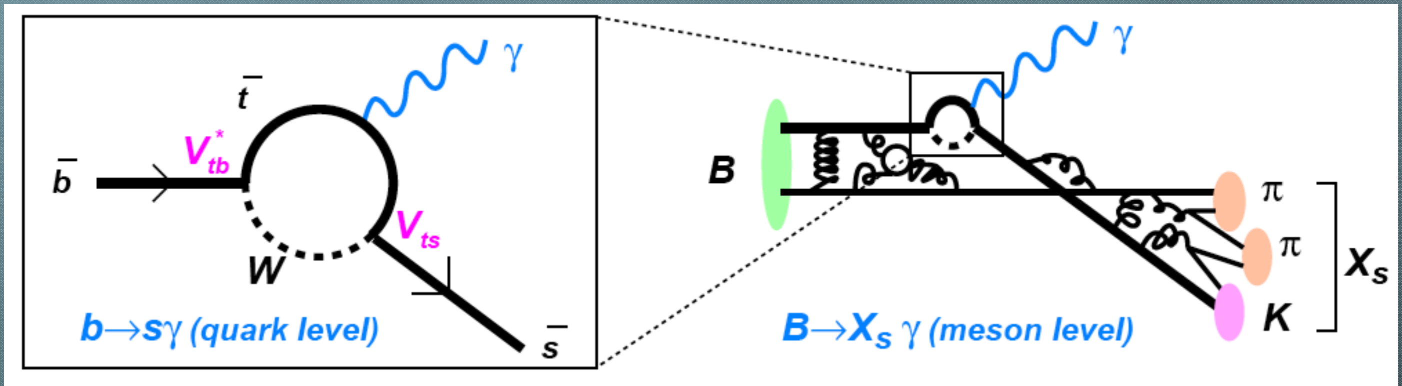
B->$X_s\gamma$ at B-factories

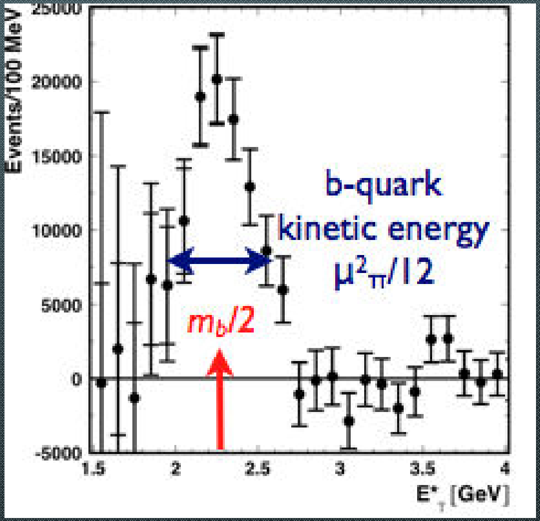
Antonio Limosani

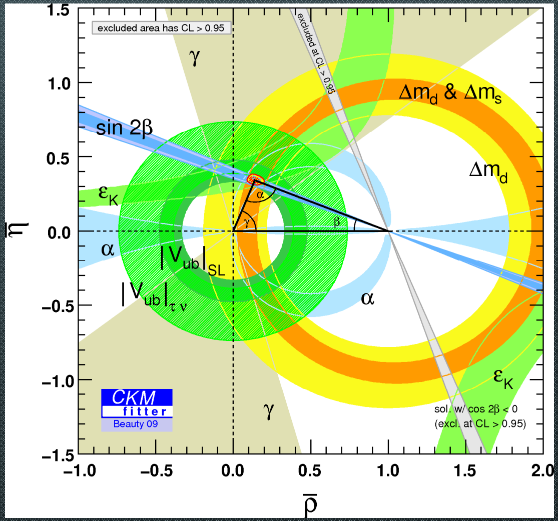
University of Melbourne

Dynamics of radiative B decays

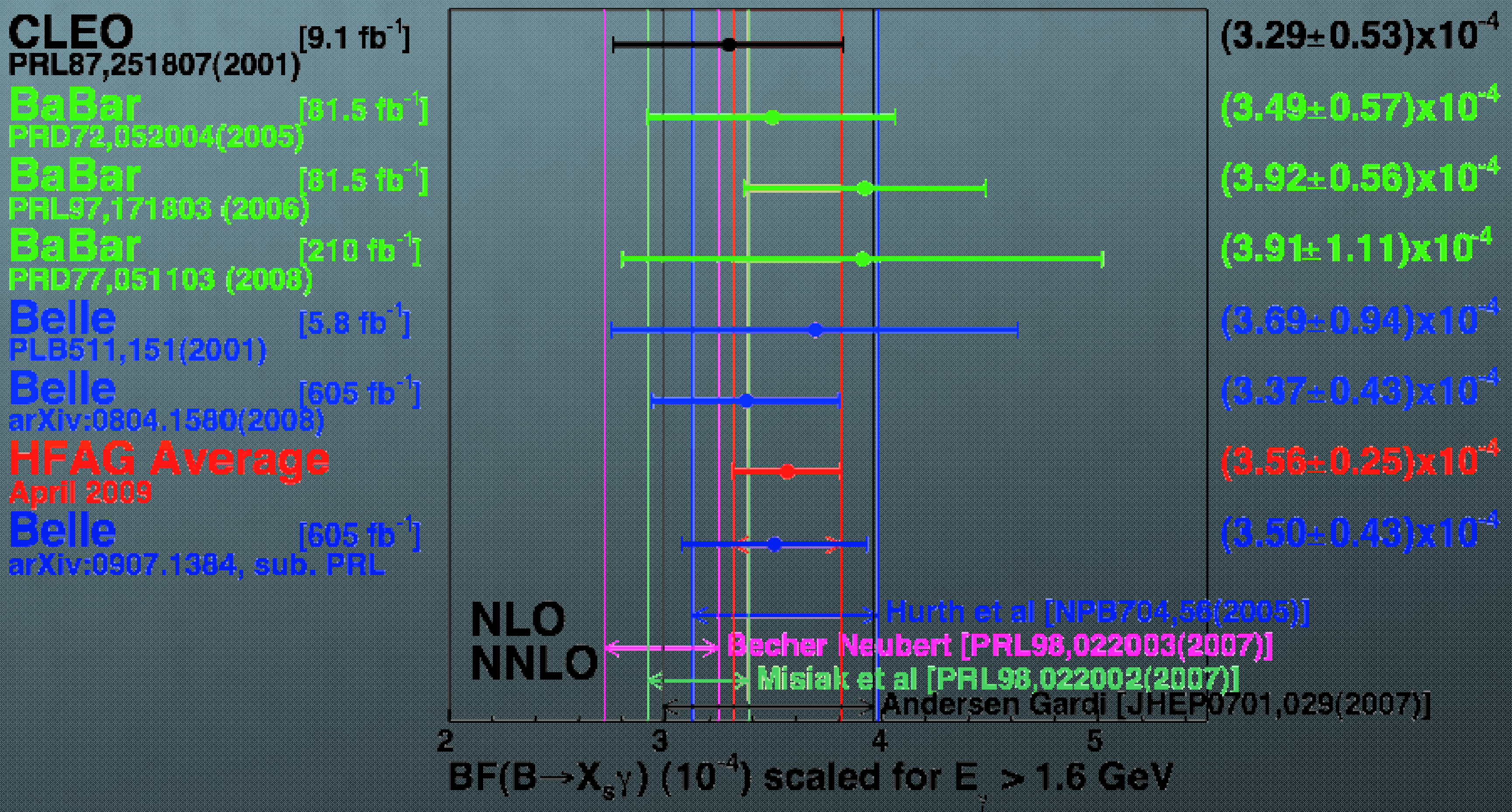


- Total decay rate and CP asymmetry: Probe for New Physics
