Measurement of $B \to \rho/\omega\gamma$ and study of $B \to K^{*}\gamma$ with BaBar

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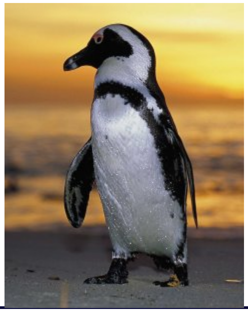
on behalf of the
BABAR collaboration

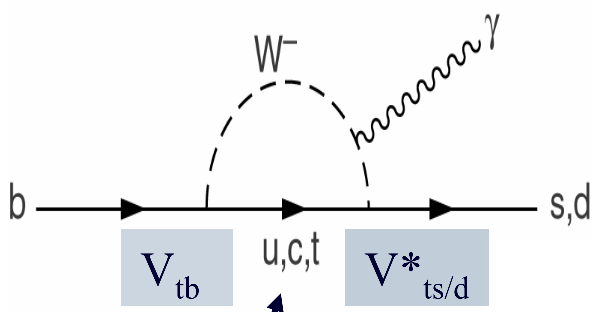
DPF2006



Charge conjugate states implied throughout talk

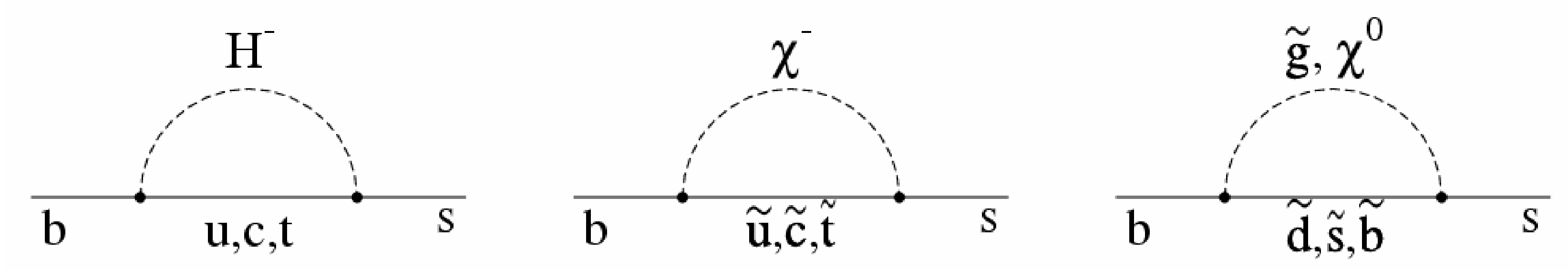
$b \rightarrow s,d$ transitions

- Flavor changing neutral current
- Exists in Standard Model only through quantum corrections
  - BF $\sim 10^{-6}$ ($\rho\gamma$) , $\sim 10^{-5}$ ($K^*\gamma$)
- Top quark dominates in loop (SM)
  - Amplitude proportional to $V_{tb}V^*_{ts/d}$



Leading order short distance contribution

- Non-Standard Model particles can contribute in the loop



Quantities Obtained from Measurements

- Extract $\left|\frac{V_{td}}{V_{ts}}\right|$ with $B\to\rho\gamma$ and $B\to K^*\gamma$
  - compare with other measurements of $\left|\frac{V_{td}}{V_{ts}}\right|$ (B_s mixing)

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

S_ρ: 1(.5) for $\rho^{\pm}$(ρ^0)

Form factor ratio $1/\zeta$ = 1.17±0.09
hep-ph/0603232

Annihilation amplitude corrections
$\Delta R = 0.1\pm0.1$
Ali, Lunghi, Parkhomenko PLB 595, 323 (2004)

- Hadronic uncertainties partially cancel in ratios
- Direct CP and isospin asymmetry measurements of $B\to K^*\gamma$ are sensitive to new physics

$$\Delta_{0+} \equiv \frac{\Gamma(B^0\to K^{*0}\gamma)-\Gamma(B^+\to K^{*+}\gamma)}{\Gamma(B^0\to K^{*0}\gamma)+\Gamma(B^+\to K^{*+}\gamma)}$$

SM: $A_{CP} < 1\%$, $\Delta_{0+} = +(2.6 \pm 0.8) \times 10^{-2}$ Matsumori, Sanda, Keum PRD 72, 014013 (2005)

