Introduction to LHCb
Status, highlights and prospects

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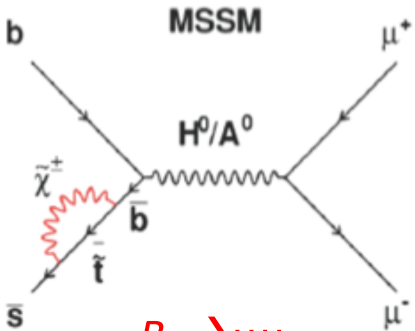
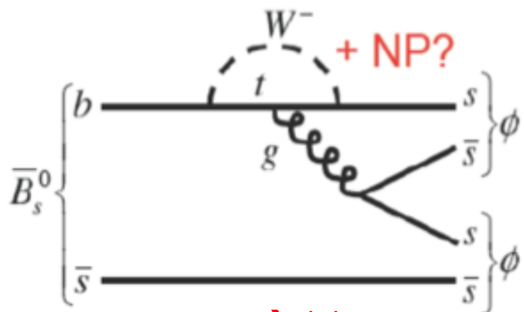
Joint BESIII-LHCb workshop
IHEP Beijing, China
8 February 2018

New physics searches in the flavour sector

- Instead of searching for NP particles directly produced, look for their indirect effects to low energy processes (e.g. *b*-hadron decays)

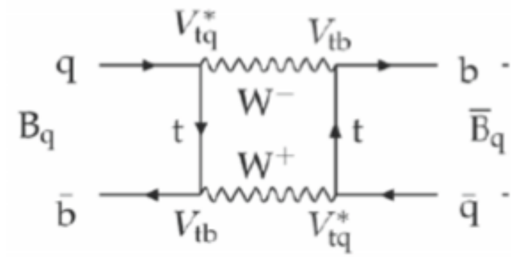


$B_s \rightarrow \mu\mu$



$B_s \rightarrow \phi\phi$

B-$\bar{B}$ mixing



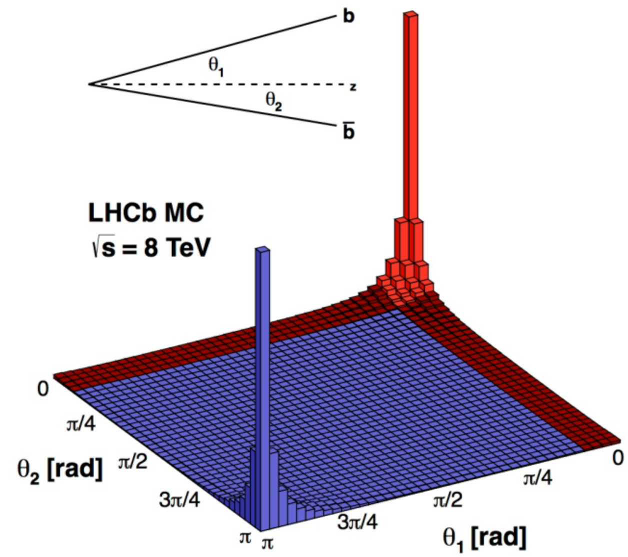
+ NP?

$$A = A_0 \left[c_{SM} \frac{1}{M_W^2} + c_{NP} \frac{1}{\Lambda^2} \right]$$

- General amplitude decomposition in terms of couplings and scales → in presence of sizeable SM contributions, NP effects might be hidden
  - Need high precision measurements of theoretically clean observables
- By studying *CP*-violating and flavour-changing processes, two fundamental tasks can be accomplished
  - Identify new symmetries (and their breaking) beyond the SM
  - Probe mass scales not accessible directly at a collider like LHC

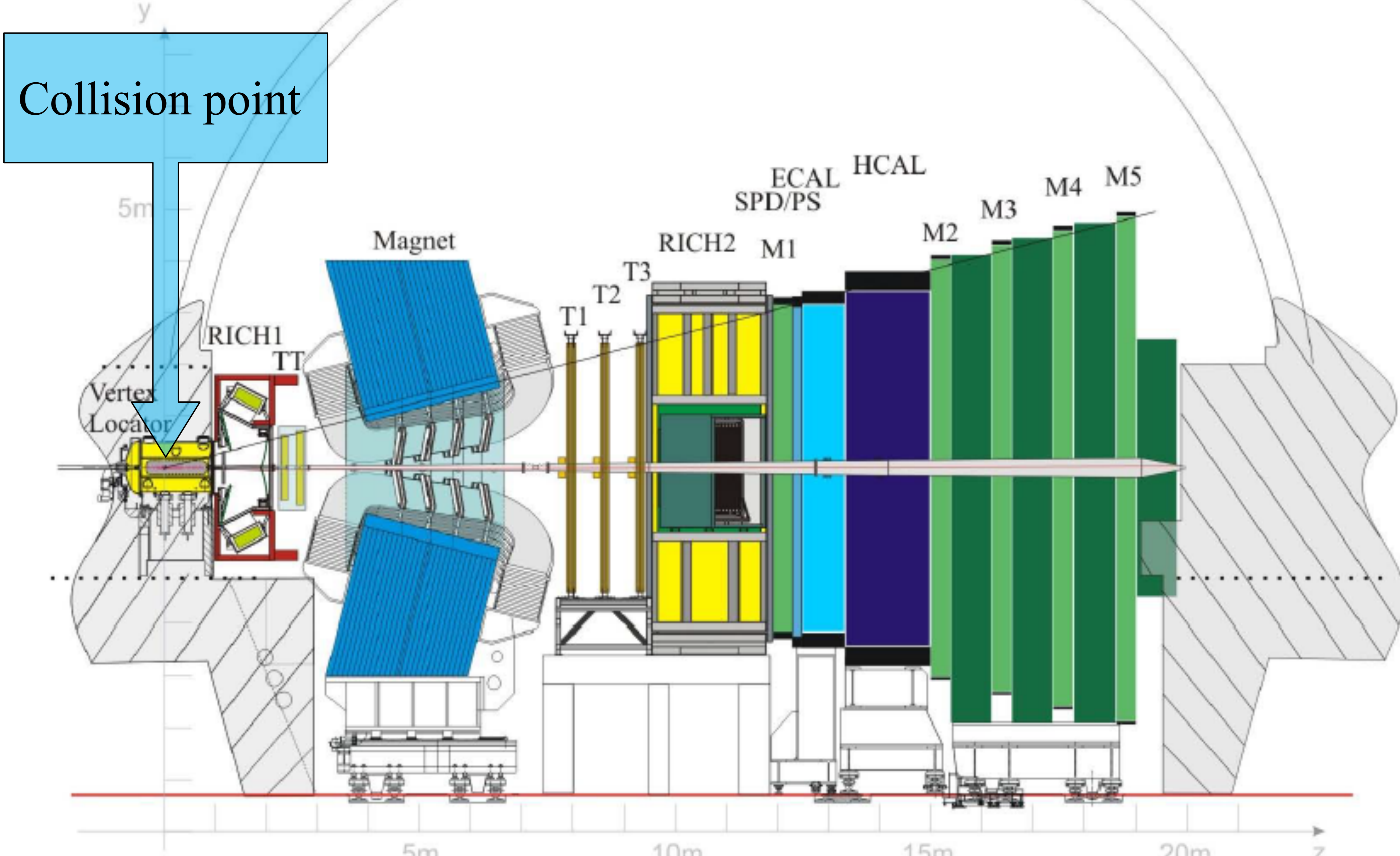
LHCb detector layout

- LHCb is mainly (but not only) studying beauty (and charm)
  - At LHC, the production of heavy quark pairs is peaked forward/backward
  - The detector is a single arm spectrometer
    - Both *b*-hadrons go together forward (or backward)
    - Acceptance $2 < \eta < 5$
  - A *b*-meson / baryon is boosted
    - It flies several millimetres before decaying
    - This is the main signature for selecting events

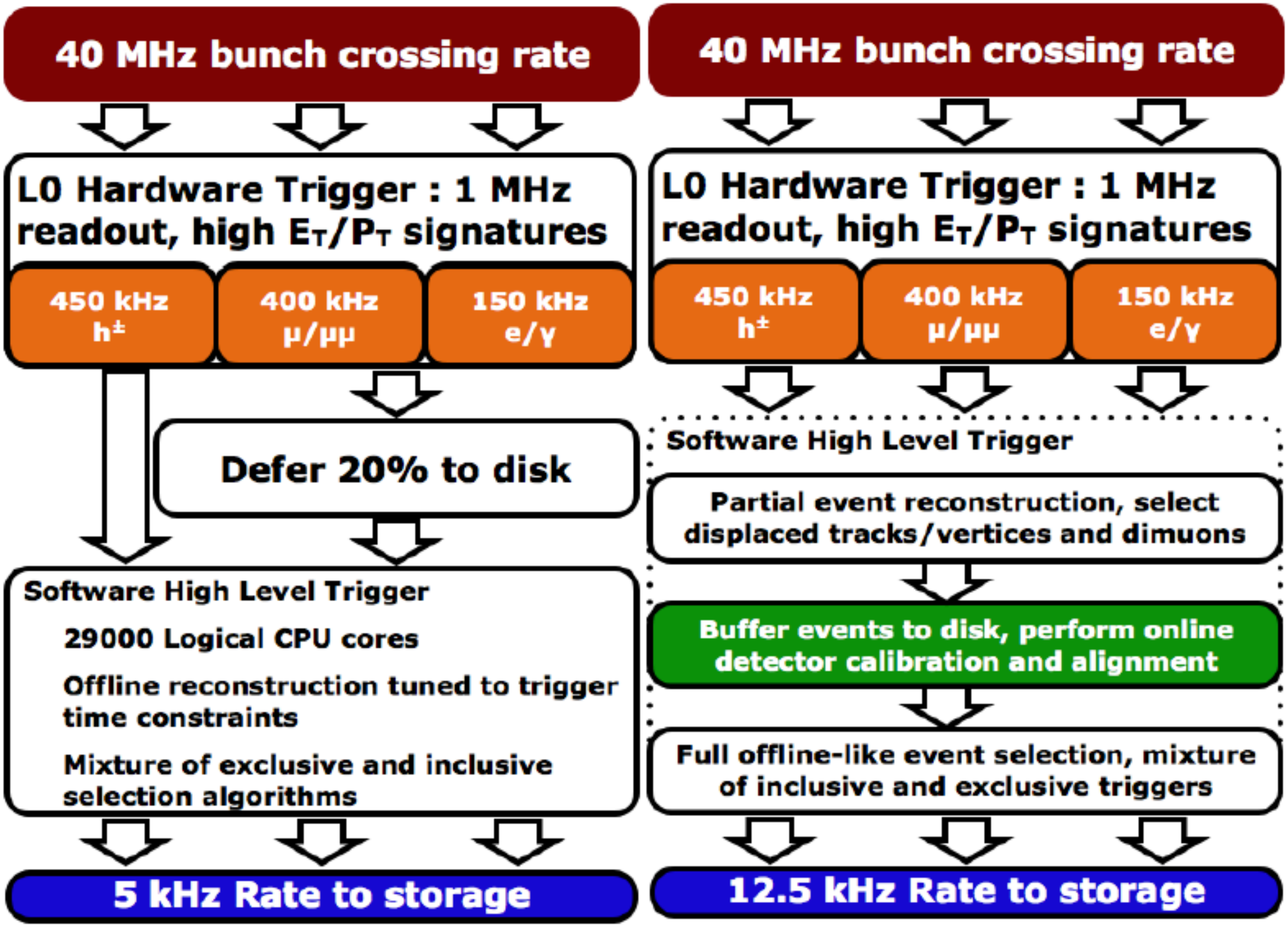


- General detector layout
  - The silicon vertex detector is a key component
  - Dipole magnet, and tracking stations after, to measure accurately the momentum
  - Particle identification by two RICH detectors, electromagnetic and hadronic calorimeters, and a muon system

LHCb detector layout



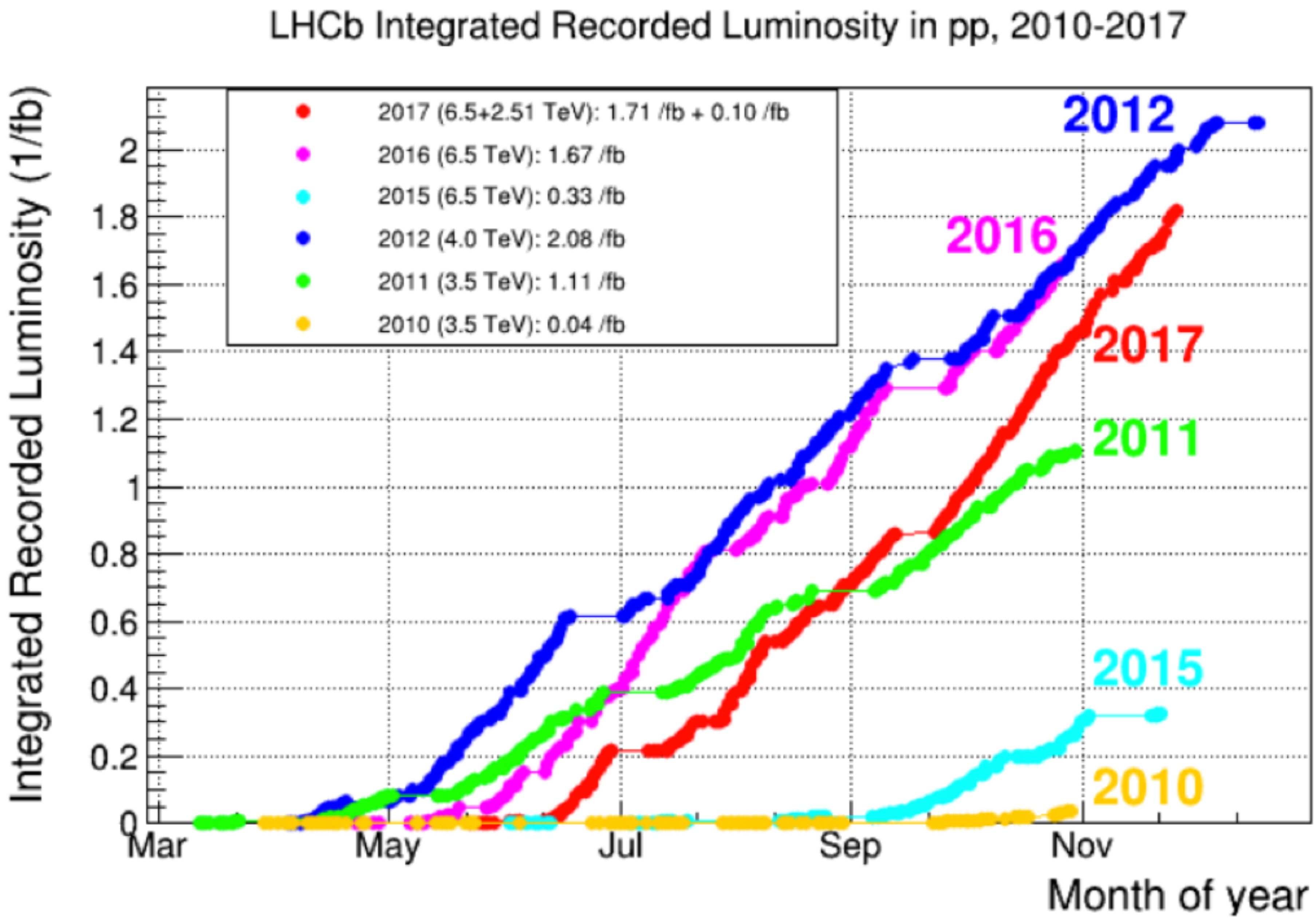
The LHCb trigger in Run 1 and Run 2



Run 1 (2010-12)

Run 2 (2015-18)

LHCb data per year

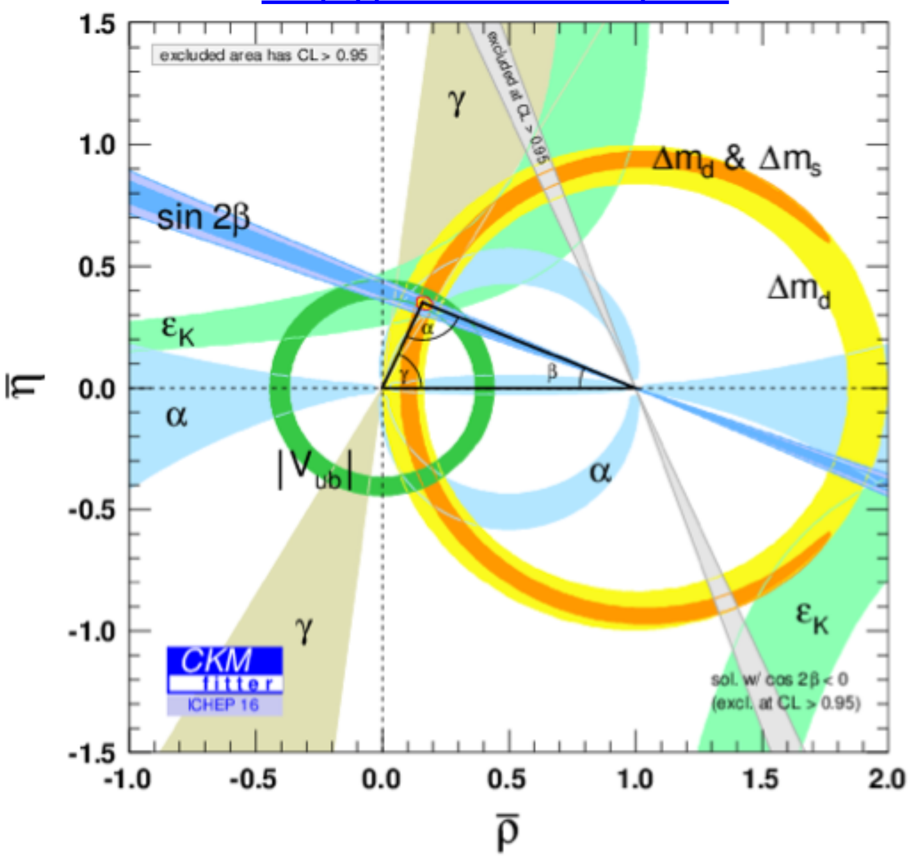


Flavour physics programme in a nutshell

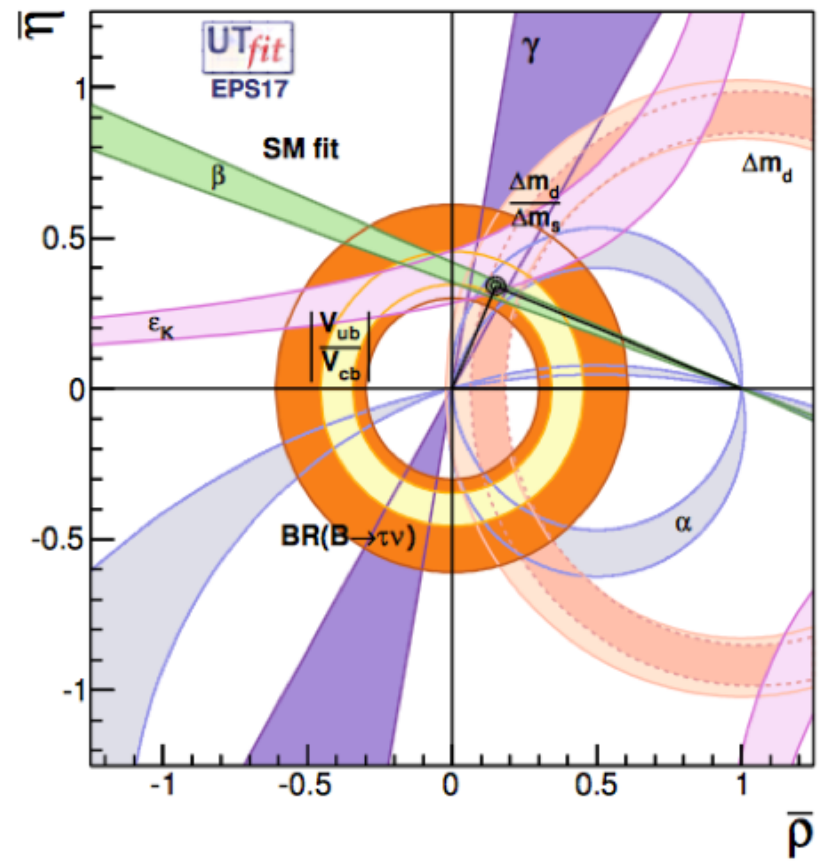
- Classic broad-range measurements
  - CKM physics, search for very rare decays
- Measurements in specific sectors where anomalies are emerging in recent years
  - Lepton-flavour universality in $b \rightarrow s\ell^+\ell^-$ transitions, and related $b \rightarrow s\ell^+\ell^-$ picture of decay rates
  - Lepton-flavour universality in semileptonic b-hadron decays
- Spectroscopy
  - While primarily looking for BSM physics, the LHC is also a unique laboratory to better understand QCD

