LHCb results on rare leptonic decays of B-mesons

QFTHEP, Sochi Russia, 25 september 2019

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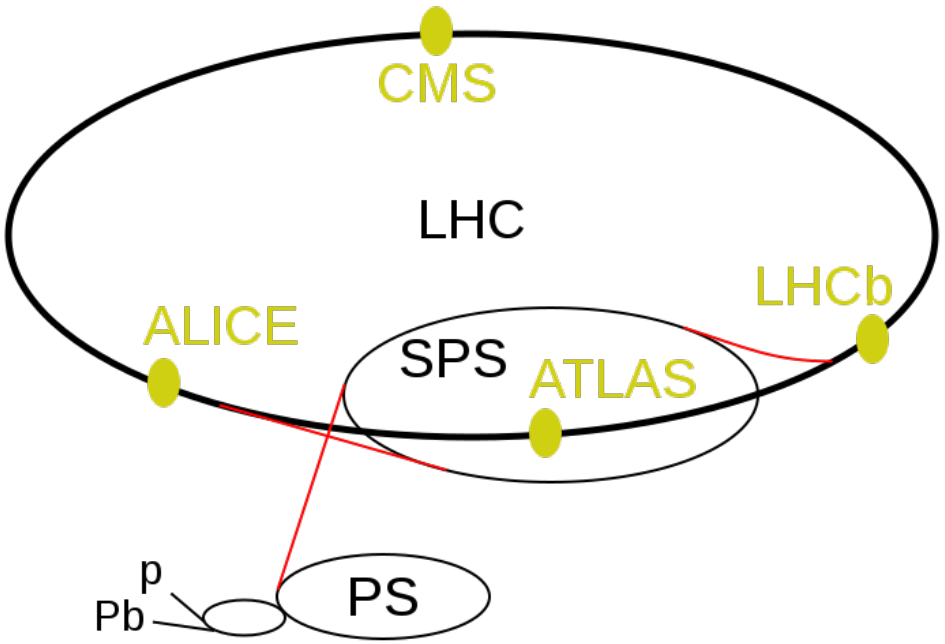
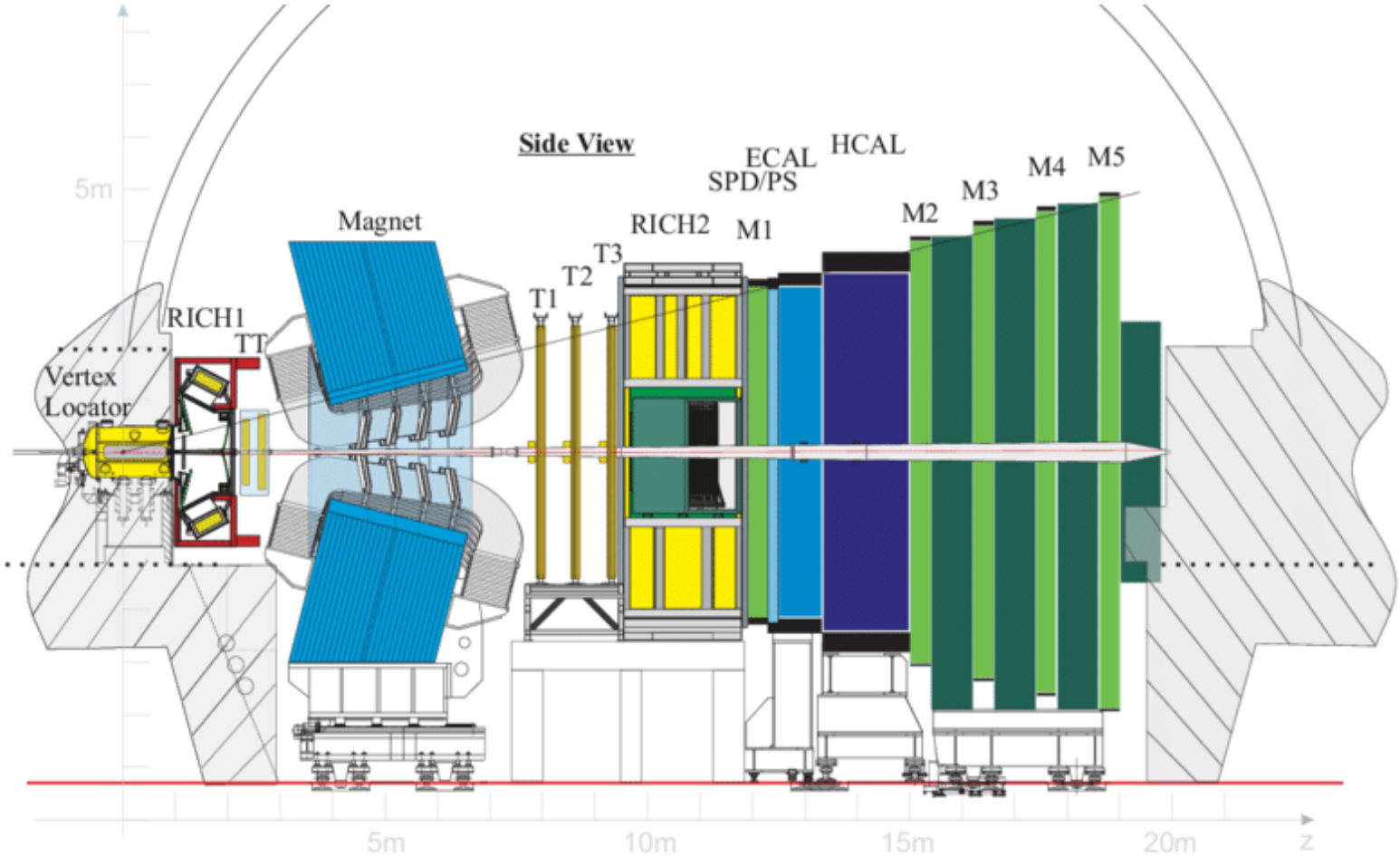
LHC



