

MITP Topical Workshop
Flavor Physics with b -baryons and B_c
mesons: Opportunities for Discovery

Status and Prospects of CKM Matrix Elements Measured with Baryons and the B_c Mesons



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CKM Matrix measurements

V_{ud}	V_{us}	V_{ub}
$\pi \rightarrow \ell \nu$ β -decay	$K \rightarrow \pi \ell \nu$ $K \rightarrow \ell \nu$	$b \rightarrow u \ell \nu$ $B \rightarrow \pi \ell \nu$
V_{cd}	V_{cs}	V_{cb}
$D \rightarrow \pi \ell \nu$ $\nu + d \rightarrow c + \ell$	$D \rightarrow K \ell \nu$ $D_s \rightarrow \ell \nu$	$b \rightarrow c \ell \nu$ $B \rightarrow D \ell \nu$
V_{td}	V_{ts}	V_{tb}
$\langle B_d \bar{B}_d \rangle$ $b \rightarrow d \gamma$	$\langle B_s \bar{B}_s \rangle$ $b \rightarrow s \gamma$	$t \rightarrow b \ell \nu$

Most CKM matrix extracted from tree-level processes

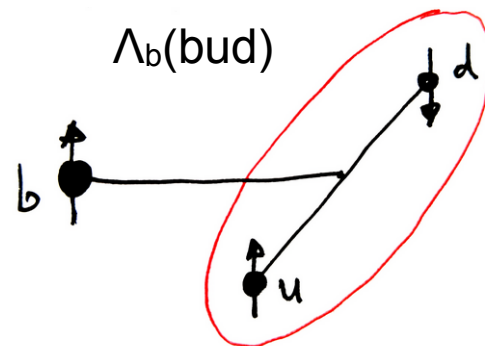
$$\left| \text{Diagram} \right|^2 \sim |V_{km}|^2$$

LHCb: unique capability with baryon decays

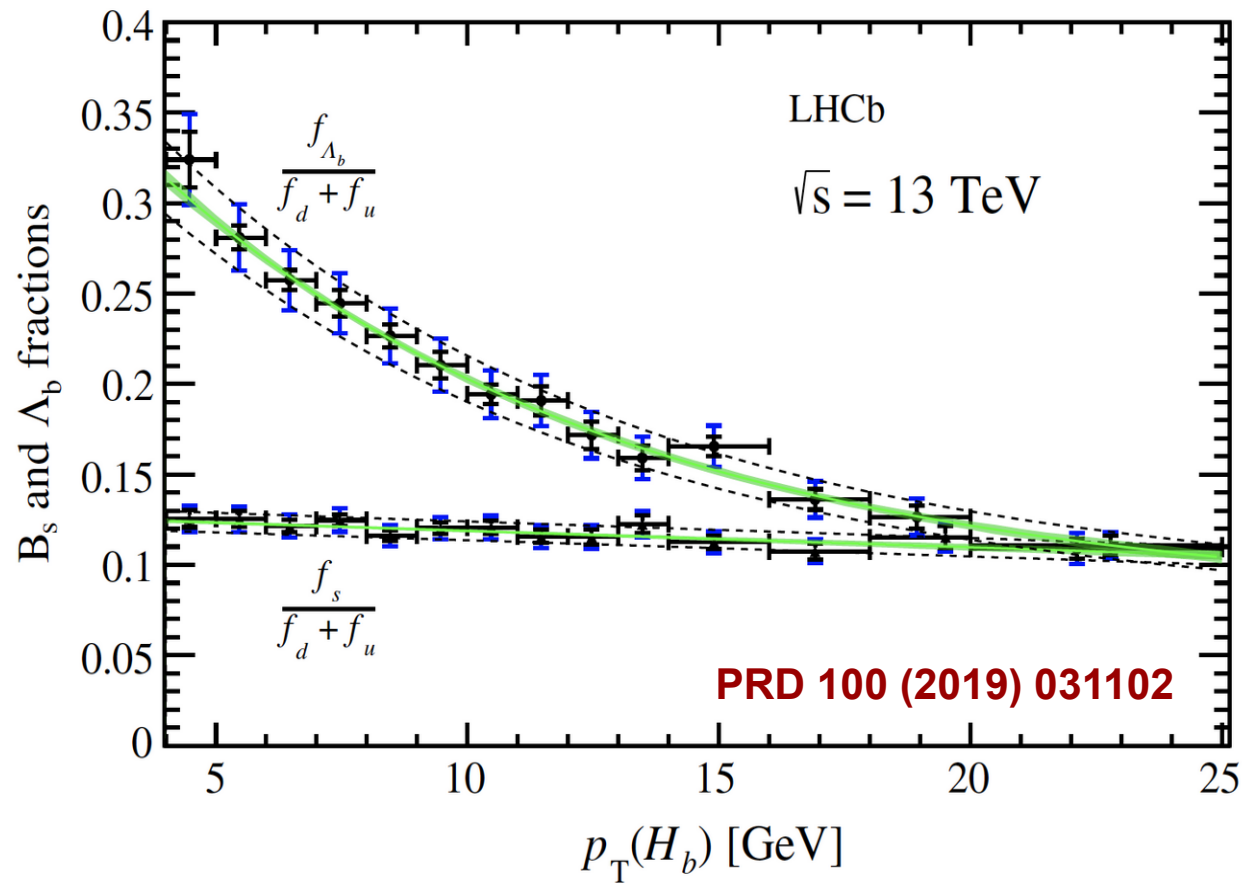
Baryons Qqq'

	Baryons	Quarks	Isospin	Mass (MeV)	1 st Experimental Evidence
$J^P = 1/2^+$					
	Λ_b^0	(bud)	0	5619.4 ± 0.7	CERN, 1981 [133]
	Σ_b^+	(buu)	1	5811.3 ± 1.9	CDF, 2007 [134]
	Σ_b^-	(bdd)	1	5815.5 ± 1.8	CDF, 2007 [134]
	Ξ_b^0	(bsu)	1/2	5788 ± 5	DELPHI, 1995 [135]
	Ξ_b^-	(bsd)	1/2	5791.1 ± 2.2	CDF, 2007 [136]
	Ω_b^-	(bss)	0	6071 ± 40	D0, 2008 [137]

- Λ_b is the Lightest b-baryon
- Λ_b spin \sim spin of the b-quark



Baryon production



Production fraction averaged in:

- p_T in (4, 25) GeV : η in (2, 5)

$\Lambda_b : 0.259 \pm 0.018$

$B_s : 0.122 \pm 0.006$

Λ_b fraction is not universal

- depends strongly on transverse momentum

- particle multiplicity of the collision

Crucial for a correct normalization of b-hadron branching fraction measurements

LHCb: unique capability with baryon decays

$$\Gamma_{55} \quad \Lambda_c^+ \ell^- \bar{\nu}_\ell \text{ anything} \quad (10.9 \pm 2.2) \%$$

$$\Gamma_{56} \quad \Lambda_c^+ \ell^- \bar{\nu}_\ell \quad (6.2^{+1.4}_{-1.3}) \%$$

$$\Gamma_{57} \quad \Lambda_c^+ \tau^- \bar{\nu}_\tau \quad (1.9 \pm 0.5) \%$$

$$\Gamma_{58} \quad \Lambda_c^+ \pi^+ \pi^- \ell^- \bar{\nu}_\ell \quad (5.6 \pm 3.1) \%$$

$$\Gamma_{59} \quad \Lambda_c(2595)^+ \ell^- \bar{\nu}_\ell \quad (7.9^{+4.0}_{-3.5}) \times 10^{-3}$$

$$\Gamma_{60} \quad \Lambda_c(2625)^+ \ell^- \bar{\nu}_\ell \quad (1.3^{+0.6}_{-0.5}) \%$$

$$\Gamma_{61} \quad \Sigma_c(2455)^0 \pi^+ \ell^- \bar{\nu}_\ell$$

$$\Gamma_{62} \quad \Sigma_c(2455)^{++} \pi^- \ell^- \bar{\nu}_\ell$$

PDG 2025

What we know about $b \rightarrow c \ell \nu$

Inputs from DELPHI and CDF

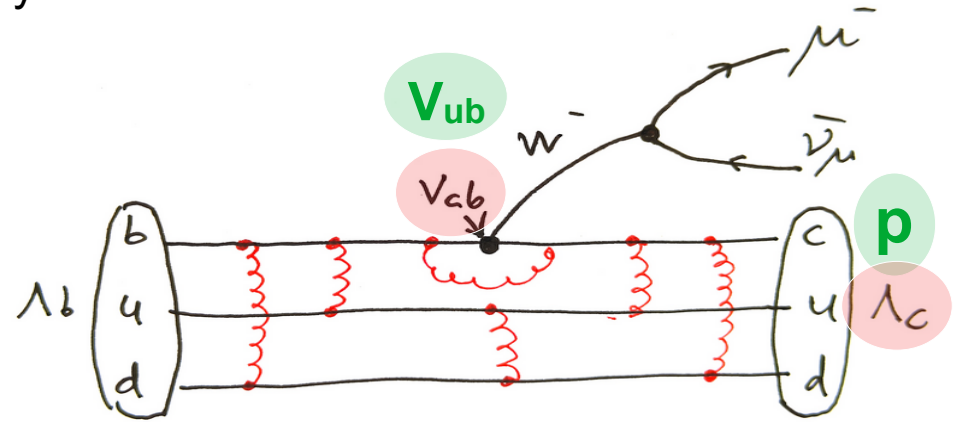
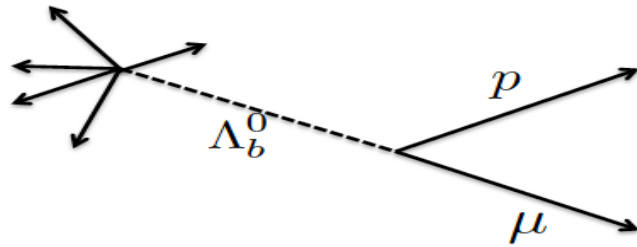
Ground state $\Lambda_c \sim 60\%$ total SL rate

Large uncertainties in the BF

LHCb measurements

- Published:
 - Determination of $|V_{ub}/V_{cb}|$ with $\Lambda_b \rightarrow p \mu \nu$
 - $d\Gamma/dq^2$ measurement of $\Lambda_b \rightarrow \Lambda_c \mu \nu$
 - Observation of $\Lambda_b \rightarrow \Lambda_c \tau \nu$, with $\tau \rightarrow 2\pi(\pi^0) \nu$
- Ongoing:
 - Angular analysis of $\Lambda_b \rightarrow \Lambda_c \mu \nu$ for New Physics, Form Factors, $|V_{cb}|$
 - Form factor measurement of $\Lambda_b \rightarrow \Lambda_c^* \mu \nu$
 - Measurement of $R(\Lambda_c)$ and $R(\Lambda_c^*)$ with $\tau \rightarrow \mu \nu \nu$

