Baryon decays involving $b \rightarrow cl\nu$ transitions @ LHCb

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b-baryon Fest workshop

6th November 2020

University of Zurich UZH

What have we done with $b \rightarrow ql\nu$ transitions ?

First observations of $b \rightarrow u$ transitions

Constrain CKM elements: $|V_{ub}|$ and $|V_{cb}|$

Tests of Lepton Flavour Universality Violation (LFUV)

Search for rare processes such as $B \rightarrow 3\mu\nu$

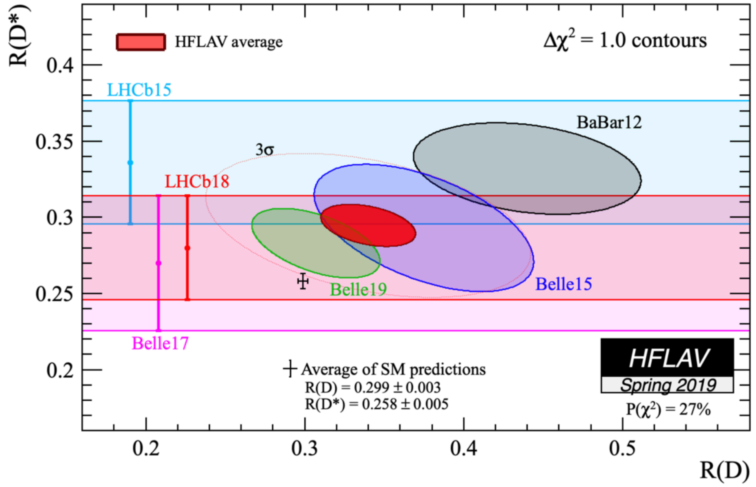
Tests of HQEFT and Lattice QCD predictions

Measurement of production fraction and production asymmetry

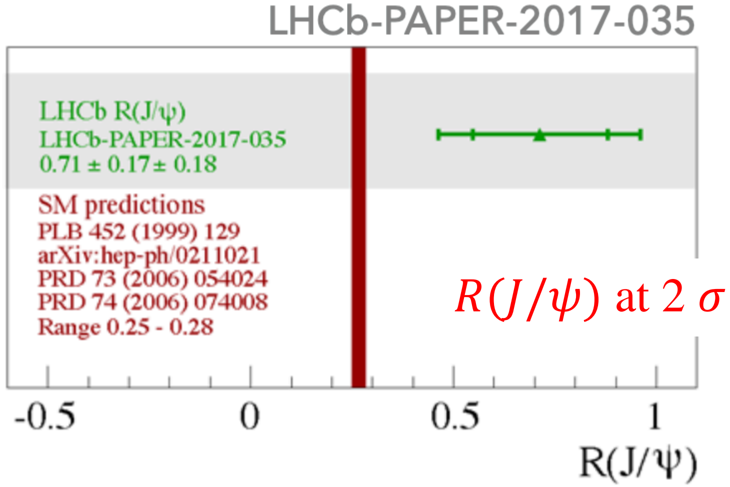
Measurement of lifetime of the non-prompt charm hadrons and CP violation in their decay.

$B^0_{d,s}$mixing: oscillation frequency and CP asymmetry.

Measurements causing a stir



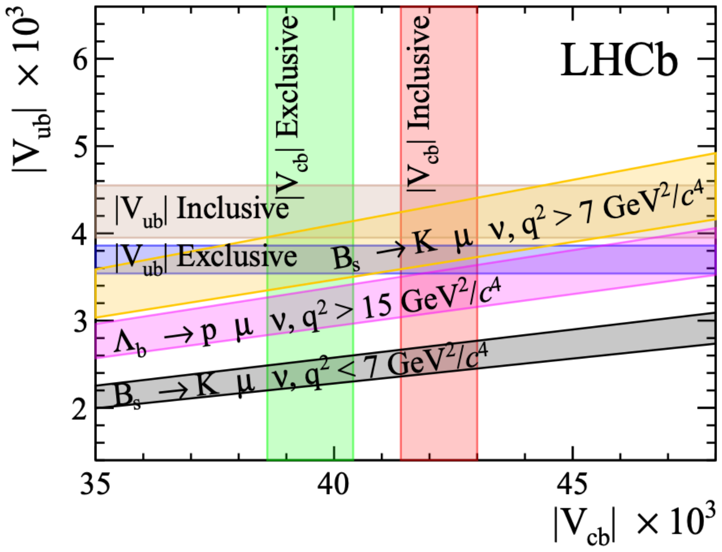
$R(D)$ Vs $R(D^*)$ at 3.08 σ



$R(J/\psi)$ at 2 σ

New measurement of $B_s \to K\mu\nu$ at Implications [workshop]

Inclusive Vs Exclusive ~ 3σ tension



Where have the b-baryon decays contributed?

First observations of suppressed $b \to u$ transitions
(Observed $\Lambda_b \to p\mu\nu$)

Constrain CKM elements: $|V_{ub}|$ and $|V_{cb}|$
(Studied $\Lambda_b \to p\mu\nu$ and $\Lambda_b \to \Lambda_c\mu\nu$)

Measurement of production fraction and production asymmetry.
[Studied inclusive sample of $\Lambda_b \to \Lambda_c\mu\nu X$ (production asymmetry ongoing)]

Tests of LFUV ($R(\Lambda_c)$ Ongoing)

Measurement of lifetime of the non-prompt charm hadrons and CP violation in their decay.
[Inclusive samples of $\Lambda_b \to \Lambda_c\mu\nu X$, $\Xi_b^{0(-)} \to \Xi_c^{+(0)}\mu^-\nu X$ and $\Omega_b^- \to \Omega_c^0\mu\nu X$ (CPV not yet)]

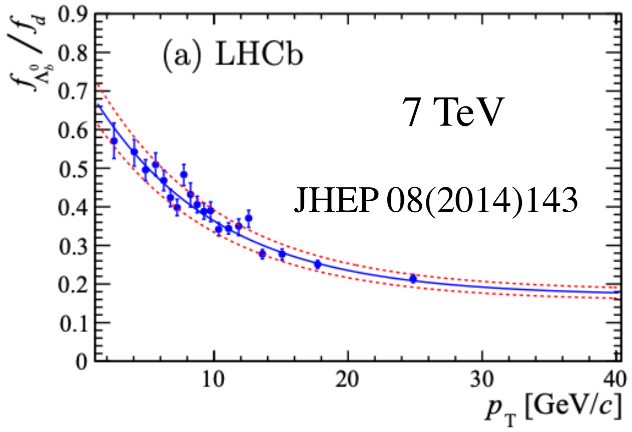
Tests of HQEFT and Lattice QCD predictions
(Shape of q^2 distribution of $\Lambda_b \to \Lambda_c\mu\nu$)

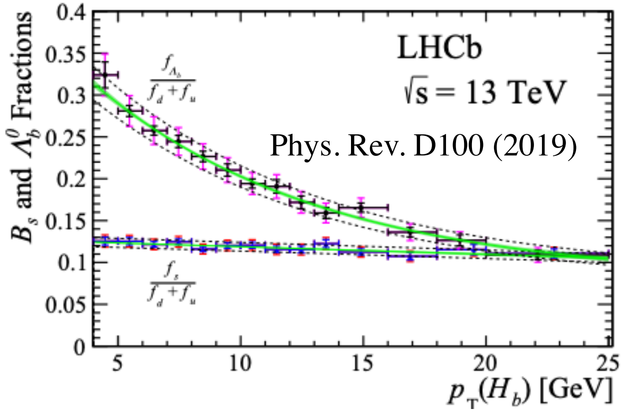
Green: b-baryon decays that have contributed towards the measurement.
Yellow: Things I will touch in this talk.

