$B \rightarrow X_{s/d}\, \gamma$ & $B \rightarrow X_{s/d}\, l^+l^-$

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(on behalf of the BaBar Collaboration)

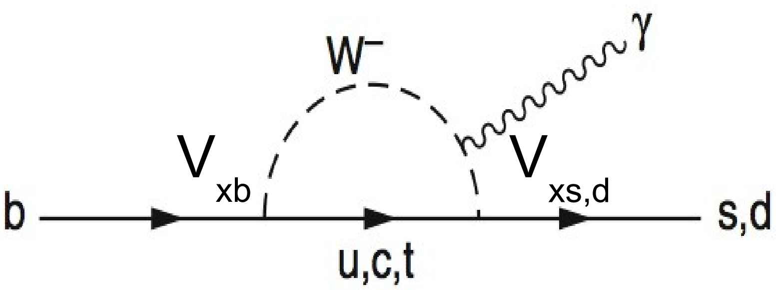
Outlook:

- **$B \rightarrow X_{s/d}\, \gamma$:**
  - **Motivations**
  - **$X_s\gamma$ (Belle), Acp ($X_{s+d}\, \gamma$) (BaBar), $|V_{td}/V_{ts}|$ (BaBar)**
  - **Spectral Moments**

- **$B \rightarrow X_{s/d}\, l^+l^-$:**
  - **Motivations**
  - **$K^{(*)}l^+l^-$ (Belle), $K^{(*)}\mu^+\mu^-$ (CDF), $K^+\tau^+\tau^-$ (BaBar)**
  - **πl^+l^-**

- **Conclusions**

$B \to X_{s/d}\, \gamma$: Motivations



FCNC process forbidden at tree level: Probe the SM!

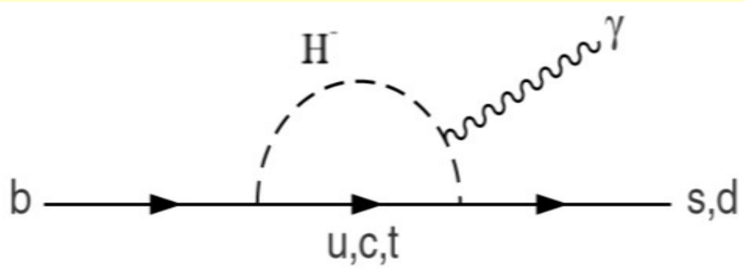
NNLL order $BR(b \to s\gamma)_{(E^*\gamma>1.6\ GeV)} = (3.15 \pm 0.23) \cdot 10^{-4}$

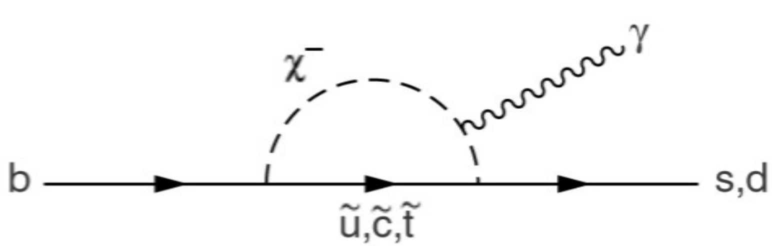
(Misiak et al. PRL 98 022002)

Search for New Physics

New heavy particles in the loop could:

- Modify BR wrt SM prediction
- Modify Direct A_{CP}





Radiative Penguins are an Excellent Laboratory to

Study the dynamics of b-quark inside B mesons

- Provide inputs to Global Fits in the Kinetic scheme to V_{cb}, V_{ub} & Heavy Quark Expansion parameters.

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

- **$BR(b \to d\gamma)/BR(b \to s\gamma)$**
- **NP could affect in different way $X_s\gamma$ vs $X_d\gamma$ final states**

$B \rightarrow X_{s/d}\ \gamma$ Measurements

Exclusive Measurements

- Experimentally easier, reconstruct resonances ($K^*\gamma$, $\rho(\omega)\gamma$) with low Background
- Need Form Factors, modeling X_s fragmentation
- Affected by large theoretical uncertainties ($\delta|V_{td}/V_{ts}|$~7%)

VS

Inclusive Measurements

- Smaller theoretical error exploiting quark-hadron duality (small hadronization effects)
- Experimentally harder, large background

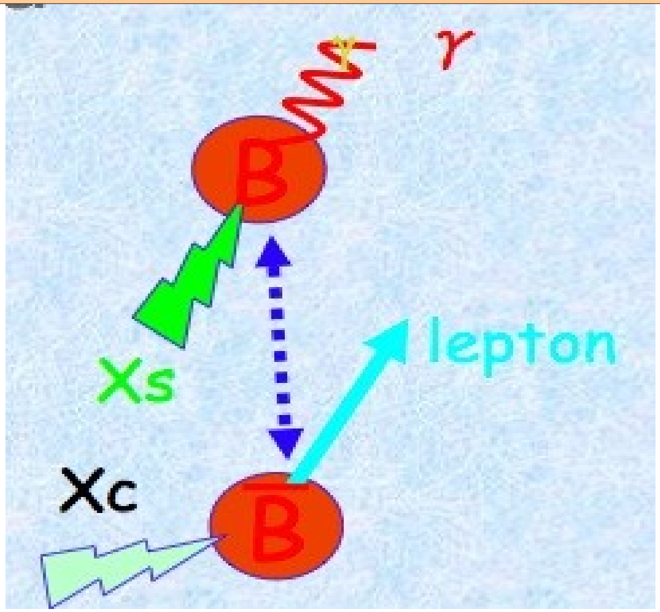
Recent Analyses Strategies:

Make the measurement **as inclusive as possible**, suppressing backgrounds via:

- Cut on E_γ>[1.7-2.0] GeV
- Use recoil of reconstructed B or Lepton Tag

OR

- Combined cut on E_γ, $M(X_{s/d})$<[1.8-2.0]GeV
- Sum over many exclusive modes



Belle Inclusive $B \to X_s \gamma$ (605 fb^{-1})

PRL 103, 241801

- **B-Meson Not Reconstructed: Not distinguish X_s & X_d !**

- Select High Energy Isolated γ
$E_\gamma(B_{CM})>1.7$ GeV
Lowest threshold up to now, covered 97% of X_s spectrum, smallest model uncertainty

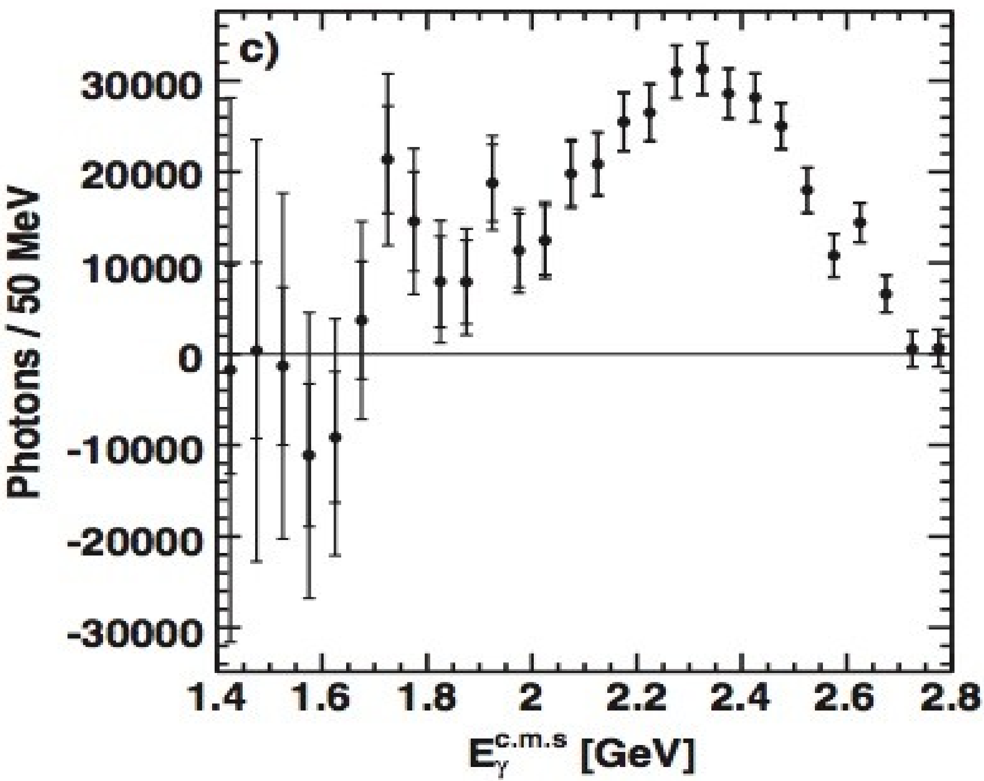
- π^0/η suppressed exploiting $m_{\gamma\gamma}$, shower profile, E_γ, θ_γ
- Bhabha events overlapped with B decays removed using timing information

- Dominant Background from Continuum suppressed by means of two different analysis streams (largely statistically uncorrelated) based on:
- Lepton Tag: (1.26 GeV<P^*_{lept}<2.20 GeV)
- Two Fisher discriminants exploiting Energy Flow & Event Shape
- Residual amount subtracted using off-resonance Data (corrected for Energy effects)

- $B\bar{B}$ Background from π^0/η decays estimated using Data-Corrected MC samples and subtracted
- BKG Subtraction checked in control regions $E_\gamma(\Upsilon_{CM})<1.7$GeV(>2.8GeV) for $B\bar{B}$ (Continuum): No bias found

Belle Inclusive $B \to X_s \gamma$ (605 fb^{-1})

PRL 103, 241801



- True Spectrum obtained by means of efficiency correction & unfolding procedure
- X_d contribution subtracted assuming $BR(X_d)/BR(X_s)=4.5\%$
[Hurth et al., Nucl. Phys. B704 56, Charles et al., Eur. Phys. C41 1]

E_γ Cut (GeV)	$BR(B \to X_s\gamma)$ (10^{-4})
1.7	3.45±0.15±0.40
2.0	3.02±0.10±0.11

To date:
- **Lowest E_γ threshold, lowest theory error**
- **Most Precise Result lowest systematic error**

- Systematics dominated by Continuum & $B\bar{B}$ BKG subtraction

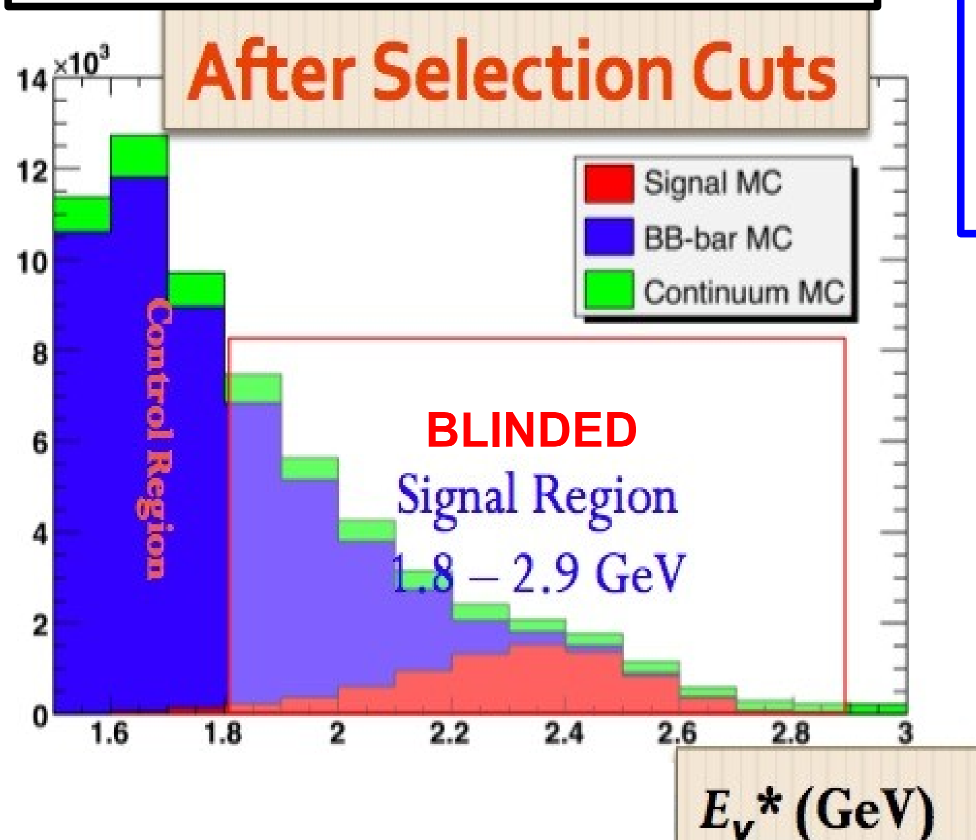
BaBar $B \to X_{s+d}\,\gamma$ Lepton Tag (347 fb^{-1})

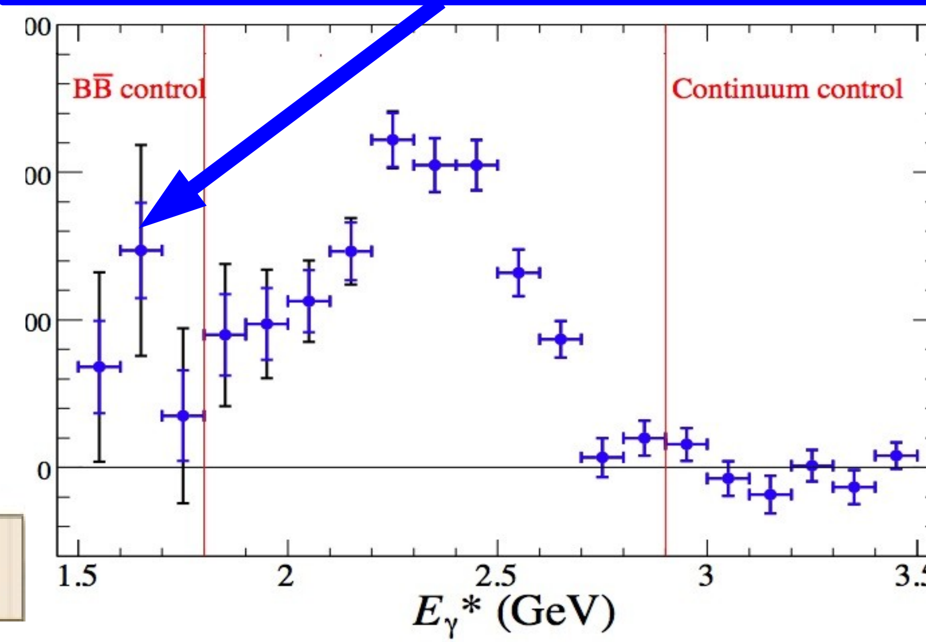
PRELIMINARY

Similar to Lepton-Tag Belle Analysis:

- Continuum suppressed using Lepton-Tag & Neural Network (Event Shape, P^*_{lept}, $\theta_{\gamma\text{-lept}}$)

- $B\bar{B}$ Background Estimated on MC & corrected on DATA control samples (97% of BKG yield: π^0/η, ω, e,...)
- Background subtraction test: 1.4σ bias found in the $B\bar{B}$ control region, partly due to a tail of 100-400 signal events (depending on model)





BaBar $B \to X_{s+d}\,\gamma$ Lepton Tag (347 fb^{-1})

$$A_{CP}(B \to X_q\gamma) = \frac{\Gamma(\bar{B} \to X_q\gamma) - \Gamma(B \to X_{\bar{q}}\gamma)}{\Gamma(\bar{B} \to X_q\gamma) + \Gamma(B \to X_{\bar{q}}\gamma)}$$