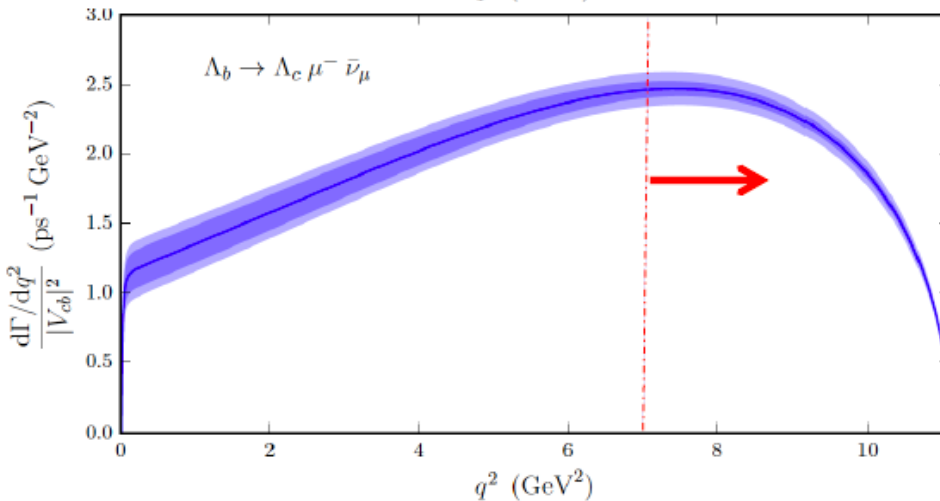
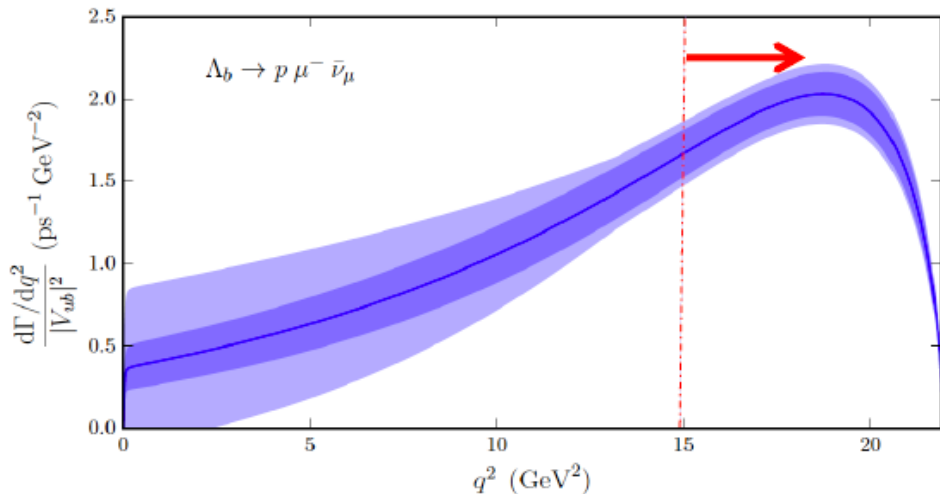
- The b-baryon decays provided complementary information to B mesons



- Proton signature
- Baryon conservation provide bkg protection from B mesons
- Large background from $\Lambda_b \rightarrow \Lambda_c\mu\nu$: $\Lambda_c \rightarrow pX$
 - Require isolated proton-muon vertex
- LHCb determines the ratio R_{exp} in the high q^2 region

$$R_{exp} = \frac{\mathcal{B}(\Lambda_b \rightarrow p\mu\nu)}{\mathcal{B}(\Lambda_b \rightarrow \Lambda_c\mu\nu)}$$

$$\frac{V_{ub}}{V_{cb}} = \sqrt{\frac{R_{exp}}{R_{TH}}}$$



The most reliable theory predictions of the ratio of FF are obtained for:

$$\Lambda_b \rightarrow \Lambda_c \mu \nu \quad q^2 > 7 \text{ GeV}^2$$

$$\Lambda_b \rightarrow p \mu \nu \quad q^2 > 15 \text{ GeV}^2$$

$$\zeta_{p\mu\bar{\nu}}(15 \text{ GeV}^2) \equiv \frac{1}{|V_{ub}|^2} \int_{15 \text{ GeV}^2}^{q_{\text{max}}^2} \frac{d\Gamma(\Lambda_b \rightarrow p \mu^- \bar{\nu}_\mu)}{dq^2} dq^2 = (12.31 \pm 0.76 \pm 0.77) \text{ ps}^{-1}$$

$$\zeta_{\Lambda_c\mu\bar{\nu}}(7 \text{ GeV}^2) \equiv \frac{1}{|V_{cb}|^2} \int_{7 \text{ GeV}^2}^{q_{\text{max}}^2} \frac{d\Gamma(\Lambda_b \rightarrow \Lambda_c \mu^- \bar{\nu}_\mu)}{dq^2} dq^2 = (8.37 \pm 0.16 \pm 0.34) \text{ ps}^{-1},$$

$$\frac{\zeta_{p\mu\bar{\nu}}(15 \text{ GeV}^2)}{\zeta_{\Lambda_c\mu\bar{\nu}}(7 \text{ GeV}^2)} = 1.471 \pm 0.095 \pm 0.109$$

($\sigma=9.8\%$)

Reconstruction of the q^2 and the corrected mass

arXiv:1912.09562

- The knowledge of the Λ_b momentum P_{Λ_b} is needed to measure $q^2 = (P_{\Lambda_b} - P_p)^2$

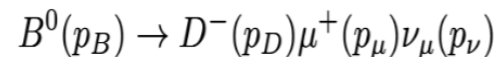
$$m_\nu^2 = (P_{\Lambda_b} - P_p - P_\mu)^2 = (P_{\Lambda_b} - P_Y)^2 = 0$$

$$E_{\Lambda_b}^2 = m_{\Lambda_b}^2 + |\vec{P}_{\Lambda_b}|^2$$

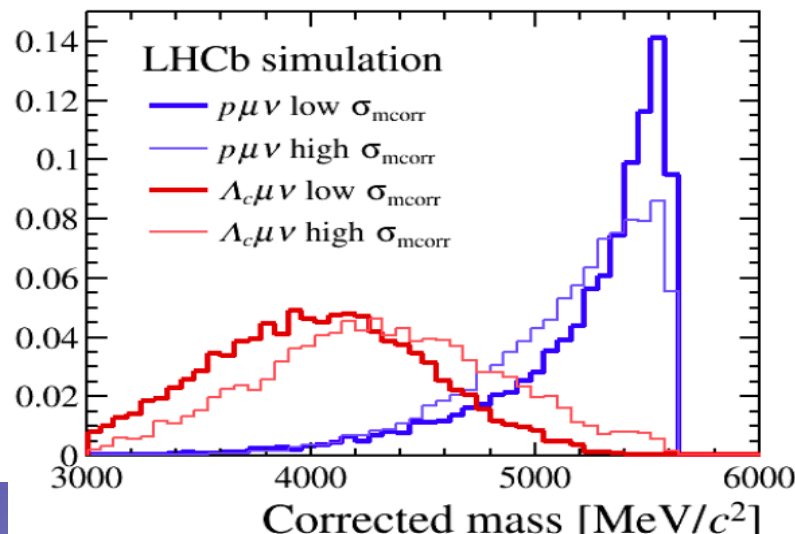
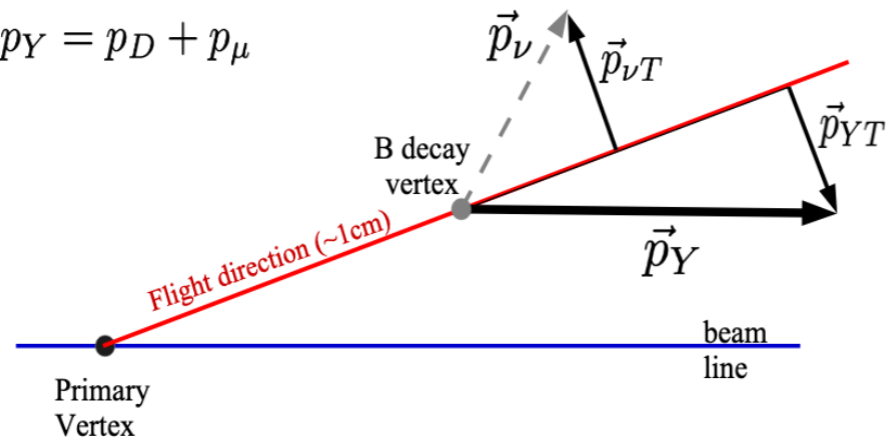
Hypothesis of just 1-neutrino missing, known masses of the particles, and the well-measured Λ_b flight direction gives the momentum with a 2-fold ambiguity

- Use the corrected mass to discriminate signal from the remaining background

$$m_{\text{corr}} = \sqrt{m_{h\mu}^2 + p_\perp^2 + p_\perp^2}$$



$$p_Y = p_D + p_\mu$$



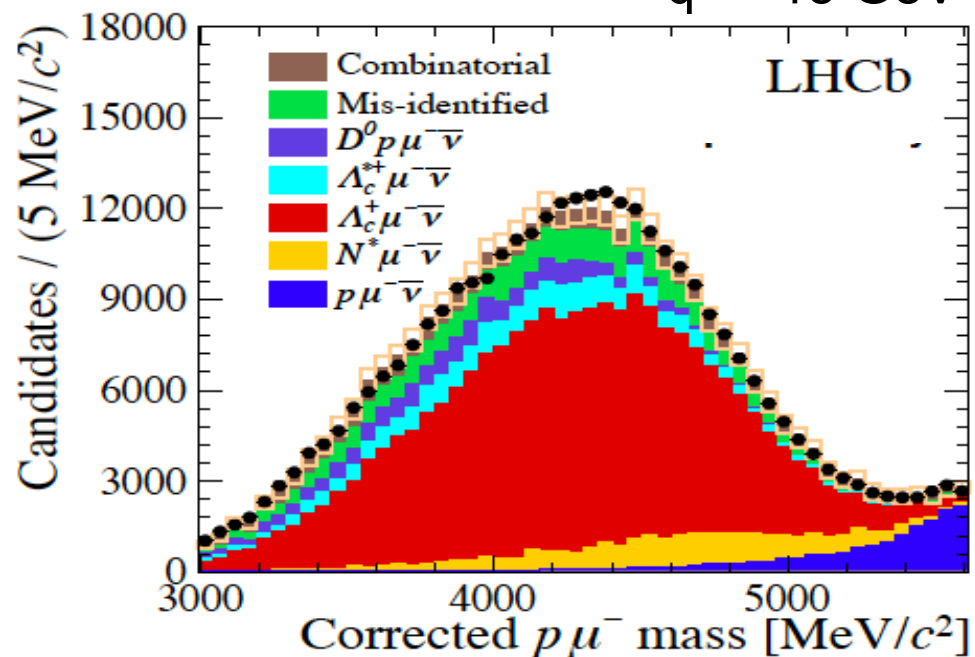
Separation between signal and backgrounds improves when requiring low uncertainty corrected mass

