Searches for new physics in rare decays of heavy flavors at CMS

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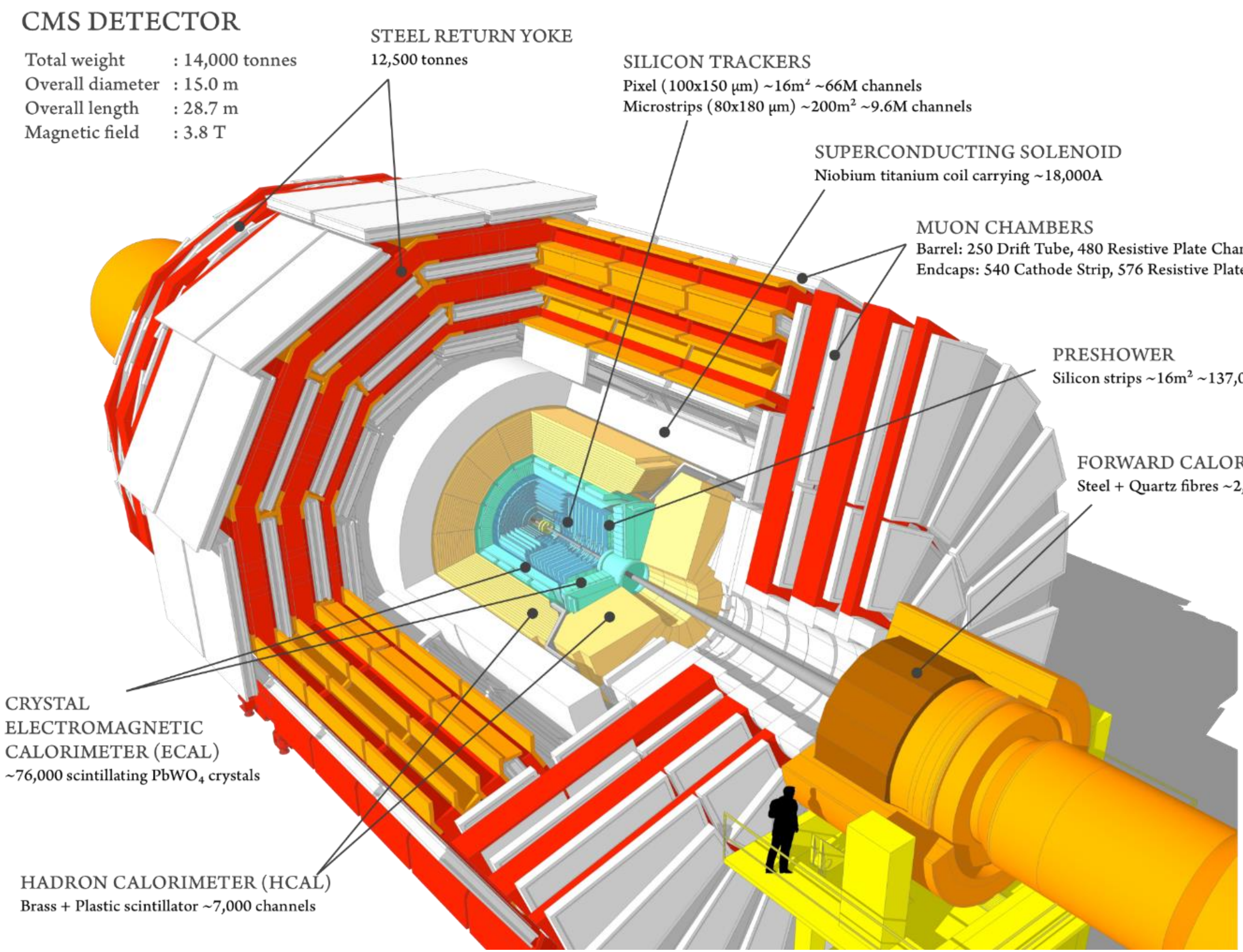
*on behalf of the **CMS** collaboration*

ICPPA-2024 Moscow 24 October 2024

Outline

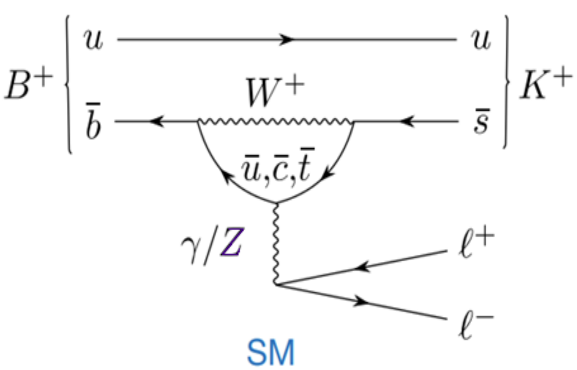
- Introduction, $b \to sll$
- Angular observables in $b \to sll$ transitions
- Searches for LFUV in heavy-flavor decays

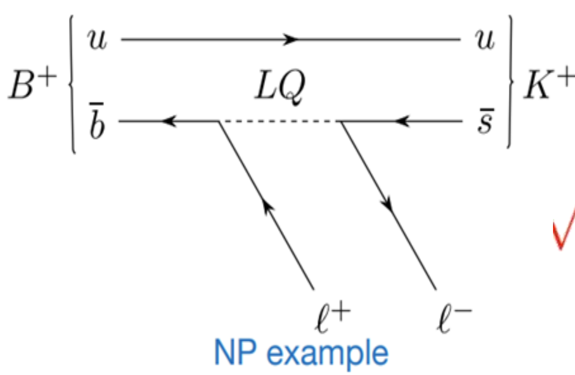
CMS experiment

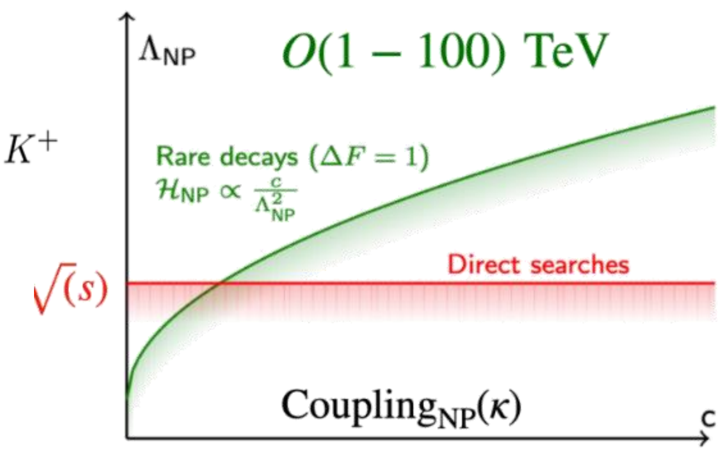


$b\to sll$ as New Physics probes

- $b\to sll$ transitions are precisely predicted by Standard Model
- Processes are rare (loop level, CKM-suppressed)
  → new interactions can be major contribution
- New interactions can have different symmetries from the SM
- NP can modify parameters of angular distributions observed in FCNC decays $B\to h\, l^+ l^-$







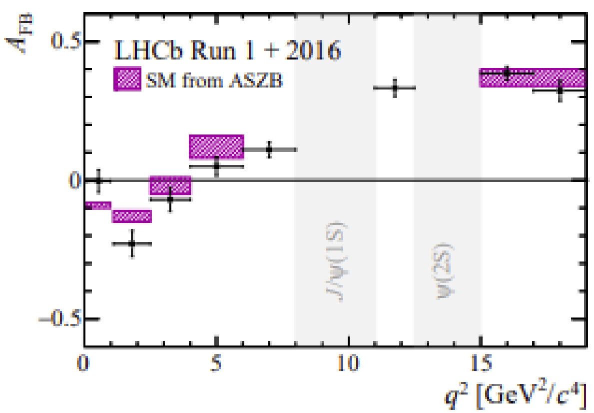
Angular analyses of *b→sll* transitions

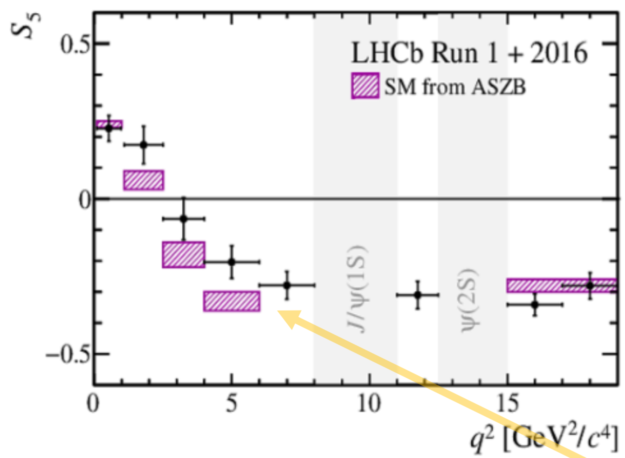
- Many recent results measuring angular parameters and differential branching fractions

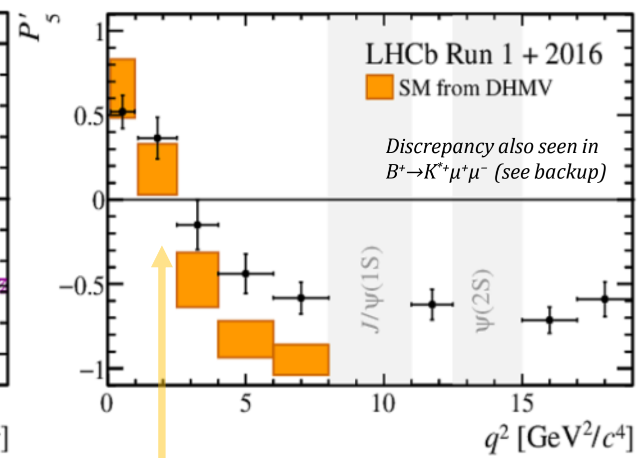
q=m(ll)

$\mathbf{B^0 \to K^{*0}\mu^+\mu^-}$, Run-1+2016, ~4500 signal

LHCb-PAPER-2020-002, Phys.Rev.Lett.125(2020)011802



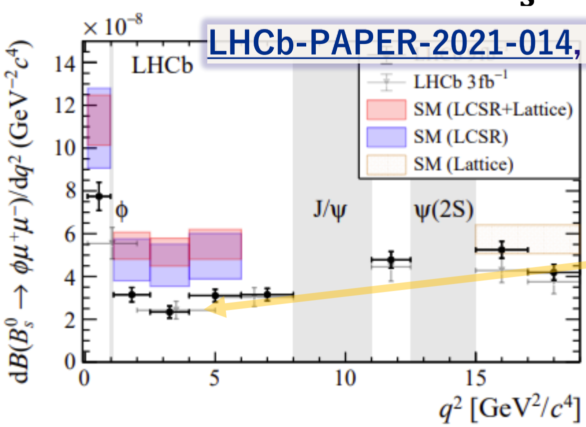




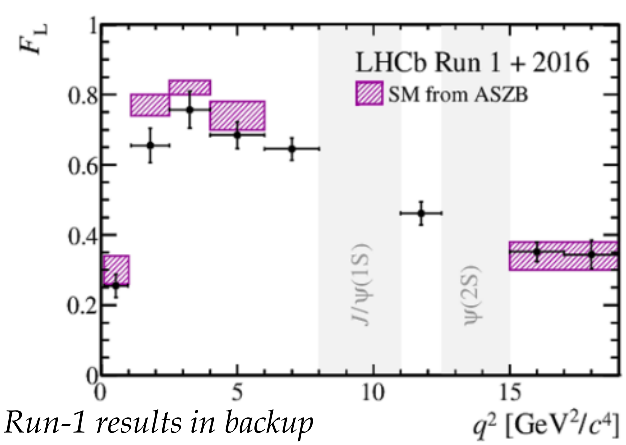
~3σ tension at low q^2 !

BF measurement of $\mathbf{B_s^0 \to \varphi\mu^+\mu^-}$

LHCb-PAPER-2021-014, Phys.Rev.Lett.127(2021)151801

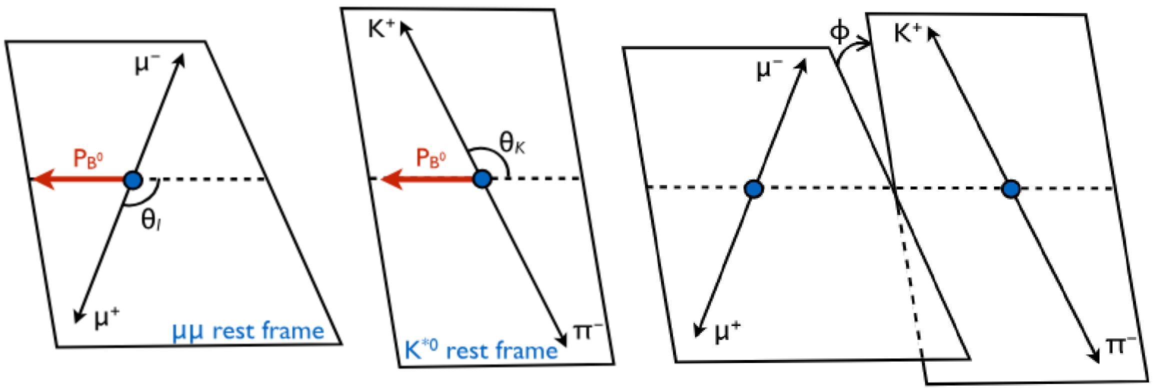


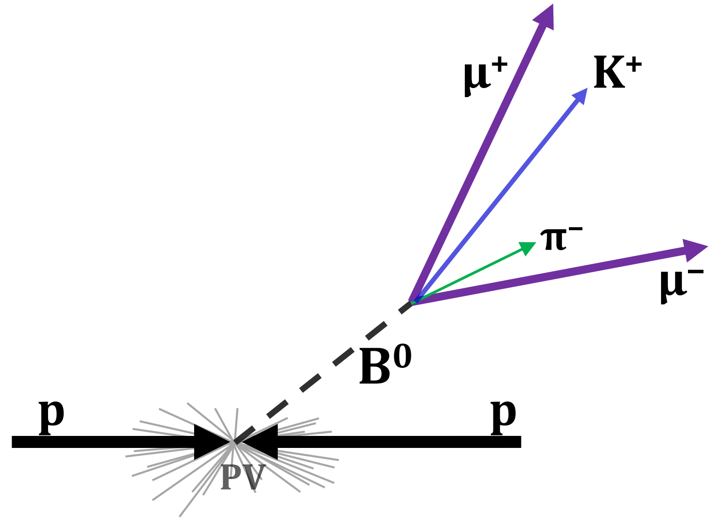
~3.6σ tension w.r.t. SM at low q^2



ATLAS and CMS Run-1 results in backup

$B^0 \to K^{*0}\mu^+\mu^-$ Angular decay rate





$$\frac{d^4\Gamma_{P-wave}}{dq^2 d^3\Omega} = \frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\mathrm{d}\cos\theta_l\mathrm{d}\cos\theta_K\mathrm{d}\phi} = \frac{9}{32\pi}\Big[\frac{3}{4}F_T\sin^2\theta_K + F_L\cos^2\theta_K$$
$$+\left(\frac{1}{4}F_T\sin^2\theta_K - F_L\cos^2\theta_K\right)\cos 2\theta_l + \frac{1}{2}P_1 F_T\sin^2\theta_K\sin^2\theta_l\cos 2\phi$$
$$+\sqrt{F_T F_L}\left(\frac{1}{2}P_4'\sin 2\theta_K\sin 2\theta_l\cos\phi + P_5'\sin 2\theta_K\sin\theta_l\cos\phi\right)$$
$$-\sqrt{F_T F_L}\left(P_6'\sin 2\theta_K\sin\theta_l\sin\phi - \frac{1}{2}P_8'\sin 2\theta_K\sin 2\theta_l\sin\phi\right)$$
$$+2P_2 F_T\sin^2\theta_K\cos\theta_l - P_3 F_T\sin^2\theta_K\sin^2\theta_l\sin 2\phi\Big]$$

