

BABAR Measurements on $B \rightarrow K^{(*)} \ell^+ \ell^-$ Rates and Rate Asymmetries

→ Direct A_{CP} , lepton flavor ratio,
and isospin asymmetry

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On Behalf of the *BABAR* Collaboration

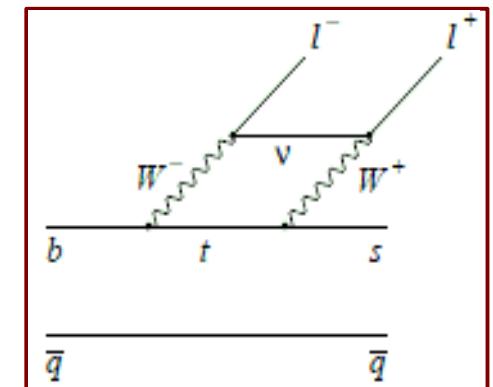
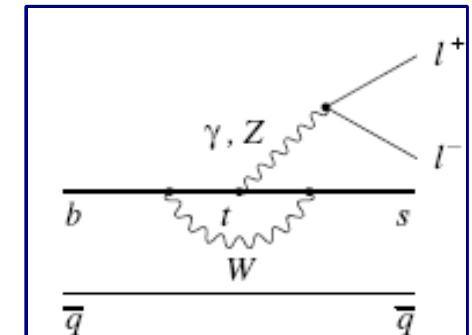
Young Scientists Forum
Rencontres de Moriond EW 2012, Lathuile, Italy
March 3rd - 10th

Motivation

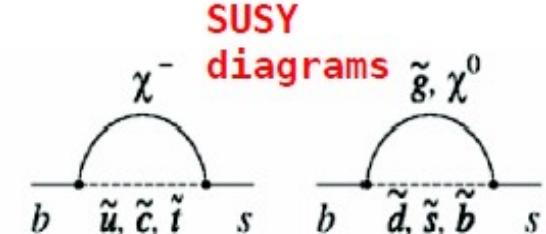
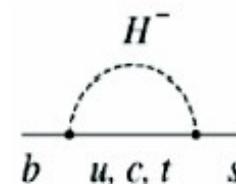
- The FCNC $b \rightarrow s \ell^+ \ell^-$ processes are forbidden at tree level in the SM
- $B \rightarrow K^{(*)} \ell^+ \ell^-$ decays are allowed in the **loop** and **box** diagrams with branching fractions $\sim 10^{-6}$
- New Physics at the electro-weak scale may bring in sizable contribution
 - Rate asymmetries can be particularly sensitive to the **NP** effects
 - NP** can be probed at a scale of a few TeV *
- We perform new analysis of eight $K^{(*)} \ell^+ \ell^-$ modes using $471 \times 10^6 B\bar{B}$ pairs with *BABAR* detector

- $K_s e^+ e^-$, $K_s^\ast e^+ e^-$, $K_s \mu^+ \mu^-$, $K_s^\ast \mu^+ \mu^-$,
 $K_s^{*+} (\rightarrow K_s \pi^+) e^+ e^-$, $K_s^{*0} (\rightarrow K^+ \pi^-) e^+ e^-$,
 $K_s^{*+} (\rightarrow K_s \pi^+) \mu^+ \mu^-$, $K_s^{*0} (\rightarrow K^+ \pi^-) \mu^+ \mu^-$

Standard Model
diagrams



* Isidori, Nir, Perez
ArXiv:1002.0900 (2010).



SUSY
diagrams

▼ BABAR 471 M $B\bar{B}$

Preliminary

■ CDF 4.4 fb^{-1}

PoS HCP2009, 033 (2009)

□ Belle 657 M $B\bar{B}$

PRL 103, 171801 (2009)

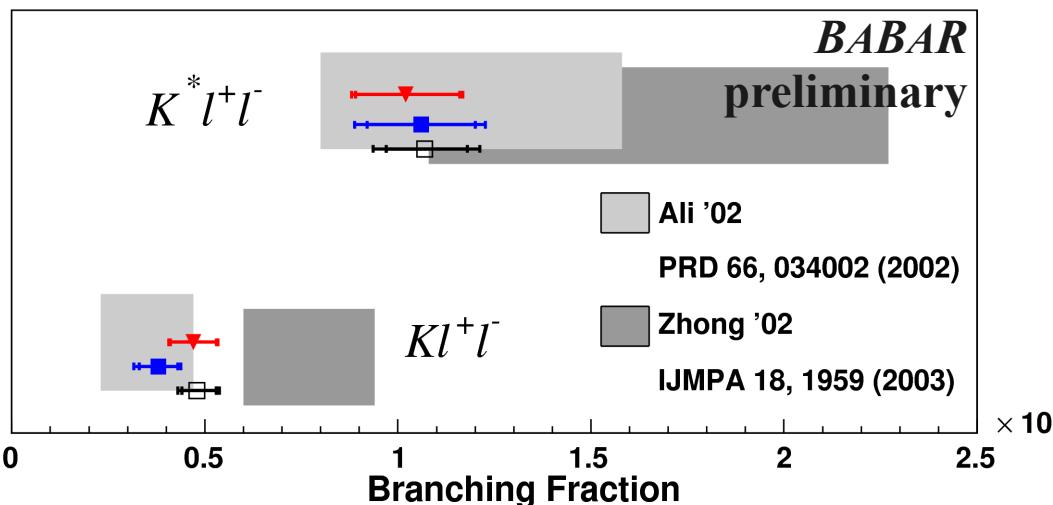
● LHCb 0.37 fb^{-1}

ArXiv:1112.3515 (2012)

