Exclusive Semileptonic $b \to ul\nu$ Decays at CLEO:

With Determination of |Vub| and Scale of Singlet Form Factor

DPF 2006, Honolulu Hawaii.

CLEO Collaboration

Talk given by: Richard Gray

Outline:

- Theory behind decays
- Method (Neutrino Reconstruction).
- Results
- Summary

Getting At $|V_{ub}|$

In Limit $M_{lepton} \to 0$

Br($B^0 \to \pi^- l^+ \nu$) Primary Route to |Vub|

P= π,….

$$\frac{d\Gamma(B^0 \to P^- \ell^+ \nu)}{dq^2\, d\cos\theta_{W\ell}} = |V_{ub}|^2 \frac{G_F^2}{32\pi^3} |\vec{p}_P|^3 \sin^2\theta_{W\ell} |f_1(q^2)|^2,$$

We Measure

$|V_{ub}|$ our goal

Predicted by theory
LCSR or LQCD

V=ρ,…

$$\frac{d\Gamma(B^0 \to V^- \ell^+ \nu)}{dq^2\, d\cos\theta_{W\ell}} = |V_{ub}|^2 \frac{G_F^2 |\vec{p}_V| q^2}{128\pi^3} \times$$

$$\left[(1-\cos\theta_{W\ell})^2 \frac{|H_+|^2}{2} + (1+\cos\theta_{W\ell})^2 \frac{|H_-|^2}{2} + \sin^2\theta_{W\ell} |H_0|^2\right]$$

The QCD Anomaly in η and η'

The physical η, η' states:

$$\begin{pmatrix} |\eta> \\ |\eta'> \end{pmatrix} = \begin{pmatrix} cos(\theta_8) & -sin(\theta_8) \\ sin(\theta_8) & cos(\theta_8) \end{pmatrix} \begin{pmatrix} |\eta^8> \\ |\eta^0> \end{pmatrix}$$

octet

$$\eta^8 = \frac{1}{\sqrt{6}}(\bar{u}u + \bar{d}d - 2\bar{s}s)$$

$$\eta^0 \equiv \frac{1}{\sqrt{3}}(\bar{u}u + \bar{d}d + \bar{s}s)$$

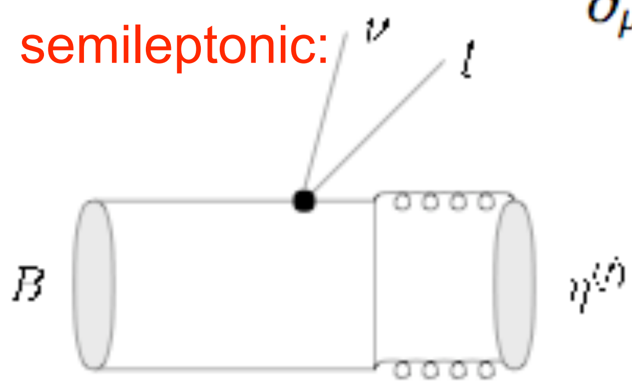
singlet

The "QCD Anomaly"
Gluon Couplins if tr[τ^a] ≠0

Singlet: *tr[τ^a]* = 1 Octet: *tr[τ^a]* = 0

$$\partial_\mu j^{\mu a 5} = -\frac{g^2}{16\pi^2}\tilde{G}^{\mu\nu c}G^d_{\mu\nu} tr[\tau^a] tr[t^c t^d]$$

Probe with semileptonic:



Form Factor From FKS Mixing:

$$F_+^{B^+\to\eta^{(\prime)}} = F_+^{B^0\to\pi^-}\frac{f^q_{\eta^{(\prime)}}}{\sqrt{2}f_\pi} + F_+^{B^+\to\eta^0}\frac{\sqrt{2}f^q_{\eta^{(\prime)}} + f^s_{\eta^{(\prime)}}}{\sqrt{3}f_\pi}$$

