Study of $b \to s \gamma$ and $b \to d \gamma$

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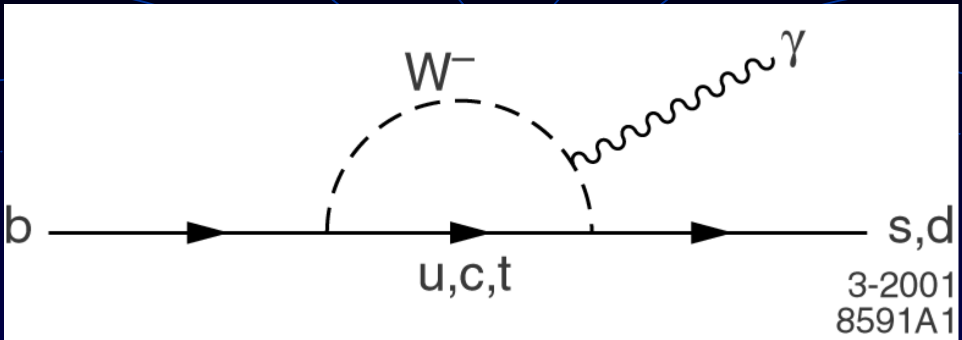
SLAC
BaBar Collaboration

Conference Papers ABS864, ABS865 and ABS866
(Also on hep-ex)

Physics Interest



<u>Exclusive Measurements:</u>

$\mathcal{B}$(B -> K*γ)	QCD test
A_{cp}(B ->K*γ)	Non SM CP violation
$\mathcal{B}$(B ->ργ)/ $\mathcal{B}$(B -> K*γ)	Constrain V_{td}/V_{ts}

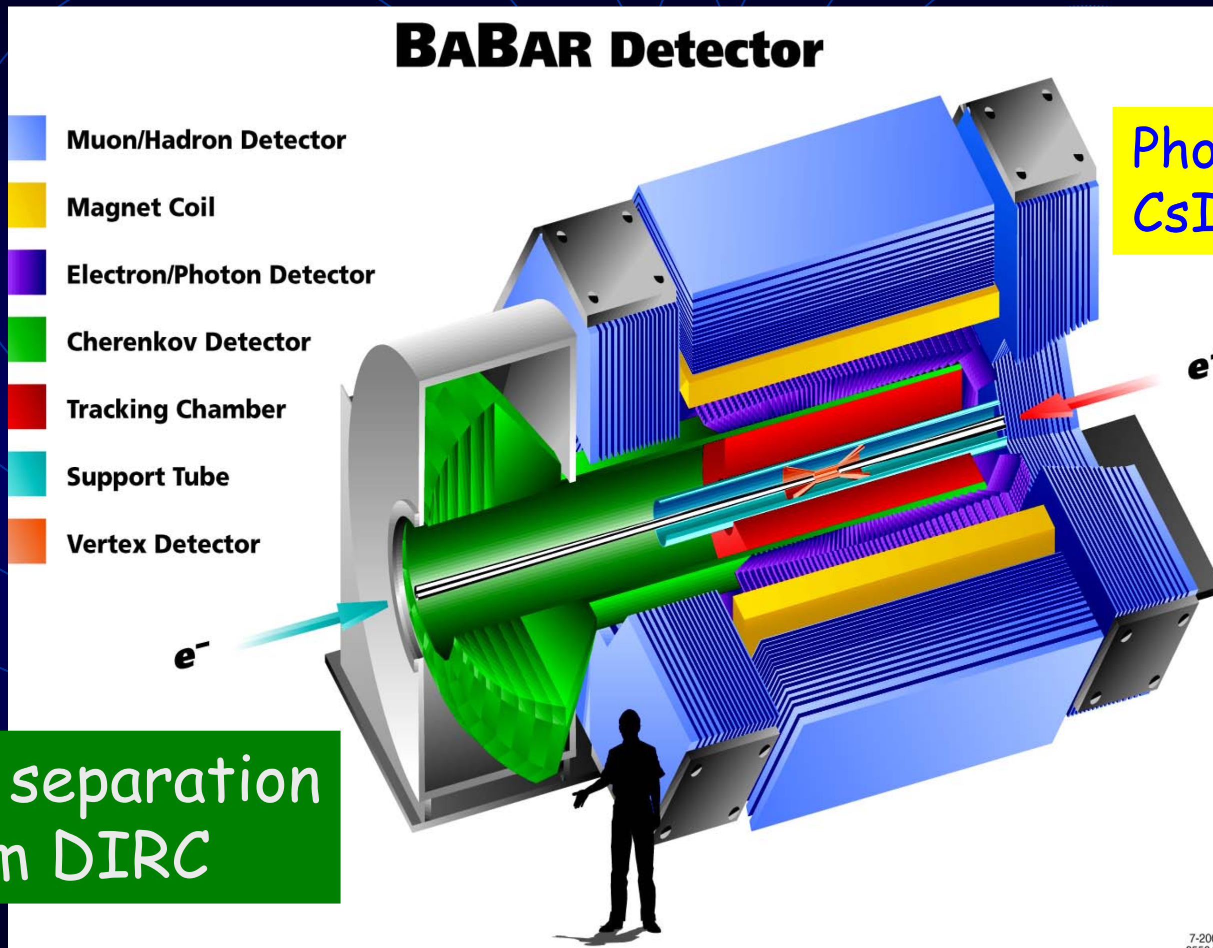
<u>Inclusive Measurements:</u>

$\mathcal{B}$(*b* -> *s*γ)	Constrain new physics
E_γ spectrum from *b* -> *s*γ	Mass and Fermi motion of *b*

(NIM A 479, 1 2002)

BaBar Detector

Strengths for $b \to s,d\gamma$ studies

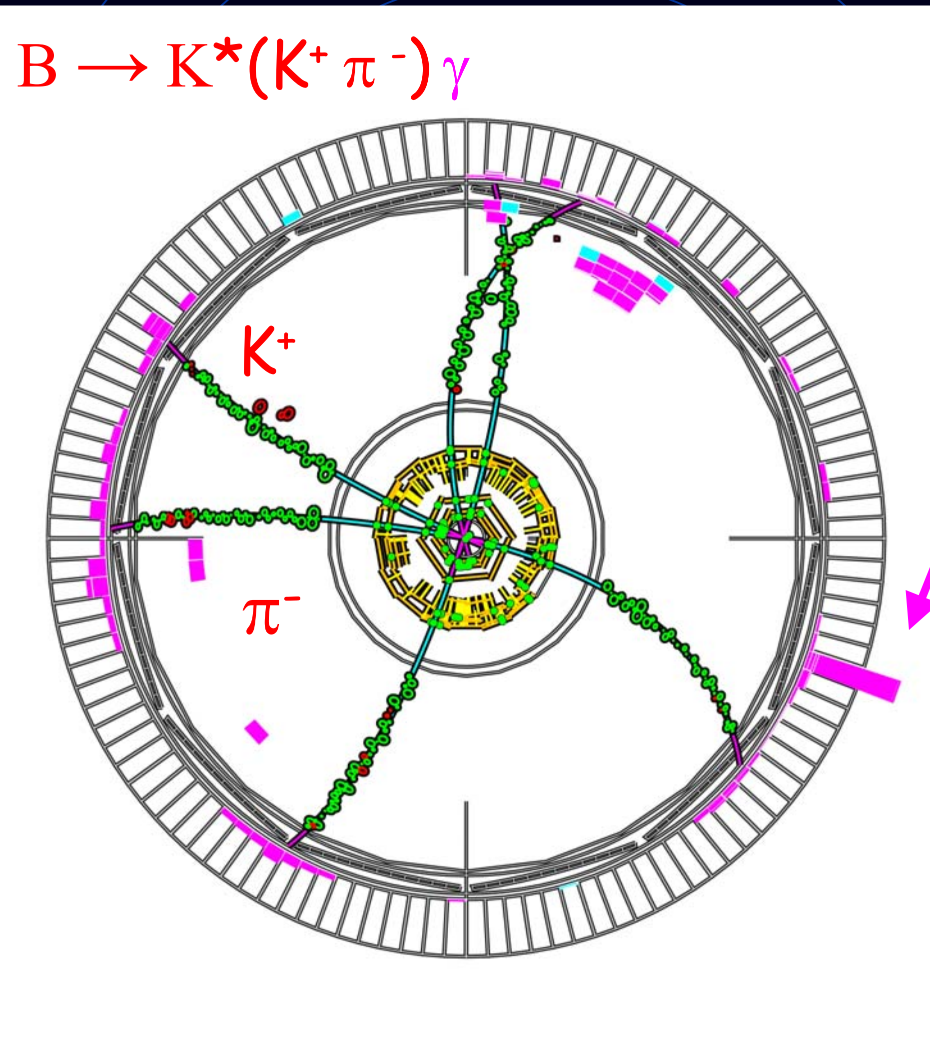


Photons from CsI Calorimeter

K/π separation from DIRC

Asymmetric e^- (9 GeV) e^+ (3.1 GeV) collisions at $\sqrt{s} = 10.56$ GeV

Event Selection - γ



Isolated high energy γ $(1.5 < E_\gamma^* < 3.5\ GeV)$

Lateral profile is EM like

Veto photons from π^0/η

(Un-vetoed π^0/η are a significant background)