$\Lambda_b \rightarrow p\mu\nu$: signal fits

Nature Phys.11(2015)743

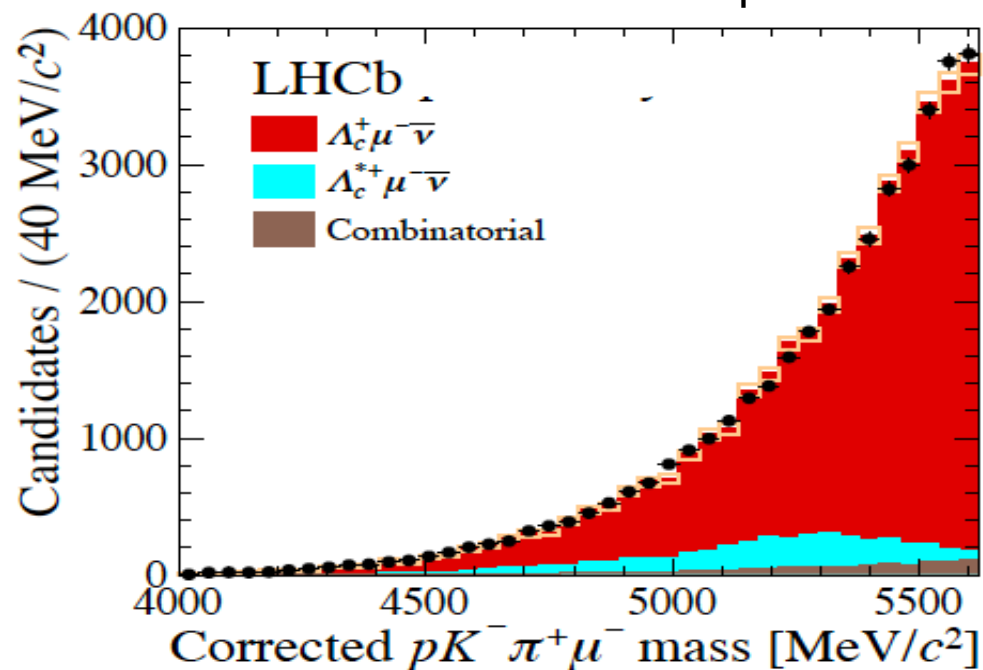
Signal $N=17687 \pm 733$

$q^2 > 15 \text{ GeV}^2$



Normalization $N=34255 \pm 571$

$q^2 > 7 \text{ GeV}^2$



$$R_{\text{exp}} = 0.92 \pm 0.04(\text{stat}) \pm 0.07(\text{syst}) \times 10^{-2}$$

Systematics dominated by
BF($\Lambda_c \rightarrow pK\pi$), trigger and
tracking efficiency

Using $\text{BF}(\Lambda_c \rightarrow pK\pi) = (6.84 \pm 0.24^{+0.21}_{-0.27})\%$

Belle PRL 113 (2014) 042002

$$R_{\text{exp}} = (1.00 \pm 0.04 \pm 0.07) \times 10^{-2}$$

$$|V_{ub} / V_{cb}| = 0.083 \pm 0.004_{\text{exp}} \pm 0.004_{\text{FF}}$$

Source	Relative uncertainty (%)	
$\mathcal{B}(\Lambda_c \rightarrow pK^+\pi^-)$	+4.7 -5.3	± 3.9
Trigger	3.2	
Tracking	3.0	
Λ_c selection efficiency	3.0	
N^* shapes	2.3	
Λ_b lifetime	1.5	
Isolation	1.4	
Form factor	1.0	
Λ_b production	0.5	
q^2 migration	0.4	
PID	0.2	
Total	+7.8 -8.2	± 7.4

HFLAV2023

Used $\text{BF}(\Lambda_c \rightarrow pK\pi) = (6.28 \pm 0.32)\%$

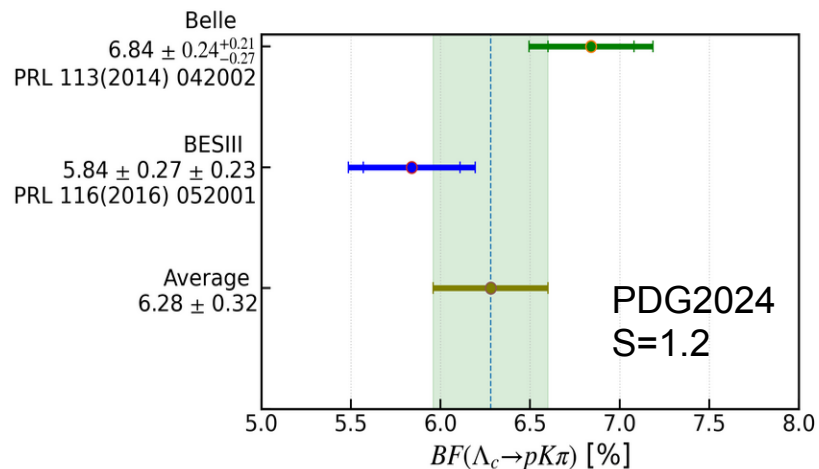
PDG2023, based on:

BESIII PRL116 (2016) 052001

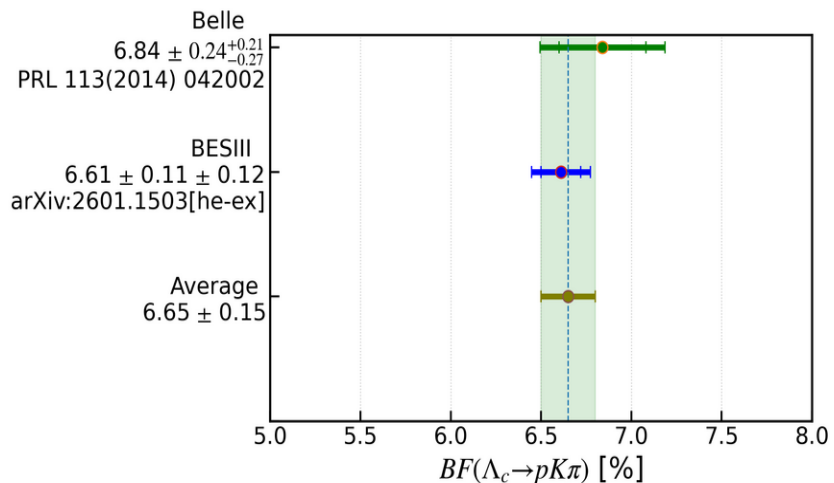
Belle PRL 113 (2014) 042002

$$R_{\text{exp}} = 0.92 \pm 0.04(\text{stat}) \pm 0.07(\text{syst}) \times 10^{-2}$$

$$|V_{ub} / V_{cb}| = 0.079 \pm 0.004_{\text{exp}} \pm 0.004_{\text{FF}}$$



BESIII: ($\sigma(\Lambda_c \rightarrow pK\pi) \sim 2.3\%$)



Theory: Need more precise L-QCD calculation

LHCb: exploit the full statistics,
 extract signal in q^2 bin

Using $\text{BF}(\Lambda_c \rightarrow pK\pi) = (6.84 \pm 0.24^{+0.21}_{-0.27})\%$

Belle PRL 113 (2014) 042002

$$R_{\text{exp}} = (1.00 \pm 0.04 \pm 0.07) \times 10^{-2}$$

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Isolation	1.4	
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Λ_b production	0.5	
q^2 migration	0.4	
PID	0.2	
Total	+7.8 -8.2	

Used $\text{BF}(\Lambda_c \rightarrow pK\pi) = (6.65 \pm 0.15)\%$

My average:

BESIII arXiv:2601.1503[hep-ex]

Belle PRL 113 (2014) 042002

$$R_{\text{exp}} = 0.97 \pm 0.04(\text{stat}) \pm 0.06(\text{syst}) \times 10^{-2}$$

$$|V_{ub} / V_{cb}| = 0.081 \pm 0.003_{\text{exp}} \pm 0.004_{\text{FF}}$$

Updated $|V_{ub}/V_{cb}|$ measurement

Nature Phys.11(2015)743

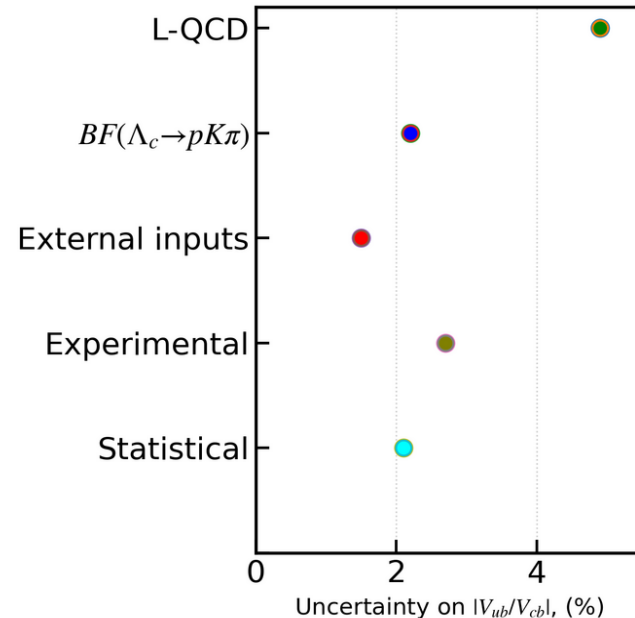
Using $BF(\Lambda_c \rightarrow pK\pi) = (6.84 \pm 0.24^{+0.21}_{-0.27})\%$

Belle PRL 113 (2014) 042002

$$R_{\text{exp}} = (1.00 \pm 0.04 \pm 0.07) \times 10^{-2}$$

$$|V_{ub}/V_{cb}| = 0.083 \pm 0.004_{\text{exp}} \pm 0.004_{\text{FF}}$$

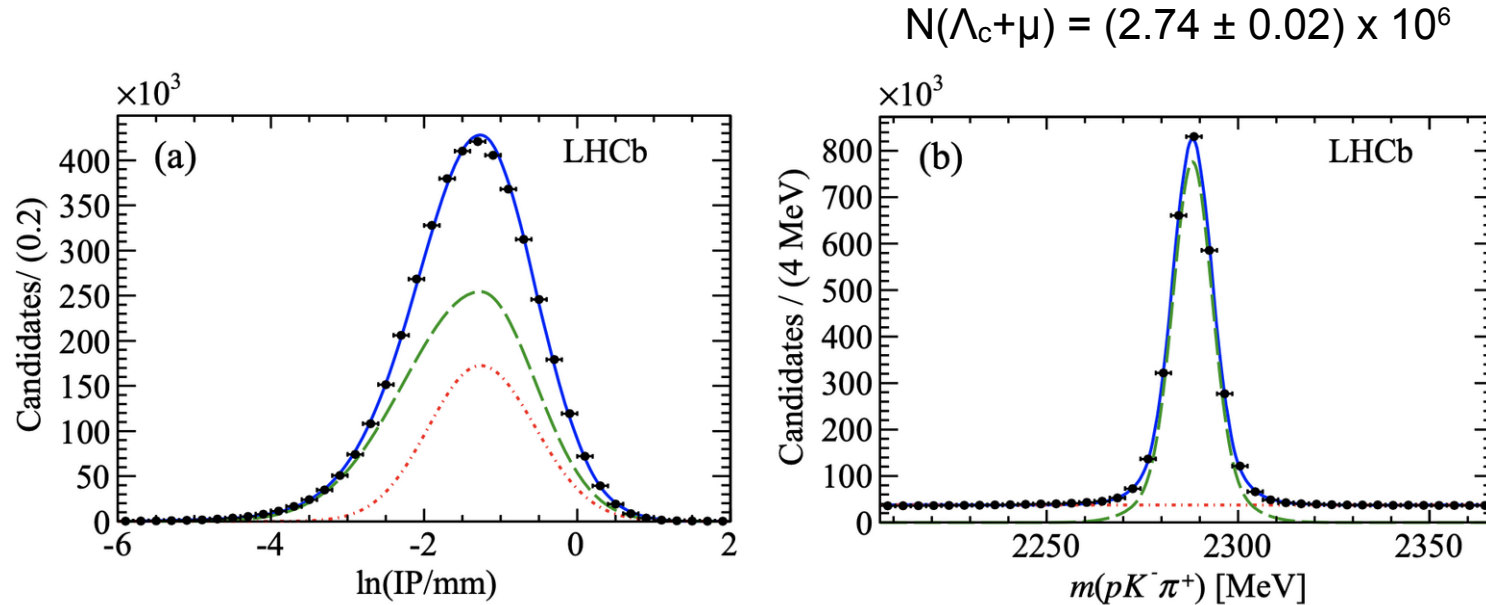
Source	Relative uncertainty (%)	
$\mathcal{B}(\Lambda_c \rightarrow pK^+\pi^-)$	+4.7 -5.3	± 2.3
Trigger	3.2	
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N^* shapes	2.3	
Λ_b lifetime	1.5	
Isolation	1.4	
Form factor	1.0	
Λ_b production	0.5	
q^2 migration	0.4	
PID	0.2	
Total	+7.8 -8.2	± 6.7



