Radiative *B* decays and new physics searches at *BABAR*
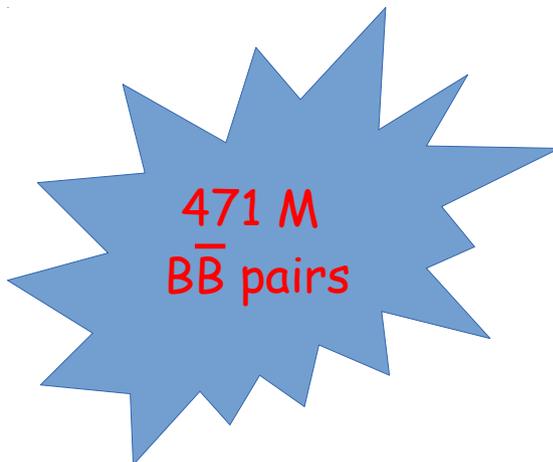

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University of Cincinnati
(on behalf of the *BABAR* collaboration)

International Workshop on Deep-Inelastic Scattering and Related Subjects
Warsaw, Poland 28 April - 02 May 2014

UNIVERSITY OF
Cincinnati

BABAR
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Included BABAR results

471 M $B\bar{B}$ pairs

- Search for direct CP violation in B → $X_s\gamma$ using a sum of exclusive final states

  – To be submitted to PRD

- Time-dependent analysis of B^0 → $K_s\pi^-\pi^+\gamma$ and studies of the $K^+\pi^-\pi^+$ system in B^+ → $K^+\pi^-\pi^+\gamma$ decays

  – To be submitted to PRD

- Measurement of the B → $X_s\ell^+\ell^-$ Branching Fraction (BF) and search for direct CP violation using a sum of exclusive final states

  – Submitted to PRL (arXiv:1312.5364)

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Radiative B decays

- Forbidden at tree-level in SM, flavor-changing neutral-current (FCNC) processes proceed via loop and box diagrams such as:

$$\mathcal{B}(B \to X_s\gamma) \sim 10^{-4}$$

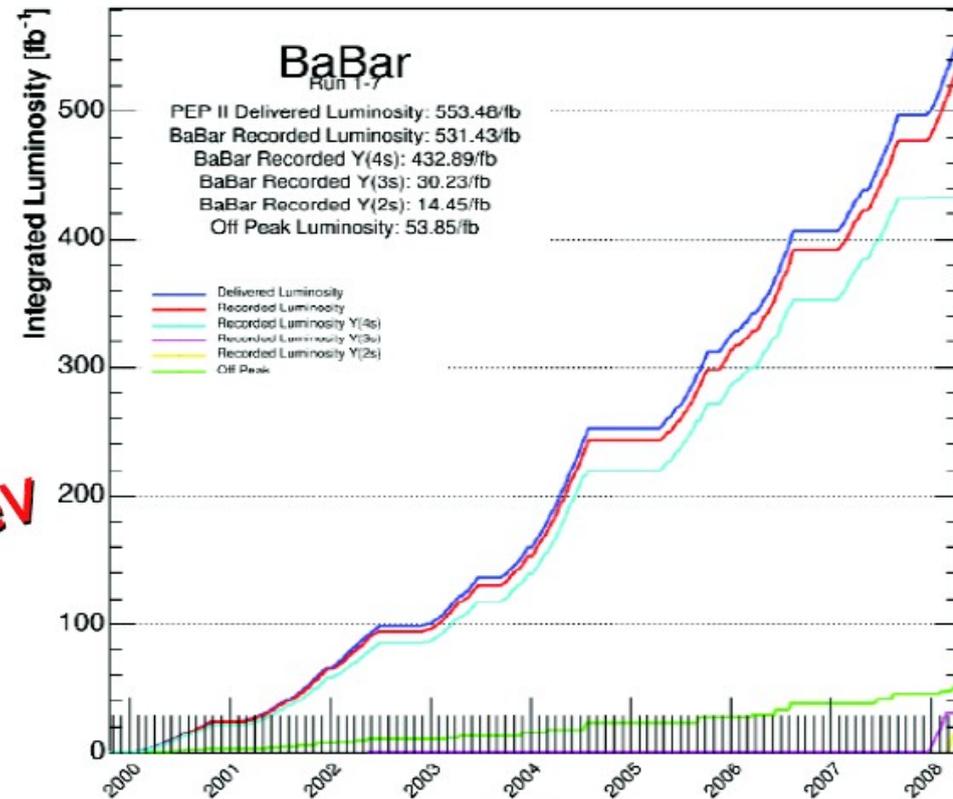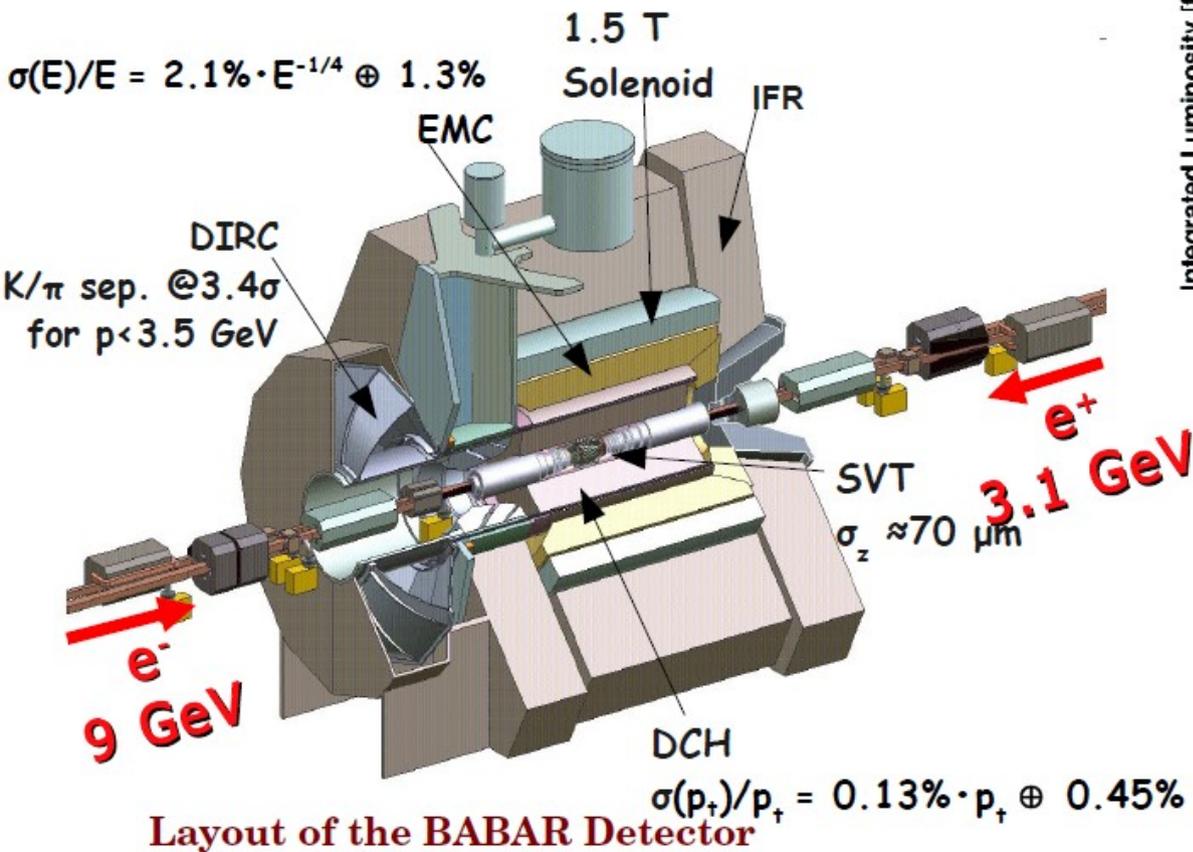$$\mathcal{B}(B \to X_s\ell^+\ell^-) \sim 10^{-6}$$
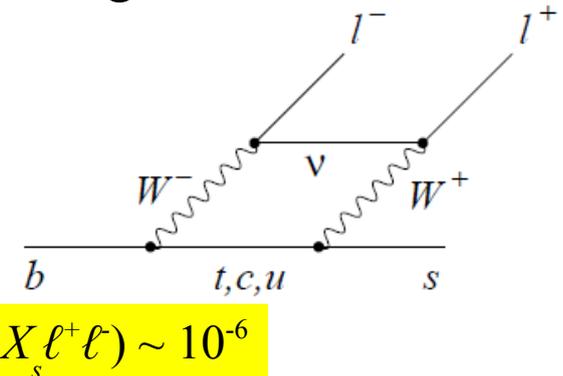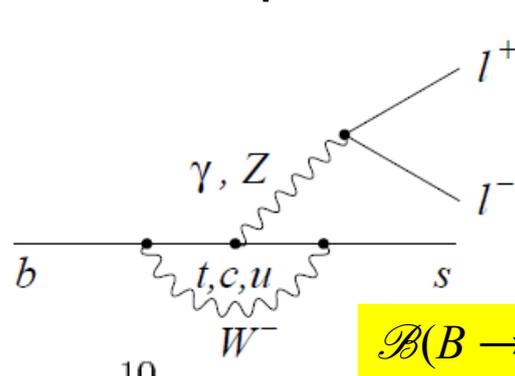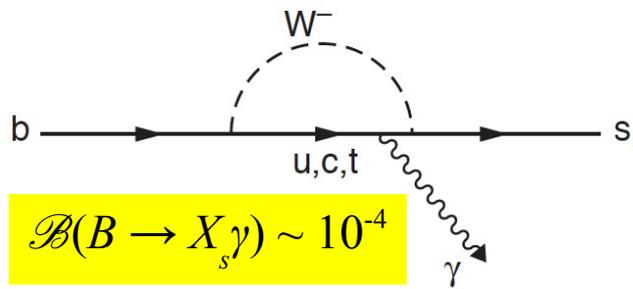
- Effective Hamiltonian $H_{Eff} \propto \sum_{i=1}^{10} C_i \mathcal{O}_i$ factorizes short-distance Wilson coefficients C_i from long-distance effects

- New physics brings in new loops, and may change the SM values of Wilson coefficients / introduce new terms, *e.g.* C_S & C_P

