Study of Lepton Violation Universality with semitauonic decays in LHCb

Status and Prospects

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on behalf of the LHCb Collaboration

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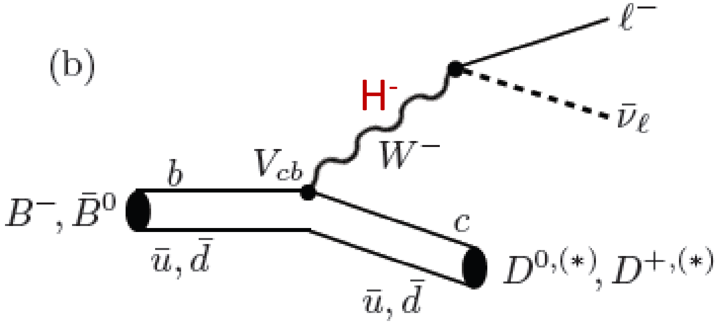
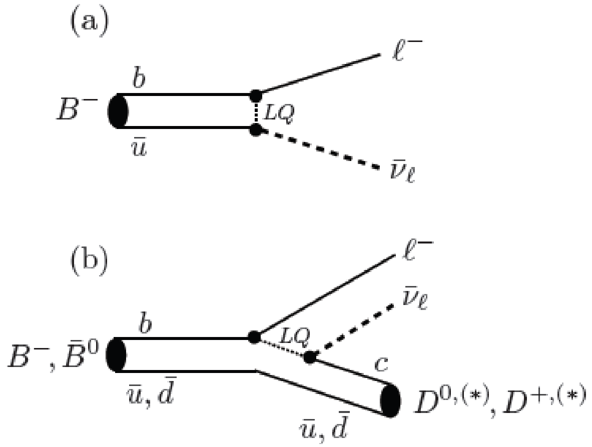
Lepton Flavour Universality

- Lepton Flavour Universality is one of many « ad hoc » symmetries and « pillars » of the Standard Model
  - Baryon number, lepton number, (charged) lepton flavour,…
- It postulates that the properties of the three charged leptons (e,μ,τ) are the exactly the same beside their mass
- This does not need to be the case in many New Physics models
- First hints of Lepton Flavour Universality violation appeared 10 years ago with BABAR publication regarding semi-tauonic B decays
- This field became « the hottest game » in town with results coming both from charged and neutral currents

CC LFUV characteristics

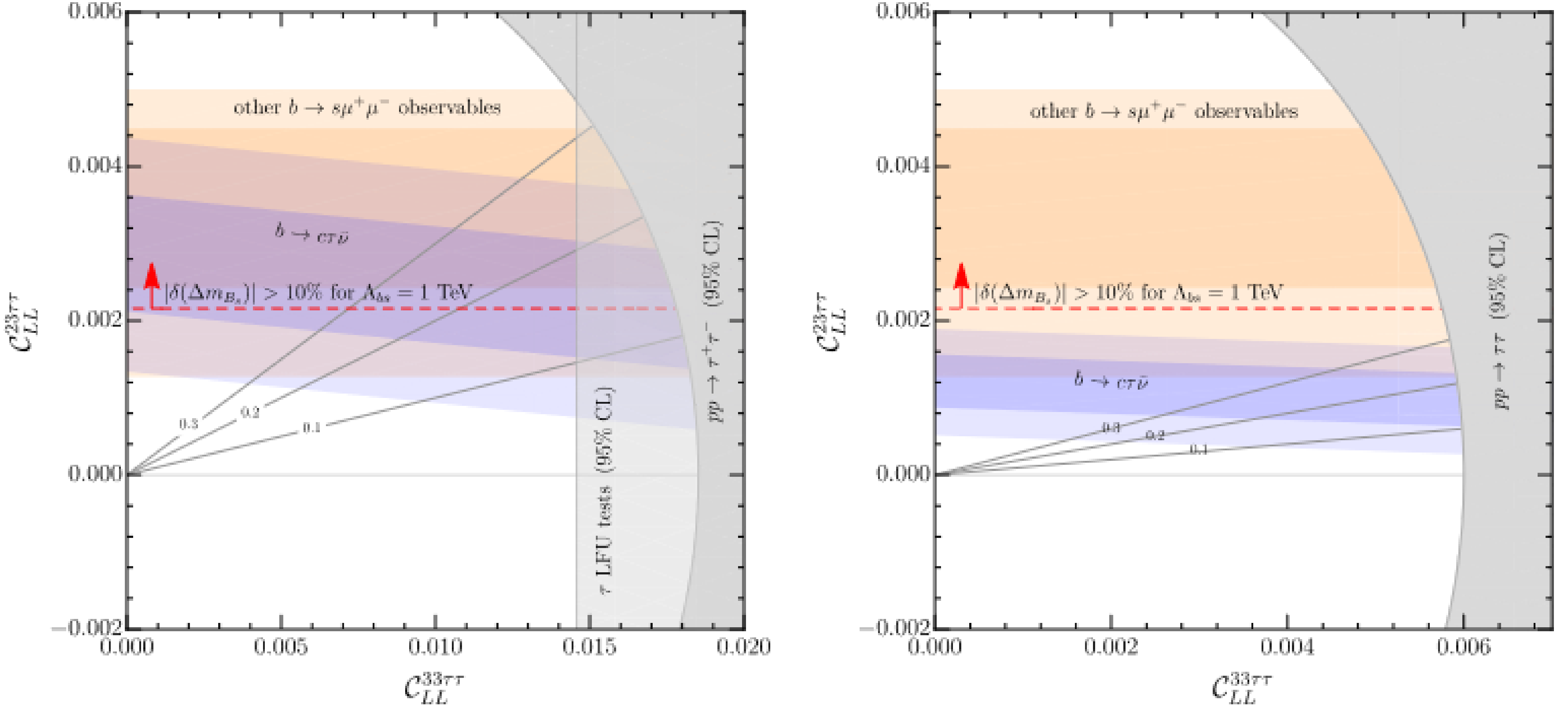




- Abundant reaction BR ~1%
- High precision of SM prediction ~1%
- **Charged Higgs, Leptoquarks** are the usual suspects
- Sensitivity in the TeV range: direct search possible at the LHC : however many scenarios still open after taking into account the present direct exclusions domains
- If the present WA average is correct, **, R(D*)/R(D*)$_{SM}$=1.1: Large new physics effects !!**
- Possibility to measure the effects for various B parents and charm spectators **: the importance of the spin :** $\Lambda_b^0 \rightarrow \Lambda_c^+ \tau^- \bar{\nu}_\tau$
- Sensitivity not only on the yield but also in the internal characteristics of the event (q^2 and angular distributions)
- New physics can couple differently to Vcb and Vub transitions
- Therefore , very important to get a high statistics sample as pure as possible !

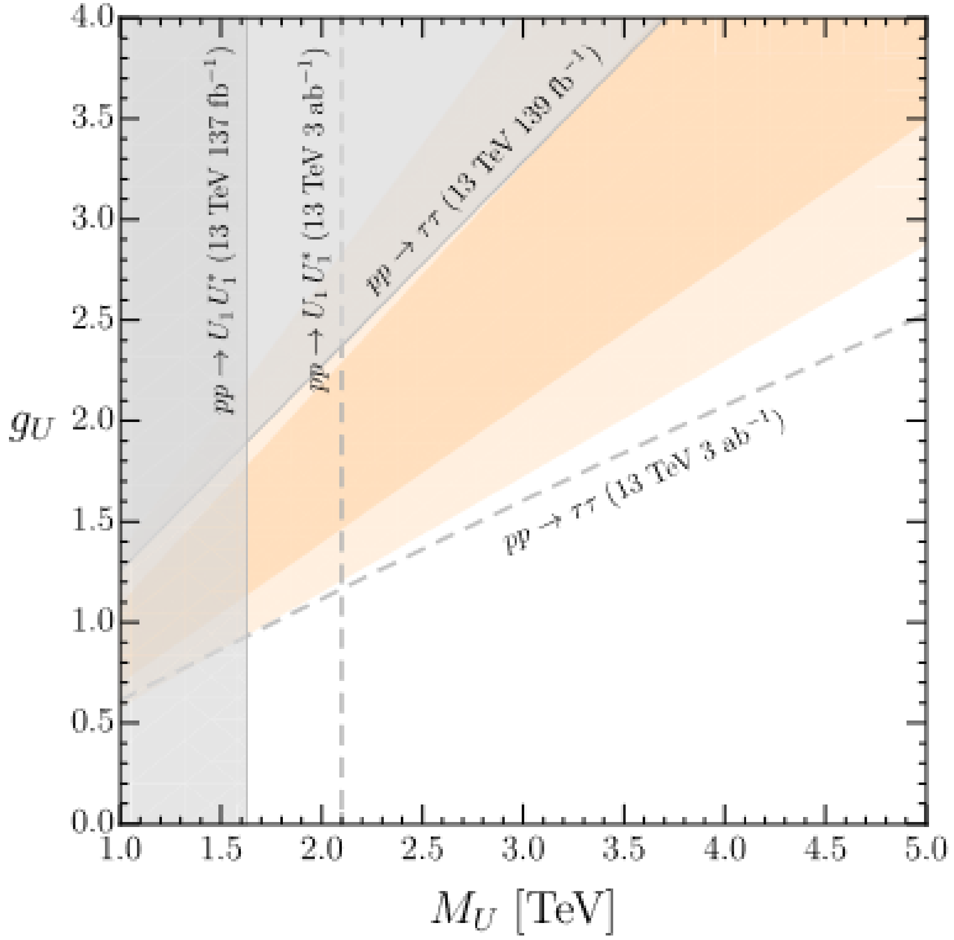
Combined interpretation in a ~TeV vector leptoquak model (U_1)

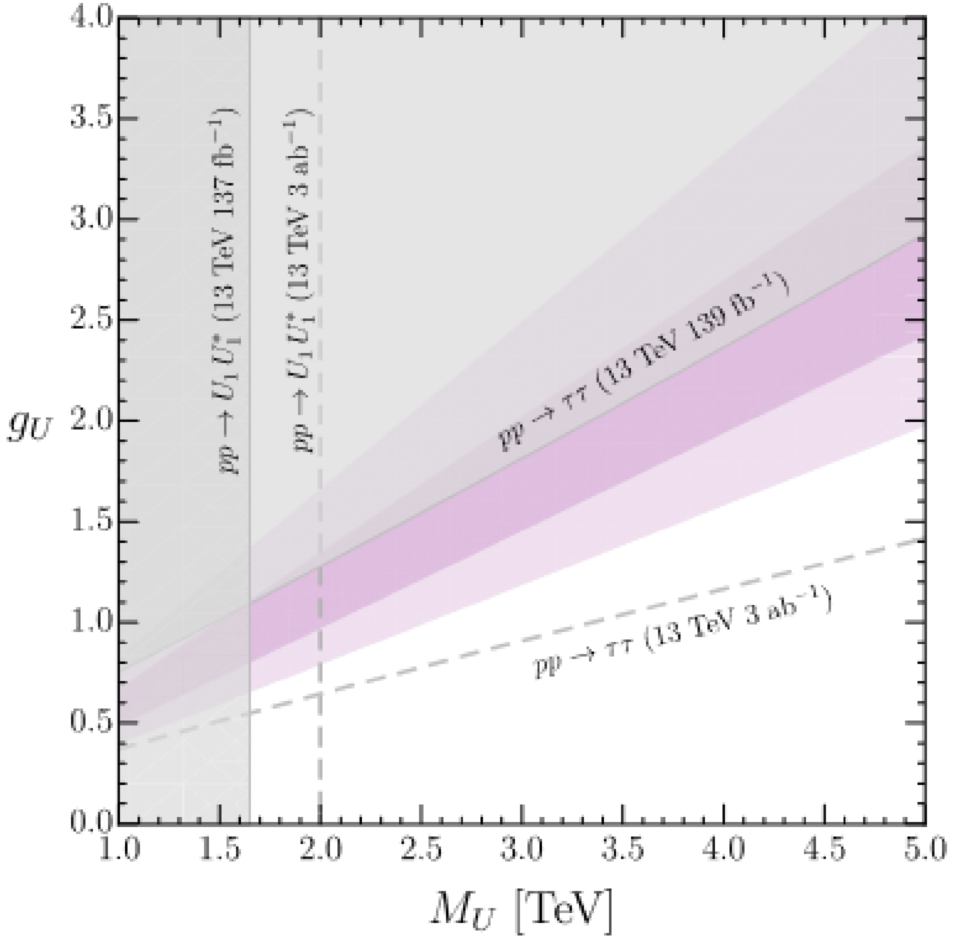
C. Cornella et al., https://arxiv.org/pdf/2103.16558.pdf



