Angular Measurements in $B \rightarrow K^{*} ll$

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On behalf of the Babar Collaboration

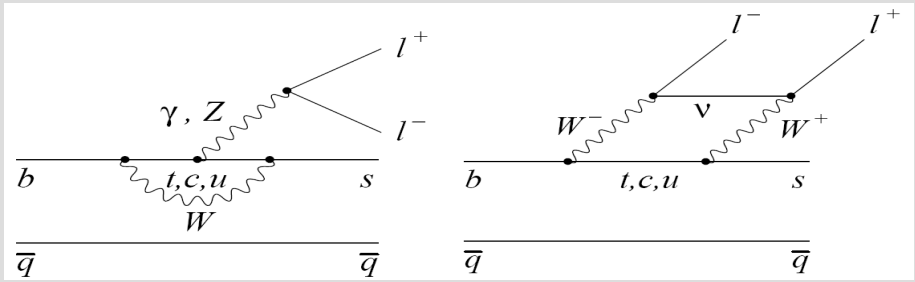
Outline

- Theoretical Motivation
- Measurements - Lepton Angular Asymmetry
  - Branching Fraction
  - Direct CP Asymmetry (A_{CP})
  - Lepton Flavor Asymmetry (LFA)
  - CP-averaged Isospin Asymmetry (A_I)
- Analysis outline
- Results
- Conclusions and Future Work

Physics Motivation

- B → $K^{(*)}ll$ where ll are charged lepton pairs e^+e^- or $\mu^+\mu^-$
- This is a flavour changing neutral current decay - do not occur at tree level in the standard model

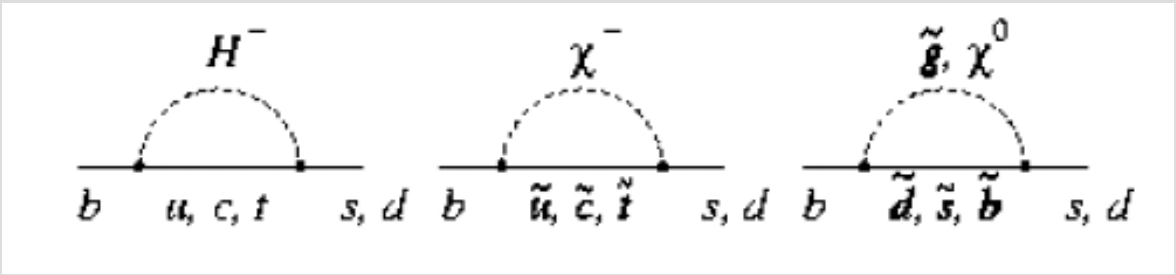
Photon penguin (C_7)



Axial-vector EW (C_{10})

Vector EW (C_9)

- These are rare processes: Branching Fraction ~10^{-6}
- Possible New Physics diagrams:



Physics Motivation

$$M(B \to K^* \ell^+ \ell^-) = \frac{G_F \alpha_{EM}}{\sqrt{2}\pi} V_{ts}^* V_{tb} \left\{ \left[C_9^{eff} \left\langle K^* \middle| \bar{s} \gamma_\mu P_L b \middle| B \right\rangle - 2 \frac{m_b}{q^2} C_7^{eff} \left\langle K^* \middle| \bar{s} i \sigma_{\mu\nu} q^\nu P_R b \middle| B \right\rangle \right] \left(\bar{\ell} \gamma^\mu \ell \right) + C_{10} \left\langle K^* \middle| \bar{s} \gamma_\mu P_L b \middle| B \right\rangle \left(\bar{\ell} \gamma^\mu \gamma_5 \ell \right) \right\}$$

photon penguin dom. at v. low q^2

mix of Z-penguin, W^+W^- box

Kruger and Matias; PRD 71, 094009 (2005)

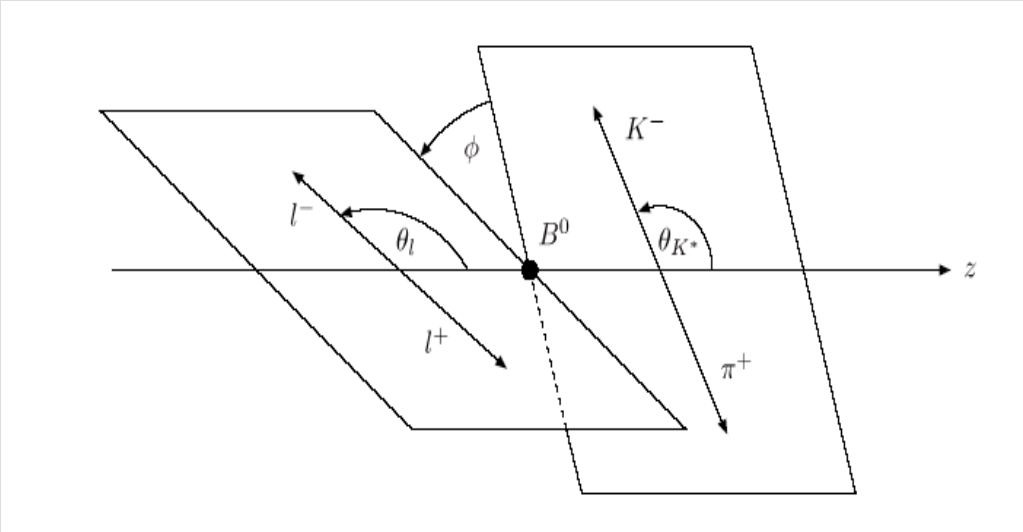
- C_i's can be affected by new physics; enters at same order as Standard Model (SM)

$$\frac{dA_{FB}}{ds} \propto -C_{10} \left\{ \mathrm{Re}\left(C_9^{eff} \right) V A_1 + \frac{m_b m_B}{s} C_7^{eff} \left[V T_2 \left(1 - \frac{m_{K^*}}{m_B} \right) + A_1 T_1 \left(1 + \frac{m_{K^*}}{m_B} \right) \right] \right\}$$

