Review and Prospects for Lepton Flavour Universality in charged current channels: semitauonic B decays

Guy Wormser (IJCLab)

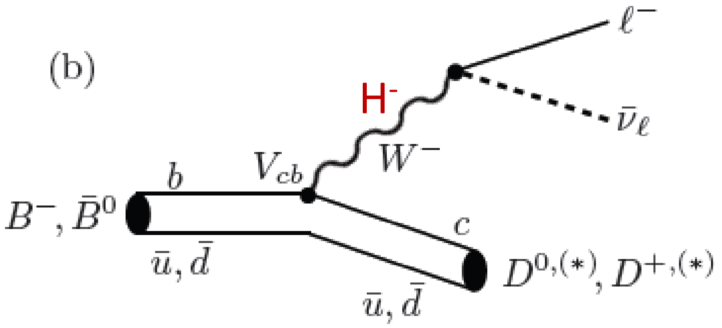
Outline

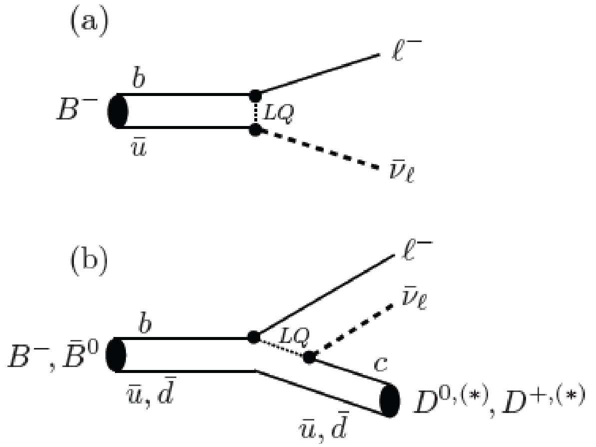
- A few words about Lepton Flavour Universality
- Overview of LFUV tests with semitauonic B decays
- Why is it interesting to measure $\Lambda_b^0 \to \Lambda_c^+ \tau^- \overline{\nu}_\tau$
- The observation of $\Lambda_b^0 \to \Lambda_c^+ \tau^- \overline{\nu}_\tau$
- Impact of the measurement
- Prospects regarding LFUV tests in the charged current sector (and related measurements)
- Improved knowledge required on D_s inclusive decays to 3π
- Conclusion

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

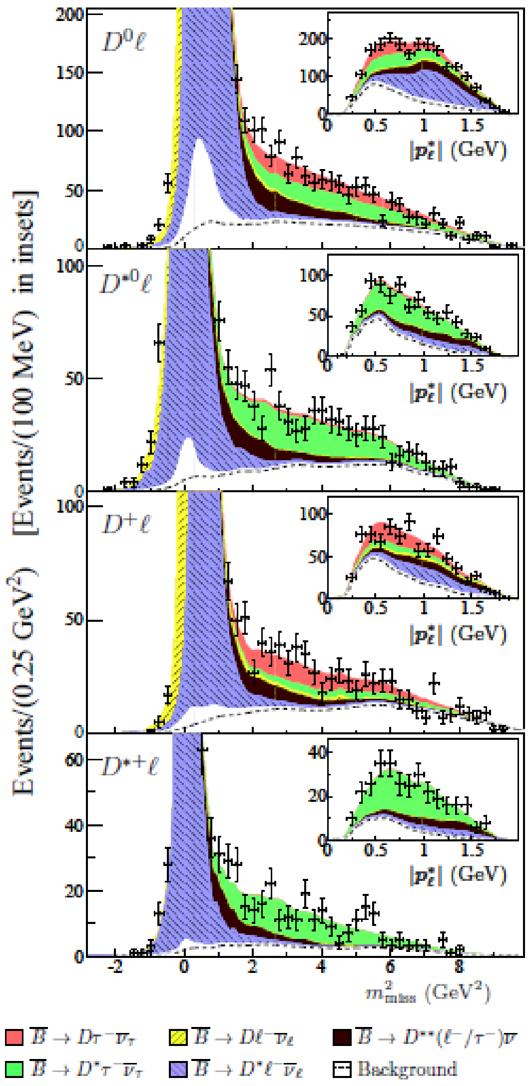




- Abundant reaction BR ~1%
- High precision of SM prediction ~1%
- **Charged Higgs, Leptoquarks** are the usual suspects
- Sensitivity in the TeV range: direct search possible at the LHC : however many scenarios still open after taking into account the present direct exclusions domains
- If the present WA average is correct, **, $R(D^*)/R(D^*)_{SM}$=1.23: Large new physics effects !!**
- Possibility to measure the effects for various B parents and charm spectators **: the importance of the spin :** $\Lambda_b^0 \to \Lambda_c^+ \tau^- \bar{\nu}_\tau$
- 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 !

The pioneering BABAR 2012 result
PRL109, 101802(2012)

- At the Υ(4S), the strategy is a priori simple :
  - Reconstruct a « tag » B to gain access to the other B center of mass frame and thus to the missing mass
  - Select events with D*μ topology on the signal side
  - Count events with μ much softer than for normal semileptonic decays
  - The winning « trick » : **much higher efficiency reconstruction of the « tag » B particle**



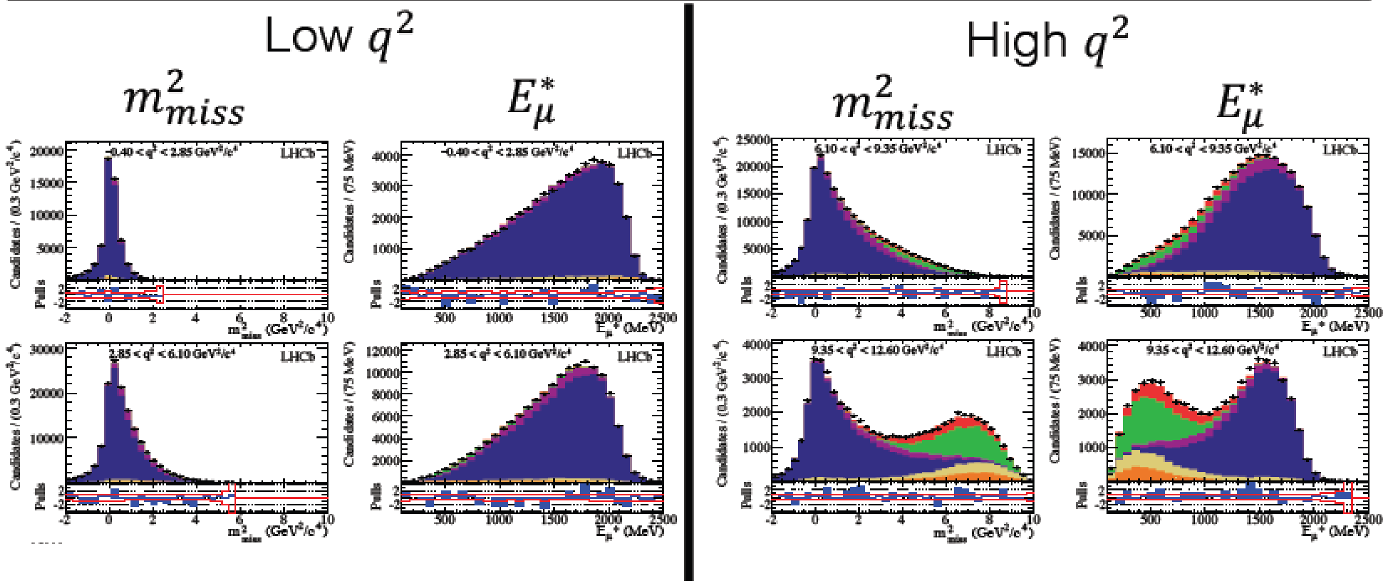
Other R(D*) results up to now

- 3 new measurements by BELLE collaboration
  - Hadronic tag as for BABAR-leptonic tau decay
    - PRD92, 072014(2015)
  - Semileptonic Tag , more statistics but worse CM and missing mass resolution- leptonic tau decay
    - PRD94, 072007 (2015)
  - Hadronic tag –hadronic tau decay in $\pi/\pi\pi°$. Important to access tau polarization information. Real challenge to fight hadronic background
    - PRL118,211801 (2017), arXiv1612. 00529
- 1 new mesurement from LHCb collaboration
    - PRL115, 1183(2015)
  - Muonic tau decay in a hadronic collider !!!!

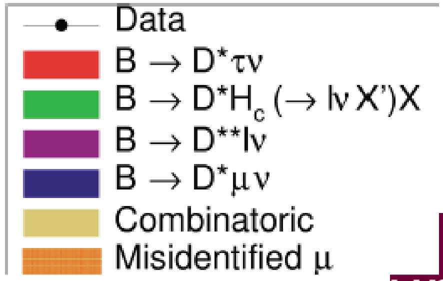
LHCb muonic result (2015)

PRL 115 111803 (2015)

Fit Result



- Shown above: signal fit to "signal" data passing isolation selection
- Result $\frac{N_\tau}{N_\mu} = (4.32 \pm 0.37)\times 10^{-2}$, $R(D^*) = 0.336 \pm 0.027 \pm 0.030$
- $N(\bar{B}^0 \to D^{*+}\mu^-\bar{\nu}_\mu) = 363{,}000 \pm 1600$



Measurement of semitauonic decays at LHCb using the hadronic decay $\tau^- \to \pi^-\pi^+\pi^-(\pi^0)\nu_\tau$

- Similar BR as the muonic channel
- 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
- The presence of only 2 neutrinos in the final state, coupled to the vertices reconstruction, allows to reconstruct the complete event kinematics: good precision on q^2 and $\cos\theta^*$
- Background control samples with exclusive mass peaks

The initial very large background : example of $B^0 \rightarrow D^*\tau\nu$

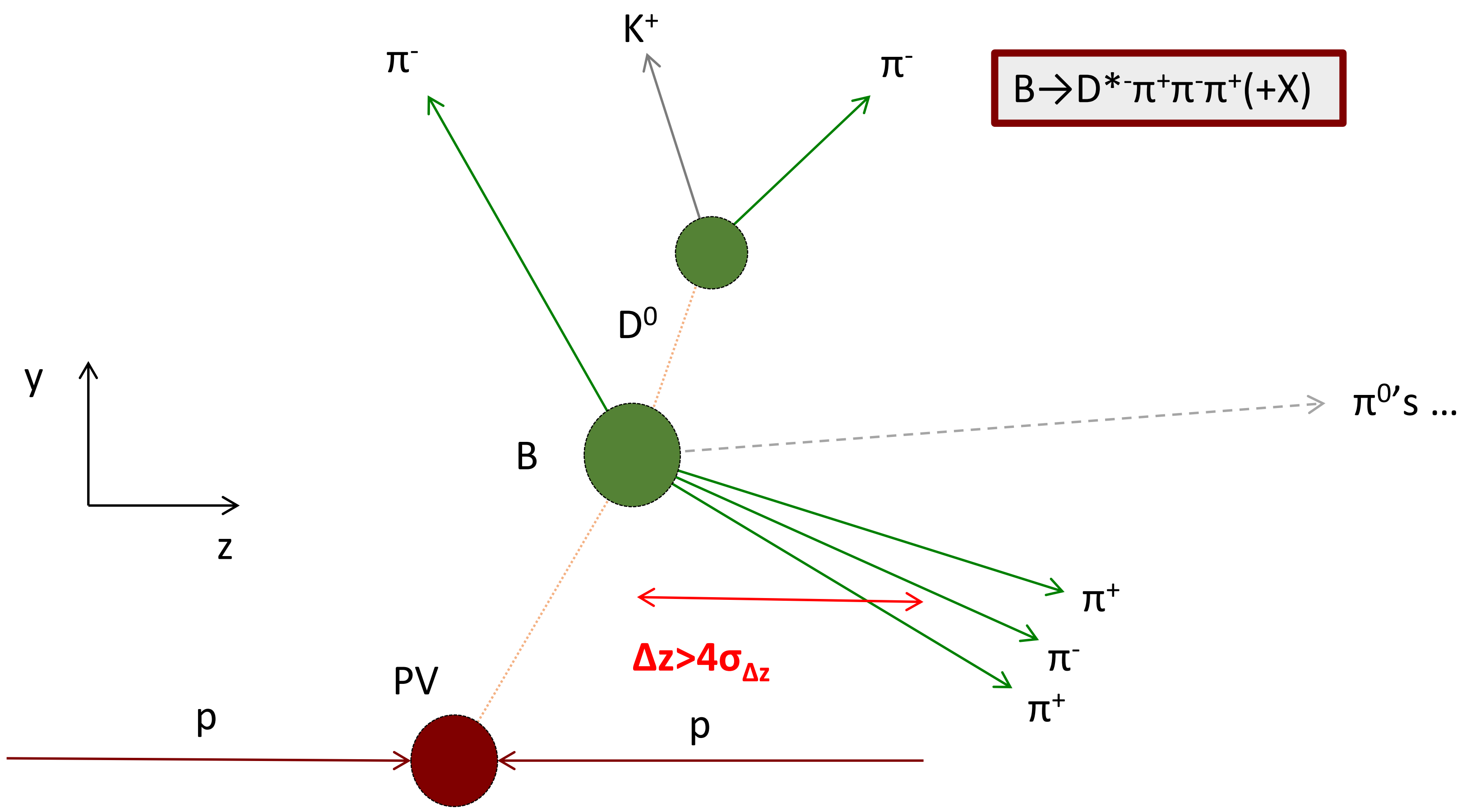
- The $D^*\tau\nu$ decay, with τ going into 3 pions (it can also be $3\pi+\pi^0$) leads to a $D^*\ 3\pi(+X)$ final state
- Nothing is more common than a $D^*3\pi\ (+X)$ final state in a typical B decay :

$$BR(B^0 \rightarrow D^*3\pi+X)/BR(B^0 \rightarrow D^*\tau\nu;\tau \rightarrow 3\pi)_{SM} \sim 100$$

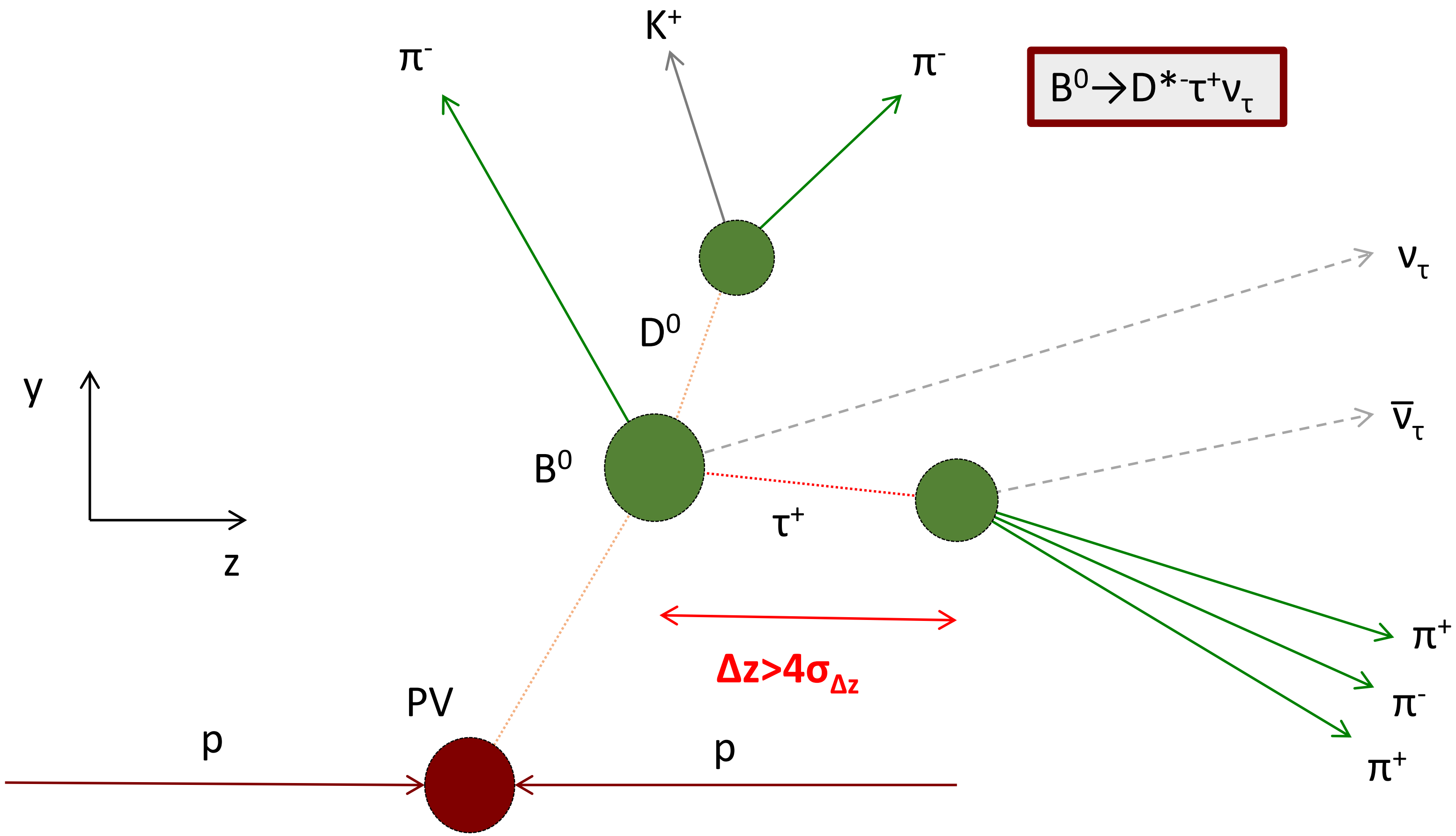
A very strong background suppression method is absolutely needed :

The DETACHED VERTEX METHOD

Vertex topology of the usual B decay

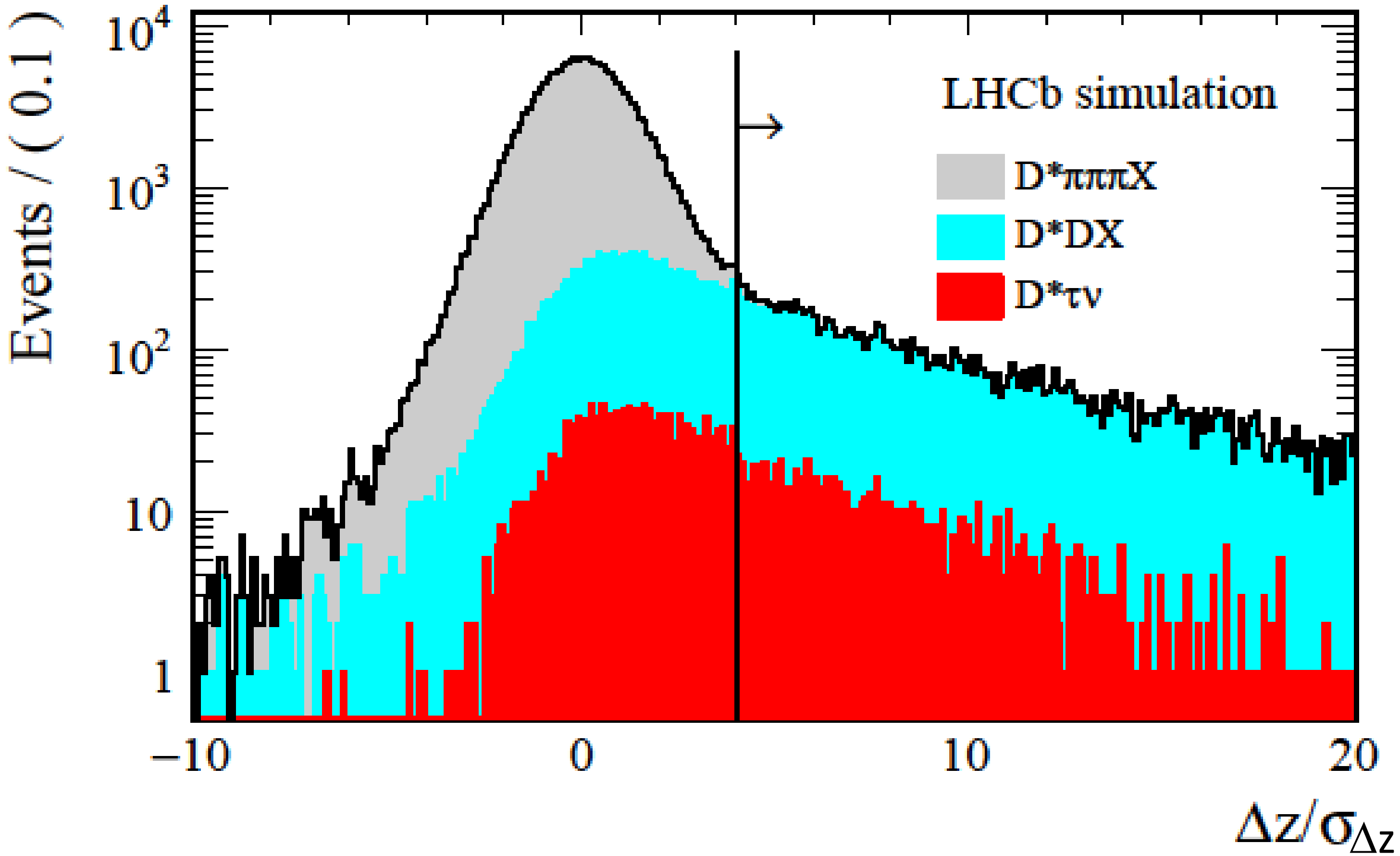


Selection: detached vertex



Selection: the detached vertex method

LHCb-PAPER-2017-027



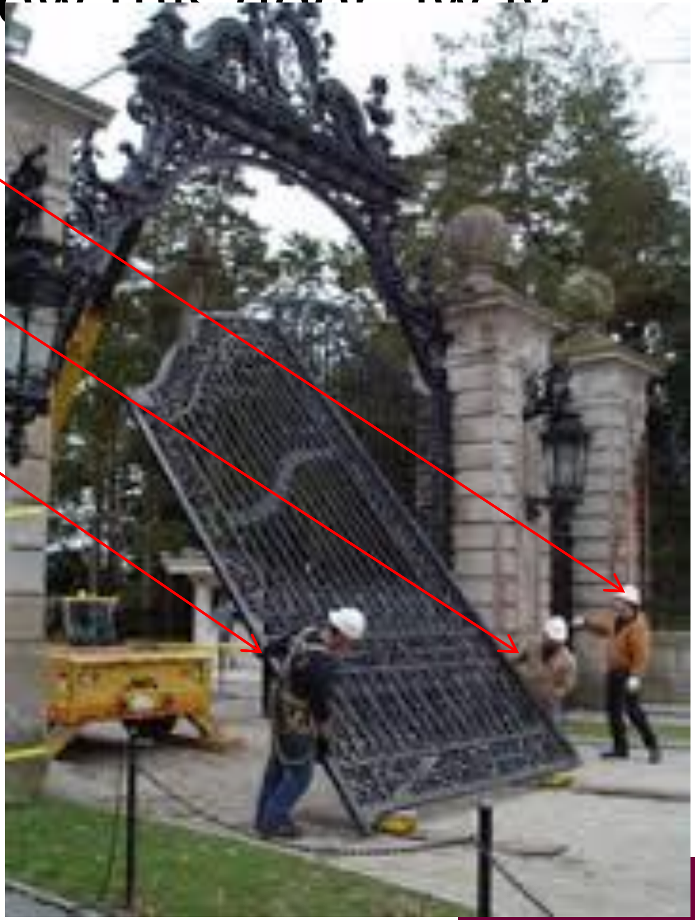
The second level of background : double charm

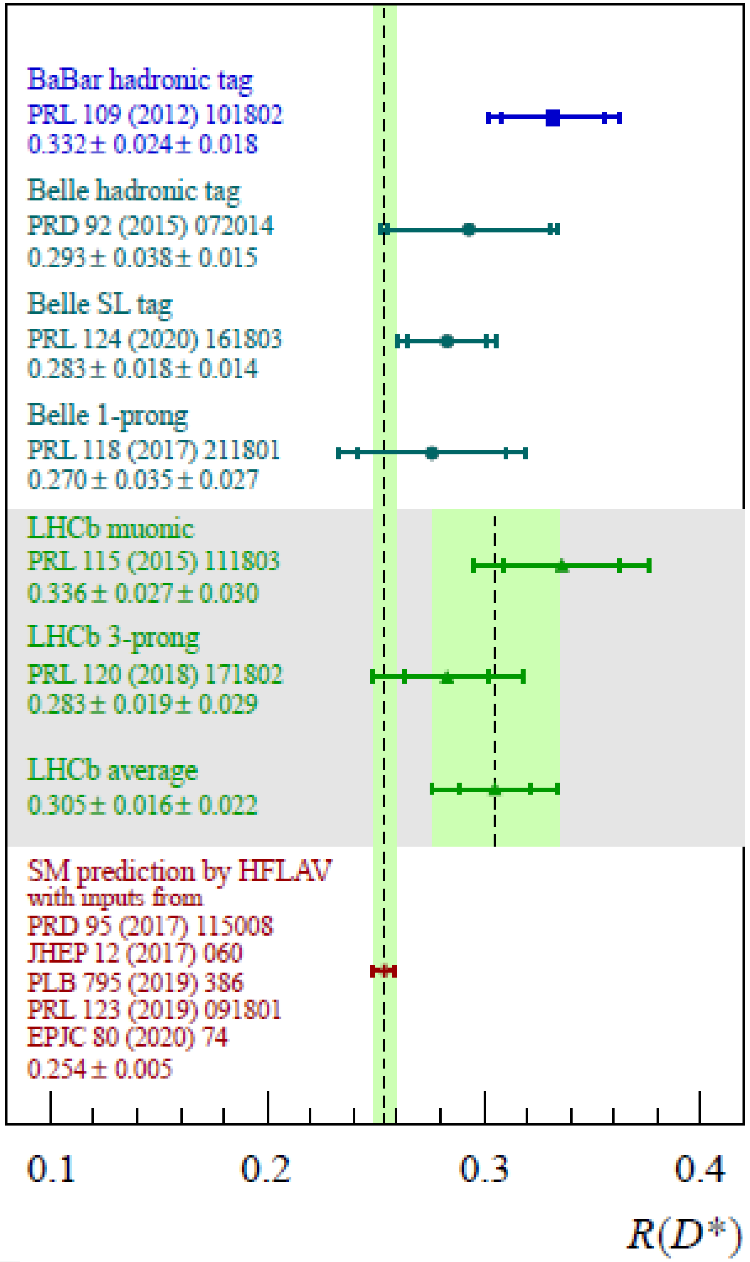
- The second gate consists of B^0 decays where the 3π vertex is transported away from the D^0 vertex by a charm carrier: D_s, D^+ or D^0 (in that order of importance)
- This gate is thinner :

BR(B^0 ->D* 'D'; 'D'→ 3πX)/ BR(B^0->$D^*\tau\nu;\tau\rightarrow 3\pi)_{SM}$~10

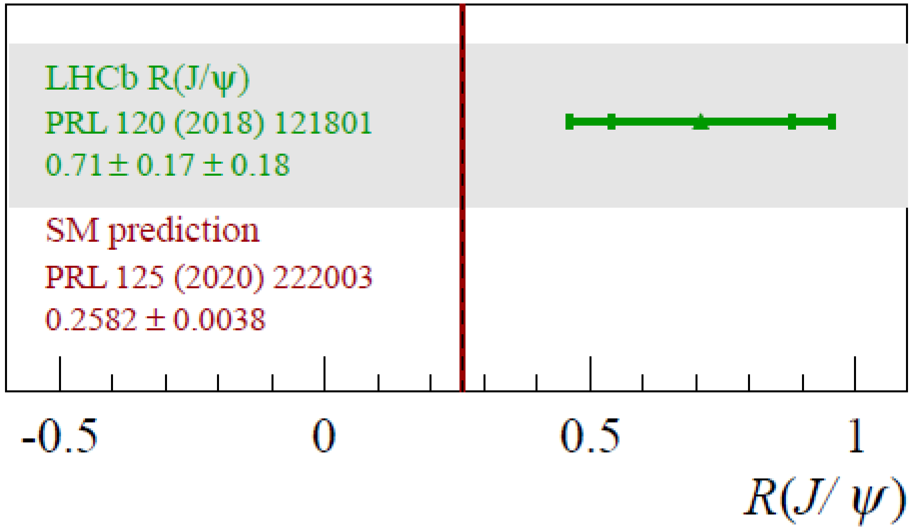
Opening the second gate !