Where we are with global UT fits

http://ckmfitter.in2p3.fr



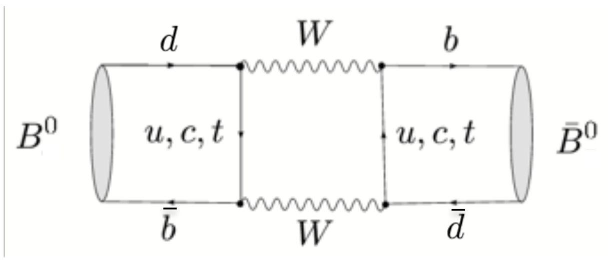
http://www.utfit.org

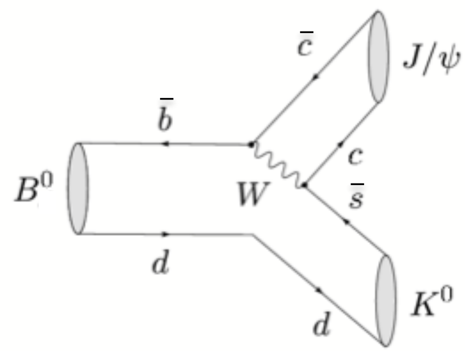


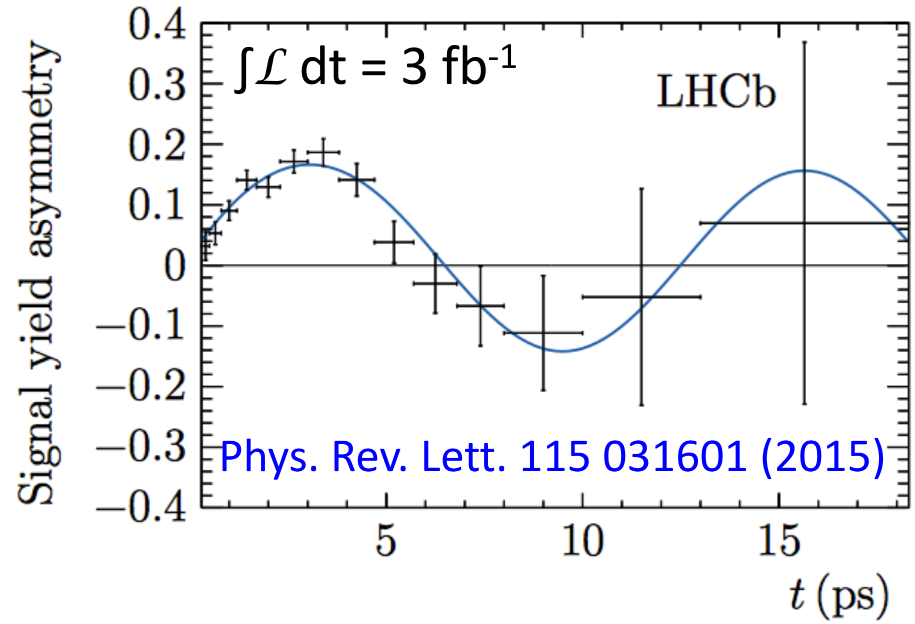
- Don't forget: relevant inputs from LQCD, flavour theory and constant dedication from the HFLAV group (http://www.slac.stanford.edu/xorg/hflav/)
- In the presence of relevant new physics effects, the various contours would not cross each other in a single point
- Certainly that's a great success of the Standard Model CKM picture, but there is still room for new physics at the 10%-15% level

Measurement of sin2β

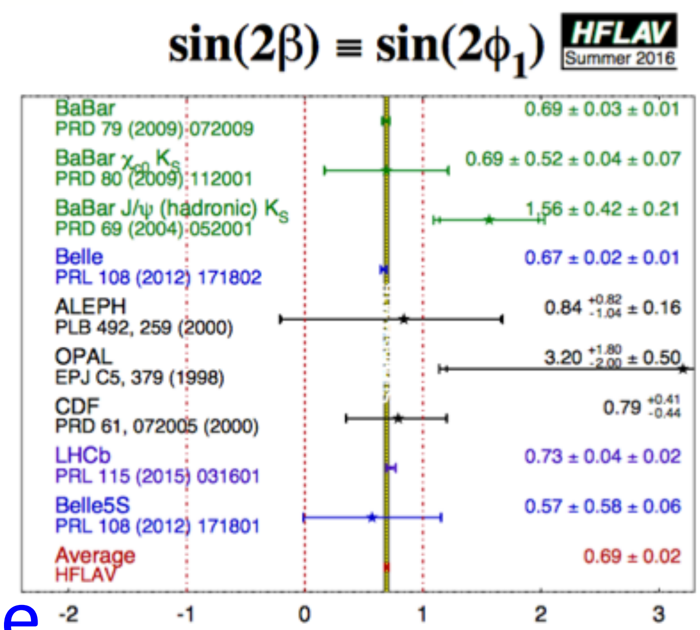
- *CP* violation due to interference between B^0-$\bar{B}^0$ mixing and b→c$\bar{c}$s transitions

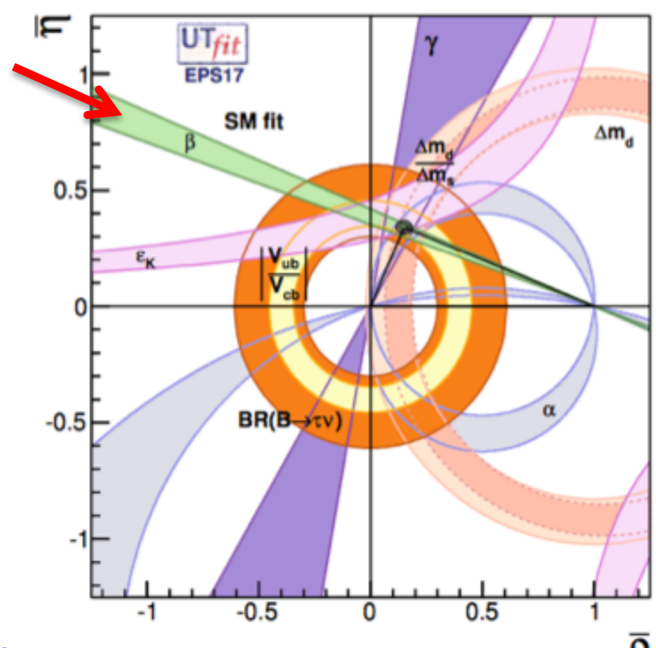






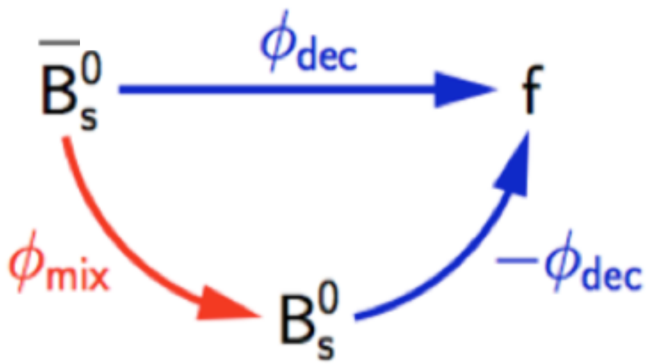
- LHCb has reached the precision of the *B* factories and will surpass that with Run-2 data



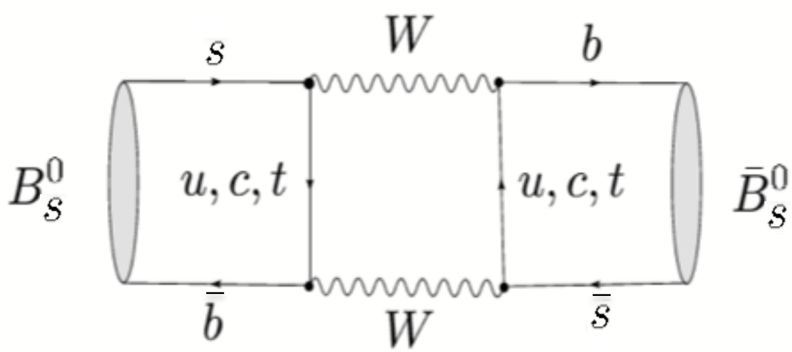


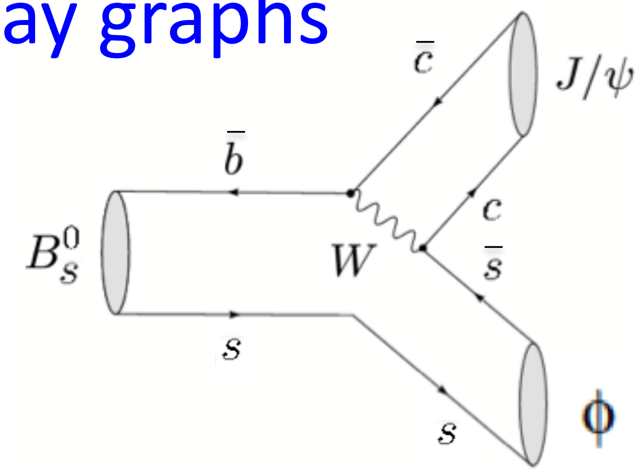
- Alternative avenue to β using $B^0 \to D\pi\pi$ decays also very relevant

ϕ_s from $b \to c\bar{c}s$ transitions



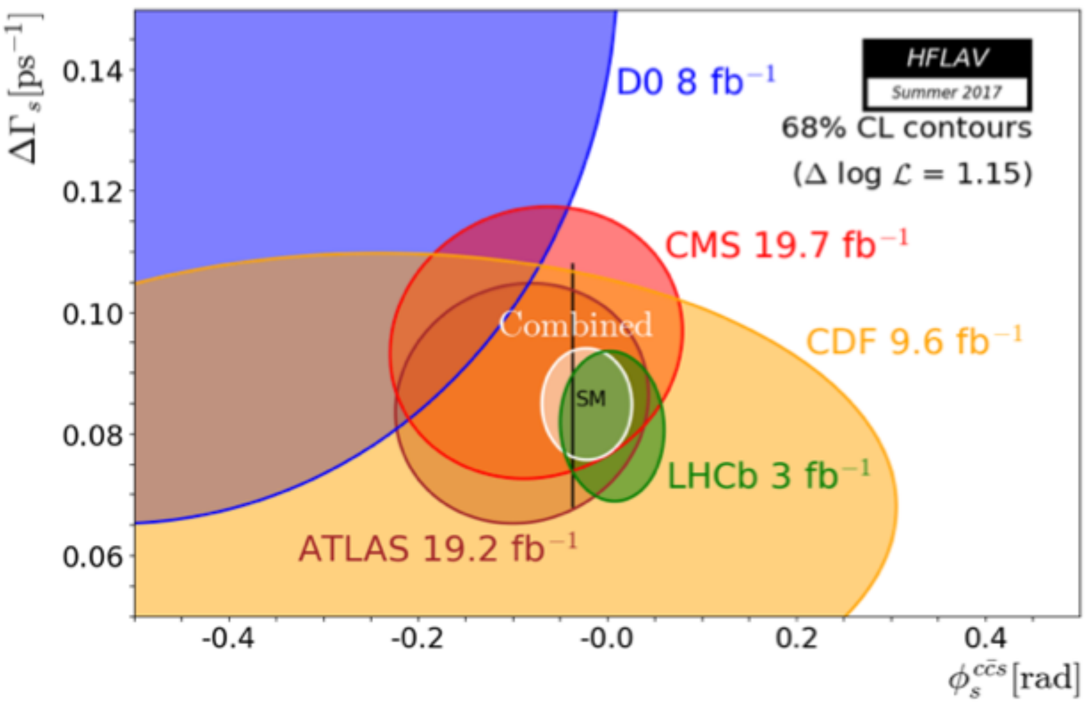
- Golden mode $B_s \to J/\psi\phi$ proceeds (mostly) via a $b \to c\bar{c}s$ tree diagram
- Interference between B_s mixing and decay graphs





- Measures the phase-difference ϕ_s between the two diagrams, precisely predicted from global CKM fits in the SM to be $\phi_s = -2\lambda^2\eta = -37.4 \pm 0.7$ mrad → can be altered by new physics
- Can be (and is) measured also via penguin modes like $B_s \to \phi\phi$ and $B_s \to K\pi K\pi$

Measurement of $\phi_s = -2\lambda^2\eta$



- ϕ_s precision mostly driven by LHCb
- Latest HFLAV world average
  - $\phi_s = -21 \pm 31$ mrad
- Still compatible with the SM at the present level of precision

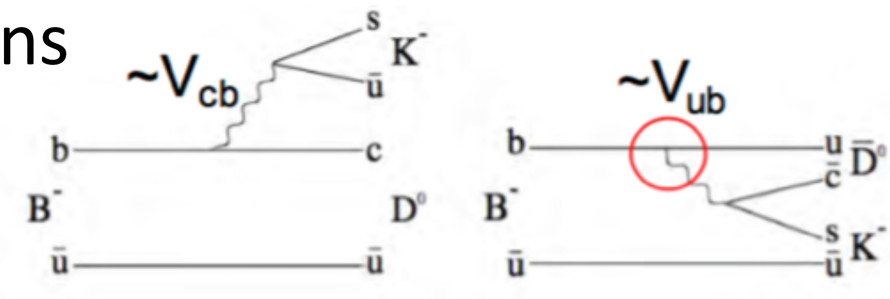
Exp.	Mode	Dataset	$\phi_s^{c\bar{c}s}$	$\Delta\Gamma_s$ (ps^{-1})	Ref.
CDF	$J/\psi\phi$	9.6 fb^{-1}	$[-0.60, +0.12]$, 68% CL	$+0.068 \pm 0.026 \pm 0.009$	[2]
D0	$J/\psi\phi$	8.0 fb^{-1}	$-0.55^{+0.38}_{-0.36}$	$+0.163^{+0.065}_{-0.064}$	[3]
ATLAS	$J/\psi\phi$	4.9 fb^{-1}	$+0.12 \pm 0.25 \pm 0.05$	$+0.053 \pm 0.021 \pm 0.010$	[4]
ATLAS	$J/\psi\phi$	14.3 fb^{-1}	$-0.110 \pm 0.082 \pm 0.042$	$+0.101 \pm 0.013 \pm 0.007$	[5]
ATLAS	above 2 combined		$-0.090 \pm 0.078 \pm 0.041$	$+0.085 \pm 0.011 \pm 0.007$	[5]
CMS	$J/\psi\phi$	19.7 fb^{-1}	$-0.075 \pm 0.097 \pm 0.031$	$+0.095 \pm 0.013 \pm 0.007$	[6]
LHCb	$J/\psi K^+K^-$	3.0 fb^{-1}	$-0.058 \pm 0.049 \pm 0.006$	$+0.0805 \pm 0.0091 \pm 0.0032$	[7]
LHCb	$J/\psi\pi^+\pi^-$	3.0 fb^{-1}	$+0.070 \pm 0.068 \pm 0.008$	—	[8]
LHCb	$J/\psi K^+K^{-a}$	3.0 fb^{-1}	$+0.119 \pm 0.107 \pm 0.034$	$+0.066 \pm 0.018 \pm 0.010$	[9]
LHCb	above 3 combined		$+0.001 \pm 0.037$(tot)	$+0.0813 \pm 0.0073 \pm 0.0036$	[9]
LHCb	$\psi(2S)\phi$	3.0 fb^{-1}	$+0.23^{+0.29}_{-0.28} \pm 0.02$	$+0.066^{+0.41}_{-0.44} \pm 0.007$	[10]
LHCb	$D_s^+D_s^-$	3.0 fb^{-1}	$+0.02 \pm 0.17 \pm 0.02$	—	[11]
All combined			-0.021 ± 0.031	$+0.085 \pm 0.006$	

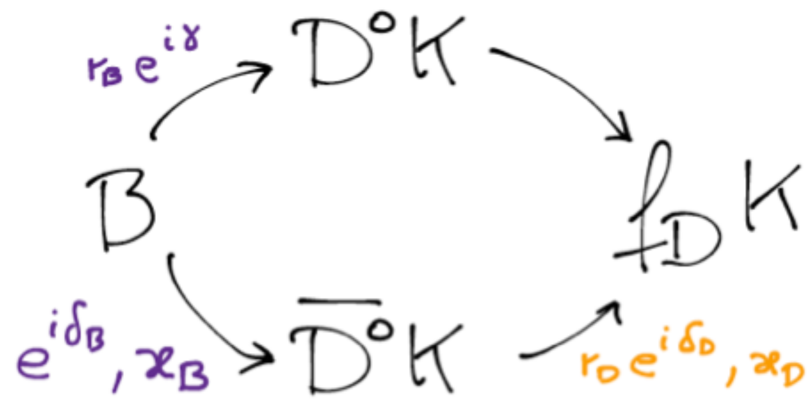
[a] $m(K^+K^-) > 1.05$ GeV$/c^2$.