Branching Fractions

- The total branching fractions:
BABAR preliminary

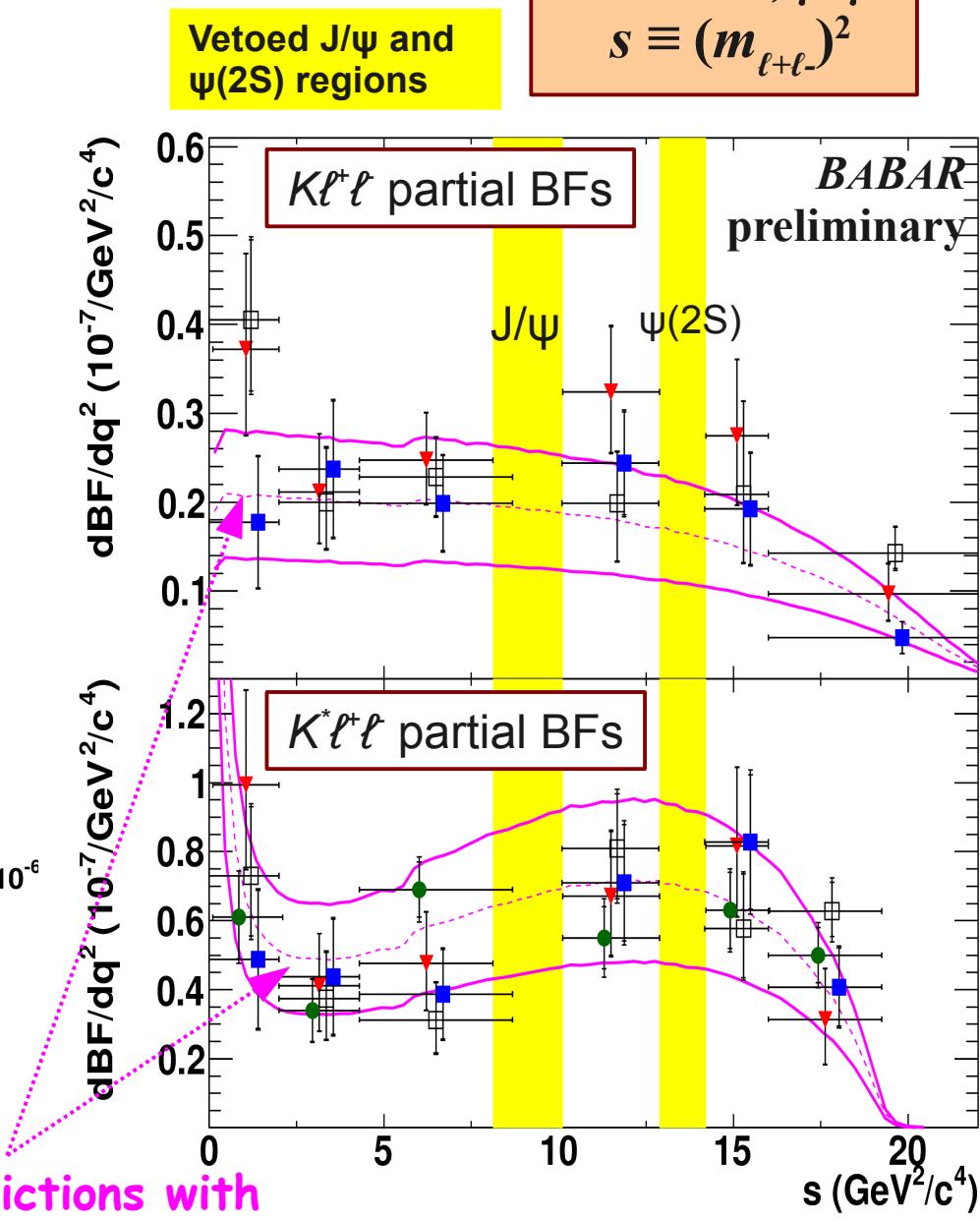
$$\begin{aligned}\mathcal{B}(B \rightarrow K\ell^+\ell^-) &= (4.7 \pm 0.6 \pm 0.2) \times 10^{-7}, \\ \mathcal{B}(B \rightarrow K^*\ell^+\ell^-) &= (10.2^{+1.4}_{-1.3} \pm 0.5) \times 10^{-7}.\end{aligned}$$



Partial BFs in three s bins below J/ψ , one between J/ψ and $\psi(2S)$, two above $\psi(2S)$