Arpad Horvath©

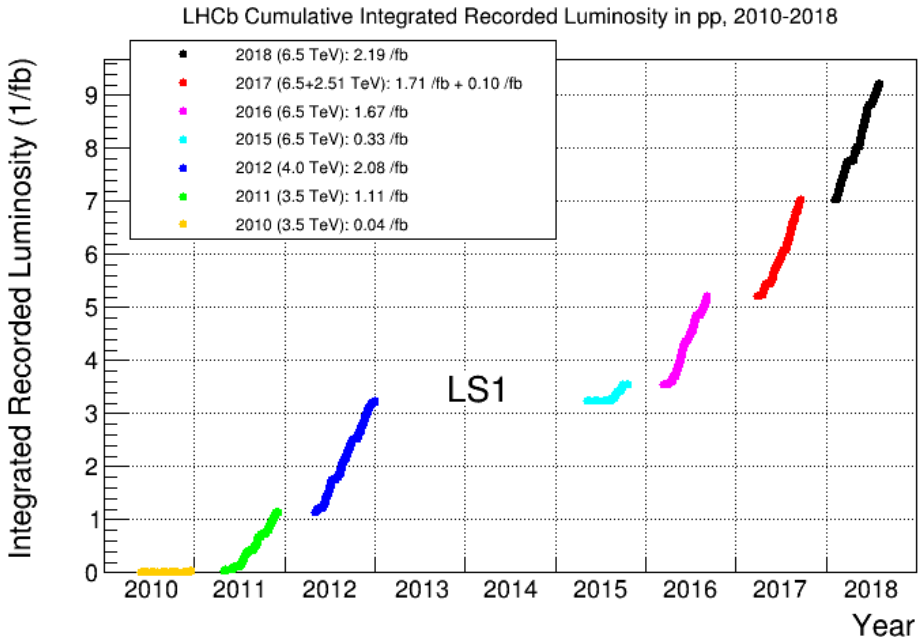
The Large Hadron Collider (LHC) is the world's largest and most powerful particle collider. It lies in a tunnel 27 kilometres in circumference and as deep as 175 metres beneath the France–Switzerland border near Geneva.

LHCb detector



Int. J. Mod. Phys. A30 (2015) 1530022

LHC runs



Two datasets of different size with different kinematics

Motivation

- Their time-integrated branching fractions are predicted in the SM with small uncertainty due to absence of hadrons in final state
- The decays are sensitive probes for physics beyond the SM
- Within the Standard Model (SM) of particle physics, fully leptonic decays of B mesons are very rare

Decays overview:

- Measurements of the $B_s^0 \to \mu^+\mu^-$ branching fraction and effective lifetime and search for $B^0 \to \mu^+\mu^-$ decays
- Search for the decays $B_s^0 \to \tau^+\tau^-$ and $B^0 \to \tau^+\tau^-$
- Search for the lepton-flavour violating decays $B_{(s)}^0 \to e^\pm\mu^\mp$
- Search for the lepton-flavour-violating decays $B_s^0 \to \tau^\pm\mu^\mp$ and $B^0 \to \tau^\pm\mu^\mp$
- Search for the rare decay $B^+ \to \mu^+\mu^-\mu^+\nu_\mu$

Measurements of the $B_s^0 \to \mu^+\mu^-$ branching fraction and effective lifetime and search for $B^0 \to \mu^+\mu^-$ decays

Results are based on data collected with the LHCb detector, corresponding to an integrated luminosity of 1 fb^{-1} of pp collisions at a centre-of-mass energy $\sqrt{s} = 7$ TeV, 2 fb^{-1} at $\sqrt{s} = 8$ TeV and 1.4 fb^{-1} recorded at $\sqrt{s} = 13$ TeV.

