

The Search for $B \rightarrow (\rho^0, \rho^+, \omega)\gamma$ Decays at
BaBar

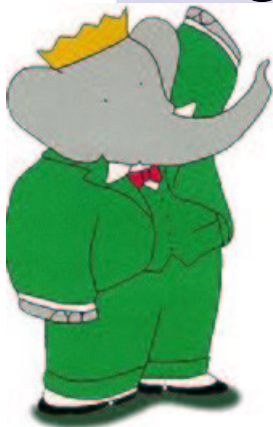
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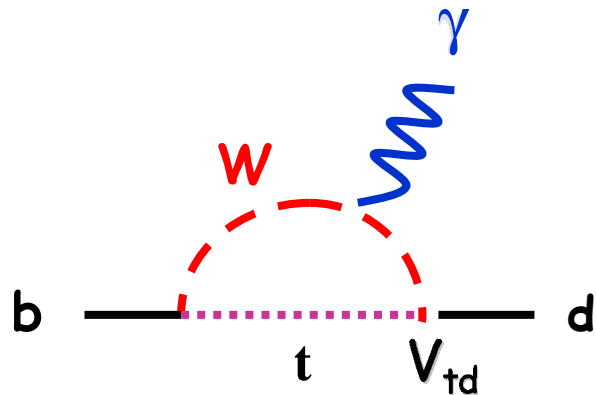
On behalf of

BaBar Collaboration

DPF 2004, August 2004



Physics Motivation



- Penguin-dominated process; CKM suppressed.
- Branching fraction, CP-asymmetry, Isospin-asymmetry.
- Test SM or probe for new physics.
- Measure $|V_{td}/V_{ts}|$ by combining with $K^* \gamma$.

$$\frac{\overline{\mathcal{B}}[B \rightarrow (\rho/\omega)\gamma]}{\mathcal{B}(B \rightarrow K^*\gamma)} = \left| \frac{V_{td}}{V_{ts}} \right|^2 \left(\frac{1 - m_\rho^2/M_B^2}{1 - m_{K^*}^2/M_B^2} \right)^3 \zeta^2 [1 + \Delta R], \text{ hep-ph/0405075}$$

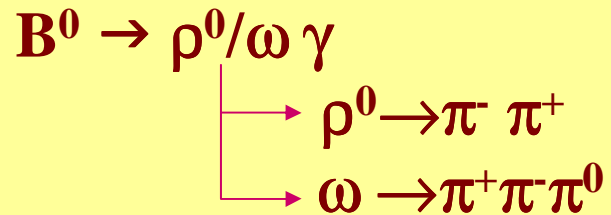
SU(3) breaking of form factors

weak annihilation correction

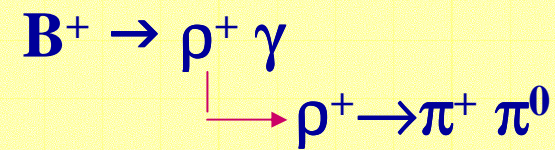
- BaBar's result on 78fb^{-1} : $\text{BF}(B \rightarrow \rho/\omega\gamma) < 1.9 \times 10^{-6}$ (90% C.L.). Published in PRL 92, 111801 (2004).
- Theoretical: $\text{BF}(B \rightarrow \rho/\omega\gamma) \sim 1.4 \pm 0.4 \times 10^{-6}$. A. Ali, et. al; hep-ph/0405075.

