Radiative B meson Decays at BaBar

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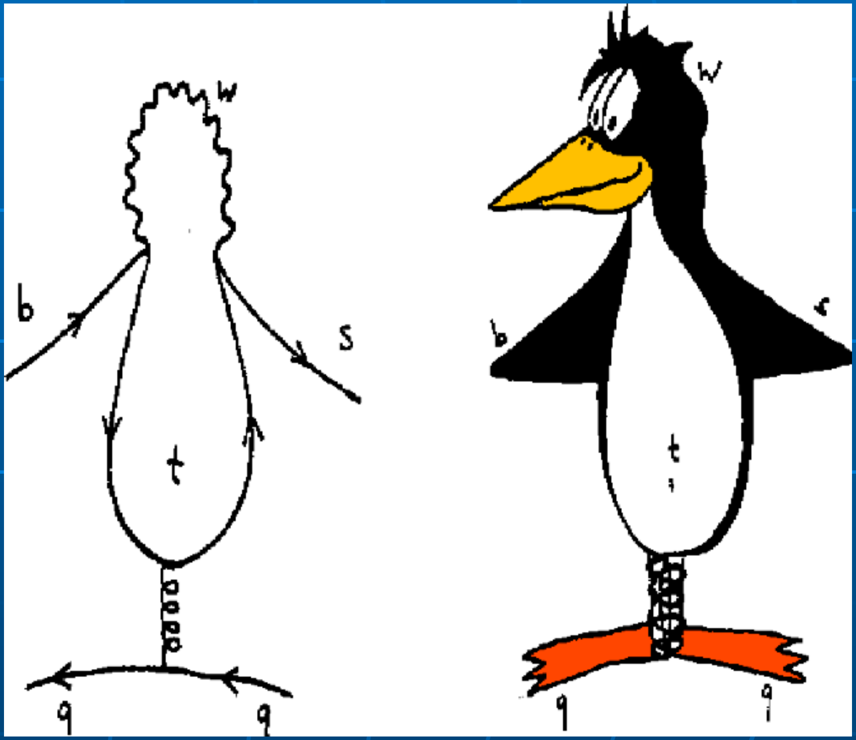
Contents

Motivations

- Window to new Physics
- Help measure the unitarity triangle
- Test QCD technology

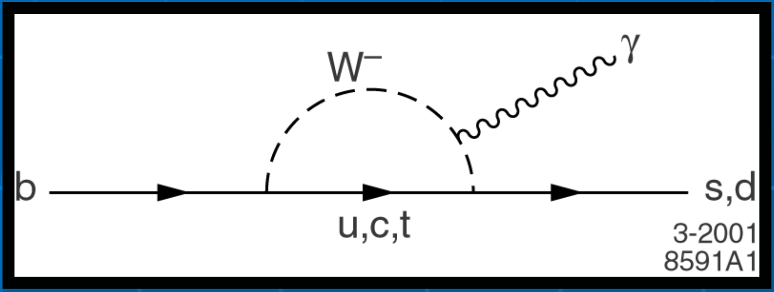


Radiative Penguin Decays

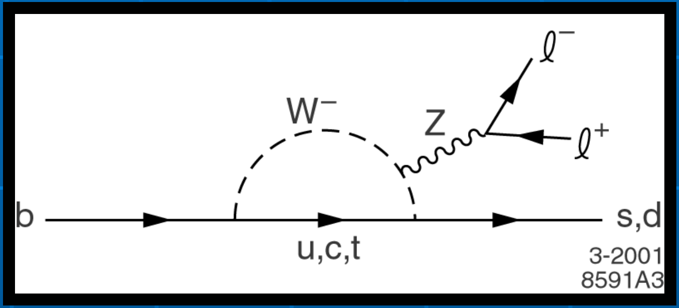
The Penguin Zoo

Several different types of penguins (not including gluonic penguins)

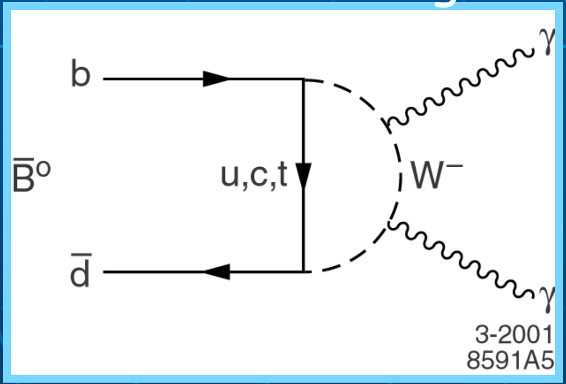
Electro-Magnetic



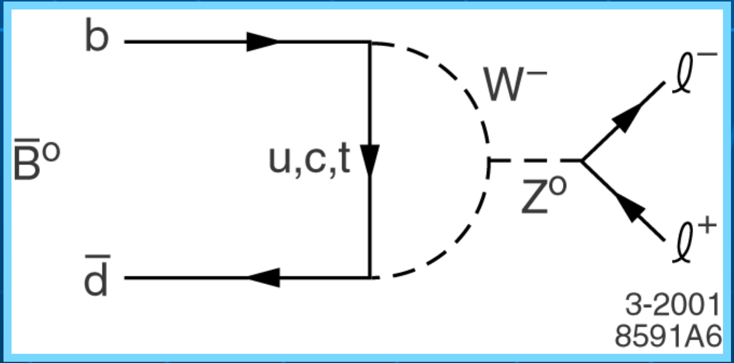
Electroweak



Vertical Electromagnetic



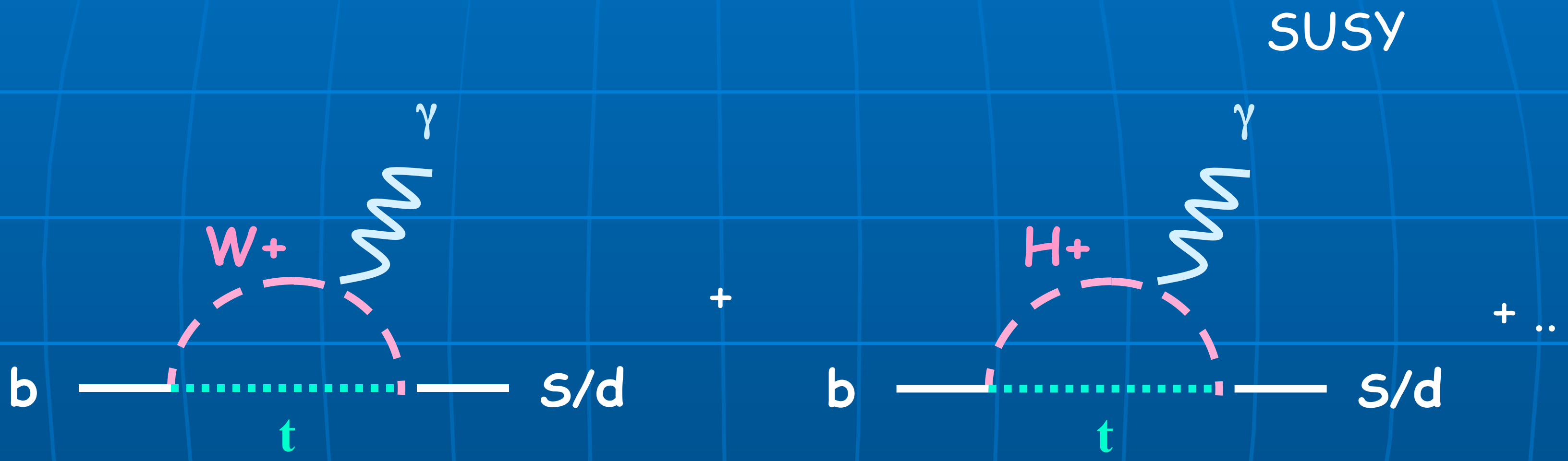
Vertical electroweak



I will focus today mostly on electromagnetic penguins. BaBar has results on all these processes

Sensitivity to New Physics

Example: If SUSY exact $B(b\to s\gamma) = 0$



New Physics enters at same order (1-loop) as Standard Model

Sensitive to many models – very extensive literature

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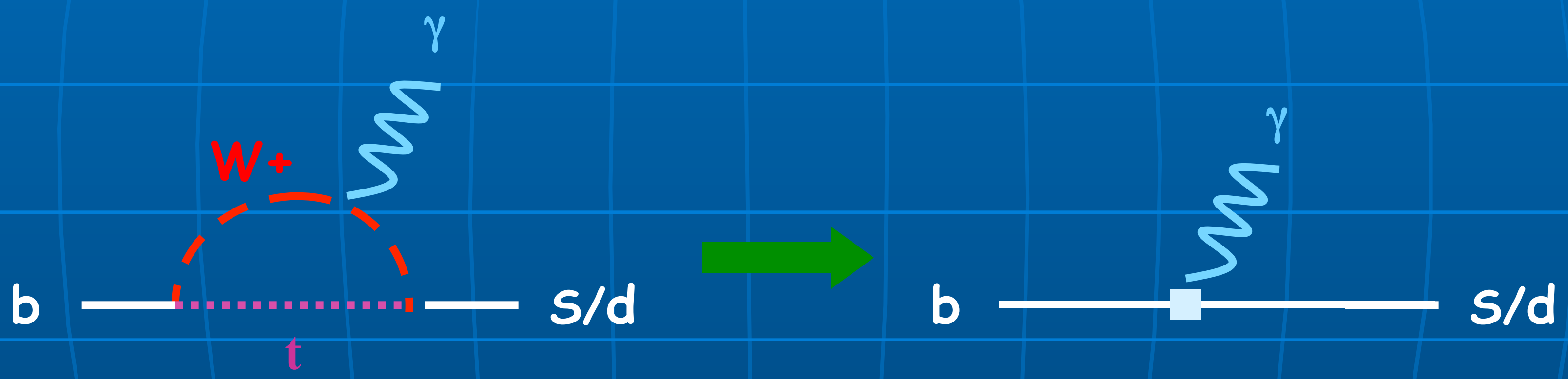
1. Motivations for studying radiative decays
2. Brief Theoretical overview
3. Experimental considerations
4. Measurements of exclusive modes
5. Measurements of inclusive modes
6. Conclusions

Penguin Theory – A brief Overview

B mesons are low energy decays at scale $\mu = m_b \sim 5$ GeV

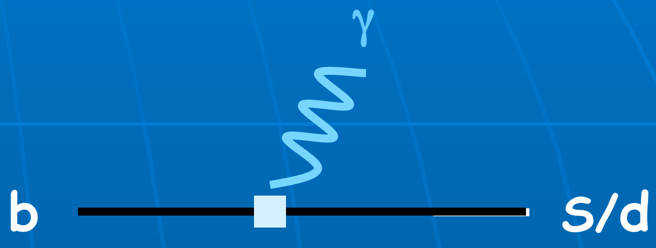
Formulate a low energy effective theory :



Generalization of Fermi Theory of β-decay.

Operator Product Expansion

$$H_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts} \sum_{i=1}^{10} C_i(\mu) Q_i(\mu)$$



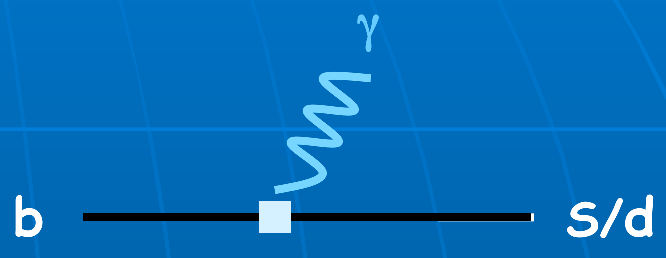
CC_i : Wilson Coefficients – contains short distance (high energy) perturbative component

Q_i : Local Operators – contains long distance (low energy) non-perturbative component

μ(renormalization) scale dependence cancels in *C* and *Q*

Wilson Coefficients

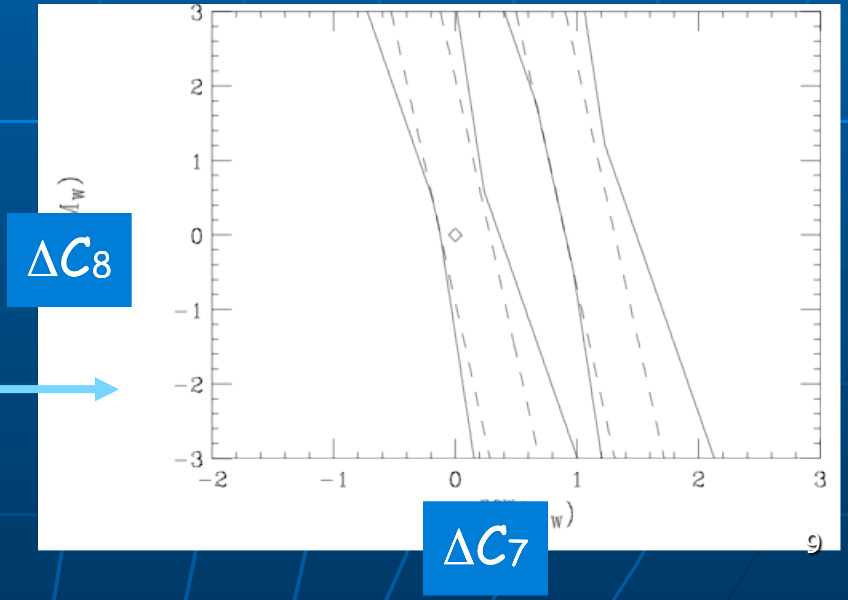
$$H_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb}V_{ts} \sum_{i=1}^{10} C_i(\mu)Q_i(\mu)$$



C_i i=1,2 current-current, i=3-6 gluonic penguins i=7-10 Electroweak Penguins
C_i calculated at μ=M_W and evolved down to μ=m_b.

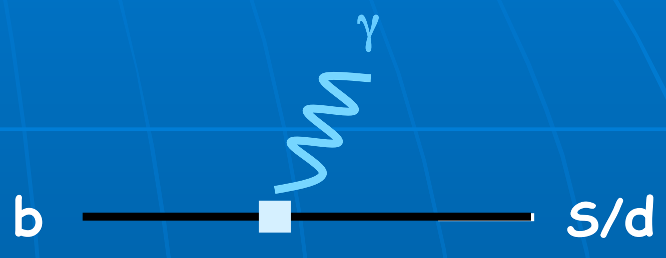
Effects of new high mass physics appear in C

e.g constraints on C_7 and C_8 from B(B->X_sγ)



Matrix Elements

$$H_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts} \sum_{i=1}^{10} C_i(\mu) Q_i(\mu)$$



‹X|Q|B› are long distance (low-energy) non-perturbative component

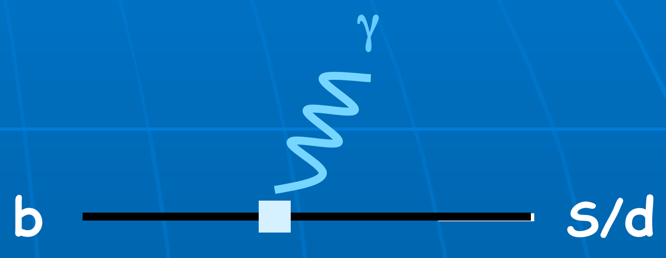
If X is exclusive state e.g | K*γ > two possibilities

1. Lattice QCD : Lattice spacing » compton wavelength of b -> Large errors
2. QCD sum rules: Relates resonances to vacuum structure of QCD

Neither approach gives precise estimates – limits exclusive physics.
Uncertainties cancel in ratios of modes or asymmetries.

Inclusive Matrix Elements

$$H_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts} \sum_{i=1}^{10} C_i(\mu) Q_i(\mu)$$



If X is an inclusive state

$$\langle X | Q | B \rangle = 1 + \mathrm{O}(\cancelto{0}{\frac{1}{m_b}}) + \mathrm{O}(\frac{1}{m_b^2}) + \ldots$$

Leading term is short distance quark contribution and non-perturbative effects appears at $1/m_b^2$ –i.e (O(1%)) corrections

Inclusive measurements are much more sensitive to new physics

General Considerations

	Exclusive		Inclusive
Mode (#Events in~400fb-1)	B->K*γ O(1000)	B->ρ/ωγ O(100)	B->X_sγ O(10000)
Backgrounds	Small	Large	Large
Theory Uncertainty	Large 30-50%	Medium (in ratios) 15%	Small 7%

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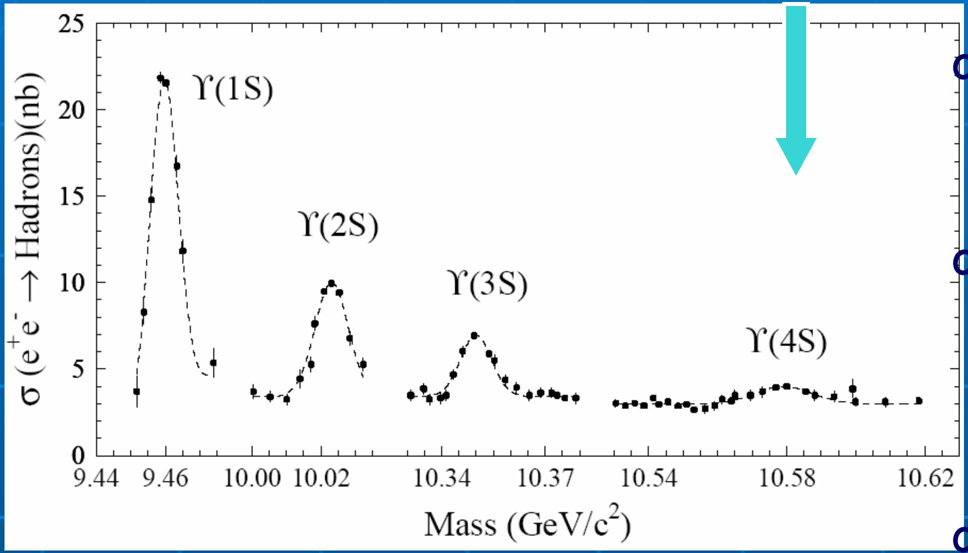
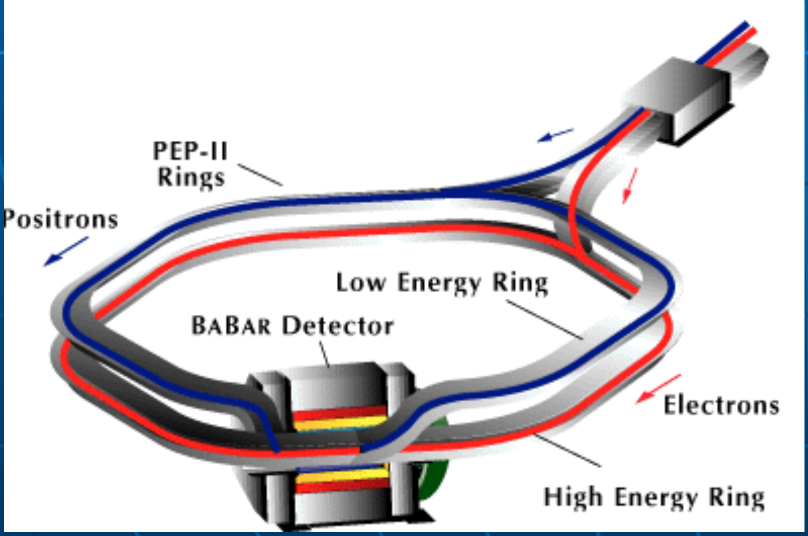
B factories: e+e- → Y(4S) → BB

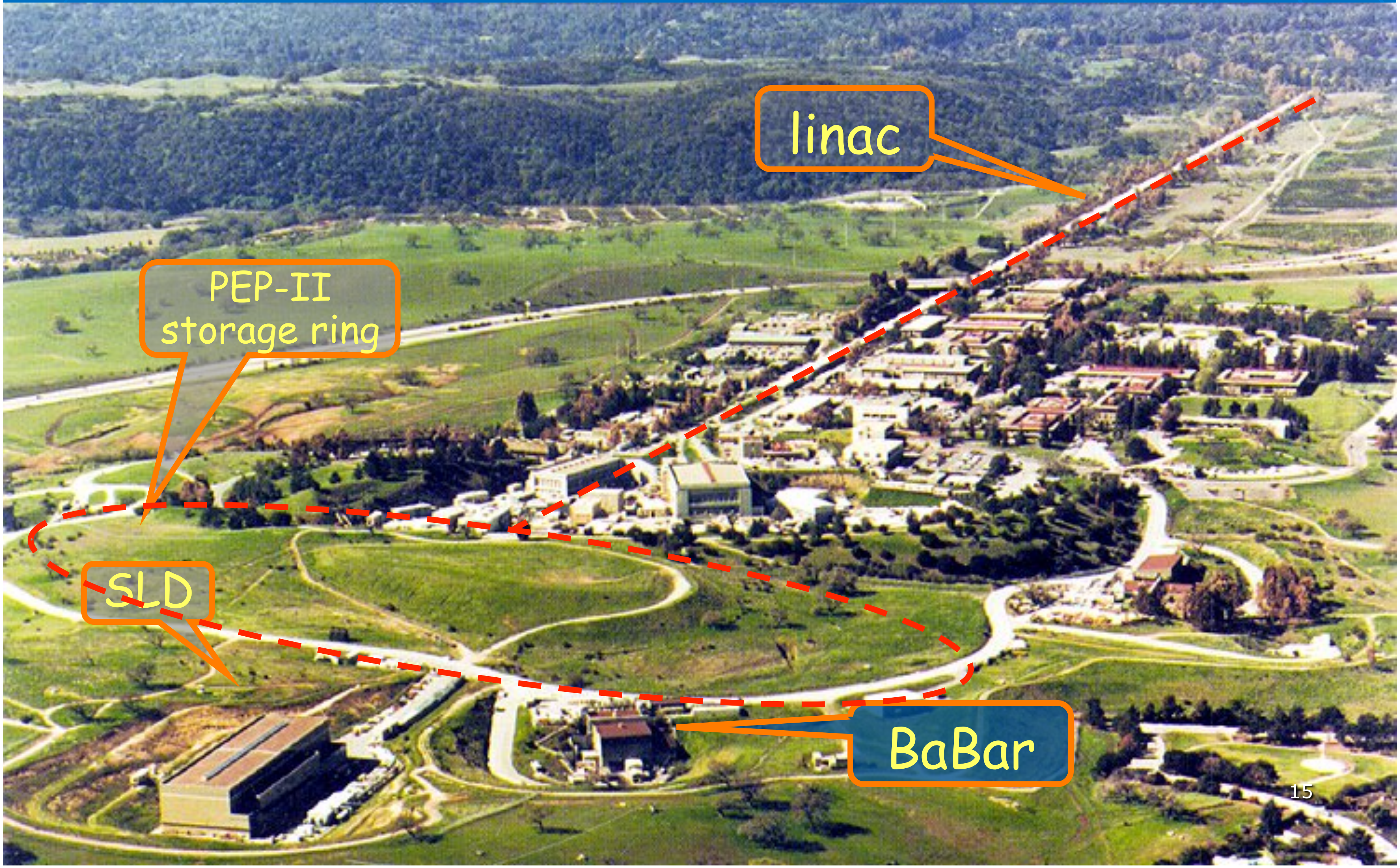


- B factories operate at the Y(4S) resonance (10.58 GeV)
- hadronic cross-sections:
  udsc:bb = 3.4:1.1 nb
- in the Y(4S) frame the B mesons are practically at rest

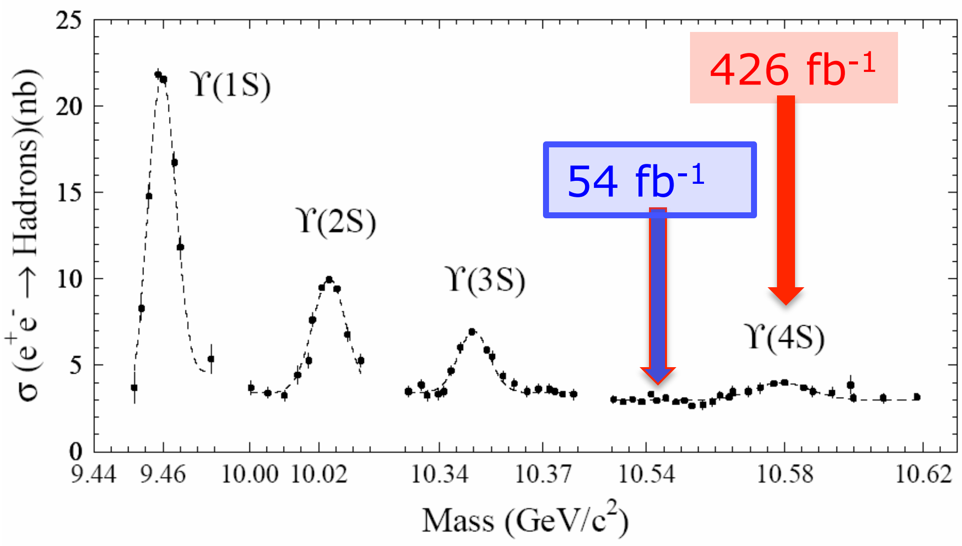
→ PEP-II is an asymmetric collider
9.0 GeV electrons vs
3.1 GeV positrons