Studies of $\Lambda_b \to \Lambda_c^{(*)} l\nu$ decays

- Crucial to study decays with the same underlying $b \to c$ transition but involve different hadrons.
  - ➢ Provides complimentary environments with different systematic uncertainties and varying sensitivities to different NP contributions.
- Will mainly concentrate on studies of $\Lambda_b \to \Lambda_c^{(*)} l\nu$ decays.
  - ➢ Why b-baryon decays? Compared to b-meson decays allows us to probe different spin dynamics (e.g. particularly sensitive to tensor NP currents).
  - ➢ Why Λ_b baryons? Copious production of Λ_b baryons (more than 20% of the b-hadrons at LHCb are Λ_b baryons).
  - ➢ Why $\Lambda_b \to \Lambda_c^{(*)}$?
    - Large BFs compared to mesonic counterpart e.g. $\mathrm{BF}(\Lambda_b \to \Lambda_c \mu\nu) \sim 3 \times BF(B^+ \to \overline{D}^0 \mu\nu)$.
    - Reduced bkg. consideration compared to mesonic counterpart due to baryon number conservation.
    - Dynamics of the $\Lambda_b \to \Lambda_c^* l\nu$ important to understand as they form irreducible background to $R(\Lambda_c)$ measurement.

Production fractions





Form factors of $\Lambda_b^0 \to \Lambda_c^+ \mu\nu$

LHCb Collaboration[Phys. Rev. D **96**, 112005]

- The decays of $\Lambda_b^0 \to \Lambda_c^+ l^- \nu$ is governed by 6 scalar form factors within SM.
- Within the framework of HQET, these form factors receive non-perturbative corrections suppressed by powers of α_S or $\frac{\Lambda_{QCD}}{m_{b,c}}$.
- In the static limit of infinite quark mass, at leading order in HQE, all the form factors are proportional to Isgur-Wise (IW) function, $\xi(w)$.
- Compared to their mesonic counterpart, the $O(\frac{\Lambda_{QCD}}{m_{b,c}})$ corrections are constants that can be absorbed into $\xi(w)$.
- Therefore, in the static limit, the decay density is proportional to phase space factor $K(w)$ and IW functions:

$$\frac{d\Gamma}{dw} \propto K(w)\, \xi^2(w)$$

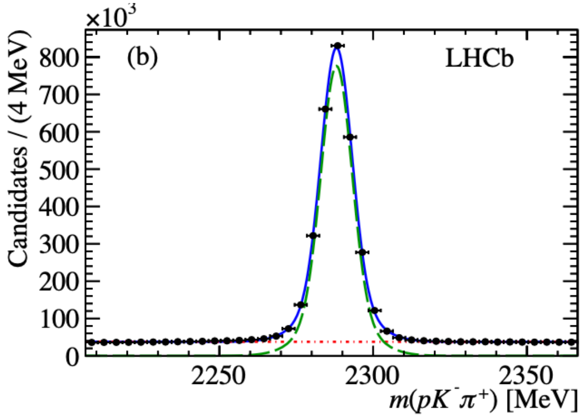
- Here the $\xi(w)$ can be Taylor expanded to around $(w-1)$ and the coefficients (ρ^2, σ^2) can be obtained from the fit to w distribution.

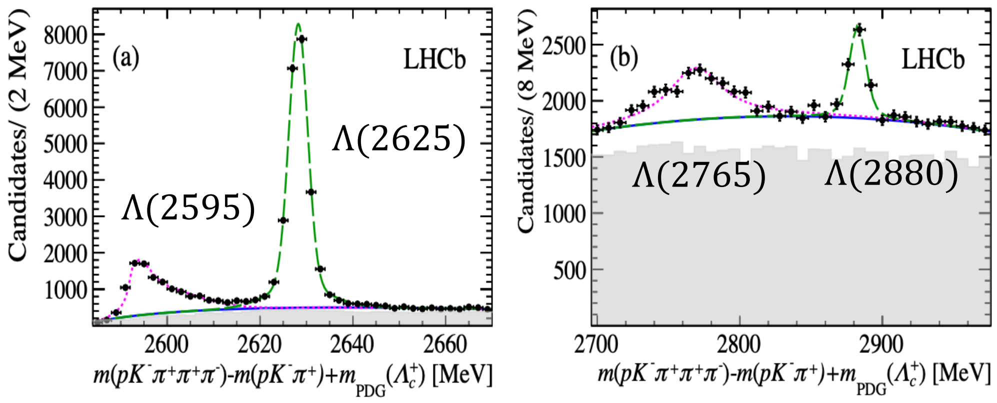
$$\xi_B(w) = 1 - \rho^2(w-1) + \frac{1}{2}\sigma^2(w-1)^2 + \ldots$$

Let's measure the w distribution

LHCb Collaboration[Phys. Rev. D **96**, 112005]

- Fit the $m(pK\pi)$ distribution in bins of reconstructed w (related to q^2) to get the yield of the inclusive $\Lambda_b \to \Lambda_c \mu \nu X$ decays.
- Identify the contribution from feed-down from excited $\Lambda_c^{*+} \to \Lambda_c^+ \pi^+ \pi^-$ by fitting $m(\Lambda_c \pi\pi)$.





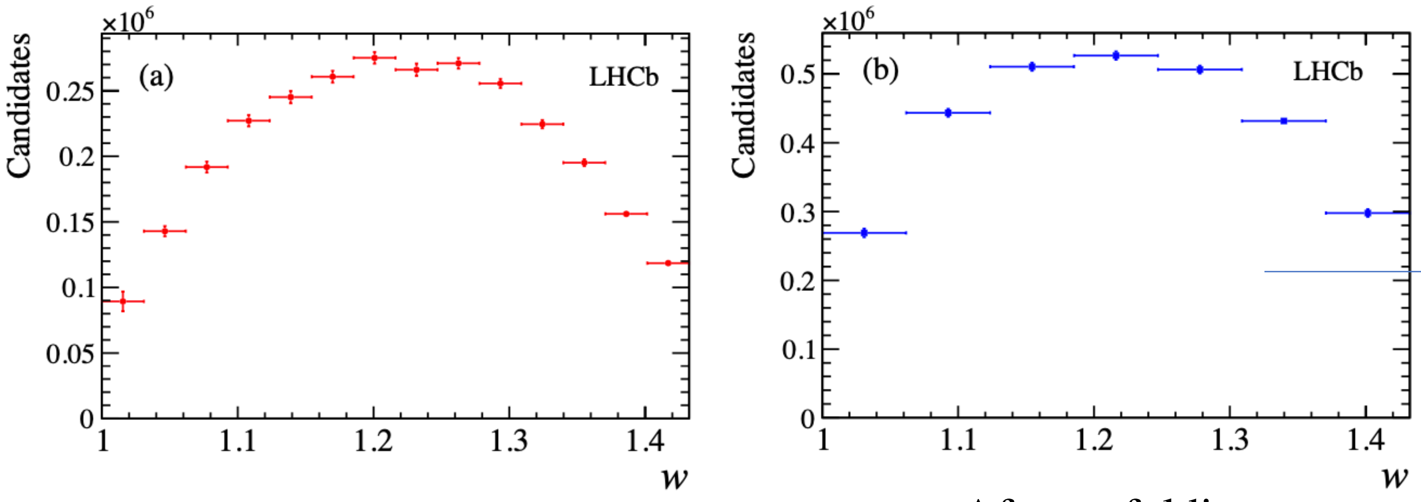
Large signal in LHCb Run I data integrated over w!

