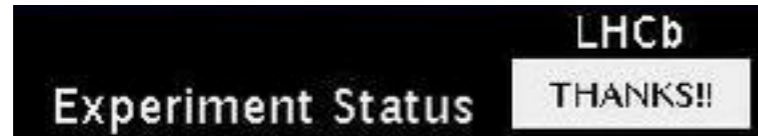




# 1.88fb<sup>-1</sup>

Delivered luminosity by the LHC



# 1 trillion

Amount of beauty hadrons produced at LHCb this year.  
A factor 1000 more than B-factory experiments

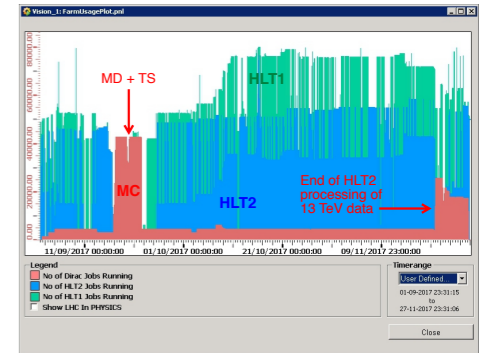
# 3

Tests of lepton universality.  
 $R_{K^*}$ ,  $R_{D^*}$  and  $R_{J/\psi}$

# 2017

# 5000

Average number of simulation jobs running in parallel to trigger on the farm.



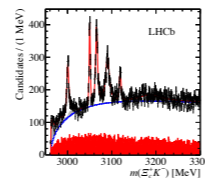
# 60

Publications submitted this year

# 3

New associate members

# 6



New particles discovered, all containing at least one charm quark.



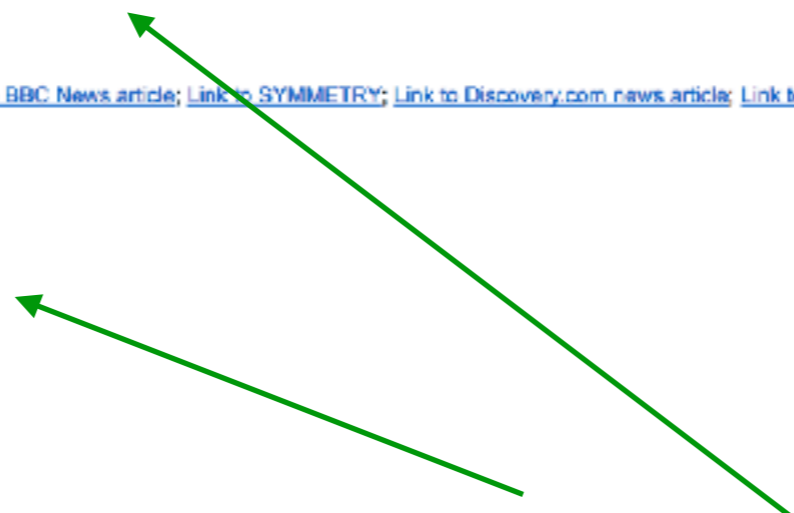
# Outline

r LHCb-PAPER\* or (a a) and r carn-ph\*)  
[\[url="Phys.Rev.Lett.155" = www\]](#) Brief format Search Easy Search Advanced Search

Sort by: earliest date desc. times cited 25 results single list Display results:

**HEP** 405 records found 1 - 25 ▶▶ jump to record: 1 Search took 3.65 s

- 1. Observation of  $J/\psi$  Resonances Consistent with Pentaquark States in  $\Lambda_b^0 \rightarrow J/\psi K^- p$  Decays**  
(468) LHCb Collaboration (Roel Aaij (CERN) et al.), Jul 13, 2015. 15 pp.  
Published in *Phys.Rev.Lett.* **115** (2015) 072001  
CERN-PH-EP-2015-153, LHCb-PAPER-2015-029  
DOI: [10.1103/PhysRevLett.115.072001](#)  
e-Print: [arXiv:1507.03414 \[hep-ex\]](#) | [PDF](#)  
[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [HarvMac](#) | [EndNote](#)  
[CERN Document Server](#); [ADS Abstract Service](#); [Interactions.org article](#); [Link to BBC News article](#); [Link to SYMMETRY](#); [Link to Discovery.com news article](#); [Link to Nature News article](#); [Link to PBS website](#); [Link to](#)  
[Detailed record](#) - Cited by 468 records ▶▶
- 2. Test of lepton universality using  $B^+ \rightarrow K^+ \ell^+ \ell^-$  decays**  
(471) LHCb Collaboration (Roel Aaij (NIKHEF, Amsterdam) et al.), Jun 25, 2014. 10 pp.  
Published in *Phys.Rev.Lett.* **113** (2014) 151801  
CERN-PH-EP-2014-140, LHCb-PAPER-2014-024  
DOI: [10.1103/PhysRevLett.113.151801](#)  
e-Print: [arXiv:1406.6482 \[hep-ex\]](#) | [PDF](#)  
[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [HarvMac](#) | [EndNote](#)  
[CERN Document Server](#); [ADS Abstract Service](#)  
[Detailed record](#) - Cited by 471 records ▶▶
- 3. First Evidence for the Decay  $B_s^0 \rightarrow \mu^+ \mu^-$**   
(453) LHCb Collaboration (R Aaij (NIKHEF, Amsterdam) et al.), Nov 2012. 9 pp.  
Published in *Phys.Rev.Lett.* **110** (2013) no.2, 021801  
CERN-PH-EP-2012-335, LHCb-PAPER-2012-043  
DOI: [10.1103/PhysRevLett.110.021801](#)  
e-Print: [arXiv:1211.2674 \[hep-ex\]](#) | [PDF](#)  
[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [HarvMac](#) | [EndNote](#)  
[CERN Document Server](#); [ADS Abstract Service](#)  
[Detailed record](#) - Cited by 453 records ▶▶
- 4. Measurement of Form-Factor-Independent Observables in the Decay  $B^0 \rightarrow K^{*0} \mu^+ \mu^-$**   
(382) LHCb Collaboration (R Aaij (NIKHEF, Amsterdam) et al.), Aug 7, 2013. 8 pp.  
Published in *Phys.Rev.Lett.* **111** (2013) 191801  
LHCb-PAPER-2013-037, CERN-PH-EP-2013-146  
DOI: [10.1103/PhysRevLett.111.191801](#)  
e-Print: [arXiv:1308.1707 \[hep-ex\]](#) | [PDF](#)  
[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [HarvMac](#) | [EndNote](#)  
[CERN Document Server](#); [ADS Abstract Service](#)  
[Detailed record](#) - Cited by 382 records ▶▶