Event Reconstruction

B⁰ Decay Modes



B[±] Decay Modes



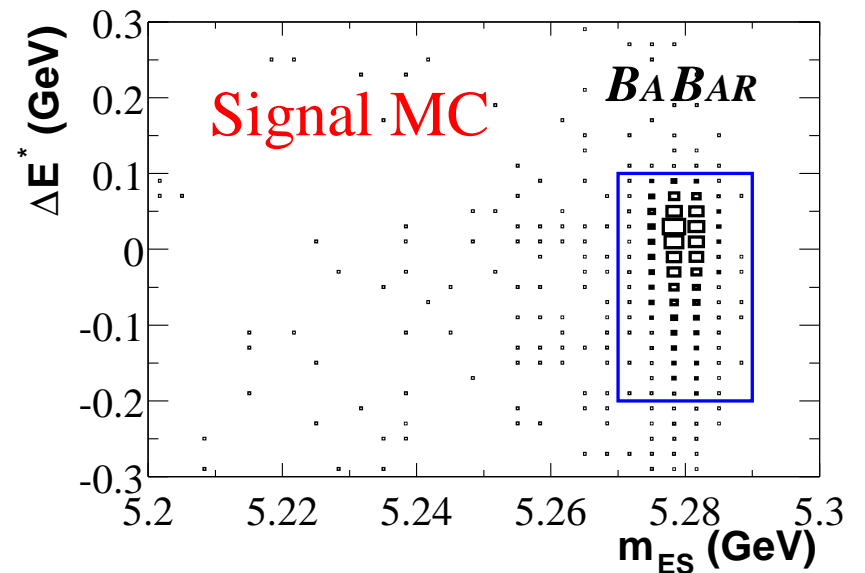
B candidate variables,

$$\Delta E^* = E_\gamma^* + E_{\rho/\omega}^* - E_{beam}^*,$$

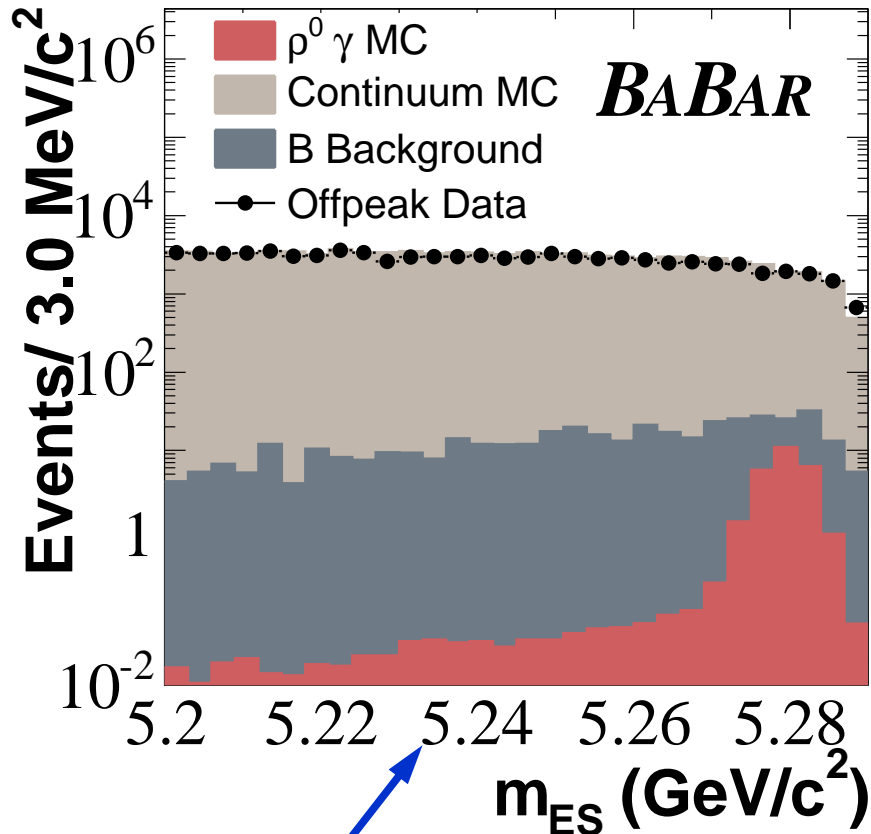
(~ 0 for signal, $\sigma_{\Delta E^*} \sim 50$ MeV)

$$m_{ES} = \sqrt{\left(E_{beam}^2 - (\vec{p}_{\rho/\omega}^* + \vec{p}_\gamma^*)^2 \right)},$$

(peak at ~ 5.28 GeV for signal, $\sigma_{m_{ES}} \sim 3$ MeV)



Background Overview



(After initial event selection cuts, including PID)

- Very rare; high background presents. Assumed BF,

$B^+ \rightarrow \rho^+ \gamma$	1.0×10^{-6}
$B^0 \rightarrow \rho^0 \gamma$	0.5×10^{-6}
$B^0 \rightarrow \omega \gamma$	0.5×10^{-6}

- Continuum background dominates.

$$e^+ e^- \rightarrow u\bar{u}, d\bar{d}, s\bar{s}, c\bar{c}$$

- Significant B background:

□ $B \rightarrow (\rho/\omega)(\pi^0/\eta)$ decays,

□ $B \rightarrow K^* \gamma$

□ $B \rightarrow X_s \gamma$.

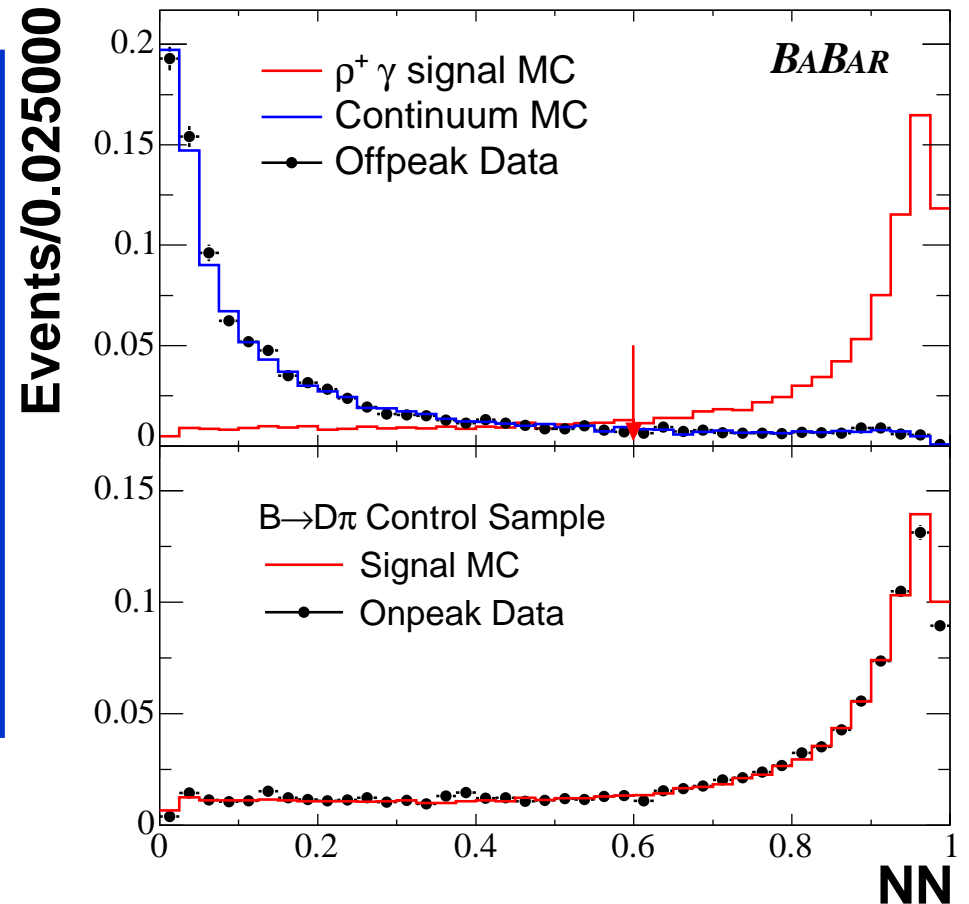
Continuum Background

NN input variables:

- Event shape variables.
- Tagging variables.
- Number of kaons (K^+ , K^- & K_S) and maximum momentum in CM frame.
- Separation between signal B vertex and rest of event.



