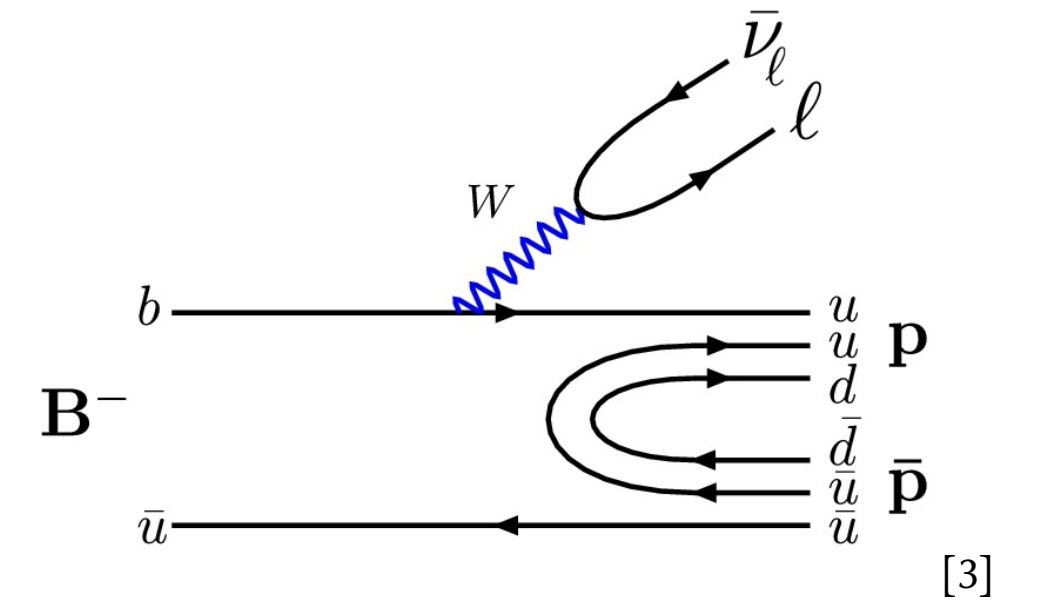


Observation of the Decay $B \rightarrow p\bar{p}\mu\nu$ and Lepton Flavour Universality with $B \rightarrow p\bar{p}\tau\nu$

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Abstract

The first observation of the $B \rightarrow p\bar{p}\mu\nu$ decay should be possible at the LHCb experiment with a significance far in excess of 5σ . As well as a branching fraction measurement, a precision measurement of the $p\bar{p}$ mass spectrum will be performed. The ratio of branching fractions $\mathcal{B}(B \rightarrow p\bar{p}\tau\nu)/\mathcal{B}(B \rightarrow p\bar{p}\mu\nu)$ is a test of lepton flavour universality in the Standard Model. This measurement is in progress at LHCb and would be the first test involving a $b \rightarrow u\tau\nu$ transition.



