Recent V_{ub} results from CLEO

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Representing the CLEO Collaboration

Quark Mixing

- Weak interaction couples weak eigenstates, not mass eigenstates: CKM matrix relates these two representations:

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix} \qquad \begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3\left(\rho - i\eta\left(1-\frac{1}{2}\lambda^2\right)\right) \\ -\lambda & 1-\frac{1}{2}\lambda^2 - i\eta A^2\lambda^4 & A\lambda^2\left(1+i\eta\lambda^2\right) \\ A\lambda^2\left(1-\rho-i\eta\right) & -A\lambda^2 & 1 \end{pmatrix}$$

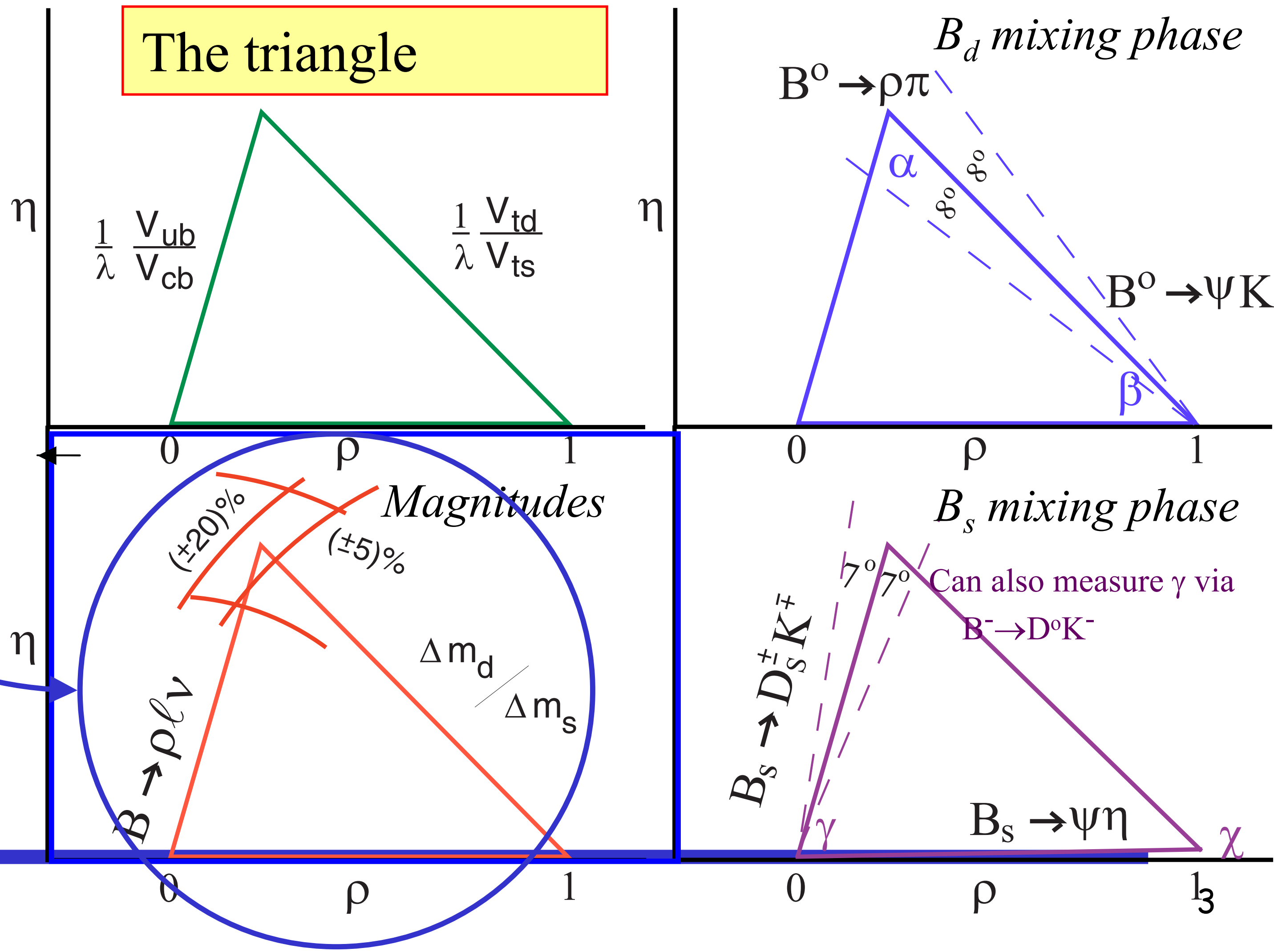
weak eigenstates | V_{CKM} | mass eigenstates | Wolfenstein parameterization