SM predicts $A_{CP}(X_{s+d}\gamma) \sim 10^{-6}$ from almost perfect cancellation between X_s and X_d

[Hurth et al., hep-ph 0312260, hep-ph 0103331]

Experimentally:

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

Lepton Charge gives B flavor

- Dilution due to mixing, cascade decays, fakes, $\omega \sim 13\%$

- **Most of the systematics common for +/- leptons cancel in A_{CP}**

Possible Bias from:

- $B\bar{B}$ Background asymmetry: checked in control region (-0.004±0.006 effect)
- Lepton tag asymmetry = 0.±0.011 measured in DATA control samples (e^+e^-, $\mu^+\mu^-\gamma$, $K^*J/\Psi(l^+l^-)$)
- Estimated error ±0.013 (Main systematic uncertainty)

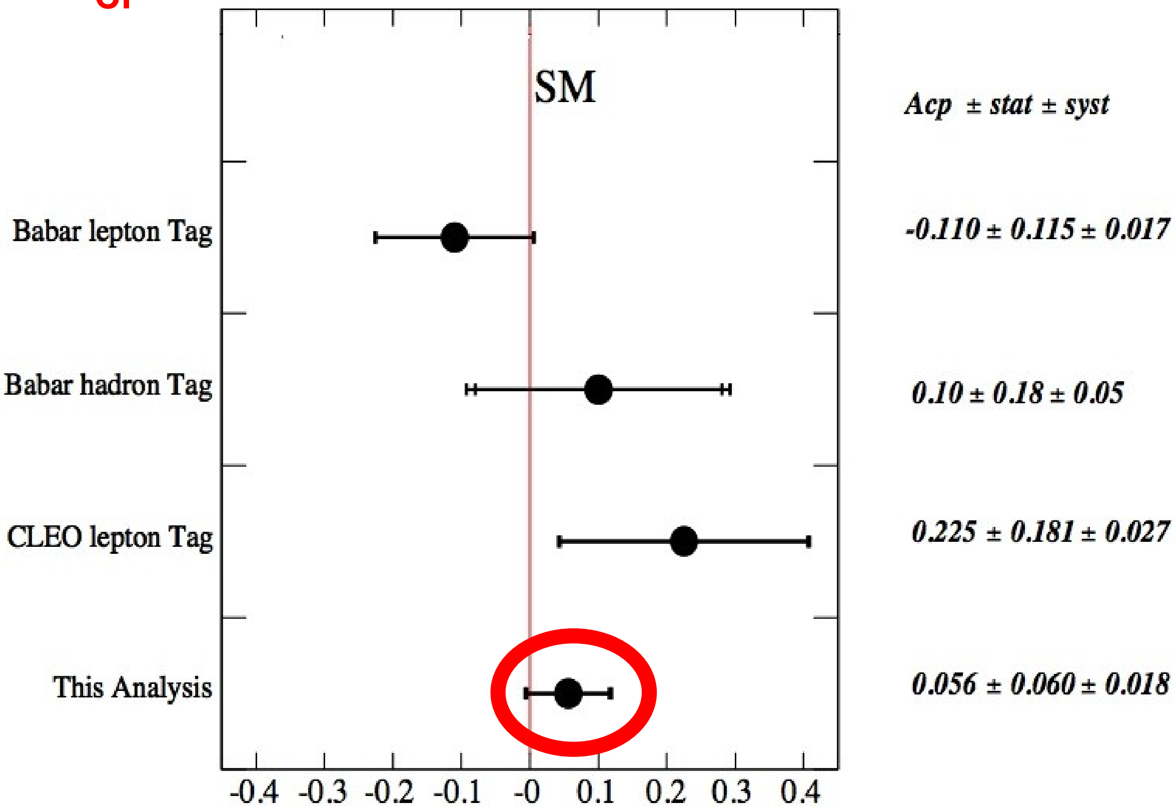
BaBar $B \rightarrow X_{s+d}\,\gamma$ Lepton Tag (347 fb^{-1})

Preliminary Result

$N(l^+)=2623\pm158$

$N(l^-)=2397\pm151$

$A_{CP}=0.056\pm0.060(stat)\pm0.018(syst)$



- A_{CP} total error minimized with $2.1GeV< E_\gamma(\Upsilon_{CM})<2.8GeV$

- Statistical error dominated by continuum subtraction

- **Most precise measurement to date**
- **Consistent with SM expectation**

Same analysis will soon provide BR and spectral moments.

BaBar $|V_{td}/V_{ts}|$ (423 fb^{-1})

[PRD-RC 82, 051101]

•Ratio of Exclusive modes $B \to (\rho,\omega)\gamma$, $K^*\gamma$ provides a $|V_{td}/V_{ts}|$ measurement complementary to the more precise result from $\Delta m_d/\Delta m_s$

•New Physics could affect $b \to s\gamma/d\gamma$ in different way

Inclusive Measurements reduce theory error from 7% to ~1%

Experimentally:

•Inclusive rates extrapolated from a sum of 7 exclusive modes:

$B \to X_d\gamma$	$B \to X_s\gamma$
$B^0 \to \pi^+\pi^-\gamma$	$B^0 \to K^+\pi^-\gamma$
$B^+ \to \pi^+\pi^0\gamma$	$B^+ \to K^+\pi^0\gamma$
$B^+ \to \pi^+\pi^-\pi^+\gamma$	$B^+ \to K^+\pi^+\pi^-\gamma$
$B^0 \to \pi^+\pi^-\pi^0\gamma$	$B^0 \to K^+\pi^-\pi^0\gamma$
$B^0 \to \pi^+\pi^-\pi^+\pi^-\gamma$	$B^0 \to K^+\pi^-\pi^+\pi^-\gamma$
$B^+ \to \pi^+\pi^-\pi^+\pi^0\gamma$	$B^+ \to K^+\pi^-\pi^+\pi^0\gamma$
$B^+ \to \pi^+\eta\gamma$	$B^+ \to K^+\eta\gamma$

Add estimated missing states using Jetset $X_{s/d}$ fragmentation models corrected for measured exclusive X_s BRs [PRD 72, 052005]

Use two hadronic mass bins:

•0.5GeV<M(X)<1.0GeV (contains the previously measured K*, ρ,ω states)

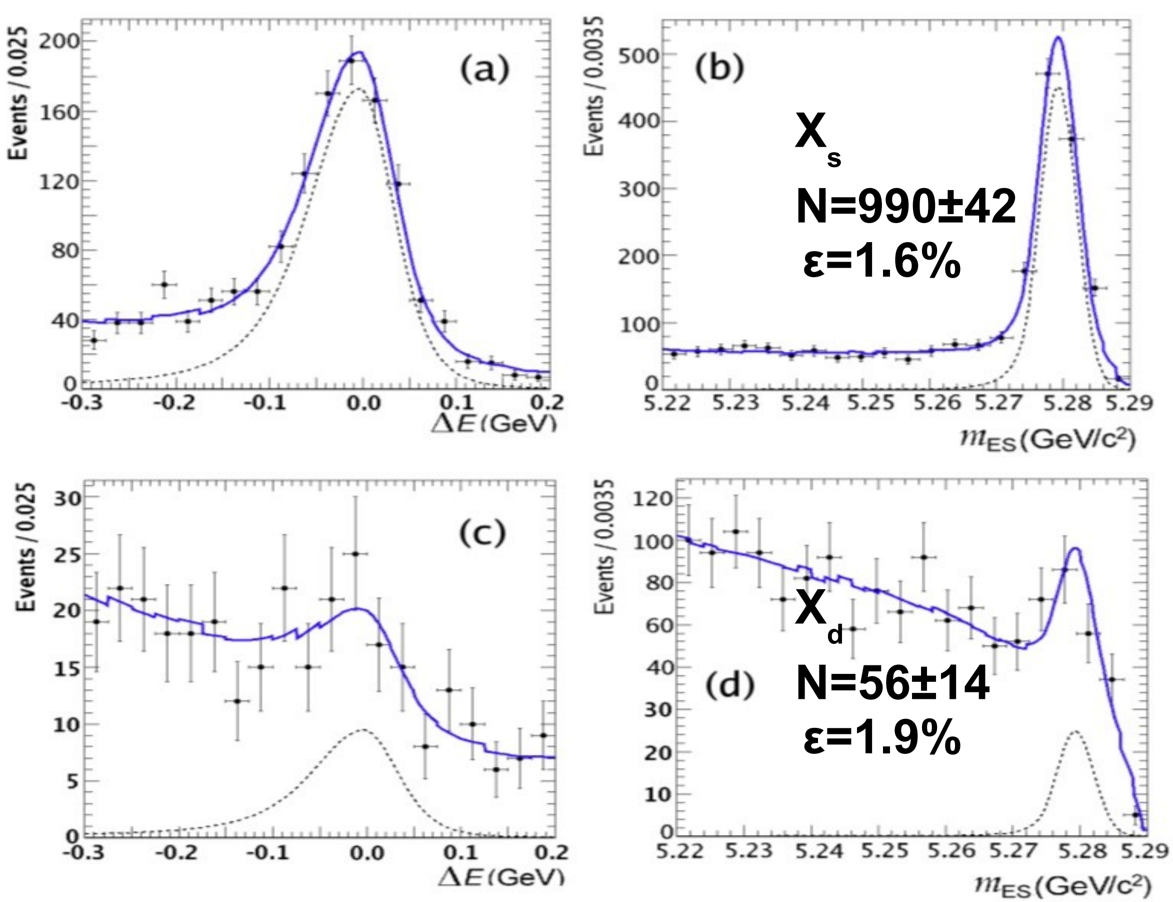
•1.0GeV<M(X)<2.0GeV

BaBar $|V_{td}/V_{ts}|$ (423 fb^{-1})

- Select High Energy Isolated γ
- π^0/η suppression by $m_{\gamma\gamma}$ cut
- Same cuts to sγ/dγ final states reduce systematics in the BR ratio

- Continuum suppressed using Neural Network (event shape)

High Mass Region 1.0 GeV<M(X)<2.0 GeV



- Yields from Simultaneous Fit to

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

$$m_{\rm ES} = \sqrt{E^{*2}_{\rm beam} - \vec{p}^{\,*2}_B}$$

0.5 GeV<M_{HAD}<2.0 GeV

BR(b→sγ)= 230±8±30 x 10^{-6}

BR(b→dγ)= 9.2±2.0±2.3 x 10^{-6}

First high M_{HAD} measurement

BaBar $|V_{td}/V_{ts}|$ (423 fb^{-1})

- **Extract $|V_{td}/V_{ts}|$ from:**

$$\frac{\Gamma(b \to d\gamma)}{\Gamma(b \to s\gamma)} = \xi^2 \left|\frac{V_{td}}{V_{ts}}\right|^2 (1+\Delta R)$$

[Ali et al. Phys. Lett. B 429, 87]

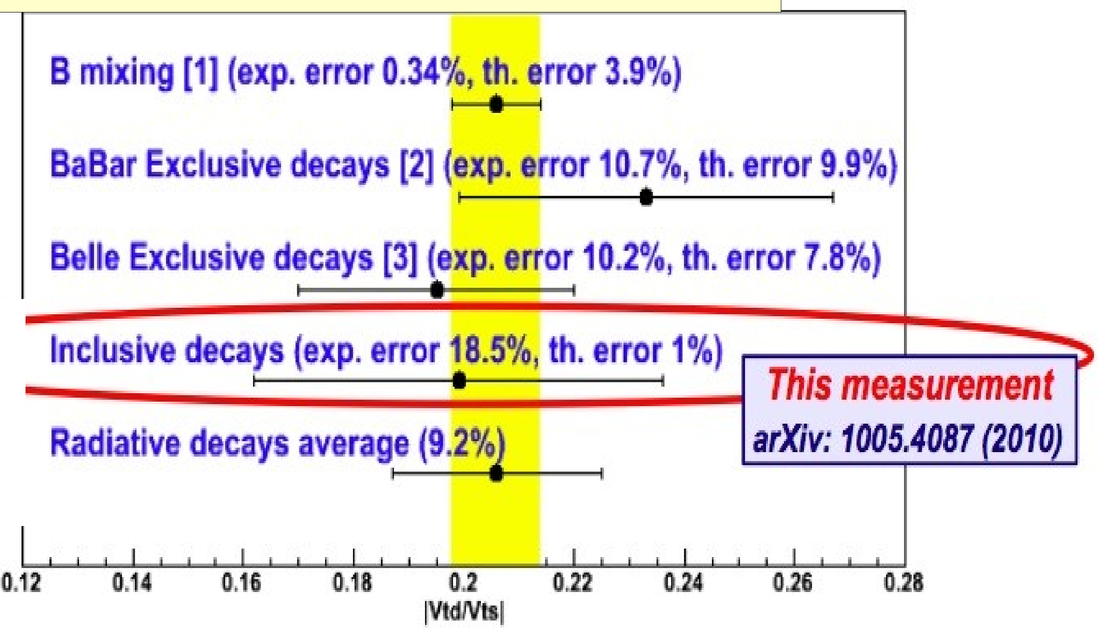
- Unmeasured M(X)>2.0 GeV extrapolated using Kagan-Neubert spectral shape [PRD 58, 094012]

- ξ(SU(3) Breaking), ΔR(annihilation correction) computed in terms of Wolfenstein parameters (ρ, η)
  - (ρ, η) re-expressed in terms of angle β to avoid circularity from previous $|V_{td}/V_{ts}|$ measurements

$|V_{td}/V_{ts}|$=0.199±0.022(stat)±0.024(syst)±0.002(th)

- Systematics dominated by Extrapolation to Inclusive Rates (alternative fragmentation models)

- **Compatible & Competitive with Previous exclusive decay results (with lower theory error) !**



BR($B \to X_s \gamma$): Summary

- Experiments cut on minimum E_γ
- BR extrapolated to E_{min}=1.6 GeV using Shape Functions (correlated error)
- Error dominated by Systematics

HFAG 2010 Inclusive BR($b \to s\gamma$)x10^{-6} :

