

Status of lepton flavour universality tests at Belle and Belle II

Tommy Martinov

INFN, Trieste

On behalf of the Belle and Belle II collaborations

The Semileptonic B frontier, Frascati, 17.02.26

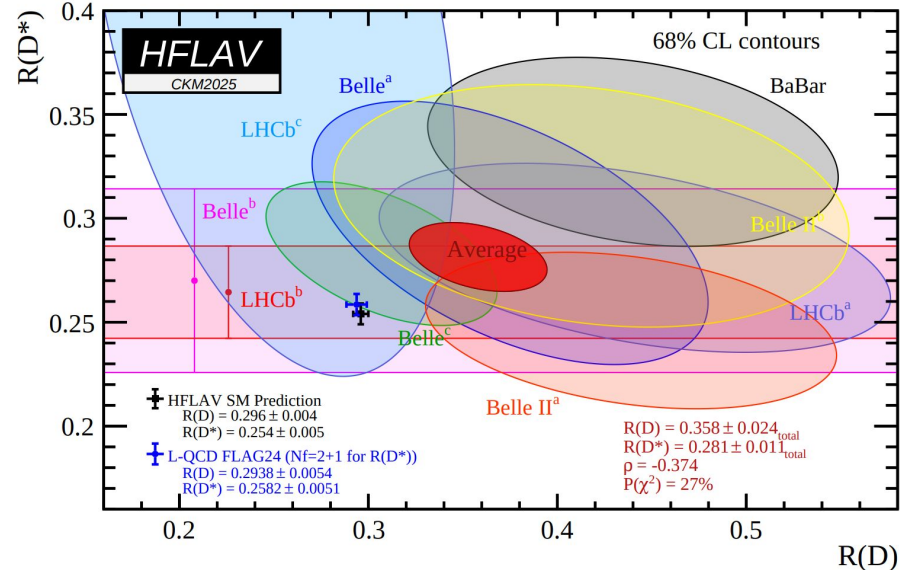


Introduction

Lepton flavour universality tests

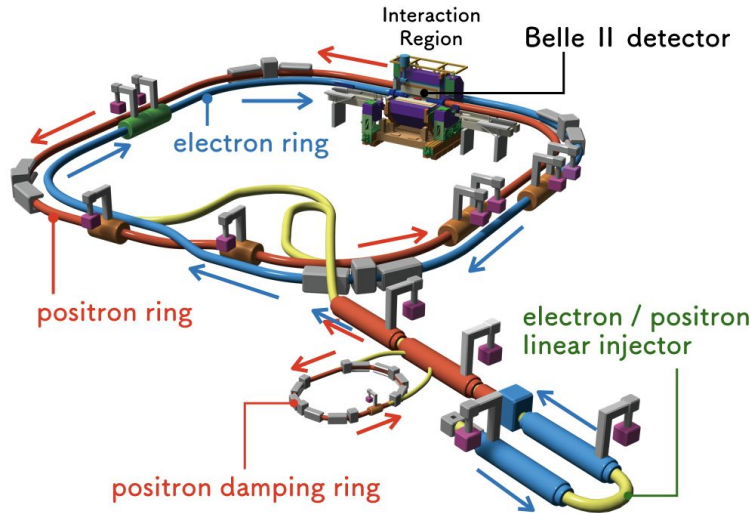
- Test **lepton flavour universality** by studying decays to **heavy τ leptons** versus **light e, μ leptons**
 - Observing lepton flavour universality violation would be a clear signature of non-SM couplings with the 3rd fermion generation
- Measurements by BaBar, Belle, LHCb and now Belle II
- Long standing **discrepancy** currently standing at **3.8σ** for the combined value of $R(D^{(*)})$
- Belle II also offers the possibility to test LFUV in angular asymmetries of SL decays

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



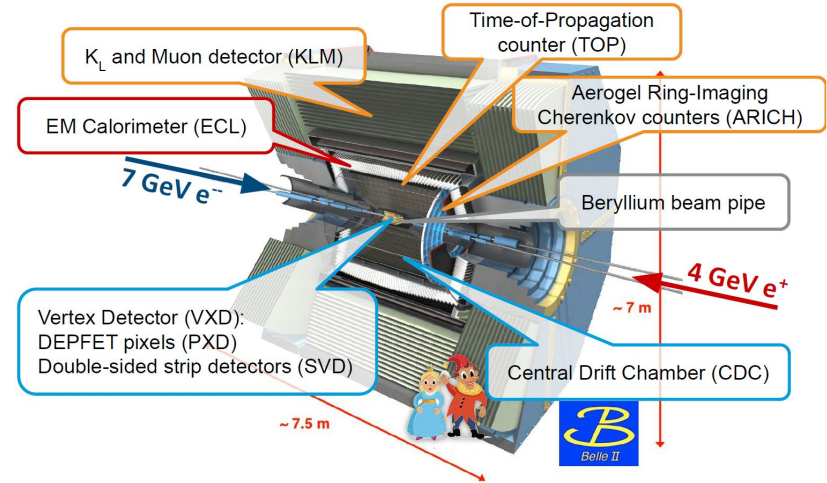
Experimental setup

SuperKEKB



Asymmetric-energy $e^+e^- \rightarrow Y(4S) \rightarrow B\bar{B}$
Centre-of-mass energy = 10.58 GeV
World record instantaneous luminosity
 $5.1 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ (27/12/2024)

Belle II



~ 4π spatial coverage

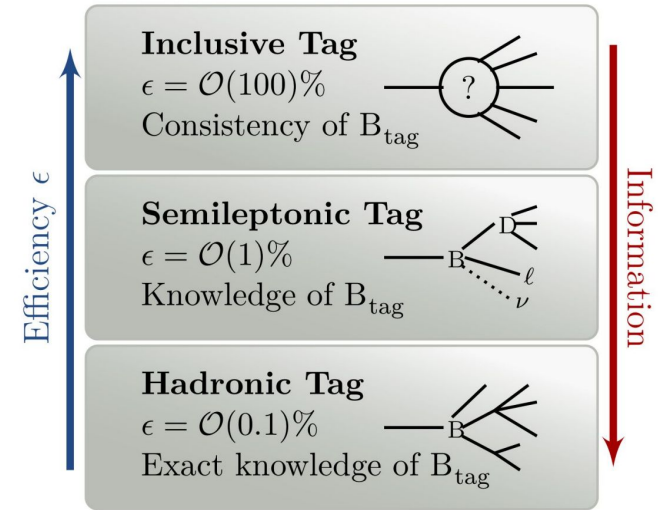
Well known initial state

⇒ Measurements with missing energy
+ Possibility to reconstruct neutral and soft particles

Run 1 luminosity: $365.37 \pm 1.70 \text{ fb}^{-1}$

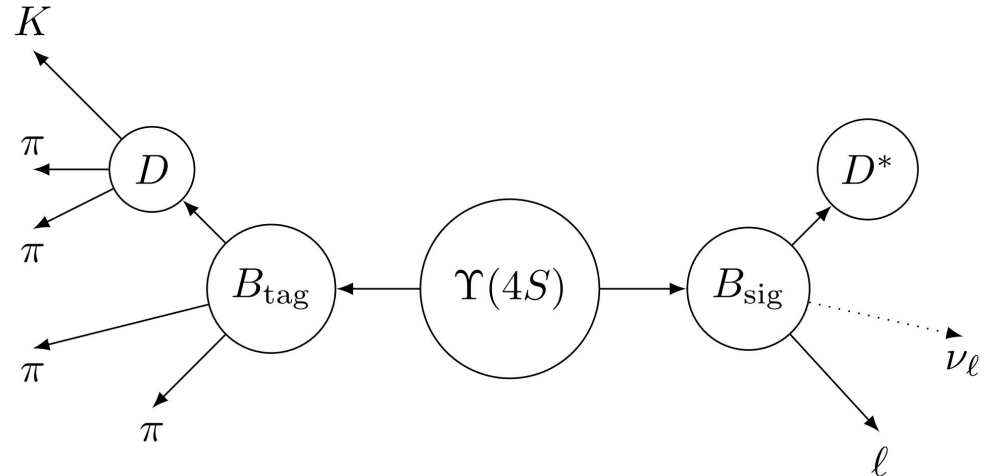
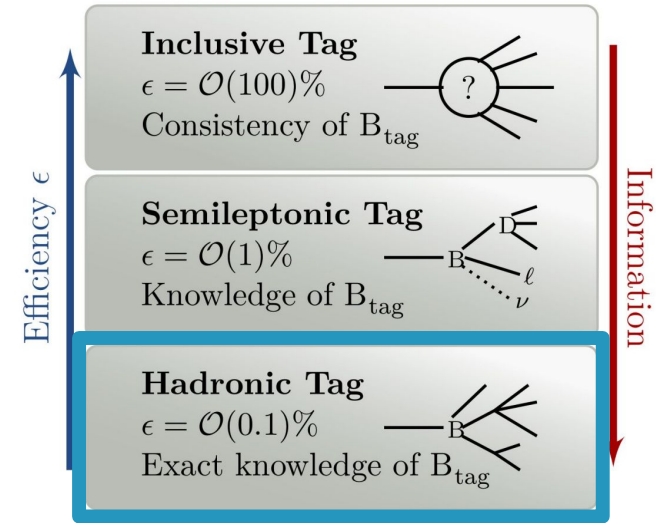
B-meson tagging

- Reconstruct one signal B decay and one partner B to constrain signal-side kinematics and suppress background



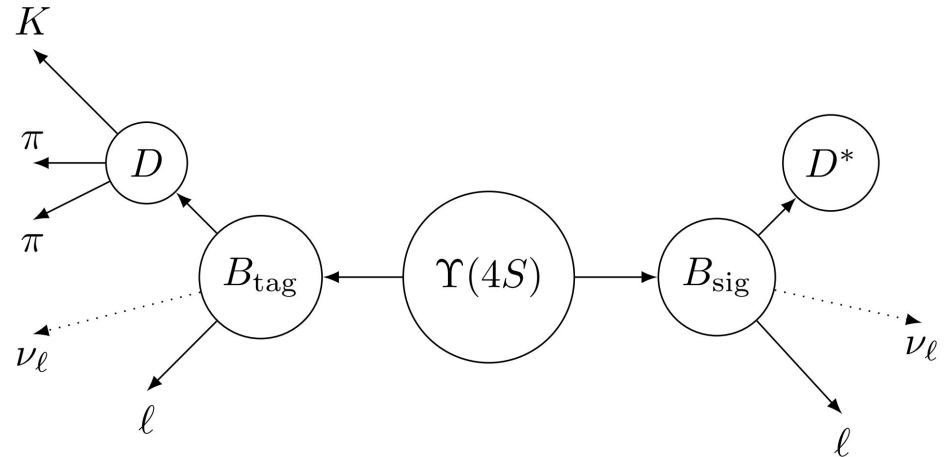
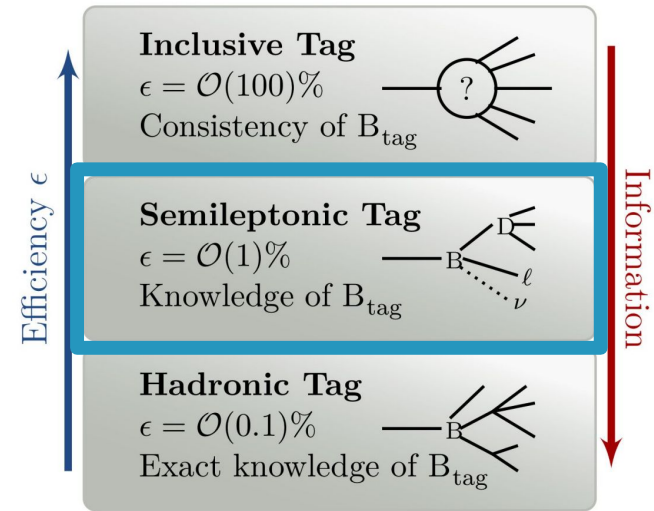
B-meson tagging

- Reconstruct one signal B decay and one partner B to constrain signal-side kinematics and suppress background
- Reconstruct tag B in its hadronic decays
- → tight kinematic constraints
 - No tag-side missing energy
- → high signal purity
- → low efficiency $\sim 0.5\%$



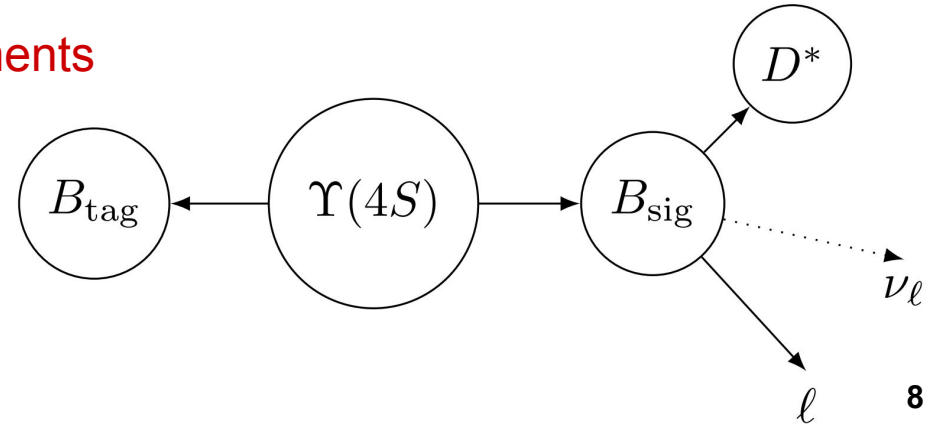
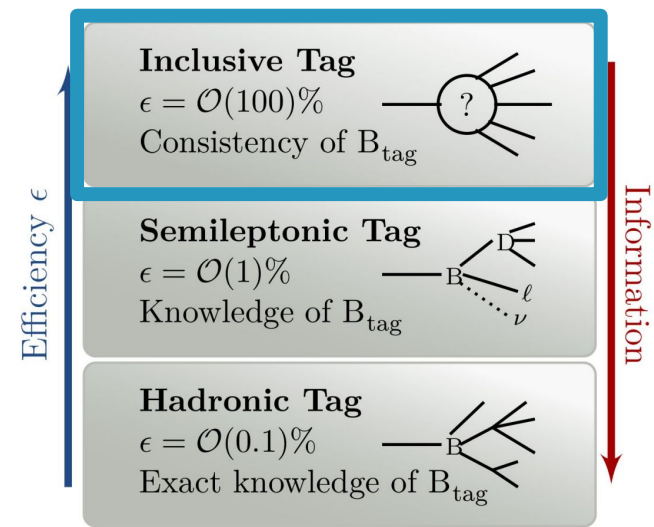
B-meson tagging

