$\overline{B} \to X_s \ell^+ \ell^-$

above the $\psi(2S)$

(Fermilab 24/2/00)

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The $b \to s \ell^+ \ell^-$ transition

- 3 operators contributing

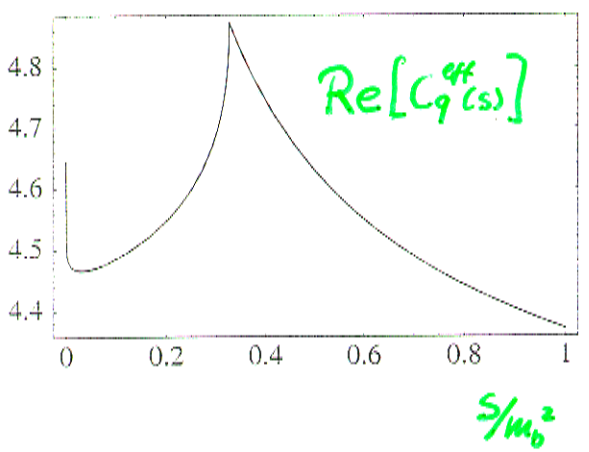
$$\mathcal{A}(b\to s\ell\ell) = \frac{G_F \alpha}{\sqrt{2}\,\pi} V_{ts}^* V_{tb} \Big[(C_{9(s)}^{eff} - C_{10})(\bar{s}\gamma_\mu L b)(\bar{\ell}\gamma^\mu L \ell)$$

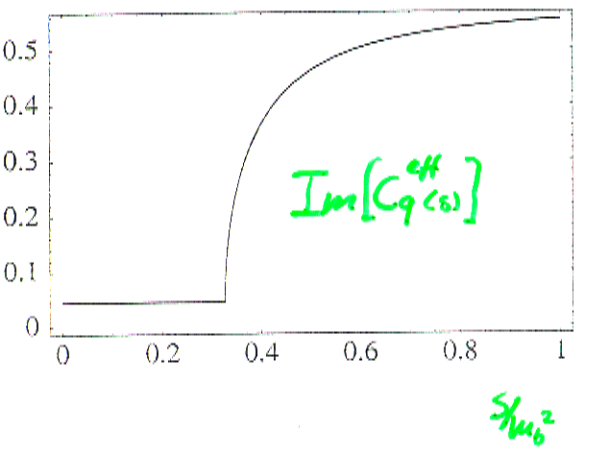
$$+ (C_{9(s)}^{eff} + C_{10})(\bar{s}\gamma_\mu L b)(\bar{\ell}\gamma^\mu R \ell) - 2C_7^{eff}\left(\bar{s}\, i\sigma_{\mu\nu}\frac{q_\nu}{q^2}(m_s L + m_b R)\right)(\bar{\ell}\gamma^\mu \ell)\Big]$$

- Wilson coefficients known at NLL

(Buras, Münz)

