Experimental Results on $b \to s l^+ l^-$ and $B^+ \to \tau^+ \nu$

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b→sll Theory

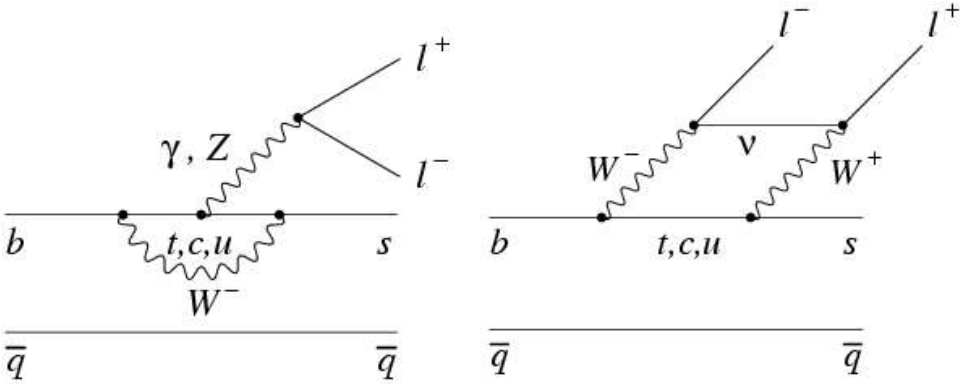
- Effective Hamiltonian factorizes short-distance from long-distance effects.
- Three short-distant Wilson coefficients:
  - C_7^{eff} from photon penguin Magnitude constrained by b→sγ BF measurement: $|C_7^{eff}| \cong 0.33$ (arXiv:0704.3575)
  - C_9^{eff}(C_{10}^{eff}) from vector (axial-vector) parts of the Z,W box

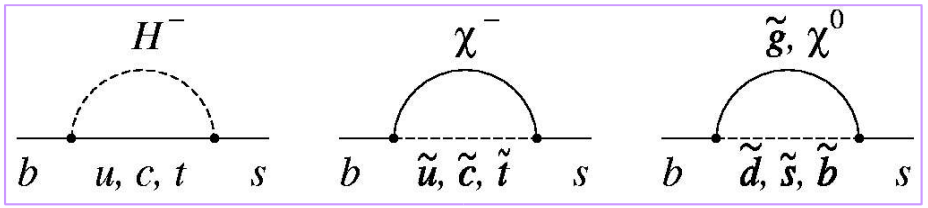
$$H_{\text{eff}} = -\frac{4G_F}{\sqrt{2}} (V_{tb}V_{ts}^*) \sum_{i=1}^{10} C_i O_i$$

CKM factors

Wilson coefficients

operators





- New physics may modify C_i's or introduce additional scalar or pseudoscalar terms

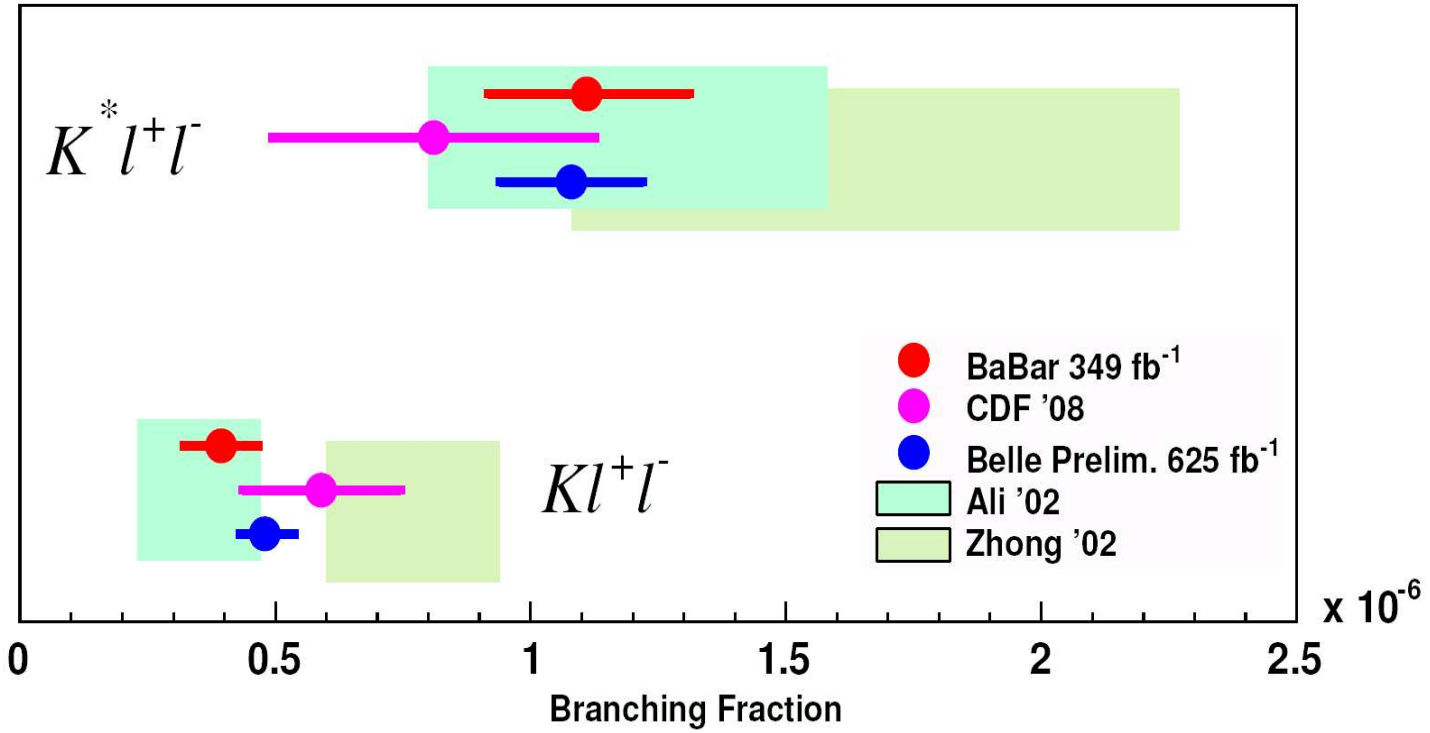
b→sll Experimental Methods

- Fully inclusive measurements not possible.
  - Use exclusive B→K(*)ll sub-modes: $\left\{ K^{\pm},\ K^{0}_{S},\ K^{\pm}\pi^{\mp},\ K^{\pm}\pi^{0},\ K^{0}_{S}\pi^{\pm} \right\} \times [e^{+}e^{-},\ \mu^{+}\mu^{-}]$
- Interference from B→K(*)J/ψ and B→K(*)ψ(2S)
  - Remove with cuts on invariant di-lepton mass
  - Provide large control samples (same topology, known BFs)
- Signal defined by m_{ES} and ΔE variables:

$$m_{\mathrm{ES}} = \sqrt{E^{*2}_{\mathrm{beam}} - p^{*2}_{B}} \qquad \Delta E = E^{*}_{B} - E^{*}_{\mathrm{beam}}$$

- Suppress combinatoric backgrounds from semileptonic B and D decays using event shape variables
- Peaking backgrounds from B→Dπ(D→Kπ) with π→μ mis-ID
  - Veto based on K(*)π mass close to D mass
- Extract signal with maximum likelihood fit

B→K(*)ll Branching Fractions



BaBar preliminary – ICHEP '08 (349 fb^{-1})

$$\mathrm{B}(B \to K^* \ell^+ \ell^-) = (11.1^{+1.9}_{-1.8} \pm 0.7) \times 10^{-7}$$
$$\mathrm{B}(B \to K \ell^+ \ell^-) = (3.9 \pm 0.7 \pm 0.2) \times 10^{-7}$$

BELLE preliminary – ICHEP '08 (625 fb^{-1})

