Rare Decays

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on behalf of the ATLAS, CMS, LHCb collaborations

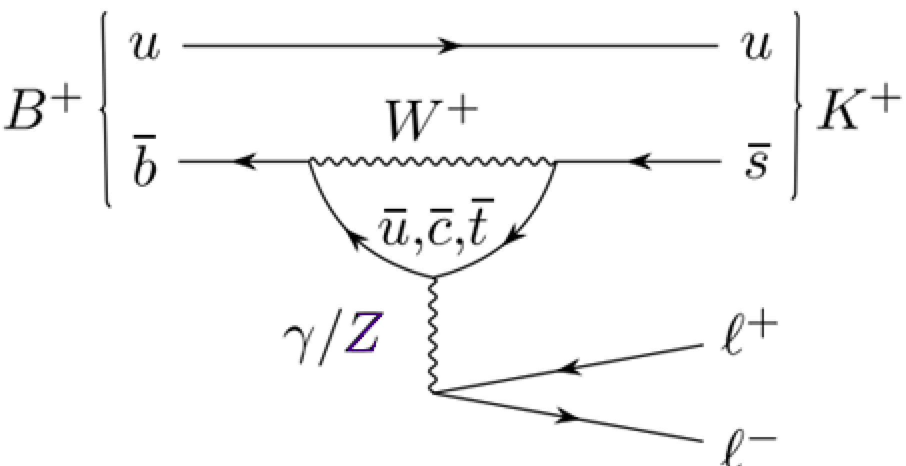
LHCP 2022 (Virtual Taipei) 18 May 2022

Outline

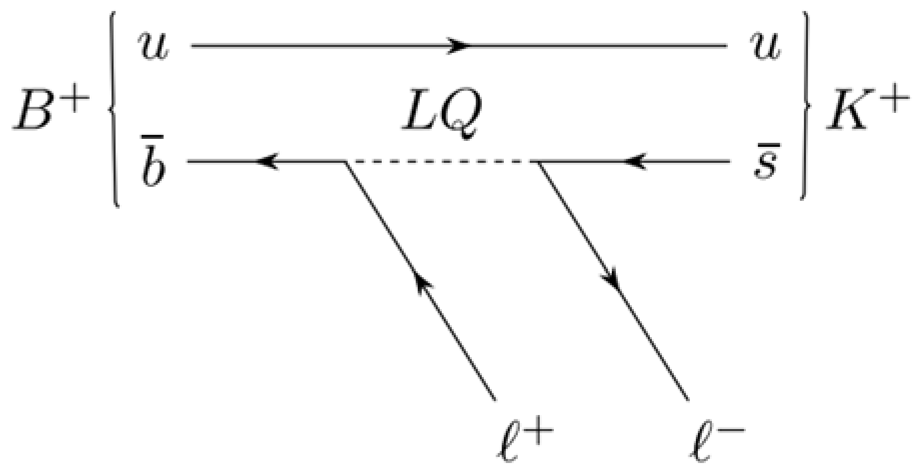
- Introduction, $b \to sll$
- Angular observables in $b \to sll$ transitions
- B meson decays to leptons
- Searches for LFV in heavy-flavor decays

$b \to sll$ 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 multibody decays $B \to h\, l^+ l^-$



SM

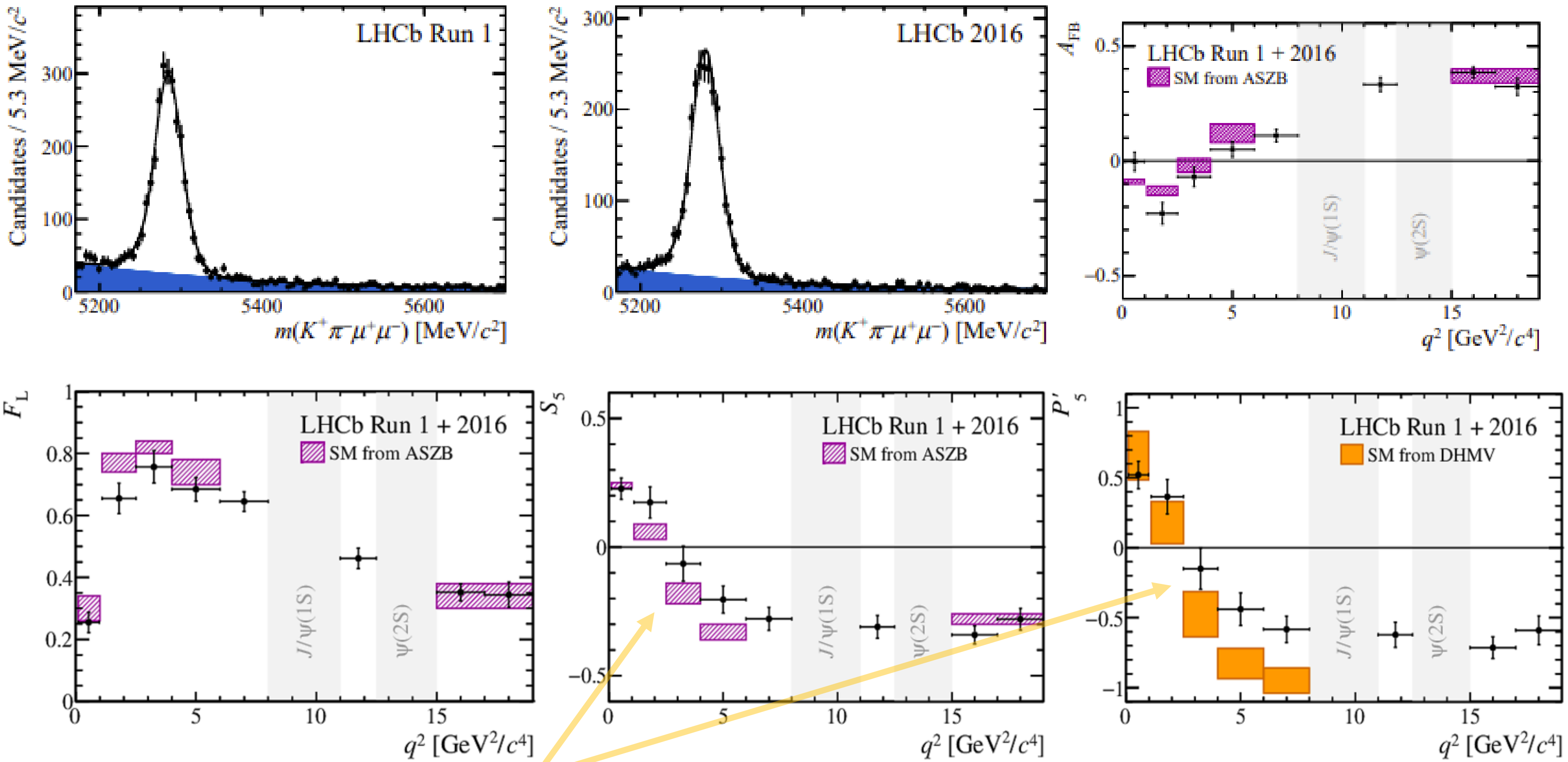


NP example

Angular analyses of *b→sll* transitions

- Many recent results measuring angular parameters and differential branching fractions

$B^0 \to K^{*0}\mu^+\mu^-$, Run-1+2016, ~4500 signal LHCb-PAPER-2020-002, Phys.Rev.Lett.125(2020)011802



ATLAS and CMS Run-1 results in backup

~3σ tension at low q^2 !

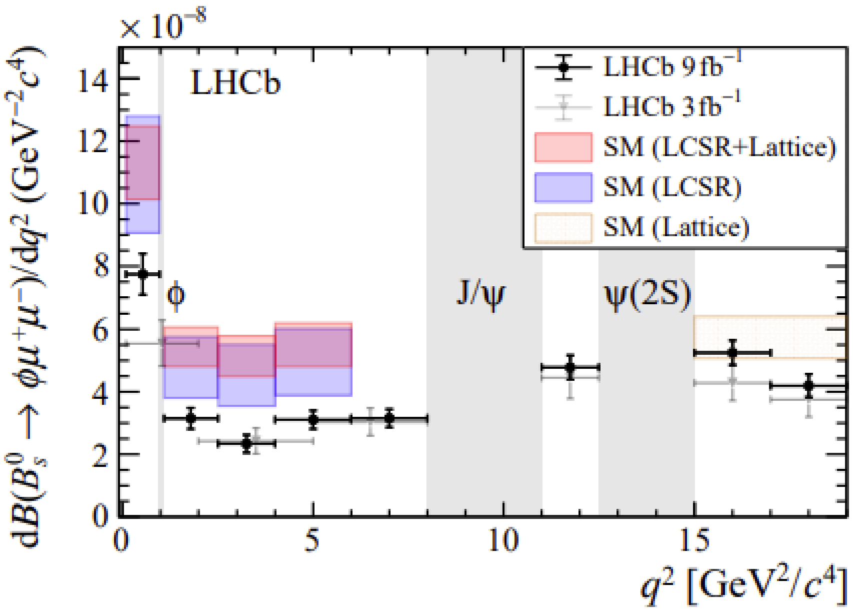
CMS Run-2 analysis in development

Angular analyses of $b \to sll$ transitions

BF measurement of $\mathbf{B_s^0 \to \phi\mu^+\mu^-}$ and $\mathbf{B_s^0 \to f_2'(1525)\mu^+\mu^-}$

LHCb Run-1 + Run-2

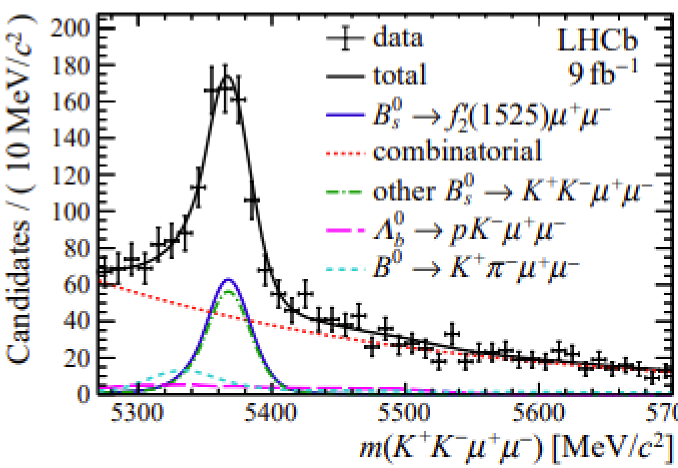
LHCb-PAPER-2021-014, Phys.Rev.Lett.127(2021)151801

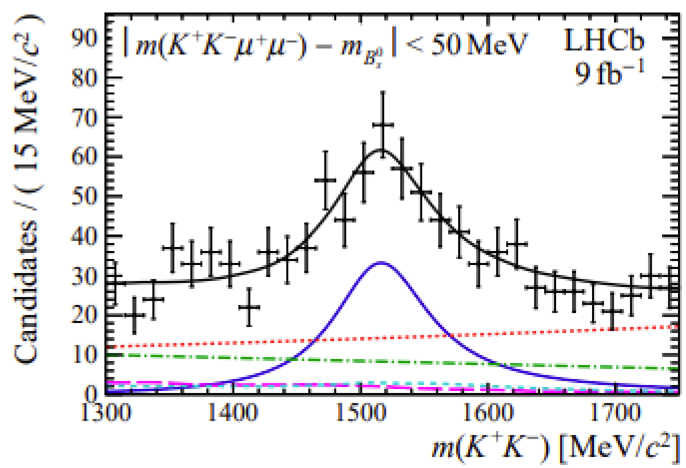


~3.6σ tension w.r.t. SM at low q^2

More details in the parallel talk by Samar N. yesterday

$$\mathcal{B}(B_s^0 \to f_2'\mu^+\mu^-) = (1.57 \pm 0.19 \pm 0.06 \pm 0.06 \pm 0.08) \times 10^{-7}$$





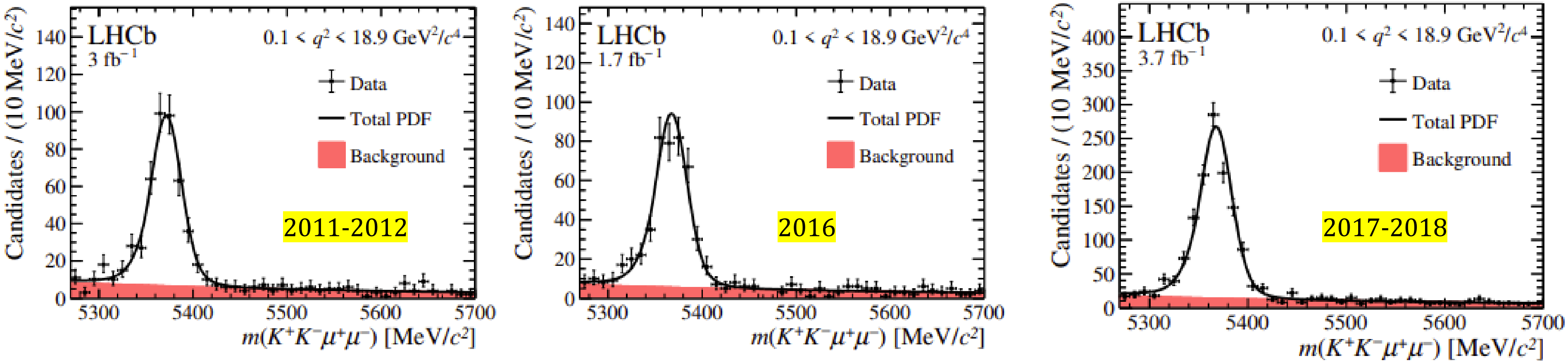
First observation!

