Recent B $\to$ K(*)$\ell^+\ell^-$ and B $\to \pi\ell^+\ell^-$ Results from BaBar

Chris J. Schilling

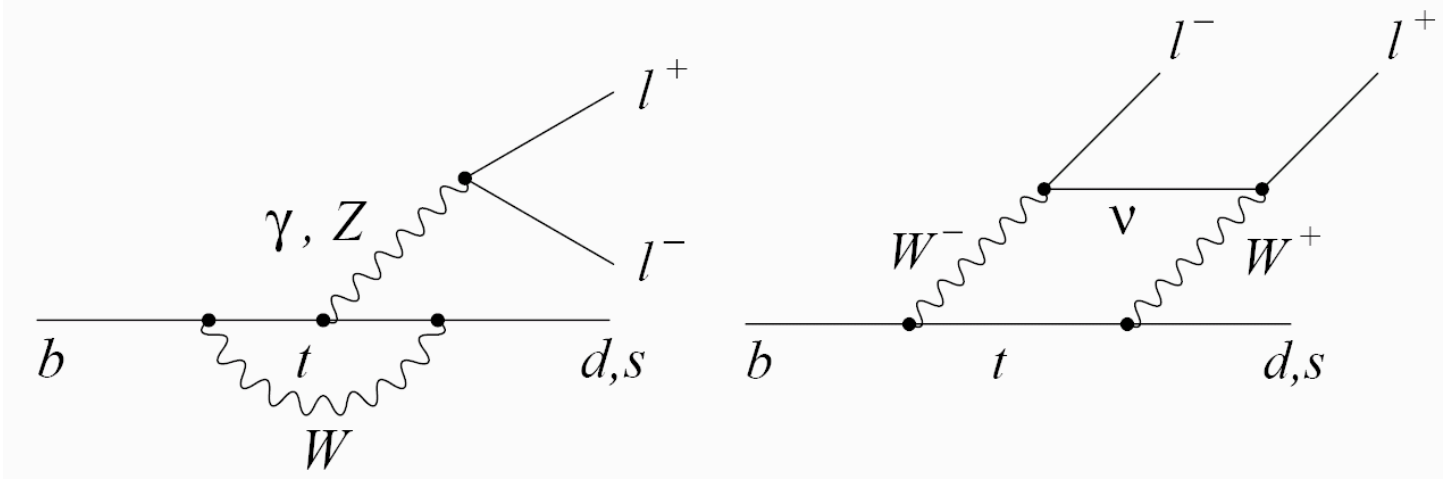
University of Texas, Austin

On behalf of the BaBar Collaboration

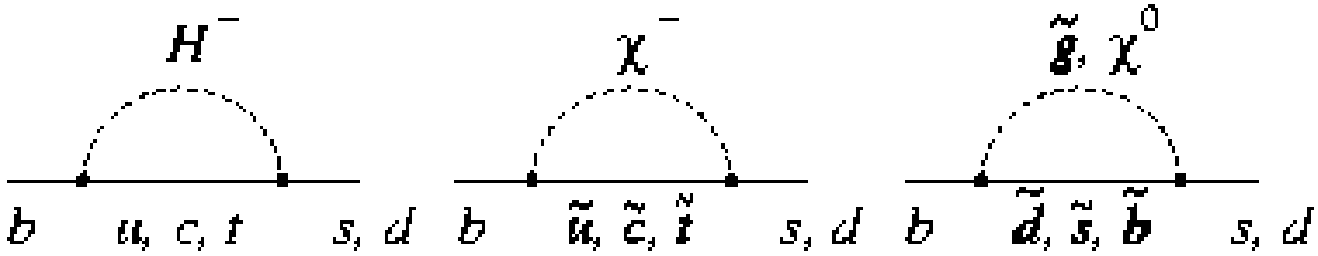
DPF 2006 Parallel

Flavor Changing Neutral Currents

- Do not occur at tree level in the Standard Model
- Lowest order contributions are penguin loops or box diagrams



- Additional new physics contributions are possible



Motivation

- **FCNC** – a well known method to look for new physics

- $b \to s/d\ l^+l^-$ - large number of observables to test SM
  - Branching fractions
    - $BF(B^+ \to \pi^+\ell^+\ell^-) = 2 \times BF(B^0 \to \pi^0\ell^+\ell^-) = 3.3 \times 10^{-8}$
      - One of the rarest searches at BaBar
    - $BF(B \to K^*\ell^+\ell^-) \approx 10^{-6}$
  - Partial Branching fractions versus q^2
  - Decay rate ratios
  - CP Asymmetries

- For $b \to d\ l^+l^-$ - observables become more significant at higher luminosity
  - Possible branching fraction enhancement from new physics contributions