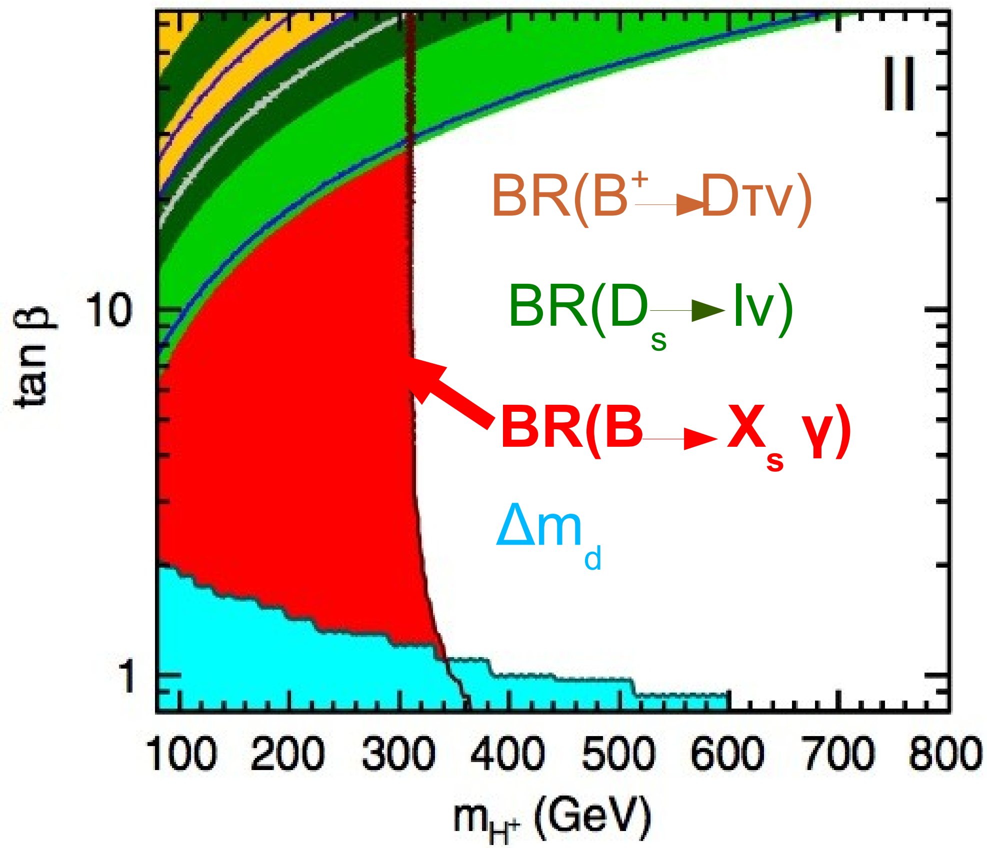
Mode	$\mathcal{B}$	$E_{\min}$	$\mathcal{B}(E_\gamma > E_{\min})$	$\mathcal{B}^{\rm cnv}(E_\gamma > 1.6)$
CLEO Inc. [3]	$321 \pm 43 \pm 27^{+18}_{-10}$	2.0	$306 \pm 41 \pm 26$	$327 \pm 44 \pm 28 \pm 6$
Belle Semi.[4]	$336 \pm 53 \pm 42^{+50}_{-54}$	2.24	–	$369 \pm 58 \pm 46^{+56}_{-60}$
BABAR Semi.[6]	$335 \pm 19^{+56+4}_{-41-9}$	1.9	$327 \pm 18^{+55+4}_{-40-9}$	$349 \pm 20^{+59+4}_{-46-3}$
BABAR Inc. [7]	–	1.9	$367 \pm 29 \pm 34 \pm 29$	$390 \pm 31 \pm 47 \pm 4$
BABAR Full [8]	$391 \pm 91 \pm 64$	1.9	$366 \pm 85 \pm 60$	$389 \pm 91 \pm 64 \pm 4$
Belle Inc.[5]	–	1.7	$345 \pm 15 \pm 40$	$347 \pm 15 \pm 40 \pm 1$
Average				$355 \pm 24 \pm 9$

SM: BR($b \to s\gamma$)$_{(E^*\gamma>1.6\ \mathrm{GeV})}$=(315±23)*$10^{-6}$
Misiak et al. PRL 98 022002 (2007)
5% non-perturbative error

Good Agreement (1.2 σ) with NNLL prediction

M. Margoni Universita` di Padova & INFN

BR($B \to X_s \gamma$): Summary



- Recent Calculations in the 2Higgs-Doublet-Model framework provide Constraints on the coupling of the 2nd & 3rd generation fermions to H^+ obtained from flavor physics experimental results:
- **BR($B \to X_s \gamma$)**, Δm_d, BR($B^+ \to (D)\tau\nu$), BR($D_s \to l\nu$)

- **Best Limit on M_{H+}>300 GeV @ 95% CL** **tanβ-independent**

[Mahmoudi, Stal, PRD81 035016]

$B \rightarrow s\gamma$ Spectral Moments

V_{cb} & V_{ub} from Inclusive Semileptonic Decays

• V_{cb} from inclusive $B \rightarrow X_c l\nu$ using HQET & OPE requires non perturbative parameters

• V_{ub} from inclusive $B \rightarrow X_u l\nu$ requires Shape functions to extrapolate the Inclusive BR from Partial Rates & compute kinematic acceptances

Universal motion of b-quark inside B meson:

• Global Fits to the moments of inclusive distributions in $B \rightarrow X_c l\nu$ & $B \rightarrow X_s\gamma$ in the kinetic mass scheme provide V_{cb} together with non-perturbative parameters (m_b, kinetic expectation value μ^2_π)

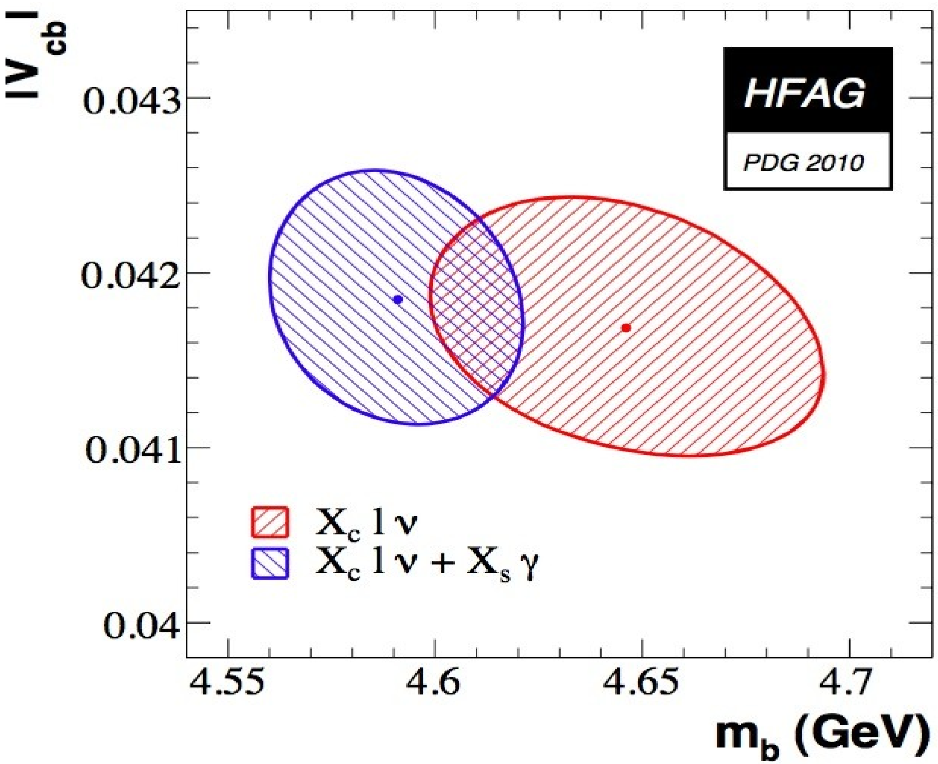
[Gambino et al., Eur. Phys. C34 181-189; Benson et al., Nucl Phys. B710, 371-401]

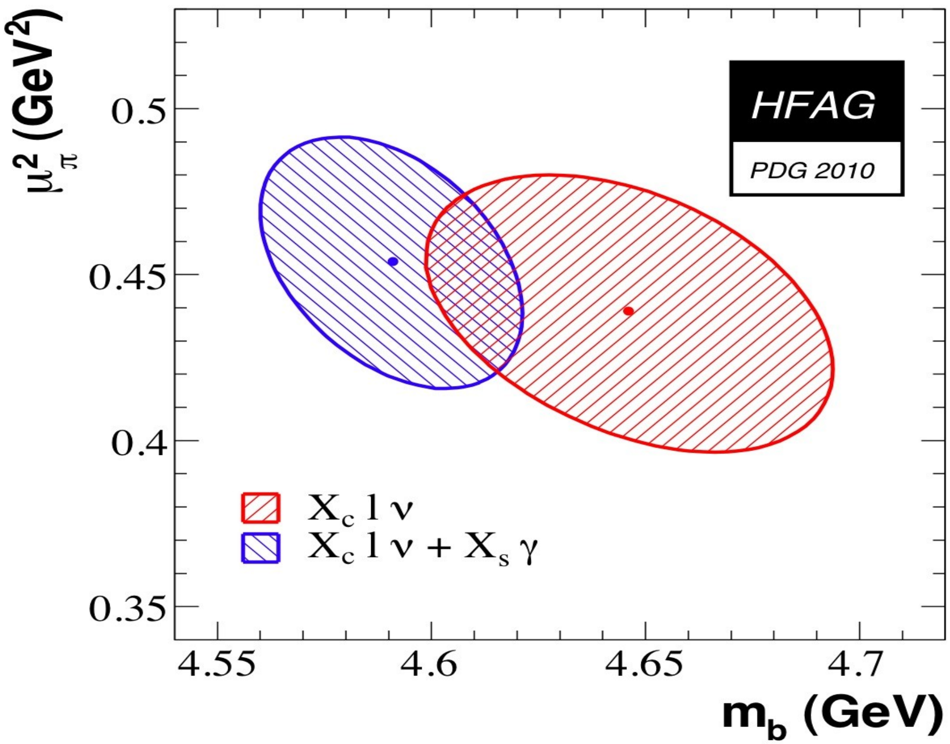
• Uncertainties on shape functions limited by comparing the inclusive $B \rightarrow X_u l\nu$ rate & inclusive $B \rightarrow X_s\gamma$ photon spectrum

[Neubert et al., PRD 49 4623-4633 ; Leibovich et al., PRD 61 053006; Lange et al., JHEP 10 084]

B→sγ Spectral Moments

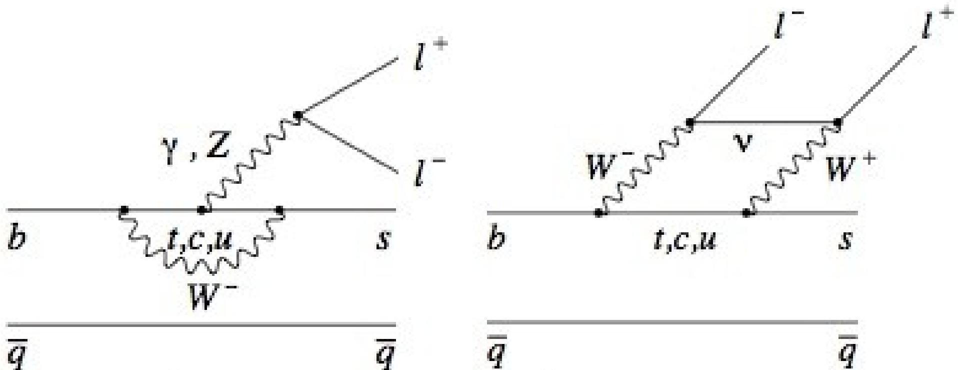
HFAG Fit in Kinetic Mass Scheme (2010)





Data	χ^2/dof	$\lvert V_{cb}\rvert$ (10^{-3})	m_b^{kin} (GeV)	μ_π^2 (GeV^2)
All moments ($X_c\ell\nu_\ell$ and $X_s\gamma$)	$29.7/(66-7)$	41.85 ± 0.73	4.591 ± 0.031	0.454 ± 0.038
$X_c\ell\nu_\ell$ only	$24.2/(55-7)$	41.68 ± 0.74	4.646 ± 0.047	0.439 ± 0.042

$B \to X_{s/d}\, l^+l^-$: Motivations



C^{eff}_7 (e.m.) C^{eff}_{10} (axial-vector)

C^{eff}_9 (vector)

FCNC process forbidden at tree level, BR~10^{-6}: Probe the SM!

Amplitudes expressed using OPE in terms of:

- Hadronic FF (accuracy ~20%) [Bharucha et al. Hep-ph 1004.3249]
- Wilson coefficients C^{eff}_7, C^{eff}_9, C^{eff}_{10} [Ali et al. PRD 61 074024, Z. Phys. C 67 417]

New Particles in the loop could:

- Modify SM Wilson Coefficients
- Introduce additional ones

Observables Include:

- **Inclusive BR, dBR/dq^2**
- **A_{CP}, $A_{ISOSPIN}$, $RK^{(*)}$ (theory error suppressed in the ratios!)**
- **Angular observables (defined below)**

SM predicts ($q^2=m^2_{l+l-}$):

$$A_{CP}^{K^{(*)}} \equiv \frac{\mathcal{B}(\overline{B} \to \overline{K}^{(*)}\ell^+\ell^-) - \mathcal{B}(B \to K^{(*)}\ell^+\ell^-)}{\mathcal{B}(\overline{B} \to \overline{K}^{(*)}\ell^+\ell^-) + \mathcal{B}(B \to K^{(*)}\ell^+\ell^-)}$$

~10^{-3}

$$A_I \equiv \frac{(\tau_{B^+}/\tau_{B^0})\mathcal{B}(K^{(*)0}\ell^+\ell^-) - \mathcal{B}(K^{(*)\pm}\ell^+\ell^-)}{(\tau_{B^+}/\tau_{B^0})\mathcal{B}(K^{(*)0}\ell^+\ell^-) + \mathcal{B}(K^{(*)\pm}\ell^+\ell^-)}$$

<10% All q^2

$$R_{K^{(*)}} \equiv \frac{\mathcal{B}(B \to K^{(*)}\mu^+\mu^-)}{\mathcal{B}(B \to K^{(*)}e^+e^-)}$$

RK=1
RK*=0.75
($q^2 \to 0$ γ-pole)

Belle $B \to K^{(*)} l^+l^-$ (605 fb^{-1}) PRL 103, 171801

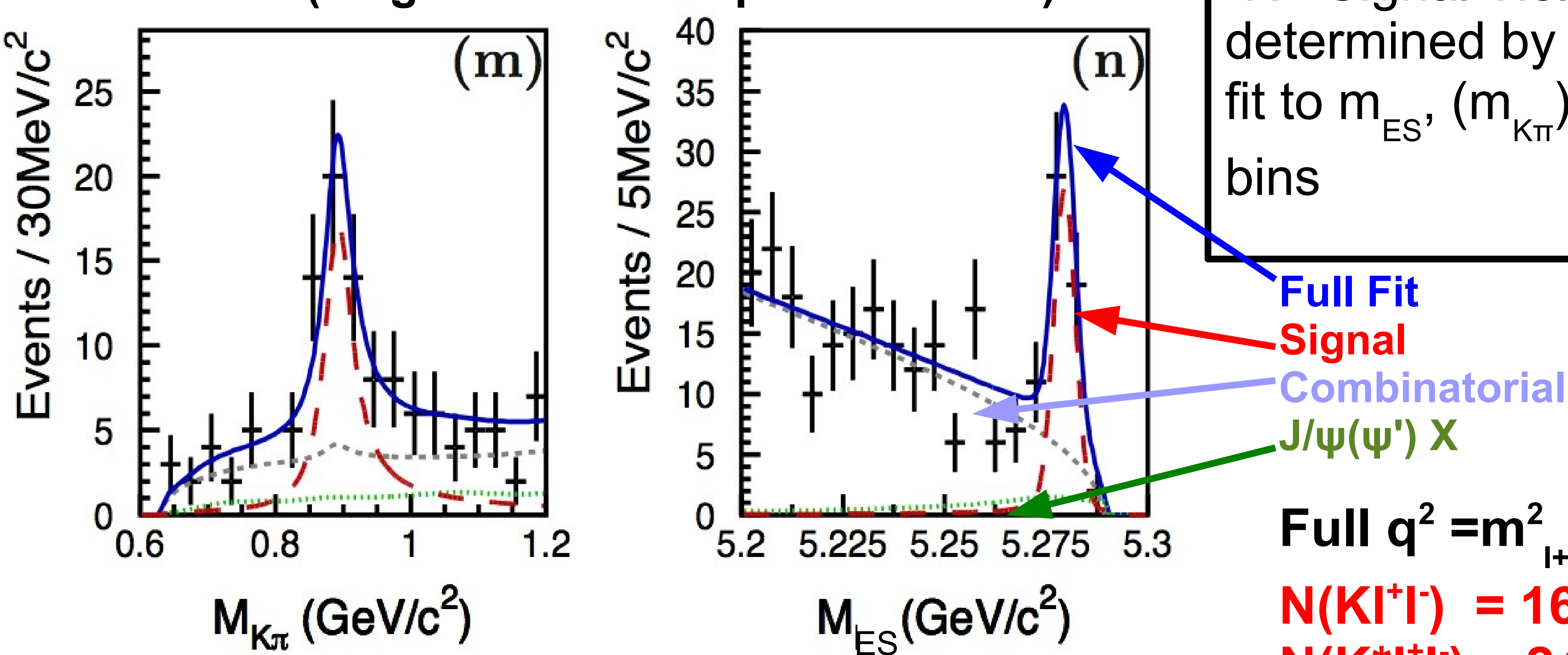
$B \to K^{(*)}l^+l^-$ fully reconstructed in 10 final states: ($K^+\pi^-$, $K^0_s\pi^+$, $K^+\pi^0$, K^+, K^0_s) + l^+l^-