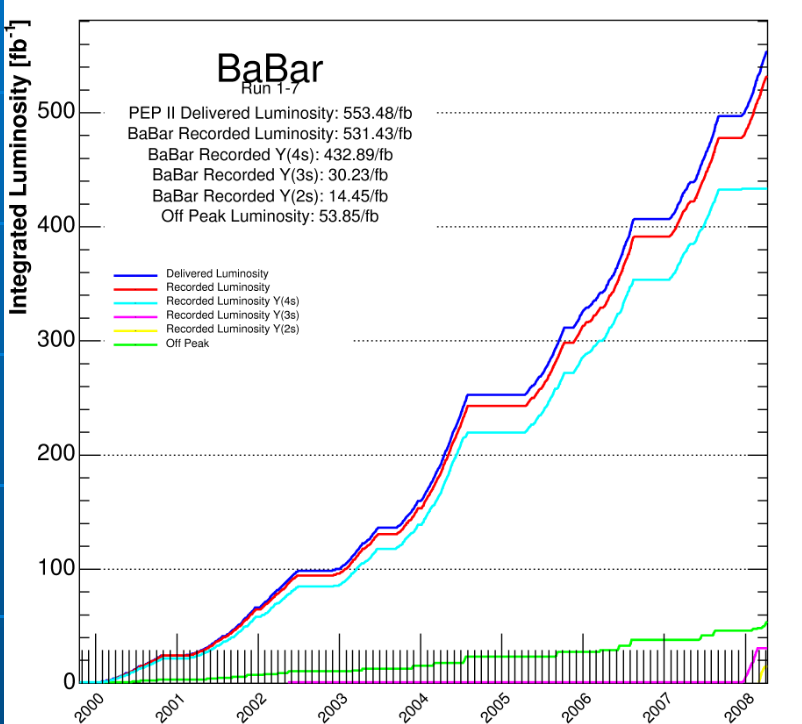


PEP-II and BaBar at SLAC



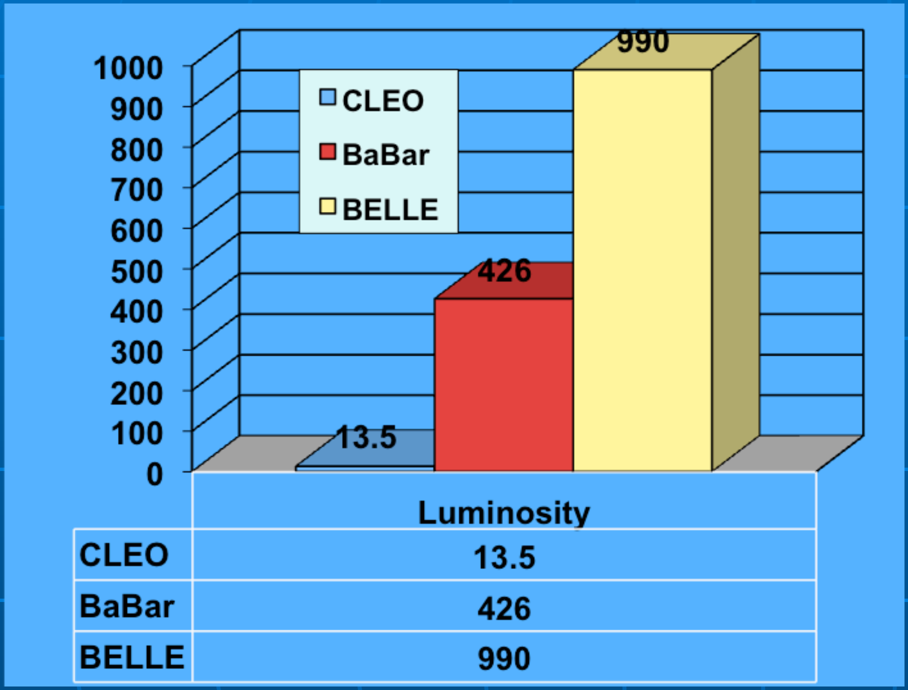
The BaBar Dataset





BaBar collected *468 M BB* pairs between 2000-2007 and 54 fb^{-1} off-resonance data (8%). This yields about 1 Billion B meson decays

Other B meson experiments



	Luminosity
CLEO	13.5
BaBar	426
BELLE	990

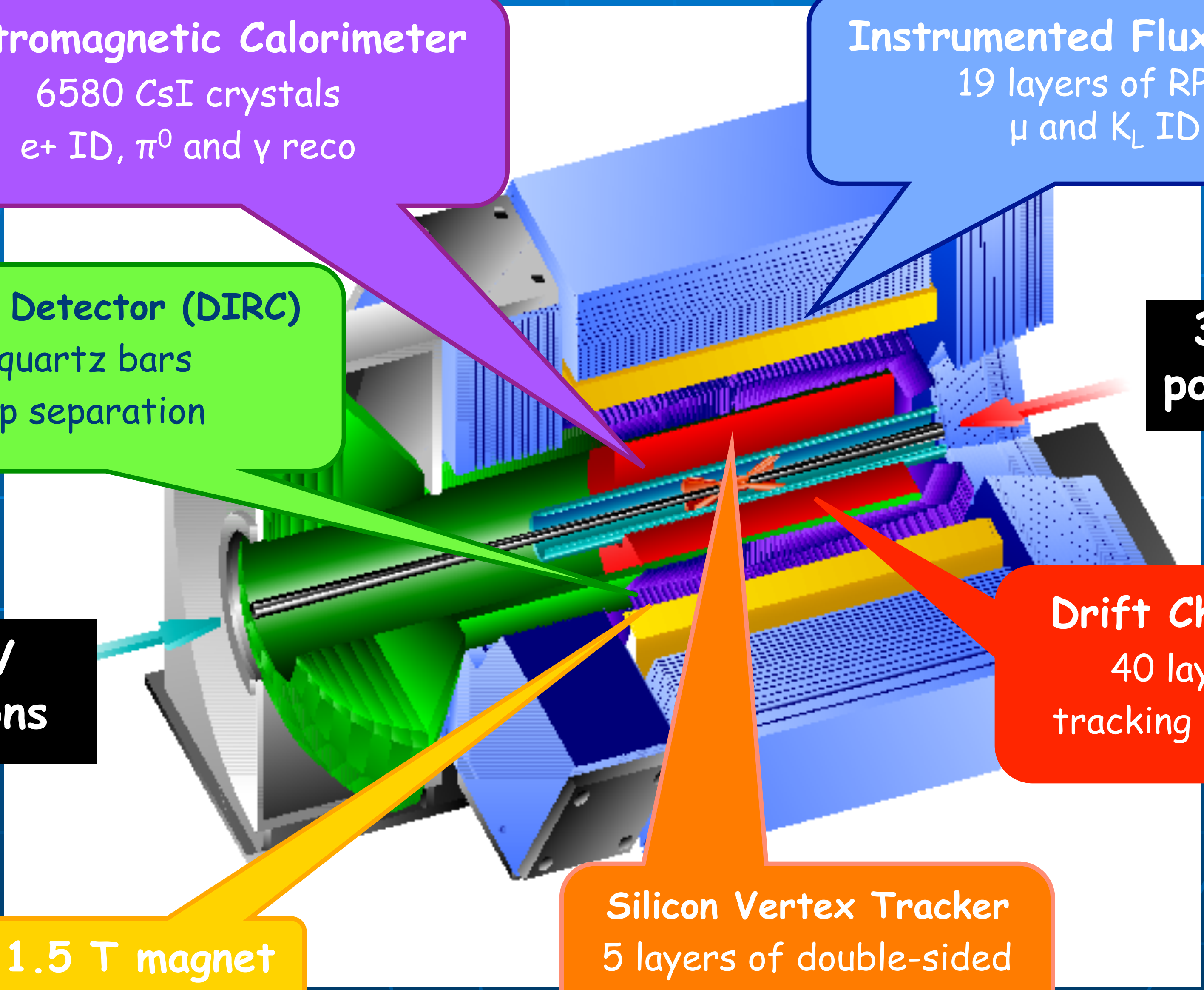
CLEO did much of the pioneering work. Stopped in 2001

BaBar forced to shut down for a year in 2004-2005 by DOE safety after accident then cancelled in 2006

Though BELLE has larger datasets BaBar remains competitive Particularly in systematics dominated measurements

When it was cancelled BaBar was performing at 7 times design Luminosity and had produced over 350 publications. One of which led to the award of the 2008 Nobel prize (to KM of CKM)

The BaBar detector



Electromagnetic Calorimeter
6580 CsI crystals
e+ ID, π^0 and γ reco

Instrumented Flux Return
19 layers of RPCs
μ and K_L ID

Cherenkov Detector (DIRC)
144 quartz bars
K, π, p separation

3 GeV positrons

9 GeV electrons

Drift Chamber
40 layers,
tracking + dE/dx

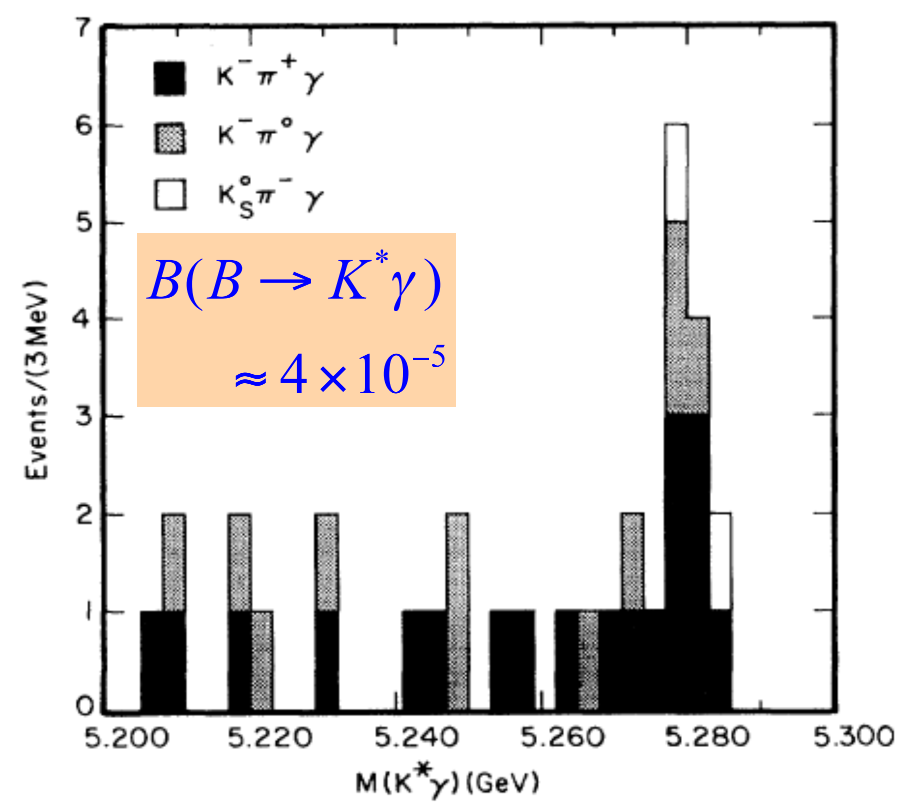
1.5 T magnet

Silicon Vertex Tracker
5 layers of double-sided
silicon strips

Contents

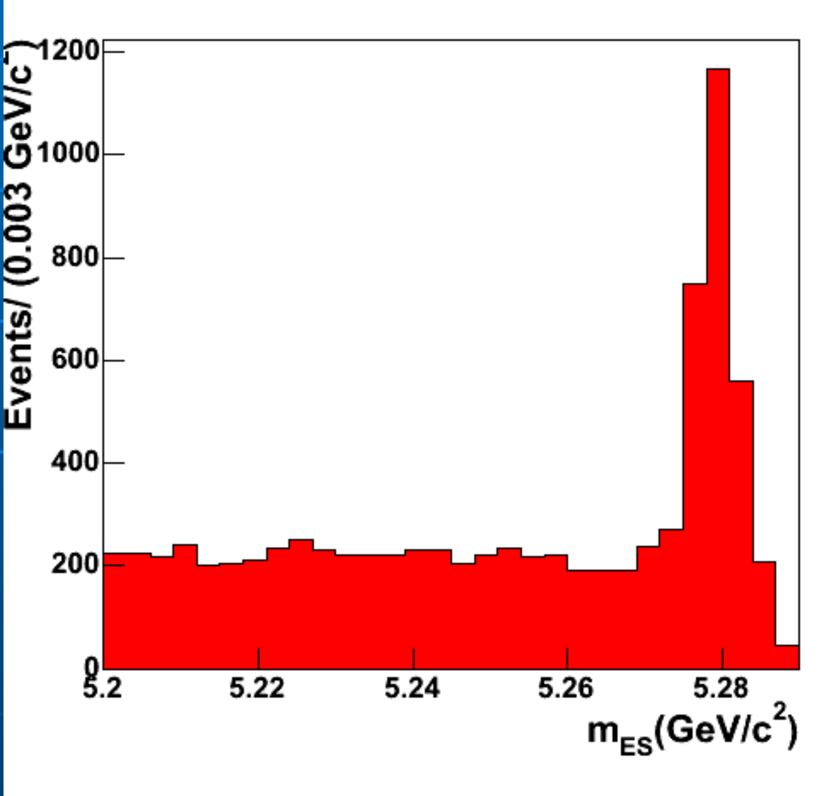
Radiative penguin decays of *B* mesons

CLEO Observation of *B*→*K* γ* *1993*



$$B(B \to K^* \gamma) \approx 4 \times 10^{-5}$$

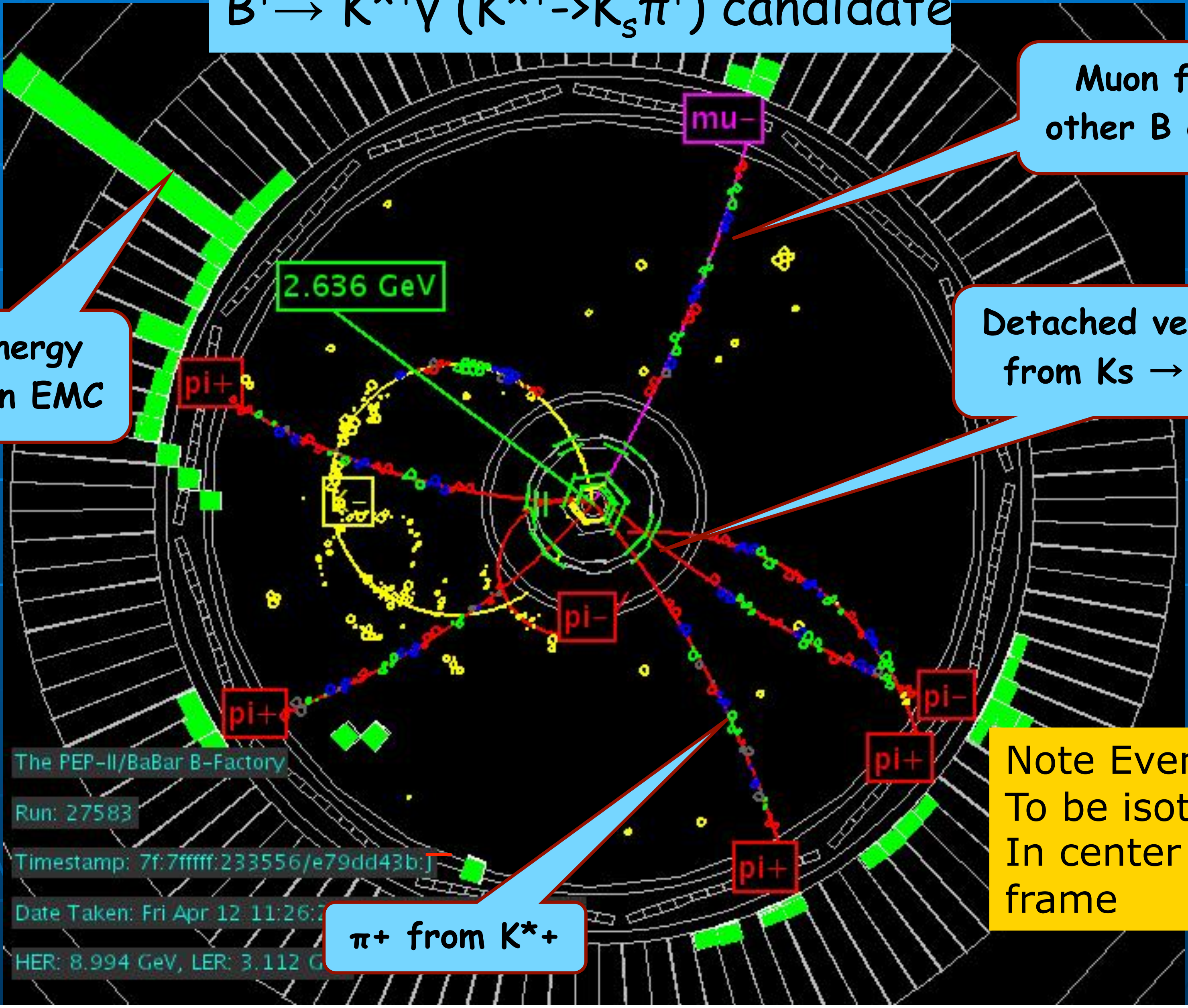
BaBar *B*→*K* γ* *2009*



First observation of penguins by CLEO. Now it's a background !

Radiative penguin portrait

$B^+ \rightarrow K^{*+}\gamma$ (K^{*+}->$K_s\pi^+$) candidate



Muon from other B decay

High energy photon in EMC

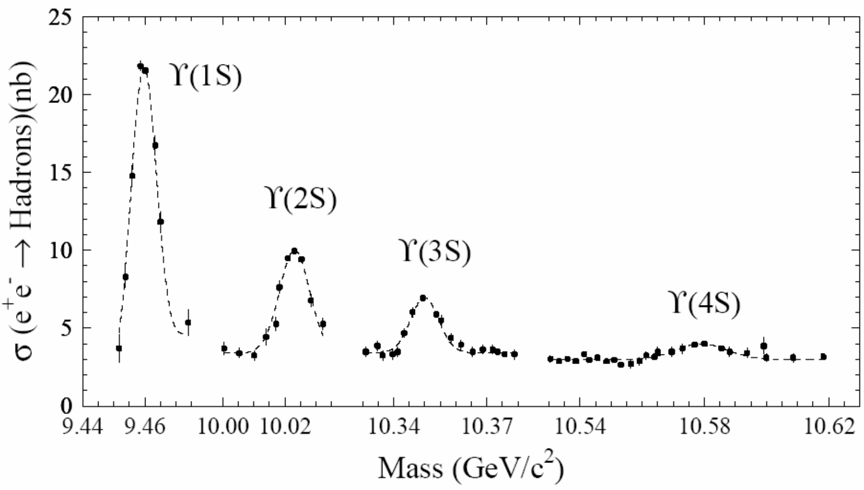
Detached vertex from Ks → ππ

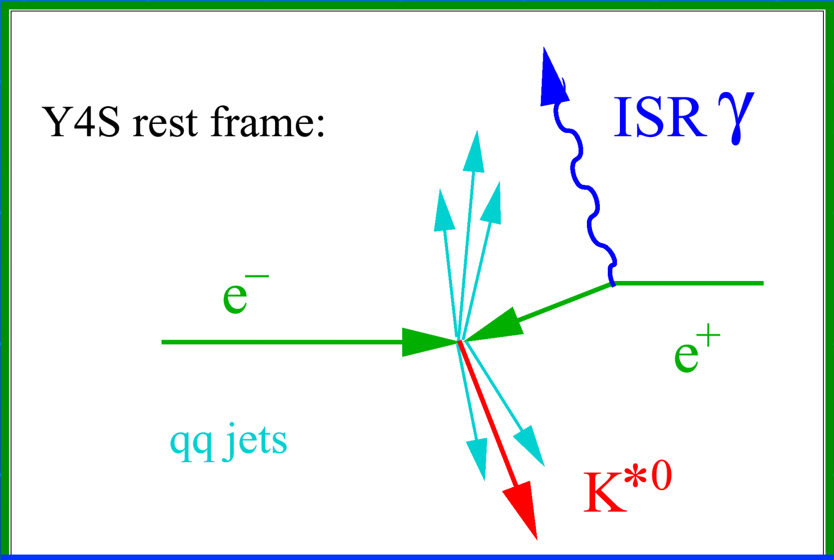
π+ from K*+

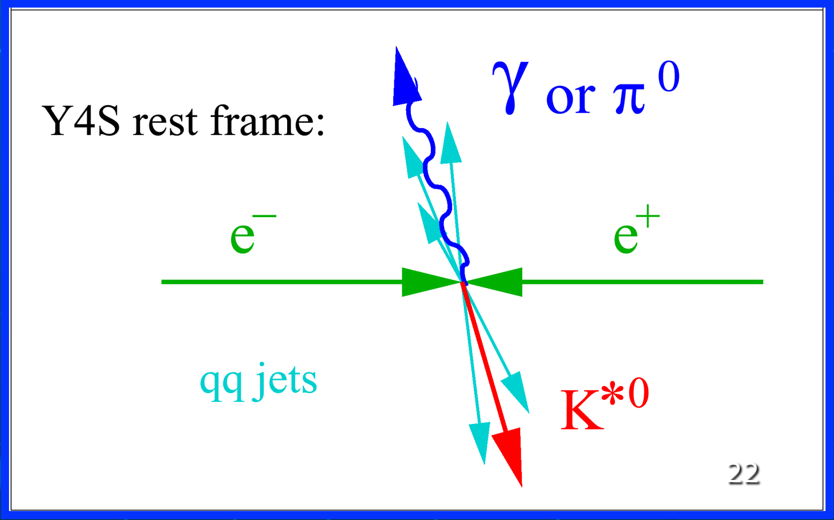
Note Event tends
To be isotropic
In center of mass
frame

Continuum Backgrounds

Production of u,d,s,c quark
and τ pairs underneath ϒ(4s)