See HFLAV page for the list of references http://www.slac.stanford.edu/xorg/hflav/

Measurement of γ

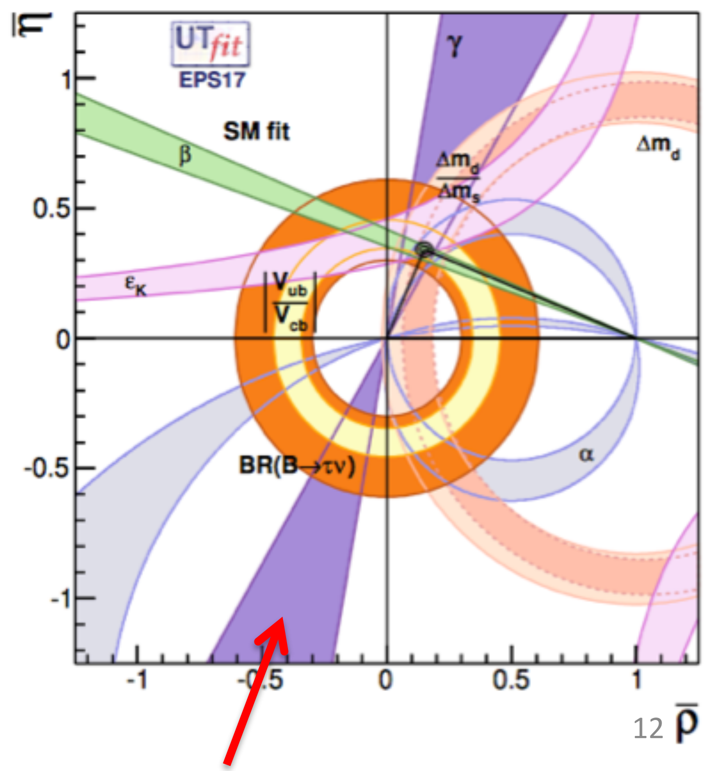
- γ is the least known angle of the UT, although not for too long yet, measured via the interference between $b \to u$ and $b \to c$ tree-level transitions





- Its measurement provides a (largely NP-free) SM standard candle against which other measurements potentially affected by NP can be compared with

- Simple and clean theoretical interpretation, but statistically very challenging



Experimental status for γ

- A plethora of independent measurements (mainly of the *B*→*DK* family, but not only) exploiting different methods
- LHCb will be approaching 4° of precision by the end of Run-2, but strong-phase measurements with D^0 mesons from CLEO-c data contribute with approximately 2° of uncertainty, thus becoming soon a bottleneck for improvements
- BESIII with its present and future ψ(3770) dataset can play a crucial role in the field!

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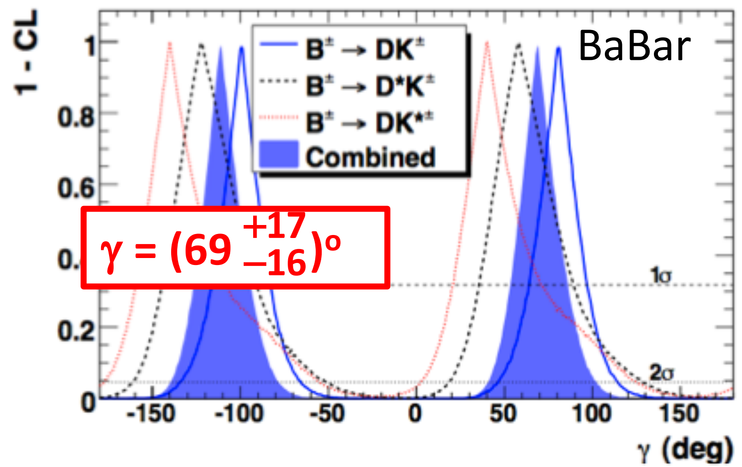
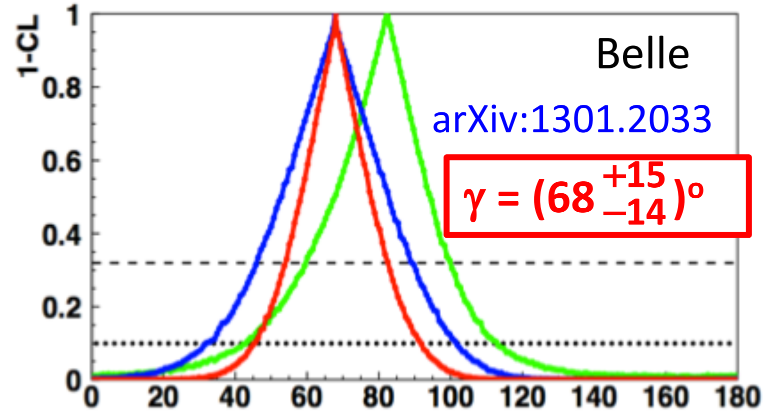
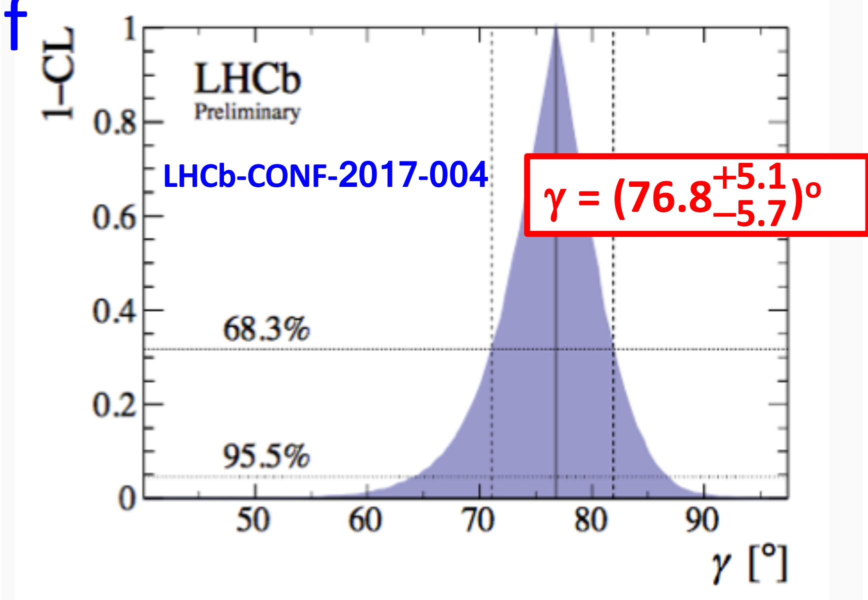
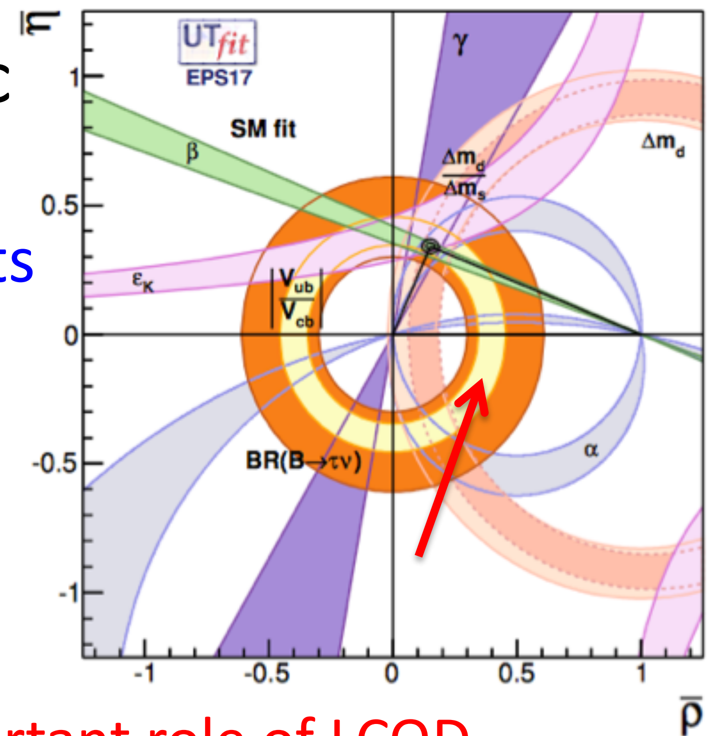




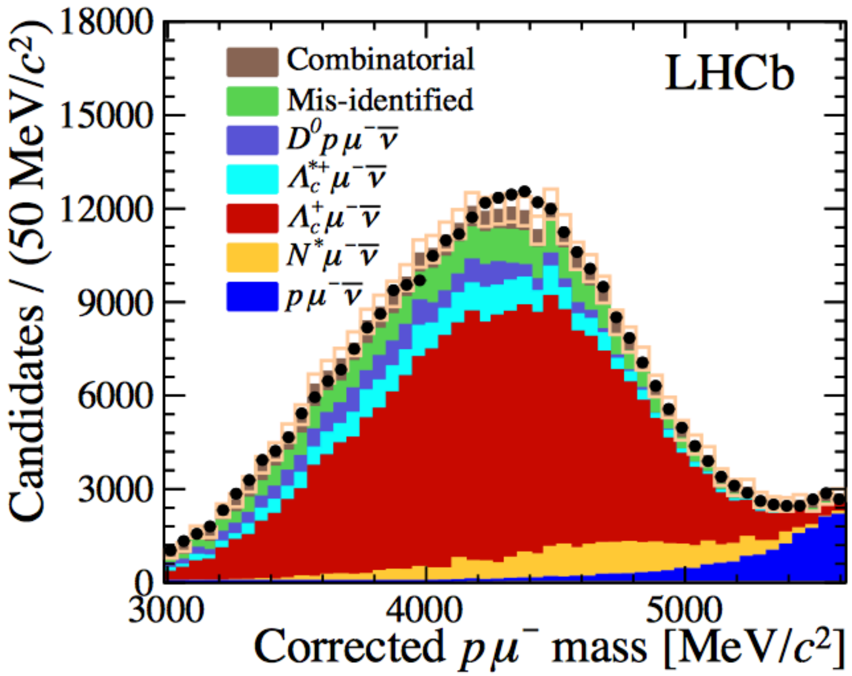


Measurement of $|V_{ub}|/|V_{cb}|$

- Measured at *B* factories and more recently by LHCb using Λ_b semileptonic decays
  - first of a rich programme of measurements with *b*-hadron semileptonics at LHCb



$$R_{exp} = \frac{\mathcal{B}(\Lambda_b^0 \to p\mu^-\overline{\nu}_\mu)_{q^2>15\,\mathrm{GeV}/c^2}}{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+\mu^-\overline{\nu}_\mu)_{q^2>7\,\mathrm{GeV}/c^2}} = (1.00 \pm 0.04 \pm 0.08) \times 10^{-2}$$



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Important role of LCQD

$$R_{exp} = R_{theory}(|V_{ub}|^2/|V_{cb}|^2)$$

$$R_{theory} = 1.470 \pm 0.115(stat) \pm 0.104(syst)$$

$$\boxed{\frac{|V_{ub}|}{|V_{cb}|} = 0.083 \pm 0.004 \pm 0.004}$$

Signal $\Lambda_b \to p\mu\nu$ decays

$$N(\Lambda_b \to p\mu^-\overline{\nu}_\mu) = 17687 \pm 733$$

Measurement of $|V_{ub}|/|V_{cb}|$

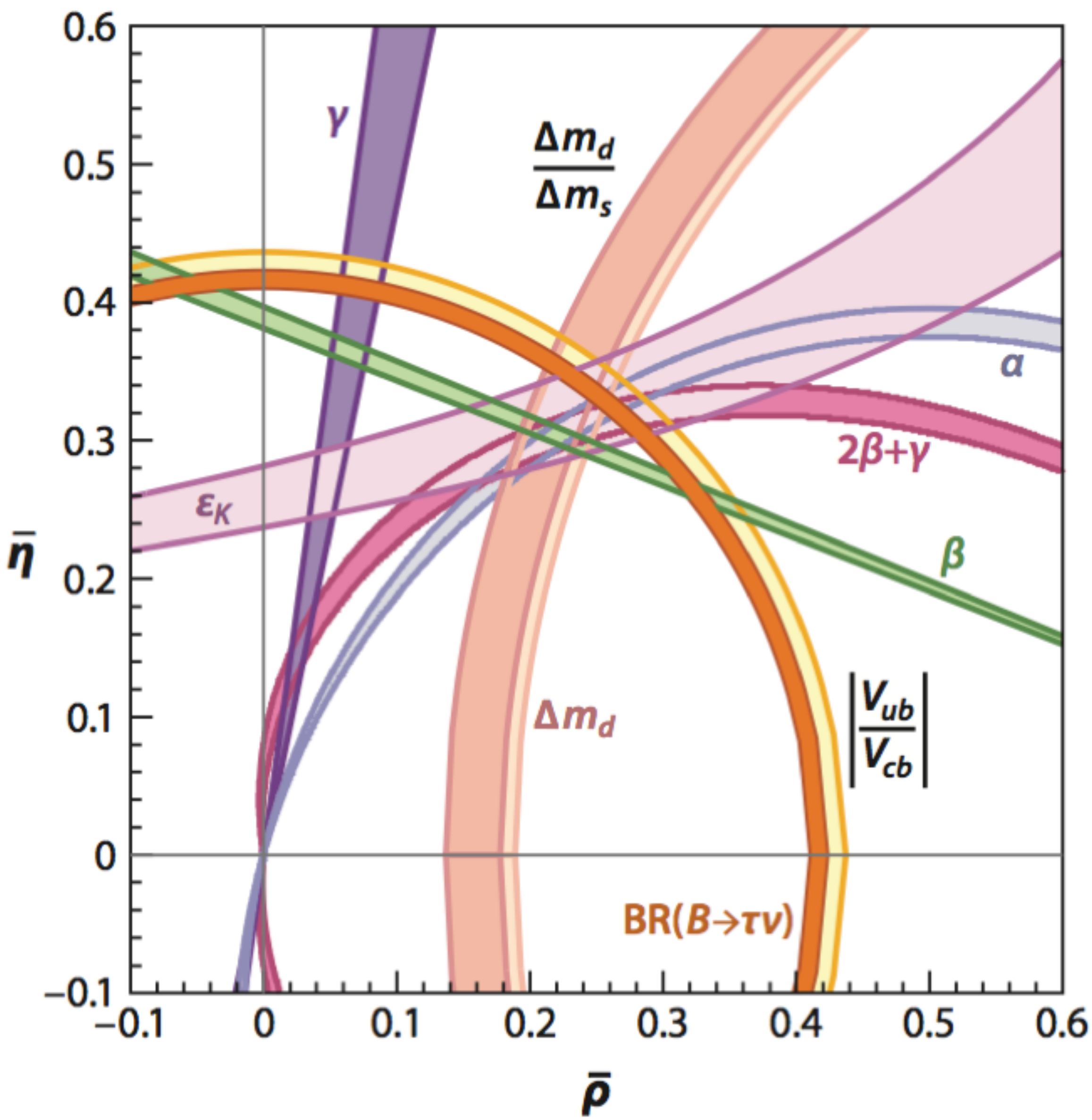
$$\frac{\mathcal{B}(\Lambda_b \to p\mu^-\overline{\nu}_\mu)_{q^2>15\,\mathrm{GeV}^2/c^4}}{\mathcal{B}(\Lambda_b \to \Lambda_c\mu\nu)_{q^2>7\,\mathrm{GeV}^2/c^4}} = \frac{N(\Lambda_b \to p\mu^-\overline{\nu}_\mu)}{N(\Lambda_b \to (\Lambda_c \to pK\pi)\mu^-\overline{\nu}_\mu)} \times \frac{\epsilon(\Lambda_b \to (\Lambda_c \to pK\pi)\mu^-\overline{\nu}_\mu)}{\epsilon(\Lambda_b \to p\mu^-\overline{\nu}_\mu)} \times \mathcal{B}(\Lambda_c \to pK\pi)$$

- As for many other LHCb measurements based on ratios of BFs, this measurement strongly depends on the availability of an absolute BF to be used as an input
- The largest systematic uncertainty actually stems from the limited knowledge of the $\Lambda_c \to pK\pi$ BF
- BESIII role is very important to improve absolute BFs of relevant decays of charm mesons and baryons

Systematic uncertainties

Source	Relative uncertainty (%)
$\mathcal{B}(\Lambda_c^+ \to pK^+\pi^-)$	$^{+4.7}_{-5.3}$
Trigger	3.2
Tracking	3.0
Λ_c^+ selection efficiency	3.0
$\Lambda_b^0 \to N^*\mu^-\overline{\nu}_\mu$ shapes	2.3
Λ_b^0 lifetime	1.5
Isolation	1.4
Form factor	1.0
Λ_b^0 kinematics	0.5
q^2 migration	0.4
PID	0.2
Total	$^{+7.8}_{-8.2}$

Just for illustration... a possible future scenario



Charm physics at LHCb in one slide

- D^0-$\bar{D}^0$ mixing established by LHCb with overwhelming sensitivity
- Both direct and indirect *CP* violation searches are being performed with unprecedented precision
  - No sign of *CP* violation yet, but approaching the interesting range
- Also a vibrant programme of searches for charm rare decays

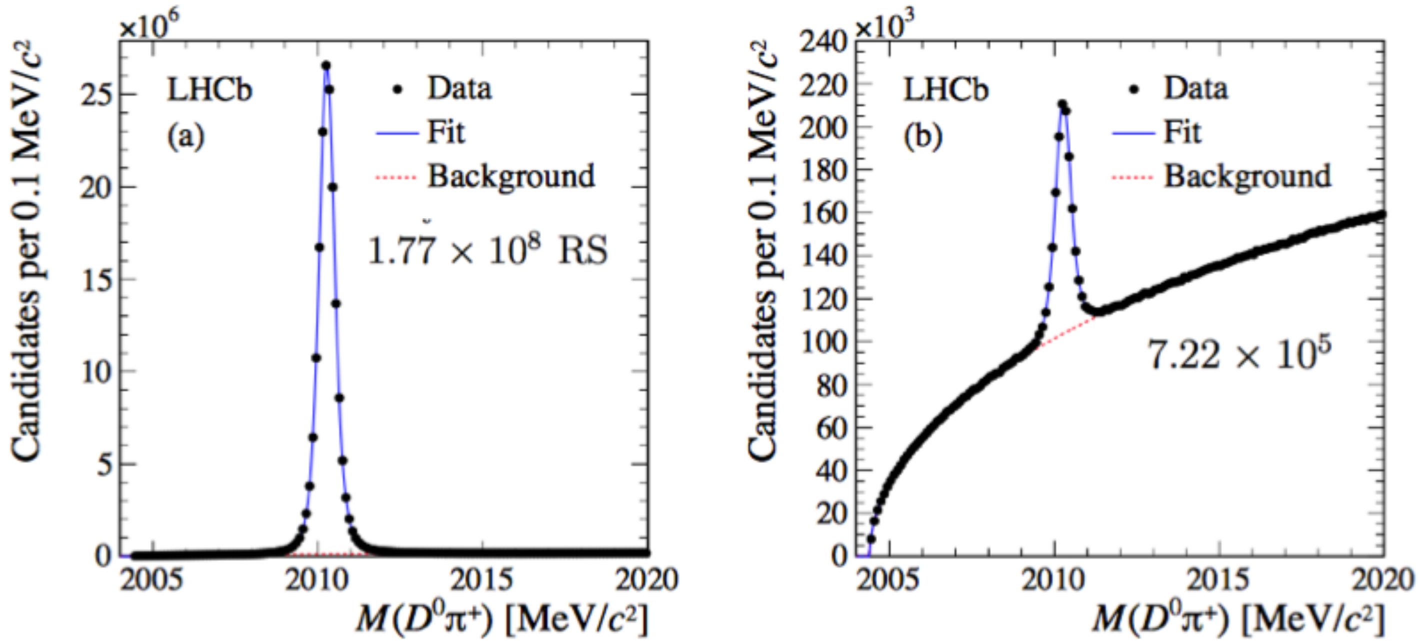
Updated determination of neutral *D*-meson mixing parameters and search for *CP* violation

arXiv:1712.03220

- Recent publication on charm mixing and search for *CP* violation using Run-1 + Run-2 data
- Measure time-dependent ratio of wrong-sign to right-sign $D^0 \rightarrow K\pi$ decays
- By far the largest sample of such decays ever

$$R(t) = \frac{N(D^0 \to K^+\pi^-)}{N(D^0 \to K^-\pi^+)}$$

$$R(t) \approx R_D + \sqrt{R_D}\, y' \,\frac{t}{\tau} + \frac{x'^2 + y'^2}{4}\left(\frac{t}{\tau}\right)^2$$



