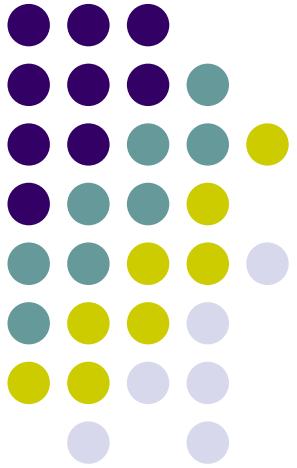
b → sll / missing energy at B-factory experiments

M. Iwasaki (U. of Tokyo)

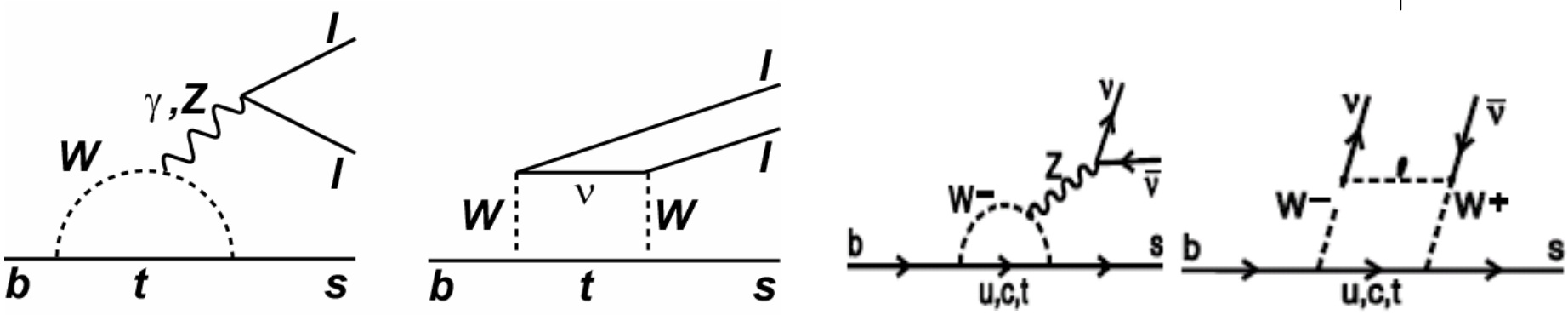
For the Belle collaboration

Results from Belle and BaBar



Introduction

$b \to s l^+ l^-$ $b \to s \nu \bar{\nu}$ decays : FCNC processes



In SM forbidden at tree level .. One loop or box

→ Sensitive to the New physics

Rare-decay … require very high statistics and superb background

B-Factory experiments

The best experiment to measure FCNC

High luminosity

e^+e^- collider → Clean environment

Introduction : Wilson Coefficients

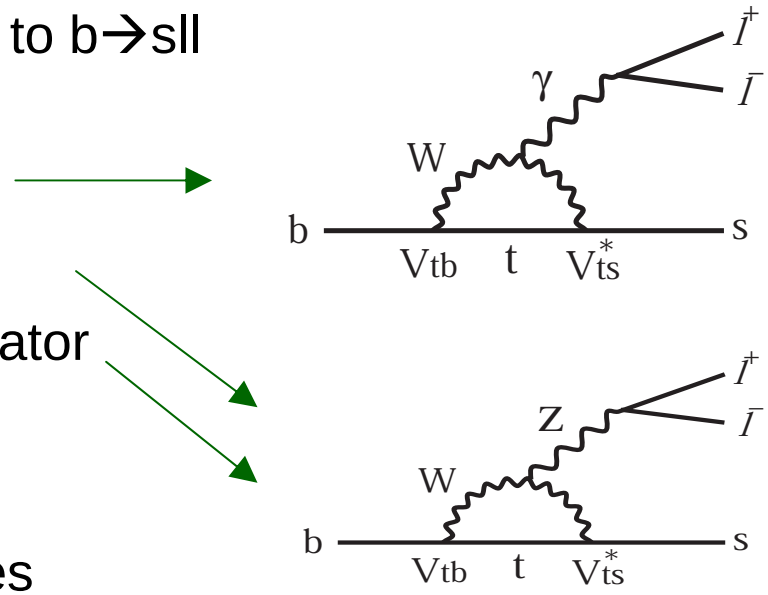
New physics at the one loop level can be described in terms an effective Hamiltonian:

$$\mathcal{H}_{\text{eff}} = -4\frac{G_F}{\sqrt{2}}V_{ts}^*V_{tb}\sum_{i=1}^{10} C_i(\mu)O_i(\mu)$$

$C_i(\mu)$ Wilson coefficients : strength of short distance interactions

To leading order, three coefficients contribute to b→sll

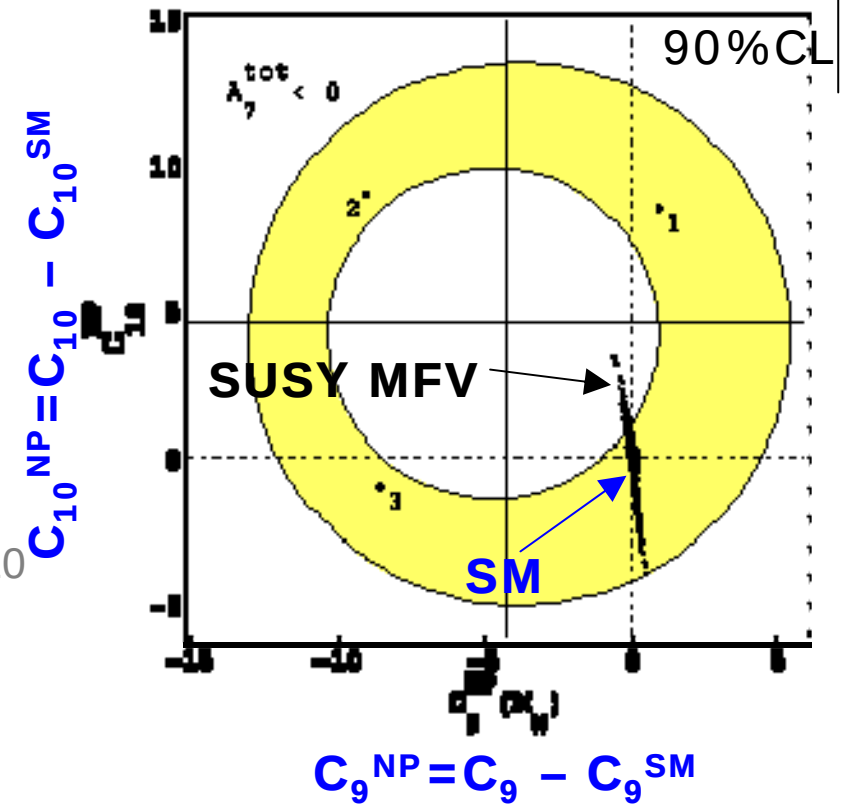
- C_7 : For electro-magnetic operator
- C_9 : For semi-leptonic vector operator
- C_{10}: For semi-leptonic axial vector operator



