R(D*) and other tauonic decays at LHCb

Federico Betti[1]
on behalf of the LHCb Collaboration
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[1]University of Bologna and INFN Bologna

Motivation

- Interactions with enhanced couplings to the third family of leptons are present in many **NP** models
- $\bar{B}^0 \to D^{(*)+}\tau^-\bar{\nu}_\tau$ decay is a sensitive probe for effects of **lepton universality violation**
- Ratio of branching fractions calculated precisely within the SM:

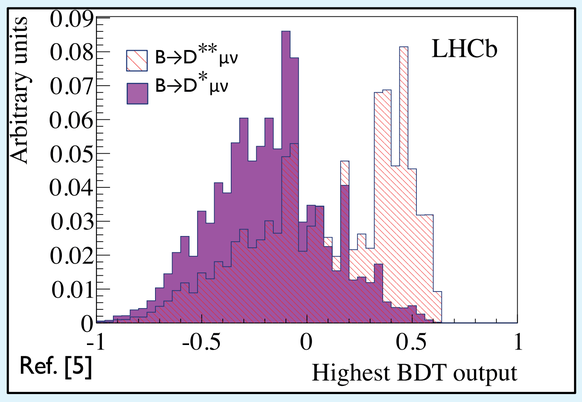
$$\mathcal{R}\left(D^{(*)}\right) = \frac{\mathcal{B}\left(\bar{B}^0 \to D^{(*)+}\tau^-\bar{\nu}_\tau\right)}{\mathcal{B}\left(\bar{B}^0 \to D^{(*)+}\mu^-\bar{\nu}_\mu\right)}$$

R(D) = 0.300±0.008 [1] R(D*) = 0.252±0.003 [2]

- **BaBar** reported measurements of R(D*) and R(D) with deviations of 2.7σ and 2.0σ from the SM [3]
- **Belle** measurements of R(D*) and R(D) do not show a significant deviation from the SM [4]

Data sample and event selection

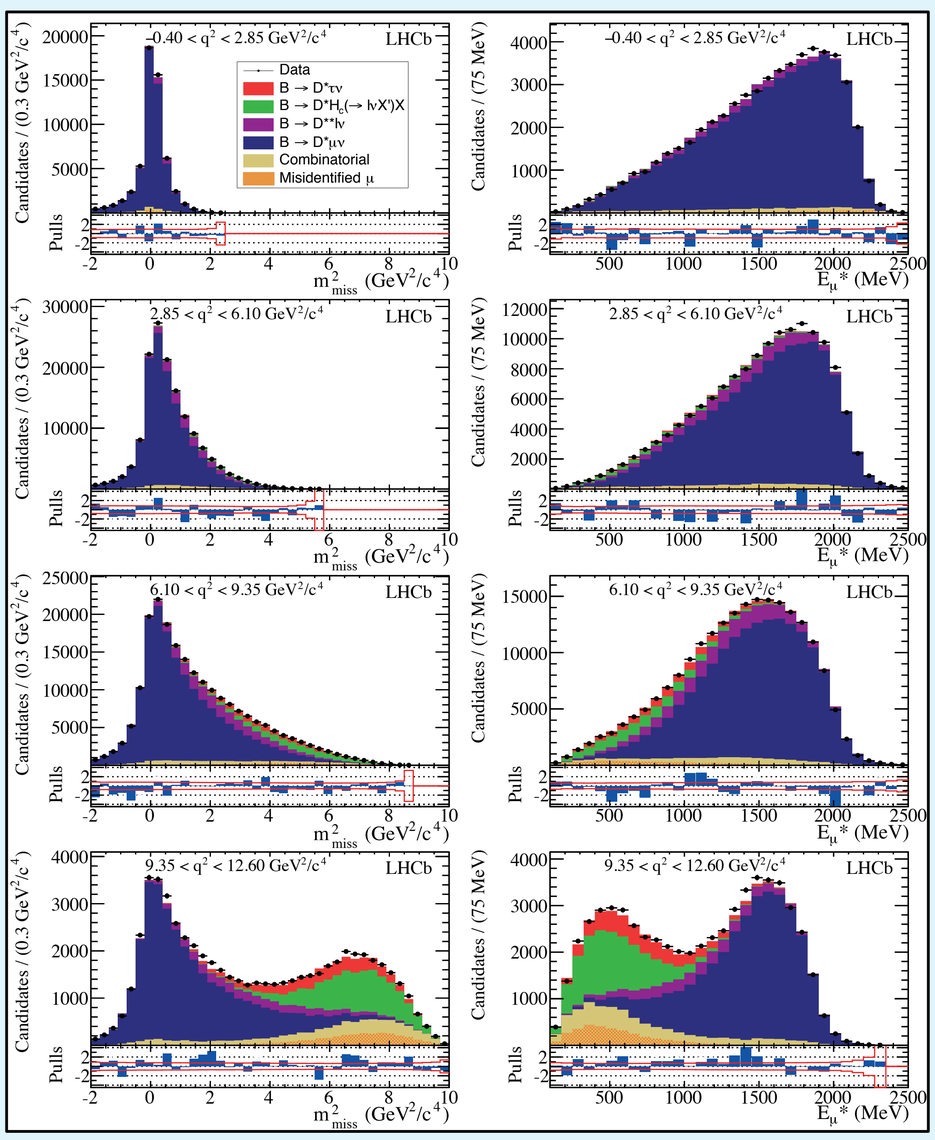
- Data collected by **LHCb** during 2011 (7 TeV) and 2012 (8 TeV), corresponding to 3.0 fb^{-1}
- **Signal** channel: $\bar{B}^0 \to D^{*+}\tau^-\bar{\nu}_\tau$ with $\tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau$
- **Normalization** channel: $\bar{B}^0 \to D^{*+}\mu^-\bar{\nu}_\mu$
  → same visible **final-state** for signal and normalization
- Reconstruct $D^{*+} \to D^0\pi^+$
- $D^{*+}\mu^-$ candidates **isolated** from additional tracks in the event (MultiVariate Analysis)