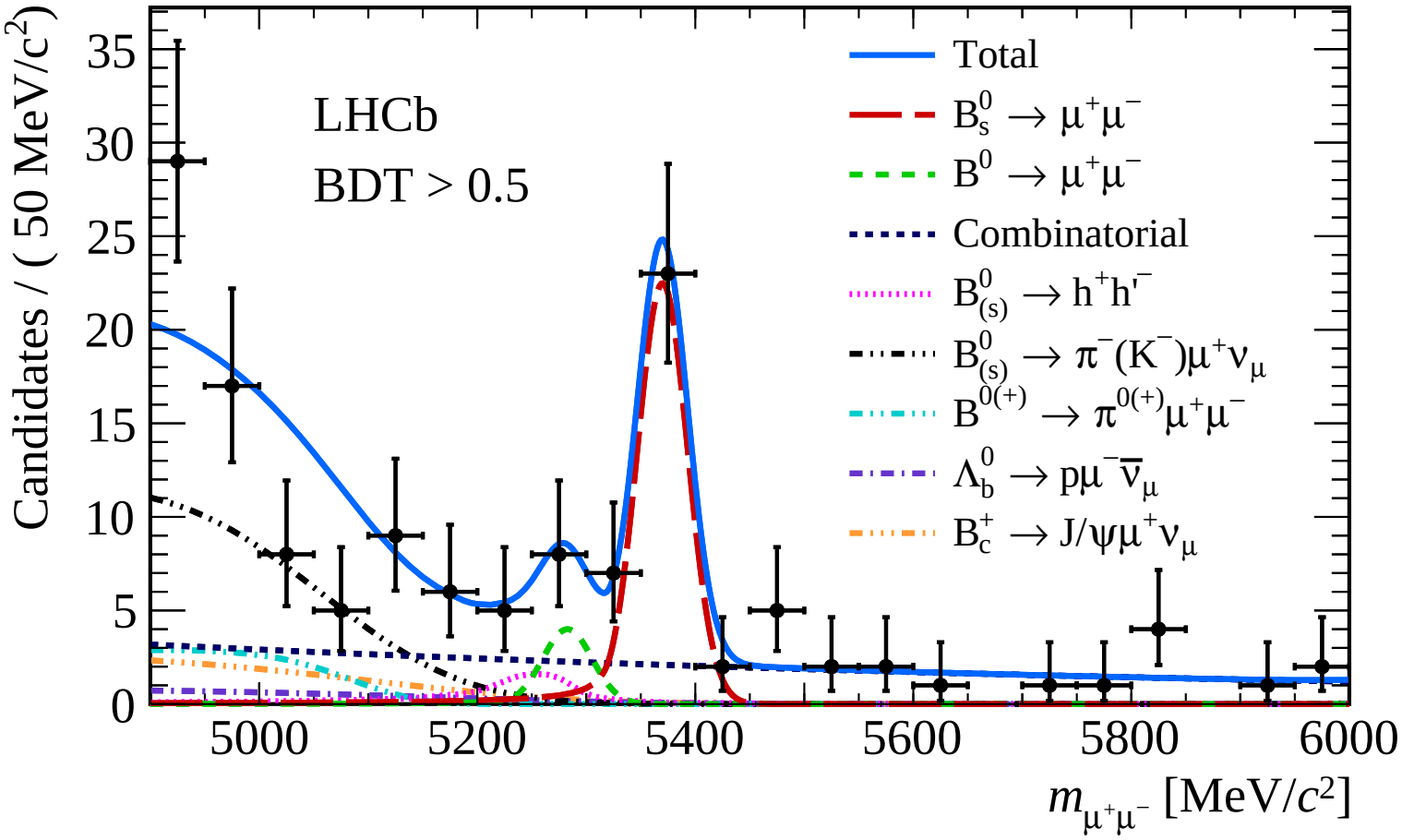
Normalization

Normalization channels are: $B^+ \to J/\psi K^+$ and $B^0 \to K^+\pi^-$

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

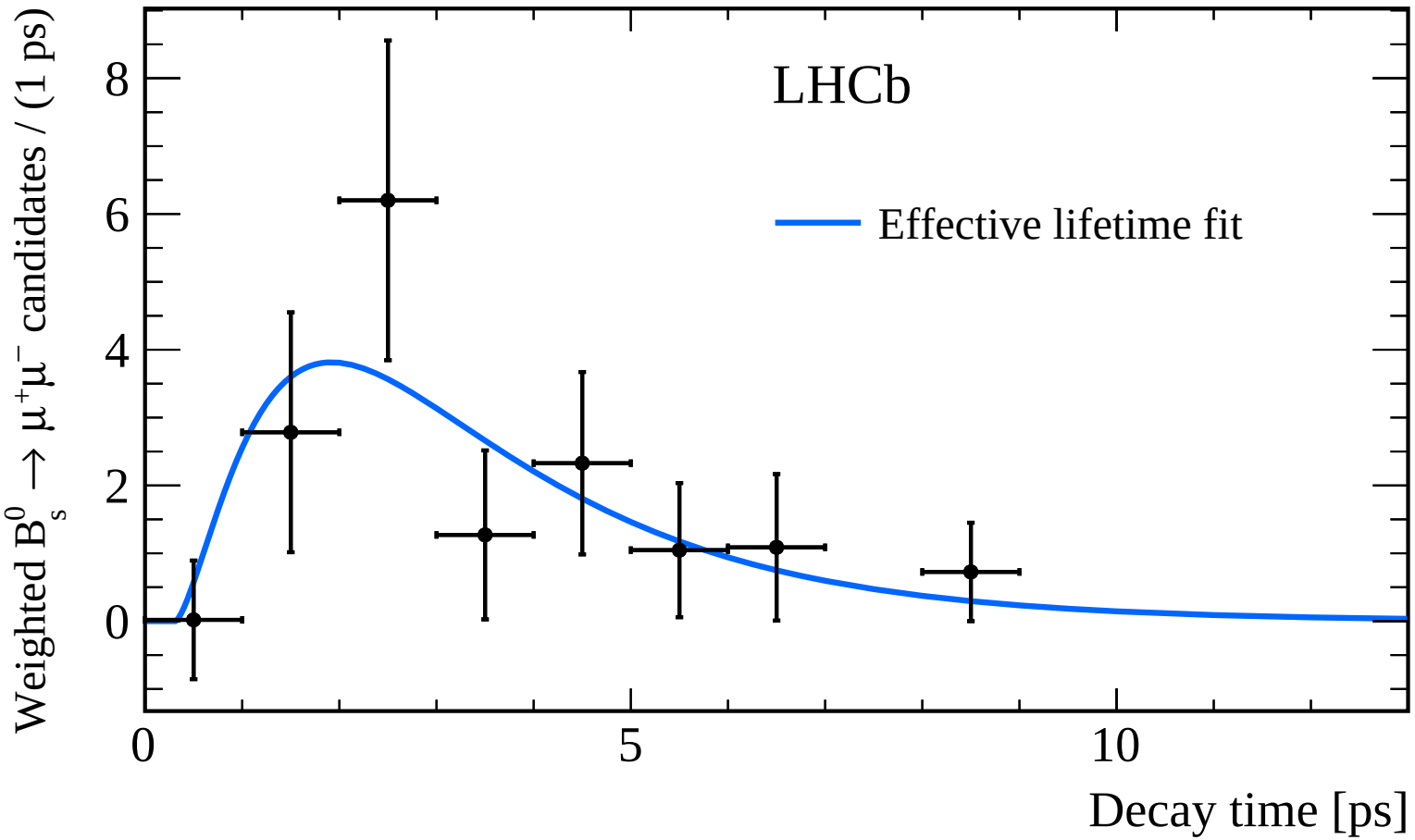
$$\equiv \alpha^{\rm norm}_{B^0_{(s)}\to\mu^+\mu^-} \times N_{B^0_{(s)}\to\mu^+\mu^-}$$