For b→sνν .. Single coefficient C_{10} contributes

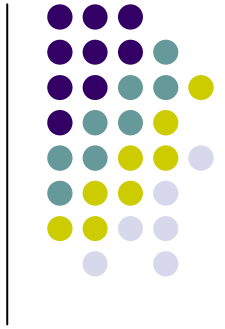
Constraints on Wilson coefficients

- BR(b→sll)
  sign of C_7
  constraints on C_9-C_{10}
  (donut-shape)
- A_{FB} in b→sll
  can determine relative
  signs of C_7 / C_{10}, C_9 / C_{10}
- b→sνν
  C_{10} only contributes



In this talk, we cover

1) Semi-inclusive B→$X_s l^+ l^-$
2) A_{FB} with exclusive B→K*$l^+ l^-$
3) Search for B→$K^{(*)}\nu\bar{\nu}$

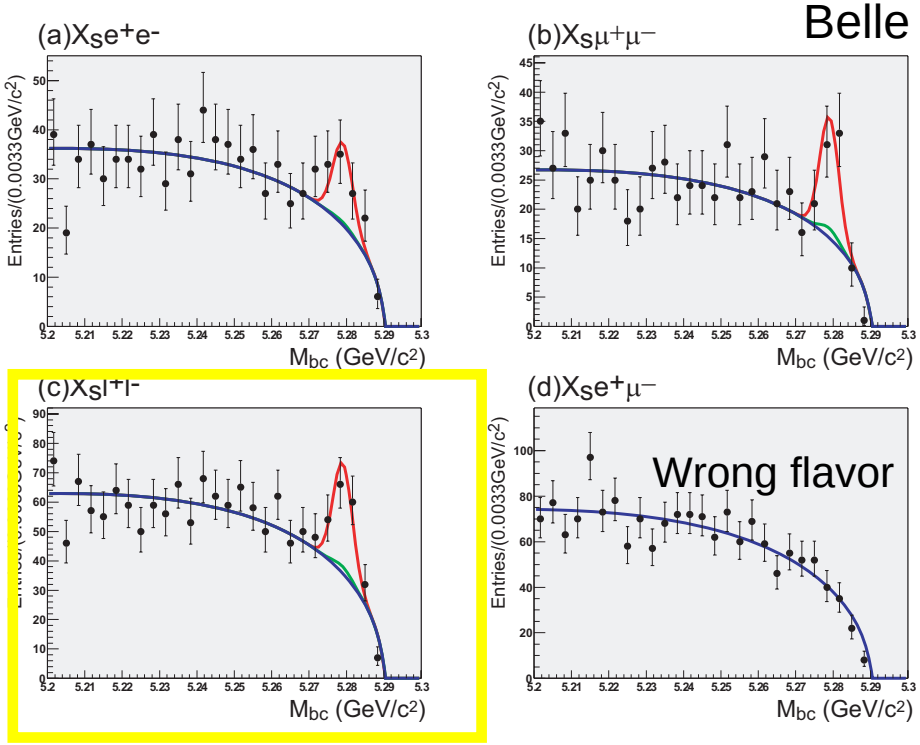


1) semi-inclusive B → $X_s l^+ l^-$

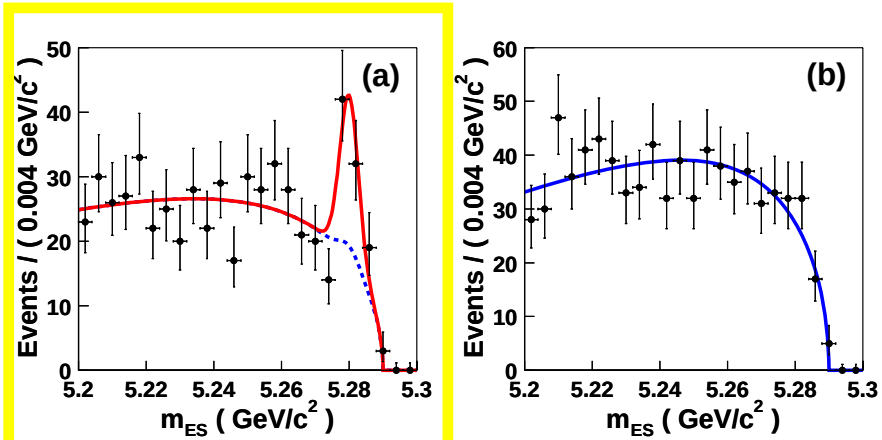
Semi-inclusive $B \rightarrow X_s l^+ l^-$

- X_s is reconstructed from
  K^+ or K_s + 0-4π (Belle) or -2π(BaBar)
  (at most one π^0 is allowed)
  - M_{Xs} < 2.0 GeV (Belle) < 1.8 GeV (BaBar)
- Electron or muon pair
  - M_{ll}>0.2GeV
  - Charmonium veto