SUSY diagrams
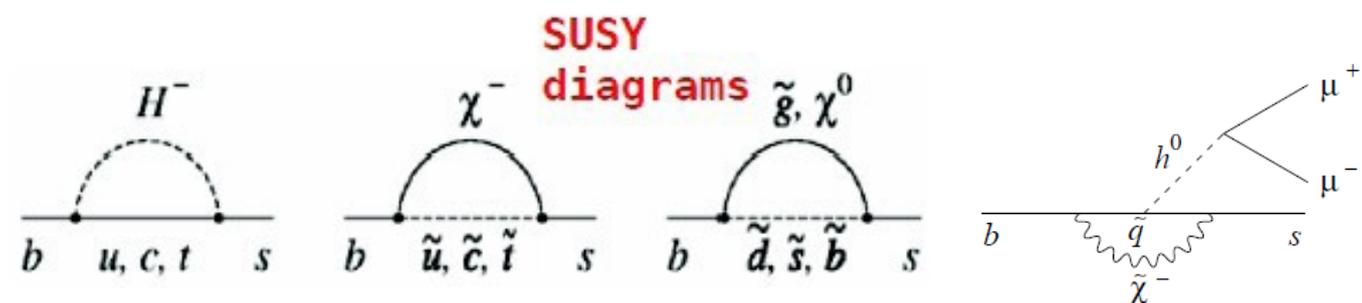
BABAR experiment

- The experimental data were collected between 1999 and 2008 with the BABAR detector at the PEP-II asymmetric energy e^+e^- collider located at SLAC

Layout of the BABAR Detector

$\sigma(E)/E = 2.1\% \cdot E^{-1/4} \oplus 1.3\%$

1.5 T Solenoid

EMC

IFR

DIRC

K/π sep. @3.4σ for p<3.5 GeV

SVT

$\sigma_z \approx 70\ \mu m$

DCH

$\sigma(p_t)/p_t = 0.13\% \cdot p_t \oplus 0.45\%$

e^+ 3.1 GeV

e^- 9 GeV

471 x 10^6 B$\bar{\text{B}}$ pairs collected at Y(4S) resonance

Common experimental techniques
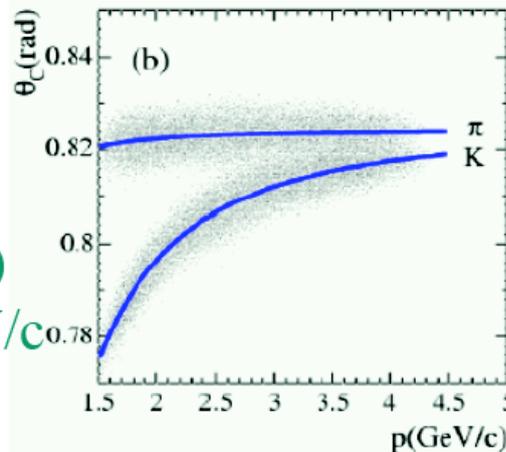
Kinematics of fully reconstructed B

$$m_{ES} = \sqrt{E_{beam}^{*2} - p_B^{*2}}$$

$$\Delta E = E_B^* - E_{beam}^*$$
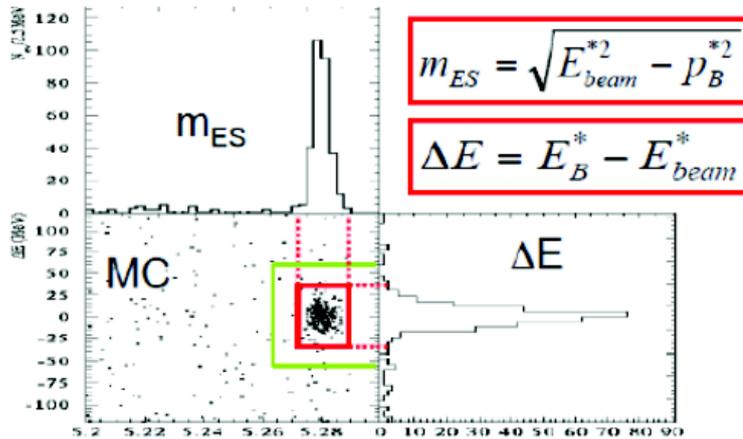
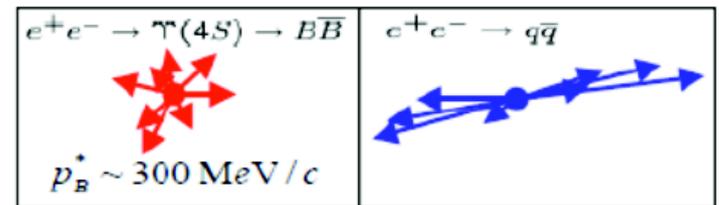Good charged particle ID (in particular K/π) up to few GeV/c

Background characterization:

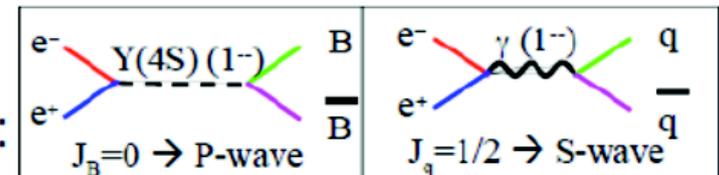→ Mainly continuum: $e^+e^- \rightarrow q\bar{q}$ (q = u,d,s,c).
Suppression by multi-variable classifiers based on event-shape variables:
Fisher discriminant, Boosted decision trees (BDT)
…

Topology:

$$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\bar{B} \qquad e^+e^- \rightarrow q\bar{q}$$

$$p_B^* \sim 300\, MeV/c$$

Angular distribution:

$J_B = 0$ → P-wave $\qquad J_q = 1/2$ → S-wave
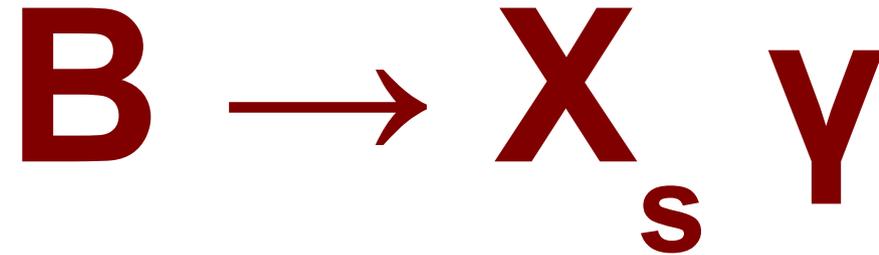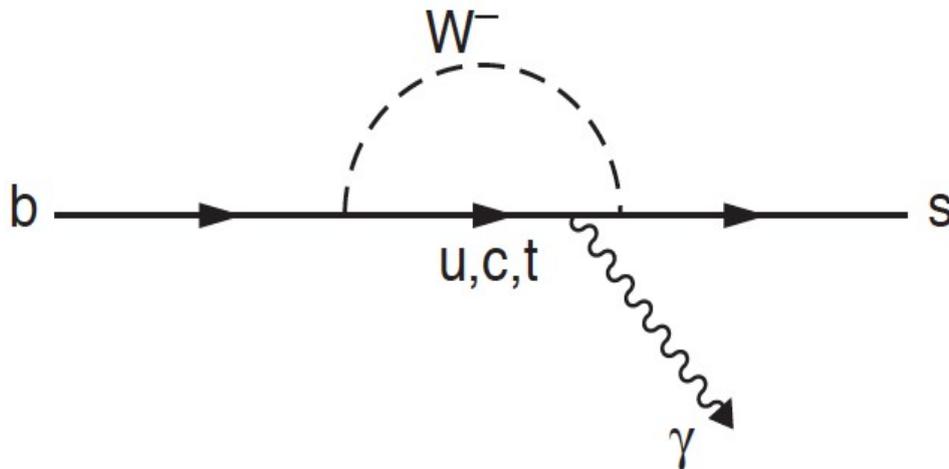
→ Background from B decays: classified by kinematic and topological properties

Variables are often combined to a likelihood function, used in a maximum likelihood fit for signal/background separation and to measure parameters of interest

B → X$_s$ γ

- Measurements of direct CP asymmetries (A$_{CP}$) from a sum of exclusive final states

Direct A_{CP} in $B \rightarrow X_s\gamma$

- Direct A_{CP} for the sum of exclusive decays is measured by:

  - $$A_{CP} = \frac{\Gamma_{\bar{B}^0/B^- \rightarrow X_s\gamma} - \Gamma_{B^0/B^+ \rightarrow X_{\bar{s}}\gamma}}{\Gamma_{\bar{B}^0/B^- \rightarrow X_s\gamma} + \Gamma_{B^0/B^+ \rightarrow X_{\bar{s}}\gamma}}$$

    HFAG avg A_{CP} = (-0.8 ± 2.9)%

- A_{CP} in the SM is expected to be small and within (-0.6, +2.8)% (1)

- Difference in direct A_{CP} in charged and neutral B mesons:

  - $$\Delta A_{X_s\gamma} = A_{B^\pm \rightarrow X_s\gamma} - A_{B^0/\bar{B}^0 \rightarrow X_s\gamma}$$

    interference amplitude
    $$17\,\mathrm{MeV} < \bar{\Lambda}_{78} < 190\,\mathrm{MeV}$$

  - Depends on two Wilson coefficients: $\Delta A_{X_s\gamma} = 4\pi^2\alpha_s \frac{\bar{\Lambda}_{78}}{m_b}\Im m\left(\frac{C_{8g}}{C_{7\gamma}}\right)$ (1)

- In the SM, $\Delta A_{X_s\gamma} = 0$ as the two Wilson coefficients are real

- NP may modify the two Wilson coefficients

  - $C_{7\gamma}$ is constrained from $b \rightarrow s\ell^+\ell^-$ and $\mathscr{B}(b \rightarrow s\gamma)$

  - C_{8g} can thus be constrained by $\Delta A_{X_s\gamma}$, **for the first time**

DIS 2014   Liang Sun   (1) Phys. Rev. Lett. 106, 141801 (2011)

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Event selections

- 16 self-tagging final states used to reconstruct B meson decays:

  – Other modes rejected for being not flavor-specific or low in yield

- Requiring in each event at least one high energy photon ($1.6 < E^*_\gamma < 3.0$ GeV in the Y(4S) rest frame)

- Requiring $0.6 < m_{Xs} < 3.2$ GeV, $m_{ES} > 5.24$ GeV, and $|\Delta E| < 0.15$ GeV

Charged Modes:

$K^0_S \, \pi^+ \, \gamma$
$K^+ \, \pi^0 \, \gamma$
$K^+ \, \pi^+ \, \pi^- \, \gamma$
$K^0_S \, \pi^+ \, \pi^0 \, \gamma$
$K^+ \, \pi^0 \, \pi^0 \, \gamma$
$K^0_S \, \pi^+ \, \pi^- \, \pi^+ \, \gamma$
$K^+ \, \pi^+ \, \pi^- \, \pi^0 \, \gamma$
$K^0_S \, \pi^+ \, \pi^0 \, \pi^0 \, \gamma$
$K^+ \, \eta \, \gamma$
$K^+ \, K^- \, K^+ \, \gamma$

