Hopes and dreams for $B \to D^{(*)}\tau\nu$ angular analysis

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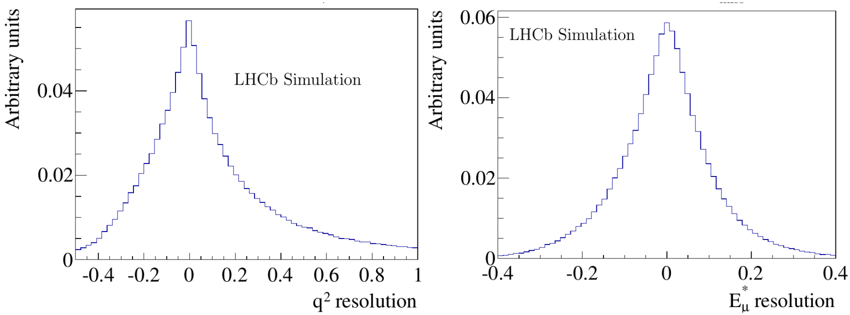
Introduction

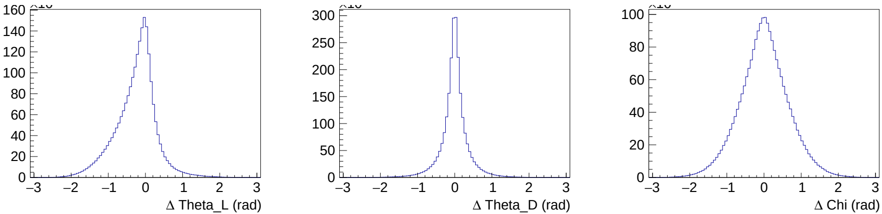
- $B \to D^{(*)}\ell\nu$ matrix element fully described by 2 (4) kinematic variables
- Most common choice: q^2 + angles
- For muonic $\mathcal{R}(D^*)$ analysis, we fit q^2, muon energy, missing mass squared
    - These partially describe matrix element $\to$ we already have some information
- At present we assume SM kinematic distributions for $\mathcal{R}(D^*)$
- What additional information should we try to fit?
- What physics should we try to measure?
- Disclaimer: talk is almost entirely opinions, hopes and speculation

Reconstruction ($\tau \to \mu\nu\nu$)



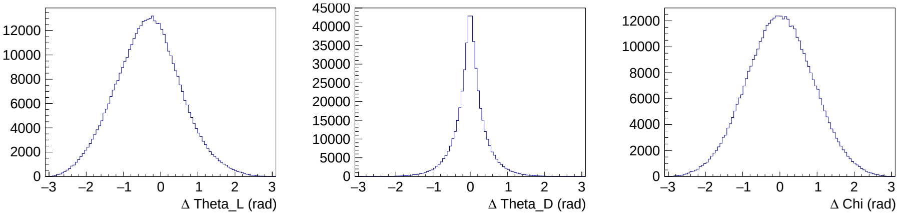
- Take $(\gamma\beta_z)_B = (\gamma\beta_z)_{D^*\mu}$
- Have approximation for rest frame with $\sim 15 - 20\%$ precision
- Can use this to calculate angles

Angular resolutions for $B \to D^* \mu\nu$



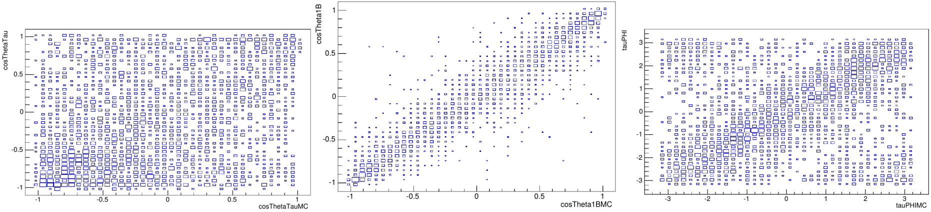
- Before taus, first look at angular resolution for $B \to D^* \mu\nu$
- Pretty wide, but have something to work with

Angular resolutions for $B \to D^* \tau \nu$ $(\tau \to \mu \nu \nu)$



- Angular resolution for $B \to D^* \tau \nu$
- Tau decay results in loss of information
  - Theta L gets very messy
  - Theta D still “good”
  - Chi worsens

Angular resolutions for $B \to D^* \tau \nu$ ($\tau \to \pi\pi\pi\nu$)



- Situation similar for $\tau \to \pi\pi\pi\nu$ mode
- Different reconstruction method:
    - Can reconstruct kinematics up to quadratic ambiguities using B and τ mass constraints + both vertex positions
    - Average over ambiguities
- Less information lost in tau decay, so Theta L a bit better

What can we do?

- Unfolding this seems a nightmare (as does background subtraction) $\rightarrow$ we are unlikely to publish corrected q^2 / angular distributions for signal
- But we can fit the data
  - Templates we fit already include effects of resolution, acceptance, tau decay, ...
  - We choose what physics model goes into templates, and can vary this in the fit
  - Fit parameters defined in terms of underlying physics
  - We already do this for systematic uncertainties

What to measure

- First need to see if the excess holds up!
- Afterwards, in order of ambition:
  - Does measured value change allowing NP operators?
  - Can enhancement be accommodated by theory uncertainty?
  - Is enhancement pure (pseudo)scalar?
  - If not, is it pure vector/axial/tensor/...?
  - Or a combination of operators?
  - Can we fit the full matrix element?

Can enhancement be accommodated by theory uncertainty?

- SM expectation for $\mathcal{R}(D^{(*)})$relies on calculation for scalar form factor
  - Lepton mass suppressed $\rightarrow$ can't measure in $B \rightarrow D^{(*)}\mu\nu$
- In flavour community, calculation seems to be trusted relative to current excess
  - But does the wider community believe it if we start making a serious new physics claim?

Scalar form factor

- Trying to measure scalar form factor doesn't seem so implausible
  - If no new (pseudo)scalar physics, and form factor agrees with prediction $\rightarrow$ model independent SM exclusion
  - Uncertainty from QED corrections?
- Testing SM only hypothesis $\rightarrow$ constrain other form factors from $B \rightarrow D^{(*)}\mu\nu$
- CLN vs general z expansion / BGL?

More complex fits

- We don't really know how far we can push this
- Where we actually have statistical power, how many parameters we can vary simultaneously
- Will slowly try progressively more complex fits, more dimensions
- The dream: 5D? fit to data, floating all operators + form factors in Z expansion
    - Sounds difficult, though

Conclusion

- We should explore what we can measure from the $B \to D^{(*)}\tau\nu$ kinematic distributions
- Our fit already incorporates some of this information
- We have some machinery to perform the fit
- In principle, we have access to the full distribution, with some resolution
- How far can we push this?