Studies of exclusive semileptonic *B* decays and extraction of |V_{ub}| at *BaBar*

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(on behalf of the *BaBar* collaboration)

Exclusive charmless semileptonic B decays

$B^0 \to \pi^- \ell^+ \nu$ $B^+ \to \pi^0 \ell^+ \nu$ $B^+ \to \eta \ell^+ \nu$ $B^+ \to \eta' \ell^+ \nu$

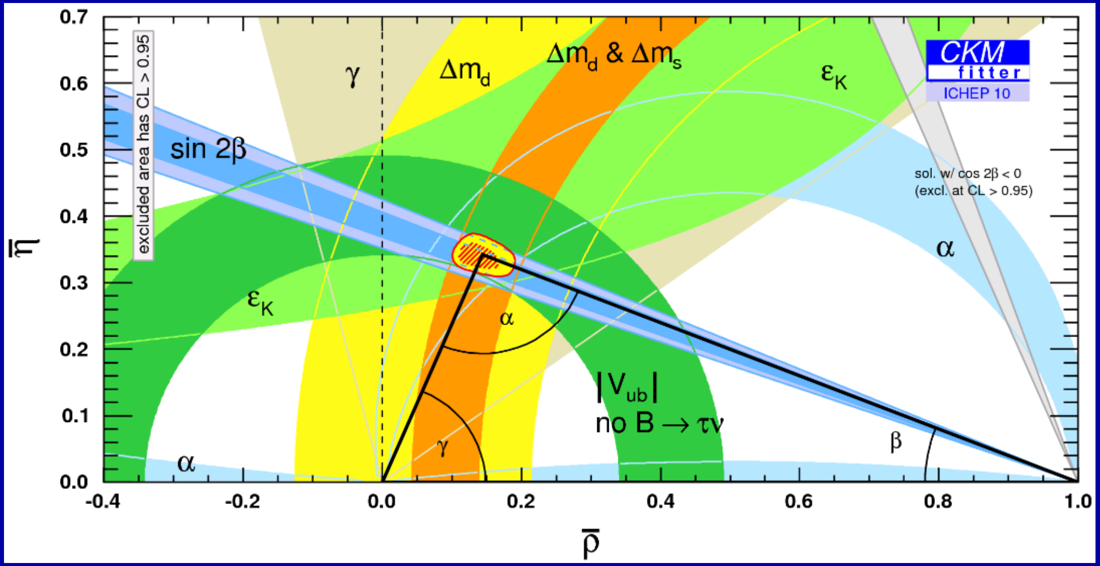
$B^0 \to \rho^- \ell^+ \nu$ $B^+ \to \rho^0 \ell^+ \nu$

In Standard model, quark flavour changes occur through weak interactions via coupling of a W gauge boson

Such couplings are prop. to relevant CKM matrix elements

Probability of a b quark to decay into a u quark is prop. to $\left|V_{ub}\right|^2$

Unitarity of CKM matrix represented by triangle in the ρ-η complex plane



$\left|V_{ub}\right|$ second poorest known element, its precise measurement would constrain the description of weak interactions and CP violation

$\left|V_{ub}\right|$ results presented at FPCP2010 (Bob Kowaleski)

$$B \to \pi \ell \nu : (2.95 \pm 0.31) \times 10^{-3}$$ (exclusive)

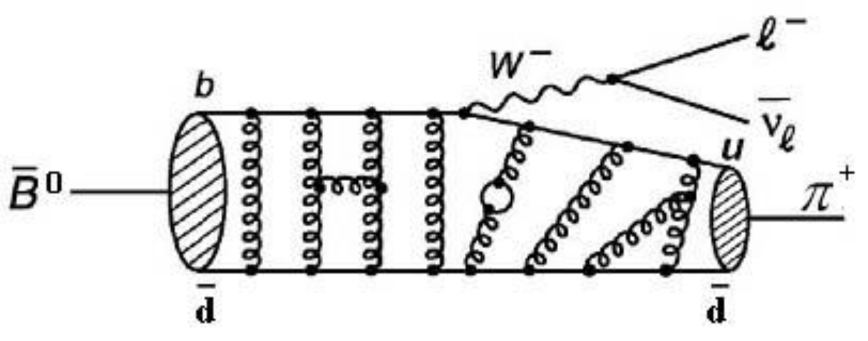
$$B \to u \ell \nu : (4.27 \pm 0.38) \times 10^{-3}$$ (inclusive)

Should we take this difference of 2.7 σ seriously?

Measurement of $|V_{ub}|$ requires study of $b \to u$ transition

Semileptonic $b \to u \ell \nu$ decays are best :
- much easier to understand theoretically than hadronic decays
- much easier to study experimentally than purely leptonic decays because far more abundant

Exclusive semileptonic decays e.g. $B^0 \to \pi^- \ell^+ \nu$ & $B^+ \to \eta^{(\prime)} \ell^+ \nu$ involve a $b \to u$ transition



The value of $\left|V_{ub}\right|$ is extracted from the measured $\Delta B(q^2)$ as a function of q^2, the momentum transferred squared

$$\Delta B(q^2) = \frac{\tau_{B^0} \left|V_{ub}\right|^2 G_F^2}{24\pi^3} \int_{q^2_{\min}}^{q^2_{\max}} |\vec{p}_{Xu}|^3 \; f_+(q^2)^2 dq^2$$

$f_+(q^2)$: form factor provided by QCD calculations

Experimental data used to discriminate between various QCD calculations by measuring the $f_+(q^2)$ *i.e.* $\Delta B(q^2)$ shape precisely

$$\left|V_{ub}\right| = \sqrt{\Delta B / (\tau_{B^0} \Delta\zeta)} \qquad \Delta\zeta = \frac{G_F^2}{24\pi^3} \int_{q^2_{\min}}^{q^2_{\max}} |\vec{p}_{Xu}|^3 \; f_+(q^2)^2 dq^2$$

Report on 2 recent analyses in *BaBar* :

- In the π-η analysis, study 3 decay modes and measure $q^2 = (P_B - P_{meson})^2$

$$B^0 \to \pi^- \ell^+ \nu \qquad B^+ \to \eta \ell^+ \nu \qquad B^+ \to \eta' \ell^+ \nu$$

- In the π-ρ analysis, study 4 decay modes and measure $q^2 = (P_\ell + P_\nu)^2$

$$B^0 \to \pi^- \ell^+ \nu \quad B^+ \to \pi^0 \ell^+ \nu \quad B^0 \to \rho^- \ell^+ \nu \quad B^+ \to \rho^0 \ell^+ \nu$$

Will concentrate on $B \to \pi \ell \nu$ mode (mostly π-η analysis)

- most precise measurement
- value of $|V_{ub}|$

Comparison of the 2 analyses

	π-η analysis	π-ρ analysis
Luminosity on peak $\Upsilon(4S)$	$422.6\ \mathrm{fb}^{-1}$	$349.0\ \mathrm{fb}^{-1}$
Number of BB pair events	464 millions	377 millions
q^2 evaluation	$(P_B-P_{meson})^2$	$(P_\ell+P_\nu)^2$
Cut strategy	q^2 dependent, cuts	q^2 dependent, NN
Cut selection	Loose ν cuts	Tighter ν cuts
Signal efficiency	8% to 15%	6% to 7%
Background/Signal	11.5	6.3
$B^0\to\pi^-\ell^+\nu$ yield	11778 ± 435	7181 ± 279
Number of q^2 bins in π mode	12	6
Fit strategy	1-mode $(\pi^-,\eta,\eta')\ell\nu$	4-modes $(\pi^-,\pi^0,\rho^-,\rho^0)\ell\nu$
Systematic uncertainties	Full gaussian	$\pm1\sigma$

Estimated overlap < 20%

$$\Delta B(q_i^2) = N_i / 2\varepsilon_i N_B$$ N_i : number of observed signal events

$$efficiency : \varepsilon_i = \frac{N_i}{N_i^0} = \frac{total\ \ yield\ in\ i^{th}\ q^2\ bin\ after\ all\ cuts}{total\ \ yield\ in\ i^{th}\ q^2\ bin\ before\ any\ cut}$$

factor of 2 since signal yield & eff. obtained for sum of e & muons

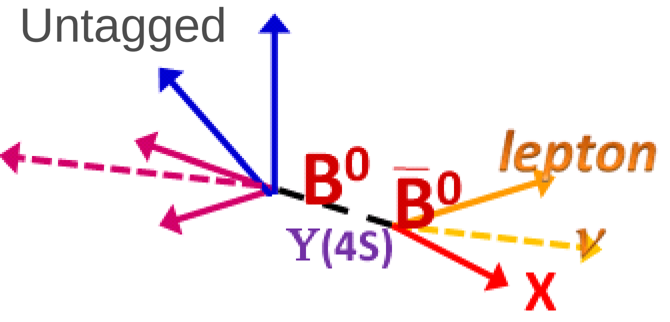
$$N_B = N_{B^+} + N_{B^-} = 2N_{BB}B(\Upsilon(4S) \to B^+B^-)$$ [2 : charge conjugate]

$$N_B = N_{B^0} + N_{\bar{B}^0} = 2N_{BB}B(\Upsilon(4S) \to B^0\bar{B}^0)$$

$$N_{BB} : total\ number\ of\ \ B\bar{B}\ \ pairs\ observed$$

Need large amounts of MC events to obtain efficiencies, to optimize the cuts, to get shapes of signal and background distributions

π-η analysis : Loose Neutrino Reconstruction



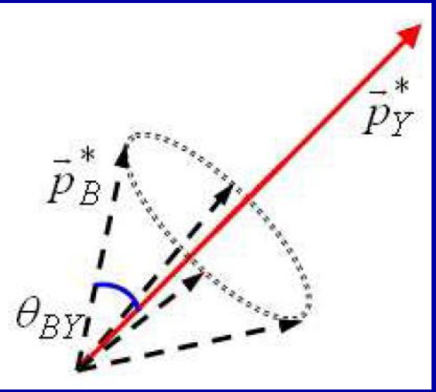
>> Untagged analysis with loose neutrino cuts

>> event's missing momentum ~ signal ν

$$P_\nu = P_{beam} - \sum P_i = \left(\left|\vec{p}_{miss}\right|, \vec{p}_{miss}\right)$$

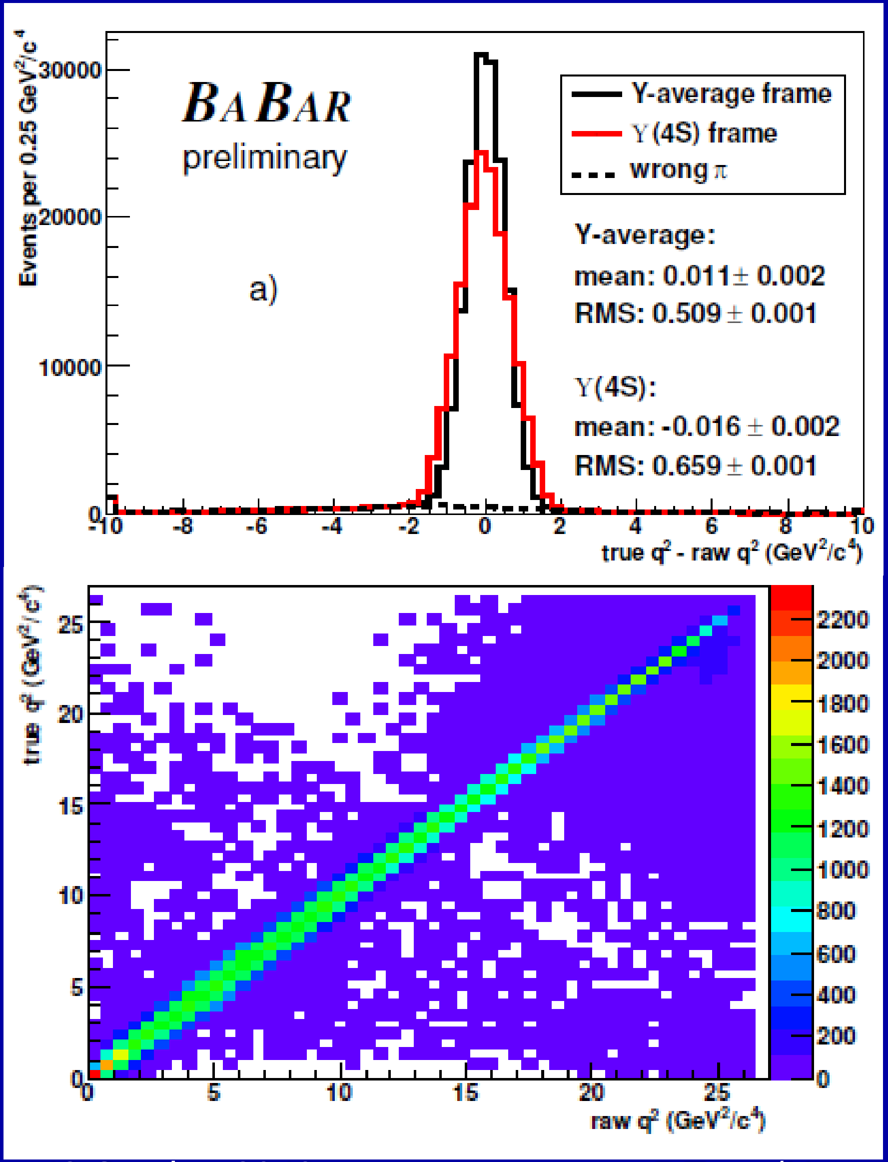
>> High signal yield allows to fit in a large (12) number of q^2 bins

>> Large background yield allows to fit in several bins



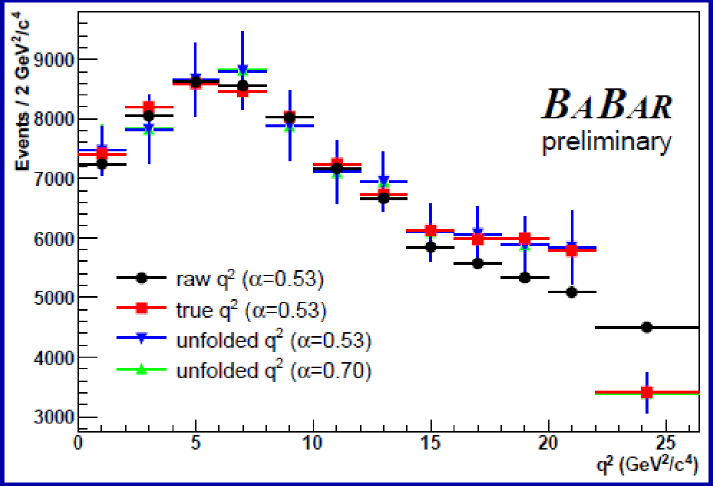
We measure $q^2 = (P_B - P_{meson})^2$ in Y-average frame approximation , $P_Y = P_\pi + P_\ell$, as the mean of 4 different values of q^2 corresponding to 4 different directions of $\vec{p}_B$ on the surface of a cone

π-η analysis : q^2 resolution

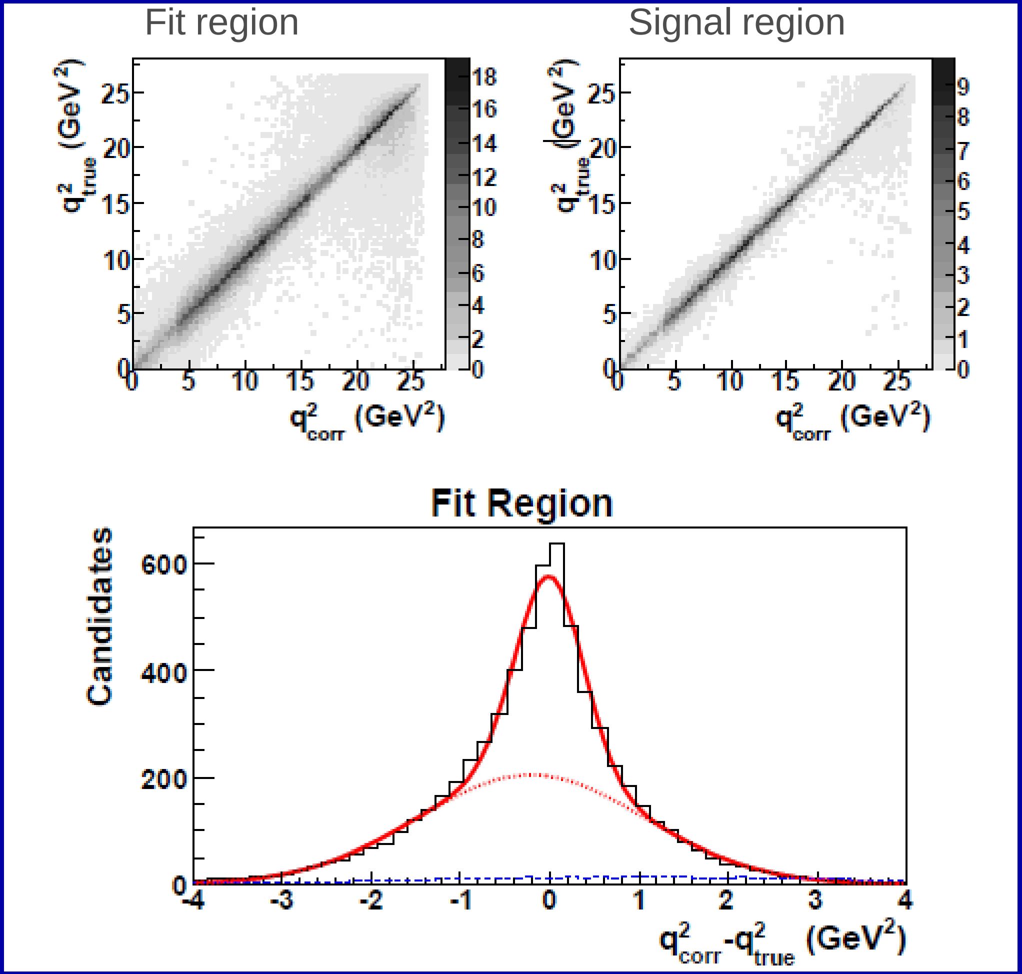


Use of Y-average approximation improves q^2 resolution

The 2D q^2 distribution yields the detector response matrix used to unfold the measured q^2 distribution onto the true q^2 distribution