Neutral Modes:

$K^+ \, \pi^- \, \gamma$
$K^+ \, \pi^- \, \pi^0 \, \gamma$
$K^+ \, \pi^+ \, \pi^- \, \pi^- \, \gamma$
$K^+ \, \pi^- \, \pi^0 \, \pi^0 \, \gamma$
$K^+ \, \eta \, \pi^- \, \gamma$
$K^+ \, K^- \, K^+ \, \pi^- \, \gamma$

Requiring K_s from $K_s \to \pi^+\pi^-$, π^0/η from $\pi^0/\eta \to \gamma\gamma$

- Primary (non-peaking) background of continuum events is suppressed by requiring the ratio of angular moments $L_{12}/L_{10} < 0.46$. Further background suppression with 2 BDTs
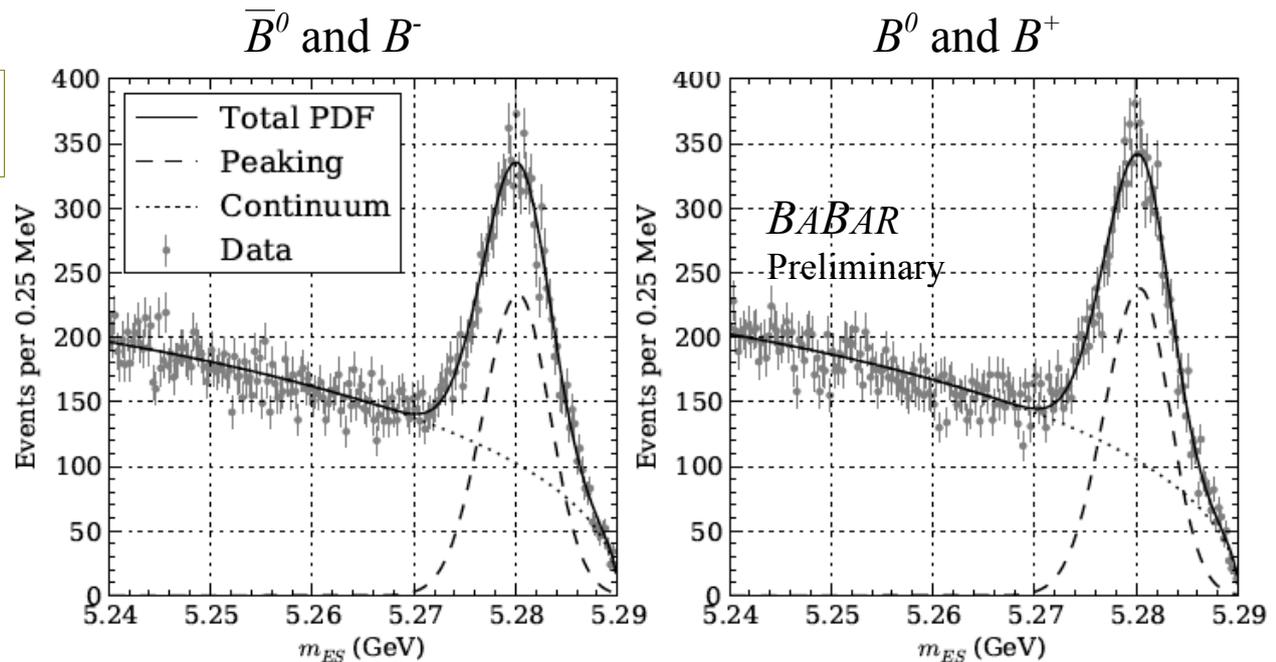
Fitting for asymmetry

- Raw asymmetry is extracted via fitting simultaneously for B and $\overline{B}$ tagged samples

- A_{CP} is measured by correcting the raw asymmetry with detector asymmetry, which is determined from the m_{ES} < 5.27 GeV sideband

- In the entire m_{Xs} range, we have: $A_{CP} = +(1.7 \pm 1.9_{stat} \pm 1.0_{syst})\%$

  - Consistent with SM

    $-0.6\% < A_{CP}^{SM} < 2.8\%$

  - The most precise measurement to date

$\Delta A_{Xs\gamma}$ and implication on $\mathrm{Im}(C_{8g}/C_{7\gamma})$

$\boxed{B \to X_s \gamma}$

- From the simultaneous fits to charged and neutral *B* samples measure

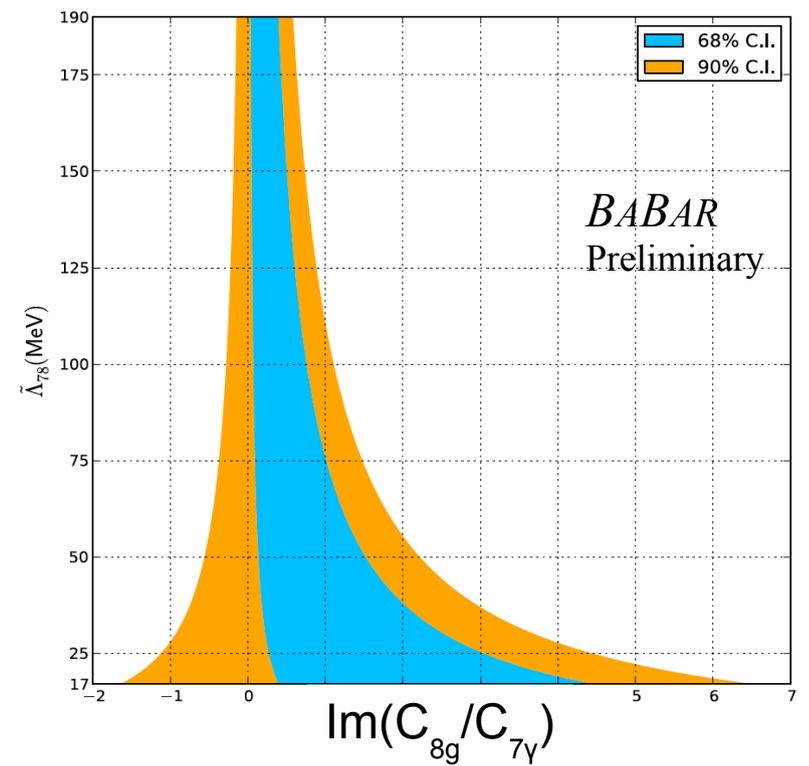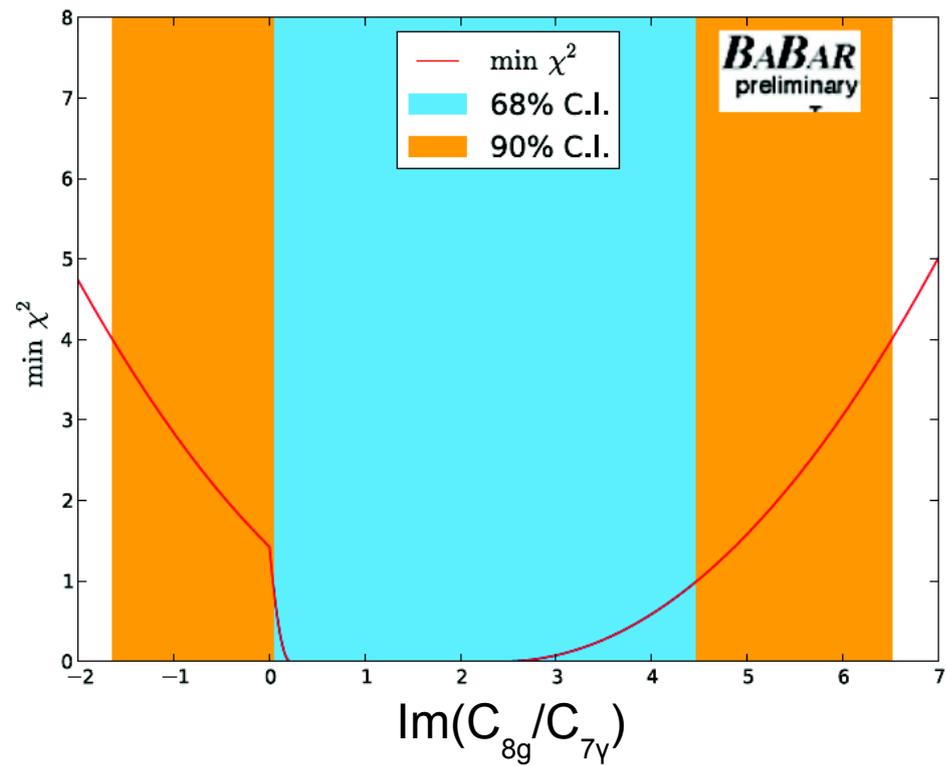$$\Delta A_{Xs\gamma} = +(5.0 \pm 3.9_{\text{stat}} \pm 1.5_{\text{syst}})\%$$

First measurement

- Confidence limits are set on $\mathrm{Im}(C_{8g}/C_{7\gamma})$:

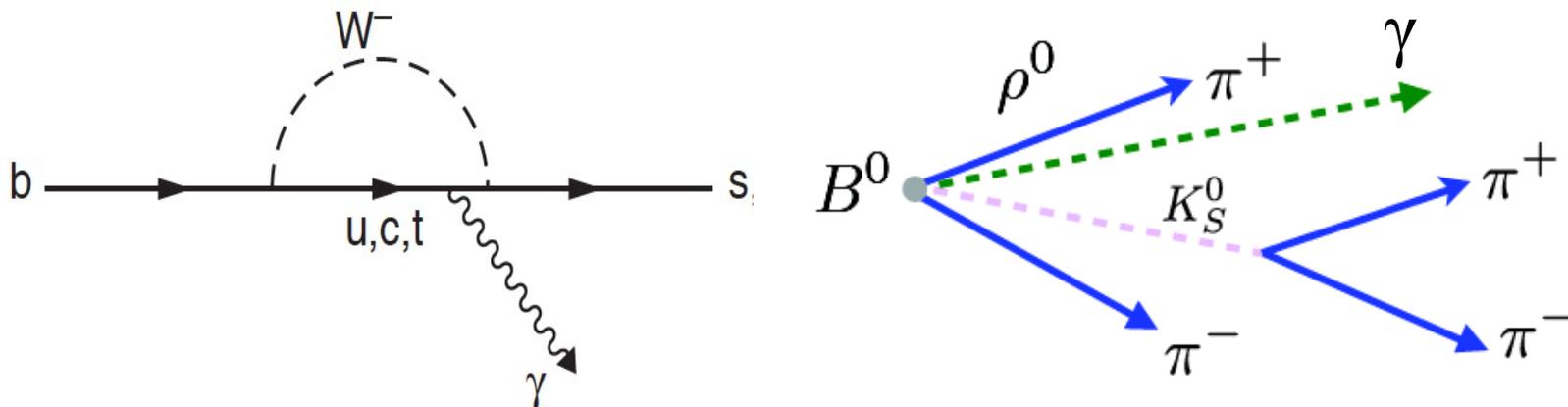**First constraint of this kind for NP**

$$0.07 \leq \mathrm{Im}\frac{C_{8g}}{C_{7\gamma}} \leq 4.48, \quad 68\%\ \text{CL},$$

$$-1.64 \leq \mathrm{Im}\frac{C_{8g}}{C_{7\gamma}} \leq 6.52, \quad 90\%\ \text{CL}.$$
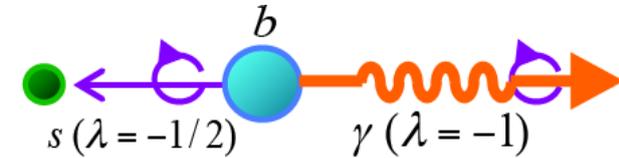
B → Kπ⁺π⁻γ

$$B \longrightarrow K\pi^+\pi^-\gamma$$

- Time dependent analysis of $B^0 \to K_S\pi^+\pi^-\gamma$ and studies of the $K^+\pi^-\pi^+$ system in $B^+ \to K^+\pi^-\pi^+\gamma$ decays