T | To λ^3 in real part & λ^5 in im. part

CKM unitary → described by 4 parameters (3 real, 1 imaginary: e.g. A,λ,ρ,η)

The unitarity triangle in the ρ–η plane

- Use different sets of measurements to define apex of triangle
- Also have ε_K (CP in K_L system)



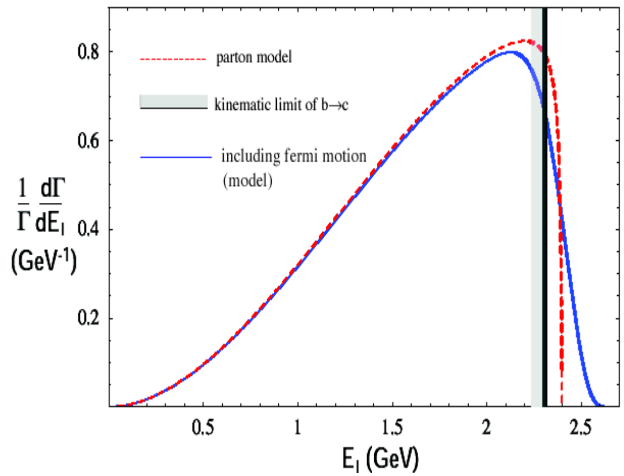
V_{ub} extraction from inclusive charmless semileptonic decays

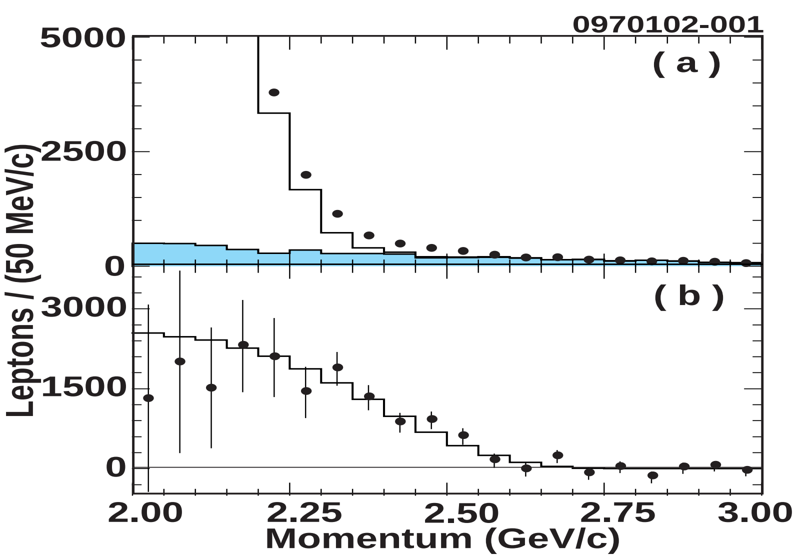
- In principle:
  - easy and reliable:

$$|V_{ub}| == (3.06 \pm 0.08 \pm 0.08) \times 10^{-3} \left(\frac{\mathcal{B}(B \to X_u \ell \bar{\nu}) 1.6 ps}{0.001 \tau_B} \right)^{1/2}$$

  - Greatest uncertainty m_b
  - Non-perturbative effects small
- But…
  - Charm background ~100 times charmless signal
    - Experimental ingenuity needed [e.g. cuts]
    - Theorists are kept busy evaluating and debating new sources of theoretical error