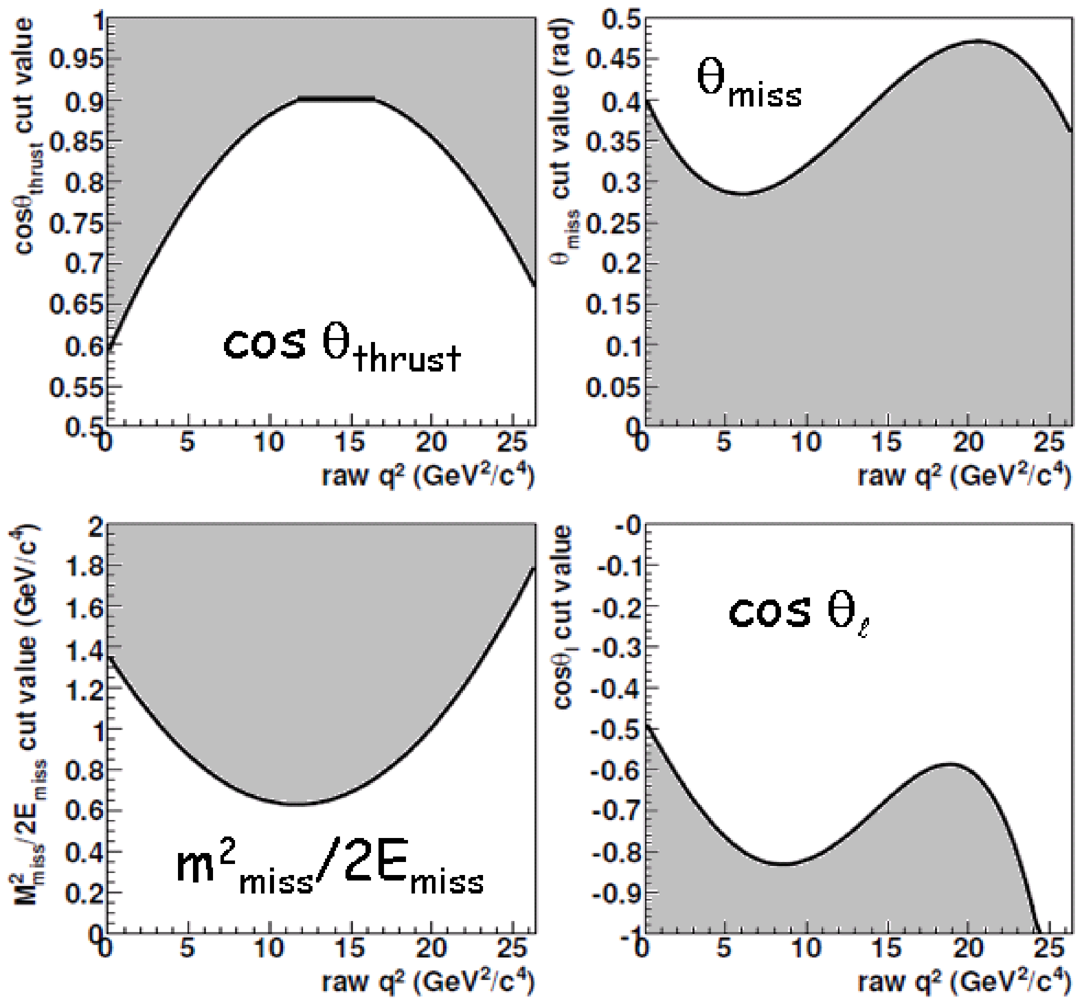
π-ρ analysis : q^2 resolution



similar to results in
$\pi-\eta$ analysis

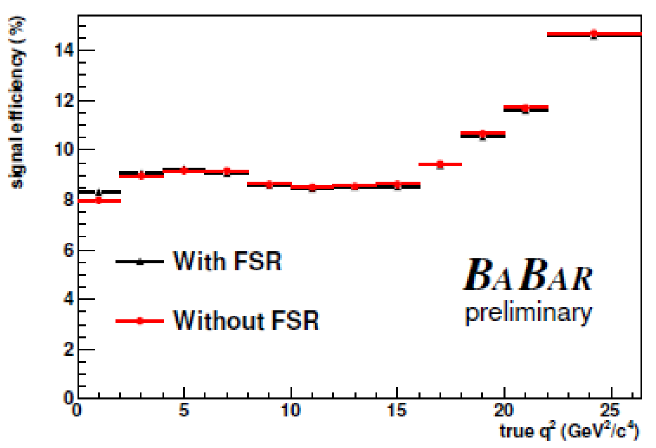
π-η analysis : Event selection

All cuts are optimized to maximize $S/\sqrt{S+B} \approx S/\sigma$



4 cuts are q^2 dependent

Signal efficiency :



π-η analysis : Backgrounds

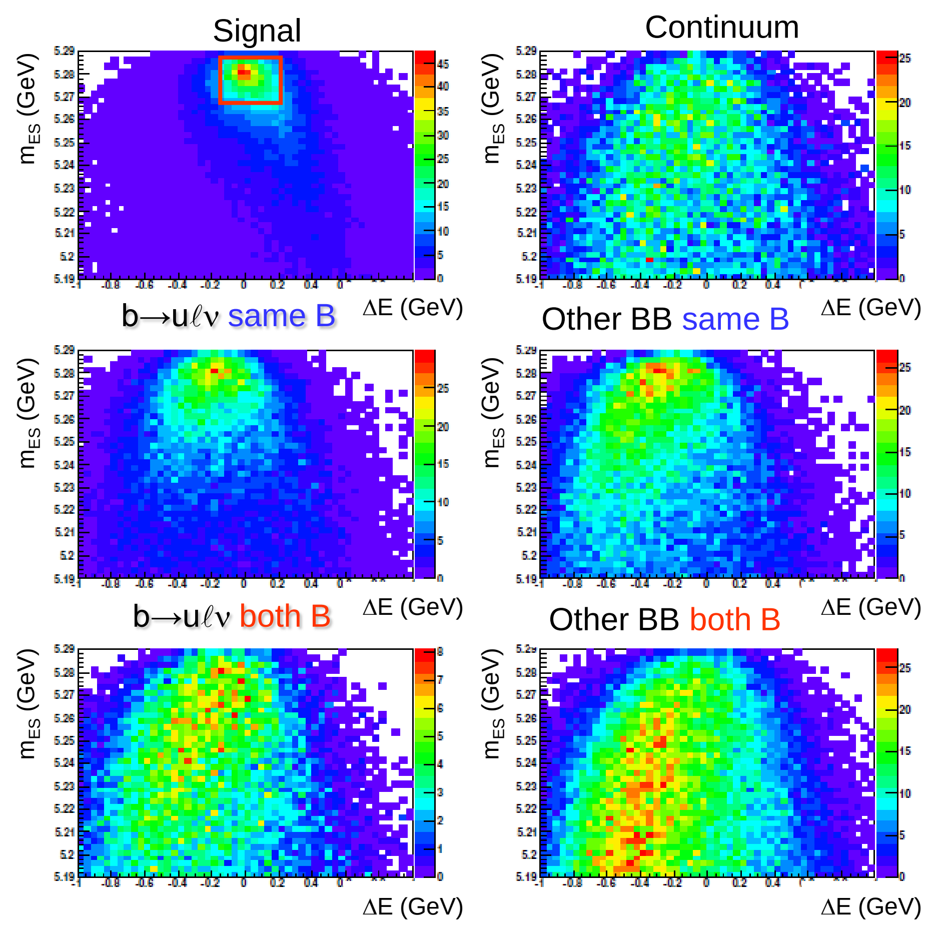
3 main sources of background :

- semileptonic $b \to c \ell \nu$ decays, mostly $B \to D \ell \nu$
- semileptonic $b \to u \ell \nu$ decays $(B \to \rho \ell \nu, B \to \omega \ell \nu, etc...)$
- continuum events

$$\Delta E = \left(P_B \cdot P_{beams} - s/2\right) / \sqrt{s}$$

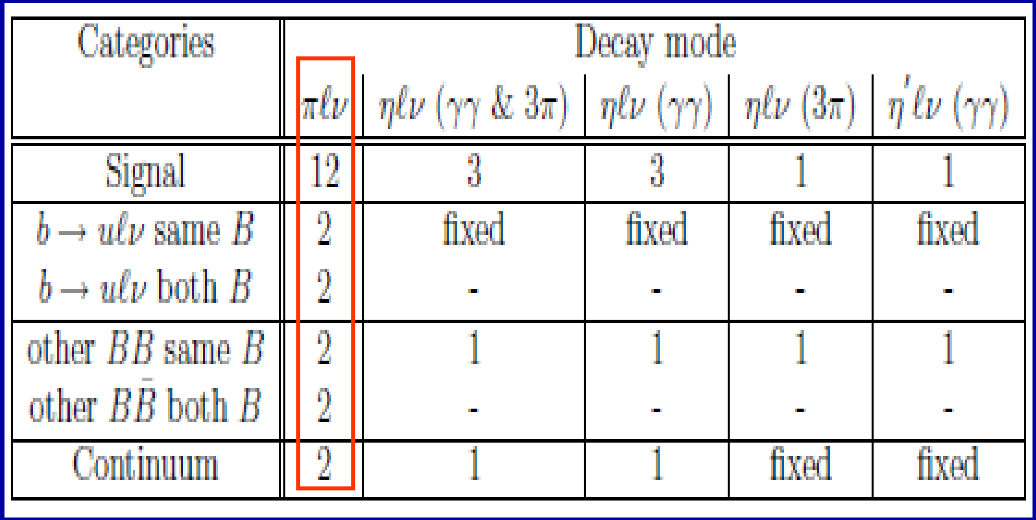
$$m_{ES} = \sqrt{\left(s/2 + \vec{p}_B . \vec{p}_{beams}\right)^2 / E_{beams}^2 - \vec{p}_B^{\,2}}$$

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



same B : ℓ and π originate from the same B meson.
both B : ℓ and π originate from different B mesons.

π-η analysis : Backgrounds categories & fit parameters

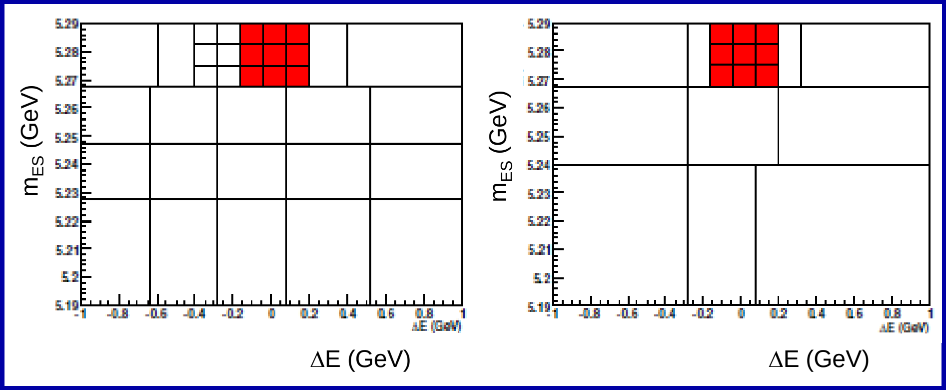


Categories	Decay mode				
	$\pi\ell\nu$	$\eta\ell\nu$ ($\gamma\gamma$ & 3π)	$\eta\ell\nu$ ($\gamma\gamma$)	$\eta\ell\nu$ (3π)	$\eta'\ell\nu$ ($\gamma\gamma$)
Signal	12	3	3	1	1
$b \to u\ell\nu$ same B	2	fixed	fixed	fixed	fixed
$b \to u\ell\nu$ both B	2	-	-	-	-
other BB same B	2	1	1	1	1
other $B\bar{B}$ both B	2	-	-	-	-
Continuum	2	1	1	fixed	fixed

For each bin of q^2 :

$B^0 \to \pi^- \ell^+ \nu$ (34 bins)

$B \to \eta^{(')} \ell \nu$ (19 bins)



π-η analysis : Fit strategy & results

Use ΔE-m_{ES} histograms, from MC as 2D PDFs, in our fit to the data to extract yields of signal and backgrounds as function of q^2

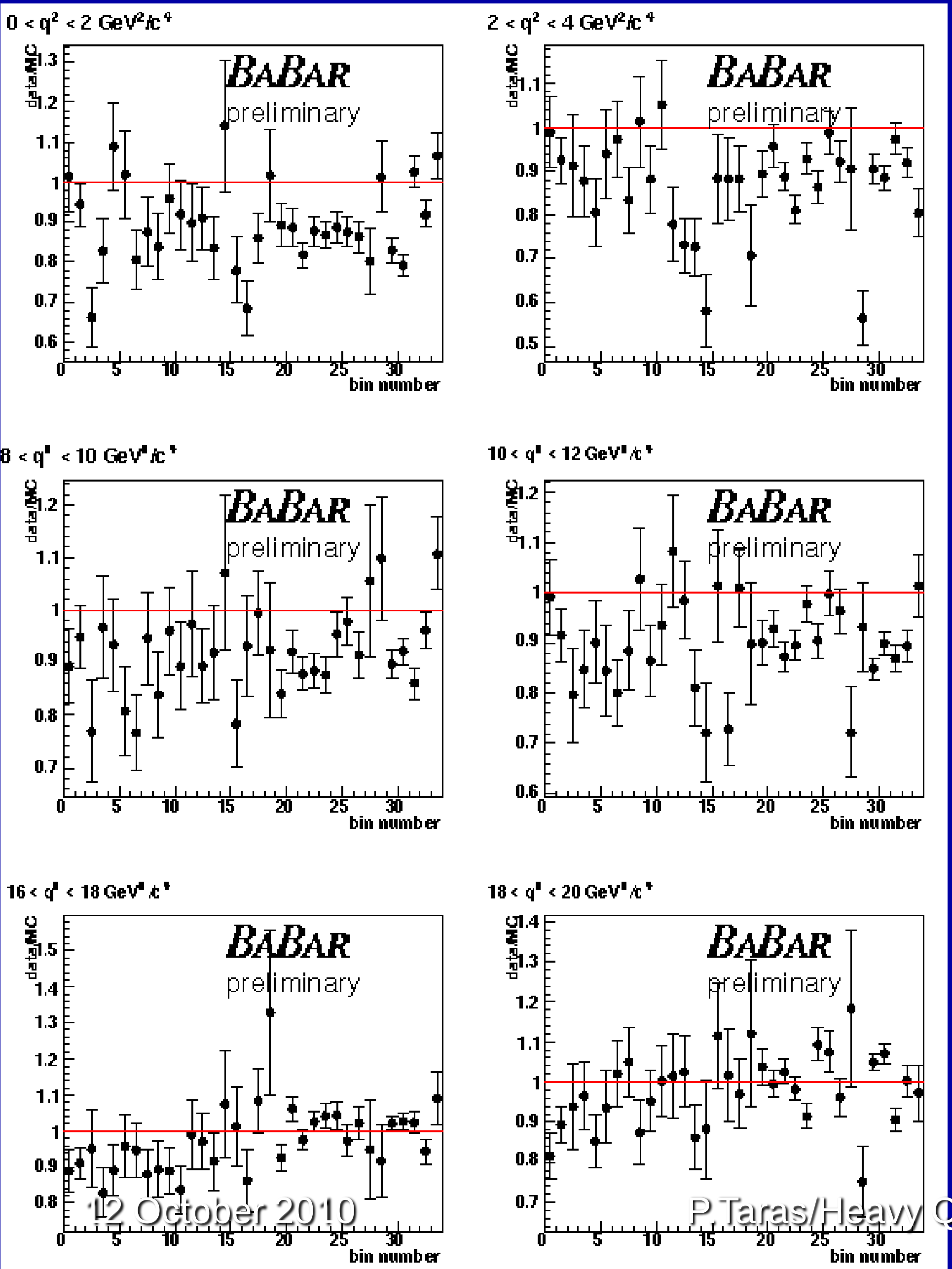
mode	$\pi\ell\nu$	$\eta\ell\nu$	$\eta'\ell\nu$
efficiency %	8.3 – 14.6	1.4 – 2.6	0.6
signal	11778(435)	888(98)	141(46)
b → uℓv	27793(929)	2201(fixed)	204(fixed)
other	80185(963)	17429(247)	2660(82)
continuum	27790(814)	3435(195)	517(fixed)
fit (χ^2/ndf)	411/386	56/52	19/17

