

$b \rightarrow s/d l^+ l^-$

*and*

$b \rightarrow s/d \gamma$

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$$b \rightarrow sl^+l^-$$

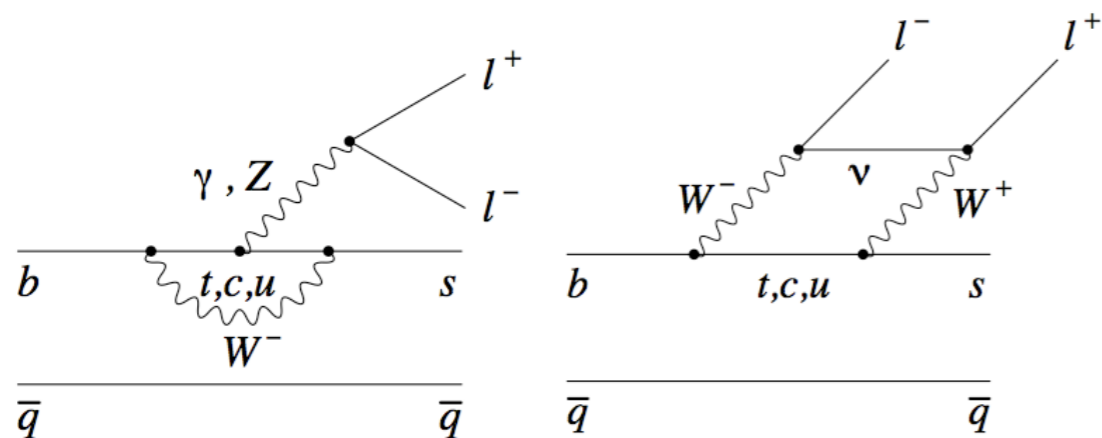
Angular Asymmetries

Isospin and CP Asymmetries

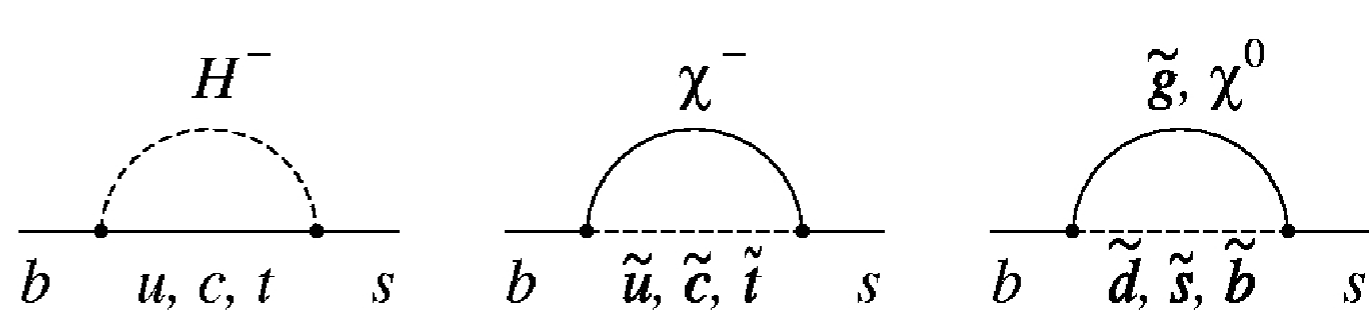
Branching Fractions and other measurements

# Radiative EW $b \rightarrow sl^+l^-$ decays

- Forbidden at tree level in SM
  - higher order penguin and box diagrams



- Sensitive to NP



- Contributing short-distance Wilson coefficients:
  - $C_7 \leftrightarrow$  magnetic penguin operator
    - (size determined by  $b \rightarrow s\gamma$ , sign by  $b \rightarrow sl\bar{l}$ )
  - $C_9, C_{10} \leftrightarrow$  vector and axial-vector electroweak operator
- Forward-Backward Asymmetry

$$A_{\text{FB}}(q^2) = -C_{10}^{\text{eff}} \xi(q^2) \left[ \text{Re}(C_9^{\text{eff}}) F_1 + \frac{1}{q^2} C_7^{\text{eff}} F_2 \right] \quad q^2 = m_{ll}^2$$

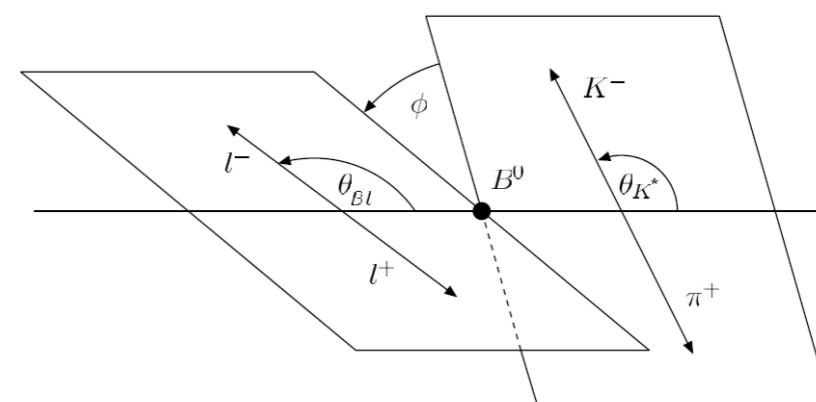
# $B \rightarrow K^{(*)} l^+ l^-$ analysis

- $N_{BB} = 384$  M BaBar
- $N_{BB} = 657$  M Belle
- Reconstruct 10 final states

B $\rightarrow$	$K^+$	$K_S(\rightarrow \pi^+ \pi^-)$	$e^+ e^-$
	$K^+ \pi^-$	$K^+ \pi^0$	$\mu^+ \mu^-$

- Measure angular asymmetries, direct CP, LFV, isospin asymmetries
  - in 2 bins of  $q^2$ : below and above  $J/\psi$  mass (BaBar)
  - in 6 bins of  $q^2$  (Belle)
- $K^*$  longitudinal polarization  $F_L$ 
  - obtained from a fit to  $\cos(\theta_K)$ , the angle between K and B in the  $K^*$  rest frame

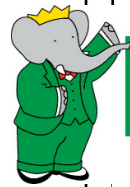
$$\frac{3}{2} F_L \cos^2 \theta_K + \frac{3}{4} (1 - F_L) (1 - \cos^2 \theta_K)$$



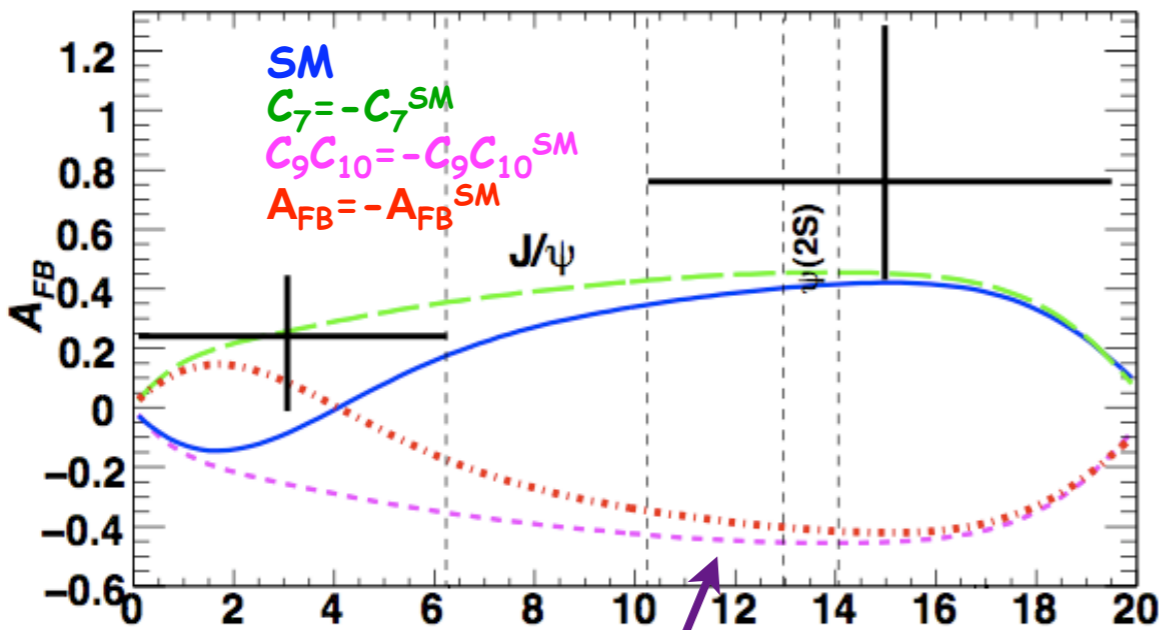
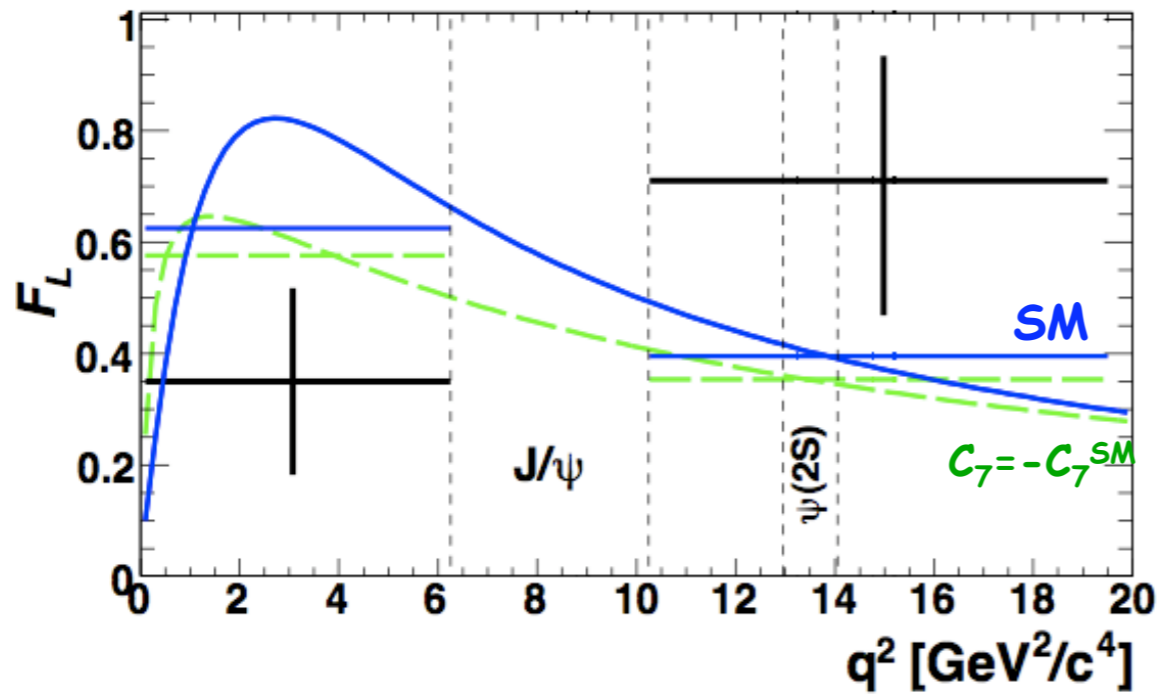
- Lepton Forward-Backward Asymmetry  $A_{FB}$ 
  - obtained from a fit to  $\cos(\theta_l)$ , the angle between  $l^+(l^-)$  and  $B(\bar{B})$  in the  $l^+ l^-$  rest frame

$$\frac{3}{4} F_L (1 - \cos^2 \theta_\ell) + \frac{3}{8} (1 - F_L) (1 + \cos^2 \theta_\ell) + \mathcal{A}_{FB} \cos \theta_\ell$$

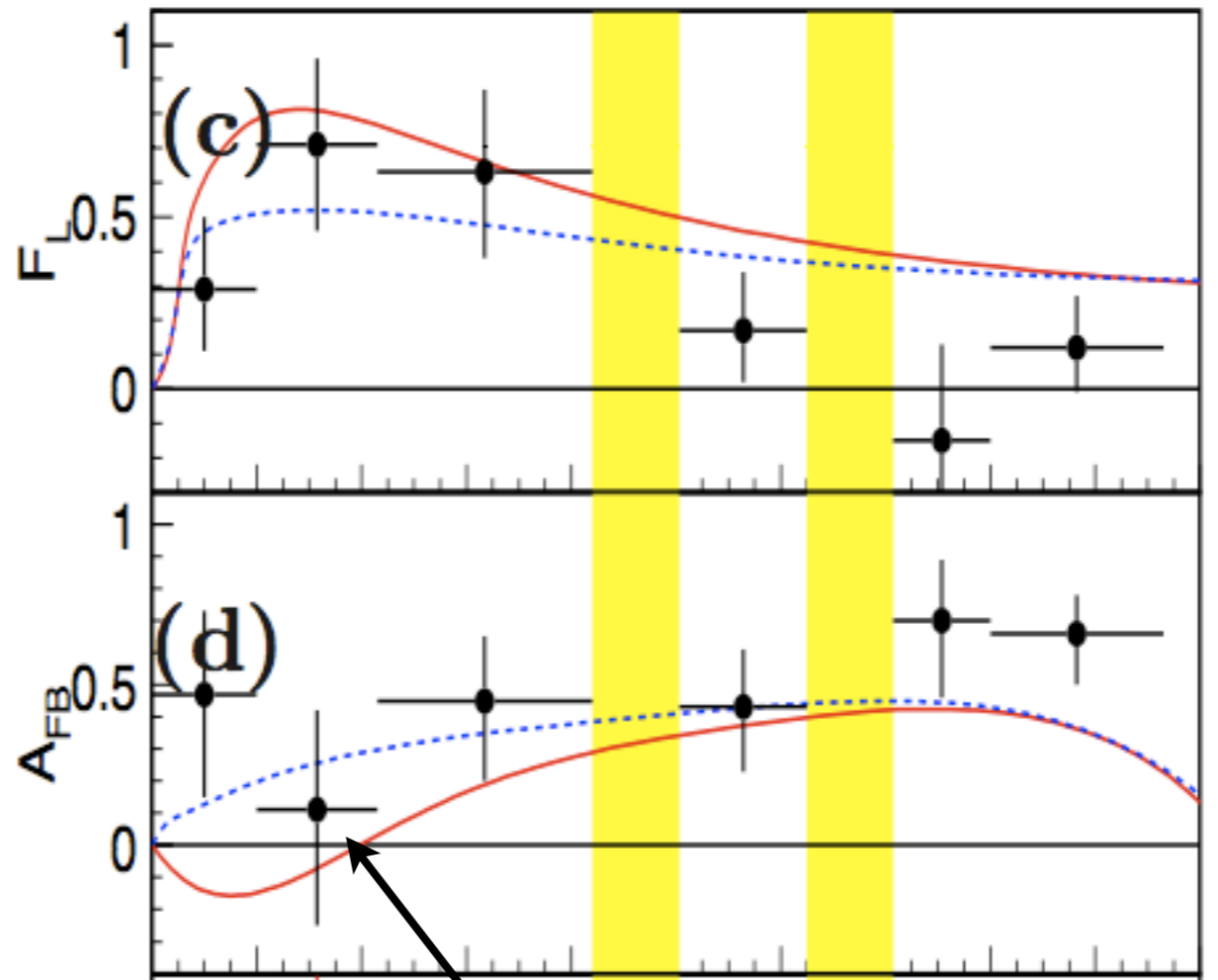
# Angular fits and Asymmetries in $B \rightarrow K^{(*)} l^+ l^-$



