BaBar Measurements of $B \to X_s \gamma$

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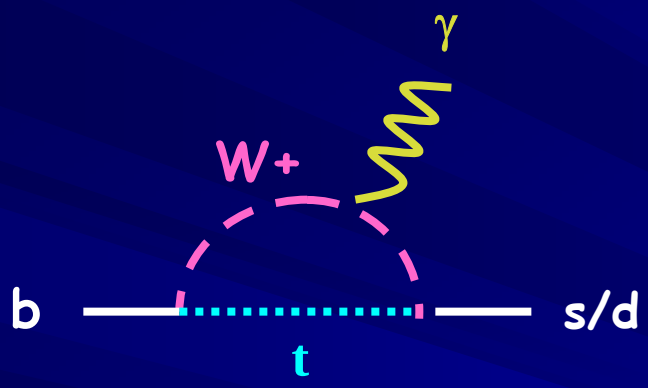
Conference Paper numbers: 664 and 665

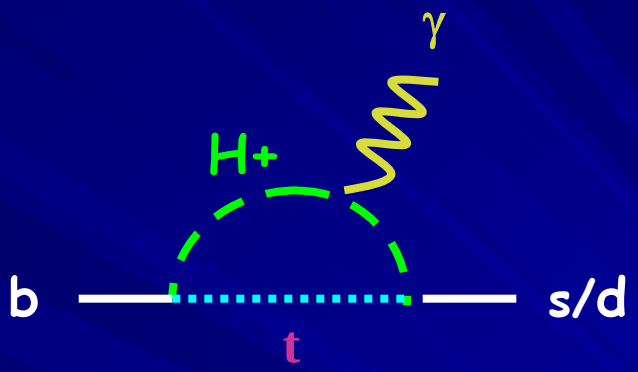
B($B \to X_s\gamma$), Acp($B \to X_s\gamma$) Sensitive to New Physics

Standard Model (SM)



+

SUSY



+ ..

New Physics enters at same order as Standard Model

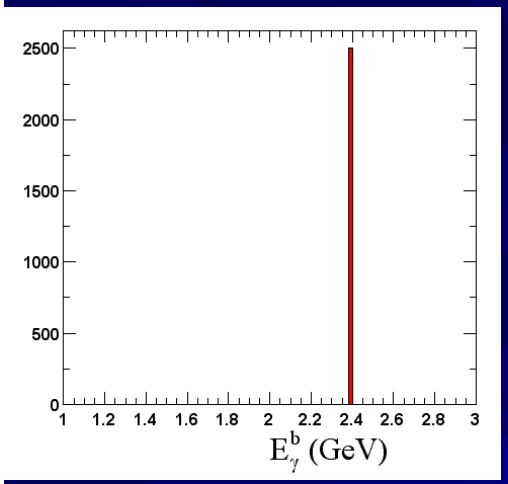
SM Theory(NLO): $B(B \to X_s\gamma) = 3.61^{+0.37}_{-0.49} \times 10^{-4}$ *Significant Improvement expected at NNLO (See next talk: T. Hurth)*

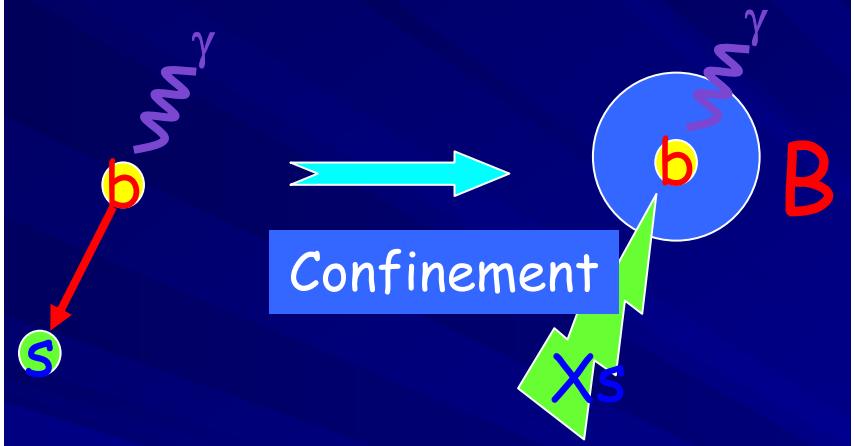
Extensive Investigation of new physics effects > 500 papers

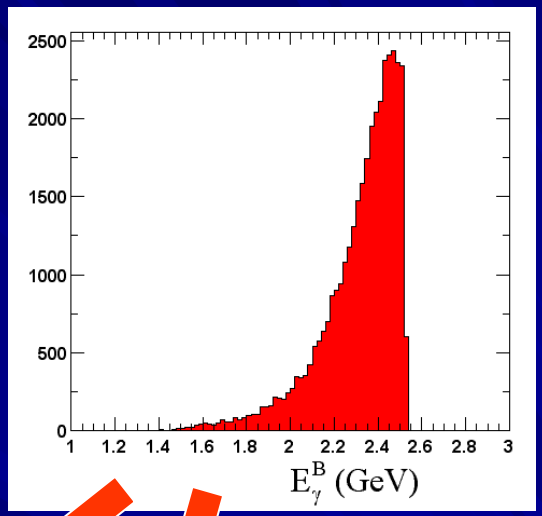
Direct CP Asymmetry (without s quark tag) : SM $A_{cp}(B \to X_{s+d}\gamma) = 0.0$

Strongly correlated to s-tagged Acp but theoretically cleaner with up 10% effects in some new physics scenarios (Hurth,Lungi and Porod)

Photon Spectrum







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

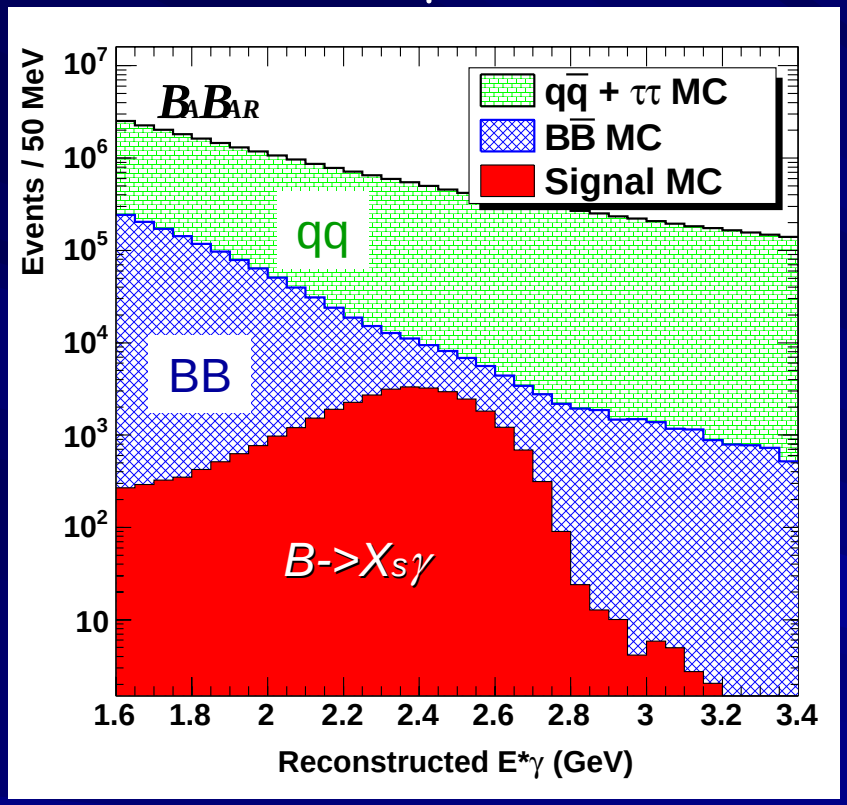
Second Moment: $\left\langle E_\gamma^{B2} \right\rangle - \left\langle E_\gamma^B \right\rangle^2 \approx \mu_\pi^2$

