1951-9

Workshop on the original of P, CP and T Violation

2 - 5 July 2008

New Physics Searches at B Factories.

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New Physics Searches at B Factories

Samo Stanič

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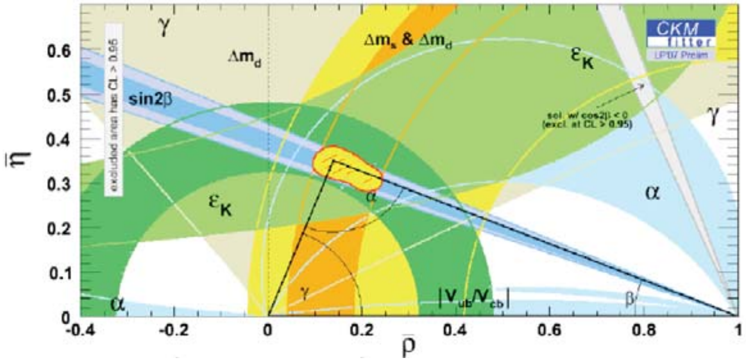
for the Belle Collaboration

B Factories are a Big Success

Precise test of CP violation in the Standard Model

- Measurements of CP violation in mixing and direct CP violation in the decays of B mesons by Belle and BaBar



- Studies of CKM matrix elements, Unitarity triangle; **CKM seems to be the dominant source of CP violation at low energy** as all pieces of the puzzle seem to fit together

New, unanticipated particles discovered

- the charmonium(-like) states; X(3872) X(3940) Y(3940) Z(3930) Y (4260) etc.

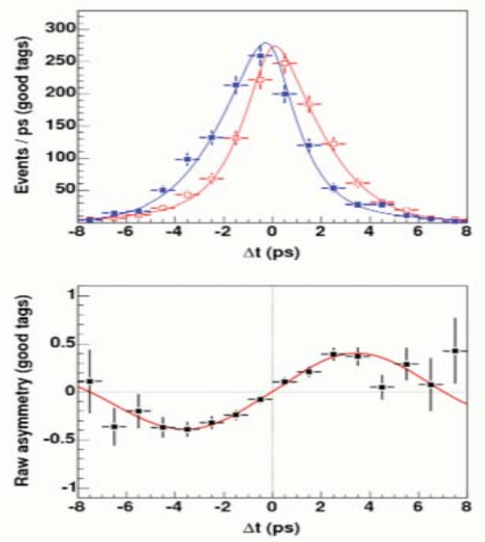
First hints of New Physics (e.g. in hadronic penguin decays, D^0 mixing, TCPV)

Experimental precision of B Factories is just getting there!

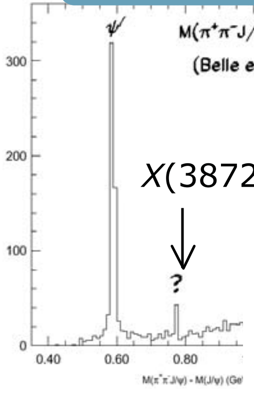
Highlights of Physics at B Factories

Discovery of CPV in B

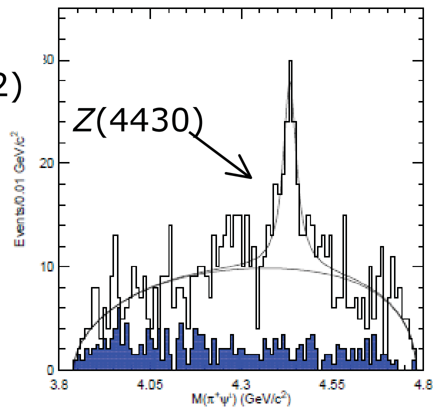
Phys.Rev.Lett.87:091802,2001
Phys.Rev.Lett.87:091801,2001



Many new resonances

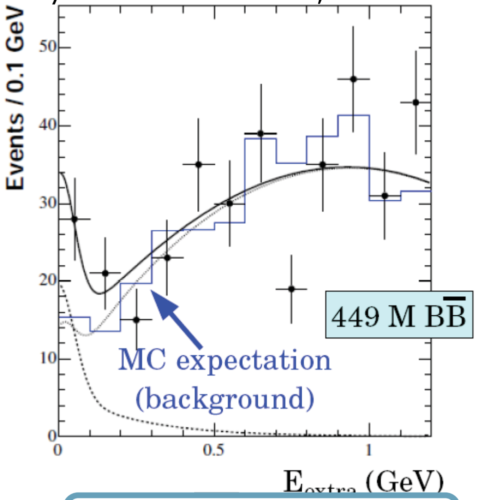


Phys.Rev.D71:071103,2005
Phys.Rev.Lett.98:082001,2007



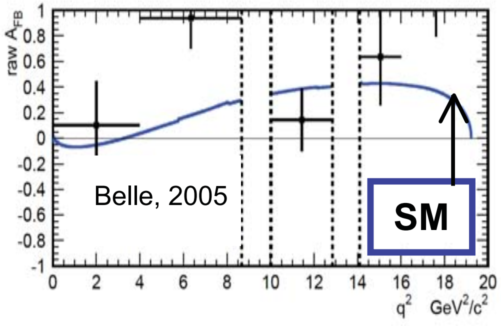
Evidence for B→τν

Phys.Rev.Lett.97:251802,2006
Phys.Rev.D77:011107,2008



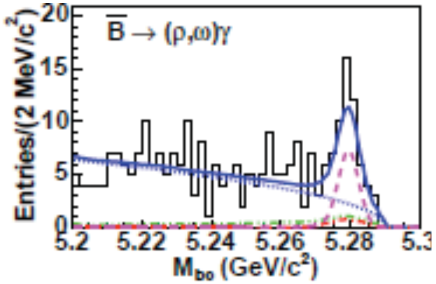
A_{FB} in B→K*l^+l^-

PRL 96, 251801(2006)



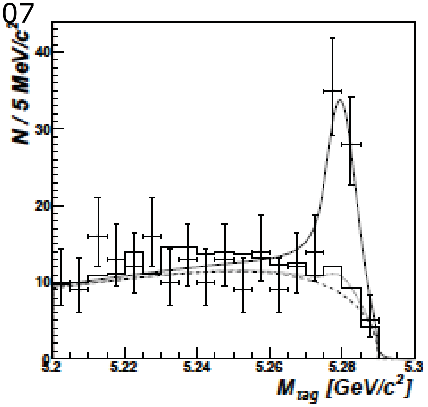
b→dγ transition

Phys.Rev.Lett.96:221601,2006
Phys.Rev.Lett.98:151802,2007



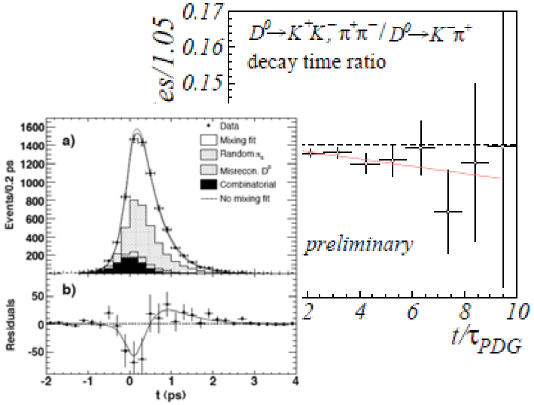
B→D*τν

arXiv:0706.4429



D^0-D^0 mixing

Phys.Rev.Lett.98:211803,2007
Phys.Rev.Lett.98:211802,2007



New Physics Searches -

Direct CP Violation in B → hh

Direct CP Violation in Hadronic B Decays

B → hh decay amplitudes can be written as

$$\mathcal{A}(B \to f) = \sum_i \mathcal{A}_i e^{i(\delta_i+\phi_i)},\ \bar{\mathcal{A}}(\bar{B} \to \bar{f}) = \sum_{i'} \mathcal{A}_{i'} e^{i(\delta_{i'}+\phi_{i'})}$$

and the asymmetry representing CP violation as

$$\mathcal{A}_{\mathcal{CP}}(B \to f) = \frac{|\bar{\mathcal{A}}|^2 - |\mathcal{A}|^2}{|\bar{\mathcal{A}}|^2 + |\mathcal{A}|^2} \propto \sum_{i,j} \mathcal{A}_i \mathcal{A}_j \sin(\delta_i - \delta_j) \sin(\phi_i - \phi_j)$$

A non-zero A_{CP} requires:

- **more than two amplitudes**
- **Non-zero strong phase difference $\Delta\delta=\delta_i-\delta_j\neq0$**
- **Non-zero weak phase difference $\Delta\phi=\phi_i-\phi_j\neq0$**

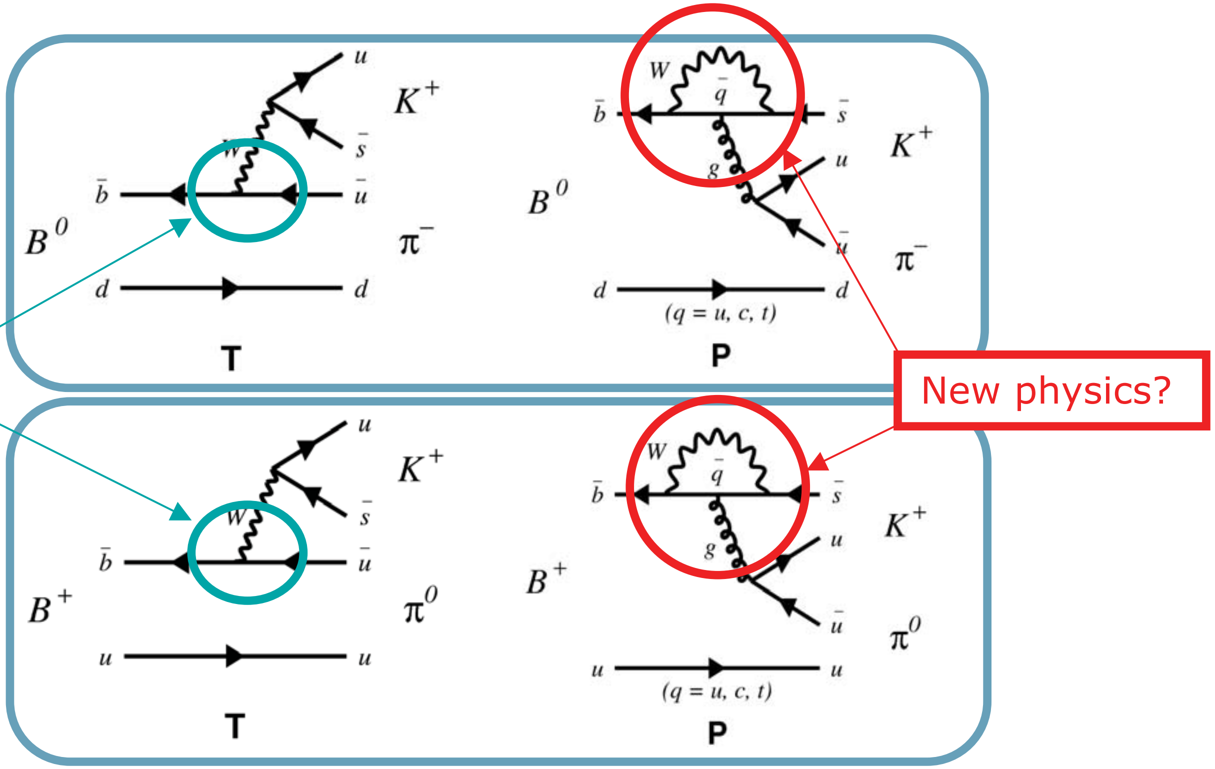
Important role in searches of new physics!

Direct CP Violation in B → hh

DCPV in **B → Kπ** arises from the interference between tree type and penguin type processes:

- $B^0 \rightarrow K^+\pi^-$ (T+P)

- $B^+ \rightarrow K^+\pi^0$ (T+P)



ϕ_3

(through b → u transition)

New physics?

Based on SM one would expect $A_{CP}(K^+\pi^-) \sim A_{CP}(K^+\pi^0)$

$$\mathcal{A}_{CP}(B^0 \to K^+\pi^-) = \frac{2|P/T|\sin\Delta\delta\sin\phi_3}{1+|P/T|^2+2|P/T|\cos\Delta\delta\cos\phi_3}$$

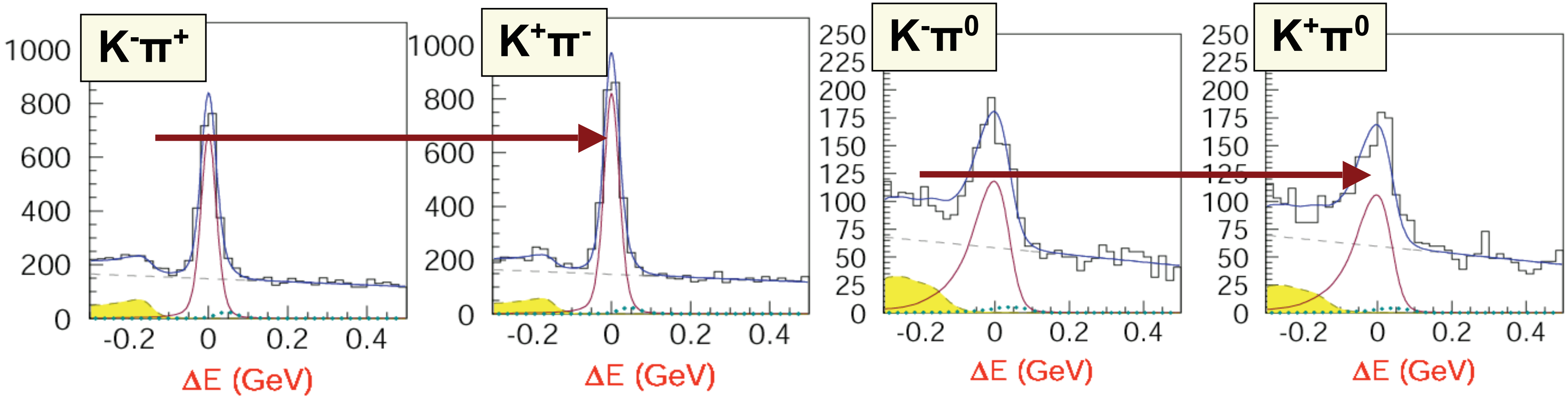
$A_{CP}(K^+\pi^-) \neq A_{CP}(K^+\pi^0)$ might indicate New Physics!

Nature 452, 332-335(2008)

The Kπ "Puzzle"

Signal
ππ reflection
continuum
charmless B

A_{CP} results from the B factories:



A_{cp}=-0.094±0.018±0.008

A_{cp}=-0.107±0.018±0.006

A_{cp}=-0.086±0.023±0.009

A_{cp}=+0.07±0.03±0.001

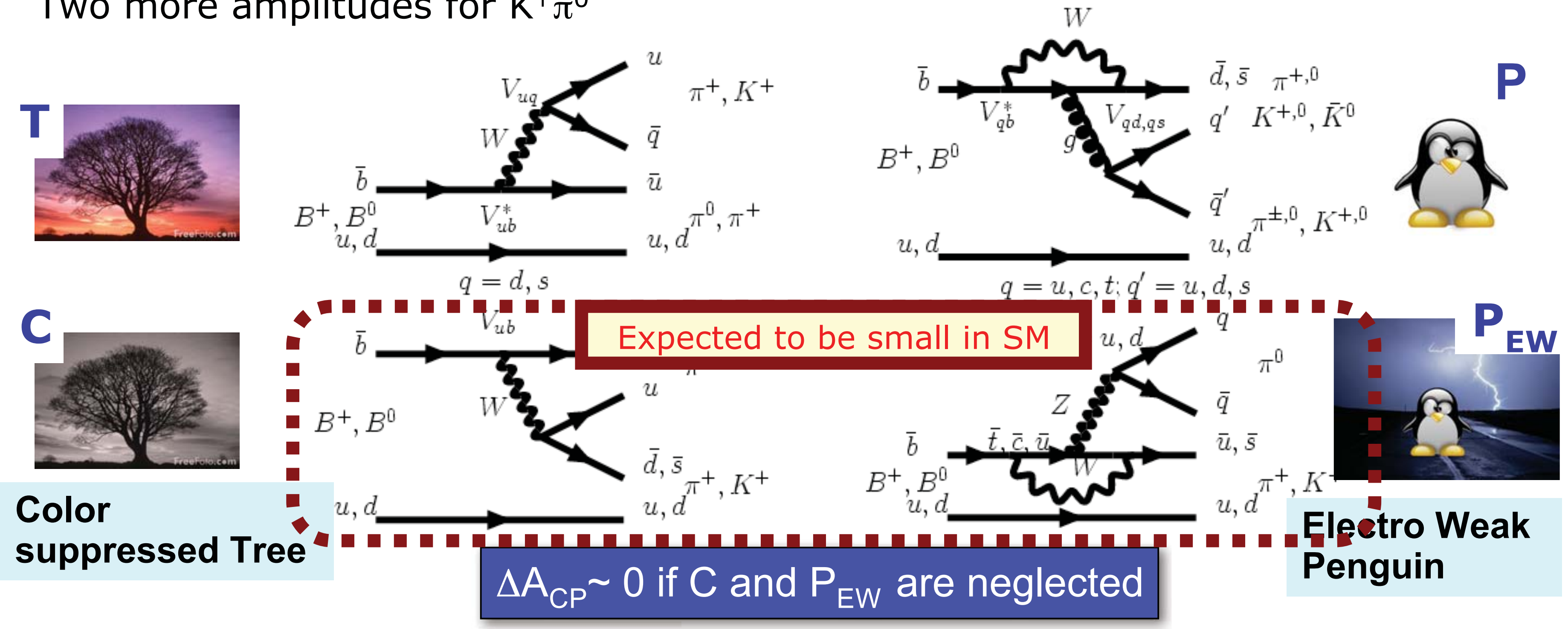
A_{cp}=+0.03±0.04±0.01

Deviation ≈ 5.2σ !

A_{cp}=-0.086±0.023±0.009 ≠ A_{cp}=+0.03±0.04±0.01

The Kπ “Puzzle”

Two more amplitudes for $K^+\pi^0$



Color suppressed Tree

Expected to be small in SM

Electro Weak Penguin

ΔA_{CP}~ 0 if C and P_{EW} are neglected

- C.-W.Chaing, et al., PRD 70, 034020
- Y.-Y.Charng, et al., PRD 71, 014036
- W.-S.Hou, et al., PRL 95, 141601
- S.Baek, et al., PRD 71, 057502
- S.Baek, et al., PLB 653, 249
- H.-n.Li,et al., PRD 72, 114005
- etc…

Enhancement of C ?