**BABAR**



$-C_9 C_{10}^{SM}$  seems disfavored



Can't distinguish between  $C_7^{SM}$  and  $-C_7^{SM}$   
Need more statistics

# Isospin Asymmetry in $B \rightarrow K^{(*)} l^+ l^-$

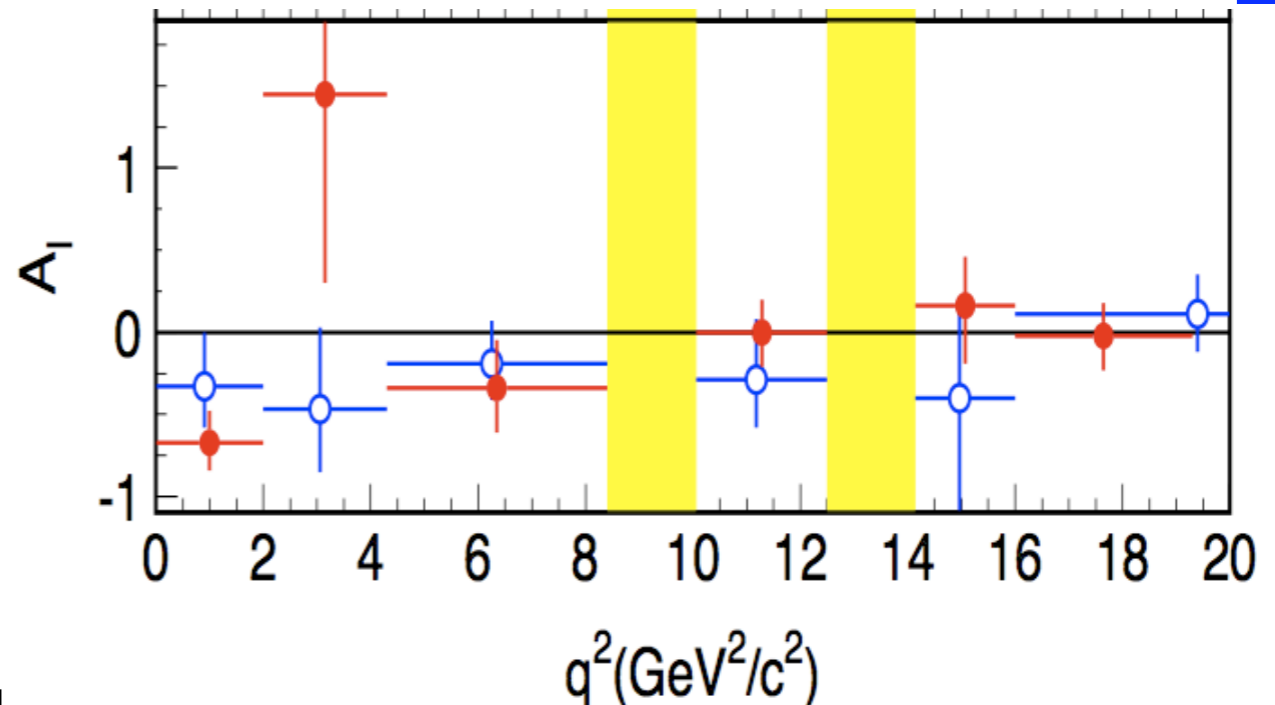
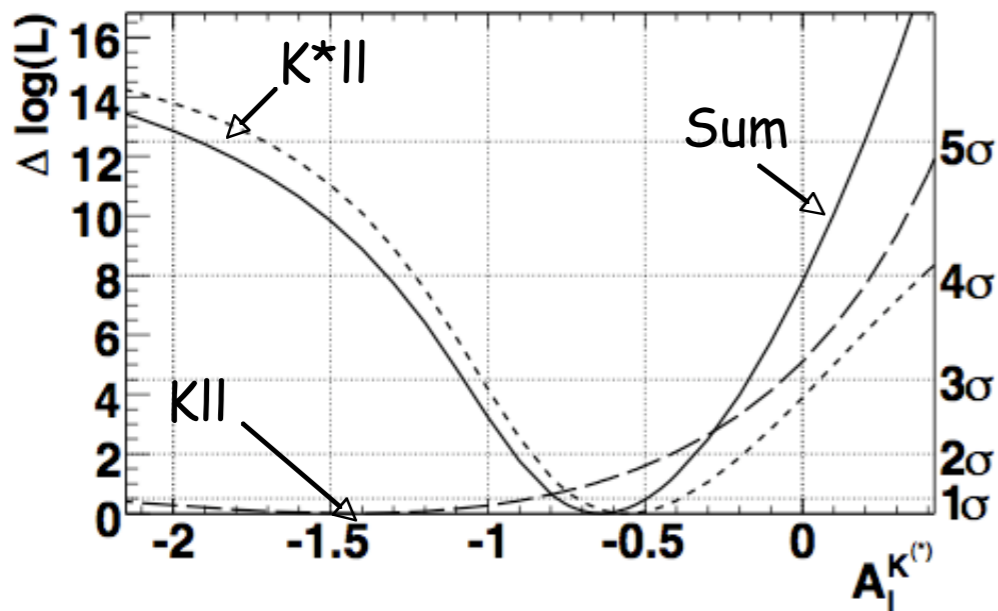
$$A_I^{K^{(*)}} \equiv \frac{\mathcal{B}(B^0 \rightarrow K^{(*)0} l^+ l^-) - r \mathcal{B}(B^\pm \rightarrow K^{(*)\pm} l^+ l^-)}{\mathcal{B}(B^0 \rightarrow K^{(*)0} l^+ l^-) + r \mathcal{B}(B^\pm \rightarrow K^{(*)\pm} l^+ l^-)}$$

$$|A_I| < \sim 0.01 \text{ SM}$$

$$r \equiv \tau_{B^0} / \tau_{B^+} = 1 / (1.07 \pm 0.01)$$

- No significant  $A_I$  measured in high mass region
- $A_I$  different from zero in low mass region with significance:
  - $Kll$ :  $3.2 \sigma$
  - $K^*ll$ :  $2.7 \sigma$
  - $K^{(*)}ll$ :  $3.9 \sigma$

$K\mu^+\mu^-$	$-0.91_{-\infty}^{+1.2} \pm 0.18$
$Ke^+e^-$	$-1.41_{-0.69}^{+0.49} \pm 0.04$
$Kl^+l^-$	$-1.43_{-0.85}^{+0.56} \pm 0.05$
$K^*\mu^+\mu^-$	$-0.26_{-0.34}^{+0.50} \pm 0.05$
$K^*e^+e^-$	$-0.66_{-0.17}^{+0.19} \pm 0.02$
$K^*l^+l^-$	$-0.56_{-0.15}^{+0.17} \pm 0.03$



# Other in $B \rightarrow K^{(*)} l^+ l^-$

$$\mathcal{B}(B \rightarrow K^* l^+ l^-) = (11.1 \pm 1.9 \pm 0.7) \times 10^{-7}$$

$$\mathcal{B}(B \rightarrow K l^+ l^-) = (3.9 \pm 0.7 \pm 0.2) \times 10^{-7}$$

$$\mathcal{B}(B \rightarrow K^* l^+ l^-) = (10.7_{-1.0}^{+1.1} \pm 0.9) \times 10^{-7}$$

$$\mathcal{B}(B \rightarrow K l^+ l^-) = (4.8_{-0.4}^{+0.5} \pm 0.3) \times 10^{-7}$$

## Lepton Flavor ratio

$R \sim 1$  in SM

Di-muon channel can be enhanced by SUSY neutral Higgs at large  $\tan\beta$

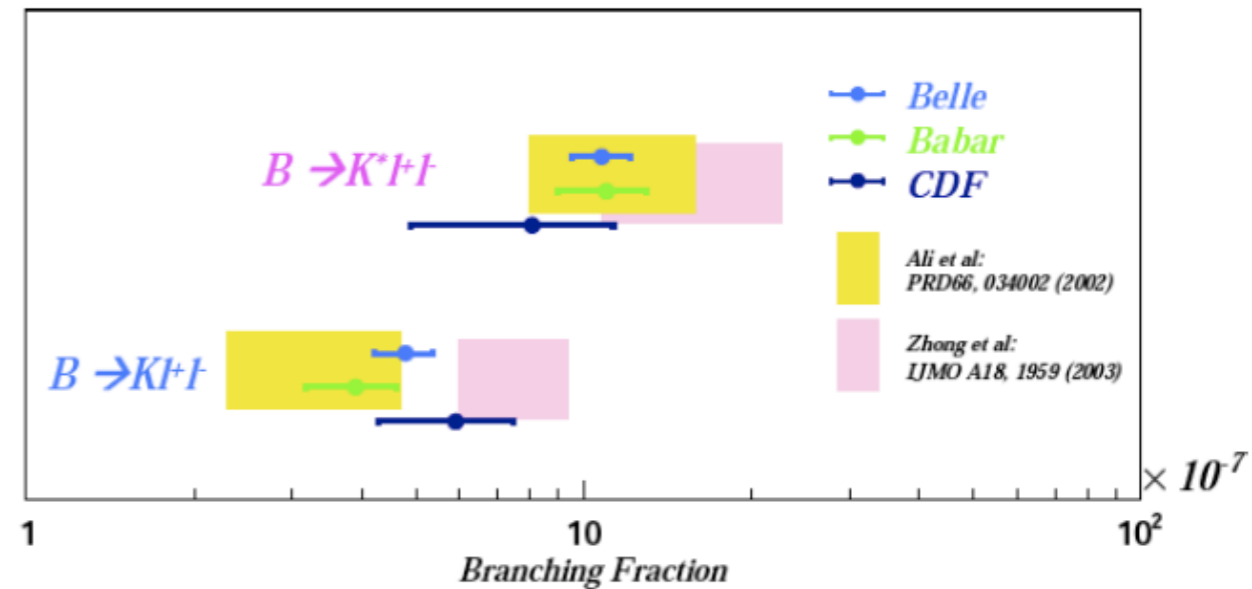
$$R_{K^{(*)}} = \frac{\mathcal{B}(B \rightarrow K^{(*)} \mu^+ \mu^-)}{\mathcal{B}(B \rightarrow K^{(*)} e^+ e^-)}$$

Belle

BaBar

$$R_K \quad 1.03 \pm 0.19 \pm 0.06 \quad 0.96_{-0.34}^{+0.44} \pm 0.05$$

$$R_{K^*} \quad 0.83 \pm 0.17 \pm 0.05 \quad 1.10_{-0.32}^{+0.42} \pm 0.07$$



## Direct $A_{CP}$

zero in SM

both BaBar and Belle's results consistent with zero

Mode	combined $q^2$	low $q^2$	high $q^2$
$K^+ l^+ l^-$	$-0.18_{-0.18}^{+0.18} \pm 0.01$	$-0.18_{-0.19}^{+0.19} \pm 0.01$	$-0.09_{-0.39}^{+0.36} \pm 0.02$
$K^{*0} l^+ l^-$	$0.02_{-0.20}^{+0.20} \pm 0.02$	$-0.23_{-0.38}^{+0.38} \pm 0.02$	$0.17_{-0.24}^{+0.24} \pm 0.02$
$K^{*+} l^+ l^-$	$0.01_{-0.24}^{+0.26} \pm 0.02$	$0.10_{-0.24}^{+0.25} \pm 0.02$	$-0.18_{-0.55}^{+0.45} \pm 0.04$
$K^* l^+ l^-$	$0.01_{-0.15}^{+0.16} \pm 0.01$	$0.01_{-0.20}^{+0.21} \pm 0.01$	$0.09_{-0.21}^{+0.21} \pm 0.02$

$$A_{CP}(K^* l^+ l^-) = -0.10 \pm 0.10 \pm 0.01$$

$$A_{CP}(K^+ l^+ l^-) = 0.04 \pm 0.10 \pm 0.02$$

$$b \rightarrow s\gamma$$

Inclusive branching fraction

Time-dependent CP Asymmetry

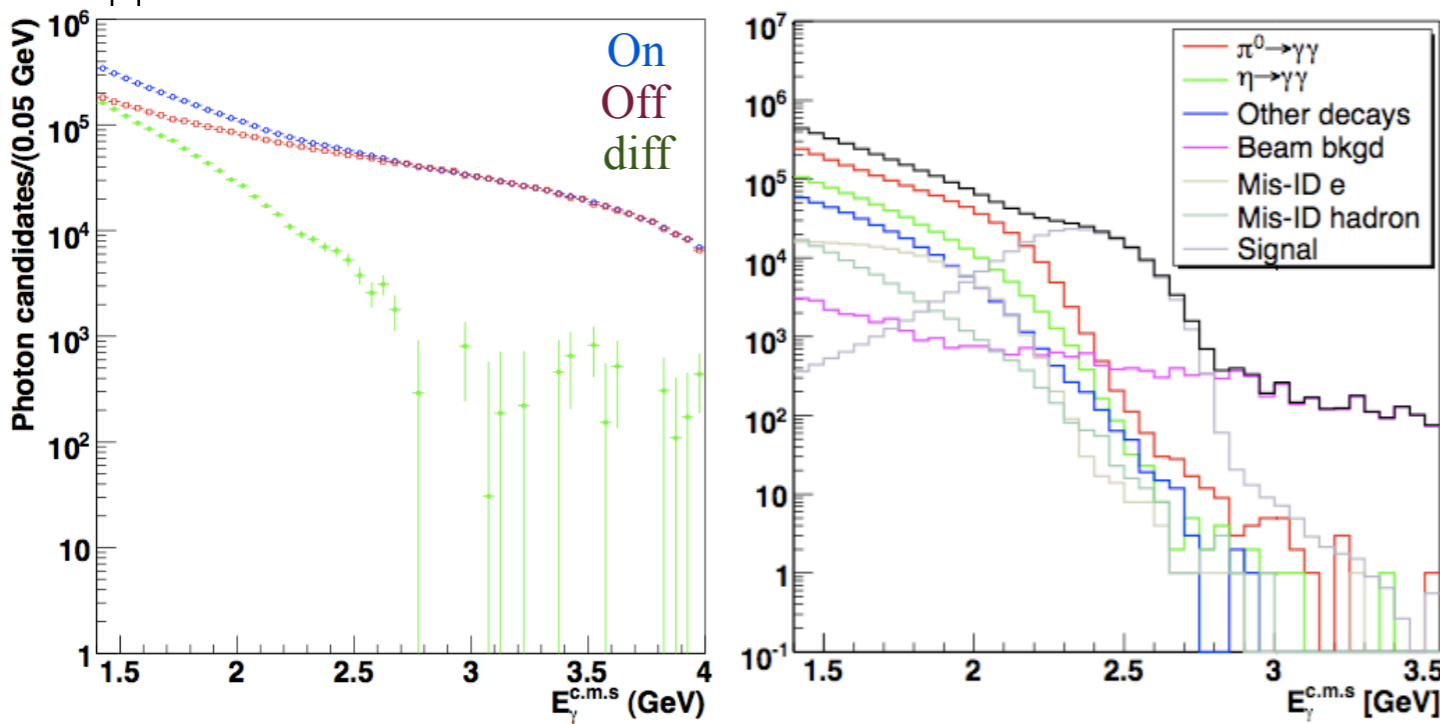
$$B_s \rightarrow \phi\gamma$$



# $B \rightarrow X_s \gamma$

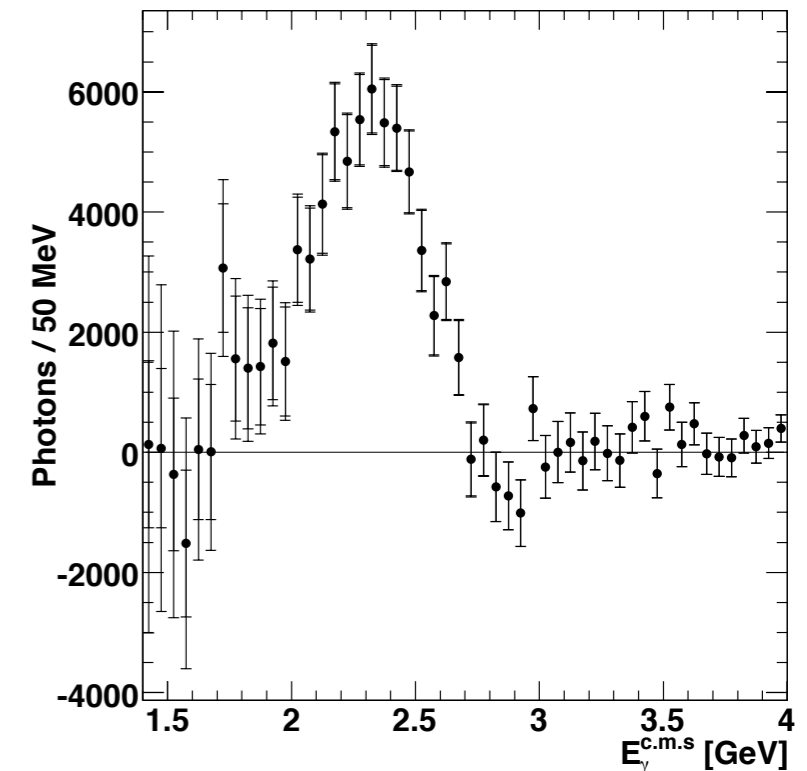
- Fully inclusive photon spectrum,  $N_{\text{BB}} = 657 \text{ M}$
- High background subtraction
  - first subtract continuum by scaling to off-peak data
  - then subtract BB events using MC distribution scaled by data samples

- Total BF obtained from integrated spectrum
- Spectrum to calculate non-pert HQ parameters
  - mean =  $m_b/2$  :  $m_b$  = b-quark mass
  - width =  $\mu_\pi^2$  : Fermi motion inside B meson
  - also used to extract  $V_{ub}$  and  $V_{cb}$  in combination with semileptonic B decays (arXiv:0803.2158)
- Photon energy cut at 1.7 GeV
  - previously Babar  $E_\gamma > 1.9 @ 81 \text{ fb}^{-1}$
  - Belle  $E_\gamma > 1.8 @ 140 \text{ fb}^{-1}$



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- previously Babar  $E_\gamma > 1.9 @ 81 \text{ fb}^{-1}$
- Belle  $E_\gamma > 1.8 @ 140 \text{ fb}^{-1}$



