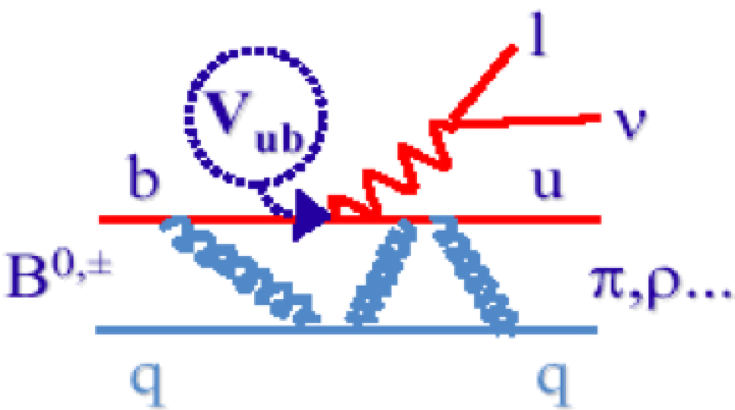
V_{ub} Measurements

Charmless semileptonic B decays, $B \to X_u l\nu$



Experimentally Challenging

Very High $B \to X_c l\nu$ BKG

➔Tight selection cuts

➔Limited phase space

➔Extrapolation uncertainties

Inclusive Measurements VS Exclusive Measurements

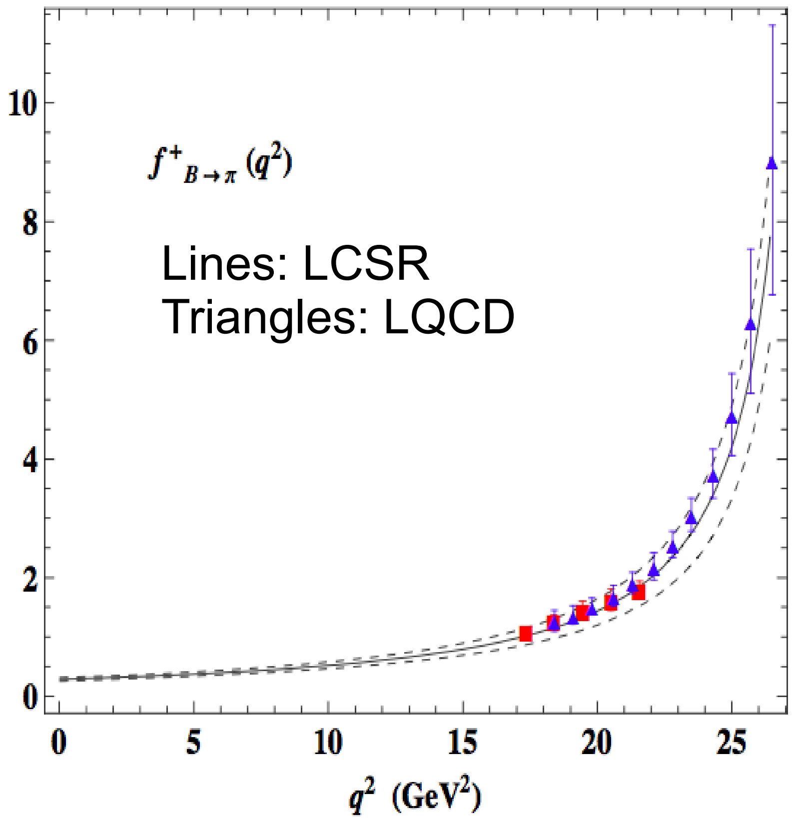
Inclusive	Exclusive
Study inclusive kinematic quantities after charm suppression; ➔V_{ub} from total BR($b \to ul\nu$) ➔Major issue: Extrapolation to the full phase space (Shape Function)	Study exclusive decay channels; ➔V_{ub} from partial BR($B \to X_u l\nu$) ➔Major issue: QCD uncertainties in Form Factor prediction (non perturbative effects)

$|V_{ub}|$: Exclusive Measurement

- In the limit of negligible lepton mass, the differential decay rate for $B \to \pi l \nu$ decays is:

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2 |V_{ub}|^2}{24\pi^3} \mathbf{p}_\pi^3 |f_+^{B\pi}(q^2)|^2$$

- $q = p_B - p_\pi$: 4-momentum transfer
- $\mathbf{p}_\pi = \left[(m_B^2 + m_\pi^2 - q^2)^2 - 4m_B^2 m_\pi^2\right]^{1/2} / (2m_B)$
- $f_+^{B\pi}(q^2)$ Form Factor for the B transition to a pseudoscalar final state



- Theory Challenge: calculation of FF
  - LQCD: High q^2. Limited computational resources prohibit calculations with real values for the u/d quarks masses. Generate data with a sequence of light-quark masses (down to $m_s/10$) and lattice spacing (down to a~0.09 fm) and extrapolate to the physical masses and zero spacing
    - Realistic estimates by HPQCD [Dalgic et al., Phys. Rev. D73, 074502 (2006)] and Ferminab MILC [Aubin et al., Phys. Rev. D70, 114501 (2004)]
  - LCSR: Low q^2. Uncertainty from quark-hadron duality approximation, values of the quark masses, renormalization scale

$|V_{ub}|$: Exclusive Measurement

- Experimental goal: measurement of the BR and the q^2 spectrum to determine the $FF(q^2)$ dependence.

- Experimental Challenge: background rejection from $B \to X_c\ l\ \nu$ decays and separation of $B \to \pi l \nu$ from other $B \to X_u\ l\ \nu$ decays

Different strategies:

- Tagged analyses
  Signal identification on the recoil of a fully (partially) reconstructed B hadronic (semileptonic) decay
  - Very clean, precise neutrino reconstruction, but statistically limited

- Untagged analyses (most precise results)
  Neutrino 4-momentum from missing energy. “Reconstructed” neutrino combined with a lepton
  - Background dominated by continuum (real lepton from hadron decays or misidentified hadrons). $B \to X_c\ l\ \nu$ contamination suppressed using squared missing mass.

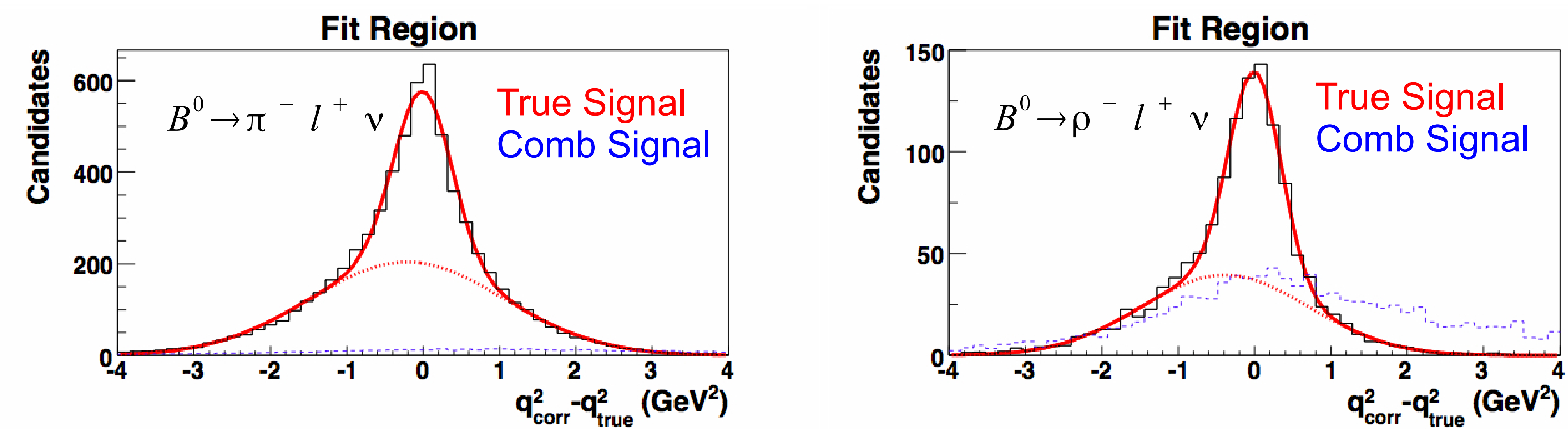
$|V_{ub}|$: Exclusive Measurement

BaBar Untagged Analysis (L=349 fb^{-1}) [Phys. Rev. D83, 052011 (2011)]

- Four signal modes selected: $B^0 \to \pi^- (\rho^-) l^+ \nu,\ B^+ \to \pi^0 (\rho^0) l^+ \nu; (\rho^- \to \pi^- \pi^0; \rho^0 \to \pi^+ \pi^-)$
  - Approach reduces uncertainties due to cross-feed between the different modes

- Signal reconstructed with p^*_π>1.3 GeV, p^*_l>2.2 (2.0) GeV, $p^*_\pi + p^*_l$>2.8(2.65) GeV for π (ρ) reconstruction and $|\cos\theta_{BY}| \leq 1.0$
  - Neutrino momentum obtained from $P_\nu^2 \simeq m^2_{\text{miss}} = E^2_{\text{miss}} - |\vec{p}_{\text{miss}}|^2$

$$q^2_{\text{raw}} = [(E_\ell, \vec{p}_\ell) + (p_{\text{miss}}, \vec{p}_{\text{miss}})]^2 \longrightarrow \vec{p}_\nu = \alpha \vec{p}_{\text{miss}} \quad \text{with } \alpha = 1 - \frac{\Delta E}{E_{\text{miss}}}$$



$|V_{ub}|$: Exclusive Measurement

BaBar Untagged Analysis (L=349 fb^{-1}) [Phys. Rev. D83, 052011 (2011)]