- Reconstruct one signal B decay and one partner B to constrain signal-side kinematics and suppress background
- Reconstruct tag B in its semileptonic decays
- → higher efficiency than hadronic tag $\sim 2\%$
 - $BF(B \rightarrow D^{(*)} | \nu) \sim 10\%$
- → less precise constraints
- → larger background



B-meson tagging

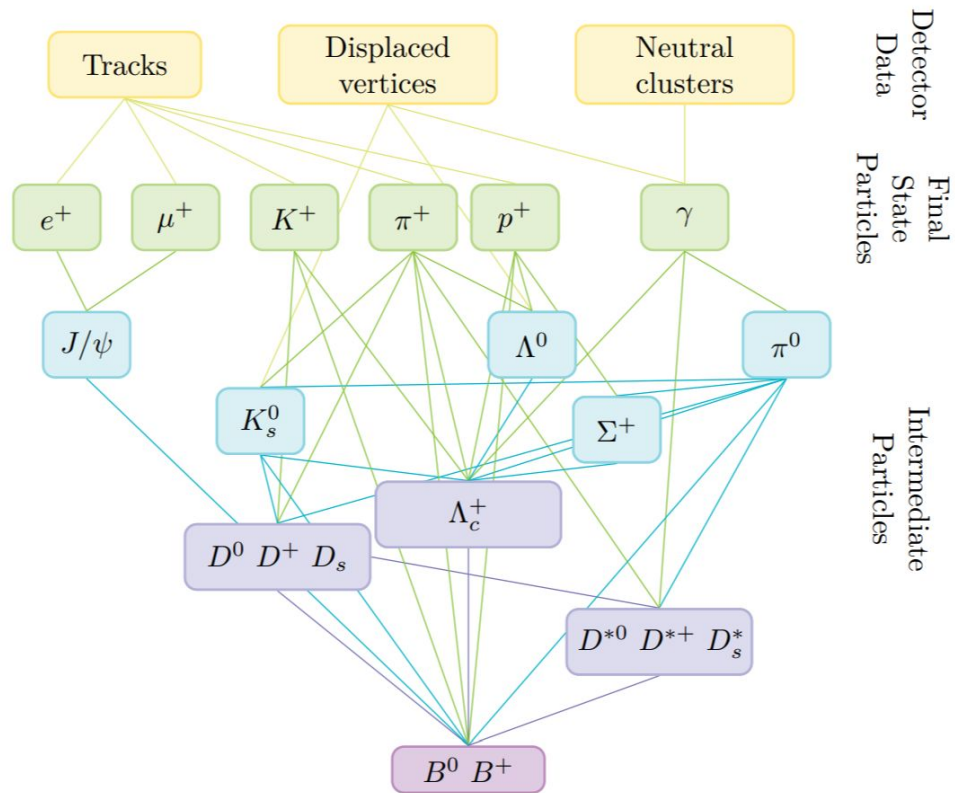
- Reconstruct one signal B decay and one partner B to constrain signal-side kinematics and suppress background
- Don't reconstruct tag B
- → very high efficiency $\sim 100\%$
- → no kinematic constraints
- Rarely used in semileptonic measurements



B-meson tagging

Full Event Interpretation

- Hierarchical approach to reconstruct B mesons
- $\sim 10^4$ decay chains
- At each stage, the reconstruction quality of a particle is determined using a BDT
- Similar method in Belle: Full Reconstruction (FR)
- FEI reconstruction efficiency $\sim 2.5\times$ larger than Belle FR

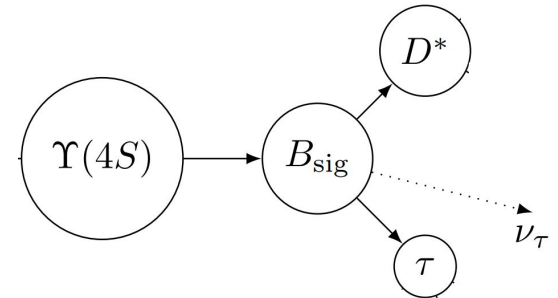


A quick guide to test LFU at Belle II



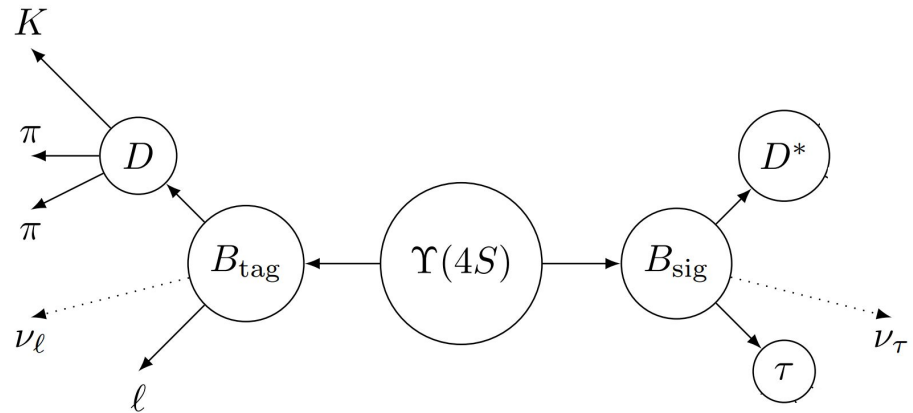
A quick guide to test LFU at Belle II

- Pick your hadronic system
 - D, D^* , inclusive system (unique to Belle II !)
 - Cannot measure $R(D)$ only because of feed-down background $B \rightarrow D^* \tau \nu$ which is hard to distinguish from $B \rightarrow D \tau \nu$



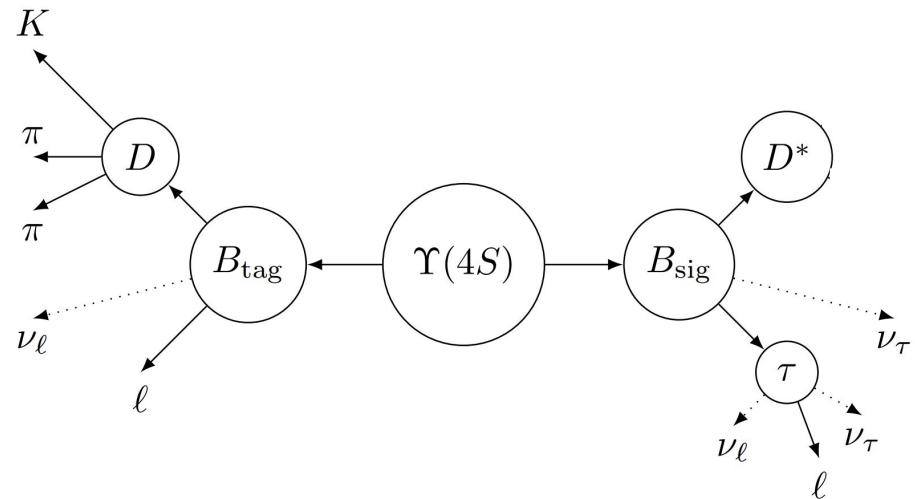
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 - Hadronic, semileptonic, inclusive



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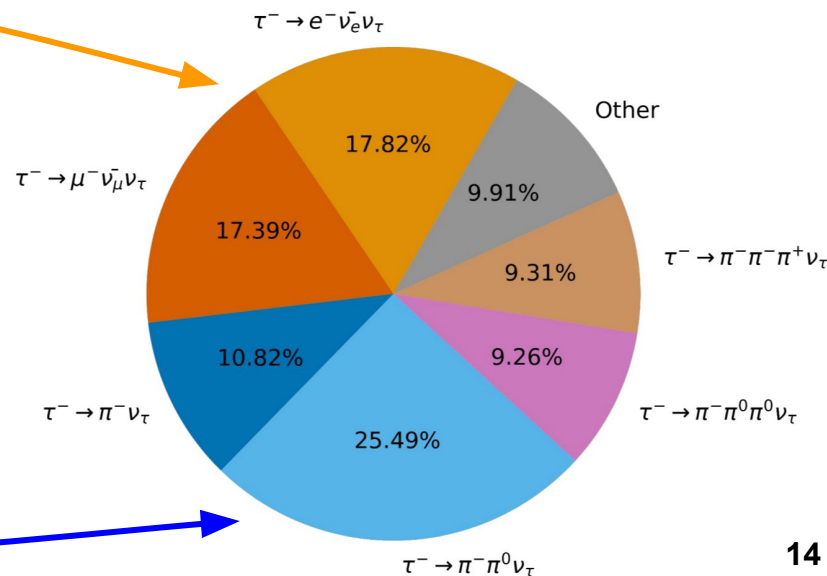
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 - Leptonic, hadronic



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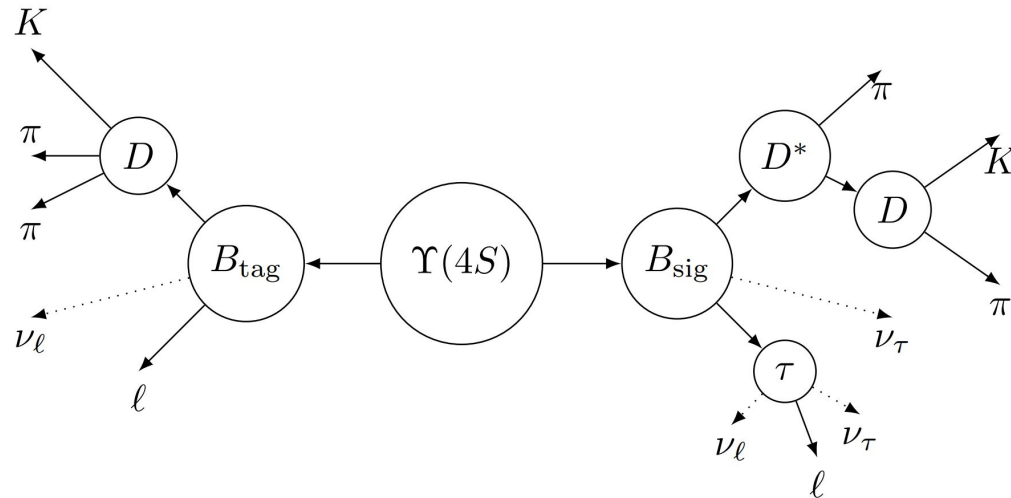
- Pick your hadronic system
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- Pick your tagging strategy
 - Hadronic, semileptonic, inclusive
- Pick your τ decays
 - **Leptonic**
 - **Hadronic**
 - More background from hadronic decays
 - Reconstruction of π^0
 - 1 neutrino \rightarrow measure τ polarisation



A quick guide to test LFU at Belle II

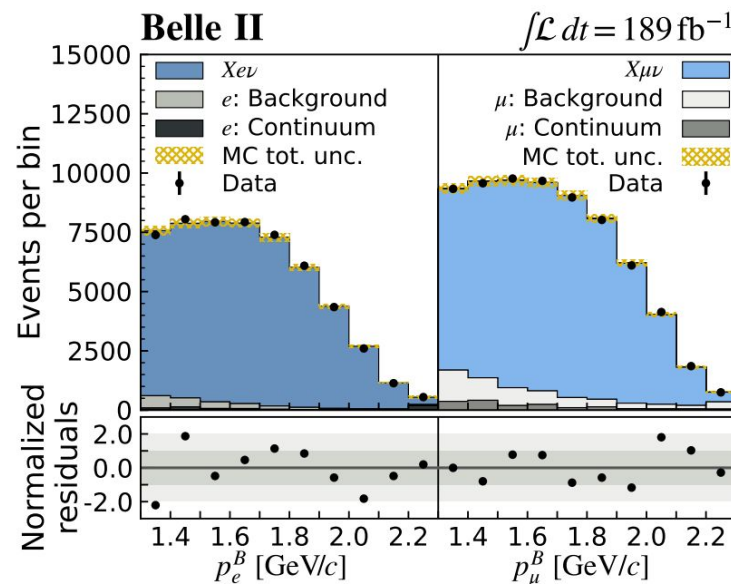


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 - D, D^* , inclusive system (unique to Belle II !)
- Pick your tagging strategy
 - Hadronic, semileptonic, inclusive
- Pick your τ decays
 - Leptonic, hadronic
- Pick your D/D^* decays



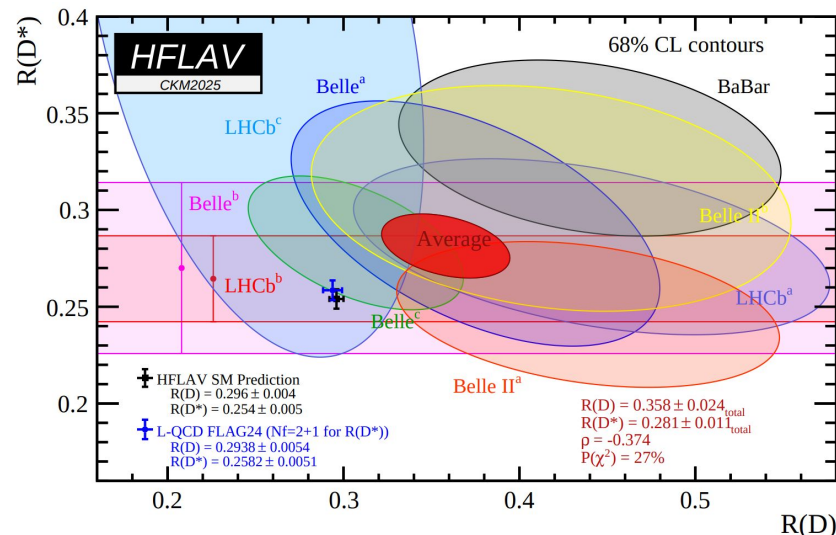
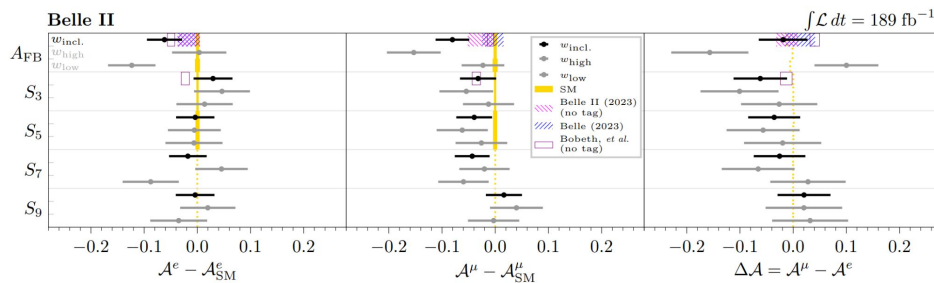
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- Pick your hadronic system
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- Pick your tagging strategy
 - Hadronic, semileptonic, inclusive
- Pick your τ decays
 - Leptonic, hadronic
- Pick your D/D^* decays
- Pick your fit variables