(Kinetic energy of b)^2

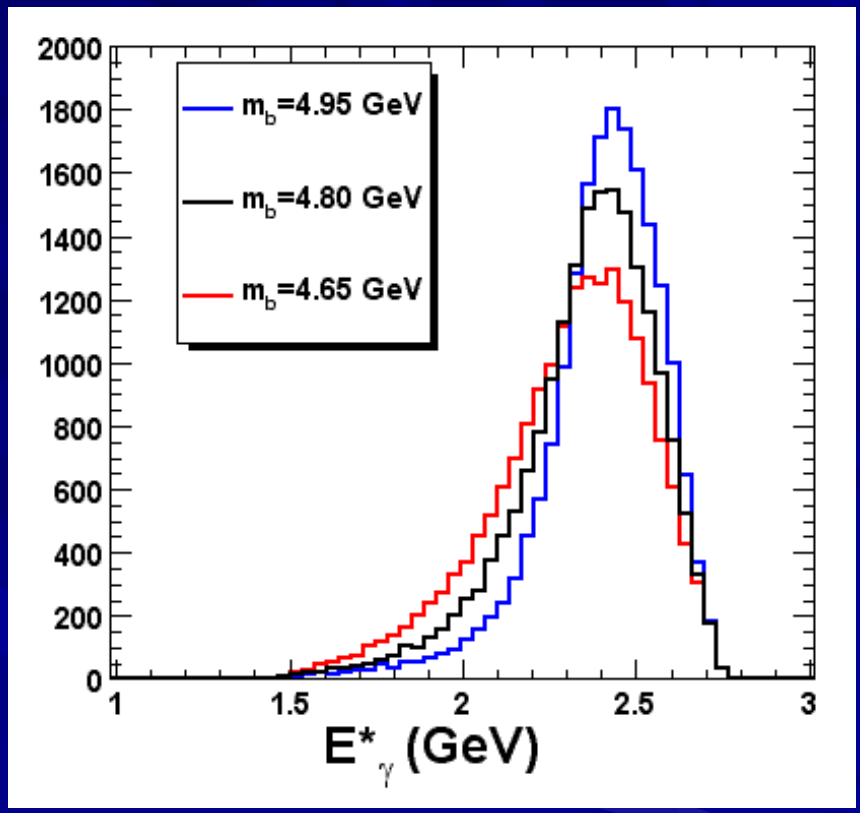
Motion of b is "universal" (like a structure function) so information from $B \to X_s\gamma$ can be used in $B \to Xl\nu$ *decays to reduce uncertainty in extraction of* V_{bc}, V_{bu}

Experimental Challenge

MC : Inclusive γ spectrum (no cuts)



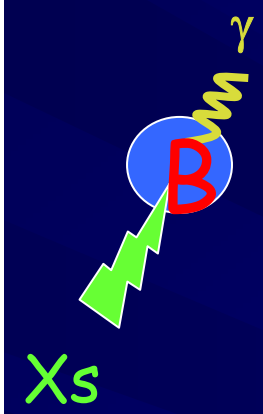
Theoretical γ distribution for different m_b



Principle Backgrounds from *qq =uu,dd,ss,cc* and B->Xs π^0 ($\gamma\gamma$), η^0 ($\gamma\gamma$)

To reduce large backgrounds without cutting on γ or Xs . E.g If cut on Eγ then model dependence incurred in correcting for missing part of spectrum