Theory: need more precise L-QCD calculation

LHCb: exploit the full statistics, extract signal in q^2 bin

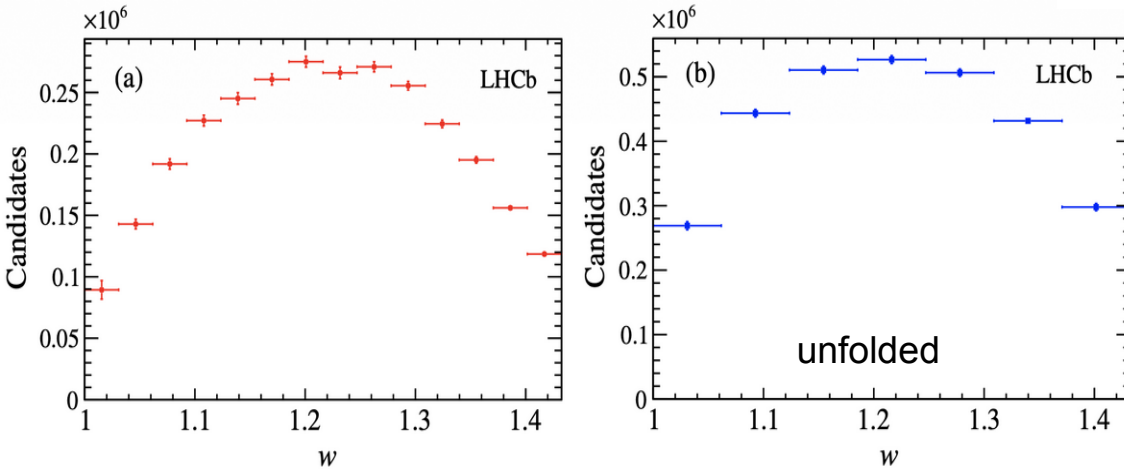
- Determine the $d\Gamma/dq^2$ differential shape: $d\Gamma/dq^2 d = G K(q^2) \xi_B^2(q^2)$



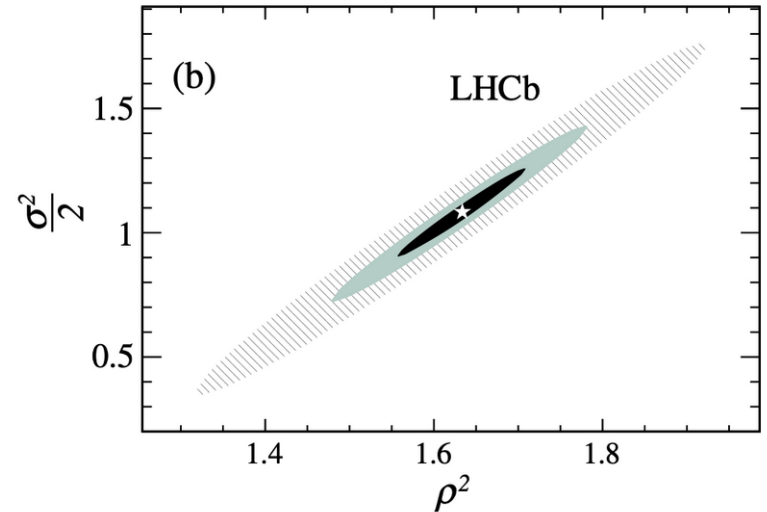
- Contribution from excited Λ_c is evaluated from a sample of $\Lambda_c \pi^+ \pi^- + \mu$

- Determine the $d\Gamma/dw^2$ differential shape

$$w = (m_{\Lambda_b^0}^2 + m_{\Lambda_c^+}^2 - q^2)/(2m_{\Lambda_b^0}m_{\Lambda_c^+})$$



$$\xi_B(w) = 1 - \rho^2(w - 1) + \frac{1}{2}\sigma^2(w - 1)^2 + \dots$$



$\Lambda_b \rightarrow \Lambda_c$ studies: 2-D differential rate and V_{cb}

Plans

- Determine double differential distributions $q^2 \cos(\theta_{L})$
- Extract form factor and Wilson Coefficients
- Future: study additional angular observables from 2-body Λ_c decays

$|V_{cb}|$

- Cannot use exclusive B SL decays for normalization, as is done for Bs
- Equality of total semileptonic decay width **Bigi et al. JHQP09(2011) 012**
 - $\Gamma(\Lambda_b) \sim \Gamma(B_s) \sim \Gamma(B_d)$
- Measure the ratio $N(\Lambda_b \rightarrow \Lambda_c \mu \nu) / N(\Lambda_b \rightarrow X_c \mu \nu)$

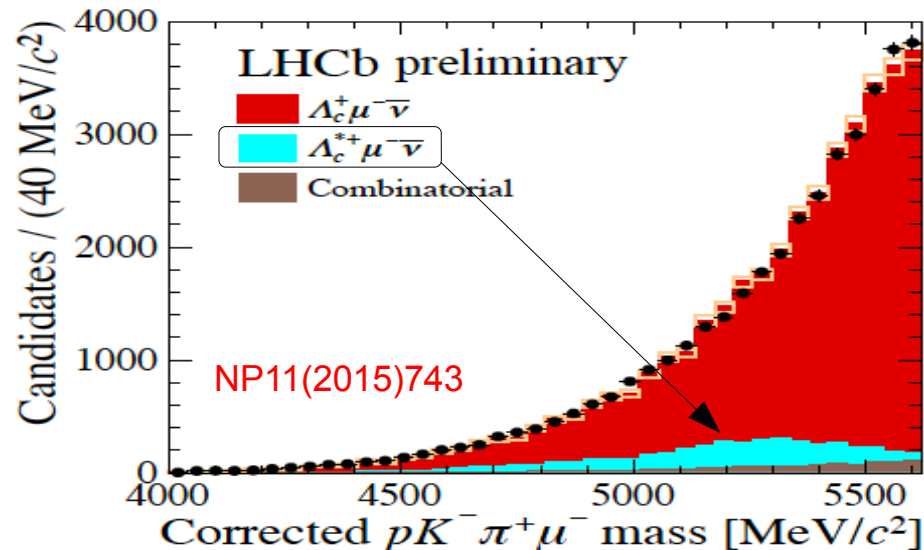
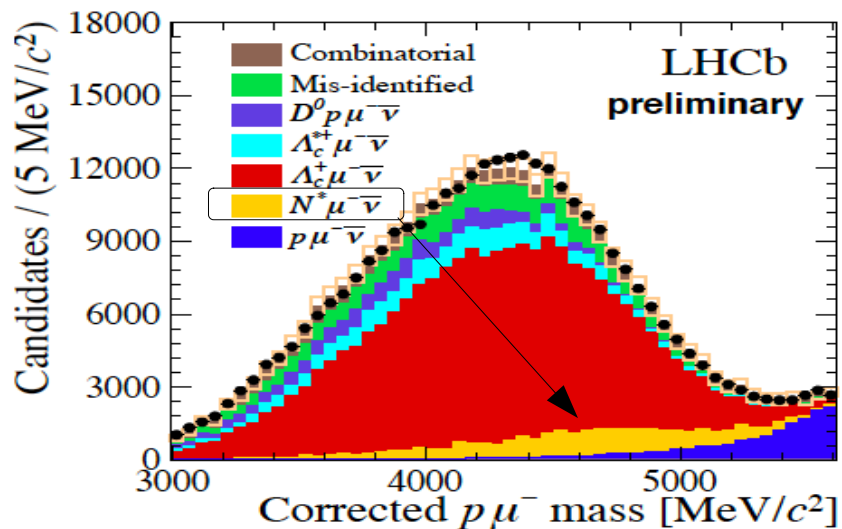
$$\Gamma_{SL}(\Lambda_b) = \Gamma_{SL}(B_d) \left[1 + \delta \right]$$

