GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN

Challenging the Standard Model with LHCb data

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technische universität
dortmund

Emmy
Noether-
Programm

Deutsche
Forschungsgemeinschaft
DFG

erc

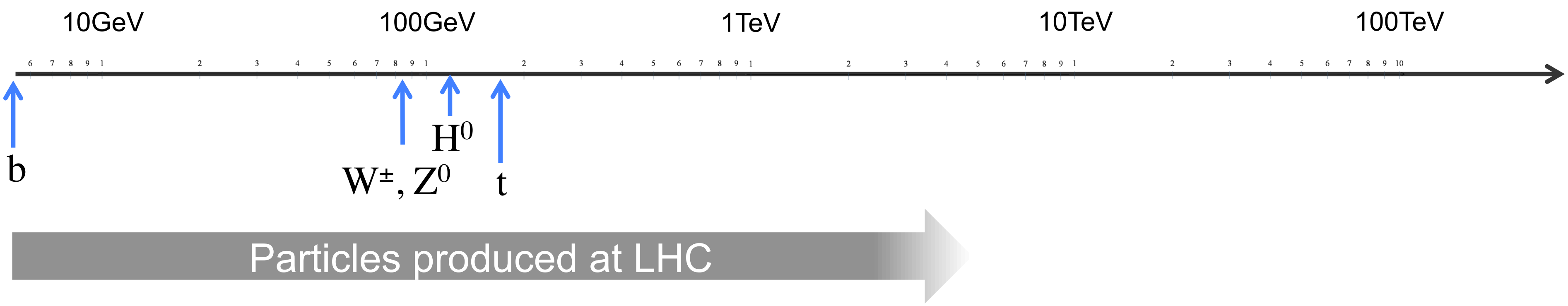
Indirect searches for New Physics

- High **energy**:
  "real" new particles can be produced and discovered via their decays
  - Discovery of the Higgs boson at the LHC → completion of the SM
  - **Tested scale : <10TeV**

- High **precision**:
  "virtual" new particles can be seen in quantum loops
  - Higher mass scale reachable (up to **~100TeV**)

Direct and indirect searches are both needed, both equally important, and complement each other

Searches for New Physics in Flavour



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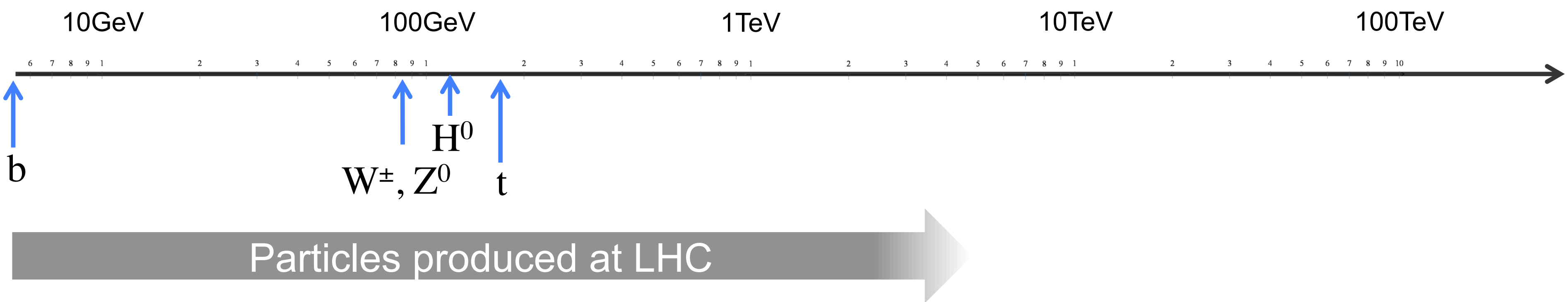
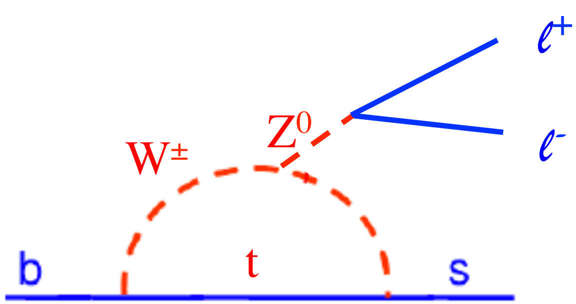
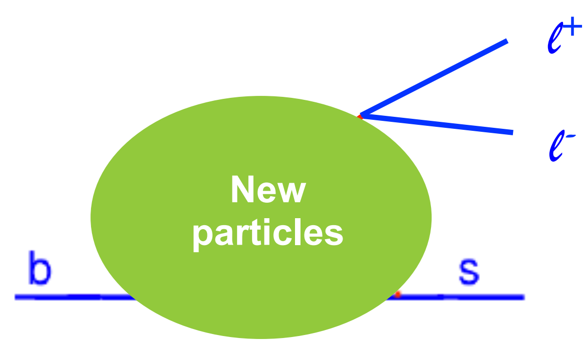


Flavour physics: Search for new heavy particles in precision measurements of quantum effects





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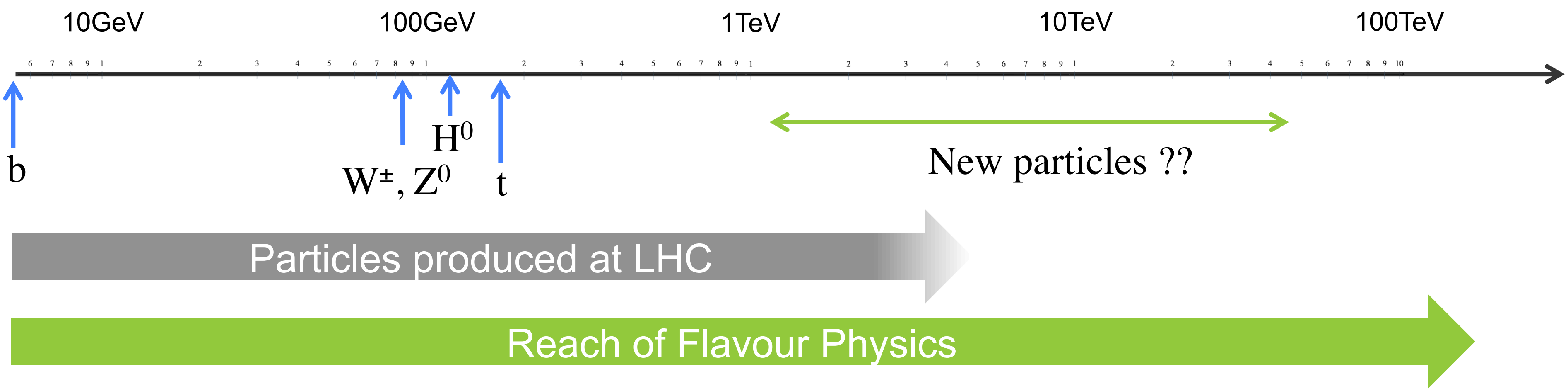

Flavour physics: Search for new heavy particles
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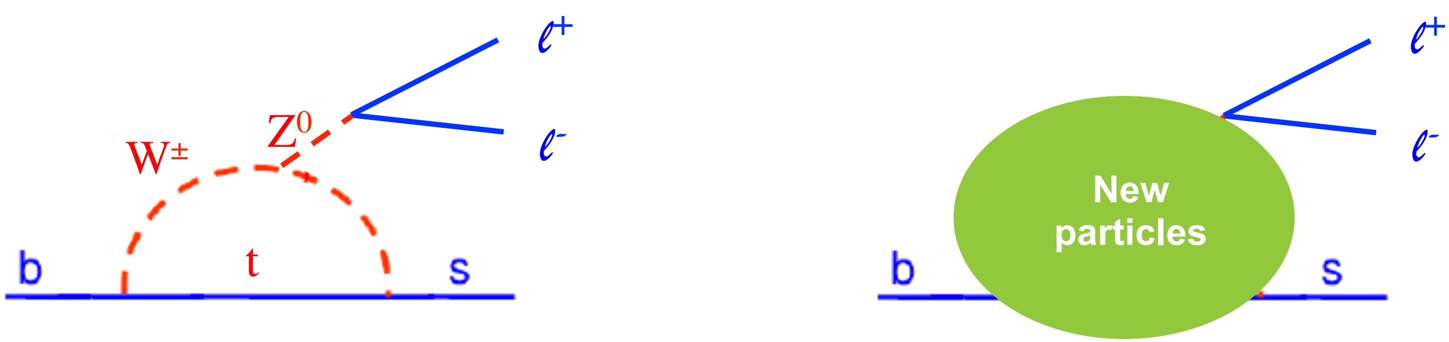


Precision data is sensitive to new particles of masses up to **~100TeV**

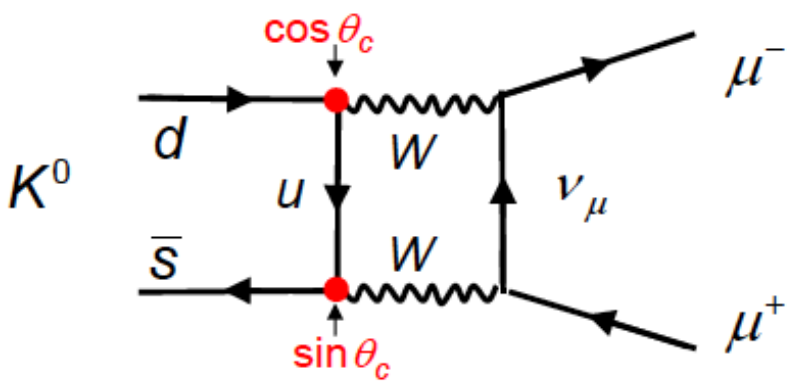
[A. Buras et al, JHEP1411(2014)121]

GIM Mechanism (1970)

Observed branching ratio $K^0 \to \mu\mu$

$$\frac{BR(K_L \to \mu^+\mu^-)}{BR(K_L \to all)} = (7.2 \pm 0.5) \cdot 10^{-9}$$

In contradiction with theoretical expectation in the 3-Quark Model



$M \sim \sin\theta_c \cos\theta_c$

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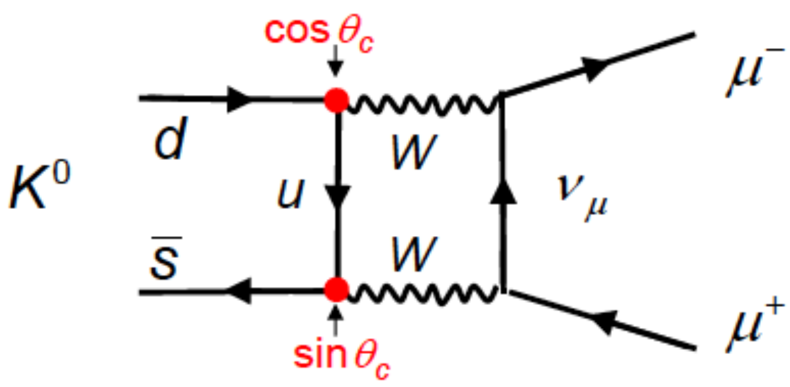
⬇

Glashow, Iliopolus, Maiani (1970):

Prediction of a 2nd up-type quark, additional Feynman graph cancels the "u box graph".



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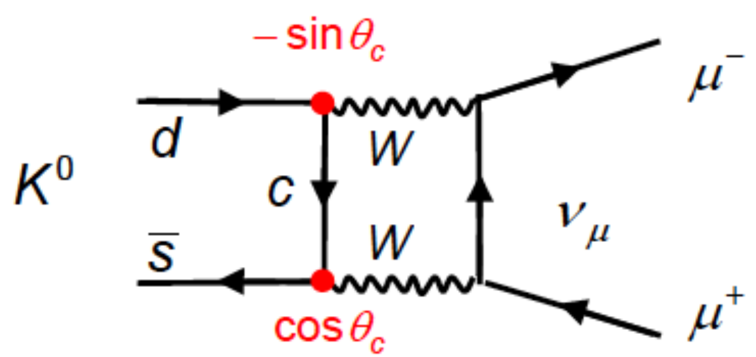
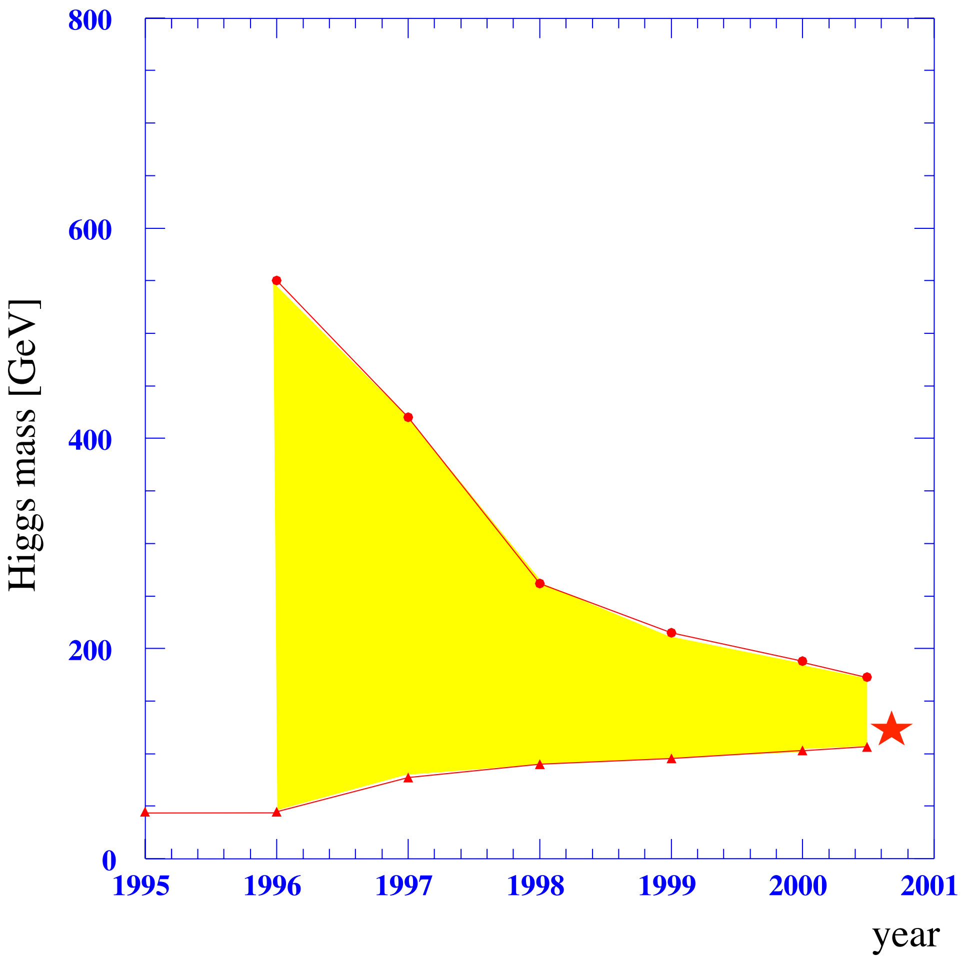


$M \sim -\sin\theta_c \cos\theta_c$

- The way to the Higgs Boson:
  - You know all the details!



Pre-discovery (2011)

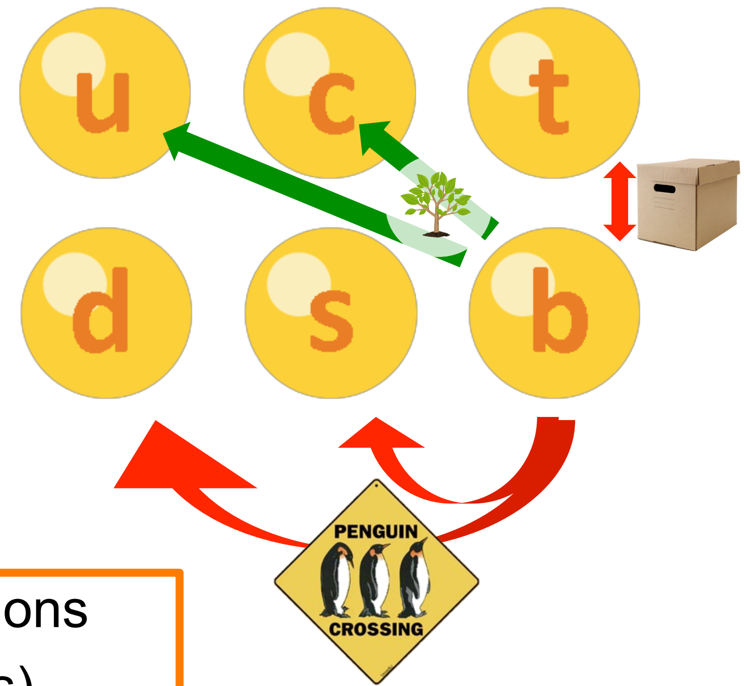
$m_H = 94^{+29}_{-24}$ GeV

ATLAS & CMS (2016):

$m_H = 125.09 \pm 0.24$ GeV

Beauty quarks: ideal for precision studies

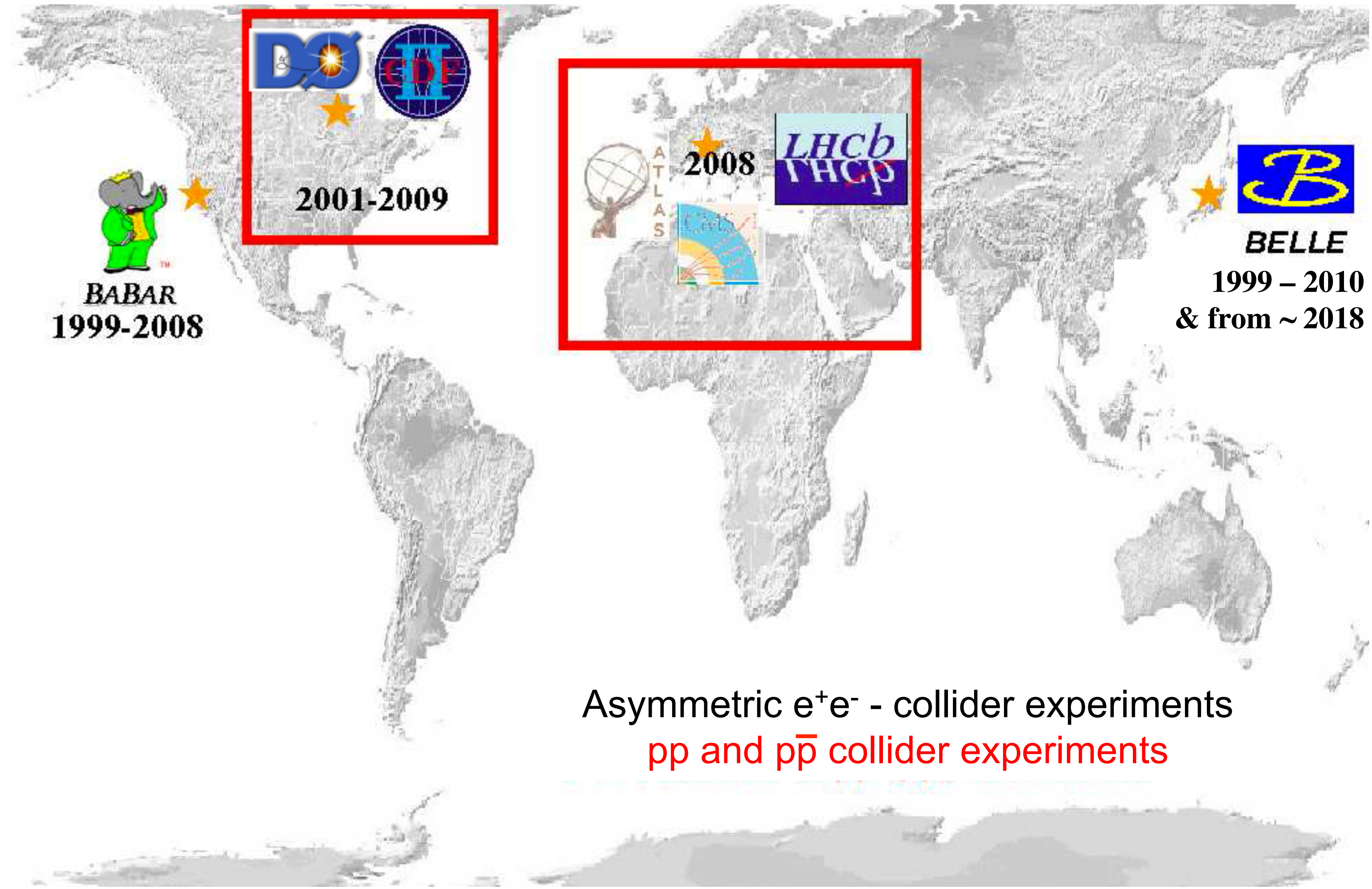
- The beauty quark …
  - Is the heaviest quark that forms hadronic bound states
    → high mass: many accessible final states
  - Must decay outside the 3rd family
    - All decays are CKM suppressed
    - Long lifetime (~1.6ps)