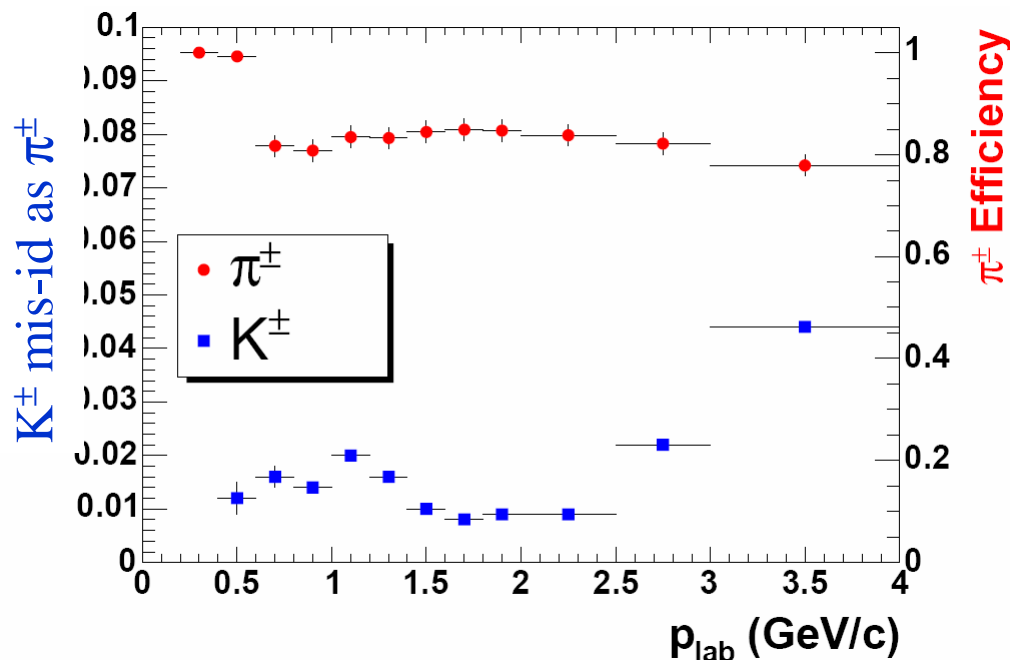
1-output neural network



NN output is well simulated!
Signal/bkg., a factor 10 improvement.

B Background – $B \rightarrow K^* \gamma$

- $B \rightarrow K^* \gamma$ background with **mis-id K^\pm as π^\pm** . (BF ~ 50 -100 times bigger!)
- Benefit from the excellent K/π separation in BaBar detector - DIRC.

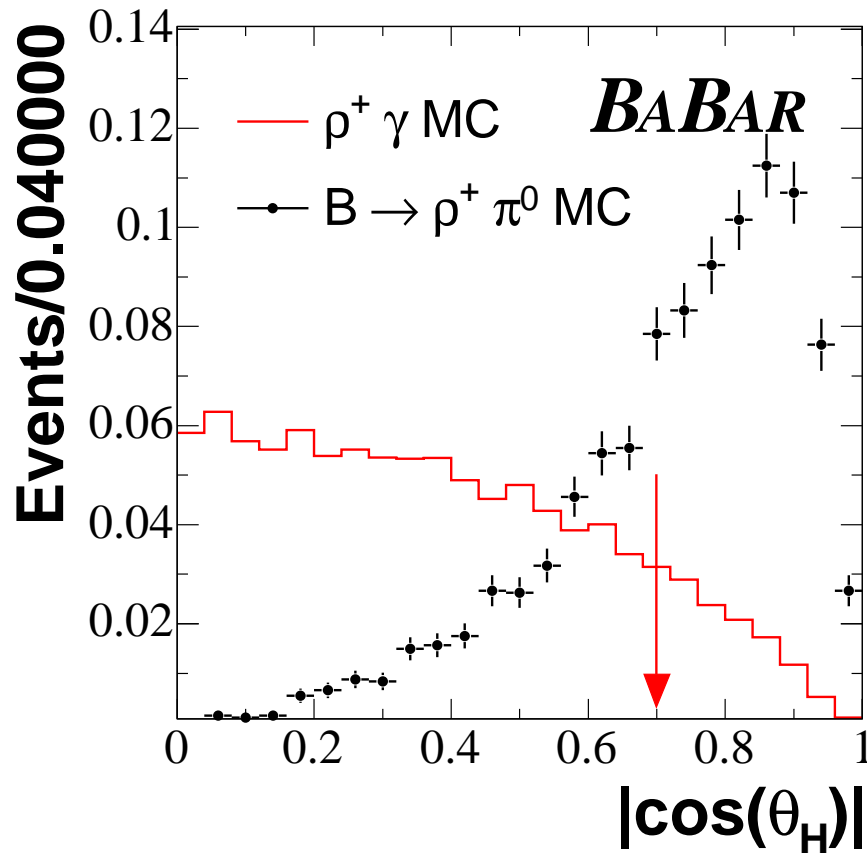


- After all the cuts (including PID).

mode	signal	$B \rightarrow K^* \gamma$
$B^+ \rightarrow \rho^+ \gamma$	28.7	5.4
$B^0 \rightarrow \rho^0 \gamma$	16.8	15.2

- In addition, suppressed by ΔE^* . ($K^* \gamma$ peaks at -60MeV on ΔE^*)
- In $\omega \gamma$, cross-feed from $K^* \gamma$ can be significantly suppressed by PID.