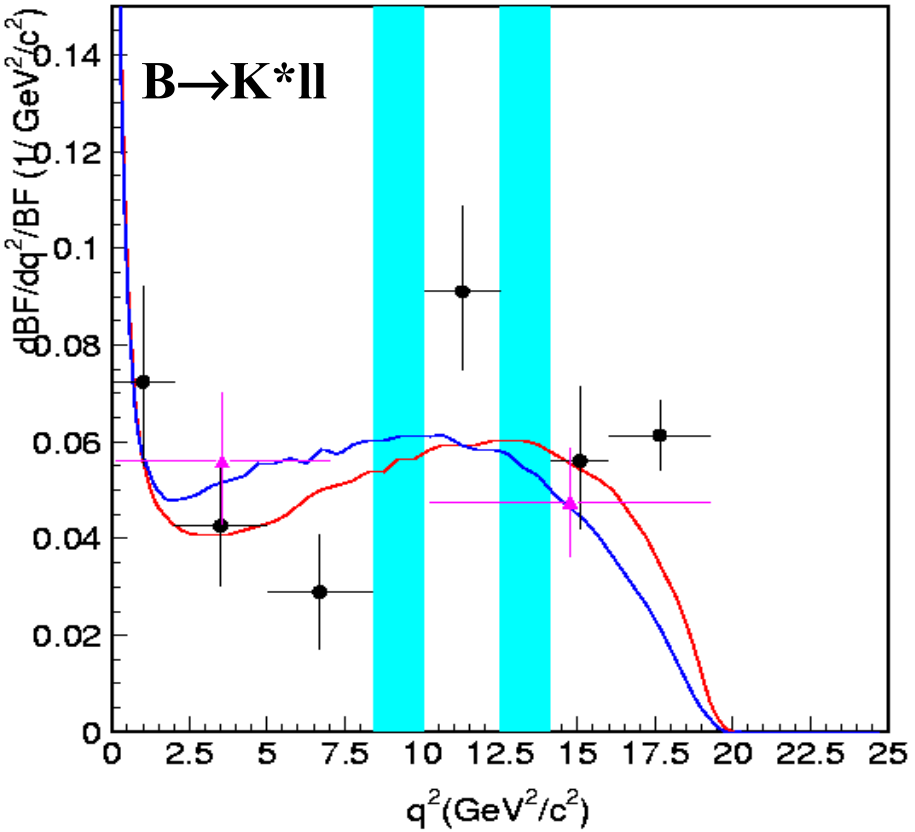
$$\mathcal{B}(B \to K^* \ell^+ \ell^-) = (10.8^{+1.0}_{-1.0} \pm 0.9) \times 10^{-7}$$
$$\mathcal{B}(B \to K \ell^+ \ell^-) = (4.8^{+0.5}_{-0.4} \pm 0.3) \times 10^{-7}$$

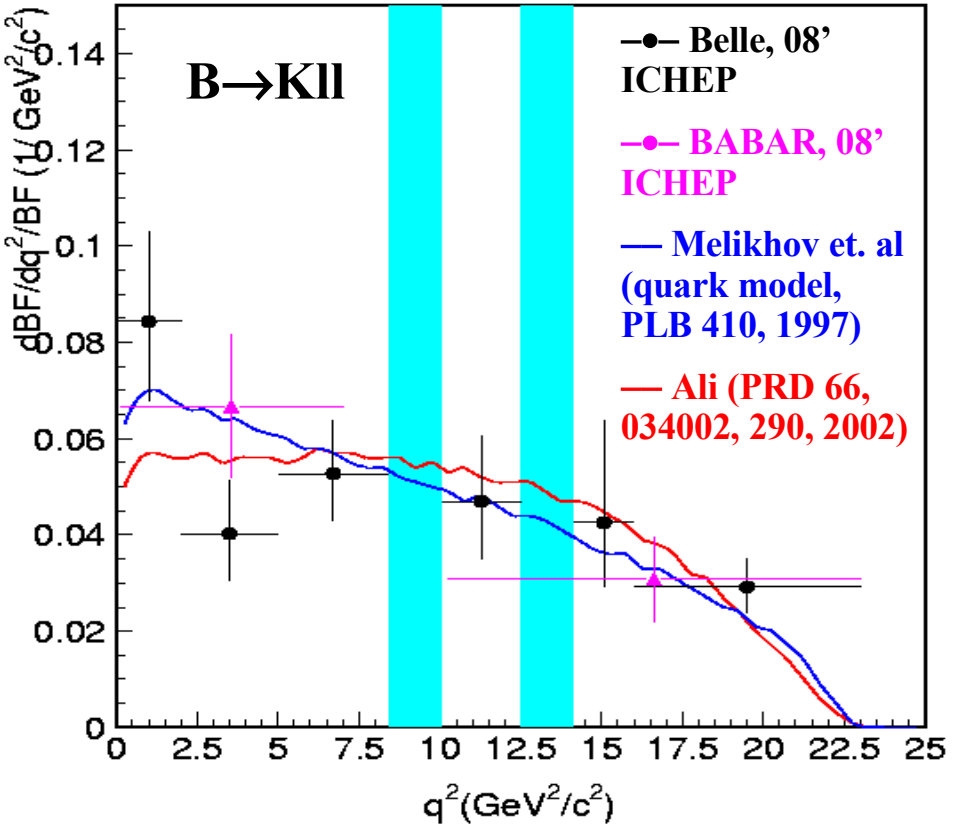
Consistent with theory.
Next level of SM tests from rate asymmetries and angular information (as functions of $q^2 = s = m_{ll}^2$)

B→K(*)ll q^2 Distributions

BaBar Result:
arXiv: 0807.4119
submitted to PRL

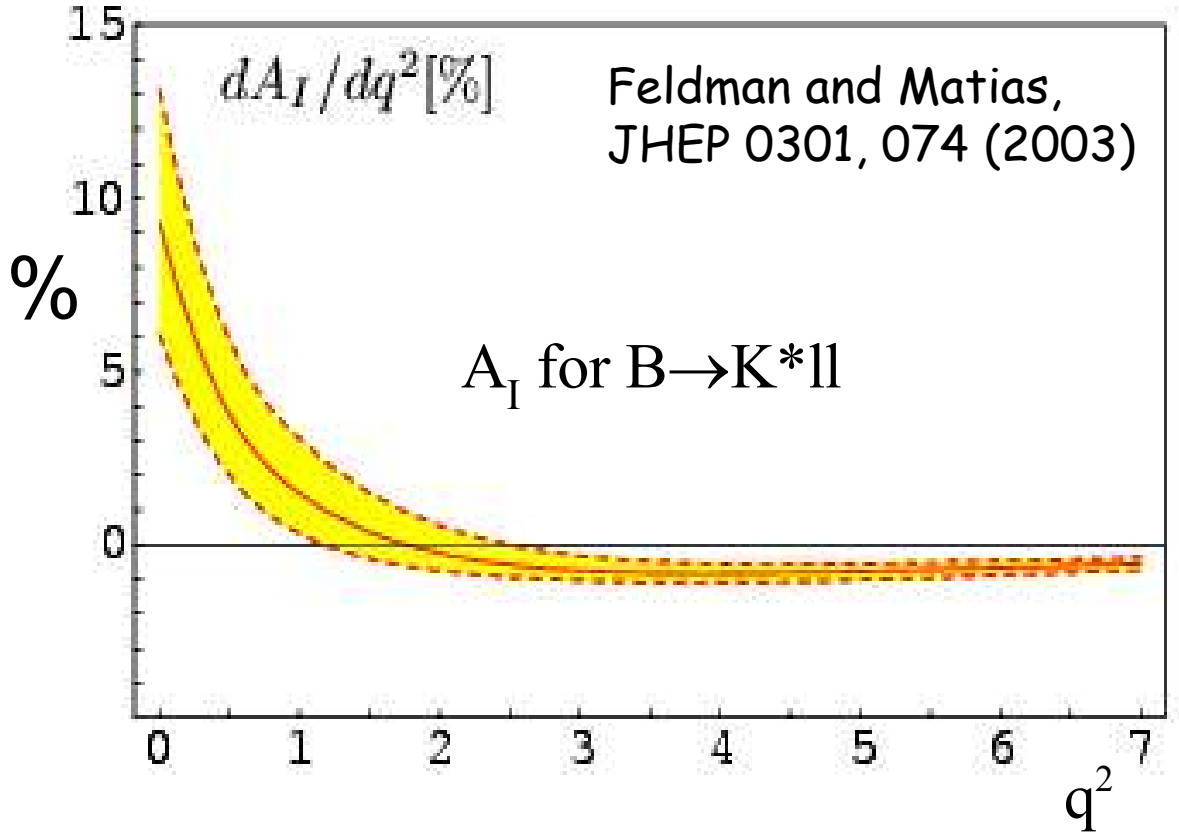
$$q^2 = m^2_{\ell\ell}$$





B→K(*)ll Isospin Asymmetries

$$A_I \equiv \frac{\mathrm{B}(B^0 \to K^{(*)0}\ell^+\ell^-) - (\frac{\tau_0}{\tau_+})\mathrm{B}(B^\pm \to K^{(*)\pm}\ell^+\ell^-)}{\mathrm{B}(B^0 \to K^{(*)0}\ell^+\ell^-) + (\frac{\tau_0}{\tau_+})\mathrm{B}(B^\pm \to K^{(*)\pm}\ell^+\ell^-)}$$