- Beauty-decays:
  - Dominant decay process: "tree" b→c transition
  - Very suppressed "tree" b→u transition
  - FCNC "penguin" b-> s and b→ d transitions
  - Flavour oscillations (b→t "box" diagrams)
  - CP violation

Focus of todays seminar

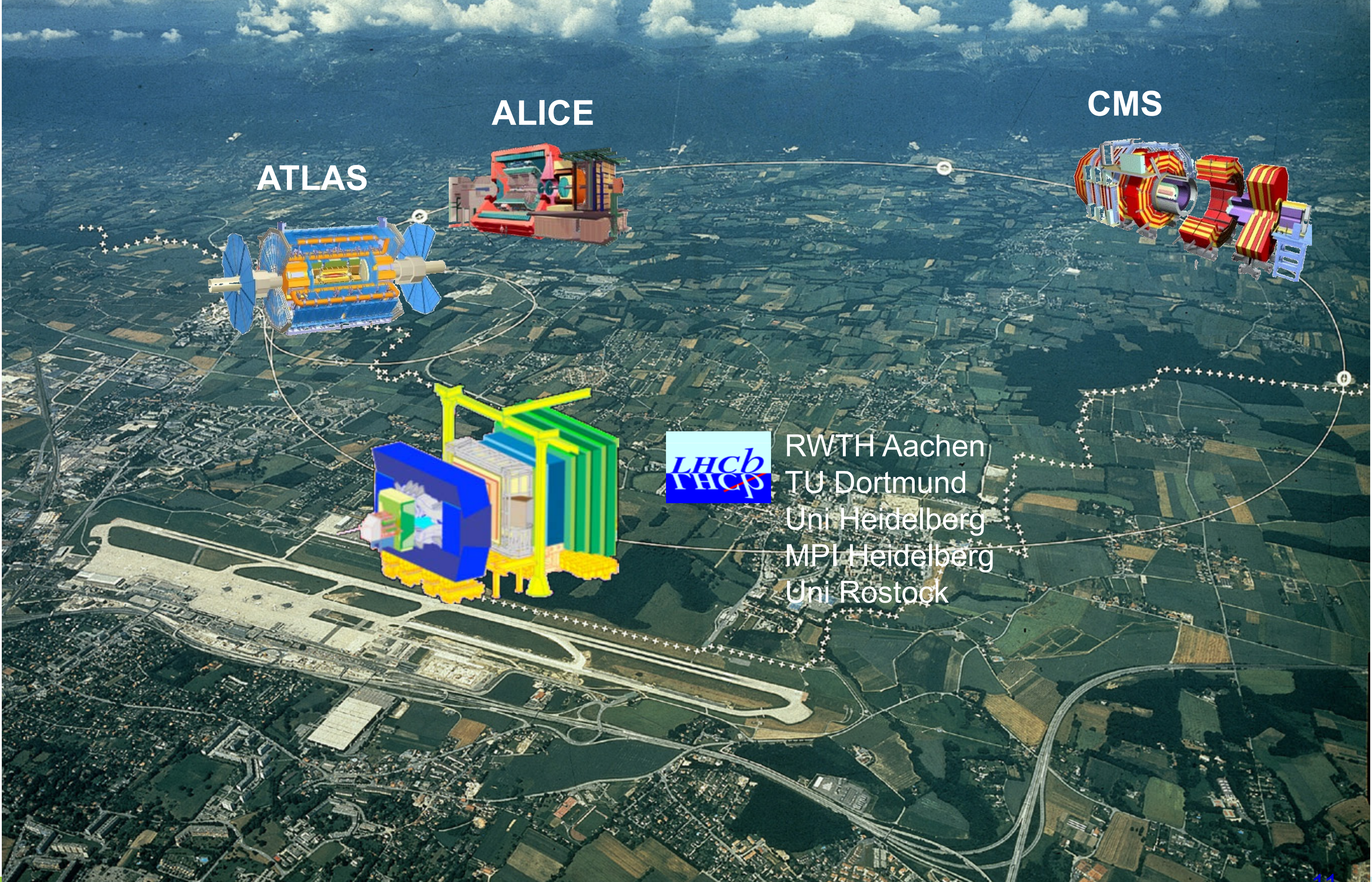
B–Physics Around the World



Asymmetric e^+e^- - collider experiments

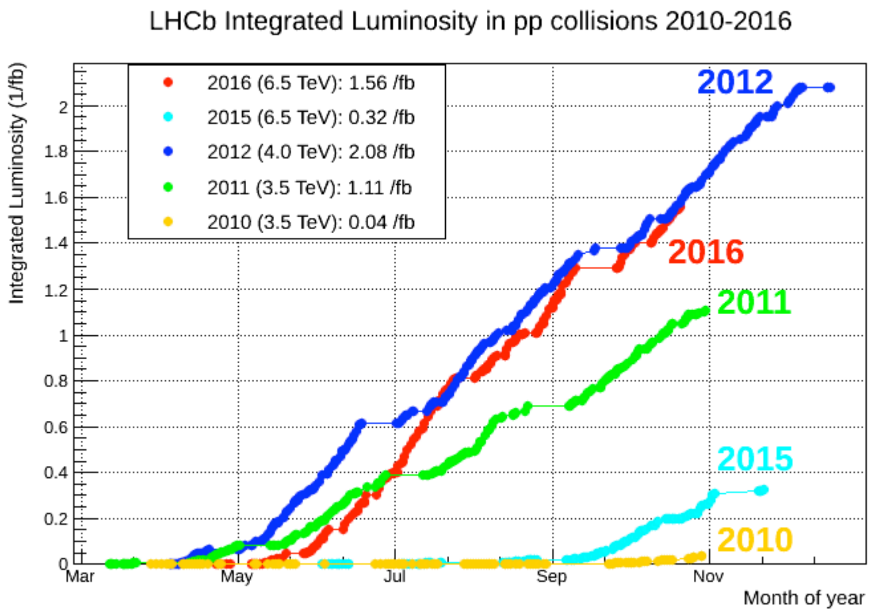
pp and $p\bar{p}$ collider experiments

Large Hadron Collider



LHCb and beauty production

- Proton collisions at 7-13TeV: huge heavy flavour production cross sections
  - In LHCb acceptance: 75kHz bb and 1.5MHz cc
  - ~1/10 events contains b or c signal



Experiment	$\int \mathcal{L}\, dt$ [fb^{-1}]	σ_{beauty} [μb]	End of life
BaBar	530 (total)	0.001 [e^+e^- at $\Upsilon(4S)$]	2008
Belle	1040 (total)	0.001 [e^+e^- at $\Upsilon(4S)$]	2010
CDF/D0	12 (total)	100 [$p\bar{p}$ at 2 TeV]	2011
ATLAS/CMS	55 (so far)	250-500 [pp at 7-13 TeV]	> 2030
LHCb*	>5 (so far)	250-500 [pp at 7-13 TeV]	> 2030

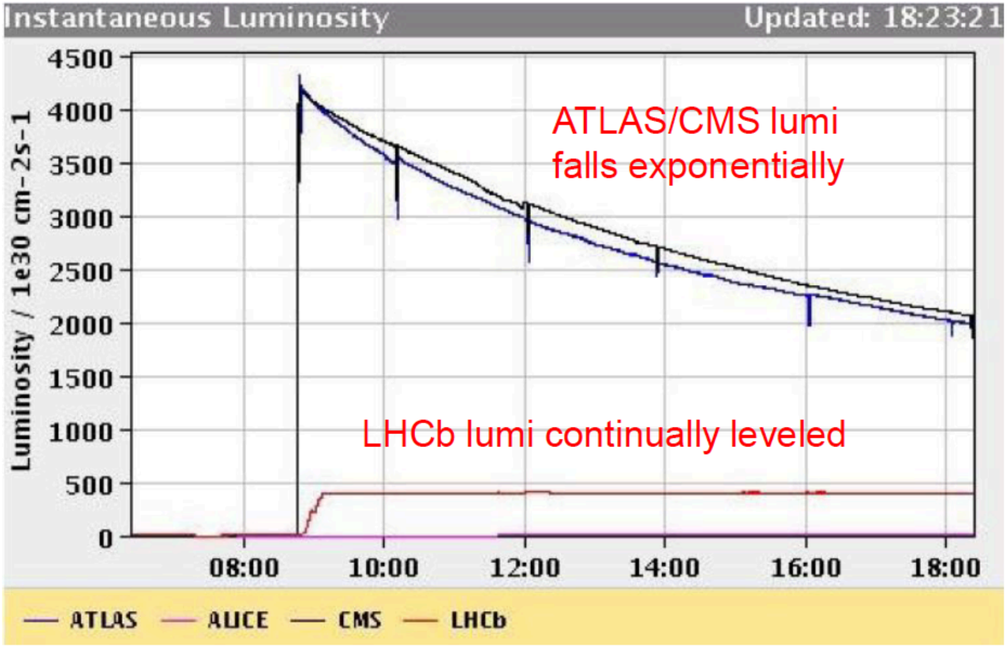
LHCb and beauty production

LHCb Integrated Luminosity in pp collisions 2010-2016

2016 (6.5 TeV): 1.56 /fb

2012

LHCb deliberately operates at lower luminosity than ATLAS/CMS

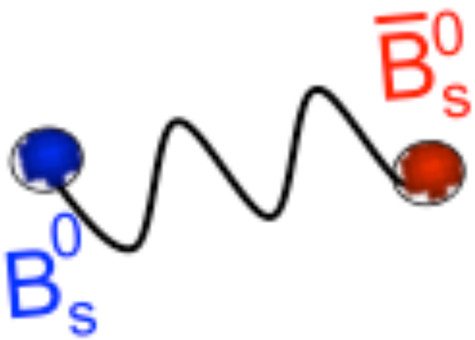
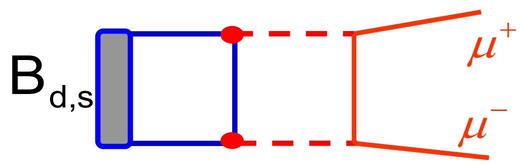


This is (current) best choice for precision *b*-physics measurements.

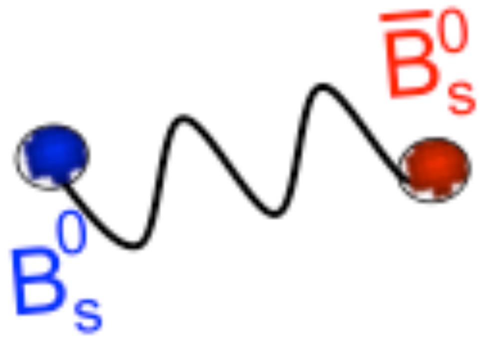
LHCb*	>5 (so far)	250-500 [pp at 7-13 TeV]	> 2030

Test of fundamental interactions

- A few selected highlights

CP violation	Rare decays	Future outlook
		
B_s mixing and CP violation	(Semi-) leptonic beauty decays	

CP violation



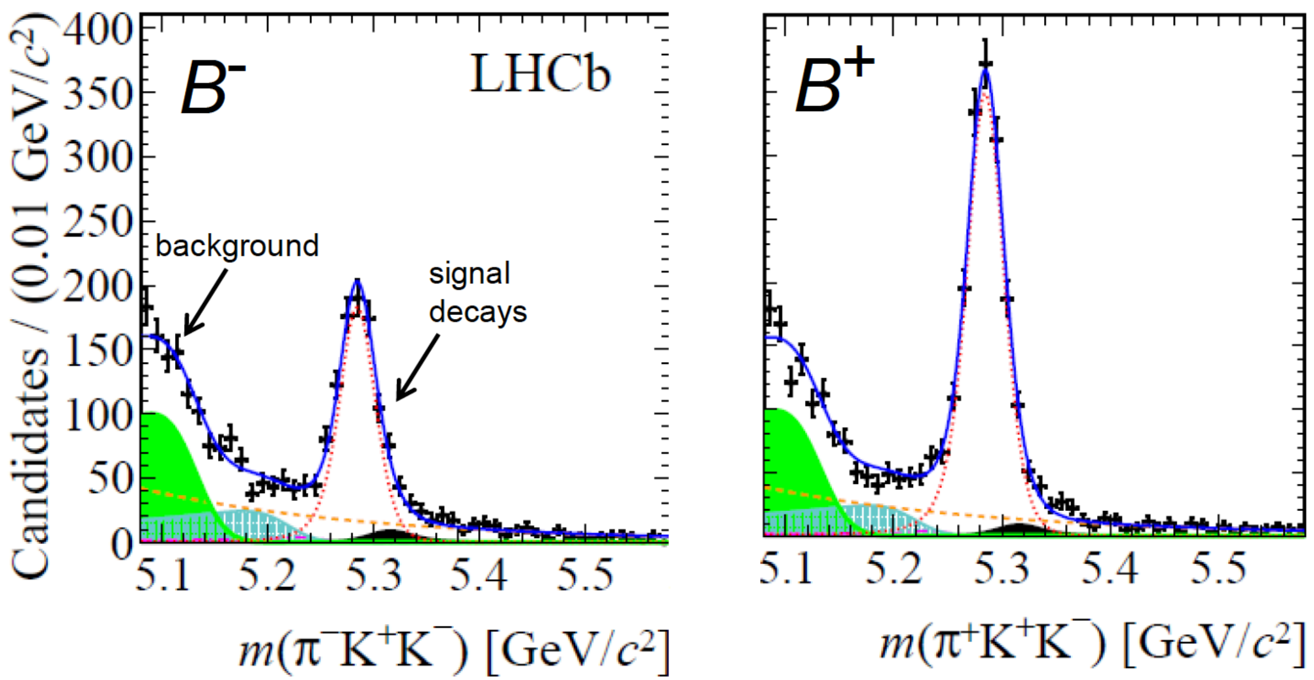
B_s mixing and
CP violation

CP Violation

CP violation (CPV) → difference in behaviour between matter and anti-matter.

First discovered in the kaon system in 1964, opportunities of study were limited until colliders arrived that could make lots & lots of *b*-quark hadrons, *e.g.* the LHC

A recent example from LHCb - look at *B* meson decaying into a pion & two kaons…



[LHCb, PRD 90 (2014) 112004]

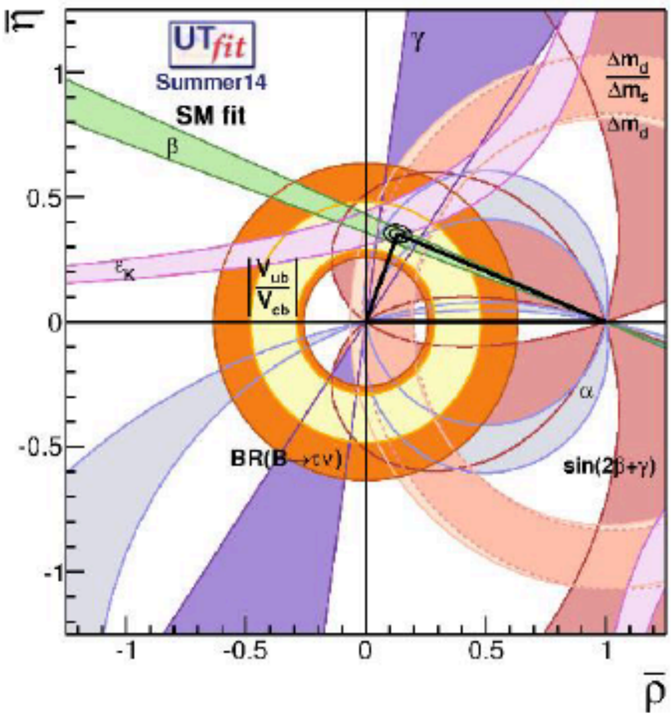
…the decay probabilities are manifestly different for B^- & B^+ ! In the Standard Model CPV is accommodated, *but not explained*, by an imaginary phase in the CKM matrix

The unitarity triangle

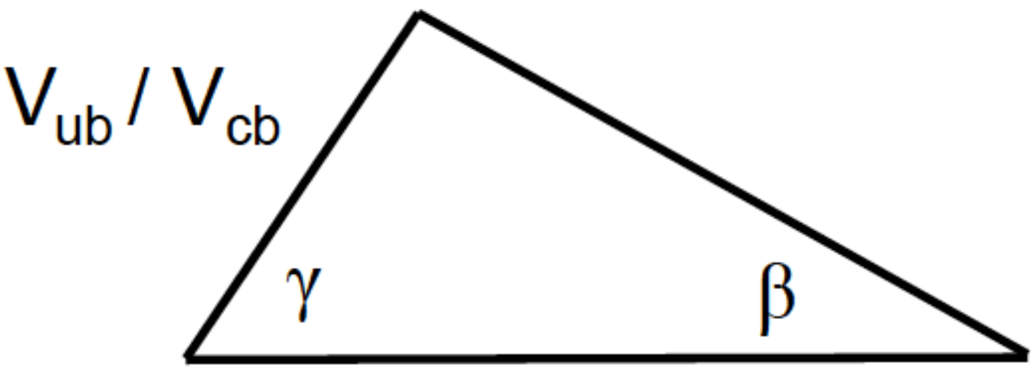
The Unitarity Triangle is a geometrical description of *CP*-violation within the context of the Standard Model, which in the flavour sector is the CKM mechanism.

We must check its consistency through precise measurements.

The *B* factories did a fantastic job and showed that the CKM paradigm dominates the picture, but New Physics contributions can still be lurking at ~20% level.



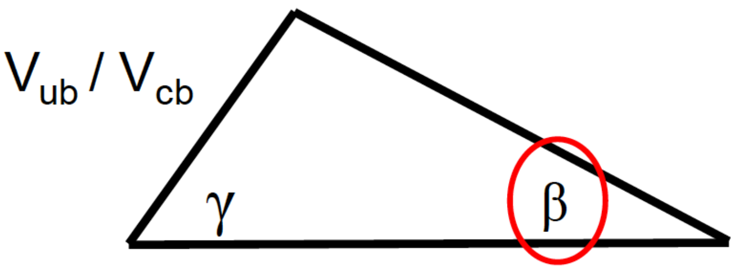
Let's see how the LHC is advancing this programme…

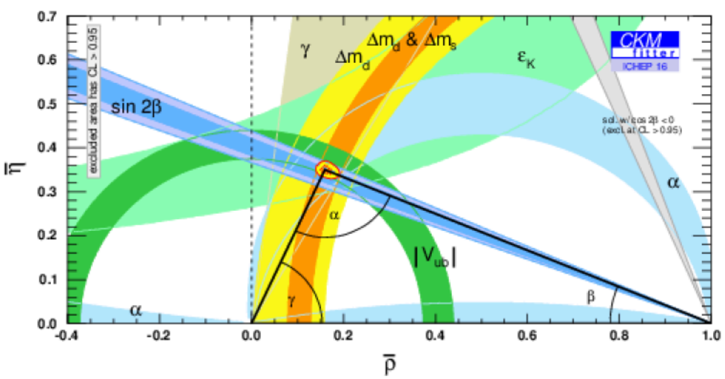


…through three key measurements.