Introduction

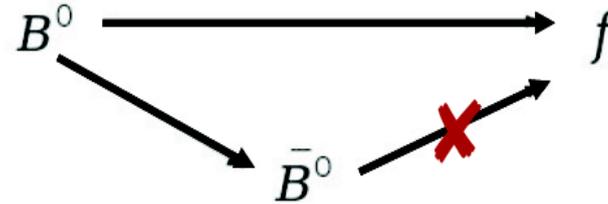- In the SM, left-handed quarks and right-handed anti-quarks

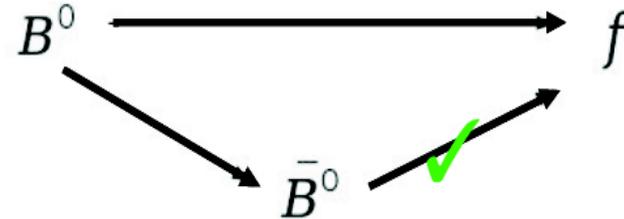**SM** $\Rightarrow$ **b** $\to$ **sγ_L** or **$\bar{b} \to \bar{s}\gamma_R$** $\Rightarrow$

CP asymmetry parameters $\approx$ 0

- In the presence of NP, opposite helicity photons may get involved

NP $\Rightarrow$ **b** $\to$ **s$\gamma_{L,R}$** or **$\bar{b} \to \bar{s}\gamma_{R,L}$** $\Rightarrow$

CP asymmetry parameters $\neq$ 0

- Time-dependent CP asymmetry:

$$\mathcal{A}_{CP}(\Delta t) = \frac{\Gamma(\bar{B}^0(\Delta t) \to f_{CP}\gamma) - \Gamma(B^0(\Delta t) \to f_{CP}\gamma)}{\Gamma(\bar{B}^0(\Delta t) \to f_{CP}\gamma) + \Gamma(B^0(\Delta t) \to f_{CP}\gamma)}$$
$$= \mathcal{S}_{f_{CP}} \sin(\Delta m_d \Delta t) - \mathcal{C}_{f_{CP}} \cos(\Delta m_d \Delta t)$$

Observable

$$\mathcal{S}_{f_{CP}} \overset{SM}{\propto} \frac{m_s}{m_b} \simeq 0.02$$
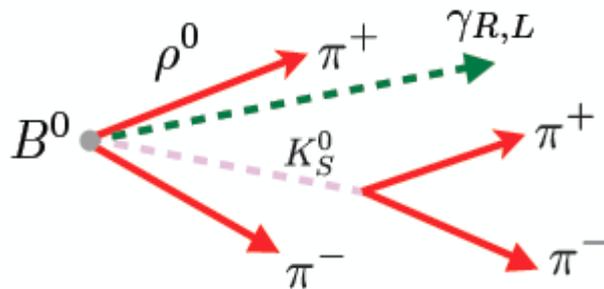
Δm_d: $B^0\bar{B}^0$ oscillation frequency, fixed to the measurement (1)

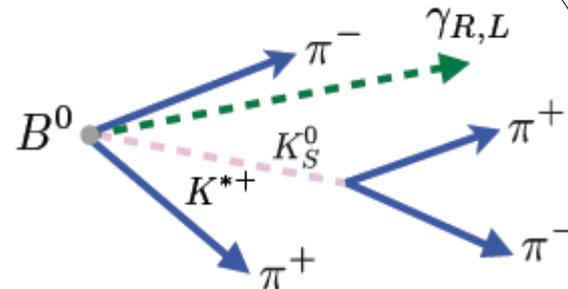**Objective: measurement of $\mathcal{S}$ in $B^0 \to K_S\rho\,\gamma$ decays**

Dilution factor

- Irreducible backgrounds from non-CP eigenstates ($K^{*+}\pi^-$) which lie underneath the $\rho^0(770)$ resonance and dilute the value of $\mathcal{S}_{K^0_S \rho \gamma}$

$B^0 \rightarrow K_S \, \rho^0 (\rightarrow \pi^- \pi^+) \, \gamma$:

$B^0 \rightarrow K^{*\pm} (\rightarrow K_S \, \pi^\pm) \, \pi^\mp \, \gamma$:

- An amplitude study is needed to extract the **dilution factor**:

  - Not possible for $K_s \pi^+ \pi^-$ events due to low statistics

$$\mathcal{D}_{K^0_S \rho \gamma} \equiv \frac{\mathcal{S}_{K^0_S \pi^+ \pi^- \gamma}}{\mathcal{S}_{K^0_S \rho \gamma}}$$
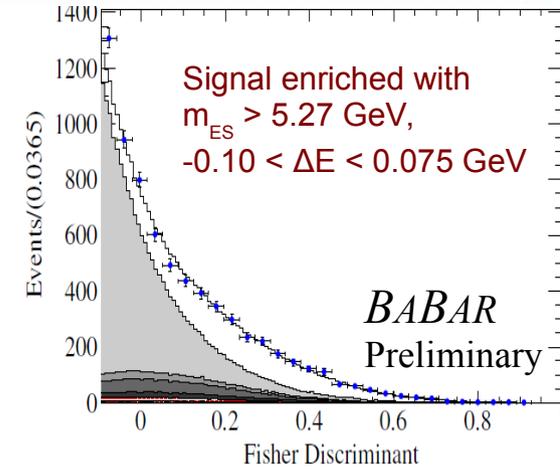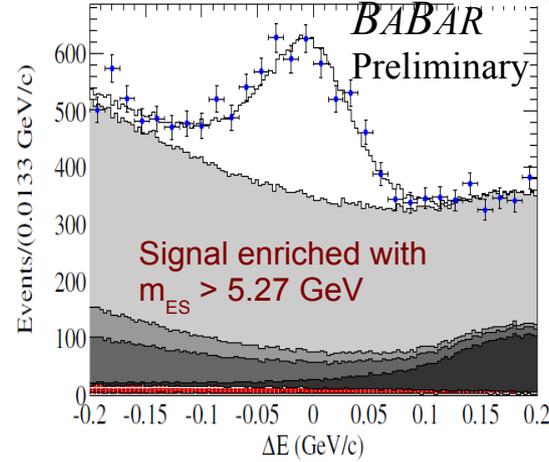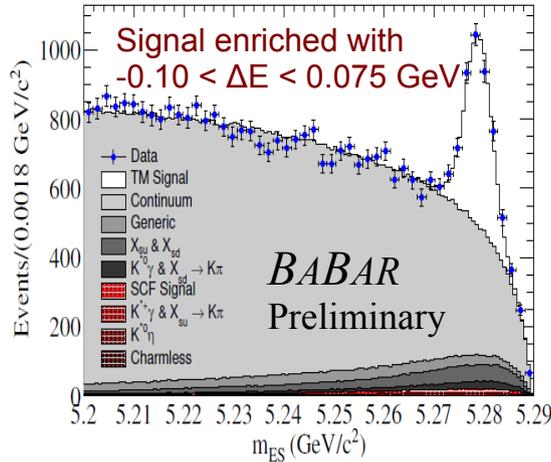
- By assuming isospin symmetry, we determine the dilution factor from the amplitude study in the $B^+ \rightarrow K^+ \pi^+ \pi^- \gamma$ decay

  - Full 2D $m_{K\pi}$ - $m_{\pi\pi}$ amplitude study is still not possible given the sample size

Fitting to K⁺π⁻π⁺ events
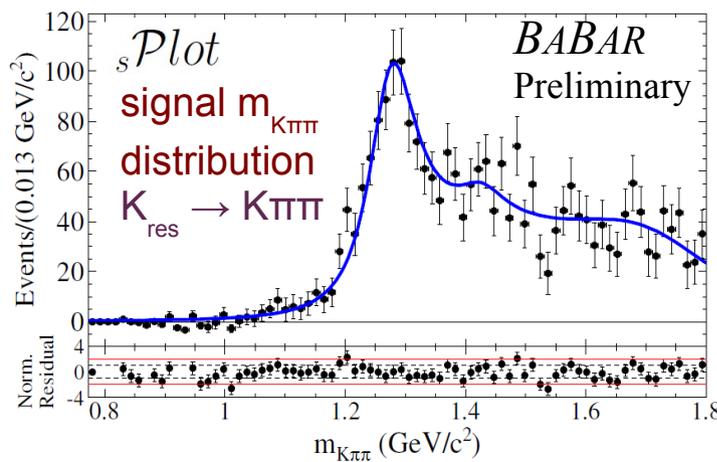
- Three stages of ML fits to find the dilution factor: $\mathcal{D}_{K^0_S \rho\gamma} = 0.549^{+0.096}_{-0.094}$
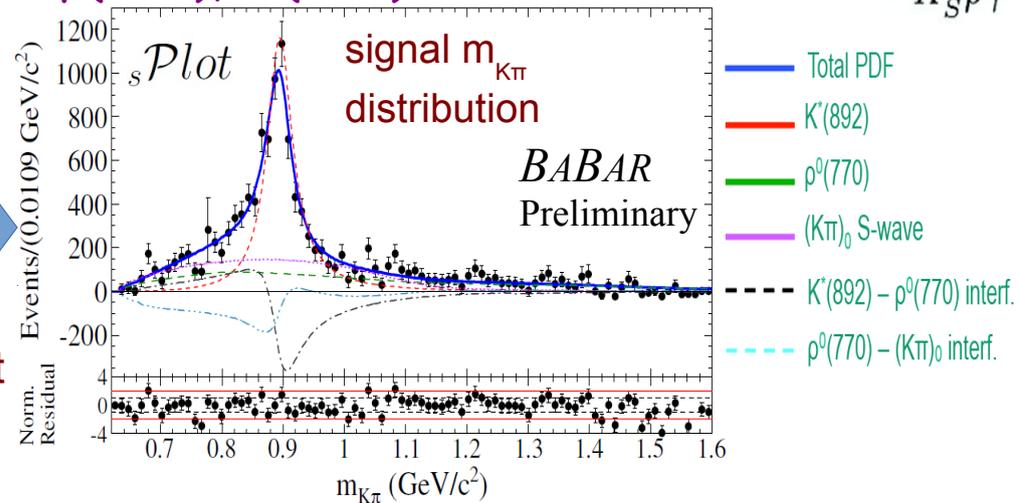
1) 3D fits to extract K⁺π⁻π⁺ signals