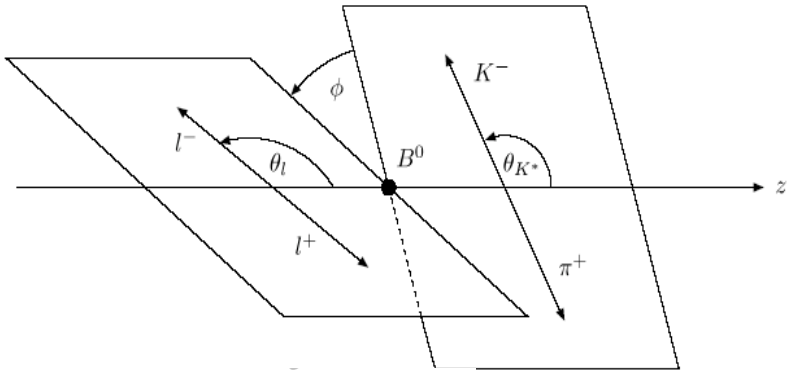
Motivation

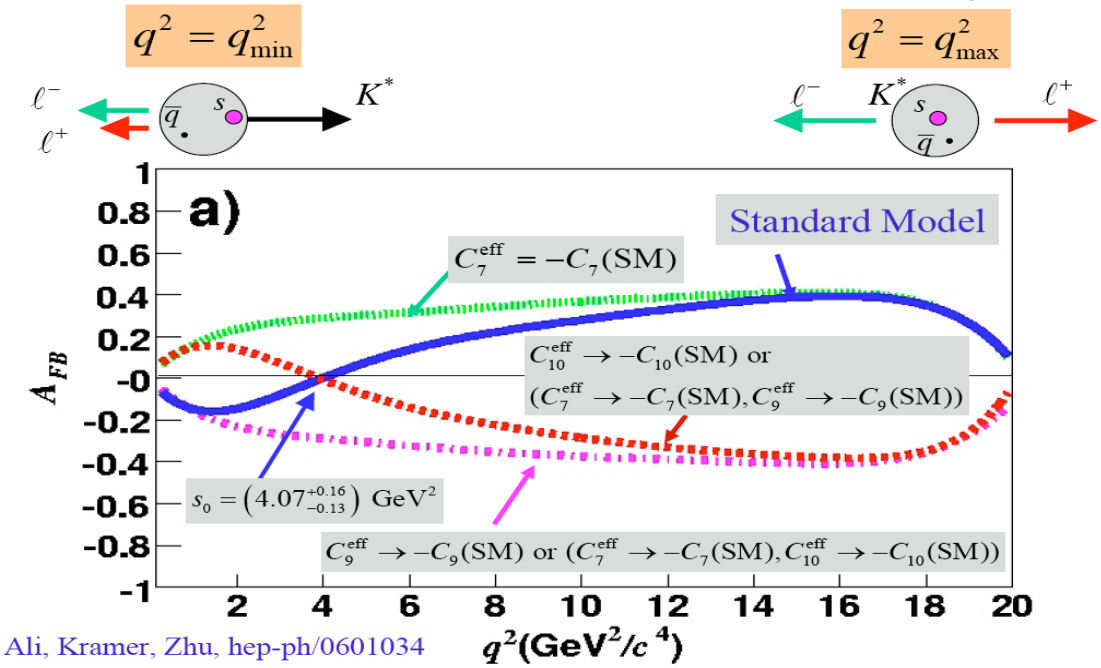
- For B→K(*)$\ell^+\ell^-$ other observables are becoming significant