A quick guide to test LFU at Belle II

- Pick your hadronic system
 - D, D^* , inclusive system (unique to Belle II !)
- Pick your tagging strategy
 - Hadronic, semileptonic, inclusive
- Pick your τ decays
 - Leptonic, hadronic
- Pick your D/D^* decays
- Pick your fit variables
- → measure your LFU ratio or asymmetry



Common features

Common variables

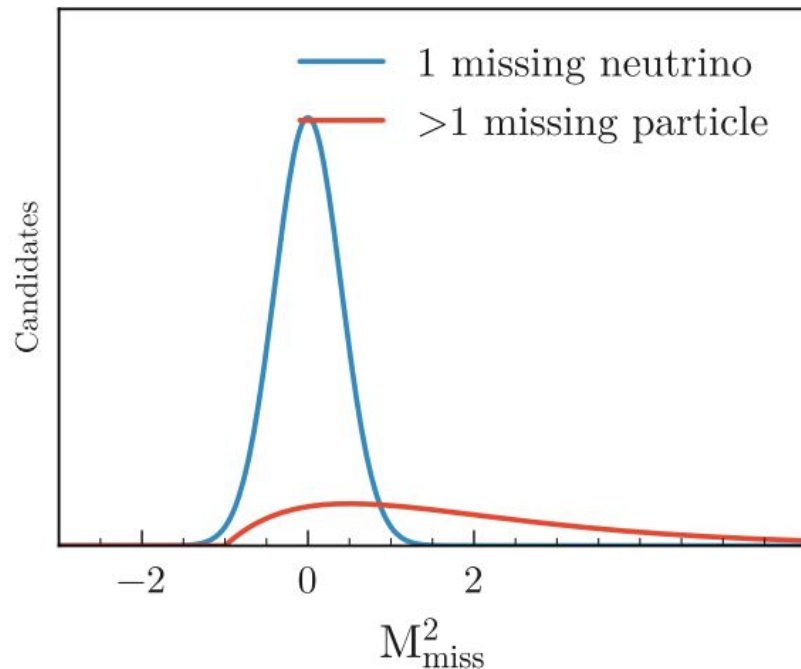
- Leptonic system mass squared: q^2
 - Recoil parameter w

$$q^2 = (p_\ell + p_{\nu_\ell})^2 \quad w = \frac{M_B^2 + M_D^2 - q^2}{2M_B M_D}$$

Common features

Common variables

- Leptonic system mass squared: q^2
 - Recoil parameter w
- Missing mass: M_{miss}^2



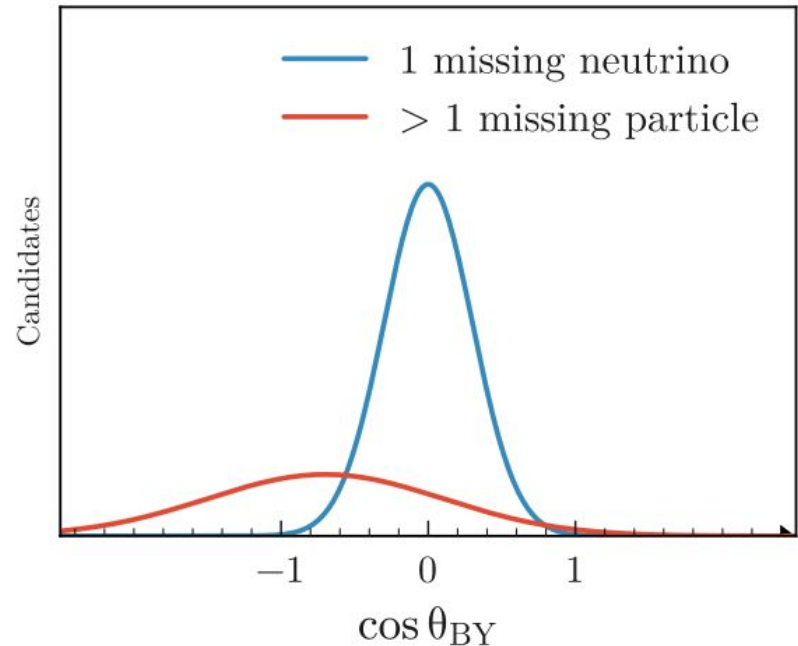
Common features

Common variables

- Leptonic system mass squared: q^2
 - Recoil parameter w
- Missing mass: M_{miss}^2
- $\cos \theta_{BY}$

$$\cos \theta_{BY} = \frac{2 E_B^* E_Y^* - M_B^2 - M_Y^2}{2 |p_B^*| |p_Y^*|}$$

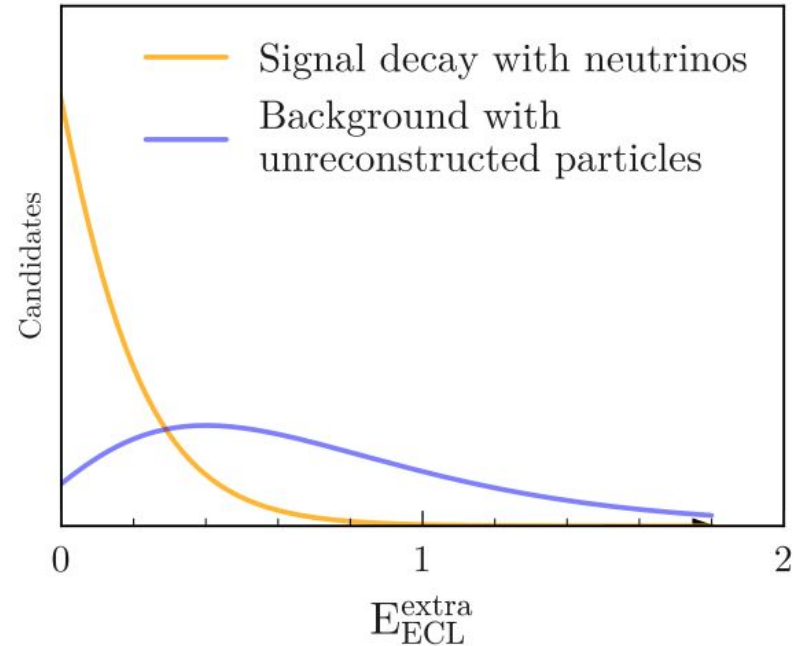
$Y = D/l$ system



Common features

Common variables

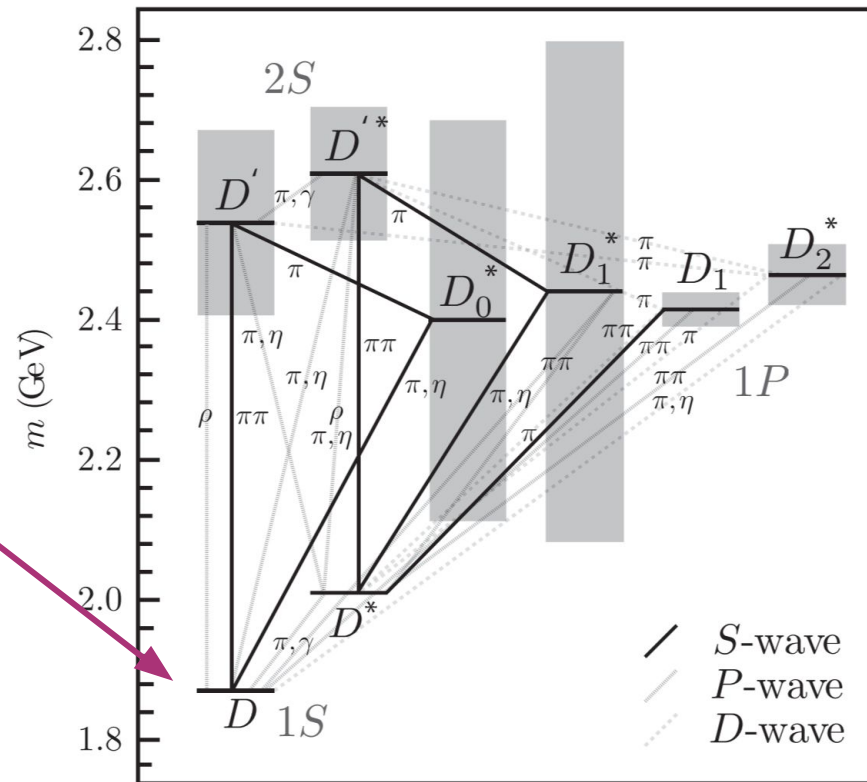
- Leptonic system mass squared: q^2
 - Recoil parameter w
- Missing mass: M_{miss}^2
- $\cos \theta_{BY}$
- Total energy of neutral clusters not used in B_{tag} or hadronic system:
 E_{ECL}



Common features

Modelling of SL decays to charm mesons

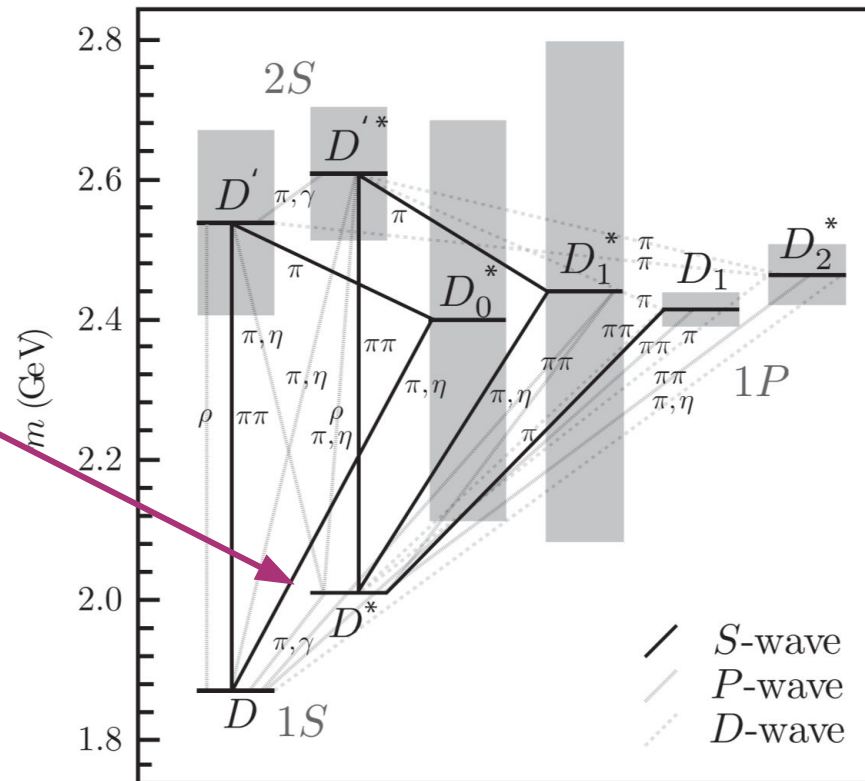
- $B \rightarrow D | v$



Common features

Modelling of SL decays to charm mesons

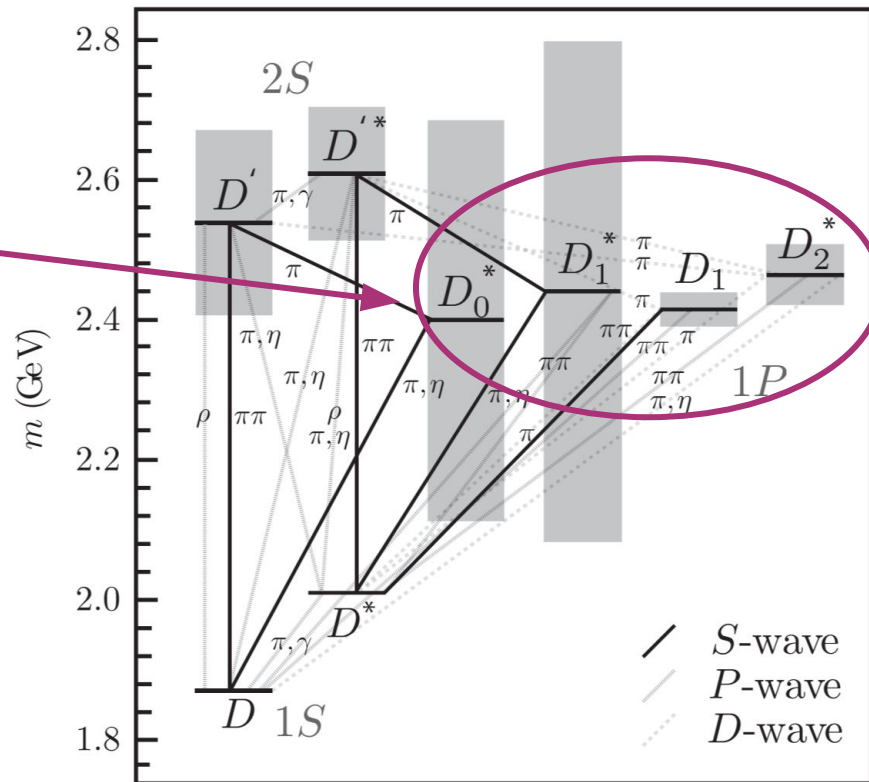
- $B \rightarrow D | \nu$
- $B \rightarrow D^* | \nu$