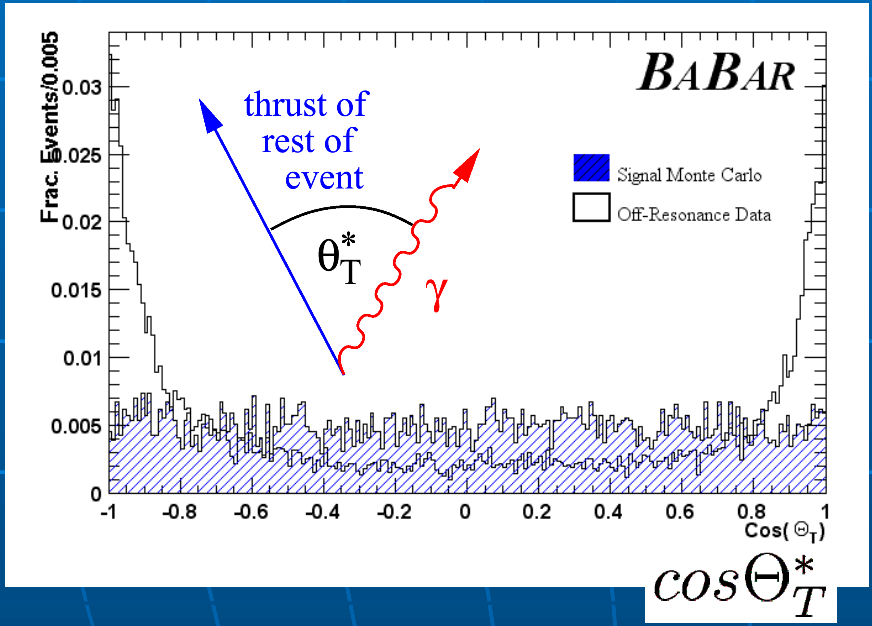




Lorentz boost makes a jet-like topology

Event Shape Variables

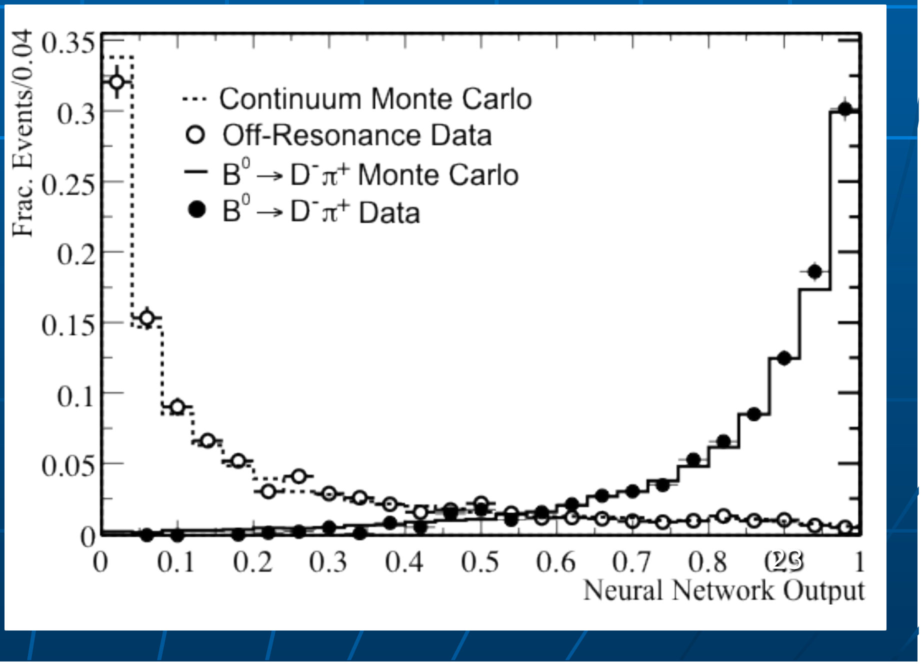
Construct "Shape" variables to distinguish between isotropy and jets



$cos\Theta^*_T$

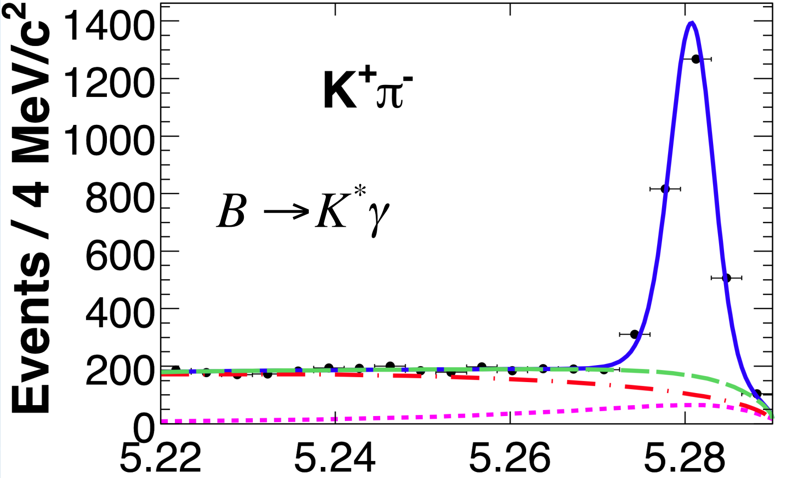
Angle between thrust and photon

Neural net combination of suite of topology variables effective with multicomponent background



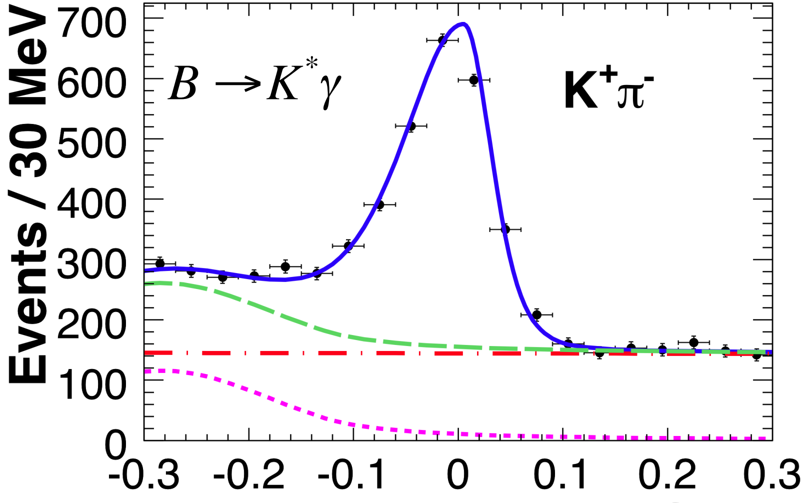
Signal Variables for Exclusive Reconstruction analyses

Beam Constrained Mass



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

Reconstructed Energy - beam Energy



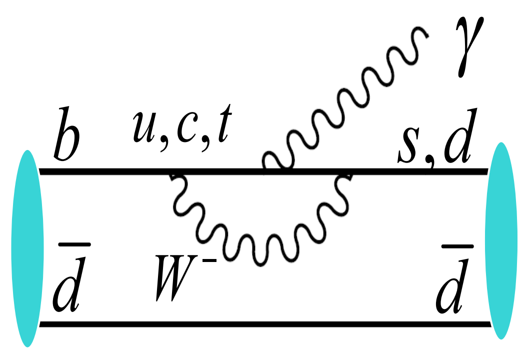
$$\Delta E^* = E_B^* - E_{beam}^*$$

Sensitivity can be enhanced by performing two dimensional likelihood fits to signal and background.

Average of Belle & BaBar: $\mathrm{B}(B \rightarrow K^*\gamma) = (4.16 \pm 0.17) \times 10^{-5}$

Theory $6.0 \pm 3.0 \times 10^{-5}$

A Colony of Penguins

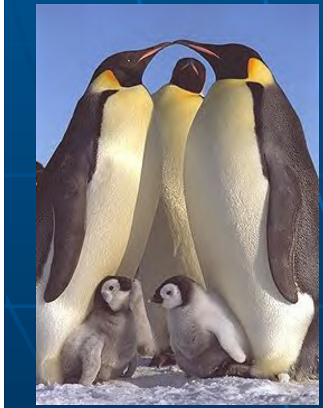


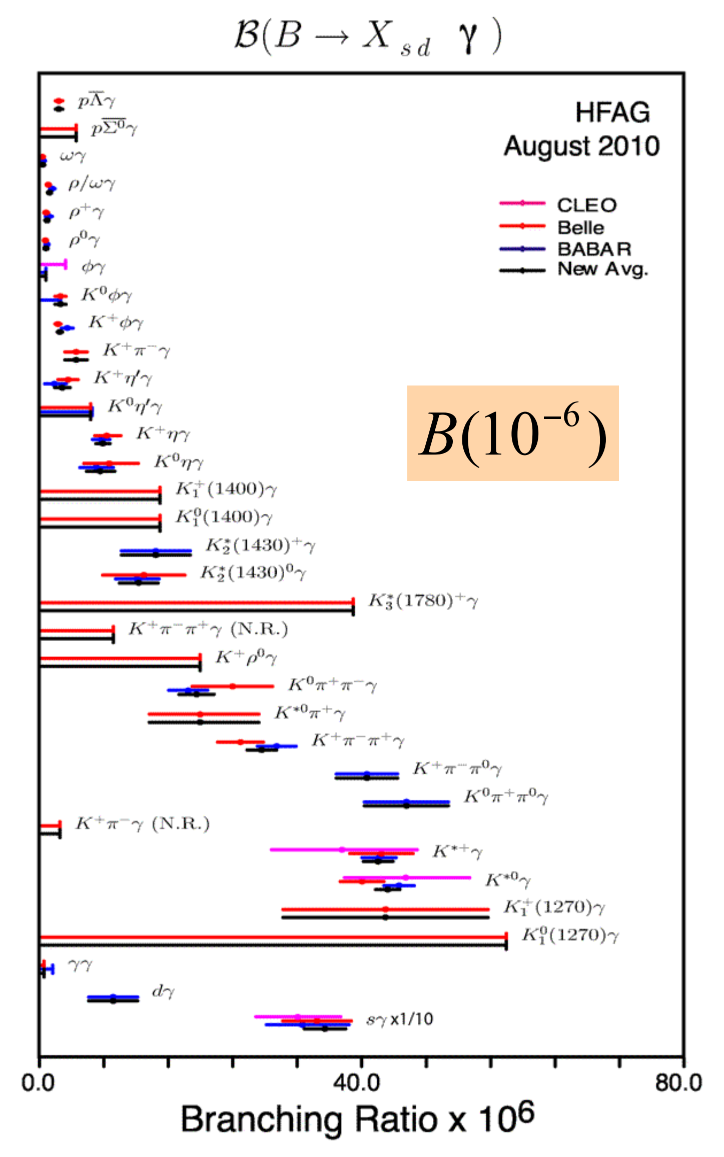
ρ,ω

dd (V_{td})

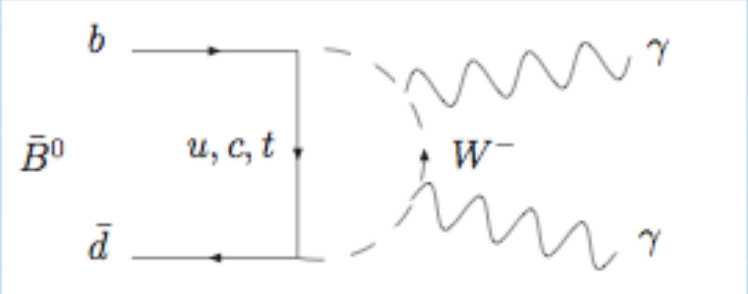
sd (V_{ts})

K*(892)
K_1(1270)
K_2(1430)
…





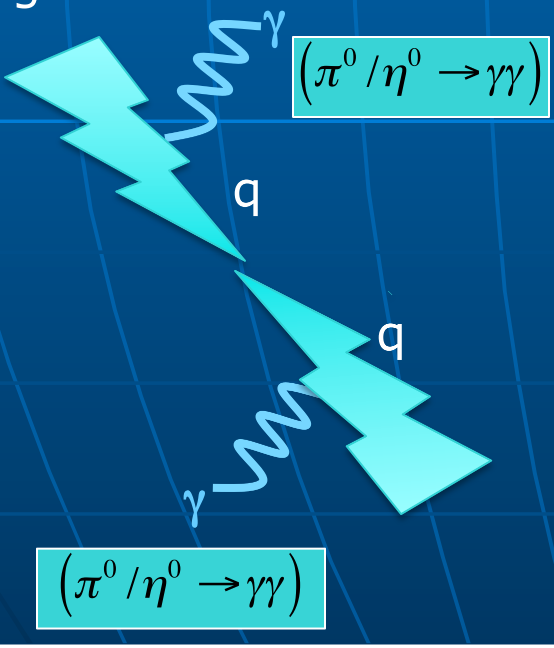
Search for $B^0 \to \gamma\gamma$

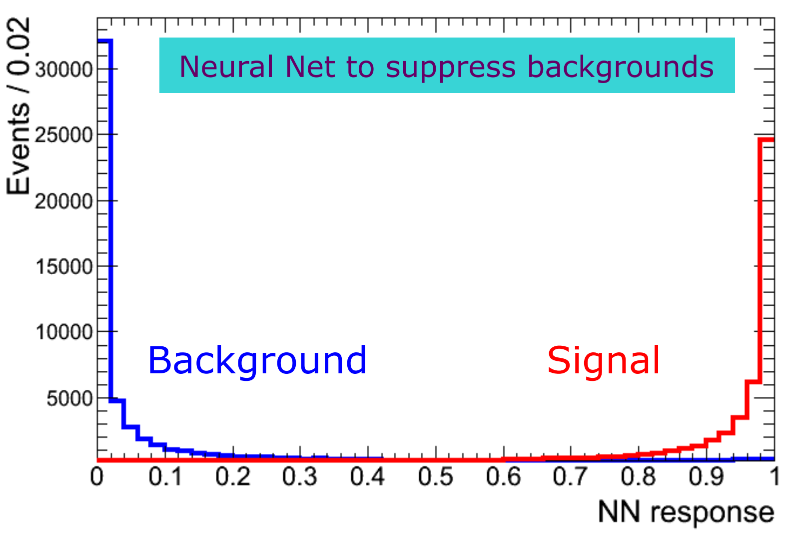


SM: Expect $B(B^0 \to \gamma\gamma)$ ~ 3 x 10^{-8}
(Bosch and Buchalla,,JHEP 0208:054 (2002))

But could be enhanced by x10 by SUSY given b->dγ constraints (Aliev and Turin, PRD 58 095014)

Backgrounds from continuum

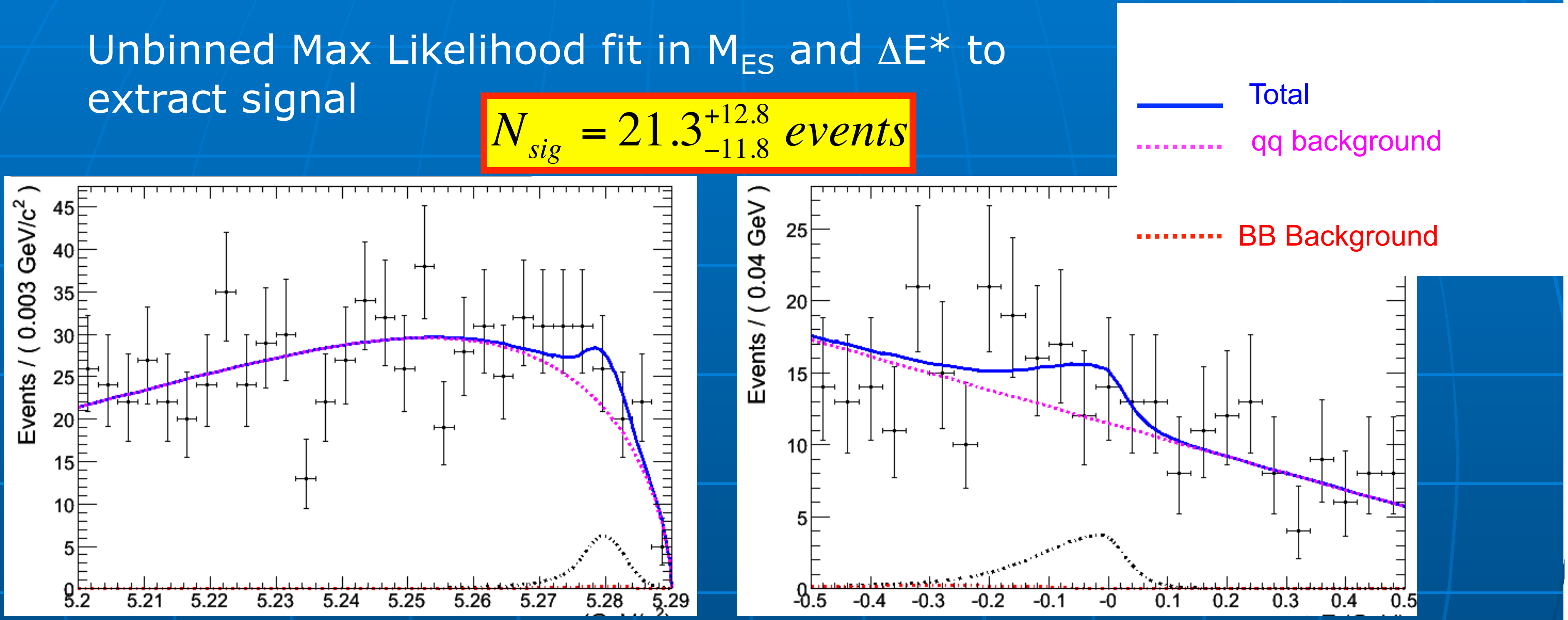




Search for $B^0 \to \gamma\gamma$ Results

Unbinned Max Likelihood fit in M_{ES} and ΔE^* to extract signal

$$N_{sig} = 21.3^{+12.8}_{-11.8}\ events$$



$$M_{ES} = \sqrt{\left(E^{*2}_{beam} - p^{*2}_{B}\right)}$$

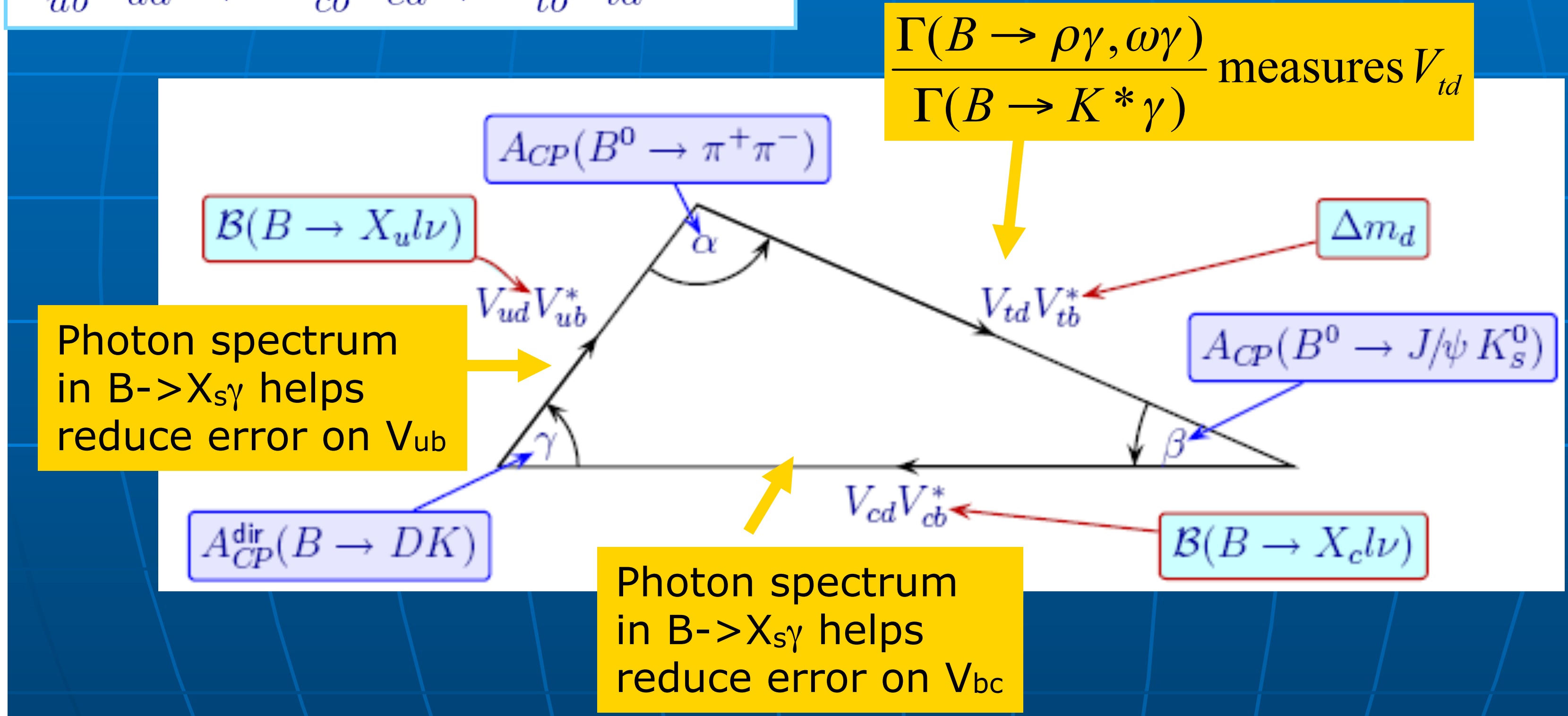
$$\Delta E^* = E^*_B - E^*_{beam}$$

$$B(B \to \gamma\gamma) = \left(1.7 \pm 1.1(stat.) \pm 0.2(sys.)\right) \times 10^{-7} \qquad (1.9\sigma\ significance)$$

$$B(B \to \gamma\gamma) < 3.3 \times 10^{-7}\ \ at\ \ 90\%\ C.L.$$

The unitarity triangle

$$V_{ub}^*V_{ud} + V_{cb}^*V_{cd} + V_{tb}^*V_{td} = 0$$



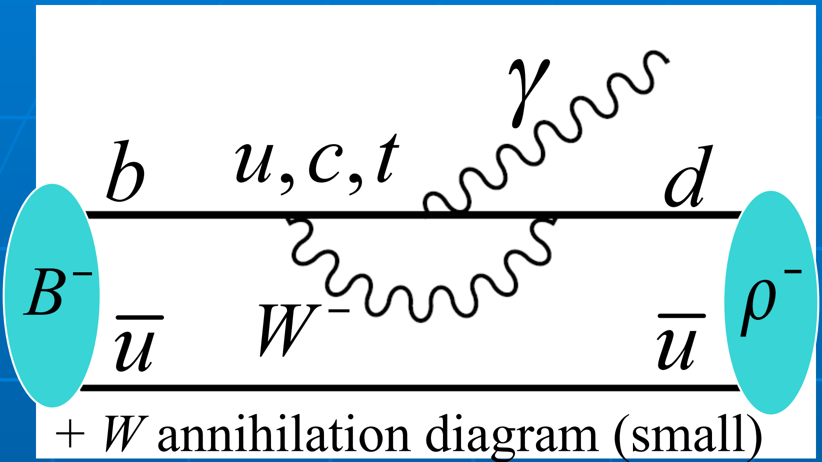
$$\frac{\Gamma(B \to \rho\gamma, \omega\gamma)}{\Gamma(B \to K^*\gamma)} \text{ measures } V_{td}$$

Photon spectrum in B->$X_s\gamma$ helps reduce error on V_{ub}

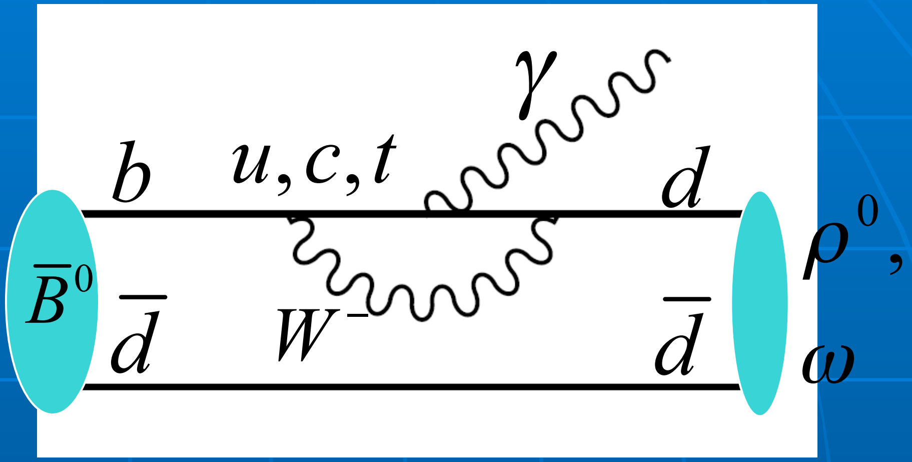
Photon spectrum in B->$X_s\gamma$ helps reduce error on V_{bc}

Overconstraining the triangle may reveal new sources of CP violation.