F_L is the fraction of longitudinally polarised K* (and F_T = 1 - F_L)

P_2 is related to A_{FB}, the muon forward backward asymmetry

$P_i^{(')}$ is the base of optimised observables

The Kπ system can also be in S-wave →

$$\frac{d^4\Gamma_{total}}{dq^2 d^3\Omega} = (1-F_S)\frac{d^4\Gamma_{P-wave}}{dq^2 d^3\Omega} + \frac{d^4\Gamma_{S/SP-wave}}{dq^2 d^3\Omega}$$

Data set and $B^0 \to K^{*0}\mu^+\mu^-$ selection

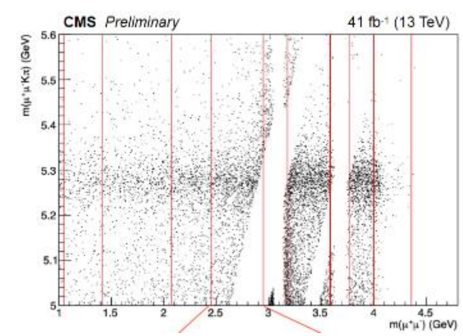
Run 2 dataset (2016-2018), corresponding to 140 fb^{-1}
Trigger requires 2 muons + a track
$B^0 \to J/\psi\ K^{*0}$ and $B^0 \to \psi(2S)\ K^{*0}$ decays with the same final-state particles $K^\pm \pi^\mp \mu^+ \mu^-$ are used for the control and validation

BDT to distinguish signal from background

- trained on signal MC and background from data sidebands
- different training per year of data taking, k-folding to avoid overtraining
- input features: decay-vertex quality and displacement, isolation, mass of Kπ system
- chosen working point optimises signal significance

$B^0 \to J/\psi K^*$ and $B^0 \to \psi(2S) K^*$ leak in the nearby signal region, mainly due to unreconstructed photon

- **combined cut on m(Kπμμ) and q^2**



Specific backgrounds

$B^+ \to K^+\mu\mu$ (plus combinatorial track)

- additional veto on mass of two $h^+\mu\mu$ systems

$B_s \to \phi(\to KK)\ \mu\mu$

- veto at preselection level on KK mass hypothesis
- residual contribution negligible wrt signal (<1%)

$B^+ \to K^+\psi(2S)$, with $\psi(2S) \to J/\psi\pi\pi$ (a π track is lost)

- only affects J/ψ control region
- combination of cuts on intermediate masses

$B_s \to KK\mu\mu$ contribution (4%) treated as combinatorial bkg

Negligible contribution from $B_s \to K^*\mu\mu$ (< 1%), no evidence of $\Lambda_b \to pK\mu^+\mu^-$

4D UML simultaneous fit in 6 q^2 bins

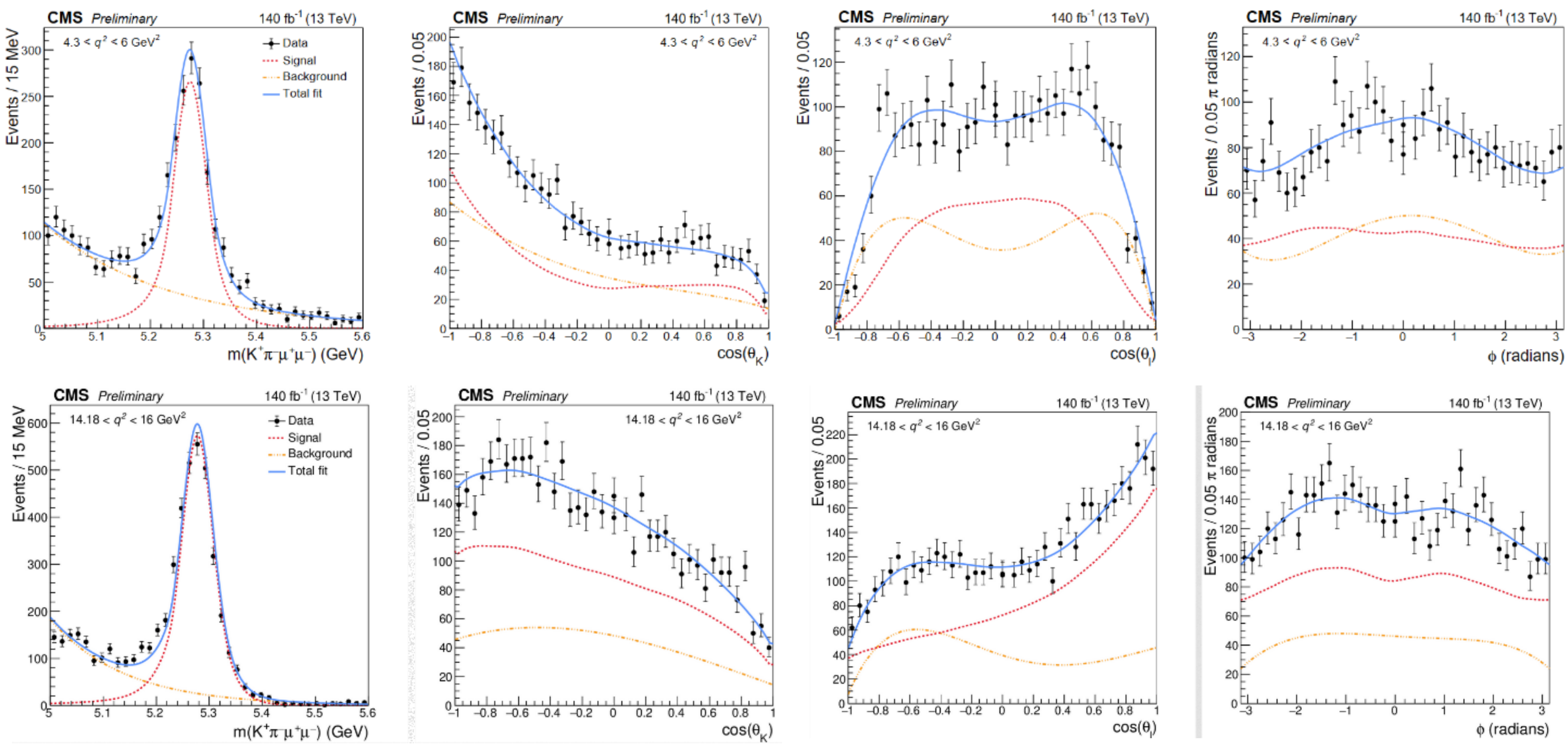
3 angles + mass

3 data-taking years

Fit to $\mathbf{B^0 \to K^{*0} \mu^+ \mu^-}$ sample additionally accounts for:

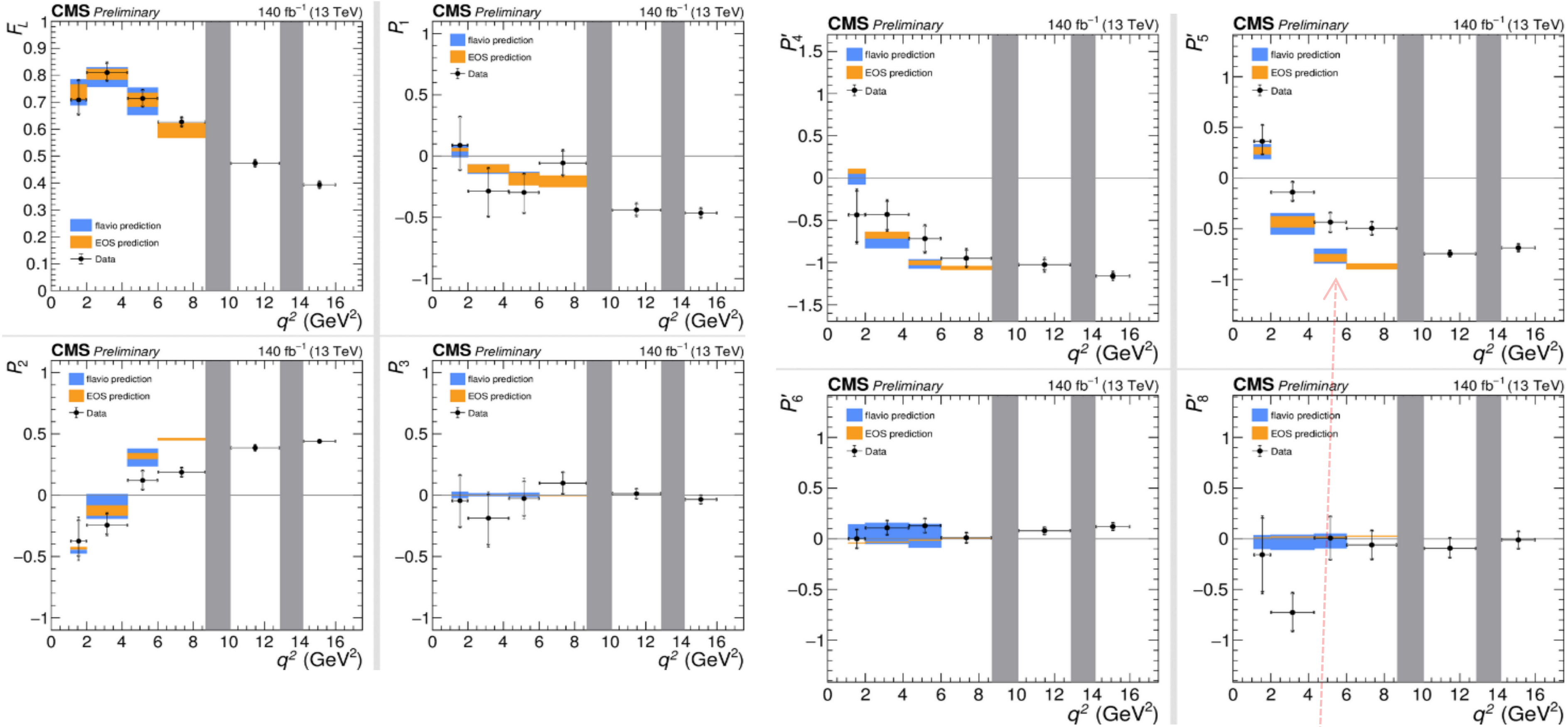
- the possibility that K and π are swapped
- Efficiency as a function of angular variables
- Background angular shape (from sidebands)
- Physical boundary in the angular observables space

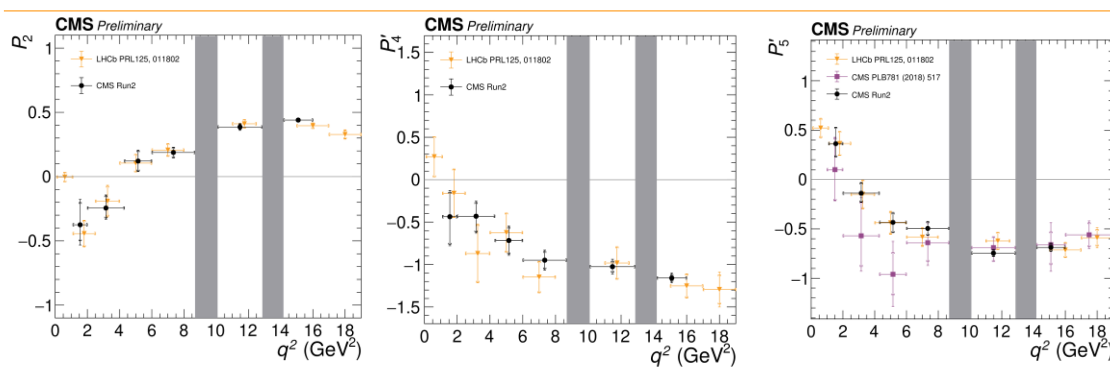
CMS-PAS-BPH-21-002, arXiv soon!



$B^0 \rightarrow K^{*0}\mu^+\mu^-$ Results

$q=m(ll)$





Good agreement with, and similar precision to the previous LHCb results

P'_5 discrepancy remains…

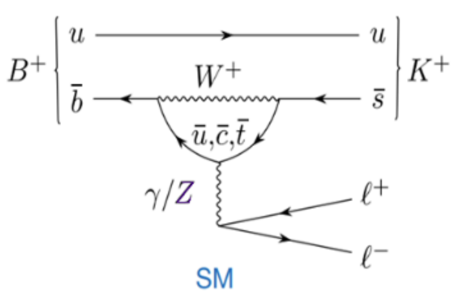
CMS-PAS-BPH-21-002, arXiv soon!

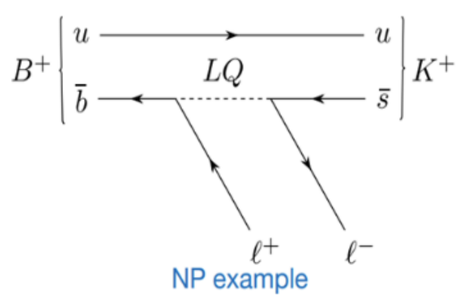
Lepton Flavour Universality Violation

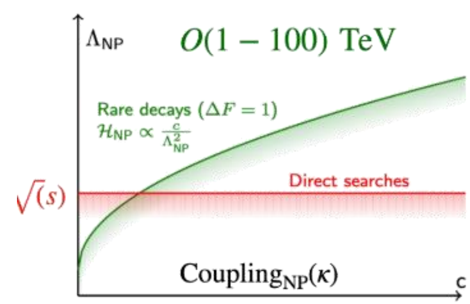
- SM has identical couplings of charged leptons to W and Z bosons
  - → **similar behavior of e,μ,τ** (some differences due to different mass)
- Observation of a significant LFUV would immediately point to New Physics contribution
- LFU tests in $b \to sll$ are theoretically-clean observables

$$R(\mathrm{K})(q^2)[q^2_{\min}, q^2_{\max}] = \frac{\mathcal{B}(\mathrm{B}^+ \to \mathrm{K}^+ \mu^+ \mu^-)[q^2_{\min}, q^2_{\max}]}{\mathcal{B}(\mathrm{B}^+ \to \mathrm{K}^+ \mathrm{e}^+ \mathrm{e}^-)[q^2_{\min}, q^2_{\max}]}$$

q=m(ll)