Updated determination of neutral *D*-meson mixing parameters and search for *CP* violation

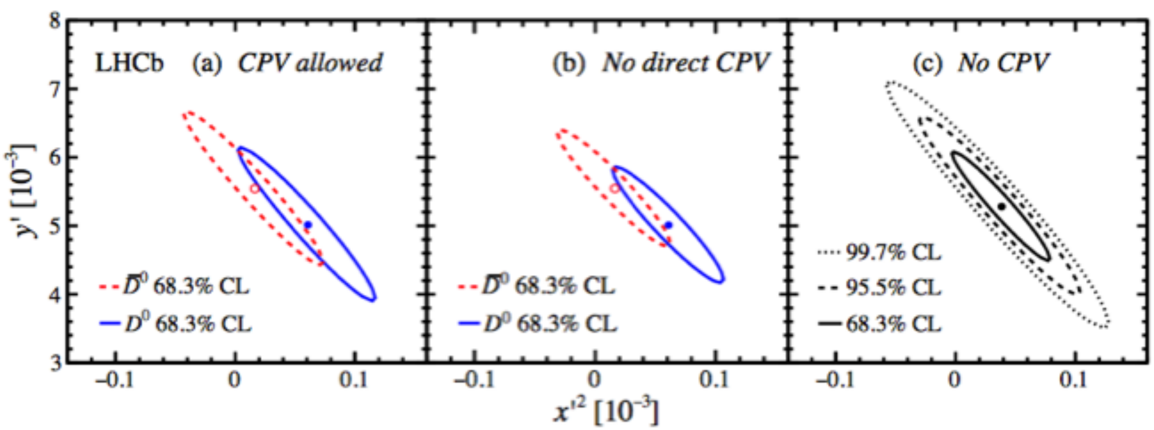
arXiv:1712.03220

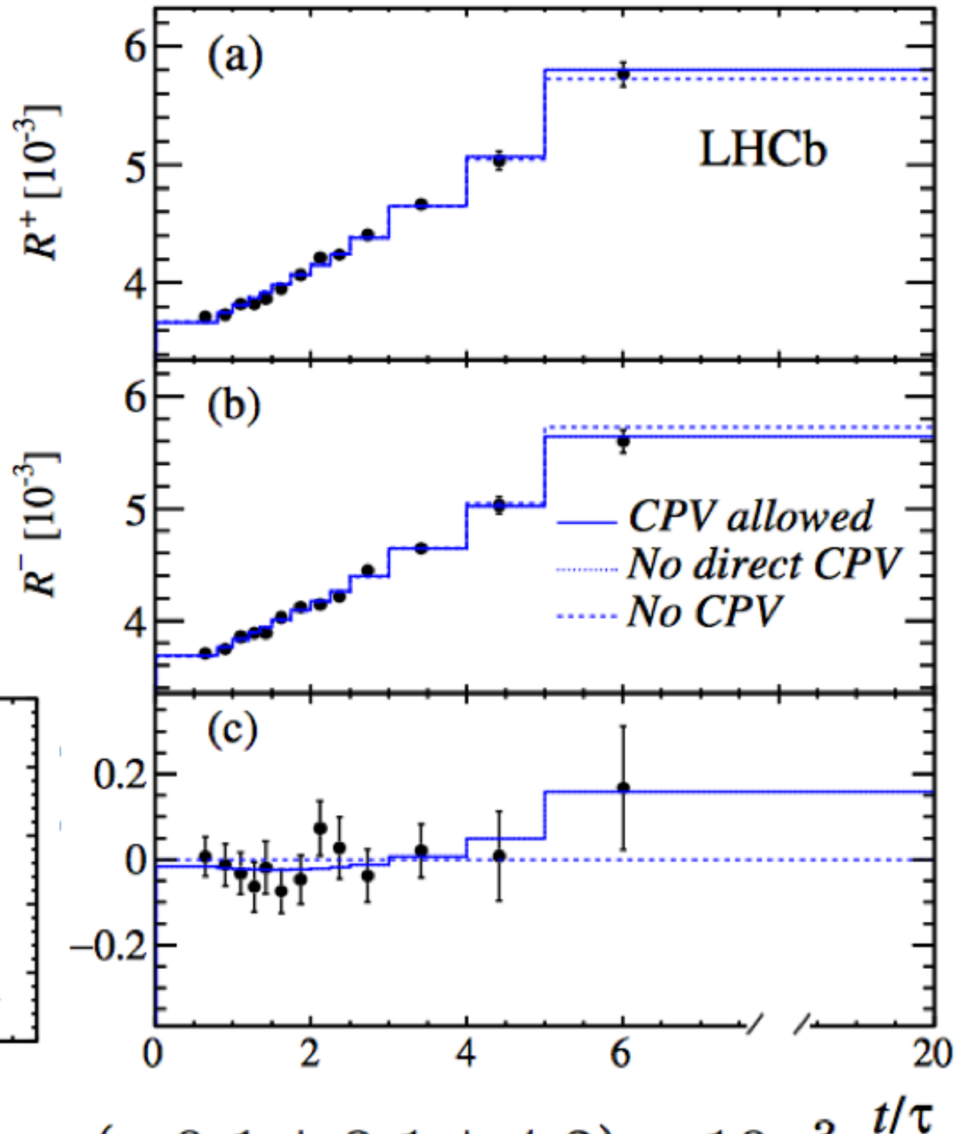
$$x'^2 = (3.9 \pm 2.7) \times 10^{-5}$$

$$y' = (5.28 \pm 0.52) \times 10^{-3}$$

$$R_D = (3.454 \pm 0.031) \times 10^{-3}$$

- The results are twice as precise as previous LHCb results (but no CPV yet)



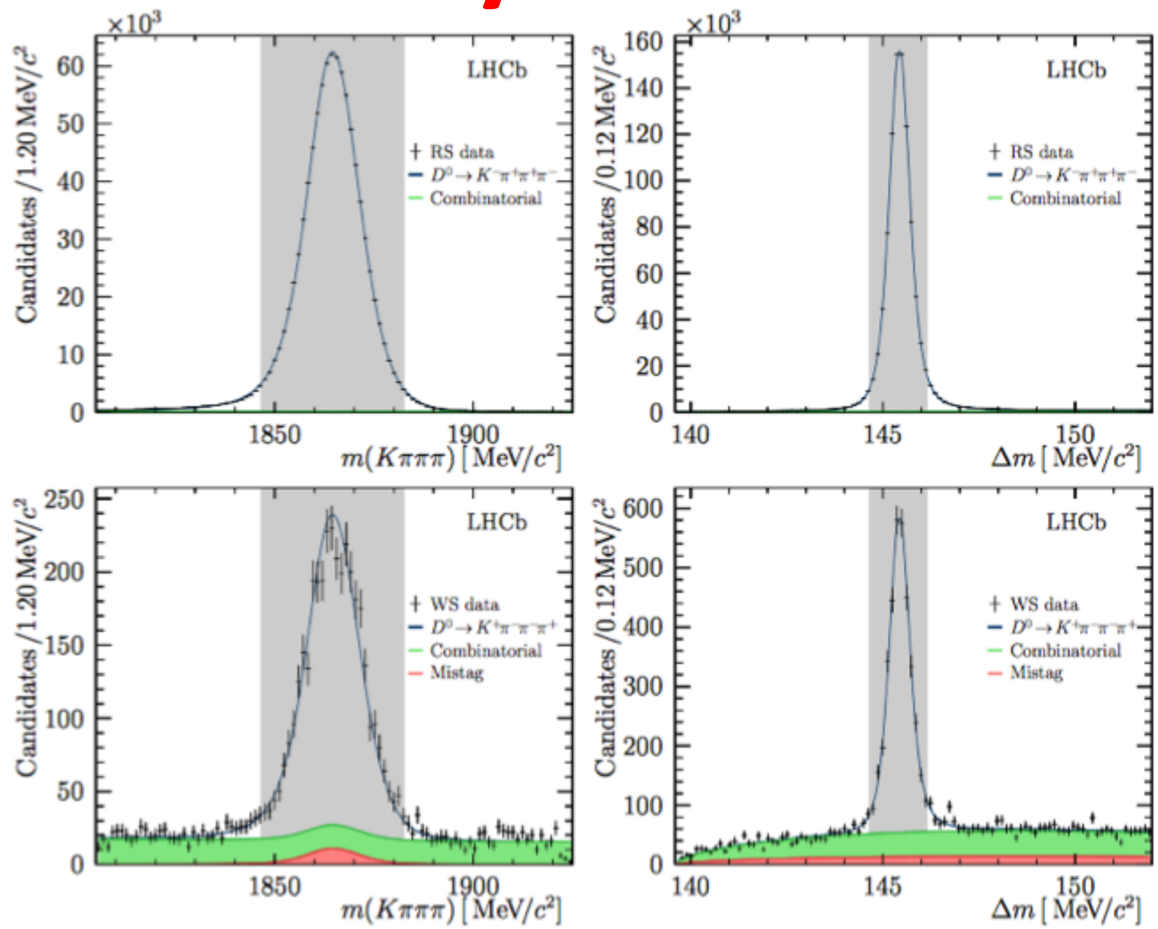


$$A_D \equiv (R_D^+ - R_D^-)/(R_D^+ + R_D^-) = (-0.1 \pm 8.1 \pm 4.2) \times 10^{-3}$$

Study of resonance structure in $D^0 \to K\pi\pi\pi$ decays

arXiv:1712.08609

	Signal
$D^0 \to K^-\pi^+\pi^+\pi^-$	
2011	$266\,368 \pm 490$
2012	$624\,332 \pm 765$
Total	$890\,701 \pm 927$
$D^0 \to K^+\pi^-\pi^-\pi^+$	
2011	875 ± 32
2012	2154 ± 51
Total	3028 ± 61

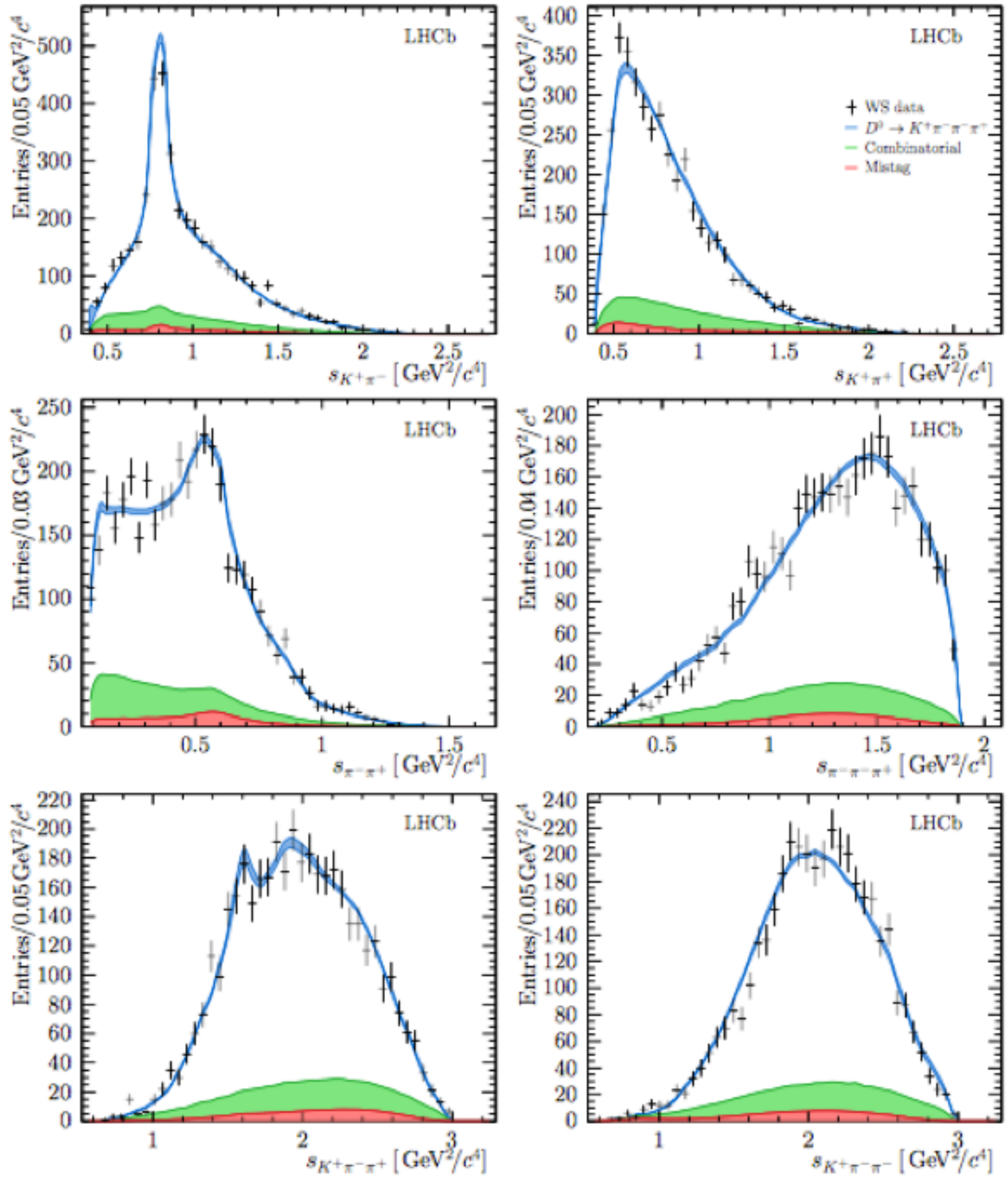


- Recent study performed using high-purity time-integrated samples obtained from doubly tagged $B \to D^{*+}(2010)[D^0\pi^+]\mu X$ decays
- To give you an idea, the right-sign decay mode has a sample size about 60 times larger than previous studies by BES-III
- For the wrong-sign mode, the sample includes about 3000 signal candidates

Study of resonance structure in $D^0 \to K\pi\pi\pi$ decays

arXiv:1712.08609

- The resonance structure of the wrong-sign decay mode is studied for the first time, one of the few studies of a DCS amplitude
- These models will be useful for a variety of future measurements
  - E.g. provide a valuable input to future binned measurements of γ and to charm-mixing studies



$B \rightarrow \mu\mu$ by LHCb with Run-2 data

- Measurement from LHCb using Run-2 data has led in 2017 to the first observation of the $B_s \rightarrow \mu\mu$ decay from a single experiment

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

- Moreover, it starts to be possible to measure other properties, such as the effective lifetime, that will be useful for discriminating between NP models
  - Experimental precision not yet in the interesting range, but important proof of concept

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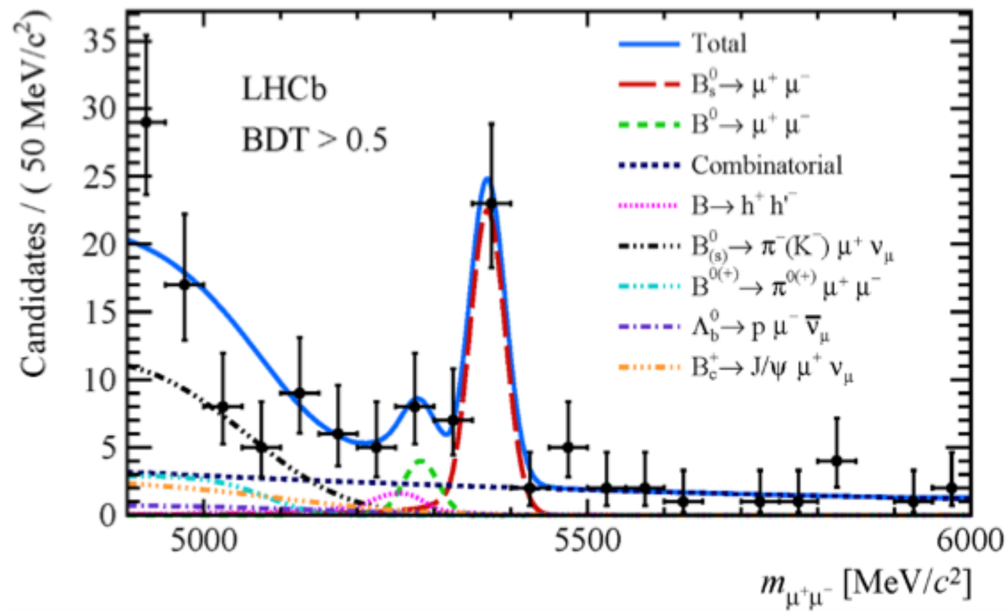
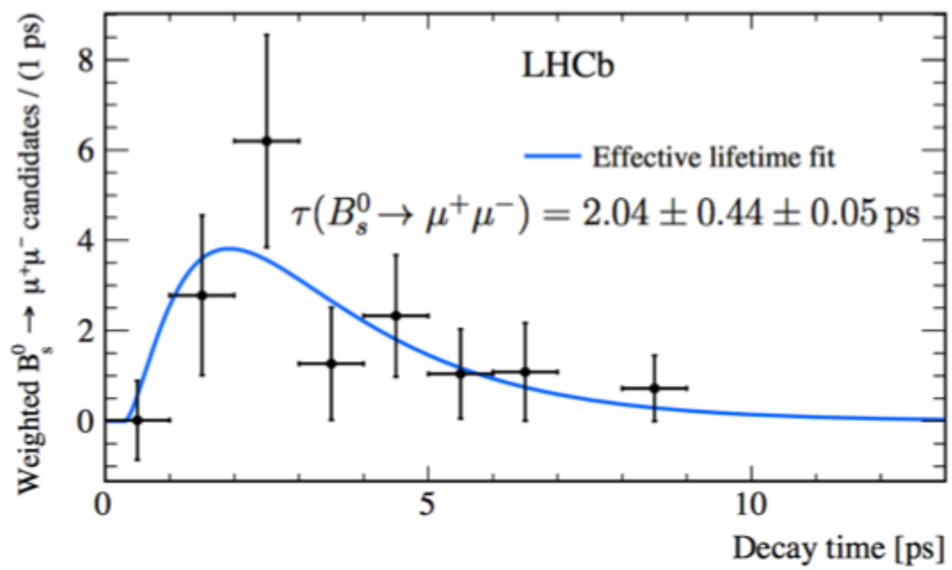
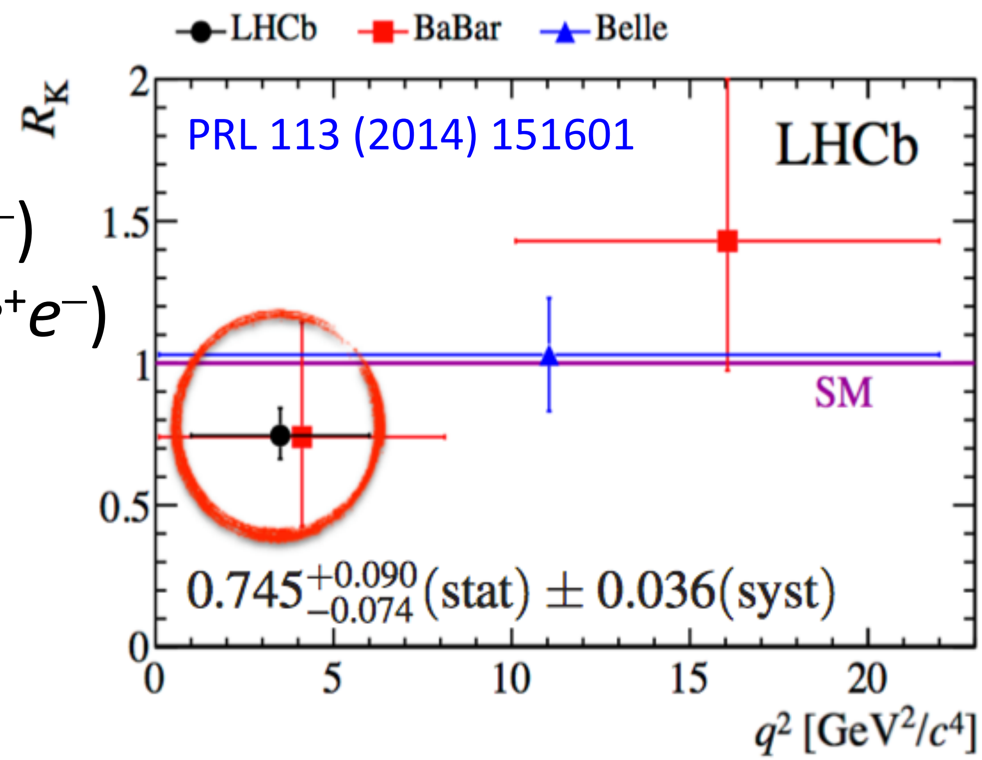
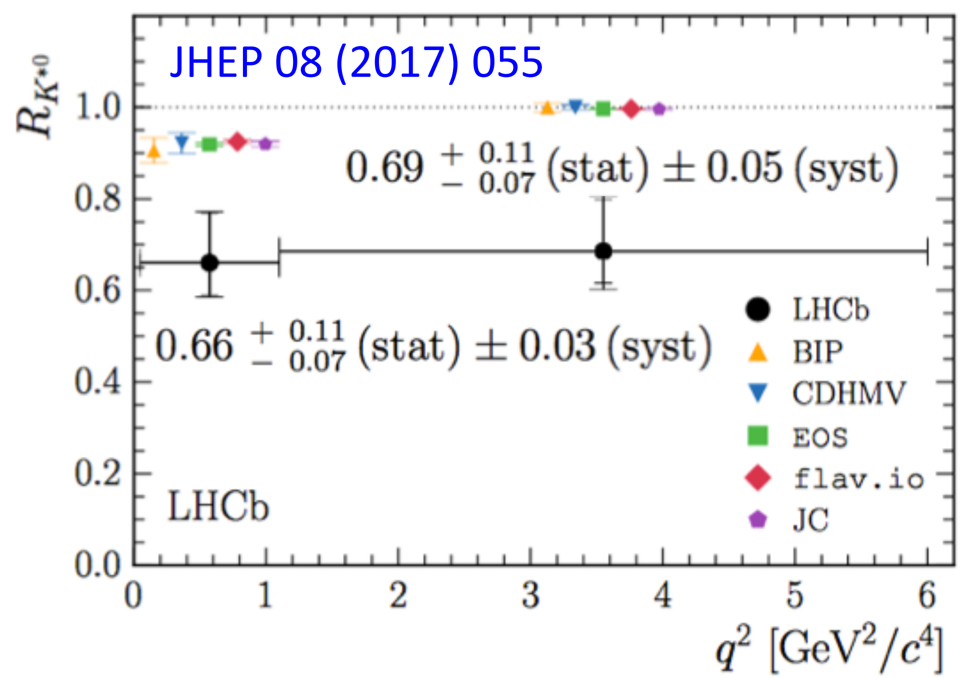