Final state	Yield
$\Lambda_c(2595)^+\mu^-\overline{\nu}_\mu$	8569 ± 144
$\Lambda_c(2625)^+\mu^-\overline{\nu}_\mu$	22965 ± 266
$\Lambda_c(2765)^+\mu^-\overline{\nu}_\mu$	2975 ± 225
$\Lambda_c(2880)^+\mu^-\overline{\nu}_\mu$	1602 ± 95
$\Lambda_c^+\mu^-\overline{\nu}_\mu X$	$(2.74\pm0.02)\times10^6$

Reconstruction and efficiency variation

LHCb Collaboration[Phys. Rev. D **96**, 112005]

- What is the reconstructed $q^2 = \left(P_{\Lambda_b} - P_{\Lambda_c}\right)^2$?
- In the case of single missing particle, one can obtain the Λ_b 4-momentum with a quadratic ambiguity exploiting the separation between the secondary ($\Lambda_c\mu$) and primary (Λ_b) vertex positions [Nucl.Instrum.Meth. A569 (2006) 824-828].
  - ➢ For this analysis, a solution is picked at random (checking that it does not introduce huge bias).
- The true q^2 or w distribution is unfolded using SVD technique [Nucl.Instrum.Meth.A372:469-481,1996].



Before unfolding

After unfolding

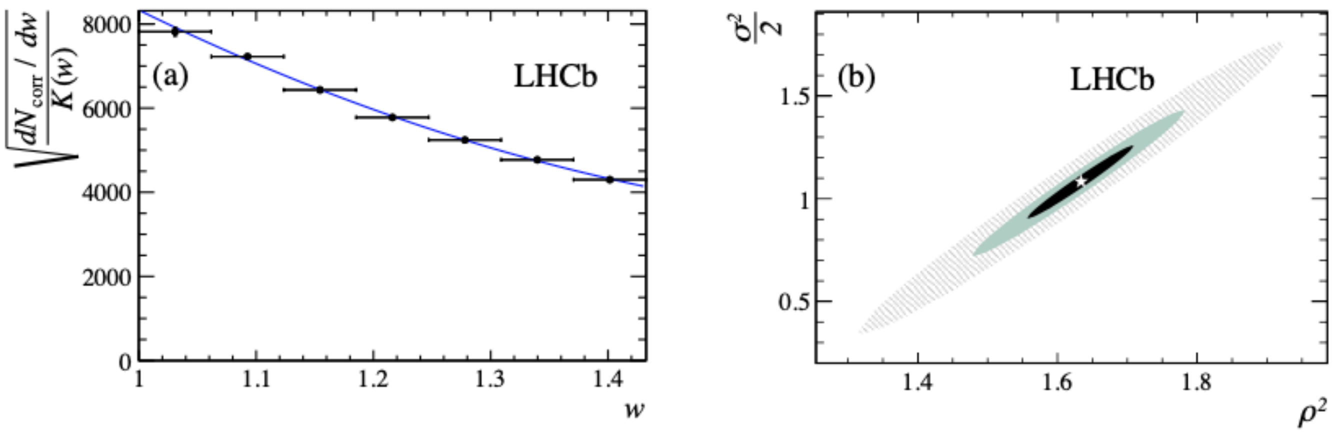
This spectrum is later corrected for selection efficiency variation over w distribution, before extracting IW function.

Results

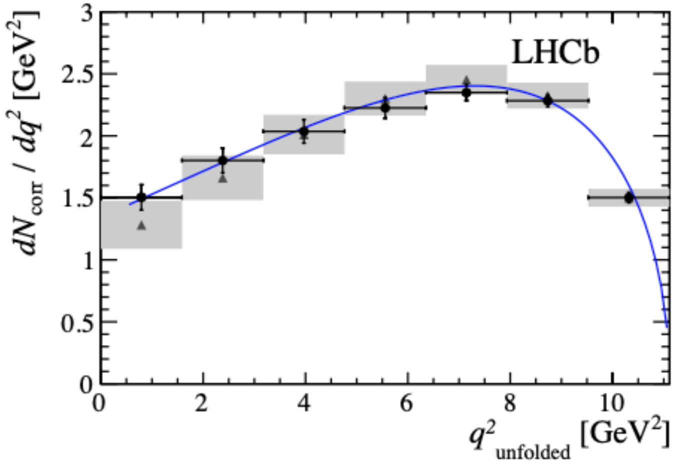
LHCb Collaboration[Phys. Rev. D **96**, 112005]

- Fitting for the IW shape, leads to the measurement of the coefficiencts ρ^2 (slope) and $\sigma^2/2$ (curvature).
- Both of these coefficients are highly correlated, difficult to disentangle with only the recoil information.
- **Both of the coefficients agree with predictions and their bounds** (Lattice: Phys. Rev. D 57, 6948, QCD sum rules: Phys. Lett. B629 (2005) 27 and relativistic quark model: Phys. Rev. D 73, 094002).
- The lattice prediction of q^2 distribution was also compared and good agreement was found [Phys. Rev. D 92, 034503].

Fit result



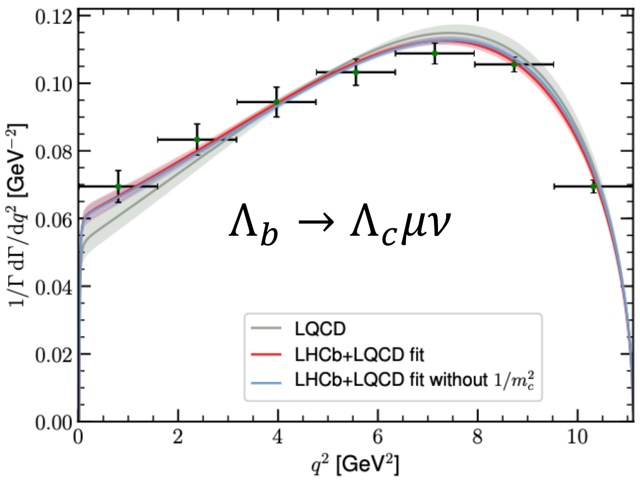
Test with Lattice QCD prediction

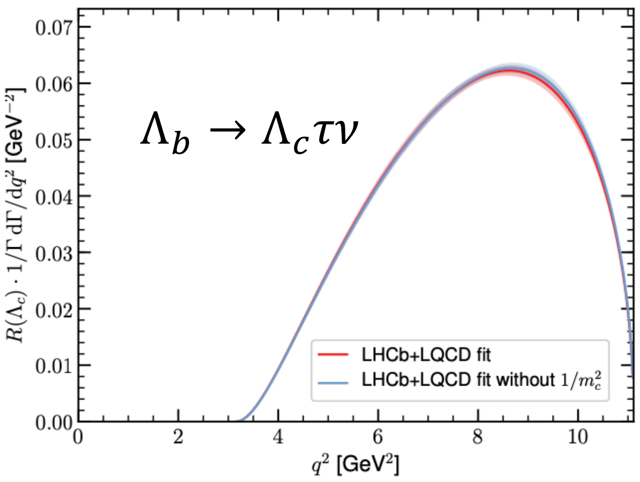


Consequence of the LHCb and Lattice result

F. Bernlochner, Z. Ligeti, D. Robinson and W. Sutcliffe [Phys. Rev. D 99, 055008 (2019)]

- The LHCb result shows that the higher order $O(\Lambda_{QCD}^2/m_c^2)$ corrections do not have large effect.
- Using both the LHCb measurement and the Lattice QCD predictions [Phys. Rev. D 92, 034503], the correction terms are quantifiable in $\Lambda_b \to \Lambda_c l \nu$ decays.
- Parameter-free predictions of tensor form factors possible at $O\left(\Lambda_{QCD}^2/m_c^2\right)$ in HQET framework.
- Leading to precise predictions of $R(\Lambda_c) = 0.3237 \pm 0.0036$ within SM and also arbitrary NP scenario.

