BABAR's Angular Analysis of $B \to K^* l^+ l^-$

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CKM2012 Sep 28 - Oct 2, 2012
University of Cincinnati

Outline

I. Rare FCNC Decays

II. $B \to K^* l^+ l^- \quad (l = e, \mu)$

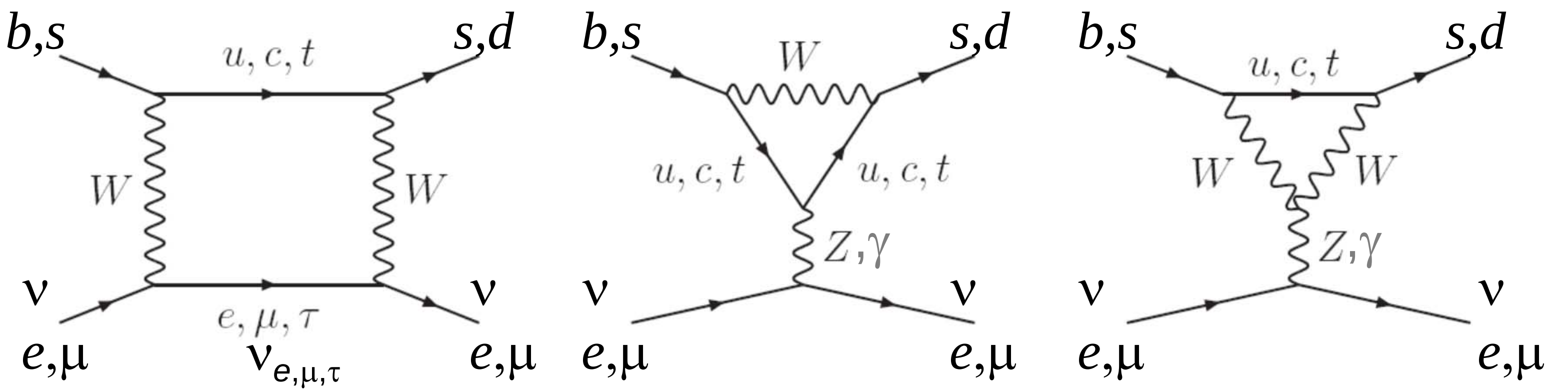
   i. Analysis Issues

   ii. Branching Fraction

   iii. Angular Analysis (preliminary results)

III. Summary/Conclusions

Flavor Changing Neutral Currents



Responsible for rare decays in Standard Model

e.g.,

$B \to X_s \gamma$

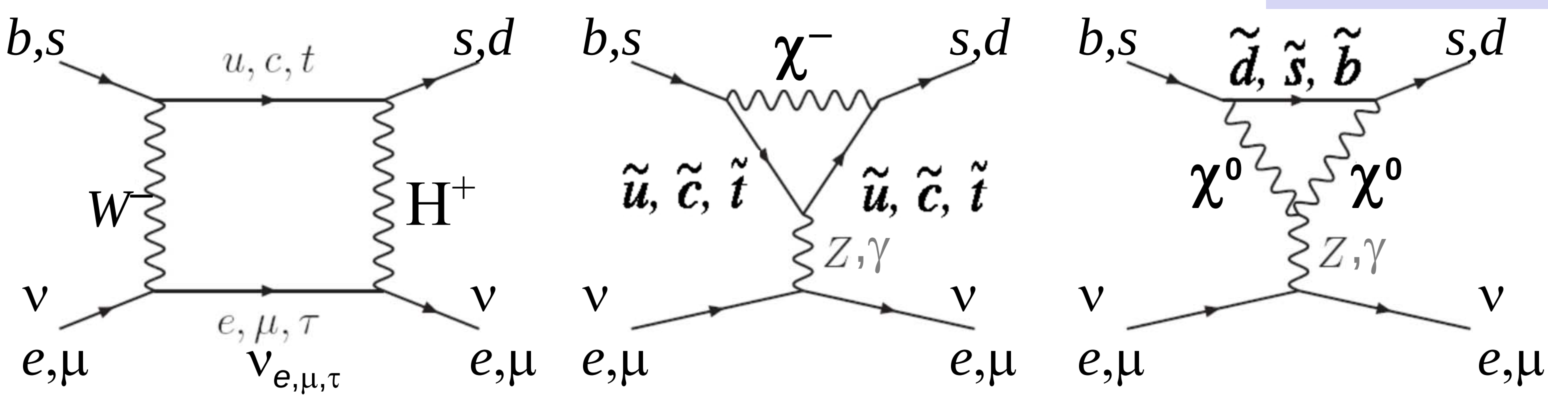
$B \to X_s \ell^+ \ell^-\ (\ell = e \text{ or } \mu)$

