Semitauonic B decays at LHCb
$\overline{B}^0 \to D^{*+}\tau\bar{\nu}_\tau$ and $\Lambda_b^0 \to \Lambda_c^+\tau\bar{\nu}_\tau$

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Introduction

Standard Model (SM) is based on **Lepton Flavour Universality** but there are tensions between SM expectations and experimental results.
→ Semitauonic B decays are a great tool to probe this discrepancy
• **Precise prediction** from SM using ratios with shared systematics cancelling:

$$R(D^{(*)}) = \frac{\mathcal{B}(\bar{B}^0 \to D^{(*)+}\tau^-\bar{\nu}_\tau)}{\mathcal{B}(\bar{B}^0 \to D^{(*)+}\mu^-\bar{\nu}_\mu)}$$

$$R(\Lambda_c) = \frac{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+\tau^-\bar{\nu}_\tau)}{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+\mu^-\bar{\nu}_\mu)}$$

R(D) = 0.300 ± 0.008 [1]
R(D*) = 0.252 ± 0.003 [2]
R(Λ_c) = 0.333 ± 0.010 [3]

• Abundant statistics
• **Enhanced sensitivity to New Physics** due to the mass of the τ lepton

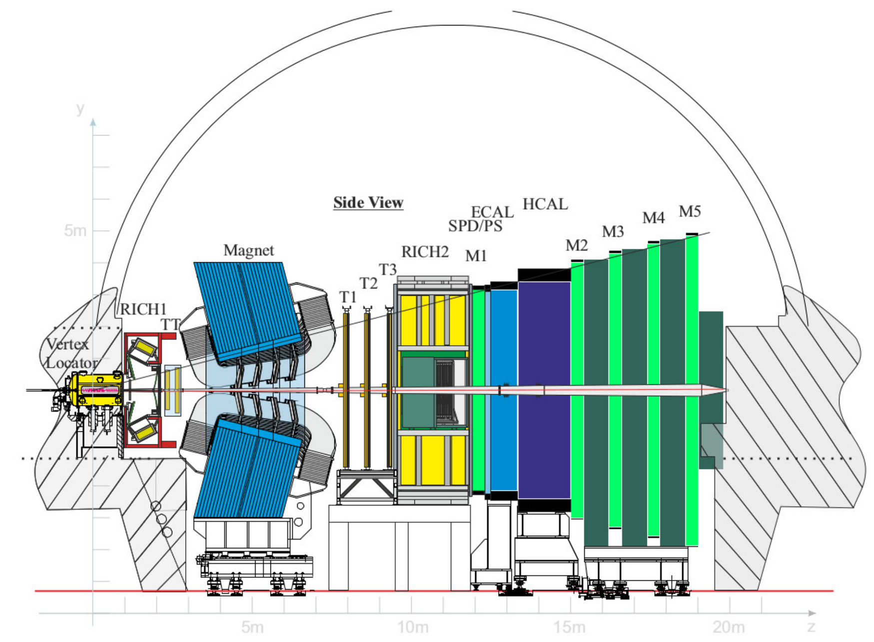
The LHCb detector

The detector is a **single arm forward spectrometer** at LHC covering the pseudo-rapidity range 2<η<5. It is optimised to study hadron decays containing b and c quarks.
Its key features are:

• **Excellent vertex resolution**:
σ_z = 100 μm, σ_{IP} = 20 μm

• **Momentum and mass resolution**:
Δp/p = 0.6 % @ 100 Gev/c^2

• **PID capabilities**: good separation K-π and muon



Analysis workflow

Both analyses share the same strategy:

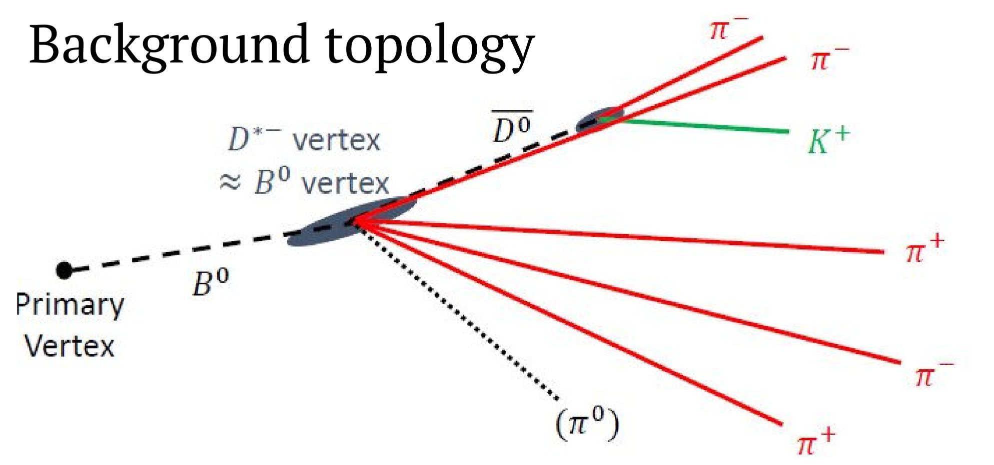
• Use of the hadronic decay $\tau^- \to \pi^-\pi^+\pi^-(\pi^0)\nu_\tau$
  • Allow the reconstruction of the τ vertex
  • Use of $B^0 \to D^{*+}\pi\pi\pi$ as normalisation channel

• No semileptonic background but huge one coming from **prompt $B^0 \to D^{*+}\pi\pi\pi X$ decays**:

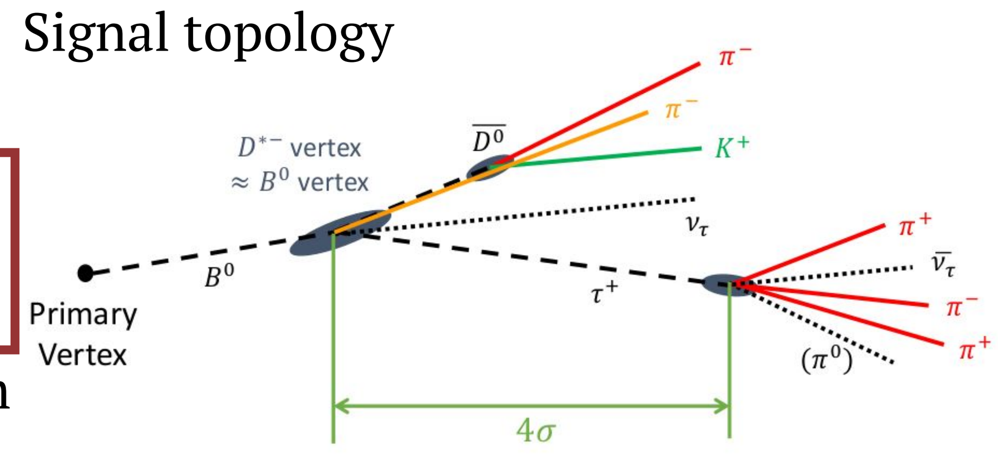
> Can be reduced by 3 orders of magnitude using **vertex detachment**

• Remaining background is made of double charm events:
  • $B^0 \to D^* D_s X$, $B^0 \to D^* D^0 X$ and $B^0 \to D^* D^+ X$

Background topology

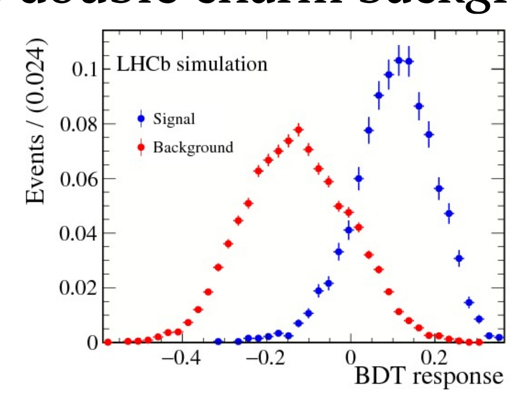


Signal topology



LHCb has three very good tools to limit this background:
• **3π dynamics**
• **Isolation** criteria against charged tracks and neutral energy deposits
• **Partial reconstruction** in both signal and background hypotheses

A **Boosted Decision Tree** (BDT) is then trained to further reduce double charm background.



Finally, a **3D template fit is performed** using q^2, τ lifetime and output of BDT.