- Differential decay rate : Photon is a messenger of the dynamics of the b-quark
- "b"-quark mass essential input to $|V_{ub}|$



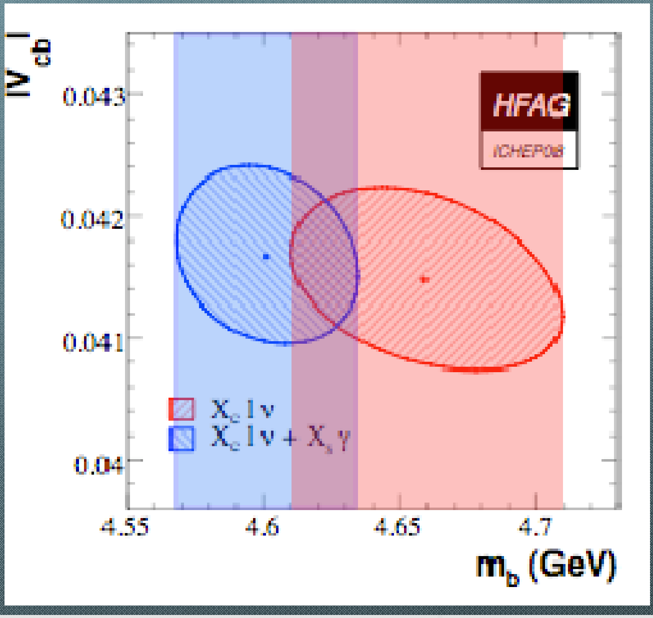


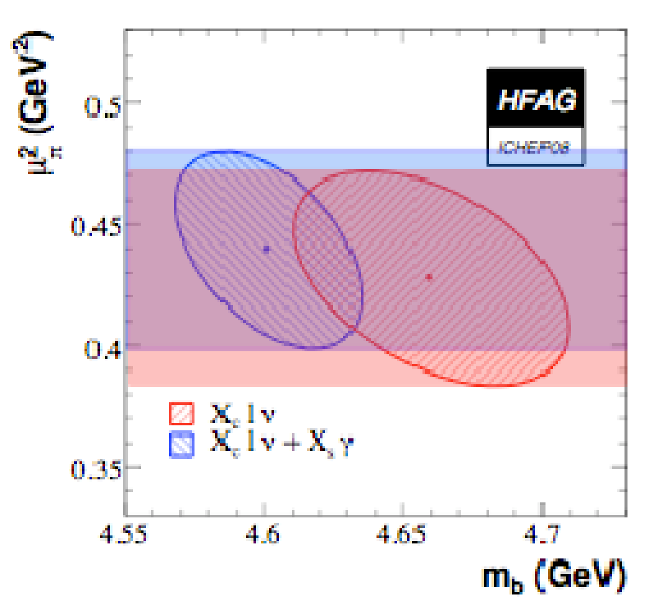
Branching fraction summary



- Moments of the spectrum are crucial to the extraction of the average.

