Minority Report on Flavor-TeV Link

George W.S. Hou (侯維恕)
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November 15, before "Detecting the Unexpected" @ Davis

臺灣大學
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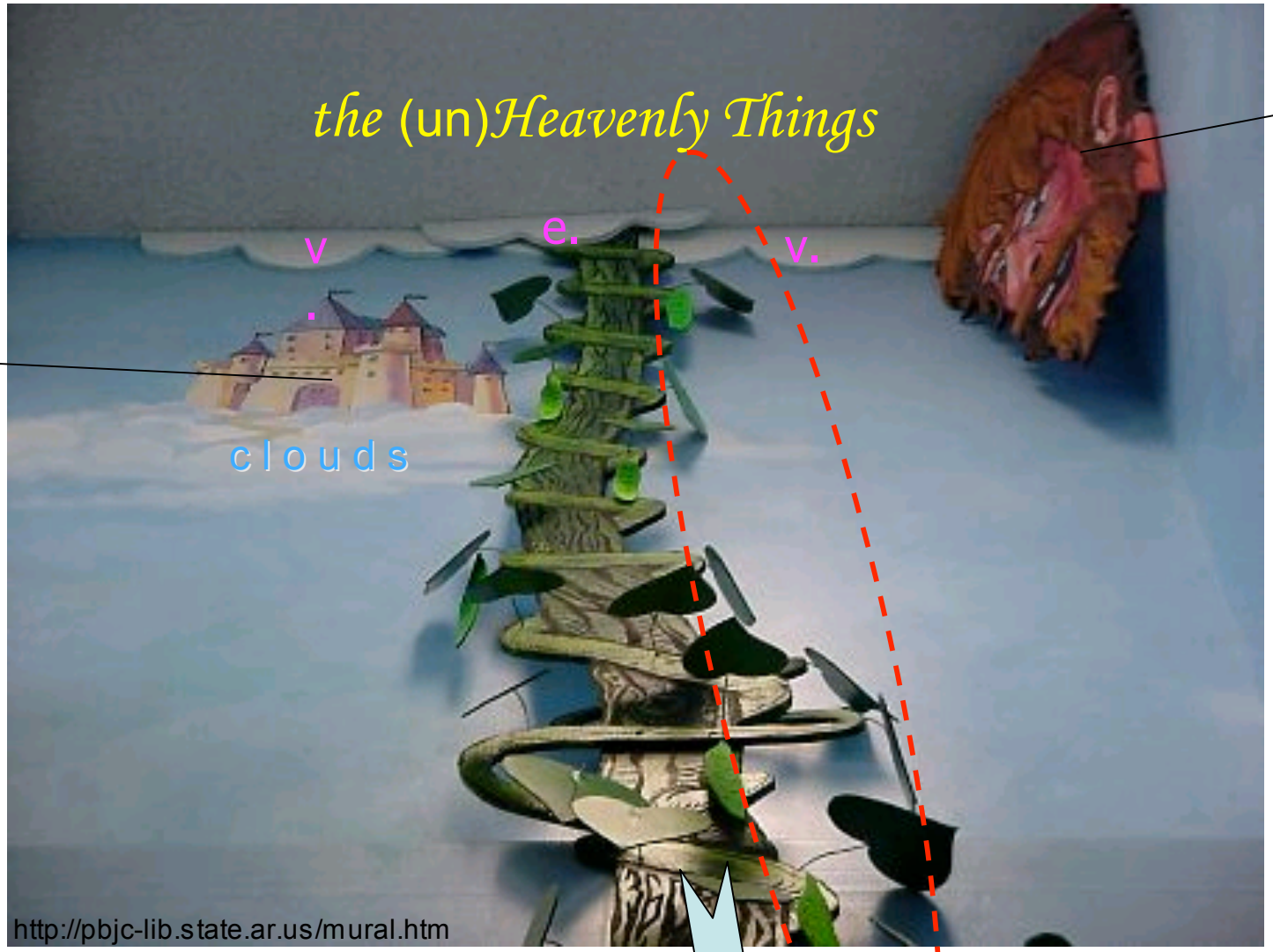
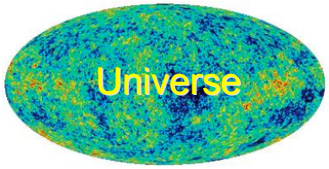

the (un)Heavenly Things
Child Eating Giant (LHC/ILC?)
Higgs Castle
v
e.
v.
clouds
http://pbjc-lib.state.ar.us/mural.htm
Down to Earth
Flavour/TeV ≅ Loops

HEFTi

SETi

Hidden Valleys

Quirks



Unparticles

Detecting the Unexpected

George W.

Outline

$b \to s$

0 "Forward to the Past" as Intro — What if ?

$\sin 2\phi_{B_d}$ ca. 2000; Δm_{B_d}, top and V_{td}

I CPV in $b \to s$ w/ Boxes and Penguins

ΔS; $\Delta \mathcal{A}_{K\pi}$; $\sin 2\phi_{B_s}$; $\mathcal{A}_{CP}(B^+ \to J/\psi K^+)$

II H^+ Probe: $b \to s\gamma$; $B \to (D^{(*)})\tau\nu$

III Electroweak Penguin: $A_{FB}(B \to K^* \ell\ell)$; $B \to K^{(*)}\nu\nu$

IV RH Currents and Scalar Interactions

TCPV in $B \to X_0\gamma$; $B_s \to \mu\mu$

V D/K: Box and EWP Redux — D_0 mixing ; Rare K

VI t : LFV and (B−L)V

$t \to \ell\gamma$, $\ell\ell\ell'$; $t \to L\pi$, $\pi\pi^0$

VII Conclusion

Addendum Very Heavy Flavor

Single top: t'; $b' \to bZ$ etc.

Strategy and Apologies

- Pertinent to BSM
  and not too tricky ...
- Physics (vs Expt'l detail — not always most up-to-date)
  [2 Unexpected days to follow
- Short-term impact

- "Traditional" on BSM topics
- Cannot cite all TH work,
  but unabashedly promote own pheno work

0. "Forward to the Past" as Intro

High Energy Physics - Phenomenology

Title: Implications of a Low sin(2 beta): A Strategy for Exploring New Flavor Physics

Authors: Alexander L. Kagan (Cincinnati), Matthias Neubert (Cornell)
(Submitted on 31 Jul 2000)

Abstract: We explore the would-be consequences of a low value of the CP-violating phase $\sin measurements that are independent of B--$\bar B$ and K--$\bar K$ mixing is stressed. It c the B_d, B_s and K systems. We discuss several constructions of this triangle, which wi eventually can be completely removed. Simultaneously, it will be possible to probe for New Ph

Comments:	9 pages, 6 figures
Subjects:	High Energy Physics - Phenomenology (hep-ph) High Energy Physics - Experimer
Journal reference:	Phys.Lett. B492 (2000) 115-122
Cite as:	arXiv:hep-ph/0007360v1

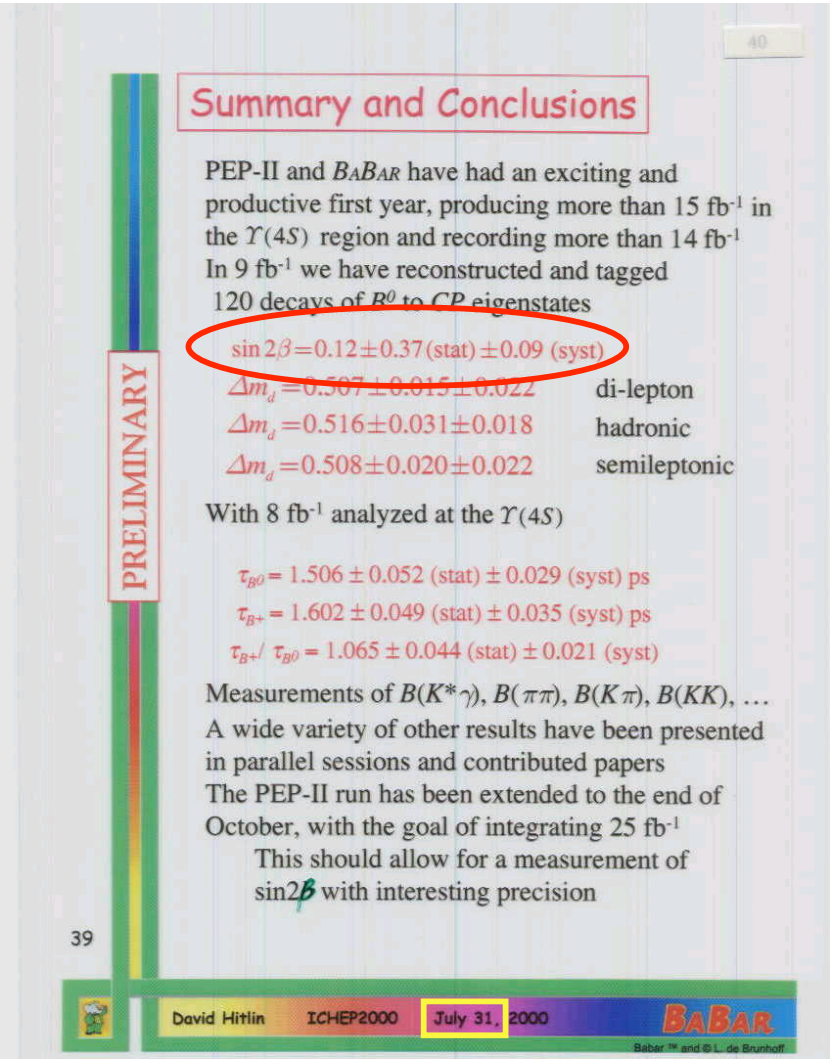
Search for Future Influence from L.H.C

Authors: Holger B. Nielsen, Masao Ninomiya
(Submitted on 13 Jul 2007)

SuperPowered Theorists ?

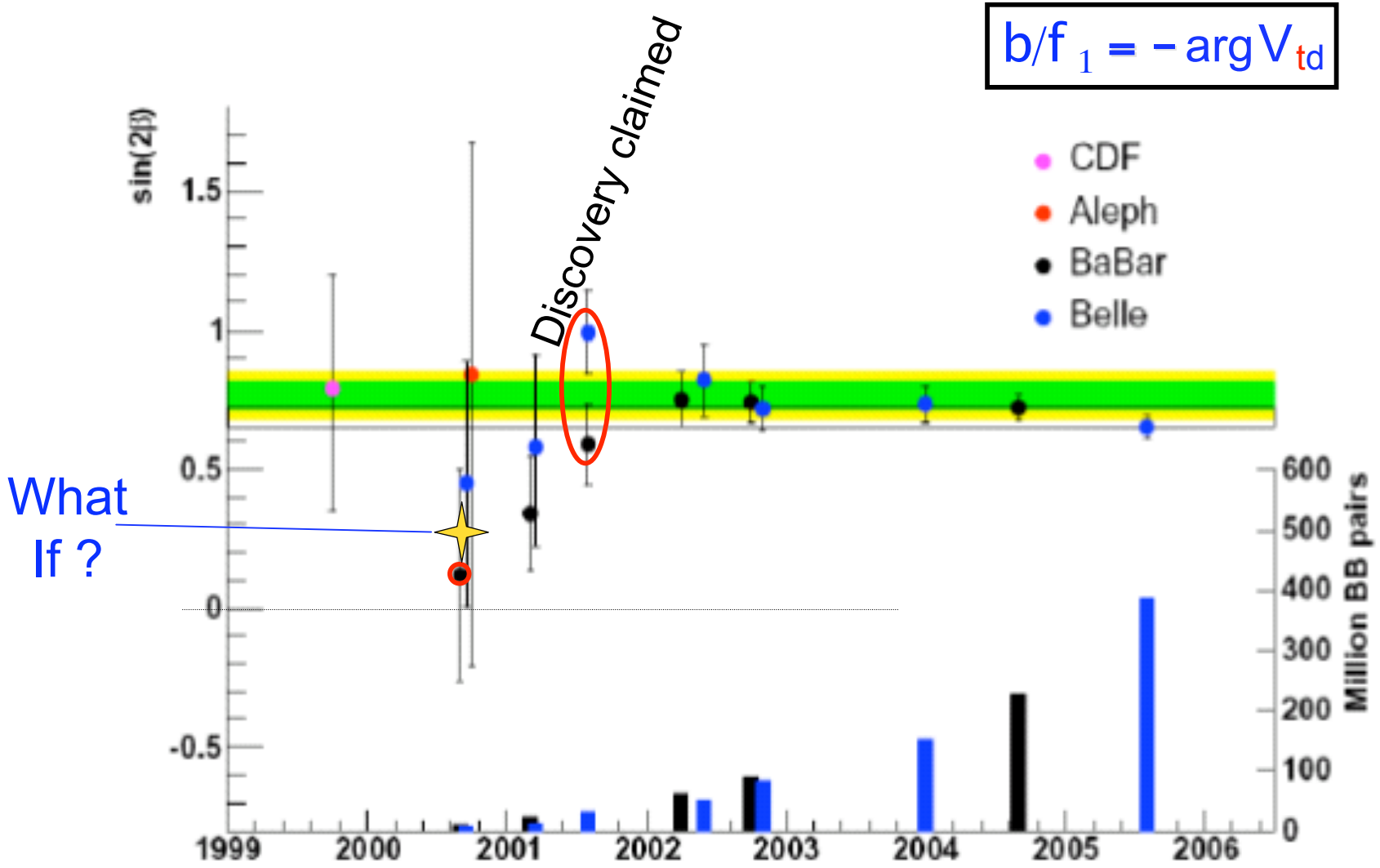
or

Wormhole from/to the Future?



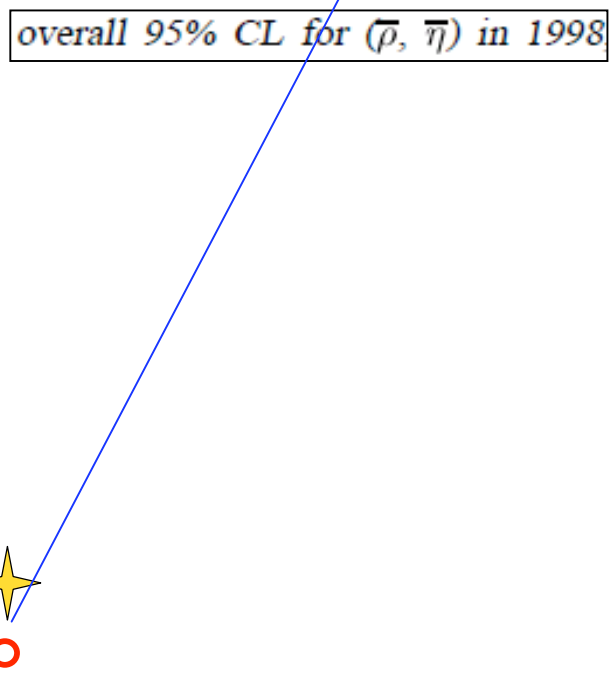
sin2b history (1999-2005)

$b/f_1 = -\arg V_{td}$



R. Cahn -- SSI-2006

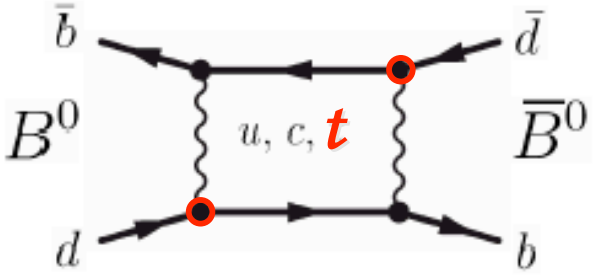
What if $\arg V_{td} \sim 0$*?*

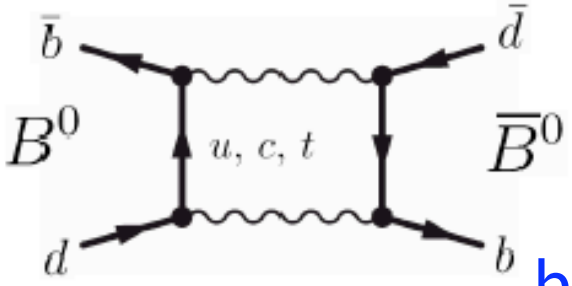


Would have heard
More about it.

Babar Physics Book

Standard Model Predictions





$\beta = -\arg V_{td}$

CPV Phase

known | calculable perturbatively | non perturbative | weak phase

$$M_{12}^d \simeq -\frac{G_F^2 m_W^2}{12\pi^2} m_B \times \eta_B S_0(m_t^2/m_W^2) \times \left(f_B^2 B_B\right) \times \left(V_{tb}V_{td}^*\right)^2 e^{-2i\xi_B}$$

with $S_0(m_t^2/m_W^2) \approx 0.55 \times m_t^2/m_W^2$ and $\eta_B \approx 0.6$

Nondecoupling — $I_t \sim 1$

"Higgs Affinity"

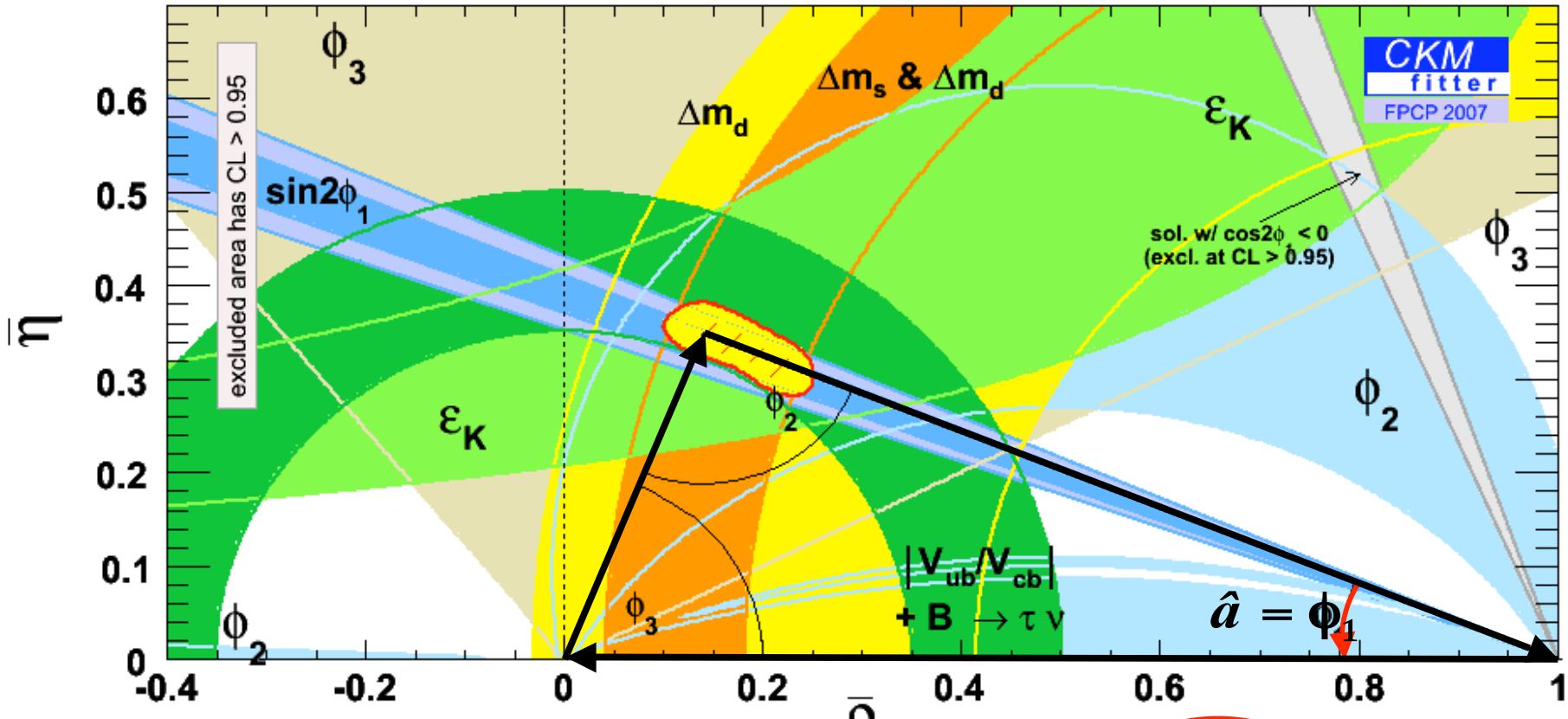
top, a v.e.v. scale quark, "discovered" 20 years ago (ARGUS)

Loops

b → d transitions consistent with SM

What about b → s transitions ?

Our Main Theme



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

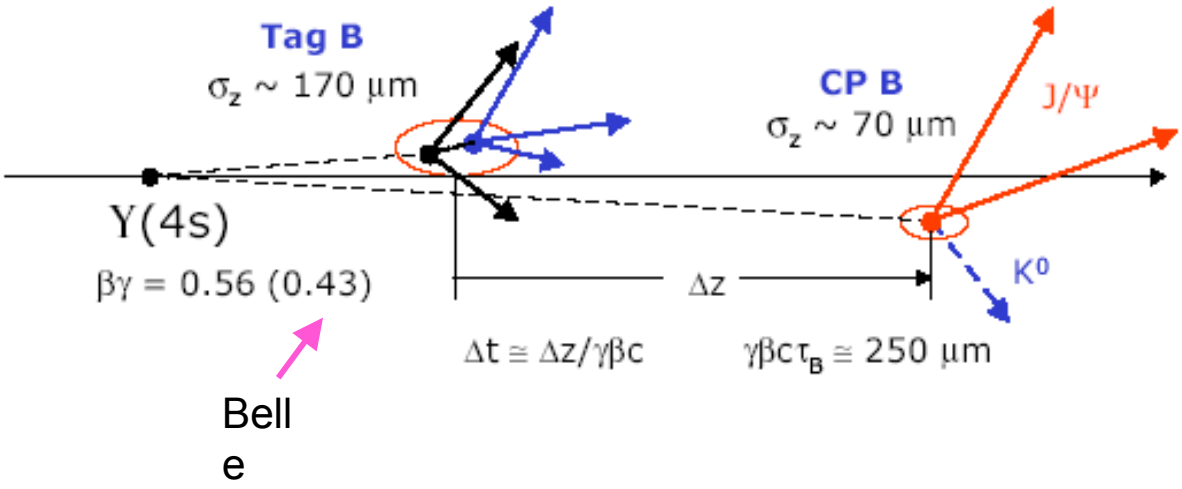
I. CPV in $b \to s$ w/ Boxes and Penguins

The Current Frontier

$t \to mE$choes

The $1B Question: Mixing-dep. CPV in $B \to J/\psi K_S$

B decays in ~ picosecond



B^0 or $\bar{B}^0$

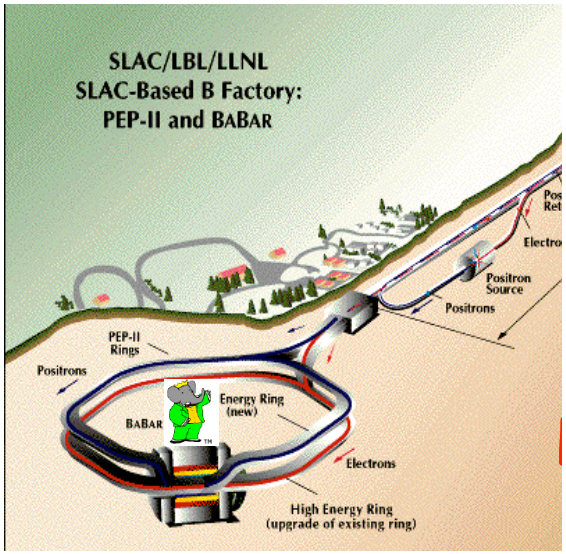
One B Decay — Tag Flavor

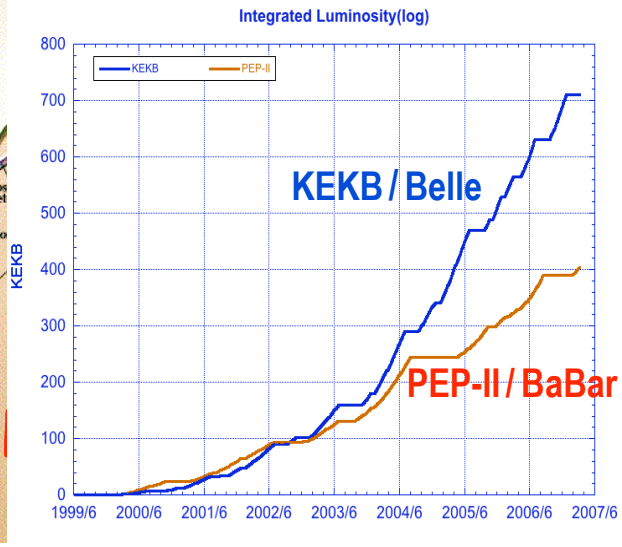
Other B Decay — CP Eigenstate — $J/\psi K_S$, p^+p^-, $h'K_S$, $f_0 K_S$, $K_S\pi^0$

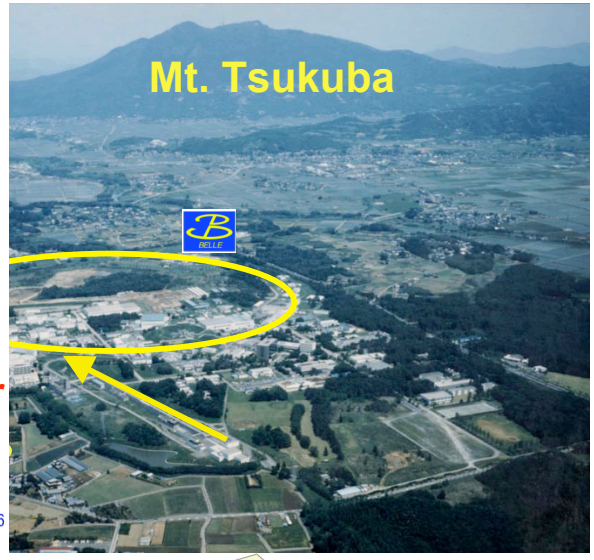
Measure Both — Decay **Vertex** — $\Delta z \propto \Delta t$

2001 !