Technique 1 – Semi-Inclusive



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

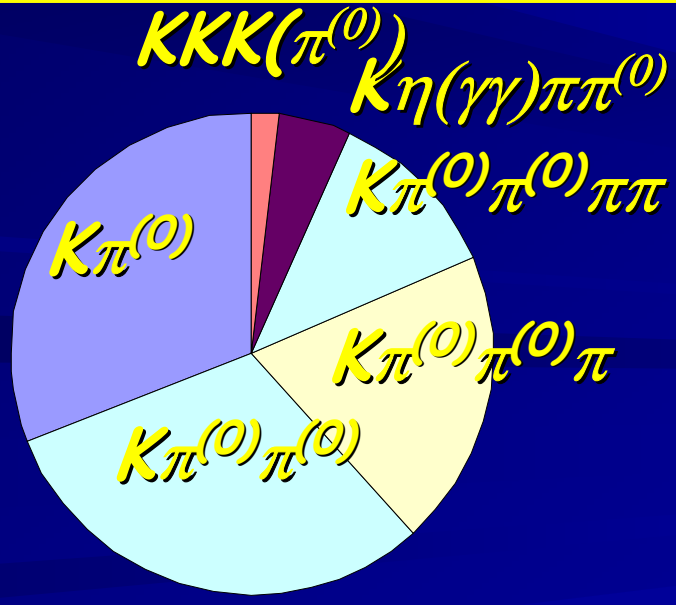
~55%

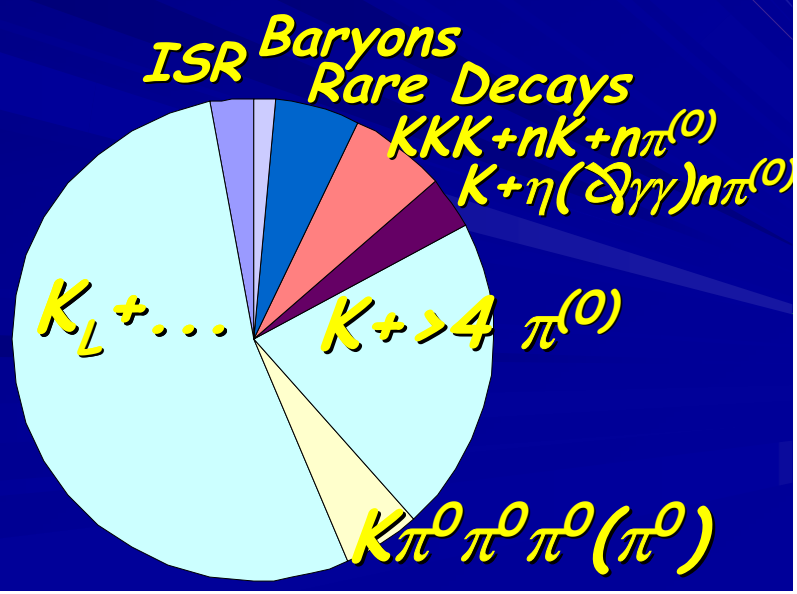
$K = K^{\pm}, K_s$

~45%

Reconstructed Final States

Missing Final States





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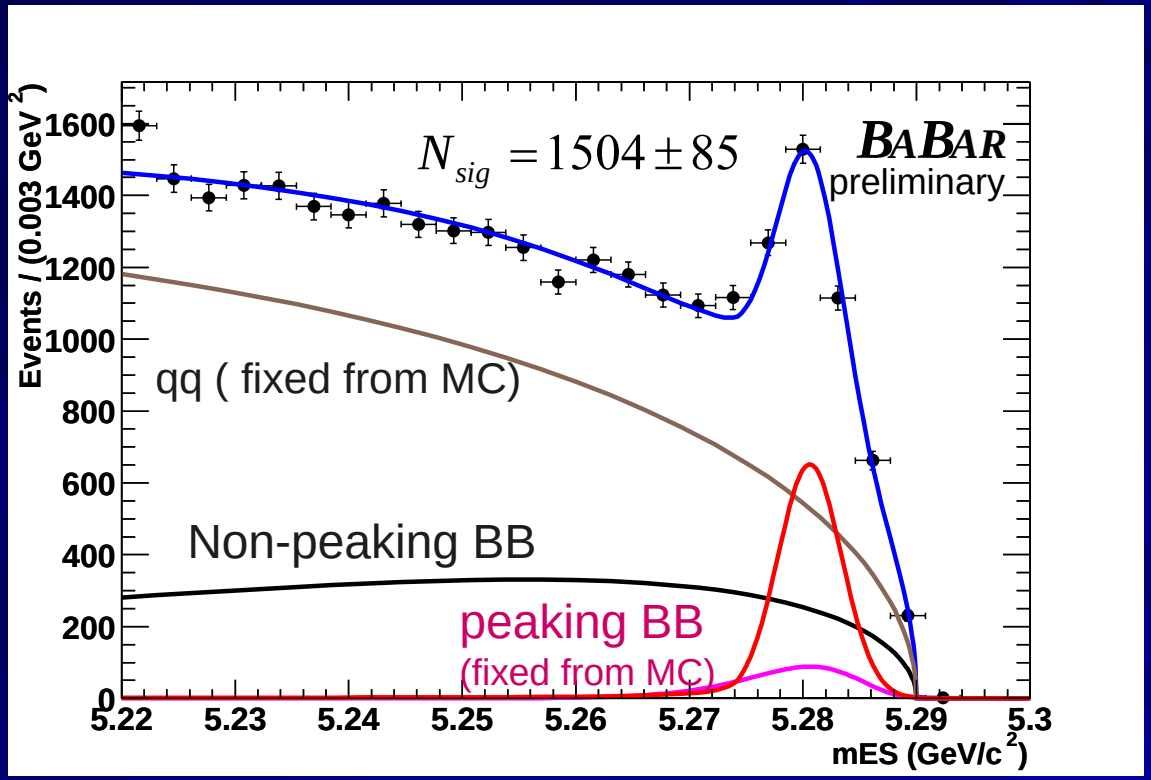
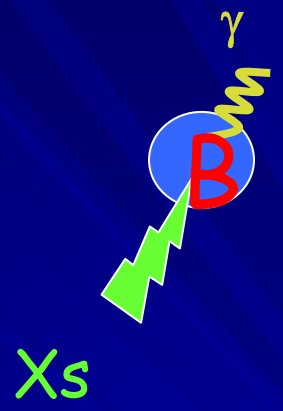




$$E_\gamma = \frac{m_B^2 - m_{Xs}^2}{2m_B}$$

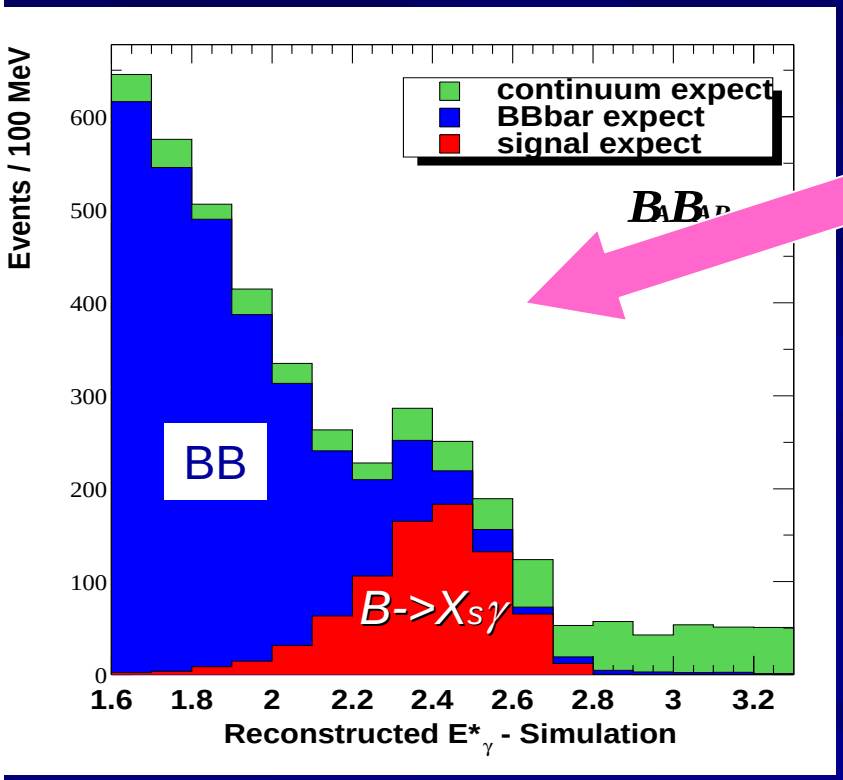
Reconstruct in bins of M_{Xs} and convert to E_γ

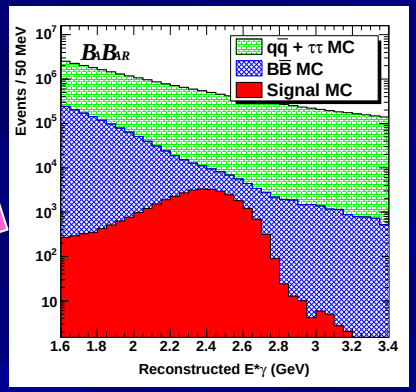
Multicomponent fit to extract signal

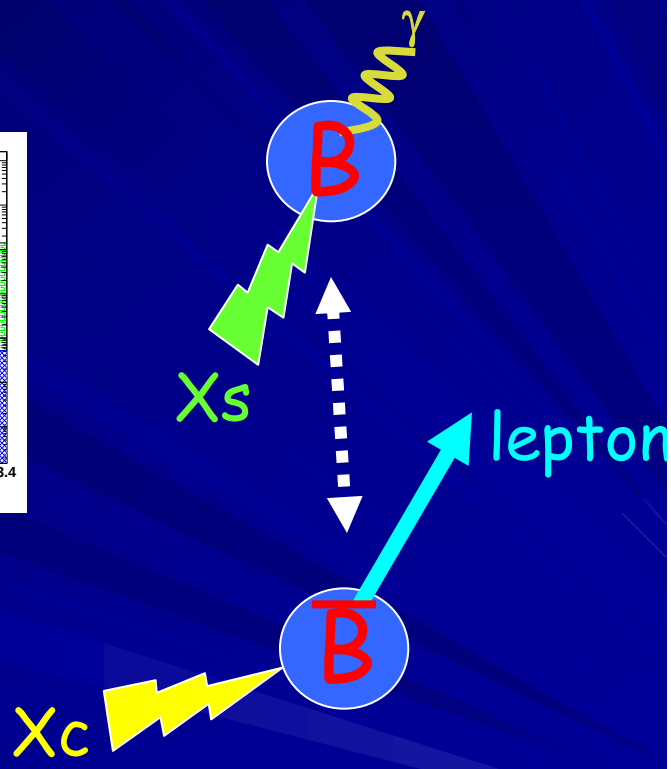
Dominant systematic is modelling missing final states