B Background – $B \rightarrow (\rho/\omega)(\pi^0/\eta)$



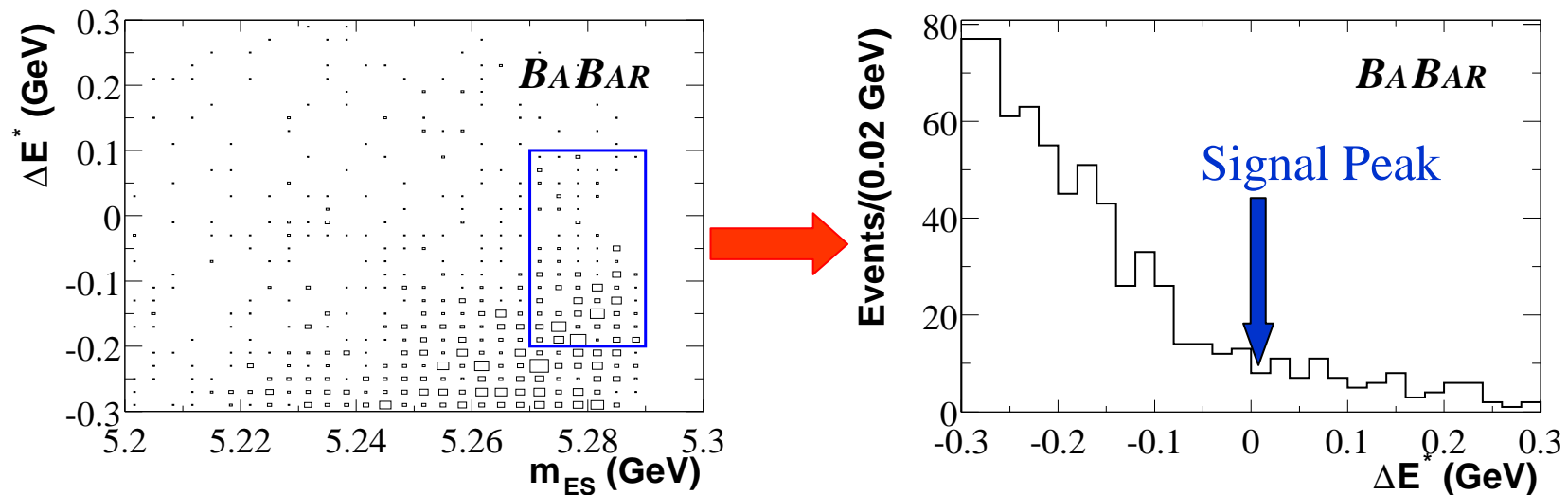
- Some BFs ~ 10 larger than signal decay.
- **Suppressed by helicity angle cut.**
 θ_H : angle between one daughter and ρ/ω direction in ρ/ω rest frame.
- **After all cuts (including $\cos\theta_H$)**

mode	signal	$B \rightarrow (\rho/\omega)(\pi^0/\eta)$
$B^+ \rightarrow \rho^+ \gamma$	28.7	12.9
$B^0 \rightarrow \rho^0 \gamma$	16.8	2.5
$B^0 \rightarrow \omega \gamma$	9.5	2.6

- **In addition, suppressed by ΔE^* .**
 $((\rho/\omega)(\pi^0/\eta)$ peaks between -60MeV to -100MeV on ΔE^*)

B Background – Combinatoric B Bkg.

- Dominated by $B \rightarrow X_s \gamma$ decays.

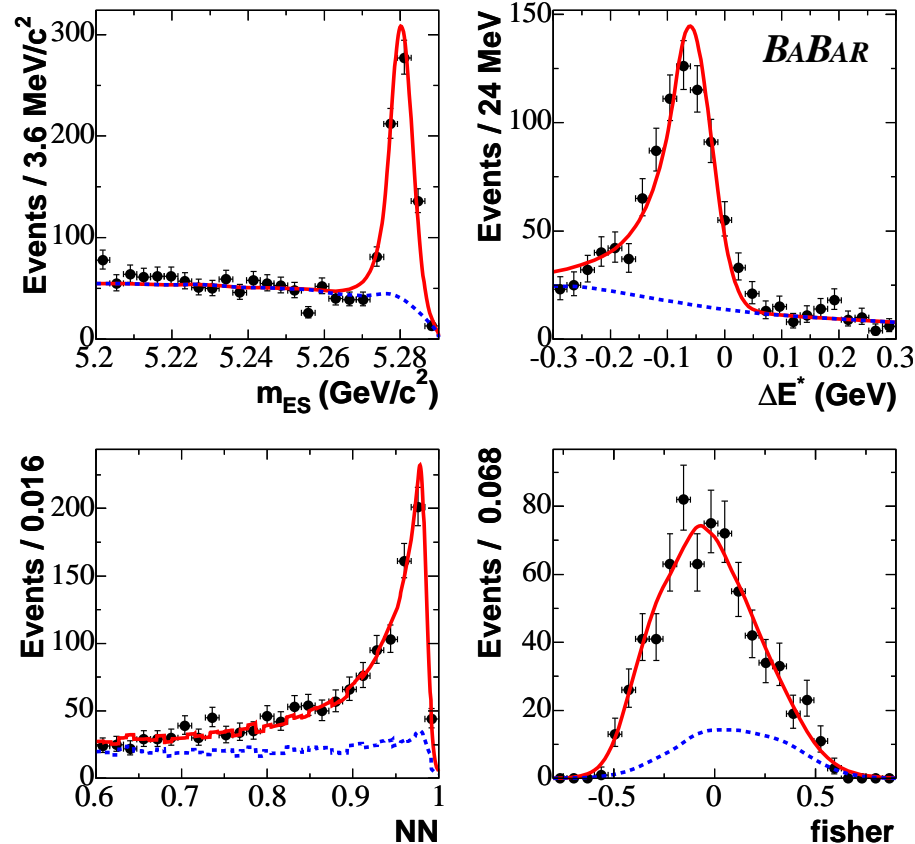


- Improve the separation in the likelihood fit by combining signal side variables, $\cos\theta_B$, $\cos\theta_H$ (after cut) and $\cos\theta_D$ ($\omega\gamma$ only), into a Fisher discriminant.
- This Fisher variable also separates continuum bkg. and $(\rho/\omega)(\pi^0/\eta)$ B bkg. from signal.

Likelihood Fit

- 4-dimension extended maximum likelihood fit:
 - m_{ES} , ΔE^* , NN and Fisher;
- Components:
 - signal;
 - continuum background;
 - $B \rightarrow K^* \gamma$;
 - $B \rightarrow (\rho/\omega)(\pi^0/\eta)$ B bkg.;
 - combinatoric B background.
- Float all yields except $B \rightarrow K^* \gamma$ and $B \rightarrow (\rho/\omega)(\pi^0/\eta)$ B bkg. (taken from MC)
- Allow m_{ES} , ΔE^* shape of cont. bkg. to float.
- Any other shape of components are fixed from MC or sideband data.
- Validate full fit on MC datasets, sideband data, off-resonance data and $K^* \gamma$ control sample.