Common features

Modelling of SL decays to charm mesons

- $B \rightarrow D | v$
- $B \rightarrow D^* | v$
- $B \rightarrow D^{**} | v$

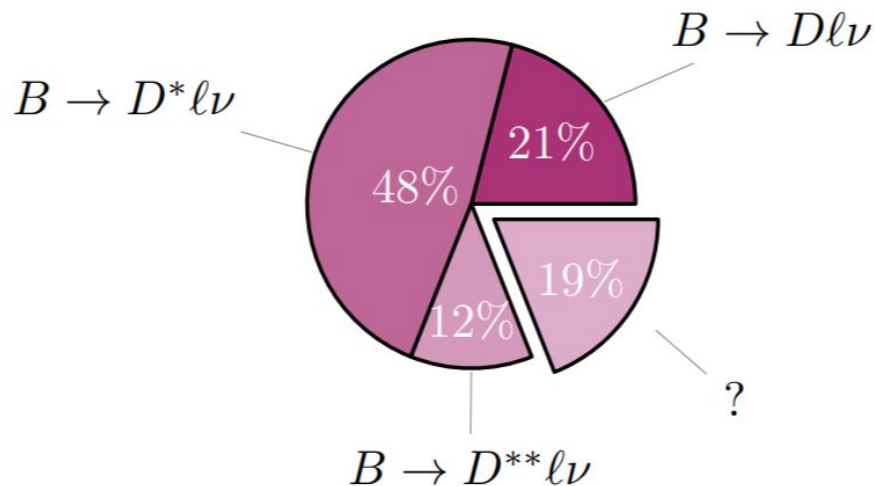


Common features

Modelling of SL decays to charm mesons

- $B \rightarrow D / \nu \sim 2.2\%$
- $B \rightarrow D^* / \nu \sim 5.1\%$
- $B \rightarrow D^{**} / \nu \sim 1.3\%$
- + small contribution from
 - $B \rightarrow D^{(*)} \pi \pi / \nu$
 - $B \rightarrow D_s^{(*)} K / \nu$
- \Rightarrow about $\frac{1}{5}$ about $B \rightarrow X_c / \nu$ decays not included

Total $B \rightarrow X_c / \nu$ inclusive BF $\sim 10.6\%$

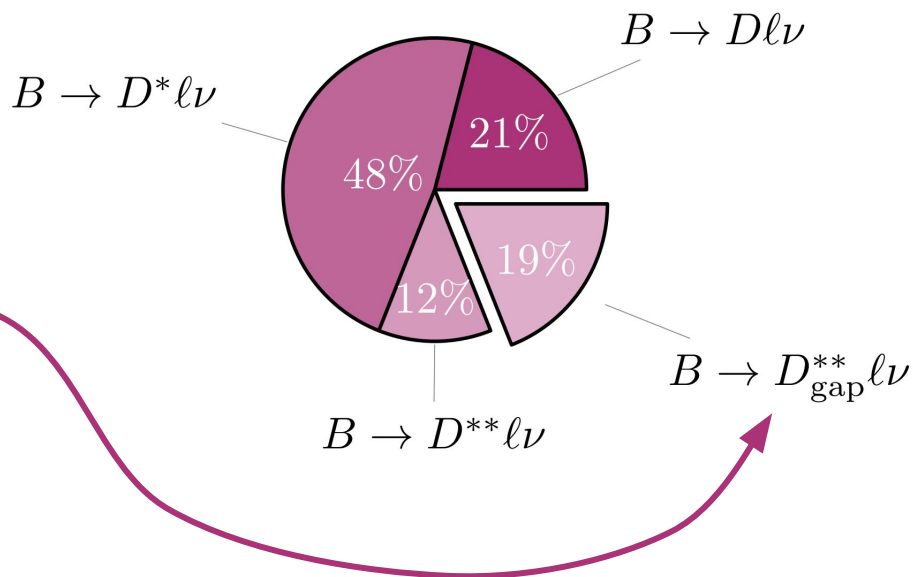


Common features

Modelling of SL decays to charm mesons

- $B \rightarrow D \ell \nu \sim 2.2\%$
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- \Rightarrow about $\frac{1}{5}$ about $B \rightarrow X_c \ell \nu$ decays not included
- \Rightarrow add $B \rightarrow D^{(*)} \eta \ell \nu$ decays simulated via decays of D^{**} resonances \rightarrow 100% BF uncertainty

Total $B \rightarrow X_c \ell \nu$ inclusive BF $\sim 10.6\%$

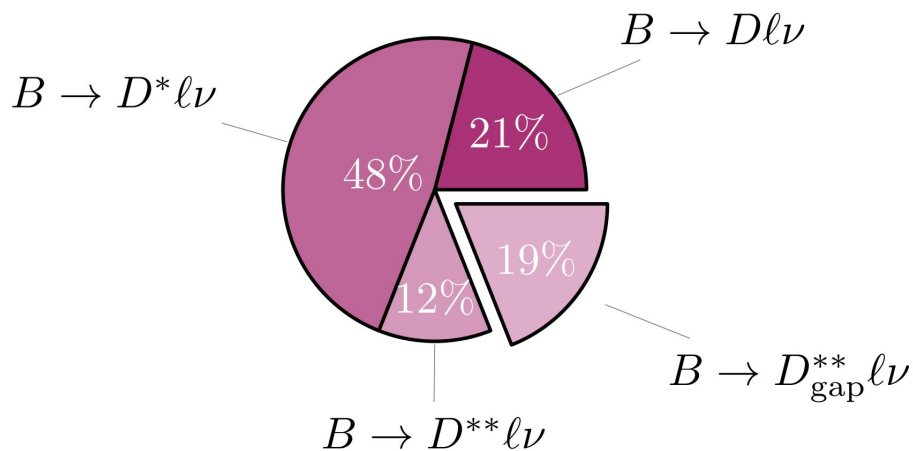


Common features

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- Form factor modelling of all $B \rightarrow X_c \ell \nu$ decays updated using Hammer

Total $B \rightarrow X_c \ell \nu$ inclusive BF $\sim 10.6\%$



LFU tests at Belle II

Presented today

- $R(D)$ and $R(D^*)$ with hadronic tag
- $R(D^+)$ and $R(D^{*+})$ with semileptonic tag
- $R(X_{e/\mu})$ and $R(X_{\tau/l})$
- Angular asymmetries in $B^0 \rightarrow D^* l \nu$

$R(D^{(*)})$ measurement with hadronic tag at Belle II

$R(D^{(*)})$ with hadronic tag

To be submitted

- This measurement supersedes the previous $R(D^*)$ measurement with hadronic tag
 - ~2× more data
 - Extends to $R(D)$
- Efficiency is maximised by reconstructing all D^* decay modes and 13 D decay modes
 - $D^{*+} \rightarrow D^0\pi^+, D^+\pi^0$
 - $D^{*0} \rightarrow D^0\pi^0, D^0\gamma$

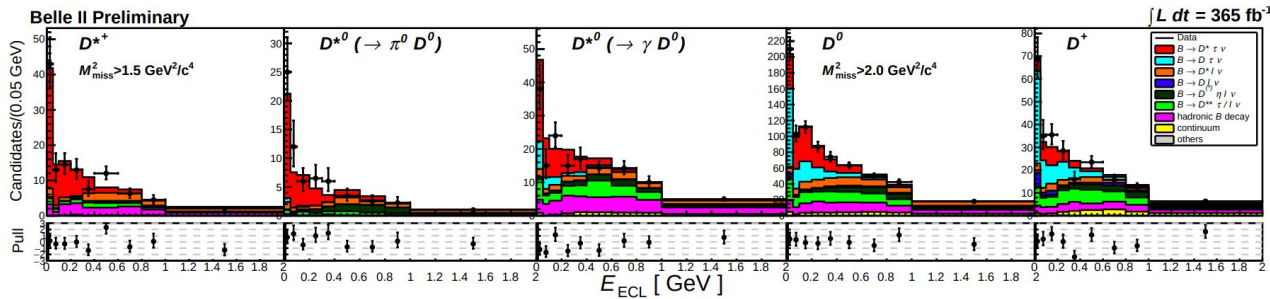
Signal
Normalisation dominates
Dominant backgrounds

	D^{*+}	$D_{[D^0\pi^0]}^{*0}$	$D_{[D^0\gamma]}^{*0}$	D^0	D^+
$B \rightarrow D^*\tau\nu$	124 ± 10	64 ± 5	107 ± 8	380 ± 30	63 ± 5
$B \rightarrow D\tau\nu$	0 ± 0	2 ± 0	32 ± 4	340 ± 43	148 ± 19
$B \rightarrow D^*\ell\nu$	2899 ± 66	1417 ± 32	2598 ± 59	10638 ± 235	1624 ± 37
$B \rightarrow D\ell\nu$	4 ± 0	7 ± 0	215 ± 7	2882 ± 87	1226 ± 37
$B \rightarrow D^{**}\tau/(\ell)\nu$	60 ± 31	29 ± 24	191 ± 58	731 ± 134	294 ± 64
gap modes	21 ± 25	42 ± 15	53 ± 50	240 ± 94	90 ± 46
hadronic B decay	86 ± 25	4 ± 12	166 ± 38	469 ± 95	126 ± 25
continuum	3	2	33	181	84
other backgrounds	0	0	0	1	4
Total	3197	1567	3395	15862	3659

$R(D^{(*)})$ with hadronic tag

To be submitted

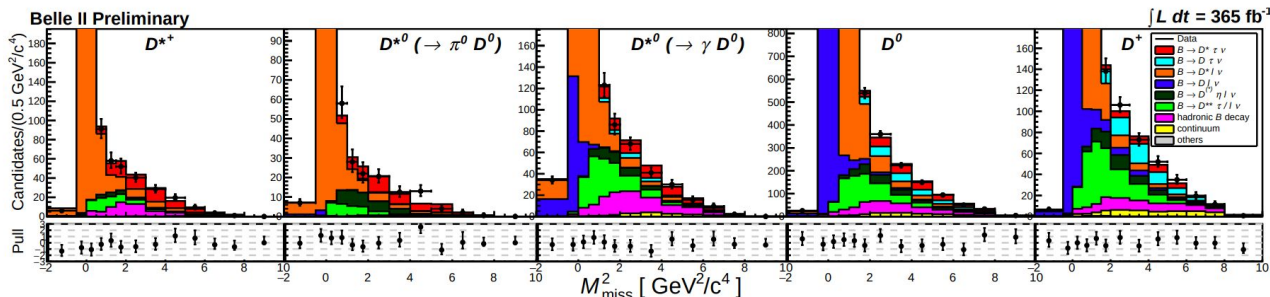
- Main backgrounds are validated using $B \rightarrow D^* \pi^0 / \nu$ events
 - From a fit to this sideband, gap modes appear to be smaller than expected
 - confirmed in the main fit (40–80% less)
- Binned extended maximum-likelihood fit to E_{ECL} and M^2_{miss}



$$B \rightarrow D^* \tau \nu$$

$$B \rightarrow D \tau \nu$$

Normalisation
modes



$R(D^{(*)})$ with hadronic tag

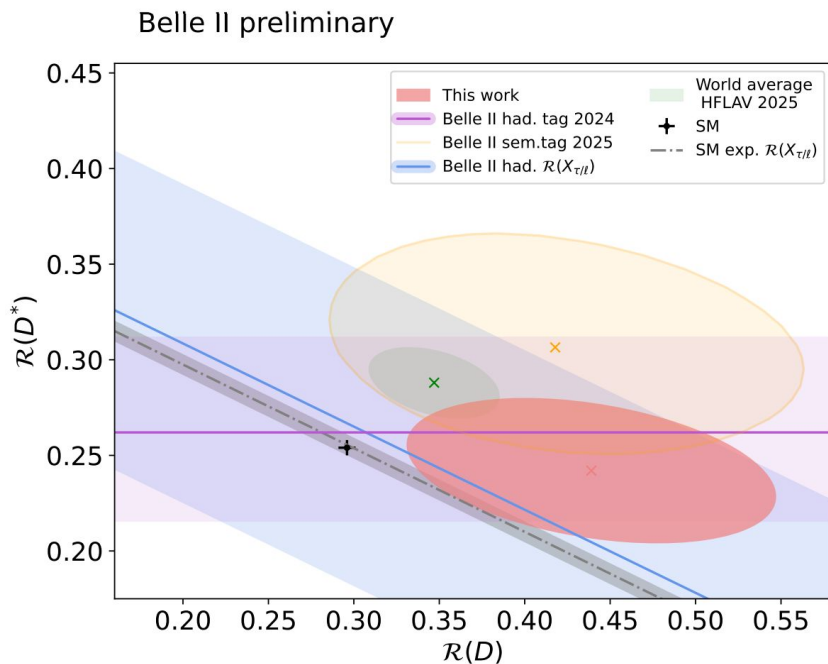
Result

$$R(D^*) = 0.242 \pm 0.019(\text{stat.}) \pm 0.016(\text{sys.})$$

$$R(D) = 0.439 \pm 0.055(\text{stat.}) \pm 0.045(\text{sys.})$$

$$\rho = -0.4(\text{stat.}) + 0.2(\text{sys.})$$

Most precise determination of $R(D^{(*)})$
with hadronic tagging



$R(D)$ agrees within 2.0σ with SM

$R(D^*)$ agrees within 0.5σ with SM

Combination agrees within 1.3σ with world average and within 1.5σ with SM prediction