$B_s \to \mu^+ \mu^-$

$K_L^0 \to \mu^+ \mu^-$

$K^+ \to \pi^+ \nu \bar{\nu}$

$K_L^0 \to \pi^0 \nu \bar{\nu}$

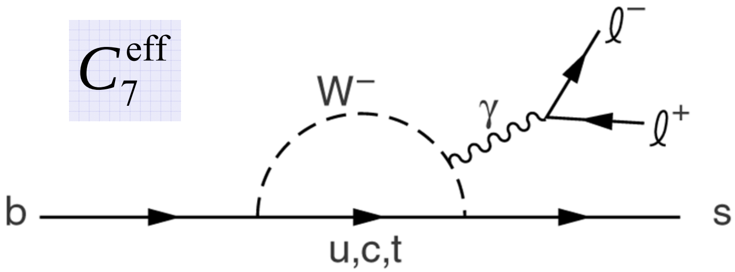


Sensitive to new (high-mass) particles in loops.

$b \to s\, l^+ l^-$

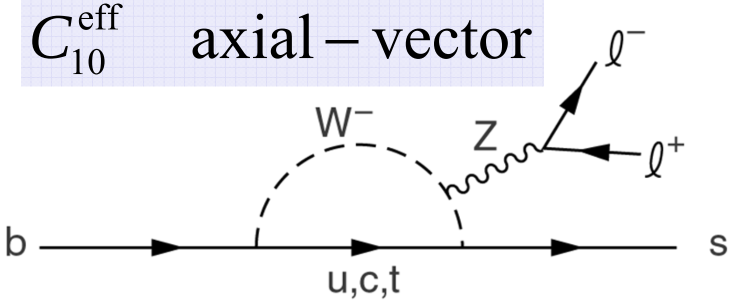
$l = e, \mu$

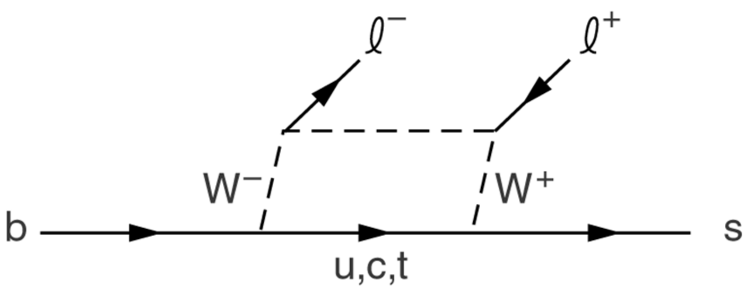
C_7^{eff}



C_9^{eff} vector

C_{10}^{eff} axial – vector





- More complex than $b \to s\, \gamma$
  - W-box and Z-penguin amplitudes important
  - $c\bar{c}$ resonances in dilepton spectrum (removed by cuts on M_{ll})

- More observables
  - partial BFs vs q^2 ($q^2 = m_{ll}^2$)
  - forward–backward asymmetry (A_{FB})
  - New Physics may induce effects in these observables

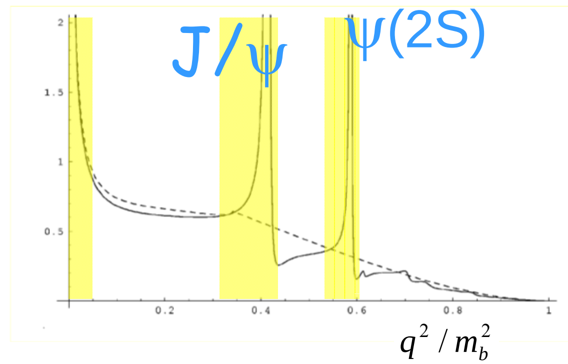
- Experimental considerations
  - Semi-inclusive (sum of exclusive modes) approach for $B \to X_s\, l^+ l^-$
  - Observables cleaner for $B \to K^*\, l^+ l^-$

$b \to s\, l^+ l^-$ Experimental Issues

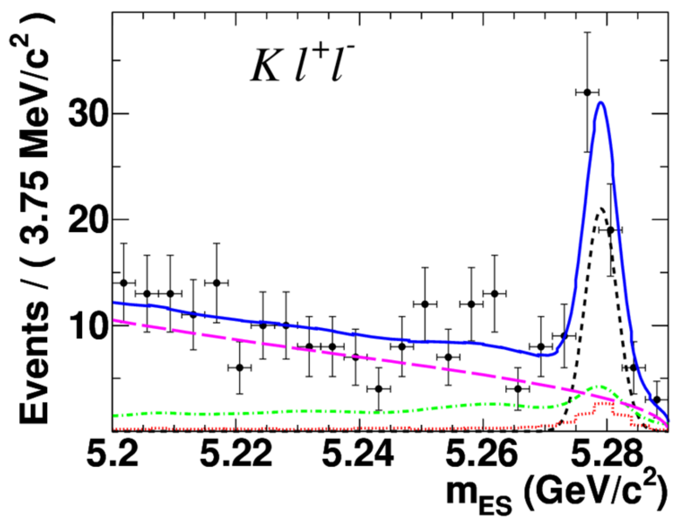
- Exclusive $B \to K\, l^+ l^-$ and $B \to K^*\, l^+ l^-$ — K, K^* submodes