- Selected sample composed by:
  - Signal:
    - True signal
    - Combiatorial signal: hadron selected from decay tracks of the other B
    - Isospin-conjugate: $B^0 \to \pi^- l^+ \nu \leftarrow\rightarrow B^+ \to \pi^0 l^+ \nu$
    - Cross-feed: $B^0 \to \rho l \nu \to B \to \pi l \nu$
  - Background:
    - Continuum (true leptons, fake leptons)
    - Different $B \to X_u$ decays
    - $B \to X_c$ decays
    - Secondary leptons from J/ψ, τ, γ
    - Fake leptons

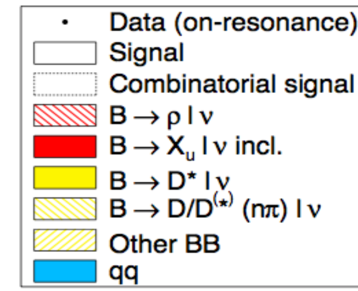
- Background suppression exploiting event shape, neutrino reconstruction and kinematical variables optimized as a function of q^2

- $N\pi^+$= 7181, $N\pi^0$= 3446, $N\rho^+$=1577, $N\rho^0$=1970
  with a S/N ~0.2

$|V_{ub}|$: Exclusive Measurement

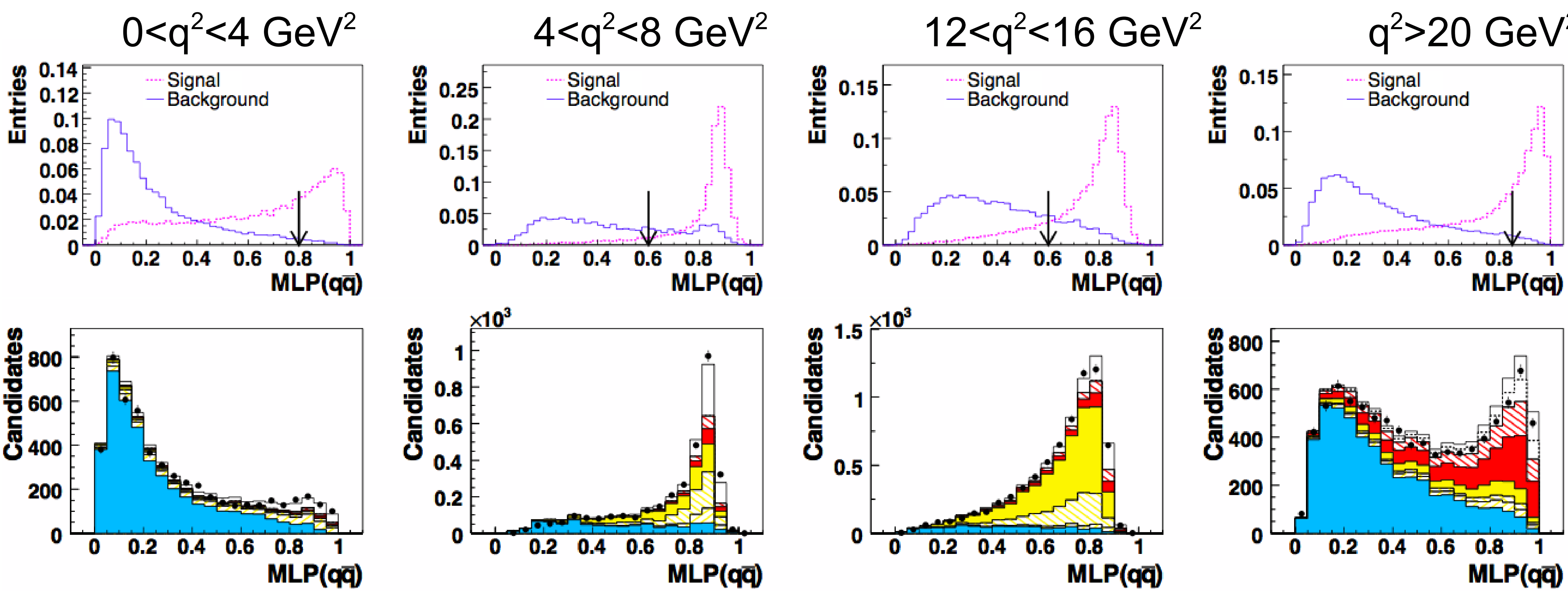
BaBar Untagged Analysis (L=349 fb^{-1}) [Phys. Rev. D83, 052011 (2011)]

- Variables included in neural-network discriminators, trained for each background class and q^2 range
- Fox-Wolfram moments, thrust, missing mass, $\cos\theta_{BY}$,...



Continuum NN discriminator:

$$B^0 \to \pi^- l^+ \nu$$



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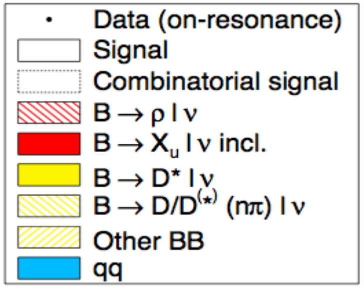
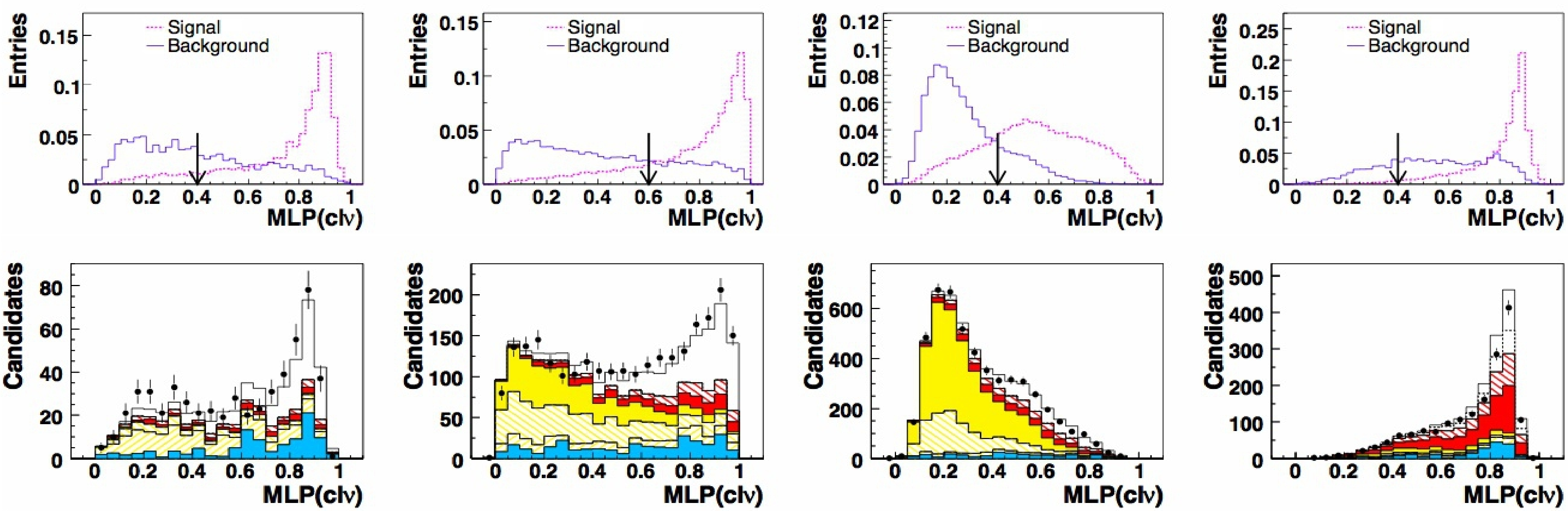


B → Xc l ν NN discriminator:

$$B^0 \to \pi^- l^+ \nu$$

0<q^2<4 GeV^2 4<q^2<8 GeV^2 12<q^2<16 GeV^2 q^2>20 GeV^2



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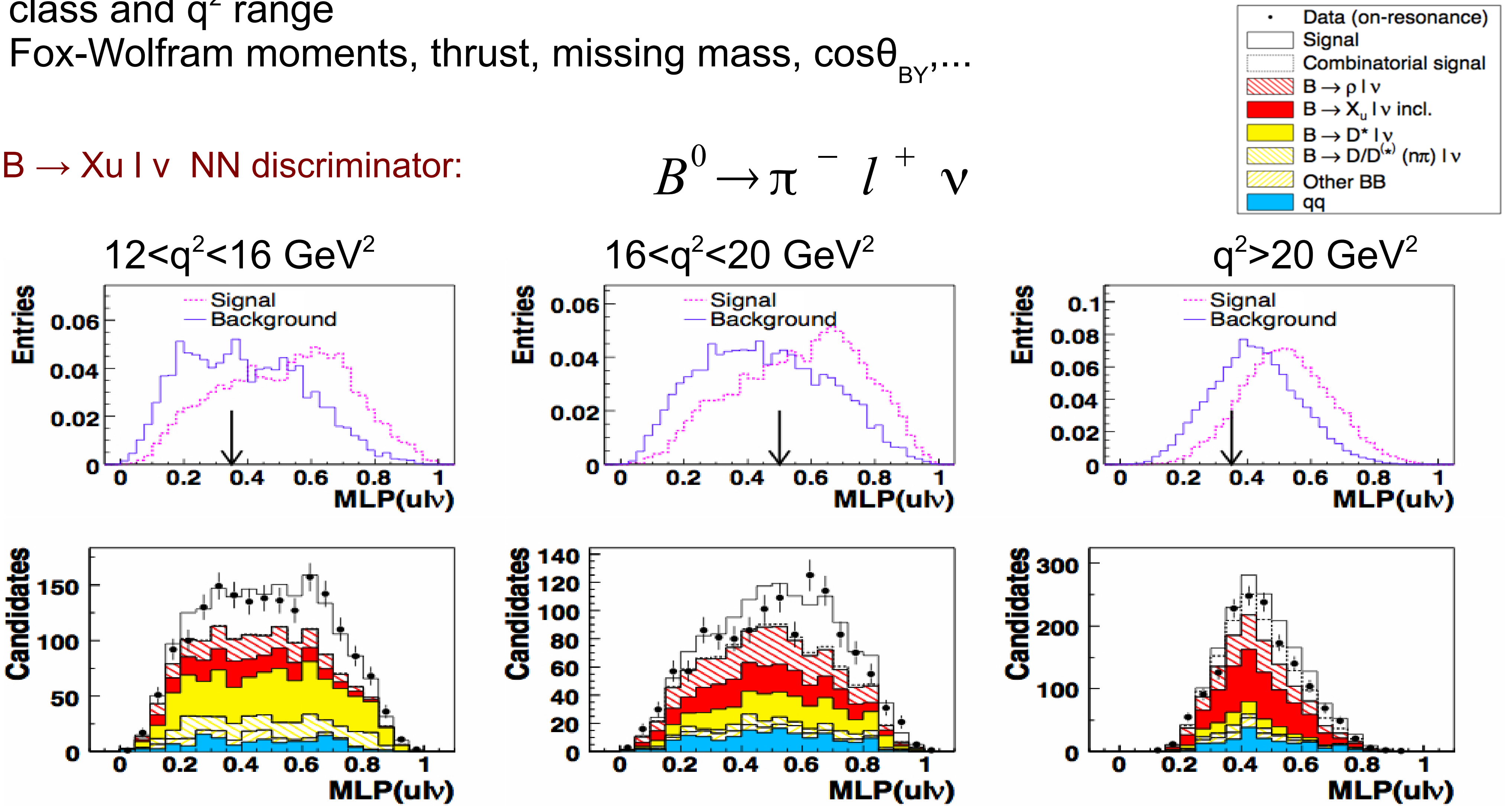

$|V_{ub}|$: Exclusive Measurement

BaBar Untagged Analysis ($L=349\ fb^{-1}$) [Phys. Rev. D83, 052011 (2011)]

- Event yields determined in 12 q^2 bins from a 2D fit to (ΔE, m_{ES}) with signal and background shapes from MC

$$\mathcal{B}(B^0 \to \pi^- \ell^+ \nu) = (1.41 \pm 0.05 \pm 0.07) \times 10^{-4}$$
$$\mathcal{B}(B^0 \to \rho^- \ell^+ \nu) = (1.75 \pm 0.15 \pm 0.27) \times 10^{-4}$$

- Systematics from:
  - K^0_L spectrum affecting neutrino reconstruction (only a small fraction of K^0_L energy is deposited in the e.m. Calorimeter),
  - Lepton identification
  - Continuum description
  - $B \to \rho l \nu$ sensitive to the $B \to X_u l \nu$ BKG parameterization

$|V_{ub}|$: Exclusive Measurement

BaBar Untagged Analysis ($L=349\ fb^{-1}$) [Phys. Rev. D83, 052011 (2011)]

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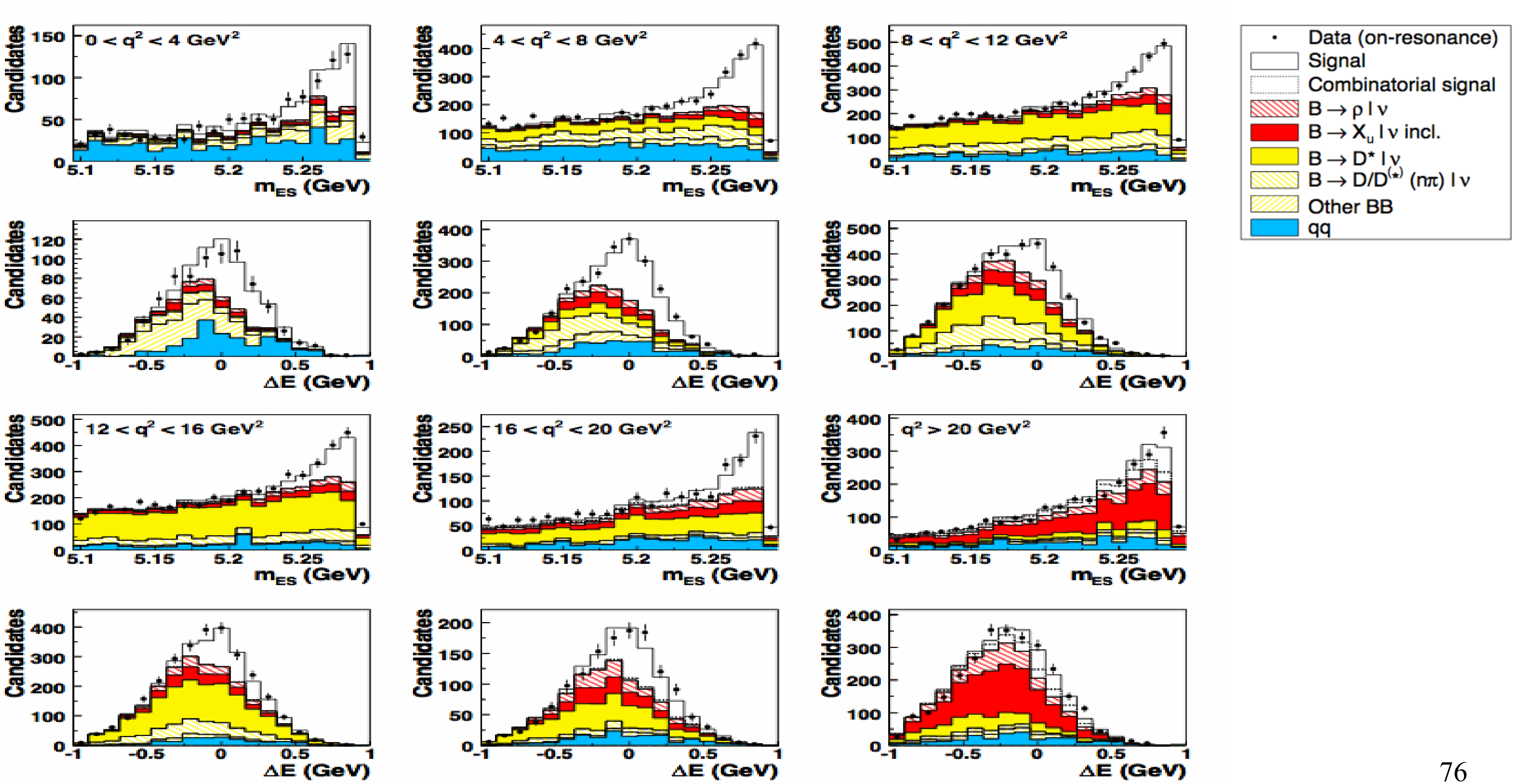
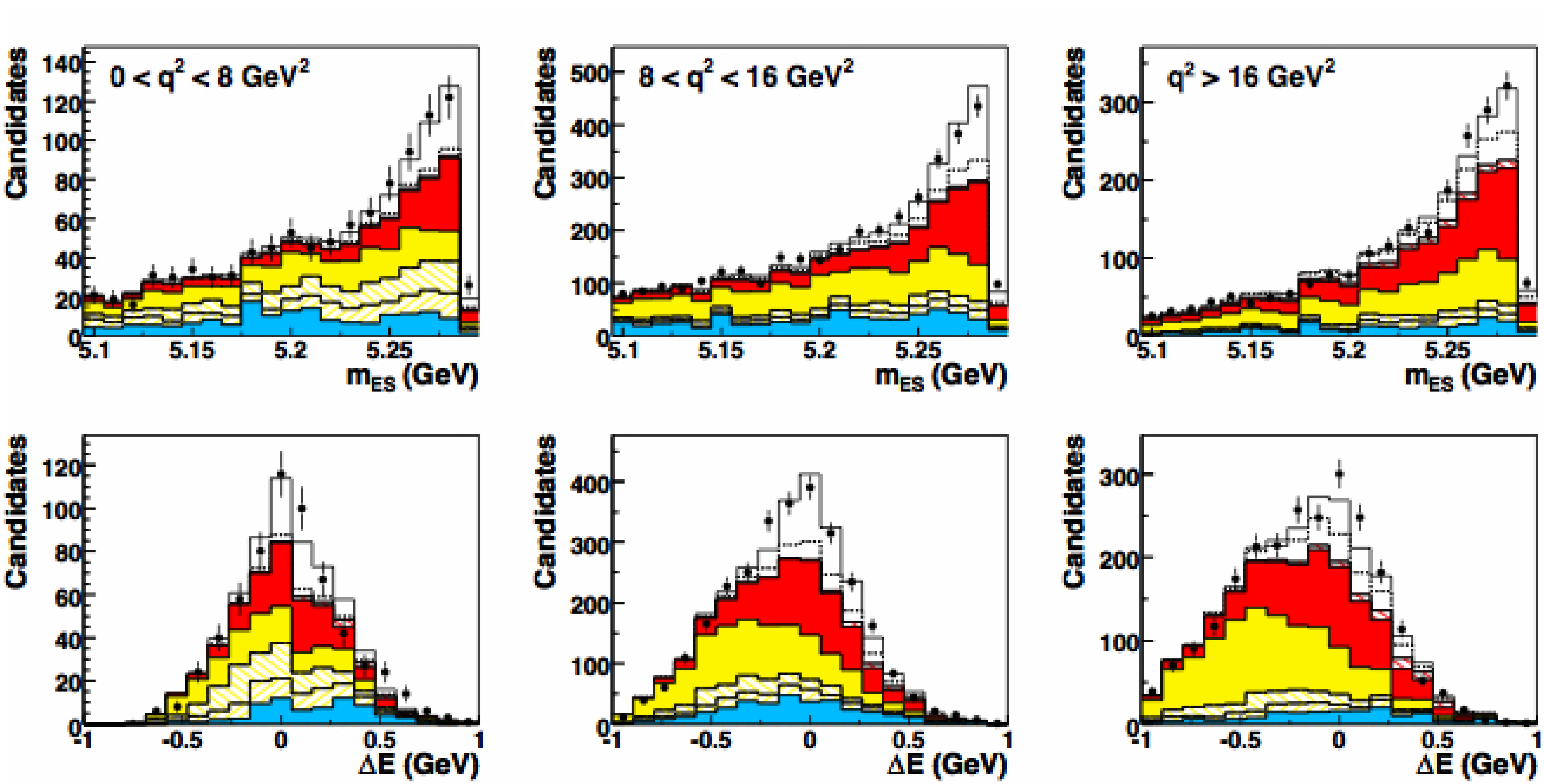