Search For The Decay $B \rightarrow p\bar{p}\mu\nu$

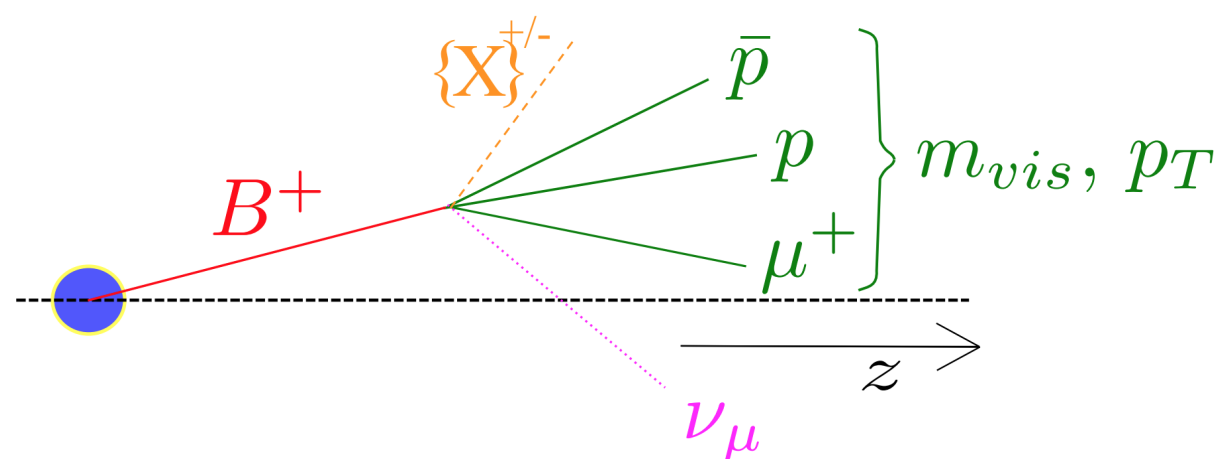
Techniques for Studying Semileptonic Decays at LHCb

- Corrected mass is a variable chosen to separate signal from background when a neutrino is missing from the visible decay products. It is given by

$$m_{corr} = \sqrt{m_{vis}^2 + |p_T'|^2 + |p_T'|^2}.$$

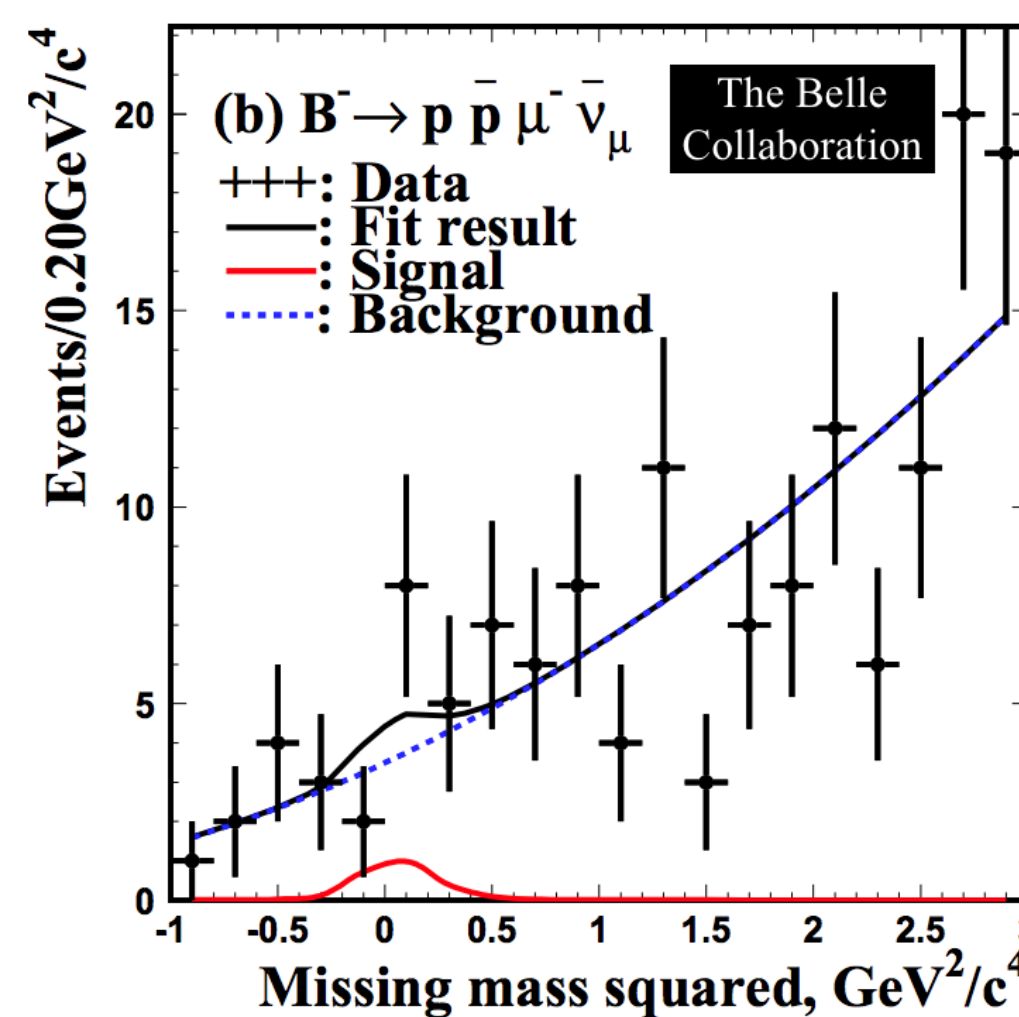
The variable $|p_T'|$ is the momentum transverse to the b -hadron flight direction.

