

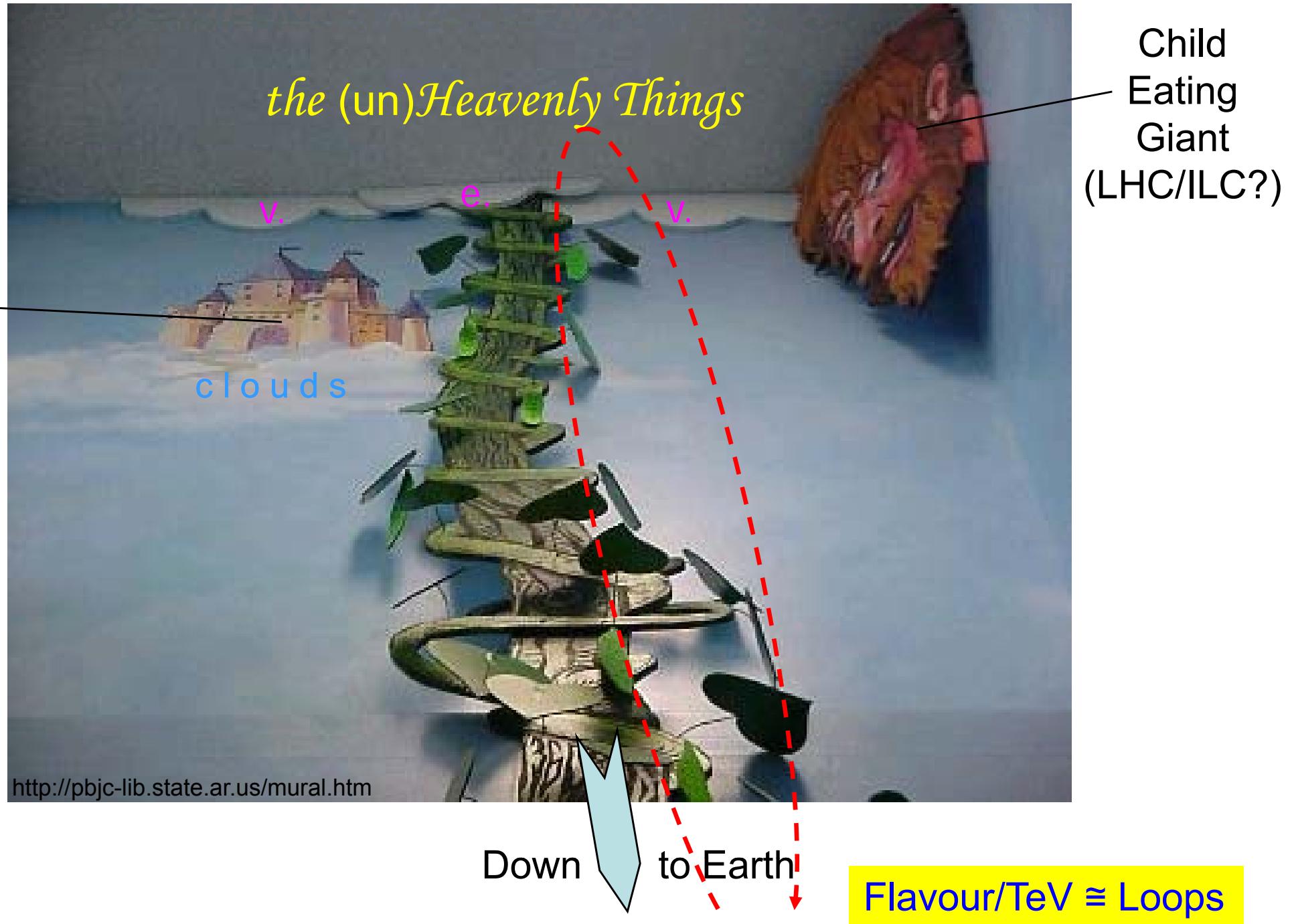


Search for TeV Scale Physics in Heavy Flavour Decays

George W.S. Hou (侯維恕)
National Taiwan University

July 28, SUSY 2007 @ Karlsruhe





Outline



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 $b \rightarrow s$ w/ Boxes and Penguins

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

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

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

IV RH Currents and Scalar Interactions

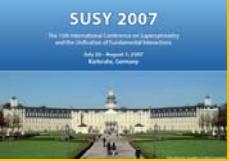
TCPV in $B \rightarrow X_0\gamma$; $B_s \rightarrow \mu\mu$

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

VI τ : LFV and $(B-L)V$

$\tau \rightarrow \ell\gamma, \ell\ell\ell'$; $\tau \rightarrow \Lambda\pi, p\pi^0$

VII Conclusion



Strategy and Apologies



- Pertinent to BSM
and not too tricky ...
- Physics (vs Expt'l detail — not always most up-to-date)
[3 TH talks 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 $\sin(2\beta)$ in measurements that are independent of $B \bar{B}$ and $K \bar{K}$ mixing. It is shown that the B_d , B_s and K_S systems. We discuss several constructions of this triangle, which will eventually can be completely removed. Simultaneously, it will be possible to probe for New Physics.

Comments: 9 pages, 6 figures

Subjects: High Energy Physics - Phenomenology (hep-ph) High Energy Physics - Experiment (hep-ex)

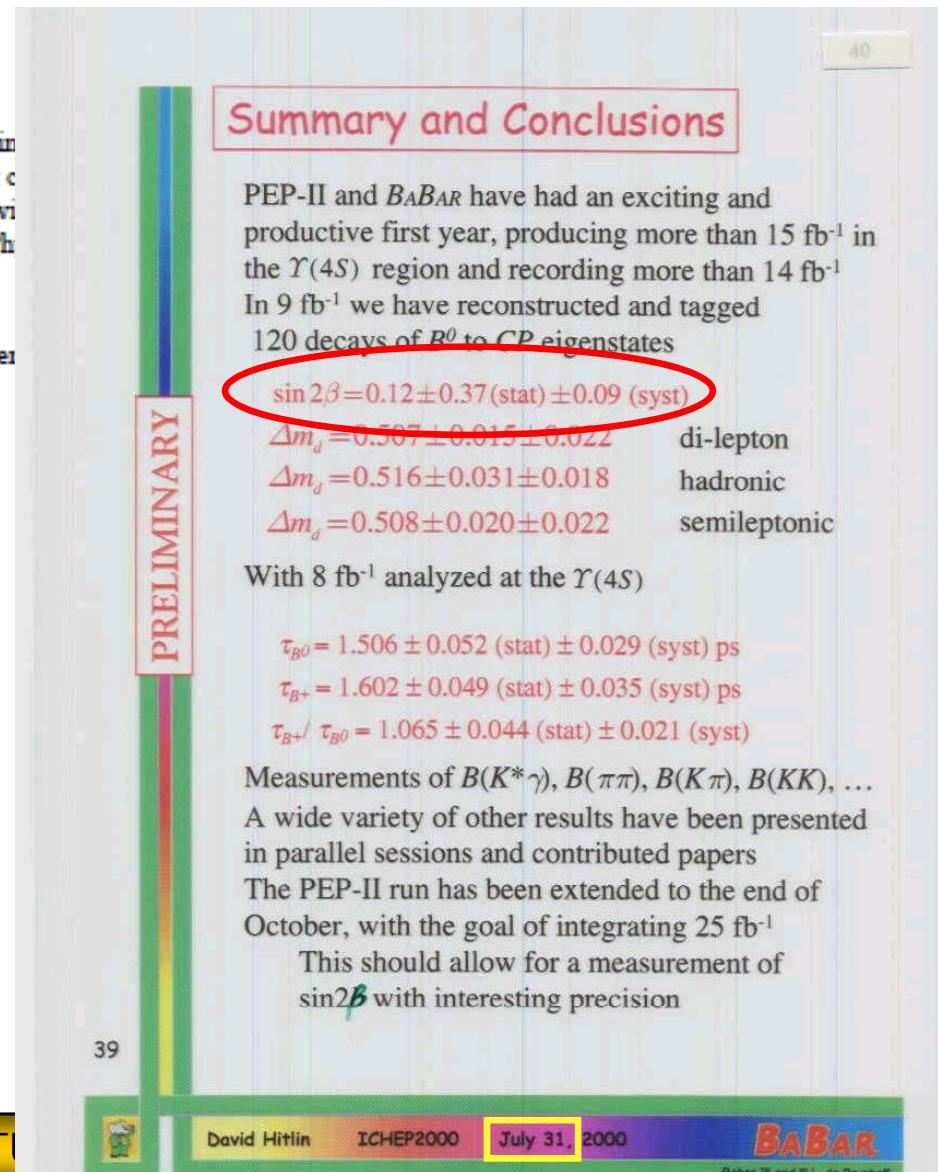
Journal reference: Phys.Lett. B492 (2000) 115-122

Cite as: [arXiv:hep-ph/0007360v1](https://arxiv.org/abs/hep-ph/0007360v1)

Search for Future Influence from L.H.C

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

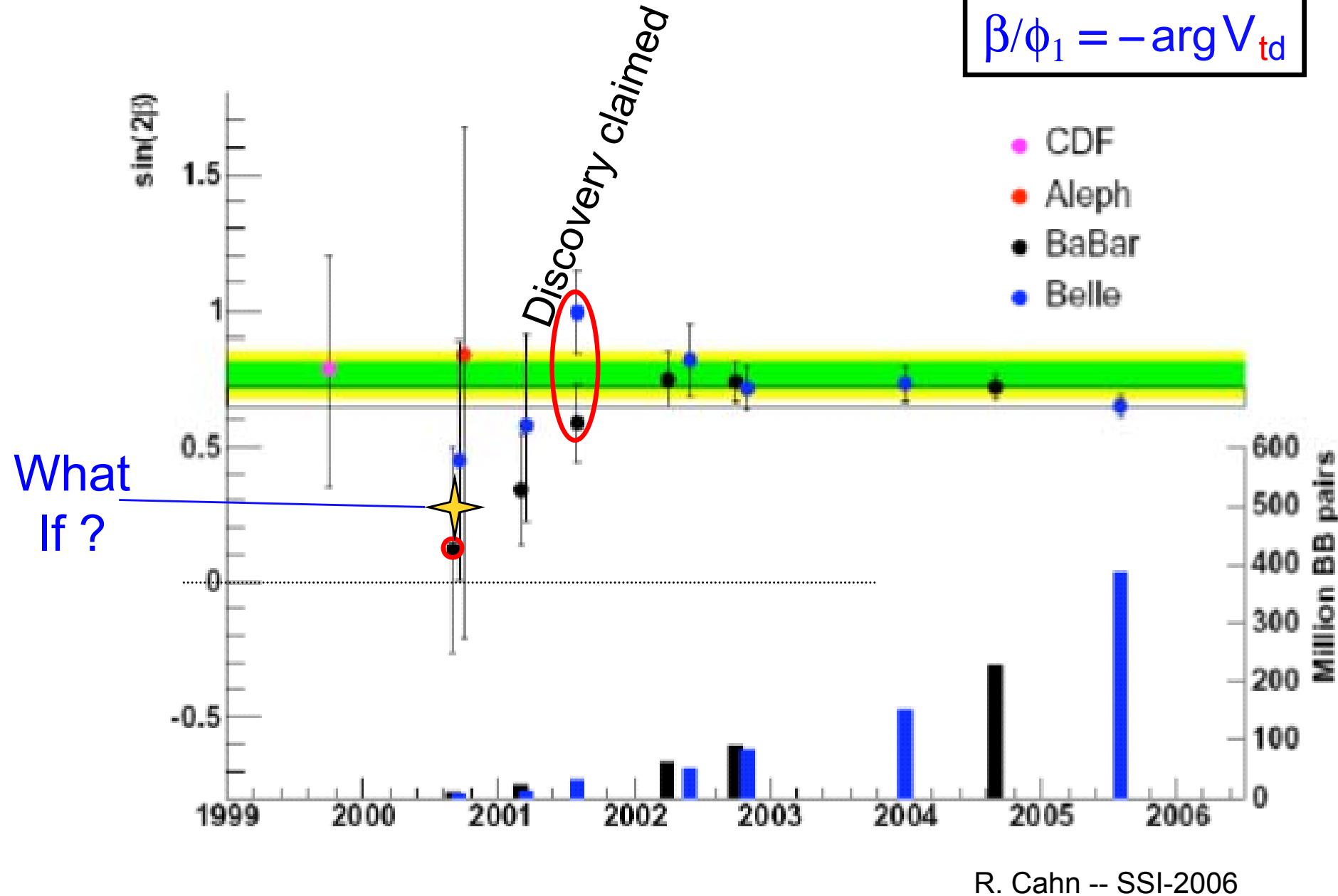
SuperPowered Theorists ?
or
Wormhole from/to the Future?



sin 2β history (1999-2005)

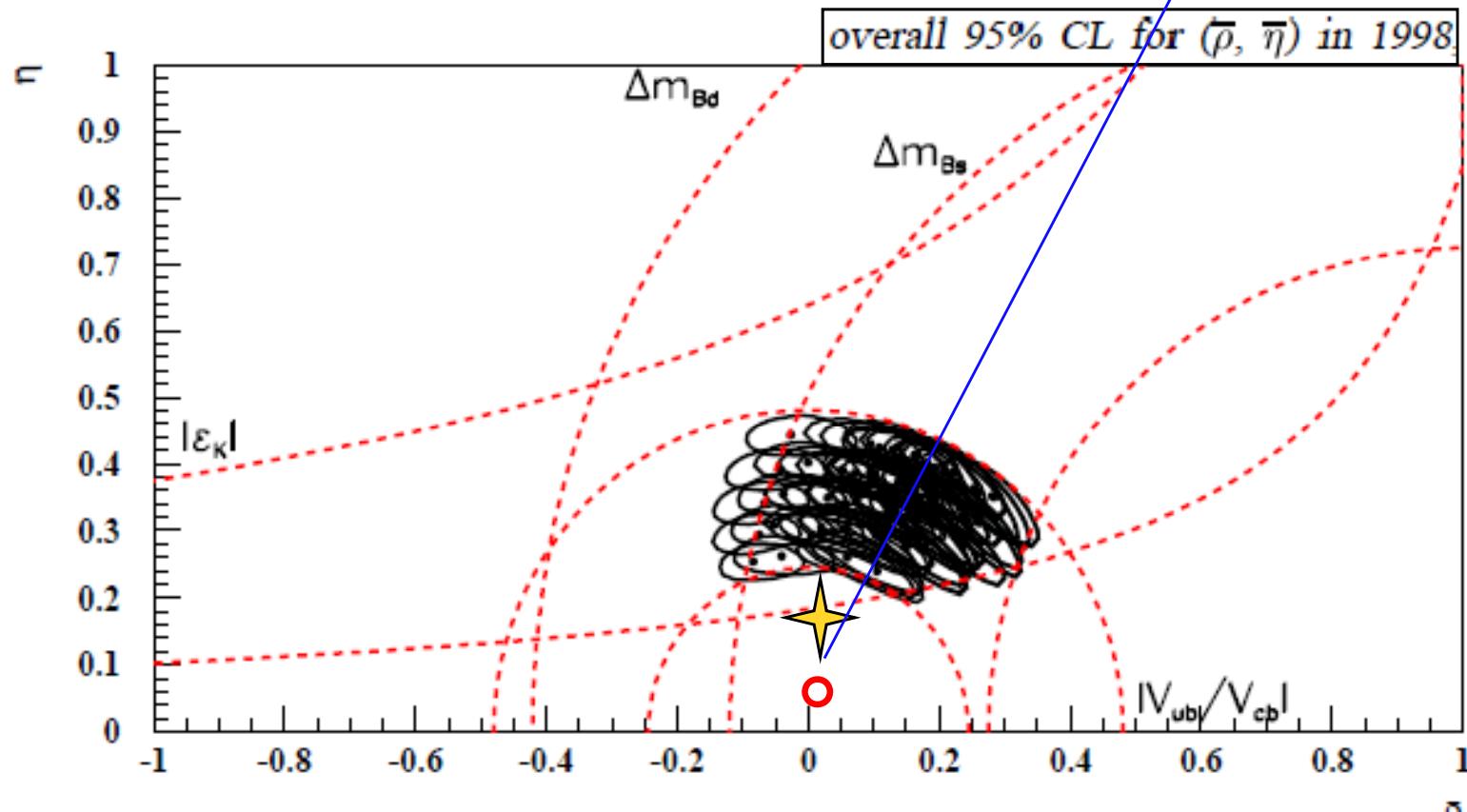


$$\beta/\phi_1 = -\arg V_{td}$$





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



Babar Physics Book

Would have heard more about it.

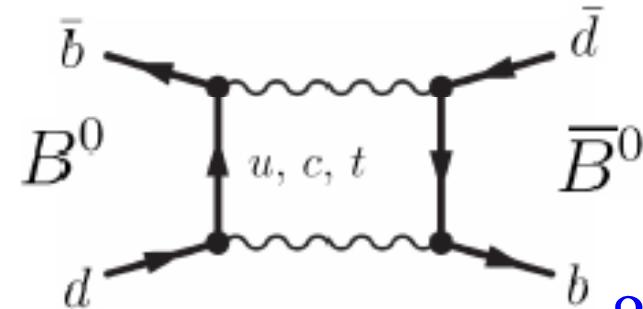
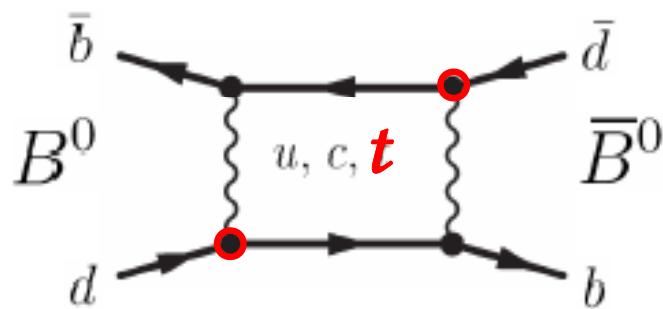




Δm_{B_d} , top and V_{td}



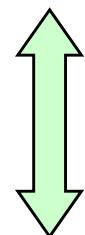
Standard Model Predictions



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

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

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



Nondecoupling — $\lambda_t \sim 1$

“Higgs Affinity”

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

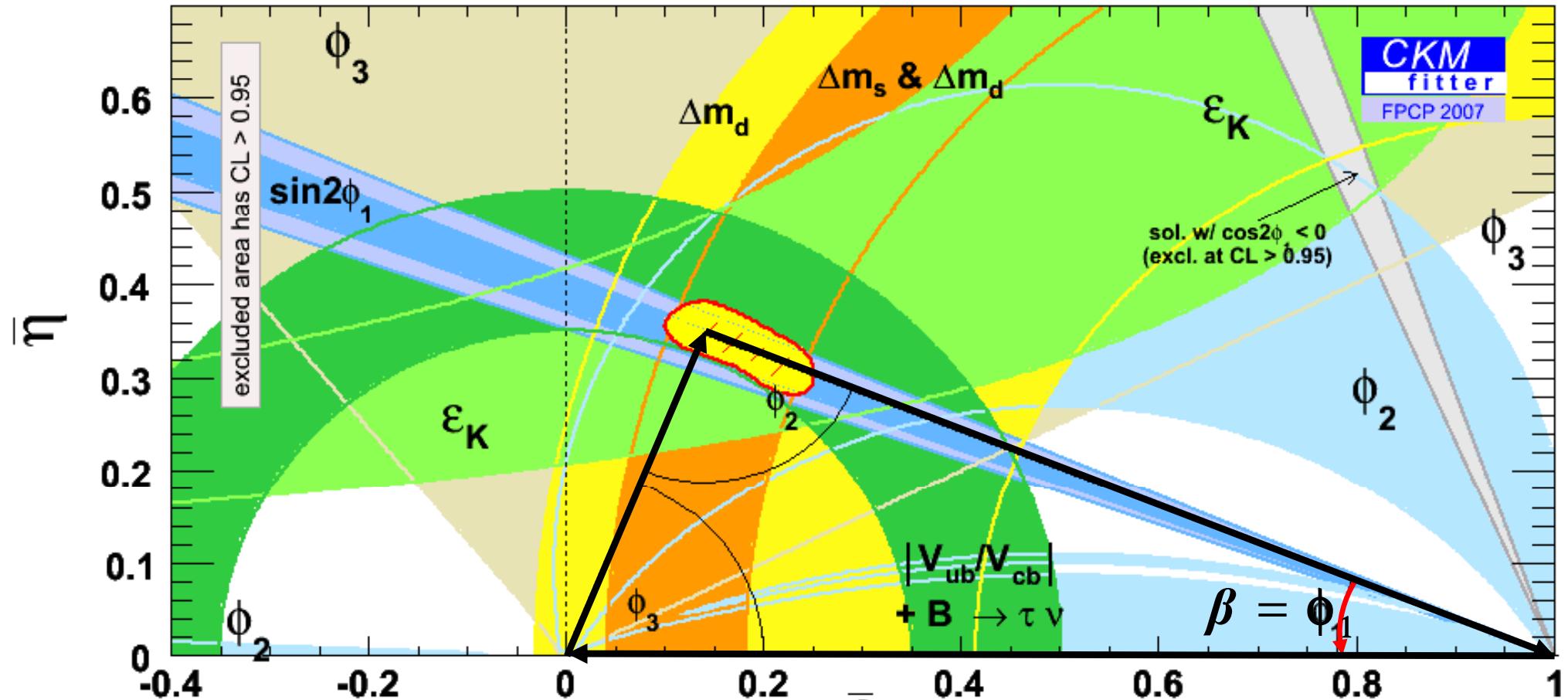
Loops



$b \rightarrow d$ transitions consistent with SM

Our
Main Theme

What about $b \rightarrow s$ transitions ?



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



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

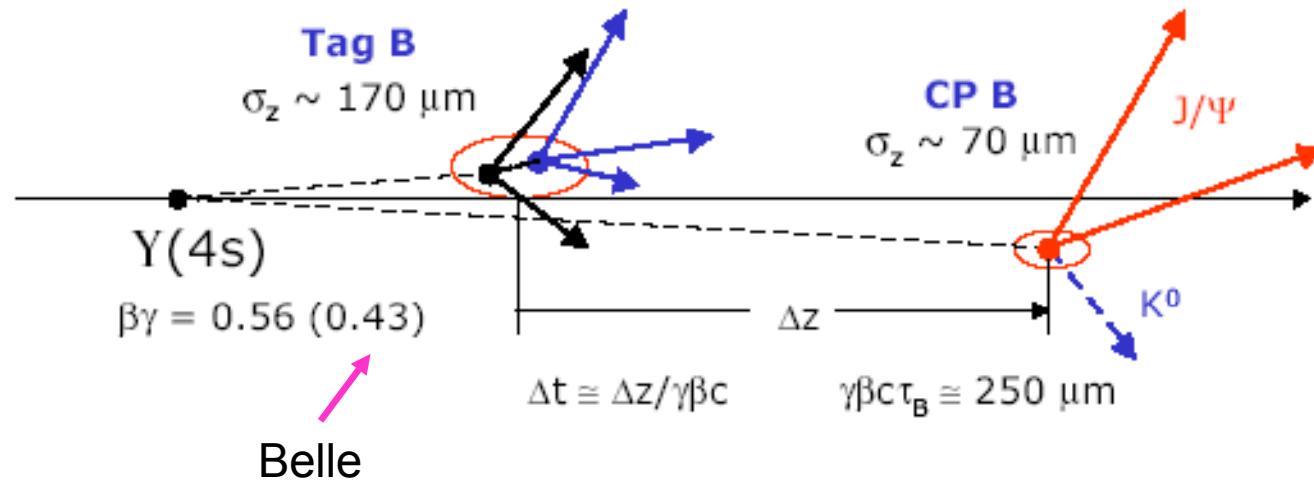
The Current Frontier
 $\tau \rightarrow \mu$ Echoes



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



B decays in \sim picosecond



One B Decay

B^0 or \bar{B}^0
Tag Flavor

Other B Decay

CP Eigenstate

Measure Both

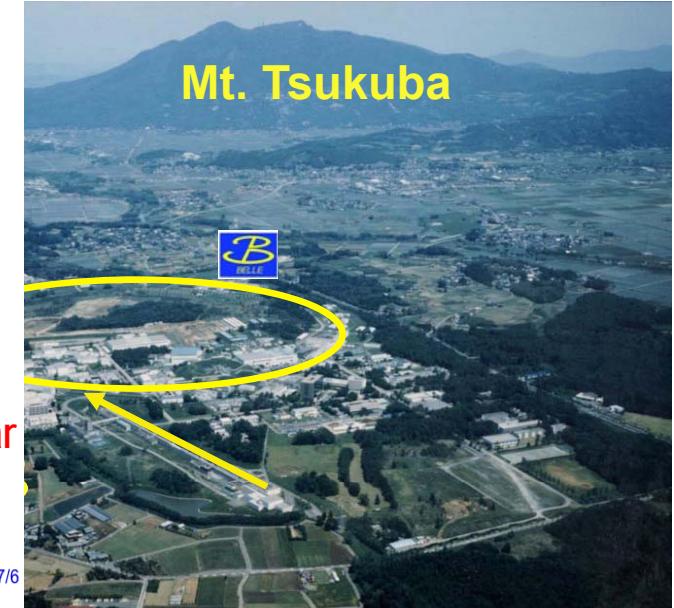
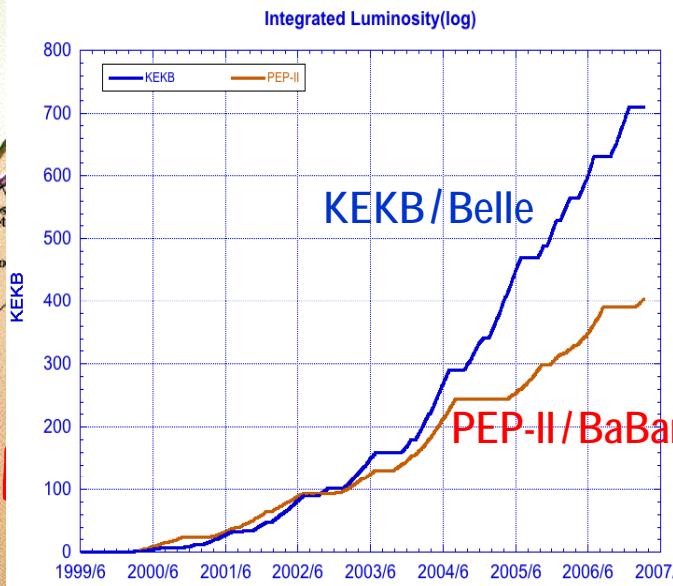
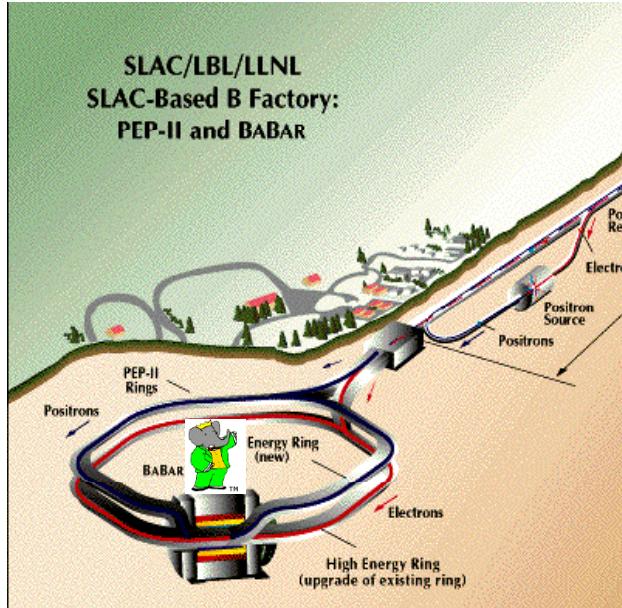
Decay Vertex
 $\Delta z \propto \Delta t$

$J/\psi K_S$, $\pi^+ \pi^-$, $\eta' K_S$, ϕK_S , $K_S \pi^0$

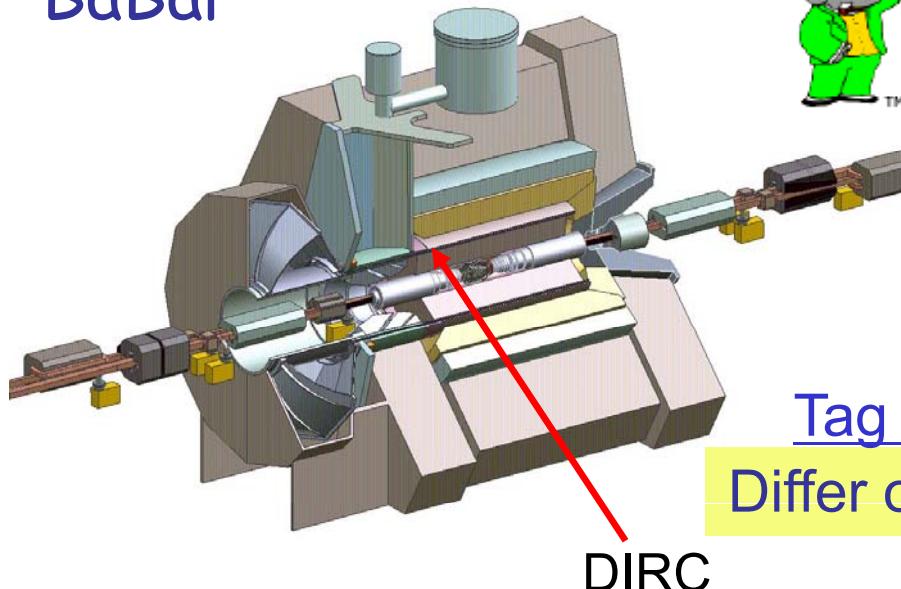
2001 !



