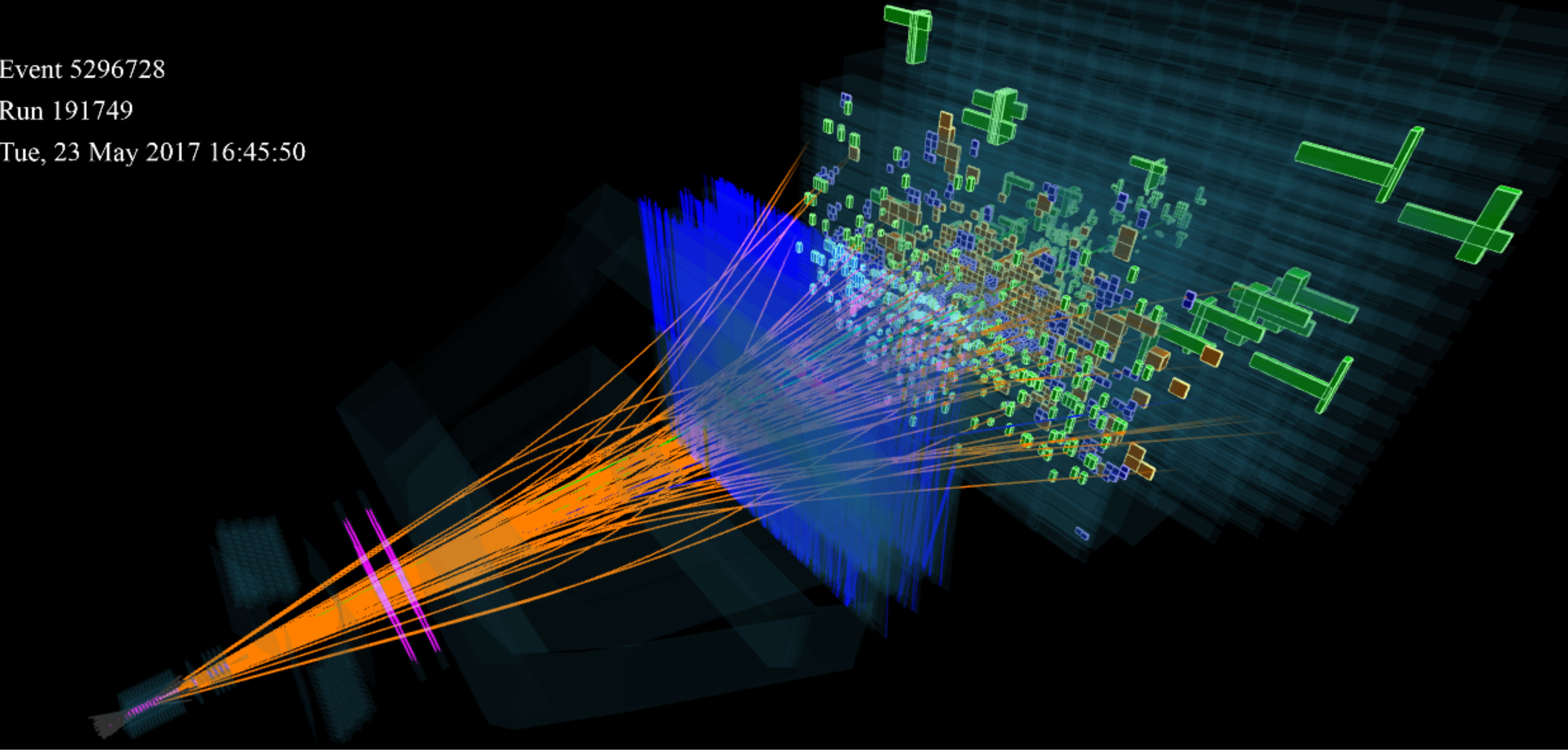

Lepton universality tests and rare decays of B mesons at LHCb

107° congresso nazionale della Società Italiana di Fisica

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on behalf of the LHCb collaboration
13/09/2021

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SOCIETÀ ITALIANA DI FISICA

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LHCb

CERN

Introduction

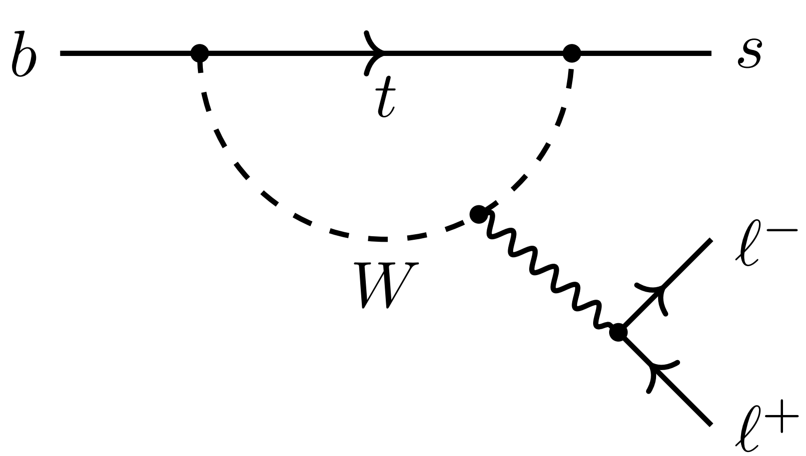
The power of indirect searches

- Precision measurements are a powerful tool to unveil new particles indirectly :
  - 1970 charm presence invoked from the suppression of $K^0 \to \mu^+\mu^-$ before the J/ψ discovery
  - 1973 3X3 CKM matrix is needed to explain the CP violation observed in kaons
  - 1987 top mass limit inferred from loop contribution in $B^0 - \overline{B}^0$ mixing: $m_t > 50$ GeV

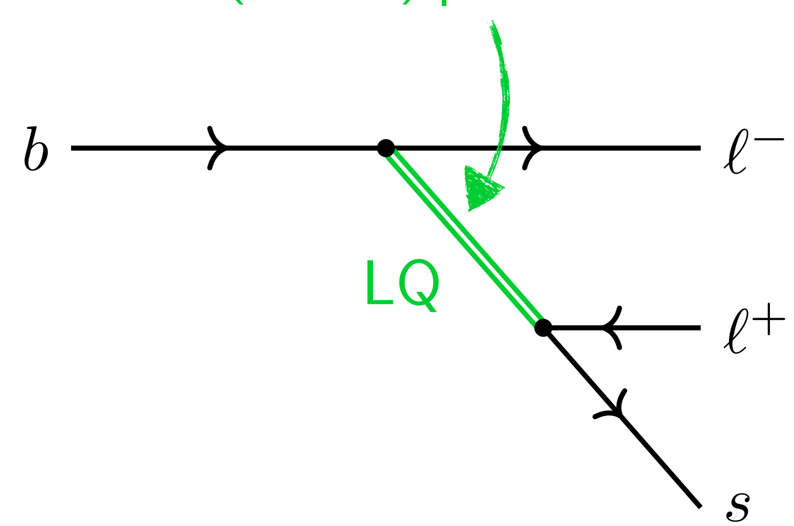
[PRD 2 (1970) 1285] [PTP 49 (1973) 652-657] [PLB 192 (1987) 245-252]

- Because of the large b mass, rare B decays offer a rich phenomenology for indirect searches of New Physics (NP) :

$b \to s\ell^+\ell^-$ are FCNC processes that can only occur via loop in the SM



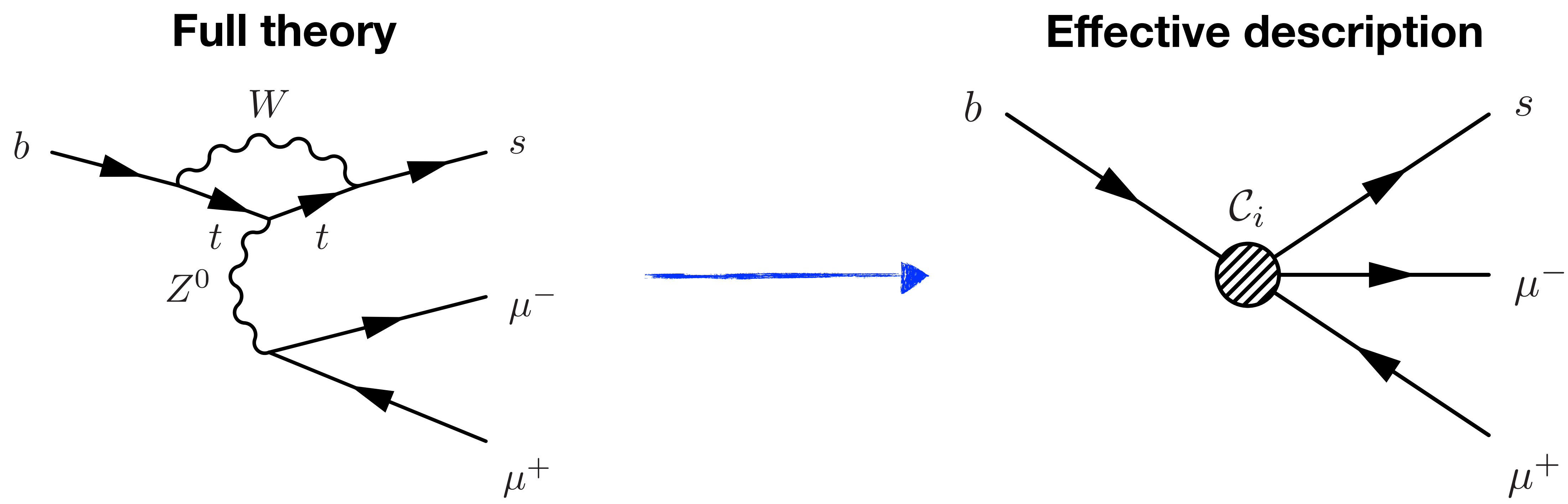
observables are altered by new (virtual) particles



Effective theory for rare B decays

[RMP 68 (1996) 1125-1144]

- $b \to s\ell^+\ell^-$ decays can be described with an "Effective Hamiltonian", where high- and low-energy contributions are factorised ($M_b \ll M_W$):



- point-like interaction as in the Fermi description of the neutron decay

$$\mathcal{H}_{eff} = \frac{G_F}{\sqrt{2}} \sum_i V^i_{CKM} C_i(\lambda) \mathcal{O}_i(\lambda)$$

- Local operators (long-distance): the corresponding form factor is computed with, e.g., lattice QCD
- Wilson coefficients (short-distance): evaluated in perturbation theory

Probing New Physics with rare B decays

- SM operators for $b \to s\ell^+\ell^-$:

$$\mathcal{O}_9^{(\prime)} = \left(\bar{s}P_{\mathrm{L(R)}}b\right)\left(\bar{\ell}\gamma^\mu\ell\right)$$
$$\mathcal{O}_{10}^{(\prime)} = \left(\bar{s}P_{\mathrm{L(R)}}b\right)\left(\bar{\ell}\gamma^\mu\gamma^5\ell\right)$$

- NP can alter $C_i^{(\prime)}$ but also introduce new operators

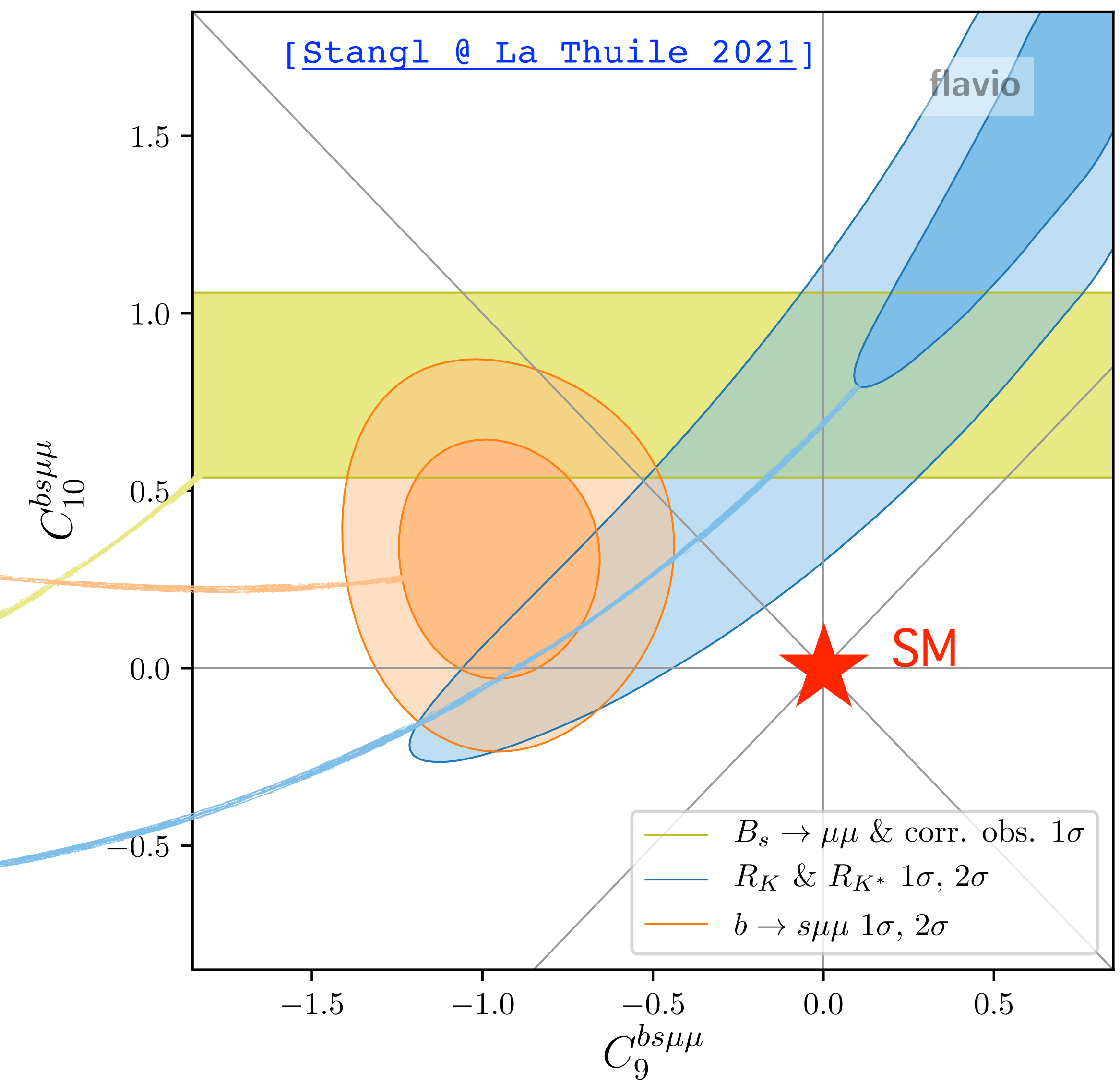
$$\Delta\mathcal{H}_{\mathrm{NP}} = \frac{c_i}{\Lambda_{\mathrm{NP}}^2}\mathcal{O}_i$$

Precision measurements go well beyond collision energies!

- The latest global fits prefer NP contributions to C_9 and C_{10}
- Due to several "anomalies", in order of precision from the theory:

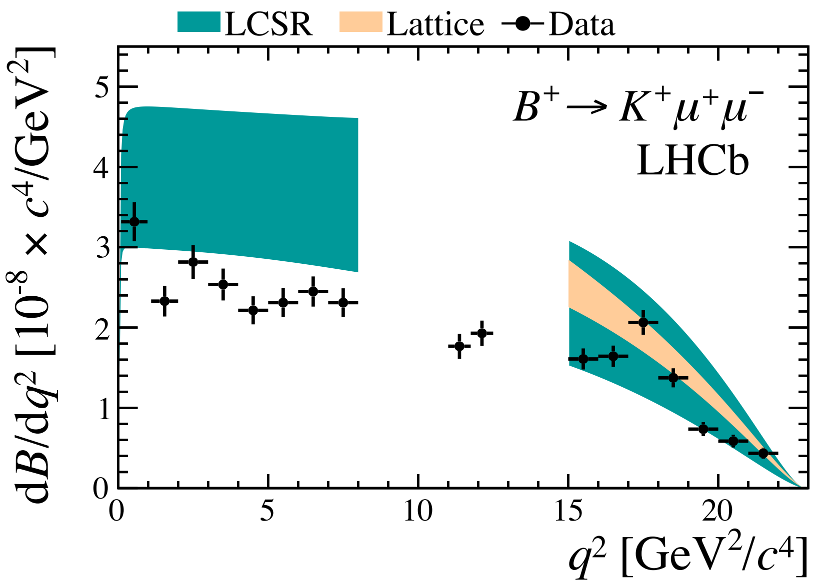
1. $b \to s\mu^+\mu^-$ differential branching fractions and angular observables
2. $\mathscr{B}(B_s^0 \to \mu^+\mu^-)$
3. R_K

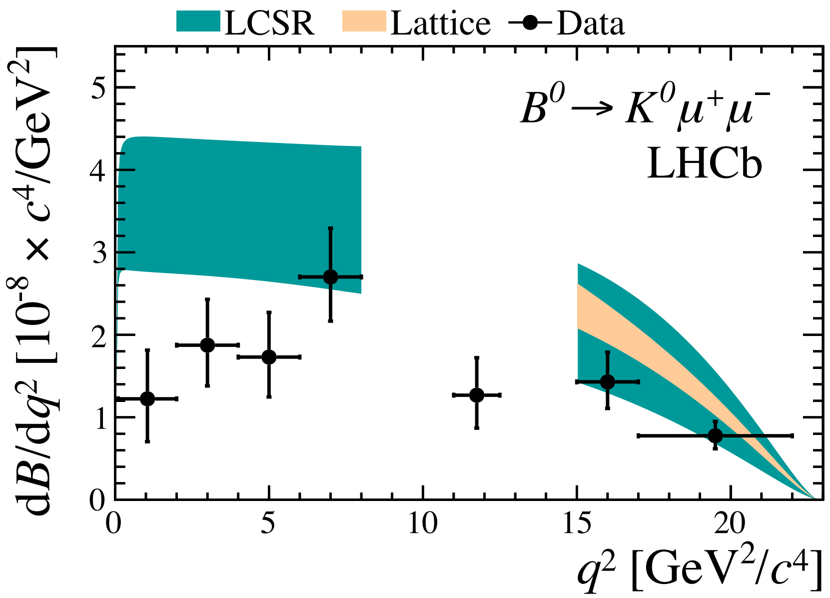
this talk

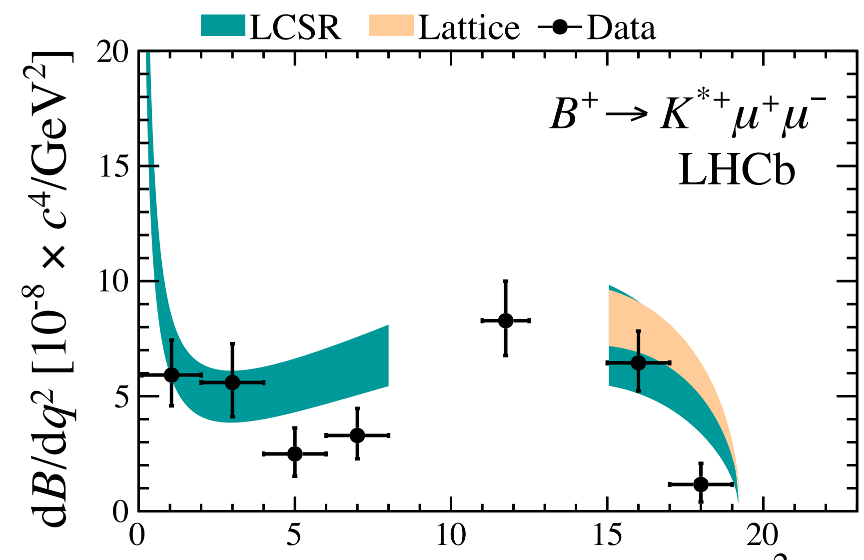


Anomalies in $b \to s\mu^+\mu^-$ differential rates

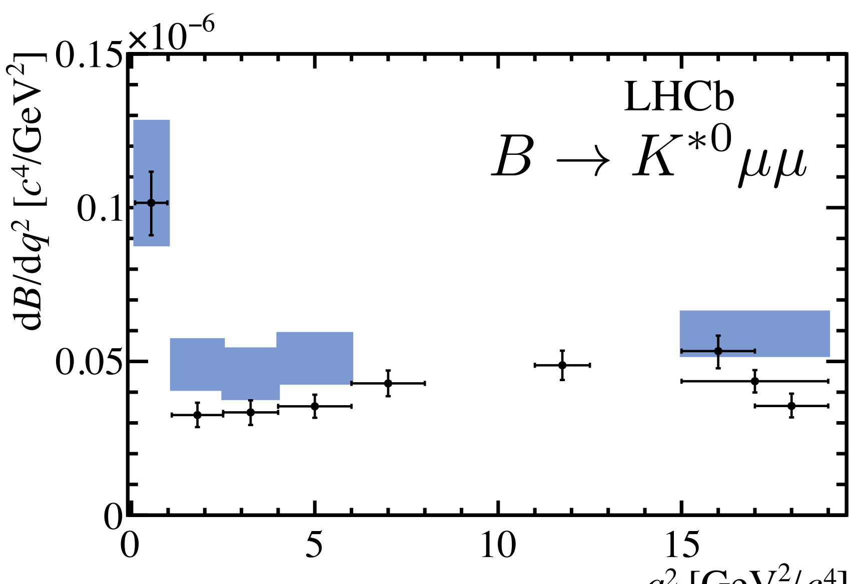
- Since Run 1, differential $b \to s\mu^+\mu^-$ rates ($q^2 = m^2_{l^+l^-}$) at LHCb indicate a downward deviation wrt SM