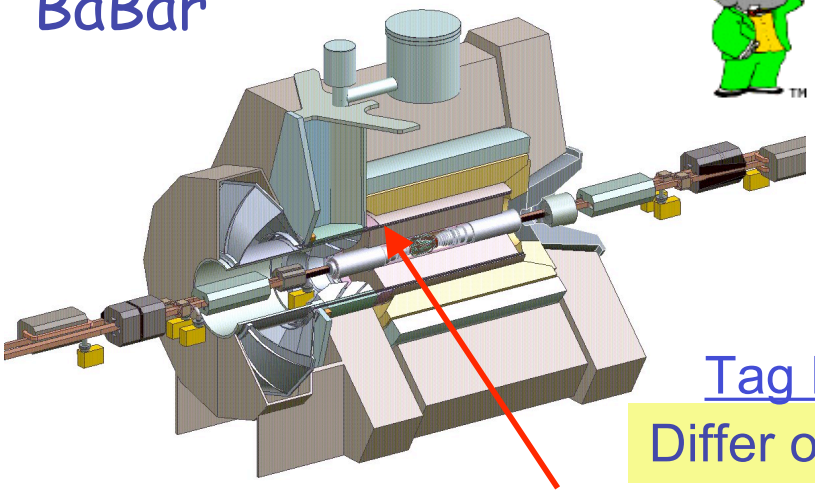
The Two B Factories



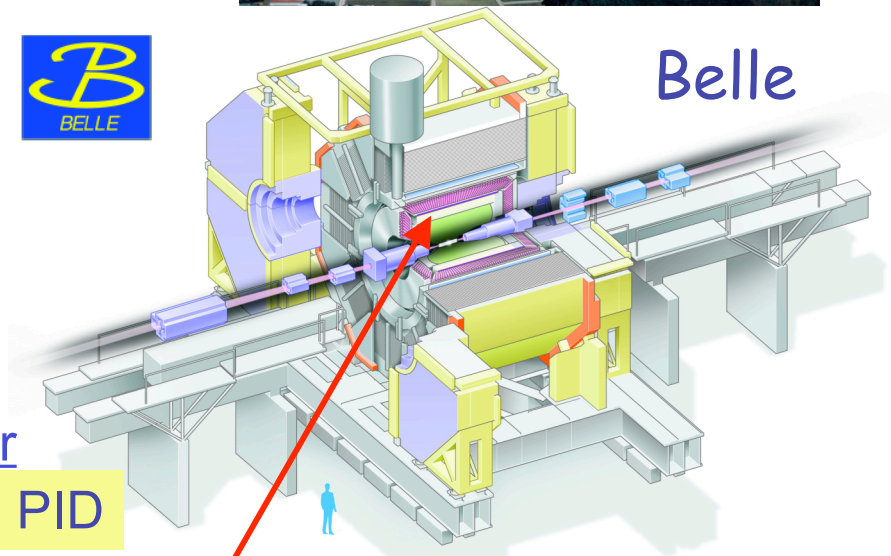




BaBar



Belle



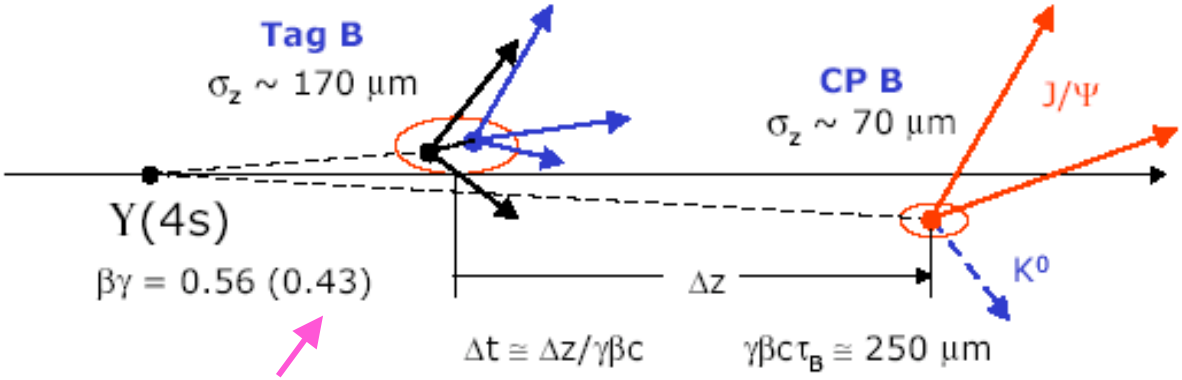
Tag Flavor

Differ only in PID

DIRC vs Aerogel Cherenkov + ToF

The $1B Question: Mixing-dep. CPV in $B \to J/\psi K_S$

B decays in ~ picosecond



Bell
e

B^0 or $\bar{B}^0$

One B Decay — Tag Flavor

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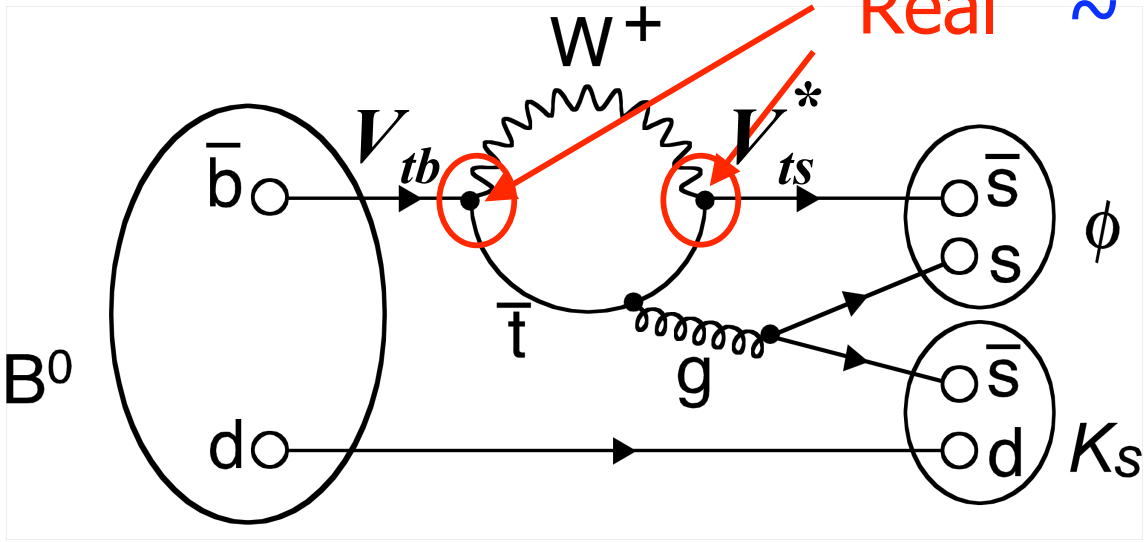
Measure Both — Decay **Vertex**

$\Delta z \propto \Delta t$

2001 !

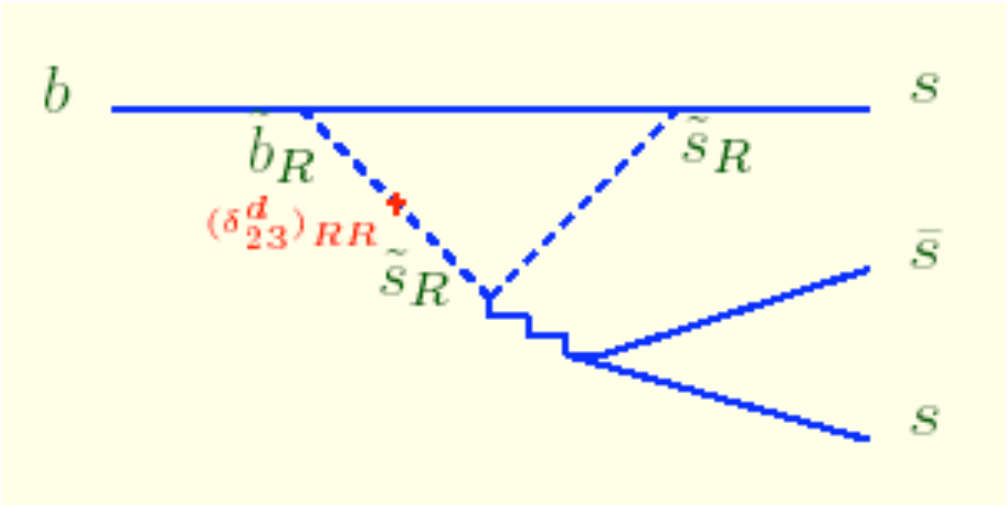
b → s Penguins (Vertex Loops)



SM (KM) Prediction

$$S_{fK_S} = \sin 2f_1$$

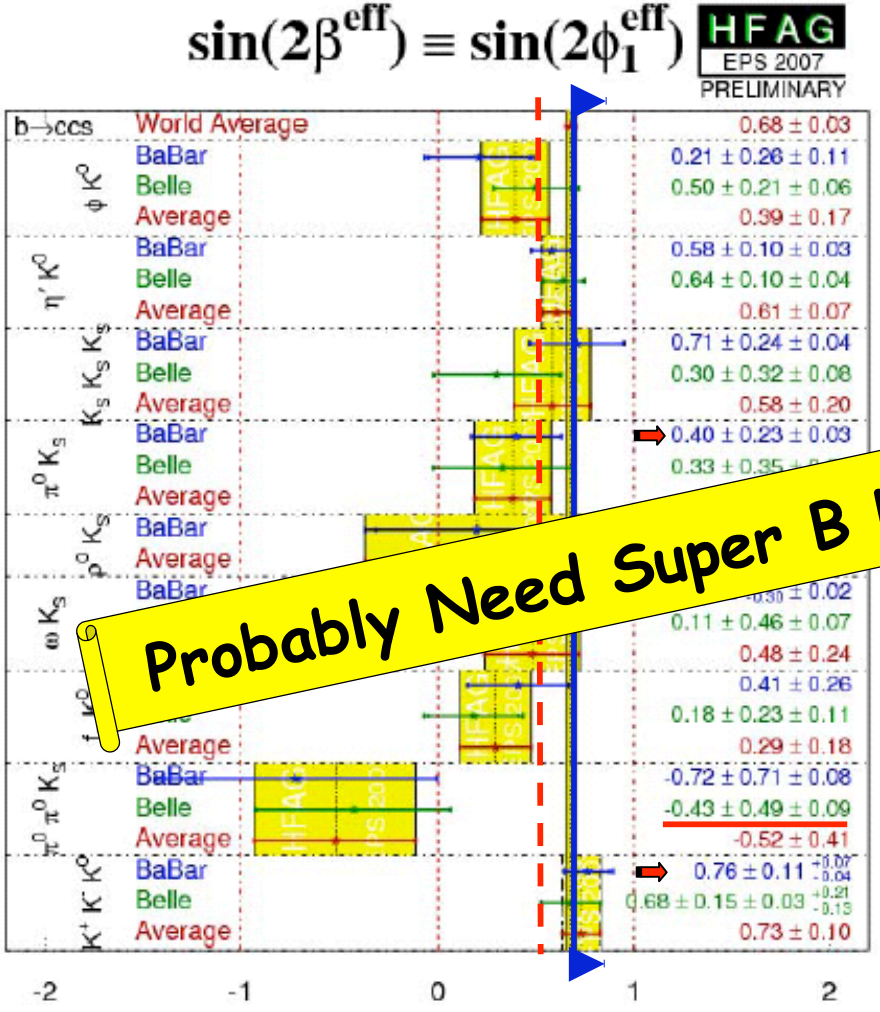
b



Possible SUSY FCNC/CPV Loop

Can Break Equality

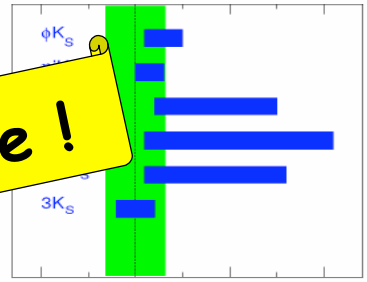
$DS = S_{sqq} - S_{ccs} < 0$ "Problem"



Smaller than $b \to c\bar{c}s$ in almost all modes

some of recent QCDF estimates

$\sin2\beta^{f}_{eff} - \sin2\beta$



Theory Expect

$\sin2f$ s-per

Probably Need Super B Factory to Resolve !

Naïve average of all b → s modes

$\sin2b^{eff} = \mathbf{0.56 \pm 0.05}$

2.1 s deviation (was 2.6) btwn b → sqq and b → ccs

New Physics !?

Need More Data !

Even deviation of ~ few deg indicate NP

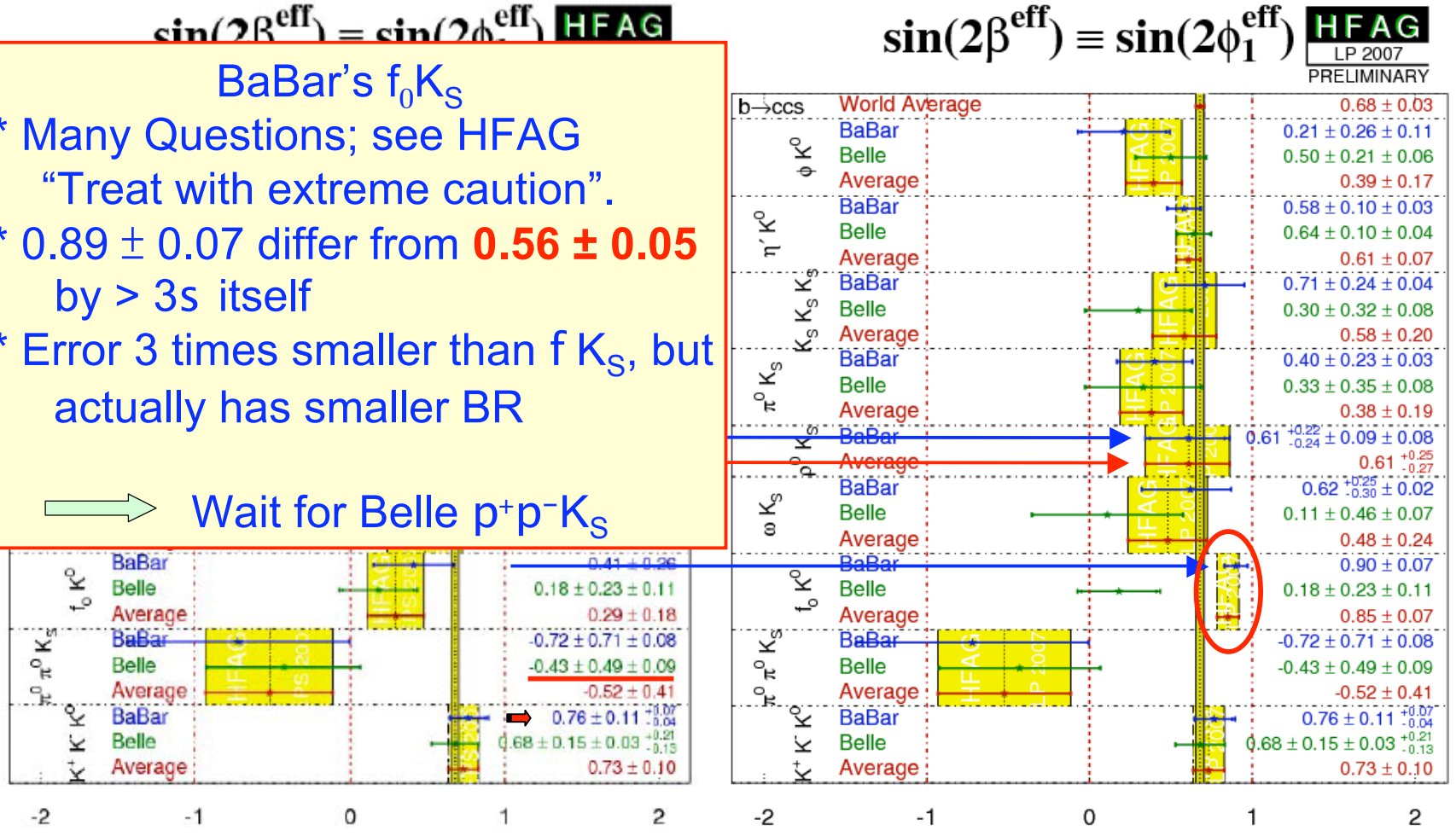
Sinha, Misra, WSH, PRL 97, 131802 (2006)

Further Diminshed?

BaBar's f_0K_S

* Many Questions; see HFAG
  "Treat with extreme caution".
* 0.89 ± 0.07 differ from **0.56 ± 0.05**
  by > 3s itself
* Error 3 times smaller than f K_S, but actually has smaller BR

⇒ Wait for Belle $p^+p^-K_S$



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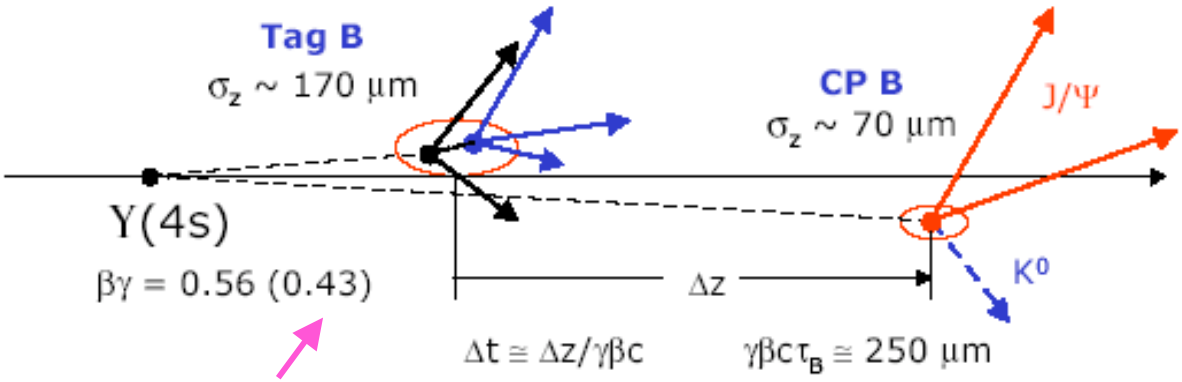


Bell
e

B^0 or $\bar{B}^0$

One B Decay — Tag Flavor

Other B Decay — CP Eigenstate — $J/\psi K_S$, 2001 ! — p^+p^-, $h'K_S$, f_0K_S, K_Sp^0

Measure Both — Decay **Vertex** — $\Delta z \propto \Delta t$

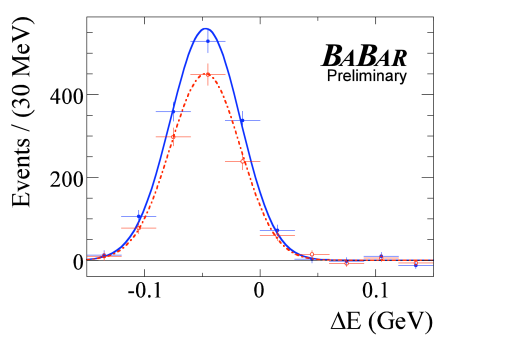
Lack of Vertex in LHCb

Acp on B → Kp

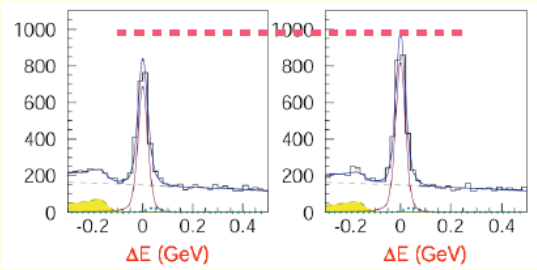
$D\mathcal{A}_{Kp}$ Problem

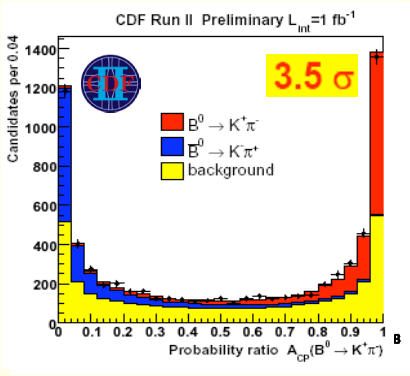
Experiment is Firm

$B \to K^{\pm}\pi^{\mp}$



Belle





Acp = $-0.107 \pm 0.018^{+0.007}_{-0.004}$ $-0.093 \pm 0.018 \pm 0.008$ $-0.086 \pm 0.023 \pm 0.009$

Direct CPV established in B system (2004) !

- World Average including CLEO: $A_{CP}(K^+\pi^-) = -0.097 \pm 0.012$
- $A_{CP}(K^+\pi^0) = +0.050 \pm 0.025 \Rightarrow$ $\Delta A(K\pi) = 0.147 \pm 0.027$ @5s
- Need to explain the deviation. Hadronic effect or new physics?
- $A(K^0\pi^0) = -0.12 \pm 0.11$; $S(K^0\pi^0) = +0.33 \pm 0.21$ $\Rightarrow$ Super B

0707.2980 [hep-ex] $A(K^0\pi^0) = -0.24 \pm 0.15 \pm 0.03$, $S(K^0\pi^0) = 0.40 \pm 0.23 \pm 0.03$

Why $D\mathcal{A}_{Kp} = \mathcal{A}_{K^+p^0} - \mathcal{A}_{K^+p^-} > 0$ a Puzzle ?

-9.7 ± 1.2 % $+4.7\pm2.6$ %

$$\mathcal{M}(B^0 \to K^+\pi^-) \propto (T + P) = re^{i\phi_3} + e^{i\delta}$$

$$\sqrt{2}\mathcal{M}_{K^+\pi^0} - \mathcal{M}_{K^+\pi^-} \propto (P_{EW} + C) \; ?$$

$$r = \frac{\text{}}{\text{}}$$

$D\mathcal{A}_{Kp}$ ~ 0 expected

C: color-suppressed tree (a_2)

P_{EW}: EW penguin $(a_{7,9})$

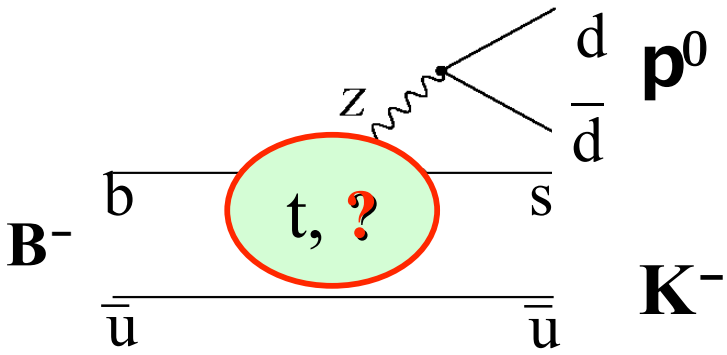
Large C ? → **Suppress Tree CPV Phase**

C/T > 1 needed !

