

Exclusive $B \rightarrow X_u l \nu$ Decays at BaBar

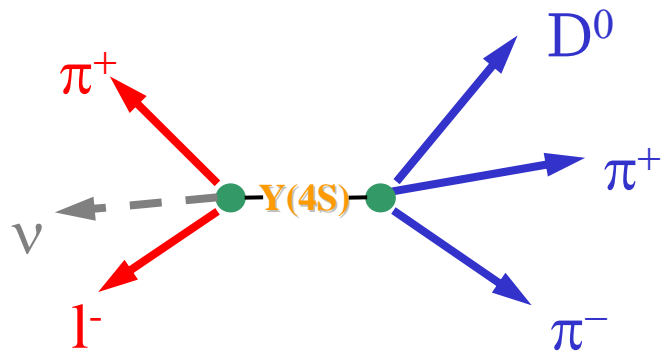


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SLAC



CKM Workshop 2005, San Diego

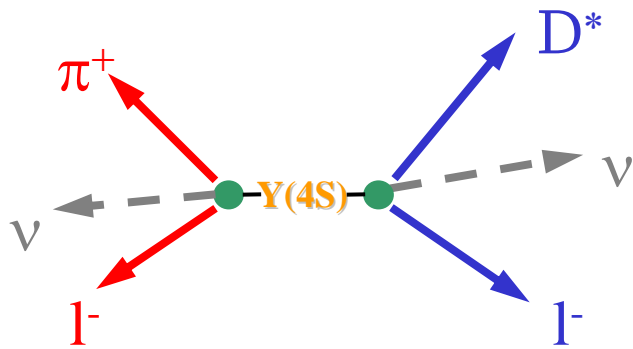
Exclusive $B \rightarrow X_u l \nu$ Decays



Breco Tags

$X_u = \pi^+, \pi^0, \rho^+, \rho^0, \omega, \eta, \eta', a_0^0, a_0^+$
low bkg, low stat.: $27\pi, \dots$ (ICHEP'04)

Exclusive $B \rightarrow X_u l \nu$ Decays



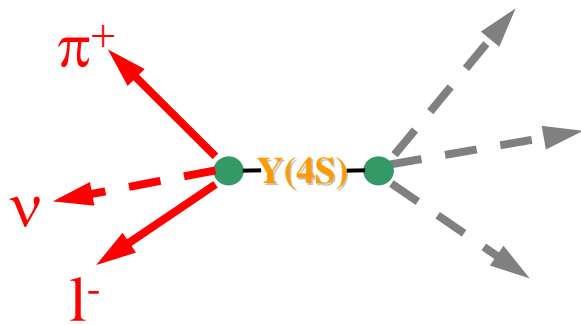
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Semilep. Tags

Balance between
efficiency and purity

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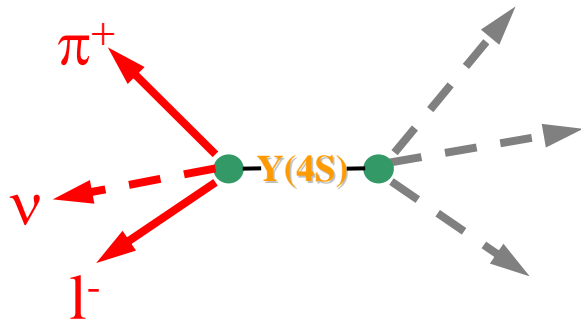
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Balance between
efficiency and purity

Untagged

High statistics, high
background ($b \rightarrow cl\nu$)

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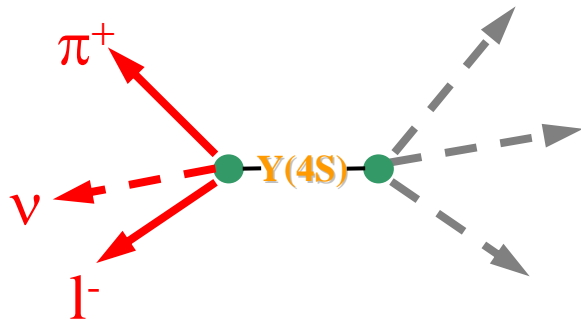
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3 new
 $\pi l \nu$
results