A_{FB} – forward-backward asymmetry of the helicity angle of l^+l^- system

- SM A_{FB} - strong q^2 dependence

F_L – longitudinal component of polarization



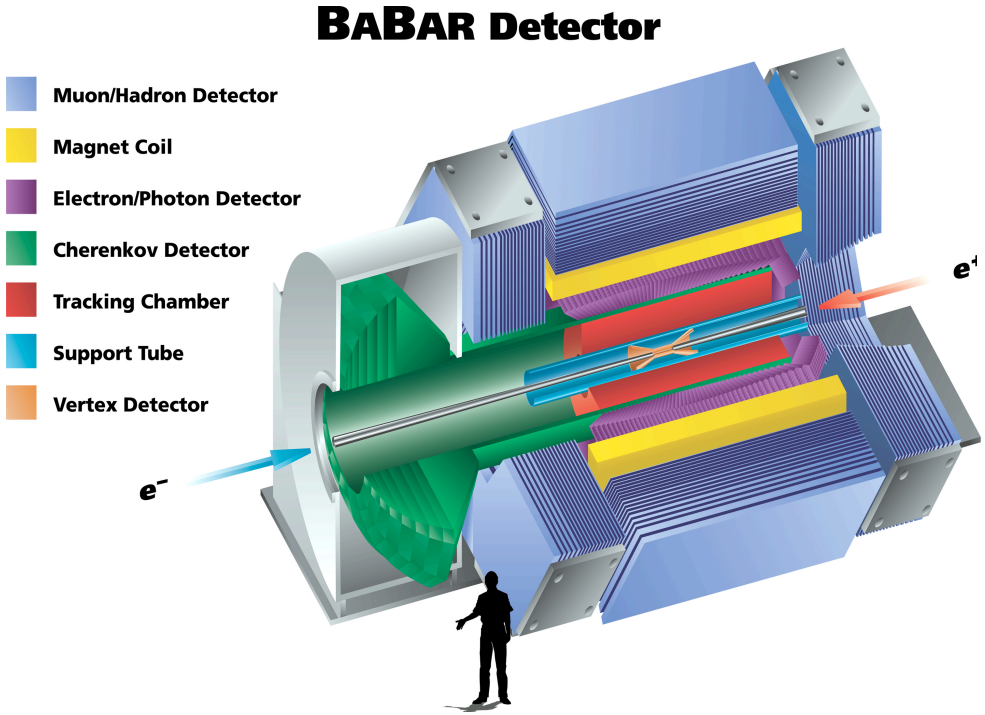


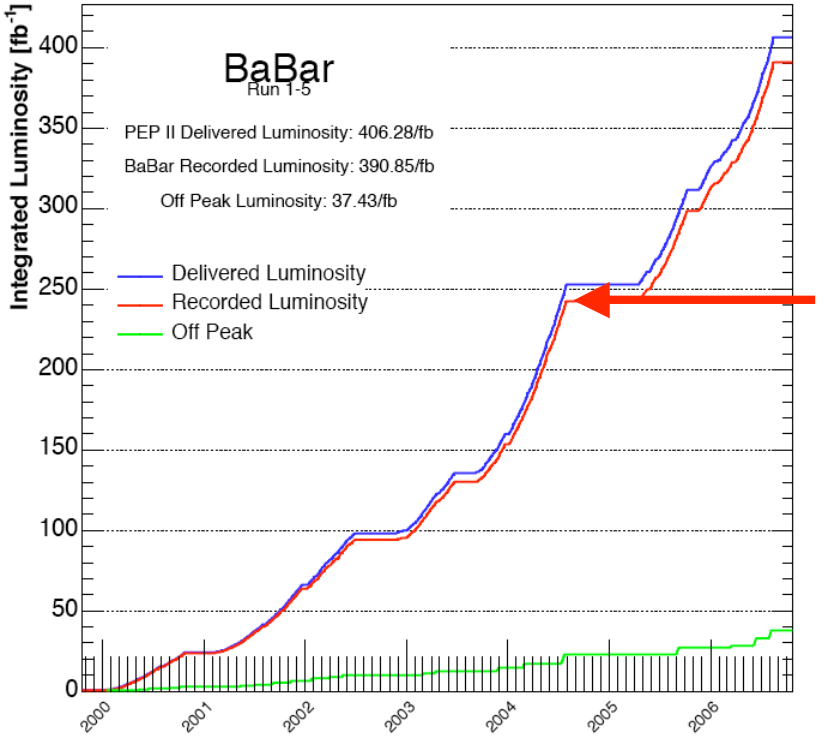
s_0: Ali, Kramer, Zhu, hep-ph/0601034

BaBar Detector and Dataset

Need large statistics to study rare decays

- To date, >400 fb^{-1} delivered by PEPII, **~370 million *B*-pairs recorded by BaBar**
- Analyses shown here use 210 fb^{-1} samples





Analyses exploit BaBar's:

- Good neutral energy resolution
- Charged K/π separation, lepton ID
- Low multiplicity environment, coherent production of B-pairs

Event Reconstruction

- $b \to d\,\ell^+\ell^-$: Reconstruct 4 modes
  - $B \to \pi\ell^+\ell^- \ (\pi = \pi^+ \text{or } \pi^0)$
- $b \to s\,\ell^+\ell^-$: Reconstruct 8 modes
  - $B \to K\ell^+\ell^- \ (K = K^+ \text{or } K_s)$
  - $B \to K^*\ell^+\ell^- \ (K^{*0} \to K^+\pi^- \text{or } K^{*+} \to K_s\pi^+)$
- ℓ = *e* or μ, including LFV (i.e. $e^+\,\mu^-$)

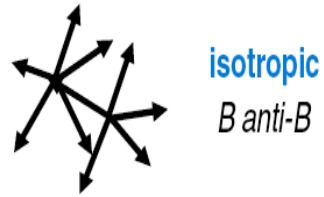
- Electrons
  - Use EM Calorimeter
  - High-quality tracks from IP (~92% efficient, ~0.1% fake rate)
  - Bremsstrahlung recovered
- DIRC and dE/dx used for charged pion/kaon identification (85-90% efficient, ~1-2% fake rate)

- Muons
  - Use BaBar's muon system(IFR)
  - High-quality tracks from IP (~65-70% efficient, 2-3% fake rate)

- Neutral pions
  - $115\ MeV/c^2 < m_{\gamma\gamma} < 150\ MeV/c^2$
    $E_\gamma > 50\ MeV$