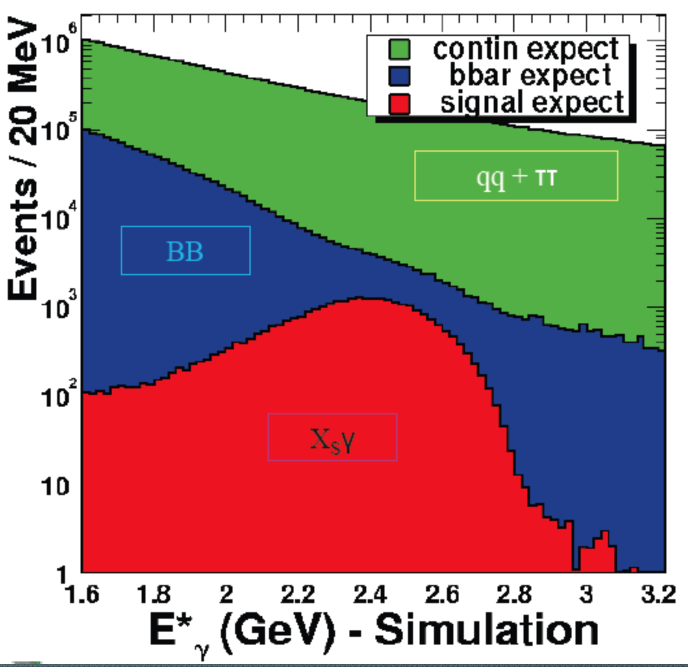
In the Global fit





Input	$\lvert V_{cb}\rvert$ (10^{-3})	m_b^{kin} (GeV)	mu^2_{pi} (GeV^2)
all moments ($X_c$lnu and $X_s$gamma)	41.67 +/- 0.43(fit) +/- 0.08(tau_B) +/- 0.58(th)	4.601 +/- 0.034	0.440 +/- 0.040
$X_c$lnu only	41.48 +/- 0.47(fit) +/- 0.08(tau_B) +/- 0.58(th)	4.659 +/- 0.049	0.428 +/- 0.044

Challenging Measurement

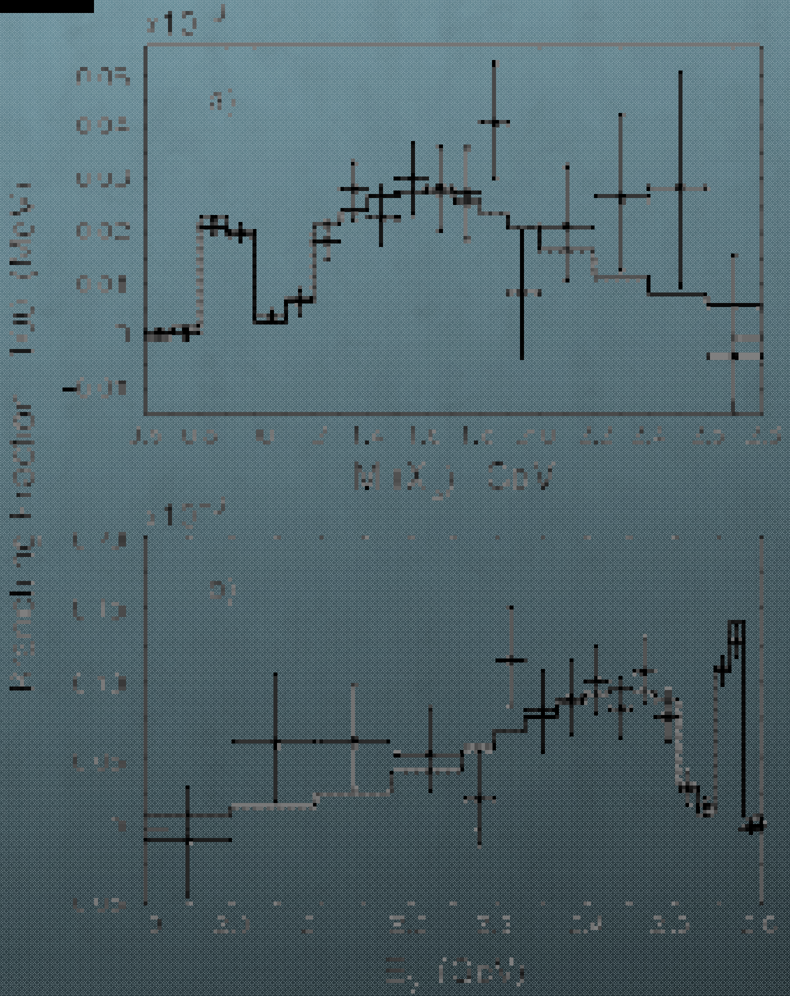


- Overwhelming background from
  1. Continuum under the Υ(4S) peak from light quarks and tau pairs
  2. Light meson decays cascaded from Υ(4S)
- Exponential rise as photon energy is lowered. But theory uncertainty decreases
- Cuts E(γ) > 1.7, 1.8, 1.9, 2.0 GeV

- Techniques
  1. Sum of exclusive modes : Reco γ and X_s as K+nπ
  2. Fully Inclusive: Reco γ with/out lepton tag
  3. Full reconstruction B-meson tag: Υ(4S)->B1B2