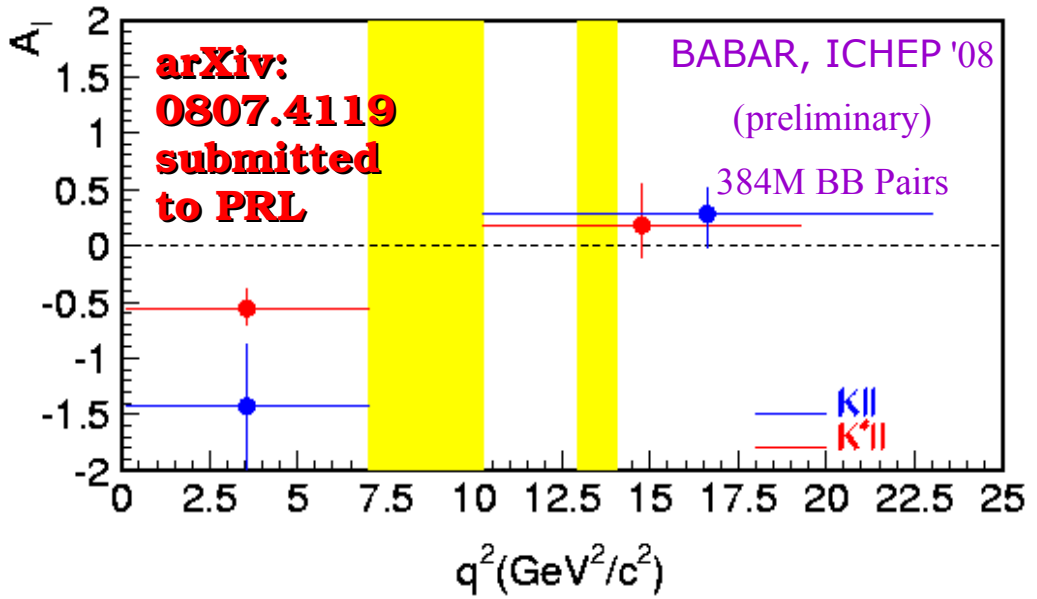
Isospin asymmetry is expected to be 0 for B→Kll

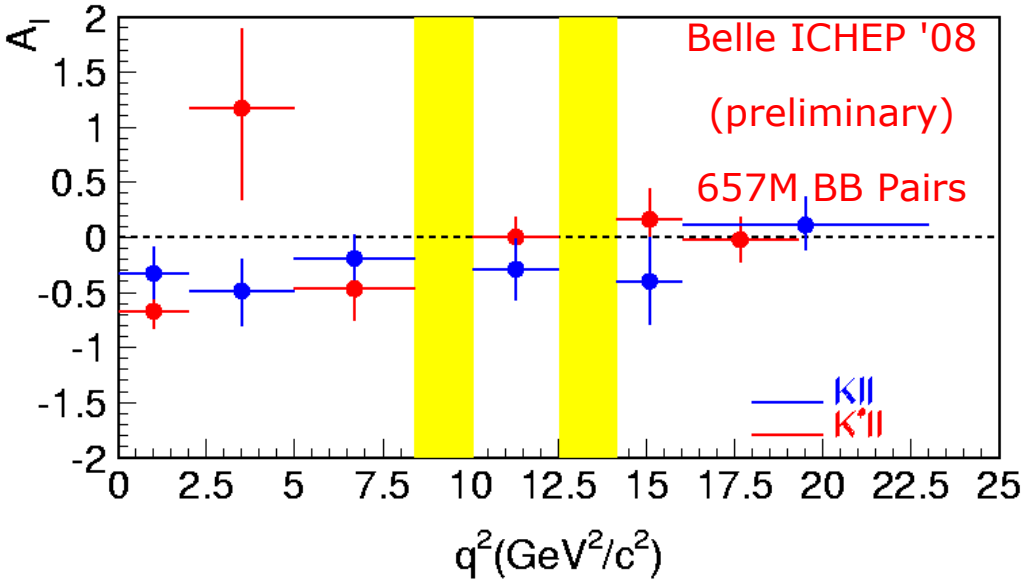
For B→K*ll: Small in Standard Model, with some variation at low-q^2, near 0 for high-q^2

Some sensitivity to the sign of C_7

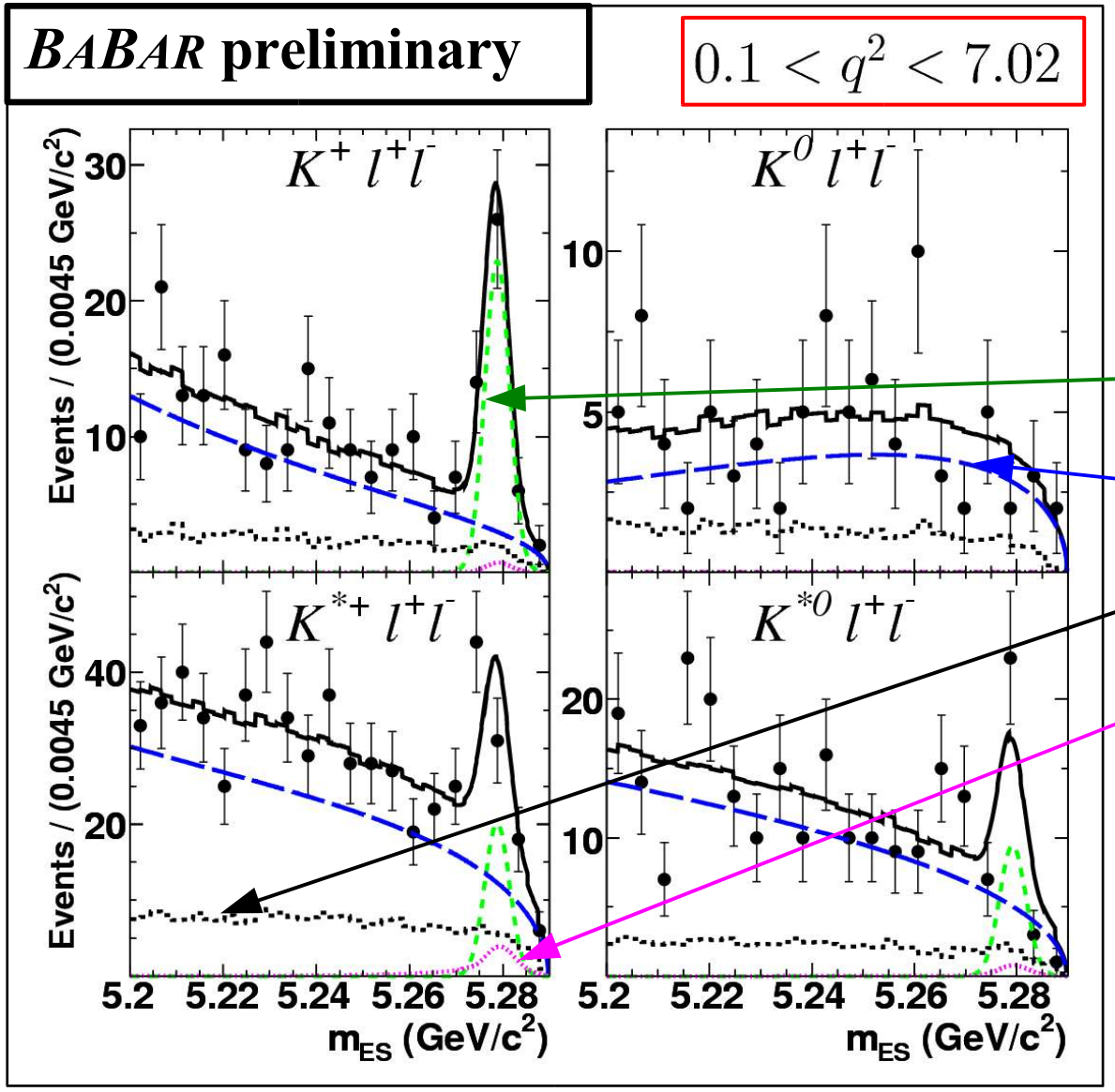
B→K(*)ll Isospin Asymmetries

- No significant asymmetry in the high q^2 region
- BaBar sees significant negative isospin asymmetries in the low q^2 region
- Belle and BaBar's results are consistent.