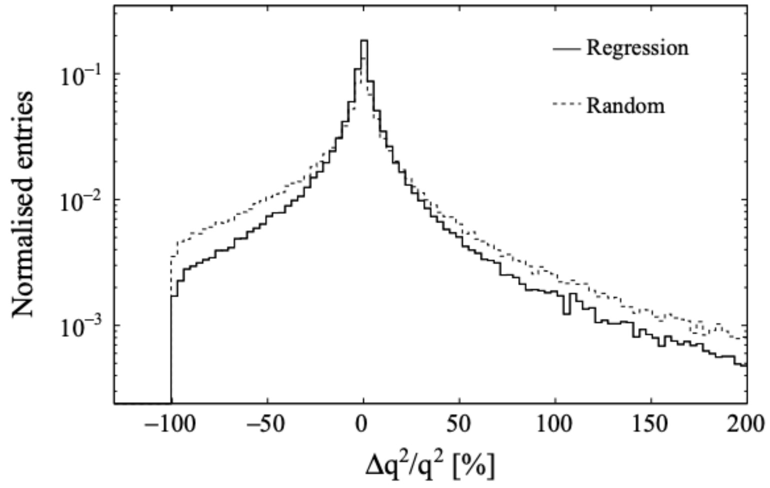




Moving forward, what to explore in $\Lambda_b \to \Lambda_c \mu \nu$ decays?

- Additional sensitivity to form factors can be gained by measuring the shape of both the q^2 and $\cos(\theta_\mu)$.
  - With a suitable normalisation channel extract $|V_{cb}|$ with good precision.
- Add more data by including also Run II sample.
- Improve the resolution of the 2D distributions to reduce bin migration.
  - Instead of picking one of the quadratic solutions randomly, train a linear regression model using flight information to pick a solution that is closer to the prediction [J. High Energ. Phys. (2017) 2017]. This can be further improved.
- New observables to explore e.g. short distance effects from different currents:
  - What is the sensitivity is achievable on these with LHCb data?
  - Exploring the phase space of different Λ_c decays $\Lambda_c \to \Lambda\pi, K_S p, pK\pi, ...$?

Resolution on q^2



Shape measurement and $|V_{cb}|$

Ongoing LHCb analysis

- Possibility to measure the shape of the q^2 and $cos\theta_\mu$ and $|V_{cb}|$ in the same analysis.
- Idea to use the inclusive $\Lambda_b \to X_c \mu\nu$ sample as the normalisation channel and measure :

$$\frac{d\Gamma_{\Lambda_b \to \Lambda_c \mu\nu}}{dq^2 dcos\theta_\mu} = \frac{N_{\Lambda_b \to \Lambda_c \mu\nu}(q^2, \cos\theta_\mu)}{N_{\Lambda_b \to X_c \mu\nu}} \times \Gamma_{\Lambda_b \to X_c \mu\nu}$$

Where $\Gamma_{\Lambda_b \to X_c \mu\nu}$ estimated in the similar way to our Λ_b production measurement [PhysRevD.100.031102].

- Combine with the theory prediction [Phys. Rev. D 99, 055008 (2019)] and estimate $|V_{cb}|$.

$$\frac{d\Gamma_{\Lambda_b \to \Lambda_c \mu\nu}}{dq^2 dcos\theta_\mu} = |V_{cb}|^2 f(q^2, \cos(\theta_\mu))$$

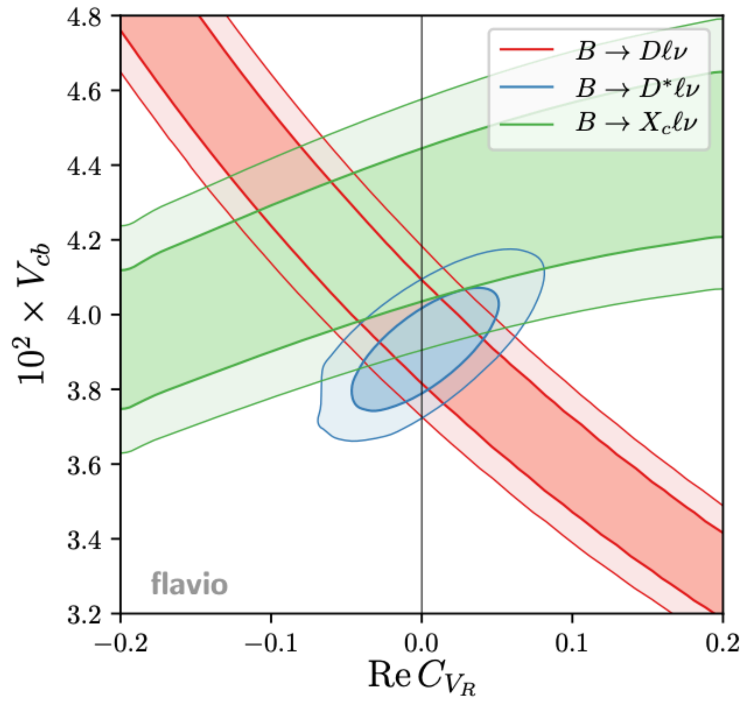
- Analysis currently underway with full LHCb data.

New Physics sensitivity in $\Lambda_b \to \Lambda_c \mu \nu$ decays

M. Ferrillo, A. Mathad, P. Owen, N. Serra [JHEP 12 (2019) 148]

- Numerous studies have shown effects of NP contributions on angular observables of $B \to D^{(*)}\tau\nu$ and global fits to $b \to c\tau\nu$ have been conducted to determine the Wilson coefficients [JHEP09(2019)103].
- A recent global fits to $b \to c\mu\nu, ce\nu$ transitions has proven that good sensitivity can be obtained on the various Wilson coefficients through studies of b-meson [JHEP01(2019)009].
- The $\Lambda_b \to \Lambda_c l\nu$ is a good candidate to complement the NP sensitivity, due to the large production cross section of Λ_b^0 baryons and the well measured form factors.
- (Topic of next presentation) Very recently angular description of unpolarised $\Lambda_b \to \Lambda_c(\to \Lambda\pi) l\nu$ semileptonic decays in the presence of NP operators had also been put forward [arXiv:1907.12554].

[JHEP01(2019)009]



Decay channel choices

M. Ferrillo, A. Mathad, P. Owen, N. Serra [JHEP 12 (2019) 148]

- To study the new physics effects, we made the following choices for the decay channels.
- Considered muonic Λ_b decay i.e. $\Lambda_b \rightarrow \Lambda_c \mu \nu$:
  - Tauonic mode is more sensitive to NP, but challenging! (irreducible bkgs and dilution of the resolution on fit variables).
- Comments on Λ_c decay considered:
  - No model available for $\Lambda_c \rightarrow pK\pi$ (Do not have to wait too long for this). Experimentally attractive higher BF and better reconstruction.
  - The next in line were $\Lambda_c \rightarrow pK_S$ and $\Lambda_c \rightarrow \Lambda\pi^+$: The uncertainty on weak decay parameter (α_{Λ_c}) for the latter is a factor ¼ compared to the former from BESIII [Phys. Rev. D 100, 072004 (2019)]. However, given our large signal yield we could investigate its sensitivity from our fit.
  - The decay of $\Lambda_c \rightarrow pK_S$ is experimentally attractive (slightly higher BF and better reconstruction efficiency of K_S at LHCb due to its smaller lifetime.
- Comment on Λ_b^0 transverse polarization:
  - Until now the Λ_b polarisations at LHC have been measured using the angular analysis of $\Lambda_b \rightarrow J/\psi\Lambda$.
  - Semileptonic decays could provide a complimentary measurement. Sensitivity needed to be investigated.