Previous publications from Babar

B→ργ

Mode	$n_{\rm sig}$	Significance (σ)	$\epsilon(\%)$	$\mathcal{B}(10^{-6})$	$\mathcal{B}(10^{-6})$ 90% C.L.
$B^+ \to \rho^+\gamma$	26^{+15+2}_{-14-2}	1.9	13.2 ± 1.4	$0.9^{+0.6}_{-0.5} \pm 0.1$	< 1.8
$B^0 \to \rho^0\gamma$	$0.3^{+7.2+1.7}_{-5.4-1.6}$	0.0	15.8 ± 1.9	$0.0 \pm 0.2 \pm 0.1$	< 0.4
$B^0 \to \omega\gamma$	$8.3^{+5.7+1.3}_{-4.5-1.9}$	1.5	8.6 ± 0.9	$0.5 \pm 0.3 \pm 0.1$	< 1.0
Combined	—	2.1	—	$0.6 \pm 0.3 \pm 0.1$	< 1.2

uses 191 fb^{-1}

SM: $(1.38\pm0.42) \times 10^{-6}$
hep-ph/0405075

Combined BF: $\mathcal{B}(B \to (\rho,\omega)\gamma) = \frac{1}{2} \cdot \{\mathcal{B}(B^\pm \to \rho^\pm\gamma) + \frac{\tau_{B^+}}{\tau_{B^0}} \cdot [\mathcal{B}(B^0 \to \rho^0\gamma) + \mathcal{B}(B^0 \to \omega\gamma)]\}$

PRL 94, 011801 (2005)

B→K*γ

Mode	$\epsilon(\%)$	N_S	Combined $\mathcal{B}(\times 10^{-5})$	Combined $\mathcal{A}_{CP}$
$K^+\pi^-$	24.4±1.4	583±30	3.92±0.20±0.24 ($K^+\pi^-$, $K_s\pi^0$)	$-0.013 \pm 0.036 \pm 0.010$ (all modes)
$K_s\pi^0$	15.3±1.9	62±15		
$K^+\pi^0$	17.4±1.6	251±23	3.87±0.28±0.26 ($K^+\pi^0$, $K_s\pi^+$)	
$K_s\pi^+$	22.1±1.4	157±16		

uses 81.9 fb^{-1}

Isospin asymmetry: $-0.046 < \Delta_{0-} < 0.146$ 90% C.L.

PRD 70 112006 (2004)

Experimental Techniques

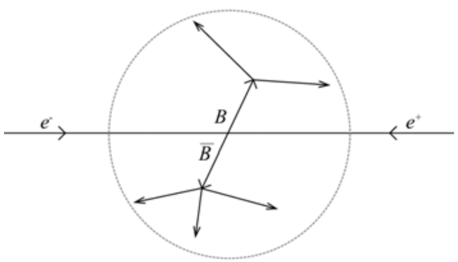
- Reconstruct $B \to \rho/\omega\, \gamma$ with modes $\rho^{+/0} \to \pi^+\pi^{0/-}$, $\omega \to \pi^+\pi^-\pi^0$

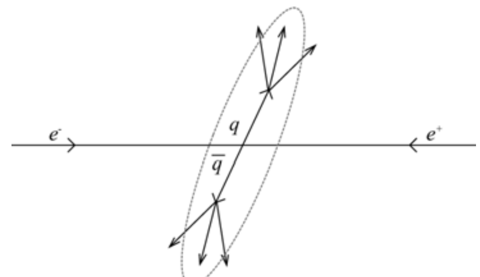
- Major sources of background
  - continuum (light $q\bar{q}$) events
  - $B \to K^*\gamma$ (BF ~ 40 times higher)

- Apply selection criteria
  - 1.5 GeV $< E_\gamma^* <$ 3.5 GeV
  - use of DIRC for particle identification (π/K separation)
  - ρ/ω mass selection
  - apply veto for γ's coming from π^0's and η's

Experimental Techniques 2

- Suppress background using different topology, angular information





- Combine background suppression variables using Neural Net

- Define variables to reconstruct B meson

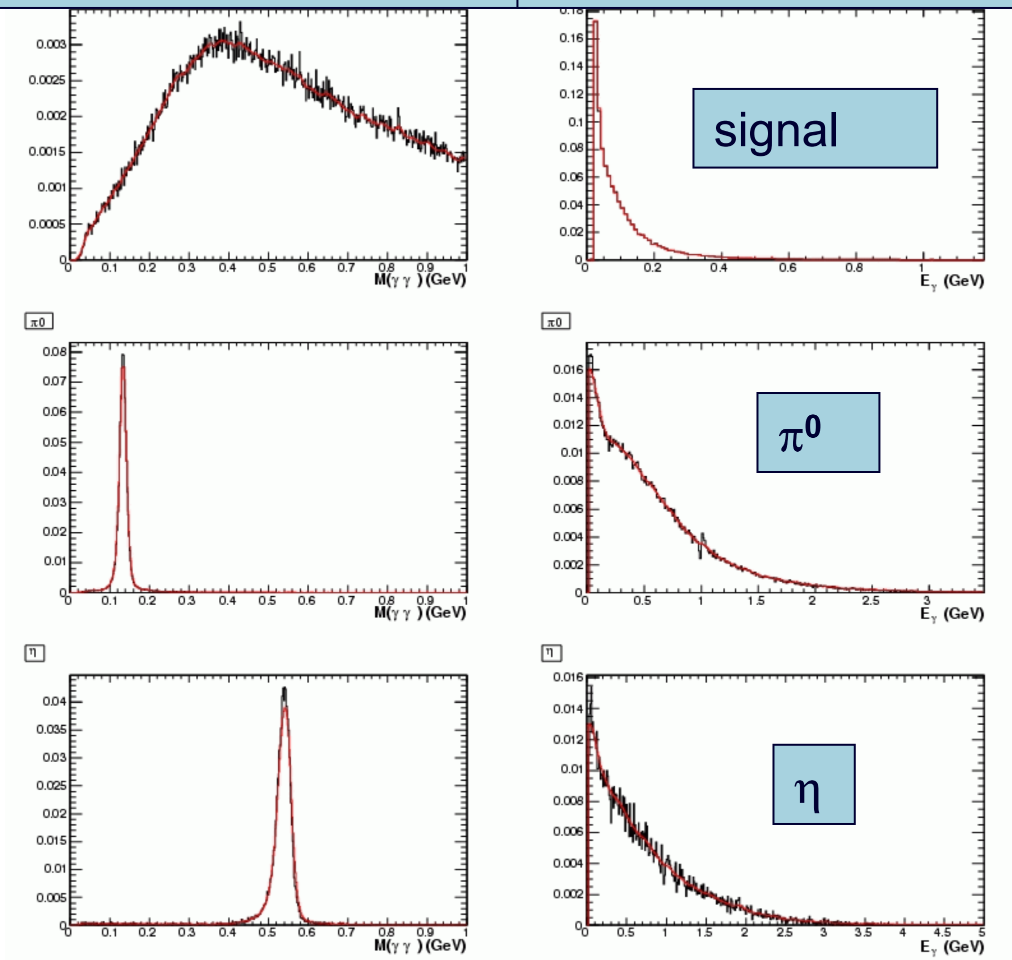
$$m_{ES} = \sqrt{\left(E^{*2}_{beam} - |\vec{p}^{\,*}_B|^2\right)} \qquad \Delta E^* = E^*_B - E^*_{beam}$$