➢ C>T is needed (C/T = 0.3–0.6 in SM)

➢ breakdown of theoretical understanding

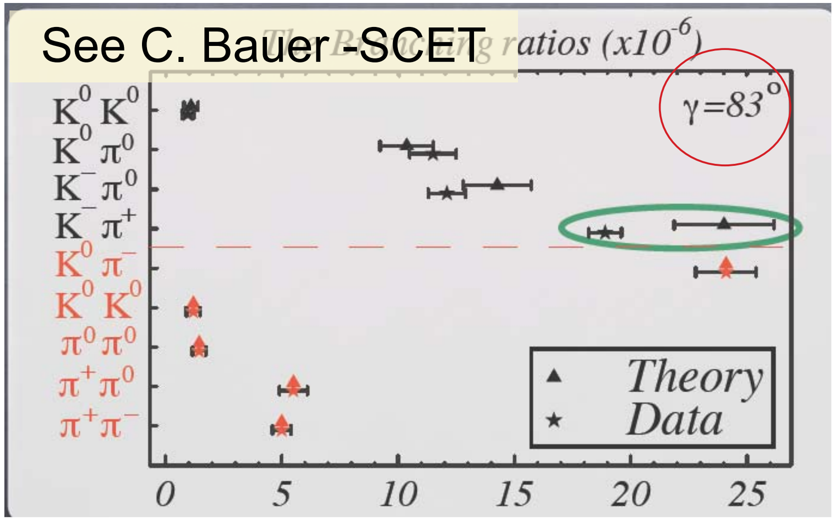
Enhancement of P_{EW} ?

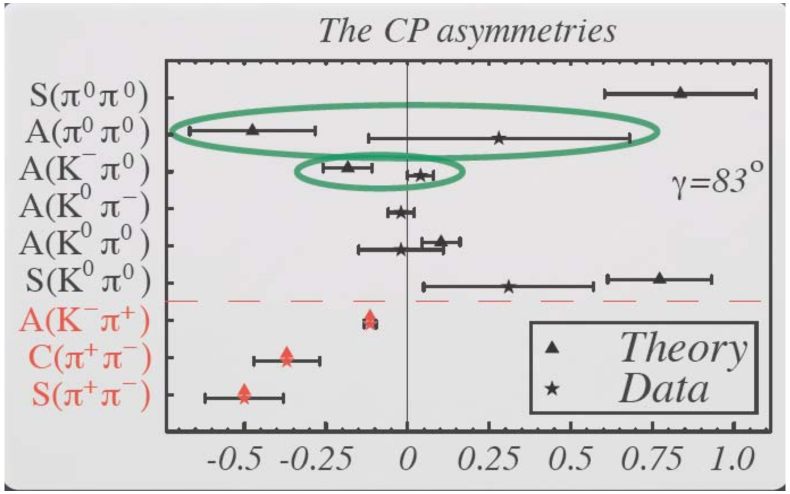
➢ Would indicate new physics

“Puzzle” due to **poor understanding of strong int.?**

Comparison With Theory of Benchmark BR's

See C. Bauer -SCET





See S. Mishima-PQCD

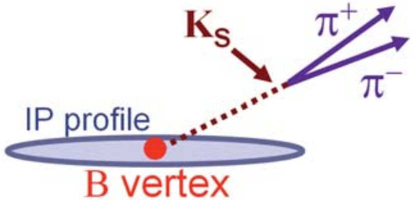
Br(10^{-6}), $A_{\rm CP}(10^{-2})$	Exp. *HFAG*	LO *Keum,Sanda(03)*	NLO
$\mathrm{Br}(B^0 \to \pi^\mp\pi^\pm)$	4.9 ± 0.4	$5.9 \sim 11.0$	$6.5^{+\,6.7}_{-\,3.8}$
$\mathrm{Br}(B^\pm \to \pi^\pm\pi^0)$	5.5 ± 0.6	$2.7 \sim 4.8$	$4.0^{+\,3.4}_{-\,1.9}$
$\mathrm{Br}(B^0 \to \pi^0\pi^0)$	1.45 ± 0.29	$0.10 \sim 0.65$	$0.29^{+0.50}_{-0.20}$
$A_{\rm CP}(B^0 \to \pi^\mp\pi^\pm)$	37 ± 10	$16.0 \sim 30.0$	18^{+20}_{-12}
$A_{\rm CP}(B^\pm \to \pi^\pm\pi^0)$	1 ± 6	0.0	0 ± 0
$A_{\rm CP}(B^0 \to \pi^0\pi^0)$	28^{+40}_{-39}	$20.0 \sim 40.0$	63^{+35}_{-34}

Br(10^{-6}), $A_{\rm CP}(10^{-2})$	Exp. *HFAG*	LO *Keum,Sanda(03)*	NLO
$\mathrm{Br}(B^\pm \to \pi^\pm K^0)$	24.1 ± 1.3	$14.4 \sim 26.3$	$23.6^{+14.5}_{-\,8.4}$
$\mathrm{Br}(B^\pm \to \pi^0 K^\pm)$	12.1 ± 0.8	$7.9 \sim 14.2$	$13.6^{+10.3}_{-\,5.7}$
$\mathrm{Br}(B^0 \to \pi^\mp K^\pm)$	18.9 ± 0.7	$12.7 \sim 19.3$	$20.4^{+16.1}_{-\,8.4}$
$\mathrm{Br}(B^0 \to \pi^0 K^0)$	11.5 ± 1.0	$4.5 \sim 8.1$	$8.7^{+\,6.0}_{-\,3.4}$
$A_{\rm CP}(B^\pm \to \pi^\pm K^0)$	-2 ± 4	$-1.5 \sim -0.6$	0 ± 0
$A_{\rm CP}(B^\pm \to \pi^0 K^\pm)$	4 ± 4	$-17.3 \sim -10.0$	-1^{+3}_{-6}
$A_{\rm CP}(B^0 \to \pi^\mp K^\pm)$	-10.8 ± 1.7	$-21.9 \sim -12.9$	-10^{+7}_{-8}
$A_{\rm CP}(B^0 \to \pi^0 K^0)$	2 ± 13	$-1.03 \sim -0.90$	-7^{+3}_{-4}

- TH & EXP agree in some areas, but not all
- TH errors still too large

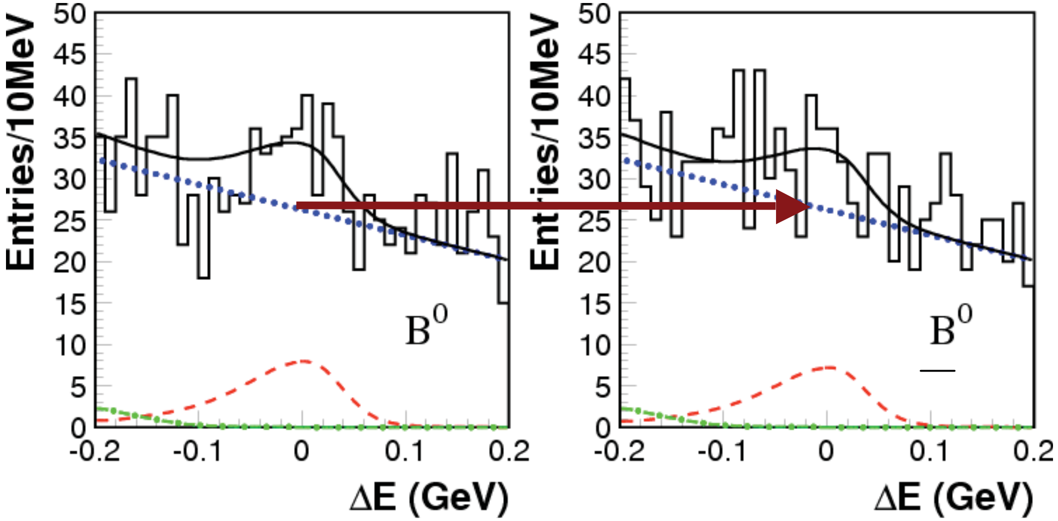
PRD 76, 091103 (2007)

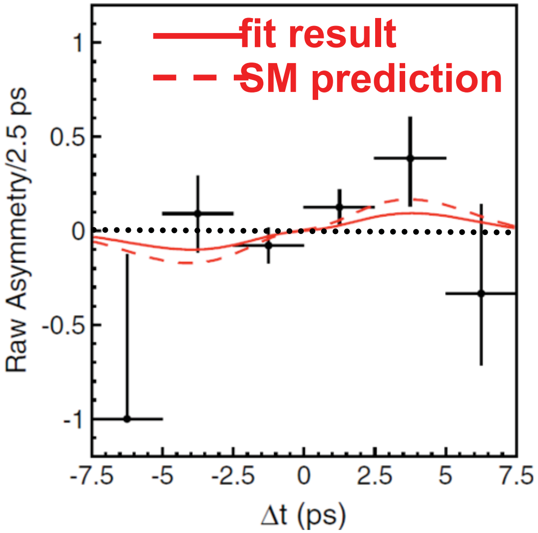
CP Asymmetry in $B^0 \to K^0\pi^0$



$A_{CP}(K^0\pi^0)$ and $S(K^0\pi^0)$ from time-dependent CP analysis

- b flavor tagging efficiency ~30%
- B vertex from K_S trajectory and IP, efficiency ~30%





$A_{CP}(K^0\pi^0)$=+0.05±0.14±0.05
"$\sin2\phi_1$" = +0.33±0.35±0.08

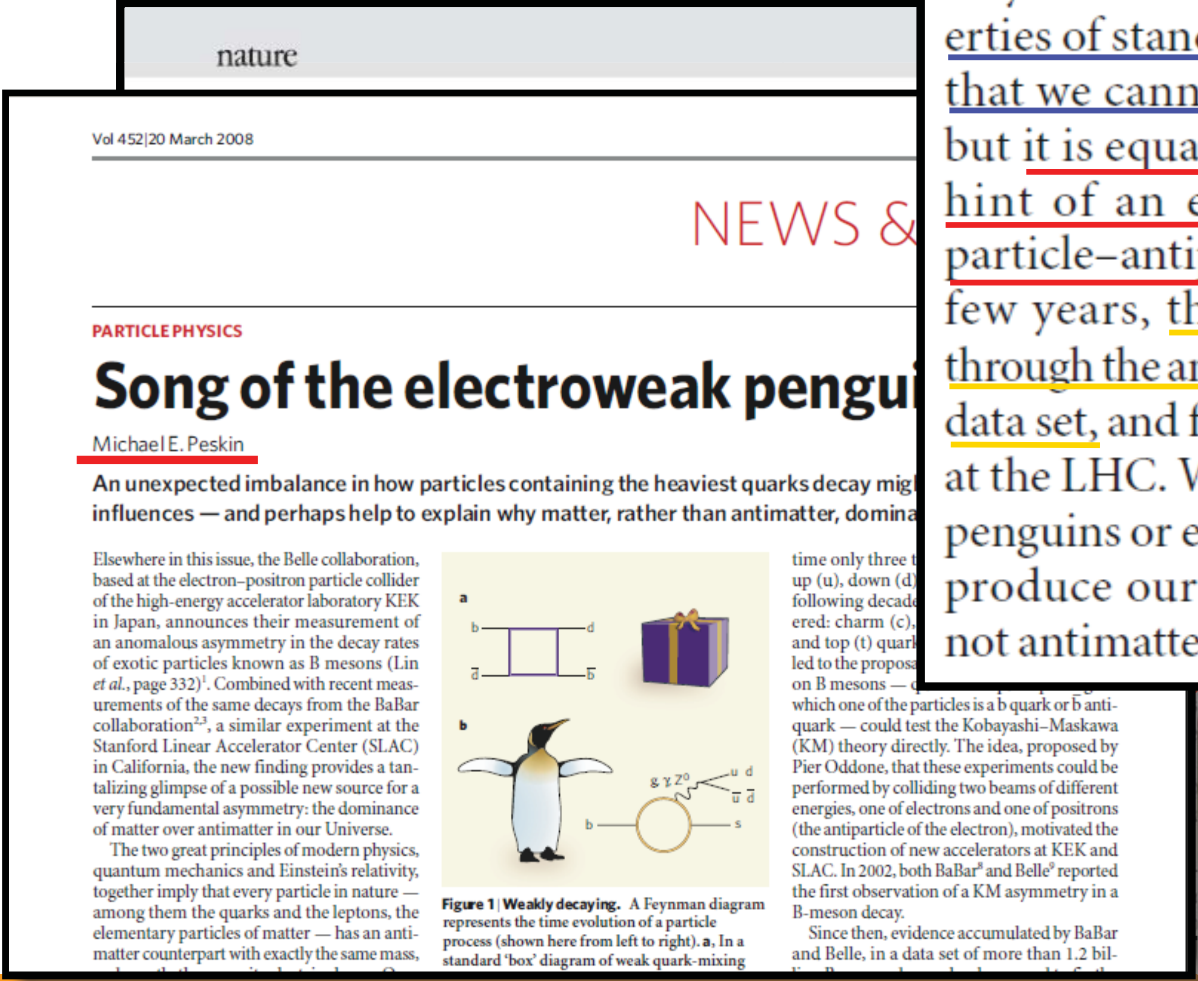
$A_{CP}(K^0\pi^0)$=+0.24±0.15±0.03
"$\sin2\phi_1$" = +0.40±0.23±0.03

$A_{CP}(K^0\pi^0)$ = –0.14±0.11
"$\sin2\phi_1$" = +0.38±0.19
HFAG W.A.
Consistent with HFAG Ave: $\sin2\phi_1$ = +0.668± 0.026

Recent Publication in Nature

$$\Delta A_{CP} = A_{CP}(K^+\pi^0) - A_{CP}(K^+\pi^-) = +0.164\pm0.037 \text{ @ } 4.4\sigma$$

What is happening with $A_{CP}(K^+$



nature

Vol 452|20 March 2008

NEWS &

PARTICLE PHYSICS

Song of the electroweak pengu

Michael E. Peskin

An unexpected imbalance in how particles containing the heaviest quarks decay mig influences — and perhaps help to explain why matter, rather than antimatter, domina

Elsewhere in this issue, the Belle collaboration, based at the electron–positron particle collider of the high-energy accelerator laboratory KEK in Japan, announces their measurement of an anomalous asymmetry in the decay rates of exotic particles known as B mesons (Lin *et al.*, page 332)[1]. Combined with recent measurements of the same decays from the BaBar collaboration[2,3], a similar experiment at the Stanford Linear Accelerator Center (SLAC) in California, the new finding provides a tantalizing glimpse of a possible new source for a very fundamental asymmetry: the dominance of matter over antimatter in our Universe.

The two great principles of modern physics, quantum mechanics and Einstein's relativity, together imply that every particle in nature — among them the quarks and the leptons, the elementary particles of matter — has an antimatter counterpart with exactly the same mass,

Figure 1 | Weakly decaying. A Feynman diagram represents the time evolution of a particle process (shown here from left to right). **a**, In a standard 'box' diagram of weak quark-mixing

time only three t
up (u), down (d)
following decade
ered: charm (c),
and top (t) quark
led to the proposa
on B mesons —

which one of the particles is a b quark or $\bar{b}$ antiquark — could test the Kobayashi–Maskawa (KM) theory directly. The idea, proposed by Pier Oddone, that these experiments could be performed by colliding two beams of different energies, one of electrons and one of positrons (the antiparticle of the electron), motivated the construction of new accelerators at KEK and SLAC. In 2002, both BaBar[8] and Belle[9] reported the first observation of a KM asymmetry in a B-meson decay.

Since then, evidence accumulated by BaBar and Belle, in a data set of more than 1.2 bil-

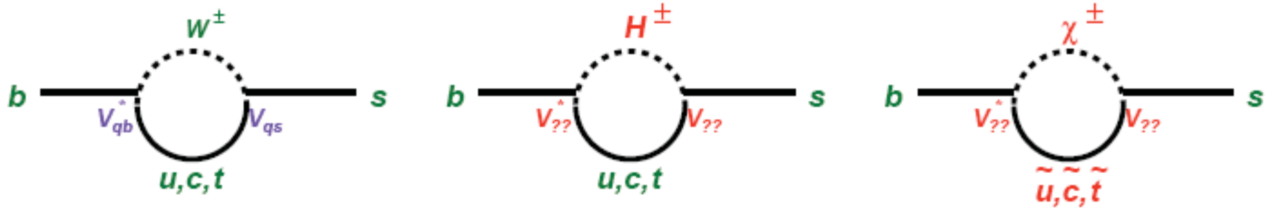
The new results[1–3] are not conclusive, but they are tantalizing. They might be due to properties of standard b-quark weak interactions that we cannot quite yet estimate precisely, but it is equally possible that this is the first hint of an entirely new mechanism for particle–antiparticle asymmetry. In the next few years, these ideas will be tested, both through the analysis of the huge Belle and BaBar data set, and from the hunt for exotic particles at the LHC. We do not yet know whether it is penguins or even more unusual creatures that produce our Universe made of matter and not antimatter. ■

New Physics Searches -

Radiative and EW Penguin Decays

b→s,d Transitions

- FCNC in SM: b→s,d transitions forbidden at tree level



- Probe for NP:
New particles in the loops can give effects of the same order
- Measurement of $|V_{td}/V_{ts}|^2$ from BF($B\rightarrow\rho\gamma$)/ BF($B\rightarrow K^*\gamma$)

b→s,d can be measured:

- Large clean sample of Y(4S)→BB, use inclusive analysis of radiative decays
- Continuum suppression with event shape variables
- Continuum subtraction with off-resonance data
- Exclusive B reconstruction with

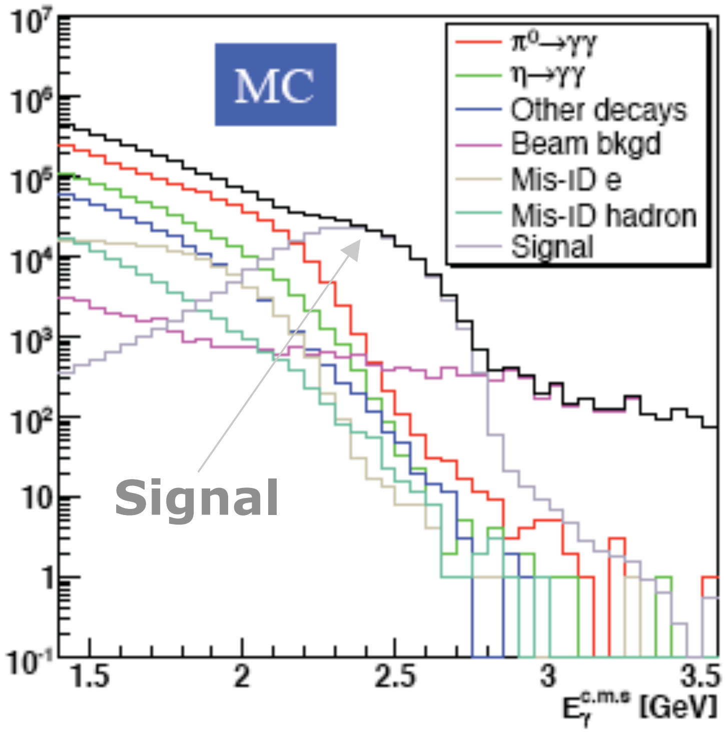
$$\Delta E = E_B^* - E_{beam}^* \text{ and } (M_{bc})^2 = (M_{ES})^2 = (E_{beam}^*)^2 - |p_B^*|^2$$

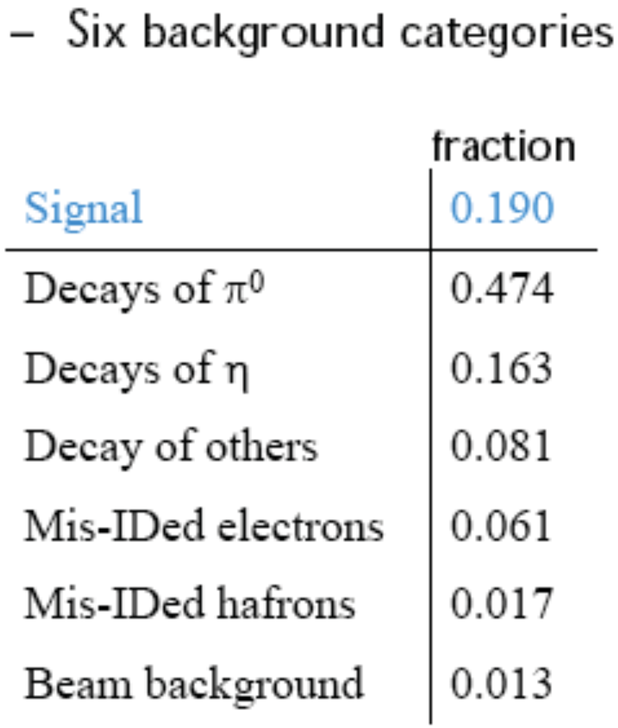
b→s Transitions

Most powerful mode to constrain new physics!