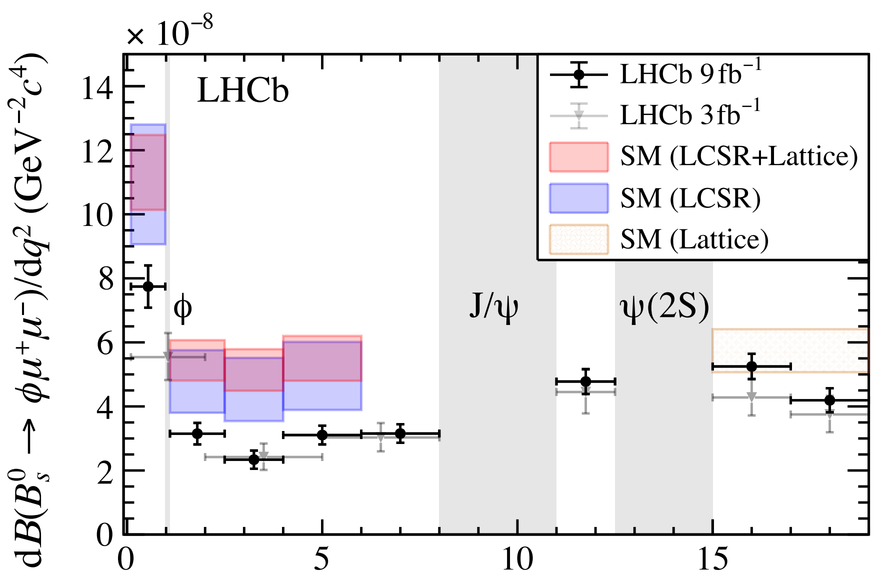




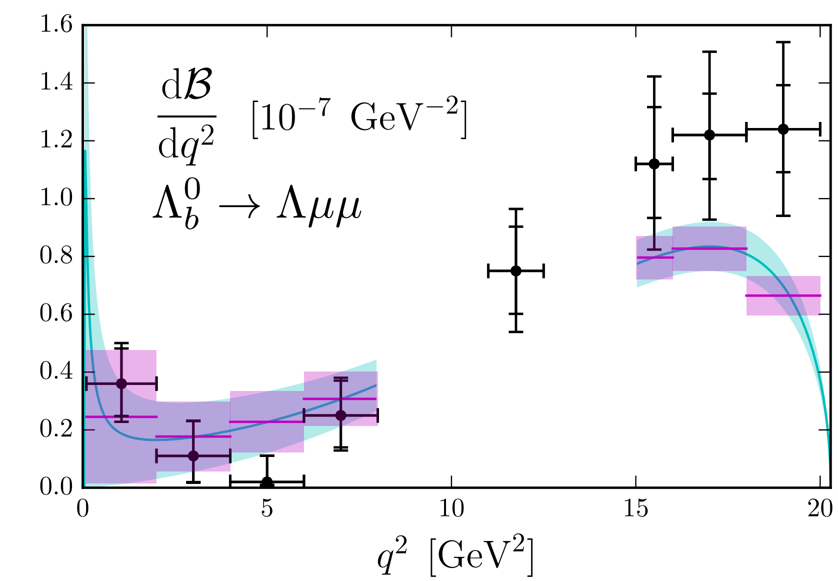
[JHEP 1406 (2014) 133]



[JHEP 1602 (2016) 104]



[LHCb-PAPER-2021-014]



[JHEP 1809 (2018) 145][PRD 93 (2016) 074501]

- Weaker muon coupling or a common issue with the hadronic interactions (i.e. form factors)?

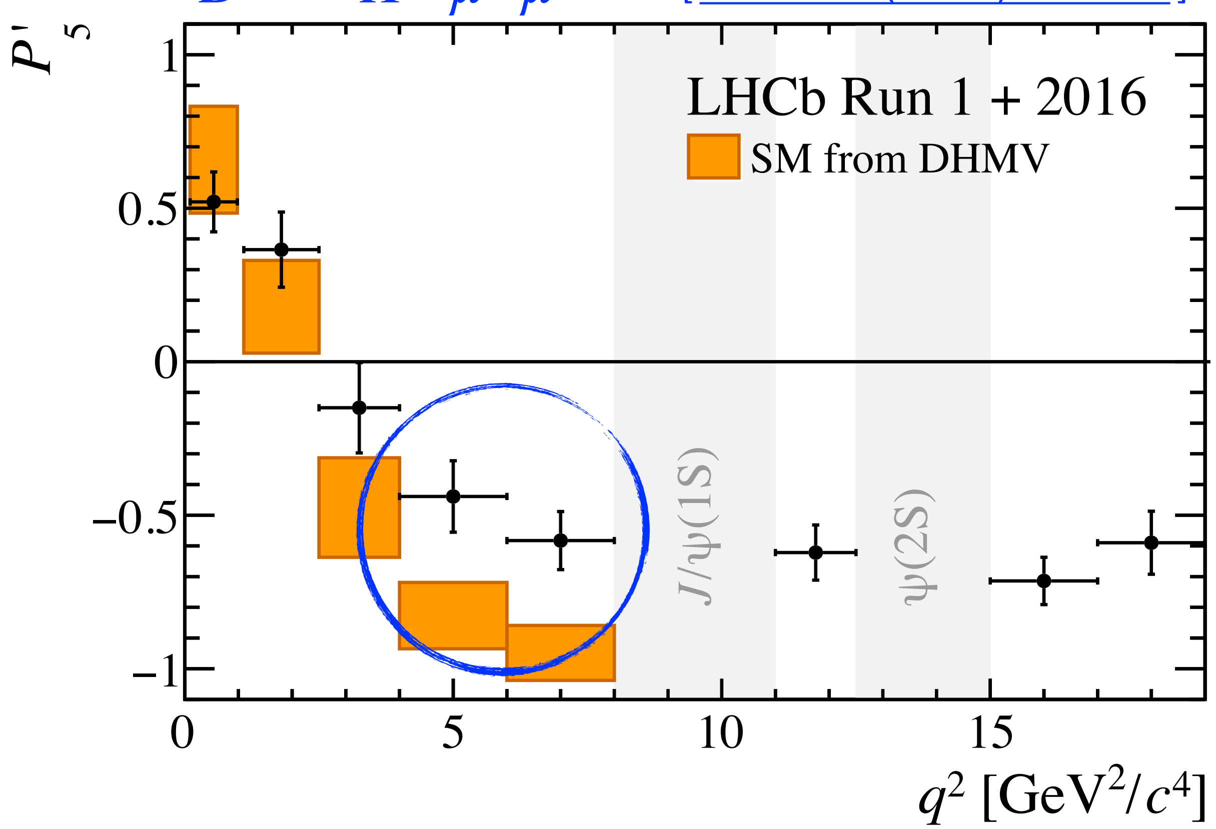
Angular analysis of $B^{0(+)} \to K^{*0(+)}\mu^+\mu^-$ decays

- Build optimised angular observable with reduced hadronic uncertainty

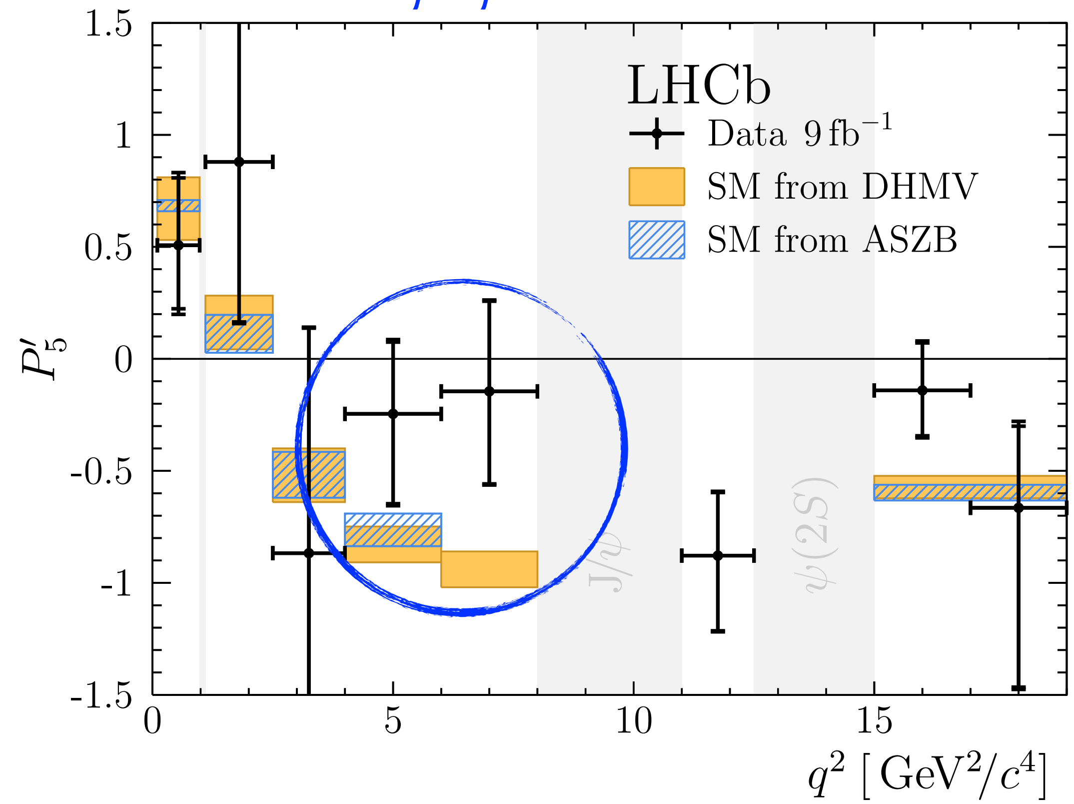
- LHCb measurements of P_5' on $B^0 \to K^{*0}\mu^+\mu^-$ decays deviate from the SM by $2.5\,\sigma$ and $2.9\,\sigma$

- New measurement on $B^+ \to K^{*+}\mu^+\mu^-$ goes in the same direction

$B^0 \to K^{*0}\mu^+\mu^-$ [PRL 125 (2020) 011802]

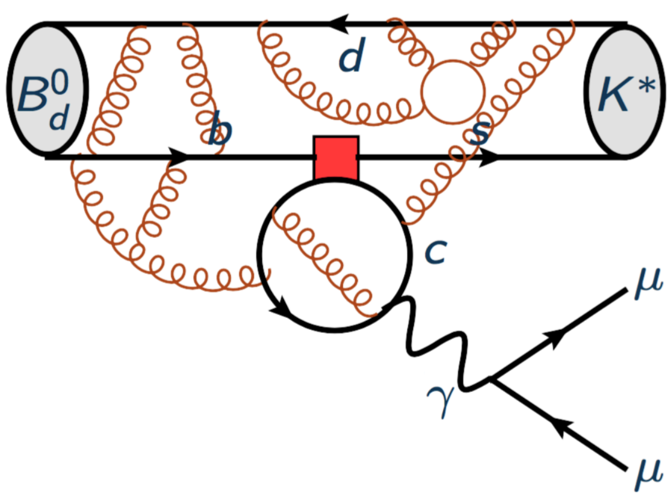


$B^+ \to K^{*+}\mu^+\mu^-$ [PRL 126 (2021) 161802]



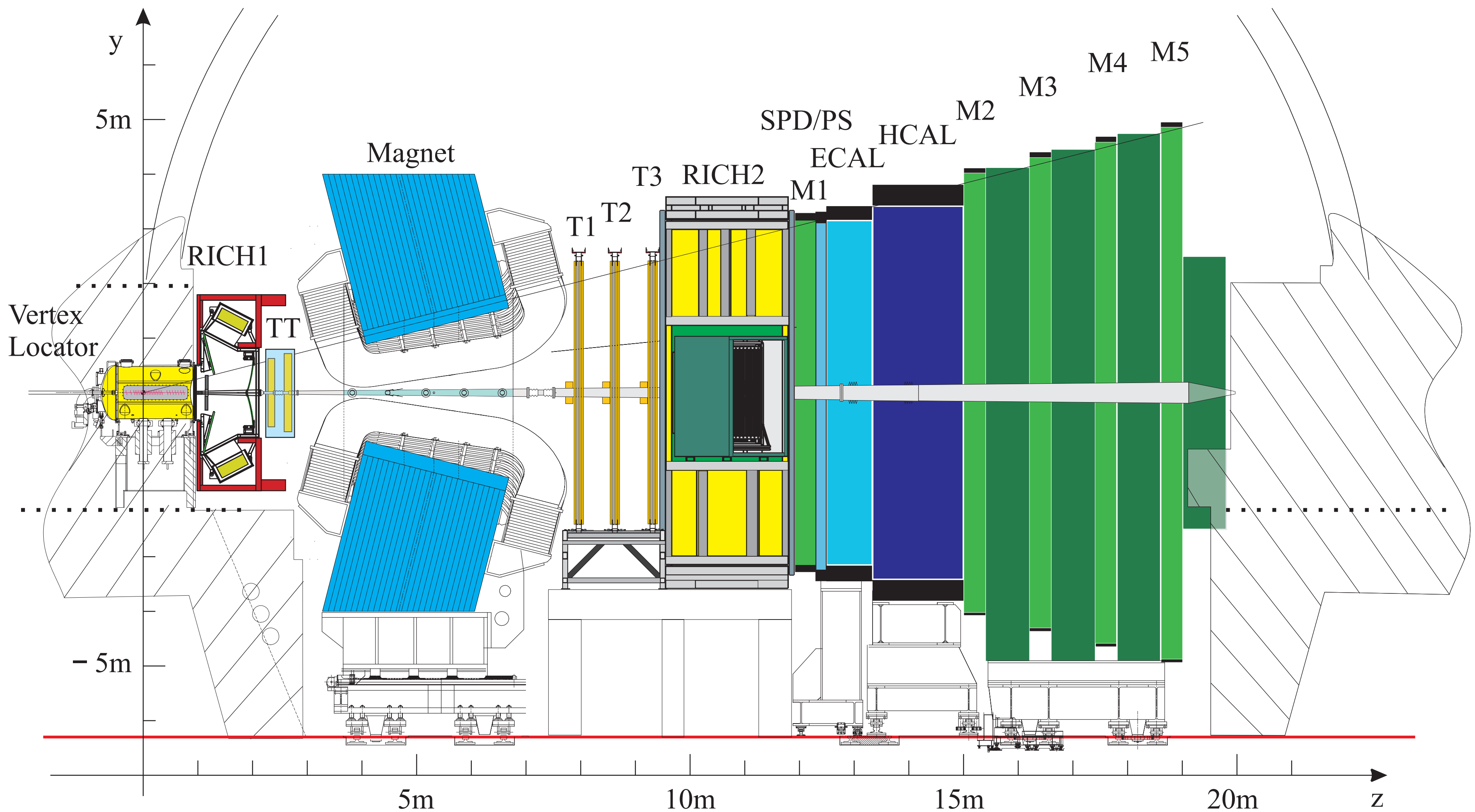
- However, non-trivial charm loop contributions are present close to the resonant regions

See e.g. [this talk by M. Ciuchini]

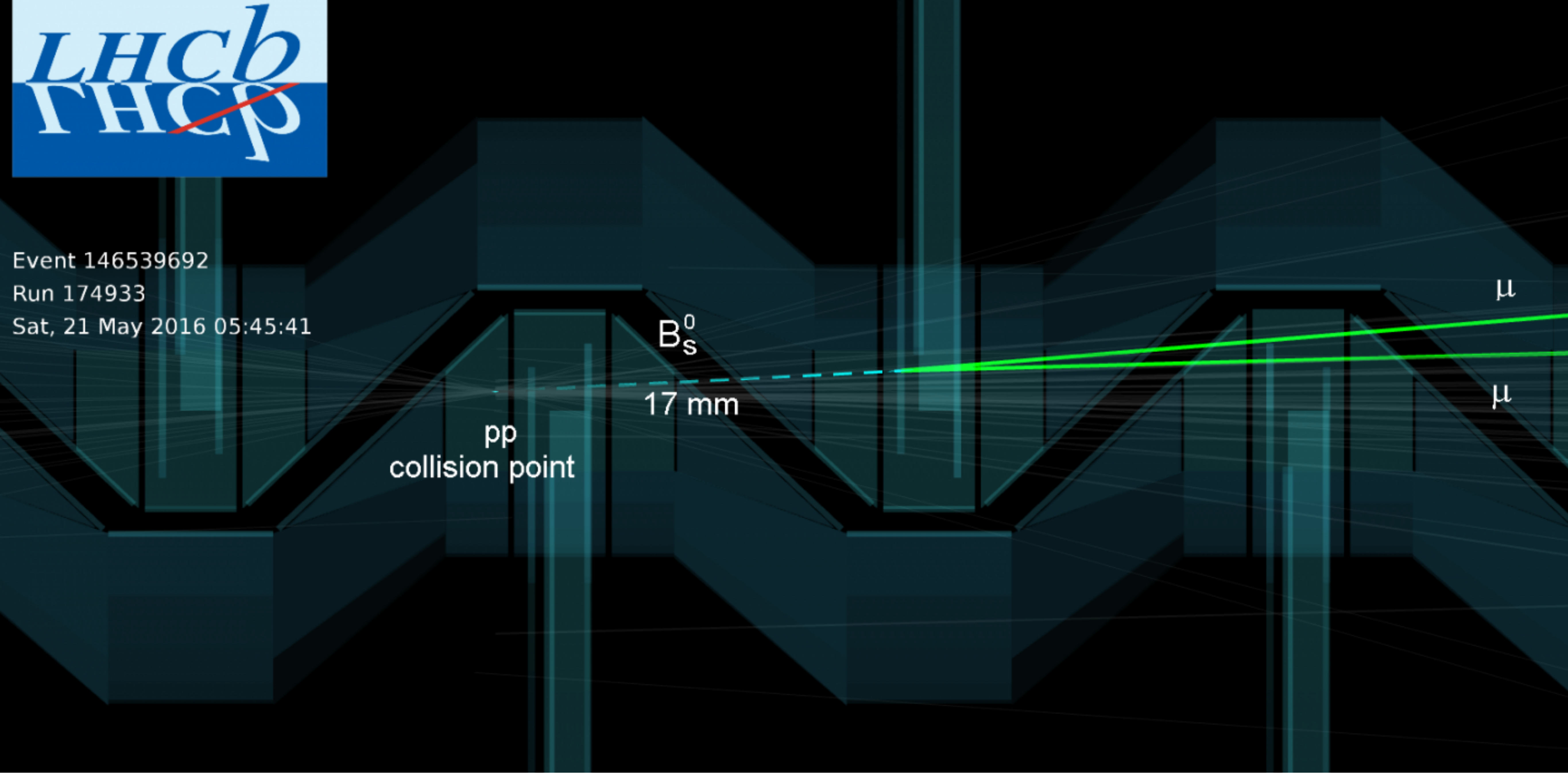


The LHCb detector

[JINST 3 (2008) S08005]
[IJMP A 30 (2015) 1530022]