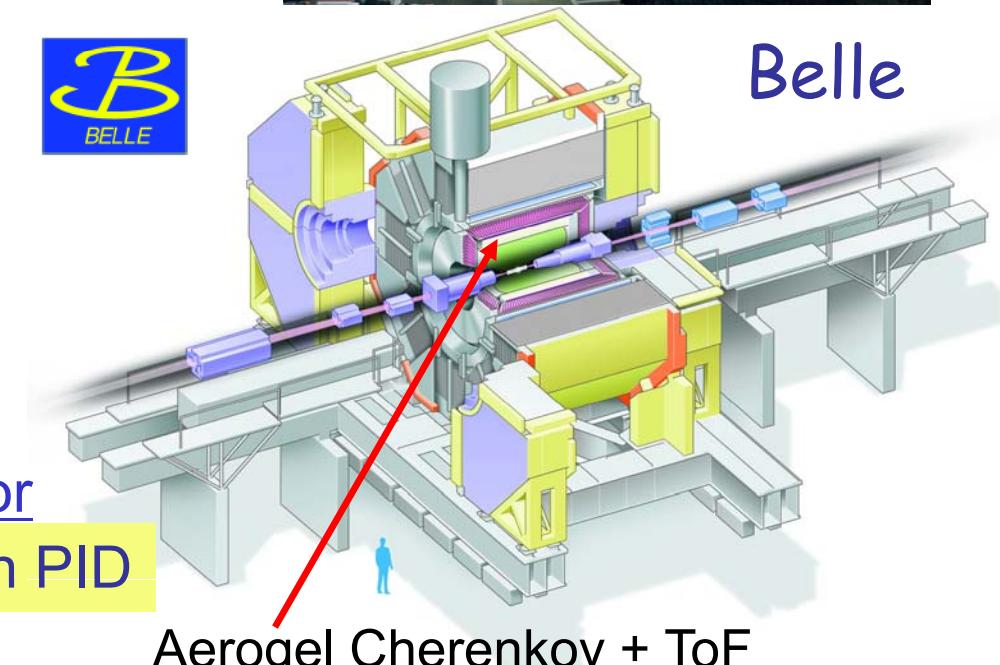
The Two B Factories



BaBar



Belle



Tag Flavor
Differ only in PID

DIRC

vs

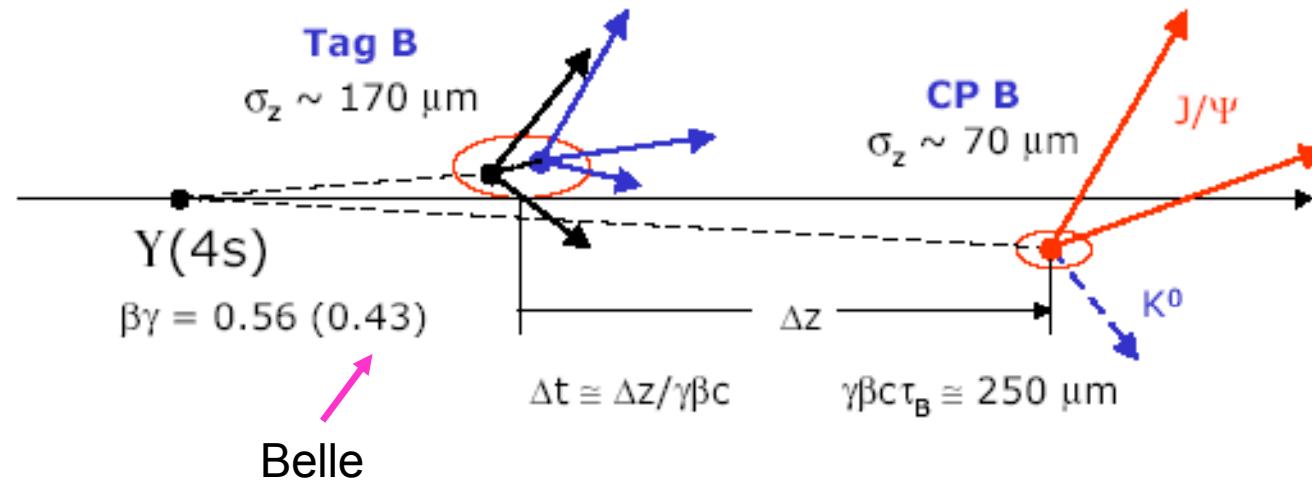
Aerogel Cherenkov + ToF



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



B decays in \sim picosecond



One B Decay

B^0 or \bar{B}^0
Tag Flavor

Other B Decay

CP Eigenstate

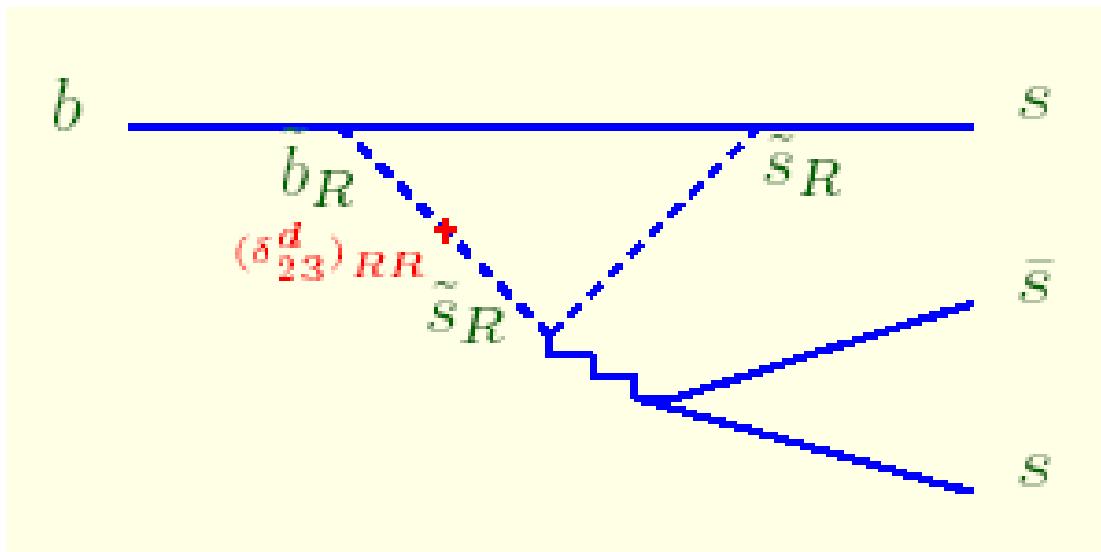
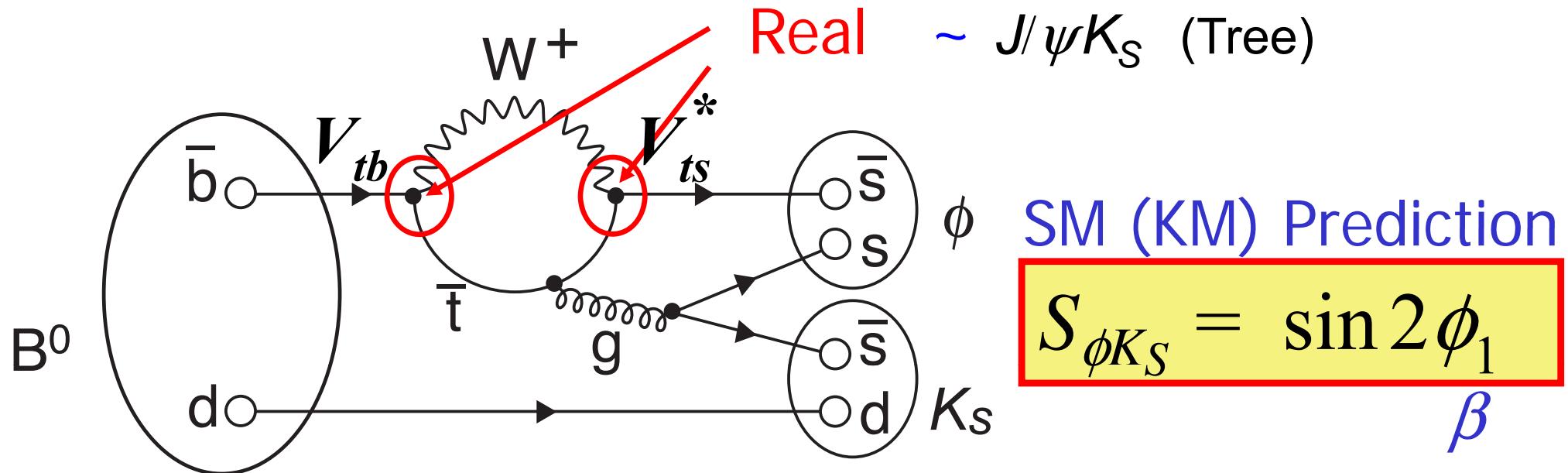
Measure Both

Decay Vertex
 $\Delta z \propto \Delta t$

$J/\psi K_S$, $\pi^+ \pi^-$, $\eta' K_S$, ϕK_S , $K_S \pi^0$
2001 !



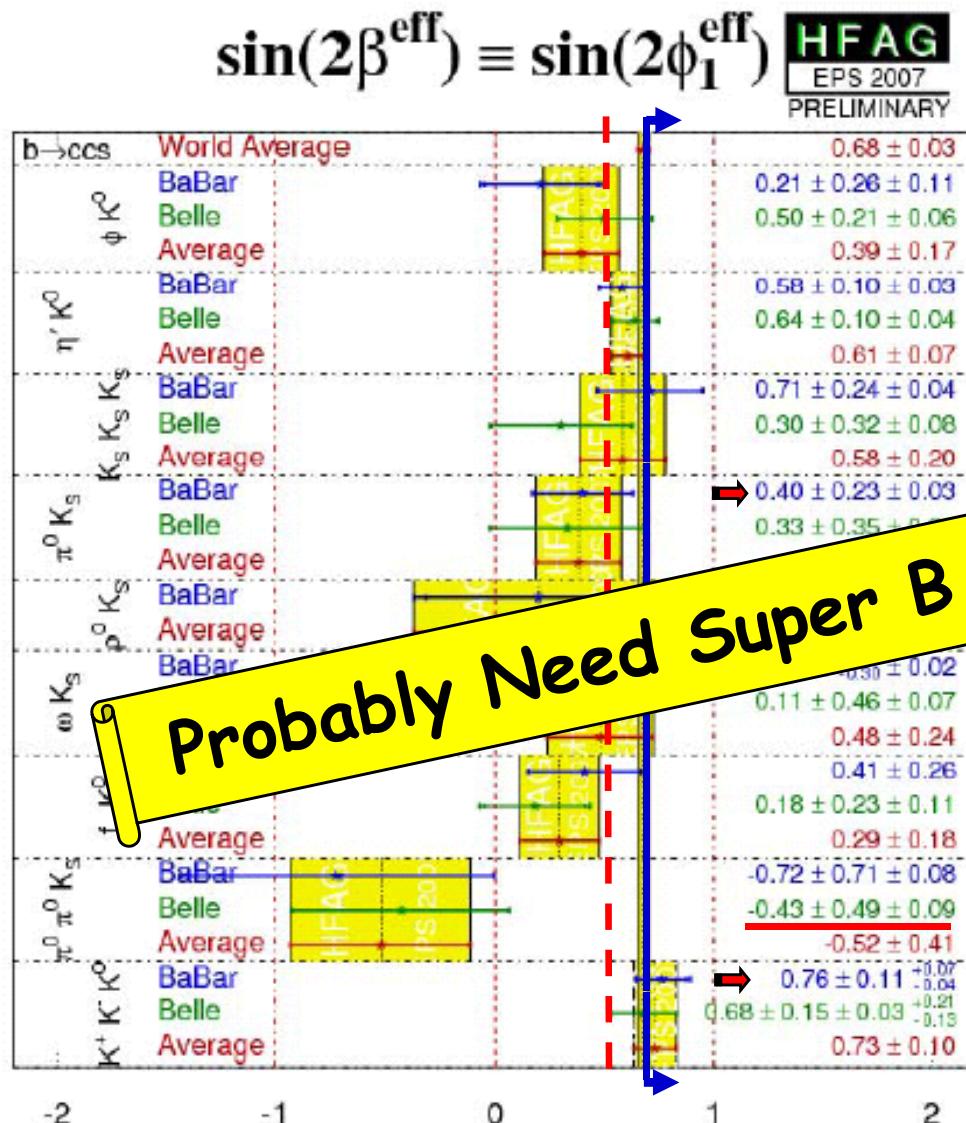
$b \rightarrow s$ Penguins (Vertex Loops)



Possible SUSY
FCNC/CPV Loop
Can Break Equality



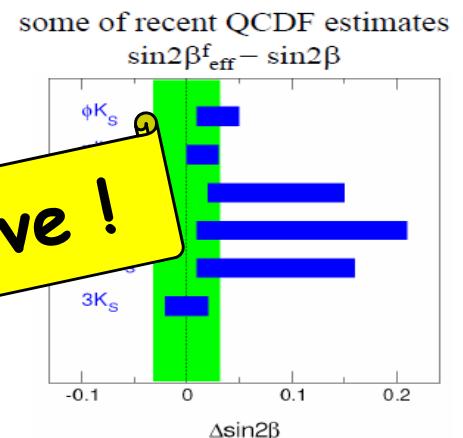
$\Delta S = S_{\text{sqq}} - S_{\text{ccs}} < 0$ "Problem"



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

Theory Expect

$\sin 2\phi_{\text{s-per}}$



Naïve average of all $b \rightarrow s$ modes

$$\sin 2\beta^{\text{eff}} = 0.56 \pm 0.05$$

2.1σ deviation (was 2.6) btwn
 $b \rightarrow \text{sqq}$ and $b \rightarrow \text{ccs}$

New Physics !?

Even deviation of ~ few deg indicate NP

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

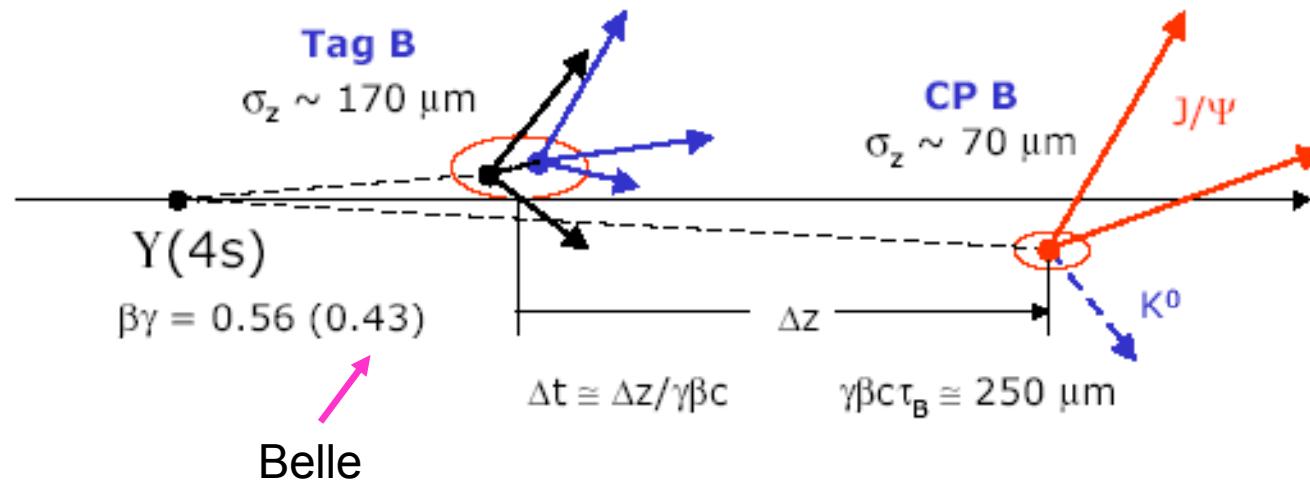
Need More Data !



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



B decays in \sim picosecond



One B Decay

B^0 or \bar{B}^0

Tag Flavor

Other B Decay

CP Eigenstate

Measure Both

Decay Vertex

$$\Delta z \propto \Delta t$$

$J/\psi K_S$

2001 !

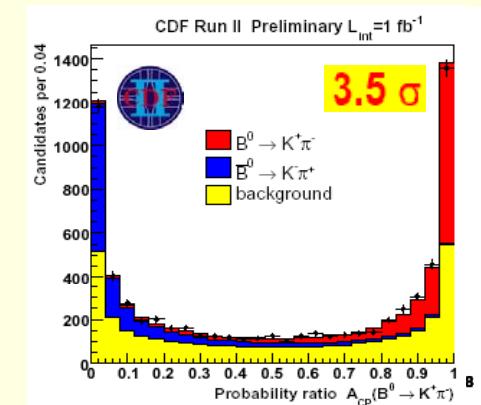
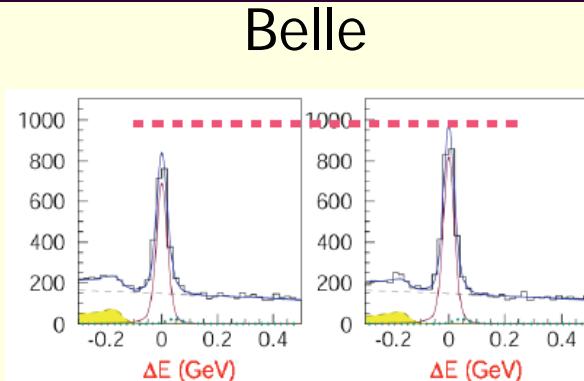
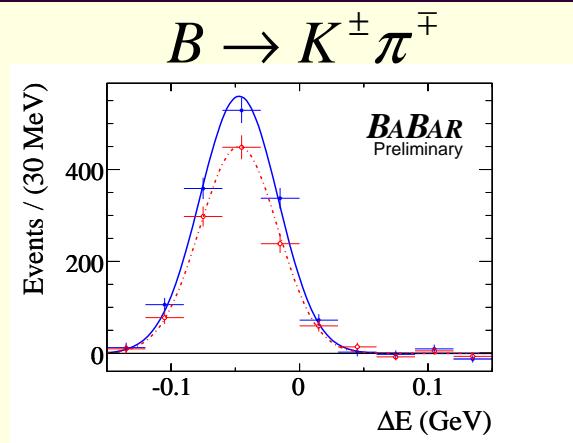
$\pi^+ \pi^-$, $\eta' K_S$, ϕK_S , $K_S \pi^0$

Lack of Vertex
in LHCb

A_{CP} on $B \rightarrow K\pi$

$\Delta A_{K\pi}$ Problem

Experiment is Firm



$$A_{CP} = -0.107 \pm 0.018^{+0.007}_{-0.004}$$

0707.2798 [hep-ex] 

$A_{CP}(K^+\pi^0) = +0.030 \pm 0.039 \pm 0.010$
strengthen conclusion

$$-0.093 \pm 0.018 \pm 0.008$$

Direct CPV established in B system (2004) !

range including CLEO: $A_{CP}(K^+\pi^-) = -0.097 \pm 0.012$

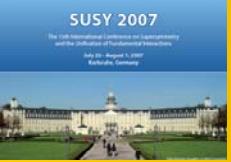
- $A_{CP}(K^+\pi^0) = +0.047 \pm 0.026 \Rightarrow \Delta A(K\pi) = 0.144 \pm 0.029 @5\sigma$

- 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 factory!

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

Rare Hadronic B Decays



Why $\Delta\mathcal{A}_{K\pi} = \mathcal{A}_{K^+\pi^0} - \mathcal{A}_{K^+\pi^-} > 0$ a Puzzle ?

$-9.7 \pm 1.2 \%$ $+4.7 \pm 2.6 \%$



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



$$r = \frac{\dots}{\dots}$$

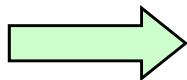
$$\sqrt{2}\mathcal{M}_{K^+\pi^0} - \mathcal{M}_{K^+\pi^-} \propto \cancel{(P_{EW} + C)}^? \quad r = \frac{\dots}{\dots}$$

$\Delta\mathcal{A}_{K\pi} \sim 0$ expected

C : color-suppressed tree (a_2)

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

Large C ?

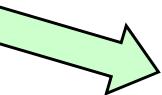


Suppress Tree CPV Phase

$C/T > 1$ needed !

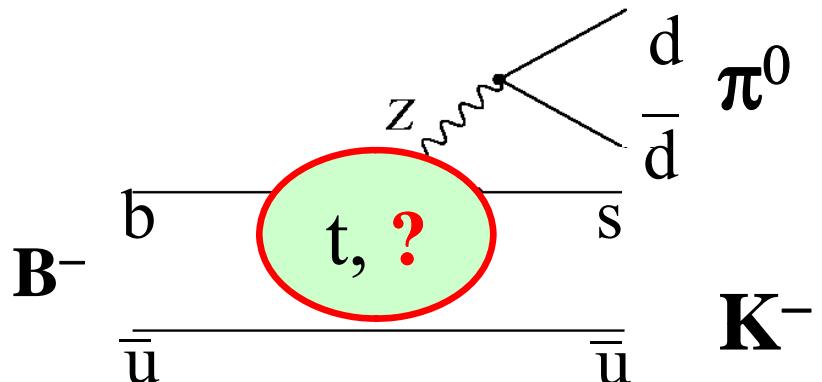
Baek, London, hep-ph/0701181

Large **EW Penguin** ?



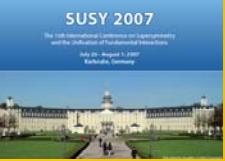
EW P not so easy for SUSY

Need NP CPV Phase



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

Neubert, Rosner, PRL'98



In Search of New Physics



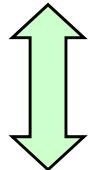
$b \leftrightarrow s$ CPV Phenomena Is Current \mathcal{NP} Frontier

Two Hints

- S_f in $b \rightarrow sqq$
- $\mathcal{A}_{K^+\pi^-} - \mathcal{A}_{K^+\pi^0}$ Puzzle

TCPV Mixing-dep.