Large s

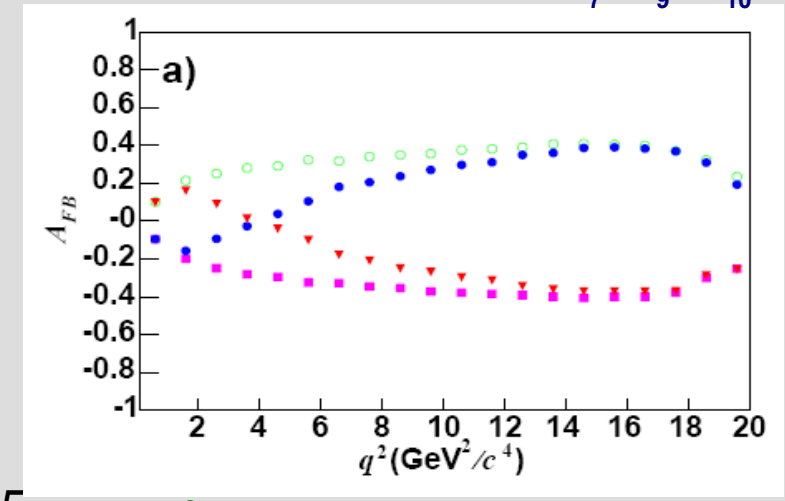
- T,V and A are hadronic form factors
- $q^2 = s = m_{ll}^2$

K*ll Lepton Angular Asymmetry



- ϑ_l - lepton angle in di-lepton rest frame. Forward-backward asymmetry (A_{FB})
- ϑ_{k^*} – kaon angle in the K* rest frame: K* polarisation (F_L)
- ϕ – angle between K* and di-lepton decay planes

Predictions for Different C_7, C_9, C_{10}



q^2 – invariant mass squared

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

SM

C7 = -C7(SM)

C9C10 = -C9C10(SM)

C7 = -C7(SM),
C9C10 = -C9C10(SM)

Rate Asymmetries

- Direct CP asymmetry, A_{CP}:

$$A_{CP} = \frac{\Gamma(\bar{B} \to \bar{K}^{(*)} l^+ l^-) - \Gamma(B \to K^{(*)} l^+ l^-)}{\Gamma(\bar{B} \to \bar{K}^{(*)} l^+ l^-) + \Gamma(B \to K^{(*)} l^+ l^-)}$$

- Lepton flavour asymmetry ratios:

$$R_K = \boldsymbol{B}(B \to K \mu^+ \mu^-) / \boldsymbol{B}(B \to K e^+ e^-)$$

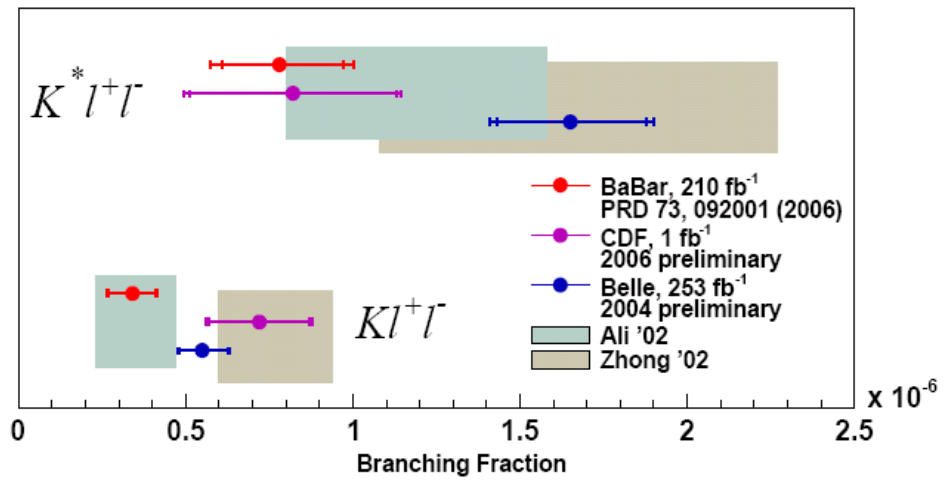
$$R_K^* = \boldsymbol{B}(B \to K^* \mu^+ \mu^-) / \boldsymbol{B}(B \to K^* e^+ e^-)$$

- CP-averaged Isospin Asymmetry A_I:

$$dA_I = \frac{d\Gamma(B^0 \to K^{(*0)} l^+ l^-)/ds - d\Gamma(B^\pm \to K^{(*\pm)} l^+ l^-)/ds}{d\Gamma(B^0 \to K^{(*0)} l^+ l^-)/ds + d\Gamma(B^\pm \to K^{(*\pm)} l^+ l^-)/ds}$$