Note isotropic topology

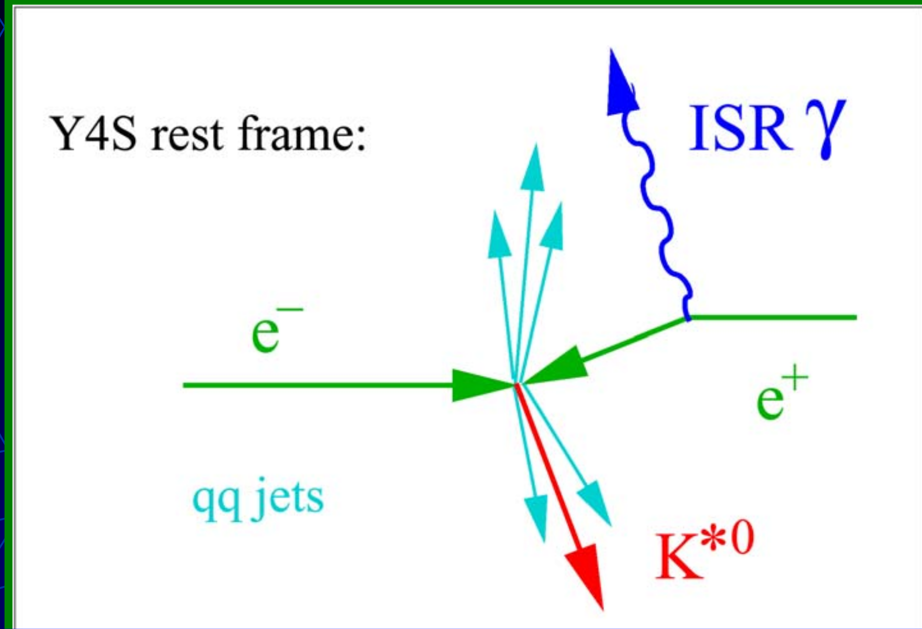
Continuum($q\bar{q}$) Background

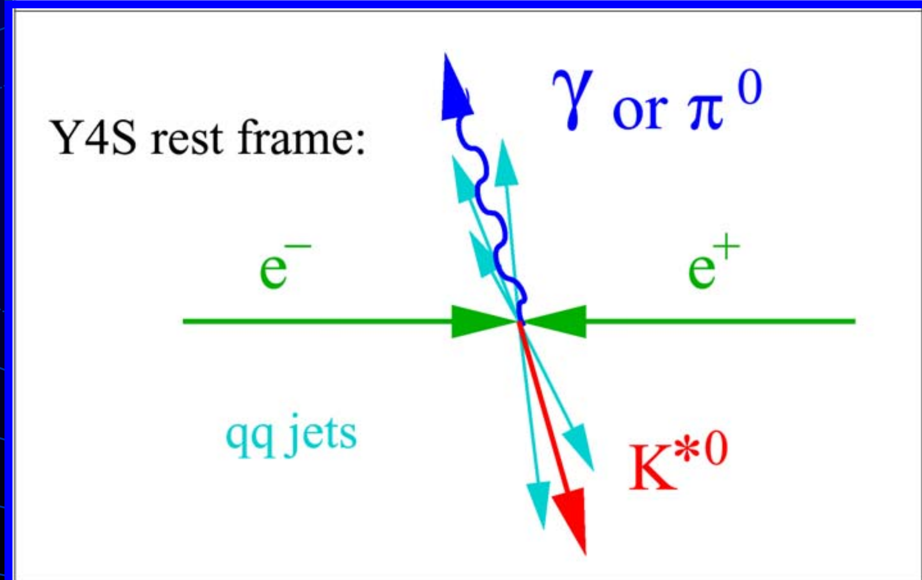
$\bar{q}q$, (q =u,d,s,c)
“underneath” the $b\bar{b}$

“Jet-like” topology as qq
produced above threshold

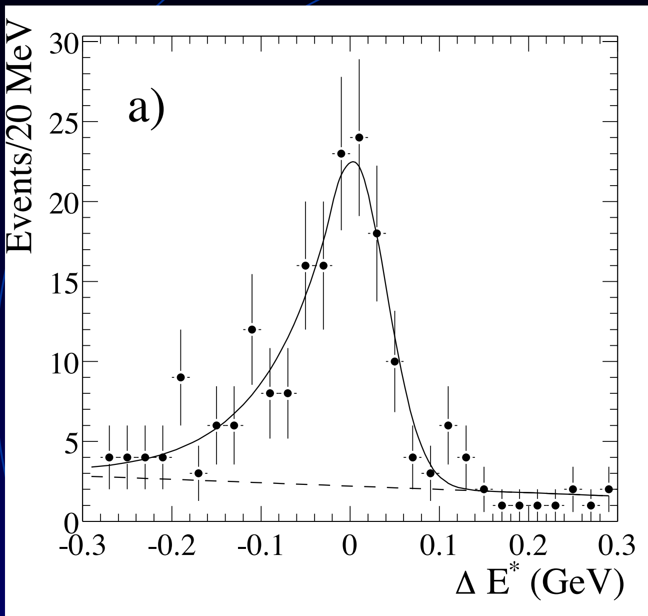
“shape” variables w.r.t to γ
e.g. cos $\theta_{Thrust-\gamma}$,energy flow

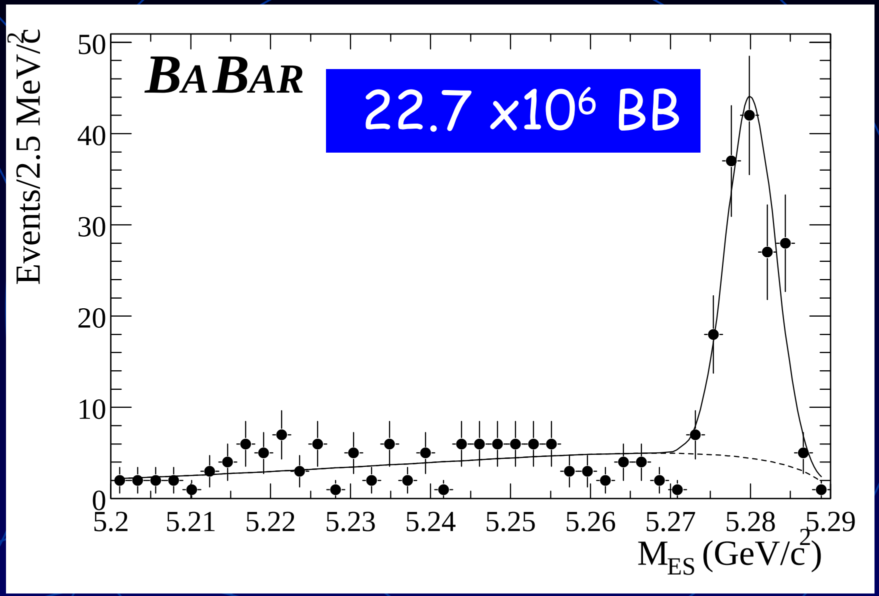
Combinations of variables,
e.g Neural Net, help with
two component background