Measurement of $b \to d\,\gamma$ and Extraction of $|V_{td}/V_{ts}|$



+ W annihilation diagram (small)



$$\frac{B(B\to\rho\gamma)}{B(B\to K^*\gamma)} = \left|\frac{V_{td}}{V_{ts}}\right|^2 \frac{\left(m_B^2-m_\rho^2\right)^3}{\left(m_B^2-m_{K^*}^2\right)^3} \underbrace{\left(\frac{T_1^\rho(0)}{T_1^{K^*}(0)}\right)^2}_{1/\xi^2} \left(1+\Delta R\right)$$

$$\xi \equiv \frac{T_1^{K^*}(0)}{T_1^\rho(0)} = 1.17 \pm 0.09$$

$$\Delta R = 0.1 \pm 0.1$$

Ali, Lunghi, Parkhomenko, PLB 595, 323 (2004)

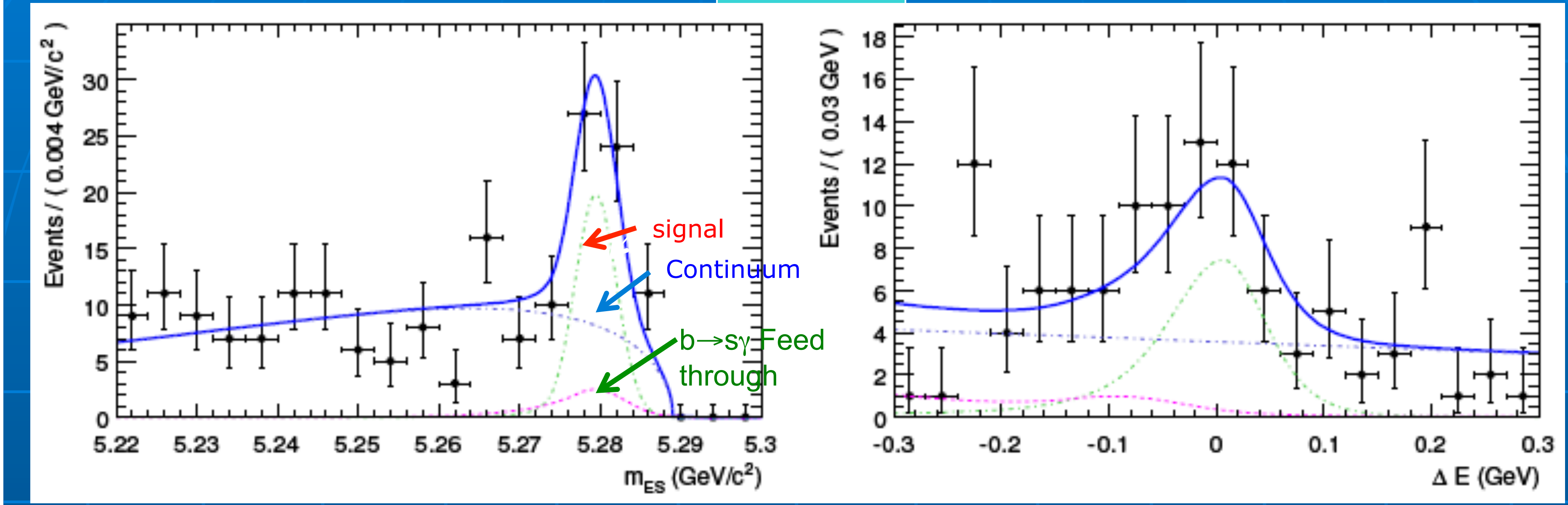
Ball and Zwicky, JHEP 0604, 046 (2006)

$$\Gamma(B\to\rho^+\gamma) = 2\frac{\tau_{B^+}}{\tau_{B^0}}\Gamma(B\to\rho\gamma) = 2\frac{\tau_{B^+}}{\tau_{B^0}}\Gamma(B\to\omega\gamma)$$

I-spin (ρ), quark model (ω). Expect small I-spin violation:(1.1+/-3.9)%.

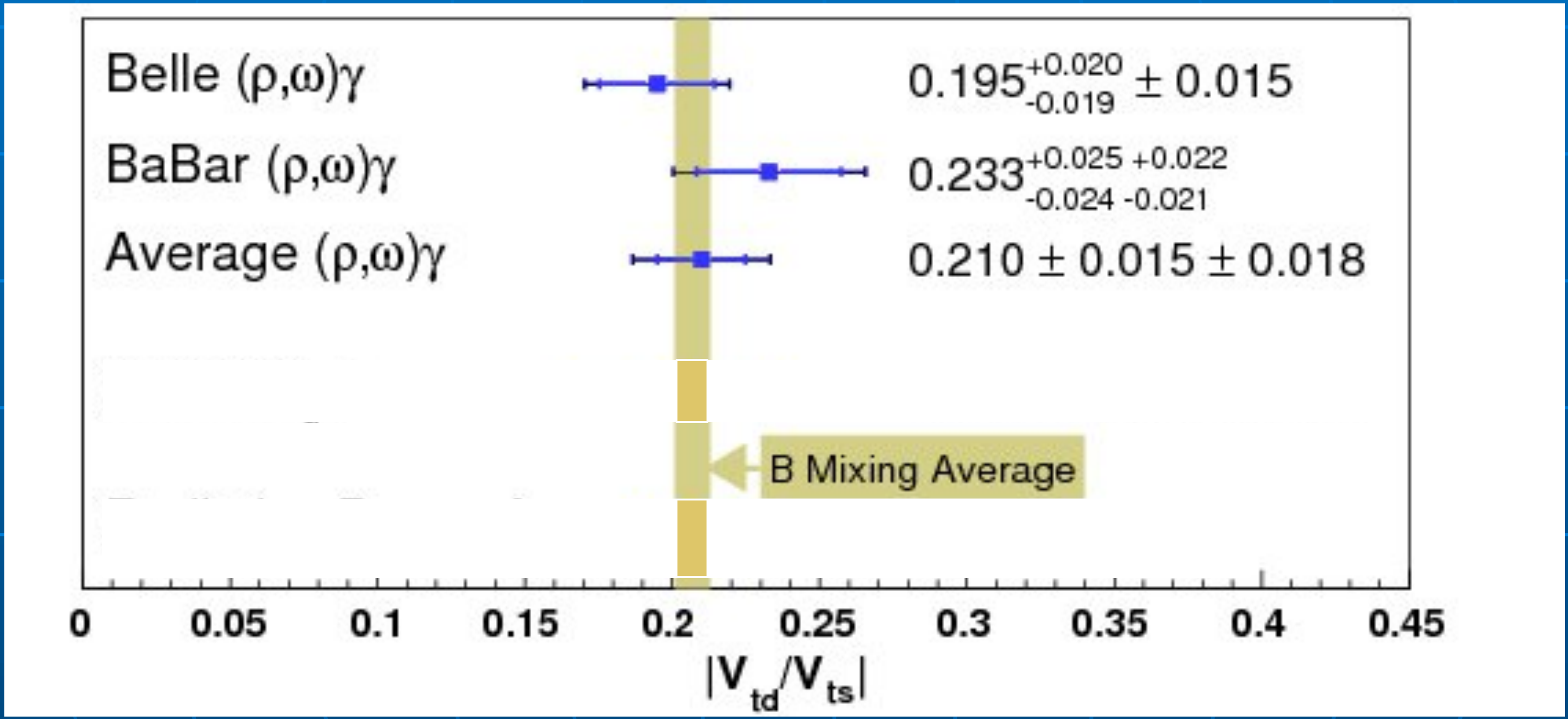
Measurement of $b \rightarrow d\,\gamma$ Branching Fractions

$B^0 \rightarrow \rho^0\gamma$



Mode	***BABAR*** **(10^{-7})** **(423 fb^{-1})**	**Belle (10^{-7})** **(598fb^{-1})**
$B^+ \rightarrow \rho^+\gamma$	$12.0^{+4.2}_{-3.7} \pm 2.0$	$8.7^{+2.9\ +0.9}_{-2.7\ -1.1}$
$B^0 \rightarrow \rho^0\gamma$	$9.7^{+2.4}_{-2.2} \pm 0.6$	$7.8^{+1.7\ +0.9}_{-1.6\ -1.0}$
$B^0 \rightarrow \omega\gamma$	$5.0^{+2.7}_{-2.3} \pm 0.9$	$4.0^{+1.9}_{-1.7} \pm 1.3$

$|V_{td}/V_{ts}|$ from penguins and B_s mixing



Contents

Inclusive Penguins: Γ(B->Xsγ)

$$\Gamma(B \to X_s\gamma) = \Gamma(b \to s\gamma) + \Delta^{non-pert}$$

Quark-hadron duality

The non-perturbative corrections are a few percent.

NNLO calculation for B(B->$X_s\gamma$)

$$B(B \to X_s\gamma) = 3.15 \pm 0.23 \times 10^{-4}$$

(Misiak,Asatrian,Bieri,Czakon,Czarnecki,Ewerth,Ferroglia,Gambino Gorbahn,Greub,Haisch,Hovhannisyan,Hurth,Mitov,Poghosyan,Slusarczyh)

Major undertaking involving thousands of diagrams. New precise Calculation has renewed interest in the field

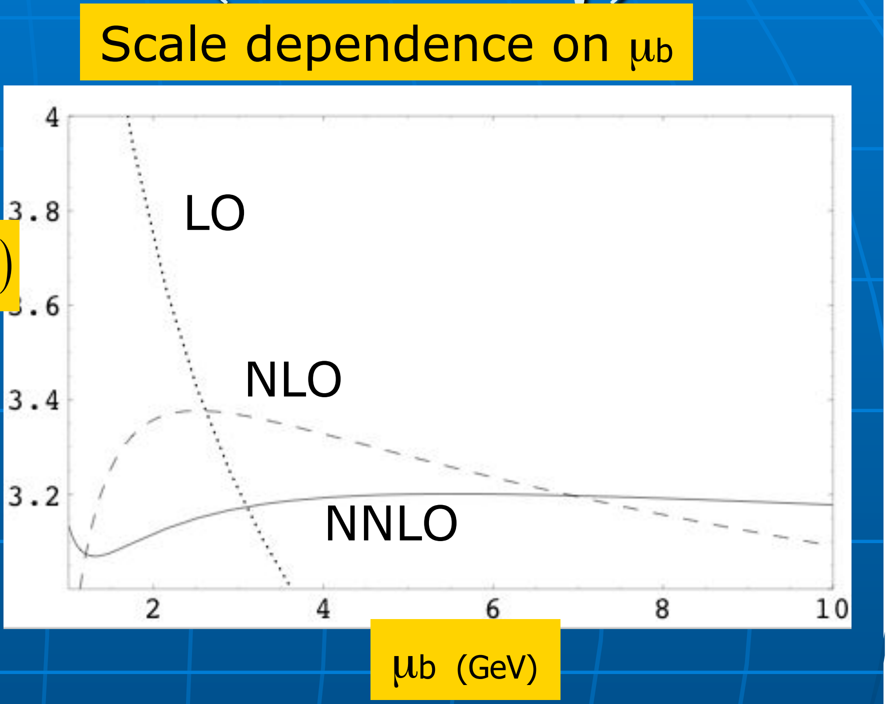
Compare to NLO: $B(B \to X_s\gamma) = 3.61 \pm 0.43 \times 10^{-4}$

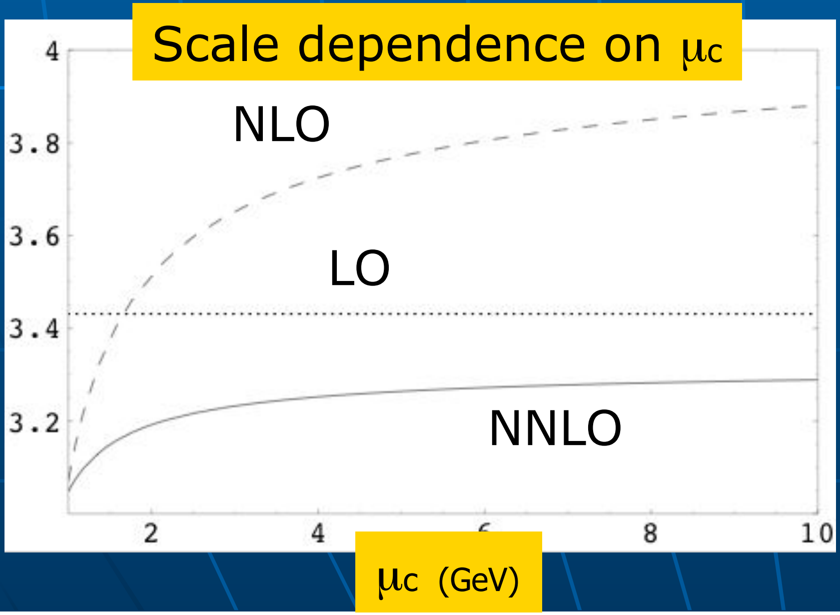
Theory Errors on B(B->Xsγ)

Theory errors from choice of Renormalization scales

As go to higher orders this is reduced as expected.

$B(B \to X_s\gamma)$


Scale dependence on μb


Scale dependence on μc

At NLO the choice of charm quark renormalization scale had been a Problem.

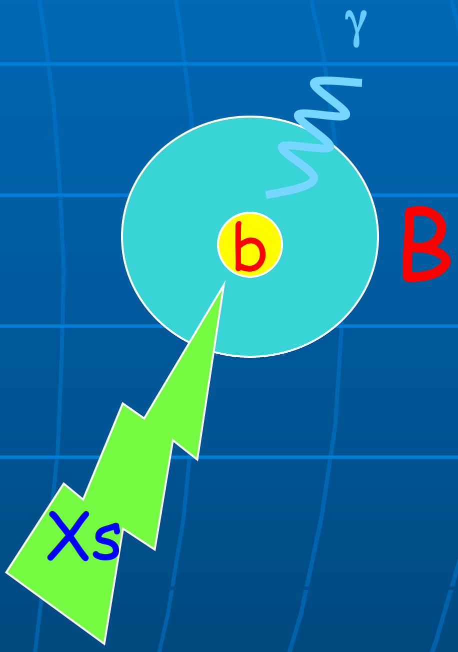
New calculation resolves this issue and errors are now understood

Quark-Hadron duality

Quarks

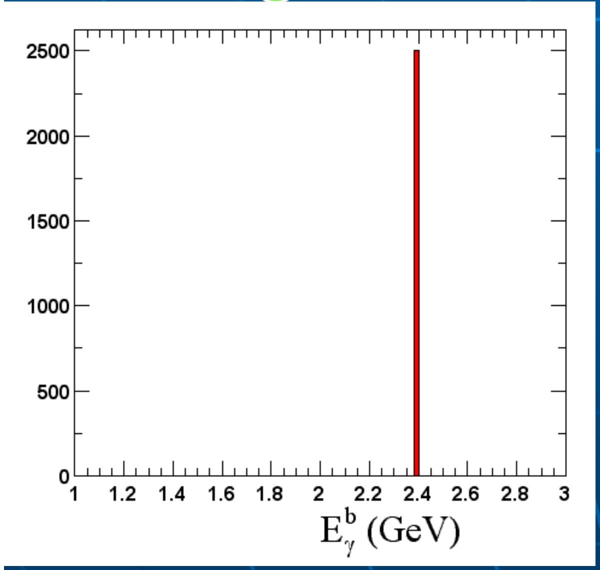
$B(b -> s\gamma) = B(B -> X_s\gamma)$

Hadrons

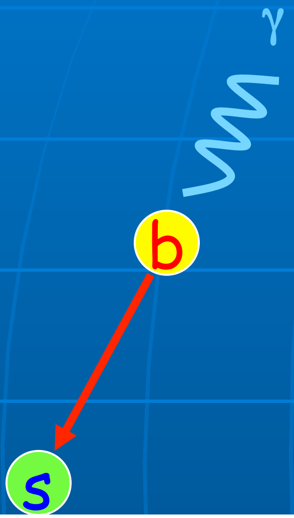


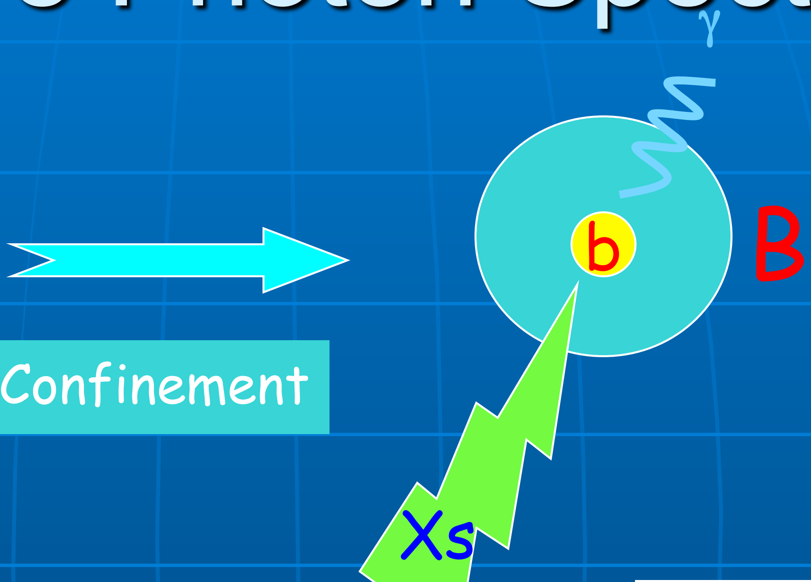
A fully inclusive measurement can be related directly to quark calculation

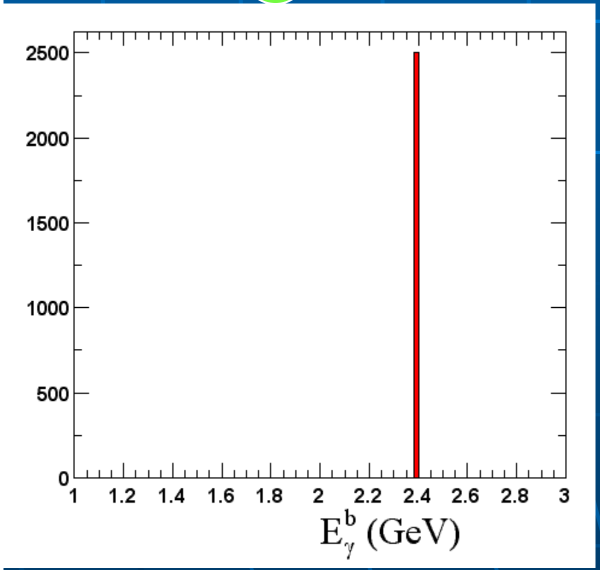
Inclusive Photon Spectrum

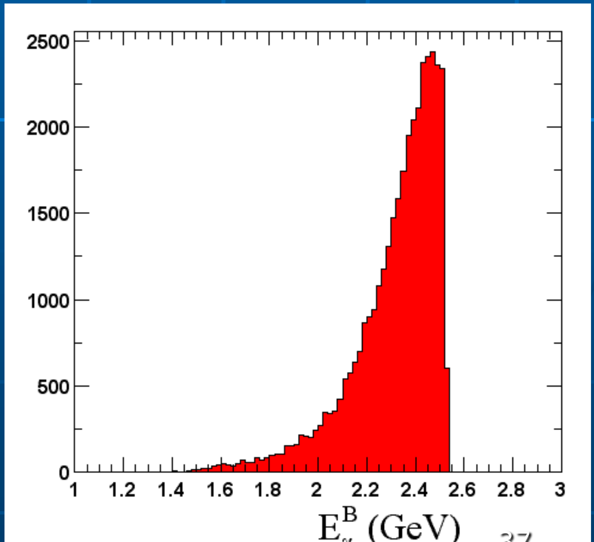


Inclusive Photon Spectrum



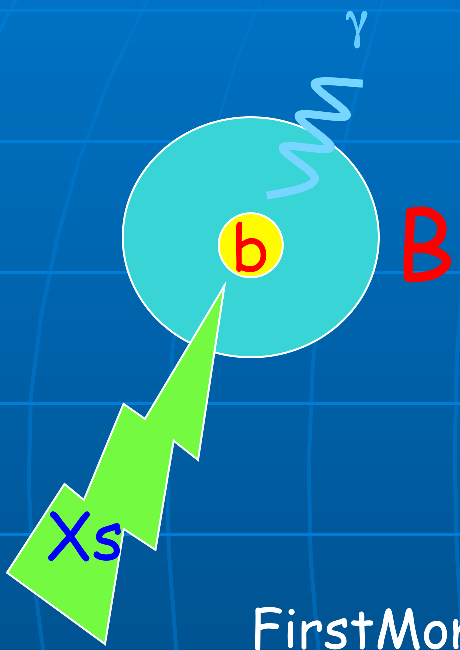


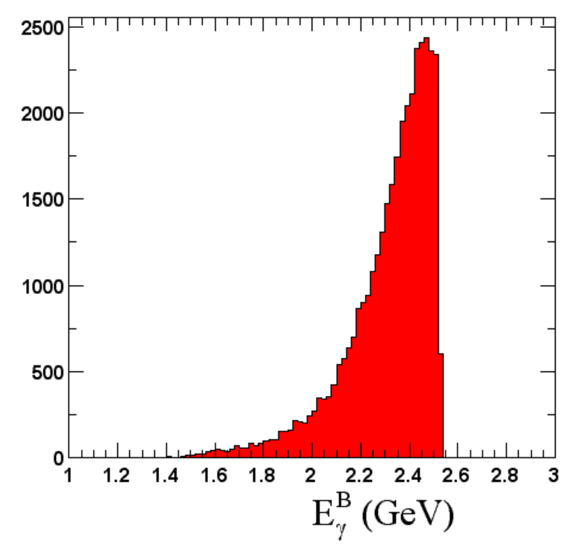




To be fully inclusive must measure all the photon spectrum

Inclusive Photon Spectrum





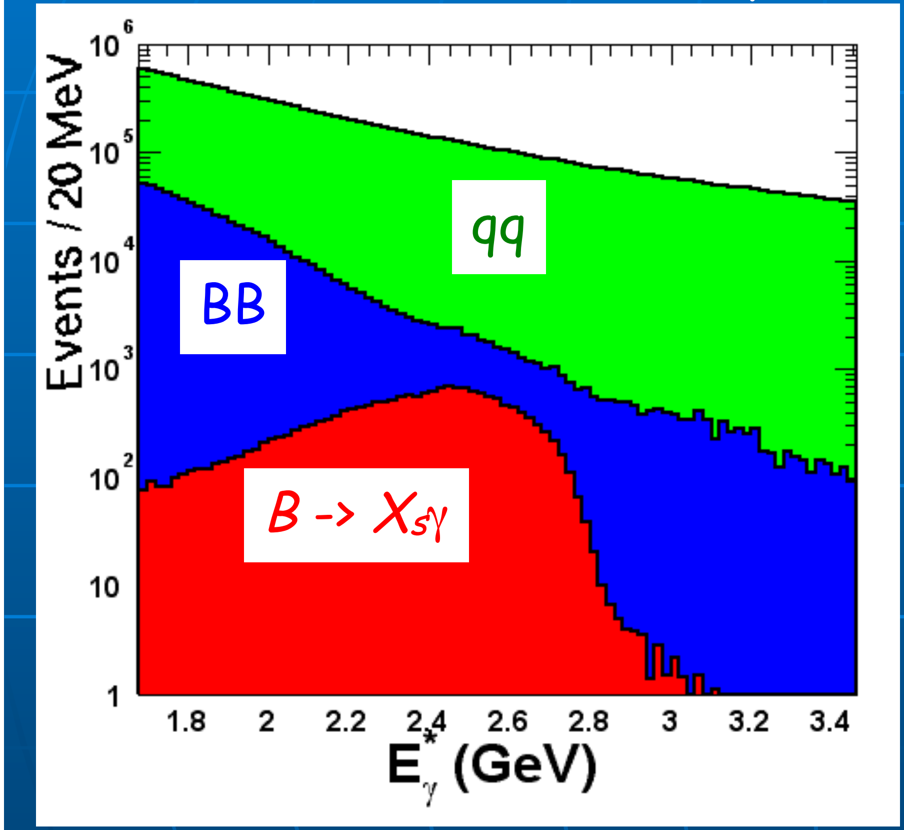
FirstMoment: $\left\langle E_\gamma^B \right\rangle \approx \frac{m_b}{2}$

Second Moment: $\left\langle E_\gamma^{B2} \right\rangle - \left\langle E_\gamma^B \right\rangle^2 \approx$ (Kinetic energy of b)^2

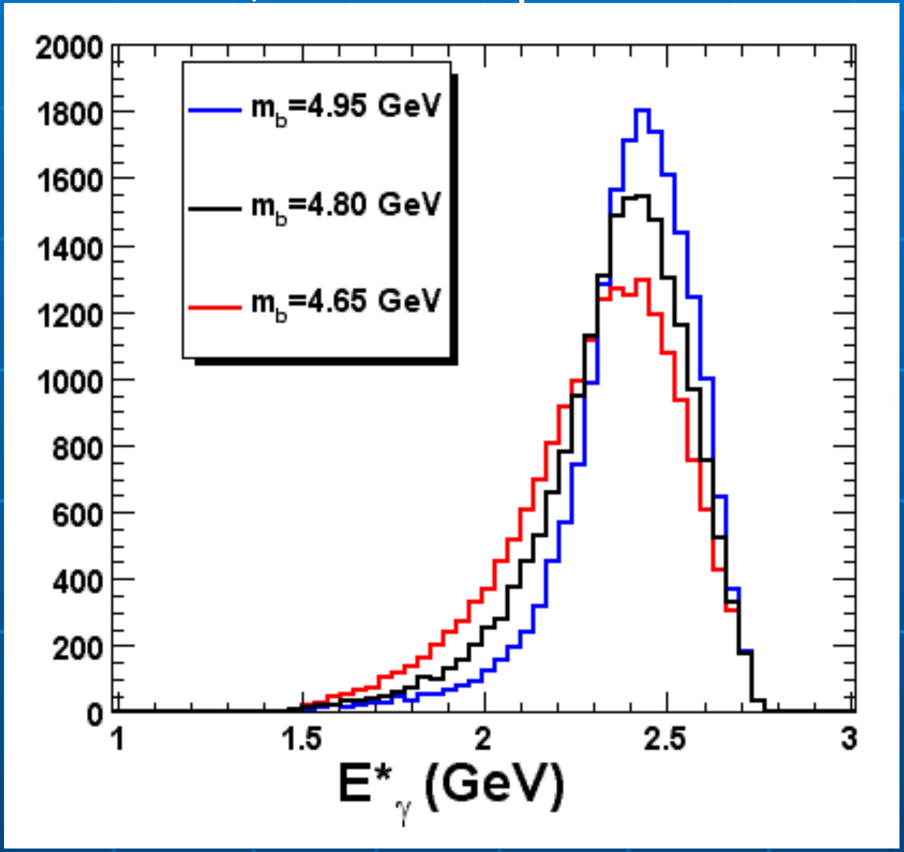
Information about motion of b-quark should be universal – i.e like a structure function and so can be applied to other inclusive processes

Experimental Challenge

Monte Carlo : Just require γ



γ Model Dependence

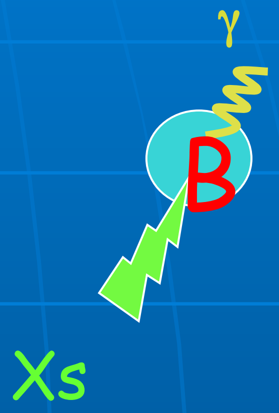


Note additional BB background

To reduce large backgrounds without cutting on γ or Xs
i.e a fully inclusive measurement

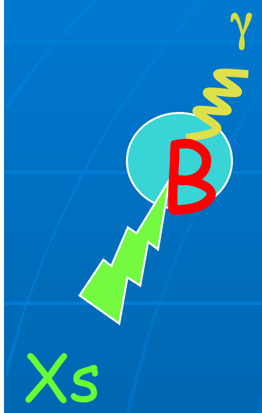
Two Methods for inclusive $B \rightarrow X_s \gamma$

Differ in treatment of Xs



Method	Advantages	Disadvantages
Fully inclusive **don't reconstruct X_s**	Closest correspondence to inclusive $\mathcal{B}(B \rightarrow X_s \gamma)$.	More Backgrounds
Sum of exclusive $B \rightarrow K\, n(\pi)\, \gamma$	Less background due to additional kinematic constraints. Better E_γ resolution.	More model dependence due to finite set of explicitly reconstructed $B \rightarrow X_s \gamma$ decays.

