for $B_s \to \tau^+\tau^-$ decays
  $BF(B^0_s \to \tau^+\tau^-) < 5.2(6.8) \times 10^{-3}$ @ 90(95)% CL
- Updated search for LFV $B^0_{(s)} \to e^\pm\mu^\mp$ decays. UL improved by 2-3 with respect to previous LHCb measurement
  $BF\left(B^0_s \to e^\pm\mu^\mp\right) < 5.4(6.3)\ 10^{-9}$ @ 90(95)% CL
  $BF\left(B^0 \to e^\pm\mu^\mp\right) < 1.0(1.3)\ 10^{-9}$ @ 90(95)% CL
- Work in progress on more $B^0_{(s)}$ leptonic decays

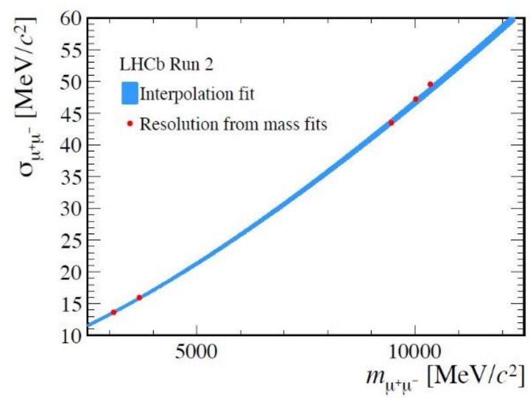
BACKUP

$B^0_{(s)} \to \mu^+\mu^-$ mass calibration

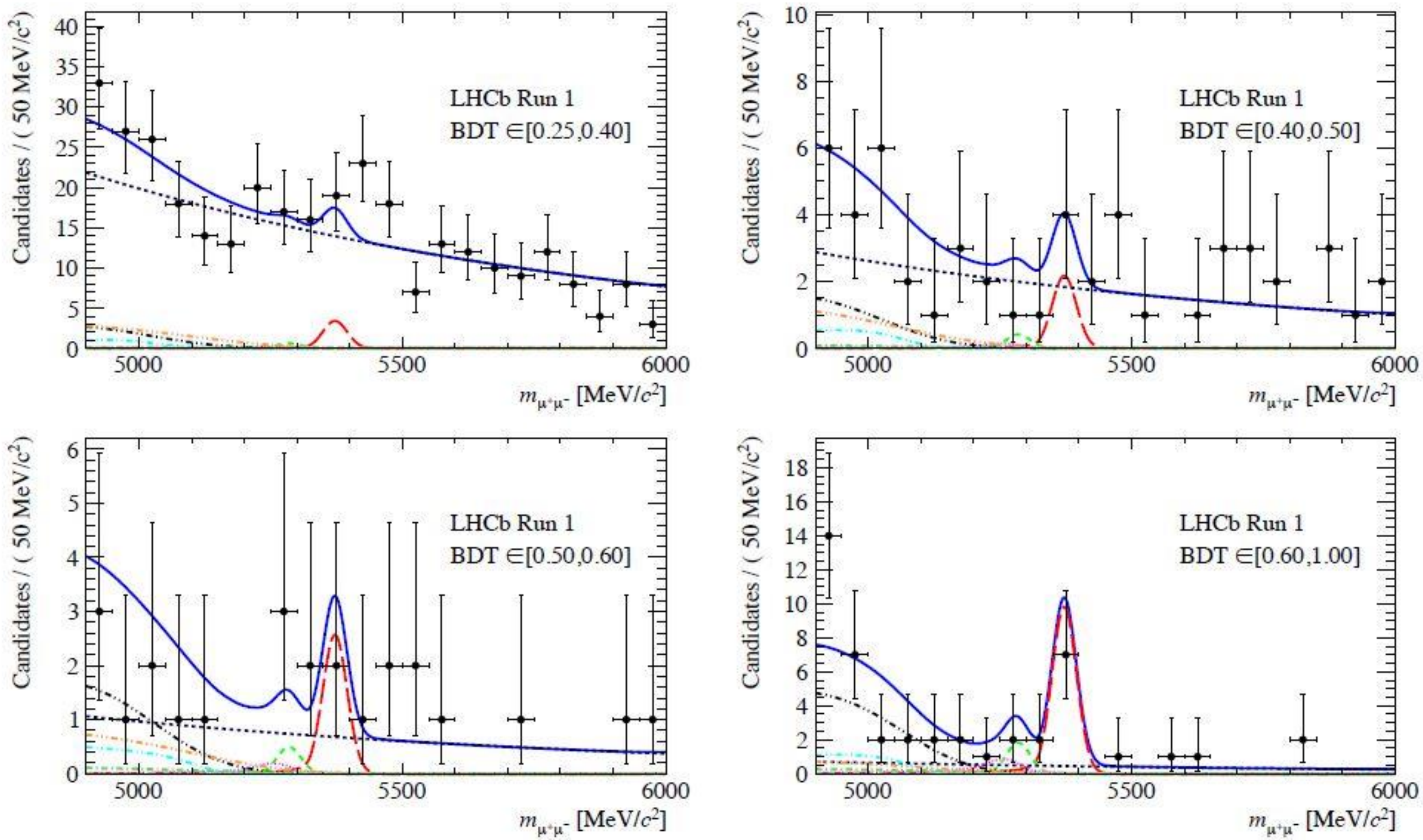
- Mass PDFs parametrized with Crystal Ball function
- Peak values obtained from $B^0_s \to K^+K^-$ and $B^0 \to K^+\pi^-$
- Core resolutions from power-law interpolation of resolutions from charmonium and bottomonium resonances (→ $\sim 23\ MeV/c^2$ resolution for $B^0_{(s)} \to \mu\mu$)
- Tails from simulated events smeared to reproduce the core resolution in data