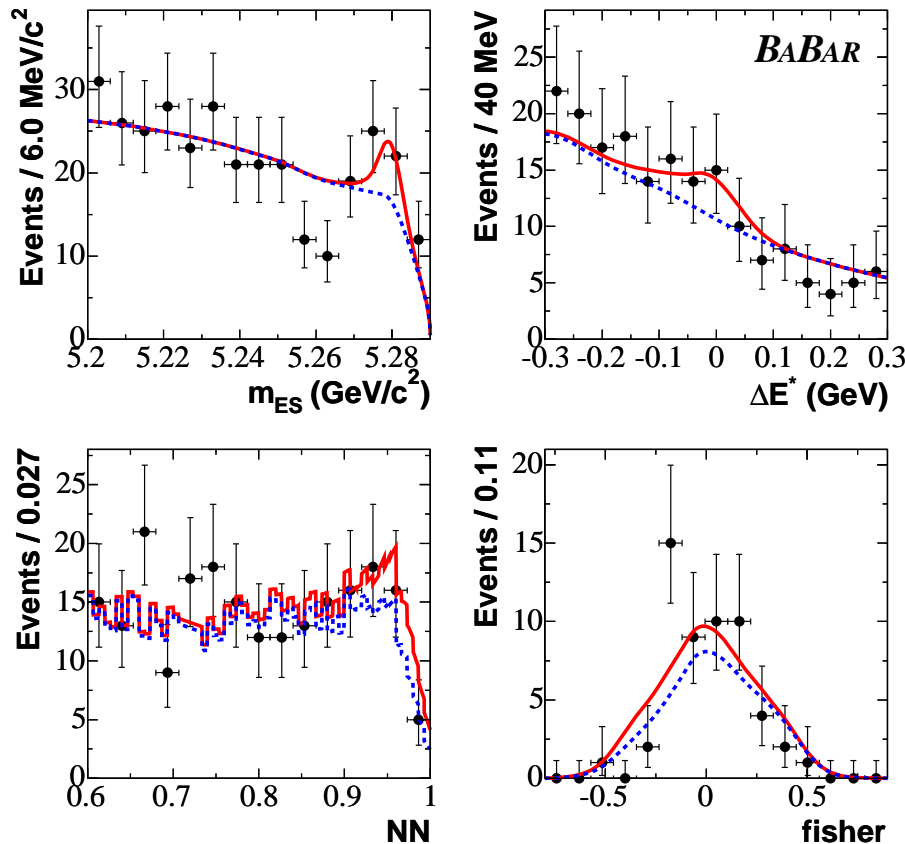
Validation with $K^* \gamma$ Sample



- Release the PID in $\rho^0 \gamma$ mode.
- Components: $K^* \gamma$, continuum bkg., $\rho^0 \pi^0 / \eta$ and combinatoric B. bkg. (only $\rho^0 \pi^0 / \eta$ fixed from MC)
- Yield agrees with expectation from previously measured BF.

$\rho^+\gamma$ Result (191 fb^{-1})

Preliminary

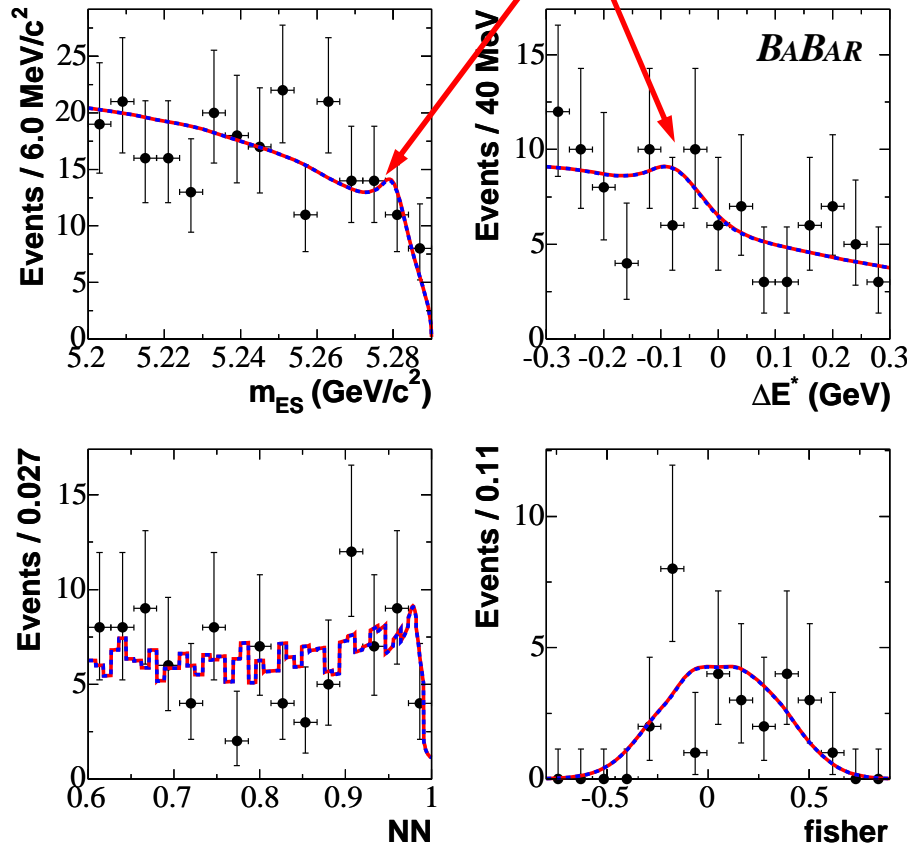


- Components: **signal**, continuum bkg., $\rho^+\pi^0/\eta$, combinatoric B. bkg. and $K^*\gamma$ ($\rho^+\pi^0/\eta$, $K^*\gamma$ fixed from MC)
- $N_{\text{sig}} = 26^{+15+2}_{-14-2}$ events.
- $\epsilon_{\text{eff}} = 13.2 \pm 1.4\%$.
- **Significance = 1.9σ .**
- Upper limit:
 $\text{BF} < 1.8 \times 10^{-6}$ (90% C.L.)