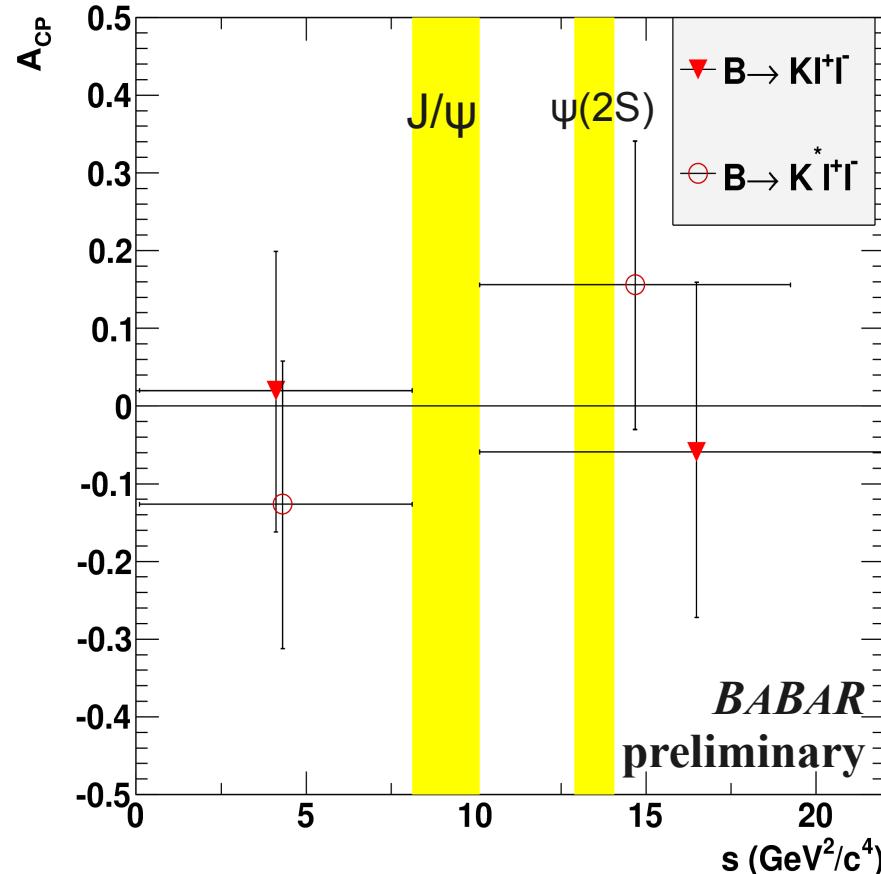
* Ball & Zwicky, PRD71, 014015(2005),
PRD71, 014029(2005);
Ali et al, PRD 66, 034002 (2002).

SM based predictions with
Uncertainties * (solid lines)

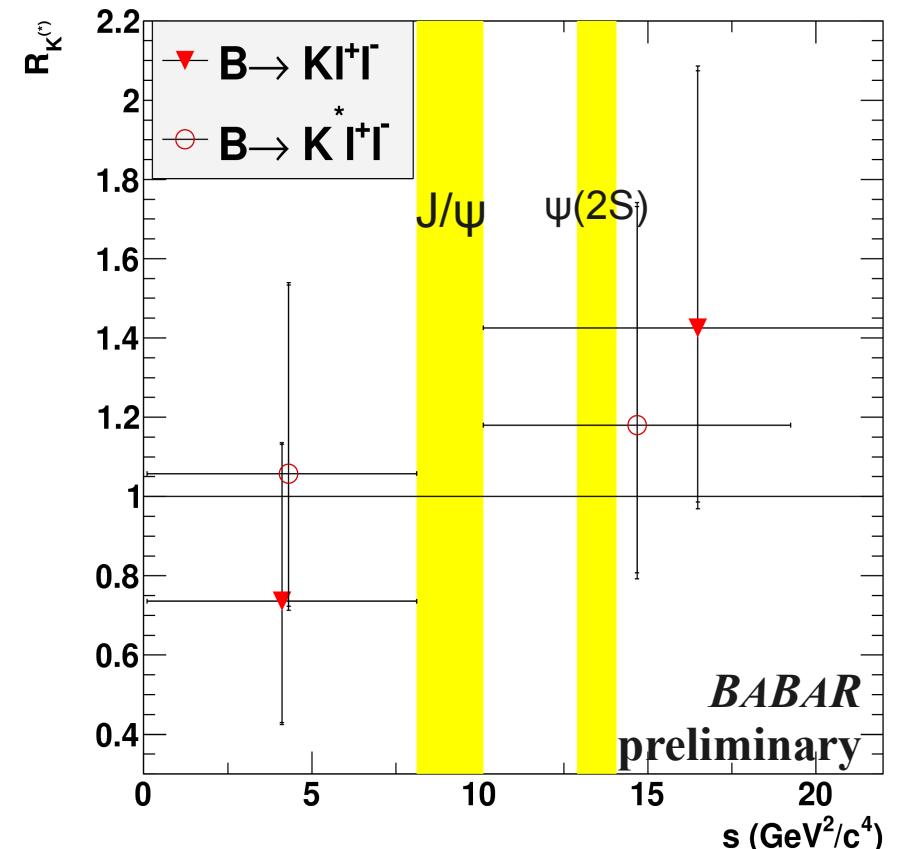


Rate Asymmetries

$$\mathcal{A}_{CP}^{K^{(*)}} \equiv \frac{\mathcal{B}(\overline{B} \rightarrow \overline{K}^{(*)}\ell^+\ell^-) - \mathcal{B}(B \rightarrow K^{(*)}\ell^+\ell^-)}{\mathcal{B}(\overline{B} \rightarrow \overline{K}^{(*)}\ell^+\ell^-) + \mathcal{B}(B \rightarrow K^{(*)}\ell^+\ell^-)}$$



$$\mathcal{R}_{K^{(*)}} \equiv \frac{\mathcal{B}(B \rightarrow K^{(*)}\mu^+\mu^-)}{\mathcal{B}(B \rightarrow K^{(*)}e^+e^-)}$$



- Direct CP asymmetries agree with null expectation (SM)

- Lepton flavor ratios agree with unity (SM)