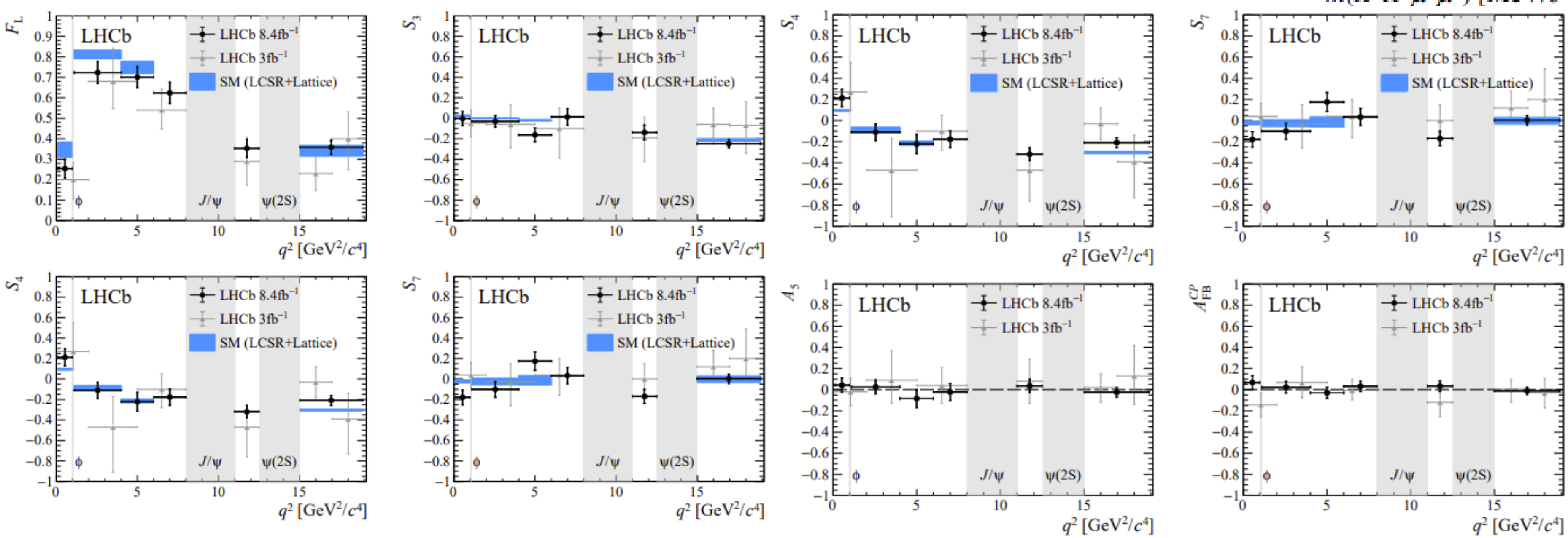
BF compatible with SM

Angular analyses of *b→sll* transitions

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

More details in the parallel talk by Samar N. yesterday





Compatible with SM

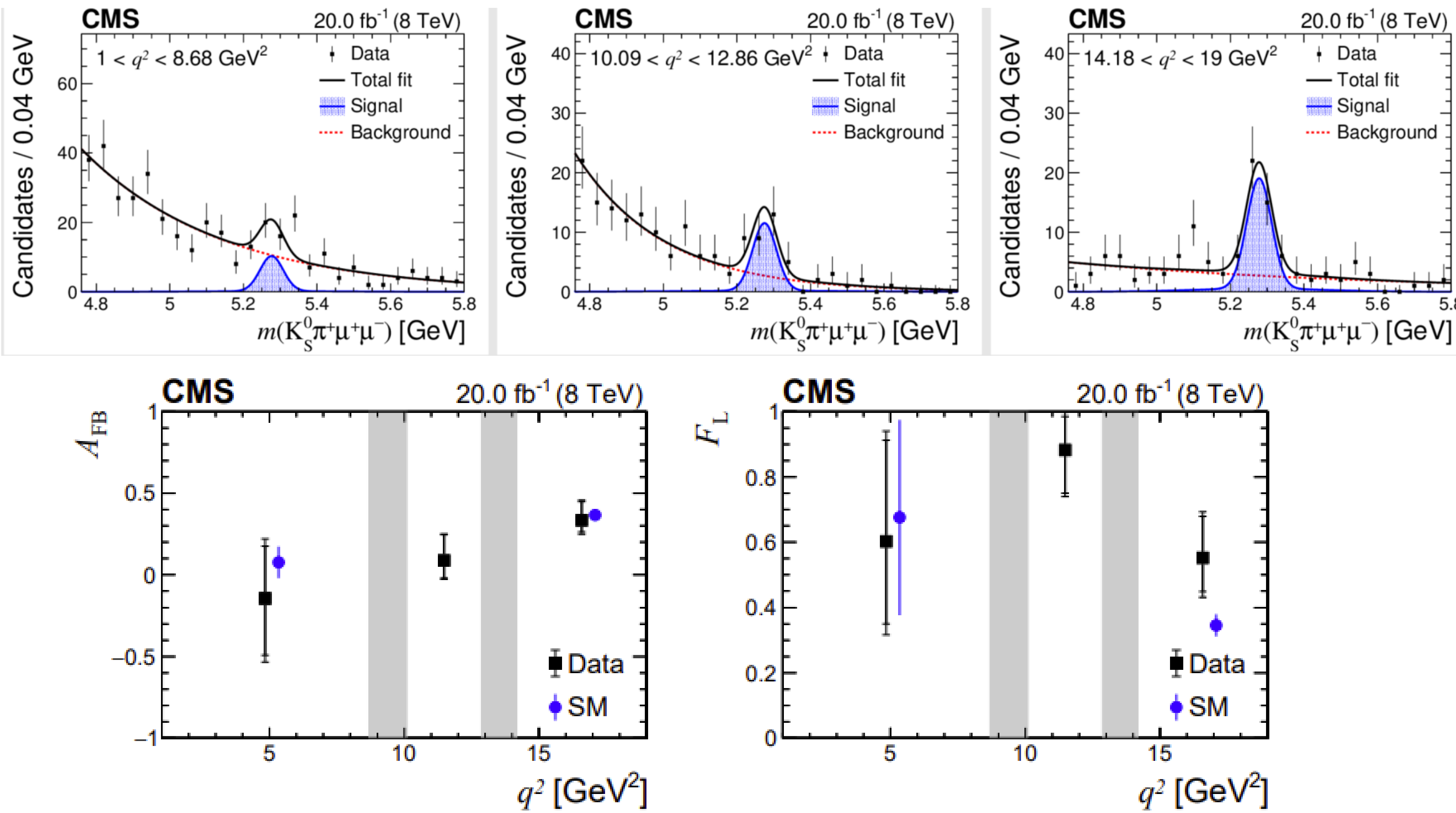
LHCb-PAPER-2021-022, JHEP11(2021)043

CMS Run-2 analysis in development

Angular analyses of $b \to sll$ 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

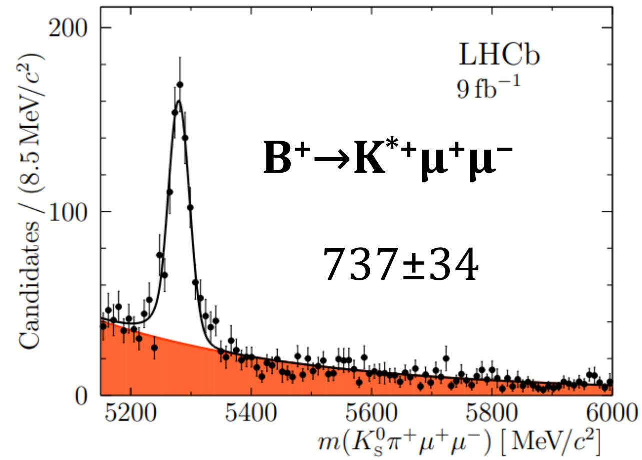


More details in the parallel talk by Samar N. yesterday

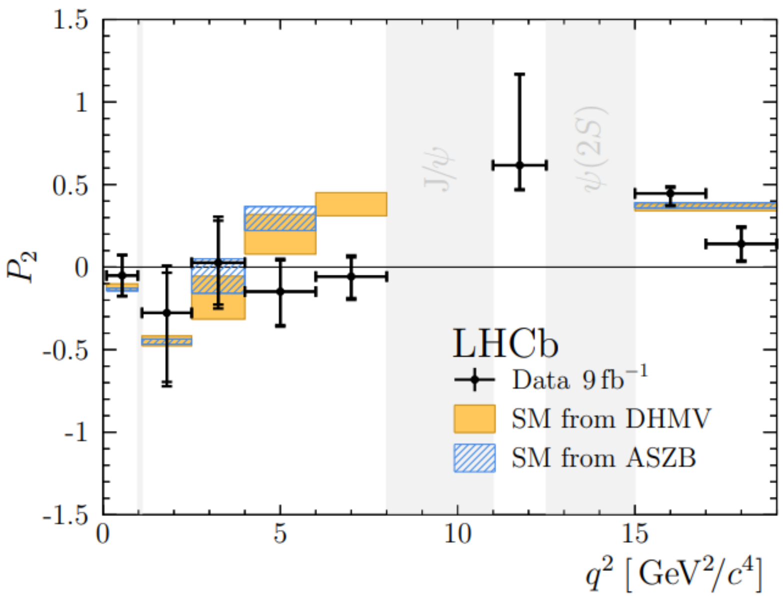
Compatible with SM

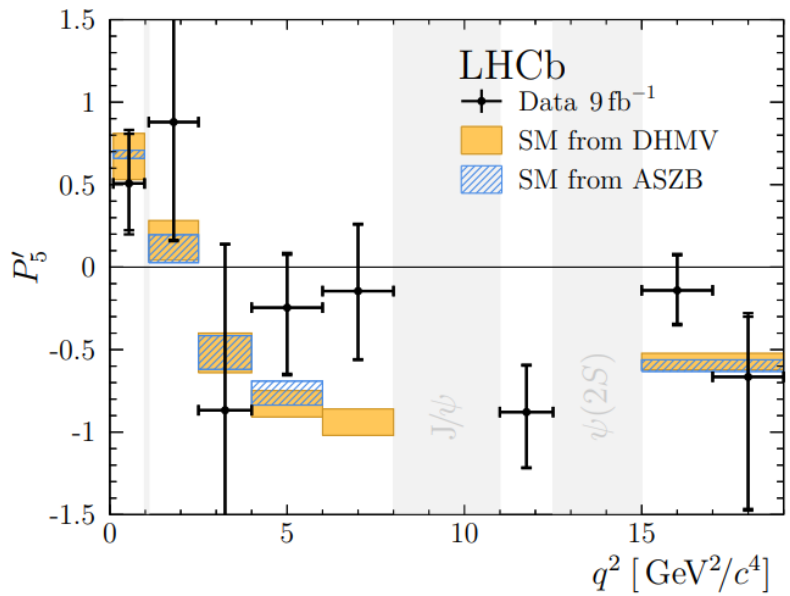
Angular analyses of $b \to sll$ transitions

$B^+ \to K^{*+}\mu^+\mu^-$, ($K^{*+} \to K^0_S \pi^+$) 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 !

More details in the parallel talk by Samar N. yesterday

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

B→μμ

- The branching fractions of B^0 and $B_s^0 \to \mu^+\mu^-$ are predicted precisely in the SM and are very low

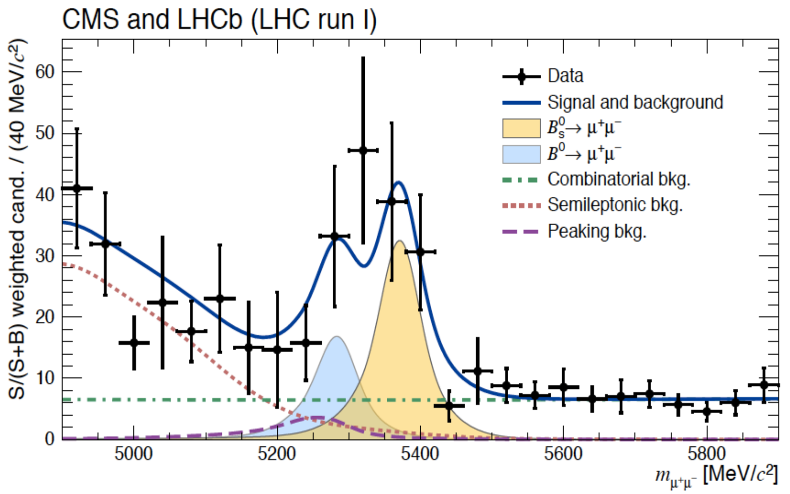
$$B(B_s^0 \to \mu^+\mu^-) = (3.66 \pm 0.14) \times 10^{-9}$$

$$B(B^0 \to \mu^+\mu^-) = (1.03 \pm 0.05) \times 10^{-10}$$

[Beneke, Bobeth, Szafron, JHEP10(2019) 232]

- The decays also present "clean" experimental signature
- Any deviations from SM would present a sign of NP

- Decay $B_s^0 \to \mu^+\mu^-$ was observed with 5σ significance from a combined analysis of LHC Run-1 CMS and LHCb data in 2014