Limited time: focus on spectroscopy and lepton universality.

+ CP violation as that was our initial raison d'être

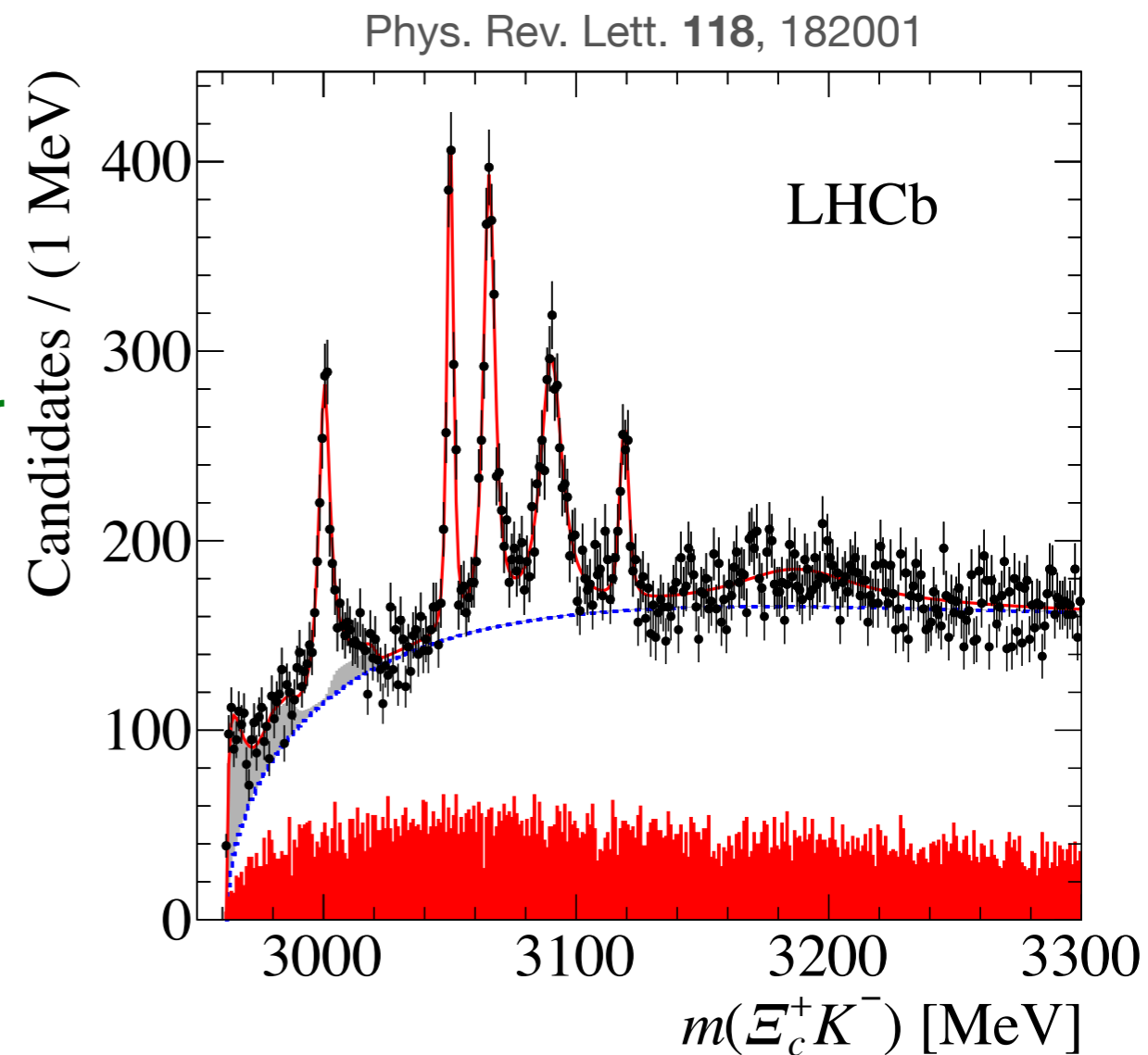
The screenshot shows the top part of the LHCb website. On the left is the CERN logo. To its right is a navigation menu with links for 'About CERN', 'Students & Educators', 'Scientists', and 'CERN community'. Below these are secondary links: 'Acceleration', 'Experiments', 'Physics', 'Computing', 'Engineering', 'Updates', and 'Opinion'. The main heading 'LHCb' is prominently displayed, followed by a short introductory paragraph: 'The LHCb experiment will shed light on why we live in a universe that appears to be composed almost entirely of matter, but no antimatter.'



