Prospects for $|V_{ub}|$ measurements at LHCb

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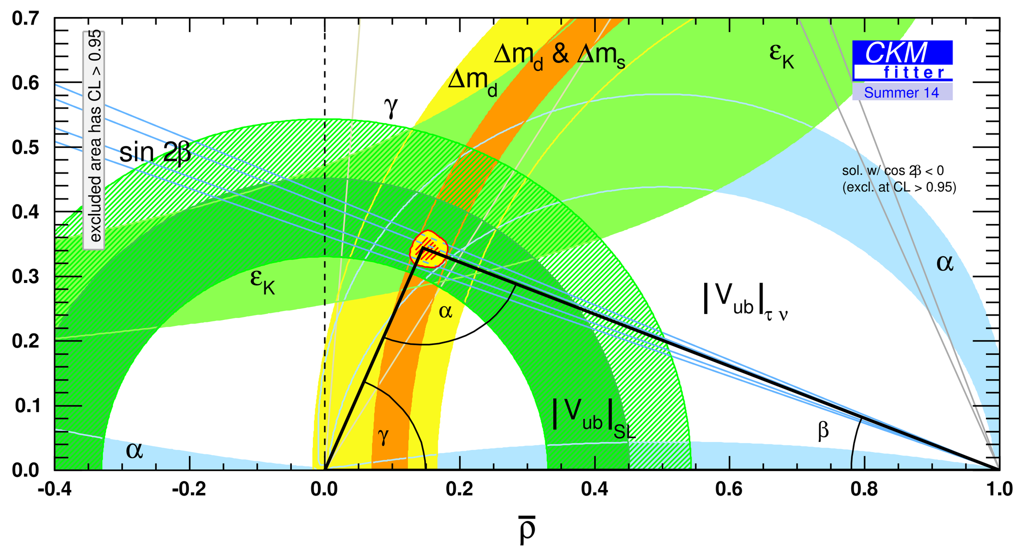
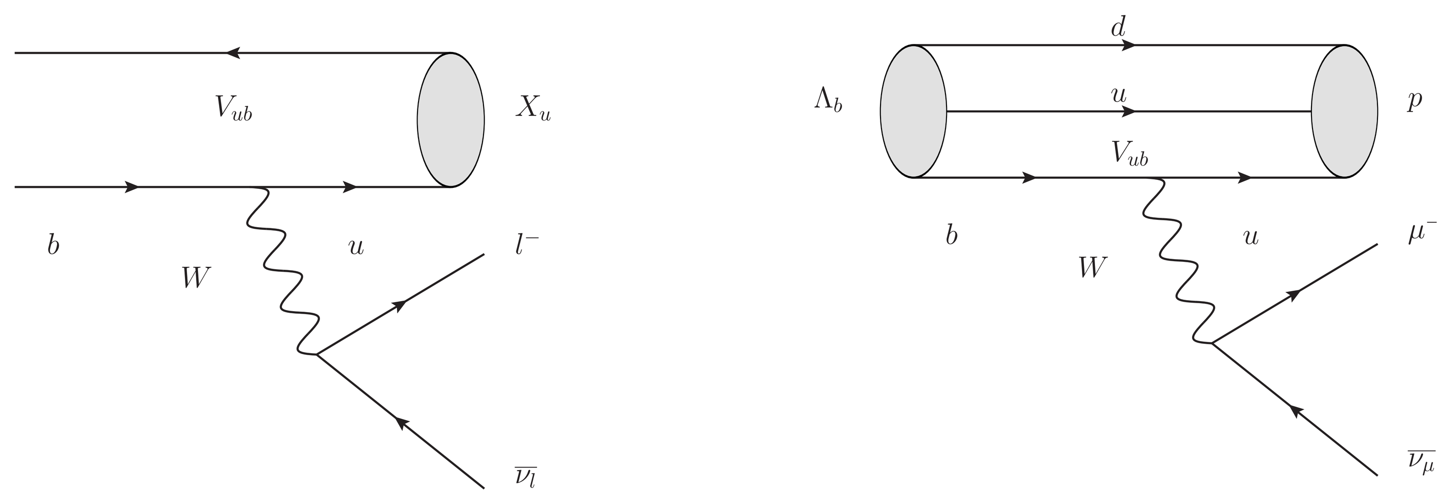
Why should LHCb measure $|V_{ub}|$?