- LHCb has three very good weapons to blow this door away:
  - Background partial reconstruction
  - 3π dynamics
  - Neutral isolation

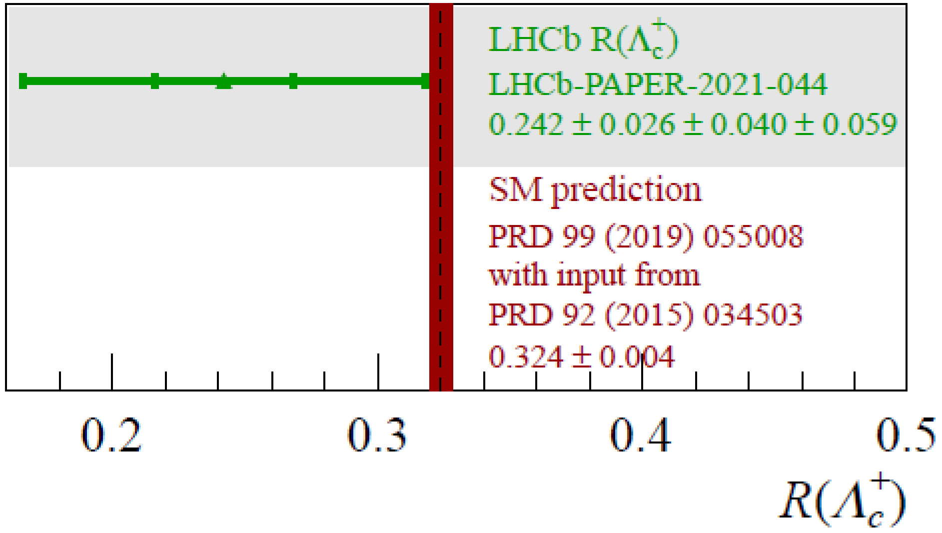




BaBar hadronic tag
PRL 109 (2012) 101802
0.332 ± 0.024 ± 0.018
Belle hadronic tag
PRD 92 (2015) 072014
0.293 ± 0.038 ± 0.015
Belle SL tag
PRL 124 (2020) 161803
0.283 ± 0.018 ± 0.014
Belle 1-prong
PRL 118 (2017) 211801
0.270 ± 0.035 ± 0.027
LHCb muonic
PRL 115 (2015) 111803
0.336 ± 0.027 ± 0.030
LHCb 3-prong
PRL 120 (2018) 171802
0.283 ± 0.019 ± 0.029
LHCb average
0.305 ± 0.016 ± 0.022
SM prediction by HFLAV
with inputs from
PRD 95 (2017) 115008
JHEP 12 (2017) 060
PLB 795 (2019) 386
PRL 123 (2019) 091801
EPJC 80 (2020) 74
0.254 ± 0.005
0.1
0.2
0.3
0.4
$R(D^*)$

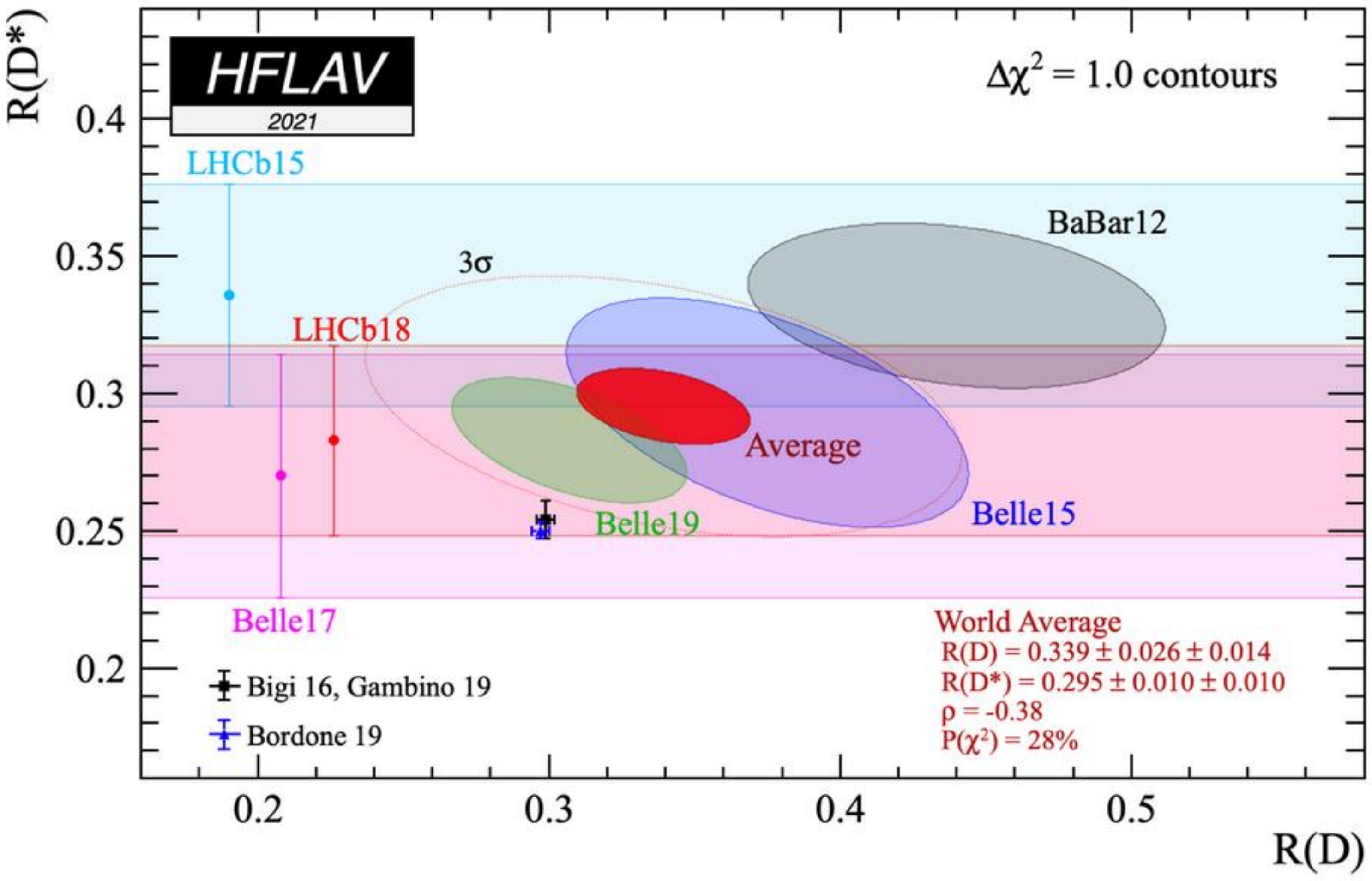


LHCb R(J/ψ)
PRL 120 (2018) 121801
0.71 ± 0.17 ± 0.18
SM prediction
PRL 125 (2020) 222003
0.2582 ± 0.0038
-0.5
0
0.5
1
$R(J/\psi)$



LHCb $R(\Lambda_c^+)$
LHCb-PAPER-2021-044
0.242 ± 0.026 ± 0.040 ± 0.059
SM prediction
PRD 99 (2019) 055008
with input from
PRD 92 (2015) 034503
0.324 ± 0.004
0.2
0.3
0.4
0.5
$R(\Lambda_c^+)$

Most recent update of $\mathcal{R}(D^*)$-$\mathcal{R}(D)$ status
$BR(B \to D^{(*)}\tau\nu)/BR(D^{(*)}\mu\nu)$



022

3.4 σ discrepancy with SM prediction

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Observation of the decay $\Lambda_b^0 \to \Lambda_c^+ \tau^- \overline{\nu}_\tau$ with $\tau^- \to \pi^- \pi^+ \pi^- (\pi^0) \nu_\tau$ decay

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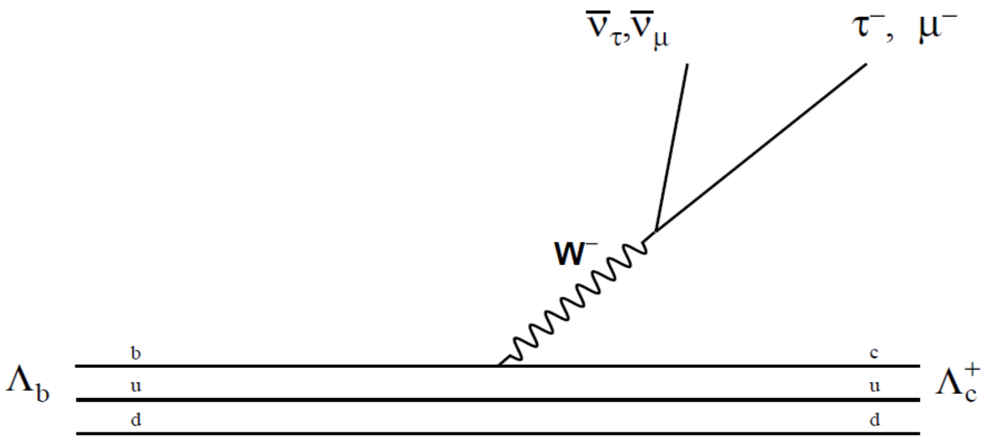
arxiv:2201:03497

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 $\mathcal{R}(D^*)$-$\mathcal{R}(D)$: 3.4 σ away from SM in the latest 2021 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 ± 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

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$\mathcal{R}(\Lambda_c^+)$ 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]

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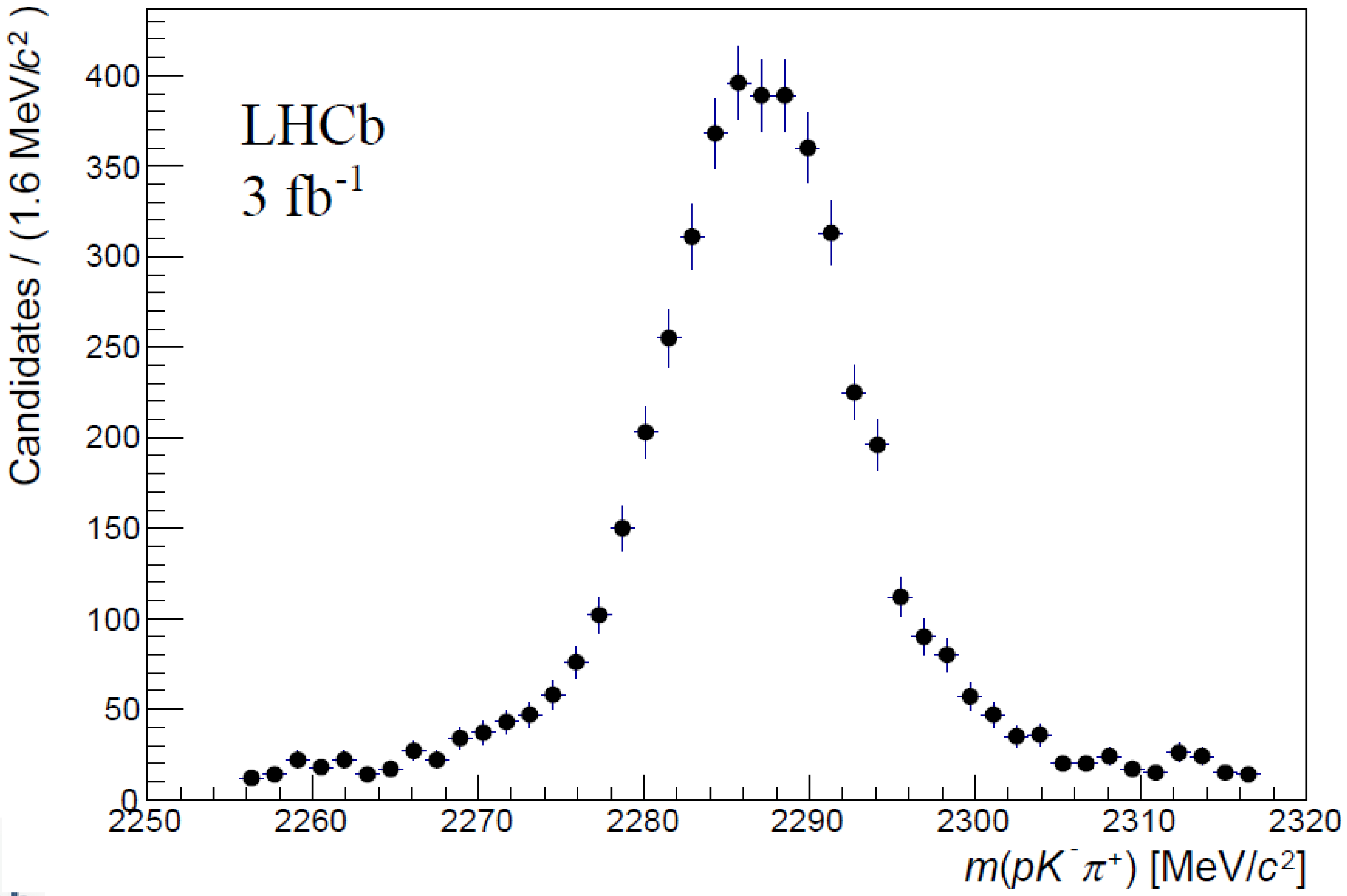
arxiv:2201:03497

Tight Λ_c^+ selection



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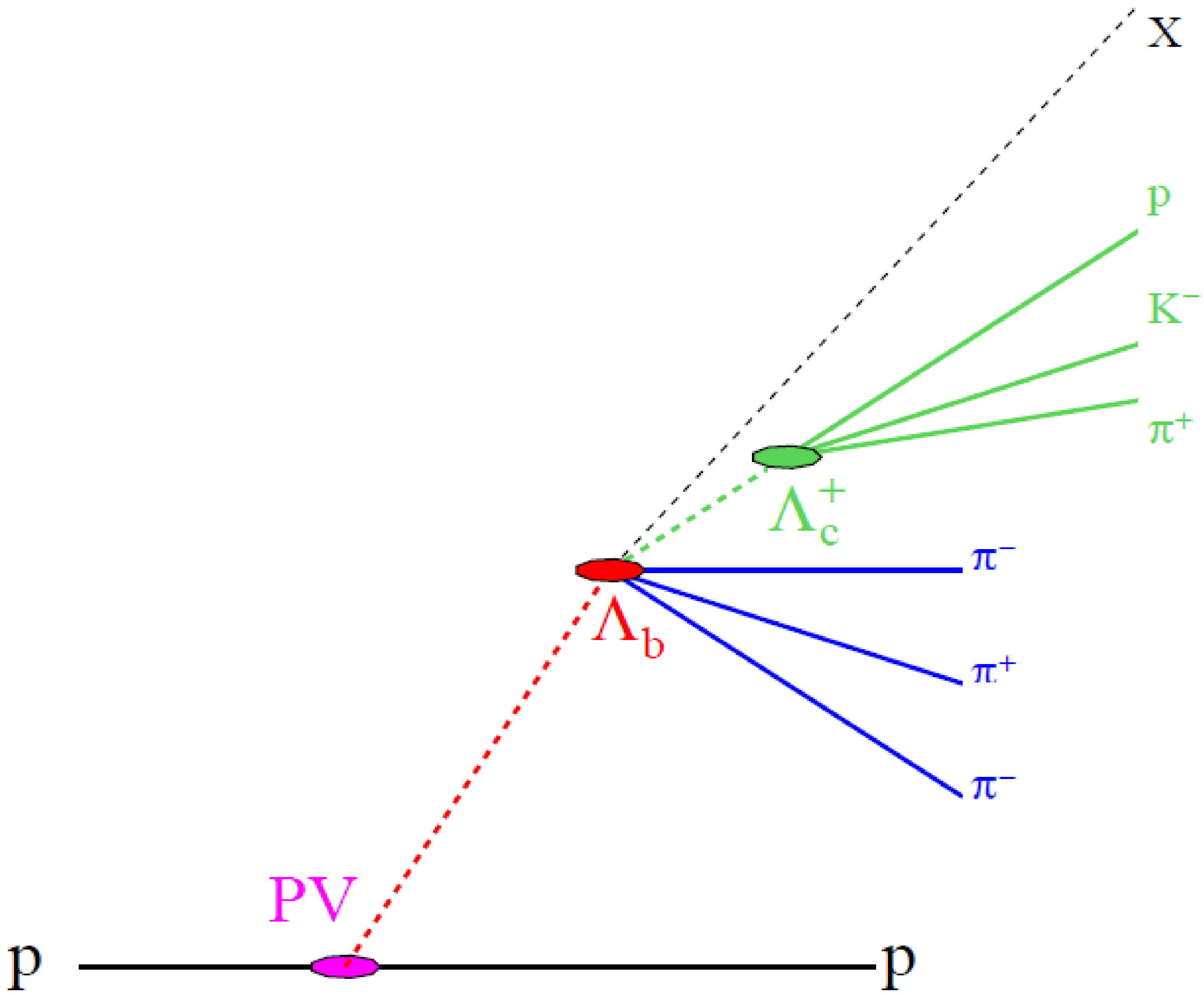
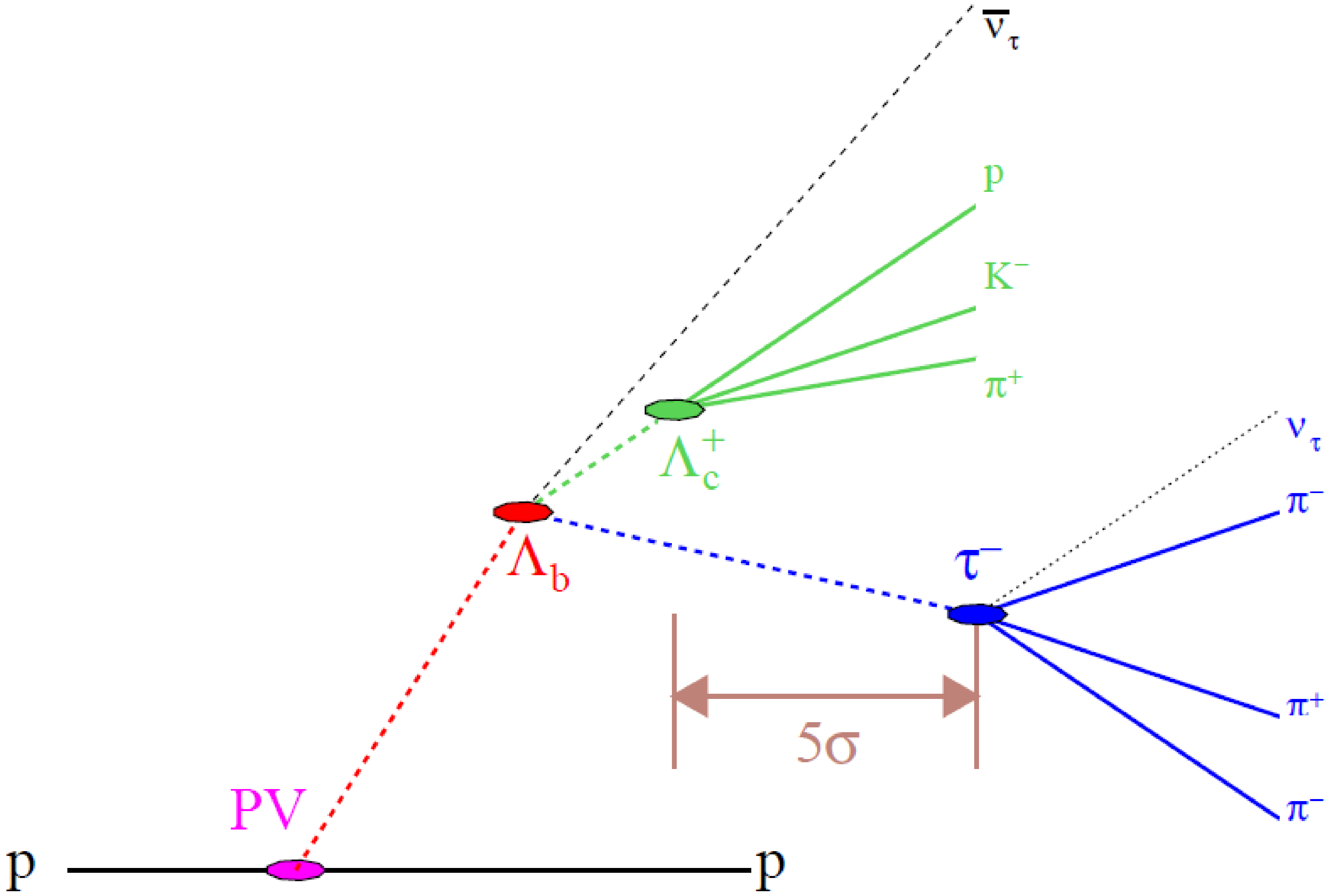
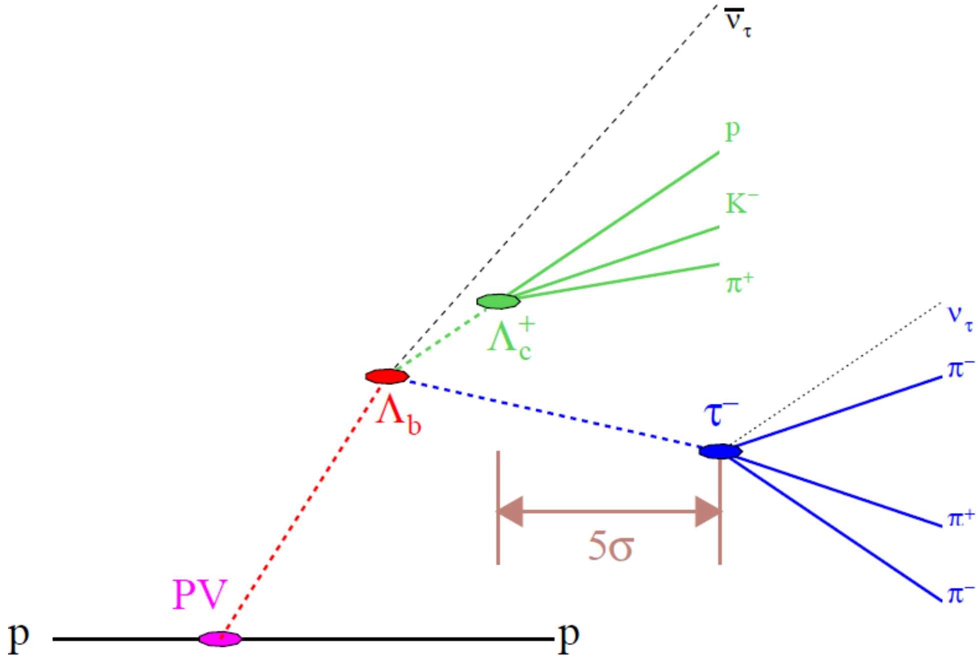

X
p
K⁻
π⁺
Λ_c^+
π⁻
Λ_b
π⁺
π⁻
PV
p
p

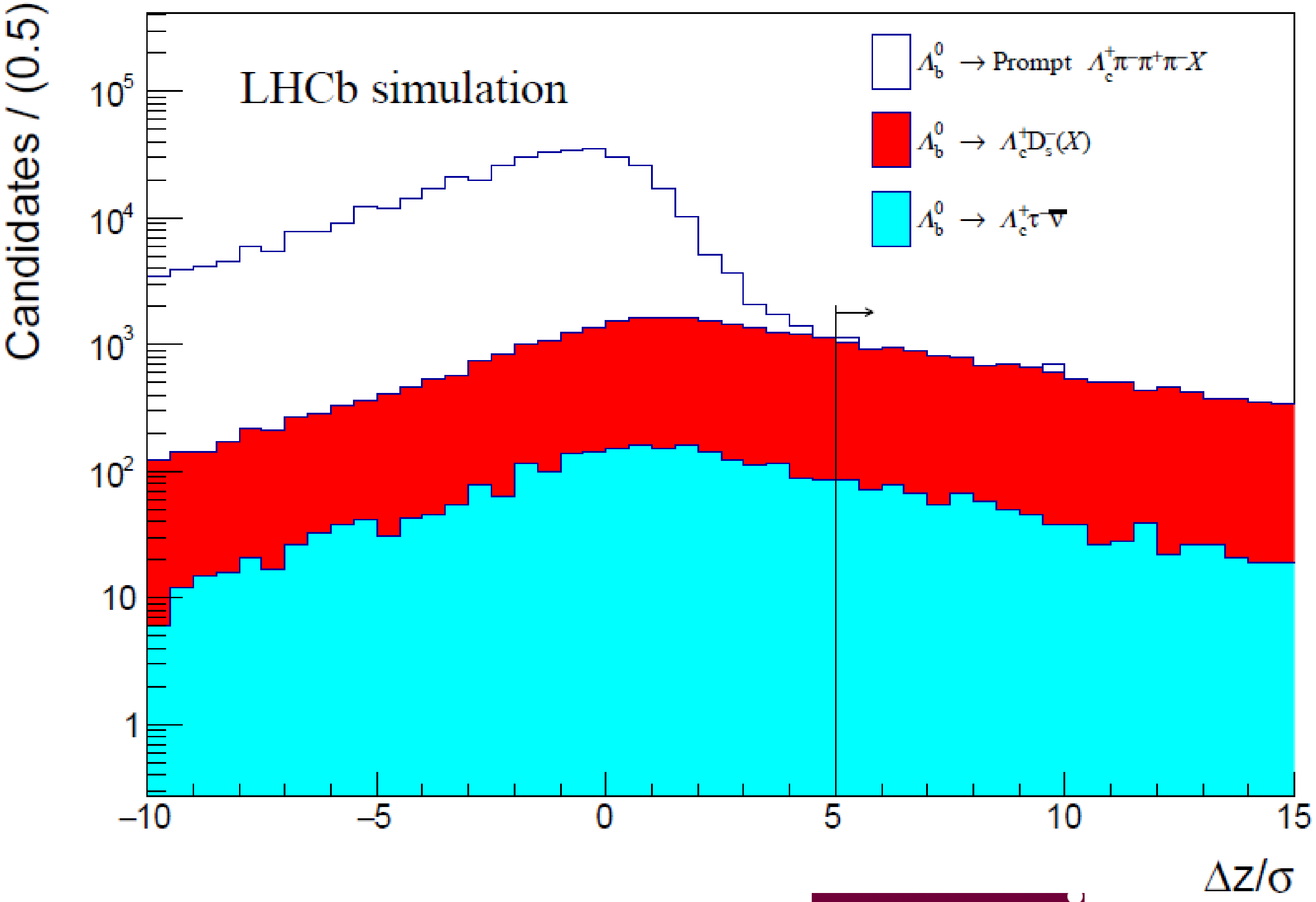


$\bar{\nu}_\tau$
p
K^-
π^+
ν_τ
Λ_c^+
π^-
Λ_b
τ^-
π^+
5σ
π^-
PV
p
p

« Prompt » background rejection



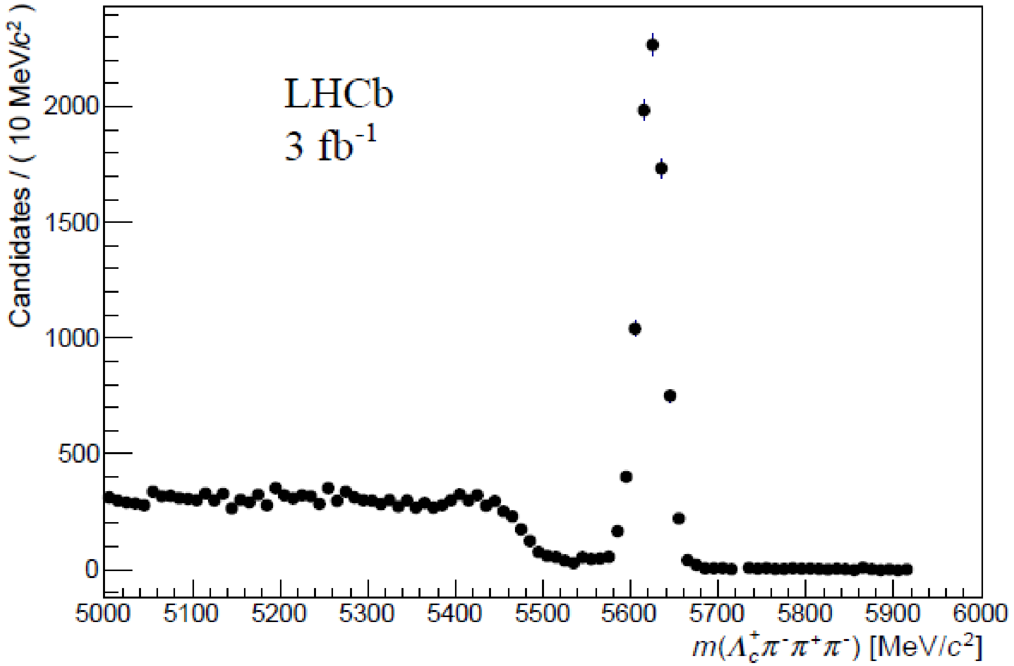
Prompt rejection ~5x10³ level after the 5σ inversion cut