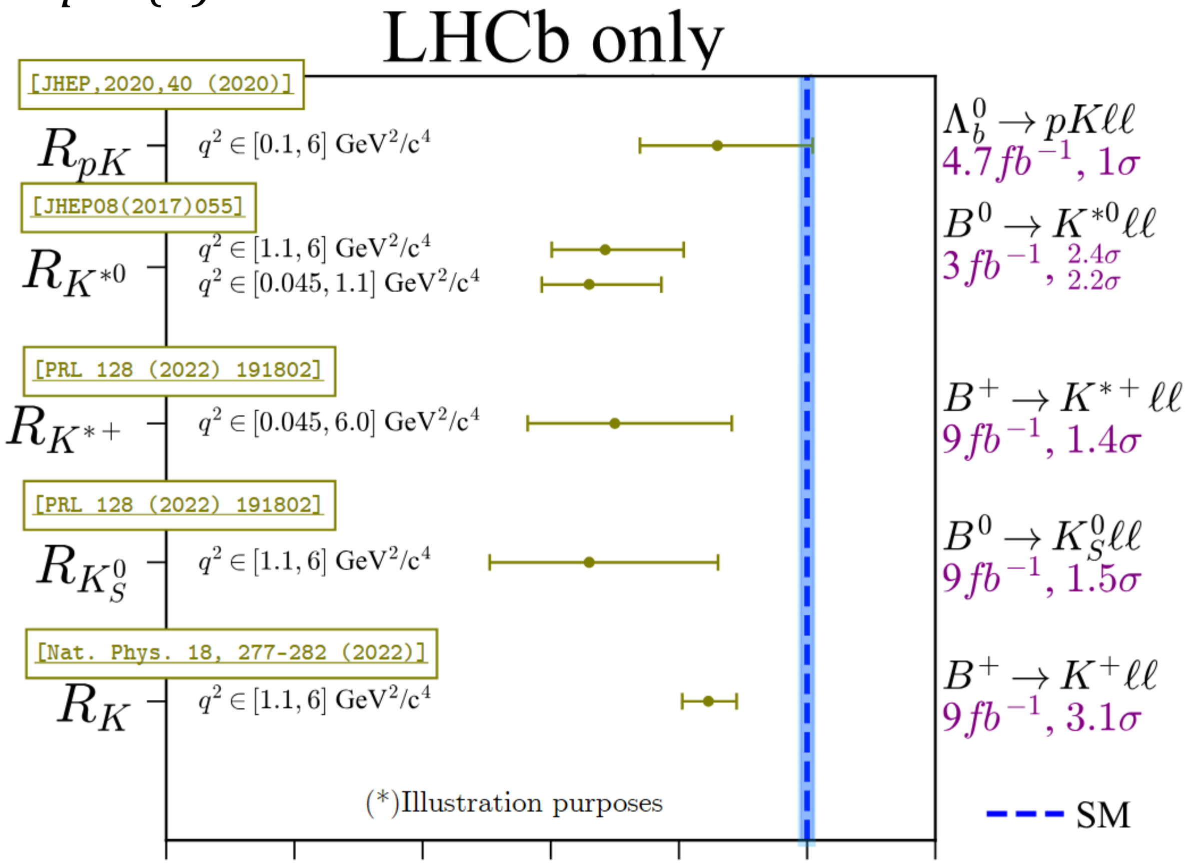






LFUV searches: previous results

q=m(ll)



$$R_X = \frac{\mathcal{B}(b \to s\mu^+\mu^-)}{\mathcal{B}(b \to se^+e^-)}$$

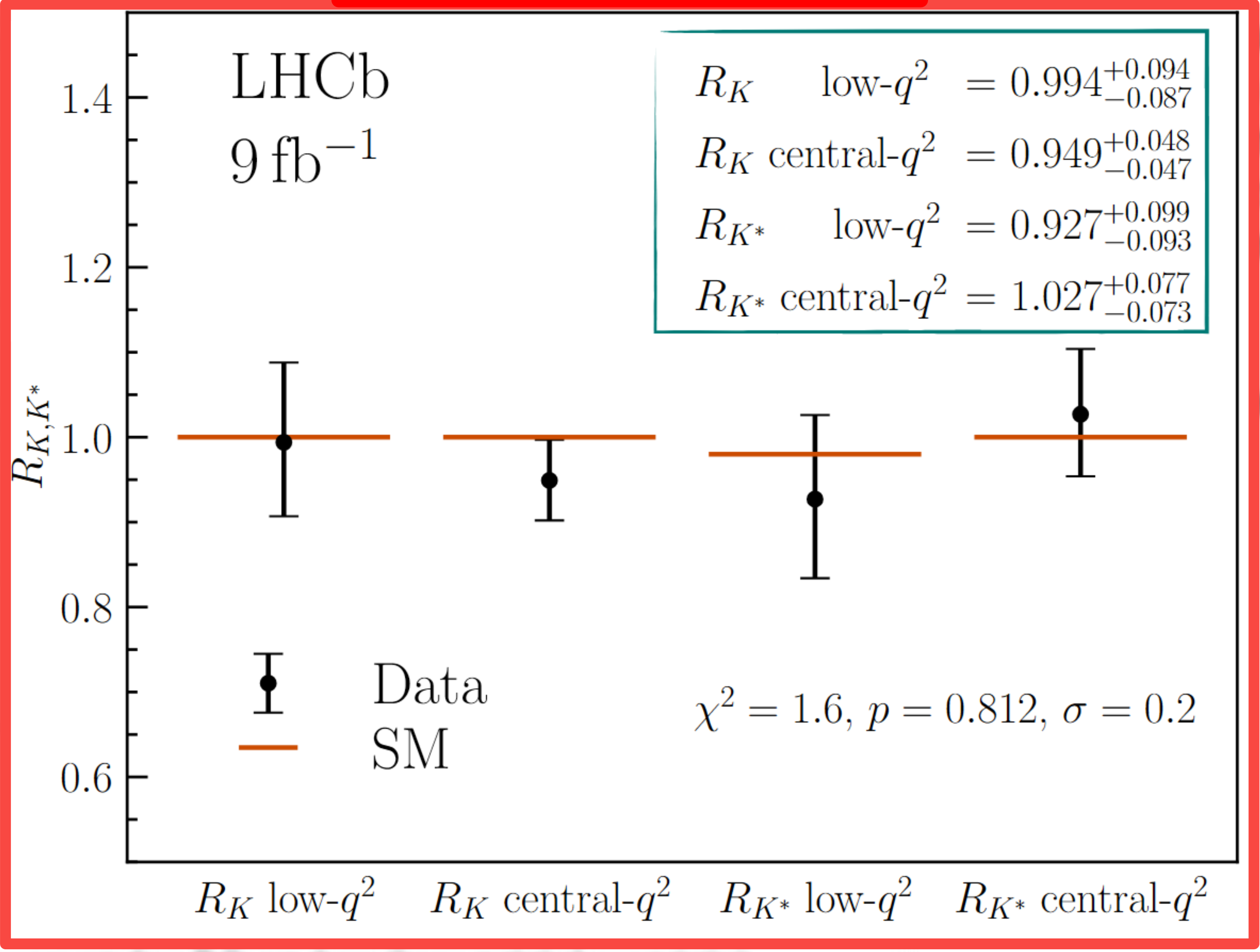
(*) Measurements from Belle not shown (larger statistical uncertainties)

A set of previous results (with precision dominated by LHCb measurements) have indicated a discrepancy from SM prediction in R_x ratios *(until 2023)*

All the ratios are lower than prediction?

LFUV searches: previous results

However, in 2023:

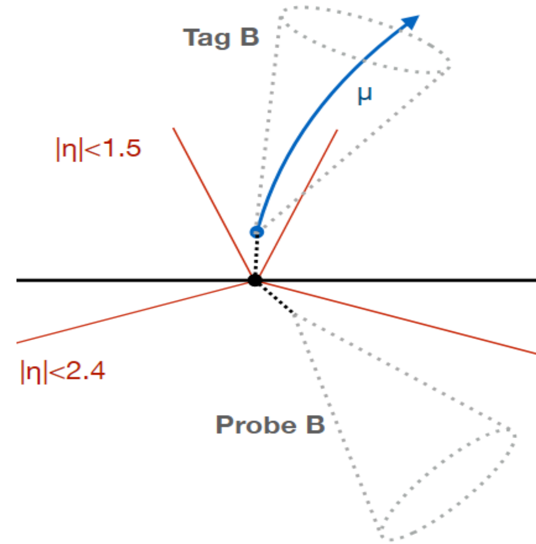


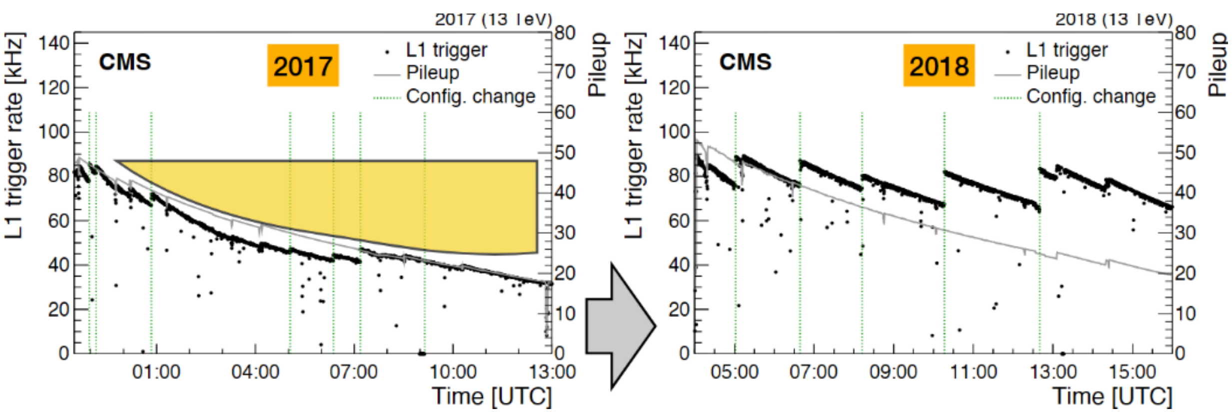
Data sample

CMS-EXO-23-007

- Data Parking stands for "data that will be reconstructed later"

- In 2018, CMS implemented "B-parking"
- triggering on low momentum electrons is very hard
  → leverage the bbbar pair production, trigger on one B and investigate the other
- Triggering on displaced muon from SL b decays
- Constantly utilize full L1 bandwidth

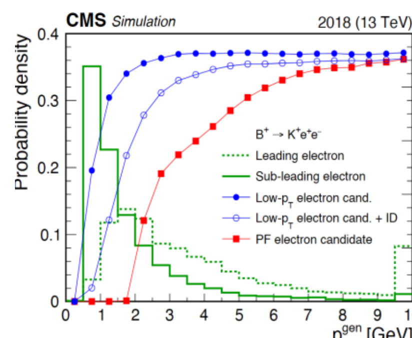


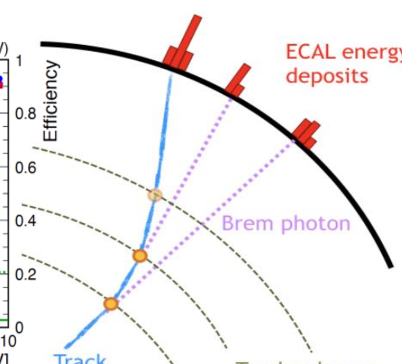


Using a family of L1 seeds with decreasing thresholds as lumi decreases, to "fill the gap to 100 kHz"

- Require muon displacement at HLT
- Resulting purity~75-80% (events with b hadron)

- Dedicated low-p_T electron reconstruction





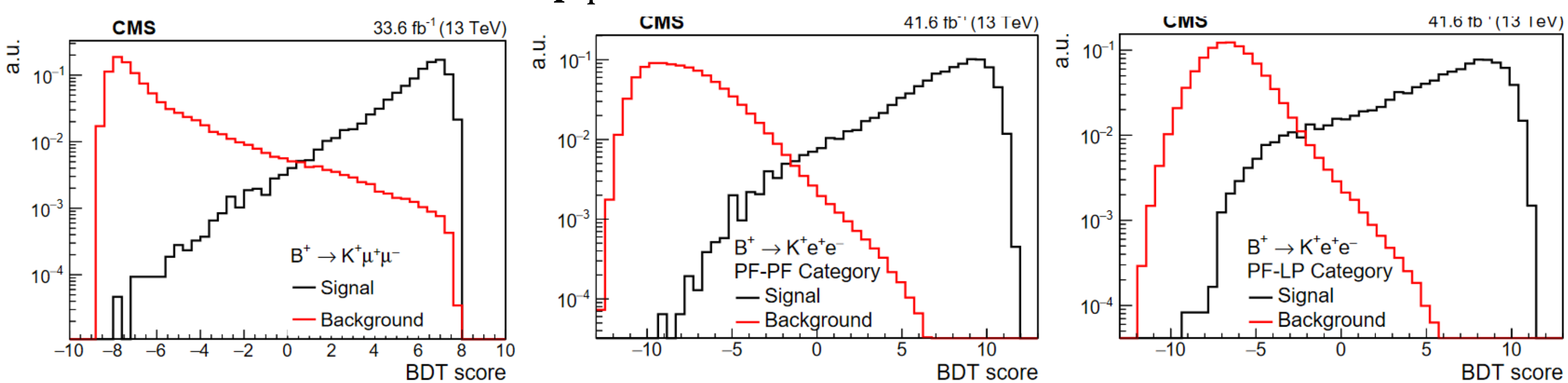
Measurement strategy

CMS-BPH-22-005,
Rep. Prog. Phys. 87 (2024) 077802

- Measuring double ratio to reduce systematics

$$R_{K,K^*}(q_a^2, q_b^2) = \frac{\int_{q_a^2}^{q_b^2} \frac{d\Gamma(B^{(+,0)} \to K^{(+,*0)}\mu^+\mu^-)}{dq^2} dq^2}{\int_{q_a^2}^{q_b^2} \frac{d\Gamma(B^{(+,0)} \to K^{(+,*0)}e^+e^-)}{dq^2} dq^2} = \frac{\mathcal{B}(B^+ \to K^+\mu^+\mu^-)[q^2_{min}, q^2_{max}]}{\mathcal{B}(B^+ \to J/\psi(\mu^+\mu^-)K^+)} \Big/ \frac{\mathcal{B}(B^+ \to K^+e^+e^-)[q^2_{min}, q^2_{max}]}{\mathcal{B}(B^+ \to J/\psi(e^+e^-)K^+)}$$

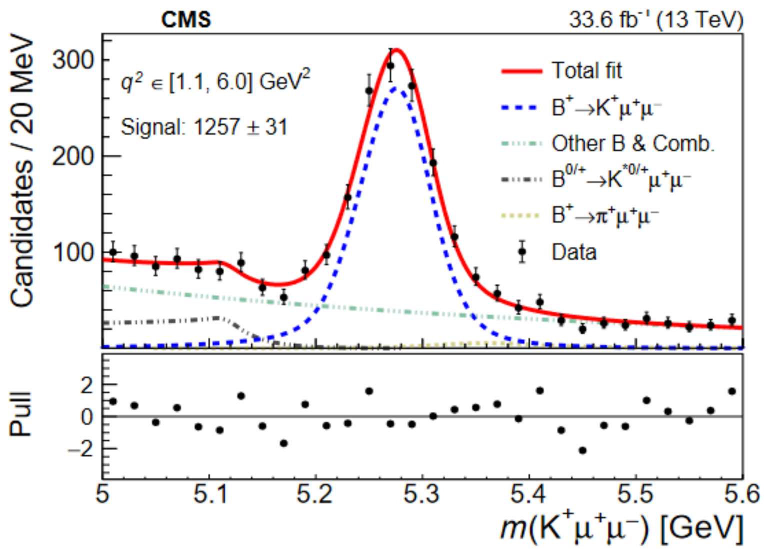
- Muon channel on tag side, electron channel on probe side
- Electrons from two algos: PF and LP → PFPF and PFLP categories
- BDT discriminator(s) for background rejection
  - Features: vertex displacement, fit probability, pointing angle
    muon isolation, kaon p_T, B p_T
    electron p_T, isolation, K IP w.r.t ee vertex, ID