$$C_7^{eff} = -0.31 \qquad C_{10} = -4.55$$



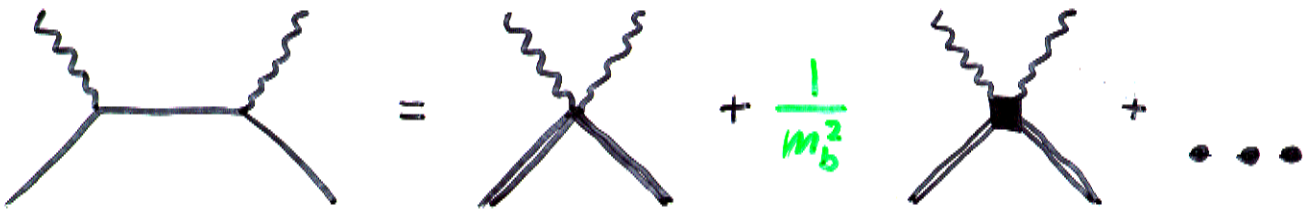


Exclusive vs. Inclusive

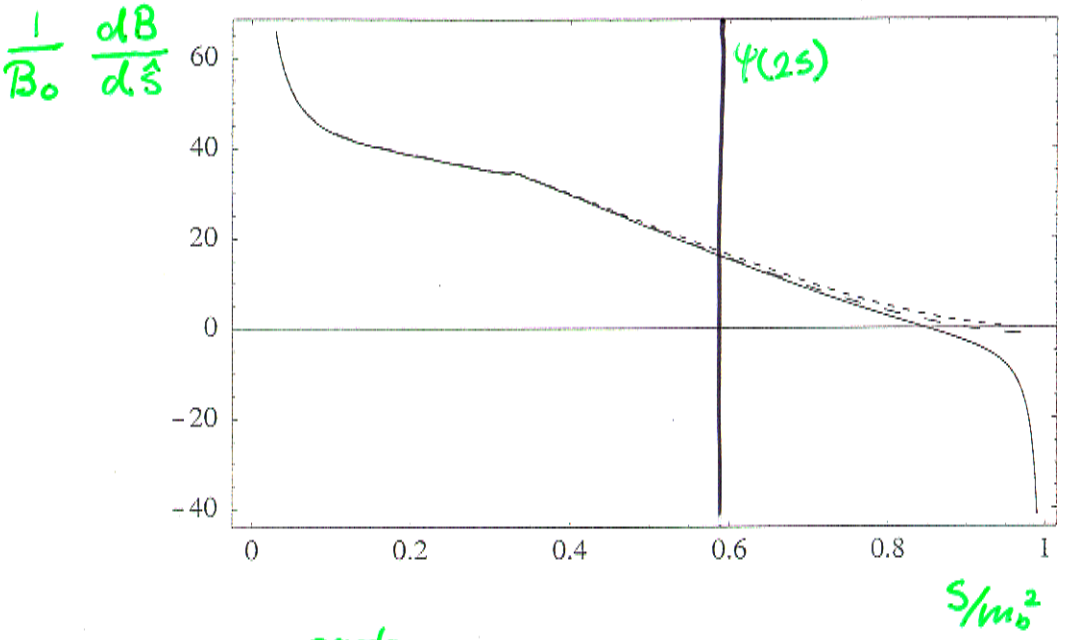
- **Exclusive**
  - need knowledge of form factors
  - model, lattice, ...

- **Inclusive**
  - factorization between hadronic and leptonic current
  - large momentum transfer $\Rightarrow$ OPE

    (Chay, Georgi, Grinstein ....)