Technique 1 – Semi-Inclusive

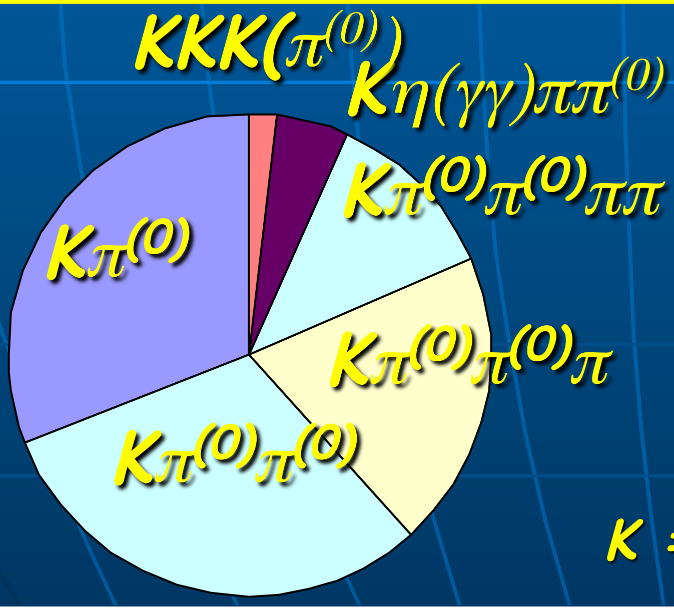


Exclusively Reconstruct as many of the final states of Xs as possible:

Fundamental problem is that composition of final states must be guessed - large systematic

~55%

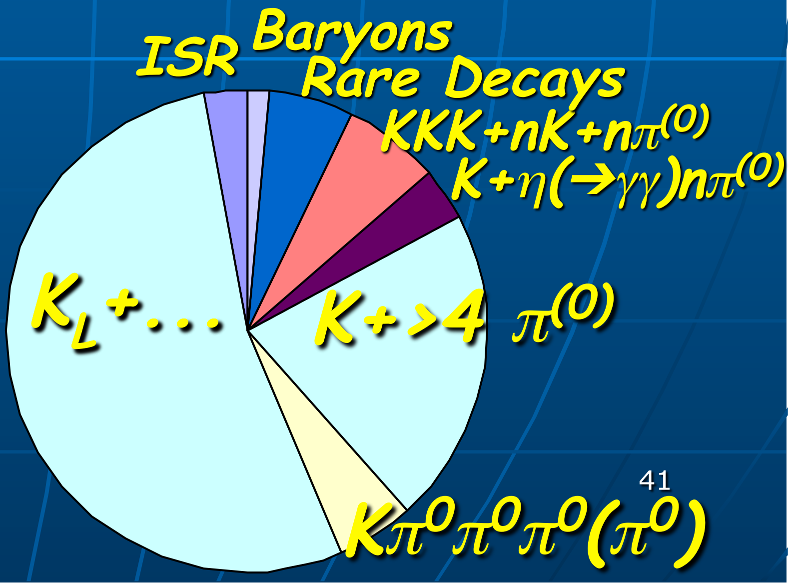
Reconstructed Final States



$K = K^{\pm}, K_s$

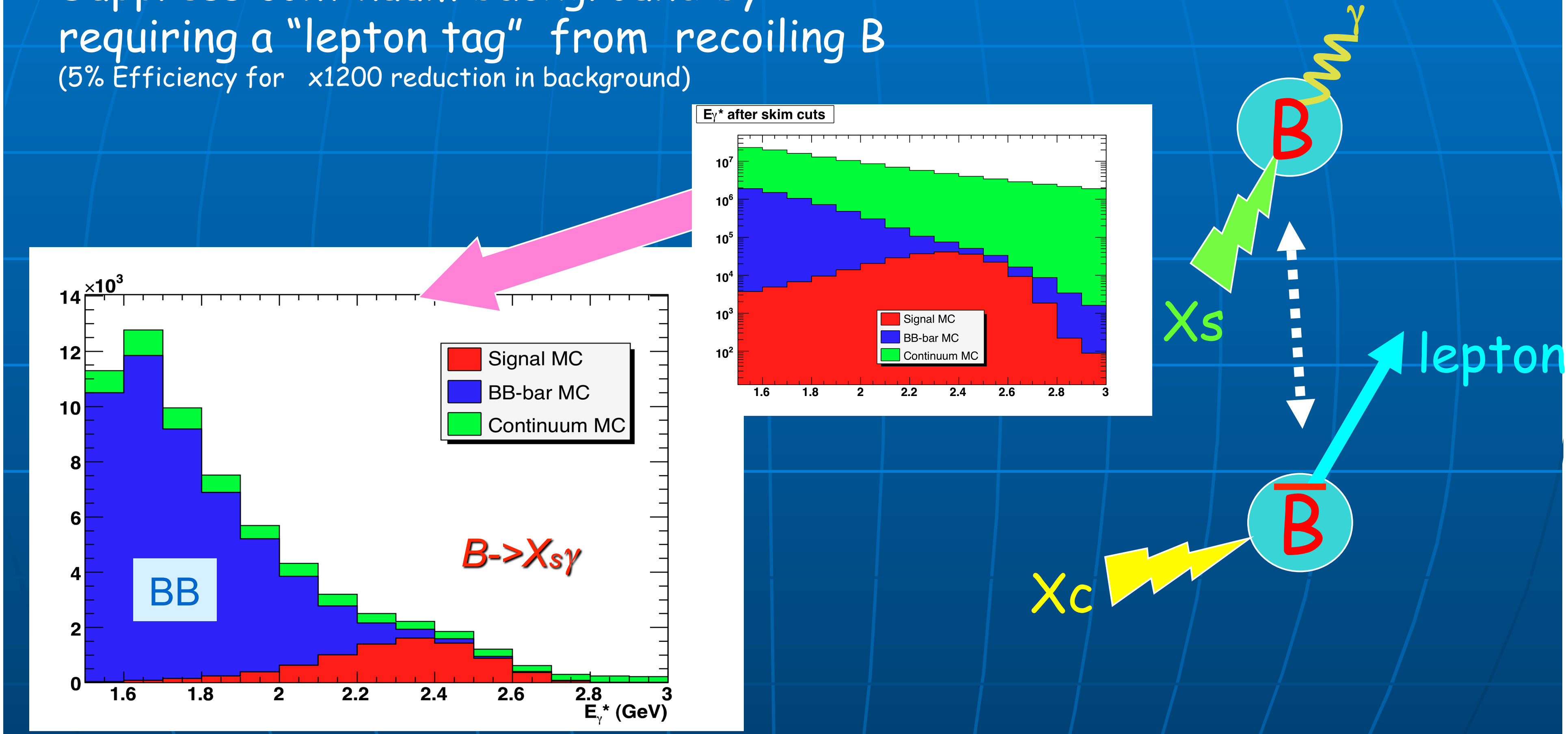
~45%

Missing Final States



Technique II "Fully Inclusive": *$B \to X_s\gamma$*

Suppress continuum background by requiring a "lepton tag" from recoiling B
(5% Efficiency for x1200 reduction in background)

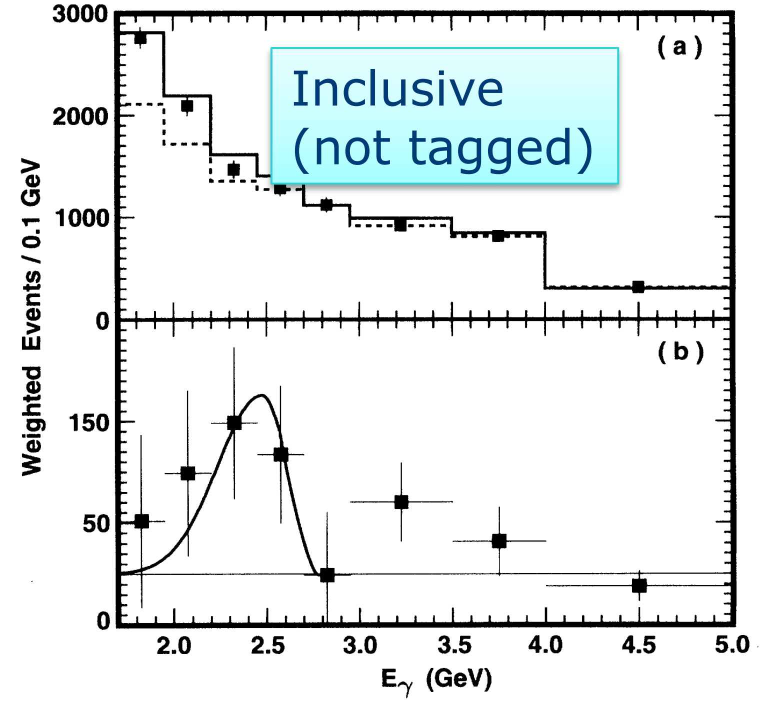


Remaining continuum subtracted with off-resonance data -> statistical uncertainty

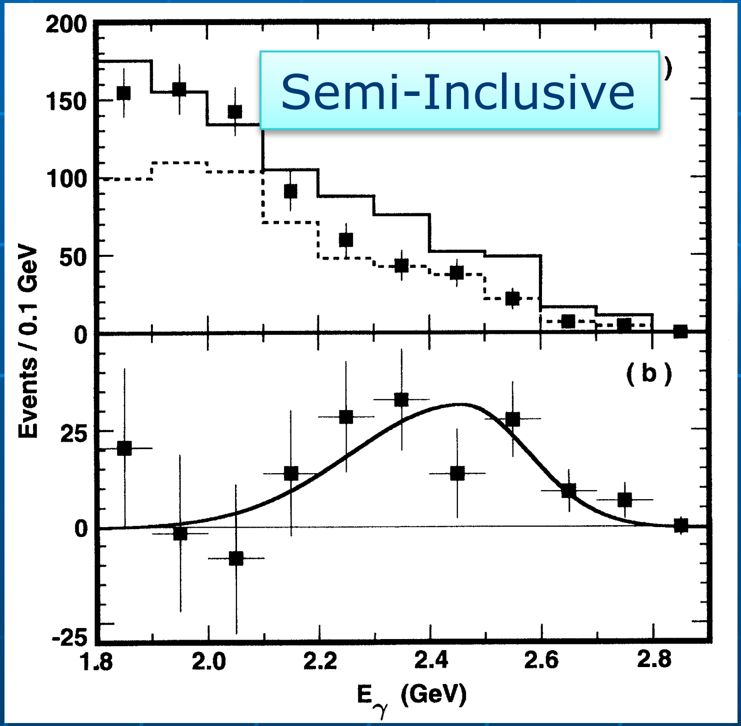
Note this can be done untagged (CLEO and BELLE do this)

Experimental History of B ->$X_s\gamma$

1995: First Measurement from CLEO

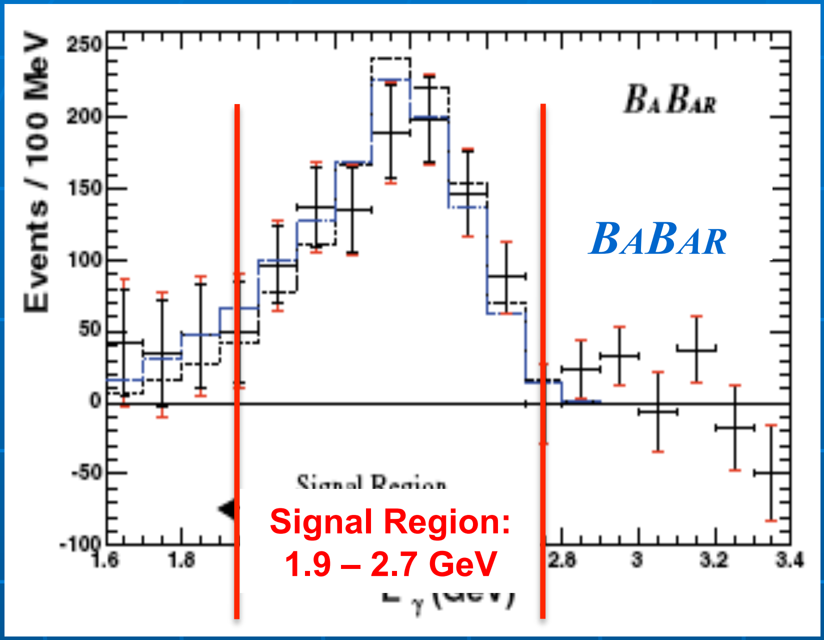


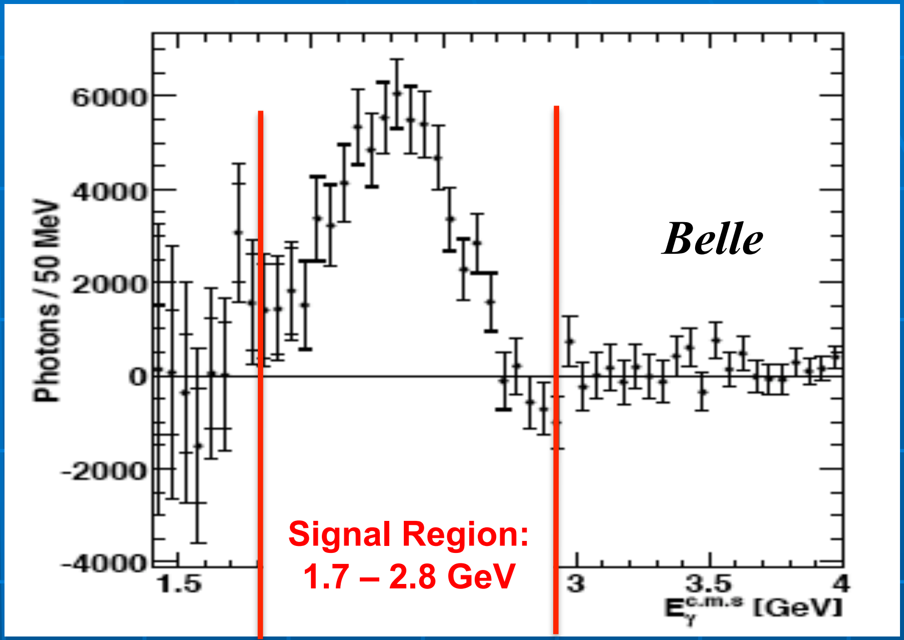
Inclusive
(not tagged)



Semi-Inclusive

Experimental History of $B \rightarrow X_s \gamma$





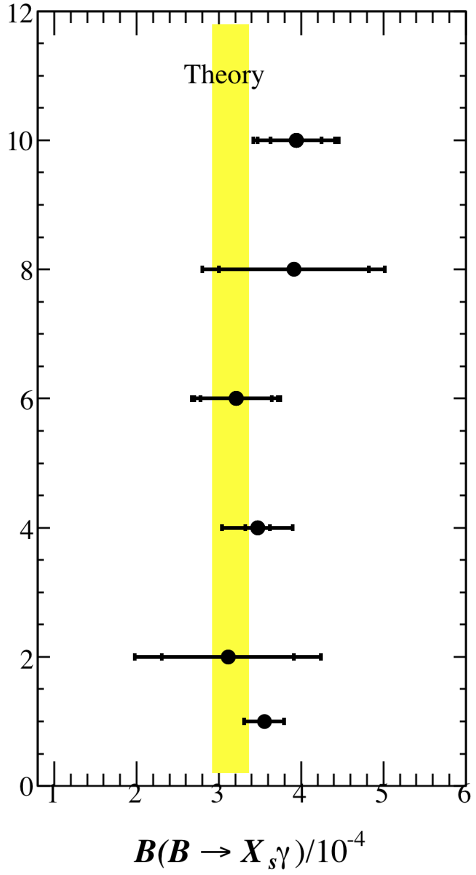
2005: BABAR: 88.5 × 10^6 $B\overline{B}$ pairs

$$\Delta\mathcal{B}(B \rightarrow X_s\gamma) = (3.67 \pm 0.29_{stat.} \pm 0.33_{syst.} \pm 0.29_{model}) \times 10^{-4}$$

2009: Belle: 656.7 × 10^6 $B\overline{B}$ pairs

$$\Delta\mathcal{B}(B \rightarrow X_s\gamma) = (3.45 \pm 0.15_{stat.} \pm 0.40_{syst.} \pm 0.01_{model}) \times 10^{-4}$$

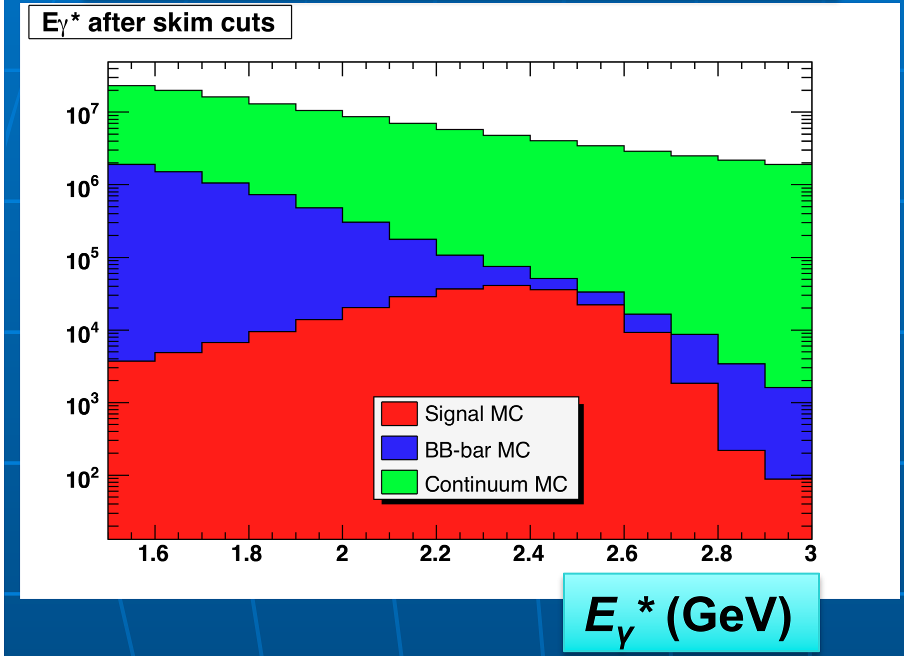
$\mathcal{B}(B \to X_s \gamma)$ Measurements



	B ± stat ± syst ± theo / 10^{-4}
BaBar Lepton Tag	3.94 ± 0.31 ± 0.36 ± 0.21
BaBar Hadron Tag	3.91 ± 0.91 ± 0.64
CLEO	$3.21 \pm 0.43 \pm 0.27^{+0.18}_{-0.10}$
Belle	3.45 ± 0.15 ± 0.40 ± 0.01
ALEPH	3.11 ± 0.80 ± 0.72
World Average	3.55 ± 0.24 ± 0.09

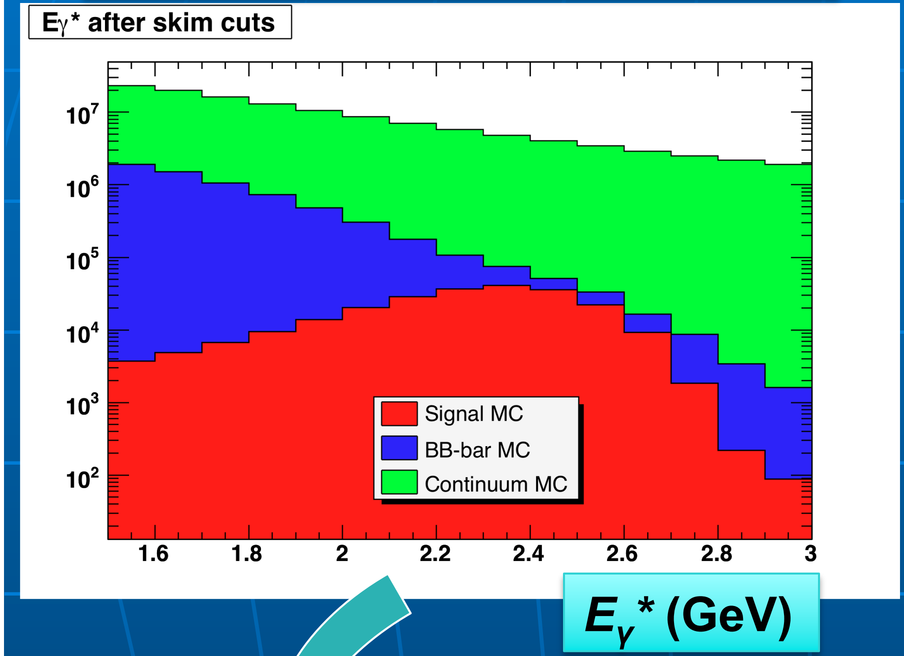
New BaBar Measurement of $\mathcal{B}(B \to X_s \gamma)$

After Pre-cuts (trigger+skim)