  $(K^\pm, K^0_S, K^\pm\pi^\mp, K^\pm\pi^0, K^0_S\pi^\pm)e^+e^-$ and $(K^\pm, K^0_S, K^\pm\pi^\mp, K^0_S\pi^\pm)\mu^+\mu^-$ with $K^0_S \to \pi^+\pi^-$

- Interference from $B \to K^{(*)}\, J/\psi$ and $B \to K^{(*)}\, \psi(2S)$
  - Remove with cuts on l^+l^- mass

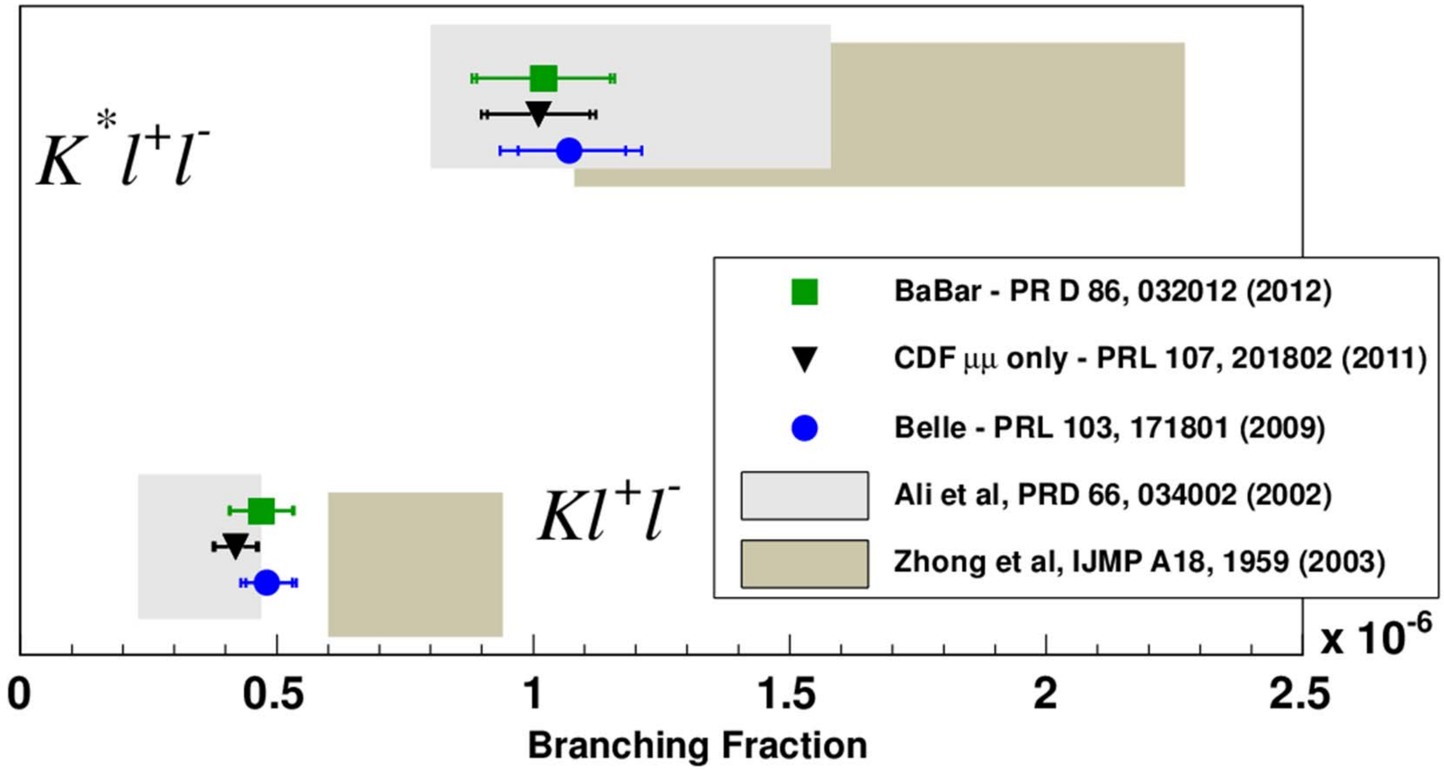


- Main backgrounds from B and D semi-leptonic decays
  - Suppress using event shape, vertex info, missing energy, …, in bagged DTs
- Background from $B \to D\pi\, (D \to K^{(*)}\pi) + \pi \to \mu$ mis-ID
  - Veto $K^{(*)}\pi$ mass close to D
- Extract signal with maximum likelihood fits
  - Using M_{ES} and likelihood ratio (LR from $B\bar{B}$ BDT), and $M_{K\pi}$ for K* modes