Previous Results

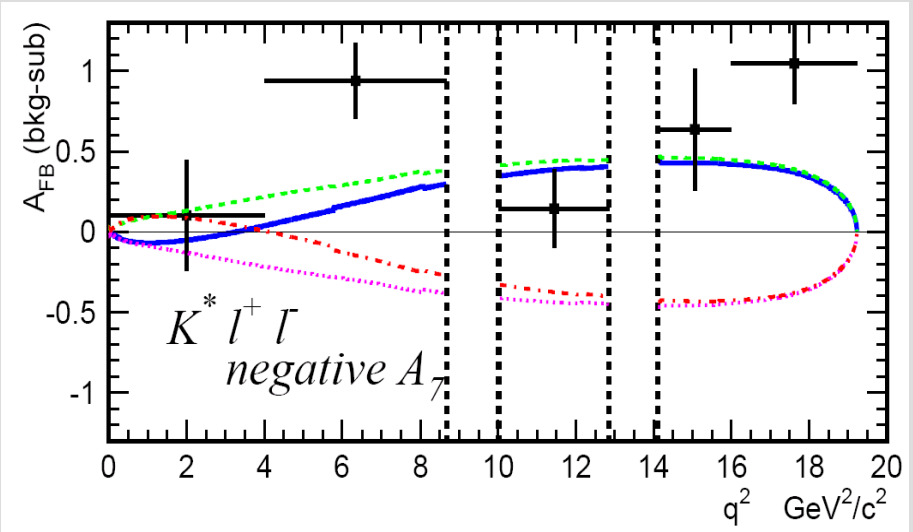
Branching Fraction



Belle branching fraction (BF) is 2x Babar, CDF

Babar and Belle both measure consistent values for K*ll and Kll A_{FB}

Belle 05, 357/fb K*ll AFB



Analysis Details

- More data - Almost twice as much as previous analysis
- More modes - Reconstruct 4 K*ll modes and 2 Kll modes

B->K*ll modes:

$$B^0 \to K^+ \pi^0 e^+ e^-$$ ***NEW***

$$B^+ \to K_s \pi^+ e^+ e^-$$

$$B^0 \to K^+ \pi^- \mu^+ \mu^-$$

$$B^0 \to K^+ \pi^- e^+ e^-$$

- Better detector - Improved muon identification
- Mass regions - Low $q^2 < 6.25$ GeV$^2/c^4$
  - High $q^2 > 10.24$ GeV$^2/c^4$

Backgrounds

- Sideband region in m_{ES} (beam constrained mass) is used to find the angular distribution of the backgrounds: $5.20 < m_{ES} < 5.27$
- Combinatoric
- Peaking - Charmonium: $B \to K^* J/Psi(\to l^+ l^-)$