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



Phys. Rev. Lett. 118, 191801

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



Phys. Rev. Lett. 118, 191801

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

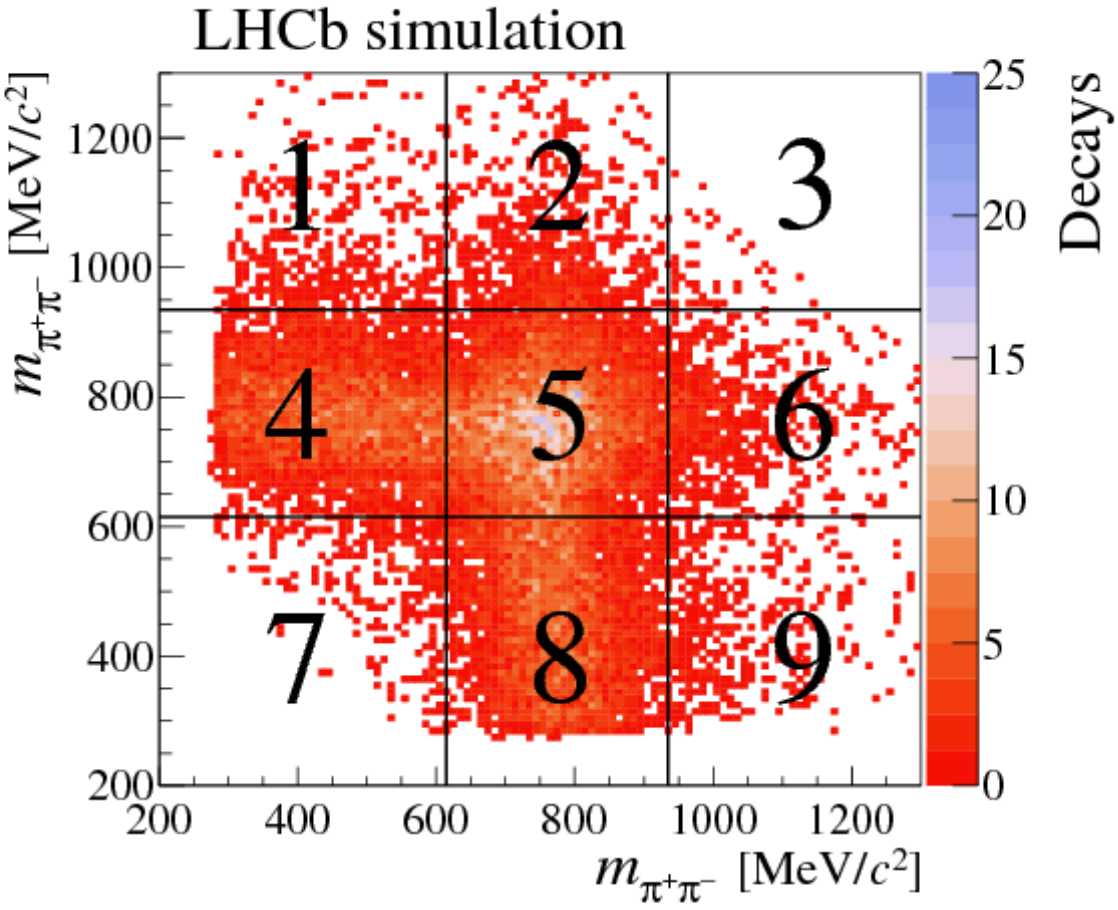
- $B_s^0 \to \mu^+\mu^-$ signal is seen with a significance of 7.8 standard deviations
- The $B_s^0 \to \mu^+\mu^-$ branching fraction is measured to be $(3.0 \pm 0.6^{+0.3}_{-0.2}) \times 10^{-9}$, where the first uncertainty is statistical and the second systematic (Phys. Rev. Lett. 118, 191801)
- SM prediction: $\mathrm{B}(B_s^0 \to \mu^+\mu^-) = (3.65 \pm 0.23) \times 10^{-9}$ (PRL 112(2014)101801)
- Previous results from LHCb + CMS data analysis: $\mathrm{B}(B_s^0 \to \mu^+\mu^-) = 2.8^{+0.7}_{-0.6} \times 10^{-9}$ (Nature 522, 68–72 (04 June 2015))