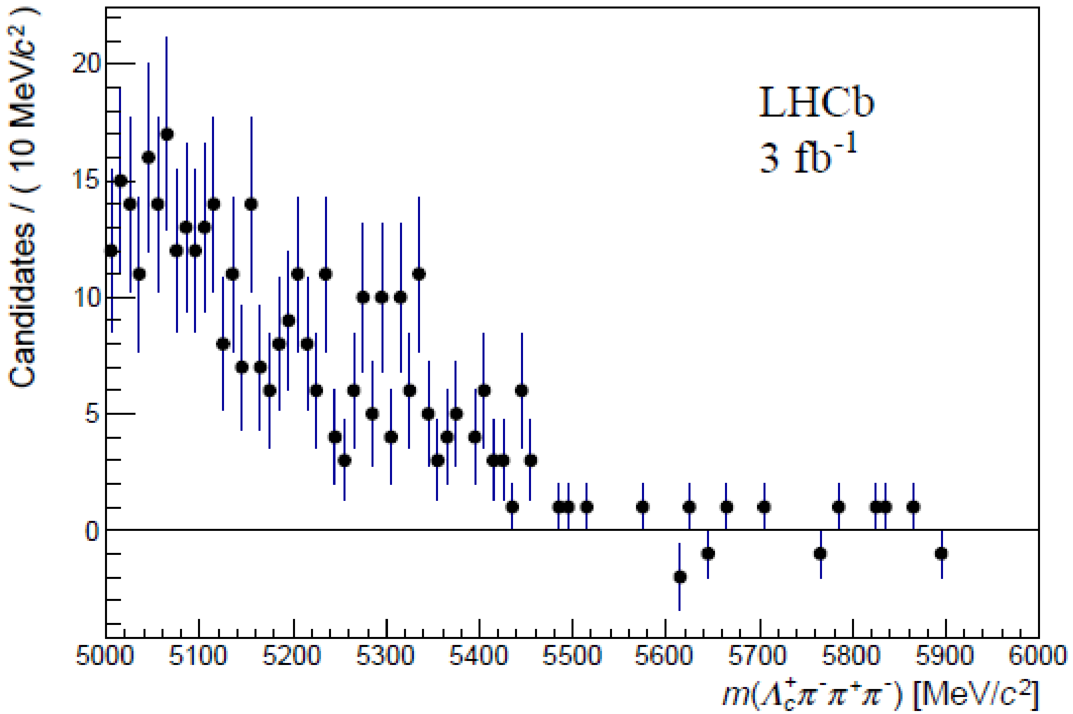
Control of the suppression factor with the normalisation channel : $\Lambda_b^0 \to \Lambda_c^+ \pi^- \pi^+ \pi^-$

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

Before inverted topology cut



After inversion



$\mathcal{R}(\Lambda_c^+)$ analysis workflow

- Tight Λ_c^+ PID selection. 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
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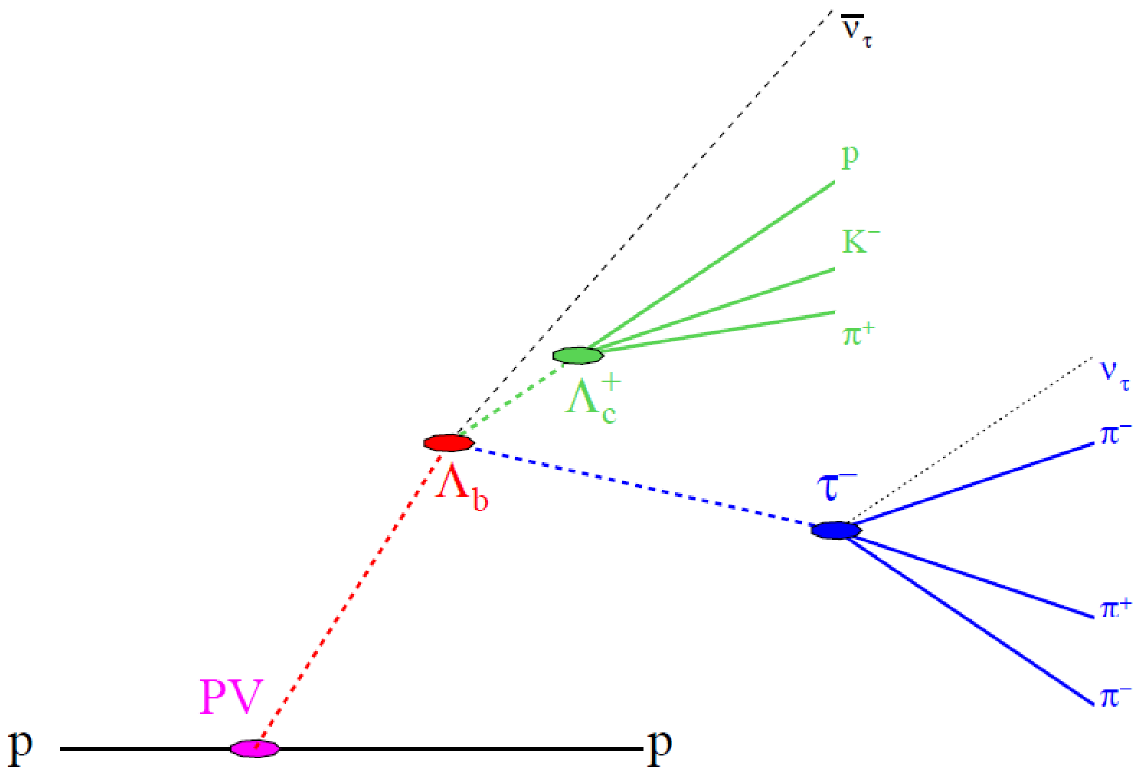
- Normalisation channel : $\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-$ (without $\Lambda_c^{*+}\pi^-$) [same final state and similar dynamics]

Reconstruction of the kinematics

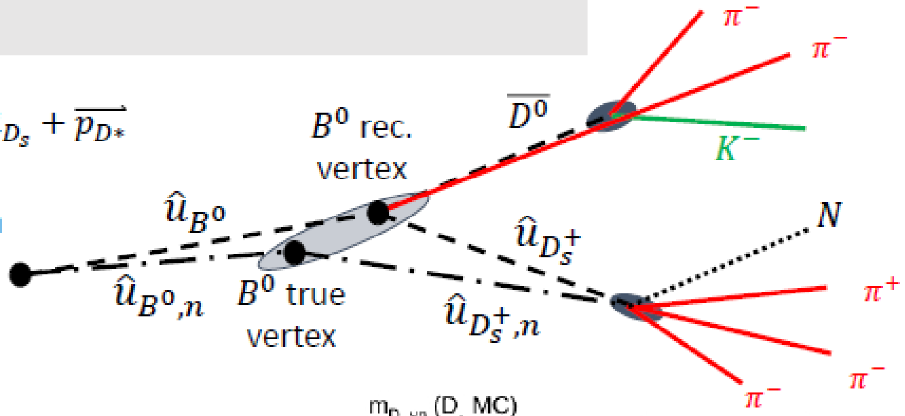


- Using the position of the three vertices, the direction of flight of the Λ_b^0 and of the τ particles can be reconstructed.
- The momenta of these 2 particles by solving two 2nd-degree equations
- τ pseudo decay time and q^2 can be measured with a 15% resolution

Background Partial reconstruction

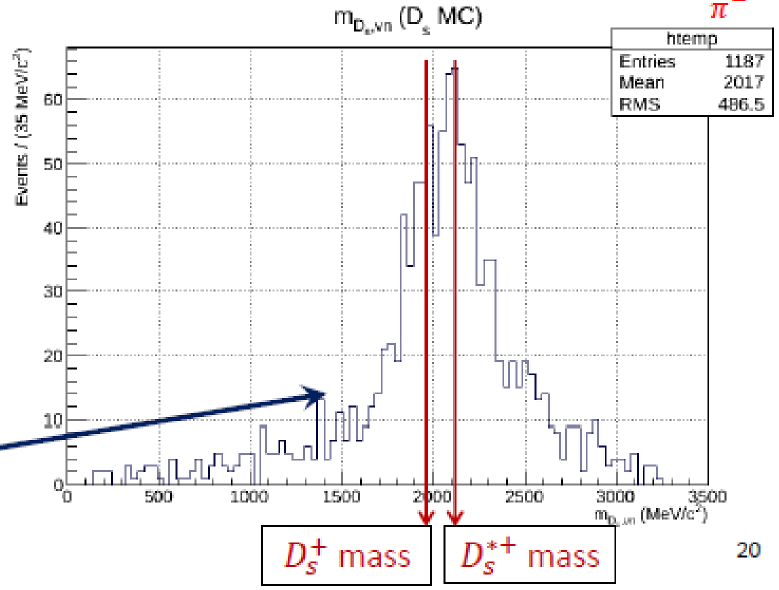
For $B^0 \to D^{*-}D_s^+$: $|\overrightarrow{p_B}|\hat{u}_B = |\overrightarrow{p_{D_s}}|\hat{u}_{D_s} + \overrightarrow{p_{D*}}$

After some vectorial algebra → get magnitude of B^0 and D_s^+ momenta



First approximation → $\hat{u}_{D_s}$ is the 3π direction

Apply a **correction** to B⁰ vertex due to the presence of neutral particles in D_s^+ decay → **parametrization** of this correction as function of 3π mass on $D^{*-}D_s^+$ MC → get B^0 and D_s^+ momenta at a **next-level of approximation**



Reconstruction of $\boldsymbol{D_s^+}$ **mass**, with nominal B^0 and D^{*-} masses values

20

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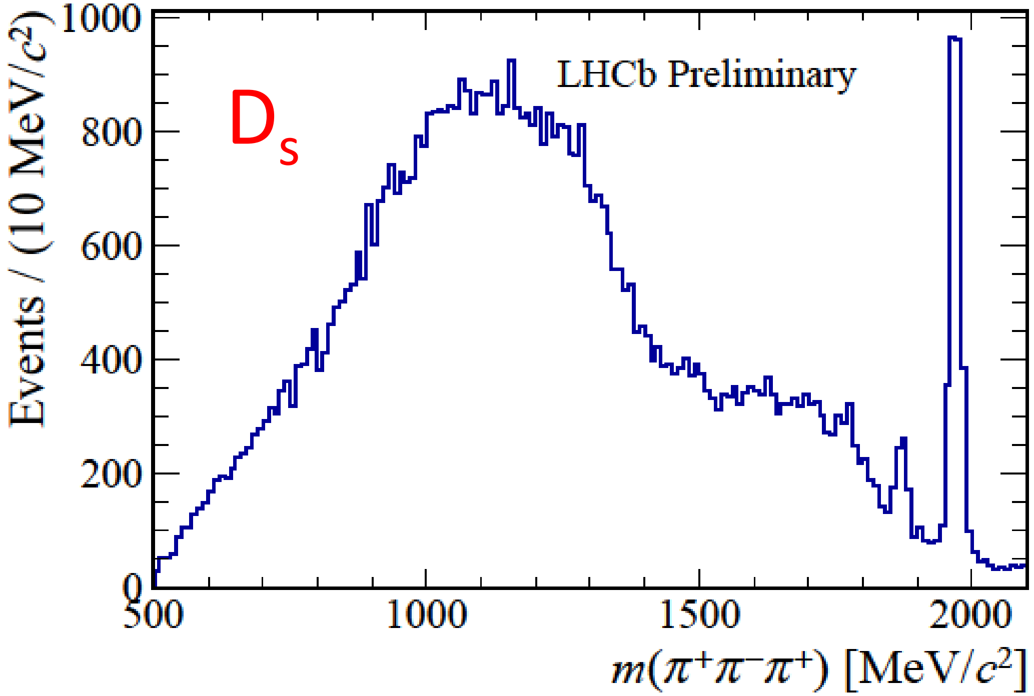
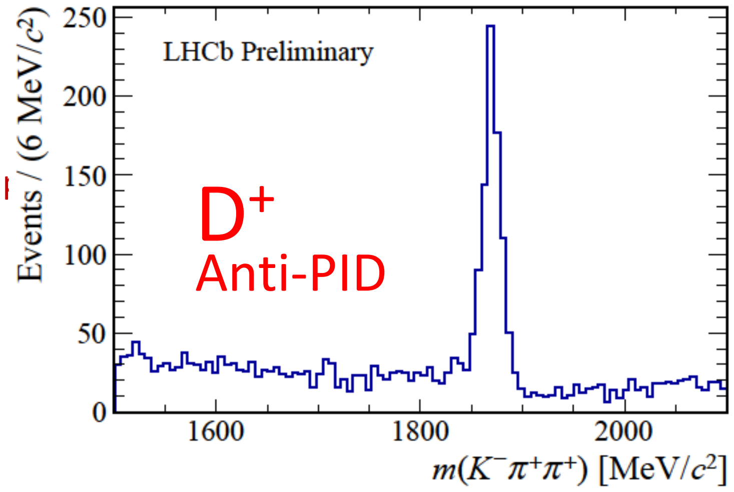
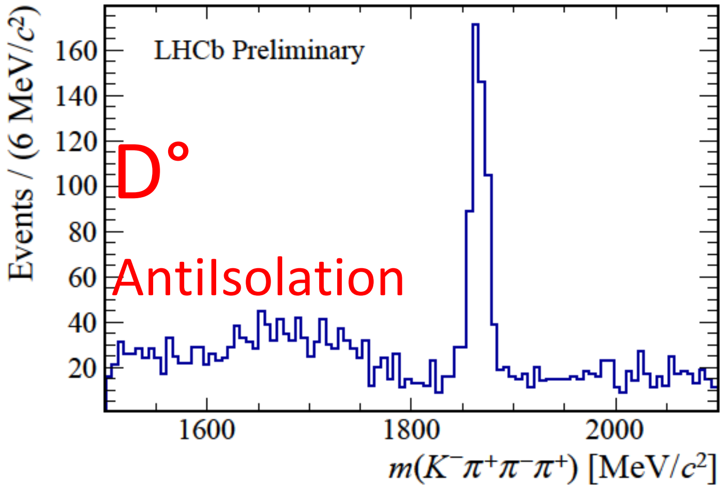
The control channels D_s, D°, and D^+





eak : Anti-Isolation cut

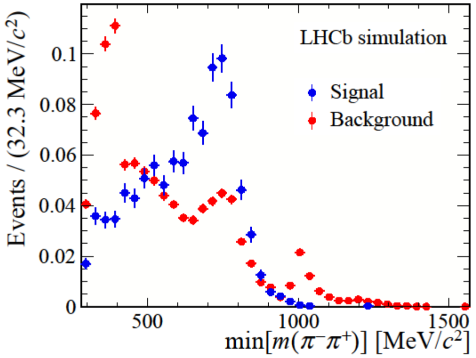


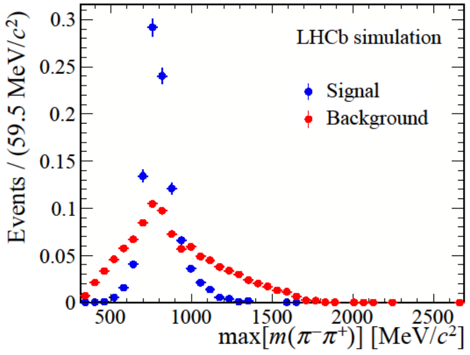
LHCb-PAPER-2017-017

Run 1, 3 fb^{-1}

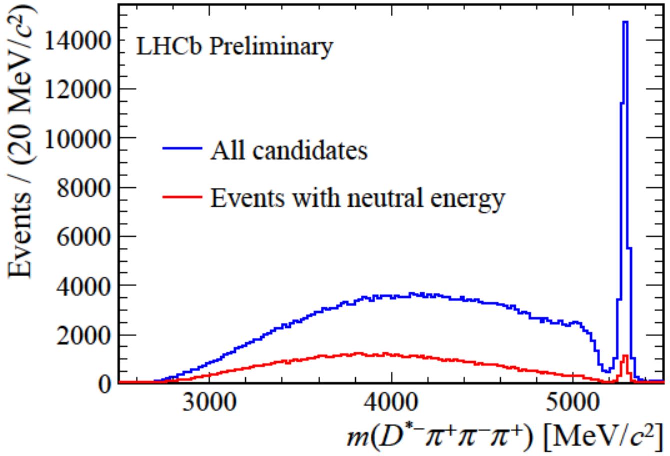
The anti-D_s BDT : 3π dynamics, partial reconstruction and isolation

Min(mass($\pi^+\pi^-$)) Max(mass($\pi^+\pi^-$))

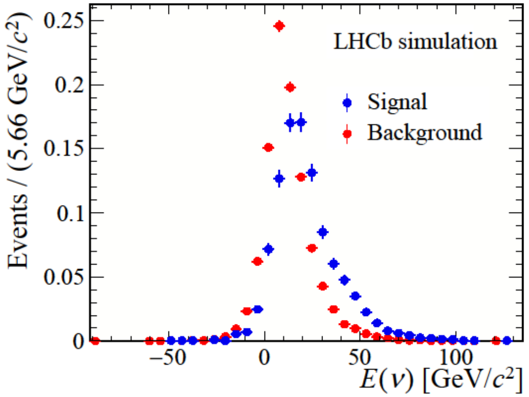


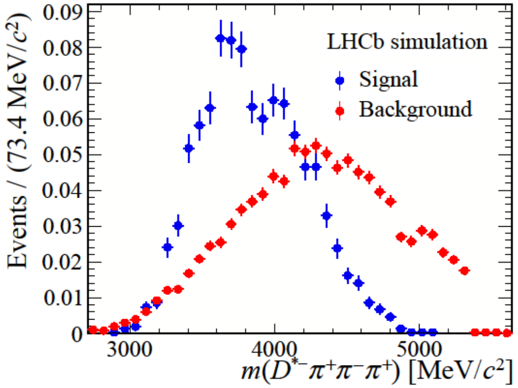


Neutral Isolation



$E(\nu)$ mass($D^{*+}\pi^-\pi^+\pi^-$)





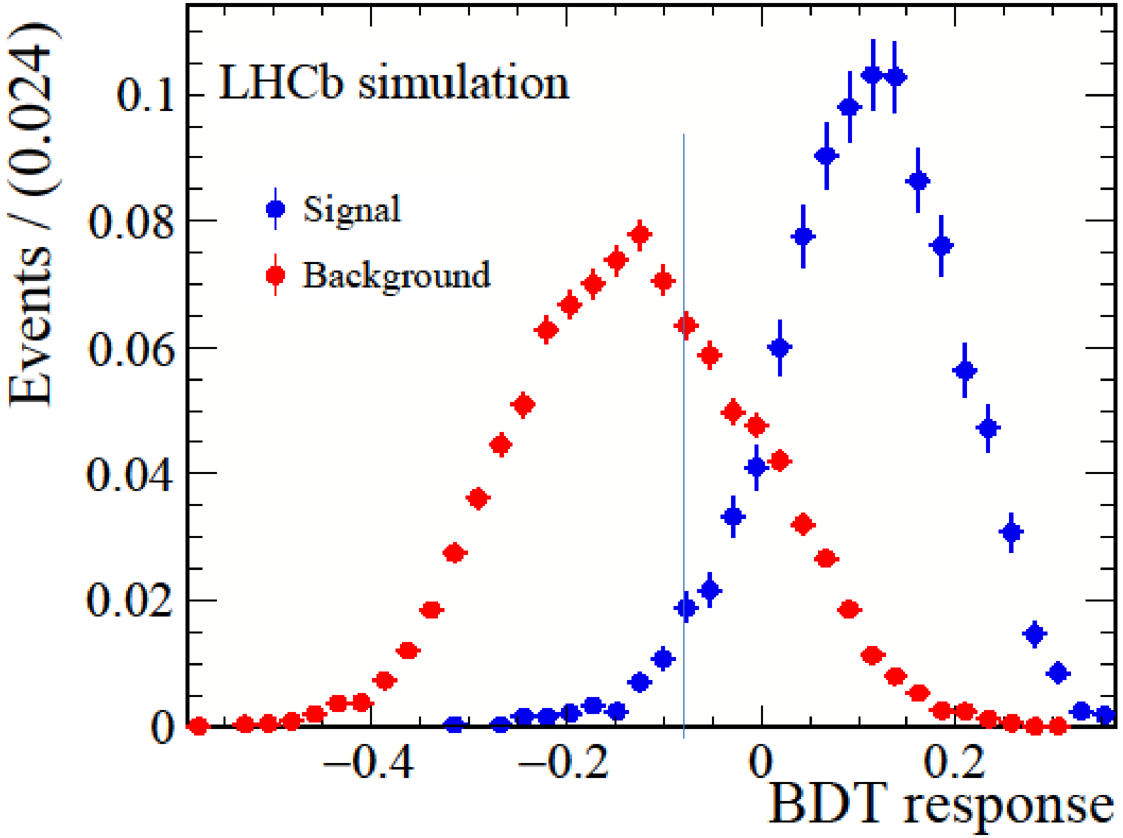
Blue : τ decays

Red : D_s background

LHCb simulation

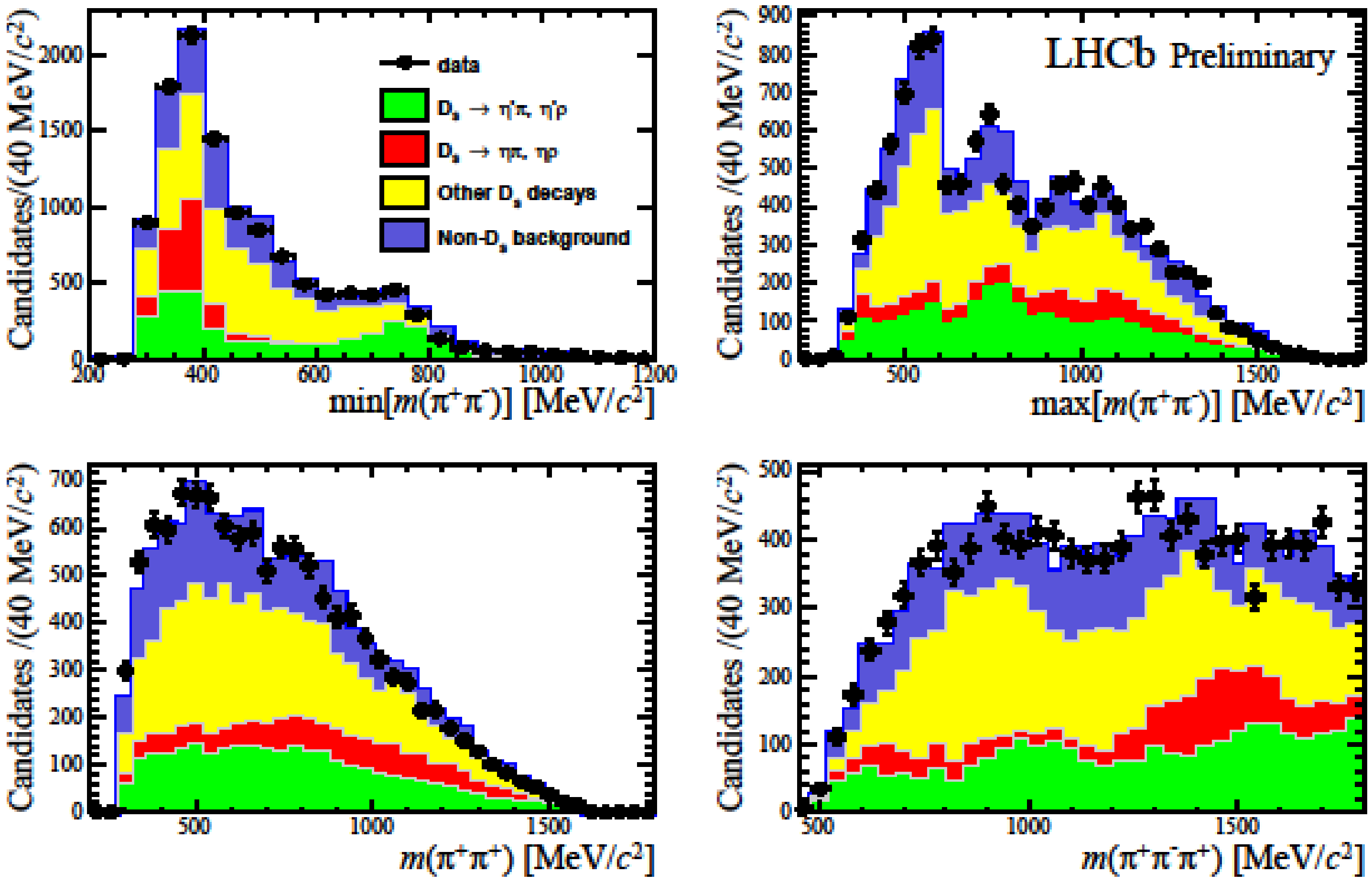
BDT results

- Good separation obtained
- Allows to select an high purity sample at high efficiency
- Charged Isolation and PID cuts are also required to select candidates



LHCb-PAPER-2017-017, in preparation

The D_s decay model fit at low BDT



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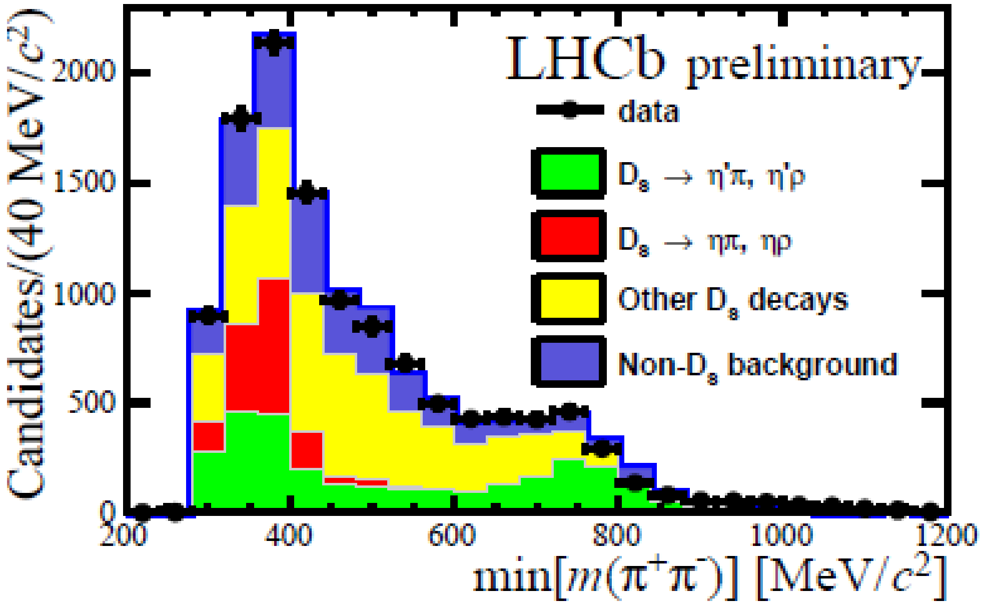
The importance of the « D_s-o-meter »