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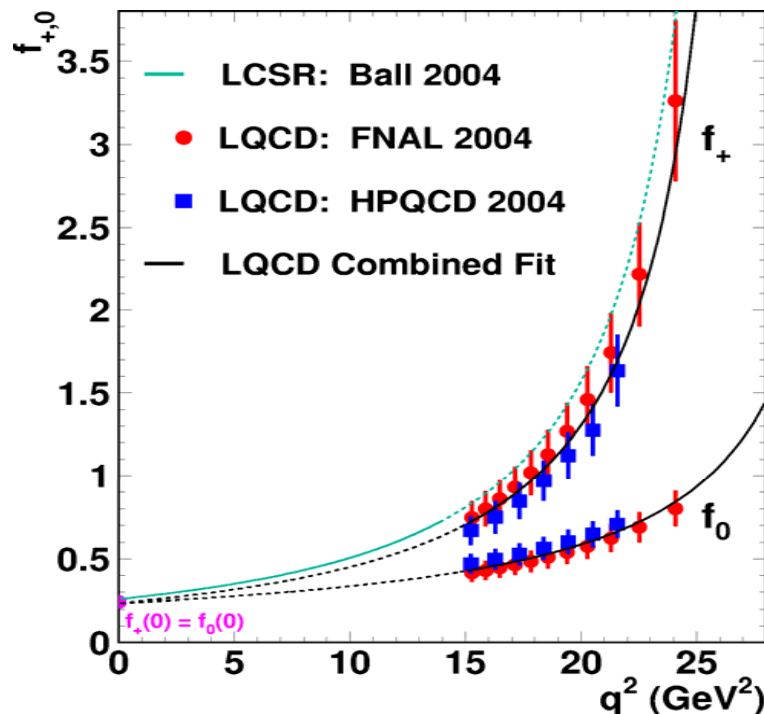
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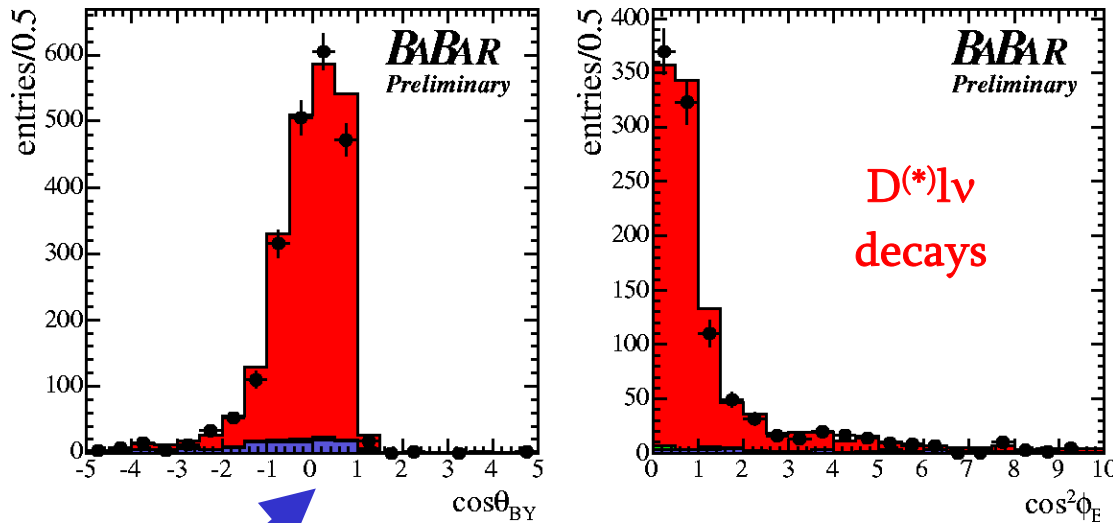
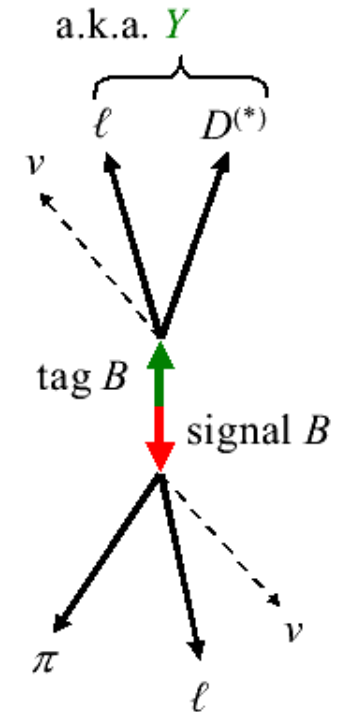
3 new
 $\pi l \nu$
results



- Goal : Measure Branching Fractions and $|V_{ub}|$
- Need FF predictions to describe QCD effects
- New unquenched LQCD calculations (HPQCD'04, FNAL'04)
- Try to measure q^2 dependence of FF with data

Semileptonic Tag Analyses

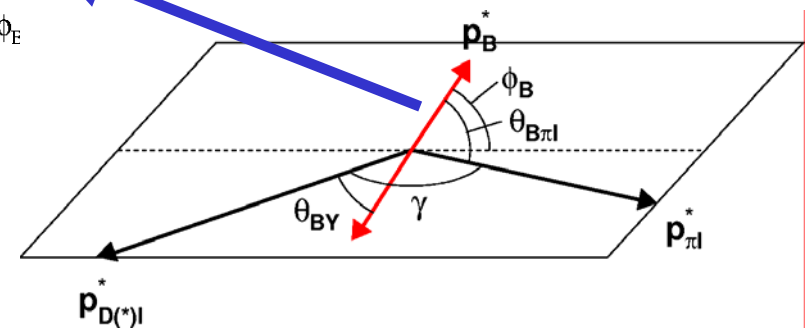
- Reconstruct $B \rightarrow D^{(*)}l\nu$ and **study semileptonic recoil**
 - use both D and D* tags \rightarrow sizable BF
 - Tagging efficiency measured with “Double Tags” (two $D^{(*)}l\nu$)



$$\cos \theta_{BY} = \frac{2E_B^* E_{D^{(*)}\ell}^* - m_B^2 - m_{D^{(*)}\ell}^2}{2p_B^* p_{D^{(*)}\ell}^2}$$

Correct sl. decay $\rightarrow |\cos \theta_{BY}| < 1$

(tag side: $\cos \theta_{BY}$, signal side: $\cos \theta_{B,\pi l}$)