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)



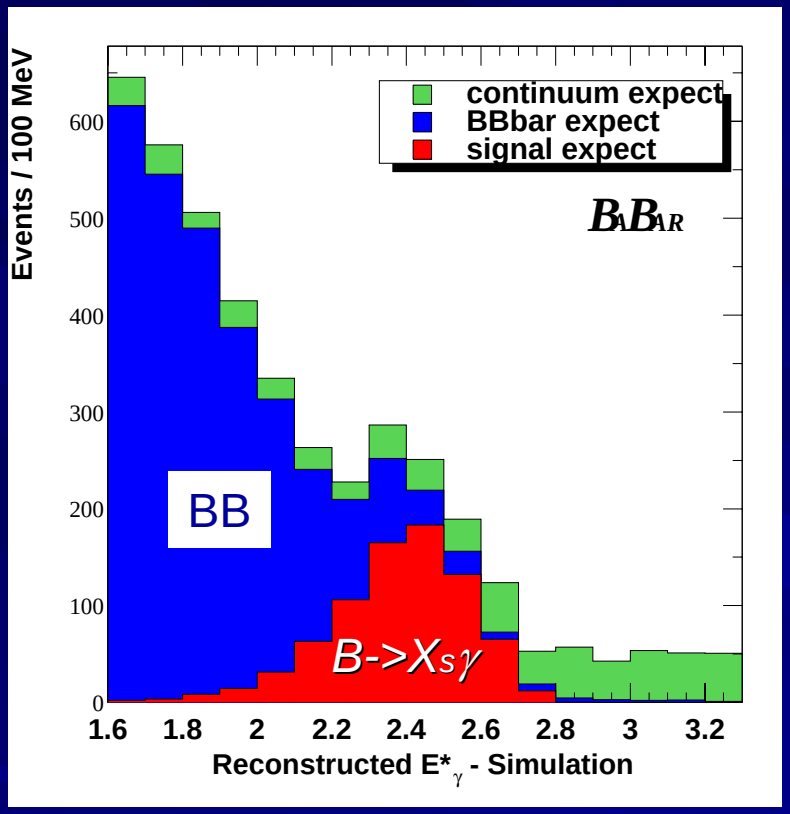




Remaining continuum subtracted with off-resonance data -> statistical uncertainty

Multi-component BB background

Fully Inclusive BB background

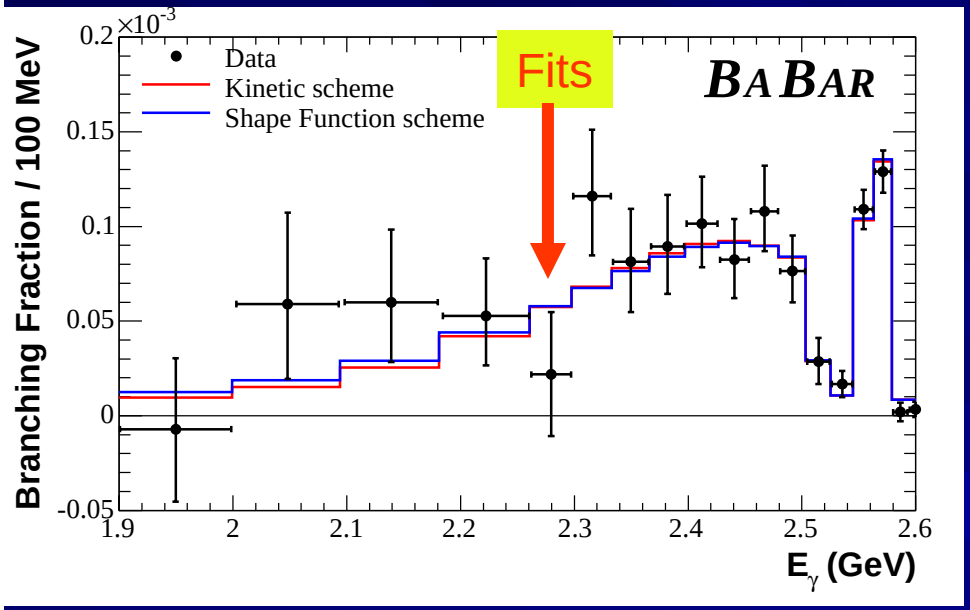


Component	%
π^0	64
η^0	17
$\overline{n}$	8
$e\pm$	4
ω & η'	3
Other	4

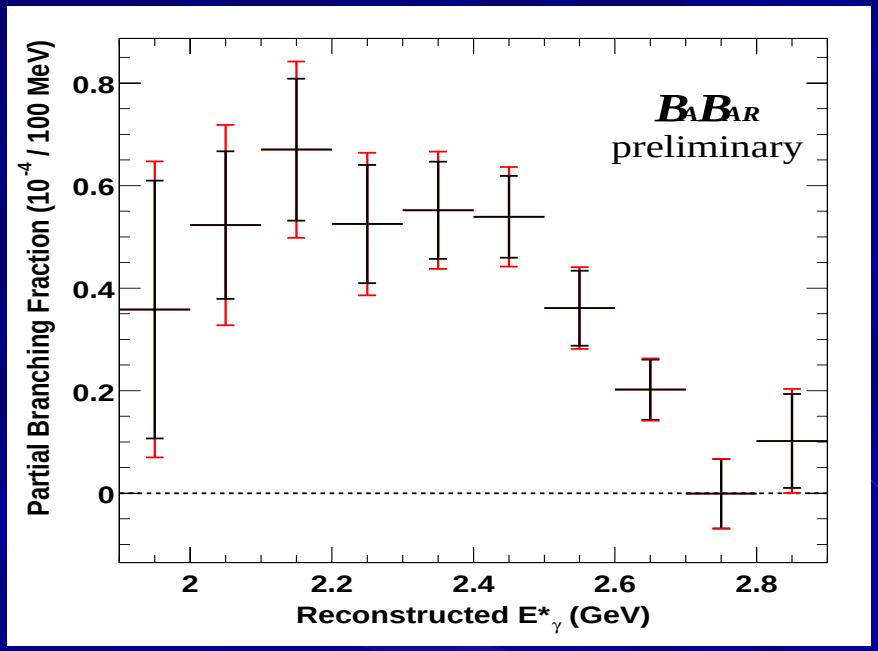
Each BB component measured independently in data. Precision of these measurements is dominant systematic.