  - Hadronic: $B \to \pi D(\to \pi\pi \text{ or } K\pi)$

  - Photon Conversions: $B \to K^* \gamma(\gamma \to e^+ e^-)$

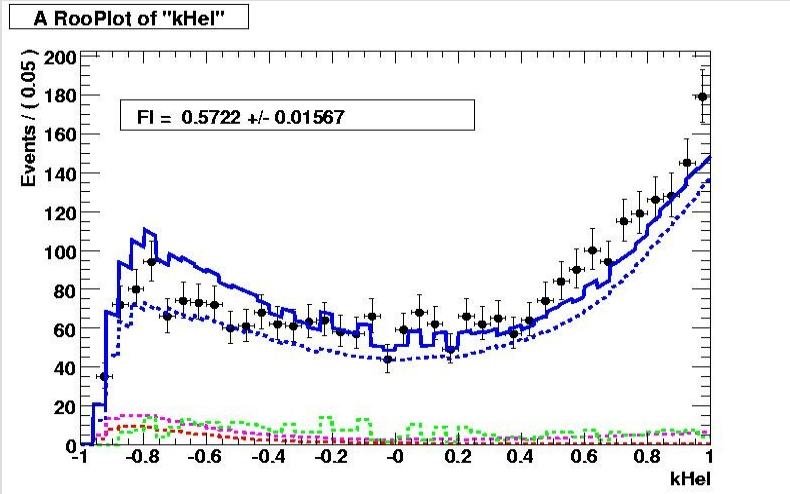
Fit Strategy

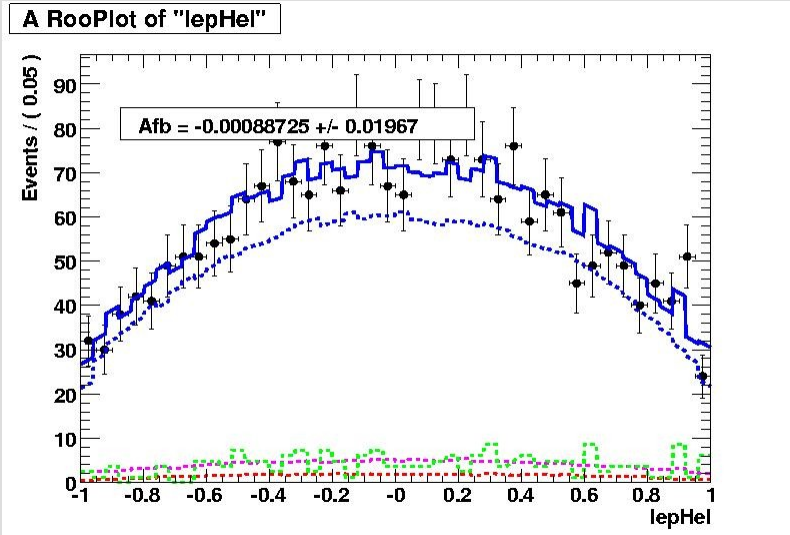
- Combine the datasets for the K*ll modes in each of the q^2 bins and fit
- Multidimensional fit in m_{ES}, $\cos\vartheta_k$, $\cos\vartheta_l$
  - signal, combinatoric and peaking background components modeled in the fit
- Fit m_{ES} to extract the signal yield
- Fit $\cos\vartheta_k$ with m_{ES} constant to extract F_L
- Fit $\cos\vartheta_l$ with m_{ES}, F_L constant to extract A_{FB}
- Fit Kll data, A_{FB} is zero - validation

Validation - Charmonium

Motivation

- Decays into the same final state
- BF is 1000x larger than K*ll
- Removed by $2.5 < m_{ll} < 3.2 GeV/c^2$ and $3.6 < m_{ll} < 3.75 GeV/c^2$
- Results consistent with recent results:
  - $F_L = 0.56 \pm 0.01$
  - $A_{FB} = 0$