- The minimum $\pi^+\pi^-$ mass contains critical information about the rate of η and η' decays
- At low mass, only η and η' (red,green) contributions are peaking

$\eta \rightarrow \pi^+\pi^- \pi^\circ$ and $\eta' \rightarrow \eta \pi^+\pi^-$

- At the ρ mass where the signal lives, only η' contributes ($\eta' \rightarrow \rho\gamma$)
- Using the low BDT region, one constraints the D_s decay model to be used at high BDT



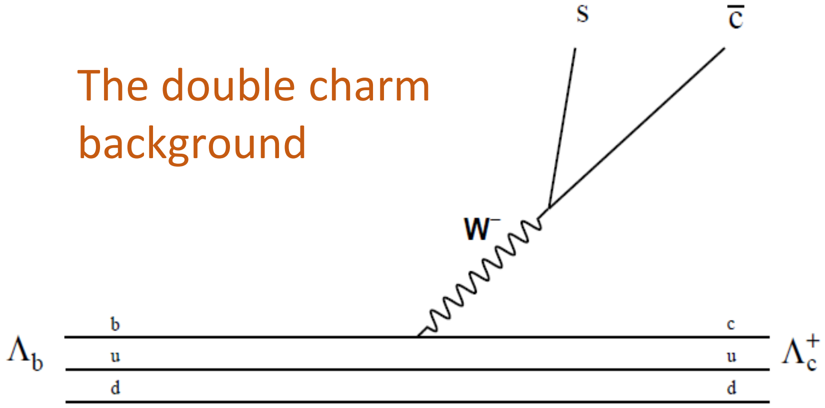
Distribution of the 3π mass after final selection

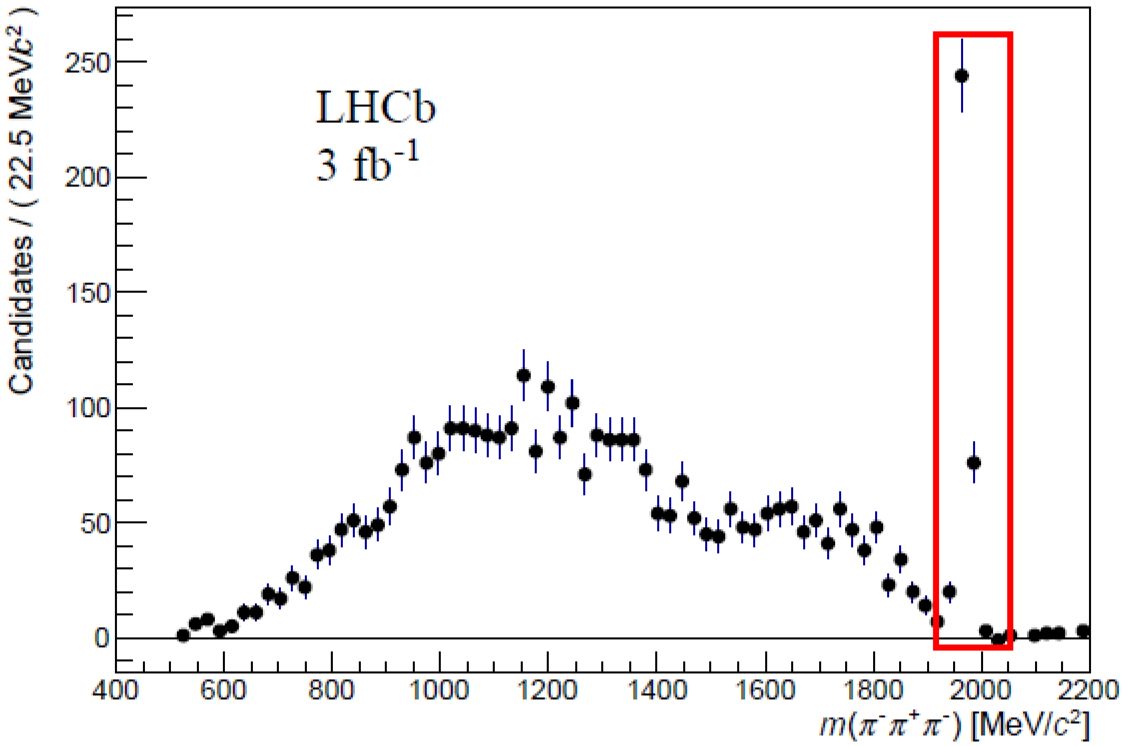
LHCb-PAPER-2021-044
arxiv:2201:03497

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

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

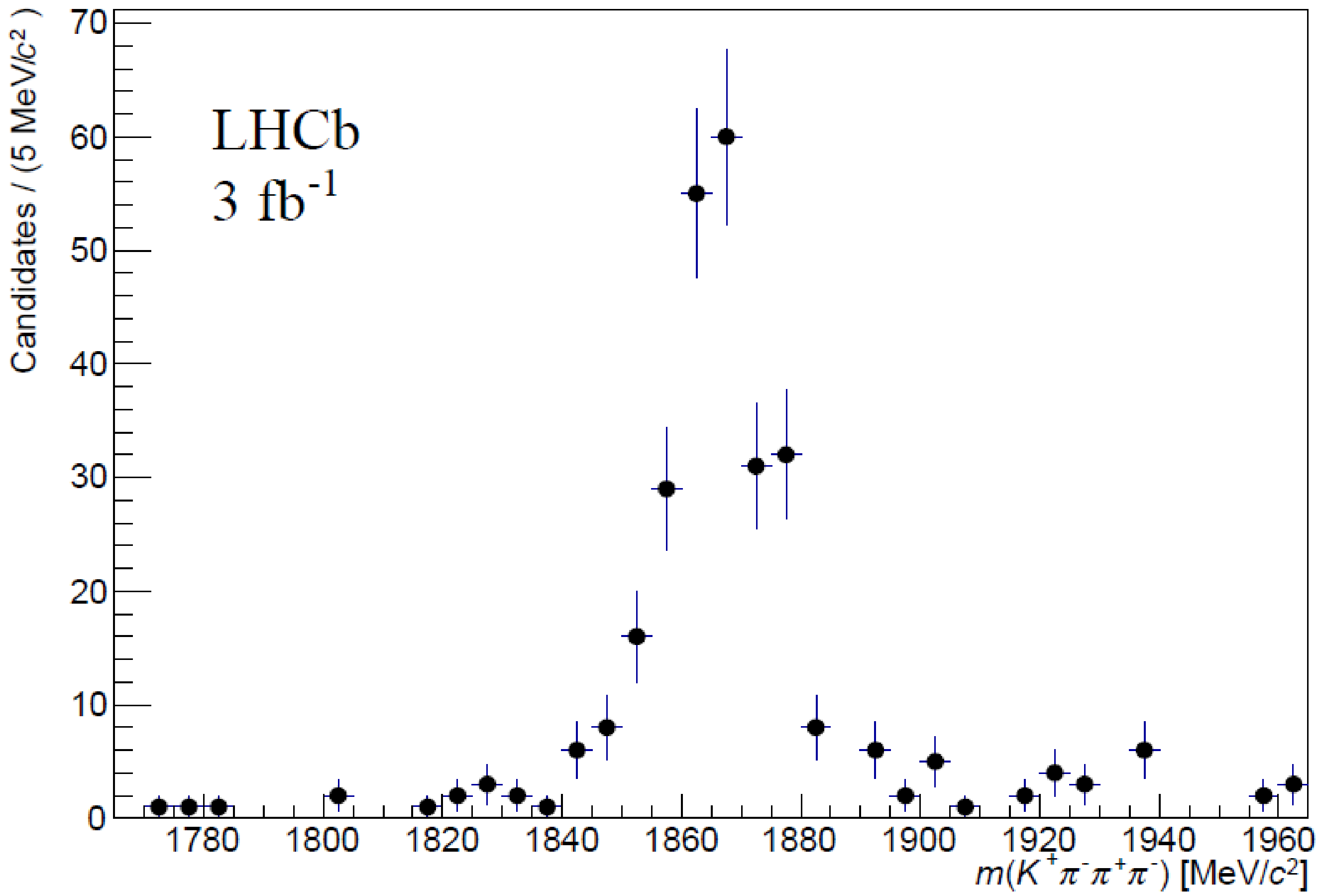
The double charm background





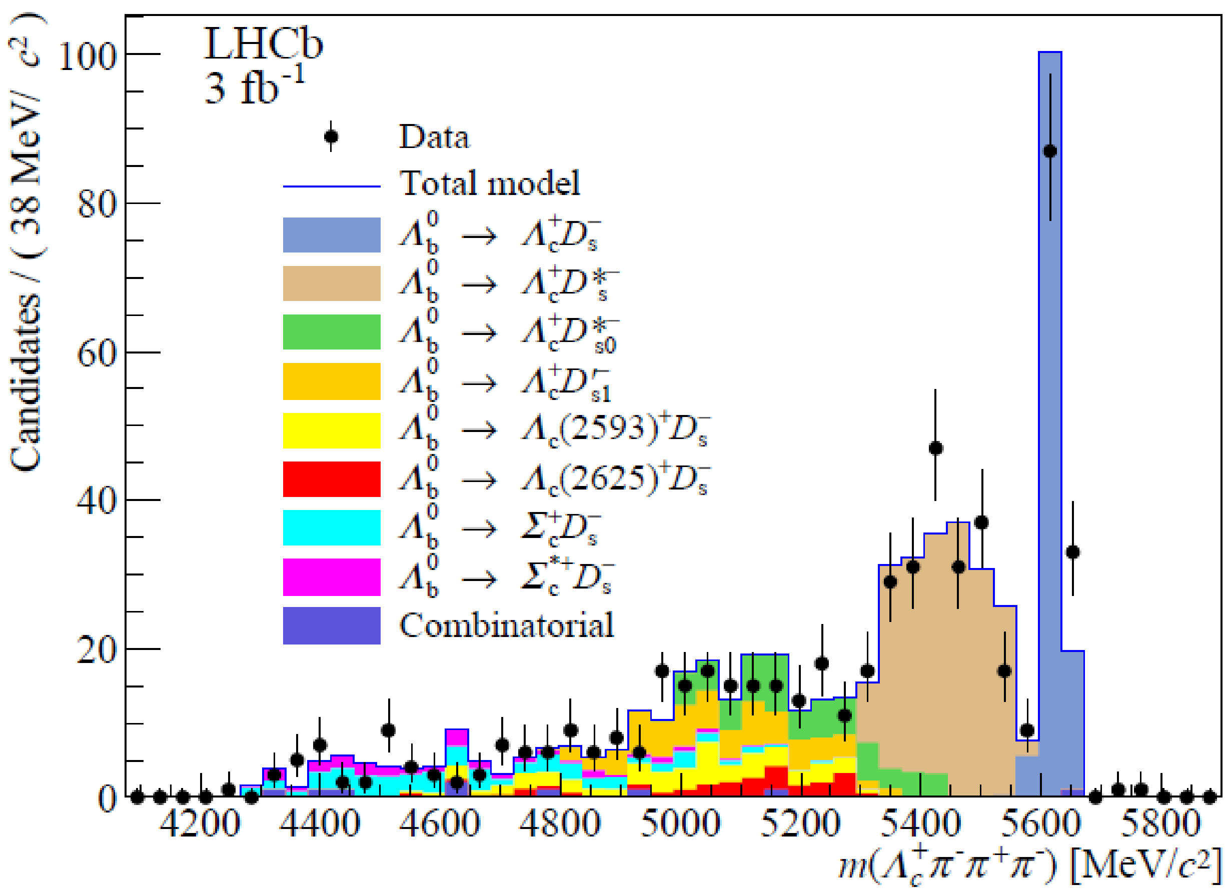
No candidates above the D_s^- mass : completely dominated by double charm background

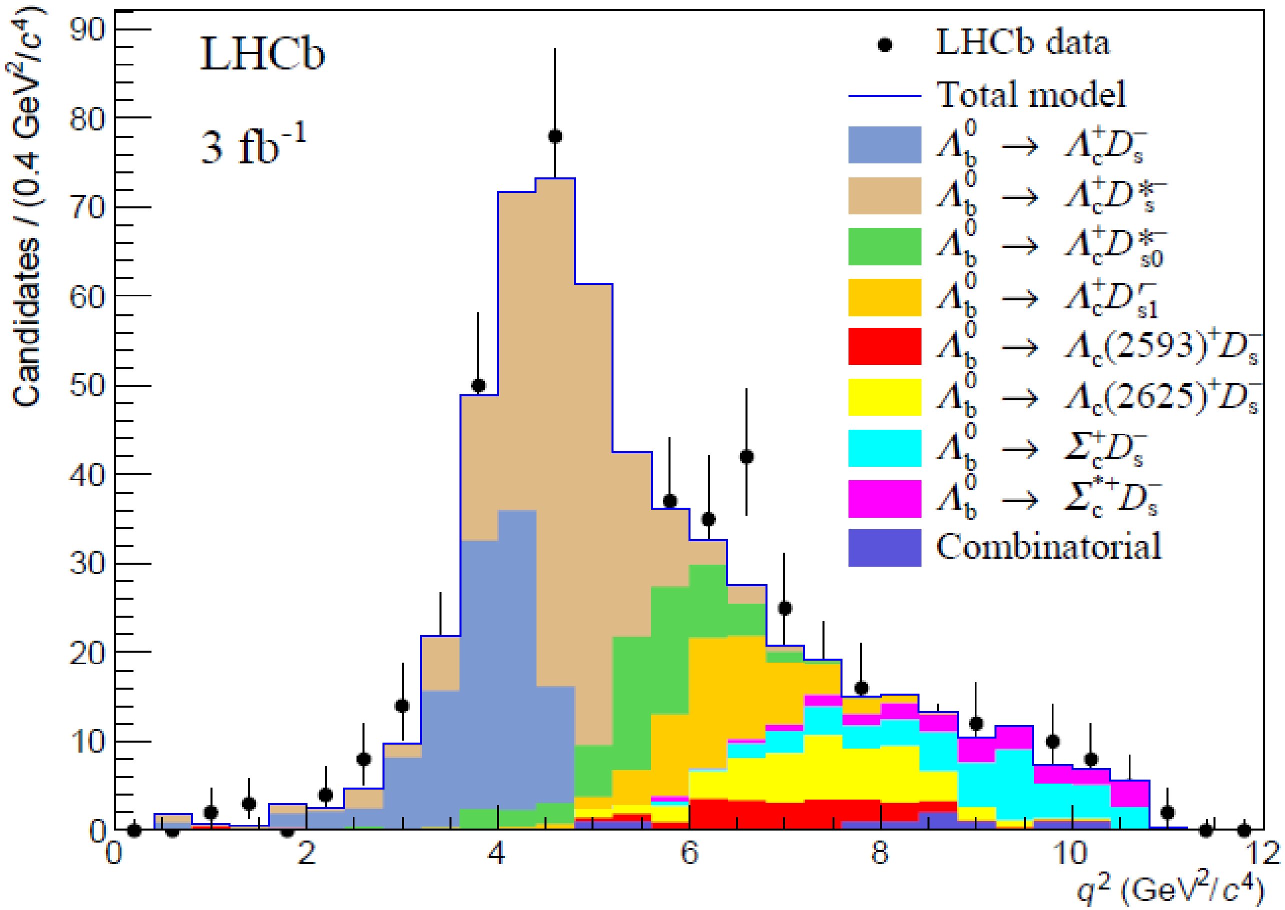
Distribution of the $K^+\pi^-\pi^+\pi^-$ mass for events with one extra kaon track at the 3π vertex



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

$\mathcal{R}(\Lambda_c^+)$ analysis workflow

- Tight Λ_c^+ PID selection. 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 : $\Lambda_b^0 \rightarrow \Lambda_c^+\pi^-\pi^+\pi^-$ (without $\Lambda_c^{*+}\pi^-$) [same final state and similar dynamics]

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

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	

Fit projections : τ decay time and BDT

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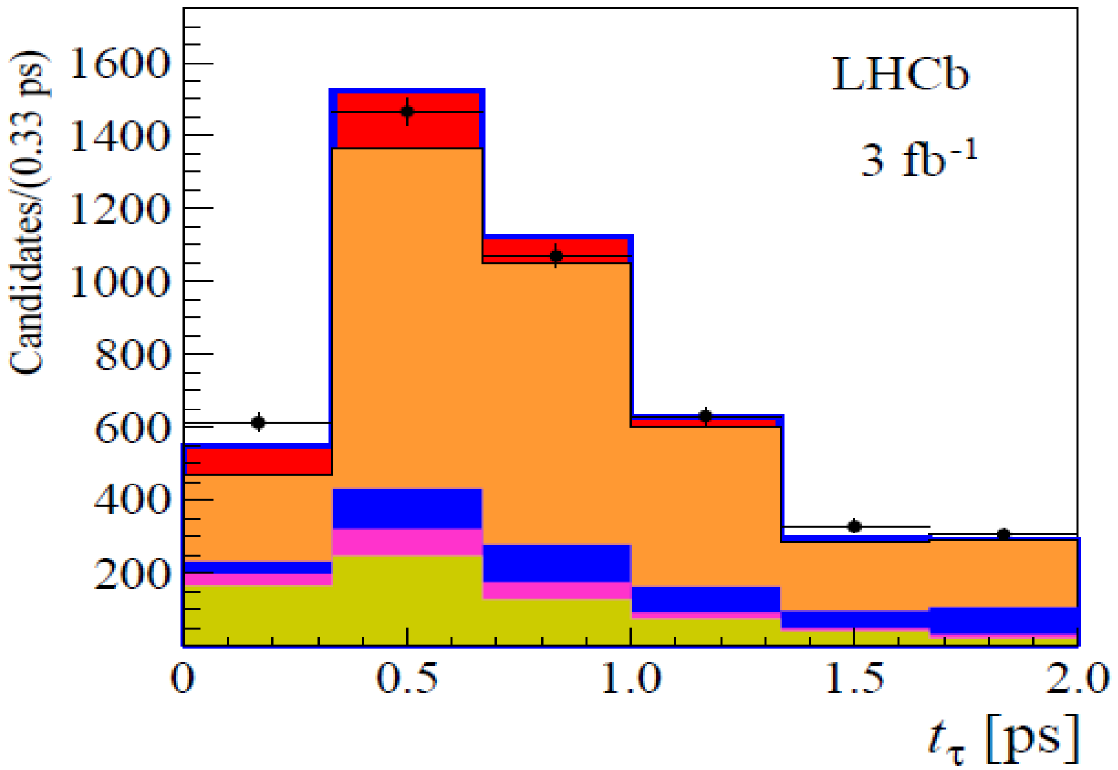

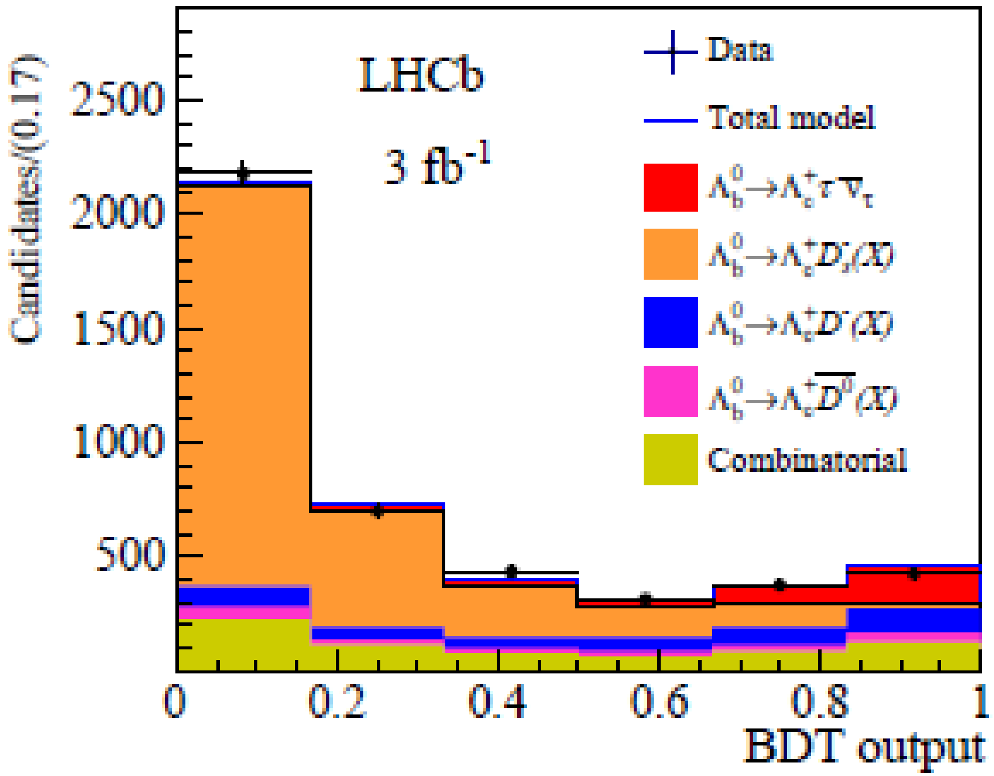

Fit projection : q^2

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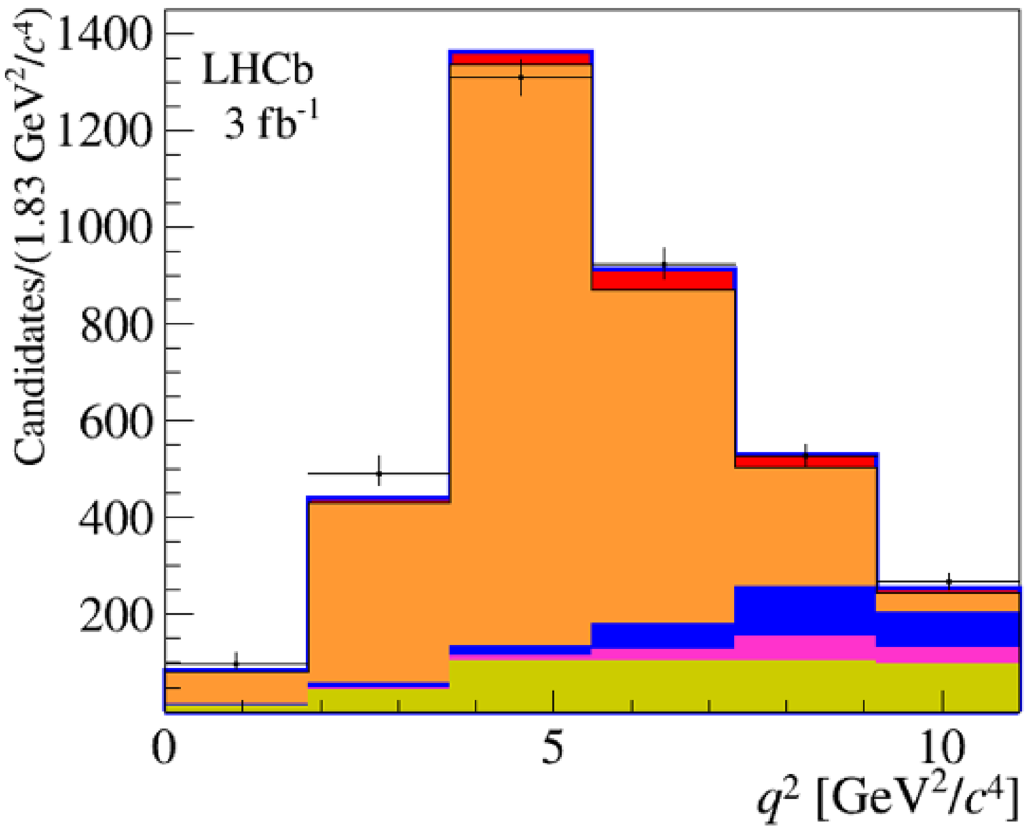
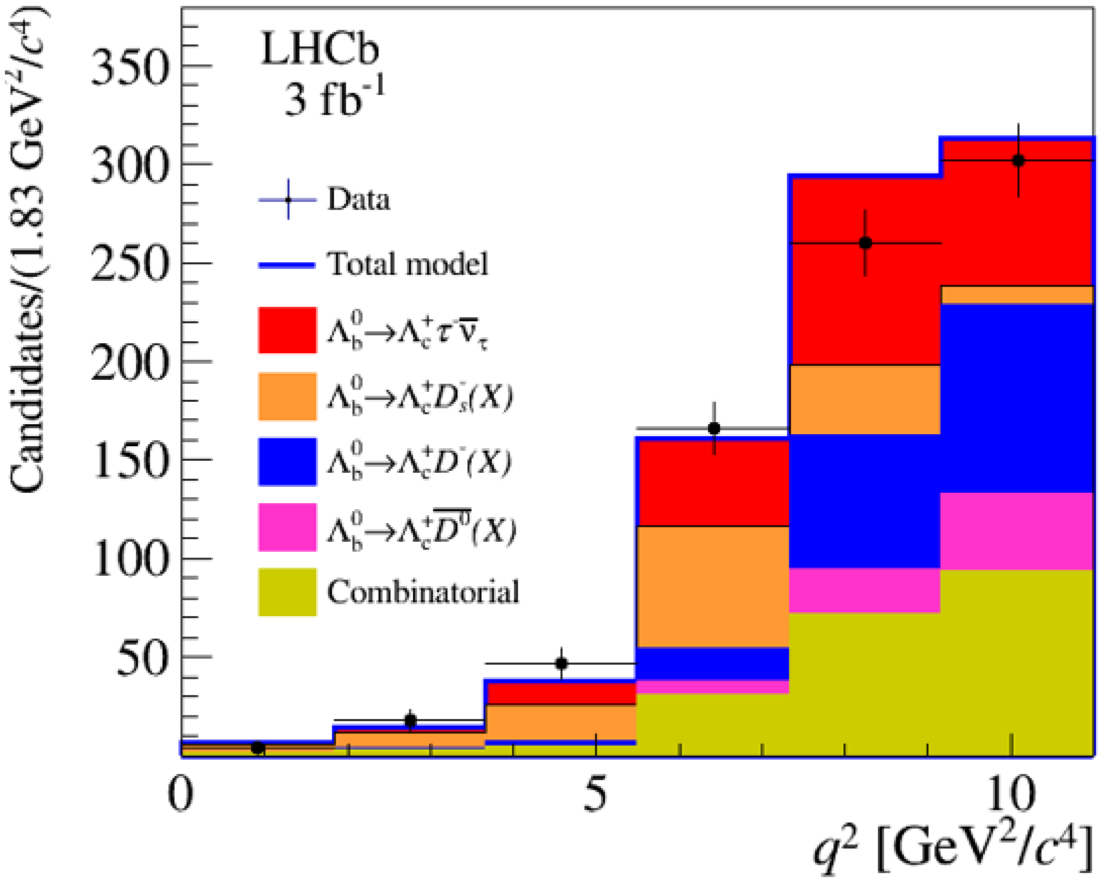
Low BDT



High BDT(>0.66)



Observation of the decay $\Lambda_b^0 \to \Lambda_c^+ \tau^- \overline{\nu}_\tau$

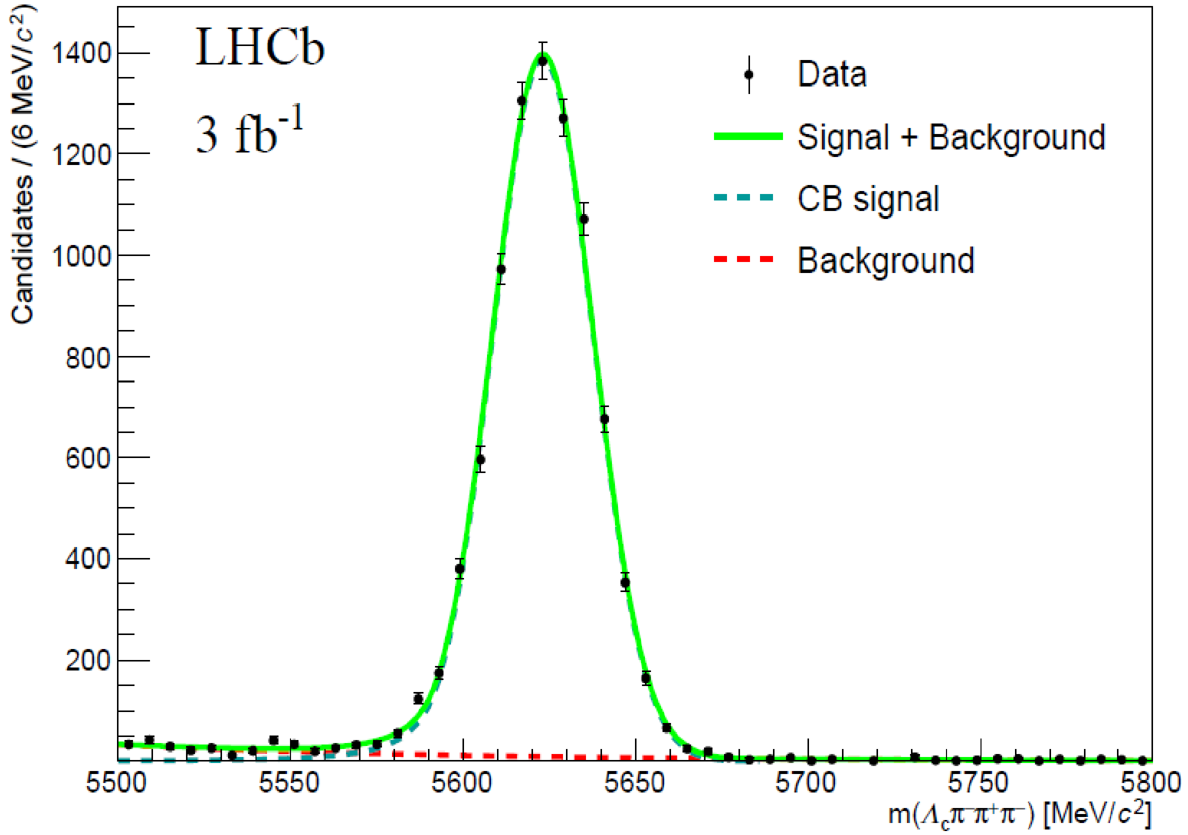
- Increase of fit χ^2 with signal forced to 0 : 7.3 σ statistical only
- Increase of fit χ^2 with signal forced to 0 after inclusion of systematic uncertainty (dominated by template shapes): 6.1 σ

- We can claim observation of the decay $\Lambda_b^0 \to \Lambda_c^+ \tau^- \overline{\nu}_\tau$!

