$|V_{ub}|$ from $B \to X\pi\ell\bar{\nu}$

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$B \to X\pi\ell\bar{\nu}$

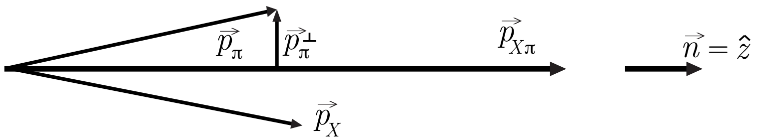
- Inclusive $B \to X_u \ell \bar{\nu}$: 3 independent kinematic variables
- Semi-inclusive decay, $|X_u\rangle \to |X\pi\rangle$, pion is identified: 3 more

$$\{p^+_{X\pi},\ p^-_{X\pi},\ p^+_{\pi},\ p^-_{\pi},\ E_\ell,\ \phi_\ell\}$$

$$p^\pm \equiv p^0 \mp p^z$$

$$p^\mu_{X\pi} = p^\mu_X + p^\mu_\pi$$

$$m^2_{X\pi} = p^\mu_{X\pi}\, p_{X\pi\,\mu} = p^+_{X\pi}\, p^-_{X\pi}$$



$$z \equiv \frac{p^-_\pi}{p^-_{X\pi}}\,,\ 0 \le z \le 1$$

- $b \to c\ell\bar{\nu}$ background: the identified pion helps, we can use events with $m_{X\pi} > m_D$, if z sufficiently large !

Factorization theorem: $|V_{ub}|$ from $B \to X\pi\ell\bar{\nu}$

Integrate the fully differential decay rate over E_ℓ, ϕ_ℓ, p_π^+ and a large range in $p_{X\pi}^+$, local OPE gives, $\{p_{X\pi}^-, p_\pi^-\} \to \{m_{X\pi}^2, z\}$:

$$\frac{d^2\Gamma}{dm_{X\pi}^2\, dz} = \sum_{i=u,\bar{u},d,g\ldots} |V_{ub}|^2 \int_z^1 \frac{dx}{x}\, H_{u,i}\Big(m_{X\pi}, \frac{z}{x}, \mu\Big)\, D_i^\pi(x,\mu) + \ldots$$

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- Hard function H is calculable in perturbation theory:

$$H \propto \delta(m_{X\pi}^2)\,\delta\Big(1 - \frac{z}{x}\Big) + H^{1-\text{loop}} + \ldots$$

MP, I. Stewart and F. Tackmann, *forthcoming*

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- Fragmentation function $D(z)$:
  - non-perturbative but universal, due to factorization theorems for single inclusive hadron production: $e^+\, e^- \to h\, X$, $e\, N \to e'\, h\, X$, $H_A\, H_B \to h\, X$ at high p_{T} ...

    Collins, Soper and Sterman ...
  - $D^\pi(x)$ from fits to (mainly) $e^+e^- \to \pi X$ cross sections
  - Unprecedented accuracy expected from analysis of B-factory data: few % uncertainty for medium-to-large z

M. Grosse Perdekamp, *private communication*

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Semi-inclusive analysis:

a new independent determination of $|V_{ub}|$ with competitive uncertainties

Subtracting the $b \to c$ background

- No $B \to X_c \pi \ell \bar{\nu}$:

$$m_X^2 < m_D^2 \quad \Longrightarrow \quad z > \frac{1}{2}\left(1 - \frac{m_D^2 - m_\pi^2}{m_{X\pi}^2}\right) \quad \text{if} \;\; p_\pi^+ \le p_\pi^-$$

Includes events with $m_{X\pi}^2 > m_D^2$. Always $z \ge m_\pi^2 / m_{X\pi}^2$

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- No $B \to (X_c \to X\pi)\ell\bar{\nu}$:

$$m_{X\pi}^2 < m_D^2 \text{ always OK}$$

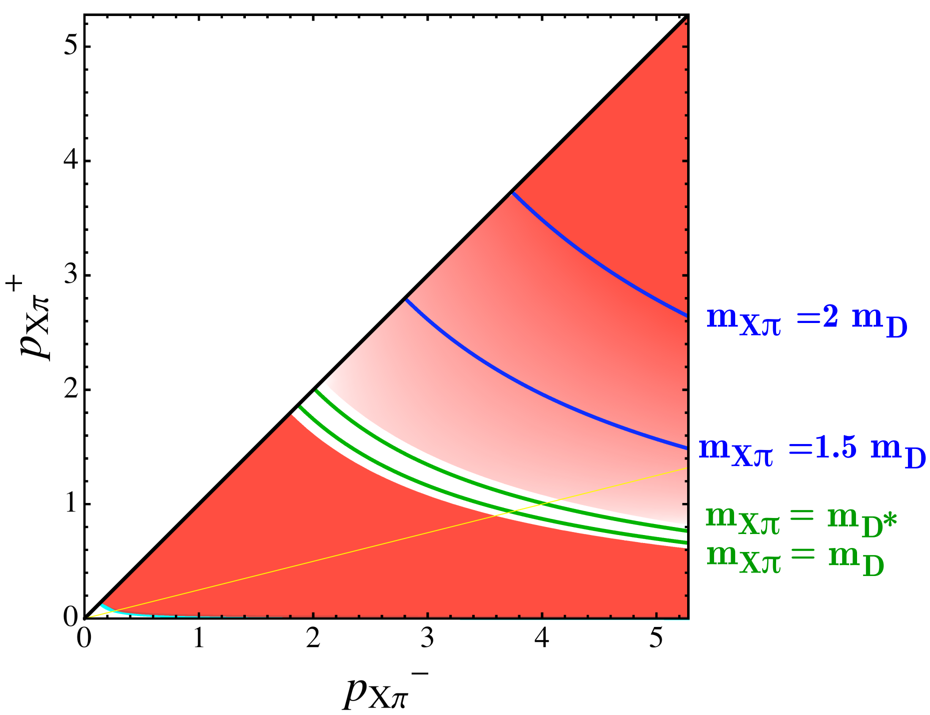
  Otherwise, $m_{X\pi}^2 > m_D^2$. In the rest frame of the decaying X_c, it requires

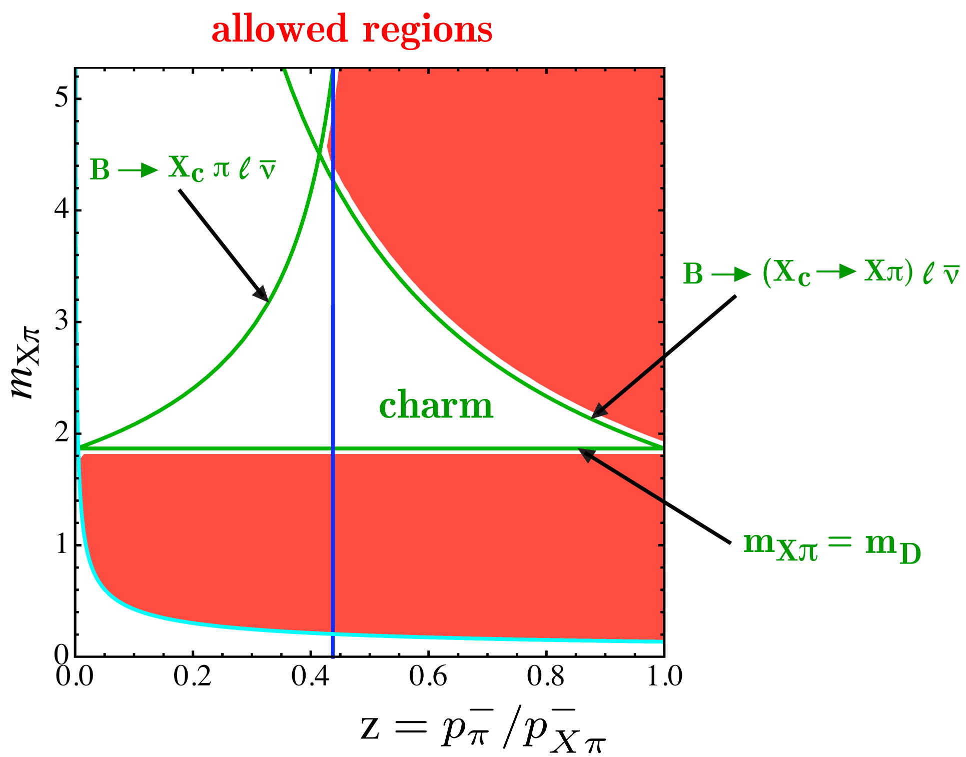
$$p_\pi^{-\,\text{rest}} > m_D$$

  Boosting to the frame where the B-meson decays at rest:

$$\frac{m_D}{\sqrt{p_{X\pi}^- \, p_{X\pi}^+}} = \frac{m_D}{m_{X\pi}} < z \leq 1$$

Subtracting the $b \to c$ background





Conclusion:

$$\frac{d\Gamma}{dm^2_{X_u}} \quad \Longrightarrow \quad \frac{d^2\Gamma}{dm^2_{X\pi}dz} \quad \Longrightarrow \quad |V_{ub}| \; !$$