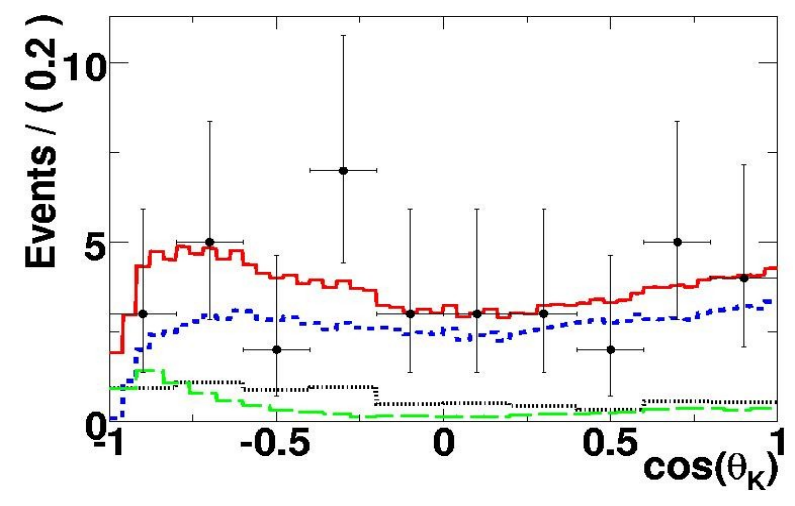


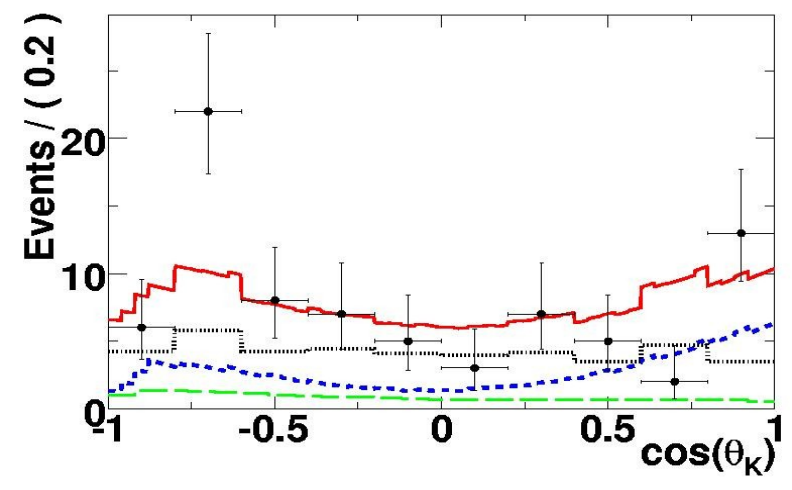
Preliminary K*ll Angular Fits

Low q^2 region

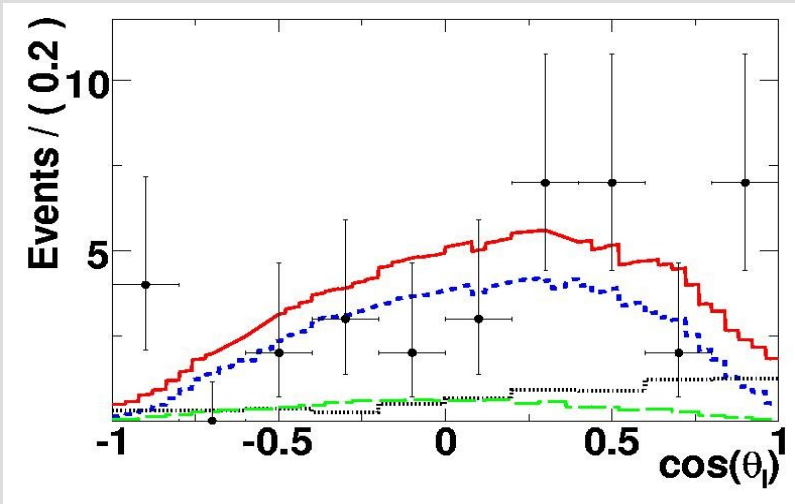
High q^2 region

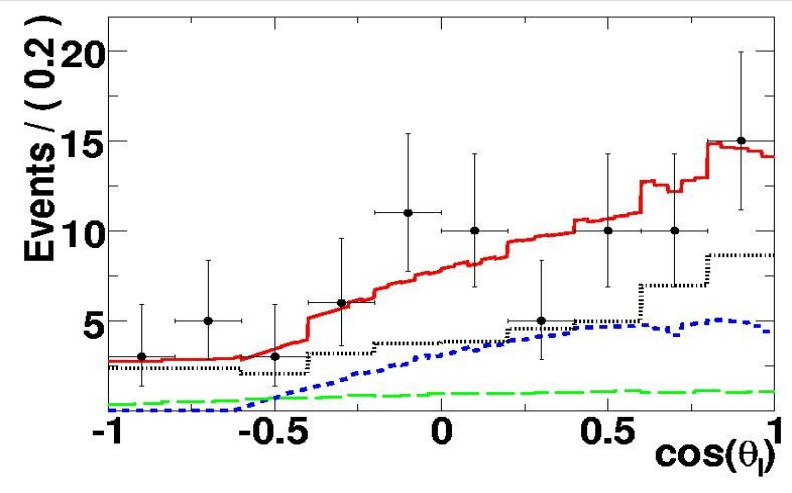
F_L





A_{FB}

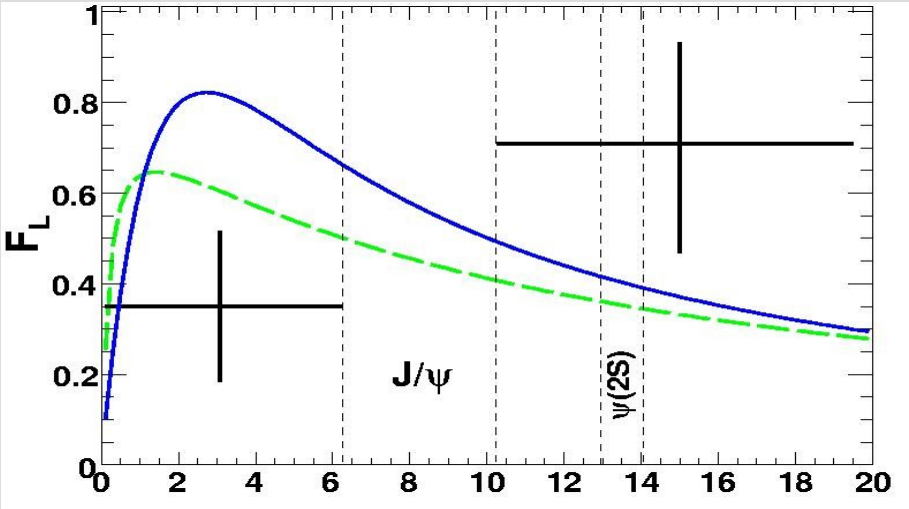




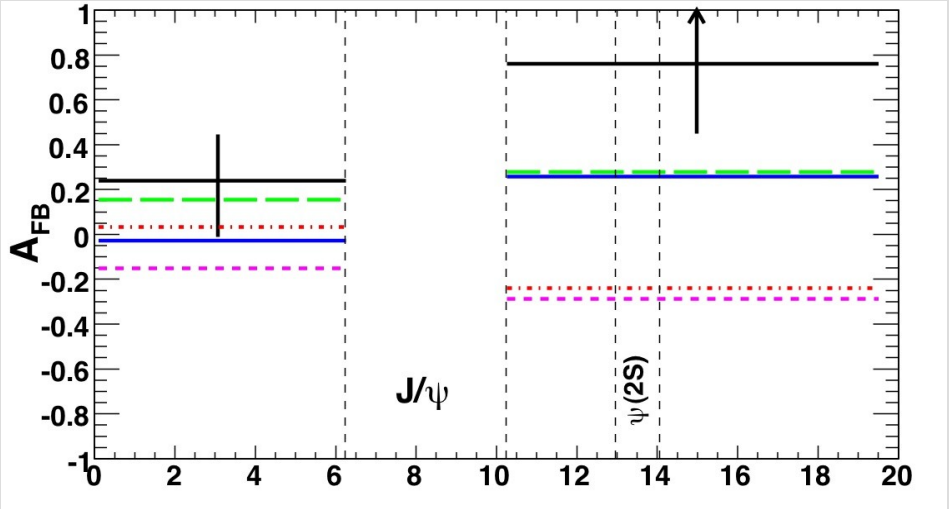
dot: signal; dot-dash: background; long dash: peaking bkg

Preliminary Results for F_L and A_{FB}

K* Polarization



Forward-backward Asymmetry



SM

C7 = -C7(SM)

C9C10 = -C9C10(SM)

C7 = -C7(SM),
C9C10 = -C9C10(SM)

	F_L	A_{FB}
LOW q^2:	$0.35 \pm 0.016 \pm 0.04$	$+0.24\,^{+0.18}_{-0.23} \pm 0.06$
HIGH q^2;	$0.71\,^{+0.20}_{-0.22} \pm 0.05$	$+0.76\,^{+0.52}_{-0.32} \pm 0.07$