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



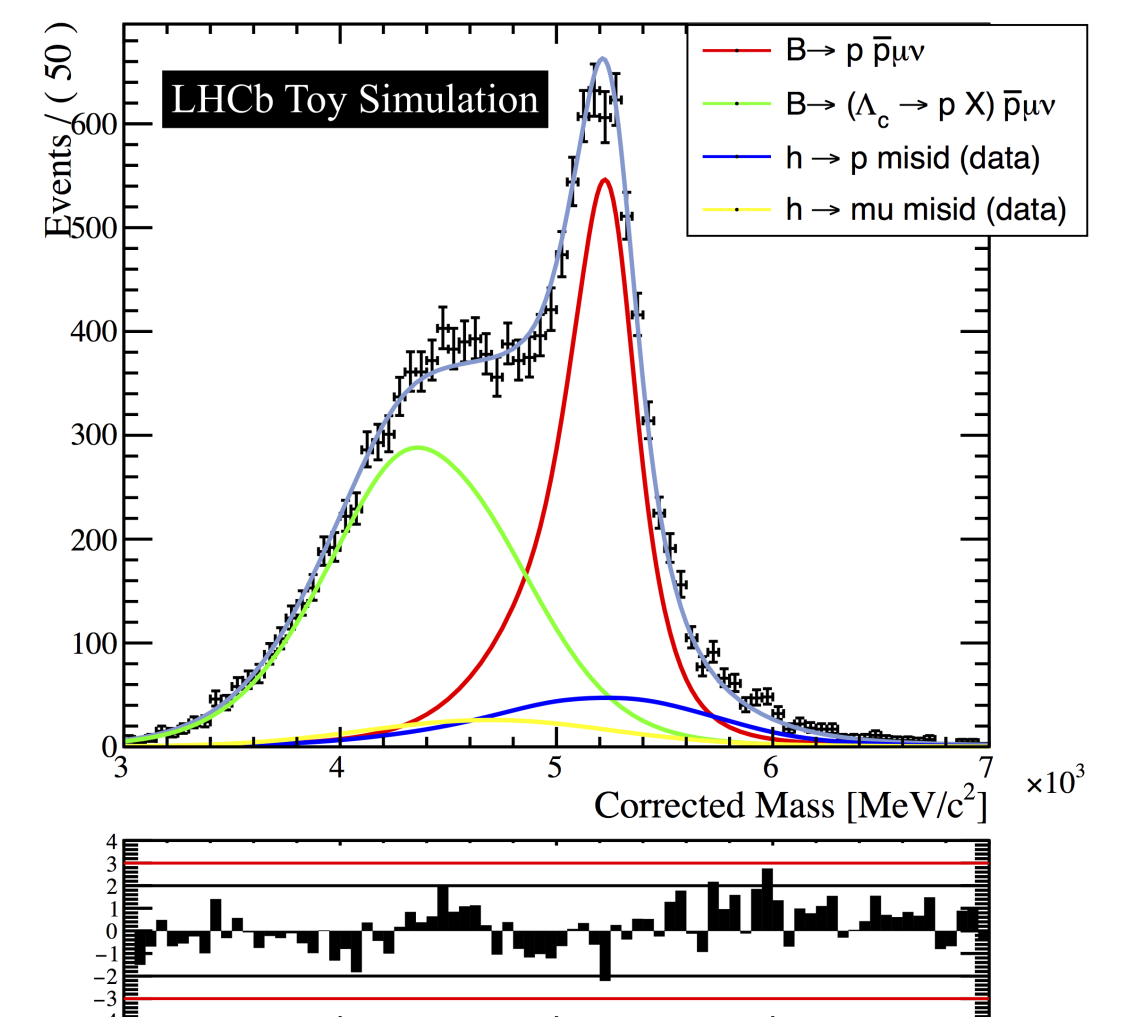
Previous Studies and Theoretical Predictions