$R(D^{(*)})$ with hadronic tag

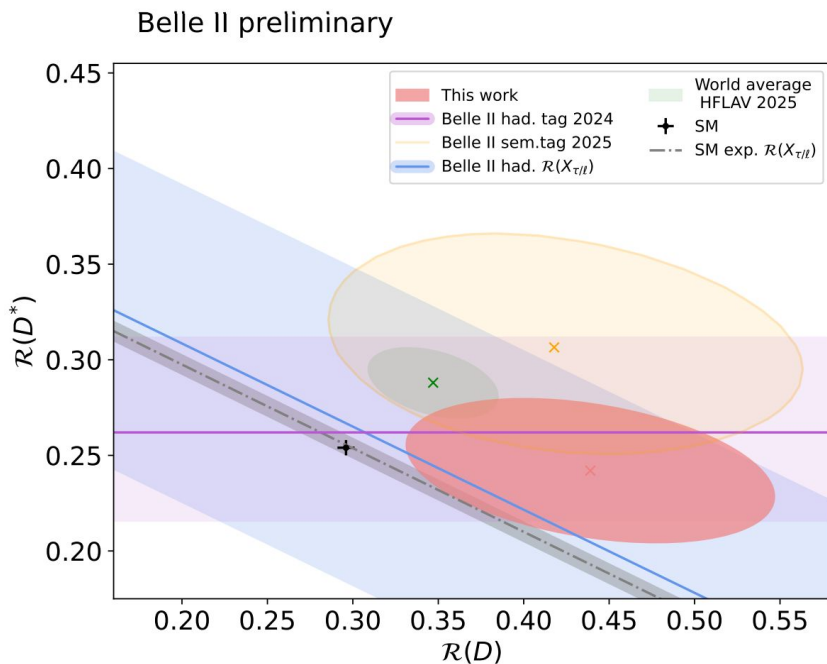
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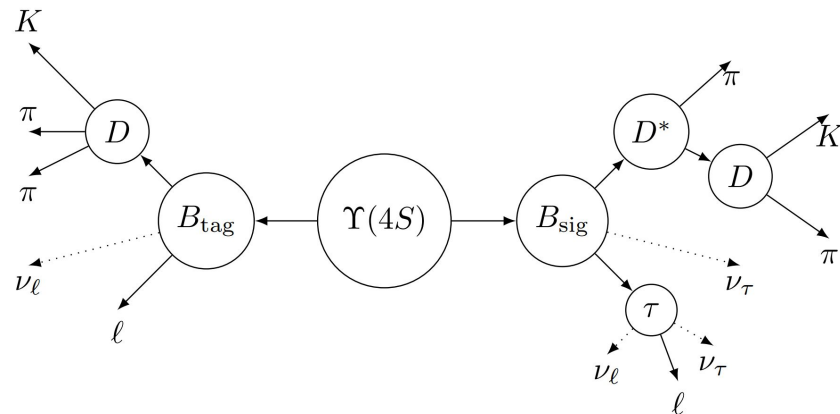
Source	$R(D^*)$	$R(D)$	ρ
Simulation sample size	4.8%	8.4%	-0.44
gap-mode branching fraction	2.6%	2.6%	0.00
$B \rightarrow D^{**}\tau^- / (\ell^-)\bar{\nu}_\ell$ branching fractions	0.3%	1.3%	0.25
Hadronic B decay branching fractions	1.6%	1.5%	-0.26
Form factors	0.5%	0.9%	-0.70
Fraction of misreconstructed $D^{(*)}$	0.5%	1.2%	0.00
Continuum background	2.4%	2.1%	0.93
Fit biases	0.3%	1.2%	0.00
Low-momentum π^0, γ efficiency	2.2%	2.4%	0.99
Other efficiency corrections	0.7%	1.4%	0.92
B -tagging efficiency of data	0.9%	1.8%	-1.00
B -tagging efficiency of $B \rightarrow D\tau\nu$	0.1%	1.8%	1.00
M_{miss}^2 resolution	0.5%	0.8%	0.48
Total systematic uncertainty	6.7%	10.2%	-0.20
Statistical uncertainty	8.3%	16.3%	-0.40

$R(D^{(*)})$ measurement with semileptonic tag at Belle II

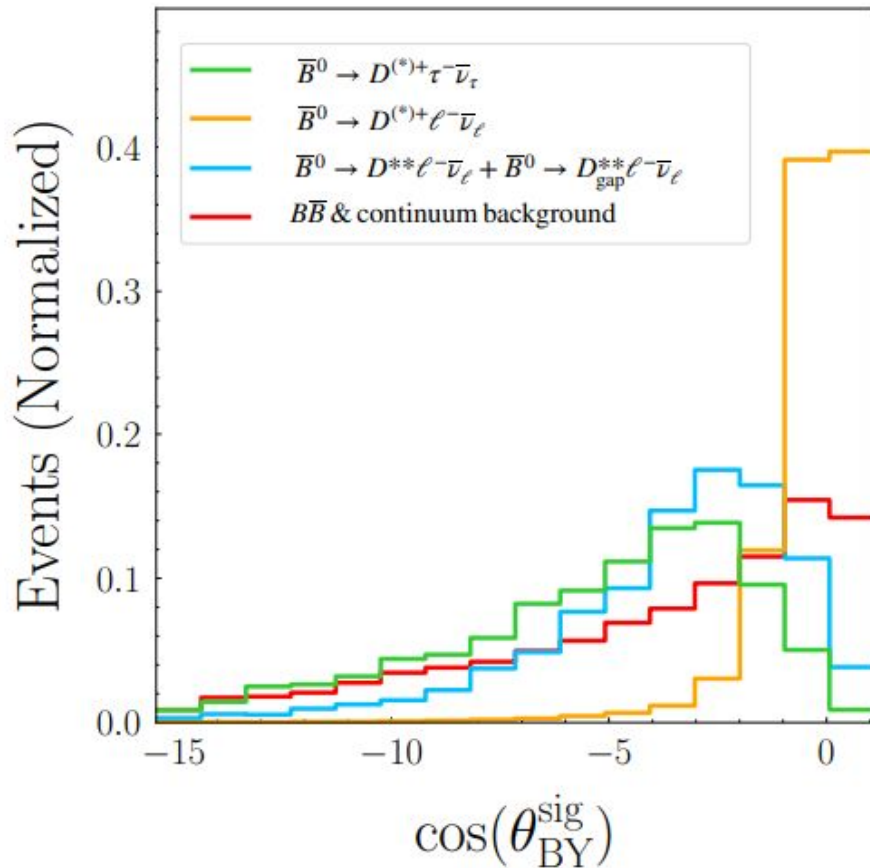
$R(D^{(*)})$ measurement at Belle II

PRD 112, 032010 (2025)

- Performed with B^0 decays and semileptonic tag
 - $B_{tag} \rightarrow D/D^* l \nu$
- τ are reconstructed in their **leptonic decay channels**
 - $\tau \rightarrow l \nu \nu$
 - Reject τ on the tag-side to avoid cross-feed
 - Lepton momentum > 1 GeV on tag-side
- D mesons on both sides are reconstructed through **various decays to K^+ , K_S , π^+ , π^0**
 - Tag side: 26 decay modes
 - Signal side: 13 decays modes



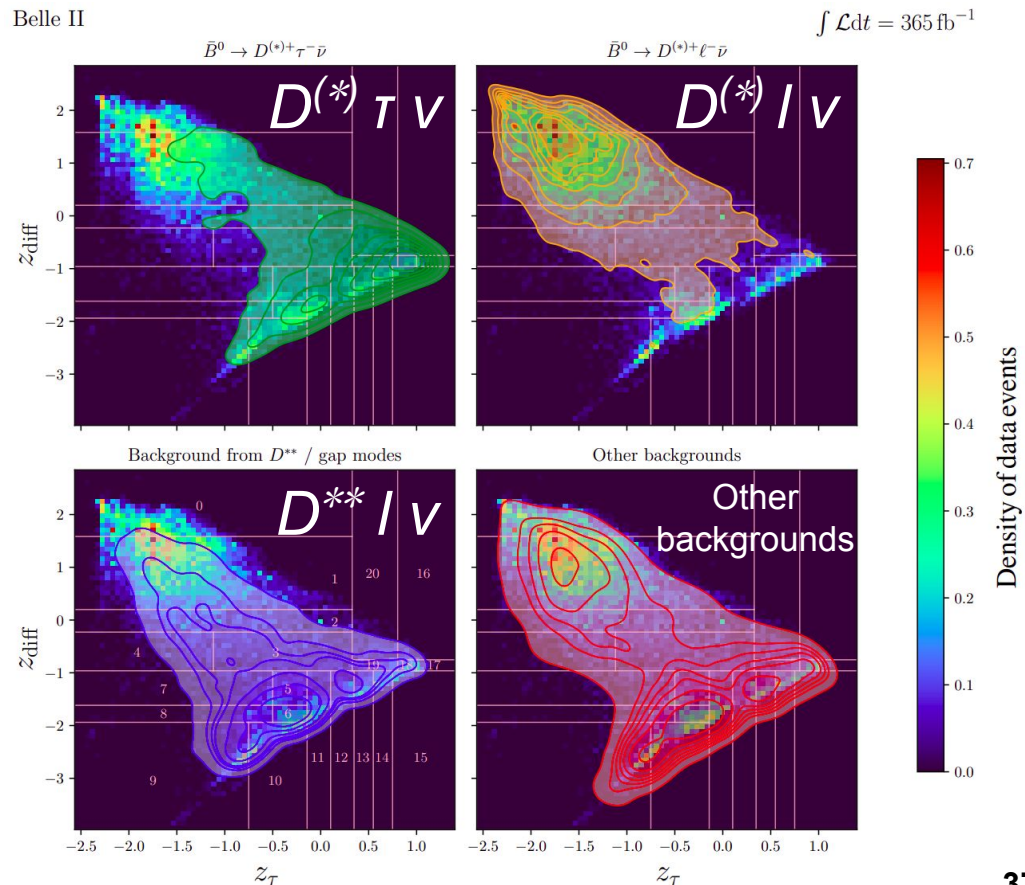
- A **BDT** algorithm is used to separate the **events in 3 classes**
 - Semitauonic signal events
 - Semileptonic events
 - Background events
- Most **discriminating** input feature is $\cos\theta_{BY}$



$R(D^{(*)})$ measurement at Belle II

PRD 112, 032010 (2025)

- A **BDT** algorithm is used to separate the **events in 3 classes**
 - Semitauonic signal events
 - Semileptonic events
 - Background events
- Most **discriminating** input feature is $\cos\theta_{BY}$
- Each event is assigned a BDT score z_τ , z_l , z_{bkg}
- The signal is extracted in a **2D binned template fit** of z_τ and $z_{diff} = z_l - z_{bkg}$



$R(D^{(*)})$ measurement at Belle II

Results

- Fit performed over 4 separate channels: D^+e^- , $D^+\mu^-$, $D^{*+}e^-$, $D^{*+}\mu^-$
- Measurement is statistically limited
- The leading systematic uncertainties are
 - The finite size of the simulated samples
 - The lepton identification efficiency and fake rate corrections

$$\mathcal{R}(D^+) = 0.418 \pm 0.075(\text{stat}) \pm 0.056(\text{syst})$$

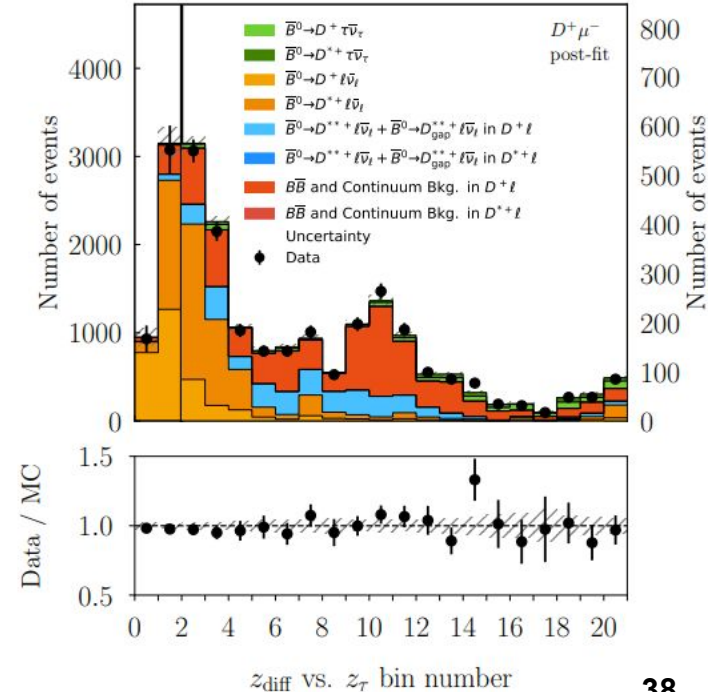
$$\mathcal{R}(D^{*+}) = 0.306 \pm 0.035(\text{stat}) \pm 0.018(\text{syst})$$

$D^{(*)} \tau \nu$

$D^{(*)} l \nu$

$D^{*+} l \nu$

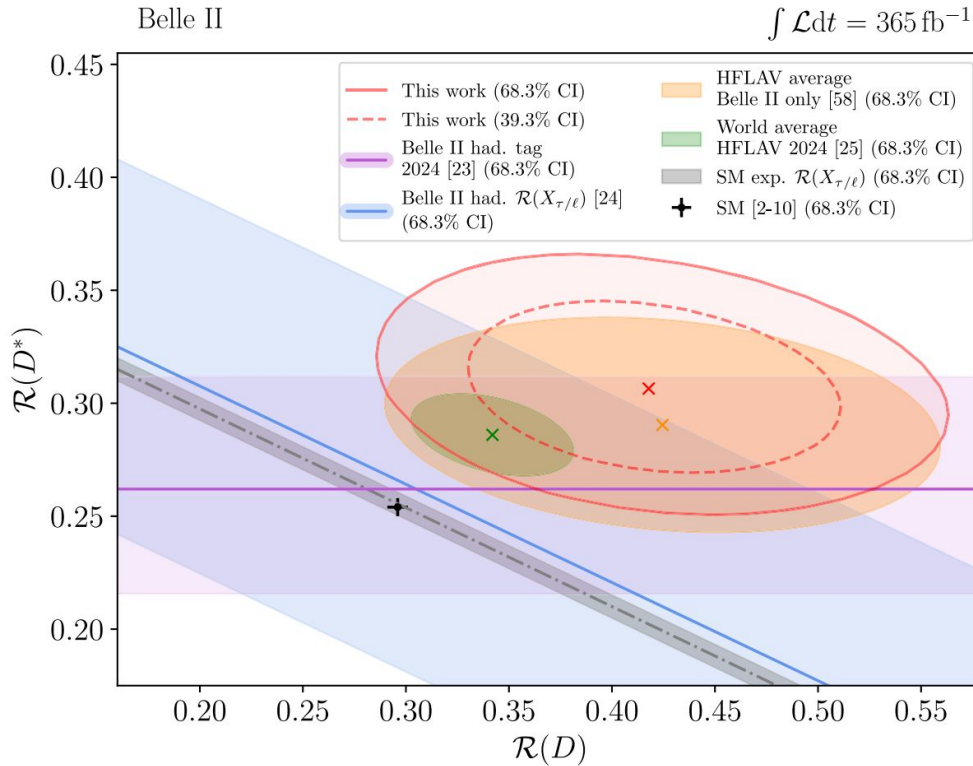
Backgrounds



$R(D^{(*)})$ measurement at Belle II

Results

PRD 112, 032010 (2025)