Belle



BaBar

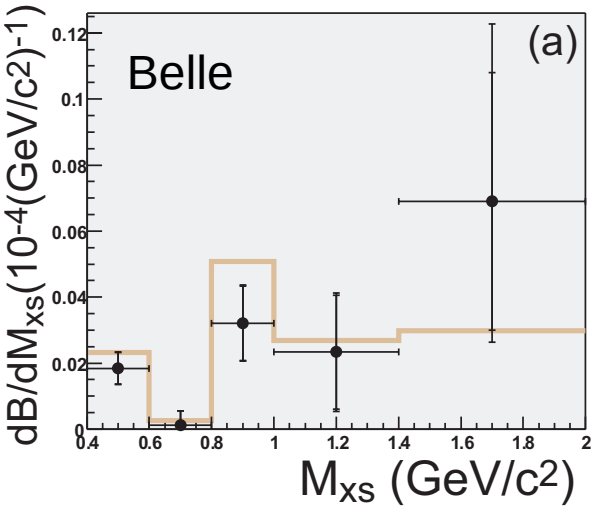


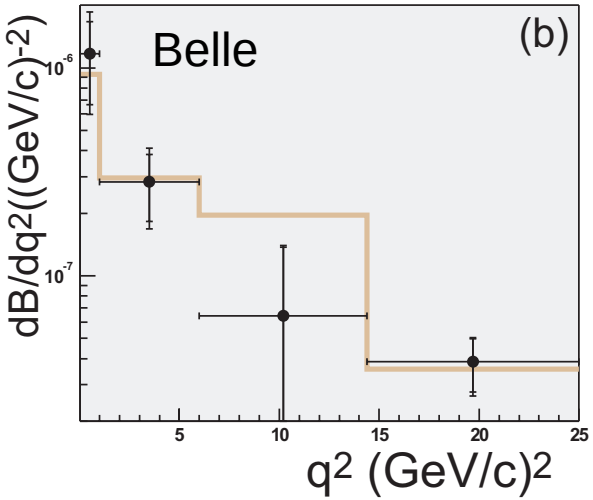
140 fb^{-1} : $B(B \rightarrow X_s ll)$ = $(4.11 \pm 0.83\ ^{+0.85}_{-0.81})10^{-6}$ (Belle PRD72, 092005(2005))

82 fb^{-1} : $B(B \rightarrow X_s ll)$ = $(5.6 \pm 1.6 \pm 0.6 \pm 1.1)10^{-6}$ (BaBar PRL93,081802(2004))

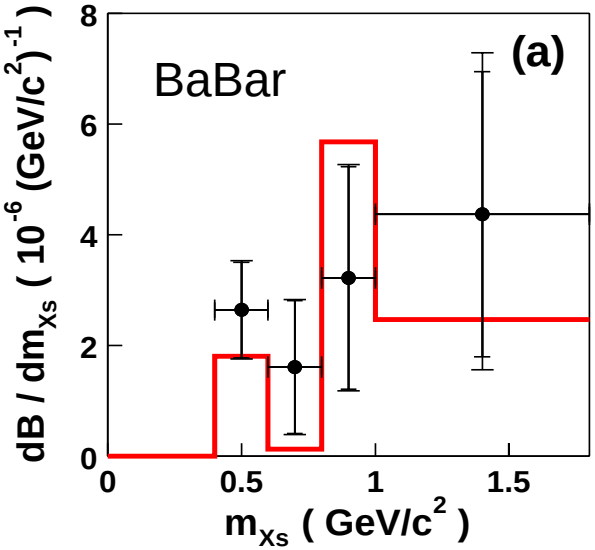
Theoretical prediction $(4.20 \pm 0.70)10^{-6}$ (A.Ali et al.)

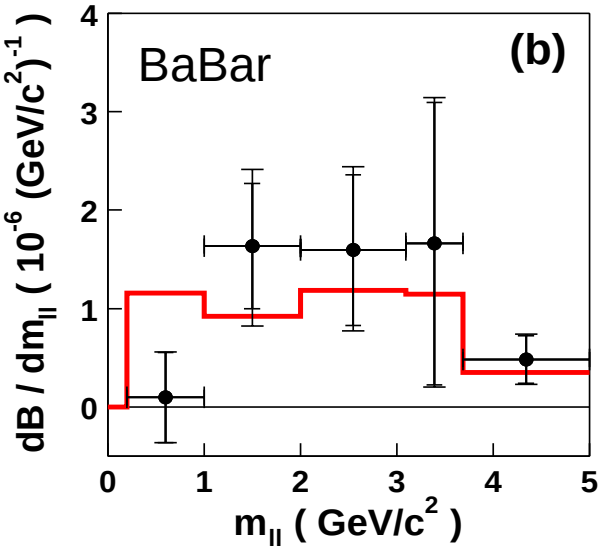
Semi-inclusive $B \rightarrow X_s l^+ l^-$





$q^2 = m_{ll}^2$





The results are in agreement with SM

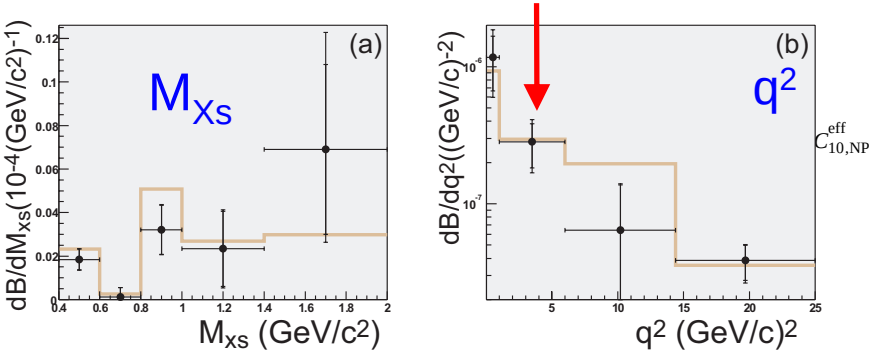
Constraints on C_i from $B(B \to X_s l^+ l^-)$