$|V_{ub}|$: Exclusive Measurement

BaBar Untagged Analysis (L=349 fb^{-1}) [Phys. Rev. D83, 052011 (2011)]

- Event yields determined in 3 q^2 bins from a 2D fit to (ΔE, m_{ES}) with signal and background shapes from MC $B^+ \to \rho^0 l^+ \nu$



$|V_{ub}|$: Exclusive Measurement

BaBar Untagged Analysis (L=349 fb^{-1}) [Phys. Rev. D83, 052011 (2011)]

Systematics on BR

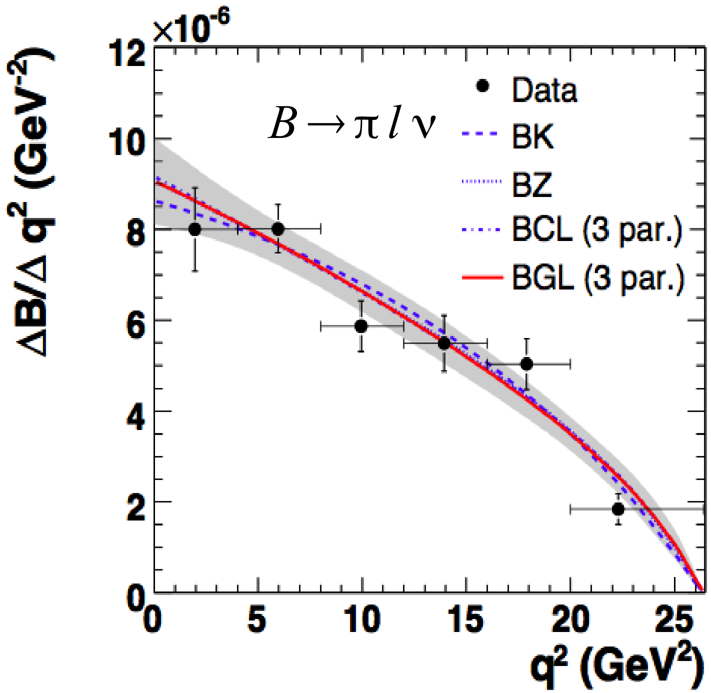
$B \to \pi \ell \nu$							
q^2 range (GeV^2)	0-4	4-8	8-12	12-16	16-20	>20	0-26.4
Track efficiency	3.4	1.5	2.3	0.1	1.5	2.8	1.9
Photon efficiency	0.1	1.4	1.0	4.6	2.8	0.3	1.8
Lepton identification	3.8	1.6	1.9	1.8	1.9	3.0	1.8
K_L efficiency	1.0	0.1	0.5	4.5	0.4	2.0	1.4
K_L shower energy	0.1	0.1	0.1	0.8	0.9	3.8	0.7
K_L spectrum	1.6	1.9	2.2	3.1	4.4	2.3	2.5
$B \to \pi \ell \nu FF\ f_+$	0.5	0.5	0.5	0.6	1.0	1.0	0.6
$B \to \rho \ell \nu FF A_1$	1.7	1.2	3.4	2.0	0.1	1.6	1.7
$B \to \rho \ell \nu FF A_2$	1.3	0.8	2.6	1.0	0.1	0.4	1.1
$B \to \rho \ell \nu FF V$	0.2	0.3	0.9	0.7	0.1	0.5	0.5
$\mathcal{B}(B^+ \to \omega \ell^+ \nu)$	0.1	0.1	0.1	0.2	0.3	1.5	0.2
$\mathcal{B}(B^+ \to \eta \ell^+ \nu)$	0.1	0.1	0.2	0.2	0.2	0.5	0.2
$\mathcal{B}(B^+ \to \eta' \ell^+ \nu)$	0.1	0.1	0.1	0.1	0.1	0.3	0.1
$\mathcal{B}(B \to X_u \ell \nu)$	0.2	0.1	0.1	0.1	1.1	1.6	0.4
$B \to X_u \ell \nu$ SF param.	0.4	0.1	0.2	0.2	0.5	4.2	0.7
$B \to D \ell \nu$ FF ρ_D^2	0.2	0.1	0.5	0.3	0.2	0.7	0.3
$B \to D^* \ell \nu$ FF R_1	0.1	0.4	0.8	0.6	0.3	0.6	0.5
$B \to D^* \ell \nu$ FF R_2	0.5	0.2	0.1	0.2	0.1	0.4	0.2
$B \to D^* \ell \nu$ FF $\rho_{D^*}^2$	0.7	0.2	0.6	0.8	0.4	1.1	0.6
$\mathcal{B}(B \to D \ell \nu)$	0.2	0.2	0.3	0.4	0.5	0.5	0.3
$\mathcal{B}(B \to D^* \ell \nu)$	0.4	0.1	0.3	0.3	0.3	0.7	0.3
$\mathcal{B}(B \to D^{**} \ell \nu)_{\mathrm{narrow}}$	0.4	0.1	0.1	0.3	0.1	0.5	0.2
$\mathcal{B}(B \to D^{**} \ell \nu)_{\mathrm{broad}}$	0.1	0.1	0.1	0.5	0.1	0.2	0.2
Secondary leptons	0.5	0.2	0.3	0.2	0.2	0.7	0.3
Continuum	5.3	1.0	2.6	1.8	3.1	6.1	2.0
Bremsstrahlung	0.3	0.1	0.1	0.1	0.1	0.4	0.2
Radiative corrections	0.5	0.1	0.1	0.2	0.2	0.6	0.3
$N_{B\bar{B}}$	1.2	1.0	1.2	1.2	1.1	1.6	1.2
B lifetimes	0.3	0.3	0.3	0.3	0.3	0.7	0.3
$f_{\pm}/f_{00}$	1.0	0.4	0.8	0.8	0.5	1.3	0.8
Total syst. error	8.2	3.9	6.7	8.3	6.9	10.6	5.0

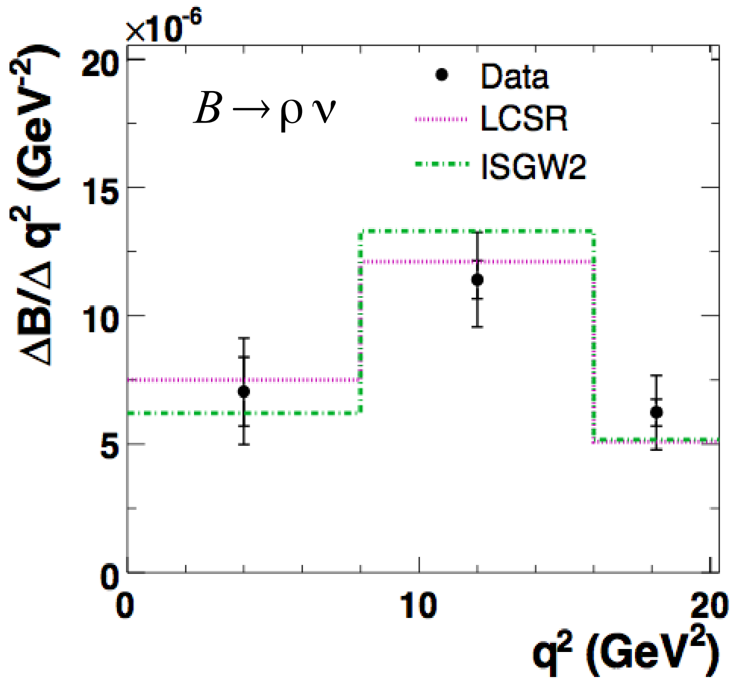
$B \to \rho \ell \nu$				
q^2 range (GeV^2)	0-8	8-16	>16	0-20.3
Track efficiency	3.2	2.9	0.3	2.5
Photon efficiency	2.6	2.0	2.6	2.4
Lepton Identification	5.7	3.0	4.0	3.4
K_L efficiency	10.3	1.2	4.9	4.8
K_L shower energy	1.6	0.8	1.0	1.1
K_L spectrum	4.2	6.1	7.0	5.7
$B \to \pi \ell \nu$ FF f_+	0.1	0.1	0.7	0.2
$B \to \rho \ell \nu$ FF A_1	10.7	6.6	4.5	7.5
$B \to \rho \ell \nu$ FF A_2	8.5	3.8	0.8	4.7
$B \to \rho \ell \nu$ FF V	3.4	3.0	3.6	3.2
$\mathcal{B}(B^+ \to \omega \ell^+ \nu)$	0.7	0.7	3.4	1.2
$\mathcal{B}(B^+ \to \eta \ell^+ \nu)$	0.8	0.1	0.6	0.4
$\mathcal{B}(B^+ \to \eta' \ell^+ \nu)$	0.8	0.5	1.2	0.7
$\mathcal{B}(B \to X_u \ell \nu)$	7.4	7.3	10.6	8.0
$B \to X_u \ell \nu$ SF param.	11.9	7.6	12.8	10.0
$B \to D \ell \nu$ FF ρ_D^2	0.9	0.2	0.1	0.4
$B \to D^* \ell \nu$FF R_1	0.7	0.1	0.3	0.3
$B \to D^* \ell \nu$FF R_2	1.7	0.1	0.2	0.6
$B \to D^* \ell \nu$FF $\rho_{D^*}^2$	2.0	0.2	0.1	0.7
$\mathcal{B}(B \to D \ell \nu)$	1.6	0.3	0.1	0.7
$\mathcal{B}(B \to D^* \ell \nu)$	0.5	0.1	0.3	0.3
$\mathcal{B}(B \to D^{**} \ell \nu)_{\mathrm{narrow}}$	1.3	0.1	0.1	0.5
$\mathcal{B}(B \to D^{**} \ell \nu)_{\mathrm{broad}}$	0.7	0.1	0.1	0.3
Secondary leptons	1.5	0.1	0.1	0.5
Continuum	8.9	3.8	5.0	4.0
Bremsstrahlung	0.9	0.1	0.2	0.4
Radiative corrections	1.3	0.1	0.7	0.6
$N_{B\bar{B}}$	2.7	2.0	2.5	2.3
B lifetimes	1.5	0.4	0.4	0.7
$f_{\pm}/f_{00}$	1.2	0.1	0.1	0.4
Total syst. error	26.1	16.1	21.3	15.7