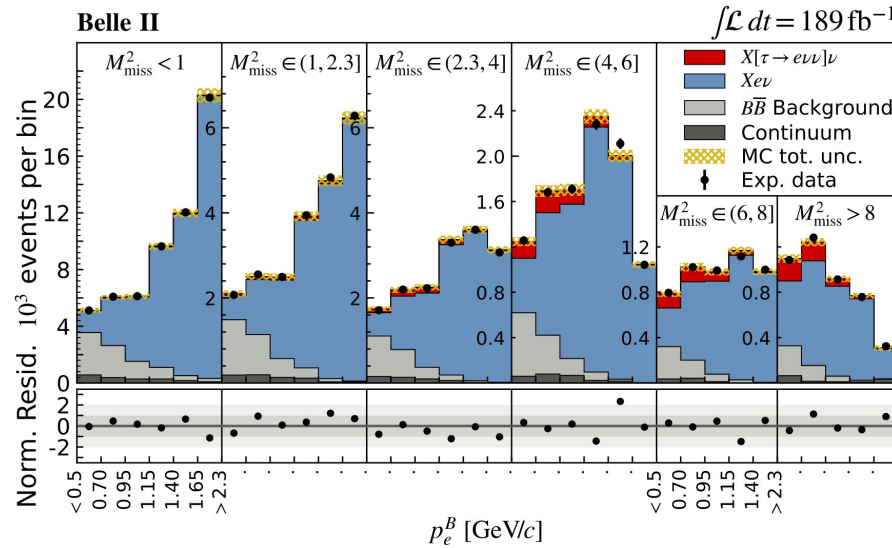


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Combination agrees within 0.6σ with world average and within 1.7σ with SM prediction

$R(X)$ measurement with hadronic tag at Belle II

- Observed mismodelling for the measurement of $R(X_{T/l})$
 - Suspect #1: D meson decays, in particular decays involving a K_L
 - → extract correction factors in bins of hadronic system mass in high-lepton-momentum region
- Fit to lepton momentum to extract $R(X_{e/\mu})$
- Fit to lepton momentum and M^2_{miss} to extract $R(X_{T/l})$



- $R(X_{e/\mu})$ compatible with SM prediction: 1.006 ± 0.001
- $R(X_{\tau/\ell})$ compatible with SM prediction: 0.223 ± 0.005

$$R(X_{e/\mu}) = 1.007 \pm 0.009 \text{ (stat)} \pm 0.019 \text{ (syst)}$$

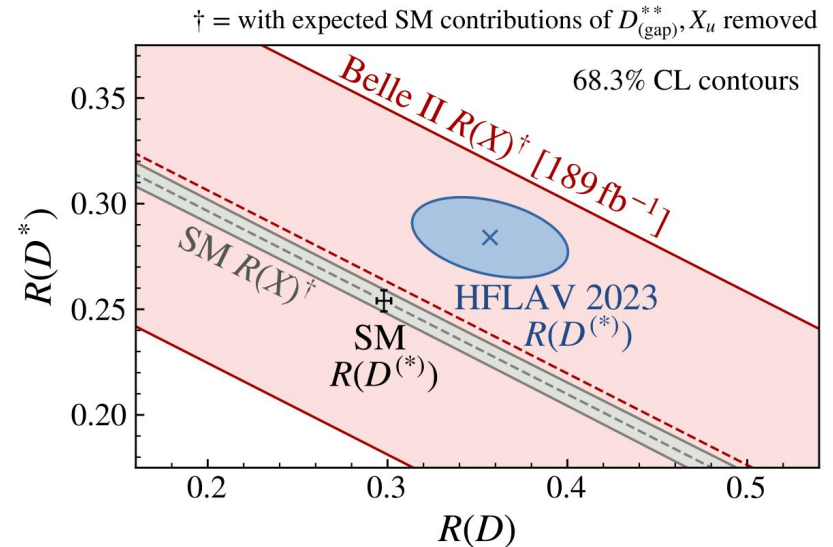
$$R(X_{\tau/\ell}) = 0.228 \pm 0.016 \text{ (stat)} \pm 0.036 \text{ (syst)}$$

Source	Uncertainty [%]		
	e	μ	ℓ
Experimental sample size	8.8	12.0	7.1
Simulation sample size	6.7	10.6	5.7
Tracking efficiency	2.9	3.3	3.0
Lepton identification	2.8	5.2	2.4
$X_c \ell \nu$ reweighting	7.3	6.8	7.1
$B\bar{B}$ background reweighting	5.8	11.5	5.7
$X \ell \nu$ branching fractions	7.0	10.0	7.7
$X \tau \nu$ branching fractions	1.0	1.0	1.0
$X_c \tau(\ell) \nu$ form factors	7.4	8.9	7.8
Total	18.1	25.6	17.3

- $R(X_{e/\mu})$ compatible with SM prediction: 1.006 ± 0.001
- $R(X_{\tau/\ell})$ compatible with SM prediction: 0.223 ± 0.005
- Subtract contribution from D^{**} , gap and charmless hadronic systems yields constraint on $R(D)$ and $R(D^*)$

$$R(X_{e/\mu}) = 1.007 \pm 0.009 \text{ (stat)} \pm 0.019 \text{ (syst)}$$

$$R(X_{\tau/\ell}) = 0.228 \pm 0.016 \text{ (stat)} \pm 0.036 \text{ (syst)}$$



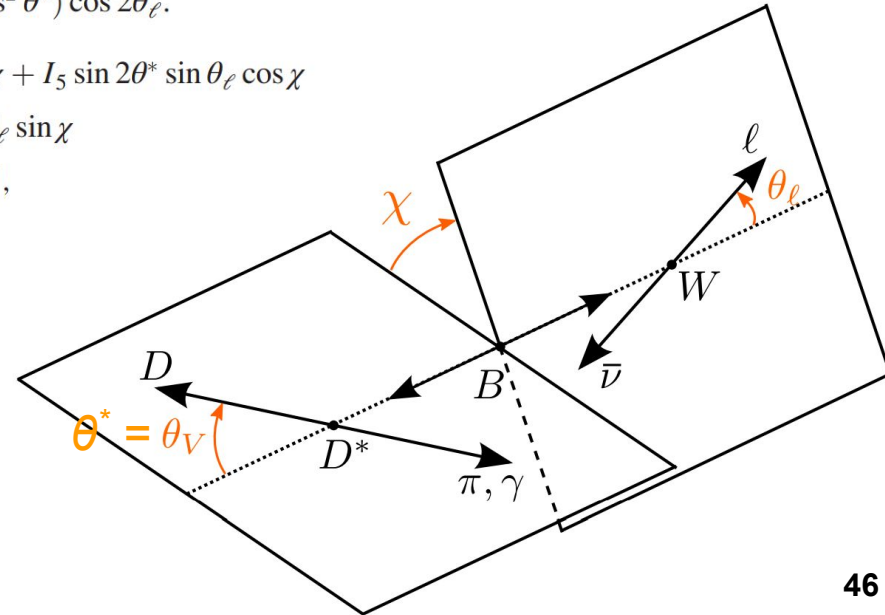
Angular asymmetries in $B \rightarrow D^* l \nu$ decays

Angular asymmetries

PRL 131, 181801 (2023)

- 3 relevant angles in $B \rightarrow D^* l \nu$ decays
- 4D differential decay rate expressed as 8 helicity amplitudes

$$\begin{aligned} \frac{d^4\Gamma}{dq^2 d\cos\theta^* d\cos\theta_\ell d\chi} = & \frac{9}{32\pi} [(I_1^s \sin^2\theta^* + I_1^c \cos^2\theta^*) + (I_2^s \sin^2\theta^* + I_2^c \cos^2\theta^*) \cos 2\theta_\ell \\ & + I_3 \sin^2\theta^* \sin^2\theta_\ell \cos 2\chi + I_4 \sin 2\theta^* \sin 2\theta_\ell \cos \chi + I_5 \sin 2\theta^* \sin \theta_\ell \cos \chi \\ & + (I_6^c \cos^2\theta^* + I_6^s \sin^2\theta^*) \cos \theta_\ell + I_7 \sin 2\theta^* \sin \theta_\ell \sin \chi \\ & + I_8 \sin 2\theta^* \sin 2\theta_\ell \sin \chi + I_9 \sin^2\theta^* \sin^2\theta_\ell \sin 2\chi], \end{aligned}$$



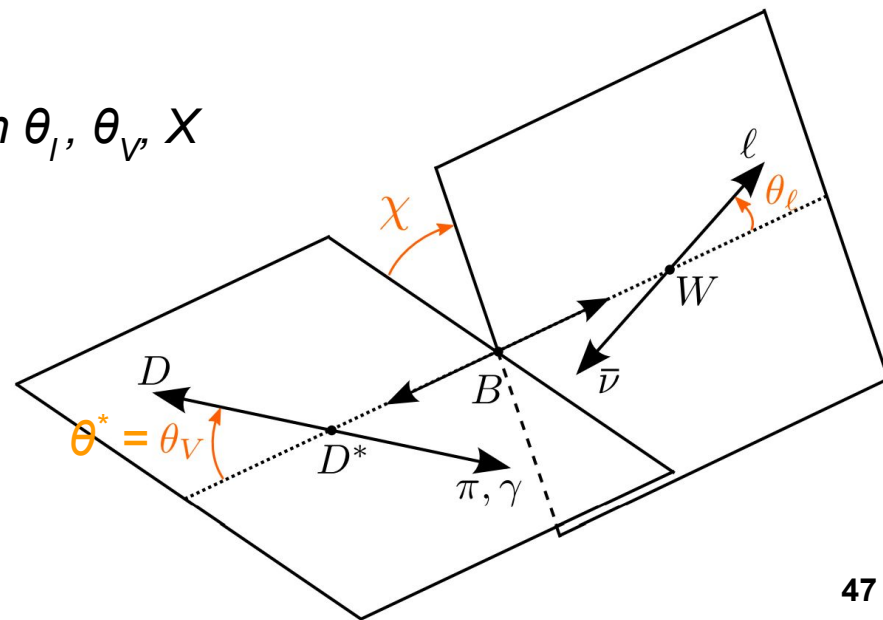
Angular asymmetries

PRL 131, 181801 (2023)

- 3 relevant angles in $B \rightarrow D^* / \nu$ decays
- 4D differential decay rate expressed as 8 helicity amplitudes
- \rightarrow construct 5 angular asymmetries from integral differences
 - $A_{FB}, S_{3'}, S_{5'}, S_{7'}, S_{9'}$

$$\mathcal{A}_x(w) \equiv \left(\frac{d\Gamma}{dw} \right)^{-1} \left[\int_0^1 - \int_{-1}^0 \right] dx \frac{d^2\Gamma}{dw dx}$$

$$x = \cos/\sin \theta_l, \theta_{\nu}, \chi$$

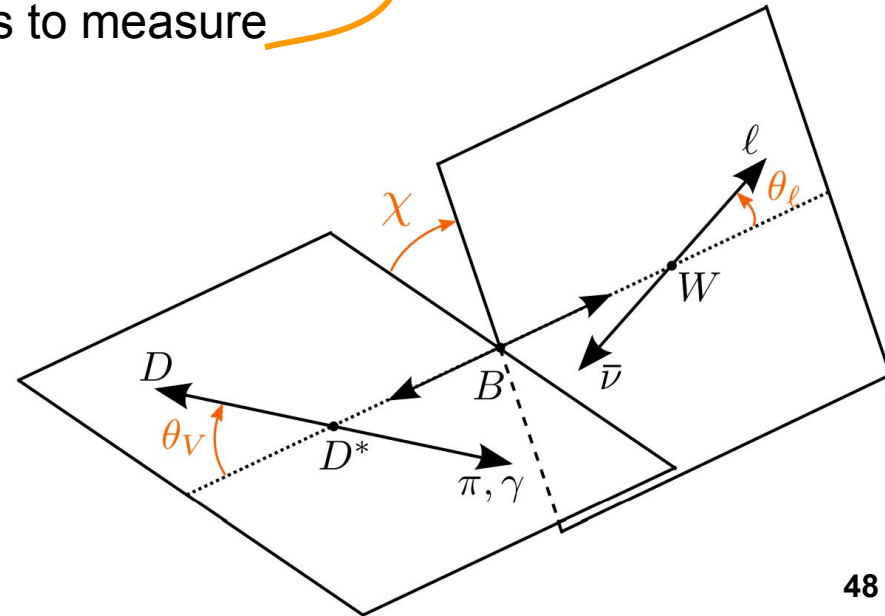


Angular asymmetries

PRL 131, 181801 (2023)

- 3 relevant angles in $B \rightarrow D^* l \nu$ decays
- 4D differential decay rate expressed as 8 helicity amplitudes
- \rightarrow construct 5 angular asymmetries
- Measure number of events in two regions to measure an asymmetry
 - Experimental uncertainties cancel

$$A_x(w) = \frac{N_x^+(w) - N_x^-(w)}{N_x^+(w) + N_x^-(w)}$$



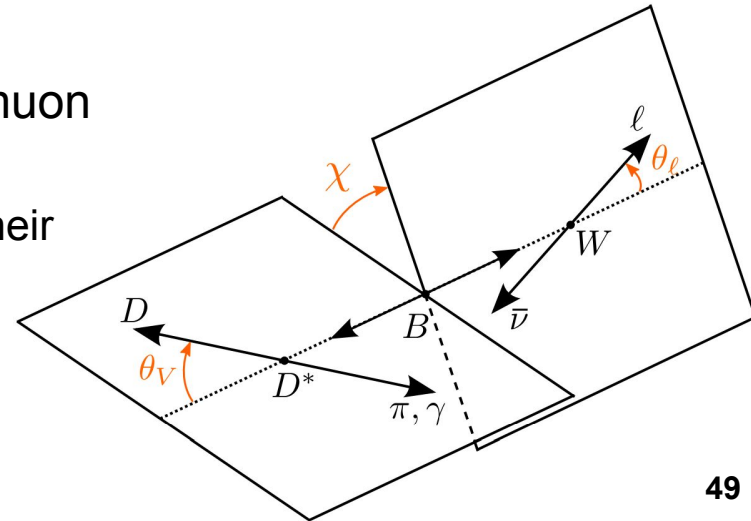
Angular asymmetries

PRL 131, 181801 (2023)