$$M_{ES} = \sqrt{E^{*2}_{\text{beam}} - p^{*2}_B}$$

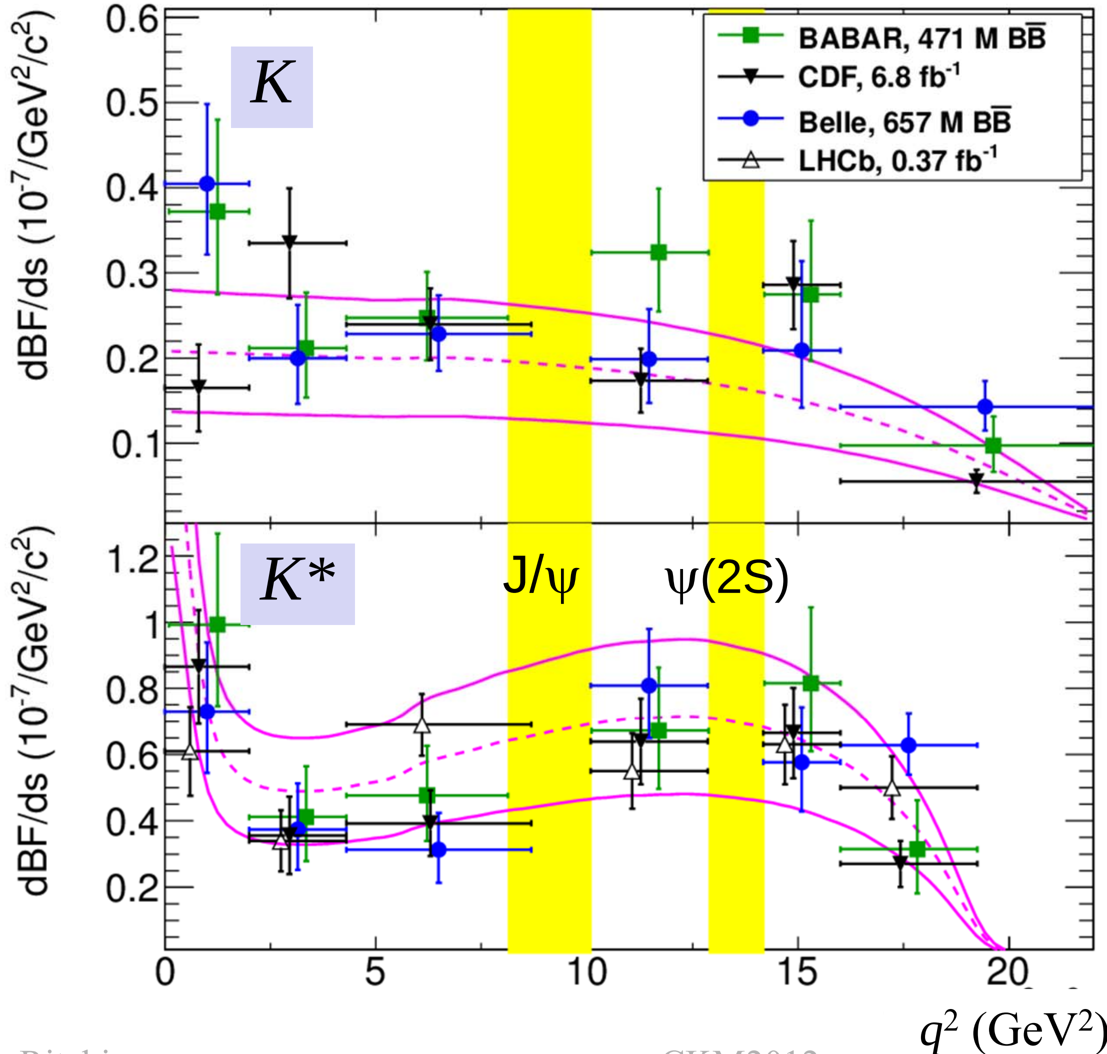
$B \to K^{(*)} l^+ l^-$ Branching Fraction



Measured BFs consistent with SM theory.

Next level of NP tests from partial BF's vs q^2, rate asymmetries, and angular information.