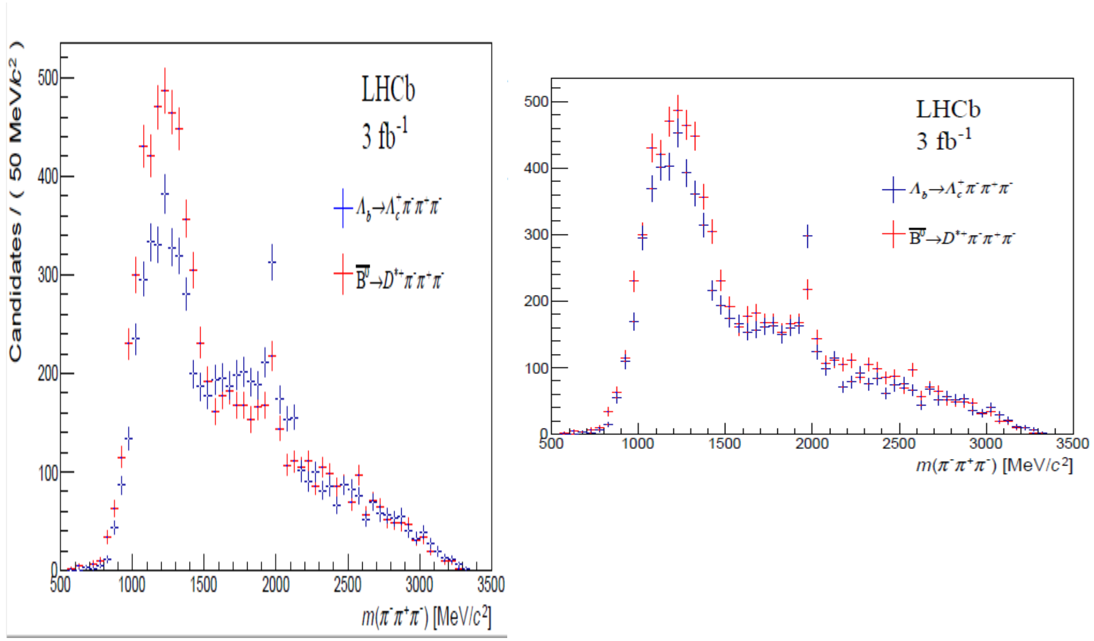
$\mathcal{R}(\Lambda_c^+)$ analysis workflow

- Tight Λ_c^+ PID selection. 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]

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



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



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

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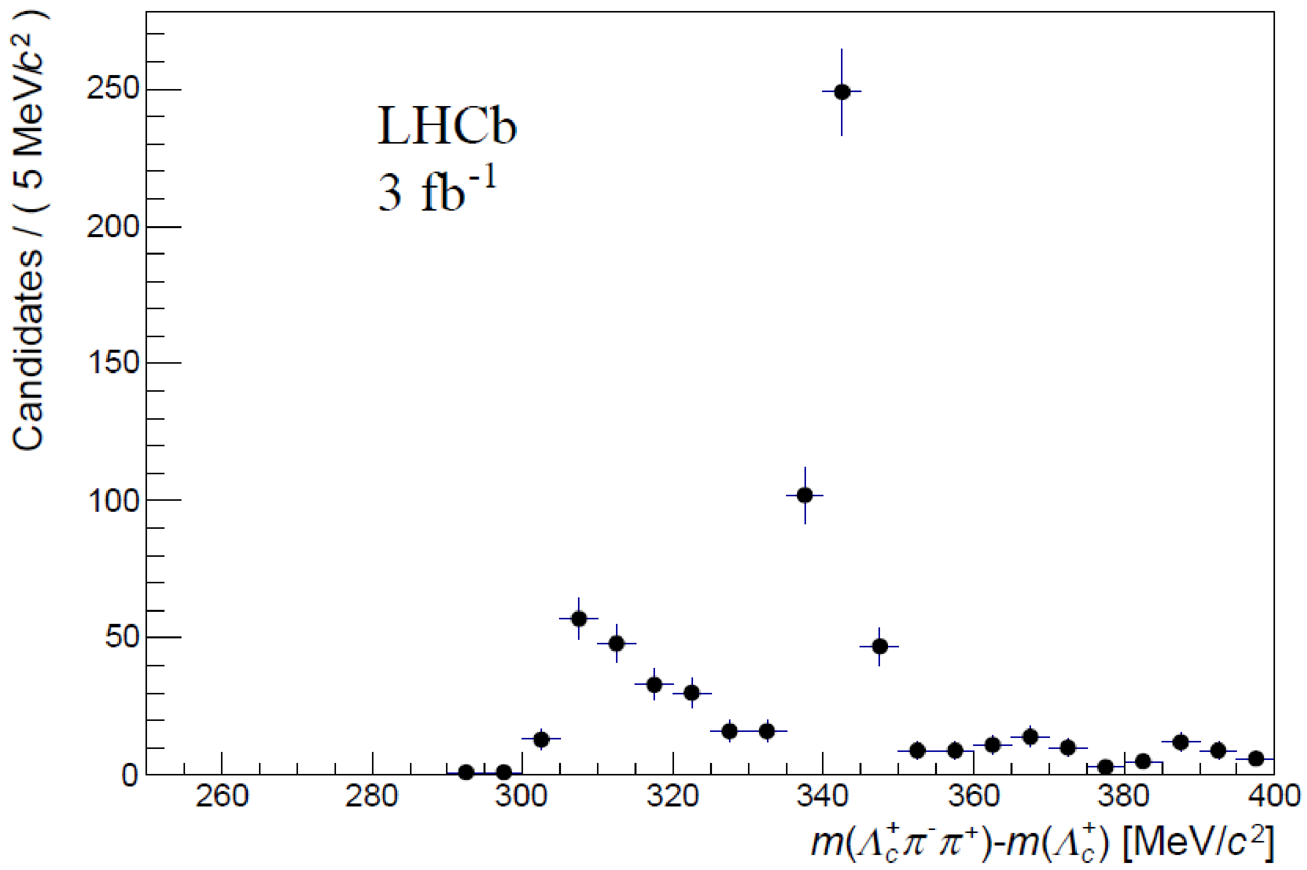
arxiv:2201:03497

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



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

$\Gamma(\Lambda_c^+\pi^+\pi^-\pi^-)/\Gamma_{\text{total}}$ **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 $[\Gamma(\Lambda_b^0 \to \Lambda_c^+\pi^+\pi^-\pi^-)/\Gamma_{\text{total}}]$ / $[B(\Lambda_b^0 \to \Lambda_c^+\pi^-)] = 3.04 \pm 0.33^{+0.70}_{-0.55}$ 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(Λ_b^0 ➔ Λ_c^+ π^-) and the 13.5% ratio coming from the ratio.)

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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LHCb-PAPER-2021-044
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)

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

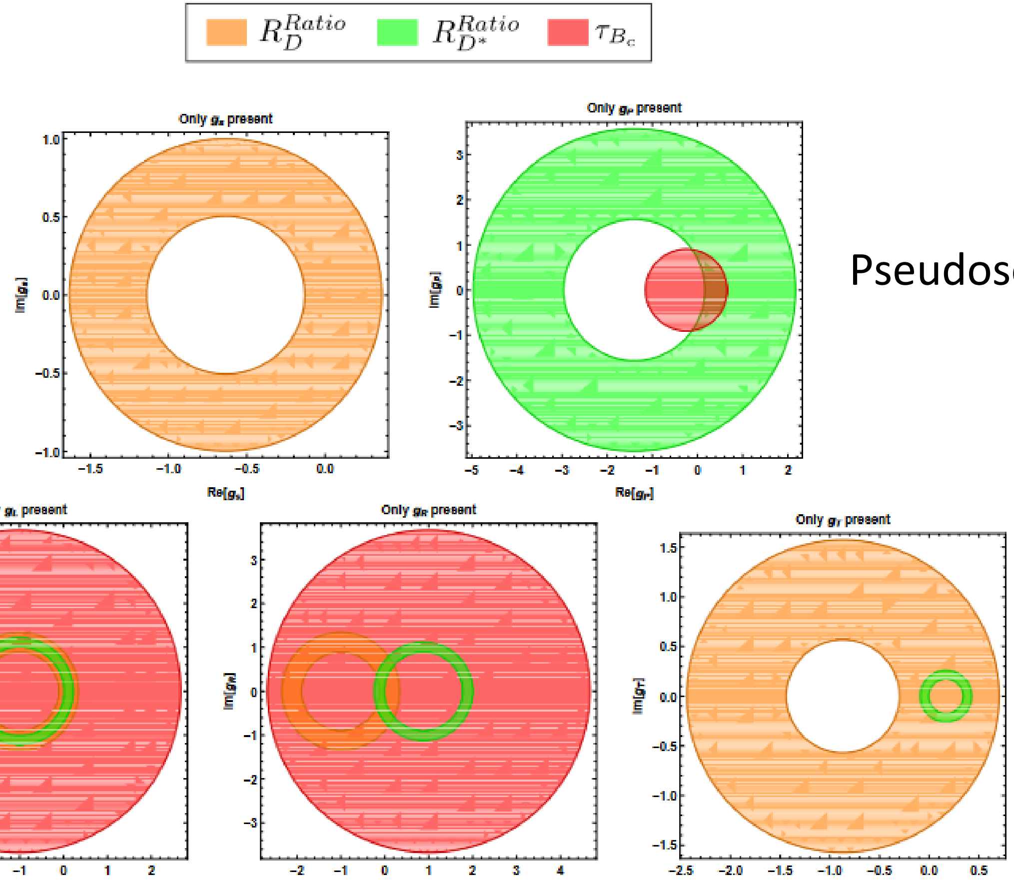
Coupling	$R(\Lambda_c)_{max}$	$R^{Ratio}_{\Lambda_c,max}$	coupling value	$R(\Lambda_c)_{min}$	$R^{Ratio}_{\Lambda_c,min}$	coupling value
g_S only	0.405	1.217	0.363	0.314	0.942	-1.14
g_P only	0.354	1.062	0.658	0.337	1.014	0.168
g_L only	0.495	1.486	$0.094 + 0.538i$	0.340	1.022	$-0.070 + 0.395i$
g_R only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

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

Constraints from $\mathcal{R}(D^*)$-$\mathcal{R}(D)$ for effective model with one mediator

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



Scalar

Pseudoscalar

Vector

Tensor

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

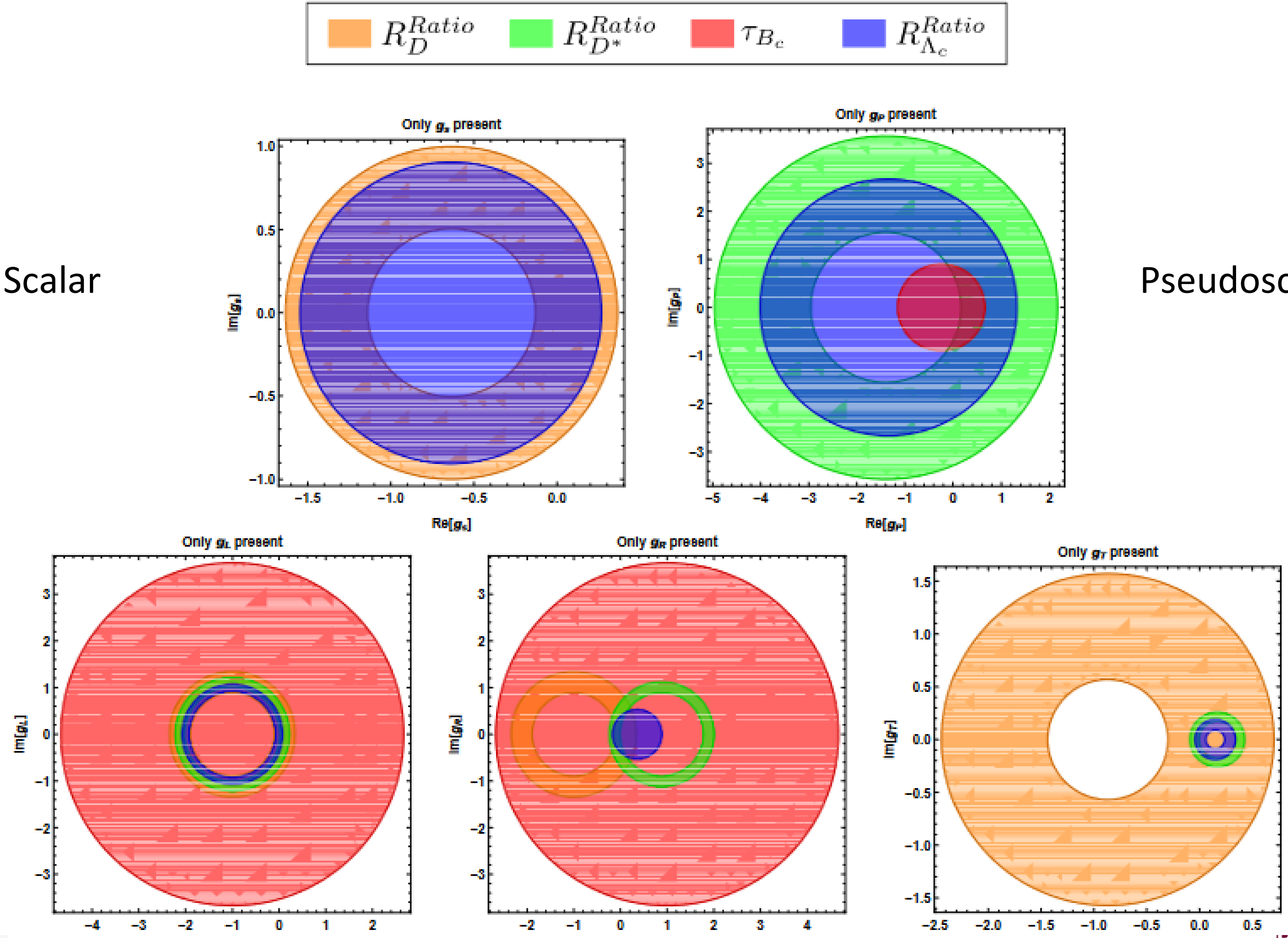
Constraints with a SM-like $\mathcal{R}(\Lambda_c^+)$

Scalar

Pseudoscalar

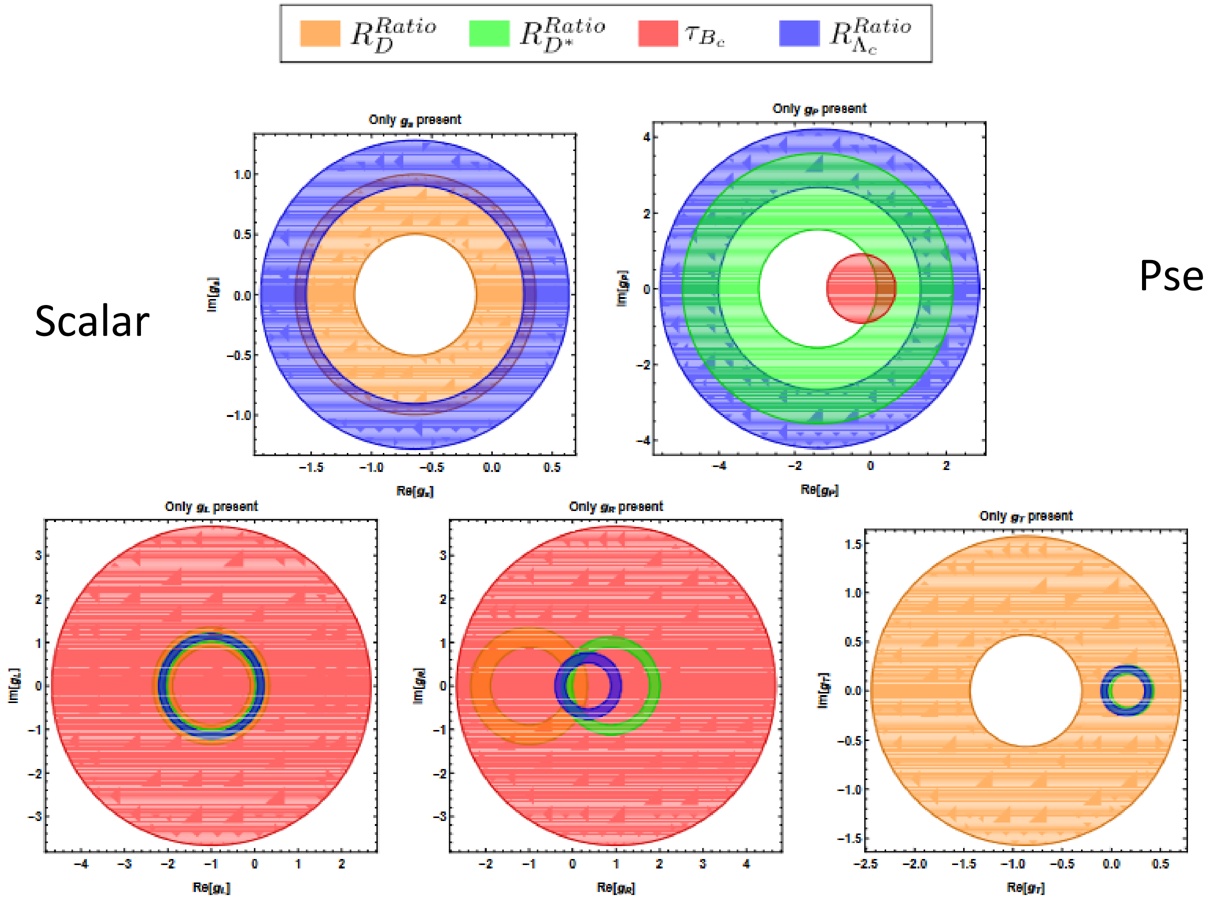
Vector

Tensor



(Constraints with a large $\mathcal{R}(\Lambda_c^+)$)

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



Future of some systematic uncertainties: D** feed-down

- B°→ D** $\tau\nu$ and B⁺→D**°$\tau\nu$ constitute potential feeddown to the signal
- New R(D**) SM predictions rather low (denomitaor is BR(B->D**$\mu\nu$)

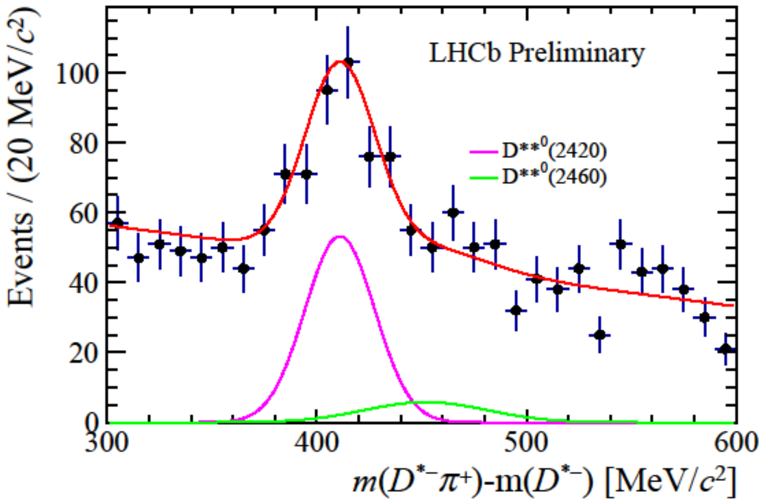
$$\mathcal{R}(D_0^*) = 0.08(3), \qquad \mathcal{R}(D_1') = 0.05(2),$$
$$\mathcal{R}(D_1) = 0.10(2), \qquad \mathcal{R}(D_2^*) = 0.07(1)\,.$$

Florian U. Bernlochner, Manuel Franco Sevilla, Dean J. Robinson, and Guy Wormser
Rev. Mod. Phys. 94, 015003

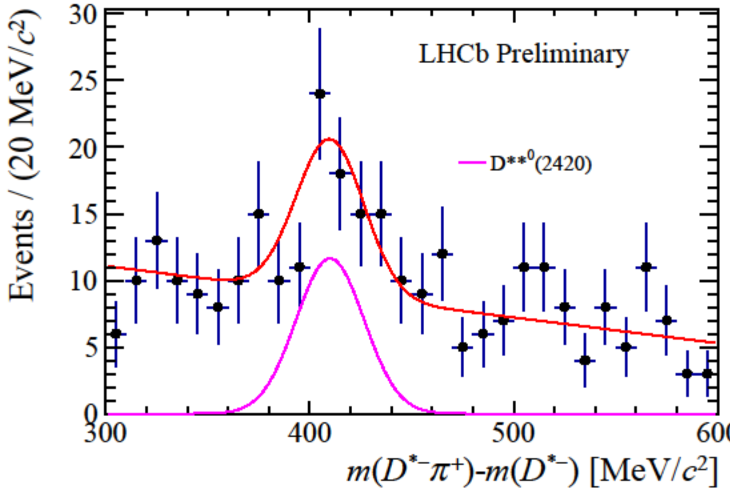
- All experiments are taking more conservative assumptions regarding the D** rate. This could enhance the discrepancy by 0.5 σ

- Experimental measurement of D**°(2420) the way :

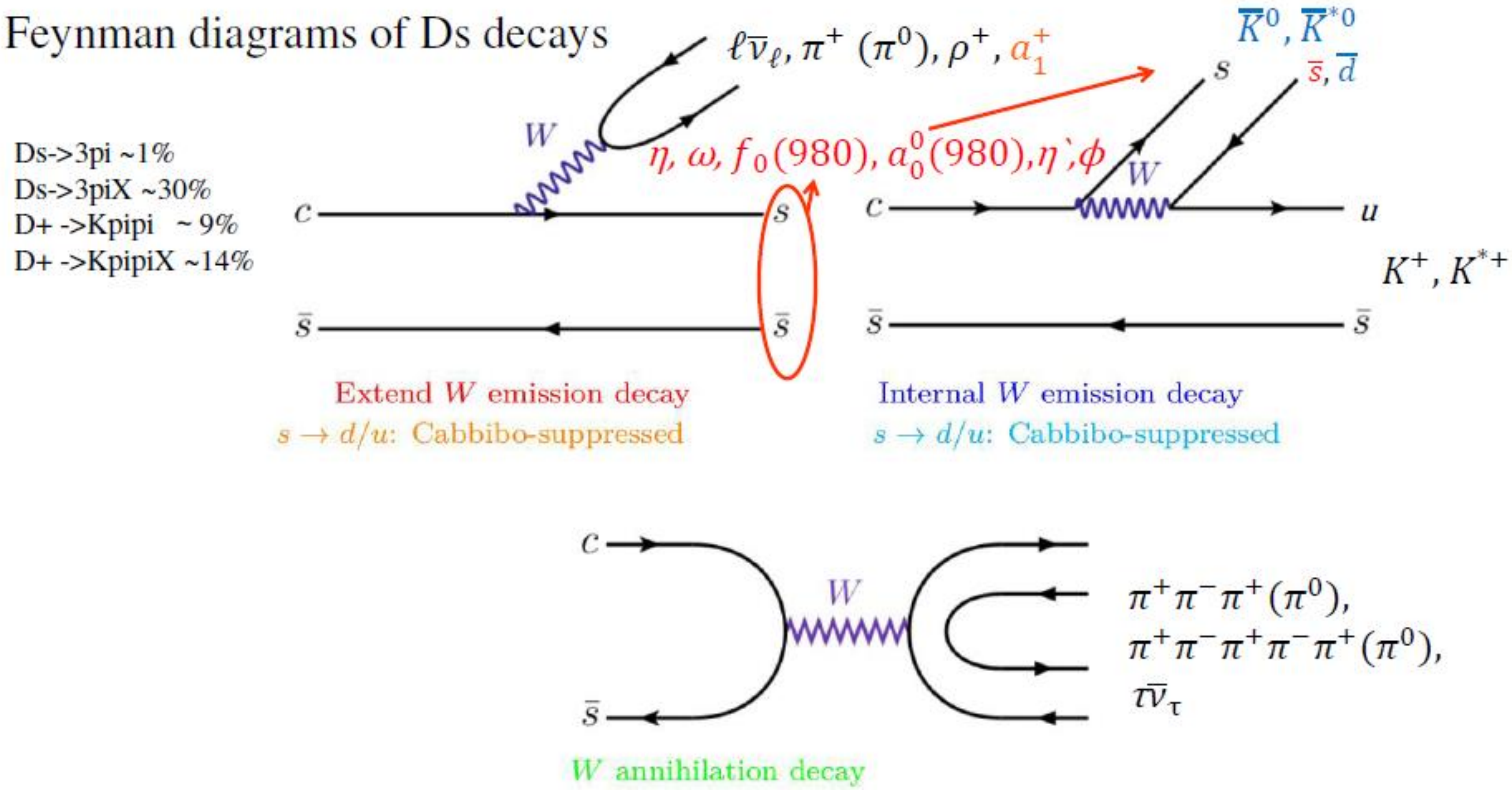
All detached vertices



Detached vertice for BDT>.0.1



Future of some systematic uncertainties: A little promenade through D_s decays

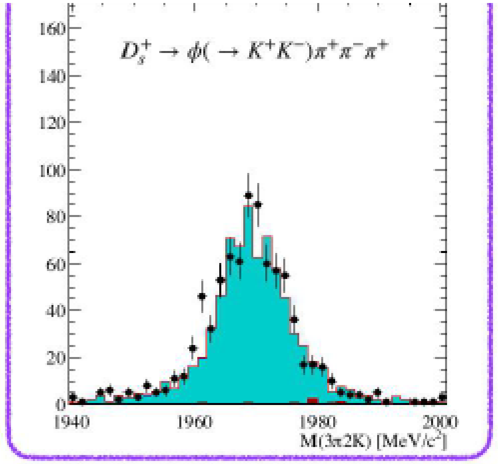


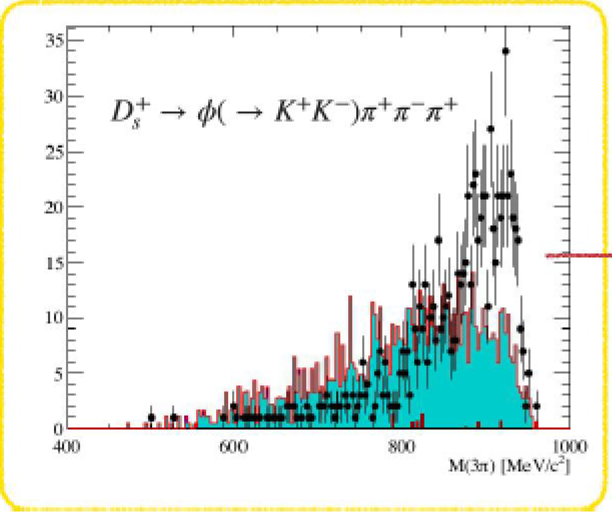
$\pi^+\pi^-\pi^+$ / a_1^+ ?