LFU tests in $b \to s\ell^+\ell^-$ transitions

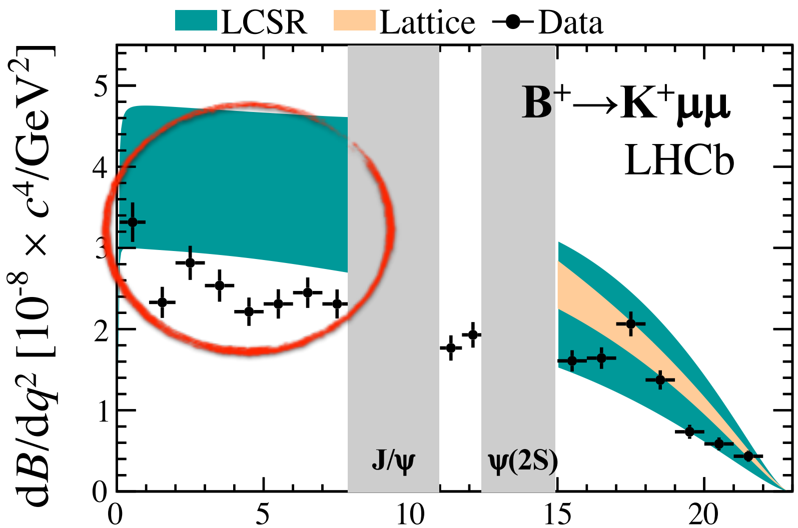
- Measure ratios
  $R_K = BF(B^+ \to K^+\mu^+\mu^-) / BF(B^+ \to K^+e^+e^-)$
  $R_{K*} = BF(B^0 \to K^{*0}\mu^+\mu^-) / BF(B^0 \to K^{*0}e^+e^-)$
- Theoretically very clean
  - Observation of non-LFU would be a clear sign of new physics
- For the moment at the 3σ-ish level from the SM
- Updates with Run-2 as well as other new measurements with different decay modes are under way





Other anomalies in the $b \to s \ell^+ \ell^-$ sector

- Differential branching fractions consistently lower than SM expectations, although predictions are still matter of discussion



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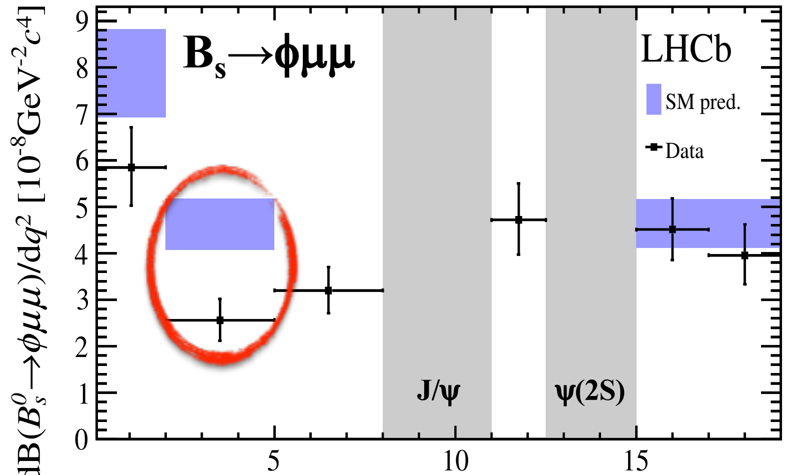

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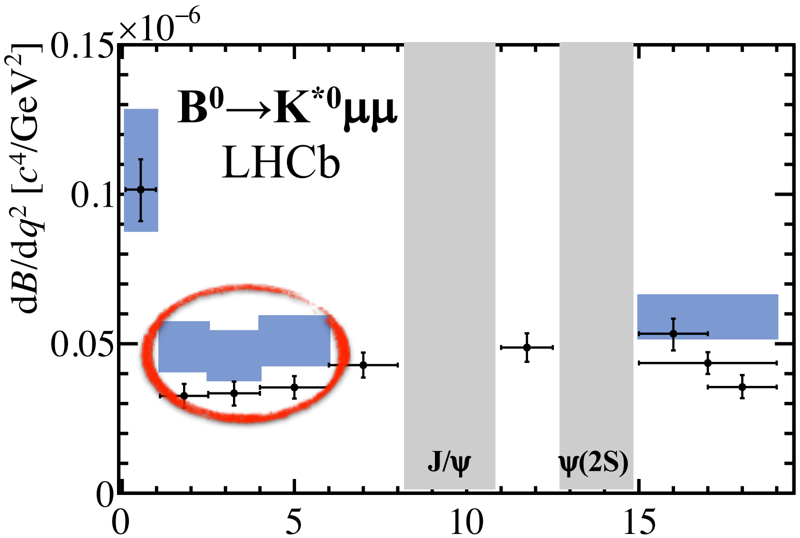
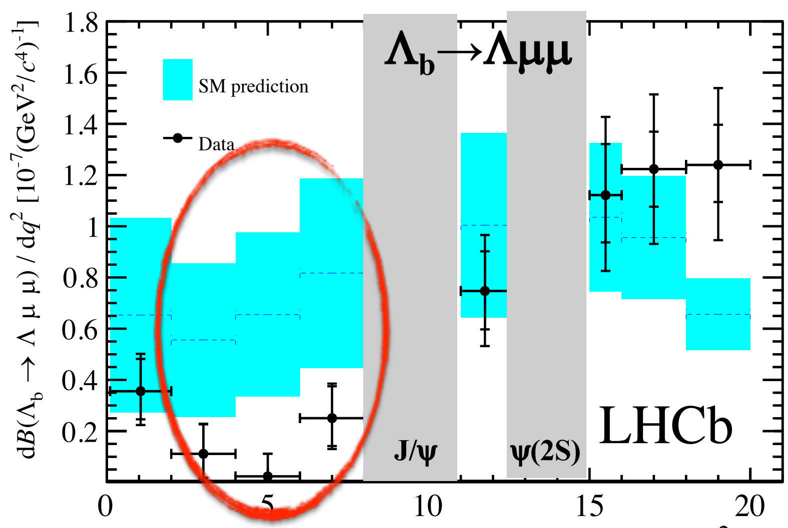


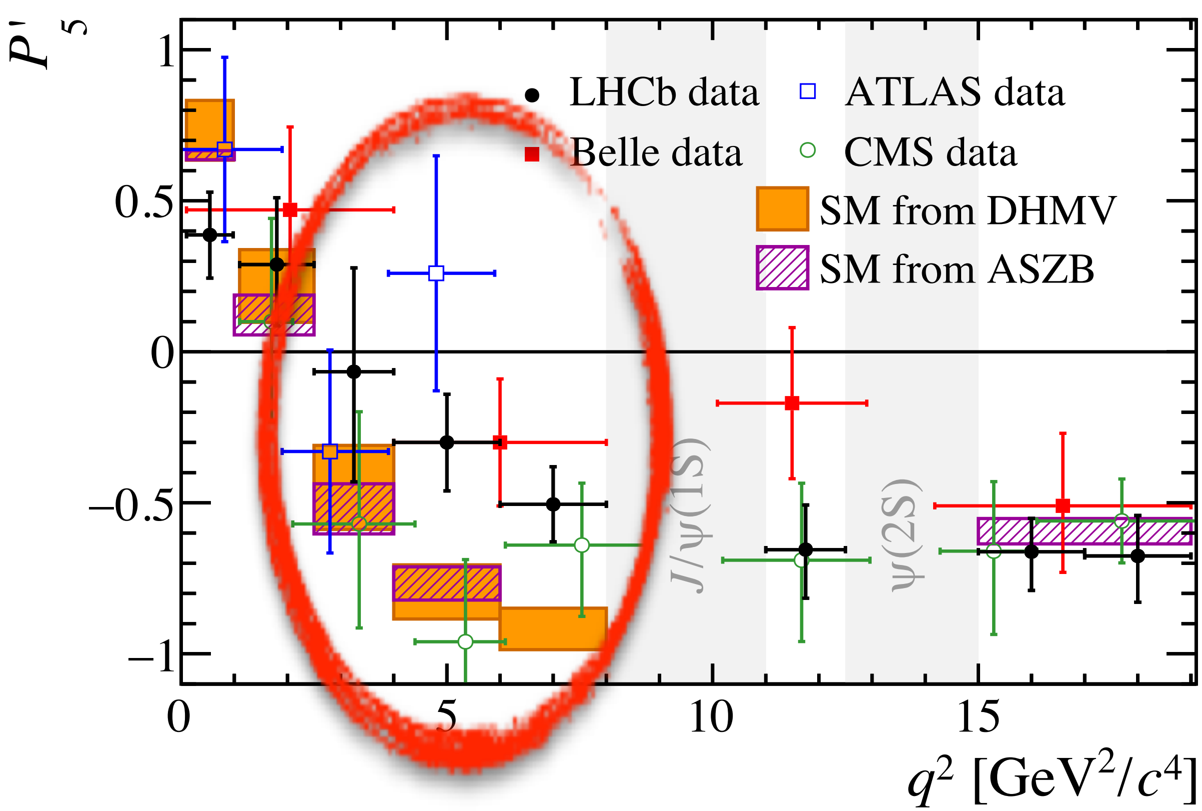
JHEP 11 (2016) 047
JHEP 04 (2017) 142



JHEP 06 (2015) 115

Other anomalies in the $b \rightarrow s\ell^+\ell^-$ sector

- Angular analysis of $B^0 \rightarrow K^{*0}\mu\mu$
- Can construct less form-factor dependent ratios of observables, like P_5'

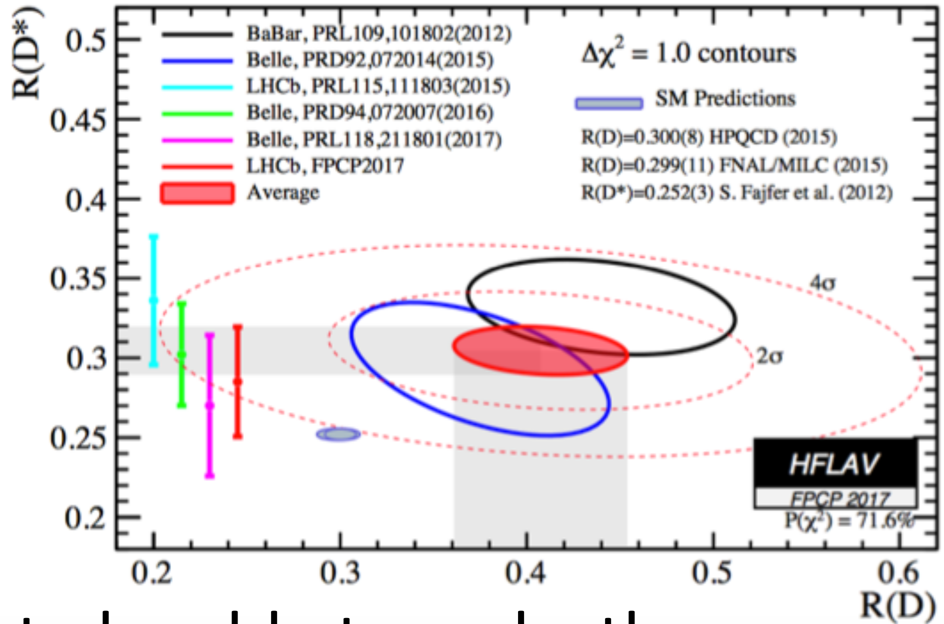


- JHEP 02 (2016) 104
- PRL 118 (2017) 111801
- ATLAS-CONF-2017-023
- CMS-PAS-BPH-15-008

- It is important to remark that global fits by several theory groups take into account up to 90 observables from various experiments, notably including $B \rightarrow \mu\mu$ and $b \rightarrow s\ell^+\ell^-$ transitions, and nicely get a consistent overall picture

LFU tests in semileptonic *b*-hadron decays

- Measure ratio
  $R_D^{(*)}$ = BF($B \to D^{(*)}\tau\nu$) / BF($B \to D^{(*)}\mu\nu$)
- Measurements of R(D) and R(D*) by BaBar, Belle and LHCb
  – Overall average shows a 4σ discrepancy from the SM
  – LHCb has recently demonstrated to be able to make the measurement also with 3-prong τ decays



- LHCb can also perform measurements with other *b* hadrons
  – Recent determination of R(J/ψ) = BF($B_c \to J/\psi\tau\nu$) / BF($B_c \to J/\psi\mu\nu$) at about 2σ from the SM [arXiv:1711.05623]
  – Other modes with B_s and Λ_b decays will also come

R(D*) with 3-prong τ decay

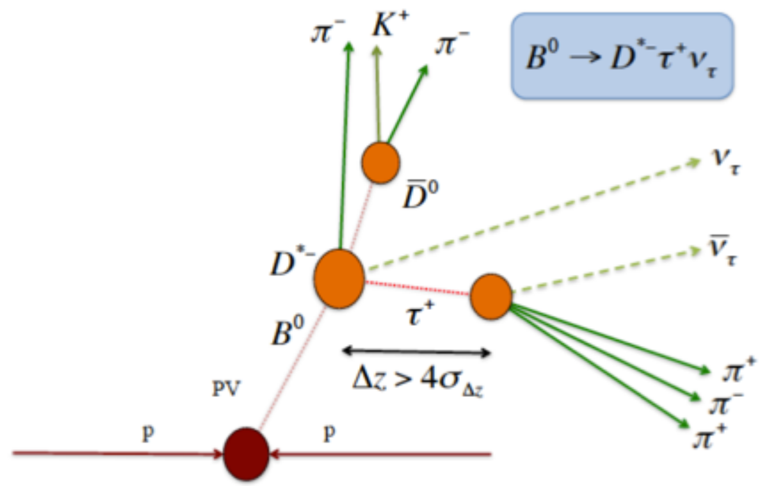
Latest measurement from LHCb look at $\tau \to \pi^+ \pi^- \pi^+ \nu$ final states

arXiv:1708.08856 arXiv:1711.02505

Normalisation done through a very similar known final state

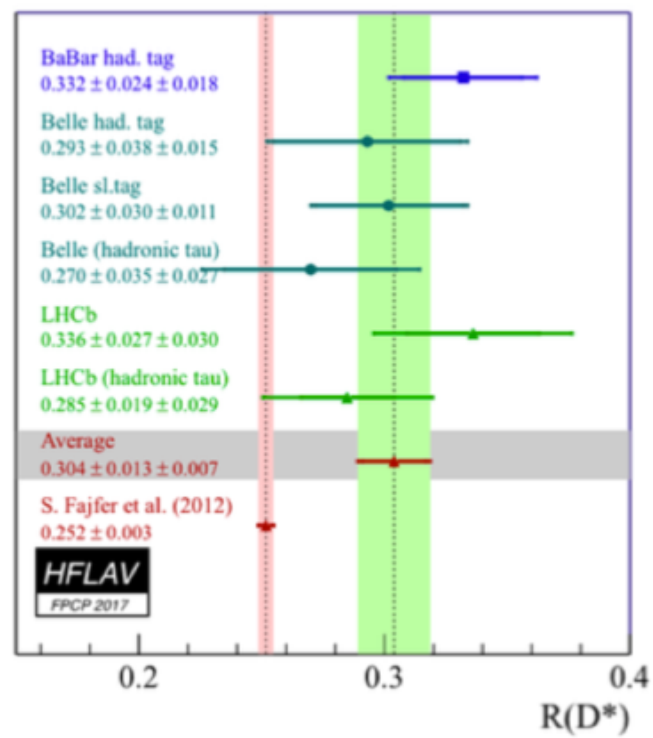
$$R(D^*) = K_{had}(D^*) \times \frac{BR(B^0 \to D^{*-}\pi^+\pi^-\pi^+)}{BR(B^0 \to D^{*-}\mu^+\nu_\mu)}$$

$$\boxed{K_{had}(D^*) = \frac{BR(B^0 \to D^{*-}\tau^+\nu_\tau)}{BR(B^0 \to D^{*-}\pi^+\pi^-\pi^+)}}$$



$$\mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau) = (1.40 \pm 0.09 \pm 0.12 \pm 0.10)\%$$

$$\mathcal{R}(D^{*-}) = 0.286 \pm 0.019 \pm 0.025 \pm 0.021$$

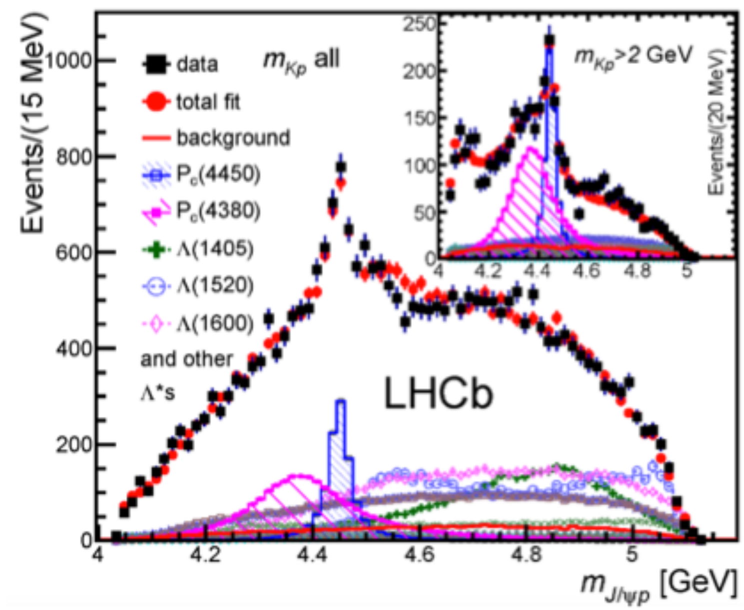


Prospects with Run-2 (and beyond) statistics are very promising, but it is necessary to know precisely charm decays with three charged pions in the final state in order to limit systematic uncertainties due to backgrounds → case for BESIII!