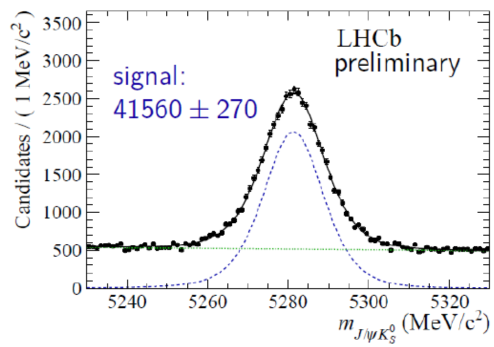
Unitarity Triangle: sin2β

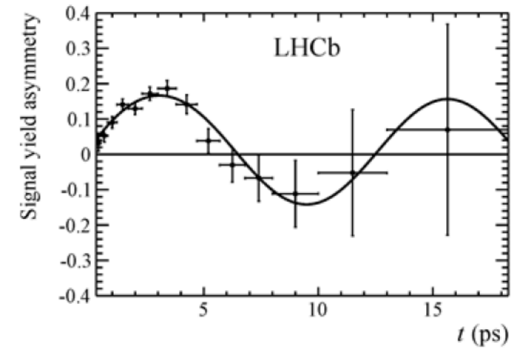
Measurement on *β* was the legacy of the *B*-factories, and helped pave way for 2008 Nobel Prize for Kobyashi and Maskawa. Now LHCb has entered the game !





This measurement requires time-dependent measurement & flavour tagging, which is trickier at a hadron collider than at an e^+e^- machine.





[PRL 115 (2015) 031601]

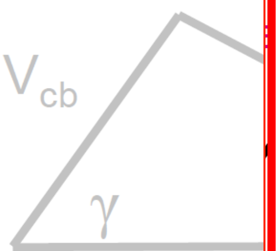
$$\sin 2\beta_{\rm eff} = 0.731 \pm 0.035\,({\rm stat}) \pm 0.020\,({\rm syst})$$

(BaBar stat error = 0.036, Belle stat error = 0.029)

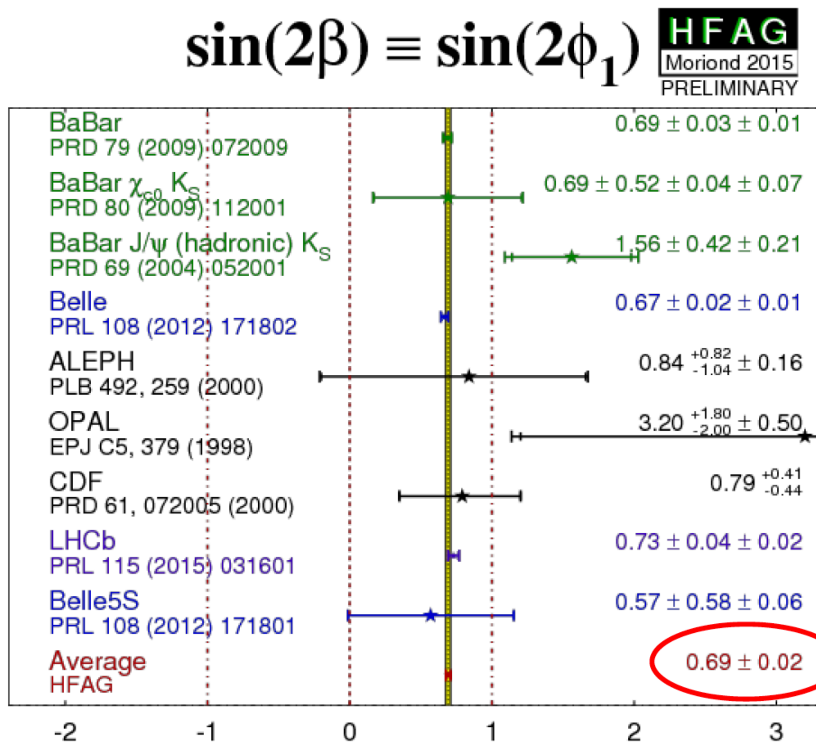
Precision obtained by LHCb with $B^0 \rightarrow J/\Psi K_S$ is very similar to that of the *B*-factories.

Unitarity Triangle: sin2β

Measurement o… ave way for
2008 Nobel Priz… red the game !

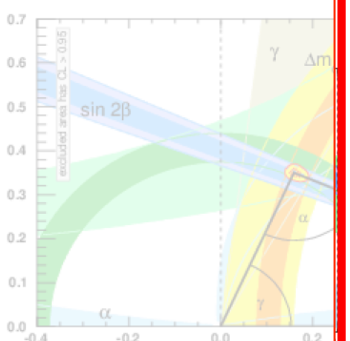


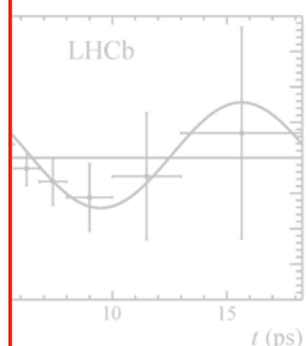
…e-dependent
…, which is trickier
…e^+e^- machine.



To be compared to prediction of $0.740^{+0.020}_{-0.025}$ CKMfitter summer'16

Some tension. Vital to keep improving the precision of this very important parameter. A long-term goal !



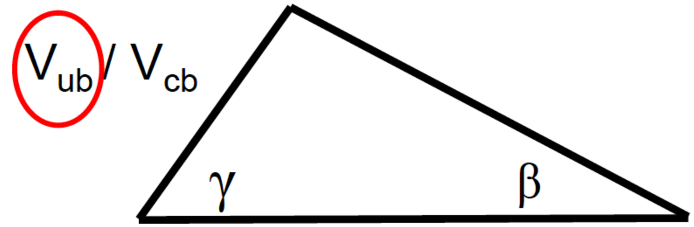


[PRL 115 (2015) 031601]

…) ± 0.020 (syst)
…tat error = 0.029)

Precision obtain… f the *B*-factories.

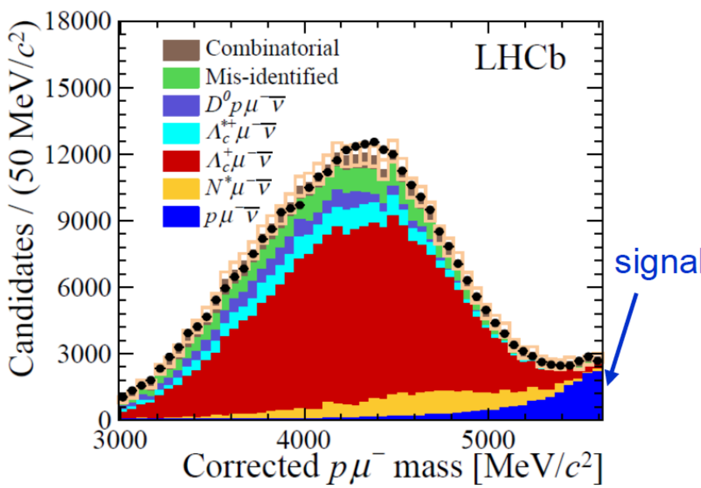
Unitarity Triangle: V_{ub}



Measurement of V_{ub} long thought essentially impossible at LHC. Challenging to separate $b \to u\mu\nu$ and $b \to c\mu\nu$ processes without any beam energy constraint.

But it can be done!
Use baryon decay $\Lambda_b \to p\mu\nu$ and benefit from RICH & vertexing capabilities.

[Nature Phys 10 (2015) 1038]

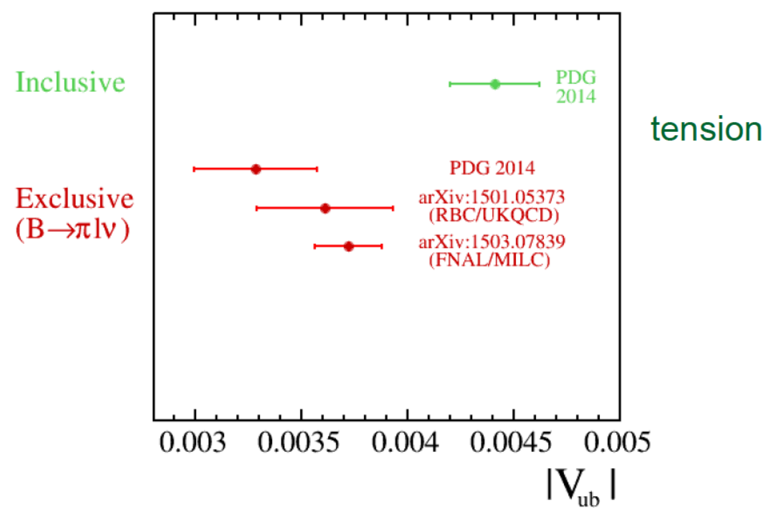


Normalise to $\Lambda_b \to \Lambda_c \mu\nu$ and use lattice QCD to interpret result.

Very precise result:

$$|V_{ub}| = (3.27 \pm 0.15 \pm 0.16 \pm 0.06) \times 10^{-3}$$

Brings new insight to long-standing 'inclusive vs exclusive' V_{ub} puzzle.



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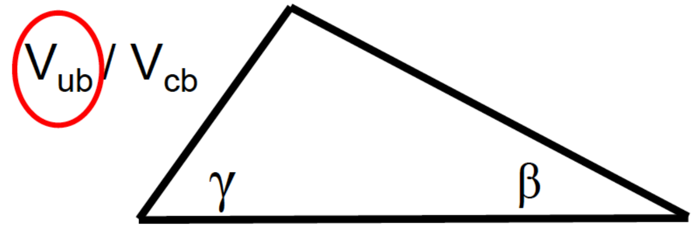

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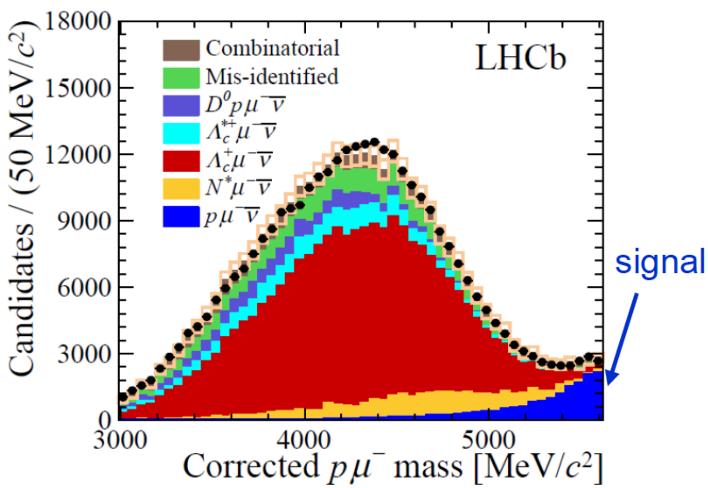

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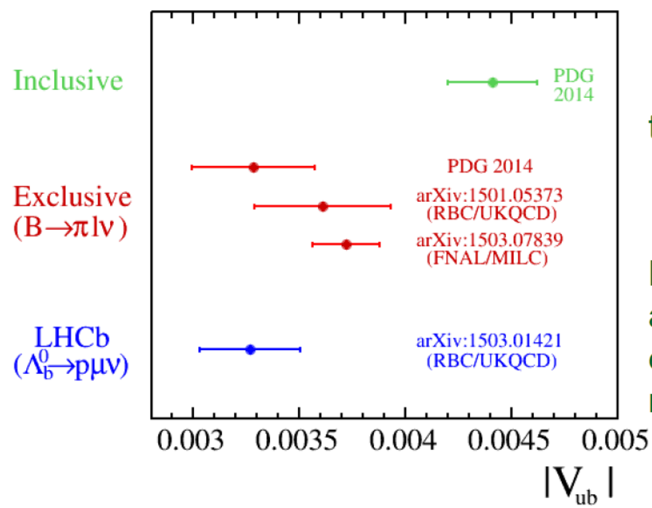
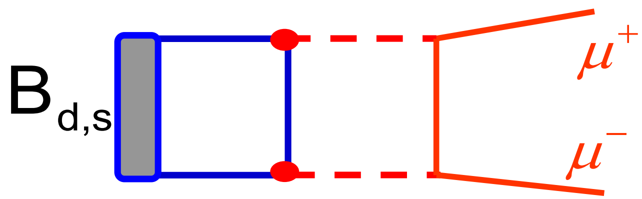


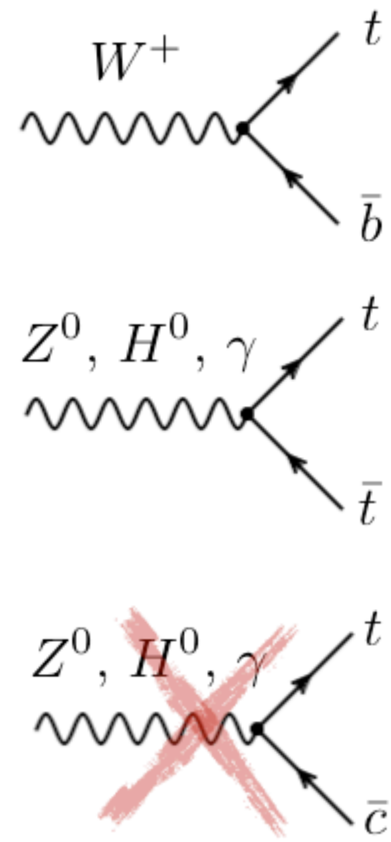
tension !

LHCb result agrees with exclusive results

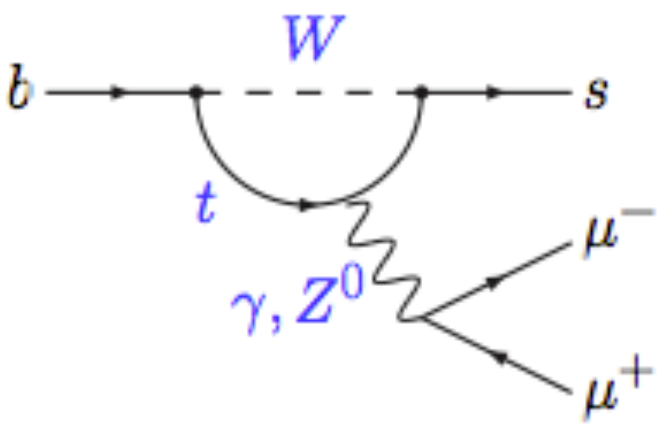
Rare decays

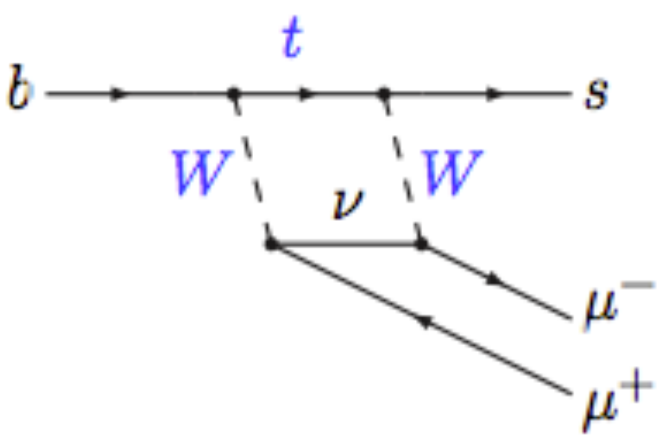


1) Leptonic decays
2) Semileptonic decays



$b \to s\, \mu^+\mu^-$ base diagram





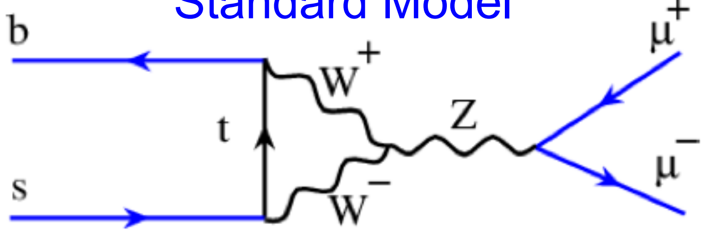
- Purely leptonic
  - "add nothing"
- Semileptonic
  - add d quark as spectator → $B^0 \to K^{*0} \mu^+\mu^-$
  - add s quark as spectator → $B_s \to \phi\, \mu^+\mu^-$
  - add u quark as spectator → $B^+ \to K^+ \mu^+\mu^-$
- Ratios:
  - Compare muons to electrons

Theory prediction: Standard Model

decay	SM
$B_s \to \mu^+\mu^-$	$3.5 \pm 0.3 \times 10^{-9}$
$B^0 \to \mu^+\mu^-$	$1.1 \pm 0.1 \times 10^{-10}$

SM: Buras, Isidori et al: arXiv:1208.0934
Mixing effects: Fleischer et al, arXiv:1204.1737

Standard Model

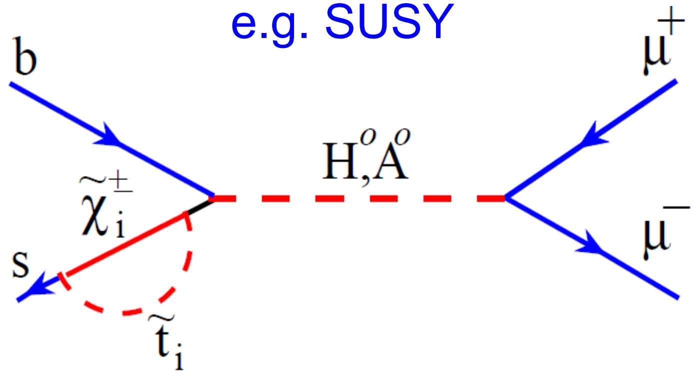


Left handed couplings
→ helicity suppressed

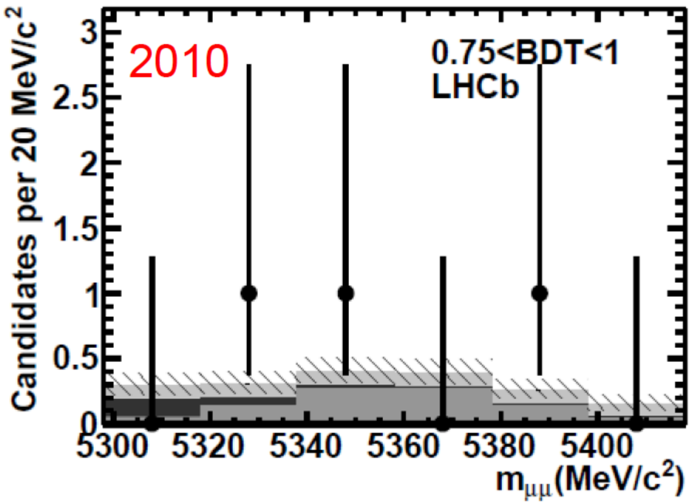
Discovery channel for New Phenomena

➔ Very **sensitive to an extended scalar sector** (e.g. extended Higgs sectors, SUSY, etc.)

e.g. SUSY



$B \to \mu^+\mu^-$: Progress through run 1

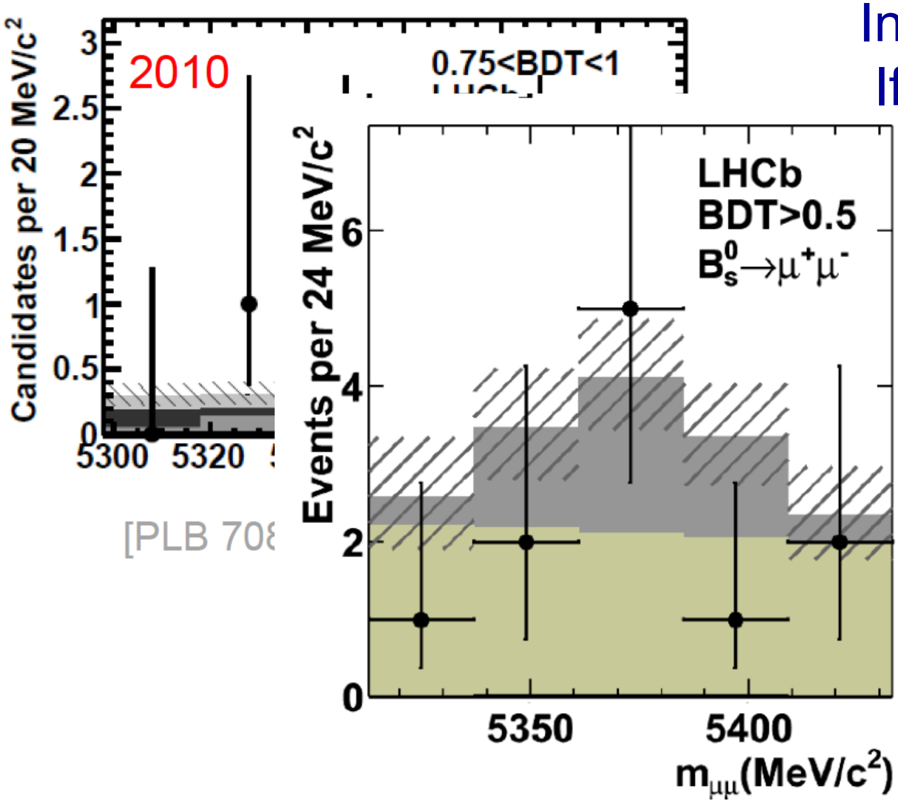


[PLB 708 (2012) 55]