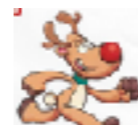
# Search for $\Omega_c$ baryons

- Search for excited  $\Omega_c$  (css) states, only two previously known.

- Add a kaon (su) to a  $\Xi_c$  baryon (csu)
- Observe **five** new states, a record for a single publication?
- Results consistent with heavy quark effective theory.



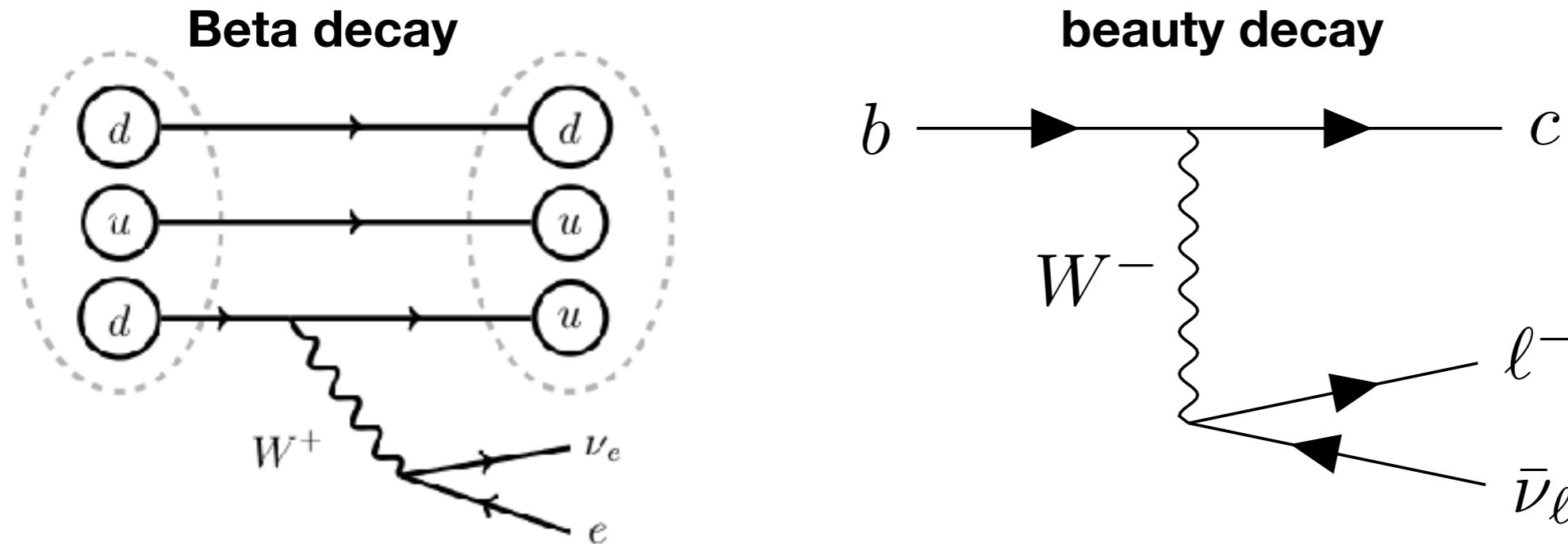
- Four of these now confirmed by Belle. [BELLE-PREPRINT-2017-22]





# New physics with B decays

- Beauty quarks decay via the weak force.

