

But what did we really measure?

- ◆ We actually observe a weighted sum of $b \rightarrow s \gamma$ decays:
 - ❖ Charged B , neutral B
 - ❖ Low mass X_s , high mass
 - ❖ Ambiguous decays for PseudoReco ($B^0 \rightarrow K^0 \dots$) are only measured by lepton analysis
 - ❖ If at most $\pm 10\%$ difference in individual A_{CP} 's:
Unevenness in our weightings \Rightarrow asymmetry that differs from uniform weighting by no more than ± 0.02 -- add to systematic
- ◆ Measure no A_{CP} dependence on M_X or $E_{\gamma'}$ (but limited stats)
- ◆ Sensitivity to $b \rightarrow d \gamma$
 - ❖ In SM, rate down by $|V_{td}/V_{ts}|^2 \approx 1/20$
 - ❖ But A_{CP} for $b \rightarrow d \gamma$ up by factor of 20 and opposite sign
 - ❖ Lepton tag: $\epsilon_d/\epsilon_s = 1.1$
PseudoReco: $\epsilon_d/\epsilon_s = 0.56$
Combined: $\epsilon_d/\epsilon_s = 0.65$
 - ❖ MisId rates
Lepton - same
PseudoReco - $\alpha = 0.4$
 - ❖ We've really measured a weighted sum
$$A_{CP} = 0.965A(b \rightarrow s\gamma) + 0.02A(b \rightarrow d\gamma)$$

Exclusive Radiative B decays

◆ Analyses:

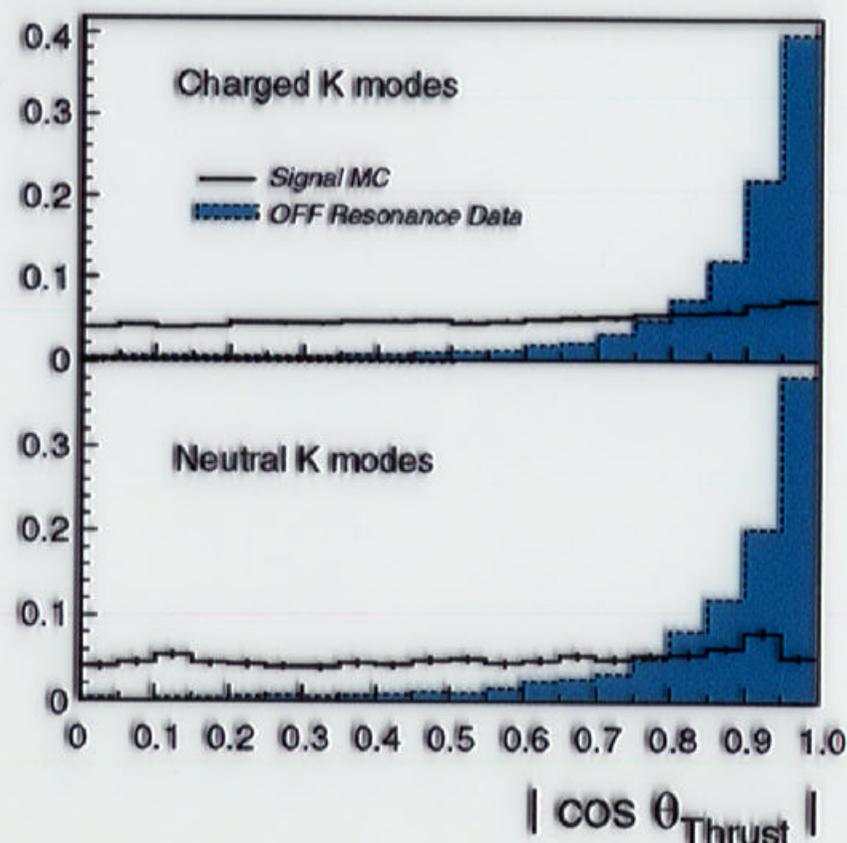
- ❖ Update the 1993 $K^*\gamma$ discovery analysis with full Cleo II+II.V dataset
 - ❖ Look for heavier K^* resonances
 - ❖ Look for exclusive $b \rightarrow d\gamma$ to set limits on $|V_{td}/V_{ts}|$
 - ❖ Look for $B \rightarrow \phi\gamma$ (non-penguin radiative box diagram) [No theoretical rate prediction]
[All new analyses above: PRL 84, 5283 (2000)]
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- ❖ and $\bar{B}^0 \rightarrow D^{*0}\gamma$ (possibly enhanced non-penguin)