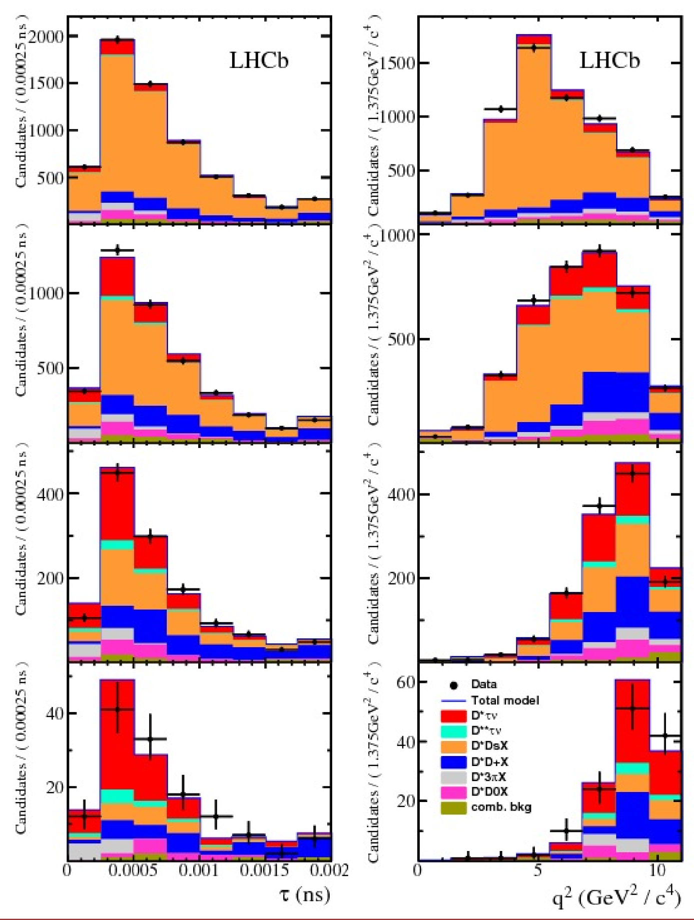
Results on hadronic R(D*)

The fit results give a branching fraction which is:
BR($B^0 \to D^{*+}\tau\nu$) = (1.39 ± 0.09(stat) ± 0.12(syst) ± 0.06(ext)) % [4]

The signal purity increases with BDT
• Using the HFLAV BR($B^0 \to D^*\mu\nu$):
R(D*) = 0.285 ± 0.019(stat) ± 0.025(syst) ± 0.013(ext)
Best statistical uncertainty for a single measurement.

• Using [5], the LHCb average of R(D*) is then:
$R_{LHCb}(D^*)$ = 0.306 ± 0.027

• Impact on World Average:
R(D*): 3.3σ → 3.4σ from SM and 4.0σ → 4.1σ adding R(D)