     Reco B1->D(nπ) + γ from B2

Sum of Exclusive modes

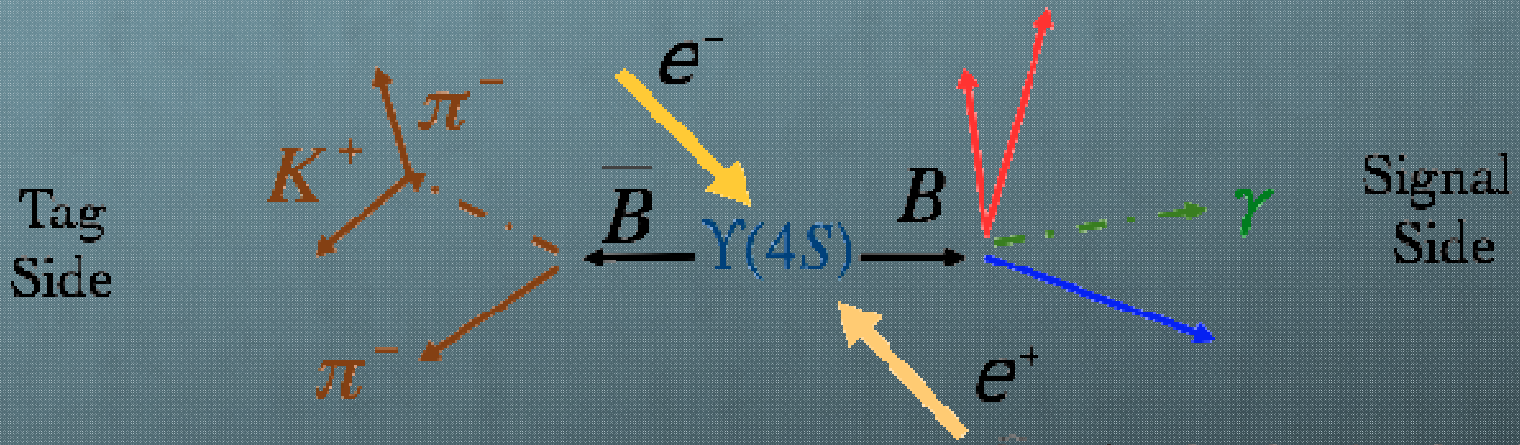


Aubert et al. Phys.Rev.D72:052004,2005.

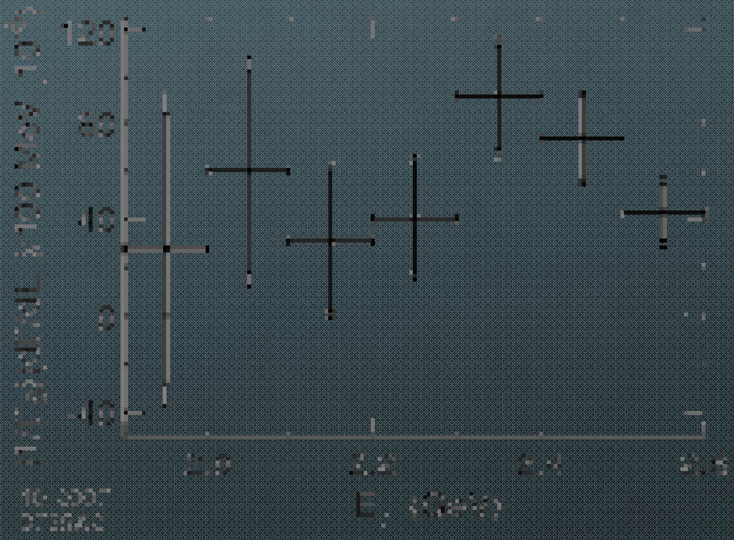
- Reconstruct the hadronic Xs system as sum of K/Ks + $n\pi^{\pm}/\pi^{0}$ and isolated γ
- Excellent resolution on $M(X_s) \rightarrow E_\gamma$ relies on momentum measurement $\rightarrow$ tracking detectors
- Spectrum in the B meson rest frame
- Eliminates much of the photon background
- "s"-quark fragmentation and un-measured Xs contribution is poorly known

~81/fb

Full Reconstruction



- Tag B is fully reconstructed in a hadronic decay mode and search for an isolated photon from the other B decay
- Negligible continuum background
- B rest frame, B flavour
- Very low efficiency for full reconstruction ~0.3%



