Importances of Slow Pion Reconstruction in Semileptonic B Decays

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FSP workshop: slow pion tracking
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Inclusive B→ X$_u$ℓν Decays

Overview

- Measurements challenging due to high background from **B→ X$_c$ lν**

- Large component of charmed background involves **D* → Dπ** decay (~68% of D* BR)

- Due to small mass difference between D* and D, emitted **π$_{slow}$< ~220 MeV c.m.s**

- **Slow pions** is a "feature" of such decay and needed in reconstructing **D***

Fight direction of π$_{slow}$ is strong correlationd with D* , **four-momentum of D*** can be approximately reconstructied from π$_{slow}$ as

Belle [PRD 104 012008 (2021)]

$B \to D\ell\nu$
$B \to D^*\ell\nu$
$B \to D^{**}\ell\nu$
Gap modes
Sec. & fake
Continuum
$B \to X_u\ell\nu$
Data
MC unc.

Backgrounds

$$E_{D^*} = \frac{m_{D^*}}{m_{D^*} - m_D} \times E_\pi$$

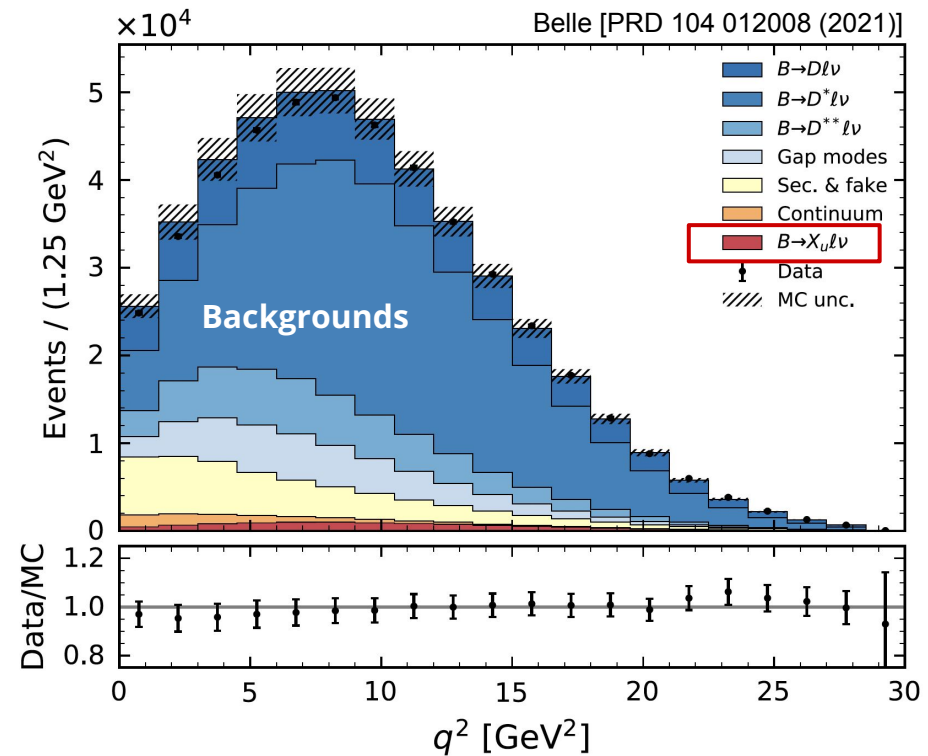$$\mathbf{p}_{D^*} = \mathbf{p}_\pi \times \frac{\sqrt{E_{D^*}^2 - m_{D^*}^2}}{|\mathbf{p}_\pi|}$$

$$M_{\mathrm{miss},D^*}^2 = (p_{\mathrm{sig}} - p_{D^*} - p_\ell)^2,$$

$$\cos\theta_{B,D^*\ell} = \frac{2E_{\mathrm{beam}}E_{D^*\ell} - m_B^2 - m_{D^*\ell}^2}{2|\mathbf{p}_B||\mathbf{p}_{D^*\ell}|},$$