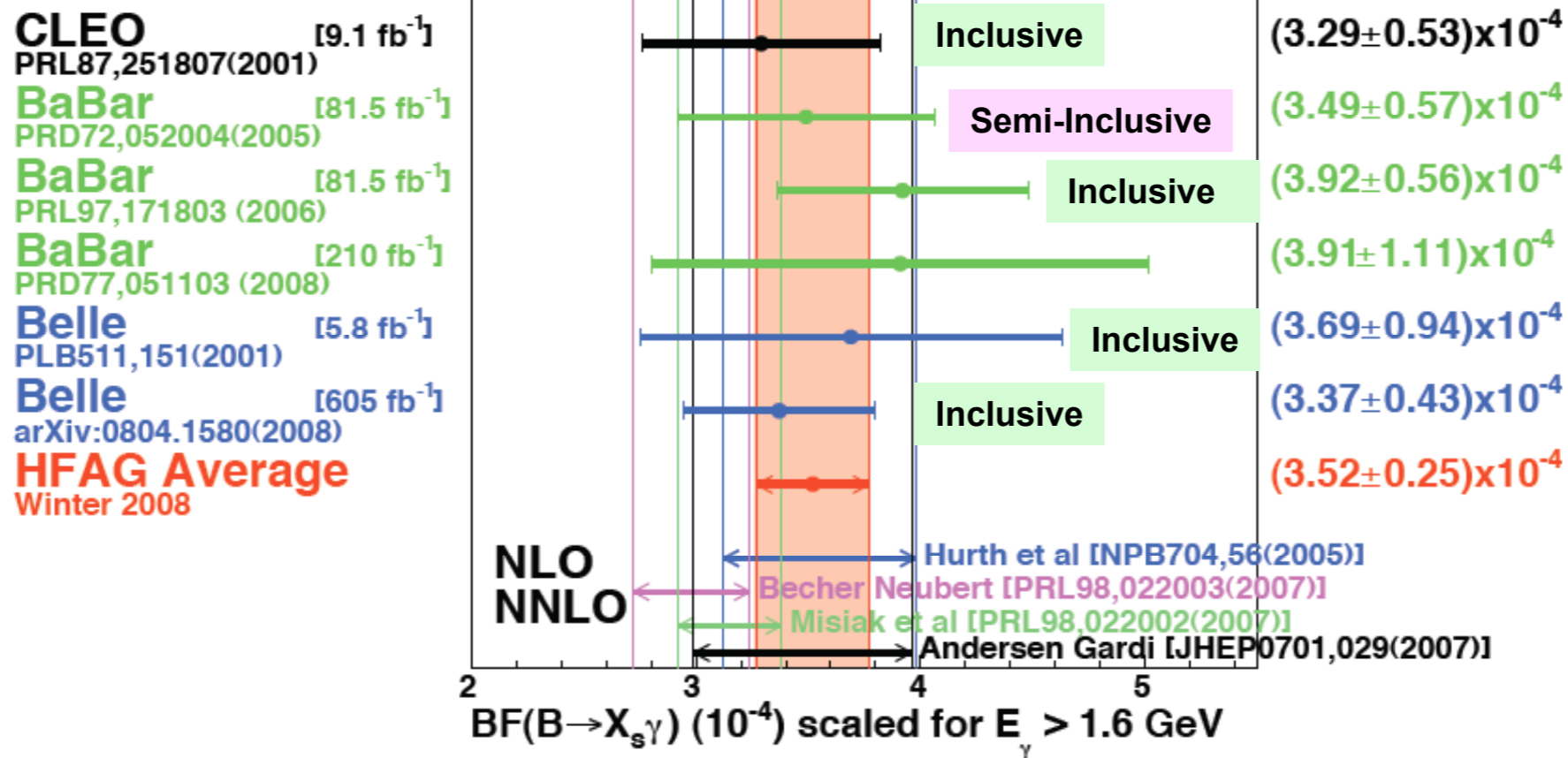
$$\mathcal{B}(B \rightarrow X_s \gamma) = (3.31 \pm 0.19 \pm 0.37 \pm 0.01) \times 10^{-4}$$

$$\langle E_\gamma \rangle = 2.281 \pm 0.032 \pm 0.053 \pm 0.002 \text{ GeV}$$

$$\langle E_\gamma^2 \rangle - \langle E_\gamma \rangle^2 = 0.0396 \pm 0.0156 \pm 0.0214 \pm 0.0012 \text{ GeV}^2$$

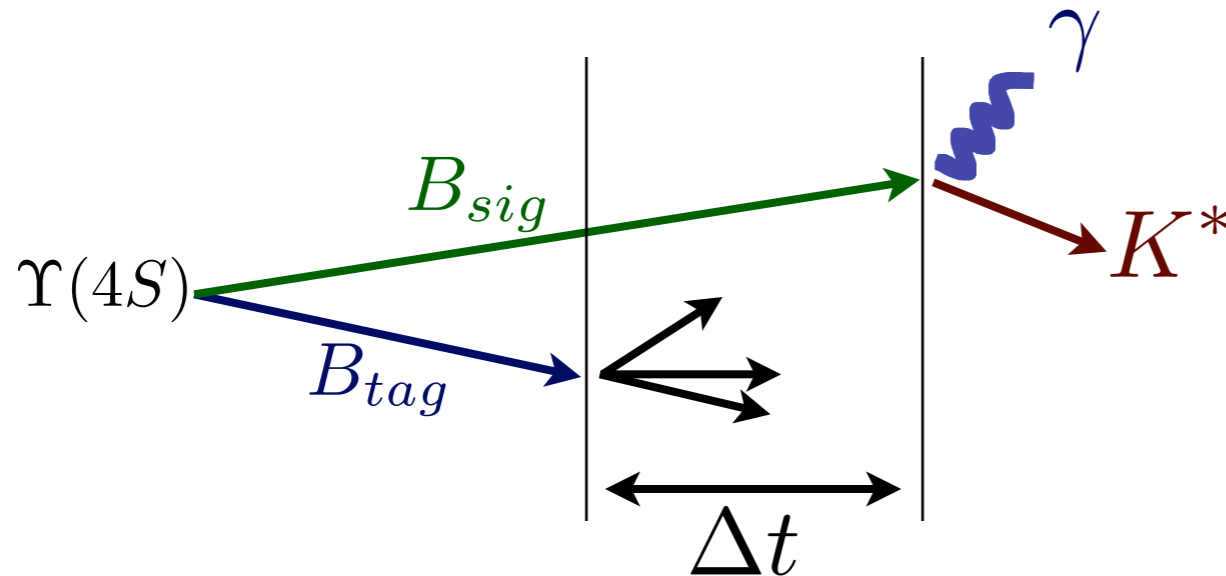
# Status of $b \rightarrow s\gamma$ rates

A. Limosani, Melbourne



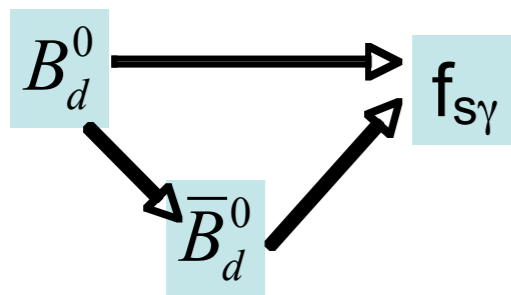
- Latest result in agreement with NNLO calculation
- Experimental errors comparable with theoretical ones

# Time-dependent CP Asymmetry in $B^0 \rightarrow K_s \pi^0 \gamma$



$$\mathcal{P}_{\pm}(\Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau} [1 \pm S \sin(\Delta m \Delta t) \mp C \cos(\Delta m \Delta t)]$$

↗  $< 1\%$  in SM

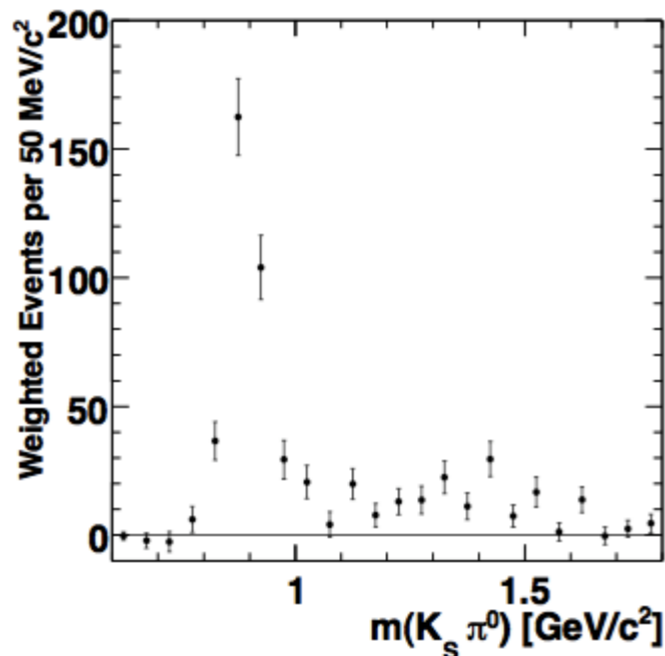


- Photon predominantly left-handed in  $b \rightarrow s\gamma$
- Photon predominantly right-handed in  $\bar{b} \rightarrow \bar{s}\gamma$
- In the SM no common  $f_{s\gamma}$ , so  $S \sim 0$
- NP scenarios predict S different from 0
  - for instance in L-R symmetric model or SUSY where S can be large being consistent with  $\Gamma$  measurements [ PRL 79, 185 (1997) ]

- Final BaBar data set :  $N_{BB} = 467 \text{ M}$

# $B^0 \rightarrow K_s \pi^0 \gamma$

- Flavor tagging from other-B
- Perform a Maximum Likelihood Fit in two regions:
- $K^*$  region :  $0.8 < m(K_s \pi^0) < 1.0$  GeV
- non- $K^*$  region :  $1.1 < m(K_s \pi^0) < 1.8$  GeV



$$S_{K^* \gamma} = -0.03 \pm 0.29 \pm 0.03$$

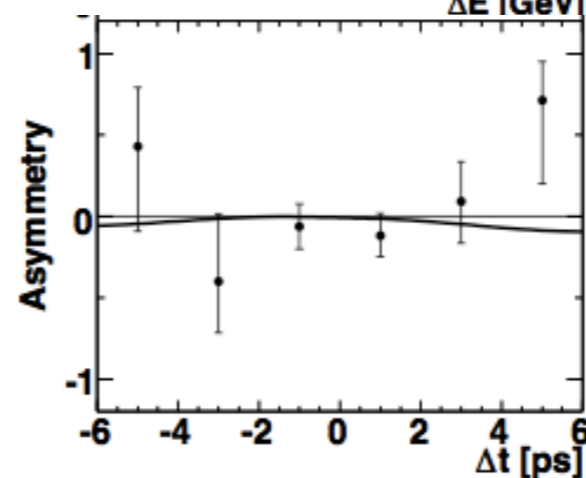
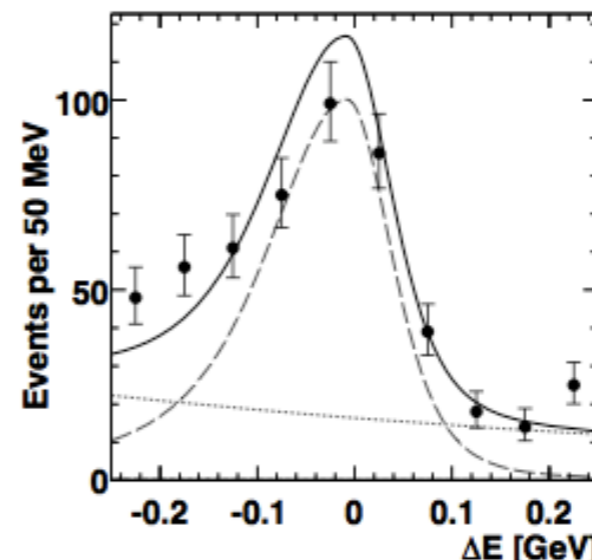
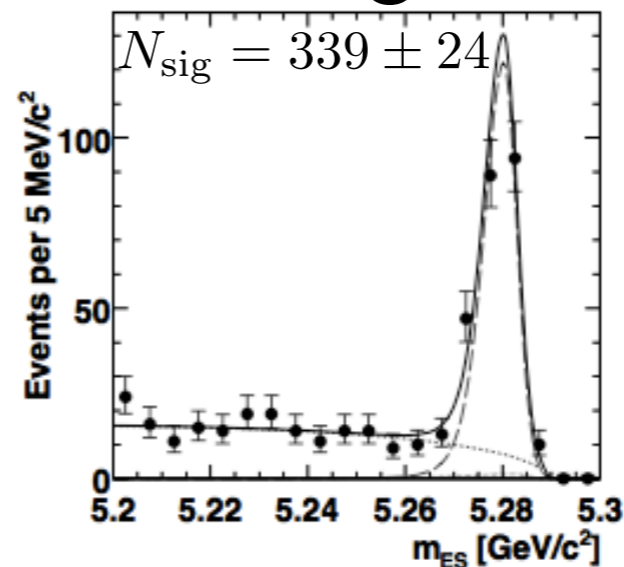
$$C_{K^* \gamma} = -0.14 \pm 0.16 \pm 0.03$$

$$S_{K_s \pi^0 \gamma} = -0.78 \pm 0.59 \pm 0.09$$

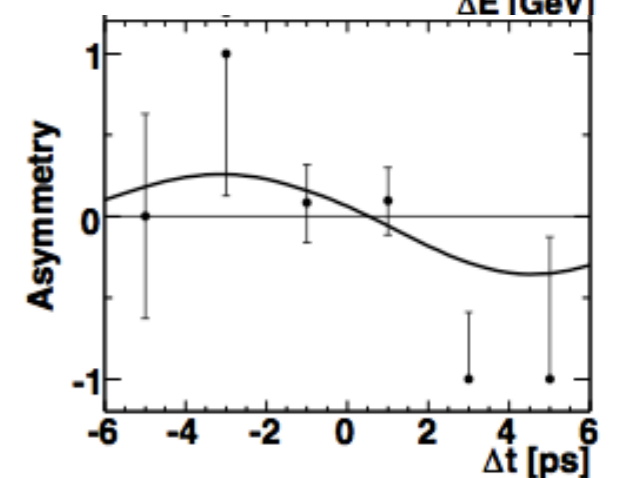
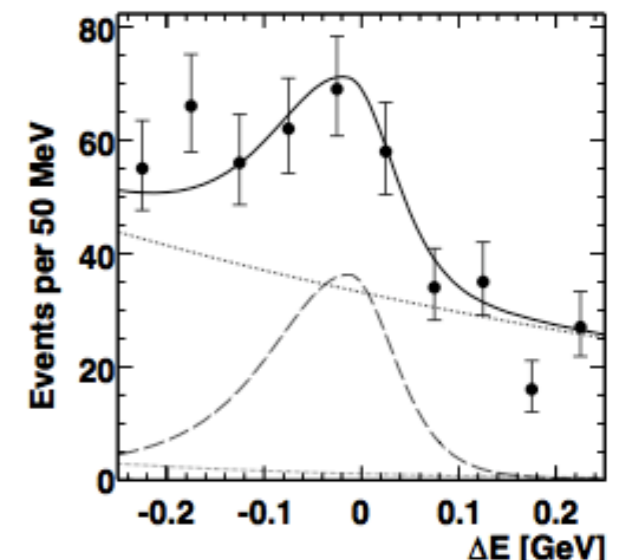
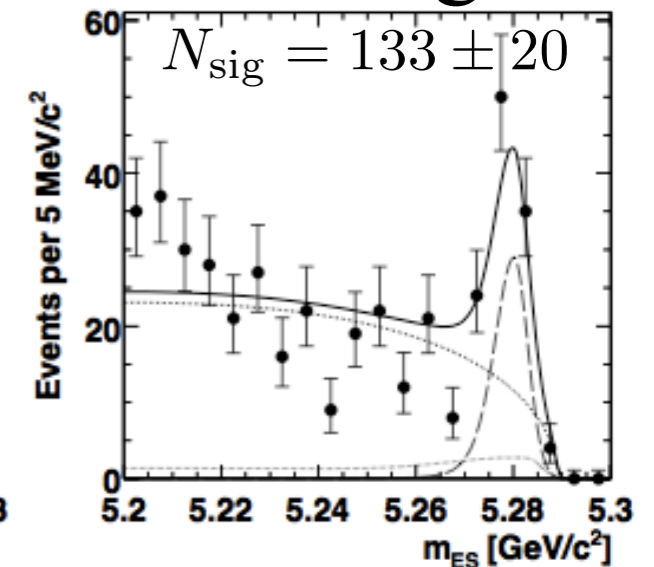
$$C_{K_s \pi^0 \gamma} = -0.36 \pm 0.33 \pm 0.04$$