DCPV Direct



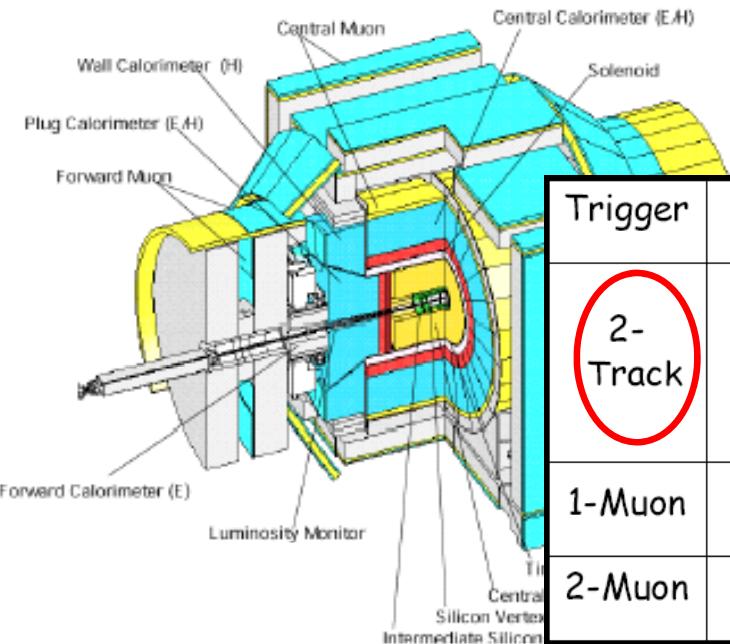
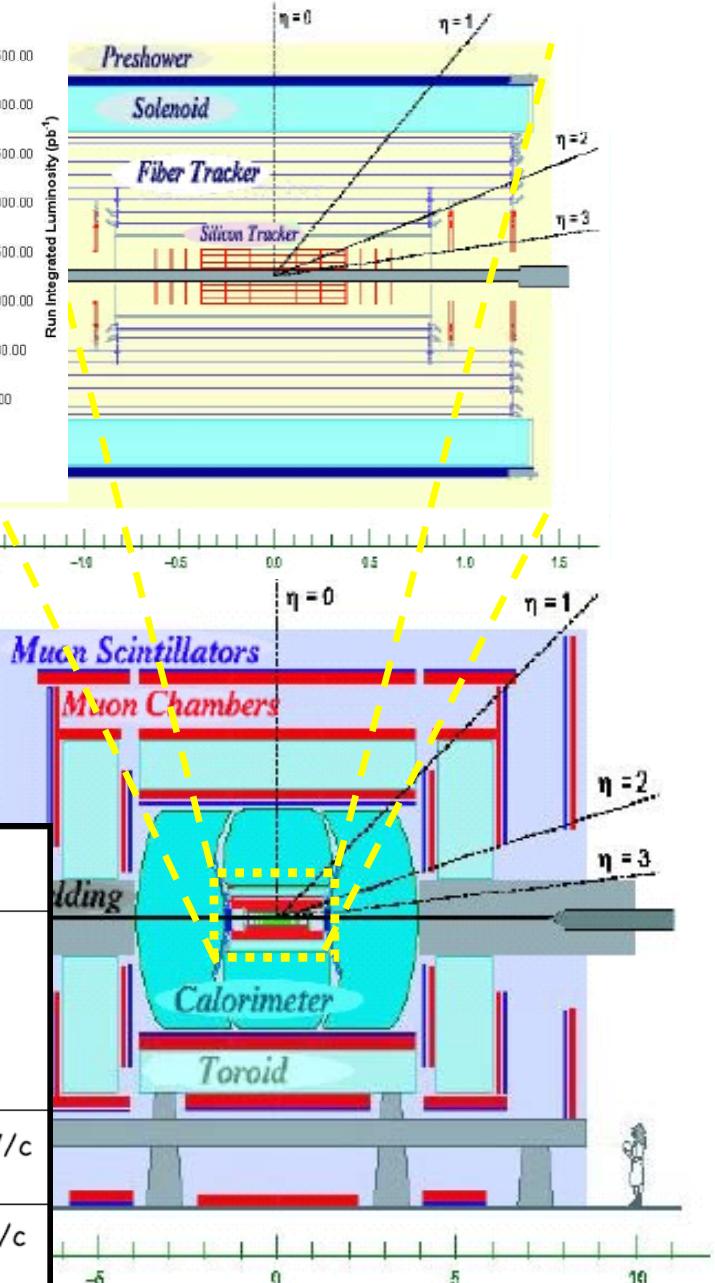
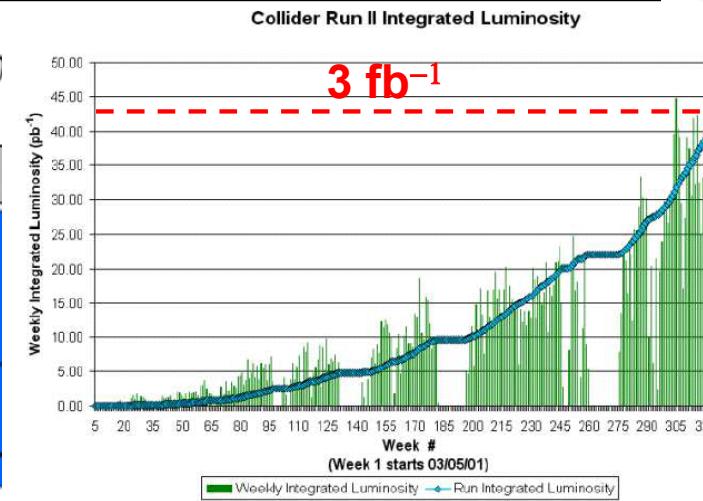
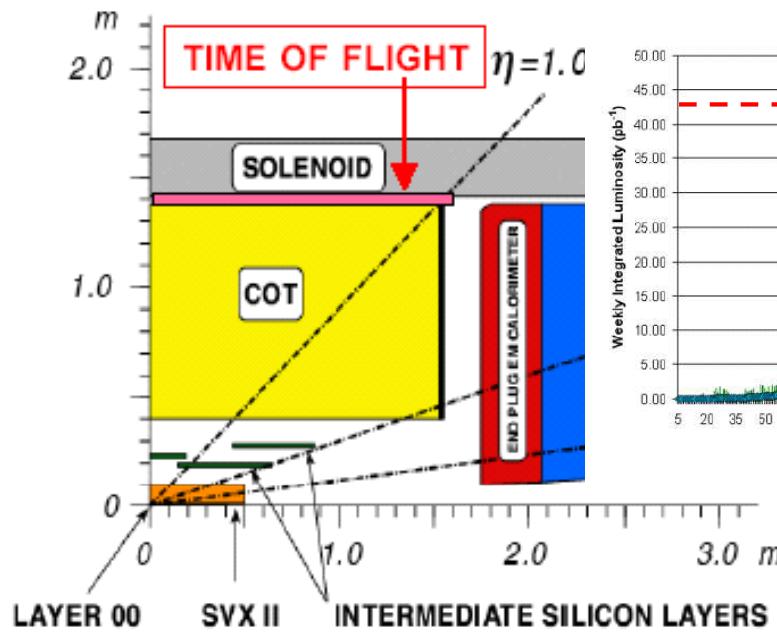
- Δm_{Bs}
- $\Delta \Gamma_{Bs}$

SM-like

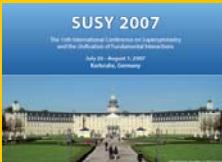
CPV ?

$\sin 2\Phi_{Bs}$

$\cos 2\Phi_{Bs}$



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



SM

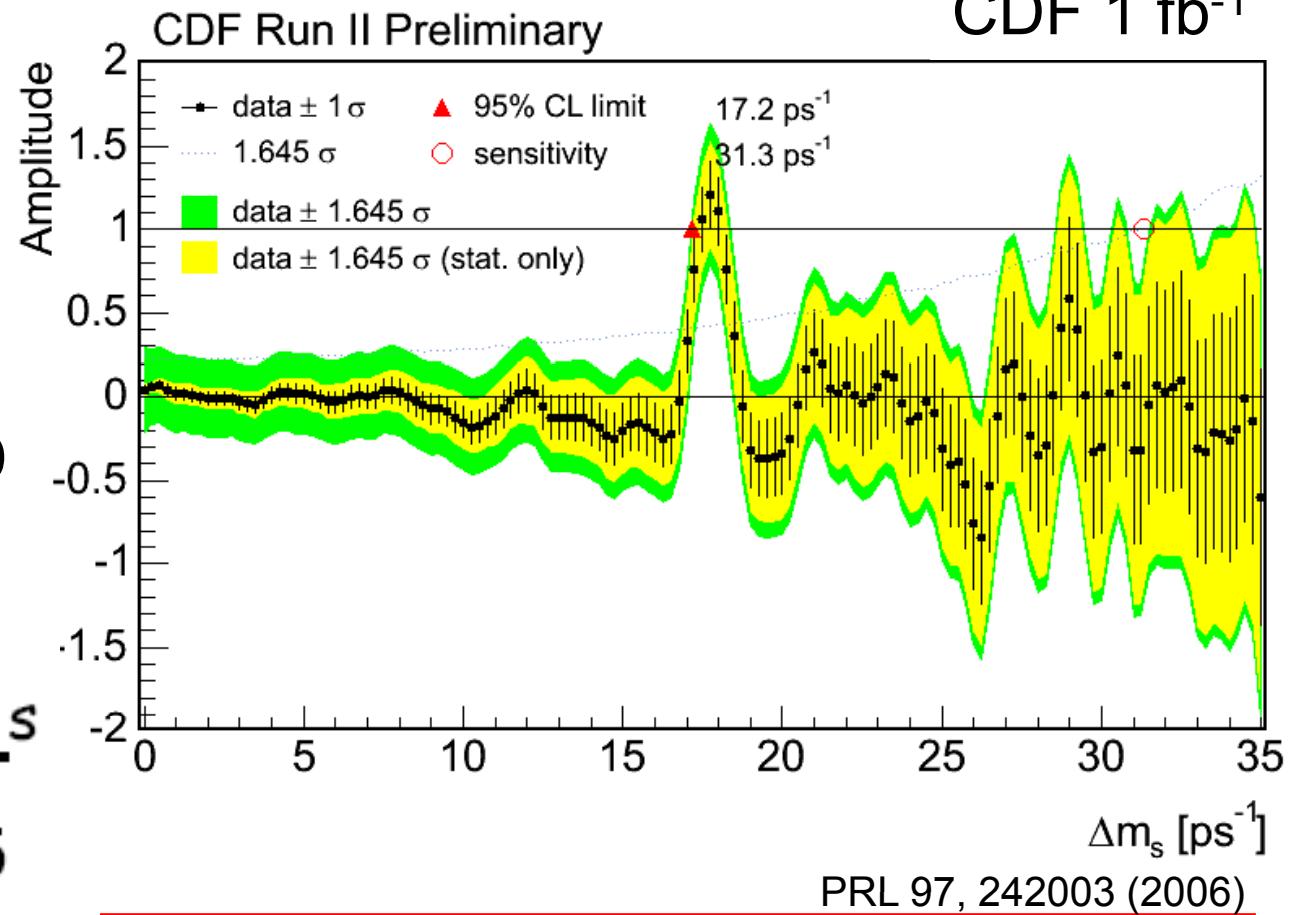
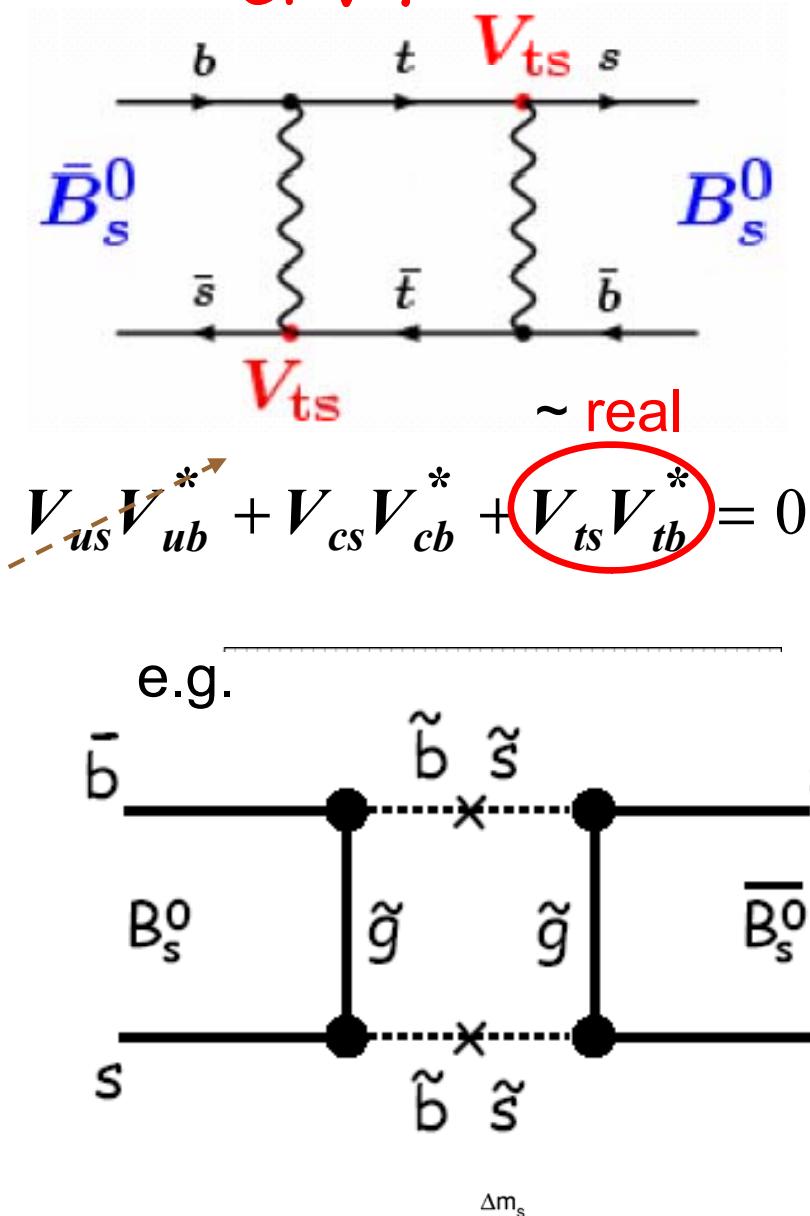
$$\Phi_{Bs} \equiv -\arg V_{ts} \sim -0.02$$

Window on BSM



CPV ?

$$\beta/\phi_1 = -\arg V_{td} \Rightarrow \Phi_{Bd} \sim 0.37 \quad \text{measured}$$



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

a bit “smallish”, if take nominal f_{B_S}



$\Delta\Gamma_s$ and ϕ_s from $B_s^0 \rightarrow J/\psi \phi$

$\Delta\Gamma_s = \Gamma_L - \Gamma_H = \Delta\Gamma_{CP} \times \cos(\phi_s)$ very sens. to NP Lifetime, but not Oscillations

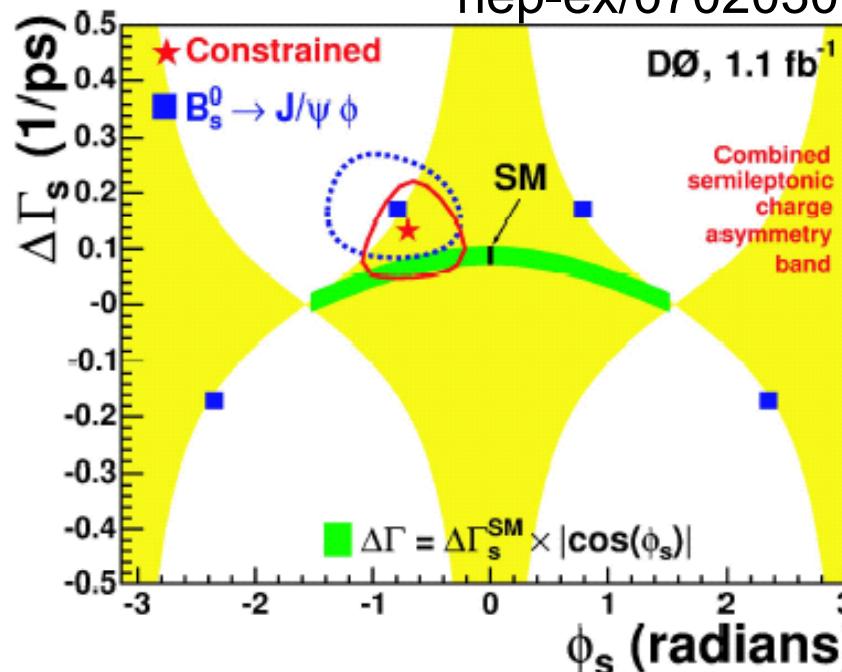
PRL 98, 121801 (2007) + hep-ex/0701012 (A_{SL})

hep-ex/0702030

Concerted $D\emptyset$ Effort

[A_{SL} advantage

— periodical reversal
of magnet polarity



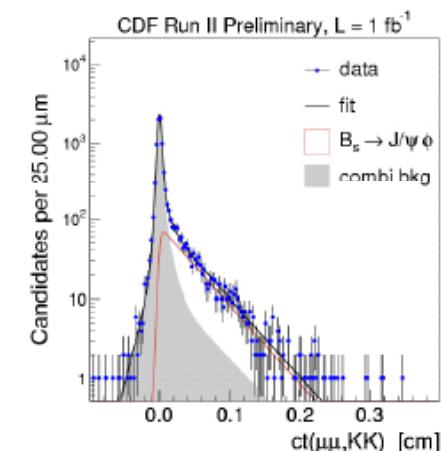
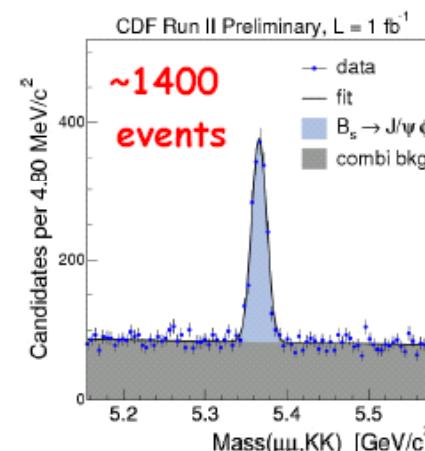
SM: Lenz, Nierste, hep-ph/0612167

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

$\cos 2\Phi_{B_s}$ somewhat
a blunt instrument.

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

Parallel talk 31/7 ?



Φ_{B_s} Prospect (short term)

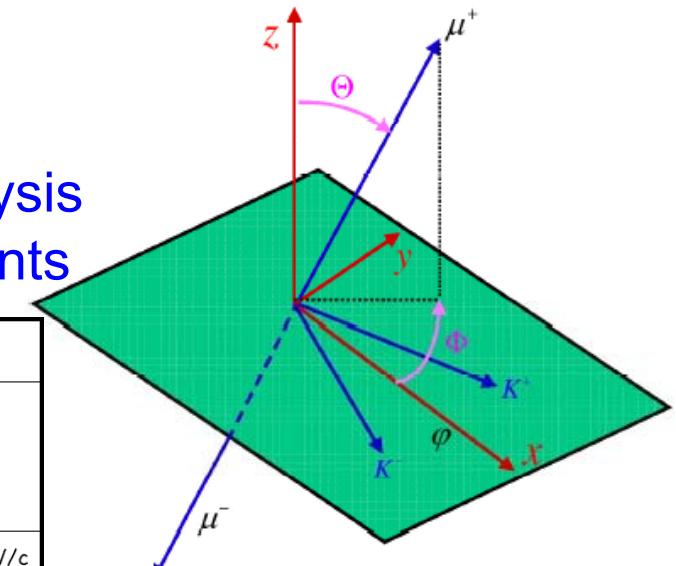


$B_s \rightarrow J/\psi \phi$ analogous to $B_d \rightarrow J/\psi K_S$

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

- **CDF/DØ**: 8 fb⁻¹ projected
 $\sigma(\sin 2\Phi_{B_s}) \sim 0.2$ (?) / exp
similar
- **LHCb**: 0.5 fb⁻¹ (2008 ?)
 $\sigma(\sin 2\Phi_{B_s}) \sim 0.04$
- **ATLAS**: 2.5 fb⁻¹ (2008 ?)
 $\sigma(\sin 2\Phi_{B_s}) \sim 0.16$
- **CMS** ?

Trigger	CDF	DØ
2-Track	$p_T > 2.0 \text{ GeV}/c$ $p_{T1} + p_{T2} > 5.5 \text{ GeV}/c$ $100 \mu\text{m} < d_{1,2} < 1 \text{ mm}$	—
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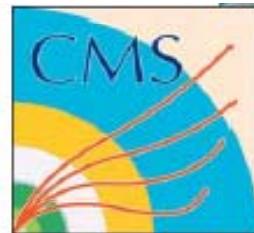
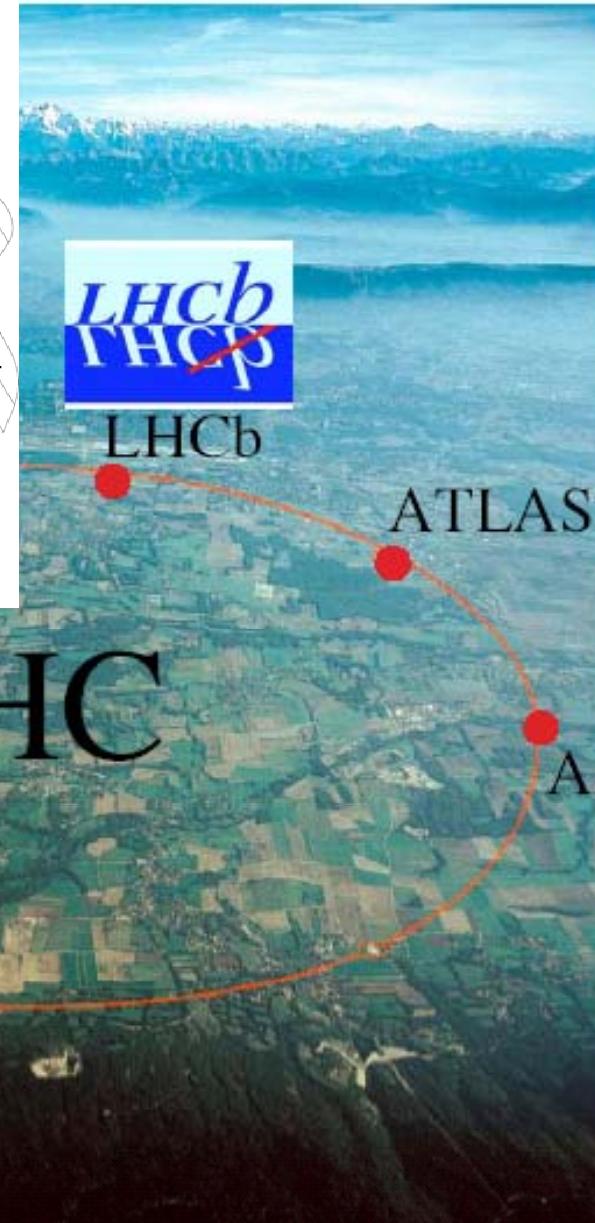
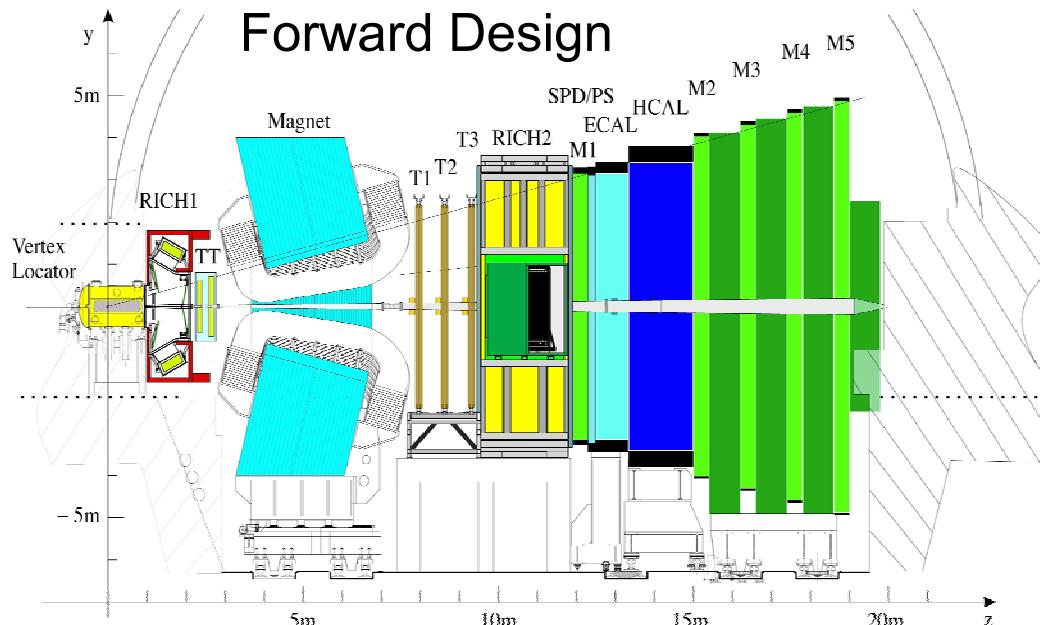


Parallel talks 31/7

Nakada @ fLHC 3/07



LHC Physics Run Starts 2008



LHC



Φ_{B_s} Prospect (short term)

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

VV \Rightarrow Angular & Vertex Resolved Analysis
to disentangle CP \pm components

- **CDF/DØ**: 8 fb⁻¹ projected

$$\sigma(\sin 2\Phi_{B_s}) \approx 0.2 \text{ (?)}/\exp \text{ similar}$$

Trigger	CDF	DØ
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- **LHCb**: 0.5 fb^{-1} (2008 ?)

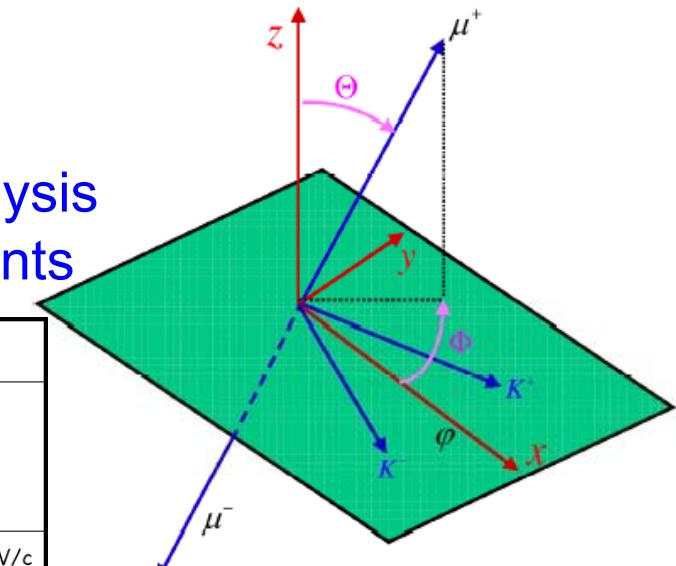
$$\sigma(\sin 2\Phi_{B_s}) \approx 0.04$$

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

$$\sigma(\sin 2\Phi_{B_s}) \approx 0.16$$

CMS ?

Nakada @ fLHC 3/07



€ LHCb the winner if \sim SM

$$\sin 2\Phi_{B_s} \sim -0.04 \text{ in SM}$$

But 2009 looks interesting !

\$ Tevatron could get lucky

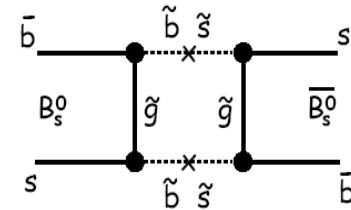
if $\sin 2\Phi_{B_s}$ large \longleftrightarrow New Physics !

Could Tevatron run beyond 2008 ?

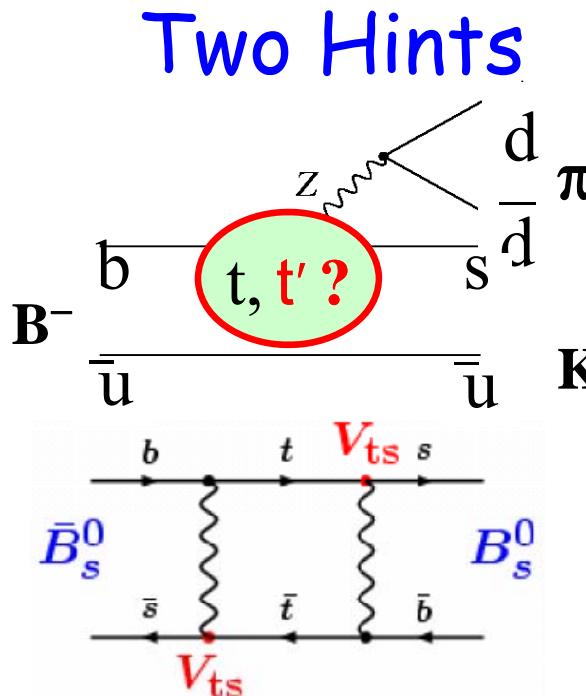


In Search of New Physics

Can $\sin^2\Phi_{Bs}$ be *large*?

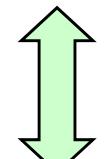


$b \leftrightarrow s$ CPV Phenomena Is Current NP Frontier



Two Hints

- S_f in $b \rightarrow sqq$
- $\mathcal{A}_{K^+\pi^-} - \mathcal{A}_{K^+\pi^0}$ Puzzle
- Δm_{Bs}
- $\Delta \Gamma_{Bs}$



EW Penguin

t' non decoupled
Boxes

SM-like

TCPV

Mixing-dep.

