LEPTON FLAVOR (UNIVERSALITY) VIOLATING B DECAYS IN LOOPS

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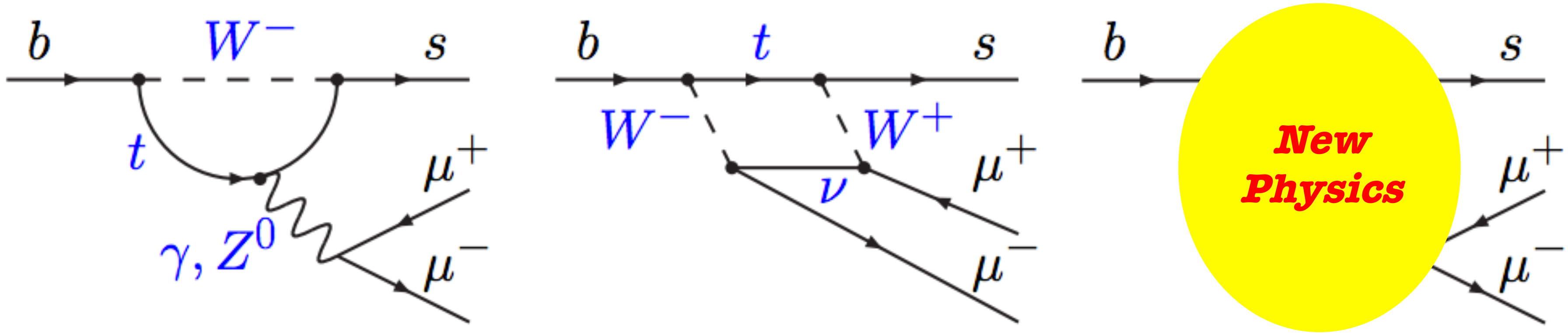
b->sll AS PROBES FOR NP

- ***b->sll* transitions are powerful probe of New Physics:**
  - FCNC proceeding via loop diagrams only;
  - suppressed in the SM, so more sensitive to NP;
  - rich phenomenology and many precise SM predictions available;
  - explore higher mass scales than the current collider energies.



- *New particles in the loop could enhance/suppress decay rates, introduce new sources of CP violation, modify angular distributions.*

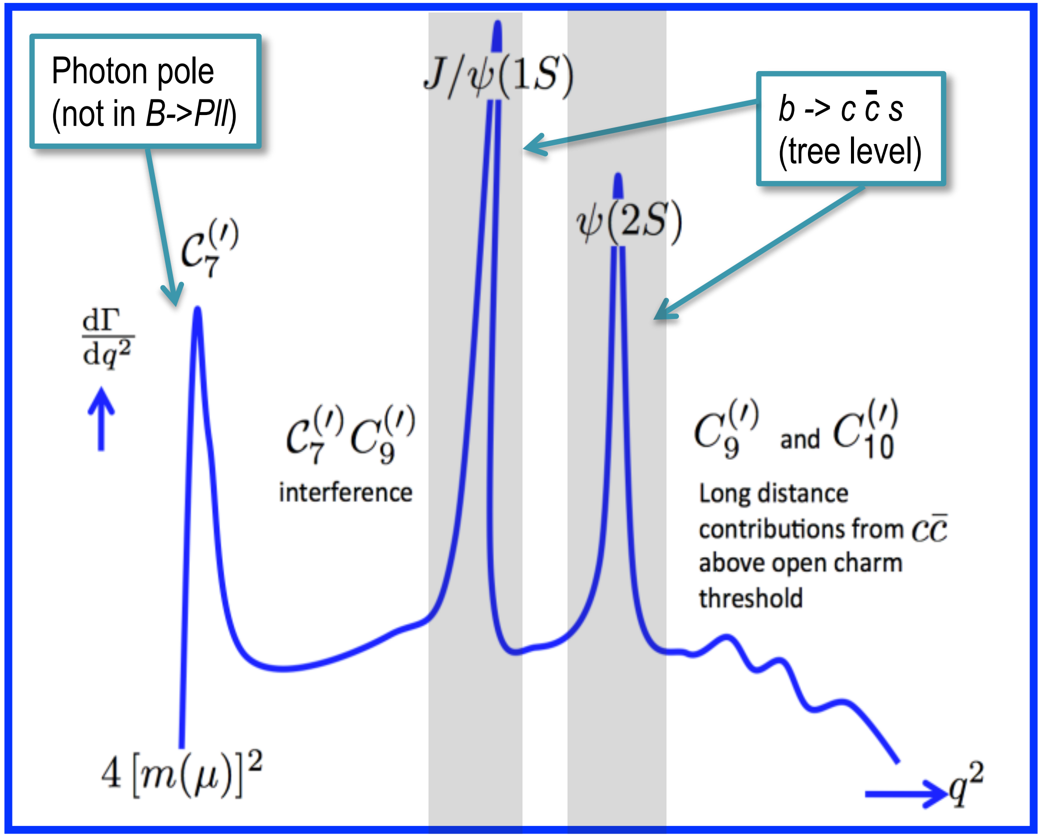
- ***NP could couple differently to lepton families***
  ==> Lepton Flavor Universality tests
- *Previous tests (ex: Z->ll) at % level*

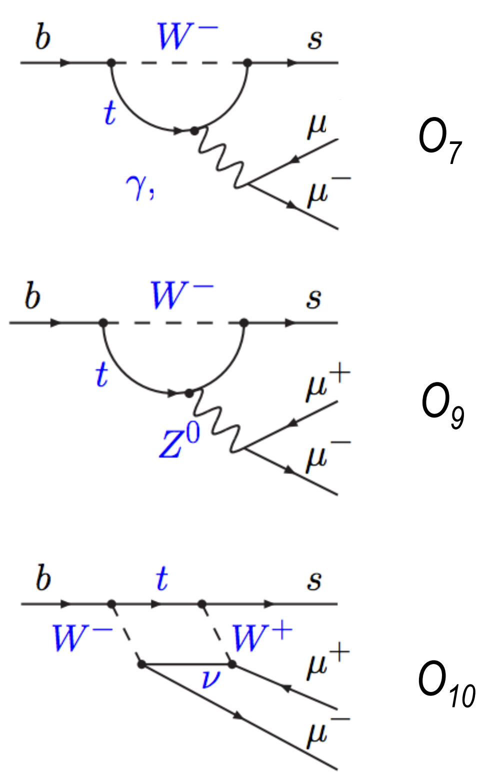
EFFECTIVE THEORY APPROACH

$$H_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i \Big[\underbrace{C_i(\mu) O_i(\mu)}_{\text{left-handed part}} + \underbrace{C_i'(\mu) O_i'(\mu)}_{\text{right-handed part suppressed in SM}} \Big]$$

Operators O_i: non-perturbative long-distance effects
Wilson coefficients C_i: perturbative short-distance effects

i = 1, 2	Tree
i = 3 -6, 8	Gluon penguin
i = 7	Photon penguin
i = 9, 10	Electroweak penguin
i = S	Higgs (scalar) penguin
i = P	Pseudoscalar penguin

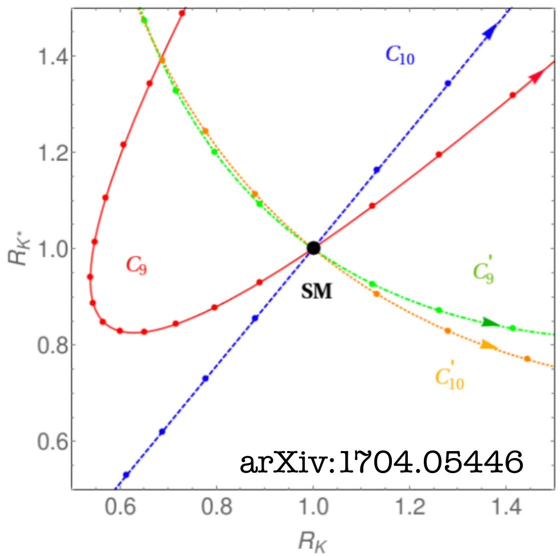




THE LU TEST R_H

$$R_X[q^2_{min}, q^2_{max}] = \frac{\int_{q^2_{min}}^{q^2_{max}} dq^2 \frac{d\Gamma(B\to X\mu^+\mu^-)}{dq^2}}{\int_{q^2_{min}}^{q^2_{max}} dq^2 \frac{d\Gamma(B\to X e^+ e^-)}{dq^2}}$$

- Expected to be 1 in the Standard Model, apart from precisely predictable phase space effects and helicity-suppressed contributions.
- Theoretical uncertainty at 10^{-3}, QED effects at % level (arXiv:1605.07633)
- Not affected by QCD effects (ex: charm loops)
- Different ratios provide complementary information:



THE R_X MEASUREMENTS @ LHCb

- In LHCb we use the double ratio of the rare to the J/ψ channel to reduce systematic uncertainties:

$$R_X = \frac{BR(B \to X\mu^+\mu^-)}{BR(B \to Xe^+e^-)} \cdot \frac{BR(B \to XJ/\psi(e^+e^-))}{BR(B \to XJ/\psi(\mu^+\mu^-))}$$

- The measurement boils down to precisely **determining yields and efficiencies**: other factors (luminosity, cross section) cancel in the ratio.

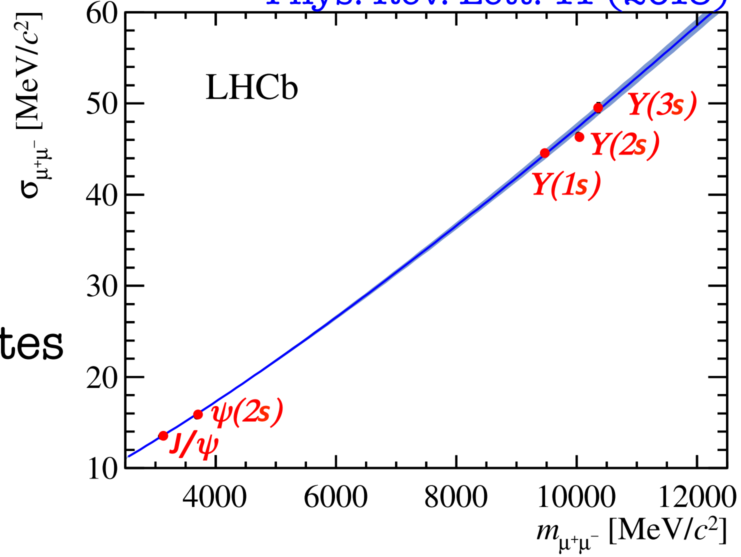
$$R_X = \frac{N(B \to X\mu^+\mu^-)}{\varepsilon(B \to X\mu^+\mu^-)} * \frac{\varepsilon(B \to XJ/\psi(\mu^+\mu^-))}{N(B \to XJ/\psi(\mu^+\mu^-))} * \frac{N(B \to XJ/\psi(e^+e^-))}{\varepsilon(B \to XJ/\psi(e^+e^-))} * \frac{\varepsilon(B \to Xe^+e^-)}{N(B \to Xe^+e^-)}$$

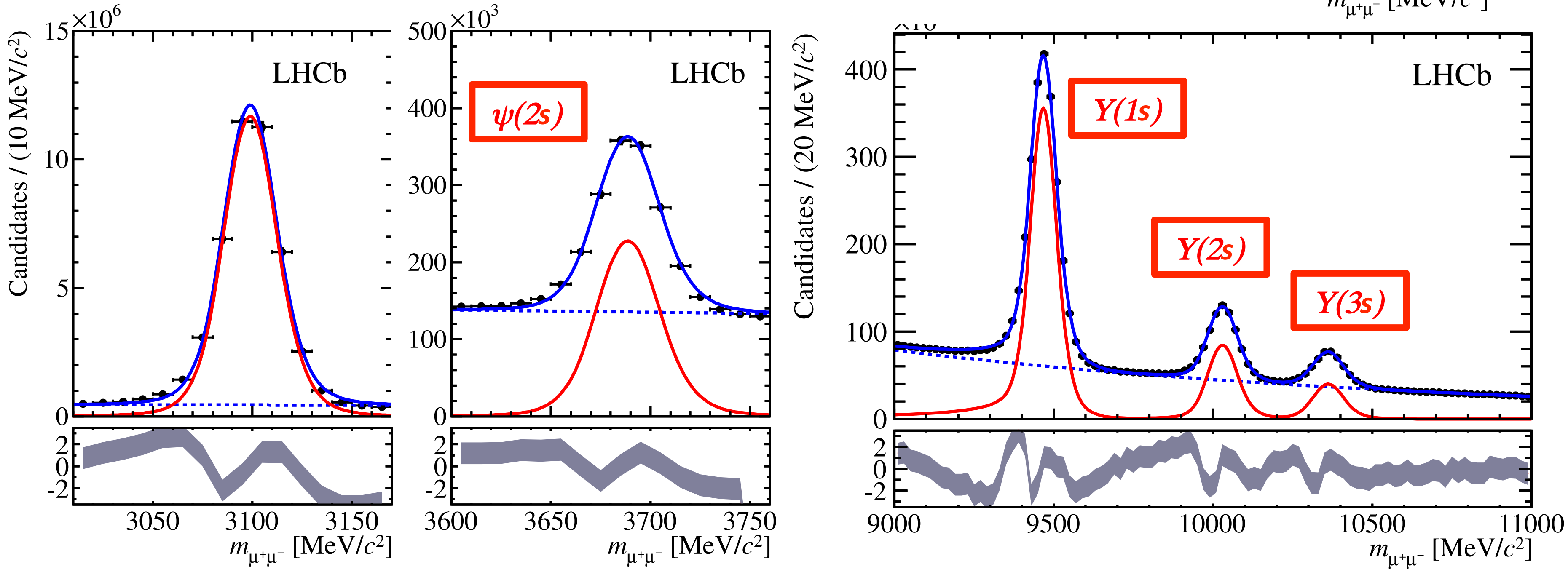
- Most of difficulties are on the electron channel.

MUON RECONSTRUCTION @ LHCb

- **Extremely performant in LHCb**:
  - dedicated muon chambers
  - very efficient tracking system.
- **A muon is a clear trigger signature**:
  ε(L0+HLT)= ~90% for di-muon channels
  ε(L0+HLT)= ~30% for multibody hadronic states
- **Very good di-muon resolution**

Phys. Rev. Lett. 11 (2013)





ELECTRON RECONSTRUCTION @ LHCb

- Identified through the electromagnetic calorimeter: $ECAL: \frac{\sigma_E}{E} \sim 1\% \otimes \frac{10\%}{\sqrt{E(GeV)}}$

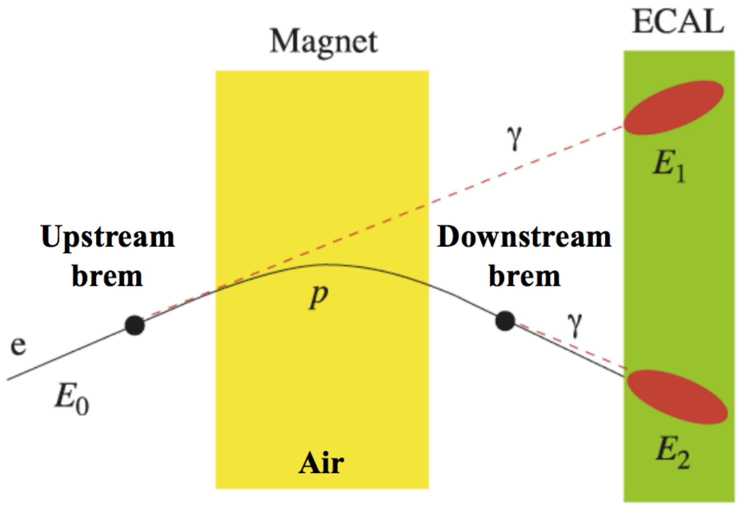
(Int. J. Mod. Phys. A 30 (2015) 1530022)

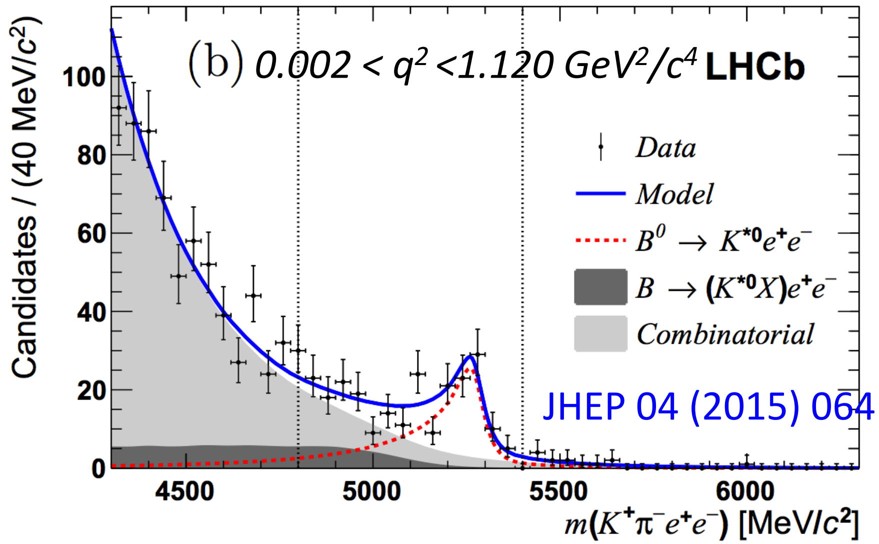
- Electrons undergo energy loss from **bremsstrahlung**.