$\mathcal{B}(B \to K^*\gamma)$ and $A_{cp}(B \to K^*\gamma)$





$$\Delta E^* = E_B^* - E_{beam}^*$$

(* = CMS frame)

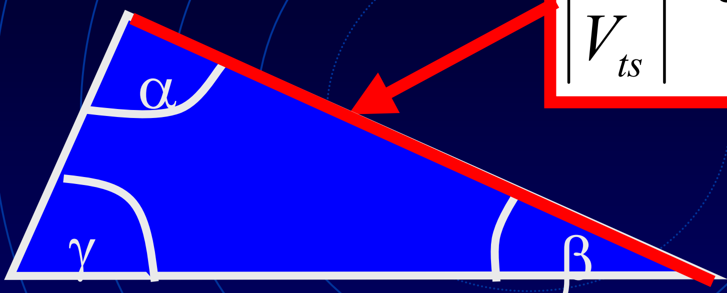
$$M_{ES} = \sqrt{\left(E_{beam}^{*2} - p_B^{*2}\right)}$$

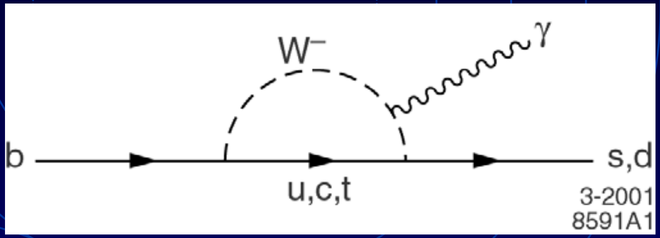
	$\mathcal{B}(B^0 \to K^{0*}\gamma)$ /10^{-5}	$\mathcal{B}(B^+ \to K^{+*}\gamma)$/$10^{-5}$	Acp
Theory(avg.)	7. 5 ± 3.0	7.5 ± 3.0	|Acp|< 0.005
BaBar PRL 88, 161805(2002)	4.23±0.40(stat.) ±0.22(sys.)	3.83 ±0.62(stat.) ±0.22(sys.)	-0.17 < Acp < 0.08 (90 % C.L)

theory=hep-ph/0106081,0106067,0105302

Search for B -> ρ,ωγ

$$\left|\frac{V_{td}}{V_{ts}}\right|^2 \propto \frac{B(B\to\rho\gamma)}{B(B\to K^*\gamma)}$$





Goal is to measure and compare to ΔMs/ΔMd B-mixing to over-constrain CKM ◣

Challenges

Experiment:

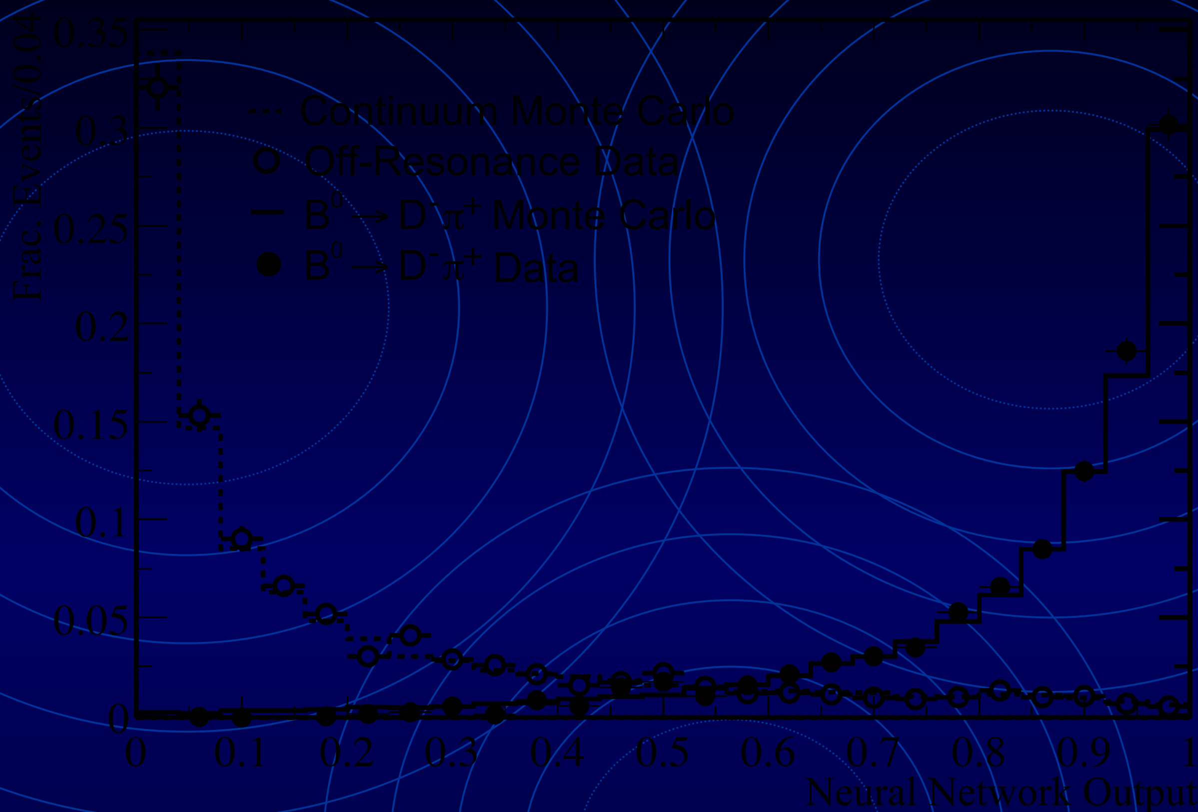
$\mathcal{B}$(B -> ργ) ~ 1/50 $\mathcal{B}$(B -> K*γ)
Γρ ~ 3 ΓK*
B ->K*γ, b->sγ, B -> $\rho\pi^0$
backgrounds

Theory:

15–35% error in
Vtd/Vts extraction

cf. $\Delta M_s/\Delta M_d$ 7% error

Background Rejection

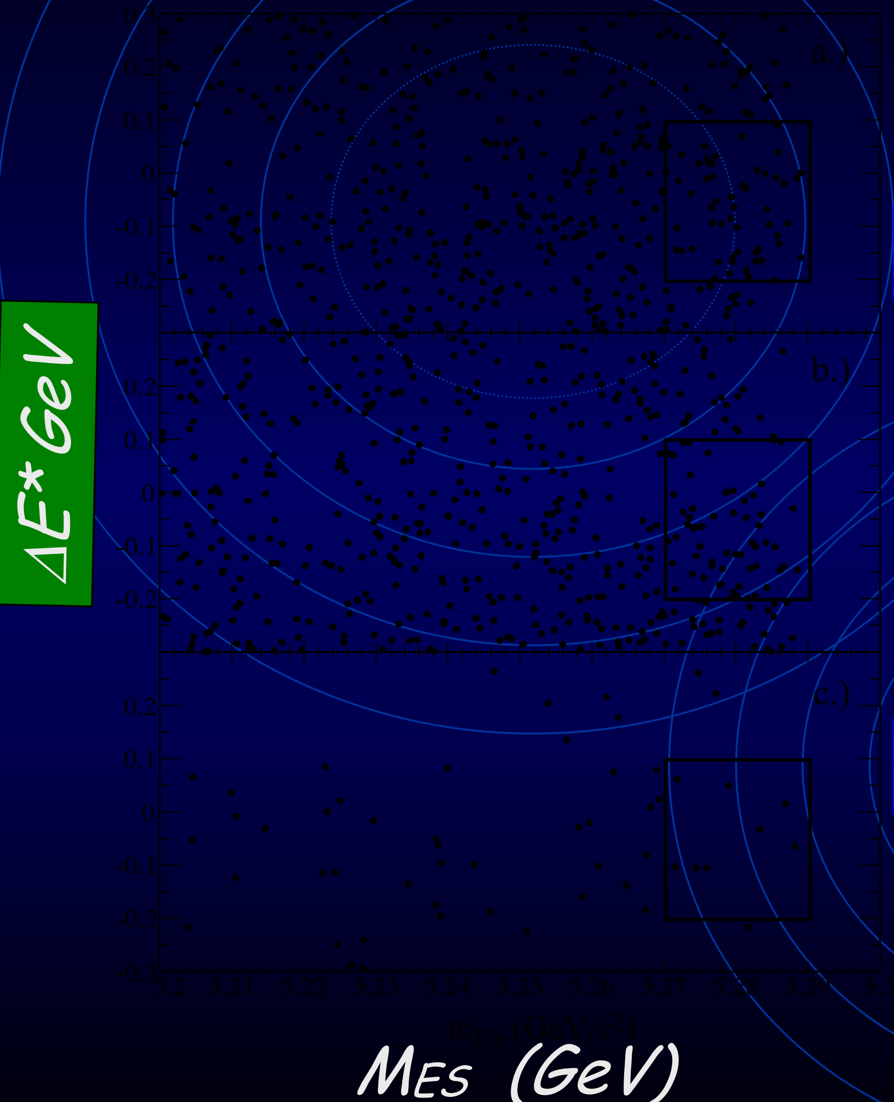


Continuum rejection variables (shape,ΔZ,flavor tag) combined in neural net. Validate with control samples.