Conclusions and Future Work

- Results for F_L and A_{FB} are consistent with the SM
- Result for the Branching Fraction and Rate Asymmetries will be published soon
- Up-date of the angular analysis is in progress
  - Will include a measurement of the decay plane angle (ϕ)
  - Final analysis over Babar's entire dataset

Backup Slides

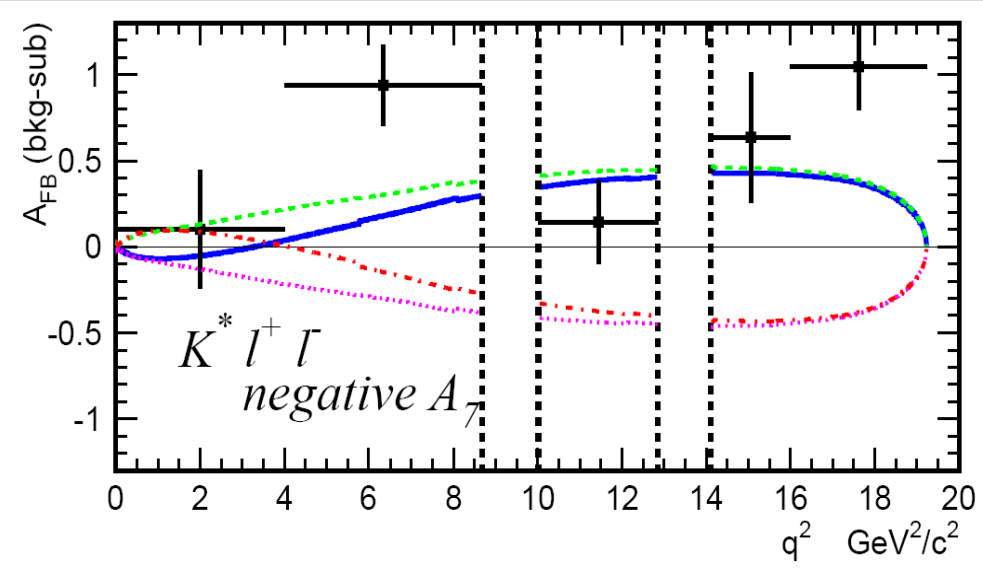
Belle

AFB(B->K*ll) = 0.50+/-0.15+/-0.02
AFB(B->Kll)=0.10+/-0.14+/-0.01

Direct CP Asymmetry

$$A_{CP}(B^+ \to K^+ l^+ l^-) = -0.07 \pm 0.22 \pm 0.02$$

$$A_{CP}(B \to K^* l^+ l^-) = +0.03 \pm 0.23 \pm 0.03$$