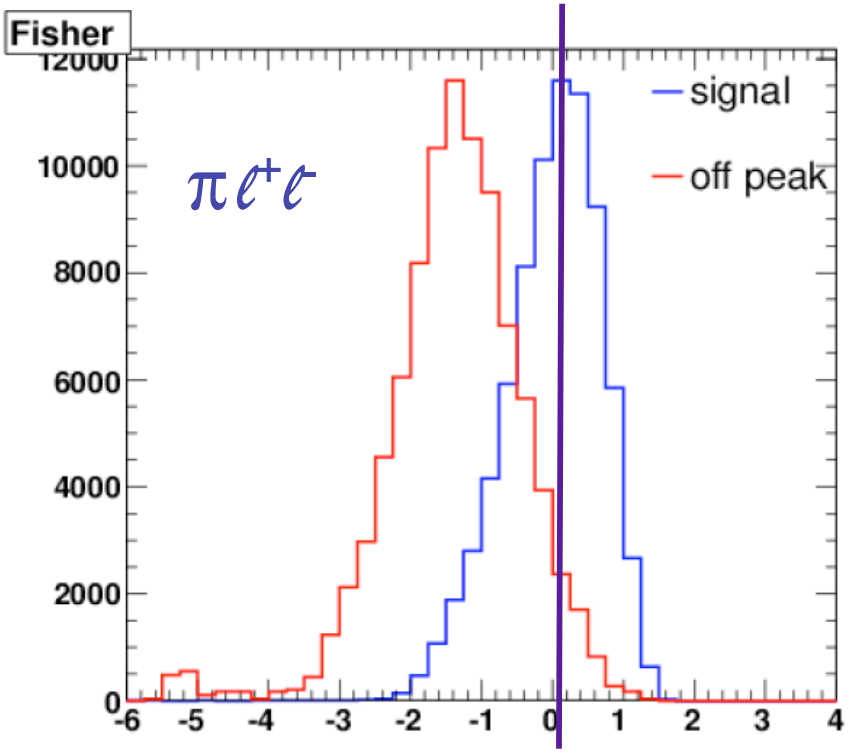
Reconstruction and Backgrounds

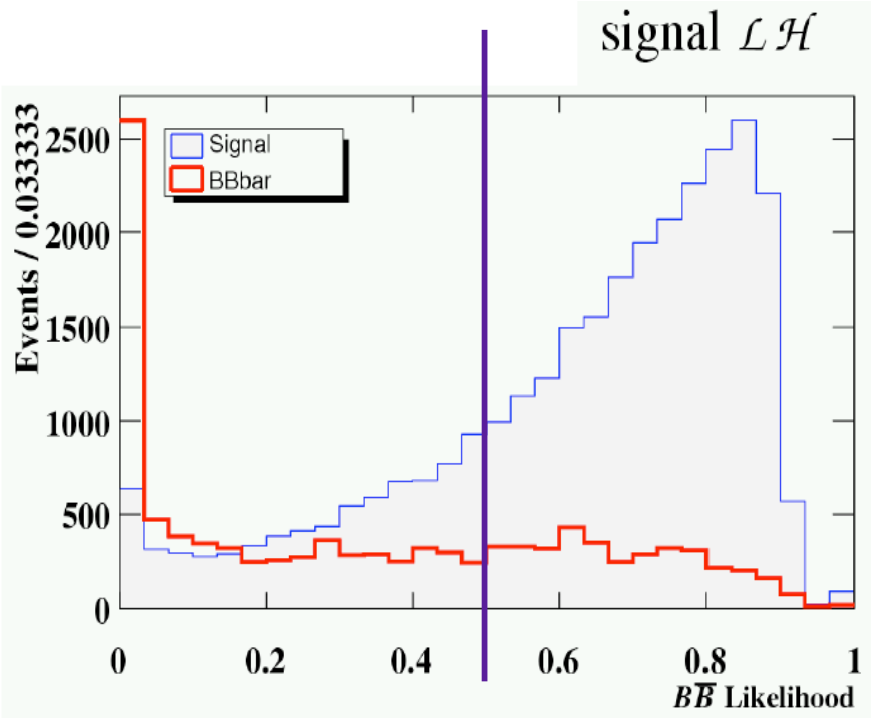
- B meson reconstruction at the $\Upsilon(4S)$
  - $m_{ES} = \sqrt{(E^*_{beam})^2 - |\vec{p}^*_B|^2}$
  - $\Delta E = E^*_B - E^*_{beam}$
  - Isotropic event distribution in the center-of-mass frame
- Continuum background: $e^+e^- \rightarrow q\bar{q}$
  - Jet-like event distribution in the center-of-mass frame
  - Use event shape variables to suppress continuum
    - Fisher and likelihood work well to suppress combinatorial backgrounds
    - Fox-Wolfram moments, event thrust angle, Legendre moments



Combinatorial rejection

- Use a Fisher discriminant to reject combinatorial continuum and a likelihood ratio to reject combinatorial bb backgrounds





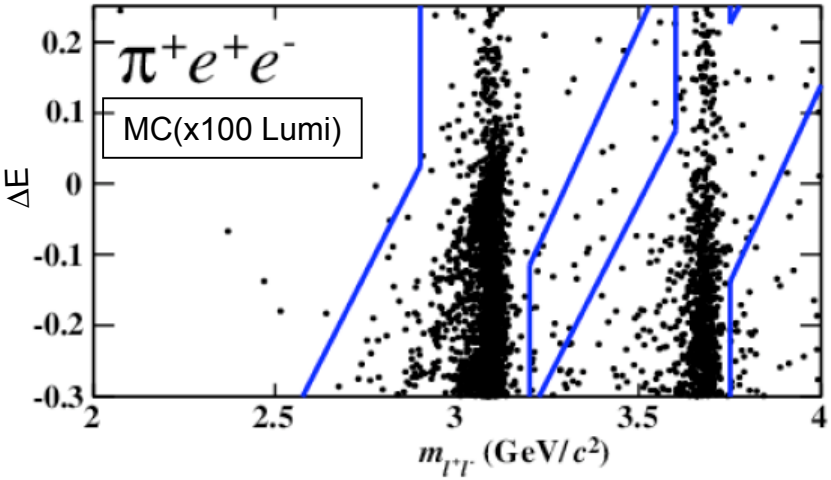
Peaking Backgrounds

- Peaking Background: (similar m_{ES}, ΔE features)
  - Real leptons: $B \to J/\psi(\to \ell^+\ell^-)$ events
    - Interfere with penguin signal at rates >10^4 times signal
    - Provides an extremely clean control sample that is used to cross check Fisher/Likelihood efficiencies and lepton efficiencies in data
  - Hadronic: $B \to D(\to \pi\pi \text{ or } K\pi)$ events where pion or kaon fakes the muons.
  - Photon Conversions: $B \to K^*\gamma(\gamma \to e^+e^-)$