•Peaking $B \to J/\Psi(\Psi')$ X rejected by m^2_{l+l-} cut

•Continuum Suppressed exploiting Event Shape Variables

•B Semileptonic Decays Suppressed using Event Shape, Missing Mass, Lepton distance of closest approach along beam axis

K* Fit (single bin: $10.09<q^2<12.86$ GeV^2)



•$K^{(*)}$ Signal Yields determined by unbinned fit to m_{ES}, ($m_{K\pi}$) in 6 q^2 bins

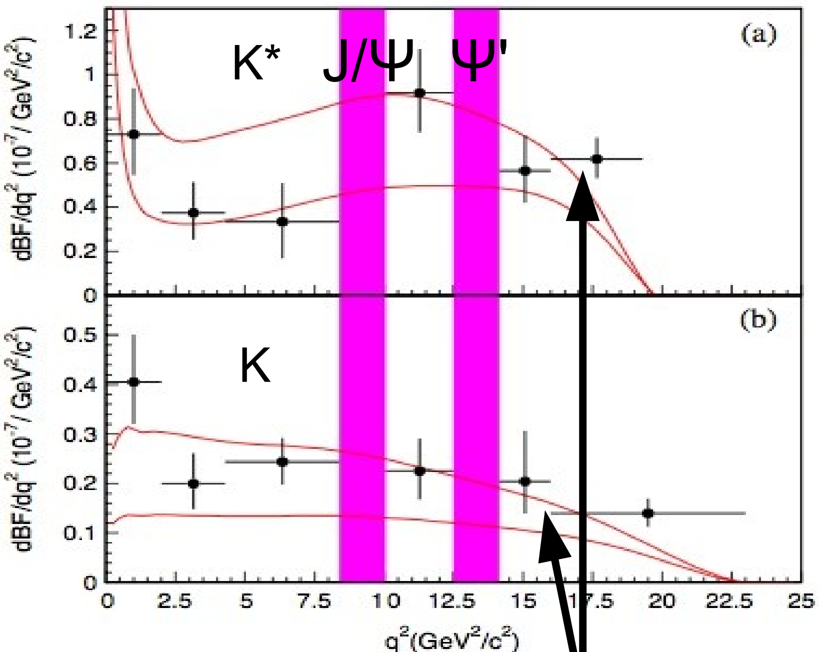
Full $q^2 = m^2_{l+l-}$ range:

$N(Kl^+l^-)$ = 162±22

$N(K^*l^+l^-)$ = 246±15

Belle $B \to K^{(*)} l^+l^-$ (605 fb^{-1})

dBR/dq^2 from Signal Yields corrected for $\varepsilon(q^2)$ PRL 103, 171801



SM prediction with different FF assumptions
[Ali et al. PRD61 074024, PRD66 034002]

Inclusive BR, A_{CP}, A_I & e/μ ratio agree with SM:

$$\mathcal{B}(B \to K^*\ell^+\ell^-) = (10.7^{+1.1}_{-1.0} \pm 0.9) \times 10^{-7},$$
$$\mathcal{B}(B \to K\ell^+\ell^-) = (4.8^{+0.5}_{-0.4} \pm 0.3) \times 10^{-7},$$

$$A_{CP}(K^*\ell^+\ell^-) = -0.10 \pm 0.10 \pm 0.01;$$
$$A_{CP}(K^+\ell^+\ell^-) = 0.04 \pm 0.10 \pm 0.02.$$

$$A_I(B \to K^*\ell^+\ell^-) = -0.29^{+0.16}_{-0.16} \pm 0.09$$
$$A_I(B \to K\ell^+\ell^-) = -0.31^{+0.17}_{-0.14} \pm 0.08$$

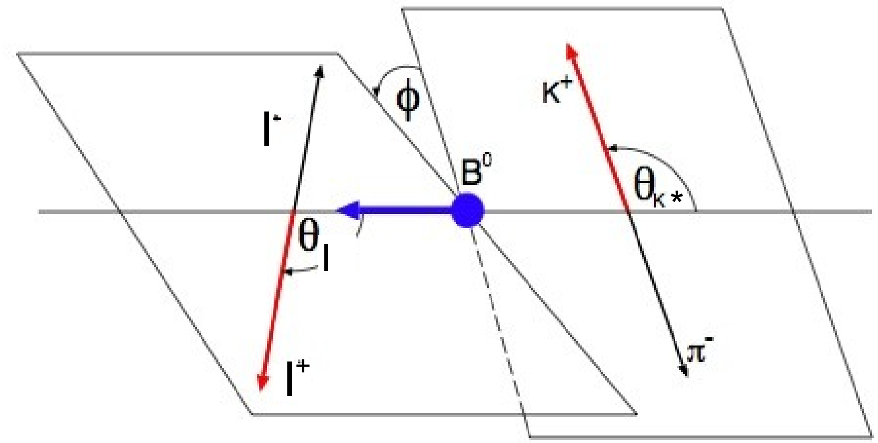
$$R_{K^*} = 0.83 \pm 0.17 \pm 0.08,$$
$$R_K = 1.03 \pm 0.19 \pm 0.06.$$

- Systematics dominated by tracking, PID, lepton selection & MC Decay Models

Belle $B \rightarrow K^{(*)} l^+l^-$ (605 fb^{-1})

PRL 103, 171801

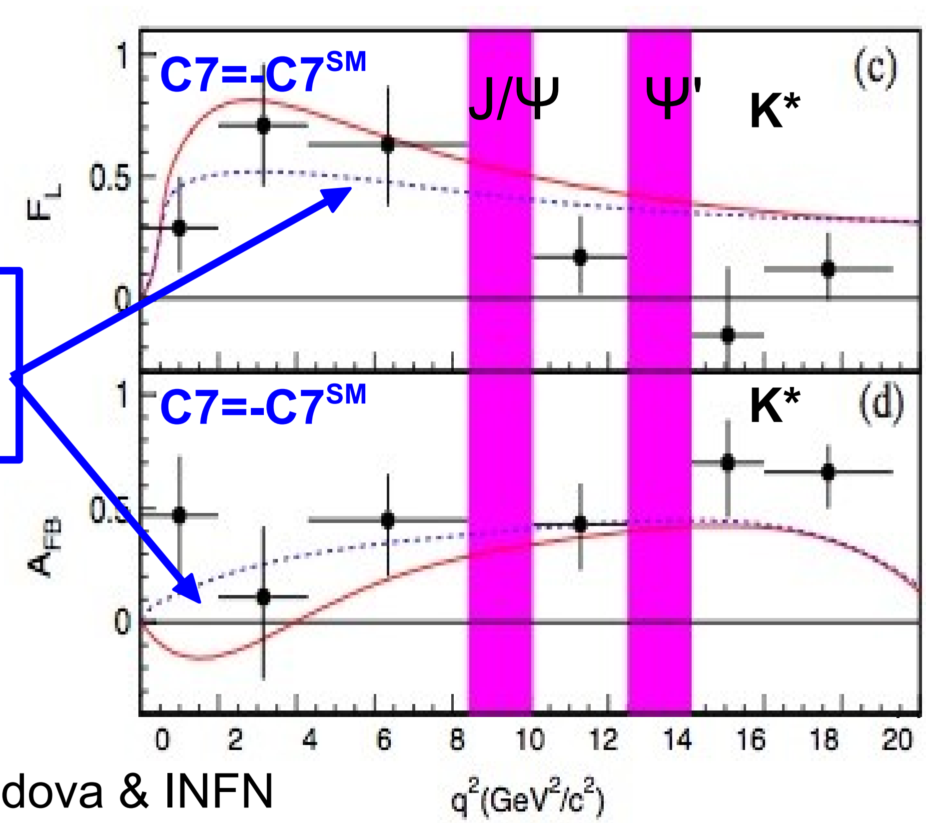
- Event Angular Distribution depends on three angles
- K* longitudinal polarization fraction F_L & lepton A_{FB} obtained from fits to θ_{K^*} & θ_l in q^2 bins



$$W(\cos\theta_K) = \frac{3}{2}\mathcal{F}_L \cos^2\theta_K + \frac{3}{4}(1-\mathcal{F}_L)\sin^2\theta_K$$

$$W(\cos\theta_\ell) = \frac{3}{4}\mathcal{F}_L \sin^2\theta_\ell + \frac{3}{8}(1-\mathcal{F}_L)(1+\cos^2\theta_\ell) + \mathcal{A}_{FB}\cos\theta_\ell$$

A_{FB}, $F_L(q^2=m^2_{l+l-} < m^2(J/\Psi))$ sensitive to C_7 sign-flip



- Dominant Systematics from fixed normalization & fixed F_L in A_{FB} fit

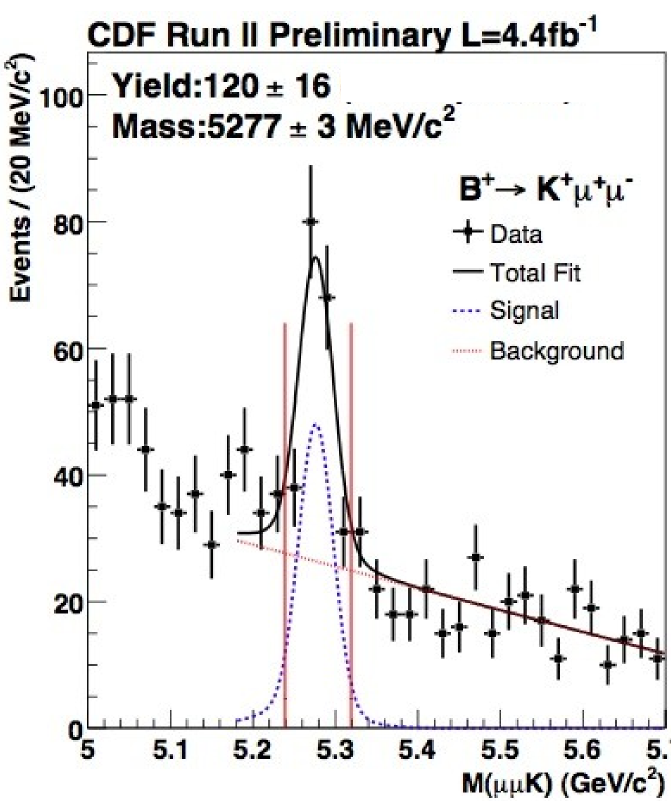
CDF $B \rightarrow K\mu^+\mu^-$ (4.4 fb^{-1})

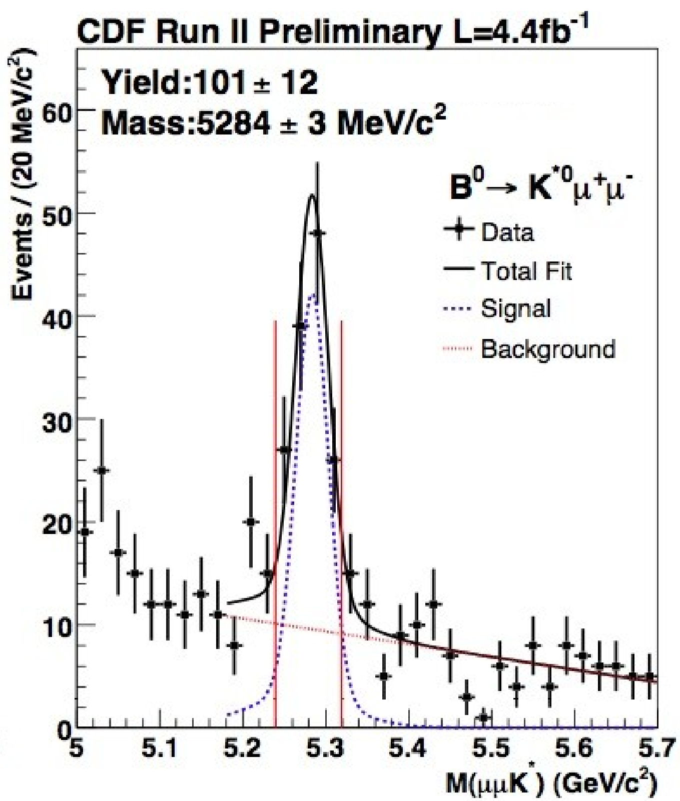
PRELIMINARY
CDF Note 10047

$B \rightarrow K^{(*)}\mu^+\mu^-$ fully reconstructed ($K^* \rightarrow K^+\pi^-$)

- Dimuon level-3 trigger applied (P_T, VTX($\mu^+\mu^-$) information)
- Vetoes applied to reject peaking $B \rightarrow J/\Psi$ (Ψ'), $D\pi$ (fake $\mu^+\mu^-$)

- Signal selected using a Neural Network (vertexes, event shape, lepton separation)





- Signal yield from unbinned likelihood fit to m(B)

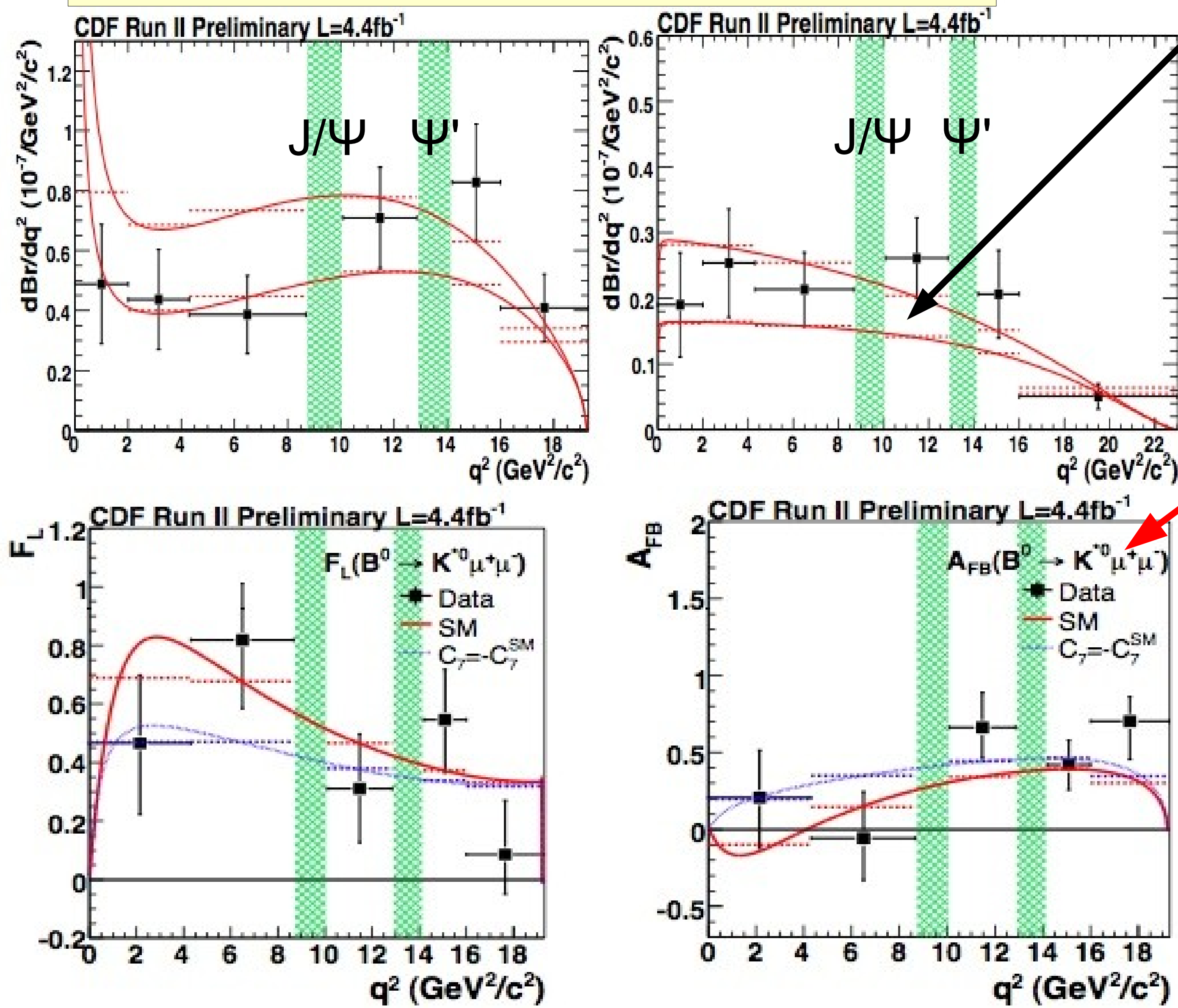
$N(Kl^+l^-) = 120 \pm 16$
$N(K^*l^+l^-) = 101 \pm 12$