Measure primary γ from B decays: monochromatic E_γ spectrum

Huge background experimentally challenging





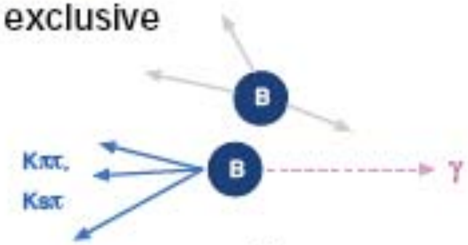
– Six background categories

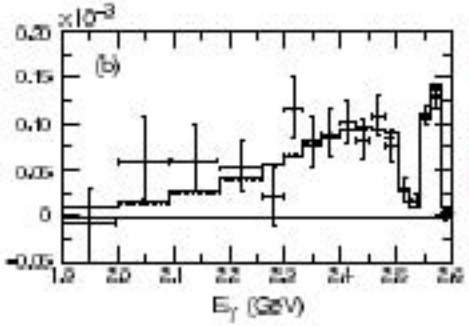
	fraction
Signal	0.190
Decays of π^0	0.474
Decays of η	0.163
Decay of others	0.081
Mis-IDed electrons	0.061
Mis-IDed hafrons	0.017
Beam background	0.013

Important to measure low E_γ to reduce model dependence

Measurement Methods

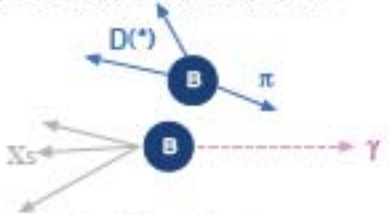
- Semi-inclusive
  - Sum of exclusive

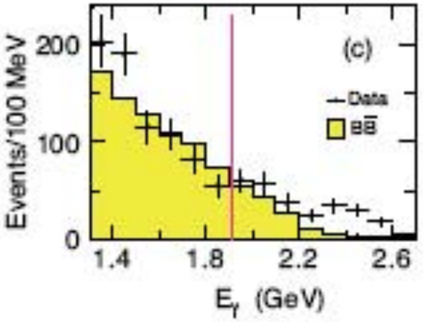




BaBar
81.5/fb
Eγ > 1.9 GeV, semi-inclusive
(PRD72, 052004 (2005))

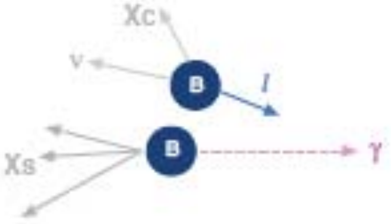
- B recoil
  - Fully reconstruct one B
  - Measure photon from other B

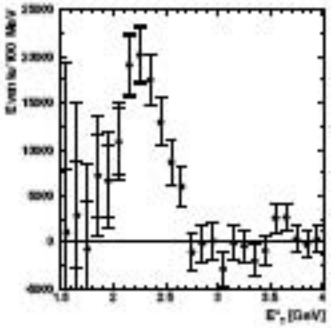




BaBar
81.5/fb
Eγ > 1.9 GeV, B recoil
(PRD77, 051103(2008))

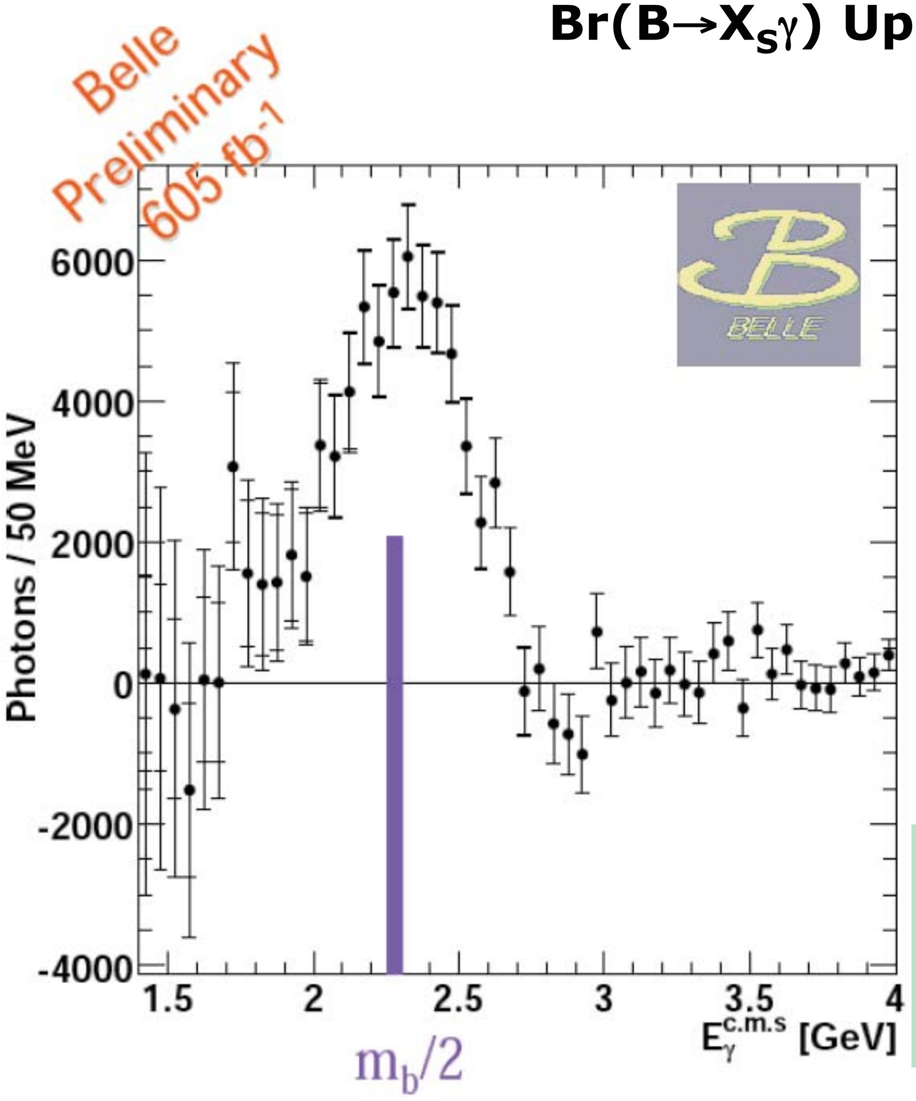
- Inclusive
  - Reconstruct only the photon
  - Reduce background with lepton tag





Belle
140/fb
Eγ > 1.8 GeV, inclusive
(PRL93, 061803(2004))

Br(B→$X_s\gamma$) Update from Belle



- Inclusive approach
  - •Reconstruct only γ
  - •Suppress background with lepton tag
- Yield above endpoint from B decay consistent with 0
- Peak at half mass of b
- Significant signal between 1.7<Eγ<2.8GeV

For $E_\gamma > 1.7$ GeV

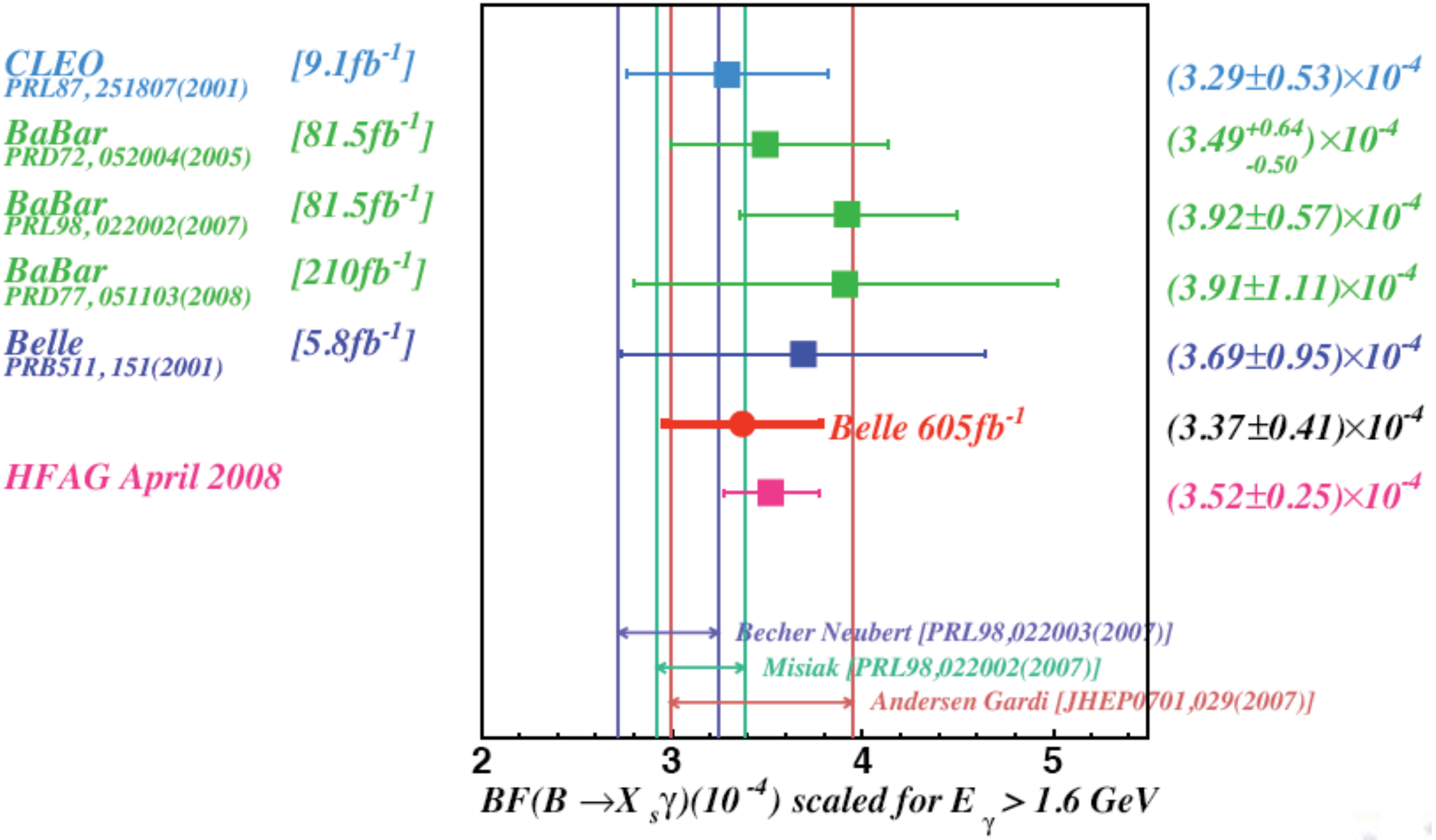
$$B.F(B \to X_s\gamma) = (3.31 \pm \underset{\text{(Stat.)}}{0.19} \pm \underset{\text{(Syst.)}}{0.37} \pm \underset{\text{(Boost.)}}{0.01}) \times 10^{-4}$$

$$\langle E_\gamma \rangle = 2.281 \pm 0.032 \pm 0.053 \pm 0.002\ \text{GeV}$$

$$\langle E_\gamma^2 \rangle - \langle E_\gamma \rangle^2 = 0.0396 \pm 0.0156 \pm 0.0214 \pm 0.0012\ \text{GeV}^2$$

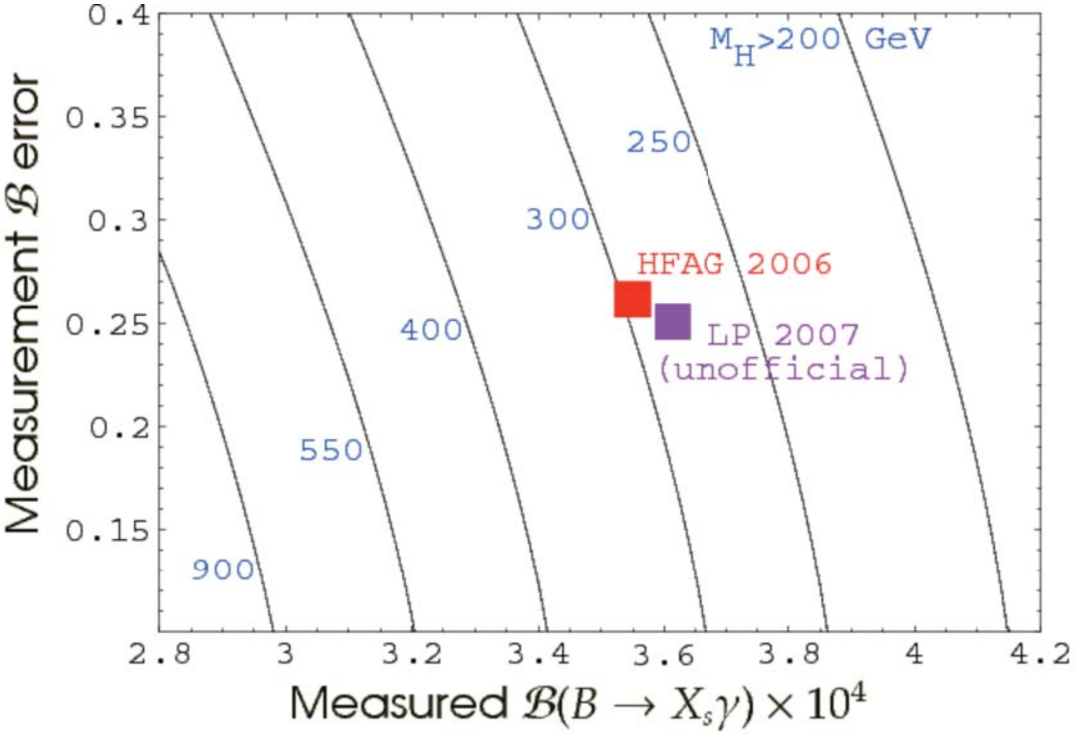
The most precise measurement today

$b \rightarrow X_s\gamma$ BF Summary



- **Tension between average and NNLO calculations?**
- **New NNLO Calculations are getting ready with smaller errors**

Limit on the Charged Higgs from B→$X_s\gamma$



from Misiak et al, PRL98,022002('07)

- Lower limit on type-II charged Higgs mass for any $\tan\beta$
  $M_{H^+} > 295$ GeV (95% CL), or $M_{H^+} \sim 650$ GeV (best-fit) for HFAG'06
- Also room for other new physics
- Need to decrease the experimental error!
  looser constraint with LP'07 average, for a higher central value

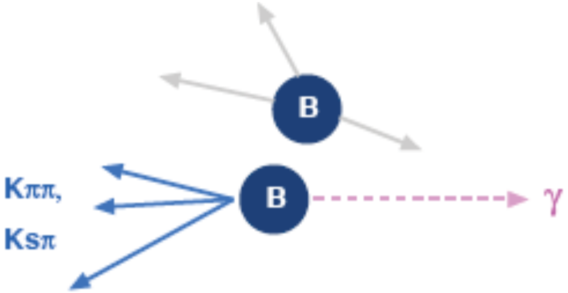
DCPV in B→$X_S\gamma$ from BaBar

New result from BaBar: Sum of exclusive modes: most accurate measurement to date

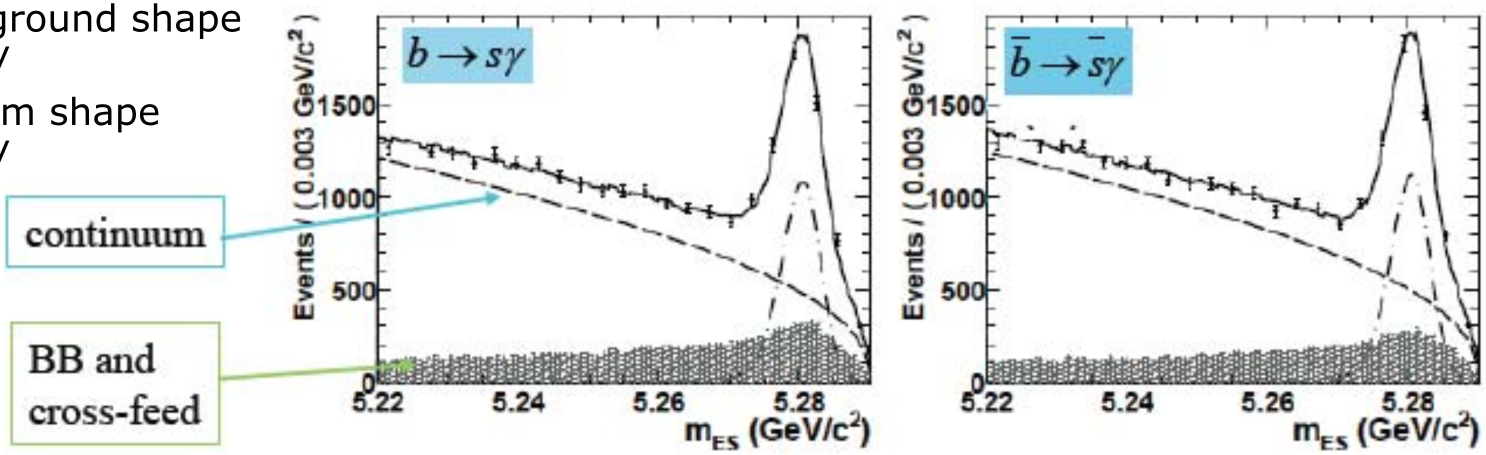
- Full reconstruction of 16 exclusive modes