Isospin Asymmetries

- $$\mathcal{A}_I^{K^{(*)}} \equiv \frac{\mathcal{B}(B^0 \rightarrow K^{(*)0} \ell^+ \ell^-) - r_\tau \mathcal{B}(B^+ \rightarrow K^{(*)+} \ell^+ \ell^-)}{\mathcal{B}(B^0 \rightarrow K^{(*)0} \ell^+ \ell^-) + r_\tau \mathcal{B}(B^+ \rightarrow K^{(*)+} \ell^+ \ell^-)}$$

$$r_\tau \equiv \tau_{B^0}/\tau_{B^+} = 1/(1.071 \pm 0.009)$$

A_I

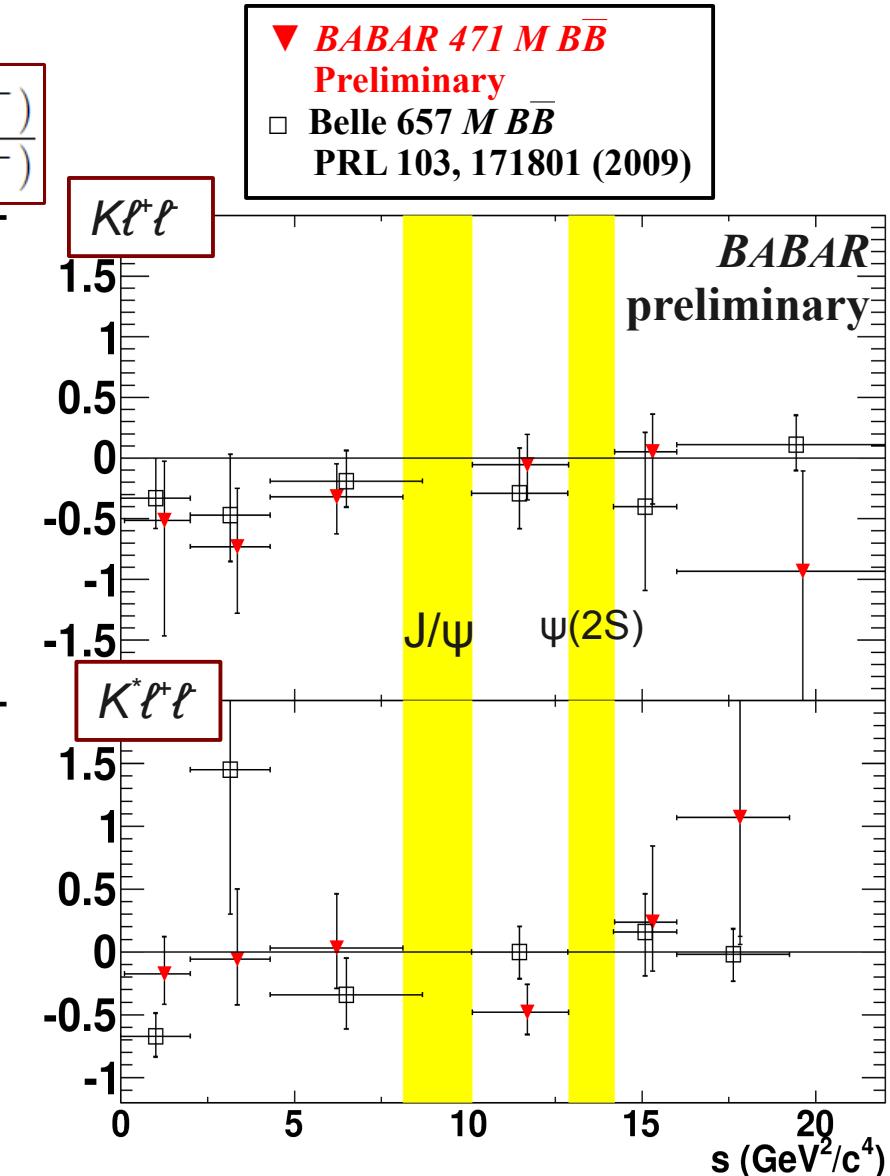
- In the SM, the isospin asymmetries are expected at $O(1\%)$ *

- Below J/ψ ($0.1 < s < 8.12 \text{ GeV}^2/c^4$) measure:

- BABAR Preliminary*

$\mathcal{A}_I^{\text{low}}(B \rightarrow K \ell^+ \ell^-) = -0.58^{+0.29}_{-0.37} \pm 0.02$
$\mathcal{A}_I^{\text{low}}(B \rightarrow K^* \ell^+ \ell^-) = -0.25^{+0.20}_{-0.17} \pm 0.03$

- Consistent with SM predictions at **2.1σ** and **1.2σ** level respectively and agree with Belle results



* Feldmann & Matias, JHEP 0301, 074 (2003).

