Imperial College London

Search for the decay $B \to p\bar{p}\mu\nu$

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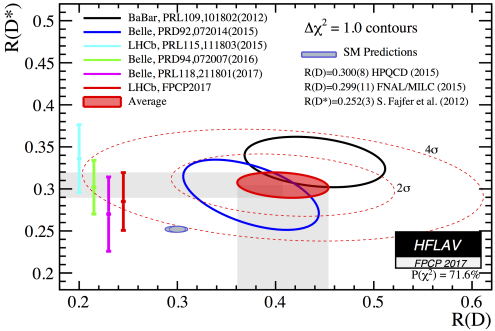
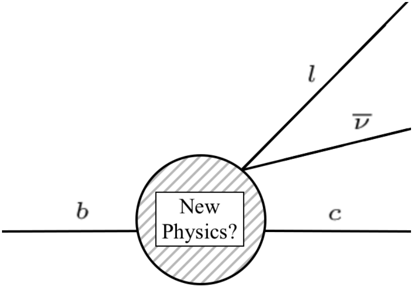
LEPTON FLAVOUR UNIVERSALITY IN $b \to c\ell\nu$



- The combination of the ratios $R(D) = \mathcal{B}(B \to D\tau\nu)/\mathcal{B}(B \to D\mu\nu)$ and $R(D^*)$ are 4σ away from the Standard Model prediction
- There is also a measurement from LHCb of $R(J/\psi)$ where the central value is about 2σ from the theoretical prediction.

https://arxiv.org/pdf/1711.05623.pdf

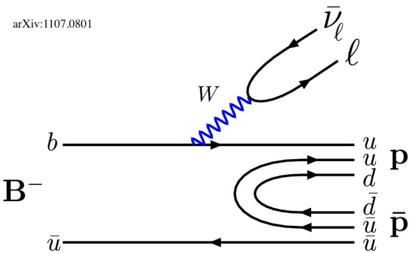
Lepton flavour universality in $b \to c\ell\nu$

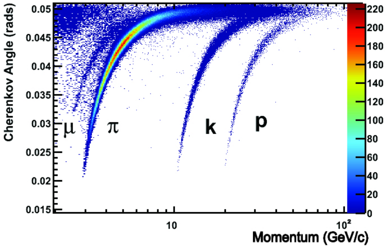


- New physics could be hidden in this $b \to c\ell\nu$ transition. For example, leptoquarks
- If it is new physics it may also produce an effect in the suppressed $b \to u\ell\nu$
- These decays include $B \to \pi\ell\nu$ and $\Lambda_b \to p\ell\nu$, but are very difficult at LHCb!

Why $B \to p\bar{p}\ell\nu$?

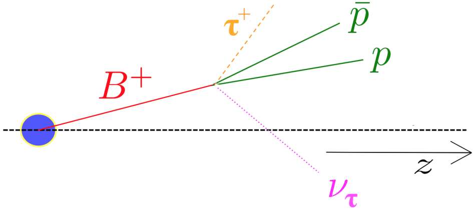
- At LHCb a candidate which is experimentally favourable is $B \to p\bar{p}\ell\nu$





- Proton identification is good with the LHCb RICH detector
- Other decays producing random protons mistakenly associated with a signal decay will be a much smaller problem than it would be with pions

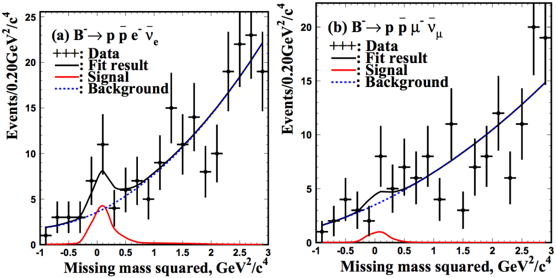
WHY $B \to p\bar{p}\ell\nu$?