Invariant mass in signal region (high BDT)
If there is a signal, we should see a peak

2010: nothing

Invariant mass in signal region (high BDT)
If there is a signal, we should see a peak

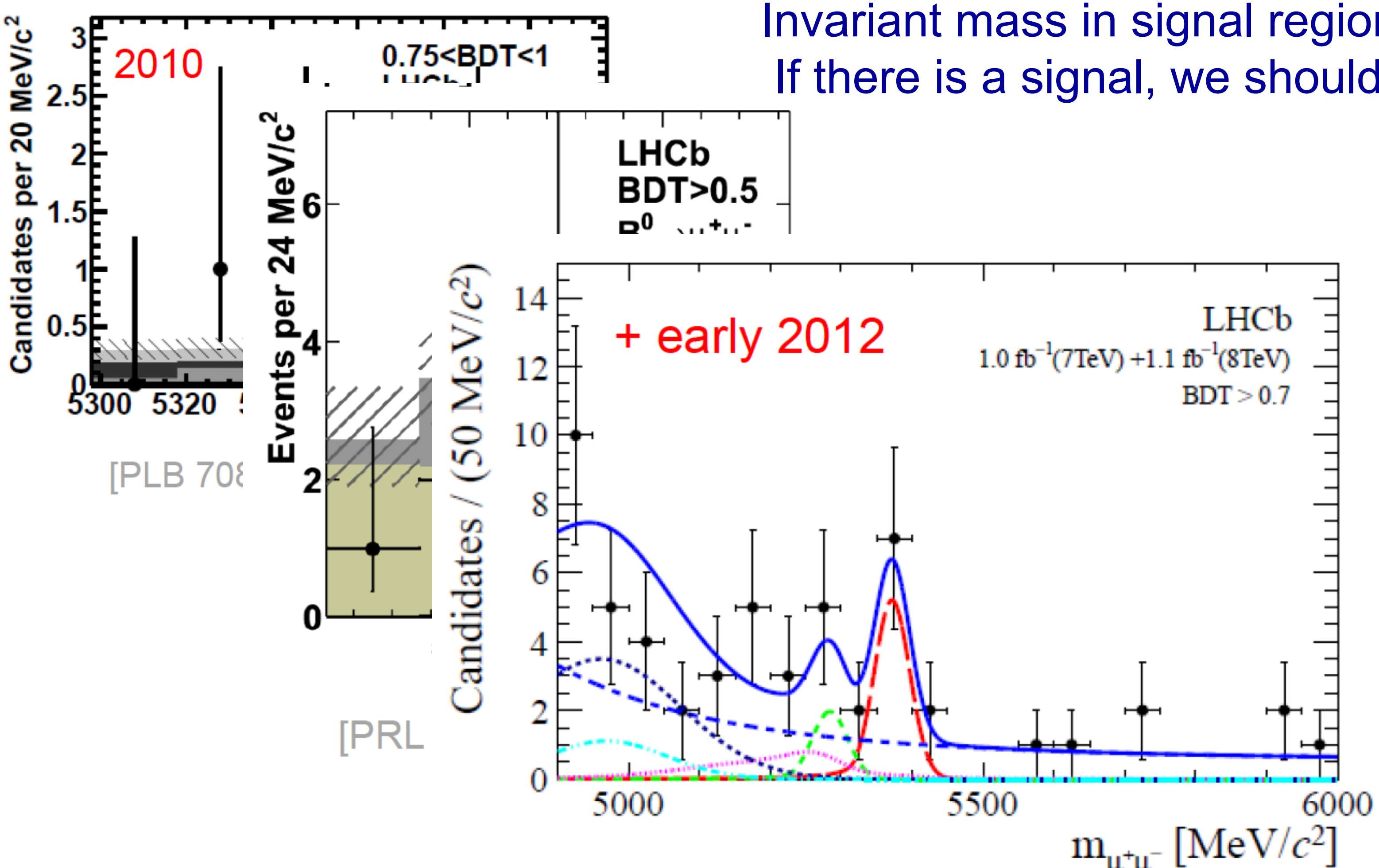


[PRL 108 (2012) 231801]

+2011: maybe??
But not significant enough for any claims

$B \rightarrow \mu^+\mu^-$: Progress through run 1

Invariant mass in signal region (high BDT)
If there is a signal, we should see a peak

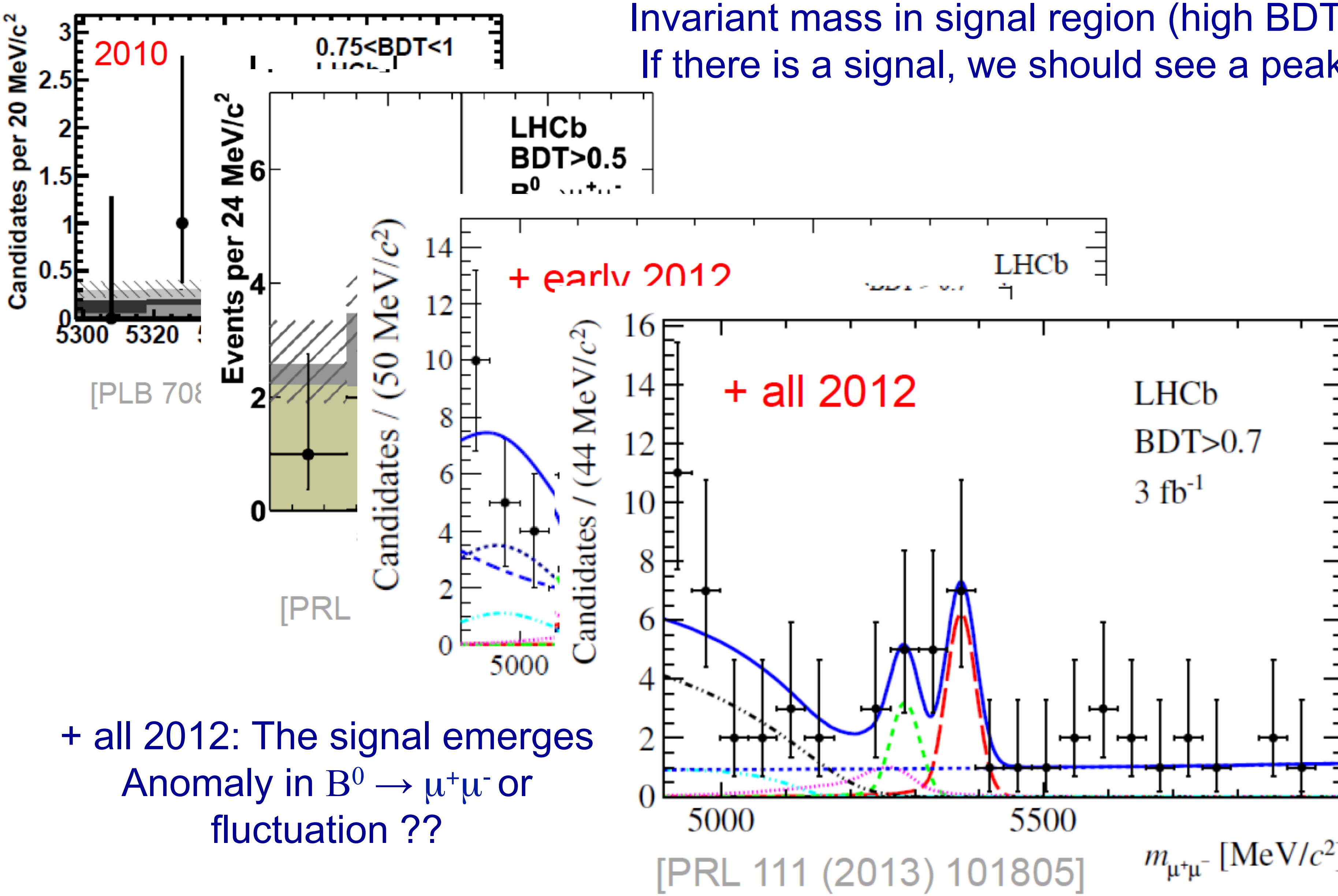


[PRL 110 (2013) 021801]

+ early 2012: First evidence of $B_s \rightarrow \mu^+\mu^-$!
Shown at HCP in Kyoto

$B \to \mu^+\mu^-$: Progress through run 1

Invariant mass in signal region (high BDT)
If there is a signal, we should see a peak

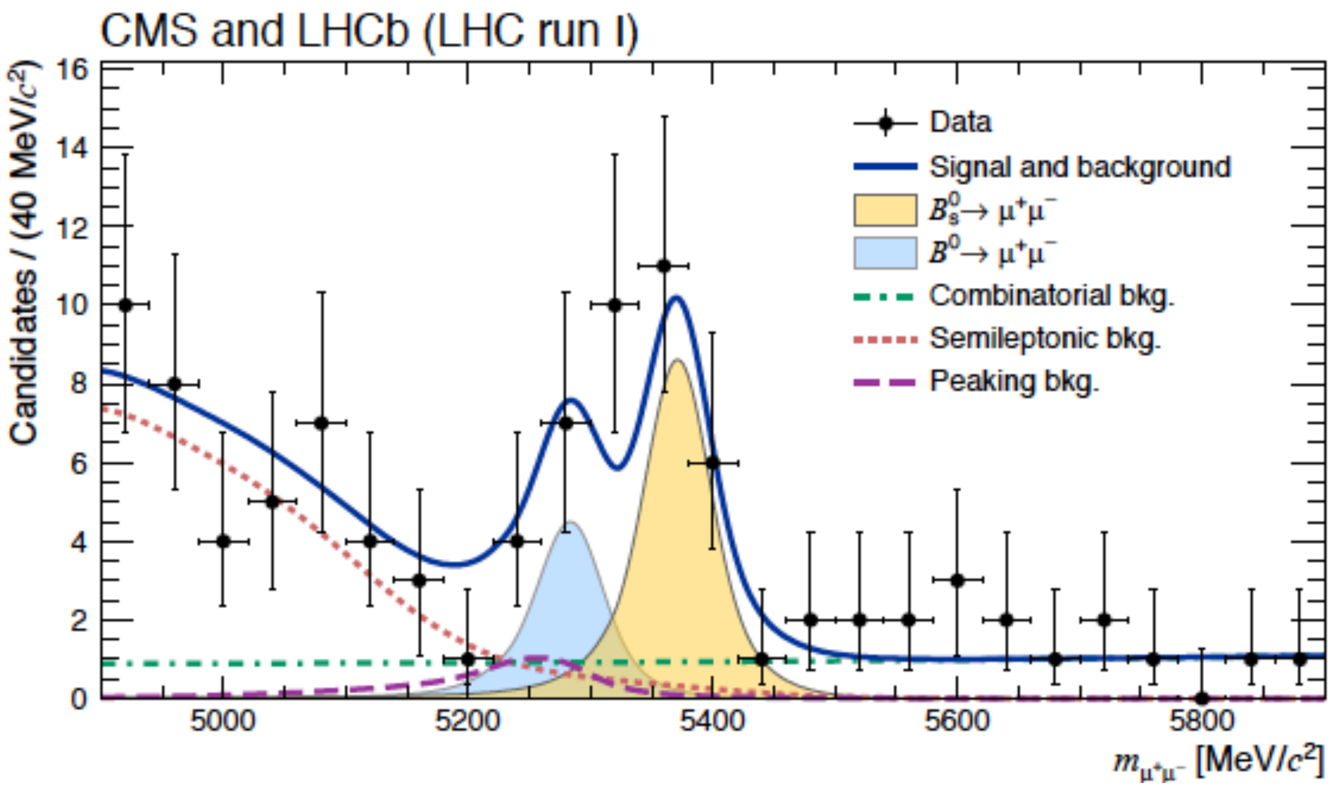


+ all 2012: The signal emerges
Anomaly in $B^0 \to \mu^+\mu^-$ or fluctuation ??

LETTER First observation of $B_s \to \mu^+\mu^-$

OPEN

doi:10.1038/nature14474



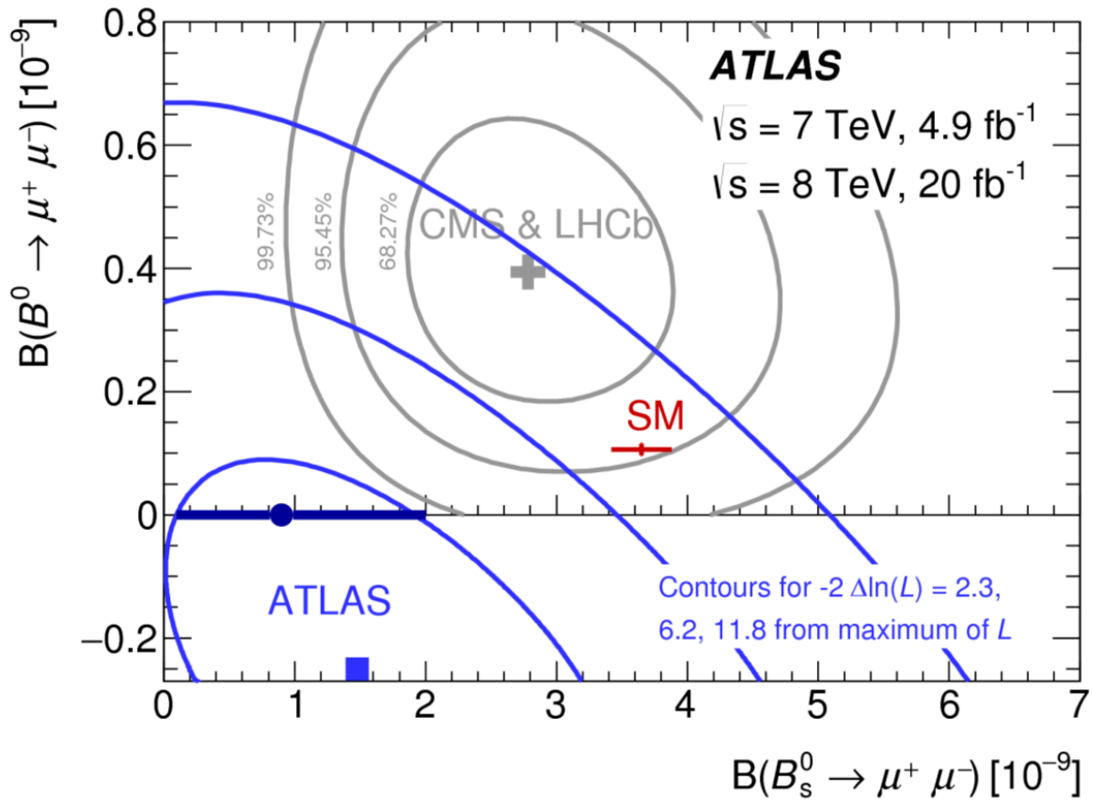
$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = 2.8^{+0.7}_{-0.6} \cdot 10^{-9}$$

6.2σ significance → first observation
- compatible with SM at 1.2σ

$$\mathcal{B}(B^0 \to \mu^+\mu^-) = 3.9^{+1.6}_{-1.4} \cdot 10^{-10}$$

3.0σ significance → first evidence
- compatible with SM at 2.2σ

And now ATLAS have joined the game [arXiv:1604.04263] !



No signal evidence in either mode… but lower intrinsic sensitivity than LHCb/CMS

B→ $\mu^+\mu^-$: First news from run 2

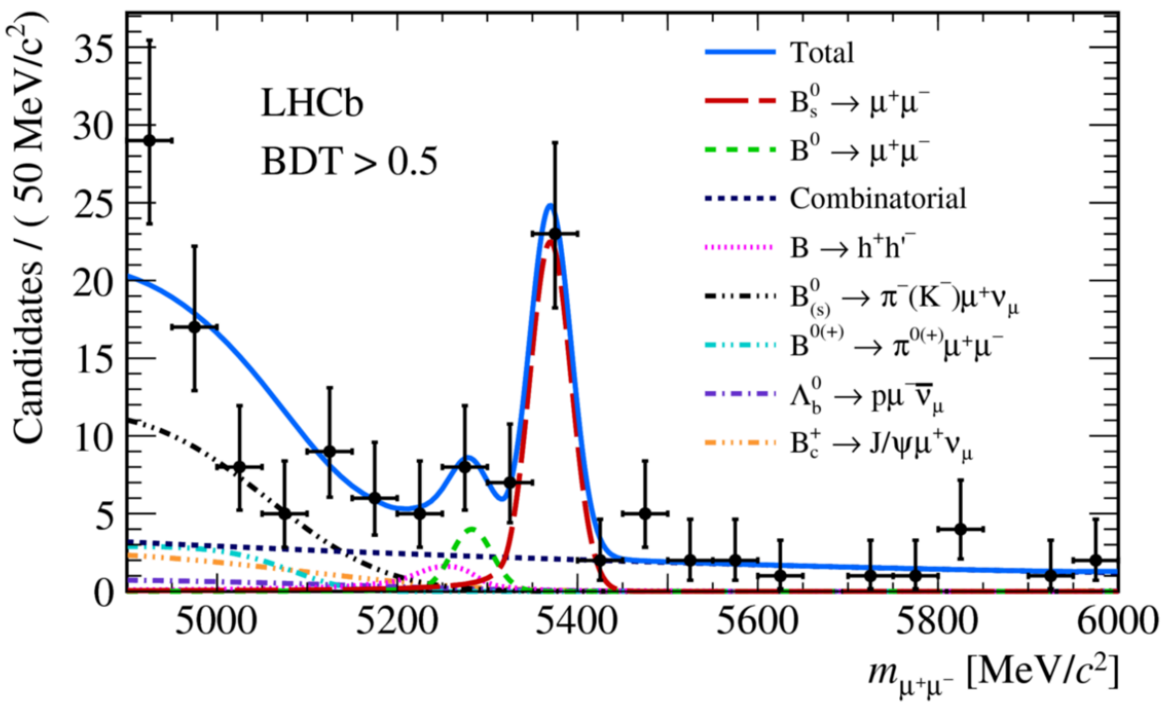
arxiv:1703.05747

LHCb has recently published a first run 1 + run 2 analysis (3+1.4fb^{-1})
updated analysis with improved background suppression

- 7.8 σ signal & first single-experiment observation !
- Precise measurement of branching fraction

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.0 \pm 0.6\,^{+0.3}_{-0.2}) \times 10^{-9}$$

- No evidence yet of the corresponding B^0_d decay (< 3.4 x 10^{-10} at 95% C.L.)



No sign of 1st order New Physics effect!
B→ $\mu^+\mu^-$ becomes a precision test

$B \to \mu^+\mu^-$: First news from run 2

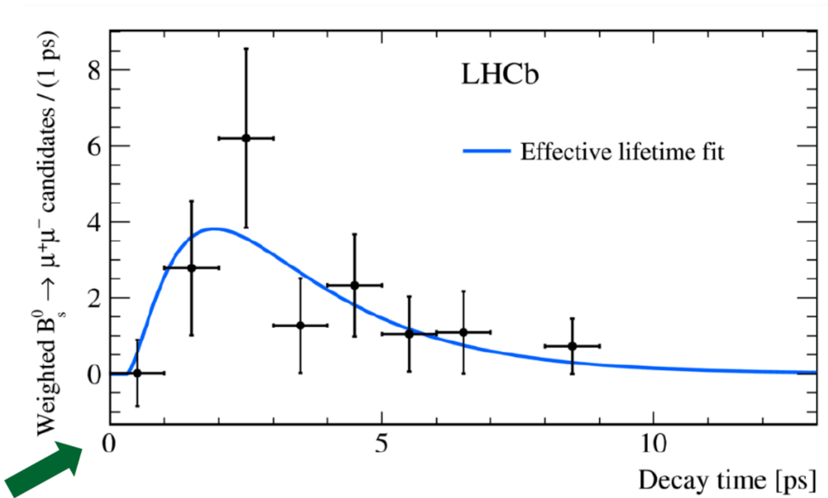
arxiv:1703.05747

LHCb has recently published a first run 1 + run 2 analysis (3+1.4fb^{-1})
updated analysis with improved background suppression

This is not the end of the story !