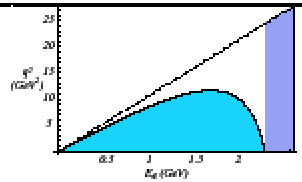
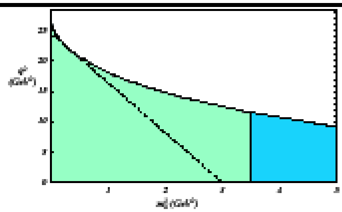
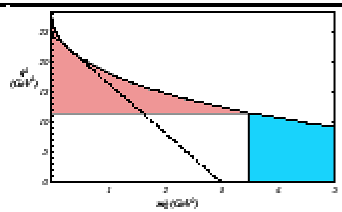
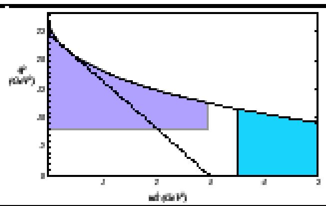
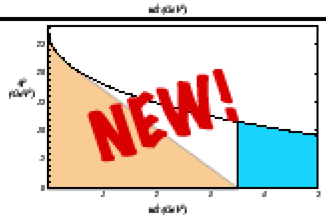
Where it all started: cut of the endpoint of the charged lepton spectrum





- Disadvantages: local OPE breaks down →sensitivity to Fermi motion of the b quark f(k+)
- Motivated extraction of f(k+) from b→sγ
- Alternative methods developed: either cutting on the hadronic invariant mass spectrum ($m_X<m_D$): same problems with Fermi motion (function of the proximity of the cut to perturbative singularities) or $q^2>(m_B-m_D)^2$

Summary of techniques available to suppress charm background

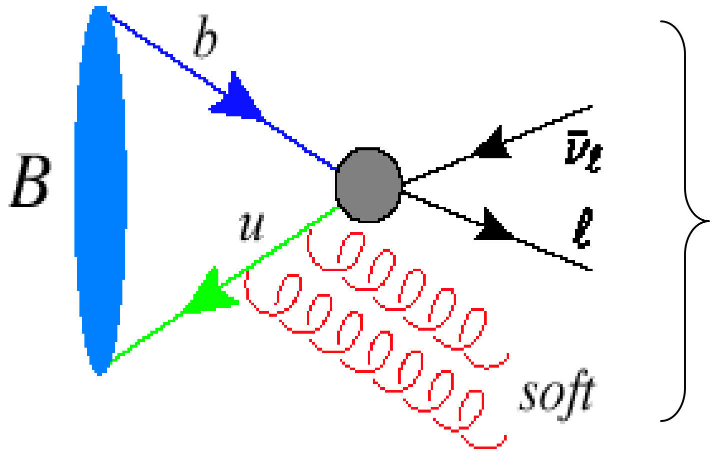
cut		% of rate	good	bad
	$E_\ell > \frac{m_B^2 - m_D^2}{2m_B}$	~10%	don't need neutrino	- depends on $f(k^+)$ (and subleading corrections) - WA effects largest - reduced phase space - duality issues?
	$s_H < m_D^2$	~80%	lots of rate	- depends on $f(k^+)$ (and subleading corrections) - need shape function over large region
	$q^2 > (m_B - m_D)^2$	~20%	insensitive to $f(k^+)$	- very sensitive to m_b - WA corrections may be substantial - effective expansion parameter is $1/m_c$
	"Optimized cut"	~45%	- insensitive to $f(k^+)$ - lots of rate - can move cuts away from kinematic limits and still get small uncertainties	- sensitive to m_b (need +/- 60 MeV for 5% error in best case)
	$P_+ > m_D^2/m_B$	~70%	- lots of rate - theoretically simplest relation to $b \to s\gamma$	depends on $f(k^+)$ (and subleading corrections)