- A calculation using perturbative QCD predicted $\mathcal{B}(B \rightarrow p\bar{p}\mu\nu) \approx 10^{-4}$ [3].
- Measurement from the Belle experiment found evidence at 3.0σ for the electron mode and 1.3σ for the muon mode. The fit for the muon mode is shown below. The branching fraction of the electron mode was measured to be $8.2^{+3.7}_{-3.2} \pm 0.6 \times 10^{-6}$ [5].



Study of the Decay $B \rightarrow p\bar{p}\mu\nu$

- The measurement of the branching fraction of $B \rightarrow p\bar{p}\mu\nu$ in bins of $p\bar{p}$ mass is ongoing.
- Background from misidentified protons and muons can be modeled from data.
- The result is still blind. The simulation plot below shows an approximated yield considering both Run 1 and Run 2 and all bins of $p\bar{p}$ mass.



The Ratio of Branching Fractions $R(p\bar{p})$

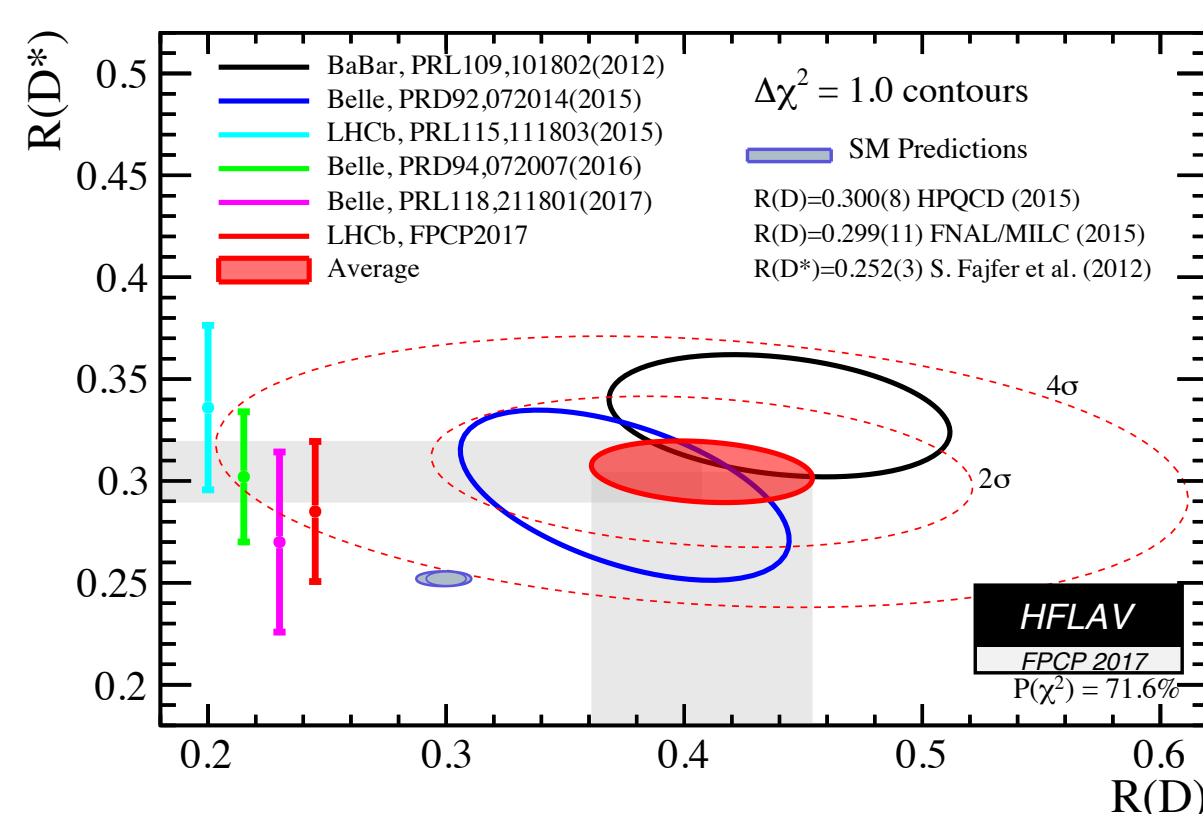
Motivation

- To test lepton universality the ratios of branching fractions for semileptonic decays involving tau particles are defined by

$$R(X) \equiv \frac{\mathcal{B}(B \rightarrow X\tau\nu)}{\mathcal{B}(B \rightarrow X\mu\nu)},$$

where X can represent any particle or collection of particles.

- An average of the best current measurements of $R(D)$ and $R(D^*)$ by the The Heavy Flavour Averaging Group (HFLAV) is in 4σ tension with the very precise Standard Model prediction [4].



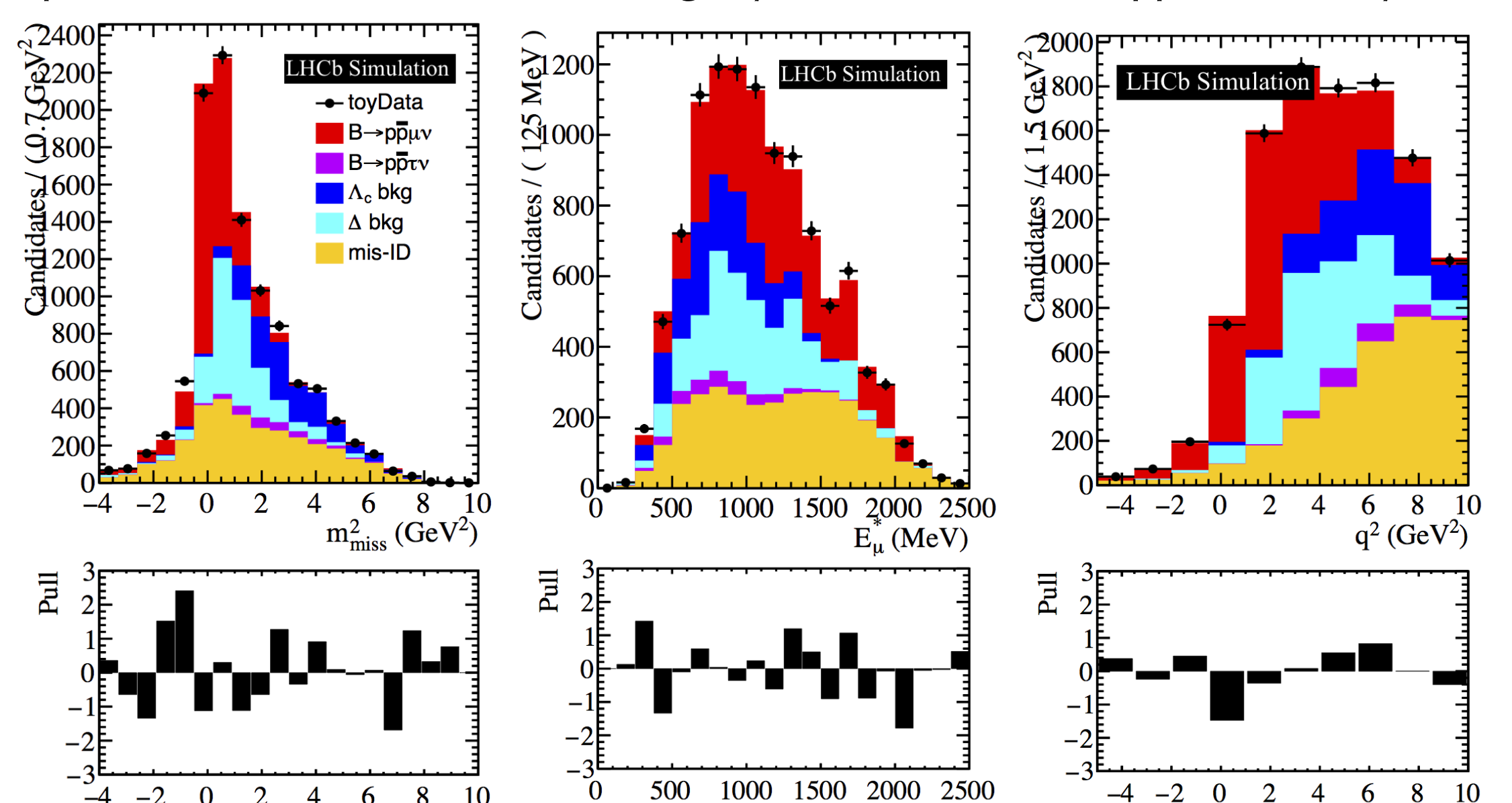
- The ratios $R(D)$, $R(D^*)$ and the recent $R(J/\psi)$ probe the $b \rightarrow c\ell\nu$ transition where $\ell = \mu$ or τ [2].
- Some new physics explanations for this discrepancy imply an enhancement in the similar $b \rightarrow u\ell\nu$ transition.