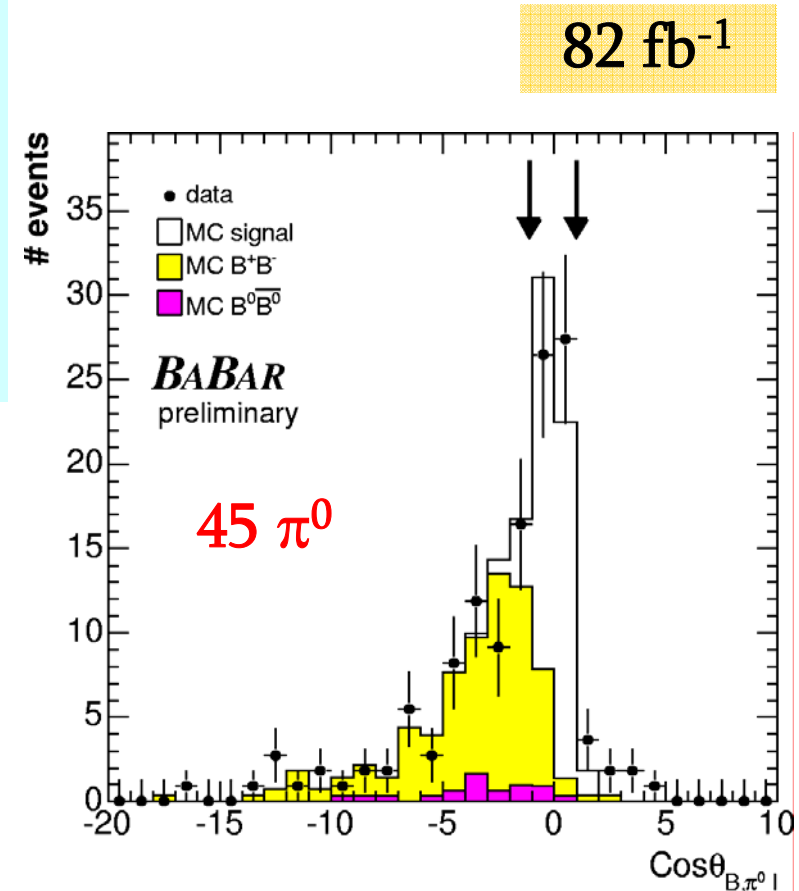


$\cos^2 \phi_B < 1$ for signal, bkg flat

$\pi^0 \ell \nu$ with SL Tag : Signal Extraction

- Cut-and-count analysis in $\cos\theta_{B,\pi\ell}$ and m_D
- Signal region: $-1.1 < \cos\theta_{B,\pi\ell} < 1.0$
- Subtract m_D sidebands
→ remove combinatoric background
- Subtract other background using MC normalized in $-10 < \cos\theta_{B\pi\ell} < -1.5$

Systematics	σ_B/B
Signal Efficiency	$\pm 6.0\%$
Tagging Efficiency	$\pm 3.9\%$
$B\bar{B}$ Background Subtraction	$\pm 7.6\%$
Total Error	$\pm 12.9\%$

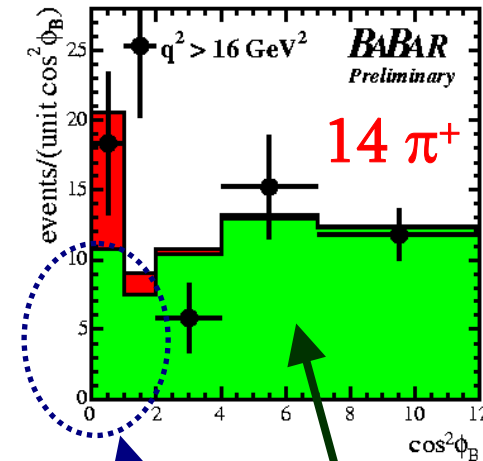
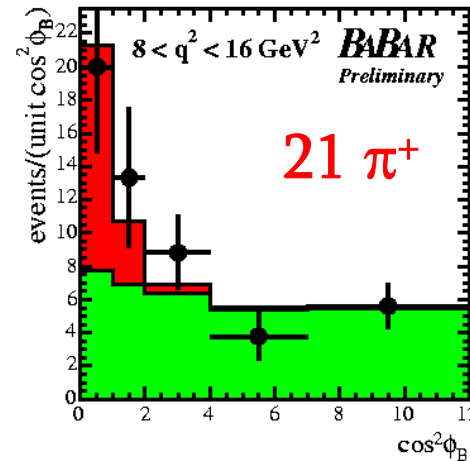
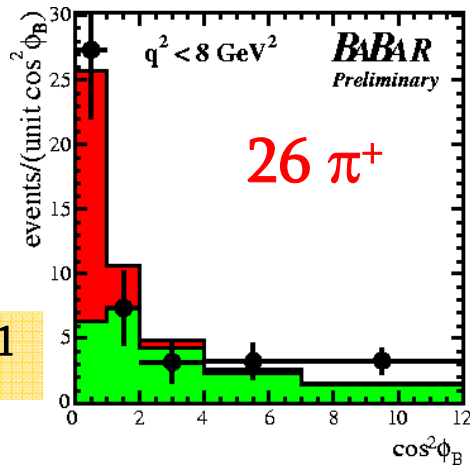


$$\mathcal{B}(B^+ \rightarrow \pi^0 \ell^+ \nu) = (1.80 \pm 0.37 \pm 0.23) \times 10^{-4}$$

$\pi^+\ell\nu$ with SL Tag : Signal Extraction

Extract **signal yields** by binned χ^2 fit to $\cos^2\phi_B$ in 3 bins of q^2 :