Nature 522 (2015) 68-72

B→μμ

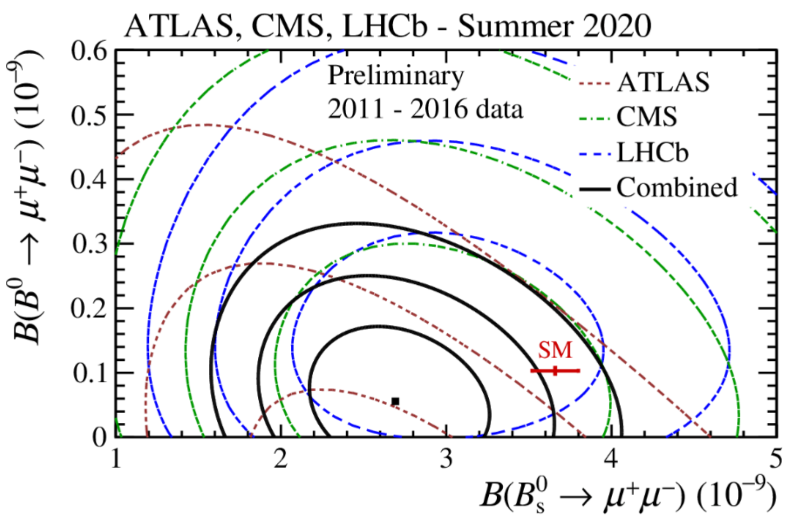
- Later the ATLAS, CMS, LHCb, have published their independent results from a larger data set:
  - ATLAS, 2015+2016 data, combined with Run-1, December 2018
  - CMS, Run-1 + 2016 data, October 2019
  - LHCb, Run-1 + 2016 data, March 2017

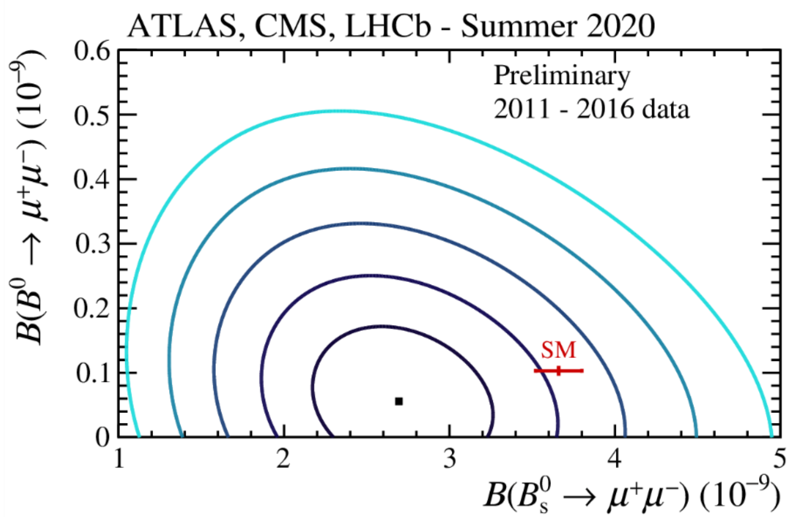
More details in the parallel talk by Samar N. yesterday

- Statistical Combination CMS+ATLAS+LHCb was performed in 2020 *(not published)*

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (2.69\,^{+0.37}_{-0.35}) \times 10^{-9}$$

CMS-PAS-BPH-20-003
ATLAS-CONF-2020-049
LHCb-CONF-2020-002

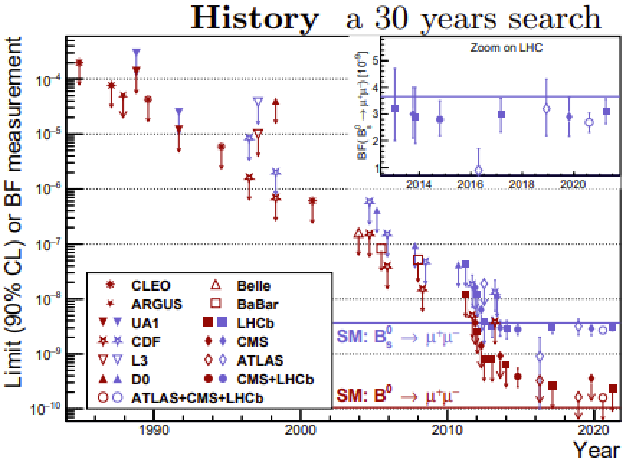




Compatible with SM within 2.1σ

B→μμ

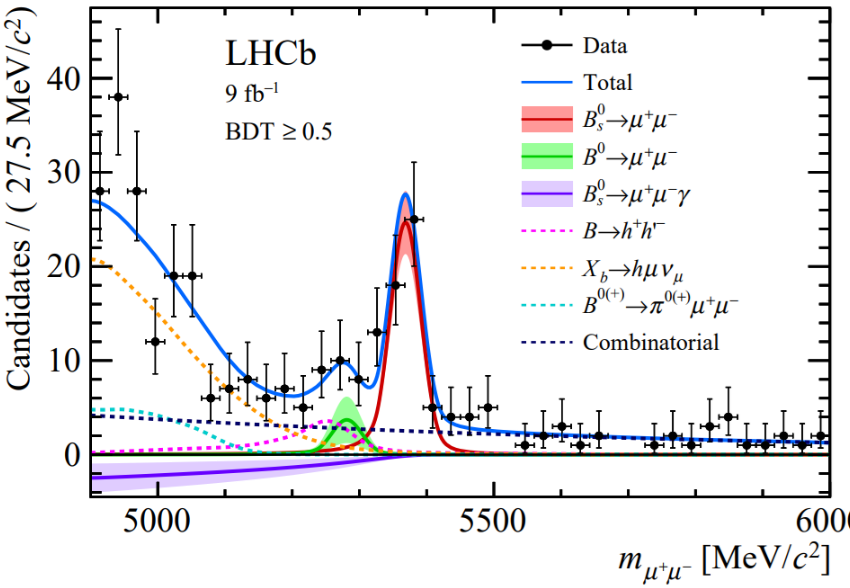
➢ The latest results on 30-year-long search are from LHCb, August 2021 Full Run-1 + Run-2

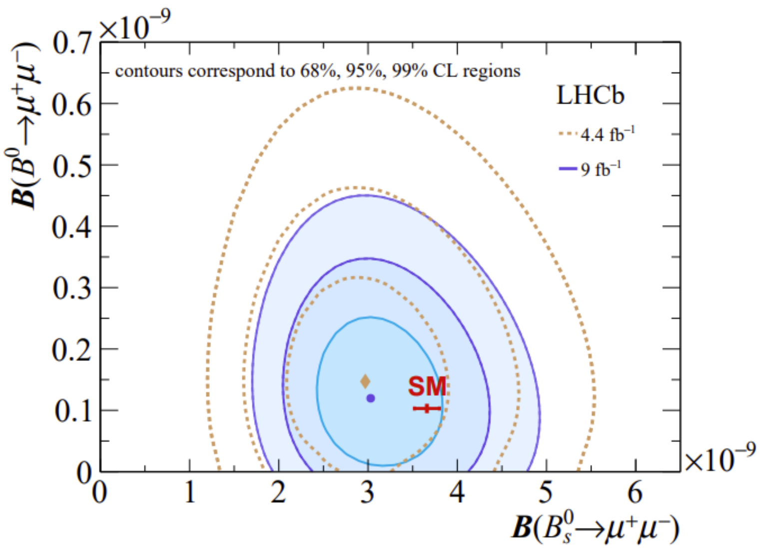


- B_s^0 >10σ, B^0 ~1.7σ

Consistent with SM

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \left(3.09\,^{+0.46}_{-0.43}\,^{+0.15}_{-0.11}\right) \times 10^{-9},$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-) = \left(1.20\,^{+0.83}_{-0.74} \pm 0.14\right) \times 10^{-10},$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 2.6 \times 10^{-10} \text{ at 95\% CL}$$





LHCb-PAPER-2021-008, Phys.Rev.D105(2022)012010
LHCb-PAPER-2021-007, Phys.Rev.Lett.128(2022)041801

Papers also reports effective lifetime and $B_s^0 \to \mu^+\mu^-\gamma$

More details in the parallel talk by Christina A. yesterday

CMS Run-2 analysis in advanced state

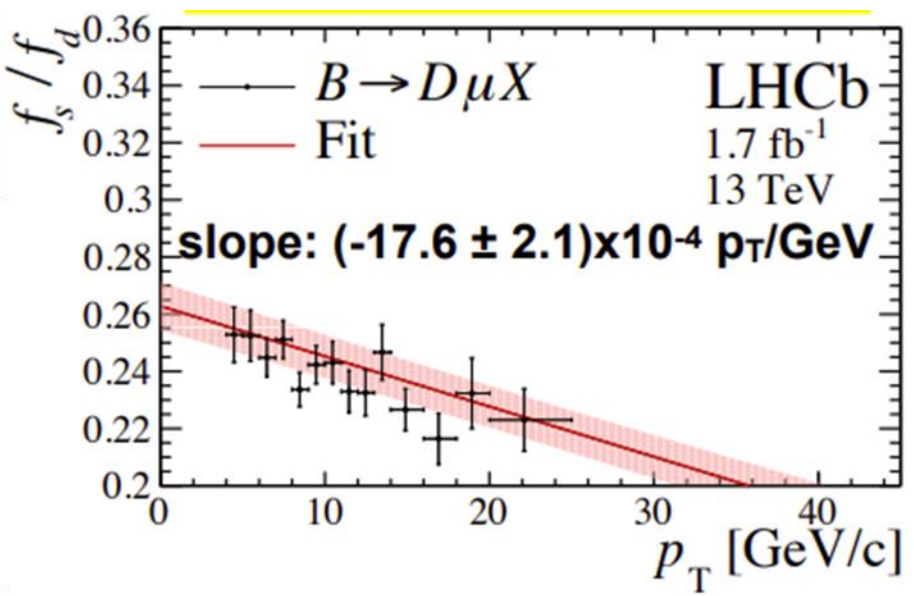
On f_s/f_u and normalization

- LHCb, CMS, ATLAS normalize B^0_s using the $B^+ \rightarrow J/\psi\, K^+$ decay;
  - LHCb in addition uses $B^0 \rightarrow K^+\pi^-$, with low relative weight
- This makes $\boldsymbol{f_s/f_u}$, ratio of B^0_s and B^+ production, a **crucial ingredient**
- The current 13 TeV LHCb best value is 0.254 ± 0.008 [assuming f_u=f_d]

- In CMS, the uncertainty is increased to cover √s and kinematic region dependence
  - CMS uses 0.015 additional uncertainty, arriving at f_s/f_u = 0.252 ± 0.019

- This 8% of additional uncertainty is one of the leading uncertainties

LHCb-PAPER-2020-046, Phys.Rev.D.104(2021)032005



On f_s/f_u and normalization

- Other possibility is to normalize using the $B_s^0 \to J/\psi\ \varphi$ decay

- Current PDG uncertainty is dominated by LHCb measurement, which is done via $B^+ \to J/\psi\ K^+$ and f_s/f_u, i.e., completely correlated with f_s/f_u

- Belle measurement of $\mathbf{B}(B_s^0 \to J/\psi\ \varphi)$ has ~20% uncertainty

- No B_s^0 decay is measured with a precision of better than 10%
  - Often, the **B** is normalized using f_s/f_d or f_s/f_u

- **The "desired" solution to get out of this vicious circle would be Belle II running on Y(5S) resonance and precisely measuring absolute B_s^0 branching fractions ☺**

- **With Run-3 data, this normalization channel issue will probably be the leading uncertainty in B($B_s^0 \to \mu\mu$) for CMS & ATLAS, larger than statistical one!**

B→ee, B→ττ

- Similar, from theoretical point of view, rare decays, predicted B are lower (higher) for e (τ) than for μ:

$$\mathcal{B}(B_s^0 \to e^+e^-) = (8.60 \pm 0.36) \times 10^{-14}$$
$$\mathcal{B}(B^0 \to e^+e^-) = (2.41 \pm 0.13) \times 10^{-15}$$
$$\mathcal{B}(B_s^0 \to \tau^+\tau^-) = (7.73 \pm 0.49) \times 10^{-7}$$
$$\mathcal{B}(B^0 \to \tau^+\tau^-) = (2.22 \pm 0.19) \times 10^{-8}$$

- However, significantly more challenging experimentally
  - *Electrons produce bremsstrahlung radiation in magnetic field, resulting in reduced precision (wide peak)*
  - *Taus quickly decay with 1 or two missing neutrinos per one τ lepton, many decay modes, large backgrounds, very broad peak in m(ττ)*

- With LFU, different NP effects can affect ee, μμ, and ττ modes differently → important to search/study all 3 decay modes!