π^+ eff. of 80% with K^+ miss-id of 1% removes B-> $K^*(K^+\pi^-/K^+\pi^0)\gamma$ bkg.

B -> ρ,ωγ result

Signal Estimated with Maximum Likelihood Fit ($\Delta E, M_{ES}, M_{\pi\pi}$)



Data: 84 x 10^6 BB pairs
No Signal, 90% C.L. set

a) $\mathcal{B}(B^0 \to \rho^0\gamma) < 1.4 \times 10^{-6}$

SM Theory: $0.49 \pm 0.16 \times 10^{-6}$
$0.76 +0.26/-0.23 \times 10^{-6}$

b) $\mathcal{B}(B^+ \to \rho^+\gamma) < 2.3 \times 10^{-6}$

SM Theory: $0.85 \pm 0.32 \times 10^{-6}$
$1.53 +0.53-0.46 \times 10^{-6}$

c) $\mathcal{B}(B^0 \to \omega\gamma) < 1.2 \times 10^{-6}$

SM Theory: Same as $\rho^0\gamma$ (isospin sym)

Analysis was performed with signal region "blinded"

Theory: hep-ph/0105302,0106081

Unitarity triangle

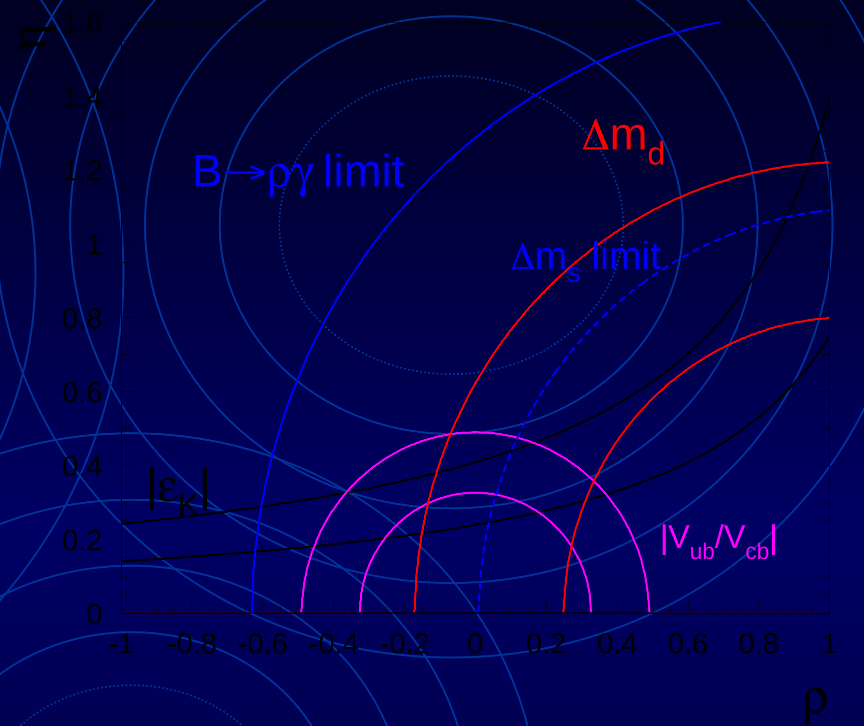
Combined limit:

$(\mathcal{B}(B^0 \to \rho^0\gamma) = \mathcal{B}(B^0 \to \omega\,\gamma) = 2.\mathcal{B}(B^+ \to \rho^+\gamma))$

$\mathcal{B}(B \to \rho\gamma) < 1.9 \times 10^{-6}$

$$\left|\frac{V_{td}}{V_{ts}}\right| < 0.036$$

90% C.L



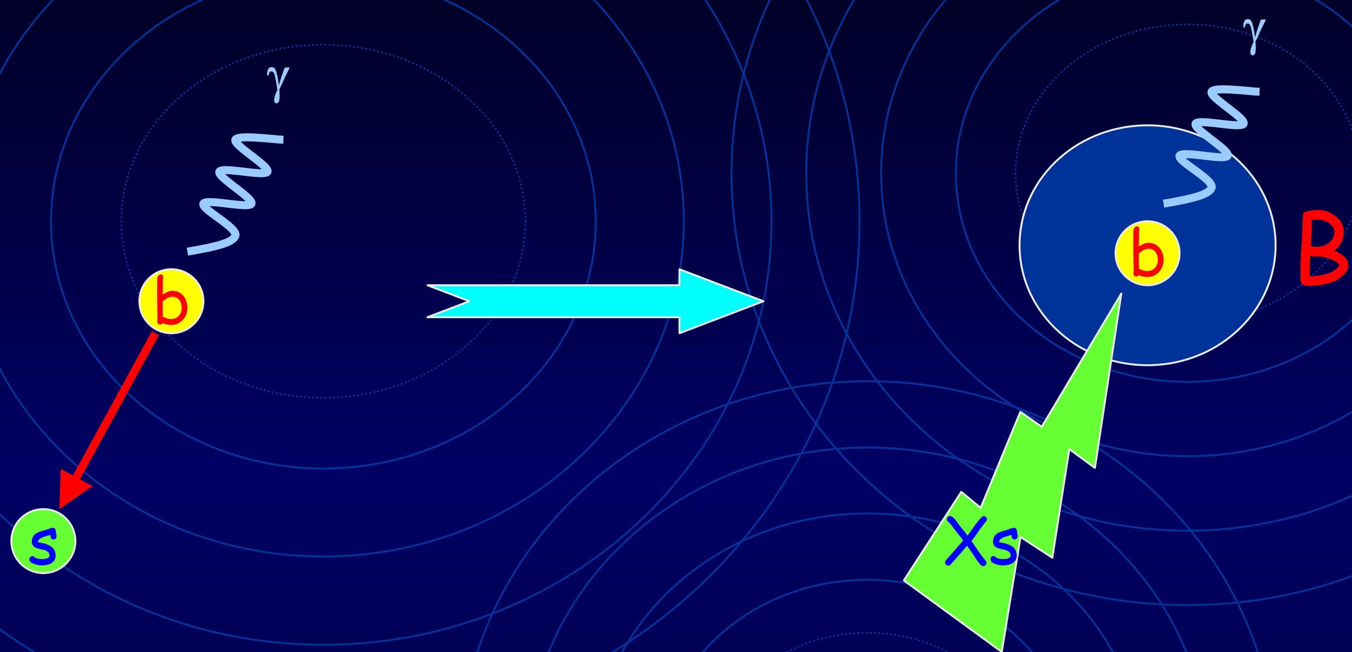
$$\left|\frac{V_{td}}{V_{ts}}\right|^2 \left(\frac{1-\left(m_\rho/M_B\right)^2}{1-\left(m_{K*}/M_B\right)^2}\right)^3 \xi^2(1+\Delta R) = \frac{B(B \to \rho\gamma)}{B(B \to K^*\gamma)} < 0.047$$