- **Babar and Belle both measure consistent values for K*ll and Kll AFB**

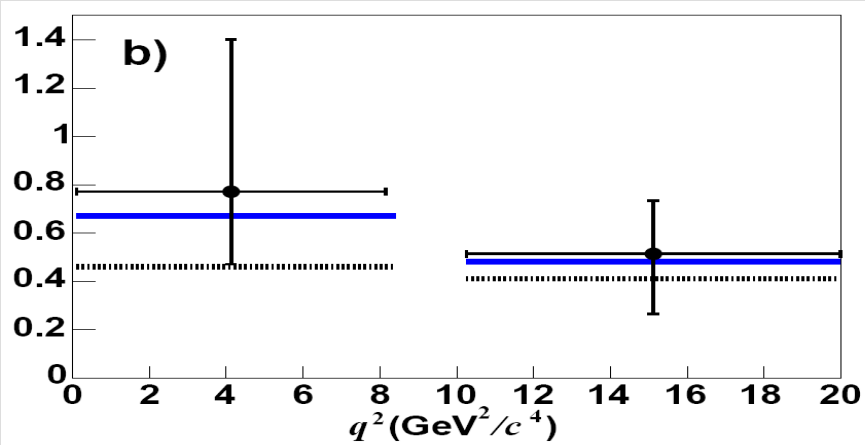
BF Fit Results

- Data fits
- Table of results

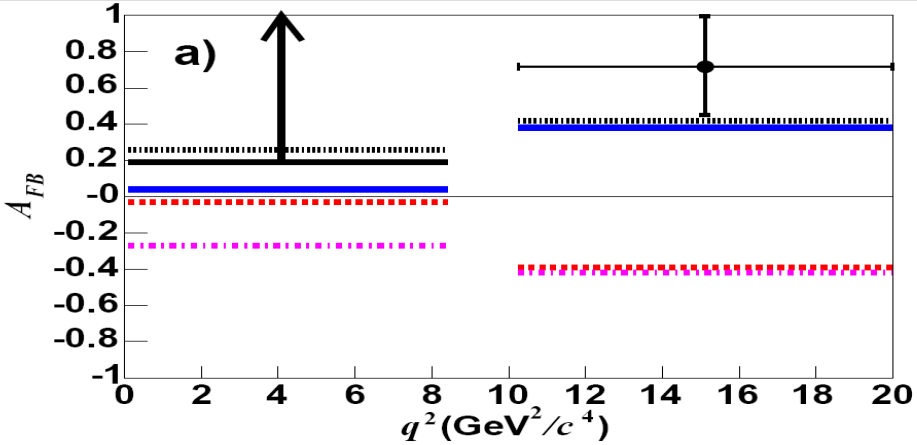
Previous Babar Results

Phys.Rev.D 73 092001 (2006)
hep-ex/0604002v2

Babar 06, 210/fb K*ll F_L



Babar 06, 210/fb K*ll A_{FB}



- **K* polarisation consistent with SM**

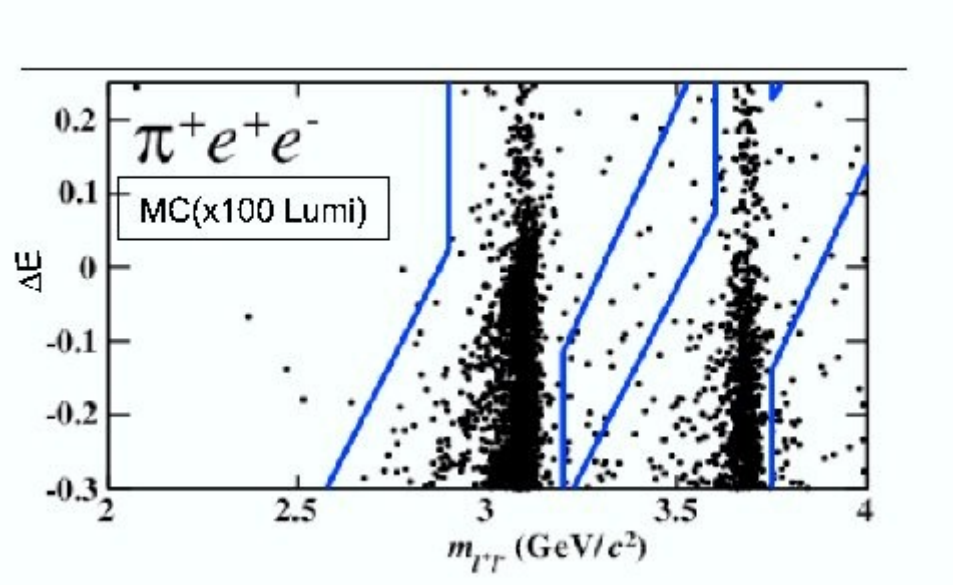
- **Low q^2 lower limit excludes SM at 98% CL (2.5σ)**

  AFB > 0.19 (95% CL)
  AFB(SM) = 0.03

- **At high q^2, wrong-sign C_9C_{10} is excluded at >3σ**

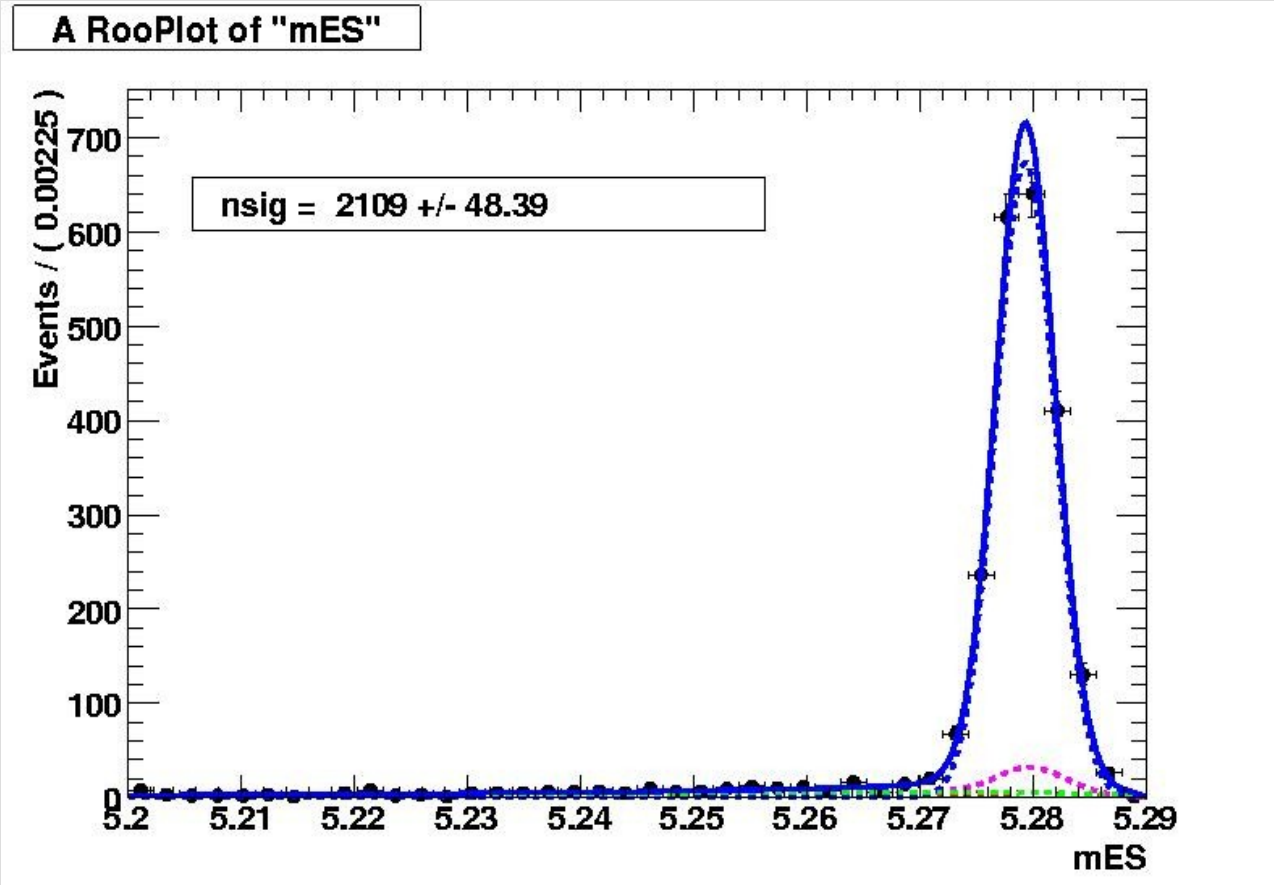
  AFB = 0.72+0.28-0.26+/-0.08
  AFB(SM) = 0.38