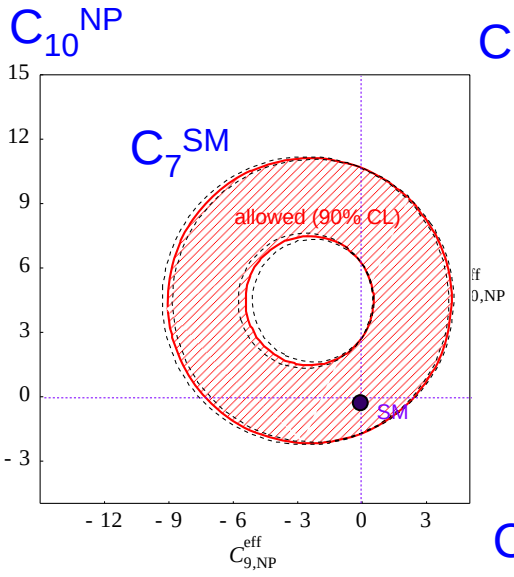
P.Gambino, U.Haisch and M.Misiak PRL 94 061803 (2005)

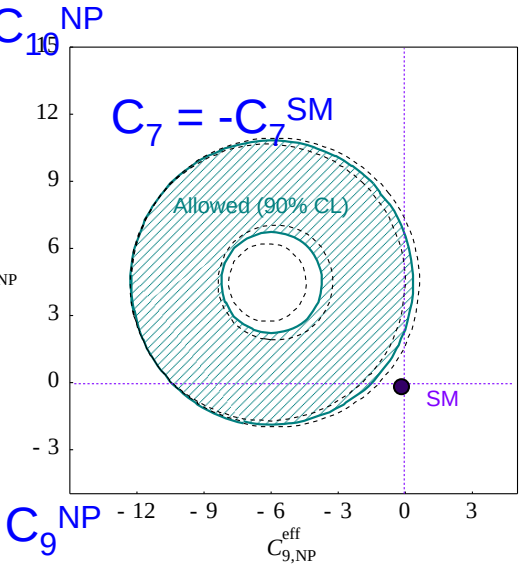
- Clean prediction for $B(B \to X_s ll)$ with $1<q^2<6GeV^2$ is available.
  - Combine Belle and Babar results
  - Sign of C_7 flipped case with SM C_9 and C_{10} value is unlikely.

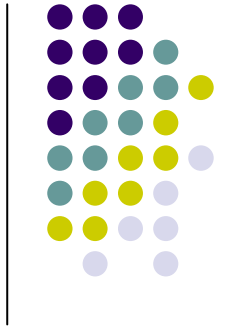
BF	Belle	Babar	WA	SM	$C_7 = -C_7^{SM}$
$q^2>(2m_\mu)^2$	4.11 ± 1.1	5.6 ± 2.0	4.5 ± 1.0	4.4 ± 0.7	8.8 ± 0.7
$1<q^2<6GeV^2$	1.5 ± 0.6	1.8 ± 0.9	1.60 ± 0.5	1.57 ± 0.16	3.30 ± 0.25

Donut : 90% CL allowed region









2) Forward-Backward Asymmetry in exclusive B → K*ll

A_{FB} in K*ll

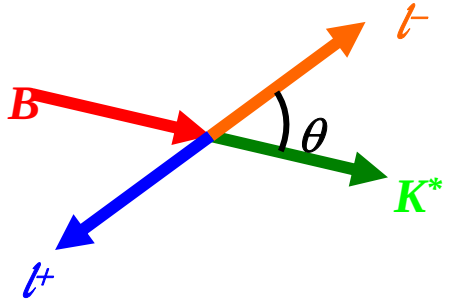
- Forward-backward asymmetry is induced by interference btw virtual photon and Z^0 contributions.
- Relative signs of C_7 to C_{10} and C_9 to C_{10} can be determined :

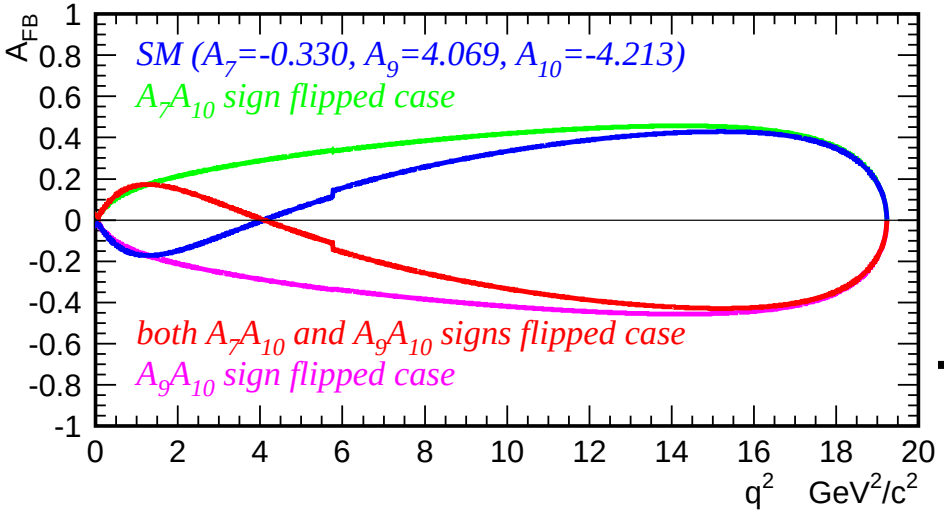
$$\frac{d}{d\hat{s}}(\Gamma_F^{K*} - \Gamma_B^{K*}) = -\frac{G_F^2 \alpha^2 m_B^5}{2^8 \pi^5} |V_{ts}^* V_{tb}|^2 \, \hat{s}\hat{u}(\hat{s})^2 \times \left[\mathrm{Re}(C_9^{\mathrm{eff}}) C_{10} V A_1 + \frac{\hat{m}_b}{\hat{s}} C_7^{\mathrm{eff}} C_{10} (V T_2 (1 - \hat{m}_{K*}) + A_1 T_1 (1 + \hat{m}_{K*})) \right] .$$

Definition of A_{FB}

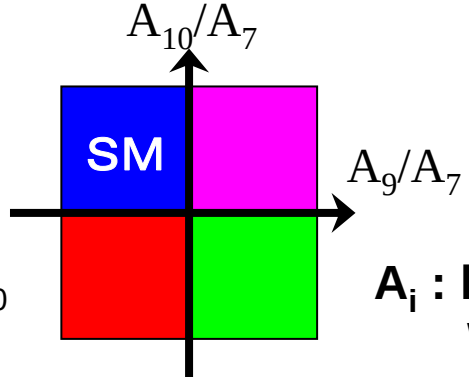
$$A_{\mathrm{FB}}(q^2) = \frac{\Gamma(q^2, \cos\theta_{B\ell^-} > 0) - \Gamma(q^2, \cos\theta_{B\ell^-} < 0)}{\Gamma(q^2, \cos\theta_{B\ell^-} > 0) + \Gamma(q^2, \cos\theta_{B\ell^-} < 0)}$$