- High vertex resolution (VELO)
  $\sigma_{\mathrm{IP}} = 15 + 29/p_T\ \mu\mathrm{m}$
  (B travel distance $\mathcal{O}(1\ \mathrm{cm})$)
- Low momentum muon trigger
  $p_{T_\mu} > 1.75$ GeV (2018)
- Particle identification capabilities (RICH+CALO+MUON)
  $\epsilon_\mu \sim 98\,\%$ with $\epsilon_{\pi\to\mu} \lesssim 1\,\%$
- Excellent momentum resolution (T stations)
  $\sigma_p/p = 0.5 - 1.0\,\%\ (p \in [2{,}200]\ \mathrm{GeV})$
  → narrow mass peak



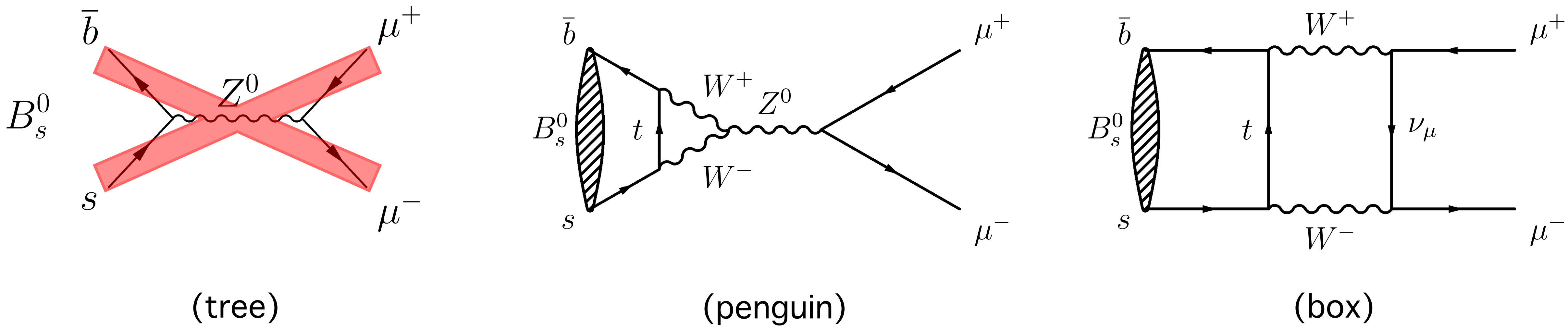
Legacy analysis of $B^0_{(s)} \to \mu^+\mu^-$ decays

[LHCB-PAPER-2021-007]

[LHCB-PAPER-2021-008]

$B^0_{(s)} \to \mu^+\mu^-$ decays in the SM

- In the SM, B^0 and B^0_s decays to two muons are FCNC and helicity suppressed :



$$\mathcal{B}(B^0_q \to \mu^+\mu^-)_{\rm SM} = \frac{\tau_{B_q} G_F^4 M_W^4 \sin^4\theta_W}{8\pi^5} |C_{10}^{\rm SM} V_{tb} V^*_{tq}|^2 f^2_{B_q} m_{B_q} m^2_\mu \sqrt{1 - \frac{4m^2_\mu}{m^2_{B_q}}} \frac{1}{1-y_q} \qquad q = d, s$$

single Wilson coefficient & single hadronic constant (known at $\simeq 0.5\,\%$!)

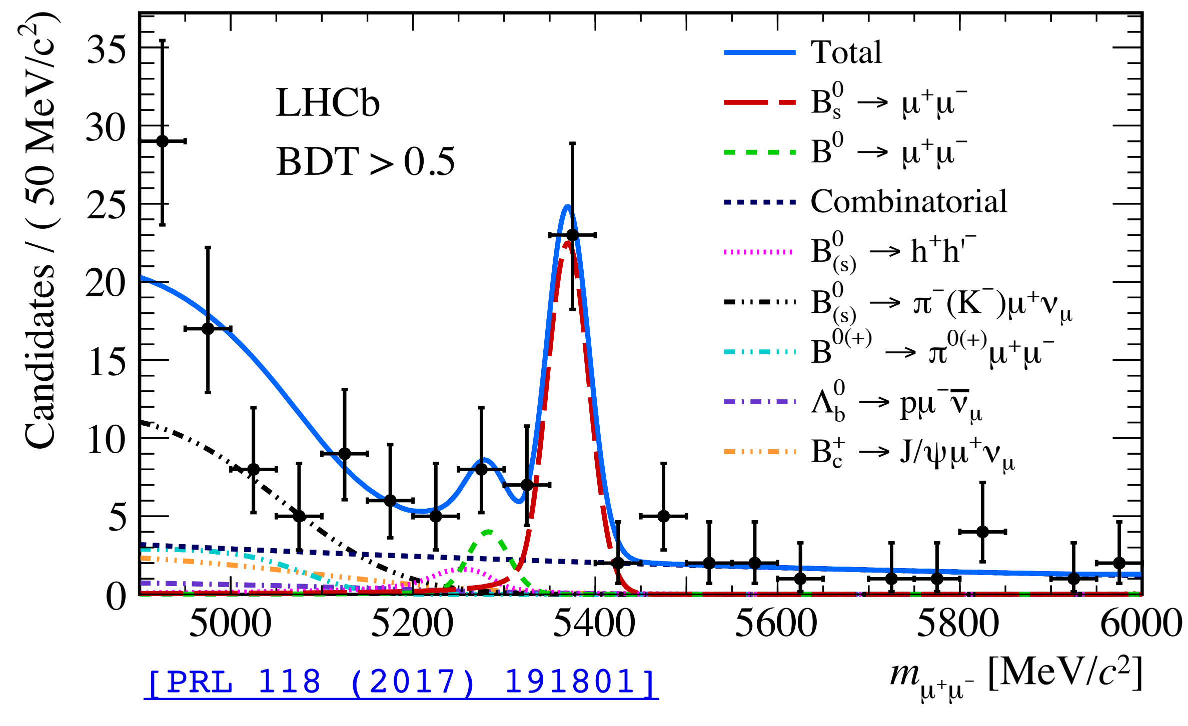
[PRD 98 (2019) 074512]

- Golden channel: very clean prediction in the SM

$$\mathcal{B}(B^0_s \to \mu^+\mu^-)_{\rm SM} = (3.66 \pm 0.14) \times 10^{-9}$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-)_{\rm SM} = (1.03 \pm 0.05) \times 10^{-10}$$ [JHEP 10 (2019) 232]

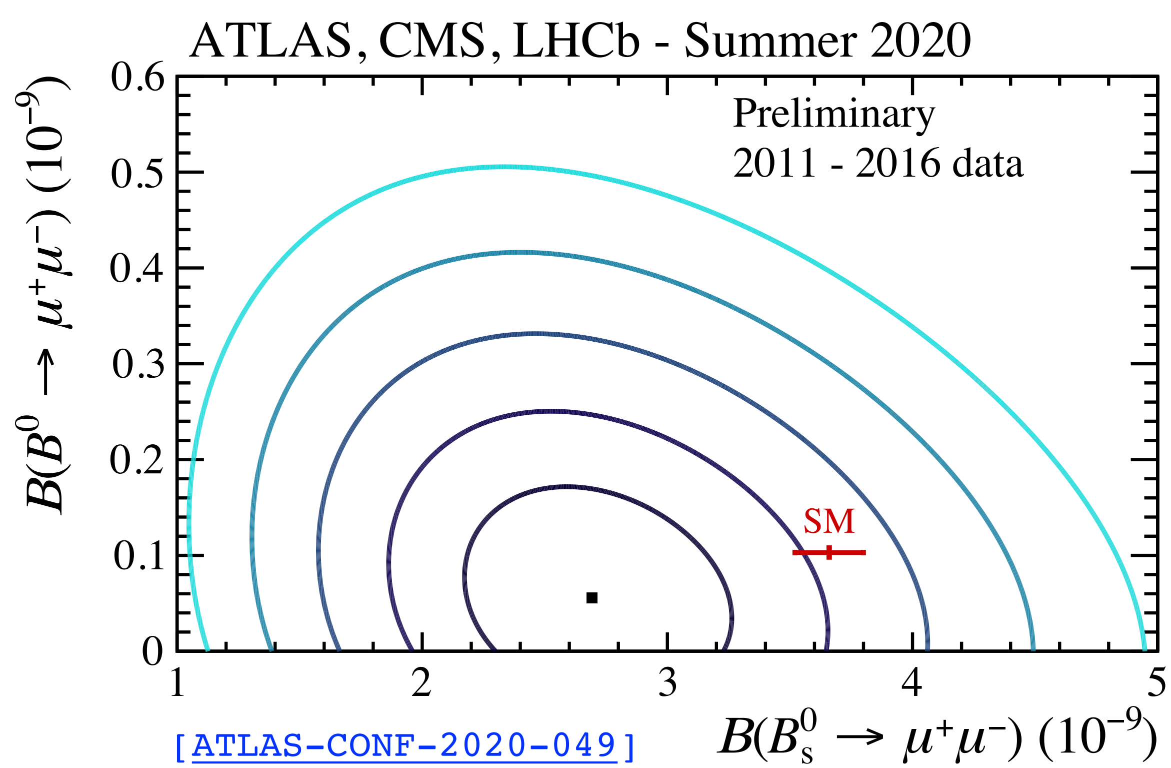
$B^0_{(s)} \to \mu^+\mu^-$ measurements

- 1984 The search begins at CLEO
  $\mathcal{B}(B^0_s \to \mu^+\mu^-) < 2 \times 10^{-4}$ (90 % CL) [PRD 30 (1984) 11]
- 2015 First observation of $B^0_s \to \mu^+\mu^-$ with CMS + LHCb (Run 1 data) [Nature 522 (2015) 68–72]
- 2017 First observation of $B^0_s \to \mu^+\mu^-$ with a single experiment by LHCb ($4.4\ \mathrm{fb}^{-1}$)
  $\mathcal{B}(B^0_s \to \mu^+\mu^-) = (3.0 \pm 0.6^{+0.3}_{-0.2}) \times 10^{-9}$



[PRL 118 (2017) 191801]

- 2020 combination of ATLAS, CMS and LHCb:
  - $\mathcal{B}(B^0_s \to \mu^+\mu^-) = (2.69^{+0.37}_{-0.35}) \times 10^{-9}$
  - 2.1σ deviation from the SM



[ATLAS-CONF-2020-049]

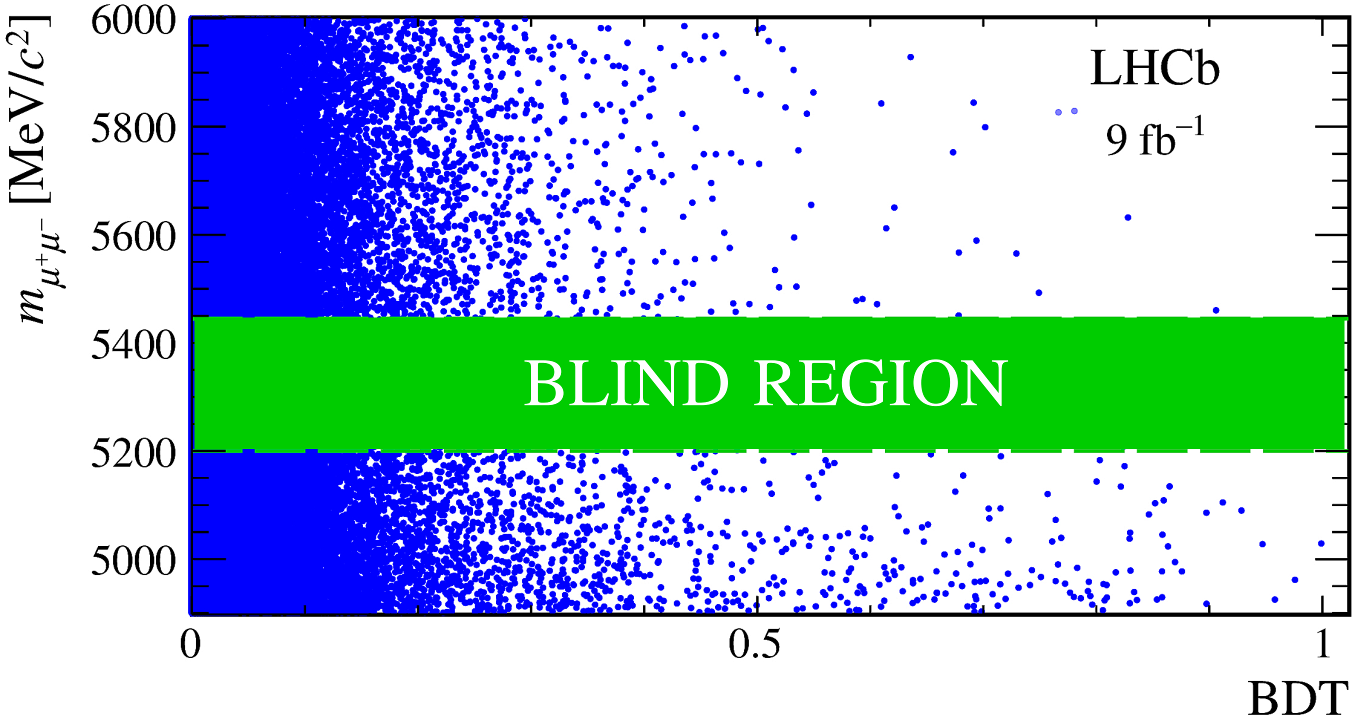
- 2021 Will show here the "legacy measurement" of LHCb on the full Run 1 + Run 2 data ($9\ \mathrm{fb}^{-1}$)

Analysis strategy

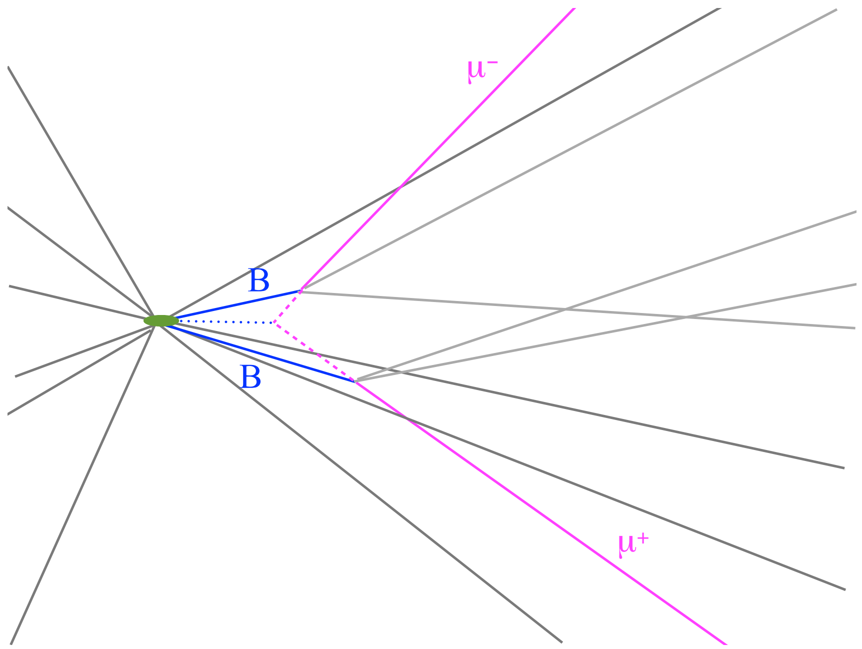
- The strategy is well established since 2017 but introduces several improvements

- Select muon pairs with $m_{\mu^+\mu^-} \in [4900,6000]$ MeV forming a displaced vertex
- Signal shape parameters calibrated from data
- Normalisation with $B^+ \to J/\psi(\to \mu^+\mu^-)K^+$ and $B^0 \to K^+\pi^-$. We expect for $\mathrm{BDT} > 0.25$:

$$N(B_s^0 \to \mu^+\mu^-)_{\mathrm{SM}} \approx 104$$
$$N(B^0 \to \mu^+\mu^-)_{\mathrm{SM}} \approx 11$$



- The pre-selected dataset is dominated by combinatorial background
- Use a a multivariate classifier "BDT" to reject it, mainly exploiting isolation and vertex detachment
- Events categorised in BDT bins: simultaneous mass fit to measure $\mathscr{B}$

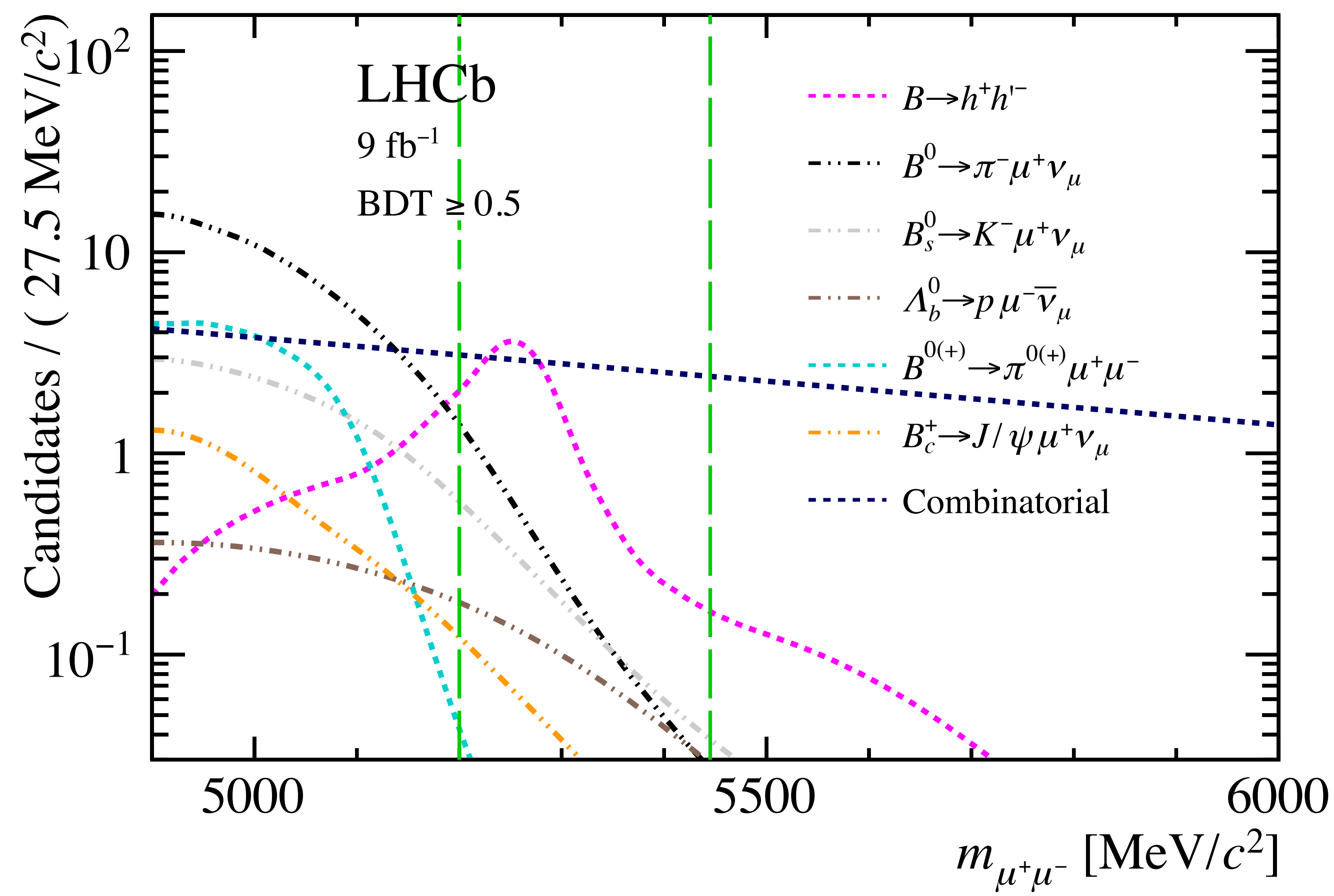


Backgrounds

[LHCB-PAPER-2021-007]
[LHCB-PAPER-2021-008]