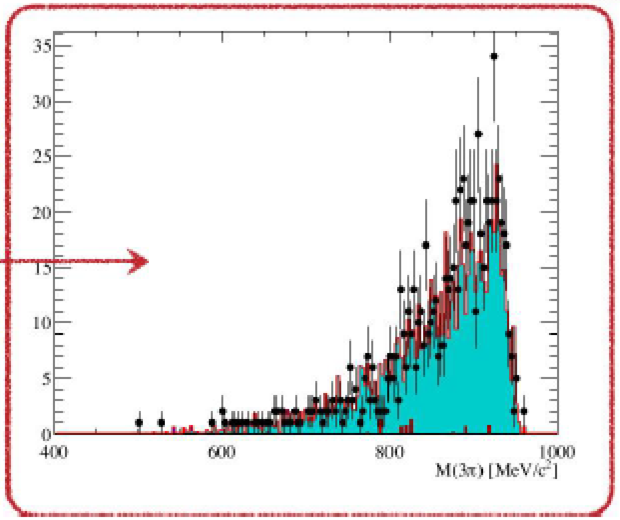
- $\eta\,\pi^+\pi^-\pi^+$, BESIII new result
- $\omega\,\pi^+\pi^-\pi^+$
- $\eta'\pi^+\pi^-\pi^+$, my another ongoing work at BESIII
- $\phi\,\pi^+\pi^-\pi^+$
- $K_S^0\pi^+\pi^-\pi^+$

$D_s^+ \to \phi\pi^+\pi^-\pi^+$ decays

- Additional distributions after fit:
  - $M(3\pi)$ requiring $M(3\pi 2K)$ around the $m(D_s^+)$
- Take into account contributions from $D_s^+ \to \phi a_1$ by reweighting the phase space $D_s^+ \to \phi 3\pi$







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Ds decays in PDG

BR in red for error larger than 20%

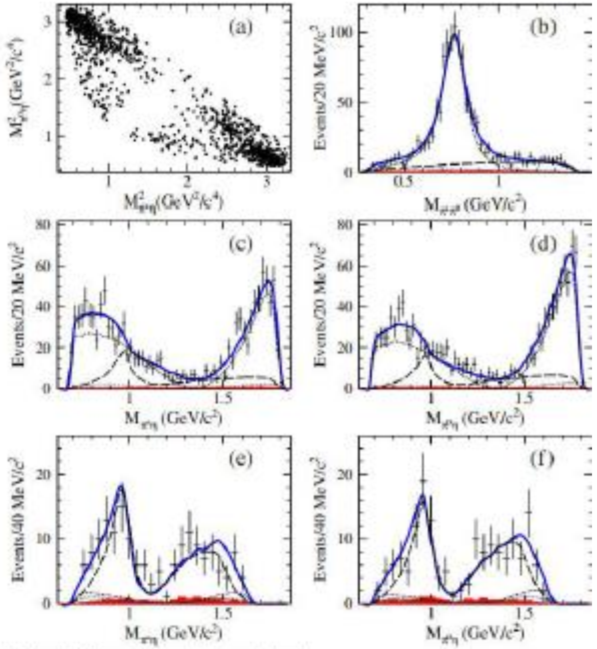
Type	Intermediate process	BR_{PDG} (%)	Comments
$\eta\pi^+$	NR	1.68	-
$\omega\pi^+$	NR	0.192	-
$\eta'\pi^+$	NR	3.94	-
$a_0^0\pi^+$	NR	1.10	BESIII $\eta 3\pi$ analysis
$\phi\pi^+$	NR	4.50	-
$\eta\pi^+\pi^0$	$\eta\rho^0, a_0^0\pi^+, a_0^+\pi^0, NR$	9.50	BESIII $\eta\pi\pi^0$ analysis
$\omega\pi^+\pi^0$	$\omega\rho^+, NR$	2.80	$BR(\omega\rho^+)/BR(\omega\pi^+\pi^0) = 0.52 \pm 0.30$
$\omega\eta\pi^+$	$\omega a_0^+, NR$	< 2.13	-
$\eta'\pi^+\pi^0$	$\eta'\rho^+, NR$	5.60	$BR(D_s^+ \to \eta'\rho^+) = 5.8\%$
$a_0^0\pi^+\pi^0$	$a_0^0\rho^+, NR$	–	BESIII $KK\pi\pi^0$ & $\eta 3\pi$ analysis
$\phi\pi^+\pi^0$	$\phi\rho^+, NR$	–	BESIII $KK\pi\pi^0$ analysis
$K^0 2\pi^+\pi^-$	$K^0 a_1^+, NR$	0.60	-
$\eta 2\pi^+\pi^-$	$\eta a_1^+, \eta'\pi^+, a_0^+\rho^0, NR$	–	BESIII $\eta 3\pi$ analysis
$\omega 2\pi^+\pi^-$	$\omega a_1^+, NR$	1.60	-
$\eta' 2\pi^+\pi^-$	$\eta' a_1^+, NR$	–	-
$a_0^0 2\pi^+\pi^-$	$\eta' a_1^+, NR$	–	-
$\phi 2\pi^+\pi^-$	$\phi a_1^+, NR$	1.21	-
$K^+K^-2\pi^+\pi^-(NR)$	–	0.09	Large uncertainty($\pm 0.07\%$).
$K^0\bar{K}^0 2\pi^+\pi^-(NR)$	–	0.336	$BR(2K_s^0 2\pi^+\pi^-) = 8.4 \pm 3.5 \times 10^{-4}$.
$2\pi^+\pi^-$	–	0.90	
$3\pi^+ 2\pi^-$	–	0.79	
$3\pi^+ 2\pi^-\pi^0(NR?)$	–	3.0	$BR(D_s^+ \to 3\pi^+ 2\pi^-\pi^0) = 4.9 \pm 3.2\%$
$\tau^+(\to 2\pi^+\pi^-(\pi^0))\bar{\nu_\tau}$	–	0.767	-

New BESIII results about Ds decays

- From $\eta\pi\pi^0$ BES paper,

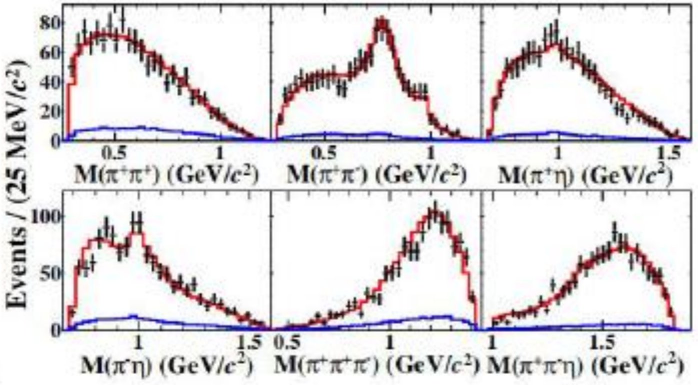
FIG. 2. (a) Dalitz plot of $M^2_{\pi^+\eta}$ vs $M^2_{\pi^0\eta}$ for data, the projections of the fit on (b) $M_{\pi^+\pi^0}$, (c) $M_{\pi^+\eta}$, and (d) $M_{\pi^0\eta}$, and the projections on (e) $M_{\pi^+\eta}$ and (f) $M_{\pi^0\eta}$ after requiring $M_{\pi^+\pi^0} > 1.0$ GeV$/c^2$. In (b)–(f), the dots with error bars and the solid line are data and the total fit, respectively; the dashed, dotted, and long-dashed lines are the contributions from $D_s^+ \to \rho^+\eta$, $D_s^+ \to (\pi^+\pi^0)_V\eta$, and $D_s^+ \to a_0(980)\pi$, respectively. The (red) hatched histograms are the simulated background.

Amplitude	ϕ_n (rad)	FF_n
$D_s^+ \to \rho^+\eta$	0.0 (fixed)	$0.783 \pm 0.050 \pm 0.021$
$D_s^+ \to (\pi^+\pi^0)_V\eta$	$0.612 \pm 0.172 \pm 0.342$	$0.054 \pm 0.021 \pm 0.025$
$D_s^+ \to a_0(980)\pi$	$2.794 \pm 0.087 \pm 0.044$	$0.232 \pm 0.023 \pm 0.033$



- From $\eta 3\pi$ BES paper,

Amplitude	Phase	FF(%)
$a_1(1260)^+(\rho(770)^0\pi^+)\eta$	0.0(fixed)	$55.4 \pm 3.9 \pm 2.0$
$a_1(1260)^+(f_0(500)\pi^+)\eta$	$5.0 \pm 0.1 \pm 0.1$	$8.1 \pm 1.9 \pm 2.1$
$a_0(980)^+\rho(770)^0$	$2.5 \pm 0.1 \pm 0.1$	$6.7 \pm 2.5 \pm 1.5$
$\eta(1405)(a_0(980)^-\pi^+)\pi^+$	$0.2 \pm 0.2 \pm 0.1$	$0.7 \pm 0.2 \pm 0.1$
$\eta(1405)(a_0(980)^+\pi^-)\pi^+$	$0.2 \pm 0.2 \pm 0.1$	$0.7 \pm 0.2 \pm 0.1$
$f_1(1420)(a_0(980)^-\pi^+)\pi^+$	$4.3 \pm 0.2 \pm 0.4$	$1.9 \pm 0.5 \pm 0.3$
$f_1(1420)(a_0(980)^+\pi^-)\pi^+$	$4.3 \pm 0.2 \pm 0.4$	$1.7 \pm 0.5 \pm 0.3$
$[a_0(980)^-\pi^+]_S\pi^+$	$0.1 \pm 0.2 \pm 0.2$	$5.1 \pm 1.2 \pm 0.9$
$[a_0(980)^+\pi^-]_S\pi^+$	$0.1 \pm 0.2 \pm 0.2$	$3.4 \pm 0.8 \pm 0.6$
$[f_0(980)\eta]_S\pi^+$	$1.4 \pm 0.2 \pm 0.3$	$6.2 \pm 1.7 \pm 0.9$
$[f_0(500)\eta]_S\pi^+$	$2.5 \pm 0.2 \pm 0.3$	$12.7 \pm 2.6 \pm 2.0$



- From $KK\pi\pi^0$ BES paper, $KK \sim \phi, \eta\pi$
  - $a_0(980)^0\rho(770)^+$
  - $\eta(1475)/f_1(1420)(\to a_0(980)^+\pi^-)\ \pi^+$
  - $\bar{K}^{*0}K^{*+}$

11/03/2022 Group meeting 19

f0 decays: potential inconsistency:

	Mode	Fraction (Γ_i/Γ)	Scale Factor/ Conf. Level	
Γ_1	$\pi\pi$	seen		476

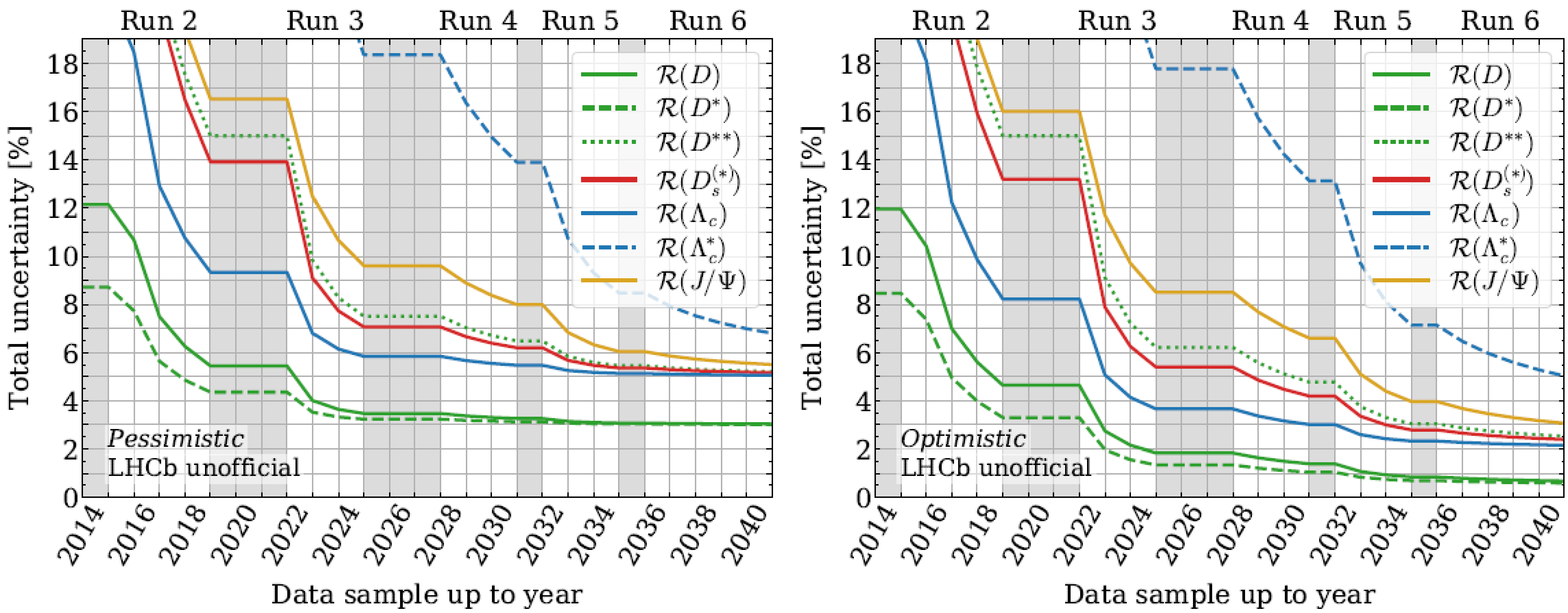
$\Gamma(f_0(980) \to \pi\pi)/[\Gamma(f_0(980) \to \pi\pi)+\Gamma(f_0(980) \to K\overline{K})]$ $\Gamma_1/(\Gamma_1+\Gamma_2)$

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • We do not use the following data for averages, fits, limits, etc. • •					
0.52 ± 0.12	9.9k	[1] AUBERT	2006O	BABR	$B^{\pm} \to K^{\pm}\pi^{\pm}\pi^{\mp}$
$0.75\ ^{+0.11}_{-0.13}$		[2] ABLIKIM	2005Q	BES2	$\chi_{c0} \to 2\pi^+2\pi^-,\ \pi^+\pi^-K^+K^-$
0.84 ± 0.02		[3] ANISOVICH	2002D	SPEC	Combined fit
~ 0.68		OLLER	1999B	RVUE	$\pi\pi \to \pi\pi,\ K\overline{K}$
0.67 ± 0.09		[4] LOVERRE	1980	HBC	$4\ \pi^- p \to n2K^0_S$
$0.81\ ^{+0.09}_{-0.04}$		[4] CASON	1978	STRC	$7\ \pi^- p \to n2K^0_S$
0.78 ± 0.03		[4] WETZEL	1976	OSPK	$8.9\ \pi^- p \to n2K^0_S$

[1] Recalculated by us using $\Gamma(K^+K^-)/\Gamma(\pi^+\pi^-) = 0.69 \pm 0.32$ from AUBERT 2006O and isospin relations.

Upcoming analysis using 3π channel

- R(D*) with 2015-2016 data (x2 compared to what is published)
- D* polarization in $D^*\tau\nu$ events
- R(D**°(2420))
- In a longer term
  - Legacy measurement with the full run 2 for R(D*), R(Λ_c), R(D°,D^+,D_s)
  - Full angular analysis
  - R(J/ψ)
- Similar set of measurements also worked on using the muonic channel



Run 2
Run 3
Run 4
Run 5
Run 6
Total uncertainty [%]
Data sample up to year
$\mathcal{R}(D)$
$\mathcal{R}(D^*)$
$\mathcal{R}(D^{**})$
$\mathcal{R}(D_s^{(*)})$
$\mathcal{R}(\Lambda_c)$
$\mathcal{R}(\Lambda_c^*)$
$\mathcal{R}(J/\Psi)$
Pessimistic
LHCb unofficial
Optimistic
LHCb unofficial

Conclusion regarding $\Lambda_b^0 \to \Lambda_c^+ \tau^- \overline{\nu}_\tau$

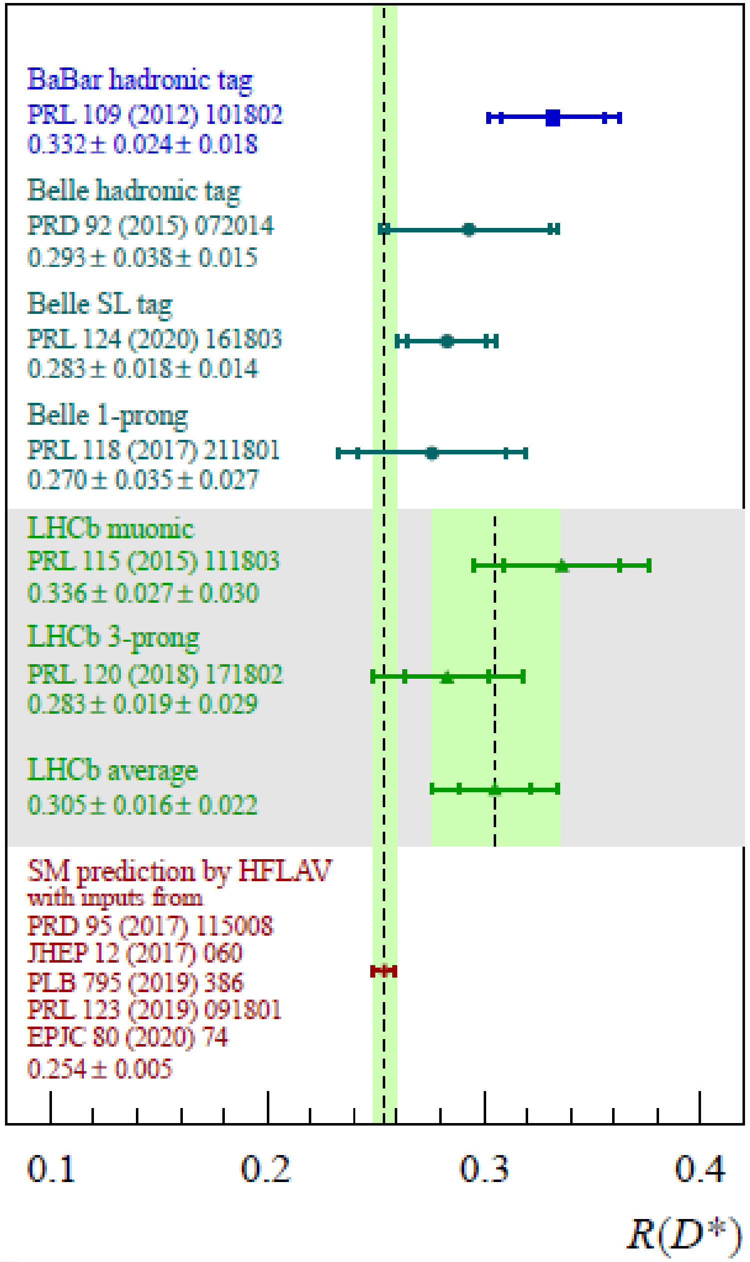
LHCb-PAPER-2021-044
arxiv:2201:03497

- The decay $\Lambda_b^0 \to \Lambda_c^+ \tau^- \overline{\nu}_\tau$ 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)
  - $\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \tau^- \overline{\nu}_\tau)$= (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)
- 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

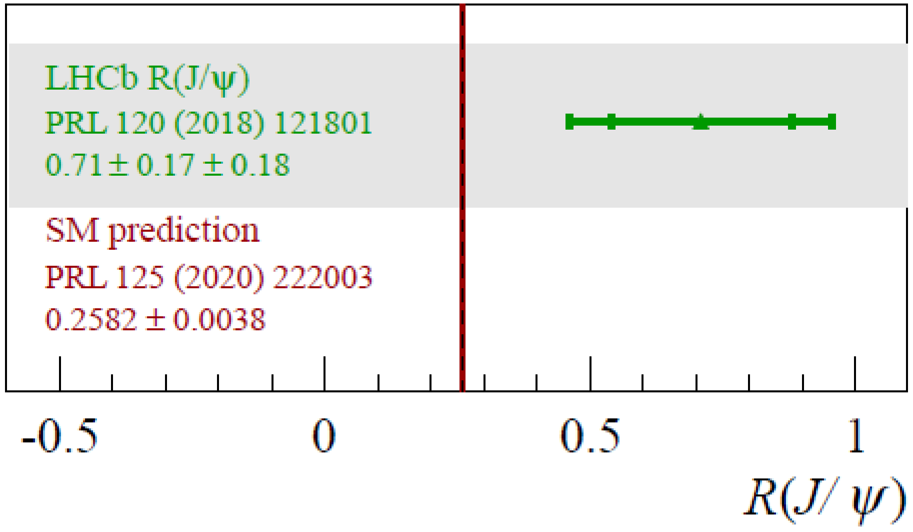
Conclusions regarding semileptonic decays

- Present hint of 3.4 σ deviation from SM in R(D*)-R(D)
- New LHCb result on R(Λ_c) compatible with SM and exclusing some NP scenarios
- This will be resolved one way or another in the next years due to an upcoming wealth of new measurements from LHCb:
  - R ratios for many particles : D*, D**, D^+,D°,Λ_c,D_s, J/ψ,
  - D* polarization, full angular analysis
  - Higher signal/noise using 3π mode
- Belle-II will also participate to this exciting game

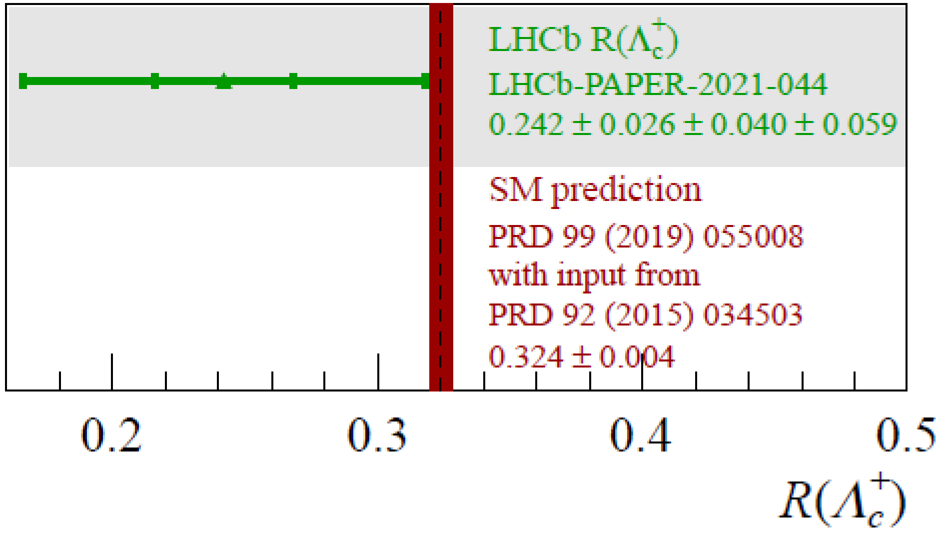
Backup



BaBar hadronic tag
PRL 109 (2012) 101802
0.332 ± 0.024 ± 0.018
Belle hadronic tag
PRD 92 (2015) 072014
0.293 ± 0.038 ± 0.015
Belle SL tag
PRL 124 (2020) 161803
0.283 ± 0.018 ± 0.014
Belle 1-prong
PRL 118 (2017) 211801
0.270 ± 0.035 ± 0.027
LHCb muonic
PRL 115 (2015) 111803
0.336 ± 0.027 ± 0.030
LHCb 3-prong
PRL 120 (2018) 171802
0.283 ± 0.019 ± 0.029
LHCb average
0.305 ± 0.016 ± 0.022
SM prediction by HFLAV
with inputs from
PRD 95 (2017) 115008
JHEP 12 (2017) 060
PLB 795 (2019) 386
PRL 123 (2019) 091801
EPJC 80 (2020) 74
0.254 ± 0.005
0.1
0.2
0.3
0.4
R(D*)



LHCb R(J/ψ)
PRL 120 (2018) 121801
0.71 ± 0.17 ± 0.18
SM prediction
PRL 125 (2020) 222003
0.2582 ± 0.0038
-0.5
0
0.5
1
R(J/ψ)



LHCb R(Λc+)
LHCb-PAPER-2021-044
0.242 ± 0.026 ± 0.040 ± 0.059
SM prediction
PRD 99 (2019) 055008
with input from
PRD 92 (2015) 034503
0.324 ± 0.004
0.2
0.3
0.4
0.5
R(Λc+)

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)%

IJCLab Irène Joliot-Curie

université PARIS-SACLAY

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 $B° \rightarrow \Lambda_c \Xi c$ BR =(0,12+_ 0.08)% similar to signal mode
  - Three-body mode $B° \rightarrow \Lambda_c \Lambda_c K°$ (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

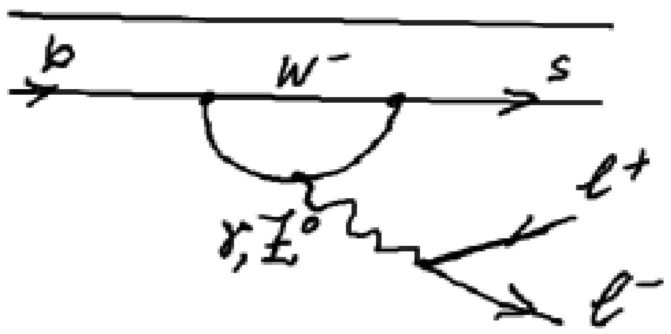
(The 3 pions have to come from the same vertex)