B→ee, B→ττ

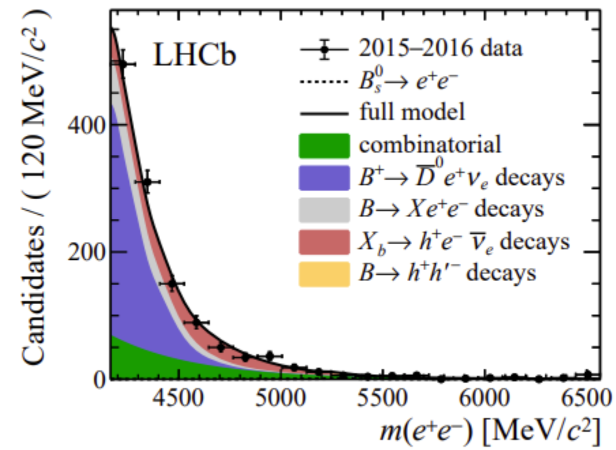
LHCb has performed searches for ee and ττ decays

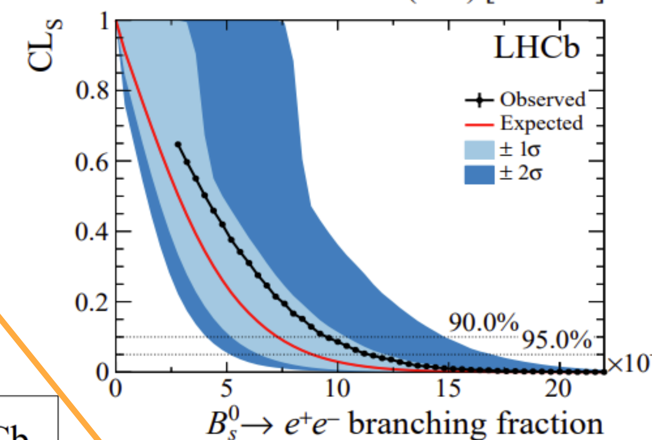
ee: *Run-1+2015+2016*

$$\mathcal{B}(B_s^0 \to e^+e^-) < 9.4\,(11.2) \times 10^{-9}$$
$$\mathcal{B}(B^0 \to e^+e^-) < 2.5\,(3.0) \times 10^{-9}$$
at 90 (95) % CL

normalized to $B^+ \to J/\psi(ee)\,K^+$

LHCb-PAPER-2020-001, Phys.Rev.Lett.124(2020)211802

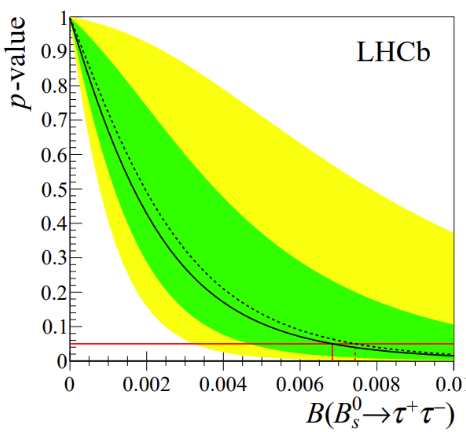


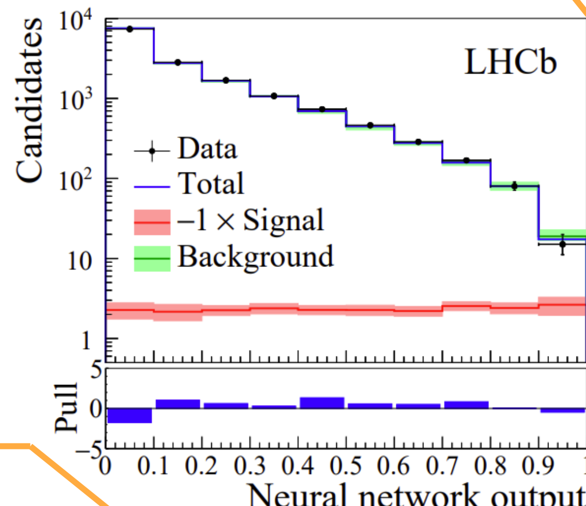


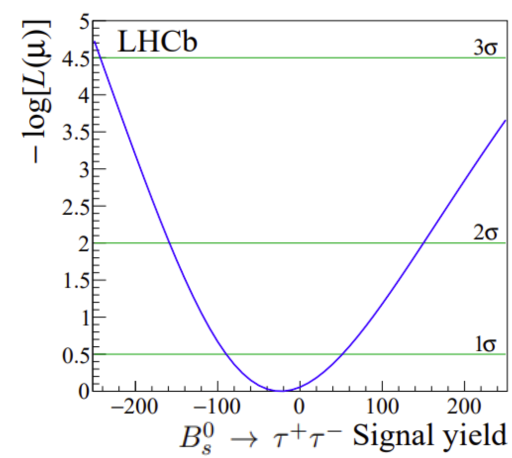
ττ: *Run-1 analysis,* normalized to $B \to DD_s$

$$\mathcal{B}(B_s^0 \to \tau^+\tau^-) < 6.8 \times 10^{-3} \text{ at } 95\% \text{ CL}$$
$$\mathcal{B}(B^0 \to \tau^+\tau^-) < 1.6\,(2.1) \times 10^{-3} \text{ at } 90\,(95)\% \text{ CL}$$

LHCb-PAPER-2017-003, Phys.Rev.Lett.118(2017)251802



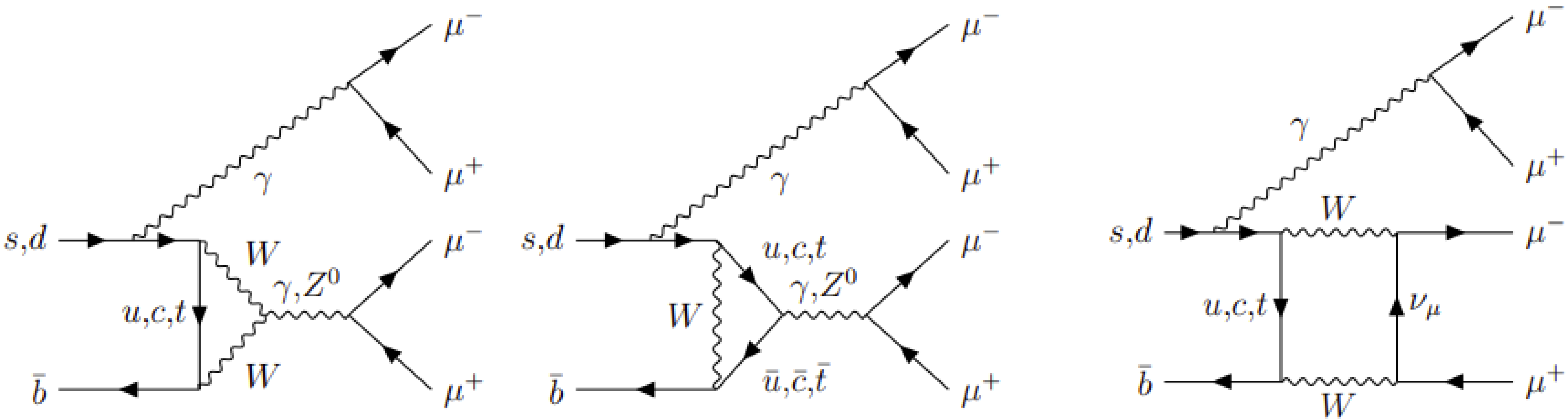




Upper limits many orders of magnitude larger than SM predictions

B→ μμμμ

- If no intermediate resonance, FCNC transitions:



- Very rare in SM:

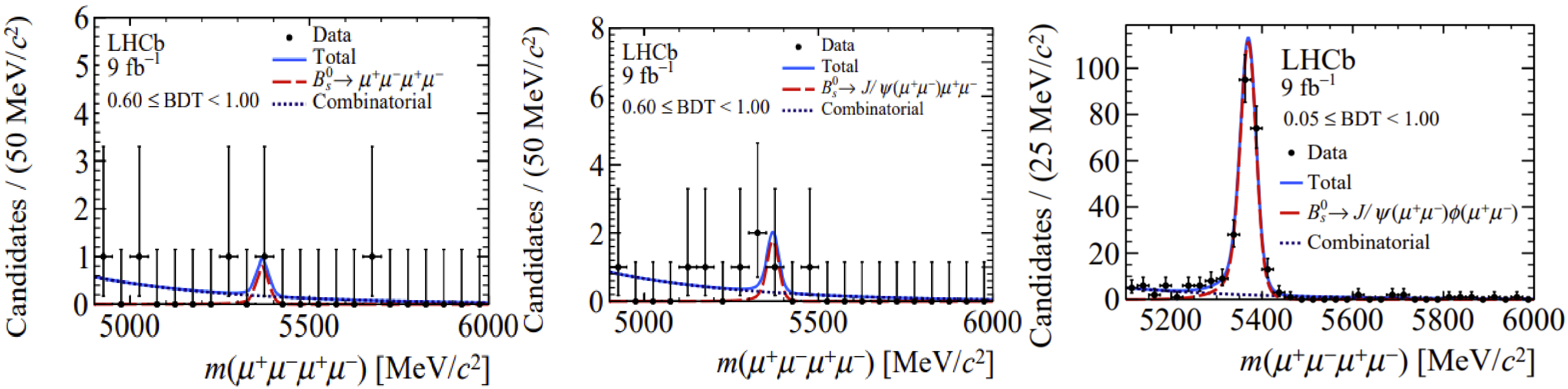
$$\mathcal{B}\left(B_s^0 \to \mu^+\mu^-\mu^+\mu^-\right) = (0.9 - 1.0) \times 10^{-10}$$
$$\mathcal{B}\left(B^0 \to \mu^+\mu^-\mu^+\mu^-\right) = (0.4 - 4.0) \times 10^{-12}$$

- Some SM extensions involve intermediate scalar
  B→aa→4μ with m(a)~1GeV

B→ μμμμ

- Recent LHCb search uses Full Run1+Run-2 data
- Using $B_s^0 \to J/\psi\varphi \to 4\mu$ for the normalization
- Search also performed for $B^0_{(s)} \to J/\psi\mu\mu$ decays

LHCb-PAPER-2021-039, JHEP03(2022)109



Upper limits (with excluded known resonance regions) are most stringent to date

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-\mu^+\mu^-) < 8.6 \times 10^{-10},$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-\mu^+\mu^-) < 1.8 \times 10^{-10},$$
$$\mathcal{B}(B_s^0 \to a(\mu^+\mu^-)\, a(\mu^+\mu^-)) < 5.8 \times 10^{-10},$$
$$\mathcal{B}(B^0 \to a(\mu^+\mu^-)\, a(\mu^+\mu^-)) < 2.3 \times 10^{-10},$$
$$\mathcal{B}(B_s^0 \to J/\psi(\mu^+\mu^-)\, \mu^+\mu^-) < 2.6 \times 10^{-9},$$
$$\mathcal{B}(B^0 \to J/\psi(\mu^+\mu^-)\, \mu^+\mu^-) < 1.0 \times 10^{-9}.$$

m(a)=1GeV, promptly decays

More details in the parallel talk by Christina A. yesterday

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

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 $\mathcal{O}(10^{-10})$

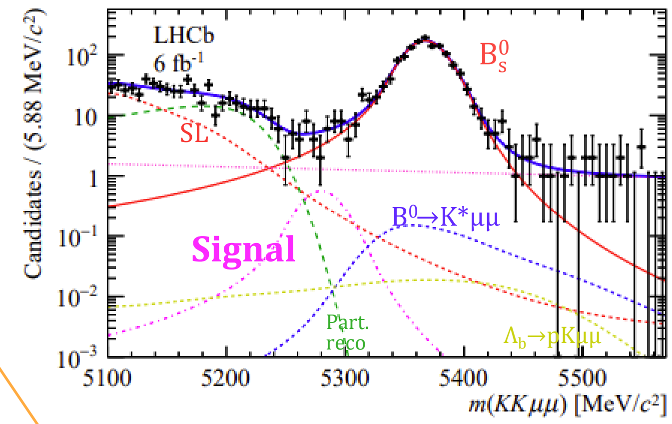
Run 1 + 2 data

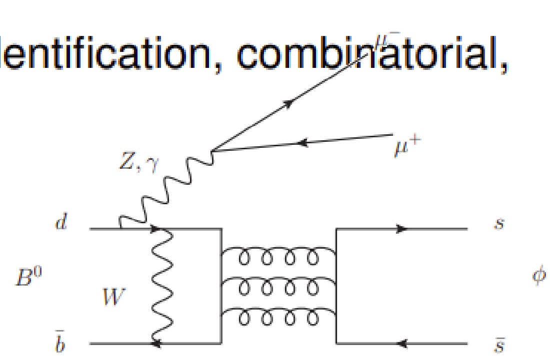
Exclude regions in q^2 corresponding to ϕ, J/ψ and $\psi(2S)$

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

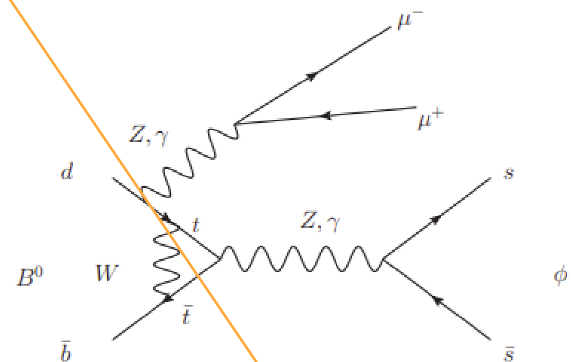
$B_s^0 \to J/\psi\phi$ used to develop a MVA discriminator

Dominant backgrounds: misidentification, combinatorial, semileptonic



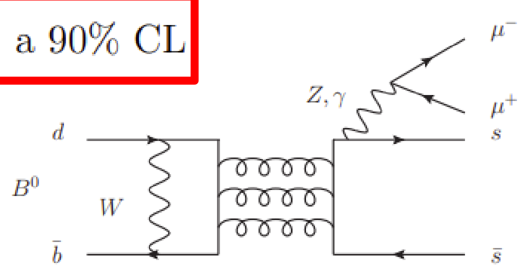


(a)

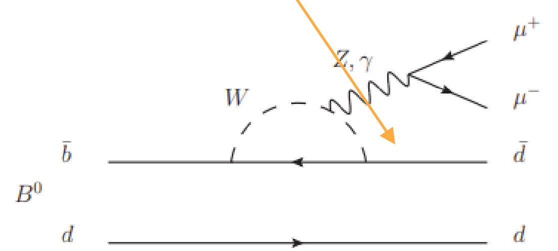


(b)

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



(c)