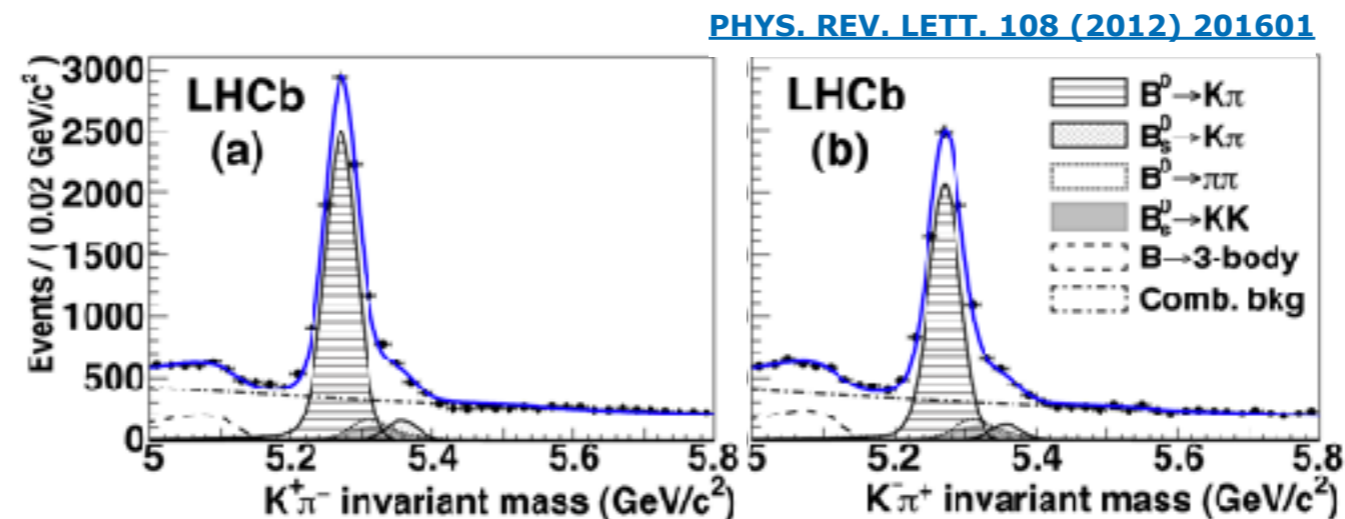


- The  $W$  and  $Z$  bosons are over 10 times heavier than the initial decaying b-hadron, but still mediate the decay.
- Measuring beauty quark decays can tell us about new high mass particles.
- Such particles can change the rate, angular distribution and CP violation of beauty decays.



# CP-violation

- We live in a matter dominated universe.
- If anti-matter and matter are treated perfectly equally, then nothing leftover after the big bang.
- The way out is CP-violation - a difference in the way the fundamental forces treat matter and anti-matter.



- But the amount of CP violation in the Standard Model is about 10 orders of magnitude too small for baryogenesis.
- **We expect to find new sources of CP violation beyond the Standard Model.**



# Search for new CPV sources

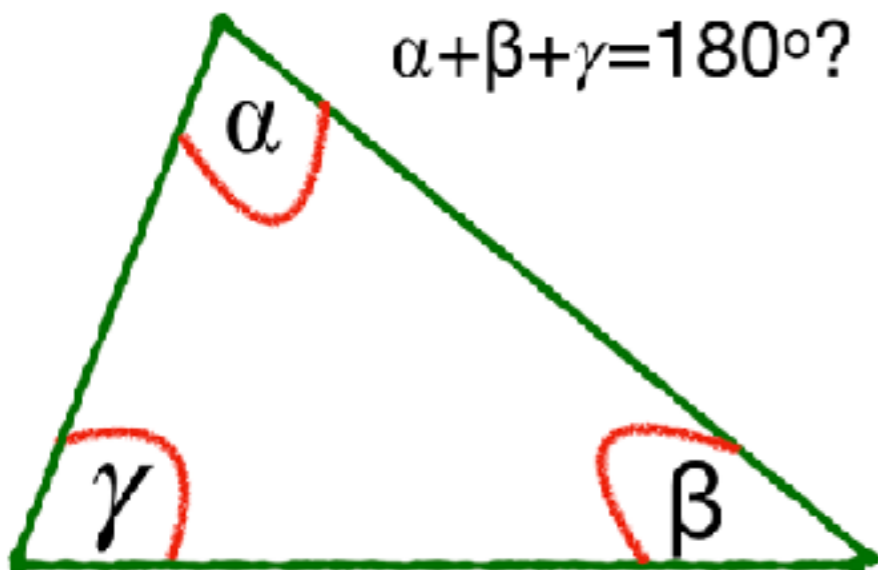
- We look for CPV by testing the unitarity of CKM matrix, and studying meson oscillations.

Latest gamma combination:

$$\gamma = (76.8^{+5.1}_{-5.7})^\circ$$

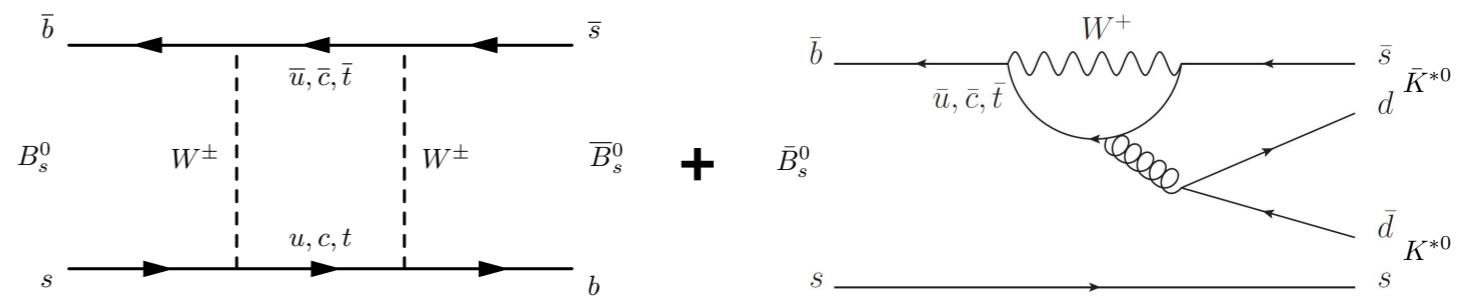
consistent with CKM unitarity.