9.7×10^6 BB pairs

4.1 fb^{-1} off resonance

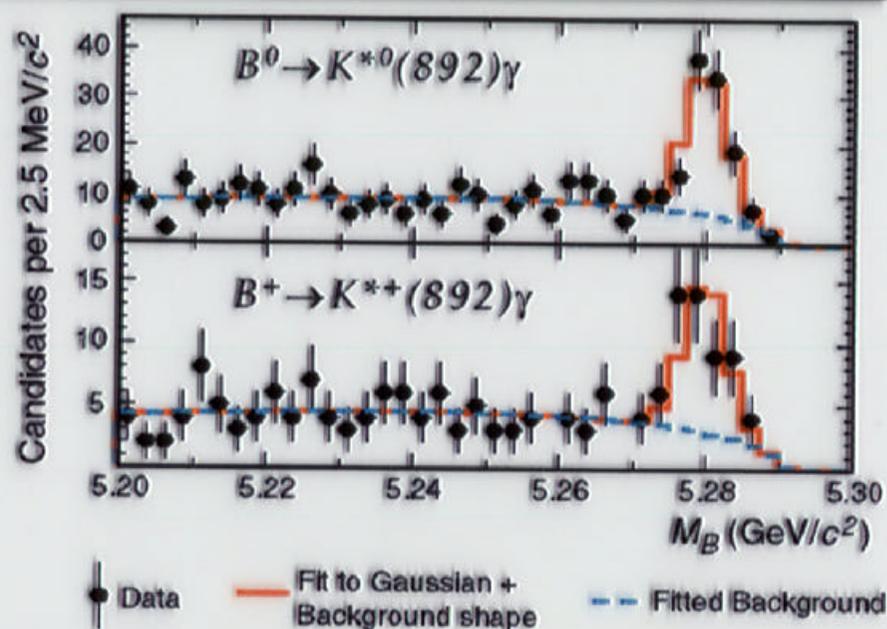
Main Analyses Requirements

- ◆ $E_\gamma > 1.5 \text{ GeV}$ $|\cos \theta| < 0.7$
- ◆ Backgrounds from continuum
 - ❖ γ from ISR – take central γ
 - ❖ γ from π^0 and η -- veto
- ◆ Mode dependent cuts to reduce remaining continuum
 - ❖ $\cos \theta_{\text{thrust}}$
 - ❖ $\cos \theta_B$
 - ❖ $\cos \theta_{\text{helicity}}$
- ◆ Mass of desired meson
- ◆ Full B reconstruction!
- ◆ Require at least
 - $|\Delta E| < 300 \text{ MeV}$,
 - $5.2 < M_B < 5.3 \text{ GeV}/c^2$



$B \rightarrow K^* \gamma$

- ◆ $K^*(892)$:
 - ❖ $|\Delta E| < 100 \text{ MeV}$
 - ❖ Simultaneous, binned maximum likelihood fit to K^* charged and neutral M_B distributions



Mode	Yield	$\epsilon[\pi^\pm]$	$\epsilon[\pi^0]$ (%)	BF (10^{-5})
$B^0 \rightarrow K^{*0}(892)\gamma$	$88.3^{+12.2}_{-11.5}$	28.4 ± 0.3	13.3 ± 0.3	$4.55^{+0.72}_{-0.68} \pm 0.34$
$B^+ \rightarrow K^{*+}(892)\gamma$	$36.7^{+8.3}_{-7.6}$	25.2 ± 0.5	13.4 ± 0.5	$3.76^{+0.89}_{-0.83} \pm 0.28$

$B \rightarrow K^* \gamma$

	$BF(10^{-5})$
CLEO:	9.7M $B\bar{B}$
$B^0 \rightarrow K^{*0}(892)\gamma$	$4.55^{+0.72}_{-0.68} \pm 0.34$
$B^+ \rightarrow K^{*+}(892)\gamma$	$3.76^{+0.89}_{-0.83} \pm 0.28$
BaBar: (ICHEP2000)	8.6M $B\bar{B}$
$B \rightarrow K^*(892)\gamma$	$5.4 \pm 0.8 \pm 0.5$
Belle: (ICHEP2000)	5.5M $B\bar{B}$
$B^0 \rightarrow K^{*0}(892)\gamma$	$4.9 \pm 0.9 \pm 0.5$
$B^+ \rightarrow K^{*+}(892)\gamma$	$2.9 \pm 1.2^{+0.5}_{-0.4}$