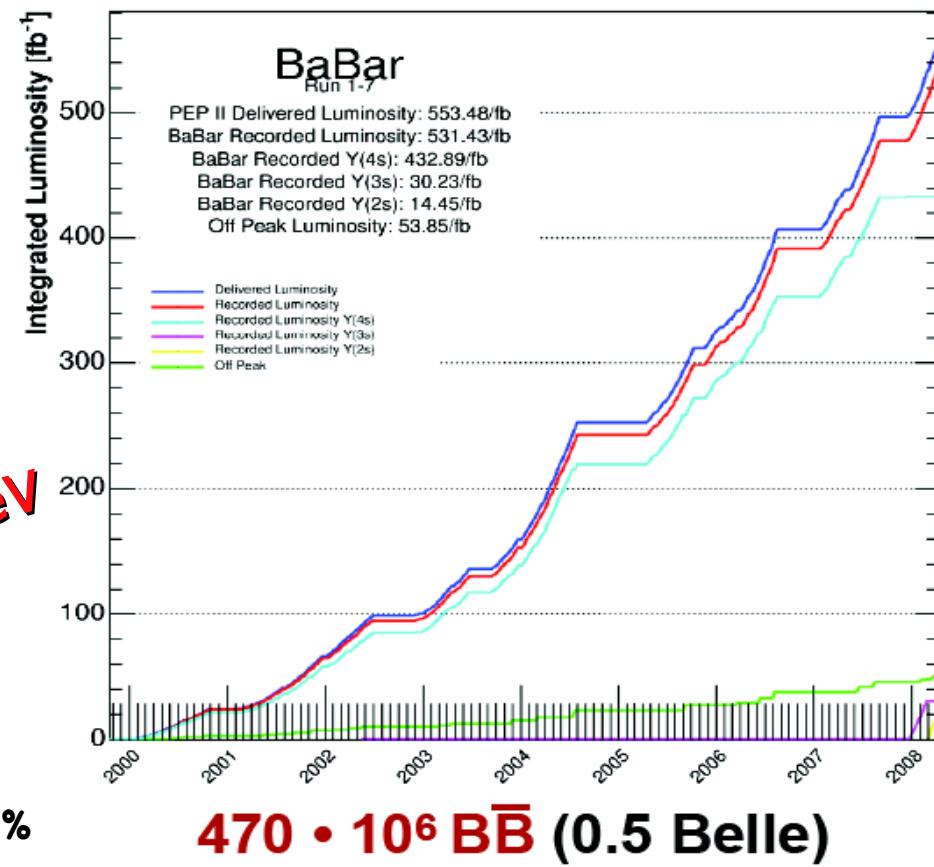
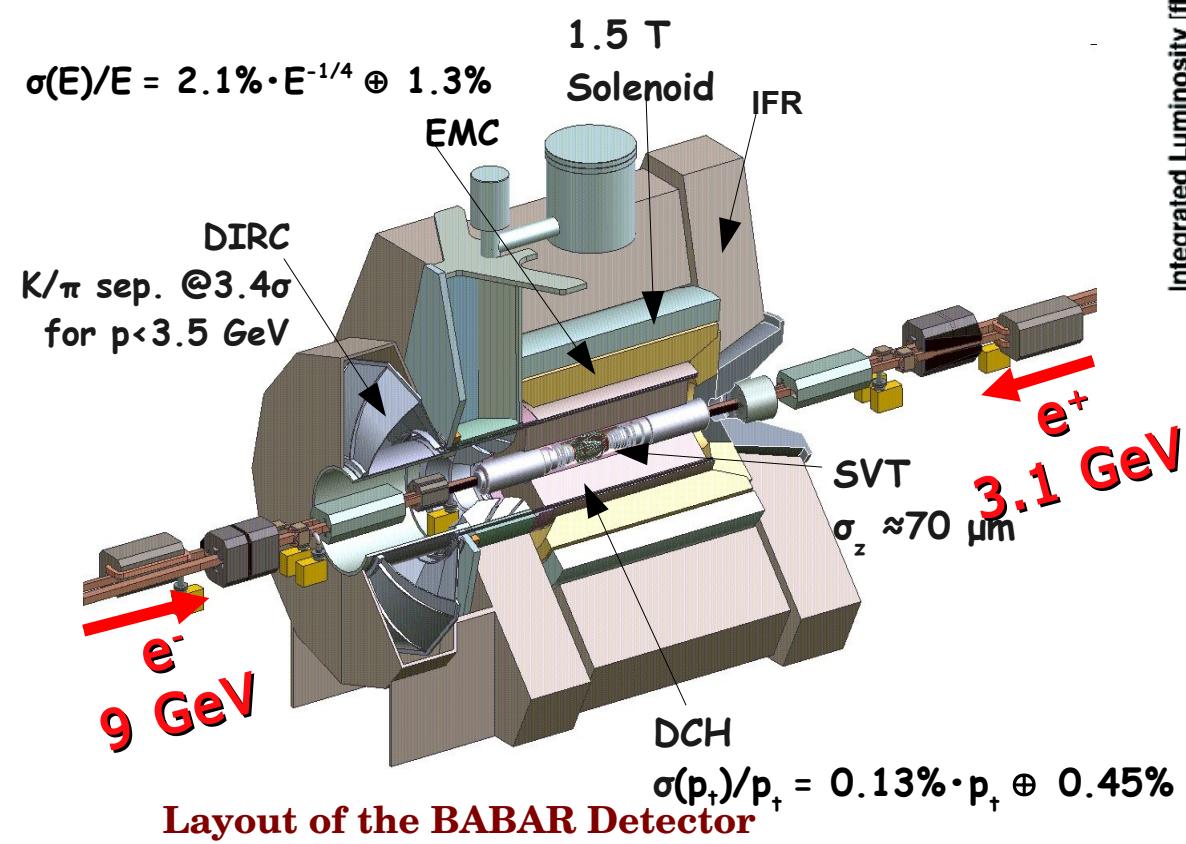
Summary

- Final *BABAR* results on $B \rightarrow K^{(*)}\ell^+\ell^-$ BFs and rate asymmetries using 471 million $B\bar{B}$ pairs
- Our results are in good agreement with the SM predictions and those from Belle, CDF, and LHCb
- At low dilepton masses, isospin asymmetries are negative as seen by Belle, the combined *BABAR/Belle* $K^{(*)}\ell^+\ell^-$ result indicates $\sim 3\sigma$ effect
- The paper is to be submitted to PRD/arXiv.org