(Xs is K to 3π, 3K and 0 or 1π, Kη(p), 3K(π))

- Main Background π^0 and η from continuum, ISR
- Extract yields from M_{ES} fit to signal region
  - background shapes from MC
- Sidebands and B→$X_S\,\pi^0$ control sample for
  - Detector bias study
  - BB Background shape uncertainty
  - Continuum shape uncertainty



$$A_{CP} = \frac{N_{b\to s\gamma} - N_{\bar{b}\to \bar{s}\gamma}}{N_{b\to s\gamma} + N_{\bar{b}\to \bar{s}\gamma}}$$

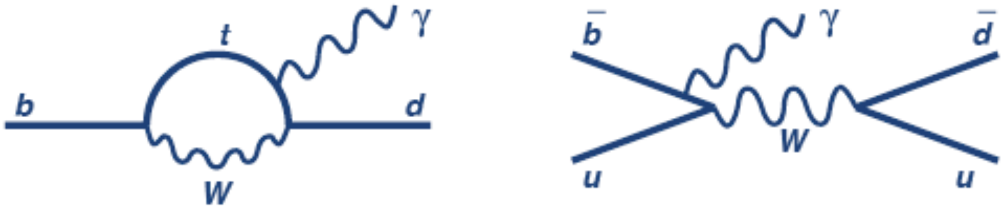


A_{CP}=-0.012 ± 0.030 (stat) ± 0.019 (syst)

Select candidates with $|\Delta E| < 0.10$ GeV

b→d γ

- Sensitive probe for physics beyond SM
- similar to b→s γ BF can be different if there is New Physics
- suppressed by $|V_{td}/V_{ts}|$



Belle, arXiv:0804.470 (657M BB) BaBar PRL98, 151802 (2007) 347M BB

	$B(10^{-7})$	(Σ)	$B(10^{-7})$	(Σ)
$B^+ \rightarrow \rho^+\gamma$	$8.7^{+2.9}_{-2.7}{}^{+0.9}_{-1.1}$	(3.3σ)	$11.0^{+3.7}_{-3.3} \pm 0.9$	(3.8σ)
$B^0 \rightarrow \rho^0\gamma$	$7.8^{+1.7}_{-1.6}{}^{+0.9}_{-1.0}$	(5.0σ)	$7.9^{+2.2}_{-2.0} \pm 0.6$	(4.9σ)
$B^0 \rightarrow \omega\gamma$	$4.0^{+1.9}_{-1.7} \pm 1.3$	(2.6σ)	$4.0^{+2.4}_{-2.0} \pm 0.5$	(2.2σ)
$B \rightarrow \rho\gamma$	$12.1^{+2.4}_{-2.2} \pm 1.2$	(5.8σ)	$13.6^{+2.9}_{-2.7} \pm 0.9$	(6.0σ)
$B \rightarrow (\rho,\omega)\gamma$	$11.4 \pm 2.0^{+1.0}_{-1.2}$	(6.2σ)	$12.5^{+2.5}_{-2.4} \pm 0.9$	(6.4σ)

Constraint on $|V_{td}/V_{ts}|$

Form factor ratio

$$R = \frac{B.F(B \to (\rho,\omega)\gamma)}{B.F(B \to K^*\gamma)} = \left|\frac{V_{td}}{V_{ts}}\right|^2 \frac{(1 - m^2_{(\rho,\omega)} / m^2_B)^3}{(1 - m^2_{K*} / m^2_B)^3} \varsigma^2 [1 + \Delta R]$$

[Ali, Lunghi, Parkhomenko, PLB 595, 323 (2004)]

Annihilation amplitude corrections

$$R = \frac{B.F(B \to (\rho,\omega)\gamma)}{B.F(B \to K^*\gamma)} = 0.0263 \pm 0.0047^{+0.0022}_{-0.0025}$$

Using Ball, Jones, Zwicky, PRD 75 054004 (2007)

$$\boxed{|V_{td} / V_{ts}| = 0.195^{+0.020}_{-0.019}(\mathrm{exp.}) \pm 0.015(\mathrm{theo.})}$$

CP Asymmetry in B → $\rho\gamma$

First CPV measurement in $b \to d\gamma$

Time dependent CPV in B → $\rho^0\gamma$: $A_{CP} = S \sin \Delta m \Delta t + A \cos \Delta m \Delta t$

- S ~ 0 in SM (Time dependent CP Asymmetry)
  - Weak phase cancellation arg(V_{td}) in mixing ⇔ arg(V_{td}) in decay
  - Suppresion due to photon polarization
- A could be non-zero in SM: Direct CP Asymmetry

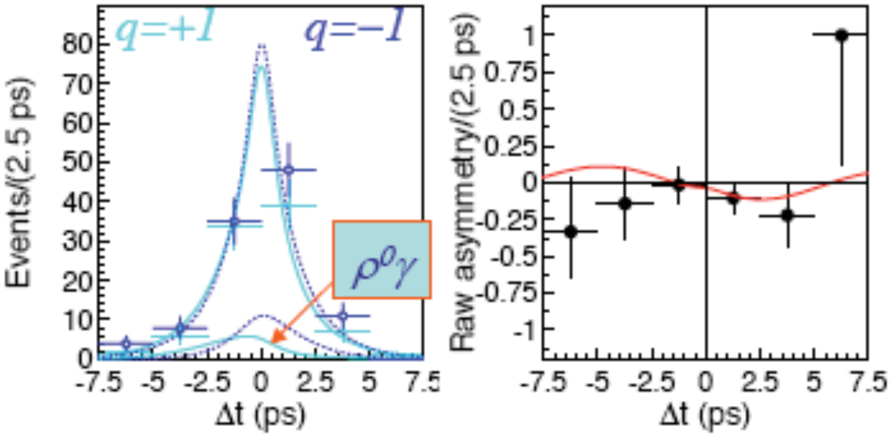
Charge asymmetry in $B^+ \to \rho^+\gamma$: Direct CP Asymmetry

- Simultaneous fit to M_{bc} and ΔE for $B^+ \to \rho^+\gamma$ and $B^- \to \rho^-\gamma$
- Asymmetries in other background sources
  - Fixed to zero at nominal point
  - Included in systematic error
- B → **D**π control sample used for detector bias

$$A(B^+ \to \rho^+\gamma) = \frac{N(B^- \to \rho^-\gamma) - N(B^+ \to \rho^+\gamma)}{N(B^- \to \rho^-\gamma) + N(B^+ \to \rho^+\gamma)}$$

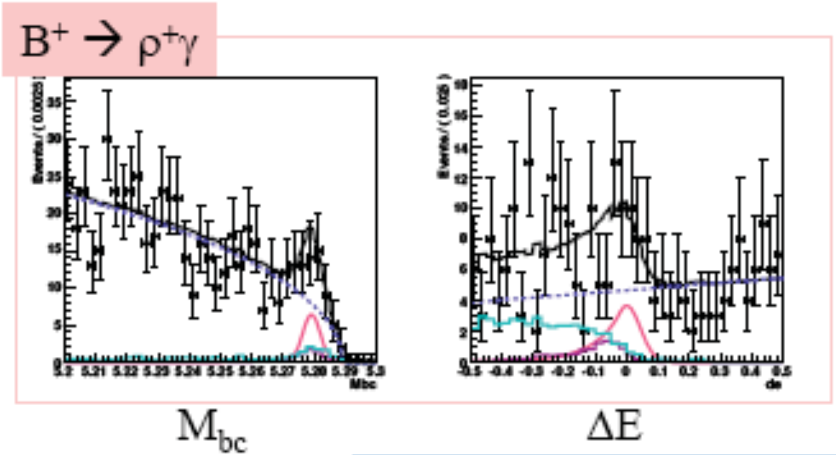
tCPV in B → $K_S\,\rho^0\,\gamma$

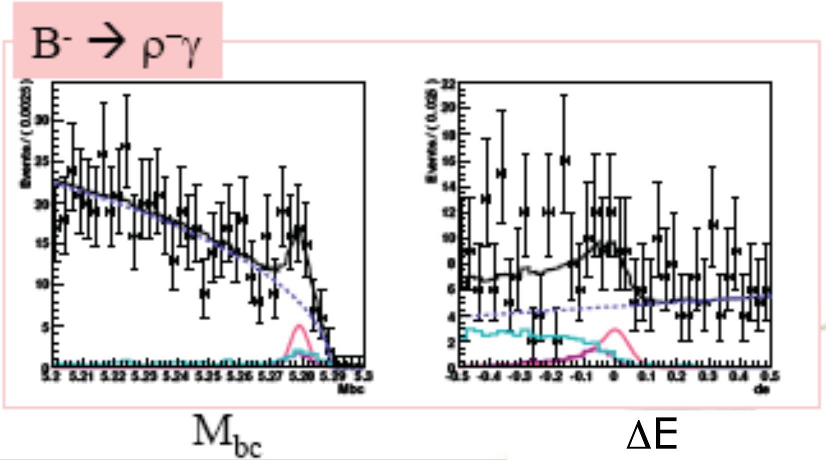
Belle PRL 100, 021602 (2008) 657M BB



$$S_{\rho^0\gamma} = -0.83 \pm 0.65(stat) \pm 0.18(sys)$$

$$A_{\rho^0\gamma} = -0.44 \pm 0.49(stat) \pm 0.14(sys)$$





$$A(B^+ \rightarrow \rho^+\gamma) = -0.11 \pm 0.32(stat) \pm 0.09(sys)$$

New Physics Searches -

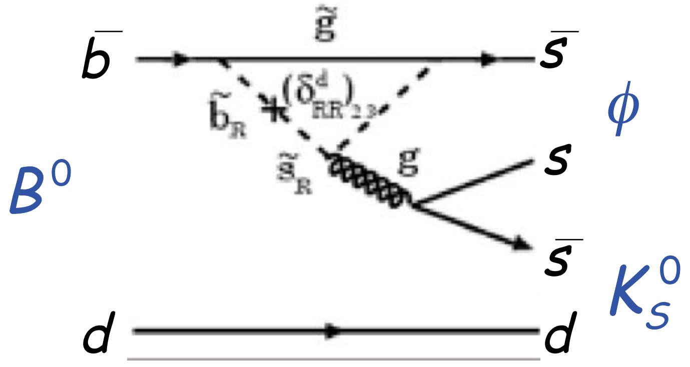
Time Dependent CP Violation in b → s

SUSY may enter b→s

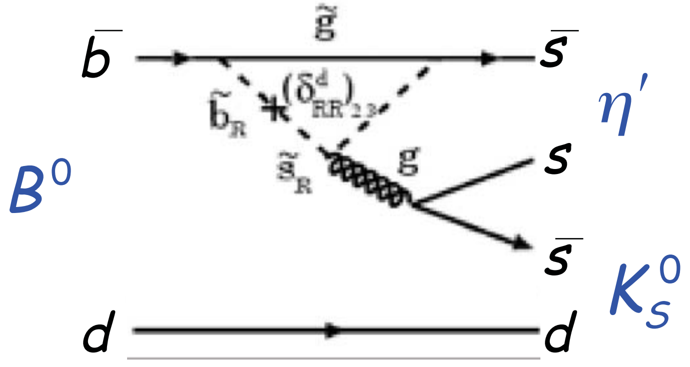
SUSY

- With enough data an effect can be seen:

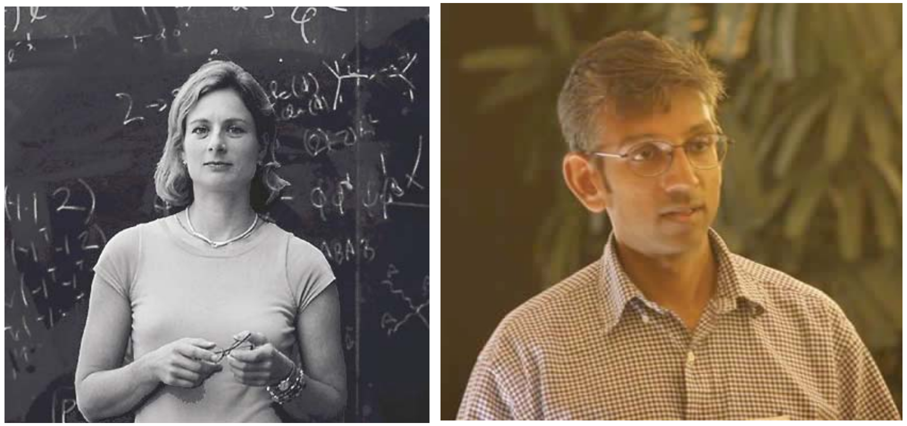
O(1) processes allowed even if SUSY scale is above 2TeV



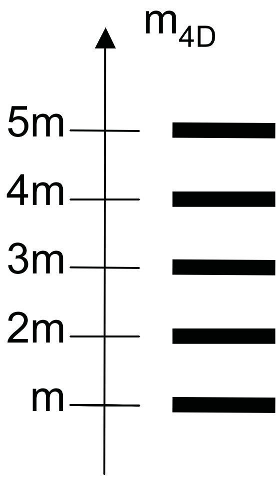
Many new phases are possible in SUSY



Models with Extra Dimensions



(By L. Randall and R. Sundrum)



New Kaluza-Klein (K.K) particles are associated with the extra dimension ("Tower of states")

Some may induce new phases and flavor-changing neutral currents

e.g. K.Agashe, G. Perez, A. Soni, PRD 71, 016002 (2005)

	$S_{B_s \to \psi\phi}$	$S_{B_d \to \phi K_s}$	$Br[b \to s l^+ l^-]$	$S_{B_{d,s} \to K^*, \phi\gamma}$	$S_{B_{d,s} \to \rho, K^*\gamma}$
RS1	$O(1)$	$\sin 2\beta \pm O(.2)$	$Br^{\rm SM}[1+O(1)]$	$O(1)$	$O(1)$
SM	λ_c^2	$\sin 2\beta$	$Br^{\rm SM}$	$\frac{m_s}{m_b}\left(\sin 2\beta, \lambda_c^2\right)$	$\frac{m_d}{m_b}\left(\lambda_c^2, \sin 2\beta\right)$

+CPV in D decay

Constant ε_K?

Model: K.K. Gluon near 3 TeV

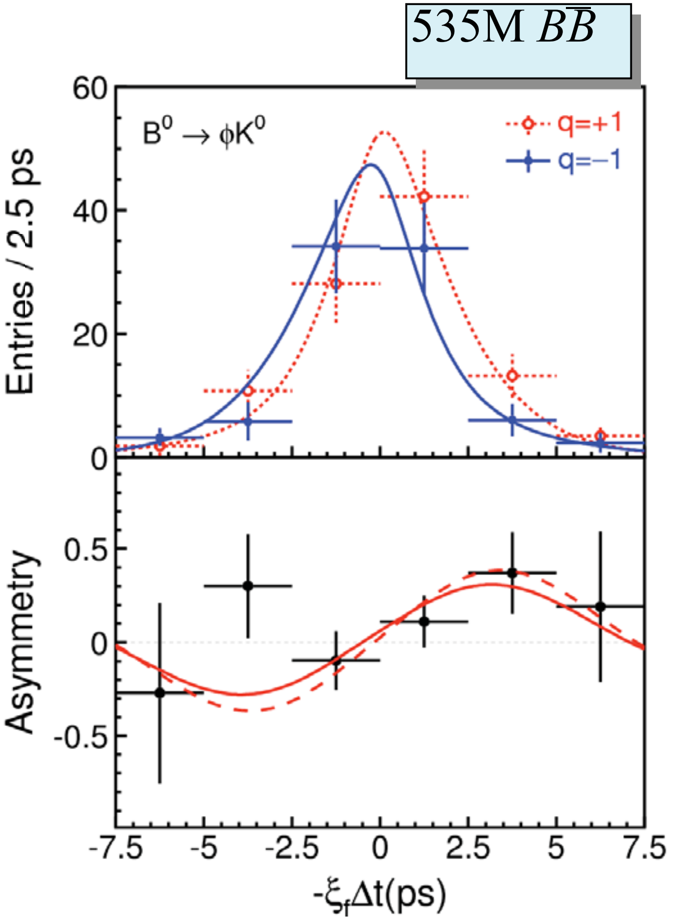
hep-ex/0608039,
PRL 98, 031802(2007)

Belle: tCPV in $B^0 \to \phi K^0$

"$\sin 2\phi_1$" = +0.50 ± 0.21(stat) ± 0.06(syst)

- Consistent with the SM (~1σ lower)
- Consistent with Belle 2005

(Belle2005:
"$\sin 2\phi_1$" = +0.44±0.27±0.05)



Δt distributions and asymmetry

—— unbinned fit
- - - SM

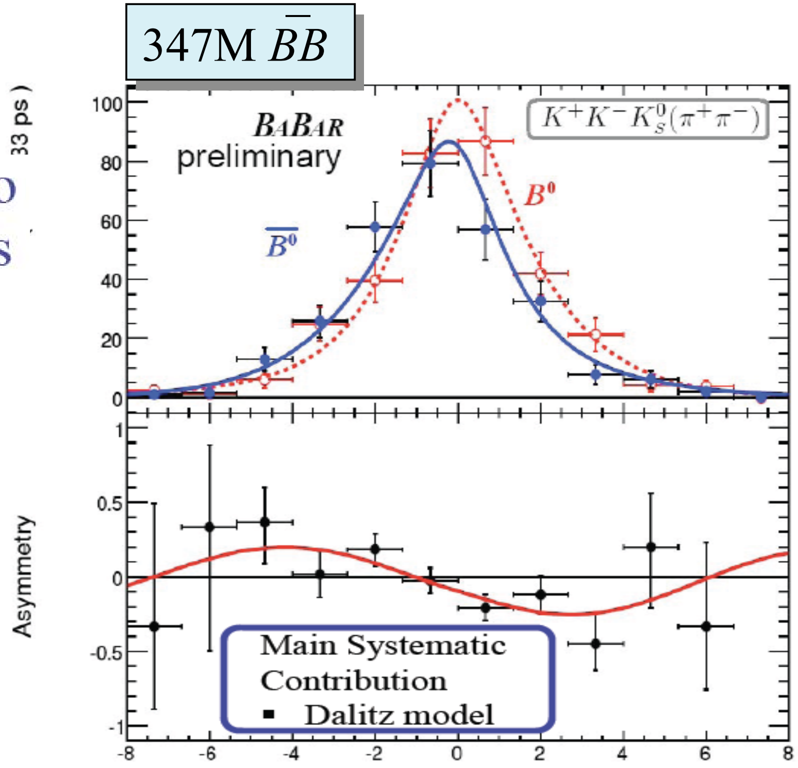
[hep-ex/0607112]

BaBar: ϕK^0 using $B^0 \to K^+K^-K^0$

Fit to low mass K^+K^- region (<1.1 GeV) to extract ϕK^0 and $f_0(980)K^0$ CPV parameters