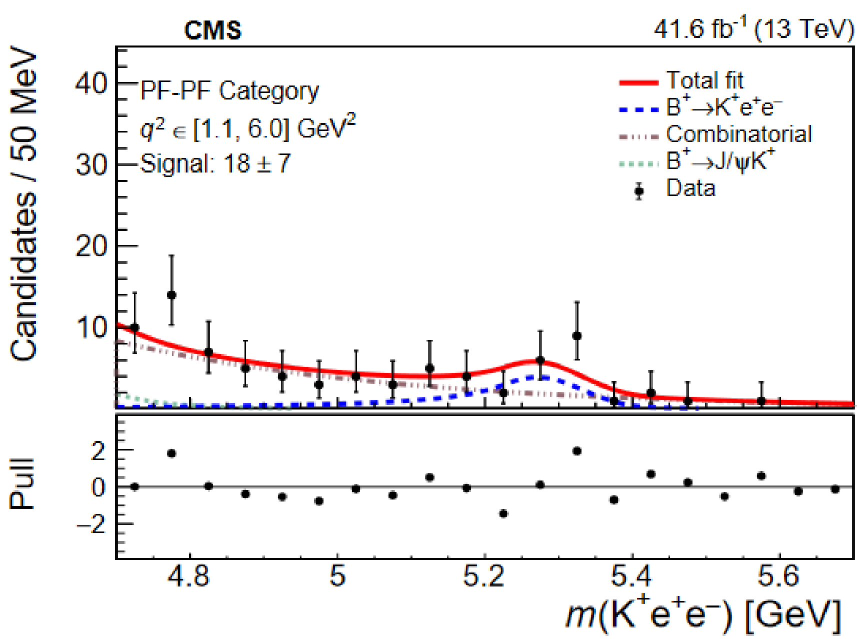
- Dedicated vetoes to kill backgrounds from charm and charmonia

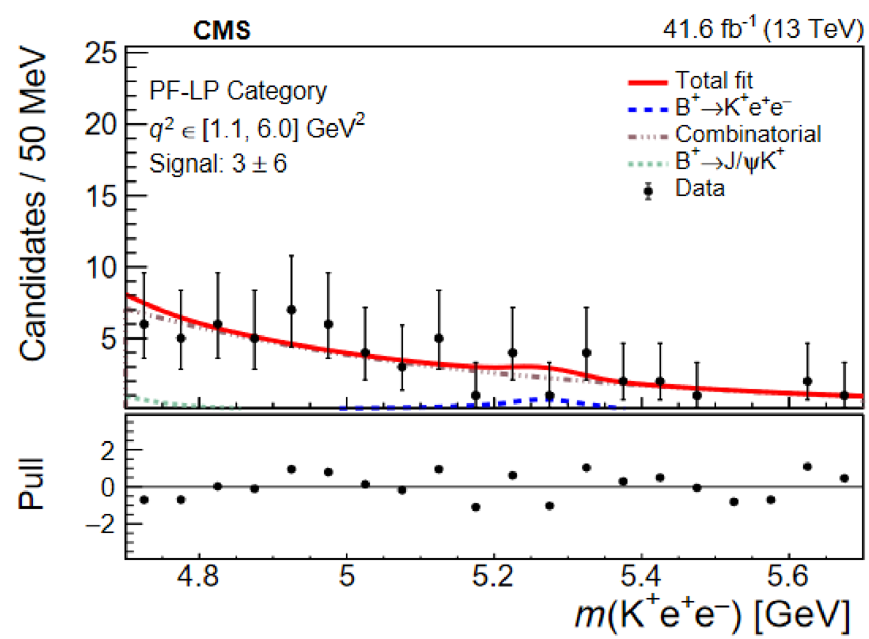
Observed signals

[CMS-BPH-22-005, Rep. Prog. Phys. 87 (2024) 077802]



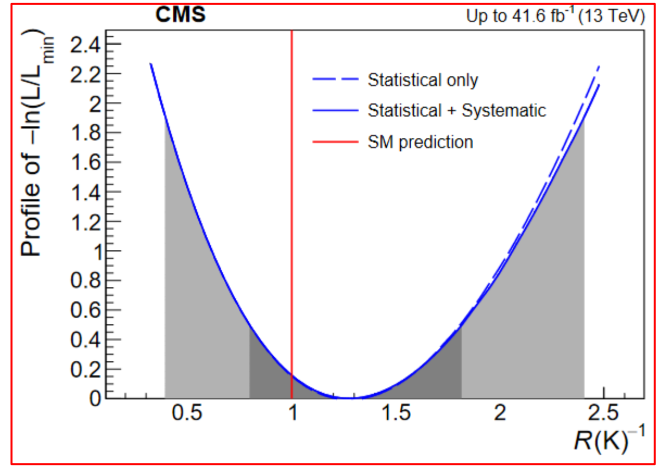
At just 20 events in the signal channel, the precision of R(K) measurement is quite low





R(K) result

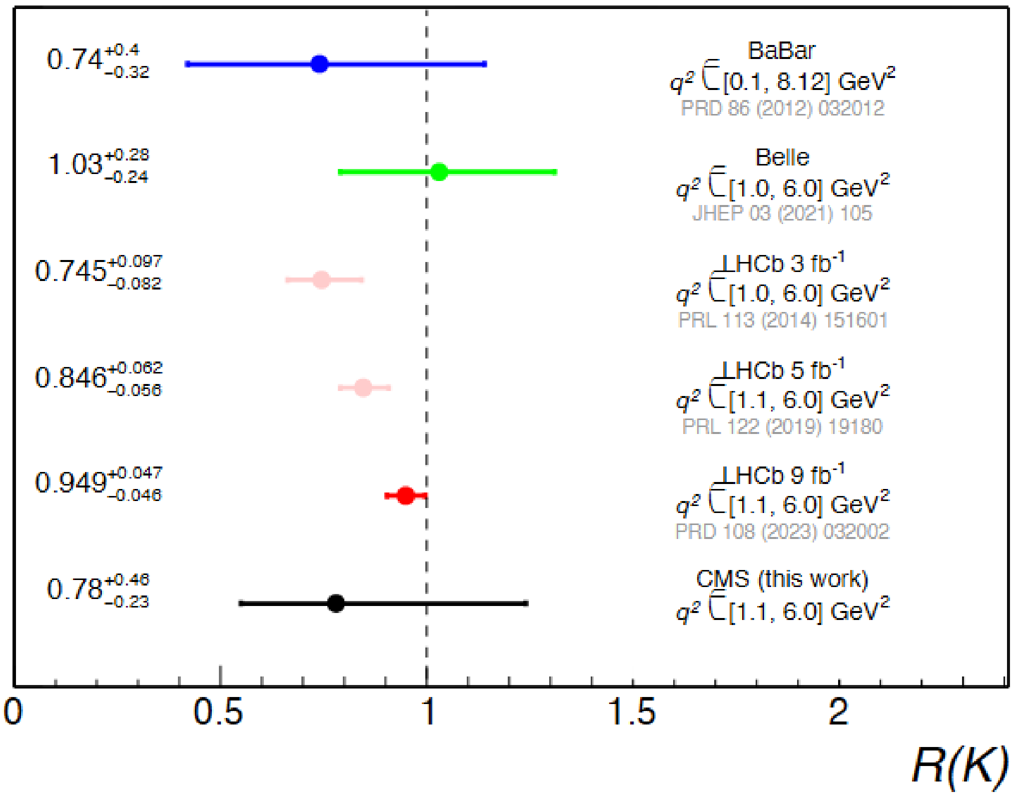
$$R(K) = 0.78^{+0.46}_{-0.23}\,(\text{stat})^{+0.09}_{-0.05}\,(\text{syst}) = 0.78^{+0.47}_{-0.23}$$



The resulting value is consistent both with SM and LHCb, but the precision is not competitive

The main reason is the difficulty with low-p_T electrons, especially at the trigger level, which is why the trigger for this analysis searches for *the other b* in an event

CMS has learned a lot and huge improvement is expected in Run-3, stay tuned!



CMS-BPH-22-005,
Rep. Prog. Phys. 87 (2024) 077802

Summary

- Many new results on rare *b→sll* decays, sensitive to NP, are obtained in the last few years
- Some **~3-4σ tensions** w.r.t. SM have been observed in B meson decays
- CMS made an angular analysis of the $B^0 \to K^{*0} \mu^+ \mu^-$ decay with full Run-2 data
  - The results agree with and are as precise as earlier LHCb results
  - Confirming the tension between experiment and SM in P'_5 parameter
- R(K) measurement is very challenging at CMS due to low-p_T electrons
  - The result agrees (with large uncertainties) with LHCb and LFU=SM
  - In the meanwhile, refreshed LHCb results from last year also agree with LFU=SM…

- Run-3 triggers will allow to make significantly more precise measurements

http://cms-results.web.cern.ch/cms-results/public-results/publications/BPH/

https://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/BPH/index.html

Thank you !

BACKUP

Search for $D^0 \to \mu\mu$

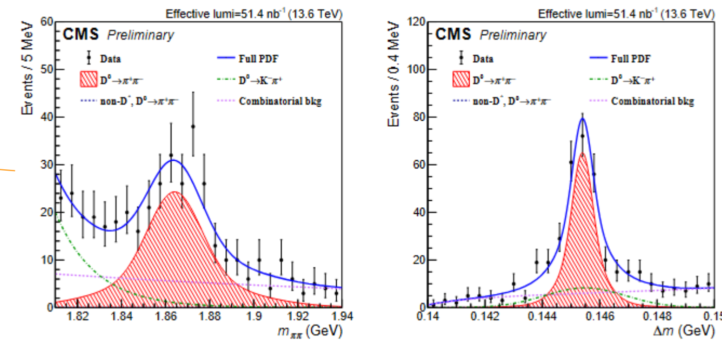
With many studies of *b→sll* transitions, even more rare *c→ull* ones are often forgotten/neglected

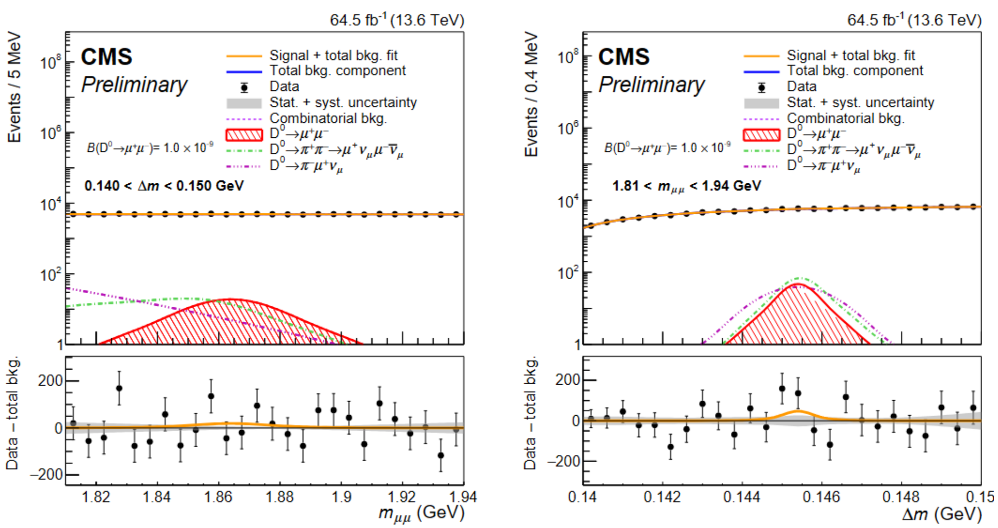
CMS searches for the $D^0 \to \mu\mu$ decay via $D^{*+} \to D^0 \pi^+$ to suppress bkg

One of the first analyses to:

- **use Run-3 13.6 TeV data!** *(2022+2023 in this case)*
- **use new inclusive dimuon triggers**

Normalization relative to $D^0 \to \pi^+\pi^-$





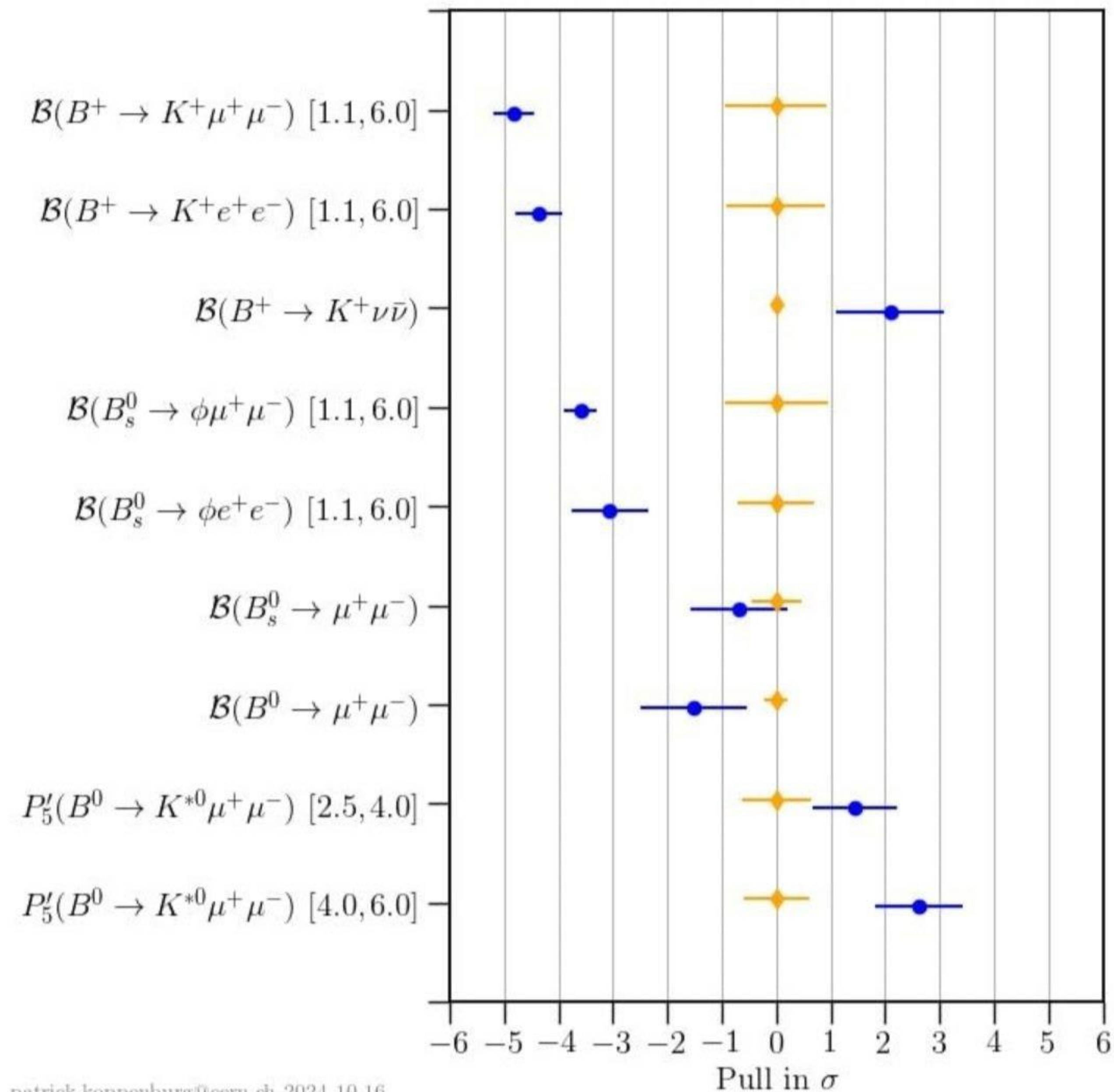
No signal observed, UL set at

$$\mathcal{B}(D^0 \to \mu^+\mu^-) < 2.6 \times 10^{-9} \text{ at } 95\% \text{ CL}$$