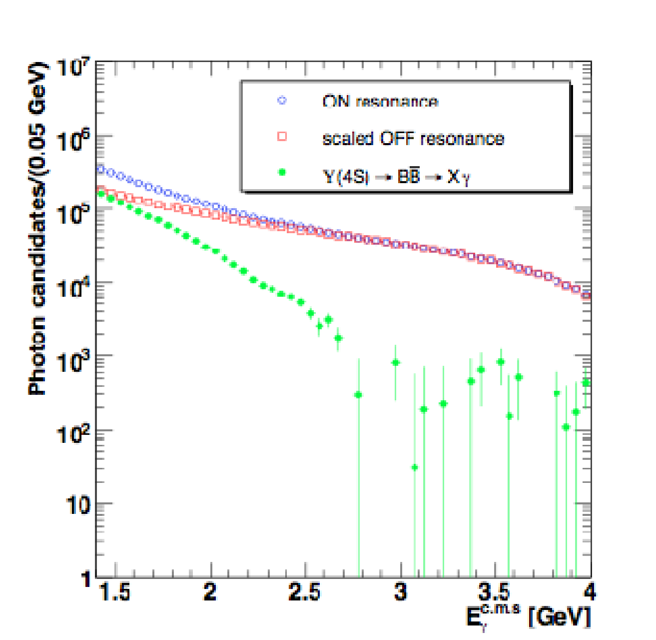
Aubert et al. Phys.Rev.D77:051103,2008

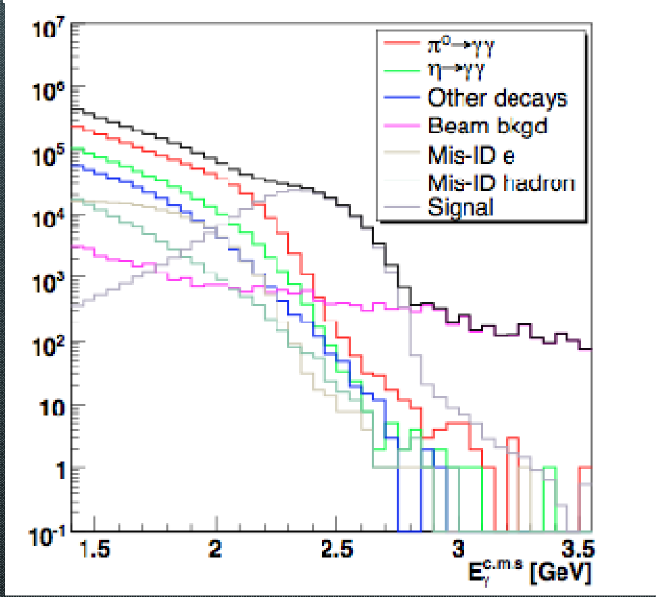
~210/fb

BABAR

Fully Inclusive

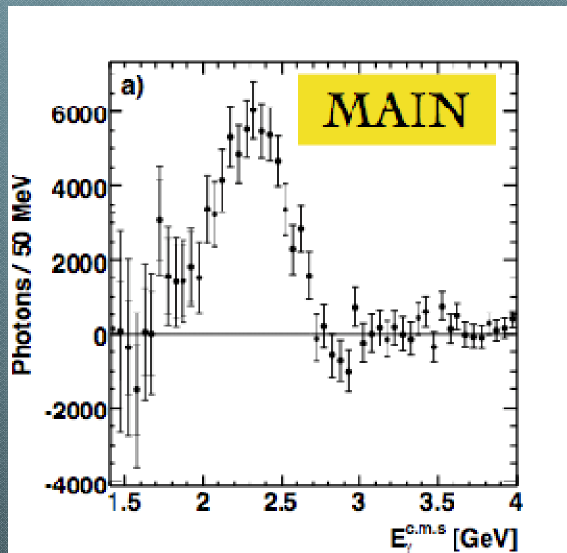
- Find isolated clusters in the calorimeter
- High Energy $E_{\gamma} > 1.4$ GeV
- Veto γ from π/η & Bhabha and use event topology and/or lepton tag to suppress continuum background
- Estimate continuum bkgd using off resonance data
- Estimate B-decays using "corrected" MC sample