Role of the direct LHC searches

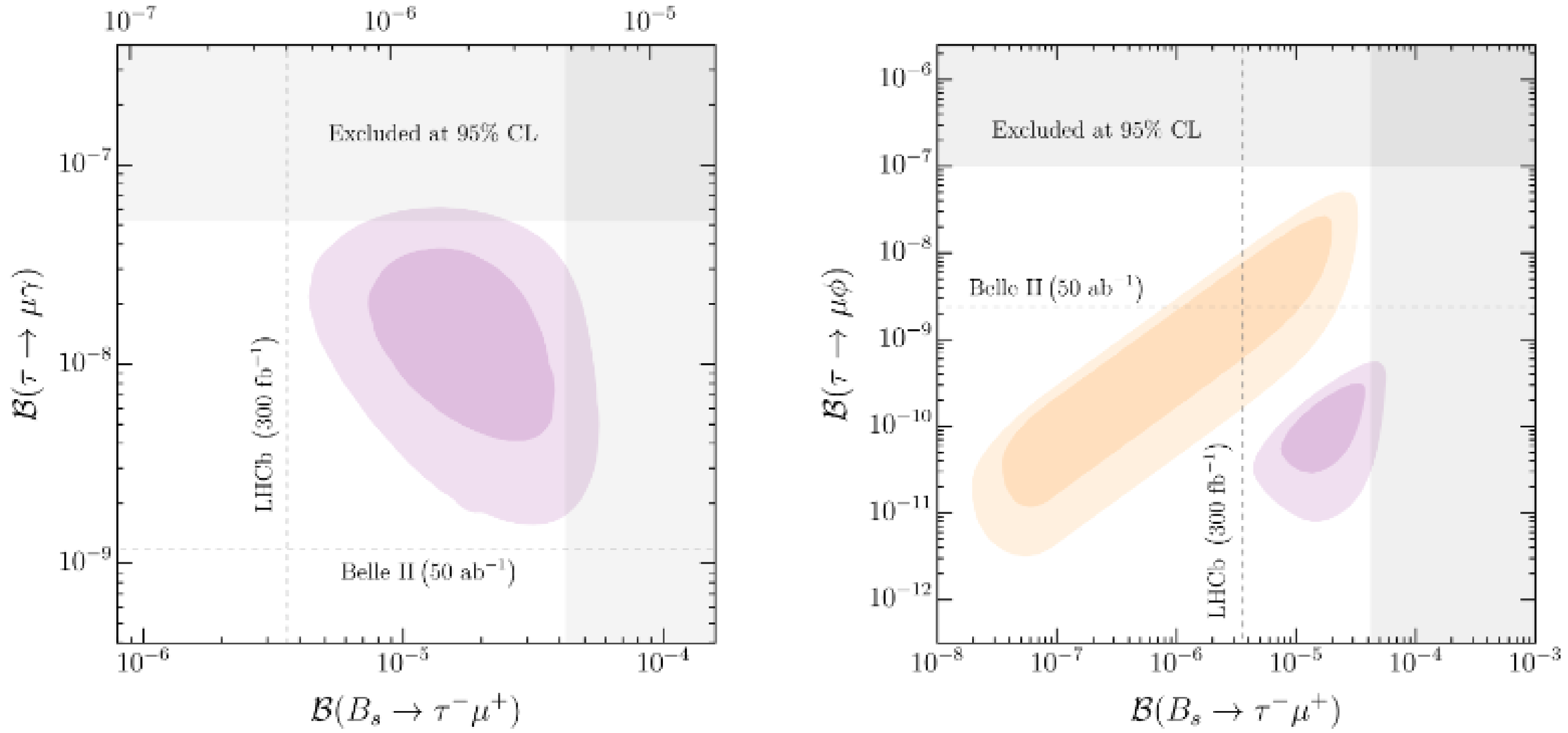
C. Cornella et al., https://arxiv.org/pdf/2103.16558.pdf





In this model, Lepton Flavour violation should be seen (B→μτ, Kμτ)

C. Cornella et al., https://arxiv.org/pdf/2103.16558.pdf



Two measurements from LHCb using two different τ decay modes

1) Simultaneous measurement of R(D)and R(D$*$) with Run 1 [D°μ^-] and [$D^{*+}\mu^-$] data ($\tau\rightarrow\mu\nu\nu$)

- Higher branching fractions and higher efficiency - [D°μ^-] sample $\sim$ 5× bigger than [$D^{*+}\mu^-$]
- LHCb-PAPER-2022-039 in preparation
  - CERN seminar : http://cds.cern.ch/record/2837207

2) R(Λ_c^+) measurement ($\tau\rightarrow\pi\pi\pi$)

LHCb-PAPER-2021-044 arxiv:2201:03497

PhysRevLett128,191803 (2022)

Two Complementary measurement techniques

$\tau^- \to \mu^- \nu_\tau \nu_\mu$

- Pros
  - Direct measurement of R(D,D*)
  - High statistics
- Cons
  - Double charm background control must be very good (mostly D^+)
  - Sensitive to D** $\mu^- \nu_\mu$

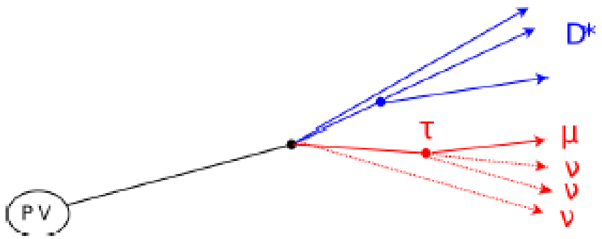
$\tau^- \to \pi^- \pi^+ \pi^- (\pi^0) \nu_\tau$

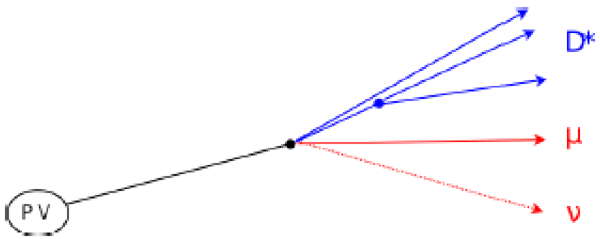
- Pros
  - The possibility to measure the τ vertex is the key to reject the background and obtain a high purity sample
  - The 3π dynamics of the τ decay is very specific : possible to distinguish τ decays from the main double charm background from D_s decays
- Cons
  - Access to R(D) requires an external BR
  - Lower statistics

Simultaneous measurement of R(D) and R(D*) using muonic τ decays

Experimental challenge

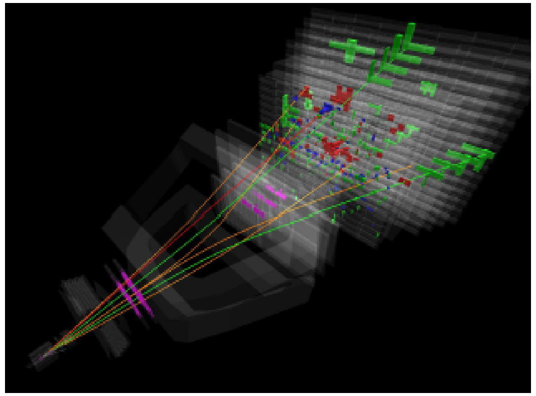
$\overline{B}^0 \to D^{*+}\tau^-\overline{\nu}_\tau$ $\qquad$ $\overline{B}^0 \to D^{*+}\mu^-\overline{\nu}_\mu$





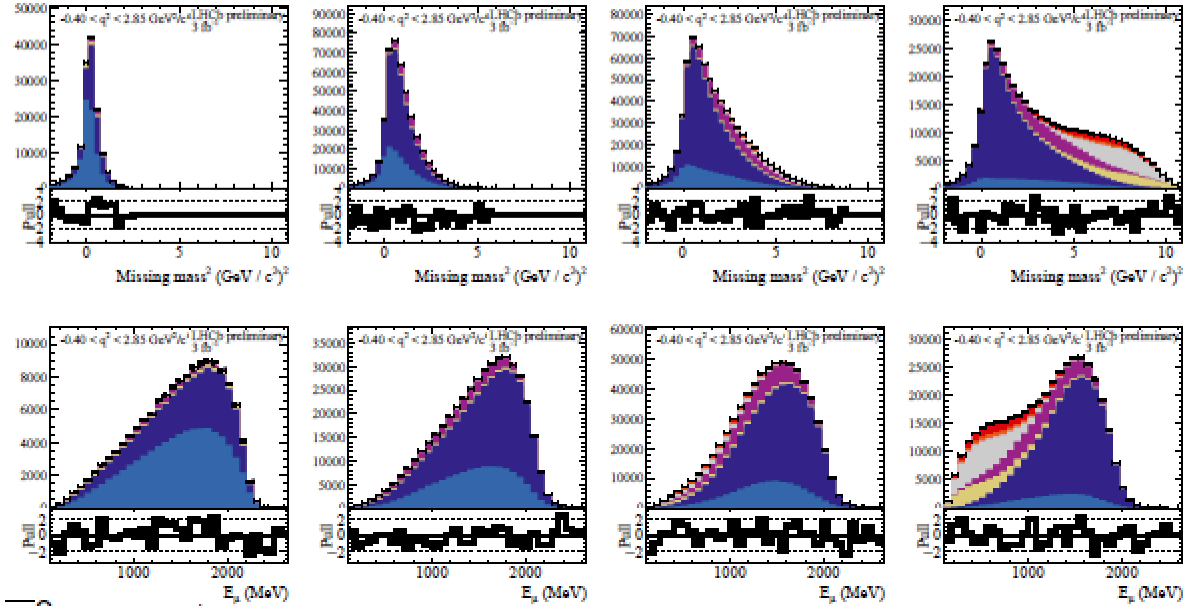
- Difficulty: neutrinos - 3 for $(\tau^- \to \mu^-\nu_\tau\overline{\nu}_\mu)\nu$
  - No narrow peak to fit (in any distribution)
- Main backgrounds: partially reconstructed B decays
  - $B \to D^*\mu\nu$,$B \to D^{**}\mu\nu$, $B \to D^*D(\to \mu X)X$ ...
- Also combinatorial, misidentified backgrounds

Selection



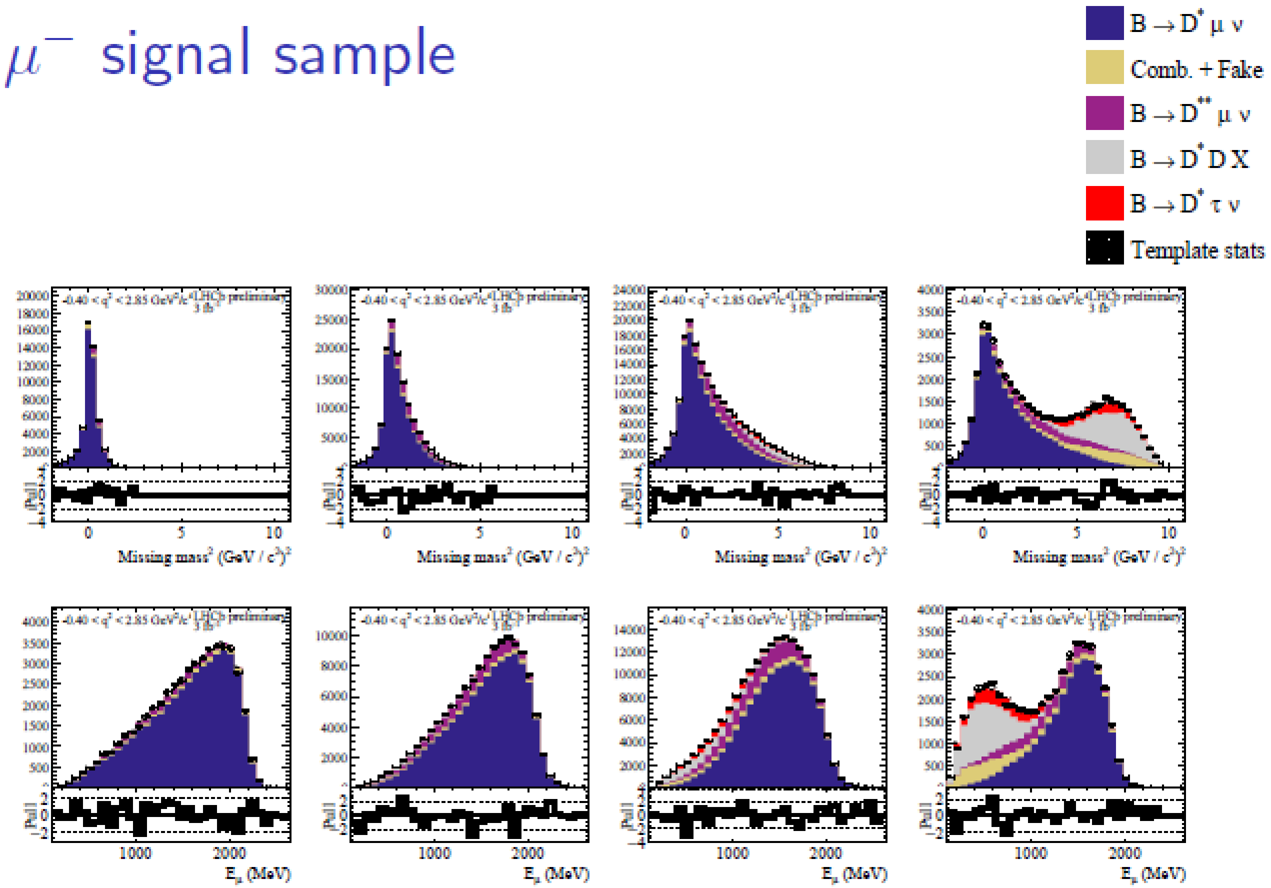
- Select displaced $[D^0(\to K^+\pi^-)\mu^+]$, add $D^{*+} \to D^0\pi^+$
  - Veto $D^{*+} \to D^0\pi^+$ in $[D^0\mu^+]$ sample
- Trigger on the D^0 - preserve acceptance for soft muons
- New: custom muon ID classifier, flatter in kinematic acceptance (uBoost method)
  - Reduced misidentified backgrounds