- Use multidimensional maximum likelihood fit with different components for signal and background ($q\bar{q}$, $B\bar{B}$)

$\pi^0/\ \eta$ veto likelihood

- combine high energy γ candidate with all other γ candidates in the event and determine consistency with π^0/η

Two-photon mass	Photon energy

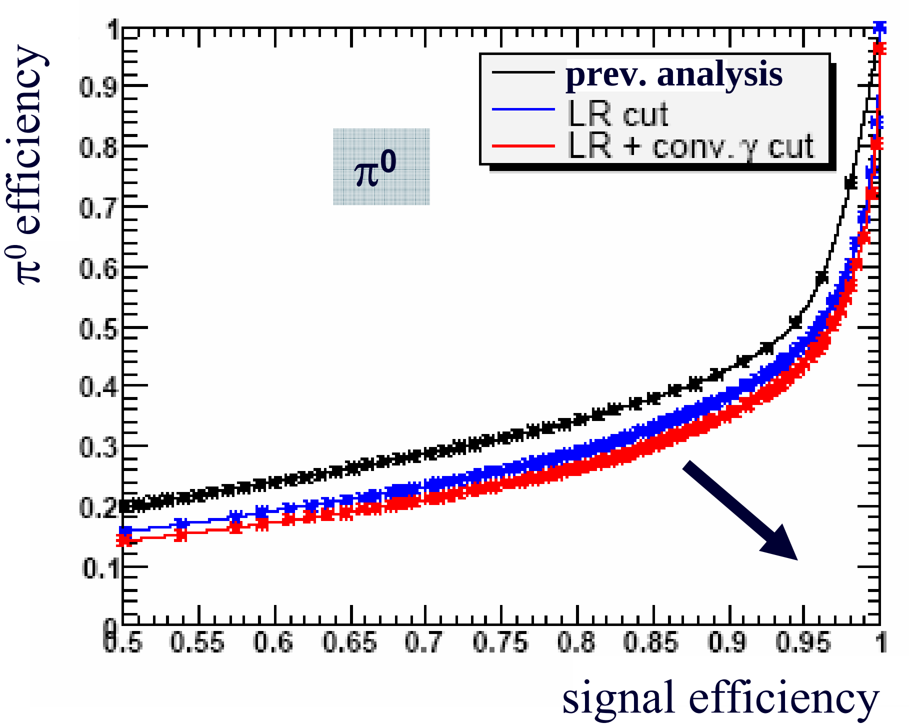


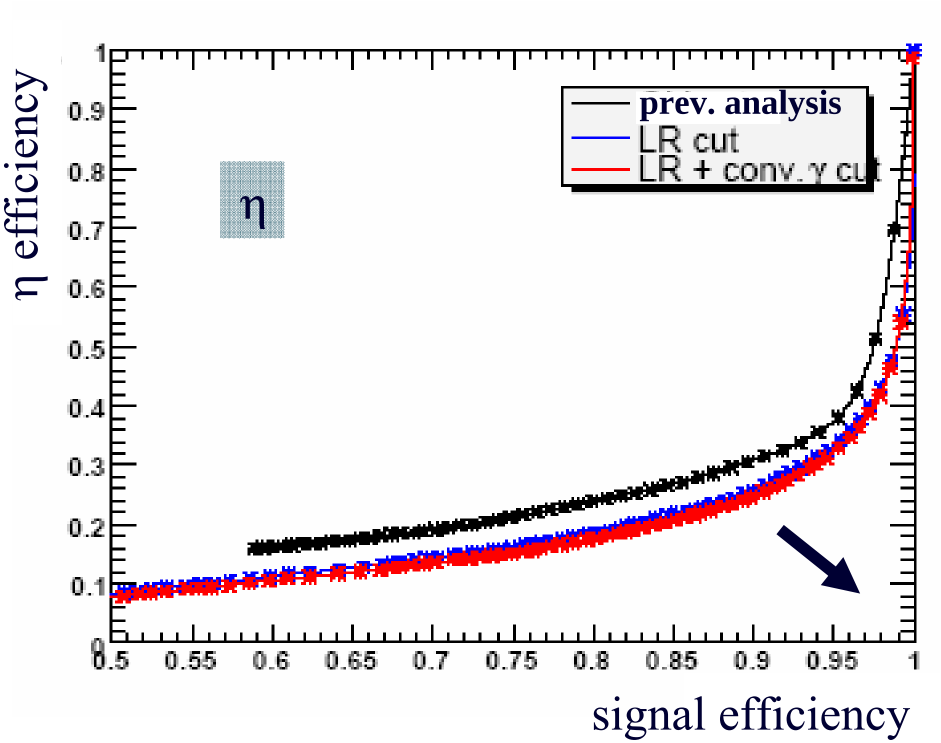
simulated signal and background

- form 2 dimensional likelihood ratio (LR)

