Studies with semileptonic decays at LHCb

Matthew Rudolph
Syracuse University

on behalf of the LHCb Collaboration

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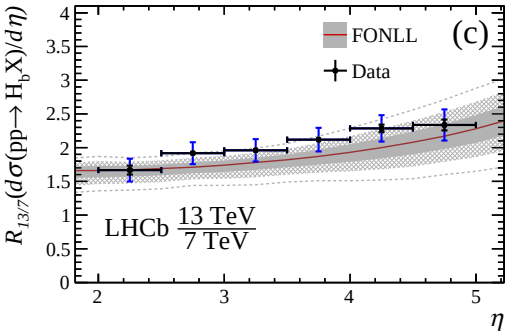
Introduction

- Semileptonic b-hadron decays important tests of the Standard Model:
  - Measure quark mixing CKM matrix elements $|V_{cb}|$, $|V_{ub}|$
  - Validate understanding of QCD in decays
- More theoretically clean than fully hadronic decays
- Can study lepton flavor universality in charged current (talk by P. Owen)
- Semileptonic decays also useful for many more measurements!

Huge data samples

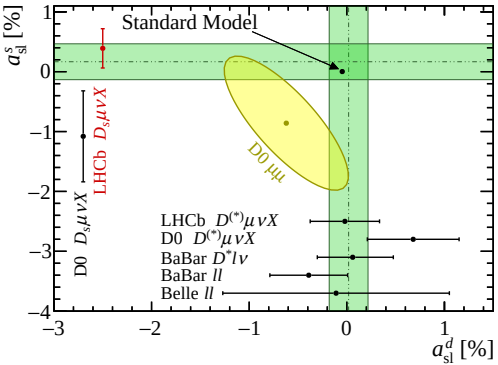
- Expect almost 100 million reconstructed semileptonic decays in Runs 1 and 2
- Access to all B flavor decays
- Clean signatures for muonic modes means low non-semileptonic backgrounds



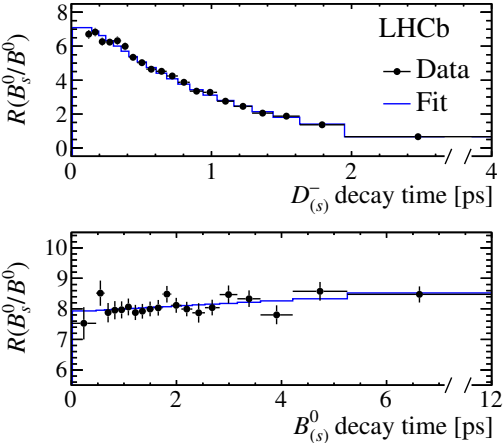
Excellent for measurements such as total cross-section

Other measurements

- Large samples also useful for other measurements



- CP violation in mixing

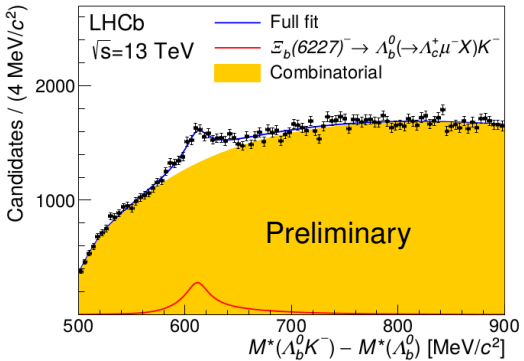


- Lifetime of B^0_s and D^+_s – see talk by M. Dorigo today

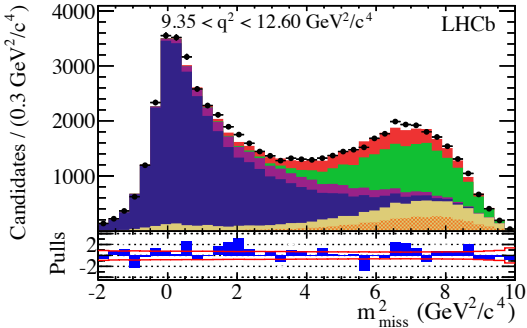
Reconstruction techniques

- Missing at least one neutrino, but still have good handles on kinematics
- Different techniques used, and still room for new ideas

Assuming one neutrino:

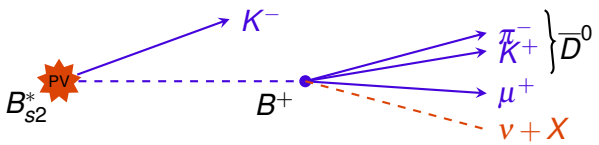


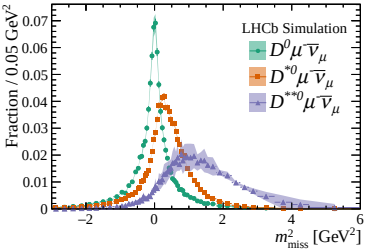
Using velocity from reconstructed part:

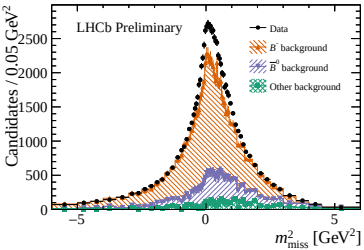


New full reconstruction

- Use B^*_{s2} decays to calculate B^+ momentum with no assumption on missing part of decay
- First application to D fractions coming soon
- Promising technique for large future datasets

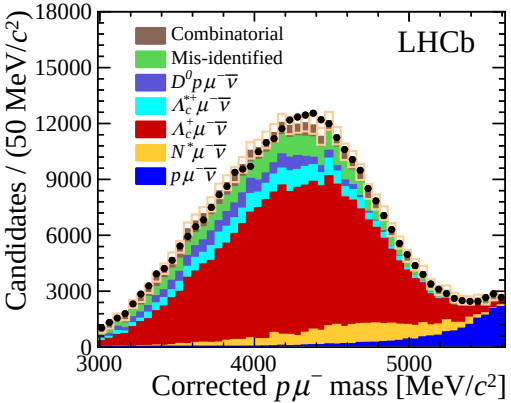


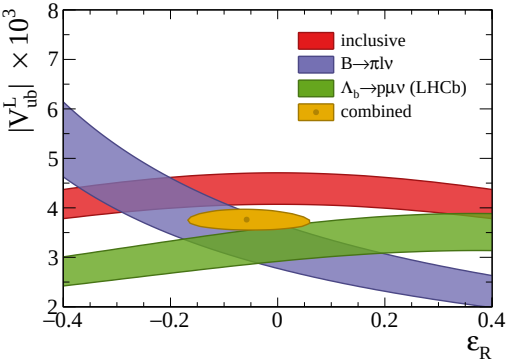




Studies with baryons

- Previously measured ratio $|V_{ub}|/|V_{cb}|$ using Λ_b^0 decays
- In the future, want to measure $|V_{cb}|$ in this channel
- First step is form factor measurement





$\Lambda_b^0 \to \Lambda_c^+ \mu \nu$

Form factor measurement

- Differential distributions key for comparisons with Heavy Quark Effective Theory and Lattice QCD
- Necessary to measure CKM parameters ($|V_{cb}|$ in overall factor G)
- Measure form-factors as one Isgur-Wise function ξ_B:

$q^2 = \text{momentum transfer}^2$

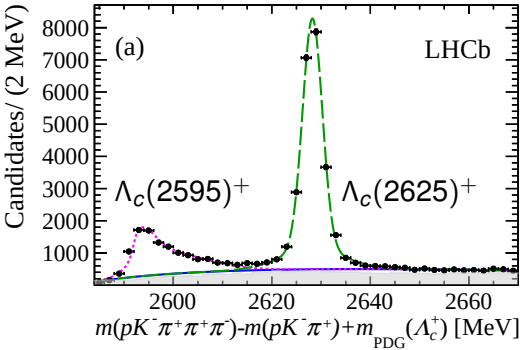
$$w = \frac{m^2_{\Lambda_b^0} + m^2_{\Lambda_c^+} - q^2}{2 m_{\Lambda_b^0} m_{\Lambda_c^+}}$$

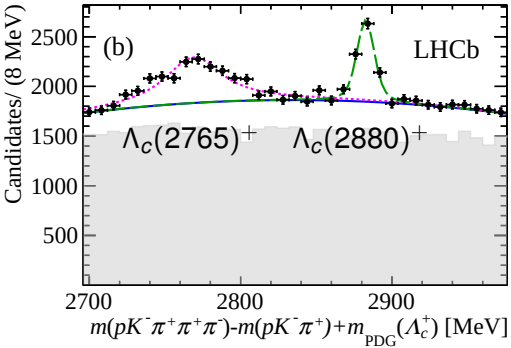
$$\frac{\mathrm{d}\Gamma}{\mathrm{d}w} = G K(w) \xi_B^2(w)$$

Kinematic factor

“Backgrounds” are interesting!