$$\delta = (4.1 \pm 1.6) \%$$

Bordone, Gambino
ArXiv 2203.13107



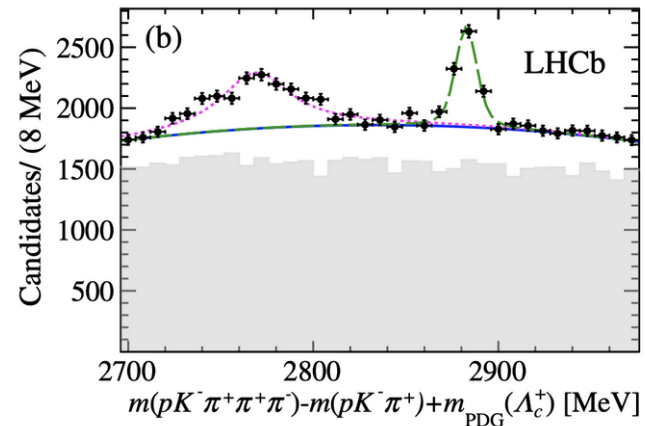
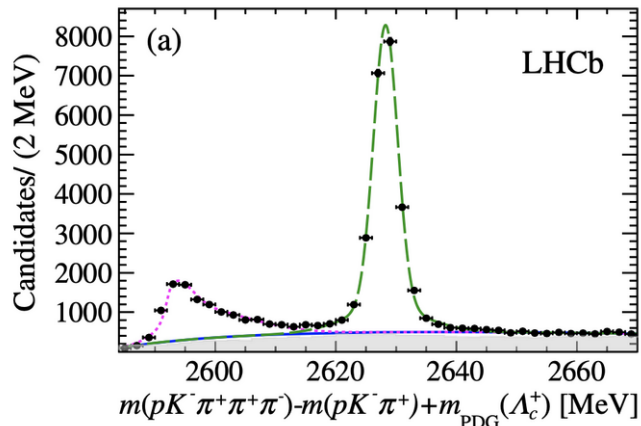
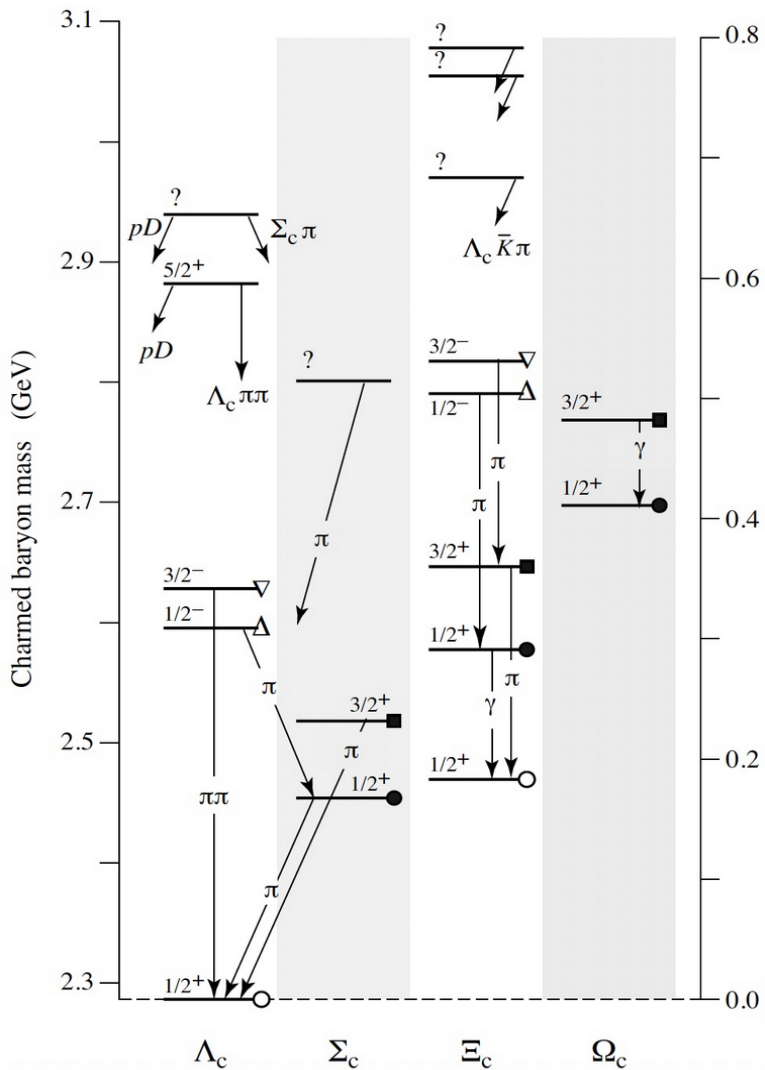
Other SL decays... in our backgrounds!



- Large contribution from $\Lambda_b \rightarrow N^* \mu \nu$
- Reconstructing $N \rightarrow p \pi \pi$
 - Reduce uncertainty due to N^* states in $\Lambda_b \rightarrow p \mu$ now included with a Gaussian constraints
 - Could be crucial in the study of backgrounds in $\Lambda_b \rightarrow p \pi \pi$

- Study explicitly the contributions from $\Lambda_b \rightarrow \Lambda_c^* \mu \nu$
 - Adding 2 pions ($\text{BF}(\Lambda_c^* \rightarrow \Lambda_c \pi^+ \pi^-) = 67\%$)
 - Crucial to understand these background in the study of $\Lambda_b \rightarrow \Lambda_c \pi \pi$

Excited state



Final state	Yield
$\Lambda_c(2595)^+ \mu^- \bar{\nu}_\mu$	8569 ± 144
$\Lambda_c(2625)^+ \mu^- \bar{\nu}_\mu$	22965 ± 266
$\Lambda_c(2765)^+ \mu^- \bar{\nu}_\mu$	2975 ± 225
$\Lambda_c(2880)^+ \mu^- \bar{\nu}_\mu$	1602 ± 95
$\Lambda_c^+ \mu^- \bar{\nu}_\mu X$	$(2.74 \pm 0.02) \times 10^6$

Lc* show up in many analysis:
 - needed to be studied
 - great opportunities

$\Lambda_b \rightarrow \Lambda_c^*$ phenomenology

- In HQ limit: $\text{BF}(\Lambda_b \rightarrow \Lambda_c^{3/2} \mu \nu) \sim 2 * \text{BF}(\Lambda_b \rightarrow \Lambda_c^{1/2} \mu \nu)$

Γ_{59}	$\Lambda_c(2595)^+ \ell^- \bar{\nu}_\ell$	$(7.9_{-3.5}^{+4.0}) \times 10^{-3}$	CDF measurements, seem to confirm this, but - Λ_c^* reconstructed in $\Lambda_c \pi^+ \pi^-$ - assumed isospin $\text{BF}(\Lambda_c^* \rightarrow \Lambda_c \pi \pi) = 2/3$
Γ_{60}	$\Lambda_c(2625)^+ \ell^- \bar{\nu}_\ell$	$(1.3_{-0.5}^{+0.6}) \%$	

$\Lambda_c(2595)$ close to the threshold: enhancement of decays into $\pi^0 \pi^0$
- 6 MeV gap between $\Sigma_c^{0,++} \pi^+$ and $\Sigma_c^{0,++} \pi^0$ threshold

$$\mathcal{B}(\Lambda_c(2595)^+ \rightarrow \Lambda_c^+ \pi^+ \pi^-) \sim 18.5\%$$

$$\mathcal{B}(\Lambda_c(2625)^+ \rightarrow \Lambda_c^+ \pi^+ \pi^-) \sim 55\%$$

Nieves PRD 101, 014018 (2020)

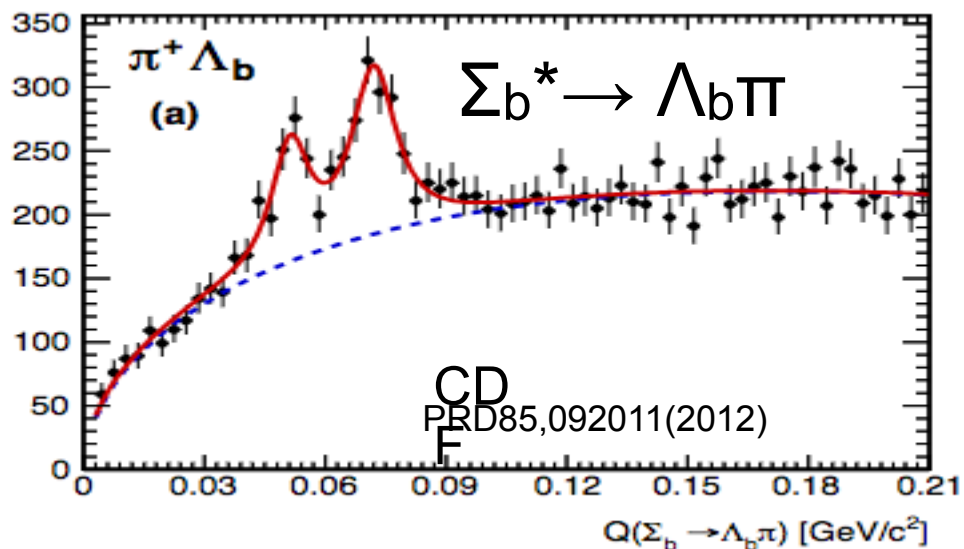
- consistent with BESIII
- Belle II could confirm

The hierarchy $3/2 > 1/2$ is reversed
Consistent with LQCD

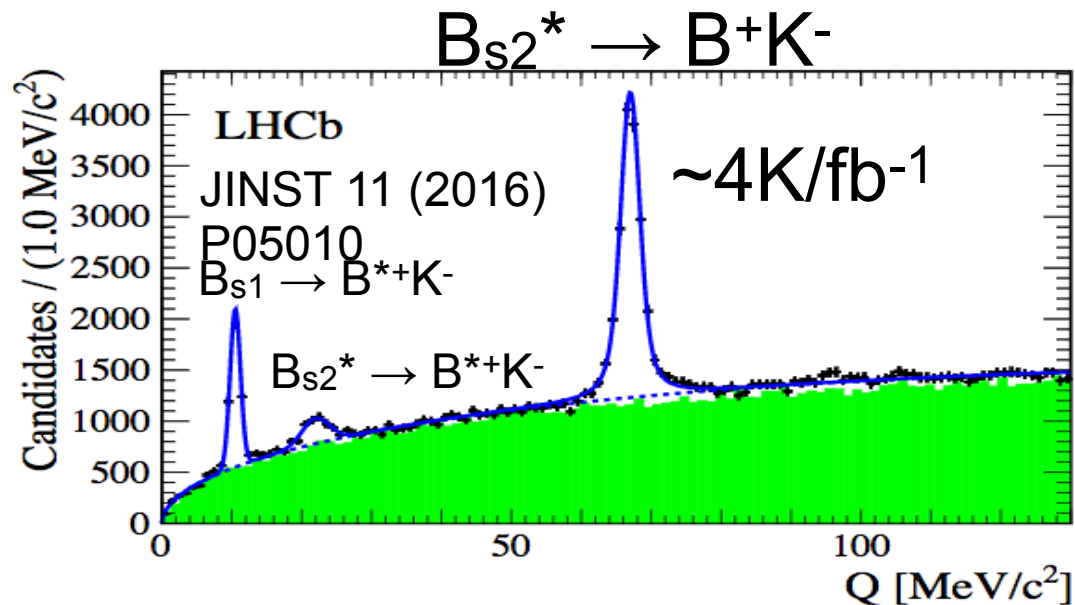
Mandatory to measure the ratio of BF
Determine form factors

Kinematics++ exploiting the resonances

- Additional constraints if the heavy meson comes from a narrow resonance
 - Sheldon, Zhang Adv.HEP 2014, 9312571



Λ_b from Σ_b , challenge from the many overlapping states

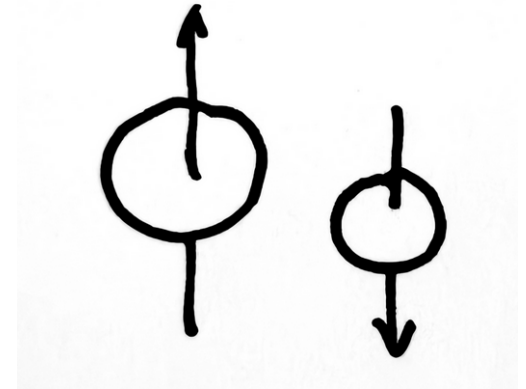


Narrow well separated resonances and clean signature due to the Kaon.
It allows to study B_u decays