Effective Hamiltonian

M. Ferrillo, A. Mathad, P. Owen, N. Serra [JHEP 12 (2019) 148]

- Considered most generic effective Lagrangian of the four-fermion interaction

$$\mathcal{H}_{\text{eff}} = \frac{4G_F}{\sqrt{2}} V_{cb} \left[(1 + C_{V_L}) \mathcal{O}_{C_{V_L}} + C_{V_R} \mathcal{O}_{C_{V_R}} + C_{S_L} \mathcal{O}_{C_{S_L}} + C_{S_R} \mathcal{O}_{C_{S_R}} + C_{T_L} \mathcal{O}_{C_{T_L}} \right] + h.c.$$

$$\begin{aligned}
\mathcal{O}_{C_{V_L}} &= \bar{c}_L \gamma^\mu b_L \, \bar{\ell}_L \gamma_\mu \nu_L \, , \\
\mathcal{O}_{C_{V_R}} &= \bar{c}_R \gamma^\mu b_R \, \bar{\ell}_L \gamma_\mu \nu_L \, , \\
\mathcal{O}_{C_{S_L}} &= \bar{c}_R b_L \, \bar{\ell}_R \nu_L \, , \\
\mathcal{O}_{C_{S_R}} &= \bar{c}_L b_R \, \bar{\ell}_R \nu_L \, , \\
\mathcal{O}_{C_{T_L}} &= \bar{c}_R \sigma^{\mu\nu} b_L \, \bar{\ell}_R \sigma_{\mu\nu} \nu_L
\end{aligned}$$

- Assume the absence of (left) right-handed ν_l ($\bar{\nu}_l$) and note that the right-handed tensor operator $O_{C_{T_R}}$ vanishes.

Six-fold differential decay density with NP

M. Ferrillo, A. Mathad, P. Owen, N. Serra [JHEP 12 (2019) 148]

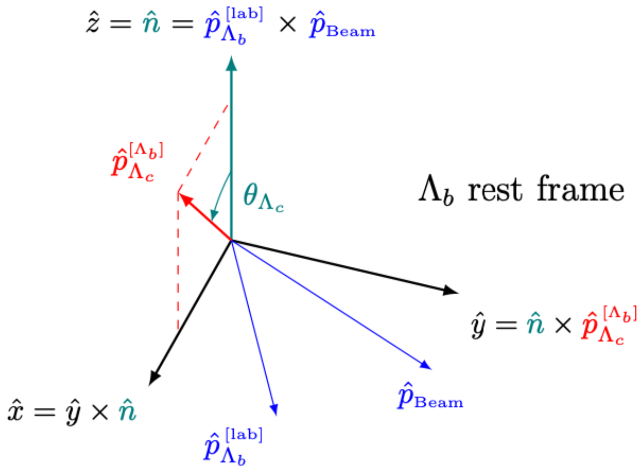
- In the paper, for the first time, we present the full six-fold differential decay density for the polarised $\Lambda_b \to \Lambda_c(\to pK_S)l\nu$ decays in the presence of NP.

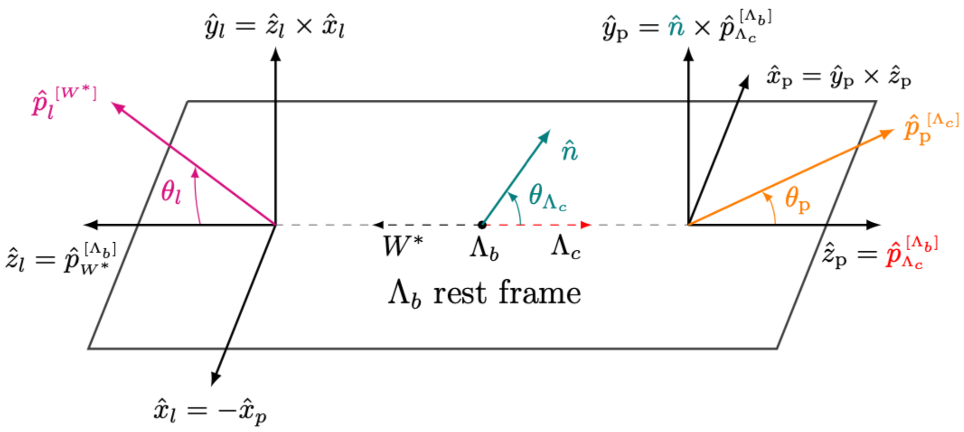
$$d^6\Gamma = \frac{N}{\Gamma}|T|^2 d\Omega'$$

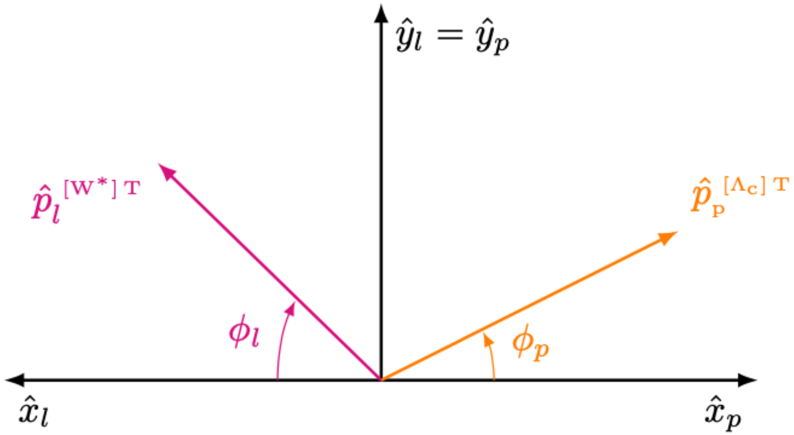
$$d\Omega' = dq^2 d\cos\theta_{\Lambda_c} d\cos\theta_p d\phi_p d\cos\theta_l d\phi_l$$

$$|T|^2 = (1+P_{\Lambda_b}) \sum_{\lambda_p,\lambda_{\ell-}} |T^{\lambda_{\Lambda_b^0}=\frac{1}{2}}_{\lambda_{\ell-},\lambda_p}|^2 + (1-P_{\Lambda_b}) \sum_{\lambda_p,\lambda_{\ell-}} |T^{\lambda_{\Lambda_b^0}=-\frac{1}{2}}_{\lambda_{\ell-},\lambda_p}|^2 ,$$
$$= K_1(1-P_{\Lambda_b}\cos\theta_{\Lambda_c}) + K_2(1+P_{\Lambda_b}\cos\theta_{\Lambda_c}) + K_3 P_{\Lambda_b}\sin\theta_{\Lambda_c}$$

K_i depend on all phase space observables except θ_{Λ_c}







Two scenarios and two channels

M. Ferrillo, A. Mathad, P. Owen, N. Serra [JHEP 12 (2019) 148]

$$d\Omega' = dq^2 d\cos\theta_{\Lambda_c} d\cos\theta_p d\phi_p d\cos\theta_l d\phi_l$$

Observables affected by missing neutrino and resolution effects need to be included.