DCPV

Direct

WSH, Nagashima, Soddu, PRL'05

WSH, Nagashima, Soddu, hep-ph/0610385

$\sin^2\Phi_{Bs} \sim -0.5 - 0.7$
in SM4



Φ_{B_s} Prospect (short term)

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

VV \Rightarrow Angular & Vertex Resolved Analysis
to disentangle CP $+/-$ components

- **CDF/DØ**: 8 fb⁻¹ projected

$$\sigma(\sin 2\Phi_{B_s}) \approx 0.2 \text{ (?)}/\exp \text{ similar}$$

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

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

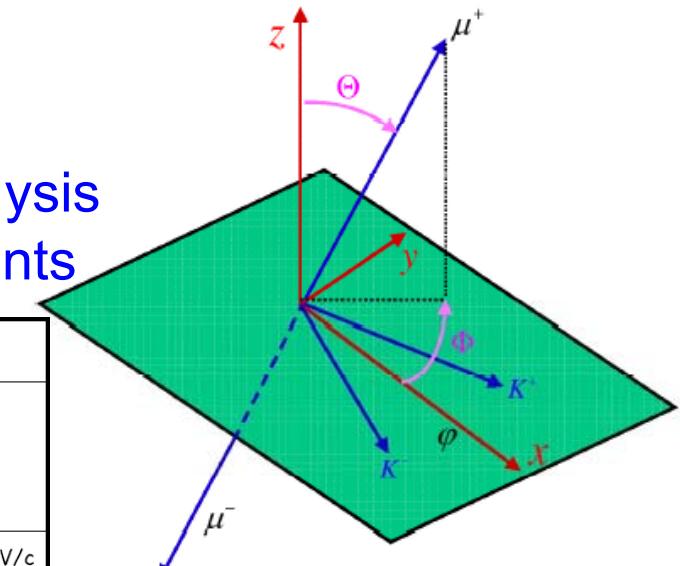
$$\sigma(\sin 2\Phi_{B_s}) \approx 0.04$$

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

$$\sigma(\sin 2\Phi_{B_s}) \approx 0.16$$

CMS ?

Nakada @ fLHC 3/07



€ LHCb the winner if \sim SM

$$\sin 2\Phi_{B_s} \sim -0.04 \text{ in SM}$$

But 2009 looks interesting !

\$ Tevatron could get lucky

if $\sin 2\Phi_{B_s}$ large \longleftrightarrow **New Physics !**

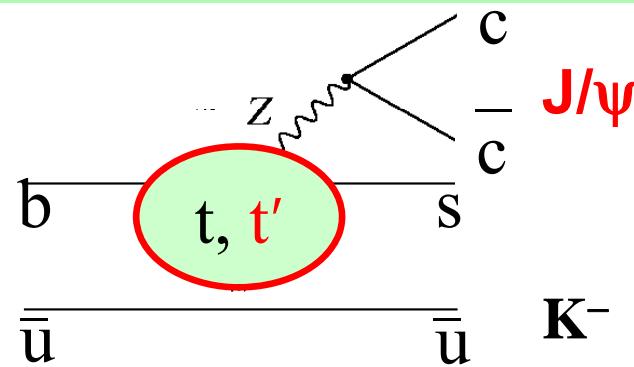
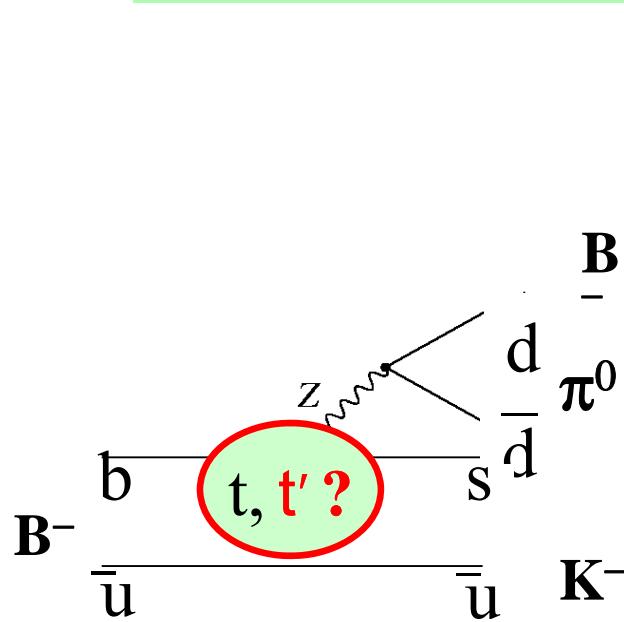
Could Tevatron run beyond 2008 ?



In Search of New Physics



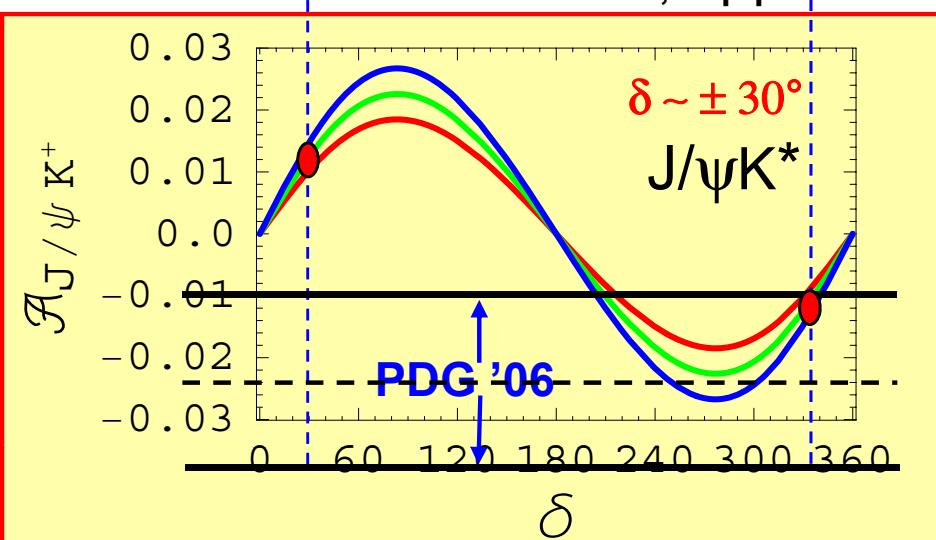
$b \leftrightarrow s$ CPV Phenomena Is Current \mathcal{NP} Frontier



lack firm SM prediction

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

WSH, Nagashima,
Soddu, hep-ph/0605080





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



PDG '07

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

VALUE

0.015 ± 0.017 OUR AVERAGE

+0.030 ± 0.014 ± 0.010

124M

-0.026 ± 0.022 ± 0.017

32M

0.018 ± 0.043 ± 0.004

10M

Error includes scale factor of 1.2.

636 AUBERT 05J BABR

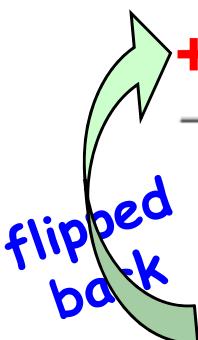
ABE 03B BELL

577 BONVICINI 00 CLE2

AUBERT 04P BABR

AUBERT 02F BABR

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



0.03 ± 0.015 ± 0.006

89M

0.003 ± 0.030 ± 0.004

636

**BaBar/Belle
Please Update !**

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

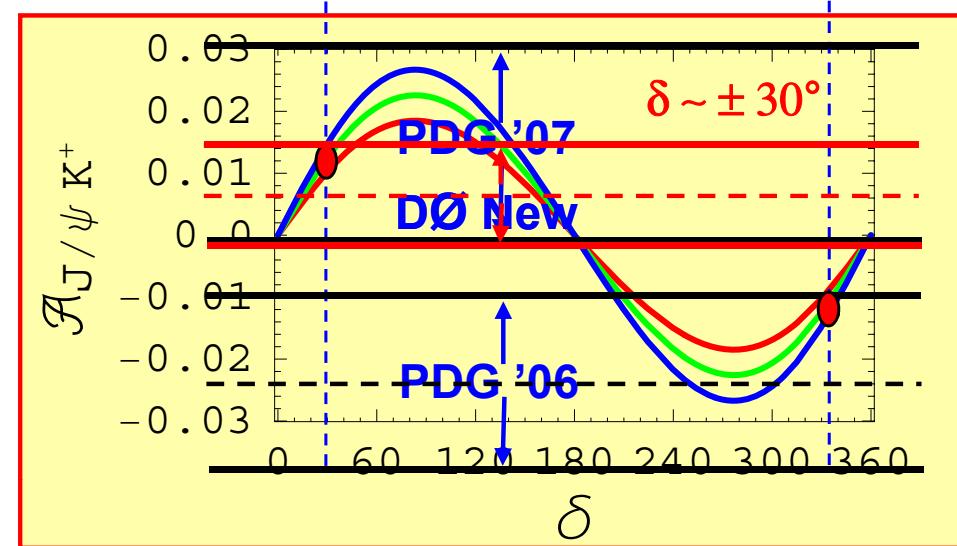
Could be seen by 2008 ?!

Better than $\Delta\mathcal{A}$ and ΔS ?



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

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



WSH, Nagashima,
Soddu, hep-ph/0605090

$\pm 0.0033 \text{ } @ 8 \text{ fb}^{-1}$
DØnote 5405-CNF 1.6 fb^{-1}
 $+0.0067 \pm 0.0074 \pm 0.0026$

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

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

matter effect



II. H^+ Probes

- $b \rightarrow s\gamma$
- $B \rightarrow (D^{(*)})\tau\nu$



$$b \rightarrow s\gamma \sim B \rightarrow X_s \gamma$$



Status of branching fraction measurements

CLEO
PRL87,251807(2001)

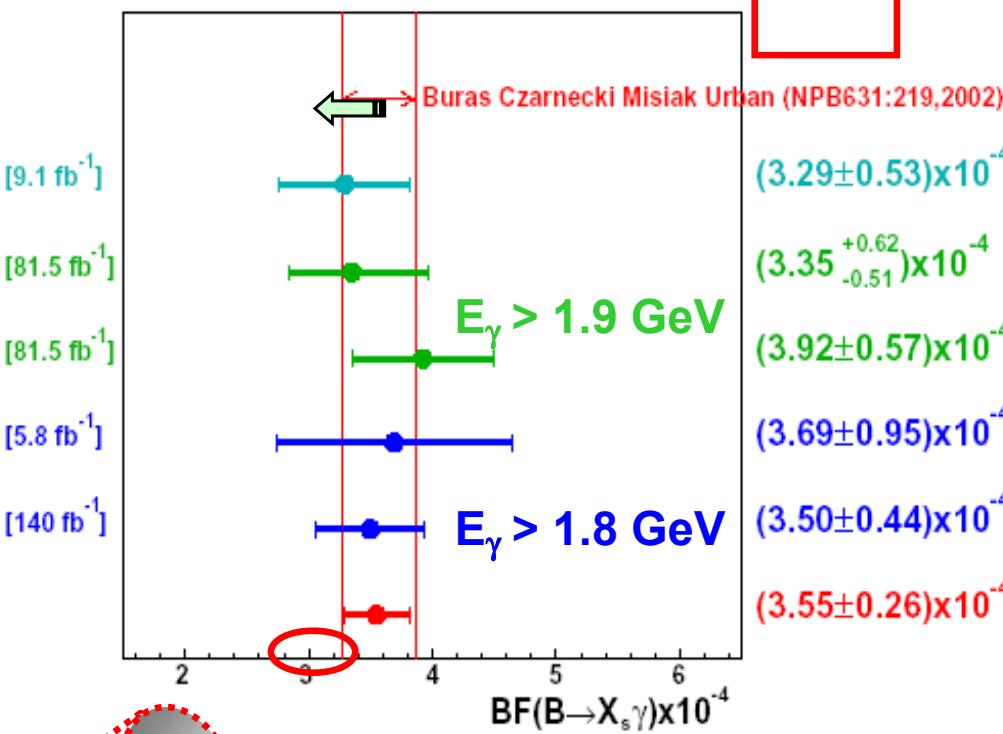
BaBar
PRD72,052004(2005)

BaBar
hep-ex/0507001

Belle
PLB511,151(2001)

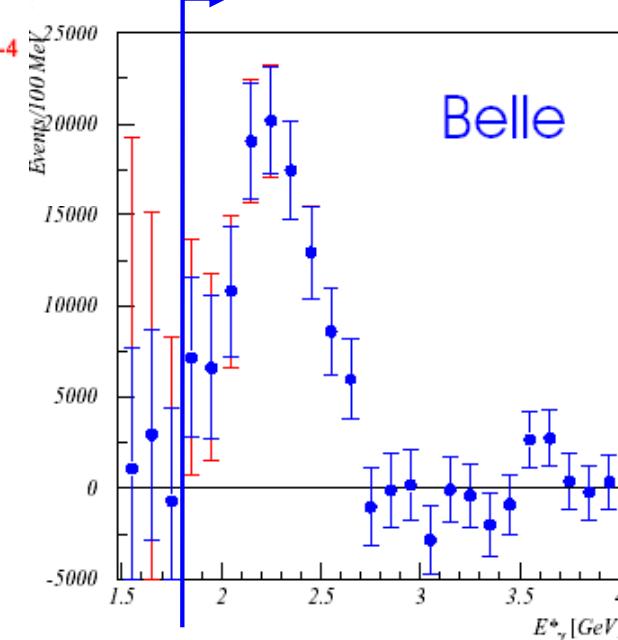
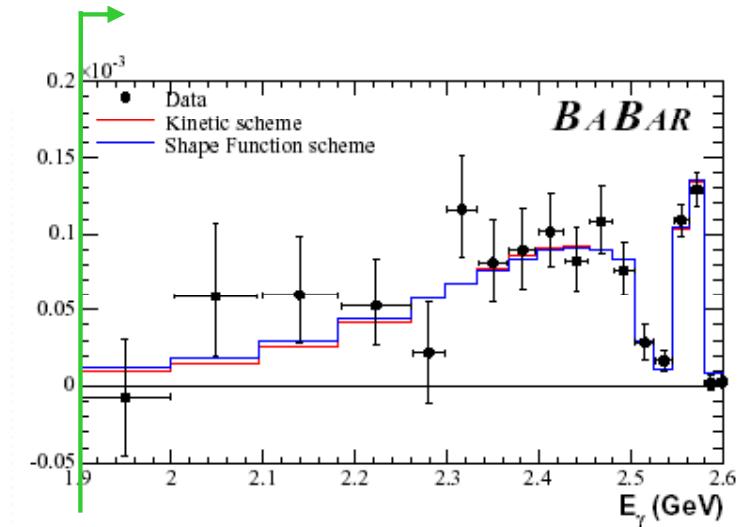
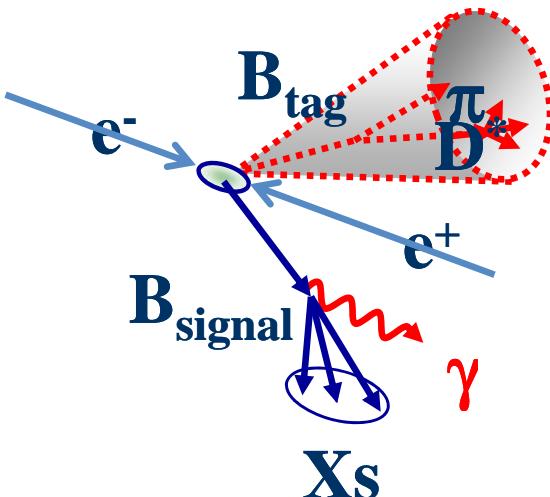
Belle
PRL93,061803(2004)

Average
HFAG hep-ex/0603003



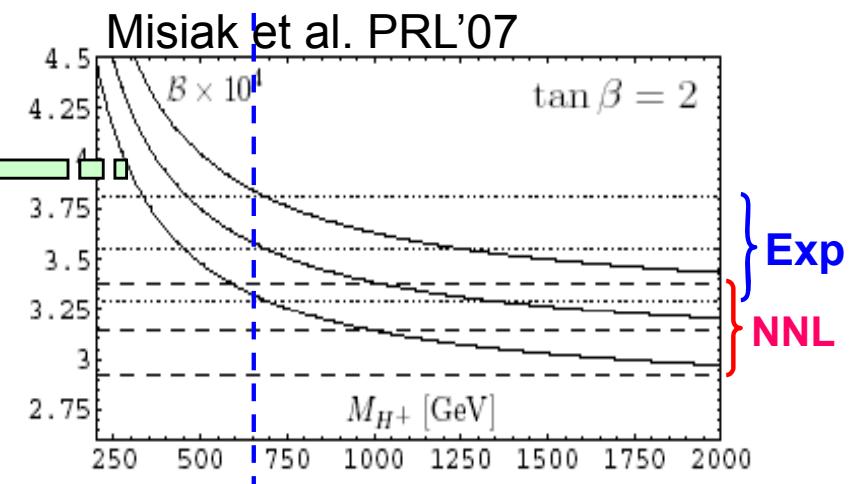
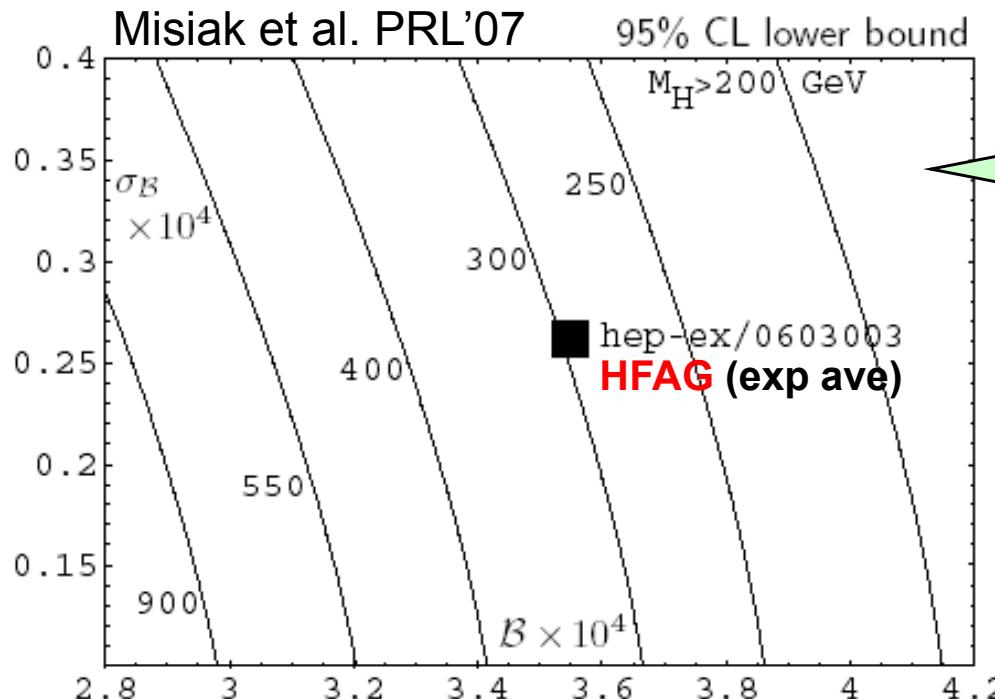
TH still unfinished, but
ball in Exp court.

Full Reconstruct
other B?



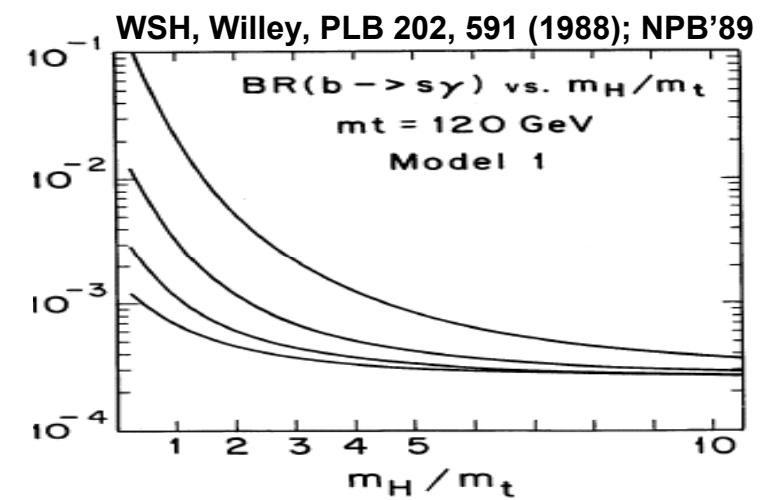
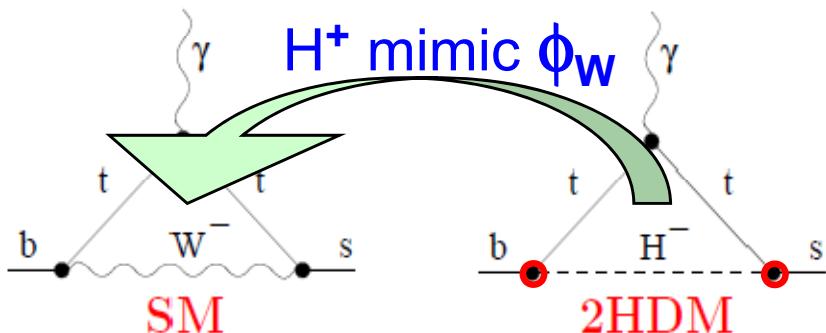


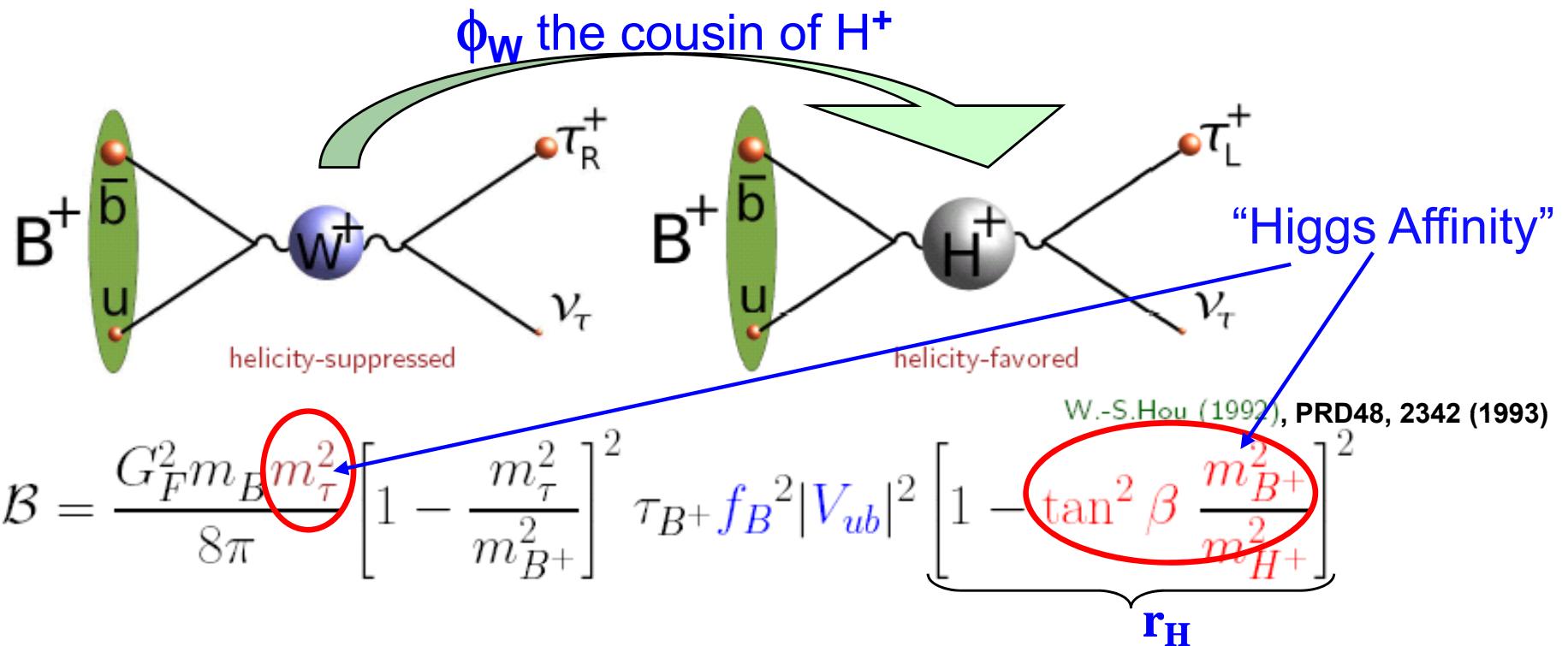
Constraint from $b \rightarrow s\gamma$ on H^+



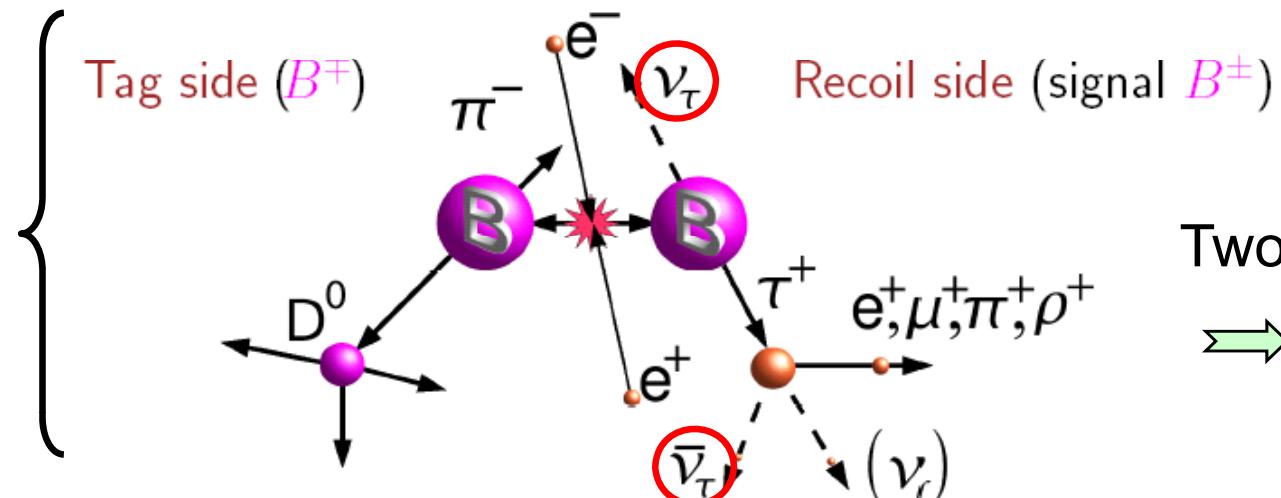
Current NNLO < Exp !
 ⇒ bound of 295 GeV
 ⇒ favor 650 GeV !?