Fit parameters = **signal** and **background** normalizations



211 fb⁻¹

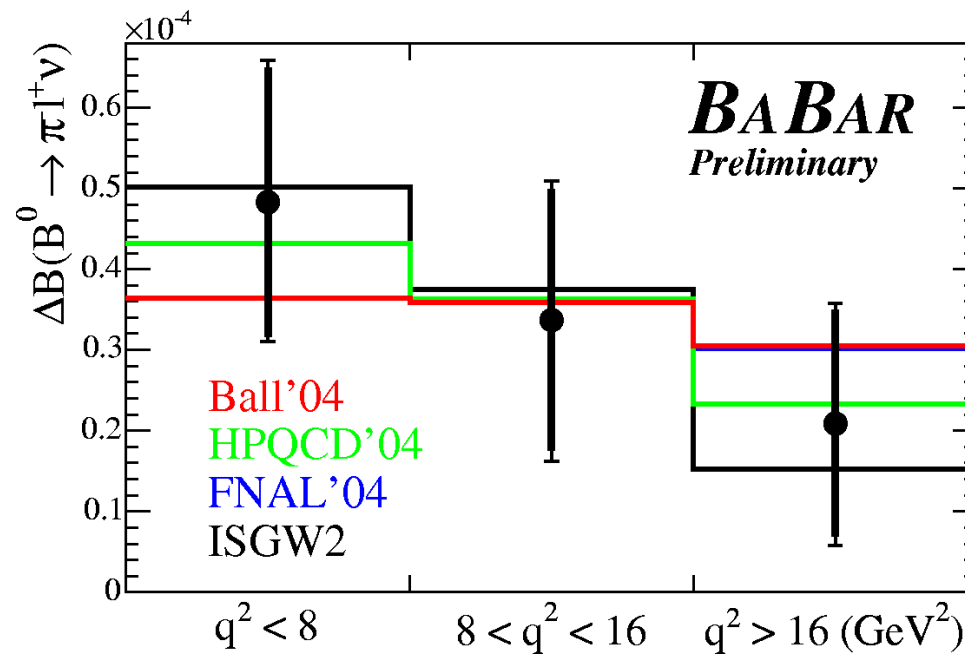
Systematics	$\sigma_{\mathcal{B}}/\mathcal{B}$	$\sigma_{\Delta\mathcal{B}}/\Delta\mathcal{B}$		
		$< 8 \text{ GeV}^2$	$8 - 16 \text{ GeV}^2$	$> 16 \text{ GeV}^2$
$\mathcal{B}(\mathcal{B} \rightarrow \rho\ell\nu)$	+2.9% -3.4%	$\pm 0.1\%$	$\pm 3.7\%$	+7.8% -10.2%
$\mathcal{B}(B \rightarrow X_c\ell\nu)$	$\pm 2.8\%$	$\pm 4.8\%$	$\pm 9.9\%$	$\pm 13.0\%$
Tagging	$\pm 4.7\%$	$\pm 4.7\%$	$\pm 4.7\%$	$\pm 4.7\%$
$B\bar{B}$ background	+8.8% -9.1%	+5.6% -1.6%	+10.1% -14.2%	+14.0% -17.9%
Total Error	+12.2% -12.5%	+11.5% -10.2%	+17.2% -19.9%	+24.1% -27.4%

$\approx 30\%$ plv X-feed

Mainly $B^0\bar{B}^0$ bkg

$\pi^+l\nu$ with SL Tag : Branching Fractions and q^2

$$\mathcal{B}(B^0 \rightarrow \pi^- \ell^+ \nu) = (1.03 \pm 0.25 \pm 0.13) \times 10^{-4}$$



- SL tag analyses **statistically limited**.
- Yields not yet large enough to **discriminate between FF models**.

Untagged $B \rightarrow \pi l \nu$ and $B \rightarrow \rho l \nu$

- **Neutrino Reconstruction:** Reconstruct ν from full event

$$(\vec{p}_{\text{miss}}, E_{\text{miss}}) = (\vec{p}_{\text{beams}}, E_{\text{beams}}) - \left(\sum_i \vec{p}_i, \sum_i E_i \right) \quad \& \text{ ensure good reco. quality}$$

- **Cut on missing mass:** $|M_{\text{miss}}^2 / 2E_{\text{miss}}| < 0.4 \text{ GeV}$

- Harsh suppression of $b \rightarrow cl \nu$ bkg (kinem. cuts on p_1^*, p_h^* ; mainly for $\rho l \nu$)
 $e^+e^- \rightarrow q\bar{q}$ bkg (topological cuts)