Using ξ=0.7 and ΔR=-0.25: Ali & Parkhomenko (Eur Phys. J. C23:89 (2002))

Implications for beyond SM in Ali & Lunghi hep-ph/0206242

Inclusive b -> $s\gamma$

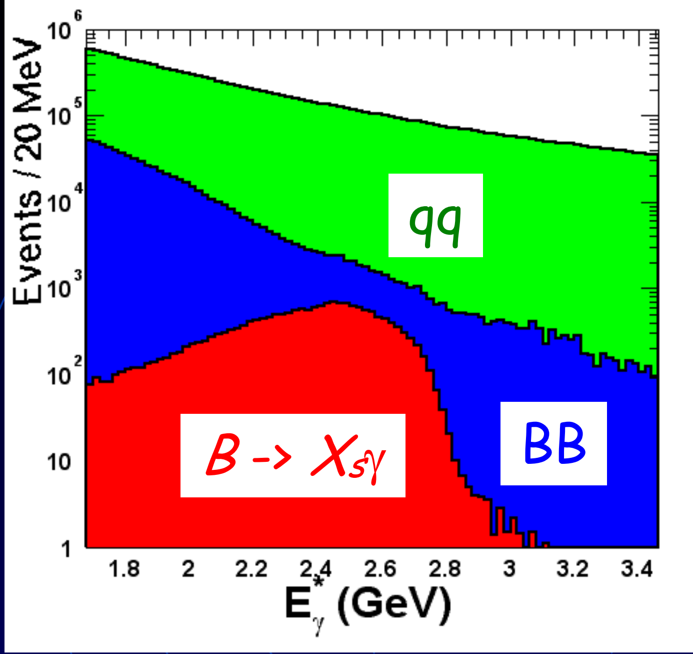
HQET: Quark-Hadron Duality $B(b \to s\gamma) = B(B \to X_s\gamma)$



Theory: NLO $B(b \to s\gamma) = 3.57 + - 0.30 \times 10^{-4}$ (hep-ph/0207131)

Phenomenological models of $E\gamma$ spectrum parameterized in m_b and λ_1.
(hep-ph/9805303)

Phenomenological Model of Xs fragmentation (JETSET) (hep-ph950891)



If require just γ bkg. ~10^3.Sig.

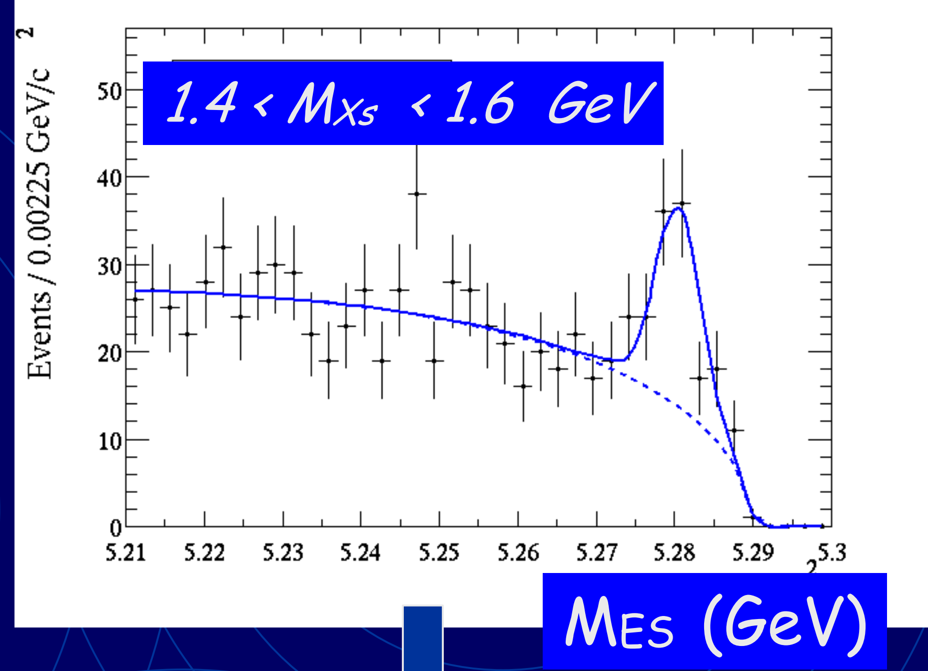
Challenge is to reduce bkg while
Minimizing stat.+sys.+model errors

Two approaches:

	Semi-Inclusive	*Fully Inclusive*
Background Rejection	*Σ(Exclusive States)*	*Lepton tags*
Efficiency	*3%*	*1%*
Fraction of Xs states:	*50%*	*100%*
qq bkg estimation	*Sideband subtraction*	*Off-resonance data*
BB bkg estimation	*Monte Carlo*	*M. Carlo – data validated*
X-feed bkg estimation	*Monte Carlo*	*No X-feed*
Spectral Resolution	*ΔMxs ~ 5 MeV*	*ΔE~100 MeV*
Model Dependence	*Xs, K*/Xs, Mxs cut*	*Eγ*

Semi-Inclusive $B \to X_s\gamma$

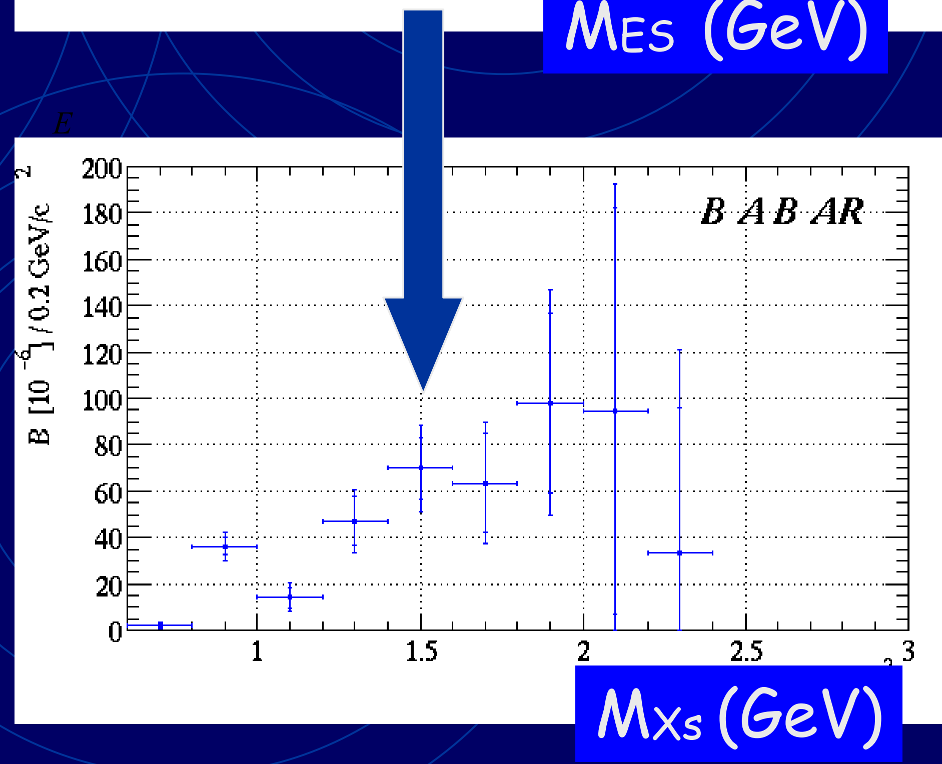
Σ(exclusive states) =
K^+/K^0_s +up to 3π ($1\pi^0$) , 12 states



Data
22M BB

Subtract continuum with sideband X-feed and BB bkg with Monte Carlo

Observe discrepency in JETSET simulation of Xs fragmentation.