Br(B→ηlν) and Br(B→η'lν) in terms of Br(B→πlν) and parameter, $\tilde{F}_s$

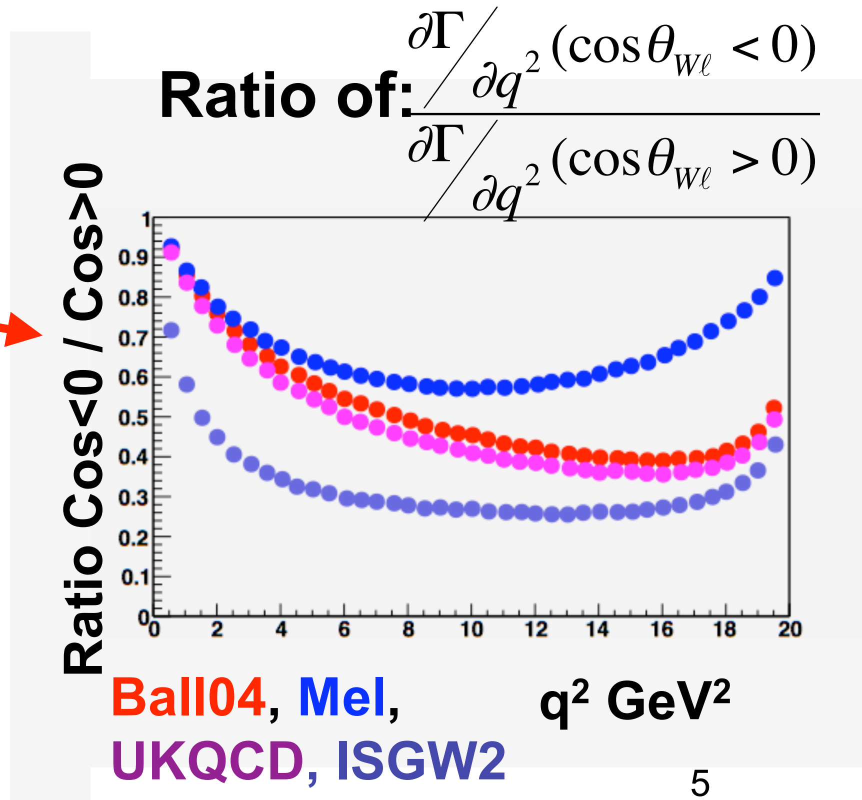
$$\tilde{F}_s = (\int |F_+^{B^+\to\eta^0}|^2\Omega_{\eta'}\partial q^2)/(\int |F_+^{B^0\to\pi^-}|^2\Omega_{\eta'}\partial q^2)$$

Measurements:

•*Br*(B→πlν) in coarse q^2 bins
•*Br*(B→ρlν) in coarse q^2 & $\cos\theta_{wl}$ bins
•*Br*(B→ηlν) all phase space
•*Br*(B→η'lν) all phase space

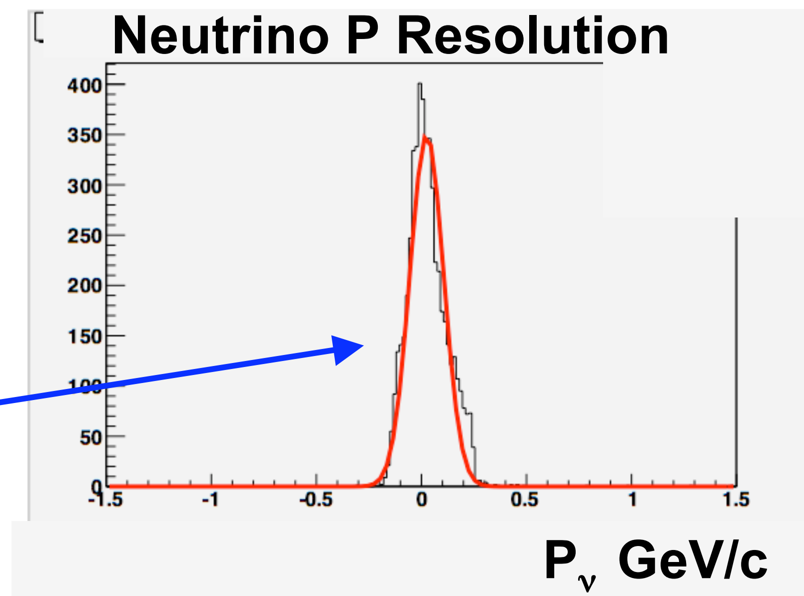
Improvements:

- 60% More Data with addition of CLEO3, now 15.4×10^6 BBbar
- Vector modes binned in $\cos\theta_{wl}$ (Previously Cut)
- Reduce Minimum P_{lepton} (1.5 to 1.0 GeV)
- Isolate Continuum with finer q^2 binning in $q^2<8\text{GeV}^2$
- Addition of η' for QCD Singlet Study



Neutrino Reconstruction

- Works best at symmetric e^+e^- collider.
  - $|Q_{total}| = 0$
  - # leptons =1
- Neutrino (ν) from Energy/Momentum conservation.
  - $E(\nu) = 2\times E(beam) - E(tracks) - E(showers)$
  - $P(\nu) = -P(tracks) - P(showers)$
- Full B Meson Reconstruction: l (lepton), h(meson), ν (neutrino).
  - $E(B) = E(\nu) + E(l) + E(h)$
  - $P(B) = P(\nu) + P(l) + P(h)$