Baek, London, PLB653, 249 (2007)

Large EWPenguin ? → **Need NP CPV Phase**

EWP not so easy for SUSY



$\because P_{EW}$ and T ≈ same strong phase in SM

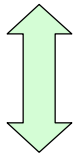
Neubert, Rosner, PRL'98

In Search of New Physics

b ↔ s CPV Phenomena Is Current NP Frontier

Two Hints

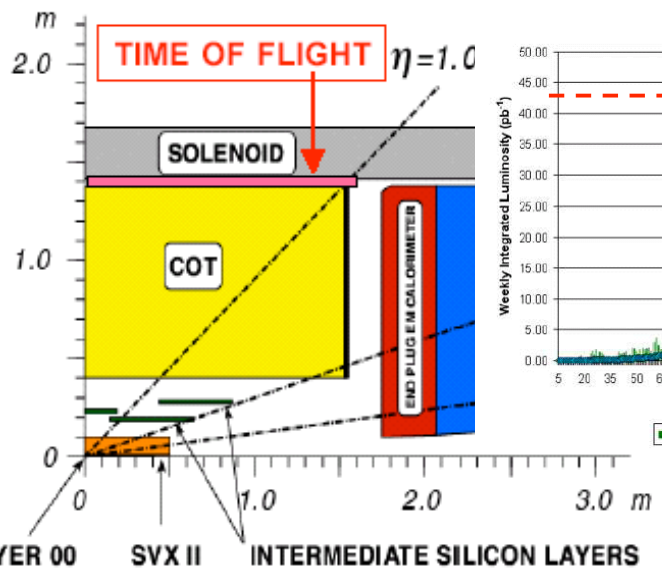
- $\mathcal{S}_f$ in $b \to sqq$ (?) — **TCPV** Mixing-dep.
- $\mathcal{A}_{K^+\pi^-} - \mathcal{A}_{K^+\pi^0}$ Puzzle — **DCPV** Direct

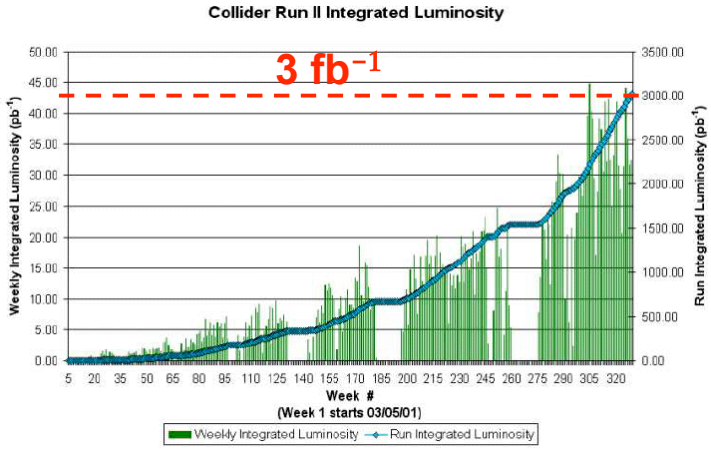


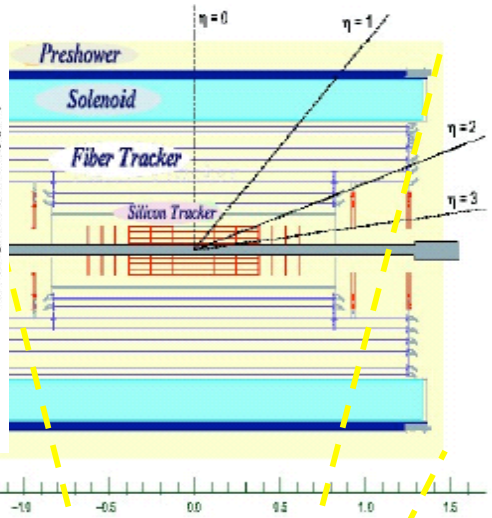
- Δm_{B_s}
- $\Delta\Gamma_{B_s}$

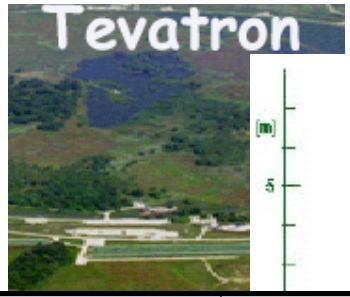
SM-like

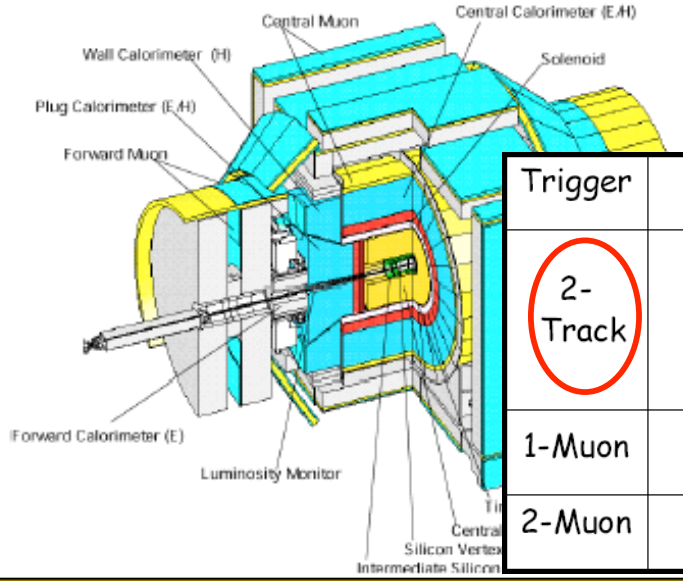
CPV ? $\sin 2\phi_{B_s}$ $\cos 2\phi_{B_s}$



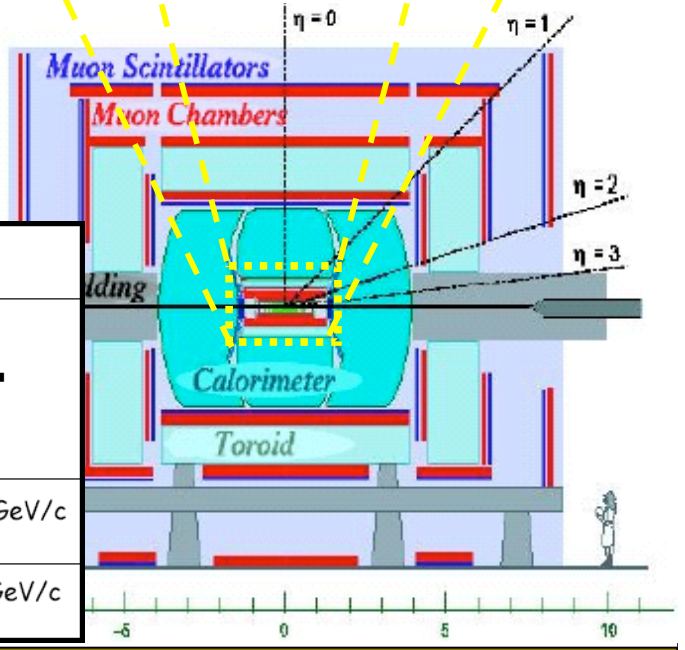








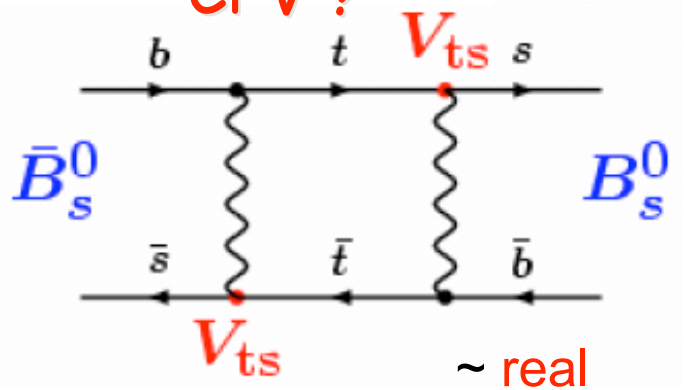
Trigger	CDF	DØ
2-Track	p_T > 2.0 GeV/c $p_{T1}+p_{T2}$ > 5.5 GeV/c 100 μm<$\lvert d_{1,2}\rvert$< 1 mm	—
1-Muon	—	p_T (μ)>3,4,5 GeV/c
2-Muon	p_T(μ's) > 1.5 GeV/c	p_T(μ's)>2.0 GeV/c



SM $F_{B_s} \equiv -\arg V_{ts} \sim -0.02$ Window on BSM

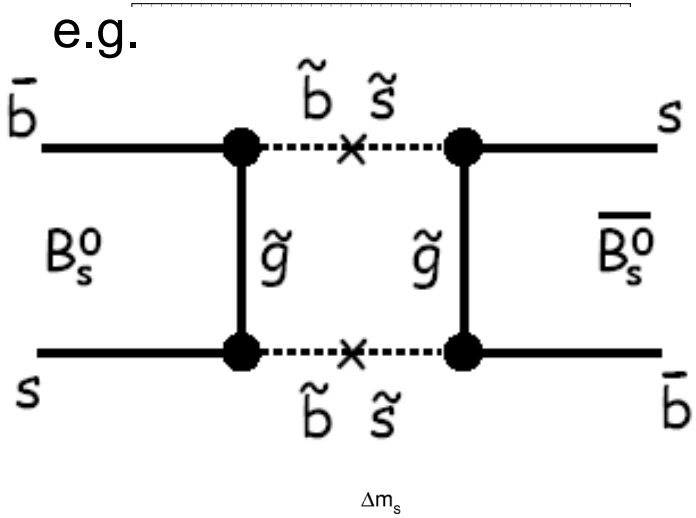
$b/f_1 = -\arg V_{td} \Rightarrow F_{B_d} \sim 0.37$ measured

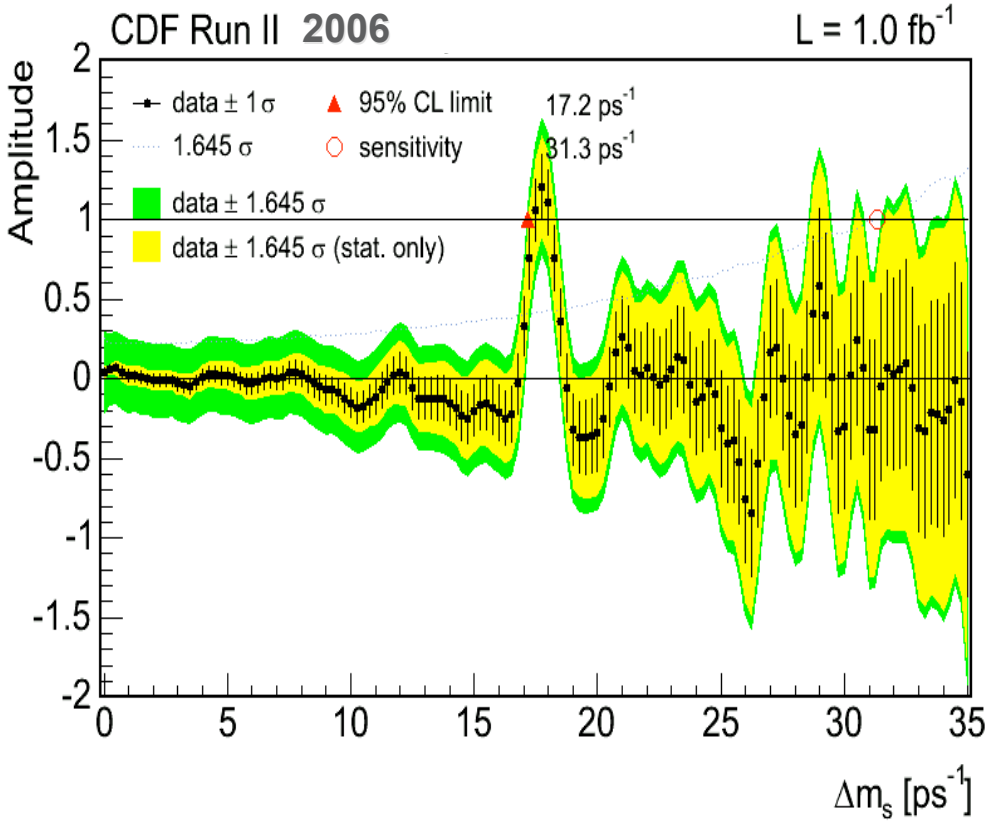
CPV ?



$$V_{us}V_{ub}^* + V_{cs}V_{cb}^* + V_{ts}V_{tb}^* = 0$$

e.g.





PRL 97, 242003 (2006)

$\Delta m_s = 17.77 \pm 0.10\,(\text{stat}) \pm 0.07\,(\text{sys})\ \text{ps}^{-1}$

a bit "smallish", if take nominal f_{B_s}

$\Delta\Gamma_s$ and ϕ_s from $B^0_s \to J/\psi\phi$

$\Delta\Gamma_s = \Gamma_L - \Gamma_H = \Delta\Gamma_{CP} \times \cos(\phi_s)$ very sens. to NP $\cos 2\mathbf{F}_{B_s}$

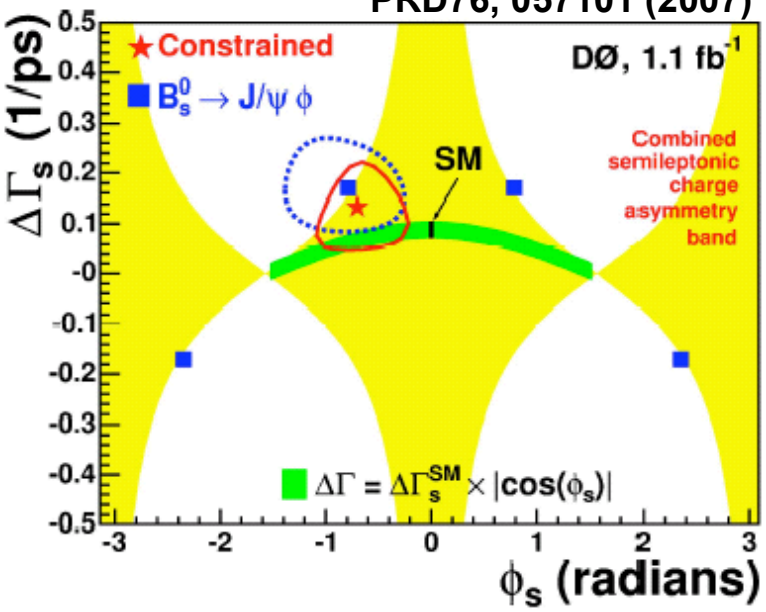
Lifetime, but not Oscillations

PRL 98, 121801 (2007) + hep-ex/0701012 (A_{SL})

Concerted DØ Effort

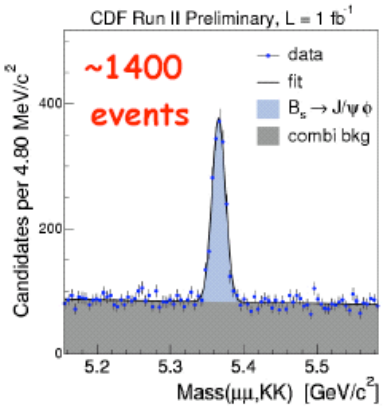
[A_{SL} advantage
— periodical reversal
of magnet polarity

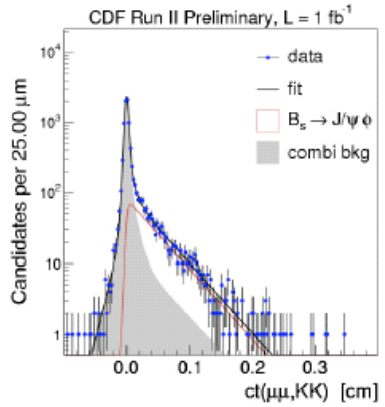
PRD76, 057101 (2007)



SM: Lenz, Nierste, JHEP 0706, 072 (2007)

For pheno digest,
see WSH, Mahajan, PRD 75, 077501 (2007)





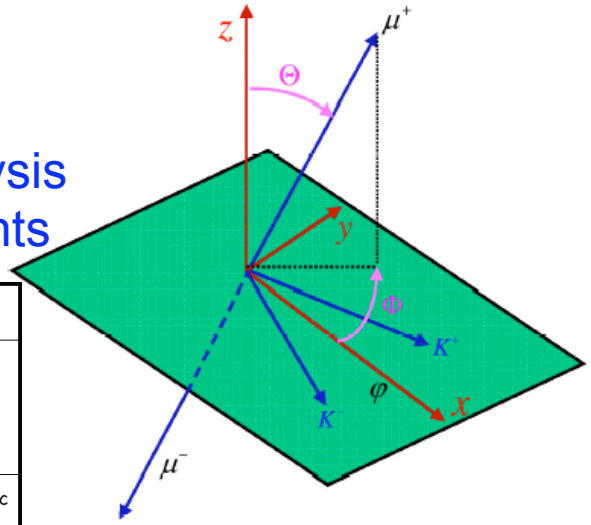
$\cos 2\mathbf{F}_{B_s}$ somewhat a blunt instrument.

CDF update on 1 fb^{-1} in progress

F_{B_s} Prospect (short term)

$B_s \to J/\psi\phi$ analogous to $B_d \to J/\psi K_S$

VV ⇒ Vertex & Angular Resolved Analysis to disentangle CP +/− components



Trigger	CDF	DØ
2-Track	p_T > 2.0 GeV/c $p_{T1}+p_{T2}$ > 5.5 GeV/c 100 μm<$\|d_{1,2}\|$< 1 mm	—
1-Muon	—	p_T (μ)>3,4,5 GeV/c
2-Muon	p_T(μ's) > 1.5 GeV/c	p_T(μ's)>2.0 GeV/c

- CDF/DØ : 8 fb^{-1} projected

  $\mathbf{S}(\sin 2\mathbf{F}_{B_s})$ ~ 0.2 (?)/exp

  similar

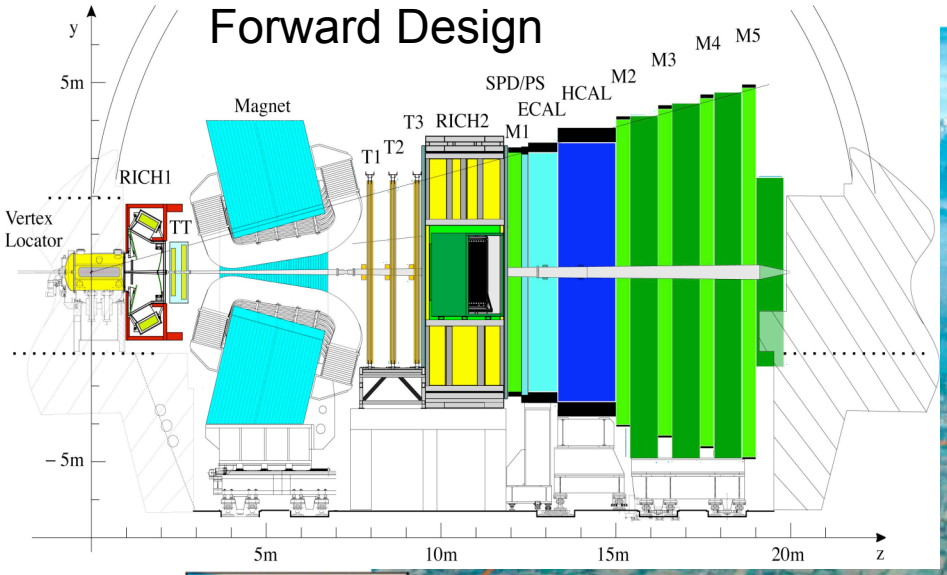
- LHCb : 0.5 fb^{-1} (2008 ?)

  $\mathbf{S}(\sin 2\mathbf{F}_{B_s})$ ~ 0.04

- ATLAS : 2.5 fb^{-1} (2008 ?)

  $\mathbf{S}(\sin 2\mathbf{F}_{B_s})$ ~ 0.16 Nakada @ fLHC 3/07

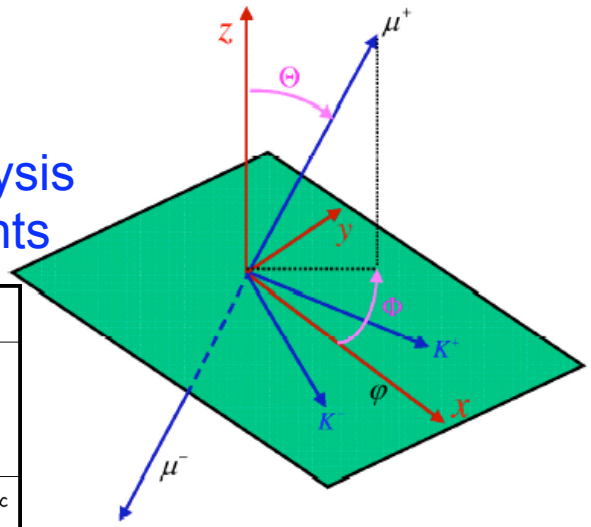
LHC Physics Run Starts 2008



F_{B_s} Prospect (short term)

$B_s \to J/\psi\phi$ analogous to $B_d \to J/\psi K_S$

VV ⇒ Angular & Vertex Resolved Analysis to disentangle CP +/− components



- CDF/DØ: 8 fb^{-1} projected

  $\mathbf{S}(\sin 2\mathbf{F}_{B_s}) \simeq$ 0.2 (?)/exp

  similar

Trigger	CDF	DØ
2-Track	p_T > 2.0 GeV/c $p_{T1}+p_{T2}$ > 5.5 GeV/c 100 μm<$\|d_{1,2}\|$< 1 mm	—
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- LHCb: 0.5 fb^{-1} (2008 ?)

  $\mathbf{S}(\sin 2\mathbf{F}_{B_s}) \simeq$ 0.04

- ATLAS: 2.5 fb^{-1} (2008 ?)

  $\mathbf{S}(\sin 2\mathbf{F}_{B_s})$ ~~Nakada~~ 0.1 @ fLHC 3/07

€ LHCb the winner if ~ SM

$\sin 2\mathbf{F}_{B_s} \sim -0.04$ in SM

But 2009 looks interesting !

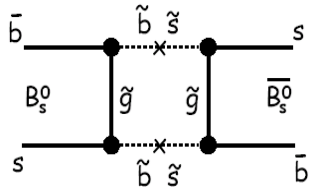
$ Tevatron could get lucky

if $\sin 2\mathbf{F}_{B_s}$ *large* ⟺ *New Physics !*

Could Tevatron run beyond 2008 ?

In Search of New Physics

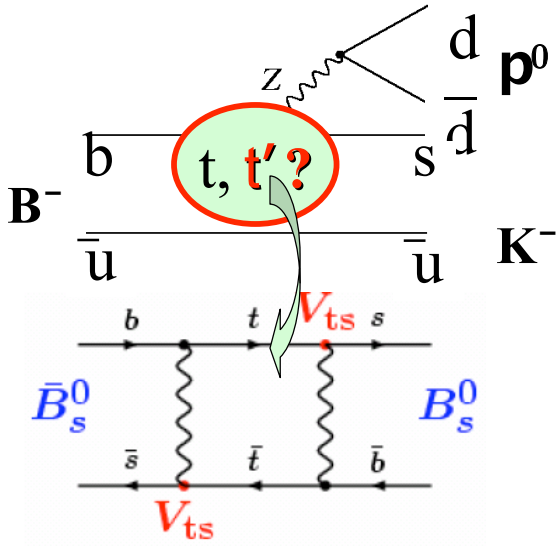
Can $\sin 2\phi_{B_s}$ be *large*?



b ↔ s CPV Phenomena Is Current NP Frontier

Two Hints

- S_f in $b \to sqq$
- $A_{K^+\pi^-} - A_{K^+\pi^0}$ Puzzle



- Δm_{B_s}
- $\Delta\Gamma_{B_s}$

↕

EWPenguin

t′ non decoupled

Boxes

SM-like

TCPV Mixing-dep.

DCPV Direct

WSH, Nagashima, Soddu, PRL'05

WSH, Nagashima, Soddu PRD76, 016004 (2007)

$\sin 2\phi_{B_s} \sim -0.5 - -0.7$ in SM4

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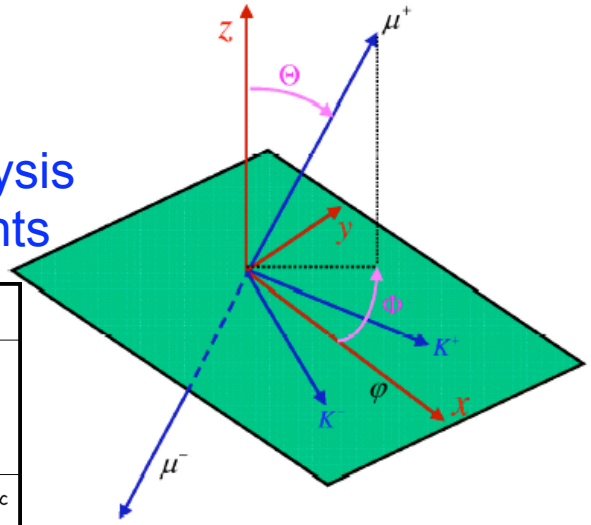

- CDF/DØ: 8 fb^{-1} projected

  $\mathbf{S}(\sin 2F_{B_s}) \simeq$ 0.2 (?)/exp

  similar

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  $\mathbf{S}(\sin 2F_{B_s})$ 0.1 Nakada @ fLHC 3/07

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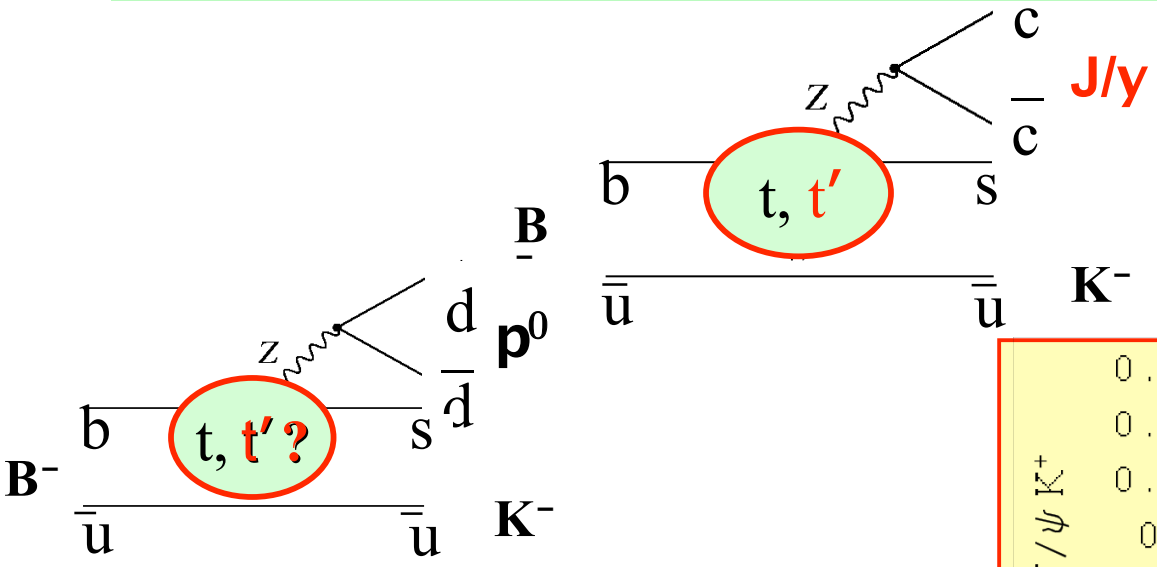
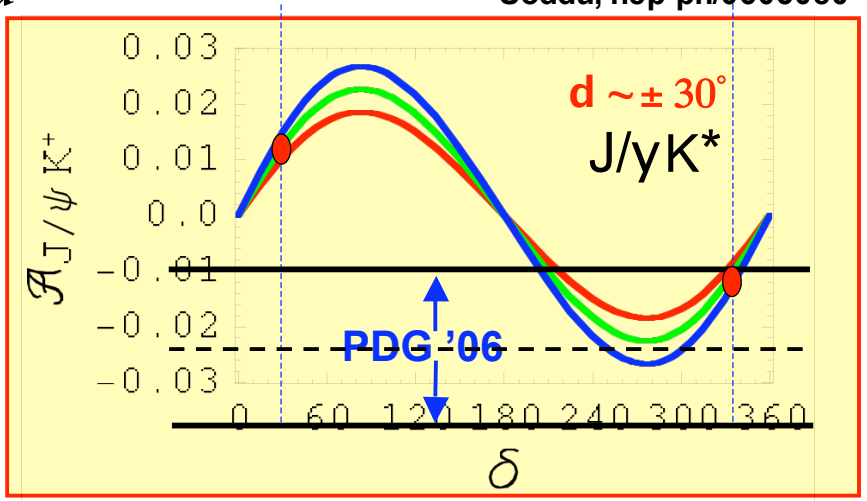


lack firm SM prediction

DCPV in $B^+ \to J/\psi K^+$?