2) Fit to determine BFs of different kaonic resonances (K$_{res}$)

K_{res} info as input

3) Fit to determine amplitudes of ρ(770), K*(892) ... => Dilution factor $\mathcal{D}_{K^0_S \rho\gamma}$

BFs in the K$^+$π$^-$π$^+$ system

BFs for K$_{res}$ → K$^+$π$^-$π$^+$

| Mode	$\mathcal{B}(B^+ \to \text{Mode}) \times$ $\mathcal{B}(K_{\text{res}} \to K^+\pi^+\pi^-) \times 10^{-6}$	$\mathcal{B}(B^+ \to \text{Mode}) \times 10^{-6}$	PDG values $(\times 10^{-6})$
Inclusive $B^+ \to K^+\pi^+\pi^-\gamma$	$\cdots$	$27.2 \pm 1.0^{+1.1}_{-1.3}$	27.6 ± 2.2
$K_1(1270)^+\gamma$	$14.5^{+2.0+1.1}_{-1.3-1.2}$	$44.0^{+6.0+3.5}_{-4.0-3.7} \pm 4.6$	43 ± 13
$K_1(1400)^+\gamma$	$4.1^{+1.9+1.3}_{-1.2-0.8}$	$9.7^{+4.6+3.1}_{-2.9-1.8} \pm 0.6$	< 15 CL$= 90\%$
$K^*(1410)^+\gamma$	$9.7^{+2.1+2.4}_{-1.9-0.7}$	$23.8^{+5.2+5.9}_{-4.6-1.4} \pm 2.4$	$\emptyset$
$K_2^*(1430)^+\gamma$	$1.5^{+1.2+0.9}_{-1.0-1.4}$	$10.4^{+8.7+6.3}_{-7.0-9.9} \pm 0.5$	14 ± 4
$K^*(1680)^+\gamma$	$17.0^{+1.7+3.5}_{-1.4-3.0}$	$71.7^{+7.2+15}_{-5.7-13} \pm 5.8$	< 1900 CL$= 90\%$

BABAR
Preliminary

BFs of different resonances decaying to K$^+$π$^-$ and π$^+$π$^-$

Mode	$\mathcal{B}(B^+ \to \text{Mode}) \times$ $\mathcal{B}(R \to hh) \times 10^{-6}$	$\mathcal{B}(B^+ \to \text{Mode}) \times 10^{-6}$	PDG values $(\times 10^{-6})$
Inclusive $B^+ \to K^+\pi^+\pi^-\gamma$	$\cdots$	$27.2 \pm 1.0^{+1.1}_{-1.3}$	27.6 ± 2.2
$K^{*0}(892)\pi^+\gamma$	$17.3 \pm 0.9^{+1.2}_{-1.1}$	$26.0^{+1.4}_{-1.3} \pm 1.8$	20^{+7}_{-6}
$K^+\rho(770)^0\gamma$	$9.1^{+0.8}_{-0.7} \pm 1.3$	$9.2^{+0.8}_{-0.7} \pm 1.3 \pm 0.02$	< 20 CL$= 90\%$
$(K\pi)_0^{*0}\pi^+\gamma$	$11.3 \pm 1.5^{+2.0}_{-2.6}$	$\cdots$	$\emptyset$
$(K\pi)_0^0\pi^+\gamma$ (NR)	$\cdots$	$10.8^{+1.4+1.9}_{-1.5-2.5}$	< 9.2 CL$= 90\%$
$K_0^*(1430)^0\pi^+\gamma$	$0.51 \pm 0.07^{+0.09}_{-0.12}$	$0.82 \pm 0.11^{+0.15}_{-0.19} \pm 0.08$	$\emptyset$

TDCP analysis in $K_s\,\pi^-\pi^+$

- ## 4D ML fit to extract CP asymmetry parameters
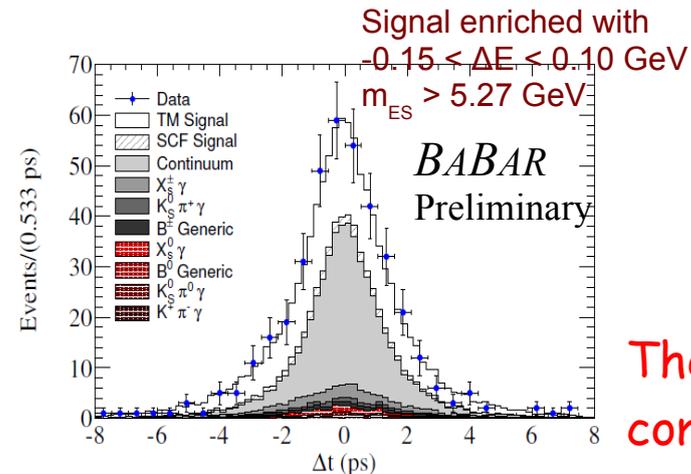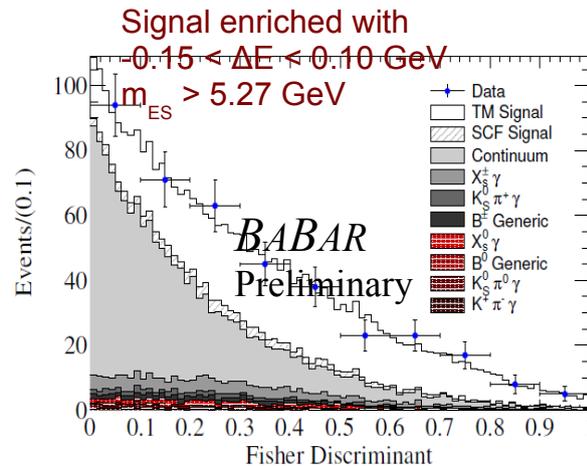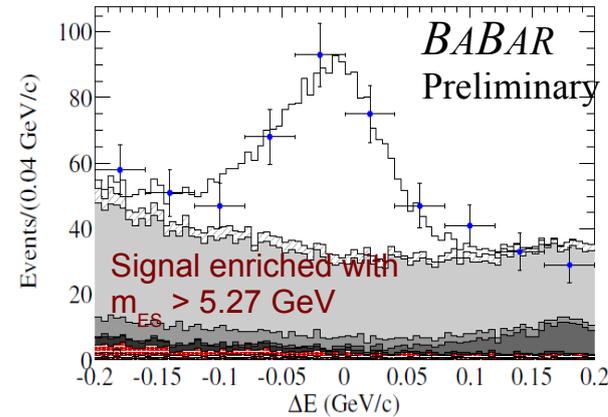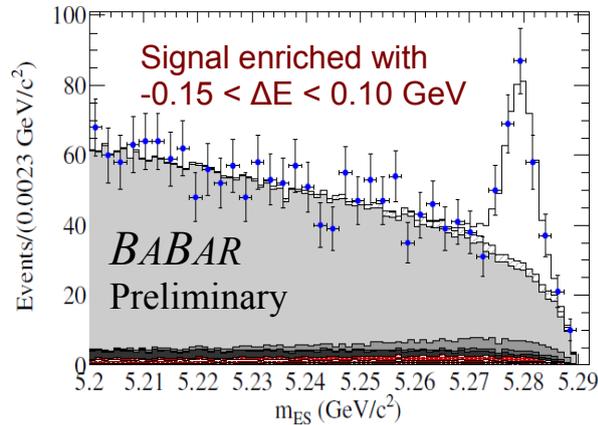
The result is compatible with SM value

$$\mathcal{S}_{K_S^0 \rho\gamma} = \frac{\mathcal{S}_{K_S^0 \pi^+\pi^-\gamma}}{\mathcal{D}_{K_S^0 \rho\gamma}} = 0.249 \pm 0.455^{+0.076}_{-0.060}$$
$$\text{(stat.) (syst.)}$$

$$\mathcal{S}_{K_S^0 \rho^0 \gamma} \overset{\text{SM}}{\sim} 0.02$$

$B \rightarrow X_s \ell^+ \ell^-$

- Measurement of the branching fraction and search for direct CP violation using a sum of exclusive final states