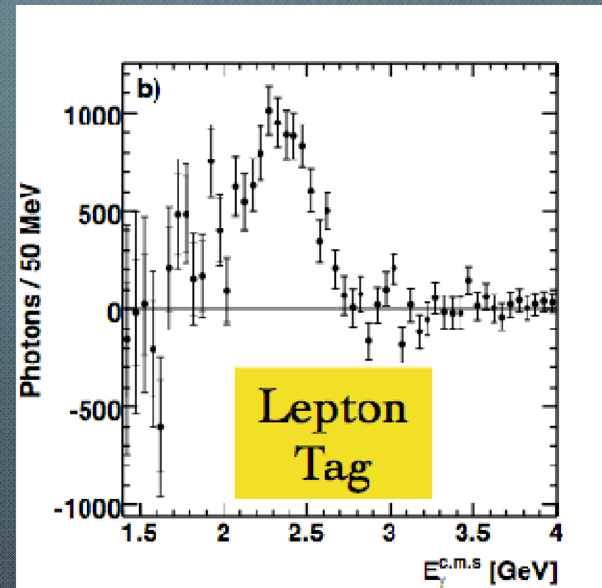


Fully Inclusive Spectrum

605/fb



arXiv 0804.1560 Proc, Moriond EW, 2008

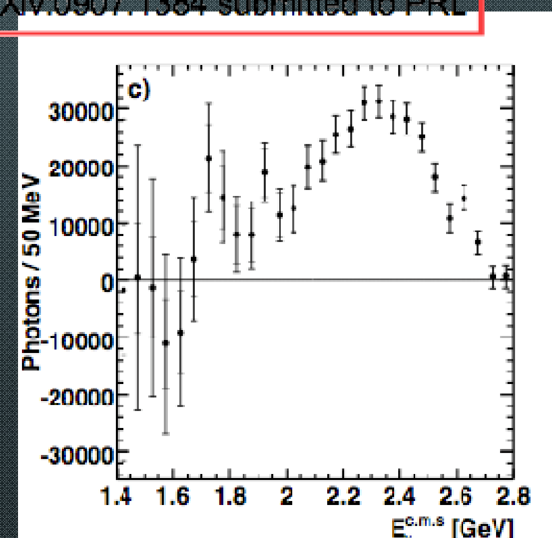


arXiv:0907.1384 submitted to PRL

After efficiency correction
MAIN and LT streams are averaged

* Small Statistical correlation

Overall effect reduces stat error



Summary of Results

	$\mathcal{B}(B \to X_s\gamma)$ (10^{-4})				$\langle E_\gamma \rangle$ (GeV)				$\Delta E_\gamma^2 \equiv \langle E_\gamma^2 \rangle - \langle E_\gamma \rangle^2$ (GeV^2)			
$E^{\mathrm{B}}_{\gamma-\mathrm{Low}}$ [GeV]	1.70	1.80	1.90	2.00	1.70	1.80	1.90	2.00	1.70	1.80	1.90	2.00
Value	3.45	3.36	3.21	3.02	2.282	2.294	2.311	2.334	0.0428	0.0370	0.0302	0.0230
±statistical	0.15	0.13	0.11	0.10	0.015	0.011	0.009	0.007	0.0047	0.0029	0.0019	0.0014
±systematic	0.40	0.25	0.16	0.11	0.051	0.028	0.015	0.009	0.0202	0.0081	0.0030	0.0016
Systematic Uncertainties												
Continuum	0.26	0.16	0.10	0.07	0.033	0.018	0.009	0.004	0.0111	0.0048	0.0016	0.0005
Selection	0.15	0.12	0.10	0.08	0.016	0.009	0.005	0.002	0.0089	0.0029	0.0011	0.0004
π^0/η	0.07	0.05	0.04	0.02	0.011	0.006	0.003	0.002	0.0068	0.0022	0.0007	0.0003
Other B	0.25	0.14	0.06	0.02	0.033	0.017	0.007	0.002	0.0121	0.0051	0.0017	0.0004
Beam	0.03	0.02	0.02	0.01	0.002	0.001	0.000	0.000	0.0006	0.0003	0.0001	0.0001
Resolution	0.05	0.03	0.01	0.00	0.007	0.004	0.001	0.000	0.0026	0.0011	0.0004	0.0001
Unfolding	0.01	0.01	0.02	0.02	0.006	0.005	0.005	0.004	0.0008	0.0006	0.0005	0.0004
Model	0.01	0.01	0.00	0.01	0.002	0.001	0.000	0.001	0.0010	0.0006	0.0004	0.0004
γ Detection	0.03	0.02	0.00	0.00	0.005	0.003	0.002	0.001	0.0015	0.0007	0.0002	0.0000
$B \to X_d\gamma$	0.01	0.01	0.01	0.01	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000	0.0000
Boost	0.01	0.01	0.02	0.02	0.002	0.002	0.004	0.005	0.0012	0.0005	0.0008	0.0009

A.L et al (Belle) Submitted to PRL **arXiv:0907.1384**

- **BF(B->Xs γ : E > 2.0 GeV)**
- **(3.02 ± 0.10 ± 0.11) x 10^{-4} Belle 2009**
- **(3.41± 0.27 ± 0.29) x 10^{-4} BABAR 2006**
- **(2.94 ± 0.39 ± 0.25) x 10^{-4} CLEO 2001**

- **μ(B->Xs γ : E > 2.0 GeV)**
- **(2.334 ± 0.007 ± 0.009) x 10^{-4} Belle 2009**
- **(2.316 ± 0.016 ± 0.010) x 10^{-4} BABAR 2006**
- **(2.346 ± 0.032 ± 0.011) x 10^{-4} CLEO 2001**

Overall summary

Analysis	Current
Inclusive full B Recoil	
Signal events	119 +/- 22
Stat error	23% @ 210/fb
Sys error	
M(ES) fit	~12%
BB bkgd	~9%
Inclusive Lepton tag	
Signal events	758 +/- 66
Stat error	8% @ 81/fb ON 9.6/fb OFF
Sys error	
Model dependence	~8%
BB bkgd	~6%
Inclusive : No tag	
Signal events	68960 +/- 3770
Stat error	5.6% @ 605/fb
Sys error	
BB bkgd	5%
Continuum	5% (dep. ON/OFF ratio)
Sum of Exclusive modes	
Signal events	1513 +/- 85
Stat error	6% @ 81/fb
Sys error	
Missing Xs fraction	~10%
Xs fragmentation	~6%

- Full recon B tag analysis is certainly the future w.r.t a Super B-factory
- Background from B in the lower energy region will be the biggest problem. Some nice techniques in untagged analyses to measure bkgd from pi0 and eta, and correct for effects of hadronic clusters in the EM calorimeter. The latter is somewhat limited. Should investigate control sample of K_L.
- Can we learn about Xs fragmentation by studying Xs in the recoil measurement?

THE UNIVERSITY OF MELBOURNE

Model errors

- In 2004 Belle inclusive analysis, model error was assigned based on the comparison of two models for B->Xs γ. 2.5% on the partial branching fraction at 1.8 GeV.

- In 2007 BABAR inclusive analysis, sophisticated iterative procedure on measured moments data to decide the model parameter. Correction factors to correct for smearing and B rest frame 7.9% on the branching fraction at 1.9 GeV.

- In 2008/9 Belle inclusive analysis, theory spectra are matched to the measured spectrum, thus model parameters are chosen based on full spectrum. Done for 5 signal models. Entire correction procedure is dependent on the given model and parameters. Correction includes unfolding for distortion in the Calorimeter. Uncertainty assigned based on the difference between models. 0.5% on the partial branching fraction at 1.7 GeV.