- $B_s^0 \to \mu^+\mu^-$ effective lifetime
  $\tau(B_s^0 \to \mu^+\mu^-) = 2.04 \pm 0.44 \pm 0.05 ps$, where the first uncertainty is statistical and the second systematic
- No evidence for a $B^0 \to \mu^+\mu^-$ signal is found,
  $\mathrm{B}(B^0 \to \mu^+\mu^-) < 3.4 \times 10^{-10}$ at 95% confidence
- Previous results from LHCb + CMS data analysis:
  $\mathrm{B}(B^0 \to \mu^+\mu^-) = 3.9^{+1.6}_{-1.4} \times 10^{-10}$ (Nature 522, 68–72 (04 June 2015))
- All results are in agreement with the Standard Model expectations

(Phys. Rev. Lett. 118, 191801)

Search for the decays $B_s^0 \to \tau^+\tau^-$ and $B^0 \to \tau^+\tau^-$

The analysis is performed with proton–proton collision data corresponding to integrated luminosities of 1.0 fb^{-1} and 2.0 fb^{-1} recorded with the LHCb detector at centre-of-mass energies of 7 and 8 TeV, respectively. The τ leptons are reconstructed through the decay $\tau \to \pi^-\pi^+\pi^-\nu_\tau$



(Phys. Rev. Lett. 118 (2017) 251802)

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

- Assuming no contribution from $B^0 \to \tau^+\tau^-$,
  $\mathrm{B}(B^0_s \to \tau^+\tau^-) < 6.8 \times 10^{-3}$ at 95% CL
- If no contribution from $B^0_s \to \tau^+\tau^-$ is assumed,
  $\mathrm{B}(B^0 \to \tau^+\tau^-) < 2.1 \times 10^{-3}$ at 95% CL
- Previous limit (BaBar collaboration): $\mathrm{B}(B^0 \to \tau^+\tau^-) < 4.10 \times 10^{-3}$ at 90% CL

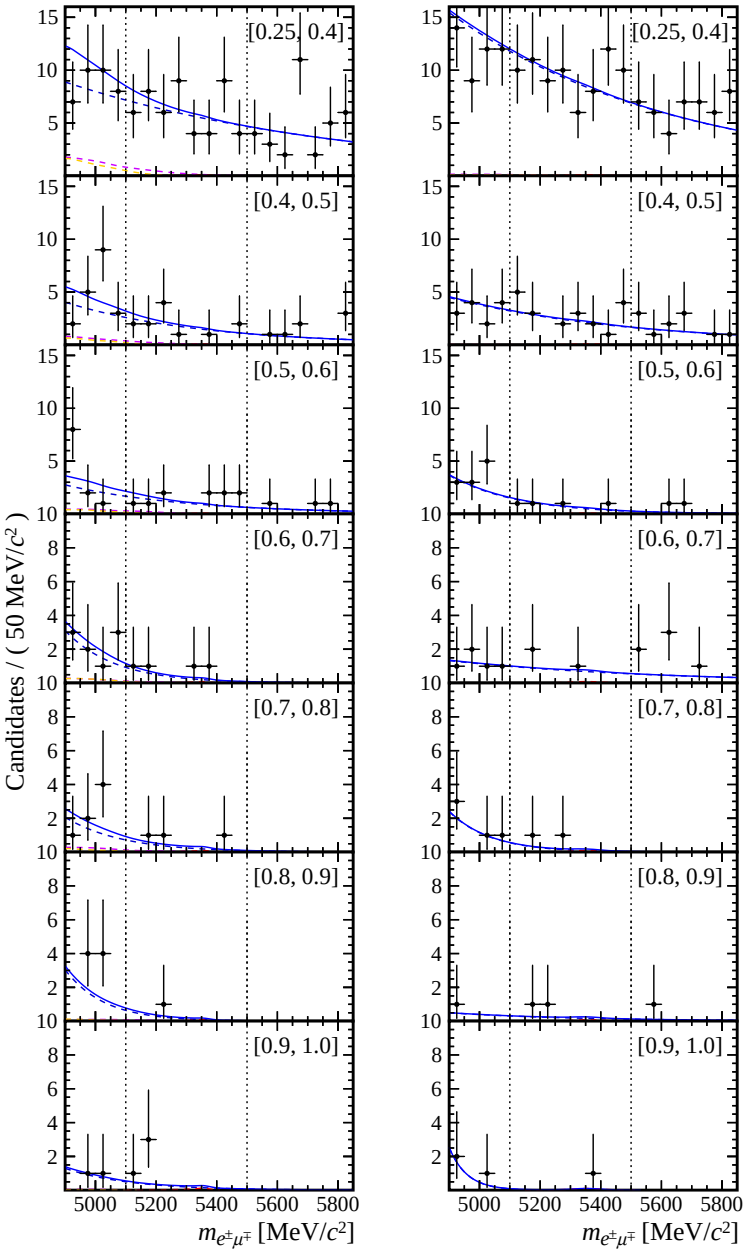
  (Phys. Rev. Lett. 96 (2006) 241802)
- These results correspond to the first direct limit on $\mathrm{B}(B^0_s \to \tau^+\tau^-)$ and the world's best limit on $\mathrm{B}(B^0 \to \tau^+\tau^-)$

(Phys. Rev. Lett. 118 (2017) 251802)

Search for the lepton-flavour violating decays $B^0_{(s)} \to e^{\pm}\mu^{\mp}$

A search for the lepton-flavour violating (LFV) decays $B^0_{(s)} \to e^{\pm}\mu^{\mp}$ was performed using pp collision data collected at centre-of-mass energies of 7 and 8TeV, corresponding to a total integrated luminosity of 3fb^{-1}.