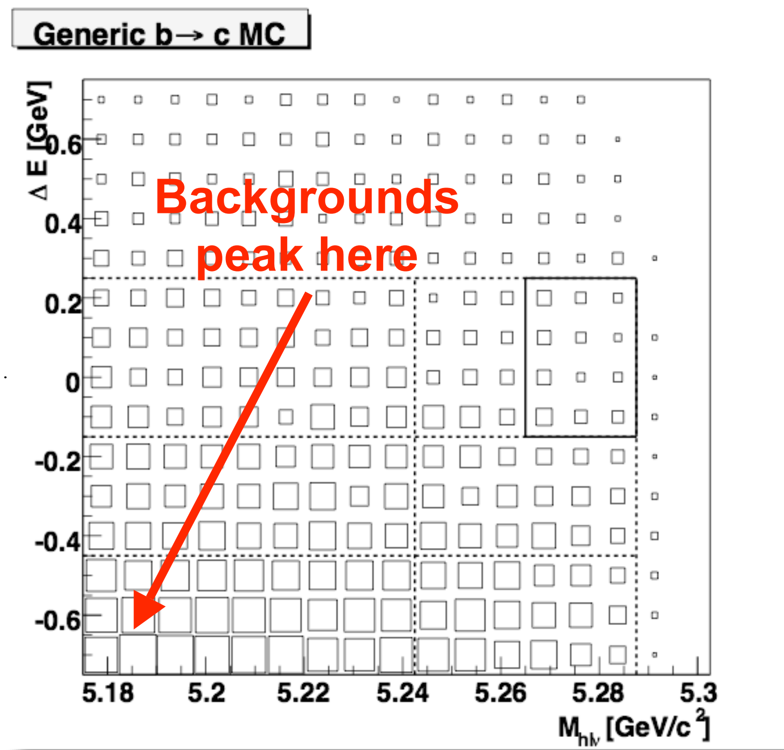
After all cuts, P resolution aprox. 0.1 GeV/c

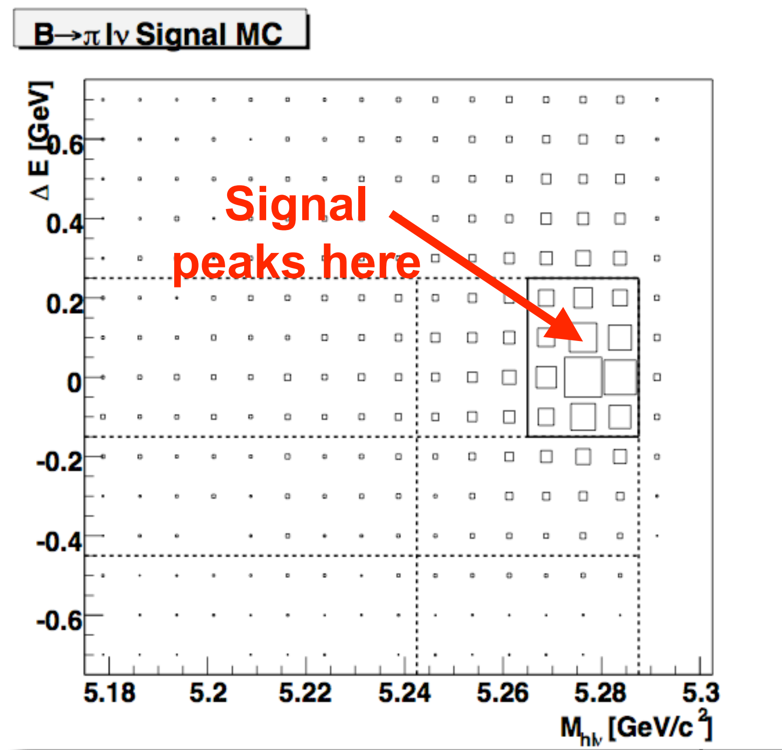
The Fit

- Signal yield by fitting distribution in $\Delta E{:}M_B$ plane.
  - – ΔE = E(beam) - E(B)
  - – $M^2_B = E^2(\text{beam}) - P^2(B)$
- Use binned log-likelihood with Barlow-Beeston method.

•Simultaneous fit in all modes and bins.