Prognosis for $\mathcal{A}_{J/\psi K^+}$ Measurement

PDG '07

$A_{CP}(B^+ \to J/\psi(1S)K^+)$

VALUE		DOCUMENT ID		TECN	
0.015±0.017 OUR AVERAGE		Error includes scale factor of 1.2.			
+ 0.030±0.014±0.010	124M	636 AUBERT	05J	BABR	
− 0.026±0.022±0.017	32M	ABE	03B	BELL	
0.018±0.043±0.004	10M	577 BONVICINI	00	CLE2	
• • We do not use the following data for averages, fits, limits,					
0.03 ±0.015±0.006		AUBERT	04P	BABR	
0.003±0.030±0.004	89M	AUBERT	02F	BABR	

636 The result reported corresponds to $-A_{CP}$.

flipped back

ICHEP06: $\mathcal{A}_{J/\psi K^0}$ **0.018 ± 0.021 ± 0.014 Belle**
−0.07 ± 0.028 ± 0.018 BaBar

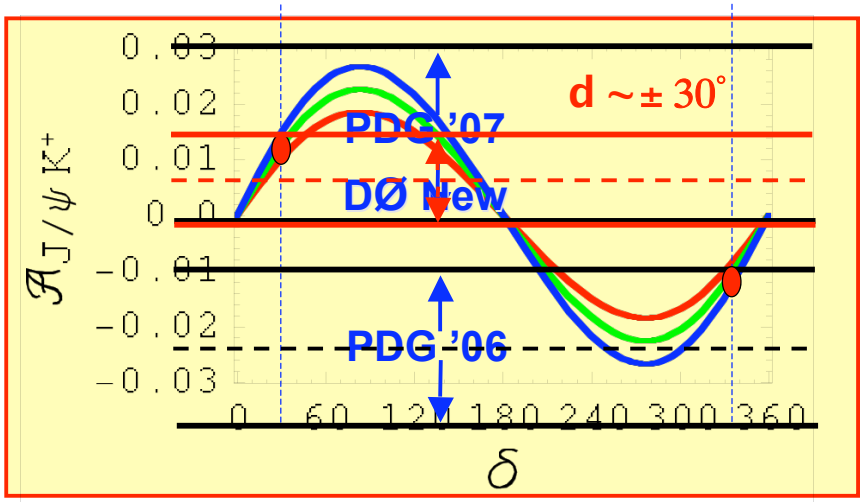
BaBar/Belle Please Update !

- $\mathcal{A}_{J/\psi K^+}$ is getting serious: careful studies started
- Systematics Study becomes future Theme
  — Needed towards SuperB !!

Could be seen by 2008 ?! **Better than $\mathcal{D}A$ and $\mathcal{D}S$?**

$\mathcal{A}_{J/\psi K^+}$: Calibration Mode turns Active

H^+ effect of Wu, Soni PRD'00 Ruled Out



WSH, Nagashima, Soddu, hep-ph/0605080

test (+CDF)

±0.0033 @ **8** fb^{-1}

DØnote 5405-CONF **1.6** fb^{-1}

+0.0067 ± 0.0074 ± 0.0026

- $\mathcal{A}_{J/\psi K^+}$ is getting serious: Tevatron!
- Larger Statistics (so just you wait for LHCb)
- Better Systematics: Large Control Sample

Correct for $K^\pm$ asymm.
+0.0139±0.0013±0.0004

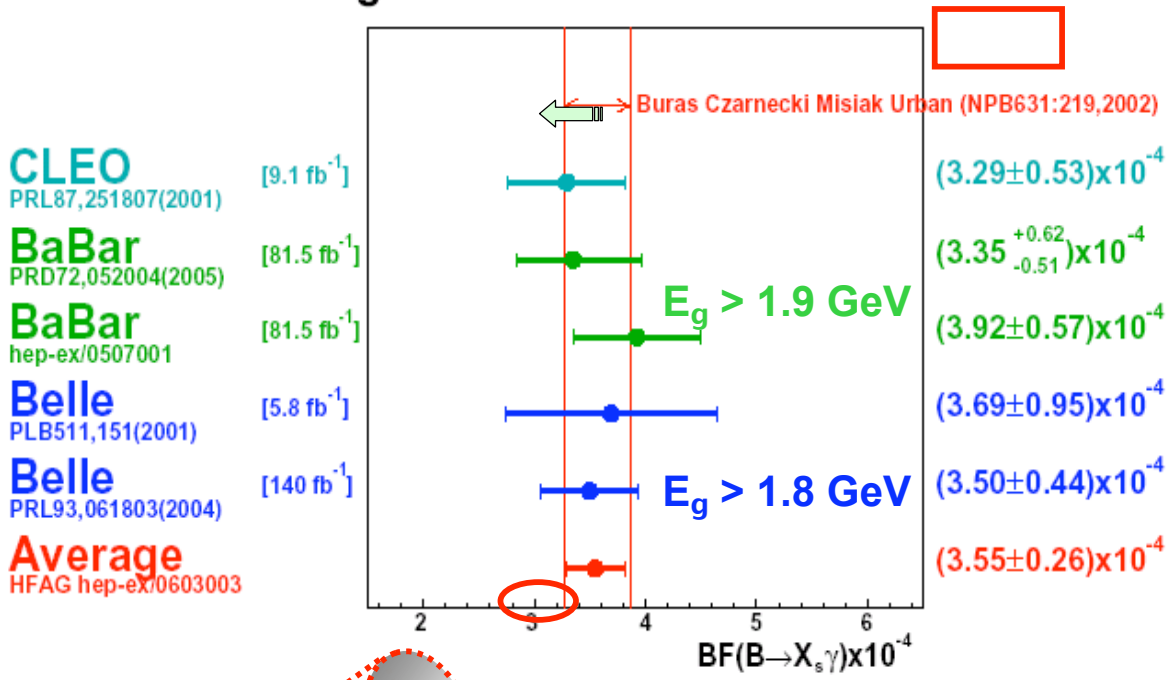
matter effect

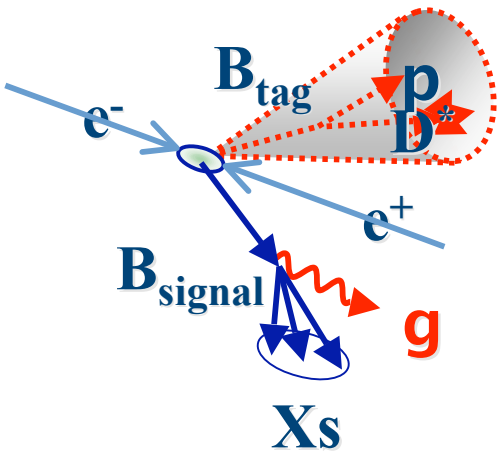
II. H^+ Probes

- $b \to s g$
- $B \to (D^{(*)}) t n$

$b \to sg \sim B \to X_s g$

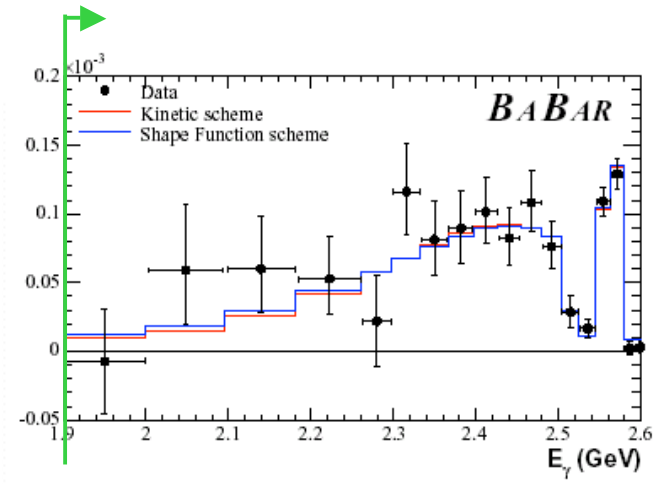
Status of branching fraction measurements

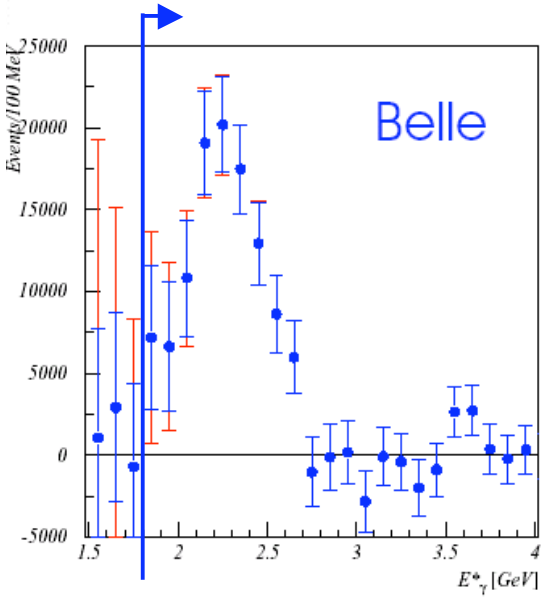




TH still unfinished, but ball in Exp court.

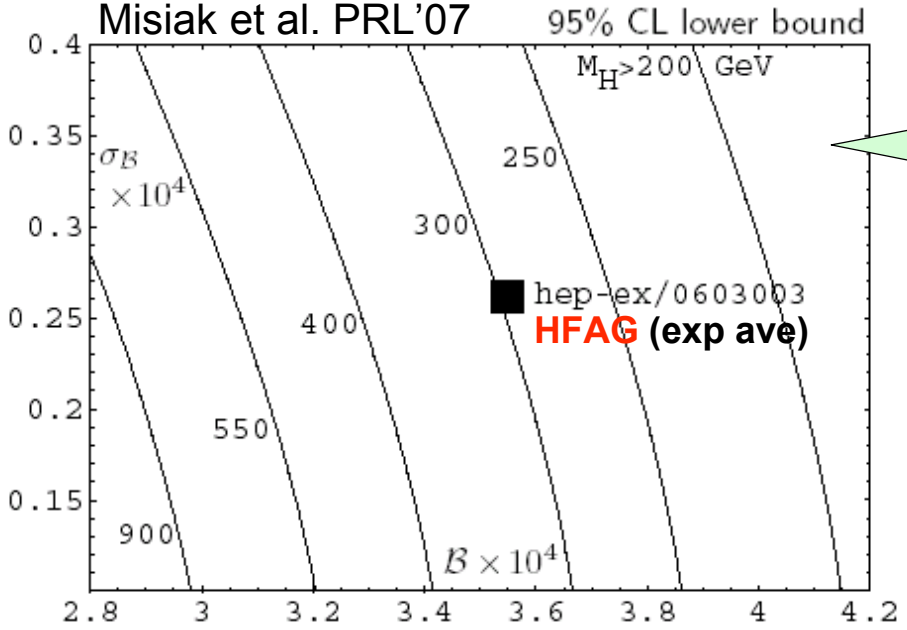
Full Reconstruct other B?



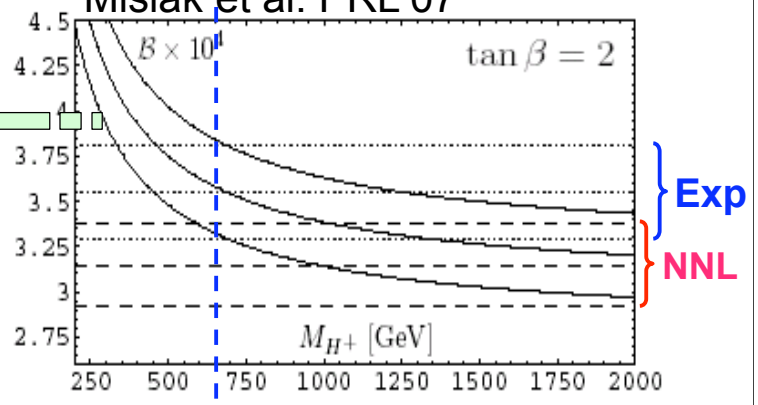


Constraint from b → sg on H^+

Misiak et al. PRL'07

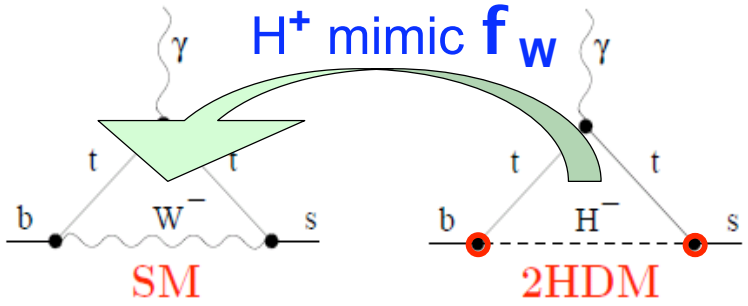


Misiak et al. PRL'07

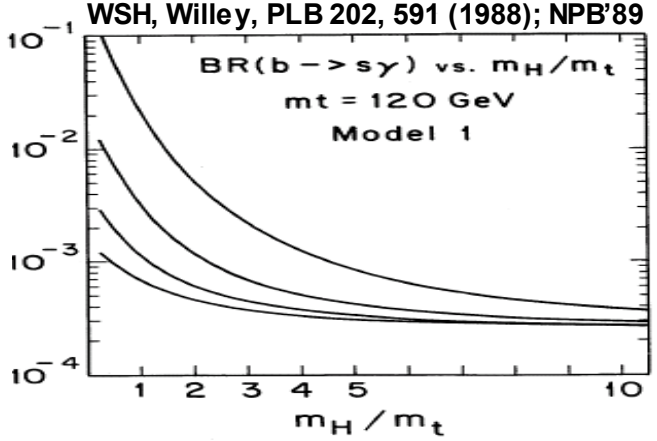


Current NNLO < Exp !
⇒ bound of 295 GeV
⇒ favor 650 GeV !?

MSSM type H^+ ***always enhance*** b → s g
regardless of tanb



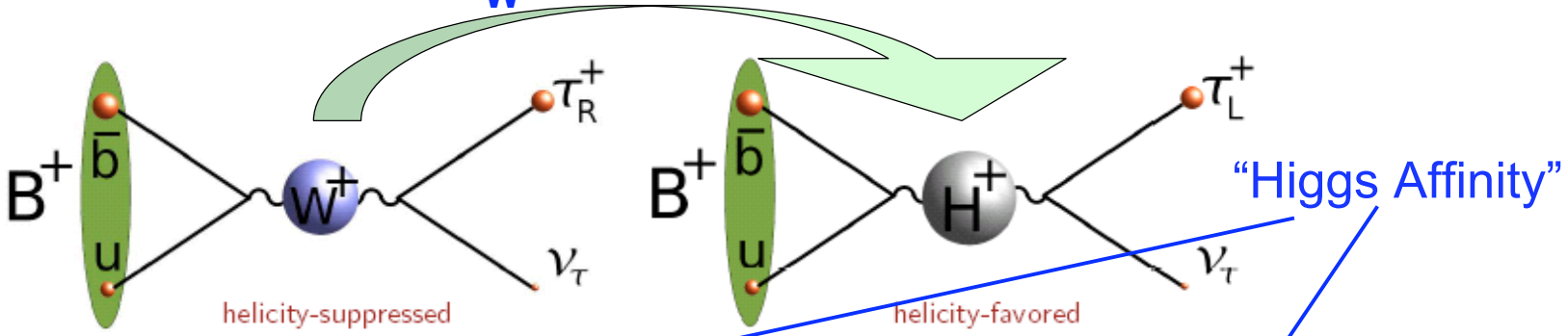
WSH, Willey, PLB 202, 591 (1988); NPB'89



Also Grinstein, Wise, PLB'88

$B \to \tau \nu$ Amazing: Tree level H^+ Effect

f_W the cousin of H^+

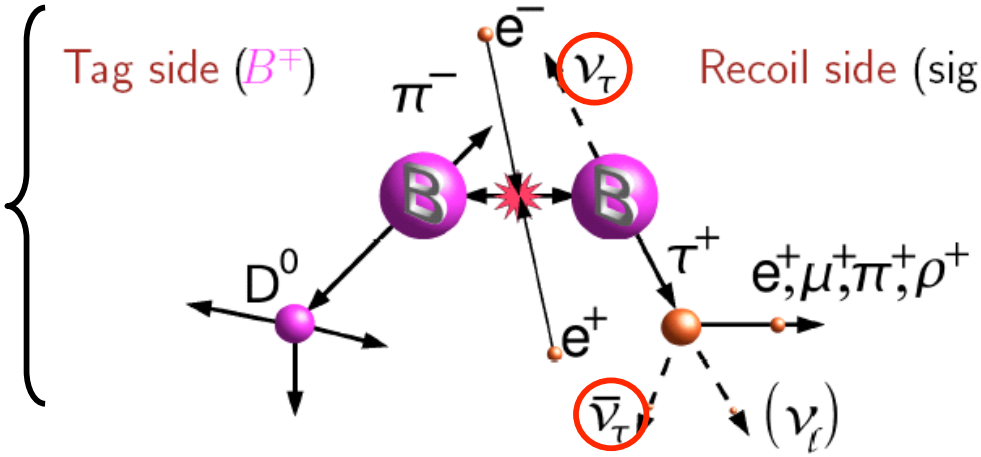


"Higgs Affinity"

W.-S.Hou (1992), **PRD48, 2342 (1993)**

$$\mathcal{B} = \frac{G_F^2 m_B m_\tau^2}{8\pi}\left[1-\frac{m_\tau^2}{m_{B^+}^2}\right]^2 \tau_{B^+} f_B{}^2 |V_{ub}|^2 \underbrace{\left[1-\tan^2\beta\,\frac{m_{B^+}^2}{m_{H^+}^2}\right]^2}_{r_H}$$

Trick/Cost:
Full Reconstruct
Tag side B
@ 0.1~0.3%



Two **n**'s

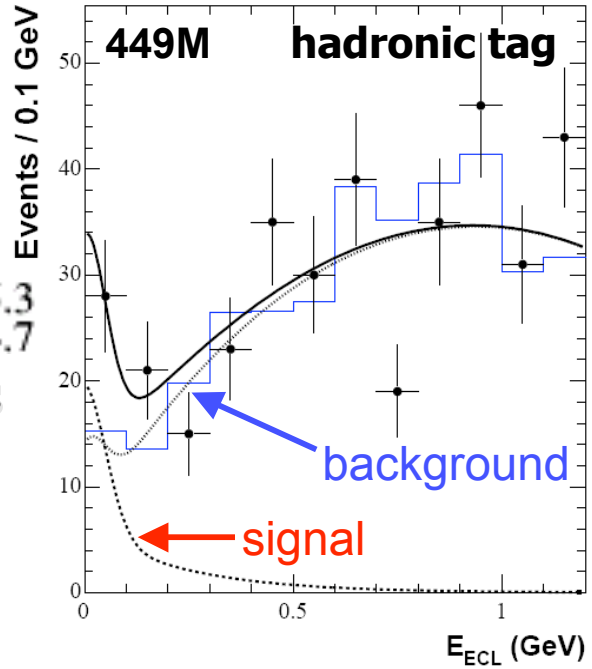
⇨ BG !!

SM expectation: $\mathcal{B} \sim (1.6 \pm 0.4) \times 10^{-4}$

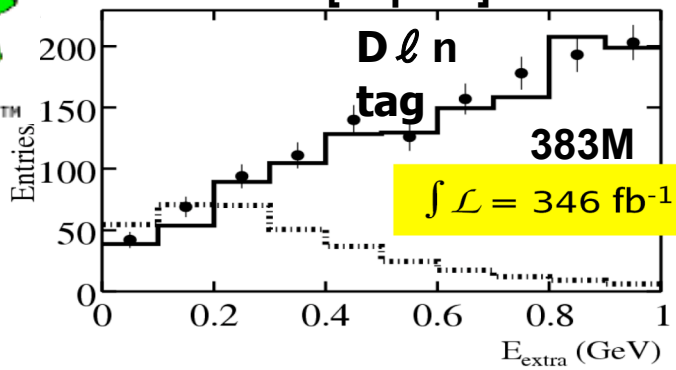
$f_B |V_{ub}| \sim 1.005$ MeV

0705.1820 [hep-ex]

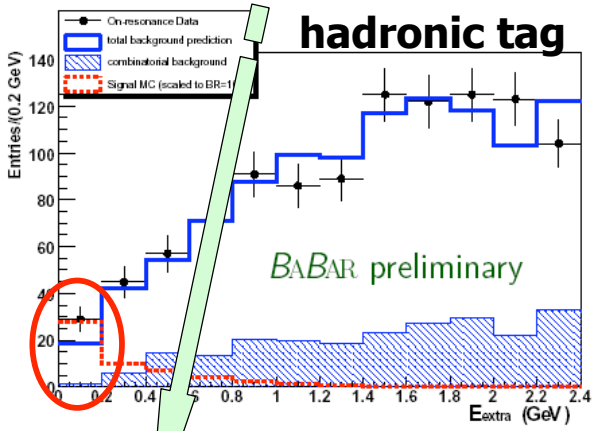
PRL97, 251802 (2006).



$17.2^{+5.3}_{-4.7}$ evts



$(0.9^{+0.6}_{-0.5} \pm 0.1) \times 10^{-4}$

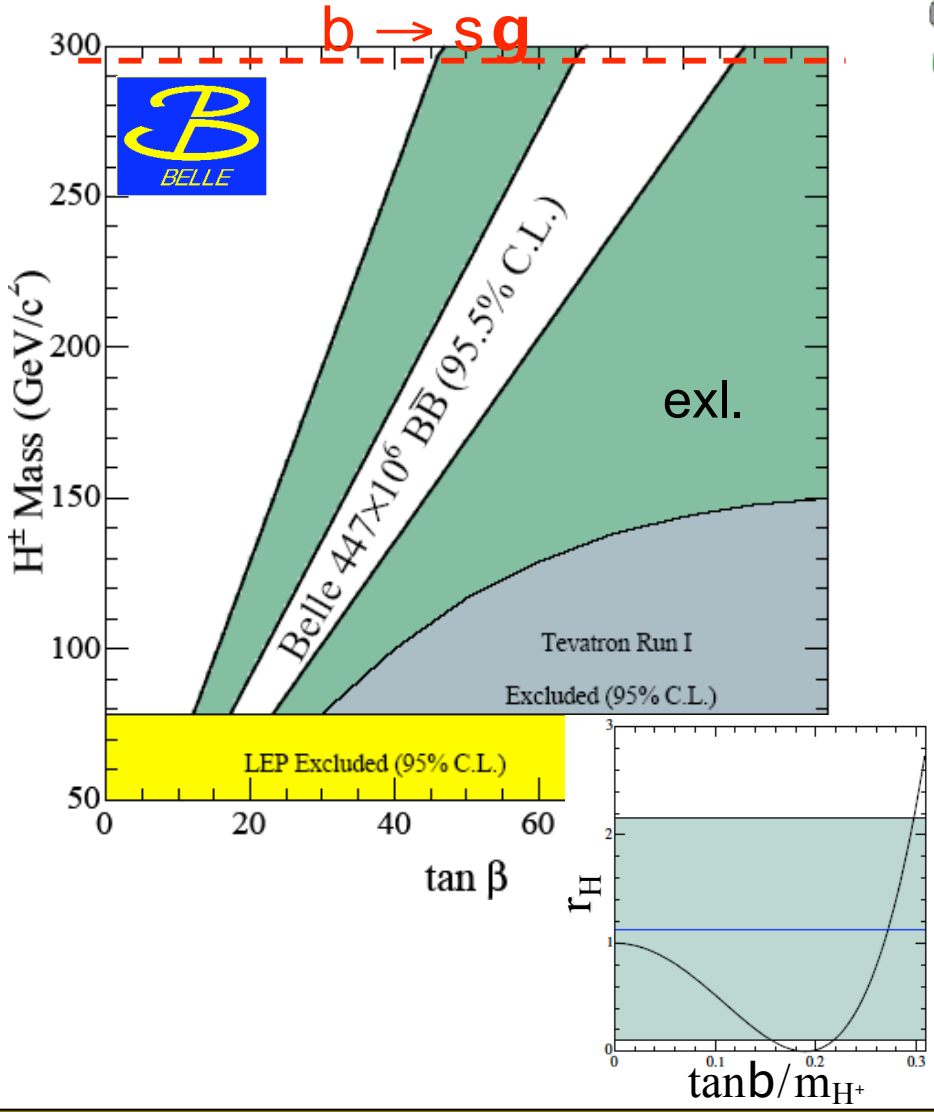


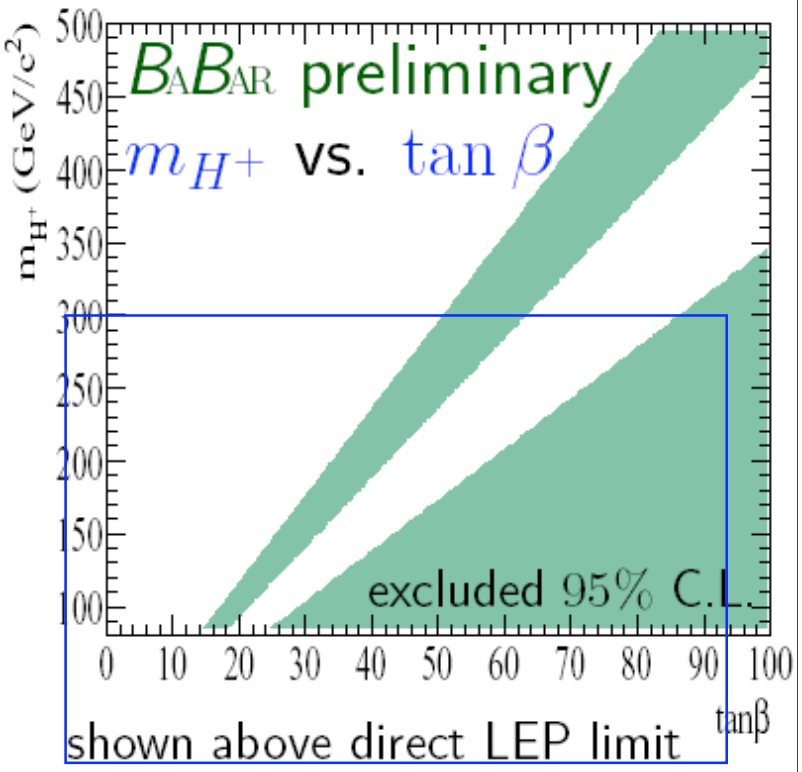
First evidence, 3.5 s

2.6 s

$(1.79^{+0.56+0.46}_{-0.49-0.51}) \times 10^{-4}$ ~ $(1.2 \pm 0.4^{stat} \pm 0.3^{bkg} \pm 0.2^{eff}) \times 10^{-4}$