$D^0\mu^+$ signal sample



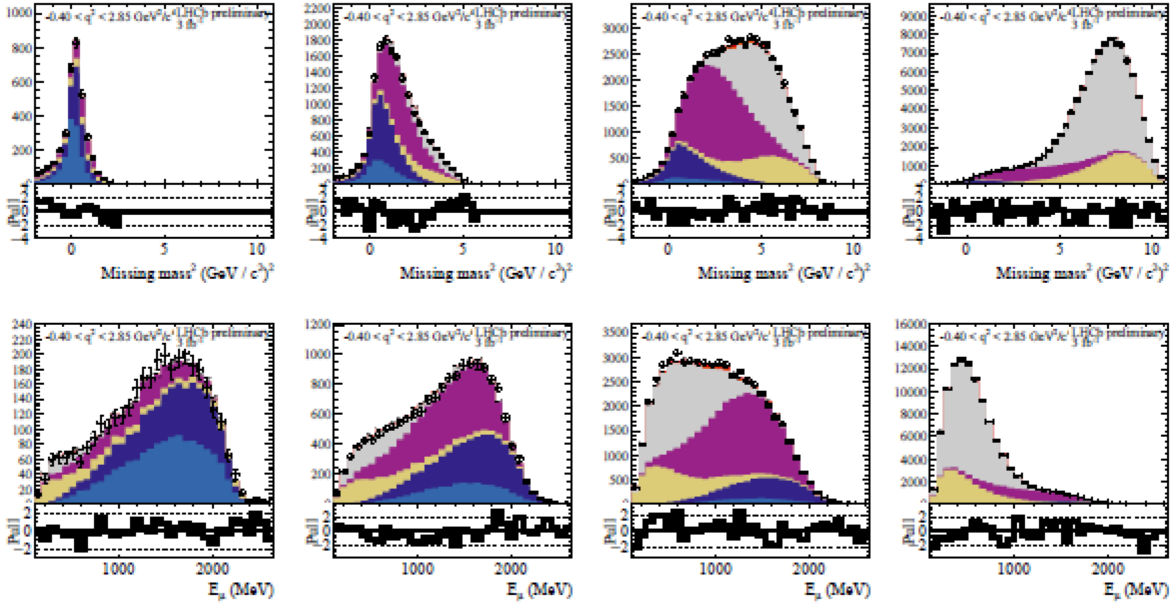
- $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}$ now modelled using BGL form-factors, $B^- \to D^0\ell^-\overline{\nu}_\ell$ with BCL
  - Helicty-suppressed terms constrained by theory, other parameters float freely
  - $B^- \to D^0\ell^-\overline{\nu}_\ell$ form factors from HPQCD
  - $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}$ form factors from: Bigi, Gambino, Schacht

$D^{*+}\mu^-$ signal sample



- Excellent fit quality throughout

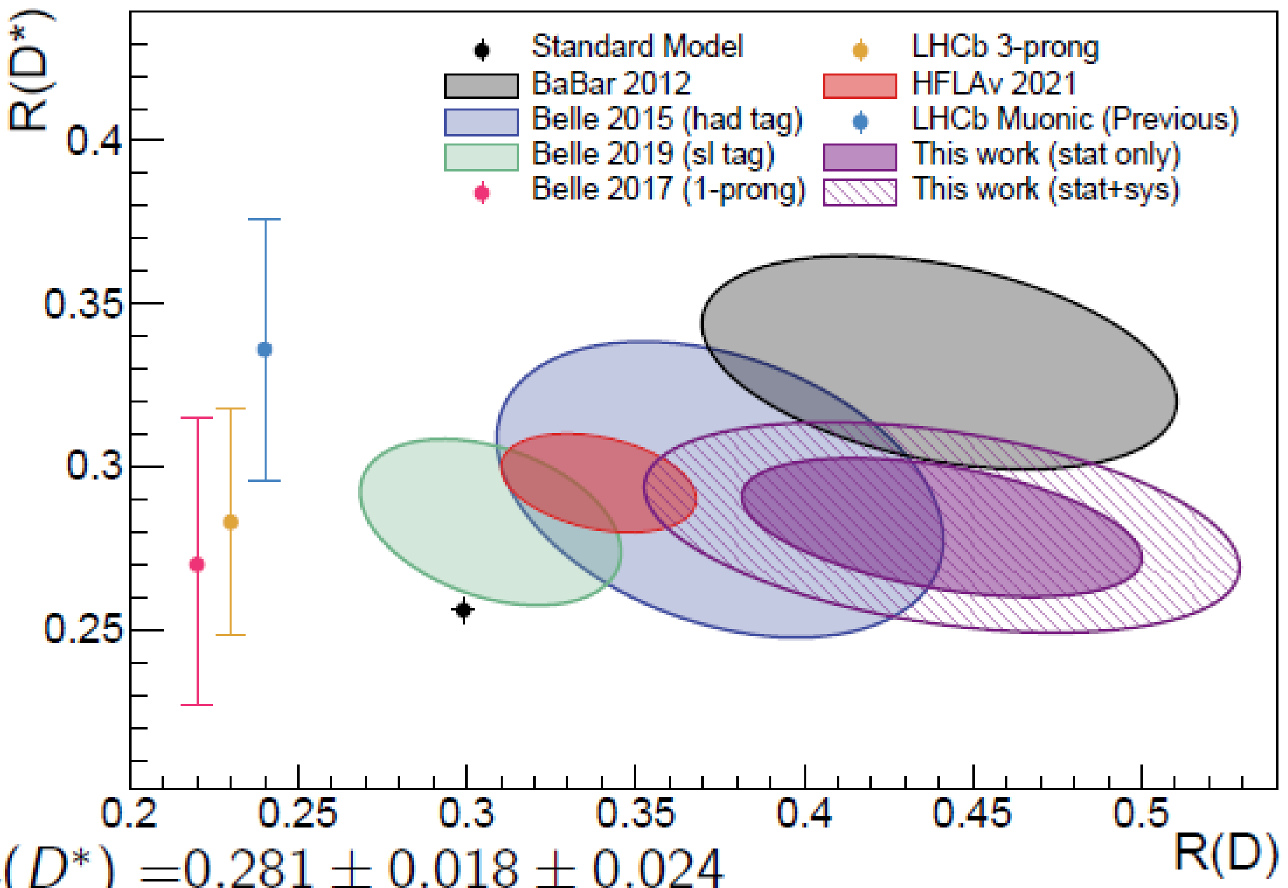
Kaon sample



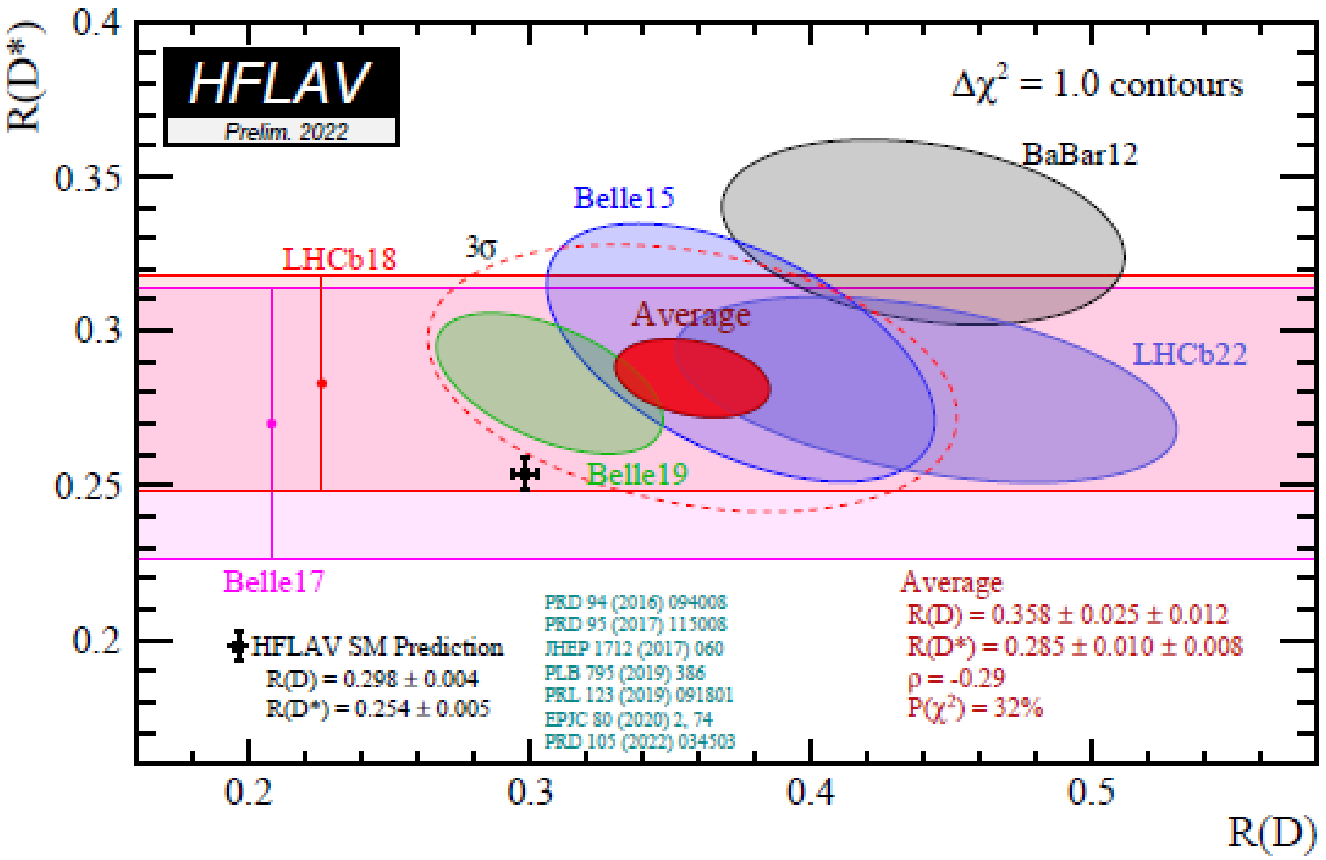
- Sample with at least one additional kaon: $B \to D^0 DX$ backgrounds
- Also, a slight disagreement in the 2nd q^2 bin, in the region dominated by $\overline{B}^0_s \to D^{**}_s \mu^- \overline{\nu}_\mu$ decays

Internal fit uncertainties	$\sigma_{\mathcal{R}(D^*)}(\times 10^{-2})$	$\sigma_{\mathcal{R}(D)}(\times 10^{-2})$
Statistical uncertainty	1.8	6.0
Simulated sample size	1.5	4.5
$B \to D^* DX$ template shape	0.8	3.2
$\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}$ form-factors	0.7	2.1
$B \to D^{**}\mu^+\nu$ form-factors	0.8	1.2
$\mathcal{B}(B \to D^*(D_s \to \tau\nu)X)$	0.3	1.2
MisID template	0.1	0.8
$\mathcal{B}(B \to D^{**}\tau^+\nu)$	0.5	0.5
Combinatorial	< 0.1	0.1
Resolution	< 0.1	0.1
Additional model uncertainty	$\sigma_{\mathcal{R}(D^*)}(\times 10^{-2})$	$\sigma_{\mathcal{R}(D)}(\times 10^{-2})$
$B \to D^{(*)} DX$ model uncertainty	0.6	0.7
$\overline{B}_s^0 \to D_s^{**}\mu^-\overline{\nu}_\mu$ model uncertainty	0.6	2.4
Data/simulation corrections	0.4	0.75
Coulomb correction to $\mathcal{R}(D^{*+})/\mathcal{R}(D^{*0})$	0.2	0.3
misID template unfolding	0.7	1.2
Baryonic backgrounds	0.7	1.2
Normalization uncertainties	$\sigma_{\mathcal{R}(D^*)}(\times 10^{-2})$	$\sigma_{\mathcal{R}(D)}(\times 10^{-2})$
Data/simulation corrections	$0.4 \times \mathcal{R}(D^*)$	$0.6 \times \mathcal{R}(D)$
$\tau^- \to \mu^-\nu_\tau\overline{\nu}_\mu$ branching fraction	$0.2 \times \mathcal{R}(D^*)$	$0.2 \times \mathcal{R}(D)$
Total uncertainty	3.0	8.9