$|V_{ub}|$: Exclusive Measurement

BaBar Untagged Analysis ($L=349\ fb^{-1}$) [Phys. Rev. D83, 052011 (2011)]

- q^2 spectrum corrected for resolution, radiative effects using an unfolding technique [Hocker, Kartvelishvili, Nucl. Instrum. Meth. A37, 469 (1996)] giving the $\Delta BR/\Delta q^2$ distributions





- Spectra are fitted to different FF parameterizations & compared with predictions
- Used for the $|V_{ub}|$ extraction

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	q^2 Range (GeV^2)	$\Delta\mathcal{B}$ (10^{-4})	$\Delta\zeta$ (ps^{-1})	$\lvert V_{ub}\rvert$ (10^{-3})
$B \to \pi\ell\nu$				
LCSR 1 [15]	$0-16$	1.10 ± 0.07	5.44 ± 1.43	$3.63 \pm 0.12^{+0.59}_{-0.40}$
LCSR 2 [19]	$0-12$	0.88 ± 0.06	$4.00^{+1.01}_{-0.95}$	$3.78 \pm 0.13^{+0.55}_{-0.40}$
HPQCD [23]	$16-26.4$	0.32 ± 0.03	2.02 ± 0.55	$3.21 \pm 0.17^{+0.55}_{-0.36}$
$B \to \rho\ell\nu$				
LCSR [17]	$0-16.0$	1.48 ± 0.28	13.79	2.75 ± 0.24
ISGW2 [14]	$0-20.3$	1.75 ± 0.31	14.20	2.83 ± 0.24

$|V_{ub}|$: Exclusive Measurement

$|V_{ub}|$ Extraction

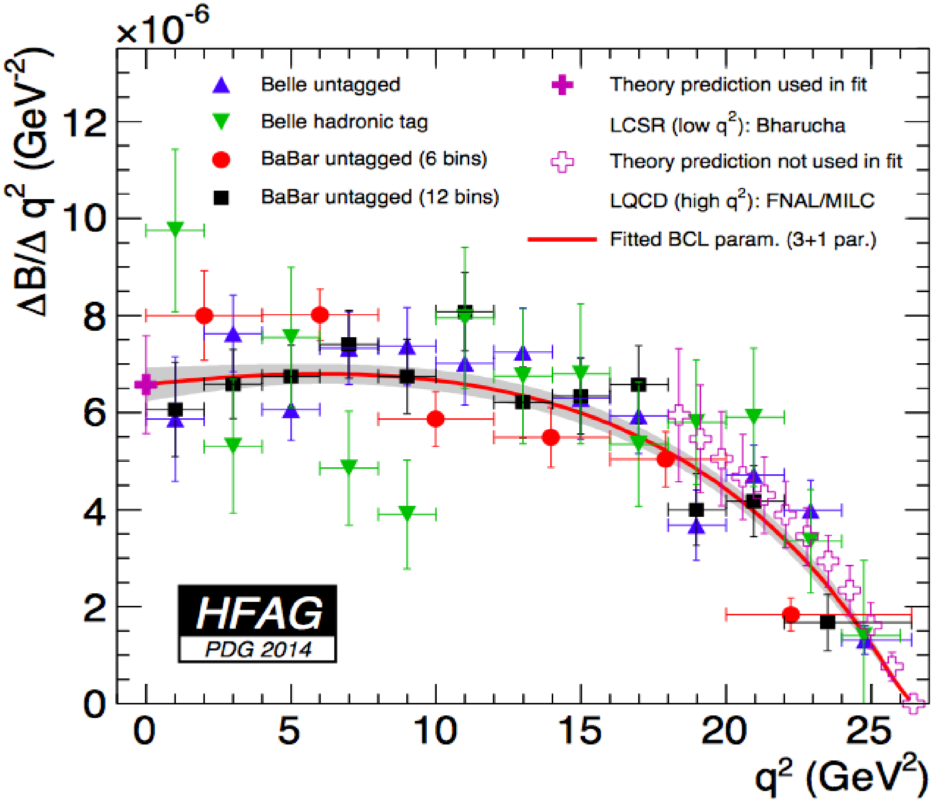
- Simultaneous fit to the q^2 spectra and the LQCD predictions in the BCL parameterization [Bourrely, Caprini, Lellouch, Phys. Rev. D79, 013008 (2009)]

- Measured partial $\Delta BR(q^2_{min}, q^2_{min})$ compared with the normalized partial decay rate $\Delta\zeta(q^2_{min}, q^2_{max})$ predicted from FF integration (LQCD: q^2>16 GeV^2, LCSR: q^2<12 GeV^2)

$$|V_{ub}| = \sqrt{\frac{\Delta B(q^2_{\rm min}, q^2_{\rm max})}{\tau_0 \Delta\zeta(q^2_{\rm min}, q^2_{\rm max})}}$$

$$\tau_0 = (1.519 \pm 0.007)\ \text{ps}$$

$$\Delta\zeta \equiv \frac{G_F^2}{24\pi^3}\int_{q_i^2}^{q_f^2} dq^2 \mathbf{p}_\pi^3 |f_+^{B\pi}(q^2)|^2$$



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	LCSR	HPQCD	FNAL/MILC	FNAL/MILC fit
$\Delta\zeta$ (ps^{-1})	$4.59^{+1.00}_{-0.85}$	2.02 ± 0.55	$2.21^{+0.47}_{-0.42}$	$2.21^{+0.47}_{-0.42}$
q^2 range (GeV^2)	$0-12$	$16-26.4$	$16-26.4$	$16-26.4$
Experiment		$\lvert V_{ub}\rvert$ (10^{-3})		
BABAR (6 bins)	$3.54\pm0.12^{+0.38}_{-0.33}$	$3.22\pm0.15^{+0.55}_{-0.37}$	$3.08\pm0.14^{+0.34}_{-0.28}$	2.98 ± 0.31
BABAR (12 bins)	$3.46\pm0.10^{+0.37}_{-0.32}$	$3.26\pm0.19^{+0.56}_{-0.37}$	$3.12\pm0.18^{+0.35}_{-0.29}$	3.22 ± 0.31
Belle	$3.44\pm0.10^{+0.37}_{-0.32}$	$3.60\pm0.13^{+0.61}_{-0.41}$	$3.44\pm0.13^{+0.38}_{-0.32}$	3.52 ± 0.34
BABAR +Belle	$3.47\pm0.06^{+0.37}_{-0.32}$	$3.43\pm0.09^{+0.59}_{-0.39}$	$3.27\pm0.09^{+0.36}_{-0.30}$	3.23 ± 0.30
Tagged	$3.10\pm0.16^{+0.33}_{-0.29}$	$3.47\pm0.23^{+0.60}_{-0.39}$	$3.32\pm0.22^{+0.37}_{-0.31}$	3.33 ± 0.39

- Error from BR measurements (3%), shapes of the q^2 spectra from data (4%), FF normalization ($f_+(0)$) from theory (8%)

$|V_{ub}|$: Inclusive Measurement

Inclusive Cabibbo-suppressed decays (most precise $|V_{ub}|$ determination)

Theoretical Summary in [Phys. Rept. 494, 197-414 (2010)]

- Theoretical description of inclusive $B \to X_u\, l\, \nu$ similar to $B \to X_c\, l\, \nu$ used for the V_{cb} determination.