Precision measurements of $|V_{ub}|$ allow :

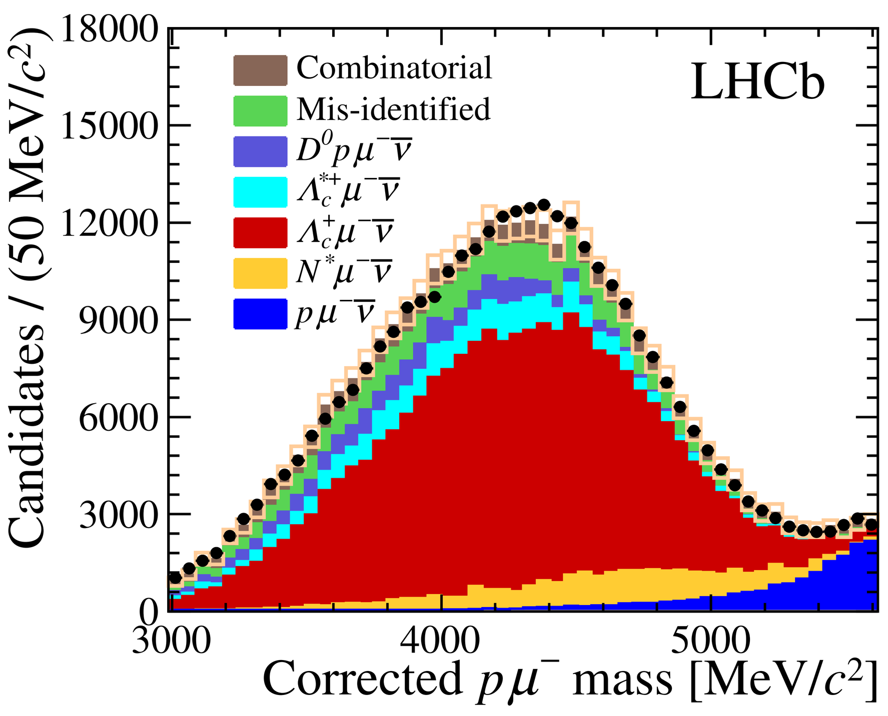
- testing of the unitarity of the CKM matrix [1] complementary to the measurement of β.
- improving precision on the least well known CKM element.
- helping to resolve tension between exclusive and inclusive measurements of this parameter.
- probing new physics.
- helping predicting other branching ratios, such as $B^+ \to \tau^+\nu_\tau$.