- 3 relevant angles in $B \rightarrow D^* l \nu$ decays
- 4D differential decay rate expressed as 8 helicity amplitudes
- \rightarrow construct 5 angular asymmetries
- Measure number of events in two regions to measure an asymmetry
 - Experimental uncertainties cancel
- Measure difference between the electron and muon asymmetry
 - A_{FB} , S_3 , and S_5 are highly sensitive to LUV via their asymmetry differences

$$\mathcal{A}_x(w) = \frac{N_x^+(w) - N_x^-(w)}{N_x^+(w) + N_x^-(w)}$$

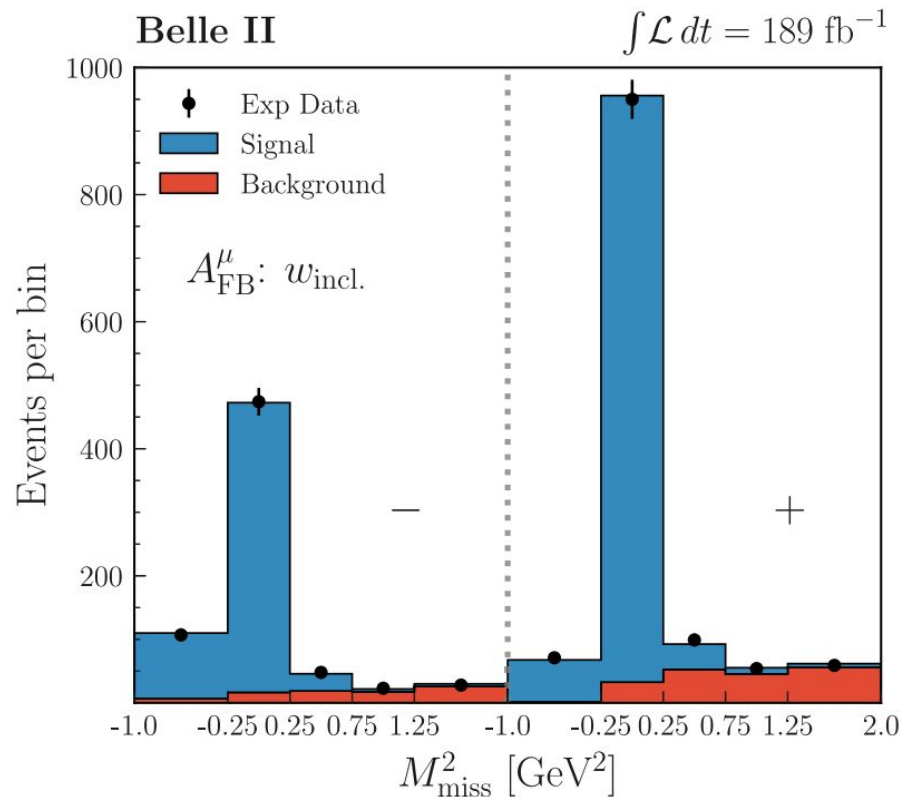
$$\Delta \mathcal{A}_x(w) \equiv \mathcal{A}_x^\mu(w) - \mathcal{A}_x^e(w)$$



Angular asymmetries

PRL 131, 181801 (2023)

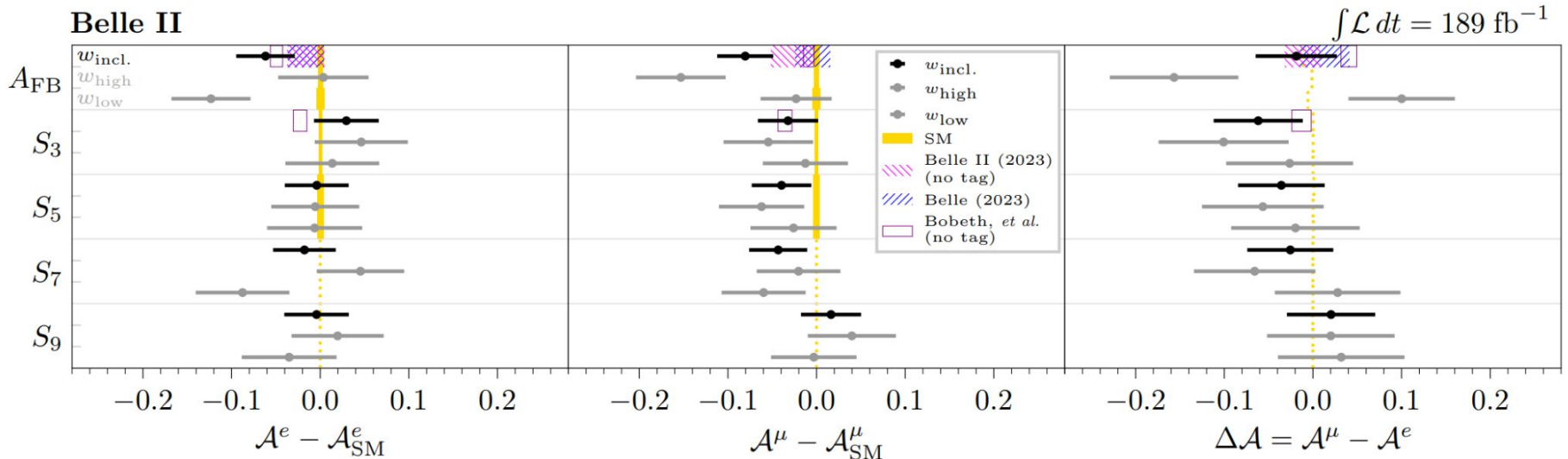
- Fit of M_{miss}^2 in 3 regions of w
 - Low ($w < 1.275$), high and full range
-



Angular asymmetries

PRL 131, 181801 (2023)

- Fit of M^2_{miss} in 3 regions of w
- Measurement is statistically limited
- All measured quantities are consistent with the SM
- Leading systematic uncertainty: size of the simulated samples



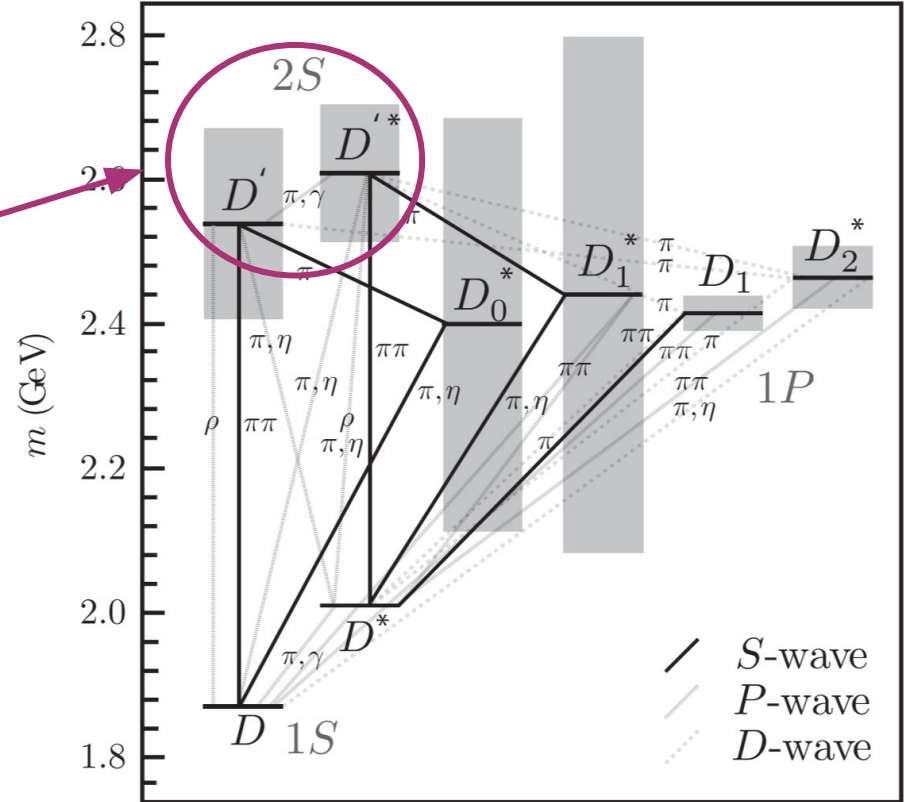
Belle measurements

Belle measurements

- 3 measurements of $R(D^{(*)})$ used by HFLAV
 - $R(D^{(*)})$, hadronic B -tagging: PRD 92, 072014 (2015)
 - $R(D^*)$, hadronic τ decay, hadronic B -tagging: PRL 118, 211801 (2017)
 - $R(D^{(*)})$, semileptonic B -tagging: PRL 124, 161803 (2020)
- + 1 measurement of angular coefficients and asymmetries in $B \rightarrow D^* l \nu$ events: PRL 133, 131801 (2024)

Belle measurements

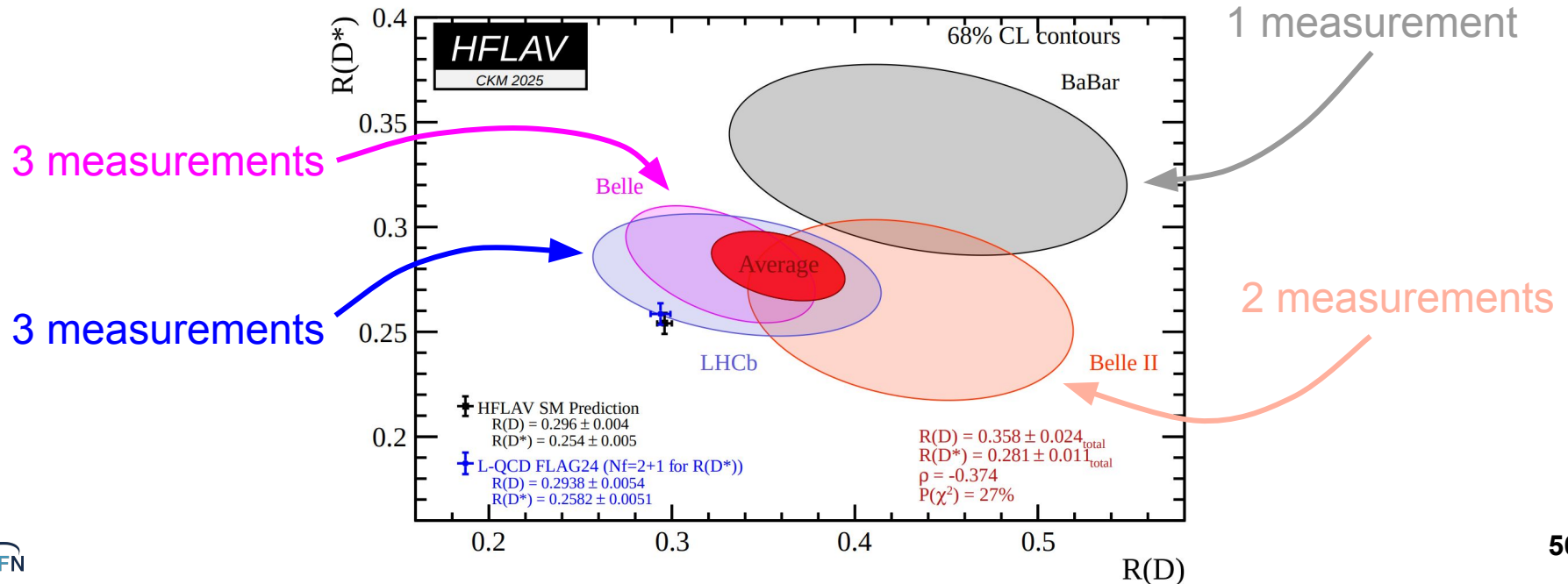
- Key difference w.r.t. Belle II → modelling of gap modes
 - Included decay modes
 - Radially-excited $D^{(*)}(2S)$ modes
 - D^{**} decays to a $D^{(*)}$ and 1 or 2 pions, a ρ/η
 - → BF computed from quantum numbers, phase-space, isospin arguments



Discussion and conclusions

Status of $R(D^{(*)})$

- HFLAV averages with all public results as of September 2025
 - $R(D)$ exceeds the SM prediction by 2.5σ
 - $R(D^*)$ exceeds the SM prediction by 2.3σ
 - Combination exceeds the SM prediction by 3.8σ

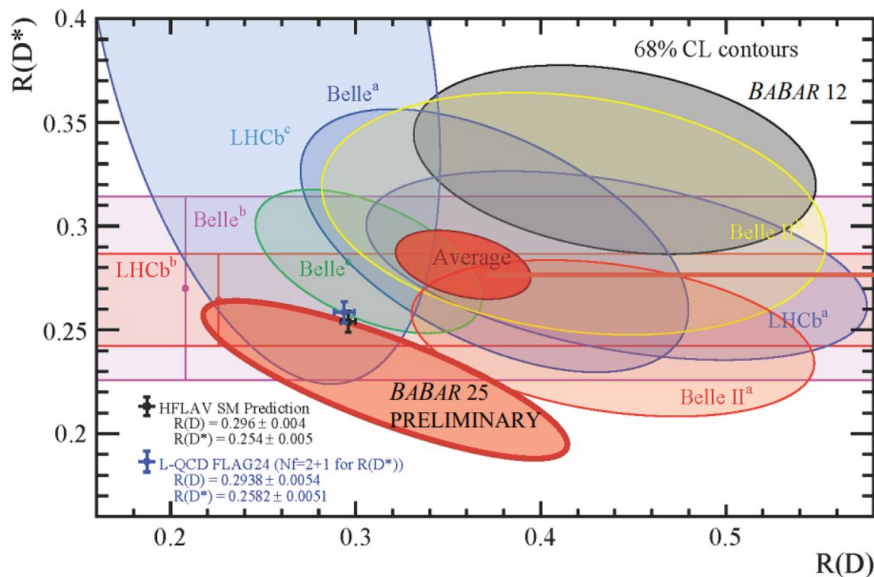


Preliminary BaBar measurement

Very preliminary so take it with a grain of salt

Experiment	$R(D)$	$R(D^*)$	Correlation
<i>BABAR</i> 12 (hadronic tag)	$0.440 \pm 0.058 \pm 0.042$	$0.332 \pm 0.024 \pm 0.018$	-0.27
HFLAV (CKM 2025 average)	0.281 ± 0.011	0.358 ± 0.024	-0.374
<i>BABAR</i> 25 (leptonic tag) PRELIMINARY	$0.316 \pm 0.062 \pm 0.019$	$0.226 \pm 0.022 \pm 0.012$	-0.82

Violation of Fundamental Symmetries with B mesons
workshop

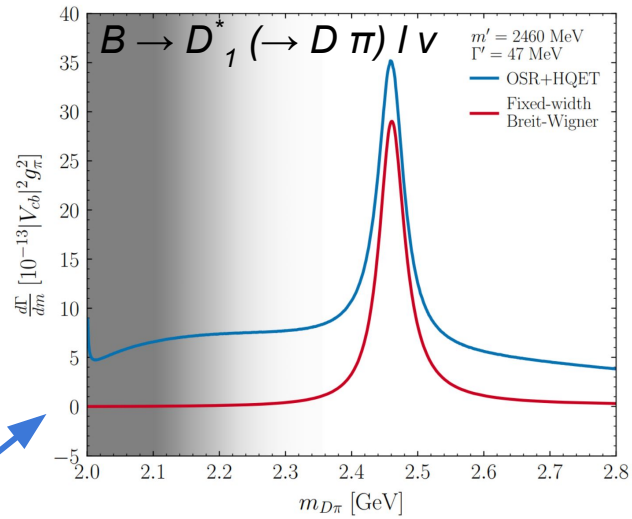


This average does not include the *BABAR* 25 preliminary result

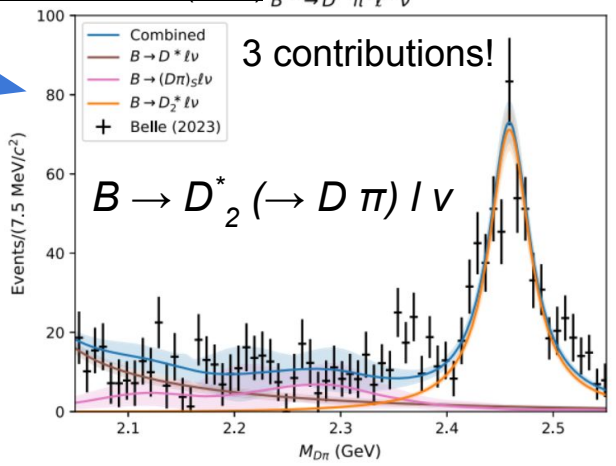
Discussion

Can we explain the tension without non-SM physics?