Fit scenario 1 (labelled *pKpi*)

Integrate all the observables except two: q^2 and $\cos(\theta_\mu)$

- Removes inherently dependence on the Λ_c weak decay parameter (α_{Λ_c}) and Λ_b polarization (P_{Λ_b}).
- To conduct the sensitivity study pseudo-experiments are generated with a projected yield of 7.5M events that LHCb has accumulated for $\Lambda_b \to \Lambda_c(\to pK\pi)\mu\nu$ in Run1&2.

Fit scenario 2 (labelled pK_S)

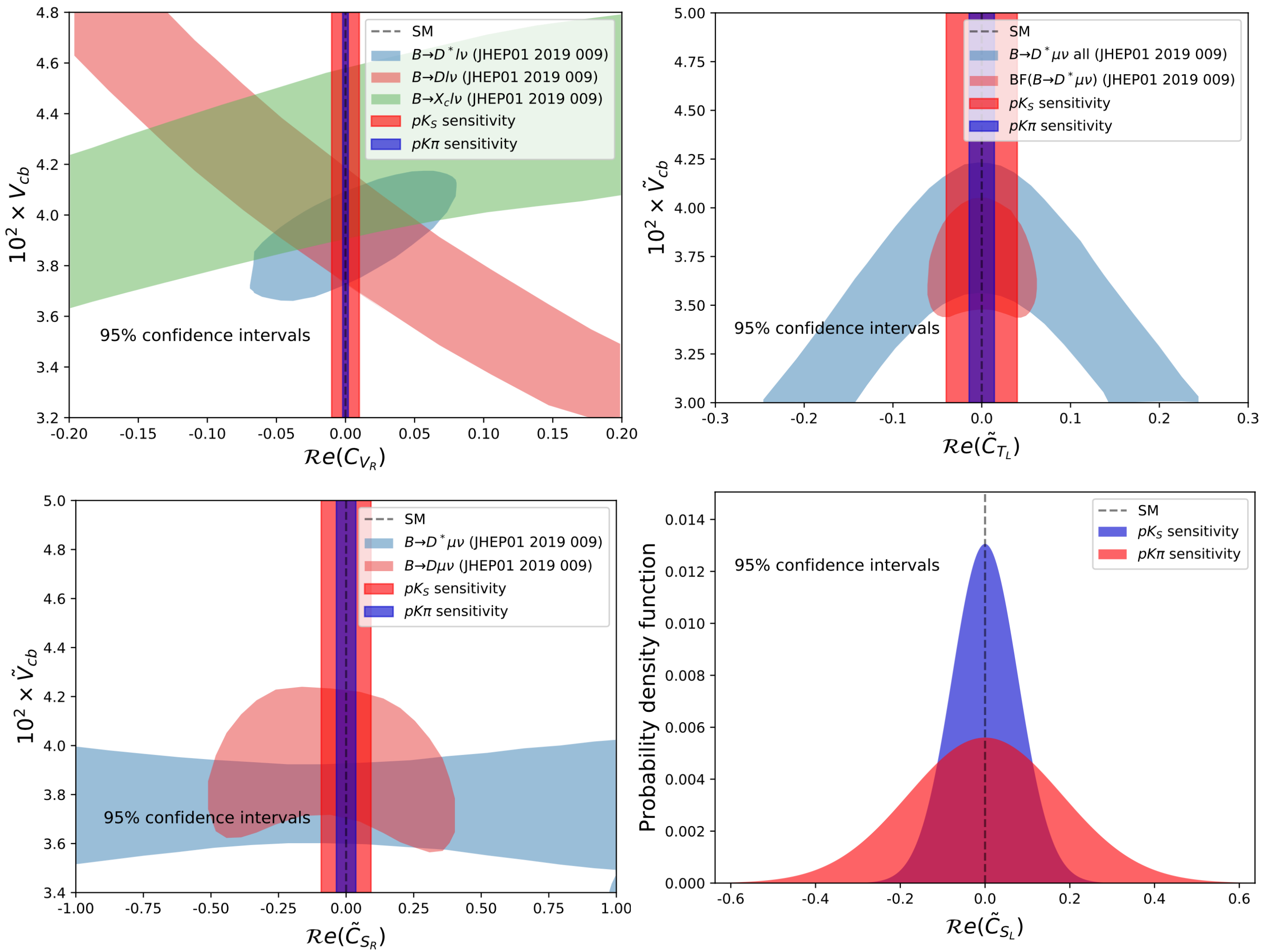
Integrate out all the observables except four: q^2, $\cos(\theta_\mu)$, $\cos(\theta_p)$ and ϕ_p

- Retained dependence α_{Λ_c} and P_{Λ_b}. However, can expect that this process reduces sensitivity to P_{Λ_b} greatly.
- Pseudo-experiments are generated with a projected yield that is a factor 1/20 compared to the $\Lambda_b \to \Lambda_c(\to pK\pi)\mu\nu$ decay (hit from Λ_c BF and K_S reco. Eff).
- Compared to scenario 1, loss in statistics, but hoping to gain information from addition of 2 extra fit variables.

Results I: Sensitivity with no NP

M. Ferrillo, A. Mathad, P. Owen, N. Serra [JHEP 12 (2019) 148]

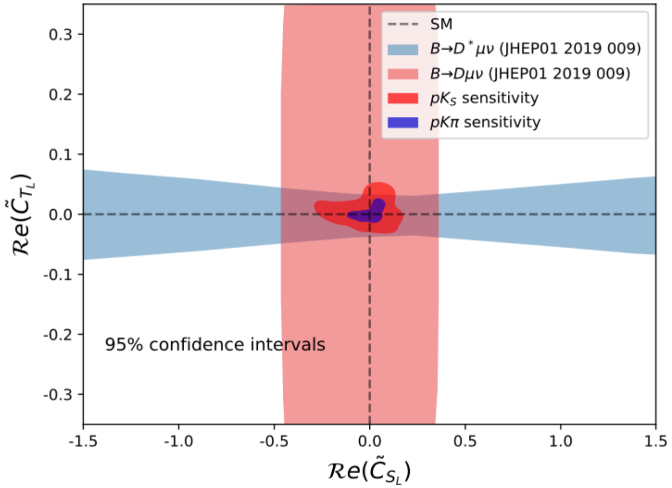
- The resolution of q^2 and $\cos(\theta_\mu)$ folded into model and variation of efficiency neglected (efficient muon trigger!).
- A binned maximum likelihood fit performed (20 bins/dim.).
- The $\Lambda_b \to \Lambda_c$ form factors (6 SM and 4 NP)) are constrained using Lattice results [JHEP 1708 (2017) 131].
- Fit only the shape (large 7% uncertainty on Λ_b prod.), implying no sensitivity to $V_{cb}(1 + C_{V_L})$.
- In the absence of NP, compare our sensitivities to the constraints from global fits to $b \to c\mu\nu, ce\nu$ transitions (from B meson decays) [JHEP01(2019)009].
- Most sensitive to C_{V_R} and then C_{T_L}.
- More data wins! Gain in statistics through $\Lambda_b \to \Lambda_c(\to pK\pi)\mu\nu$ decays better than gain in sensitivity through addition of the $\cos(\theta_p)$ and ϕ_p corresponding to $\Lambda_b \to \Lambda_c(\to pK_S)\mu\nu$ decays.