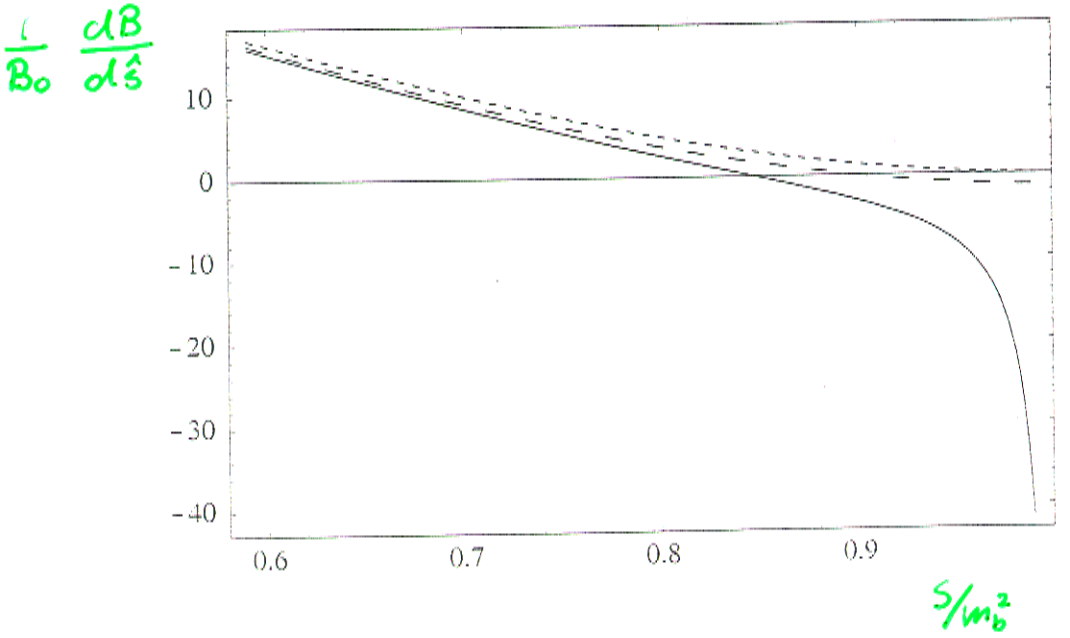
The lepton invariant mass spectrum



parton

parton + $1/m^2$

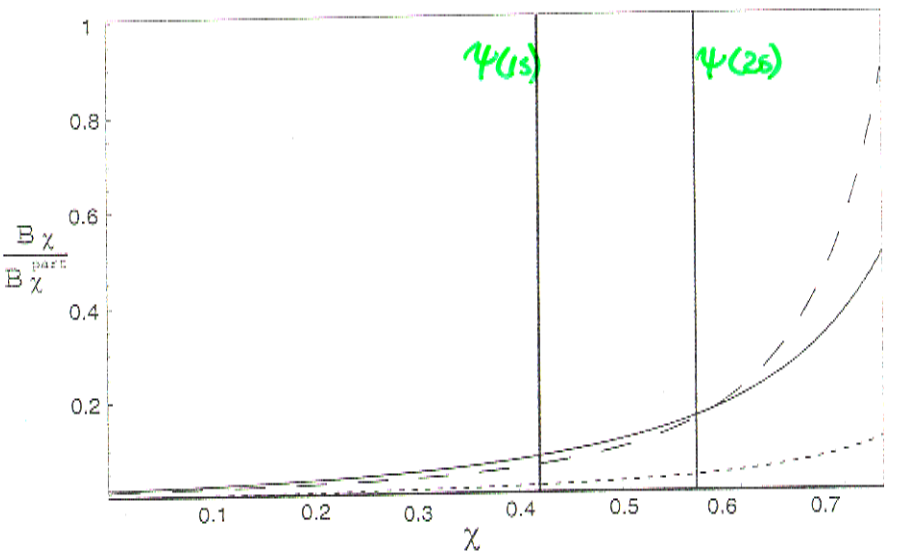
parton + $1/m^2$ + $1/m^3$



The partially integrated rate

The rate with a lower cut on q^2

$$B_x = \int_x^1 \frac{dB}{d\hat{s}}\, d\hat{s}\,, \qquad x = \frac{s_0}{m_b^2}$$



The size of the nonperturbative contributions

for $x = \frac{14.3\,\mathrm{GeV}^2}{m_b^2} = 0.59$

$$B_{0.59} = 3.8 + 1.9\left(\frac{\lambda_1}{m_b^2} + \frac{\tau_1 + 3\tau_2}{m_b^3}\right) - 134.7\left(\frac{\lambda_2}{m_b^2} + \frac{\tau_3 + 3\tau_4}{m_b^3}\right)$$

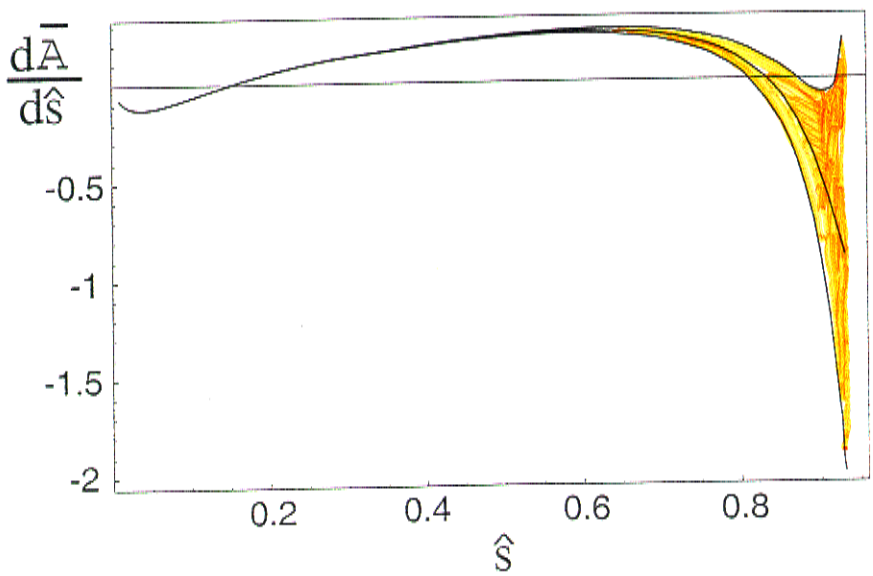
$$+ 614.9\,\frac{\rho_1}{m_b^3} + 134.7\,\frac{\rho_2}{m_b^3} + 560.2\,\frac{f_1}{m_b^3}$$