- Why are they so different?

- These numbers propagate to the global fit, we need to be aware and estimate if they are having an impact

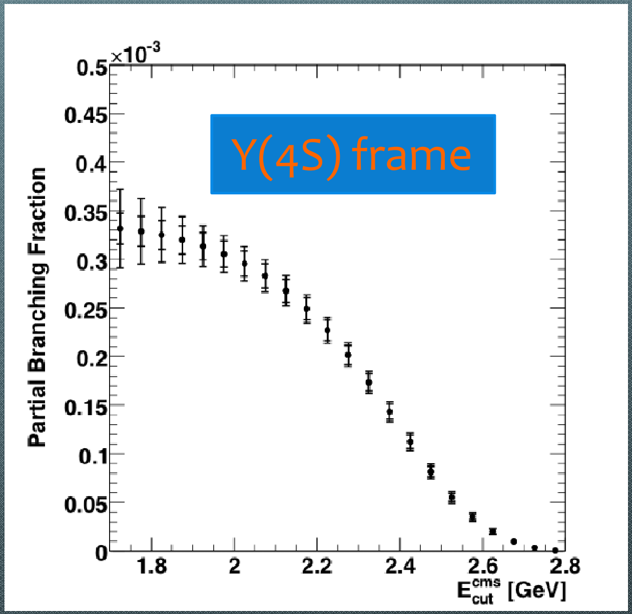
Υ(4S) to B frame

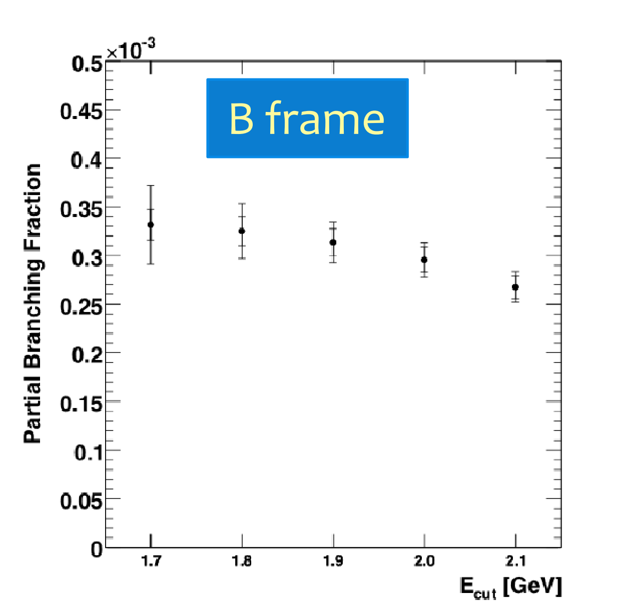
- Fully inclusive measurements are our most precise to date, but all in Υ(4S)
- Correction to B-frame is model dependent, and, moreover increases as the lower threshold energy cut is raised
- This model error can't be avoided, can we use Υ(4S) data instead of B frame data

Υ(4S) frame

B frame

E(cut) GeV	PBF $[10^{-4}]$
2.0	2.95±0.14±0.12
2.0	2.94±0.14±0.12±0.02
2.1	2.68±0.12±0.10
2.1	2.62±0.12±0.10±0.05





Global fit of all data

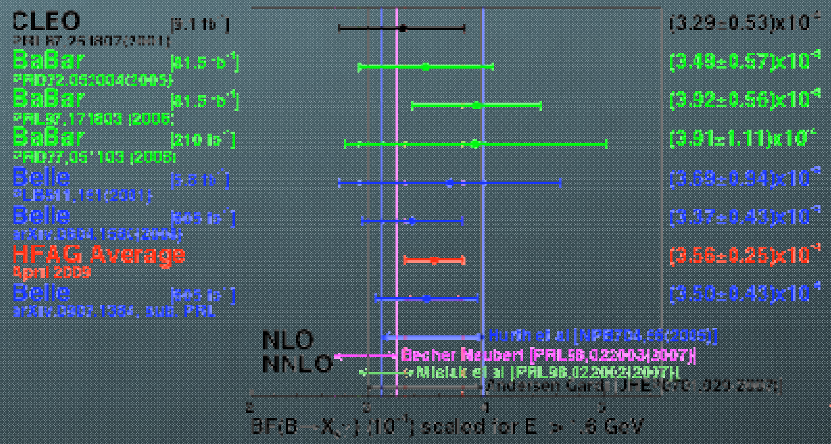
- As is done with Vcb, mb, and other HQET parameters, it is time we performed a fit to all B->$X_s\gamma$ data?
- The expression for B->$X_s\gamma$ BF is normalised by the B->$X_c l\nu$ branching fraction and moreover the extrapolation to low threshold depends on HQET parameters. Can we add the BF for B->$X_s\gamma$ to the global fit?
- Otherwise all B->$X_s\gamma$ partial branching fractions and moments alone can be fit in a given scheme/model to yield
  - BF(B->$X_s\gamma$: E>1.6 GeV)
  - b-quark mass
  - $\mu^2{}_\pi$