Promising but we still need to fully exploit these techniques

B_c

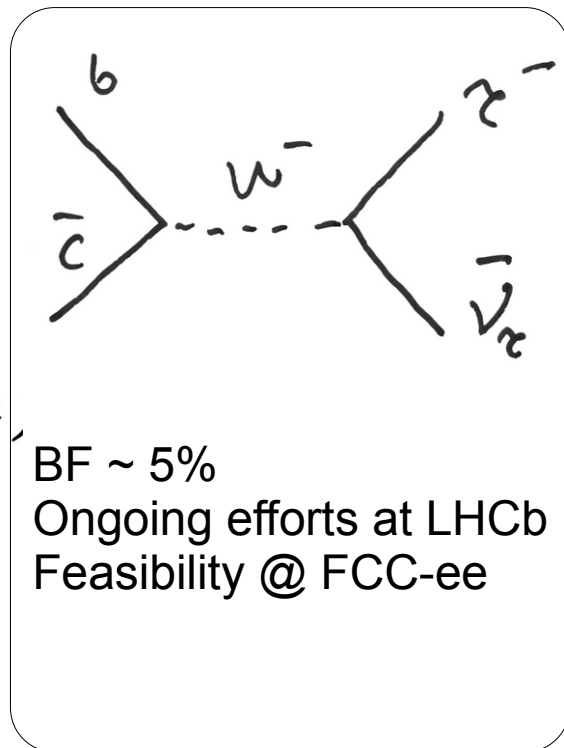
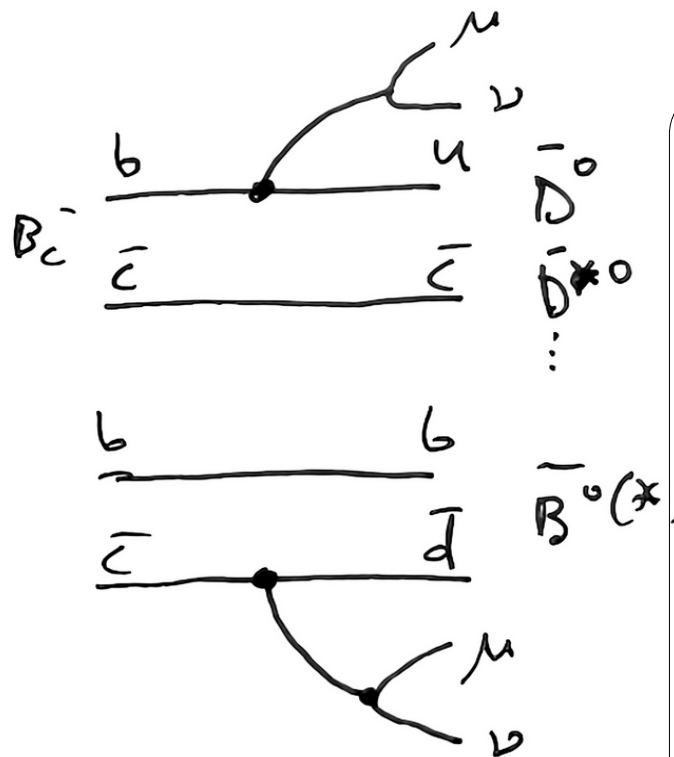
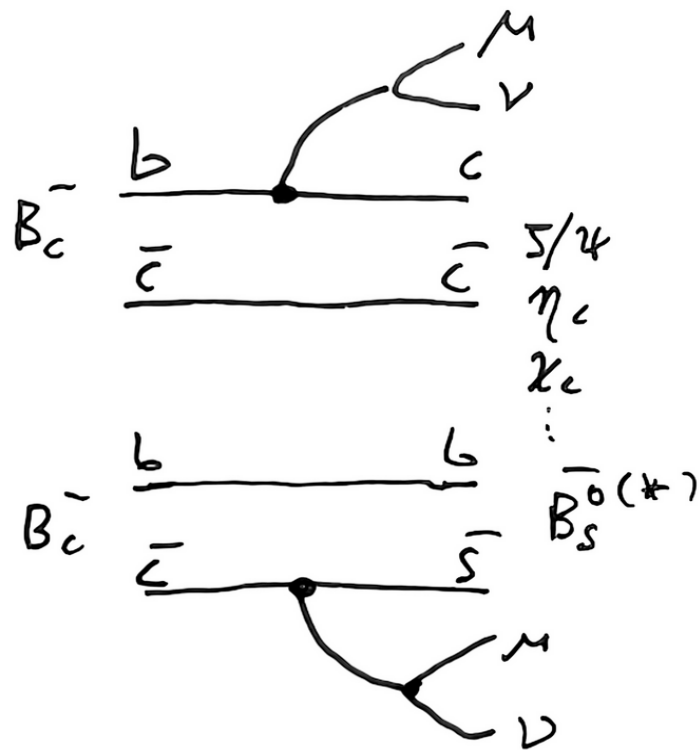
- Meson with 2-heavy quarks with open flavor (bc)
- Non-relativistic Qq system: mass spectrum similar to quarkonium
- Decays only via the weak interaction; absolute branching fractions are not known
- Not accessible at B-Factories
- Production rate $f(B_c)/f(B^+) \sim 1\%$
- Lifetime 1/3 of other light b-mesons



Meson	Mass	Lifetime
B_u	$5.28 \text{ GeV}/c^2$	1.64ps
B_d	$5.28 \text{ GeV}/c^2$	1.51ps
B_c	$6.28 \text{ GeV}/c^2$	0.51ps

Bc mesons

- Bc decays, in principle allow to access various CKM elements V_{cb} , V_{ub} , V_{cs} , V_{cd}



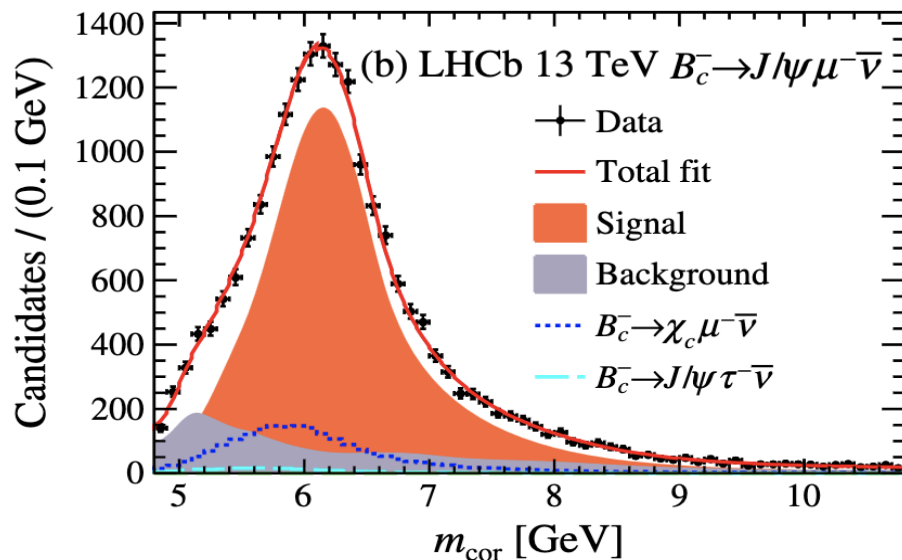
LHCb measurements

- Published:
 - Determination of $fB_c/(f_d+f_u)$ with $B_c \rightarrow J/\Psi \mu \nu$
 - Lifetime measurement with $B_c \rightarrow J/\Psi \mu \nu$
 - Observation of $B_c \rightarrow J/\Psi \tau \nu$, with $\tau \rightarrow \mu \nu \nu$, $\rightarrow R(J/\Psi)$ (Run1 and Run2)
 - Observation of $B_c \rightarrow B_s \pi$
- Ongoing:
 - Measurement of $R(J/\Psi)$ with $\tau \rightarrow 3\pi \nu$
 - Form Factors for $B_c \rightarrow J/\Psi \mu \nu$
- Started but in hold (finished PhD thesis)
 - Determination of $|V_{ub}|/|V_{cb}|$ with $B_c \rightarrow D^0 \mu \nu$
 - Search for $B_c \rightarrow B_{s/d} \mu \nu$

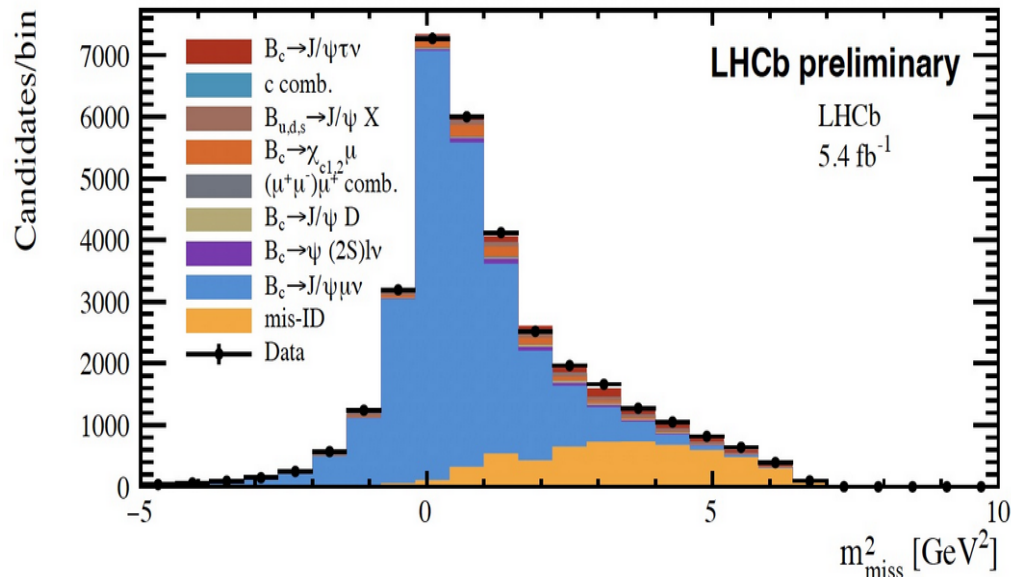
$B_c \rightarrow J/\psi \mu \nu$

- Golden channel at LHC: 3 muons in the final state
 - Used for many analysis: lifetime, production fraction, $R(J/\Psi)$, most of the known decay channels are normalized to $B_c \rightarrow J/\Psi \mu \nu$

PRD 100, 112006

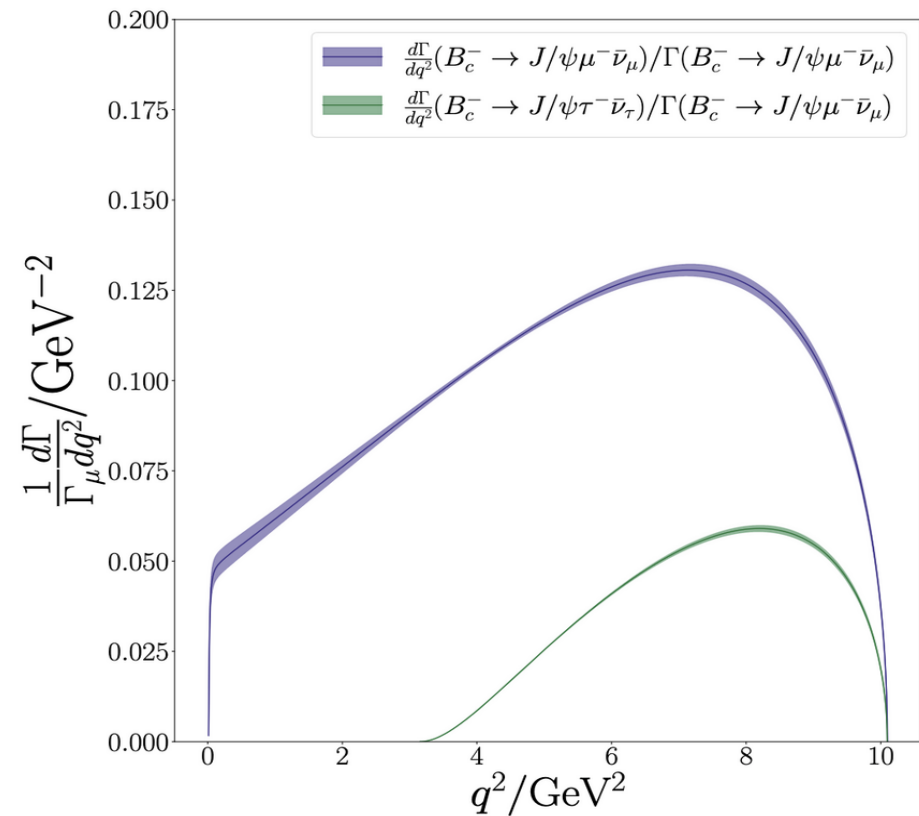


CERN seminar May 2026



$B_c \rightarrow J/\psi \mu \nu$ on L_QCD

HPQCD PRD 112 (2025) 3, 034503



Predicted BF:

$$15.3 \pm 0.4_{\text{LQCD}} \pm 0.6_{v_{cb}} \pm 0.3_{\tau}$$

+

$$\frac{f_c}{f_u + f_d} \cdot \mathcal{B}(B_c^- \rightarrow J/\psi \mu^- \bar{\nu})$$

$$= (7.36 \pm 0.08 \pm 0.30) \times 10^{-5} \quad \text{for 13 TeV}$$

$$\frac{f_c}{f_d + f_u} = (4.81 \pm 0.20_{\text{exp}} \pm 0.24_{\text{LQCD+ext.}}) \cdot 10^{-3}$$