All consistent with SM

## $K^*$ region

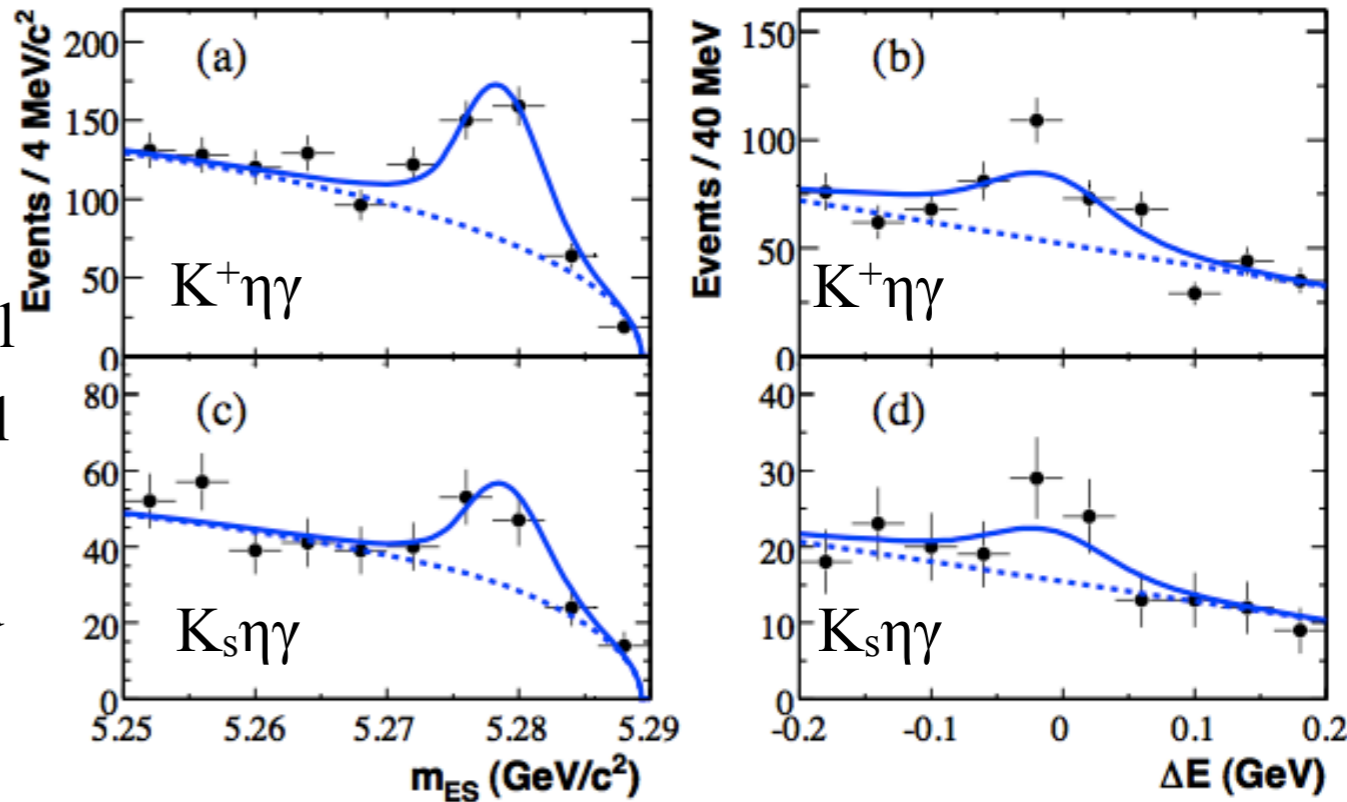


## non- $K^*$ region



# Time-dependent CPV in $B \rightarrow K\eta\gamma$

- Final BaBar data set  $N_{\text{BB}} = 467 \text{ M}$
- **First measurement** of TDCPV in this channel
- Includes also BF and  $A_{\text{CP}}$  of charged channel
- Technique similar to  $K_s\pi^0\gamma$
- ML Fit includes invariant mass of  $\eta \rightarrow \gamma\gamma$  and  $\eta \rightarrow \pi^+\pi^-\pi^0$
- Results consistent with SM



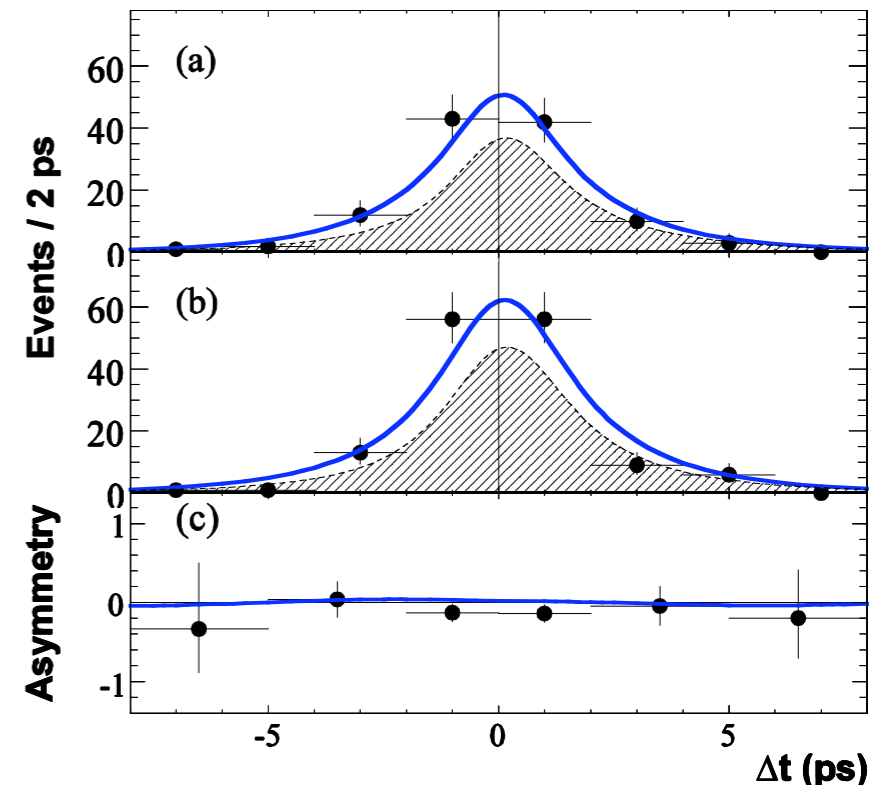
$$S_{K_s\eta\gamma} = -0.18_{-0.46}^{+0.49} \pm 0.12$$

$$C_{K_s\eta\gamma} = -0.32_{-0.39}^{+0.40} \pm 0.07$$

$$\mathcal{B}(B^0 \rightarrow K_s\eta\gamma) = (7.1_{-2.0}^{+2.1} \pm 0.4) \times 10^{-6}$$

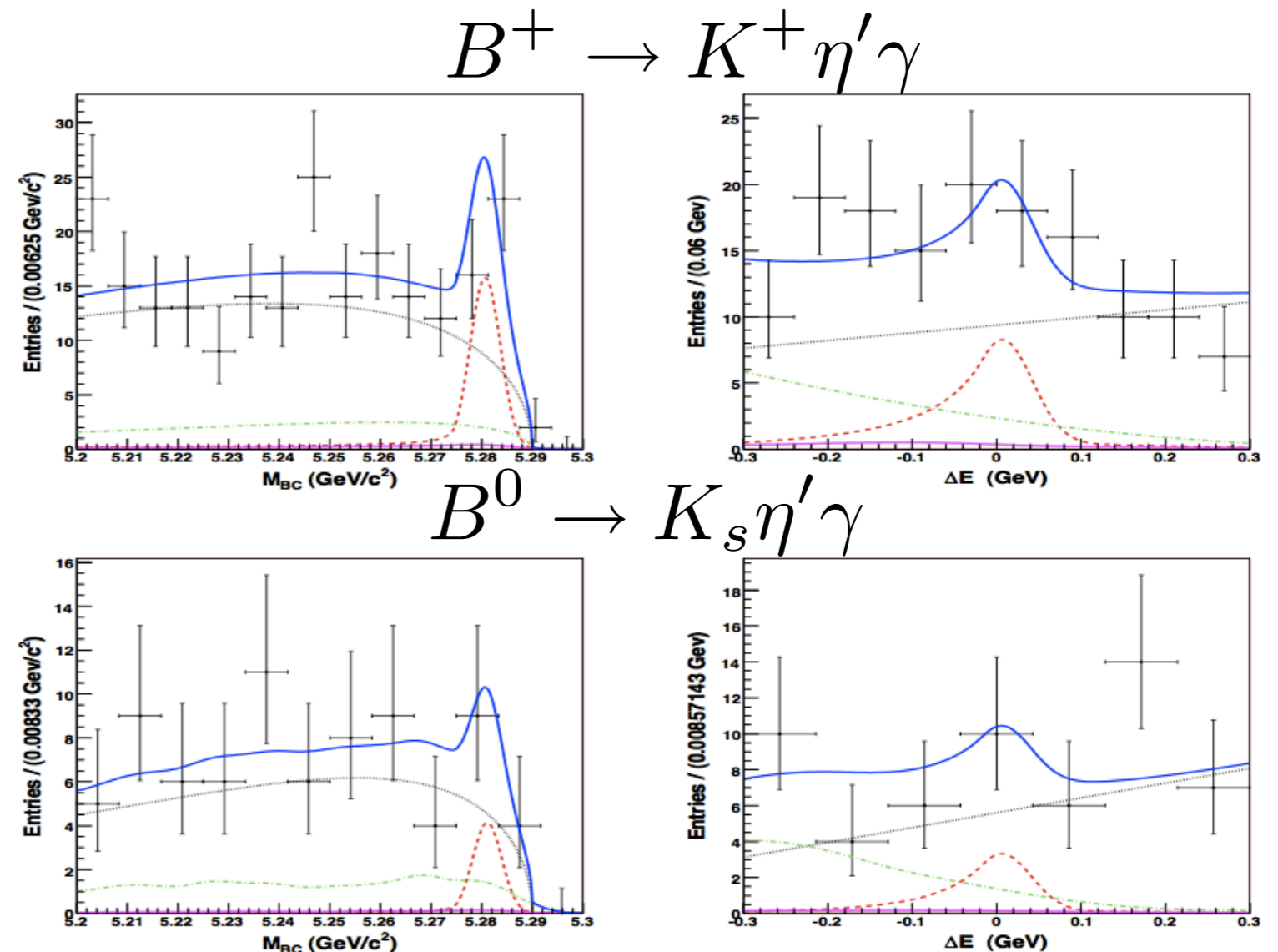
$$\mathcal{B}(B^+ \rightarrow K^+\eta\gamma) = (7.7 \pm 1.0 \pm 0.4) \times 10^{-6}$$

$$A_{\text{CP}}(B^+ \rightarrow K^+\eta\gamma) = (-9.0_{-9.8}^{+10.4} \pm 1.4) \times 10^{-2}$$



# Search for $B \rightarrow K \eta' \gamma$

- Possible suppression with respect to  $K \eta \gamma$  due to interference between two penguin diagrams (similar to  $K^* \eta'$ , but opposite to  $K \eta'$ )
- $N_{BB} = 657 \text{ M}$
- $\eta'$  reconstructed in decay to  $\eta \pi \pi$  or to  $\rho \gamma$
- Continuum suppression: Likelihood built with event shape variables,  $\Delta z$  and B direction
- ML fit with  $m_{BC}$  and  $\Delta E$



$$\mathcal{B}(B^+ \rightarrow K \eta' \gamma) = (3.2_{-1.1}^{+1.2} \pm 0.3) \times 10^{-6} \quad (3.3\sigma) \quad \text{First evidence}$$

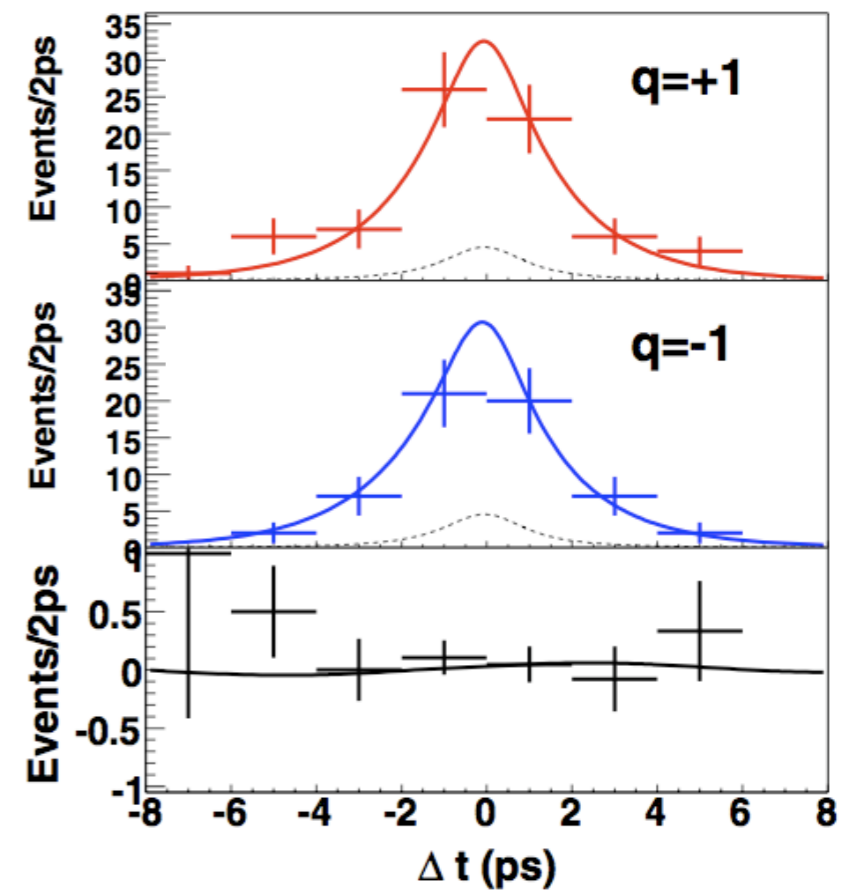
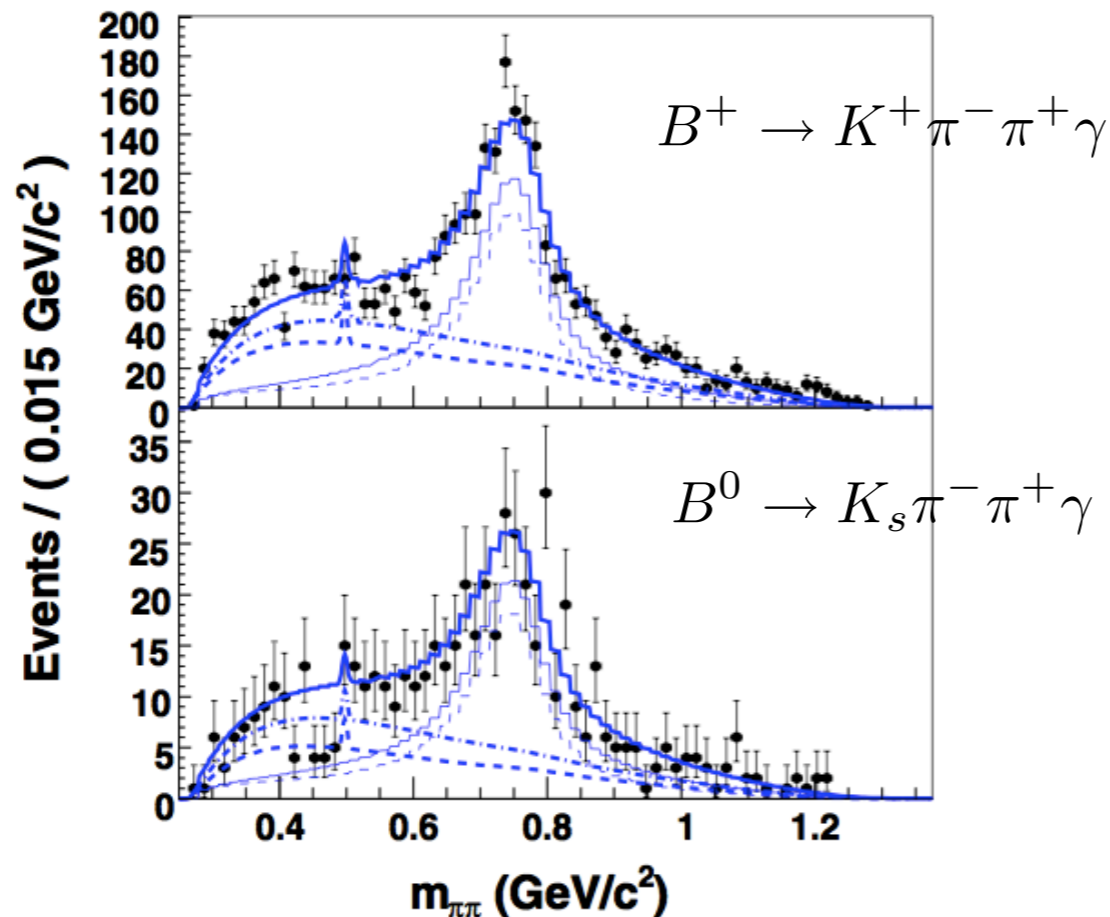
$$B^0 \rightarrow K^0 \eta' \gamma < 6.3 \times 10^{-6} \quad (90\% \text{ C.L.})$$