From Mile Luke- CKM2005

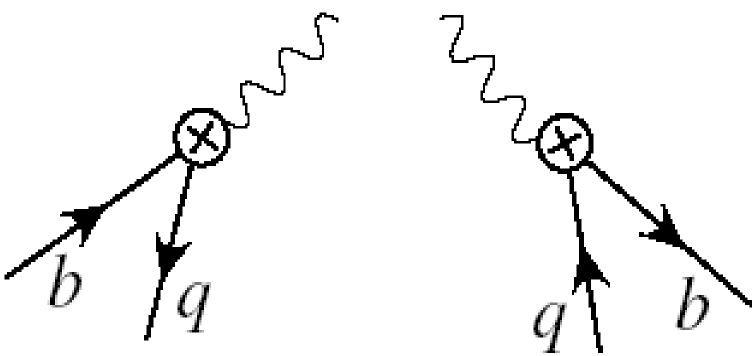
Theoretical issues

- Fermi motion – at leading order (extracted from $b \to s\gamma$) and subleading order
- Weak-annihilation (common to all the methods)
- m_b : rate proportional to m_b^5 & restricting phase space increases sensitivity
- Perturbative corrections
- $f(k^+)$: determine from the photon spectrum in $B \to X_s\gamma$ [subleading terms]

Weak Annihilation



- Weak annihilation in local OPE:
  - An issue for tall inclusive determinations
  - Relative size of the effect gets worse the more severe the cut
  - Estimate: comparison between B^0 and B^+, D, D_s SL widths
- Weak annihilation in non-local OPE



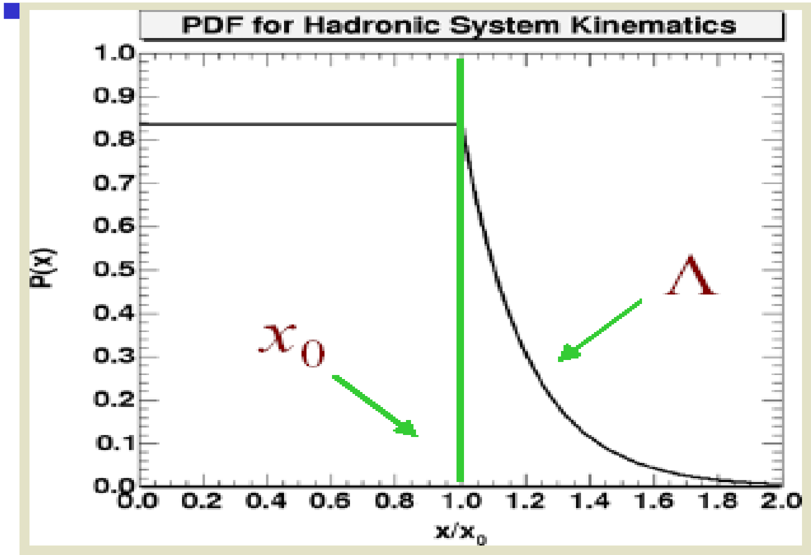
$$O\left(16\pi^2 \times \frac{\Lambda_{QCD}^2}{m_B^2} \times \Delta B\right)$$

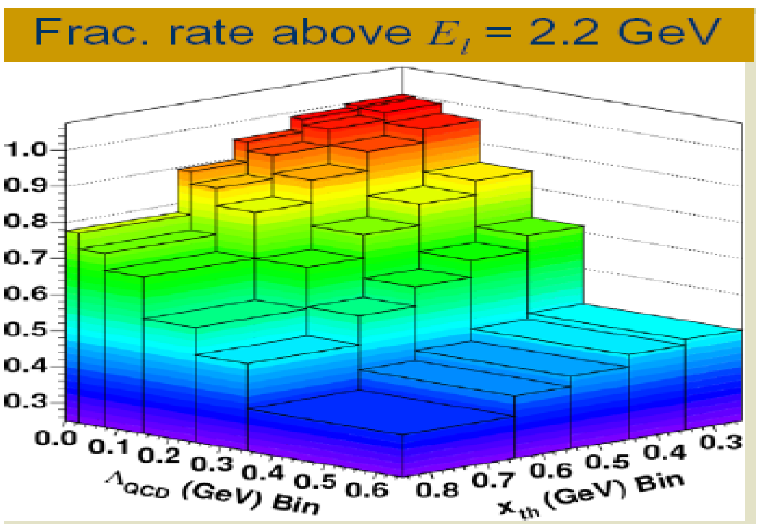
- Can be >20% shift to integrated rate for E_ℓ>2.3GeV