$\rho^0\gamma$ Result (191 fb^{-1})

Preliminary

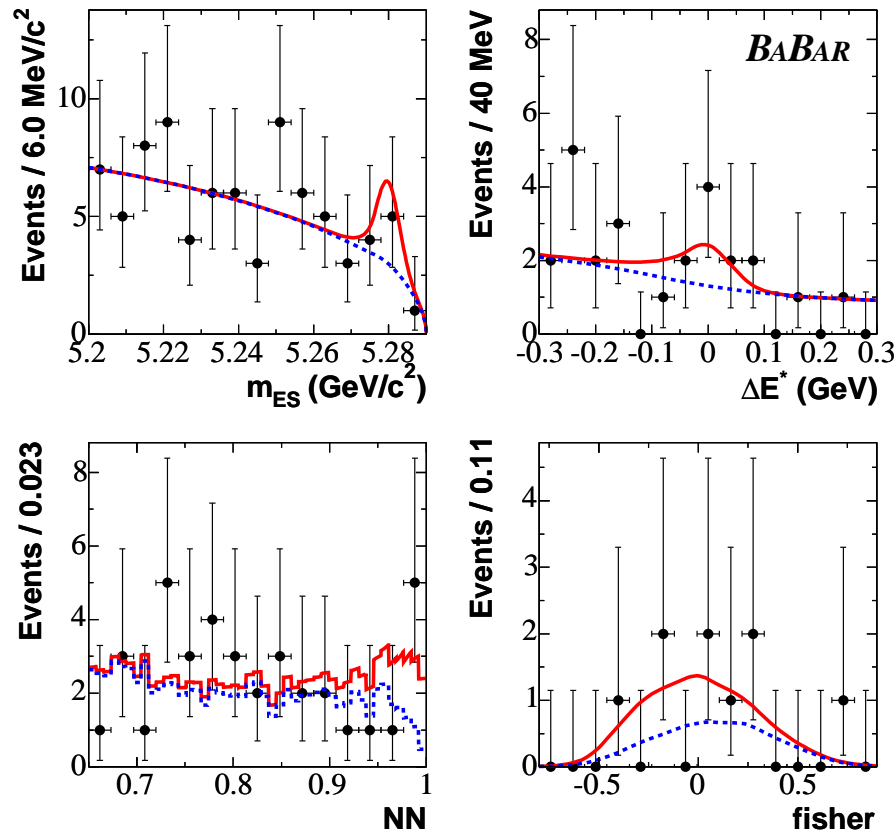
Small peaking background



- Components: **signal**, continuum bkg., $\rho^0\pi^0/\eta$, combinatoric B. bkg. and $K^*\gamma$ ($\rho^0\pi^0/\eta$, $K^*\gamma$ fixed from MC)
- $N_{\text{sig}} = 0.3^{+7.2+1.7}_{-5.4-1.6}$ events.
- $\epsilon_{\text{eff}} = 15.8 \pm 1.9\%$.
- Upper Limit: **$BF < 0.4 \times 10^{-6}$ (90% .C.L.)**

$\omega\gamma$ Result (191 fb^{-1})

Preliminary

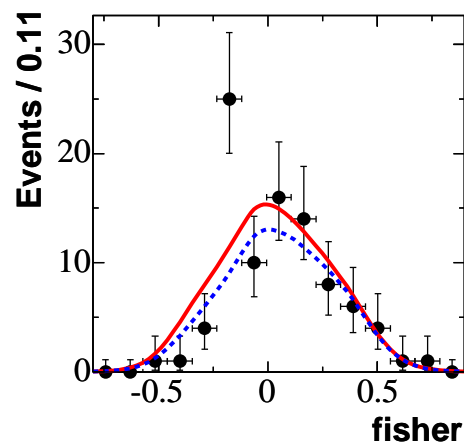
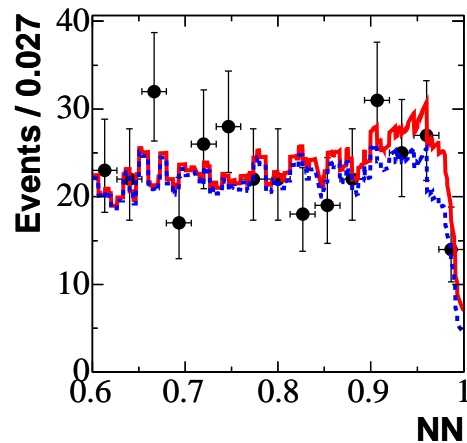
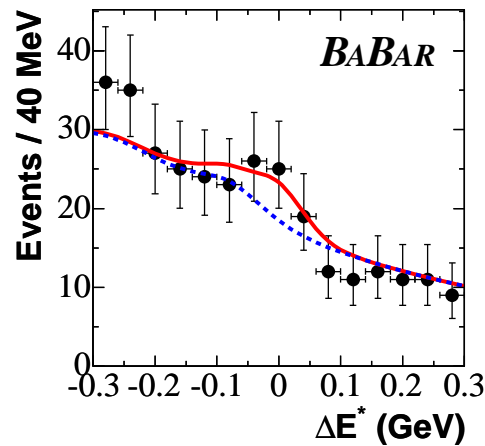
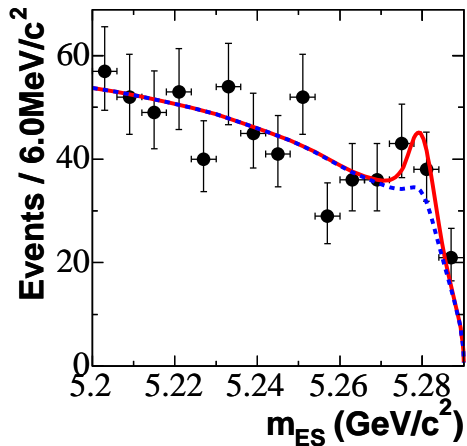


- Components: **Signal**, continuum bkg., $\omega\pi^0/\eta$.
- $N_{\text{sig}} = 8.3^{+7.2+1.3}_{-5.4-1.9}$ events.
- $\epsilon_{\text{eff}} = 8.6 \pm 0.9\%$.
- **Significance = 1.5σ**
- Upper Limit:
 $\text{BF} < 1.0 \times 10^{-6}$ (90% .C.L.)