MSSM type H^+ **always enhance** $b \rightarrow s\gamma$
regardless of $\tan \beta$





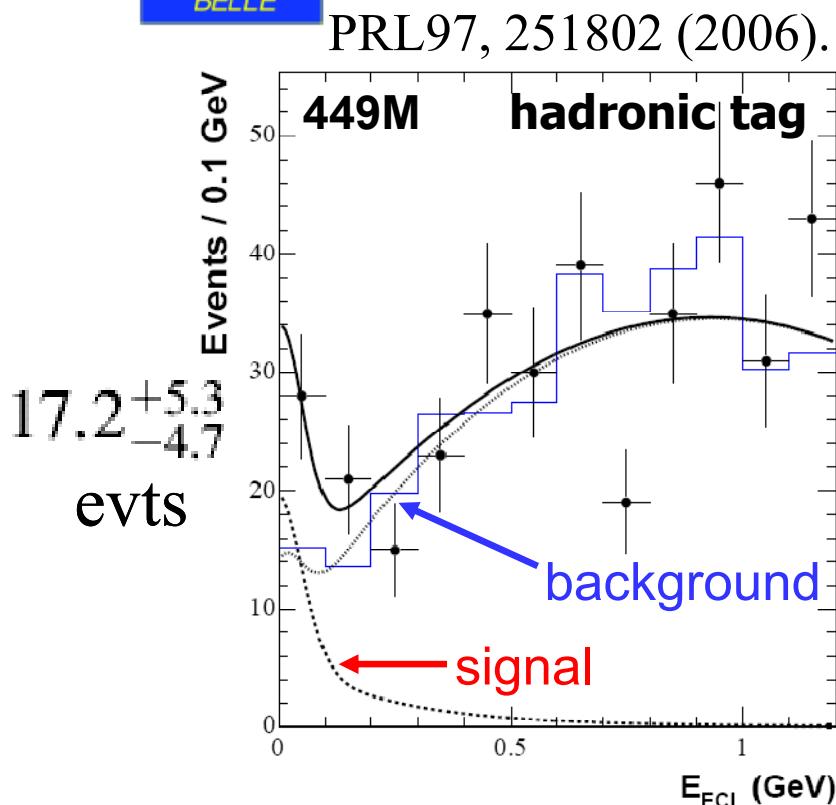
Trick/Cost:
Full Reconstruct
Tag side B
@ 0.1~0.3%





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

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



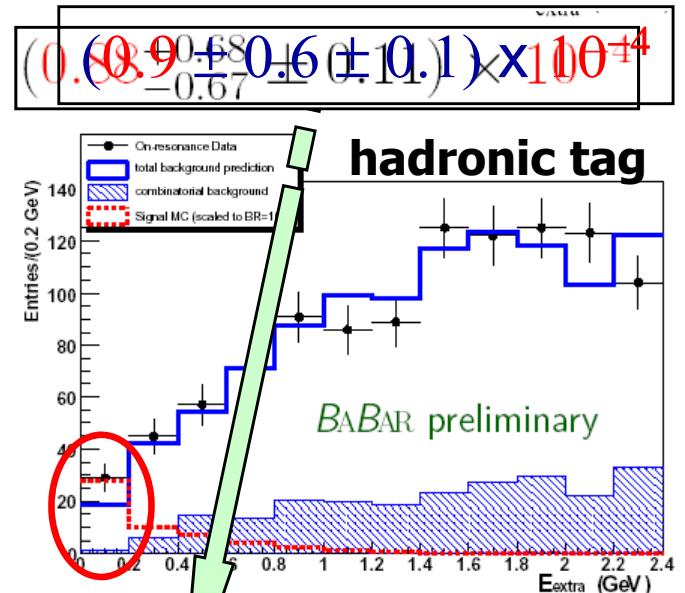
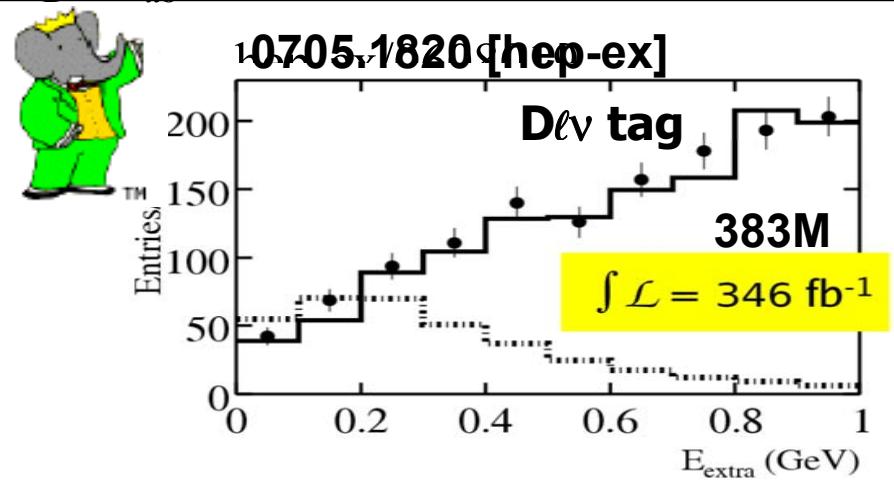
First evidence, 3.5σ

$$(1.79^{+0.56+0.46}_{-0.49-0.51}) \times 10^{-4}$$

~

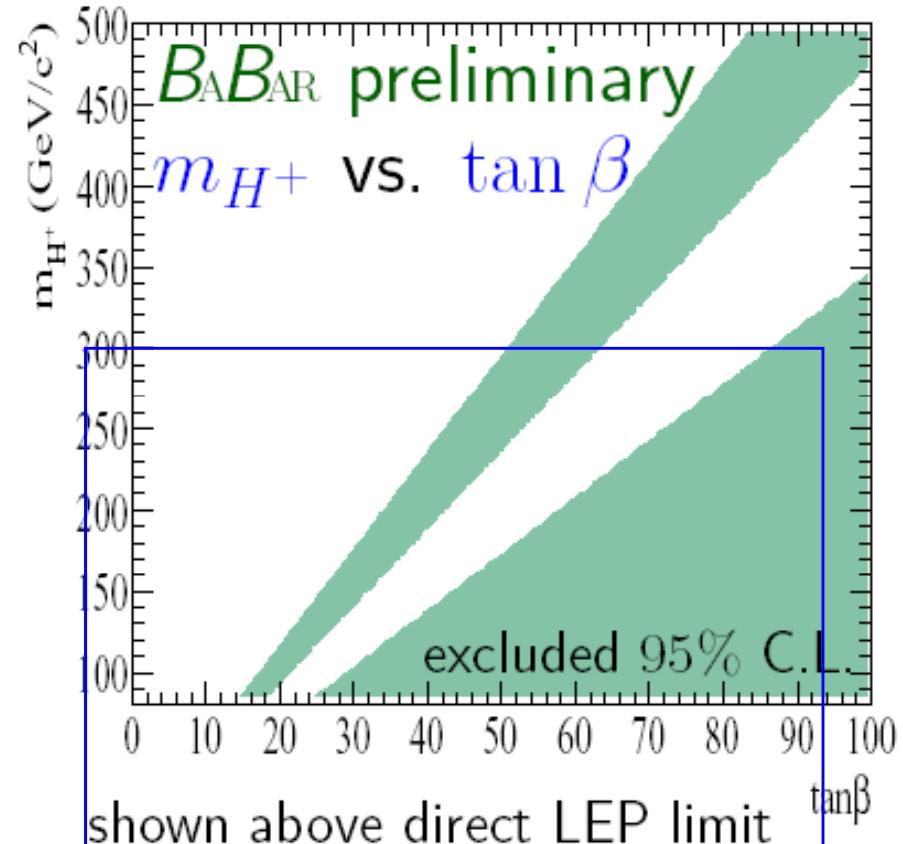
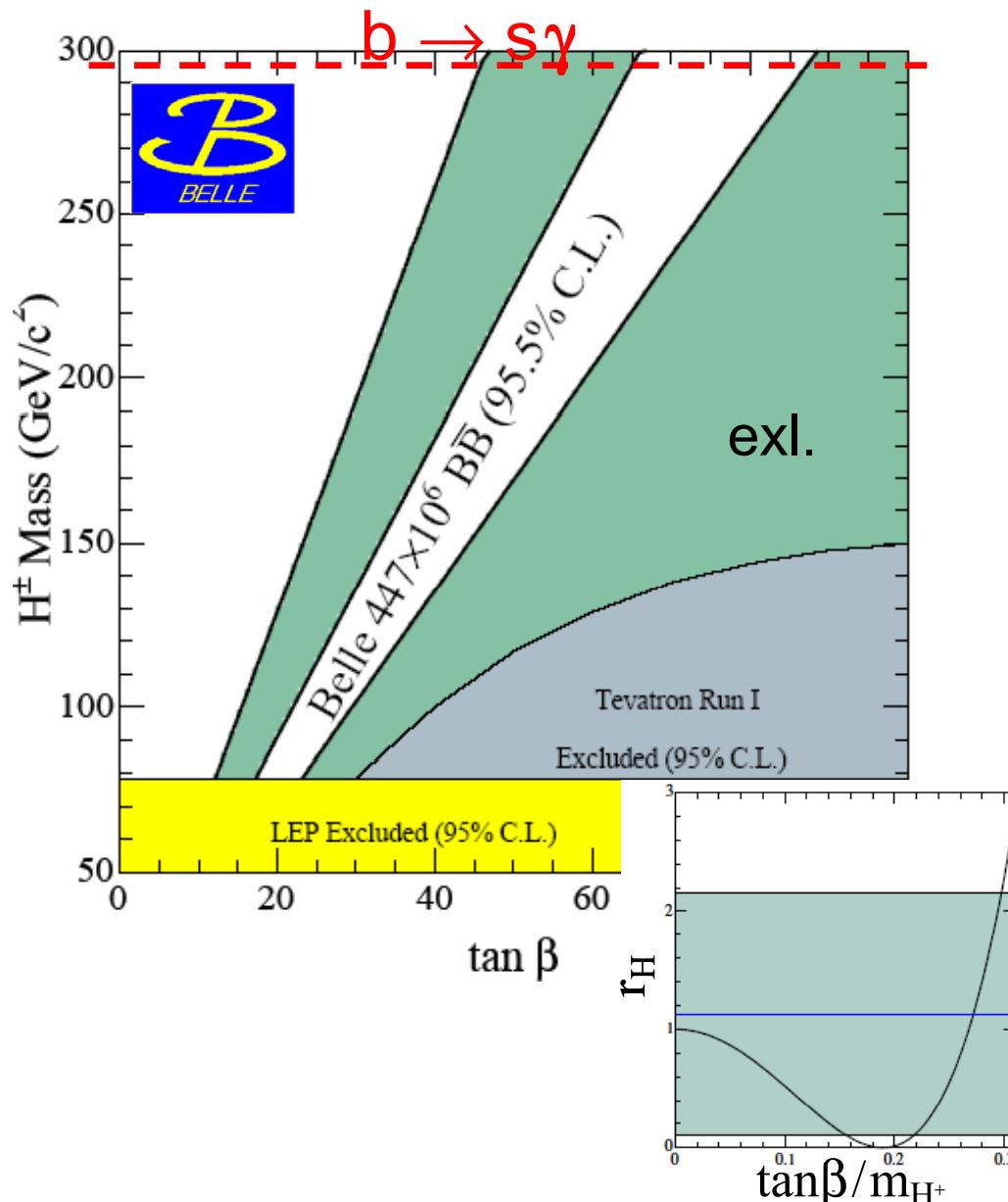
2.6σ

$$(1.2 \pm 0.4^{\text{stat}} \pm 0.3^{\text{bkg}} \pm 0.2^{\text{eff}}) \times 10^{-4}$$





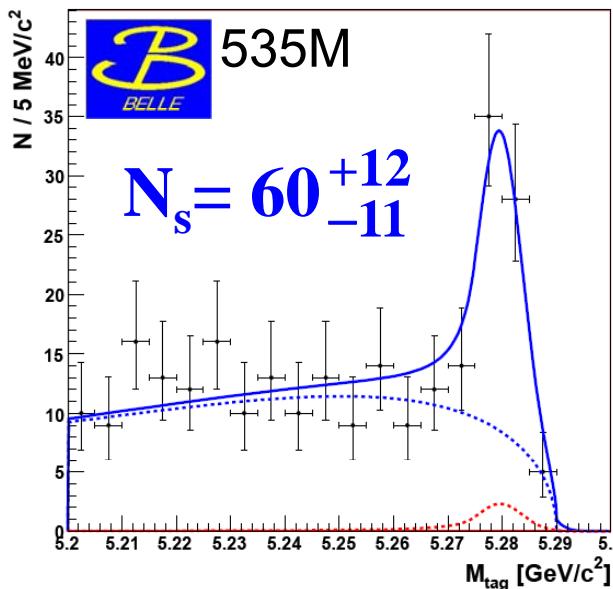
Constraint from $B \rightarrow \tau\nu$ on H^+





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

H⁺ sensitive



0706.4429 [hep-ex]

submitted to PRL

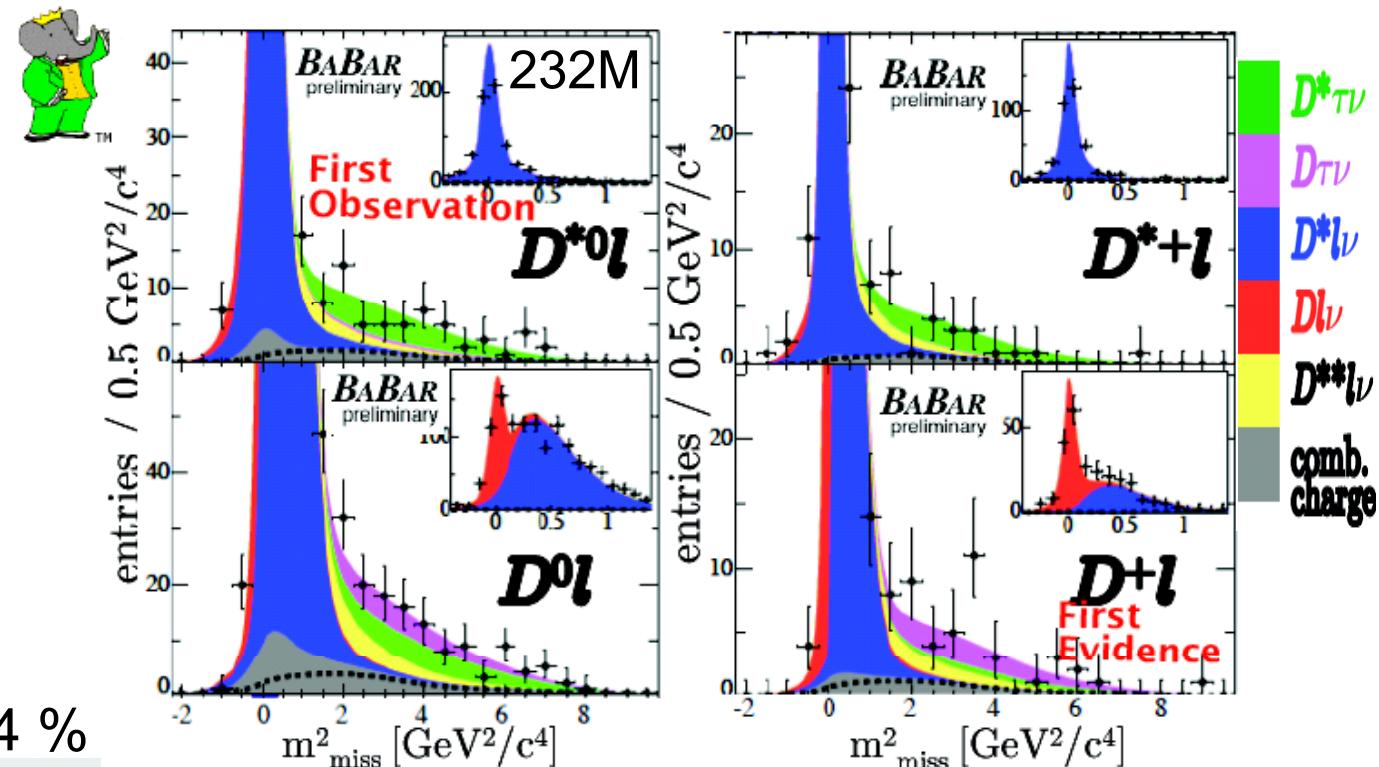
SM~1.4 %

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

First observation 5.2σ

Curious: 2%, now ...

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



0707.2758 [hep-ex]

BABAR $N_s \sim 105$

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 $B \rightarrow D\tau\nu$
First Observation of $B^- \rightarrow D^0 \tau\nu$

Verena Klose - TU Dresden

14

@ EPSHEP07 "V_{cb}" talk



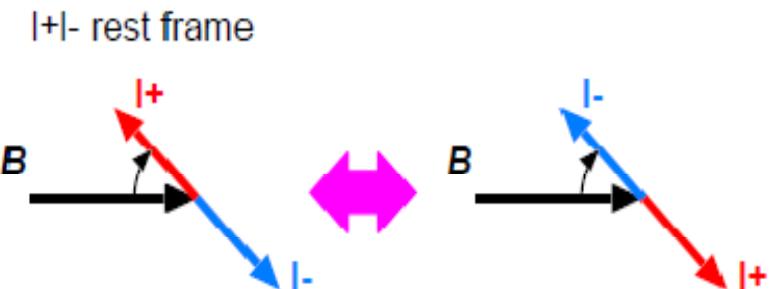
III. Electroweak Penguin

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



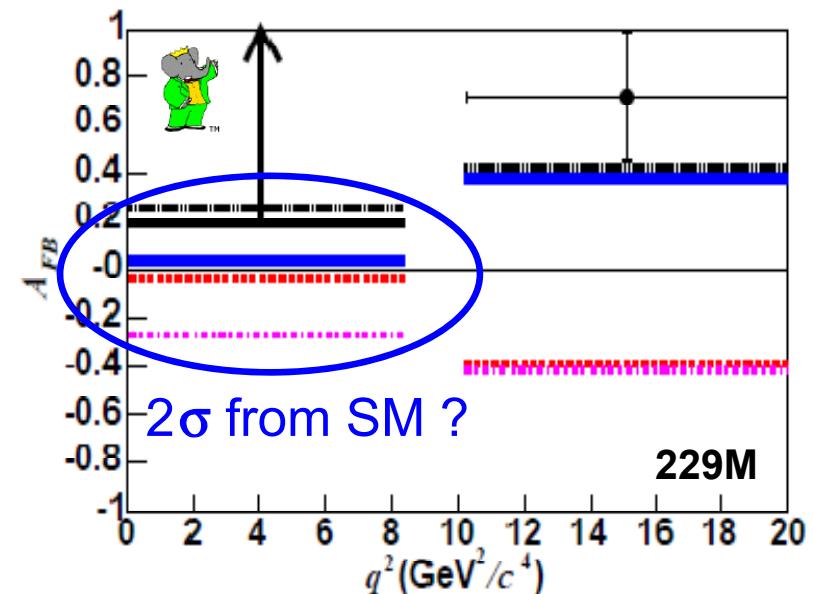
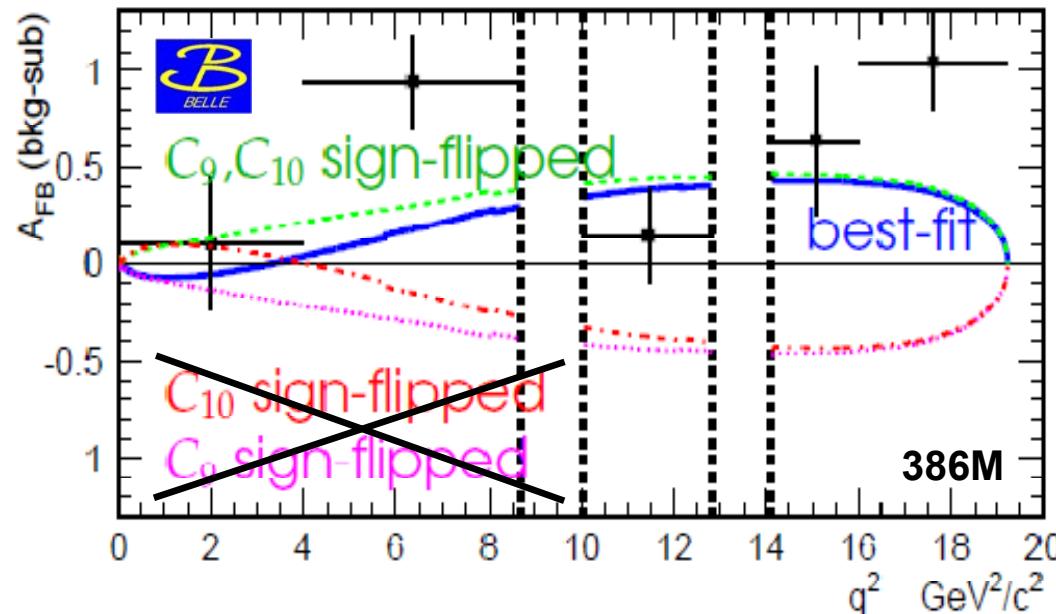


Forward-backward asymmetry (A_{FB})
in $b \rightarrow s\ell^+\ell^-$ due to interference
between γ and weak couplings



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

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





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

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

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



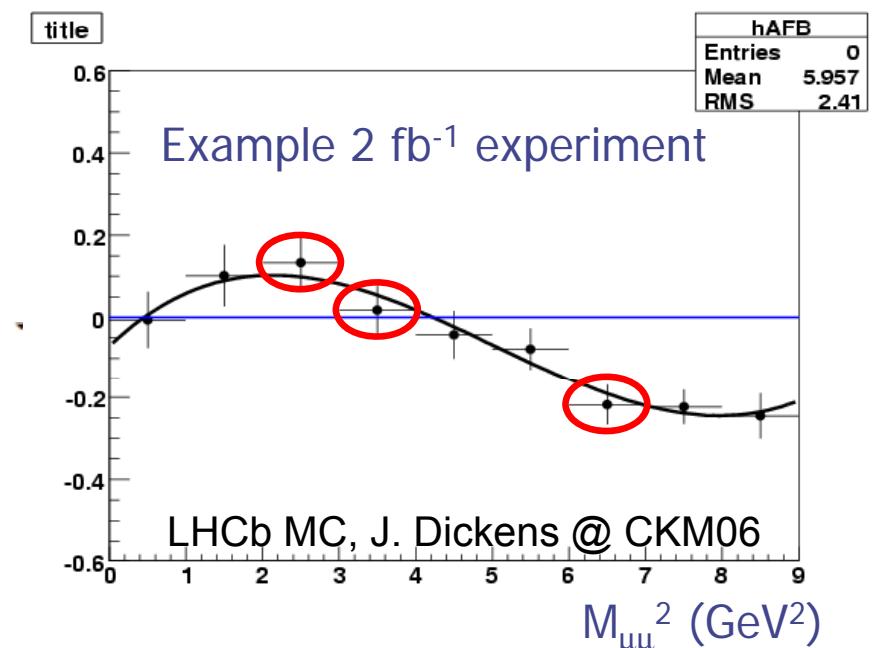
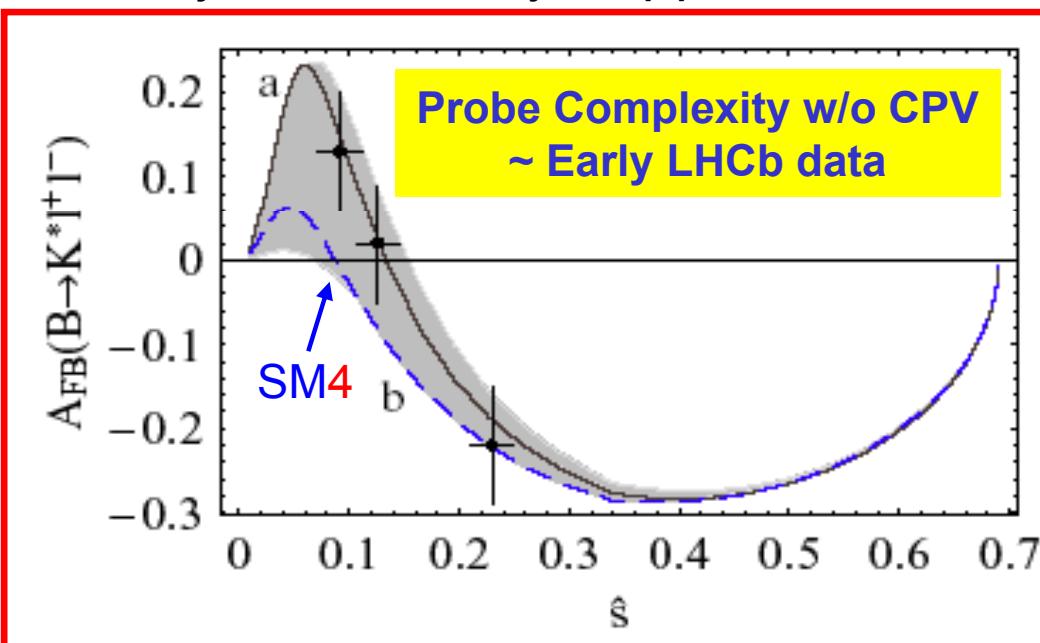
$$\text{Re } (C_9^{\text{eff}} C_{10}^*)$$

$$\text{Re } (C_7^{\text{eff}} C_{10}^*)$$

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

Hovhannисyan, WSH and Mahajan, hep-ph/0701046

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



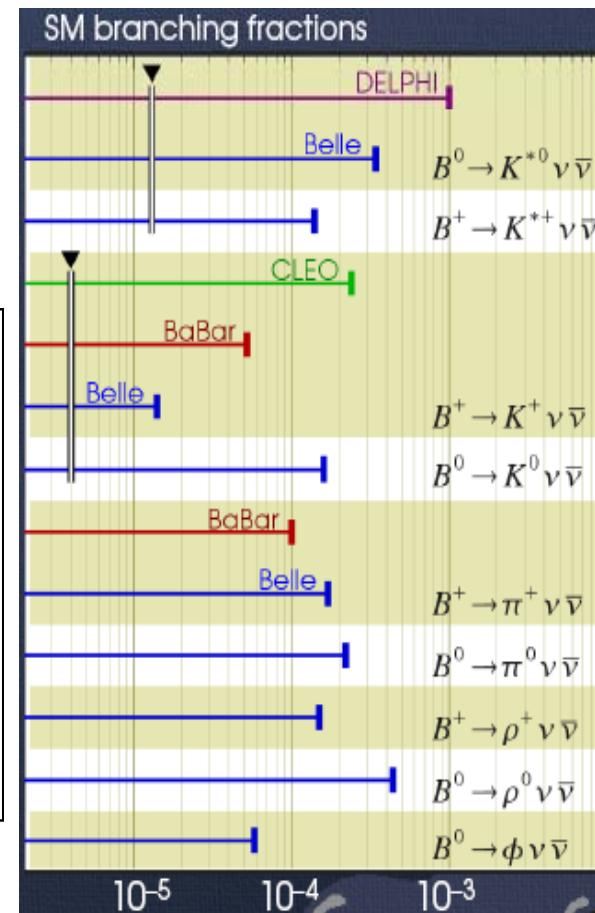
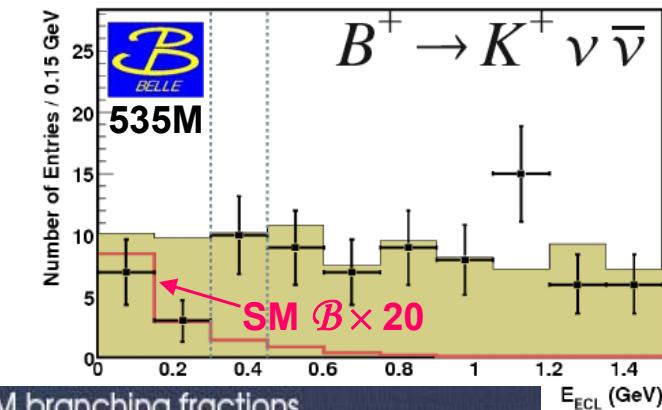
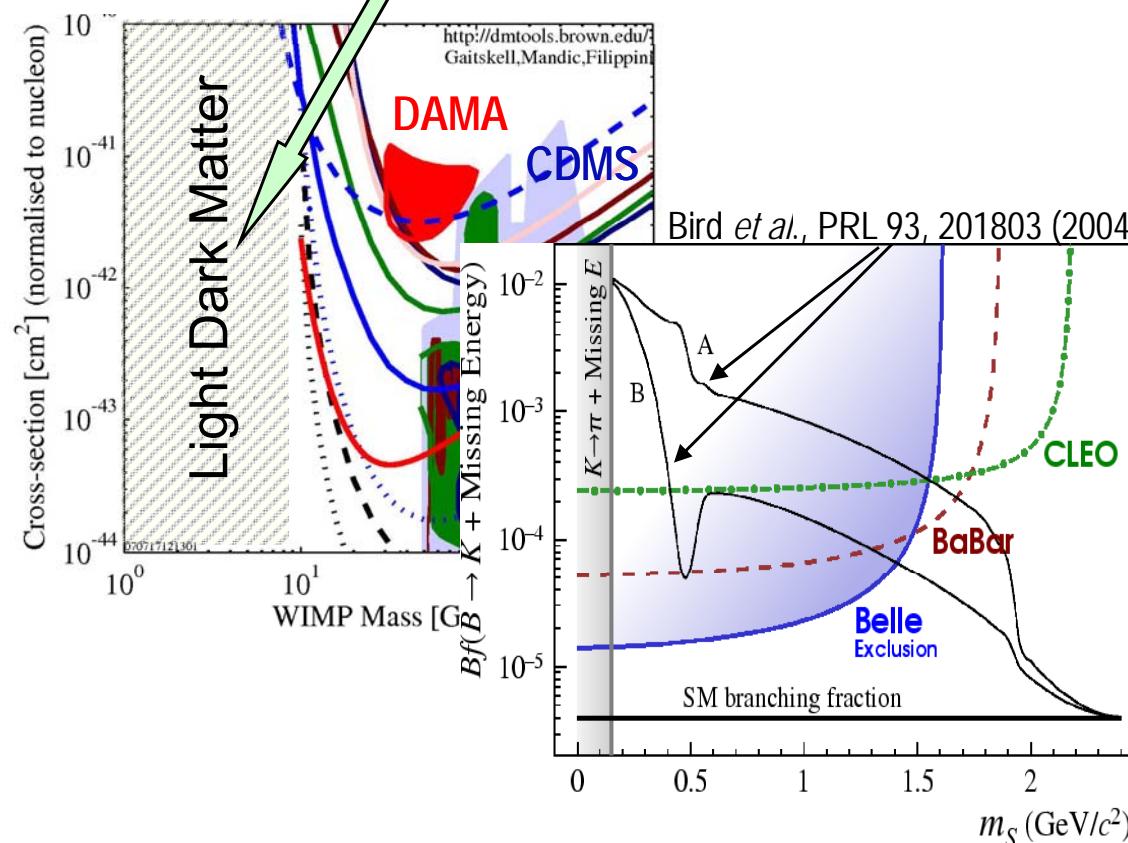
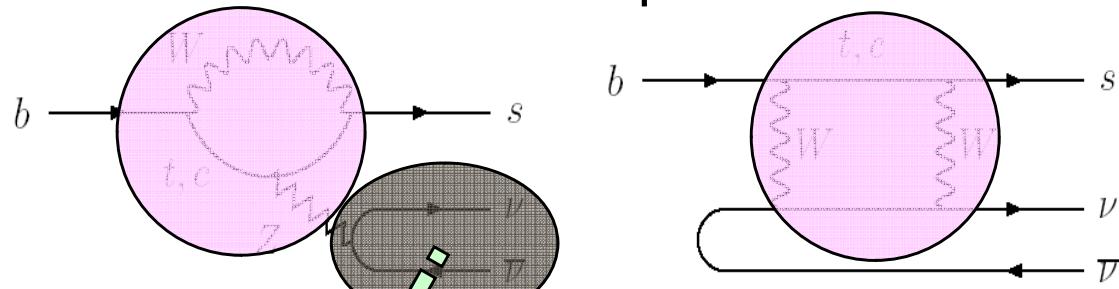