Backup Slides

The *BABAR* Experiment

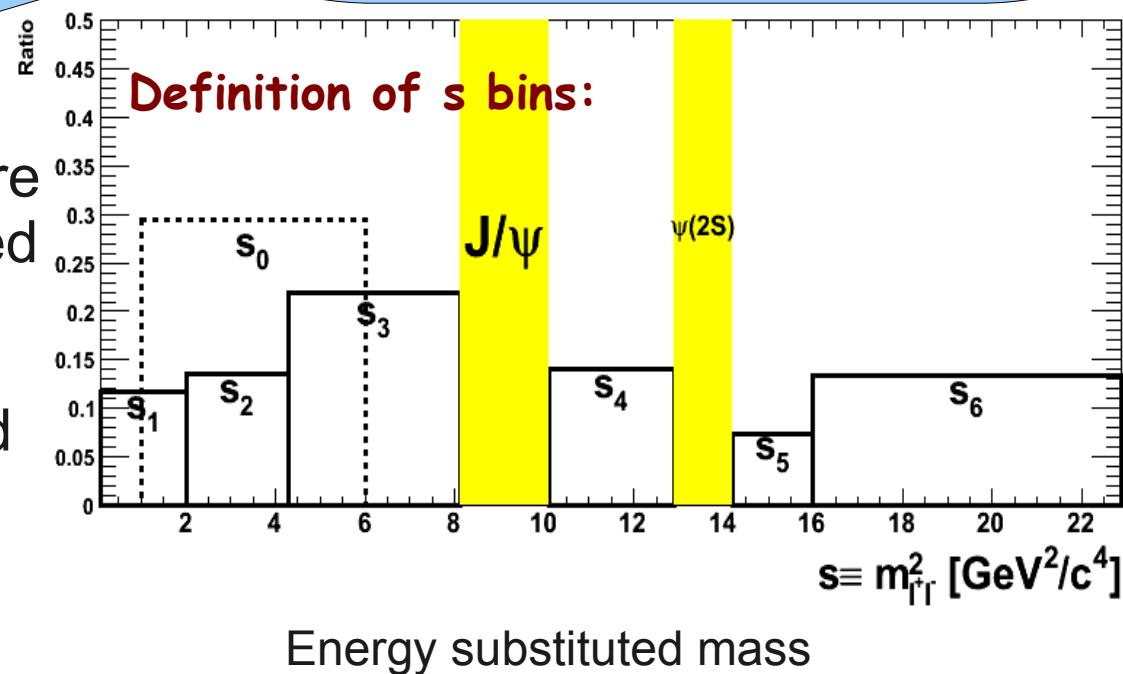
- The experimental data is collected with the *BABAR* detector at the PEP-II asymmetric e^+e^- collider located at SLAC



Experimental Details

- 471 M $B\bar{B}$ pairs collected with the *BABAR* detector
- Background suppression with bagged decision trees
- Eight $K^{(*)}\ell^+\ell^-$ final states
- $J/\psi K^{(*)}$ and $\psi(2S)K^{(*)}$ events are vetoed based on $m_{\ell^+\ell^-}$ and used as control samples
- Unbinned maximum likelihood fits to extract signal yields
 - 1D m_{ES} fits for $K\ell^+\ell^-$
 - 2D m_{ES} and $m_{K\pi}$ for $K^*\ell^+\ell^-$

$K_s e^+e^-$, $K^+e^+e^-$, $K_s \mu^+\mu^-$, $K^+\mu^+\mu^-$,
 $K_s^{*+}(\rightarrow K_s \pi^+)e^+e^-$, $K_s^{*0}(\rightarrow K^+ \pi^-)e^+e^-$,
 $K_s^{*+}(\rightarrow K_s \pi^+)\mu^+\mu^-$, $K_s^{*0}(\rightarrow K^+ \pi^-)\mu^+\mu^-$,
with $K_s \rightarrow \pi^+\pi^-$ *