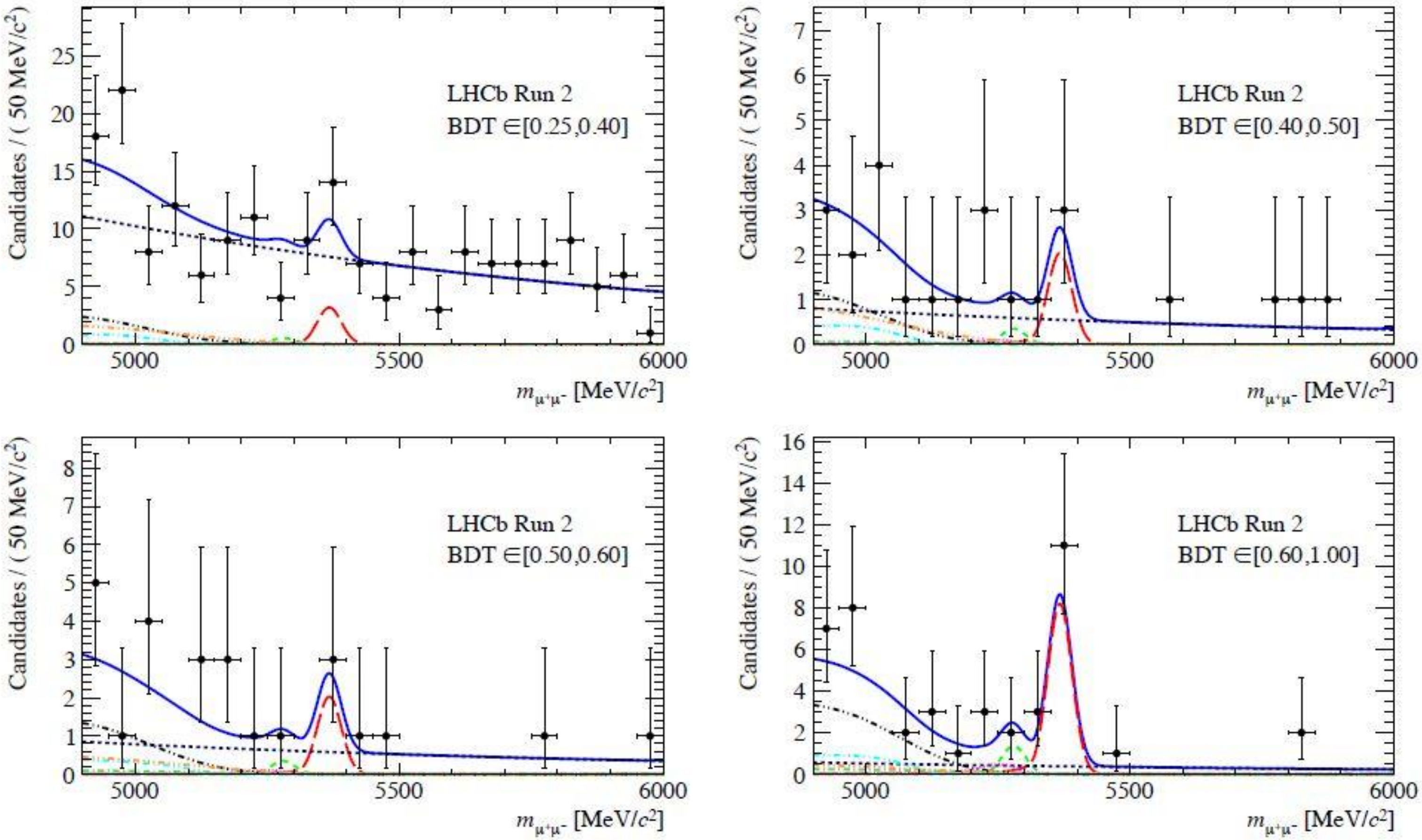




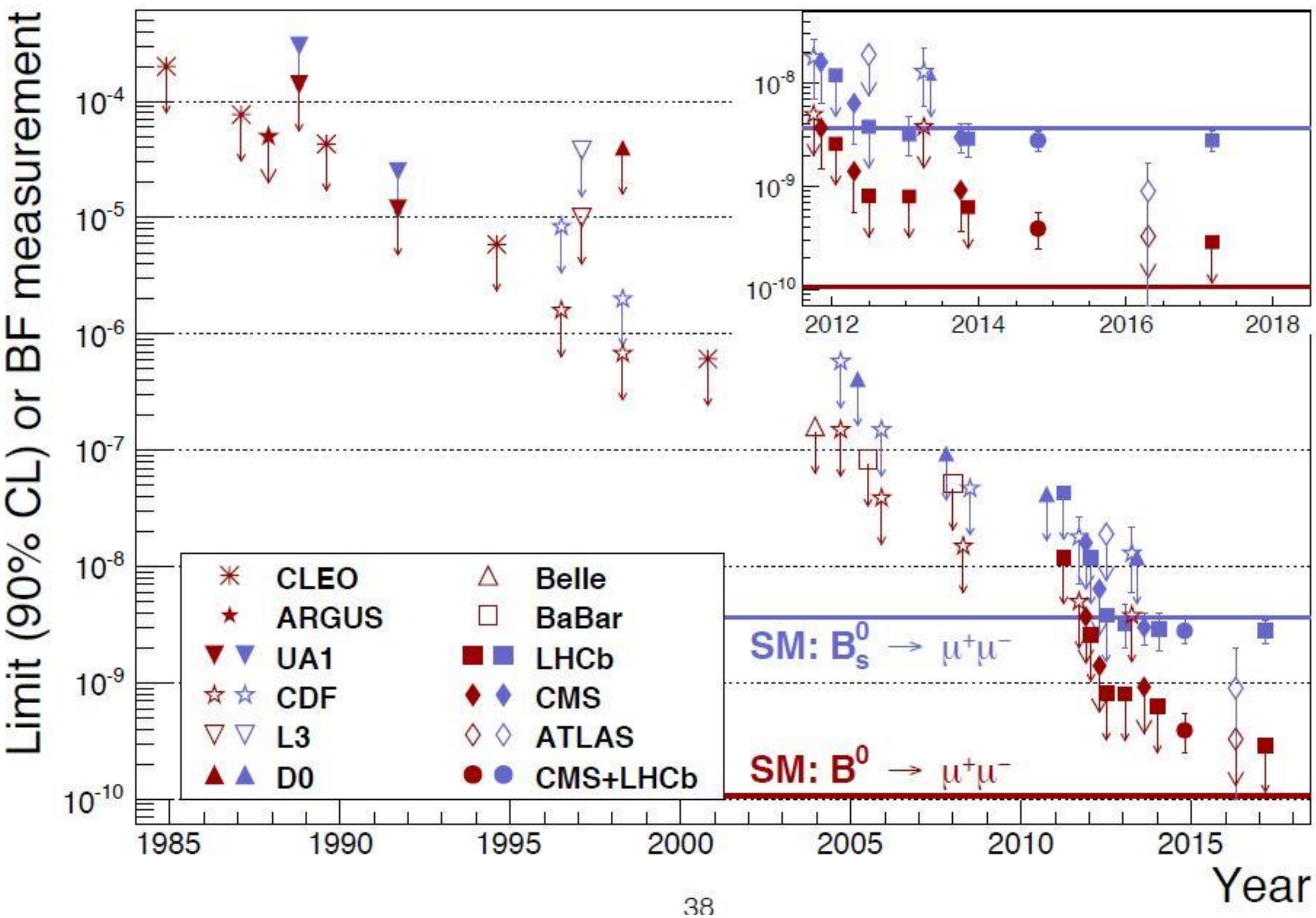
$B \to \mu\mu$ mass fit Run 1