[LHCb-CONF-2017-004]



First measurement of  $\phi_s^{d\bar{d}}$  from  $B_s^0 \rightarrow K^* K^*$

Exploit interference between oscillation and decay.



Results consistent with Standard Model.

$$\phi_s^{d\bar{d}} = -0.10 \pm 0.13 \pm 0.14 \text{ rad (preliminary)}$$

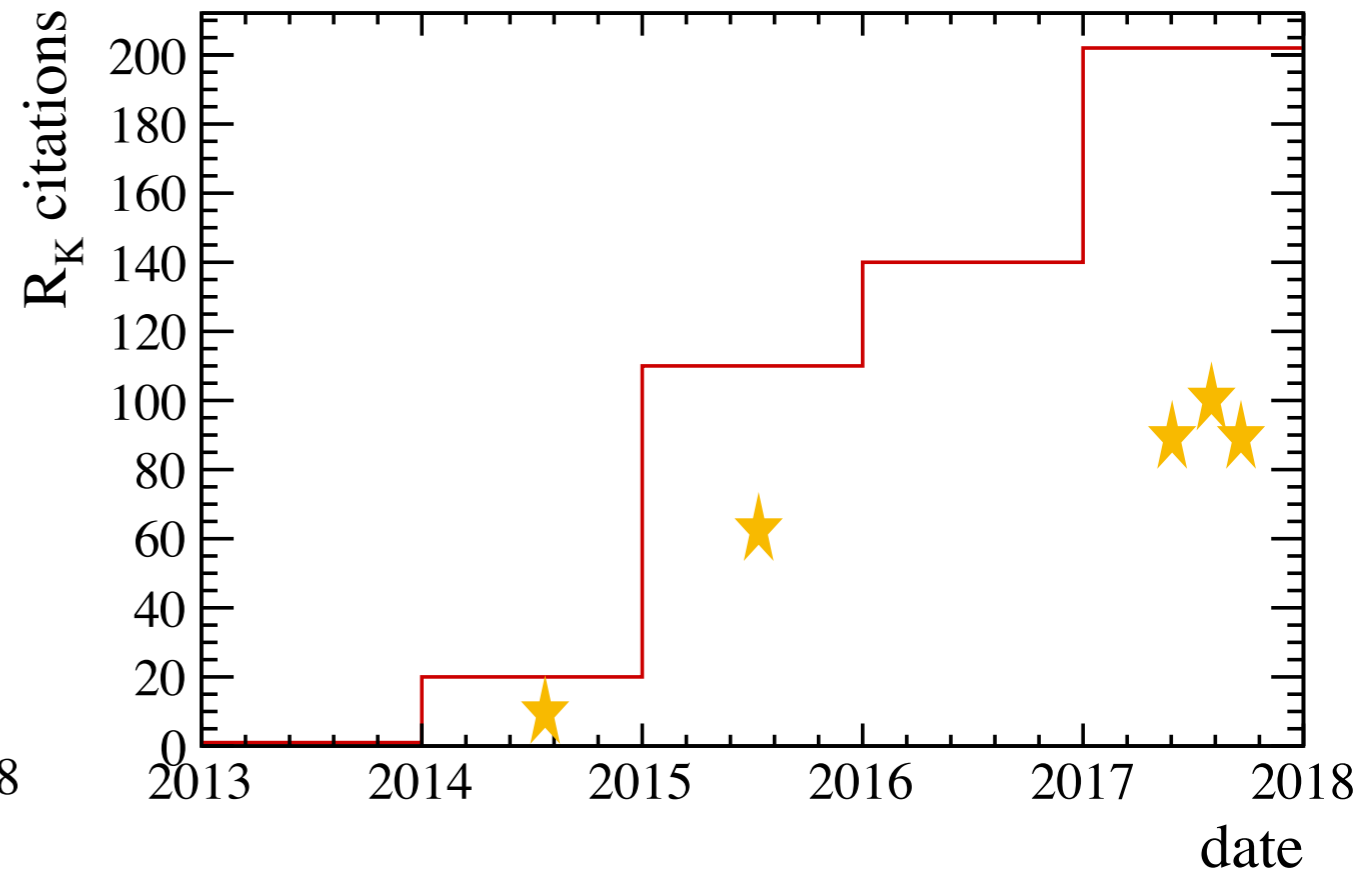
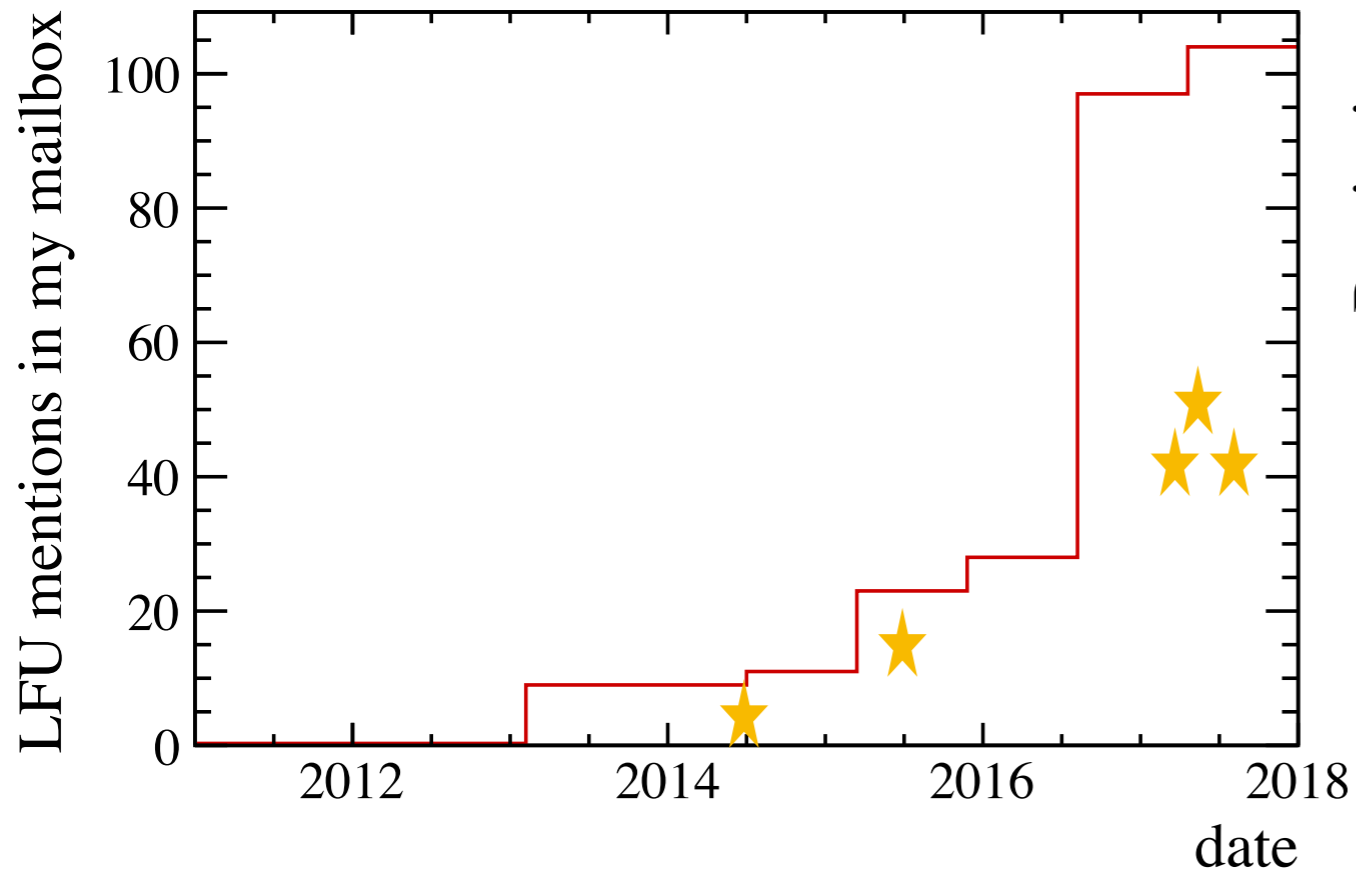
[LHCb-PAPER-2017-048]