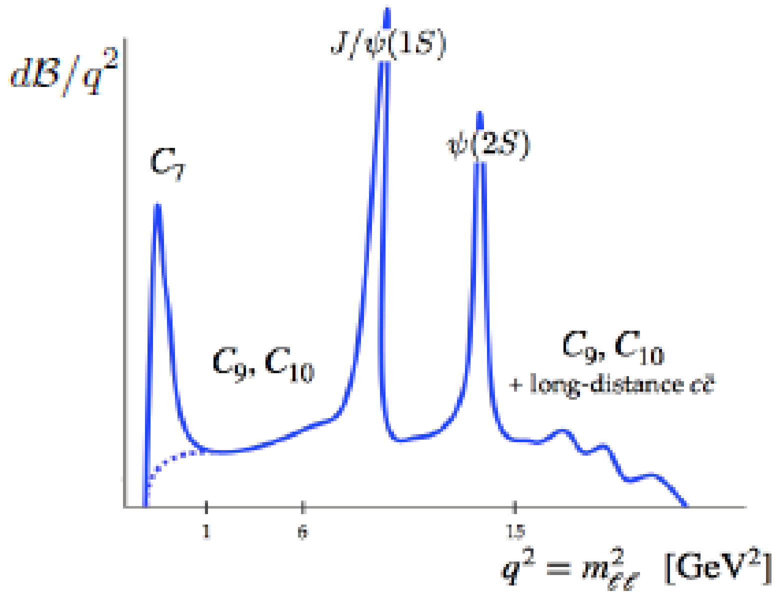
- Small but $f_d=4*f_\Lambda$

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

- B^+ contribution suppressed by isolation requirements

Most recent experimental results: rare decays





- Integrated and differential branching fractions of $b \to s\mu^+\mu^-$ decays
- Angular observables
- Fully leptonic decays (e.g. $B_s \to \mu^+\mu^-$)
  - See **Cristina Lazzeroni** 's talk, Tue 9:00AM
- Lepton Universality Tests
  - See **Carla Marin Benito**'s talk Tue 2:40PM
  - See **Saurabh Sandilya**'s talk Tue 3:00PM
- Belle-II results: **Slavomira Stefkova** 's talk, Tue 2:20M

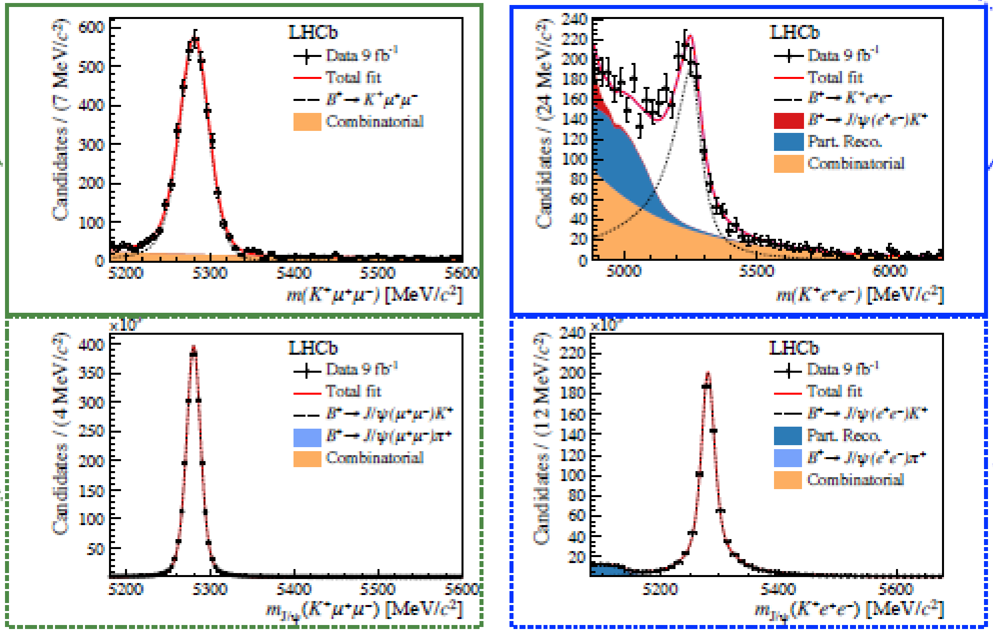
Lepton Universality – R_K & R_{K^*} @LHCb

arXiv:2103.11769 16

- Double ratio:

$$R_K = \frac{\mathcal{B}(B^+ \to K^+\mu^+\mu^-)}{\mathcal{B}(B^+ \to K^+(J/\psi \to \mu^+\mu^-))} \Bigg/ \frac{\mathcal{B}(B^+ \to K^+e^+e^-)}{\mathcal{B}(B^+ \to K^+(J/\psi \to e^+e^-))}$$

$$= \frac{N_{K^+\mu^+\mu^-}/\epsilon_{K^+\mu^+\mu^-}}{N_{K^+(J/\psi\to\mu^+\mu^-)}/\epsilon_{K^+(J/\psi\to\mu^+\mu^-)}} \Bigg/ \frac{N_{K^+e^+e^-}/\epsilon_{K^+e^+e^-}}{N_{K^+(J/\psi\to e^+e^-)}/\epsilon_{K^+(J/\psi\to e^+e^-)}}$$



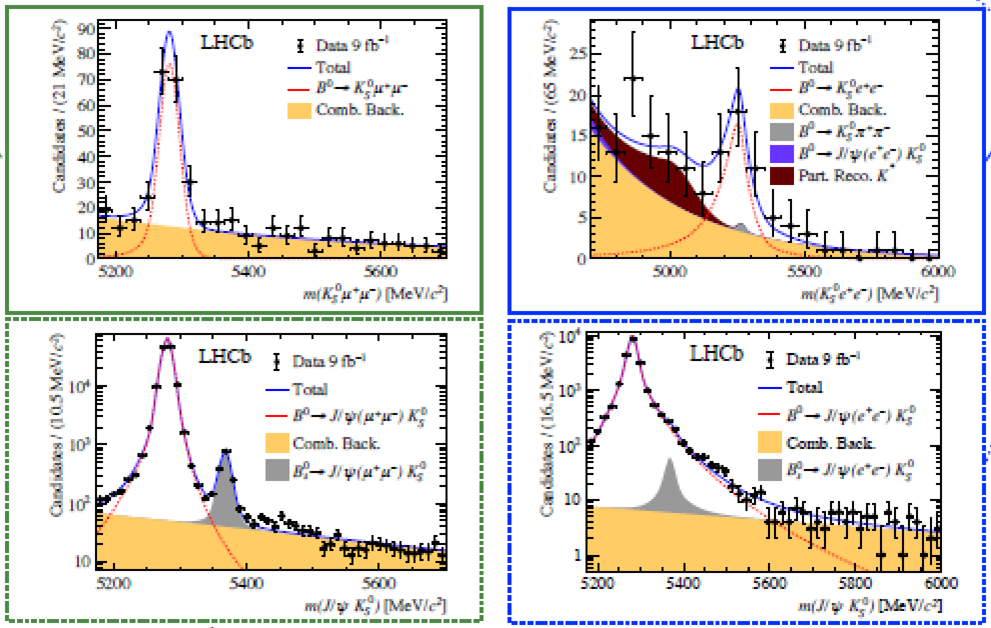
- See **Carla Marin Benito**'s talk Tue 2:40PM

Lepton Universality – RK & RK* @LHCb

- Isospin partners:

$$R_{K_S^0} = \frac{\mathcal{B}(B^0 \to K_S^0 \mu^+\mu^-)}{\mathcal{B}(B^0 \to K_S^0 (J/\psi \to \mu^+\mu^-))} \Bigg/ \frac{\mathcal{B}(B^0 \to K_S^0 e^+e^-)}{\mathcal{B}(B^0 \to K_S^0 (J/\psi \to e^+e^-))}$$

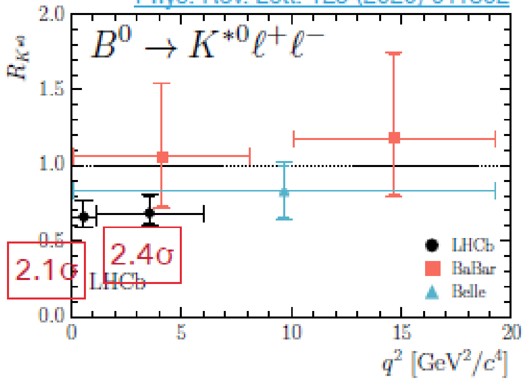
$$= \frac{N_{K_S^0\mu^+\mu^-}/\epsilon_{K_S^0\mu^+\mu^-}}{N_{K_S^0(J/\psi\to\mu^+\mu^-)}/\epsilon_{K_S^0(J/\psi\to\mu^+\mu^-)}} \Bigg/ \frac{N_{K_S^0e^+e^-}/\epsilon_{K_S^0e^+e^-}}{N_{K_S^0(J/\psi\to e^+e^-)}/\epsilon_{K_S^0(J/\psi\to e^+e^-)}}$$



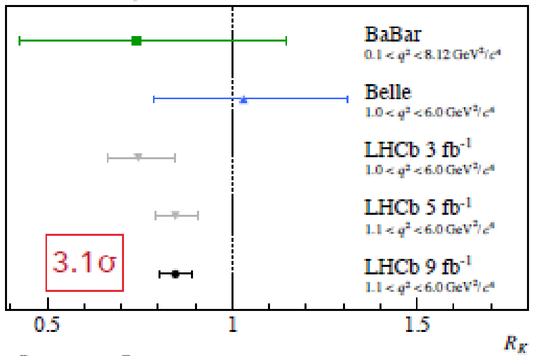
- See **Carla Marin Benito**'s talk Tue 2:40PM

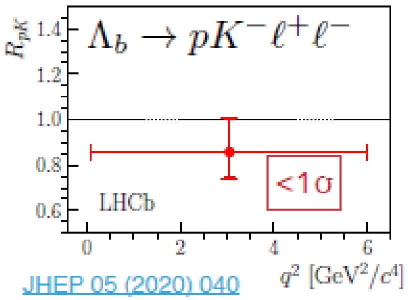
Lepton Universality – LFU ratios results summary

Phys. Rev. Lett. 125 (2020) 011802



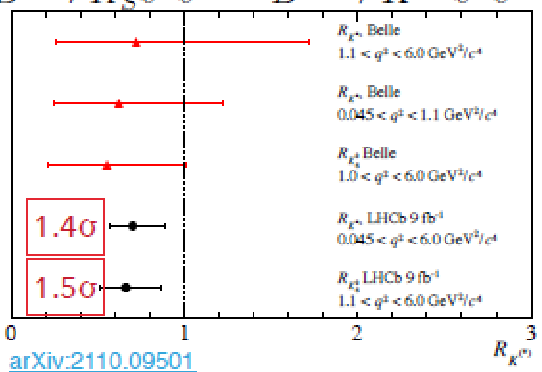
$B^+ \to K^+\ell^+\ell^-$ arXiv:2103.11769





JHEP 05 (2020) 040

$B^0 \to K^0_S\ell^+\ell^-$ $B^+ \to K^{*+}\ell^+\ell^-$

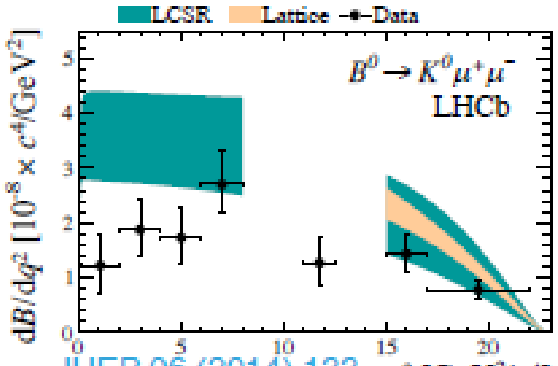


arXiv:2110.09501

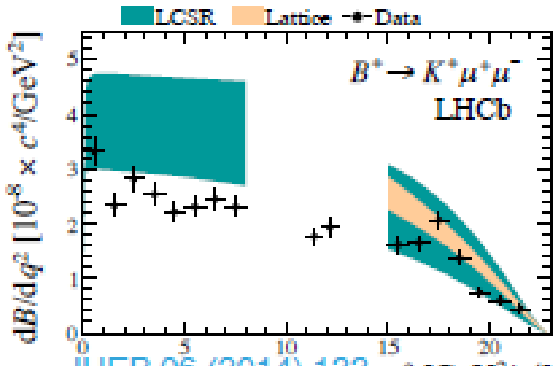
- See **Carla Marin Benito**'s talk Tue 2:40PM

Branching Fractions of $b \to s\ell^+\ell^-$ decays

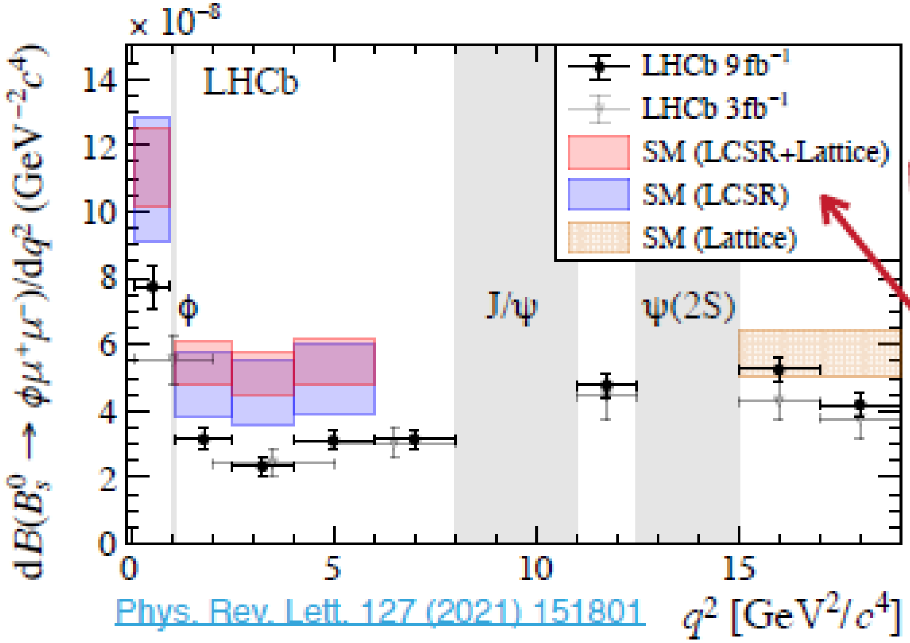
- $d\mathcal{B}/dq^2$ seems to undershoot SM
  - 20-30% theory uncertainty (hadronic form factors)
  - correlated prediction uncertainties



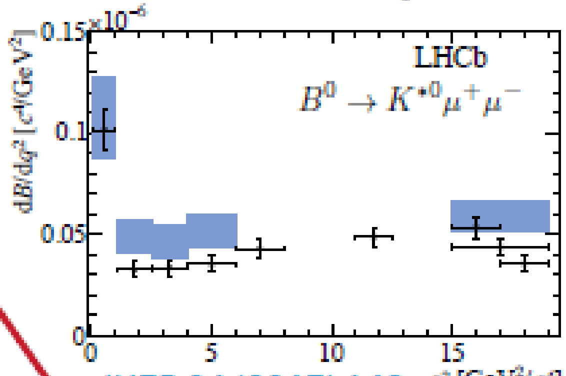
JHEP 06 (2014) 133



JHEP 06 (2014) 133



Phys. Rev. Lett. 127 (2021) 151801



JHEP 04 (2017) 142

$\sim 3.6\sigma$

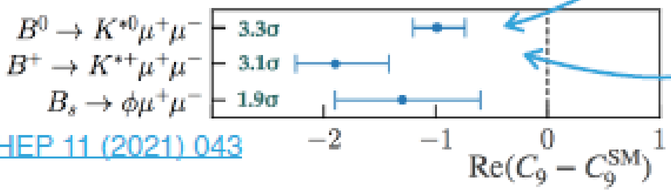
$\sim 1.8\sigma$

Angular analyses of $b \to s\ell^+\ell^-$ decays

- SM prediction challenging, but uncertainties smaller than for BFs
- Optimised observables where hadronic uncertainties cancel out at 1st order (e.g. P5′)
- A growing number of global fits to $b \to s\ell\ell$ results (and others)

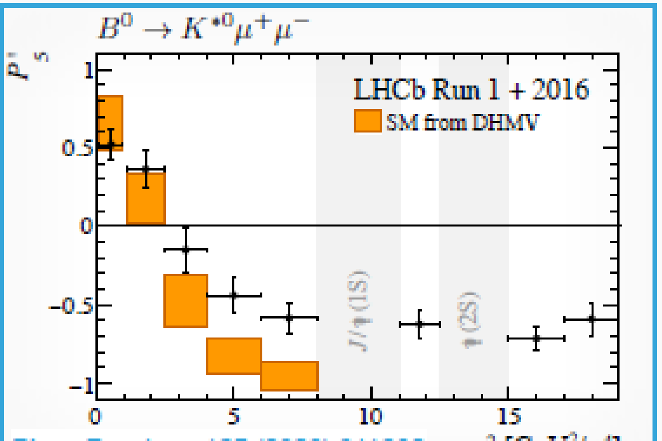
Algueró et al: arXiv:2104.08921
Altmannshofer et al: arXiv:2103.13370
Ciucchini et al: arXiv:1903.09632
Geng et al arXiv:2103.12738
Hurth et al: arXiv:2104.10058
Kowalska et al: arXiv:1903.10932 ...

- Global tension with SM:

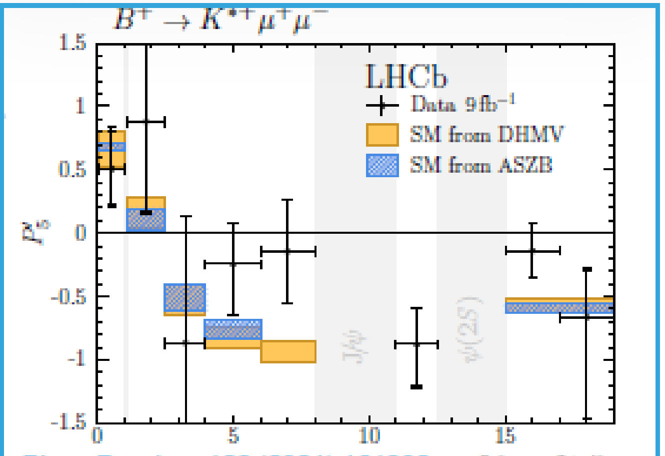


JHEP 11 (2021) 043

- Theory uncertainty under scrutiny
  - See **Danny van Dyk**'s talk

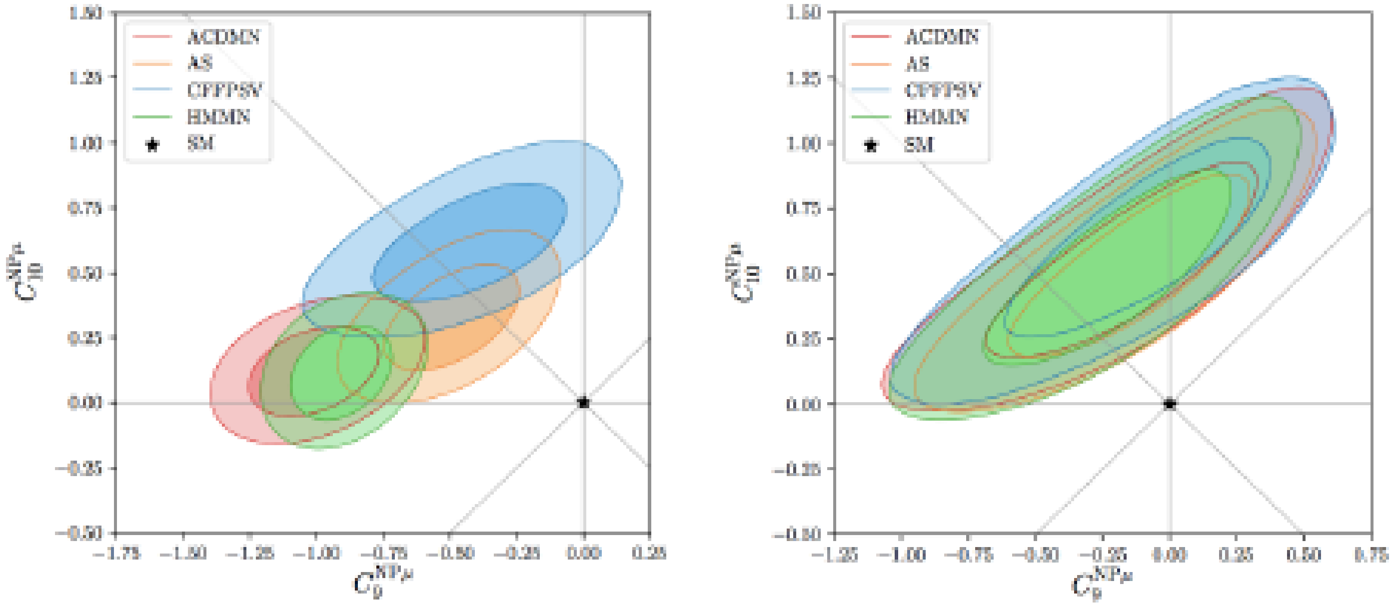


Phys. Rev. Lett. 125 (2020) 011802



Phys. Rev. Lett.126 (2021) 161802

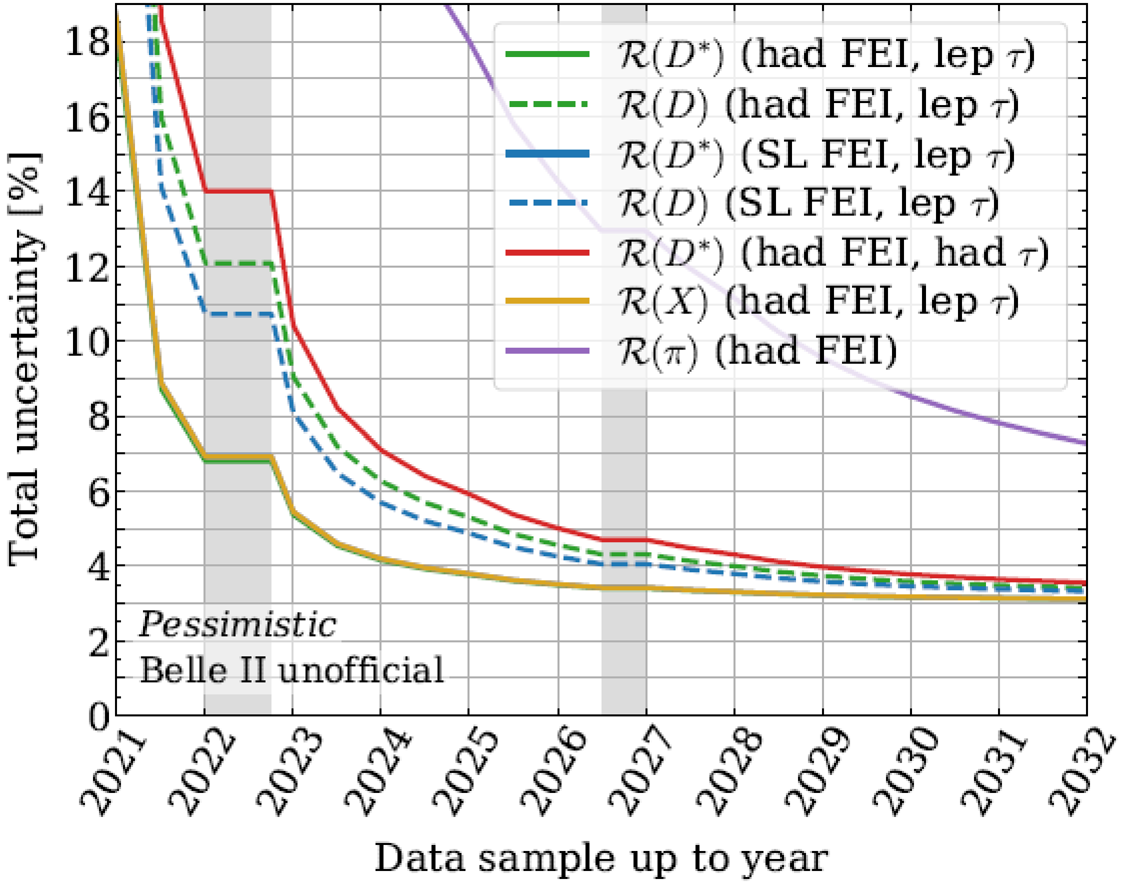
- Combine the information from so many observables and channels fitting the EFT coefficients [B. Capdevila, M. Fedele, S. Neshatpour, P. Stangl, Flavour Anomany Workshop '21]



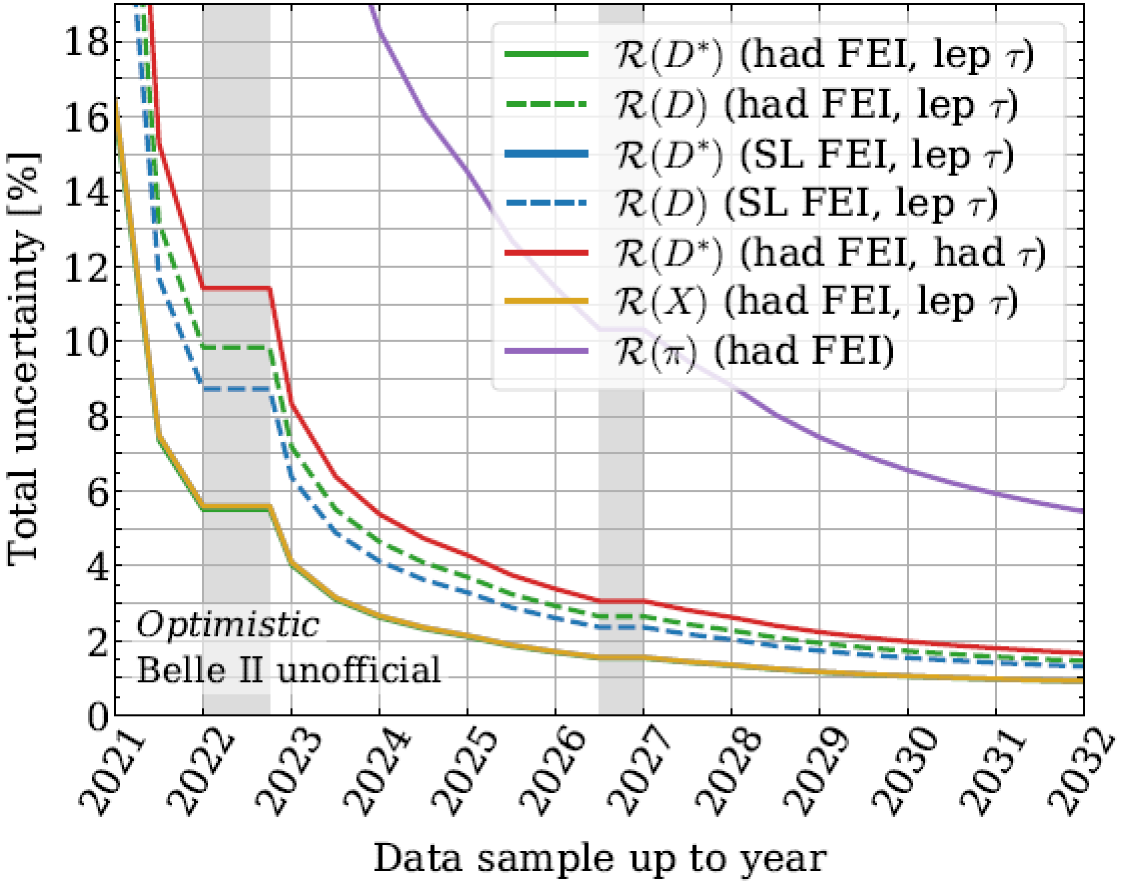
global fit

fit to LFU observables + $B_s \to \mu\mu$

- Attempt to have a best estimate of combined global significance to SM fitting all WC together: 4.3 σ tension with SM [arXiv:2104.05631] with only clean observables
- See **Davide Lancierini**'s poster