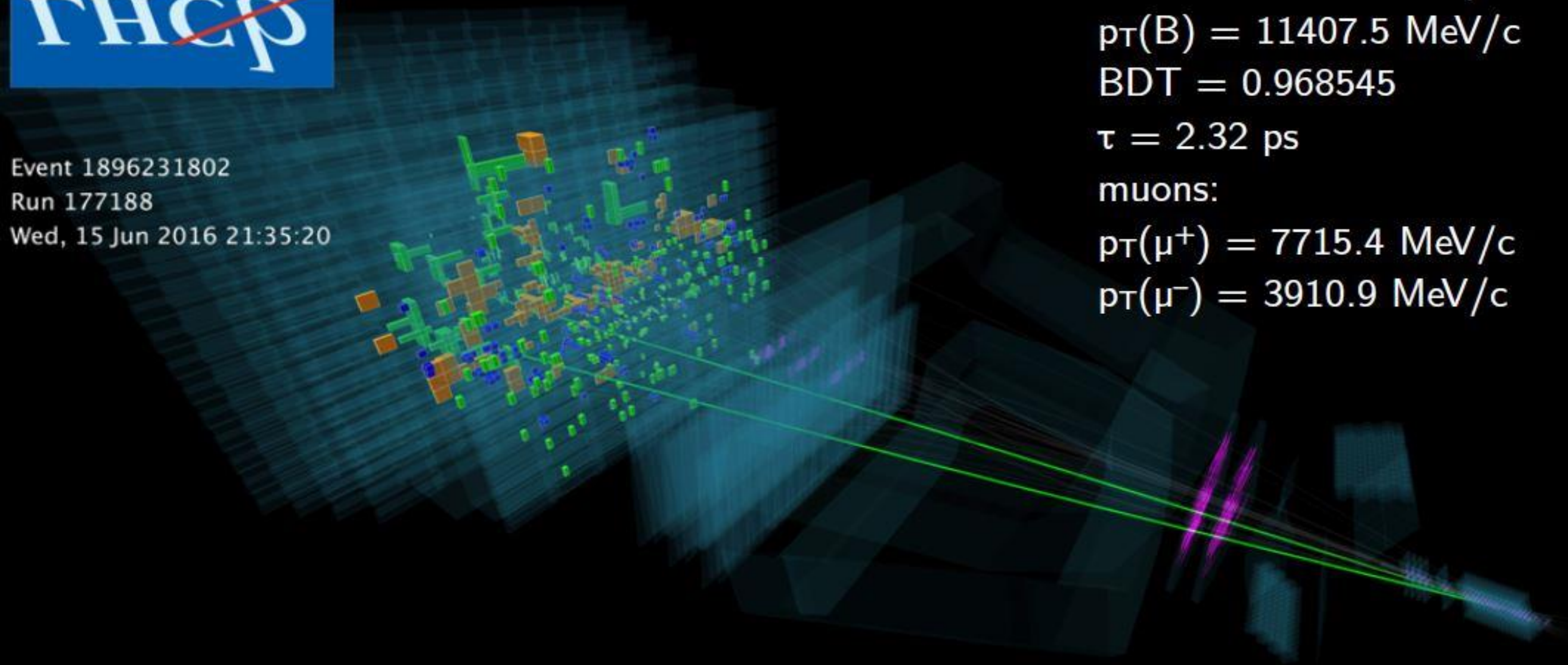
$B \to \mu\mu$ mass fit Run 2



$BF(B \to \mu\mu)$ measurement history



A nice candidate



B:
mass = 5379.31 MeV/c^2
$p_T(B)$ = 11407.5 MeV/c
BDT = 0.968545
τ = 2.32 ps
muons:
$p_T(\mu^+)$ = 7715.4 MeV/c
$p_T(\mu^-)$ = 3910.9 MeV/c