θ_{Bl-} : angle btw B and l^- in the dilepton rest frame



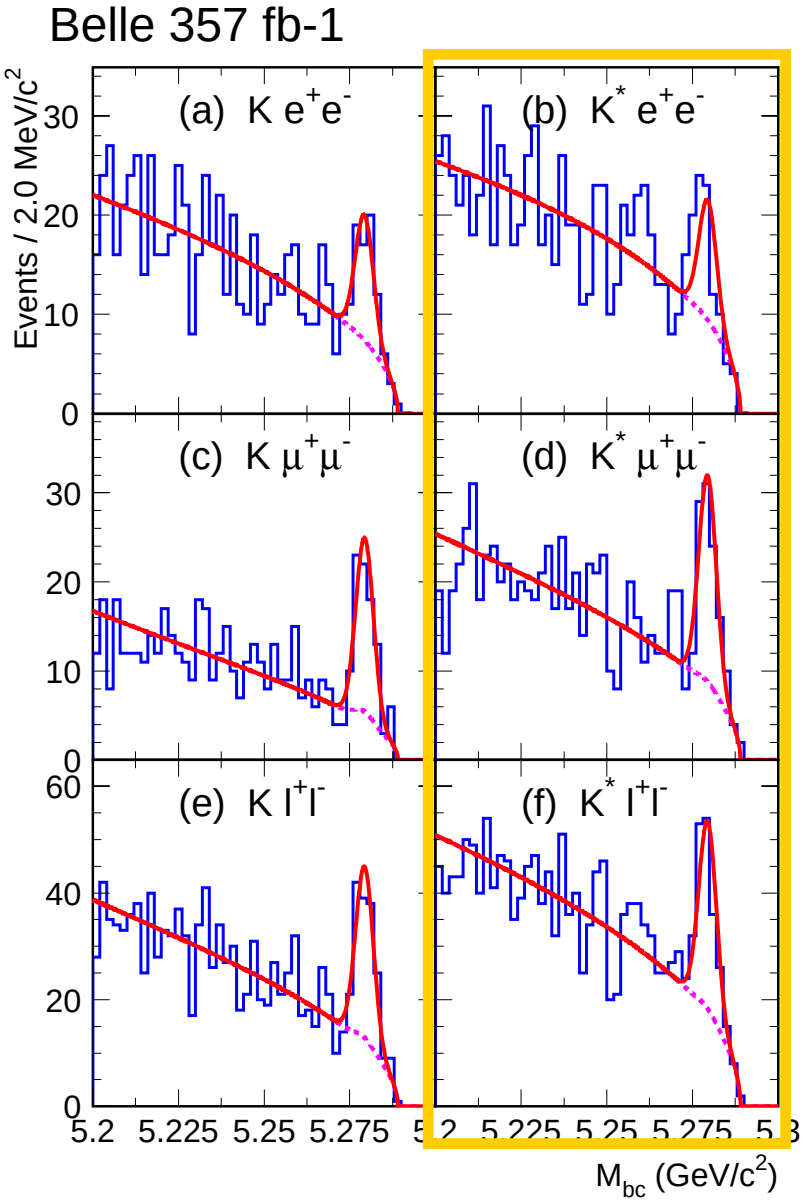


We can examine the sign of A_{10}/A_7 and A_9/A_7 with $A_{FB}(q^2)$



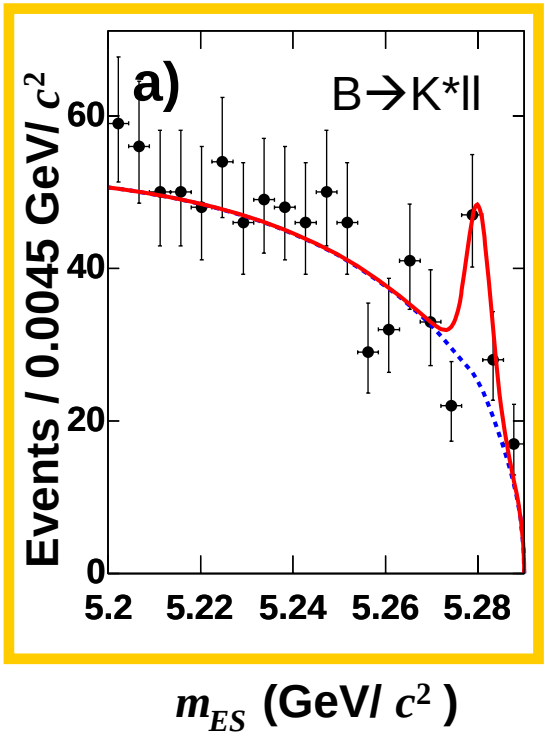
A_i : leading terms of the Wilson coefficients C_i

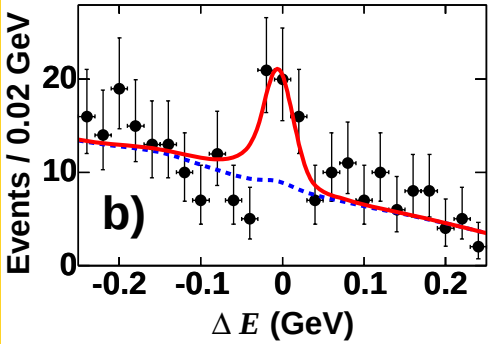
Signals for exclusive B→K*l⁺l⁻

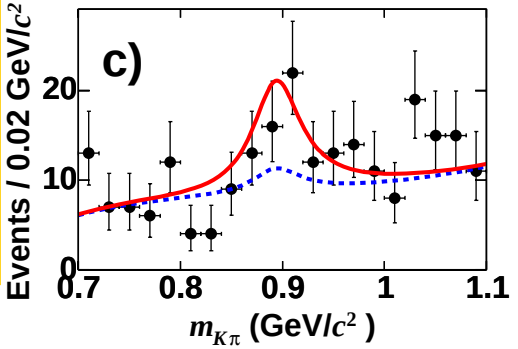


- Electron or muon pair
  - Charmonium veto
- Reconstruct K*($K^+\pi^-$, $K_S\pi^+$, $K^+\pi^0$)