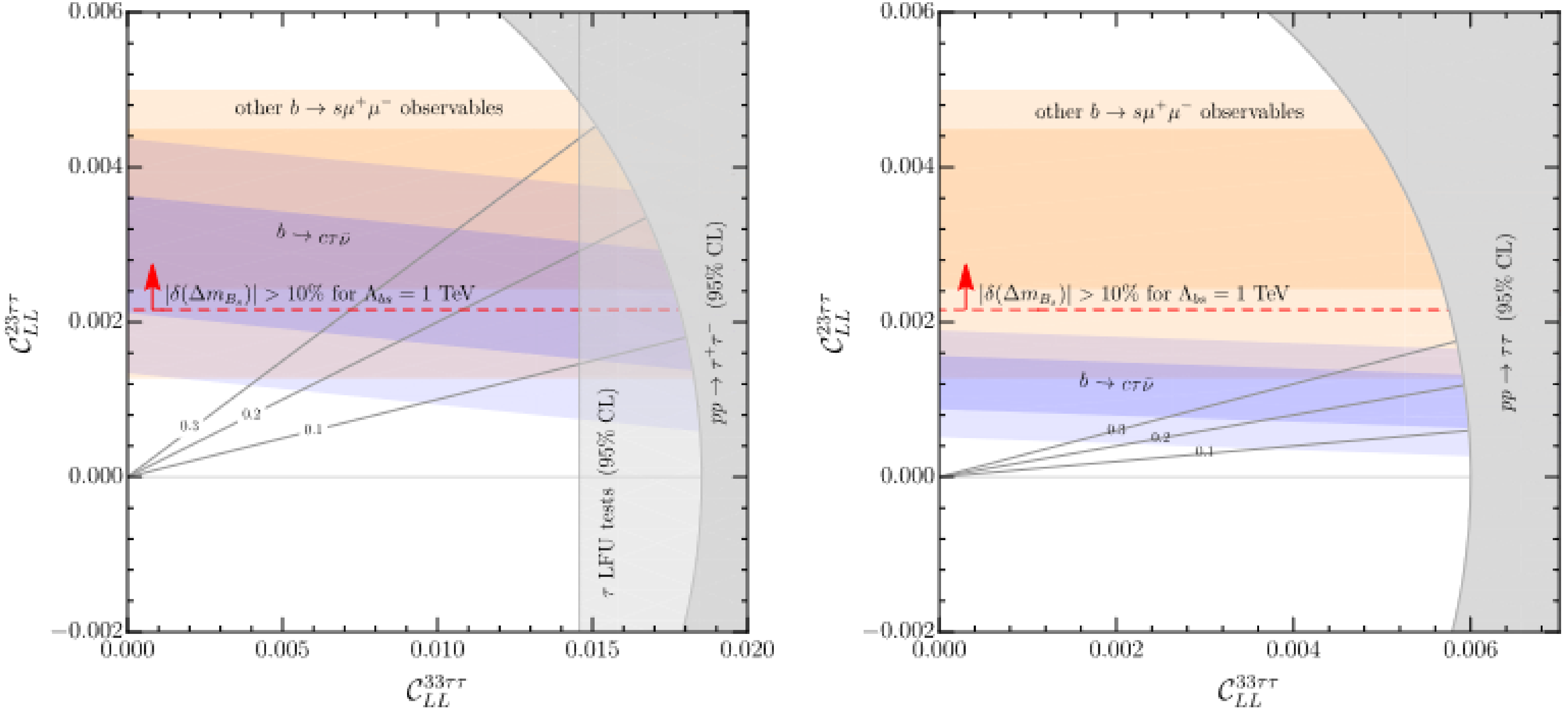
Total uncertainty [%]
$\mathcal{R}(D^*)$ (had FEI, lep τ)
$\mathcal{R}(D)$ (had FEI, lep τ)
$\mathcal{R}(D^*)$ (SL FEI, lep τ)
$\mathcal{R}(D)$ (SL FEI, lep τ)
$\mathcal{R}(D^*)$ (had FEI, had τ)
$\mathcal{R}(X)$ (had FEI, lep τ)
$\mathcal{R}(\pi)$ (had FEI)
Pessimistic
Belle II unofficial
Data sample up to year



Total uncertainty [%]
$\mathcal{R}(D^*)$ (had FEI, lep τ)
$\mathcal{R}(D)$ (had FEI, lep τ)
$\mathcal{R}(D^*)$ (SL FEI, lep τ)
$\mathcal{R}(D)$ (SL FEI, lep τ)
$\mathcal{R}(D^*)$ (had FEI, had τ)
$\mathcal{R}(X)$ (had FEI, lep τ)
$\mathcal{R}(\pi)$ (had FEI)
Optimistic
Belle II unofficial
Data sample up to year

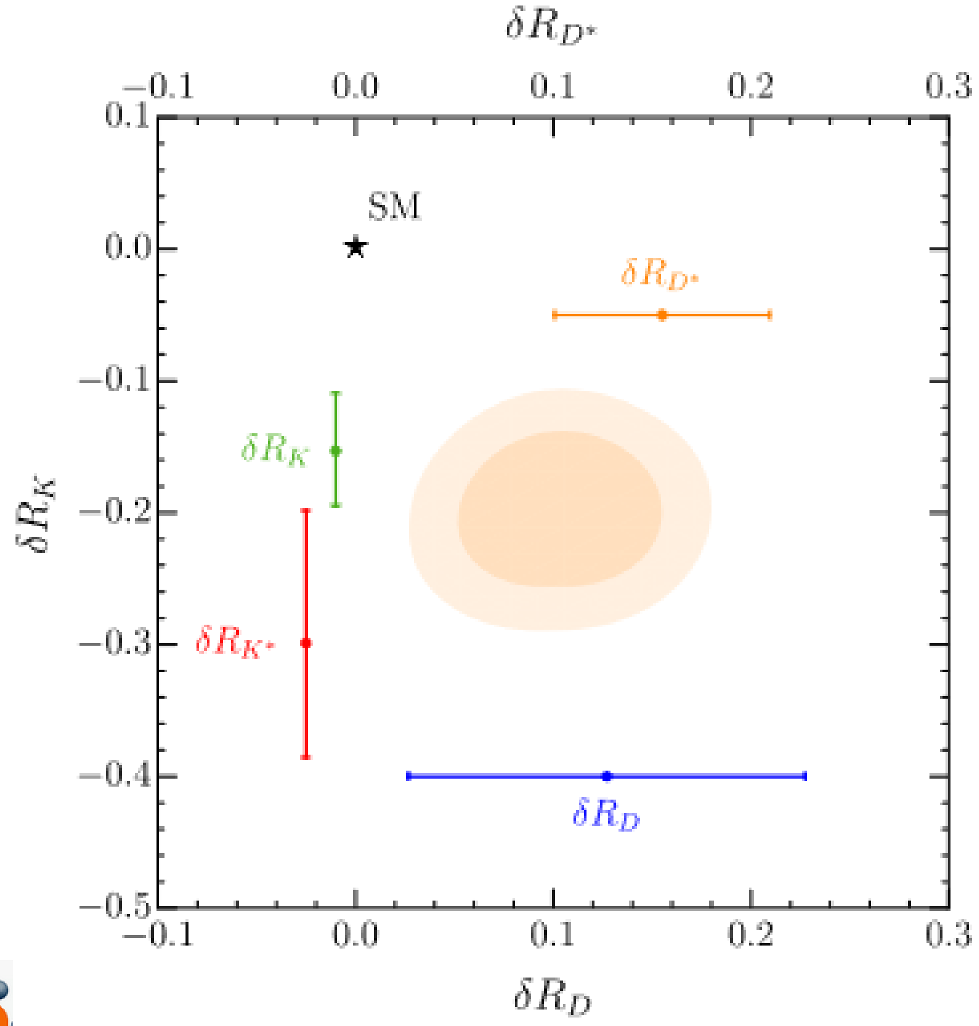
Combined interpretation in a ~TeV vector leptoquak model (U_1)

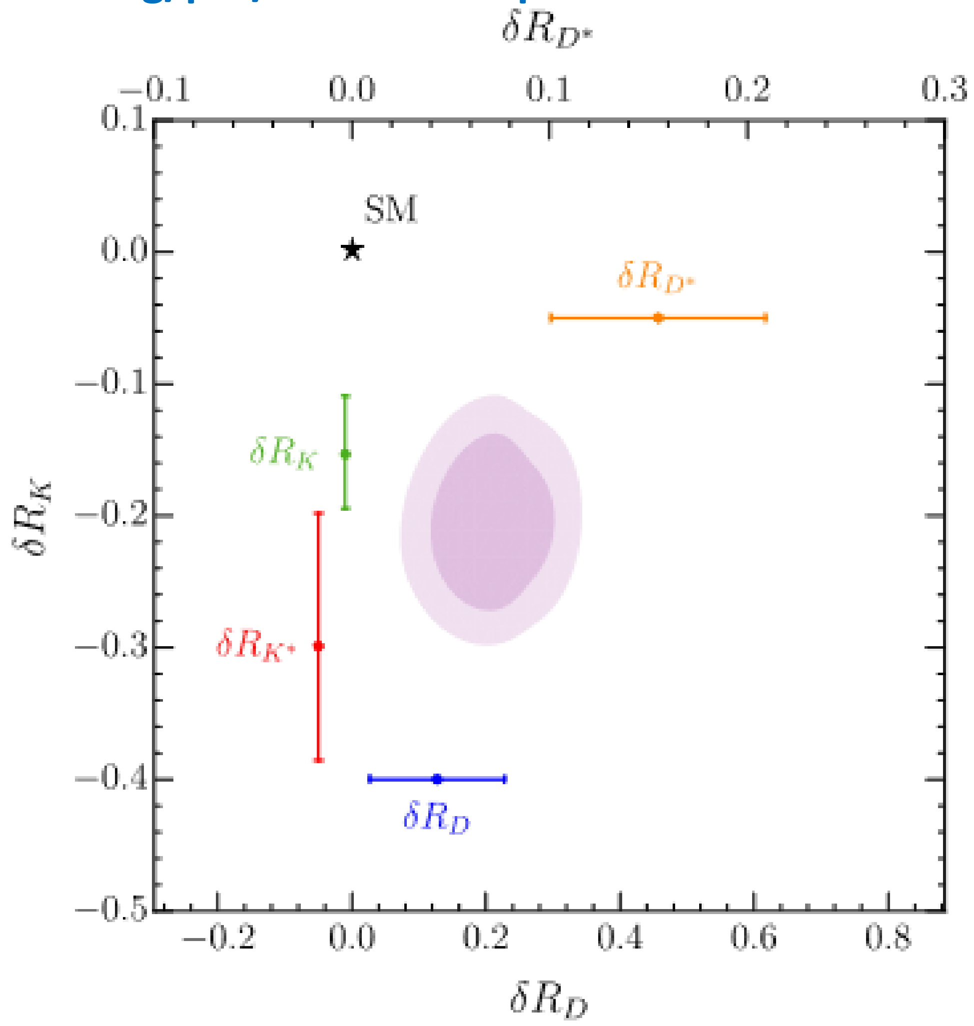
C. Cornella et al., https://arxiv.org/pdf/2103.16558.pdf



Best fit including $\mathcal{R}(D^{(*)})$-$\mathcal{R}(K)$

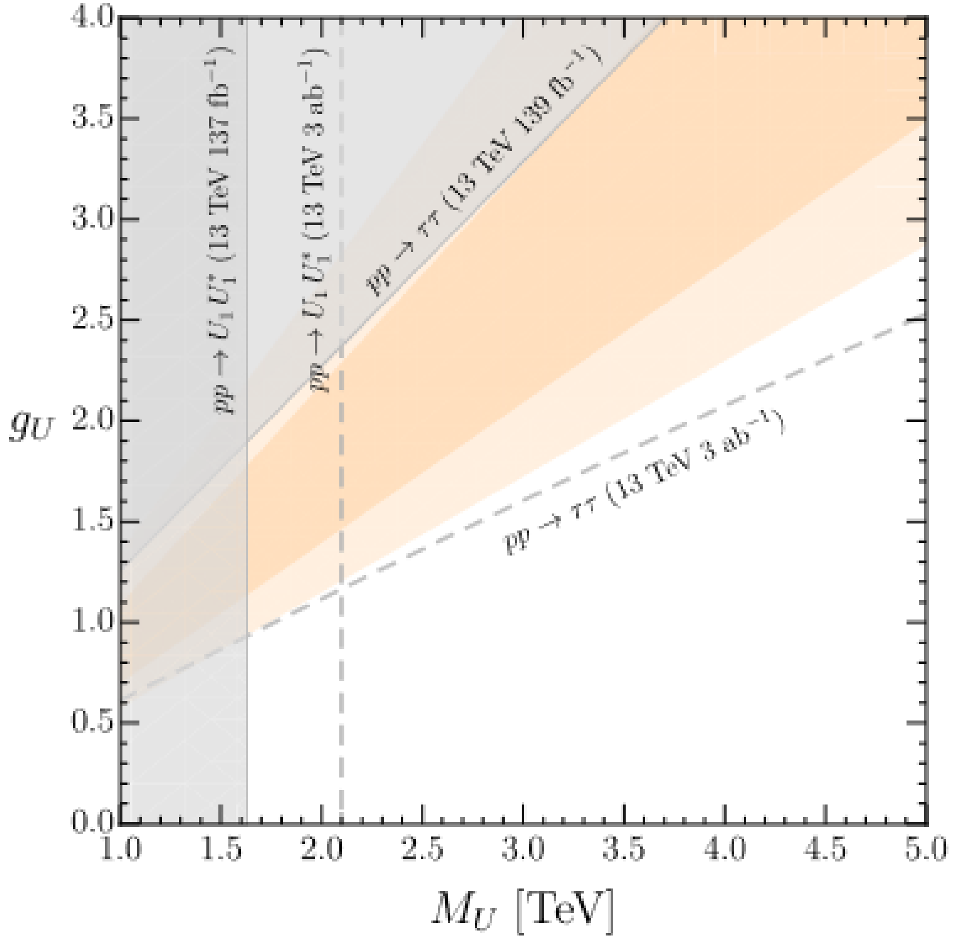
C. Cornella et al., https://arxiv.org/pdf/2103.16558.pdf

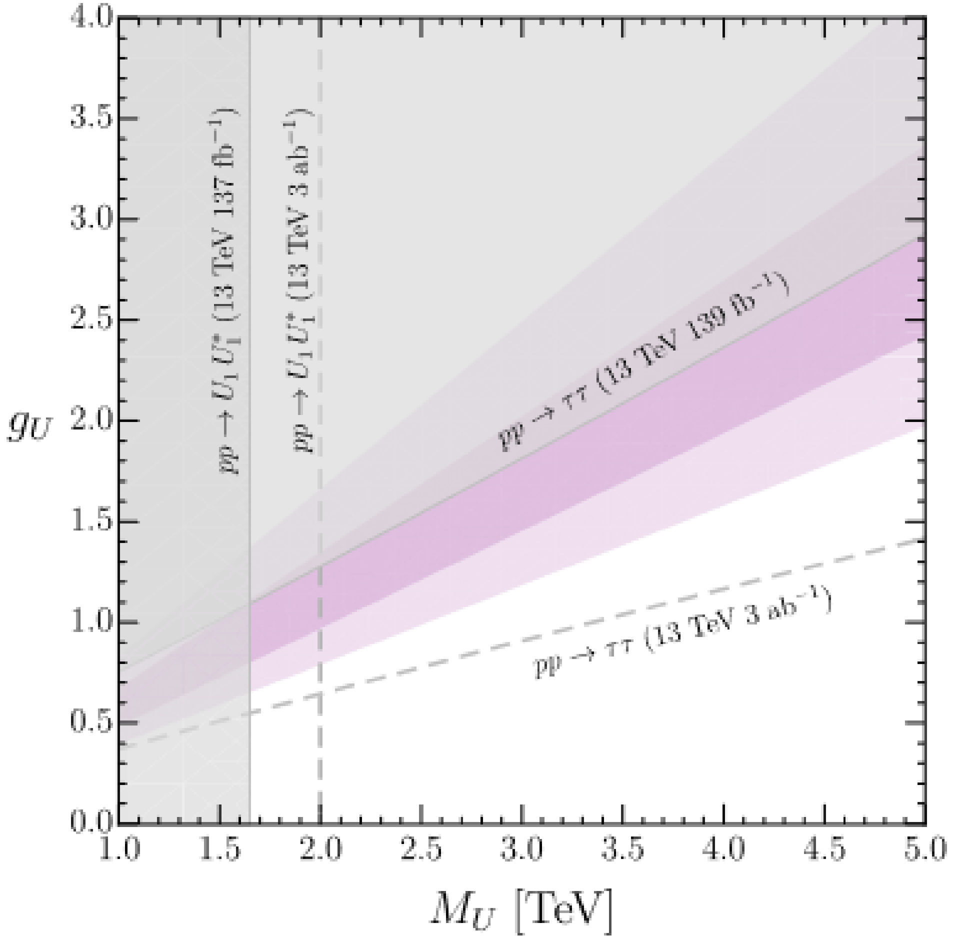




Role of the direct LHC searches

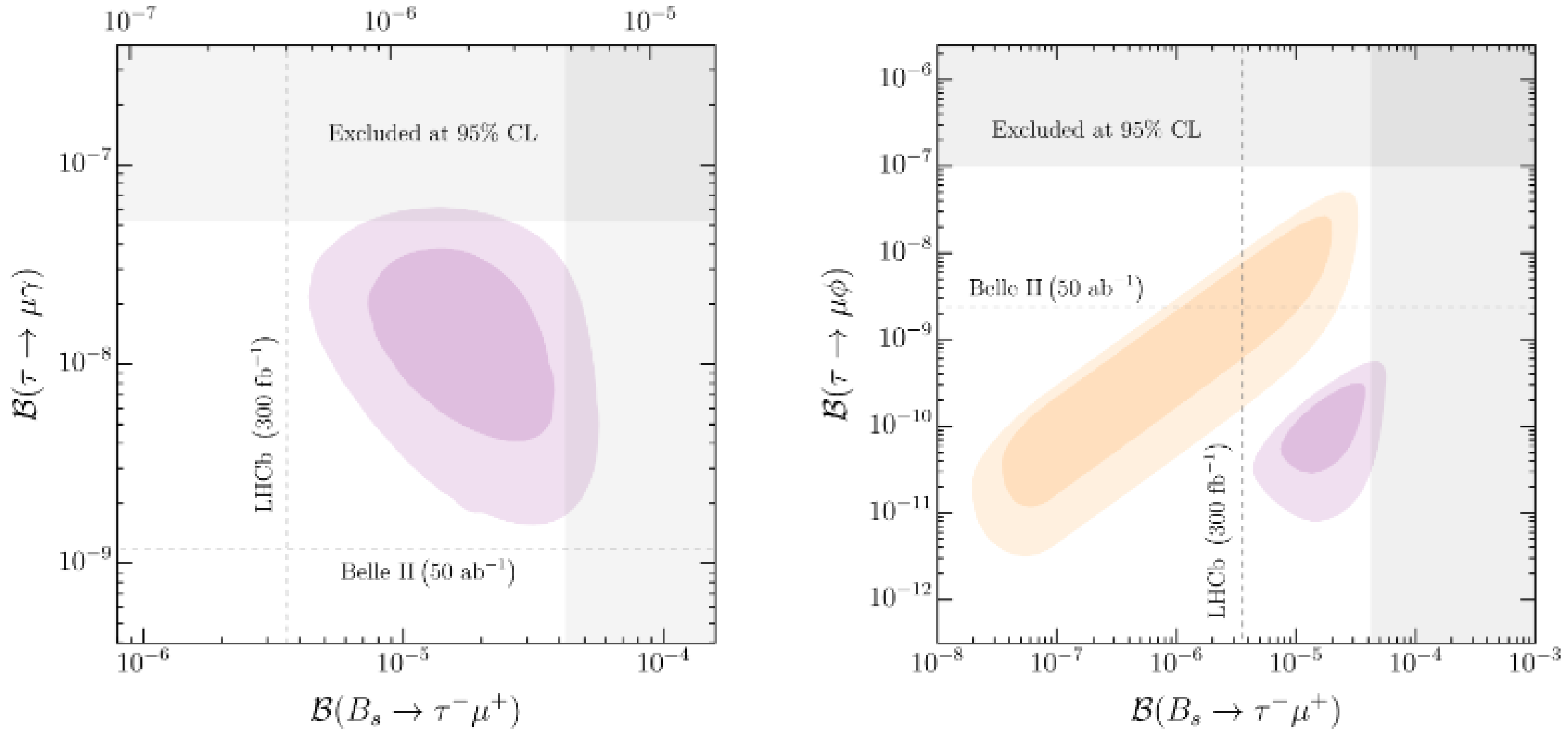
C. Cornella et al., https://arxiv.org/pdf/2103.16558.pdf





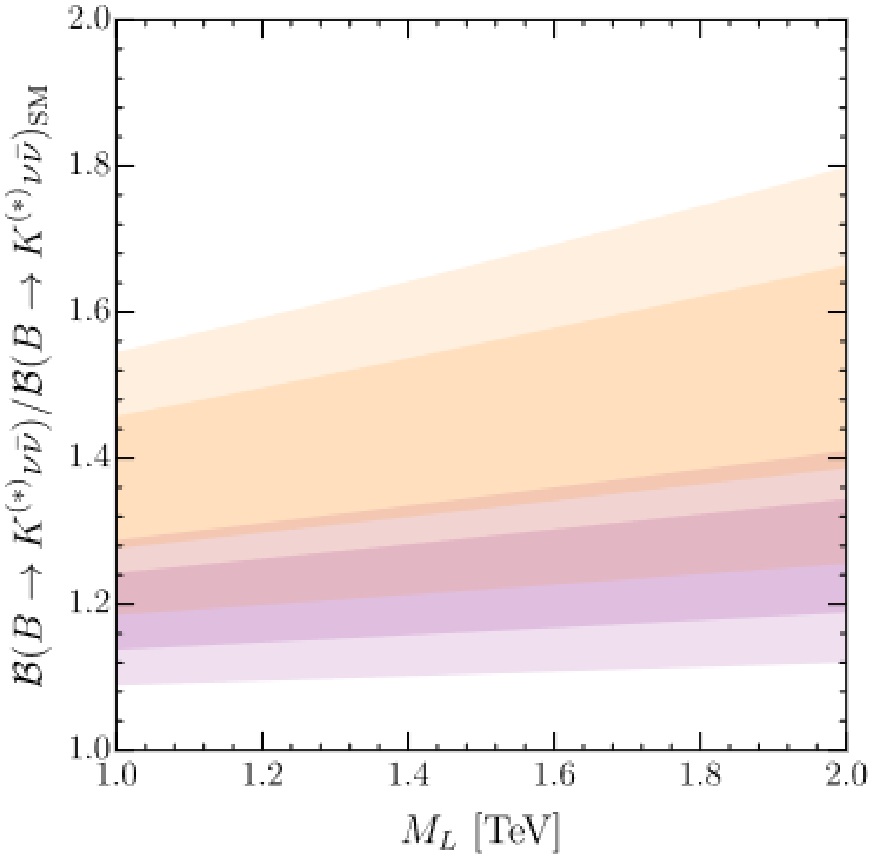
In this model, Lepton Flavour violation should be seen ($B \to \mu\tau$, $K\mu\tau$)

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



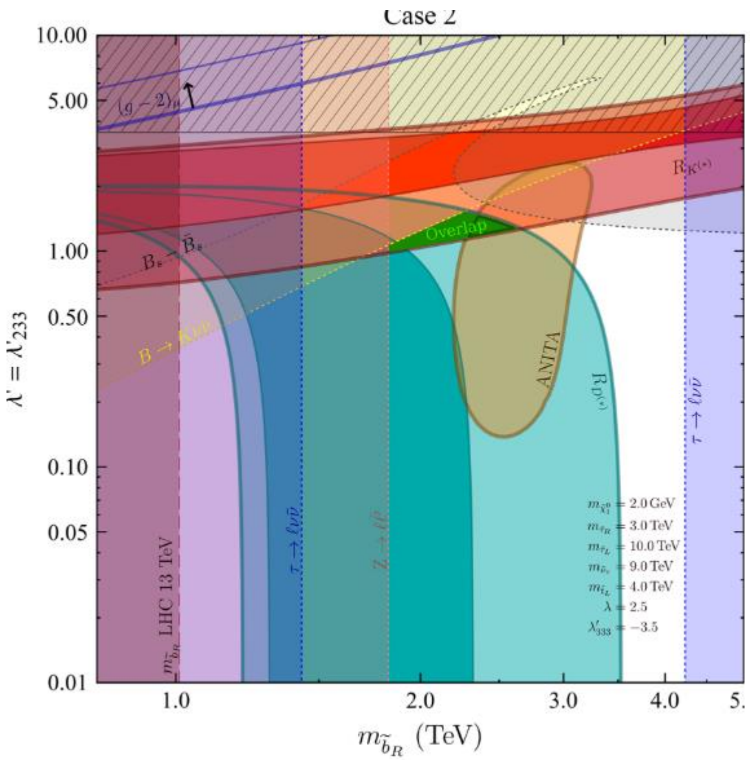
For Belle-II, large deviation expected in B→Kνν̄

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



RPV3 : another model that can accomodate all present LFU results + g-2

W. Altmannshofer, P. S. Bhupal Dev , A.Soni, and Y.Sui Phys. Rev.D 102, 015031 (2020)



Flavor-violating decay mode	λ, λ' dependence	RPV3 Prediction Case 1	Case 2	Case 3	Current experimental bound/measurement
$\tau \to \mu\phi$	$\lambda'_{332}\lambda'_{232}$, $\lambda_{323}\lambda'_{322}$	1.9×10^{-15}	3.8×10^{-10}	2.6×10^{-12}	$<8.4 \times 10^{-8}$ [202]
$\tau \to \mu KK$	$\lambda'_{332}\lambda'_{232}$, $\lambda_{323}\lambda'_{322}$	1.2×10^{-17}	2.4×10^{-12}	2.9×10^{-13}	$<4.4 \times 10^{-8}$ [203]
$\tau \to \mu K_s^0$	$\lambda'_{332}\lambda'_{231}$, $\lambda'_{312}\lambda_{323}$	4.5×10^{-19}	8.7×10^{-12}	3.1×10^{-13}	$<2.3 \times 10^{-8}$ [204]
$\tau \to \mu\gamma$	$\lambda'_{333}\lambda'_{233}$, $\lambda_{133}\lambda_{123}$	1.3×10^{-10}	1.3×10^{-8}	2.4×10^{-10}	$<4.4 \times 10^{-8}$ [205]
$\tau \to \mu\mu\mu$	$\lambda_{323}\lambda_{322}$	1.7×10^{-11}	1.2×10^{-9}	1.2×10^{-11}	$<2.1 \times 10^{-8}$ [206]
$B_{(s)} \to K^{(*)}(\phi)\mu\tau$	$\lambda'_{333}\lambda'_{232}$, $\lambda'_{233}\lambda'_{332}$, $\lambda'_{332}\lambda_{323}$	4.1×10^{-9}	1.2×10^{-7}	2.2×10^{-10}	$<2.8 \times 10^{-5}$ [207]
$B_s \to \tau\mu$	$\lambda'_{333}\lambda'_{232}$, $\lambda'_{233}\lambda'_{332}$, $\lambda'_{332}\lambda_{323}$	4.4×10^{-10}	1.3×10^{-8}	2.3×10^{-11}	$<3.4 \times 10^{-5}$ [208]
$b \to s\tau\tau$	$\lambda'_{333}\lambda'_{332}$	3.4×10^{-7}	2.8×10^{-8}	1.3×10^{-13}	N/A
$B \to K^{(*)}\tau\tau$	$\lambda'_{333}\lambda'_{332}$	3.7×10^{-6}	4.2×10^{-8}	9.6×10^{-12}	$<2.2 \times 10^{-3}$ [209]
$B_s \to \tau\tau$	$\lambda'_{333}\lambda'_{332}$	3.7×10^{-8}	3.0×10^{-9}	1.4×10^{-14}	$<6.8 \times 10^{-3}$ [210]
$b \to s\mu\mu$	$\lambda'_{233}\lambda'_{232}$, $\lambda'_{332}\lambda_{232}$	5.9×10^{-9}	3.2×10^{-8}	8.8×10^{-9}	4.4×10^{-6} [211]
$B_s \to \mu\mu$	$\lambda'_{233}\lambda'_{232}$, $\lambda'_{332}\lambda_{232}$	4.1×10^{-11}	6.5×10^{-11}	1.8×10^{-11}	3.0×10^{-9} [212]