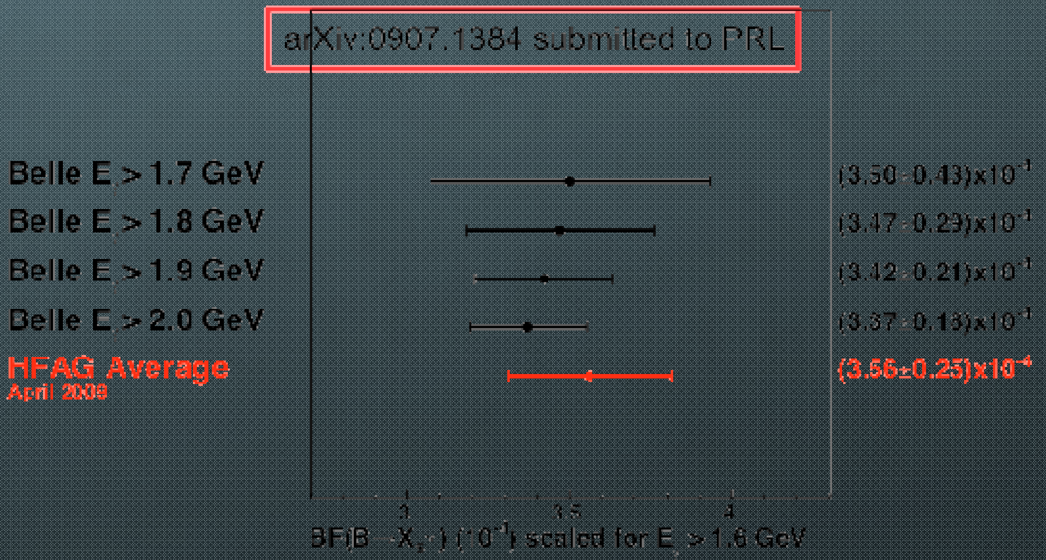
Problem with the W.A ?

Extrapolation factors used by HFAG from Buchmuller & Flacher PRD73 073008 (2006)

Table 1: Extrapolation factor in various scheme with various minimum photon energy requirement (in GeV).

Scheme	$E_\gamma < 1.7$	$E_\gamma < 1.8$	$E_\gamma < 1.9$	$E_\gamma < 2.0$	$E_\gamma < 2.242$
Kinetic	0.986 ± 0.001	0.968 ± 0.002	0.939 ± 0.005	0.903 ± 0.009	0.656 ± 0.031
Neubert SF	0.982 ± 0.002	0.962 ± 0.004	0.930 ± 0.008	0.888 ± 0.014	0.665 ± 0.035
Kagan-Neubert	0.988 ± 0.002	0.970 ± 0.005	0.940 ± 0.009	0.892 ± 0.014	0.643 ± 0.033
Average	0.985 ± 0.004	0.967 ± 0.006	0.936 ± 0.010	0.894 ± 0.016	0.655 ± 0.037





Much lower uncertainty if E>2.0 GeV cut is used!
Old measurements have a disproportionate weight in the average!

Proposed solution

- One way to alleviate this problem is to include all measured data in the fit, e.g all PBF measurements at the different cuts. To do this correctly one needs to use the correlations between correlated measurements.

- A.L. did this in Artuso, Barberio & Stone "B Meson Decays" PMC Phys.A3:3,2009.

Table 13: Measured branching fractions, minimum photon energy, and branching fractions for $E_{min} = 1.6$ GeV photon energy for $b \to s\gamma$. The third error is the model uncertainty quoted by the experiment. Two world averages are calculated extrapolating all the branching fractions using two different theoretical calculations [178] and [200]. The Belle semi-inclusive measurement sums up 16 modes, BaBar 38 modes. The Belle inclusive analysis calculates the branching fraction for different photon energy cut-offs.

Experiment	$E_{\rm min}$	$\mathcal{B}$ (10^{-6}) at $E_{\rm min}$	$\mathcal{B}_{\rm Modif.}(10^{-6})$ [200] $E_{\rm min} = 1.6$ GeV	$\mathcal{B}_{\rm Modif.}(10^{-6})$ [178] $E_{\rm min} = 1.6$ GeV
CLEO(Incl.) [204]	2.0	$306 \pm 41 \pm 26$	337	323
Belle(Semi-inc) [205]	2.24	$336 \pm 53 \pm 42$	496	434
BaBar(Semi-inc) [206]	1.9	$327 \pm 18^{+55}_{-40}$	354	337
BaBar(Incl.) [207]	1.9	$367 \pm 29 \pm 34$	397	378
BaBar(recoil) [208]	1.9	$366 \pm 85 \pm 60$	396	377
Belle(Incl.) [209]	1.7	$331 \pm 19 \pm 37$	337	333
Belle(Incl.) [209]	1.8	$324 \pm 17 \pm 24$	339	329
Belle(Incl.) [209]	1.9	$312 \pm 15 \pm 16$	338	321
Belle(Incl.) [209]	2.0	$294 \pm 14 \pm 12$	334	310
Average	1.6	–	$350 \pm 14_{exp} \pm 5_{m_b} \pm 8_{\mu_\pi^2}$ $\chi^2/ndf = 7.3/8$	$322 \pm 14_{exp} \pm 3_{m_b}$ $\chi^2/ndf = 8.3/8$

The uncertainty on the average of experimental measurements is reduced from 7% to 5%. In terms of constraining new physics this would have have a big impact! Including unused data from BABAR would improve the average even further.