V_{cb} from semileptonic B decays

Theoretical aspects

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SLAC

Welcome to paradise . . .

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- Exclusive decay

- Inclusive rate

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- V_{cb} is large.
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  - Heavy quark symmetry normalizes formfactors.
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Much better situation than for V_{ub}:

- V_{cb} is large.
- Exclusive decay
  - Heavy quark symmetry normalizes formfactors.
- Inclusive rate
  - Calculable using OPE.

Exclusive decay $\bar{B} \to D^* \ell \bar{\nu}$

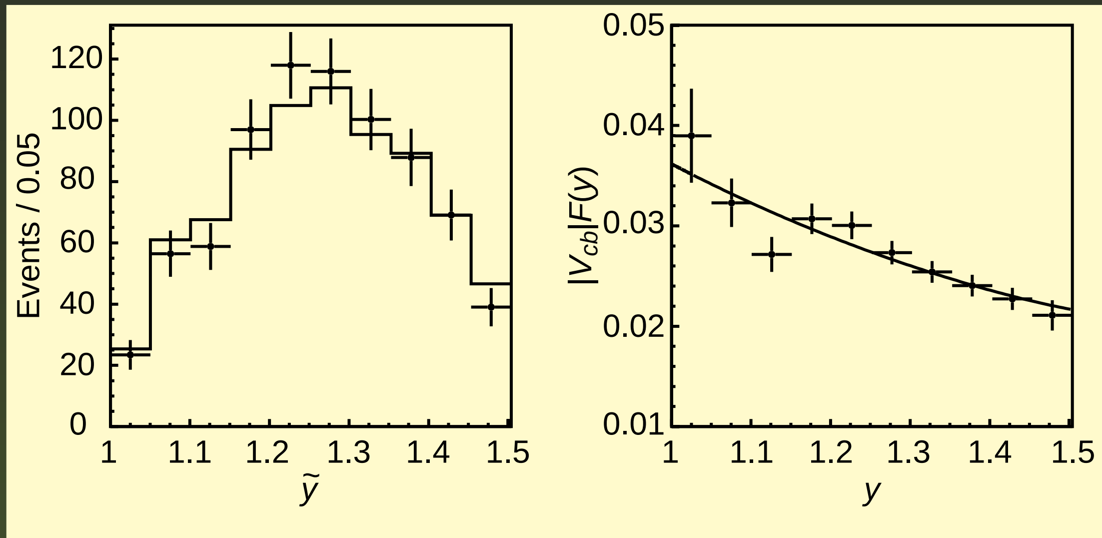
$$\frac{d\Gamma}{d\omega} = \sqrt{\omega^2 - 1} f(\omega, m_B, m_{D^*}) |V_{cb} \mathcal{F}(\omega)|^2$$

$$\text{with } q^2 = m_B^2 + m_{D^*}^2 - 2 m_B m_{D^*} \omega,$$

- $\mathcal{F}(\omega) = \xi(\omega) \left[1 + O(\frac{\Lambda}{m_Q}) + O(\alpha_s)\right]$
- Zero recoil: $\mathcal{F}(1) = \eta_{\text{pert}} \left[1 + O(\frac{\Lambda^2}{m_Q^2})\right]$

  Rate vanishes as $\sqrt{\omega^2 - 1}$ for $\omega \to 1$.
- Basic strategy:
  - *Th.* Supply $\mathcal{F}(1) \to$ A. Kronfeld's talk.
  - *Exp.* Measure $|V_{cb} \mathcal{F}(\omega)|$, extrapolate to $\omega \to 1$.

Extrapolation to the zero recoil point



Parametrize

BELLE Collaboration `hep-ex/0111037`

$$\mathcal{F}(\omega) = \mathcal{F}(1)\left[1 - \hat{\rho}^2(\omega - 1) + c(\omega - 1)^2 + \ldots\right]$$

- Unconstrained fit: Number of events needed to reduce the statistical error increases drastically.

$\rightarrow$ Need theoretical input for the shape of $\mathcal{F}(\omega)$.

Shape of $\mathcal{F}(\omega)$

$$\mathcal{F}(\omega) = \mathcal{F}(1)\left[1 - \hat{\rho}^2(\omega - 1) + c(\omega - 1)^2 + \ldots\right]$$

- Unitarity and analyticity correlate $\hat{\rho}$ with c and higher order terms.
- $\rightarrow$ One parameter representation, accuracy better than 2%.

Inclusive determination

Performing the OPE, the total decay rate $\bar{B} \to X_c \, \ell \, \bar{\nu}$ is

$$\Gamma = \frac{G_F^2 \, m_b^5}{192\pi^3} \left[c_3(x) \left(1 + \frac{\lambda_1 + 3\lambda_2}{2 \, m_b^2} \right) + c_5(x) \, \frac{6\lambda_2}{m_b^2} + \ldots \right] ,$$

with $x = m_c / m_b$.

- Coefficients $c_3(x)$ and $c_5(x)$ can be calculated perturbatively (assuming quark hadron duality).
- λ_1, λ_2: Nonperturbative parameters.
  $4 \, \lambda_2 \approx m_{B^*}^2 - m_B^2$.

Theoretical uncertainties

$$\Gamma = \frac{G_F^2 \, m_b^5}{192\pi^3} \left[c_3(x) \left(1 + \frac{\lambda_1 + 3\lambda_2}{2\, m_b^2} \right) + c_5(x) \, \frac{6\lambda_2}{m_b^2} + \ldots \right],$$

- $\left\{ \begin{array}{l} \text{Large perturbative corrections to } c_3. \\ \text{Uncertainty of the pole masses } m_b \text{ and } m_c. \end{array} \right.$

$\rightarrow$ correlated. Appropriate mass definition leads to better behaviour of PT.

- $O(\Lambda^3/m_b^3)$

Moment analysis

Can eliminate pole mass (or $\bar{\Lambda}$) and λ_1 with additional experimental input. Moments of the decay spectrum $\frac{d\Gamma}{dX}$:

$$\langle X^n \rangle = \frac{1}{\Gamma} \int dX \, \frac{d\Gamma}{dX} \, X^n$$

- CLEO uses
  - Hadronic mass spectrum of $\bar{B} \to X_c \ell \bar{\nu}$
    $\langle m_X^2 \rangle \to \bar{\Lambda}$
  - Photon energy spectrum of $\bar{B} \to X_s \gamma$:
    $\langle E_\gamma \rangle \to \lambda_1$
- . . . in $\overline{\mathrm{MS}}$ at $O(\alpha_s^2 \, \beta_0)$