Result



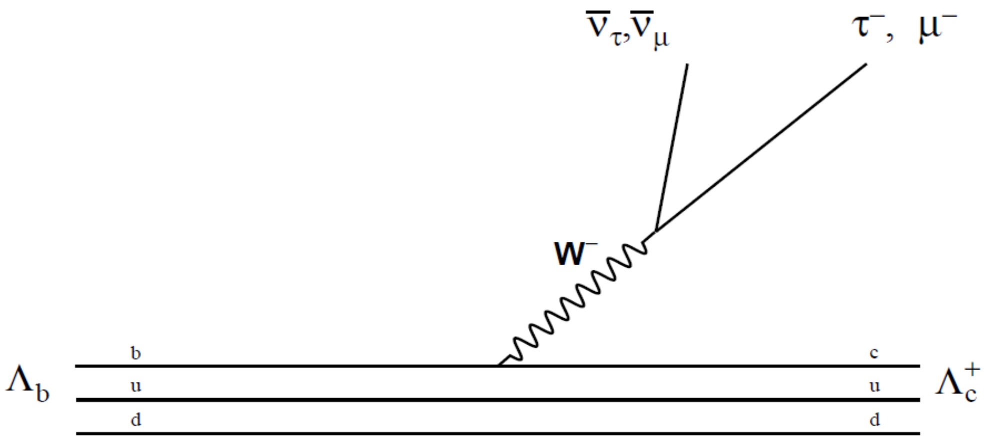
- $\mathcal{R}(D^*) = 0.281 \pm 0.018 \pm 0.024$
- $\mathcal{R}(D) = 0.441 \pm 0.060 \pm 0.066$
- $\rho = -0.43$
- 1.9σ agreement with SM



- New preliminary average: slightly lower $\mathcal{R}(D^*)$, slightly higher $\mathcal{R}(D)$, reduced correlation
  - $3.3\sigma \to 3.2\sigma$ agreement with SM
  - Excellent overall agreement between measurements

Why Lepton Flavour Universality tests with Λ_b^0 are interesting ?

$$\mathcal{R}(\Lambda_c^+) \equiv \mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \tau^- \overline{\nu}_\tau)/\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \mu^- \overline{\nu}_\mu)$$



- Lepton Flavour Universality violation hints in the meson sector $\mathcal{R}(D^*)$-$\mathcal{R}(D)$: 3.2 σ away from SM in the latest 2022 HFLAV update
- With spin ½ spectator, the baryonic channel adds a very complementary test
- Similar precision on SM prediction with lattice QCD computations

$\mathcal{R}(\Lambda_c^+)_{SM} = 0{,}324 \pm 0{,}004$ F. Bernlochner et al., Physical Review D 99 055008 (2019)

with input from Lattice QCD FF: W. Detmold, C. Lehner, S. Meinel, Physical Review D 92 034503 (2015)

- But different NP couplings: could help pin down NP source
- Unique to LHCb. Never searched for before!

NP expectations for $\mathcal{R}(\Lambda_c^+)$ in various models

A. Datta et al., Journal of High Energy Physics 1708 (2017) 131

	g_S only	g_P only	g_L only	g_R only	g_T only
	-0.4	0.3	-2.2	-0.044	0.4
$R(\Lambda_c)$	0.290 ± 0.009	0.342 ± 0.010	0.479 ± 0.014	0.344 ± 0.011	0.475 ± 0.037
$R^{Ratio}_{\Lambda_c}$	0.872 ± 0.007	1.026 ± 0.001	1.44	1.033 ± 0.003	1.426 ± 0.100
	$-1.5 - 0.3i$	$0.4 - 0.4i$	$0.15 - 0.3i$	$0.08 - 0.67i$	$0.2 - 0.2i$
$R(\Lambda_c)$	0.384 ± 0.013	0.346 ± 0.011	0.470 ± 0.014	0.465 ± 0.014	0.404 ± 0.021
$R^{Ratio}_{\Lambda_c}$	1.154 ± 0.008	1.040 ± 0.002	1.412	1.397 ± 0.005	1.213 ± 0.050

$\mathcal{R}(\Lambda_c^+)$ can be below or well above SM, when satisfying $\mathcal{R}$(D*)-$\mathcal{R}$(D) constraints

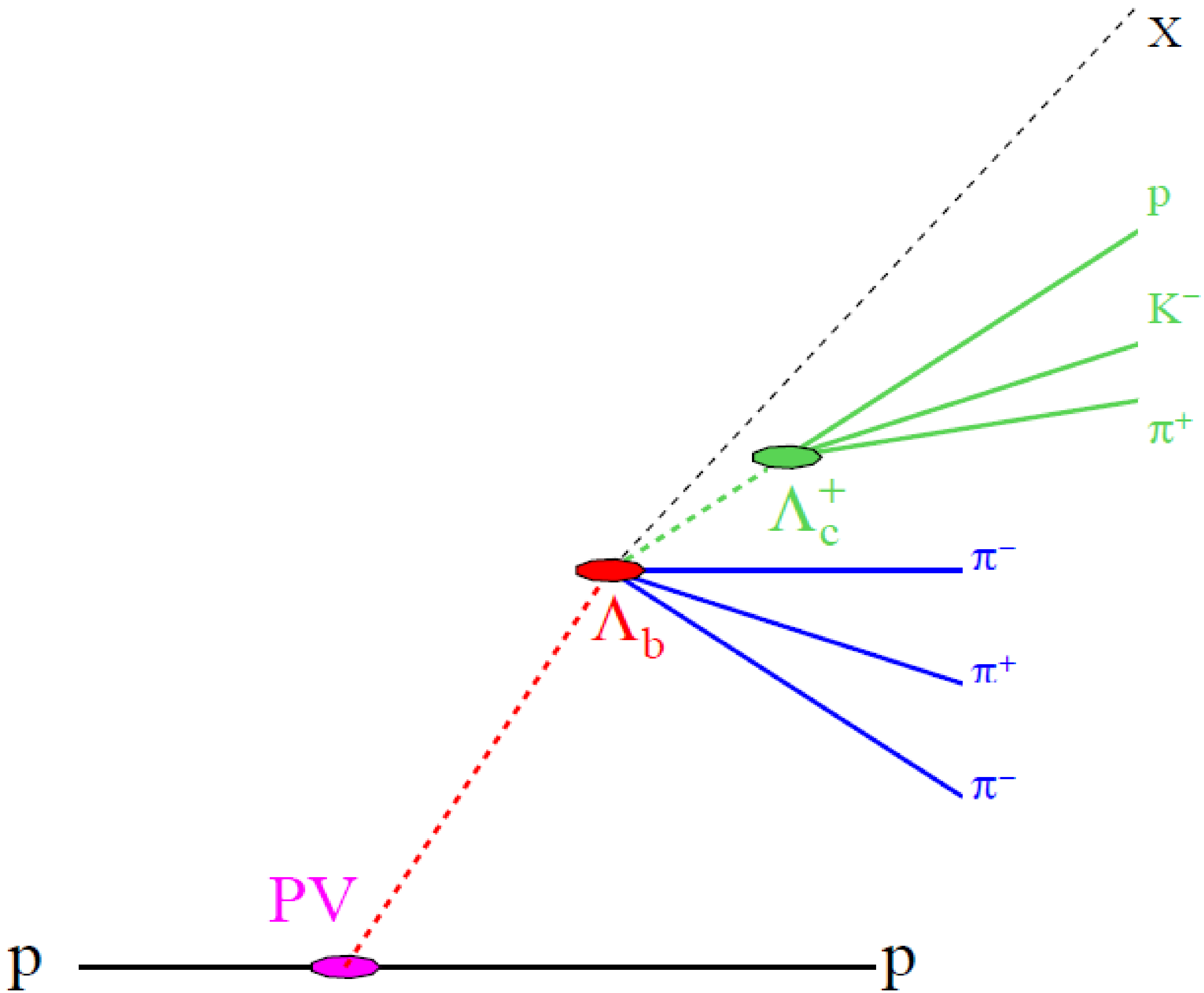
NP predictions with all present constraints from the meson sector

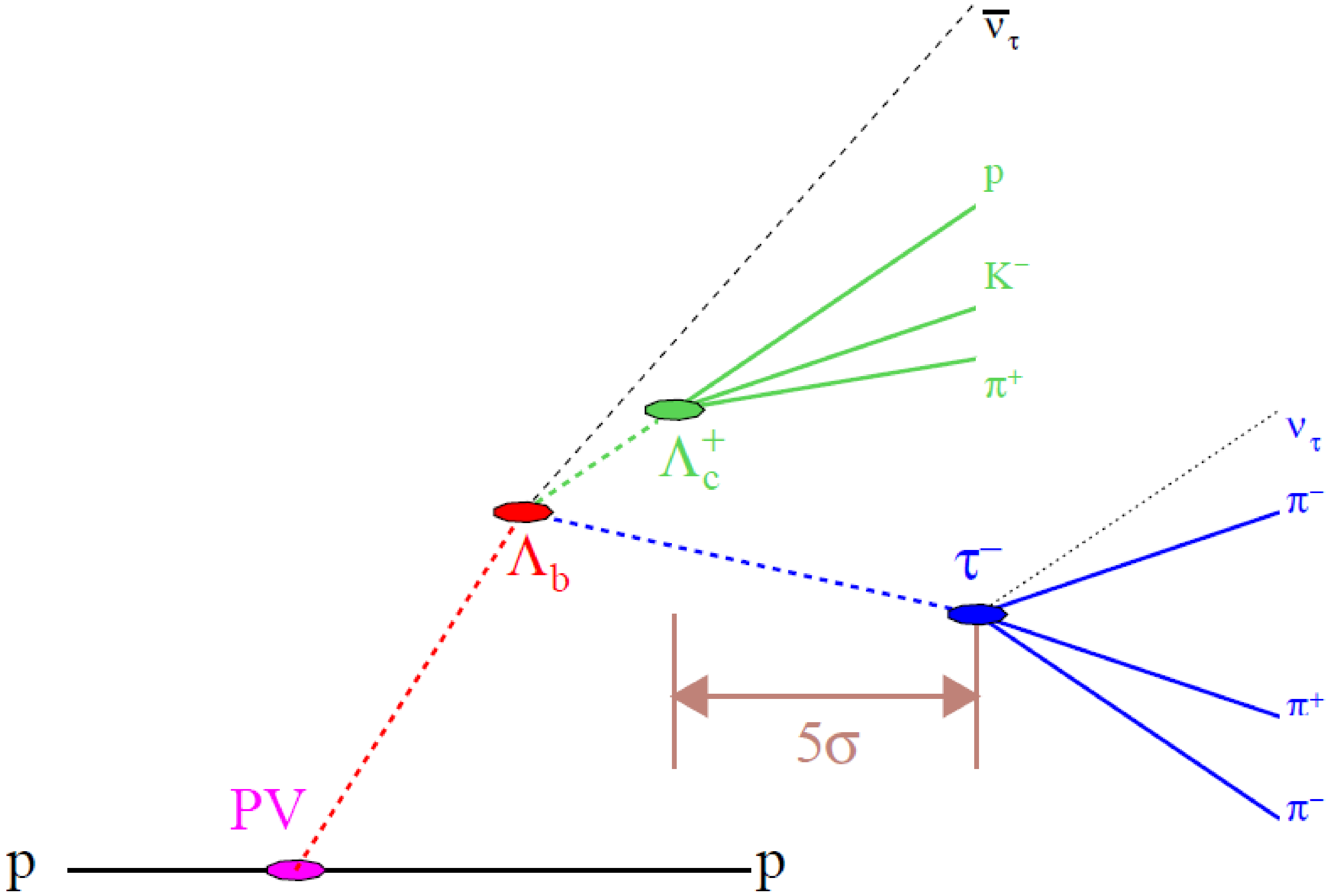
Coupling	$R(\Lambda_c)_{max}$	$R^{Ratio}_{\Lambda_c,max}$	coupling value	$R(\Lambda_c)_{min}$	$R^{Ratio}_{\Lambda_c,min}$	coupling value
g_S only	0.405	1.217	0.363	0.314	0.942	-1.14
g_P only	0.354	1.062	0.658	0.337	1.014	0.168
g_L only	0.495	1.486	$0.094 + 0.538i$	0.340	1.022	$-0.070 + 0.395i$
g_R only	0.525	1.576	$0.085 + 0.793i$	0.336	1.009	-0.012
g_T only	0.526	1.581	0.428	0.338	1.015	-0.005

Caveat **: $\mathcal{R}(\Lambda_c^+)$ should be (1.15 ± 0.04)*SM prediction when taking in account R(D) and R(D*) according to M. Blanke et al. Phys. Rev. D 100, 035035 (2019)**