Interpretation of Rate Results



Validation - Charmonium

Fit to mES for Charmonium: B^0 u $K^u u^u u^u u^u$



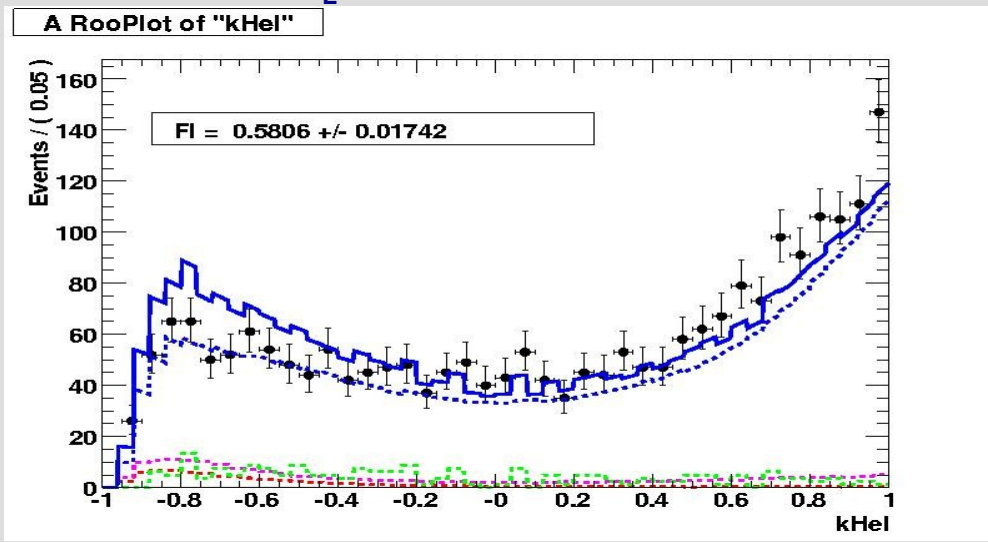
- **Fit to the dataset – good agreement**
- **BF =** $1.38210^{23}\ 2\ 3.16210^{25}$
- **BF for all modes agree with PDG within a few %**

Validation - Charmonium

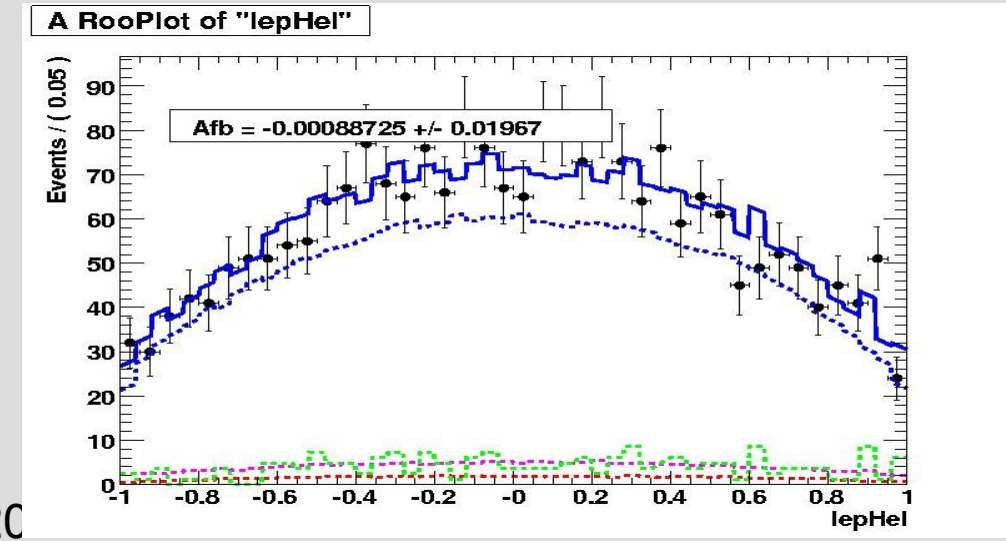
hep-ex/0607081

- Fit to F_L are consistent with recent Babar result: $5.622\,10^{21}\ 2\,12\,10^{22}\ 21.42\,10^{22}$

Fit to F_L for charmonium dataset



Fit to A_{FB} for charmonium dataset



- A_{FB} is zero for charmonium
- Consistent with null A_{FB}

BaBar Detector