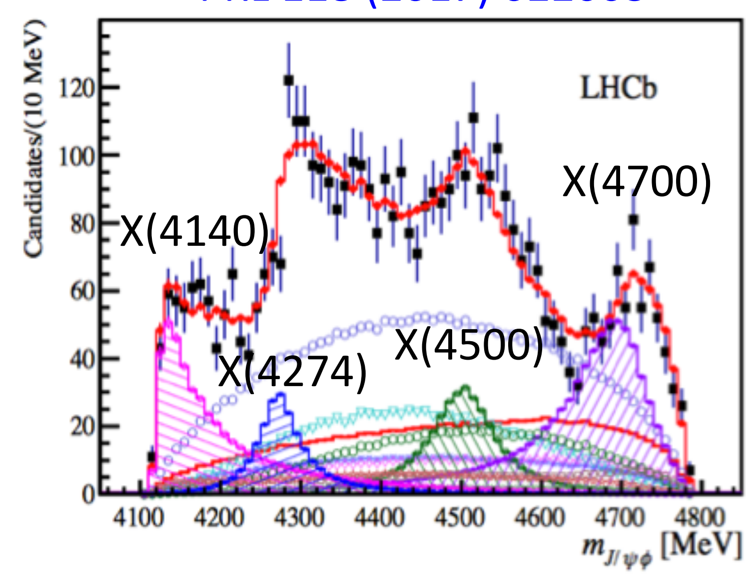
Tetraquarks and pentaquarks

- Sector in great expansion over the last decade
  - A renaissance of QCD in the non-perturbative regime
- Several "exotic" candidates have been identified and are now under the magnifying glass of experiments
  - Lots of work still needed to clarify the global picture and understand the nature of these states

PRL 115 (2015) 072001



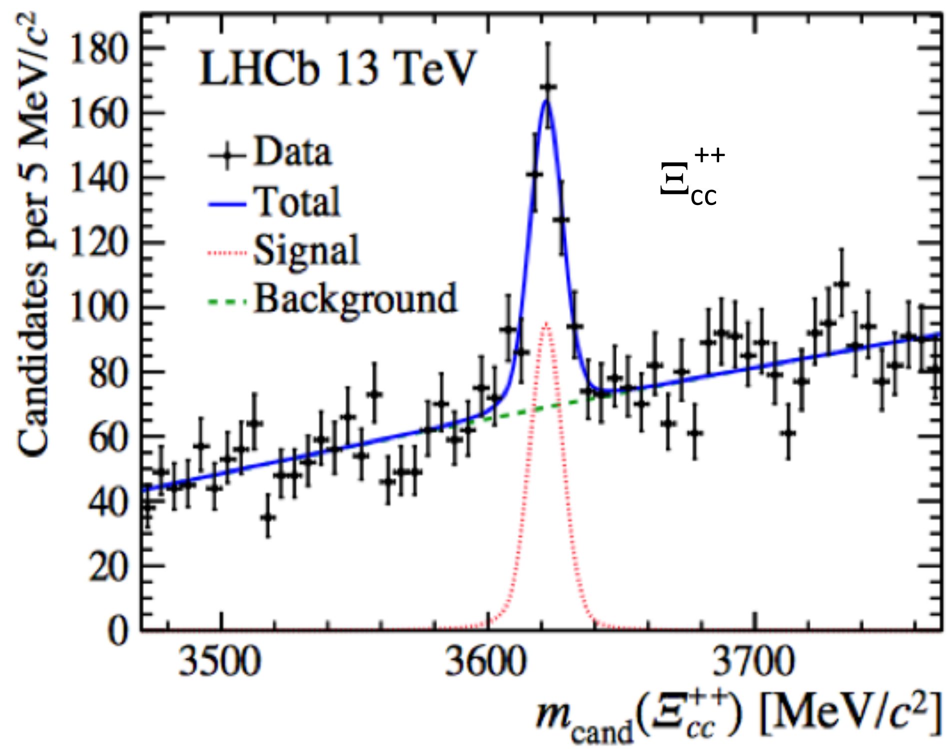
PRL 118 (2017) 022003



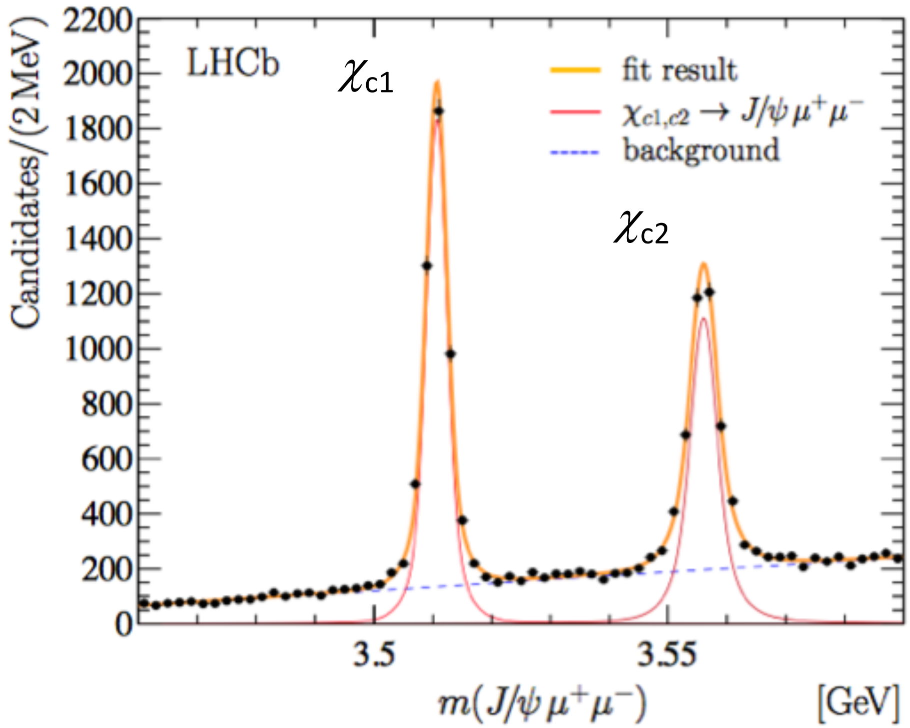
First observations and precision measurements

- First observation of a doubly-charmed baryon, the Ξ_{cc}^{++}
  - Now working on measuring properties and partners

PRL 119 (2017) 112001



PRL 119 (2017) 221801



- Precision measurements of masses and widths of χ_{c1} and χ_{c2} mesons via the decay mode $\chi_{c2} \rightarrow J/\psi\mu\mu$
  - New avenues are opened, e.g. to study χ_{bJ} states

Short, medium and long term future in one slide

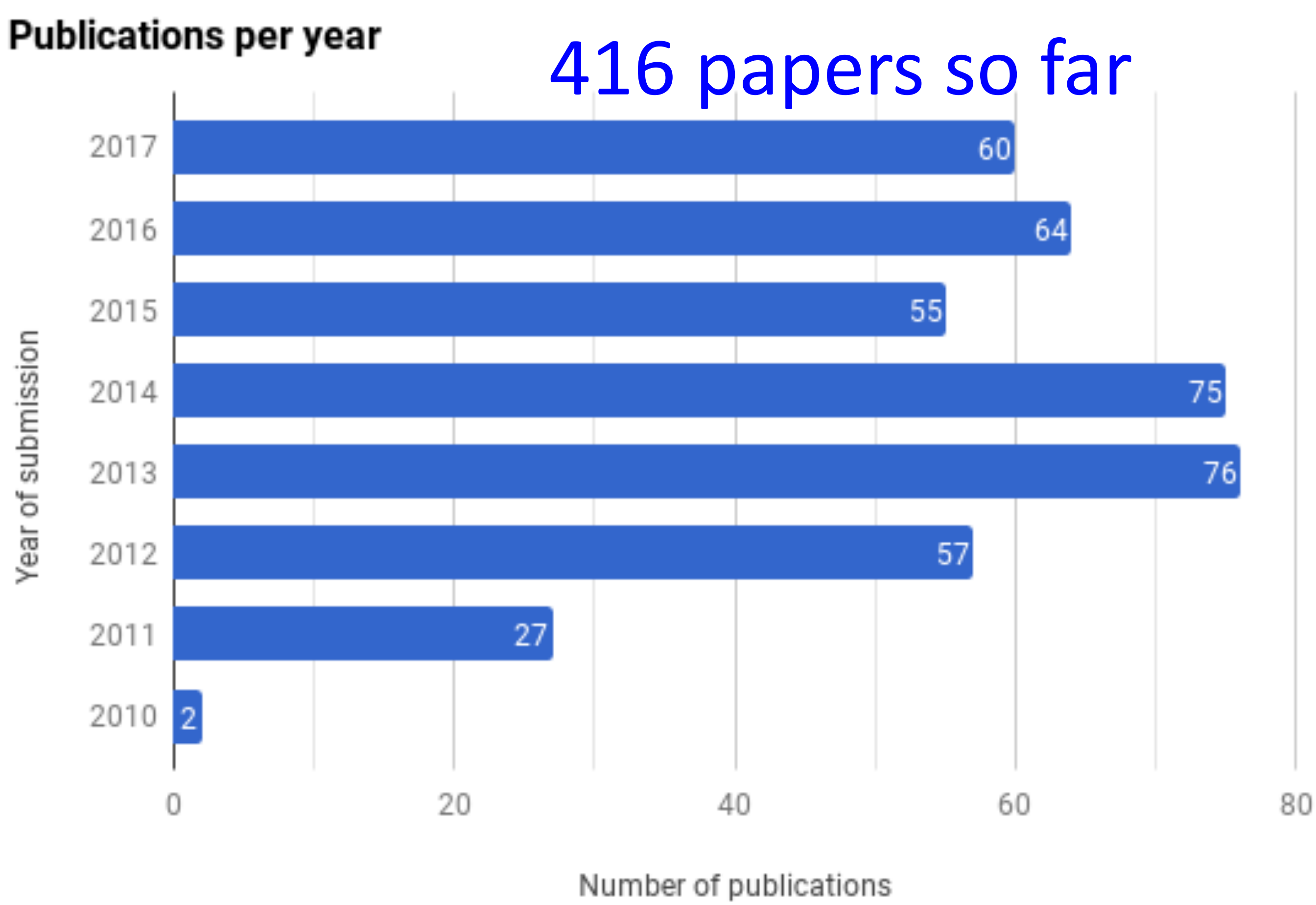
LHC era			HL-LHC era	
Run 1 (2010-12)	Run 2 (2015-18)	Run 3 (2021-24)	Run 4 (2027-30)	Run 5+ (2031+)
3 fb^{-1}	9 fb^{-1}	30 fb^{-1}	50 fb^{-1}	*300 fb^{-1}

* assumes a future LHCb upgrade to raise the instantaneous luminosity to $2x10^{34}\ cm^{-2}s^{-1}$

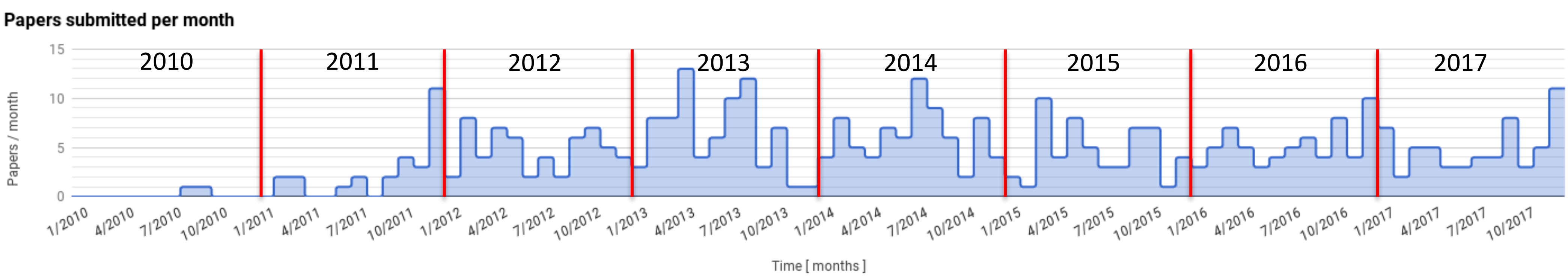
- A first LHCb upgrade will be operational in Run-3
  - Will raise the instantaneous luminosity to $2x10^{33}\ cm^{-2}s^{-1}$ (x5)
  - Improved tracking and new “trigger-less” scheme
- LHCb has submitted at the beginning of 2017 an Expression of Interest for a further upgrade to reach $2x10^{34}\ cm^{-2}s^{-1}$ (x50 wrt now)

CERN-LHCC-2017-003 https://cds.cern.ch/record/2244311

There's much more!



http://lhcbproject.web.cern.ch/lhcbproject/Publications/LHCbProjectPublic/Summary_all.html



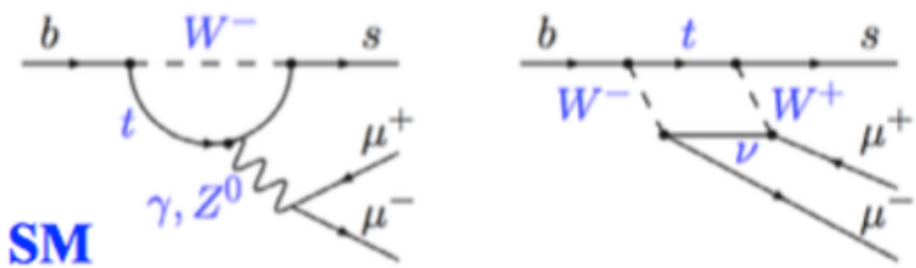
Concluding remarks

- In the current state with fundamental physics, it is necessary to have a programme as diversified as possible
  - In the unfortunate event that no direct evidence of new physics pops out of the LHC, flavour physics can play a key role in indicating the way for future developments of elementary particle physics
  - If instead new particles will be detected in direct searches, flavour physics will be a fundamental ingredient in understanding the structure of what lies beyond the Standard Model
- A strong synergy between BESIII and LHCb is one of the keys to the success of the flavour physics programme!

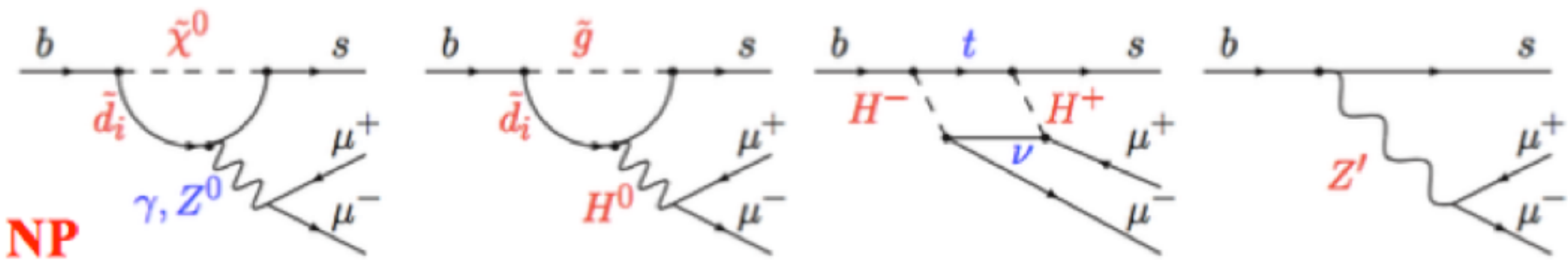
Stop!

Why is $b \rightarrow s\ell^+\ell^-$ relevant?