- also consider converted photons and make selection based on $M(\gamma e^+e^-)$

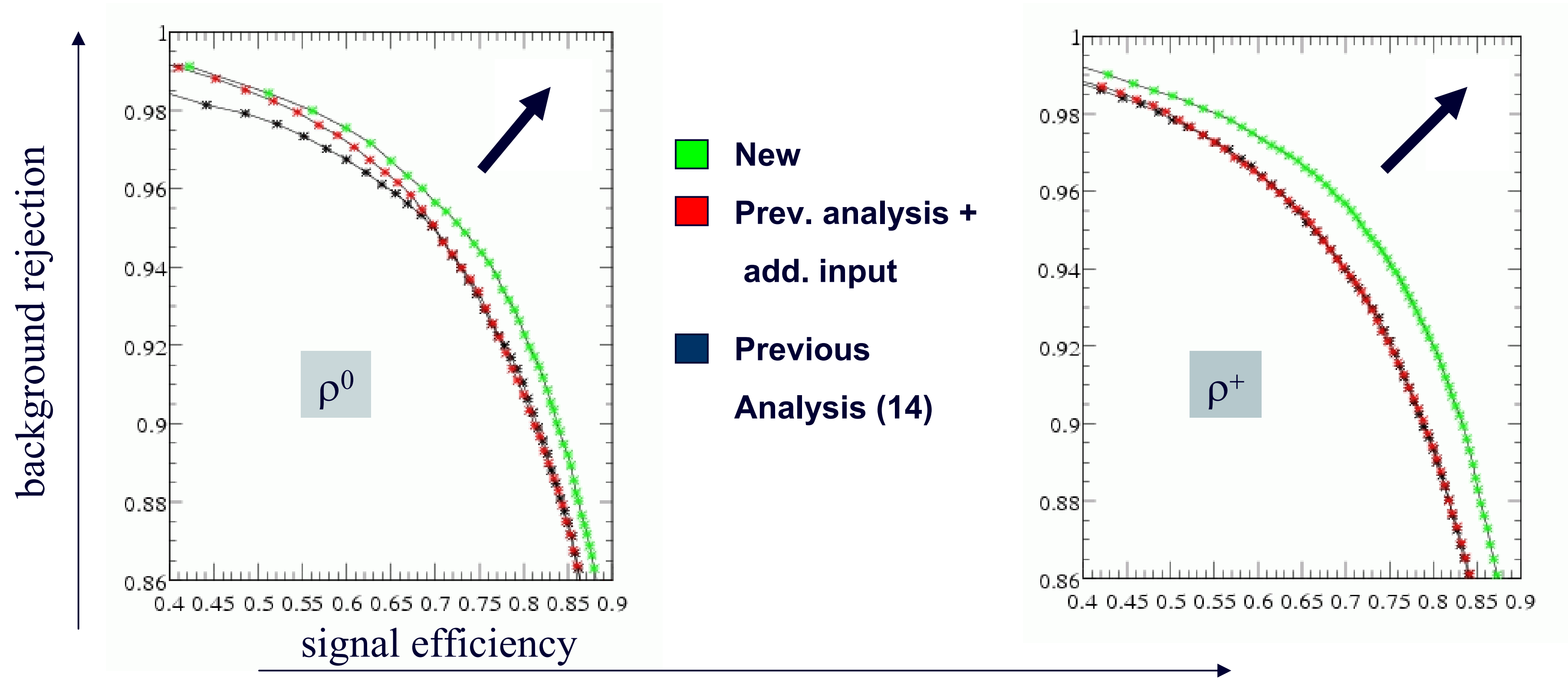
π^0/η veto performance





$B \to \rho/\omega\gamma$ continuum suppression

- Neural net contains 33 input variables
  - Event shape variables (2nd Fox-Wolfram moment, angle between γ and thrust axis….) (11)
  - Variables that detect the presence of flavor in rest of event (4)
  - Kinematic properties of e, μ, K in rest of event (18)