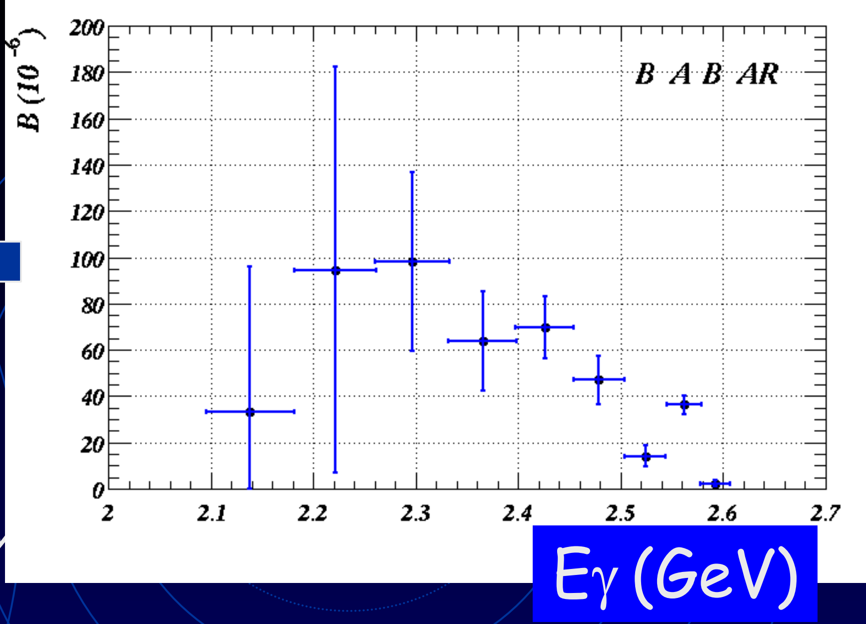


Efficiency from Monte Carlo weighted to correct discrepency

Correct for undetected modes

$$E_\gamma = \frac{m_B^2 - m_{X_s}^2}{2m_B}$$

$\langle E_\gamma \rangle = 2.35 \pm 0.04$ (stat.) ± 0.04(sys.)

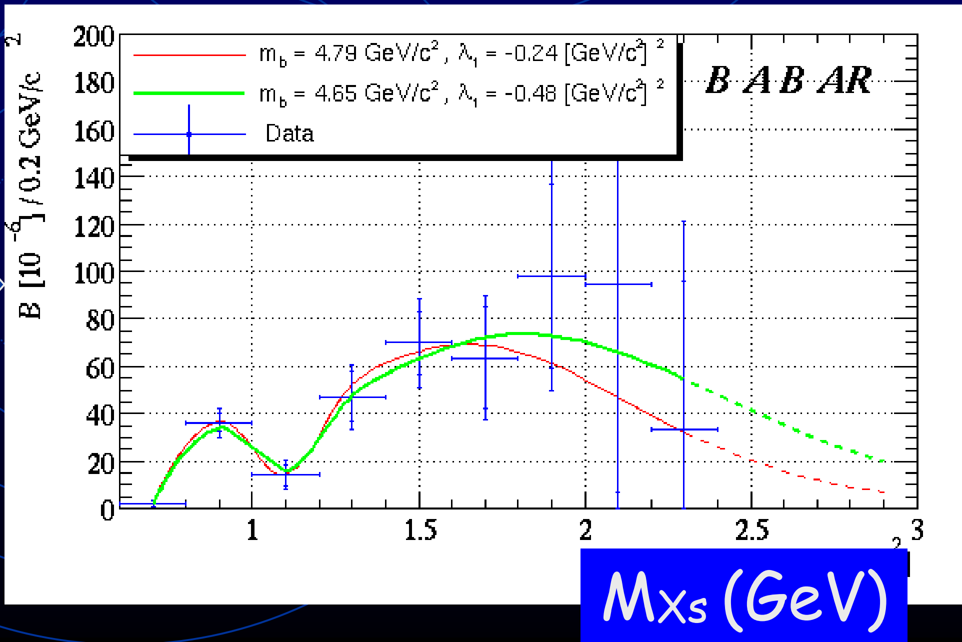


$\Lambda = 0.37 \pm 0.09$ (stat.) ± 0.07(sys.) ± 0.10(theory
(Using Ligeti et.al PRD 60, 034019 (1999))

&

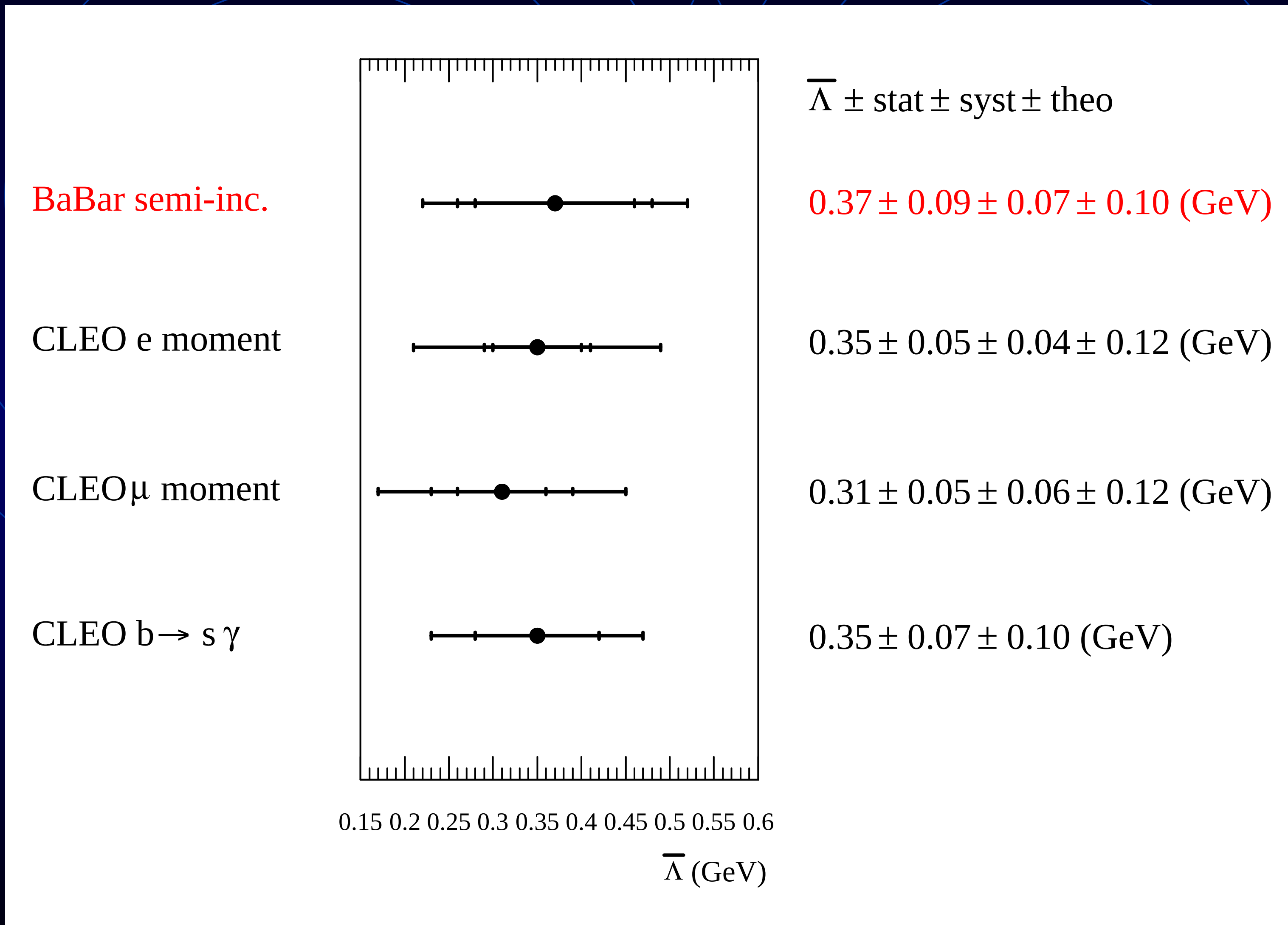
$m_b = 4.79 \pm 0.08$ (stat.) ± 0.10(sys.) ± 0.10(theory)
(Ligeti - private comm.)