  Recovery of bremsstrahlung photons can not be 100% efficient.

  Consequences:

  - significant **degradation of the *B* mass resolution**
  - **large contribution from partially reconstructed** backgrounds
  - **bin migration**

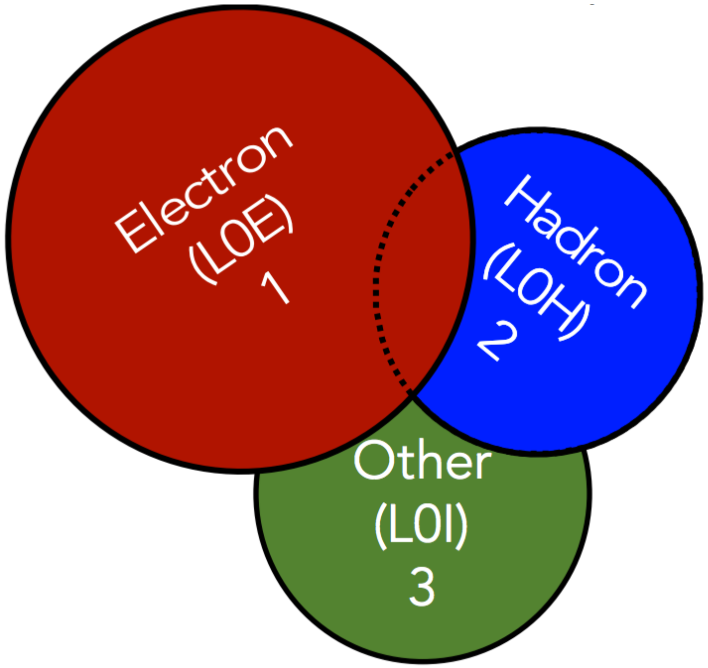




Approach: use exclusive bremsstrahlung categories, with different resolutions and purities

TRIGGER FOR ELECTRON CHANNELS @ LHCb

- High occupancy of calorimeters
  => **hardware thresholds on electron E_T higher than on muon p_T**
- Use different triggers to increase the yields:



L0E: trigger fired by one of the electrons (E_T>2.5GeV)

L0H: trigger fired by the K or the π (E_T>3.5GeV)

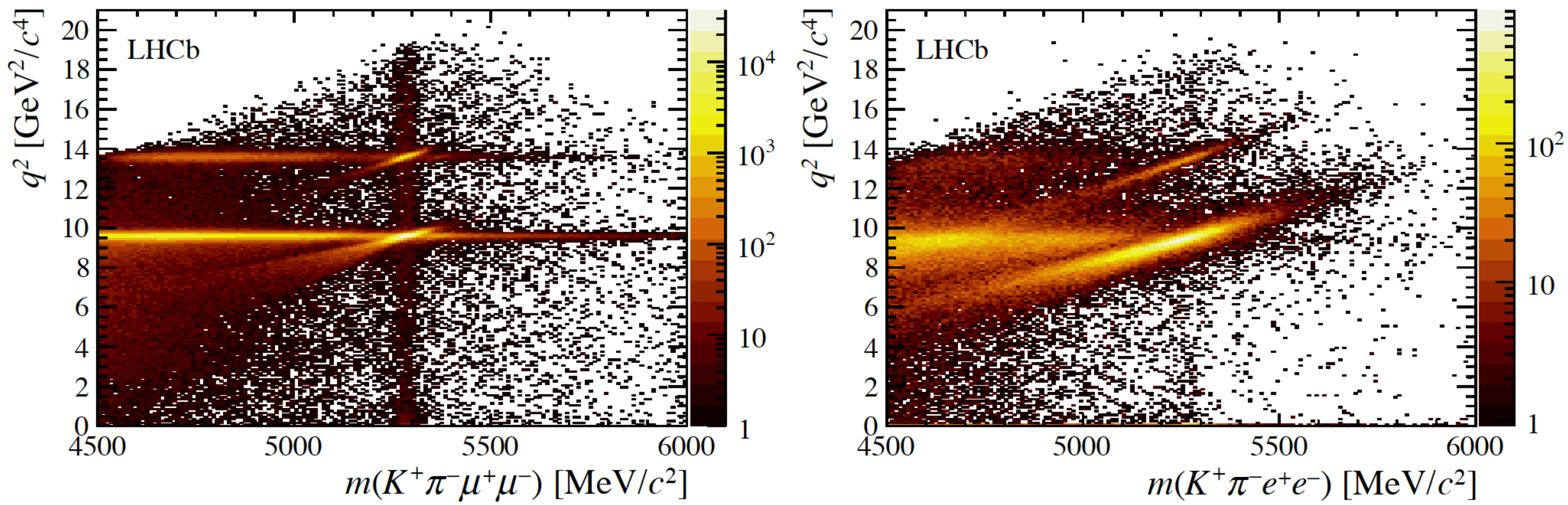
L0I: trigger fired by particles not associated to the signal candidate

Approach: use exclusive trigger categories, with different resolutions and purities

R_{K^*} DATASET AFTER PRESELECTION @ LHCb

- All run1 ($3fb^{-1}$)
- Analysis in two q^2 bins:
  - low-q^2 [0.045, 1.1] GeV^2/c^4
  - central-q^2 [1.1, 6] GeV^2/c^4

JHEP 08 (2017) 055



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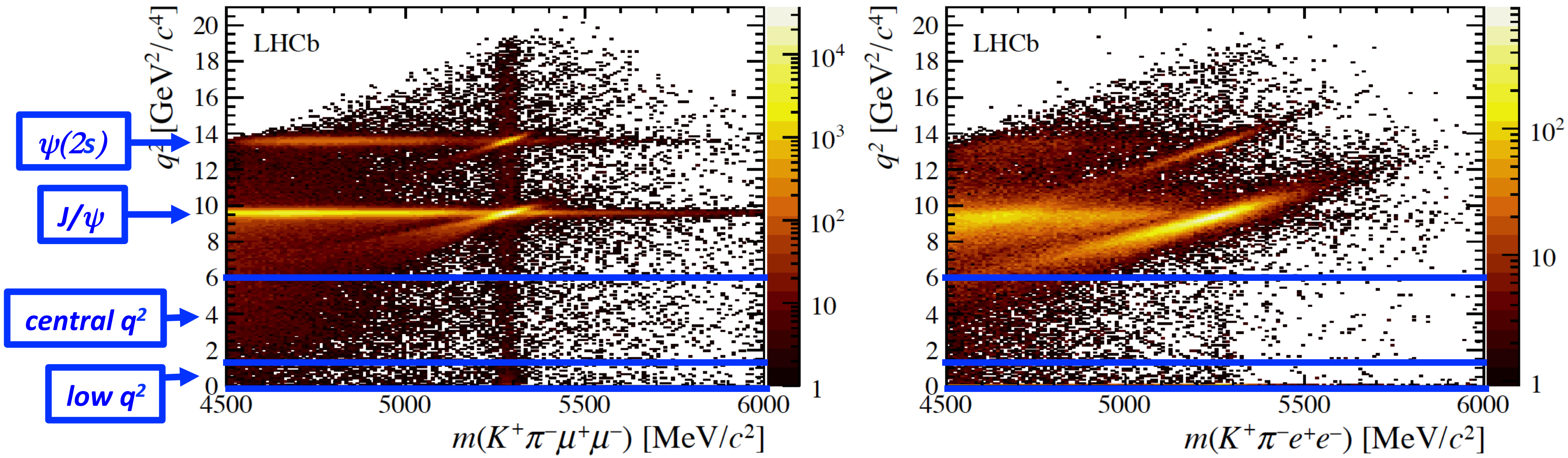

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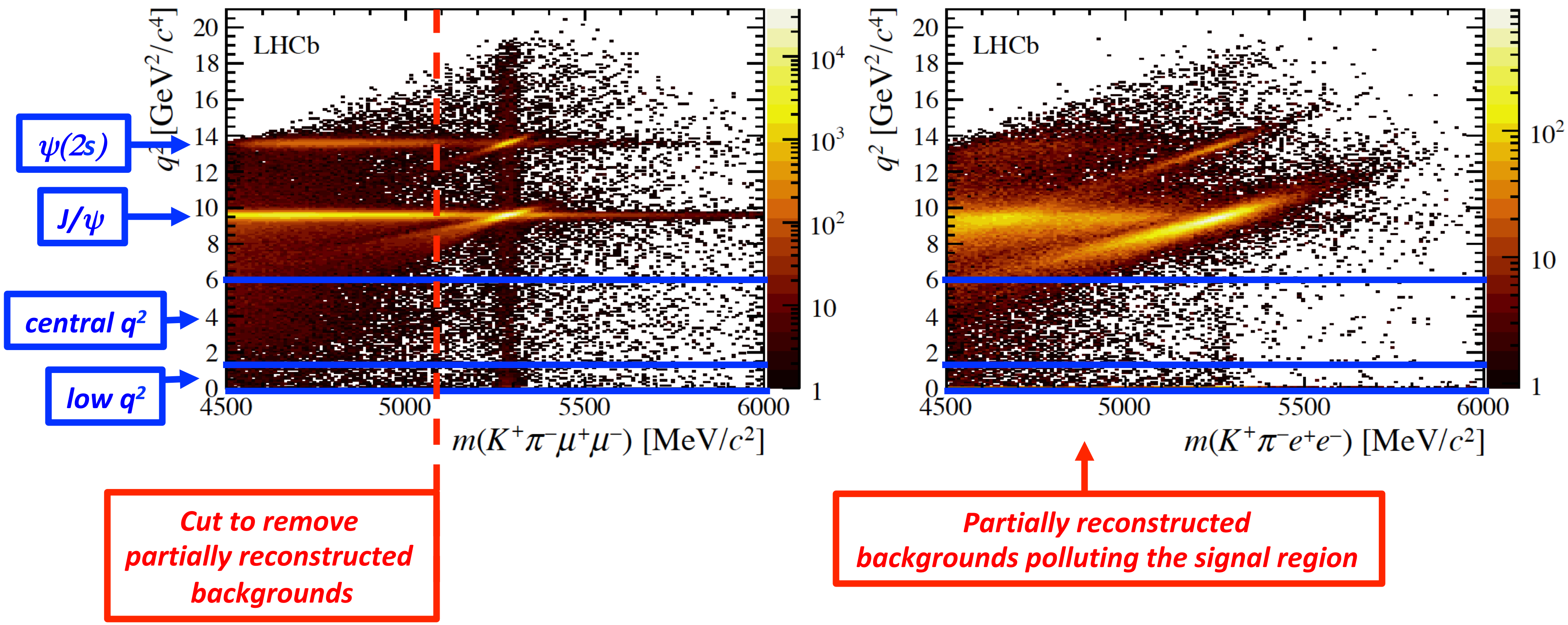

R_{K^*} YIELDS @ LHCb

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

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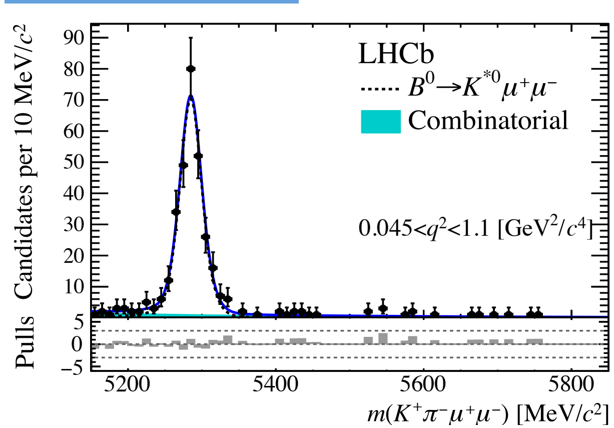
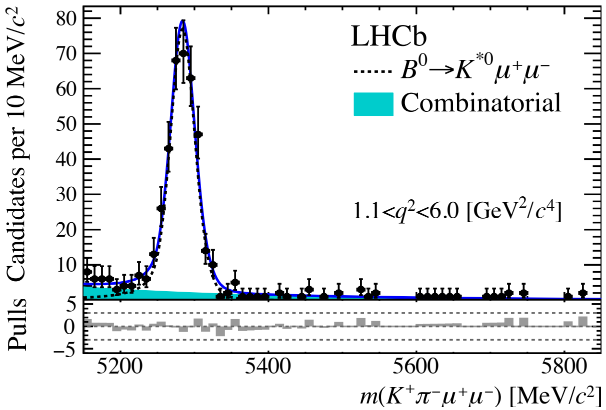
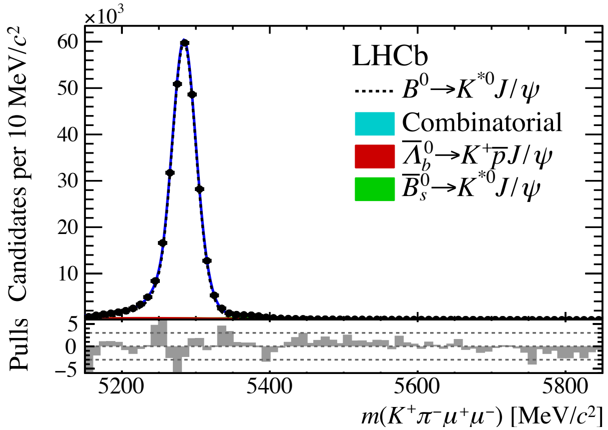