◆ Asymmetry

$$A_{CP} = \left(\frac{1}{1-2\alpha} \right) \frac{BF(\bar{B} \rightarrow \bar{K}^* \gamma) - BF(B \rightarrow K^* \gamma)}{BF(\bar{B} \rightarrow \bar{K}^* \gamma) + BF(B \rightarrow K^* \gamma)}$$

❖ Use $K^\pm \pi^0, K_s^0 \pi^\pm, K^\pm \pi^\mp$

❖ Mistake rate α only for $K^\pm \pi^\mp$

- Require $|p_\pi - p_K| > 500 \text{ MeV}/c$
- From MC $\alpha = (3.45 \pm 0.02)\%$

◆ Fit M_B distributions:

◆ Neutral K^* $A_{CP} = -0.13 \pm 0.17$

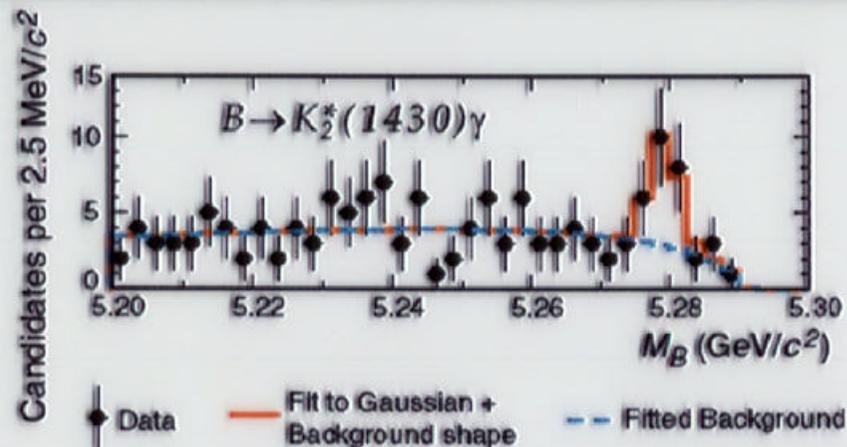
◆ Charged K^* $A_{CP} = +0.38^{+0.20}_{-0.19}$

◆ Combined:

$$A_{CP} = +0.08 \pm 0.13 \pm 0.03$$

$B \rightarrow K^* \gamma$ Heavier Resonances

- ◆ $K_2^*(1430), K^*(1410)$:
 - ❖ Use θ_{helicity} and resonance widths to distinguish (1430) from (1410).
 - ❖ See no $K^*(1410)$
 - ❖ Fit $K^*(1430) M_B$
- ◆ $B \rightarrow K_2^*(1430) \gamma$:
 - ❖ Yield = $15.9^{+5.7}_{-5.1}$ events
 - ❖ $\epsilon[\pi^\pm] = (18.5 \pm 0.7)\%$
 - ❖ $\epsilon[\pi^0] = (7.7 \pm 0.7)\%$
 - ❖ **BF = $(1.66^{+0.59}_{-0.53} \pm 1.3) \times 10^{-5}$**
- ◆ BF($B \rightarrow K^*(1410) \gamma$)
 - < 12.7×10^{-5} @ 90% CL