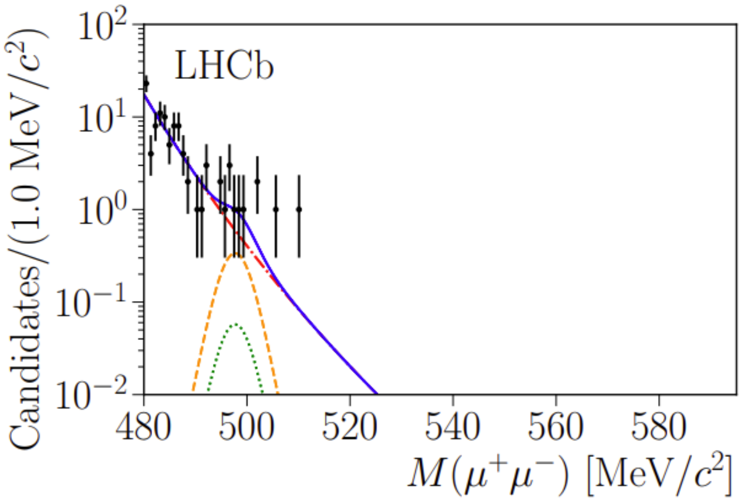
(d)

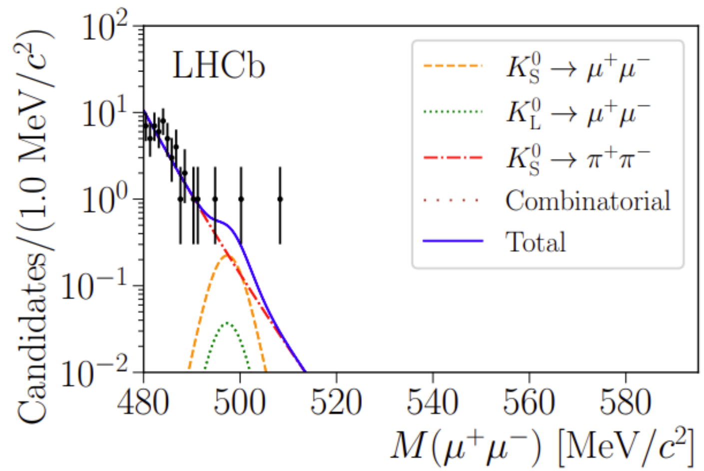
More details in the parallel talk by Christina A. yesterday

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

- 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:

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

LFV searches

- Lepton Flavor is conserved in SM to a very good precision

- Observation of LFV process at a rate above SM prediction would immediately point to New Physics contribution

$\tau \to \mu\mu\mu$

At LHC, two main channels for this search (depending on τ leptons' source):

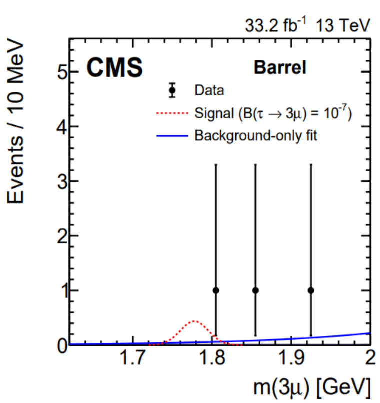
- Heavy Flavor: abundant (especially from D_s^+) but challenging because of very low p_T, forward muons
- $W \to \boldsymbol{\tau}\nu$: $\sim 10^4$ time less yield, but very clear signature

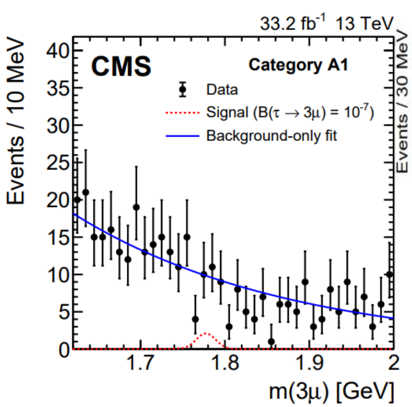
Results from search @LHC: **No evidence** found

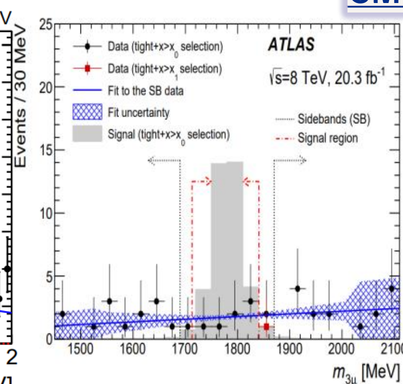
- **LHCb**: **HF** channel, $\mathcal{L} = 3\ fb^{-1}$ — $\mathcal{B}(\tau \to 3\mu) < 4.6 \cdot 10^{-8}$ at **95% C.L.**
- **ATLAS**: **W** channel, $\mathcal{L} = 20\ fb^{-1}$ — $\mathcal{B}(\tau \to 3\mu) < 3.8 \cdot 10^{-7}$ at **95% C.L.**
- **CMS**: Both **HF and W** channels, $\mathcal{L} = 33\ fb^{-1}$ — $\mathcal{B}(\tau \to 3\mu) < 8.0 \cdot 10^{-8}$ at **95% C.L.**

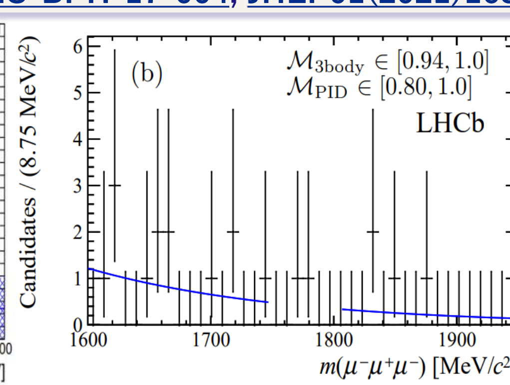
Best UL set by the **Belle** experiment: $\mathcal{B}(\tau \to 3\mu) < 2.1 \cdot 10^{-8}$ at **95% C.L.**

LHCb-PAPER-2014-052, JHEP02(2015)121
ATLAS-EXOT-2014-14, Eur.Phys.J.C76(2016)5,232
CMS-BPH-17-004, JHEP01(2021)163









CMS Run-2 analysis in development

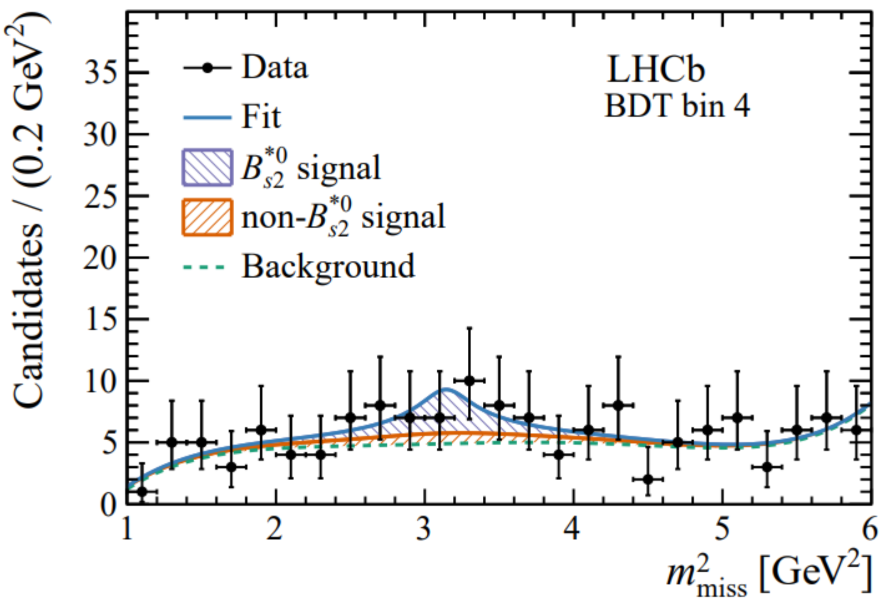
$B^+ \to K^+\mu^-\tau^+$

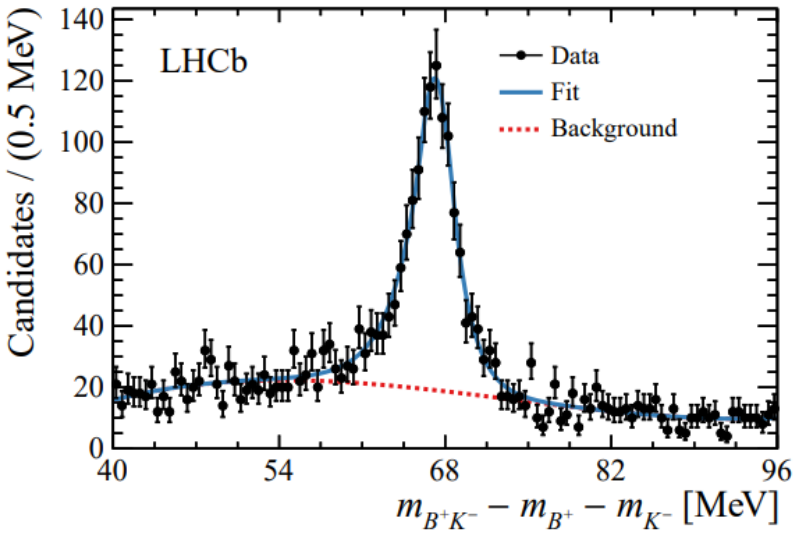
LHCb-PAPER-2019-043, JHEP06(2020)129

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

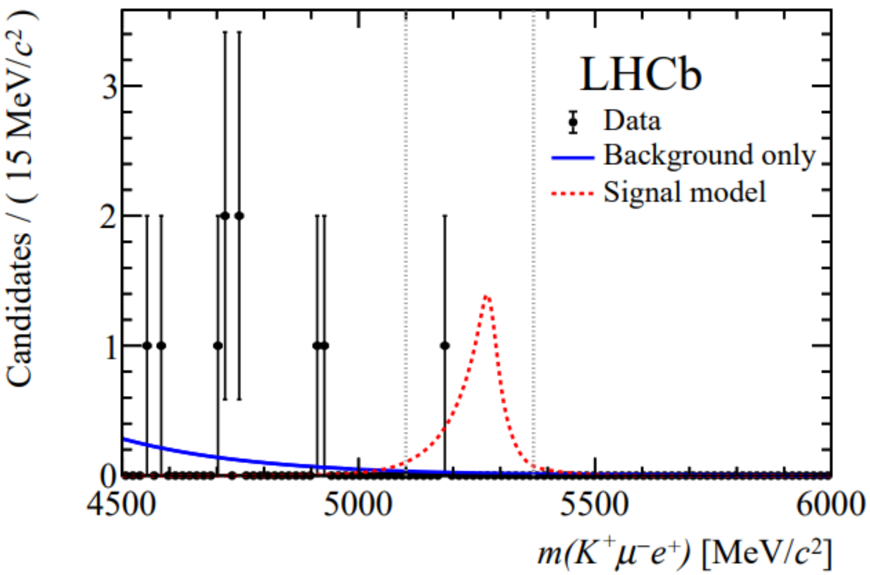
$$\mathcal{B}(B^+ \to K^+\mu^-\tau^+) < 2.8 \times 10^{-5} \text{ at } 90\%$$

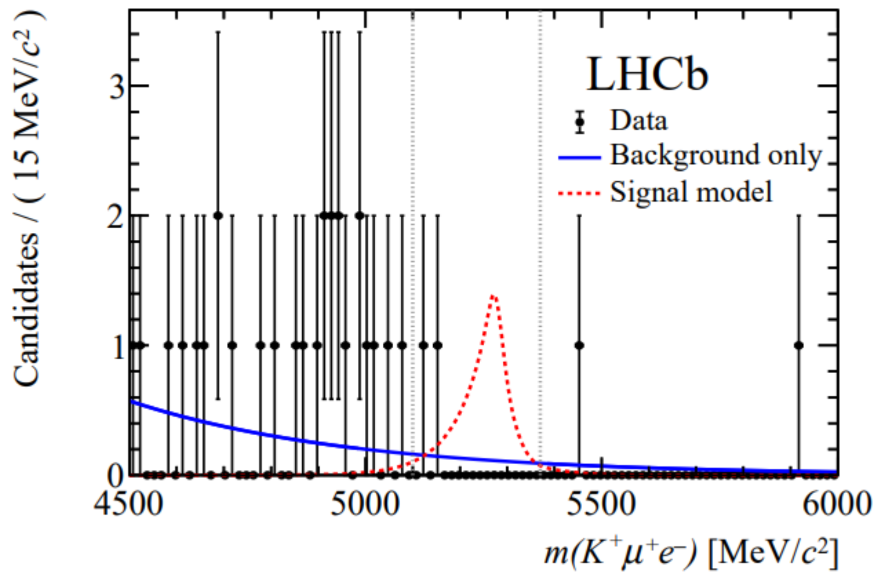
More details in the parallel talk by Liang S. yesterday

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

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

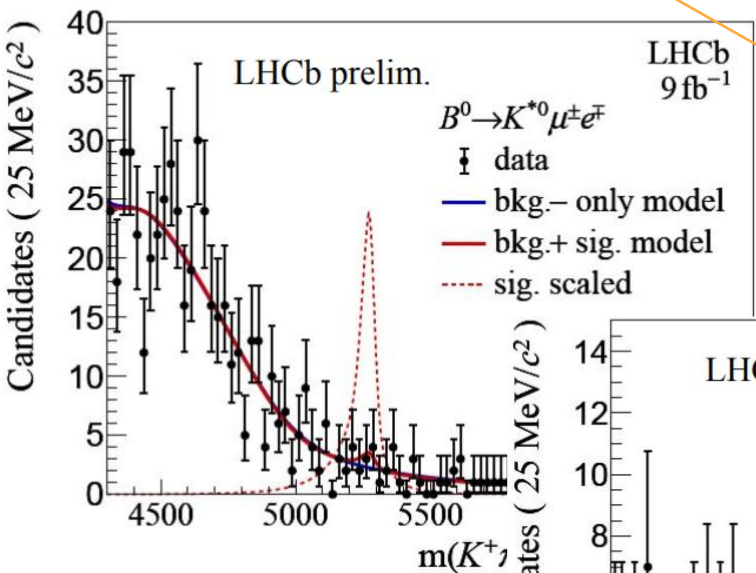
More details in the parallel talk by Liang S. yesterday