π-η analysis : Data/MC ratios in 34 bins of ΔE-m_{ES}

Before the fit

After the fit

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

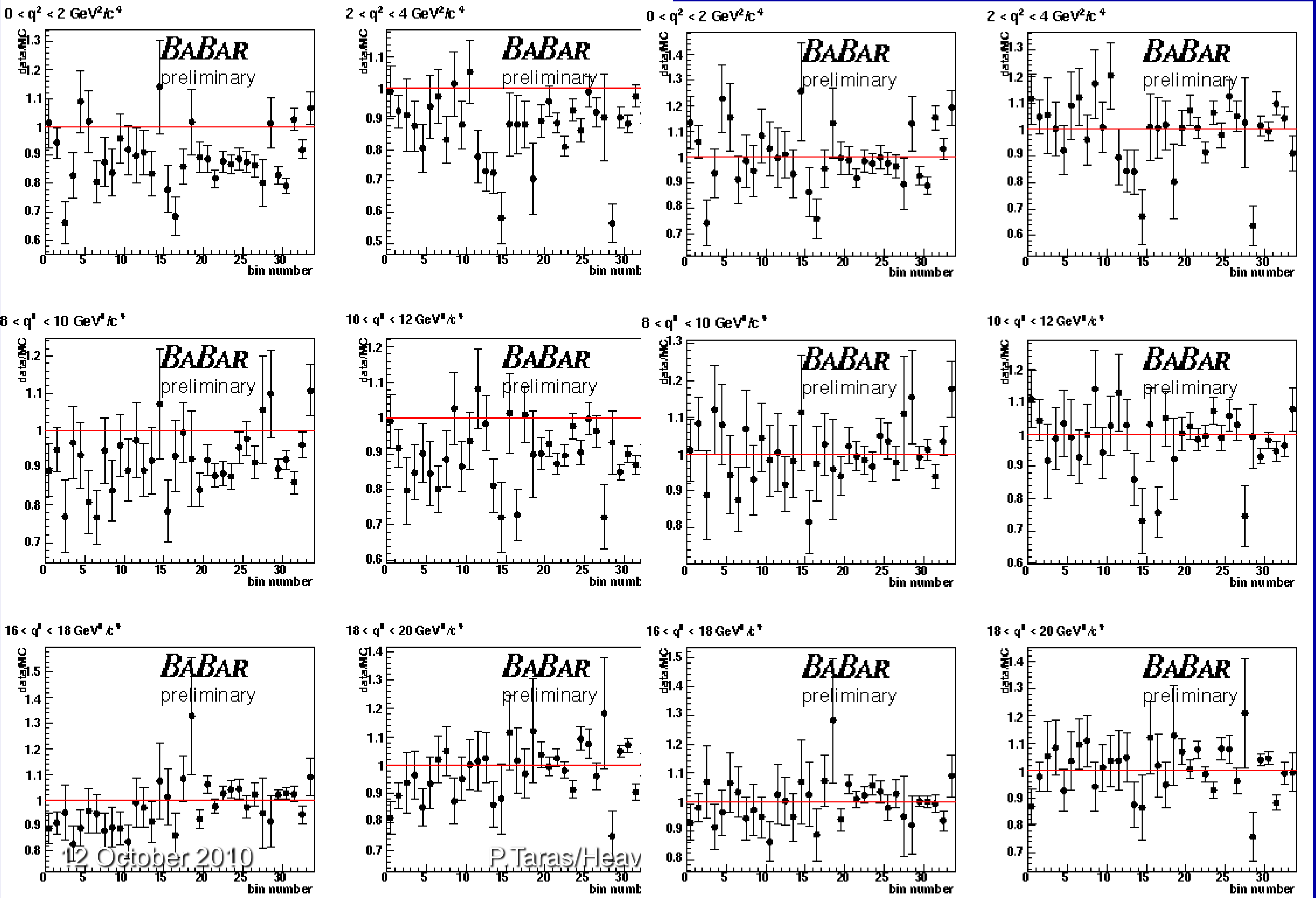


π-η analysis : Data/MC ratios in 34 bins of ΔE-m_{ES}

Before the fit

After the fit

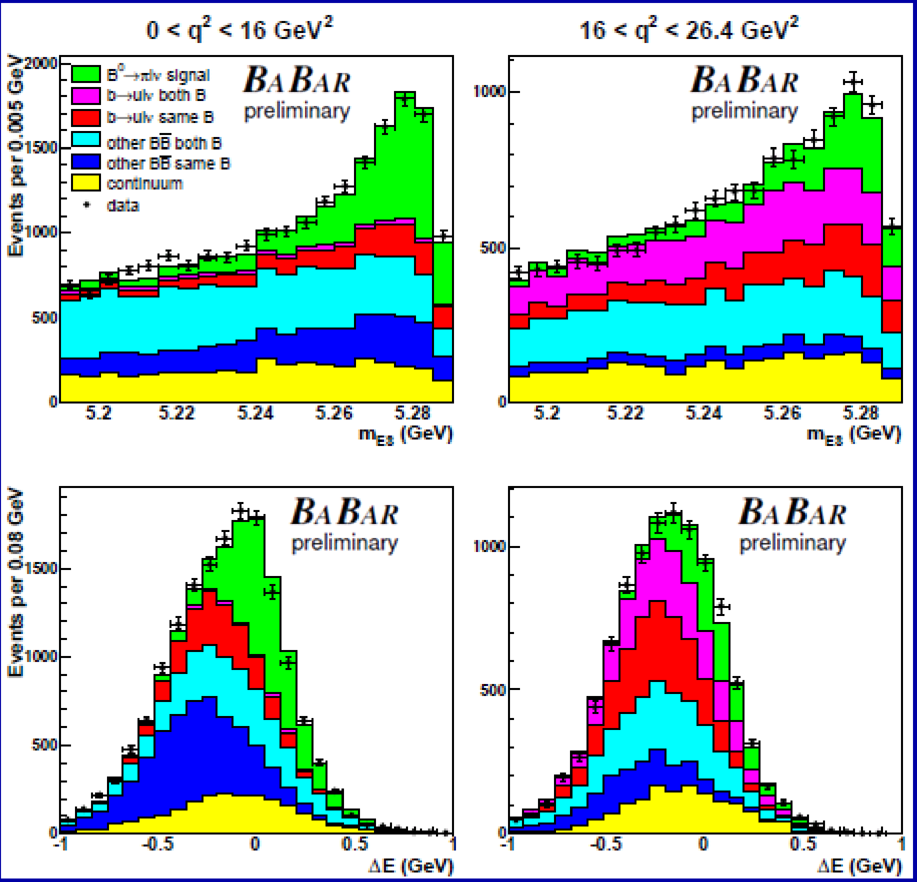
$B^0 \to \pi^- \ell^+ \nu$



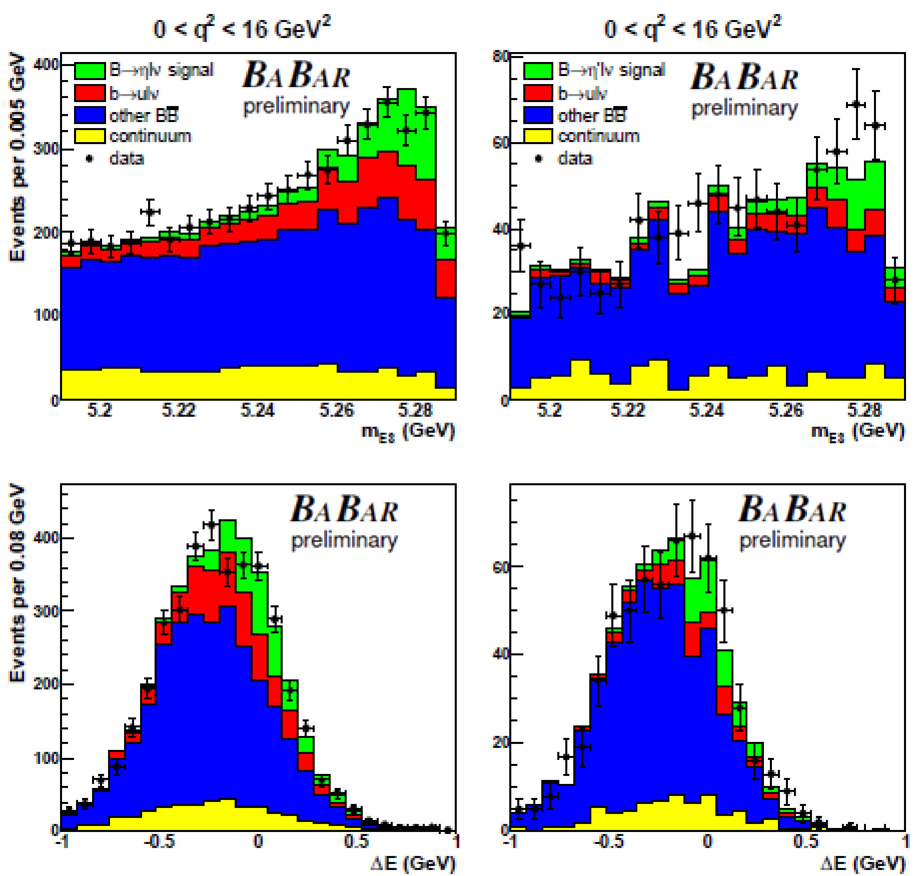
π-η analysis : Fit projections

Signal enhanced region : $-0.16 < \Delta E < 0.20$ GeV; $m_{ES} > 5.268$ GeV

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



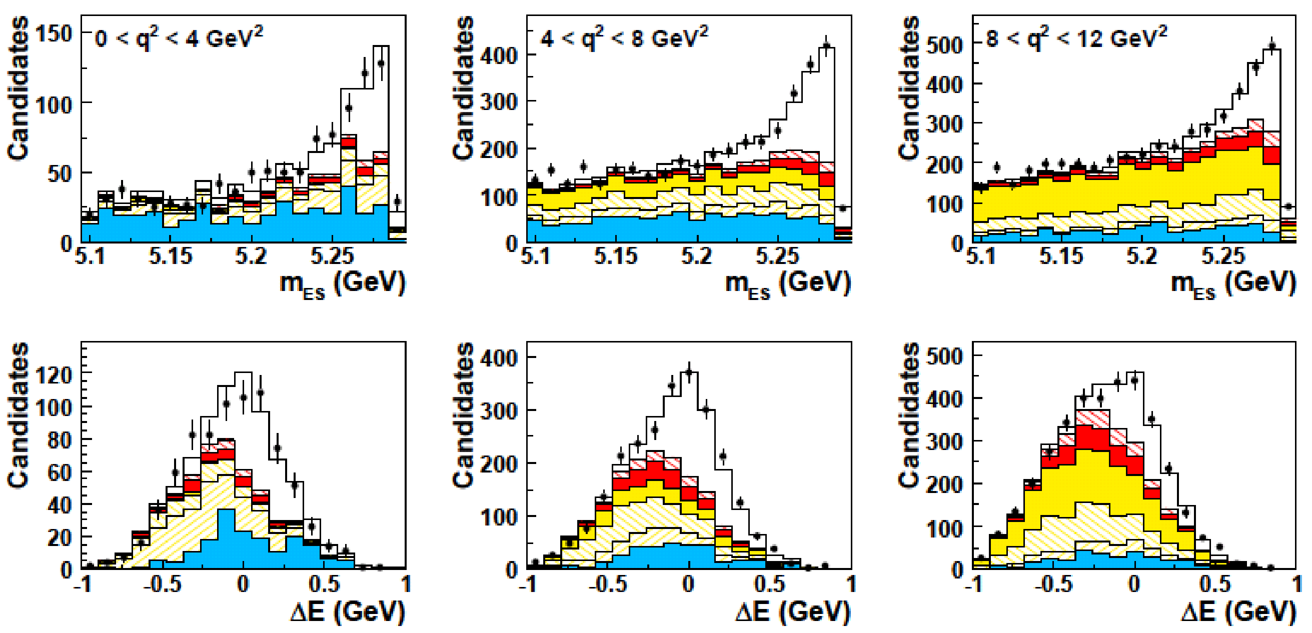
$B \to \eta \ell \nu$ $B \to \eta' \ell \nu$

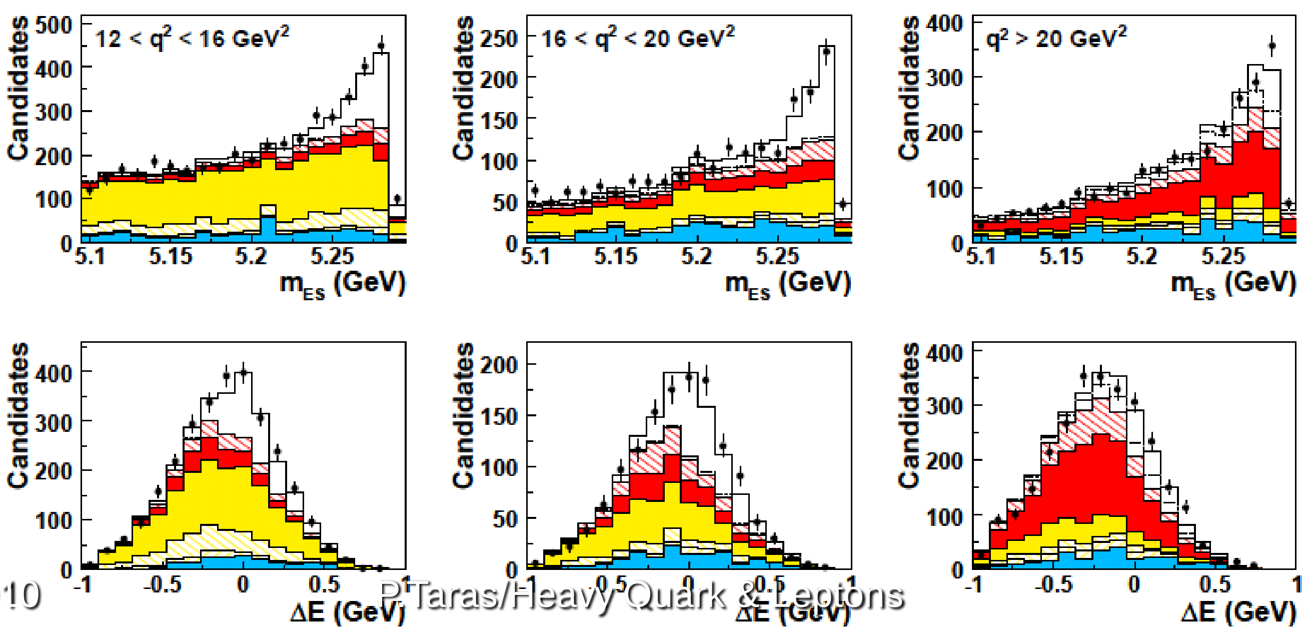


Good agreement between data and fitted MC distributions

π-ρ analysis : Fit projections

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





π-η analysis : Systematic uncertainties & their correlations

- Systematic uncertainties in the partial BF values and their correlations among the q^2 bins investigated