CLEO study of WA in inclusive semileptonic decays

- Inclusive neutrino reconstruction analysis
  - p_ν from missing momentum and energy in BB event
  - Signal leptons (e and μ): $|p_\ell|$>1.5 GeV
- Data sample CLEO II +II.5 at Υ(4S) (9.7 fb^{-1})
- Event sample contains:
  - Signal b $\rightarrow$u (spectator diagram + weak annihilation)
  - Dominant b $\rightarrow$c background
  - Continuum background e+e- $\rightarrow q\bar{q}$
  - Background from events with fake leptons
- Signal model:
  - b $\rightarrow$u [hybrid approach combining exclusive model [ISGW2 for the lightest charmless final states + HQET motivated inclusive model to produce non-resonant n-body final states] + WA modeling

Model for WA

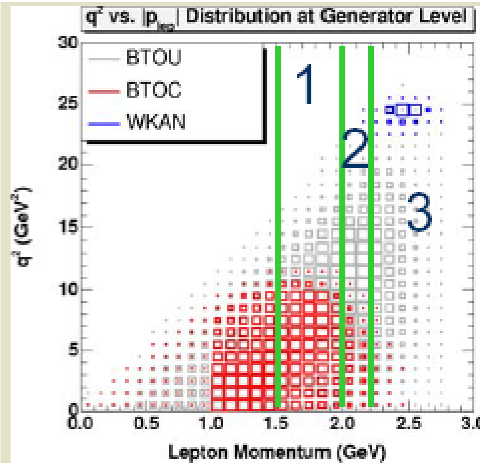




- Motivated by leading annihilation-like graph
  - Most of the energy is carried by the l-n pair
  - Hadronic system produced in the "debris"
  - Kinematics driven by Λ_{QCD}
    - $E_x, M_x, P_x \sim \Lambda$
    - $Q^2 \sim M_B^2 - \Lambda M_B$

  $\Rightarrow$ Soft PDF: box with width x_0 and cutoff Λ
- Model parameters varied through 5x6 values
- Each 100K sample represents an "realization of WA"

Fit Strategy



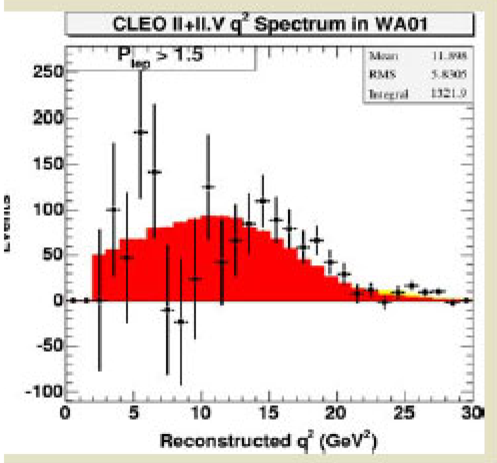
MC: q^2 versus El Dalitz plot

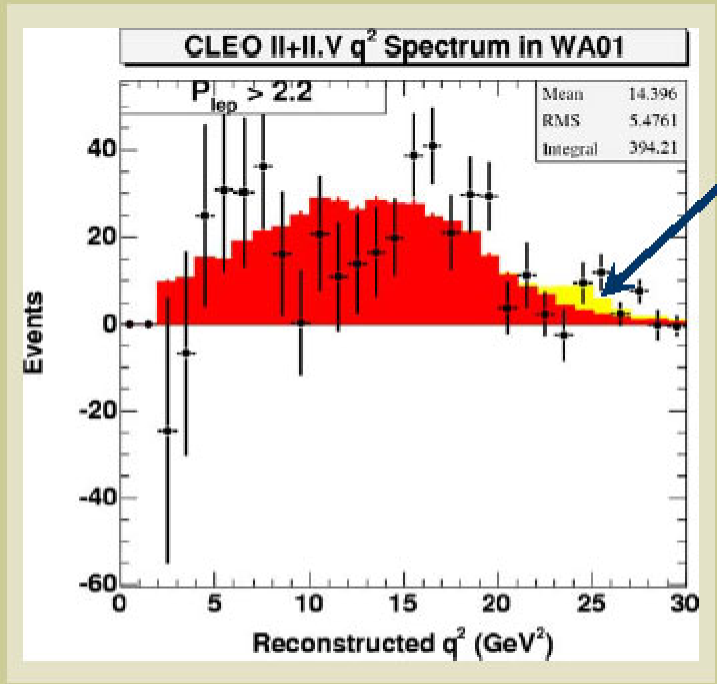
On $\Upsilon(4S)$ + continuum data samples