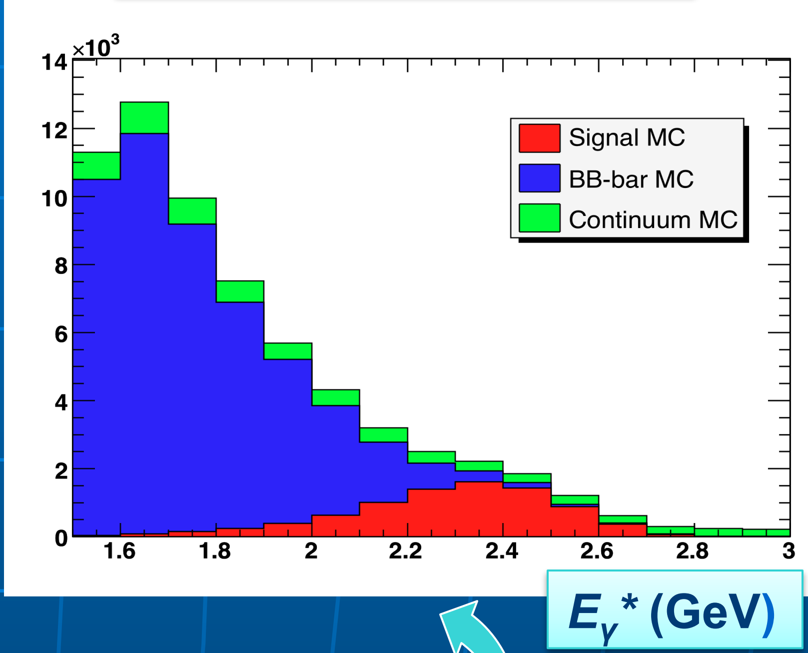


New BaBar Measurement of $\mathcal{B}(B \to X_s \gamma)$

After Pre-cuts (trigger+skim)



After all selection cuts

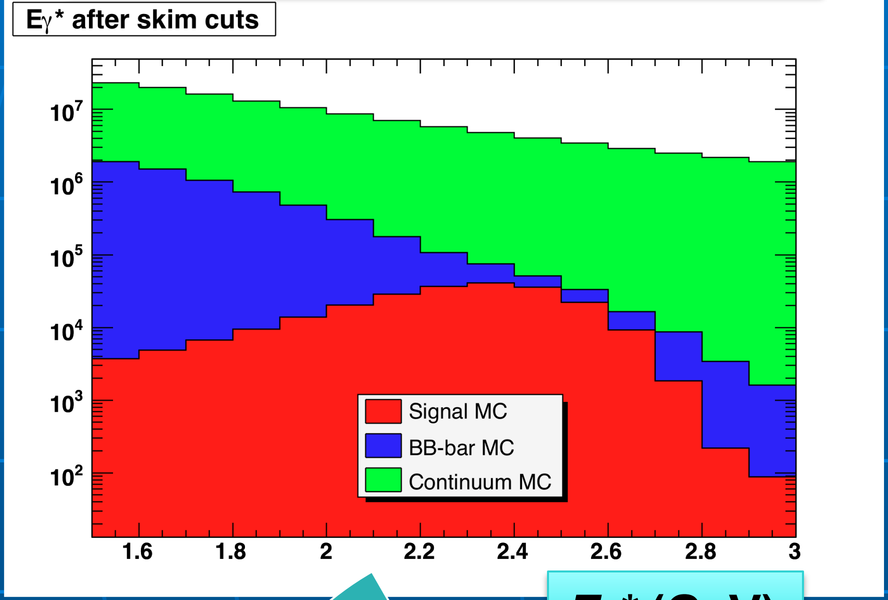


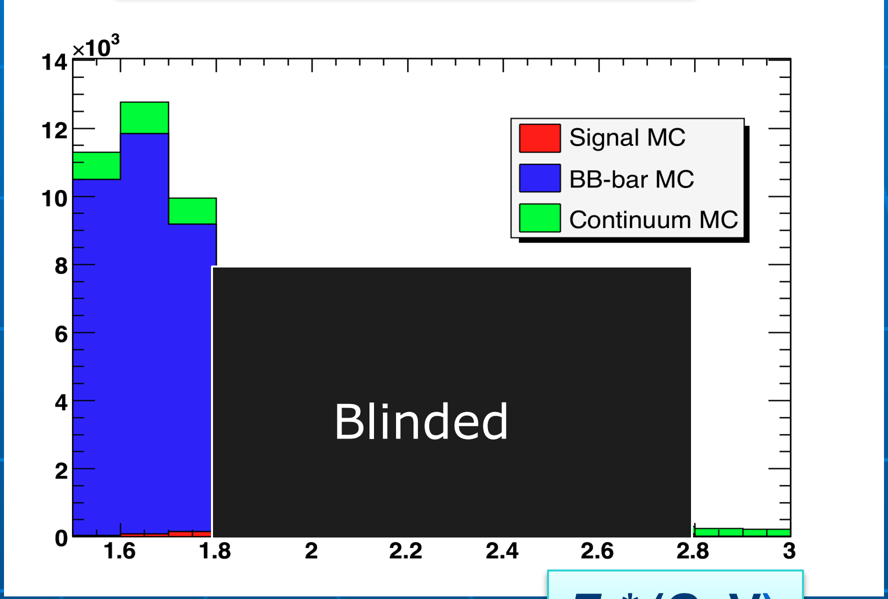
Lepton tag
Neural Net for event topology cuts
Missing Energy

New BaBar Measurement of $\mathcal{B}(B \rightarrow X_s \gamma)$

After Pre-cuts (trigger+skim)

After all selection cuts





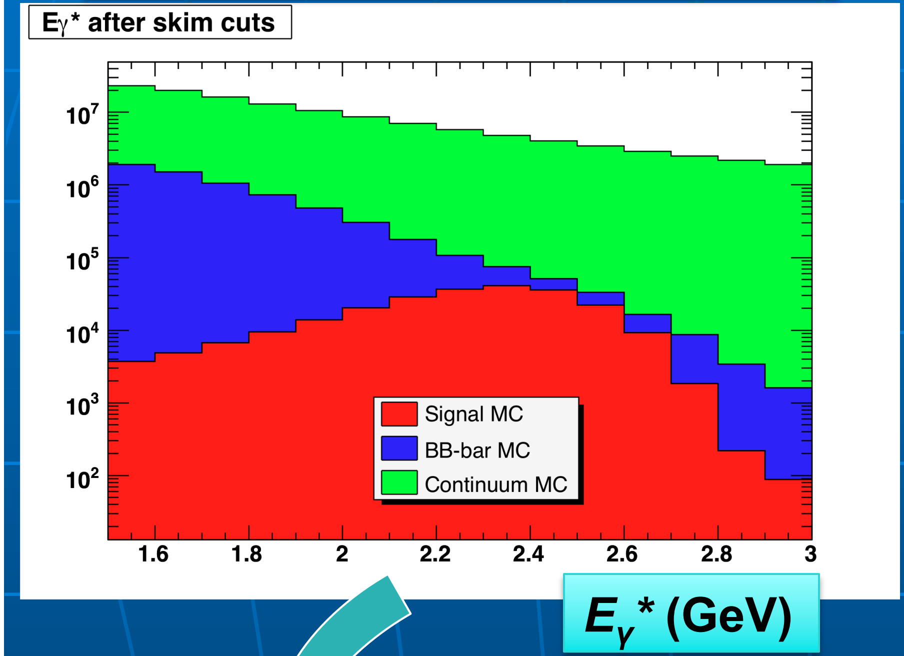
E_γ* (GeV)

E_γ* (GeV)

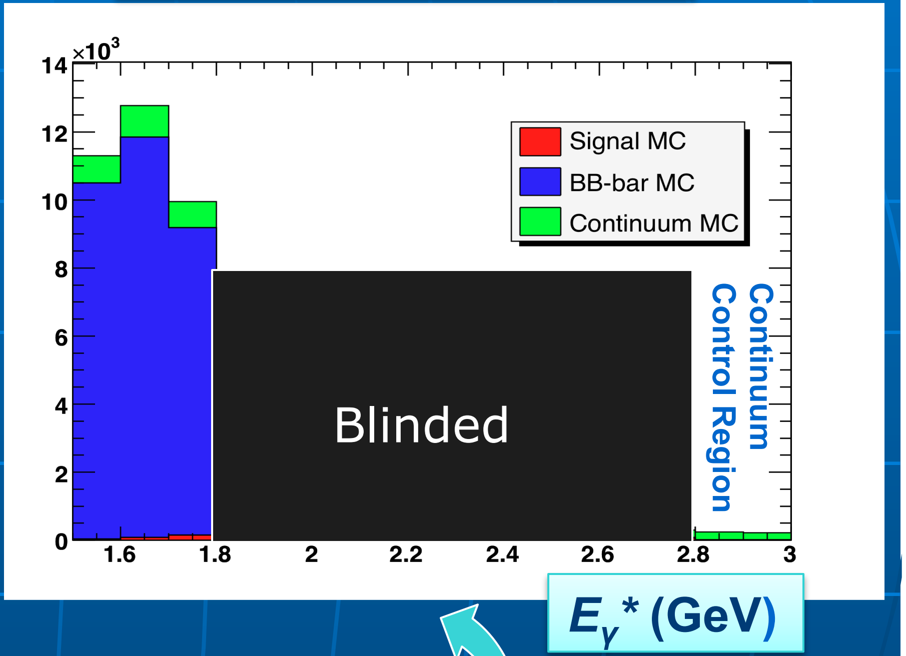
Lepton tag
Neural Net for event topology cuts
Missing Energy

New BaBar Measurement of $\mathcal{B}(B \to X_s \gamma)$

After Pre-cuts (trigger+skim)



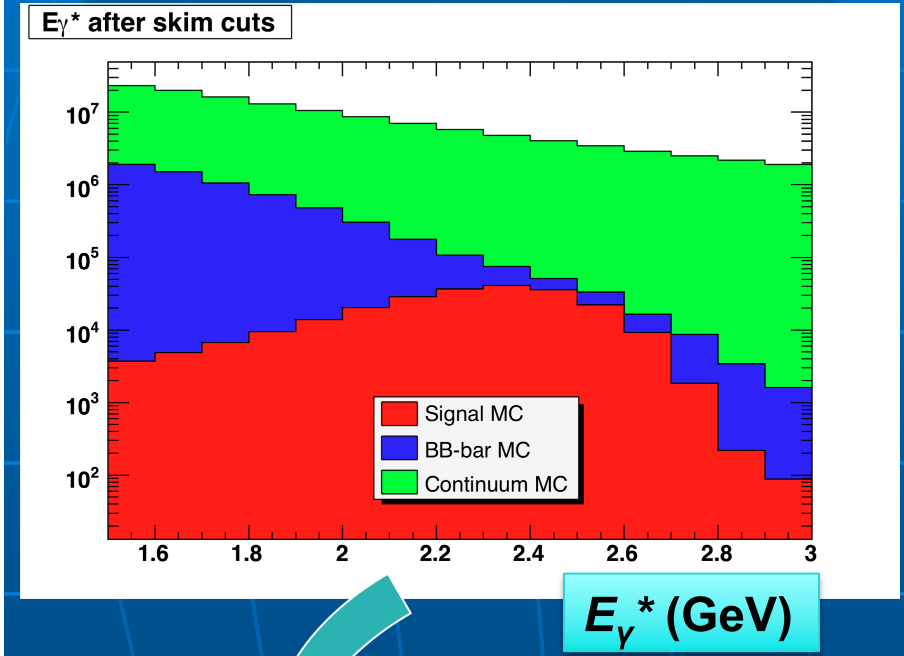
After all selection cuts



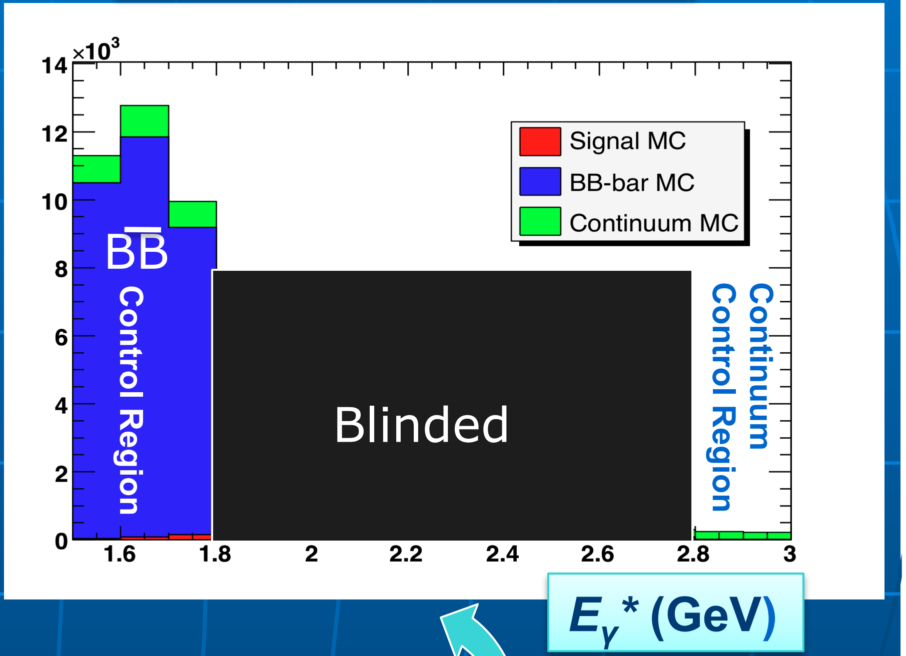
Lepton tag
Neural Net for event topology cuts
Missing Energy

New BaBar Measurement of $\mathcal{B}(B \to X_s \gamma)$

After Pre-cuts (trigger+skim)



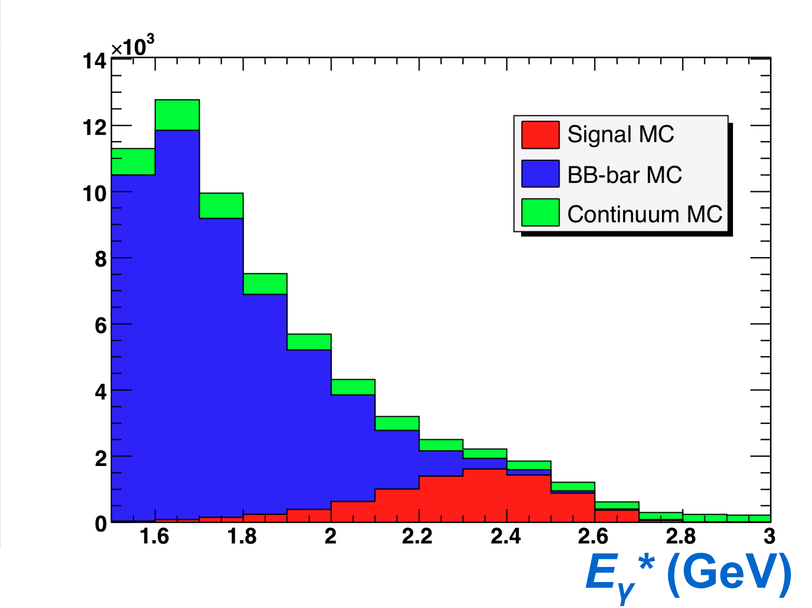
After all selection cuts

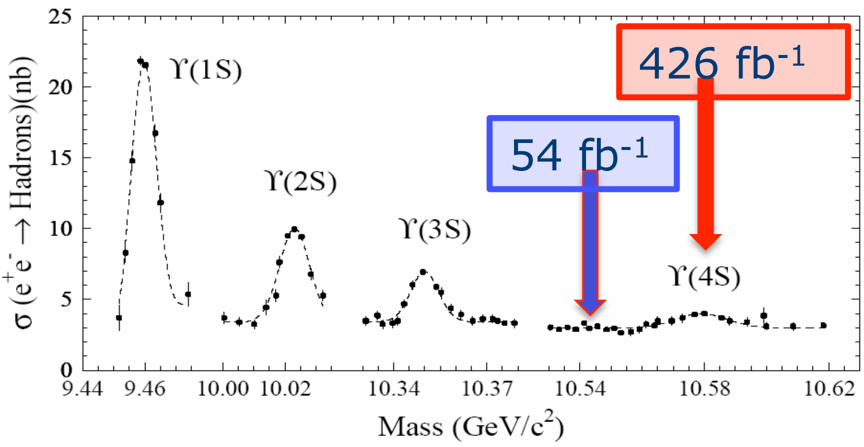


Lepton tag
Neural Net for event topology cuts
Missing Energy

Continuum Subtraction

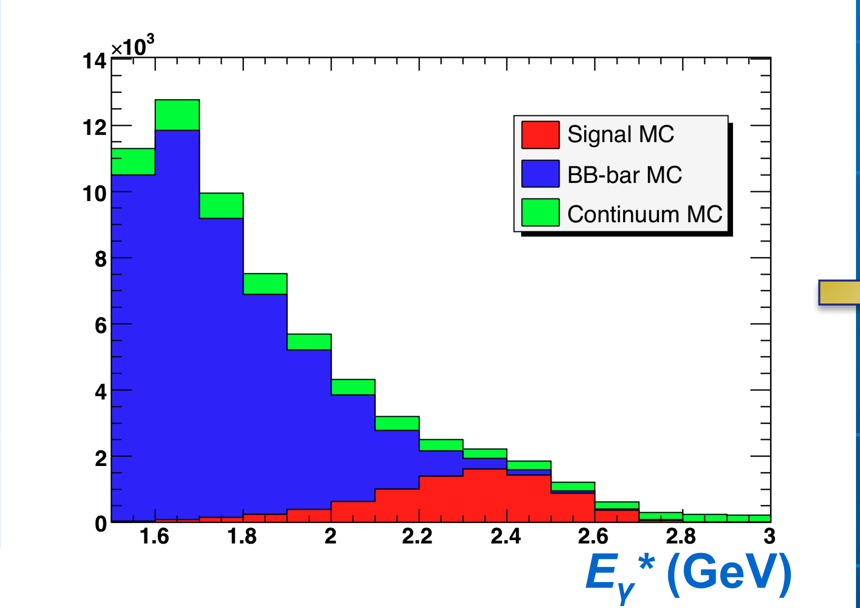
After all selection cuts



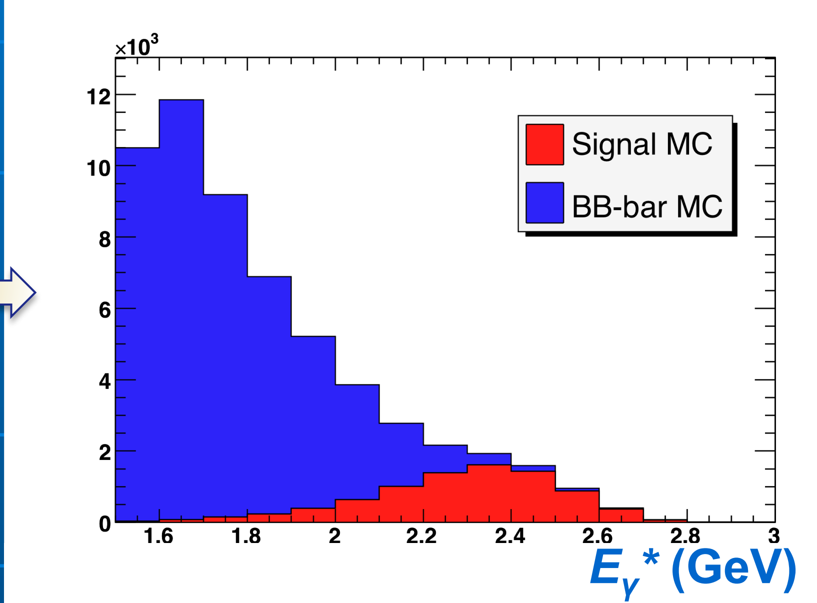


Spectrum after Continuum Subtraction

After all selection cuts

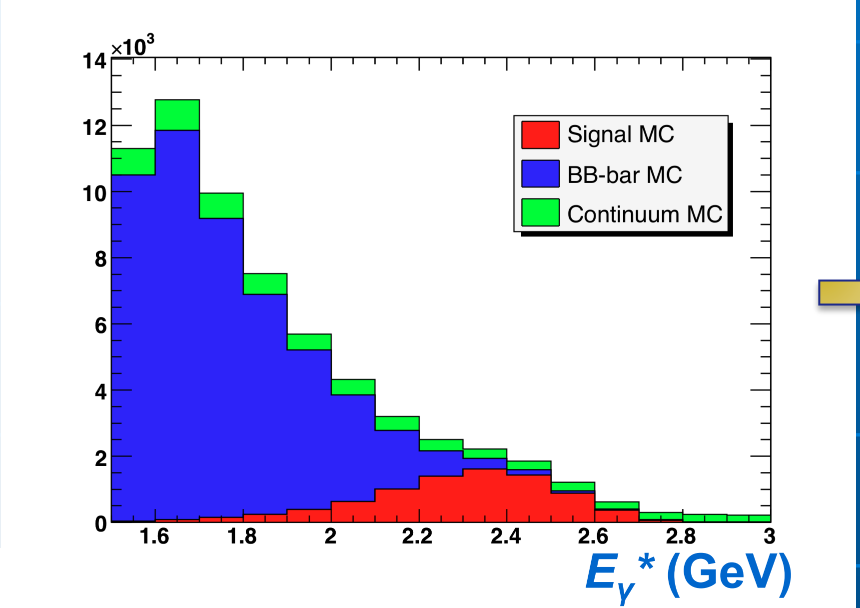


After continuum subtraction

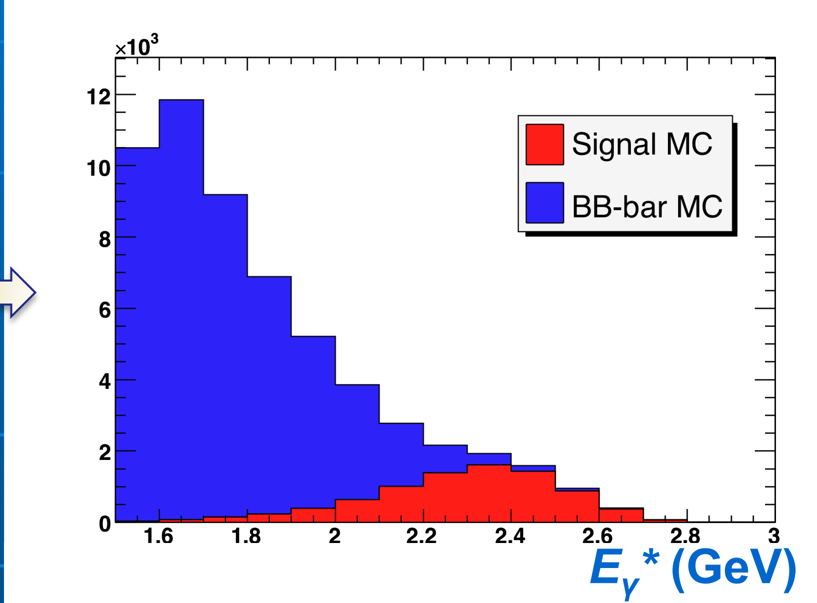


Spectrum after Continuum Subtraction

After all selection cuts



After continuum subtraction

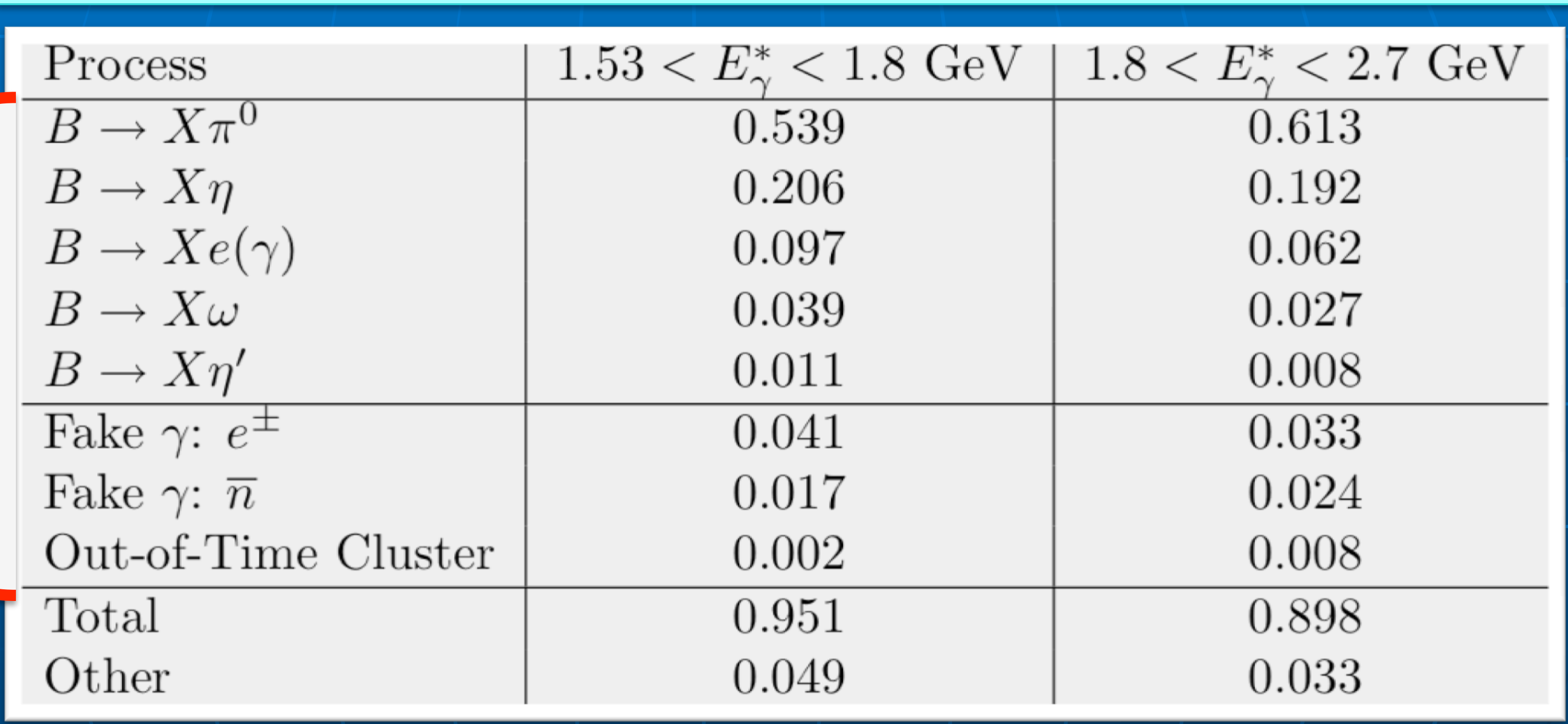


- **Subtracting $B\bar{B}$ background requires extensive comparisons between Data and MC for the various $B\bar{B}$ backgrounds.**
- **For each significant $B\bar{B}$ background, we derive a Data/MC correction factor which is applied to MC.**