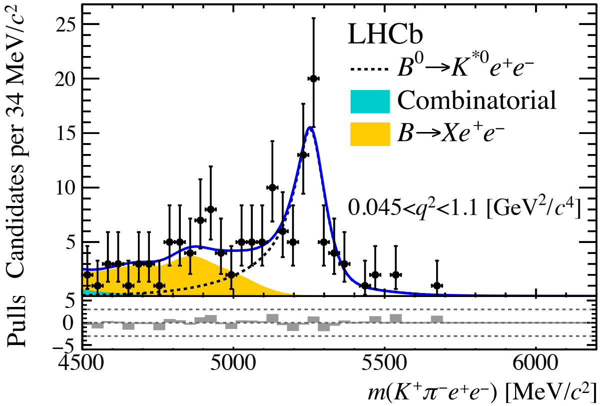


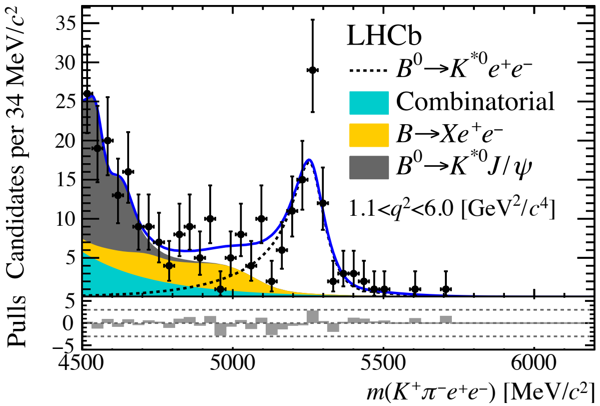
Low q^2 : 285 ± 18

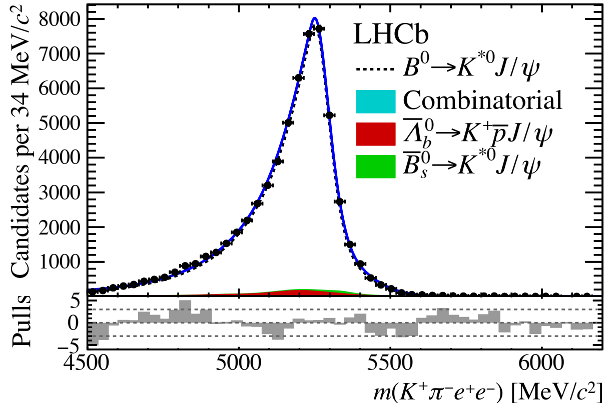
Central q^2 : 353 ± 21

J/ψ region : 274K

$B^0 \to K^{*0}ee$







Low q^2 : 89 ± 11

Central q^2 : 111 ± 14

J/ψ region : 58K

R_{K^*} CROSSCHECKS @ LHCb

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- $r_{J/\psi}$ **ratio** : compatible with 1 and flat as function of kinematics and event multiplicity => very stringent test! (not a double ratio)

$$r_{J/\psi} = \frac{\mathcal{B}(B^0 \to K^{*0} J/\psi(\to \mu^+\mu^-))}{\mathcal{B}(B^0 \to K^{*0} J/\psi(\to e^+e^-))} = 1.043 \pm 0.006\,(\text{stat}) \pm 0.045\,(\text{syst})$$

- $R_{\psi(2s)}$ **and** r_γ **ratios** : consistent with expectations

$$\mathcal{R}_{\psi(2S)} = \frac{\mathcal{B}(B^0 \to K^{*0}\psi(2S)(\to \mu^+\mu^-))}{\mathcal{B}(B^0 \to K^{*0} J/\psi(\to \mu^+\mu^-))} \Big/ \frac{\mathcal{B}(B^0 \to K^{*0}\psi(2S)(\to e^+e^-))}{\mathcal{B}(B^0 \to K^{*0} J/\psi(\to e^+e^-))}$$

$$r_\gamma = \frac{\mathcal{B}(B^0 \to K^{*0}\gamma(\to e^+e^-))}{\mathcal{B}(B^0 \to K^{*0} J/\psi(\to e^+e^-))}$$

- *BR(B->K*μμ)* : in agreement with published LHCb result [arXiv:1606.04731].

- **No corrections to MC** : less than 5% variation on R_{K^*}.

- **Population of bremsstrahlung categories** : consistent between data and MC.

- **Kinematic distributions** : consistent among MC/background subtracted data.

R_{K^*} RESULTS @ LHCb

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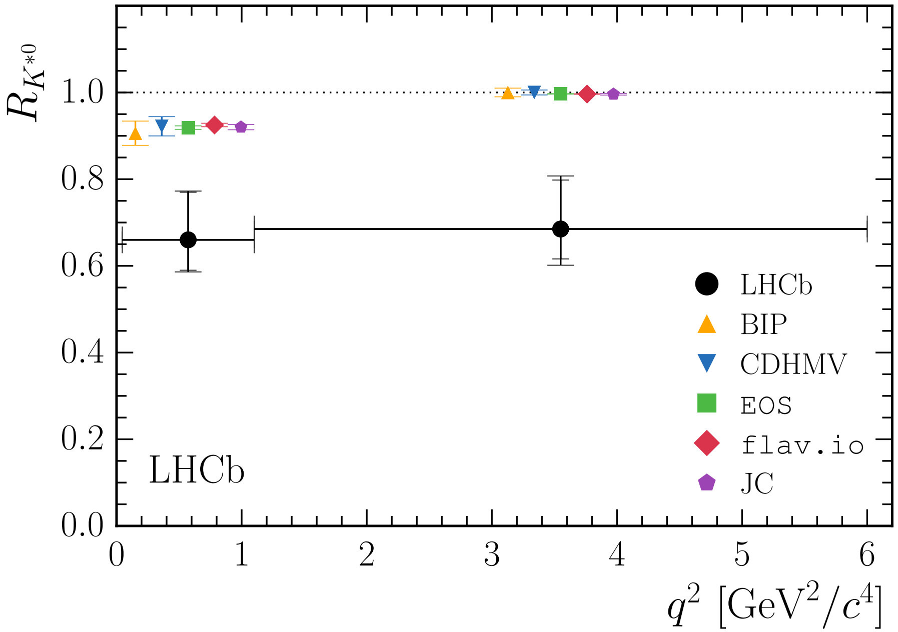
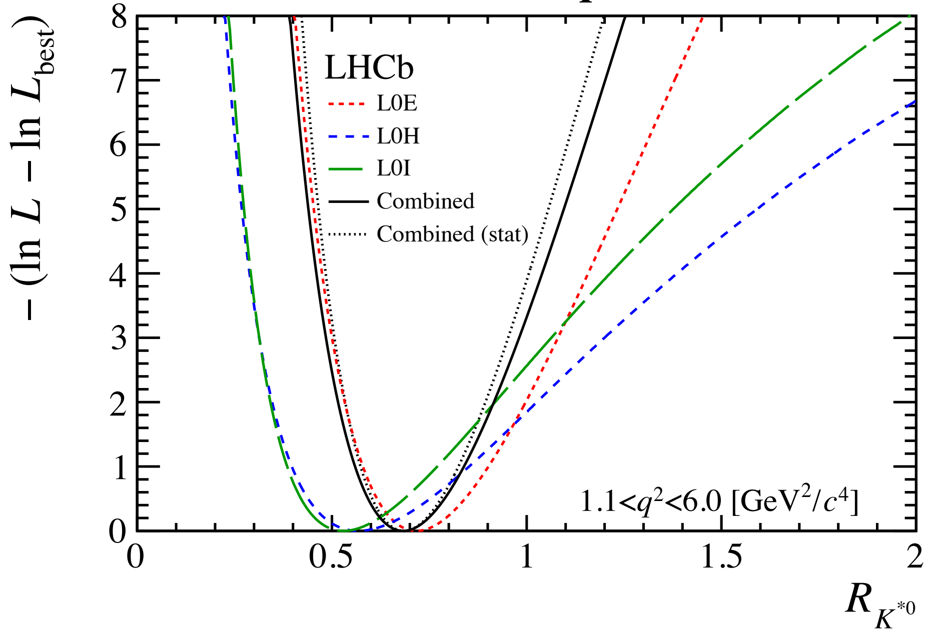
Compatibility with the SM:
- **2.1-2.3 standard deviations (low-q^2)**
- **2.4-2.5 standard deviations (central-q^2)**

The measurement is statistically dominated (15%)

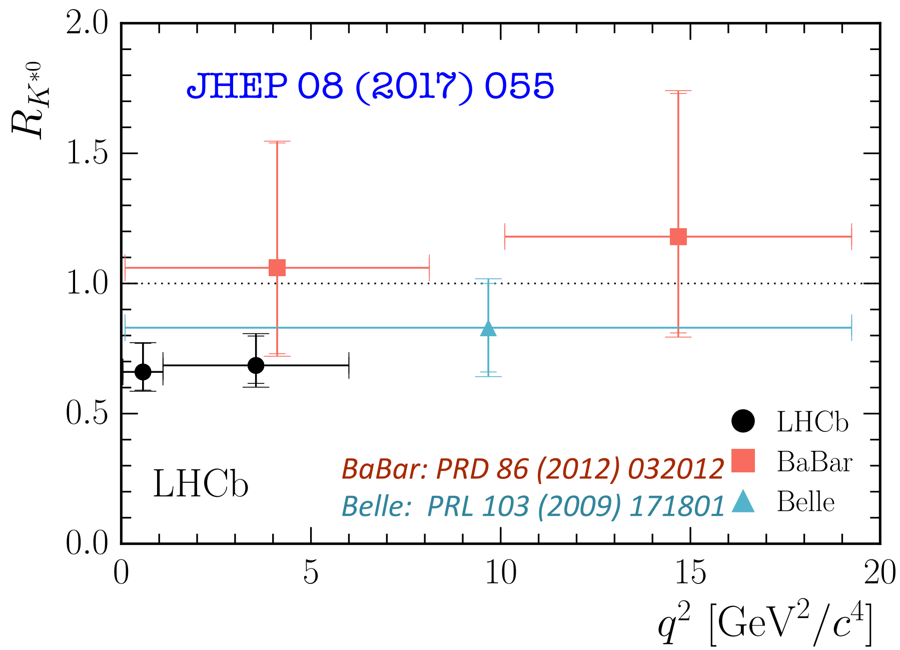
Central q^2

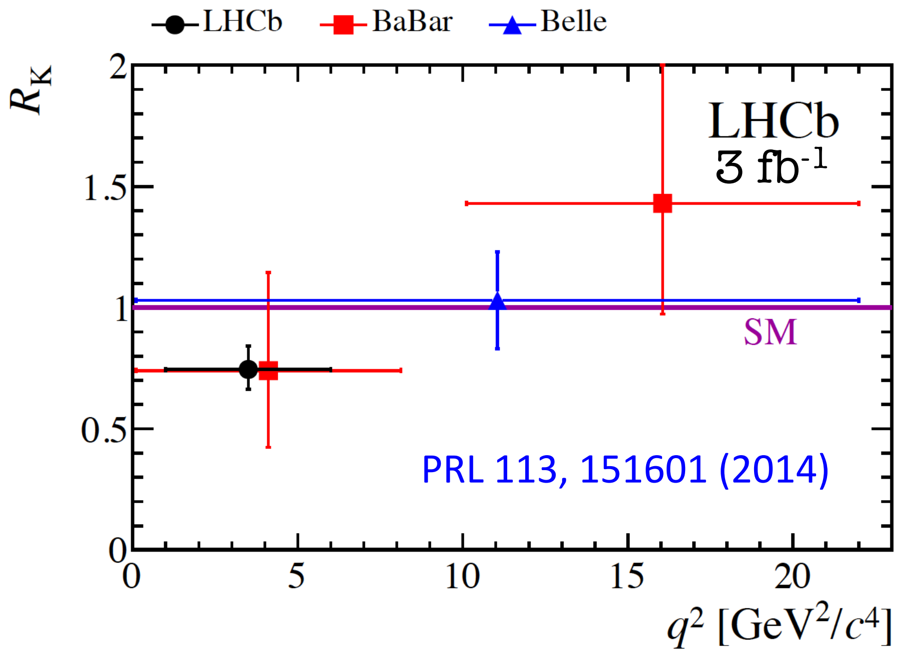




BIP	arXiv:1605.07633
CDHMV	arXiv:1510.04239, 1605.03156, 1701.08672
EOS	arXiv:1610.08761, https://eos.github.io
flav.io	arXiv:1503.05534, 1703.09189, flav-io/flavio
JC	arXiv:1412.3183

RESULTS ON LFU TESTS IN LOOPS



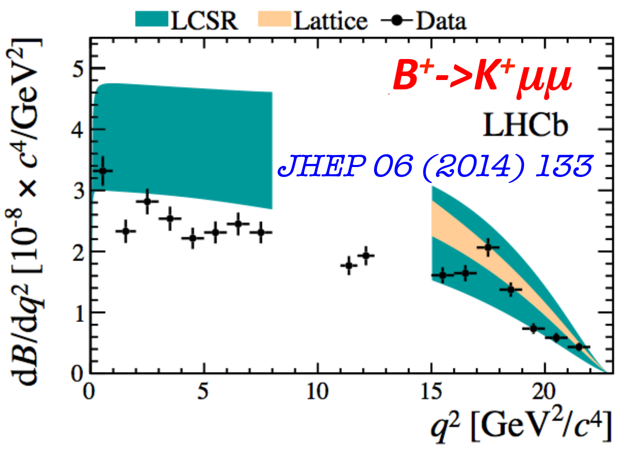


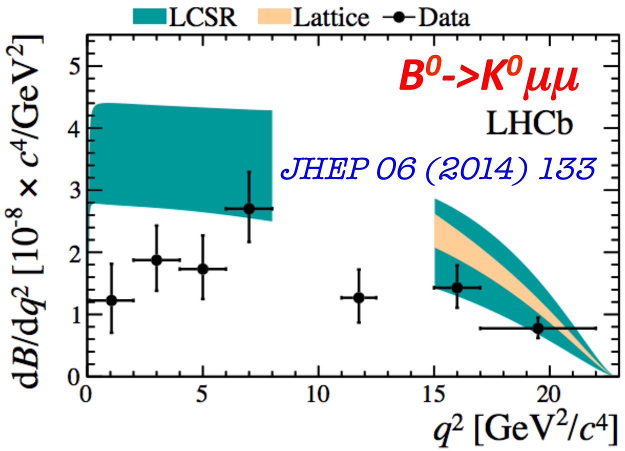
Compatible with Standard Model at 2.5σ

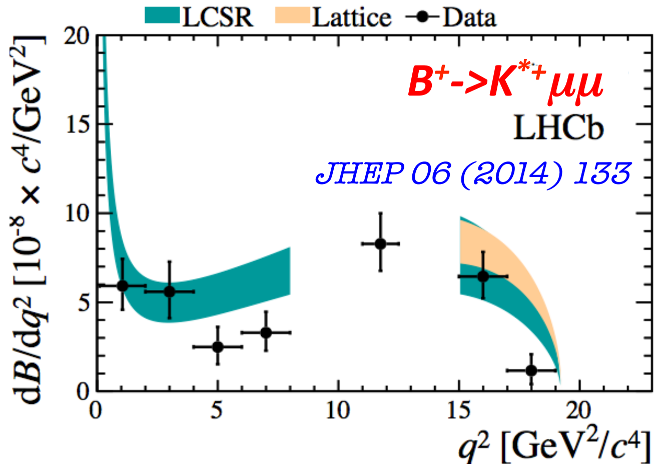
Compatible with Standard Model at 2.6σ

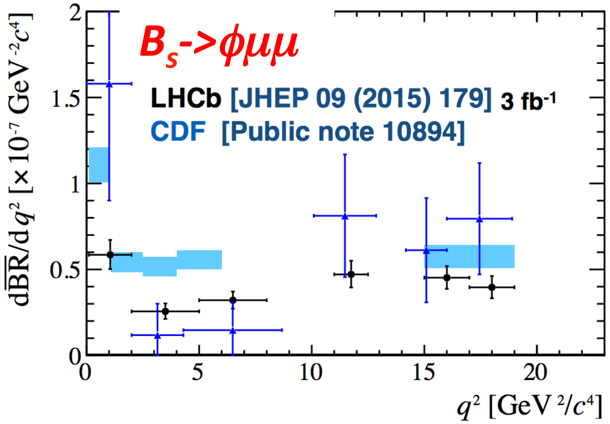
REMINDER OF OTHER b->sll RESULTS

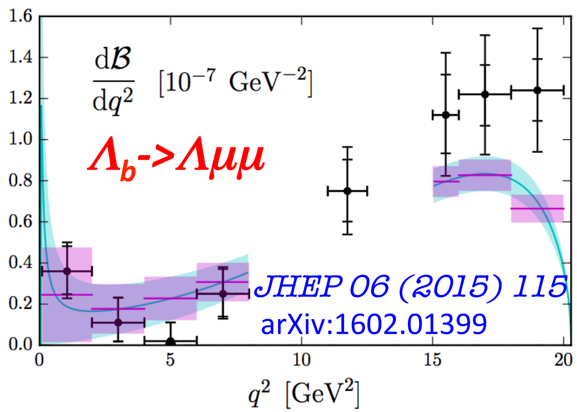
Measured ***BR* with muons are consistently lower than predicted in SM**