$B \to K^{(*)} l^+ l^-$ versus q^2

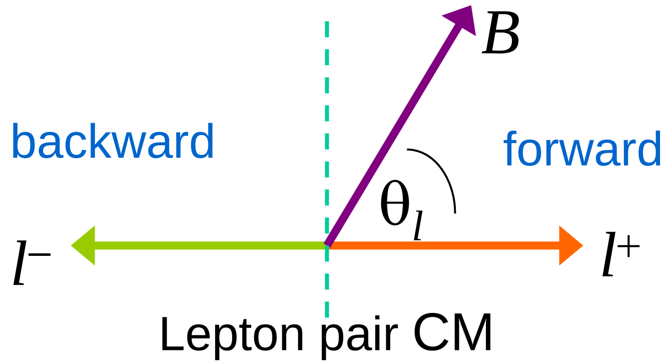


BaBar – PR D **86**, 032012 (2012)
CDF – PRL **107**, 201802 (2011)
Belle – PRL **103**, 171801 (2009)
LHCb – PRL **108**, 181806 (2012)

Ali et al., PR D **66**, 034002 (2002)

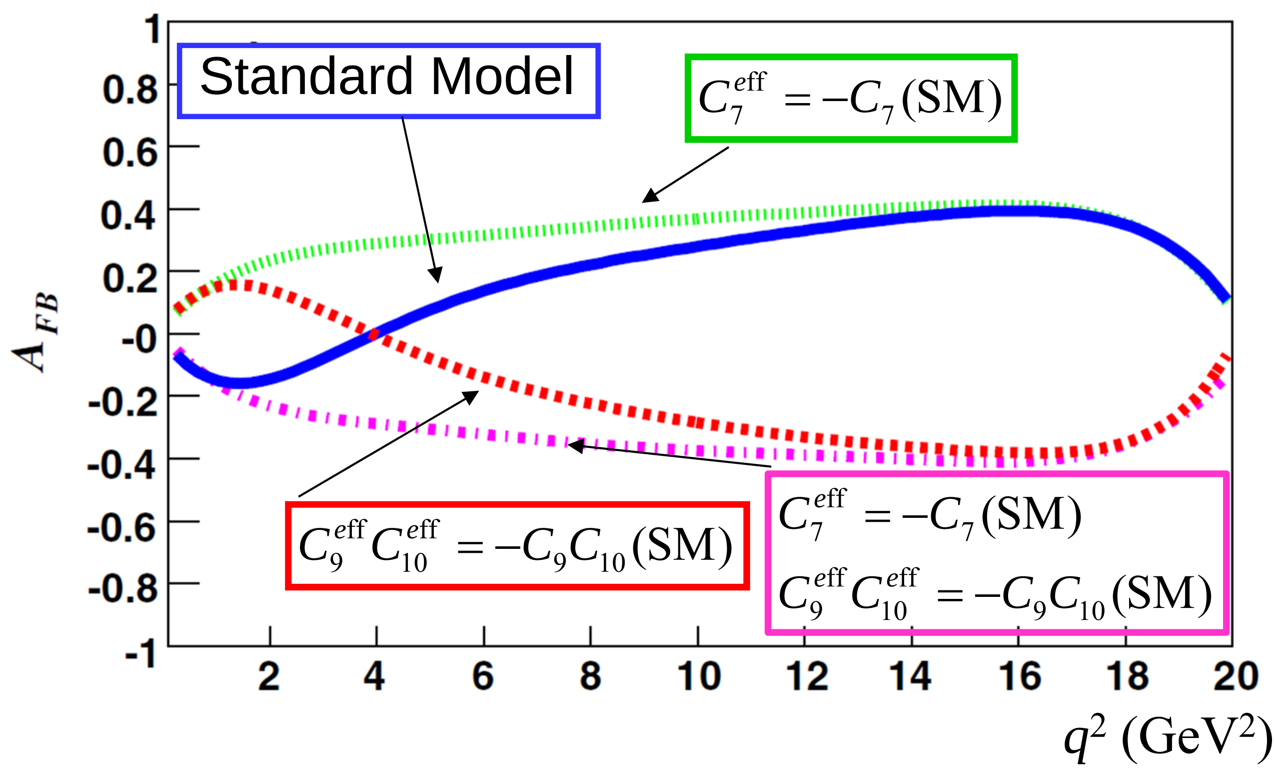
$(q^2 = m_{ll}^2)$

A_{FB} in $B \rightarrow K^* l^+ l^-$



Lepton forward–backward asymmetry (A_{FB})

- Measures forward-backward asymmetry in decay distribution in θ_l
- Sensitive to values (and relative signs) of effective Wilson coefficients $C_7^{\text{eff}}, C_9^{\text{eff}}, C_{10}^{\text{eff}}$



$B \to K^* l^+ l^-$ Angular Analysis

K* longitudinal polarization F_L

From distribution of the angle θ_K between the K and B in the K* rest frame

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_K} = \frac{3}{2}F_L\cos^2\theta_K + \frac{3}{4}(1-F_L)(1-\cos^2\theta_K)$$