- Binned χ^2 fit:
  - p_ℓ:1.5-2.0,2.0-2.2,>2.2 GeV
  - 30 bins of q^2 (0-30 GeV^2)
- Float $b \to u$, $b \to c$,WA normalizations; fix fakes +cont
- 30 fits, one for each WA sample

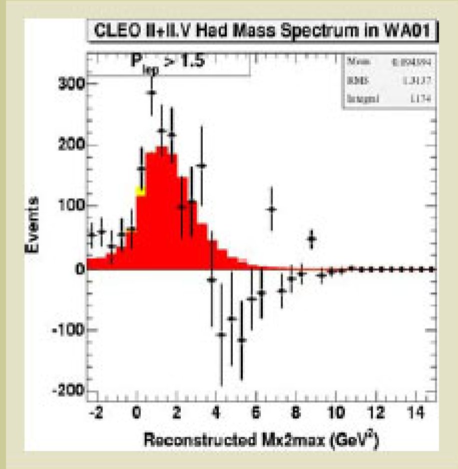
Sample fit results (background subtracted)

b →u signal, including WA





WA



q^2 ($|p_l| > 1.5$ GeV)

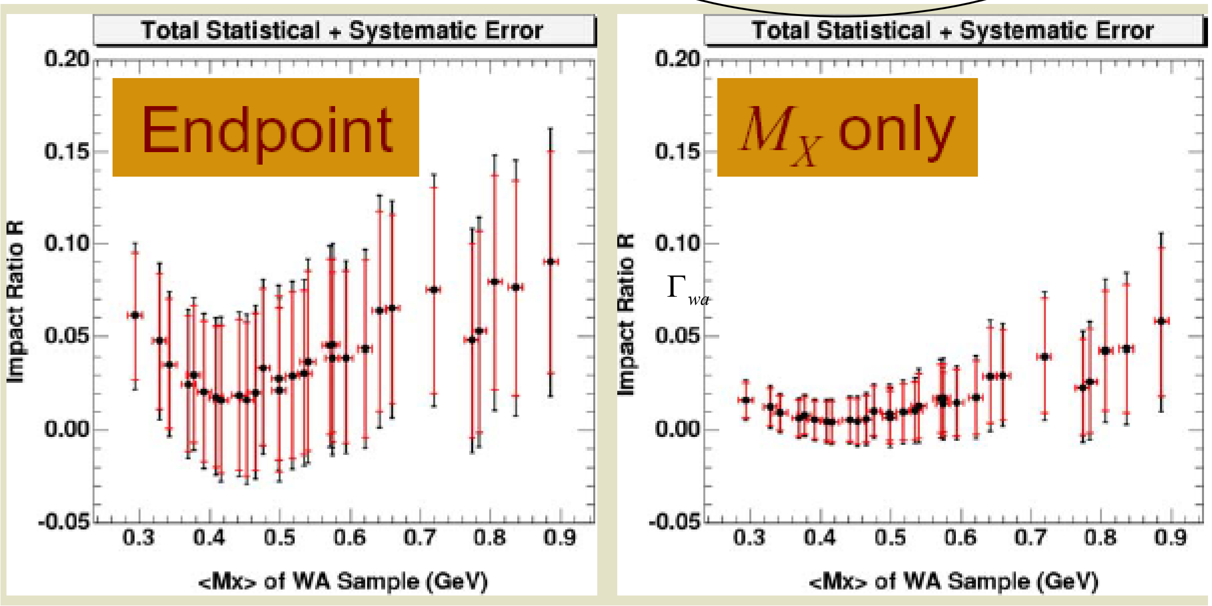
q^2 ($|p_l| > 2.2$ GeV)