BaBar 229M BB-bar



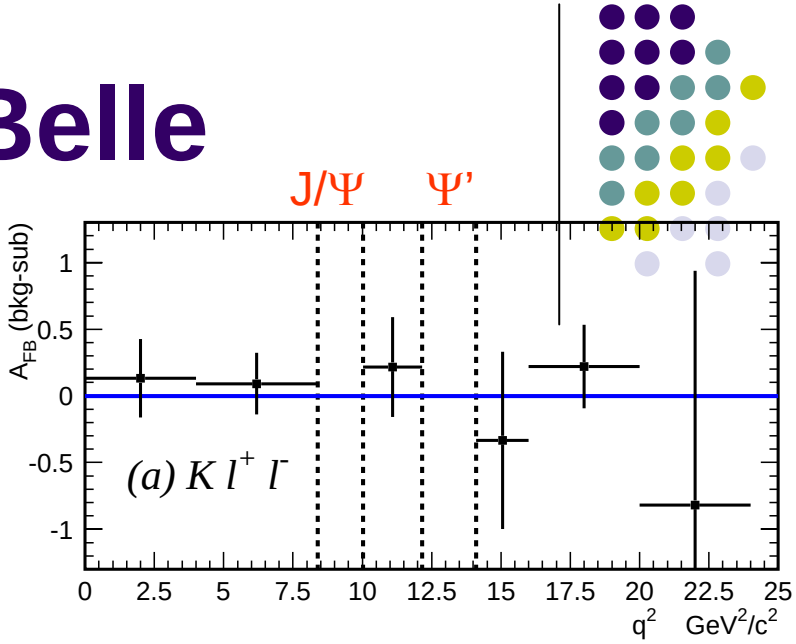




A_{FB} in B→K*ll from Belle

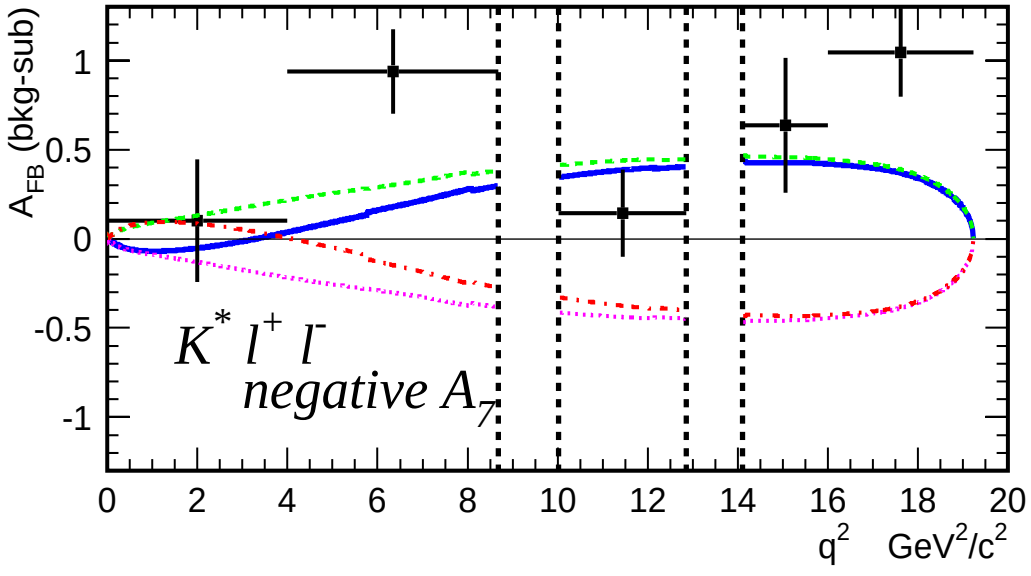
- Null test using K⁺ll

$$A_{FB}^{\text{bkg-sub}}(B \to K^+\ell\ell) = 0.09 \pm 0.14(\text{stat.})$$



- Projection to A_{FB} for K*ll

$$A_{FB}^{\text{bkg-sub}}(B \to K^*\ell\ell) = 0.56 \pm 0.13(\text{stat.})$$



Best fit for negative A_7 (SM like)

$$A_9/A_7 = -15.3\,^{+3.4}_{-4.8} \pm 1.1,$$
$$A_{10}/A_7 = 10.3\,^{+5.2}_{-3.5} \pm 1.8,$$

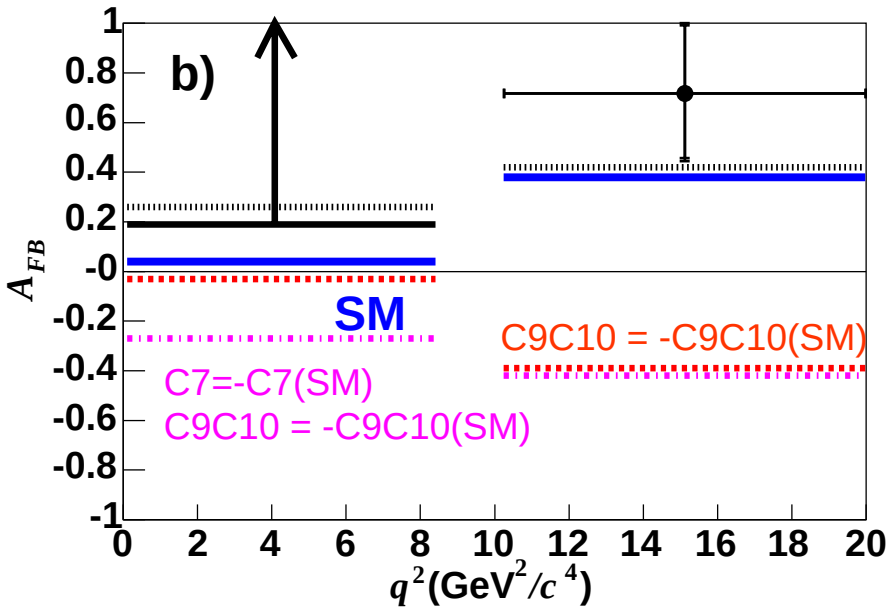
SM $A_9/A_7 = -12.3,$ $A_{10}/A_7 = 12.8.$

fit result
A_7A_{10} sign flipped (to SM)
Both A_7A_{10} and A_9A_{10} signs flipped
A_9A_{10} sign flipped