Combined Result (191 fb^{-1})

Preliminary

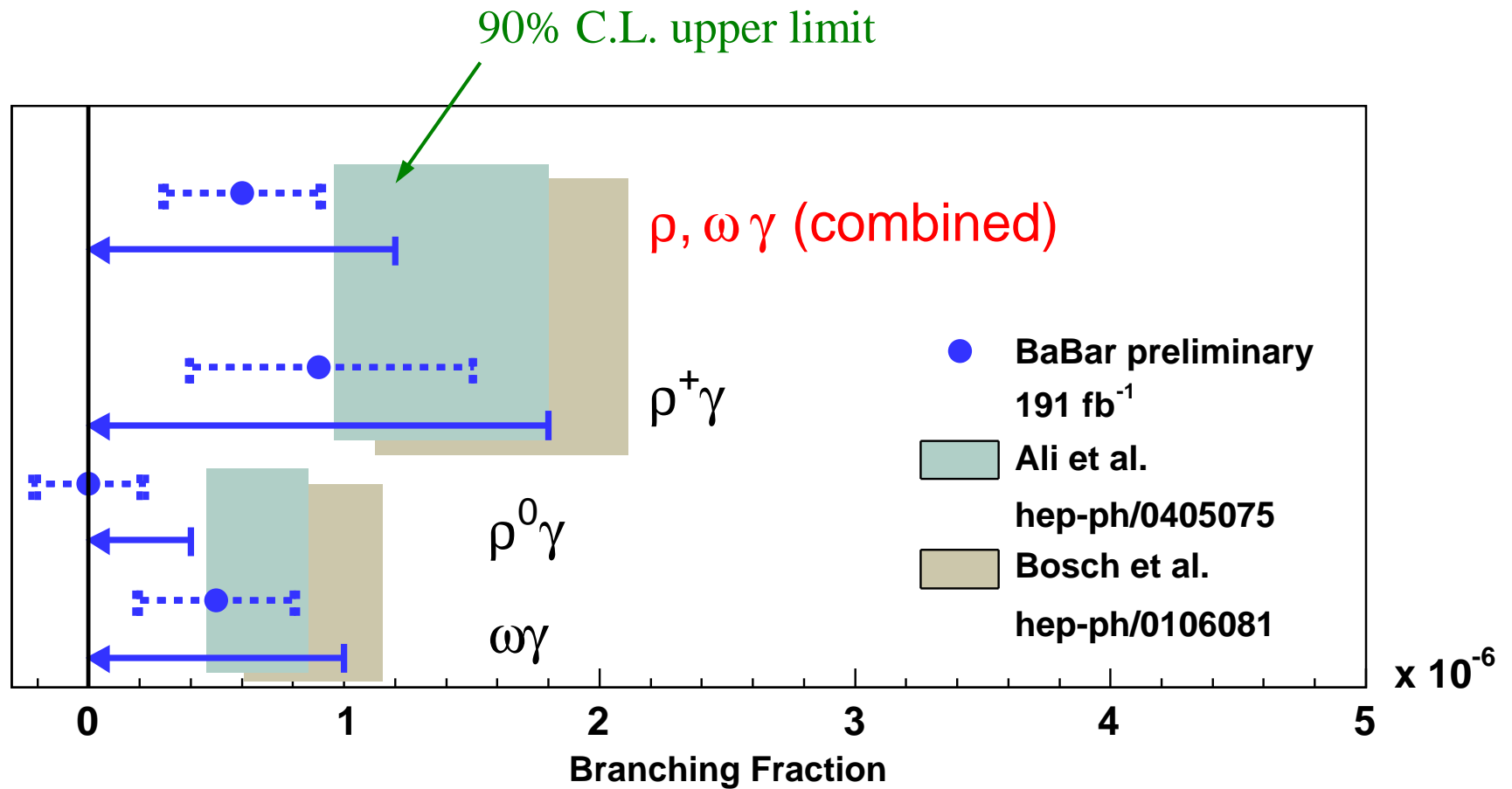
$$\bar{B}[B \rightarrow (\rho, \omega) \gamma] \equiv \frac{1}{2} \left\{ \mathcal{B}(B^+ \rightarrow \rho^+ \gamma) + \frac{\tau_{B^+}}{\tau_{B^0}} [\mathcal{B}(B_d^0 \rightarrow \rho^0 \gamma) + \mathcal{B}(B_d^0 \rightarrow \omega \gamma)] \right\}$$



- Simultaneous fit over three decay modes with:
 $\Gamma(\rho^0 \gamma) = \Gamma(\omega \gamma) = 0.5 \cdot \Gamma(\rho^+ \gamma)$
- $N_{\text{eff}} = \text{BF}(\rho/\omega \gamma) \cdot N_B$:
 $269^{+126+40}_{-120-45}$ events.
- **Significance = 2.1 σ .**
- Upper Limit:
 $\text{BF} < 1.2 \times 10^{-6}$ (90% C.L.)