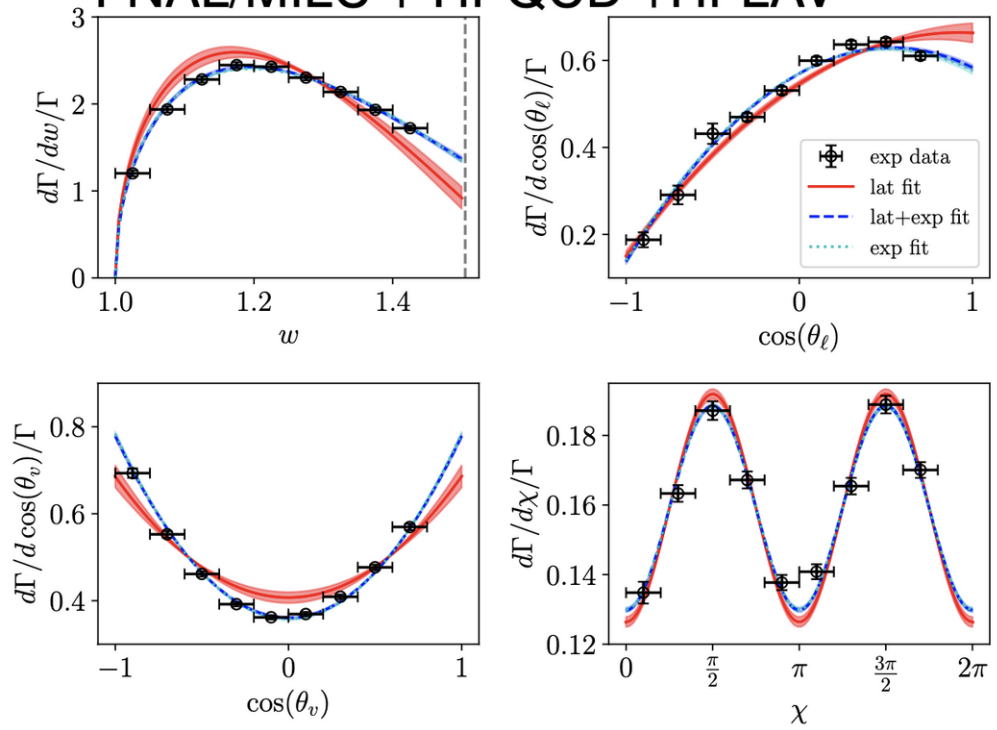
High precision on many
observables of interest!

But...

$B \rightarrow D^* l \nu$

FNAL/MILC + HPQCD + HFLAV

[MB, A]



Mandatory to study the differential rate for $B_c \rightarrow J/\Psi \tau \nu$

Extend study of differential q^2 spectrum and ratio of BFs, to other final states:

- $\Psi(2S)$: background in various analysis
- η_c ($\Phi\Phi, p\bar{p}, \dots$): fundamental state, but the cleanest η_c decay modes, $BF \sim 10^{-3}$
- χ_{c1} ?
- $\chi_{c1} \leftrightarrow X(3872)$?

- Interesting channel

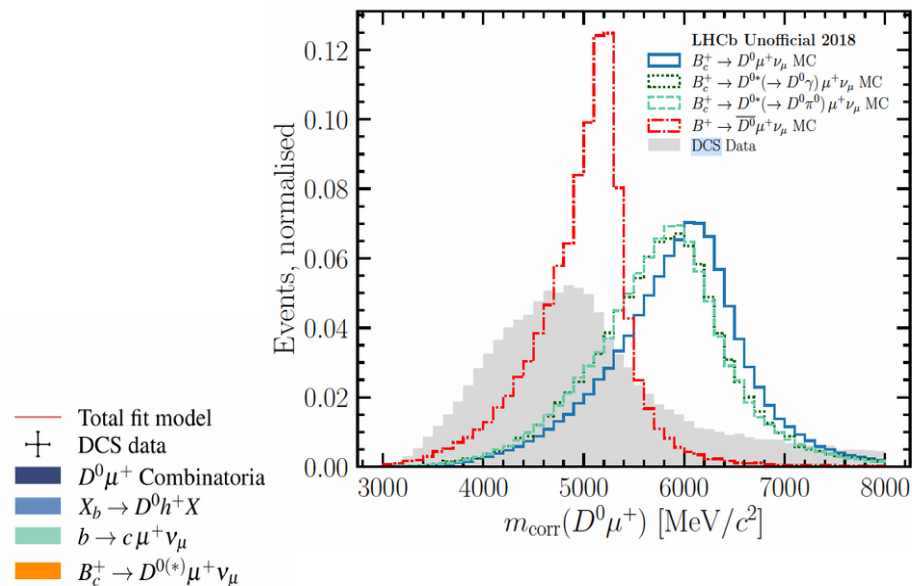
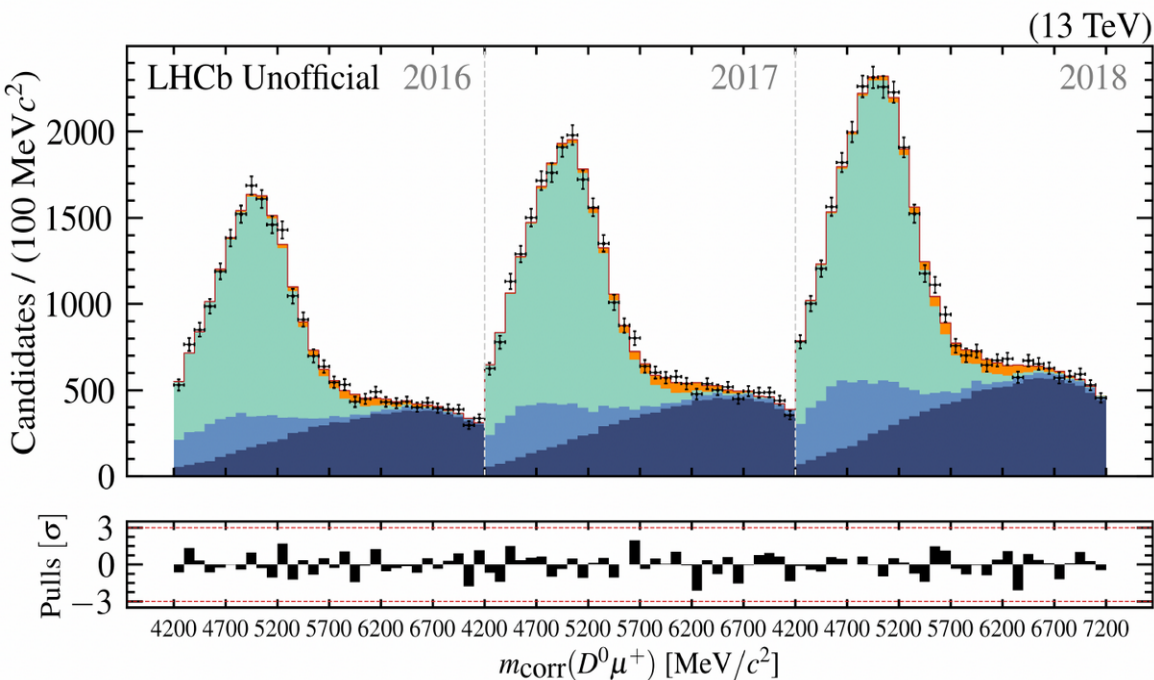
$$\begin{aligned} \frac{\mathcal{B}(B_c^+ \rightarrow D^{(*)0} \mu^+ \nu_\mu)}{\mathcal{B}(B_c^+ \rightarrow J/\psi \mu^+ \nu_\mu)} &= \frac{N_{D^{(*)0}}}{N_{J/\psi}} \frac{\varepsilon_{J/\psi}}{\varepsilon_{D^{(*)0}}} \frac{\mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-)}{\mathcal{B}(D^0 \rightarrow K^- \pi^+)} \\ &= (R_{\text{FF}}^{D^0} + R_{\text{FF}}^{D^{*0}}) \frac{|V_{ub}|^2}{|V_{cb}|^2}, \end{aligned}$$

R^D and R^{D^*} from theory input

Channel [10^{-18} GeV]	3ptSR [39]	LQCD [41, 40]	Ebert <i>et al.</i> [21]	Kiselev [22]	ISGW2 [23, 42]
$\Gamma(B_c^+ \rightarrow D^0 \mu^+ \nu_\mu)$	31 ± 6	43.1 ± 9.3	19	59	26
$\Gamma(B_c^+ \rightarrow D^{*0} \mu^+ \nu_\mu)$	85 ± 33	—	110	270	53
$\Gamma(B_c^+ \rightarrow J/\psi \mu^+ \nu_\mu)$	—	$(19.51 \pm 1.85) \times 10^3$	17.70×10^3	28.00×10^3	16.50×10^3

Measurement of V_{ub}/V_{cb}

- Reconstructing only $D^0 \rightarrow K \pi$
- Exploit 1) the Bc lifetime; 2) Bc-B mass difference
- Contamination from $B \rightarrow D^0 \mu \nu$ only enter through DCS of the D^0



$$N(B_c^+ \rightarrow D^{(*)0} \mu^+ \nu_\mu) = 2291 \pm 464,$$

$$N(B_c^+ \rightarrow J/\psi \mu^+ \nu_\mu) = 47486 \pm 873$$

Not competitive:

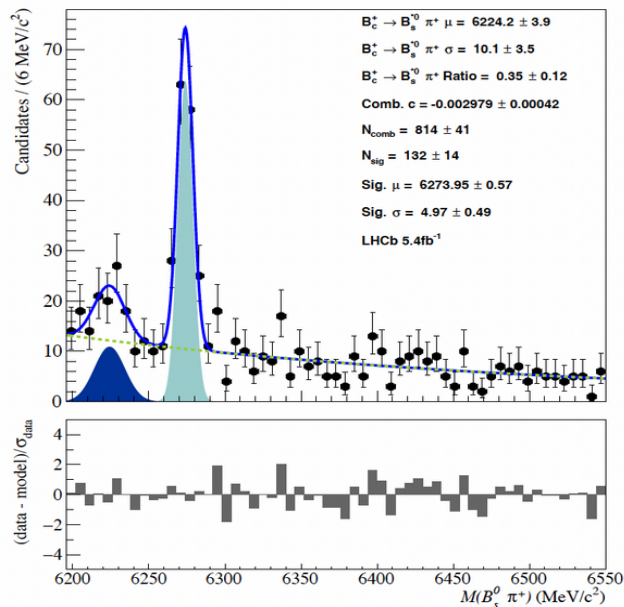
- Add D decay modes and Run3
- Improve knowledge of the $B_c \rightarrow D^*$ FFs

$$\frac{\mathcal{B}(B_c^+ \rightarrow B_s^0 \mu^+ \nu_\mu)}{\mathcal{B}(B_c^+ \rightarrow B_s^0 \pi^+)} = \frac{N(B_c^+ \rightarrow B_s^0 \mu^+ \nu_\mu)}{N(B_c^+ \rightarrow B_s^0 \pi^+)} \cdot \frac{\epsilon_{\text{tot}}(B_c^+ \rightarrow B_s^0 \pi^+)}{\epsilon_{\text{tot}}(B_c^+ \rightarrow B_s^0 \mu^+ \nu_\mu)}$$

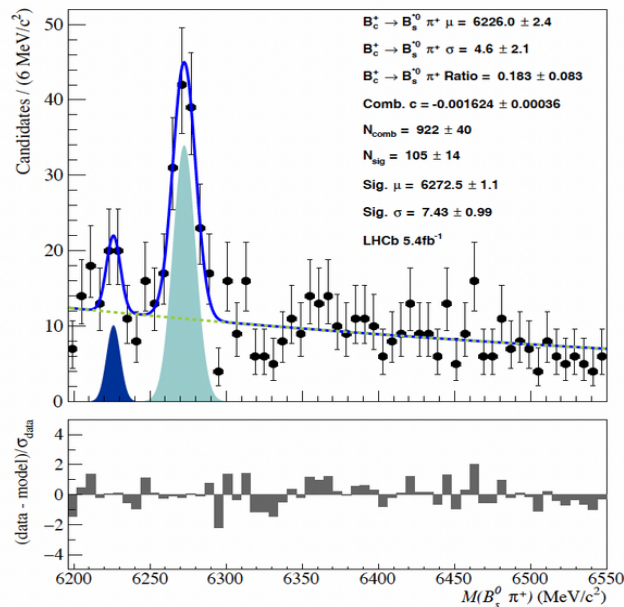
Theory predictions from L-QCD and from continuum exploiting spin-symmetry are available

The SL is limited by statistics
With run2: U.L. on this ratio

Add more B_s decay modes
(maybe all use all the B_s reconstructable at LHCb)



(A) $B_c^+ \rightarrow (B_s^0 \rightarrow D_s^- \pi^+) \pi^+$



(B) $B_c^+ \rightarrow (B_s^0 \rightarrow J/\psi \phi) \pi^+$

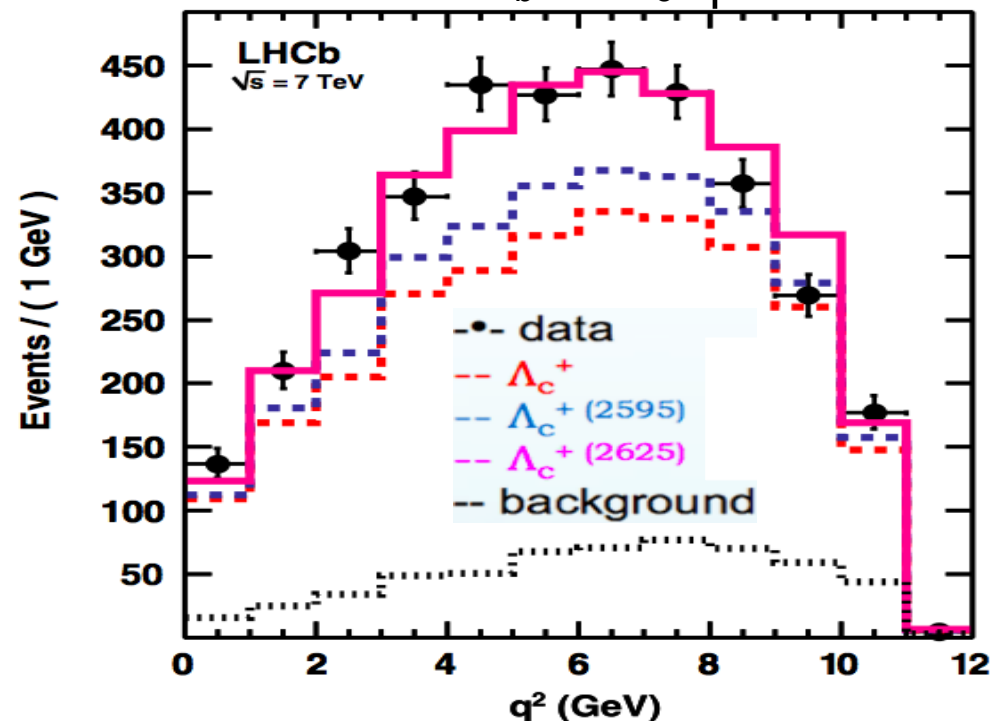
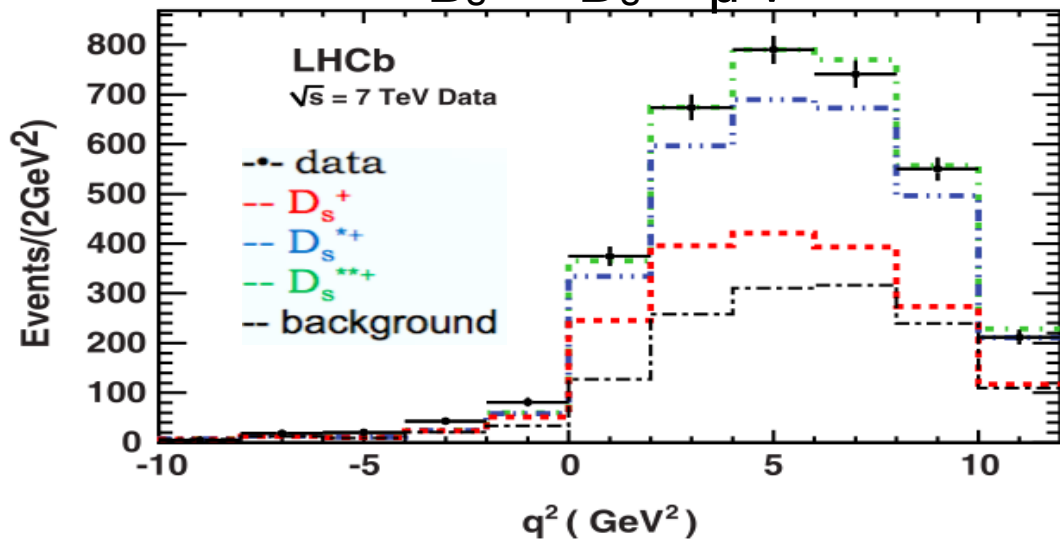
Summary / Outlook / New ideas

- Many interesting opportunities
- And many challenges!
- ...

To be filled during this Workshop

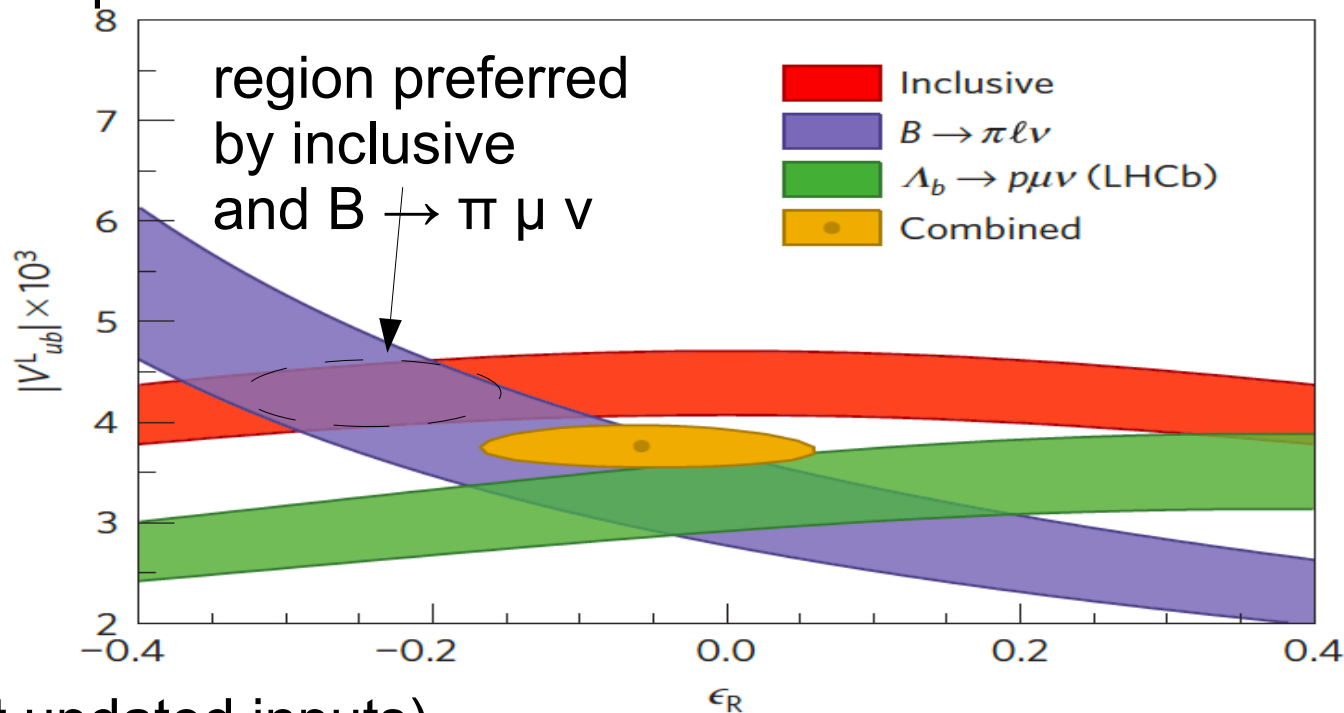
Backup

- Crucial to perform the measurements in bins of q^2
 - SL decays as a function of the q^2 already studied with only 3pb^{-1} (high efficient trigger)
 - Need further studies to translate in measurements of the Form Factors
 - $B_s \rightarrow D_s^{(*)} \mu \nu$
 - $\Lambda_b \rightarrow \Lambda_c^* \mu \nu$



Crude assumptions on the FFs and
on the D_s^*/D_s and Λ_c^*/Λ_c rates

- The right-handed current model could explain the historical difference between inclusive and exclusive $|V_{ub}|$
- The $\Lambda_b \rightarrow p \mu \nu$ has also contribution from axial vector current: different dependence on the RH current



The inclusion of LHCb does not support a significant RH contribution

(not updated inputs)