- Max-LH fit of signal and background in ΔE , m_{ES} , and q^2

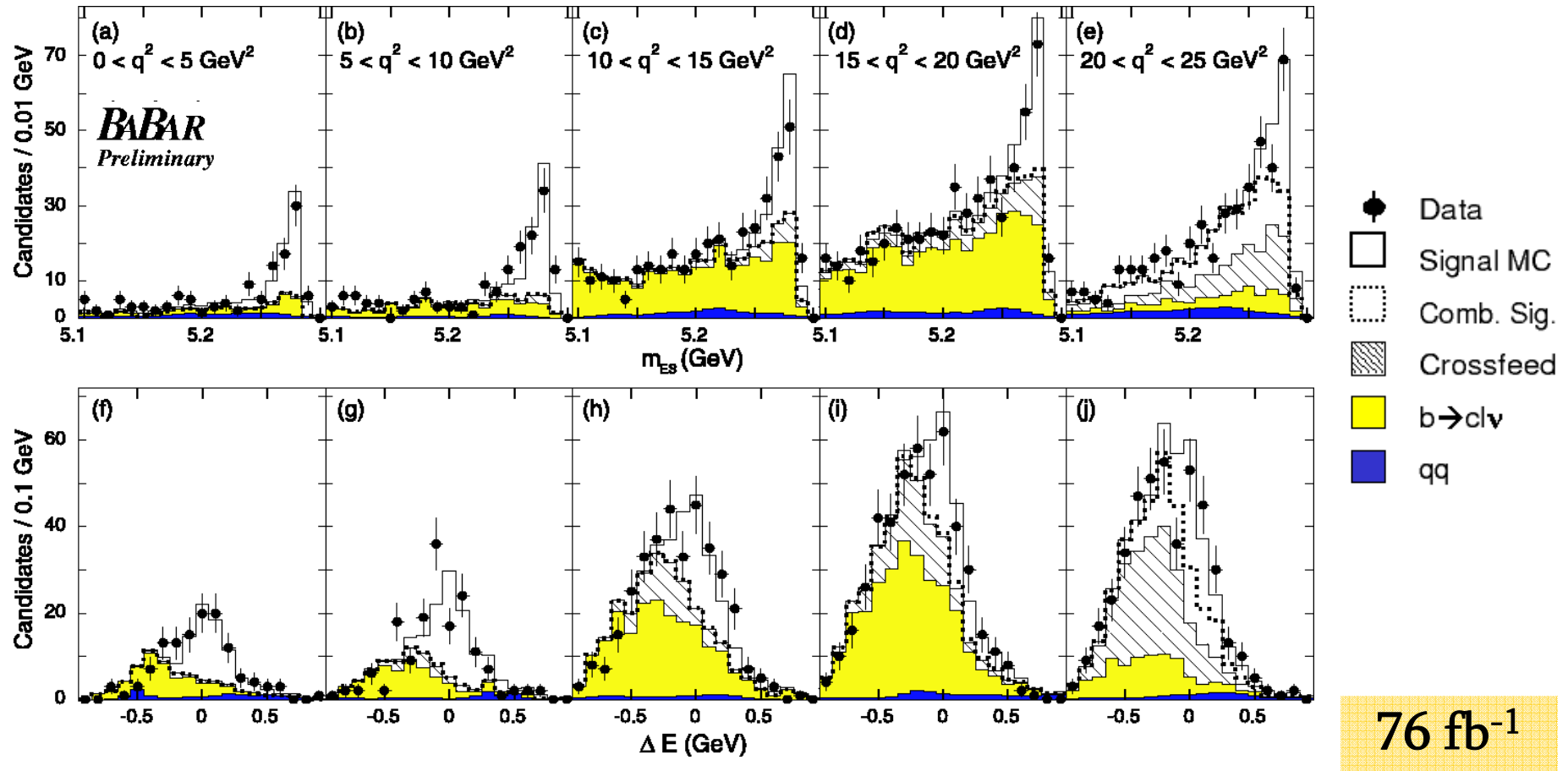
$$\Delta E = E_B^* - \sqrt{s}/2 \quad m_{ES} = \sqrt{s/4 - |\vec{p}_B^*|^2} \quad q^2 = (p_l + p_\nu)^2$$

- Fit all 4 signal modes simultaneously (π^+ , π^0 , ρ^+ , ρ^0)
- Use isospin relations to reduce number of signal parameters :

$$\Gamma(B^0 \rightarrow \pi^- l^+ \nu) = 2 \Gamma(B^+ \rightarrow \pi^0 l^+ \nu)$$

$$\Gamma(B^0 \rightarrow \rho^- l^+ \nu) = 2 \Gamma(B^+ \rightarrow \rho^0 l^+ \nu)$$