Best limit to date, 35% improvement over LHCb
*SM prediction ~3*10^{-13}*

CMS-PAS-BPH-23-008

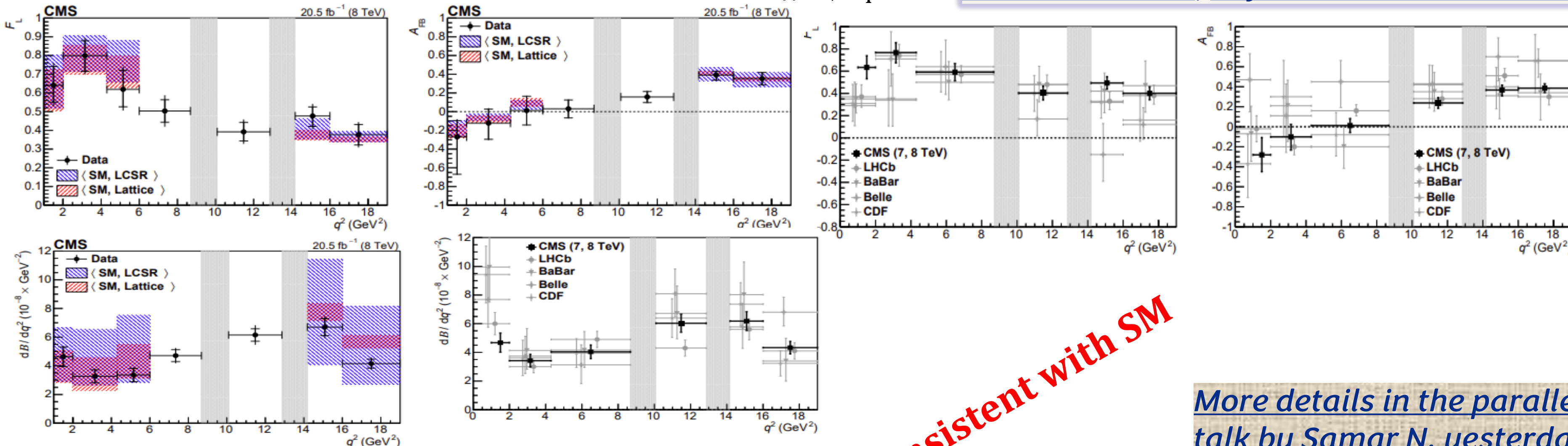
“anomalies” in **FCNC** transitions



$B^0 \to K^{*0}\mu^+\mu^-$, CMS and ATLAS Run-1

~1450 signal, 7q^2 bins

[CMS-BPH-13-010, Phys. Lett. B 753 (2016) 424]

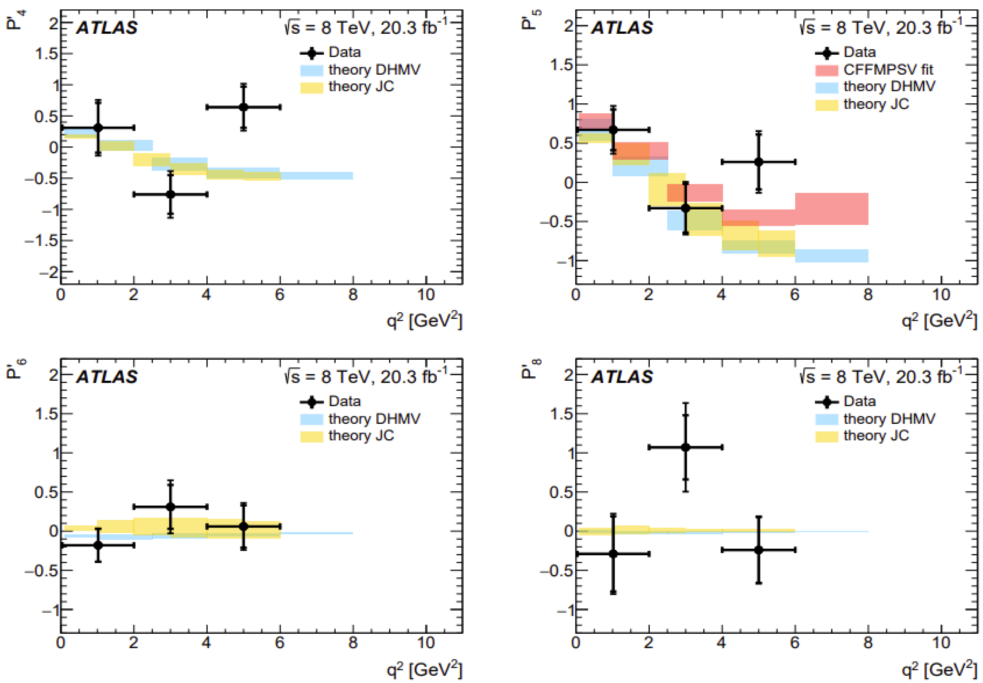


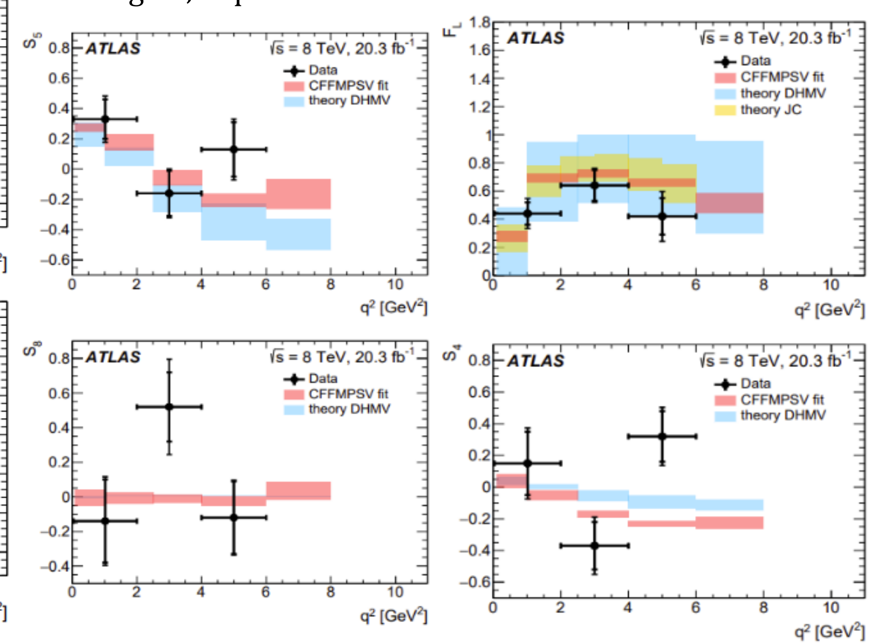
More details in the parallel talk by Samar N. yesterday

Consistent with SM

[ATLAS-BPHY-13-02, JHEP10(2018)047]

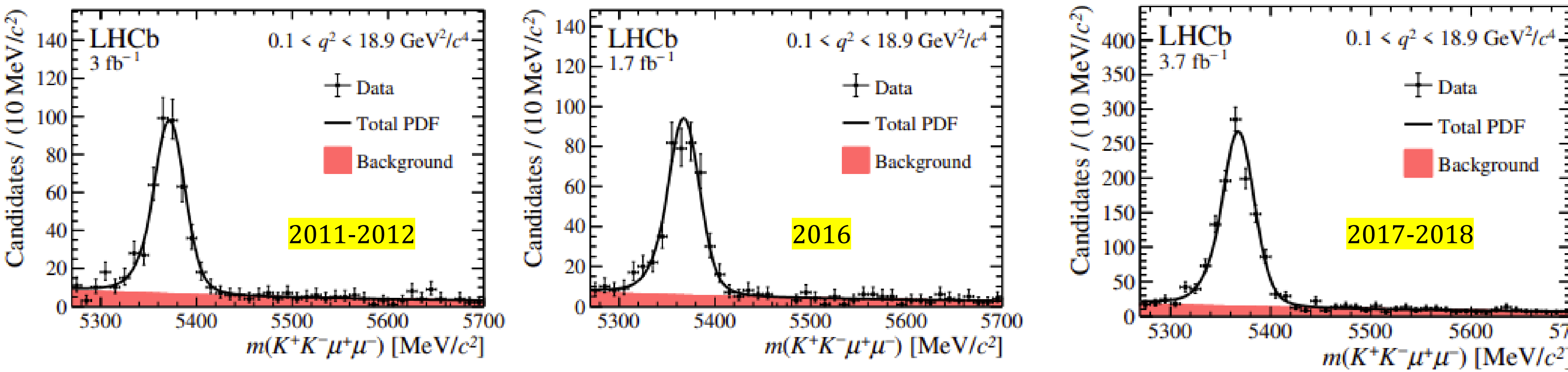
~350 signal, 3 q^2 bins

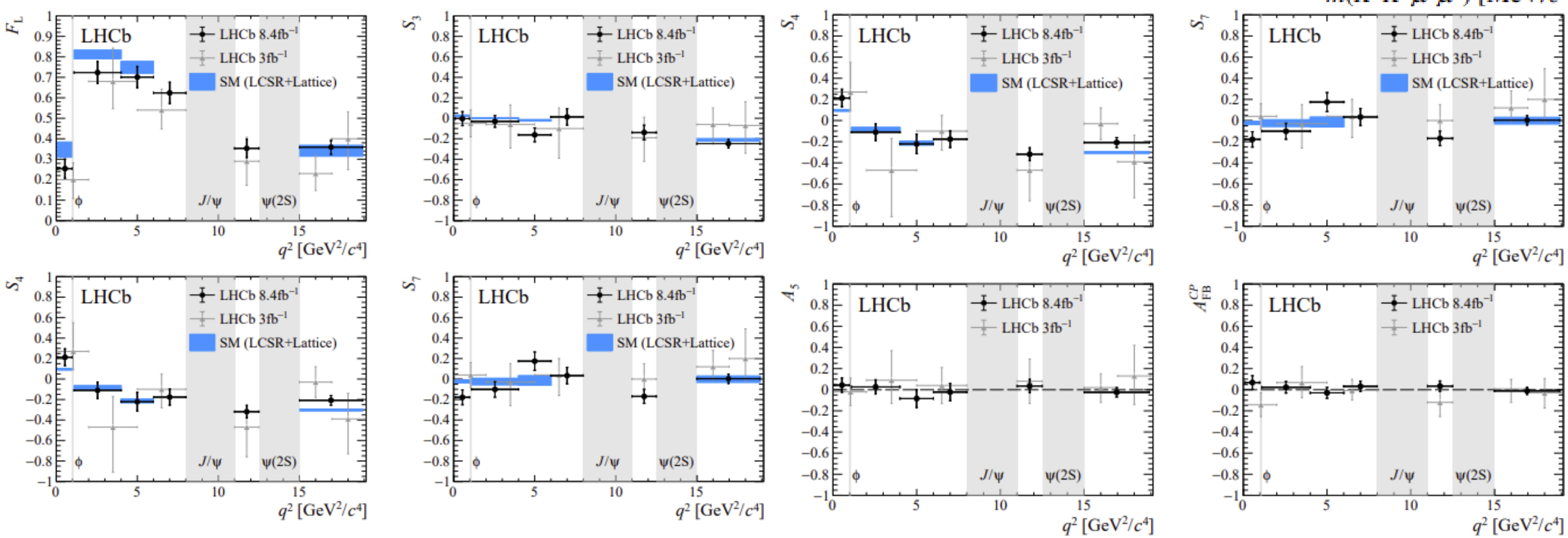




Angular analyses of *b→sll* transitions

$B_s^0 \to \varphi\mu^+\mu^-$ angular, Run-1+Run-2 (no 2015), ~2000 signal





Compatible with SM

LHCb-PAPER-2021-022, JHEP11(2021)043

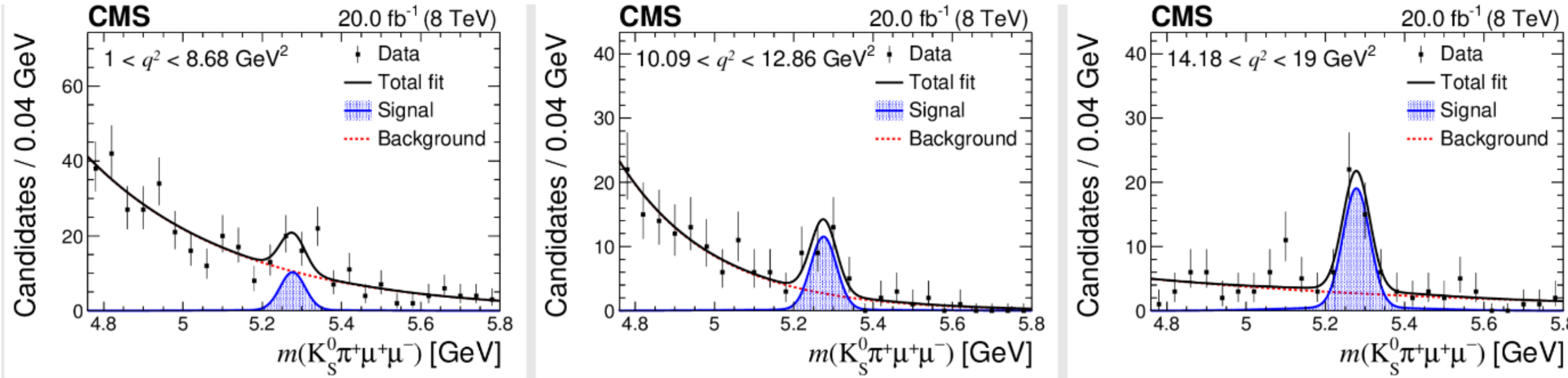
CMS Run-2 analysis in development

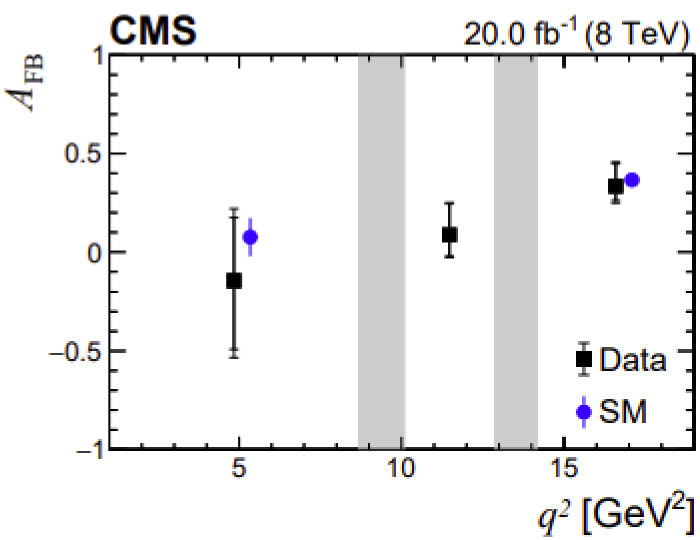
Angular analyses of *b→sll* transitions

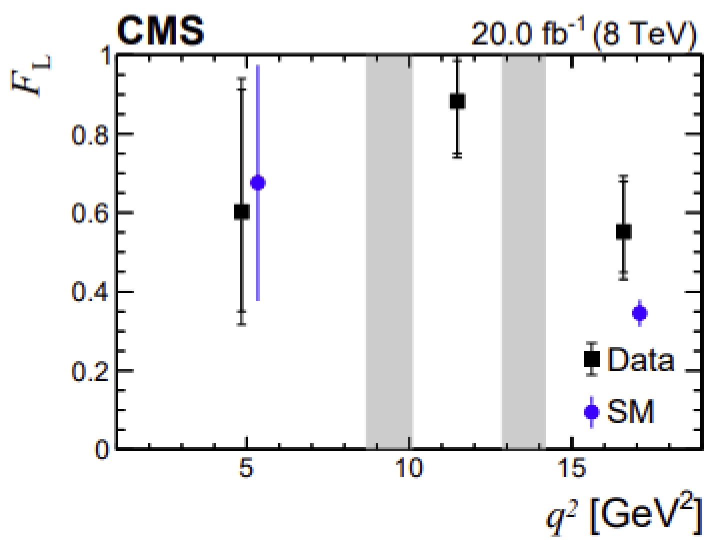
$B^+ \to K^{*+}\mu^+\mu^-$, ($K^{*+} \to K^0_S\pi^+$) CMS Run-1, ~90 signal