# Time-dependent CPV in $B \rightarrow K_s \rho^0 \gamma$

- Vertex from  $\rho^0 \rightarrow \pi^+ \pi^-$
- Dilution due to  $B \rightarrow K^* \pi \gamma$  is small (measured in  $B^+ \rightarrow K^+ \pi^+ \pi^- \gamma$ )
  - first perform a CP fit in the  $m_{BC}$  signal region to find effective S and A parameters
  - then correct by the D factor estimated from a fit

$$S_{K_s \rho^0 \gamma} = +0.11 \pm 0.33^{+0.05}_{-0.09}$$

$$A_{K_s \rho^0 \gamma} = +0.05 \pm 0.18 \pm 0.06$$

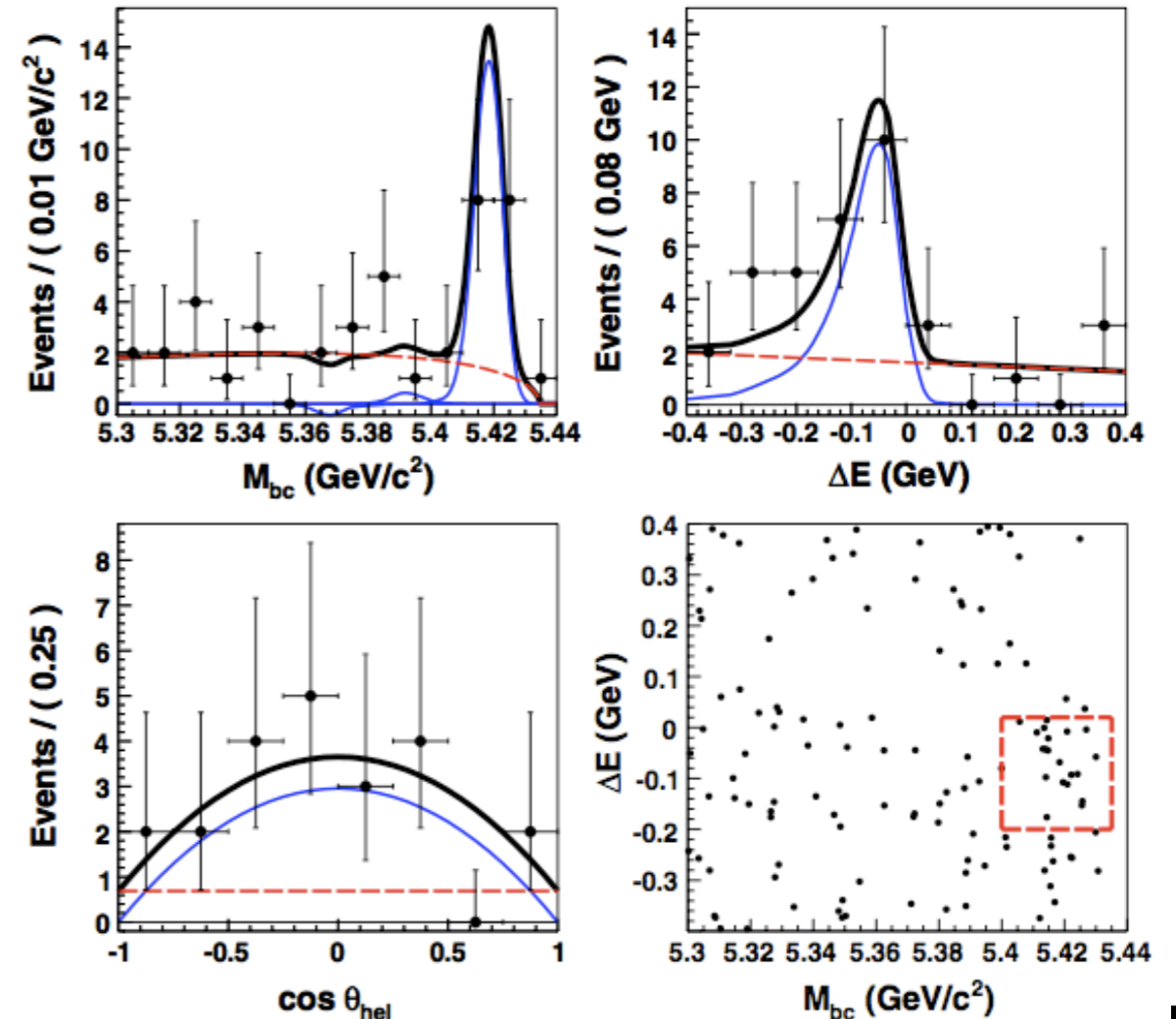
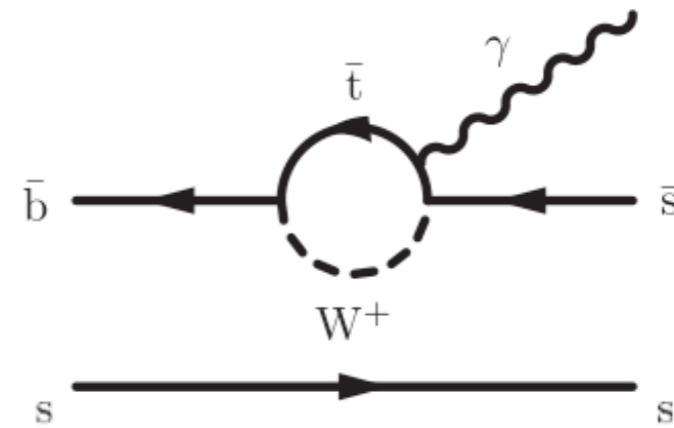


# $B_s \rightarrow \phi \gamma$

- First radiative decay of  $B_s$
- $BF \sim 40 \times 10^{-6}$  in SM
- $23.6 \text{ fb}^{-1}$  at Y(5S) resonance
- $\phi \rightarrow K^+ K^-$  reconstruction
- Continuum suppressed with Fisher
- Signal from ML fit to  $m_{BC}$ ,  $\Delta E$  and helicity angle
- Three different signals

$$B_s^* \bar{B}_s^*, B_s^* \bar{B}_s^0, \text{ and } B_s^0 \bar{B}_s^0$$

- contribution only from the first one



Mode	$\epsilon$ (%)	$S_{B_s^0 \bar{B}_s^0}$	$S_{B_s^* \bar{B}_s^0}$	$S_{B_s^* \bar{B}_s^*}$	$\mathcal{B}$ ( $10^{-6}$ )	Significance
$B_s^0 \rightarrow \phi \gamma$	24.7	$-0.7^{+2.5}_{-1.6}$	$0.5^{+2.9}_{-1.9}$	$18^{+6}_{-5}$	$57^{+18+12}_{-15-11}$	5.5
$B_s^0 \rightarrow \gamma \gamma$	17.8	$-4.7^{+3.9}_{-2.8}$	$-0.8^{+4.8}_{-3.8}$	$-7.3^{+2.4}_{-2.0}$	$< 8.7$	...



$$b \rightarrow d\gamma$$

$$|V_{td}/V_{ts}|$$

Isospin Asymmetry  $\Delta(\rho\gamma)$

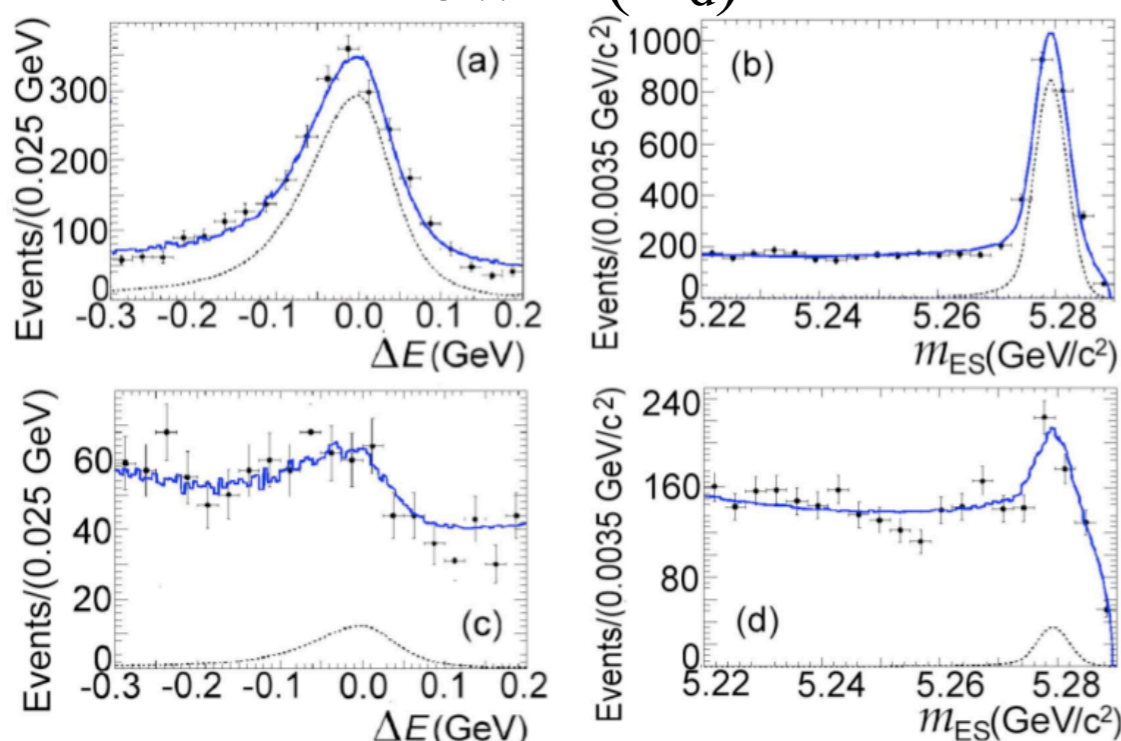
Time-dependent CP Asymmetry in  $B \rightarrow \rho\gamma$

# Semi-inclusive $b \rightarrow d\gamma$ and $|V_{td}/V_{ts}|$

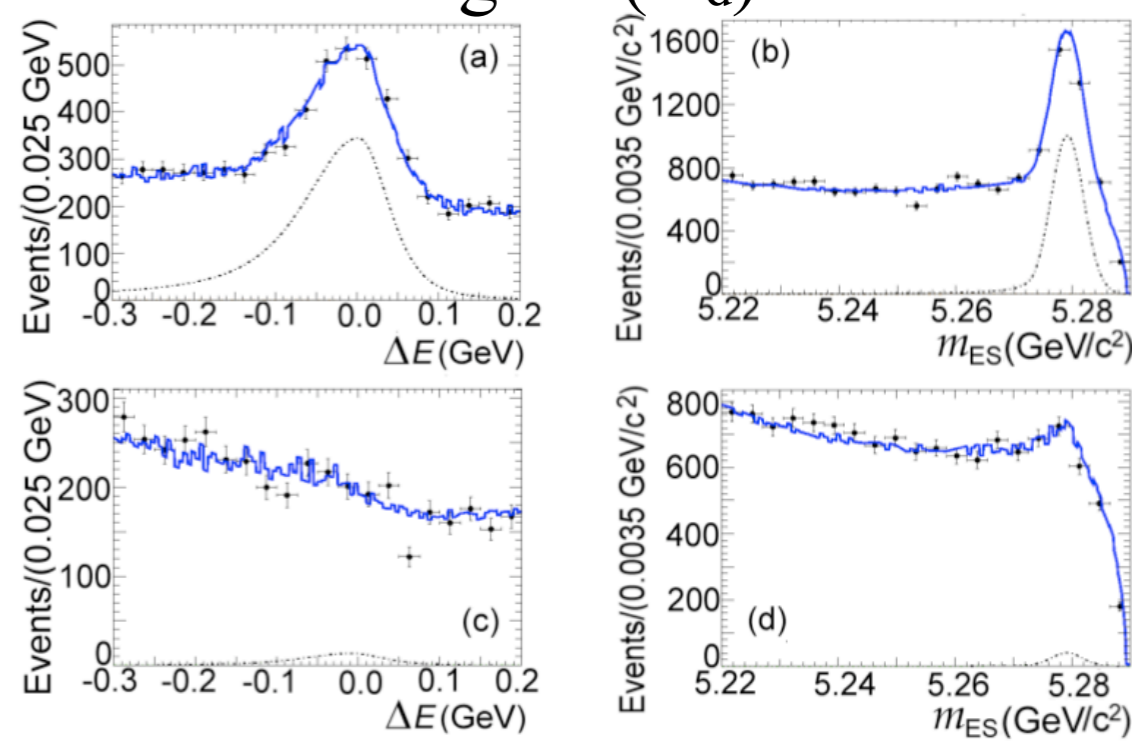
- Reconstruct 7 final  $X_d$  states and the corresponding  $X_s$  states with  $\pi \rightarrow K$
- $N_{BB} = 383 \text{ M}$
- Two mass regions studied:
- $0.6 < m(X_d) < 1.0 \text{ GeV}/c^2$  ( $\rho/\omega$  mass region)
- $1.0 < m(X_d) < 1.8 \text{ GeV}/c^2$  (previously unmeasured)
- Many systematics cancel in the ratio, but  $\sim 2x$  corrections due to missing states

$B \rightarrow X_d \gamma$	$B \rightarrow X_s \gamma$
$B^0 \rightarrow \pi^+ \pi^- \gamma$	$B^0 \rightarrow K^+ \pi^- \gamma$
$B^+ \rightarrow \pi^+ \pi^0 \gamma$	$B^+ \rightarrow K^+ \pi^0 \gamma$
$B^+ \rightarrow \pi^+ \pi^- \pi^+ \gamma$	$B^+ \rightarrow K^+ \pi^- \pi^+ \gamma$
$B^0 \rightarrow \pi^+ \pi^- \pi^0 \gamma$	$B^0 \rightarrow K^+ \pi^- \pi^0 \gamma$
$B^0 \rightarrow \pi^+ \pi^- \pi^+ \pi^- \gamma$	$B^0 \rightarrow K^+ \pi^- \pi^+ \pi^- \gamma$
$B^+ \rightarrow \pi^+ \pi^- \pi^+ \pi^0 \gamma$	$B^+ \rightarrow K^+ \pi^- \pi^+ \pi^0 \gamma$
$B^+ \rightarrow \pi^+ \eta \gamma$	$B^+ \rightarrow K^+ \eta \gamma$