- Quark-level transitions entering some of the most relevant decay amplitudes to search for new physics effects

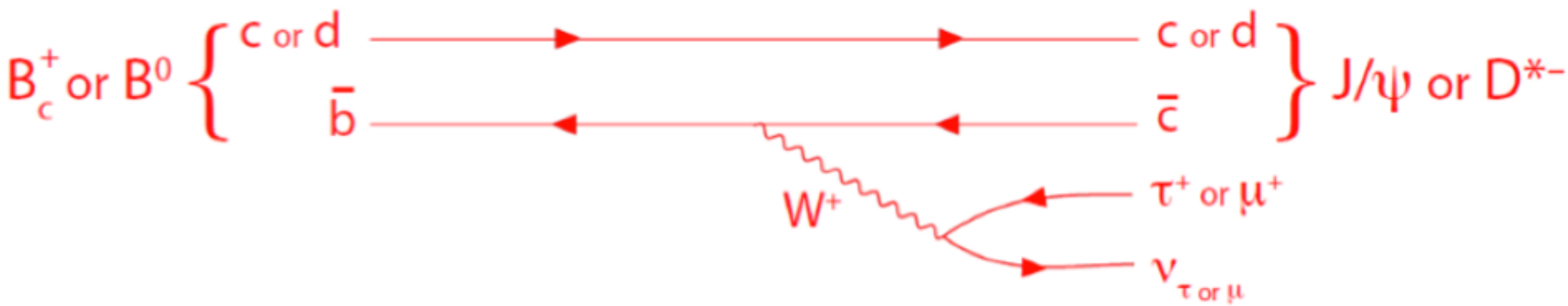


- The presence of new particles may lead to sizeable effects beyond the Standard Model

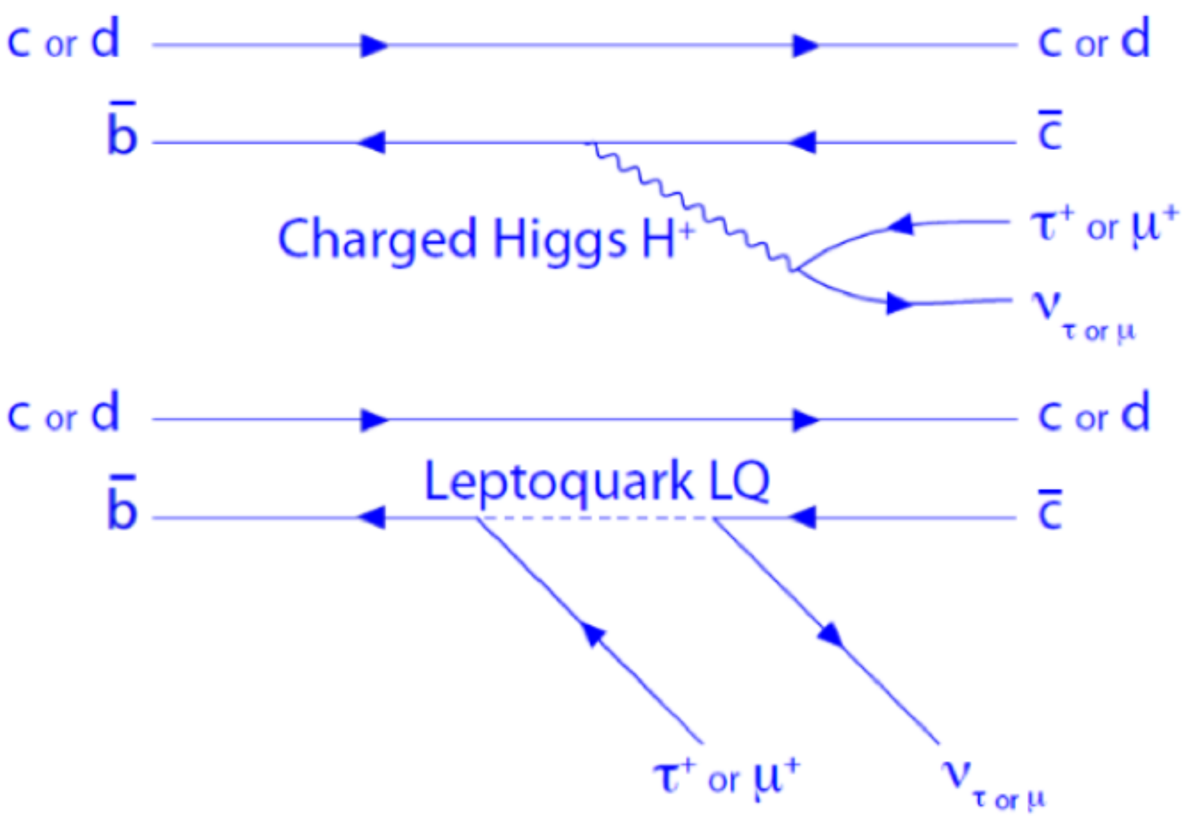


LFU tests in semileptonic *b*-hadron decays

Standard Model



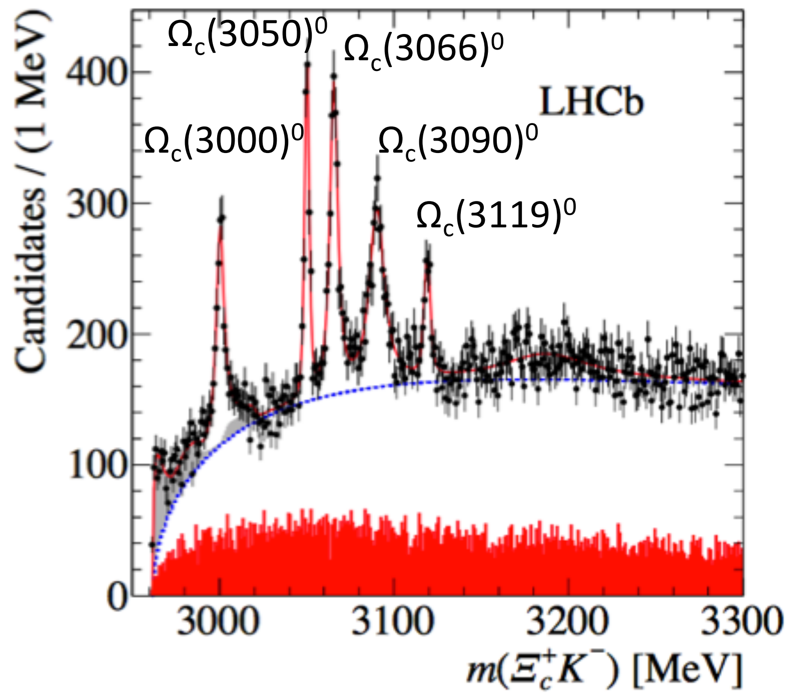
Possible new physics scenarios



Spectroscopy: excited Ω_c (?) states

- Besides new physics searches, LHCb can do relevant measurements to improve our understanding of QCD
- This is an example of a recent analysis that led to the discovery of five new states, most likely excited versions of the Ω_c baryon decaying to a Ξ_c baryon and a kaon, but some of them could also have a more exotic origin (e.g., multiquark states)

Phys. Rev. Lett. 118 (2017) 182001



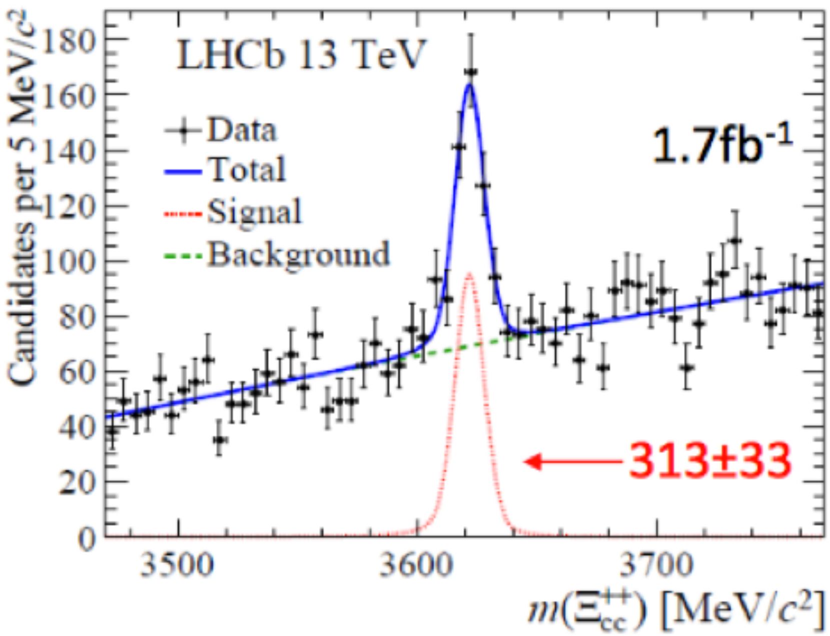
Doubly charmed baryons

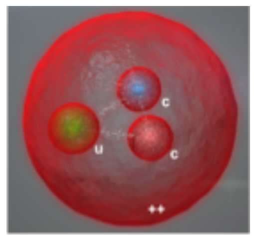
PAPER-2017-018

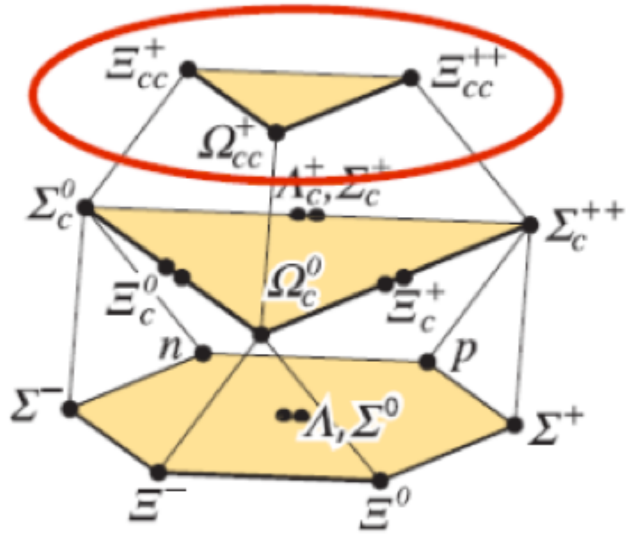
3 states expected from quark model:

Ξ_{cc}^{++}= ccu, Ξ_{cc}^{+}= ccd, Ω_{cc}^{+}= ccs

Ξ_{cc}^{+} observation reported by the SELEX experiment (*PRL89(2002)112001, PRB628(2005)18*)







SU(4) flavor multiplets, PDG Review of Particle Physics, Phys.Rev. D86, 010001.

First observation of Ξ_{cc}^{++}

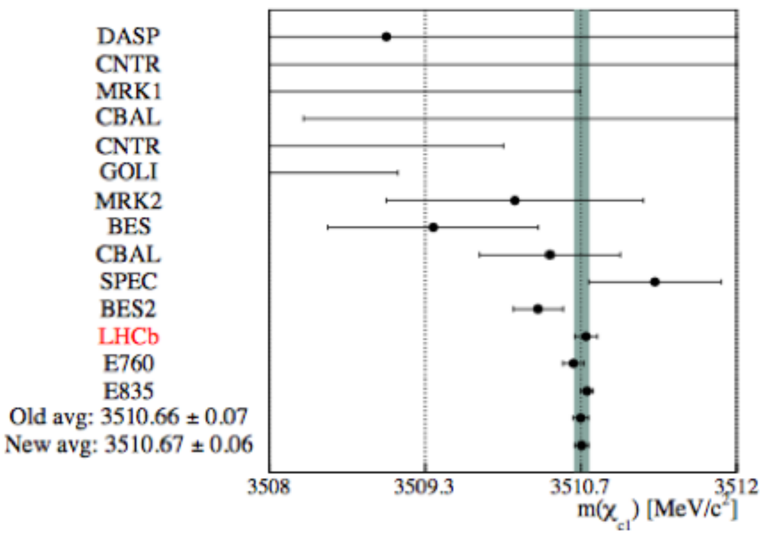
Mass ~100 MeV larger than the one reported by SELEX for Ξ_{cc}^{+}, disfavouring the Ξ_{cc}^{+} hypothesis of SELEX

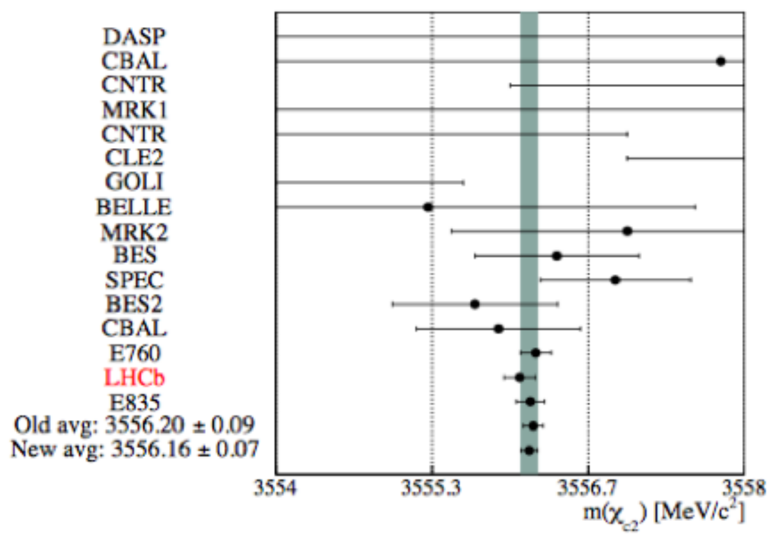
arXiv:1707.01621

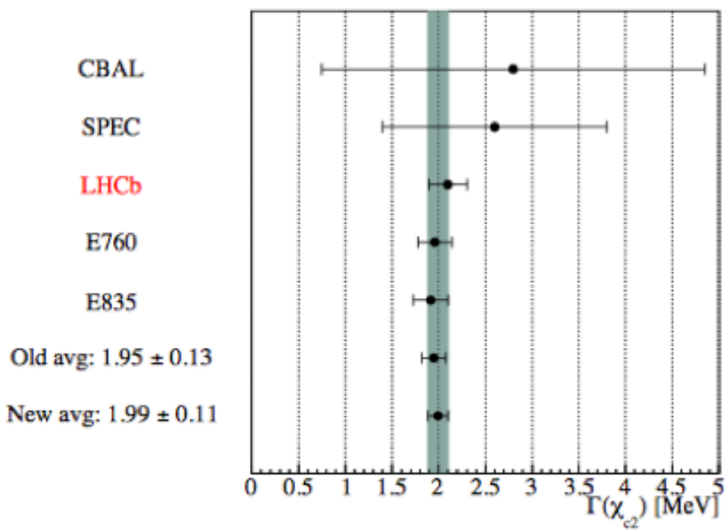
First observation of a baryon containing two heavy quarks

- Now at work to measure properties: lifetime, production mechanisms, decay modes, ...
- ... as well as to observe singly charged and strange partners

First observation of the decays $\chi_{c1,2} \rightarrow J/\psi\mu\mu$ and precision measurements of χ_c masses and widths





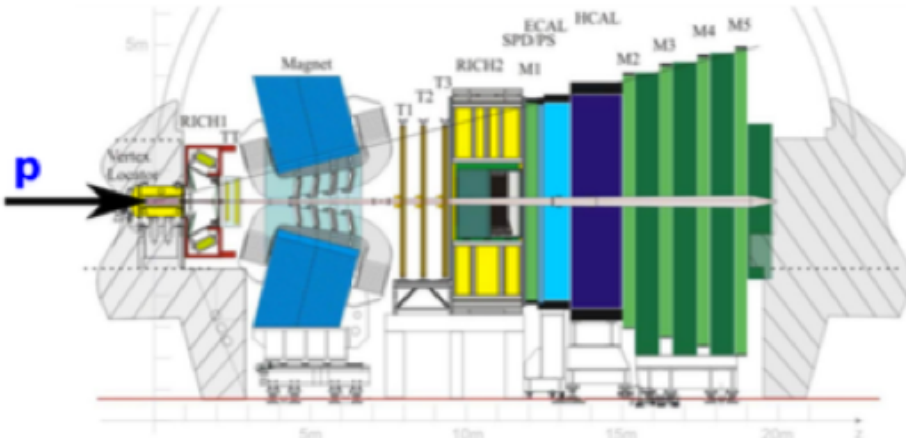


E760/E835 are the other precise measurements. They are based on energy scan with ppbar beam

[Very different technique/systematic]

Heavy-ion collisions

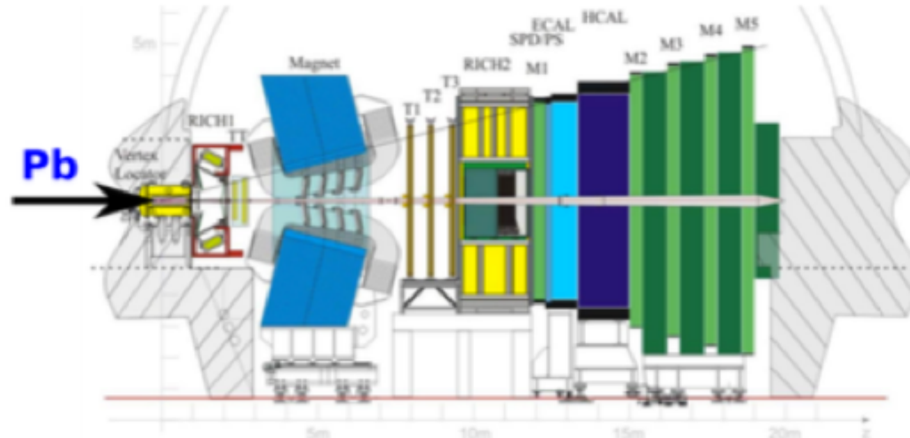
Data taken during 2016 p-Pb and Pb-p runs @ $\sqrt{s_{NN}} = 8.16$ TeV



Forward

$1.5 < y^* < 4.5$

$y^* = y_{lab} - 0.465$



Backward

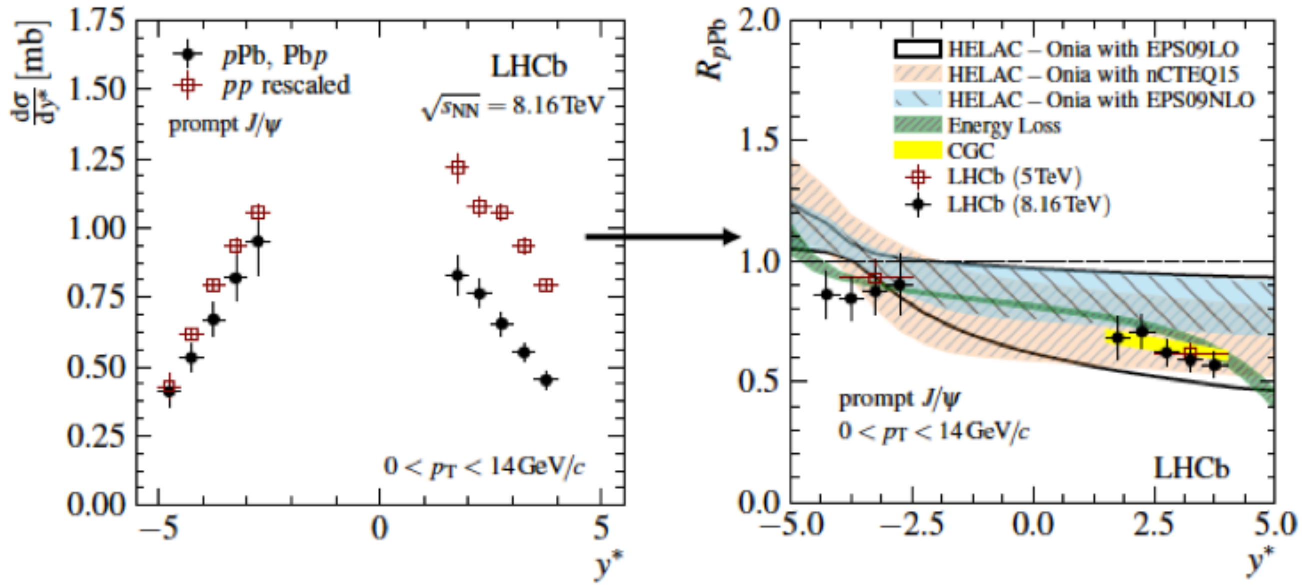
$-5.5 < y^* < -2.5$

$y^* = -(y_{lab} + 0.465)$

J/ψ production in pPb at 8 TeV

- Nuclear effects seen in the comparison with pp collisions and in the comparison of pPb with Pbp

$$R_{p\mathrm{Pb}}(p_{\mathrm{T}}, y^*) \equiv \frac{1}{A}\frac{\mathrm{d}^2\sigma_{p\mathrm{Pb}}(p_{\mathrm{T}}, y^*)/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y^*}{\mathrm{d}^2\sigma_{pp}(p_{\mathrm{T}}, y^*)/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y^*}$$ and $$R_{\mathrm{FB}}(p_{\mathrm{T}}, y^*) \equiv \frac{\mathrm{d}^2\sigma_{p\mathrm{Pb}}(p_{\mathrm{T}}, +y^*)/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y^*}{\mathrm{d}^2\sigma_{p\mathrm{Pb}}(p_{\mathrm{T}}, -y^*)/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y^*}$$