$$B \rightarrow K^{(*)} \nu \bar{\nu}$$



0707.0138 [hep-ex] submitted

Probe Loop



$< 3.4 \times 10^{-4}$
 $< 1.4 \times 10^{-4}$

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

Full Recon
Other B



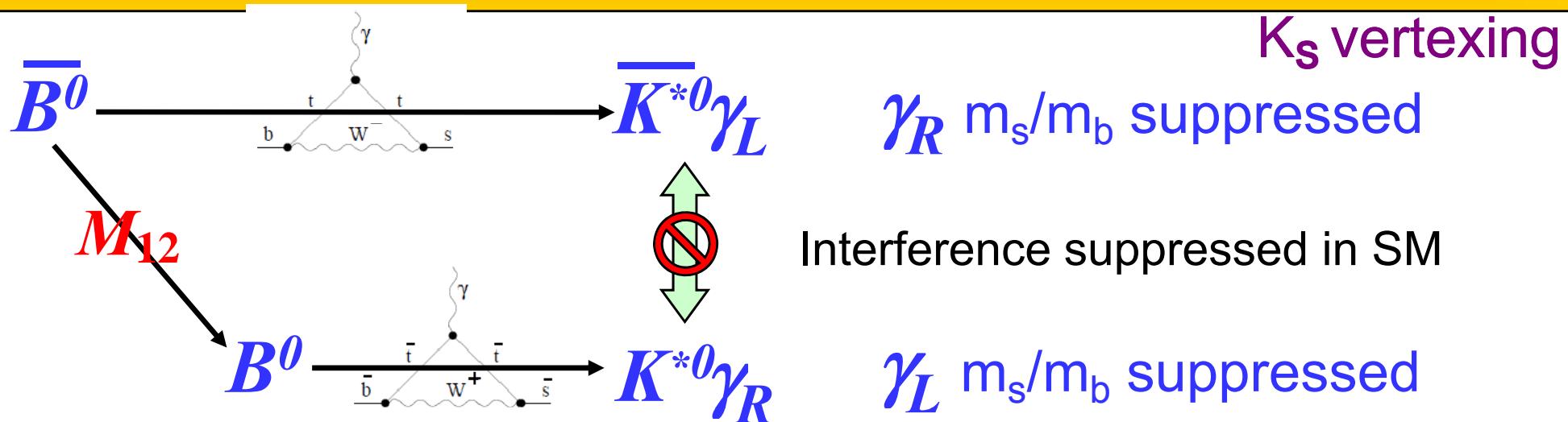
IV. RH Currents and Scalar Interactions

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

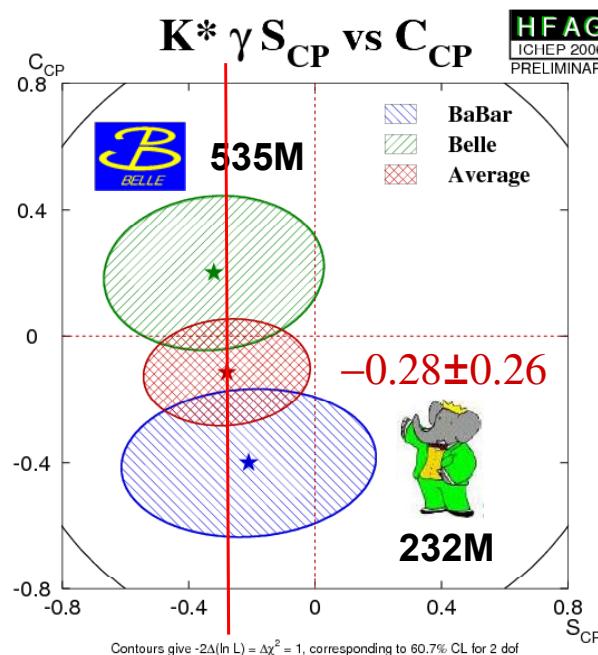




TCPV in $B^0 \rightarrow (K_S\pi^0)_{K^*}\gamma$: Probe RH Currents



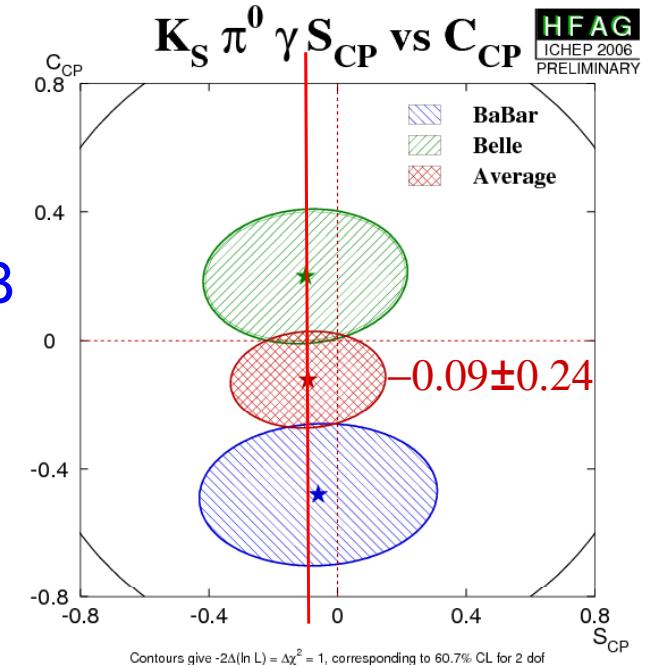
Atwood, Gronau, Soni, PRL79, 185 (1997)



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

Consistent with zero.
Future probe at SuperB
explore also e.g. $B \rightarrow K\phi\gamma$

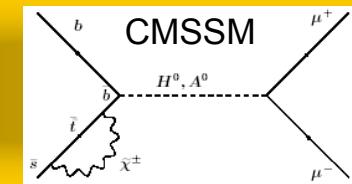
Also, angular probes
 $F_L, A_T^{(2)}$ in $B \rightarrow K^*\ell^+\ell^-$



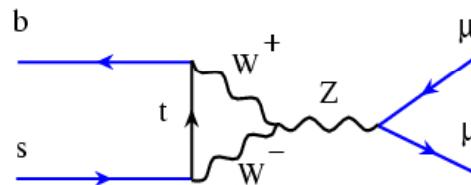
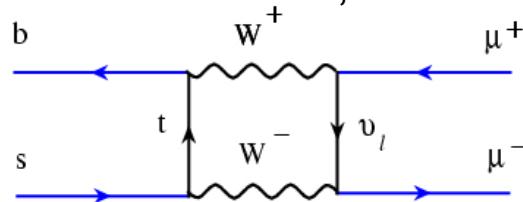


$B_s \rightarrow \mu\mu$

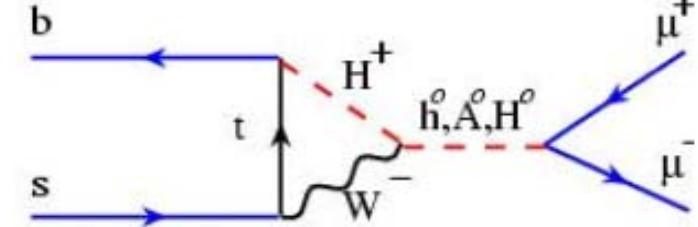
$\sim 3.5 \times 10^{-9}$ in SM



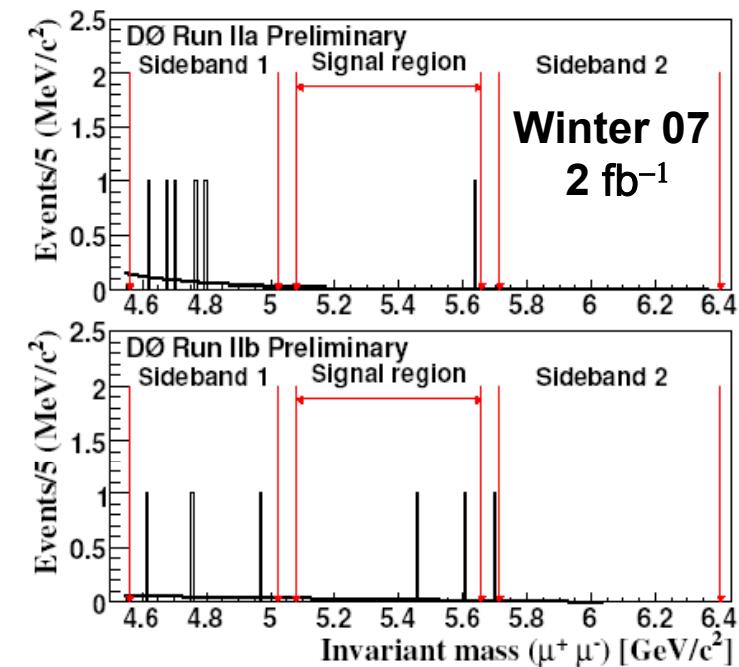
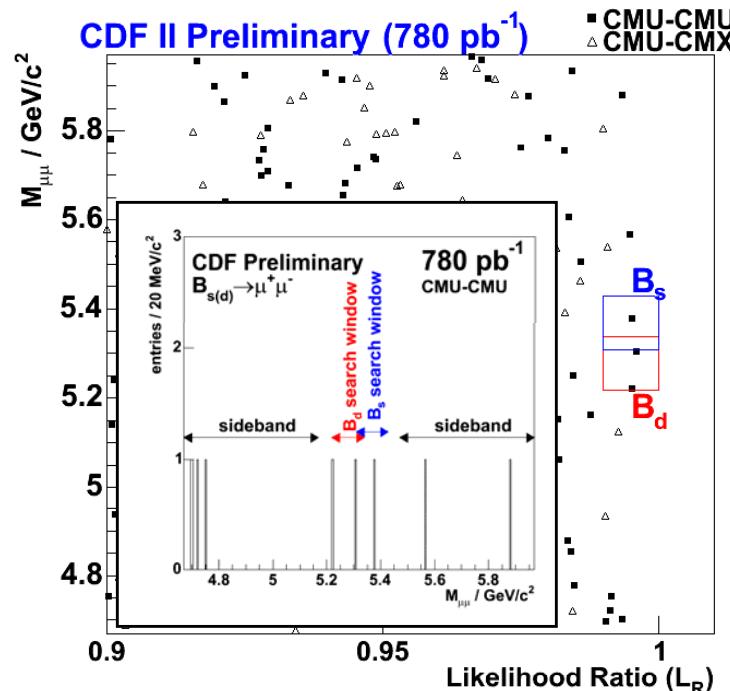
Buchalla, A. Buras, NPB398,285 (1993)



Babu, Kolda, PRL84, 228 (2000)



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



DØnote
5344-CONF

$$\mathcal{BR}(B_s^0 \rightarrow \mu^+ \mu^-) < 1.0 \times 10^{-7} \text{ (95%CL)}$$

$$\mathcal{BR}(B_s^0 \rightarrow \mu^+ \mu^-) < 9.3 \times 10^{-8} \text{ (95%CL)}$$

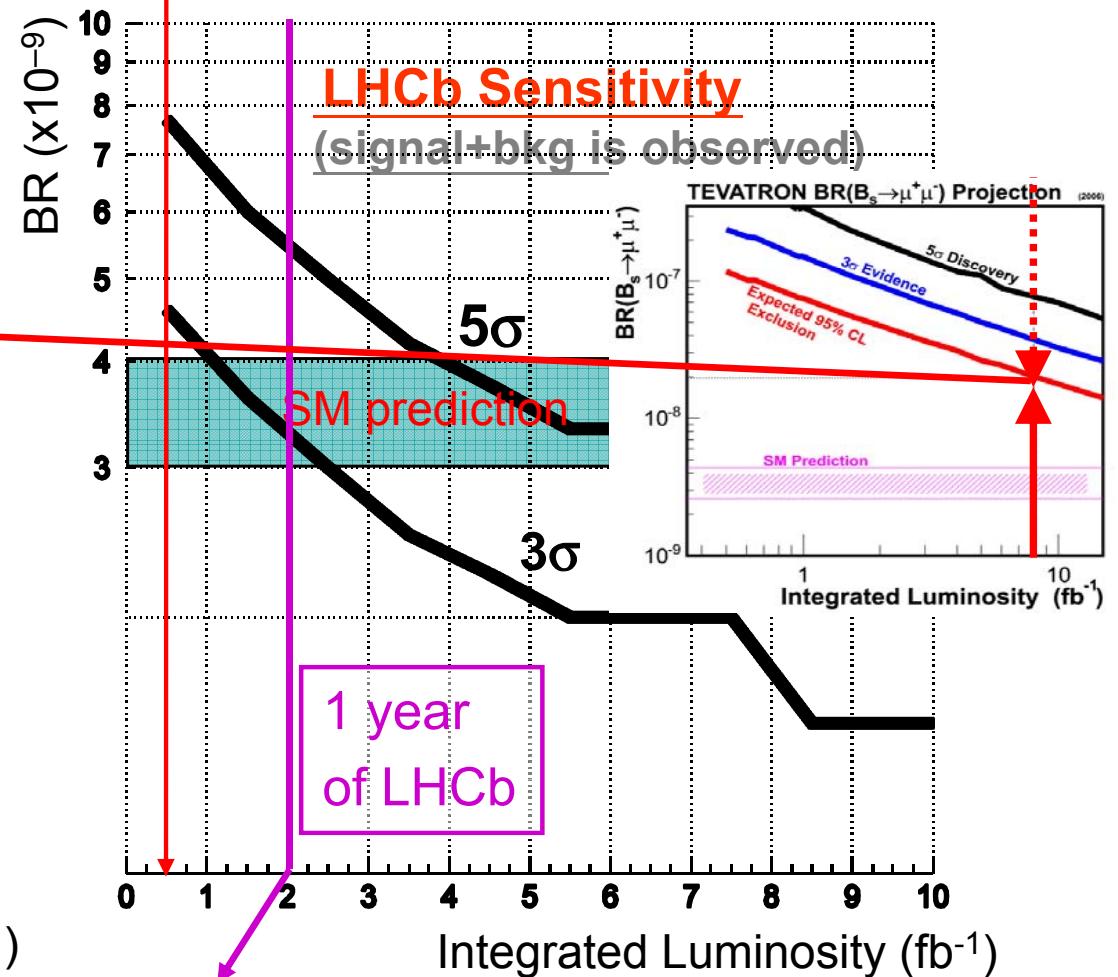
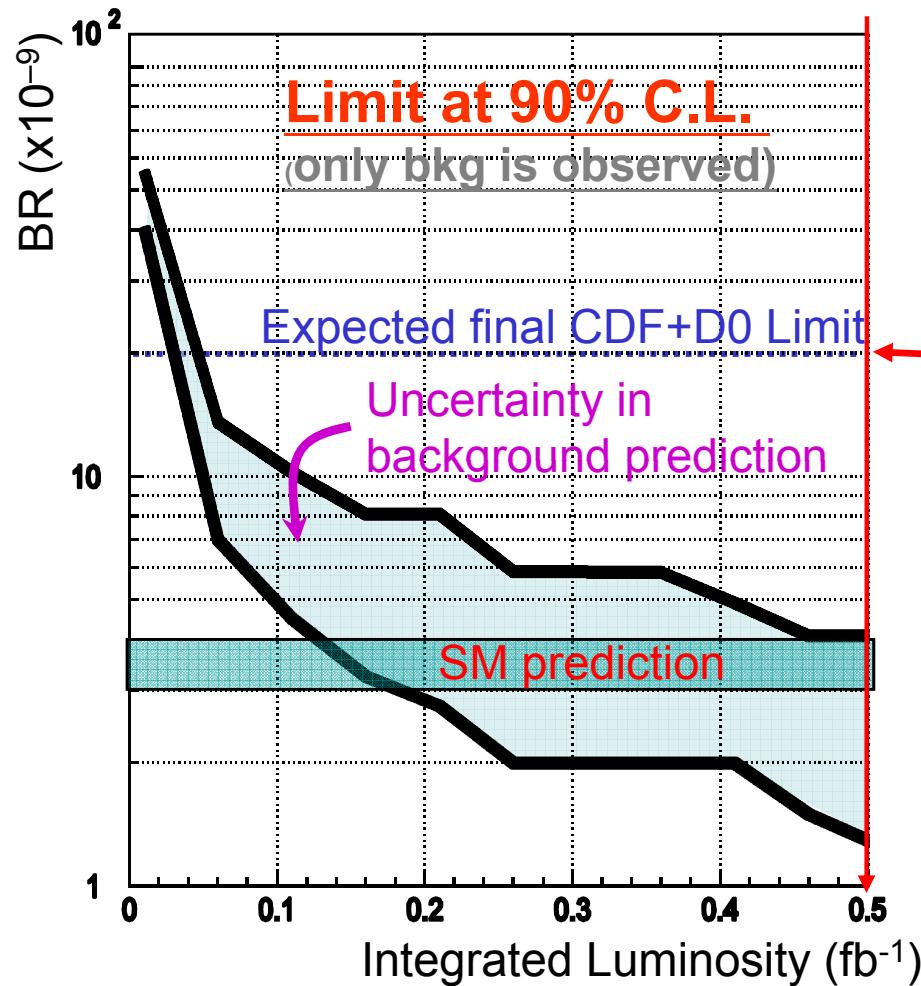
$$\boxed{\mathcal{BR}(B_s^0 \rightarrow \mu^+ \mu^-) < 5.8 \times 10^{-8} \text{ (95%CL)}}$$

combined

$B_s \rightarrow \mu^+ \mu^-$

sensitivity

LHCb
THCP



$0.05 \text{ fb}^{-1} \Rightarrow$ overtake CDF+D0

$0.5 \text{ fb}^{-1} \Rightarrow$ exclude BR values down to SM

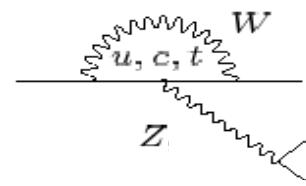
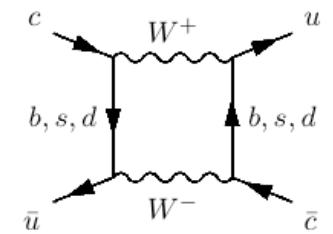
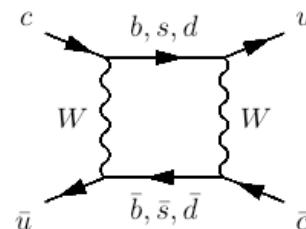
$2 \text{ fb}^{-1} \Rightarrow$ 3 σ evidence of SM signal

$10 \text{ fb}^{-1} \Rightarrow$ >5 σ observation of SM signal



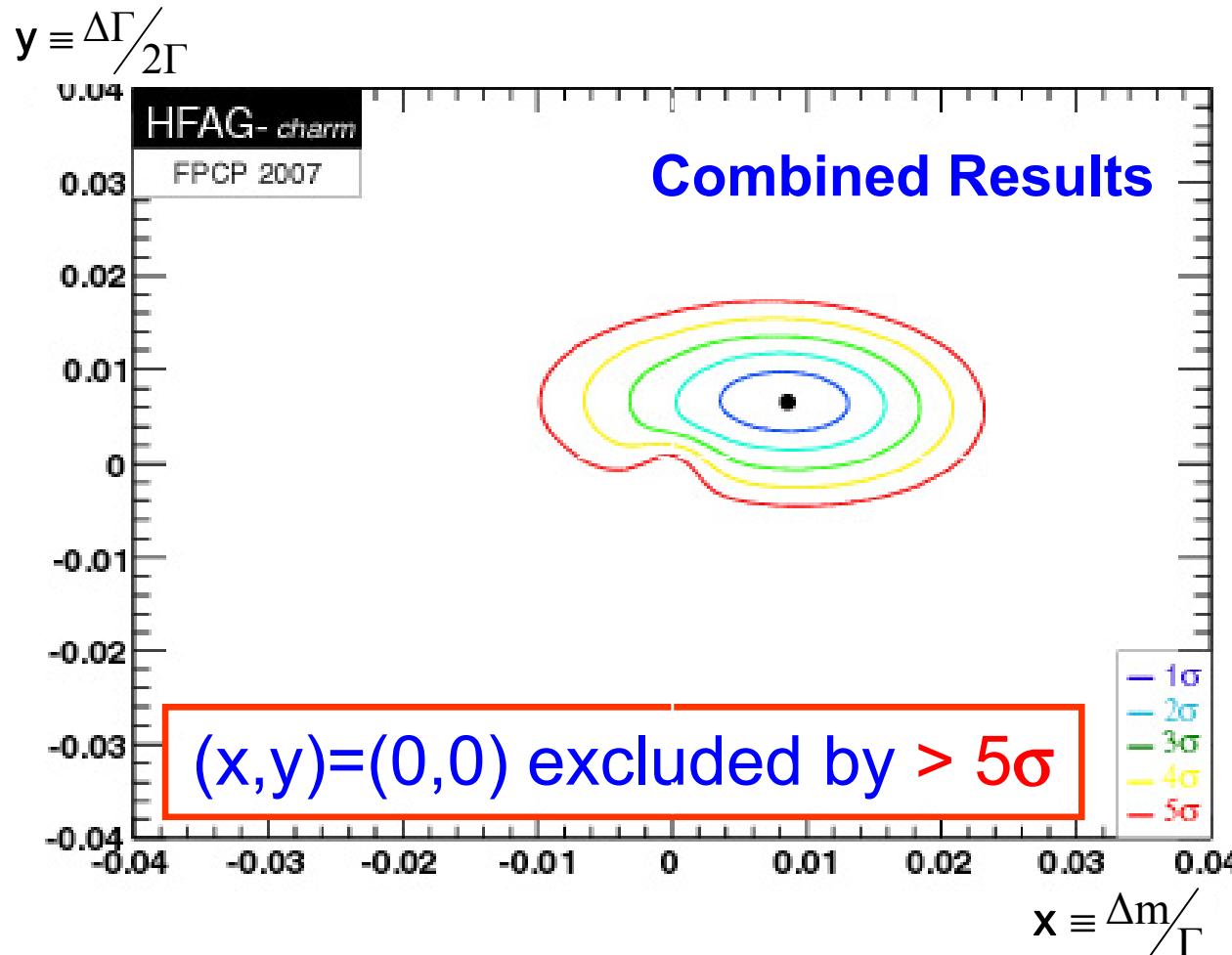
V. D/K: Box and EWP Redux

- D⁰ Mixing
- Rare K





D⁰ Mixing: Observed Recently



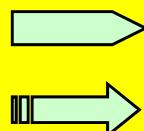
\mathcal{B} $D^0 \rightarrow K^+K^-/\pi^+\pi^-$ y_{CP}
 540 fb^{-1}
 $D^0 \rightarrow K_S \pi^+\pi^-$ Dalitz x, y
 $D^0 \rightarrow K^\square \pi^\pm$ x'^2, y'
 384 fb^{-1} 400 fb^{-1}

$x = 0.87^{+0.30}_{-0.34} \%$
 $y = 0.66^{+0.21}_{-0.20} \%$
 $\delta = 0.33^{+0.26}_{-0.29}$

Assuming no CPV
(no evidence yet)