Two normalisation channels were used: the $B^0 \to K^+\pi^-$ decay which has a similar topology to that of the signal, and the $B^+ \to J/\Psi\ K^+$ decay, with $J/\Psi \to \mu^+\mu^-$,which has an abundant yield and a similar purity and trigger selection



(JHEP 1803 (2018) 078)

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

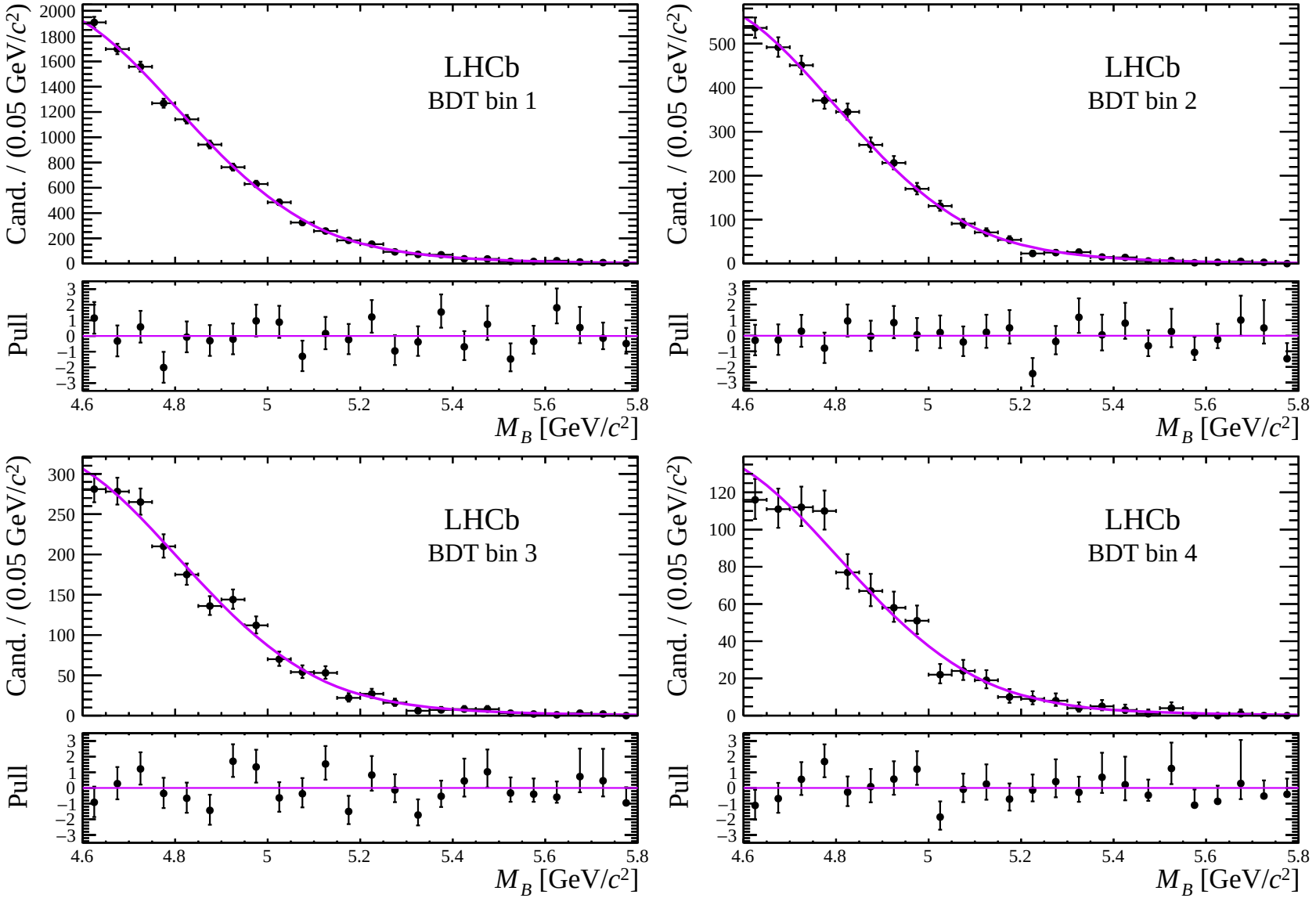
- No excesses are observed and upper limits on the branching fractions are set to $\mathrm{B}(B^0_s \to e^{\pm}\mu^{\mp}) < 6.3 \times 10^{-9}$ and $(B^0 \to e^{\pm}\mu^{\mp}) < 1.3 \times 10^{-9}$ at 95% CL
- These results represent the best upper limits to date and are a factor 2 to 3 better than the previous results from LHCb ($\mathrm{B}(B^0_s \to e^{\pm}\mu^{\mp}) < 1.4 \times 10^{-8}$ and $\mathrm{B}(B^0 \to e^{\pm}\mu^{\mp}) < 3.7 \times 10^{-9}$ at 95% CL) (Phys. Rev. Lett. 111 (2013) 141801)

(JHEP 1803 (2018) 078)

Search for the lepton-flavour-violating decays $B_s^0 \to \tau^\pm\mu^\mp$ and $B^0 \to \tau^\pm\mu^\mp$

A search for $B_s^0 \to \tau^\pm\mu^\mp$ and $B^0 \to \tau^\pm\mu^\mp$ decays is performed using data corresponding to an integrated luminosity of 3 fb^{-1} of proton-proton collisions, recorded with the LHCb detector in 2011 and 2012.