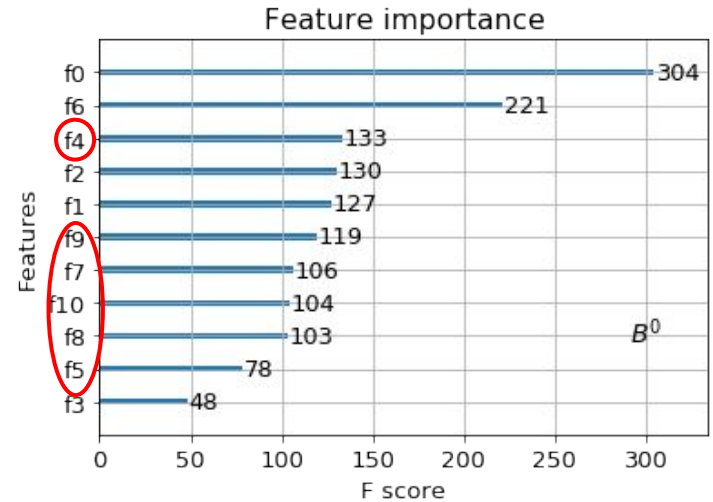$$\cos\theta^* = \frac{\mathbf{p}_\ell \cdot \mathbf{p}_{D^*}}{|\mathbf{p}_\ell||\mathbf{p}_{D^*}|},$$

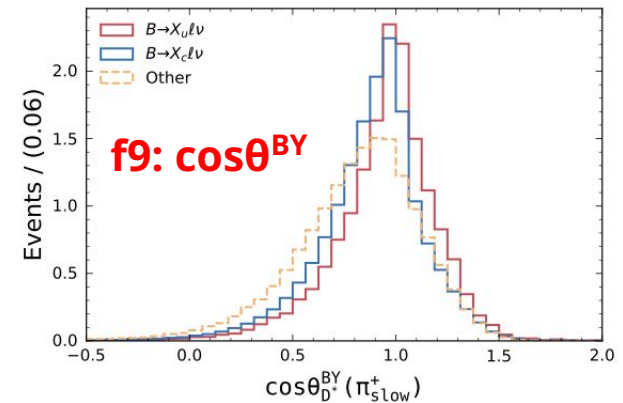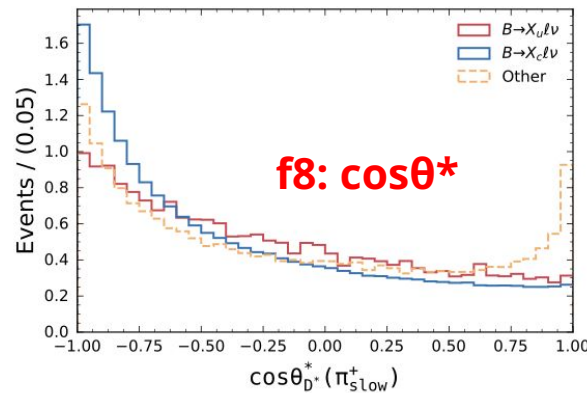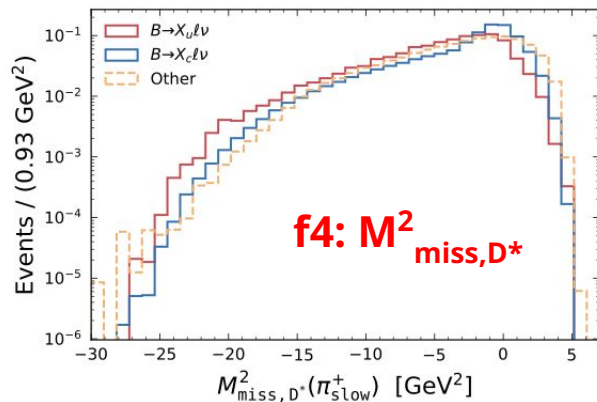**Powerful discriminate variables for separating signal and bkg**

Inclusive B→ $X_u\ell\nu$ Decays

Backgroun suppression features related to slow pion

- Use machine learning (BDT) to suppress backgrounds with 11 trainning features

- Slow pion related features gain high ranking of importanfe
  - **π^+_{slow}: f4, f8, f9**
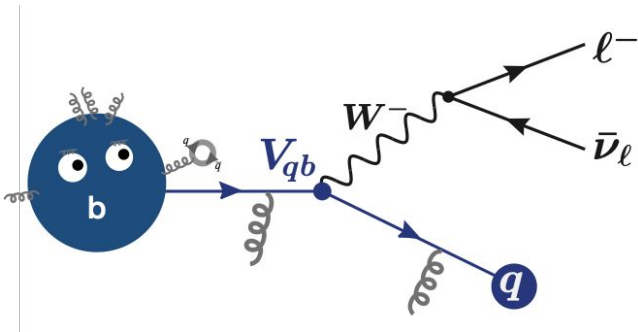 - π^0_{slow}:   f5, f7, f10