Results: Spectrum

Semi Inclusive



Fully Inclusive



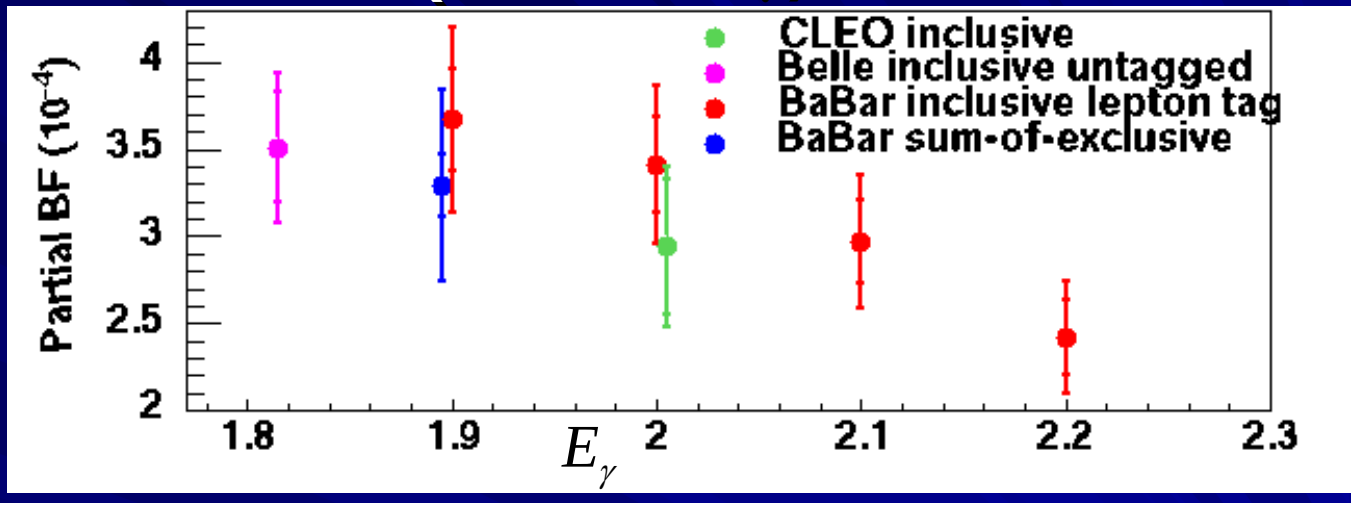
Semi-Inclusive analysis reconstruct M_{Xs} with resolution 5 MeV so K*(892) peak visible

Fully inclusive measures Eγ in C.M. frame with resolution 40 MeV

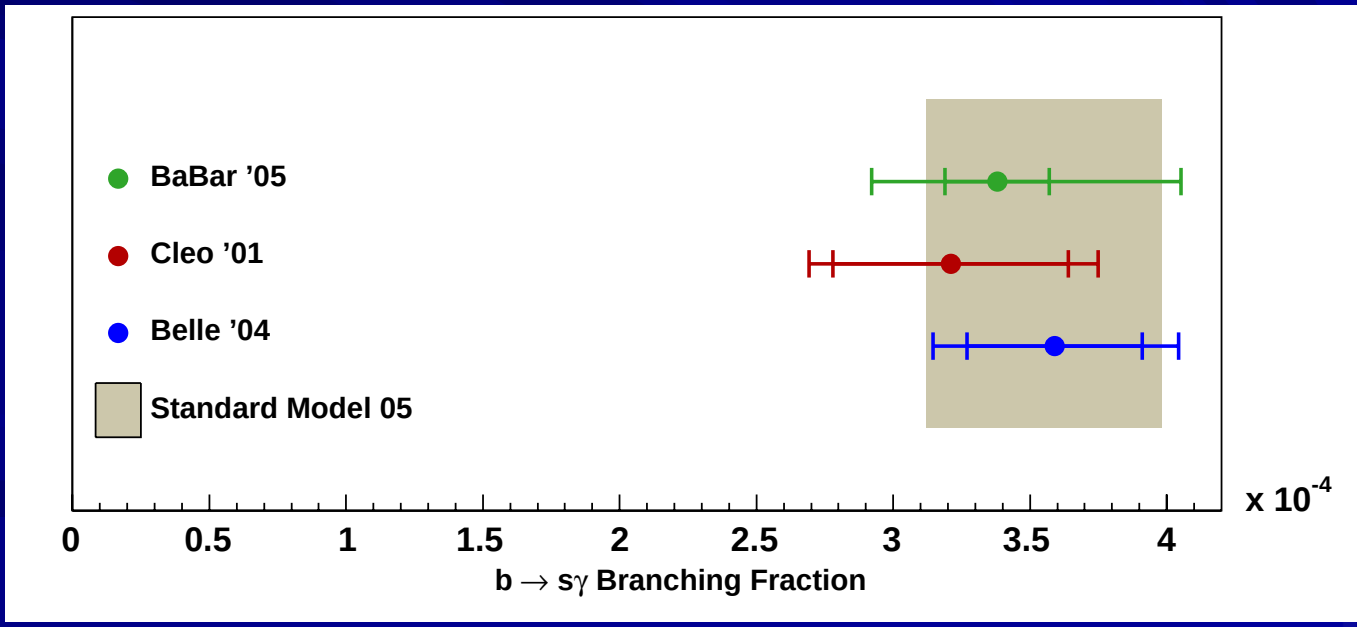
Theoretically interesting quantities are integrals over whole spectrum for which resolution difference has negligible effect. Note fits to semi-inclusive

Results: B($B \to X_s\gamma$)

Partial BF vs E_γ



Extrapolated to
$E_\gamma > 1.6$ GeV
(semi inclusive only)



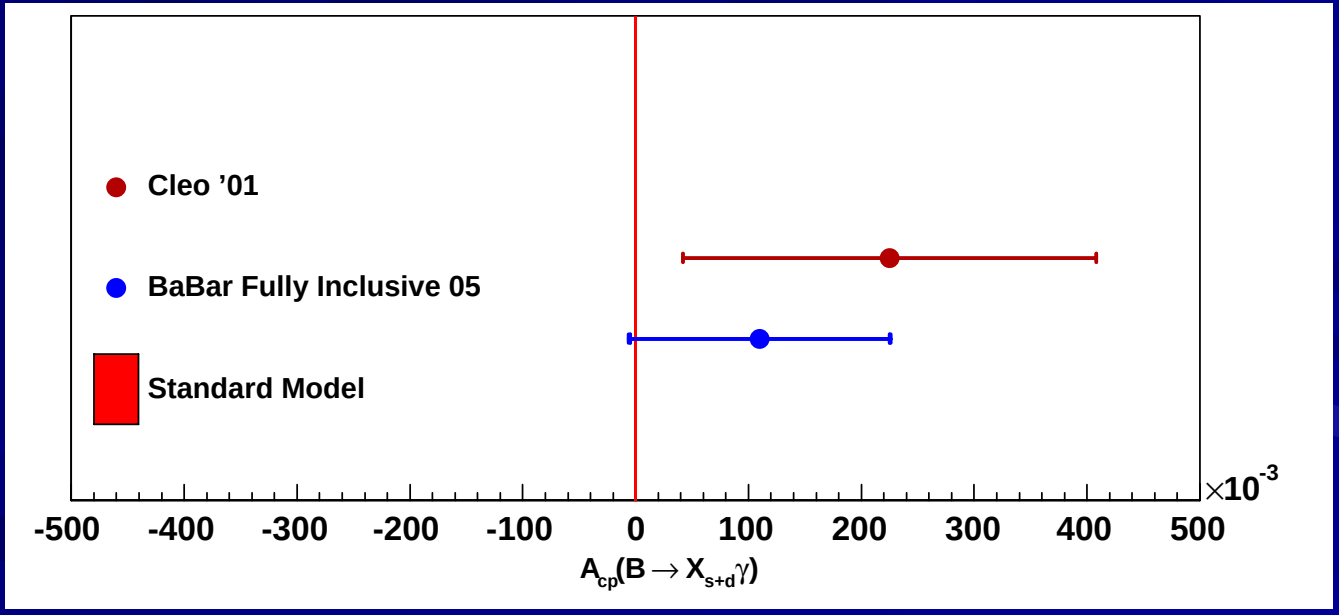
Consistent with SM and Previous Measurements

Results: A_{cp}

$$A_{cp}(B \to X_{s+d}\gamma) = \frac{\Gamma(\bar{B} \to X_{s+d}\gamma) - \Gamma(B \to X_{s+d}\gamma)}{\Gamma(\bar{B} \to X_{s+d}\gamma) + \Gamma(B \to X_{s+d}\gamma)}$$

Fully-Inclusive: Lepton charge tags flavor. Dilution from mixing.