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

Recall Δm_K , however,



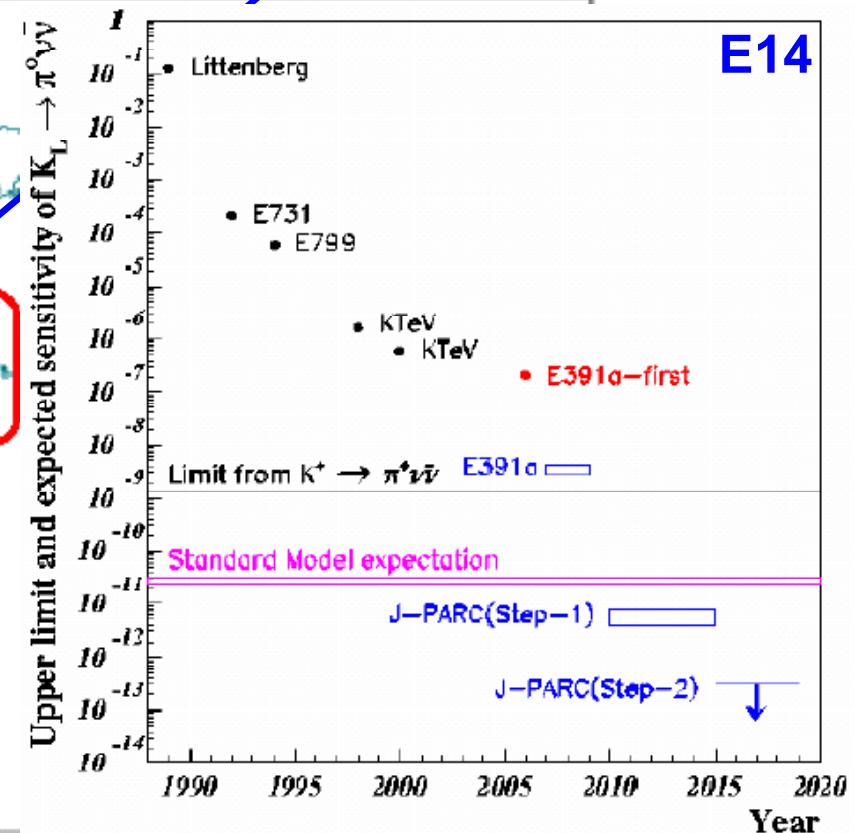
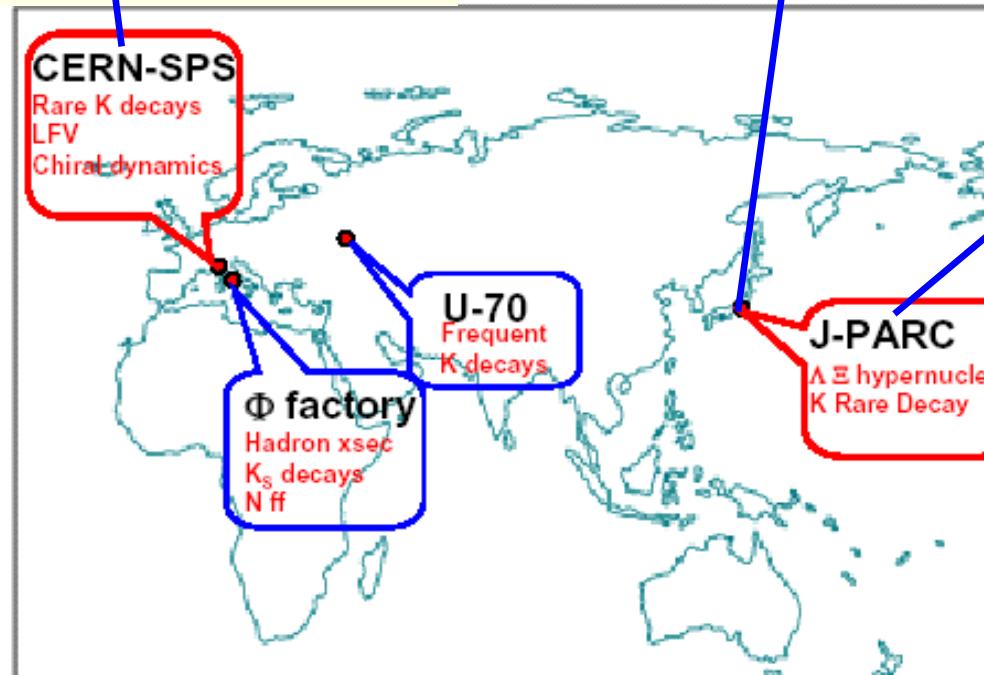
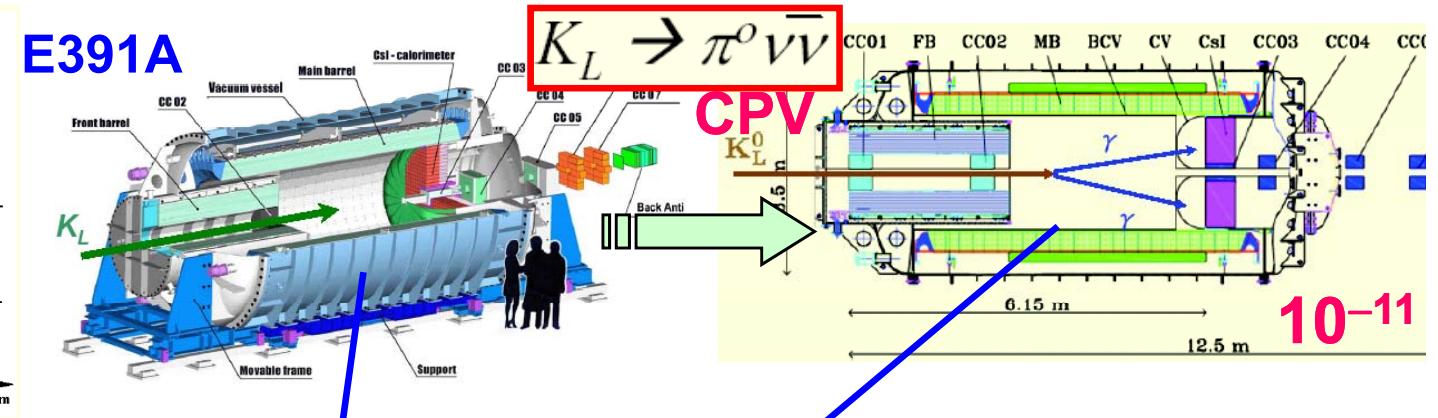
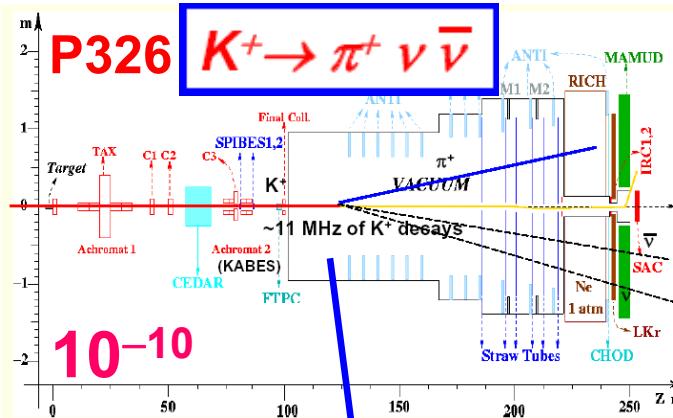
Comparable BSM allowed
To be unequivocal: CPV

Falk et al.
PRD'02,'04



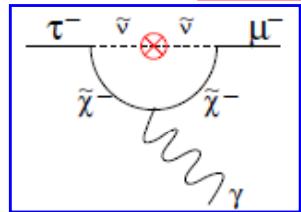
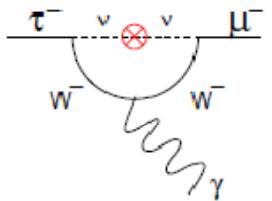
Kaon Facilities

After many activities were cancelled in USA





VI. τ : LFV and (B–L)V



- $\tau \rightarrow \ell\gamma, \ell\ell\ell'$
- $\tau \rightarrow \Lambda\pi, p\pi^0$

$b \rightarrow s$ echoes ?



Lepton Flavor Violating (LFV) τ decay

Observation of LFV is a clear signature of New Physics!

Many Models

SUSY

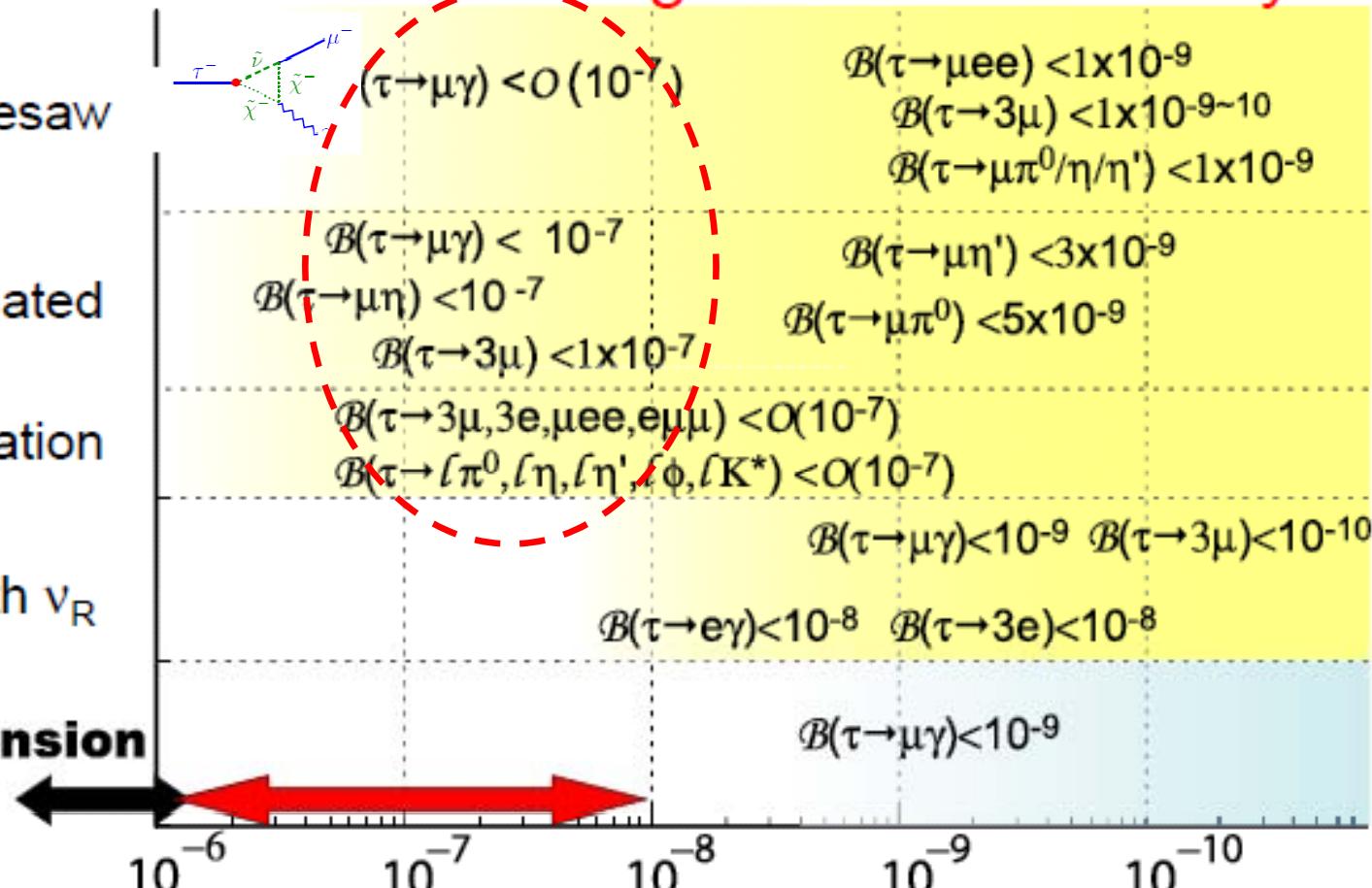
MSSM+Seesaw

Higgs-mediated

R-parity Violation

SO(10) with v_R

Extra dimension



CLEO

B-factory
a τ -factory!

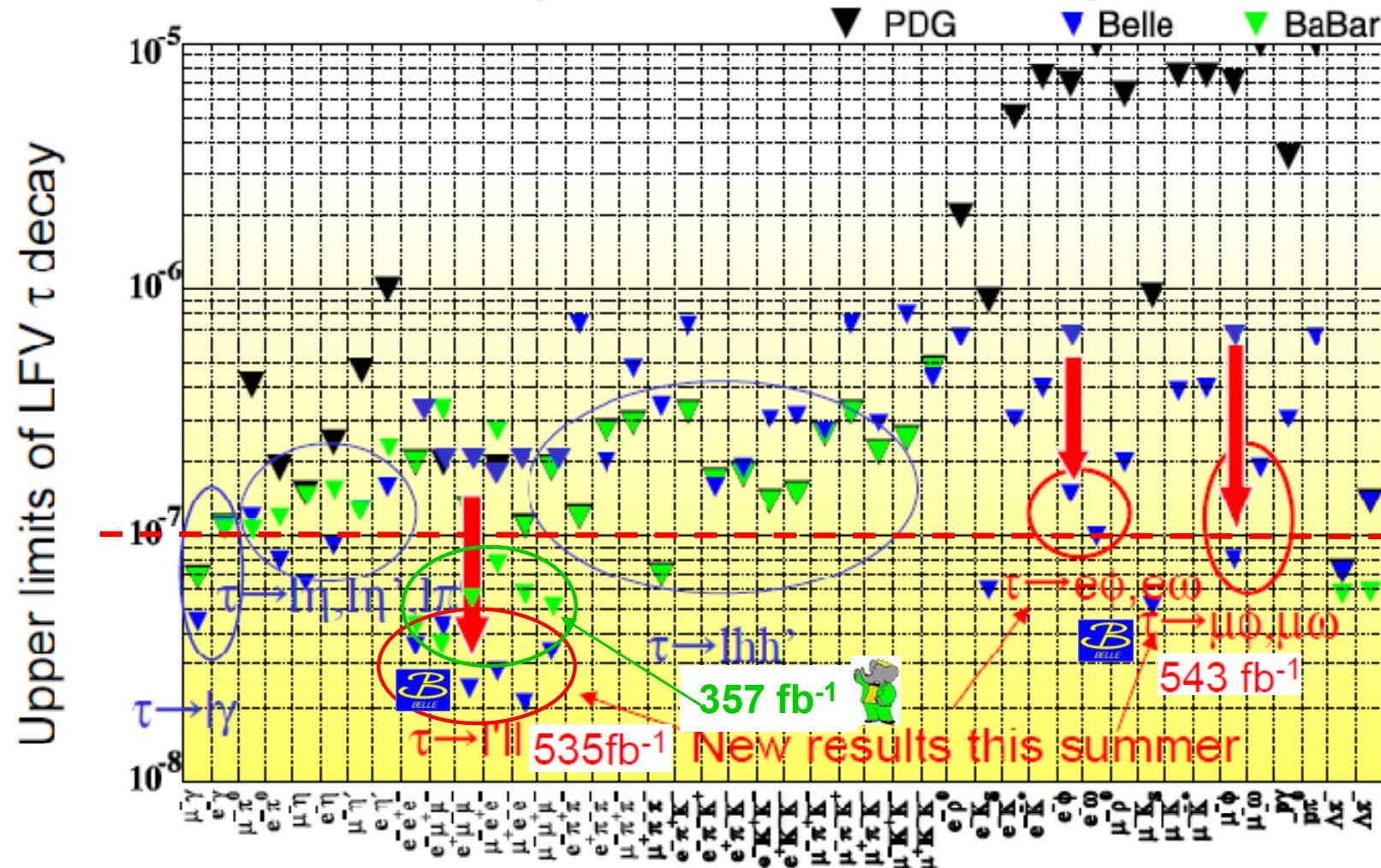
$B(LFV)$

$\sigma(\tau\tau) \sim 0.9 \text{ nb}, \sigma(bb) \sim 1.1 \text{ nb}$



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 $b \rightarrow s$ w/ Boxes and Penguins

ΔS ; $\Delta \mathcal{A}_{K\pi}$;

$\sin 2\Phi_{Bs}$;

$\mathcal{A}_{CP}(B^+ \rightarrow J/\psi K^+)$

Hints for BSM

Thing to watch in 2008-09 !

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

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

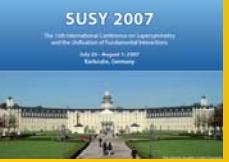
IV RH Currents and Scalar Interactions

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

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

VI τ : LFV and $(B-L)\nu$

$\tau \rightarrow \ell\gamma, \ell\ell\ell'$; $\tau \rightarrow \Lambda\pi, p\pi^0$

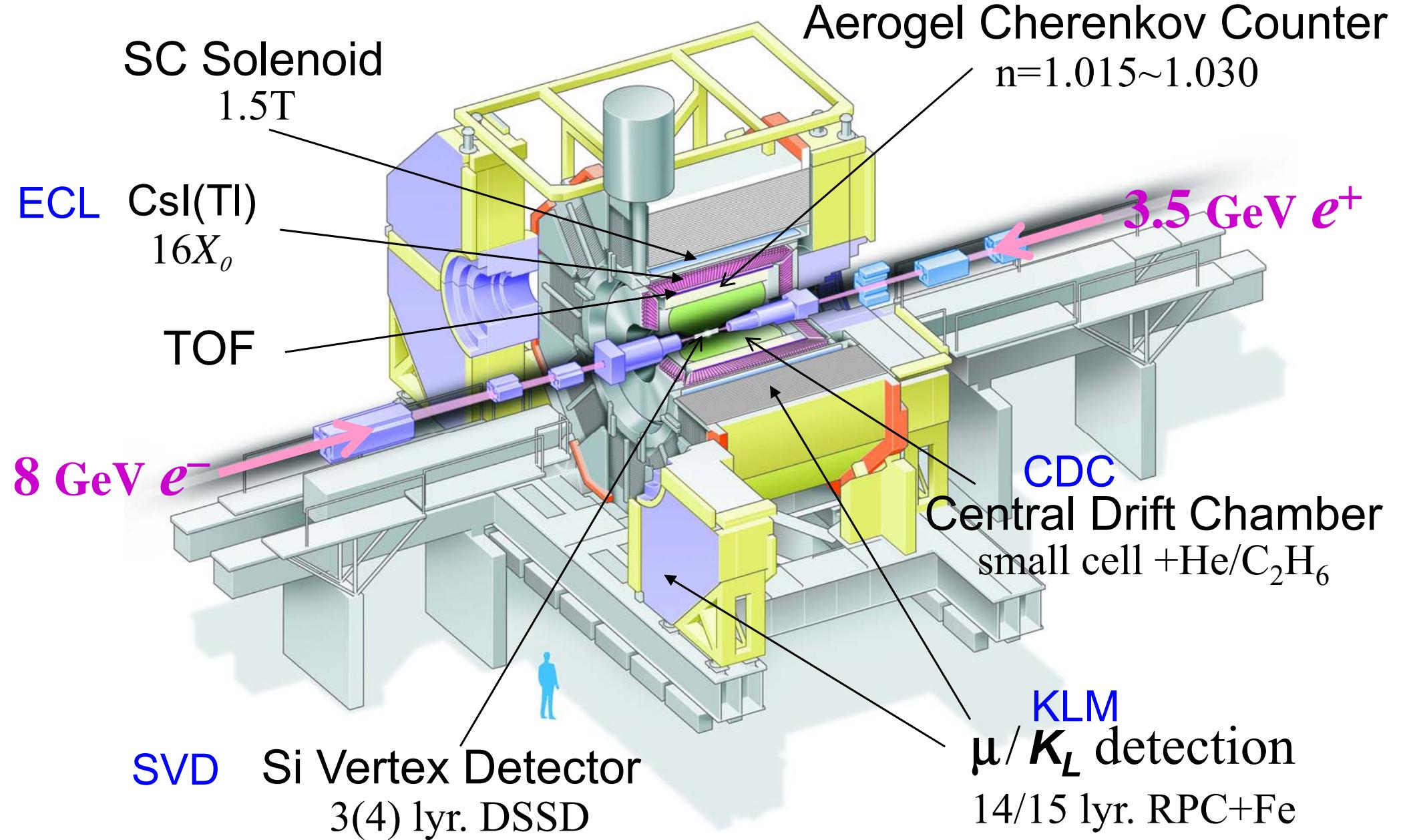




Belle Detector

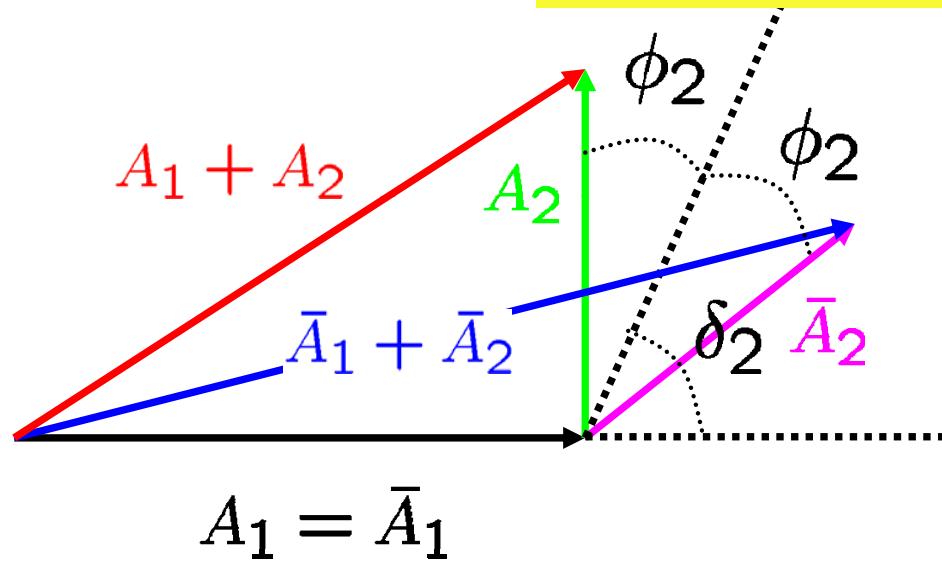
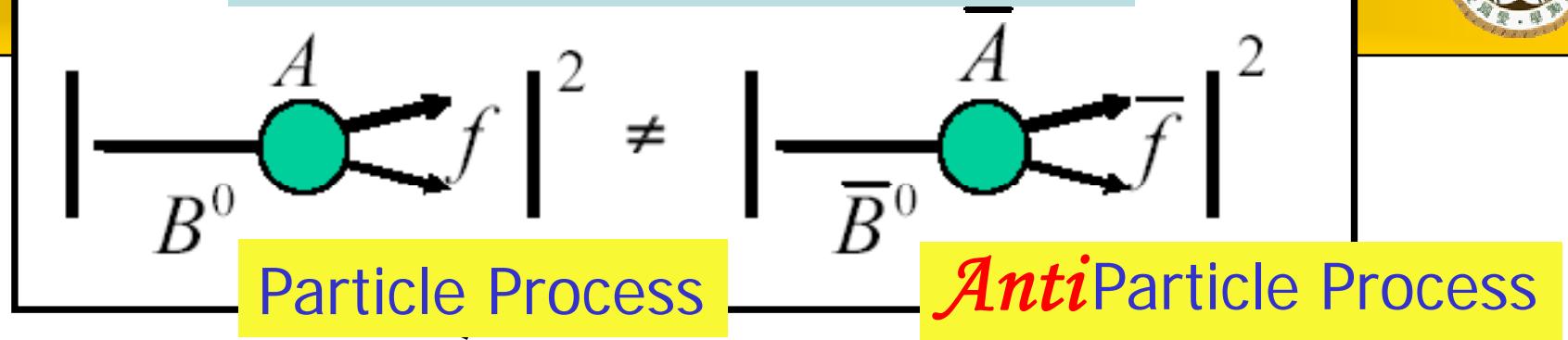


ACC (PID)





CP Violation Primer



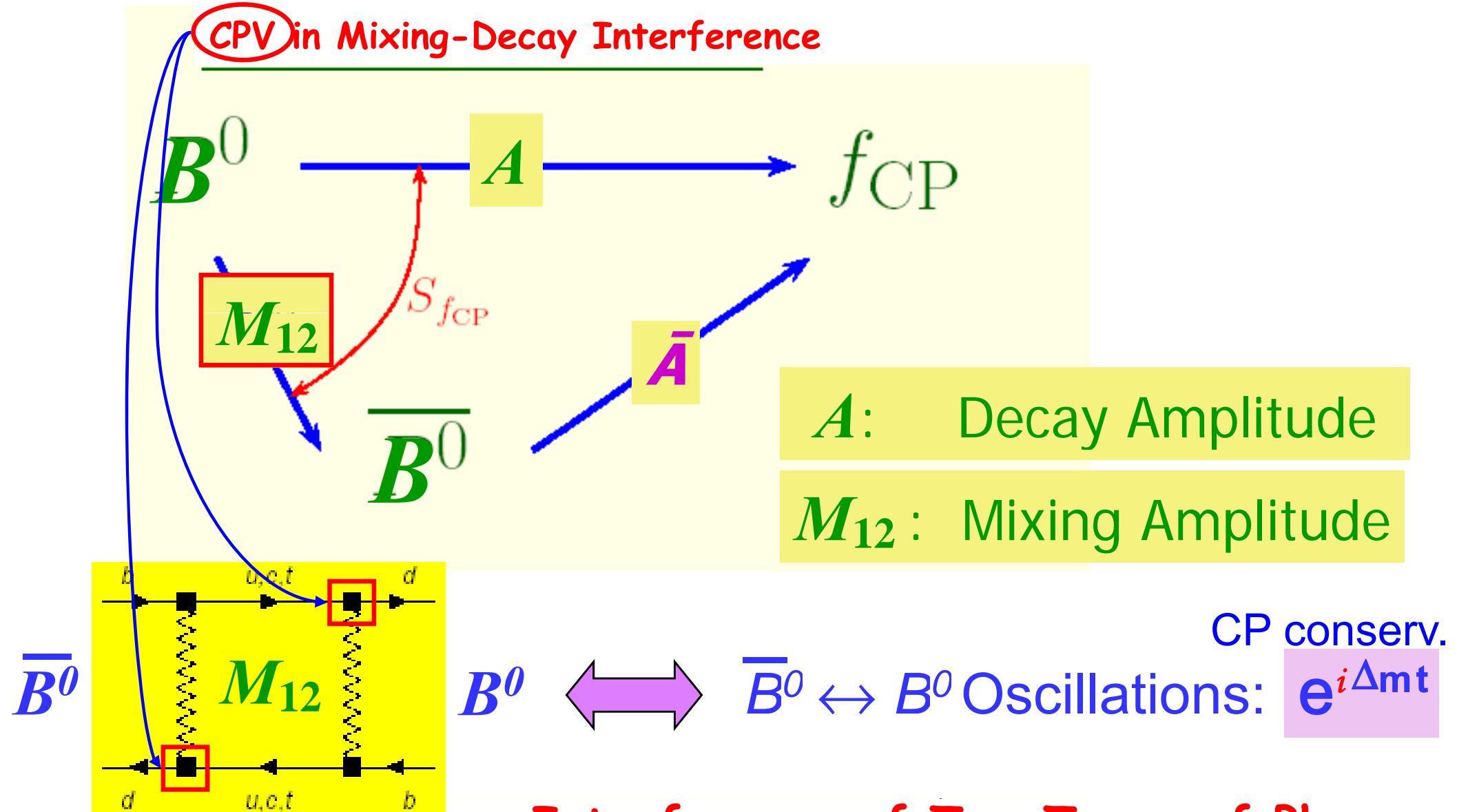
$$A = A_1 + A_2 = a_1 + a_2 e^{i\delta_2} e^{i\phi_2}$$