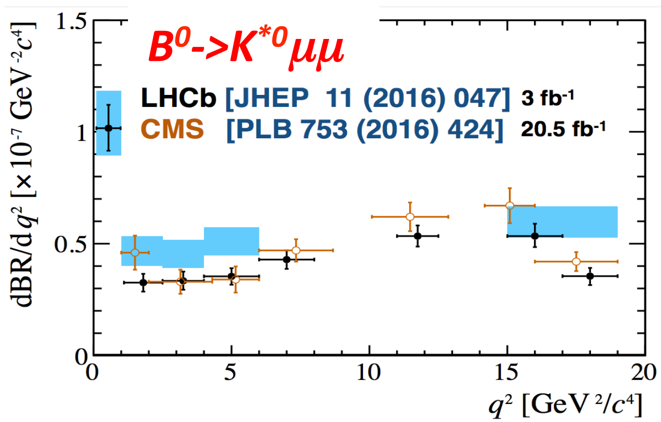






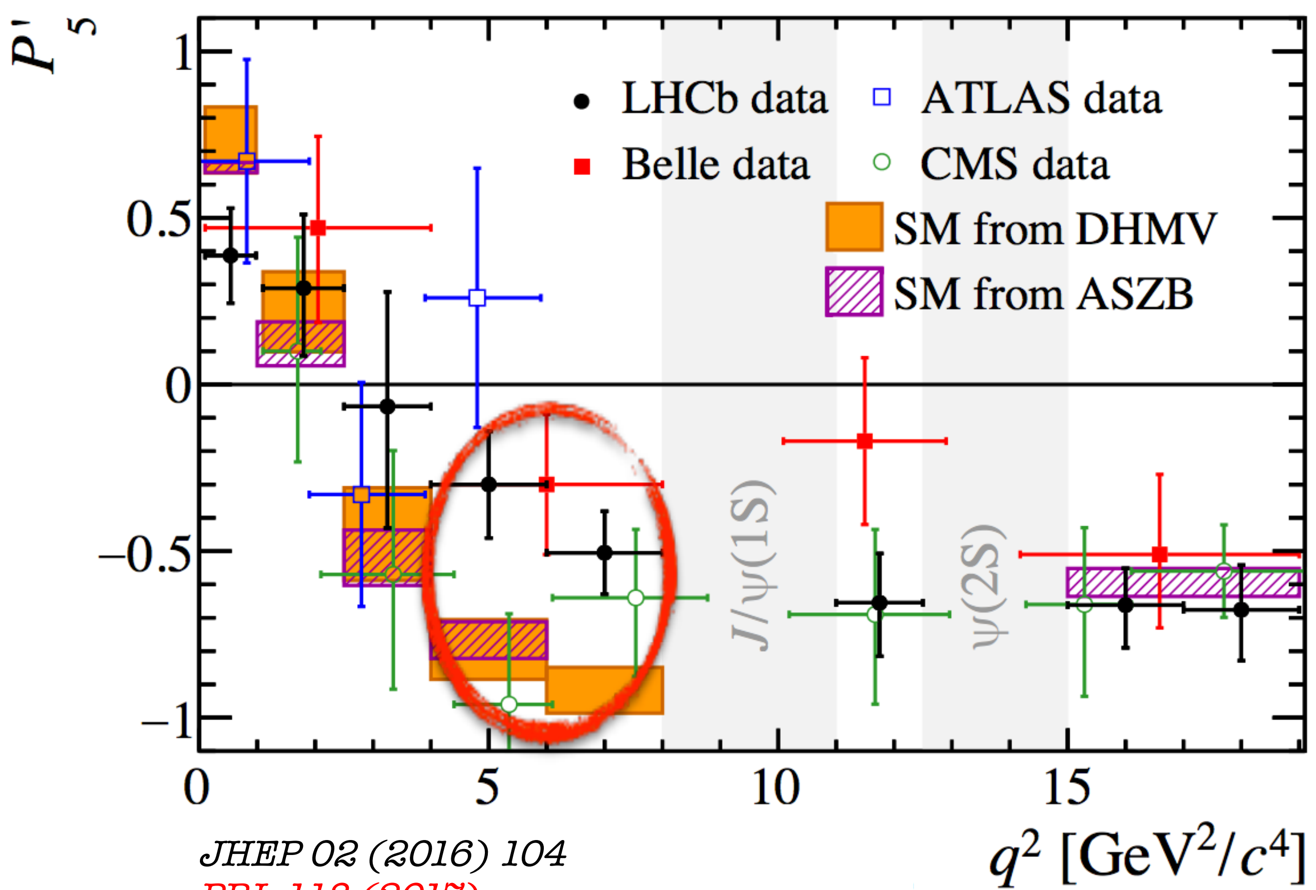






REMINDER OF OTHER b->sll RESULTS

Angular observables in $B \to K^*\mu\mu$ show about 3.4σ discrepancy



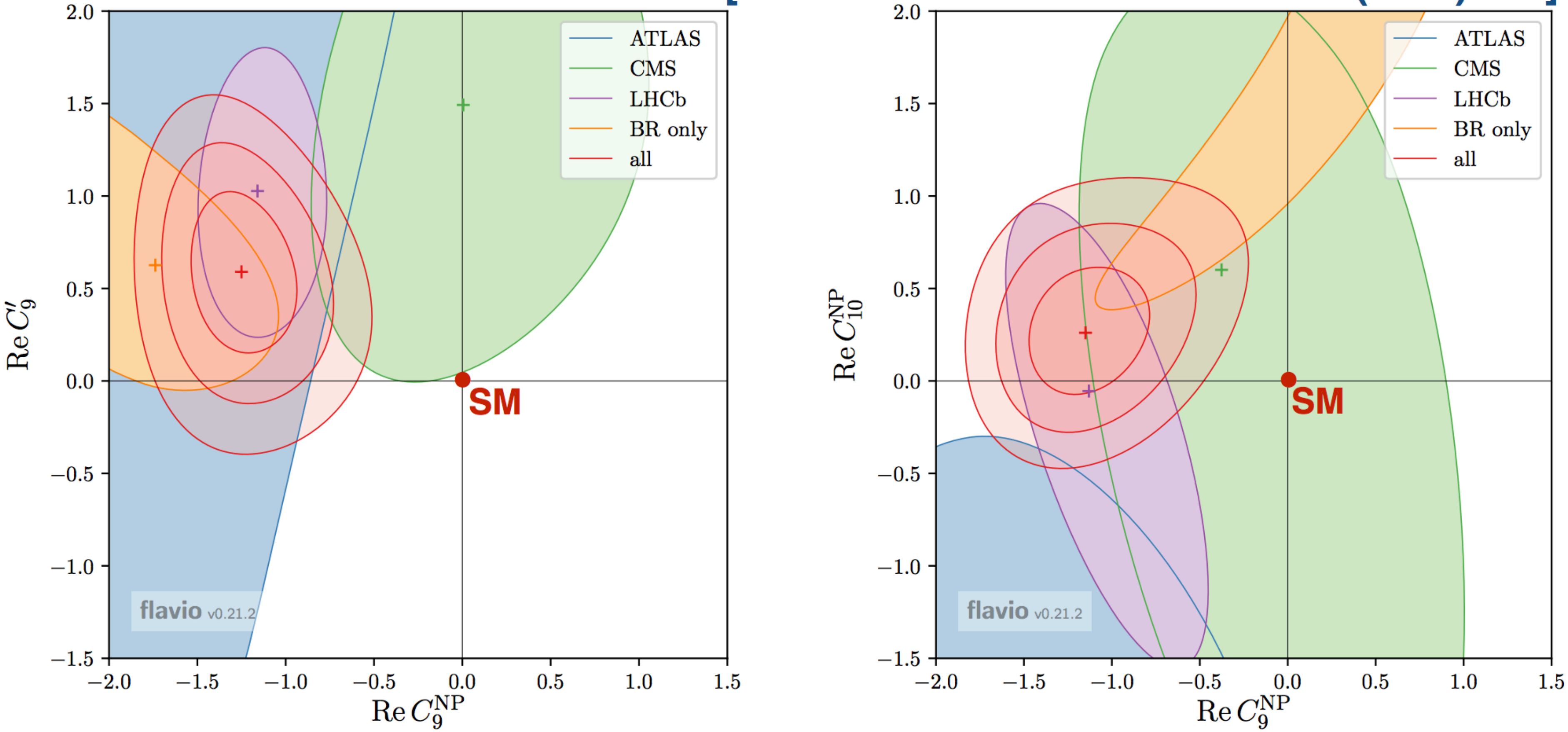
JHEP 02 (2016) 104
PRL 118 (2017)
ATLAS-CONF-2017-023
CMS-PAS-BPH-15-008

THE GLOBAL PICTURE

- Adding BRs and angular observables of $b \to \mu\mu$, $b \to sll$, $b \to s\gamma$
  => up to 5σ deviation from the SM

- Mostly affecting $C_{9\mu}$ and $C_{10\mu}$ Wilson coefficients

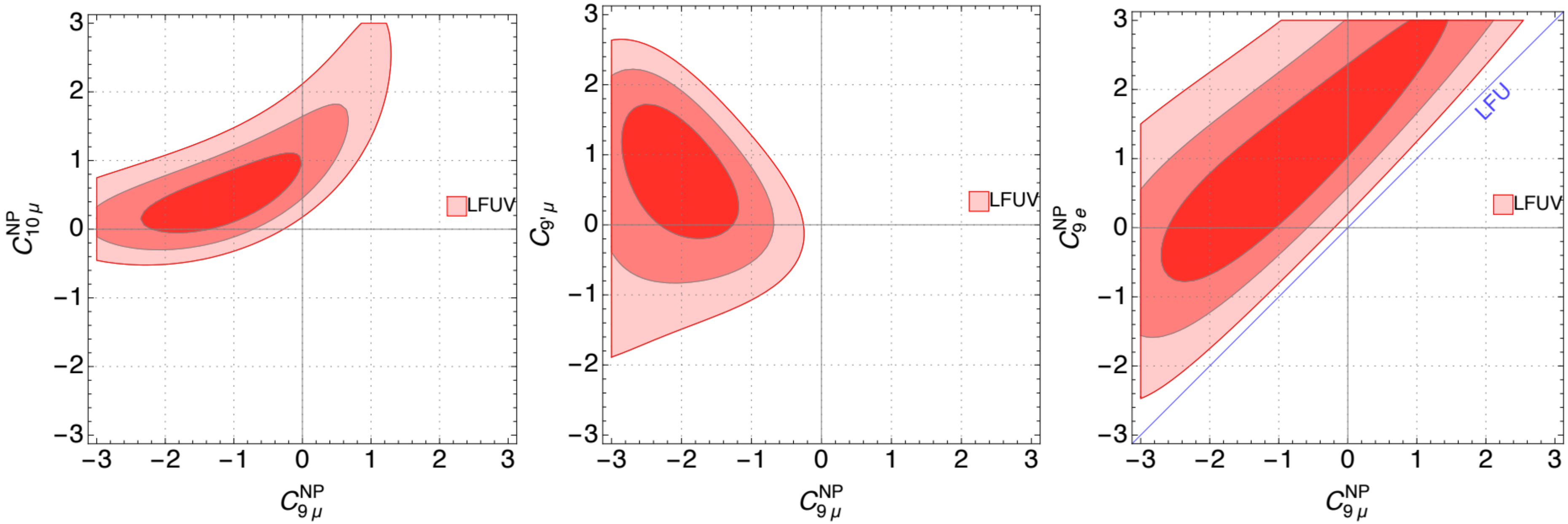
[W. Altmannshofer et al. EPJC 77 (2017) 377]



THE GLOBAL PICTURE

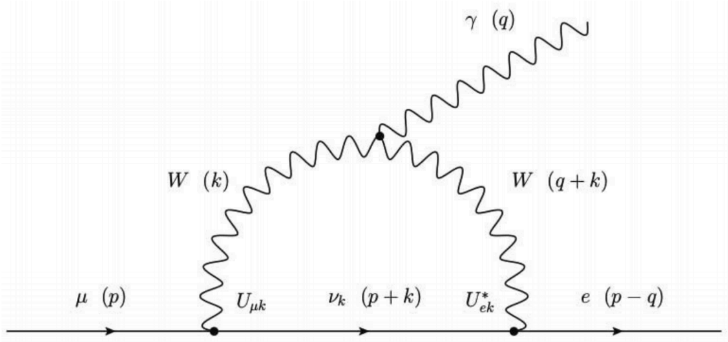
- Adding BRs and angular observables of *b->μμ, b->sll, b->sγ*
  => up to 5σ deviation from the SM
- Mostly affecting $C_{9\mu}$ and $C_{10\mu}$ Wilson coefficients
- **Global fits of LFU only shows about 3σ discrepancy from SM**
- Remember: LFU tests are not affected by QCD effects (ex: charms loops)

arXiv:1704.05340



LEPTON FLAVOUR VIOLATION

- Lepton flavour violation occurs in the Standard Model at very low rate, through neutrino oscillations (Br < 10^{-40})
  => charged LFV decays in the SM have **rates of the order of 10^{-54} !**



$$\mathcal{B}(\mu \to e\gamma) \simeq \frac{3\alpha}{32\pi}\left|\sum_{k=1,3}\frac{U_{\mu k}U^*_{ek}m^2_{\nu_k}}{M_W^2}\right|^2 \simeq 10^{-55} - 10^{-54}$$