$B\bar{B}$ Background Components

- **Breakdown $B\bar{B}$ background according to MC**

Data/MC corrected



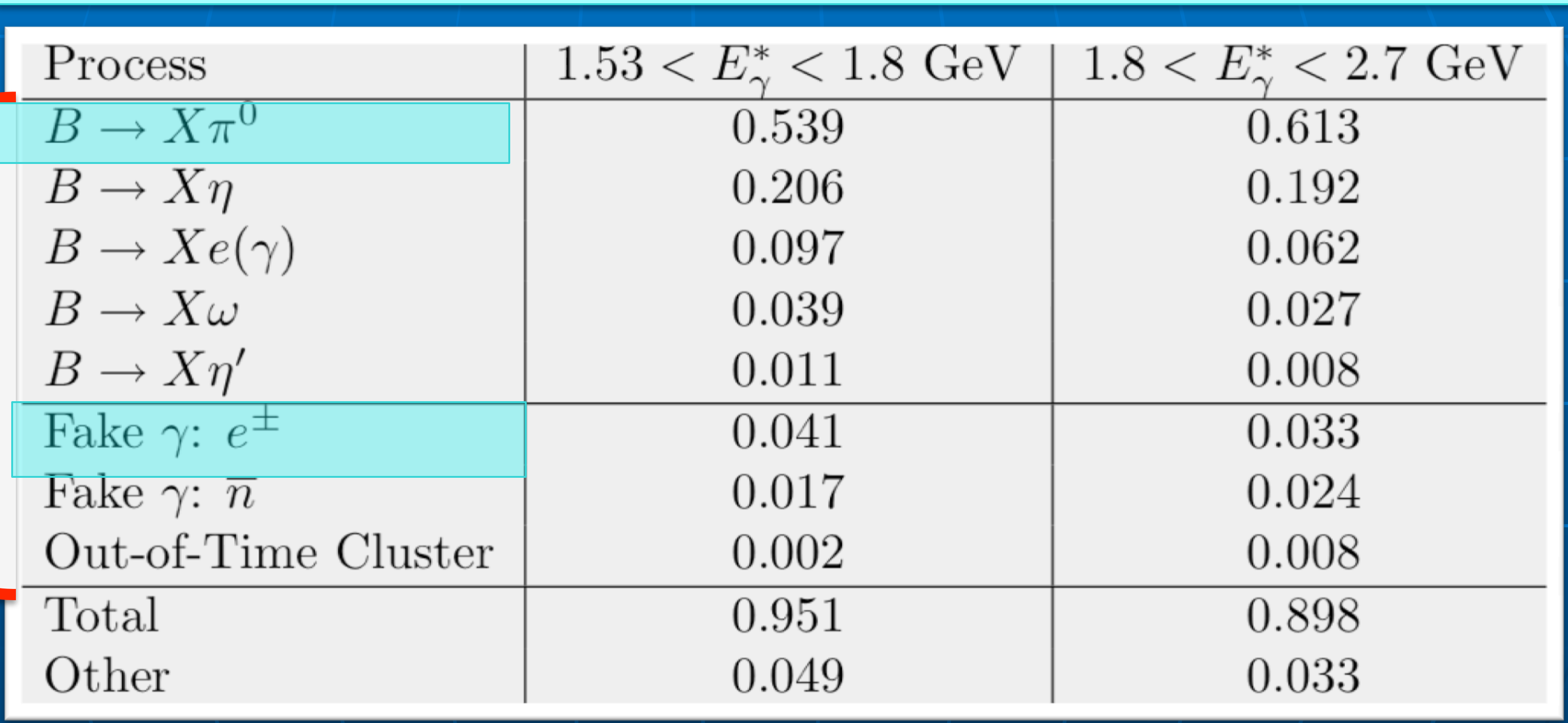
Process	$1.53 < E^*_\gamma < 1.8$ GeV	$1.8 < E^*_\gamma < 2.7$ GeV
$B \rightarrow X\pi^0$	0.539	0.613
$B \rightarrow X\eta$	0.206	0.192
$B \rightarrow Xe(\gamma)$	0.097	0.062
$B \rightarrow X\omega$	0.039	0.027
$B \rightarrow X\eta'$	0.011	0.008
Fake γ: $e^\pm$	0.041	0.033
Fake γ: $\overline{n}$	0.017	0.024
Out-of-Time Cluster	0.002	0.008
Total	0.951	0.898
Other	0.049	0.033

- **95 – 97% of $B\bar{B}$ background is data-corrected.**

$B\bar{B}$ Background Components

Data/MC corrected

- **Breakdown $\bar{B}B$ background according to MC**



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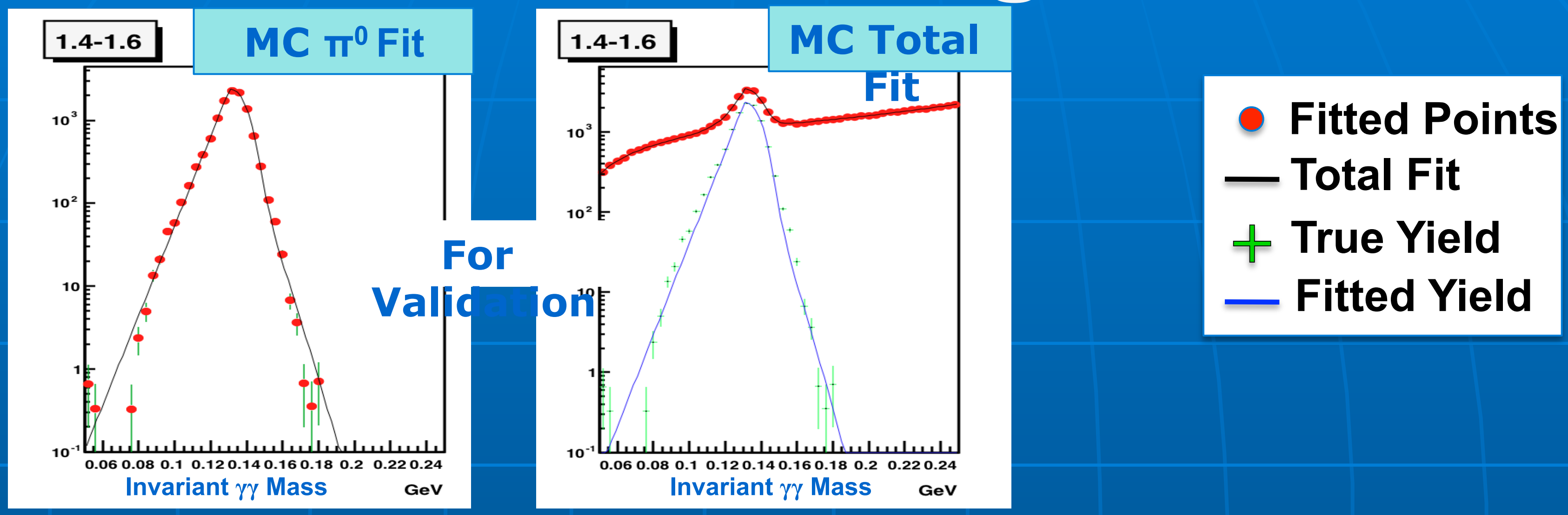
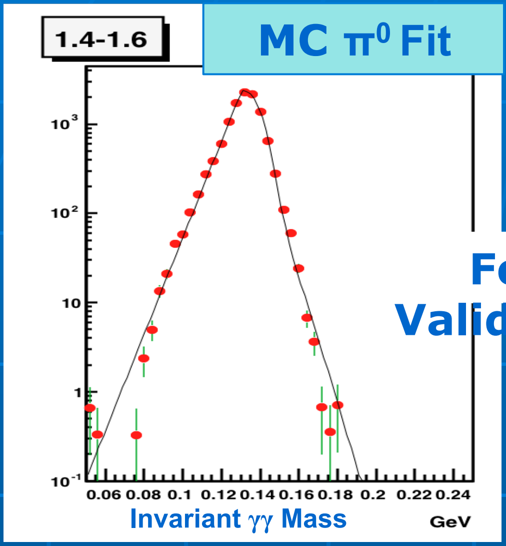
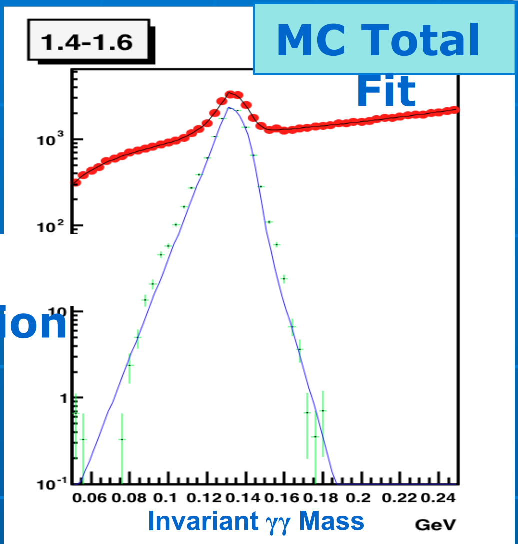
$B \rightarrow X\pi^0$ Background



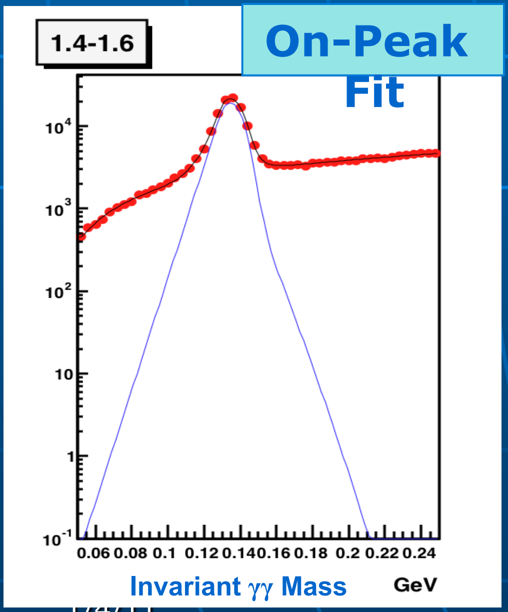
Define a $B \rightarrow X\pi^0$ *sample with same cuts as* $B \rightarrow X\gamma$ except π^0 <-> γ *then compare MC to data*

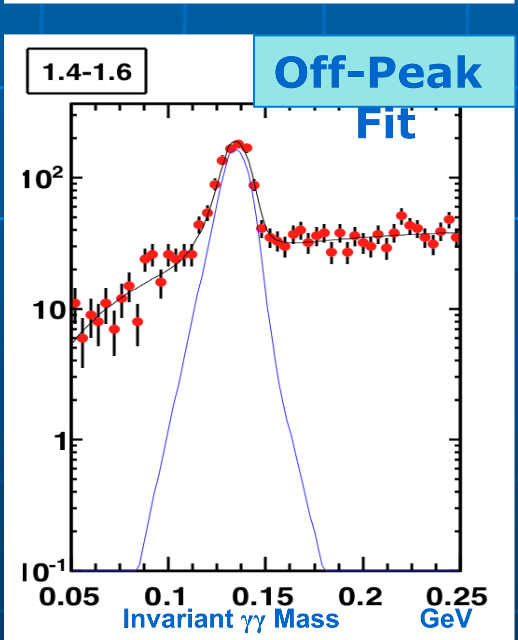
$B \rightarrow X\pi^0$ Background





For Validation





- ● **Fitted Points**
- — **Total Fit**
- + **True Yield**
- — **Fitted Yield**

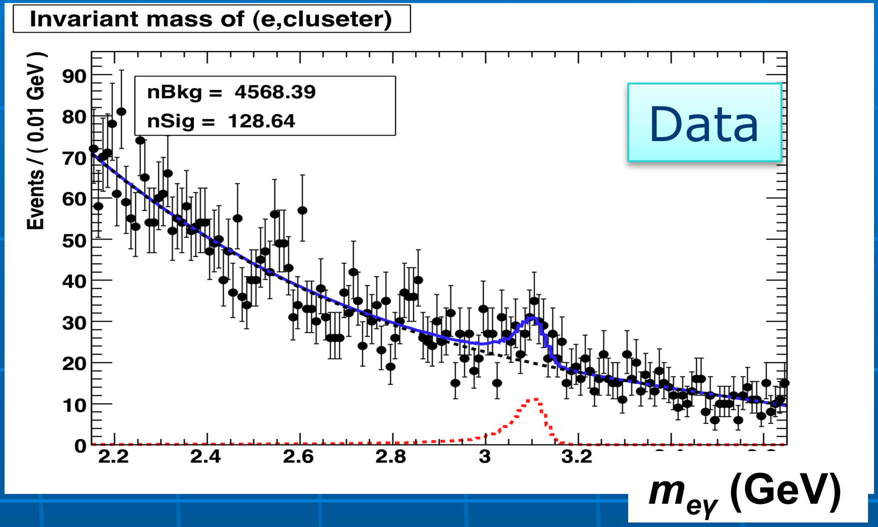
Stat. Errors only

$E_{\pi^0}*$ (GeV)	Correction Factor
1.2 to 1.4	0.962 ± 0.006
1.4 to 1.6	0.959 ± 0.006
1.6 to 1.8	0.933 ± 0.009
1.8 to 2.0	0.990 ± 0.012
2.0 to 2.2	0.992 ± 0.016
2.2 to 2.4	0.899 ± 0.035
2.4 to 3.0	1.489 ± 0.259

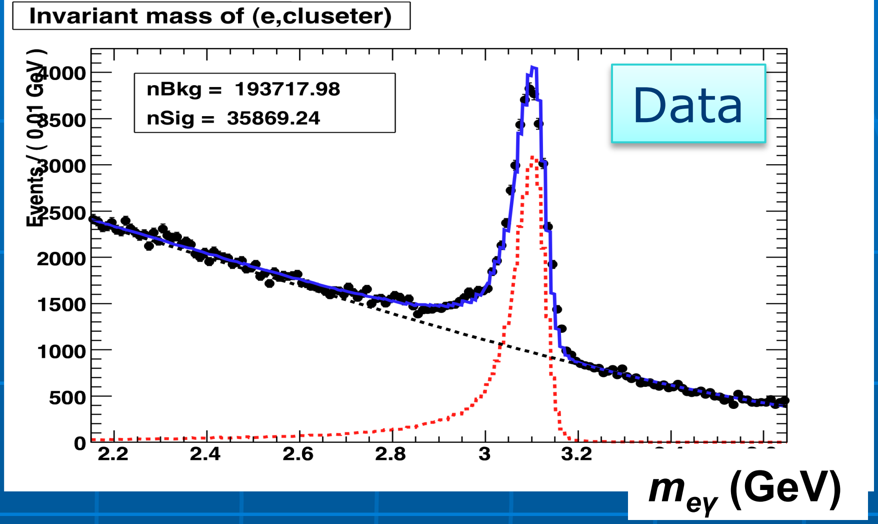
Systematic Errors: ~1.5%

Fake e -> γ background from $B \rightarrow X\varphi$

$\psi(e^{+}_{track}e^{-}_{cluster})$



$\psi(e^{+}_{track}e^{-}_{track})$



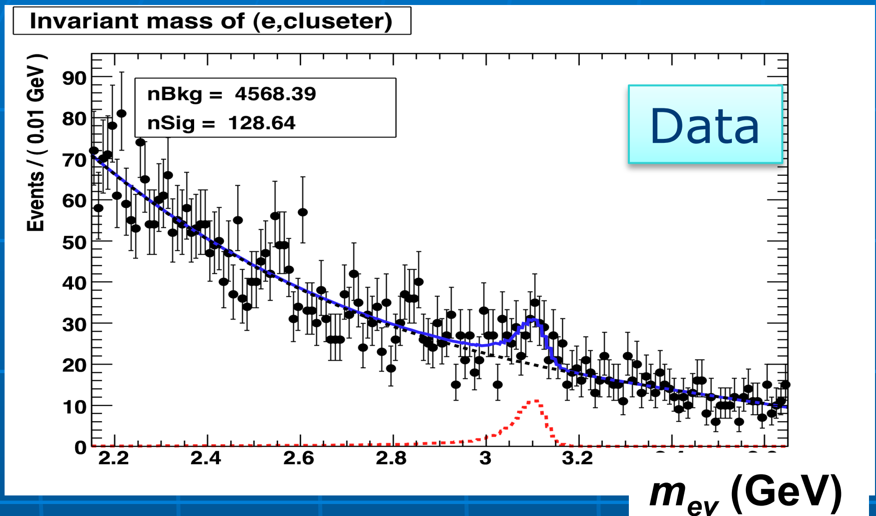
Background is from electron track mis-id which gives fake g
Use J/psi to e+e- from $B \rightarrow X\varphi$. Look for one leg of decay to be a tracked

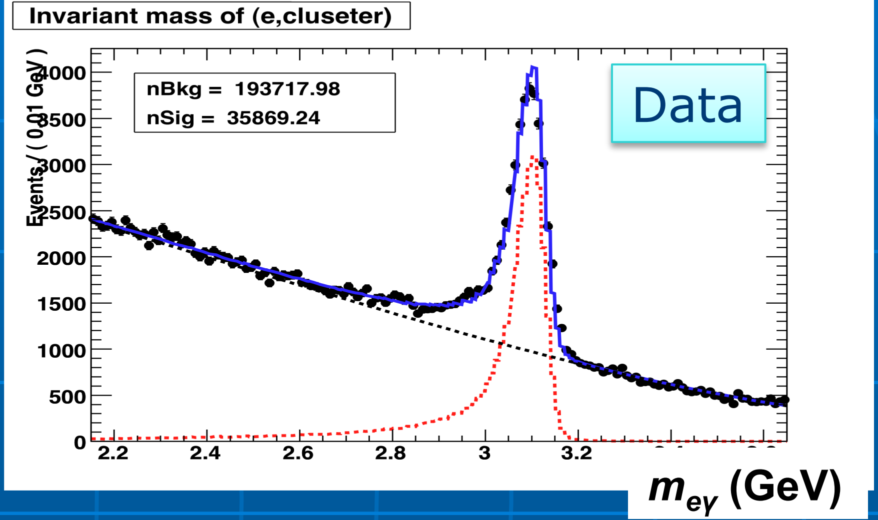
Reconstruct other leg from either good electron or one where the track has
Been missed to just leave a cluster

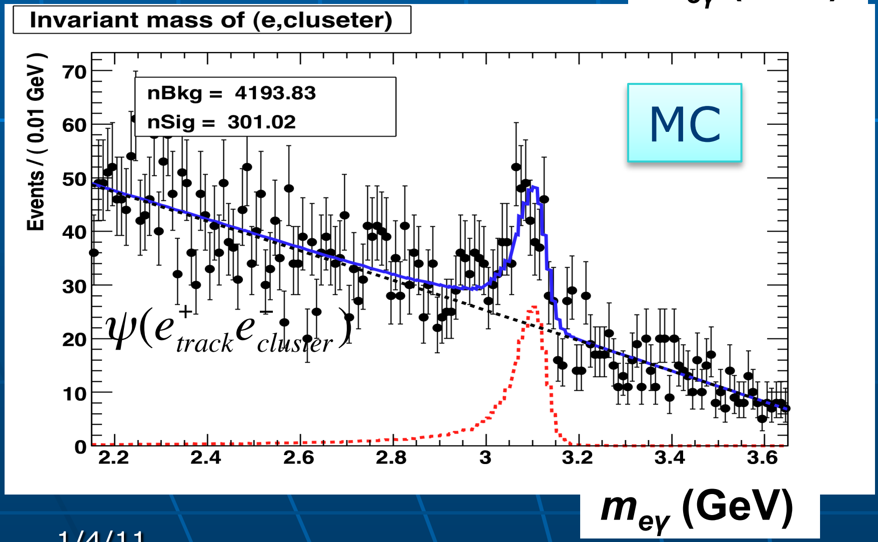
Fake e -> γ background from $B \rightarrow X\varphi$

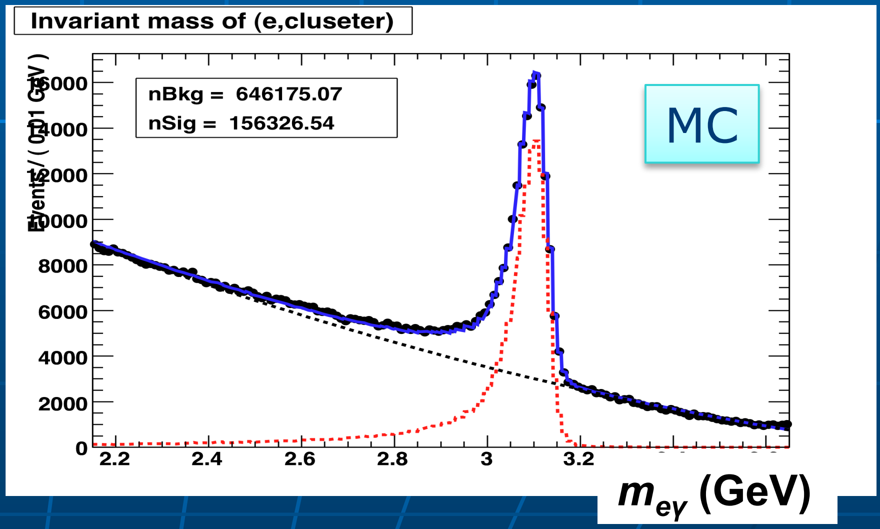
$\psi(e^{+}_{track}e^{-}_{cluster})$

$\psi(e^{+}_{track}e^{-}_{track})$









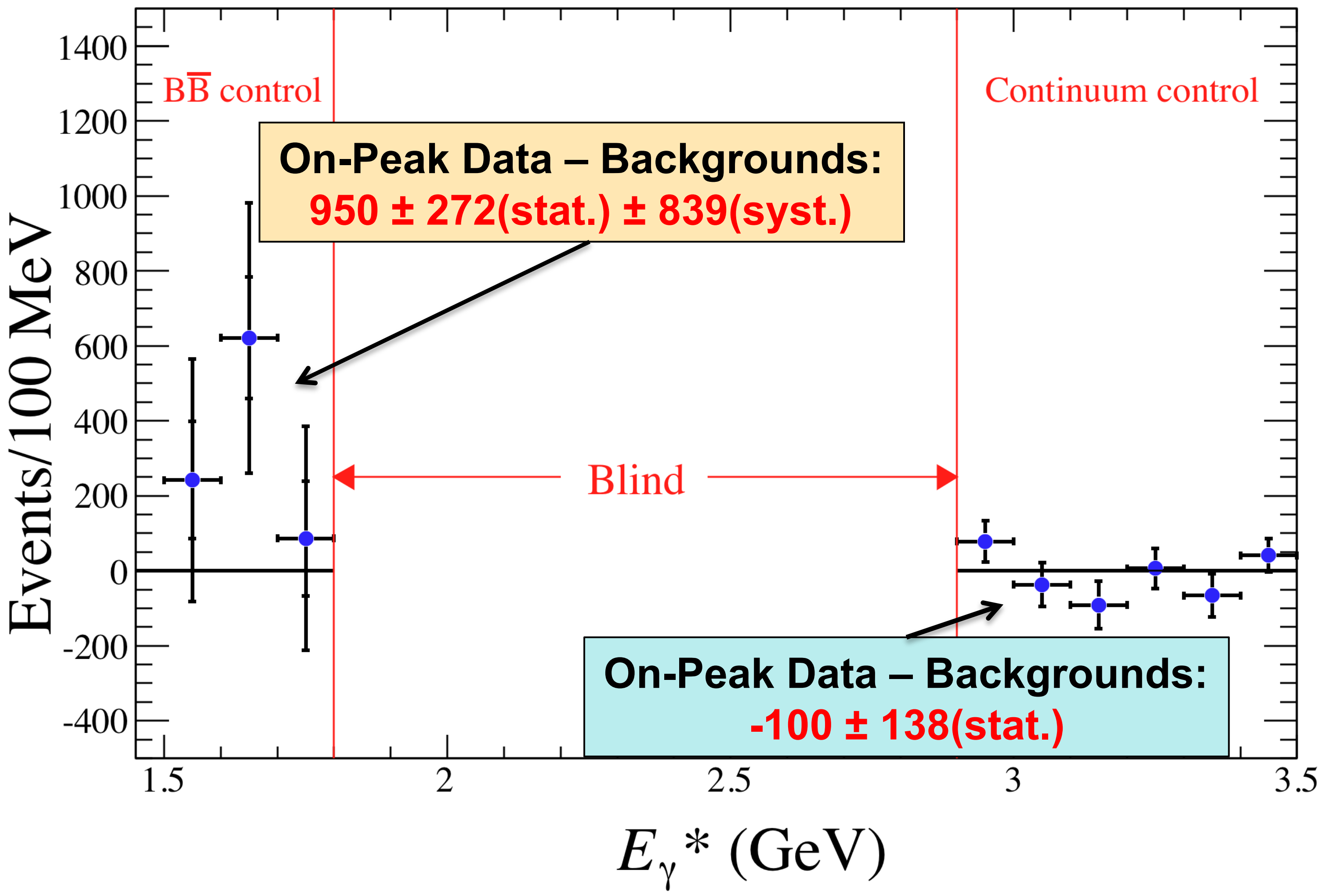
α_e = 1.57 ± 0.27 (stat) ± 0.22 (syst)

Overall $B\bar{B}$ Corrections

- All applied corrections to $B\bar{B}$ background simulation
  - π^0/η Corrections
  - ω Corrections
  - η' Corrections
  - Electron Corrections
  - Antineutron Corrections
  - Semi-leptonic Corrections
  - Particle ID Corrections
  - Out-of-Time Cluster Corrections
  - Veto Corrections
- Measurement is done in bins of photon energy.
- Convert to overall *BB* corrections in photon energy bins.