low  $m(X_d)$



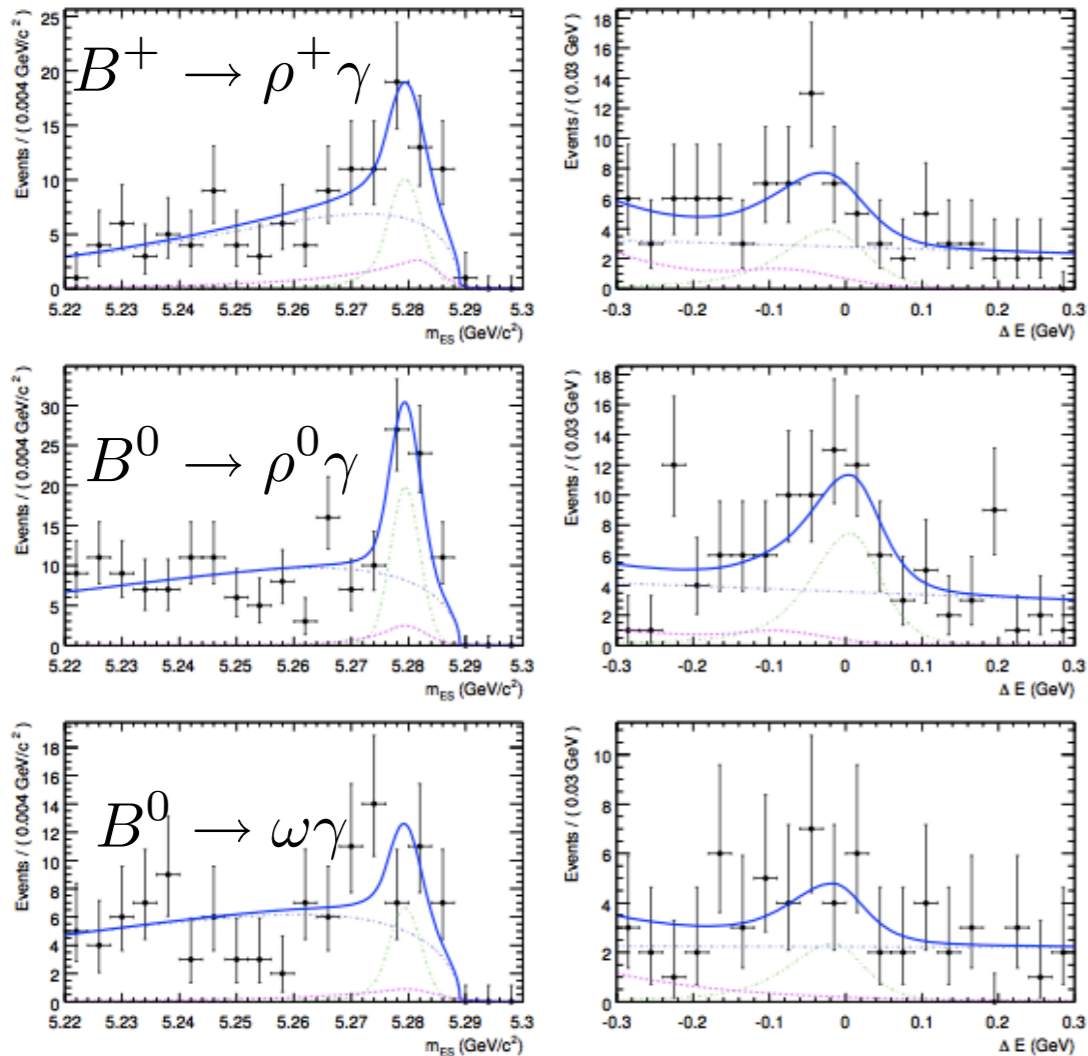
high  $m(X_d)$



$$\mathcal{B}(B \rightarrow X_d \gamma) = (7.2 \pm 2.7 \pm 2.3) \times 10^{-6}$$

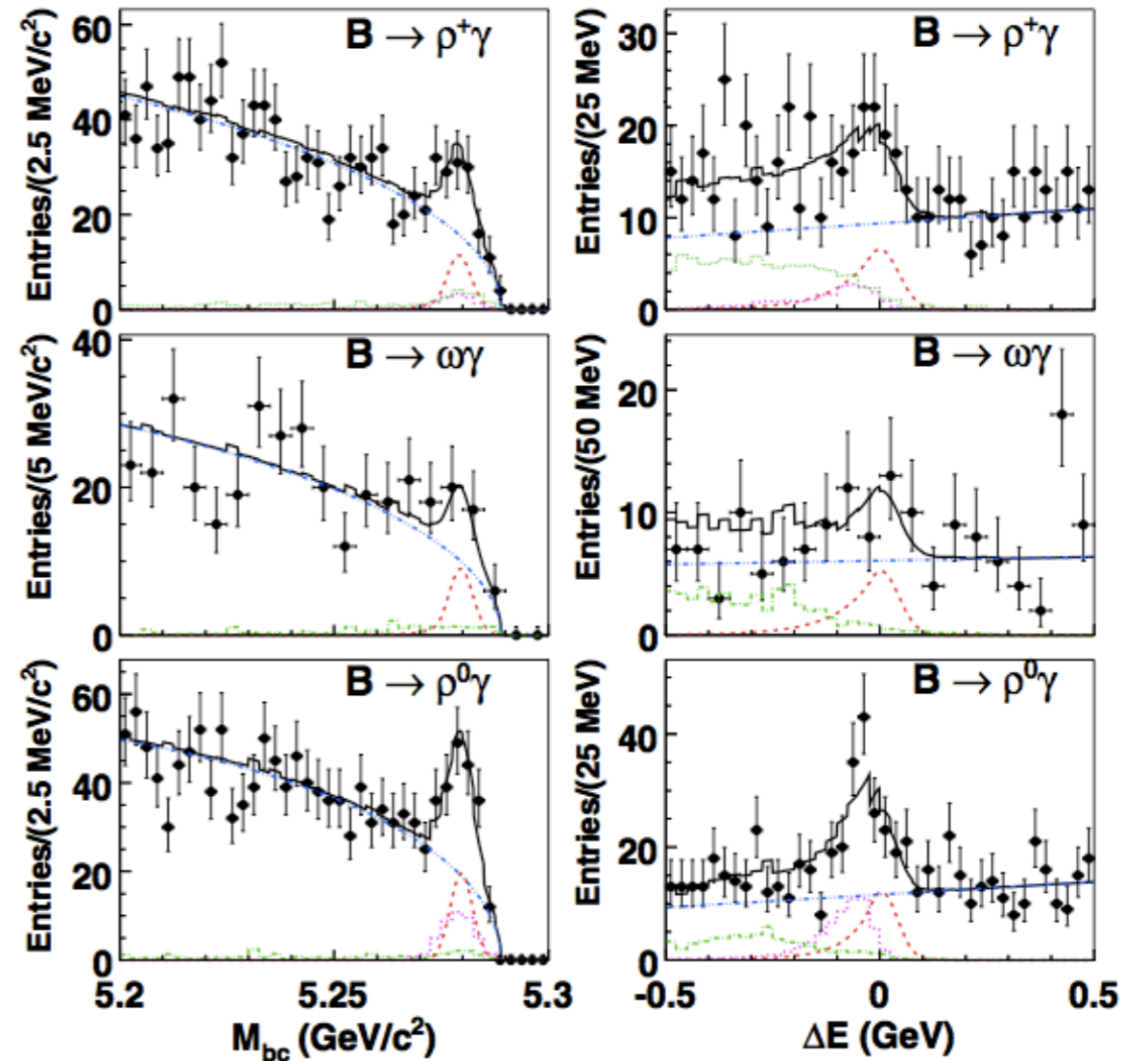
$$|V_{td}/V_{ts}| = 0.177 \pm 0.043$$

# $B \rightarrow \rho/\omega \gamma$ and $|V_{td}/V_{ts}|$



$N_{BB} = 465 \text{ M}$

$$\begin{aligned} \mathcal{B}(B^+ \rightarrow \rho^+ \gamma) &= (1.20_{-0.37}^{+0.42} \pm 0.20) \times 10^{-6} \\ \mathcal{B}(B^0 \rightarrow \rho^0 \gamma) &= (0.97_{-0.22}^{+0.24} \pm 0.06) \times 10^{-6} \\ \mathcal{B}(B^0 \rightarrow \omega \gamma) &< 0.9 \times 10^{-6} \text{ (90\% C.L.)} \end{aligned}$$



$N_{BB} = 657 \text{ M}$

$$\begin{aligned} \mathcal{B}(B^+ \rightarrow \rho^+ \gamma) &= (8.7_{-2.7}^{+2.9+0.9}) \times 10^{-7} \\ \mathcal{B}(B^0 \rightarrow \rho^0 \gamma) &= (7.8_{-1.6}^{+1.7+0.9}) \times 10^{-7} \\ \mathcal{B}(B^0 \rightarrow \omega \gamma) &= (4.0_{-1.7}^{+1.9} \pm 1.3) \times 10^{-7} \end{aligned}$$

# Status of $|V_{td}/V_{ts}|$

well measured

Isospin factor  
1. (.5)  $\rho^+$  ( $\rho^0$ )

Form factor ratio

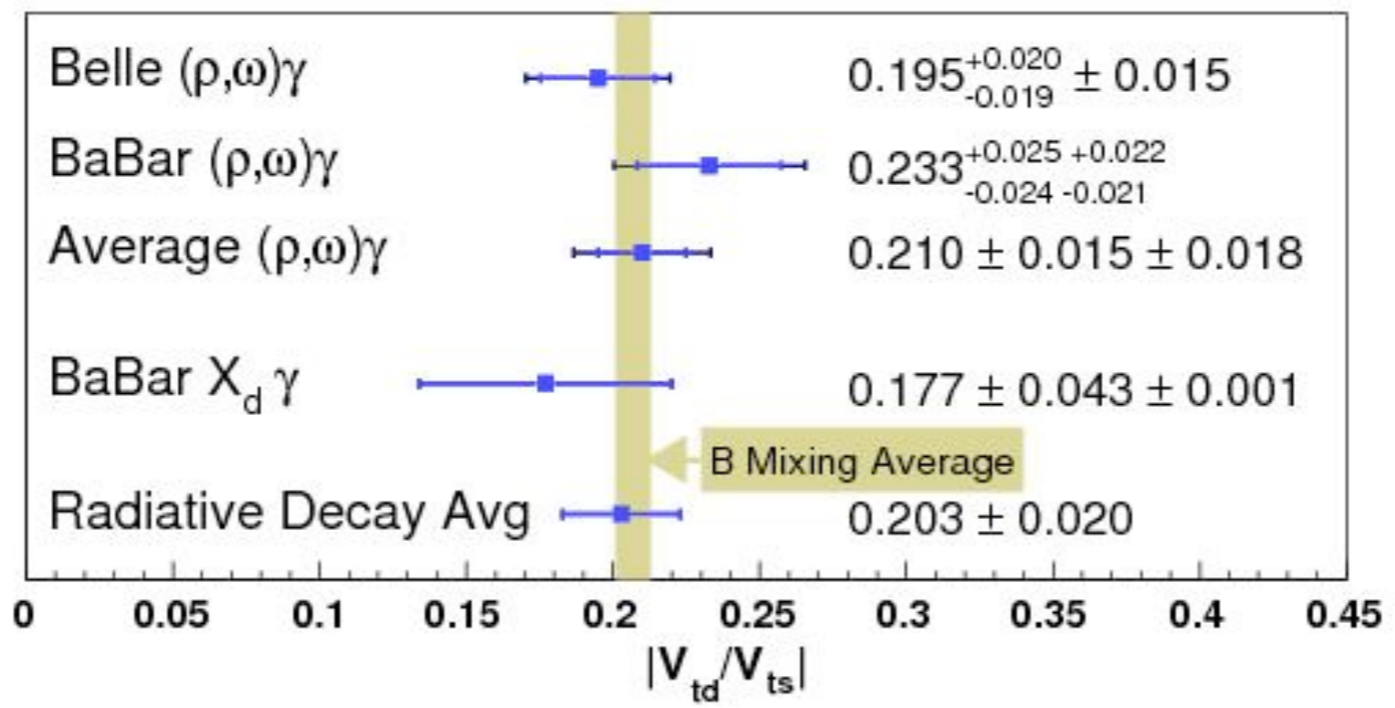
Annihilation amplitude correction

$$\frac{\mathcal{B}(B \rightarrow \rho\gamma)}{\mathcal{B}(B \rightarrow K^*\gamma)} = S_\rho \left| \frac{V_{td}}{V_{ts}} \right|^2 \left( \frac{1 - m_\rho^2/M_B^2}{1 - m_{K^*}^2/M_B^2} \right) \zeta^2 [1 + \Delta R]$$

$$|V_{td}/V_{ts}|_{\rho/\omega} = 0.233^{+0.025+0.022}_{-0.024-0.021}$$

$$|V_{td}/V_{ts}|_{\rho/\omega} = 0.195^{+0.020}_{-0.019} \pm 0.015$$

$$|V_{td}/V_{ts}|_{\text{mixing}} = 0.209 \pm 0.001 \pm 0.006$$

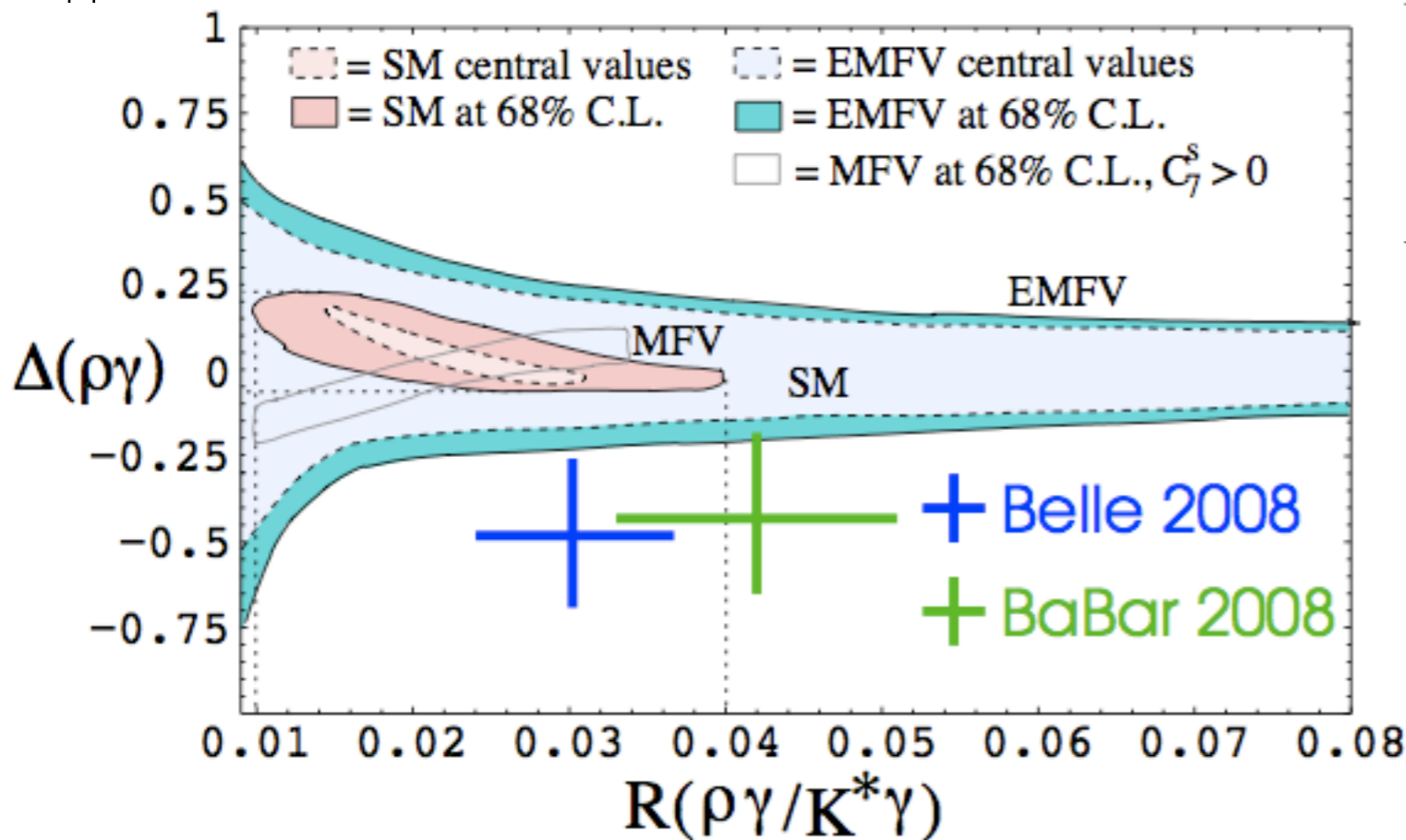


- All results compatible with the  $B_s$  and  $B_d$  mixing
- No evidence of NP

# Isospin Asymmetry in $B \rightarrow \rho\gamma$

- Test of isospin symmetry
- Most theoretical calculation predict a small  $\Delta(\rho\gamma)$
- Large values can be signs of NP [Ali,Lunghi EPJ C26, 195 (2002)]
- or could be explained by non-perturbative charming penguins [Kim et al. PRD 78, 054024 (2008)]

$$\Delta(\rho\gamma) = \frac{\Gamma(B^+ \rightarrow \rho^+\gamma)}{2\Gamma(B^0 \rightarrow \rho^0\gamma)} - 1$$