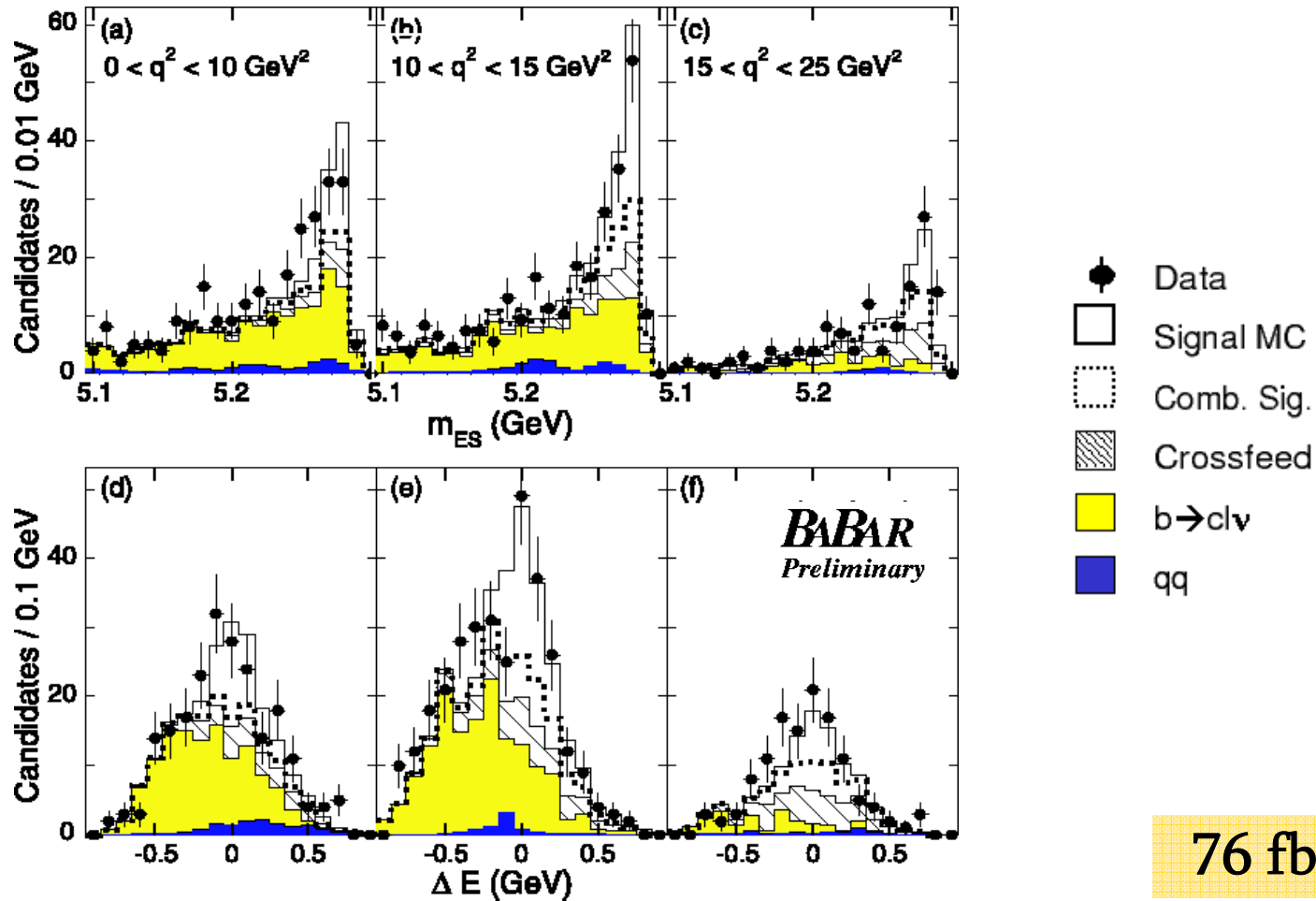
Untagged $\pi\nu$: Fitted ΔE and m_{ES}



427 π^+ , 147 π^0

5 bins for $\pi\nu$

Untagged $\pi l \nu$: Fitted ΔE and m_{ES}



76 fb⁻¹

3 bins for $\rho l \nu$

101 ρ^+ , 104 ρ^0

Fitting the Form-Factor Shape

Fit Becirevic-Kaidalov (BK) Parametrization to data:

$$f_+(q^2) = \frac{c_B(1-\alpha)}{(1-q^2/m_{B^*}^2)(1-\alpha q^2/m_{B^*}^2)} \quad \alpha = \text{shape parameter, } c_B = \text{norm. factor}$$

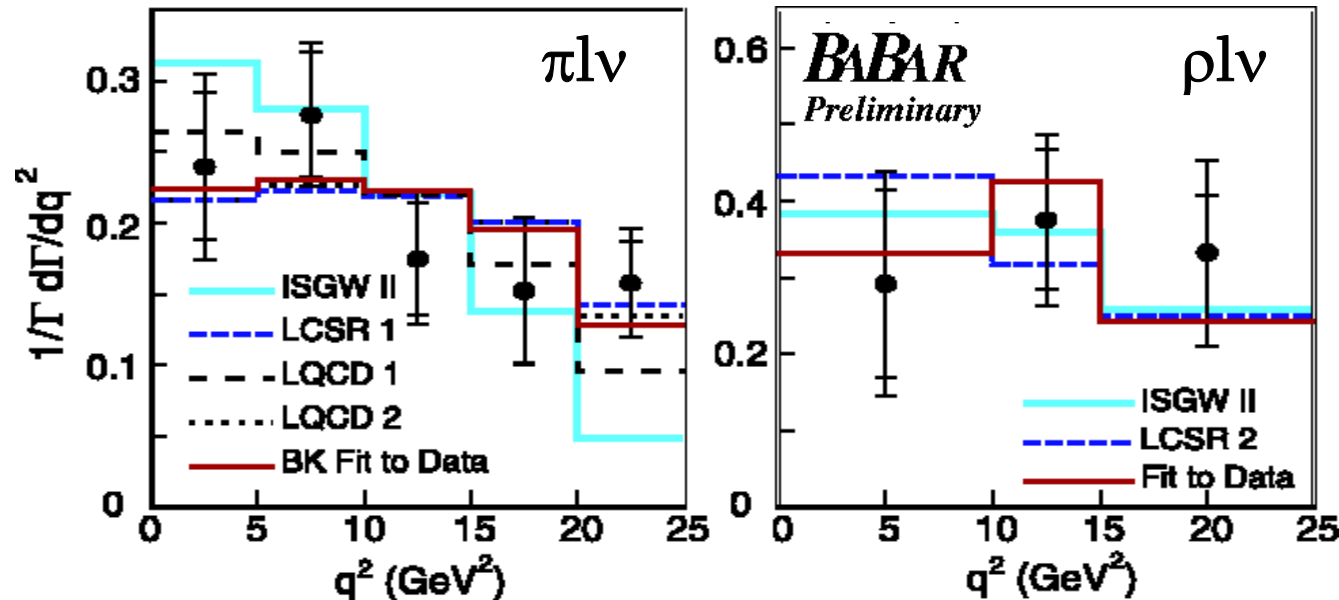
Fit result: $\alpha = 0.60 \pm 0.15$ (HPQCD : $\alpha = 0.42$, FNAL : $\alpha = 0.62$)

π Model	ρ Model	$\mathcal{B}(B^0 \rightarrow \pi^- \ell^+ \nu)$ (10^{-4})	$\mathcal{B}(B^0 \rightarrow \rho^- \ell^+ \nu)$ (10^{-4})
BK Fit to Data	BALL05	1.38 ± 0.10	2.14 ± 0.21
ISGW2	BALL05	1.41 ± 0.14	2.08 ± 0.26
BALL04	BALL05	1.37 ± 0.10	2.15 ± 0.21
HPQCD04	BALL05	1.40 ± 0.10	2.13 ± 0.22
FNAL04	BALL05	1.38 ± 0.10	2.14 ± 0.21
BK Fit to Data	ISGW2	1.46 ± 0.10	1.85 ± 0.15
Total Spread		-1% +6%	+1% -13%

Dependence on $\pi \ell \nu$ FF small.
Biggest effect from $\rho \ell \nu$ X-feed

Acceptance effect due to
harsh kinematic cuts

Measured q^2 Distributions and Form Factors



- Recent LQCD and LCSR calculations agree well with data
- ISGW2 shows marginal agreement for $\pi l\nu$

π FF Model	ISGW II	BALL'04	FNAL'04	HPQCD'04	BK Fit to Data
Prob(χ^2) (%)	3	52	49	39	51
ρ FF Model	ISGW II	BALL'98	BALL'05	Fit to Data	
Prob(χ^2) (%)	52	26	48	68	

- Errors for $\rho l\nu$ still too large to study 3 form factors.