$\mathcal{A}_{CP}(\phi K^0)$	$-0.18 \pm 0.20 \pm 0.10$
$\beta_{\text{eff}}(\phi K^0)$	$0.06 \pm 0.16 \pm 0.05$

β measurement (not $\sin 2\beta$)



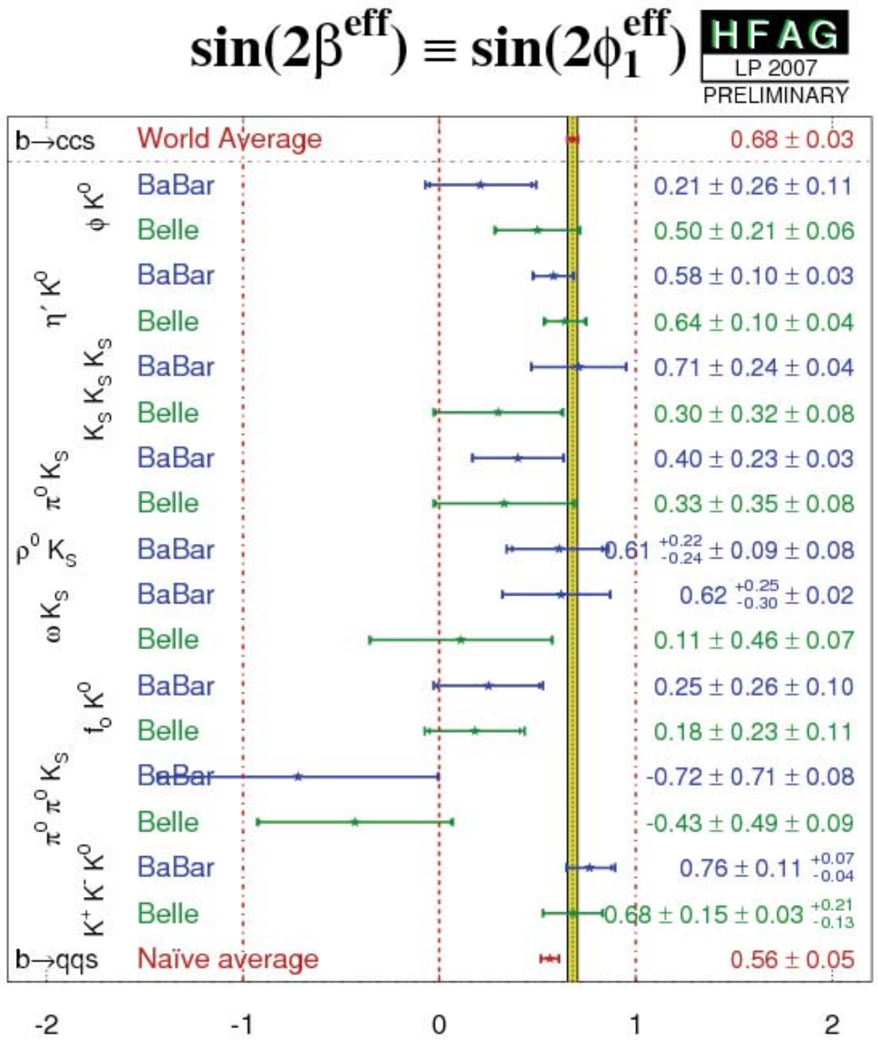
Main Systematic Contribution

- ▪ Dalitz model

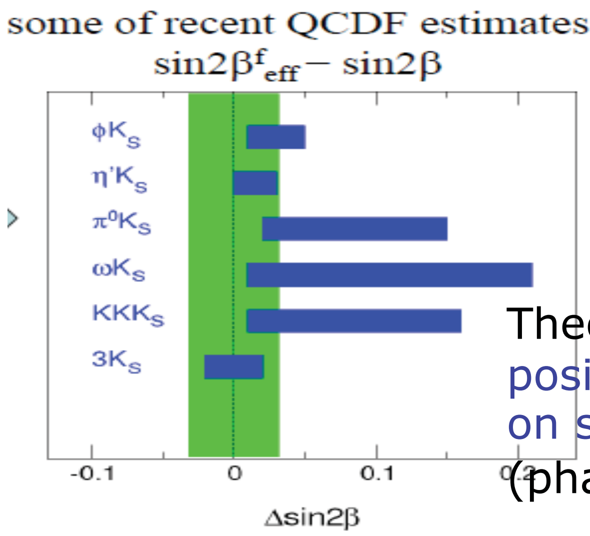
ϕK^0: $\sin 2\beta_{\text{eff}} = +0.12 \pm 0.31(\text{stat}) \pm 0.10$ (syst)

a.k.a. $\sin(2\phi_1)$

$\phi_1(\beta)$ from b → s Penguins
Hints Already There?



Smaller than $b\to c\bar{c}s$
in 7 of 9 modes

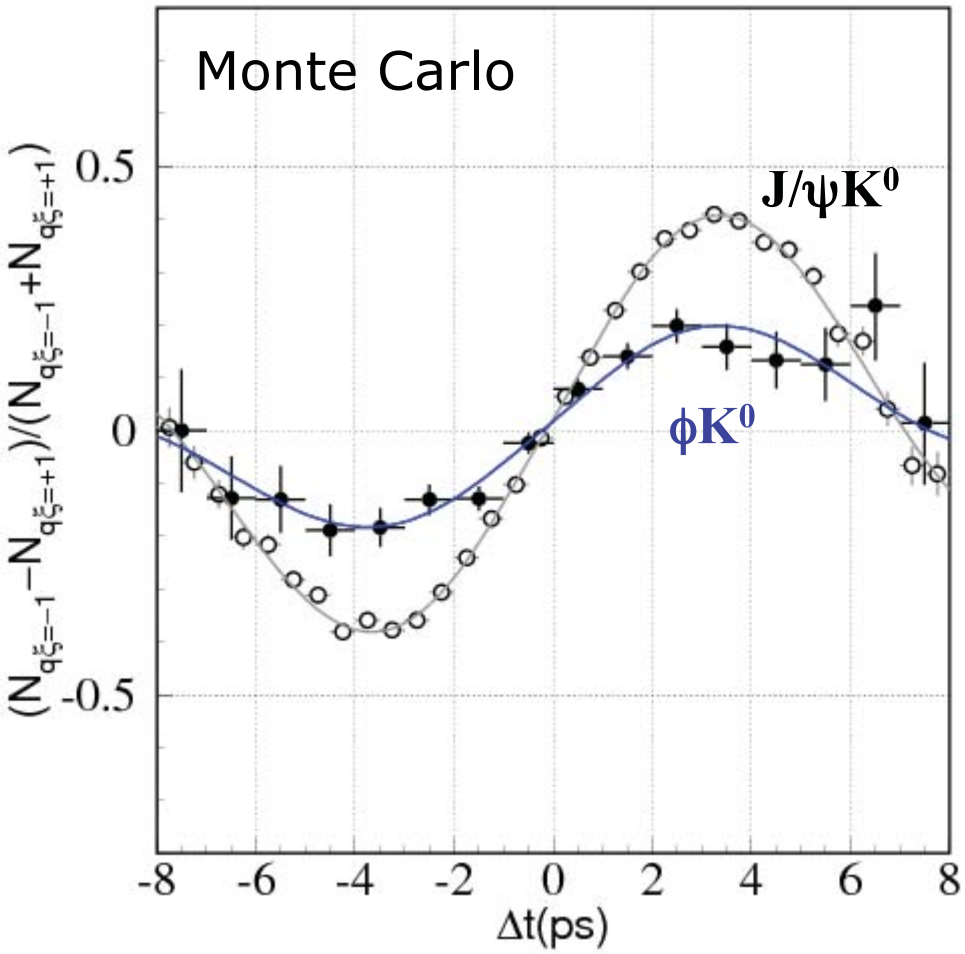


Theory predicts
positive shifts
on $\sin2\beta_{\mathrm{eff}}$
(phase in V_{ts})

An average of all b → s modes
$\sin2\phi_1^{\mathrm{eff}} = 0.56 \pm 0.05$
2.2 σ deviation between penguin
and tree (CL=3%)

More statistics needed in each studied mode!

Extraction: B → ϕK^0 at 50 ab^{-1} with present WA values



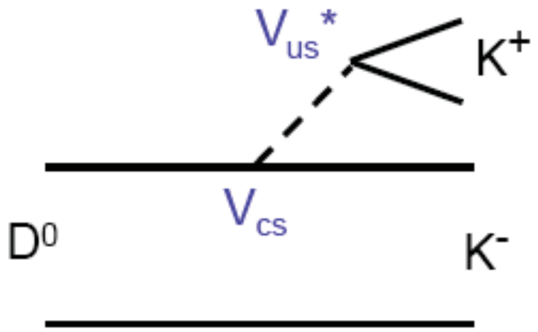
This would establish the existence of a **New Physics phase**

Compelling measurement in a clean mode

New Physics Searches -

D^0 - $\overline{D}^0$ mixing

CPV in the Case of D⁰ Mesons



D^0 consists of first two generation quarks

- CKM elements ≈ Real

- Using CKM Unitarity gives:

$$\arg\left(\frac{\langle \bar f|\bar D^0\rangle}{\langle f|D^0\rangle}\right) \approx \Im \frac{V_{cb}^* V_{ub}}{V_{cs}V_{us}^*} \sim \mathcal{O}(10^{-3})$$

This is below current experimental sensitivity: CPV would signal New Physics

Measurements of decays into CP eigenstates
$D^0 \rightarrow K^+K^- / \pi^+\pi^-$

Decay into a CP even final state, if no CPV:
$CP|D_1\rangle = |D_1\rangle$, $\tau = 1/\Gamma_1$

$K^-\pi^+$ is a mixture of CP states, $\tau = f(1/\Gamma_1, 1/\Gamma_2)$

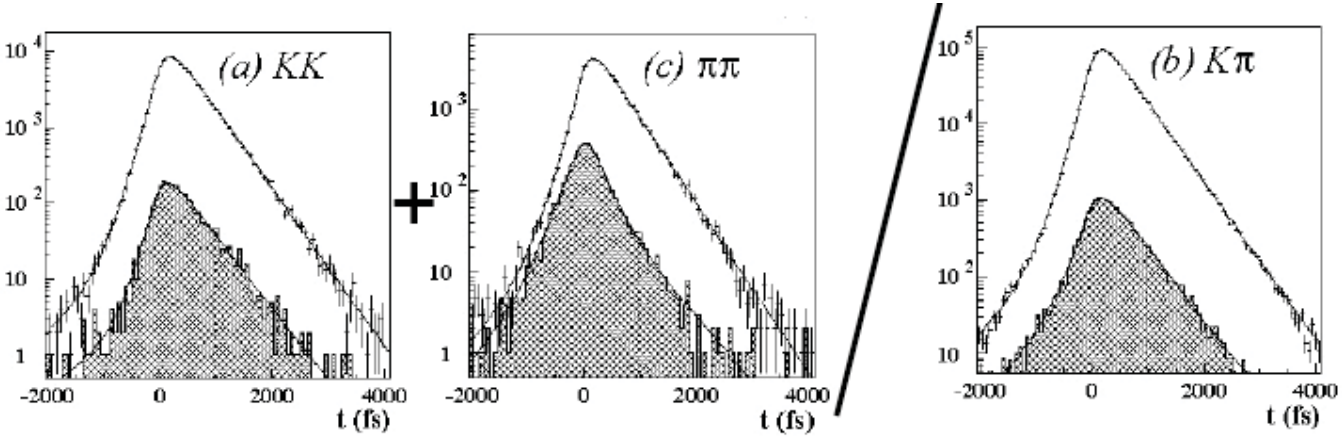
Bergman et al.
PLB 486, 418 (2000)

$$y_{CP} \equiv \frac{\tau(K^-\pi^+)}{\tau(K^-K^+)} - 1 \approx$$

$$y\cos\varphi - \frac{A_M}{2} x\sin\varphi \underset{no\,CPV}{=} y$$

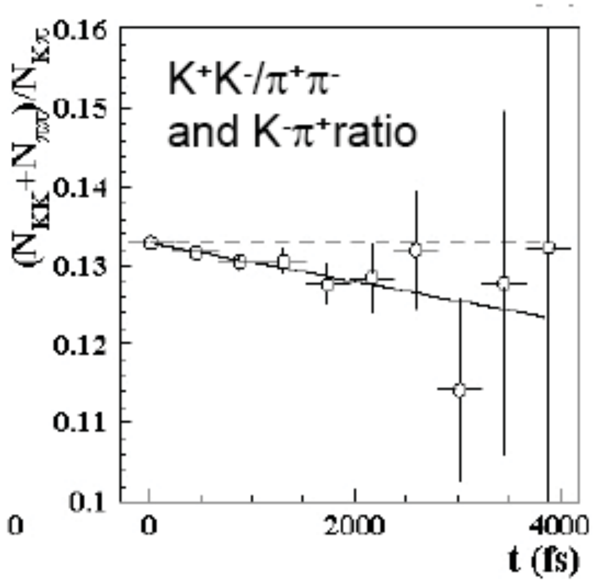
Measurements of D^0 decays at a B Factory

Decays to CP Eigenstates, **Belle PRL 98, 211803 (2007)**



y_{CP}=(1.31±0.32 ±0.25)%

(3.2σ error)



Evidence for D^0 Mixing, regardless of eventual CPV

Confirmation by **Babar, arXiv:0712.2249**

y_{CP} is at present the most precisely measured parameter, SM predictions on x,y very uncertain

CPV Asymmetries

Time dependent asymmetries:

A_Γ=(0.01±0.30 ±0.15)%
Belle, PRL98 211803 (2007)

A_Γ=(0.26±0.36 ±0.08)%
Babar, arXiv:0712.2249

Time integrated asymmetries:
($A_{CP}^{meas}=A_\varepsilon^\pi+A_{FB}+A_{FB}^f$)

A_{CP}^{KK}=(0.00±0.34 ±0.13)% ⇔
Babar, PRL 100 061803 (2007), 386/fb

A_{CP}^{KK}=(-0.43±0.30 ±0.11)%
Belle, preliminary, 540/fb

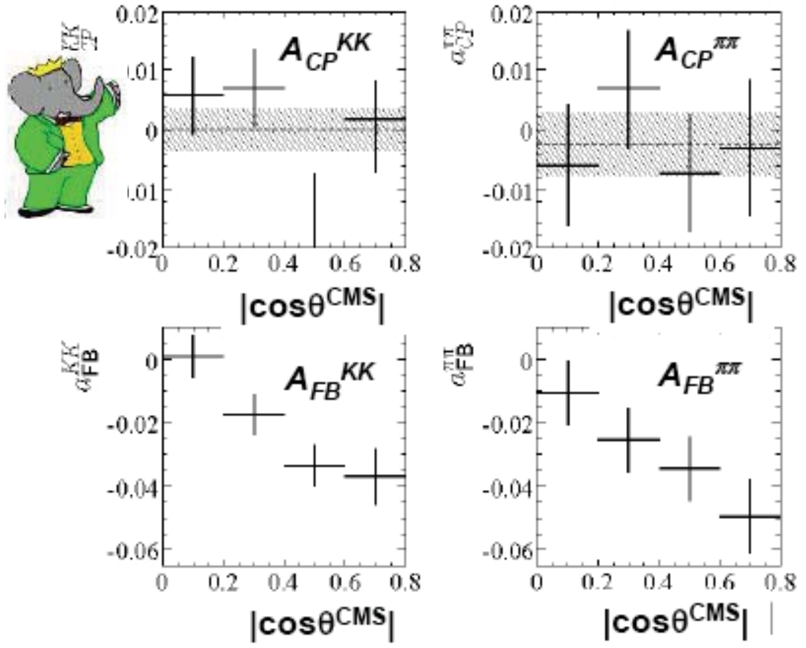
- **Insofar No CPV**
- **CPV in D^0 Mixing clear signal for NP ⇒ good motivation for Super B!**
- **Measured values put constraints on NP models**

$$A_{CP}^f = \frac{\Gamma(D^0\to f)-\Gamma(\overline{D}^0\to f)}{\Gamma(D^0\to f)+\Gamma(\overline{D}^0\to f)} =$$

$$= a_{dec}^f + a_{mix} + a_{int}$$ with a_{dec}<<1:

$$A_\Gamma = \frac{\tau(\overline{D}^0\to K^+K^-)-\tau(D^0\to K^+K^-)}{\tau(\overline{D}^0\to K^+K^-)+\tau(D^0\to K^+K^-)} \approx$$

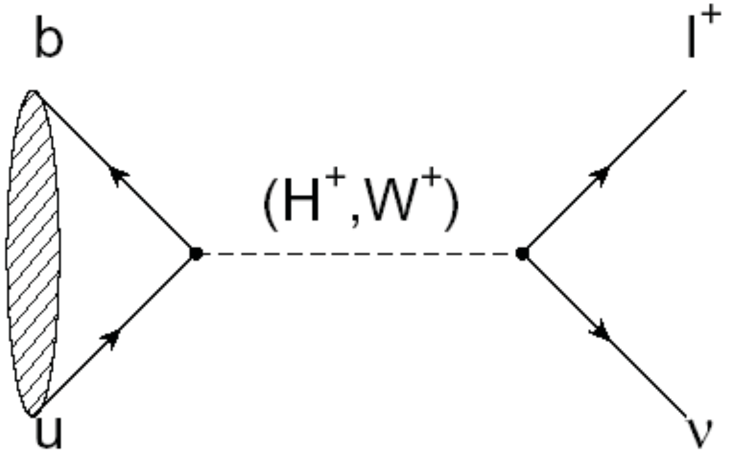
$$\approx \frac{A_M}{2} y\cos\varphi - x\sin\varphi \underbrace{=}_{no\ CPV} 0$$