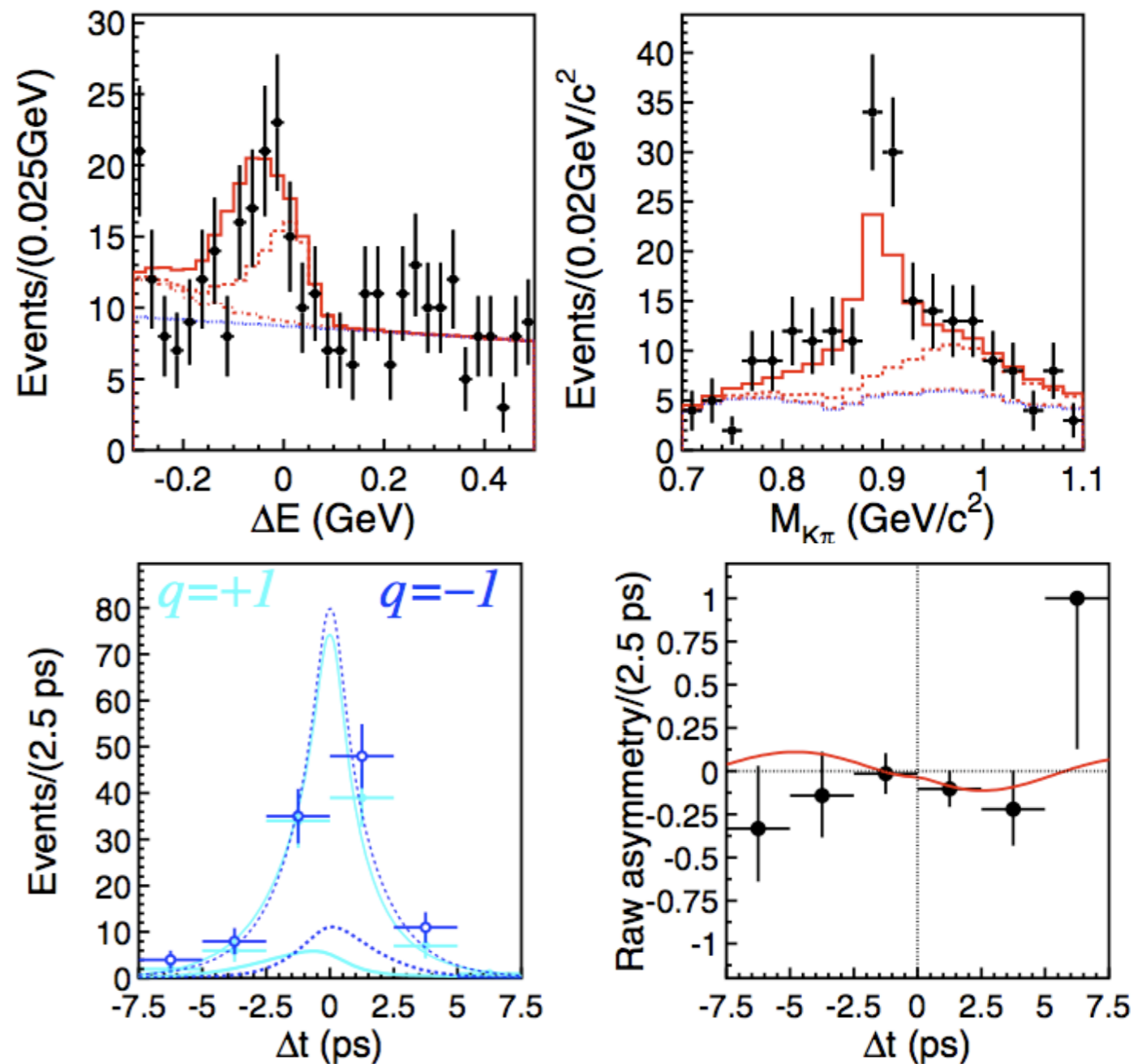
	Belle	BaBar
$R(\rho\gamma/K^*\gamma)$	$0.0302^{+0.0060}_{-0.0055}^{+0.0026}_{-0.0028}$	$0.042 \pm 0.009$
$A_{CP}(\rho^+\gamma)$	$-0.11 \pm 0.32 \pm 0.09$	—
$\Delta(\rho\gamma)$	$-0.48^{+0.21}_{-0.19}^{+0.08}_{-0.09}$	$-0.43^{+0.25}_{-0.22} \pm 0.10$

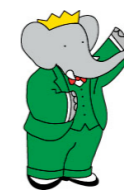
# Time-dependent CP Asymmetry in $B^0 \rightarrow \rho^0 \gamma$

- $N_{BB} = 657 \text{ M}$
- $S=0, A=-0.1$  in SM
- $\rho \rightarrow \pi^+ \pi^-$  reconstruction
- likelihood ratio with Fisher,  $\cos\theta_B$  and  $\cos\theta_h$  to suppress continuum
- After selection, big  $K^{*0} \gamma$  background component, included in the ML fit
- Result consistent with SM

$$S_{\rho^0 \gamma} = -0.83 \pm 0.65 \pm 0.18$$

$$A_{\rho^0 \gamma} = -0.44 \pm 0.49 \pm 0.14$$





# Summary

- Radiative and electroweak penguin decays at **BaBar** and **Belle**
  - $B \rightarrow K^{(*)} l^+ l^-$ : Angular and Isospin Asymmetries
  - Inclusive  $B \rightarrow X_s \gamma$
  - Time dependent CP Asymmetries in exclusive  $b \rightarrow s \gamma$
  - First radiative decay of  $B_s$
  - $|V_{td}/V_{ts}|$  measurement with semi-inclusive and exclusive  $b \rightarrow d \gamma$
  - Isospin Asymmetry in  $B \rightarrow \rho \gamma$
  - TCPV in  $B^0 \rightarrow \rho^0 \gamma$
- Most results consistent with SM
  - but statistical errors still large
  - $B \rightarrow K^* l l$  will be studied at LHC, but for the others...

... we DO need the next generation B factories

# *Backup slides*



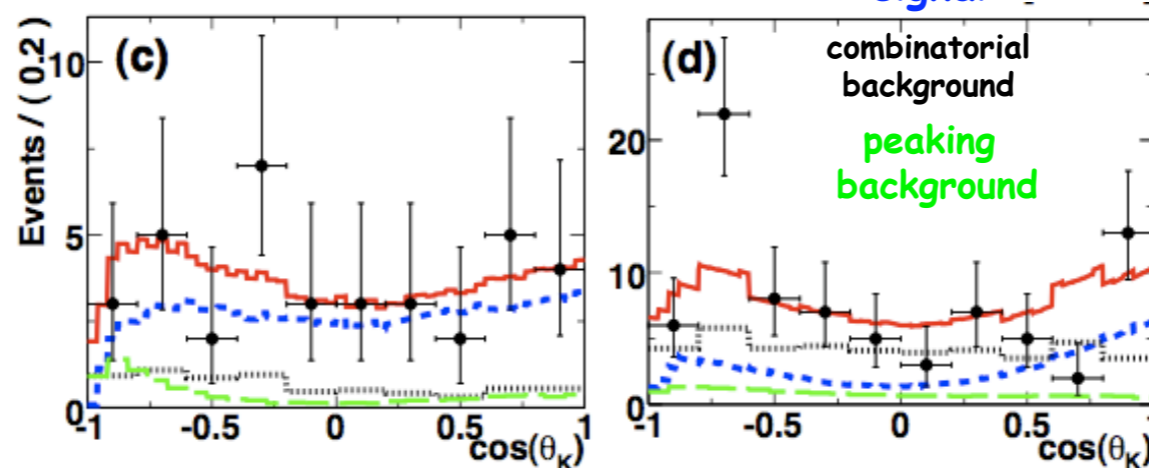
# $B \rightarrow K^{(*)} l^+ l^-$ : Analysis details

- 349 fb<sup>-1</sup>
- Reconstruct 10 final states
- Use Neural Networks to remove random combinatoric backgrounds coming from B,D semileptonic decays
- Simultaneously optimize NN and  $\Delta E$
- Final signal yield extracted from fit to  $m_{ES}$
- Veto J/ $\psi$  and  $\psi(2S)$  dilepton events
- Measure angular asymmetries, direct CP, LFV, isospin asymmetries
  - all results in low/high mass range below/above J/ $\psi$
  
- 605 fb<sup>-1</sup>
- Reconstruct 10 final states
- Semileptonic decay suppression relies on missing mass, lepton vertex separation and  $\cos\theta_B$
- 2D ML fit to  $(m_{K\pi}, m_{BC})$  for  $K^*ll$ , 1D ML fit to  $m_{BC}$  for  $Kll$
- Veto J/ $\psi$  and  $\psi(2S)$  dilepton events
- Measure angular asymmetries, direct CP, LFV, isospin asymmetries
  - all results in 6 bins of  $q^2$

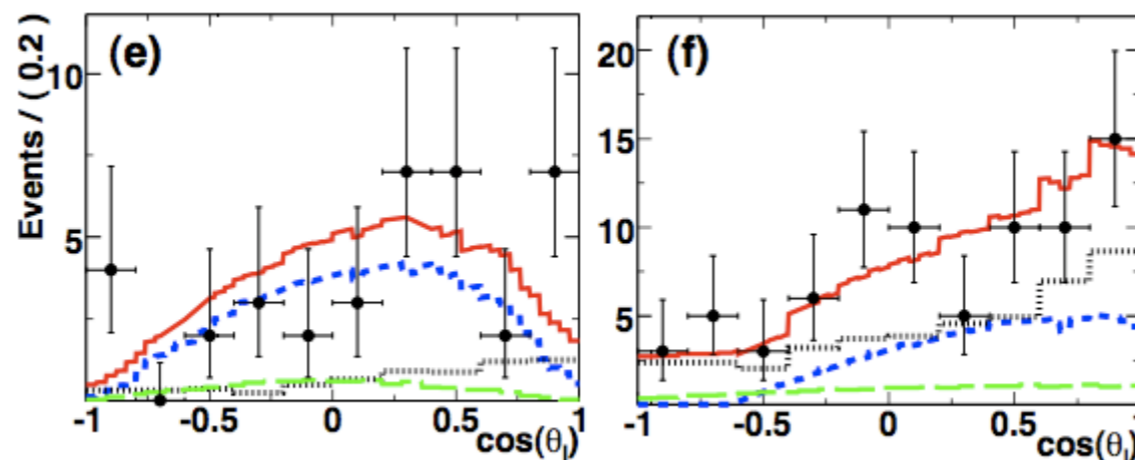
# $B \rightarrow K^{(*)} l^+ l^-$ : Angular asymmetries

	$M_{\ell^+ \ell^-} < 2.5 \text{ GeV}$	$M_{\ell^+ \ell^-} > 3.2 \text{ GeV}$
$A_{\text{FB}}$	$0.24^{+0.18}_{-0.23} \pm 0.05$	$0.76^{+0.52}_{-0.32} \pm 0.07$
$F_L$	$0.35 \pm 0.16 \pm 0.04$	$0.71^{+0.20}_{-0.22} \pm 0.04$

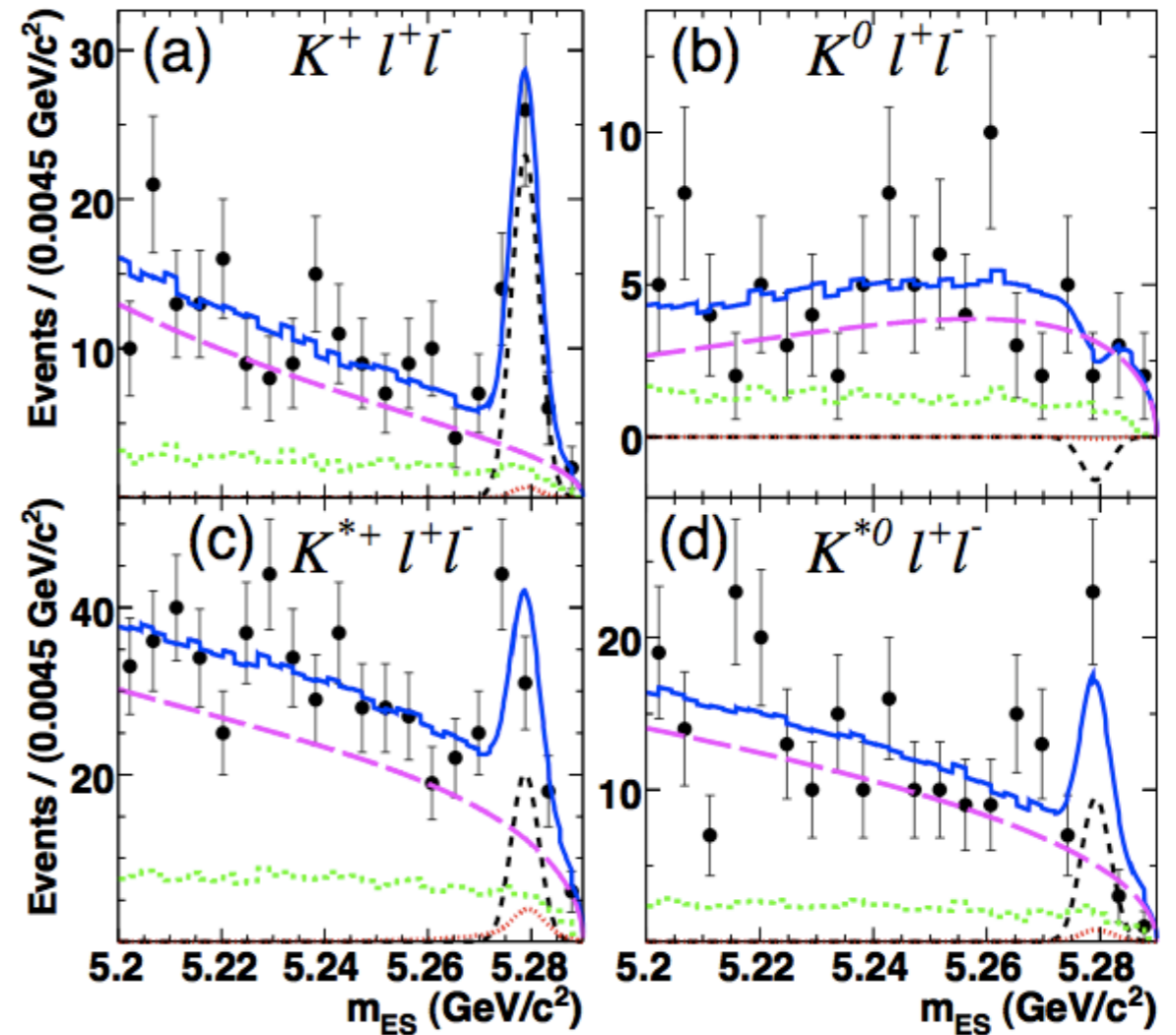
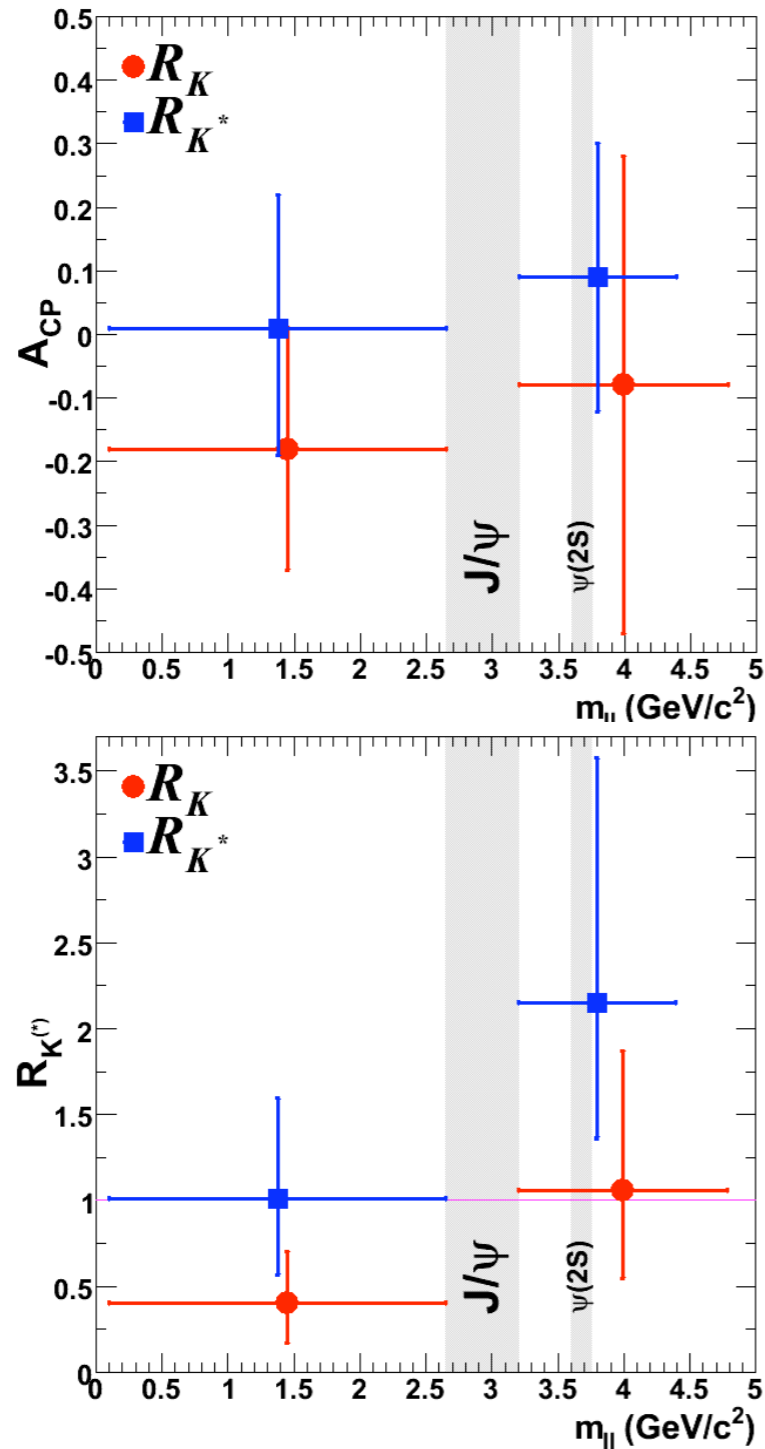
Fit to  $\cos\theta_K$  in  $m_{\text{ES}} > 5.27$  region to extract  $F_L$