- **A natural consequence of LFUV models is LFV in B decays:**

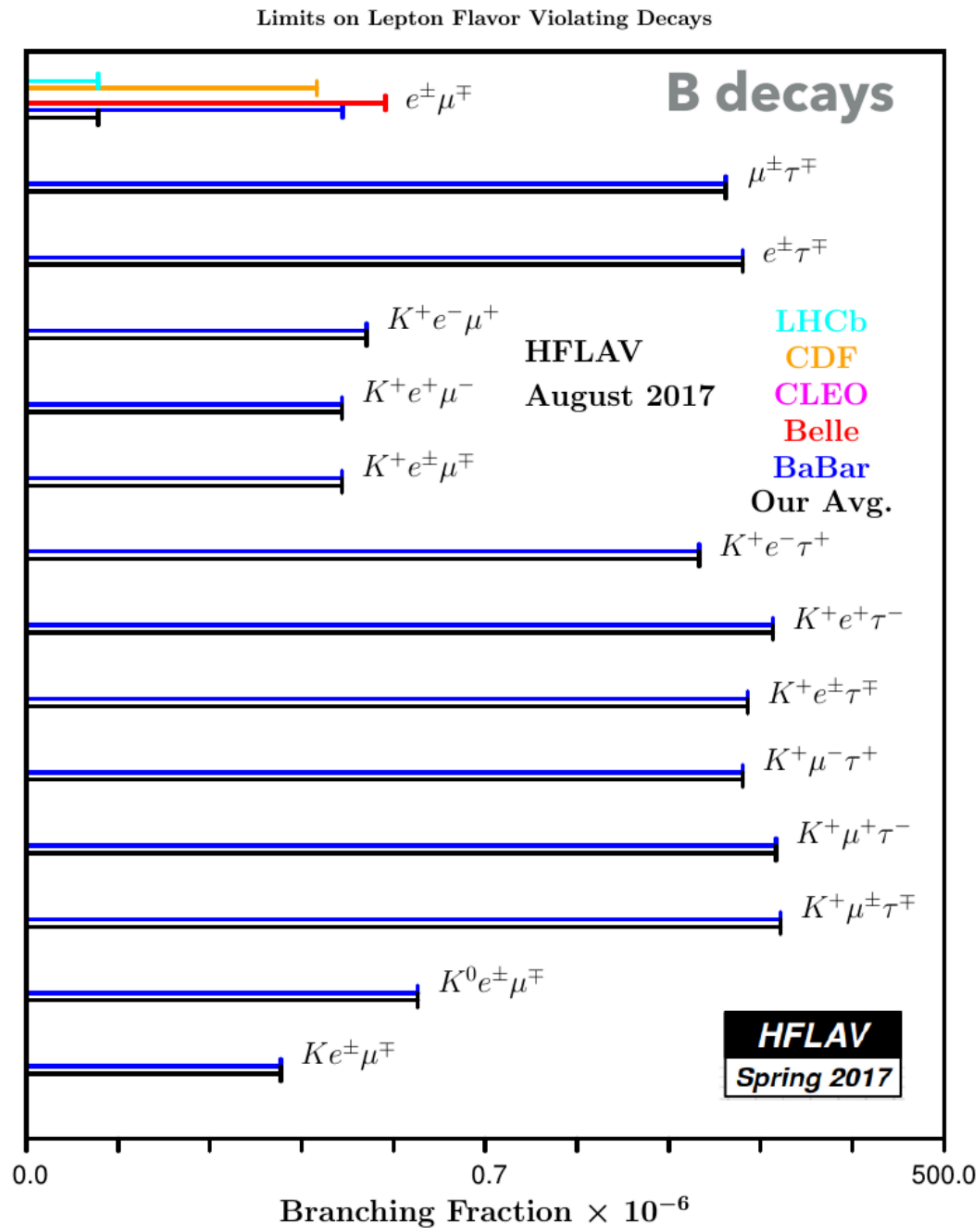
$$\mathcal{B}(B \to K\mu^{\pm}e^{\mp}) \sim 3\cdot 10^{-8}\left(\frac{1-R_K}{0.23}\right)^2, \quad \mathcal{B}(B \to K(e^{\pm},\mu^{\pm})\tau^{\mp}) \sim 2\cdot 10^{-8}\left(\frac{1-R_K}{0.23}\right)^2,$$

$$\frac{\mathcal{B}(B_s \to \mu^+e^-)}{\mathcal{B}(B_s \to \mu^+\mu^-)_{\rm SM}} \sim 0.01\left(\frac{1-R_K}{0.23}\right)^2, \quad \frac{\mathcal{B}(B_s \to \tau^+(e^-,\mu^-))}{\mathcal{B}(B_s \to \mu^+\mu^-)_{\rm SM}} \sim 4\left(\frac{1-R_K}{0.23}\right)^2.$$

[Hiller, Loose, Schönwald (2016)]

Observation of a charged LFV decay would be a striking sign of new physics!

LFV: EXPERIMENTAL OVERVIEW FOR B DECAYS

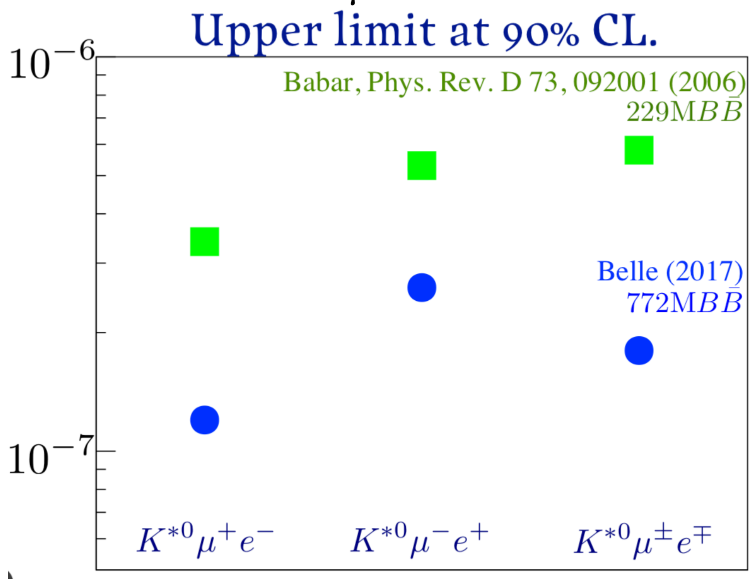


+

update from LHCb on *B->eμ* ~10-9 (see later)

+

measurement of *B->K*eμ* from Belle



EVEN MORE RESULTS ON LFV

μ^- DECAY MODES		Fraction (Γ_i/Γ)		Confidence level	p (MeV/c)
$e^- \nu_e \overline{\nu}_\mu$	LF	[f] < 1.2	%	90%	53
$e^- \gamma$	LF	< 4.2	$\times 10^{-13}$	90%	53
$e^- e^+ e^-$	LF	< 1.0	$\times 10^{-12}$	90%	53
$e^- 2\gamma$	LF	< 7.2	$\times 10^{-11}$	90%	53

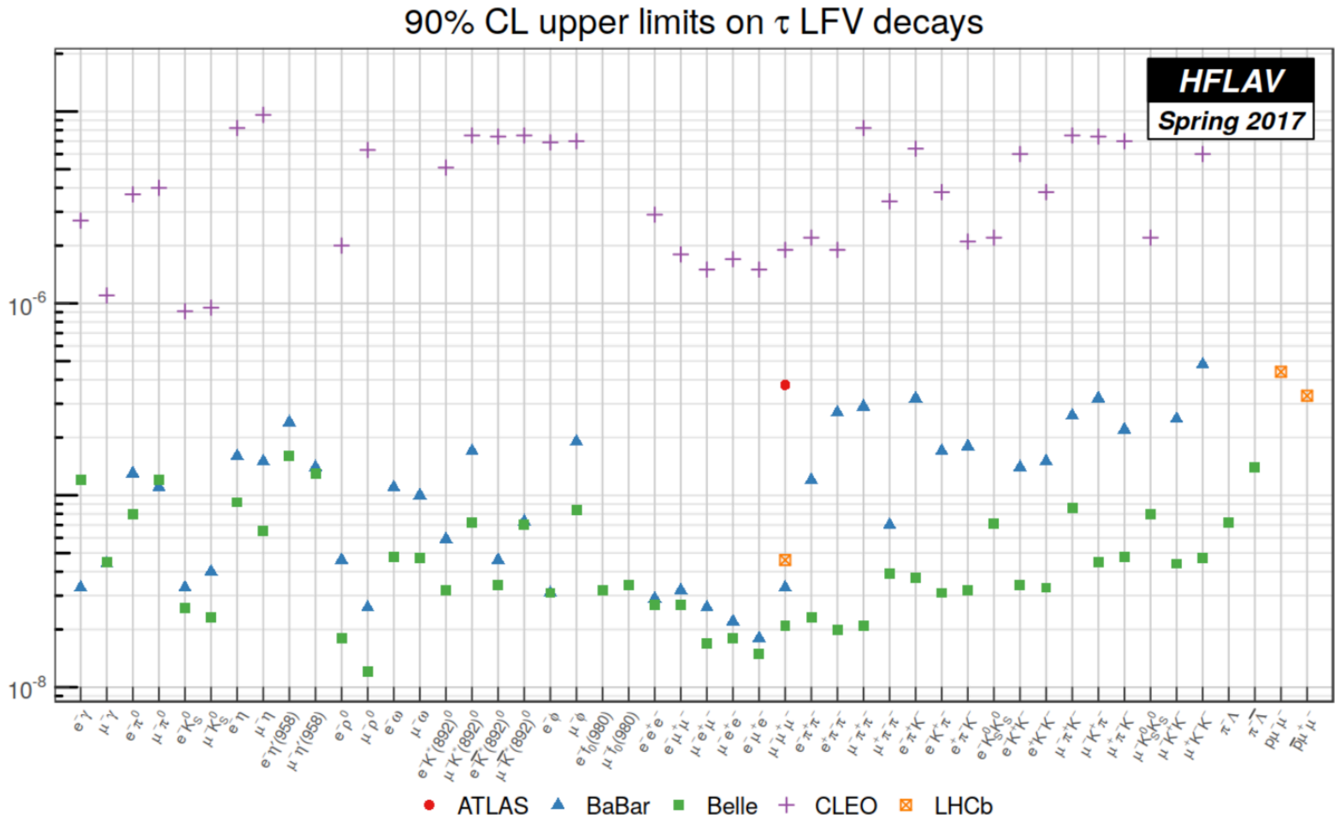
$$\mathcal{B}(Z^0 \to e^\pm \mu^\mp) < 7.5 \times 10^{-7} \text{ (@95\%CL)}$$

$$\mathcal{B}(Z^0 \to e^\pm \tau^\mp) < 9.8 \times 10^{-6} \text{ (@95\%CL)}$$

$$\mathcal{B}(Z^0 \to \mu^\pm \tau^\mp) < 1.2 \times 10^{-5} \text{ (@95\%CL)}$$

$$\mathcal{B}(H^0 \to \mu\tau) < 0.25\% \text{ (@95\%CL)}$$

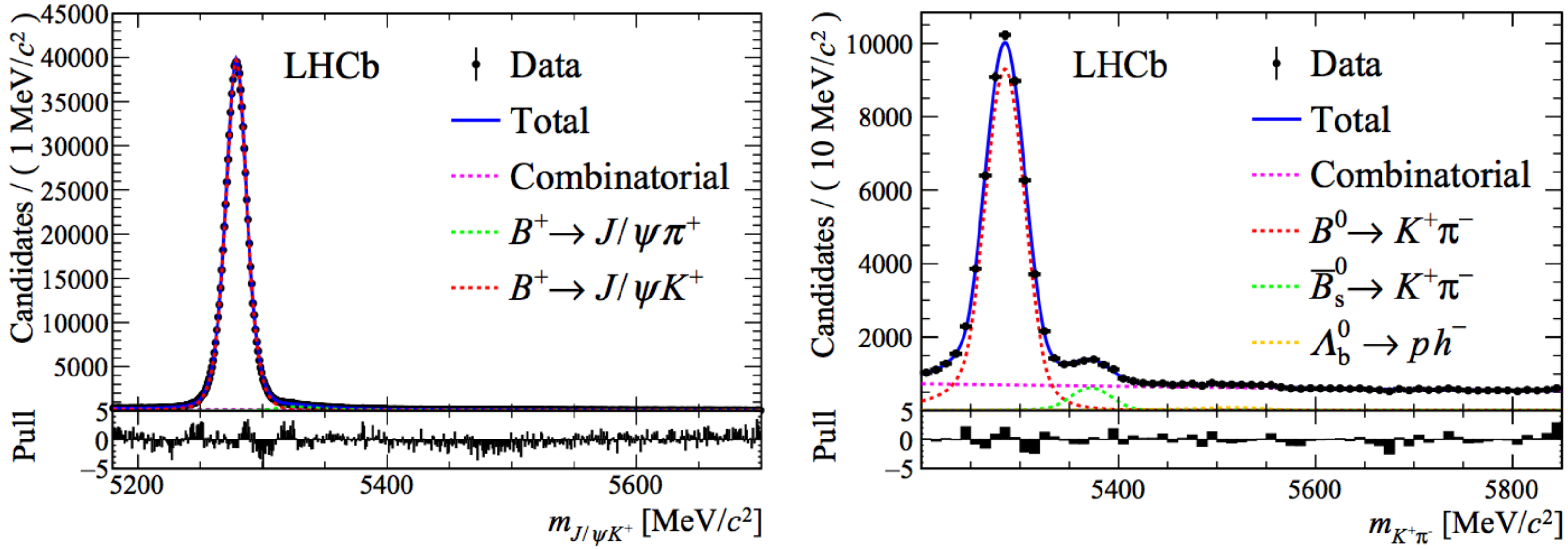
$$\mathcal{B}(H^0 \to e\tau) < 0.61\% \text{ (@95\%CL)}$$



$B_{(s)}$ -> e μ @ LHCb

JHEP 1803 (2018) 078

- In LFUV models, Br enhanced up to 10^{-11}
- Update using full Run1 sample
- Two normalization channels:
  - $B^+ \to J/\psi K^+$ (clean final state)
  - $B^0 \to K^+\pi^-$(same topology as the signal)



No Brem photons   Brem photons

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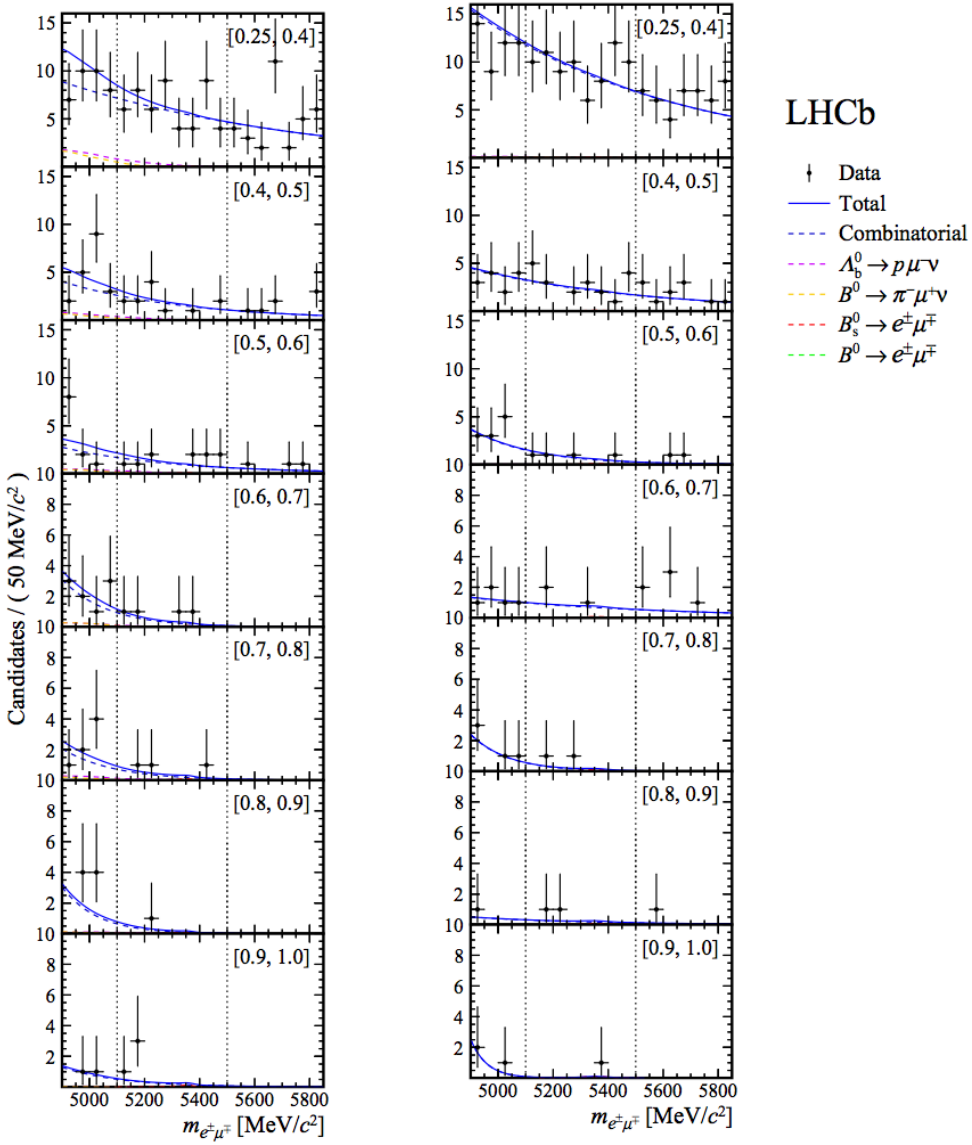


$\mathcal{B}(B_s^0 \to e^\pm \mu^\mp) < 5.4(6.3) \times 10^{-9}$

@90%(95%) C.L.