- BR computed relative to BR($B \rightarrow J/\Psi K^{(*)}$) (identical final states) to reduce efficiency systematics in the ratio

CDF B→Kμ⁺μ⁻ (4.4 fb⁻¹)

$$\mathcal{B}(B^+ \to K^+\mu^+\mu^-) = [0.38 \pm 0.05(\text{stat}) \pm 0.03(\text{syst})] \times 10^{-6}$$
$$\mathcal{B}(B^0 \to K^{*0}\mu^+\mu^-) = [1.06 \pm 0.14(\text{stat}) \pm 0.09(\text{syst})] \times 10^{-6}$$

Results consistent with SM



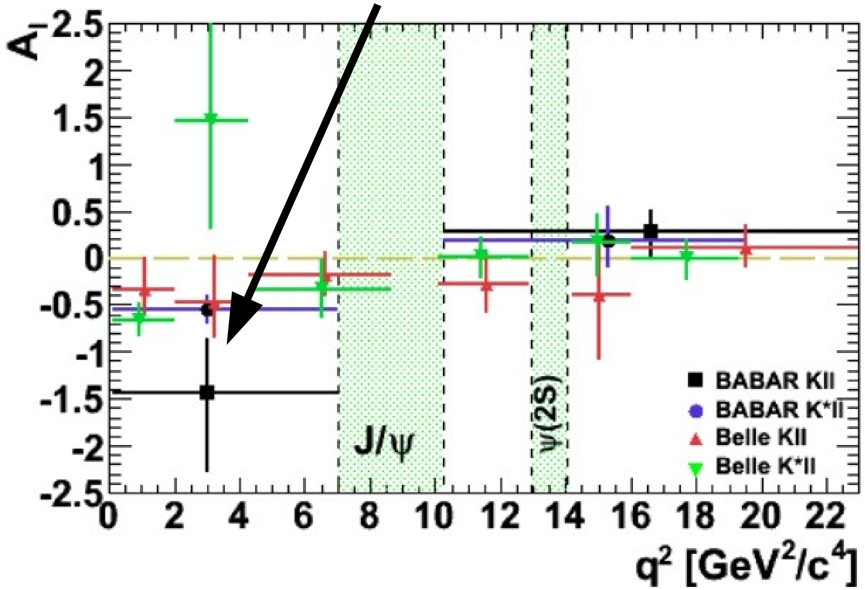
BR Systematics from:
- Background m(B) PDF
- BR(B→J/Ψ K$^{(*)}$)

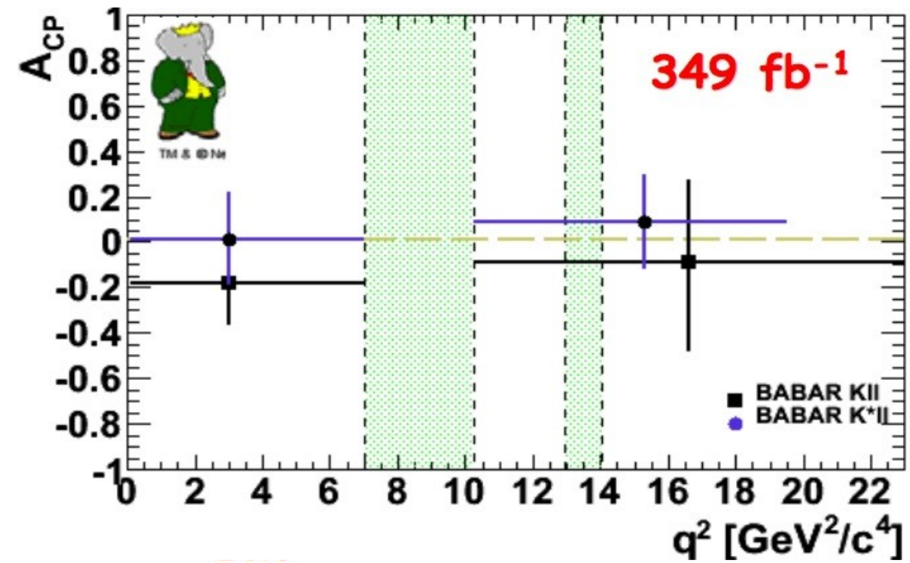
A_{FB} : first measurement from hadron collider !

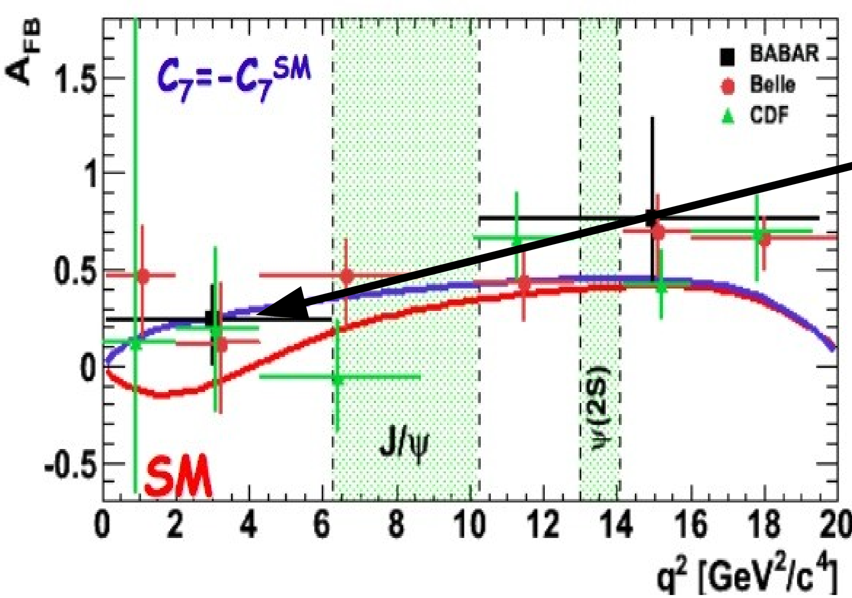
Angular Analysis Systematics from:
- Fraction of K-π swapped K* (~7%)
- Combinatorial PDF from B-mass Side Band

$B \to X_s\, l^+l^-$: Summary

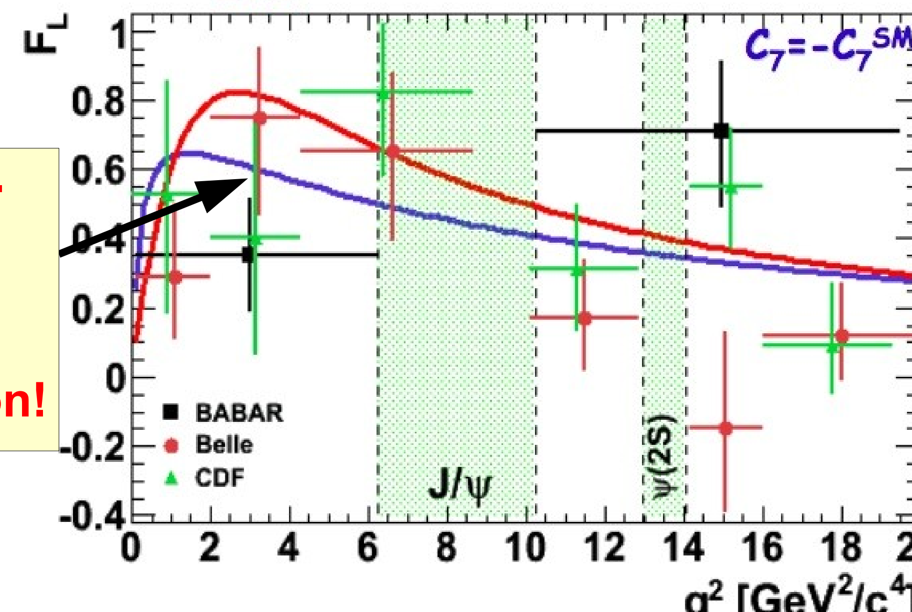
- BaBar finds a hint of $A_{ISOSPIN}$ deviation in the low q^2 region [PRL 102 091803]
- Belle results in agreement both with SM & BaBar [PRL 103 171801]







C7 sign-flip? Wait for error reduction!



BaBar $B^{\pm} \to K^{+}\tau^{+}\tau^{-}$ (423 fb^{-1})

- $BR(B \to X_s l^+ l^-)$ expected to show weak dependence on lepton flavor in the high q^2 region
- $B^+ \to K^+\tau^+\tau^-$ ~50% of total $X_s\tau^+\tau^-$ inclusive rate

[Hewett, PRD53 4964-4969]

$BR(B \to X_s l^+ l^-)$ $0.6<(q/m_b)^2<1$

Electron	8.5×10^{-7}
Muon	8.5×10^{-7}
Tau	4.3×10^{-7}

- **In NMSSM New Physics could couple with strength ~m^2_{LEPTON}**

[Hiller, PRD70 034018]

→ **Important Channel!**

Experimentally:

Exclusive reconstruction not possible due 2-4 neutrinos in the final state

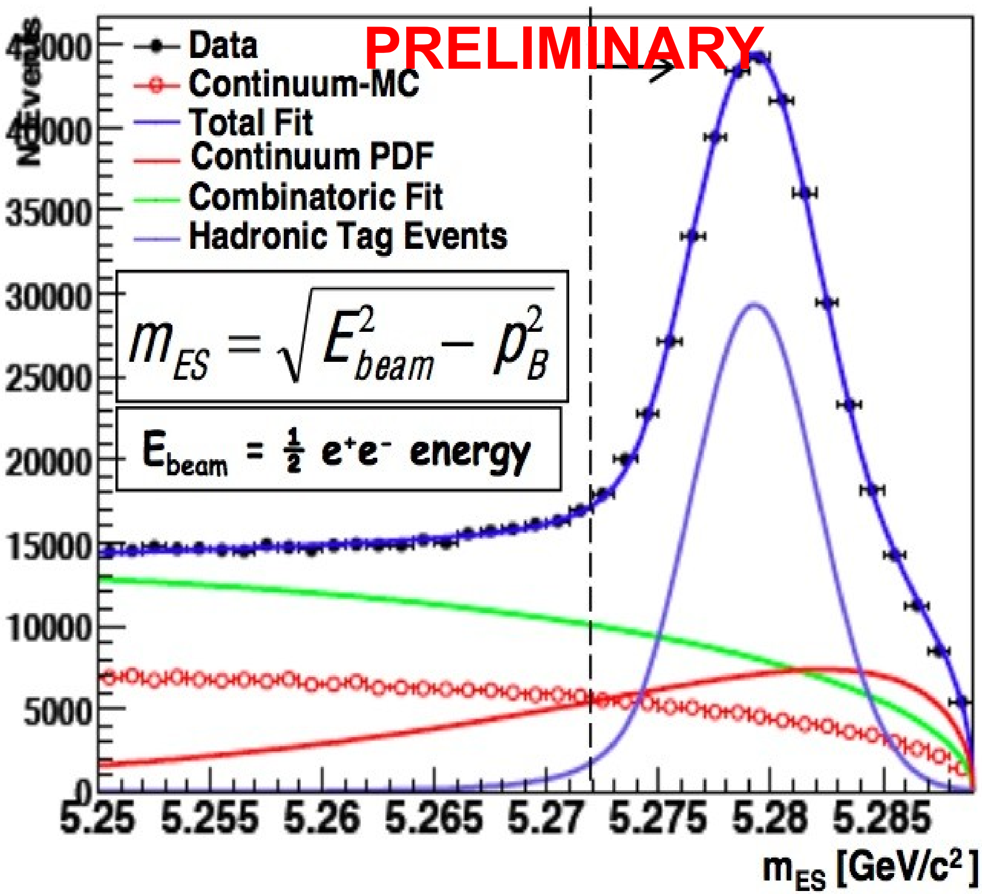
BaBar performed the first search for $B^+ \to K^+\tau^+\tau^-$!