The τ lepton is reconstructed in the $\tau \to \pi^-\pi^+\pi^-\nu_\tau$ channel.



(arXiv:1905.06614)

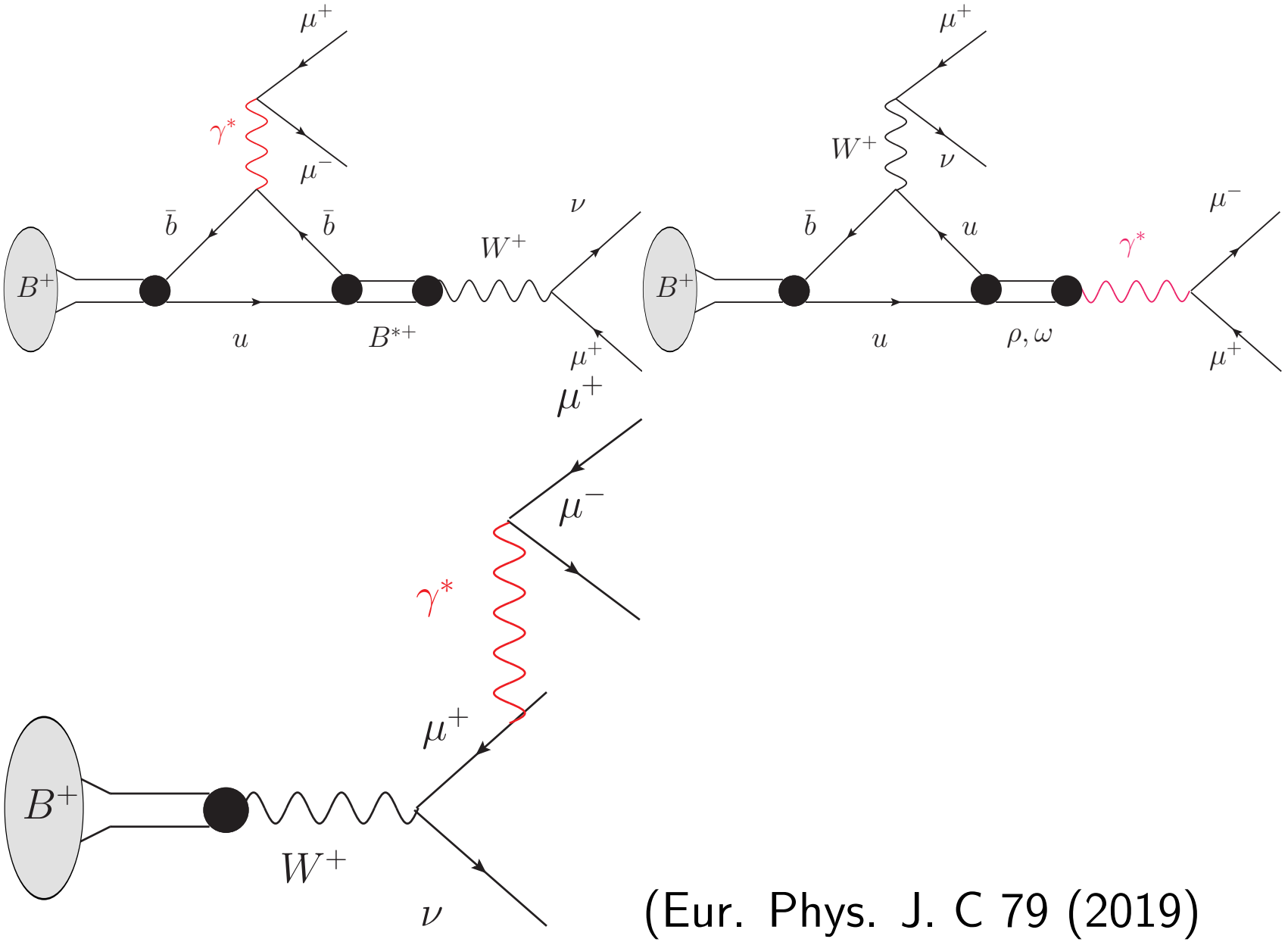
$B^0_{(s)} \to \tau^{\pm}\mu^{\mp}$

- B($B^0_s \to \tau^{\pm}\mu^{\pm}$) $< 4.2\times10^{-5}$ at 95% CL (Assuming no contribution from $B^0 \to \tau^{\pm}\mu^{\pm}$)
- B($B^0 \to \tau^{\pm}\mu^{\pm}$) $< 1.4\times10^{-5}$ at 95% CL (Assuming no contribution from $B^0_s \to \tau^{\pm}\mu^{\pm}$)
- These are the first limit on B($B^0_s \to \tau^{\pm}\mu^{\pm}$) and the world's best limit on B($B^0 \to \tau^{\pm}\mu^{\pm}$)