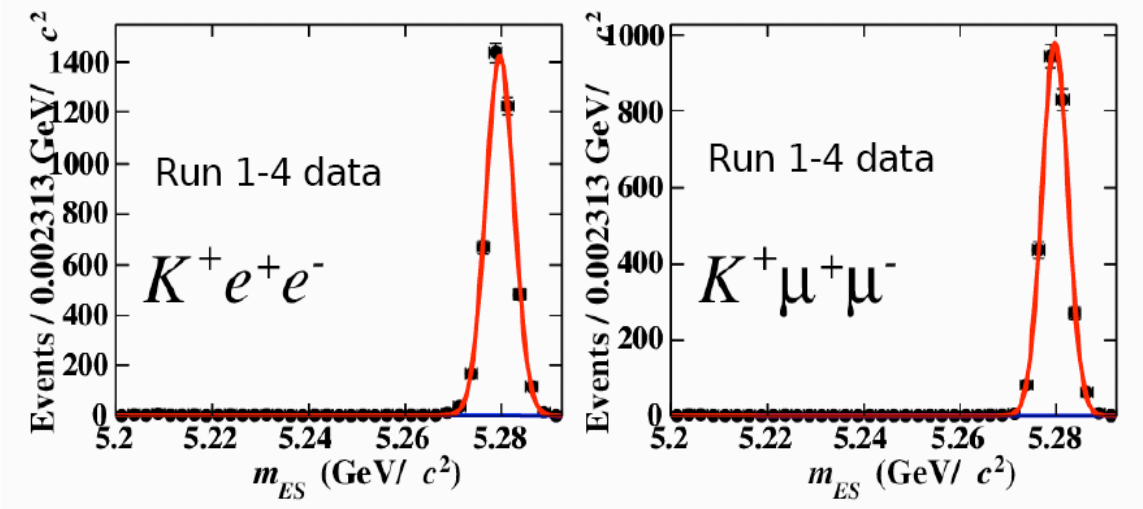
Charmonium Veto/Control Sample

- Veto the $\ell^+\ell^-$ invariant mass

$J/\psi \to \mu^+\mu^-$:	$3.00\ \text{GeV}/c^2 < m_{\mu^+\mu^-} < 3.20\ \text{GeV}/c^2$
$\psi(2S) \to \mu^+\mu^-$:	$3.60\ \text{GeV}/c^2 < m_{\mu^+\mu^-} < 3.75\ \text{GeV}/c^2$
$J/\psi \to e^+e^-$:	$2.90\ \text{GeV}/c^2 < m_{e^+e^-} < 3.20\ \text{GeV}/c^2$
$\psi(2S) \to e^+e^-$:	$3.60\ \text{GeV}/c^2 < m_{e^+e^-} < 3.75\ \text{GeV}/c^2$



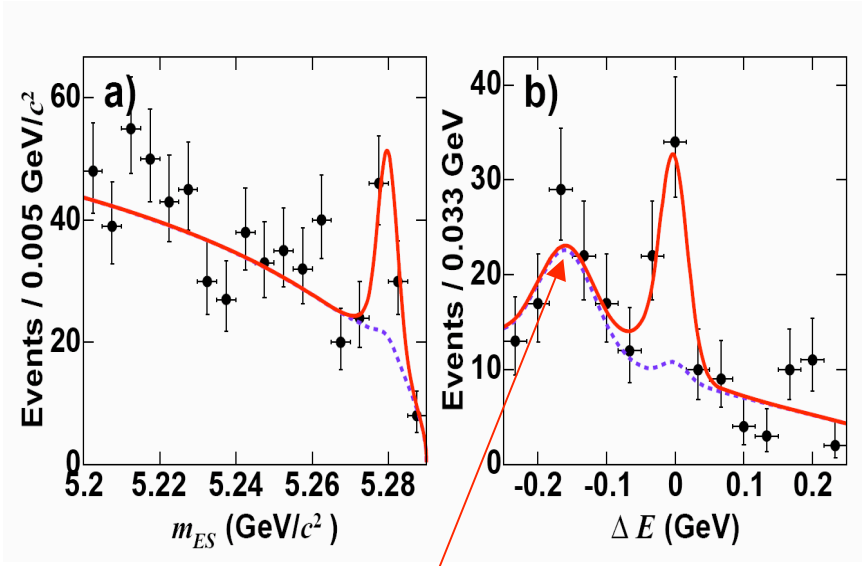
- The vetoed charmonium sample provides a high-statistics control sample with characteristics similar to the penguin signal



$K\ell^+\ell^-$ Signal

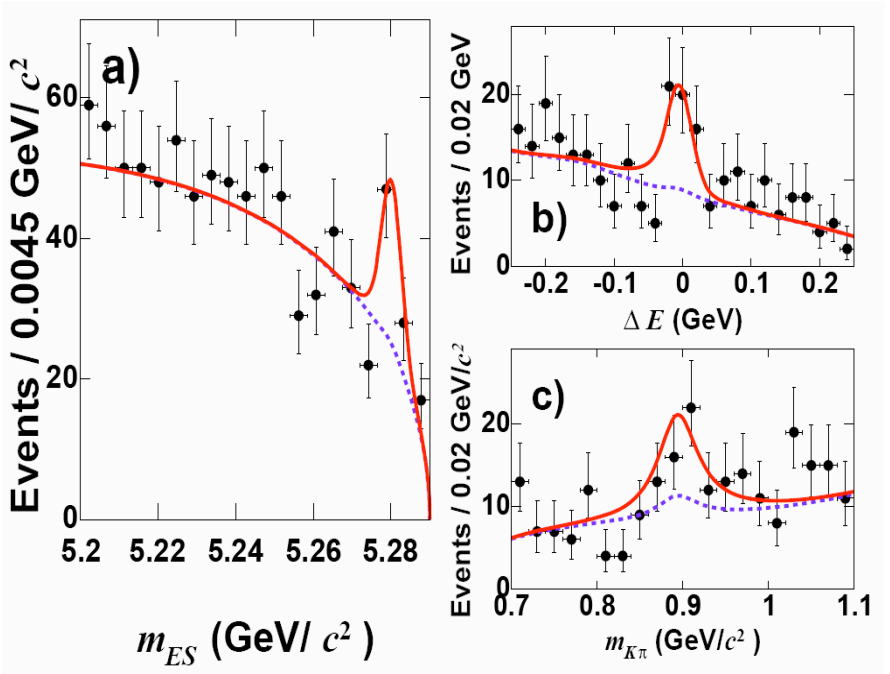
Extract signal using a maximum likelihood fit.
Total event sample from 229 Million BB pairs.