The LHCb detector

Calorimeter system:
Spd, Prs, Ecal, Hcal
(for measuring energy)

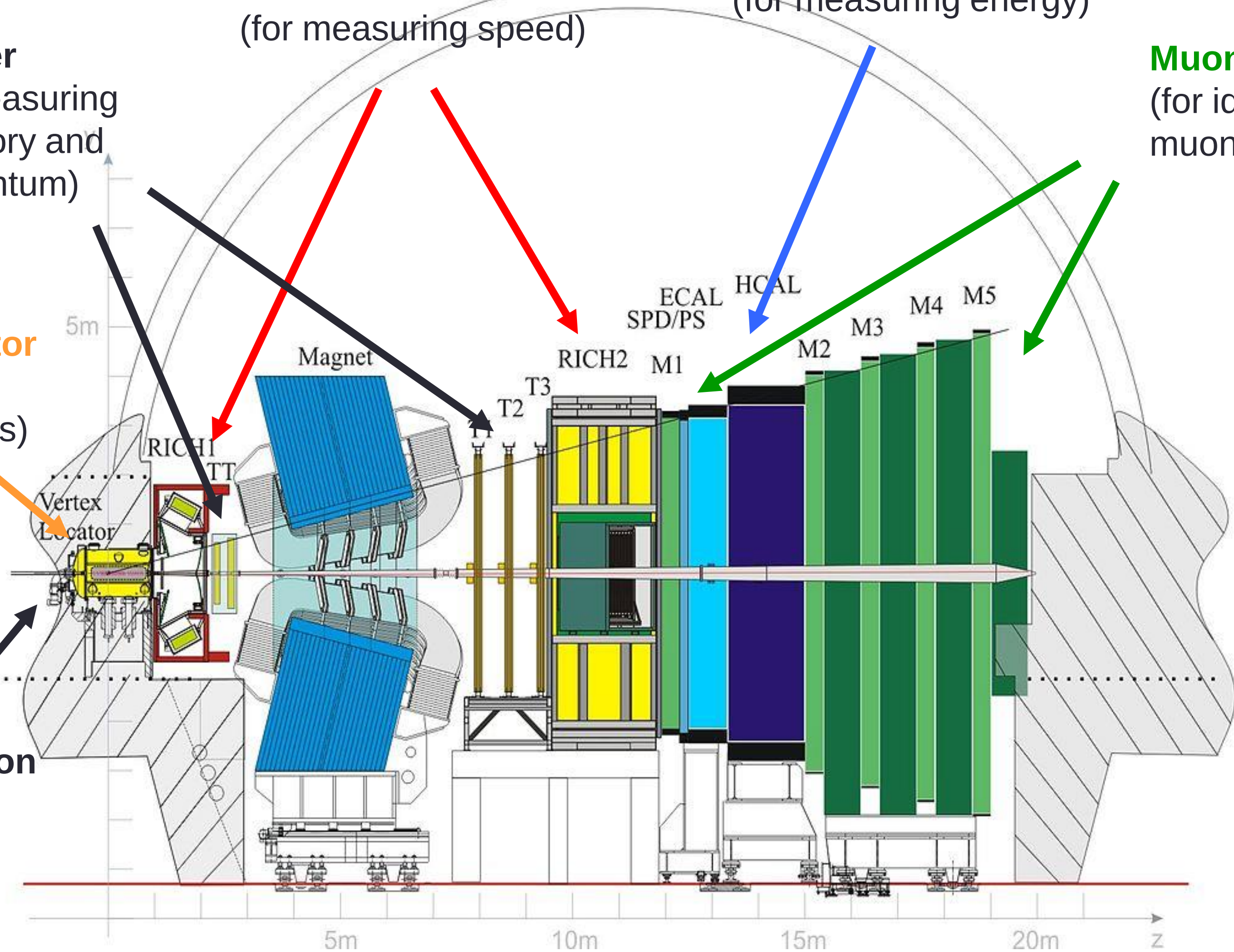
Cherenkov detectors
(for measuring speed)

Tracker
(for measuring trajectory and momentum)

Muon system
(for identifying muons)

Vertex detector
(for locating particle decays)

pp interaction point



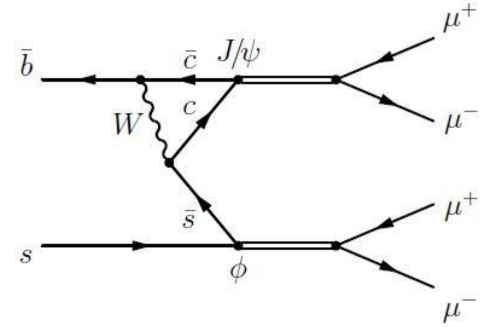
LHCb collaboration, A. A. Alves Jr. et al., The LHCb detector at the LHC, JINST 3 (2008) S08005.