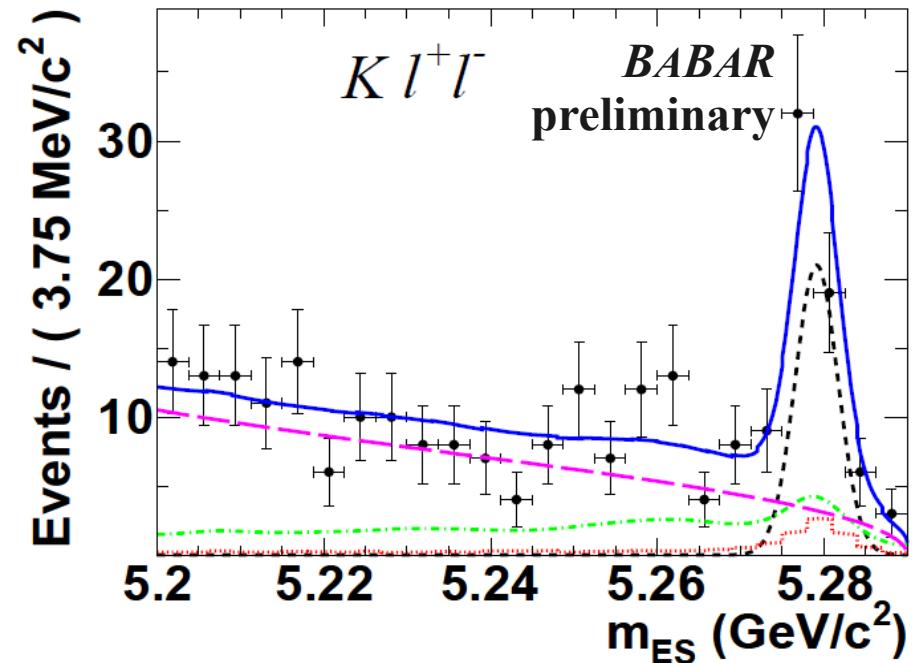
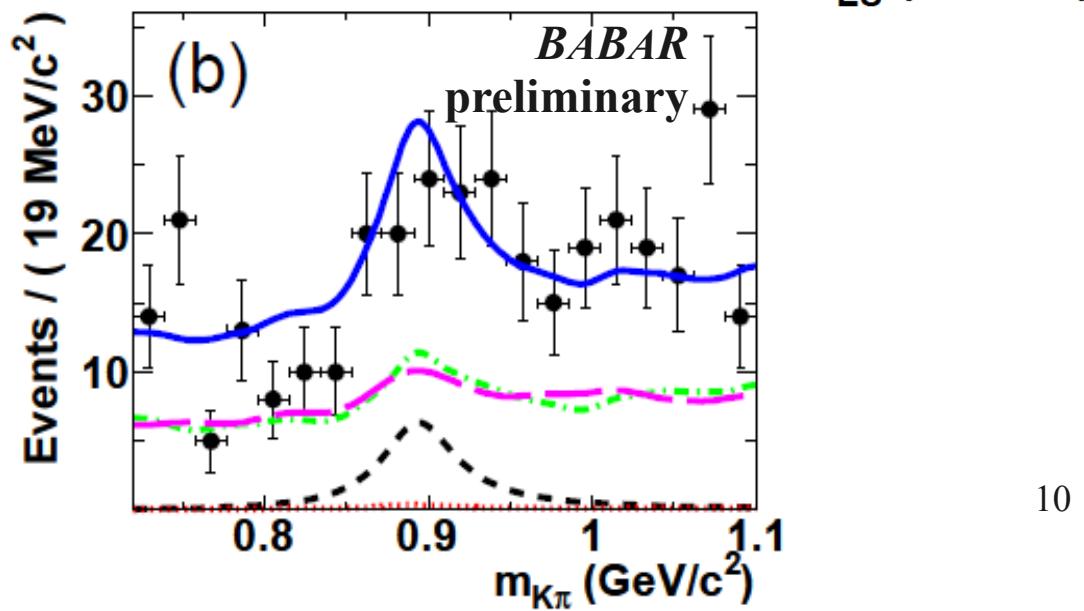
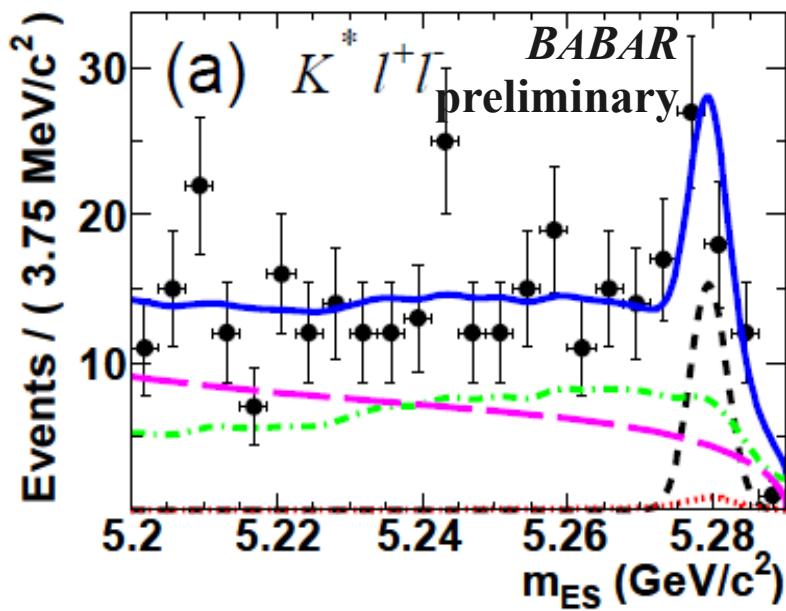