Fit strategy

- Maximum likelihood **3D** fit in distributions of:
  1. E^*_μ = muon energy in the B rest frame
  2. q^2 = squared four-momentum of the lepton system
  3. m^2_{miss} = B^0 missing mass squared
- Variables computed using the **approximation**: $(p_B)_z = \frac{m_B}{m_{reco}}(p_{reco})_z$
  the resolution is sufficient to preserve the **discrimination** between signal and background
- Background and signal shapes extracted from **control samples** and simulations validated against data

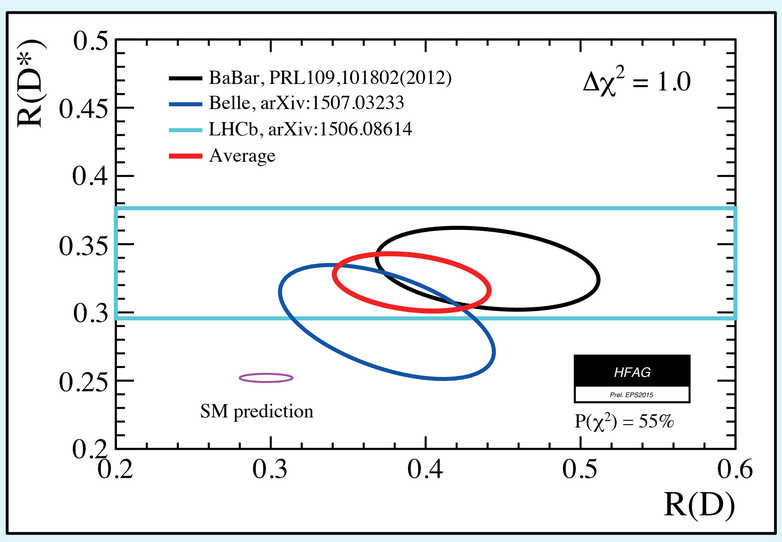
Background sources	Control samples
$D^{*+}h^\pm$ (misidentified μ)	Candidates where the track paired with the D^* fails the muon ID requirements
$D^{**}\mu\nu_\mu$	Candidates where two tracks have a high MVA output
$B \to D^*H_cX$ with $H_c \to \mu\nu_\mu X$	Candidates where one track has a high MVA output and passes $K^\pm$ identification requirements
Combinatorial	Wrong sign candidates ($D^{*+}\mu^+$ and $D^0\pi^-\mu^-$)



Results

$$\mathcal{R}(D^*) = 0.336 \pm 0.027\ (\text{stat}) \pm 0.030\ (\text{syst})$$ [5]

2.1σ larger than the SM expectation

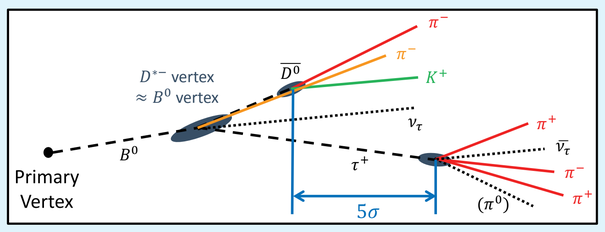


HFAG combination gives tension with SM at **3.9σ**

Prospects for measurements in other final states

$\bar{B}^0 \to D^{*+}\tau^-\bar{\nu}_\tau$ with $\tau^- \to \pi^-\pi^+\pi^-\nu_\tau$ (analysis ongoing)

- Reconstruct τ decay vertex with good precision
  → suppress $\bar{B}^0 \to D^{*+}3\pi X$ background
- Remaining background $\bar{B}^0 \to D^*D_{(s)}X$ suppressed requiring signal isolation criteria
- Expected precision **competitive** with [5] (stat ~6%, sist ~6%)



LHCb can potentially study also:
$\bar{B}^0 \to D^+\tau^-\bar{\nu}_\tau$ $\Lambda_b^0 \to \Lambda_c^{(*)+}\tau^-\bar{\nu}_\tau$ $B_c^- \to J/\psi\tau^-\bar{\nu}_\tau$ $\bar{B}_s^0 \to D_s^+\tau^-\bar{\nu}_\tau$
With both muonic and hadronic τ modes

References

[1] Phys.Rev. D92, 054510 (2015) **[2]** Phys.Rev. D85, 094025 (2012) **[3]** Phys. Rev. Lett. 109, 101802 (2012) **[4]** Phys. Rev. D 92, 072014 (2015) **[5]** Phys. Rev. Lett. 115, 111803 (2015)