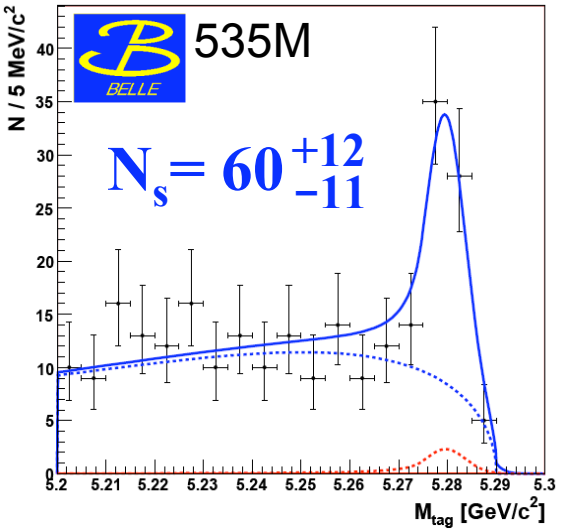
Constraint from B → t n on H^+





Measurement of $B \to D^{(*)}\tau\nu$

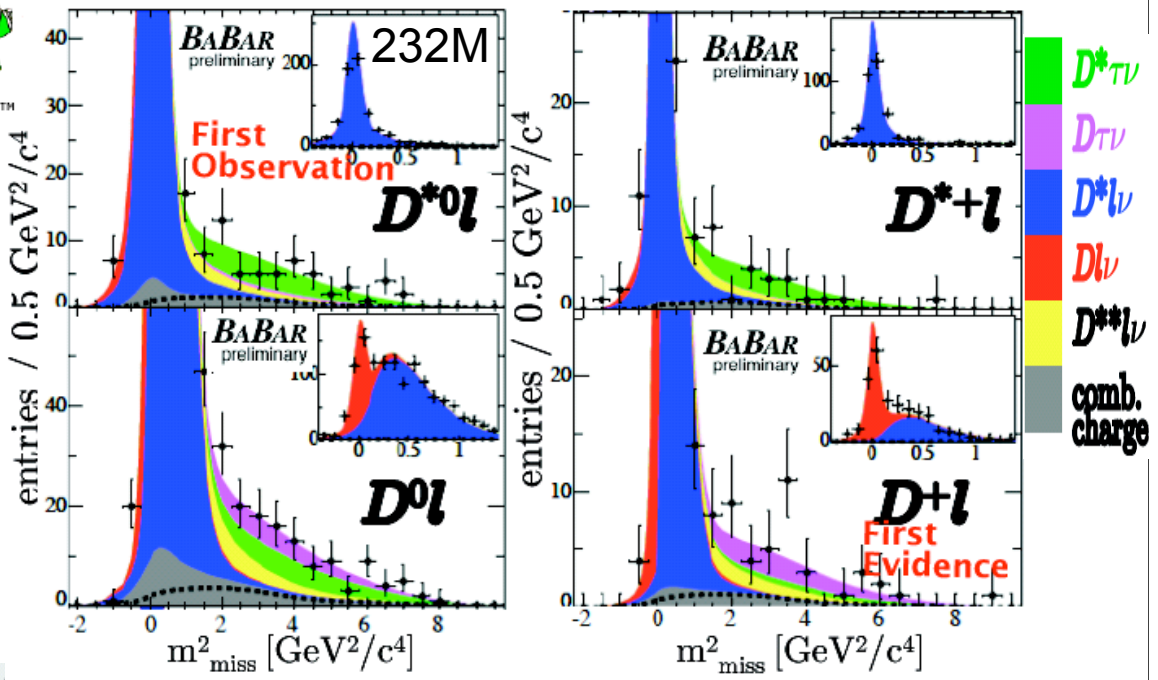
H⁺ sensitive



0706.4429 [hep-ex]
to appear in PRL

SM~1.4 %

$$\mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau) = (2.02^{+0.40}_{-0.37} \pm 0.37)\%$$



0707.2758 [hep-ex]

First observation 5.2 s

Curious: 2%, now ...

More TH (SM) needed for BSM interpretation [polarizations]

preliminary

$N_s \sim 65$

Mode	$\mathcal{B}$[%]	sys.	norm.	sign.
$D\tau\nu$	$0.90 \pm 0.26 \pm 0.11 \pm 0.06$			3.5
$D^*\tau\nu$	$1.81 \pm 0.33 \pm 0.11 \pm 0.06$			6.2

First Evidence for $B \to D\tau\nu$

First Observation of $B^- \to D^{*0}\tau\nu$

BABAR $N_s \sim 105$

Verena Klose - TU Dresden 14

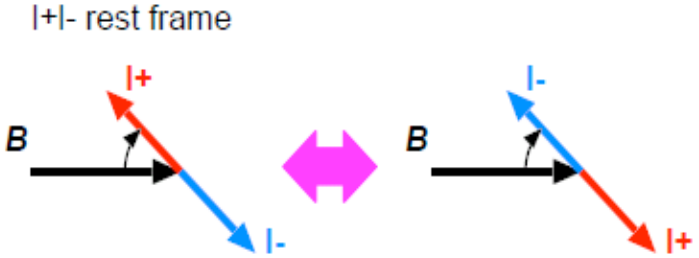
@ EPSHEP07 "V_{cb}" talk

III. Electroweak Penguin

- $A_{FB}(B \to K^* \ell\ \ell)$
- $B \to K^{(*)} \nu\nu$

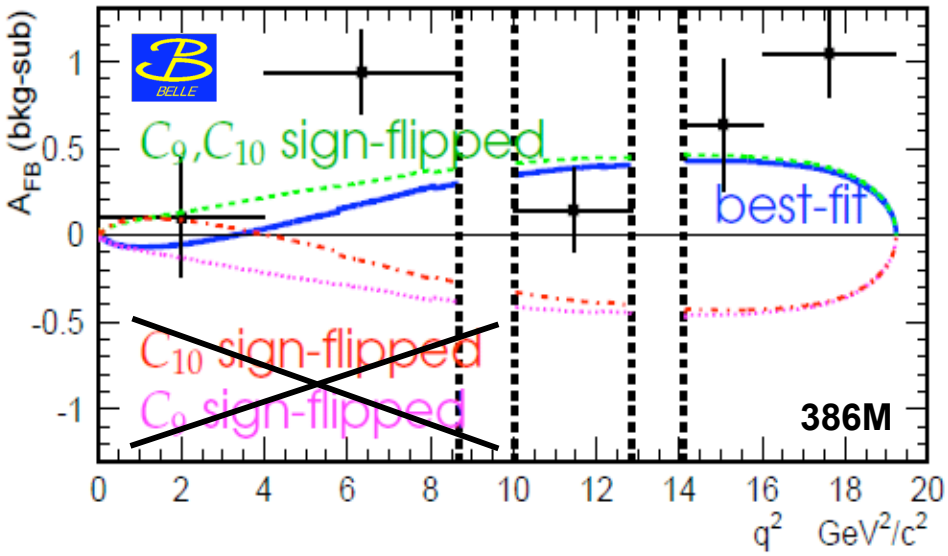
$A_{FB}(B \to K^*\ell^+\ell^-)$

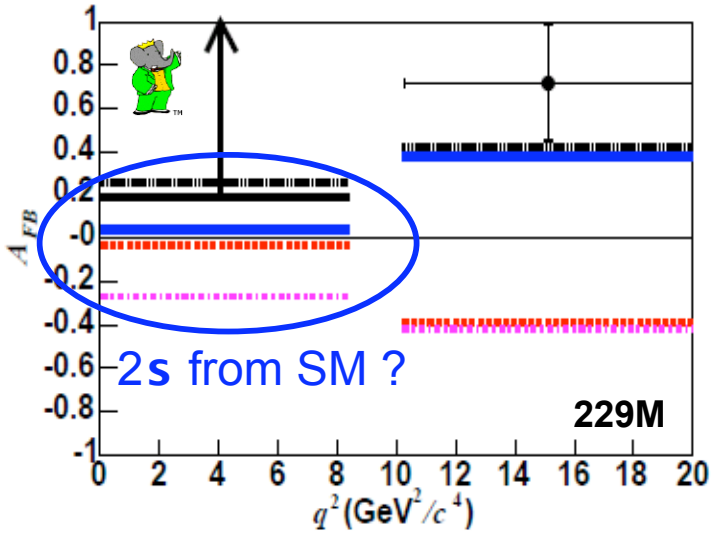
Forward-backward asymmetry (A_{FB}) in $b \to s\ell^+\ell^-$ due to interference between γ and weak couplings



$$A_{FB}(B \to K^*\ell^+\ell^-) = -C_{10}\xi(q^2)\left[Re(C_9)F_1 + \frac{1}{q^2}C_7F_2\right]$$

Ali, Mannel, Morozumi, PLB273, 505 (1991)

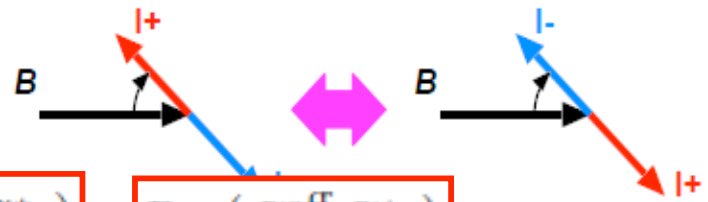




$A_{FB}(B \to K^* \ell^+ \ell^-)$

No Reason ***a priori*** why C_7, C_9, C_{10} should be Real

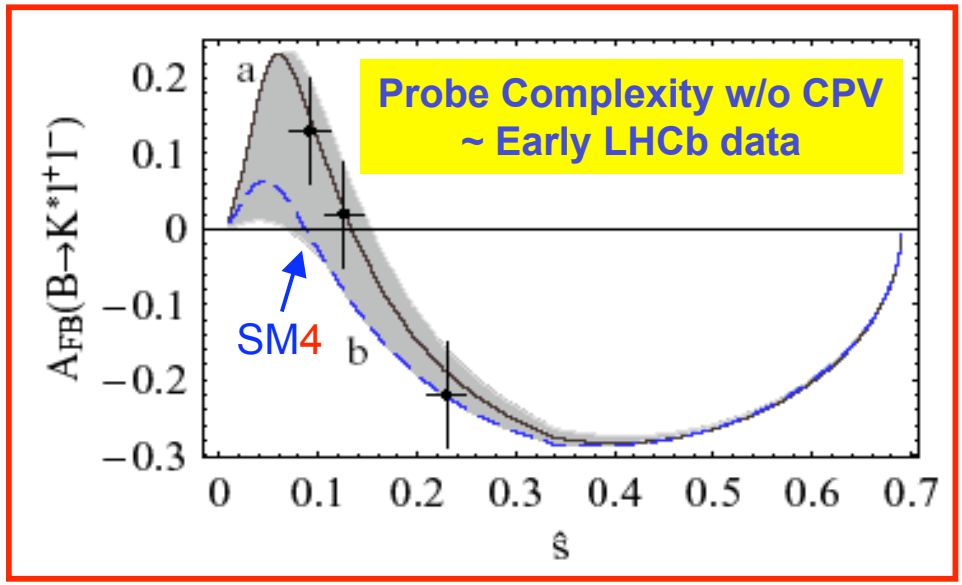
Forward-backward asymmetry (A_{FB}) in $b \to s\ell^+\ell^-$ due to interference between γ and weak couplings



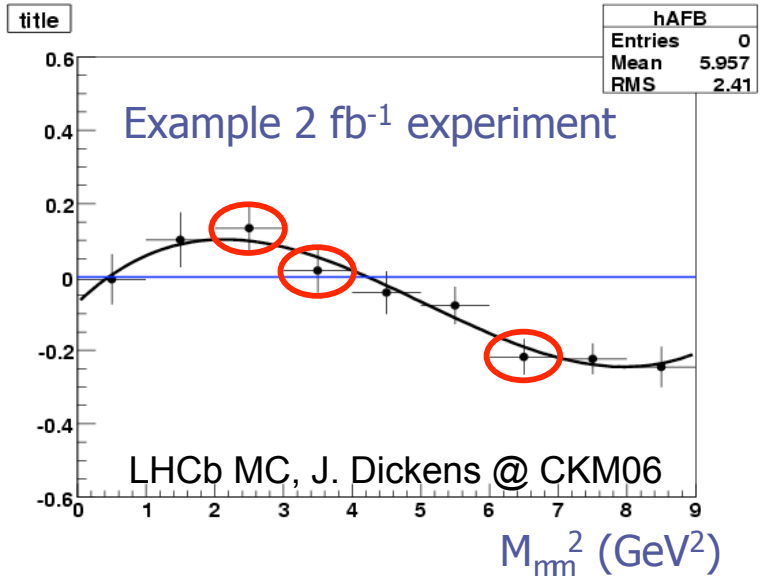
$$\mathrm{Re}\left(C_9^{\mathrm{eff}} C_{10}^*\right) \qquad \mathrm{Re}\left(C_7^{\mathrm{eff}} C_{10}^*\right)$$

$$A_{FB}(B \to K^* \ell^+ \ell^-) = -C_{10}\xi(q^2)\left[Re(C_9)F_1 + \frac{1}{q^2}C_7 F_2\right]$$

Hovhannisyan, WSH and Mahajan, hep-ph/0701046



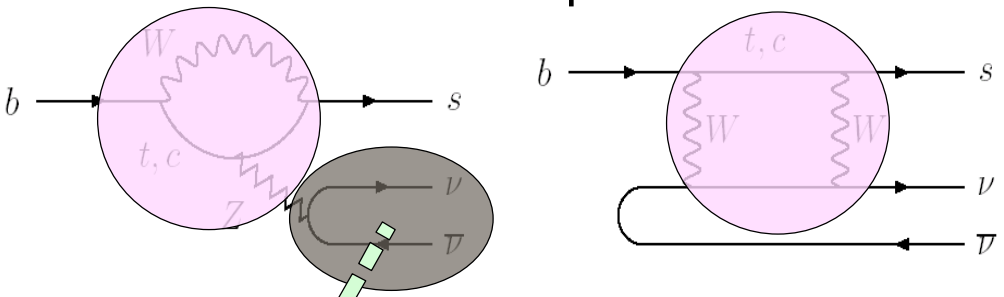
Ali, Mannel, Morozumi, PLB273, 505 (1991)

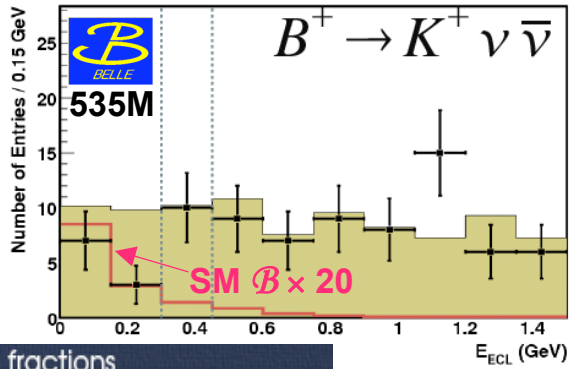


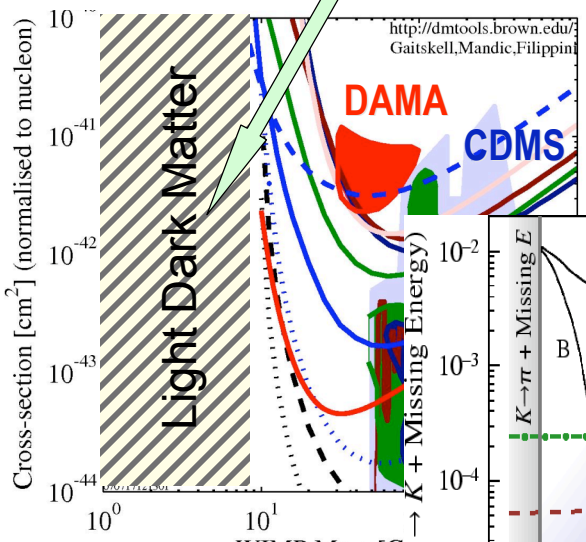
$B \to K^{(*)} \nu\bar{\nu}$

0707.0138 [hep-ex]

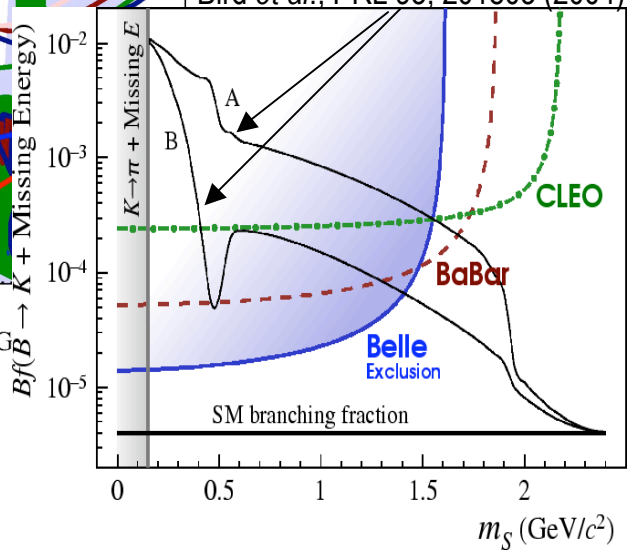
Probe Loop

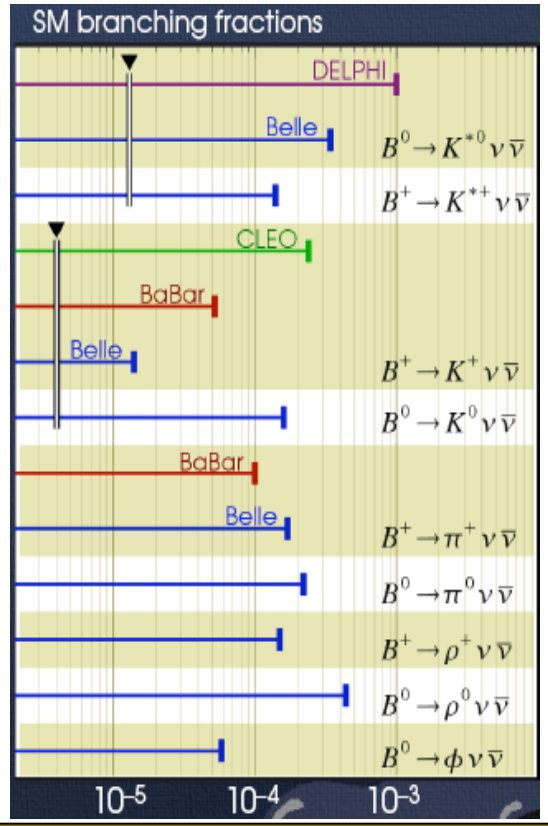






Bird *et al.*, PRL 93, 201803 (2004)





< 3.4 x 10^{-4}
< 1.4 x 10^{-4}

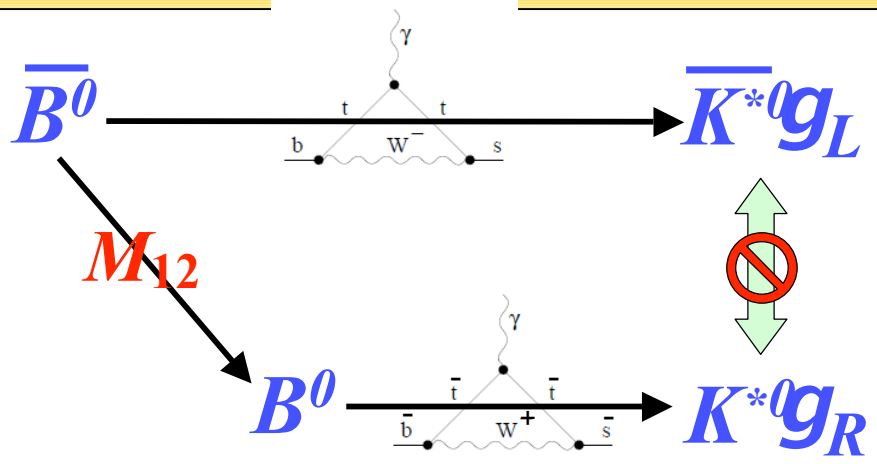
Still 3x SM
< 1.4 x 10^{-5}
< 1.6 x 10^{-4}

Full Recon
Other B

IV. RH Currents and Scalar Interactions

- TCPV in $B \to X_0 \gamma$
- $B_s \to \mu\mu$

TCPV in $B^0 \to (K_S\pi^0)_{K^*}\gamma$: Probe RH Currents



K_S vertexing

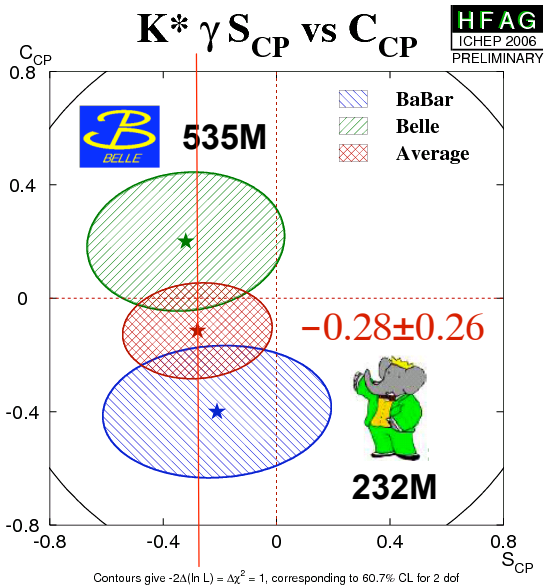
γ_R m_s/m_b suppressed

Interference suppressed in SM

γ_L m_s/m_b suppressed

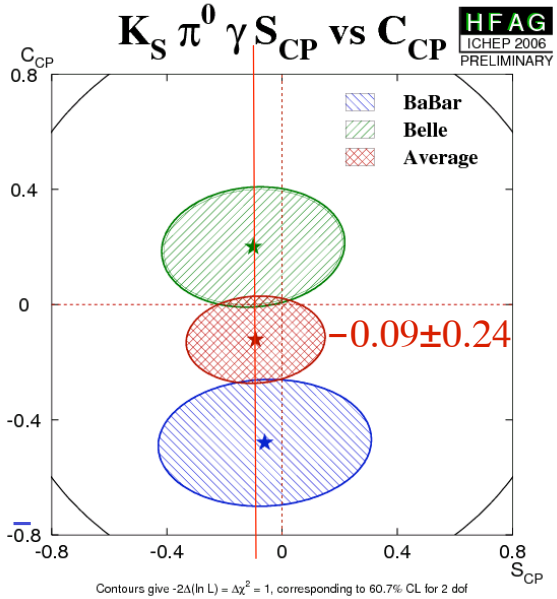
Atwood, Gronau, Soni, PRL79, 185 (1997)

Atwood, Gershon, Hazumi, Soni, PRD71, 076003 (2005)



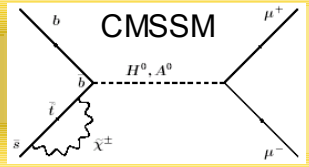
Consistent with zero.
Future probe at SuperB

Also, angular probes
F_L, $A_T^{(2)}$ in $B \to K^* \ell^+ \ell^-$

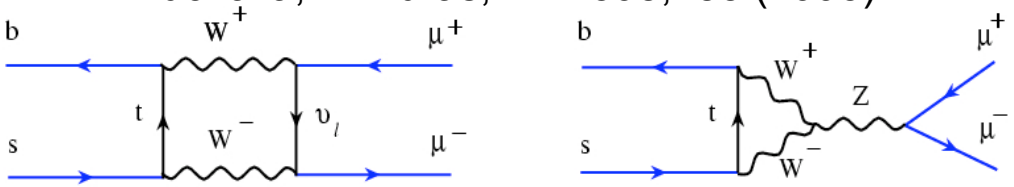


$B_s \to \mu\mu$

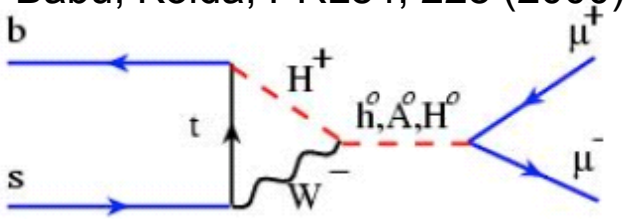
~ 3.5 x 10^{-9} in SM



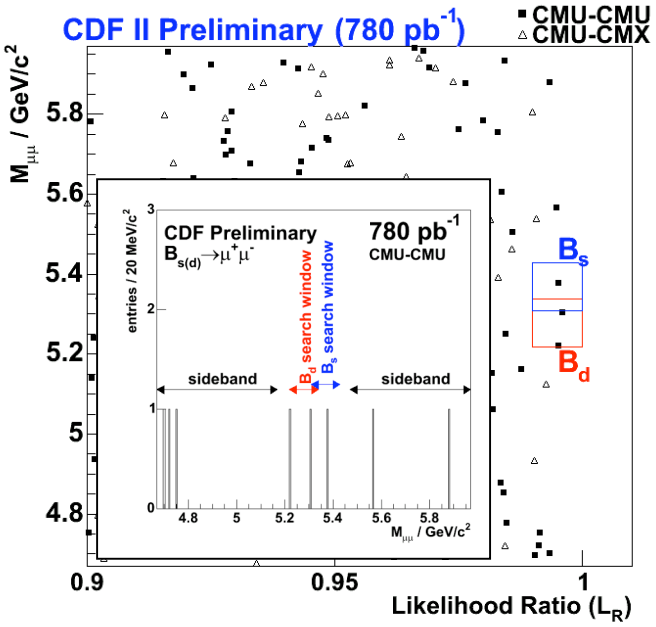
Buchalla, A. Buras, NPB398,285 (1993)