- Excited states are backgrounds to ground state decay
- Measure excited Λ_c^+ with $\Lambda_c^+\pi^+\pi^-$





- $\Lambda_c(2765)^+$ not well measured previously

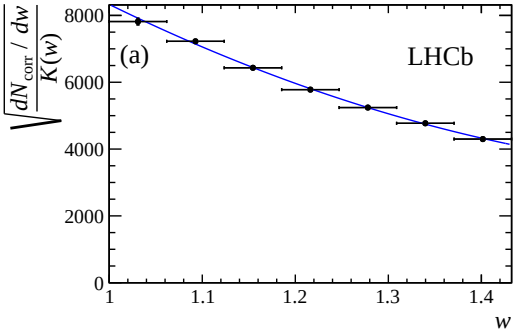
Future measurements

- Thousands of excited Λ_c^+ in Run 1 alone
- More data provides large samples of decays to *e.g.* $D_{(s)1}$ and $D^*_{(s)2}$
- More detailed studies will also help understand feed-down contributions

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
$\Lambda_c^+\mu^-\overline{\nu}_\mu X$	$(2.74\pm0.02)\times10^6$

Unfolding to w

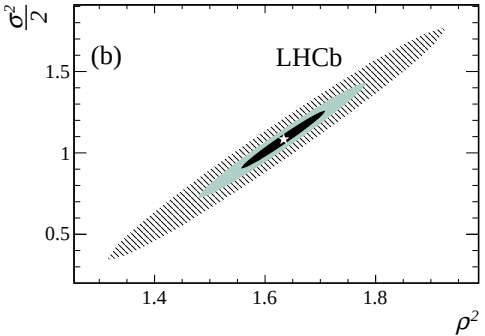
- Kinematics assume one neutrino in final state
- Unfold using Singular Value Decomposition
- Corrected for acceptance and efficiency
- Final w distribution fit with multiple ansatz



Slope of ξ_B

- Slope of ξ_B at $w = 1$ is key observable
- Measured:

$$\rho^2 = 1.63 \pm 0.07 \pm 0.08$$



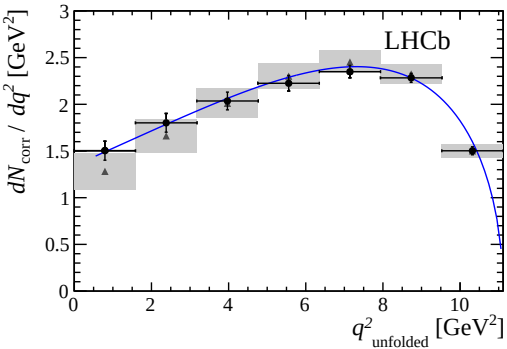
Theory:

Lattice[1]	QCD sum rules[2]	HQET[3]
$\rho^2 = 1.2^{+0.8}_{-1.1}$	1.35 ± 0.13	1.51

[1] Phys. Rev. D57 (1998) 6948, [2] Phys. Lett. B629 (2005) 27, [3] Phys. Rev. D73 (2006) 094002

Comparison to lattice

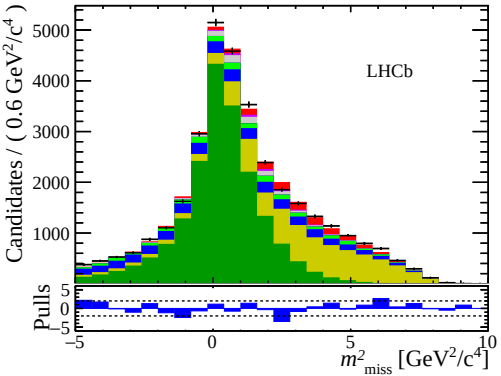
- Unfold also to q^2
- Comparison with lattice calculation[1] (gray band)
- Also described by single form factor fit (blue line)
- Future studies with normalization channel can extract $|V_{cb}|$

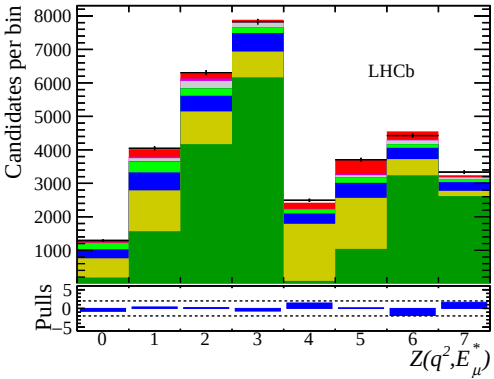


Future directions

B_c^+ decays

- Results from the $R(J/\psi)$ measurement demonstrate possibility to measure form factor parameters for B_c^+ decays
  - 20,000 normalization decays in Run 1 with selection designed for τ





Conclusions

- LHCb continues to accumulate large data samples of semileptonic decays of all flavors
  - Many potential measurements of semileptonic dynamics still to be made
  - Also useful for many other types of measurements
- Developing new analysis ideas that will take advantage of future datasets
- Continue to probe the decay of Λ_b^0 with form factor measurement
- Understanding excited final states necessary for strong future results