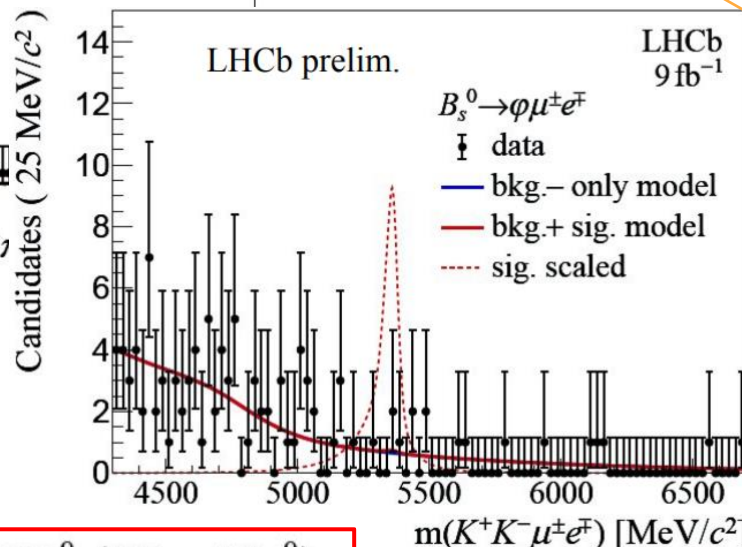
Run-2 analysis ongoing

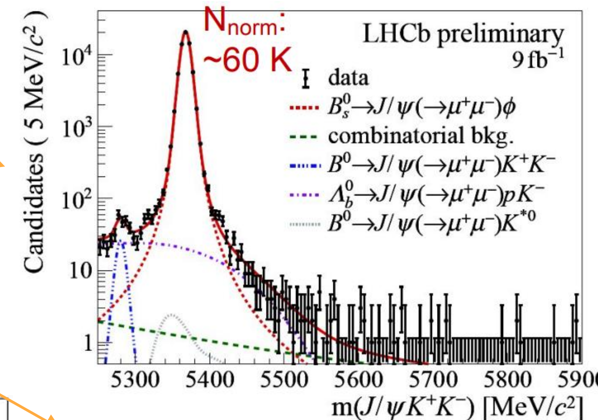
$B^0 \to K^{*0}\mu^{\mp}e^{\pm}$ and $B_s^0 \to \varphi\mu^{\mp}e^{\pm}$

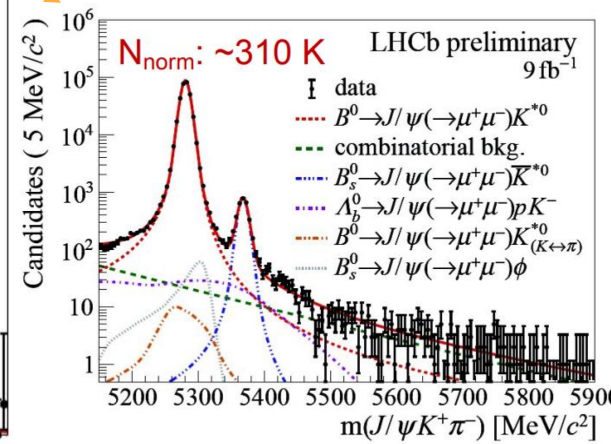
LHCP-PAPER-2022-008, in preparation. Full Run-1 + Run-2 analysis

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

More details in the parallel talk by Liang S. yesterday

Summary

- NP can show itself as modified **B**, as well as modified decay dynamics
- Many new results on rare $b \to sll$ decays are obtained in the last few years
  - And many more are coming!
- Some **~3-4σ tensions** w.r.t. SM are observed in B meson decays
  - in parameters of angular distributions and differential **B**
- B→μμ is reaching 10-15% precision (consistent with SM)
  - Limited by f_s/f_u for CMS and ATLAS
- Many LFV processes in heavy-flavor are searched for
  - no significant signals are observed

With more than 3 years from the end of LHC Run-2,
the rate of new results is still high!

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/BPhysPublicResults
http://cms-results.web.cern.ch/cms-results/public-results/publications/BPH/
https://lhcbproject.web.cern.ch/lhcbproject/Publications/LHCbProjectPublic/Summary_RD.html

Run-3 will bring additional sensitivity with improved triggering techniques!

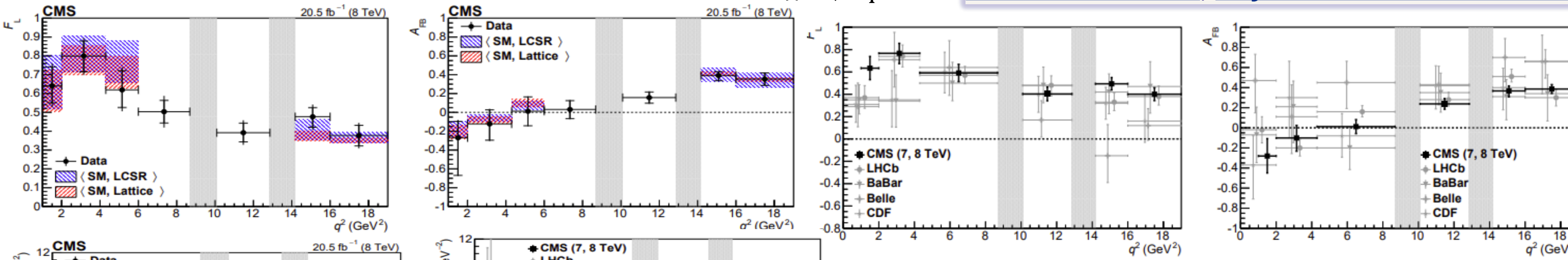
Thank you !

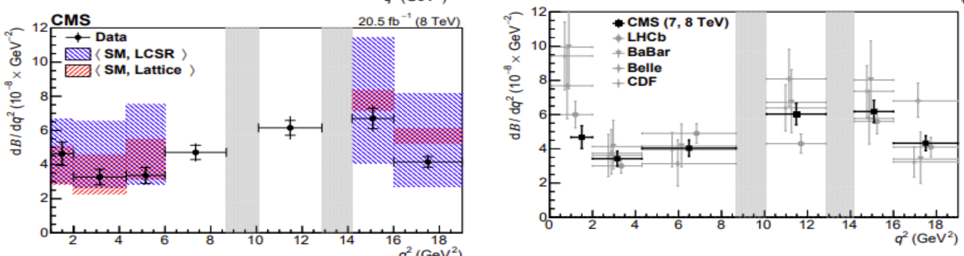
BACKUP

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

~1450 signal, $7q^2$ bins

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



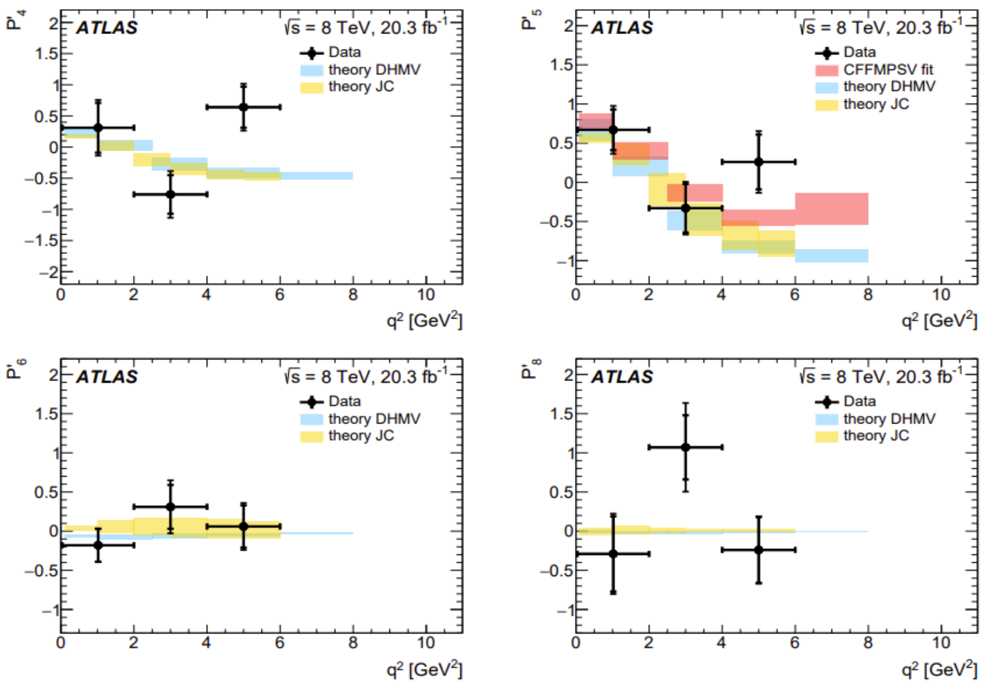


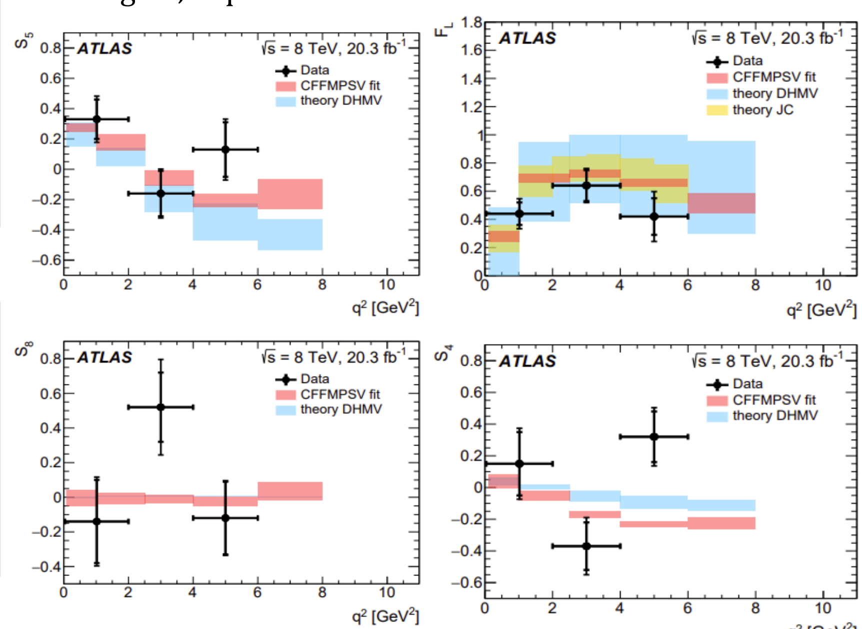
Consistent with SM

More details in the parallel talk by Samar N. yesterday

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

~350 signal, $3\ q^2$ bins



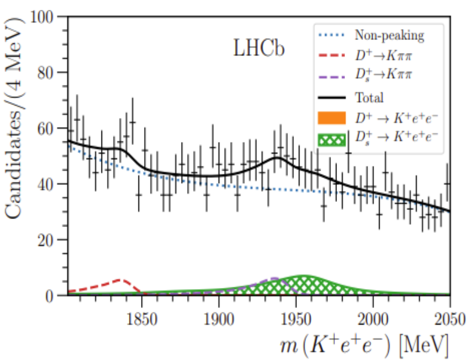


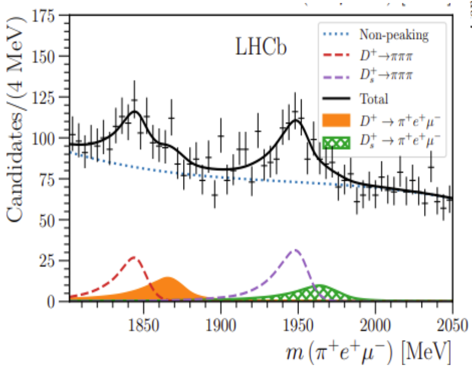
Rare charm decays

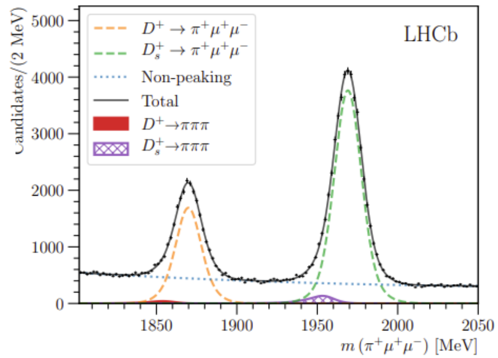
LHCb *JHEP 06 (2021) 044*

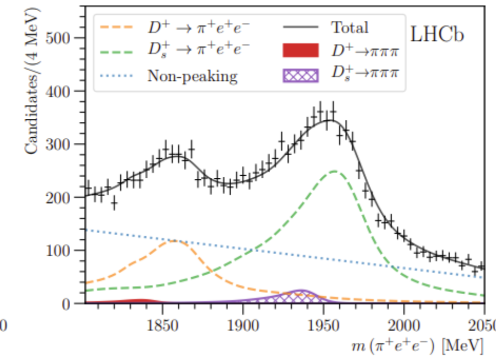
Searches for 25 rare and forbidden decays of D^+ and D_s^+ mesons