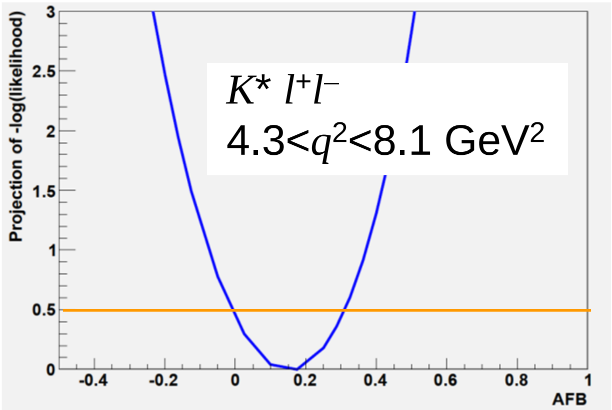
Lepton forward-backward asymmetry A_{FB}

From distribution of the angle θ_l between the l^+ and B in the l^+l^- rest frame

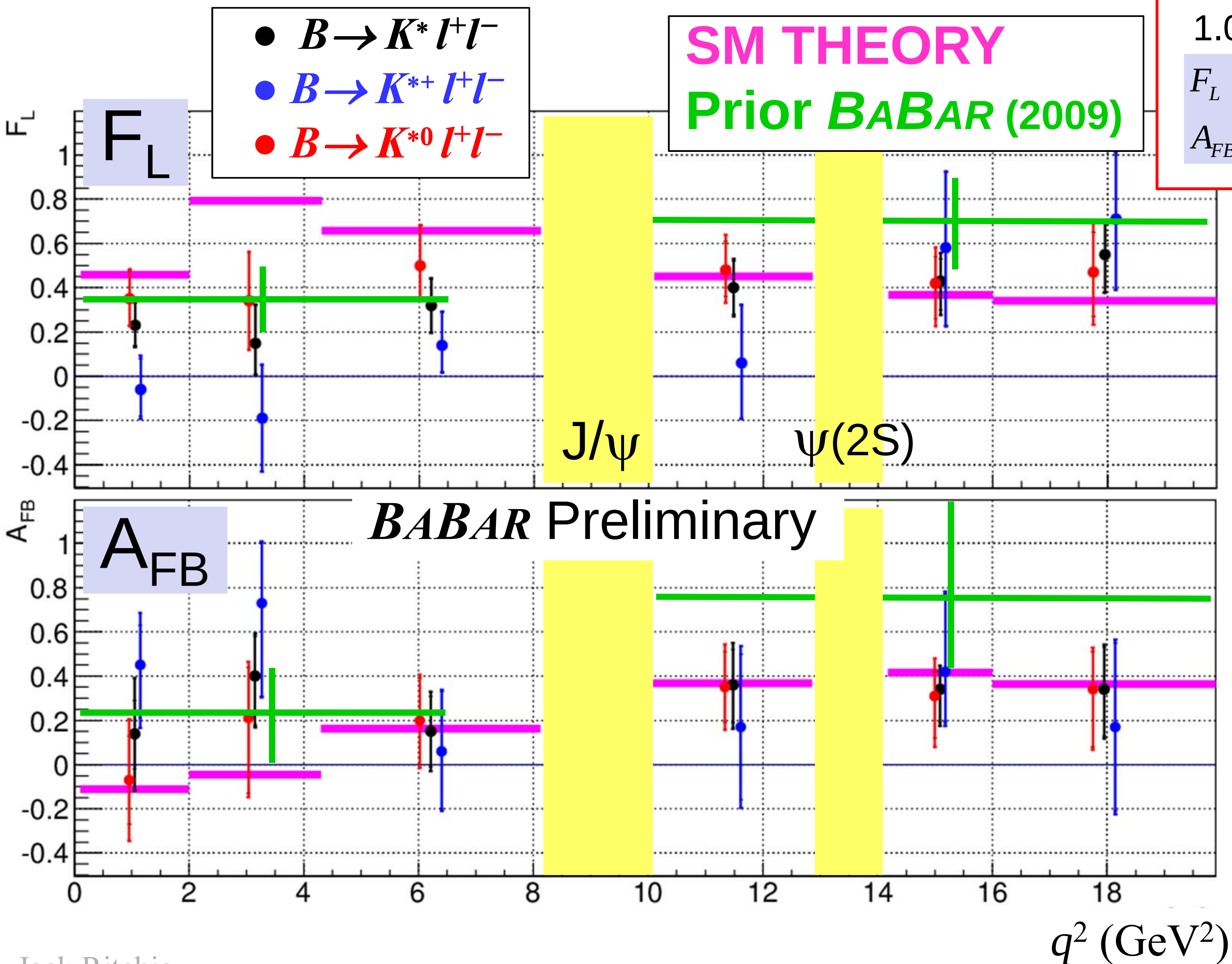
$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_\ell} = \frac{3}{4}F_L(1-\cos^2\theta_\ell) + \frac{3}{8}(1-F_L)(1+\cos^2\theta_\ell) + A_{FB}\cos\theta_\ell$$