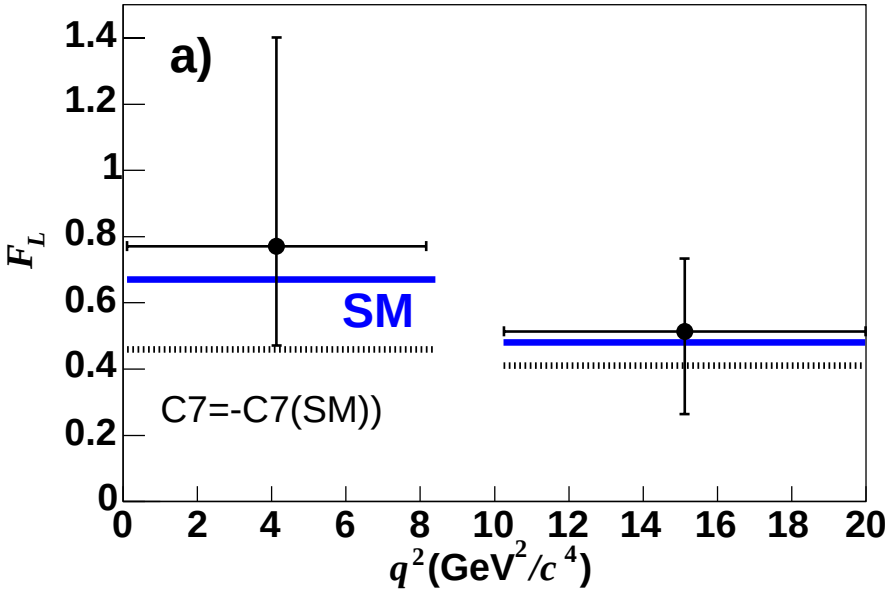
Sign of A_9A_{10} flipped case is excluded

A_{FB} and K* polarization from BaBar

A_{FB}

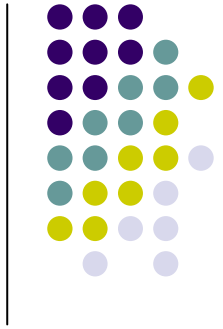


K* polarization F_L
(fraction of longitudinal polarization)



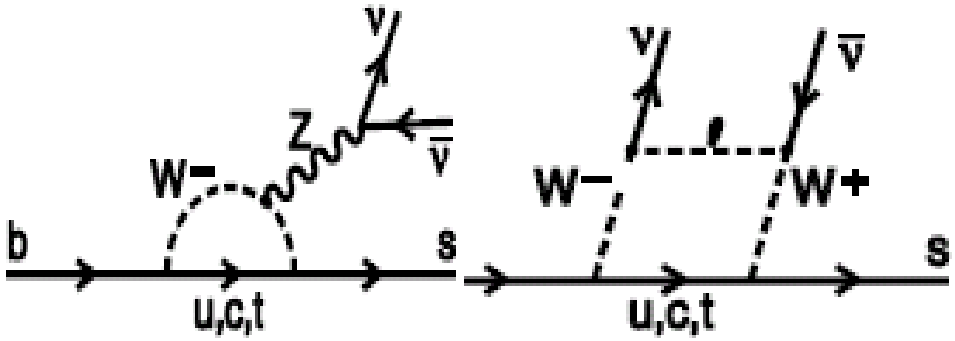
Low q^2 : excludes SM at 98% CL
A_{FB} > 0.19 at 95% CL (SM A_{FB} = 0.03)

SM and alternate predictions from NNLO OPE + LCSR form factors.
Ali et al. Phys. Rev. D66 (2002) 034002
Ball and Zwicky Phys. Rev. D71 (2005) 014029



3) Search for $B \rightarrow K^{(*)}\nu\bar{\nu}$

$B \rightarrow K^{(*)} \nu\bar{\nu}$ decay



- Effective Hamiltonian for $b \rightarrow s\nu\nu$ gets contribution from a single Wilson coefficient of C_{10}

- Theoretically $B \rightarrow X_s \nu\nu$ is very clean, but difficult to measure. Search for exclusive decay instead

SM: $Br(B \rightarrow K\nu\nu) = \sim 4 \times 10^{-6}$ $Br(B \rightarrow K^*\nu\nu) = \sim 1.3 \times 10^{-5}$

(G.Buchalla, G.Hiller and G.Isidori Phys. Rev D63 (2001) 014015)

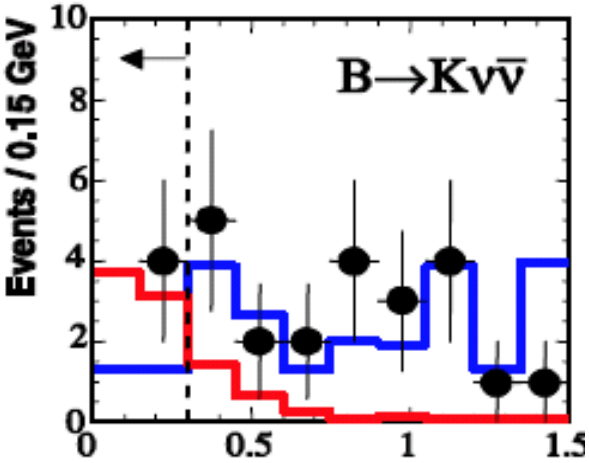
Deviation from the SM expectation might be a sign of a new physics

Two-Higgs doublet model (2HDM), light dark matter scalar particles can enhance the BR by one or two orders of magnitude