Vital that these branching ratios are measured ever more precisely - a key goal of the LHCb Upgrade.

In addition, we may start to probe over observables associated with the decay, *e.g.* the effective lifetime.



Proof-of-principle measurement

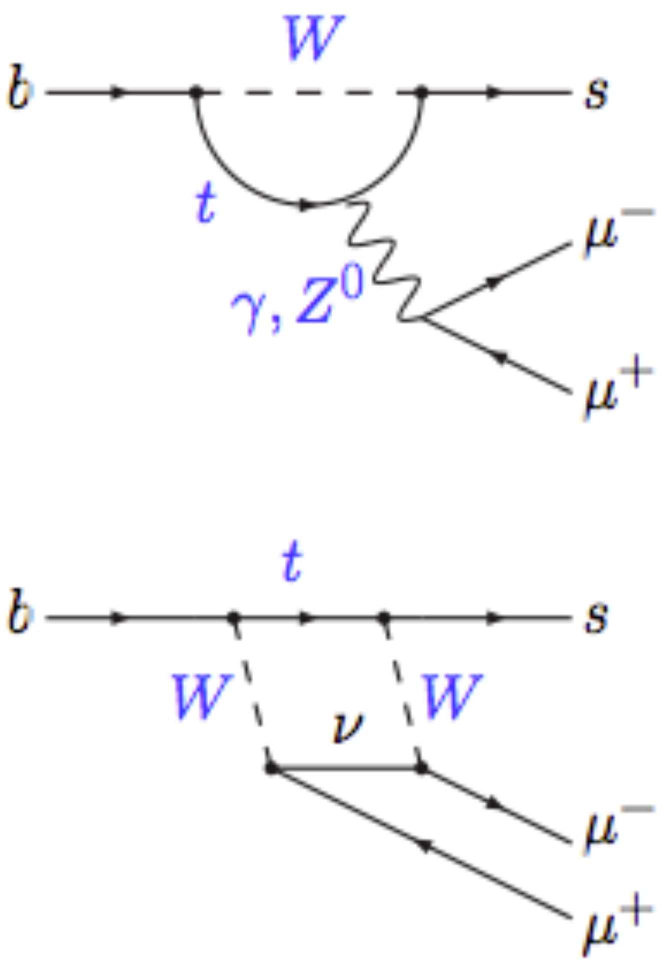
(< 3.4 x 10^{-10} at 95% C.L.)

5000 5200 5400 5600 5800 6000
$m_{\mu^+\mu^-}$ [MeV/c^2]

No sign of 1st order New Physics effect!
$B \to \mu^+\mu^-$ becomes a precision test

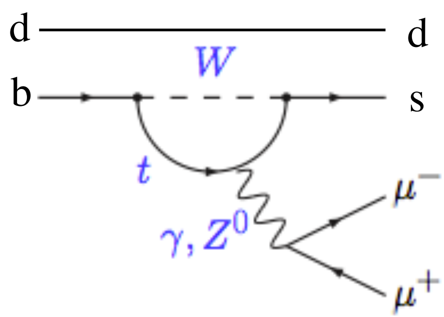
Rare menu

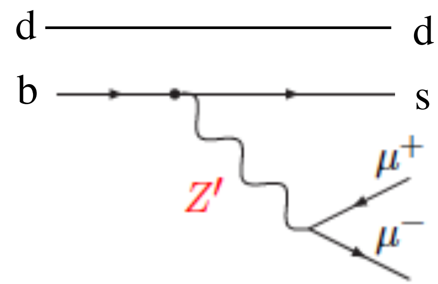
$b \to s\, \mu^+\mu^-$ base diagram



- Purely leptonic
  - "add nothing"
- Semileptonic
  - add d quark as spectator → $B^0 \to K^{*0}\, \mu^+\mu^-$
  - add s quark as spectator → $B_s \to \phi\, \mu^+\mu^-$
  - add u quark as spectator → $B^+ \to K^+\, \mu^+\mu^-$
- Ratios:
  - Compare muons to electrons

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





$$\frac{1}{\mathrm{d}(\Gamma+\bar{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}^3(\Gamma+\bar{\Gamma})}{\mathrm{d}\vec{\Omega}}\bigg|_{\mathrm{P}} = \frac{9}{32\pi}\Big[\tfrac{3}{4}(1-F_{\mathrm{L}})\sin^2\theta_K + F_{\mathrm{L}}\cos^2\theta_K + \\ +\tfrac{1}{4}(1-F_{\mathrm{L}})\sin^2\theta_K\cos 2\theta_l \\ -F_{\mathrm{L}}\cos^2\theta_K\cos 2\theta_l + S_3\sin^2\theta_K\sin^2\theta_l\cos 2\phi \\ +S_4\sin 2\theta_K\sin 2\theta_l\cos\phi + S_5\sin 2\theta_K\sin\theta_l\cos\phi \\ +\tfrac{4}{3}A_{\mathrm{FB}}\sin^2\theta_K\cos\theta_l + S_7\sin 2\theta_K\sin\theta_l\sin\phi \\ +S_8\sin 2\theta_K\sin 2\theta_l\sin\phi + S_9\sin^2\theta_K\sin^2\theta_l\sin 2\phi\Big]$$

fraction of longitudinal polarisation of the K*

forward-backward asymmetry of the dilepton system

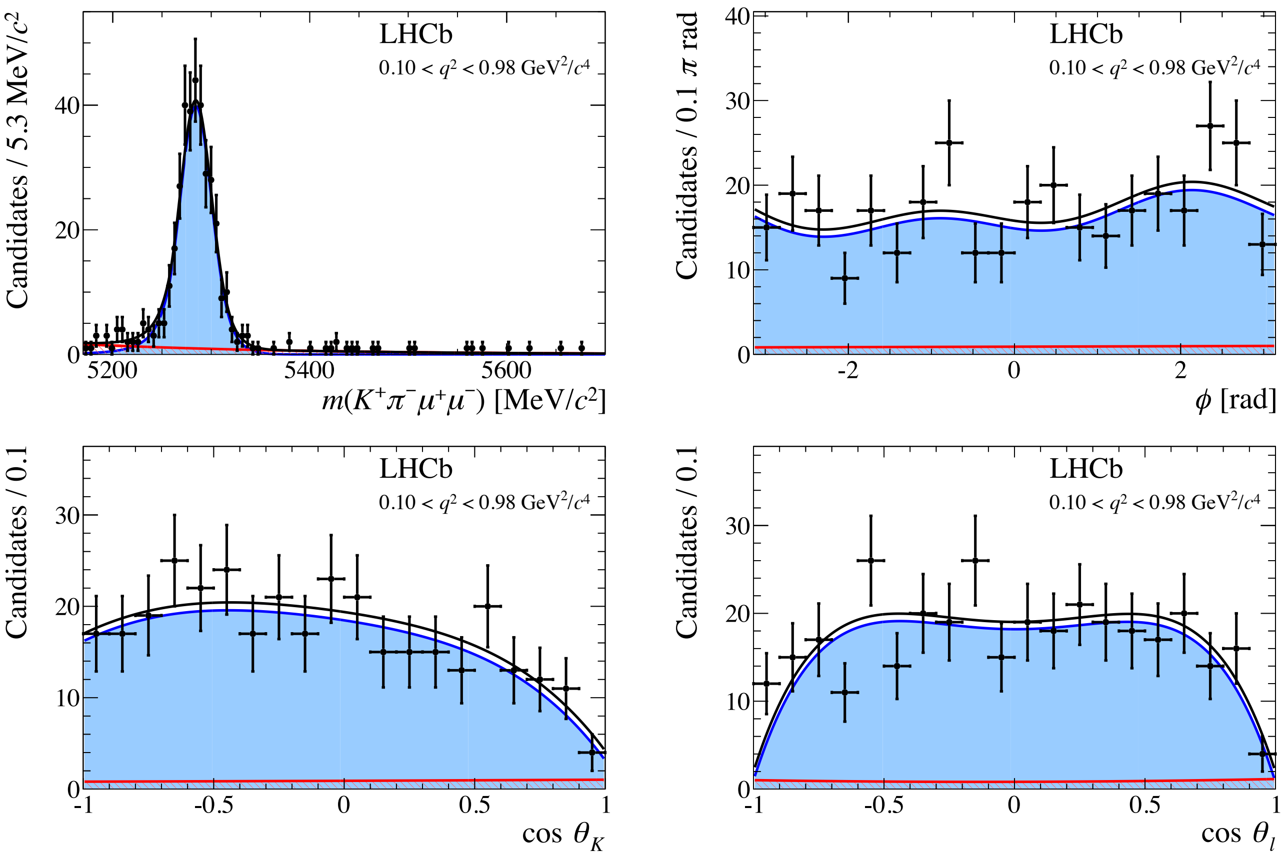
Observables depend on B→K* form factors and on short distance physics

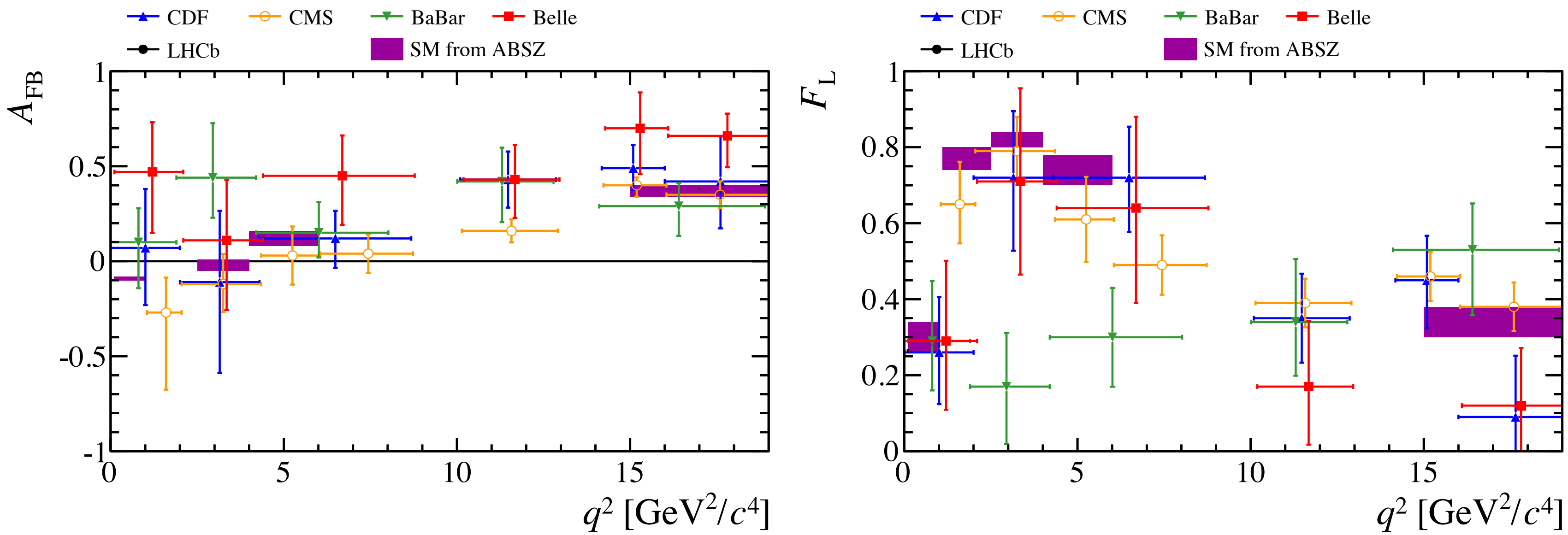
Angular analysis of $B^0 \to K^{*0} \mu^+\mu^-$

- LHCb published the first full angular analysis of the decay
  - Unbinned maximum likelihood fit to $K\pi\mu\mu$ mass and three decay angles
  - Simultaneously fit $K\pi$ mass to constrain s-wave configuration
  - Efficiency modelled in four dimensions
  - Binned in $q^2 = m_{\mu\mu}{}^2$

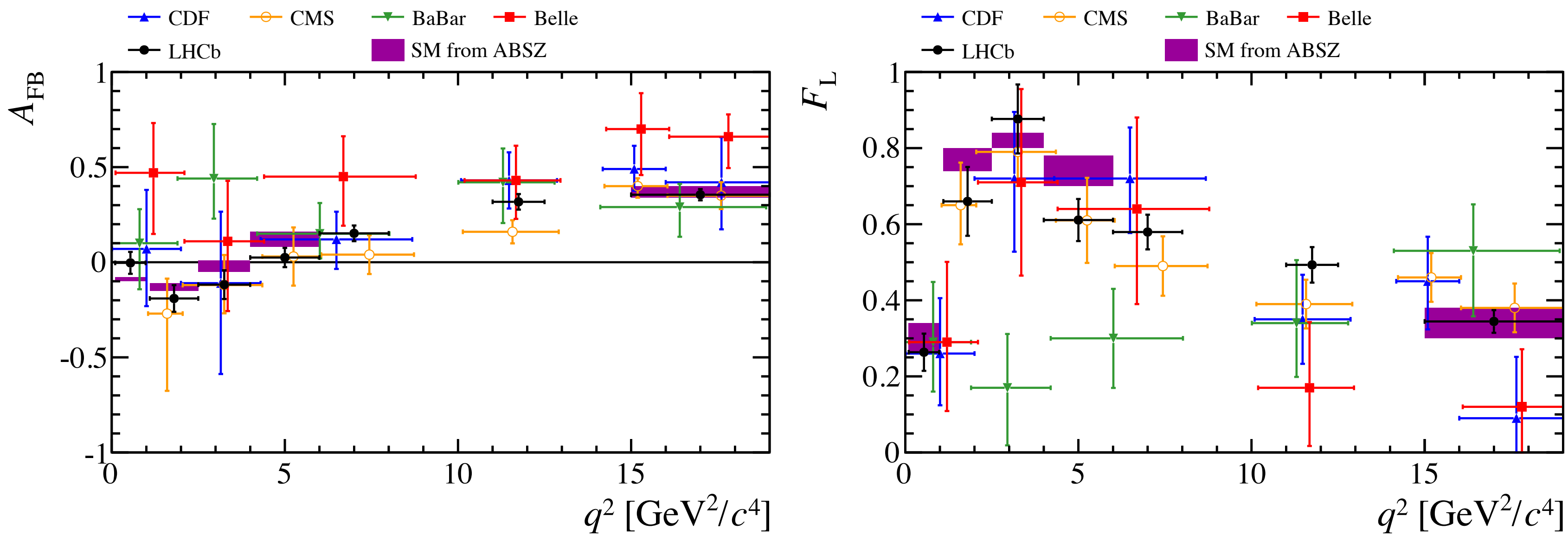
JHEP02(2016)104

Example fit projections in low q^2 bin





References:
LHCb [JHEP 02 (2016) 104] ,
CMS [PLB 753 (2016) 424]
BaBar [arXiv:1508.07960]
CDF [PRL 108 (2012) 081807]
Belle [PRL 103 (2009) 171801].

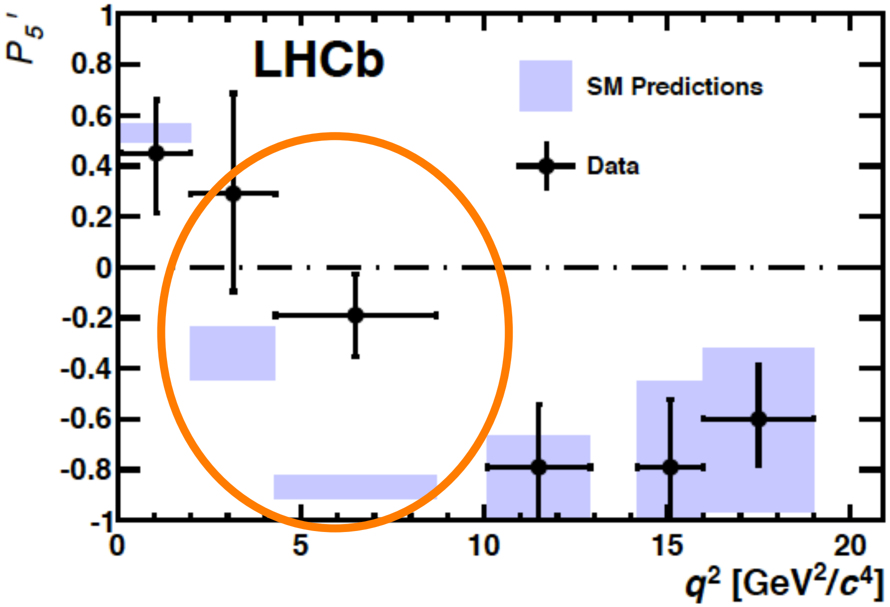


References:
LHCb [JHEP 02 (2016) 104] ,
CMS [PLB 753 (2016) 424]
BaBar [arXiv:1508.07960]
CDF [PRL 108 (2012) 081807]
Belle [PRL 103 (2009) 171801].