Search for $B^0_{(s)} \to \mu^+\mu^-\mu^+\mu^-$ decays

Standard Model:

- Dominated by $B^0_s \to J/\psi(\to \mu^+\mu^-)\phi(\to \mu^+\mu^-)$
  $\mathrm{BF} = (1.83 \pm 0.18) \times 10^{-8}$
- SM B^0_s non-resonant BF $\sim 3.5 \times 10^{-10}$, dominated by $B^0_{(s)} \to \mu^+\mu^-\,\gamma(\to \mu^+\mu^-)$

$B^0_s \to J/\psi(\to \mu^+\mu^-)\phi(\to \mu^+\mu^-)$

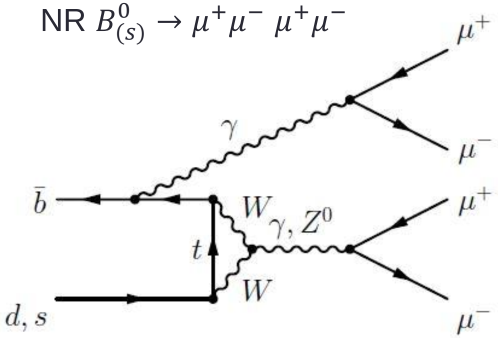


Beyond Standard Model:

- BF can be significantly enhanced, for example in MSSM: $B \to S(\to \mu^+\mu^-)P(\to \mu^+\mu^-)$, S and P sgoldstino particles

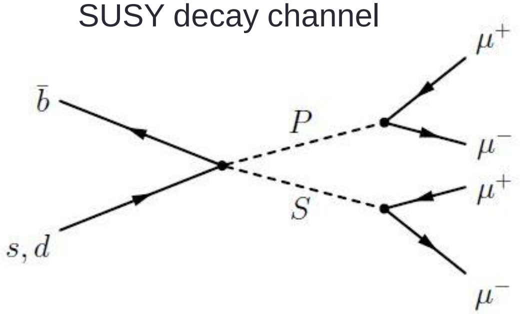
[PRD85,077701 (2012)]

NR $B^0_{(s)} \to \mu^+\mu^-\,\mu^+\mu^-$



Interest also related to the evidence of $\Sigma^+ \to p\mu^+\mu^-$ by the HyperCP Collaboration consistent with existence of $P \to \mu^+\mu^-$ with M(P)=214.3 ± 0.5 MeV (PRL94, 021801 (2005), not confirmed by LHCb (LHCB-PAPER-2017-049)

SUSY decay channel



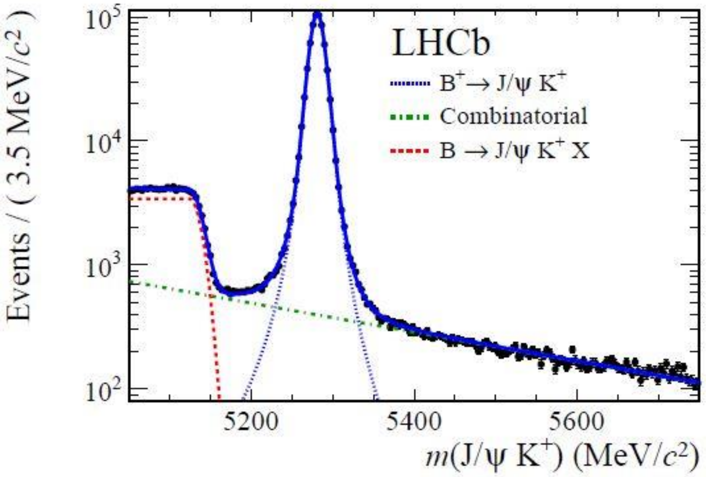
Search for $B^0_{(s)} \to \mu^+\mu^-\mu^+\mu^-$ decays