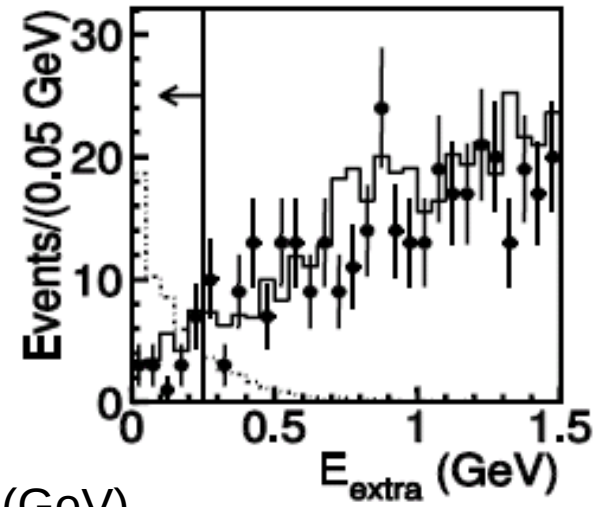
(Y.Grossman, Z.Ligeti and E.Nardi Nucl.Phys. B465 (1996)369
C.Bird et al, PRL93 (2004)201803)

Search for $B^+ \to K^+ \nu\bar{\nu}$

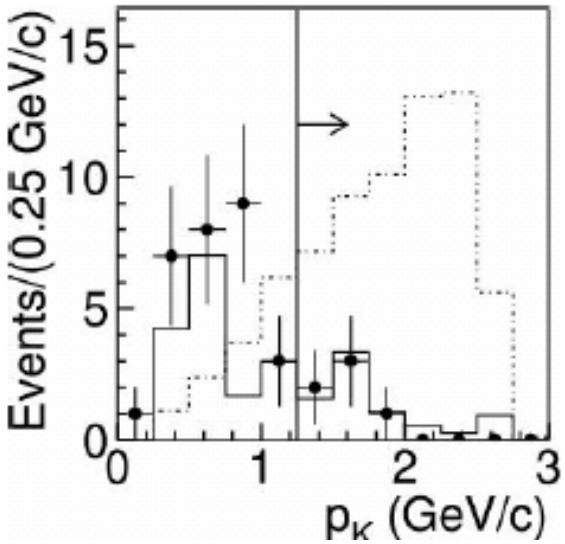
Belle Hadronic Tag



BaBar Hadronic Tag



Semileptonic Tag



Nsig	4	3	6
Nbg	2.6±1.6	3.9±1.1	3.4±1.2

Upper limit 90% CL

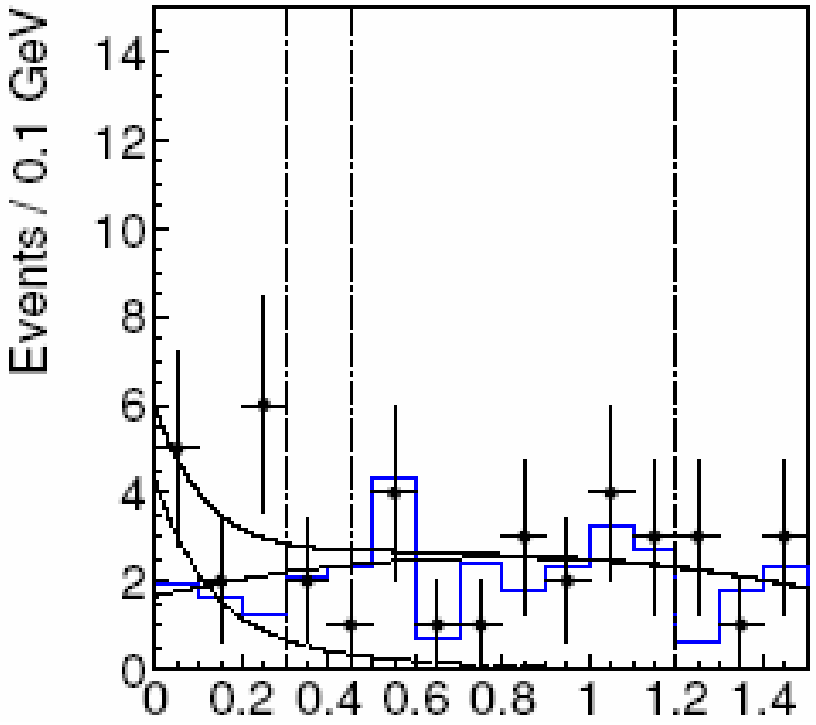
253 fb^{-1} : $\mathcal{B}(B^+ \to K^+ \nu\nu) < 3.6\ 10^{-5}$ (Belle hep-ex/0507034)

82 fb^{-1} : $\mathcal{B}(B^+ \to K^+ \nu\nu) < 5.2\ 10^{-5}$ (BaBar PRL94,101801(2005))

Search for $B \to K^* \nu\bar{\nu}$ from Belle

Belle 535M BBbar

hep-ex/0608047



Extra Calorimeter Energy (GeV)

Result from a blind analysis.

$$Yield = 4.7^{+3.1}_{-2.6}$$

(1.7 σ stat. significance)

Sideband = 19

MC expectation = 18.7±3.3

SM (Buchalla, Hiller, Isidori) 1.3 x 10^{-5}

$$B(B^0 \to K^{*0}\nu\nu) < 3.4 \times 10^{-4} \quad \text{(at 90\% C.L)}$$

Summary

- Semi-inclusive measurement of $B \rightarrow X_s l^+ l^-$
  - Consistent with SM expectations
  - C_7 sign flipped case with SM C_9 and C_{10} is unlikely
- Wilson coefficients measurement with A_{FB} in $B \rightarrow K^* l^+ l^-$
  - Forward-backward asymmetry is observed.
  - Belle: New physics scenarios with positive $A_9 A_{10}$ are excluded.
  - BaBar: Exclude SM at low q^2
- Search for the $B \rightarrow K^{(*)} \nu\bar{\nu}$
  - UL is still a factor of 10 above the SM range

Further dramatic progress will require

Super B Factory class luminosity