- –Uses isospin constraints
- –Automatic unfolding and efficiency matrix





Fit Components

<u>Backgrounds</u>

$B \rightarrow X_u l\nu$ other

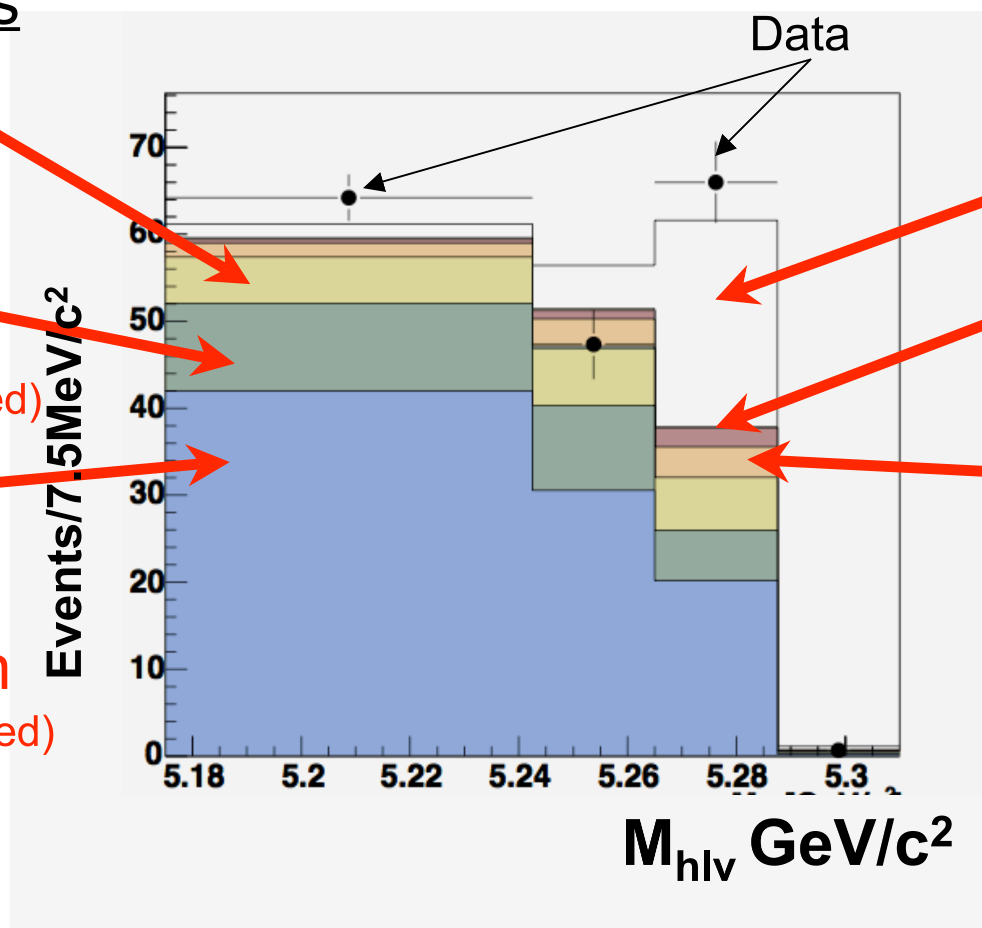
Continuum

(absolutely normalized)

$B \rightarrow X_c l\nu$

Fake Lepton

(absolutely normalized)