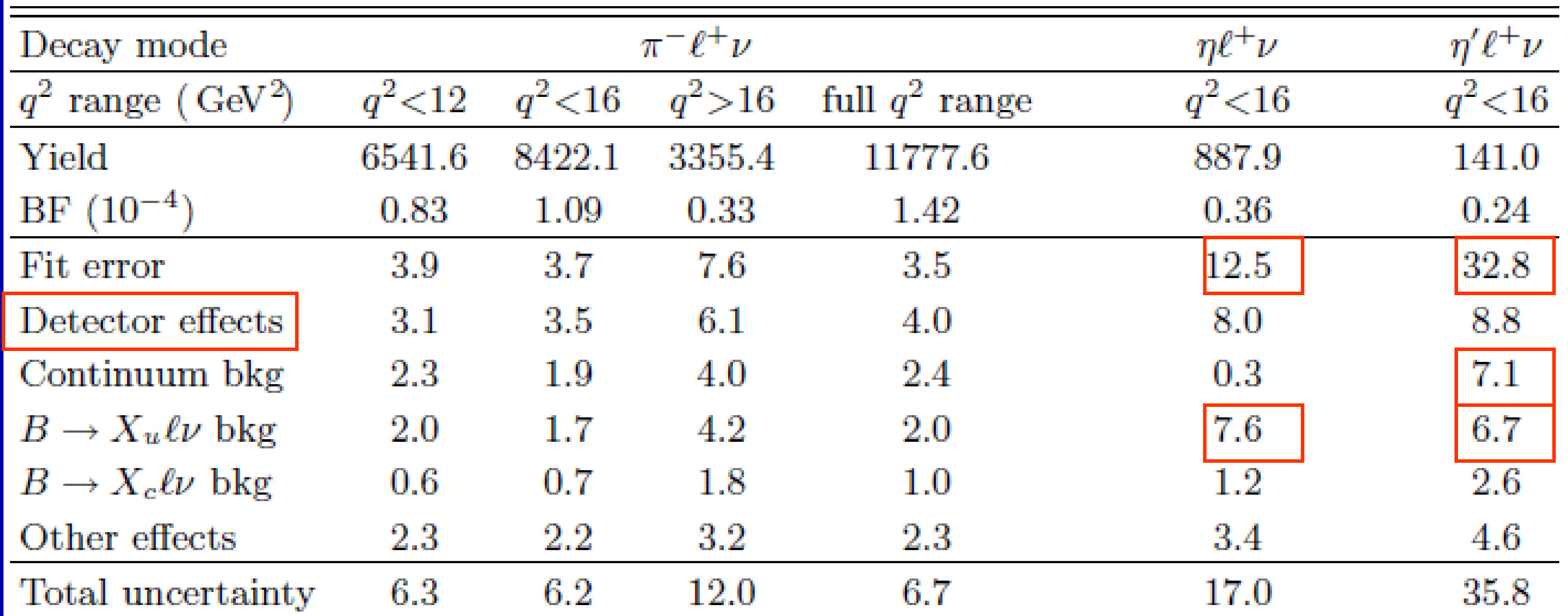
- For each parameter, generate one hundred MC event samples

- Each MC sample contains new $\Delta E - m_{ES}$ distributions generated by varying randomly only the parameter of interest over a full gaussian distribution whose σ is given by the uncertainty on the parameter investigated

- Each MC sample is analyzed the same way as the real data to yield values of partial and total BF

- The contribution of the parameter to the systematic uncertainty is given by the RMS of the distribution of these values over the 100 samples

π-η analysis : Statistical & systematic relative uncertainties

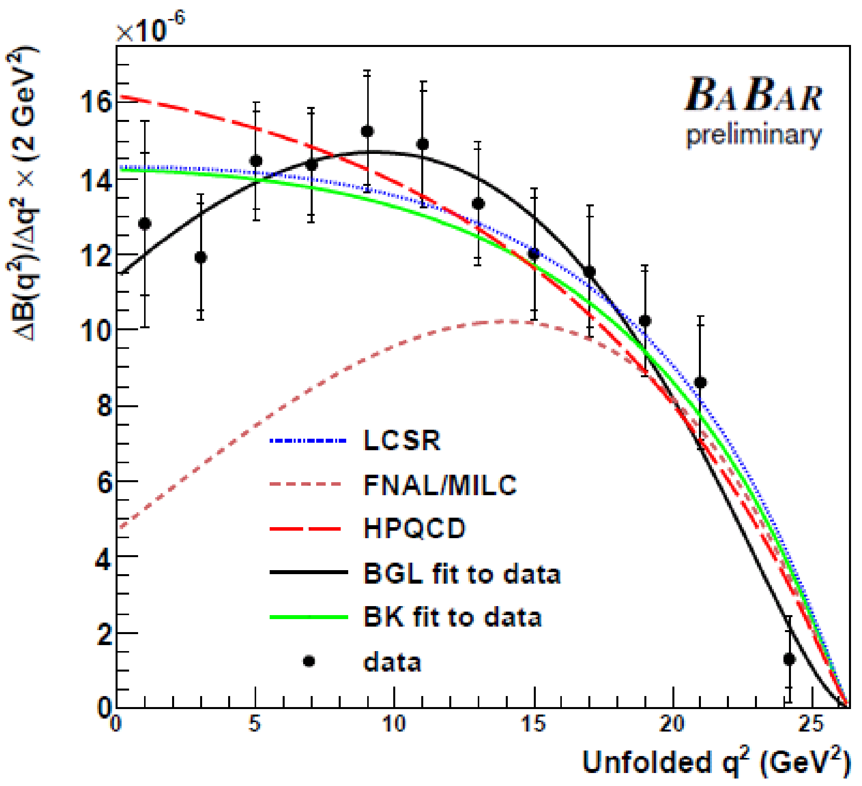


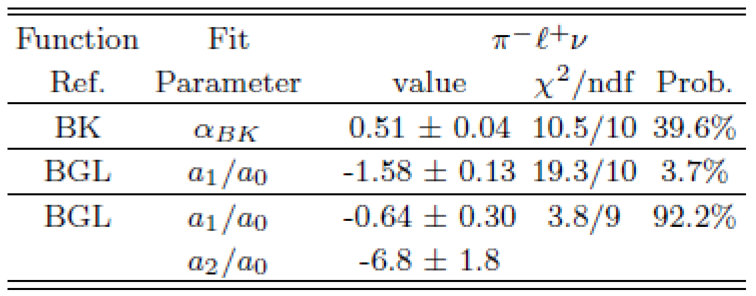
Decay mode	$\pi^- \ell^+ \nu$				$\eta \ell^+ \nu$	$\eta' \ell^+ \nu$
q^2 range (GeV^2)	$q^2 < 12$	$q^2 < 16$	$q^2 > 16$	full q^2 range	$q^2 < 16$	$q^2 < 16$
Yield	6541.6	8422.1	3355.4	11777.6	887.9	141.0
BF (10^{-4})	0.83	1.09	0.33	1.42	0.36	0.24
Fit error	3.9	3.7	7.6	3.5	12.5	32.8
Detector effects	3.1	3.5	6.1	4.0	8.0	8.8
Continuum bkg	2.3	1.9	4.0	2.4	0.3	7.1
$B \to X_u \ell \nu$ bkg	2.0	1.7	4.2	2.0	7.6	6.7
$B \to X_c \ell \nu$ bkg	0.6	0.7	1.8	1.0	1.2	2.6
Other effects	2.3	2.2	3.2	2.3	3.4	4.6
Total uncertainty	6.3	6.2	12.0	6.7	17.0	35.8

- Complete tables and correlation matrices available in backup slides

π-η analysis : Theoretical & experimental ΔB(q^2) distributions

$B^0 \rightarrow \pi^- \ell^+ \nu$





Function	Fit	$\pi^-\ell^+\nu$		
Ref.	Parameter	value	χ^2/ndf	Prob.
BK	α_{BK}	0.51 ± 0.04	10.5/10	39.6%
BGL	a_1/a_0	-1.58 ± 0.13	19.3/10	3.7%
BGL	a_1/a_0	-0.64 ± 0.30	3.8/9	92.2%
	a_2/a_0	-6.8 ± 1.8		

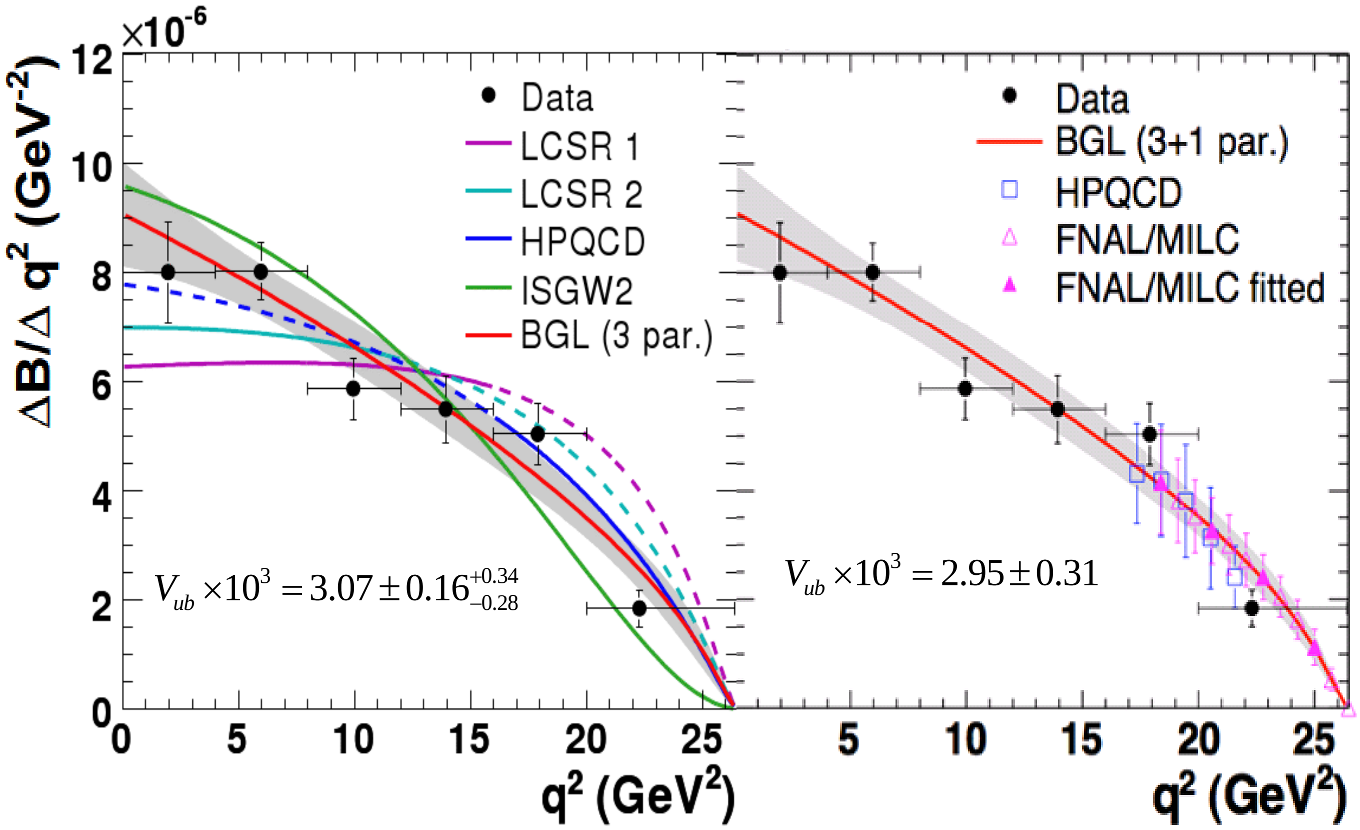
QCD calculations agree with data
in their ranges of validity

arXiv:1010.0987, submitted to Phys. Rev. D

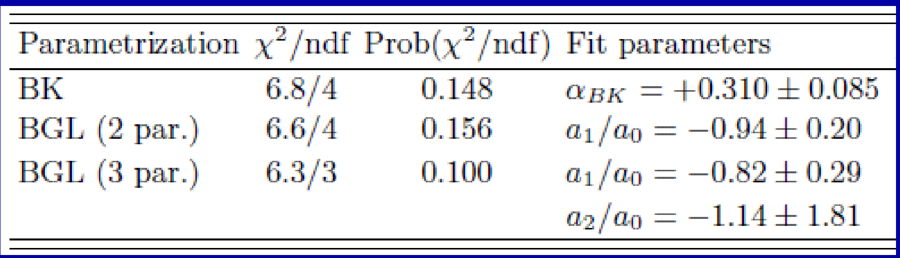
π-ρ analysis : Theoretical & experimental $\Delta B(q^2)$ distributions

B→$\pi\ell\nu$ (combine charged and neutral pions in fit)

Fit to expt data only



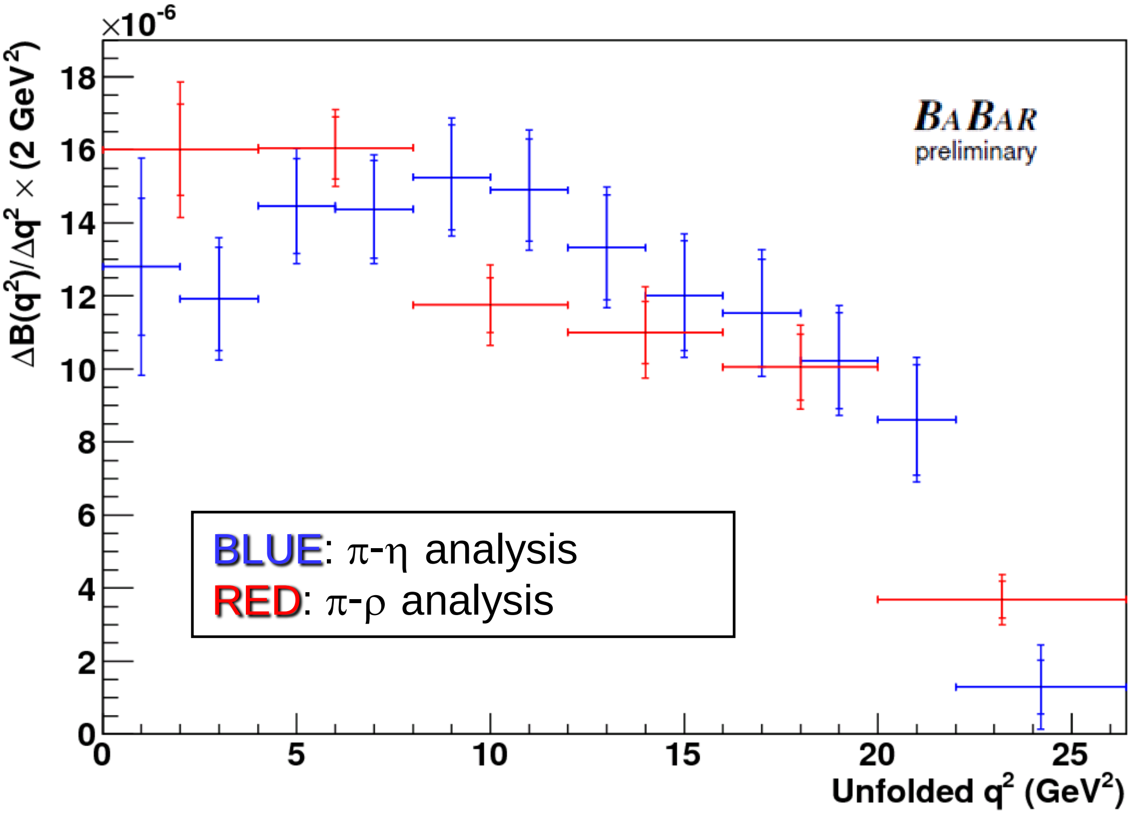
Fit to expt data & theor values



Parametrization	χ^2/ndf	Prob(χ^2/ndf)	Fit parameters
BK	6.8/4	0.148	$\alpha_{BK} = +0.310 \pm 0.085$
BGL (2 par.)	6.6/4	0.156	$a_1/a_0 = -0.94 \pm 0.20$
BGL (3 par.)	6.3/3	0.100	$a_1/a_0 = -0.82 \pm 0.29$
			$a_2/a_0 = -1.14 \pm 1.81$

arXiv:1005.3288, accepted by Phys. Rev. D

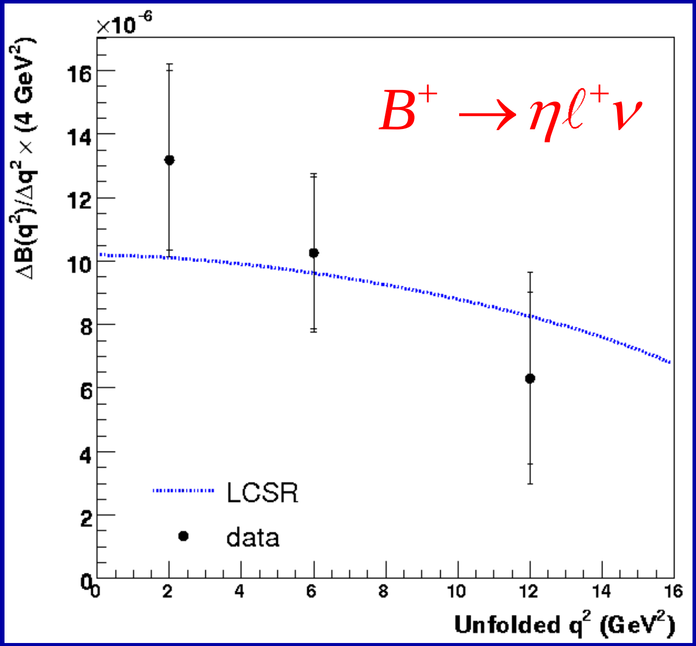
Comparison of the two $B \to \pi \ell \nu$ results