New Physics Searches -

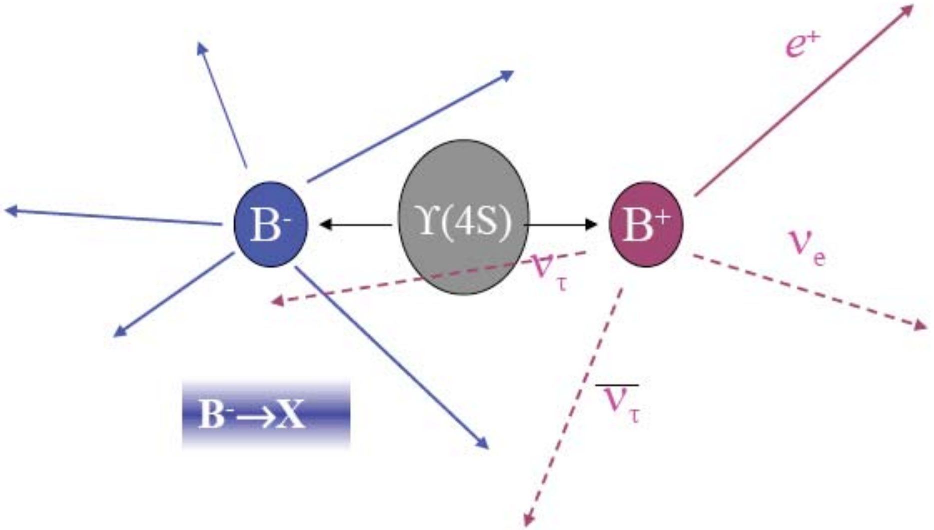
Decays with Large Missing Energy

Motivation for $B^+ \to \tau^+ \nu$



Sensitive to New Physics from charged Higgs if the B decay constant is known

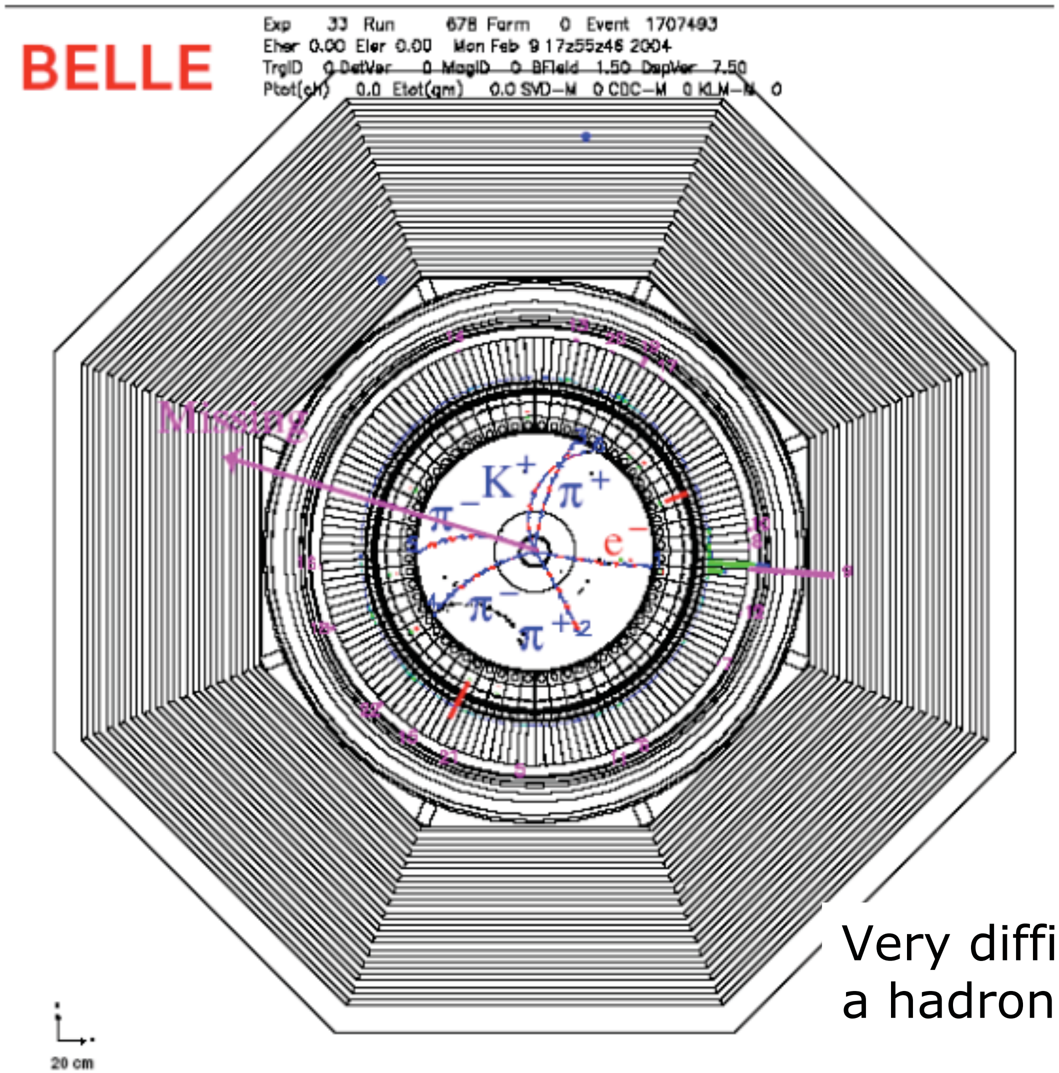
$$\mathcal{B}(B^+ \to \tau^+ \nu_\tau) = \frac{G_F^2 m_B}{8\pi} m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$



Experimentally very demanding:

- B decays to a single charged track + nothing else

$B \rightarrow \tau\, \nu$ Candidate

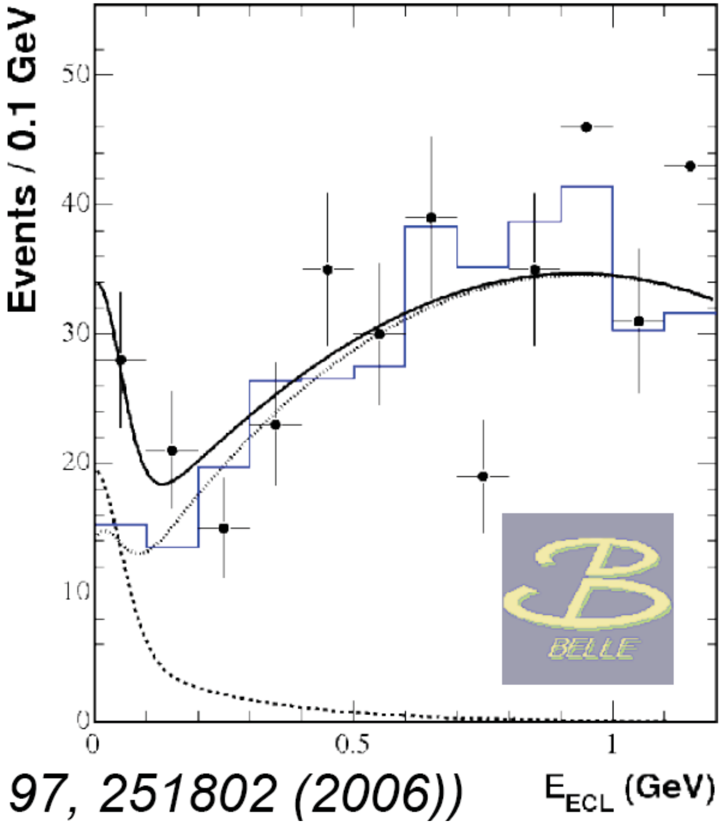


Tag: $B \rightarrow D^0\, \pi$

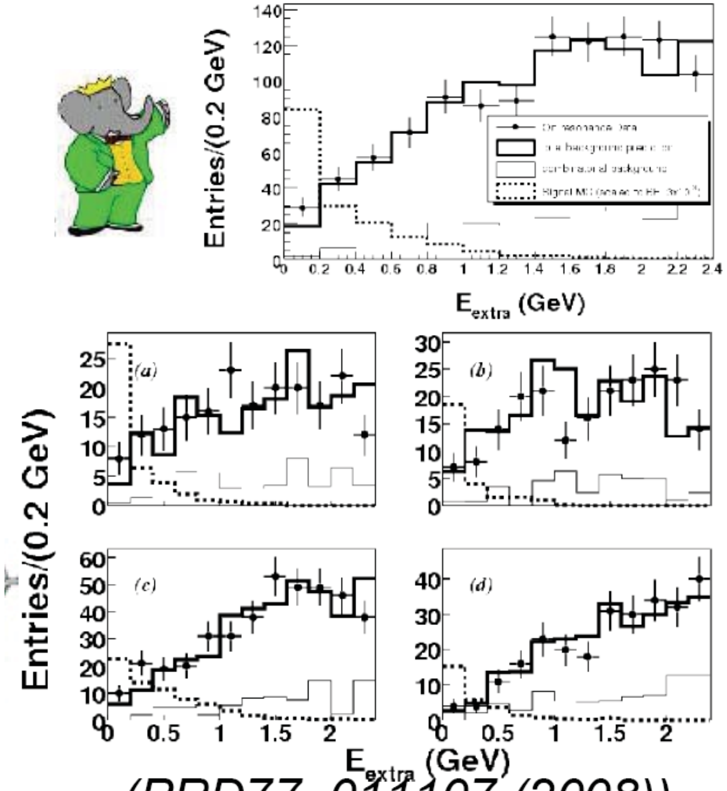
$D^0 \rightarrow K\, \pi\, \pi\, \pi$

Very difficult of impossible at a hadron collidr

Results from Belle and BaBar



(PRL 97, 251802 (2006))



(PRD77, 011107 (2008))

Br(B → τ ν)=(1.8±0.6 ± 0.5) x10^{-4}

f_b $|V_{ub}|$=(10.1±1.5 ± 1.2) x10^{-4} GeV

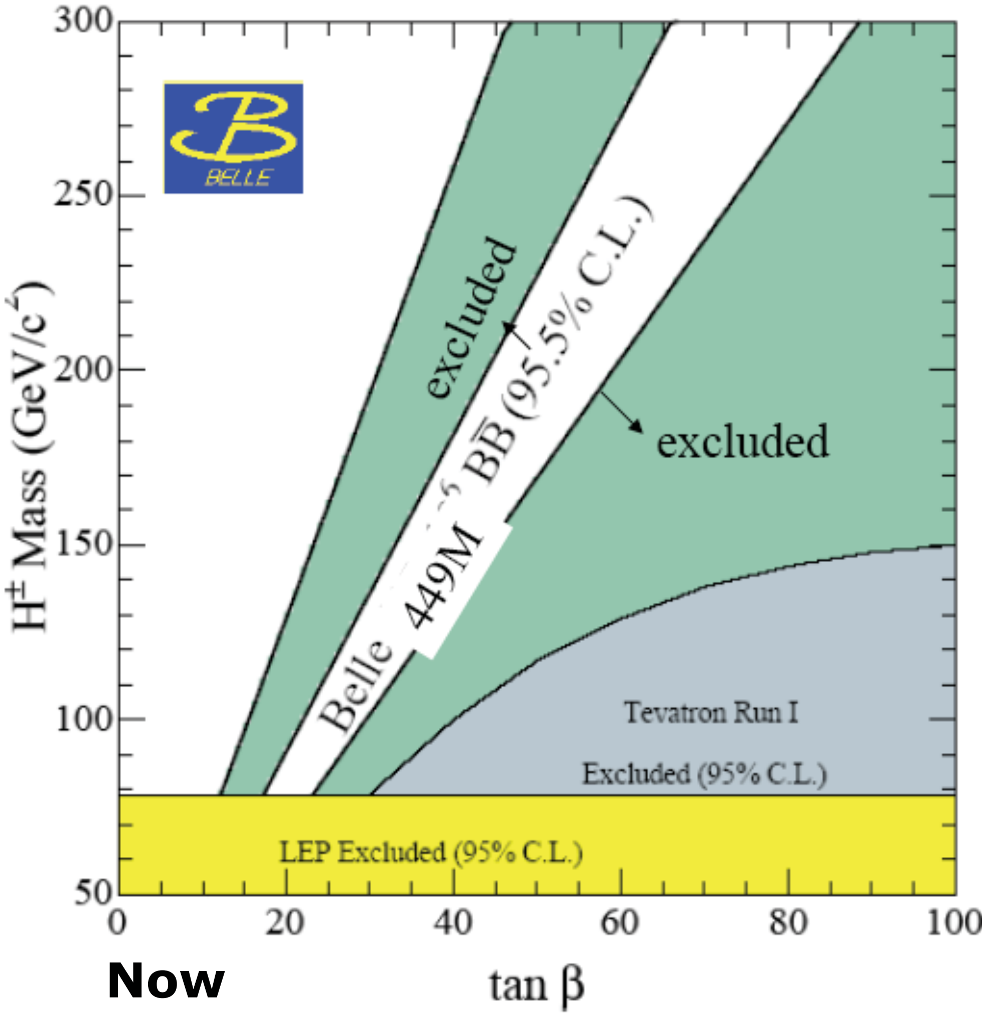
f_b=229 $^{+36+30}_{-31-34}$ MeV

Br(B → τ ν)=(1.2±0.4 ± 0.4) x 10^{-4}

f_b $|V_{ub}|$=(10.1±2.4 ± 1.4) x10^{-4} GeV

f_b=216±0.22 MeV

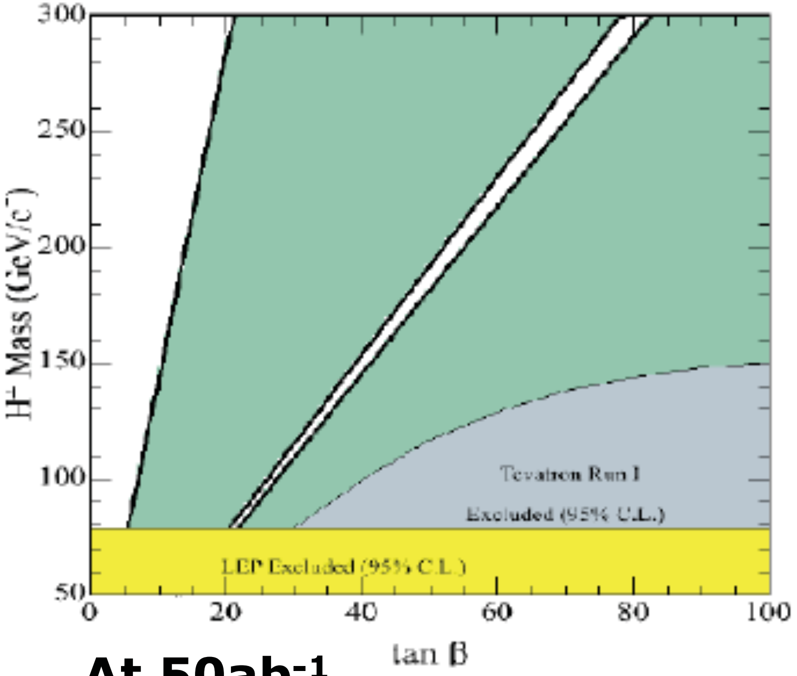
Constraints on Charged Higgs Mass



Now

$$r_H = (1 - \frac{m_B^2}{m_H^2} \tan^2 \beta)^2$$

r_H=1.13±0.51



At 50ab^{-1}

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

Several modes measured, consistent with SM predictions

Br (%)	Belle	BaBar	SM
$B^- \to D^0\tau^-\nu$		0.63±0.38±0.10±0.06	0.7
$B^- \to D^{*0}\tau^-\nu$		2.35±0.49±0.22±0.18	1.4
$B^0 \to D^+\tau^-\nu$		1.03±0.35±0.14±0.10	0.7
$B^0 \to D^{*+}\tau^-\nu$	2.02+0.4-0.37 ± 0.37	1.15±0.52±0.04±0.04	1.4