Apply a strong PID cut on both muons, three classes of backgrounds remain:

1. Combinatorial
2. Semileptonic backgrounds (with either 2 real muons or 1 misID hadron)
3. $B^0_{(s)} \to h^+ h^{'-} \to \mu^+\mu^-$ (double misID)



- Estimates from simulation, PID efficiency calibrated on data
- The background components are gaussian-constrained in the fit

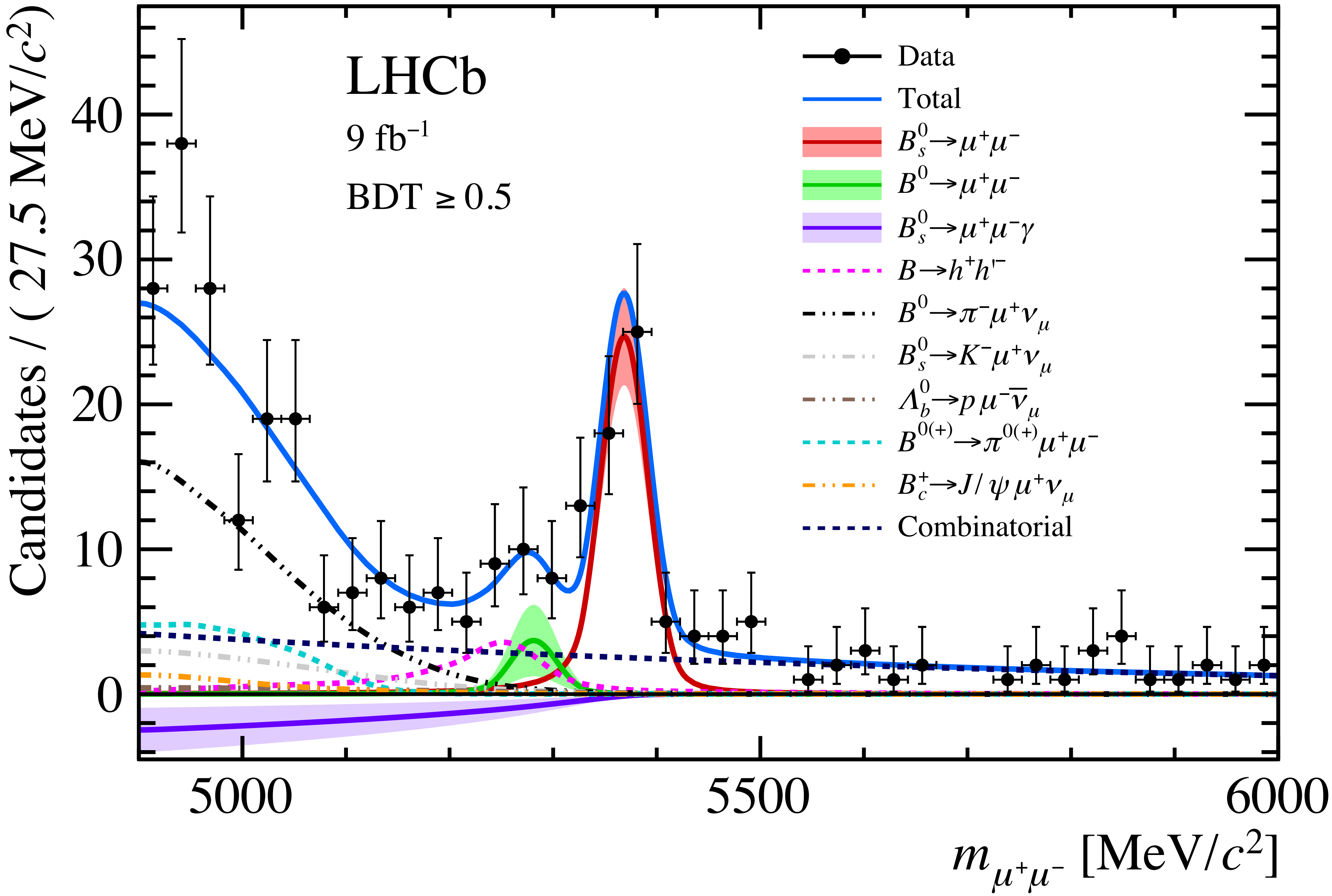
BDT > 0.5

$B^0 \to \pi^-\mu^+\nu_\mu$	91 ± 4	[PDG]
$B^0_s \to K^-\mu^+\nu_\mu$	23 ± 3	[PRL 126 (2021) 081804]
$\Lambda^0_b \to p\mu^-\overline{\nu}_\mu$	4 ± 2	[Nature Physics 10 (2015) 1038]
$B^{+(0)} \to \pi^{+(0)}\mu^+\mu^-$	26 ± 3	[JHEP 10 (2015) 034] & [PRD 86 (2012) 114025]
$B^+_c \to J/\psi(\mu^+\mu^-)\mu^+\nu_\mu$	7.2 ± 0.3	[PRD 100 (2019) 112006]
$B^0_{(s)} \to h^+h^{'-} \to \mu^+\mu^-$	22 ± 1	[PDG]

(LHCb inputs shown in red)

Mass fit

[LHCB-PAPER-2021-007]
[LHCB-PAPER-2021-008]



- $\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.09^{+0.46+0.15}_{-0.43-0.11}) \times 10^{-9}$ (10.8σ)

- $B^0 \to \mu^+\mu^-$ and $B_s^0 \to \mu^+\mu^-\gamma$ compatible with background only at 1.7σ and 1.5σ

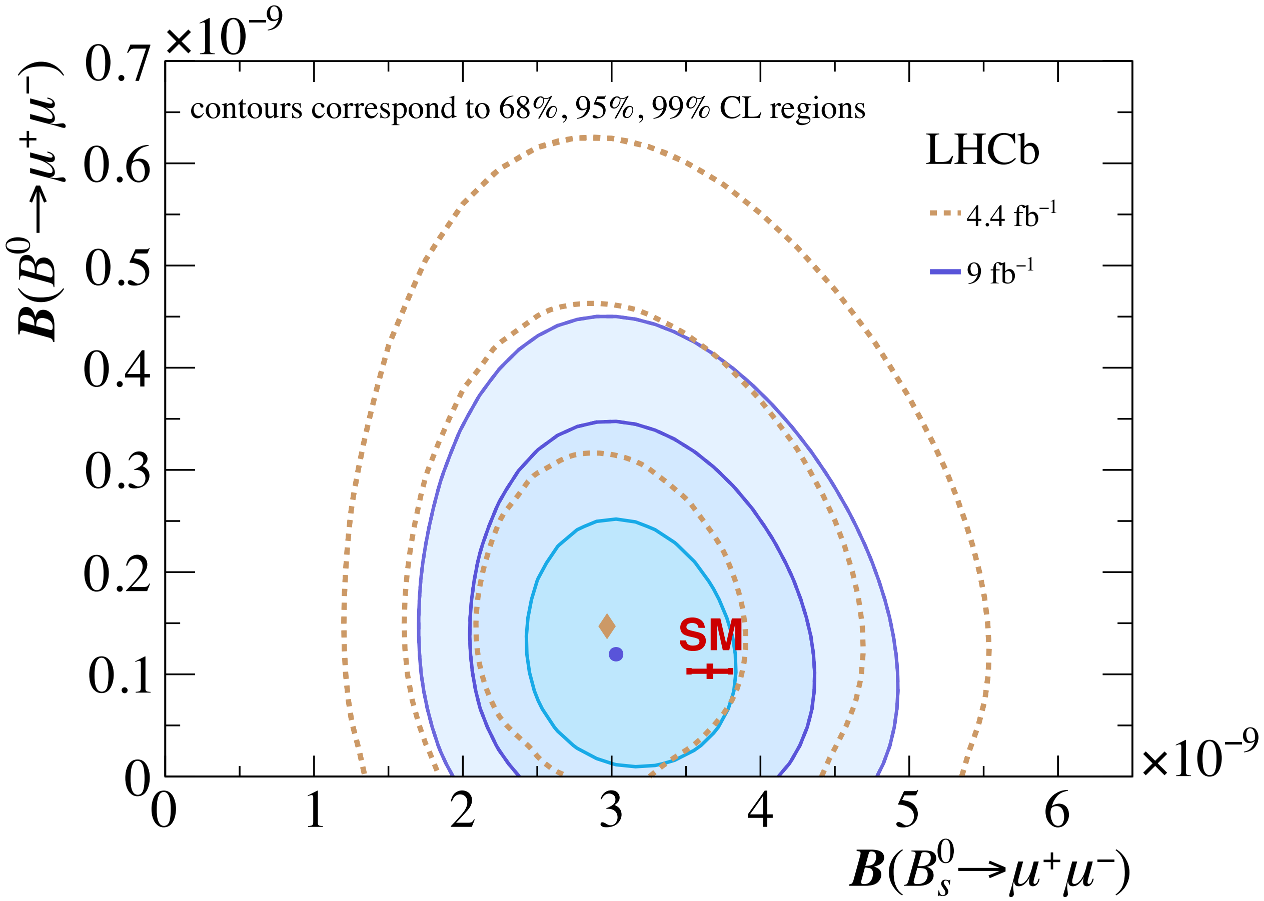
Results

[LHCB-PAPER-2021-007]
[LHCB-PAPER-2021-008]

- $\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.09^{+0.46+0.15}_{-0.43-0.11}) \times 10^{-9}$ spot on previous LHCb result and SM compatible
- Limits set with the $\mathrm{CL_s}$ method:
  [J. Phys. G28 (2002) 2693]

  $\mathcal{B}(B^0 \to \mu^+\mu^-) < 2.6 \times 10^{-10}$ (95 % CL)

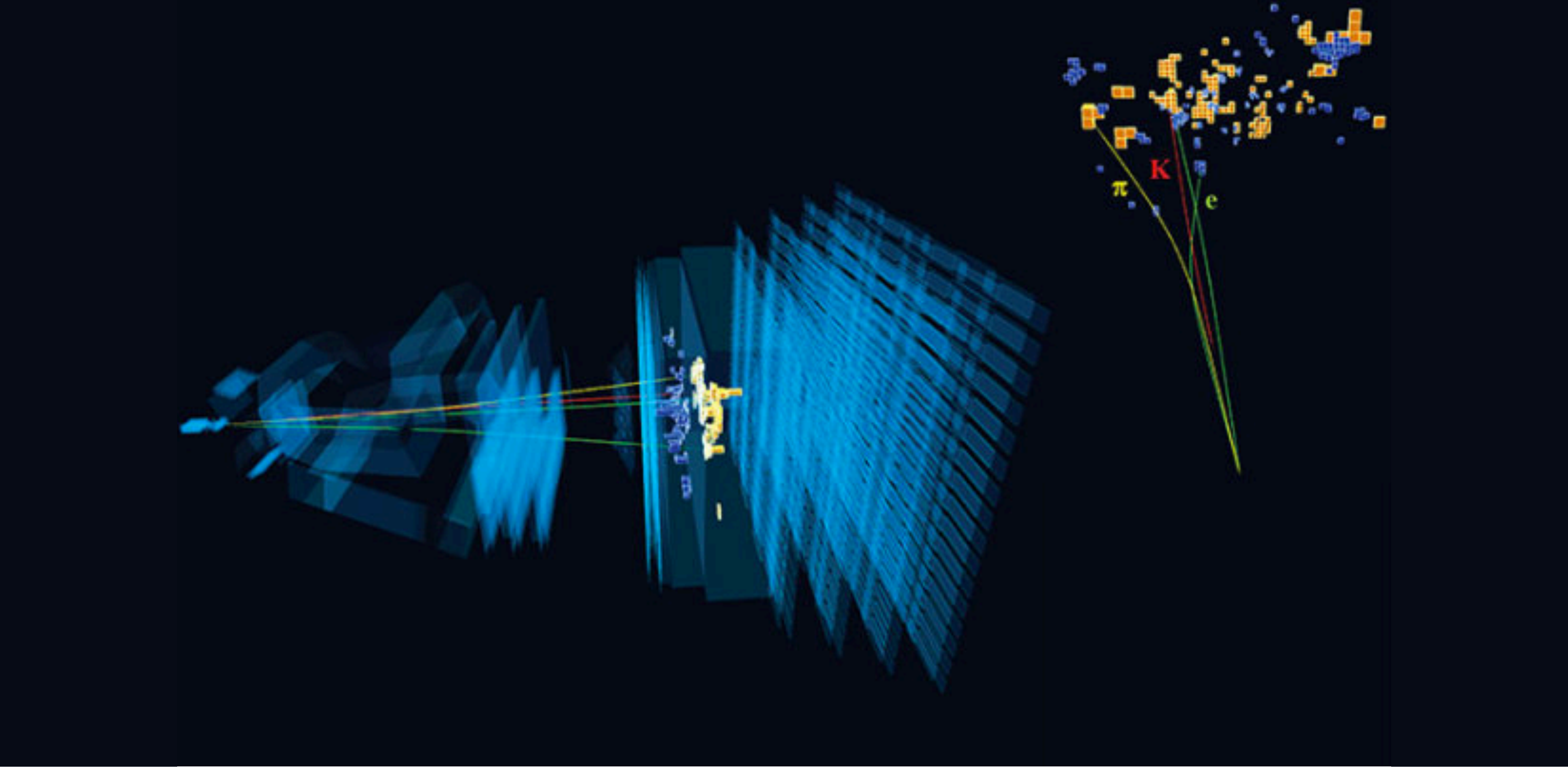
  $\mathcal{B}(B_s^0 \to \mu^+\mu^-\gamma)_{m_{\mu^+\mu^-}>4.9\ \mathrm{GeV}} < 2.0 \times 10^{-9}$ (95 % CL)



- Achieved the most precise single-experiment measurement of the $\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ with $\sim 15\,\%$ error
- Most precise measurement of the $B_s^0 \to \mu^+\mu^-$ effective lifetime (see →backup)
- $\mathcal{B}(B^0 \to \mu^+\mu^-)$ limit at 2.5X the SM prediction: its observation in Run 3 heavily relies on the PID

[JINST 15 (2020) T12005]

- LHC synergy: ATLAS and CMS can achieve similar precision
- LHCb + ATLAS + CMS combination with full luminosity expected to reach $< 10\,\%$ precision

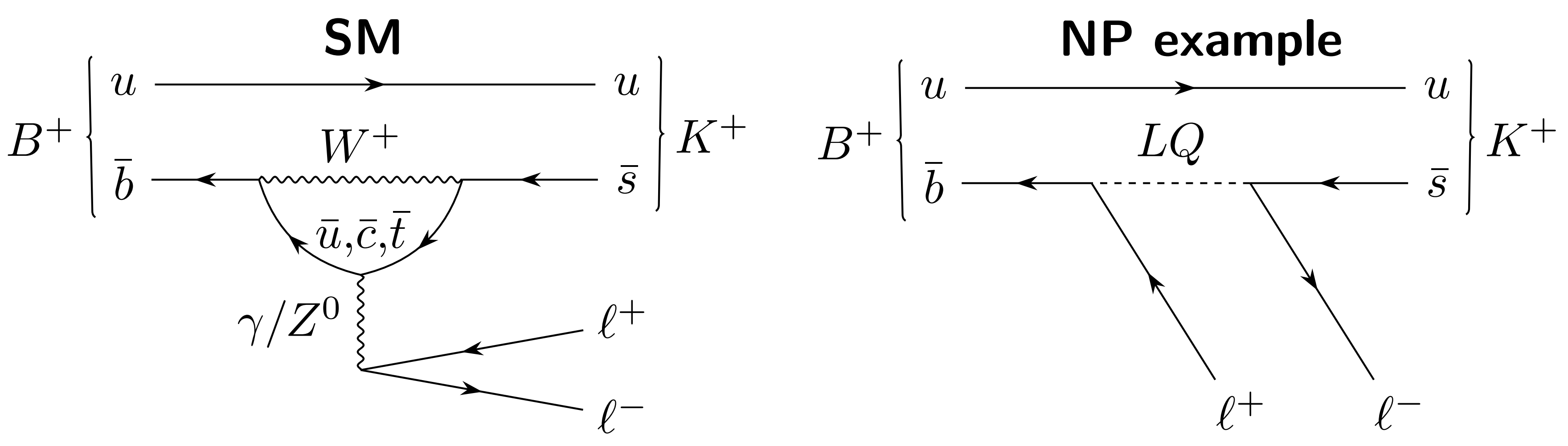


Legacy measurement of R_K

[LHCB-PAPER-2021-004]

The cleanest observable: R_K

- $B^+ \to K^+ l^+ l^-$ is experimentally the easiest $b \to s l^+ l^-$ channel to reconstruct at LHCb
- SM process is FCNC with $\mathscr{B} \sim 10^{-7}$



- To avoid hadronic uncertainty, build observables with reduced contributions from QCD
- The R_H $(H = K, K^*, \ldots)$ ratio is free from hadronic uncertainties to a large extent and probes μ/e coupling strengths:

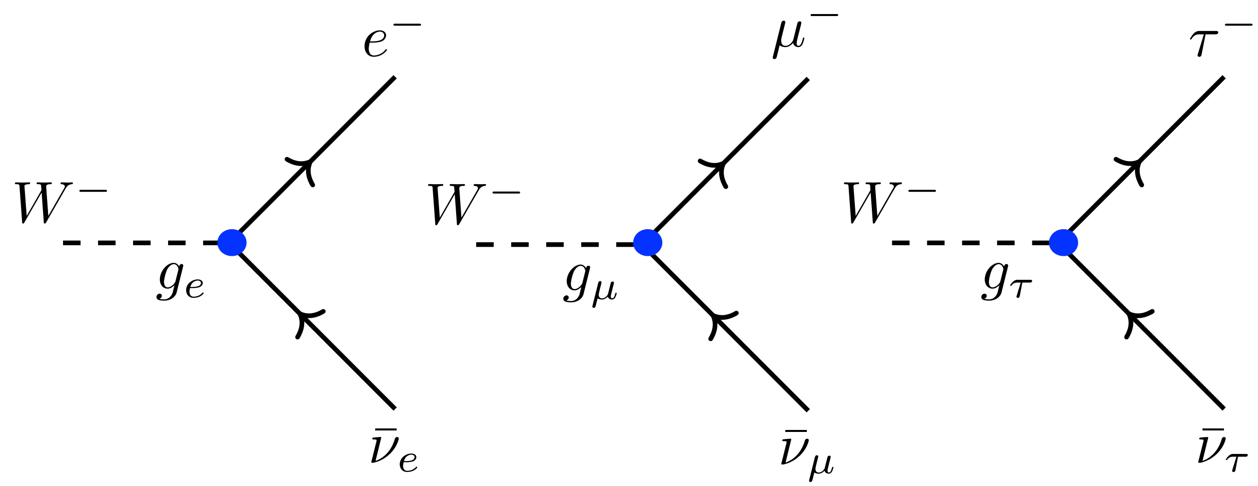
$$R_H = \frac{\int_{q^2_{\min}}^{q^2_{\max}} \frac{\mathrm{d}\Gamma[B \to H\mu^+\mu^-]}{\mathrm{d}q^2} \mathrm{d}q^2}{\int_{q^2_{\min}}^{q^2_{\max}} \frac{\mathrm{d}\Gamma[B \to He^+e^-]}{\mathrm{d}q^2} \mathrm{d}q^2}$$