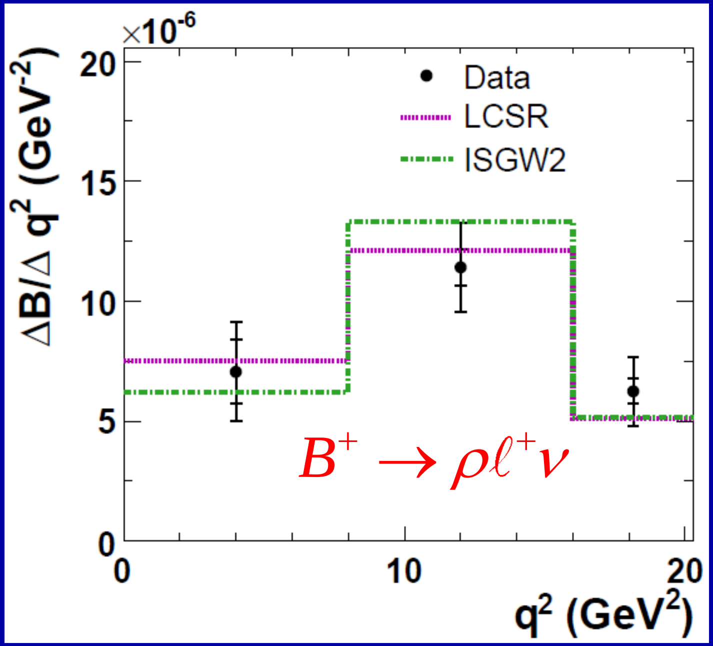
Results are consistent. Statistical correlations between the 2 data sets fairly low (estimated < 20 %)

Form factor shapes for other decay channels

π-η analysis



π-ρ analysis



LCSR calculations compatible with data

Main results

Branching fractions :

π-η analysis

$$\mathcal{B}(B^0 \to \pi^- \ell^+ \nu) = (1.42 \pm 0.05_{stat} \pm 0.08_{syst}) \times 10^{-4}$$
$$\mathcal{B}(B^+ \to \eta \ell^+ \nu) = (3.61 \pm 0.45_{stat} \pm 0.44_{syst}) \times 10^{-5}$$
$$\mathcal{B}(B^+ \to \eta^{'} \ell^+ \nu) = (2.43 \pm 0.80_{stat} \pm 0.34_{syst}) \times 10^{-5}$$

$$\mathcal{B}(B^+ \to \eta' \ell^+ \nu)/\mathcal{B}(B^+ \to \eta \ell^+ \nu) = 0.67 \pm 0.24_{stat} \pm 0.11_{syst}$$

π-ρ analysis

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

|Vub| :

π-η analysis

	q^2 (GeV^2)	$\Delta\zeta$ (ps^{-1})	$\lvert V_{ub}\rvert$ (10^{-3})
HPQCD	> 16	2.07 ± 0.57	$3.24 \pm 0.13 \pm 0.16\ {}^{+0.57}_{-0.37}$
FNAL	> 16	$2.21\ {}^{+0.47}_{-0.42}$	$3.14 \pm 0.12 \pm 0.16\ {}^{+0.35}_{-0.29}$
LCSR	< 12	$4.00\ {}^{+1.01}_{-0.95}$	$3.70 \pm 0.07 \pm 0.09\ {}^{+0.54}_{-0.39}$

$$|V_{ub} f_+(0)| = (8.6 \pm 0.3_{stat} \pm 0.3_{syst}) \times 10^{-4}$$

π-ρ analysis

$3.21 \pm 0.17^{+0.55}_{-0.36}$
(2.95 ± 0.31)
$3.78 \pm 0.13^{+0.55}_{-0.40}$

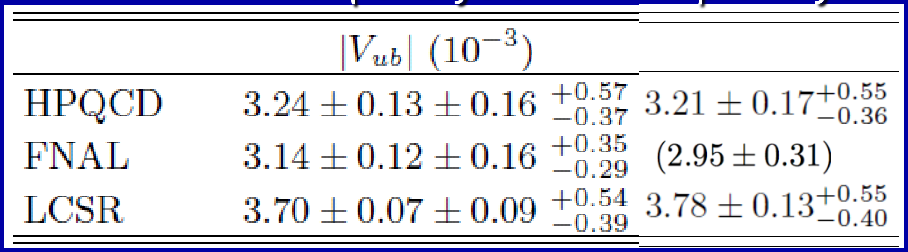
$(10.8 \pm 0.6) \times 10^{-4}$

Summary

- New precise BF measurements for $B\to\pi\ell\nu$, $B\to\eta^{(\prime)}\ell\nu$ and $B\to\rho\ell\nu$

- Two different BaBar analyses consistent with each other

- All three QCD calculations of the form factor for $B\to\pi\ell\nu$ decays are consistent with data and yield values of |Vub| consistent with the value of |Vub| measured in inclusive semileptonic decays



	π-η analysis	π-ρ analysis
	$\vert V_{ub}\vert$ (10^{-3})	
HPQCD	$3.24 \pm 0.13 \pm 0.16\ ^{+0.57}_{-0.37}$	$3.21 \pm 0.17^{+0.55}_{-0.36}$
FNAL	$3.14 \pm 0.12 \pm 0.16\ ^{+0.35}_{-0.29}$	(2.95 ± 0.31)
LCSR	$3.70 \pm 0.07 \pm 0.09\ ^{+0.54}_{-0.39}$	$3.78 \pm 0.13^{+0.55}_{-0.40}$

Inclusive value of $|V_{ub}|$

$|V_{ub}| = (4.27 \pm 0.38) \times 10^{-3}$

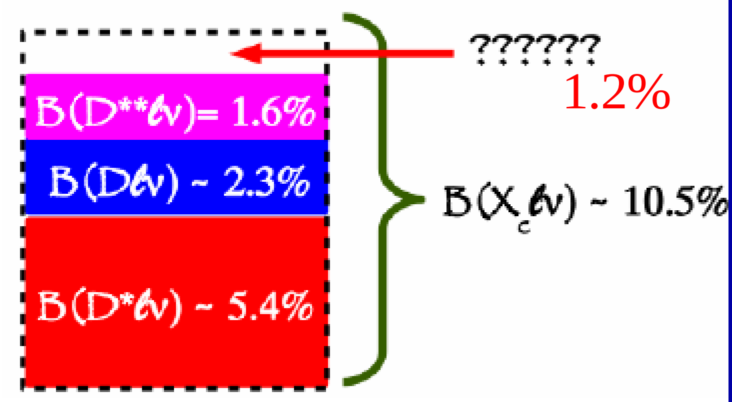
The end

Backup slides

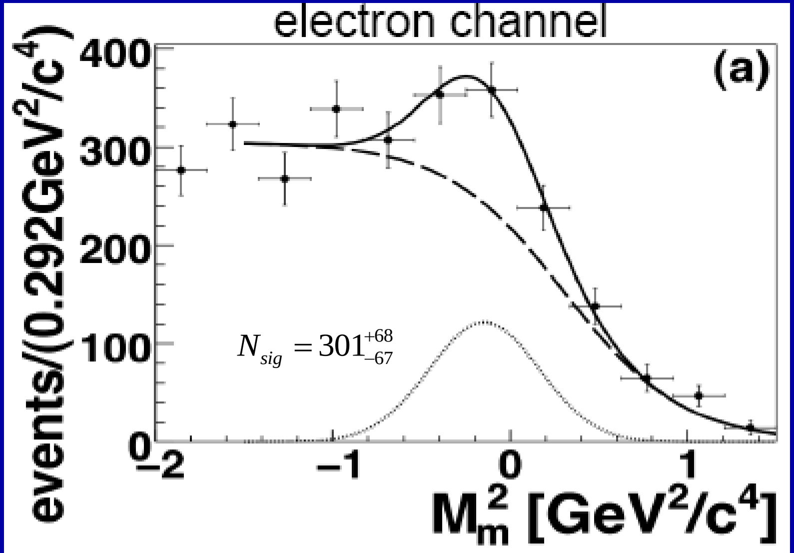
Backup Slides for $B \rightarrow D_s K \ell \nu$ analysis

Puzzle in exclusive $B \to D^{(*,**)}\ell\nu$ branching fractions

$$BF(B \to X_c \ell\nu) > BF(B \to D\ell\nu) + BF(B \to D^{*}\ell\nu) + BF(B \to D^{**}\ell\nu)$$



Measure $BF(B \to D_S K \ell\nu)$



$342\ fb^{-1}$

$$M_m^2 = \left(E_{beam} - E_Y\right)^2 - \left|\vec{p}_Y\right|^2 = m_\nu^2$$

$$Y = D_S K \ell\ candidate$$

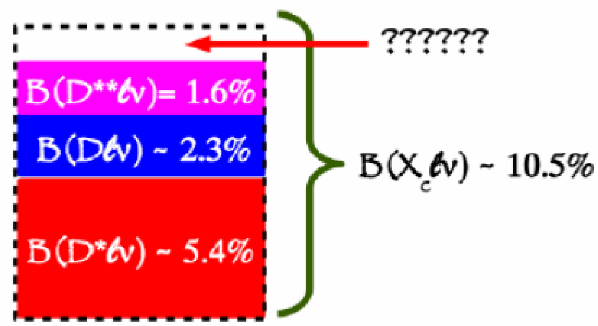
$$BF\left(B^- \to D_S^+ K^- \ell^- \overline{\nu}_\ell\right) = \left(6.13^{+1.04}_{-1.03 stat} \pm 0.43_{syst} \pm 0.51(BF(D_s))\right) \times 10^{-4}$$

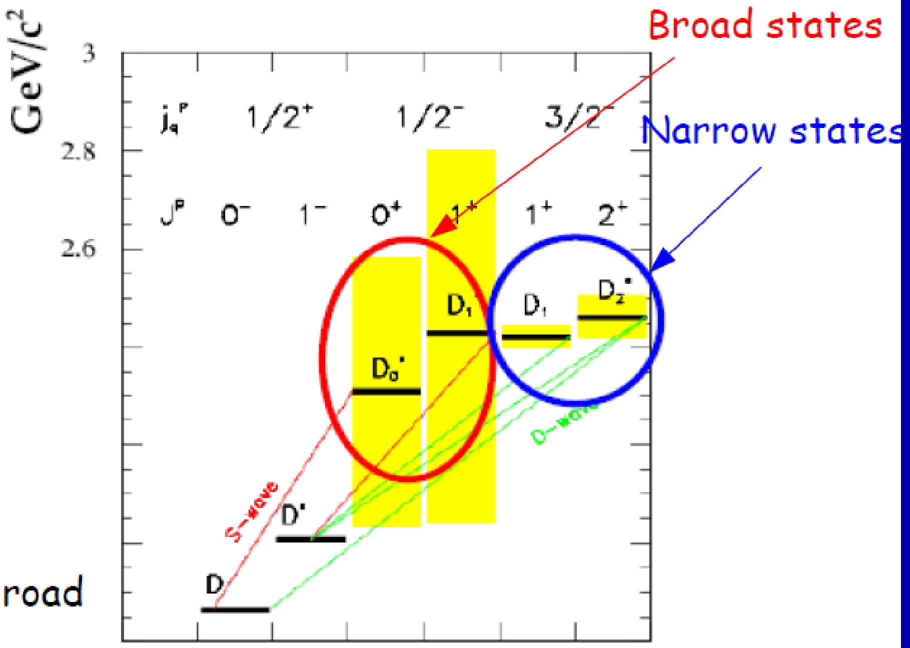
BF too small to solve the BF puzzle (presented at ICHEP2010)

$\mathcal{B}(B^- \to D_s^{(*)+} K^- \ell^- \bar{\nu}_\ell)$

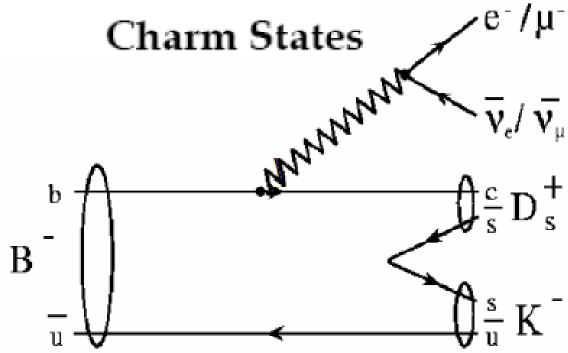
Puzzle in exclusive B→ D$^{(*,**)}$lν Branching Fractions:

$$\boxed{\mathcal{B}(B \to X_c \ell \nu) > \mathcal{B}(B \to D \ell \nu) + \mathcal{B}(B \to D^* \ell \nu) + \mathcal{B}(B \to D^{**} \ell \nu)}$$





Charm States



- experimentally: similar rate for broad and narrow (QCD sum rule: narrow >> broad)
- small statistics doesn't allow to separate broad from non resonant
- B→D$_s^{(*)}$Klν similar to B→D$^{(*)}$πlν. Study hadronic mass spectrum above 2.46 GeV/c^2
- $\mathcal{B}$(B→D$_s^{(*)}$Klν) expected ~ 10^{-3}

A. Petrella ICHEP 2010

$\mathcal{B}(B^- \to D_s^{(*)+} K^- \ell^- \bar{\nu}_\ell)$

- Exclusive reconstruction

$$D_s \to \phi(K^+K^-)\pi$$

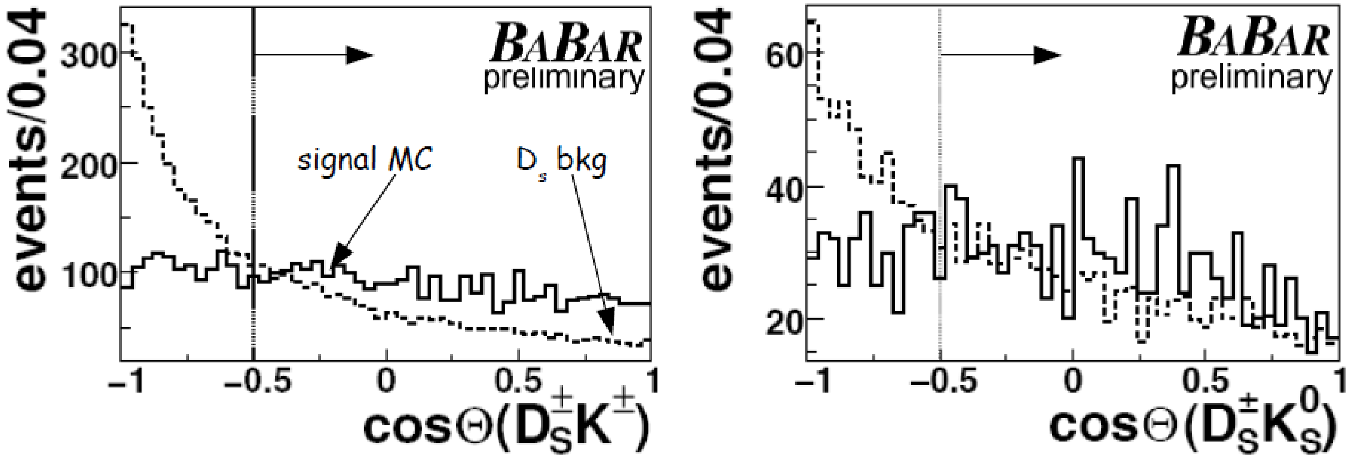
$$D_s \to \bar{K}^{*0}(K^\pm\pi^\mp)K$$

$$D_s \to K_s^0(\pi^+\pi^-)K$$

Feed Forward NN to suppress combinatorial bkg.