Fix $m_b = 4.79$ and fit using spectrum
Of Kagan & Neubert Euro.Phys. J. C 7,5(1999)



$B(B \to X_s\gamma) =$
4.3 ± 0.5 (stat.)
± 0.8(sys.) ± 1.3(theory)$\times 10^{-4}$

$\bar{\Lambda}$ from b -> sγ

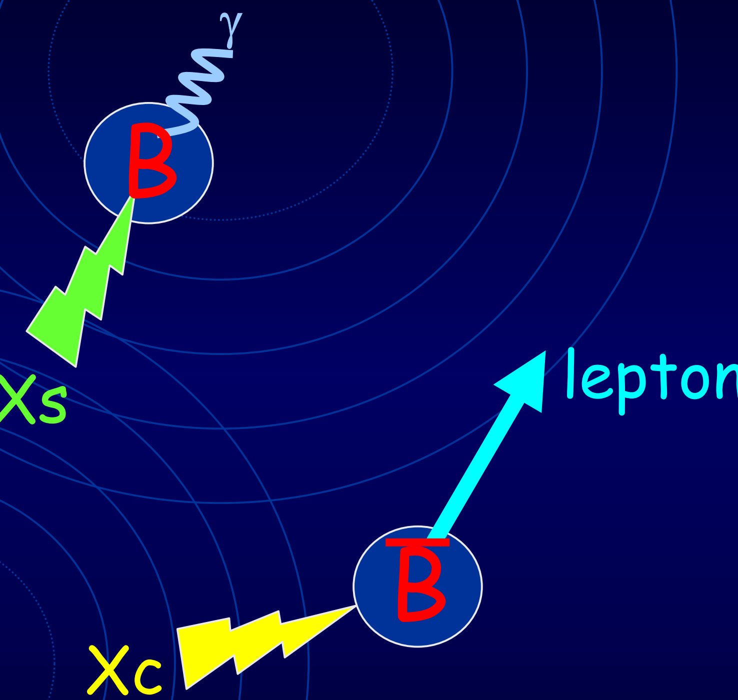


Fully Inclusive B -> $X_s\gamma$

Suppress continuum background
by requiring high momentum lepton tag
$(P_e(P_\mu) > 1.3(1.55)$ GeV

Additional shape variable
$\cos(\theta_{e\gamma})(\cos(\theta_{\mu\gamma}))>-0.75(-0.7)$

Missing E > 1.2 GeV (Signal leptons from
$B \rightarrow Xl\upsilon$)

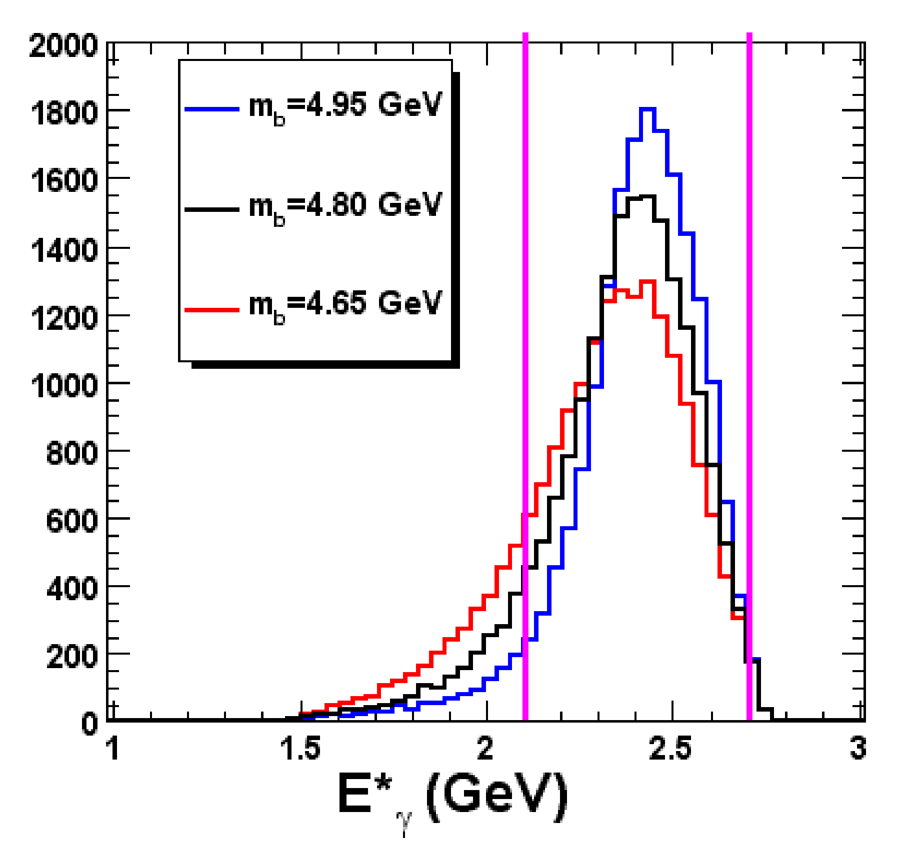


5% Efficiency for x1200 reduction in background

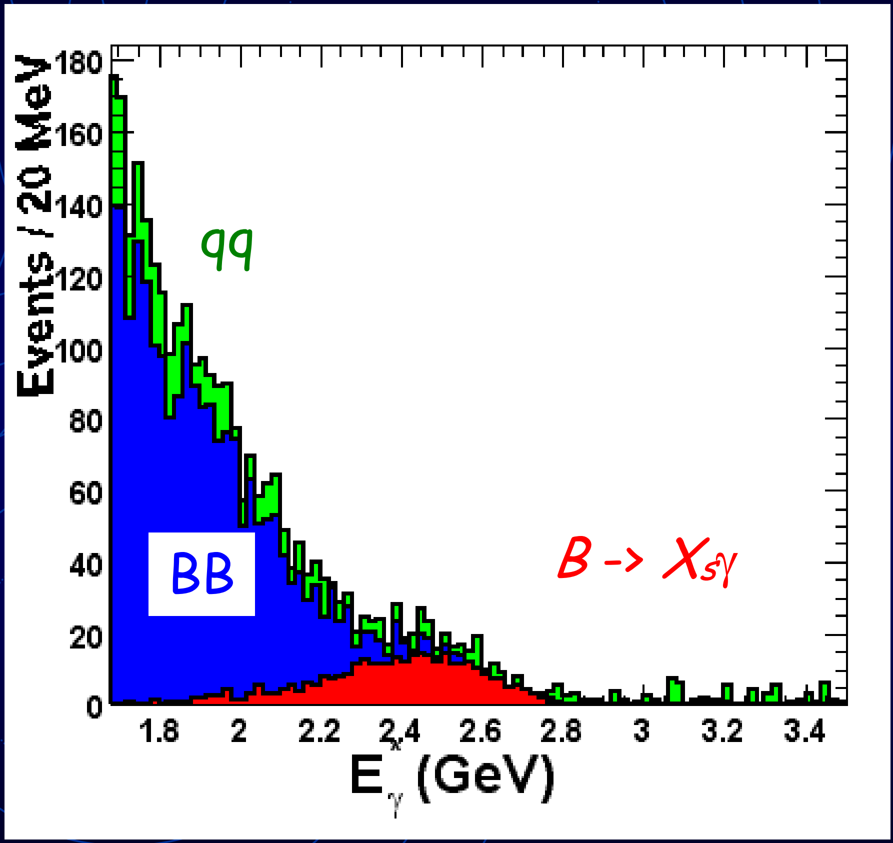
The tag is uncorrelated with signal B so no model dependence