- A major challenge is the missing neutrino. This becomes three neutrinos in the case where $\tau \to \mu\nu\nu$ is used. With $B \to p\bar{p}\tau\nu$ we can still reconstruct the B decay vertex.
- However, a theoretical prediction of $R(p\bar{p})$ is difficult
  - A study of the decay $B \to p\bar{p}\mu\nu$ will be very useful for theorists!
- $B \to p\bar{p}\mu\nu$ is also interesting to study its own right
  - Threshold enhancement behaviour for $p\bar{p}$ seen in $B \to p\bar{p}K^{(*)}$ and $B \to p\bar{p}\pi$ arXiv:0706.4167

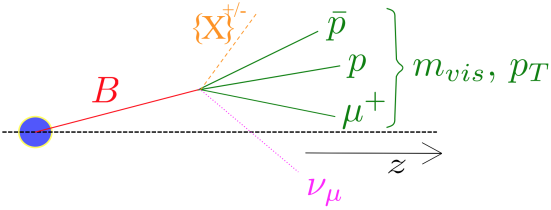
Previous studies of $B \to p\bar{p}\ell\nu$

- Belle found evidence for $B \to p\bar{p}e\nu$ (3.0σ) and $B \to p\bar{p}\mu\nu$ (1.3σ)
- A theoretical calculation by Geng et al. relies heavily on assumptions associated with the $p\bar{p}$ mass spectrum. These assumptions can be tested at LHCb



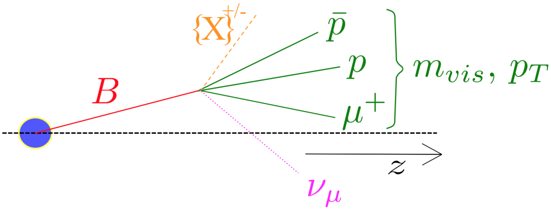
https://arxiv.org/pdf/1107.0801.pdf https://arxiv.org/pdf/1306.3353.pdf

Semileptonic Analysis Strategies at LHCb



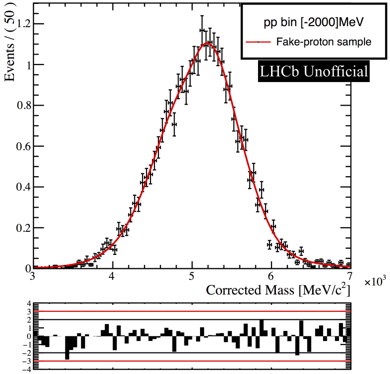
- Due to the neutrino we cannot fully reconstruct the decay
- Using the visible products we can apply a correction to the mass, $m_{\text{corr}} \equiv |p'_T| + \sqrt{|p'_T|^2 + m^2_{\text{vis}}}$
  - This will peak at the B mass for the signal only and can help distinguish signal from backgrounds with additional missing particles

Semileptonic Analysis Strategies at LHCb



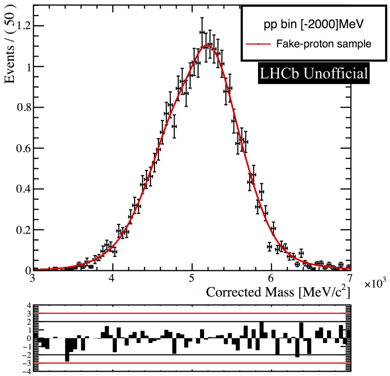
- Charged Track Isolation is a method to remove partially reconstructed backgrounds where X is a set of particles which includes some charged tracks
- A machine learning algorithm is trained to remove events with charged tracks likely to be associated with the B decay vertex

Misidentification Background



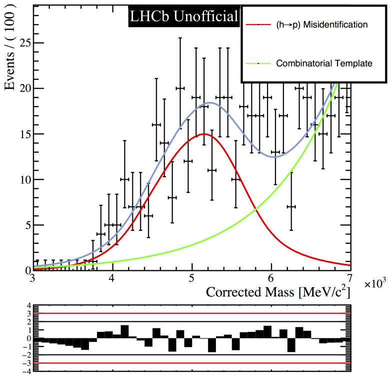
- A calibration sample can be used to assess the efficiency of identifying a particle track as a π, K, p or μ
- Using these efficiencies we can calculate the level and shape of misidentification background for $B \to p\bar{p}\mu\nu$