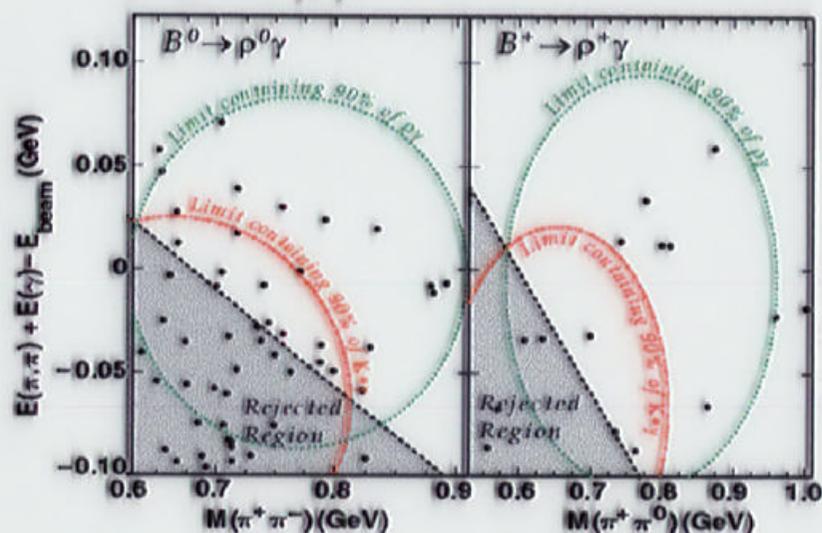


$$R_{1430/892} \equiv \frac{BF(B \rightarrow K_2^*(1430) \gamma)}{BF(B \rightarrow K^*(892) \gamma)}$$

Veseli & Olsson	0.37 ± 0.10
Ali, Mannel, & Ohl	3.0 - 4.9
CLEO	$0.39^{+0.15}_{-0.13}$

$b \rightarrow d\gamma$

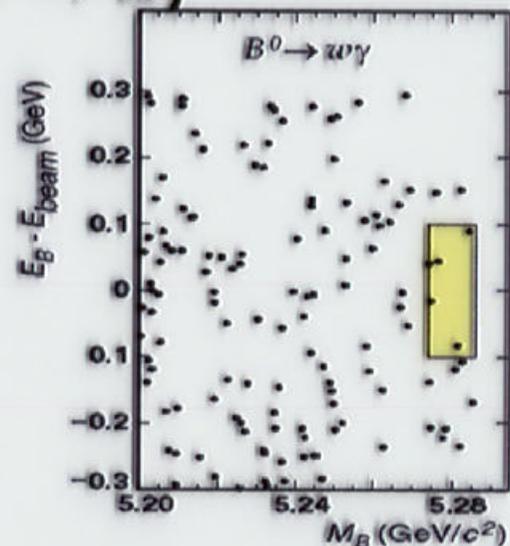
◆ $B \rightarrow \rho\gamma$



ϵ (%)	12.8 ± 0.7	8.5 ± 0.6
$K^*\gamma$ \times -feed	5.4 ± 0.8	2.6 ± 0.6
$q\bar{q}$ bkg	9.3 ± 0.6	5.2 ± 0.4
BF (90% CL)	$< 1.7 \times 10^{-5}$	$< 1.3 \times 10^{-5}$
BELLE BF (ICHEP 2000)	$< 0.6 \times 10^{-5}$	$< 2.3 \times 10^{-5}$

A. Lyon (CLEO) - 2001

◆ $B \rightarrow \omega\gamma$



combinatoric bkg = 2.7 ± 0.1 events

$\epsilon = (9.7 \pm 0.8)\%$

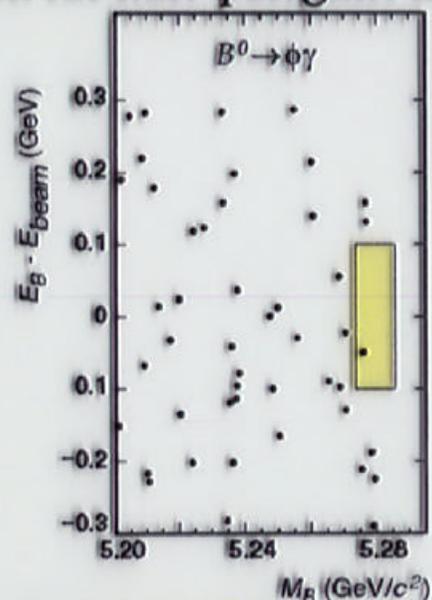
BF($B \rightarrow \omega\gamma$) $< 0.92 \times 10^{-5}$ @ 90% CL

No observed $b \rightarrow d\gamma$

$B \rightarrow \phi \gamma$

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

- ◆ Look for non-penguin decay:



- ◆ Combinatoric bkg = 1.2 ± 0.2
- ◆ $\epsilon = (23.0 \pm 0.6)\%$
- ◆ $BF(B \rightarrow \phi \gamma) < 0.33 \times 10^{-5}$
@ (90% CL)

$$R \equiv \frac{BF(B \rightarrow \rho \gamma)}{BF(B \rightarrow K^* \gamma)} = \zeta \left| \frac{V_{td}}{V_{ts}} \right|^2$$