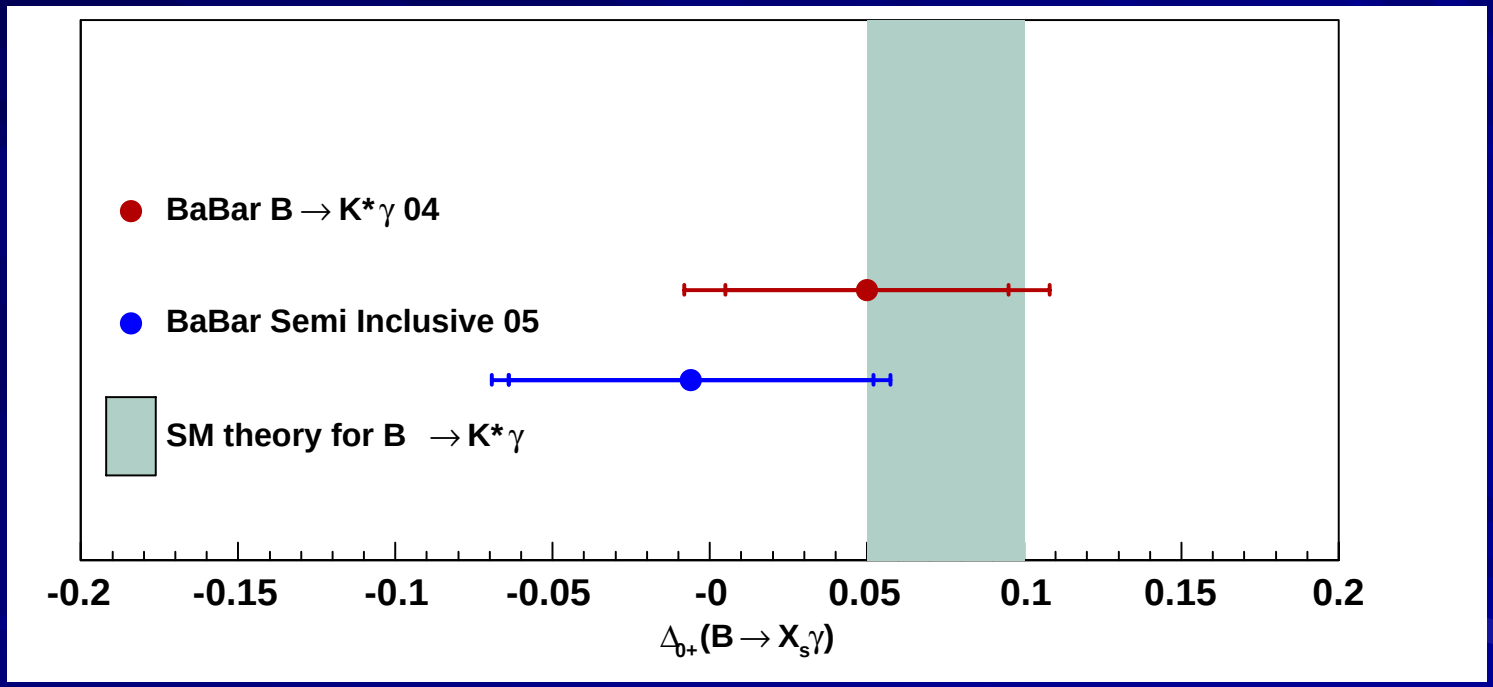
$$A_{cp}(B \to X_{s+d}\gamma) = -0.110 \pm 0.115(stat) \pm 0.017(sys)$$



Asymmetry consistent with Standard Model and previous measurements

Results Δ_{0+}

$$\Delta_{0+}(B \to X_s\gamma) = \frac{\Gamma(B^0 \to X_s\gamma) - \Gamma(B^+ \to X_s\gamma)}{\Gamma(B^0 \to X_s\gamma) + \Gamma(B^+ \to X_s\gamma)}$$



SM theory for exclusive B->K*γ $5-10\%$ (Kagan and Neubert). Sensitive to new physics such as MSSM with large tan β.