<u>Signals</u>

$B \rightarrow \rho l\nu$ Signal

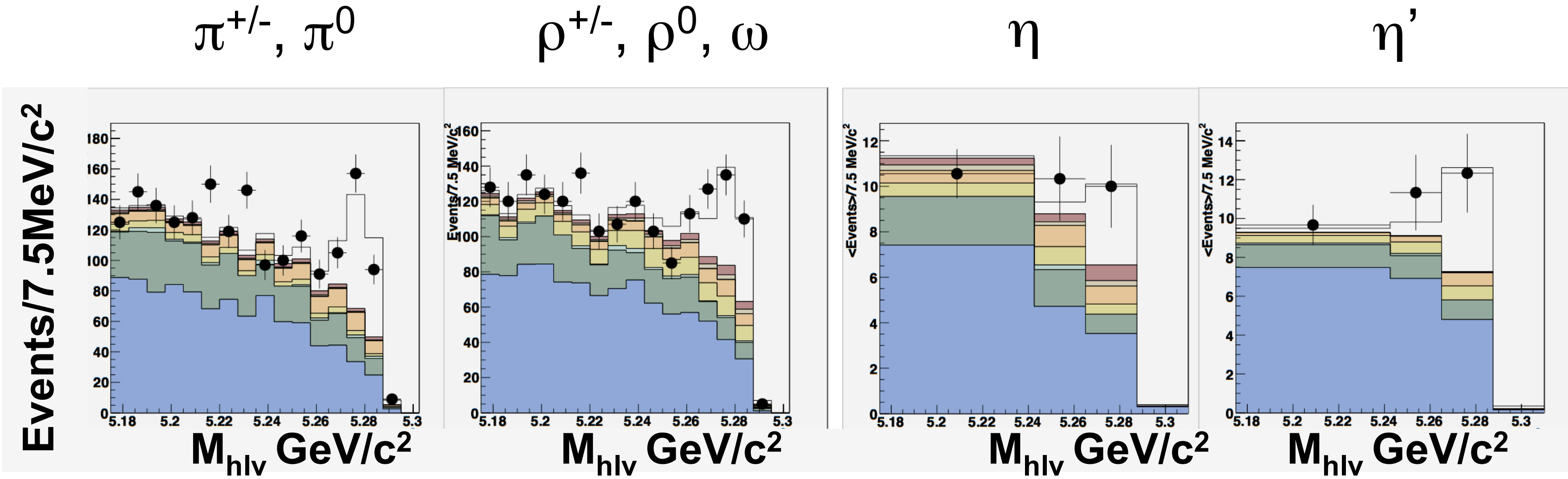
$\rho^{+/-}\rho^0\omega$ XFeed

$\pi^{+/-}$, π^0 XFeed

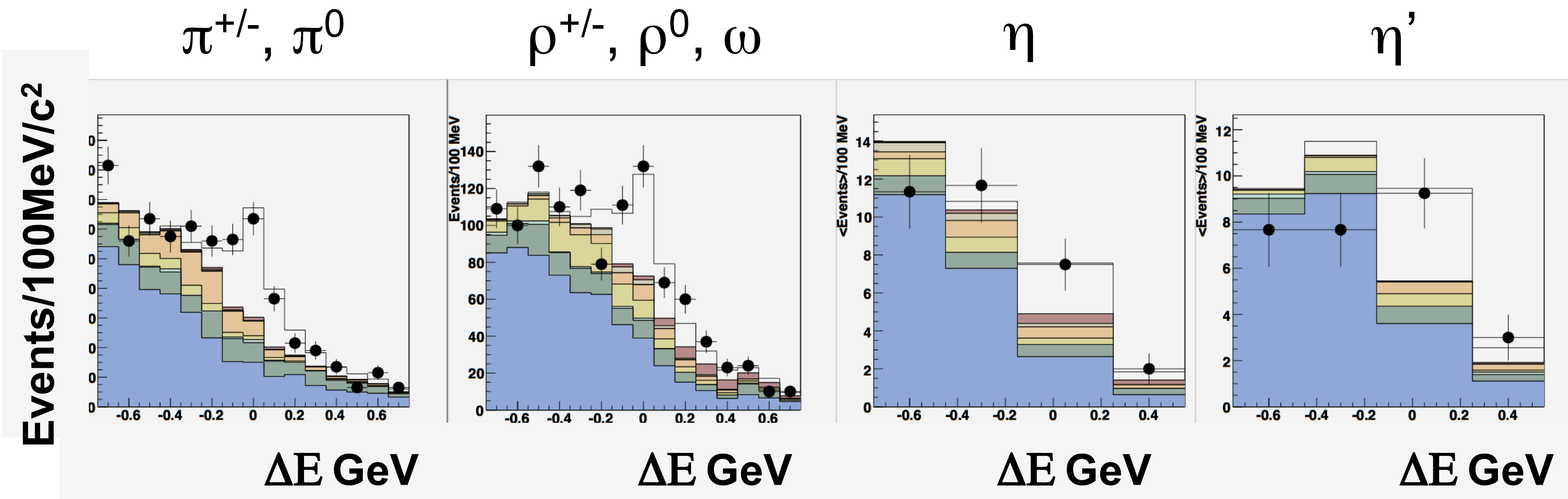
η, η' XFeed

Fit Results

$M_{Hl\nu}$ Distribution 0.15< ΔE<0.25



ΔE Distribution 5.265< $M_{Hl\nu}$ < 5.28



Systematic Uncertainties

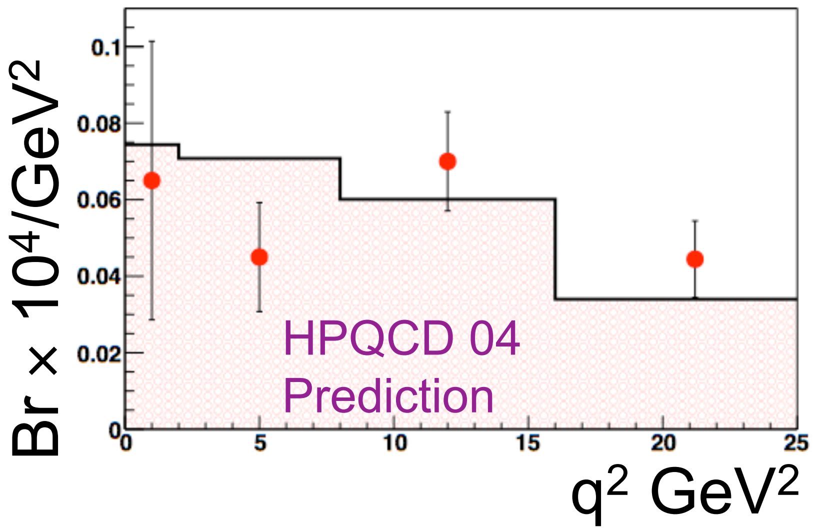
Largest Source Of Systematic Uncertainty

	Systematic Error [%]			
	$B^0 \to \pi^- \ell^+ \nu$	$B^0 \to \rho^- \ell^+ \nu$	$B^+ \to \eta \ell^+ \nu$	$B^+ \to \eta' \ell^+ \nu$
Neutrino Reconstruction	5.9	8.9	23.4	19.3
Continuum Suppression	1.1	1.5	1.5	0.8
$B \to X_c \ell \nu$ Model	1.5	5.8	2.1	4.8
Other $B \to X_u \ell \nu$	2.5	2.8	3.5	3.0
Fake Leptons	1.7	1.1	1.1	3.7
Lepton Identification	2.0	2.0	2.0	2.0
π^0 Identification	0.1	1.4	0.2	0.1
Number of $\Upsilon \to B\bar{B}$	3.6	3.6	3.6	3.6
τ_{B^+}/τ_{B^0}	0.4	0.7	0.2	0.2
f_{+-}/f_{00}	0.7	0.1	2.1	2.0
Non-Resonant $\pi\pi$	0.6	2.3	2.1	2.1
Final State Radiation	2.8	4.4	3.1	4.0
Total Experiment	**8.6**	**13.2**	**24.5**	**21.5**
$B \to \pi \ell \nu$ Form Factor	0.8	0.4	0.3	0.2
$B \to \rho \ell \nu$ Form Factor	0.8	1.8	0.3	1.5
Total Theory	**1.1**	**1.8**	**0.4**	**1.5**