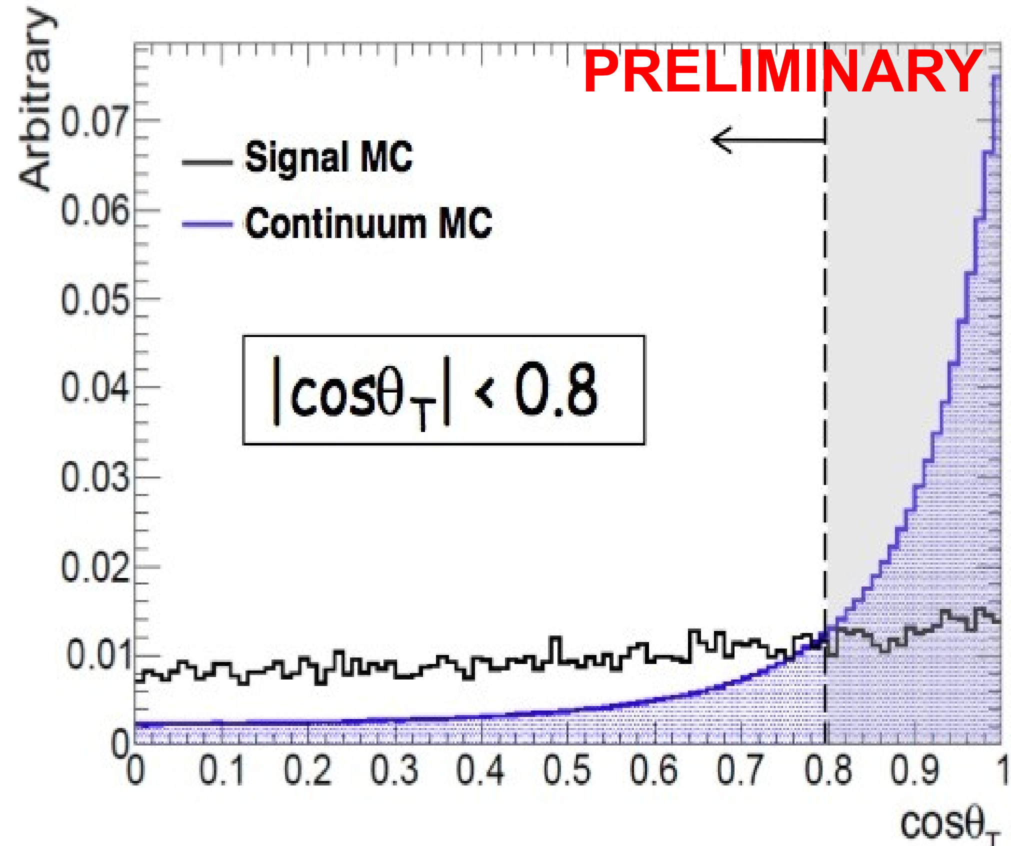
BaBar $B^{\pm} \rightarrow K^{+}\tau^{+}\tau^{-}$ (423 fb^{-1})

PRELIMINARY

- $K^{+}\tau^{+}\tau^{-}$ Decays searched on the recoil of fully reconstructed $B \rightarrow D^{(*)}X$
- ε_{tag}=0.13%

- Continuum Background suppressed exploiting the opening angle between the tag B thrust and the rest-of-event thrust:





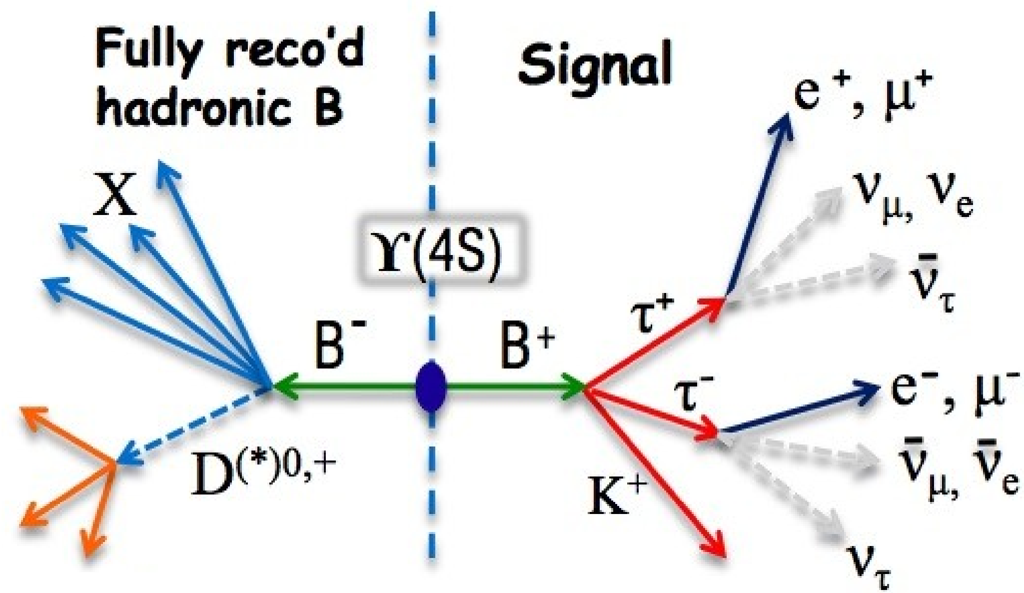
BaBar $B^{\pm} \rightarrow K^{+}\tau^{+}\tau^{-}$ (423 fb^{-1})

PRELIMINARY

•One-prong τ decays reconstructed:
$\tau \rightarrow e(\mu)\nu\nu$, $\pi\nu$

•Di-tau candidates selected with 3 charged tracks only
(K^{+} & neutral pair of e, μ, π)

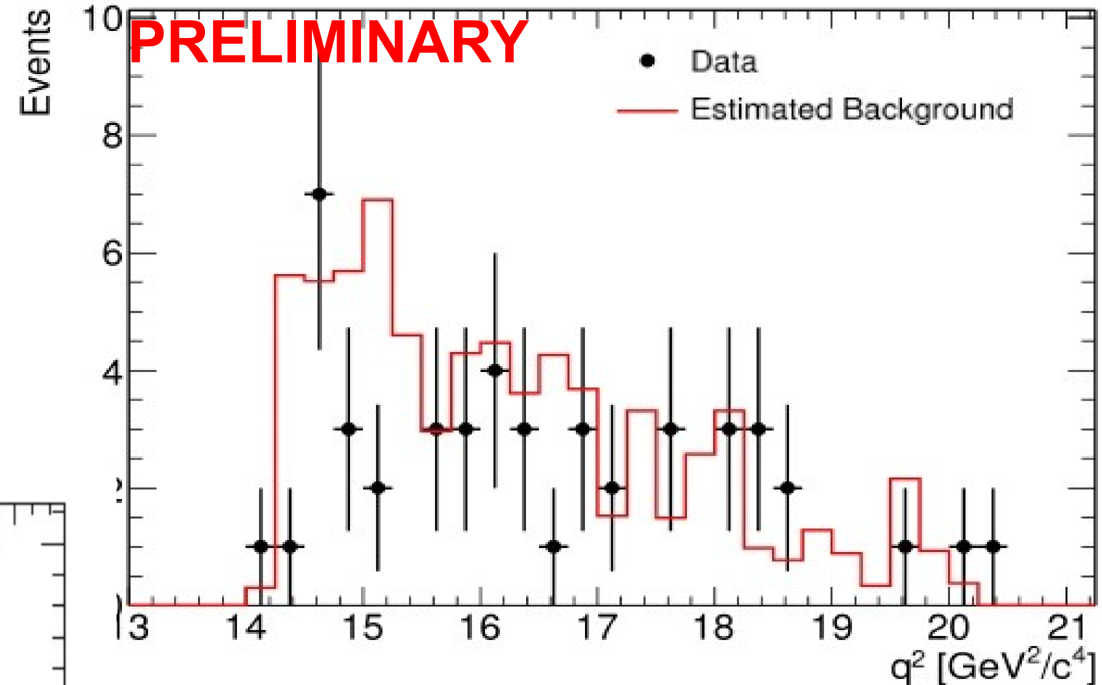
•Signal searched exploiting:
Missing Energy,
Extra neutral energy,
$q^2=(p_{Y(4S)}-p_{TAG}-p_K)^2$



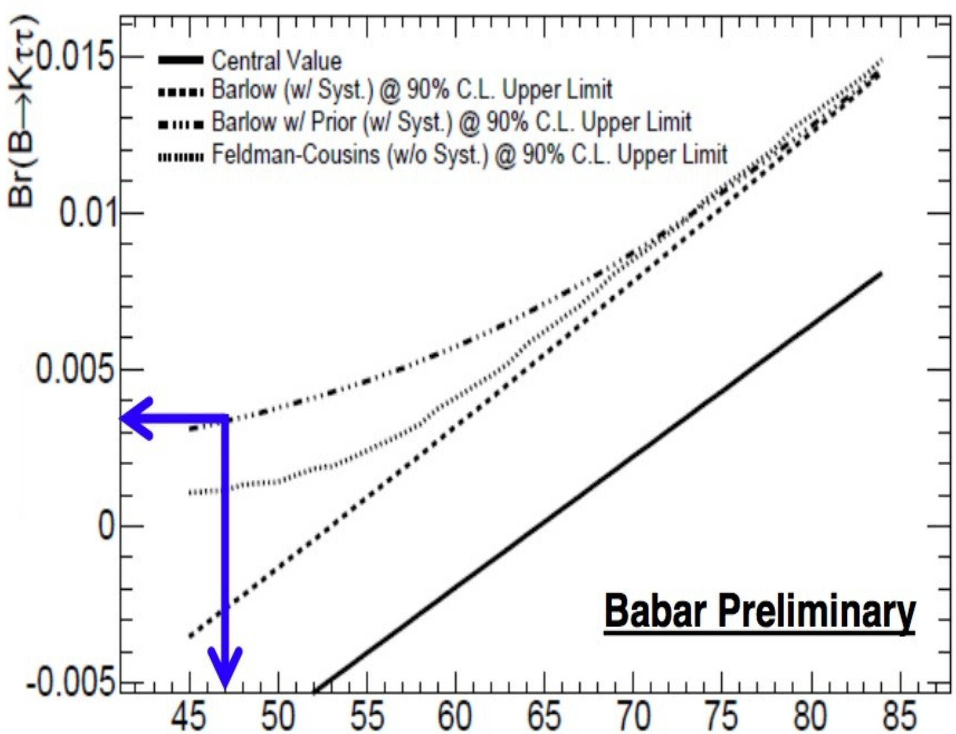
Peaking Background:
•B semileptonic Decays Suppressed by P_{Lepton} cut<1.59 GeV
•$B \rightarrow DX$ Reduced by combining the signal K^{+} with the signal τ daughter of opposite charge assigned a π mass hypothesis and requiring the resulting invariant mass to be m(Kπ)>1.96 GeV

BaBar $B^{\pm} \rightarrow K^{+}\tau^{+}\tau^{-}$ (423 fb^{-1})

- Systematics from ε_{SIGNAL} (tracking, PID), Background m_{ES} shape & yield



47 events observed
(65 expected from BKG)



- Upper Limit obtained using Barlow method [Comput. Phys. Commun. 149, 97] with Bayesian prior
- Conservative Approach!

$BR(B^{+} \rightarrow K^{+}\tau^{+}\tau^{-}) < 3.3 \times 10^{-3}$ @ 90%CL PRELIMINARY

$B \to \pi l^+ l^-$

No Inclusive Analyses performed. Experiments Fully reconstruct $B \to \pi l^+ l^-$

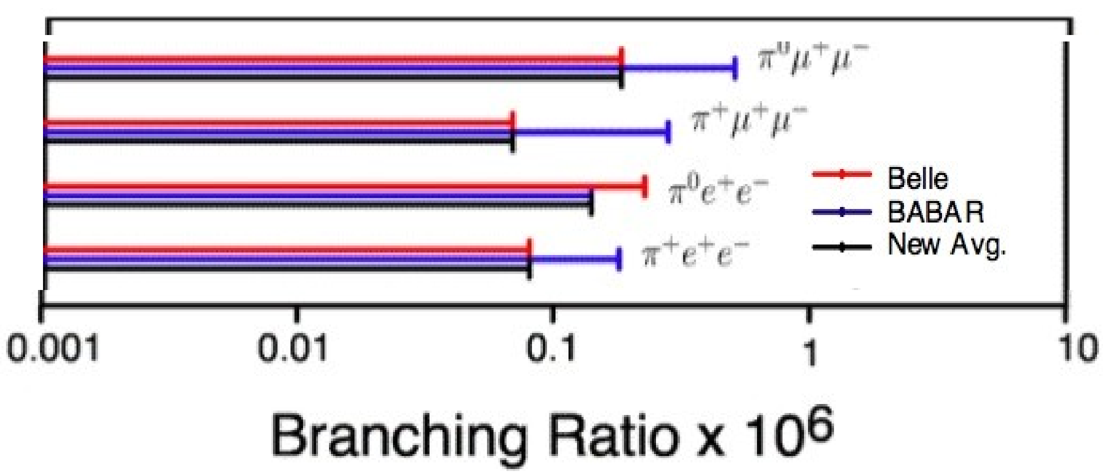
- J/Ψ(Ψ'), γ conversion vetoes applied

Main Backgrounds:

- Continuum reduced exploiting event shape variables & B-flavor tagging
- B & D Semileptonic Decays suppressed by means of missing energy, vertex fit information

Belle (605 fb^{-1}) [PRD 78 011101R] **$BR(B \to \pi l^+ l^-) < 6.2 \cdot 10^{-8}$**

BaBar (209 fb^{-1}) [PRL 99 051801] **$BR(B \to \pi l^+ l^-) < 9.1 \cdot 10^{-8}$**



HFAG 2010:
$BR(B \to \pi l^+ l^-) < 6.2 \cdot 10^{-8}$

SM:
$BR(B \to \pi l^+ l^-) = 3.3 \cdot 10^{-8}$
[Aliev, Savic, PRD60 014005]

Conclusions

Radiative penguin decays are an excellent laboratory for the search for physics beyond the SM & the study of b-quark dynamics

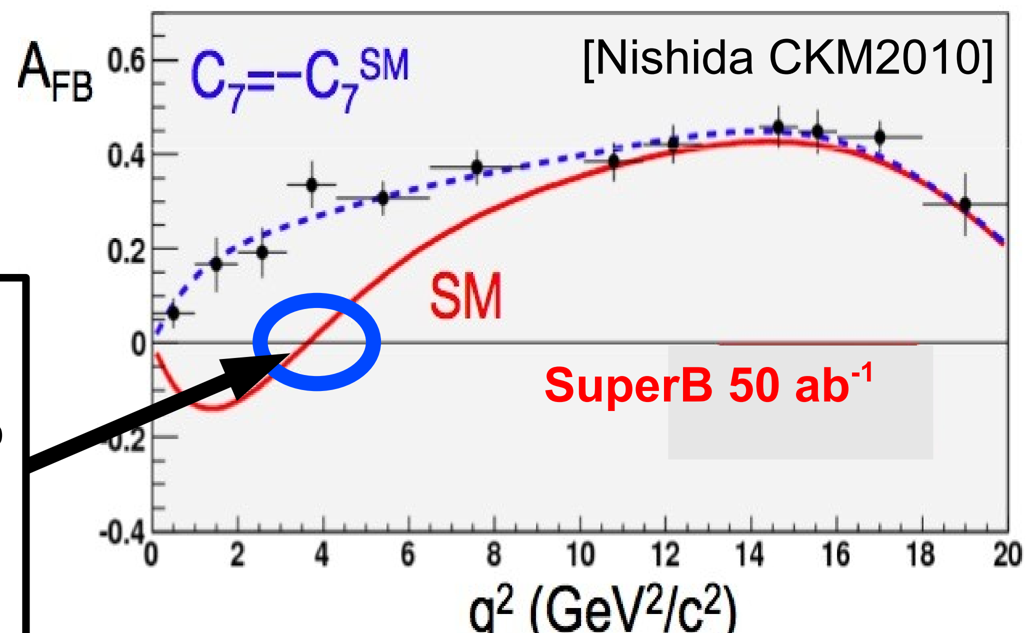
Almost all results in agreement with expectations

In the Future they will offer Opportunity to:

•Improve Experimental Techniques by using new angular observables with reduced dependence on Form Factors (e.g. Transversity Amplitudes)
[Bobeth et al., arXiv:1006.5013]

$A_{FB}(q^2_0)=0$
SuperBelle($50ab^{-1}$) δq^2_0~5%
LHCb($2fb^{-1}$): δq^2_0~13%
LHCb($100fb^{-1}$): δq^2_0~2%

•Provide very stringent SM tests:



•**Hopefully discover/understand New Physics**

M. Margoni Universita` di Padova & INFN

Backup

BaBar $|V_{td}/V_{ts}|$ (423 fb^{-1})

- Fragmentation of hadronic system in MC not the same in data – need to correct what we can.
- $B \to X_s \gamma$ has high signal yield – can measure fragmentation of hadronic system here and correct the MC.
- We measure 7 modes, also take advantage of data/MC differences found in previous sum-of-inclusive $b \to s\gamma$ analysis.