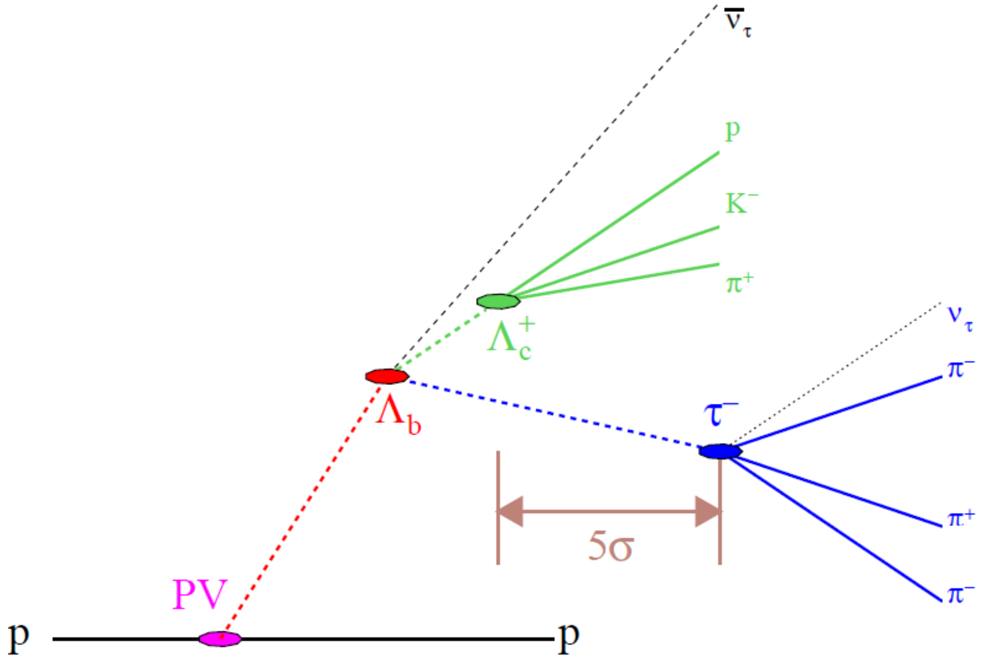
$\mathcal{R}(\Lambda_c^+)$ analysis workflow with $\tau^- \to \pi^-\pi^+\pi^-(\pi^0)\nu_\tau$

- Tight Λ_c^+ PID selection in pKπ mode. Λ_c^+ sideband template used in the signal fit to remove the background under the Λ_c^+ peak
- Combine with detached $\pi^-\pi^+\pi^-$ triplet forming τ^- candidates
- Prompt background rejection thanks to vertex topology
- Reconstruct decay kinematics
- D_s^- and D^0 exclusive peaks to control double charm background
- Anti-D_s^- to reject double charm background
- Normalisation channel : $\Lambda_b^0 \to \Lambda_c^+\pi^-\pi^+\pi^-$ (without $\Lambda_c^{*+}\pi^-$) [same final state and similar dynamics]

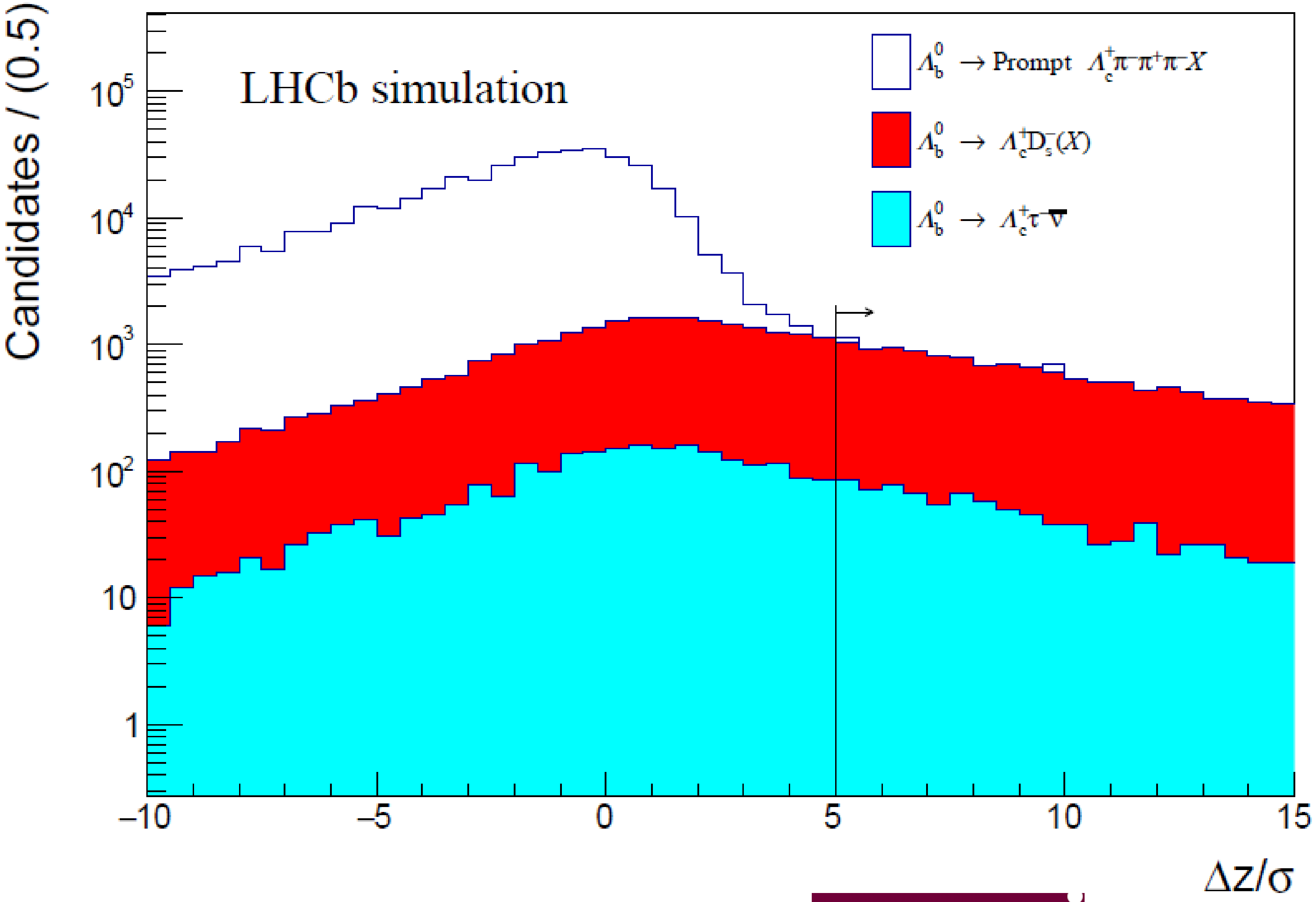

X
p
K⁻
π⁺
Λ_c^+
π⁻
Λ_b
π⁺
π⁻
PV
p
p


$\bar{\nu}_\tau$
p
K^-
π^+
ν_τ
π^-
Λ_c^+
Λ_b
τ^-
5σ
π^+
π^-
PV
p
p

« Prompt » background rejection



Prompt rejection ~5x10³ level after the 5σ inversion cut



Distribution of the 3π mass after final selection

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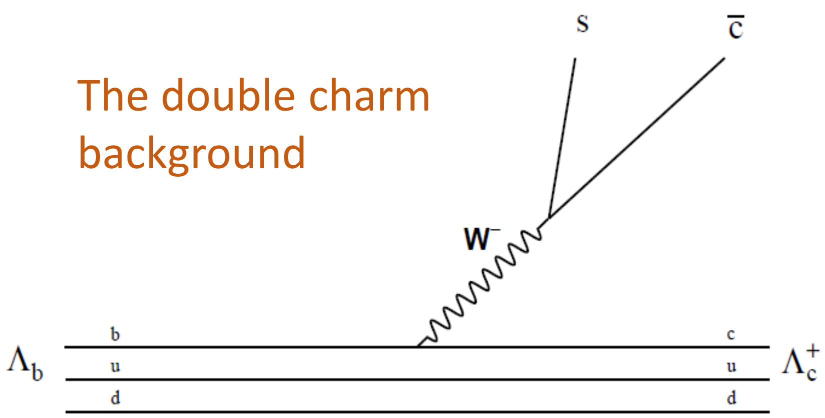
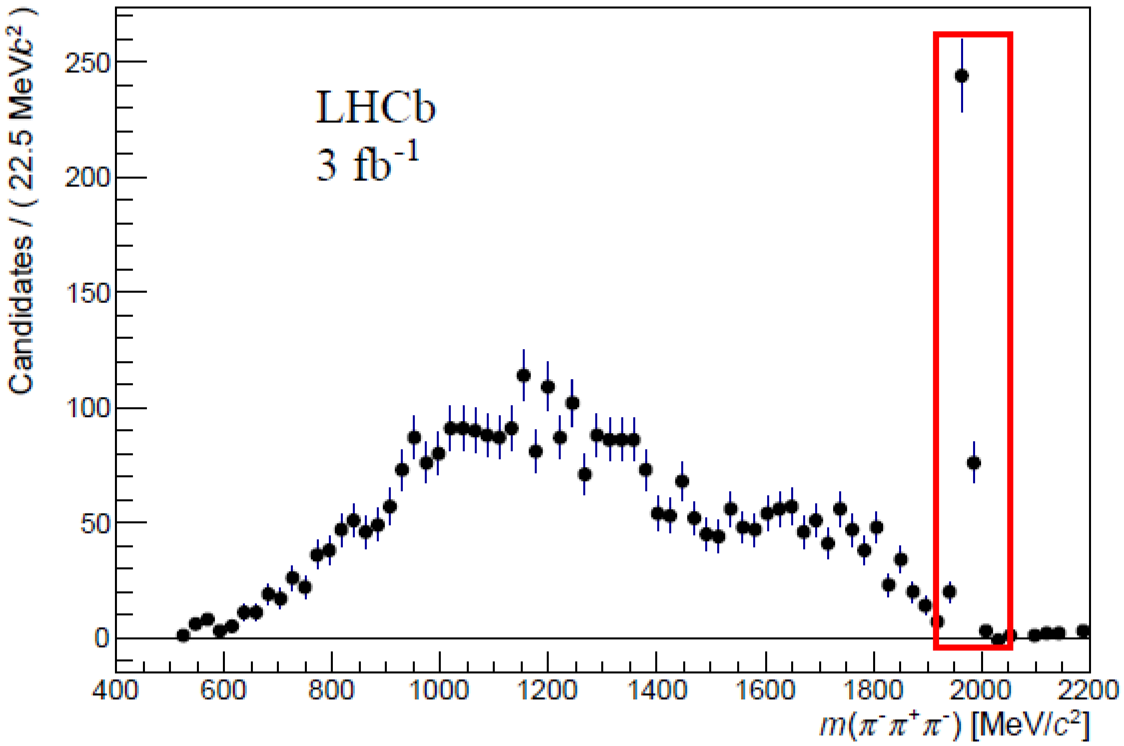
arxiv:2201:03497

BR($D_s^- \to 3\pi X$)~ 30xBR($D_s^- \to \pi\pi\pi$)