Measured Branching Fractions

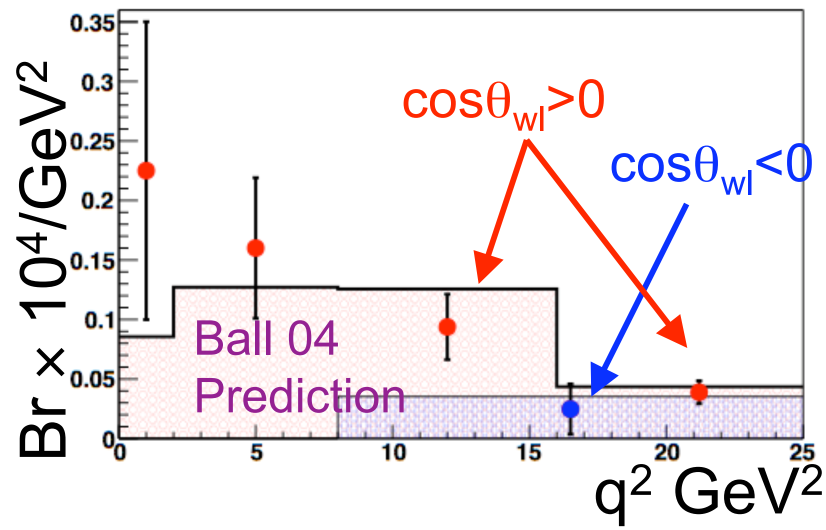
$Br(B^0 \to \pi^+ l^- \nu)$

$(1.37 \pm 0.15 \pm 0.12 \pm 0.01) \times 10^{-4}$



$Br(B^0 \to \rho^+ l^- \nu)$

$(2.93 \pm 0.37 \pm 0.39 \pm 0.04) \times 10^{-4}$



$Br(B^+ \to \eta l^+ \nu) \times 10^4 = 0.44 \pm 0.23 \pm 0.11 \pm 0.00$;
$< 1.01 \times 10^{-4}$ 90% C.L.

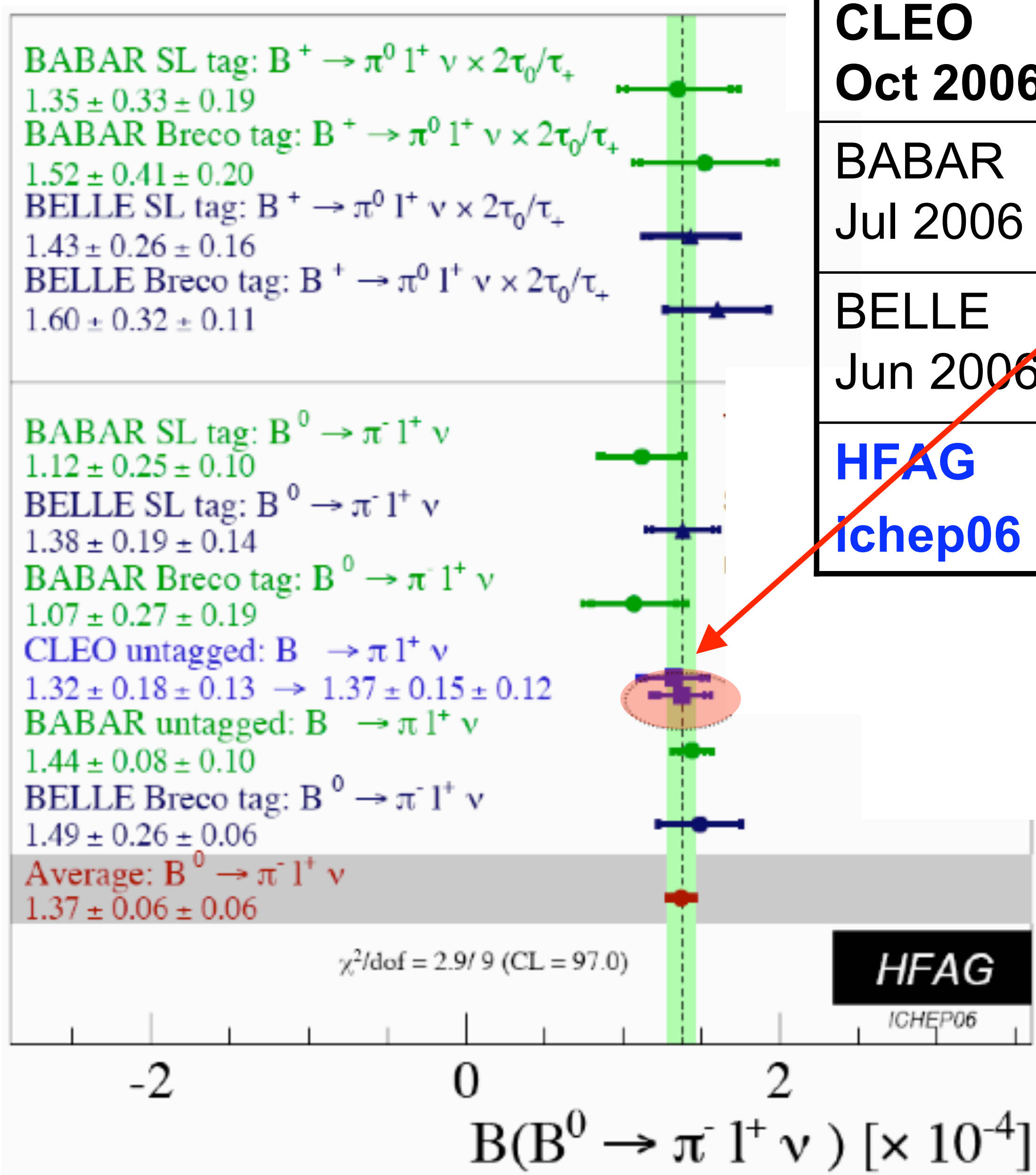
$Br(B^+ \to \eta' l^+ \nu) \times 10^4 = 2.66 \pm 0.80 \pm 0.57 \pm 0.04$;
$p_{\text{back fluct}} = 0.00118$ ~ "3σ"
"evidence for"