Lower statistics compared to K^{*0} channel because of K^0_S

CMS-BPH-15-009, JHEP04(2021)124







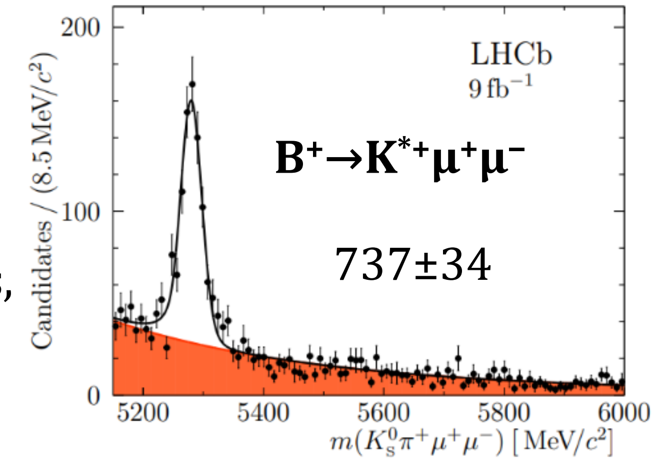
$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{dq^2\,d\cos\theta_l\,d\cos\theta_K\,d\phi} = (1-F_S)\Gamma_P + \frac{3}{16\pi}(F_S\sin^2\theta_l + A_S\sin^2\theta_l\cos\theta_K + A_S^4\sin\theta_K\sin2\theta_l\cos\phi + A_S^5\sin\theta_K\sin\theta_l\cos\phi + A_S^7\sin\theta_K\sin\theta_l\sin\phi + A_S^8\sin\theta_K\sin2\theta_l\sin\phi)$$

S-wave

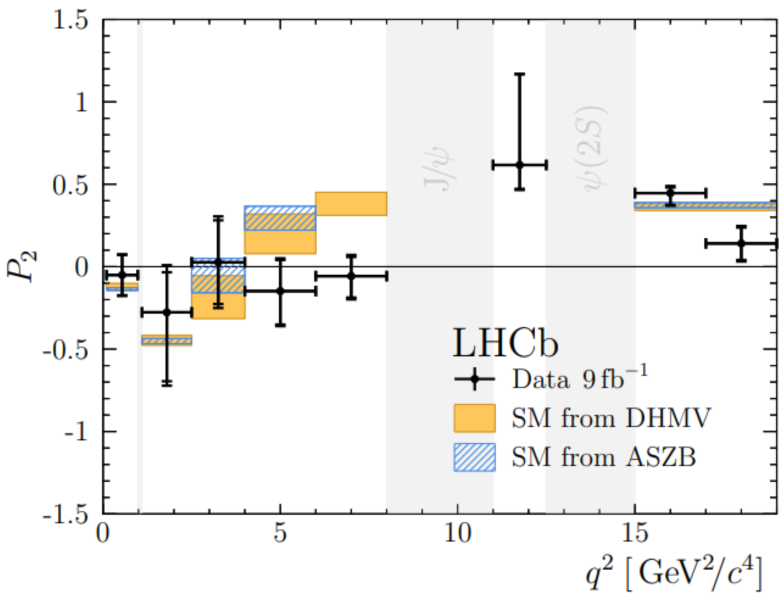
Compatible with SM

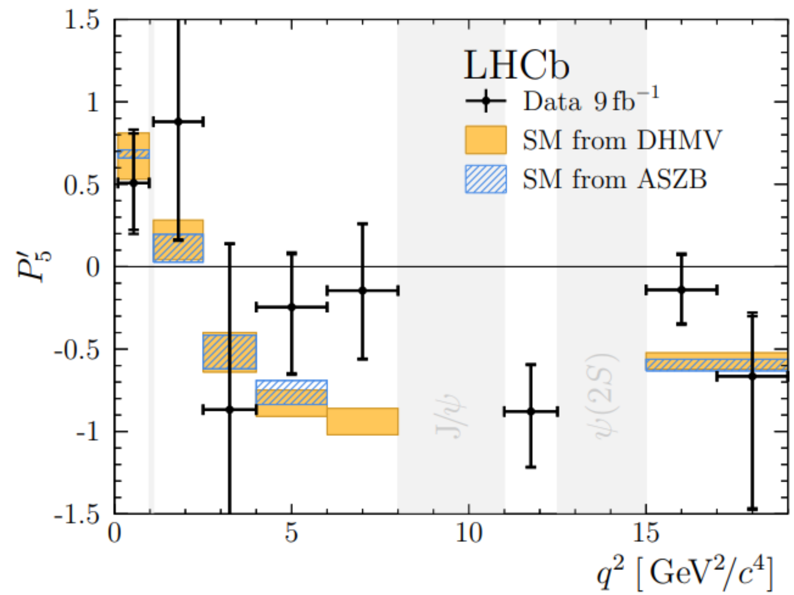
Angular analyses of $b\to sll$ transitions

$B^+\to K^{*+}\mu^+\mu^-$, ($K^{*+}\to K^0_S\pi^+$) LHCb Run-1 + Run-2, ~90 signal
Lower statistics compared to K^{*0} channel because of K^0_S
Two categories based on K^0_S decay vertex position



Angular analysis, measuring full set of optimized variables,
F_L, S_3, S_4, S_5, A_{FB}, S_7, S_8, S_9, P_1, P_2, P_3, P'_4, P'_5, P'_6, P'_8
in 5 folds of the data, due to limited stat.





3.1σ tension w.r.t SM at low q^2 !

LHCb-PAPER-2020-041, Phys.Rev.Lett.126(2021)161802

Angular analyses of $b \to sll$ transitions

Table 2: Measured CP-averaged angular observables, in the corresponding q^2 bins. The first uncertainties are statistical and the second systematic.

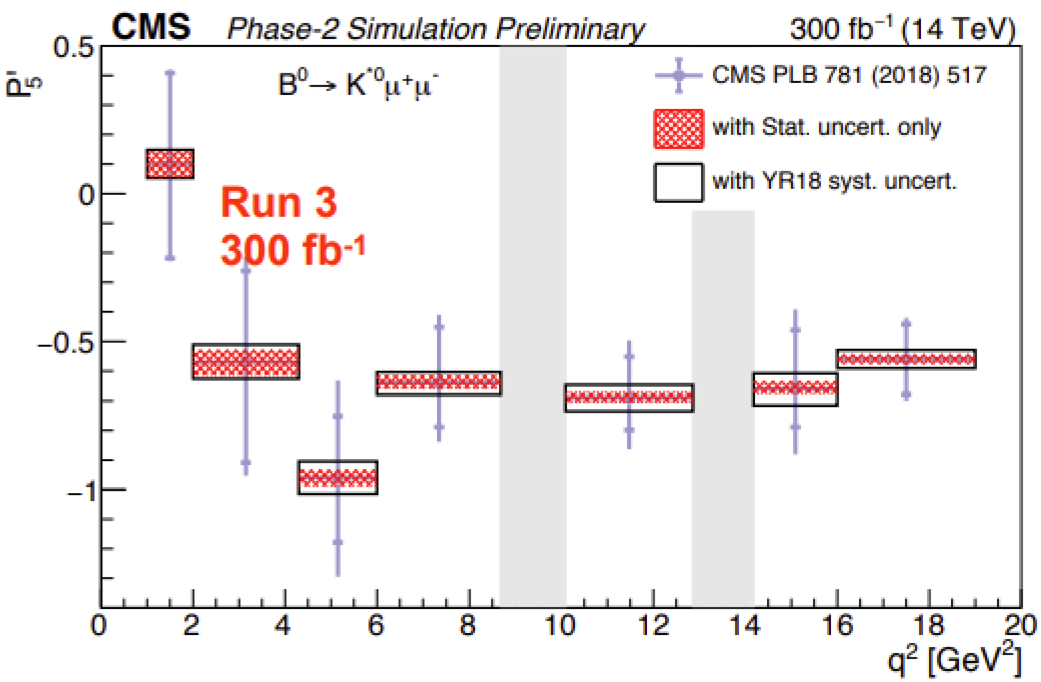
	$1.1 < q^2 < 2$ GeV^2	$2 < q^2 < 4.3$ GeV^2	$4.3 < q^2 < 6$ GeV^2
F_L	$0.709^{+0.073}_{-0.054} \pm 0.021$	$0.810^{+0.036}_{-0.030} \pm 0.016$	$0.714^{+0.032}_{-0.030} \pm 0.012$
P_1	$0.089^{+0.234}_{-0.204} \pm 0.040$	$-0.285^{+0.187}_{-0.208} \pm 0.051$	$-0.297^{+0.153}_{-0.168} \pm 0.038$
P_2	$-0.374^{+0.173}_{-0.125} \pm 0.095$	$-0.244^{+0.094}_{-0.077} \pm 0.039$	$0.121^{+0.080}_{-0.076} \pm 0.030$
P_3	$-0.045^{+0.209}_{-0.216} \pm 0.044$	$-0.187^{+0.196}_{-0.218} \pm 0.089$	$-0.027^{+0.143}_{-0.143} \pm 0.081$
P_4'	$-0.436^{+0.289}_{-0.323} \pm 0.111$	$-0.431^{+0.160}_{-0.185} \pm 0.075$	$-0.717^{+0.154}_{-0.158} \pm 0.074$
P_5'	$0.363^{+0.165}_{-0.132} \pm 0.028$	$-0.139^{+0.103}_{-0.087} \pm 0.039$	$-0.435^{+0.096}_{-0.101} \pm 0.027$
P_6'	$0.000^{+0.094}_{-0.097} \pm 0.021$	$0.108^{+0.075}_{-0.071} \pm 0.018$	$0.129^{+0.074}_{-0.071} \pm 0.011$
P_8'	$-0.157^{+0.368}_{-0.369} \pm 0.113$	$-0.727^{+0.193}_{-0.184} \pm 0.056$	$0.007^{+0.215}_{-0.216} \pm 0.036$

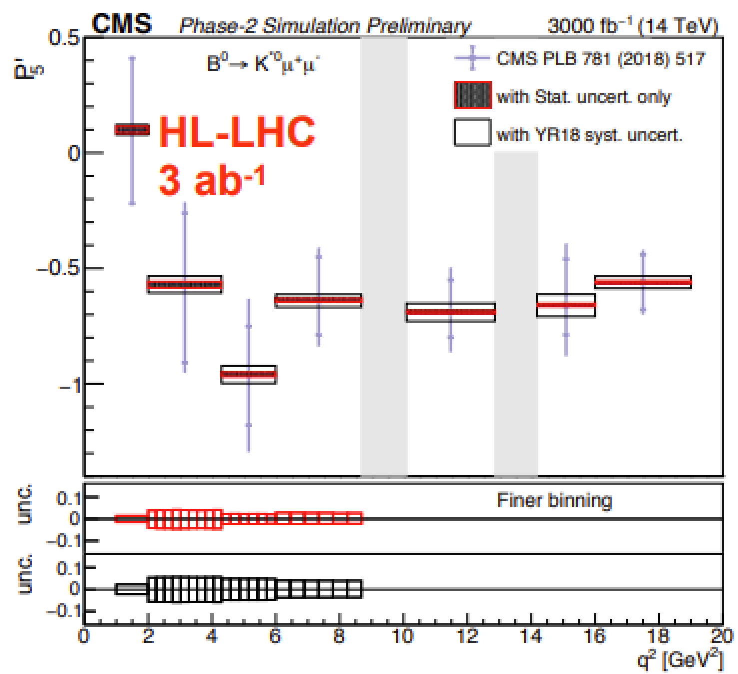
	$6 < q^2 < 8.68$ GeV^2	$10.09 < q^2 < 12.86$ GeV^2	$14.18 < q^2 < 16$ GeV^2
F_L	$0.627^{+0.016}_{-0.016} \pm 0.011$	$0.474^{+0.011}_{-0.013} \pm 0.009$	$0.394^{+0.012}_{-0.012} \pm 0.009$
P_1	$-0.056^{+0.101}_{-0.102} \pm 0.046$	$-0.439^{+0.051}_{-0.047} \pm 0.030$	$-0.465^{+0.037}_{-0.037} \pm 0.025$
P_2	$0.188^{+0.039}_{-0.040} \pm 0.014$	$0.386^{+0.021}_{-0.019} \pm 0.018$	$0.440^{+0.008}_{-0.010} \pm 0.008$
P_3	$0.099^{+0.092}_{-0.090} \pm 0.014$	$0.013^{+0.041}_{-0.043} \pm 0.007$	$-0.034^{+0.037}_{-0.038} \pm 0.010$
P_4'	$-0.949^{+0.102}_{-0.101} \pm 0.058$	$-1.025^{+0.064}_{-0.066} \pm 0.059$	$-1.159^{+0.042}_{-0.038} \pm 0.041$
P_5'	$-0.495^{+0.067}_{-0.067} \pm 0.023$	$-0.746^{+0.033}_{-0.032} \pm 0.014$	$-0.688^{+0.038}_{-0.036} \pm 0.021$
P_6'	$0.010^{+0.052}_{-0.052} \pm 0.016$	$0.080^{+0.037}_{-0.041} \pm 0.011$	$0.121^{+0.040}_{-0.039} \pm 0.011$
P_8'	$-0.061^{+0.143}_{-0.143} \pm 0.042$	$-0.093^{+0.104}_{-0.094} \pm 0.029$	$-0.011^{+0.086}_{-0.089} \pm 0.022$