B→Kll ($45.5^{+9.8}_{-8.9}$ events)

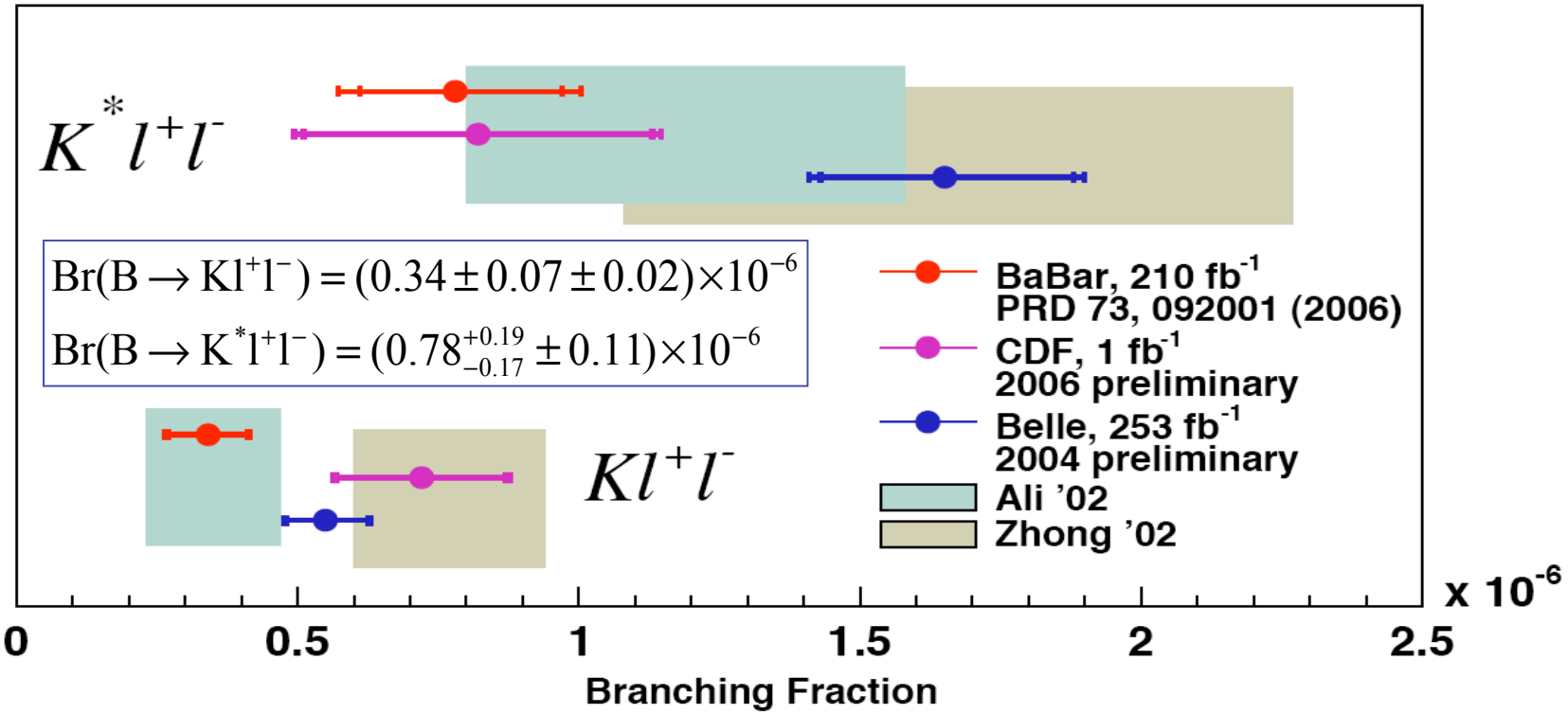


Feed-down component from $K^*\ell^+\ell^-$

B→K*ll ($57.1^{+13.7}_{-12.5}$ events)



$K\ell^+\ell^-$ BF/ACP/Rate Results



$$A_{CP} \equiv \frac{\Gamma(\overline{B} \to \overline{K}^{(*)}\ell^+\ell^-) - \Gamma(B \to K^{(*)}\ell^+\ell^-)}{\Gamma(\overline{B} \to \overline{K}^{(*)}\ell^+\ell^-) + \Gamma(B \to K^{(*)}\ell^+\ell^-)}$$

$$R_K \equiv \frac{\Gamma(B \to K\mu^+\mu^-)}{\Gamma(B \to Ke^+e^-)}$$

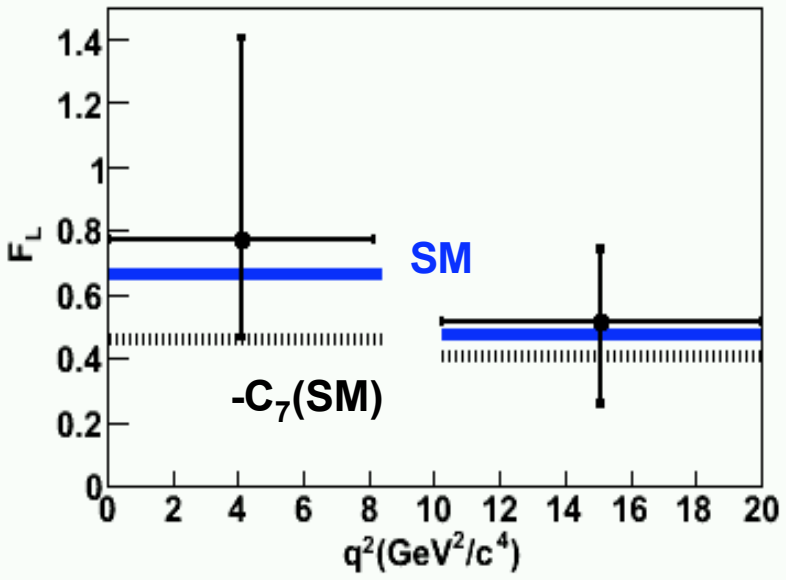
$$A_{CP}(B^+ \to K^+l^+l^-) = -0.07 \pm 0.22 \pm 0.02$$