$B \to \rho/\omega\gamma$ likelihood fit

- Optimize cuts by maximizing signal significance in fit region defined by
  $|\Delta E^*| < 0.3$ and $m_{ES} > 5.22$

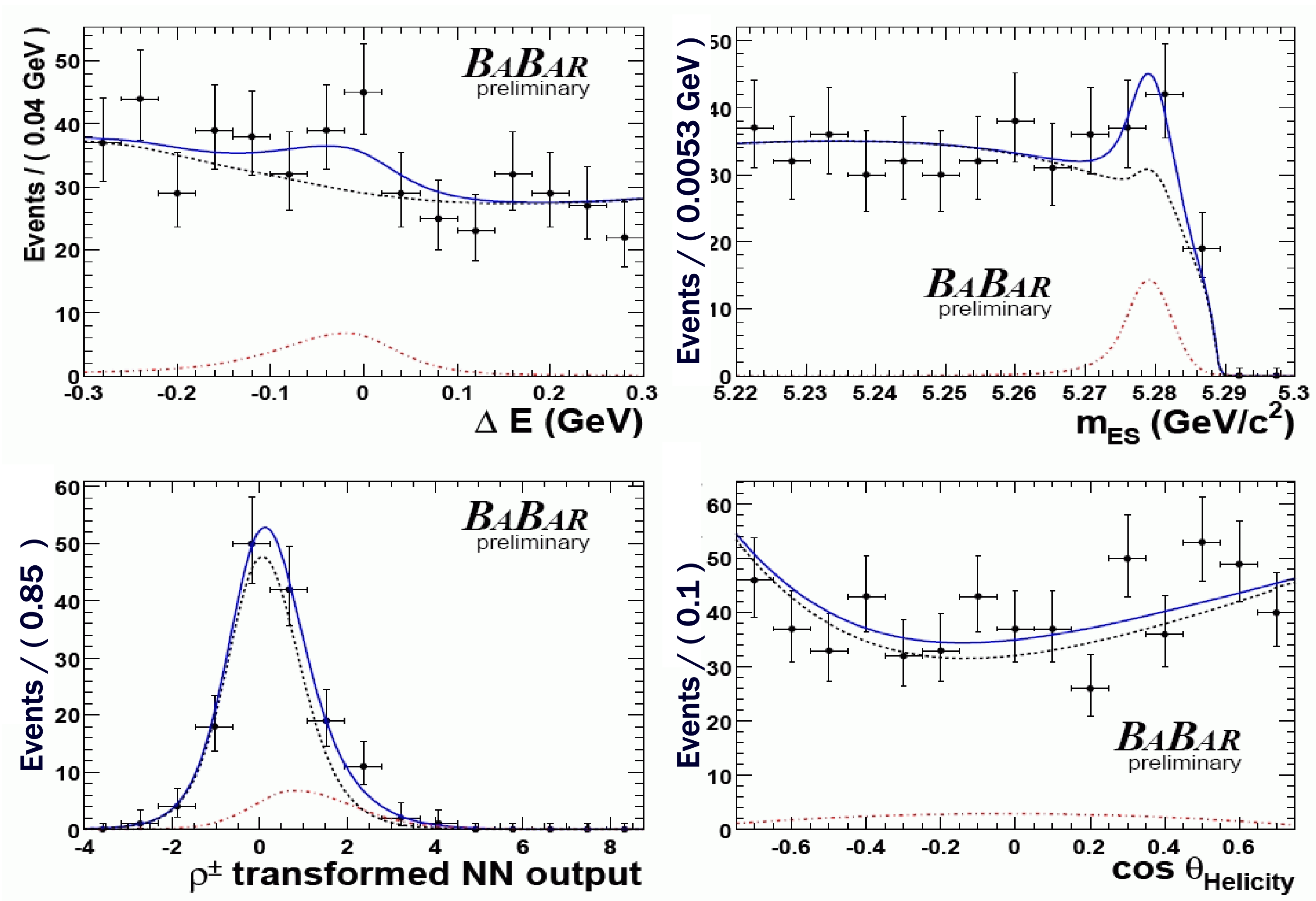
- Four dimensional fit for $\rho\gamma$ and five for $\omega\gamma$
  - Fit variables: m_{ES}, ΔE^*, transformed NN output, $\cos\theta_{helicity}$
    + $\cos\theta_{dalitz}$ ($\omega\gamma$)

$\theta_{helicity}(\rho\gamma)$ = angle between π^+ and B in ρ rest frame
$\theta_{helicity}(\omega\gamma)$ = angle between the normal of $\pi^+\pi^-$ plane and B in ω rest frame
θ_{dalitz} = angle between π^0 and π^+ in $\pi^+\pi^-$ rest frame

transformed NN output $= \tanh^{-1}\left(\frac{(NN - c_1)\cdot(1-c_2)}{c_3}\right), \quad c_i = \text{constant}$