P5' HL-LHC

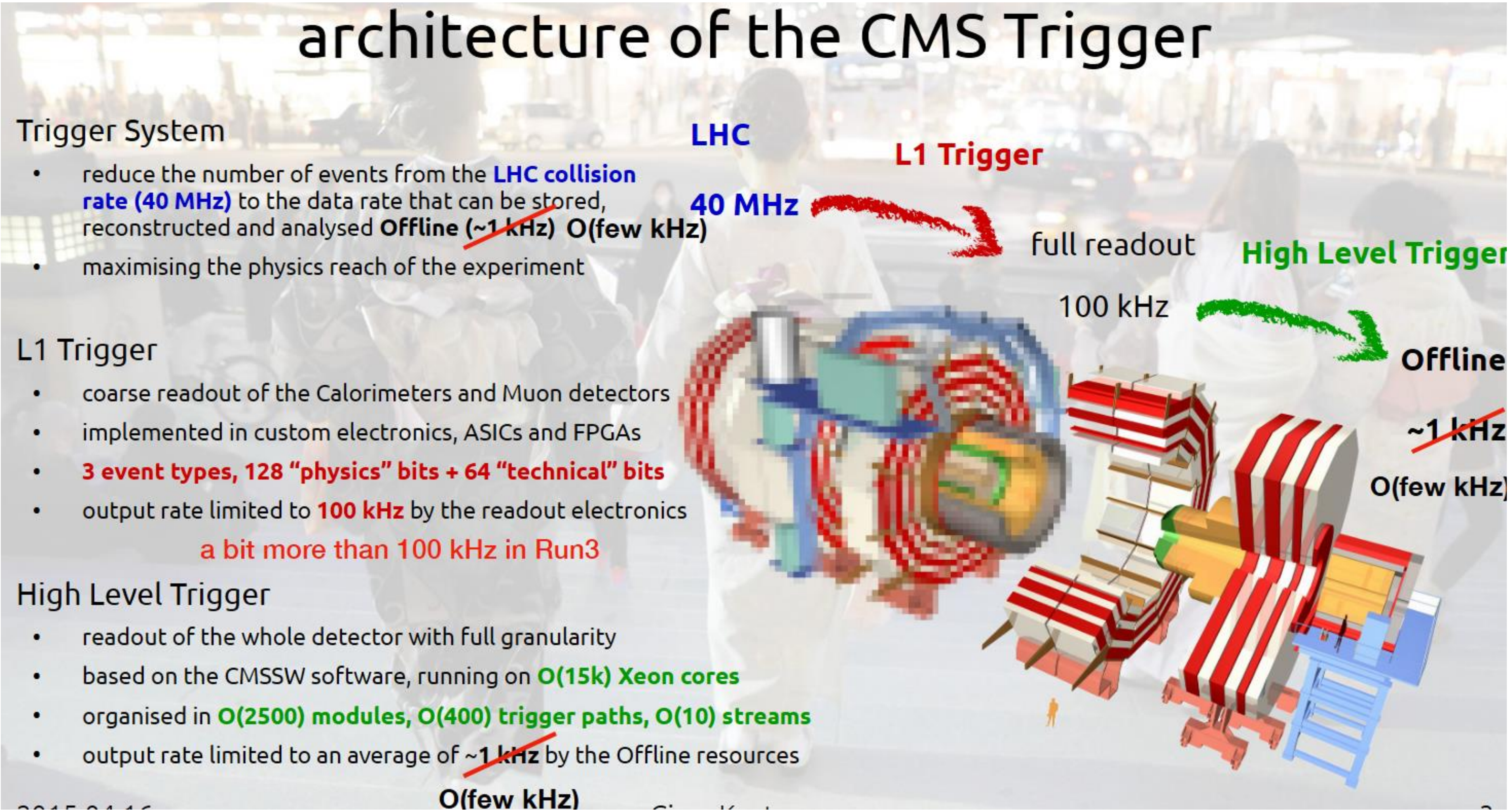
- Run 3 and HL-LHC projections
  - Up to x15 improvement w/ 3 ab^{-1} compared to the 8 TeV CMS result [PLB 781 (2018) 517]
  - Should be possible to resolve the situation experimentally already in Run 3

CMS PAS FTR-18-033





CMS experiment



$B^0 \to \varphi\,\mu\mu$

LHCb-PAPER-2021-042, JHEP05(2022)067

It proceeds mainly via the color-suppressed penguin annihilation diagrams $\mathcal{O}(10^{-12})$

$\omega - \phi$ mixing can have a sizeble contribution $\mathcal{O}(10^{-10})$

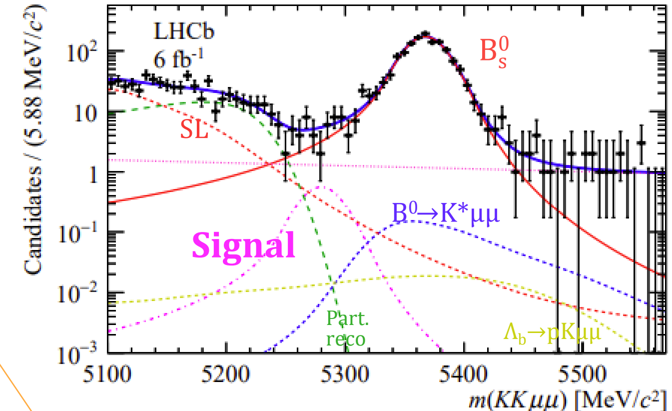
Run 1 + 2 data

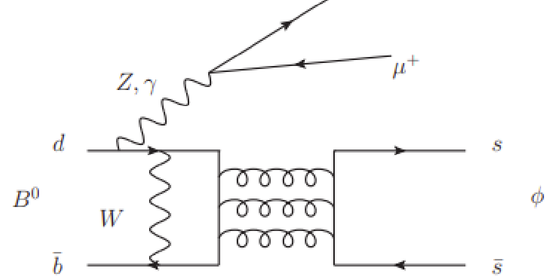
Exclude regions in q^2 corresponding to ϕ, J/ψ and $\psi(2S)$

$B_s^0 \to \phi\mu^+\mu^-$ used as normalisation

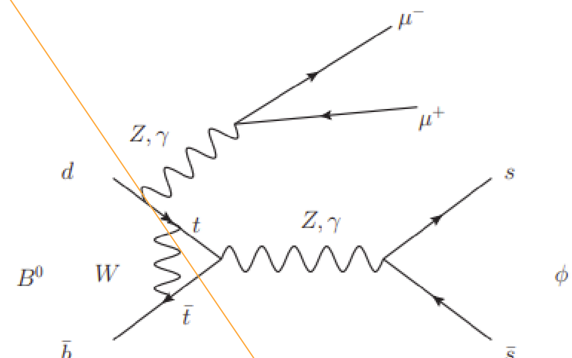
$B_s^0 \to J/\psi\phi$ used to develop a MVA discriminator

Dominant backgrounds: misidentification, combinatorial, semileptonic



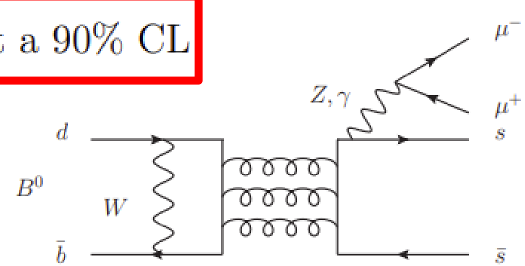


(a)

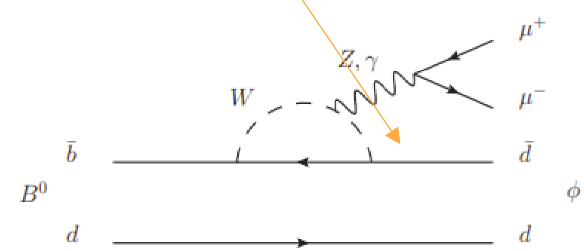


(b)

$$\mathcal{B}(B^0 \to \phi\mu^+\mu^-) < 3.2 \times 10^{-9} \text{ at a } 90\% \text{ CL}$$



(c)

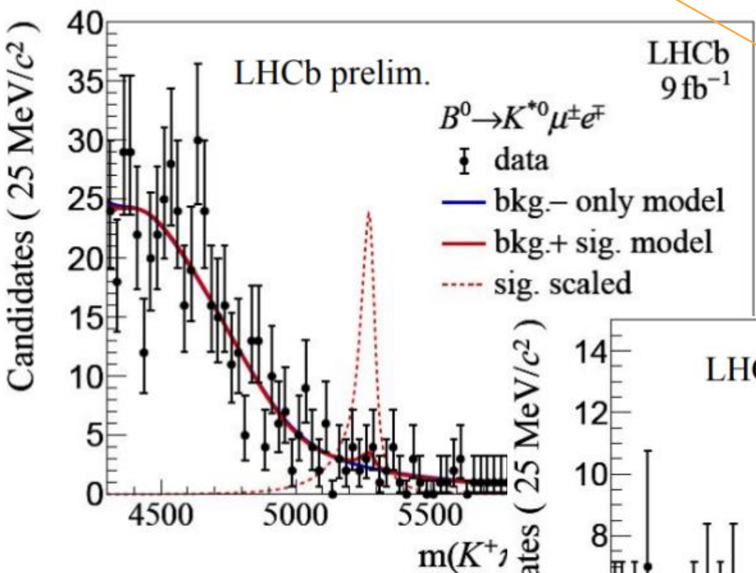


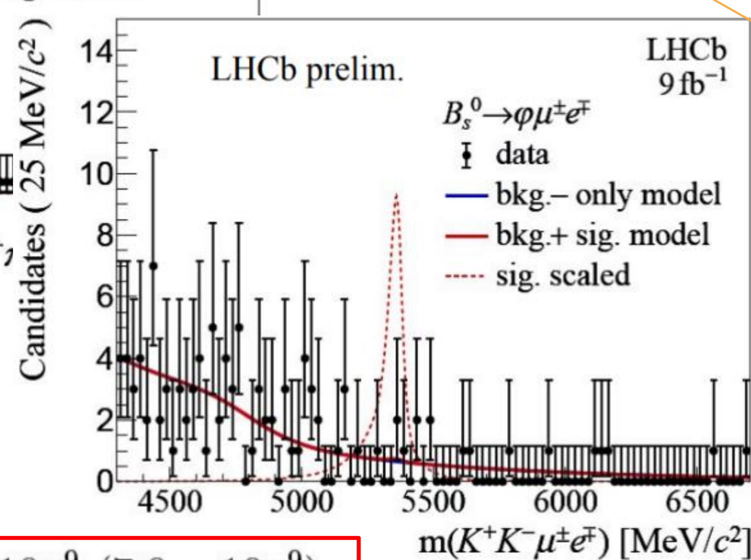
(d)

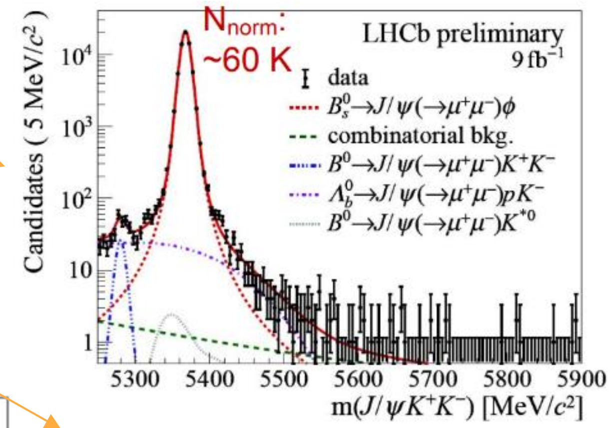
$B^0 \to K^{*0}\mu^{\mp}e^{\pm}$ and $B_s^0 \to \varphi\mu^{\mp}e^{\pm}$

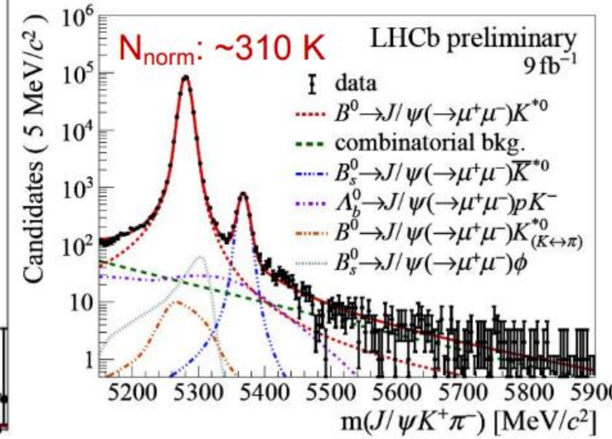
LHCP-PAPER-2022-008. Full Run-1 + Run-2 analysis

Normalization using $B^0 \to J/\psi K^{*0}$ and $B_s^0 \to J/\psi\varphi$









$$\mathcal{B}(B^0 \to K^{*0}\mu^+e^-) < 5.7 \times 10^{-9}\ (7.0 \times 10^{-9}),$$
$$\mathcal{B}(B^0 \to K^{*0}\mu^-e^+) < 6.7 \times 10^{-9}\ (7.9 \times 10^{-9}),$$
$$\mathcal{B}(B^0 \to K^{*0}\mu^{\pm}e^{\mp}) < 9.9 \times 10^{-9}\ (11.6 \times 10^{-9})$$

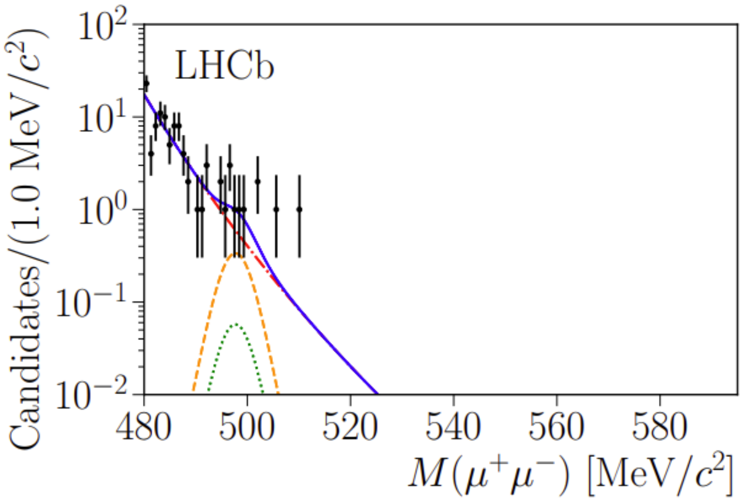
$$\mathcal{B}(B_s^0 \to \phi\mu^{\pm}e^{\mp}) < 15.9 \times 10^{-9}\ (19.4 \times 10^{-9})$$

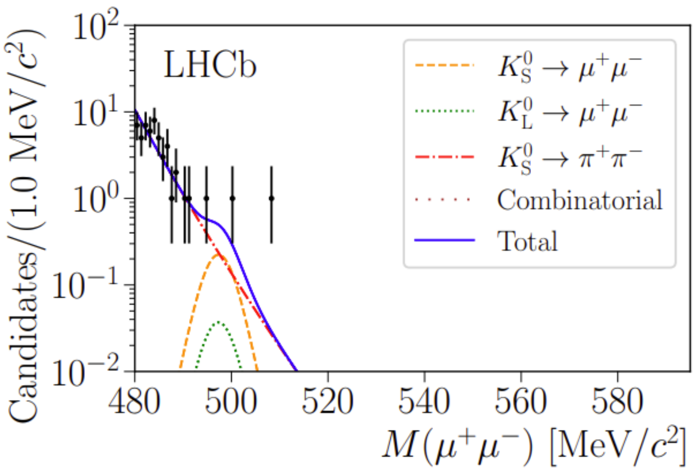
World-best limits

$K^0_S \to \mu\mu$

- FCNC process, in SM $\mathcal{B}(K^0_S \to \mu^+\mu^-)_{SM} = (5.18 \pm 1.50_{LD} \pm 0.02_{SD}) \times 10^{-12}$
- Some NP (SUSY/LQ) models modify the **B**
- LHCb performed a search using Run-2 data
- Normalization using decay to $\pi^+\pi^-$
  - This decay is also the main background

LHCb-PAPER-2019-038, Phys.Rev.Lett.125(2020)231801





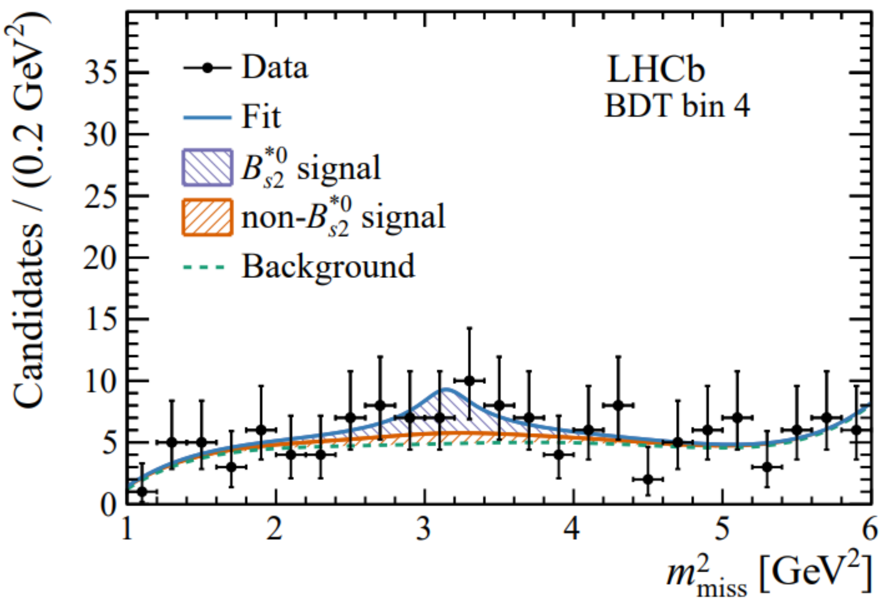
Statistically combined with Run-1 result upper limit is most stringent to date:

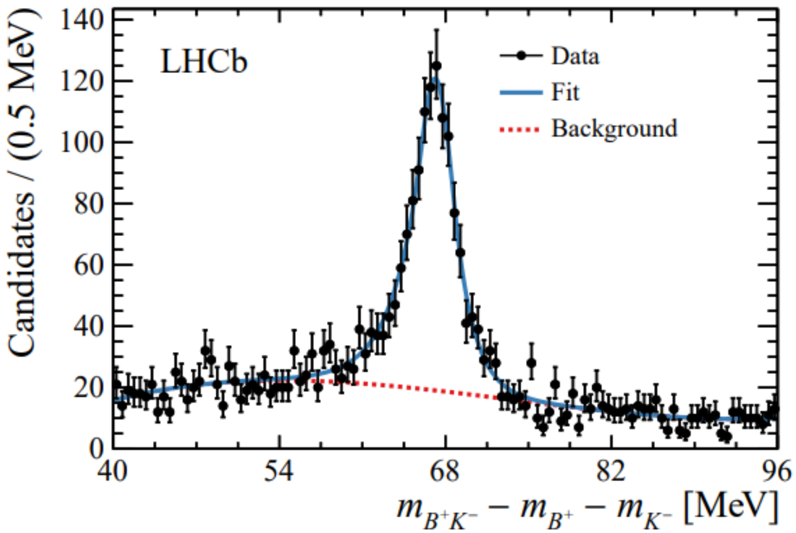
$$\mathcal{B}(K^0_S \to \mu^+\mu^-) < 2.1 \times 10^{-10} \text{ at } 90\% \text{ CL}$$

$B^+ \to K^+\mu^-\tau^+$

LHCb-PAPER-2019-043, JHEP06(2020)129

LHCb Full Run 1 + Run 2 analysis
Using $B^*_{s2} \to B^+K^-$ decays to tag partially-reconstructed B^+ mesons
Normalization using $B^+ \to K^+\mu^-\mu^+$ (with J/ψ)





$$\mathcal{B}(B^+ \to K^+\mu^-\tau^+) < 3.9 \times 10^{-5} \text{ at } 90\% \text{ CL}$$

Weaker than 2012 BaBar upper limit

$$\mathcal{B}(B^+ \to K^+\mu^-\tau^+) < 2.8 \times 10^{-5} \text{ at } 90\%$$

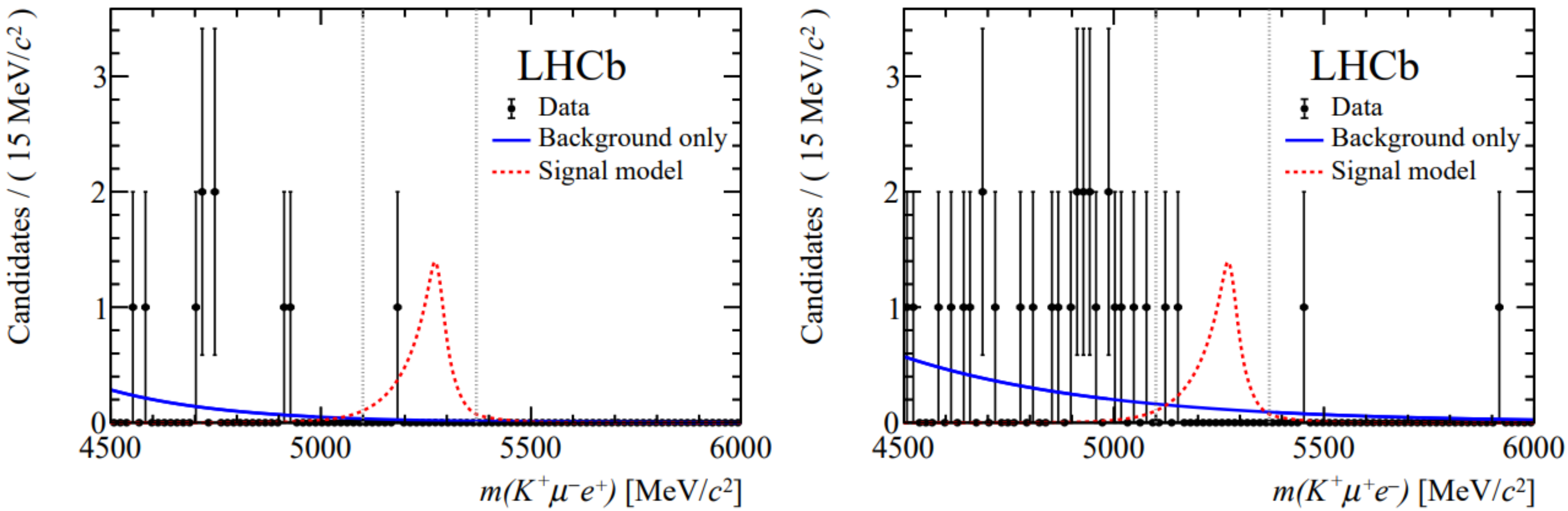
More details in the parallel talk by Liang S. yesterday

$B^+ \to K^+\mu^\mp e^\pm$

[LHCb-PAPER-2019-022](), [Phys.Rev.Lett.123(2019)241802]()

LHCb Run-1 analysis

Normalization using $B^+ \to K^+\mu^-\mu^+$ (with J/ψ)



$$\mathcal{B}(B^+ \to K^+\mu^-e^+) < 7.0\ (9.5) \times 10^{-9}$$

$$\mathcal{B}(B^+ \to K^+\mu^+e^-) < 6.4\ (8.8) \times 10^{-9}$$

World-best limits

More details in the parallel talk by Liang S. yesterday

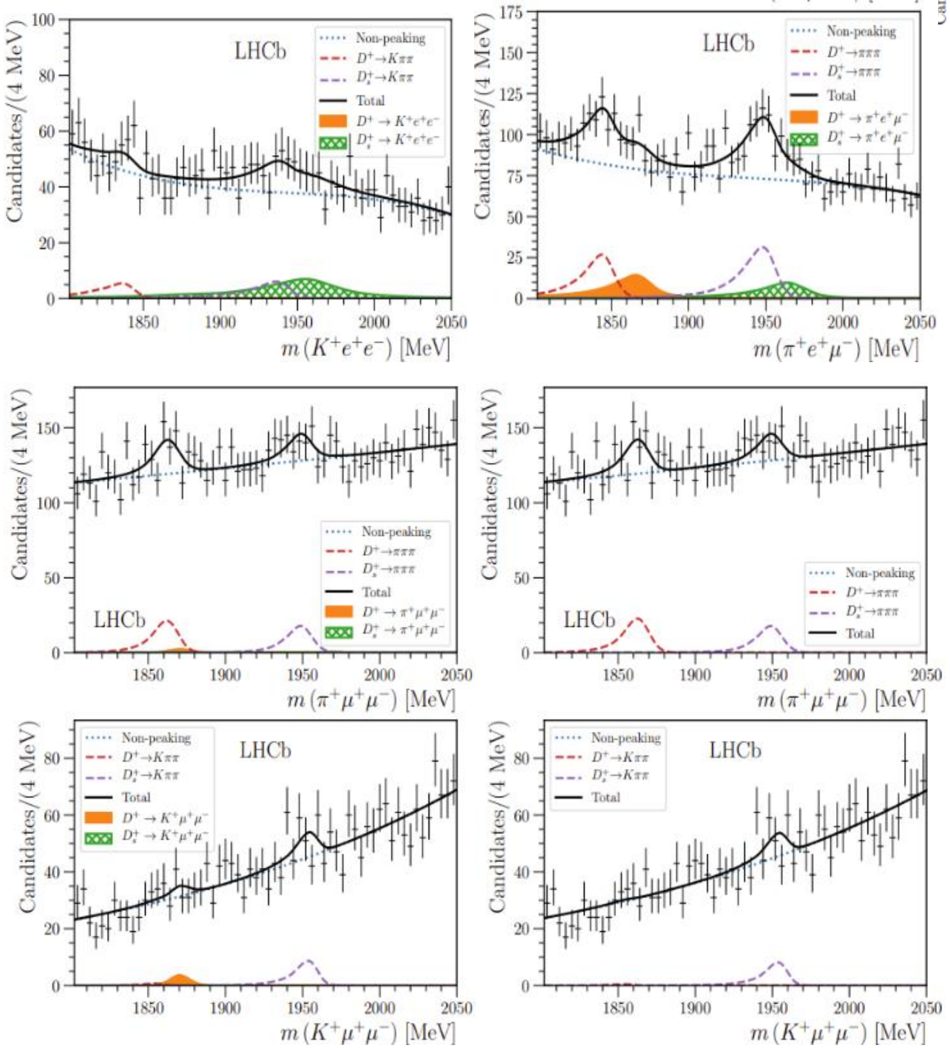
Run-2 analysis ongoing

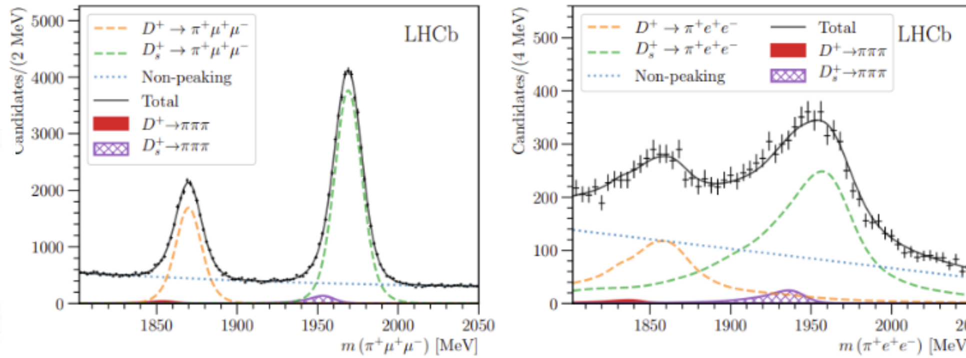
Rare charm decays

LHCb *JHEP* 06 (2021) 044

Searches for 25 rare and forbidden decays of D^+ and D_s^+ mesons

$$\mathcal{B}_{D^+_{(s)}\to h^\pm\ell^+\ell^{(\prime)\mp}} = \frac{N_{D^+_{(s)}\to h^\pm\ell^+\ell^{(\prime)\mp}}}{N_{D^+_{(s)}\to(\phi\to\mu^+\mu^-)\pi^+}} \cdot \frac{\epsilon_{D^+_{(s)}\to(\phi\to\mu^+\mu^-)\pi^+}}{\epsilon_{D^+_{(s)}\to h^\pm\ell^+\ell^{(\prime)\mp}}} \cdot \mathcal{B}_{D^+_{(s)}\to(\phi\to\mu^+\mu^-)\pi^+}$$





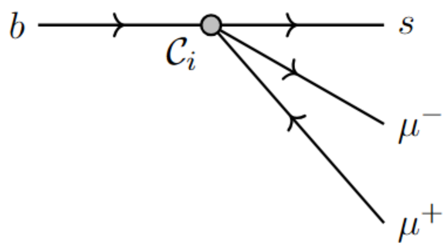
Decay	D^+ SES	D^+ 90 % CL	D^+ 95 % CL	D_s^+ SES	D_s^+ 90 % CL	D_s^+ 95 % CL
$D^+_{(s)}\to\pi^+\mu^+\mu^-$	0.6	67	74	2.4	180	210
$D^+_{(s)}\to\pi^-\mu^+\mu^+$	0.3	14	16	1.8	86	96
$D^+_{(s)}\to K^+\mu^+\mu^-$	1.2	54	61	3.8	140	160
$D^+_{(s)}\to K^-\mu^+\mu^+$	-	-	-	1.2	26	30
$D^+_{(s)}\to\pi^+e^+\mu^-$	0.6	210	230	3.1	1100	1200
$D^+_{(s)}\to\pi^+\mu^+e^-$	0.4	220	220	2.2	940	1100
$D^+_{(s)}\to\pi^-\mu^+e^+$	0.4	130	150	2.0	630	710
$D^+_{(s)}\to K^+e^+\mu^-$	0.7	75	83	3.7	790	880
$D^+_{(s)}\to K^+\mu^+e^-$	0.5	100	110	2.5	560	640
$D^+_{(s)}\to K^-\mu^+e^+$	-	-	-	2.4	260	320
$D^+_{(s)}\to\pi^+e^+e^-$	1.9	1600	1800	8.1	5500	6400
$D^+_{(s)}\to\pi^-e^+e^+$	0.9	530	600	4.1	1400	1600
$D^+_{(s)}\to K^+e^+e^-$	4.4	850	1000	14.8	4900	5500
$D^+_{(s)}\to K^-e^+e^+$	-	-	-	4.1	770	840

Branching fraction upper limit $[10^{-9}]$

EFT for b→sll decays

In general, b→ sll transitions can be described using an EFT approach

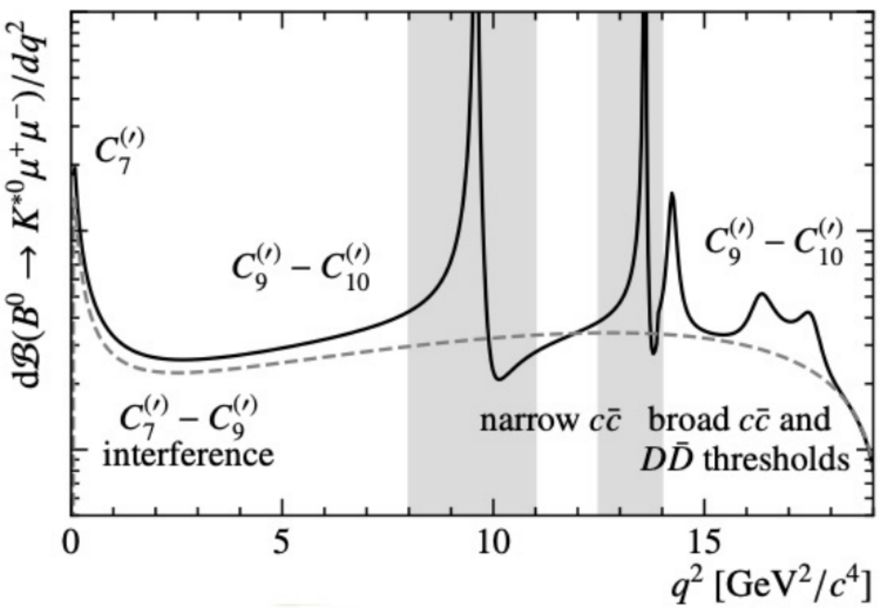
Effective description



$$\mathcal{H}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}} V_{\text{tb}} V_{\text{ts}}^* \frac{e^2}{16\pi^2} \sum_i \mathcal{C}_i \mathcal{O}_i$$

Effective coupling
"Wilson coefficient"
short distance physics

Local operator
long distance physics



NP could modify the Wilson Coefficients, or enable new operators

different dimuon mass (q) ranges sensitive to different operators

NP contribution to C_9 expected to be constant vs q^2 (M. B. talk)