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

@90%(95%) C.L.

B_s^0 limit assumes only heavy mass eigenstate to contribute

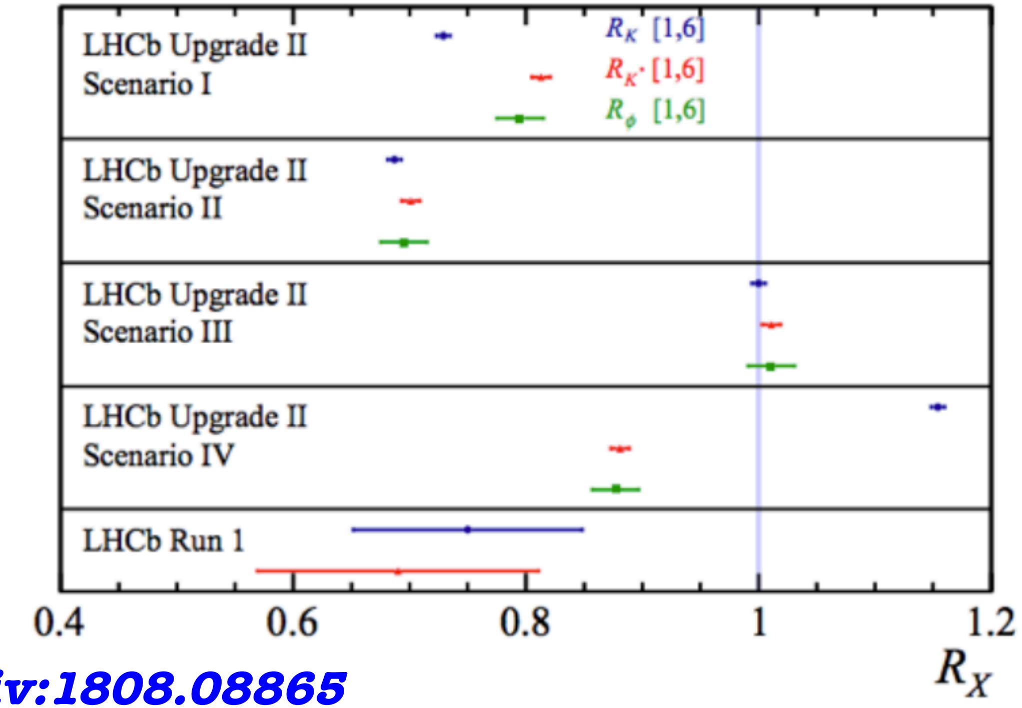
WHAT SHOULD WE EXPECT FOR THE FUTURE FROM LHCb?

2018-2021	Run 3 (2021-2023)	2023-2025	Run 4 (2025-2028)	2028-2030	Run 5 (2030-2035+)
Shutdown	~23fb^{-1}	Shutdown	~50fb^{-1}	Shutdown	~300fb^{-1}
LHCb upgrade PhaseI				LHCb upgrade PhaseII	

MORE LFU TESTS IN b->sll

- $\mathbf{R_K}$, $\mathbf{R_{K^*}}$, $\mathbf{R\phi}$ and similar ratios also for baryons need to be measured using the full run1+run2 statistics, and in all the q^2 bins.
- Measurements will be still statistically limited after Upgrade I
- Improving precision will allow to discriminate among NP scenarios.

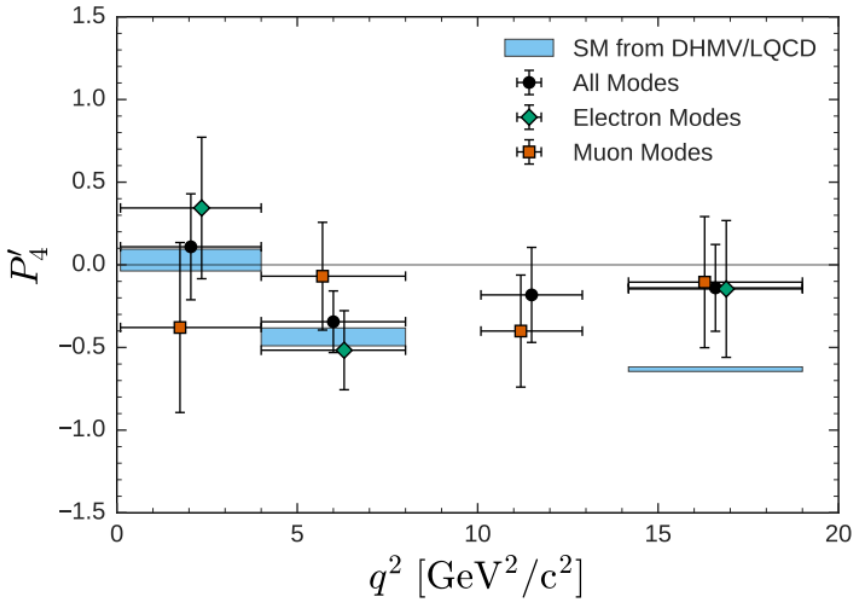
scenario	C_9^{NP}	C_{10}^{NP}	C_9'	C_{10}'
I	−1.4	0	0	0
II	−0.7	0.7	0	0
III	0	0	0.3	0.3
IV	0	0	0.3	−0.3

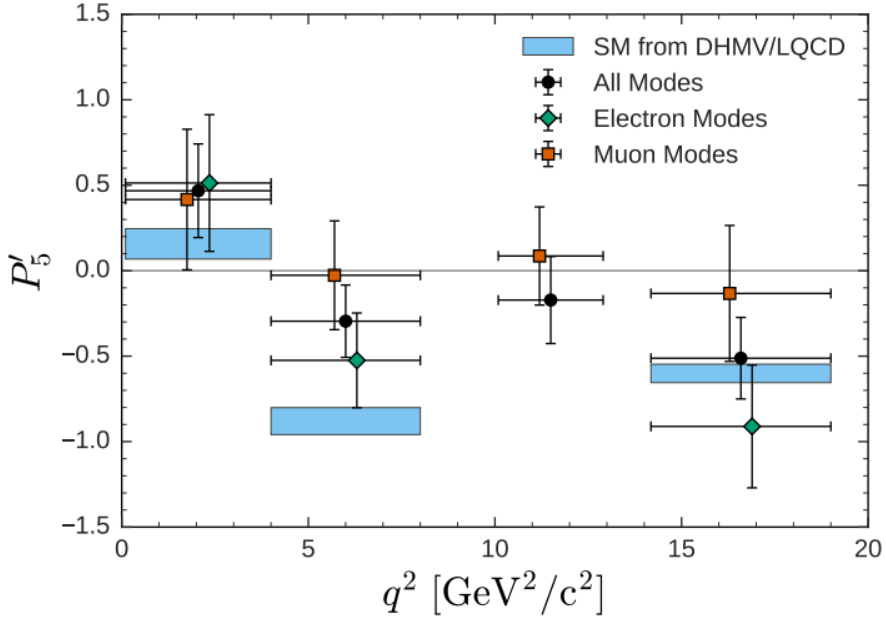


arXiv:1808.08865

LFU ANGULAR TESTS

- Perform LFU angular tests [as from Belle: Phys.Rev.Lett.118, 111801 (2017)].





- LFUV tests in b->dll transitions?

KEEP SEARCHING FOR LFV B DECAYS

The whole family need to be searched for:

$B_{(s)} \to \tau\,\mu$, $B_{(s)} \to e\,\mu$, $B^+ \to K^+\,\tau\,\mu$, $B^0 \to K^{*0}\,\tau\,\mu$, $B^+ \to K^+\,e\,\mu$, $B^0 \to K^{*0}\,e\,\mu$, $B_s \to \phi\,\tau\,\mu$, $B_s \to \phi\,e\,\mu$, etc...

Some limit expectations from *arXiv:1808.08865*:

- Run1+2: $B^+ \to K^+\,e\,\mu < \sim 10^{-9}$
  $B^0 \to K^{*0}\,\tau\,\mu < \underset{\sim}{\ }10^{-5}$
- Upgrade I: $B \to e\,\mu < 8\text{x}10^{-10}$
  $B_s \to e\,\mu < 2\text{x}10^{-10}$
- Upgrade II: $B \to e\,\mu < 3\text{x}10^{-10}$
  $B_s \to e\,\mu < 9\text{x}10^{-11}$
  $B \to \tau\,\mu < 3\text{x}10^{-6}$

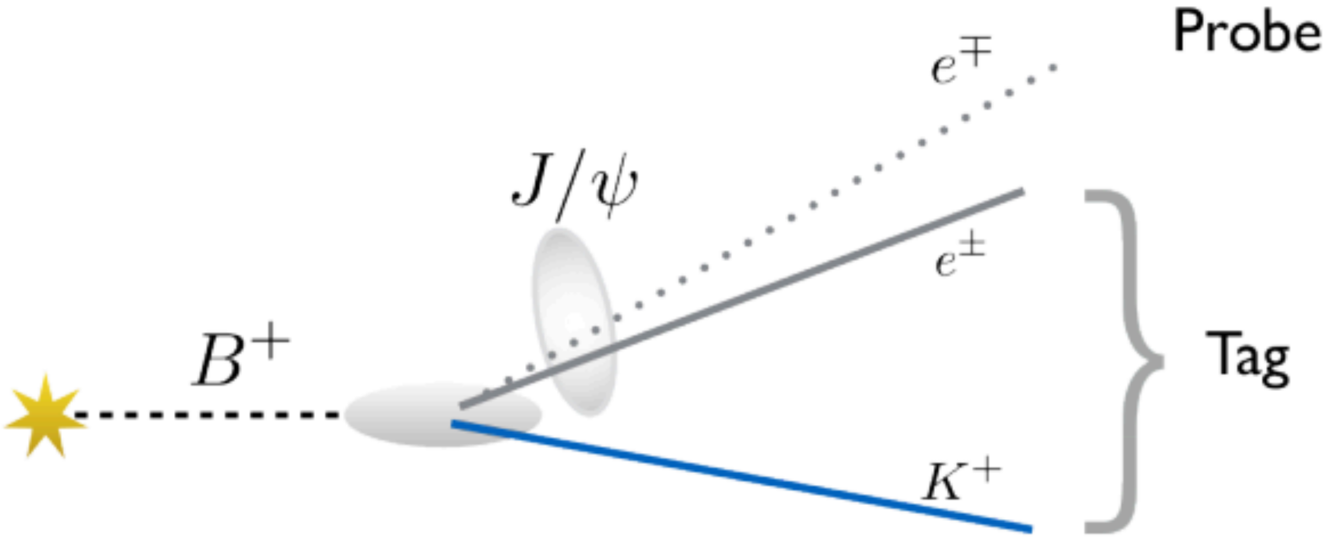
Without considering improvements in electron reconstruction, removal of velo material, etc….

CONSOLIDATING MASTERY OF ELECTRONS

Bremsstrahlung decreases electron reconstruction efficiency downstream of the VELO.

A **new data driven method for measuring electron reconstruction efficiency** is under development, using kinematically constrained VELO tracks from B+ ->Jpsi (ee) K :

- Direction inferred from VELO segment
- Probe momentum inferred from Jpsi mass constraint
- B mass with Jpsi mass constraint used to extract signal



CONCLUSION

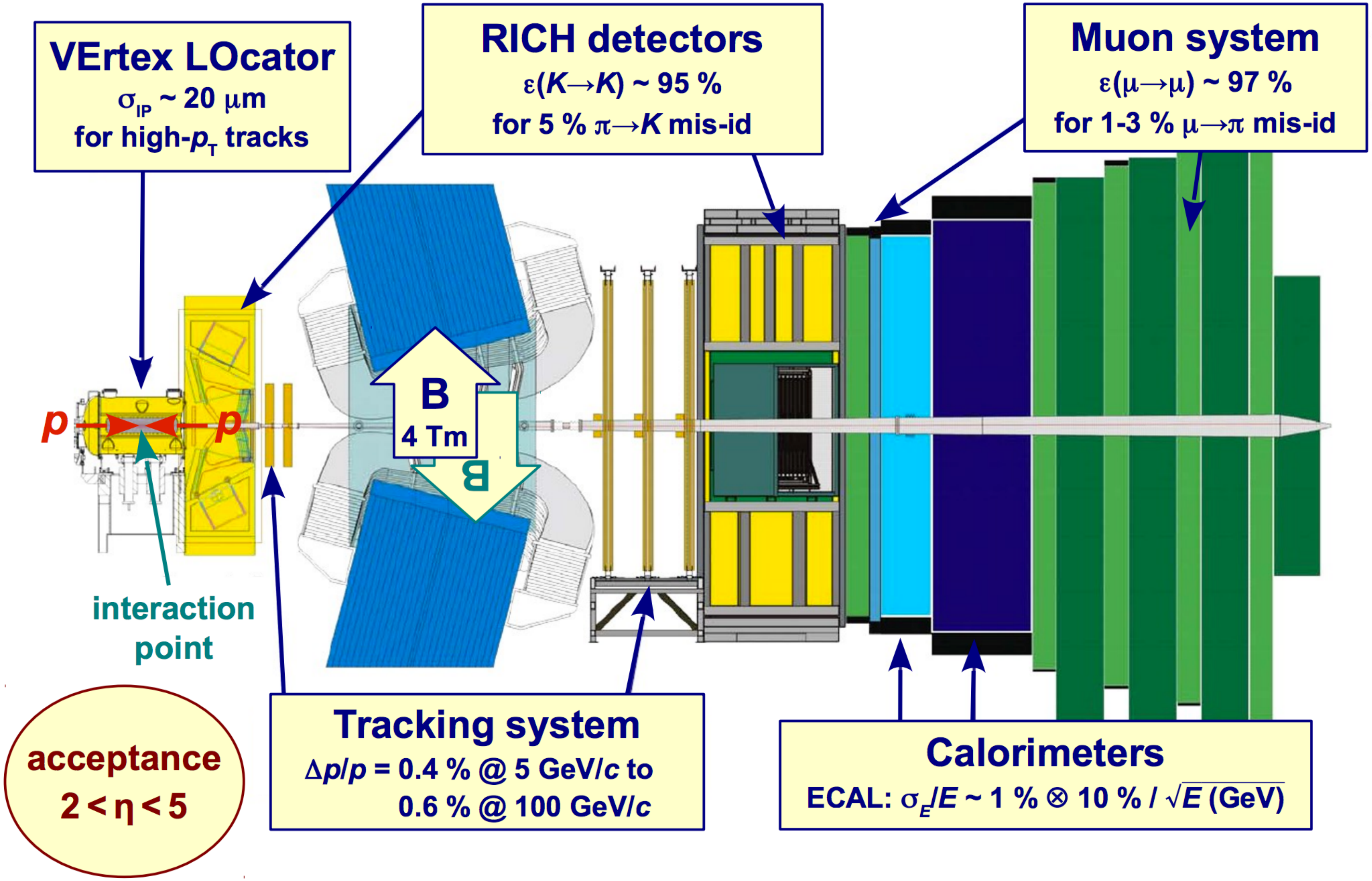
Lot of activities currently ongoing in LHCb for consolidating the results about lepton flavor universality tests and lepton flavor violating searches in B decays.