Puzzling deviations: $B^0 \to K^{*0} \mu^+\mu^-$

- 2013, LHCb has observed a deviation in angular observables in $B^0 \to K^{*0} \mu^+\mu^-$ decays

LHCb, Phys.Rev.Lett. 111 (2013) 191801



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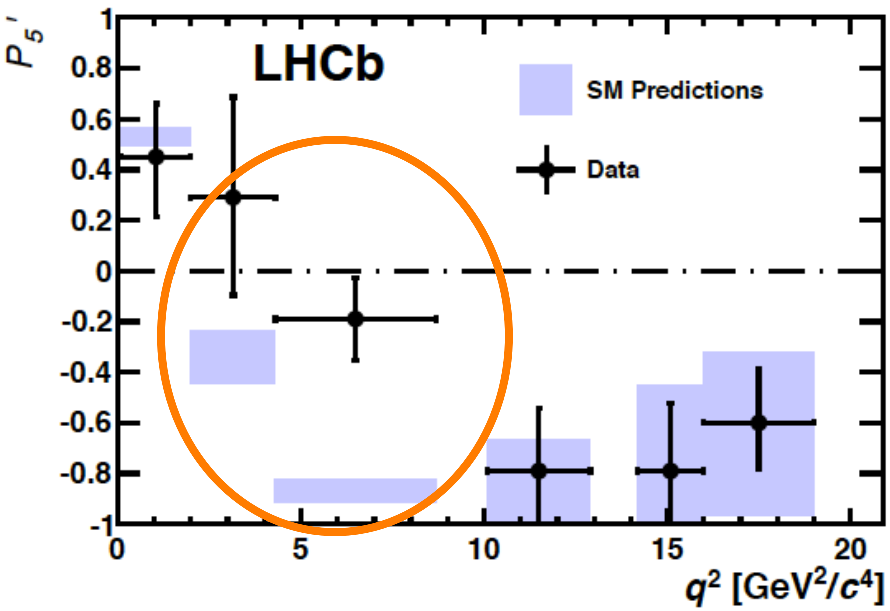
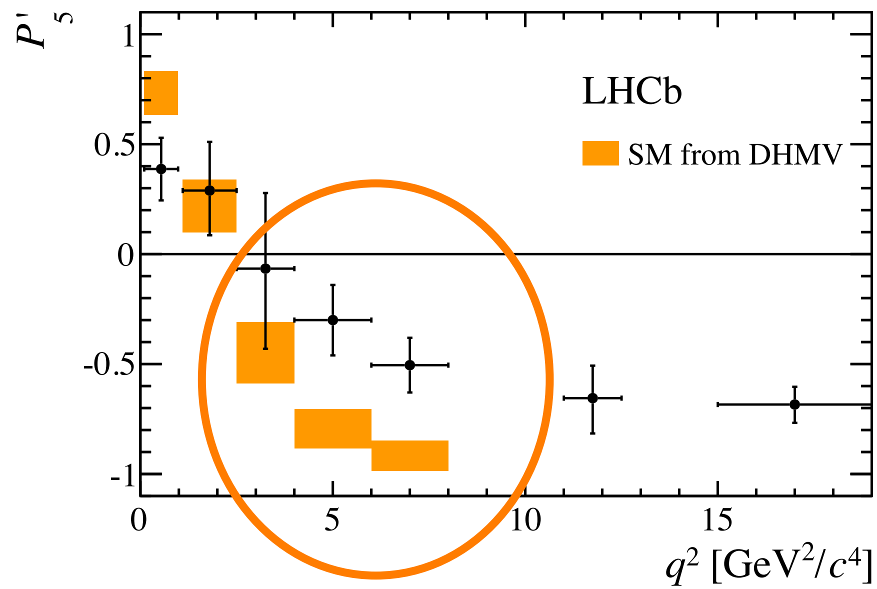
LHCb, Phys.Rev.Lett. 111 (2013) 191801





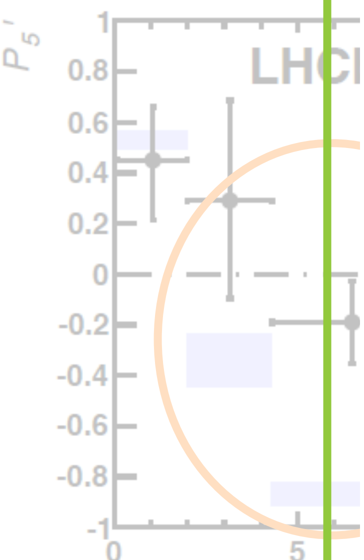
[LHCb, JHEP 02 (2016) 104]

- Full Run 1 analysis confirms effect

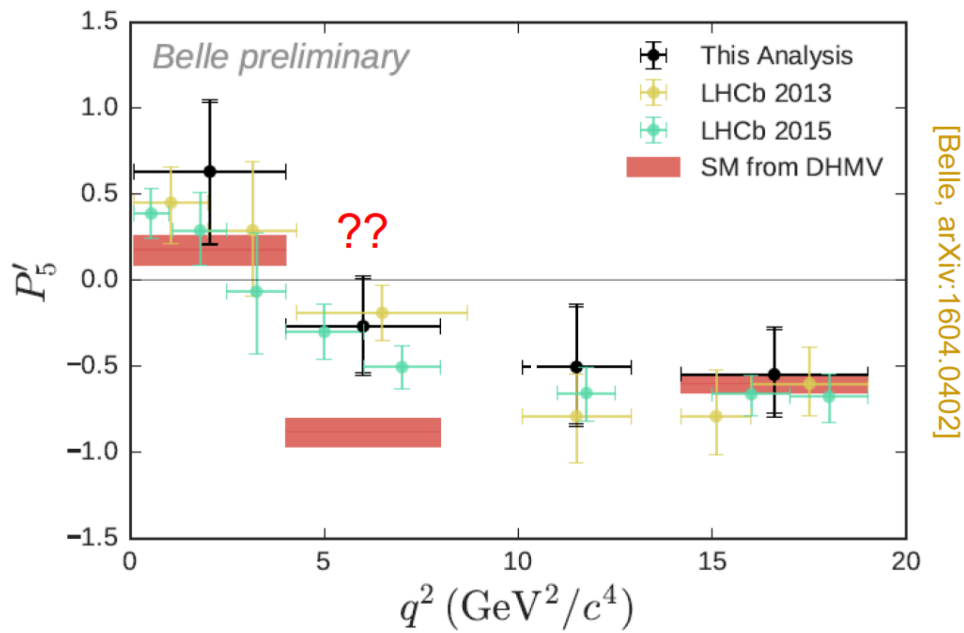
Puzzling deviations: $B^0 \to K^{*0} \mu^+\mu^-$

- 2013, LHCb has observed a deviation in angular observables in $B^0 \to K^{*0} \mu^+\mu^-$ decays

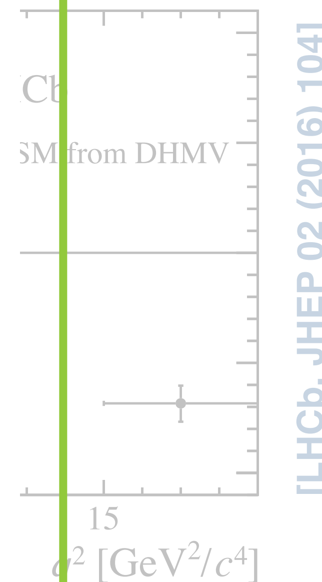
LHCb, Phys.



Belle still has a word to say



Lower statistical power, but very consistent



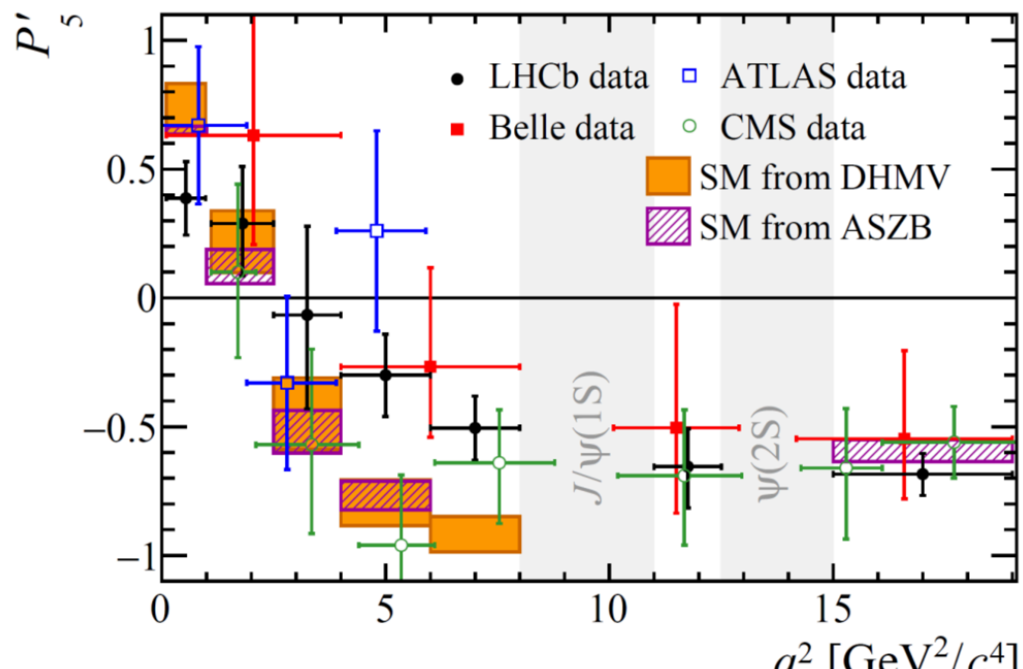
- Full Run

Puzzling deviations: $B^0 \to K^{*0} \mu^+\mu^-$

- 2013, LHCb has observed a deviation in angular observa... decays

LHCb, Phys. ...

… very recently ATLAS and CMS joined



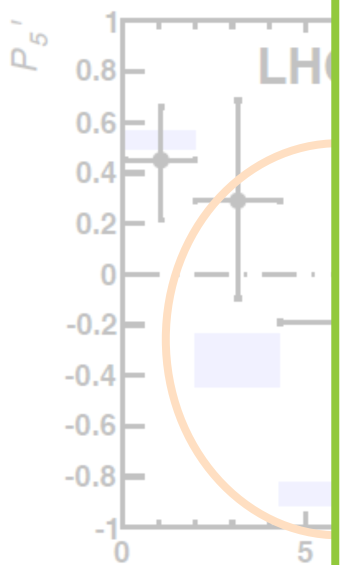
[ATLAS-CONF-2017-023, CMS-PAS-BPH-15-007]

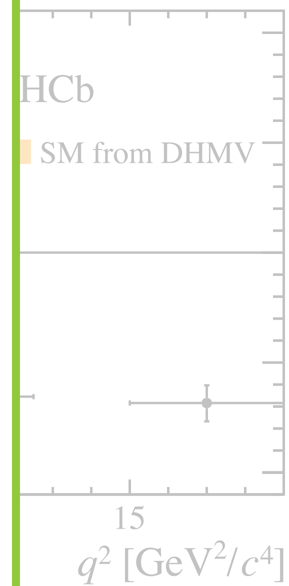
[LHCb, JHEP 02 (2016) 104]

- Full Ru...

- 2013, LHCb has observed a deviation in angular observables in $B^0 \to K^{*0}\mu^+\mu^-$ decays

LHCb, Phys.





[LHCb, JHEP 02 (2016) 104]

- Full Ru

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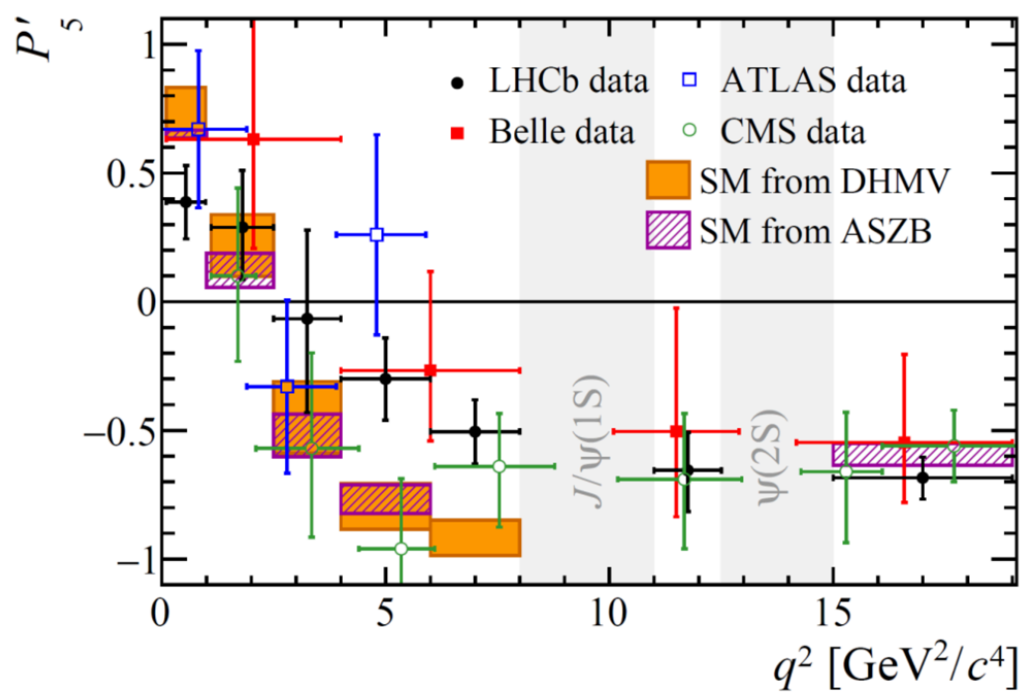
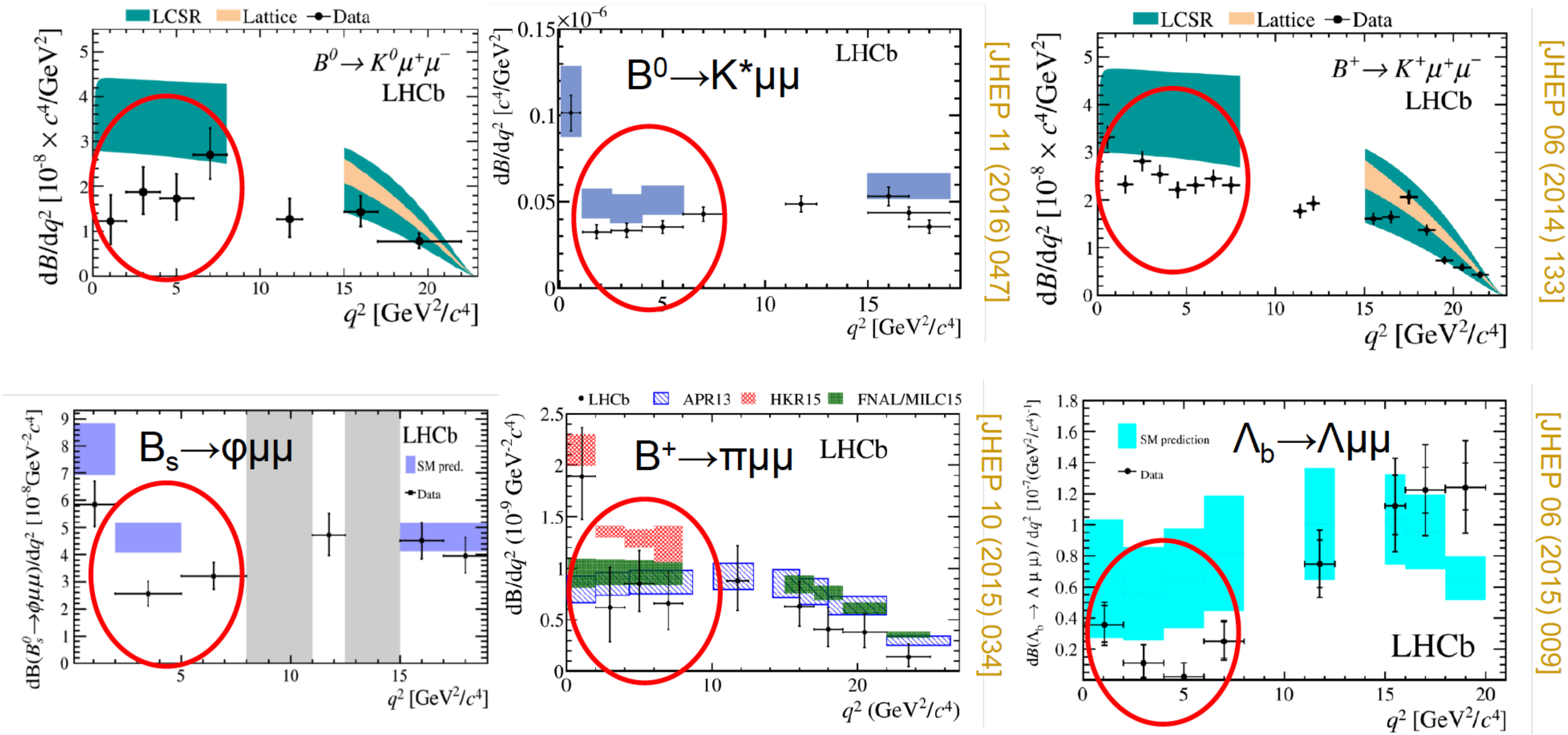


[ATLAS-CONF-2017-023, CMS-PAS-BPH-15-007]

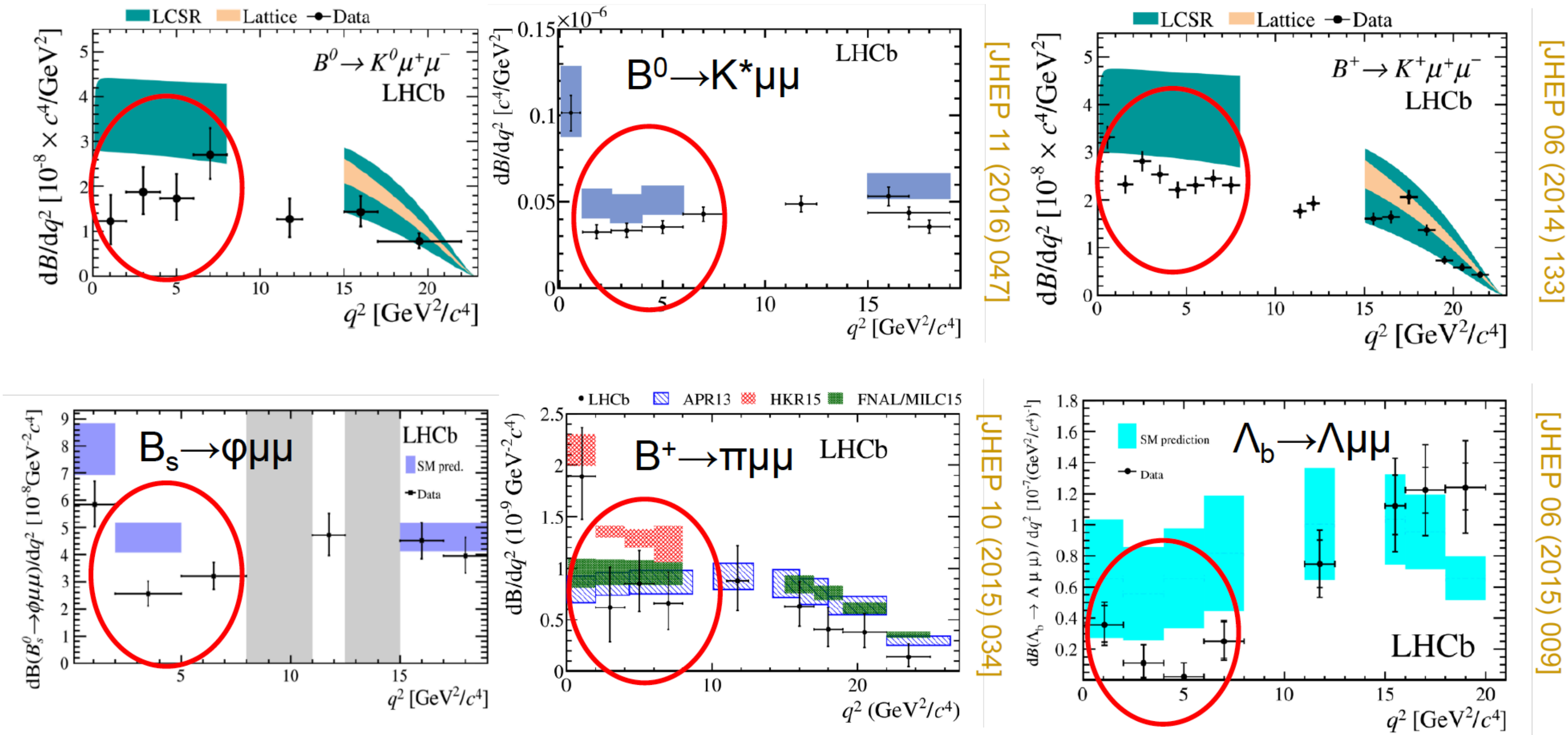
Situation unclear…. If real, expect discrepancies in **other $b \to s$ decays** ..

Branching fractions of $b \to s\, \mu^+\mu^-$



- Analysis of large class of $b \to s,d\ \mu^+\mu^-$ decays
  - Several tensions seen, but individual significance is moderate
  - Tendency to undershoot prediction of differential x-sections

Branching fractions of $b \rightarrow s\,\mu^+\mu^-$



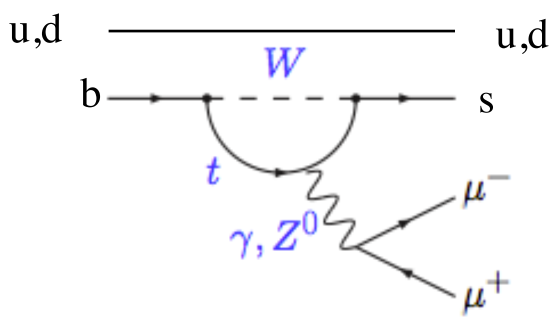
- Analysis of large class of $b \rightarrow s,d\ \mu^+\mu^-$ decays
  - Several tensions seen, but individual significance is moderate
  - Tendency to undershoot prediction of differential x-sections
    → intriguing hint or TH issue in prediction?