Fully Inclusive $B \to X_s\gamma$

Model Dependence of E^*_γ



MC Expectation in 61×10^6 BB

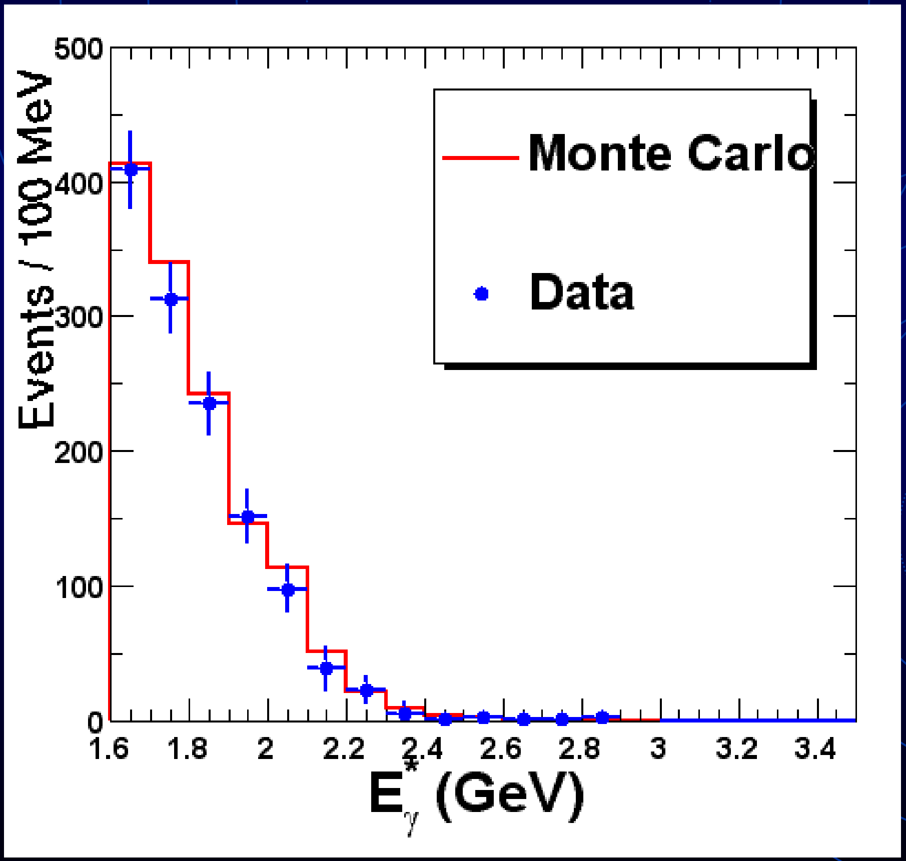


2.1 < Eγ < 2.7 Signal Region (from considering stat+sys+model error)

Fully Inclusive $B \rightarrow X_s\gamma$

Dominant Systematic Uncertainty is from BB bkg, subtraction

BB π^0/η Background Control Sample



BB Background
~90% $\pi^0\eta$
~6% hadrons in EM

MC is used for BB subtraction
To Test: Same Selection as Signal sample except require γ to be from $\pi^0\eta$

Correct MC for integral in $2.1 < E^*\gamma < 2.7$ GeV by factor 0.89 ± 0.17

Fully Inclusive $B \to X_s\gamma$

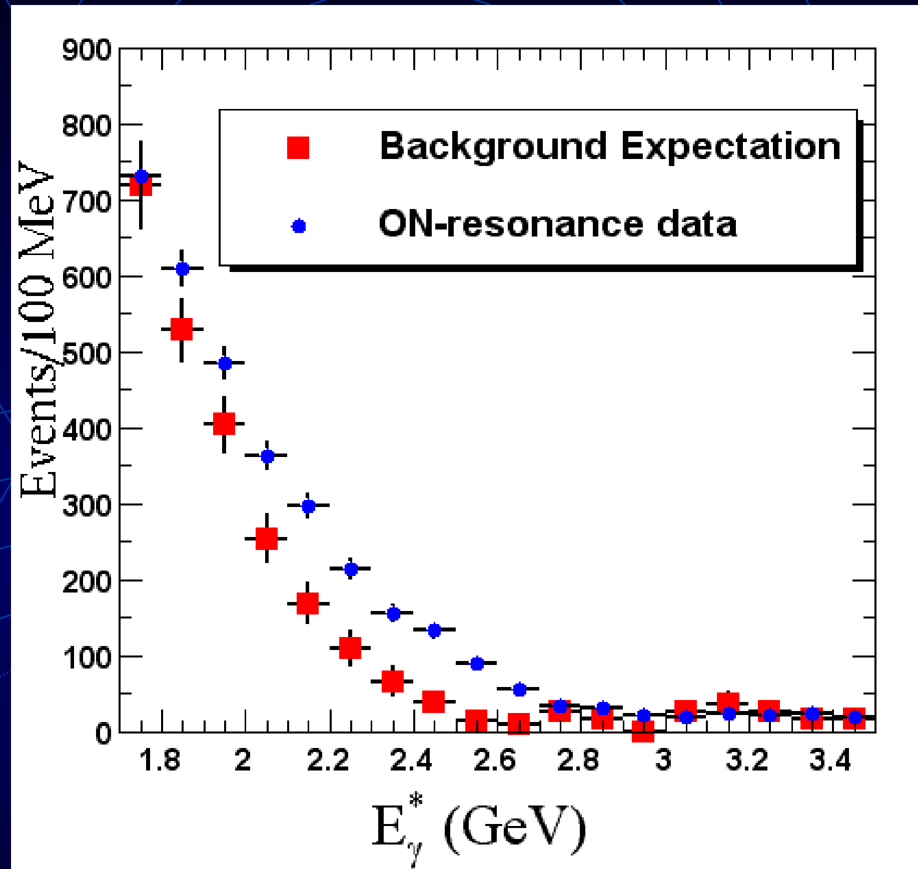
61×10^6 BB (54.6 fb^{-1})

Continuum Subtraction with 6.4 fb^{-1} of "off-resonance" data

BB subtraction with Monte Carlo

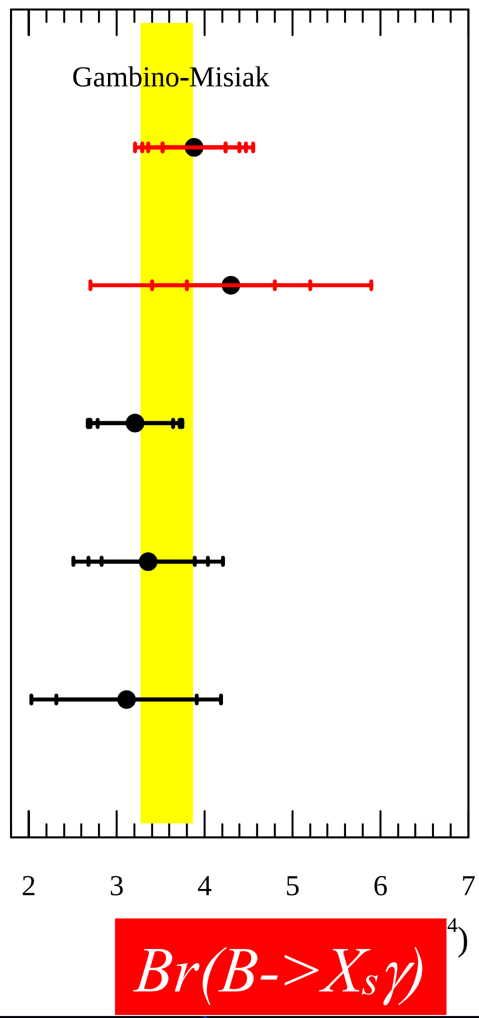
Subtract assumed 4±1.6% $b \to d\gamma$

Signal Region was "blinded"



$\mathcal{B}(B \to X_s\gamma)$ = 3.88±0.36(stat.)±0.37(sys.)+0.43/-0.23 (theory) x 10^{-4}

Br(B->$X_s\gamma$)



	B ± stat ± syst ± theo
BaBar **Full.**	$(3.88 \pm 0.36 \pm 0.37^{+0.43}_{-0.28})\text{x}10^{-4}$
BaBar **semi.**	$(4.3 \pm 0.5 \pm 0.8 \pm 1.3)\text{x}10^{-4}$
CLEO	$(3.21 \pm 0.43 \pm 0.27^{+0.18}_{-0.10})\text{x}10^{-4}$
BELLE	$(3.36 \pm 0.53 \pm 0.42 \pm 0.52)\text{x}10^{-4}$
ALEPH	$(3.11 \pm 0.80 \pm 0.72)\text{x}10^{-4}$

Conclusions

New limits on B -> $\rho,\omega\gamma$, Will soon help constrain CKM ◣

First results from BaBar on $B \to X_s\gamma$

New techniques for measuring $B \to X_s\gamma$ provides competitative $\mathcal{B}(B \to X_s\gamma)$ and will improve rapidly (< 10% soon)

Experimental precision is approaching theoretical errors