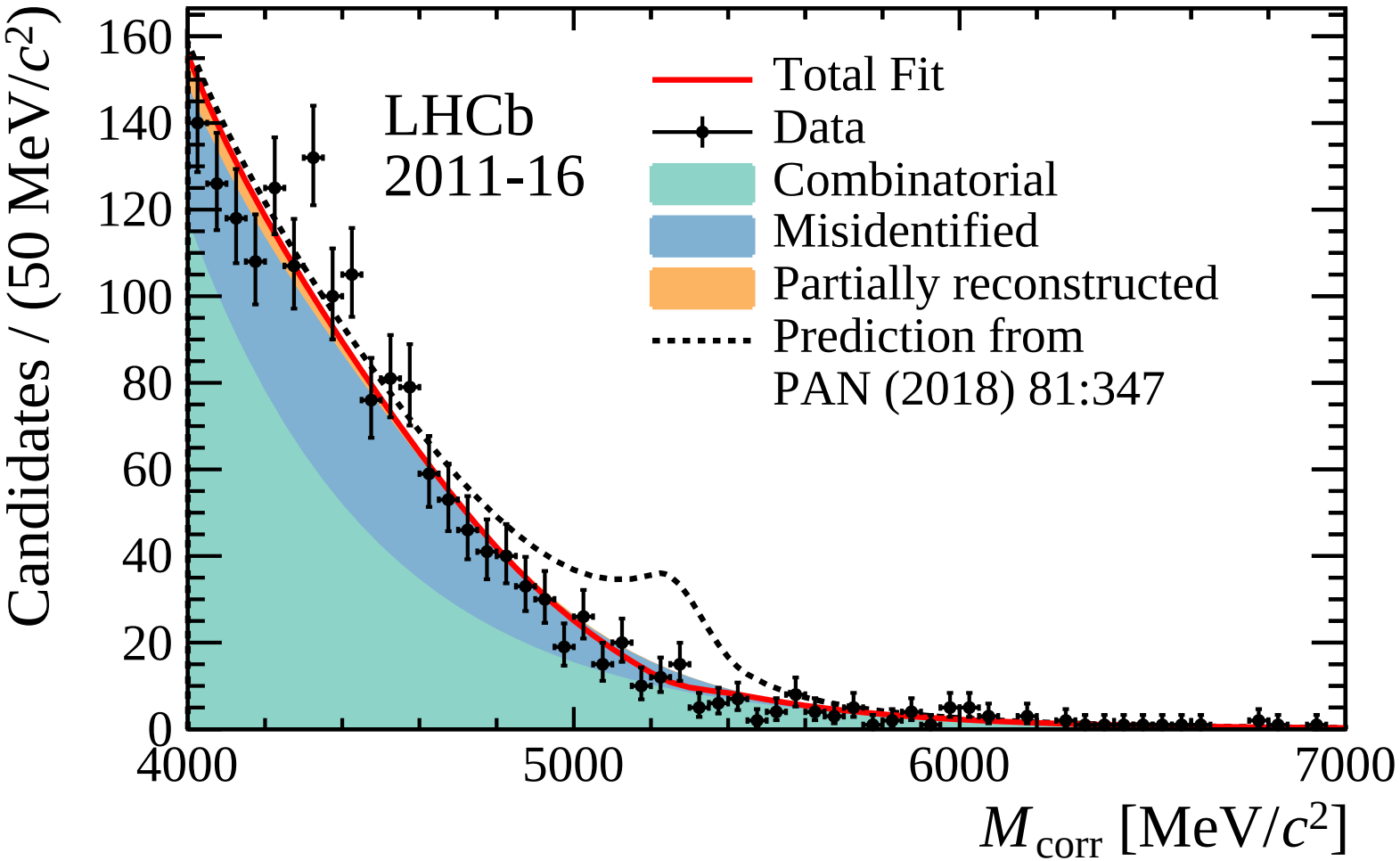
arXiv:1905.06614

Search for the rare decay $B^+ \to \mu^+\mu^-\mu^+\nu_\mu$

A search for the rare leptonic decay $B^+ \to \mu^+\mu^-\mu^+\nu_\mu$ is performed using proton-proton collision data corresponding to an integrated luminosity of 4.7 fb^{-1} collected by the LHCb experiment. The search is carried out in the region where the lowest of the two $\mu^+\mu^-$ mass combinations is below 980 MeV/c^2. The branching fraction of a $B^+ \to \mu^+\mu^-\mu^+\nu_\mu$ signal is obtained by normalising to the $B^+ \to J/\Psi(\to \mu^+\mu^-)K^+$ decays.



(Eur. Phys. J. C 79 (2019) 675)



Eur. Phys. J. C 79 (2019) 675)

$B^+ \to \mu^+\mu^-\mu^+\nu_\mu$

- No signal is observed for the $B^+ \to \mu^+\mu^-\mu^+\nu_\mu$ decay
- An upper limit of 1.6×10^{-8} at 95% confidence level is set on the branching fraction, where the lowest of the two $\mu^+\mu^-$ mass combinations is below 980MeV/c^2.
- The limit for the full kinematic region stays the same under the assumption that the decay is dominated by intermediate vector mesons.

Eur. Phys. J. C 79 (2019) 675)

Conclusions

- Lot of rare B mesons decays were studied by the LHCb team
- All results are consistent with the Standard Model
- Nearly all results presented are either unique or the most accurate for the time

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