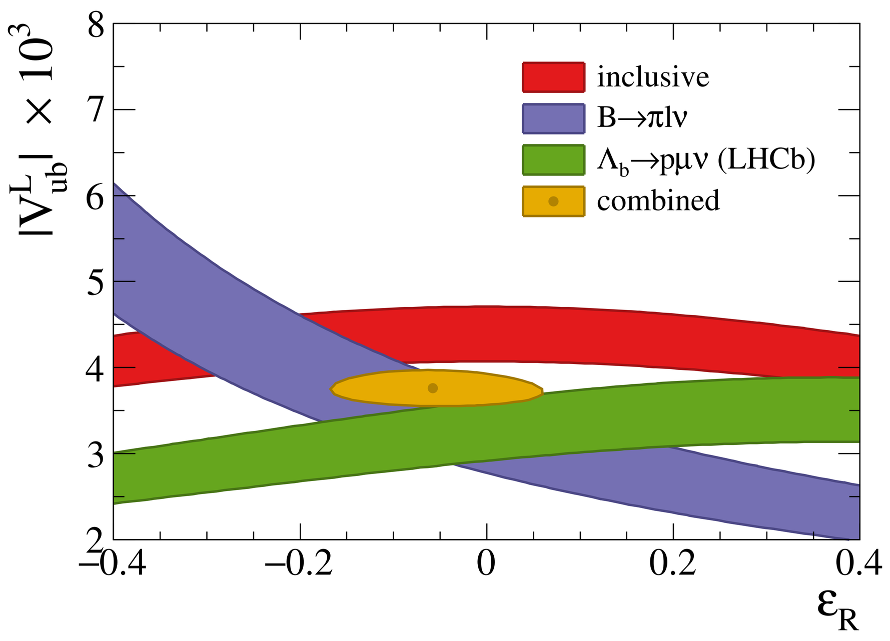
Tension in $|V_{ub}|$ measurements



- Inclusive measurements: $|V_{ub}| = (4.49 \pm 0.16(exp)^{+0.16}_{-0.18}(theo)) \times 10^{-3}$ [2].
  Problem: Large background from $\overline{B} \to X_c l \overline{\nu_l}$ and big theoretical uncertainty in region of suppressed $\overline{B} \to X_c l \overline{\nu_l}$ contribution.
- Exclusive measurements: $|V_{ub}| = (3.72 \pm 0.19) \times 10^{-3}$ [2] $\to$ combination of $B^- \to \pi l^- \overline{\nu_l}$ measurements.
  Problem: Smaller branching fractions, theoretical uncertainty due to form factors.

First LHCb measurement: $\Lambda_b^0 \to p\mu^-\overline{\nu_\mu}$ decay [3]





- First observation of the decay of $\Lambda_b^0 \to p\mu^-\overline{\nu_\mu}$ using LHCb's unique Λ_b^0s sample.
- First measurement of the $|V_{ub}|$ in hadron collider.
- LHCb measured of the ratio of branching fractions in theory favorable q^2 region

$$\frac{\mathcal{B}(\Lambda_b^0 \to p\mu^-\overline{\nu_\mu})_{q^2>15GeV/c^2}}{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+\mu^-\overline{\nu_\mu})_{q^2>7GeV/c^2}}.$$

Together with relevant form factors by LQCD predictions and world average of $|V_{cb}|$ from exclusive modes, LHCb measures

$$|\mathbf{V_{ub}}| = (3.27 \pm 0.15(\mathrm{exp}) \pm 0.16(\mathrm{theo}) \pm 0.06(|\mathbf{V_{cb}}|)) \times 10^{-3}.$$

- Fit was performed to corrected mass variable which accounts for missing neutrino in a final state,

$$M_{(\Lambda_b^0)_{corr}} = \sqrt{M^2_{p\mu^-} + |p_T'^2|} + |p_T'|,$$

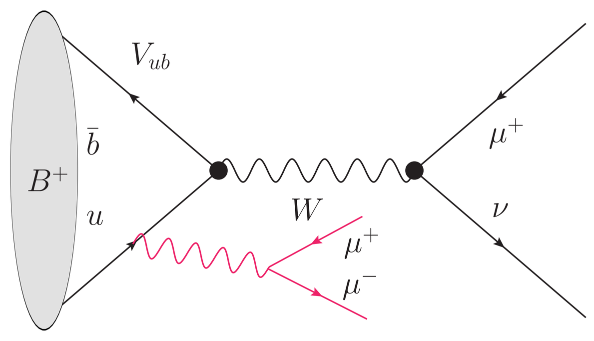
where the $M^2_{p\mu^-}$ is the invariant visible mass squared and $p_T'^2$ is the missing momentum squared transverse to the direction of flight of Λ_b^0, see left figure.
- One of the most precise exclusive measurements of $|V_{ub}|$.
- Confirms tension between exclusive and inclusive measurements at 3.5 σ.
- Sizeable right-handed coupling is not feasible [4] , see right figure.