M_X^2 (est)

Impact on a specific analysis

$$R \equiv \frac{\Gamma_{wa}}{\Gamma(b \to u)} = \frac{\Gamma_{wa}}{\Gamma'(b \to u) + \Gamma_{wa}}$$

From fits

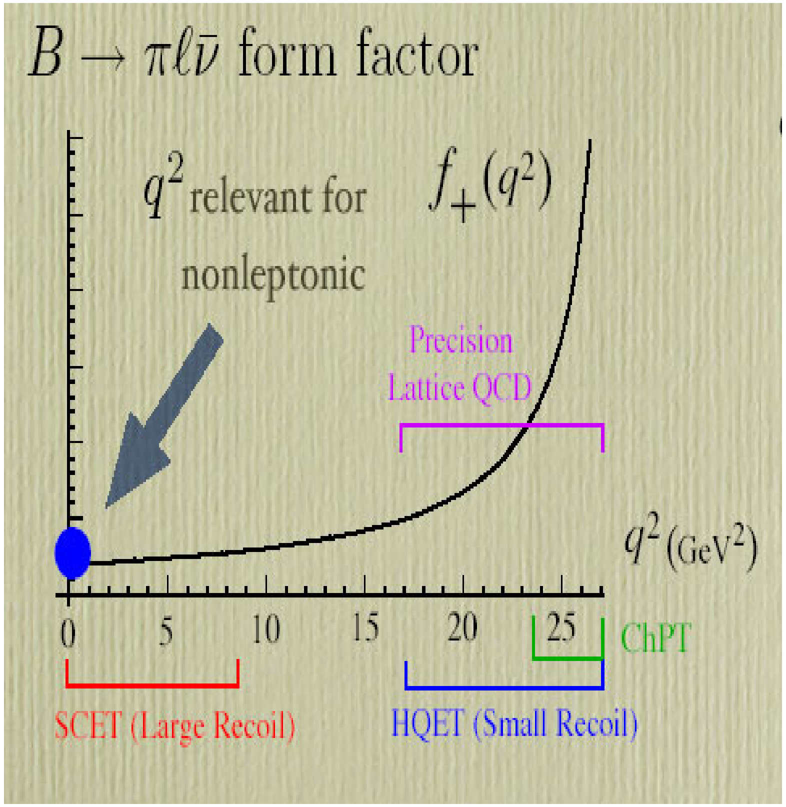


E_l >2.2 GeV

P_l>1 GeV, Mx<1.55 GeV

CLEO data constrains results of WA as modeled to be small

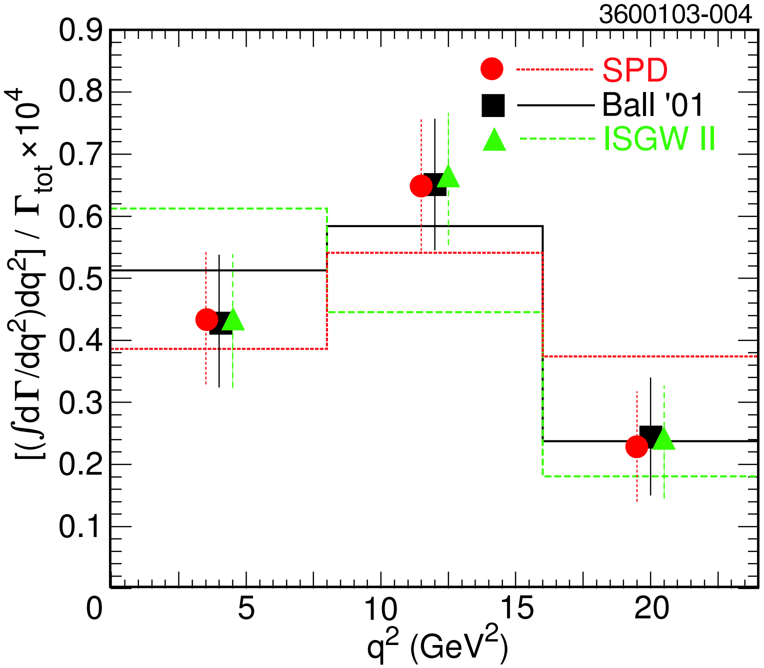
Exclusive B $\to X_u \ell \nu$ results



- Heavy to light transition ⇒ HQET is not expected to give predictions with the same level of accuracy as for B $\to X_c \ell \nu$
- Theoretical work theme: pin down regions of phase space where theoretical error small
  - Use HQET to relate FF in B $\to \pi \ell \nu$ and D $\to \pi \ell \nu$ (Ligeti,Wise PDR D53, 4937
  - Use unquenched lattice QCD at high q2