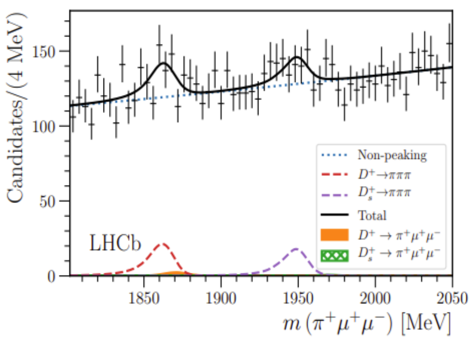
$$\mathcal{B}_{D^+_{(s)}\to h^\pm \ell^+ \ell^{(\prime)\mp}} = \frac{N_{D^+_{(s)}\to h^\pm \ell^+ \ell^{(\prime)\mp}}}{N_{D^+_{(s)}\to(\phi\to\mu^+\mu^-)\pi^+}} \cdot \frac{\epsilon_{D^+_{(s)}\to(\phi\to\mu^+\mu^-)\pi^+}}{\epsilon_{D^+_{(s)}\to h^\pm \ell^+ \ell^{(\prime)\mp}}} \cdot \mathcal{B}_{D^+_{(s)}\to(\phi\to\mu^+\mu^-)\pi^+}$$

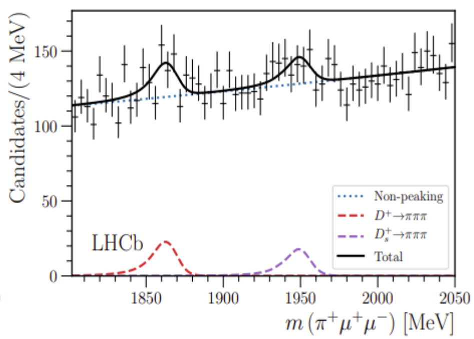


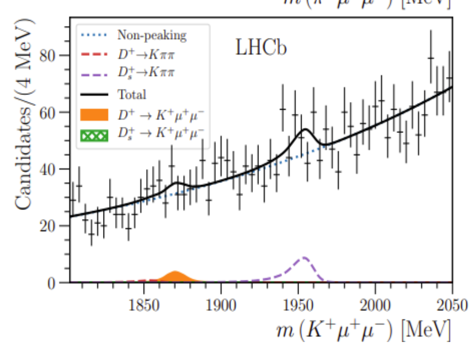


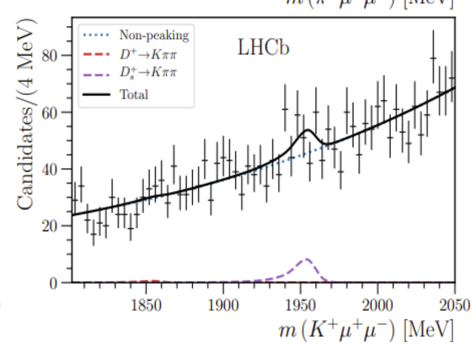










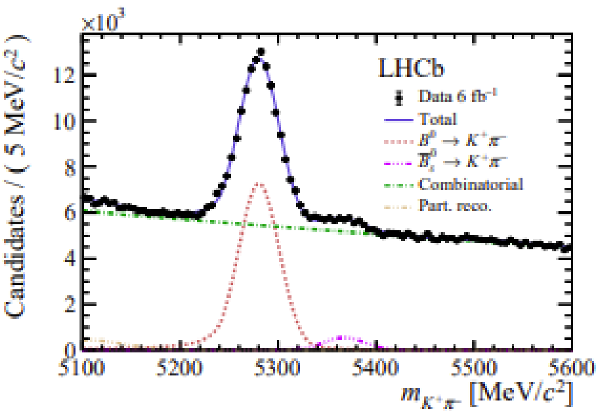


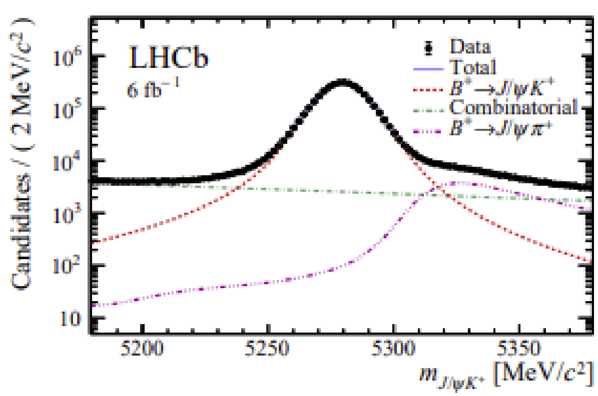
Decay	Branching fraction upper limit $[10^{-9}]$					
	D^+			D_s^+		
	SES	90 % CL	95 % CL	SES	90 % CL	95 % CL
$D^+_{(s)}\to\pi^+\mu^+\mu^-$	0.6	67	74	2.4	180	210
$D^+_{(s)}\to\pi^-\mu^+\mu^+$	0.3	14	16	1.8	86	96
$D^+_{(s)}\to K^+\mu^+\mu^-$	1.2	54	61	3.8	140	160
$D^+_{(s)}\to K^-\mu^+\mu^+$	-	-	-	1.2	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

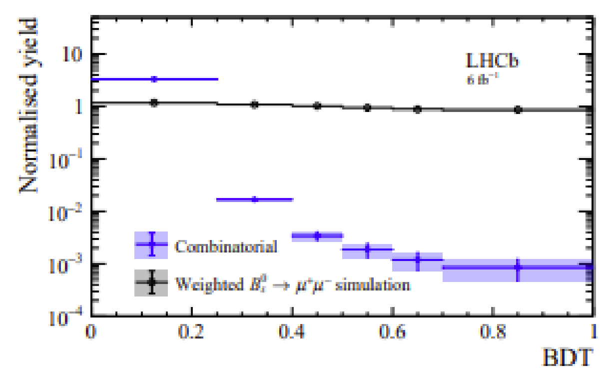
B→μμ LHCb

- Normalised to two channels: $B^+ \to J/\psi K^+$ and $B^0 \to K^+\pi^-$
- Multivariate operator against combinatorial background
- Tight PID calibrated on data against misID
- Significant improvement in hadronisation fraction $\frac{f_s}{f_d}(13\,\mathrm{TeV}) = 0.2539 \pm 0.0079$ from combined measurement [LHCb-PAPER-2020-046 - PRD 104, 032005 (2021)]

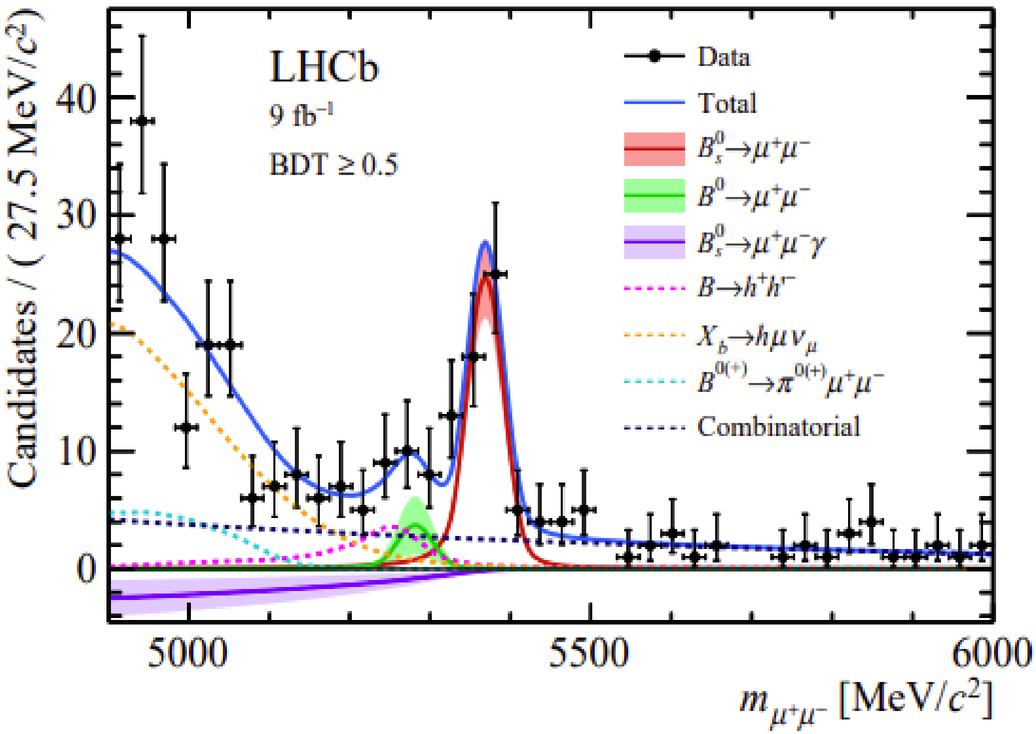
$$\mathcal{B}(B^0_{d,s} \to \mu^+\mu^-) = \underbrace{\frac{f_{\rm norm}}{f_{\rm sig}}}_{\text{Hadronisation fractions}} \overbrace{\frac{\varepsilon_{\rm norm}}{\varepsilon_{\rm sig}}}^{\text{Efficiencies}} \underbrace{\frac{N_{\rm sig}}{N_{\rm norm}}}_{\text{Yields}} \mathcal{B}(\text{norm}) = \underbrace{\alpha_{\rm sig}}_{\text{Single event sensitivity}} \mathrm{N}_{\rm sig}$$







B→μμ LHCb



- Simultaneous fit in 10 bins
  2 datasets (Run 1, 2) × 5 BDT bins
- External constraints on yield and shape of misidentified backgrounds
- Combinatorial background free
- Signal shapes calibrated and constrained
- All systematic uncertainties directly propagated

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

$$\mathcal{B}(B^0\to\mu^+\mu^-) = \left(1.2\,^{+0.8}_{-0.7}\pm 0.1\right)\times 10^{-10} < 2.6\times 10^{-10}$$

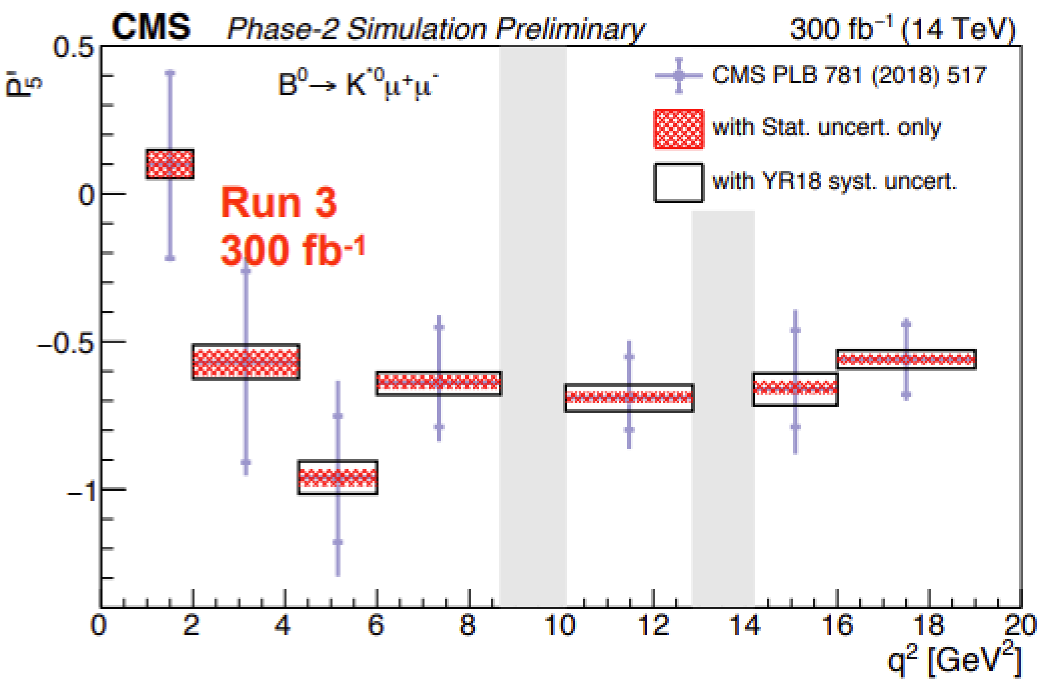
$$\mathcal{B}(B_s^0\to\mu^+\mu^-\gamma)_{m_{\mu\mu}>4.9\,\mathrm{GeV}} = (-2.5\pm 1.4\pm 0.8)\times 10^{-9} < 2.0\times 10^{-9}$$

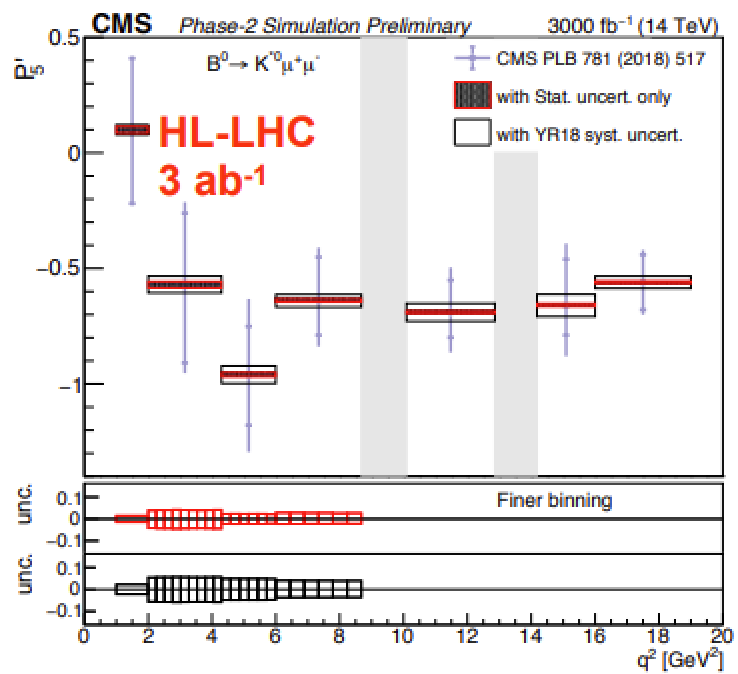
No significant signal for $B^0\to\mu^+\mu^-$ and $B_s^0\to\mu^+\mu^-\gamma$, upper limits at 95%
First world limit on $B_s^0\to\mu^+\mu^-\gamma$ decay
Measured effective lifetime $\tau_{\mathrm{eff}}(B_s^0\to\mu^+\mu^-) = 2.07\pm 0.29\pm 0.03\,\mathrm{ps}$
Consistent at 1.5σ and 2.2σ with the heavy and light B_s^0 eigenstates lifetimes