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

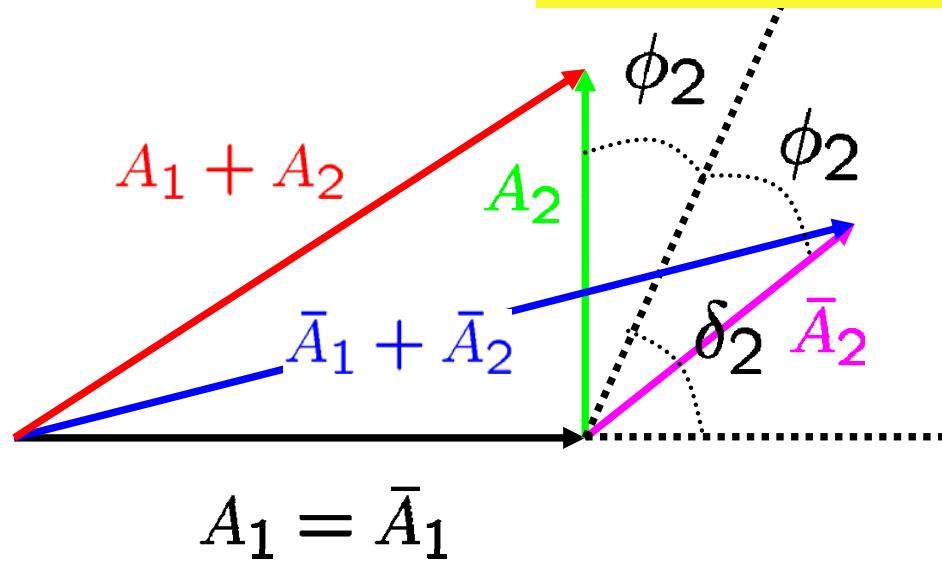
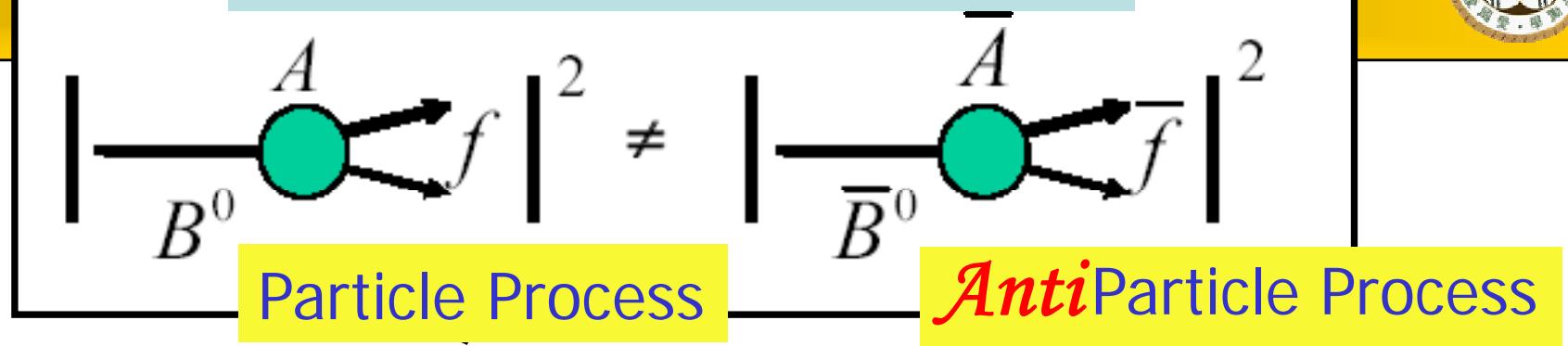
$$A_1 = \bar{A}_1$$

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

CP Asymmetry needs both CP Conserv/Violating Phase



CP Violation Primer



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

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

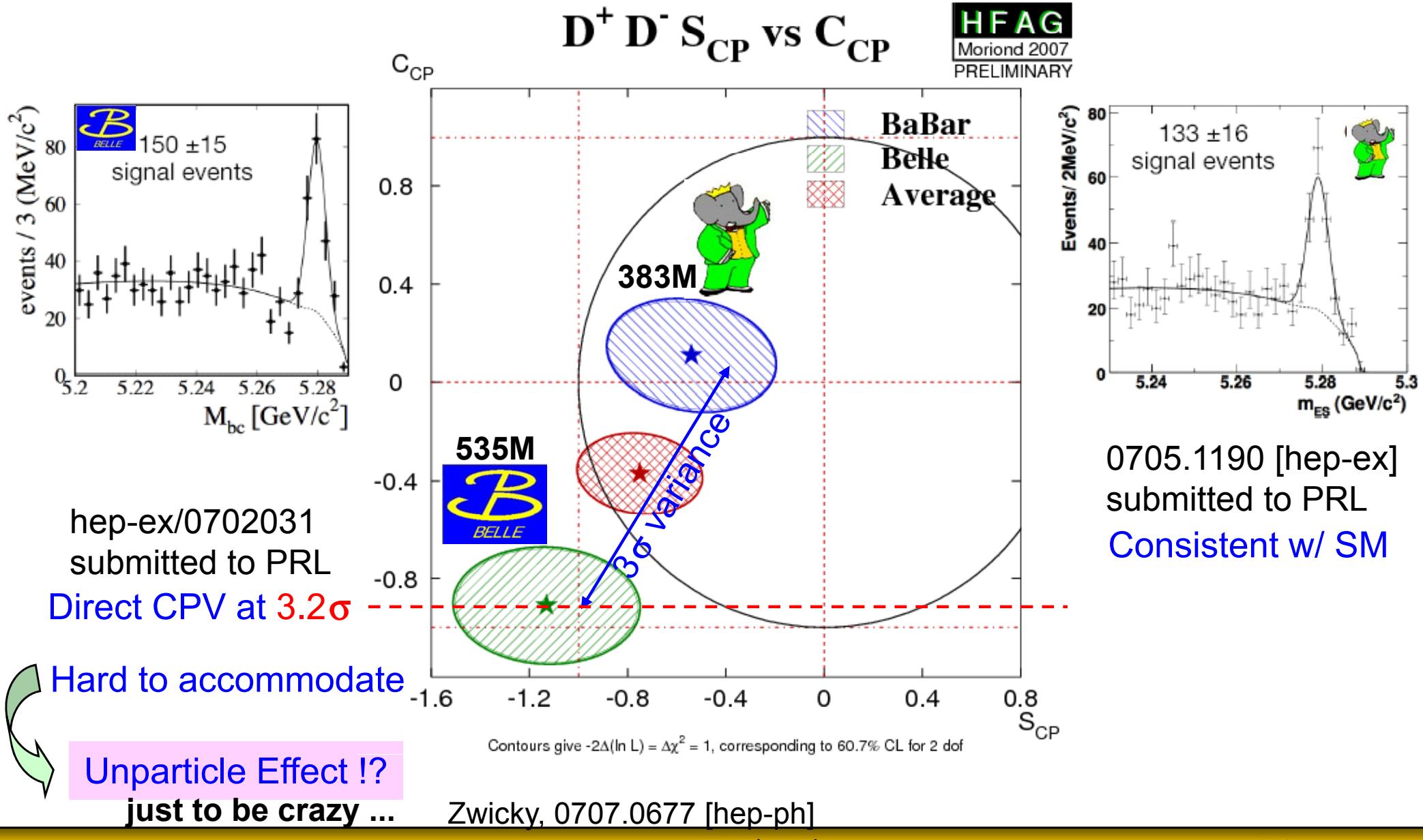
TCPV: $\delta_2 = \Delta m t$

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

CP Asymmetry needs *both* CP Conserv/Violating Phase



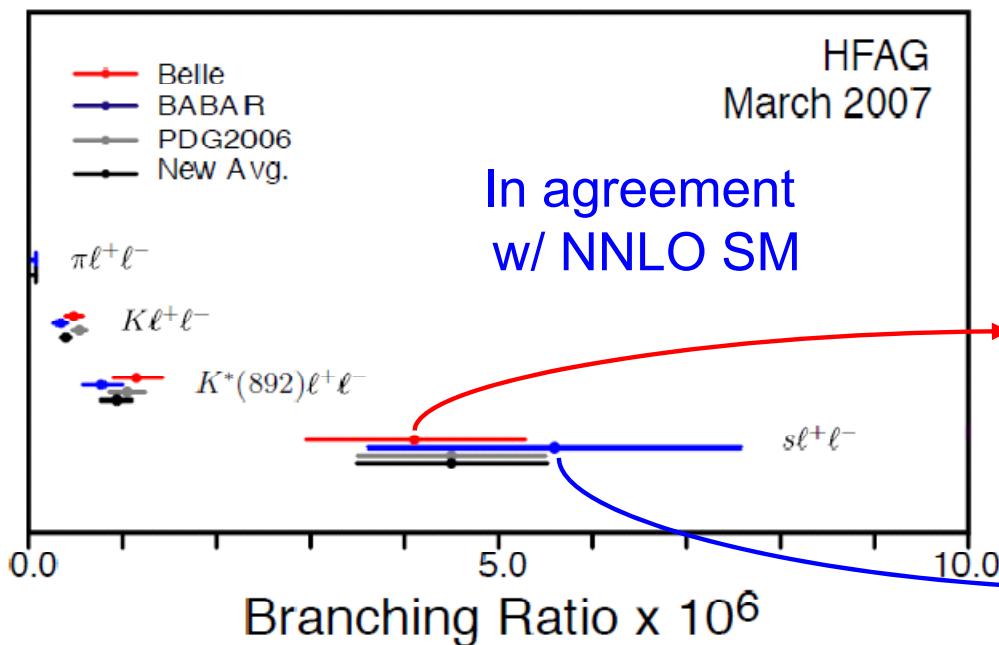
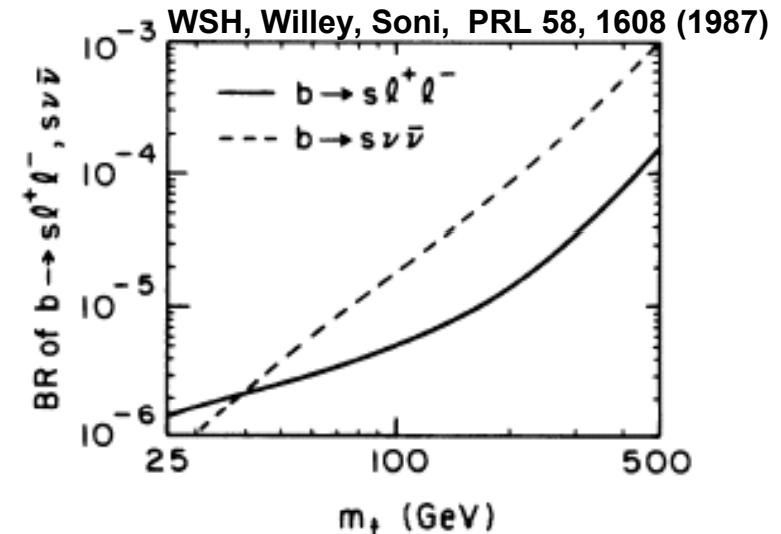
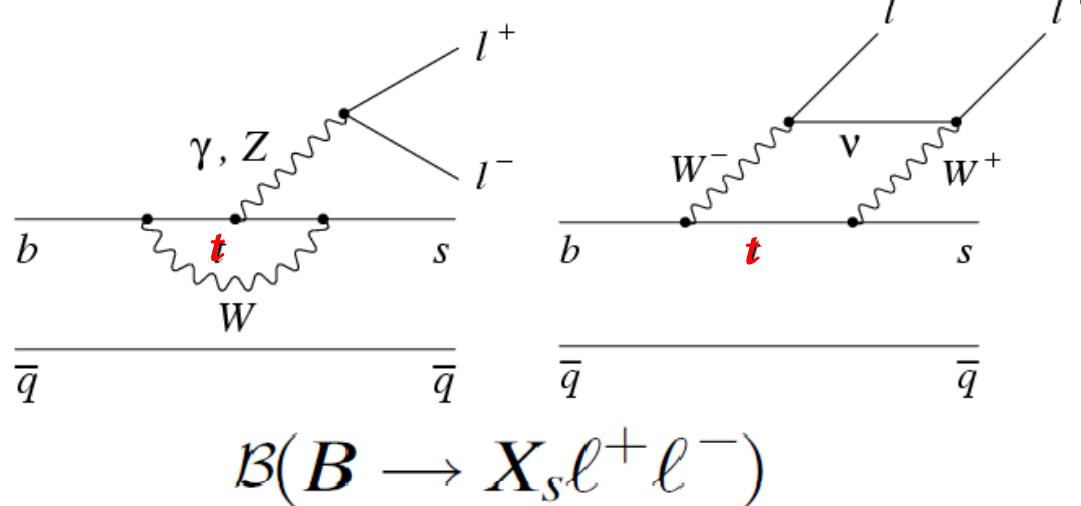
$B^0 \rightarrow D^- D^+$: Belle vs BaBar



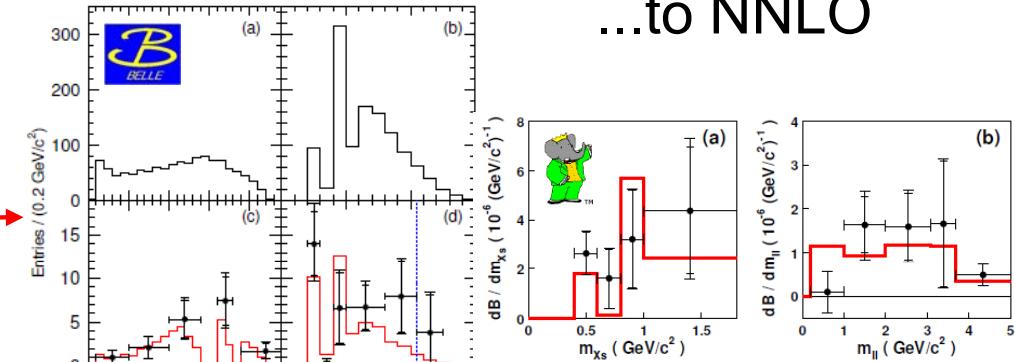
$b \rightarrow s \ell^+ \ell^-$ Rates



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



Much TH work
...to NNLO





Belle running at the Y(5S)

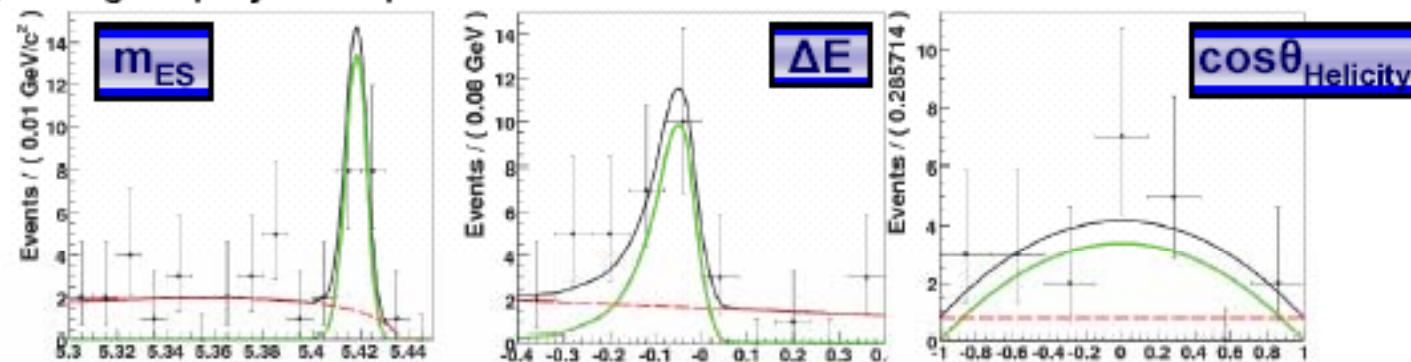
Results:

Preliminary

23.6 fb⁻¹ $B_s \rightarrow \phi\gamma$

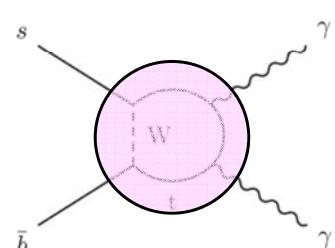
- (18 ± 6) signal events found: $\mathcal{B}(B_s \rightarrow \phi\gamma) = (5.7^{+1.8 +1.2}_{-1.5 -1.7}) \times 10^{-5}$
- Significance (including systematics): 5.5σ.
- Signal region projection plots:

First observation of a
radiative B_s penguin decay!



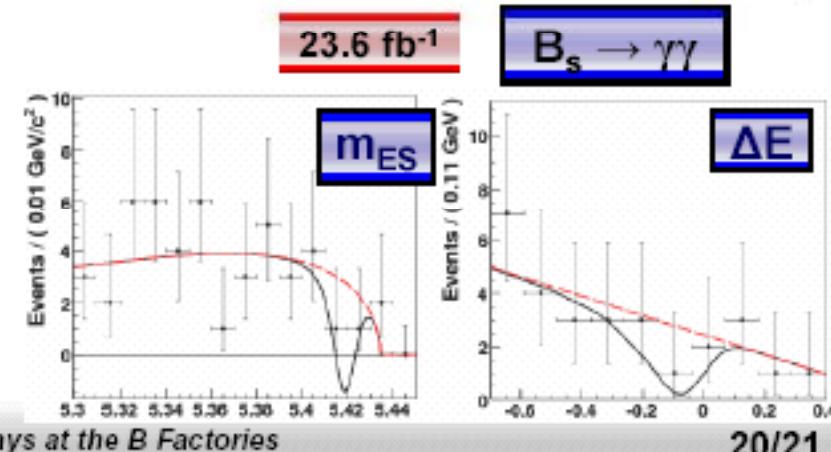
Final fit finds no signal:

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



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

Karsten Köneke
SUSY 2007, July 27th



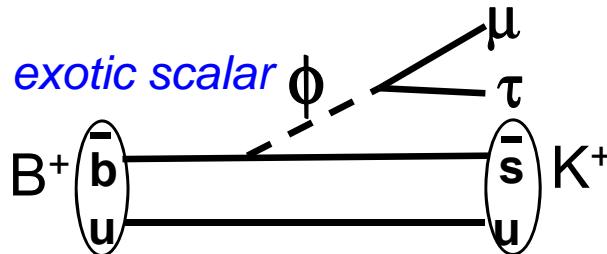
Radiative Penguin Decays at the B Factories

20/21



D. Monorchio @ EPS

346 fb⁻¹



First search ever done for this channel

Events in signal window

$$N_e = 1$$

$$N_\mu = 0$$

$$N_\pi = 2$$

Expected background

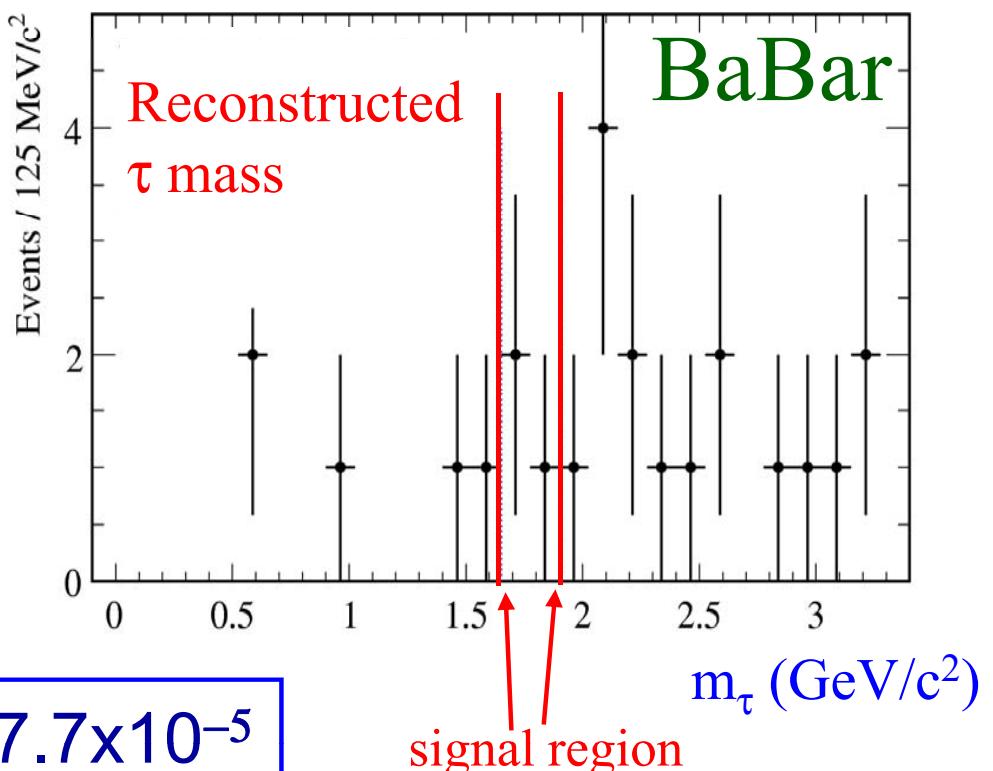
$$b_e = 0.5 \pm 0.3$$

$$b_\mu = 0.6 \pm 0.3$$

$$b_\pi = 1.8 \pm 0.6$$

No evidence of signal

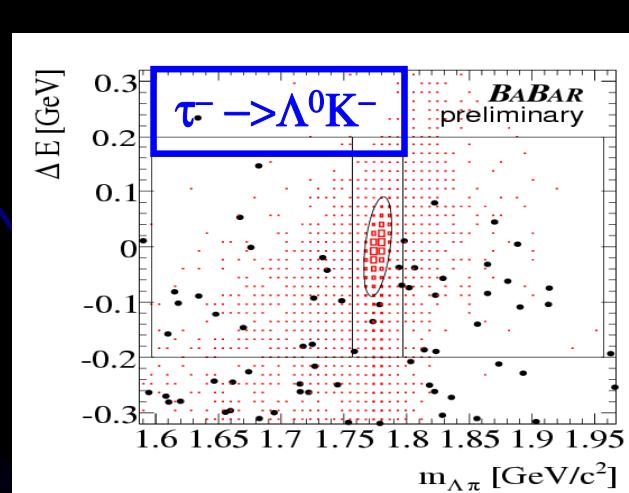
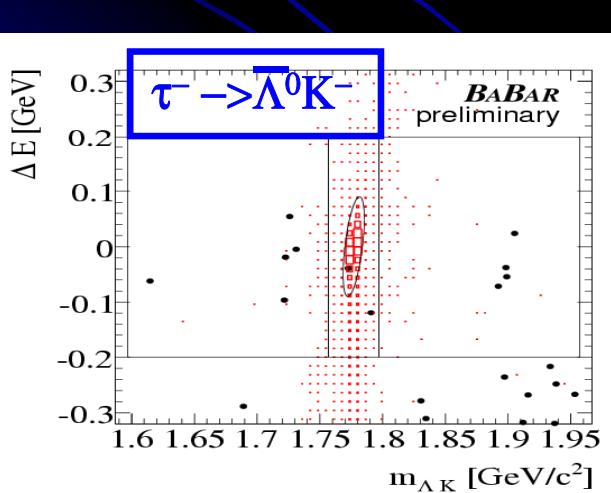
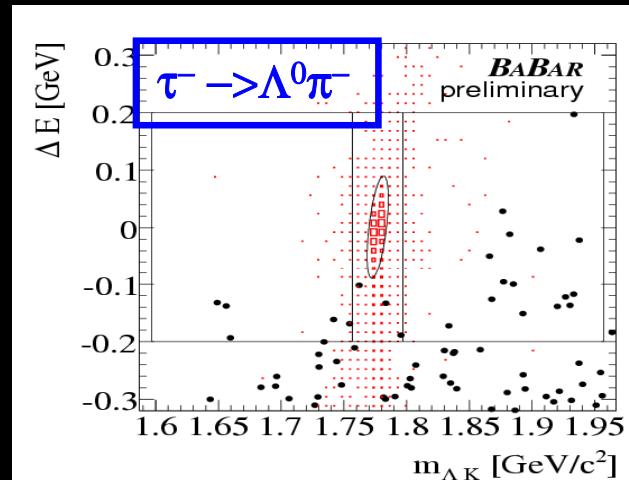
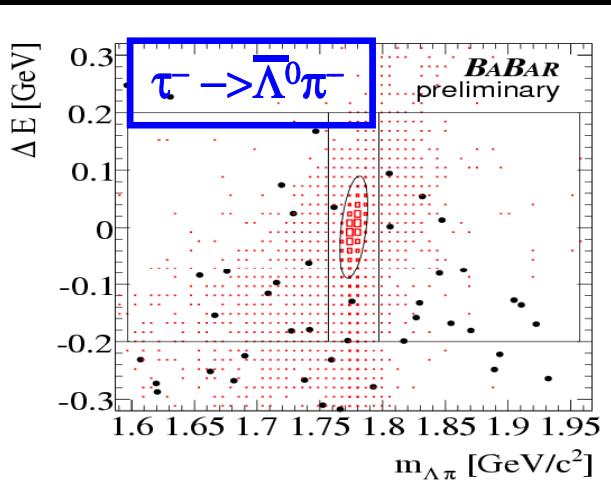
UL (90%CL): $\mathcal{B}(B \rightarrow K\tau\mu) < 7.7 \times 10^{-5}$



Lepton and baryon number violating τ -decay

Swain

- The baryon asymmetry of the universe → Baryon number violation (Sakharov condition)
- For lepton \rightarrow baryon + meson decays, the angular momentum conservation requires, $\Delta(B-L) = 0$ or 2



The following decays modes used in this analysis: (237 fb⁻¹)

(hep-ex: 0607040)

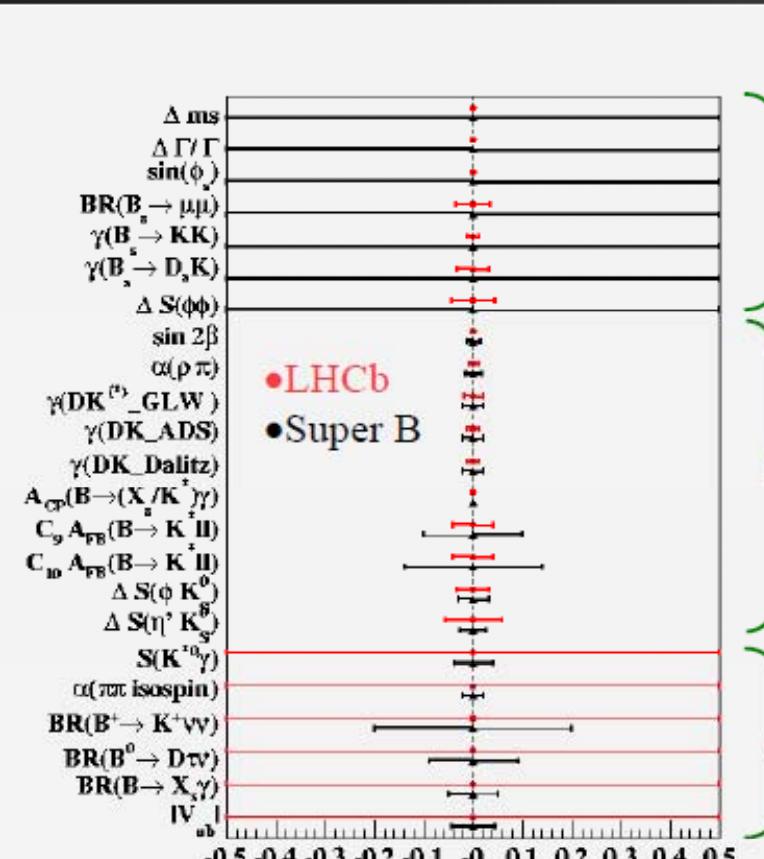


mode	upper limit on \mathcal{B} @ 90% C.L.
$\tau^- \rightarrow \bar{\Lambda}^0 \pi^-$	5.9×10^{-8}
$\tau^- \rightarrow \Lambda^0 \pi^-$	5.8×10^{-8}
$\tau^- \rightarrow \bar{\Lambda}^0 K^-$	7.2×10^{-8}
$\tau^- \rightarrow \Lambda^0 K^-$	15×10^{-8}



Comparison with Super B factory

Sensitivity Comparison ~2020
LHCb 100 fb^{-1} vs Super-B factory 50 ab^{-1}



P

Preliminary

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