May 2007 **July 2007**

Observation of B→D* $\tau\nu$

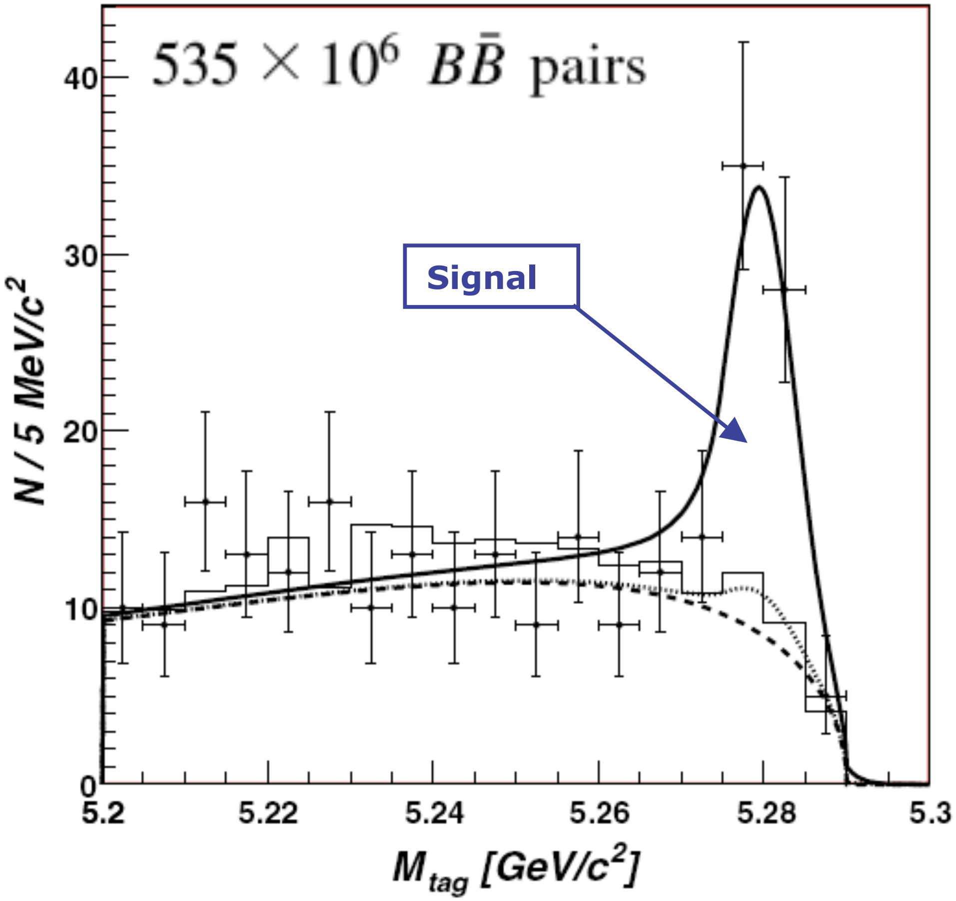
Phys.Rev.Lett.99:191807,2007

- First observation
- Signal of 60^{+12}_{-11}

with significance 5.2σ

- Consistent with SM predictions
- More theoretical work needed

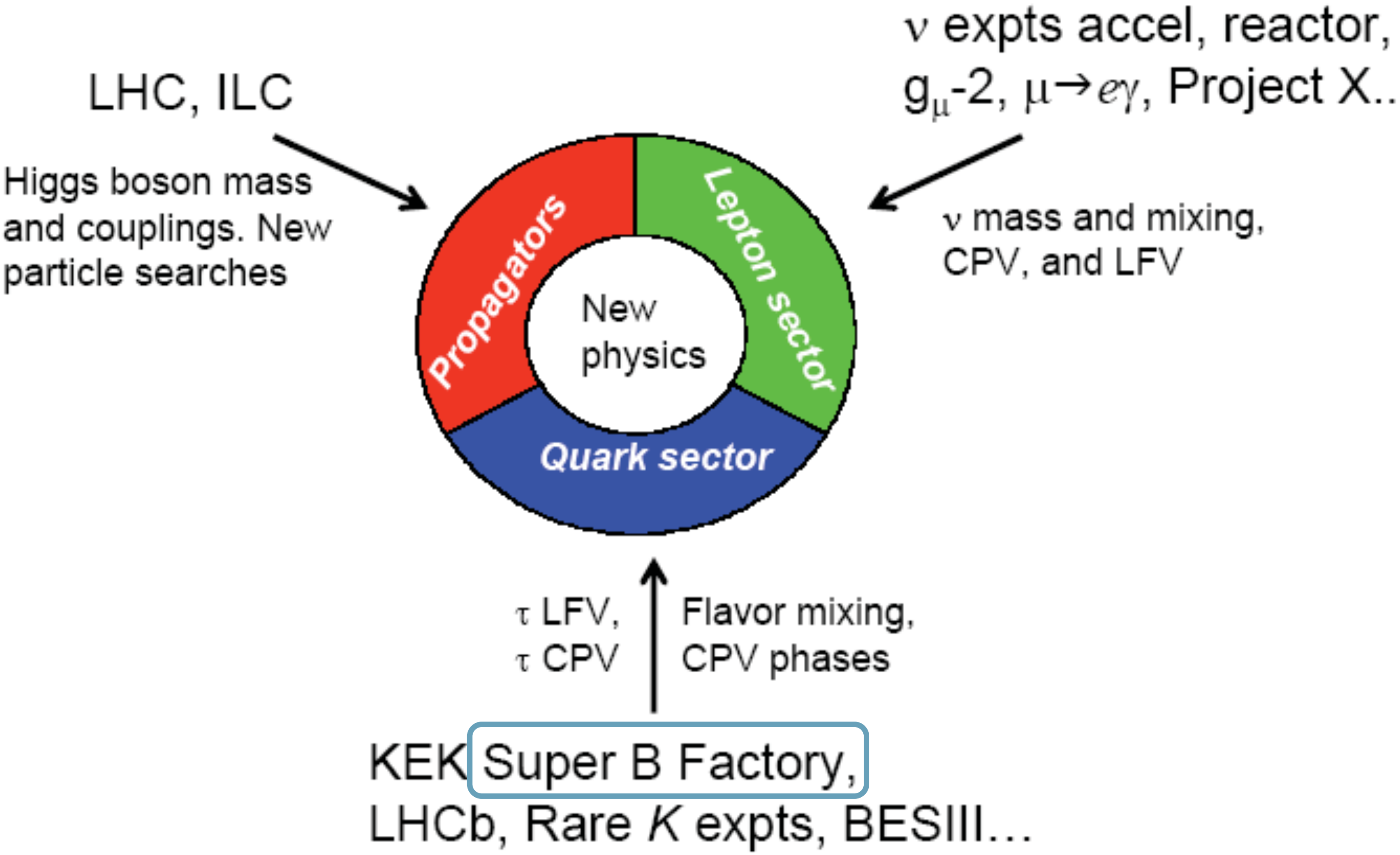
for beyond SM interpretation



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

What Lies Ahead -
New Physics Searches at Super B

Super B Factory -
A Part of the Unified Approach to Find New Physics



LHC, ILC

Higgs boson mass
and couplings. New
particle searches

ν expts accel, reactor,
g_μ-2, $\mu \rightarrow e\gamma$, Project X..

ν mass and mixing,
CPV, and LFV

Propagators

Lepton sector

Quark sector

New
physics

τ LFV,
τ CPV

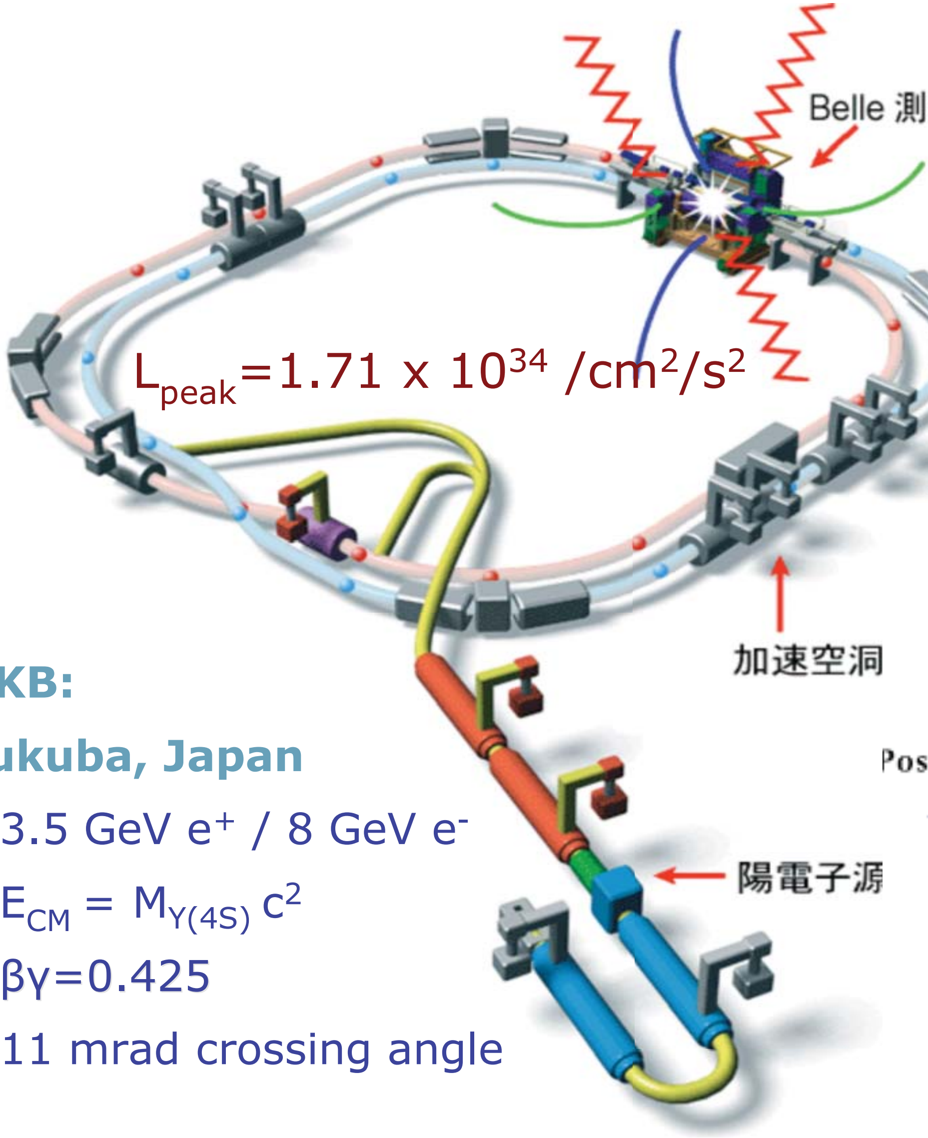
Flavor mixing,
CPV phases

KEK Super B Factory,
LHCb, Rare *K* expts, BESIII…

Detectors and Accelerators

Present & Future

Present B Factories - Accelerators



L_{peak}=1.71 x 10^{34} /cm^2/s^2

KEKB:

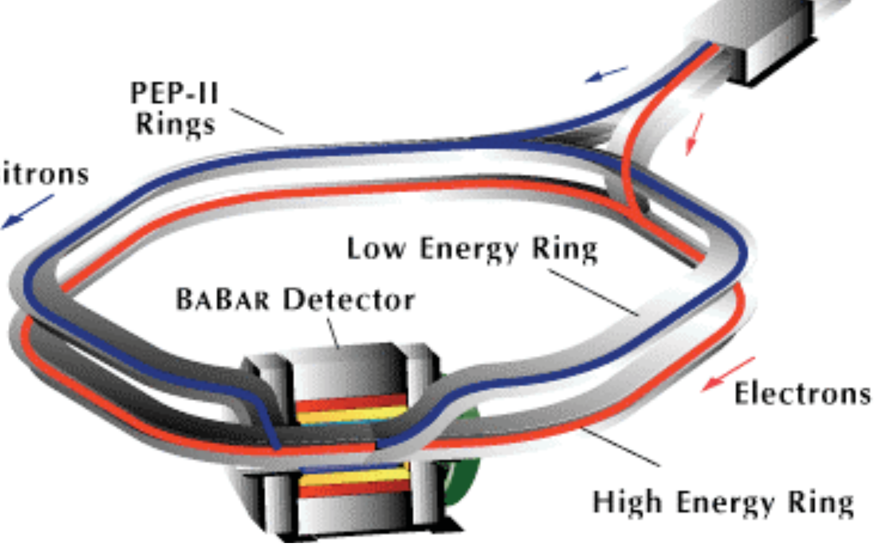
Tsukuba, Japan

- 3.5 GeV e^+ / 8 GeV e^-
- $E_{CM} = M_{Y(4S)}\ c^2$
- βγ=0.425
- 11 mrad crossing angle

PEP II: Stanford, USA

- 3.1 GeV e^+ / 9 GeV e^-
- $E_{CM} = M_{Y(4S)}\ c^2$
- βγ=0.56

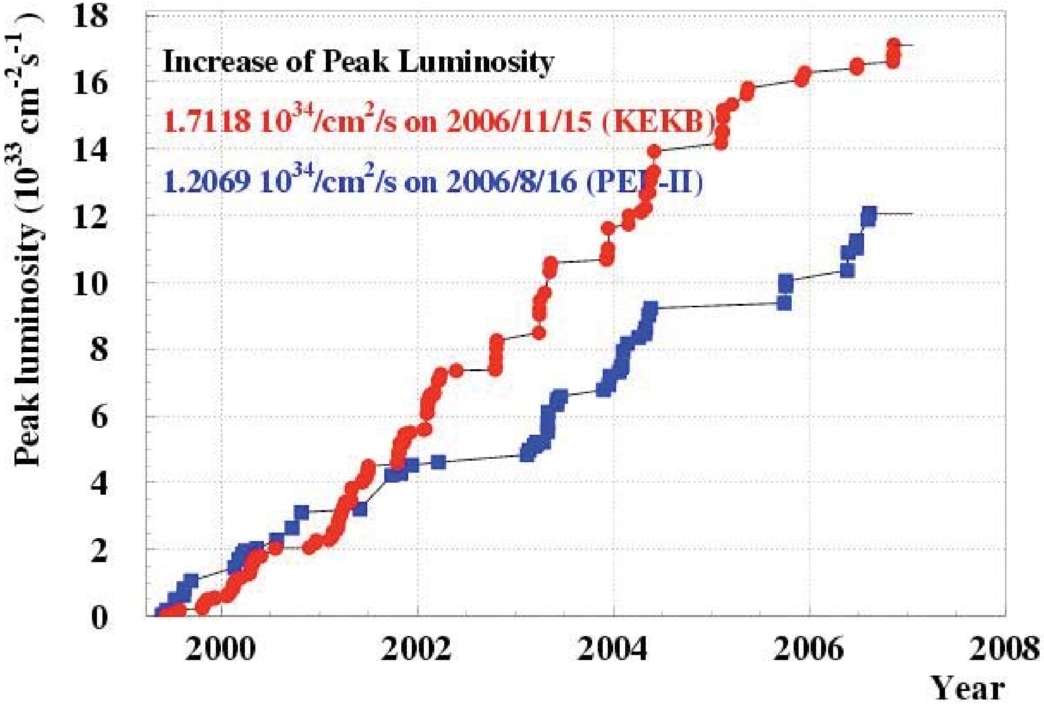
L_{peak}=1.21 x 10^{34} /cm^2/s^2

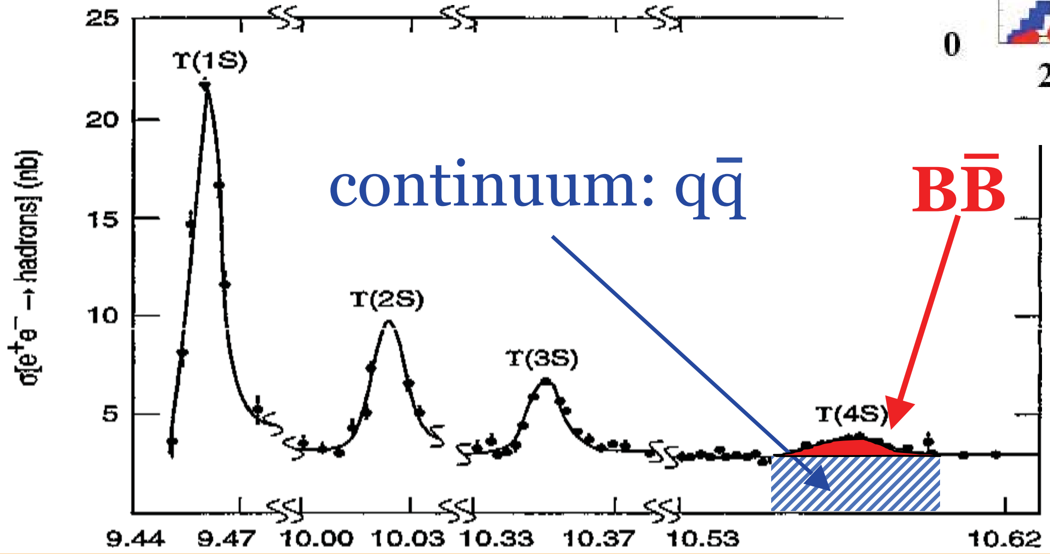


Accelerator Luminosity Trends

Both Colliders

- Operating at the Y(4S) resonance just above the b b-bar production threshold
- Exceeded design luminosity



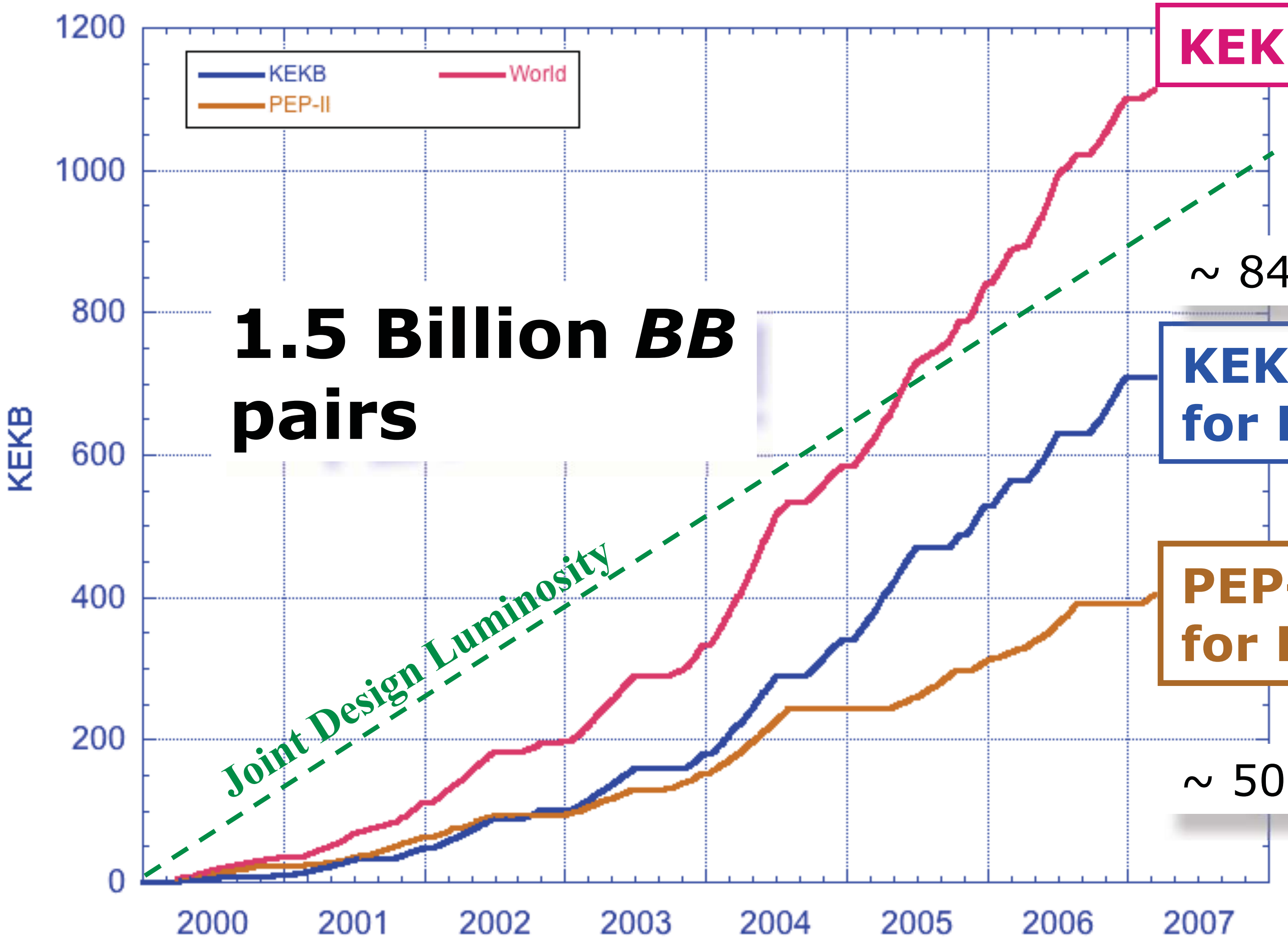


continuum: $q\bar{q}$

$B\bar{B}$

- Optimized operation for largest possible data sample (i.e. continuous injection)

Track Record of Present B Factories



1.5 Billion *BB* pairs

KEKB + PEP-II

~ 840/fb (June 10)

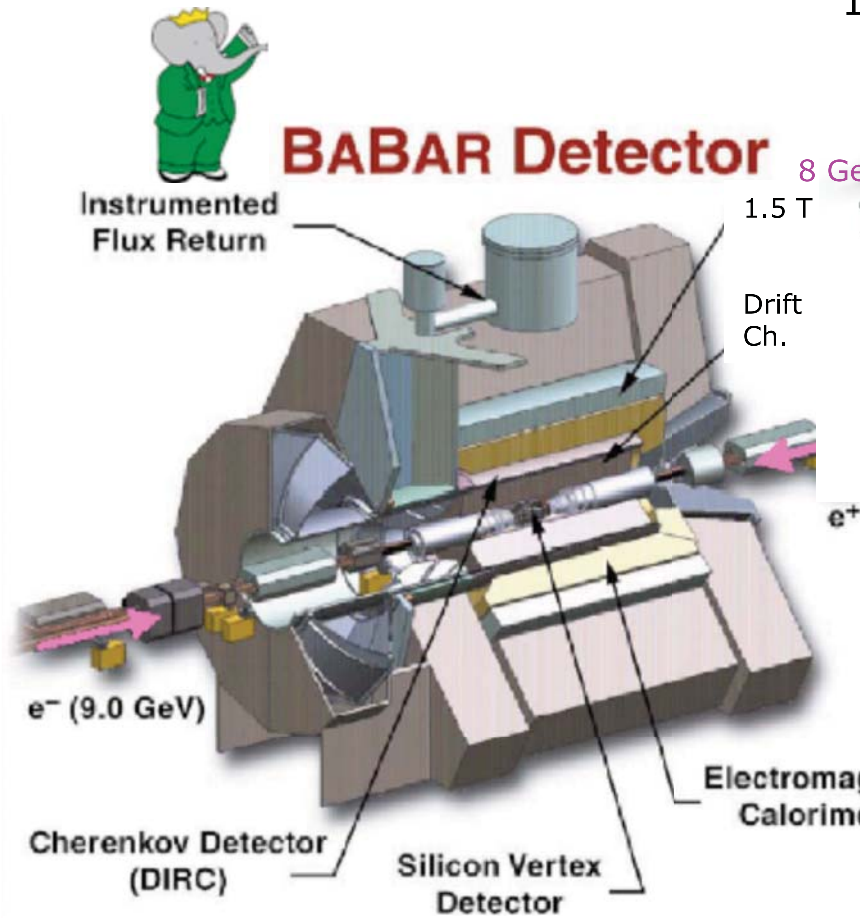
KEKB for Belle

PEP-II for BaBar

~ 506/fb (Feb 20)