→ We need cleaner tests …

Lepton universality

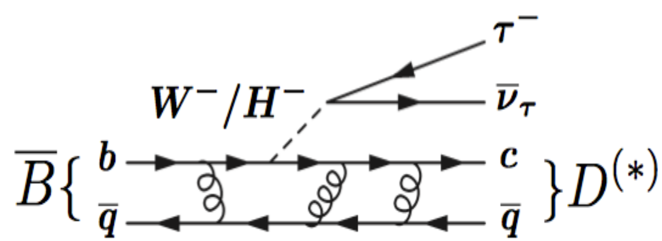
- In the SM, leptons couple universal to $W^{\pm}$ and Z^0
  → test this in ratios of semileptonic decays

<u>electrons / muons</u>



$$R_K = \frac{BR(B^+ \to K^+ \mu^+ \mu^-)}{BR(B^+ \to K^+ e^+ e^-)}$$

<u>tau / muons</u>



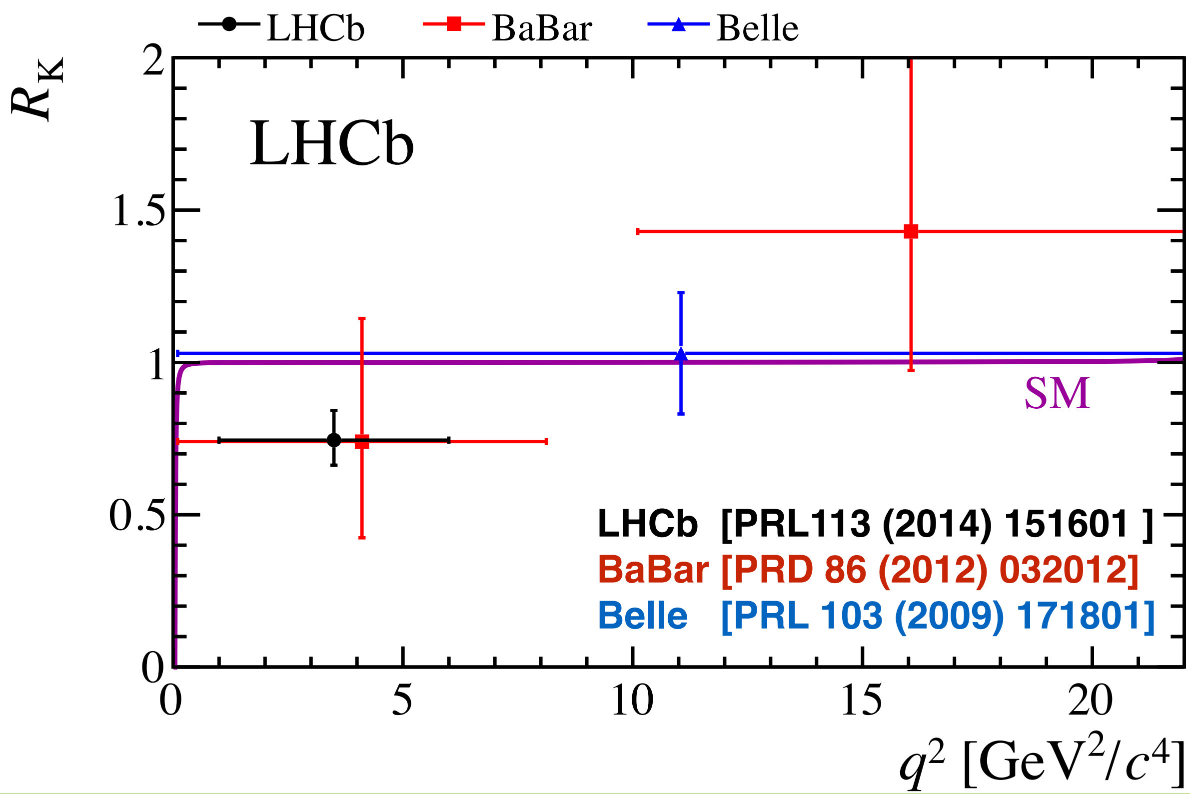
$$R_{D*} = \frac{BR(B^0 \to D^{*+} \tau^- \overline{\nu})}{BR(B^0 \to D^{*+} \mu^- \overline{\nu})}$$

- Ratios differ from unity only by phase space
  → hadronic uncertainties cancel in the ratio

LHCb measures with $3fb^{-1}$

$$R_K = \frac{BR(B^+ \to K^+\mu^+\mu^-)}{BR(B^+ \to K^+e^+e^-)} = 0.745 \begin{matrix} +0.090 \\ -0.074 \end{matrix} (stat) \pm 0.036(syst)$$

(SM: R_k=1.0, consistent at 2.6σ)



LFU: new Result with $B^0 \to K^{*0} \ell^+ \ell^-$

An analogous measurement has now been performed with $B^0 \to K^* l^+ l^-$
[LHCb-PAPER-2017-013]

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

This double ratio, involving the control mode $B^0 \to J/\psi K^*$, ensures that all 1st order systematics in efficiency cancel – robust ! Nonetheless, great efforts are made to understand these efficiencies from data, and also to check that $\mathcal{B}(B^0 \to J/\psi K^*)$ is measured to be the same in both muon and electron channel – a stringent test !

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

Similar cross-checks performed with *e.g.* $\psi(2S)$.

Attention paid to partially reconstructed region & potential leakage from J/ψ region.

Analysis regions

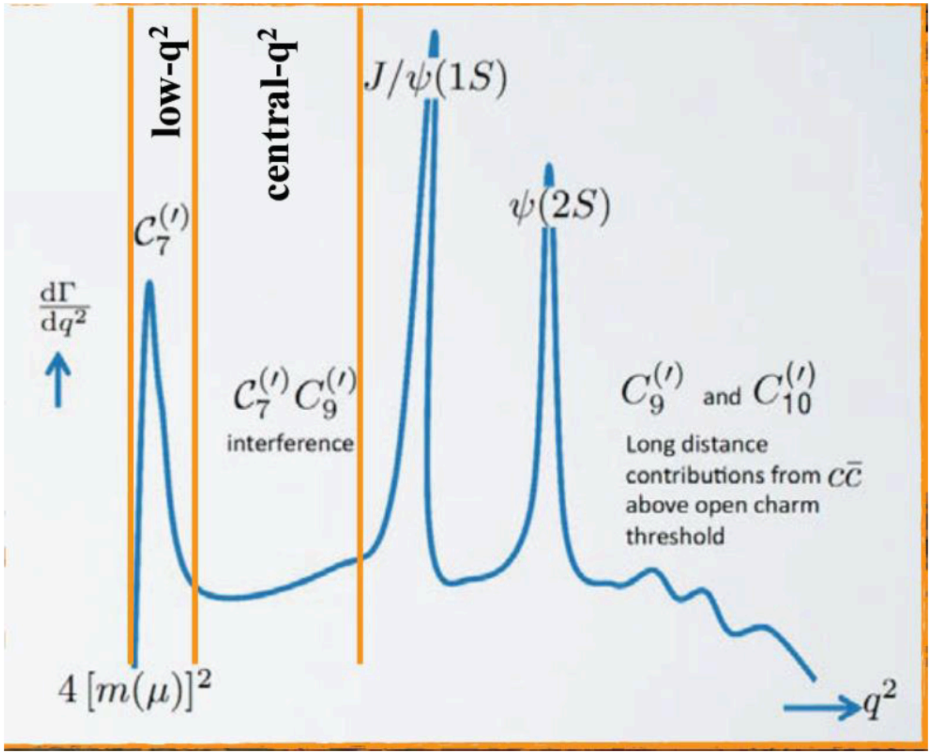
Measurement performed
in two q^2 regions:

Low: $0.045 < q^2 < 1.1$ GeV^2

Central: $1.1 < q^2 < 6.0$ GeV^2

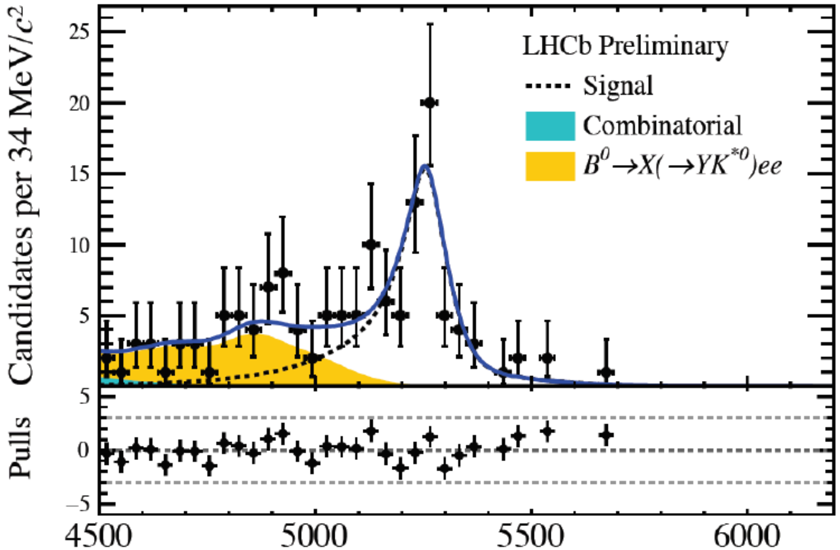
(high q^2 region, above resonances, is certainly of interest, but this presents different experimental challenges, and requires a separate analysis)

Comic of di-lepton spectrum

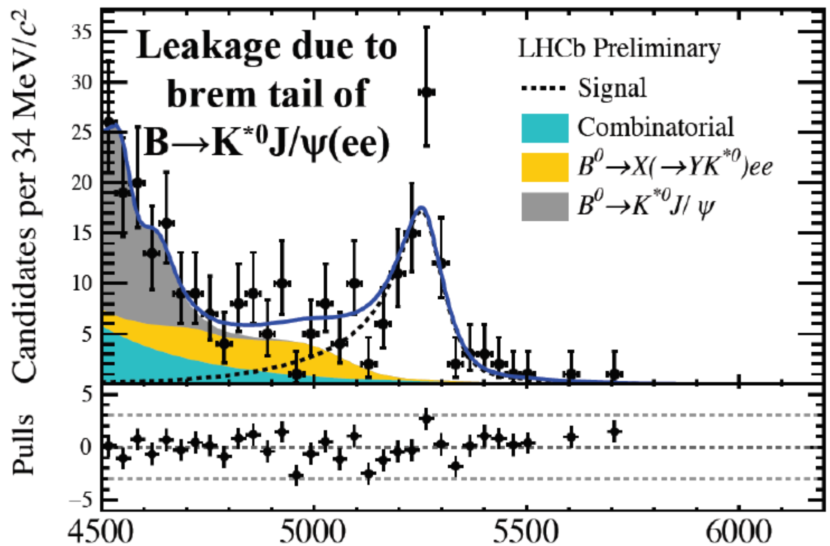


For $K^*e^+e^-$, three exclusive trigger categories are used, depending on whether triggered on electron(s) (L0E), K* candidate(s) (L0H), or not on signal (TIS)

Mass spectra in di-electron final state



low-q^2

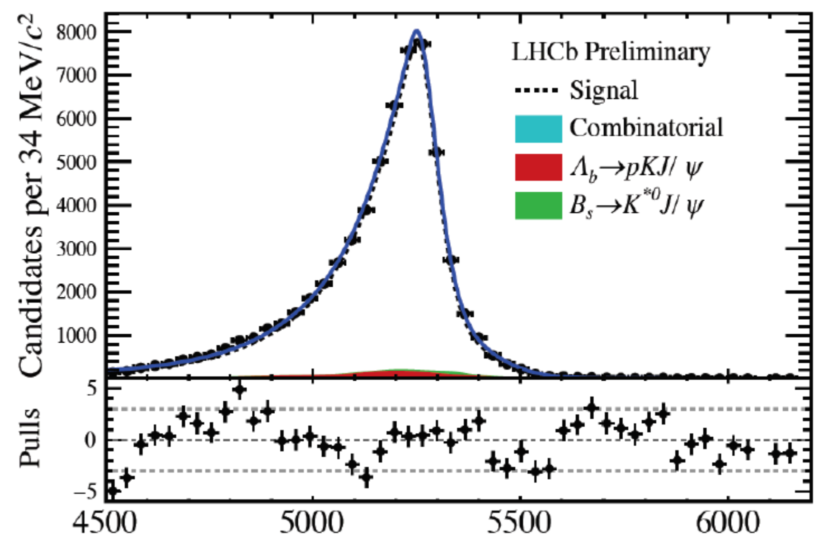


central-q^2

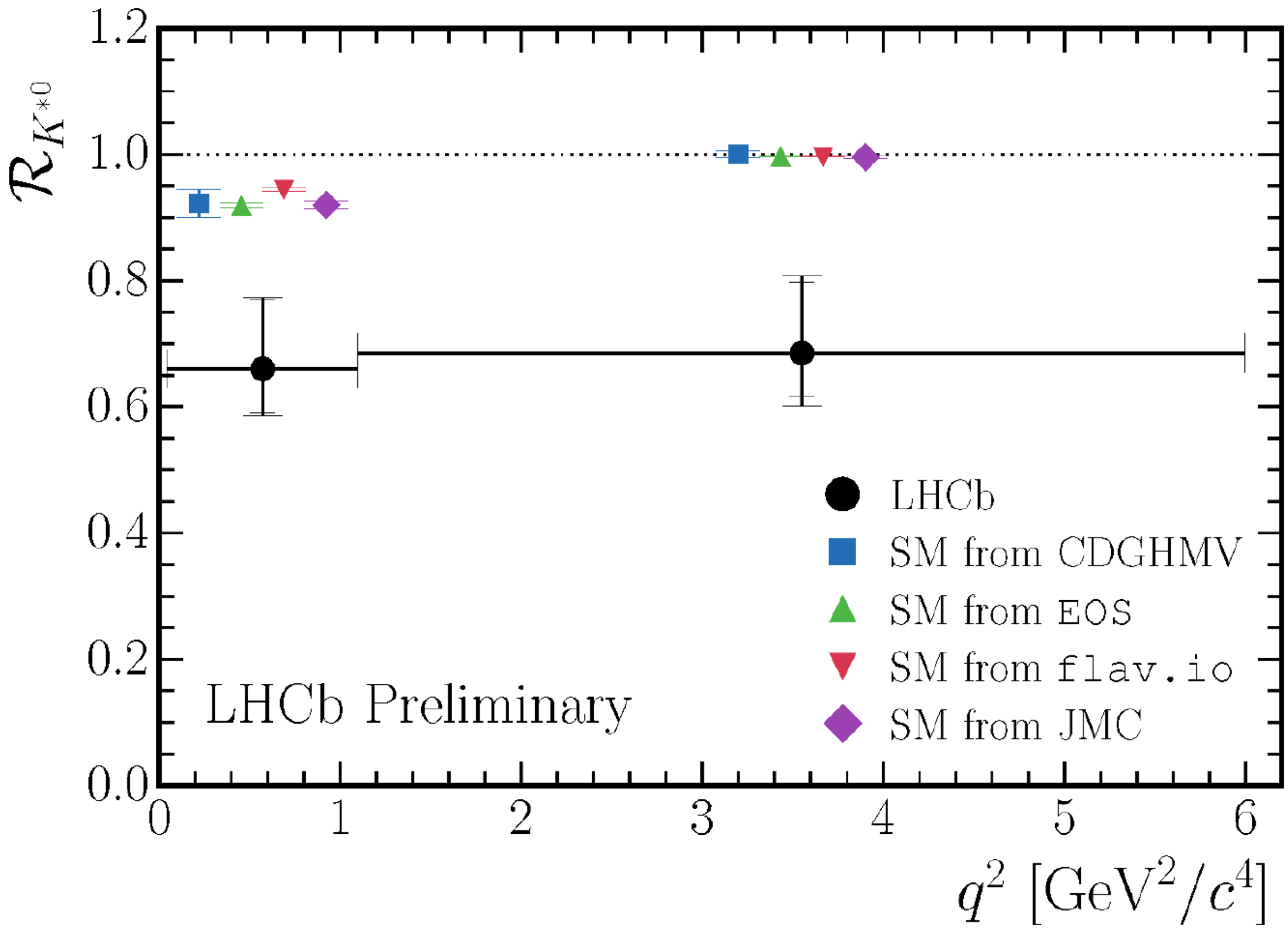
Around 90 and 110 signal candidates in low-q^2 and central q^2, respectively.

58k in control channel

Muon samples 3-5x larger



$B^0 \to J/\psi\ (e^+e^-)\ K^{*0}$



2.2-2.4 σ and 2.4-2.5 σ away from SM at low and central-q^2, respectively.

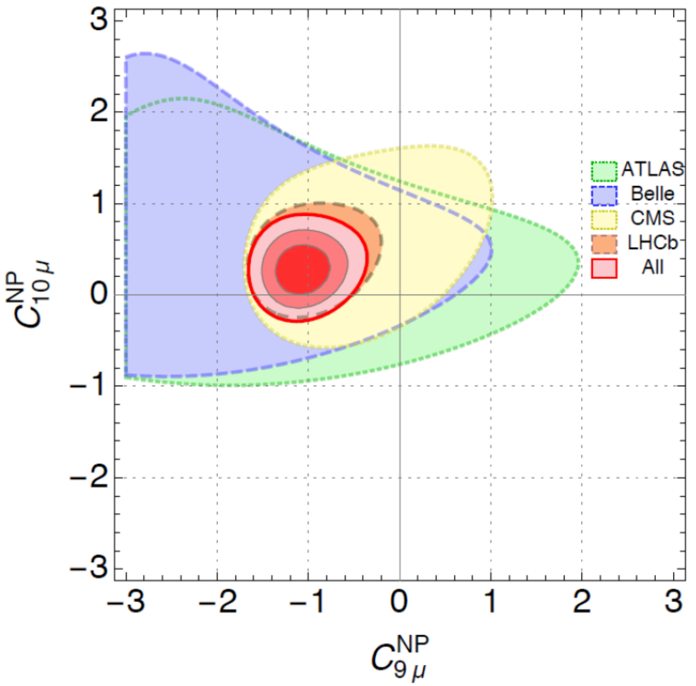
Interpretation?

Already much theoretical interest in b→(s,d)l^+l^- sector prior to latest result.

Typical approach – global analysis of all observables and fit to Wilson coefficients.

What is intriguing, and undeniable, is that a coherent picture emerges. The R_{K^*} result fits this picture well (certainly, at central-q^2).

One example [arXiv:1704.05340].
These fits can give >5σ pulls w.r.t. SM, & have led to excited discussion of Z's, leptoquarks *etc*.