Decay mode	Efficiency-corrected fraction in MC	Efficiency-corrected fraction in data	Ratio data/MC	Ratio data/MC in previous analysis
$B \to K^+\pi^-\gamma$	0.193	0.098	0.51 ±0.04	0.65 ±0.04
$B \to K^+\pi^0\gamma$	0.118	0.033	0.28 ±0.05	0.36 ±0.06
$B \to K^+\pi^-\pi^+\gamma$	0.206	0.230	1.21 ±0.08	1.34 ±0.11
$B \to K^+\pi^-\pi^0\gamma$	0.250	0.370	1.48 ±0.08	1.35 ±0.11
$B \to K^+\pi^-\pi^+\pi^-\gamma$	0.058	0.079	1.36 ±0.30	0.75 ±0.27
$B \to K^+\pi^-\pi^+\pi^0\gamma$	0.158	0.182	1.15 ±0.25	1.00 ±0.23
$B \to K^+\eta\gamma$	0.017	0.009	0.50 ±0.25	1.05 ±0.41

BaBar $|V_{td}/V_{ts}|$ (423 fb^{-1})

- Low mass regions easy – correct for unreconstructed K*/ ω decays.
- High mass regions – how much width do our 7 decay modes cover?
  - Use weighted MC for b→sγ, unweighted MC for b→dγ.
- For systematic error, vary each category of missing modes (high and low multiplicity) by some amount, then renormalise to retain total BF in mass region, and see how proportion of our reconstructed modes changes.
  - Known b→sγ data/MC corrections are varied within their errors.
  - What about unknown missing fractions? Consider alternative fragmentation models e.g. applying b→sγ corrections to b→dγ, "hybrid" mix of resonances + non-res MC.

Proportion in $b \to s\gamma$ 1.0-2.0 GeV/c^2	Default model	Hybrid model
7 reconstructed modes	35.6%	40.0%
"known" 2/3/4 body modes	35.8%	40.2%
unreconstructed 2/3/4 body modes	12.6%	11.5%
unreconstructed 5+ body modes	16.1%	8.3%

Proportion in $b \to d\gamma$ 1.0-2.0 GeV/c^2	Default model	$b \to s\gamma$ weights applied	Hybrid model
7 reconstructed modes	42.3%	39.5%	46.9%
unreconstructed 2/3/4 body modes	27.0%	34.5%	34.9%
unreconstructed 5+ body modes	30.7%	26.0%	18.3%

BaBar $|V_{td}/V_{ts}|$ (423 fb^{-1})

Extract $X=|V_{td}/V_{ts}|$ from Ratio of Inclusive BFs

- Use NLO calculation [Ali et a., Phys. Lett. B429 87]

$$R = \lambda^2[1+\lambda^2(1-2\bar{\rho})]\left[(1-\bar{\rho})^2+\bar{\eta}^2+\frac{D_u}{D_t}(\bar{\rho}^2+\bar{\eta}^2)+\frac{D_r}{D_t}(\bar{\rho}(1-\bar{\rho})-\bar{\eta}^2)\right]$$

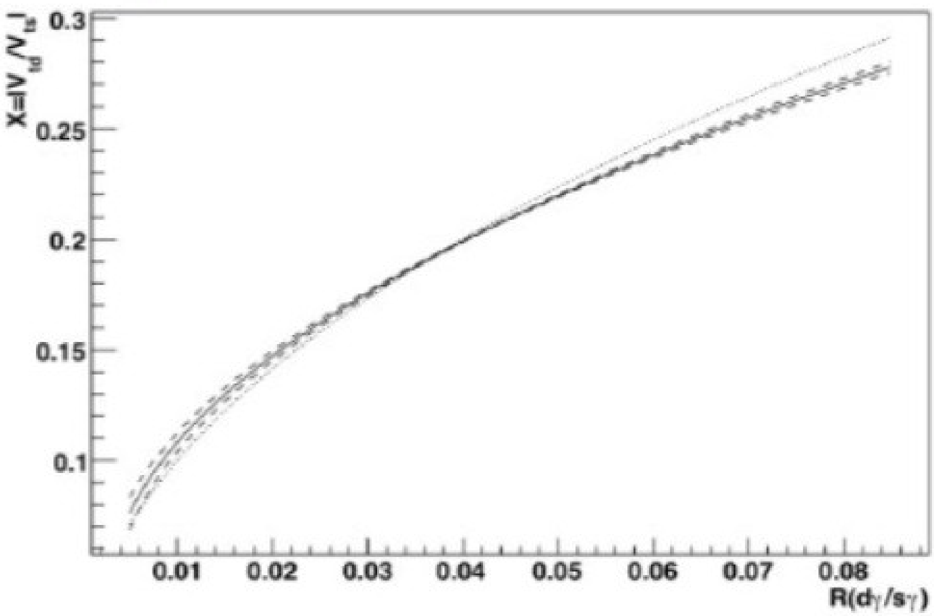
- Rewrite in terms of X and UT angle β

$$R = \kappa_1 X^2 + \kappa_2 X + \kappa_3,$$

$$\kappa_1 = 1+\frac{D_u}{D_t}(1-2\lambda^2\cos^2\beta)-\frac{D_r}{D_t}(\lambda^2\cos^2\beta+1),$$

$$\kappa_2 = \lambda\cos\beta\left[\frac{D_u}{D_t}(3\lambda^2-2)+\frac{D_r}{D_t}\left(1+\frac{\lambda^2}{2}\right)\right],$$

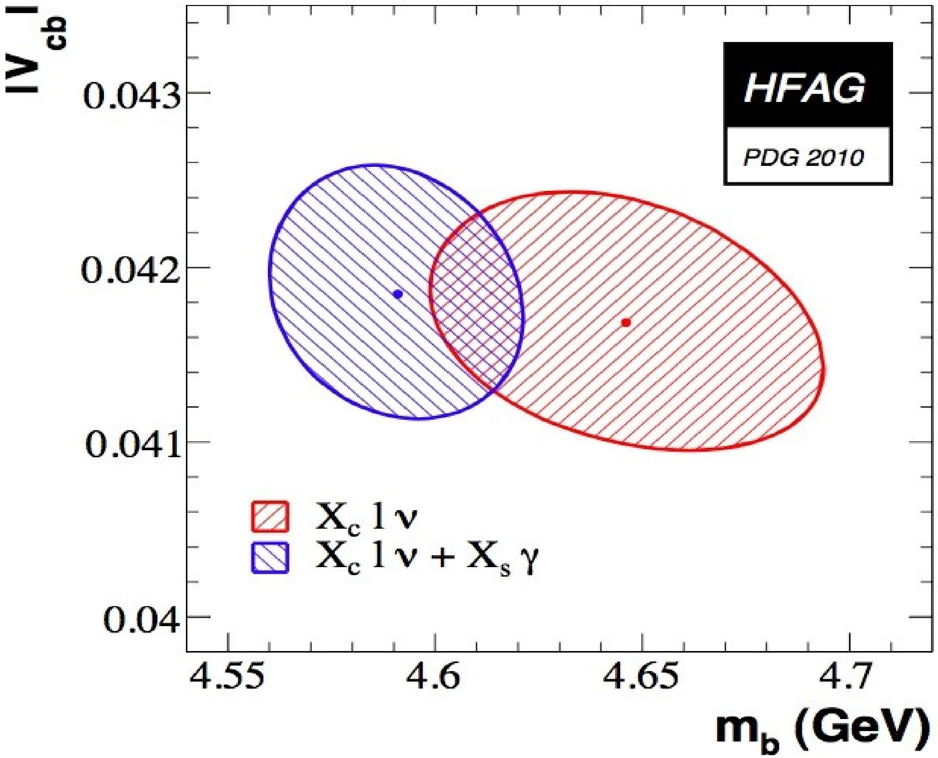
$$\kappa_3 = \lambda^2\frac{D_u}{D_t}(1-\lambda^2).$$



- Uncertaintes from PDG & numerical calculation of D factors

B→sγ Spectral Moments

HFAG Fit in Kinetic Mass Scheme (2010)

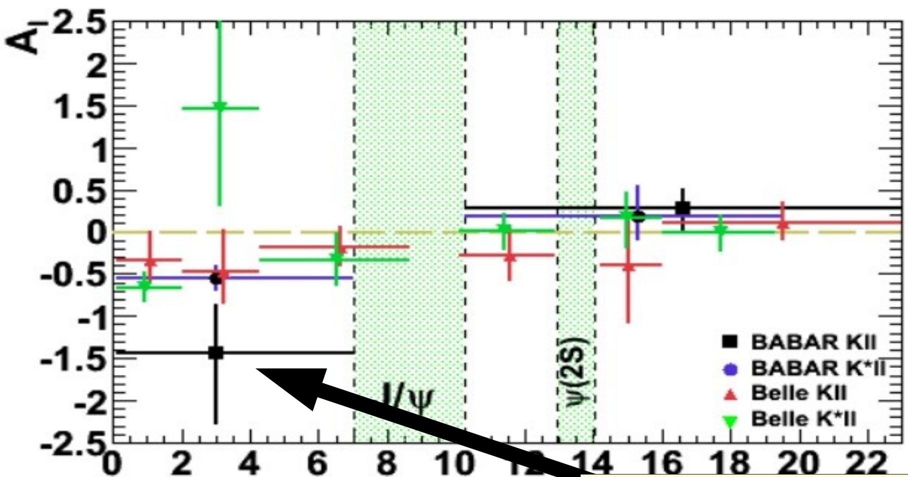


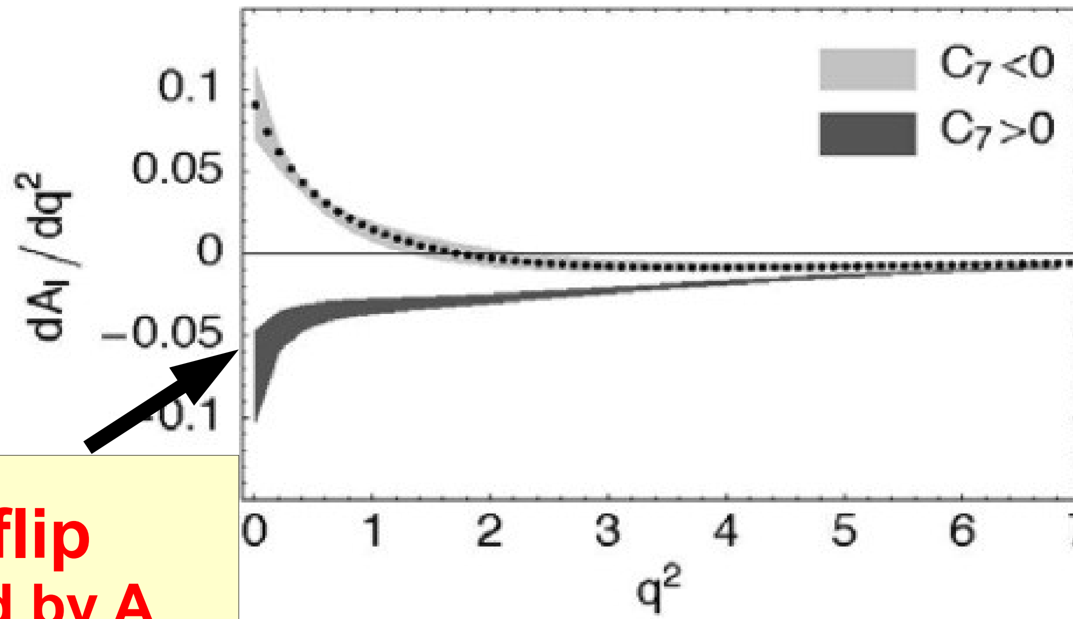
|Vub| From Inclusive BR in different Theoretical Frameworks using $X_s\gamma$ Moments [HFAG2010]

Framework	$\lvert V_{ub}\rvert [10^{-3}]$
BLNP	$4.32 \pm 0.16^{+0.22}_{-0.23}$
DGE	$4.46 \pm 0.16^{+0.18}_{-0.17}$
GGOU	$4.34 \pm 0.16^{+0.15}_{-0.22}$
ADFR	$4.16 \pm 0.14^{+0.25}_{-0.22}$
BLL (m_X/q^2 only)	$4.87 \pm 0.24 \pm 0.38$
LLR (BABAR) [394]	$4.43 \pm 0.45 \pm 0.29$
LLR (BABAR) [395]	$4.28 \pm 0.29 \pm 0.29 \pm 0.26 \pm 0.28$
LNP (BABAR) [395]	$4.40 \pm 0.30 \pm 0.41 \pm 0.23$

Data	χ^2/dof	$\lvert V_{cb}\rvert$ (10^{-3})	m_b^{kin} (GeV)	μ_π^2 (GeV^2)
All moments ($X_c\ell\nu_\ell$ and $X_s\gamma$)	29.7/(66 − 7)	41.85 ± 0.73	4.591 ± 0.031	0.454 ± 0.038
$X_c\ell\nu_\ell$ only	24.2/(55 − 7)	41.68 ± 0.74	4.646 ± 0.047	0.439 ± 0.042

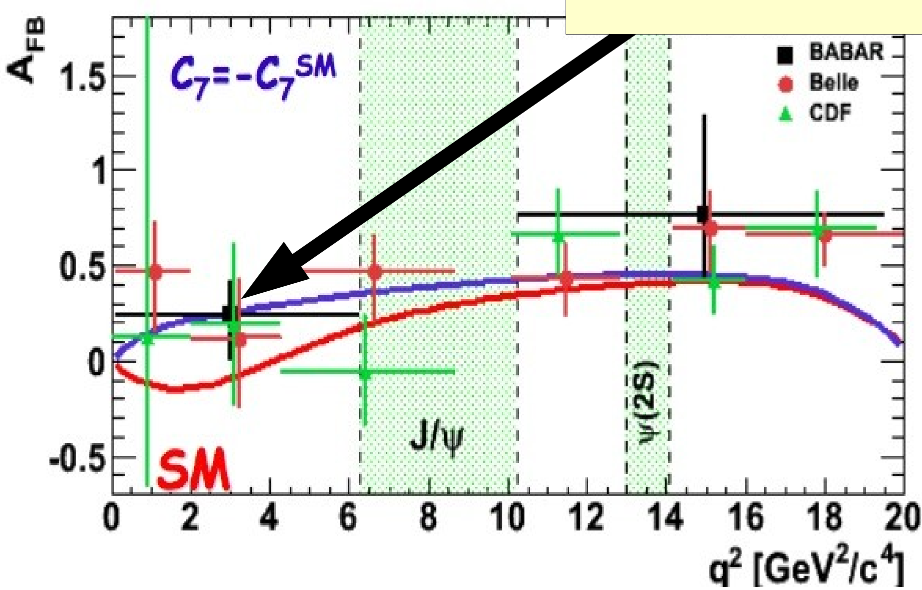
$A_{ISOSPIN}$ vs q^2





C7 sign-flip

Not rejected by A_{FB}



Feldman et al. JHEP 0301,074

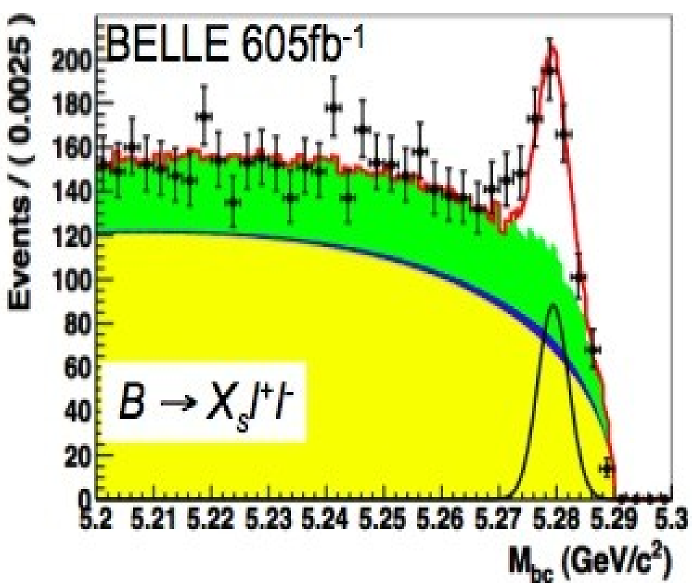
Hubert et al., Nucl. Phys. B802 40]