Toy Studies of $R(p\bar{p})$

A similar strategy to the $R(D^*)$ measurement at LHCb is considered, three of the most distinguishing features can be used to separate the modes in a fit [1].

- Missing mass squared.
- Lepton energy in B -hadron rest frame.
- Four-momentum transferred to the leptons in the decay, (q^2) .

The shapes of these are shown below using toy simulations with approximated yields.



- [1] R. Aaij et al. Measurement of the ratio of branching fractions $\mathcal{B}(\bar{B}^0 \rightarrow D^{*+}\tau^-\bar{\nu}_\tau)/\mathcal{B}(\bar{B}^0 \rightarrow D^{*+}\mu^-\bar{\nu}_\mu)$. *Phys. Rev. Lett.*, 115(11):111803, 2015, 1506.08614.
- [2] R. Aaij et al. Measurement of the ratio of branching fractions $\mathcal{B}(B_c^+ \rightarrow J/\psi\tau^+\nu_\tau)/\mathcal{B}(B_c^+ \rightarrow J/\psi\mu^+\nu_\mu)$. 2017, 1711.05623.
- [3] C. Q. Geng and Y. K. Hsiao. Semileptonic $B^- \rightarrow p\bar{p}\ell^-\bar{\nu}_\ell$ decays. *Phys. Lett.*, B704:495–498, 2011, 1107.0801.
- [4] HFLAV. Average of $R(D)$ and $R(D^*)$. FPCP 2017, <http://www.slac.stanford.edu/xorg/hflav/>.
- [5] K. J. Tien et al. Evidence for semileptonic $B^- \rightarrow p\bar{p}\ell^-\bar{\nu}_\ell$ decays. *Phys. Rev.*, D89(1):011101, 2014, 1306.3353.