$q^2 = m^2(l^+l^-)$

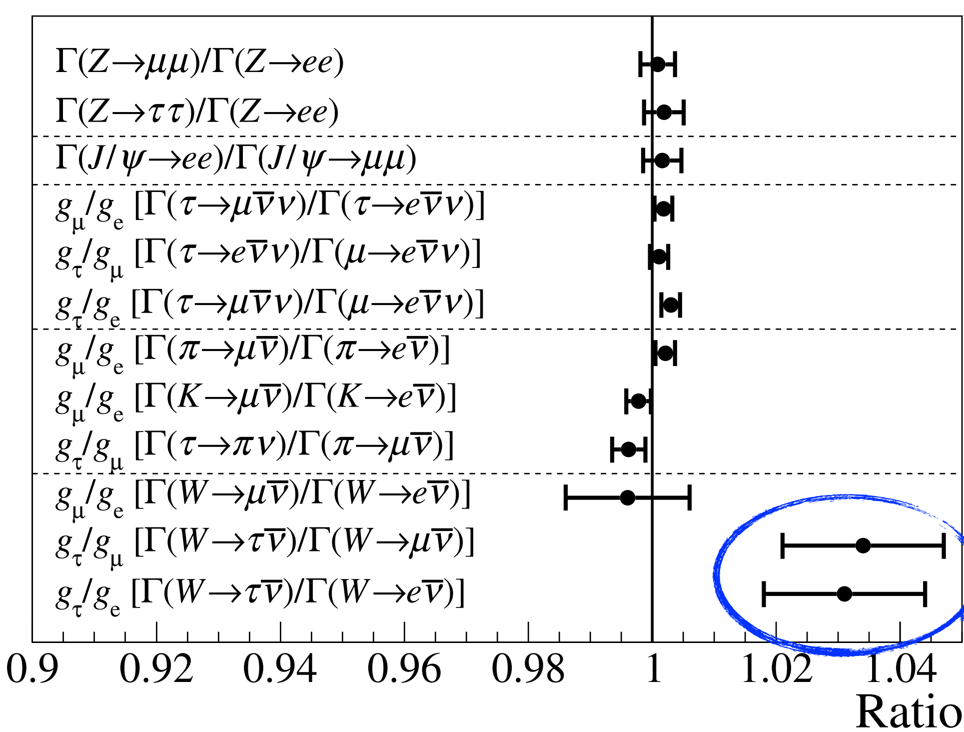
The SM predicts $R_K = 1$ with $\mathcal{O}(1\%)$ uncertainty [EPJC 76 (2016) 8, 440]

Lepton Flavour Universality

- In the SM, the EW couplings of the leptons are accidentally equal ($g_e = g_\mu = g_\tau$), their only difference is the masses (Lepton Flavour Universality)

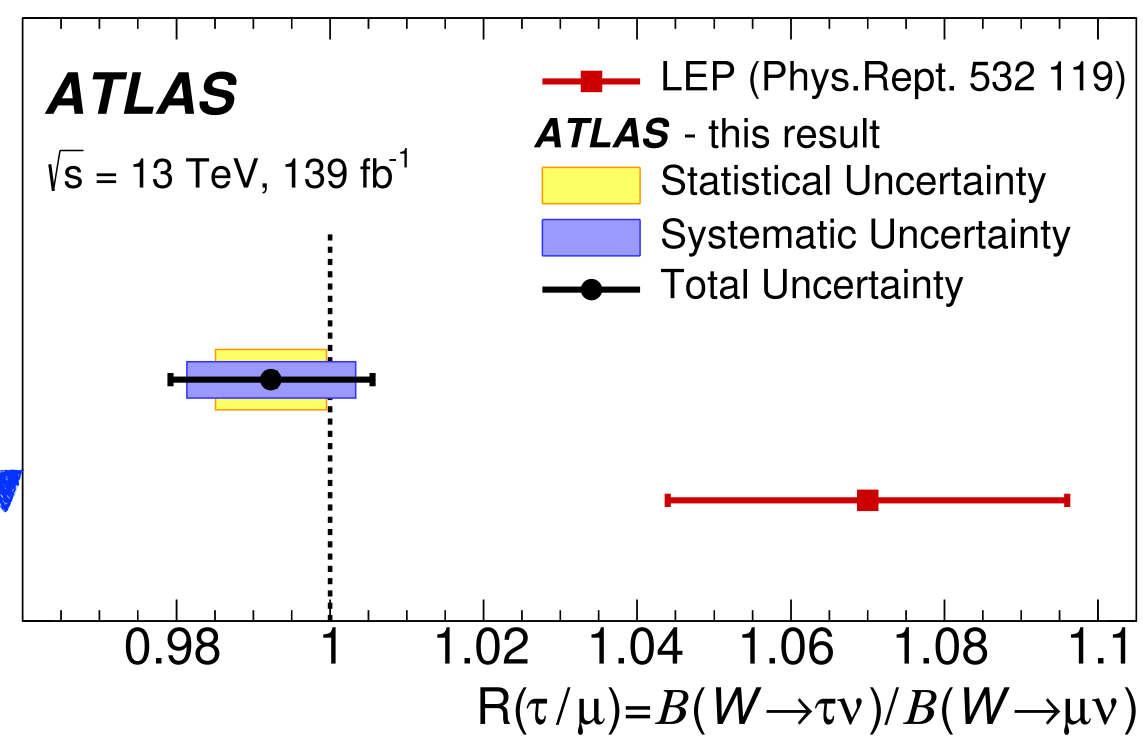


- Well established property in $Z \to ll$; $J/\psi \to ll$; $\pi, K \to l\nu$ (with sub-percent precision):



[PRD 98 (2018) 030001]

updated!

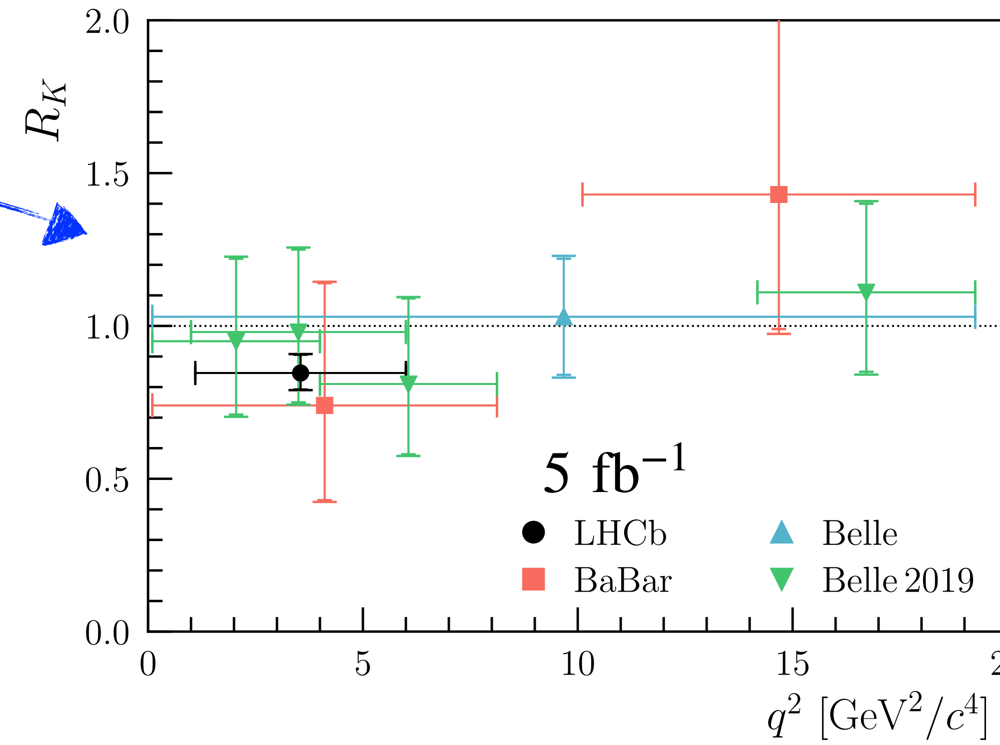


[NP 17 813–818 (2021)]

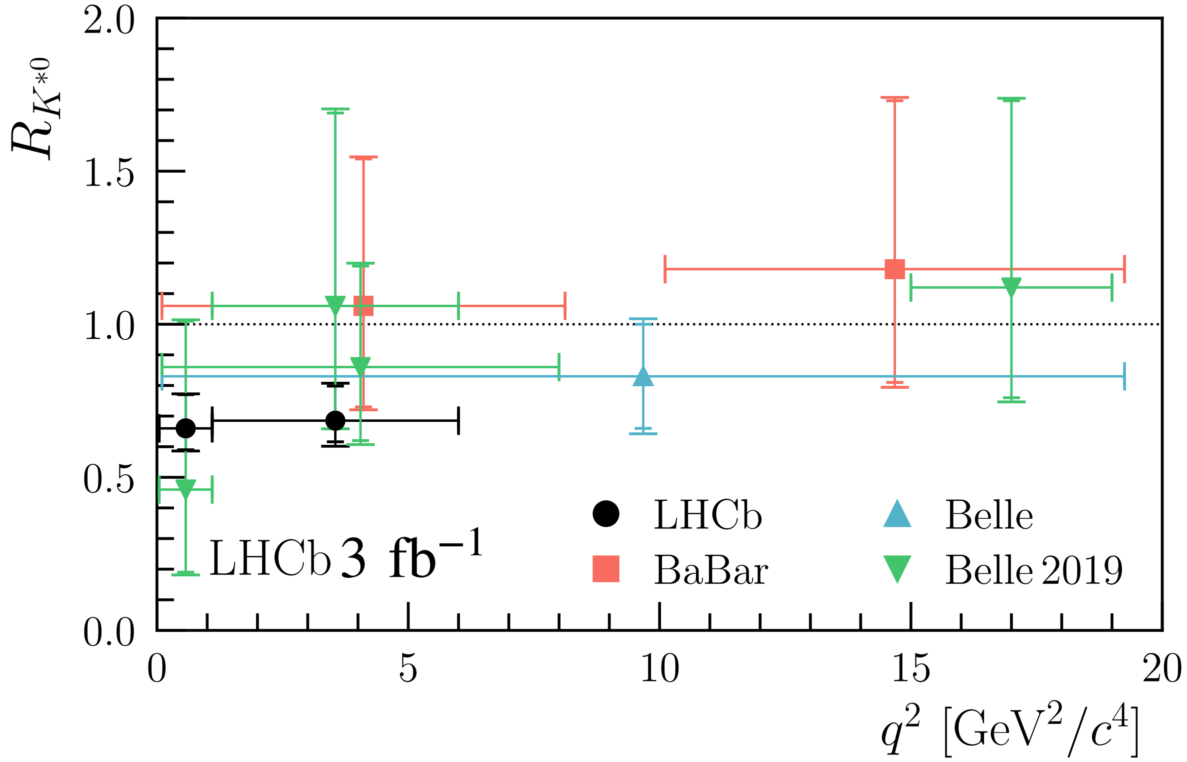
Present experimental picture

- The 2019 R_K measurement from LHCb was done on $5\ \mathrm{fb}^{-1}$ and it's $2.5\ \sigma$ below the SM
- Belle 2 update on combined $R_K - R_{K^0_s}$: $1.03^{+0.28}_{-0.24} \pm 0.01$

[PRL 122 (2019) 191801] [JHEP 03 (2021) 105]

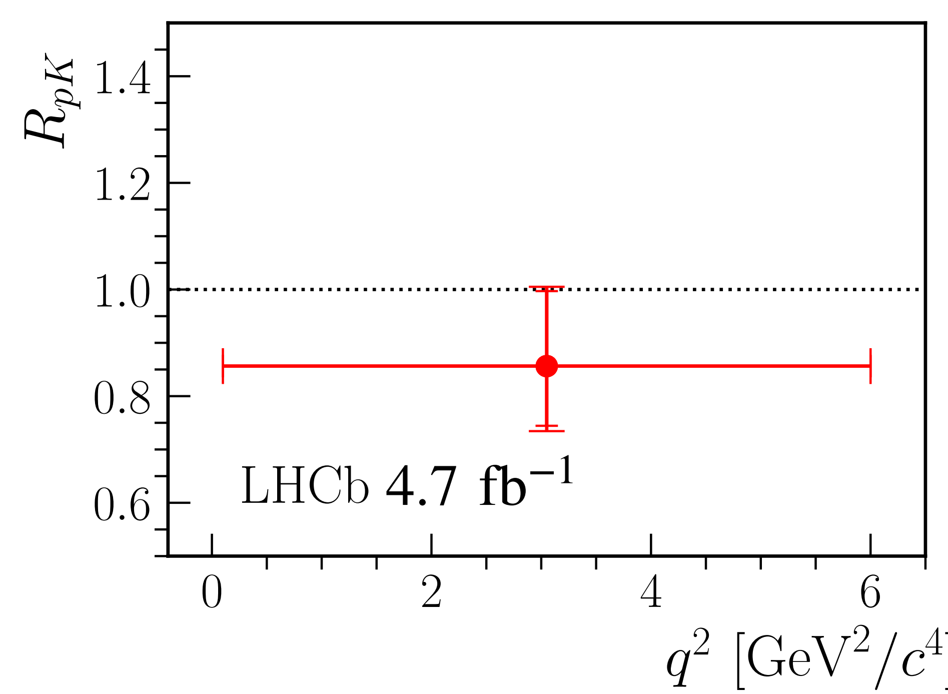


- LFU tests also performed on other channels:
  $B^0 \to K^{*0} l^+ l^- \to R_{K^{*0}}$



[JHEP 08 (2017) 055]

- $\Lambda^0_b \to pK l^+ l^- \to R_{pK}$



[JHEP 40 (2020) 2020]

- Will show here the "legacy measurement" of R_K on the full Run 1 + Run 2 data ($9\ \mathrm{fb}^{-1}$)

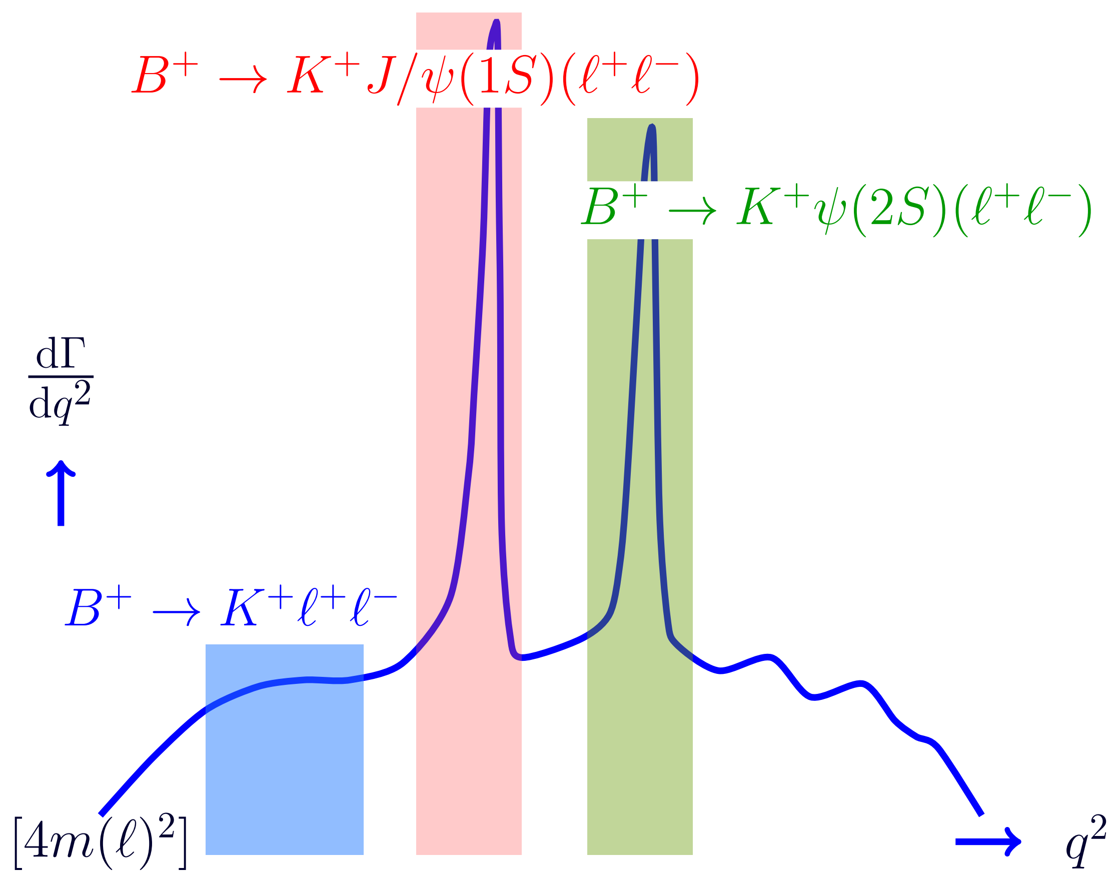
R_K step 1: fits to resonant modes

[LHCB-PAPER-2021-004]

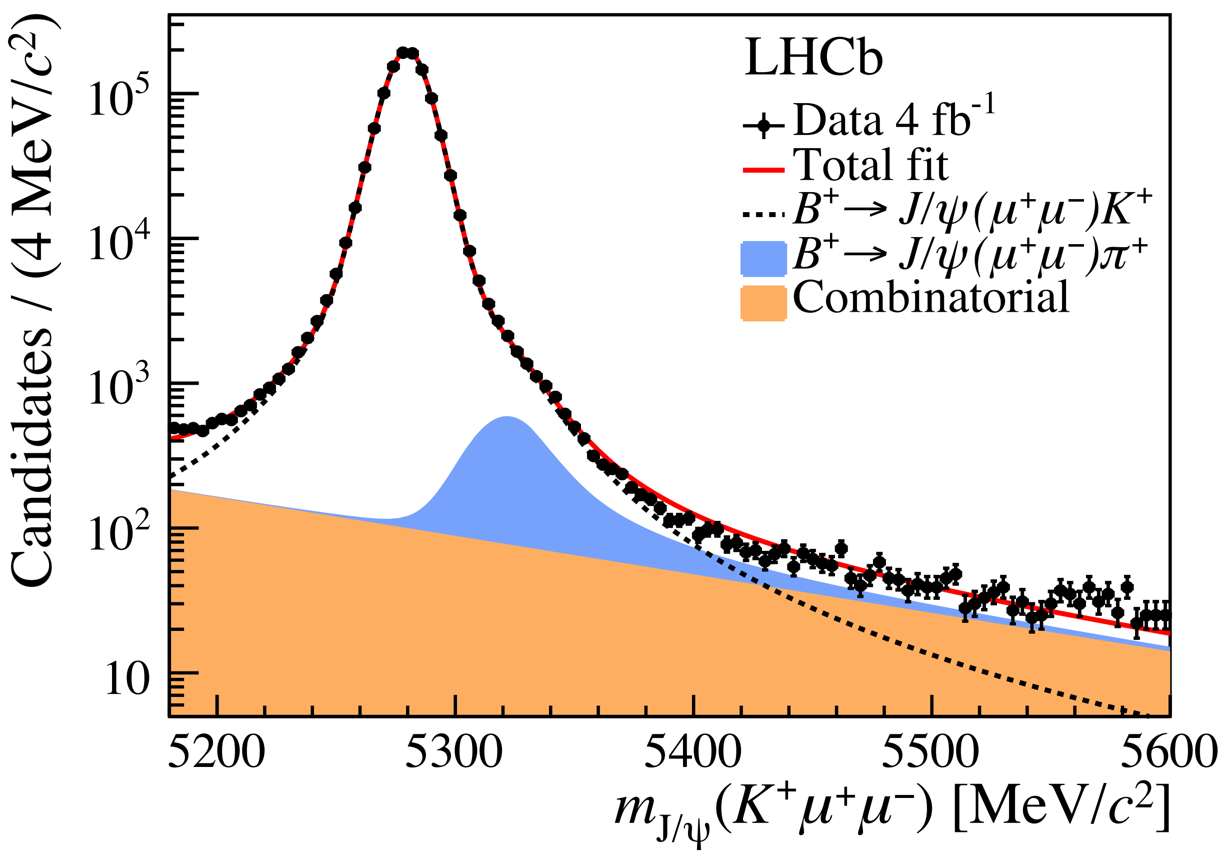
$$R_K = \frac{\mathcal{B}(B^+ \to K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \to K^+ J/\psi(\mu^+ \mu^-))} \Big/ \frac{\mathcal{B}(B^+ \to K^+ e^+ e^-)}{\mathcal{B}(B^+ \to K^+ J/\psi(e^+ e^-))} = \frac{N^{\rm rare}_{\mu^+\mu^-}\ \varepsilon^{J/\psi}_{\mu^+\mu^-}}{N^{J/\psi}_{\mu^+\mu^-}\ \varepsilon^{\rm rare}_{\mu^+\mu^-}} \times \frac{N^{J/\psi}_{e^+e^-}\ \varepsilon^{\rm rare}_{e^+e^-}}{N^{\rm rare}_{e^+e^-}\ \varepsilon^{J/\psi}_{e^+e^-}}$$