The FB asymmetry

$$\frac{dA}{d\hat{s}} = \int_0^1 \frac{dB}{dz\,d\hat{s}}\,dz - \int_{-1}^0 \frac{dB}{dz\,d\hat{s}}\,dz \quad , \quad z = \cos\theta$$

normalized FB asymmetry

$$\frac{d\bar{A}}{d\hat{s}} = \frac{dA}{d\hat{s}} \Big/ \frac{dB}{d\hat{s}}$$



Importance of structure function

- OPE breaks down if phase space restricted too close to the endpoint

- required phase space can be estimated from difference in hadronic and partonic endpoint

$$\Delta q^2 \sim \Delta M_X^2 \sim M_B^2 - m_b^2 \sim 2\Lambda_{QCD} m_b$$

- If endpoint contains highly energetic light quark jet

  $\Rightarrow$ structure function required $\quad M_X^2 < 2\Lambda_{QCD} m_b$

- If endpoint contains only soft light quark jet

  $\Rightarrow$ no structure function required $\quad M_X^2 < \Lambda_{QCD}^2$

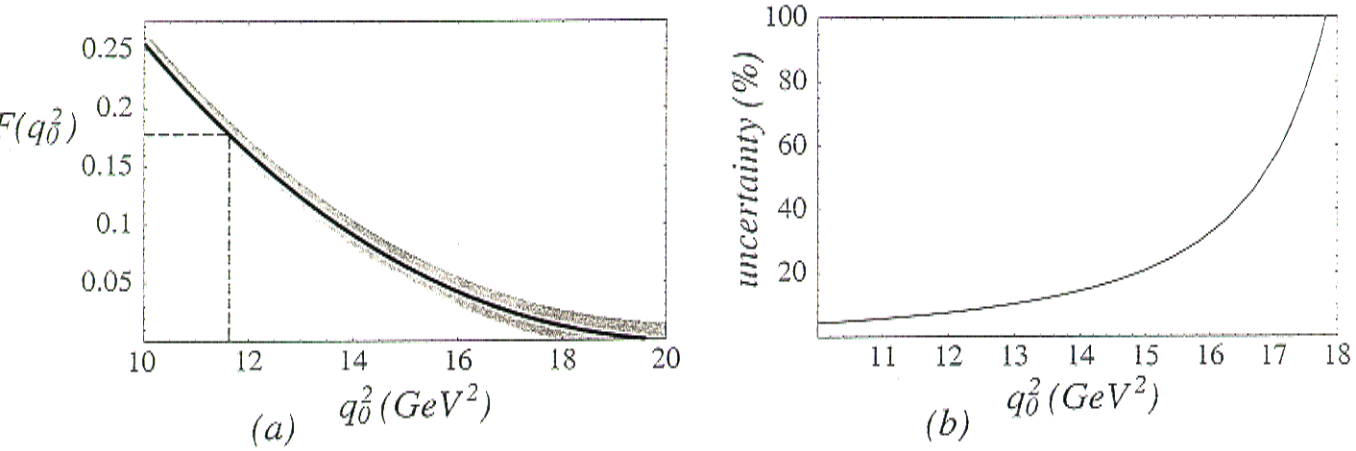
$\Rightarrow$ for $\frac{dB}{dq^2}$ no shape function analysis possible

V_{ub} with input from $\bar{B} \to X_s \ell^+ \ell^-$

- since no structure function for $d\Gamma/dq^2$

  $\Rightarrow$ extract $|V_{ub}|$ from q^2 spectrum of $\bar{B} \to X_u \ell \bar{\nu}$