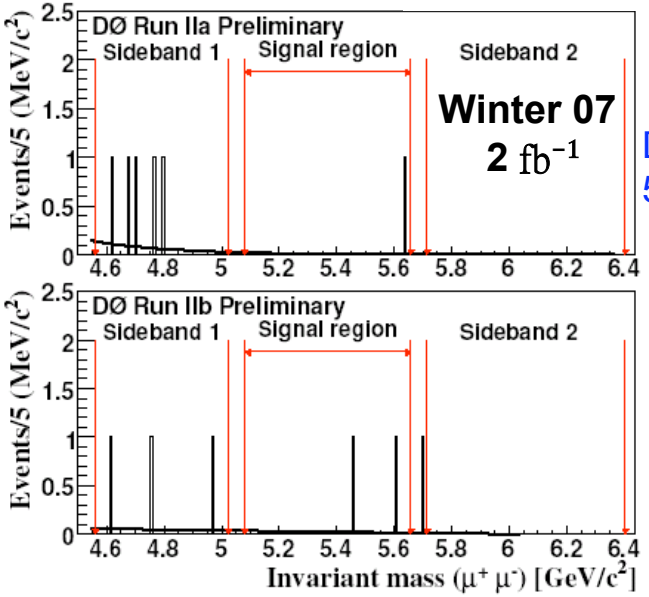


Babu, Kolda, PRL84, 228 (2000)



$\propto \tan^6\beta/(M_A)^4$





DØnote 5344-CONF

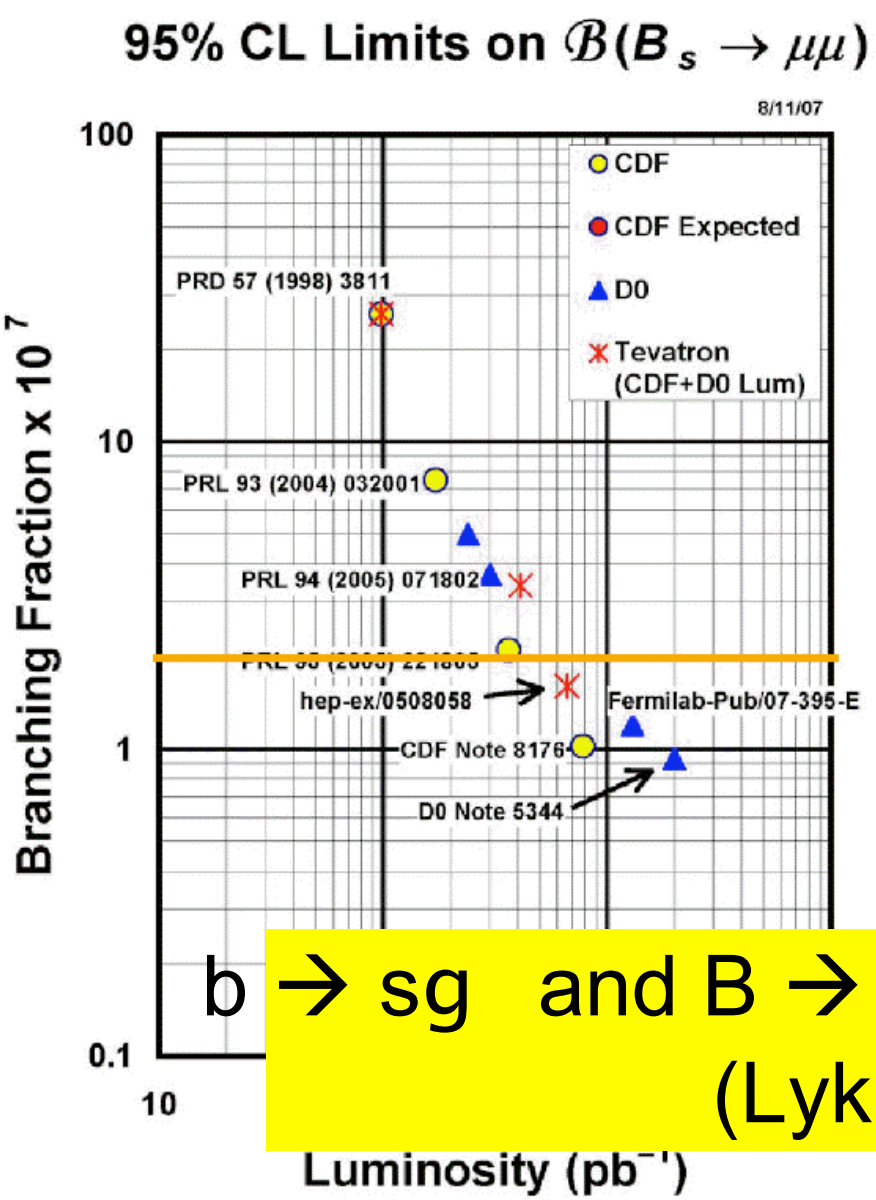
$\mathcal{BR}(B_s^o \to \mu^+\mu^-) < 1.0 \times 10^{-7}$ (95%CL)

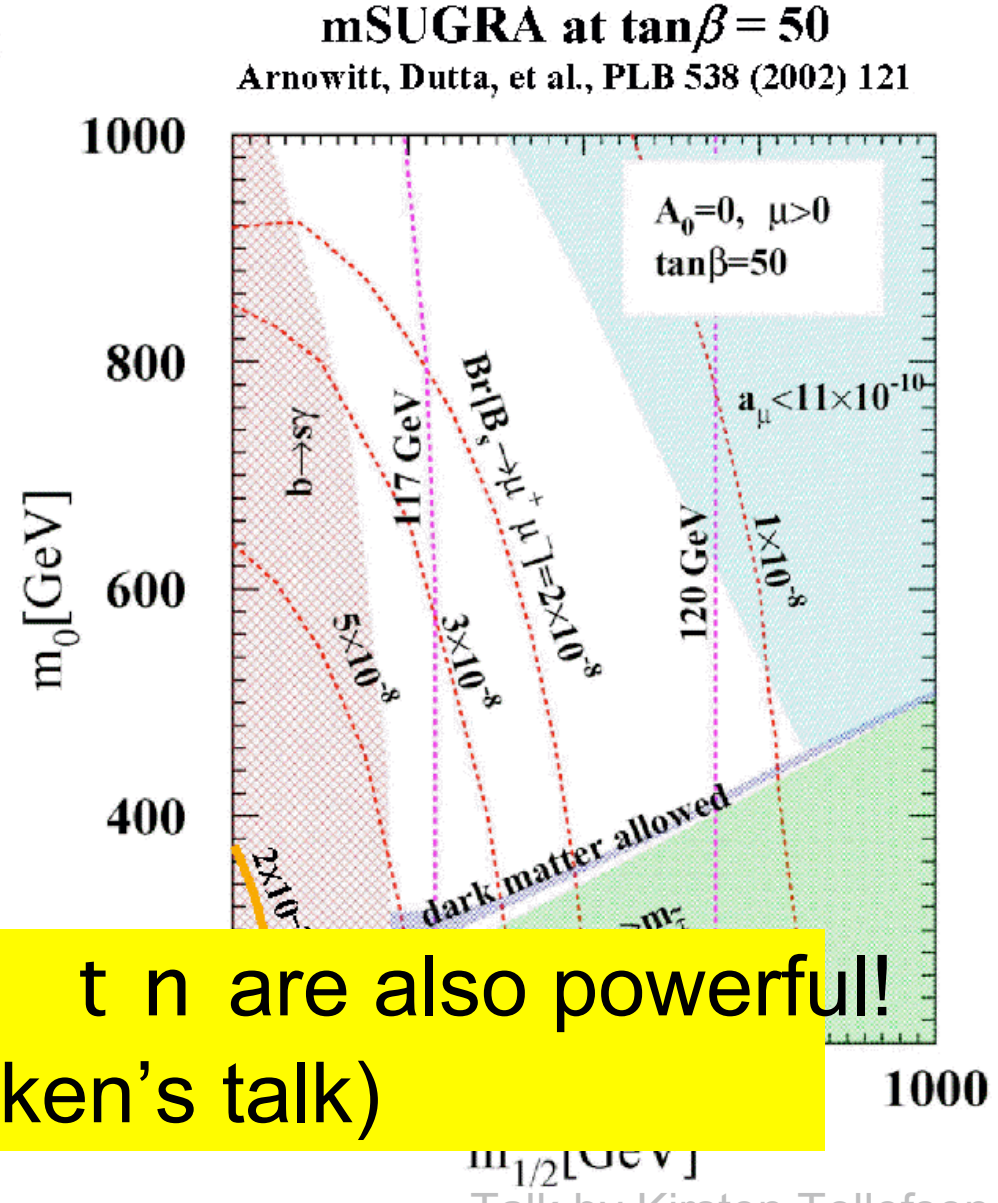
$\mathcal{BR}(B_s^o \to \mu^+\mu^-) < 9.3 \times 10^{-8}$ (95%CL)

$$\mathcal{BR}(B_s^o \to \mu^+\mu^-) < 5.8 \times 10^{-8} \ (95\%CL)$$

combined

$\mathcal{B}(B_s \to \mu\mu)$ and Cosmological Connection

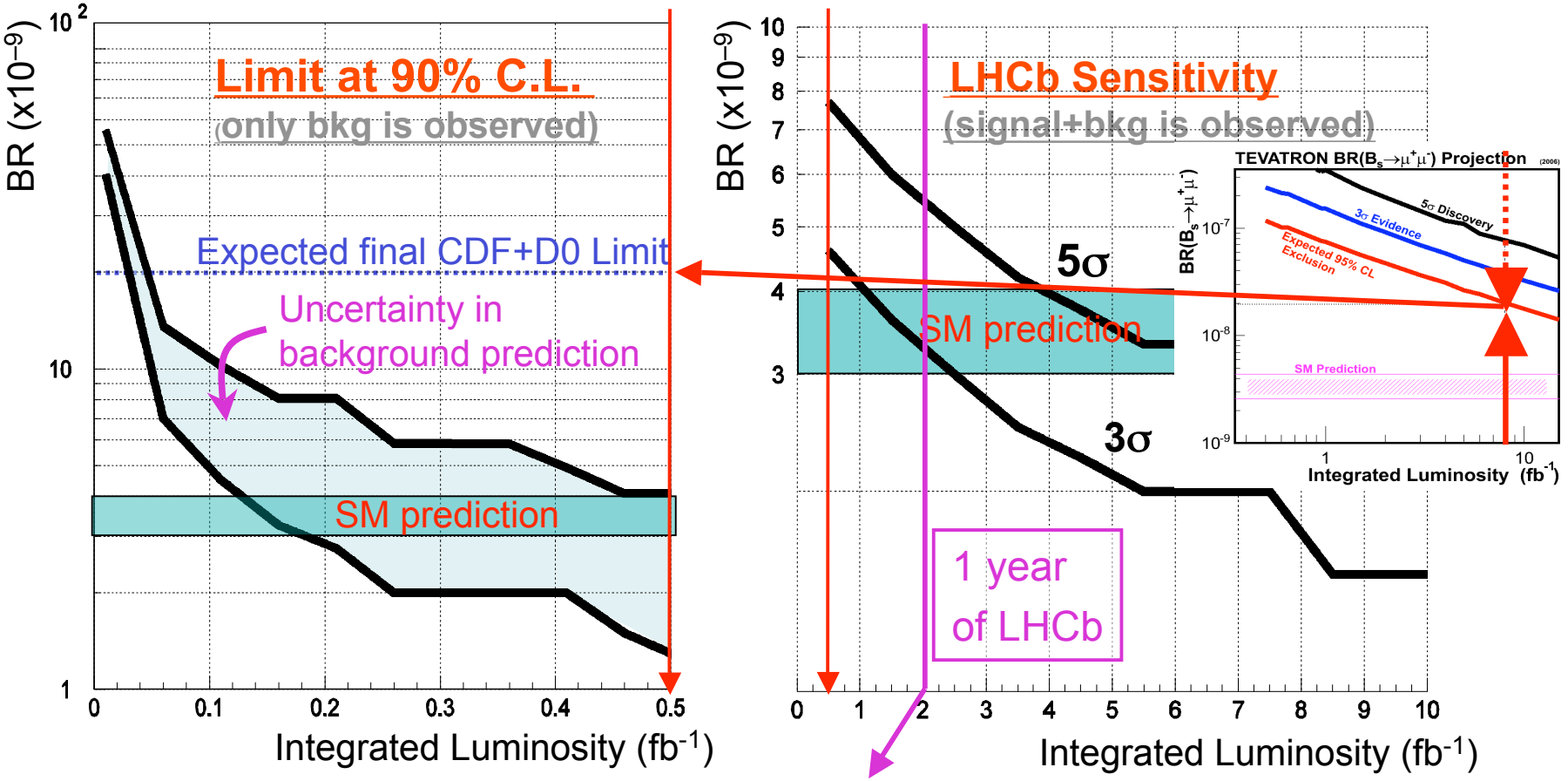




b → sg and B → t n are also powerful!
(Lykken's talk)

Talk by Kirsten Tollefson

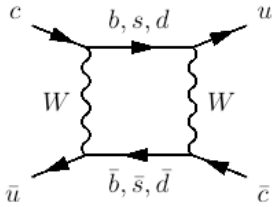
$B_s \to \mu^+\mu^-$ sensitivity

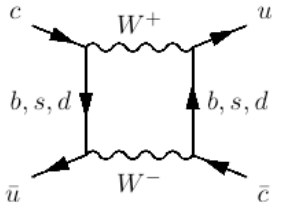


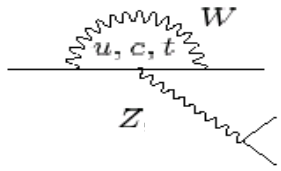
0.05 $fb^{-1} \Rightarrow$ overtake CDF+D0	2 $fb^{-1} \Rightarrow$ 3σ evidence of SM signal
0.5 $fb^{-1} \Rightarrow$ exclude BR values down to SM	10 $fb^{-1} \Rightarrow$ >5σ observation of SM signal

V. D/K: Box and EWP Redux

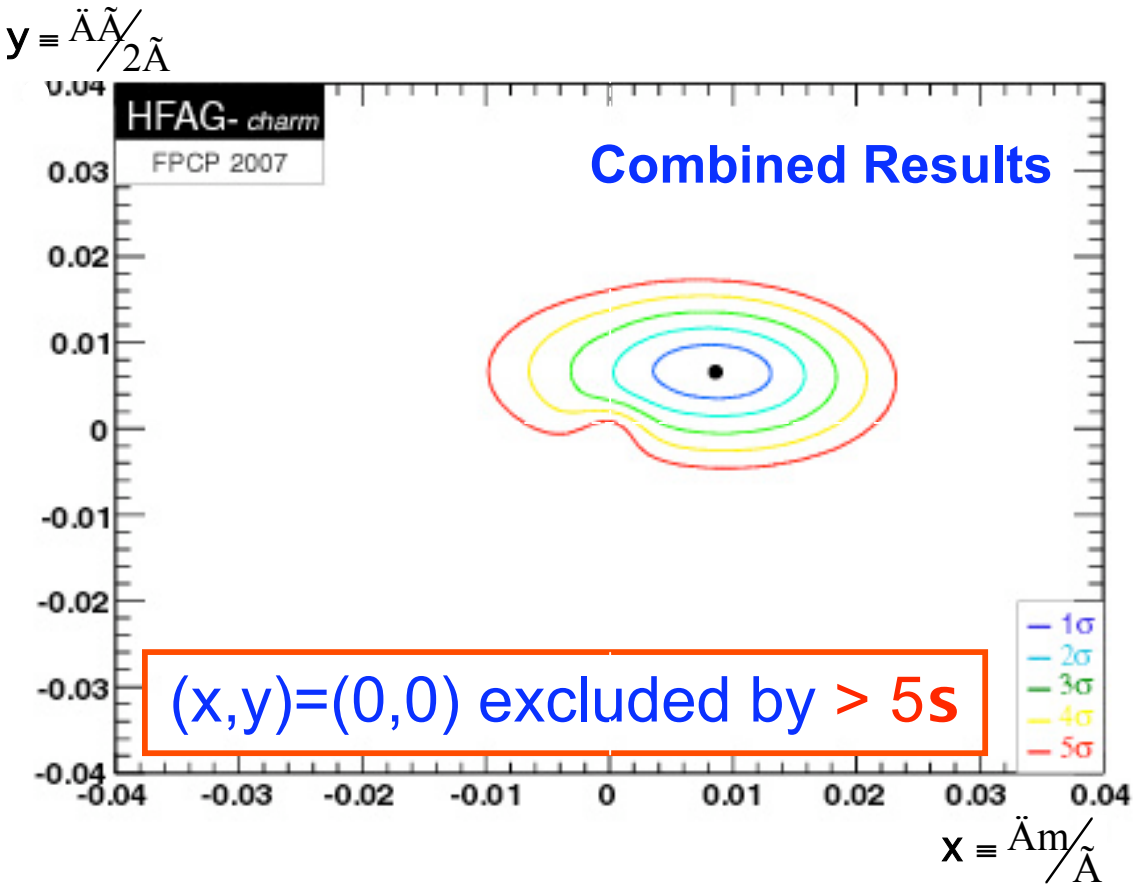
- D^0 Mixing
- Rare K







D^0 Mixing: Measured Recently



540 fb^{-1}	$D^0 \to K^+K^-/p^+p^-$	y_{CP}
	$D^0 \to K_S p^+p^-$ Dalitz	x, y
384 fb^{-1} 400 fb^{-1}	$D^0 \to K^\mp p^\pm$	x'^2, y'

$$x = 0.87^{+0.30}_{-0.34}\ \%$$

$$y = 0.66^{+0.21}_{-0.20}\ \%$$

$$\delta = 0.33^{+0.26}_{-0.29}$$

Assuming no CPV
(no evidence yet)

Unfortunately, all can arise from y, or $\Delta\Gamma$, or long distance.

Falk et al. PRD'02,'04

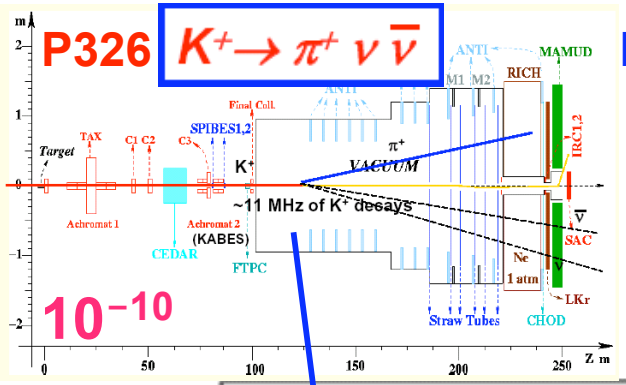
Recall Δm_K, however, ⇒ Comparable BSM allowed

⇒ To be unequivocal: CPV

Kaon Facilities

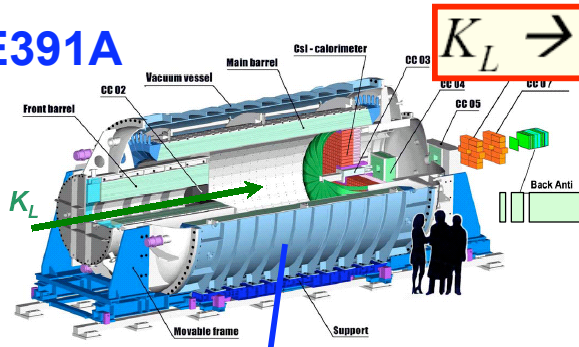
After many activities were cancelled in USA