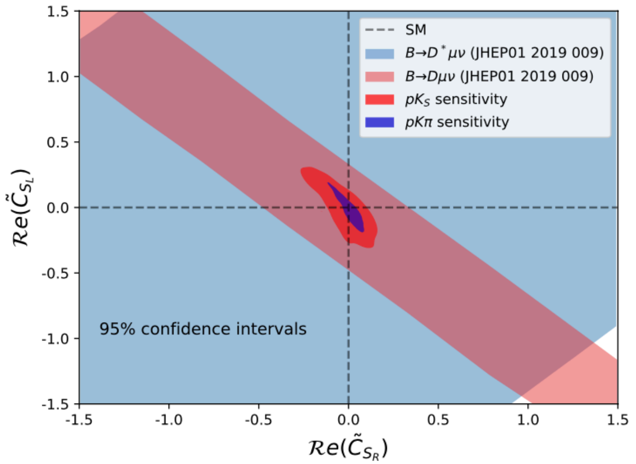


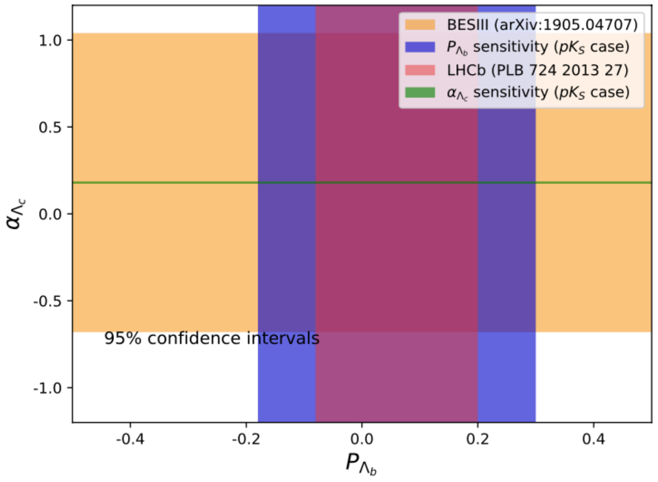
Results II: Sensitivity with no NP

M. Ferrillo, A. Mathad, P. Owen, N. Serra [JHEP 12 (2019) 148]

- Interplay between different Wilson coefficients explored in presence of no NP.
- Large non-Gaussian correlations are observed.
- When all the Wilson coefficients are floated, large correlations and contributions from tensor and scalar currents difficult to disentangle.
- With the clever treatment of resolution and with full six-dimensional angular analysis, the sensitivity on Λ_b polarisation could be improved.
- Sensitivity on the weak decay asymmetry parameter of Λ_c is two orders of magnitude better than the BESIII estimate [Phys. Rev. D 100, 072004 (2019)].







Form factor of $\Lambda_b \to \Lambda_c^* \mu \nu$

P. Boer, M. Bordone, E. Graverini, P. Owen, M. Rotondo, D. van Dyk [JHEP 1806 (2018) 155]

- Observed large irreducible feed-down from $\Lambda_b \to \Lambda_c^*(2595)^{[1/2^-]}\mu\nu$ and $\Lambda_b \to \Lambda_c^*(2625)^{[3/2^-]}\mu\nu$ into $\Lambda_c \mu\nu X$.
- These decays are expressed in terms of 6 (for spin 1/2) and 8 form factors (for spin 3/2).
- Provide new definitions of the form factors, extending Ref [Phys. Rev. D 57, 5620 (1998)] at $O(\frac{\Lambda_{QCD}}{m_{b,c}})$, to include $O(\alpha_S)$ corrections.
- For both states, propose an exponential parametrisation of the leading and sub-leading IW functions (inspired by ground state $\Lambda_b \to \Lambda_c e\nu$ [Nucl.Phys.B396:38-52,1993].

Leading term
$$\zeta(q^2)\Big|_{\text{lin}} \equiv \zeta(q^2_{\text{max}})\left[1 + \rho\left(\frac{q^2}{q^2_{\text{max}}} - 1\right)\right],$$

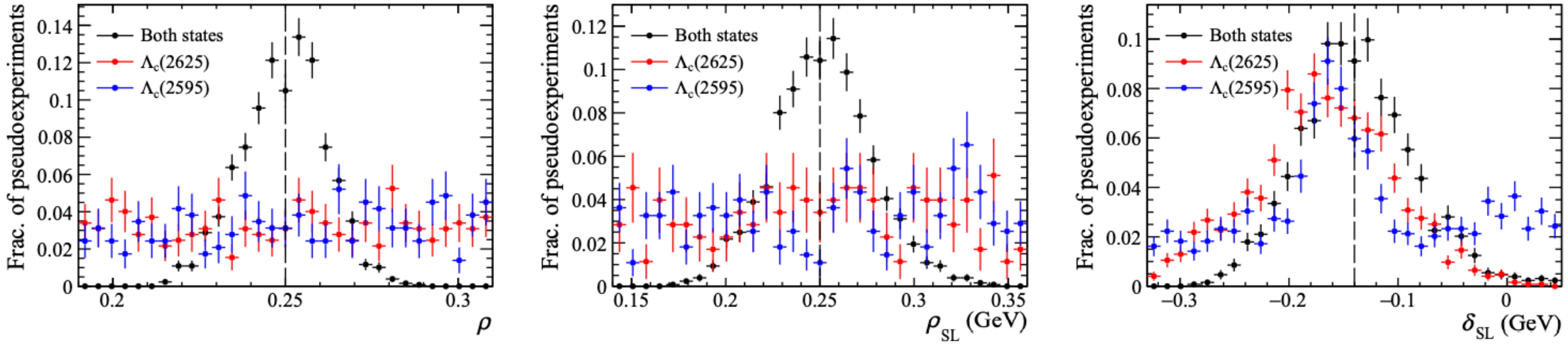
Sub-leading (SL) term
$$\zeta_{\text{SL}}(q^2)\Big|_{\text{lin}} \equiv \zeta(q^2_{\text{max}})\left[\delta_{\text{SL}} + \rho_{\text{SL}}\left(\frac{q^2}{q^2_{\text{max}}} - 1\right)\right]$$

- Obtain the parameters ρ, ρ_{SL} and δ_{SL} from fits to the shapes of q^2 and $\cos(\theta_\mu)$, as result no sensitivity to normalisation $\zeta(q^2_{max})$ so no sentivity to

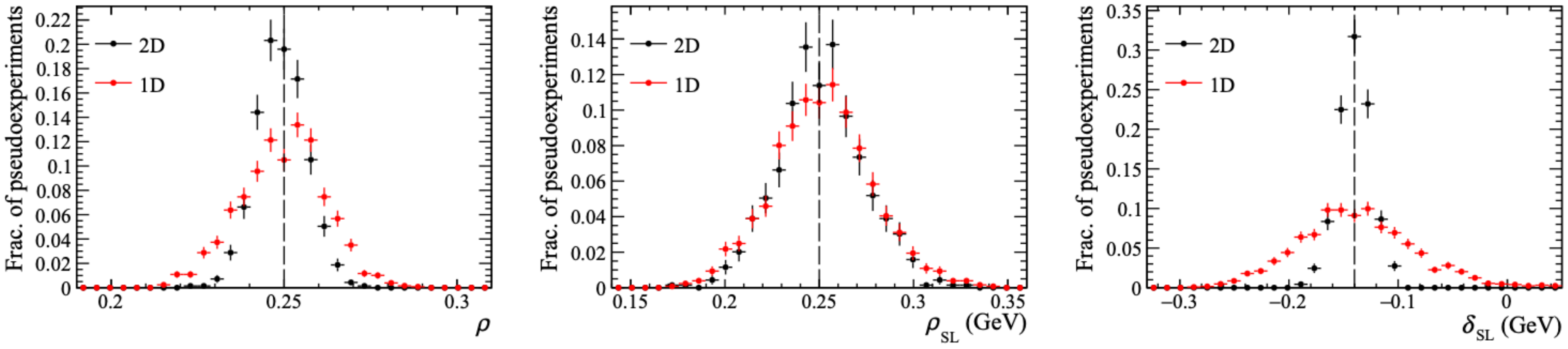
Form factor of $\Lambda_b \to \Lambda_c^* \mu \nu$

P. Boer, M. Bordone, E. Graverini, P. Owen, M. Rotondo, D. van Dyk [JHEP 1806 (2018) 155]

- To conduct sensitivity studies, benchmark points obtained from Zero Recoil Sum Rules.
- Pseudo experiments generated with projected yields for Run II i.e. 50k (spin ½) and 20k (spin 3/2) events.
- Large irreducible systematic due to no knowledge of $O(\frac{\Lambda_{QCD}^2}{m_c^2})$ corrections. ~~Lattice QCD predictions would be helpful.~~ (Paper in prep, see yesterday's talk by Stefan).
- Can both Lattice and LHCb data can comment the $O\left(\frac{\Lambda_{QCD}^2}{m_c^2}\right)$ corr.?