- Color glass condensate (saturation of gluon density at low x) and energy loss (scattering of the colliding gluon in nuclear matter) are found to be very accurate when comparing with data

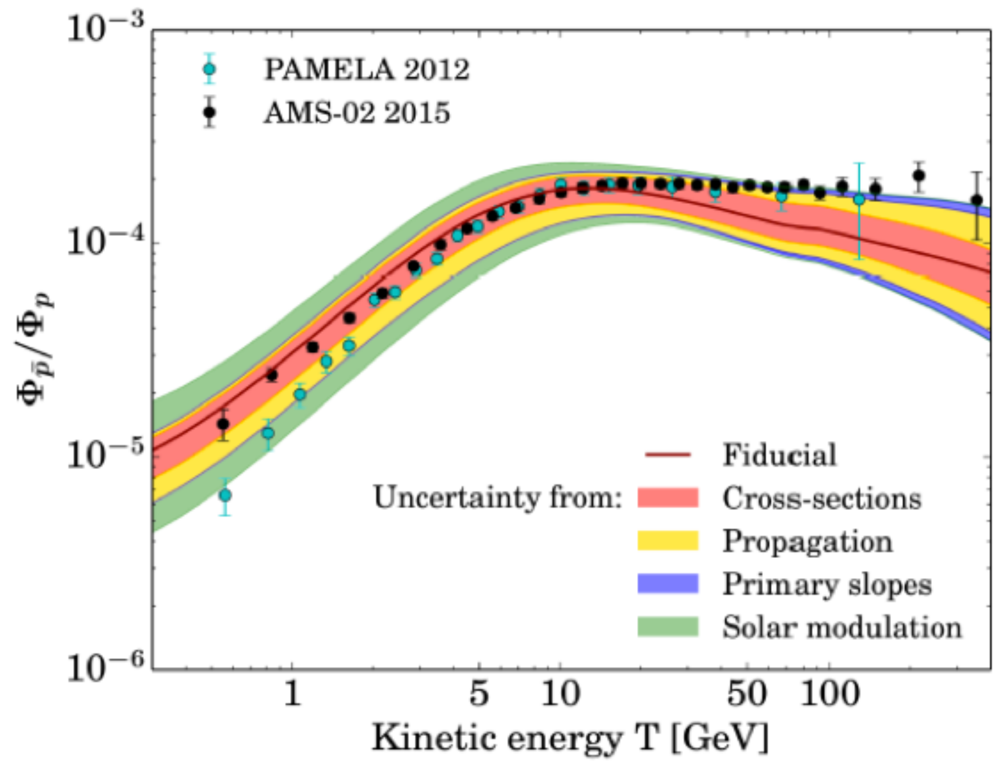
Phys. Lett. B774 (2017) 159

- First LHC paper with 2016 data, out of the Turbo trigger!

Antiproton production in fixed-target *p*He collisions

LHCb-CONF-2017-002

- Measurement motivated by the need to understand energy dependence of $\bar{p}$ component from cosmic rays in space
- Theoretical uncertainties are limited by precise knowledge of cross section for basic processes in the interstellar medium, like those arising from *p*He collisions

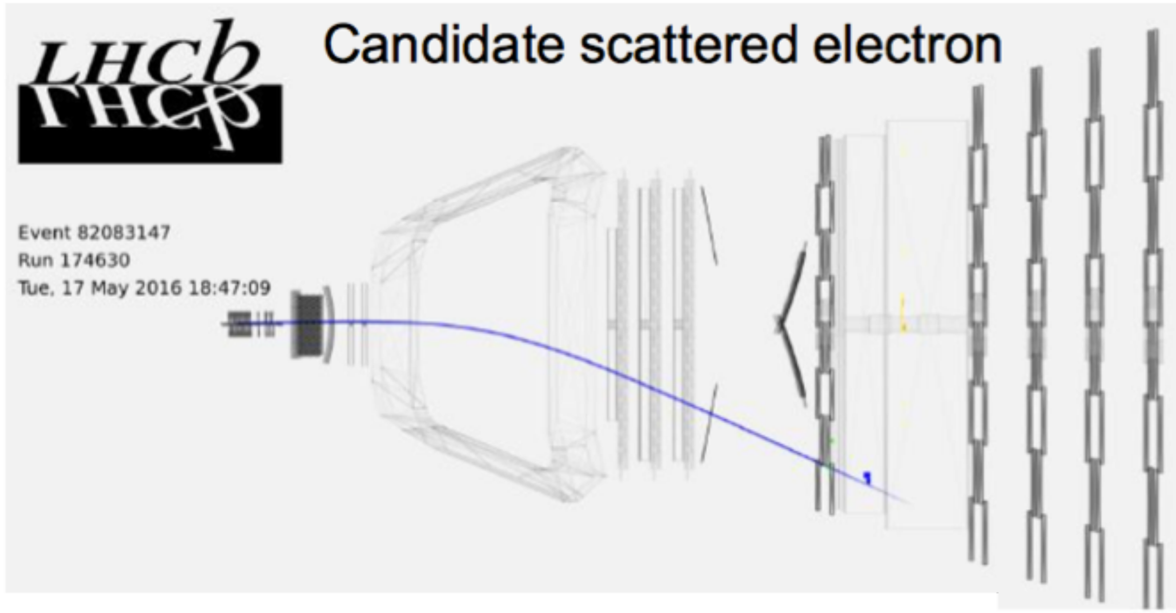


- LHCb can inject gas into the beam pipe for relevant cross-section measurements in the sector

Antiproton production in fixed-target pHe collisions

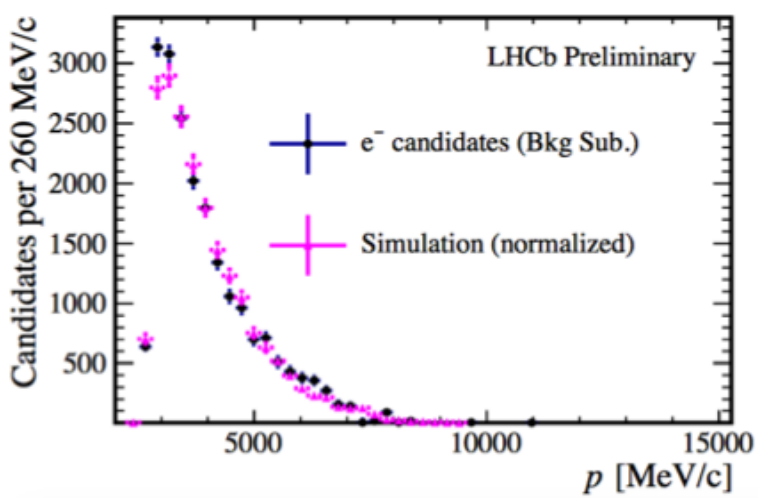
LHCb-CONF-2017-002

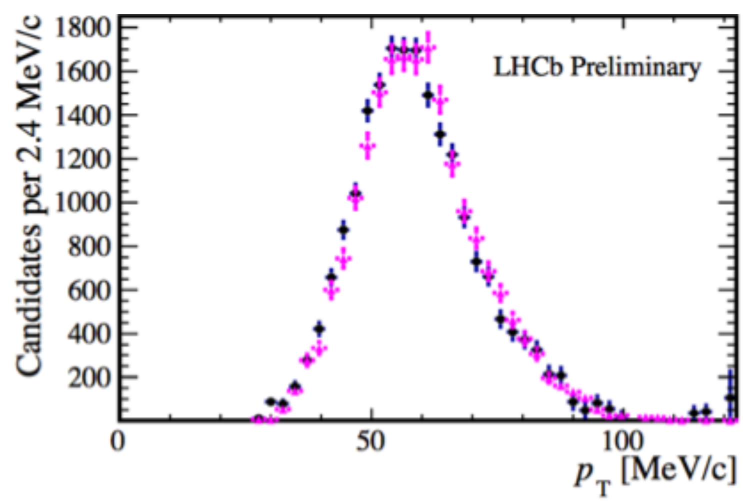
- One difficulty to measure absolute cross sections with gas injection is the determination of luminosity
  - A novel method has been developed to exploit elastic pe^- interactions



$$\mathcal{L} = \mathbf{0.443 \pm 0.011 \pm 0.027\ nb^{-1}}$$

- Very good agreement between simulation and data

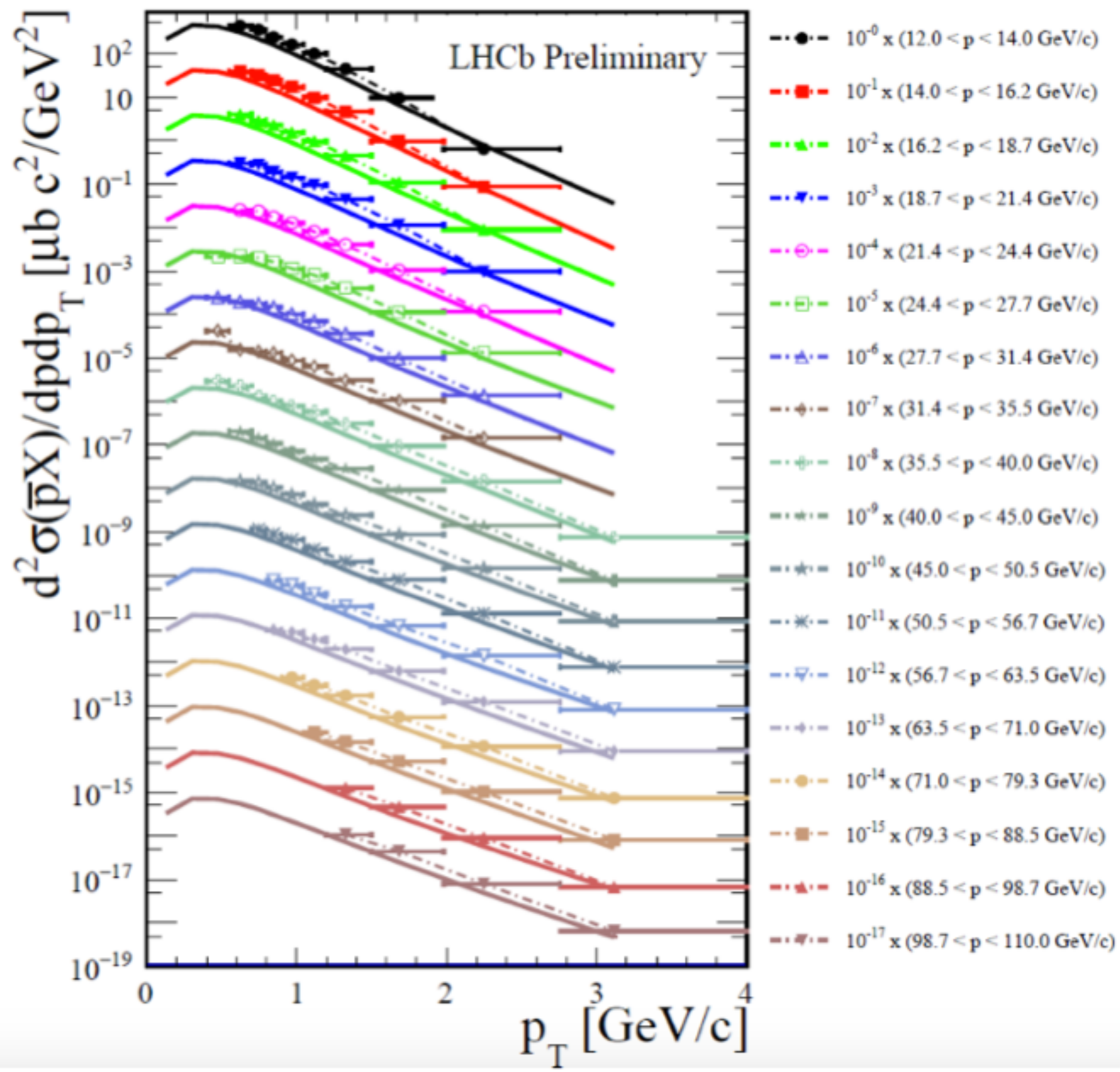




Antiproton production in fixed-target *p*He collisions

LHCb-CONF-2017-002

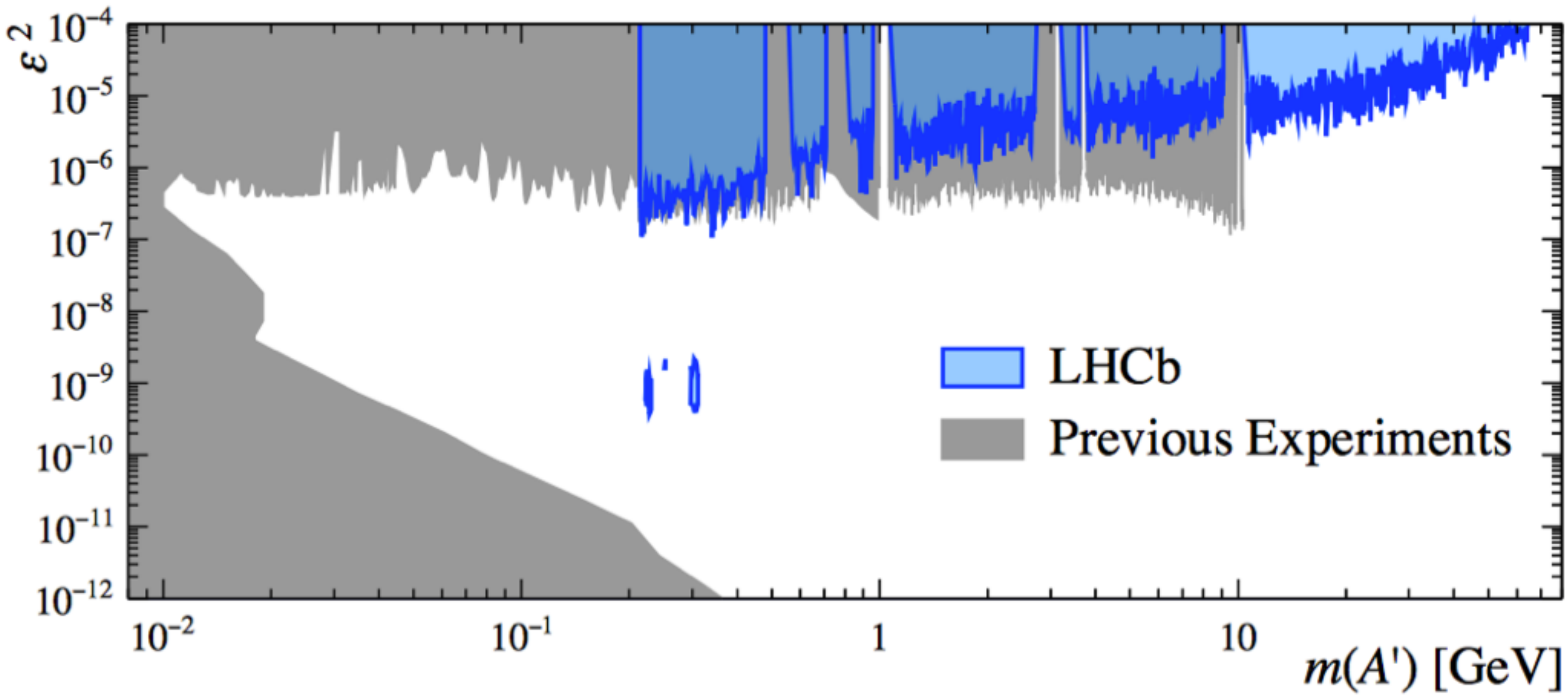
- Antiproton cross section measured with 10% precision
  - The measurement is larger by 1.5 with respect to EPOS LHC event generator
- Theoretical interpretation ongoing
- Additional production measurements are also important
  - E.g., antiprotons from Λ decays
- Rich programme to develop with fixed target!



Search for dark photons decaying to a dimuon

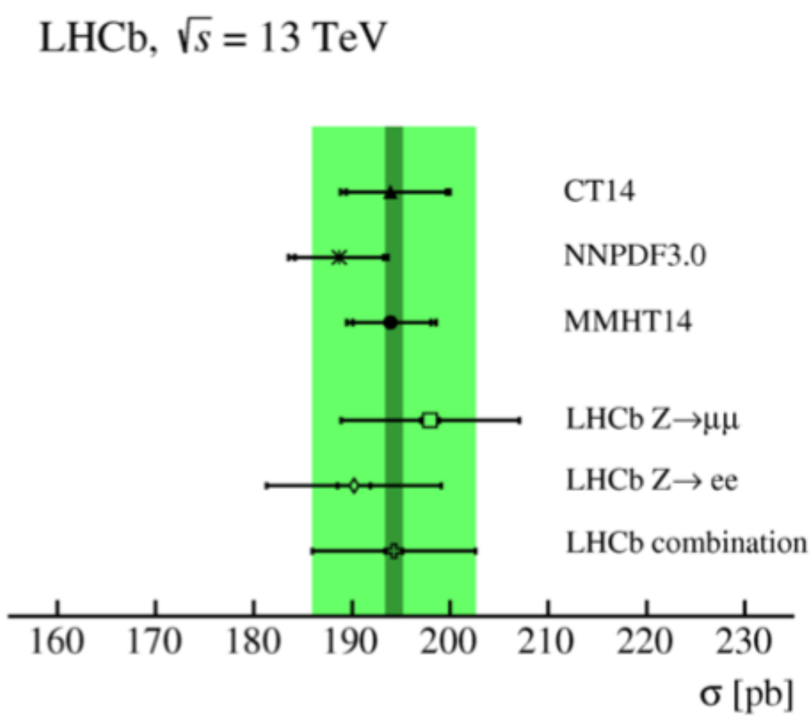
arXiv:1710.02867

First LHCb search for A' is complete. Despite O(10%) L0 efficiency at low mass— and only have 1.5/fb of data — we already equal BaBar in the prompt search. Above 10 GeV, these are the first limits. The displaced search excludes a small region — first ever non-beam-dump long-lived sensitivity — and a large region is within reach for Run 2.



Forward Z^0 boson production

- $Z^0 \to \mu\mu$ and $Z^0 \to ee$ cross section at 13 TeV measured in LHCb acceptance



$$\sigma_{\mathrm{Z}}^{\ell\ell} = 194.3 \pm 0.9 \pm 3.3 \pm 7.6\,\mathrm{pb}$$

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