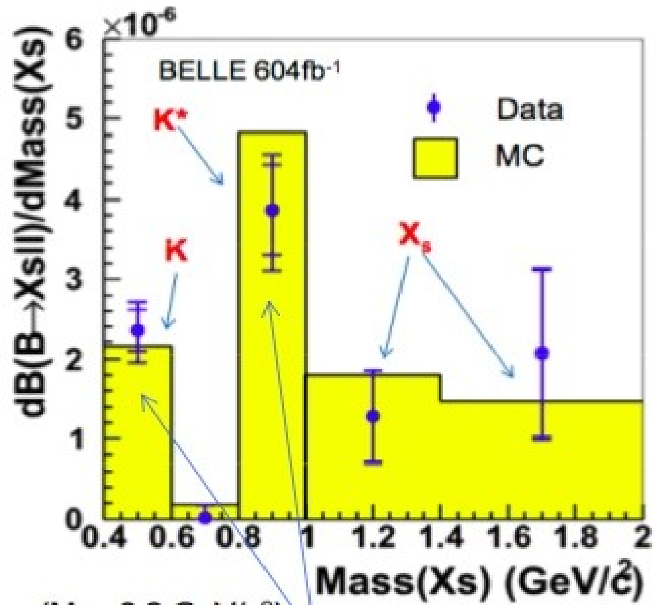
Belle $B \to X_s l^+l^-$ (605 fb^{-1})

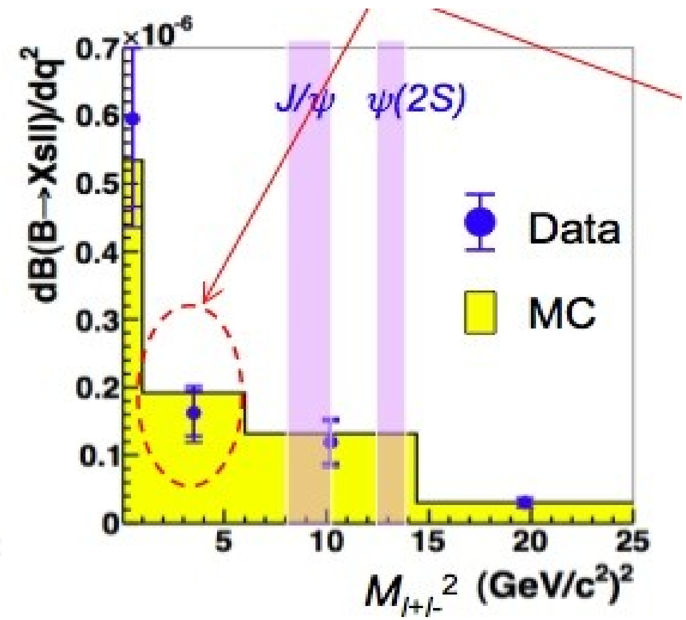
PRELIMINARY

Improved Analysis, sum up 36 exclusive modes (~80% coverage)

- Continuum Suppressed by event shape variables
- Cascades $b \to c \to s/d$ rejected exploiting missing mass & energy







Mode	Yield	BF (x 10^{-6})
$B \to X_s e^+e^-$	121.6 ± 19.3(stat.) ± 2.0(syst.)	$4.56 \pm 1.15(\text{stat.})\,^{+0.33}_{-0.40}(\text{syst.})$
$B \to X_s \mu^+\mu^-$	118.5 ± 17.3(stat.) ± 1.5(syst.)	$1.91 \pm 1.02(\text{stat.})\,^{+0.16}_{-0.18}(\text{syst.})$
$B \to X_s l^+l^-$	238.3 ± 26.4(stat.) ± 2.3(syst.)	$3.33 \pm 0.80(\text{stat.})\,^{+0.19}_{-0.24}(\text{syst.})$

ps: $BF(X_s e^+e^-) / BF(X_s \mu^+\mu^-) = 2.39 \pm 1.41$

SM:
BF=$(4.2 \pm 0.7) \cdot 10^{-6}$
[Ali et al.]

C_7 sign-flip:
BF=$(8.8 \pm 1.0) \cdot 10^{-6}$
[Gambino et al.]

Transversity Amplitudes

[Bobeth et al., arXiv:1006.5013]

- HQET Calculations give possibility to disentangle QCD Effects from possible New Physics Effects at high $q^2=m_{l+l-}^{\ 2}$ in $B \rightarrow K^* l^+ l^-$ angular analyses
- New Observables defined which **do not depend on FF** at low recoil and cleanily test SM:

$$H_T^{(1)} = \frac{\mathrm{Re}(A_0^L A_\parallel^{L*} + A_0^{R*} A_\parallel^R)}{\sqrt{\left(|A_0^L|^2 + |A_0^R|^2\right)\left(|A_\parallel^L|^2 + |A_\parallel^R|^2\right)}}$$

$$H_T^{(2)} = \frac{\mathrm{Re}(A_0^L A_\perp^{L*} - A_0^{R*} A_\perp^R)}{\sqrt{\left(|A_0^L|^2 + |A_0^R|^2\right)\left(|A_\perp^L|^2 + |A_\perp^R|^2\right)}}$$

$$H_T^{(3)} = \frac{\mathrm{Re}(A_\parallel^L A_\perp^{L*} - A_\parallel^{R*} A_\perp^R)}{\sqrt{\left(|A_\parallel^L|^2 + |A_\parallel^R|^2\right)\left(|A_\perp^L|^2 + |A_\perp^R|^2\right)}}$$

Computed in terms of left & right Transversity Amplitudes:

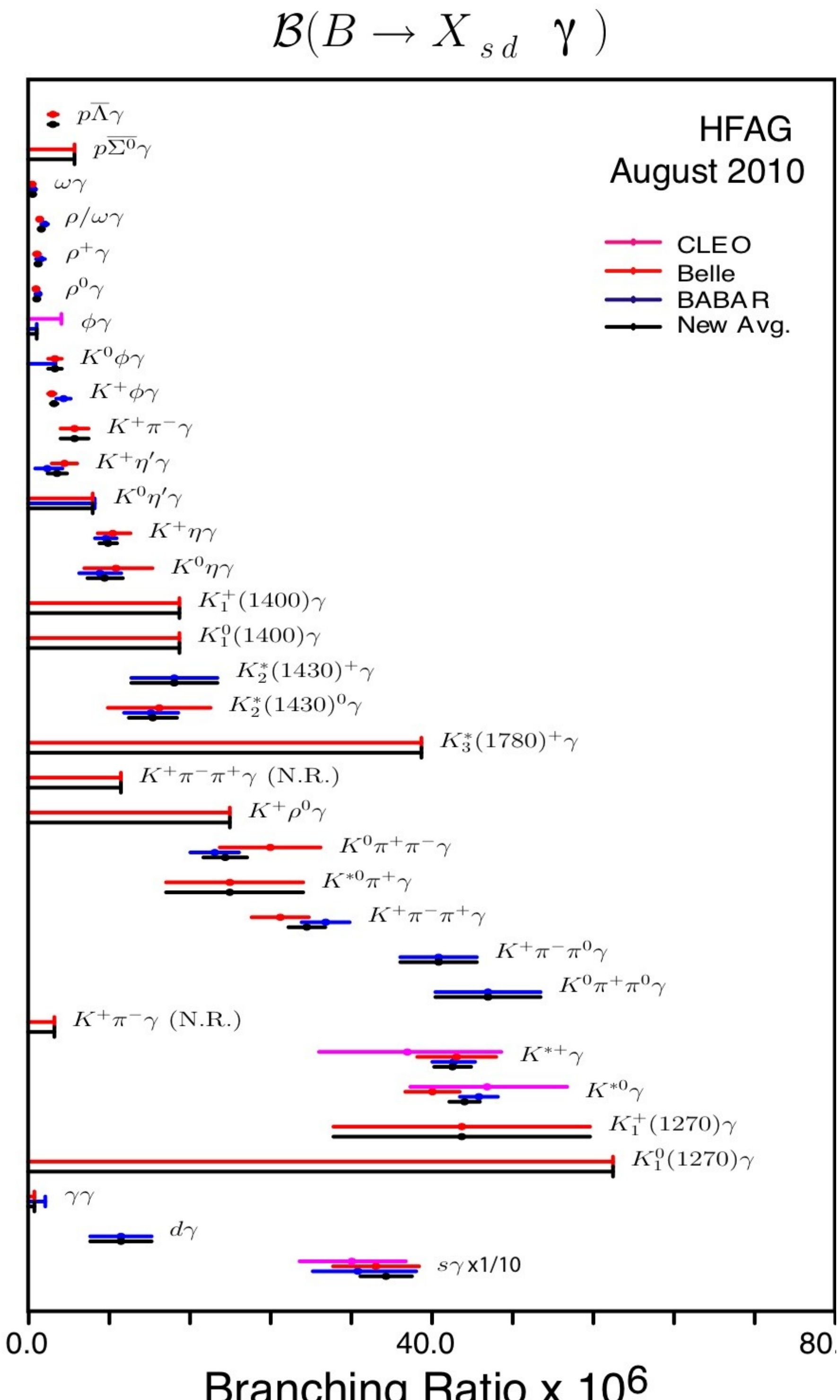
$$A_\perp^{L,R} = +i\left\{(\mathcal{C}_9^{\mathrm{eff}} \mp \mathcal{C}_{10}) + \kappa\frac{2\hat{m}_b}{\hat{s}}\,\mathcal{C}_7^{\mathrm{eff}}\right\} f_\perp,$$

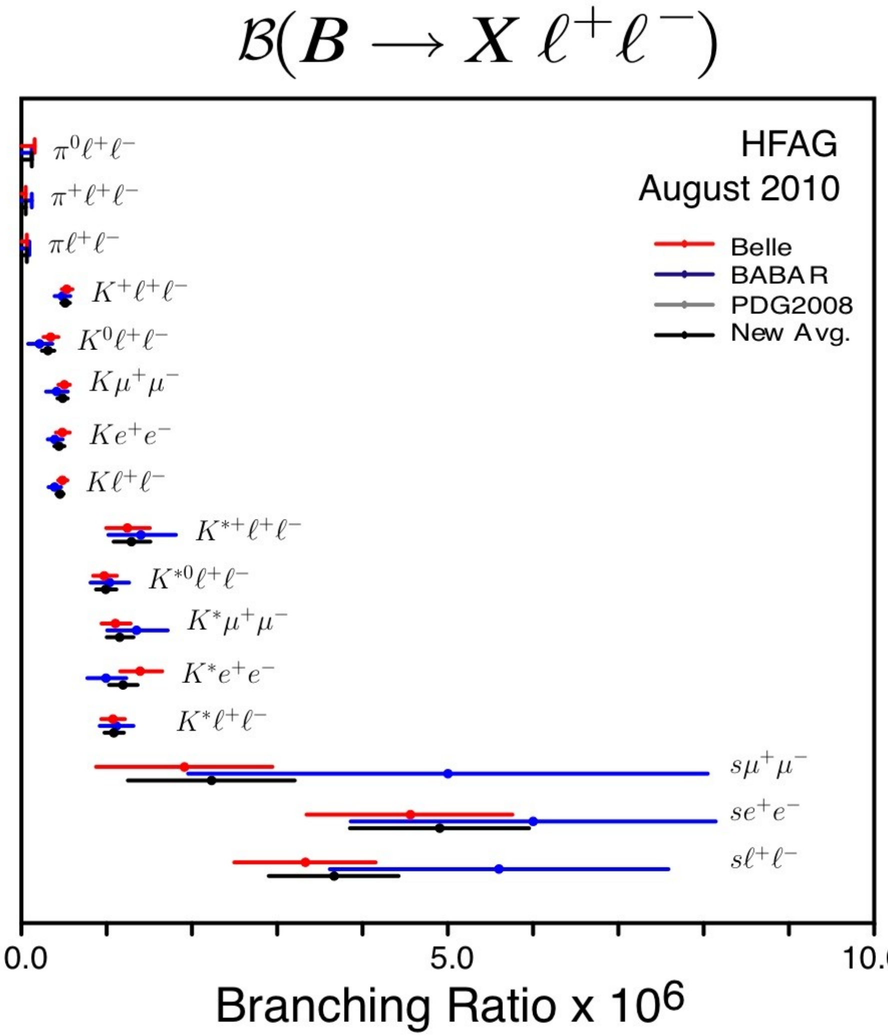
$$A_\parallel^{L,R} = -i\left\{(\mathcal{C}_9^{\mathrm{eff}} \mp \mathcal{C}_{10}) + \kappa\frac{2\hat{m}_b}{\hat{s}}\,\mathcal{C}_7^{\mathrm{eff}}\right\} f_\parallel,$$

$$A_0^{L,R} = -i\left\{\left(\mathcal{C}_9^{\mathrm{eff}} \mp \mathcal{C}_{10}\right) + \kappa\frac{2\hat{m}_b}{\hat{s}}\,\mathcal{C}_7^{\mathrm{eff}}\right\} f_0,$$

Form Factors ($f_\perp$, $f_\parallel$, f_0)

- Other Observables which do not depend on Wilson Coefficients at low recoil probe some $B \rightarrow K^*$ FF combinations


$\mathcal{B}(B \to X_{sd}\ \gamma)$
HFAG
August 2010
CLEO
Belle
BABAR
New Avg.
$p\bar{\Lambda}\gamma$
$p\overline{\Sigma^0}\gamma$
$\omega\gamma$
$\rho/\omega\gamma$
$\rho^+\gamma$
$\rho^0\gamma$
$\phi\gamma$
$K^0\phi\gamma$
$K^+\phi\gamma$
$K^+\pi^-\gamma$
$K^+\eta'\gamma$
$K^0\eta'\gamma$
$K^+\eta\gamma$
$K^0\eta\gamma$
$K_1^+(1400)\gamma$
$K_1^0(1400)\gamma$
$K_2^*(1430)^+\gamma$
$K_2^*(1430)^0\gamma$
$K_3^*(1780)^+\gamma$
$K^+\pi^-\pi^+\gamma$ (N.R.)
$K^+\rho^0\gamma$
$K^0\pi^+\pi^-\gamma$
$K^{*0}\pi^+\gamma$
$K^+\pi^-\pi^+\gamma$
$K^+\pi^-\pi^0\gamma$
$K^0\pi^+\pi^0\gamma$
$K^+\pi^-\gamma$ (N.R.)
$K^{*+}\gamma$
$K^{*0}\gamma$
$K_1^+(1270)\gamma$
$K_1^0(1270)\gamma$
$\gamma\gamma$
$d\gamma$
$s\gamma$ x1/10
0.0
40.0
80.
Branching Ratio x 10^6


$\mathcal{B}(B \to X\ \ell^+\ell^-)$
HFAG
August 2010
Belle
BABAR
PDG2008
New Avg.
$\pi^0\ell^+\ell^-$
$\pi^+\ell^+\ell^-$
$\pi\ell^+\ell^-$
$K^+\ell^+\ell^-$
$K^0\ell^+\ell^-$
$K\mu^+\mu^-$
Ke^+e^-
$K\ell^+\ell^-$
$K^{*+}\ell^+\ell^-$
$K^{*0}\ell^+\ell^-$
$K^*\mu^+\mu^-$
$K^*e^+e^-$
$K^*\ell^+\ell^-$
$s\mu^+\mu^-$
se^+e^-
$s\ell^+\ell^-$
0.0
5.0
10.0
Branching Ratio x 10^6