  – arXiv:1312.5364
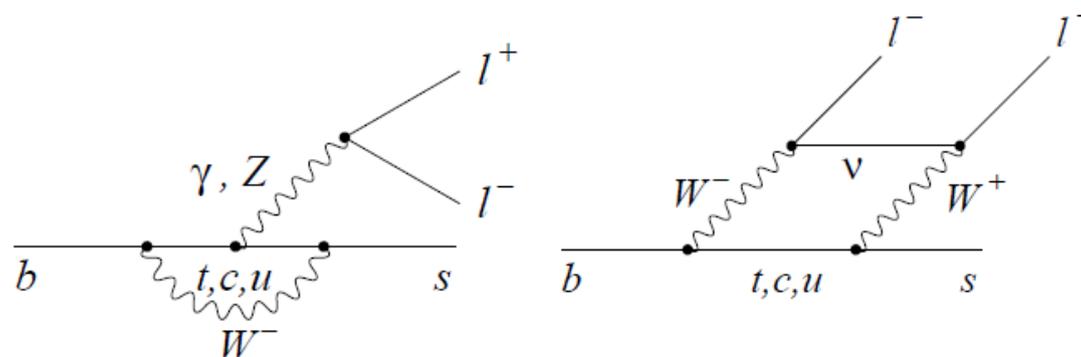
Event selection

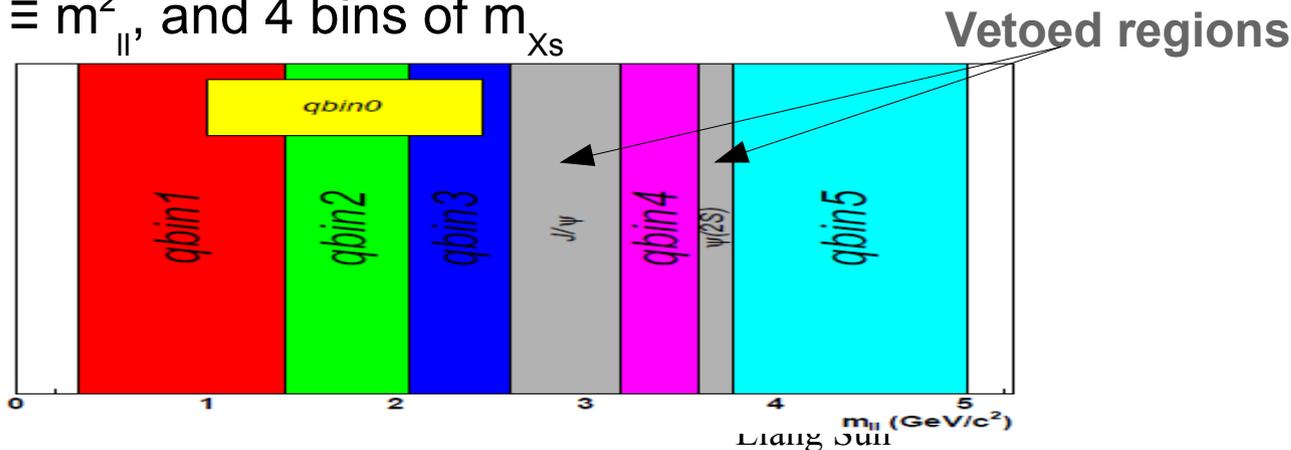$$B \to X_s \ell^+ \ell^-$$

- 20 exclusive final states with ≤ 2 pions and ≤ 1 π^0:

- m_{ES} > 5.225 GeV

- -0.1 (-0.05) < ΔE < 0.05 GeV for $X_s e^+ e^-$ ($X_s \mu^+ \mu^-$)

- Selection represent ~70% of the inclusive rate with m_{Xs} < 1.8 GeV, accounting for K^0_L modes, $K^0_s \to \pi^0 \pi^0$ and π^0 Dalitz decays

- We extrapolate for the missing modes, and those with m_{Xs} > 1.8 GeV, using JETSET fragmentation and theory prediction

- We measure the total BF and partial BFs in 6 bins of $q^2 \equiv m^2_{ll}$, and 4 bins of m_{Xs}

Vetoed regions

m_{Xs} < 1.8 GeV

$B^0 \to K^0_s \mu^+ \mu^-$
$B^+ \to K^+ \mu^+ \mu^-$
$B^0 \to K^0_s e^+ e^-$
$B^+ \to K^+ e^+ e^-$

$B^0 \to K^{*0} (K^0_s \pi^0)\mu^+\mu^-$
$B^+ \to K^{*+} (K^+ \pi^0)\mu^+\mu^-$
$B^+ \to K^{*+} (K^0_s \pi^+)\mu^+\mu^-$
$B^0 \to K^{*0} (K^+ \pi^-)\mu^+\mu^-$
$B^0 \to K^{*0} (K^0_s \pi^0)e^+e^-$
$B^+ \to K^{*+} (K^+ \pi^0)e^+e^-$
$B^+ \to K^{*+} (K^0_s \pi^+)e^+e^-$
$B^0 \to K^{*0} (K^+ \pi^-)e^+e^-$

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

Requiring K_s from $K_s \to \pi^+\pi^-$, π^0 from $\pi^0 \to \gamma\gamma$

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Event selection

$m_{Xs} < 1.8$ GeV

- 20 exclusive final states with ≤ 2 pions and ≤ 1 π^0:

- $m_{ES} > 5.225$ GeV

- $-0.1\ (-0.05) < \Delta E < 0.05$ GeV for $X_s e^+e^-$ ($X_s \mu^+\mu^-$)

- Selection represent ~70% of the inclusive rate with $m_{Xs} < 1.8$ GeV, accounting for K^0_L modes, $K^0_s \to \pi^0\pi^0$ and π^0 Dalitz decays

- We extrapolate for the missing modes, and those with $m_{Xs} > 1.8$ GeV, using JETSET fragmentation and theory prediction

- We separate B and $\overline{B}$ samples in the 14 **self-tagging modes** to measure direct CP asymmetry

$$A_{CP} \equiv \frac{\Gamma(\bar{b} \to \bar{s}\ell\ell) - \Gamma(b \to s\ell\ell)}{\Gamma(\bar{b} \to \bar{s}\ell\ell) + \Gamma(b \to s\ell\ell)}$$

SM expectation well below 1% (1)

(1) Phys. Rev. D 54, 882 (1996); Eur. Phys. J. C 8, 619 (1999); JHEP 0807, 106 (2008); JHEP 0901, 019 (2009)

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

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

$B^+ \to K^{*+}\ (K^+\ \pi^0)\mu^+\mu^-$
$B^+ \to K^{*+}\ (K^0_s\ \pi^+)\mu^+\mu^-$
$B^0 \to K^{*0}\ (K^+\ \pi^-)\mu^+\mu^-$

$B^+ \to K^{*+}\ (K^+\ \pi^0)e^+e^-$
$B^+ \to K^{*+}\ (K^0_s\ \pi^+)e^+e^-$
$B^0 \to K^{*0}\ (K^+\ \pi^-)e^+e^-$
$B^+ \to K^0_s\ \pi^+\ \pi^0\ \mu^+\mu^-$
$B^0 \to K^+\ \pi^-\ \pi^0\ \mu^+\mu^-$

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

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

Requiring K_s from $K_s \to \pi^+\pi^-$, π^0 from $\pi^0 \to \gamma\gamma$

Fitting strategy

- Signal extraction with 2D ML fit to m_{ES} and likelihood ratio L_R which is based on boosted decision trees and peaks ~ 1 for signals

Example fit for $X_s e^+ e^-$ events with $2.0 < q^2 < 4.3$ GeV^2
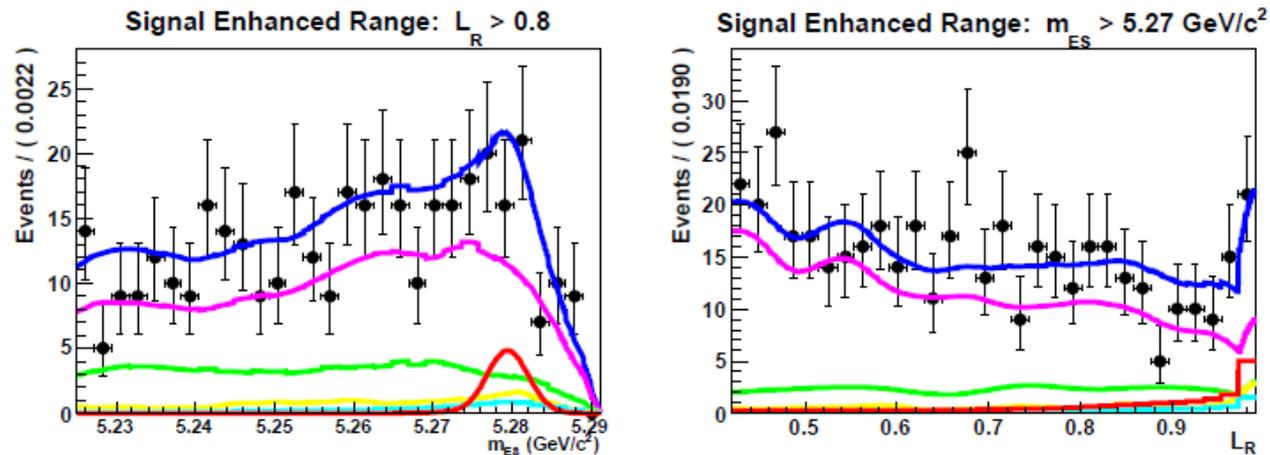
$$L_R = \frac{\mathcal{P}_S}{\mathcal{P}_S + \mathcal{P}_B}$$

$\mathcal{P}_{S/B}$: signal/bkg. probability from $B\bar{B}$ BDT output
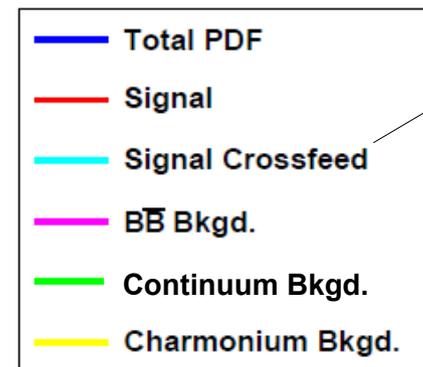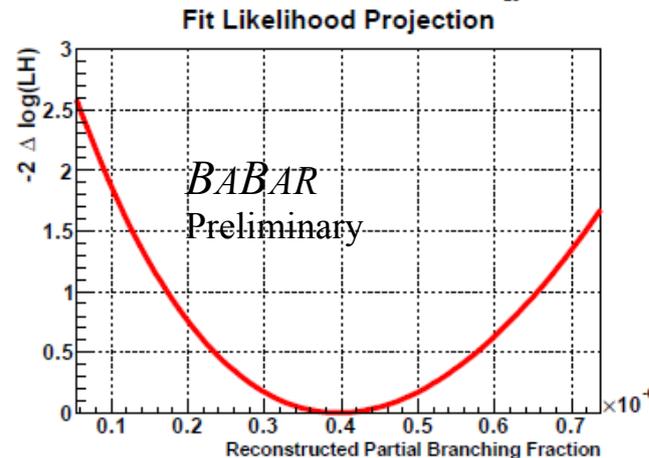
Mis-reconstructed signal events

Different background categories

Legend:
- Total PDF
- Signal
- Signal Crossfeed
- $B\bar{B}$ Bkgd.
- Continuum Bkgd.
- Charmonium Bkgd.