- lepton (p_{lep} > 0.8 GeV/c) and Kaon added to D_s candidate
- Bkg from B→DD_s reduced using angular correlation between D_s and D (signal events no correlation)

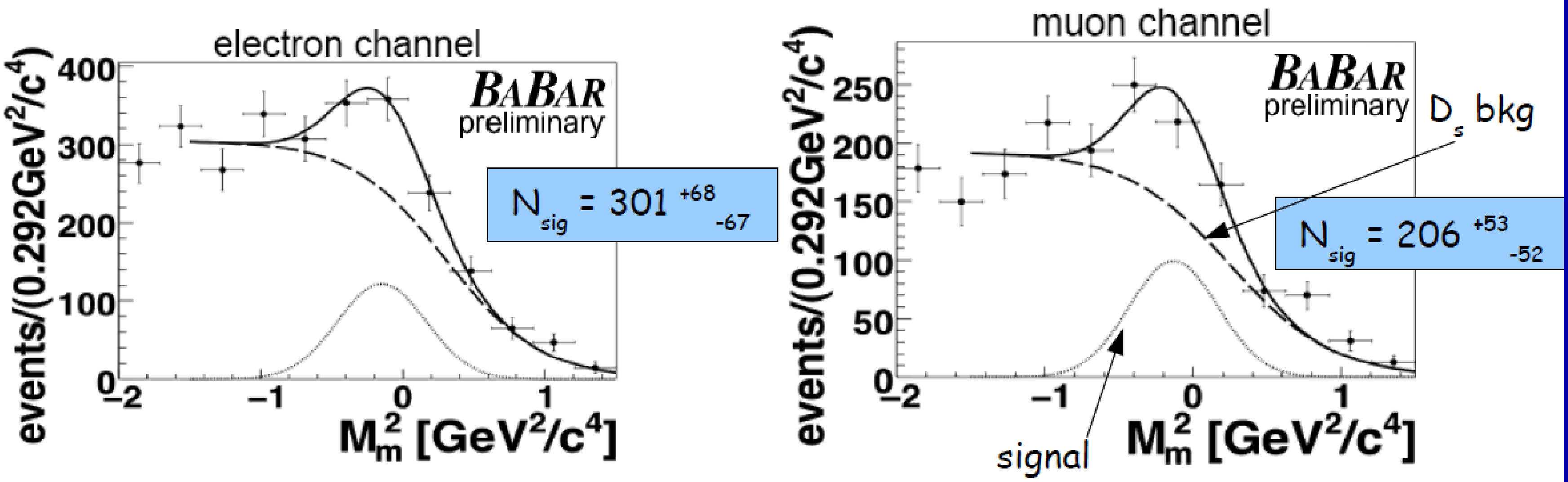
~30% of D_s bkg rejected



$\mathcal{B}(B^- \to D_s^{(*)+} K^- \ell^- \bar{\nu}_\ell)$

- Signal yields extracted via unbinned extended maximum likelihood fit to Missing mass

$$M_m^2 = (E_{beam} - E_Y)^2 - |\vec{p}_Y|^2 = m_\nu^2 \qquad Y = D_s K \ell \text{ candidate}$$



- leading systematic uncertainty: signal MC modelling (~3%- 8% depending on channel)

Signal MC statistics (~2%)

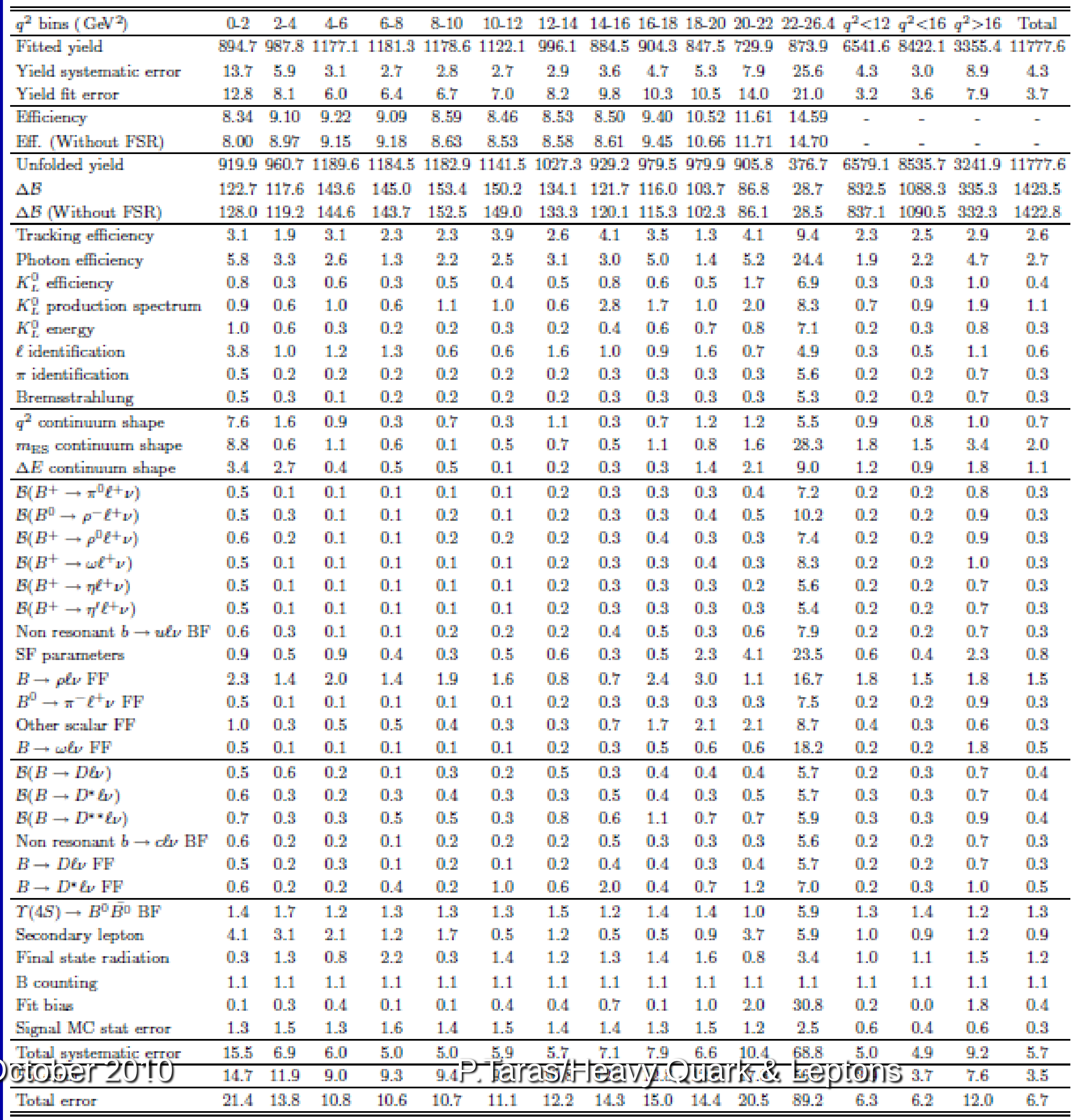
342 fb^{-1}

$$\mathcal{B}(B \to D_s^+ K^- \ell^- \bar{\nu}_\ell) = (6.13^{+1.04}_{-1.03} stat. \pm 0.43_{syst.} \pm 0.51(\mathcal{B}(D_s))) \times 10^{-4}$$

- Result in agreement with ARGUS measurement: $\mathcal{B}(B \to D_s^+ K^- \ell^- \bar{\nu}_\ell) < 5 \times 10^{-3}$
- BR too small to solve the BR puzzle

Backup Slides for π-η analysis

Statistical and Systematic relative uncertainties



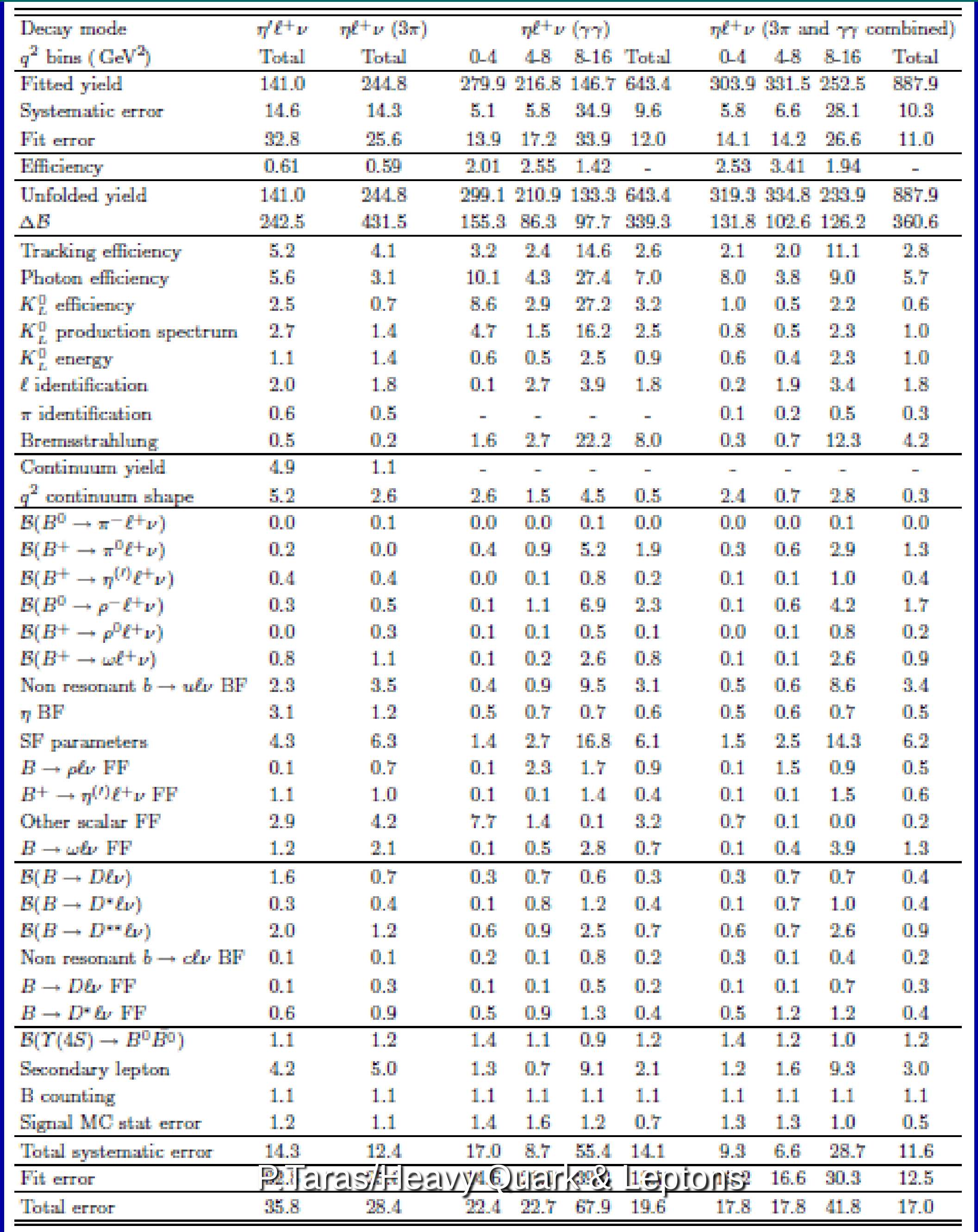
q^2 bins (GeV^2)	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-26.4	q^2<12	q^2<16	q^2>16	Total
Fitted yield	894.7	987.8	1177.1	1181.3	1178.6	1122.1	996.1	884.5	904.3	847.5	729.9	873.9	6541.6	8422.1	3355.4	11777.6
Yield systematic error	13.7	5.9	3.1	2.7	2.8	2.7	2.9	3.6	4.7	5.3	7.9	25.6	4.3	3.0	8.9	4.3
Yield fit error	12.8	8.1	6.0	6.4	6.7	7.0	8.2	9.8	10.3	10.5	14.0	21.0	3.2	3.6	7.9	3.7
Efficiency	8.34	9.10	9.22	9.09	8.59	8.46	8.53	8.50	9.40	10.52	11.61	14.59	-	-	-	-
Eff. (Without FSR)	8.00	8.97	9.15	9.18	8.63	8.53	8.58	8.61	9.45	10.66	11.71	14.70	-	-	-	-
Unfolded yield	919.9	960.7	1189.6	1184.5	1182.9	1141.5	1027.3	929.2	979.5	979.9	905.8	376.7	6579.1	8535.7	3241.9	11777.6
$\Delta\mathcal{B}$	122.7	117.6	143.6	145.0	153.4	150.2	134.1	121.7	116.0	103.7	86.8	28.7	832.5	1088.3	335.3	1423.5
$\Delta\mathcal{B}$ (Without FSR)	128.0	119.2	144.6	143.7	152.5	149.0	133.3	120.1	115.3	102.3	86.1	28.5	837.1	1090.5	332.3	1422.8
Tracking efficiency	3.1	1.9	3.1	2.3	2.3	3.9	2.6	4.1	3.5	1.3	4.1	9.4	2.3	2.5	2.9	2.6
Photon efficiency	5.8	3.3	2.6	1.3	2.2	2.5	3.1	3.0	5.0	1.4	5.2	24.4	1.9	2.2	4.7	2.7
K_L^0 efficiency	0.8	0.3	0.6	0.3	0.5	0.4	0.5	0.8	0.6	0.5	1.7	6.9	0.3	0.3	1.0	0.4
K_L^0 production spectrum	0.9	0.6	1.0	0.6	1.1	1.0	0.6	2.8	1.7	1.0	2.0	8.3	0.7	0.9	1.9	1.1
K_L^0 energy	1.0	0.6	0.3	0.2	0.2	0.3	0.2	0.4	0.6	0.7	0.8	7.1	0.2	0.3	0.8	0.3
ℓ identification	3.8	1.0	1.2	1.3	0.6	0.6	1.6	1.0	0.9	1.6	0.7	4.9	0.3	0.5	1.1	0.6
π identification	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	5.6	0.2	0.2	0.7	0.3
Bremsstrahlung	0.5	0.3	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	5.3	0.2	0.2	0.7	0.3
q^2 continuum shape	7.6	1.6	0.9	0.3	0.7	0.3	1.1	0.3	0.7	1.2	1.2	5.5	0.9	0.8	1.0	0.7
m_{ES} continuum shape	8.8	0.6	1.1	0.6	0.1	0.5	0.7	0.5	1.1	0.8	1.6	28.3	1.8	1.5	3.4	2.0
ΔE continuum shape	3.4	2.7	0.4	0.5	0.5	0.1	0.2	0.3	0.3	1.4	2.1	9.0	1.2	0.9	1.8	1.1
$\mathcal{B}(B^+ \to \pi^0\ell^+\nu)$	0.5	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.4	7.2	0.2	0.2	0.8	0.3
$\mathcal{B}(B^0 \to \rho^-\ell^+\nu)$	0.5	0.3	0.1	0.1	0.2	0.1	0.2	0.3	0.3	0.4	0.5	10.2	0.2	0.2	0.9	0.3
$\mathcal{B}(B^+ \to \rho^0\ell^+\nu)$	0.6	0.2	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.3	0.3	7.4	0.2	0.2	0.9	0.3
$\mathcal{B}(B^+ \to \omega\ell^+\nu)$	0.5	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.4	0.3	8.3	0.2	0.2	1.0	0.3
$\mathcal{B}(B^+ \to \eta\ell^+\nu)$	0.5	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.2	5.6	0.2	0.2	0.7	0.3
$\mathcal{B}(B^+ \to \eta'\ell^+\nu)$	0.5	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.3	5.4	0.2	0.2	0.7	0.3
Non resonant $b \to u\ell\nu$ BF	0.6	0.3	0.1	0.1	0.2	0.2	0.2	0.4	0.5	0.3	0.6	7.9	0.2	0.2	0.7	0.3
SF parameters	0.9	0.5	0.9	0.4	0.3	0.5	0.6	0.3	0.5	2.3	4.1	23.5	0.6	0.4	2.3	0.8
$B \to \rho\ell\nu$ FF	2.3	1.4	2.0	1.4	1.9	1.6	0.8	0.7	2.4	3.0	1.1	16.7	1.8	1.5	1.8	1.5
$B^0 \to \pi^-\ell^+\nu$ FF	0.5	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.3	7.5	0.2	0.2	0.9	0.3
Other scalar FF	1.0	0.3	0.5	0.5	0.4	0.3	0.3	0.7	1.7	2.1	2.1	8.7	0.4	0.3	0.6	0.3
$B \to \omega\ell\nu$ FF	0.5	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.5	0.6	0.6	18.2	0.2	0.2	1.8	0.5
$\mathcal{B}(B \to D\ell\nu)$	0.5	0.6	0.2	0.1	0.3	0.2	0.5	0.3	0.4	0.4	0.4	5.7	0.2	0.3	0.7	0.4
$\mathcal{B}(B \to D^*\ell\nu)$	0.6	0.3	0.2	0.3	0.4	0.3	0.3	0.5	0.4	0.3	0.5	5.7	0.3	0.3	0.7	0.4
$\mathcal{B}(B \to D^{**}\ell\nu)$	0.7	0.3	0.3	0.5	0.5	0.3	0.8	0.6	1.1	0.7	0.7	5.9	0.3	0.3	0.9	0.4
Non resonant $b \to c\ell\nu$ BF	0.6	0.2	0.2	0.1	0.2	0.2	0.2	0.5	0.3	0.3	0.3	5.6	0.2	0.2	0.7	0.3
$B \to D\ell\nu$ FF	0.5	0.2	0.3	0.1	0.2	0.1	0.2	0.4	0.4	0.3	0.4	5.7	0.2	0.2	0.7	0.3
$B \to D^*\ell\nu$ FF	0.6	0.2	0.2	0.4	0.2	1.0	0.6	2.0	0.4	0.7	1.2	7.0	0.2	0.3	1.0	0.5
$\Upsilon(4S) \to B^0\bar{B}^0$ BF	1.4	1.7	1.2	1.3	1.3	1.3	1.5	1.2	1.4	1.4	1.0	5.9	1.3	1.4	1.2	1.3
Secondary lepton	4.1	3.1	2.1	1.2	1.7	0.5	1.2	0.5	0.5	0.9	3.7	5.9	1.0	0.9	1.2	0.9
Final state radiation	0.3	1.3	0.8	2.2	0.3	1.4	1.2	1.3	1.4	1.6	0.8	3.4	1.0	1.1	1.5	1.2
B counting	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Fit bias	0.1	0.3	0.4	0.1	0.1	0.4	0.4	0.7	0.1	1.0	2.0	30.8	0.2	0.0	1.8	0.4
Signal MC stat error	1.3	1.5	1.3	1.6	1.4	1.5	1.4	1.4	1.3	1.5	1.2	2.5	0.6	0.4	0.6	0.3
Total systematic error	15.5	6.9	6.0	5.0	5.0	5.9	5.7	7.1	7.9	6.6	10.4	68.8	5.0	4.9	9.2	5.7
[illegible]	14.7	11.9	9.0	9.3	9.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.7	7.6	3.5
Total error	21.4	13.8	10.8	10.6	10.7	11.1	12.2	14.3	15.0	14.4	20.5	89.2	6.3	6.2	12.0	6.7