Fit Strategy

- After event selection, perform 3-d fits (m_{ES}, $M_{K\pi}$, LR) to determine signal and background yields for each submode in each q^2 bin.
- For m_{ES} > 5.27 GeV, with submode yields fixed, perform a simultaneous fit (including cos θ_K) over all submodes to determine F_L.
- With F_L fixed, perform a simultaneous fit (including cos θ_l) over all submodes to determine A_{FB}.
- Validate the method using charmonium modes $B \to K^* J/\psi$ and $B \to K^* \psi(2S)$



BaBar Angular Results (Preliminary)



BaBar preliminary
$1.0 < q^2 < 6.0$ GeV^2

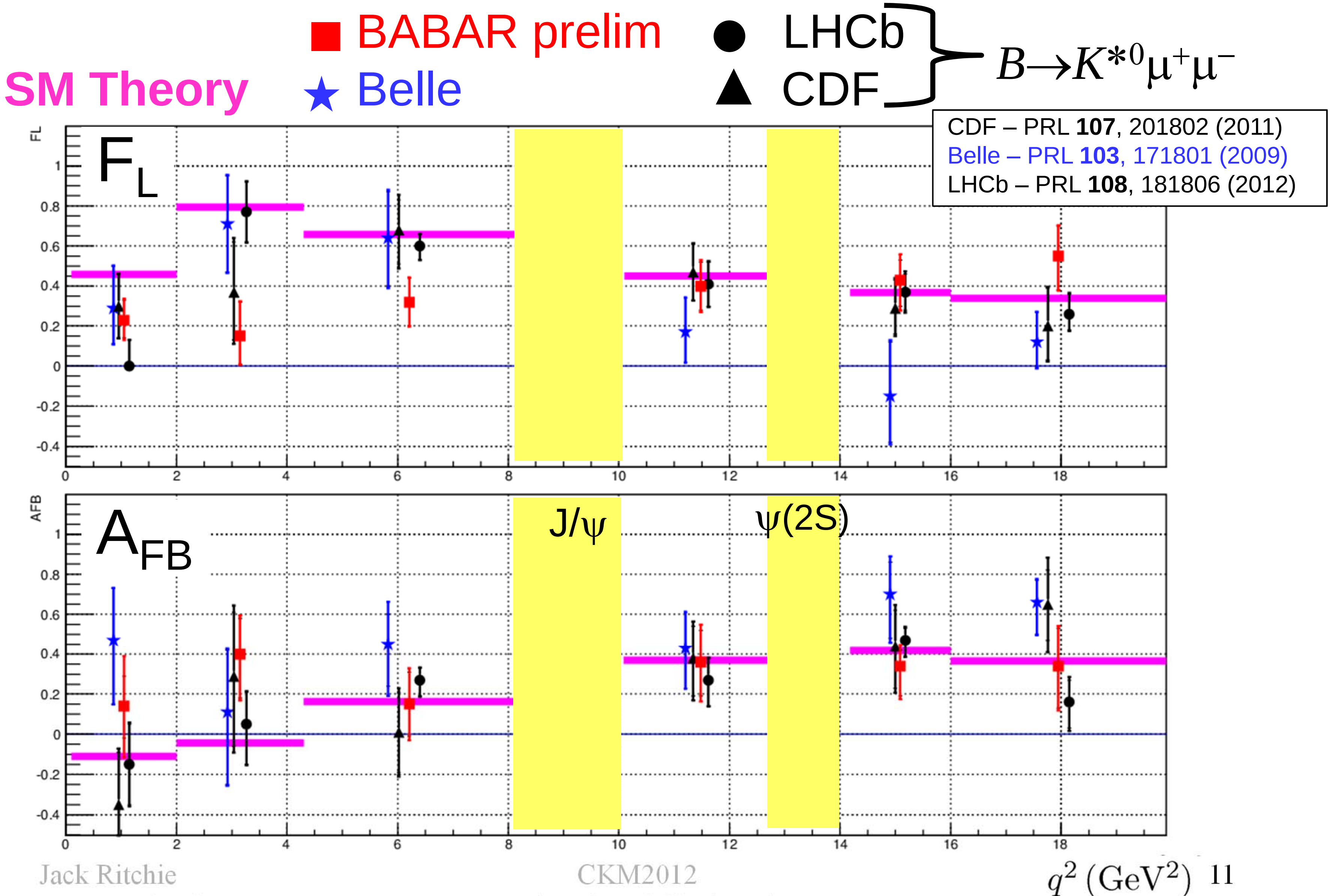
$F_L = 0.25^{+0.09}_{-0.08} \pm 0.03$

$A_{FB} = 0.17^{+0.13}_{-0.14} \pm 0.07$

429 fb^{-1}

Statistical and systematic errors included

$B \to K^* l^+ l^-$ Angular Results Compared



Summary/Conclusions

- There has been enormous progress in the study of rare FCNC B decays, including angular variables in the $B \to K^* l^+ l^-$ decay.
  - Both e^+e^- and hadron collider experiments