- $\rho^0\gamma$ fit has $K^{*0}\gamma$ and $K^{*+}\gamma$ as separate components
  $\rho^+\gamma$ treats $K^{*+}\gamma$ ($K^{*+} \to K^+\pi^0$) separately

$B^+ \to \rho^+\gamma$ fit projections



Preliminary results

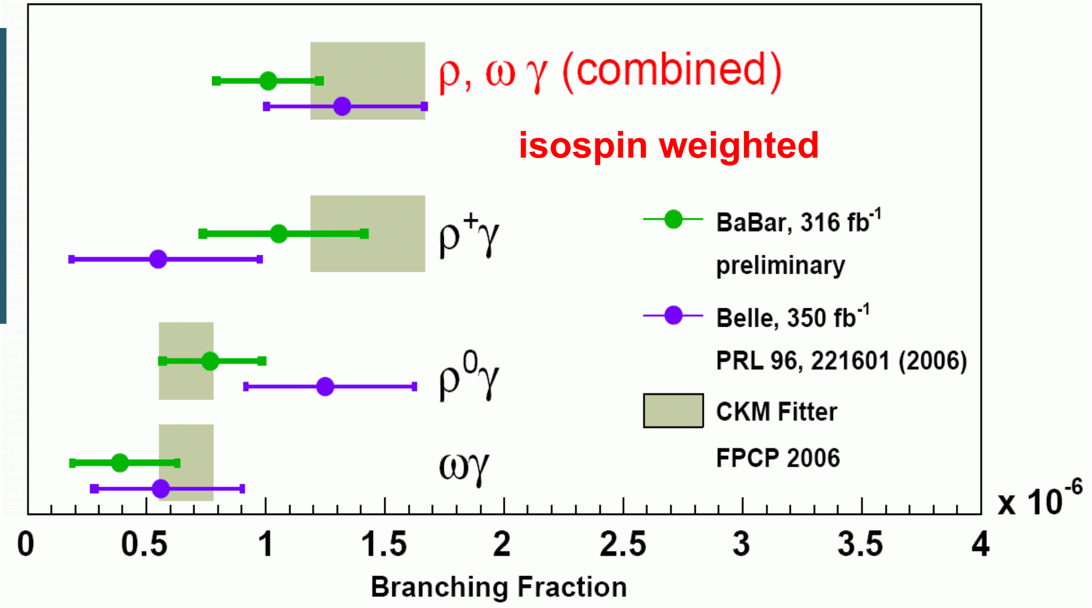
Mode	n_{sig}	Significance	$\epsilon(\%)$	$\mathcal{B}(10^{-6})$	
$B^+ \to \rho^+\gamma$	$42.4^{+14.1}_{-12.6}$	4.1σ	11.6	$1.06^{+0.35}_{-0.31} \pm 0.09$	
$B^0 \to \rho^0\gamma$	$38.7^{+10.6}_{-9.8}$	5.2σ	14.5	$0.77^{+0.21}_{-0.19} \pm 0.07$	
$B^0 \to \omega\gamma$	$11.0^{+6.7}_{-5.6}$	2.3σ	8.1	$0.39^{+0.24}_{-0.20} \pm 0.03$	$(< 0.84$ at 90% C.L.$)$

Isospin asymmetry:

$$\frac{\Gamma(B^+ \to \rho^+\gamma)}{2\Gamma(B^0 \to \rho^0\gamma)} - 1 = -0.36 \pm 0.27$$

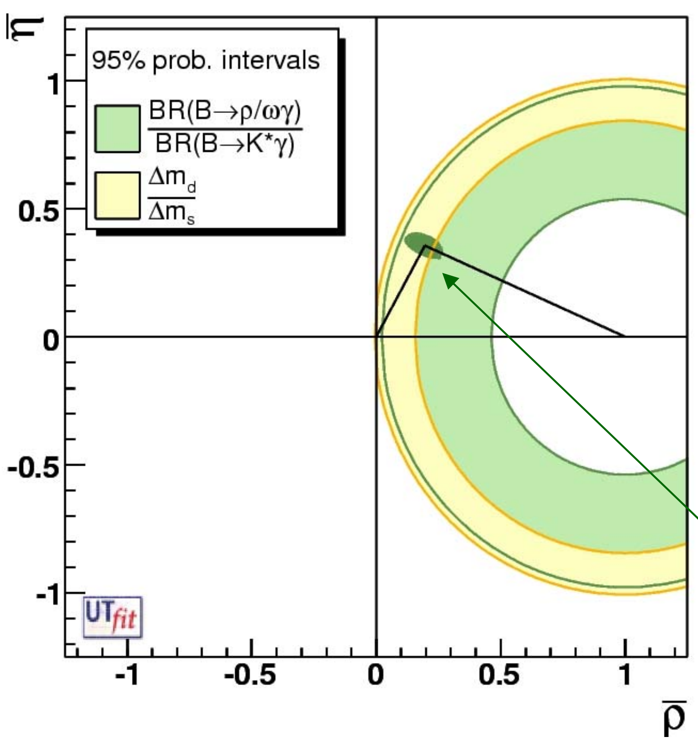
Simultaneous fit result:

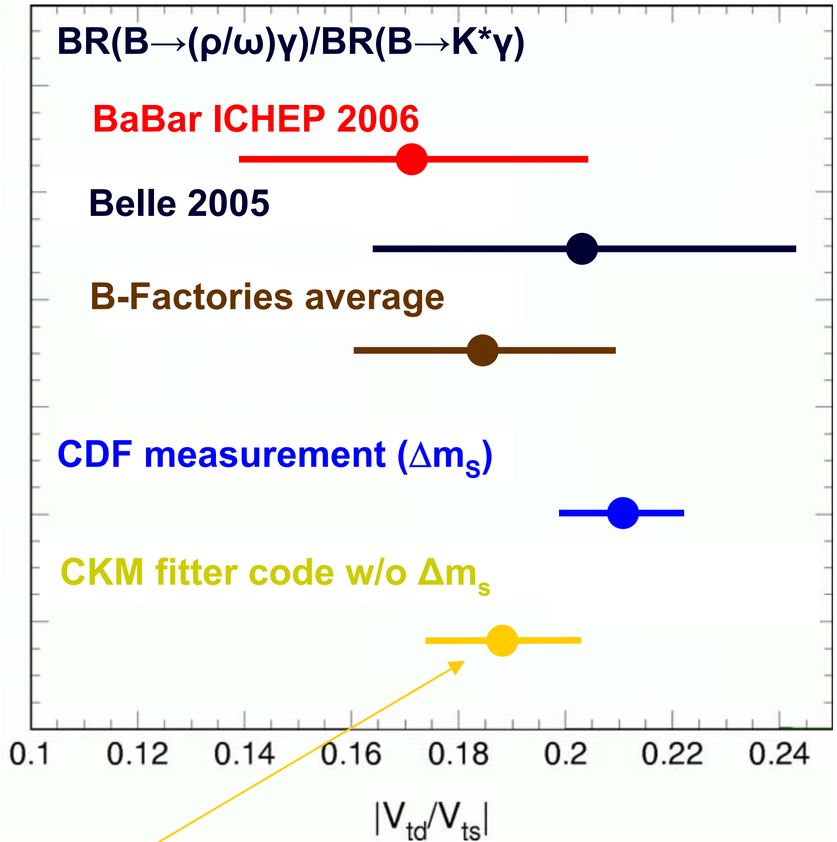
$$\mathrm{BF}[B \to (\rho,\omega)\gamma] = (1.01 \pm 0.21 \pm 0.08) \times 10^{-6}$$



$\left|\frac{V_{td}}{V_{ts}}\right|$ comparisons

$$\left|\frac{V_{td}}{V_{ts}}\right| = 0.171^{+0.018}_{-0.021}(\text{exp})^{+0.017}_{-0.014}(\text{theory})$$