- At LHCb R_K is measured as a double ratio wrt the resonant modes (J/ψ)

- Same event selection, separated by q^2: rare, J/ψ, $\psi(2S)$



1. Mass fits to measure the yields:



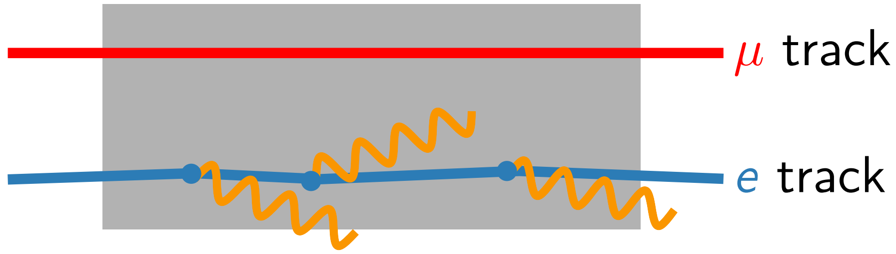
R_K step 2: efficiencies

[LHCB-PAPER-2021-004]

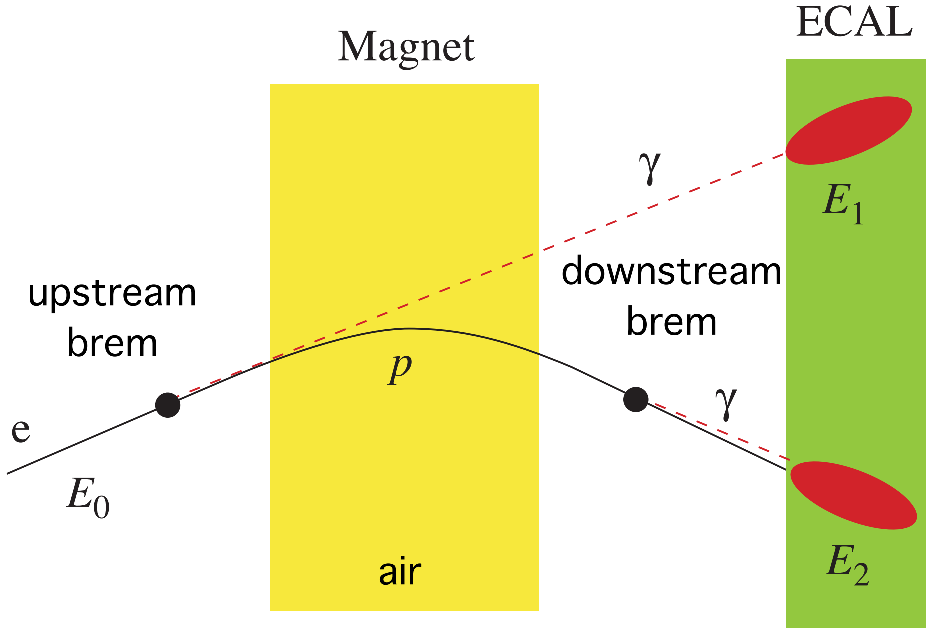
$$R_K = \frac{\mathcal{B}(B^+ \to K^+\mu^+\mu^-)}{\mathcal{B}(B^+ \to K^+J/\psi(\mu^+\mu^-))} \Bigg/ \frac{\mathcal{B}(B^+ \to K^+e^+e^-)}{\mathcal{B}(B^+ \to K^+J/\psi(e^+e^-))} = \frac{N^{\rm rare}_{\mu^+\mu^-}\,\varepsilon^{J/\psi}_{\mu^+\mu^-}}{N^{J/\psi}_{\mu^+\mu^-}\,\varepsilon^{\rm rare}_{\mu^+\mu^-}} \times \frac{N^{J/\psi}_{e^+e^-}\,\varepsilon^{\rm rare}_{e^+e^-}}{N^{\rm rare}_{e^+e^-}\,\varepsilon^{J/\psi}_{e^+e^-}}$$

2. Efficiency ratio(s) : The control of efficiencies is at the core of the analysis

Electrons emit significant bremsstrahlung photons at LHCb



To improve the momentum resolution, a photon cluster in the calorimeter is searched for



- Efficiencies evaluated from simulation, with trigger, PID, B kinematics and q^2 resolution calibrated from data

R_K step 2.5: efficiency checks

[LHCB-PAPER-2021-004]

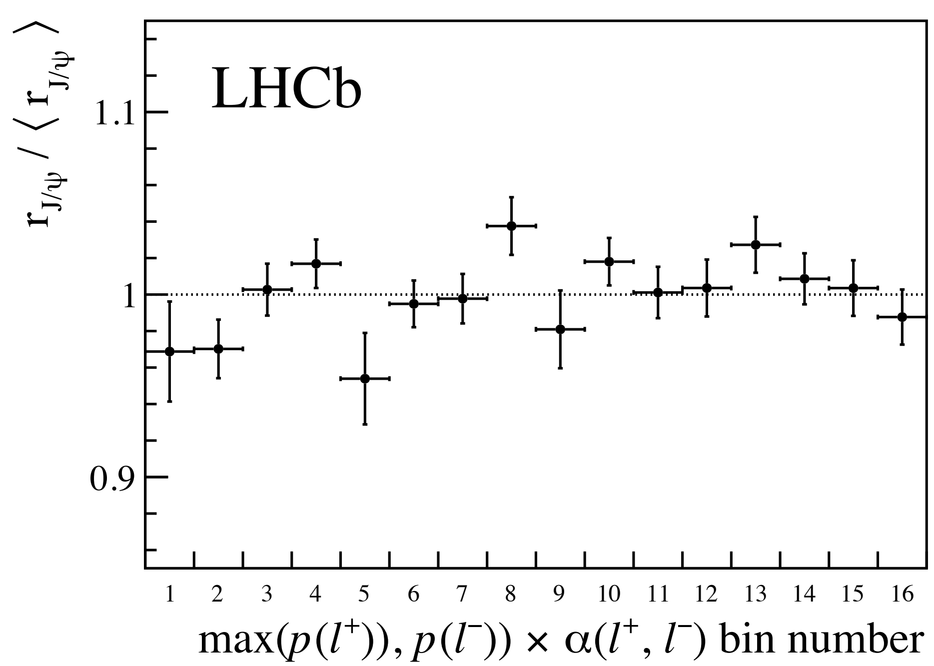
$$R_K = \frac{\mathcal{B}(B^+ \to K^+\mu^+\mu^-)}{\mathcal{B}(B^+ \to K^+J/\psi(\mu^+\mu^-))} \Bigg/ \frac{\mathcal{B}(B^+ \to K^+e^+e^-)}{\mathcal{B}(B^+ \to K^+J/\psi(e^+e^-))} = \frac{N^{\mathrm{rare}}_{\mu^+\mu^-}}{N^{J/\psi}_{\mu^+\mu^-}} \frac{\varepsilon^{J/\psi}_{\mu^+\mu^-}}{\varepsilon^{\mathrm{rare}}_{\mu^+\mu^-}} \times \frac{N^{J/\psi}_{e^+e^-}}{N^{\mathrm{rare}}_{e^+e^-}} \frac{\varepsilon^{\mathrm{rare}}_{e^+e^-}}{\varepsilon^{J/\psi}_{e^+e^-}}$$

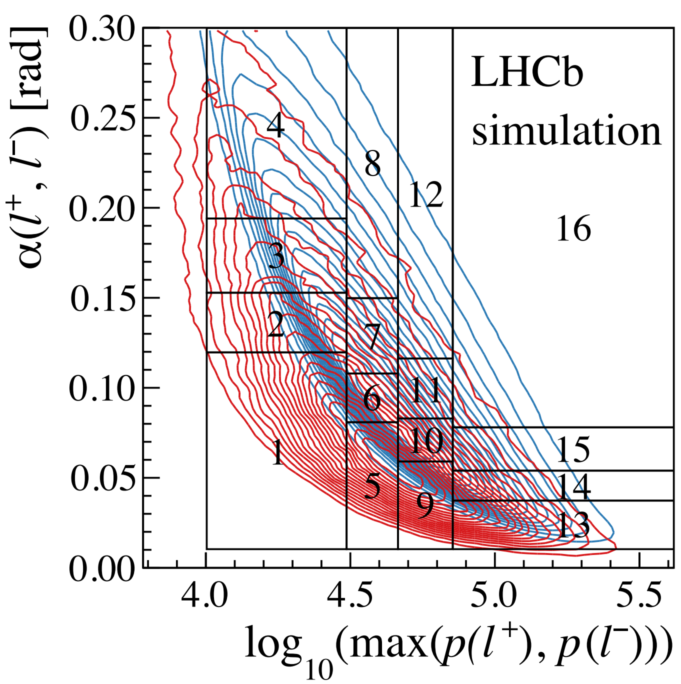
- The double ratio cancels most of the $e-\mu$ systematic effects, however we check:

$$r_{J/\psi} = \frac{\mathcal{B}(B^+ \to K^+J/\psi(\mu^+\mu^-))}{\mathcal{B}(B^+ \to K^+J/\psi(e^+e^-))} = 0.981 \pm 0.020$$

→ stringent test as it requires muon and electron efficiencies to be controlled individually (not needed for R_K)

- $r_{J/\psi}$ tested in kinematic bins: no trend observed





- Also in a different q^2 region ($\psi(2S)$)

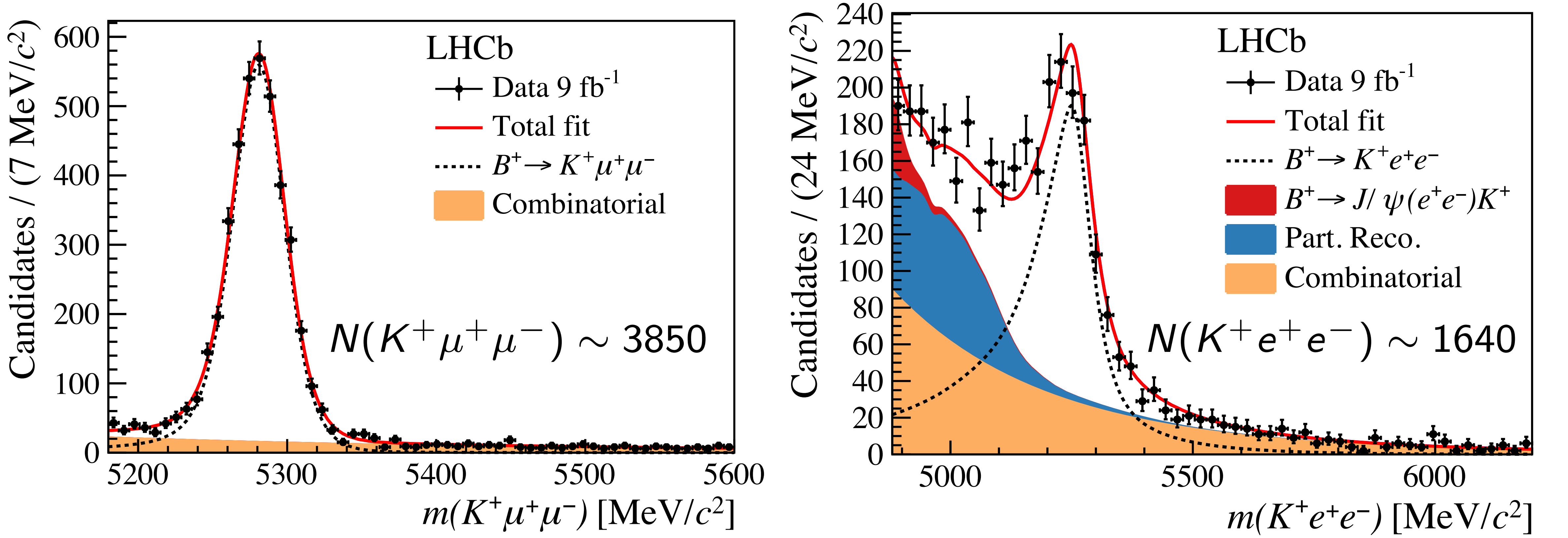
$$R_{\psi(2S)} = \frac{\mathcal{B}(B^+ \to K^+\psi(2S)(\mu^+\mu^-))}{\mathcal{B}(B^+ \to K^+J/\psi(\mu^+\mu^-))} \Bigg/ \frac{\mathcal{B}(B^+ \to K^+\psi(2S)(e^+e^-))}{\mathcal{B}(B^+ \to K^+J/\psi(e^+e^-))} = 0.997 \pm 0.011$$

R_K step 3: fits to rare modes

[LHCB-PAPER-2021-004]

$$R_K = \frac{\mathcal{B}(B^+ \to K^+\mu^+\mu^-)}{\mathcal{B}(B^+ \to K^+J/\psi(\mu^+\mu^-))} \bigg/ \frac{\mathcal{B}(B^+ \to K^+e^+e^-)}{\mathcal{B}(B^+ \to K^+J/\psi(e^+e^-))} = \frac{N^{\rm rare}_{\mu^+\mu^-}\ \varepsilon^{J/\psi}_{\mu^+\mu^-}}{N^{J/\psi}_{\mu^+\mu^-}\ \varepsilon^{\rm rare}_{\mu^+\mu^-}} \times \frac{N^{J/\psi}_{e^+e^-}\ \varepsilon^{\rm rare}_{e^+e^-}}{N^{\rm rare}_{e^+e^-}\ \varepsilon^{J/\psi}_{e^+e^-}}$$

- 3. R_K parameter of a simultaneous fit to e^+e^- and $\mu^+\mu^-$ rare modes

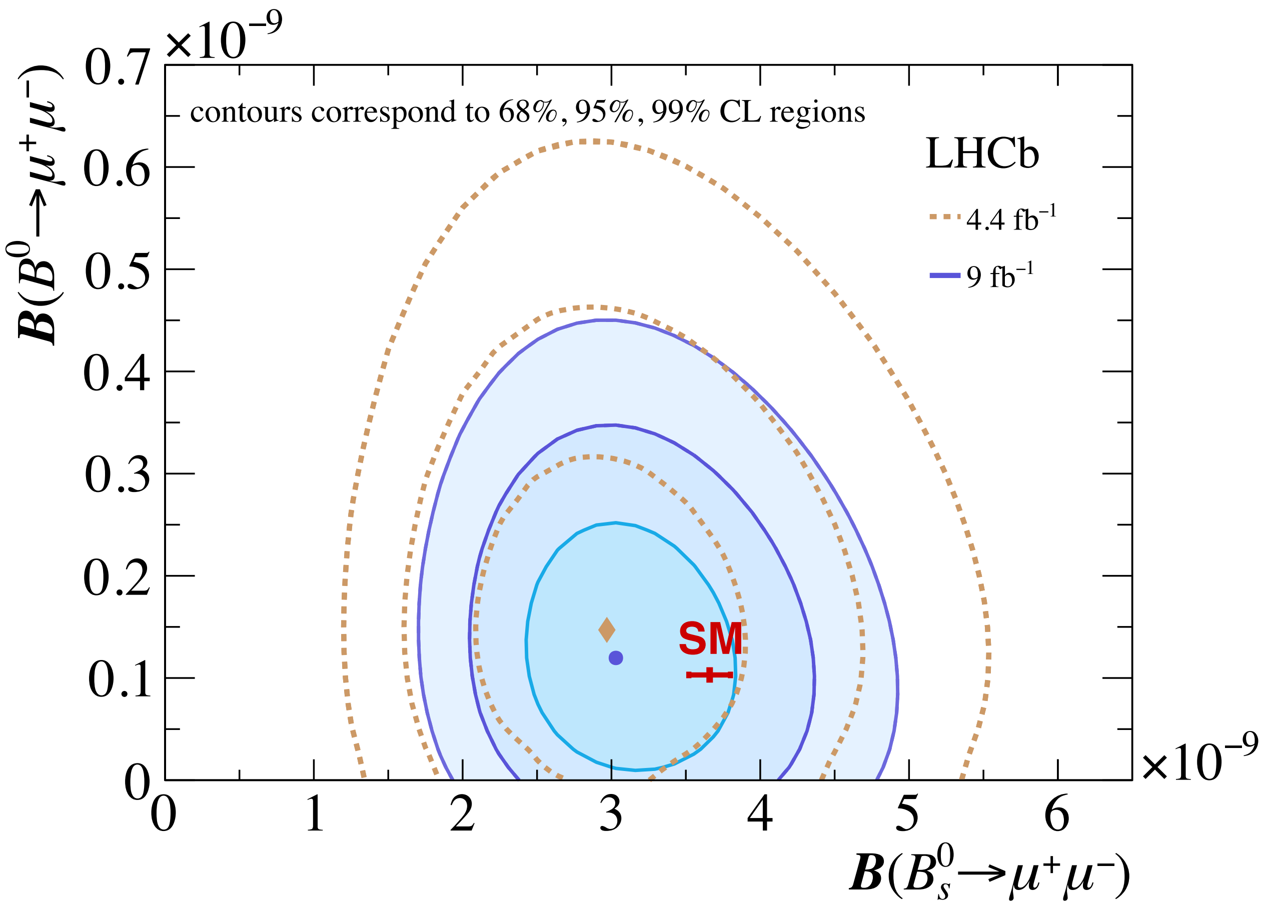


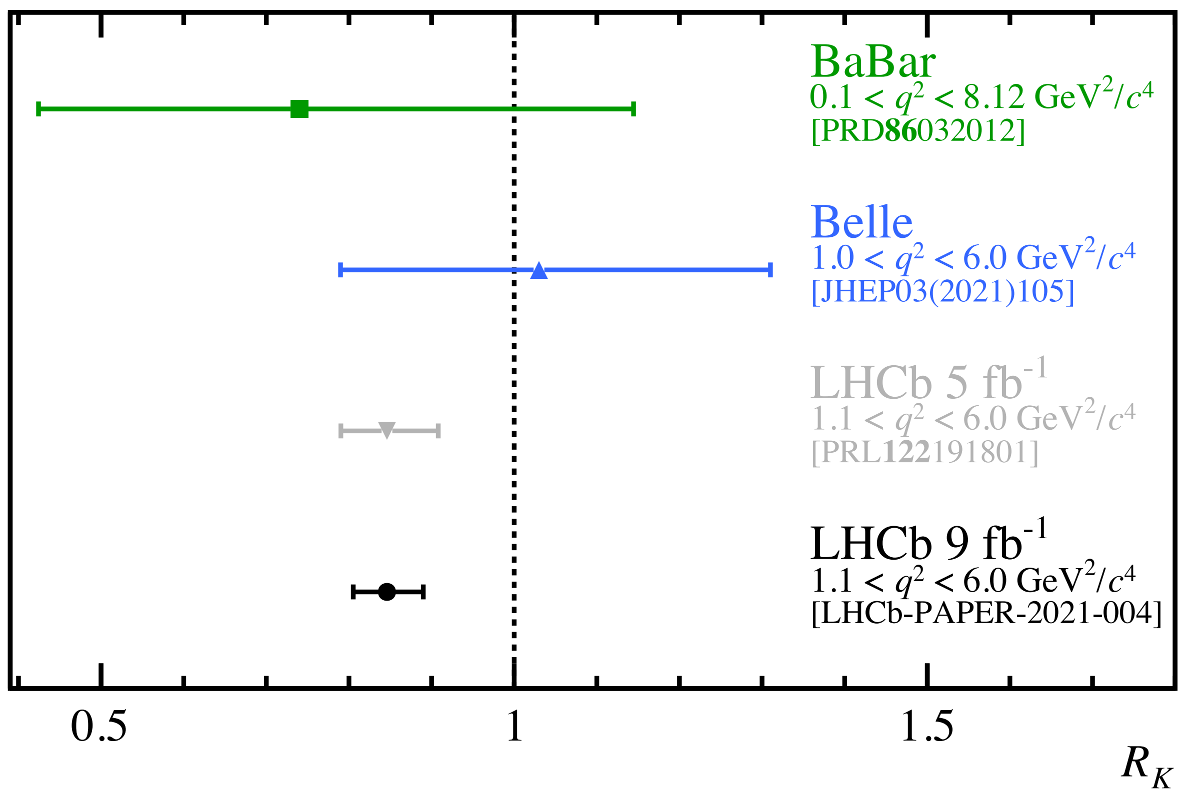
- Result:

$$R_K = 0.846\ ^{+0.042}_{-0.039}\ (\text{stat})\ ^{+0.013}_{-0.012}\ (\text{syst})$$