P5’ HL-LHC

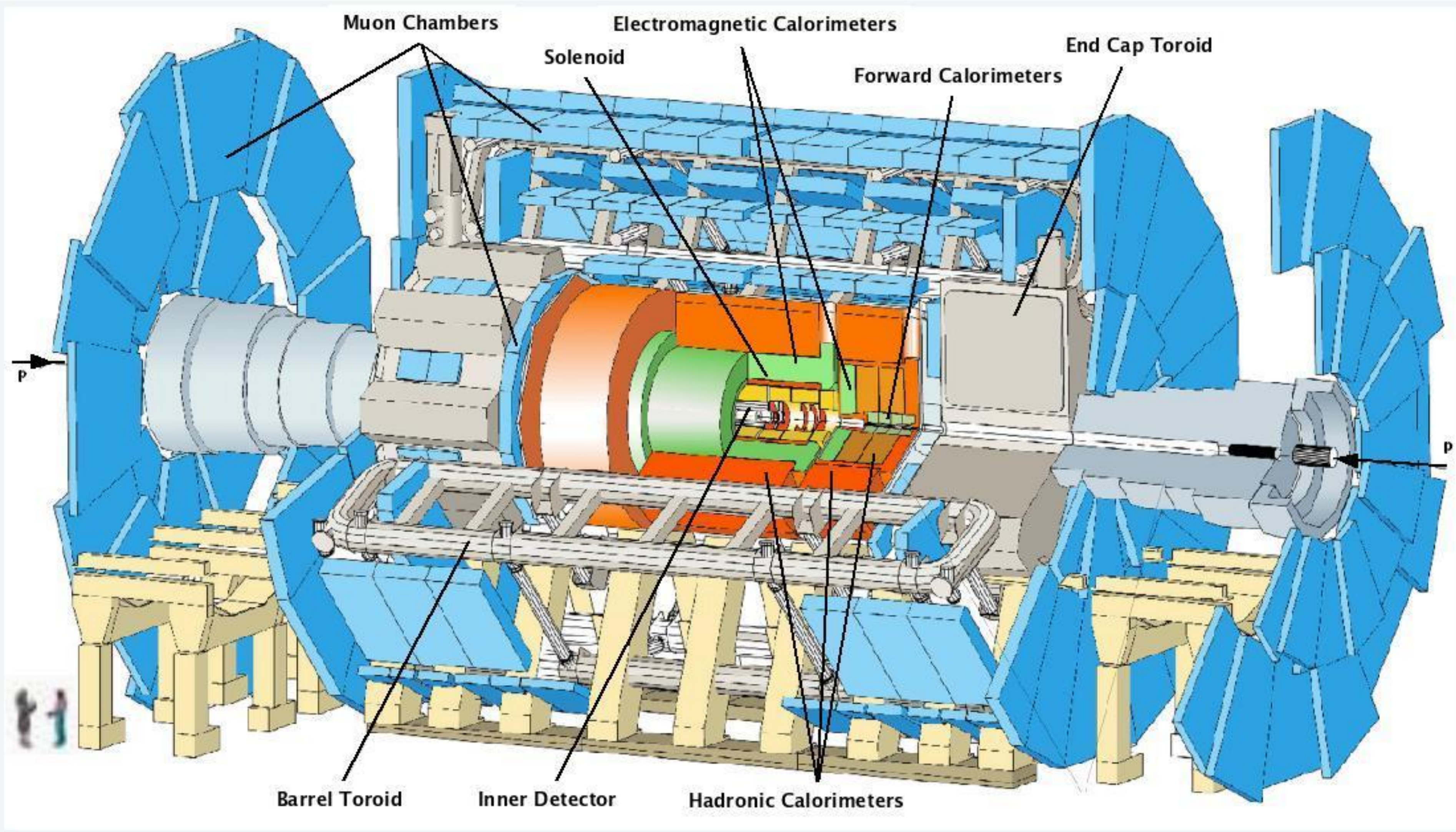
- Run 3 and HL-LHC projections
  - Up to x15 improvement w/ 3 ab^{-1} compared to the 8 TeV CMS result [PLB 781 (2018) 517]
  - Should be possible to resolve the situation experimentally already in Run 3

CMS PAS FTR-18-033

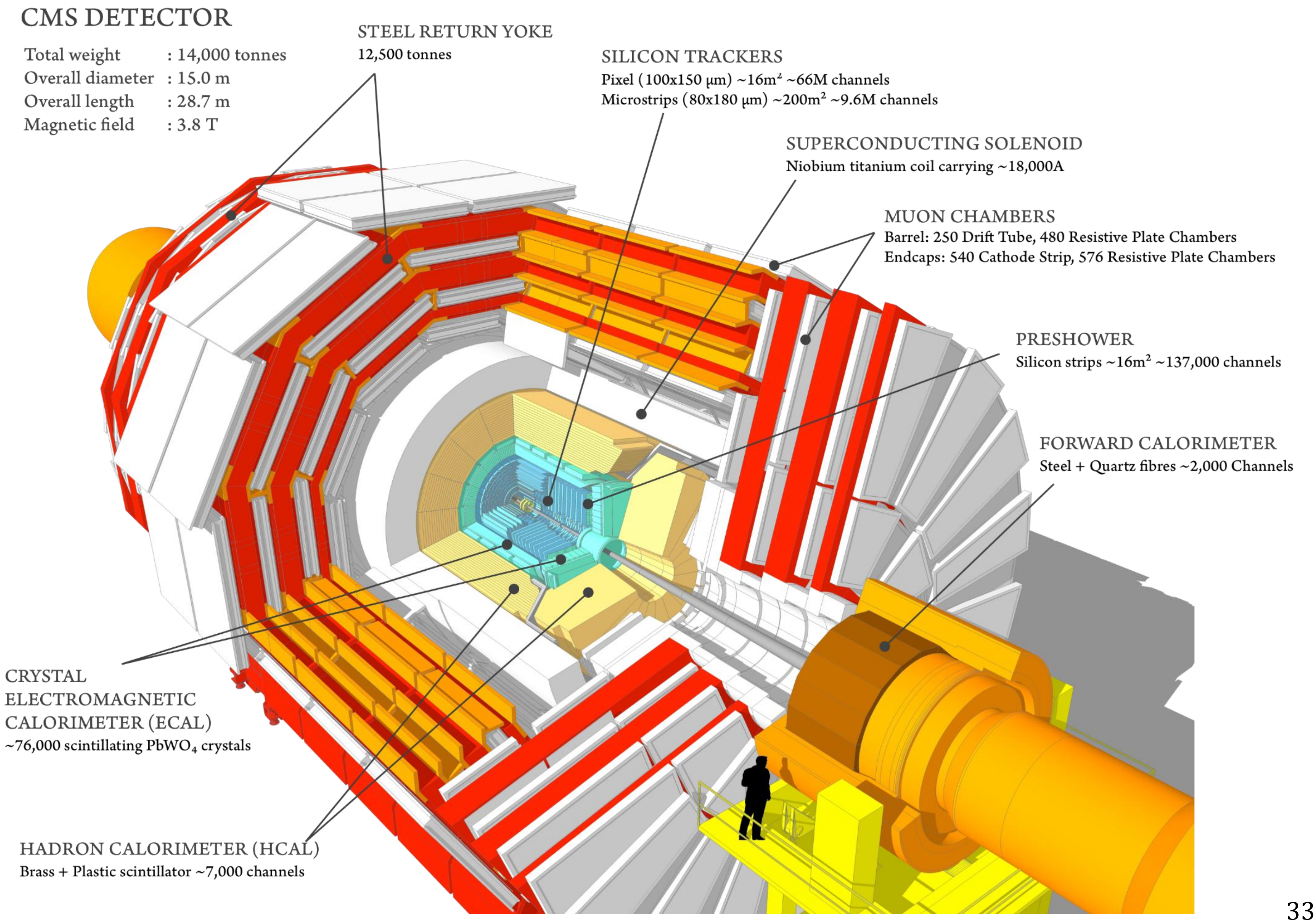




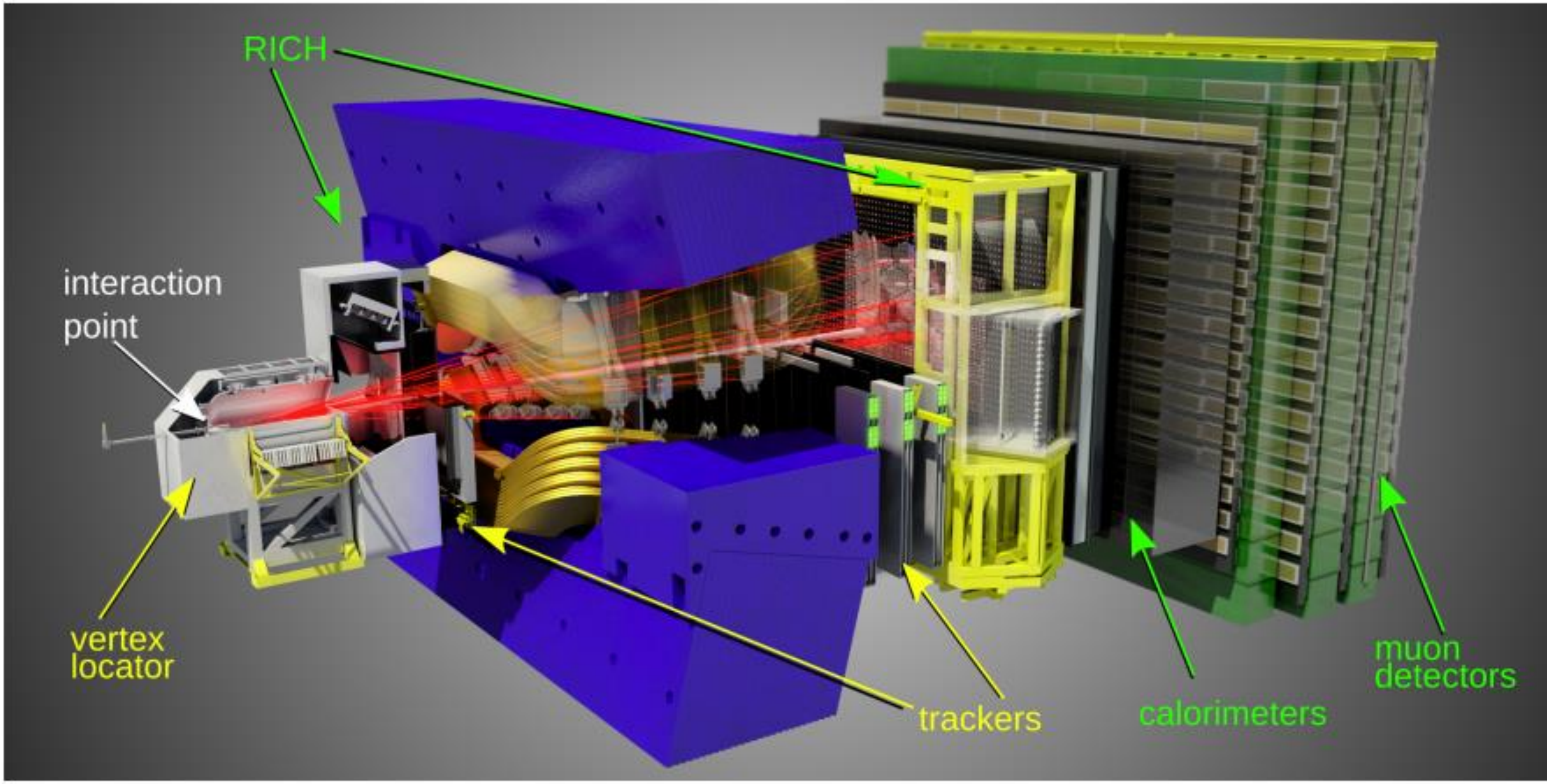
ATLAS experiment



CMS experiment



LHCb



- pp collisions at $\sqrt{s} = 7, 8, 13$ TeV
- 3 (6) fb^{-1} in Run 1 (Run 2)

https://indico.cern.ch/event/1109611/page/24092-conference-policies

/indico.cern.ch/event/1109611/page/24092-conference-policies

Participants from Russian/Belarussian institutes

Considering measures taken by many institutions, the LHCP2022 conference organisers, with the support of the International Advisory Committee, have agreed to suspend the participation of the institutions located in the Russian Federation and in the Republic of Belarus in the LHCP2022 conference. As a consequence, people employed by these institutions may only participate in the conference activities in a personal capacity, without indication of their affiliation, or, if necessary, with an IUPAP affiliation, subject to approval by IUPAP.