Systematic Uncertainties (Untagged)

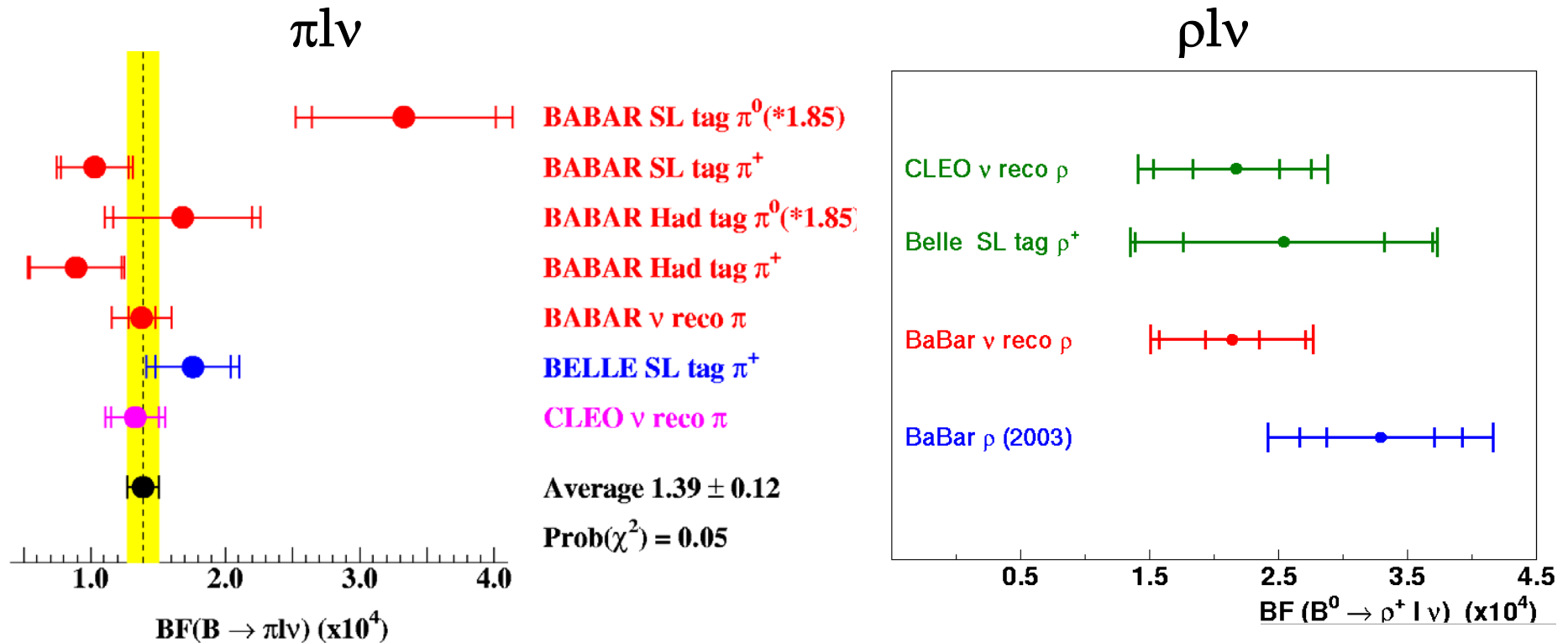
q^2 Range (GeV ²)	$\delta\mathcal{B}_\pi/\mathcal{B}_\pi$ (%)						$\delta\mathcal{B}_\rho/\mathcal{B}_\rho$ (%)			
	0-5	5-10	10-15	15-20	20-25	0-25	0-10	10-15	15-25	0-25
Neutrino Reconstruction	8.3	7.0	11.4	3.7	11.0	8.1	21.0	12.7	18.2	17.0
K_L^0 Interactions	4.2	1.4	1.8	3.7	3.6	2.9	11.9	2.7	2.8	5.9
$b \rightarrow cl\nu$	5.0	3.9	3.9	4.3	3.6	4.2	7.2	1.8	3.8	4.2
$b \rightarrow ul\nu$	0.7	1.6	0.8	3.2	7.7	2.8	10.9	9.0	21.2	12.9
non- $B\bar{B}$ Background	13.5	2.4	1.0	2.2	7.8	5.6	11.2	0.9	1.6	4.6
Total Error	17.4	9.2	12.6	8.3	16.8	12.8	30.5	16.8	28.6	24.7

$$\mathcal{B}(B^0 \rightarrow \pi^- \ell^+ \nu) = (1.38 \pm 0.10 \pm 0.17 \pm 0.08) \times 10^{-4}$$

$$\mathcal{B}(B^0 \rightarrow \rho^- \ell^+ \nu) = (2.14 \pm 0.21 \pm 0.51 \pm 0.28) \times 10^{-4}$$

- Better statistical precision than previous measurements.
- Syst. error dominated by ν reconstruction. Will decrease with improved track/neutral reconstruction.
- Results less dependent on theoretical predictions (own FF measurement).