- The fraction of events with $q^2 > q_0^2$, $F(q_0^2)$

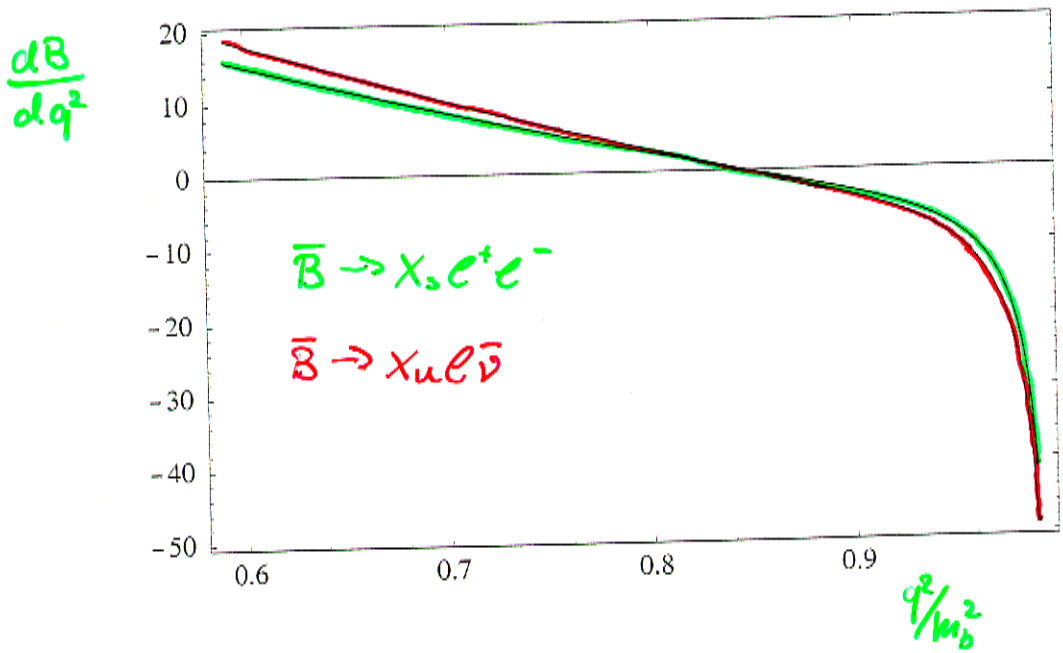


- Uncertainties get large for $q_0^2 \gtrsim 15\ GeV^2$

- Can use information from $\bar{B} \to X_s e^+ e^-$ in this case

- $\tilde{C}_9 \sim -C_{10} \gg C_7$

$\Rightarrow$ the $\bar{B} \to X_s e^+ e^-$ spectrum is very close to the $(V-A)\times(V-A)$ spectrum of $\bar{B} \to X_u \ell \bar{\nu}$



- $$\frac{B(\bar{B} \to X_u \ell \bar{\nu})|_{q^2 > q_0^2}}{B(\bar{B} \to X_s e^+ e^-)|_{q^2 > q_0^2}} = \frac{|V_{ub}|^2}{|V_{ts} V_{tb}|^2} \frac{8\pi^2}{\alpha^2} \frac{1}{|\tilde{C}_9|^2 + |C_{10}|^2 + 12\,\mathrm{Re}(C_7 \tilde{C}_9)\, B(q_0^2)}$$

$$B(q_0^2) = \frac{2}{3(1+Q_0^2)} - \frac{4\bar{\Lambda}}{3\bar{M}_B} \frac{Q_0^2}{(1+Q_0^2)^2}$$

- Expected to hold at $\sim 15\%$ level

Conclusions

- the inclusive decay $\bar{B} \to X_s e^+ e^-$ can be calculated model independently
- the convergence of the OPE is poor for $q^2 > M_{2S}^2$
- this is not due to a structure function
- shape of q^2 spectrum similar to $\bar{B} \to X_u e \bar{\nu}$ for high q^2
- this can be used to extract $|V_{us}|$