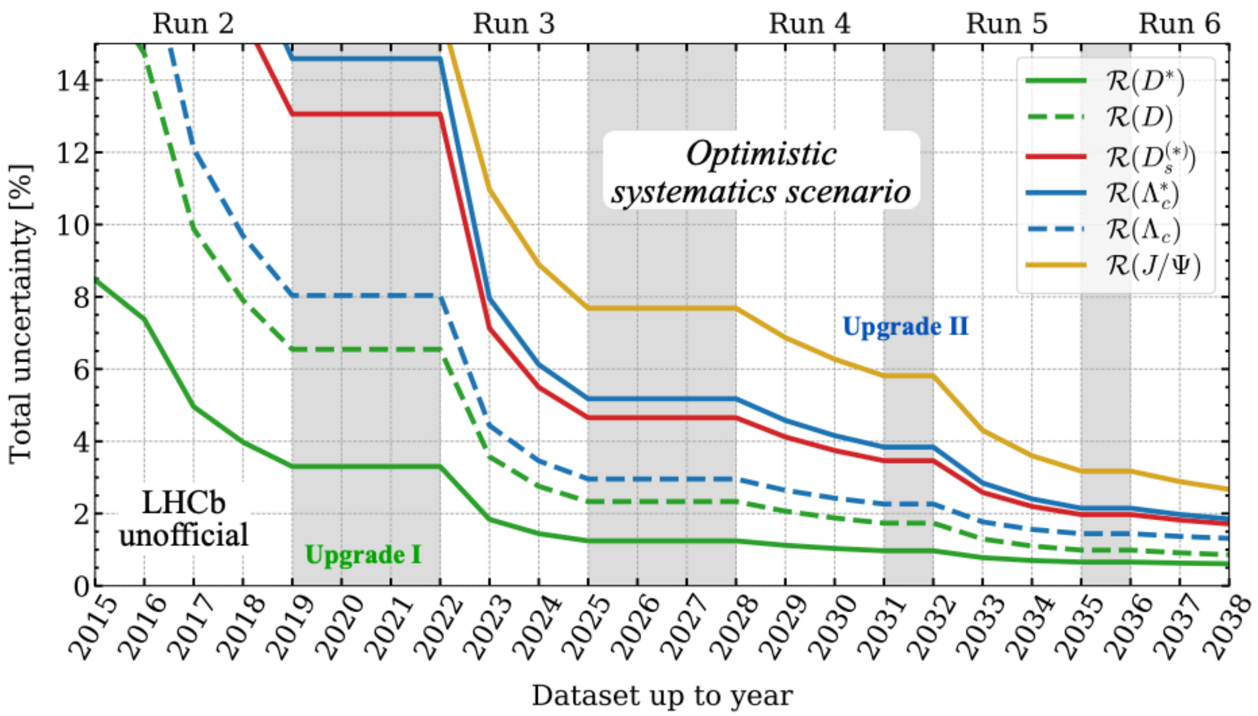
Simultaneous study of both Λ^* states breaks the degeneracy b/w ρ and ρ_{SL}.



Inspecting q^2 and $\cos(\theta_\mu)$ very much improves the sensitivity on δ_{SL}

Immediate future of baryonic $b \to c$ transitions

- (Not b-baryon) $R(D) - R(D^*)$ with $\tau \to \mu 2\nu$ in review (Could be early next year!)
- Analysis of $R(\Lambda_c)$ both with $\tau \to \mu 2\nu$ and $\tau \to 3\pi\nu$ ongoing (Could be next year!)
- Phase space of $\Lambda_c \to pK\pi$ decays tagged by inclusive $\Lambda_c \mu\nu X$ (Could be next year!).
- Phase space shapes, $|V_{cb}|$ and NP (for ground-state) in $\Lambda_b \to \Lambda_c^{(*)} \mu\nu$ (Could be next year!).
- Analysis of $R(\Lambda_c^*)$ (May or may not be next year!).



LFUV projections from talk by Manuel Franco Sevilla

Near future of baryonic $b \to c$ transitions

9 fb^{-1} — Goal: 50 fb^{-1} — Goal: 250 fb^{-1}

Upgrade I (LS2) — Upgrade II (LS4)

Run 1	LS1	Run 2	LS2	Run 3	LS3	Run 4	LS4	Run 5	LS5	Run 6
2011 2012	2013 2014	2015 2016 2017 2018	2019 2020 2021	2022 2023 2024	2025 2026 2027	2028 2029 2030	2031	2032 2033 2034	2035	2036 2037

- Explore $\Lambda_b \to \Lambda_c(\to pK_S, \Lambda\pi)\mu\nu$ decays (Hadronic A_{FB}).
- Angular analysis of $\Lambda_b \to \Lambda_c^{(*)}\tau\nu$, with $\tau \to \mu 2\nu$ (large statistics) & $\tau \to 3\pi\nu$ (better resolution).
- Explore heavier b-baryon SL decays of Ξ_b^- and Ω_b^- (no lattice predictions).
- Electron modes (challenging in upgrade scenarios).
- Semileptonic decays tagged by excited b-baryon states [arXiv:1402.4205].

- What are the interesting observables?
  - ➢ Triple product asymmetries (TPA) in $\Lambda_b \to \Lambda_c^{(*)} l\nu$ decays? [For $B \to D^{*+}l^-\nu$: arXiv:1906.07752].
  - ➢ Exploring the decays of $\Lambda_c \to pK\pi$ tagged by inclusive or exclusive SL Λ_b decays? (CPV could constrain relative phases of the Wilson coefficients of Λ_b decays).
  - ➢ Where does $R(\Lambda_c^*)$ fit into this model independent expression? [Phys. Rev. D 99, 075006]

$$\frac{\mathcal{R}(\Lambda_c)}{\mathcal{R}_{\rm SM}(\Lambda_c)} \simeq 0.262\frac{\mathcal{R}(D)}{\mathcal{R}_{\rm SM}(D)} + 0.738\frac{\mathcal{R}(D^*)}{\mathcal{R}_{\rm SM}(D^*)}$$

Conclusions

I have presented a summary of what the next measurements at LHCb will be for baryonic $b \to c$ transitions and their motivations.

- Current priorities with LHCb lie in publishing the LFUV tests.
- We have started to explore different kinematic distributions of both b-baryon and associated c-baryon decays. Different ways to distinguish and constrain new physics here are very welcome!
- There are places where lattice QCD inputs are essential (SL decays Ξ_b^- and Ω_b^-).
- There are also exciting prospects with baryonic $b \to u$ transitions, which are not covered here.
- I am very much looking forward to the exciting road ahead!