$D_s^{(*,**)-}$, $D^{(*)0}K^-$, $D^{(*)+}K^0$

The double charm background

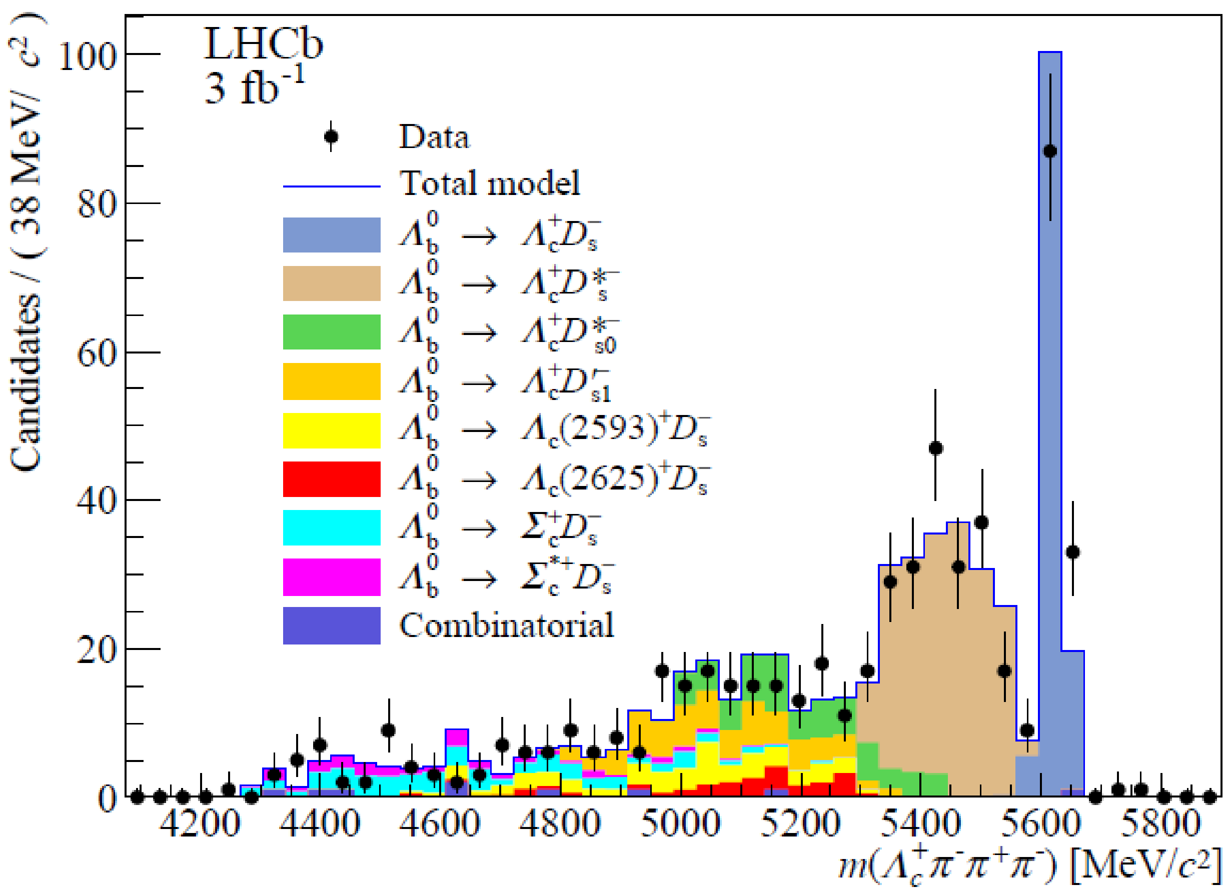




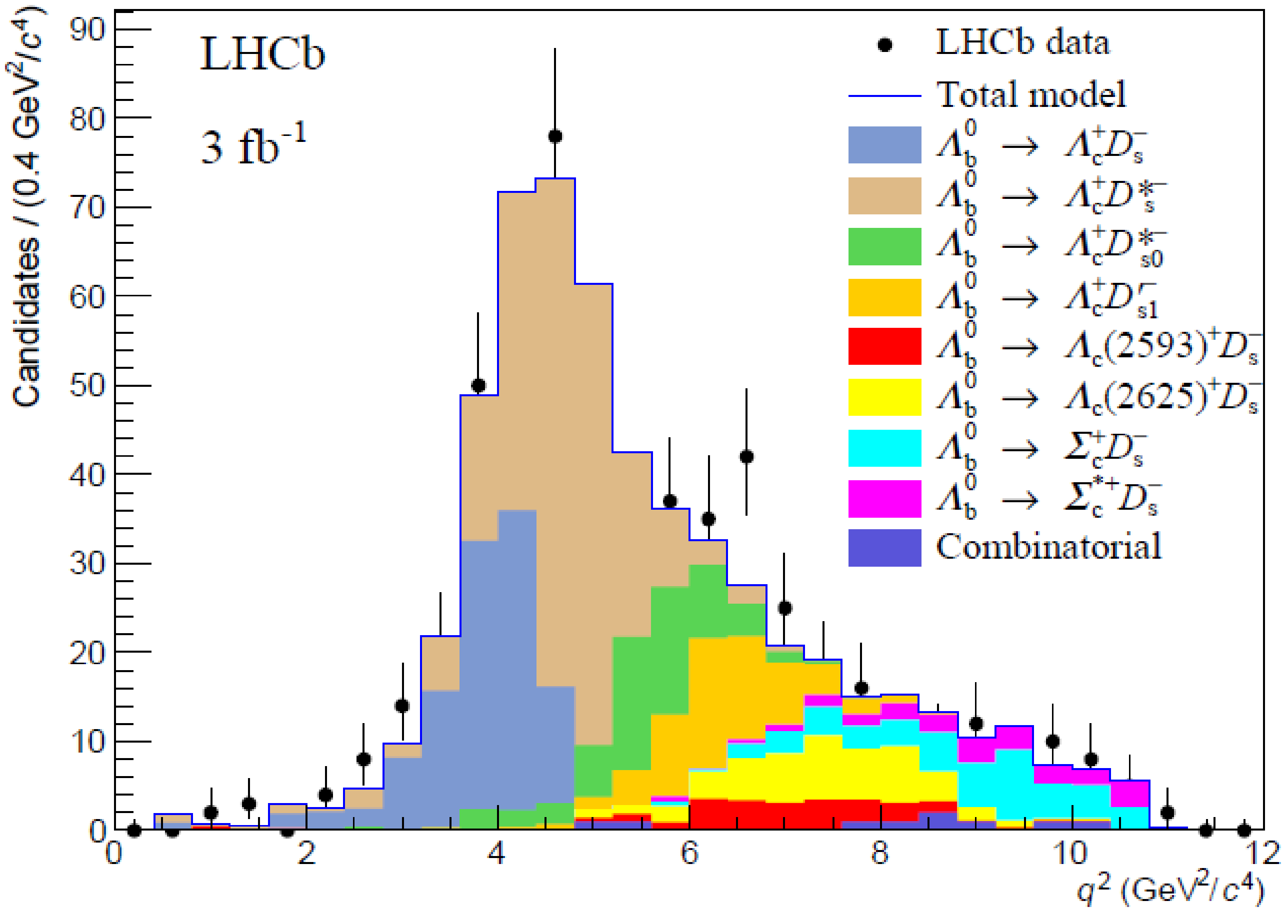
No candidates above the D_s^- mass : completely dominated by double charm background

The exclusive $\Lambda_c^+ D_s^-(X)$ control sample

LHCb-PAPER-2021-044 arxiv:2201:03497



Fit to the $\Lambda_b \rightarrow \Lambda^+_c \pi^- \pi^+ \pi^-$ mass distribution



Projection on q^2

3D Fit results

- The fit is a 3D binned (6x6x6) maximum likelihood template fit to the data
- 3 variables :
  - τ decay time
  - q^2
  - Anti-D_s^- BDT
- Fit results :

  χ^2/dof=1.3

Signal yield = 349 ± 40

$\Lambda_c^* \tau \nu$ =35

N D_s^- =2757 ± 80

N D^+= 443 ± 55

N D^0 = 186 ± 7

Combinatorial 679

Fit projections : τ decay time and BDT

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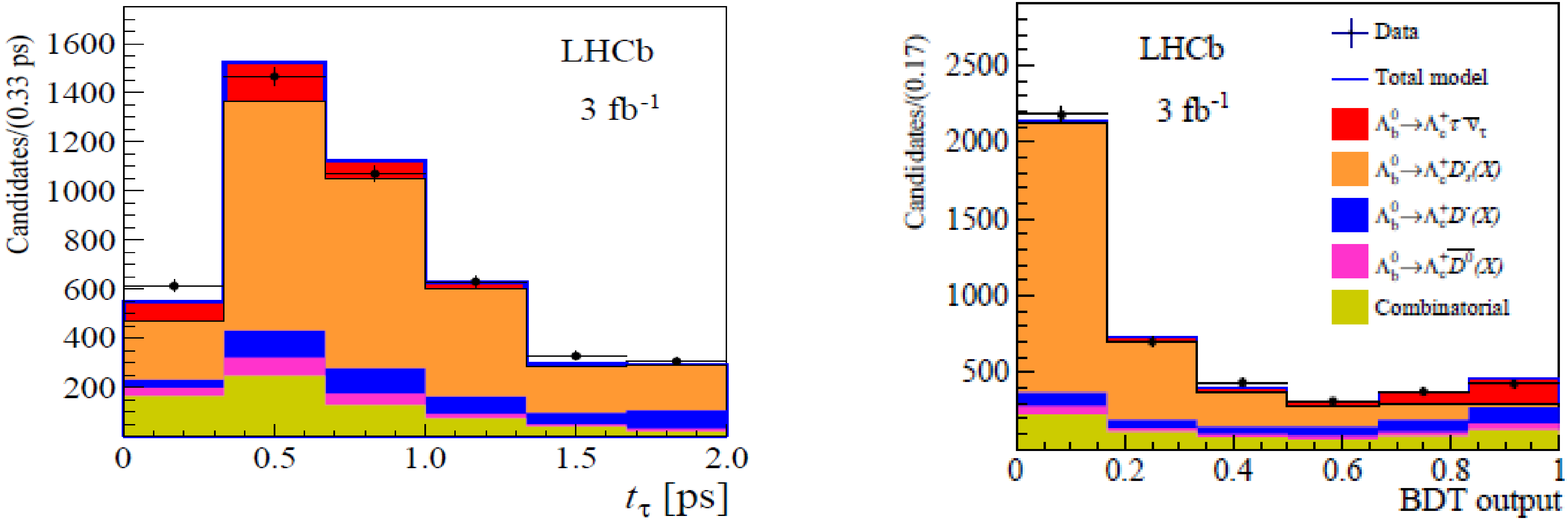

Fit projection : q^2

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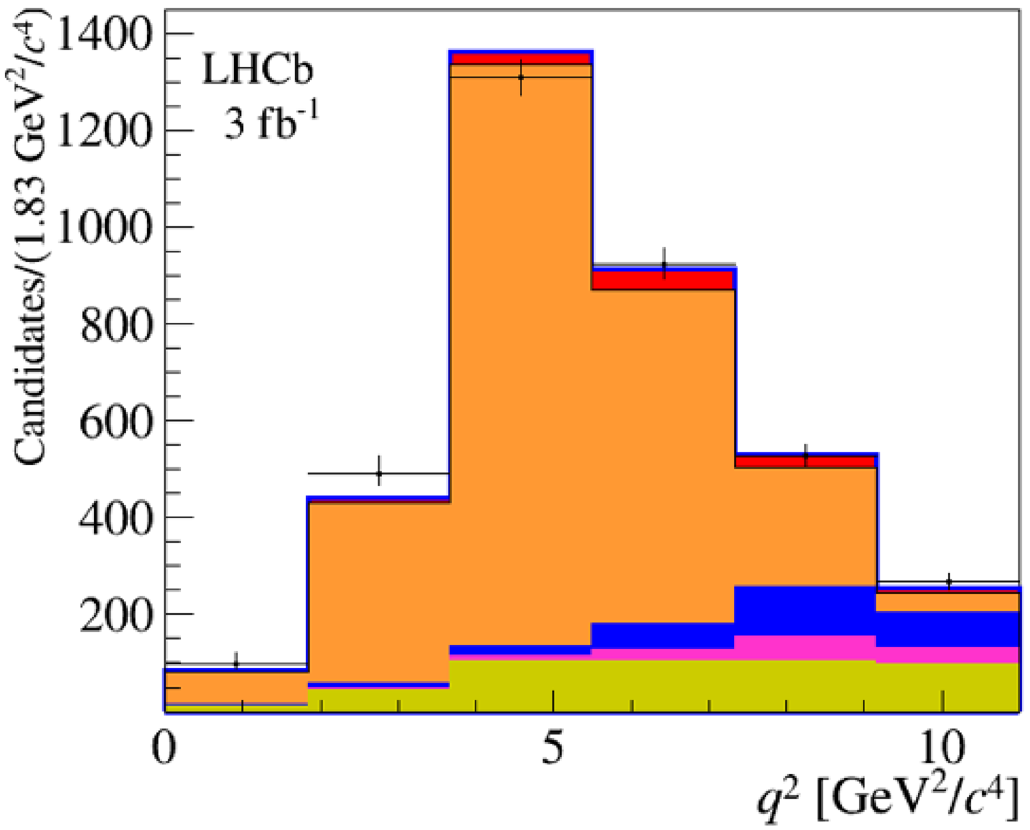
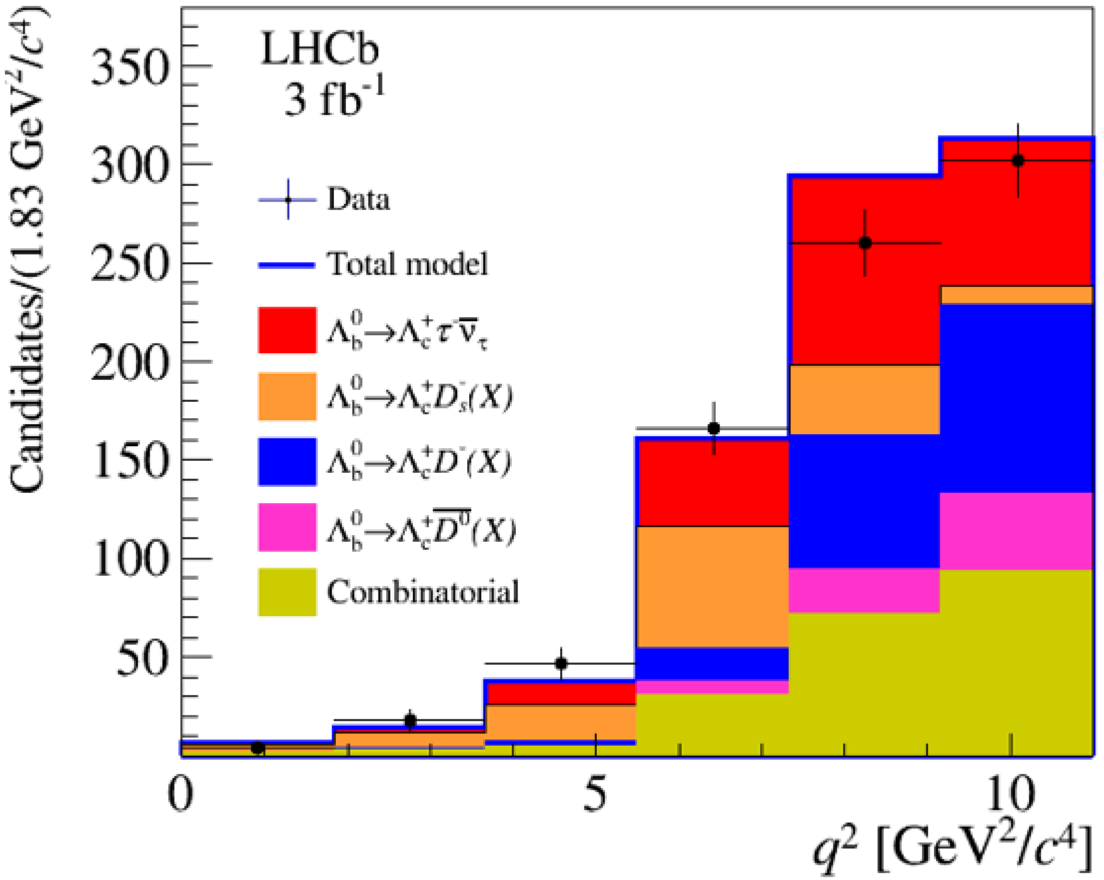
Low BDT