Theory for no singlet:
$Br(B \to \eta l \nu) \times 10^4 = 0.4$
$Br(B \to \eta' l \nu) \times 10^4 = 0.2$

$$\frac{Br(B \to \eta' l \nu)}{Br(B \to \eta l \nu)} > 2.5$$

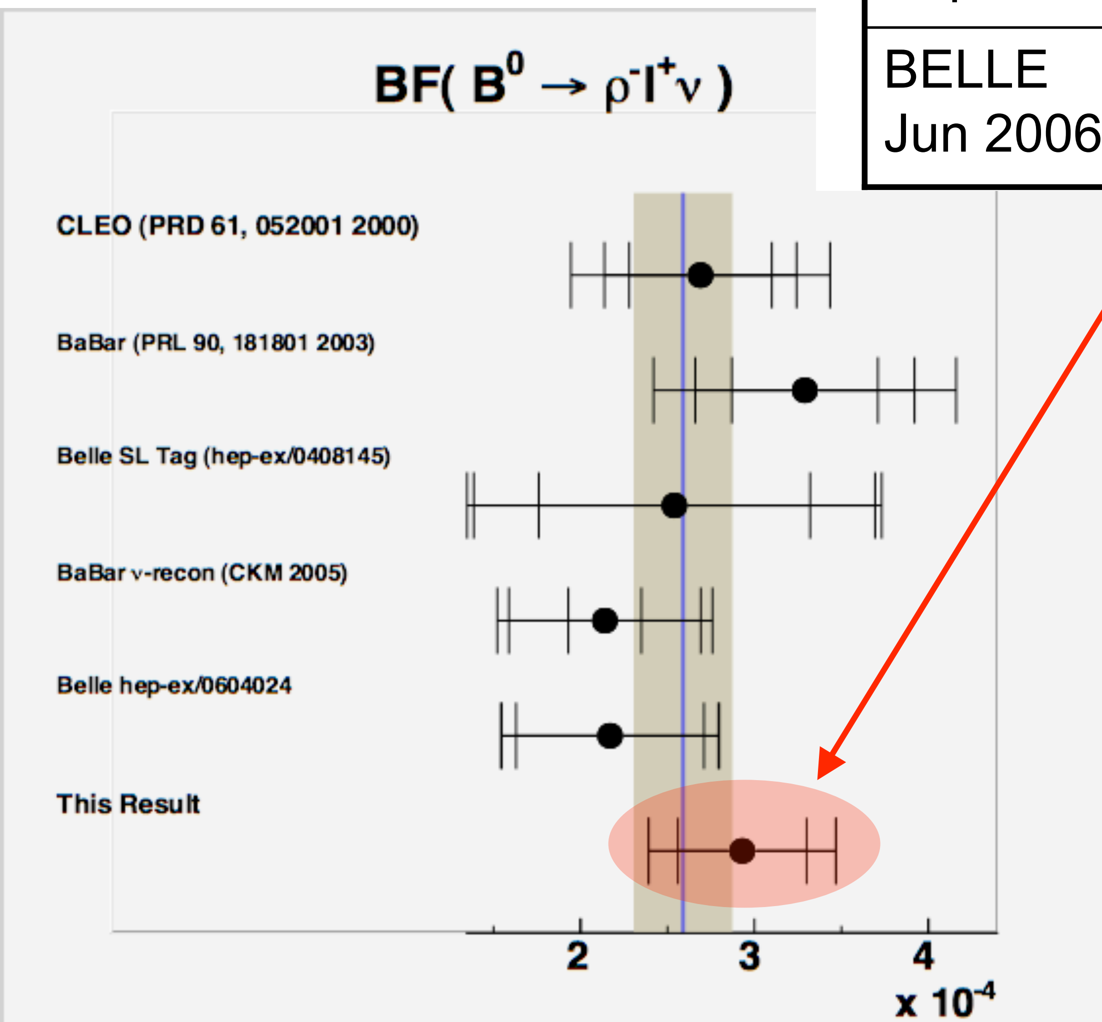
90% C.L.