It takes time because **analysis are complicated** and **published results are extensively scrutinized to be solid.**

New actors coming: **interplay among experiments is beneficial and needed**, especially in case of new physics evidence.

BACKUP

THE LHCb DETECTOR



TAU RECONSTRUCTION

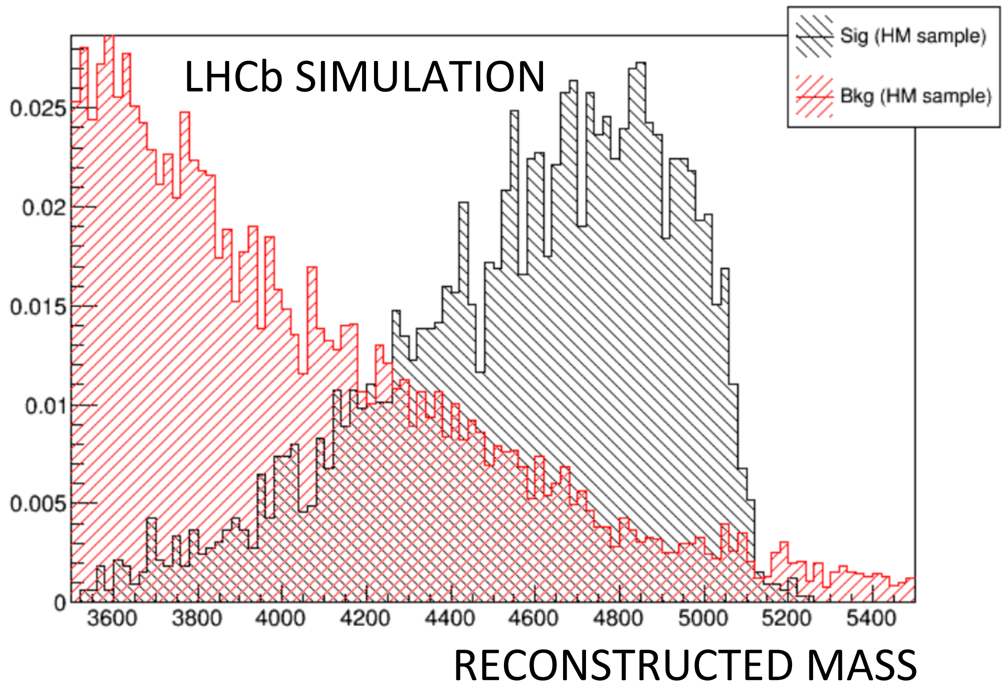
- Taus reconstructed through their decays.
- Accompanied by neutrinos: missing energy and degradation of the B mass resolution
- Tau decay vertex not always identified
- Traditional and new reconstruction techniques based on the kinematics are explored (see also talk from Alessandro Morda)

Leptonic:

- $BR(\tau^- \to \mu^- \nu\nu) = 17.41 \pm 0.04$ %
- $BR(\tau^- \to e^- \nu\nu) = 17.83 \pm 0.04$ %

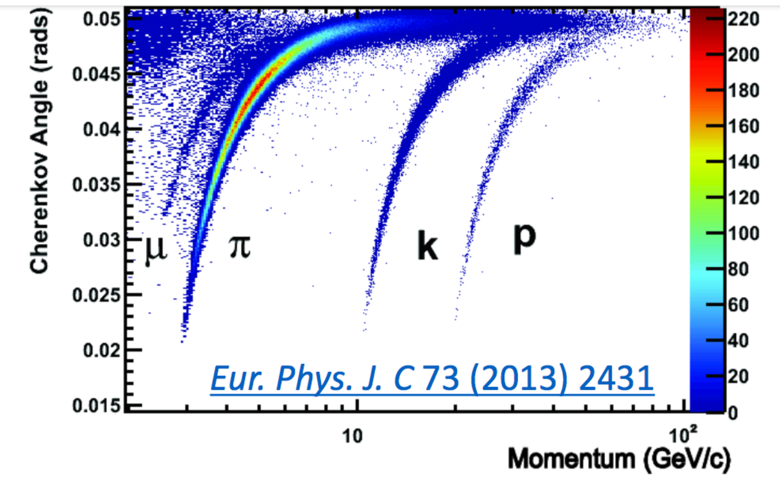
Hadronic:

- $BR(\tau^- \to \pi^- \nu) = 10.83 \pm 0.06$ %
- $BR(\tau^- \to \pi^- \pi^0 \nu) = 25.52 \pm 0.09$ %
- $BR(\tau^- \to \pi^- \pi^0 \pi^0 \nu) = 9.30 \pm 0.11$ %
- $BR(\tau^- \to \pi^- \pi^+ \pi^- \nu) = 9.31 \pm 0.06$ %
- $BR(\tau^- \to \pi^- \pi^+ \pi^- \pi^0 \nu) = 4.62 \pm 0.06$ %

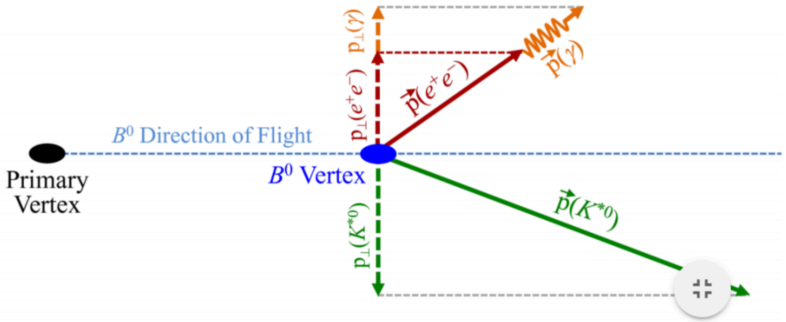


R_{K^*} ANALYSIS STRATEGY @ LHCb

JHEP 08 (2017) 055



- **Blind analysis**
- **Selection as similar as possible for the electron and muon channels:**
  - Quality of the candidates
  - Vetoes against peaking backgrounds
  - Particle identification
  - Multivariate classifier using quality of the candidates and kinematics
  - Kinematic discriminant to reduce partially reconstructed backgrounds



- **Efficiencies determined using simulations, tuned with data**
- **Exclusive trigger categories and bremsstrahlung categories**
- **Simultaneous fit to resonant and non-resonant channels**

R_{K^*} SYSTEMATICS @ LHCb

JHEP 08 (2017) 055

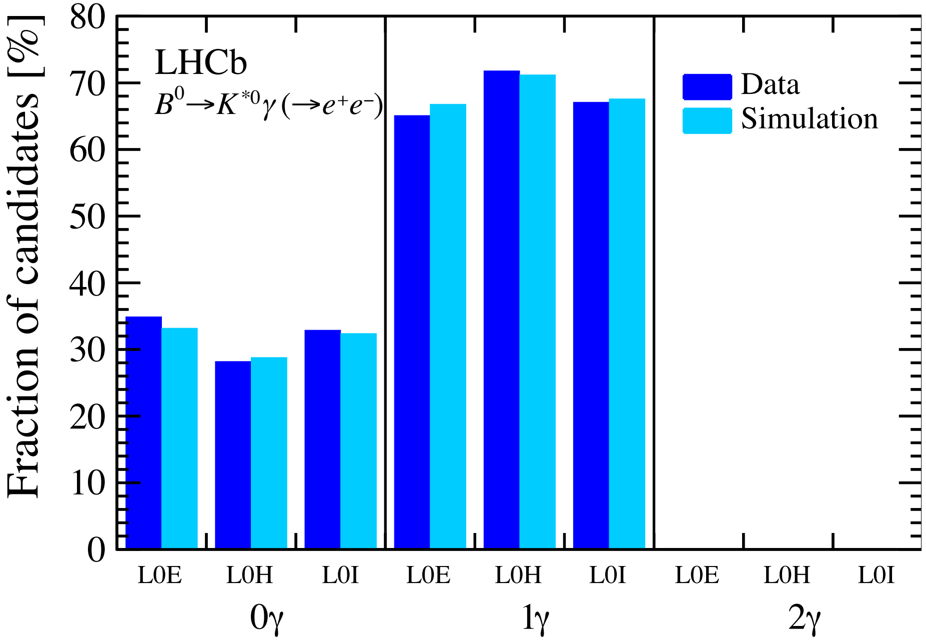
- **The double ratio cancels a lot of systematics**
- **The measurement is statistically dominated (15%)**

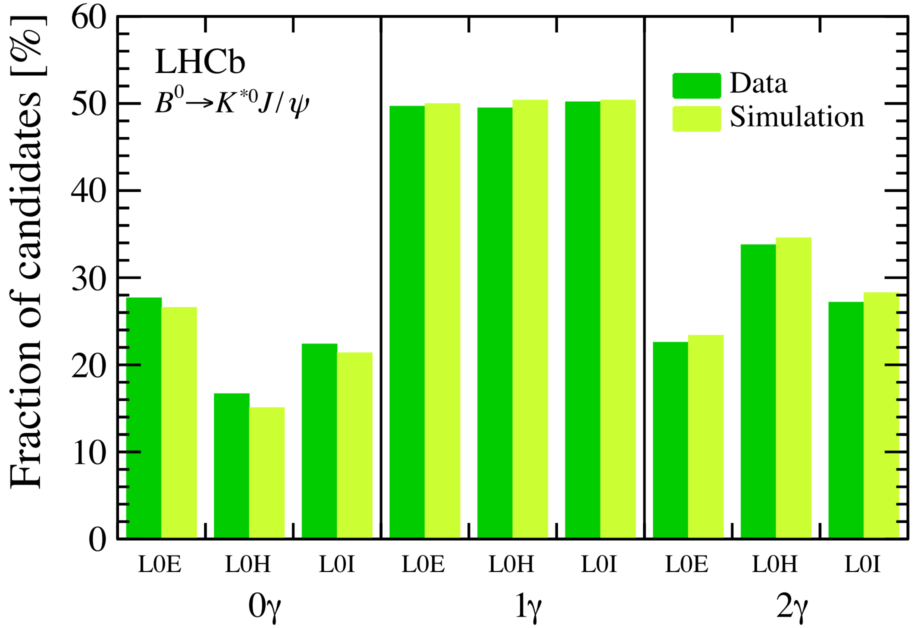
	$\Delta R_{K^{*0}}/R_{K^{*0}}$ [%]					
	low-q^2			central-q^2		
Trigger category	L0E	L0H	L0I	L0E	L0H	L0I
Corrections to simulation	2.5	4.8	3.9	2.2	4.2	3.4
Trigger	0.1	1.2	0.1	0.2	0.8	0.2
PID	0.2	0.4	0.3	0.2	1.0	0.5
Kinematic selection	2.1	2.1	2.1	2.1	2.1	2.1
Residual background	–	–	–	5.0	5.0	5.0
Mass fits	1.4	2.1	2.5	2.0	0.9	1.0
Bin migration	1.0	1.0	1.0	1.6	1.6	1.6
$r_{J/\psi}$ ratio	1.6	1.4	1.7	0.7	2.1	0.7
Total	4.0	6.1	5.5	6.4	7.5	6.7

R_{K^*} YIELDS

arXiv:1705.05802

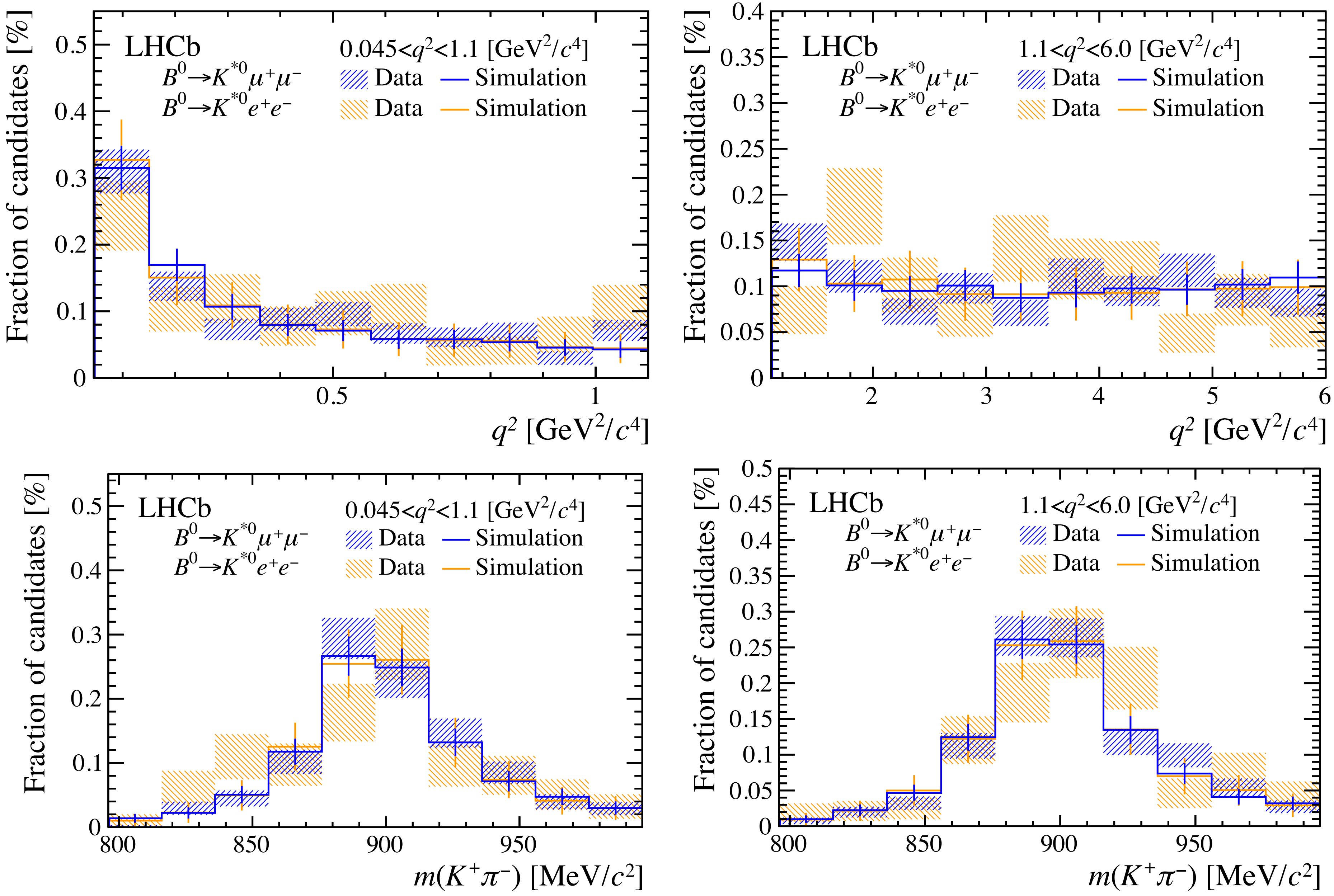
	$B^0 \to K^{*0}\ell^+\ell^-$		$B^0 \to K^{*0} J/\psi (\to \ell^+\ell^-)$
	low-q^2	central-q^2	
$\mu^+\mu^-$	$285\ ^{+\ 18}_{-\ 18}$	$353\ ^{+\ 21}_{-\ 21}$	$274416\ ^{+\ 602}_{-\ 654}$
e^+e^- (L0E)	$55\ ^{+\ 9}_{-\ 8}$	$67\ ^{+\ 10}_{-\ 10}$	$43468\ ^{+\ 222}_{-\ 221}$
e^+e^- (L0H)	$13\ ^{+\ 5}_{-\ 5}$	$19\ ^{+\ 6}_{-\ 5}$	$3388\ ^{+\ 62}_{-\ 61}$
e^+e^- (L0I)	$21\ ^{+\ 5}_{-\ 4}$	$25\ ^{+\ 7}_{-\ 6}$	$11505\ ^{+\ 115}_{-\ 114}$