B^0 vs. $B^+ \to K(*)ll$ Comparison (BaBar)



$\mathrm{B}(B^\pm \to K^\pm \ell^+ \ell^-) = (2.5^{+0.52}_{-0.47} \pm 0.1) \times 10^{-7}$

$\mathrm{B}(B^0 \to K^0 \ell^+ \ell^-) < 0.9 \times 10^{-7}$ (90% CL)

- **Signal**
- **Combinatoric BG**
- **Fake Muons**
- **Crossfeed/peaking**

$\mathrm{B}(B^0 \to K^{*0} \ell^+ \ell^-) = (2.6^{+1.1}_{-1.0} \pm 0.2) \times 10^{-7}$

$\mathrm{B}(B^\pm \to K^{*\pm} \ell^+ \ell^-) = (9.8^{+2.6}_{-2.4} \pm 0.6) \times 10^{-7}$

Lepton Flavor and CP Asymmetries

- The ratio of electron BF to muon BF ($R_{K(*)}$) should be R_{K^*}=1.33 for K* modes (contribution from the pole region) and R_K=1.0 for K modes in the SM.
- R_K is predicted to be larger than 1.0 in the two Higgs doublet model with large tan(β)
- Results:

Lepton Asy.	Belle (657M)	BABAR (384M)
$K^*\ell\ell$	$1.21\pm0.25\pm0.07$	$1.37^{+0.53}_{-0.40}$
$K\ell\ell$	$0.97\pm0.18\pm0.05$	$0.96^{+0.44}_{-0.34}$

- CP Asymmetry:

$$A_{CP} = \frac{N_{\bar{B}} - N_B}{N_{\bar{B}} + N_B}$$

CP Asy.	Belle (657M)	BABAR (384M)
$K^*\ell\ell$	-0.10±0.10±0.03	-0.02±0.16
$K\ell\ell$	0.04±0.10±0.02	-0.18±0.18

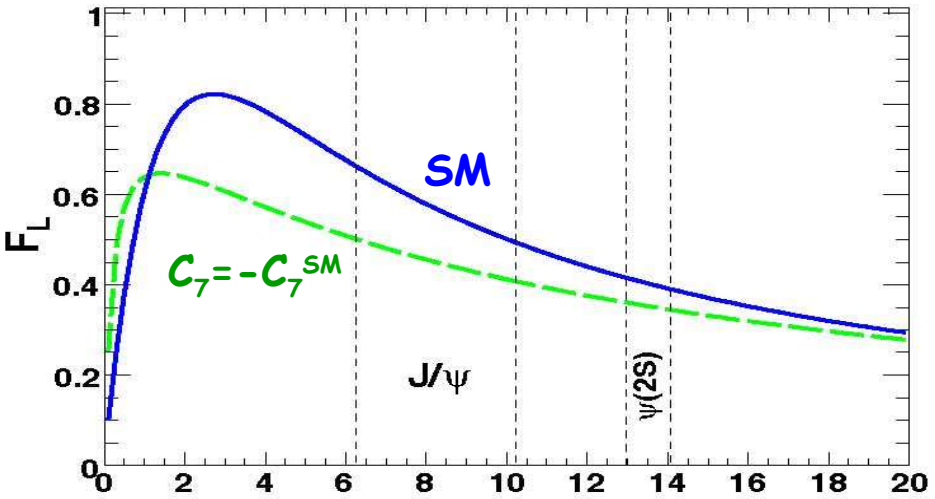
Angular Distributions

Angular distributions as functions of q^2 are particularly sensitive to possible new physics.

K* longitudinal polarization F_L

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

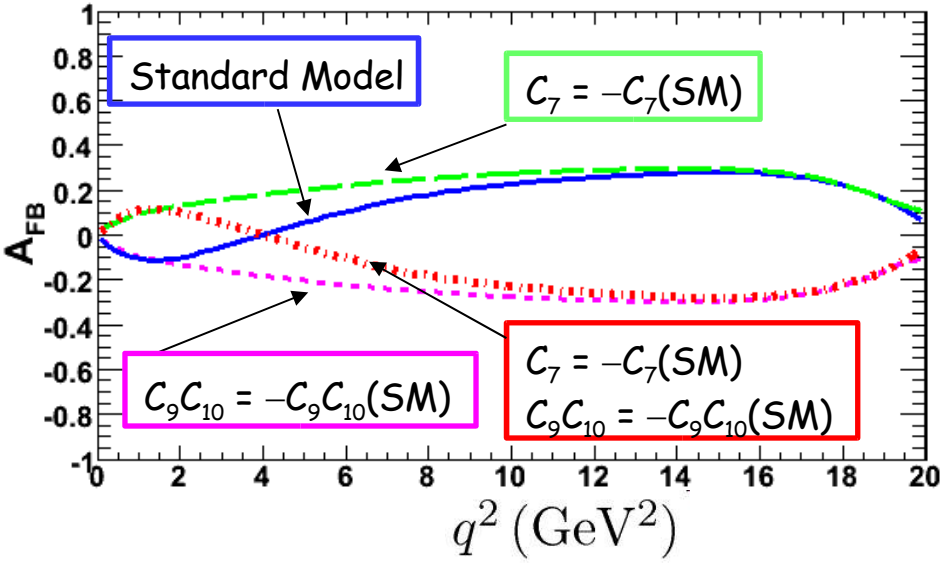
$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_K} = \frac{3}{2}F_L\cos^2\theta_K + \frac{3}{4}(1-F_L)(1-\cos^2\theta_K)$$



Lepton forward-backward asymmetry A_{FB}

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

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



BaBar Angular Fits

Two q^2 bins:

low – $0.1 < q^2 < 6.25\ \mathrm{GeV}^2$

high - $q^2 > 10.24\ \mathrm{GeV}^2$

except $12.96 < q^2 < 14.06$

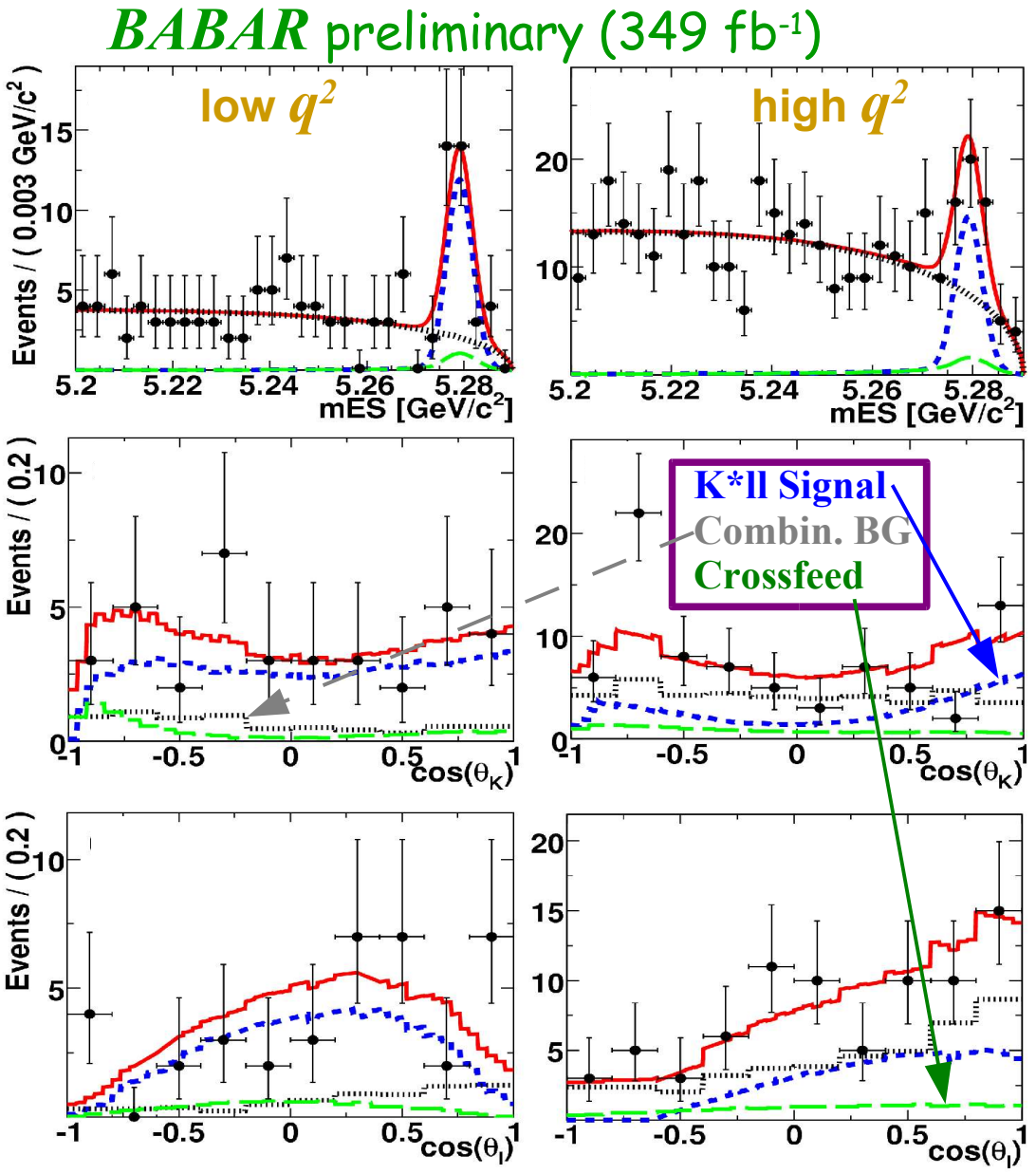
Three Step Fit Procedure:

2. Combine K^*l^+l modes, fit for yields.
3. Fix yields. For $m_{ES}>5.27$, fit $\cos(\theta_K)$ for F_L
4. Fix F_L, fit $\cos(\theta_l)$ for A_{FB}

Angular PDFs:

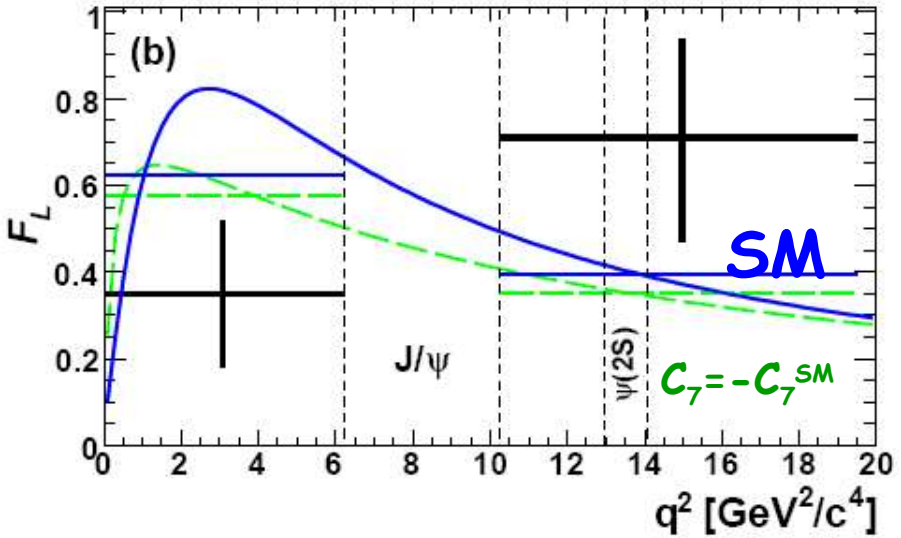
- Signal weighted by detector efficiency from MC

- Combinatorial background from m_{ES} sidebands in data



BaBar F_L, A_{FB} (Preliminary) Results

Longitudinal K* polarization



$$F_L^{low\ s} = 0.35 \pm 0.16 \pm 0.04$$

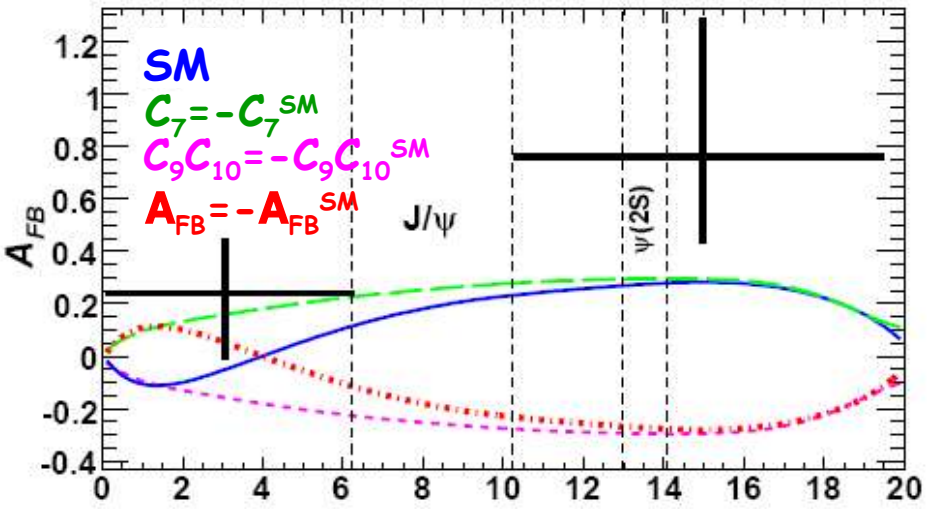
$$F_L^{high\ s} = 0.71^{+0.20}_{-0.22} \pm 0.05$$

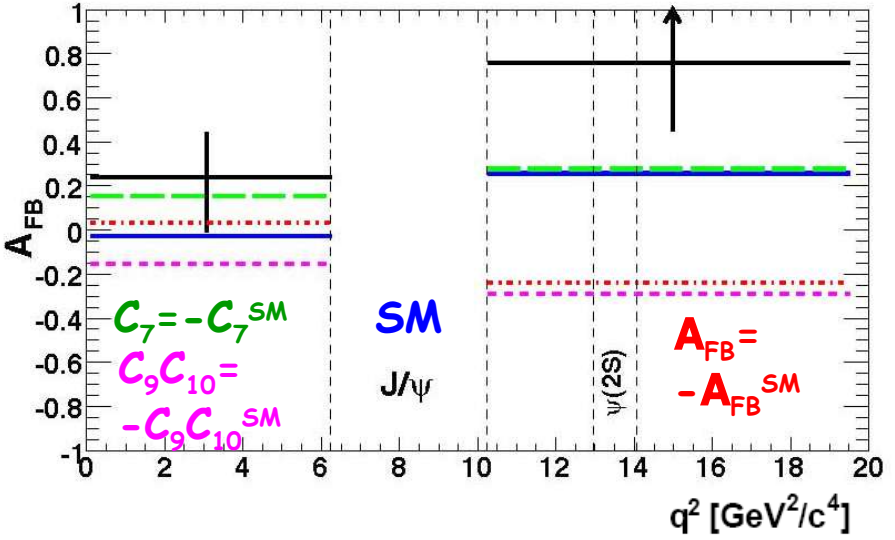
$$A_{FB}^{low\ s} = 0.24^{+0.18}_{-0.23} \pm 0.06$$