Feature importance

Belle [PRD 104 012008 (2021)]
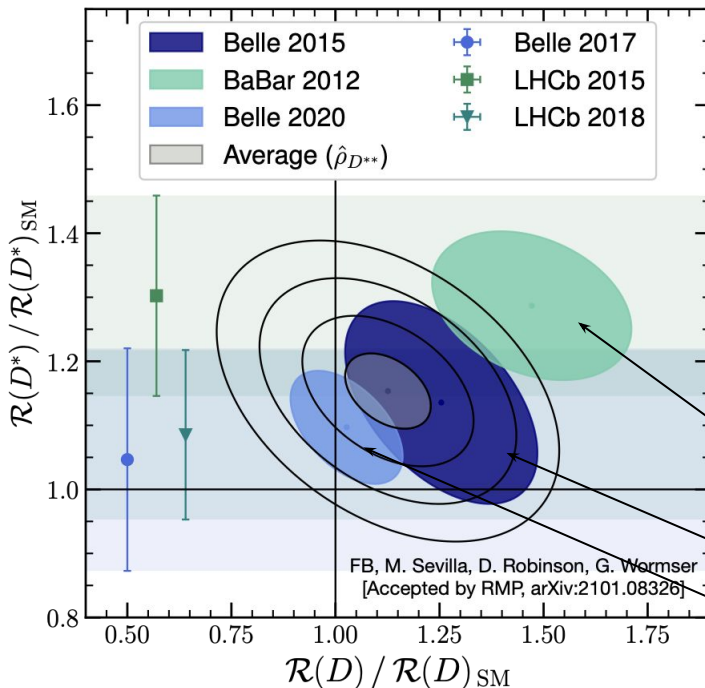

f4: $M^2_{miss,D*}$

f8: cosθ*

f9: cosθ^{BY}

Measurement of R(D) and R(D*)

Overview

$$R = \frac{b \to q\,\tau\,\bar{\nu}_\tau}{b \to q\,\ell\,\bar{\nu}_\ell}$$

$\ell = e, \mu$

| Obs.	Current World Av./Data	Current SM Prediction	Significance	
$\mathcal{R}(D)$	0.340 ± 0.030	0.299 ± 0.003	1.2σ	$\Big\}3.1\sigma$
$\mathcal{R}(D^*)$	0.295 ± 0.014	0.258 ± 0.005	2.5σ	
$P_\tau(D^*)$	$-0.38 \pm 0.51^{+0.21}_{-0.16}$	-0.501 ± 0.011	0.2σ	
$F_{L,\tau}(D^*)$	$0.60 \pm 0.08 \pm 0.04$	0.455 ± 0.006	1.6σ	
$\mathcal{R}(J/\psi)$	$0.71 \pm 0.17 \pm 0.18$	0.2582 ± 0.0038	1.8σ	
$\mathcal{R}(\pi)$	1.05 ± 0.51	0.641 ± 0.016	0.8σ	
$\mathcal{R}(D)$	$\mathbf{0.337 \pm 0.030}$	0.299 ± 0.003	1.3σ	$\Big\}\mathbf{3.6\sigma}$
$\mathcal{R}(D^*)$	$\mathbf{0.298 \pm 0.014}$	0.258 ± 0.005	2.5σ	

FB, M. Sevilla, D. Robinson, G. Wormser
[Accepted by RMP, arXiv:2101.08326]

All experimental results of simultaneous R(D/D*) are **anti-correlated**; contributing factor **D* downfeed** into **D** reconstruction **categories**

Measurement of R(D) and R(D*)