- 3.1σ distance from the SM
- "Evidence" of LFU violation

Conclusions



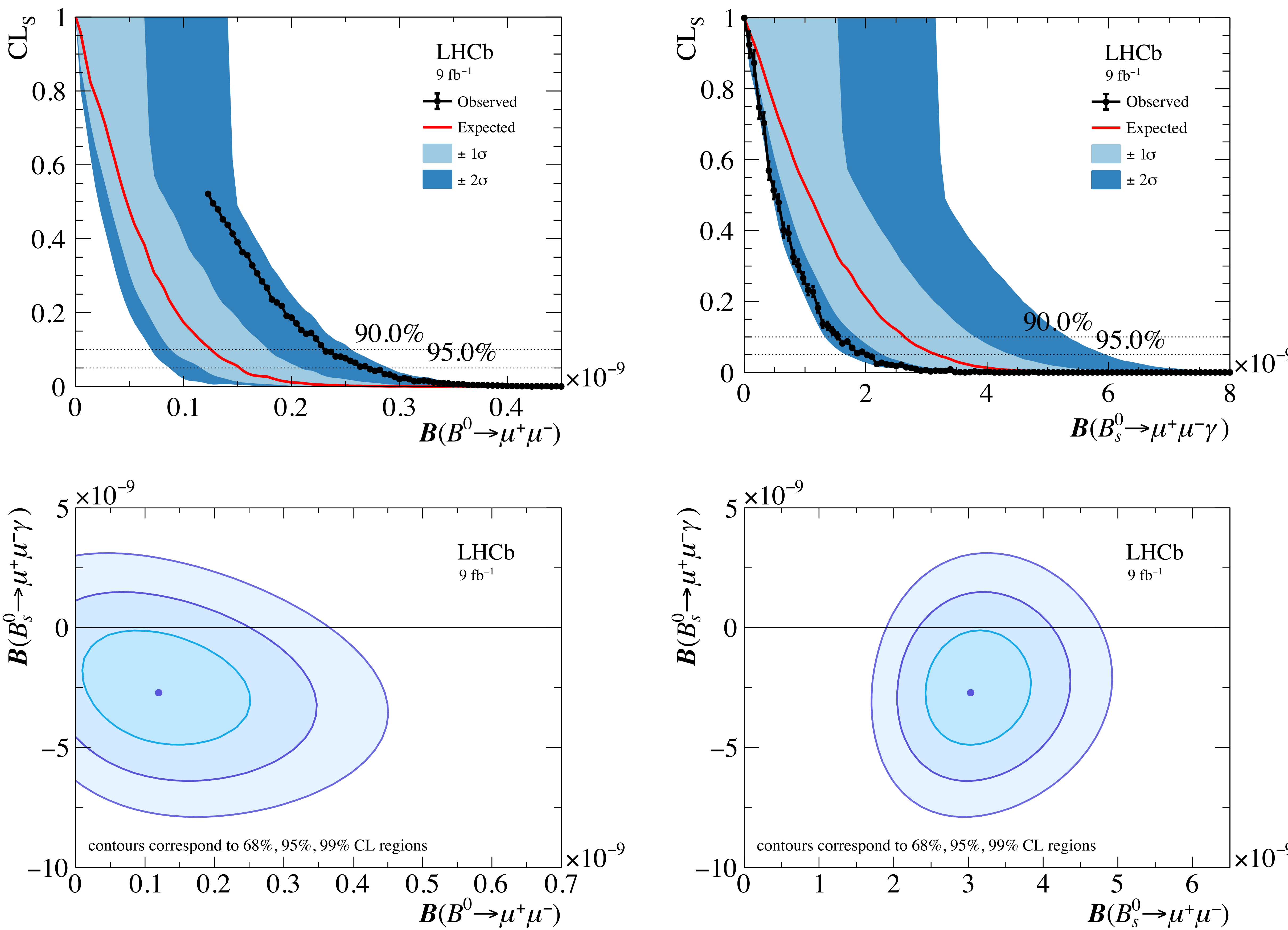


- Two very clean observables measured on the full LHCb dataset, protagonists in the "anomalies" scenario
- Other legacy measurements on LFU tests ongoing: hope for a clarification in 1-2 years
- Synergy with ATLAS and CMS on several observables is essential
- LHCb Run 3 to profit from extensive hardware interventions and fully software trigger

backup slides

CL_s scans & contours

[LHCB-PAPER-2021-007]
[LHCB-PAPER-2021-008]



$B_s^0 \to \mu^+\mu^-$: normalisation

[LHCB-PAPER-2021-007]
[LHCB-PAPER-2021-008]

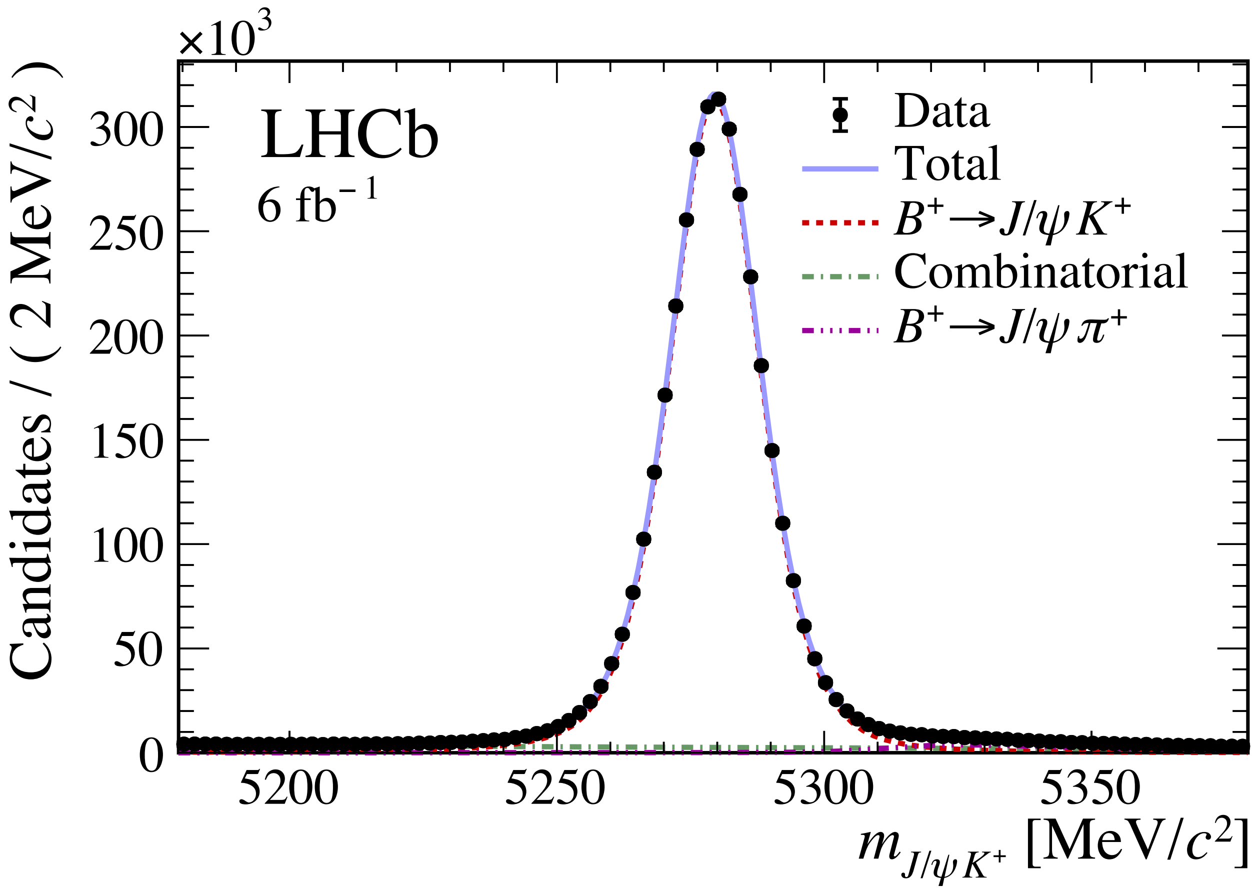
- Two normalisation channels are employed to compute the branching fraction from the signal yield

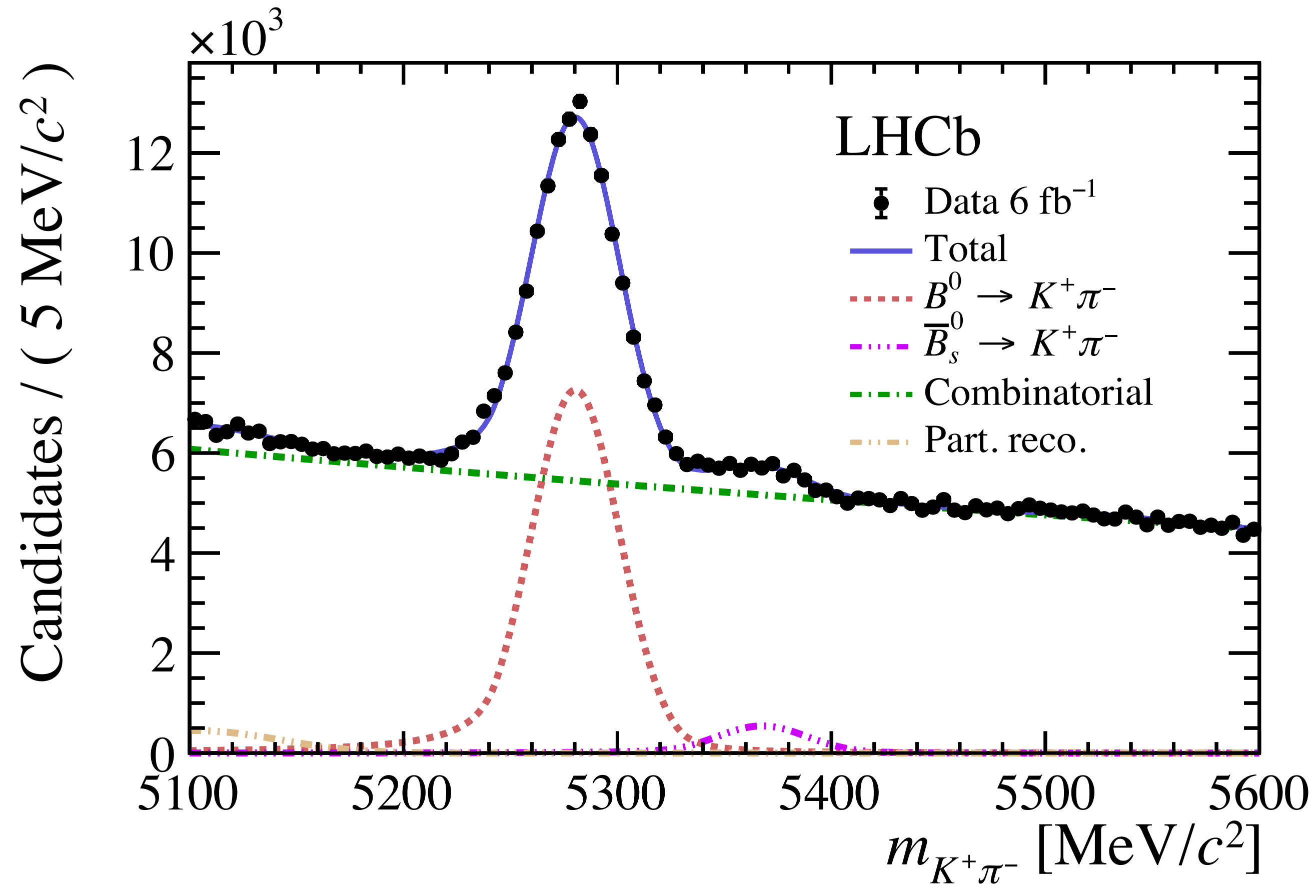
1. $B^+ \to J/\psi(\to \mu^+\mu^-)K^+$

Two muons in the final state
→ similar trigger and reconstruction

2. $B^0 \to K^+\pi^-$

Two-body B decay
→ same signal topology





$$\mathcal{B}(B^0_{d,s} \to \mu^+\mu^-) = \overbrace{\underbrace{\frac{\mathcal{B}_{norm}}{N_{norm}} \times \frac{\epsilon_{norm}}{\epsilon_{sig}}}_{\alpha_d} \times \frac{f_{norm}}{f_{d,s}}}^{\alpha_s} \times N_{B^0_{d,s}\to\mu^+\mu^-}$$

f_s/f_d (7 TeV) $= 0.239 \pm 0.008$

f_s/f_d (13 TeV) $= 0.254 \pm 0.008$

[LHCb-PAPER-2020-046]

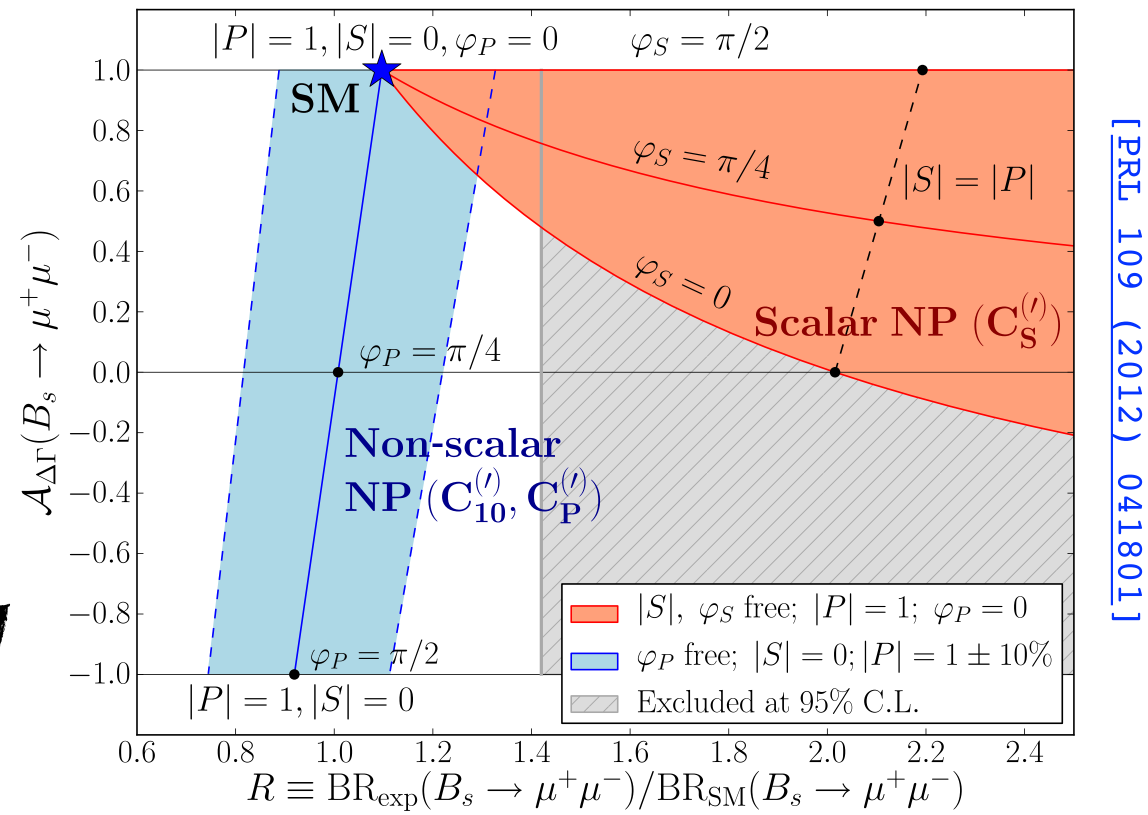
$B_s^0 \to \mu^+\mu^-$: observables

- By measuring the $B_s^0 \to \mu^+\mu^-$ effective lifetime:

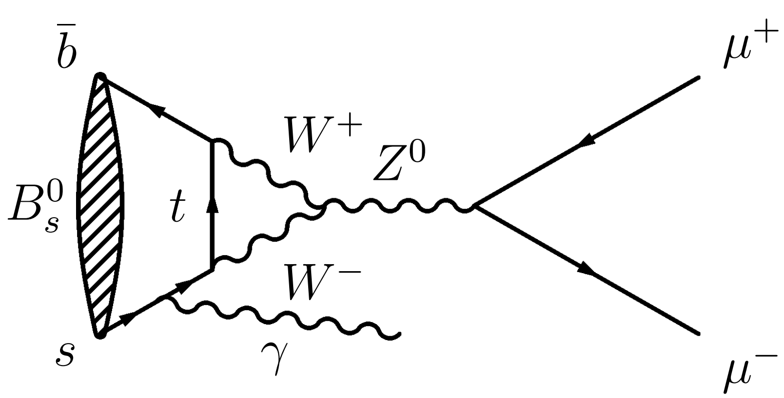
$$A_{\Delta\Gamma}^{\mu^+\mu^-} \equiv \frac{R_H^{\mu^+\mu^-} - R_L^{\mu^+\mu^-}}{R_H^{\mu^+\mu^-} + R_L^{\mu^+\mu^-}}$$

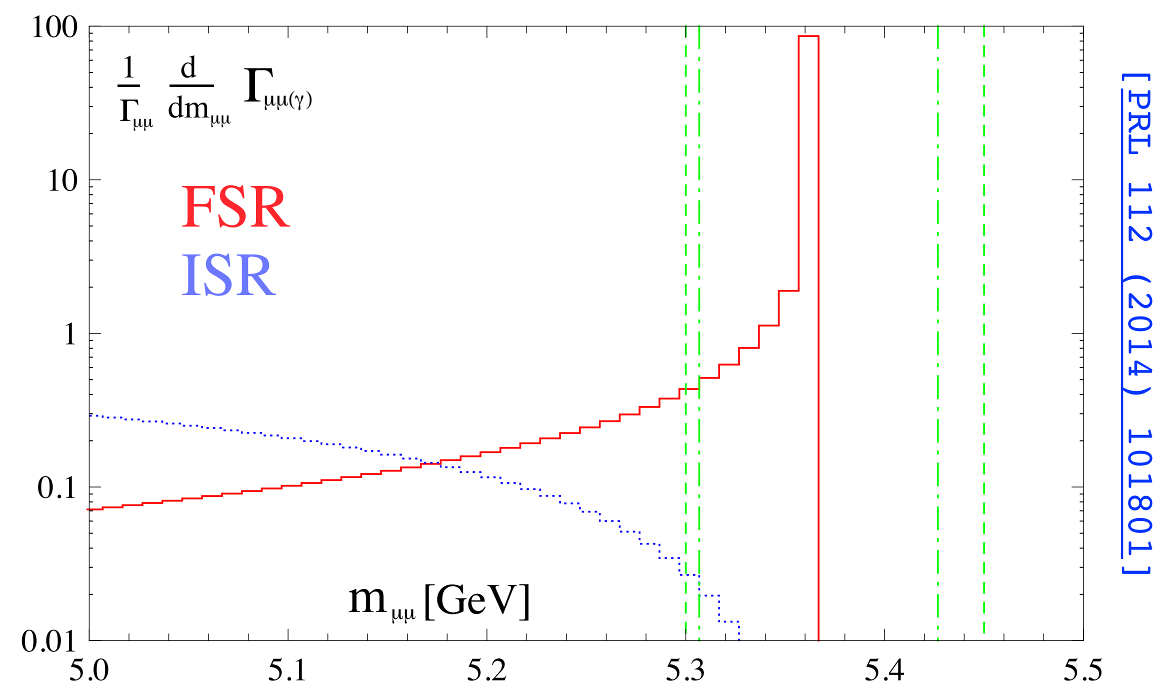
$$\tau_{\mu^+\mu^-} = \frac{\tau_{B_s}}{1-y_s^2}\left[\frac{1+2A_{\Delta\Gamma}^{\mu^+\mu^-}y_s + y_s^2}{1+A_{\Delta\Gamma}^{\mu^+\mu^-}y_s}\right] \qquad y_s = \frac{\Delta\Gamma_s}{2\Gamma_s}$$