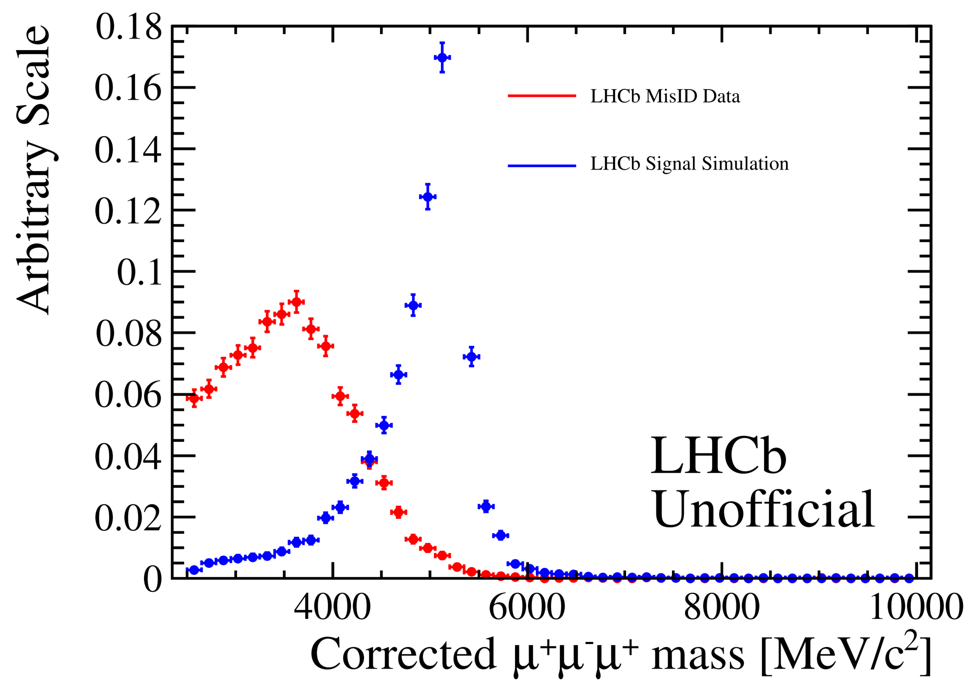
Analysis of $B^+ \to \mu^+\mu^-\mu^+\nu_\mu$ at LHCb

✓ Purely leptonic measurement of $|V_{ub}|$ at LHCb $\to$ similar search in Belle[5] and BaBar[6] factories is $B^+ \to \tau^+\nu_\tau$ with

$$\mathcal{B}(B^+ \to \tau^+\nu_\tau) = \frac{G_F^2 m_{B^+} m_{\tau^+}^2}{8\pi}\left[1 - \frac{m_{\tau^+}^2}{m_{B^+}^2}\right]^2 f_{B^+}^2 |V_{ub}|^2 \tau_{B^+}.$$

✓ Three muons in final state $\to$ uses the excellent muon identification at LHCb and lifts helicity suppresion of $B^+ \to \mu^+\nu$ with respect to tauonic mode.
✓ Not been observed yet.
✓ Sensitive to new physics such as a charged Higgs boson.
✓ As in $\Lambda_b^0 \to p\mu^-\overline{\nu_\mu}$, missing neutrino prevents mass fit $\to$ use instead corrected mass.
✗ If $\mathcal{B}(B^+ \to \mu^+\mu^-\mu^+\nu_\mu) \approx 10^{-8}$ $\to$ expect 35 events in Run 1, analysis ongoing.