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

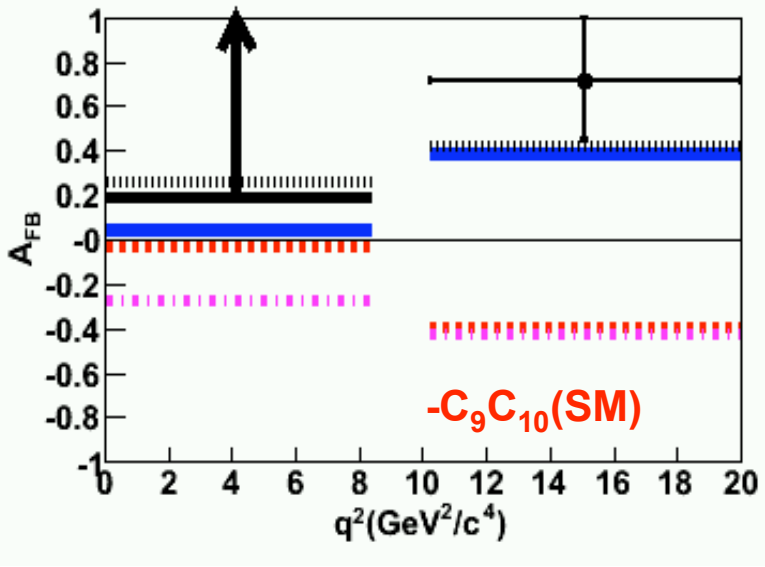
$$R_K = 1.06 \pm 0.48 \pm 0.08 \qquad SM: 1.0$$

$$R_{K^*} = 0.91 \pm 0.45 \pm 0.06 \qquad SM: 0.75$$

$K\ell^+\ell^-$ AFB/Angular Results



- First measurement of *K** polarization in this mode
- **Consistent with SM**



- High q^2 A_{FB} agrees with SM
- Low q^2 limit is consistent with SM at 2% (2.05 σ)
- We are in a regime where we can begin to discriminate against theoretical models.

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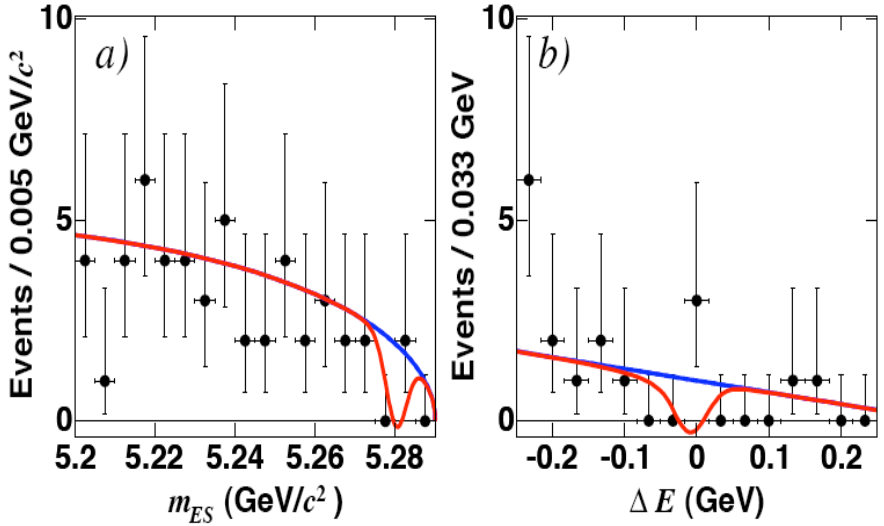
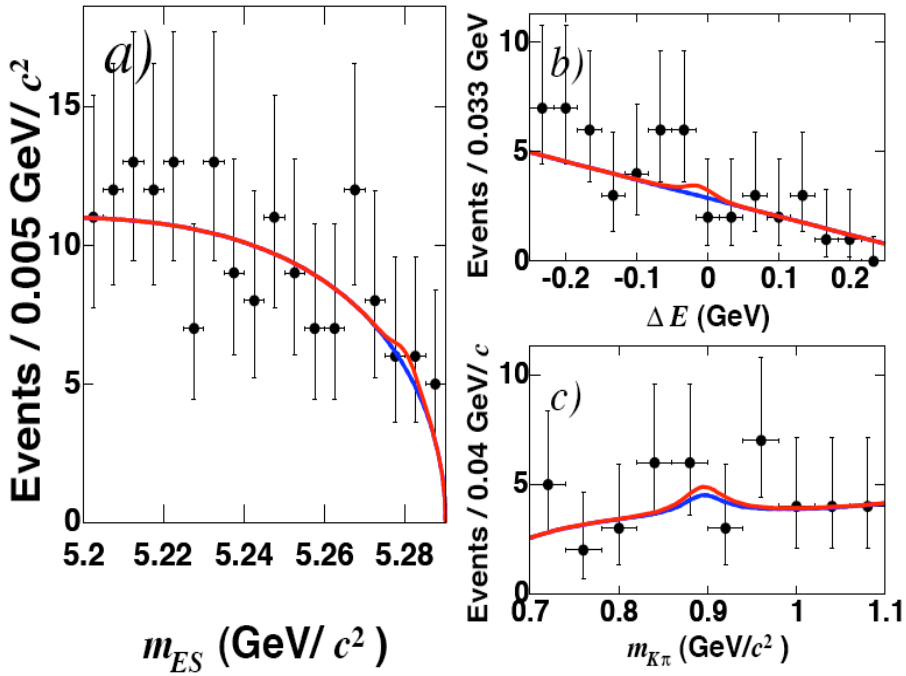
$K\ell^+\ell^-$ LFV Results