P326 $K^+ \to \pi^+ \nu \bar{\nu}$



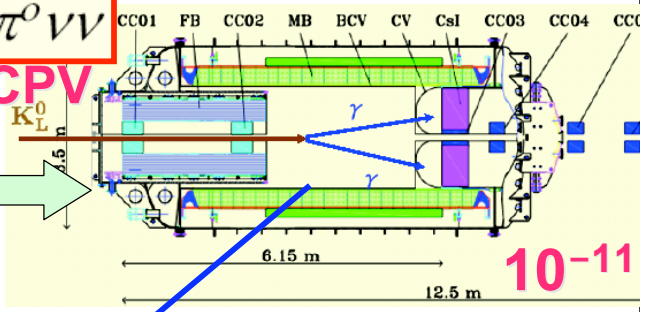
10^{-10}

E391A

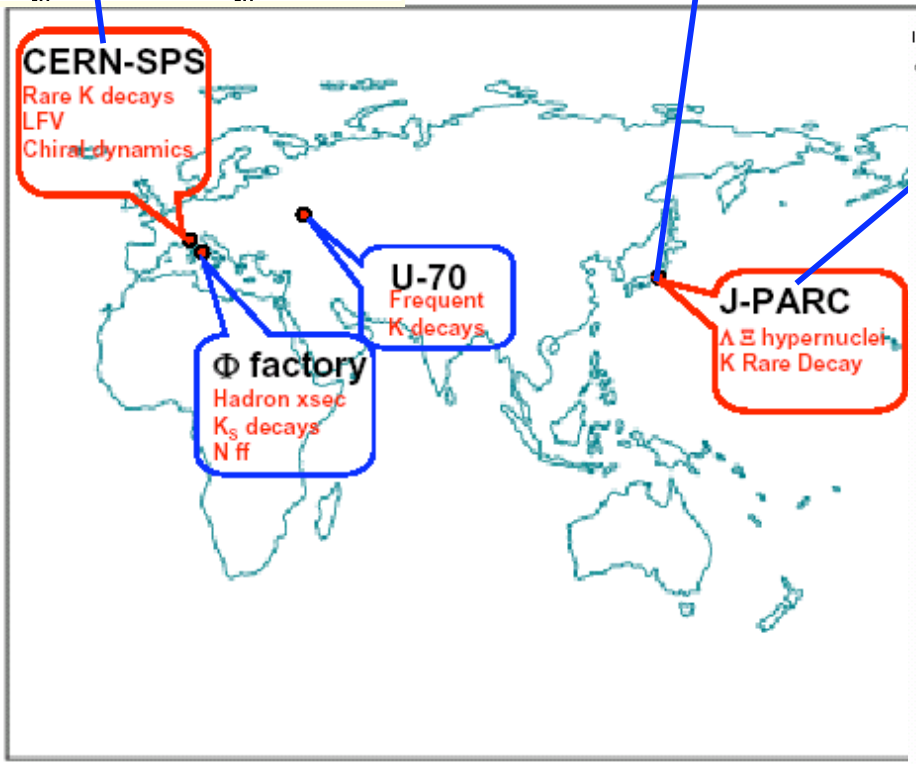


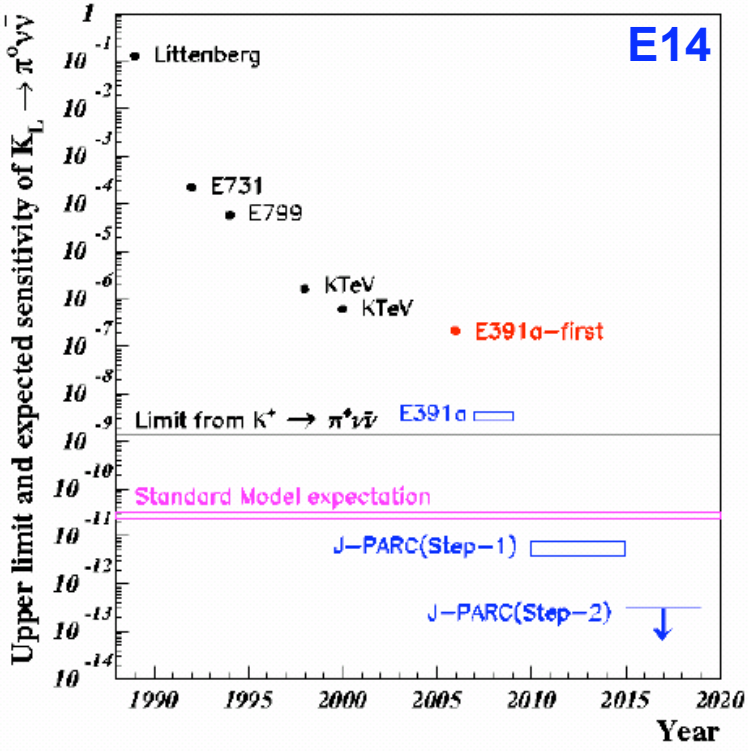
$K_L \to \pi^o \nu \bar{\nu}$

CPV

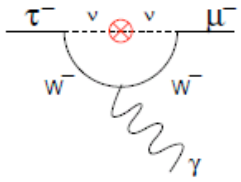


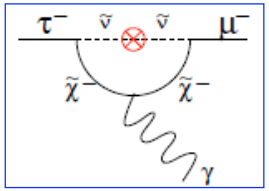
10^{-11}





VI. t : LFV and (B−L)V



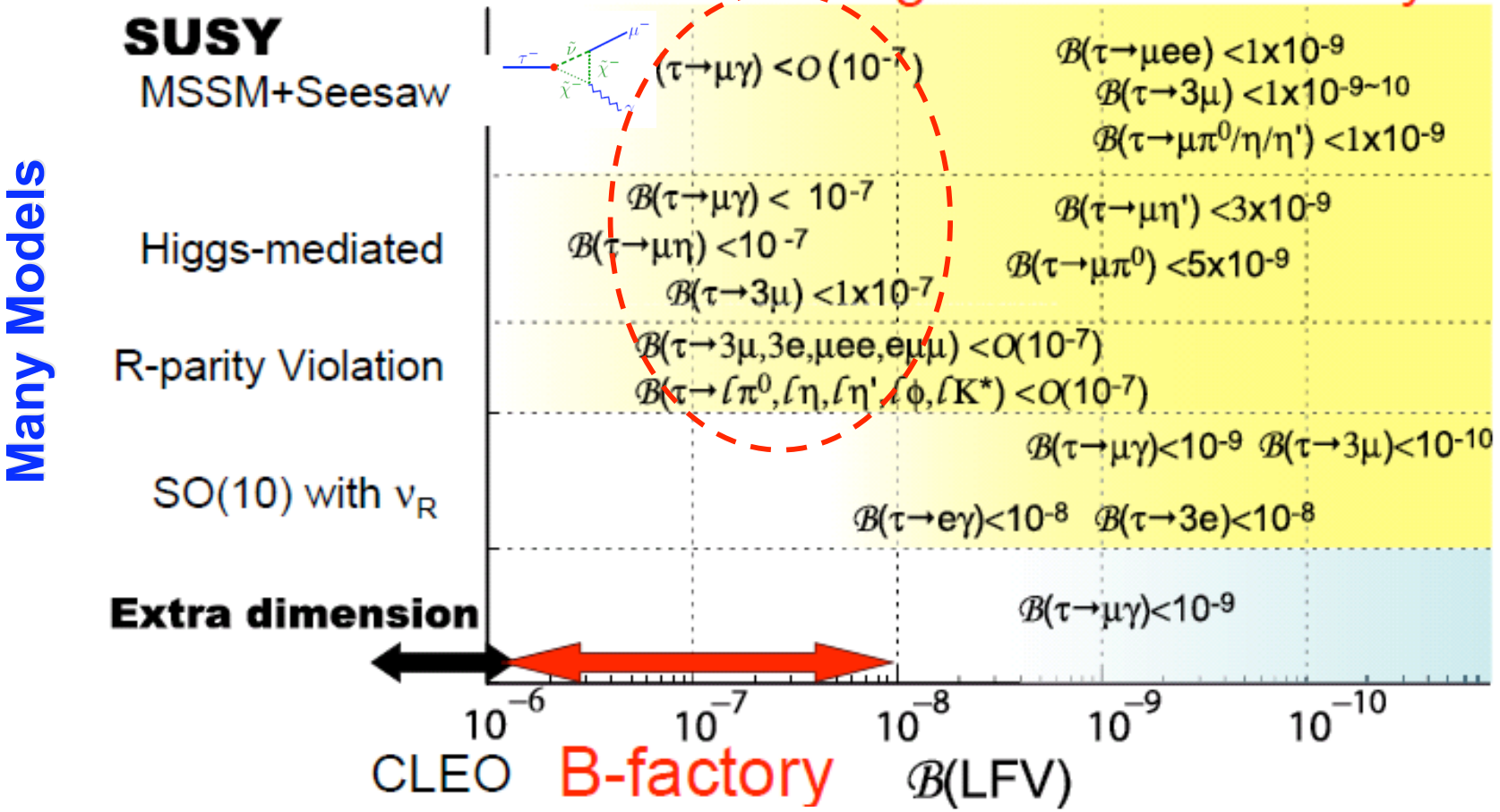


- **t → ℓ g, ℓ ℓ ℓ′**
- **t → Lp, pp⁰**

b → s echoes ?

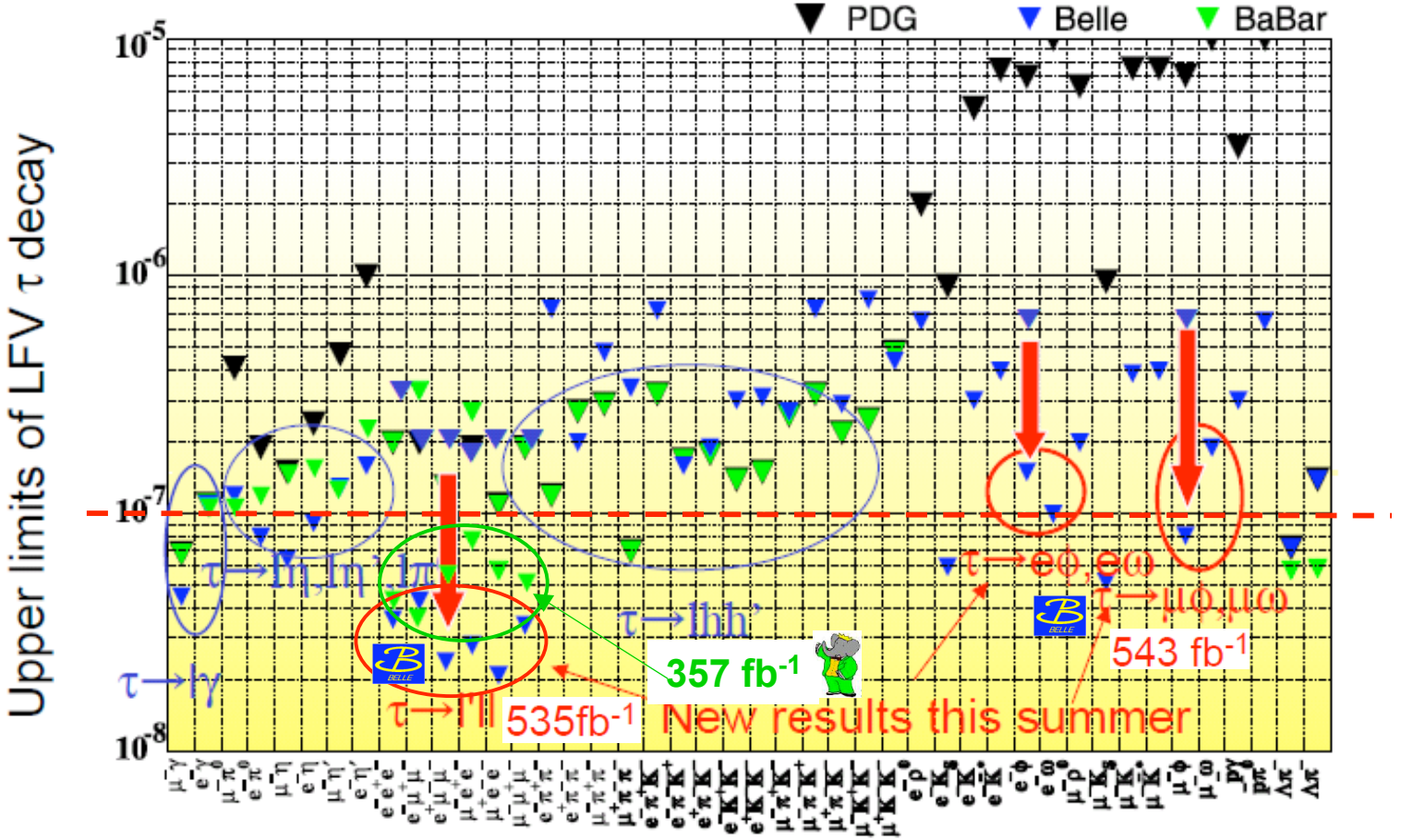
Lepton Flavor Violating (LFV) τ decay

Observation of LFV is a clear signature of New Physics!



caution: partially doctored by me

Summary for LFV τ Decays



ULs for all LFV τ decays are approaching the 10^{-8} level

Conclusion: Best Bet for BSM Soon

I CPV in b → s w/ Boxes and Penguins

$D\mathcal{S}$; $D\mathcal{A}_{Kp}$; **$\sin 2\beta_{B_s}$**; $\mathcal{A}_{CP}(B^+ \to J/\psi K^+)$

Hints for BSM

Thing to watch in 2008-09 !

II H^+ Probe: $b \to s\gamma$; **$B \to \tau\nu$** $(+D^{(*)})$

III Electroweak Penguin: **$A_{FB}(B \to K^* \ell\ell)$**; $B \to K^{(*)}\nu\bar{\nu}$

IV RH Currents and Scalar Interactions

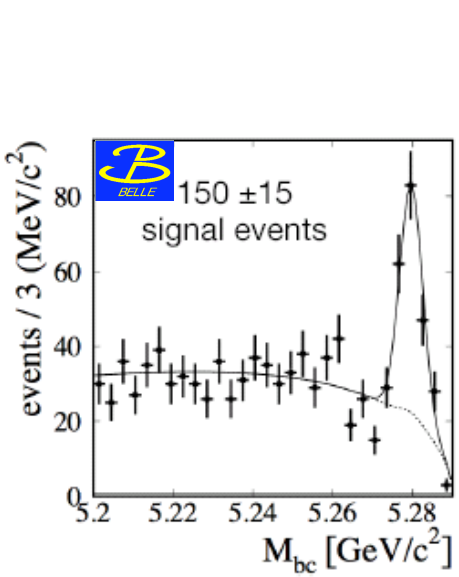
TCPV in $B \to X_0\gamma$; **$B_s \to \mu\mu$**

V D/K: Box and EWP Redux — D^0 mixing; Rare K

VI t : LFV and (B−L)V

$t \to \ell\gamma$, $\ell\ell\ell'$; $t \to \Lambda p$, pp^0

$B^0 \to D^- D^+$: Belle vs BaBar

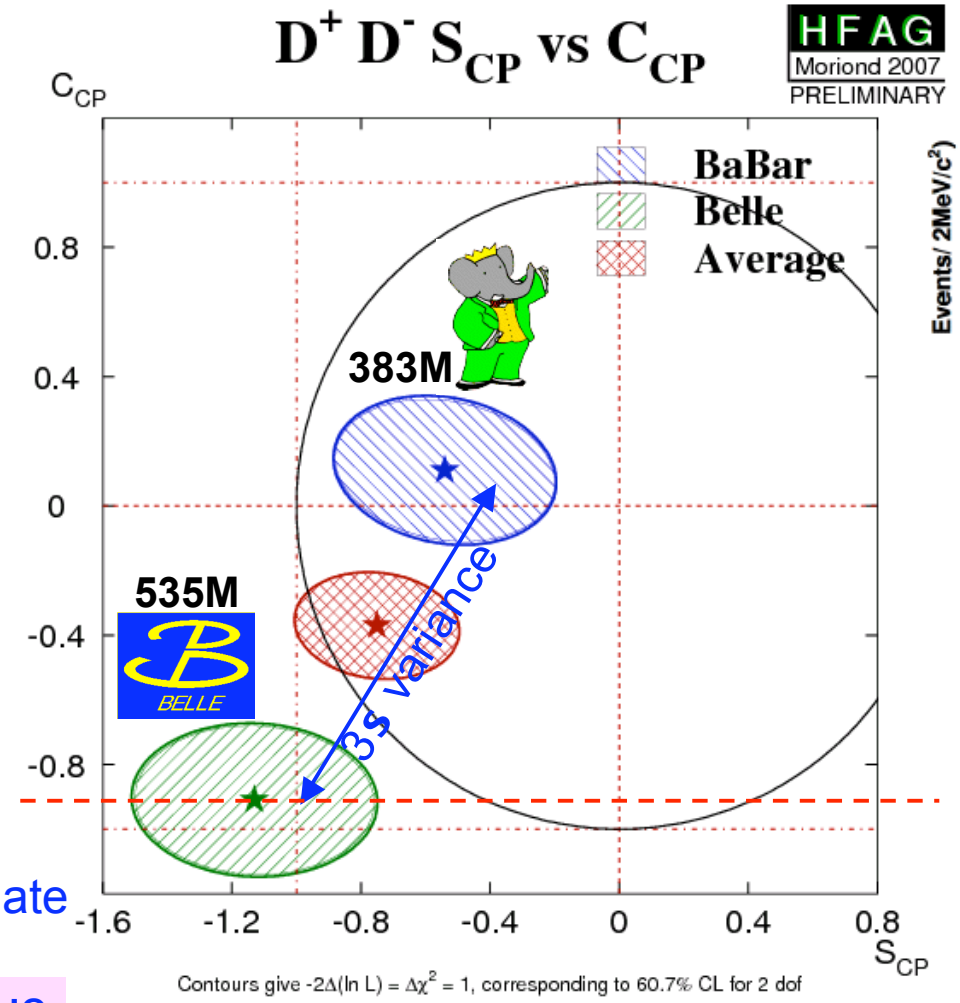


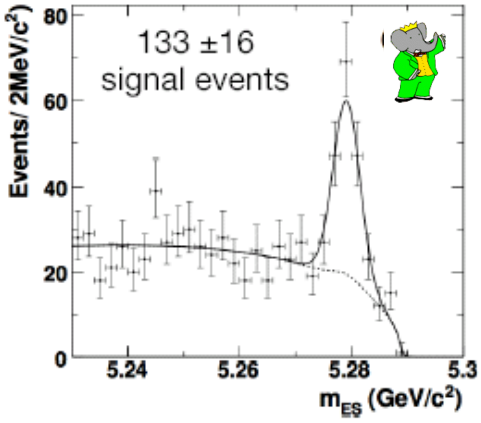
hep-ex/0702031
submitted to PRL
Direct CPV at 3.2**s**

Hard to accommodate

Unparticle Effect !?

just to be crazy ... Zwicky, 0707.0677 [hep-ph]





0705.1190 [hep-ex]
submitted to PRL
Consistent w/ SM

Physics Output

49/237 Submitted Belle papers

Subject	Journal	TW%	Taiwan Authors
1. $B \to \pi\pi, K\pi$	PRL	$\sim 50\%$	P.T. Chang, K.F. Chen
2. $B \to \pi\pi, K\pi$ A_{CP}	PRD-RC	$\sim 50\%$	P.T. Chang, K.F. Chen
3. $B \to \eta' K$	PLB	100%	P.T. Chang, C.H. Wang, S.C. Hsu
4. $B \to D^{(*)0} h^0$ (3 modes)	PRL	100%	R.S. Lu, H.C. Huang, K.F. Chen
5. $B \to p\bar{p}K$	PRL	100%	M. Z. Wang, H.C. Huang, K.F. Chen
6. $B \to p\bar{p}, p\bar{\Lambda}, \Lambda\bar{\Lambda}$	PRD-RC	100%	M. Z. Wang
7. $B \to \rho\pi$	PLB	50%	Y. Chao, P.T. Chang
8. $B \to \omega K$	PRL	100%	R.S. Lu
9. $B \to \eta' K$ CP	PLB	50%	K.F. Chen, Y.B. Hsiung, P. Yeh
10. $B \to sq\bar{q}$ CP	PRD-RC	$\sim 50\%$	K.F. Chen, Y.B. Hsiung
11. $B \to p\bar{\Lambda}K$	PRL	100%	Y.J. Lee, M.Z. Wang
12. $B \to \phi\phi K$	PRL	100%	H.C. Huang
13. $B \to \phi K^*$ Pol.	PRL	70%	K.F. Chen
14. $B \to \phi K^0_S (S_{\phi K^0_S})$	PRL	70%	K.F. Chen
15. $B \to \phi K\gamma$	PRL	(30%)	A. Drutskoy (vistor)
16. $B \to l^+ l^-$ Limits	PRD-RC	100%	M.C. Chang, P.T. Chang
17. $B \to p\bar{p}\pi^+$, etc.,	PRL	100%	P.H. Chu, M.z. Wang
18. $B \to K\pi, \pi\pi, KK$	PRD	40%	Y. Chao
19. $B \to \omega K, \omega\pi$	PRD	100%	C.H. Wang
20. $B \to \Lambda\bar{\Lambda}K$	PRL	100%	Y.J. Lee, M.Z. Wang
21. $B \to K\pi\pi^0$	PLB	100%	P.T. Chang
22. $B \to hh$ A_{CP} update	PRD-RC	100%	Y. Chao, P.T. Chang
23. $B \to \rho\pi$ CP	PRL	100%	C.C. Wang
24. $A_{CP}(K\pi)$	PRL	100%	Y. Chao, P.T. Chang
25. $B \to \eta h$	PRD-RC	100%	P.T. Chang
26. $B \to \pi^0\pi^0$	PRL	100%	Y. Chao, P.T. Chang
27. $B \to p\bar{p}$ update	PRD-RC	100%	M.C. Chang, P.T. Chang
28. $B \to D^{(*)0}\eta'$	PRD-RC	100%	J. Schuemann, P.T. Chang
29. $B \to p\bar{\Lambda}\gamma$	PRL	100%	Y.J. Lee, M.Z. Wang
30. $B \to p\bar{p}h$	PLB	100%	Z.L. Guo, M.Z. Wang
31. CP in $b \to s\bar{q}q$	PRD-RC	30%	K.F. Chen
32. $B \to \phi K^*$ Pol. update	PRL	100%	K.F. Chen
33. $\gamma\gamma \to p\bar{p}$	PLB	100%	C.C. Kuo
34. $B \to KK$	PRL	100%	Y. Chao and P.T. Chang
35. J/ψ polarization	PRL	100%	C.H. Wu and M.Z. Wang
36. $B \to \omega h$	PRD-RC	100%	C.M. Ren and P.T. Chang
37. $B \to \eta' h$	PRL	100%	J. Schuemann
38. ICPV in $b \to s$ penguin	PRL	30%	K.-F. Chen
39. $B^0 \to D^{(*)0}\pi^0, D^{(*)0}\eta, D^{(*)0}\omega$	PRD	100%	S. Blyth
40. $B \to KK$	PRL	100%	S.-W. Lin, P.T. Chang
41. $B \to K\pi, \pi\pi$	PRL	100%	S.-W. Lin, P.T. Chang
42. $B \to \eta h$	PRD-RC	100%	P.T. Chang
43. $B \to \eta K^*, \eta\rho$	PRD	100%	C.H. Wang
44. $B \to \eta' K^*, \eta'\rho$	PRD	100%	J. Schuemann
45. $B \to p\bar{p}$	PRD-RC	100%	Y.-T. Tsai, P.T. Chang
46. ICPV on $\omega K^0, K^0\pi^0$	PRD	50%	Y. Chao, K.F. Chen
47. $\gamma\gamma \to K^0_S K^0_S$	PRL	100%	W.T. Chen
48. $B \to p\bar{\Lambda}h, p\bar{\Lambda}\gamma$	PRD	100%	M.Z. Wang, Y.J. Lee
49. $B \to h^{(*)}\nu\bar{\nu}$	PRL	100%	K.F. Chen

Table 3: Physics papers submitted or under reviewed.

Subject	Journal	TW%	Taiwan Authors
1. $A_{CP}(K\pi)$	NATURE	75%	S.-W. Lin, W.-S. Hou, P. Chang
2. $B \to p\bar{p}K, p\bar{p}\pi$	PLB	100%	J.T. Wei, M.Z. Wang
3. $B \to p\bar{p}K^*$	PRL	100%	C.C. Chen, M.Z. Wang
4. $B \to \phi\phi K$	PRD-RC	100%	Y.-T. Shen, P.T. Chang
5. $B \to \rho\pi$	PRD	100%	C.C. Wang
6. $\Upsilon(5S) \to \Upsilon(1S)h^+h^-$	PRL	100%	K.F. Chen, W.-S. Hou

Learning Analysis

Available on CMS information server

CMS NOTE 2006/086

The Compact Muon Solenoid Experiment

CMS Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

30 May 2006

Search for W-associated Production of Single Top Quarks in CMS

P. Yeh, K.F. Chen, Y.J. Lei, J. Schuemann, Y. Chao, J.-G. Shiu

National Taiwan University, Taipei, Taiwan

A. Giammanco

Université catholique de Louvain, Louvain-la-Neuve, Belgium

G. Petrucciani

SNS & INFN Pisa, Pisa, Italy

S. Blyth

National Central University, Chungli, Taiwan

A 2nd rung non-discovery ...

4th generation? — The jury is out …

In era of LHC, can Directly Search for b′, t′
Once and For All !

Find b′, t′, or Rule Out @ LHC

It's a Duty.

Strategy Considerations (漢中策略)

- **Well shielded training ground — All Tools**
  - ☞ Move on to Greener Pastures ~ 2 years
- **Publish early — Large Cross Section**
  - **If "Limits", then easy to publish**
  - **If "Signal", Lucked Out!**

b′ Signatures

For $m_{b'} < m_t + M_W = 255$ GeV

b′ → cW dominance — for sizable $V_{cb'}$

b′ → tW* dominance — for suppressed $V_{cb'}$

Kinematic suppressed for $m_{b'} \lesssim 230$ GeV

Initial discovery should consider

b′ → cW ~ b′ → bZ, bH ~ b′ → tW*

Rich Signature

cc(bar)WW; cWbZ; cWbH; Bonus !!
tc(bar)WW*;
tt(bar)W*W*; tW*bZ; tW*bH;

For $m_{b'} > m_t + M_W = 255$ GeV

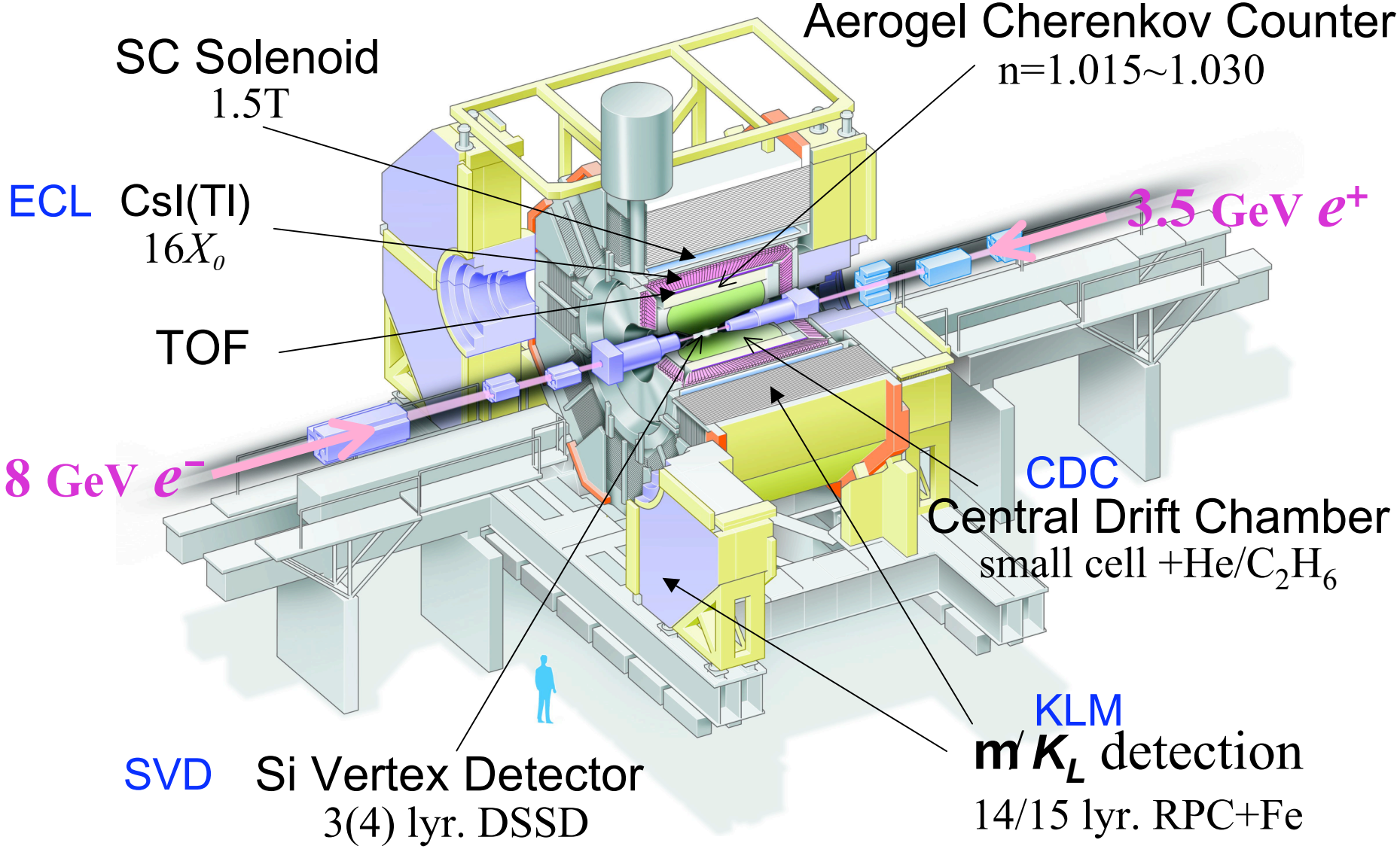
b′ → tW dominance; FCNC searchable

$tt(bar)WW \to bb(bar)W^+W^-W^+W^-$

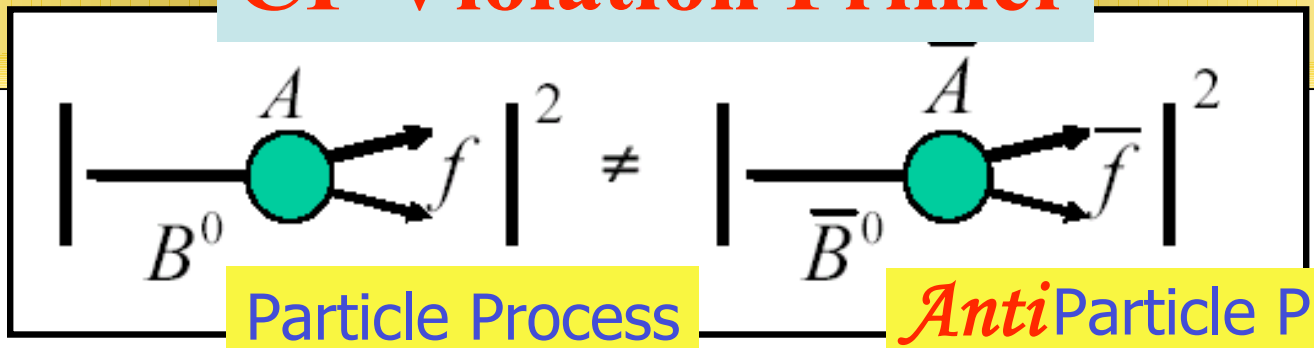
Heavy Q related To EWSB ?