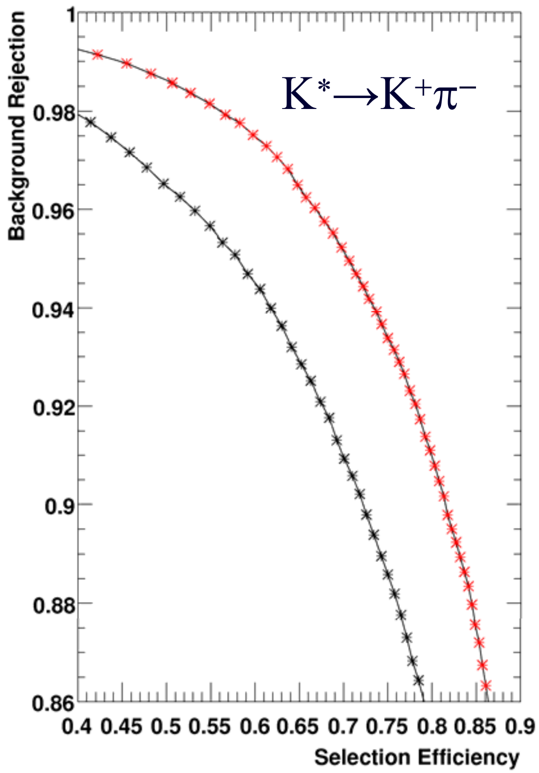




Global fit excludes Δm_s and $B \to \rho(\omega)\gamma$

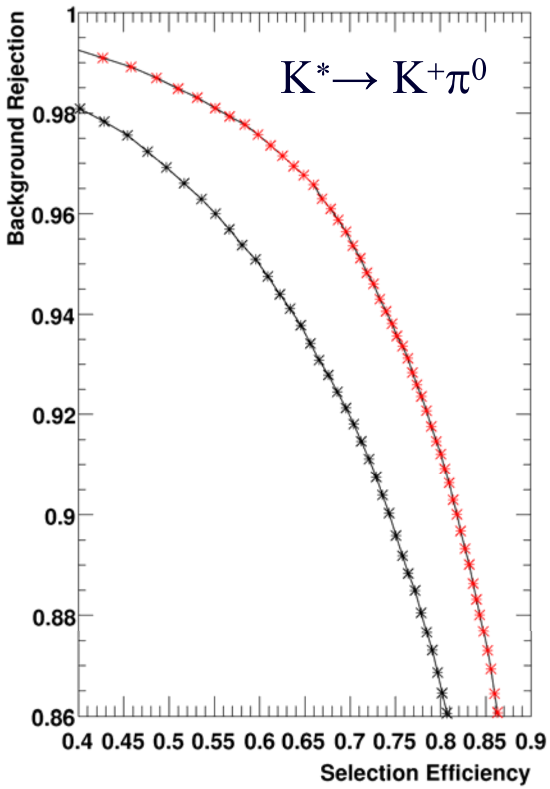
$B \to K^*\gamma$ (in progress)

- Reconstruct in modes: $K^{*0} \to K^+\pi^-$, $K_S\,\pi^0$ / $K^{*+} \to K^+\pi^0$, $K_S\,\pi^+$
- use same framework as $B \to \rho\gamma$ (use π^0/η likelihood ratios)
- Neural Net (13 inputs)
  - event shape variables in addition to variables that detect presence of flavor



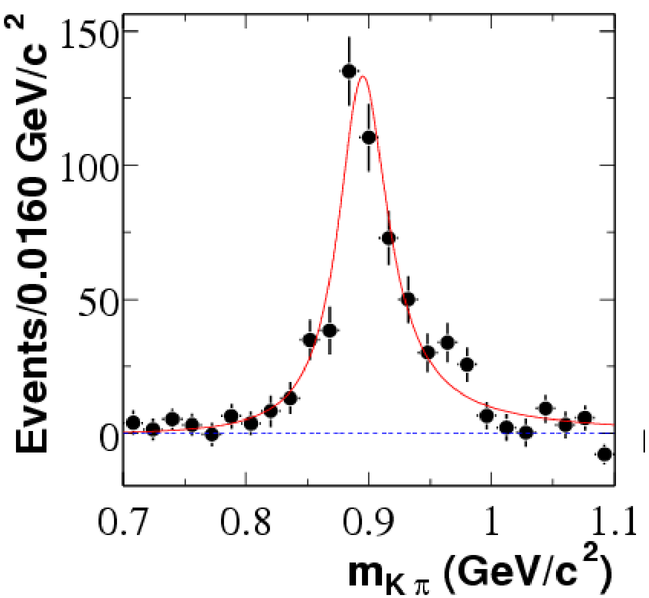
New analysis

Previous analysis



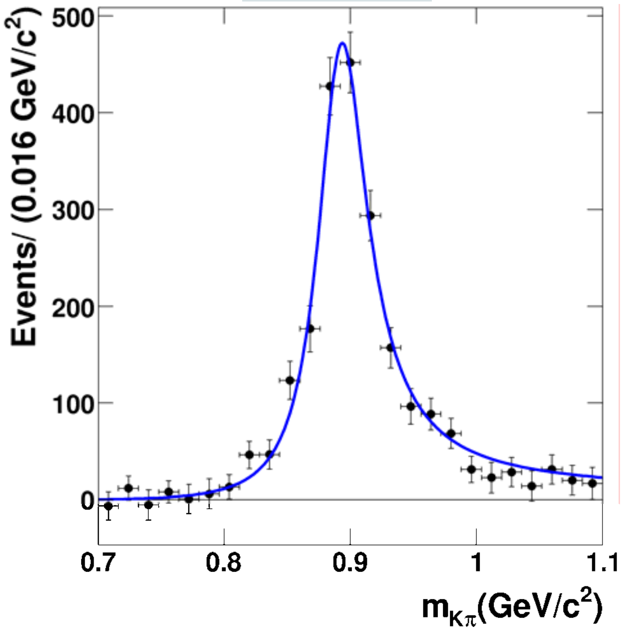
$B \to K^*\gamma$ $(K^* \to K^+\pi^-)$

81.9 fb^{-1}



Previous mass peak

288 fb^{-1}



New mass peak

- Background subtracted using m_{ES} sidebands
- P-wave relativistic Breit-Wigner line shapes used to represent data

Conclusions

- Improved upon previous $B \to \rho/\omega\gamma$ analysis
- Babar observes the decay $B^0 \to \rho^0\gamma$ now , and finds the first evidence for the decay $B^+ \to \rho^+\gamma$. The combined branching fraction from Babar is

$$\overline{\mathrm{BF}}[B \to (\rho/\omega)\gamma] = (1.01 \pm 0.21 \pm 0.08) \times 10^{-6}$$

which is the most precise measurement of this decay rate. This is used to obtain

$$\left|\frac{V_{td}}{V_{ts}}\right| = 0.171^{+0.018}_{-0.021}(\mathrm{exp})^{+0.017}_{-0.014}(\mathrm{theory})$$

- stay tuned for result from the $B \to K^*\gamma$ analysis