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

Statistical and Systematic relative uncertainties

$B \rightarrow \eta' \ell \nu$

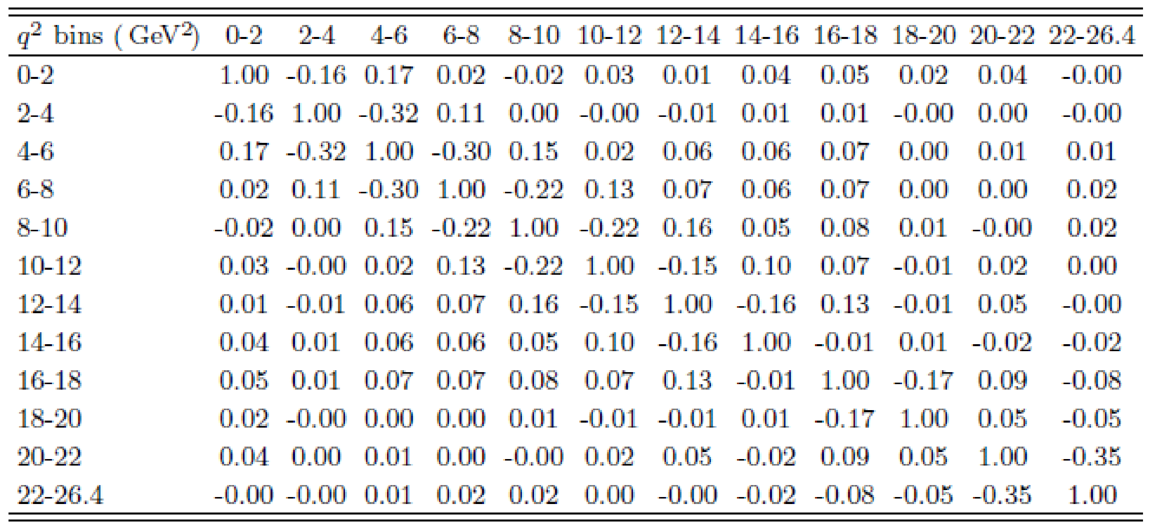
$B \rightarrow \eta \ell \nu$



Decay mode	$\eta' \ell^+ \nu$	$\eta \ell^+ \nu$ (3π)	$\eta \ell^+ \nu$ ($\gamma\gamma$)				$\eta \ell^+ \nu$ (3π and $\gamma\gamma$ combined)			
q^2 bins (GeV^2)	Total	Total	0-4	4-8	8-16	Total	0-4	4-8	8-16	Total
Fitted yield	141.0	244.8	279.9	216.8	146.7	643.4	303.9	331.5	252.5	887.9
Systematic error	14.6	14.3	5.1	5.8	34.9	9.6	5.8	6.6	28.1	10.3
Fit error	32.8	25.6	13.9	17.2	33.9	12.0	14.1	14.2	26.6	11.0
Efficiency	0.61	0.59	2.01	2.55	1.42	-	2.53	3.41	1.94	-
Unfolded yield	141.0	244.8	299.1	210.9	133.3	643.4	319.3	334.8	233.9	887.9
$\Delta\mathcal{B}$	242.5	431.5	155.3	86.3	97.7	339.3	131.8	102.6	126.2	360.6
Tracking efficiency	5.2	4.1	3.2	2.4	14.6	2.6	2.1	2.0	11.1	2.8
Photon efficiency	5.6	3.1	10.1	4.3	27.4	7.0	8.0	3.8	9.0	5.7
K_L^0 efficiency	2.5	0.7	8.6	2.9	27.2	3.2	1.0	0.5	2.2	0.6
K_L^0 production spectrum	2.7	1.4	4.7	1.5	16.2	2.5	0.8	0.5	2.3	1.0
K_L^0 energy	1.1	1.4	0.6	0.5	2.5	0.9	0.6	0.4	2.3	1.0
ℓ identification	2.0	1.8	0.1	2.7	3.9	1.8	0.2	1.9	3.4	1.8
π identification	0.6	0.5	-	-	-	-	0.1	0.2	0.5	0.3
Bremsstrahlung	0.5	0.2	1.6	2.7	22.2	8.0	0.3	0.7	12.3	4.2
Continuum yield	4.9	1.1	-	-	-	-	-	-	-	-
q^2 continuum shape	5.2	2.6	2.6	1.5	4.5	0.5	2.4	0.7	2.8	0.3
$\mathcal{B}(B^0 \to \pi^- \ell^+ \nu)$	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
$\mathcal{B}(B^+ \to \pi^0 \ell^+ \nu)$	0.2	0.0	0.4	0.9	5.2	1.9	0.3	0.6	2.9	1.3
$\mathcal{B}(B^+ \to \eta^{(\prime)} \ell^+ \nu)$	0.4	0.4	0.0	0.1	0.8	0.2	0.1	0.1	1.0	0.4
$\mathcal{B}(B^0 \to \rho^- \ell^+ \nu)$	0.3	0.5	0.1	1.1	6.9	2.3	0.1	0.6	4.2	1.7
$\mathcal{B}(B^+ \to \rho^0 \ell^+ \nu)$	0.0	0.3	0.1	0.1	0.5	0.1	0.0	0.1	0.8	0.2
$\mathcal{B}(B^+ \to \omega \ell^+ \nu)$	0.8	1.1	0.1	0.2	2.6	0.8	0.1	0.1	2.6	0.9
Non resonant $b \to u \ell \nu$ BF	2.3	3.5	0.4	0.9	9.5	3.1	0.5	0.6	8.6	3.4
η BF	3.1	1.2	0.5	0.7	0.7	0.6	0.5	0.6	0.7	0.5
SF parameters	4.3	6.3	1.4	2.7	16.8	6.1	1.5	2.5	14.3	6.2
$B \to \rho \ell \nu$ FF	0.1	0.7	0.1	2.3	1.7	0.9	0.1	1.5	0.9	0.5
$B^+ \to \eta^{(\prime)} \ell^+ \nu$ FF	1.1	1.0	0.1	0.1	1.4	0.4	0.1	0.1	1.5	0.6
Other scalar FF	2.9	4.2	7.7	1.4	0.1	3.2	0.7	0.1	0.0	0.2
$B \to \omega \ell \nu$ FF	1.2	2.1	0.1	0.5	2.8	0.7	0.1	0.4	3.9	1.3
$\mathcal{B}(B \to D \ell \nu)$	1.6	0.7	0.3	0.7	0.6	0.3	0.3	0.7	0.7	0.4
$\mathcal{B}(B \to D^* \ell \nu)$	0.3	0.4	0.1	0.8	1.2	0.4	0.1	0.7	1.0	0.4
$\mathcal{B}(B \to D^{**} \ell \nu)$	2.0	1.2	0.6	0.9	2.5	0.7	0.6	0.7	2.6	0.9
Non resonant $b \to c \ell \nu$ BF	0.1	0.1	0.2	0.1	0.8	0.2	0.3	0.1	0.4	0.2
$B \to D \ell \nu$ FF	0.1	0.3	0.1	0.1	0.5	0.2	0.1	0.1	0.7	0.3
$B \to D^* \ell \nu$ FF	0.6	0.9	0.5	0.9	1.3	0.4	0.5	1.2	1.2	0.4
$\mathcal{B}(\Upsilon(4S) \to B^0 \bar{B}^0)$	1.1	1.2	1.4	1.1	0.9	1.2	1.4	1.2	1.0	1.2
Secondary lepton	4.2	5.0	1.3	0.7	9.1	2.1	1.2	1.6	9.3	3.0
B counting	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Signal MC stat error	1.2	1.1	1.4	1.6	1.2	0.7	1.3	1.3	1.0	0.5
Total systematic error	14.3	12.4	17.0	8.7	55.4	14.1	9.3	6.6	28.7	11.6
Fit error	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16.6	30.3	12.5
Total error	35.8	28.4	22.4	22.7	67.9	19.6	17.8	17.8	41.8	17.0

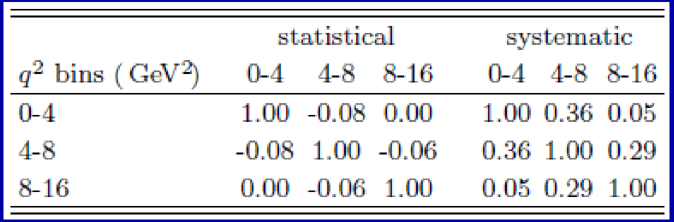
Correlation Matrices

$B^0 \to \pi^- \ell^+ \nu$ Statistical



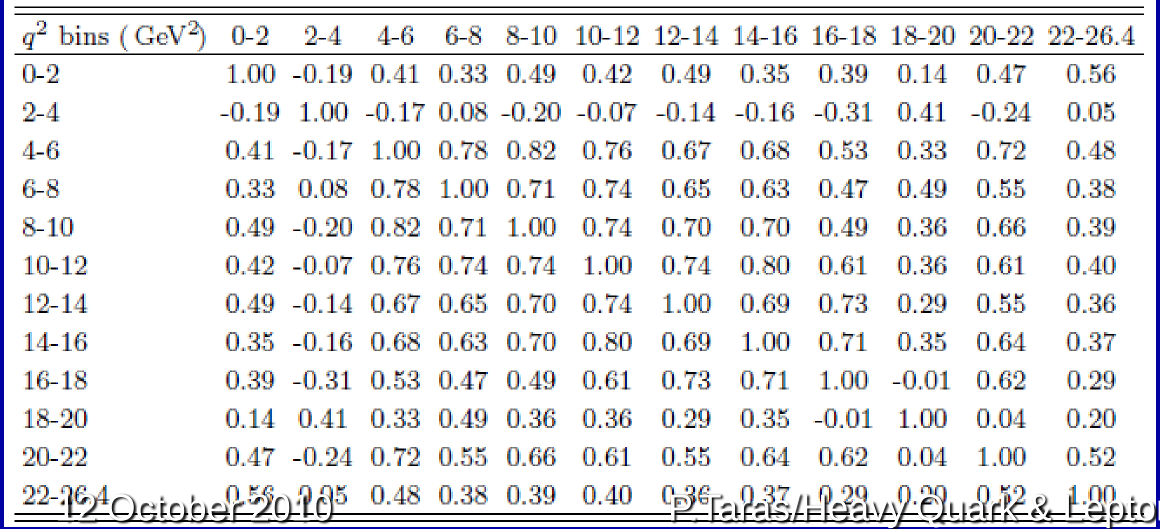
q^2 bins (GeV^2)	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-26.4
0-2	1.00	-0.16	0.17	0.02	-0.02	0.03	0.01	0.04	0.05	0.02	0.04	-0.00
2-4	-0.16	1.00	-0.32	0.11	0.00	-0.00	-0.01	0.01	0.01	-0.00	0.00	-0.00
4-6	0.17	-0.32	1.00	-0.30	0.15	0.02	0.06	0.06	0.07	0.00	0.01	0.01
6-8	0.02	0.11	-0.30	1.00	-0.22	0.13	0.07	0.06	0.07	0.00	0.00	0.02
8-10	-0.02	0.00	0.15	-0.22	1.00	-0.22	0.16	0.05	0.08	0.01	-0.00	0.02
10-12	0.03	-0.00	0.02	0.13	-0.22	1.00	-0.15	0.10	0.07	-0.01	0.02	0.00
12-14	0.01	-0.01	0.06	0.07	0.16	-0.15	1.00	-0.16	0.13	-0.01	0.05	-0.00
14-16	0.04	0.01	0.06	0.06	0.05	0.10	-0.16	1.00	-0.01	0.01	-0.02	-0.02
16-18	0.05	0.01	0.07	0.07	0.08	0.07	0.13	-0.01	1.00	-0.17	0.09	-0.08
18-20	0.02	-0.00	0.00	0.00	0.01	-0.01	-0.01	0.01	-0.17	1.00	0.05	-0.05
20-22	0.04	0.00	0.01	0.00	-0.00	0.02	0.05	-0.02	0.09	0.05	1.00	-0.35
22-26.4	-0.00	-0.00	0.01	0.02	0.02	0.00	-0.00	-0.02	-0.08	-0.05	-0.35	1.00

$B \to \eta \ell \nu$



	statistical			systematic		
q^2 bins (GeV^2)	0-4	4-8	8-16	0-4	4-8	8-16
0-4	1.00	-0.08	0.00	1.00	0.36	0.05
4-8	-0.08	1.00	-0.06	0.36	1.00	0.29
8-16	0.00	-0.06	1.00	0.05	0.29	1.00

$B^0 \to \pi^- \ell^+ \nu$ Systematic



q^2 bins (GeV^2)	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-26.4
0-2	1.00	-0.19	0.41	0.33	0.49	0.42	0.49	0.35	0.39	0.14	0.47	0.56
2-4	-0.19	1.00	-0.17	0.08	-0.20	-0.07	-0.14	-0.16	-0.31	0.41	-0.24	0.05
4-6	0.41	-0.17	1.00	0.78	0.82	0.76	0.67	0.68	0.53	0.33	0.72	0.48
6-8	0.33	0.08	0.78	1.00	0.71	0.74	0.65	0.63	0.47	0.49	0.55	0.38
8-10	0.49	-0.20	0.82	0.71	1.00	0.74	0.70	0.70	0.49	0.36	0.66	0.39
10-12	0.42	-0.07	0.76	0.74	0.74	1.00	0.74	0.80	0.61	0.36	0.61	0.40
12-14	0.49	-0.14	0.67	0.65	0.70	0.74	1.00	0.69	0.73	0.29	0.55	0.36
14-16	0.35	-0.16	0.68	0.63	0.70	0.80	0.69	1.00	0.71	0.35	0.64	0.37
16-18	0.39	-0.31	0.53	0.47	0.49	0.61	0.73	0.71	1.00	-0.01	0.62	0.29
18-20	0.14	0.41	0.33	0.49	0.36	0.36	0.29	0.35	-0.01	1.00	0.04	0.20
20-22	0.47	-0.24	0.72	0.55	0.66	0.61	0.55	0.64	0.62	0.04	1.00	0.52
22-26.4	0.56	0.05	0.48	0.38	0.39	0.40	0.36	0.37	0.29	0.20	0.52	1.00