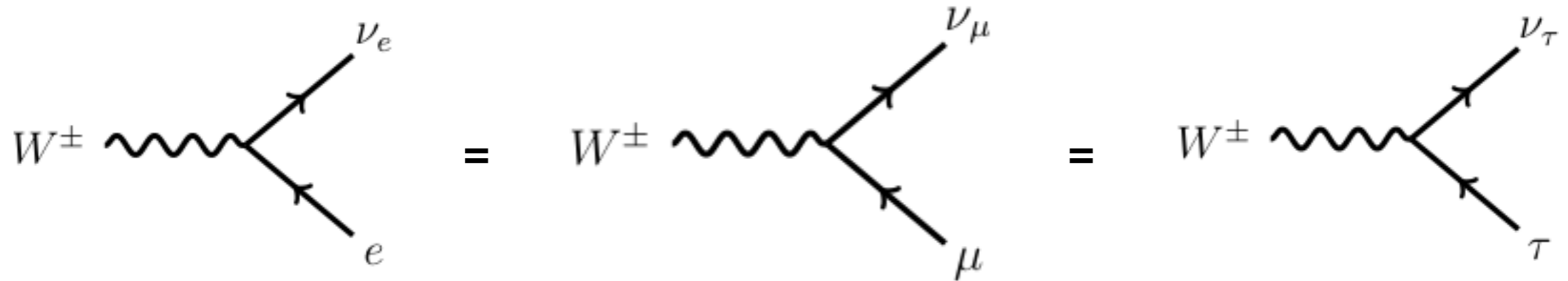
# Lepton universality

★ = Lepton universality publication

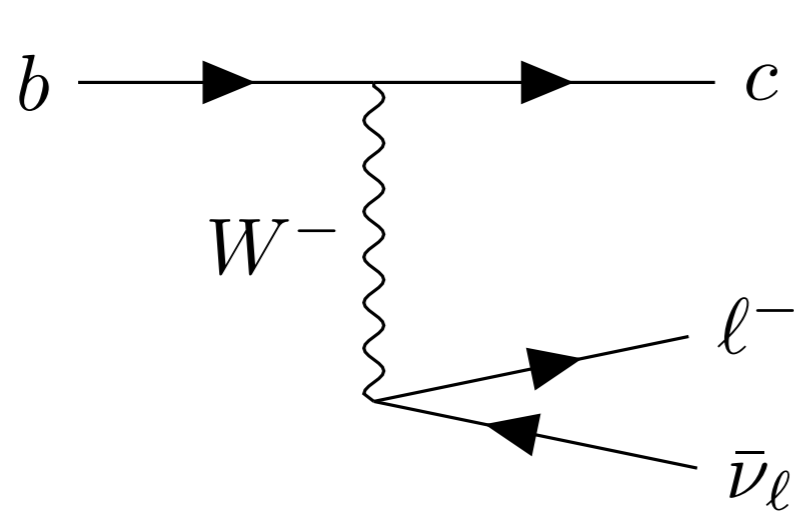


# Lepton universality

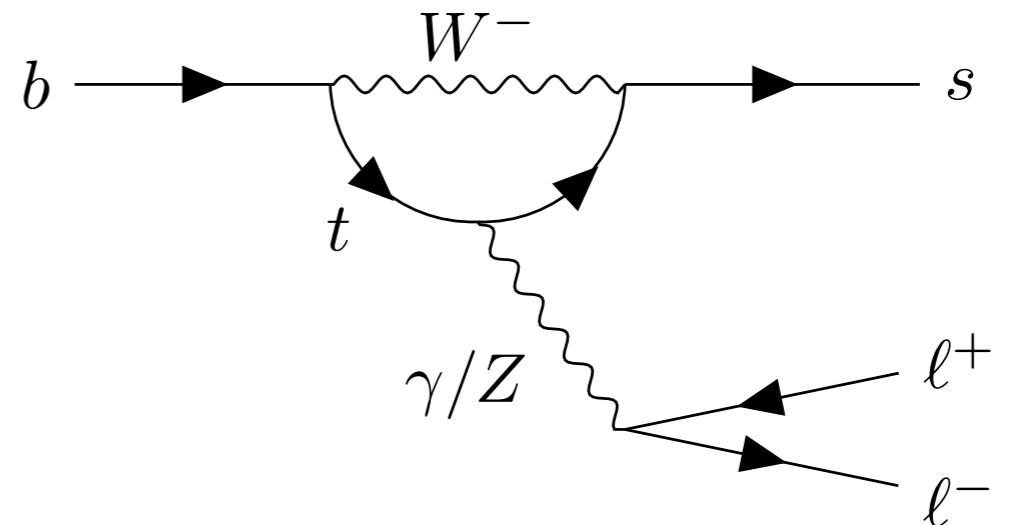
In the Standard Model, the three charged leptons, apart their mass, are identical copies of each other - a concept known as **lepton universality**.



We want to test this in  $B$  decays:



$$R_{D^{(*)}} = \frac{\mathcal{B}(B \rightarrow D^{(*)} \tau \nu)}{\mathcal{B}(B \rightarrow D^{(*)} \mu \nu)}$$

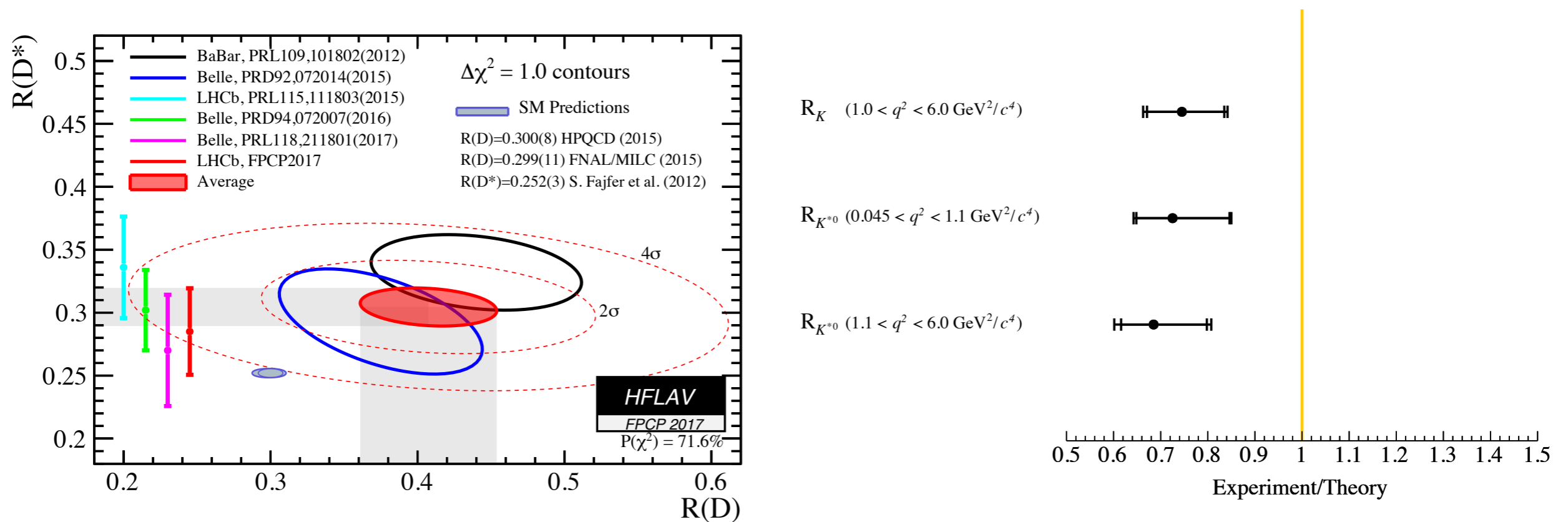


$$R_{K^{(*)}} = \frac{\mathcal{B}(B \rightarrow K^{(*)} \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K^{(*)} e^+ e^-)}$$



# Lepton universality violation?

- In 2014, we measured  $R_K$ , in 2015, we measured  $R_{D^*}$ .
- This year, we measured  $R_{K^*}$ ,  $R_{D^*}$  and  $R_{J/\psi}^{1,2,3}$ .