High BDT(>0.66)



Largest systematic : template shapes

Source	$\delta\mathcal{K}(\Lambda_c^+)/\mathcal{K}(\Lambda_c^+)[\%]$
Simulated sample size	3.8
Fit bias	3.9
Signal modeling	2.0
$\Lambda_c^{*+}\tau^-\overline{\nu}_\tau$	2.5
$D_s^- \to 3\pi X$ decay model	2.5
$\Lambda_b^0 \to \Lambda_c^+ D_s^- X$, $\Lambda_b^0 \to \Lambda_c^+ D^- X$, $\Lambda_b^0 \to \Lambda_c^+ \overline{D}^0 X$ background	4.7
Combinatorial background	0.5
Particle identification and trigger corrections	1.5
Data/simulation agreement for isolation and vertex	4.5
D_s^+, D^-, $\overline{D}^0$ templates shapes	13.0
Efficiency ratio	2.8
Normalization channel efficiency (modeling of $\Lambda_b^0 \to \Lambda_c^+ 3\pi$)	3.0
Total uncertainty	16.5

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arxiv:2201:03497

Physics results

$$\mathcal{K}(\Lambda_c^+) \equiv \mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \tau^- \overline{\nu}_\tau)/\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \pi^- \pi^+ \pi^-)$$

$$\mathcal{K}(\Lambda_c^+) = 2.46 \pm 0{,}27\ (\text{stat}) \pm 0{,}40\ (\text{syst})$$

- Using $\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \pi^- \pi^+ \pi^-)_{\text{no } \Lambda_c^{*+}}$ =(0. 614 ± 0.094)% [PDG2020],

$$\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \tau^- \overline{\nu}_\tau) = (1{,}50 \pm 0{,}16\ (\text{stat}) \pm 0{,}25\ (\text{sys}) \pm 0{,}23\ (\text{ext}))\ \%$$

(SM expectation=(1.8± 0.1)%

- Using $\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \mu^- \overline{\nu}_\mu) = (6.2 \pm 1.4)\%$ [PDG2020],

$$\mathcal{R}(\Lambda_c^+) = 0.242 \pm 0.026\ (\text{stat}) \pm 0.040\ (\text{syst}) \pm 0.059\ (\text{ext})$$

(SM expectation=0.324 ± 0.004)

F. Bernlochner et al., Physical Review D 99 055008 (2019)
with input from W. Detmold, C. Lehner, S. Meinel, Physical Review D 92 034503 (2015)

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Constraints on New Physics models (including all meson-based results)

Coupling	$R(\Lambda_c)_{max}$	$R^{Ratio}_{\Lambda_c,max}$	coupling value	$R(\Lambda_c)_{min}$	$R^{Ratio}_{\Lambda_c,min}$	coupling value
g_S only	0.405	1.217	0.363	0.314	0.942	-1.14
g_P only	0.354	1.062	0.658	0.337	1.014	0.168
g_L only	0.495	1.486	$0.094 + 0.538i$	0.340	1.022	$-0.070 + 0.395i$
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g_T only	0.526	1.581	0.428	0.338	1.015	-0.005

A. Datta et al., Journal of High Energy Physics 1708 (2017) 131

Our result excludes regions of the parameter space of effective theories with only one vector, axial-vector or tensor coupling

Semitauonic prospects in LHCb

- Many more semitauonic results expected soon using the muonic and hadronic τ decay channel :
  - $\mathcal{R}(D^*)$ using 2015-2016 data
  - D* polarization measurement
  - $\mathcal{R}(\Lambda_c^+)$ using the full Run2 data
  - $\mathcal{R}(D^+)$
- Work is also ongoing on $\mathcal{R}(D_s)$, $\mathcal{R}(J/\psi)$, full angular analysis

Conclusions

- New simultaneous measurement of R(D) and R(D*)using muonic channel

$$\mathcal{R}(D^*) = 0.281 \pm 0.018 \pm 0.024$$
$$\mathcal{R}(D) = 0.441 \pm 0.060 \pm 0.066$$

- Discrepancy level between new WA and SM prediction 3.2 σ
  - « Le canard est toujours vivant »
- The decay $\Lambda_b^0 \rightarrow \Lambda_c^+ \tau^- \overline{\nu}_\tau$ has been observed for the first time with a significance of 6.1 σ
  - $\mathcal{K}(\Lambda_c^+)$ = 2.46 ± 0.27 (stat) ± 0.40 (syst)
  - $\mathcal{B}(\Lambda_b^0 \rightarrow \Lambda_c^+ \tau^- \overline{\nu}_\tau)$= (1,50 ± 0,16 (stat) ± 0,25 (sys) ± 0,23 (ext)) %
  - $\mathcal{R}(\Lambda_c^+)$=0.242 ± 0.026 (stat) ± 0.040 (syst) ± 0.059 (ext)

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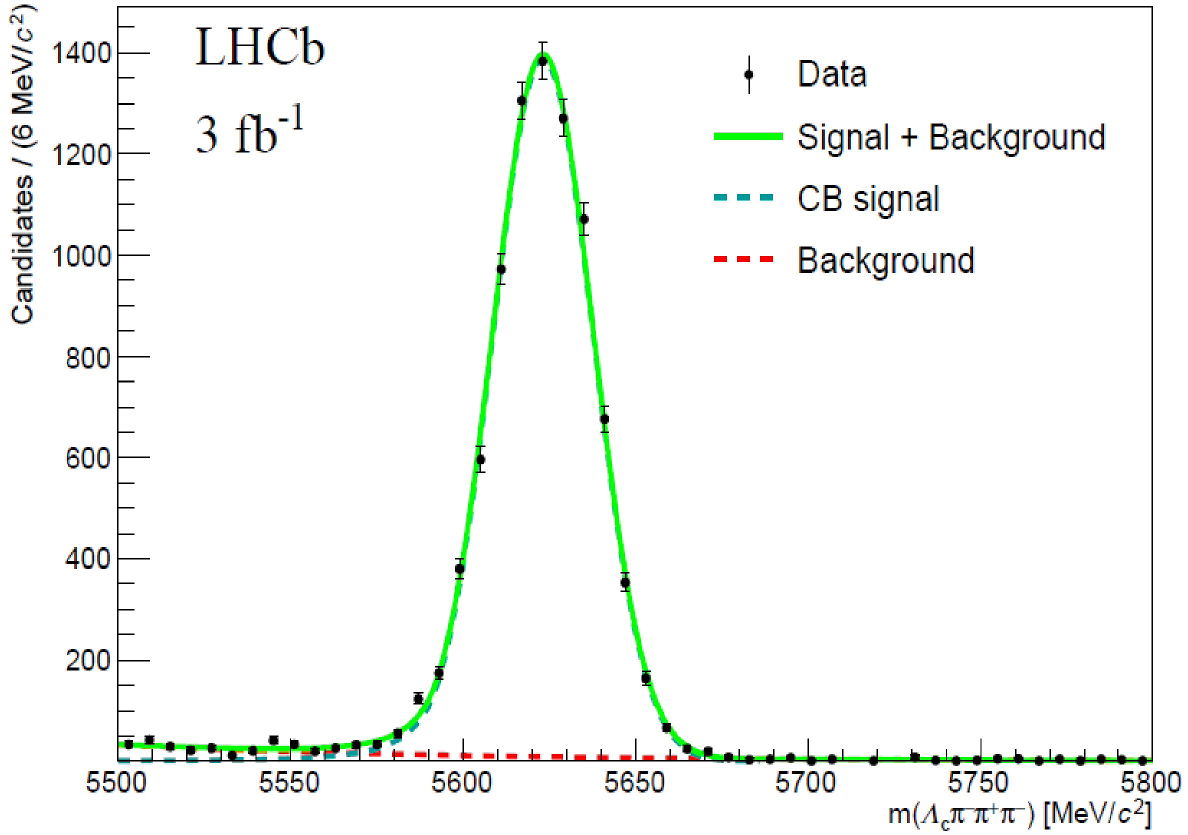
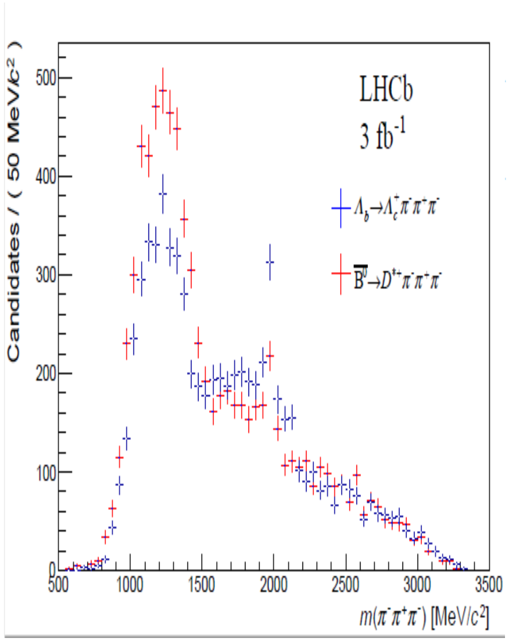
- Everything compatible with SM (~1 σ below)
- A fraction of the parameter space of effective theories with only one vector, axial-vector or tensor couplings can be excluded

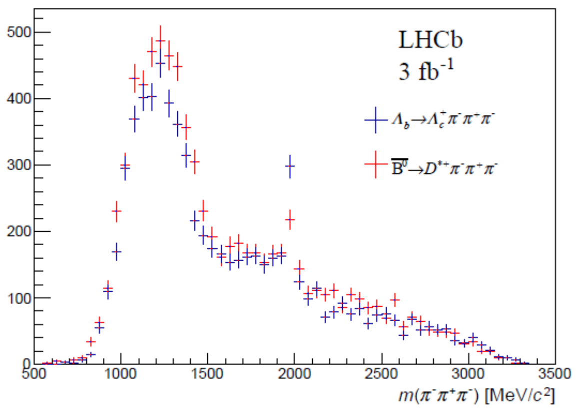
Backup slides

$\Lambda_b^0 \to \Lambda_c^+\pi^-\pi^+\pi^-$ normalisation peak



Comparison of the 3π mass distribution for $\Lambda_c^+ 3\pi$ and D*3π events before and after $\Lambda_c^{*+}\pi$ events removal





Normalisation yield after Λ_c^{*+} subtraction: 8584 ± 102

LHCb-PAPER-2021-044
arxiv:2201:03497

Regarding $\Lambda_c^+\pi^+\pi^-\pi^+$ mode: PDG2020

$\Gamma(\Lambda_c^+\pi^+\pi^-\pi^-)/\Gamma_{total}$ **Γ_{29}/Γ**

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	COMMENT
7.7±1.1 OUR FIT Error includes scale factor of 1.1.					
$14.9^{+3.8}_{-3.2}\pm1.2$		[1] AALTONEN	12A	CDF	$p\bar{p}$ at 1.96 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
seen	90	BARI	91	SFM	$\Lambda_c^+ \to pK^-\pi^+$

[1] AALTONEN 12A reports $[\Gamma(\Lambda_b^0 \to \Lambda_c^+\pi^+\pi^-\pi^-)/\Gamma_{total}] / [B(\Lambda_b^0 \to \Lambda_c^+\pi^-)] = 3.04 \pm 0.33^{+0.70}_{-0.55}$ which we multiply by our best value $B(\Lambda_b^0 \to \Lambda_c^+\pi^-) = (4.9 \pm 0.4) \times 10^{-3}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\Gamma(\Lambda_c^+\pi^+\pi^-\pi^-)/\Gamma(\Lambda_c^+\pi^-)$ **Γ_{29}/Γ_{24}**

VALUE	DOCUMENT ID		TECN	COMMENT
1.56±0.21 OUR FIT				
1.43±0.16±0.13	AAIJ	11E	LHCB	pp at 7 TeV

For $\Lambda_c^+\pi^+\pi^-\pi^+$ data, the PDG error is 14%. (a bit better for some reason than the combination of the 8% of the absolute BR($\Lambda_b^0 \to \Lambda_c^+\pi^-$) and the 13.5% ratio coming from the ratio.)