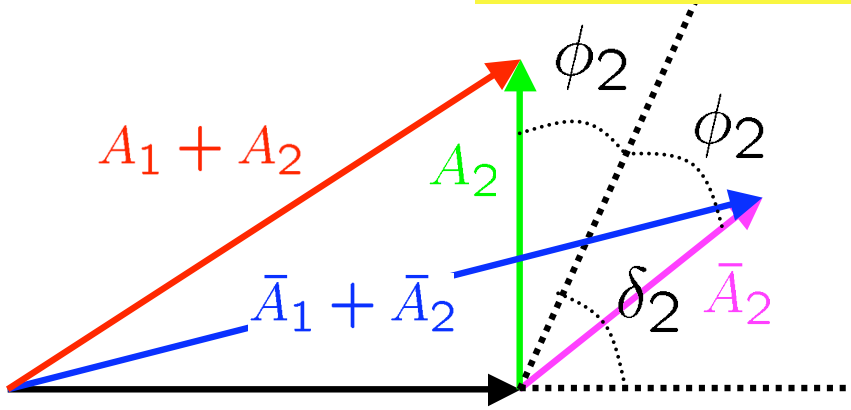
4 W's + 2b's

Belle Detector



CP Violation Primer





$$A = A_1 + A_2 = a_1 + a_2 e^{i\delta_2} e^{i\phi_2}$$

$$\bar{A} = \bar{A}_1 + \bar{A}_2 = a_1 + a_2 e^{i\delta_2} e^{-i\phi_2}$$

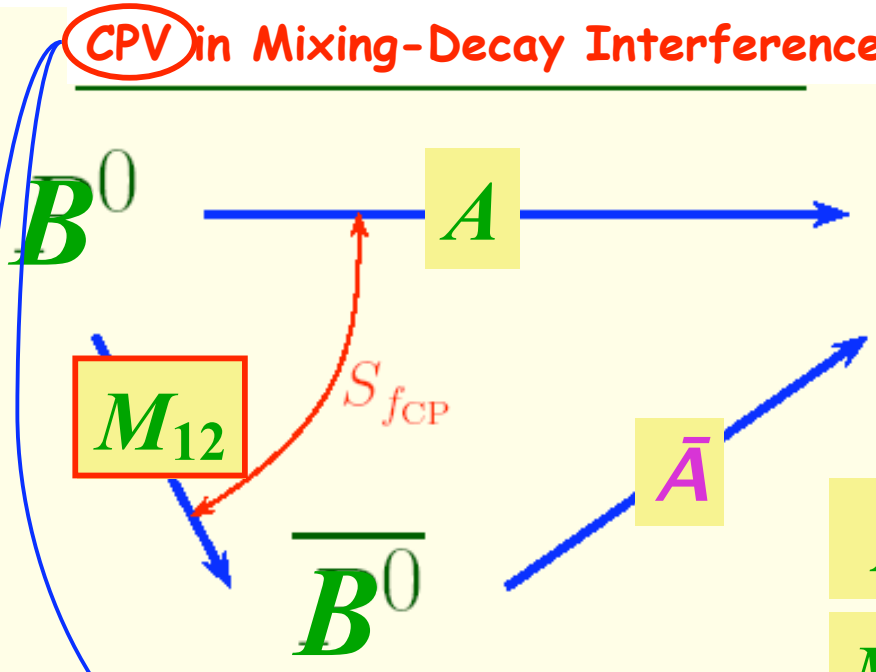
$$A_1 = \bar{A}_1$$

$$A^{CP} = \frac{\Gamma(\bar{B}^0 \to \bar{f}) - \Gamma(B^0 \to f)}{\Gamma(\bar{B}^0 \to \bar{f}) + \Gamma(B^0 \to f)} = \frac{2a_1 a_2 \sin\phi_2 \sin\delta_2}{a_1^2 + a_2^2 + 2a_1 a_2 \cos\phi_2 \cos\delta_2}$$

CP Asymmetry needs *both* CP Conserv/Violating Phase

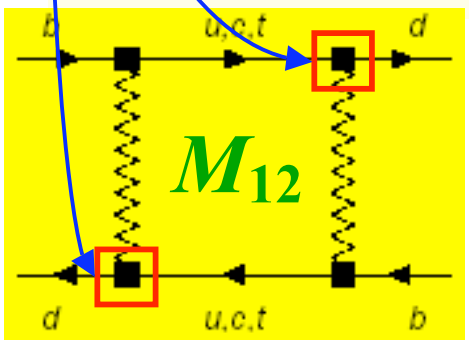
T-dep. CPV Primer

CPV in Mixing-Decay Interference



A: Decay Amplitude

M_{12}: Mixing Amplitude



$\overline{B}^0$ B^0 $\overline{B}^0 \leftrightarrow B^0$ Oscillations: $e^{i\Delta mt}$

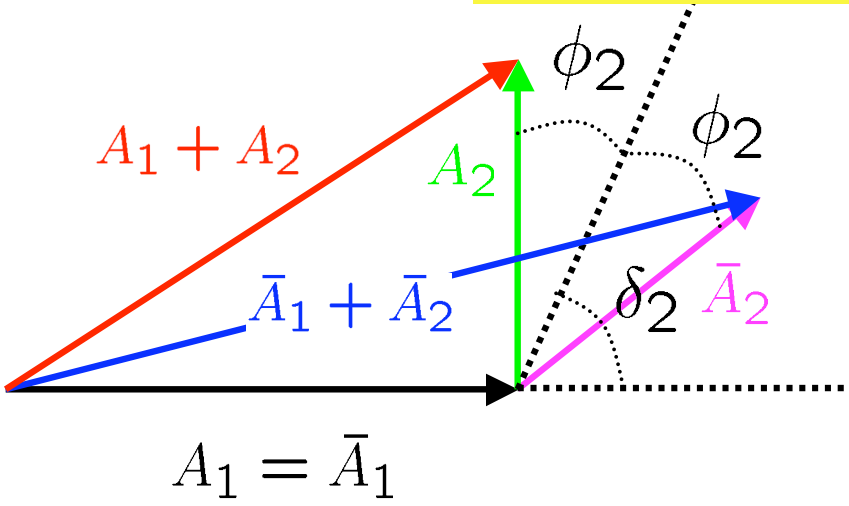
CP conserv.

Interference of Two Types of Phases

CP Violation Primer

$$\left| A(B^0 \to f) \right|^2 \neq \left| \bar{A}(\bar{B}^0 \to \bar{f}) \right|^2$$

Particle Process | *Anti*Particle Process



$$A = A_1 + A_2 = a_1 + a_2 e^{i\delta_2} e^{i\phi_2}$$

$$\bar{A} = \bar{A}_1 + \bar{A}_2 = a_1 + a_2 e^{i\delta_2} e^{-i\phi_2}$$

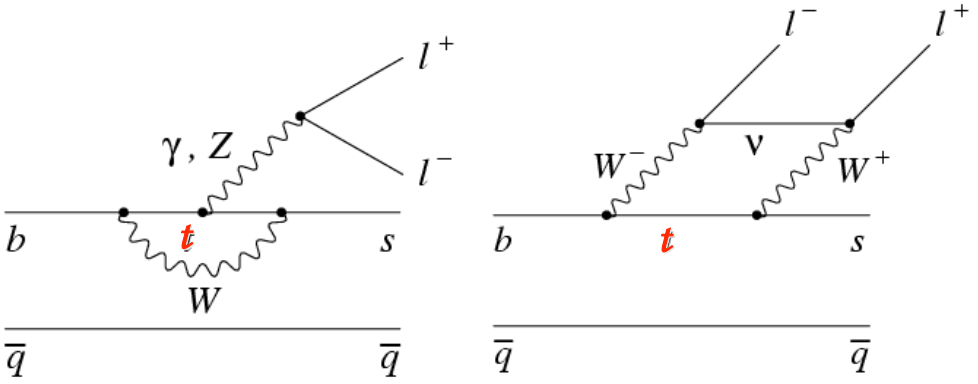
TCPV: $d_2 \neq 0$

$$A^{CP} = \frac{\Gamma(\bar{B}^0 \to \bar{f}) - \Gamma(B^0 \to f)}{\Gamma(\bar{B}^0 \to \bar{f}) + \Gamma(B^0 \to f)} = \frac{2a_1 a_2 \sin\phi_2 \sin\delta_2}{a_1^2 + a_2^2 + 2a_1 a_2 \cos\phi_2 \cos\delta_2}$$

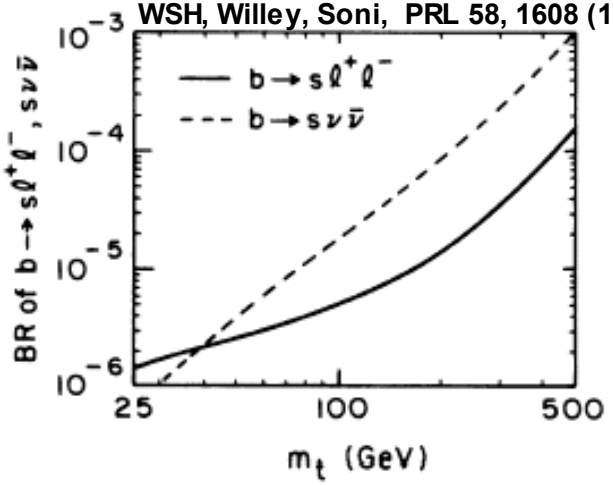
CP Asymmetry needs *both* CP Conserv/Violating Phase

$b \to s \ell^+ \ell^-$ Rates

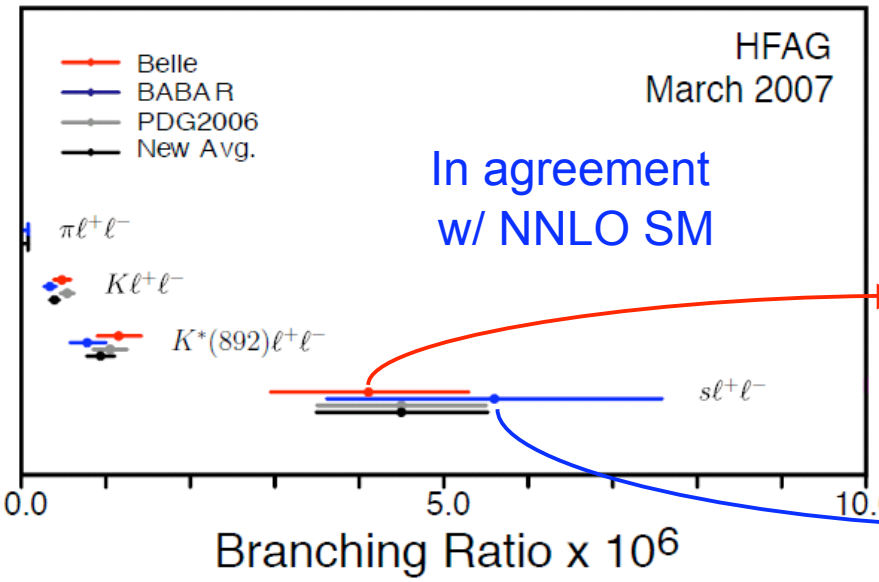
Nondecoupling of top in EWP — $I_t \sim 1$



WSH, Willey, Soni, PRL 58, 1608 (1987)

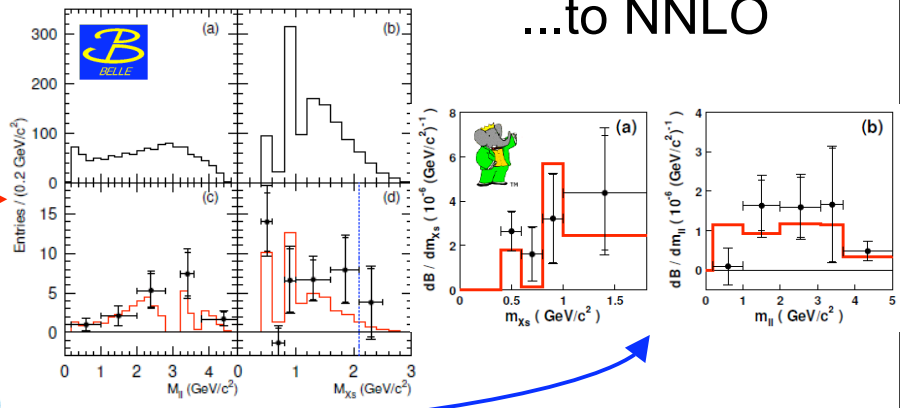


$$\mathcal{B}(B \to X_s \ell^+ \ell^-)$$



In agreement w/ NNLO SM

Much TH work ...to NNLO



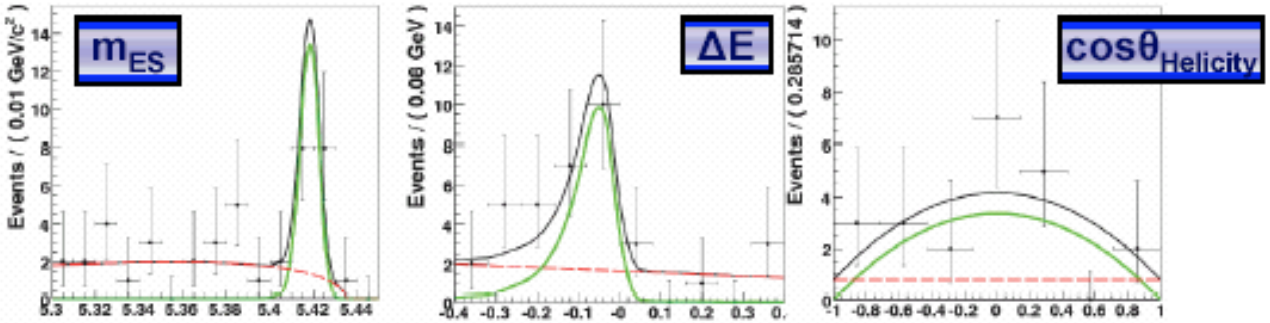
Belle running at the Y(5S)

Results:

Preliminary | 23.6 fb^{-1} | $B_s \to \phi\gamma$

- (18 ± 6) signal events found: $\mathcal{B}(B_s \to \phi\gamma) = \left(5.7^{+1.8}_{-1.5}{}^{+1.2}_{-1.7}\right) \times 10^{-5}$
- Significance (including systematics): 5.5σ.
- Signal region projection plots:

First observation of a radiative B_s penguin decay!

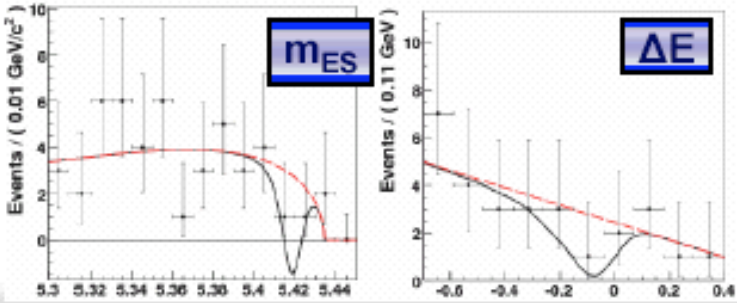


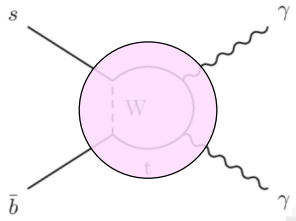
Final fit finds no signal:

23.6 fb^{-1} | $B_s \to \gamma\gamma$

	m_{ES} (M_{bc})	ΔE
Signal:	Smoothed MC-histogram	
Background:	ARGUS	1st order Polynomial

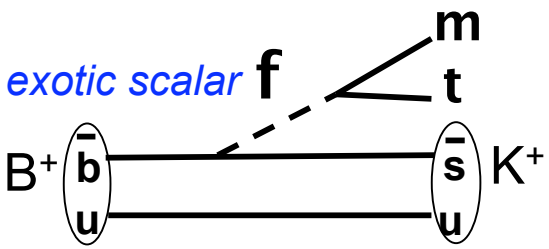
$\mathcal{B}(B_s \to \gamma\gamma) < 8.6 \times 10^{-6}$ (90% CL)





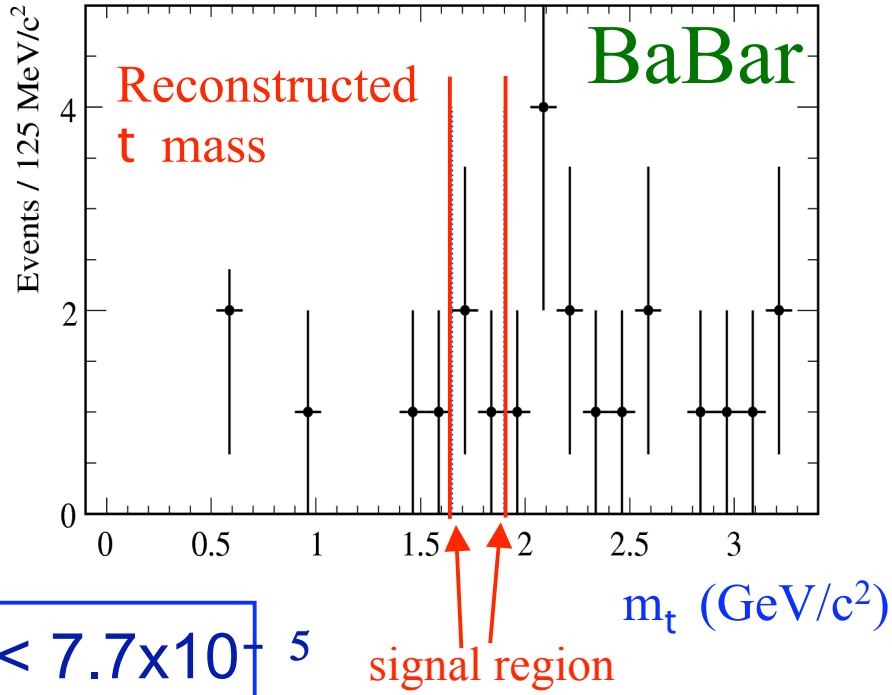
B → Kt m

346 fb^{-1}



First search ever done for this channel

Events in signal window	*Expected background*
$N_e = 1$	$b_e = 0.5 \pm 0.3$
$N_m = 0$	$b_m = 0.6 \pm 0.3$
$N_p = 2$	$b_p = 1.8 \pm 0.6$



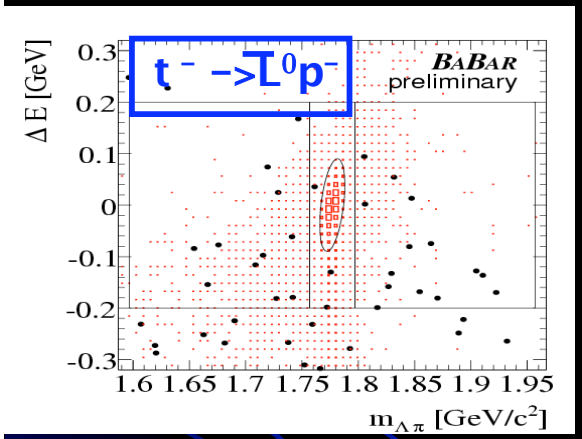
No evidence of signal

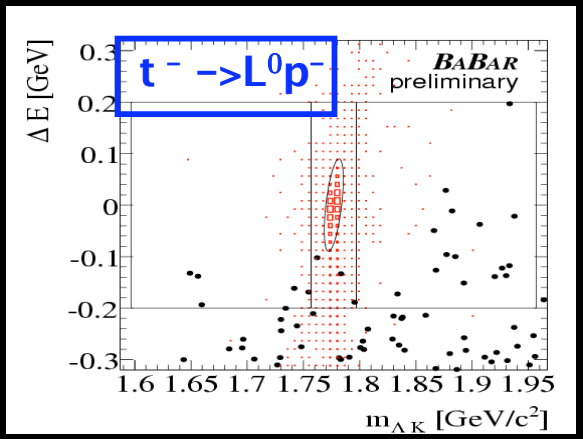
UL (90%CL): $\mathcal{B}(B \to Kt\ m) < 7.7 \times 10^{-5}$

Lepton and baryon number violating τ -decay

Swain

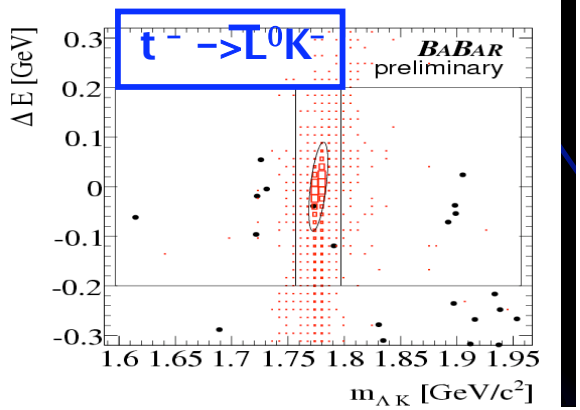
- The baryon asymmetry of the universe –> Baryon number violation (Sakharov condition)
- For lepton -> baryon + meson decays, the angular momentum conservation requires, D(B-L) = 0 or 2

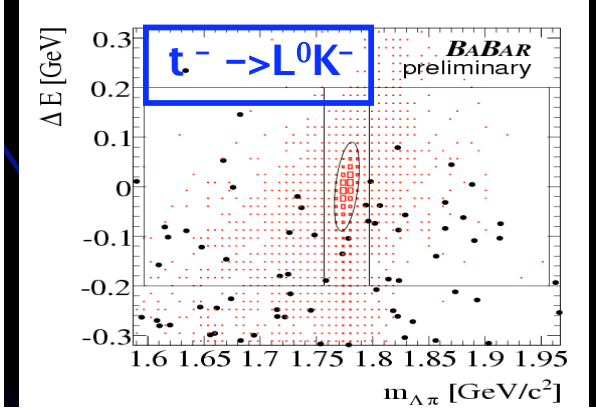




The following decays modes used in this analysis: (237 fb^{-1})

(hep-ex: 0607040)





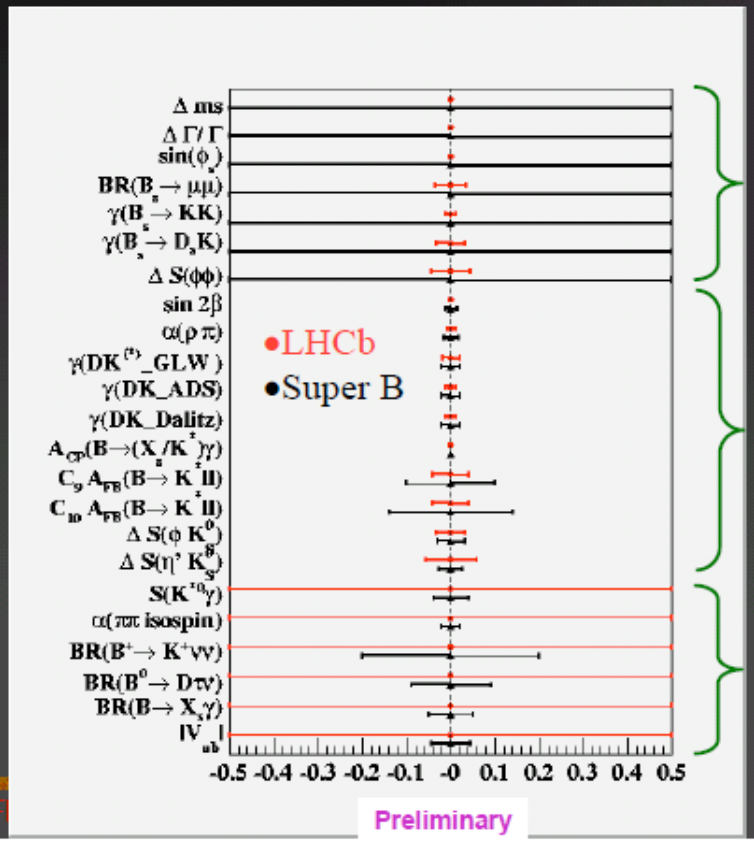
mode	upper limit on $\mathcal{B}$ @ 90% C.L.
$\tau^- \to \bar{\Lambda}^0\pi^-$	5.9×10^{-8}
$\tau^- \to \Lambda^0\pi^-$	5.8×10^{-8}
$\tau^- \to \bar{\Lambda}^0 K^-$	7.2×10^{-8}
$\tau^- \to \Lambda^0 K^-$	15×10^{-8}

Comparison with Super B factory

Sensitivity Comparison ~2020

LHCb 100 fb^{-1} vs Super-B factory 50 ab^{-1}

SuperB numbers from M Hazumi - Flavour in LHC era workshop; LHCb numbers from Muheim



B_s only accessible at LHCb

Common

No IP
Neutrals, ν

46