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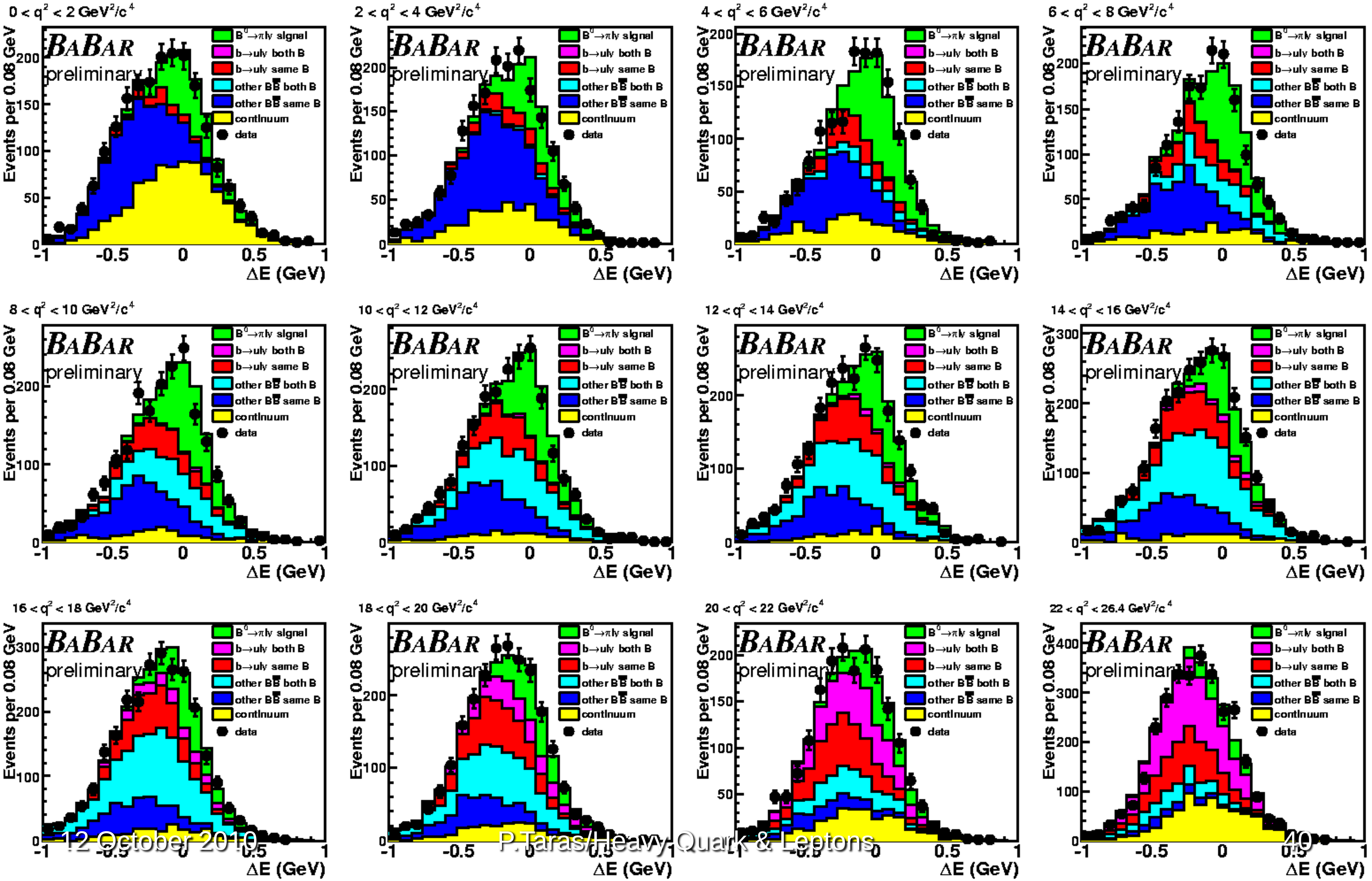
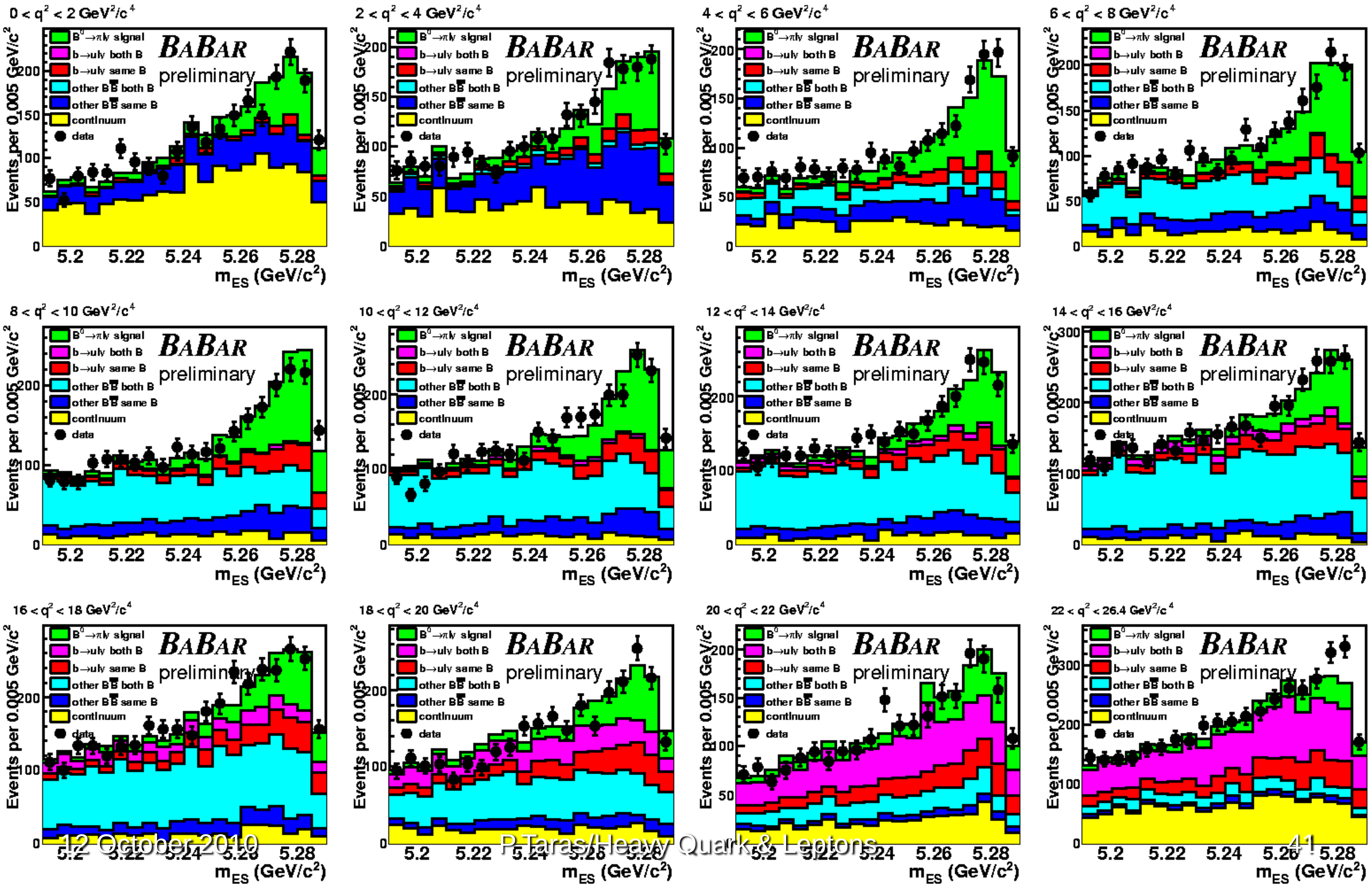
$B^0 \to \pi^- \ell^+ \nu$ Projections on Δ E axis



$B^0 \to \pi^- \ell^+ \nu$ Projections on m_{ES} axis



Branching fraction results

$$Total\ BF\ \ for\ B^+ \to \eta'\ell^+\nu : (2.43 \pm 0.80_{stat} \pm 0.34_{syst}) \times 10^{-5},$$

$$significance\ \ of\ \ 2.67\sigma$$

an order of magnitude smaller than most recent result of CLEO

$$(2.66 \pm 0.80_{stat} \pm 0.56_{syst}) \times 10^{-4}$$

$$Total\ BF\ \ for\ B^+ \to \eta\ell^+\nu : (3.61 \pm 0.45_{stat} \pm 0.44_{syst}) \times 10^{-5},$$

$$most\ \ precise, compatible\ with\ \ previous\ BaBar\ result :$$

$$(3.7 \pm 0.6_{stat} \pm 0.7_{syst}) \times 10^{-5}$$

$$BF(B^+ \to \eta'\ell^+\nu) \big/ BF(B^+ \to \eta\ell^+\nu) = 0.67 \pm 0.27 \quad allows\ an$$

$$important\ gluonic\ singlet\ contribution\ to\ the\ \eta'\ \ form\ \ factor$$

Backup Slides for π-ρ analysis

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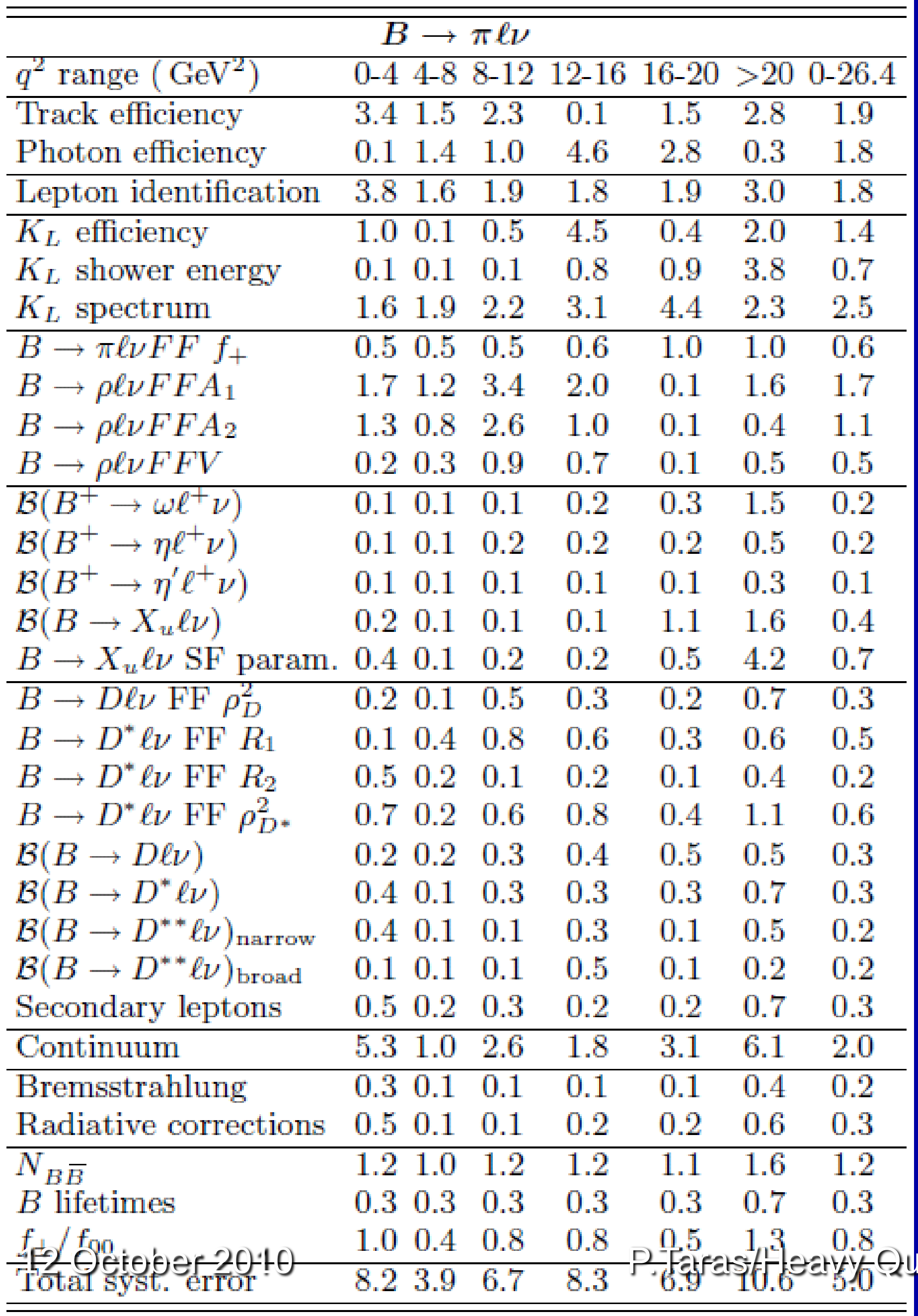
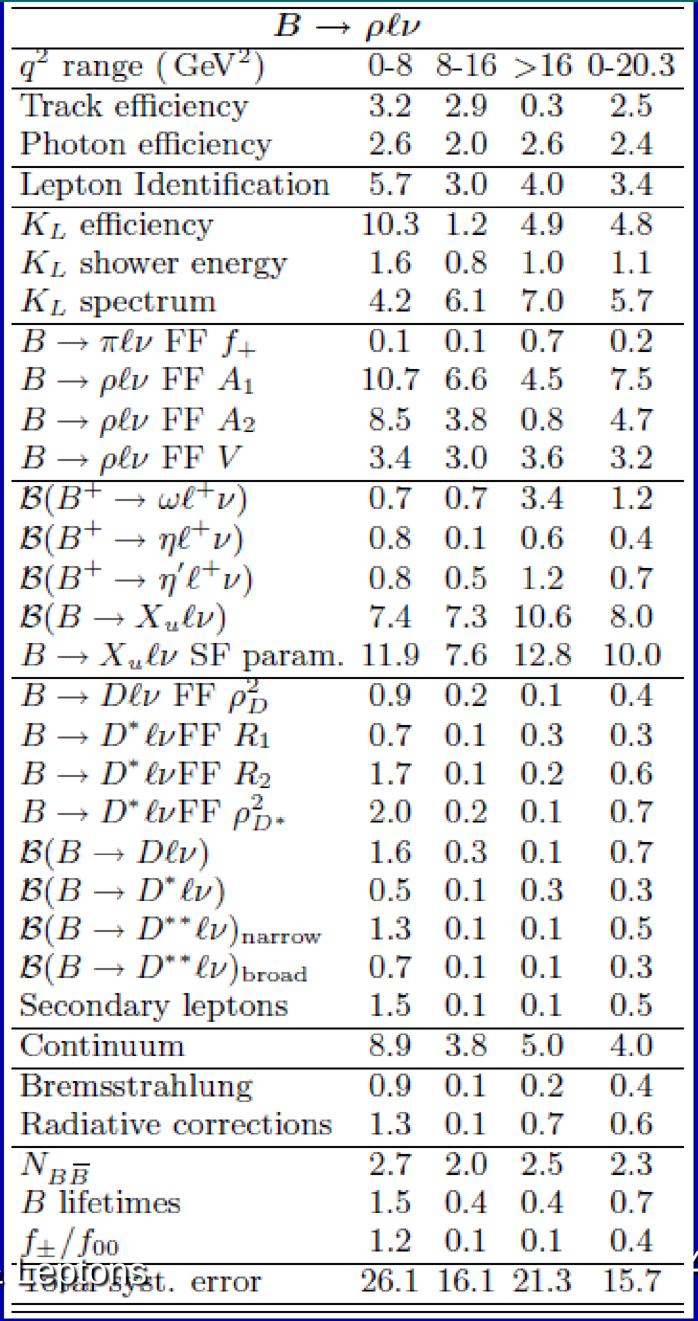
Statistical and Systematic relative uncertainties



$B \to \pi\ell\nu$

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

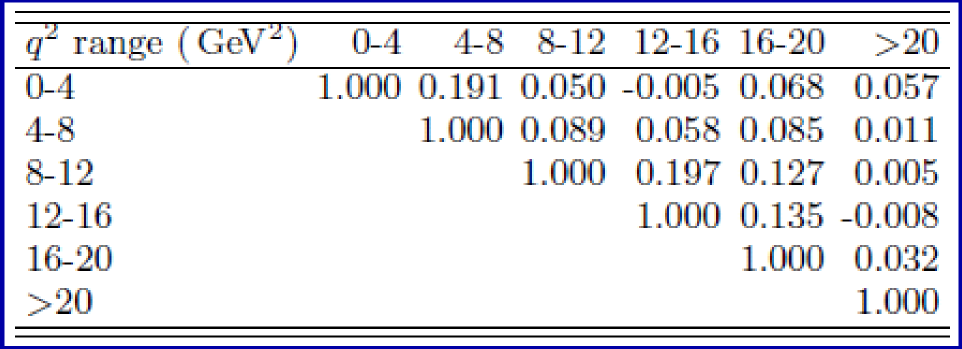


$B \to \rho\ell\nu$

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

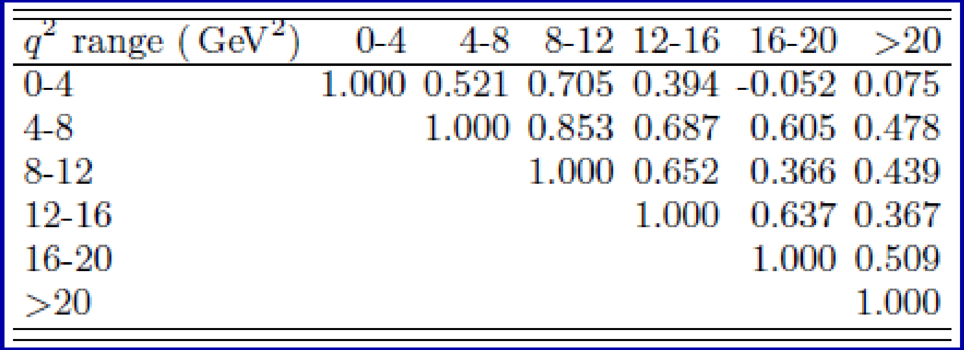
Correlation Matrices

B→πℓν Statistical



q^2 range (GeV^2)	0-4	4-8	8-12	12-16	16-20	>20
0-4	1.000	0.191	0.050	-0.005	0.068	0.057
4-8		1.000	0.089	0.058	0.085	0.011
8-12			1.000	0.197	0.127	0.005
12-16				1.000	0.135	-0.008
16-20					1.000	0.032
>20						1.000

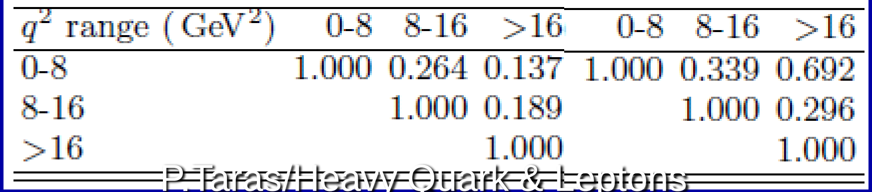
B→πℓν Systematic



q^2 range (GeV^2)	0-4	4-8	8-12	12-16	16-20	>20
0-4	1.000	0.521	0.705	0.394	-0.052	0.075
4-8		1.000	0.853	0.687	0.605	0.478
8-12			1.000	0.652	0.366	0.439
12-16				1.000	0.637	0.367
16-20					1.000	0.509
>20						1.000

B→ρℓν Statistical

B→ρℓν Systematic



	B→ρℓν Statistical			B→ρℓν Systematic		
q^2 range (GeV^2)	0-8	8-16	>16	0-8	8-16	>16
0-8	1.000	0.264	0.137	1.000	0.339	0.692
8-16		1.000	0.189		1.000	0.296
>16			1.000			1.000