Misidentification Background



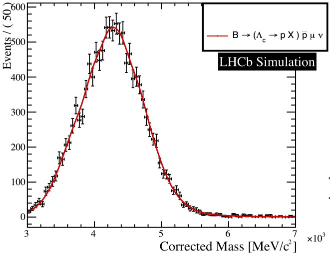
- This is done by taking a 'fake' sample where particle identification is not applied to one of the tracks
- The efficiencies can then be used to obtain the probability that and event would make up a misidentified background
- The 'fake' sample is then weighted by the probabilities. This provides a data driven determination of a major background

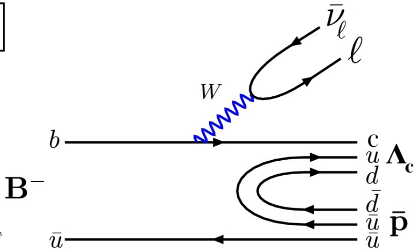
Background From Combinations of Multiple Decays



- For example, a background could come from two baryon decays $(\Lambda_b \to p\mu X) + (\overline{\Lambda_b} \to \overline{p}X)$
- A data sample with $pp\mu$ and $\overline{pp}\mu$ can help determine the shape of this background
- The component arising from misidentification is removed with the same unfolding procedure described previously

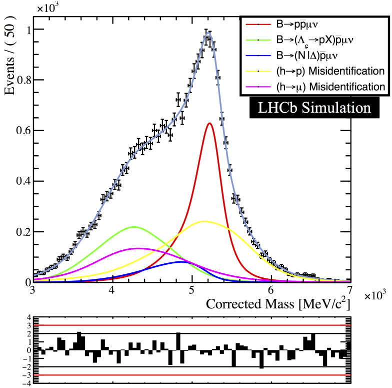
Major Exclusive Backgrounds





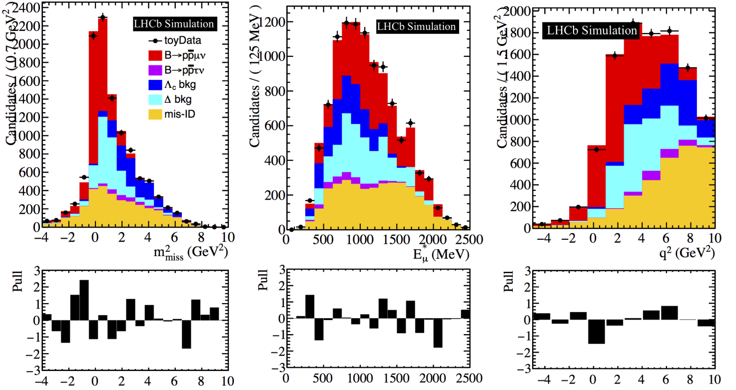
- Decays included in $B \to (\Lambda_c \to pX)\bar{p}\mu\nu$ and $B \to ([N^*/\Delta] \to pX)\bar{p}\mu\nu$ have not been observed and are a potentially large source of background
- These decays are simulated and the shape in corrected mass is extracted for a fit
- Charged track isolation can reduce many of these backgrounds
- Additionally, a BDT is trained on the kinematics of the decays to remove these backgrounds

Expectation at LHCb for $B \to p\bar{p}\mu\nu$



- The result remains blind
- This is a simulation based on the branching fraction measured by Belle for $B \to p\bar{p}e\nu \approx 10^{-5}$
- The misidentification background level is set from data
- For the analysis this is split into bins of $p\bar{p}$ mass for a precision measurement of the $p\bar{p}$ mass spectrum
- Expectation is far in excess of a 5σ discovery

STUDY OF $B \to p\bar{p}\tau\nu$



- Work is also ongoing on $R(p\bar{p}) = \mathcal{B}(B \to p\bar{p}\tau\nu)/\mathcal{B}(B \to p\bar{p}\mu\nu)$
- A 3D fit similar to the study of $R(D^{*})$ at LHCb will be used to extract the τ events

Conclusion

- The branching fraction of the decay $B \to p\bar{p}\mu\nu$ will be measured at LHCb
- The $p\bar{p}$ mass spectrum will also be measured to provide theorists with experimental input
- The measurement of the ratio of branching fractions $R(p\bar{p})$ is ongoing and will be a test of lepton universality in the $b \to u\ell\nu$ transition

Thank you for listening