Fraction of candidates [%]
LHCb
$B^0 \to K^{*0}\gamma(\to e^+e^-)$
Data
Simulation
L0E
L0H
L0I
0γ
1γ
2γ


Fraction of candidates [%]
LHCb
$B^0 \to K^{*0} J/\psi$
Data
Simulation
L0E
L0H
L0I
0γ
1γ
2γ

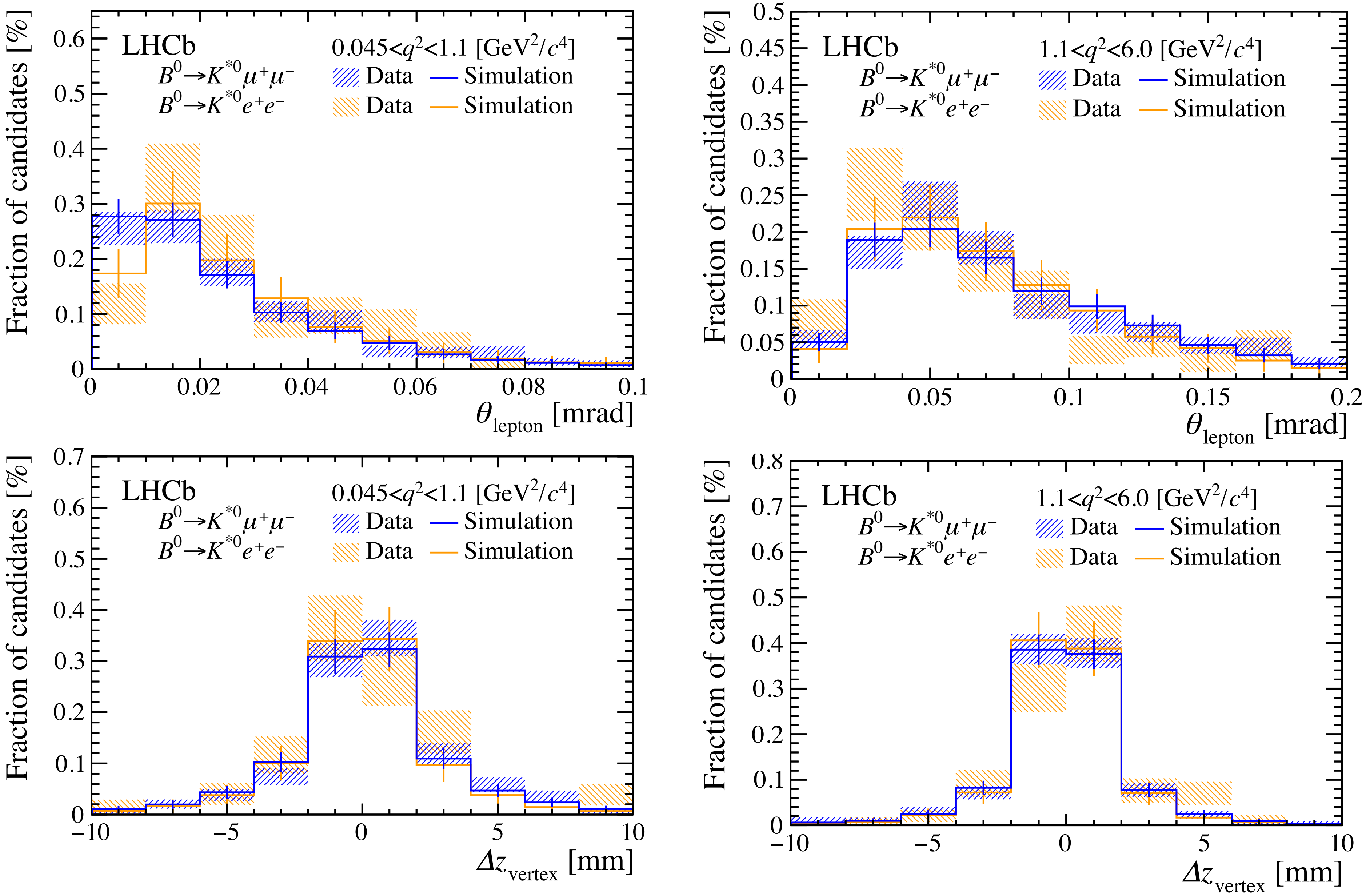
R_{K^*} CROSSCHECKS

arXiv:1705.05802



R_{K^*} CROSSCHECKS

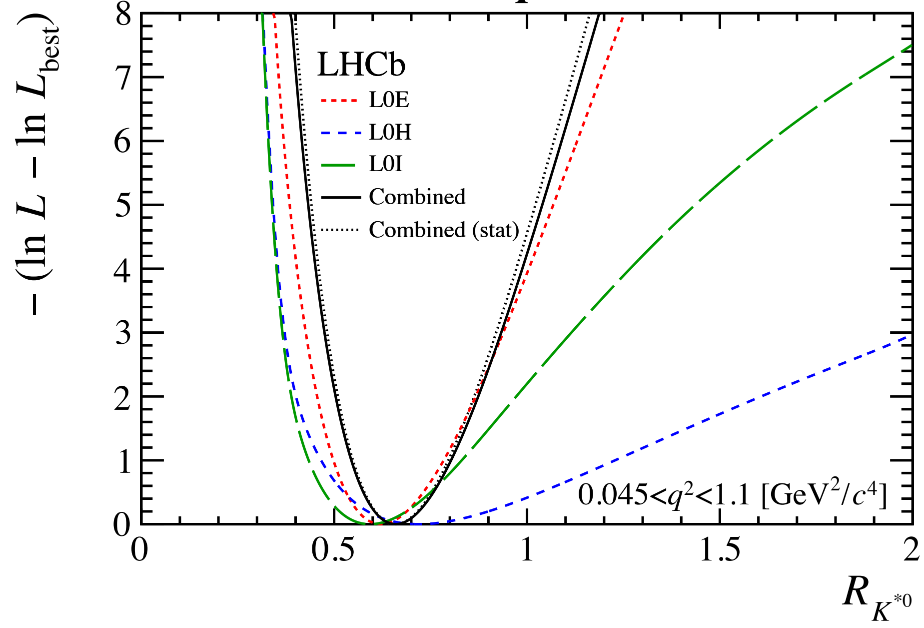
arXiv:1705.05802



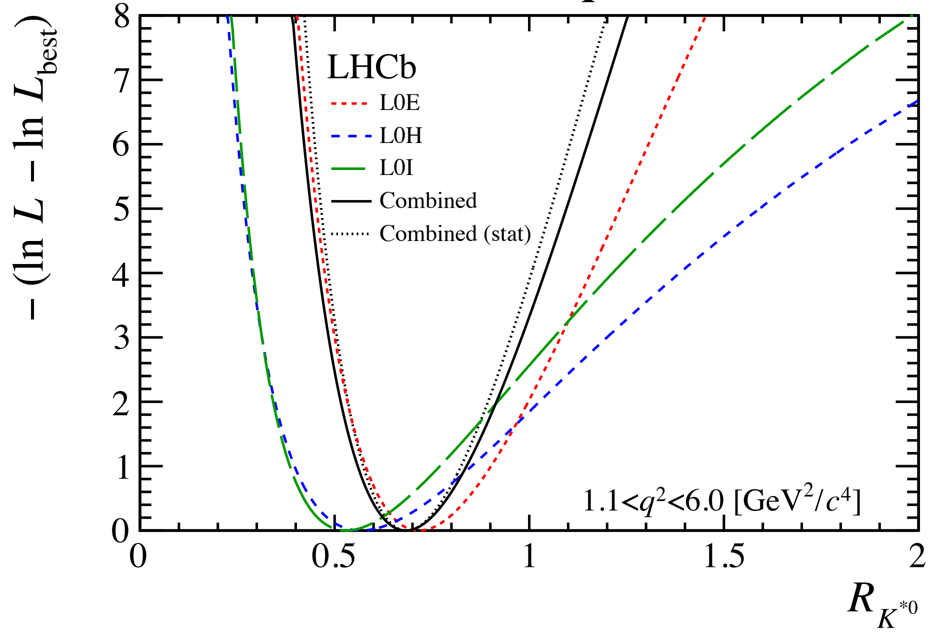
R_{K^*} RESULTS

arXiv:1705.05802

Low q^2



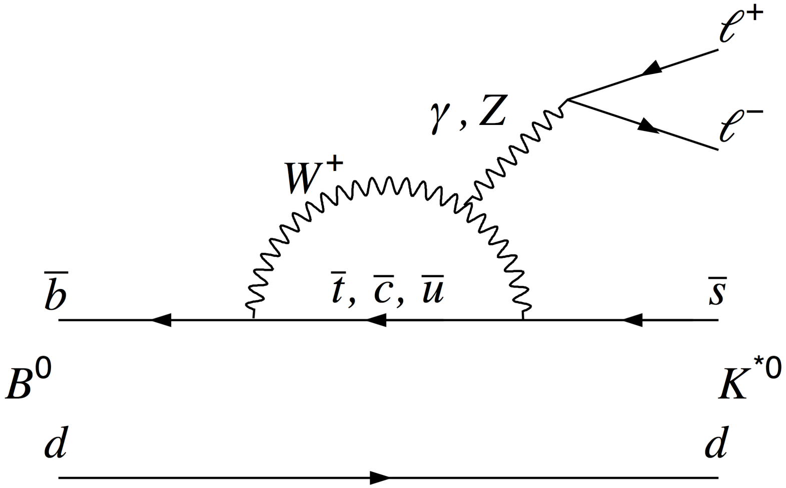
Central q^2

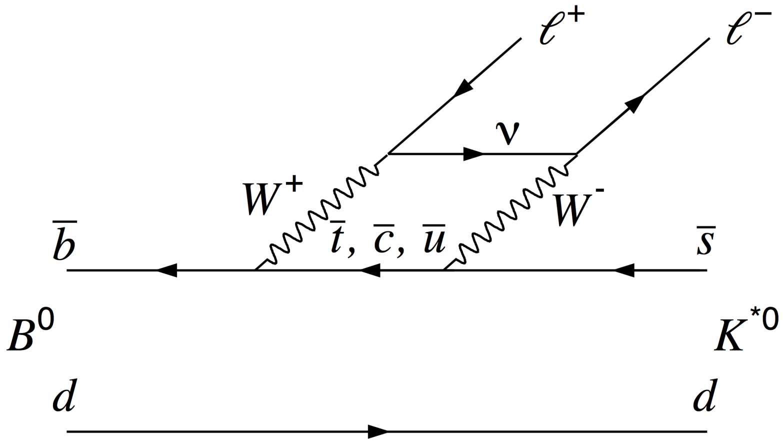


	low-q^2	central-q^2
$R_{K^{*0}}$	$0.66\ ^{+\ 0.11}_{-\ 0.07} \pm 0.03$	$0.69\ ^{+\ 0.11}_{-\ 0.07} \pm 0.05$
95.4% CL	$[0.52, 0.89]$	$[0.53, 0.94]$
99.7% CL	$[0.45, 1.04]$	$[0.46, 1.10]$

R_{K^*} FEYNMAN DIAGRAMS arXiv:1705.05802

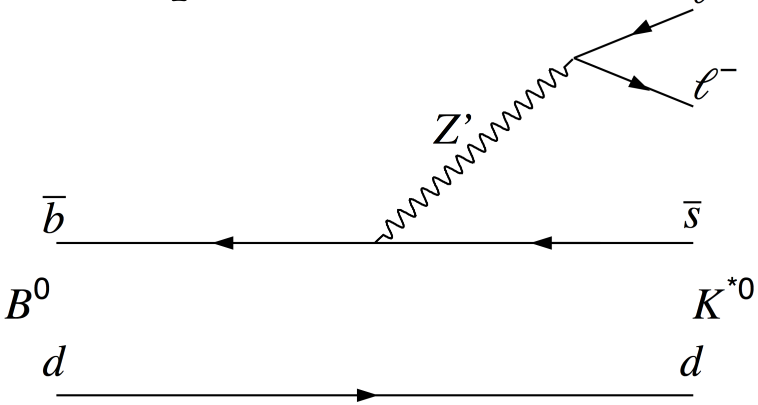
Standard Model



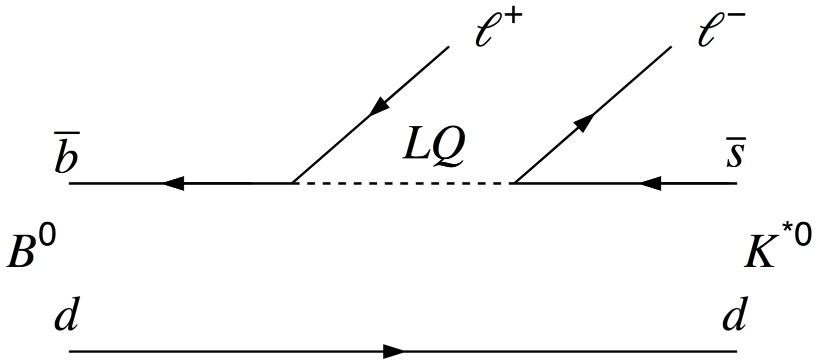


Some NP hypotheses mentioned

Non lepton universal Z' ?



Leptoquarks?



Yield	Run 1 result	$9\,\text{fb}^{-1}$	$23\,\text{fb}^{-1}$	$50\,\text{fb}^{-1}$	$300\,\text{fb}^{-1}$
$B^+ \to K^+e^+e^-$	254 ± 29 [274]	1 120	3 300	7 500	46 000
$B^0 \to K^{*0}e^+e^-$	111 ± 14 [275]	490	1 400	3 300	20 000
$B_s^0 \to \phi e^+e^-$	–	80	230	530	3 300
$\Lambda_b^0 \to pKe^+e^-$	–	120	360	820	5 000
$B^+ \to \pi^+e^+e^-$	–	20	70	150	900
R_X precision	Run 1 result	$9\,\text{fb}^{-1}$	$23\,\text{fb}^{-1}$	$50\,\text{fb}^{-1}$	$300\,\text{fb}^{-1}$
R_K	$0.745 \pm 0.090 \pm 0.036$ [274]	0.043	0.025	0.017	0.007
$R_{K^{*0}}$	$0.69 \pm 0.11 \pm 0.05$ [275]	0.052	0.031	0.020	0.008
R_ϕ	–	0.130	0.076	0.050	0.020
R_{pK}	–	0.105	0.061	0.041	0.016
R_π	–	0.302	0.176	0.117	0.047

LFV SEARCHES IN LHCb

$\tau^- \to p\mu^-\mu^-$	$\mathcal{B} < 4.4 \times 10^{-7}$ @ 90% CL	[Physics Letters B 724 (2013)]
$\tau^- \to \bar{p}\mu^+\mu^-$	$\mathcal{B} < 3.3 \times 10^{-7}$ @ 90% CL	[Physics Letters B 724 (2013)]
$\tau \to \mu\mu\mu$	$\mathcal{B} < 4.7 \times 10^{-8}$ @ 90% CL	[JHEP 02 (2015) 121]
$D^0 \to e^\pm\mu^\mp$	$\mathcal{B} < 1.3 \times 10^{-8}$ @ 90% CL	[Phys. Lett. B754 (2016) 167]
$B^0 \to e^\pm\mu^\mp$	$\mathcal{B} < 1.0 \times 10^{-9}$ @ 90% CL	[JHEP 1803 (2018) 078]
$B_s^0 \to e^\pm\mu^\mp$	$\mathcal{B} < 5.4 \times 10^{-9}$ @ 90% CL	[JHEP 1803 (2018) 078]
$H^0 \to \mu^\pm\tau^\mp$	$\mathcal{B} < 26\%$ @ 95% CL	[arXiv:1808.07135]