$$m_{ES} = \sqrt{E_{CM}^2/4 - p_B^{*2}}$$

Data Fits

Right: $B \rightarrow K \ell^+ \ell^-$ bin s_4

Bottom: $B \rightarrow K^* \ell^+ \ell^-$ bin s_1



Rates and Rate Asymmetries

BABAR preliminary

s (GeV $^2/c^4$)	$B \rightarrow K\ell^+\ell^-$		$B \rightarrow K^*\ell^+\ell^-$	
	N_{sig}	$\mathcal{B}[10^{-7}]$	N_{sig}	$\mathcal{B}[10^{-7}]$
0.10–2.00	$20.6^{+5.9}_{-5.4}$	$0.71^{+0.20}_{-0.18} \pm 0.02$	$26.0^{+7.1}_{-6.4}$	$1.89^{+0.52}_{-0.46} \pm 0.06$
2.00–4.30	$17.4^{+5.4}_{-4.8}$	$0.49^{+0.15}_{-0.13} \pm 0.01$	$14.5^{+5.3}_{-4.6}$	$0.95^{+0.35}_{-0.30} \pm 0.04$
4.30–8.12	$37.1^{+8.0}_{-7.5}$	$0.94^{+0.20}_{-0.19} \pm 0.02$	$29.3^{+9.1}_{-8.3}$	$1.82^{+0.56}_{-0.52} \pm 0.09$
10.11–12.89	$36.0^{+8.2}_{-7.6}$	$0.90^{+0.20}_{-0.19} \pm 0.04$	$31.6^{+8.8}_{-8.1}$	$1.86^{+0.52}_{-0.48} \pm 0.10$
14.21–16.00	$19.7^{+6.2}_{-5.6}$	$0.49^{+0.15}_{-0.14} \pm 0.02$	$24.1^{+6.7}_{-6.0}$	$1.46^{+0.41}_{-0.36} \pm 0.06$
>16.00	$22.3^{+7.7}_{-6.9}$	$0.67^{+0.23}_{-0.21} \pm 0.05$	$14.1^{+6.6}_{-5.9}$	$1.02^{+0.47}_{-0.42} \pm 0.06$
1.00–6.00	$39.4^{+7.7}_{-7.1}$	$1.36^{+0.27}_{-0.24} \pm 0.03$	$33.1^{+8.6}_{-7.8}$	$2.05^{+0.53}_{-0.48} \pm 0.07$

s (GeV $^2/c^4$)	\mathcal{A}_I	
	$B \rightarrow K\ell^+\ell^-$	$B \rightarrow K^*\ell^+\ell^-$
0.10–2.00	$-0.51^{+0.49}_{-0.95} \pm 0.04$	$-0.17^{+0.29}_{-0.24} \pm 0.03$
2.00–4.30	$-0.73^{+0.48}_{-0.55} \pm 0.03$	$-0.06^{+0.56}_{-0.36} \pm 0.05$
4.30–8.12	$-0.32^{+0.27}_{-0.30} \pm 0.01$	$0.03^{+0.43}_{-0.32} \pm 0.04$
10.11–12.89	$-0.05^{+0.25}_{-0.29} \pm 0.03$	$-0.48^{+0.22}_{-0.18} \pm 0.05$
14.21–16.00	$0.05^{+0.31}_{-0.43} \pm 0.03$	$0.24^{+0.61}_{-0.39} \pm 0.04$
>16.00	$-0.93^{+0.83}_{-4.99} \pm 0.04$	$1.07^{+4.27}_{-0.95} \pm 0.35$
1.00–6.00	$-0.41 \pm 0.25 \pm 0.01$	$-0.20^{+0.30}_{-0.23} \pm 0.03$

s (GeV $^2/c^4$)	$A_{CP}(B^+ \rightarrow K^+\ell^+\ell^-)$	$A_{CP}(B \rightarrow K^*\ell^+\ell^-)$
All	$-0.03 \pm 0.14 \pm 0.01$	$0.03 \pm 0.13 \pm 0.01$
0.10–8.12	$0.02 \pm 0.18 \pm 0.01$	$-0.13^{+0.18}_{-0.19} \pm 0.01$
>10.11	$-0.06^{+0.22}_{-0.21} \pm 0.01$	$0.16^{+0.18}_{-0.19} \pm 0.01$

s (GeV $^2/c^4$)	\mathcal{R}_K	R_{K^*}
All	$1.00^{+0.31}_{-0.25} \pm 0.07$	$1.13^{+0.34}_{-0.26} \pm 0.10$
0.10–8.12	$0.74^{+0.40}_{-0.31} \pm 0.06$	$1.06^{+0.48}_{-0.33} \pm 0.08$
>10.11	$1.43^{+0.65}_{-0.44} \pm 0.12$	$1.18^{+0.55}_{-0.37} \pm 0.11$

Systematic Uncertainties

- Individual systematic uncertainties [%] for measurements of total branching fractions:

BABAR preliminary

Mode	$K_S^0 \mu^+ \mu^-$	$K^+ \mu^+ \mu^-$	$K_S^0 e^+ e^-$	$K^+ e^+ e^-$	$K_S^0 \pi^+ \mu^+ \mu^-$	$K^+ \pi^- \mu^+ \mu^-$	$K_S^0 \pi^+ e^+ e^-$	$K^+ \pi^- e^+ e^-$
$B\bar{B}$ counting	± 0.6	± 0.6	± 0.6	± 0.6	± 0.6	± 0.6	± 0.6	± 0.6
Tracking	± 1.4	± 1.0	± 1.4	± 1.0	± 1.8	± 1.4	± 1.8	± 1.4
PID	± 1.6	± 0.3	± 0.7	± 0.4	± 1.5	± 0.3	± 0.5	± 1.2
K_s^0 ID	± 0.9	—	± 0.9	—	± 0.9	—	± 0.9	—
BDT selections	± 2.2	± 1.7	± 4.7	± 1.5	± 8.3	± 2.5	± 9.1	± 2.7
MC statistics	± 0.3	± 0.3	± 0.3	± 0.3	± 0.4	± 0.3	± 0.4	± 0.4
Sig. Shape	± 0.5	± 0.4	± 1.5	± 0.4	± 1.5	± 0.7	± 1.5	± 0.7
Hadronic	± 3.3	± 5.8	—	—	± 2.3	± 1.6	—	—
Peaking	± 0.3	± 0.8	± 1.2	± 0.8	± 0.7	± 1.7	± 0.8	± 1.2
Comb. $m_{K\pi}$ shape	—	—	—	—	± 1.2	± 0.6	± 0.6	± 1.6
Total	± 4.7	± 6.3	± 5.4	± 2.2	± 9.3	± 3.9	± 9.5	± 4.0

- Most of uncertainties listed above cancel out for the rate asymmetries