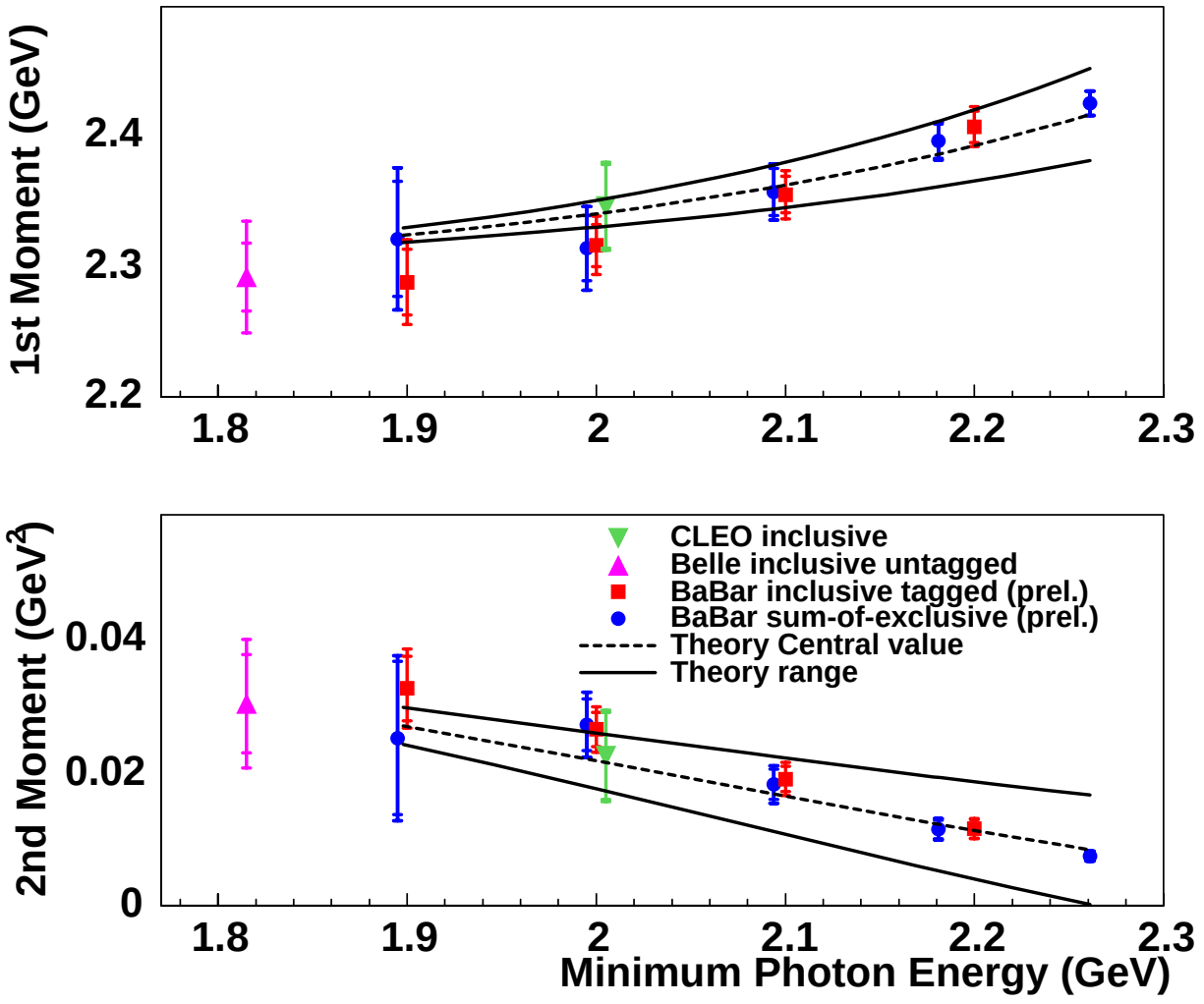
Results: Moments

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

$$\left\langle E_\gamma^{B2} \right\rangle - \left\langle E_\gamma^B \right\rangle^2 \approx \mu_\pi^2$$

(kinetic energy of b)^2

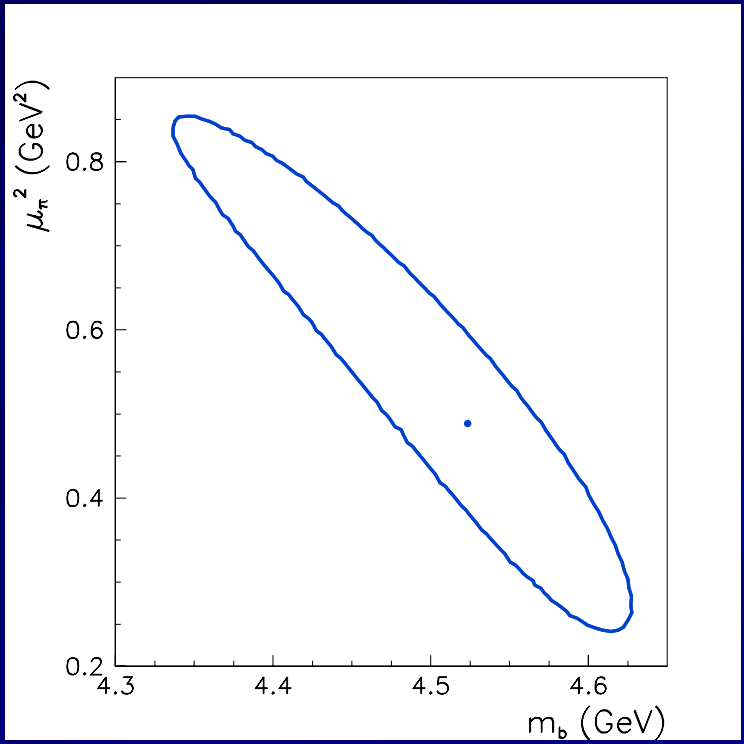
Theory is Bigi,Benson and Uraltsev (Nucl Phys B 710 371 2005) using BaBar measured B->$X_c l\nu$ PRL 93 011803 2004



Good agreement with theory and previous measurements

Extraction of HQET Parameters I

"Kinetic Scheme" (Benson,Bigi and Uraltsev)



Thanks to O. Buchmueller and H. Flaescher

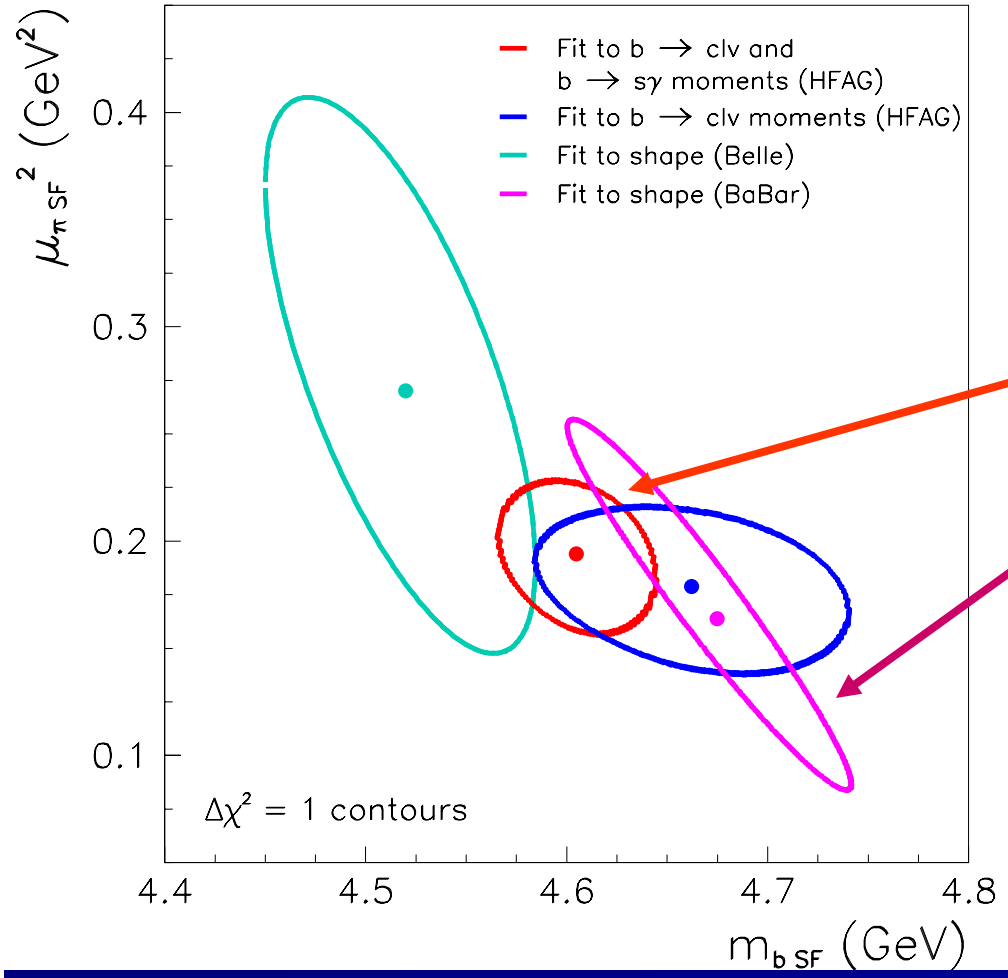
Fit to moments in kinectic scheme scheme to obtain μ_π and m_b

Ellipse because of correlations between first and second moments

Includes theoretical errors

Correlation matrices provided in papers to allow fitting to any theoretical calculation