E^*_γ (GeV)	α_{all}
$1.53 - 1.6$	0.999 ± 0.027
$1.6 - 1.7$	0.988 ± 0.028
$1.7 - 1.8$	0.992 ± 0.029
$1.8 - 1.9$	0.999 ± 0.031
$1.9 - 2.0$	1.004 ± 0.030
$2.0 - 2.1$	0.997 ± 0.028
$2.1 - 2.2$	1.004 ± 0.032
$2.2 - 2.3$	0.990 ± 0.042
$2.3 - 2.4$	0.978 ± 0.062
$2.4 - 2.5$	1.250 ± 0.158
$2.5 - 2.6$	1.128 ± 0.158
$2.6 - 2.7$	1.165 ± 0.232
$2.7 - 2.8$	0.497 ± 0.092

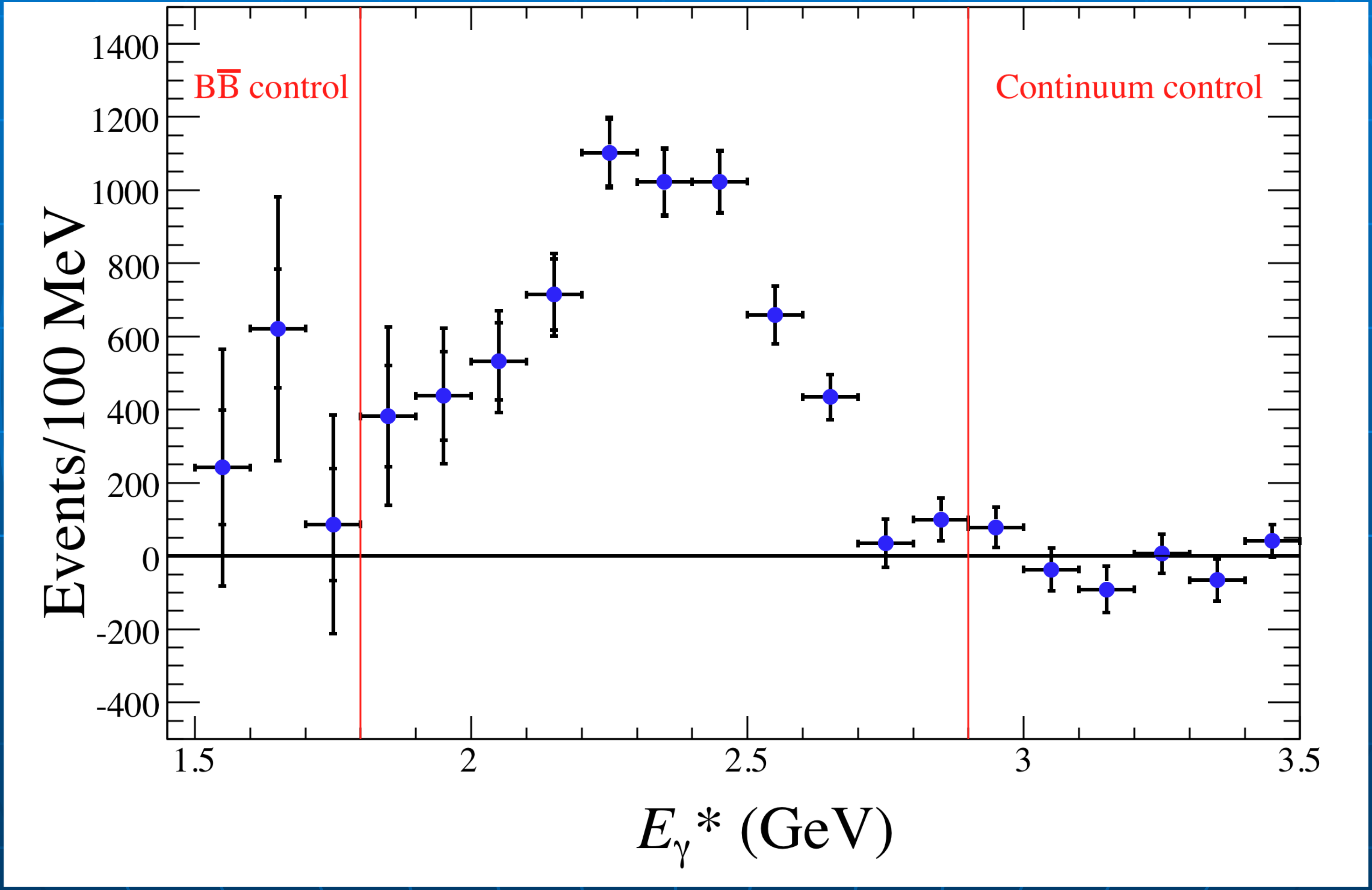
Control Region Check



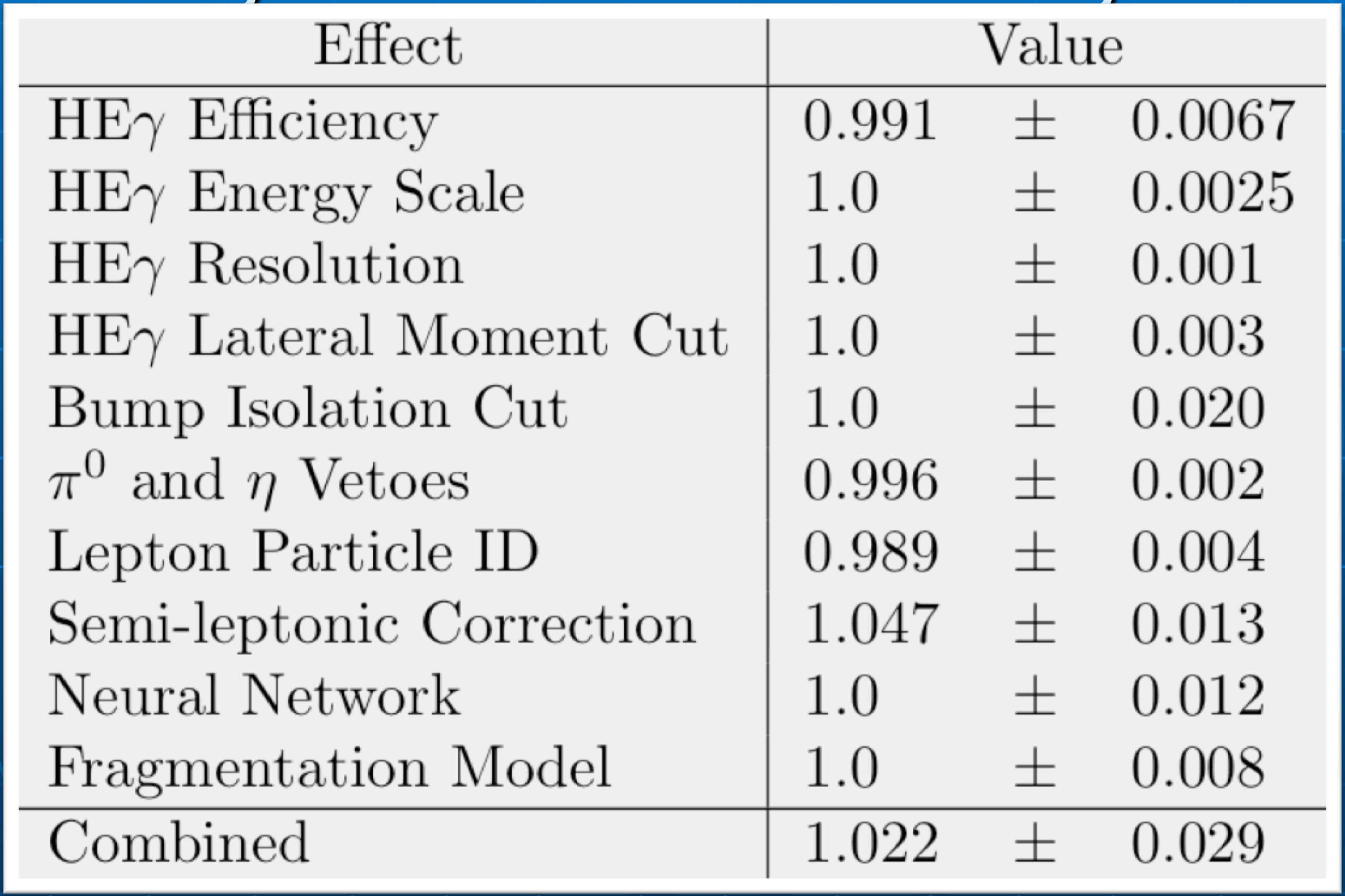
On-Peak Data – Backgrounds:
950 ± 272(stat.) ± 839(syst.)

On-Peak Data – Backgrounds:
-100 ± 138(stat.)

Unblinding the Spectrum



Systematics Summary



Effect	Value		
HEγ Efficiency	0.991	±	0.0067
HEγ Energy Scale	1.0	±	0.0025
HEγ Resolution	1.0	±	0.001
HEγ Lateral Moment Cut	1.0	±	0.003
Bump Isolation Cut	1.0	±	0.020
π^0 and η Vetoes	0.996	±	0.002
Lepton Particle ID	0.989	±	0.004
Semi-leptonic Correction	1.047	±	0.013
Neural Network	1.0	±	0.012
Fragmentation Model	1.0	±	0.008
Combined	1.022	±	0.029

Removing the $B \rightarrow X_d\gamma$ Contribution

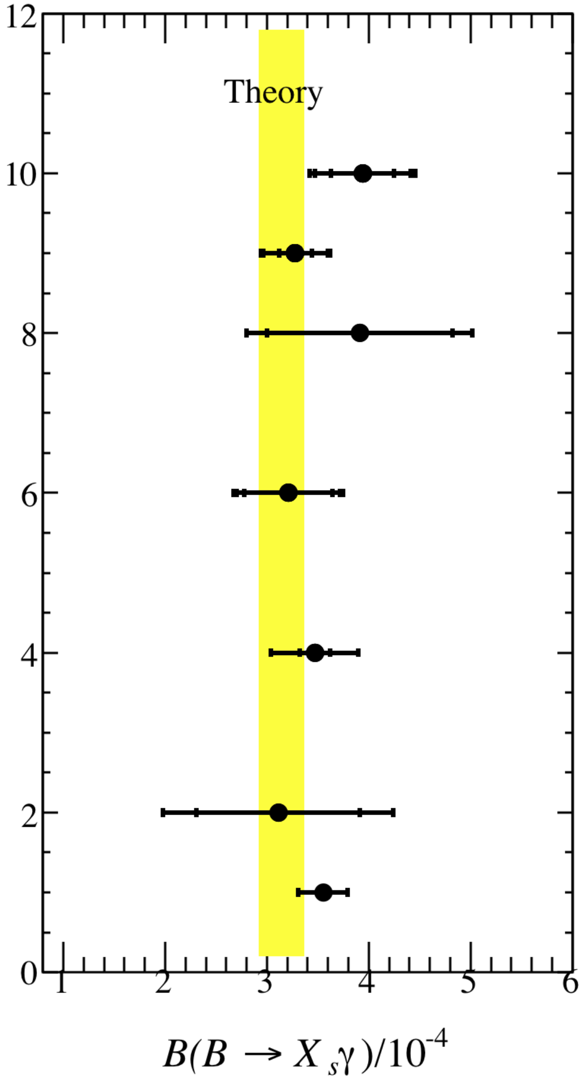
- Event selection is insensitive to hadronic final state—must remove $B \rightarrow X_d\gamma$ contribution.

$$\mathcal{B}(B \to X_{s+d}\gamma)_{E_\gamma > 1.6\ \mathrm{GeV}} \to \mathcal{B}(B \to X_s\gamma)_{E_\gamma > 1.6\ \mathrm{GeV}}$$

- Assume $B \rightarrow X_s\gamma$ and $B \rightarrow X_d\gamma$ spectra are similar.
- Subtract $B \rightarrow X_d\gamma$ contribution by simple correction ($1 - |V_{td}/V_{ts}|^2$) , where $|V_{td}/V_{ts}|$ = 0.209 ± 0.006

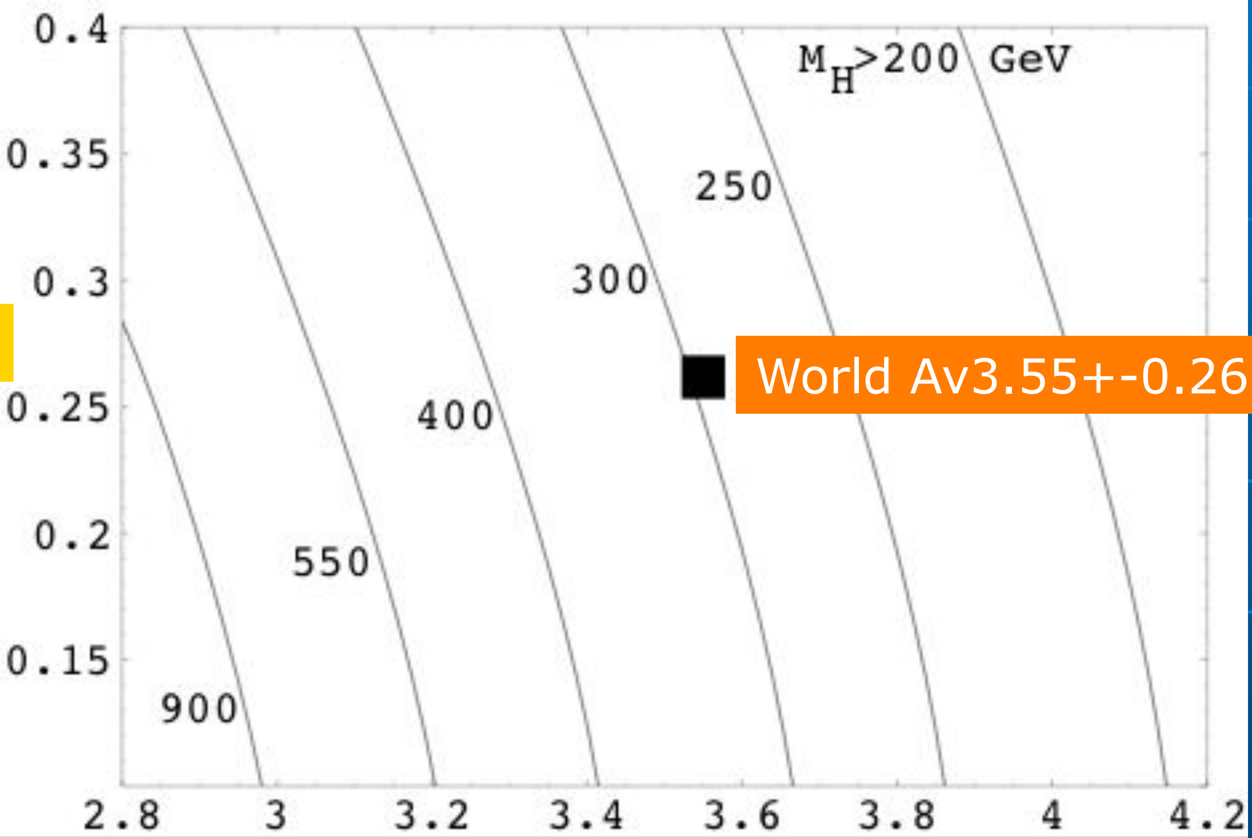
$$\mathcal{B}(B \to X_s\gamma)_{E_\gamma > 1.6\ \mathrm{GeV}} = (3.28 \pm 0.16 \pm 0.28 \pm 0.10) \times 10^{-4}$$

Result *vs.* Other Measurements



	B ± stat ± syst ± theo / 10^{-4}
BaBar Lepton Tag	3.94 ± 0.31 ± 0.36 ± 0.21
BaBar This Analysis	3.28 ± 0.16 ± 0.28 ± 0.10
BaBar Hadron Tag	3.91 ± 0.91 ± 0.64
CLEO	$3.21 \pm 0.43 \pm 0.27^{+0.18}_{-0.10}$
Belle	3.45 ± 0.15 ± 0.40 ± 0.01
ALEPH	3.11 ± 0.80 ± 0.72
World Average	3.55 ± 0.24 ± 0.09

B(B-$X_s\gamma$) constraints many models



Error x 10^{-4}

World Av3.55+-0.26 x 10^{-4}

B(B->$X_s\gamma$) x 10^{-4}

Example: Two Higgs doublet model M_{H+}>300 GeV cf. direct search > 79.3 GeV

Direct CP Asymmetry in $B \rightarrow X_s \gamma$

$$A_{CP}(B \to X_{s+d}\gamma) = \frac{\Gamma(B \to X_{s+d}\gamma) - \Gamma(B \to X_{s+d}\gamma)}{\Gamma(\overline{B} \to \overline{X}_{s+d}\gamma) + \Gamma(B \to X_{s+d}\gamma)}$$

$$A_{CP}^{SM}(B \to X_{s+d}\gamma) \sim 10^{-6}$$

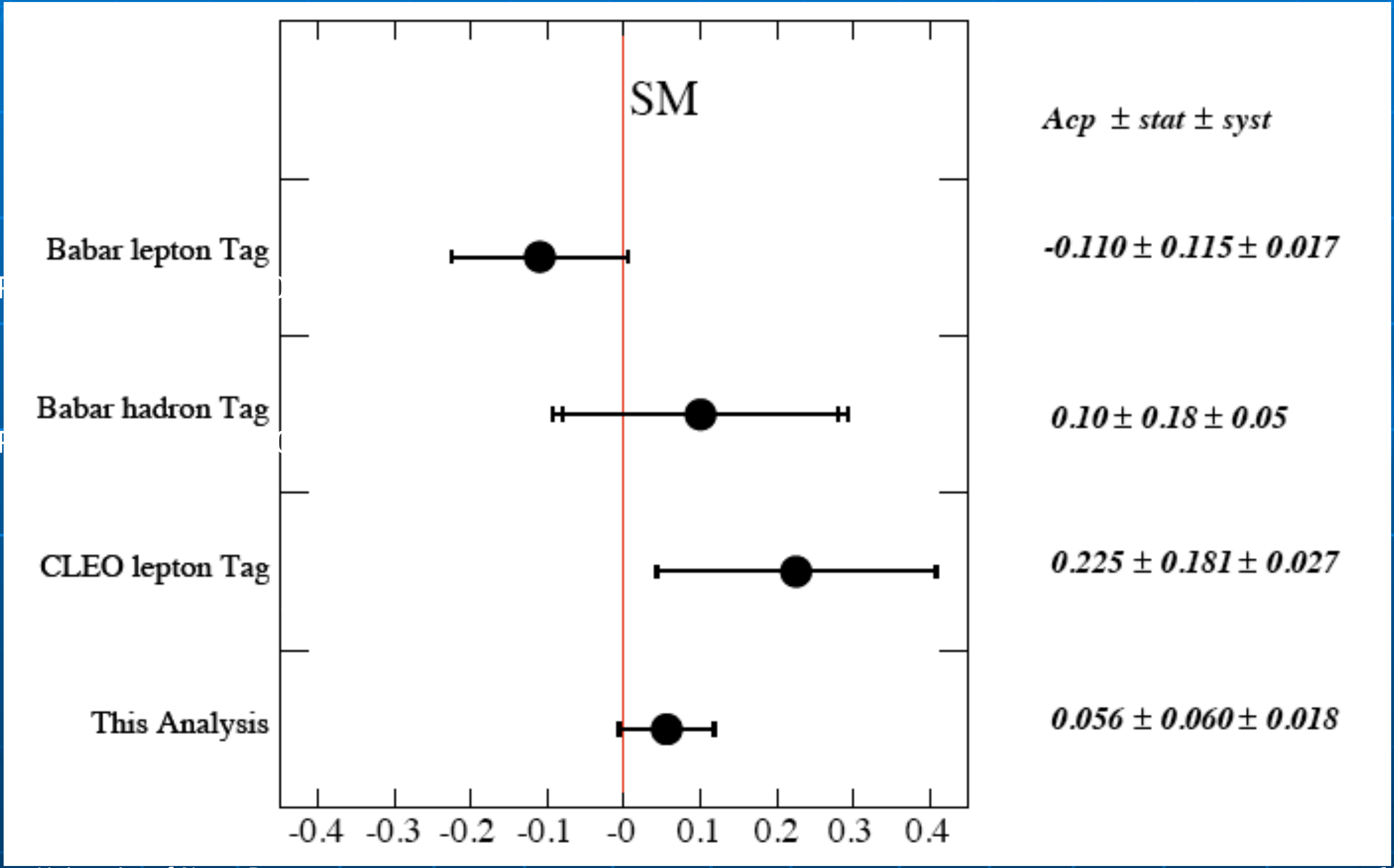
In SM is CKM and GIM suppressed. Non MFV SUSY could enhance Dramatically.

Use lepton tag charge to tag flavor

$$A_{CP}(B \to X_{s+d}\gamma) = \frac{1}{1-2\omega} A_{CP}^{\text{meas}}(B \to X_{s+d}\gamma$$

$$\omega = \frac{\chi_d}{2} + \omega_{\text{cascade}} + \omega_{\text{mis-ID}}$$

$A_{cp}(B \rightarrow X_{s+d}\gamma)$ *Result*



Conclusions

Radiative Decays are a powerful tool in the indirect search for
new physics.

An extensive program of study at BaBar is nearing completion
(it will be continued by Super BELLE and possibly superB)

No evidence of new physics has been found but significant constraints
Are placed on beyond SM physics.