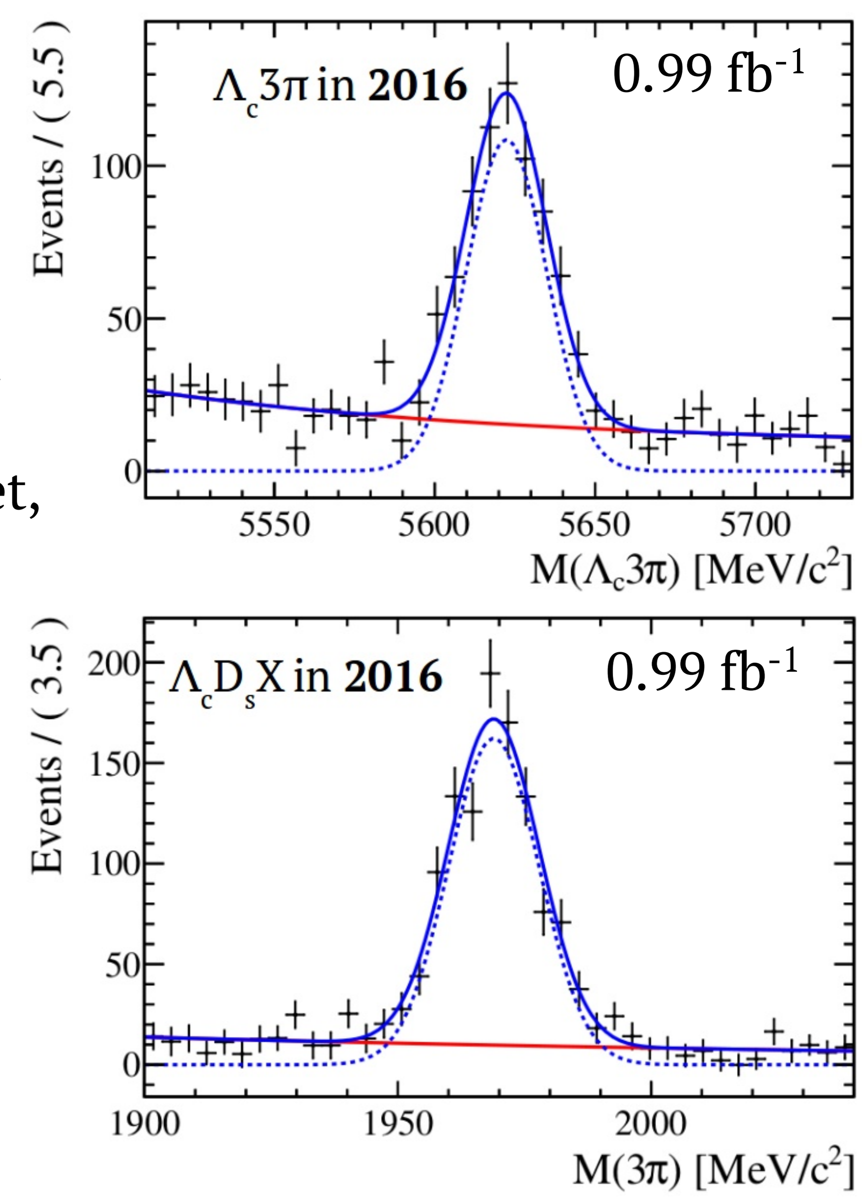


Prospects on R(Λ_c)

The specificities of this analysis are:
• The use of $\Lambda_b^0 \to \Lambda_c 3\pi$ as normalization channel
• **Λ_c is a baryon with a 1/2 spin** and a shorter lifetime than the D^0 meson
• The use of the whole available dataset, taken at 7, 8 and 13.5 TeV (same luminosity but more event per fb^{-1})

Λ_c	4.32 ± 0.07
$\Lambda_c D_s X$	4.46 ± 0.29
$\Lambda_c D_s$	2.75 ± 0.51
$\Lambda_c 3\pi$	4.07 ± 0.36

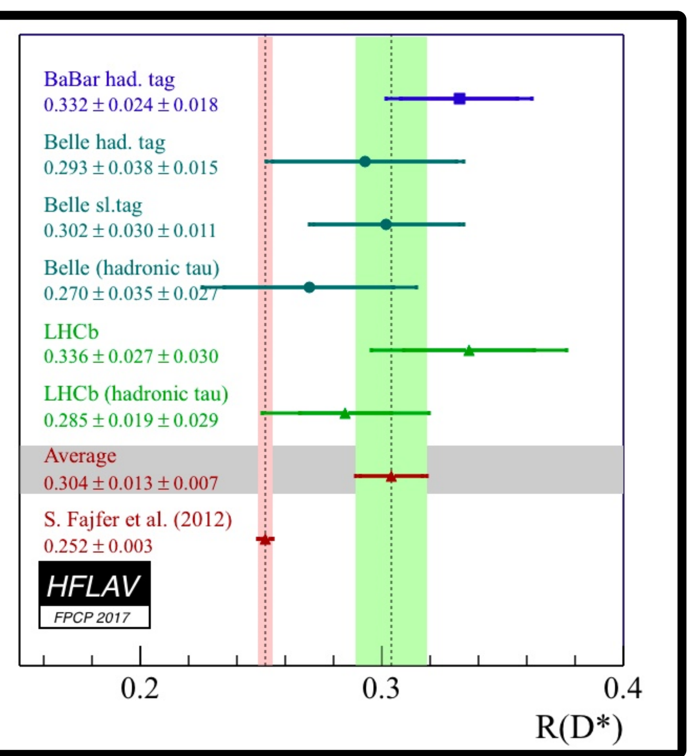
Ratio of yields for 2016 (13,5 TeV) and 2012 (8 TeV) years of data taking.



Conclusion

• R(D*) result using hadronic τ increases the WA tension with SM to 4.1σ even though it is compatible with SM thanks to the low uncertainty.
• The successful Run2 data taking leads to a 4x bigger dataset wich will contribute to reduce both statistical and systematic uncertainties !

• Several other analyses are already ongoing or planned to probe different spin structures
• R(Λ_c) is ongoing and the same sensibility as R(D*) is expected.



References

• [1] Phys. Rev. D92, 054510 (2015)
• [2] Phys. Rev. D85, 094025 (2012)
• [3] Phys. Rev. D92, 034503 (2015)
• [4] LHCB-PAPER-2017-017, in preparation
• [5] Phys. Rev. Lett. 115, 111803 (2015)