- *BABAR* has reported preliminary F_L and A_{FB} versus q^2 for $B \to K^* l^+ l^-$ with the binning used by Belle, CDF, and LHCb.

- Current experimental results are generally consistent with each other and with the SM.

- Complete study of these processes will require much larger data samples.

Backup/Extra Slides

Preliminary F_L results with systematics.

$s(\mathrm{GeV}^2/c^4)$	$B \to K^*\ell^+\ell^-$	$B^0 \to K^{*0}\ell^+\ell^-$	$B^+ \to K^{*+}\ell^+\ell^-$
$0.1 - 2.00$	$0.23^{+0.10}_{-0.09} \pm 0.04$	$0.35^{+0.13}_{-0.12} \pm 0.04$	$-0.06^{+0.14}_{-0.12} \pm 0.06$
$2.00 - 4.30$	$0.15^{+0.17}_{-0.14} \pm 0.04$	$0.34^{+0.22}_{-0.22} \pm 0.08$	$-0.19^{+0.24}_{-0.24} \pm 0.04$
$4.30 - 8.68$	$0.32^{+0.12}_{-0.12} \pm 0.06$	$0.50^{+0.18}_{-0.15} \pm 0.05$	$0.14^{+0.15}_{-0.12} \pm 0.05$
$10.09 - 12.86$	$0.40^{+0.12}_{-0.12} \pm 0.06$	$0.48^{+0.13}_{-0.12} \pm 0.10$	$0.06^{+0.26}_{-0.25} \pm 0.05$
$14.18 - 16.00$	$0.43^{+0.10}_{-0.13} \pm 0.09$	$0.42^{+0.12}_{-0.16} \pm 0.11$	$0.58^{+0.34}_{-0.35} \pm 0.06$
> 16.00	$0.55^{+0.15}_{-0.17} \pm 0.03$	$0.47^{+0.18}_{-0.20} \pm 0.13$	$0.71^{+0.30}_{-0.32} \pm 0.03$
$1.00 - 6.00$	$0.25^{+0.09}_{-0.08} \pm 0.03$	$0.47^{+0.13}_{-0.13} \pm 0.04$	$0.03^{+0.11}_{-0.10} \pm 0.03$

BABAR **Preliminary**

Preliminary $\mathcal{A}_{FB}$ results with systematics.

$s(\mathrm{GeV}^2/c^4)$	$B \to K^*\ell^+\ell^-$	$B^0 \to K^{*0}\ell^+\ell^-$	$B^+ \to K^{*+}\ell^+\ell^-$
$0.1 - 2.00$	$0.14^{+0.15}_{-0.16} \pm 0.20$	$-0.07^{+0.20}_{-0.20} \pm 0.19$	$0.45^{+0.18}_{-0.24} \pm 0.15$
$2.00 - 4.30$	$0.40^{+0.18}_{-0.22} \pm 0.07$	$0.21^{+0.23}_{-0.34} \pm 0.11$	$0.73^{+0.27}_{-0.42} \pm 0.07$
$4.30 - 8.68$	$0.15^{+0.16}_{-0.16} \pm 0.08$	$0.20^{+0.19}_{-0.20} \pm 0.08$	$0.06^{+0.27}_{-0.26} \pm 0.07$
$10.09 - 12.86$	$0.36^{+0.16}_{-0.17} \pm 0.10$	$0.35^{+0.16}_{-0.16} \pm 0.11$	$0.17^{+0.33}_{-0.33} \pm 0.16$
$14.18 - 16.00$	$0.34^{+0.08}_{-0.15} \pm 0.07$	$0.31^{+0.11}_{-0.19} \pm 0.13$	$0.42^{+0.35}_{-0.23} \pm 0.09$
> 16.00	$0.34^{+0.19}_{-0.21} \pm 0.07$	$0.34^{+0.17}_{-0.26} \pm 0.08$	$0.17^{+0.38}_{-0.38} \pm 0.11$
$1.00 - 6.00$	$0.17^{+0.12}_{-0.14} \pm 0.07$	$0.02^{+0.16}_{-0.18} \pm 0.07$	$0.31^{+0.12}_{-0.14} \pm 0.07$