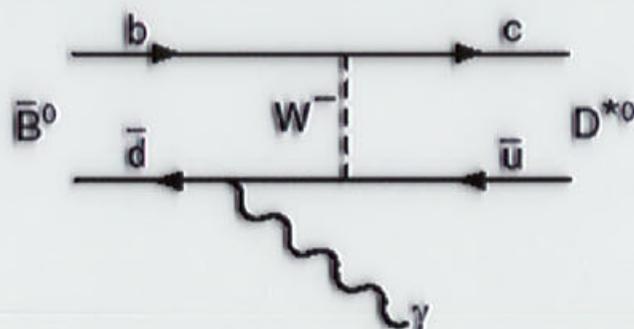
- ◆ CLEO: $R < 0.32$ @ 90% CL

If $\zeta = 0.58$,
 $|V_{td} / V_{ts}| < 0.75$

- ◆ Assume top-quark electromagnetic penguin dominates
- ◆ Belle: $R < 0.28$ @ 90% CL (ICHEP2000)

$$\bar{B}^0 \rightarrow D^{*0} \gamma$$

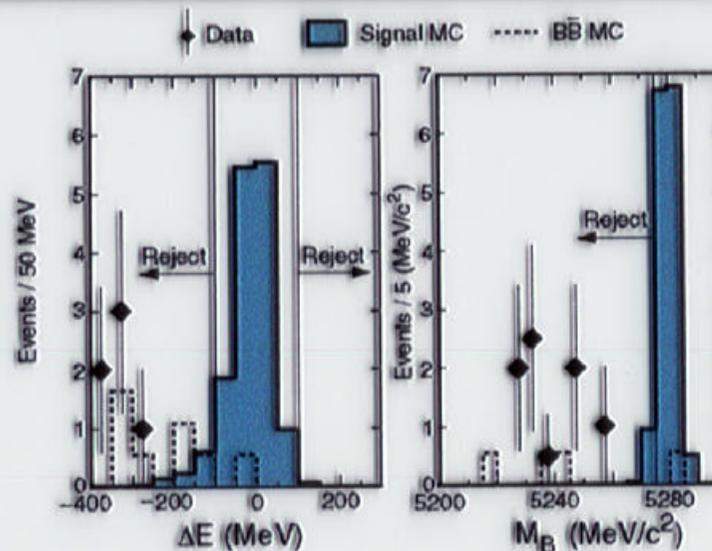
PRL 84, 4292 (2000)



◆ Strongly suppressed in SM (10^{-6})

◆ But possibly enhanced by $10\times$

- ❖ Gluon emission from initial state quark
- ❖ Large $q\bar{q}g$ component in the B wave function
- ❖ Could be bkg to radiative penguin decays



- ◆ $E_\gamma > 1.5$ GeV, π^0 veto, Fisher
- ◆ $\epsilon = 2.3\%$
- ◆ In signal region: 0.5 event $\bar{q}q$, 0.9 event BB , No Data Observed
- ◆ $BF(\bar{B}^0 \rightarrow D^{*0} \gamma) < 5.0 \times 10^{-5}$
- ◆ No big enhancement observed

Conclusions

- ◆ CLEO has examined >60 charmless B modes!
- ◆ New results for $B \rightarrow \phi K^{(*)}$
 - ❖ $BF(B \rightarrow \phi K) = (5.5_{-1.5}^{+1.8} \pm 0.7) \times 10^{-6}$
 - ❖ $BF(B \rightarrow \phi K^*) = (11.2_{-3.1}^{+3.6} \pm 1.8) \times 10^{-6}$
- ◆ Small branching fractions $\sim 10^{-6}$
 - ❖ $BF(B \rightarrow \pi^+ \pi^-) = (4.3_{-1.4}^{+1.6} \pm 0.5) \times 10^{-6}$
- ◆ All but $B \rightarrow \eta' K$ in agreement with theoretical predictions (many want more precision)
 - ❖ $BF(B \rightarrow \eta' K^0) = (8.9_{-1.6}^{+1.8} \pm 0.9) \times 10^{-5}$
- ◆ No hint of CP violation
 - ❖ from $b \rightarrow s\gamma$: $-0.27 < A_{CP} < +0.10$