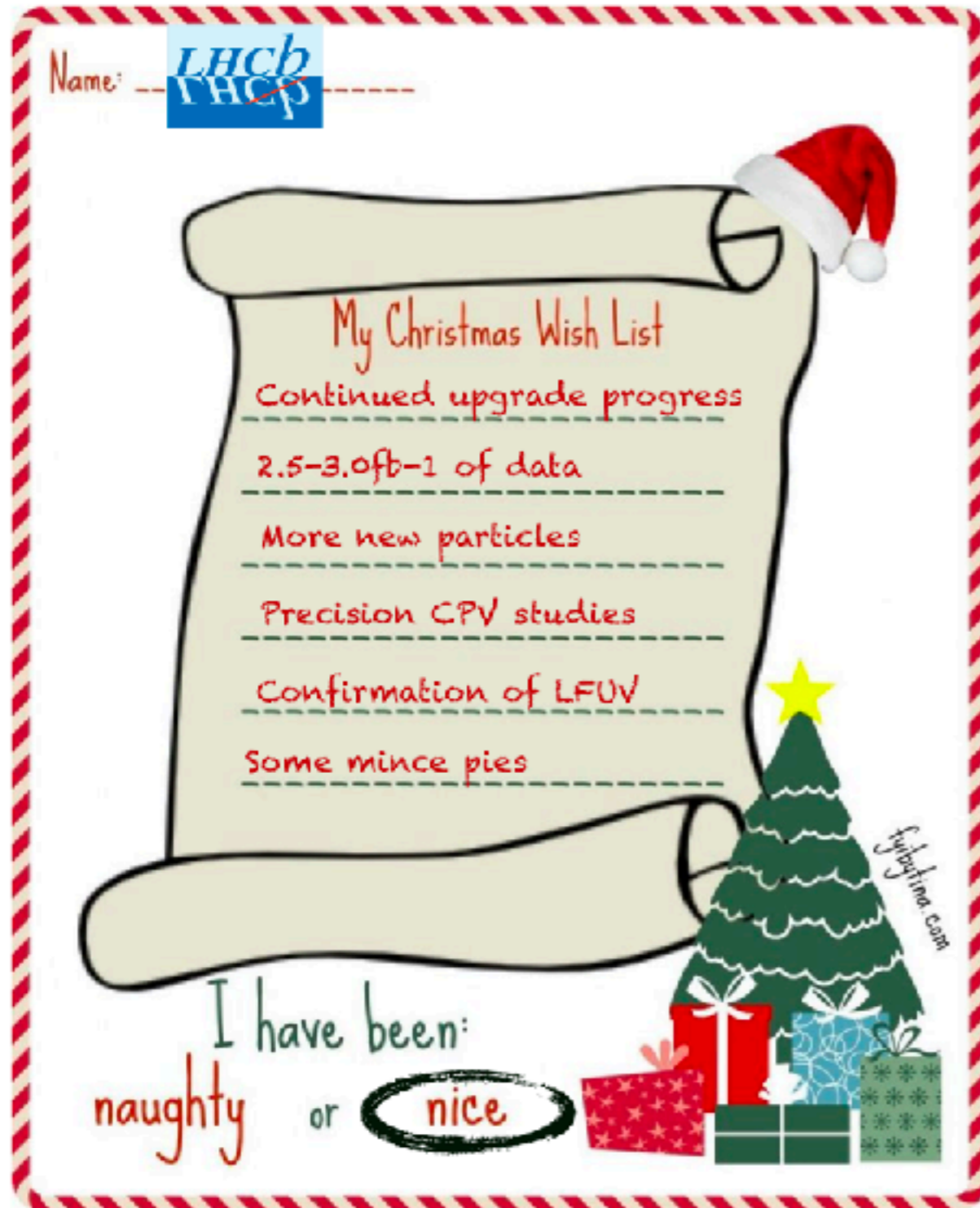


- Deviations in both tree- and loop-level B decays, hints of new physics?
- For tree-level decays, the mass scale  $\sim 1.5\text{TeV}$ , interesting for direct searches now. For loop-level up to  $\sim 50\text{TeV}$  scale, interesting for future collider.



# Summary and prospects

- 2017 has been an excellent year for LHCb, with plenty of data and exciting results.



- I could not talk about everything we do today: anti-proton production in pHe collisions, electroweak and heavy ion physics to name a few.
- Looking to the future with the LS2 upgrade 1 and possibly with an LS4 upgrade 2 [\[EOI\]](#).
- For now we hope for ~TeV scale NP!