  - Use double ratio

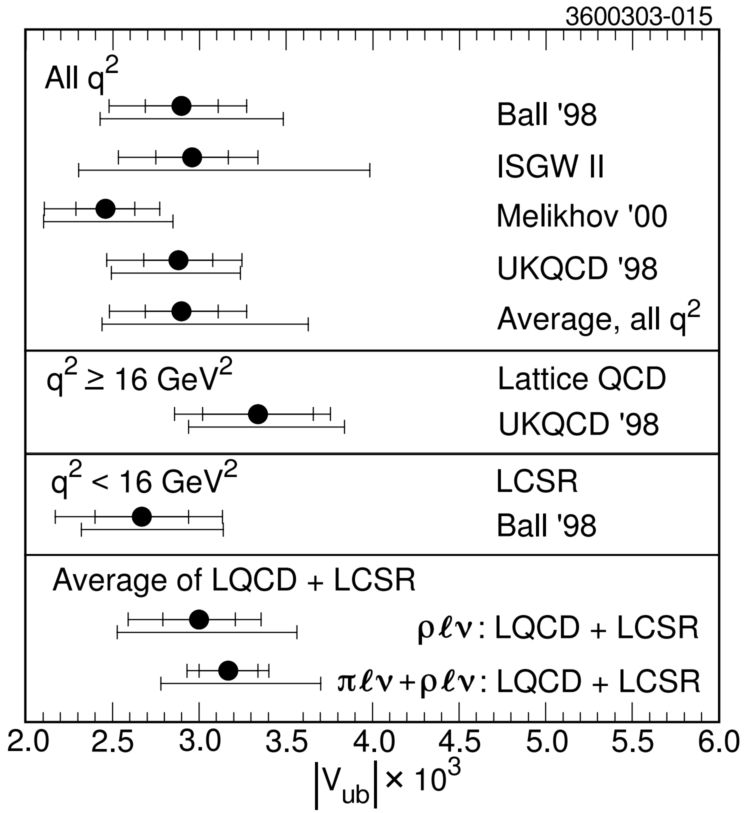
$$\frac{\dfrac{B \to K^* ee}{B \to \rho e \nu}}{\dfrac{D \to K^* e \nu}{D \to \rho e \nu}}$$

To make progress…



- It is important to make a good measurement of $d\Gamma/dq^2$
- Technique pioneered by CLEO, now data available also from BELLE
  - Exploit very well understood ν reconstruction technique
  - Extract B, $d\Gamma/dq^2$, and $|V_{ub}|$
  -
- Based on CLEO II+ CLEO II.5

V_{ub} from exclusive analysis



$B \to \rho \ell \nu$

$$|V_{ub}| = (\underbrace{3.17 \pm 0.17 \,^{+0.16}_{-0.17}}_{\text{exp}} \underbrace{\,^{+0.53}_{-0.39} \pm 0.03}_{\text{th}}) \times 10^{-3}.$$

$|V_{ub}|$=(4.08±0.22(exp), ±0.40(lattice+SCET+disp))x10^{-3}