Branching fraction results

$$B \to X_s \ell^+ \ell^-$$

- Total branching fraction ($q^2 > 0.1$ GeV^2)

$$\mathcal{B}(B \to X_s \ell^+ \ell^-) = (6.73^{+0.70+0.34}_{-0.63-0.25} \pm 0.5) \times 10^{-6}$$

$$\mathcal{B}_{SM}(B \to X_s \ell^+ \ell^-) = (4.6 \pm 0.8) \times 10^{-6} \quad (1)$$

  - < 2σ higher than the SM expectation

- In the low mass range ($1 < q^2 < 6$ GeV^2):

$$\mathcal{B}(B \to X_s \ell^+ \ell^-) = (1.60^{+0.41+0.17}_{-0.39-0.13} \pm 0.18) \times 10^{-6}$$

$$\mathcal{B}_{SM}(B \to X_s e^+ e^-) = (1.64 \pm 0.11) \times 10^{-6} \quad (2)$$

  - In good agreement with the SM

- In the high mass range ($q^2 > 14.2$ GeV^2)

$$\mathcal{B}(B \to X_s \ell^+ \ell^-) = (0.57^{+0.16+0.03}_{-0.15-0.02} \pm 0.0) \times 10^{-6}$$

$$\mathcal{B}_{SM}(B \to X_s e^+ e^-) = (0.21 \pm 0.07) \times 10^{-6} \quad (2)$$

  - ~ 2σ higher than the SM expectation

(1) Nucl.Phys.B 685, 351 (2004)
(2) Nucl.Phys.B 802, 40 (2008)

In the listed results, the first uncertainty is statistical, the second experimental systematics and the third model-dependent systematics

Branching fraction results

$$B \to X_s \ell^+ \ell^-$$

- Total branching fraction ($q^2 > 0.1$ GeV^2)

$$\mathcal{B}(B \to X_s \ell^+ \ell^-) = (6.73^{+0.70+0.34}_{-0.63-0.25} \pm 0.5) \times 10^{-6}$$

$$\mathcal{B}_{SM}(B \to X_s \ell^+ \ell^-) = (4.6 \pm 0.8) \times 10^{-6} \quad (1)$$

- – < 2σ higher than the SM expectation

The BF measurement for $q^2 > 14.2$ GeV^2 disfavors by ~2.5-3σ the δC_9 NP interpretation of the recent LHCb "anomaly" for an angular observable from $B^0 \to K^{*0} \mu^+ \mu^-$ (3)
  - ➢ Expected pBF lower than SM in this interpretation

- In the high mass range ($q^2 > 14.2$ GeV^2)

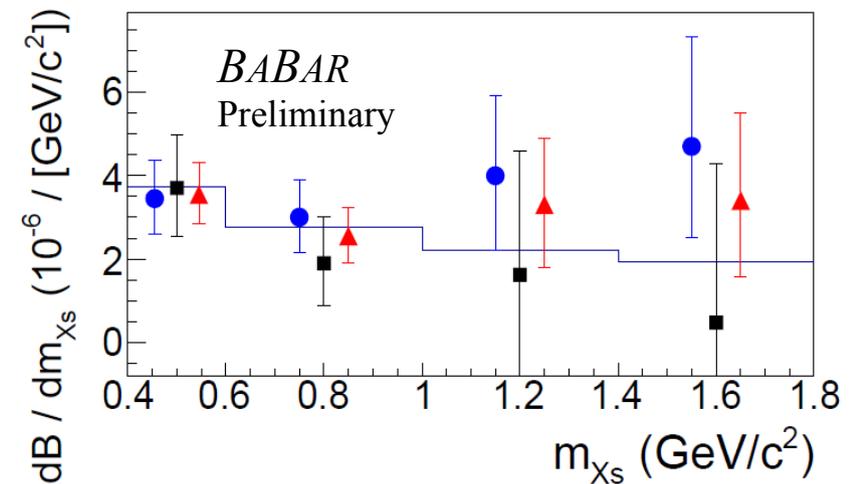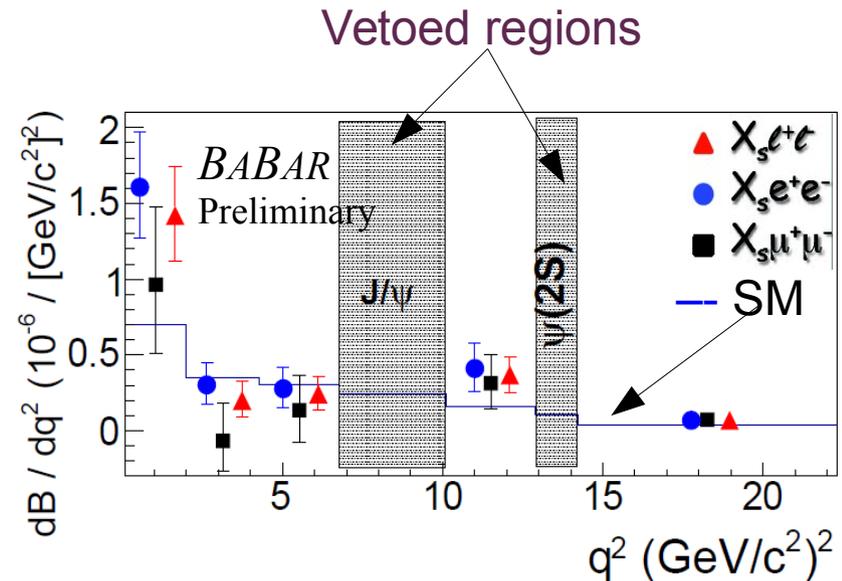$$\mathcal{B}(B \to X_s \ell^+ \ell^-) = (0.57^{+0.16+0.03}_{-0.15-0.02} \pm 0.0) \times 10^{-6}$$

$$\mathcal{B}_{SM}(B \to X_s e^+ e^-) = (0.21 \pm 0.07) \times 10^{-6} \quad (2)$$

- – ~ 2σ higher than the SM expectation

(1) Nucl.Phys.B 685, 351 (2004)
(2) Nucl.Phys.B 802, 40 (2008)
(3) PRL 111, 191801 (2013)

Results on direct A$_{CP}$
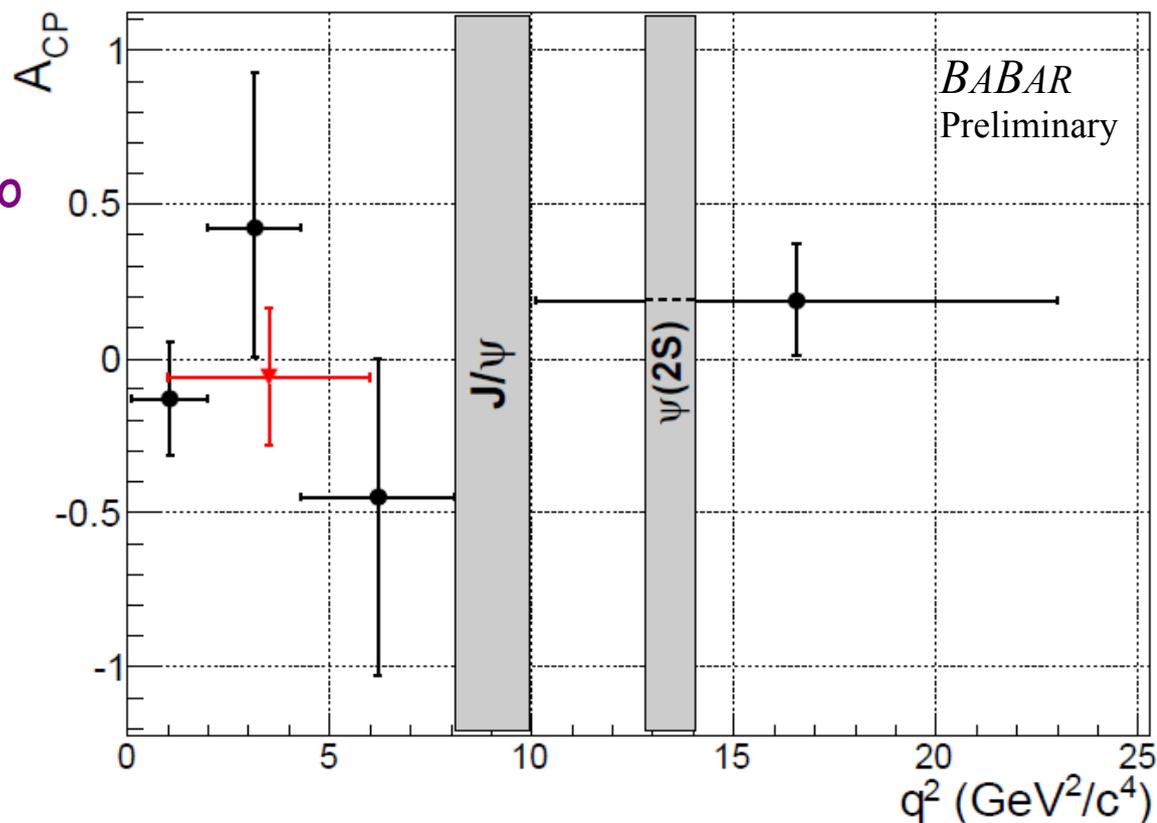
- Over the full dilepton mass range, we have:

  BABAR Preliminary

  $$A_{CP}(B \to X_s \ell^+ \ell^-) = 0.04 \pm 0.11[\text{stat}] \pm 0.01[\text{syst}]$$

- Direct A$_{CP}$ is measured in different regions of q²:

➢ CP asymmetry is found to be consistent with zero everywhere

Summary

- With the full data set of 471 M $B\overline{B}$ pairs, BABAR continues to produce exciting results in radiative B decays

- $A_{CP}(B \to X_s\gamma)$ is the most precise result to date and agrees with the SM

- Mixing-induced CPV parameter for $B^0 \to K_s \rho^0\gamma$ is found to be compatible with the SM

- $\mathscr{B}(B \to X_s\ell^+\ell^-)$ and $A_{CP}(B \to X_s\ell^+\ell^-)$ are generally consistent with the SM, however some tensions exist for the total $\mathscr{B}$ and partial $\mathscr{B}$ with $q^2 > 14.2$ GeV^2

  - The high q^2 $\mathscr{B}$ disfavors the δC_9 NP interpretation of LHCb "anomaly"

- To continue searching for NP, high-statistics data sample from Belle II and LHCb are needed for conclusive answers

Backup Slides

Liang Sun

Our $\mathscr{B}(B \to X_s \ell^+ \ell^-)$ results

LHCb "anomaly"

PRL 111, 191801 (2013)