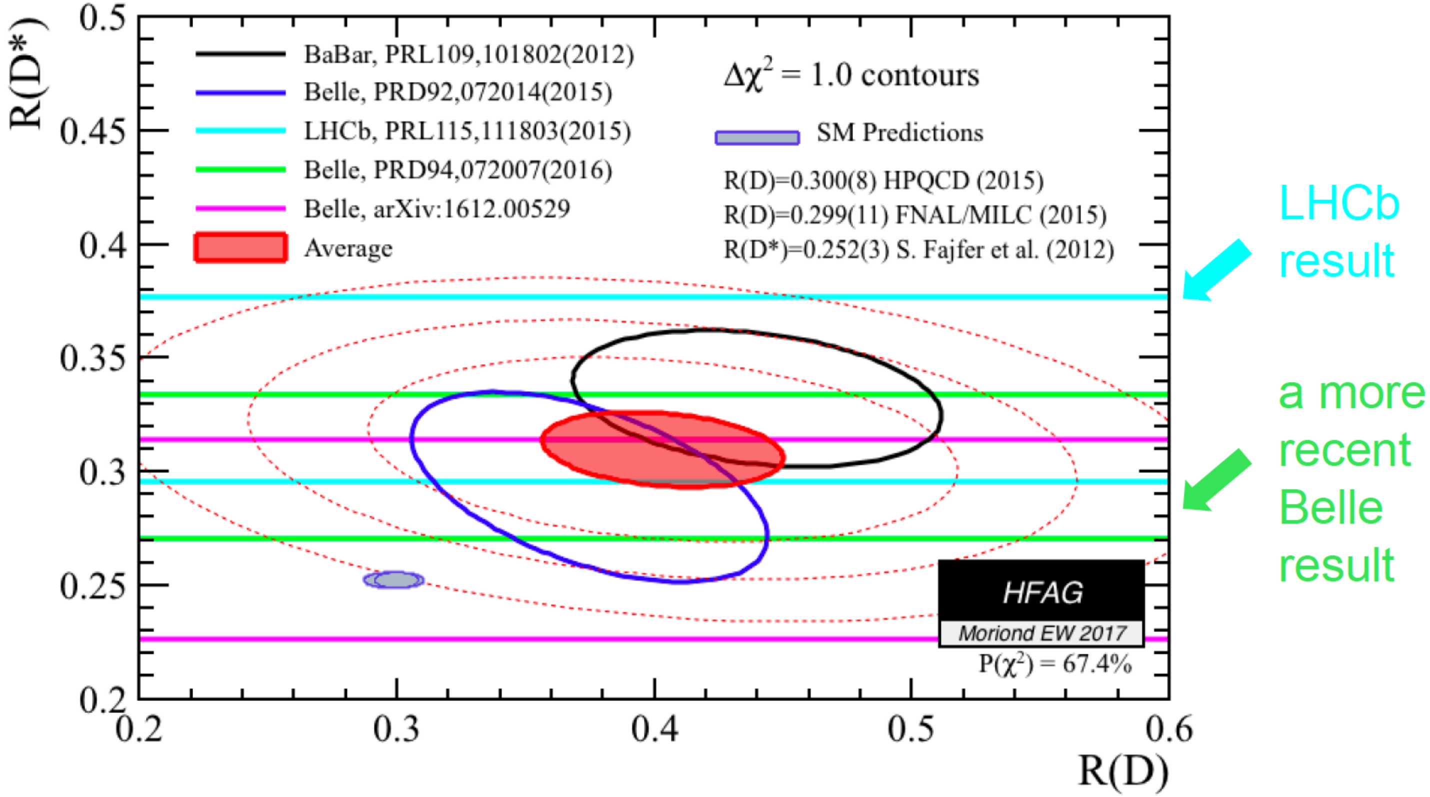


The experimentalist's view:

- Hypotheses non fingo !
- Recall, for several of observables there is no consensus on the theory errors.
- Excitement premature: we should wait until we see highly significant deviations in one or more LFU observables. Wait for run-2 updates on R_K, R_{K^*} & indeed R_φ.

R(D) and R(D*)

Combination of measurements paint an intriguing picture…

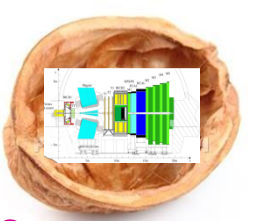


…3.9σ away from SM predictions. New measurements will come from LHCb, including (very soon) a determination of *R(D*)* using $\tau \to \pi\pi\pi\nu$, which will be rather precise. If the central value remains stable, we may well have a 'crisis' !

Heavy Flavour Future

Heavy quark flavour physics experiments

LHCb upgrade in a nutshell



Our knowledge of flavour physics has advanced spectacularly thanks to LHCb.
Maintaining this rate of progress beyond run 2 requires significant changes.

The LHCb Upgrade

1) Full software trigger
- Allows effective operation at higher luminosity
- Improved efficiency in hadronic modes

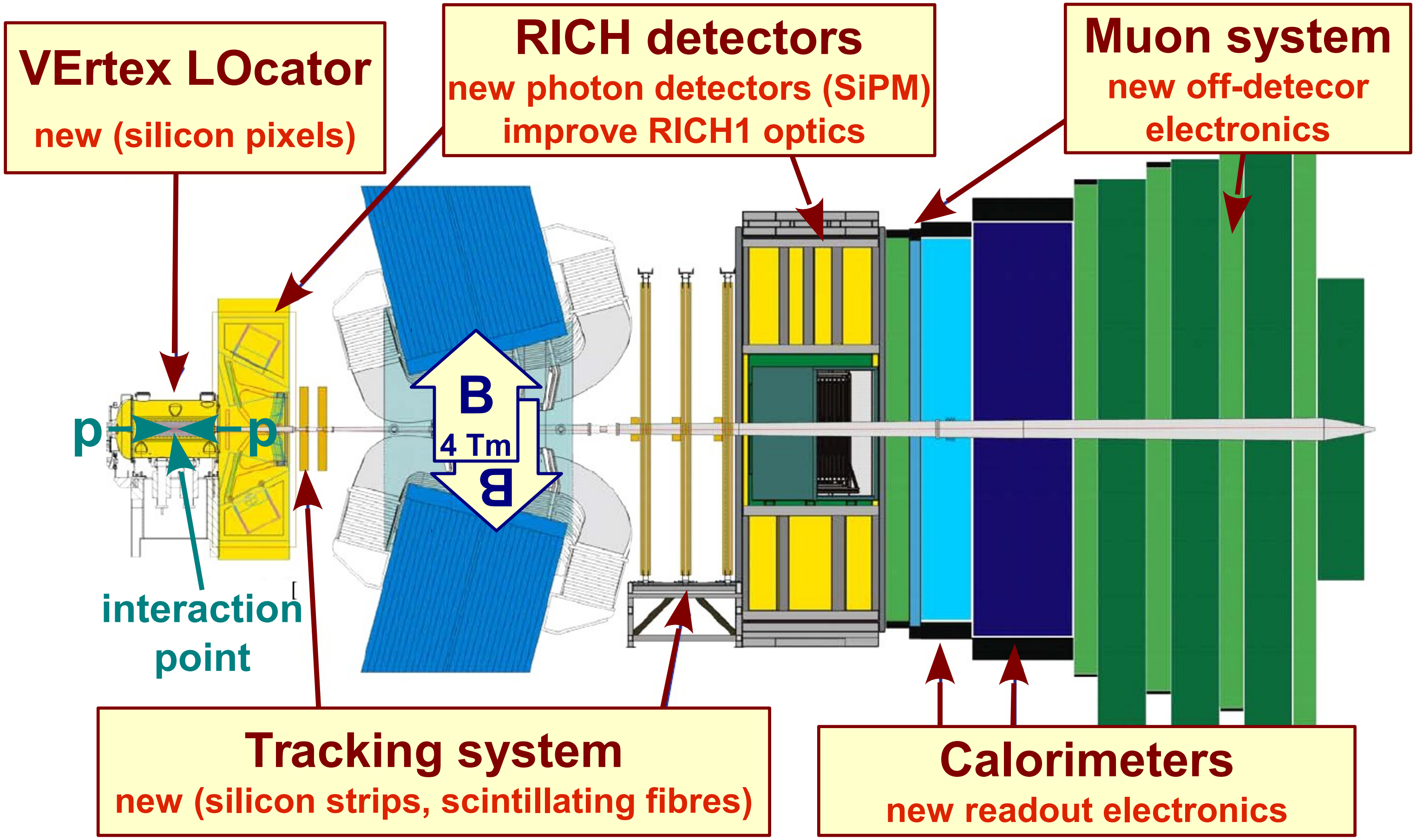
2) Raise operational luminosity to 2×10^{33} cm^{-2} s^{-1}

Necessitates redesign of several sub-detectors & overhaul of readout

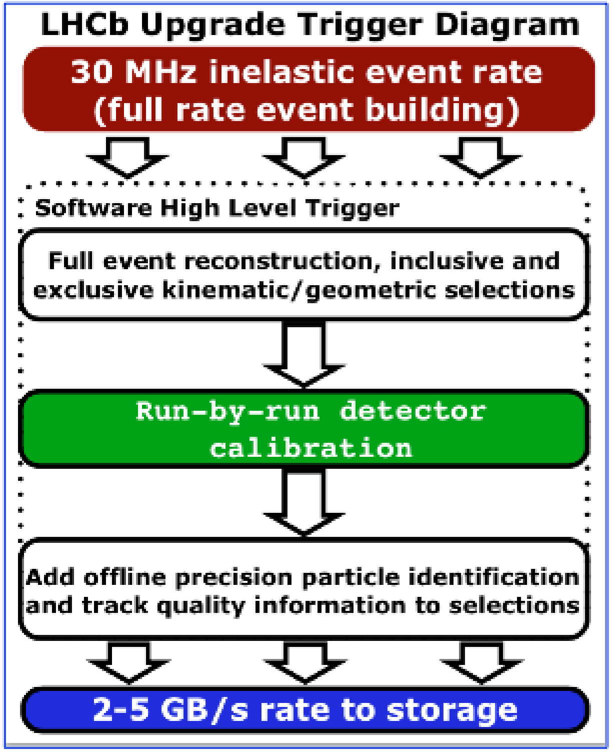
Huge increase in precision, in many cases to the theoretical limit, and the ability to perform studies *beyond the reach of the current detector*.

Flexible trigger and unique acceptance also opens up opportunities in other topics apart from flavour ('a general purpose detector in the forward region')

LHCb upgrade scheme

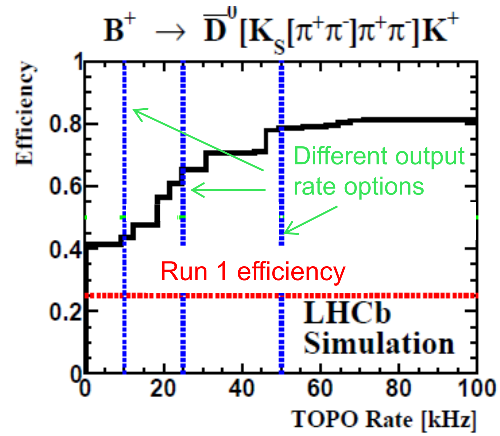


- **40 MHz readout → replace sub-systems with embedded front-end electronics**
- **5 × higher luminosity → adapt detector technology where needed to maintain excellent performance**



Upgrade software trigger

Full event information → much improved efficiency



NB: many of run-2 innovations can also be considered as R&D for the Upgrade trigger !

- Detector readout and trigger at 40 MHz + higher rate to storage will be the drivers to handle 5x luminosity and collect larger samples
- Based on new front-end electronics, large PC-based event-builder network, and large expansion of online CPU farm
- Real-time data calibration and reconstruction

Complementarity LHCb – Belle 2

- Time dependent B_s physics
  - CPV in $B_s \to J/\psi\ \phi$, $B_s \to \phi\phi$
- $B_s \to \mu^+\mu^-$
- CKM angle γ
- CPV in B_d
- $B \to X_s\ \ell^+\ell^-$ (exklusive)
- $B \to X_s\ \gamma$ (exklusive)
- Charm physics
- Semileptonic B decays
- $B \to D\ \tau^-\ \nu$, $B \to D^*\ \tau^-\ \nu$
- Dark matter
- τ – physics: LFV
- $B \to \tau^-\ \nu$, $B \to \mu^-\ \nu$
- $B \to K^*\ \nu\nu$, $B \to \nu\nu$
- $B \to X_s\ \ell^+\ell^-$ (inclusive)
- $B \to X_s\ \gamma$ (inclusive)

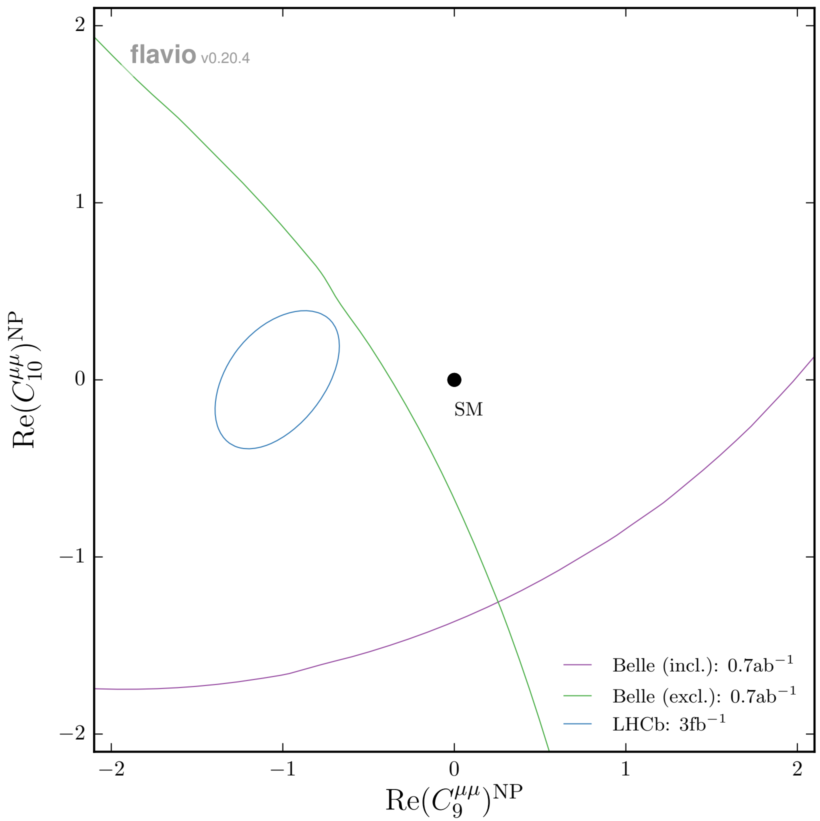
"B_s & charged tracks"

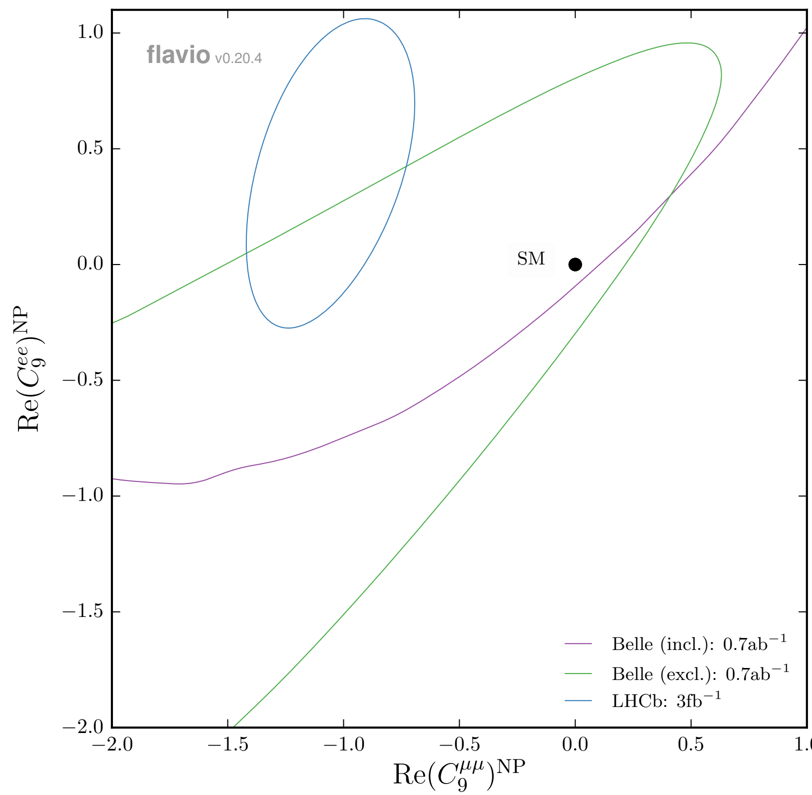
Important overlap: sporty competition!

"inclusive & neutrals "

Expected future sensitivities

- Global fit to $b \rightarrow s$ data
- Many such fits around → essentially consistent results



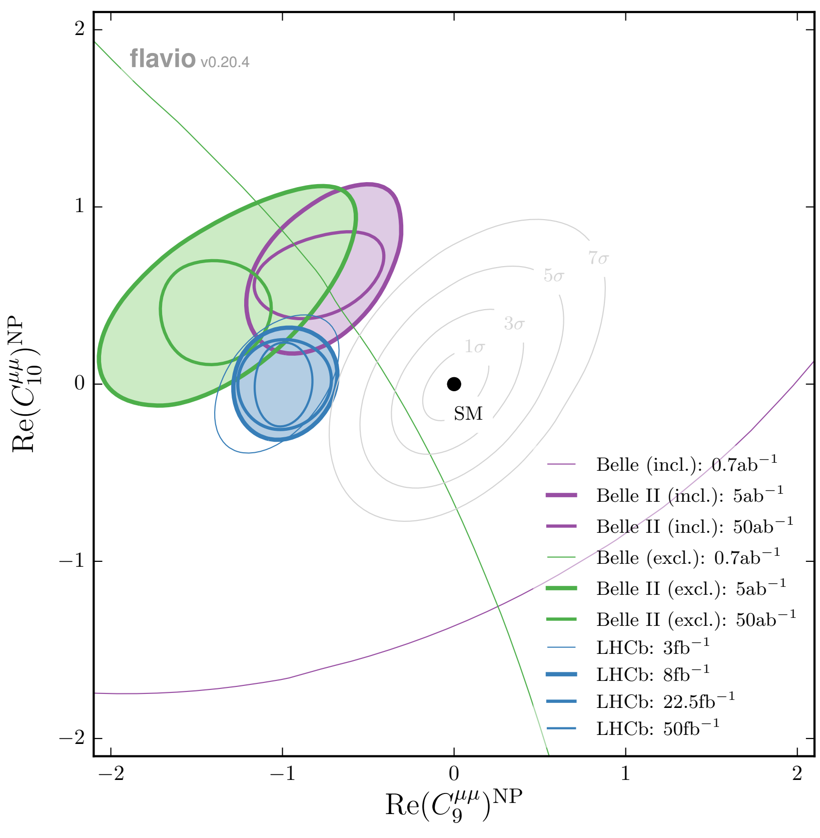


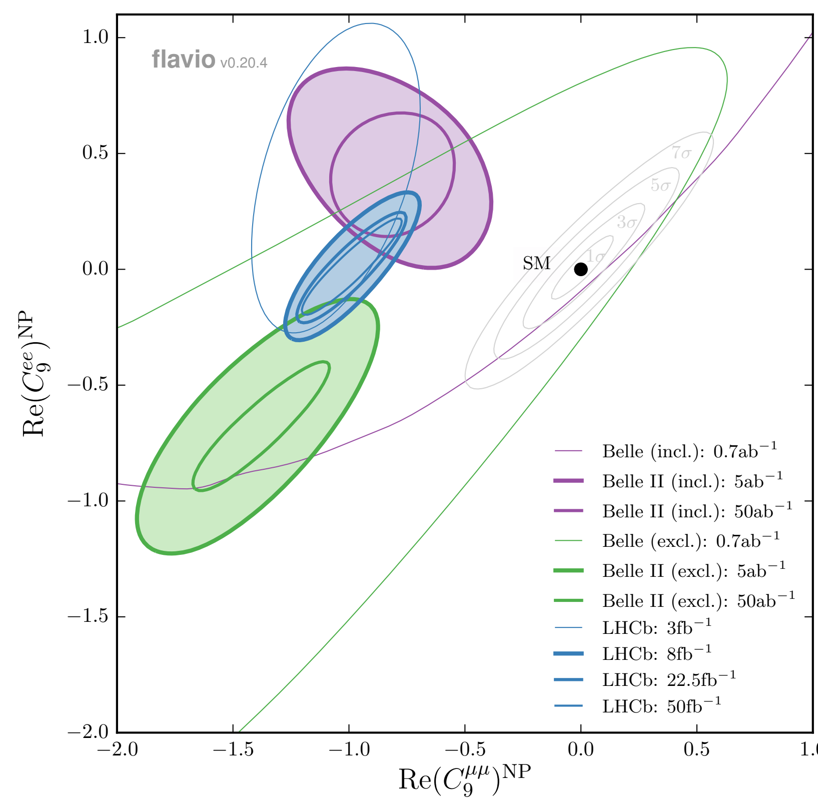
Central value moved for illustration

Wilson scan: S. Reichert, D. Straub, F. Bernlochner, J.A.

Expected future sensitivities

- Global fit to $b \to s$ data
- Many such fits around → essentially consistent results
- Project sensitivity to final Belle2 & LHCb dataset





Central value moved for illustration

Wilson scan: S. Reichert, D. Straub, F. Bernlochner, J.A.

Summary

- The Standard Model is tested in a variety of channels

  → many measurements consistent with predictions

  → **significant deviations in of $b \rightarrow s\, \ell^+ \ell^-$ channels, lepton flavour universality is currently a hot topic**

  → **need for data to conclude**

- Interesting flavour data coming soon
  - LHCb Run 2 → tripling the dataset (~factor 2 already!)
  - LHCb Upgrade – record data with „Trigger-less Readout“
  - Belle2 in the starting blocks