Down-feed & anti-correlations

Reconstruction channel
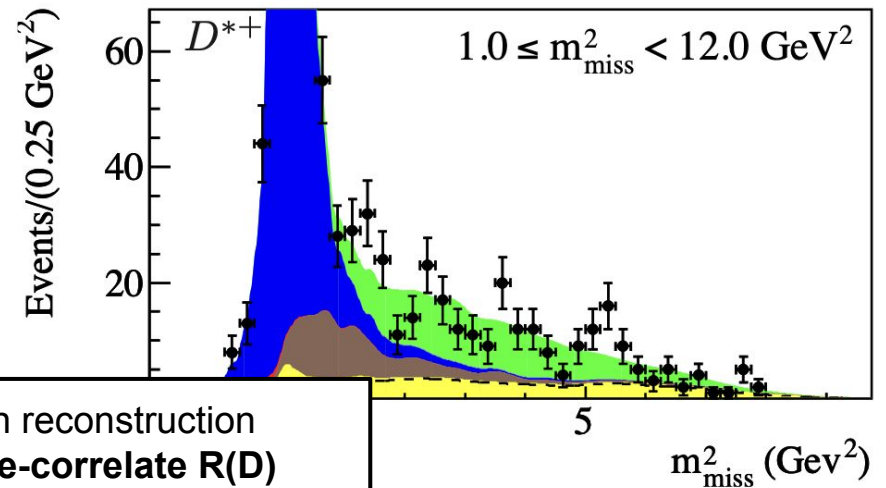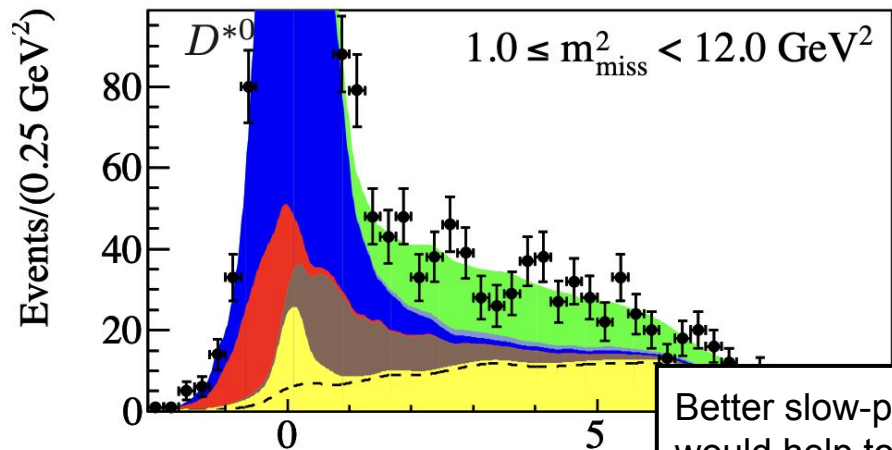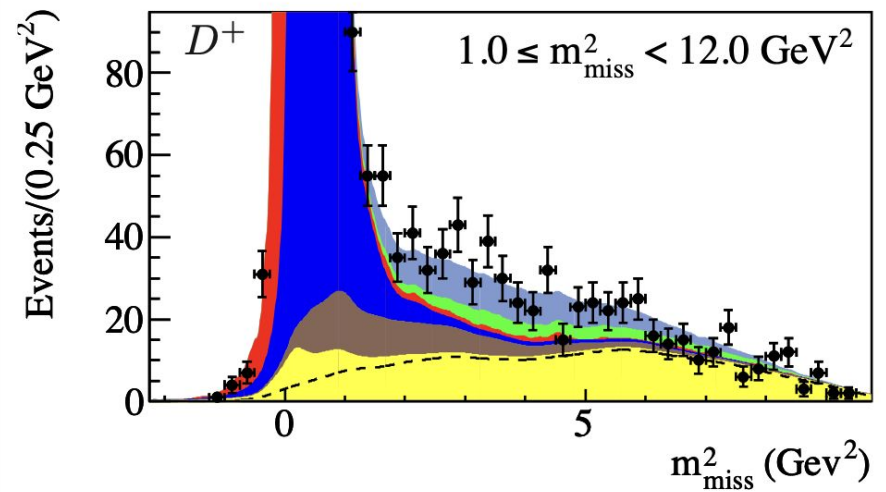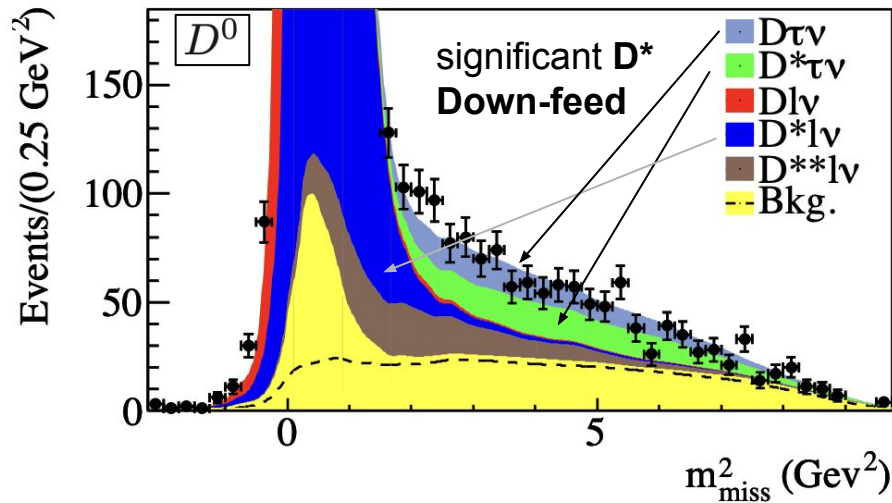
Better slow-pion reconstruction would help to **de-correlate R(D)** from **R(D*)** and **improve** sensitivity

Summary

- Slow pion is a crutial final state particles in many semipletonic decays, either as signal or important background

- Correct reconstruction of four-momentum of slow pion is important for those physics analyses

- Improvement of slow pion tracking efficiency performance/precision is needed

slow… but vital !!!