- Modelling of $B \rightarrow D^{**} \ell \nu$ decays
 - Modelling of D^{**} lineshapes relies on narrow-width approximation
 - \rightarrow Breit-Wigner lineshape
 - But off-shell effects play an important role!
 - Use on-shell recursion and HQET
 - Generalise the BGL parametrisation to decays with multiple final state hadrons
 - Heavy hadron chiral perturbation theory [JHEP06(2025)190]



PRD 110, L091502 (2024)



- What is the true mass of the D_0^* ? [EPJC 85, 1289 (2025)]

Discussion

Can we explain the discrepancy without non-SM physics?

- Modelling of gap modes?
 - $B \rightarrow D^{(*)} \eta / \nu$ decays have never been observed and are used as an *ad hoc* solution
 - Latest semileptonic (and hadronic) studies in Belle II show a tendency to prefer smaller gap mode BF
 - Ongoing investigation of decay modes which could fill this gap
 - $B \rightarrow D X / \nu$? $B \rightarrow D K_L K_L / \nu$?
 - Decays to hadrons?
 - $B^- \rightarrow \Lambda_c p / \nu$, $B \rightarrow p/n p/n / \nu \dots$
- Modelling of D decays?
 - Multibody D decays are simulated via phase-space modelling instead of decay specific models
 - Ongoing effort to implement Dalitz models taken from BESIII
- $B \rightarrow D^* / \nu$ form factors?
 - See talks from yesterday
 - [S. Simula](#), [A. Vaquero](#), [N. Gubernari](#)

Discussion

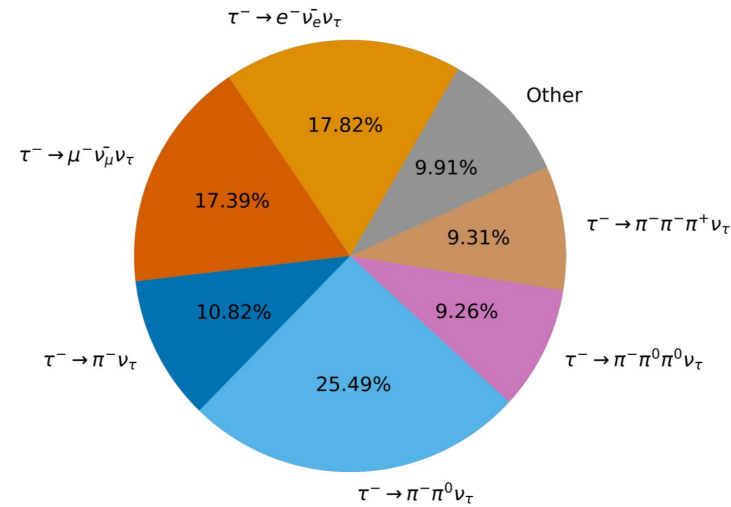
What can we improve now?

- Develop and implement improved modelling of signal and background contributions as shown on previous slides
- Align the Belle II and LHCb decay cocktails
 - Important beyond LFU and semileptonic decay measurements
- Unify relevant selections within Belle II in view of $R(D^{(*)})$ combination
- Measure optimised $R(D^{(*)})$ to minimise the theoretical form factor uncertainty [EPJC 80, 1078 (2020)]

Discussion

Can we reduce the statistical uncertainty?

- Belle II LFU tests are limited by statistics
 - Currently collecting data
 - Goal: $1/ab$ by the end of 2026
- Use the inclusive tag?
 - Large background yields make the measurement extremely difficult
 - Tight selections required and largely reduce the efficiency
- Include more τ decay channels?
 - Hadronic decay modes make the measurements harder because of large hadronic background
 - Allows to measure the τ polarisation because there is only one neutrino in the τ decay



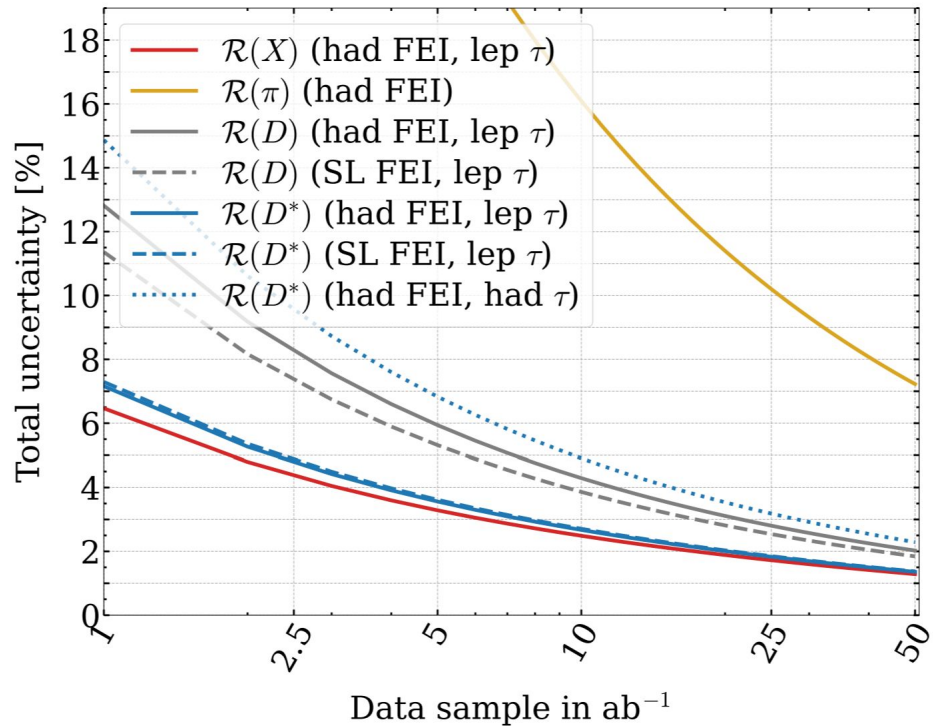
Prospects

- Current uncertainties
 - $R(D)$: 16–22% (365/fb)
 - $R(D^*)$: 10–13% (365/fb)
 - $R(X)$: ~17% (189/fb)
- Extrapolating to 1/ab without changing systematic uncertainties and central values
 - $R(D)$: 13–15% (365/fb)
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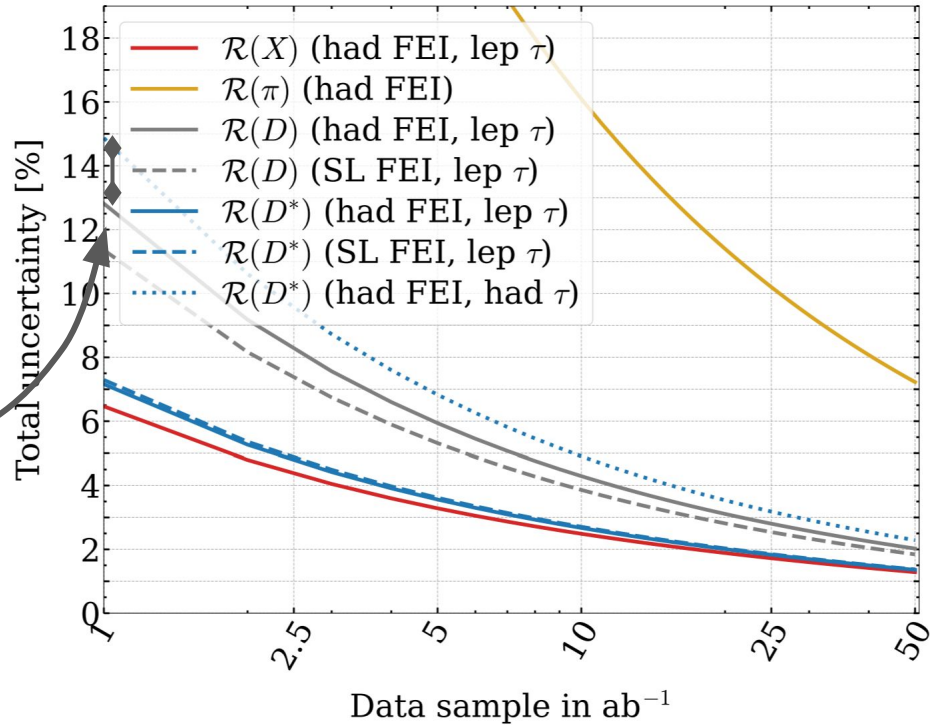
Snowmass White Paper (2022)



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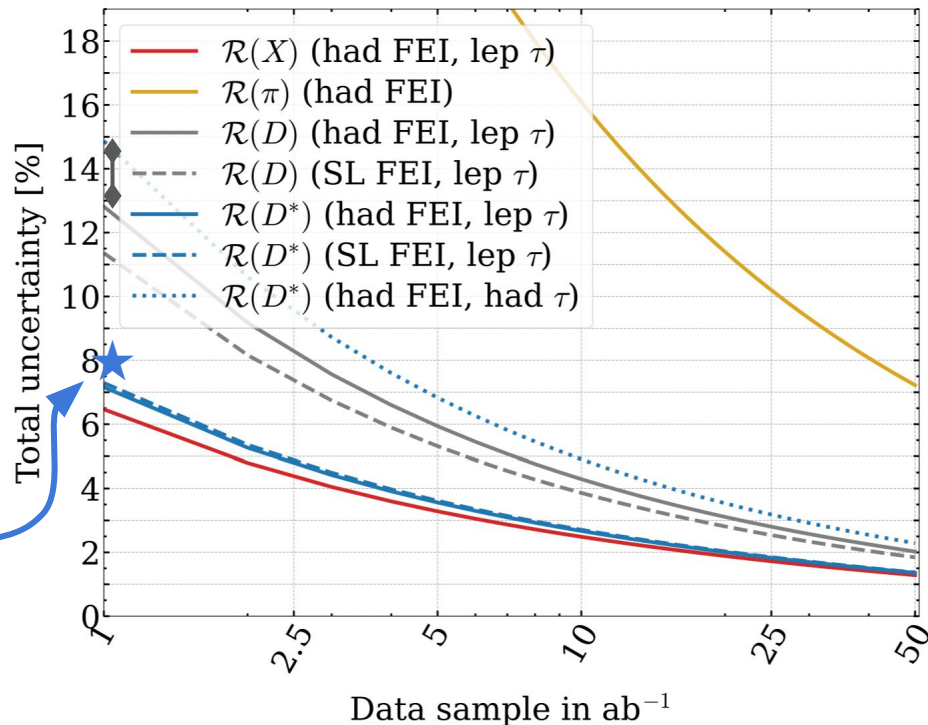
Snowmass White Paper



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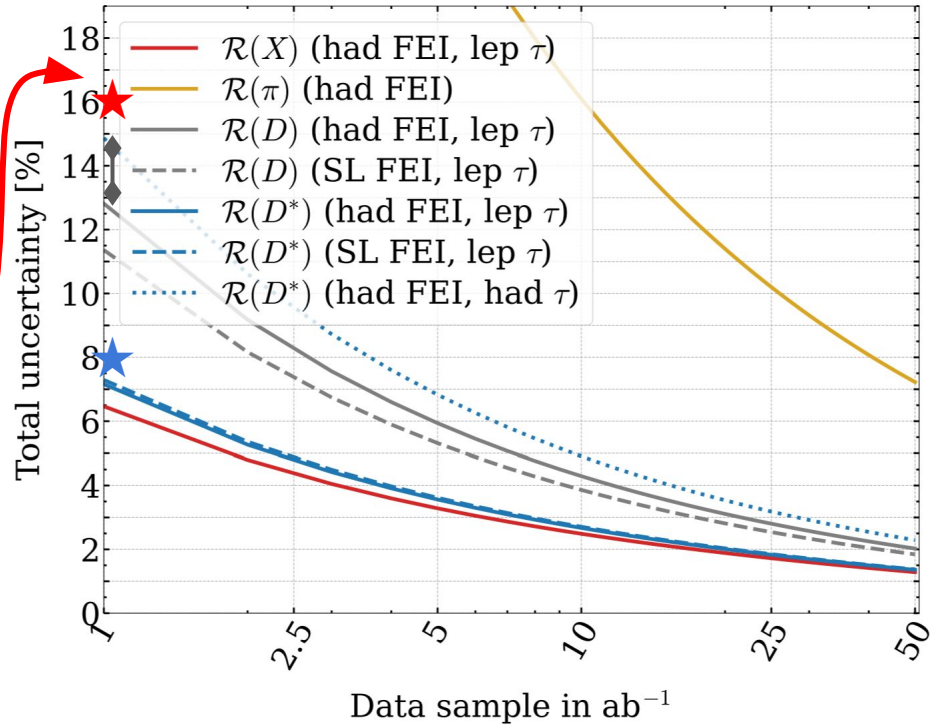
Snowmass White Paper



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 - Can be reduced with improved modelling and better knowledge of form factors and BF

Snowmass White Paper



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Belle II plays a crucial role for testing LFU via SL B decays so stay tuned for more results!

Thanks for listening!