Overview: Branching Fraction Measurements



Testing isospin symmetry:

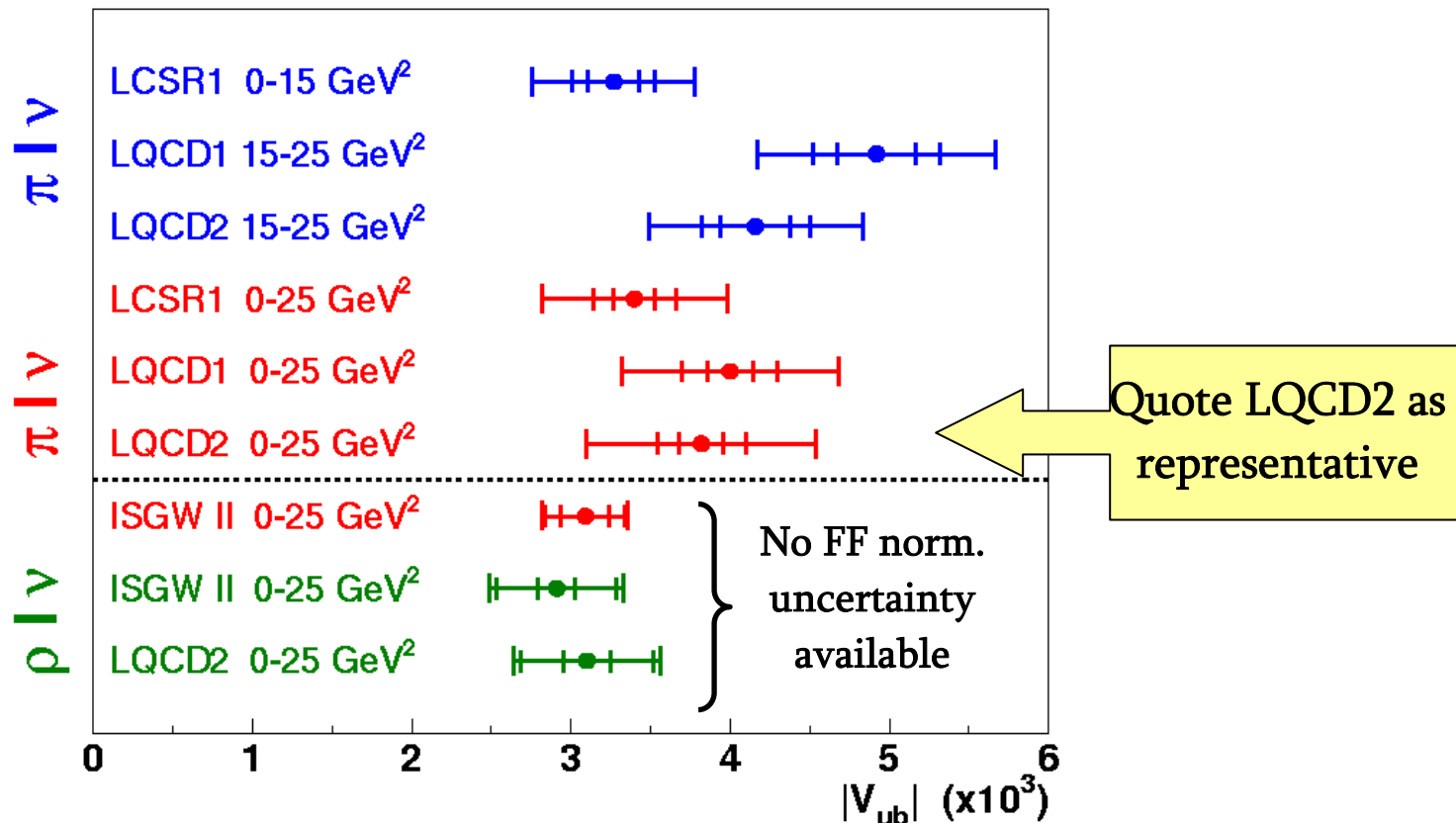
Measure $\pi^+ l \nu$, $\pi^0 l \nu$ separately (untagged)

$$\Gamma(B^0 \rightarrow \pi^- \ell^+ \nu) / \Gamma(B^+ \rightarrow \pi^0 \ell^+ \nu) = 1.85 \pm 0.34$$

Extraction of $|V_{ub}|$

- Measurement in bins of q^2 allows extraction of $|V_{ub}|$ for various q^2 regimes and FF calculations :

LCSR $q^2 < 15 \text{ GeV}^2$, LQCD $q^2 > 15 \text{ GeV}^2$
 or extrapolation to whole q^2 range



Prospects and Conclusions

- Error on BF will decrease through:

- more precise measurements of $b \rightarrow clv$ and $b \rightarrow ulv$ (res & non-res) BFs, FFs
- improved **track** and **neutral reconstruction** ($\rightarrow \nu$ reco)
- more data \rightarrow prospects for 500 fb^{-1} :

	Now	500 fb^{-1}			
	$\pi + \pi^0$	$\pi + \pi^0$	σ_{stat}	σ_{syst}	$\sigma_{\text{stat+syst}}$
$B_{\text{reco tags}}$	27	165	10%	4%	11%
SL tags	107	380	8%	6%	10%
Untagged	619	4070	3%	8%	9%

- Ready to analyze more signal modes: $\eta, \eta', \omega, \dots$

- Need help from theory: FF calculation for $\omega lv, \eta lv$

- Reliable error estimate for ρlv FF \rightarrow needed for π and ρ BFs and $|V_{ub}|$
- Uncertainty on $|V_{ub}|$ dominated by theory!