SM

δC_9 NP

$< 10^{-6}$

X 10^{-6}
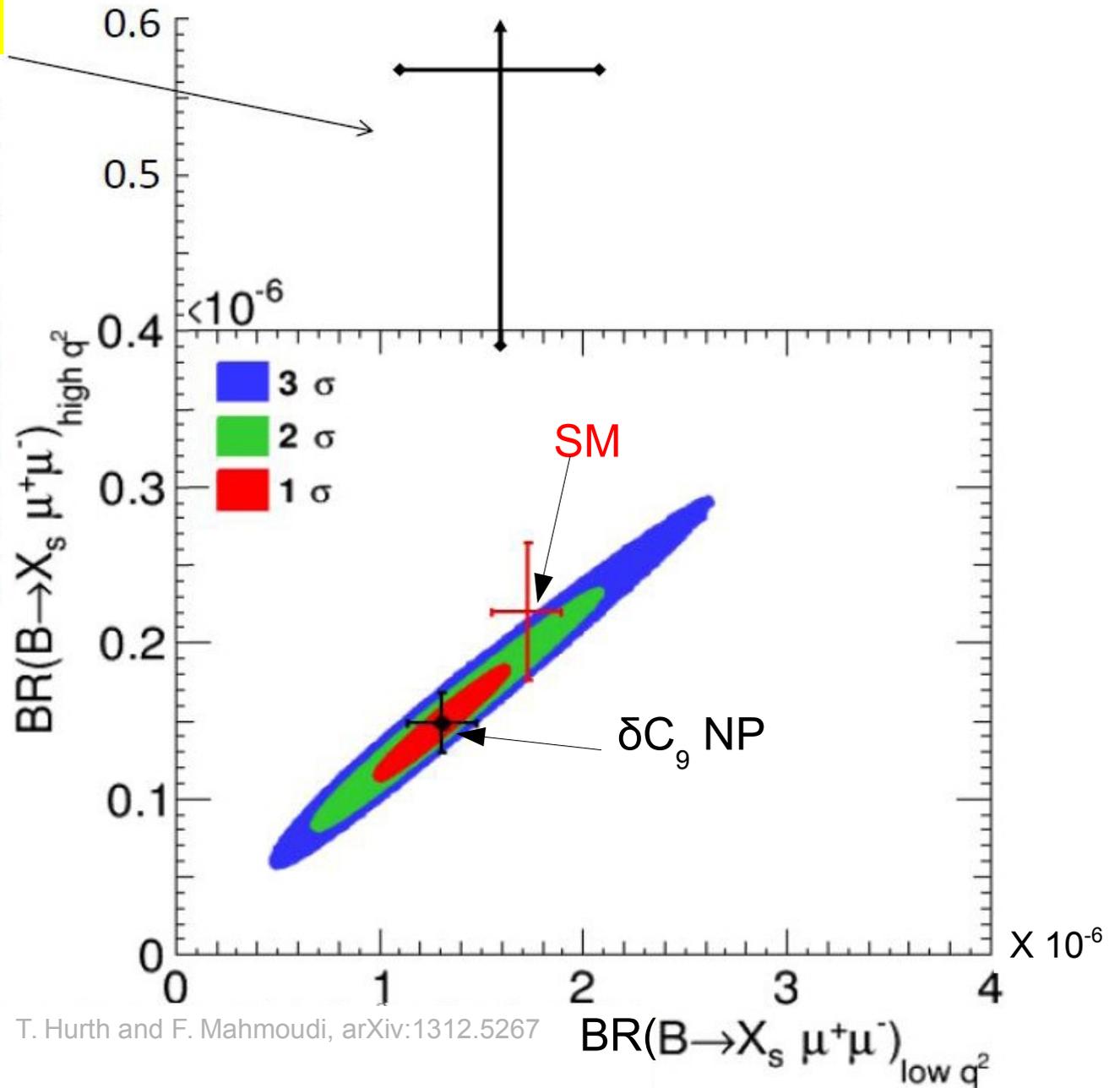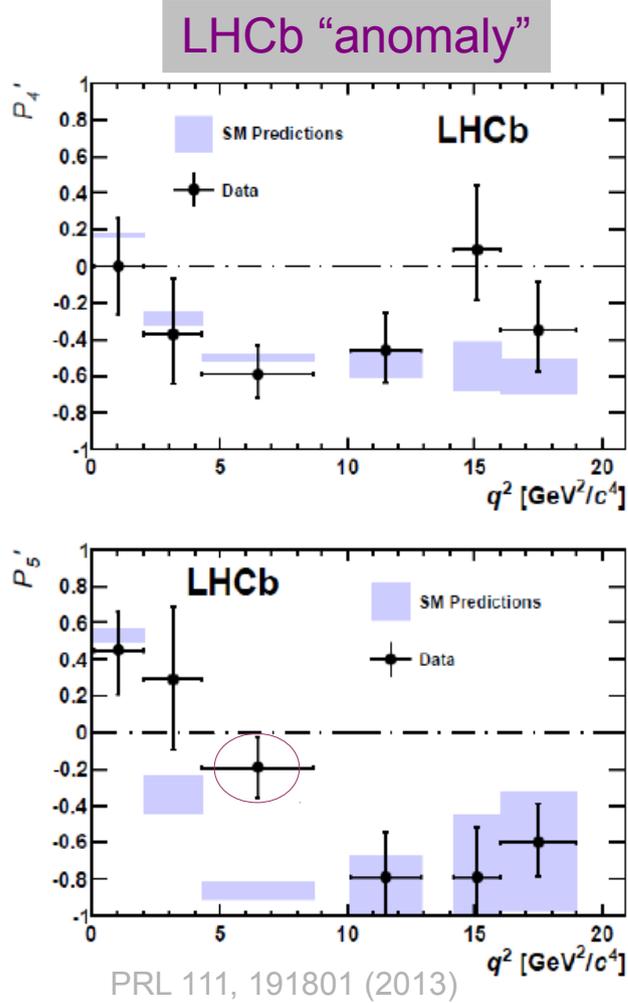
T. Hurth and F. Mahmoudi, arXiv:1312.5267

$BR(B \to X_s \mu^+ \mu^-)_{high \, q^2}$

$BR(B \to X_s \mu^+ \mu^-)_{low \, q^2}$

TABLE I: $B \to X_s\,e^+e^-$, $B \to X_s\,\mu^+\mu^-$ and $B \to X_s\,\ell^+\ell^-$ partial BFs (in units of 10^{-6}) and A_{CP} by $q^2(\,\mathrm{GeV}^2/c^4)$ and $m_{X_s}(\,\mathrm{GeV}/c^2)$ bin. The number in parentheses after each result is the multiplier which is applied to the measured semi-inclusive rate to account for unreconstructed and $m_{X_s} > 1.8\,\mathrm{GeV}/c^2$ final states. Estimated contributions from the vetoed charmonium q^2 regions are included in both the total and m_{X_s} binned results, but not in the total A_{CP}. The first uncertainties are statistical, the second experimental systematics and the third model-dependent systematics associated with the multiplicative factor. There are no model-dependent A_{CP} systematics and A_{CP} is not measured as a function of m_{X_s}; the multiplicative factors are not used in calculating the total A_{CP}.

Bin	Range	$B \to X_s\,e^+e^-$	$B \to X_s\,\mu^+\mu^-$	$B \to X_s\,\ell^+\ell^-$	$A_{CP\,B\to X_s\,\ell^+\ell^-}$
q_0^2	$1.0 < q^2 < 6.0$	$1.93^{+0.47+0.21}_{-0.45-0.16} \pm 0.18$ (1.71)	$0.66^{+0.82+0.30}_{-0.76-0.24} \pm 0.07$ (1.78)	$1.60^{+0.41+0.17}_{-0.39-0.13} \pm 0.18$	$-0.06 \pm 0.22 \pm 0.01$
q_1^2	$0.1 < q^2 < 2.0$	$3.05^{+0.52+0.29}_{-0.49-0.21} \pm 0.35$ (1.96)	$1.83^{+0.90+0.30}_{-0.80-0.24} \pm 0.20$ (2.02)	$2.70^{+0.45+0.21}_{-0.42-0.16} \pm 0.35$	$-0.13 \pm 0.18 \pm 0.01$
q_2^2	$2.0 < q^2 < 4.3$	$0.69^{+0.31+0.11}_{-0.28-0.07} \pm 0.07$ (1.73)	$-0.15^{+0.50+0.26}_{-0.43-0.14} \pm 0.01$ (1.80)	$0.46^{+0.26+0.10}_{-0.23-0.06} \pm 0.07$	$0.42\ ^{+0.50}_{-0.42} \pm 0.01$
q_3^2	$4.3 < q^2 < 6.8$	$0.69^{+0.31+0.13}_{-0.29-0.10} \pm 0.05$ (1.53)	$0.34^{+0.54+0.19}_{-0.50-0.15} \pm 0.03$ (1.59)	$0.60^{+0.27+0.10}_{-0.25-0.08} \pm 0.05$	$-0.45^{+0.44}_{-0.57} \pm 0.01$
q_4^2	$10.1 < q^2 < 12.9$	$1.14^{+0.42+0.22}_{-0.40-0.10} \pm 0.04$ (1.16)	$0.87^{+0.51+0.11}_{-0.47-0.08} \pm 0.03$ (1.18)	$1.02^{+0.32+0.10}_{-0.30-0.07} \pm 0.04$	
q_5^2	$14.2 < q^2$	$0.56^{+0.19+0.03}_{-0.18-0.03} \pm 0.00$ (1.02)	$0.60^{+0.31+0.05}_{-0.29-0.04} \pm 0.00$ (1.02)	$0.57^{+0.16+0.03}_{-0.15-0.02} \pm 0.00$	
q_{45}^2	$q_4^2 \cup q_5^2$	—	—	—	$0.19\ ^{+0.18}_{-0.17} \pm 0.01$
$m_{X_s,1}$	$0.4 < m_{X_s} < 0.6$	$0.69^{+0.18+0.04}_{-0.17-0.03} \pm 0.00$ (1.00)	$0.74^{+0.25+0.04}_{-0.23-0.04} \pm 0.00$ (1.00)	$0.71^{+0.15+0.03}_{-0.14-0.03} \pm 0.00$	
$m_{X_s,2}$	$0.6 < m_{X_s} < 1.0$	$1.20^{+0.34+0.10}_{-0.33-0.07} \pm 0.00$ (1.00)	$0.76^{+0.44+0.08}_{-0.40-0.07} \pm 0.00$ (1.00)	$1.02^{+0.27+0.06}_{-0.25-0.05} \pm 0.00$	
$m_{X_s,3}$	$1.0 < m_{X_s} < 1.4$	$1.60^{+0.72+0.27}_{-0.69-0.19} \pm 0.05$ (1.18)	$0.65^{+1.16+0.27}_{-1.08-0.25} \pm 0.02$ (1.18)	$1.32^{+0.61+0.19}_{-0.58-0.15} \pm 0.05$	
$m_{X_s,4}$	$1.4 < m_{X_s} < 1.8$	$1.88^{+0.76+0.71}_{-0.73-0.47} \pm 0.12$ (1.91)	$0.19^{+1.35+0.70}_{-1.25-0.50} \pm 0.10$ (1.91)	$1.36^{+0.67+0.50}_{-0.63-0.34} \pm 0.12$	
Total	$0.1 < q^2$	$7.69^{+0.82+0.50}_{-0.77-0.33} \pm 0.50$	$4.41^{+1.31+0.57}_{-1.17-0.42} \pm 0.27$	$6.73^{+0.70+0.34}_{-0.64-0.25} \pm 0.50$	$0.04 \pm 0.11 \pm 0.01$