- we can extract the asymmetry $A_{\Delta\Gamma}^{\mu^+\mu^-}$, = 1 in the SM
- Clean observable → additional NP constraints



- Sensitivity to $B_s^0 \to \mu^+\mu^-\gamma$ (ISR) at high $m_{\mu^+\mu^-}$, new observable included this analysis

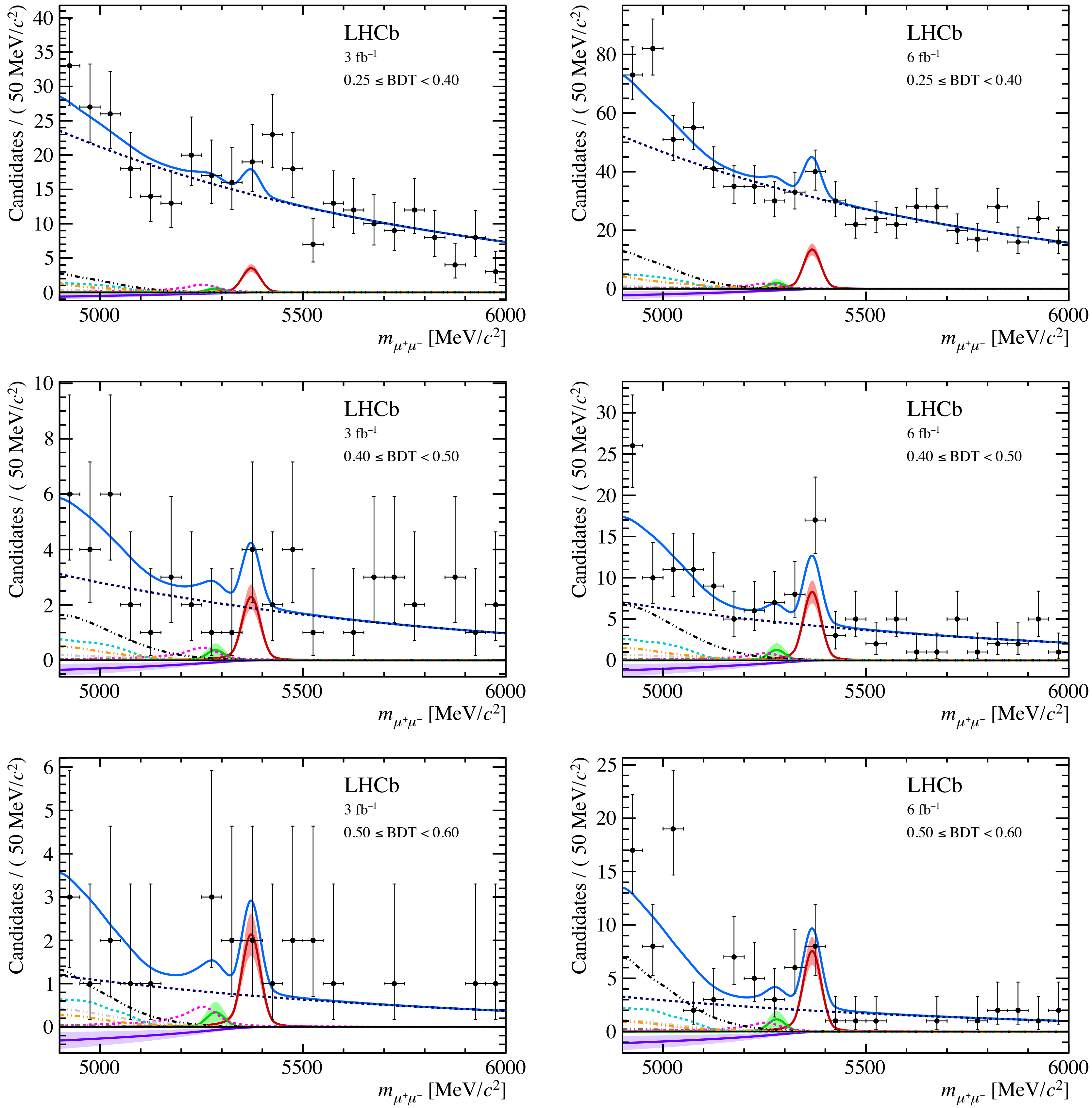




- SM prediction at $\mathcal{O}(10^{-10})$ for $m_{\mu^+\mu^-} > 4.9$ GeV
  [JHEP 11 (2017) 184] [PRD 97 (2018) 053007]
- Bremsstrahlung (FSR) experimentally included in $\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ via PHOTOS

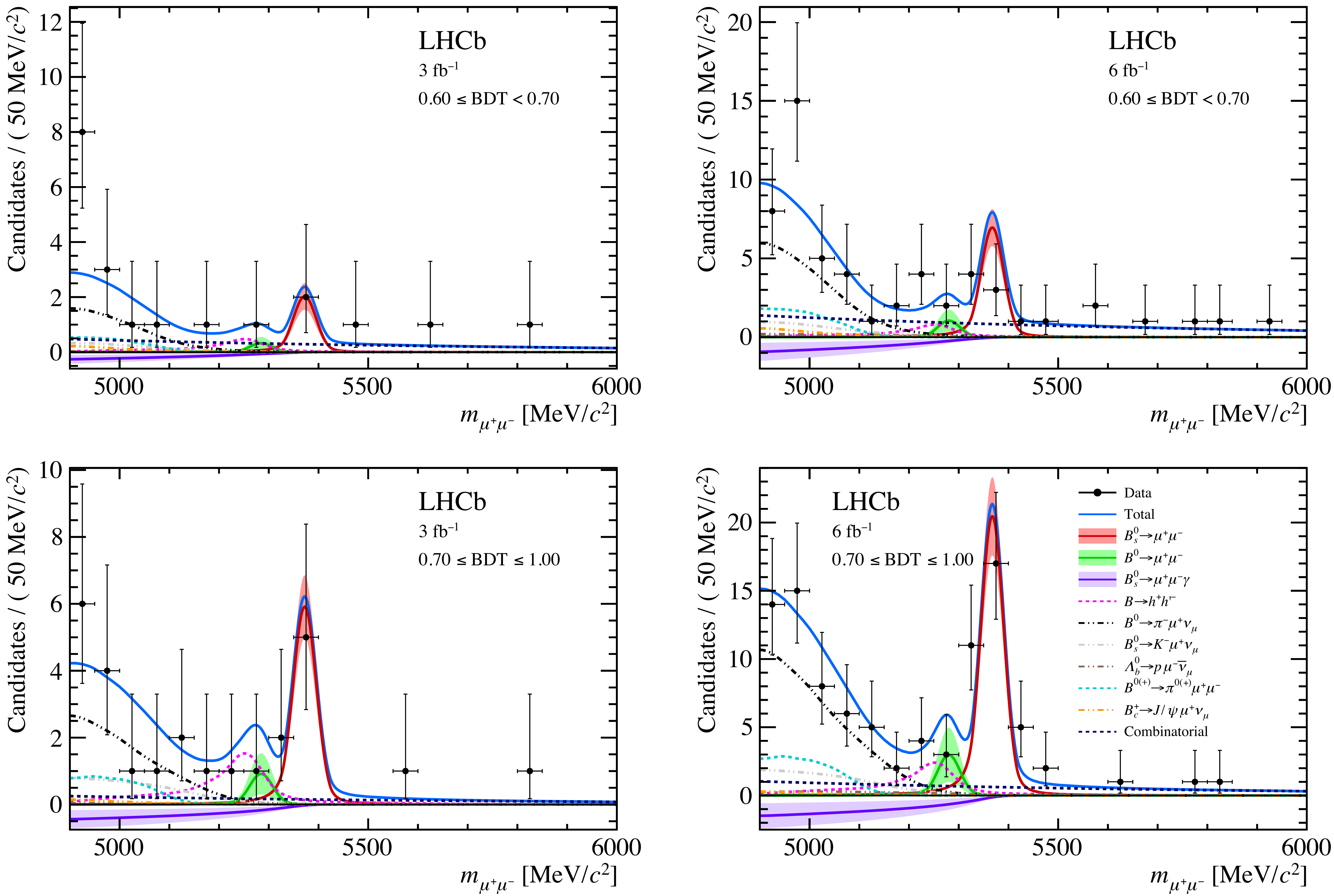
Mass fits: low BDT regions

[LHCB-PAPER-2021-007]
[LHCB-PAPER-2021-008]



Mass fits: high BDT regions

[LHCB-PAPER-2021-007]
[LHCB-PAPER-2021-008]

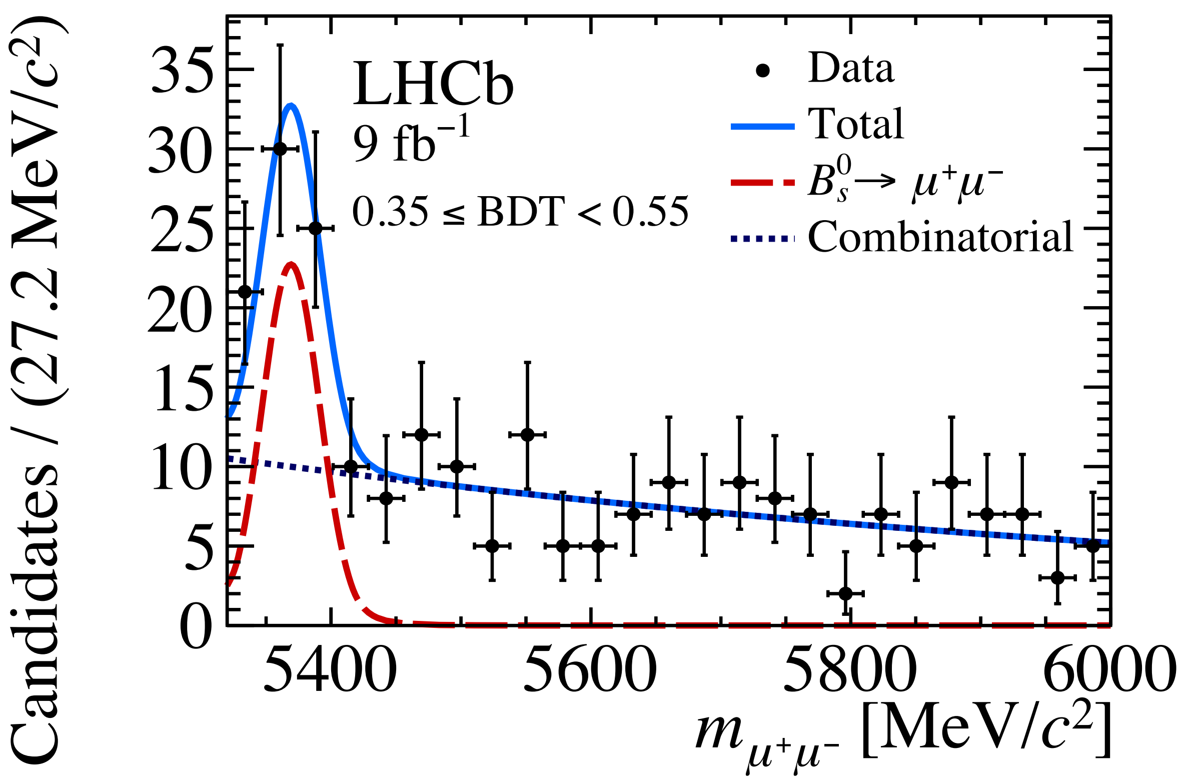


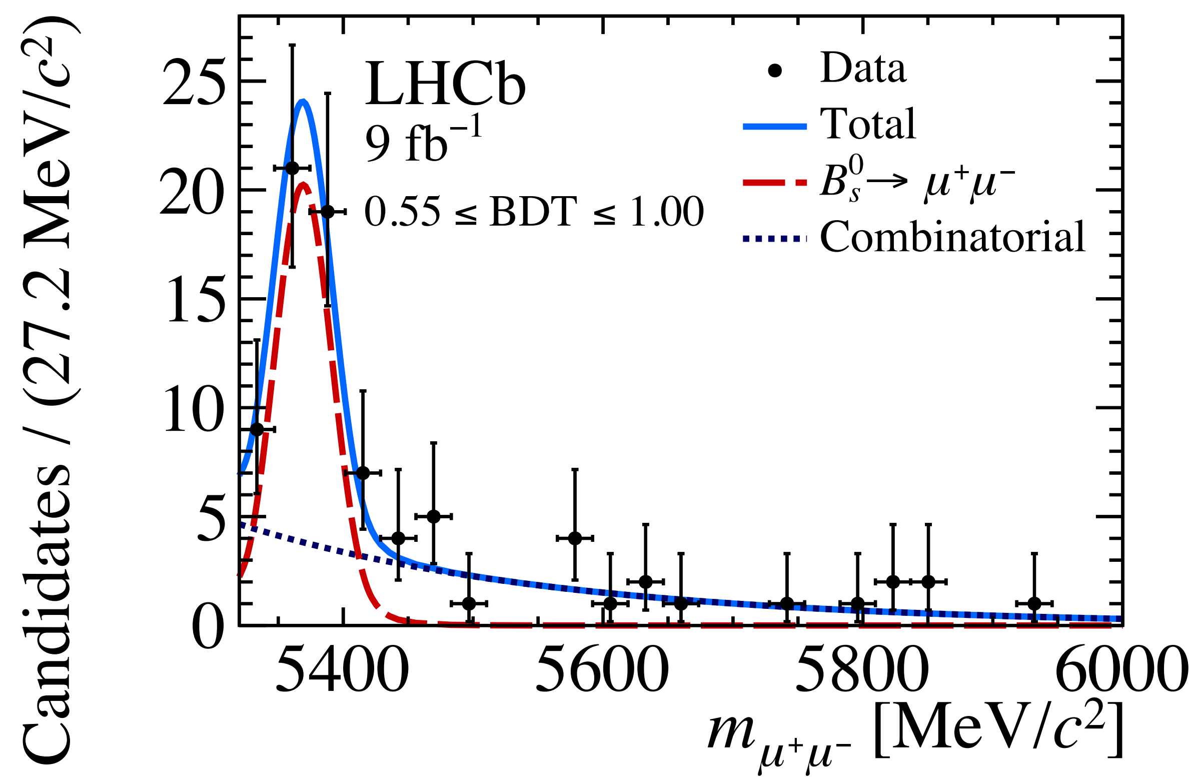
$B_s^0 \to \mu^+\mu^-$ effective lifetime 1/2

[LHCB-PAPER-2021-007]
[LHCB-PAPER-2021-008]

Since the expected sensitivity on $A_{\Delta\Gamma}^{\mu^+\mu^-}$ is low, the effective lifetime measurement introduces some simplifications wrt the branching fraction analysis:

- Tighter mass cut, $m_{\mu^+\mu^-} > 5320$ MeV: mass fit model with $B_s^0 \to \mu^+\mu^-$ signal + combinatorial
- Looser PID requirement (no misidentified backgrounds)
- 1. Mass fit on two BDT bins is performed to extract sWeights [NIM A555 (2005) 356–369]

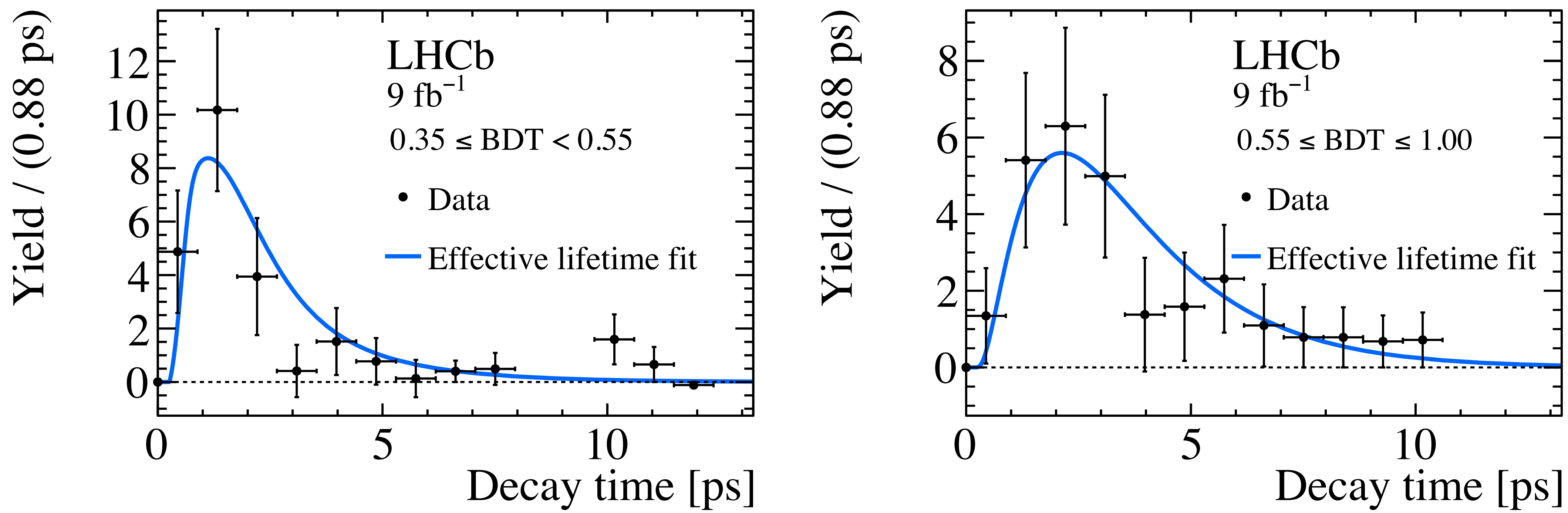




$B_s^0 \to \mu^+\mu^-$ effective lifetime 2/2

[LHCB-PAPER-2021-007]
[LHCB-PAPER-2021-008]

- 2. The sWeights are applied to obtain the background-subtracted decay time distribution
- which is then fitted with an exponential X acceptance function



- The acceptance function (efficiency vs decay time) is tested by measuring the known $B^0 \to K^+\pi^-$ and $B_s^0 \to K^+K^-$ effective lifetimes

$$\tau_{\mu^+\mu^-} = 2.07 \pm 0.29 \pm 0.03 \text{ ps}$$

- Result compatible at 1.5σ with $A\Delta_\Gamma^{\mu^+\mu^-} = 1$ (SM) and at 2.2σ with $A\Delta_\Gamma^{\mu^+\mu^-} = -1$
- Run 3 data are needed to say more

$B_s^0 \to \mu^+\mu^-$ what's next?

- Combined power of $\mathscr{B}$ and $\tau_{\mu\mu}$ to constrain MSSM
- $\sim 20\,\%$ precision on the time-dependent CP asymmetry ($S_{\mu\mu}$) with $300\ \text{fb}^{-1}$