Signal selection:

- Dataset: 3 fb^{-1} (Run1)
- 4 muon candidates originating from single vertex and far from the primary vertex
- J/ψ, $\psi(2S)$ and ϕ mass vetoes to remove the dominant SM resonant decays
- Multivariate classifier (B kinematic and position w.r.t primary vertex) to reject background

1611.07704, JHEP 03 (2017) 001

normalization mode $B^+ \to J/\psi(\to \mu^+\mu^-)\, K^+$



BF measurement:

- $B^+ \to J/\psi(\to \mu^+\mu^-)\, K^+$ used as normalization channel
- $\mathcal{B}(B^0_{(s)} \to \mu^+\mu^-\mu^+\mu^-) = N(B^0_{(s)} \to \mu^+\mu^-\mu^+\mu^-) \times$

$$\frac{\varepsilon(B^+ \to J/\psi(\to \mu^+\mu^-)K^+) \times \mathcal{B}(B^+ \to J/\psi(\to \mu^+\mu^-)K^+)}{\varepsilon(B^0_{(s)} \to \mu^+\mu^-\mu^+\mu^-) \times N(B^+ \to J/\psi(\to \mu^+\mu^-)K^+)} \times \frac{f_u}{f_{d,s}}$$

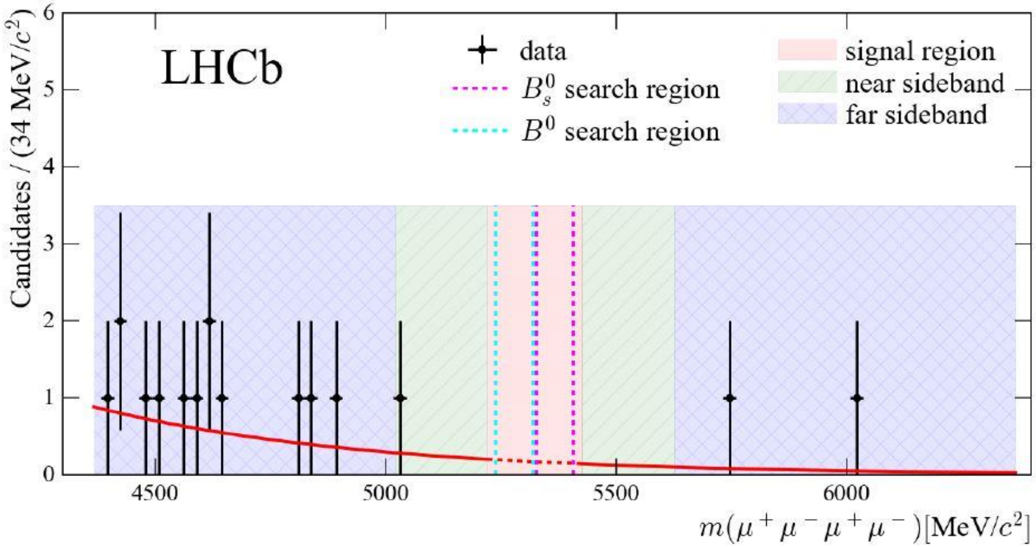
$f_s/f_d = 0.259 \pm 0.015$ B^0/B^0_s production fraction

[JHEP 1304 (2013) 001, LHCb-CONF-2013-011]

Search for $B^0_{(s)} \to \mu^+\mu^-\mu^+\mu^-$ decays

1611.07704, JHEP 03 (2017) 001

0 events in B^0 and B^0_s signal regions
Consistent with background and (null) SM signal expectation



Set 95% CL upper limits with phase space model:

$$BF(B^0_s \to \mu^+\mu^-\mu^+\mu^-) < 2.5 \times 10^{-9}$$
$$BF(B^0 \to \mu^+\mu^-\mu^+\mu^-) < 6.9 \times 10^{-10}$$

Improved by a factor 6.4 (B^0_s) and 9.5 (B^0) compared to previous limits

Set 95% CL upper limits for MSSM model with $m_{P(S)} = 214.3$ MeV (2.5 GeV) (*):

$$BF(B^0_s \to SP \to 4\mu) < 2.2 \times 10^{-9}$$
$$BF(B^0 \to SP \to 4\mu) < 6.0 \times 10^{-10}$$

(*) compared to phase space model: tiny change of reconstruction efficiency due to different **p** distribution of muons