$$A_{FB}^{high\ s} = 0.76^{+0.52}_{-0.32} \pm 0.07$$

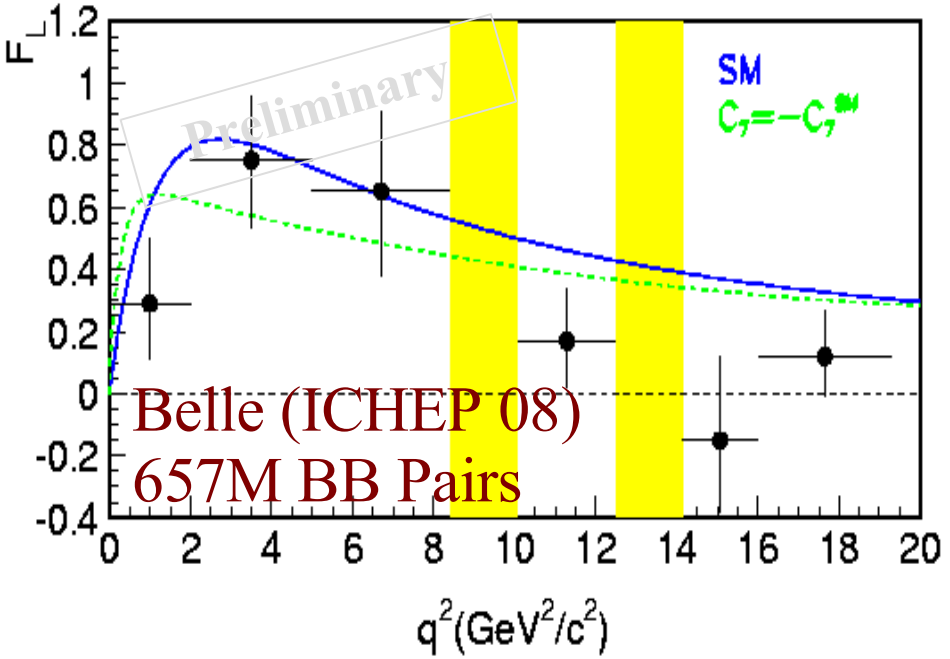
arXiv: 0804.4412 submitted to PRL

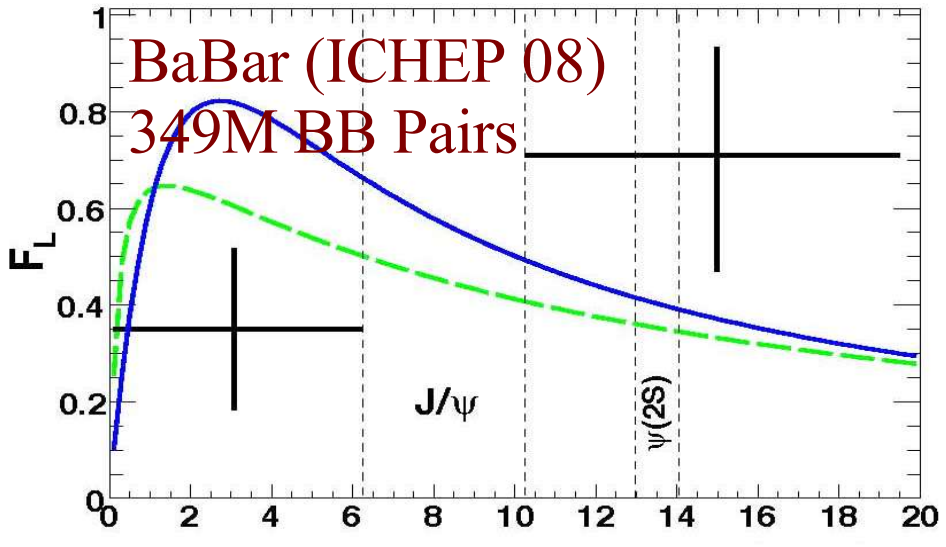
Forward-backward Asymmetry

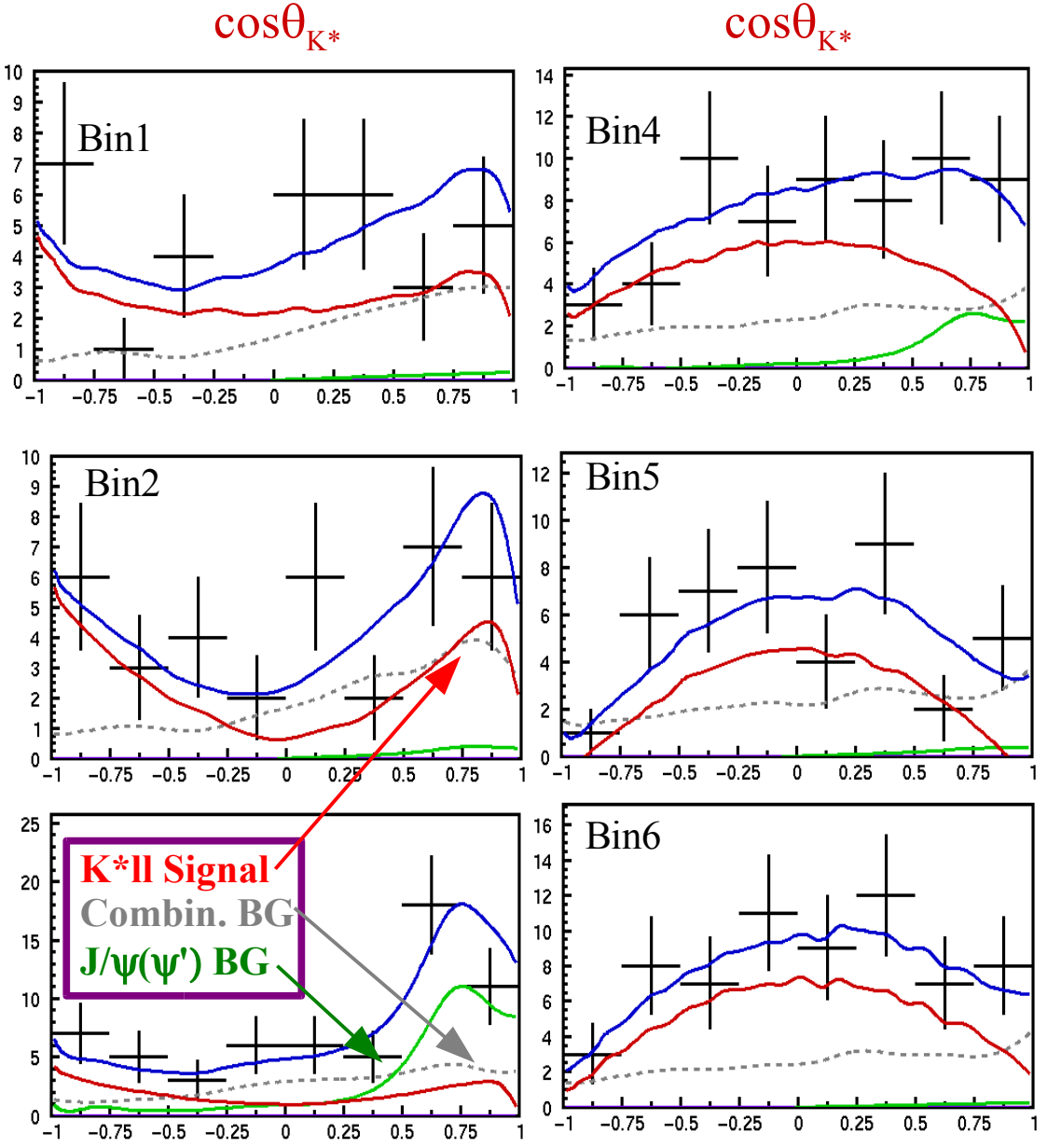




Belle Angular Fits (Preliminary): F_L

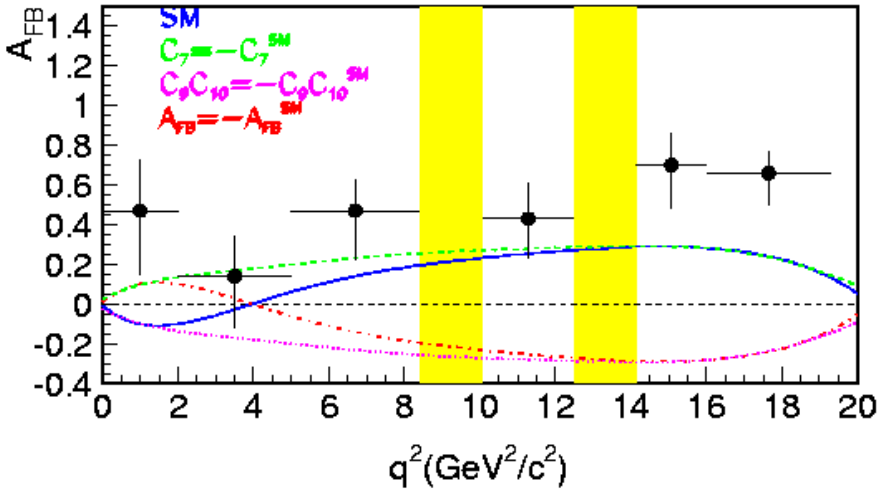




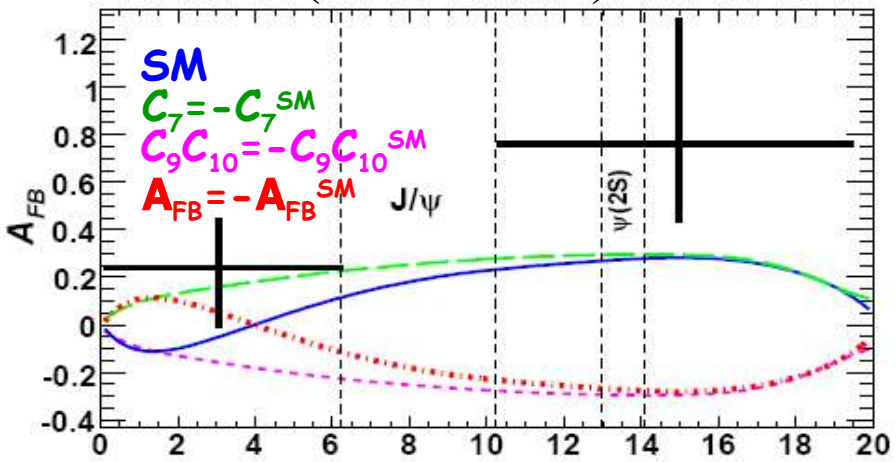


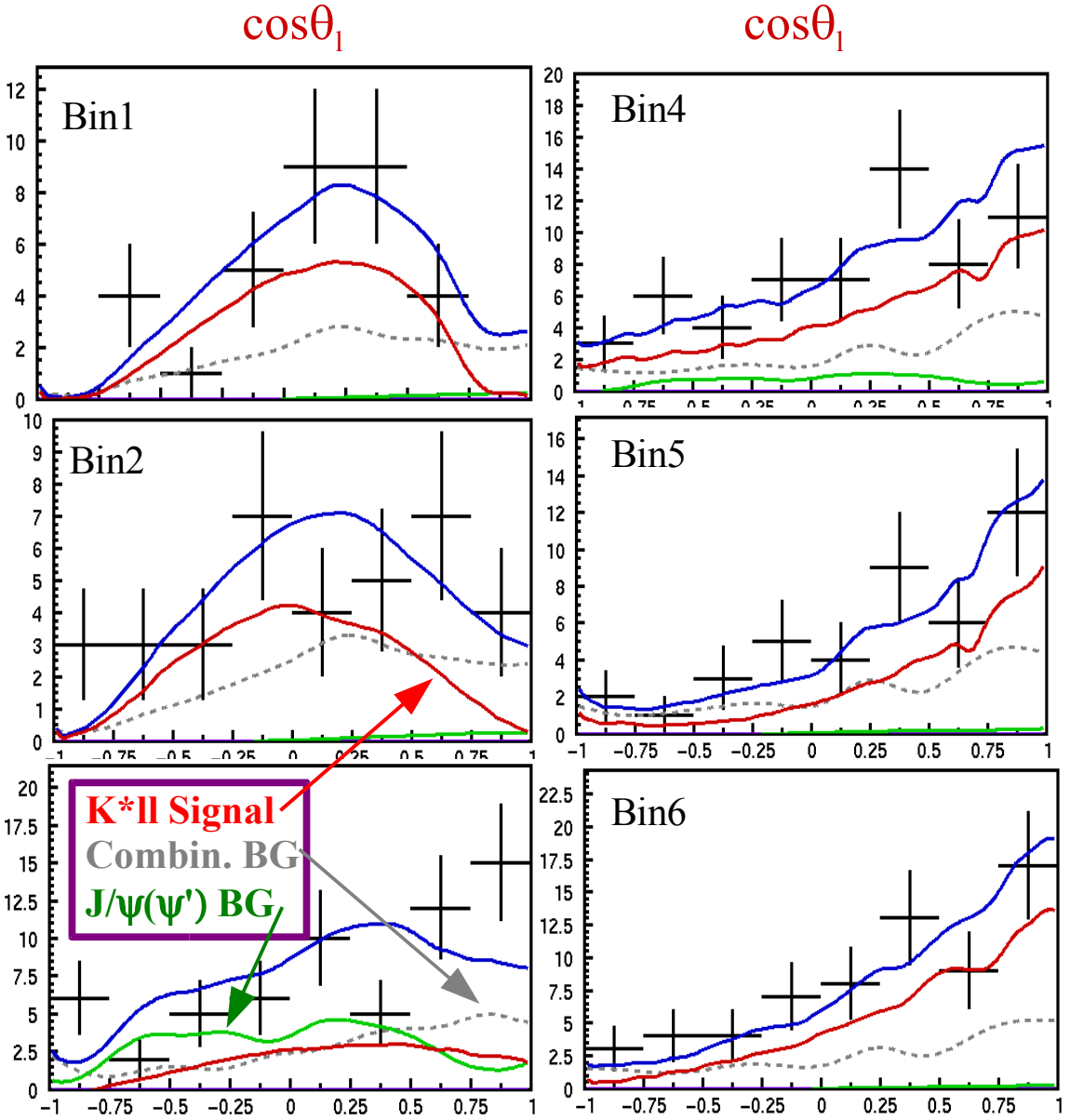
Belle Angular Fits (Preliminary): A_{FB}

Belle (ICHEP '08)

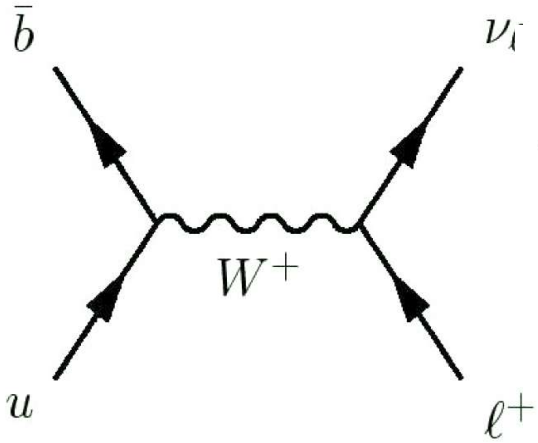


BaBar (ICHEP '08)





$B^+ \to \tau^+ \nu$ Motivation



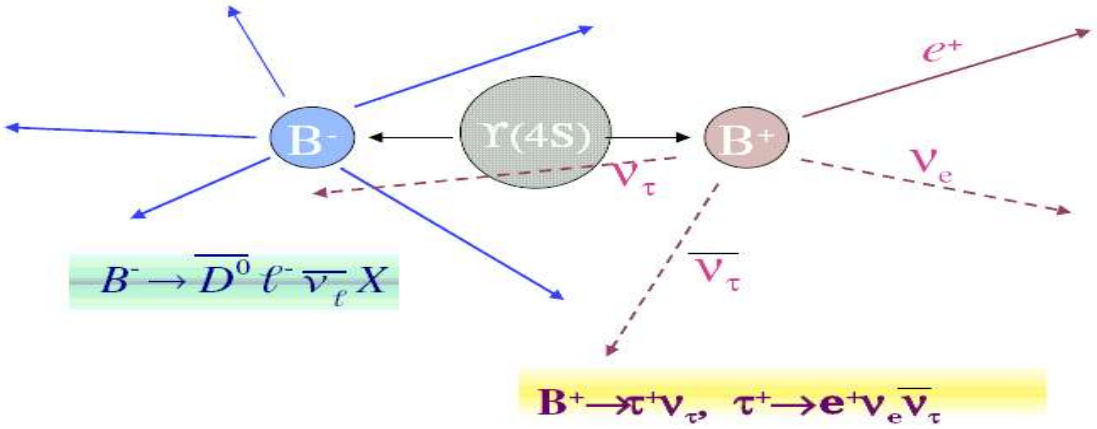
$$\mathcal{B}(B^+ \to \ell^+ \nu_\ell) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left[1 - \frac{m_\ell^2}{m_B^2}\right]^2 \tau_{B^+} f_B^2 |V_{ub}|^2$$

Measurement of BF used to deduce $f_B|V_{ub}|$

- $B \to \tau\nu$ dominates: Helicity suppresses the branching fractions of the light leptons
- Possible enhancement in the two Higgs doublet model
- **SM Predictions:**
  $|V_{ub}| = (4.39 \pm 0.54)\times 10^{-3}$, $f_B = 0.189 \pm 0.027$ GeV
- **SM BF = $(1.2 \pm 0.4)\times 10^{-4}$, PDG BF = $(1.8 \pm 0.7)\times 10^{-4}$**
- New (Prelim.) Belle result (ICHEP '08): $\mathcal{B}(B \to \tau\nu) = [1.65^{+0.38}_{-0.37}(stat)^{+0.35}_{-0.37}(syst)]\times 10^{-4}$

$B^+ \to \tau^+ \nu$ Experimental Method

- Reconstruct the ***tag*** B^- from $B^- \to \overline{D^0} l^- \nu X$ events
  $l = e^-$ or μ-, X = nothing, π^0 or γ from higher mass charm