	$\#B\bar{B} \times 10^6$	$Br(B \to \pi l \nu) \times 10^4$
CLEO Oct 2006	**15.4**	**$1.37 \pm 0.15_{stat} \pm 0.12_{syst}$**
BABAR Jul 2006	227.0	$1.44 \pm 0.08_{stat} \pm 0.10_{syst}$
BELLE Jun 2006	275.0	$1.38 \pm 0.19_{stat} \pm 0.14_{syst}$
HFAG ichep06	**Av**	**$1.37 \pm 0.06_{stat} \pm 0.06_{syst}$**



$B \to \pi l \nu$ Comparisons

	#N×10^6	$Br(B\rightarrow\rho l\nu)\times 10^4$
CLEO Oct 2006	**15.4**	**$2.93\pm0.37_{stat}\pm0.39_{syst}$**
BABAR Sep 2005	83.0	$2.14\pm0.21_{stat}\pm0.56_{syst}$
BELLE Jun 2006	275.0	$2.17\pm0.54_{stat}\pm0.32_{sys}$



B→ρlν Comparisons

Extracting $|V_{ub}|$

- We use our measurement for $B \to \pi l \nu$ for $q^2 > 16 GeV^2$
- We use recent results from HPQCD (PRD 73, 074502, 2006).

CLEO (2006): $|V_{ub}| = (4.3 \pm 0.4 \pm 0.2 ^{+0.6}_{-0.4}) \times 10^{-3}$

BABAR (2006): $|V_{ub}| = (4.1 \pm 0.2 \pm 0.2 ^{+0.6}_{-0.4}) \times 10^{-3}$

BELLE (2006): $|V_{ub}| = (4.0 \pm 0.5 \pm 0.2 ^{+0.6}_{-0.4}) \times 10^{-3}$

QCD Singlet Effect

- Model Independent: 90% C.L. on ratio $Br(B \to \eta' l\nu)/Br(B \to \eta l\nu) > 2.5$
  - If No singlet contribution we expect $Br(B \to \eta' l\nu)/Br(B \to \eta l\nu) \sim 0.5$
- Model dependent: Consider FKS Mixing Scheme + Benke & Neubert
  - We fit CLEO data to find a value for: $\tilde{F}_s$

$$\tilde{F}_s = \left(\int |F_+^{B^+ \to \eta^0}|^2 \Omega_{\eta'} \partial q^2\right) / \left(\int |F_+^{B^0 \to \pi^-}|^2 \Omega_{\eta'} \partial q^2\right)$$

CLEO DATA: $\tilde{F}_s = 1.02 \pm 0.46_{stat} \pm 0.38_{exp} \pm 0.16_{theory}$

Theory uncertainty includes FKS mixing parameters, and form factor shape uncertainties.

BABAR +
CLEO DATA: $\tilde{F}_s = 0.48 \pm 0.21_{stat} \pm 0.20_{exp} \pm 0.08_{theory}$

Preliminary Results BABAR July 2006:
$Br(B \to \eta l\nu) < 1.4 \times 10^{-4}$ 90% C.L.
$Br(B \to \eta' l\nu) < 1.3 \times 10^{-4}$ 90% C.L.

Agree at 5% level

Summary:

- Measured Branching fractions for π, ρ, η' and upper limit for η using neutrino reconstruction.
  - $Br(B \to \pi l \nu) = (1.37 \pm 0.15 \pm 0.12 \pm 0.01) \times 10^{-4}$
  - $Br(B \to \rho l \nu) = (2.93 \pm 0.37 \pm 0.39 \pm 0.04) \times 10^{-4}$
  - $Br(B \to \eta' l \nu) = (2.66 \pm 0.80 \pm 0.57 \pm 0.04) \times 10^{-4}$ “evidence for“
  - $Br(B \to \eta l \nu) < 1.01 \times 10^{-4}$ 90% C.L.
- Extracted |Vub| using π $q^2 > 16 GeV^2$ and HPQCD prediction.
  - $|V_{ub}| = (4.3 \pm 0.4 \pm 0.2\, ^{+0.6}_{-0.4}) \times 10^{-3}$
- 90% Lower Limit on $Br(B \to \eta' l \nu) / Br(B \to \eta l \nu) > 2.5$ imply singlet contribution.