- Challenge: large BKG from $B \to X_c\, l\, \nu$
  - Highest experimental sensitivity in the region of phase space less impacted by the dominant $B \to X_c\, l\, \nu$ background: for $m_X < m_D$ & $p_l(b) > p_l(c)$
  - Requires extrapolation to the full spectrum using theoretical parameterizations to describe the unmeasured regions of phase space (Shape Functions) reflecting in theory error

- Discriminating variables: lepton energy, $p_X^+ = E_X - |\boldsymbol{p}_X|$, $\quad p_X^- = E_X + |\boldsymbol{p}_X|$

- Differential decay rate:

$$\frac{d^3\Gamma}{dp_X^+\, dp_X^-\, dE_\ell} = \frac{G_F^2 |V_{ub}|^2}{192\pi^3} \int dk\, C(E_\ell, p_X^-, p_X^+, k)\, F(k) + O\left(\frac{\Lambda_{\rm QCD}}{m_b}\right).$$

- $C(E_\ell, p_X^-, p_X^+, k)$: perturbative description of the b quark decay

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- F(k): non-perturbative shape function describing the momentum distribution of the b quark inside the B meson
  [Bigi et al., Int. J. Mod. Phys. A9, 2467-2504 (1994), Neubert, Phys. Rev. D49, 4623-4633 (1994)]

$|V_{ub}|$: Inclusive Measurement

Untagged Analyses

- First evidence for charmless B semileptonic decays by CLEO [Phys. Rev. Lett. 71, 4111-4115 (1993)] from observation of charged lepton above the kinematical endpoint for $B \to X_c\, l\, \nu$ (p^*_l=2.3 GeV)
- Inclusive $B \to X_u\, l\, \nu$ are described by the sum of three-body decays involving a single light charmless meson (20%) and decays to non-resonant multi-body final states. Two components normalized to reproduce the OPE inclusive prediction, and adjusted to the measured inclusive charmless BR.

Tagged Analyses

- Lepton with P_l>1 GeV on the recoil of a reconstructed hadronic decay taken as a signature of B_{SL} : low rate due to ε(Tag), but reduced combinatorial BKG
  - Phase-space restriction covers 90% of the total inclusive rate to reduce error on extrapolation. Theory errors from m_b, higher-order perturbative corrections, signal shape functions used for the efficiency calculation

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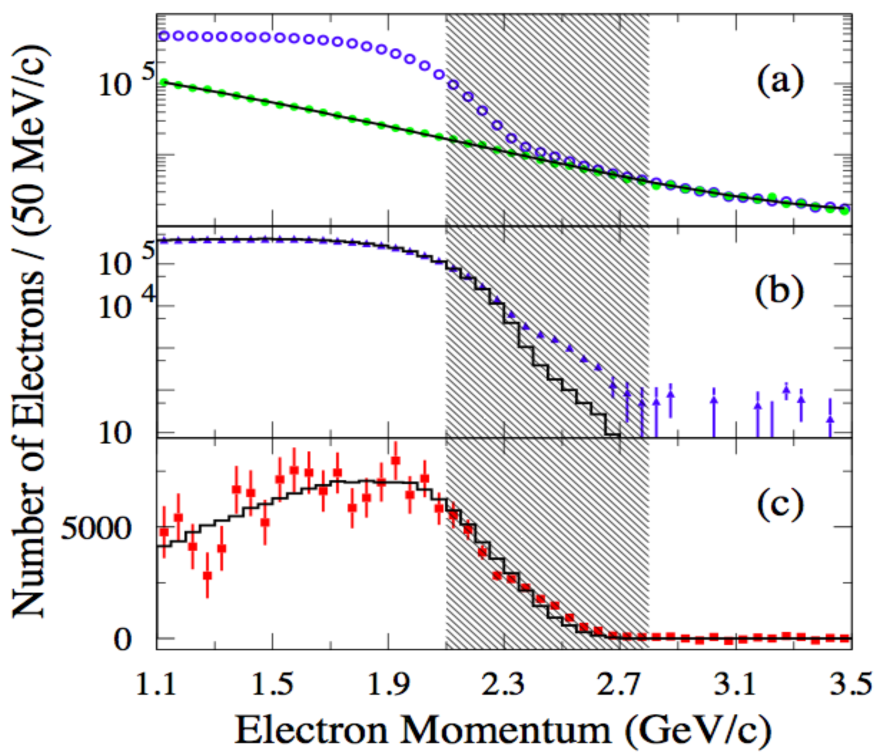
Tagged Analyses

- Observables: q^2, m_X:
  - $B \rightarrow X_c\, l\, \nu$ BKG suppressed by vetoing K and slow pions from D decays
  - Events with additional missing particles rejected by cuts on the missing mass squared
  - Systematics from tag efficiency cancels in the ratio of charmless to inclusive SL decays

$|V_{ub}|$: Inclusive Measurement

BaBar Untagged Analysis (L=80 fb^{-1}) [Phys. Rev. D73, 012006 (2006)]

- Observed spectra of the highest momentum electron in the ϒ(4S) frame
- Challenge: $B \rightarrow X_c\, l\, \nu$ subtraction, secondary leptons from D (J/Ψ) and fakes.
- Signal yield from a fit using MC shapes for signal and background components
- Sensitivity of the fitted yield from the MC shape of the signal spectrum reduced by combining the data between 2.1 to 2.8 GeV in a single bin



On-resonance
Scaled Off-resonance
Fit to non-BB background

On-resonance after non-BB BKG subtraction
Simulated BB BKG

On-resonance BKG subtracted
Simulated $B \rightarrow X_u\, l\, \nu$ spectrum

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Δp (GeV/c)	2.0–2.6	2.1–2.6	2.2–2.6	2.3–2.6	2.4–2.6
Total sample	609.81 ± 0.78	295.76 ± 0.54	133.59 ± 0.37	65.48 ± 0.26	35.38 ± 0.19
Non-$B\overline{B}$ background	142.38 ± 0.63	105.20 ± 0.48	74.86 ± 0.36	50.13 ± 0.25	29.96 ± 0.16
$X_c e \nu$ background	416.22 ± 2.52	157.17 ± 1.29	38.82 ± 0.47	4.00 ± 0.10	0.09 ± 0.01
J/ψ and $\psi(2S)$	6.17 ± 0.14	4.00 ± 0.10	2.33 ± 0.06	1.17 ± 0.04	0.47 ± 0.02
Other $e^{\pm}$ background	1.61 ± 0.05	0.62 ± 0.02	0.24 ± 0.01	0.08 ± 0.01	0.03 ± 0.00
π misidentification	1.34 ± 0.04	0.98 ± 0.03	0.64 ± 0.02	0.34 ± 0.02	0.10 ± 0.01
K misidentification	0.47 ± 0.02	0.26 ± 0.01	0.13 ± 0.01	0.05 ± 0.01	0.01 ± 0.00
Other misidentification	0.27 ± 0.01	0.15 ± 0.01	0.08 ± 0.01	0.04 ± 0.01	0.02 ± 0.00
$X_u e \nu$ background	1.62 ± 0.10	0.66 ± 0.05	0.20 ± 0.02	0.03 ± 0.01	0.01 ± 0.00
$X_u e \nu$ signal	39.72 ± 2.70	26.72 ± 1.49	16.31 ± 0.71	9.64 ± 0.38	4.70 ± 0.25
$X_u e \nu$ efficiency (%)	42.1 ± 0.3	41.2 ± 0.4	40.2 ± 0.5	39.5 ± 0.7	37.9 ± 1.0

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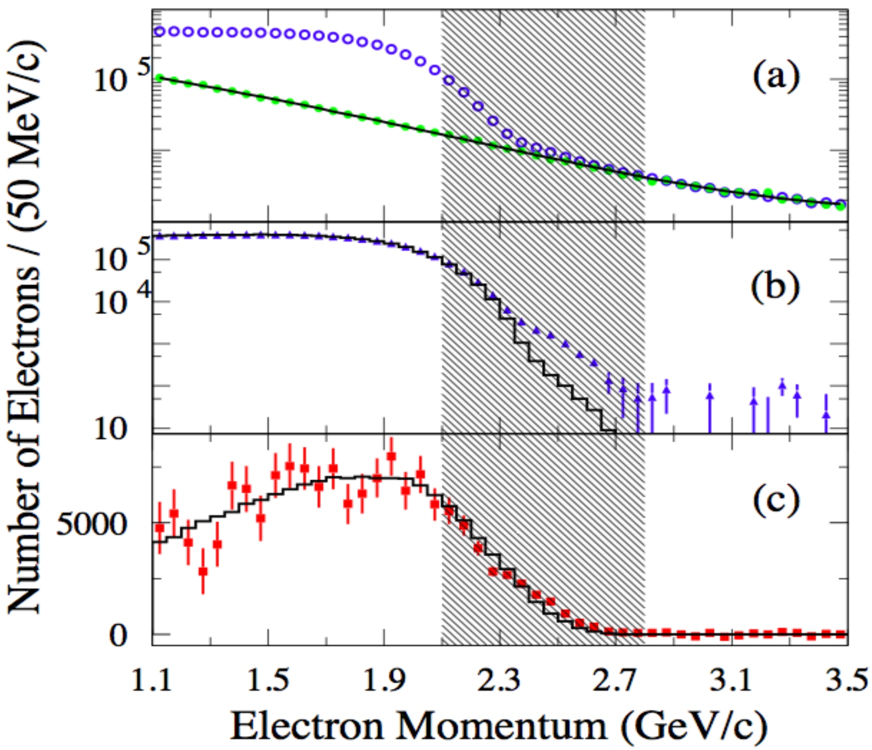

- Fitted yield with $2.0<p^*_e<2.6$ GeV:

$N_e = 610 \times 10^3$

$N_{signal} = (39.72 \pm 2.70)\ 10^3$

$\Delta B(B \rightarrow X_u\, l\, \nu)=(0.572 \pm 0.41 \pm 0.065)10^{-3}$

$$\Delta\mathcal{B}(\Delta p) = \frac{N_{tot}(\Delta p) - N_{bg}(\Delta p)}{2\epsilon(\Delta p)N_{B\bar{B}}}(1 + \delta_{rad}(\Delta p))$$

Δp= momentum interval

δ_{rad}=accounts for distortion due to Final State Radiation

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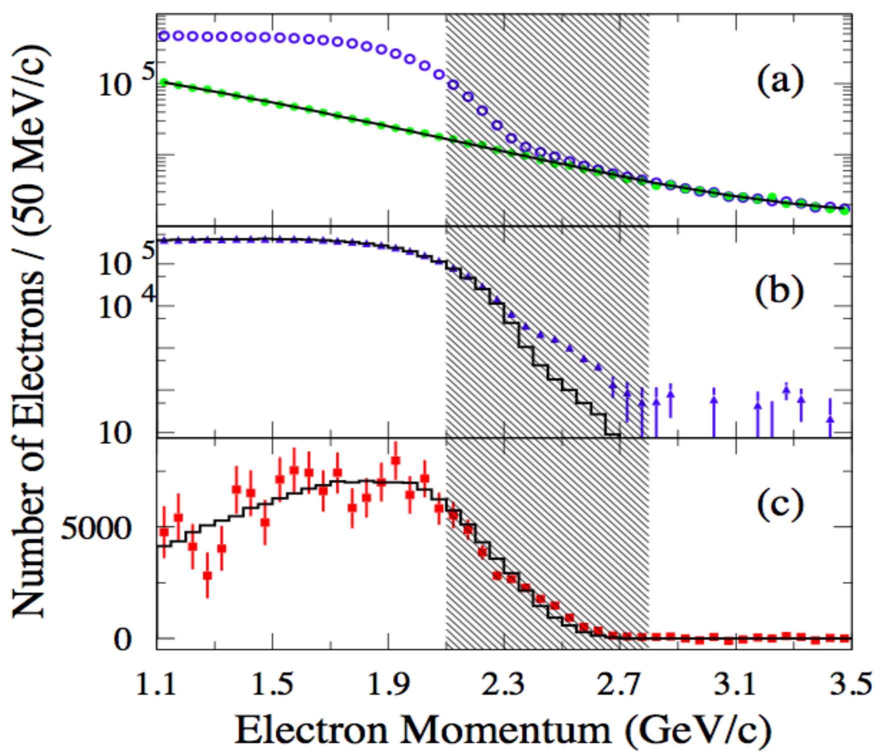

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  $\Delta B(B \to X_u\ l\ \nu)=(0.572 \pm 0.41 \pm 0.065)10^{-3}$

- First analysis extending below the $B \to X_c\ l\ \nu$ endpoint p^*_e~2.3 GeV covering about 25% of the spectrum

$|V_{ub}|$: Inclusive Measurement

BaBar Untagged Analysis (L=80 fb^{-1}) [Phys. Rev. D73, 012006 (2006)]

p^{min} (GeV/c)	2.0	2.1	2.2	2.3	2.4
Track finding efficiency	0.7	0.7	0.7	0.7	0.7
Electron identification	1.4	1.4	1.3	0.9	0.8
Event selection efficiency	6.8	6.7	6.1	5.5	7.9
Non-$B\bar{B}$ background	2.4	2.5	2.4	2.5	2.3
J/ψ and $\psi(2S)$ background	0.9	0.8	0.8	0.6	0.5
$B \to D^* l \nu$ form factor	2.4	2.3	2.0	1.3	0.5
$B \to D l \nu$ form factor	0.7	0.9	0.8	0.2	0.4
$B \to D^{**} e \nu$ spectrum	2.8	2.5	2.4	0.9	0.7
Other $e^{\pm}$ background	0.5	0.3	0.2	0.1	0.1
$B \to X_u e \nu$ background	1.1	0.6	0.3	0.1	0.0
π misidentification background	0.8	0.9	0.9	0.8	0.5
K misidentification background	0.4	0.4	0.3	0.2	0.1
Other hadron misidentification	0.2	0.2	0.2	0.1	0.1
B movement	1.3	1.7	1.5	0.6	0.1
Bremsstrahlung and FSR	1.0	1.2	1.2	0.9	0.9
N_{BB} normalization	1.1	1.1	1.1	1.1	1.1
Total experimental error	8.8	8.6	7.9	6.6	8.5
$B \to X_u e \nu$ spectrum					
$X_s \gamma$ SF, fit to spectrum	6.0	3.5	1.6	0.3	0.1
$X_s \gamma$ SF, fit to moments	11.3	6.7	3.1	0.6	0.1
$X_c e \nu$ SF, fit to moments	13.3	8.6	4.0	0.8	0.0
SF, combined fit to moments	7.2	4.8	2.3	0.5	0.0
Total systematic error					
$X_s \gamma$ SF, fit to spectrum	10.7	9.3	8.1	6.6	8.5
$X_s \gamma$ SF, fit to moments	14.3	10.9	8.5	6.6	8.5
$X_c e \nu$ SF, fit to moments	15.9	12.2	8.9	6.6	8.5
SF, combined fit to moments	11.4	9.8	8.2	6.6	8.5

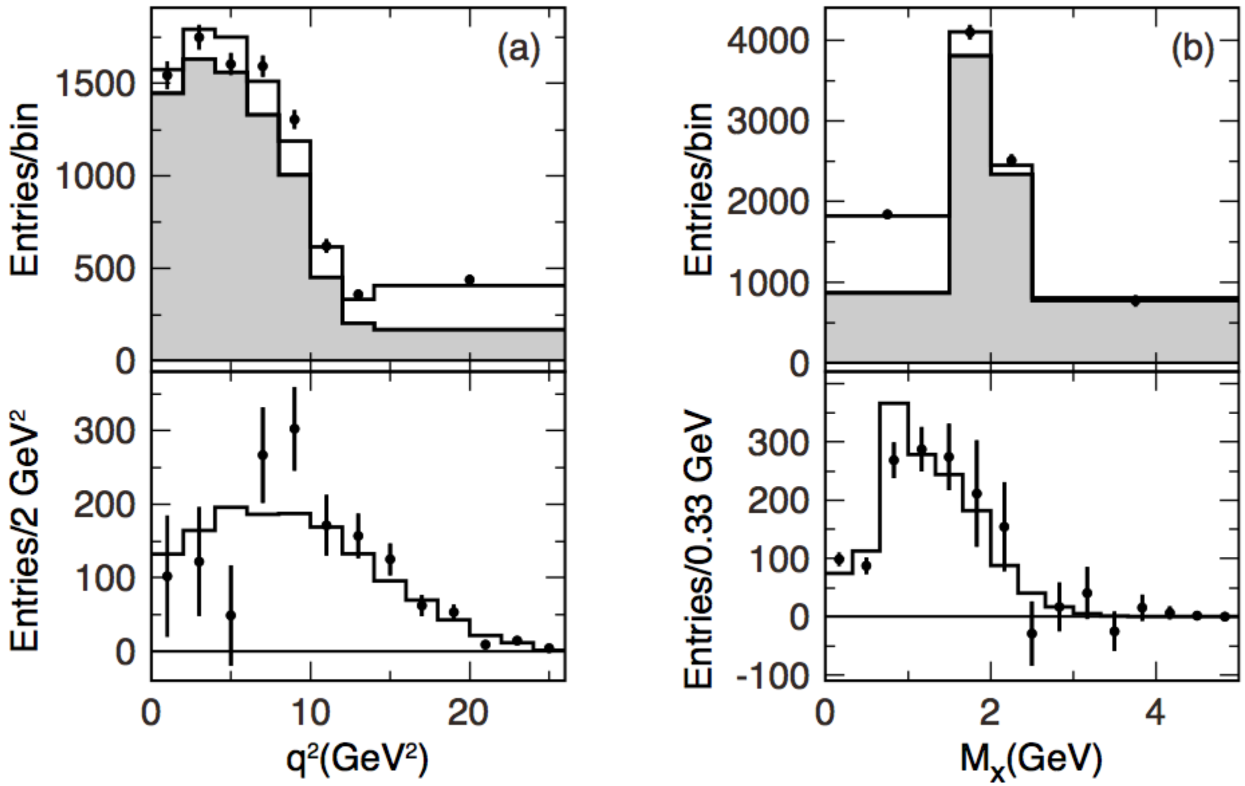
Common Upper limit 2.6 GeV

- Experimental Systematics dominated by efficiency and BKG subtraction
- $B \to X_u l \nu$ spectrum modeling systematic dominated by signal shape: Shape-Function parameters computed from:
  - Fit to $B \to X_s \gamma$ spectrum
  - Moments of $B \to X_s \gamma$
  - Moments of $B \to X_c l \nu$ inclusive lepton spectrum
  - Combined fit to all the moments

$|V_{ub}|$: Inclusive Measurement

- Tagged Analyses
- Partial BR ($B \rightarrow X_u\, l\, \nu$) from 2D fit to ($m_X$, q^2) on the recoil of fully reconstructed hadronic decays
- Systematics from shape of the distribution from simulation and Shape Function for the extrapolation to the full phase space
- From average of Belle [Phys. Rev. Lett. 104, 021801 (2010)] & Babar [arXiv:1112.0702 (2011)] results:

$\Delta BR(p^*_l > 1\ \mathrm{GeV}) = (1.87 \pm 0.10 \pm 0.11) \times 10^{-3}$



BaBar

Signal BKG subtracted

$|V_{ub}|$: Inclusive Measurement

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- Partial BR ($B \to X_u\, l\, \nu$) from 2D fit to (m_X, q^2) on the recoil of fully reconstructed hadronic decays
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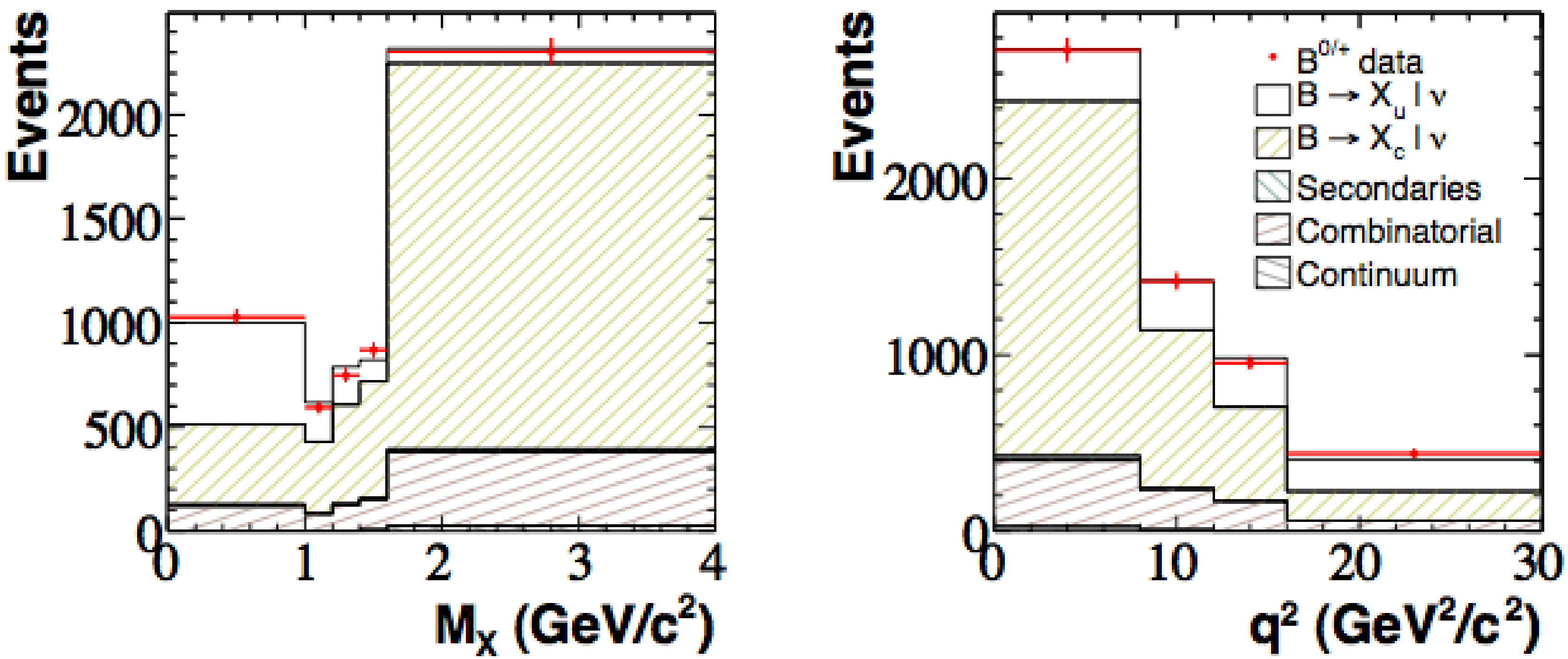

Belle

$|V_{ub}|$: Inclusive Measurement

$|V_{ub}|$ Extraction

- Measured partial ΔBR(Δp) (Δp=momentum interval) compared with the predicted partial decay rate ΔΓ(Δp) for the selected phase space region

$$|V_{ub}| = \sqrt{\Delta\mathcal{B}/(\tau_B\,\Delta\Gamma_{\text{theory}})}$$

	BLNP	GGOU	DGE
m_b scheme	SF scheme	Kinetic scheme	$\overline{\text{MS}}$ scheme
m_b (GeV)	$4.588 \pm 0.023 \pm 0.011$	4.560 ± 0.023	4.194 ± 0.043
μ_π^2 (GeV^2)	$0.189^{+0.041}_{-0.040} \pm 0.020$	0.453 ± 0.036	—
Experiment		$\lvert V_{ub}\rvert$ (10^{-3})	
CLEO (Bornheim et al., 2002)	$4.19 \pm 0.49^{+0.26}_{-0.34}$	$3.93 \pm 0.46^{+0.22}_{-0.29}$	$3.82 \pm 0.43^{+0.23}_{-0.26}$
Belle (Limosani, 2005)	$4.88 \pm 0.45^{+0.24}_{-0.27}$	$4.75 \pm 0.44^{+0.17}_{-0.22}$	$4.79 \pm 0.44^{+0.21}_{-0.24}$
BABAR (Aubert, 2006x)	$4.48 \pm 0.25^{+0.27}_{-0.28}$	$4.29 \pm 0.24^{+0.18}_{-0.24}$	$4.28 \pm 0.24^{+0.22}_{-0.24}$
BABAR (Aubert, 2005h)	$4.66 \pm 0.31^{+0.31}_{-0.36}$	—	$4.32 \pm 0.29^{+0.24}_{-0.29}$
Average untagged	$4.65 \pm 0.22^{+0.26}_{-0.29}$	$4.39 \pm 0.22^{+0.18}_{-0.24}$	$4.44 \pm 0.21^{+0.21}_{-0.25}$
Belle (Urquijo, 2010)	$4.47 \pm 0.27^{+0.19}_{-0.21}$	$4.54 \pm 0.27^{+0.10}_{-0.11}$	$4.60 \pm 0.27^{+0.11}_{-0.13}$
BABAR (Lees, 2011l)	$4.28 \pm 0.24^{+0.18}_{-0.20}$	$4.35 \pm 0.24^{+0.09}_{-0.11}$	$4.40 \pm 0.24^{+0.12}_{-0.13}$
Average tagged	$4.35 \pm 0.19^{+0.19}_{-0.20}$	$4.43 \pm 0.21^{+0.09}_{-0.11}$	$4.49 \pm 0.21^{+0.13}_{-0.13}$
Average all	$4.40 \pm 0.15^{+0.19}_{-0.21}$	$4.39 \pm 0.15^{+0.12}_{-0.14}$	$4.45 \pm 0.15^{+0.15}_{-0.16}$

$|V_{ub}|$: Inclusive Measurement

$|V_{ub}|$ Extraction [Antonelli at al., Phys. Rept. 494, 197-414 (2010)]

$$\frac{d^3\Gamma}{dp_X^+\,dp_X^-\,dE_\ell} = \frac{G_F^2|V_{ub}|^2}{192\pi^3}\int dk\, C(E_\ell, p_X^-, p_X^+, k)\, F(k) + O\left(\frac{\Lambda_{QCD}}{m_b}\right).$$

$$p_X^+ = E_X - |\boldsymbol{p}_X|, \qquad p_X^- = E_X + |\boldsymbol{p}_X|$$

- BLNP [Bosch, Lange, Neubert, Paz, Nucl. Phys. B699, 335-386 (2004), Lange. Neubert, Paz, Phys. Rev. D72, 073006 (2005)]: $P^+_X \ll P^-_X$ (C dependences on P^+_X, P^-_X factorize). Resummation of double log to NNLL. Full $O(\alpha_s)$ corrections included.
- GGOU [Gambino, Giordano, Ossola, Uraltsev, JHEP 0710, 058 (2007)]: $P^+_X \ll P^-_X$ and $P^+_X \sim P^-_X$. C computed at fixed order to $O(\alpha_s)$, no resummation at small P^+_X.
- DGE [Anderson, Gardi, JHEP 0601, 097 (2006)]: NNLL resummation and full Full $O(\alpha_s)$ corrections included. Perturbative model for the leading shape function, non-perturbative correctios included via its moments. Most predictive model.

$|V_{ub}|$: Inclusive Measurement

$|V_{ub}|$ Extraction

- Measured partial ΔBR(Δp) (Δp=momentum interval) compared with the predicted partial decay rate ΔΓ(Δp) for the selected phase space region

$$|V_{ub}| = \sqrt{\Delta\mathcal{B}/(\tau_B\,\Delta\Gamma_{\mathrm{theory}})}$$

$$|V_{ub}|_{\mathrm{incl}} = (4.42 \pm 0.20_{\mathrm{exp}} \pm 0.15_{\mathrm{th}}) \times 10^{-3}$$

- Uncertainty dominated by experimental error. Similar statistical and systematic uncertainties (from particle identification and reconstruction efficiency).

- Theoretical error due to Shape Function for the extrapolation to the full phase space dominated by μ^2_π, m_b depending on the scheme obtained from fits to $B \to X_c\, l\, \nu$ moments (see before)

- Good agreement between the different QCD calculations

Summary on $|V_{ub}|$

- $|V_{ub}|$:
  - Inclusive fits to $B \to X_u l \nu$ gives comparable experimental and theoretical errors

$$|V_{ub}|_{\rm incl} = [4.42\ (1 \pm 0.045_{\rm exp} \pm 0.034_{\rm th})] \times 10^{-3}$$

  - From exclusive decay $B^0 \to \pi l \nu$ using LQCD and the measured spectrum

$$|V_{ub}|_{\rm excl} = [3.23\ (1 \pm 0.05_{\rm exp} \pm 0.08_{\rm th})] \times 10^{-3}$$

    - 3 σ difference

- As for V_{cb}, discrepancy between exclusive and inclusive measurements is one of the most long standing tensions in the SM and still an open question