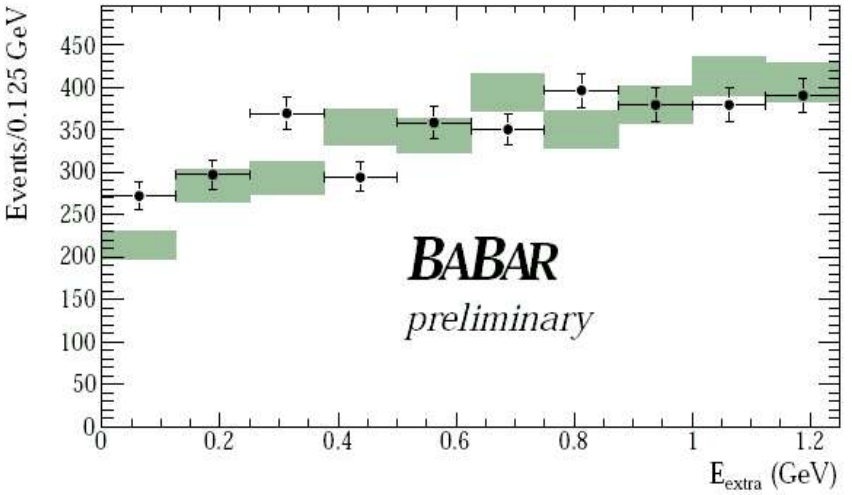
- Reconstruct the ***signal*** $B^+ \to \tau^+ \nu$ using 4 τ decays:
  $\tau^+ \to e^+ \nu\nu$, $\tau^+ \to \mu^+ \nu\nu$, $\tau^+ \to \pi^+ \nu$, $\tau^+ \to \rho^+ (\to \pi^+ \pi^0) \nu$
- Signal Variables:
  - E_{extra} = all energy after both Bs are reconstructed:
    Should be near zero for a fully reconstructed signal event.
- Likelihood ratios used to separate continuum and BB background from signal decays.

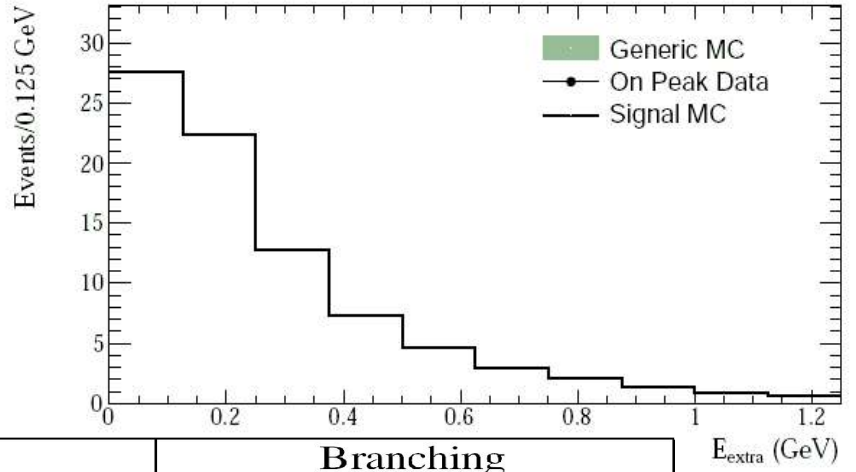
B→τν Results

- Mode dependent cuts on E_{extra}:

Mode	E_{extra}
$\tau^+ \to e^+\nu_e\overline{\nu}_\tau$	[0,0.24] GeV
$\tau^+ \to \mu^+\nu_\mu\overline{\nu}_\tau$	[0,0.24] GeV
$\tau^+ \to \pi^+\overline{\nu}_\tau$	[0,0.35] GeV
$\tau^+ \to \pi^+\pi^0\overline{\nu}_\tau$	[0,0.24] GeV

- BG shape taken from MC, normalization taken from E_{extra} sideband and cross-checked with control samples.
- BF calculated using Feldman-Cousins technique





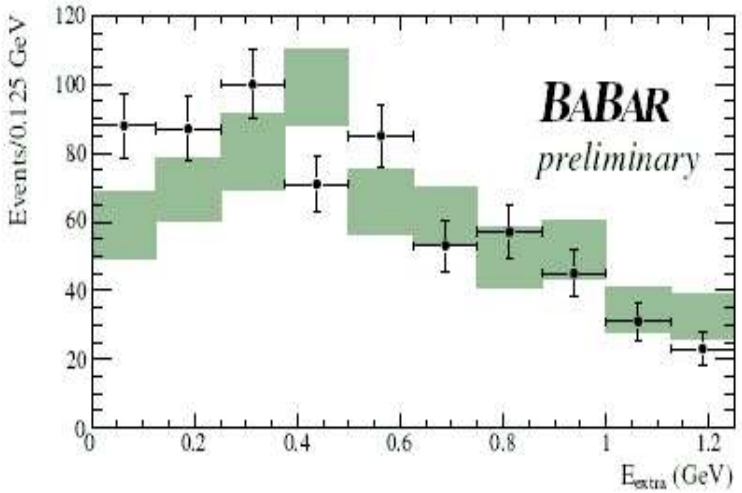
Mode	Expected Background (N_{BG})	Observed Events (N_{obs})	Overall Efficiency (ε)	Branching Fraction
$\tau^+ \to e^+\nu_e\overline{\nu}_\tau$	91 ± 13	148	$(3.08 \pm 0.14) \times 10^{-4}$	$(4.0 \pm 1.2) \times 10^{-4}$
$\tau^+ \to \mu^+\nu_\mu\overline{\nu}_\tau$	137 ± 13	148	$(2.28 \pm 0.11) \times 10^{-4}$	$\left(1.0^{+1.2}_{-0.9}\right) \times 10^{-4}$
$\tau^+ \to \pi^+\overline{\nu}_\tau$	233 ± 19	243	$(3.89 \pm 0.15) \times 10^{-4}$	$\left(0.6^{+1.1}_{-0.5}\right) \times 10^{-4}$
$\tau^+ \to \pi^+\pi^0\overline{\nu}_\tau$	59 ± 9	71	$(1.30 \pm 0.07) \times 10^{-4}$	$\left(2.0^{+1.4}_{-1.3}\right) \times 10^{-4}$
$B^+ \to \tau^+\nu_\tau$	521 ± 31	610	$(10.54 \pm 0.41) \times 10^{-4}$	$(1.8 \pm 0.8 \pm 0.1) \times 10^{-4}$

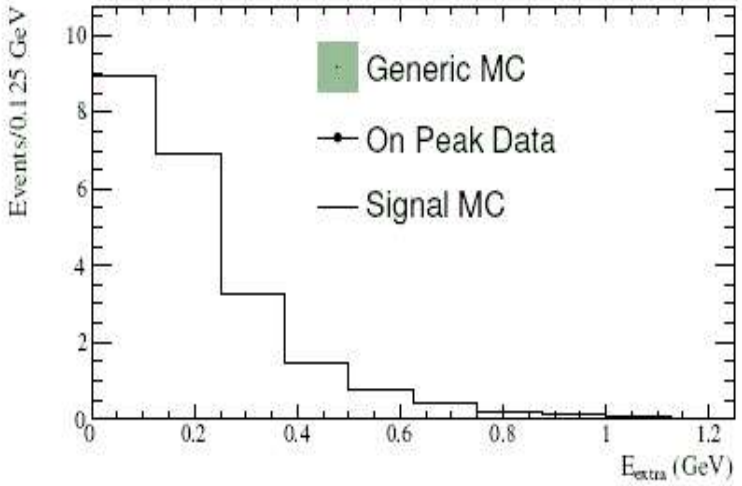
Summary

- $b \to s l^+ l^-$ decays are experimentally accessible and provide a rich menu of observables
  - … but results so far are statistically limited
  - looking forward to more data from LHC or SuperB
- $B \to K(*) ll$ q^2 distributions are in agreement with the SM.
- Significant isospin asymmetries from BaBar are unexpected. Belle's results are consistent.
- A_{FB} measurements from both Belle and BaBar show no sign of a 0-crossing point and strongly disfavor a flipped-sign $C_9 C_{10}$ scenario. New physics possible???
- New $B \to \tau\nu$ result in agreement with previous measurements.

Backup Slides

Excess in $\tau \to e\nu\nu$





- Large excess in first 3 bins gives:
  $BF(B \to \tau\nu(\tau \to e\nu\nu)) = (4.0 \pm 1.2) \times 10^{-4}$
- Many sideband/control sample studies performed:
  - two photon fusion QED events: where a fake D0 is reconstructed and the e^+,e^- are reconstructed as the tag or signal leptons. No excess seen in the D0 sidebands.
  - events that contain overlapping e^+e^- collisions: study the separation of the reconstructed B vertices, Δz: possible excess at high Δz, however no excess found.
  - other samples studied include photon pair production and Bremstrahlung recovered electrons
  - Same number of electrons, muons from the tag B: expected for true signal

Excess in $\tau \to e\nu\nu$