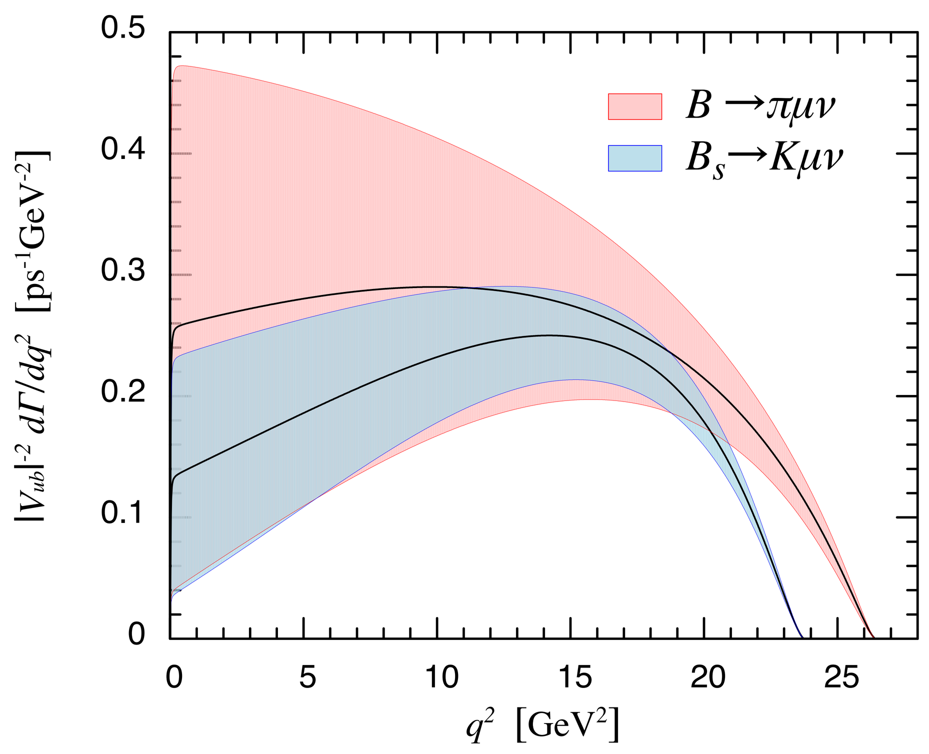


Background Studies

To be able to supress different backgrounds series of Boosted Decision Trees (BDTs) were trained with simulation signal sample.
Main backgrounds to consider are:

- misidentified background - one of the muon is misidentified as kaon, pion or proton, e.g. cascade decays $B \to D(K\mu\nu)\mu\nu$.
- combinatorial background - random combinations of tracks passing the stripping selection.
- partially reconstructed background - where not all final state particles are reconstructed, e.g. $B^+ \to D^0(K^+\pi^-\mu^+\mu^-)\mu^+\nu_\mu$.

Possible other LHCb $|V_{ub}|$ Measurements



- Possible semileptonic exclusive modes that could be considered:
  (a) The lattice predictions [7] for $B_s^0 \to K^+\mu^-\nu_\mu$ are twice as good as for $B \to \pi l\nu$ or $\Lambda_b^0 \to pl\nu$, however, many backgrounds coming from Λ_c^+, D_s, D^+, D^0 to consider. Analysis ongoing.
  (b) Use of B_c mesons, e.g $B_c^+ \to D^0\mu^+\nu_\mu$.
  (c) Excited versions of viable modes, e.g. $B \to p\overline{p}\mu\nu$, $B \to \rho\mu\nu$.

References

[1] CKMfitter Group, J. Charles et al., Eur. Phys. J. C41, 1-131 (2005).
[2] K.A. Olive et al. (Particle Data Group), Chin. Phys. C, 38, 090001 (2014) and 2015 update.
[3] LHCb collaboration, R. Aaij et al., Nature Phys. 11 (2015) 743-747.
[4] F. U. Bernlochner, Z. Ligeti, and S. Turczyk, Phys. Rev. D90 (2014) 094003.
[5] Belle Collaboratiom, I. Adachi et al., Phys. Rev. Lett. 110 (2013), no. 13 131801.
[6] BaBar Collaboration, J. P. Lees et al., Phys. Rev. D88 (2013), no. 3 031102.
[7] J. M. Flynn et al., Phys. Rev. D91 (2015), no. 7 074510.

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