Extraction of HQET Parameters II



"Shape function" scheme
Lange,Neubert & Paz

Fits to moments (+B->$X_c l\nu$)
(semi and fully inclusive)

Fit to spectrum (semi inclusive)

Fits to moments and plot -
thanks to O. Buchmueller
and H. Flaecher

Extraction of moments and application to V_{bu} is ongoing

Conclusion

New results on $B \to X_s\gamma$ from two independent techniques

Branching fractions, moments and Acp

Results may be used to improve constraints new physics and extract CKM Parameters more precisely

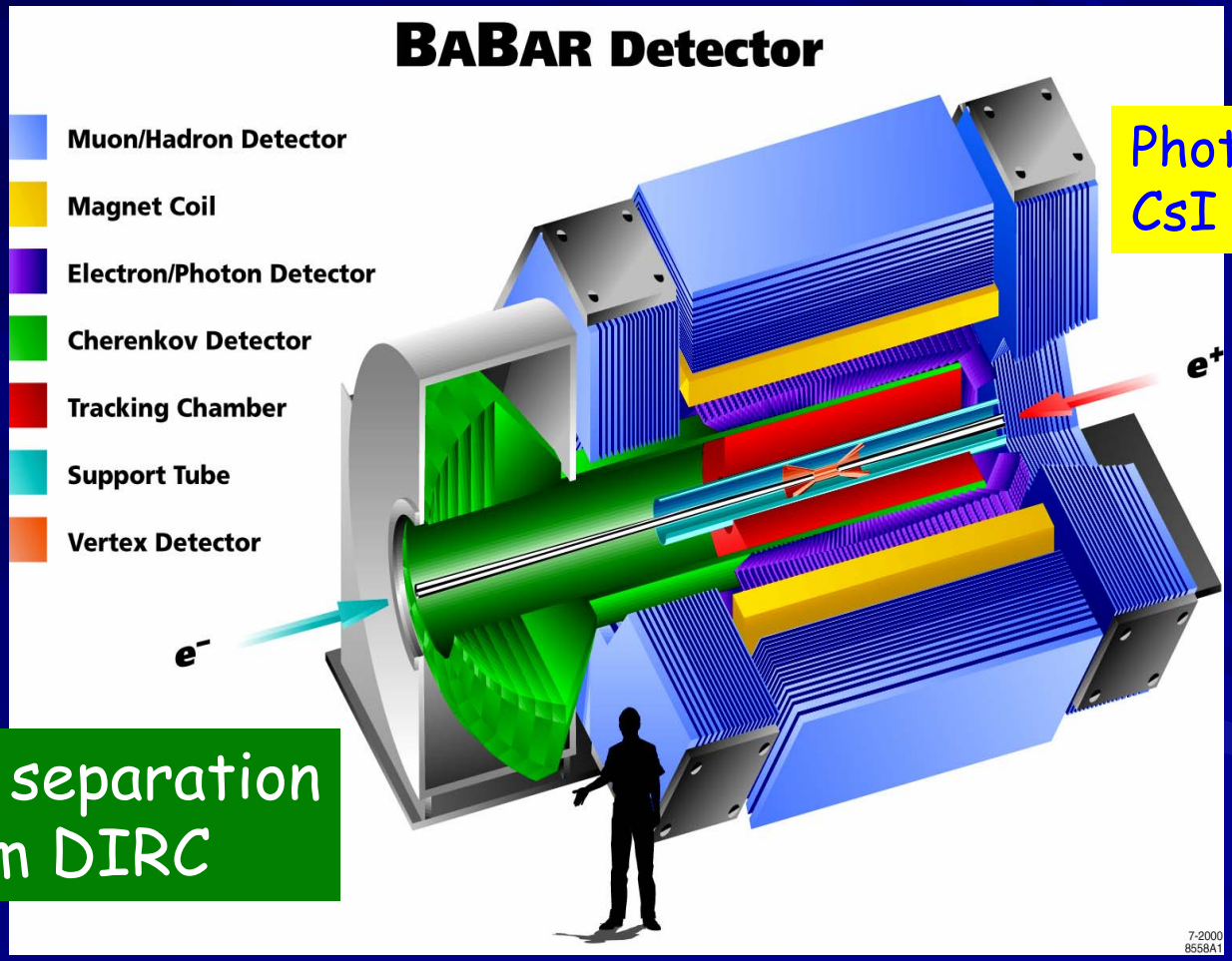
Larger datasets will continue to improve precision and results from $B \to X_s\gamma$ will remain compelling even into LHC era

Backup Slides

(NIM A 479, 1 2002)

BaBar Detector

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



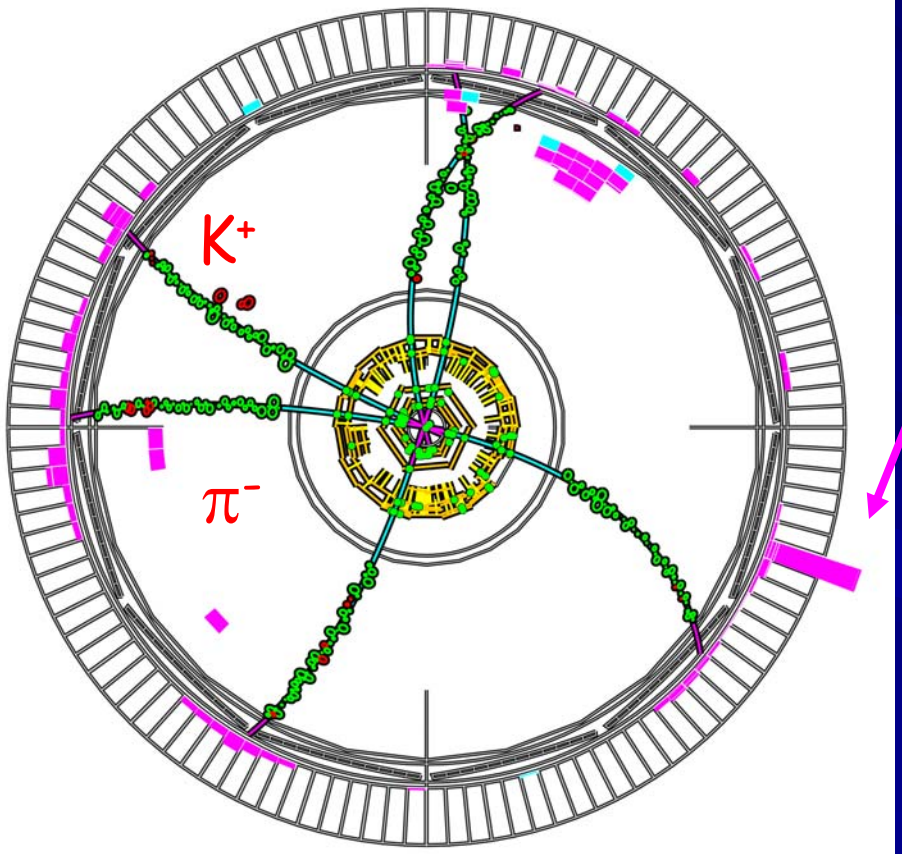
Photons from CsI Calorimeter

K/π separation from DIRC

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

Event Selection - γ

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



Isolated high energy γ
(1.5 < E_γ^* < 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