$$BF(B \to K^* e\mu) < 5.07 \times 10^{-7}$$



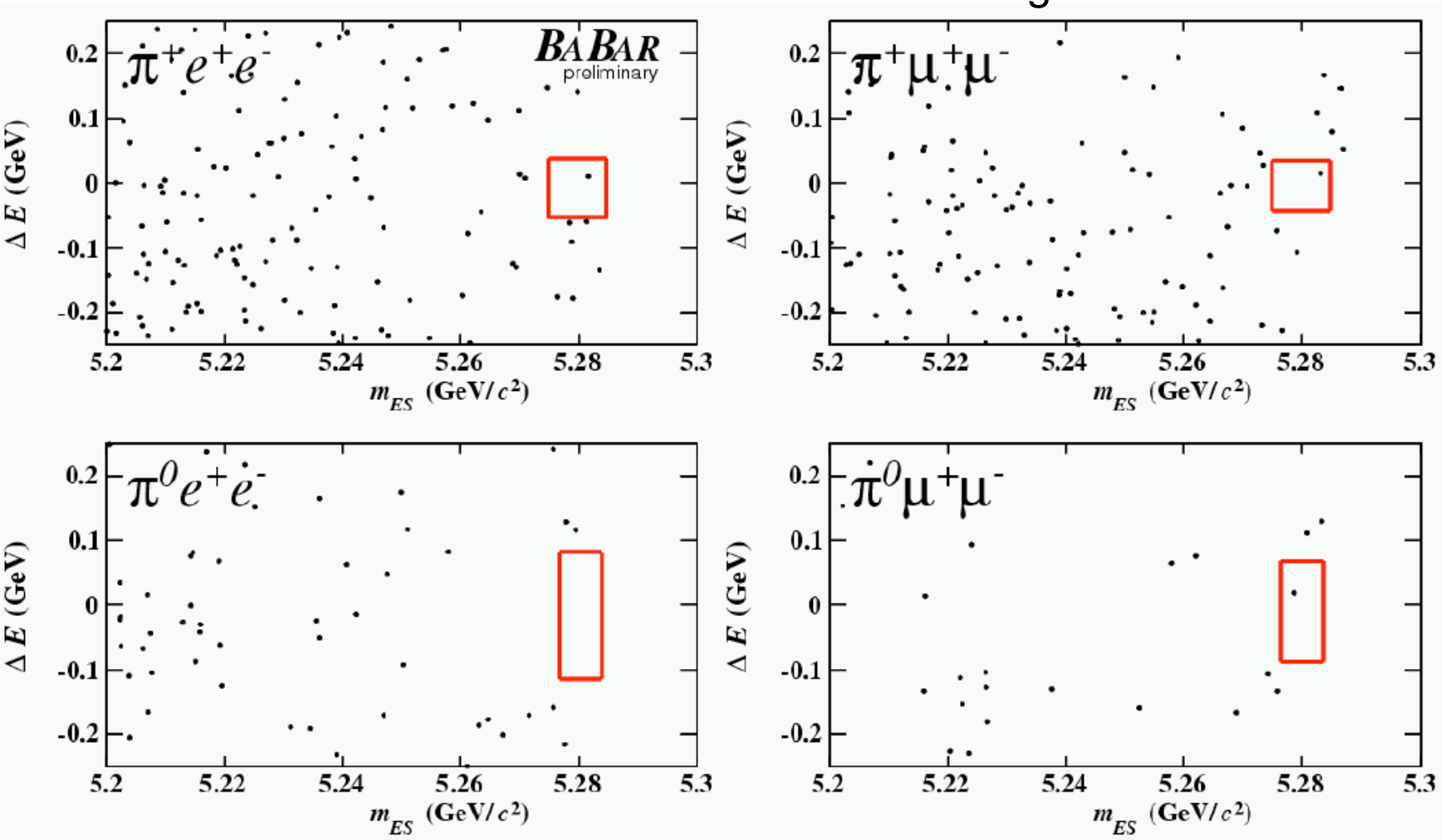
$$BF(B \to Ke\mu) < 3.8 \times 10^{-8}$$



Upper limit extracted using Cousins-Highland

$\pi\ell^+\ell^-$ Results

We expect less than 1 event in the signal box for each mode, so a cut-and-count method is used to extract the signal.



$\pi\ell^+\ell^-$ Results

Mode	Observed Events	Expected Background	BF UL 90% C.L. (10^{-7})
$B^+ \to \pi^+ e^+ e^-$	1	0.96 ± 0.32	1.72
$B^0 \to \pi^0 e^+ e^-$	0	0.46 ± 0.22	1.29
$B^+ \to \pi^+ \mu^+ \mu^-$	1	0.96 ± 0.30	2.47
$B^0 \to \pi^0 \mu^+ \mu^-$	1	0.35 ± 0.19	4.56
$B^+ \to \pi^+ e^+ \mu^-$	1	1.48 ± 0.48	1.72
$B^0 \to \pi^0 e^+ \mu^-$	0	1.13 ± 0.47	1.50
$B^+ \to \pi^+ \ell^+ \ell^-$			1.06
$B^0 \to \pi^0 \ell^+ \ell^-$			1.02
$B^+ \to \pi \ell^+ \ell^-$			0.79
$B^0 \to \pi e \mu$			0.98

And combined, assuming: $\mathcal{B}(B^+ \to \pi^+ \ell^+ \ell^-) = 2 \times \frac{\tau_{B^+}}{\tau_{B^0}} \mathcal{B}(B^0 \to \pi^0 \ell^+ \ell^-)$

Summary

- Rare B-decays provide an excellent avenue to constrain new physics models.
- For $K(*)\ell^+\ell^-$, we measured, Branching Franctions, Decay Rate Ratios and CP Asymmetries consistent with the Standard Model
- A_{FB} measurement in $K^*\ell^+\ell^-$ is in a regime where we can start ruling out theoretical models.
- We were able to set an Upper Limit on the B->πll BF.

$$\mathcal{B}(B \to \pi \ell^+ \ell^-) < 7.9 \times 10^{-8}$$

  - This is twice the SM prediction.