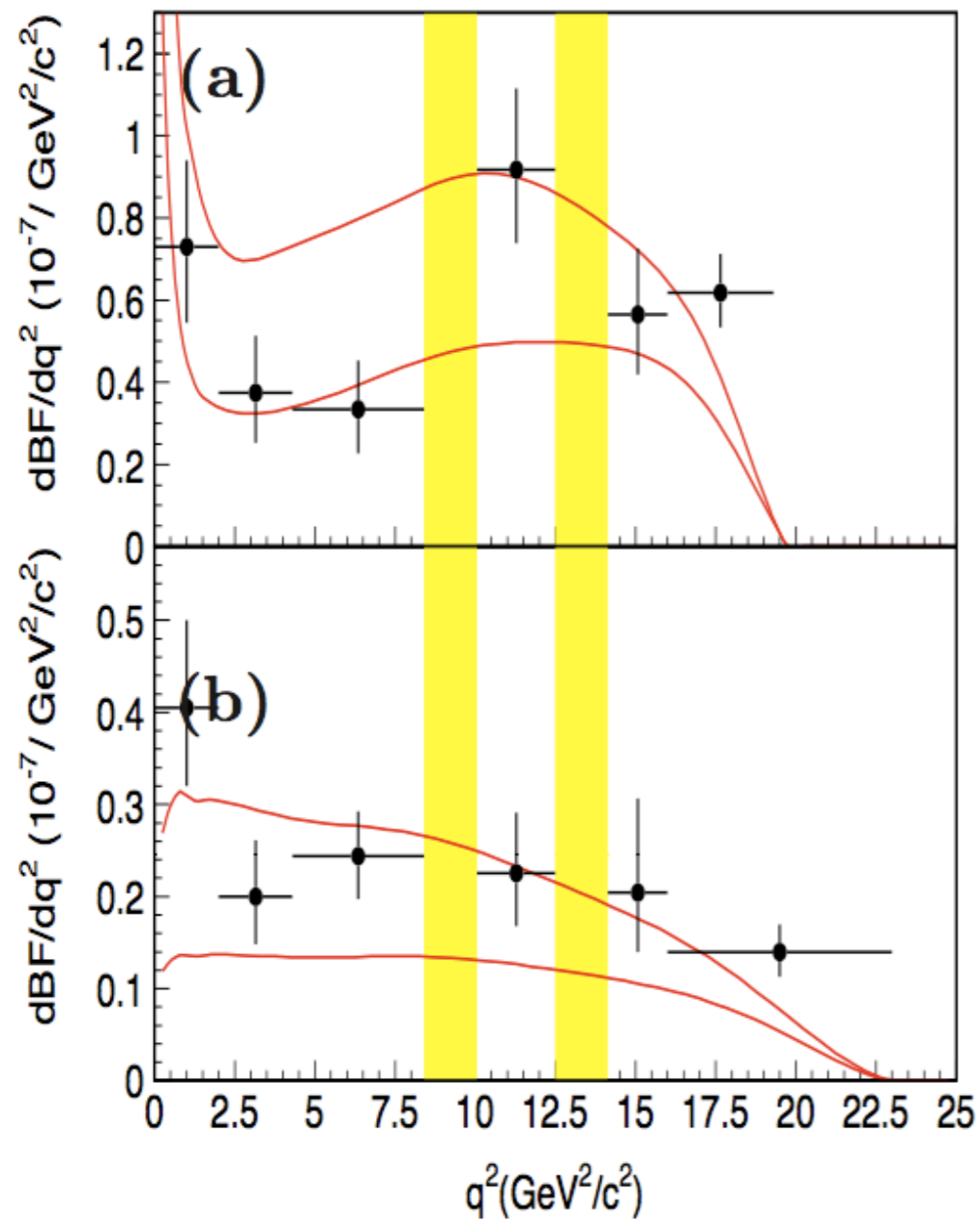
Fit to  $\cos\theta_l$  in  $m_{\text{ES}} > 5.27$  region to extract  $A_{\text{FB}}$



# $B \rightarrow K^{(*)} l^+ l^-$ : Asymmetries



# $B \rightarrow K^{(*)} l^+ l^-$



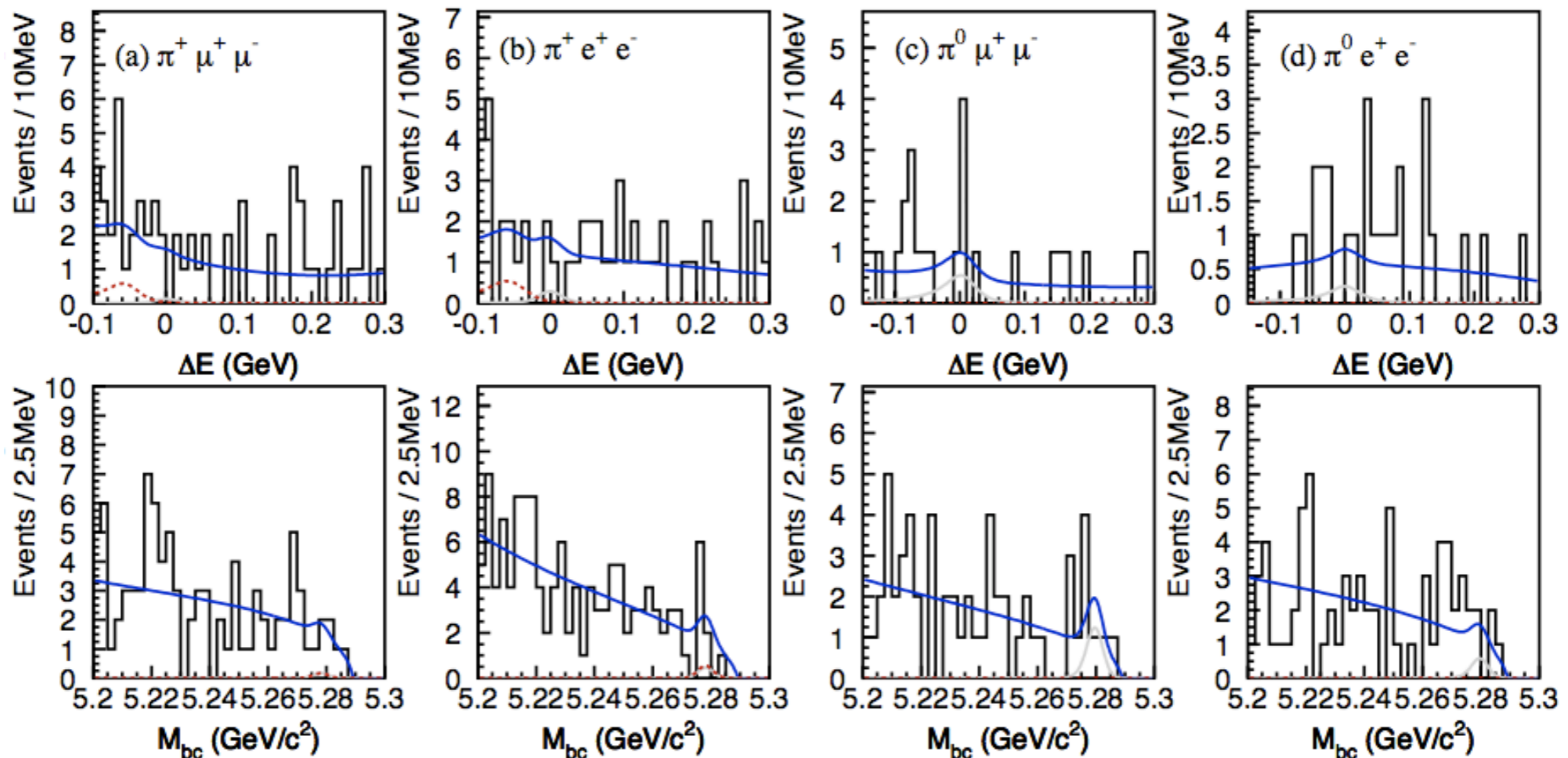
$$\begin{aligned}
 A_I(B \rightarrow K^* l^+ l^-) &= -0.29_{-0.16}^{+0.16} \pm 0.03 \quad \sigma = 1.40, \\
 A_I(B \rightarrow K l^+ l^-) &= -0.31_{-0.14}^{+0.17} \pm 0.05 \quad \sigma = 1.75, \\
 A_I(B \rightarrow K^{(*)} l^+ l^-) &= -0.30_{-0.11}^{+0.12} \pm 0.04 \quad \sigma = 2.24,
 \end{aligned}$$

# $B \rightarrow \pi l^+ l^-$

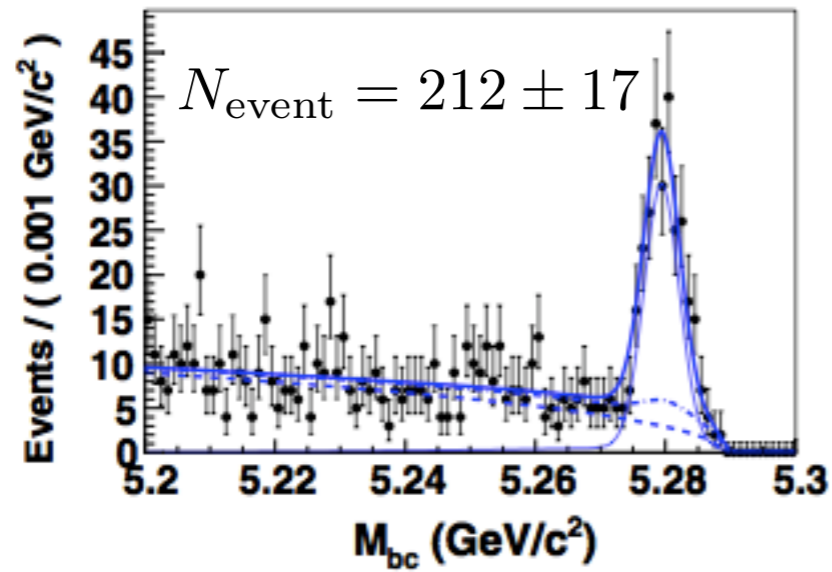
- $N_{BB} = 657 \text{ M}$

$$\mathcal{B}(B \rightarrow \pi l^+ l^-) < 6.2 \times 10^{-8}$$

	$\pi\mu^+\mu^-$	$\pi e^+e^-$	$\pi l^+l^-$
$B^+$	$<6.9 \times 10^{-8}$	$<8.0 \times 10^{-8}$	$<22.7 \times 10^{-8}$
$B^0$	$<18.4 \times 10^{-8}$	$<4.9 \times 10^{-8}$	$<15.4 \times 10^{-8}$



# Time-dependent CPV in $B \rightarrow K_s \rho^0 \gamma$

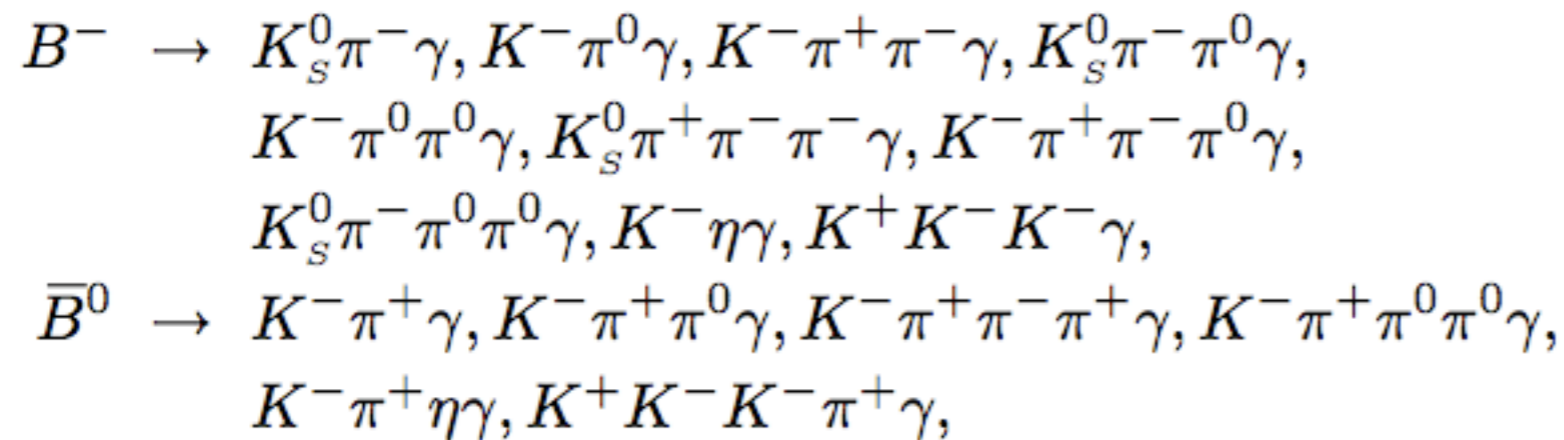


	$K_S^0 \rho^0 \gamma$	$K^* \pi \gamma$	interf	
			$K\rho/K^*\pi$	$K^*/\bar{K}^*$
$1^+$	151.0	35.1	7.5	4.4
$1^-$	11.3	8.0	4.9	1.3
$K_2^*$	2.2	6.1	2.0	4.5
total	164.4	49.2	14.5	10.2

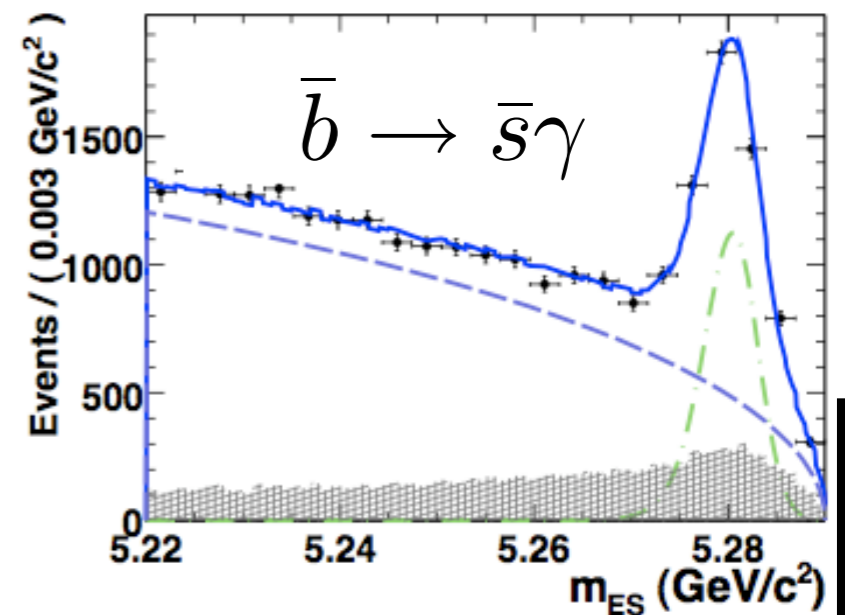
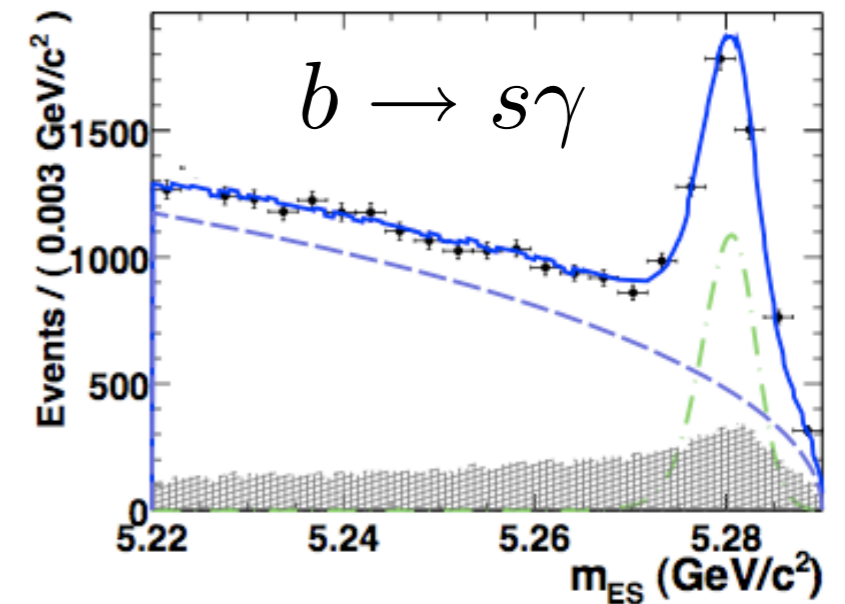
$$\mathcal{D} = 0.83^{+0.19}_{-0.03}$$

# $A_{CP} (B \rightarrow X_s \gamma)$ sum of exclusive modes

- $N_{BB} = 384 \text{ M}$
- Sum of 16 exclusive modes with  $m(X_s) < 2.8 \text{ GeV}$



$M_{X_s}$ ( $\text{GeV}/c^2$ )	$A_{CP}$
0.6–1.1	$0.010 \pm 0.029 \pm 0.015$
1.1–1.5	$0.000 \pm 0.049 \pm 0.016$
1.5–2.0	$-0.047 \pm 0.077 \pm 0.014$
2.0–2.8	$-0.077 \pm 0.180 \pm 0.182$
0.6–2.8	$-0.011 \pm 0.030 \pm 0.014$



# Status of $|V_{td}/V_{ts}|$