Subtracting $\Lambda_c^{*+}\pi^-$

$\Gamma(\Lambda_c(2595)^+\pi^-, \Lambda_c(2595)^+ \to \Lambda_c^+\pi^+\pi^-)/\Gamma(\Lambda_c^+\pi^+\pi^-\pi^-)$ Γ_{30}/Γ_{29}

VALUE (units 10^{-2})	*DOCUMENT ID*	*TECN*	*COMMENT*
$4.4\pm1.7^{+0.6}_{-0.4}$	AAIJ 11E	LHCB	pp at 7 TeV

HTTP://PDG.LBL.GOV Page 11 Created: 6/1/2020 08:33

Citation: P.A. Zyla *et al.* (Particle Data Group), Prog. Theor. Exp. Phys. **2020**, 083C01 (2020)

$\Gamma(\Lambda_c(2625)^+\pi^-, \Lambda_c(2625)^+ \to \Lambda_c^+\pi^+\pi^-)/\Gamma(\Lambda_c^+\pi^+\pi^-\pi^-)$ Γ_{31}/Γ_{29}

VALUE (units 10^{-2})	*DOCUMENT ID*	*TECN*	*COMMENT*
$4.3\pm1.5\pm0.4$	AAIJ 11E	LHCB	pp at 7 TeV

$\Gamma(\Sigma_c(2455)^0\pi^+\pi^-, \Sigma_c^0 \to \Lambda_c^+\pi^-)/\Gamma(\Lambda_c^+\pi^+\pi^-\pi^-)$ Γ_{32}/Γ_{29}

VALUE (units 10^{-2})	*DOCUMENT ID*	*TECN*	*COMMENT*
$7.4\pm2.4\pm1.2$	AAIJ 11E	LHCB	pp at 7 TeV

$\Gamma(\Sigma_c(2455)^{++}\pi^-\pi^-, \Sigma_c^{++} \to \Lambda_c^+\pi^+)/\Gamma(\Lambda_c^+\pi^+\pi^-\pi^-)$ Γ_{33}/Γ_{29}

VALUE (units 10^{-2})	*DOCUMENT ID*	*TECN*	*COMMENT*
$4.2\pm1.8\pm0.7$	AAIJ 11E	LHCB	pp at 7 TeV

for a total of (20.3±4) % of the full $\Lambda_c^+\pi^-\pi^+\pi^-$ yield. This corresponds to a total error of 14.8% .

Regarding $\Lambda_c^+\mu^-\overline{\nu}_\mu$

$\Gamma(\Lambda_c^+\ell^-\overline{\nu}_\ell)/\Gamma_{total}$ — **Γ_{39}/Γ**

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
$0.062^{+0.014}_{-0.013}$ OUR FIT				
$0.050^{+0.011}_{-0.008}{}^{+0.016}_{-0.012}$	[1] ABDALLAH	04A	DLPH	$e^+e^- \to Z^0$

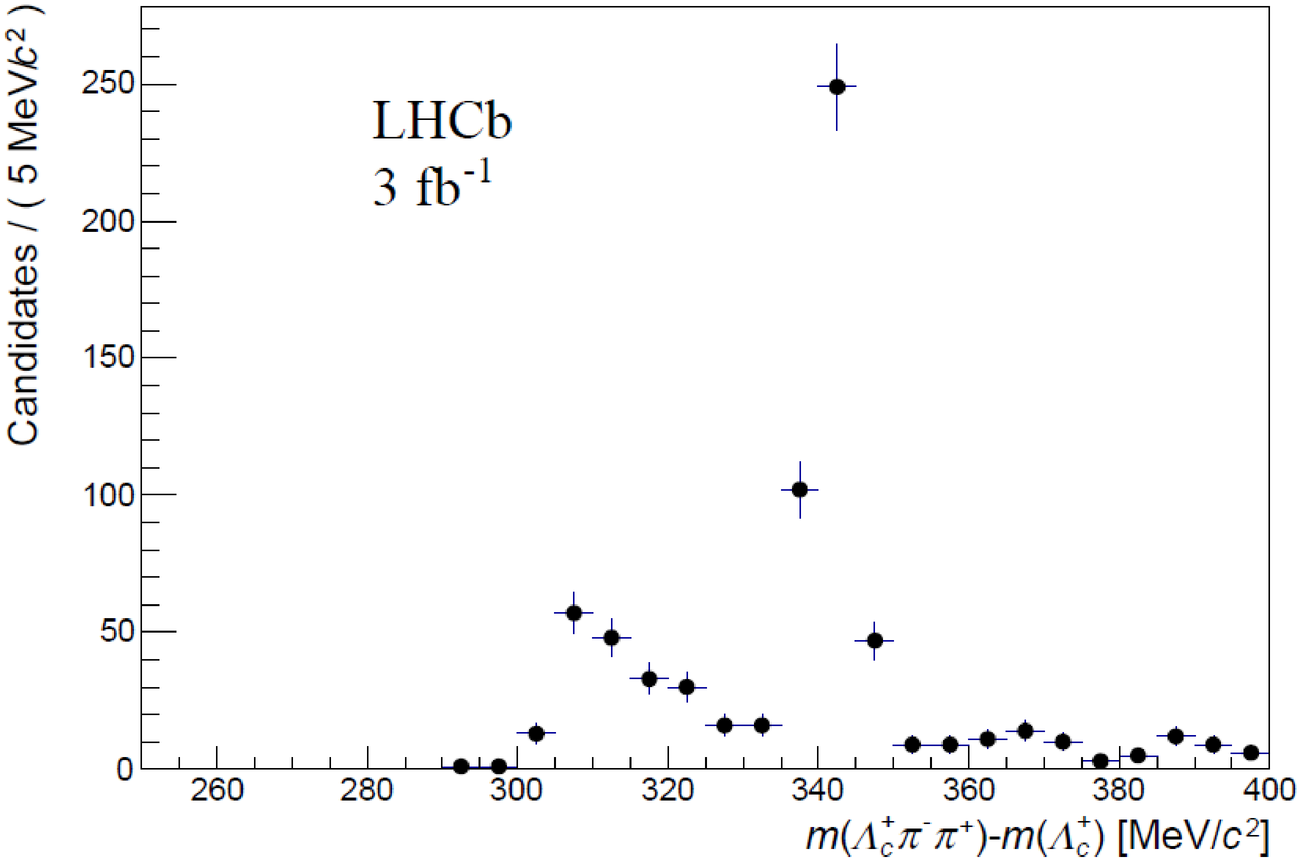
[1] Derived from a combined likelihood and event rate fit to the distribution of the Isgur-Wise variable and using HQET. The slope of the form factor is measured to be $\rho^2 = 2.03 \pm 0.46^{+0.72}_{-1.00}$.

$\Gamma(\Lambda_c^+\ell^-\overline{\nu}_\ell)/\Gamma(\Lambda_c^+\pi^-)$ — **Γ_{39}/Γ_{24}**

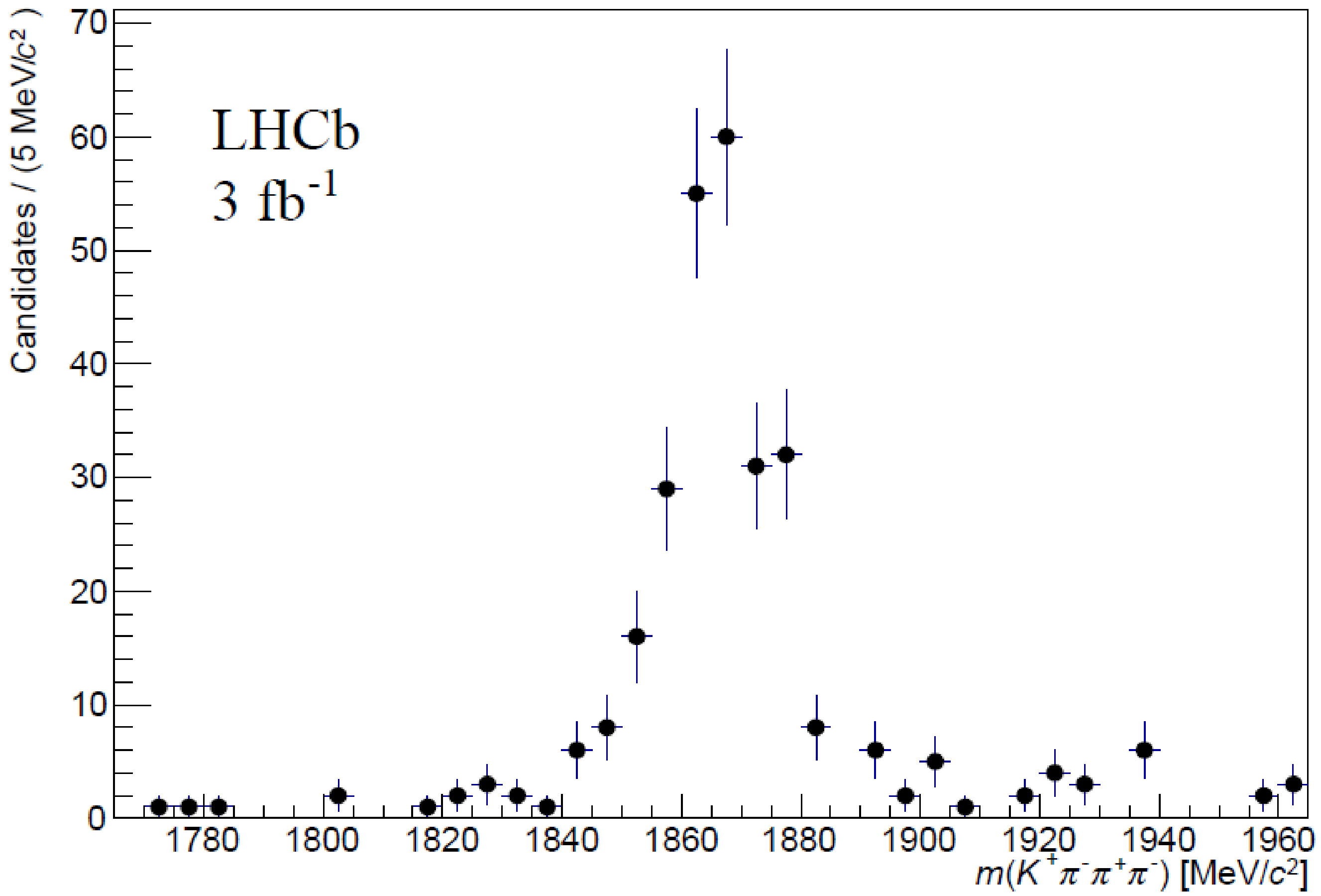
VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
$12.7^{+3.1}_{-2.7}$ OUR FIT				
$16.6\pm3.0^{+2.8}_{-3.6}$	AALTONEN	09E	CDF	$p\overline{p}$ at 1.96 TeV

- 22.6% for the semileptonic channel
- Combining with the $\Lambda_c^+\pi^-\pi^+\pi^-$ the crude number is 27%.
- It reduces to 24% by removing the 13% relative error mentioned in the PDG for their $f_{\Lambda b}$ fraction (8.4+1.1)%

Distribution of the difference m($\Lambda_c^+\pi^+\pi^-$)-m(Λ_c^+) in the $\Lambda_b^0 \rightarrow \Lambda_c^+\ \pi^-\pi^+\pi^-$ mass peak



Distribution of the $K^+\pi^-\pi^+\pi^-$ mass for events with one extra kaon track at the 3π vertex



Results of the nominal fit

Parameter	Fit result	Constraint value
N_{sig}	349 ± 40 (11.8%)	
$f_{\tau \to 3\pi\nu}$		0.78
$f_{\Lambda_c^* \tau \overline{\nu}_\tau}$		0.1
$N_{D^0}^{same}$	80.2 ± 8.3	81.4 ± 7.4
$f_{D^0}^{v_1 - v_2}$	1.3 ± 0.7	
N_{D_s}	2755.9 ± 81	
f_{D_s}	0.49 ± 0.09	0.65 ± 0.08
$f_{D_{s0}^*}$	0.0 ± 0.012	0.28 ± 0.12
$f_{D'_{s1}}$	0.41 ± 0.07	0.29 ± 0.12
$f_{\Lambda_c(2625) D_s^{(*)}}$	0.19 ± 0.06	0.22 ± 0.09
$f_{\Sigma_c \pi D_s^{(*)}}$	0.0 ± 0.02	0.22 ± 0.05
N_{D+}	443 ± 54	
N_{combi}		40.3
$N_{\Lambda_c^+}^{bkg}$		639
χ^2	256	
reduced χ^2 ($ndof = 216$)	1.30	

Baryon production from B mesons

- The only way to get $\Lambda_c 3\pi$ with the inverted vertex topology is the production of two charmed baryons
- Two such decays exist
  - Two-body mode B°→ $\Lambda_c \Xi c$ BR =(0,12+_ 0.08)% similar to signal mode
  - Three-body mode B°→ $\Lambda_c \Lambda_c$ K° (can come partially from $\Lambda_c \Xi_c$ (2930)
    BR= (0.04+_0.009)%

The decay $\Xi_c \rightarrow \Xi 3\pi$ (BR=1.7%) or $\Lambda_c \rightarrow \Lambda 3\pi$ (BR=5%) is then needed

(The 3 pions have to come from the same vertex)

- Small but f_d=4*f_Λ

  Important to note that mass(3π) <1.1 GeV

- B^+ contribution suppressed by isolation requirements