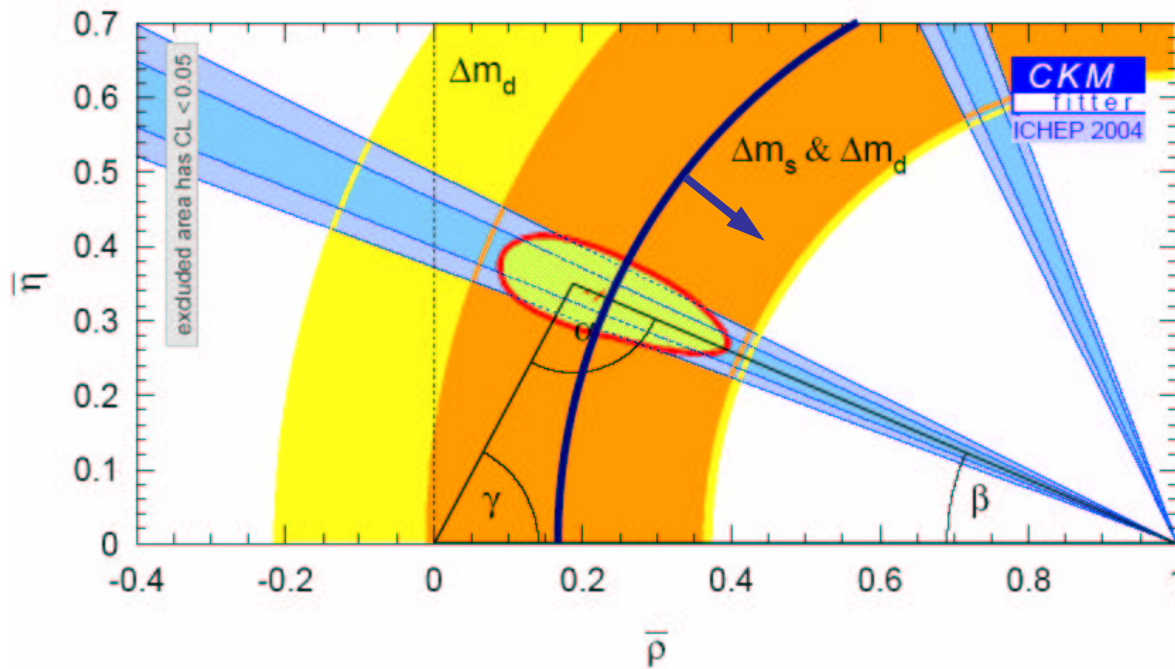
Result Discussion

No evidence for $b \rightarrow d\gamma$ transition in 191fb^{-1} *BaBar* data!



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

$$\frac{\overline{\mathcal{B}}[B \rightarrow (\rho/\omega)\gamma]}{\mathcal{B}(B \rightarrow K^*\gamma)} = \left| \frac{V_{td}}{V_{ts}} \right|^2 \left(\frac{1 - m_\rho^2/M_B^2}{1 - m_{K^*}^2/M_B^2} \right)^3 \zeta^2 [1 + \Delta R]$$



BF ratio < 0.029 →
 $|V_{td}/V_{ts}| < 0.19$ (90% CL)
 ($\zeta^2 = 0.85$, $\Delta R = 0.10$)

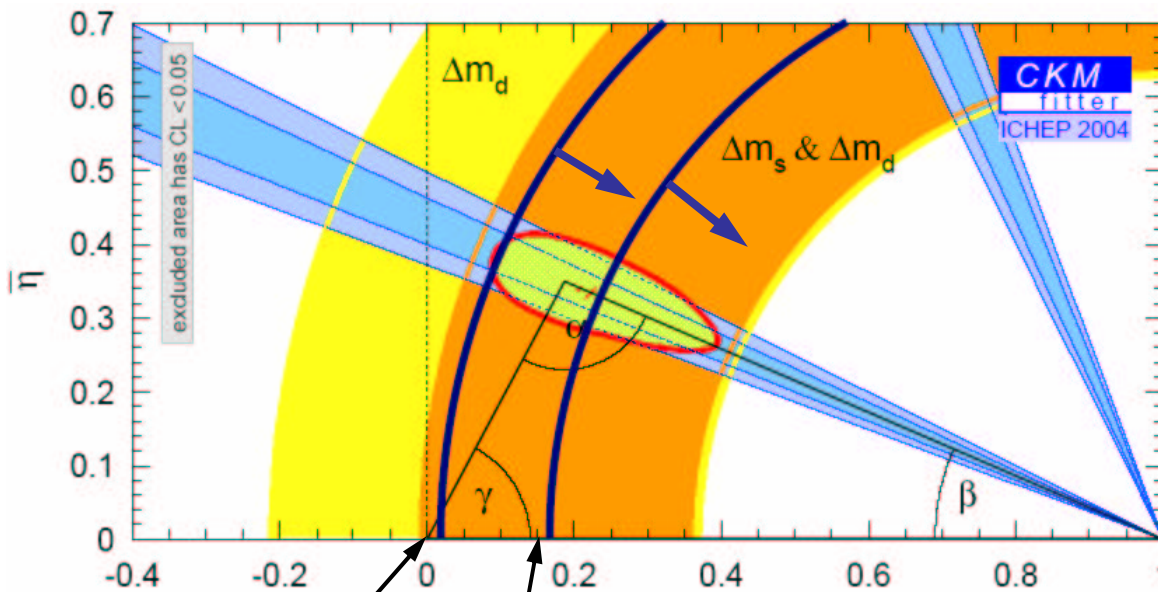
(95% C.L. constraint!)

Constraint on $|V_{td}/V_{ts}|$ (II)

$$\frac{\overline{\mathcal{B}}[B \rightarrow (\rho/\omega)\gamma]}{\mathcal{B}(B \rightarrow K^*\gamma)} = \left| \frac{V_{td}}{V_{ts}} \right|^2 \left(\frac{1 - m_\rho^2/M_B^2}{1 - m_{K^*}^2/M_B^2} \right)^3 \zeta^2 [1 + \Delta R]$$

weak annihilation
correction $\Delta R = 0.1 \pm 0.1$

SU(3) breaking of
form factors $\zeta^2 = 0.85 \pm 0.10$



$(\zeta^2, \Delta R) = (0.75, 0.00)$
 $(\zeta^2, \Delta R) = (0.85, 0.10)$

(95% C.L. constraint!)

BF ratio < 0.029 →
 $|V_{td}/V_{ts}| < 0.19$ (90% CL)
($\zeta^2 = 0.85, \Delta R = 0.10$)

Summary



- With 191fb^{-1} BaBar data, no evidence for $b \rightarrow d\gamma$ transitions! Submitted to PRL, hep-ex/0408034.
- But penguin decays are starting to constrain the SM allowed region on the ρ - η plane.
- In the next 1-2 years, the measurement of $b \rightarrow d\gamma$ on BaBar dataset is highly possible; then $|V_{td}/V_{ts}|$.
- The determination of $|V_{td}/V_{ts}|$ using penguin decays requires more accurate theoretical determination of ζ and ΔR parameters.