Present B Factories - Detectors

- Similar design
- Cross-checking each other

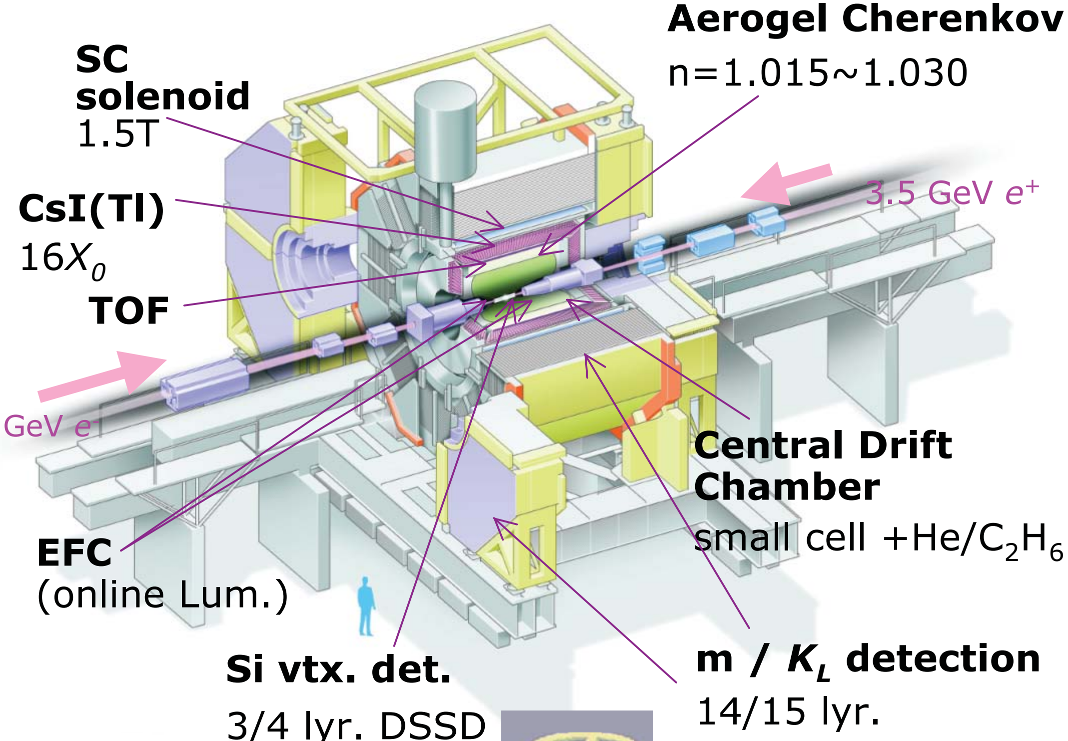


1.5 T

Drift Ch.

e⁺ (3.1 GeV)

Electromagnetic Calorimeter



SC solenoid
1.5T

CsI(Tl)
$16X_0$

TOF

8 GeV e^-

3.5 GeV e^+

Aerogel Cherenkov
n=1.015~1.030

Central Drift Chamber
small cell +He/C_2H_6

EFC
(online Lum.)

Si vtx. det.
3/4 lyr. DSSD

m / K_L detection
14/15 lyr.
RPC+Fe

BELLE Detector

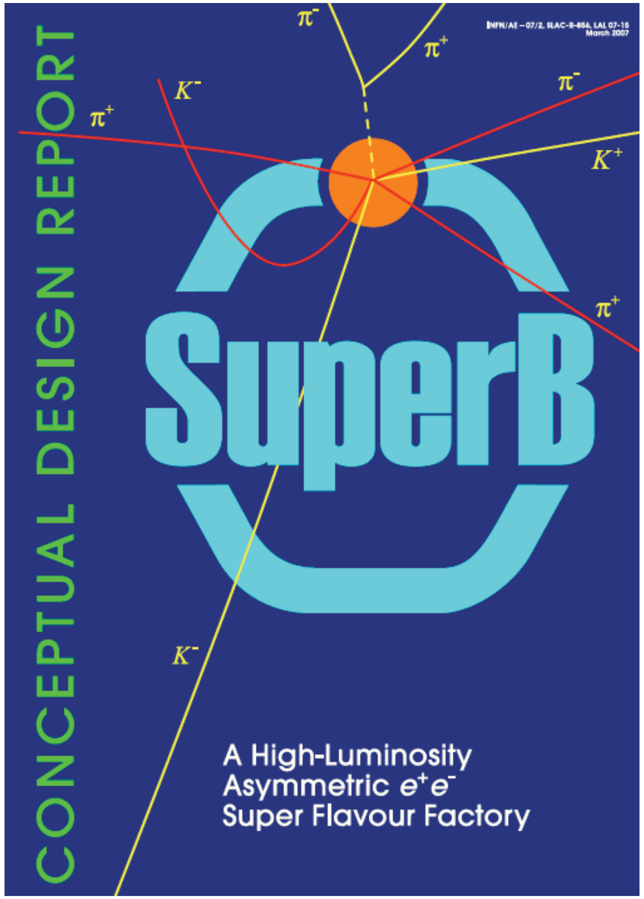
Both very successful!

Proposed “Super B Factories”

Upgrade of the existing KEKB/Belle

Super
KEKB
Quest for CPV
kekb.jp

New SuperB Factory in Rome



INFN/AE – 07/2, SLAC-R-856, LAL 07-15
March 2007

CONCEPTUAL DESIGN REPORT

SuperB

A High-Luminosity
Asymmetric e^+e^-
Super Flavour Factory

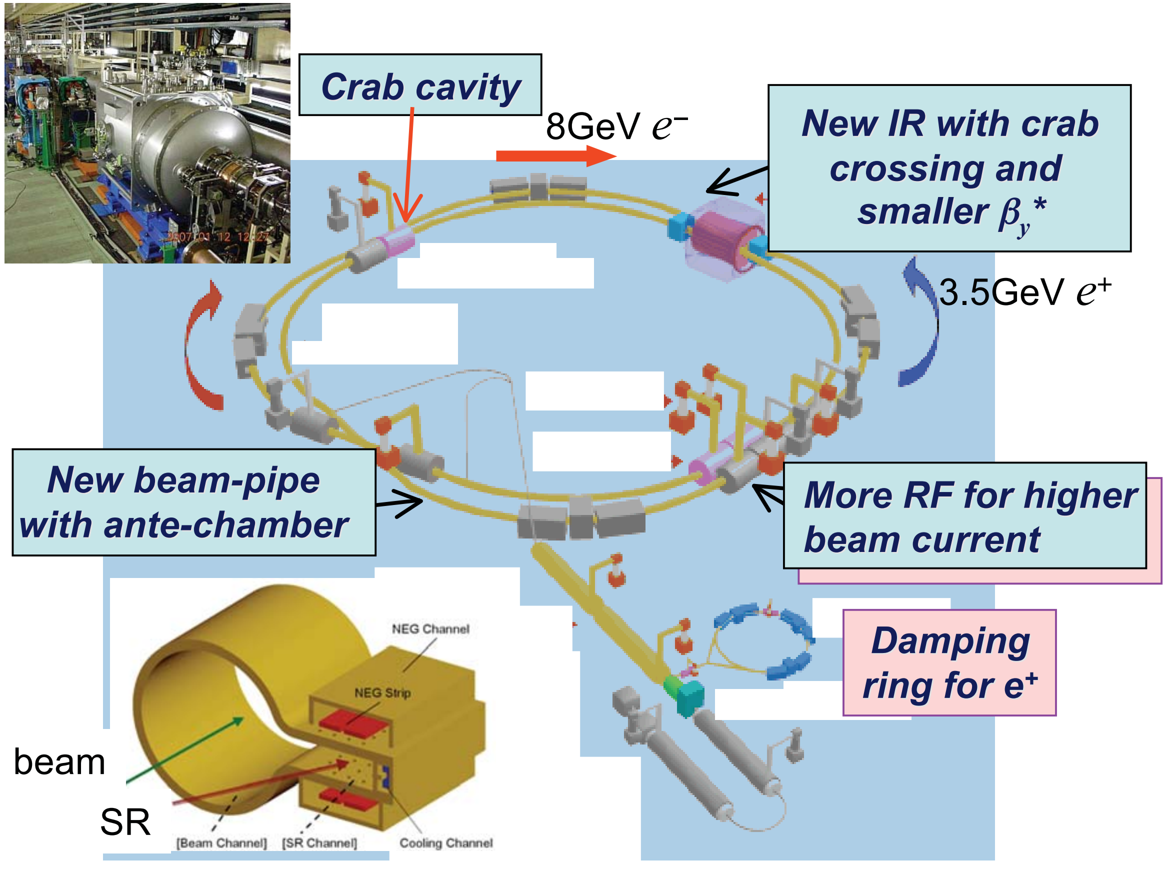
The "Super B"

- Asymmetric energy e^+e^- collider at $E_{CM}=m(\Upsilon(4S))$ will be realized by upgrading the existing KEKB collider

- Initial target:
10 × higher luminosity
$\cong 2 \times 10^{35}/\mathrm{cm}^2/\mathrm{sec}$
$\rightarrow 2\times10^{9}$ BB and $\tau^+\tau^-$/year

- Final goal:
$L=8 \times 10^{35}/\mathrm{cm}^2/\mathrm{sec}$
and **$\int L\, dt = 50\ \mathrm{ab}^{-1}$**

After 3 Year Shudown



Crab cavity

New IR with crab crossing and smaller β_y^*

New beam-pipe with ante-chamber

More RF for higher beam current

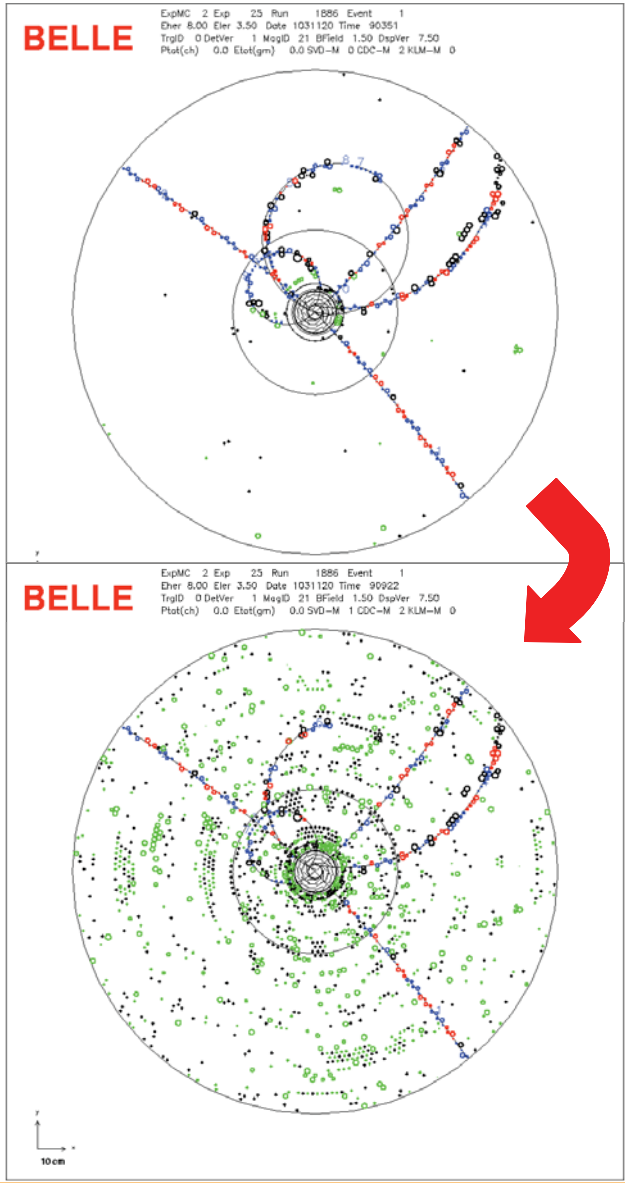
Damping ring for e^+

Many Super B components are being tested now

Features of Super Belle Detector

Needed for New Physics Searches

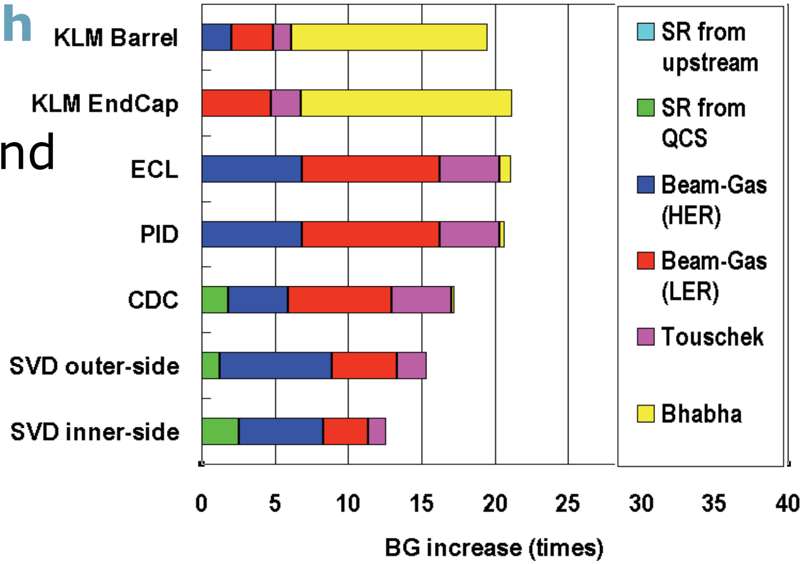
- Designed to discover new FCNC and new CPV
- In contrast to LHCb, superb neutral detection capabilities; i.e. $B \to K_S \pi^0 \gamma$ can be used to detect right-handed currents
- Capable of observing rare "missing energy modes" such as $B \to K \nu \nu$ with B tags



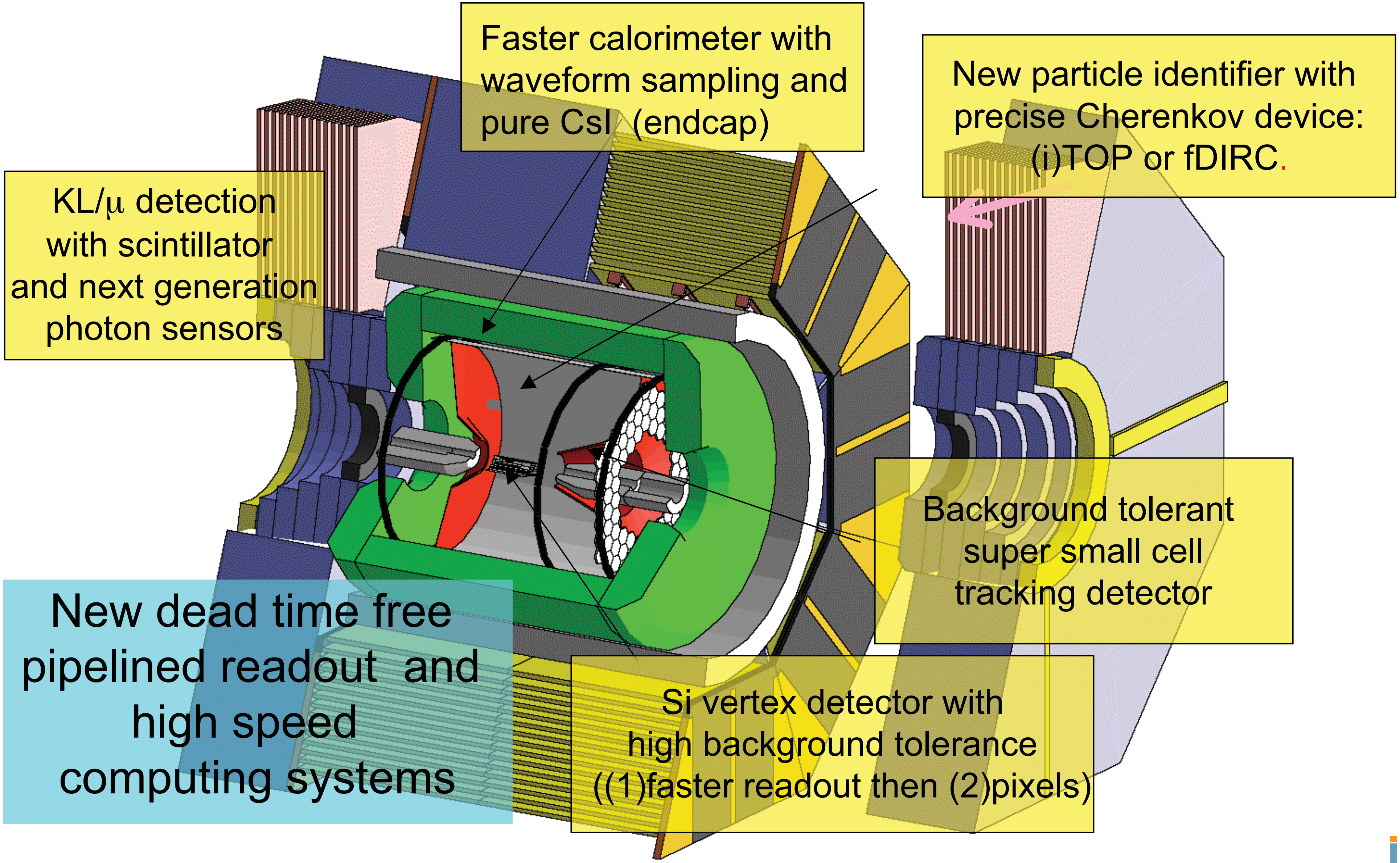
Must Deal With

- 10 x higher beam background
- 50 x higher event rates

(estimate based on Geant sim. and Belle/KEKB experience)



SuperBelle -
A Detector for Super B



Faster calorimeter with waveform sampling and pure CsI (endcap)

New particle identifier with precise Cherenkov device: (i)TOP or fDIRC.

KL/μ detection with scintillator and next generation photon sensors

Background tolerant super small cell tracking detector

New dead time free pipelined readout and high speed computing systems

Si vertex detector with high background tolerance ((1)faster readout then (2)pixels)

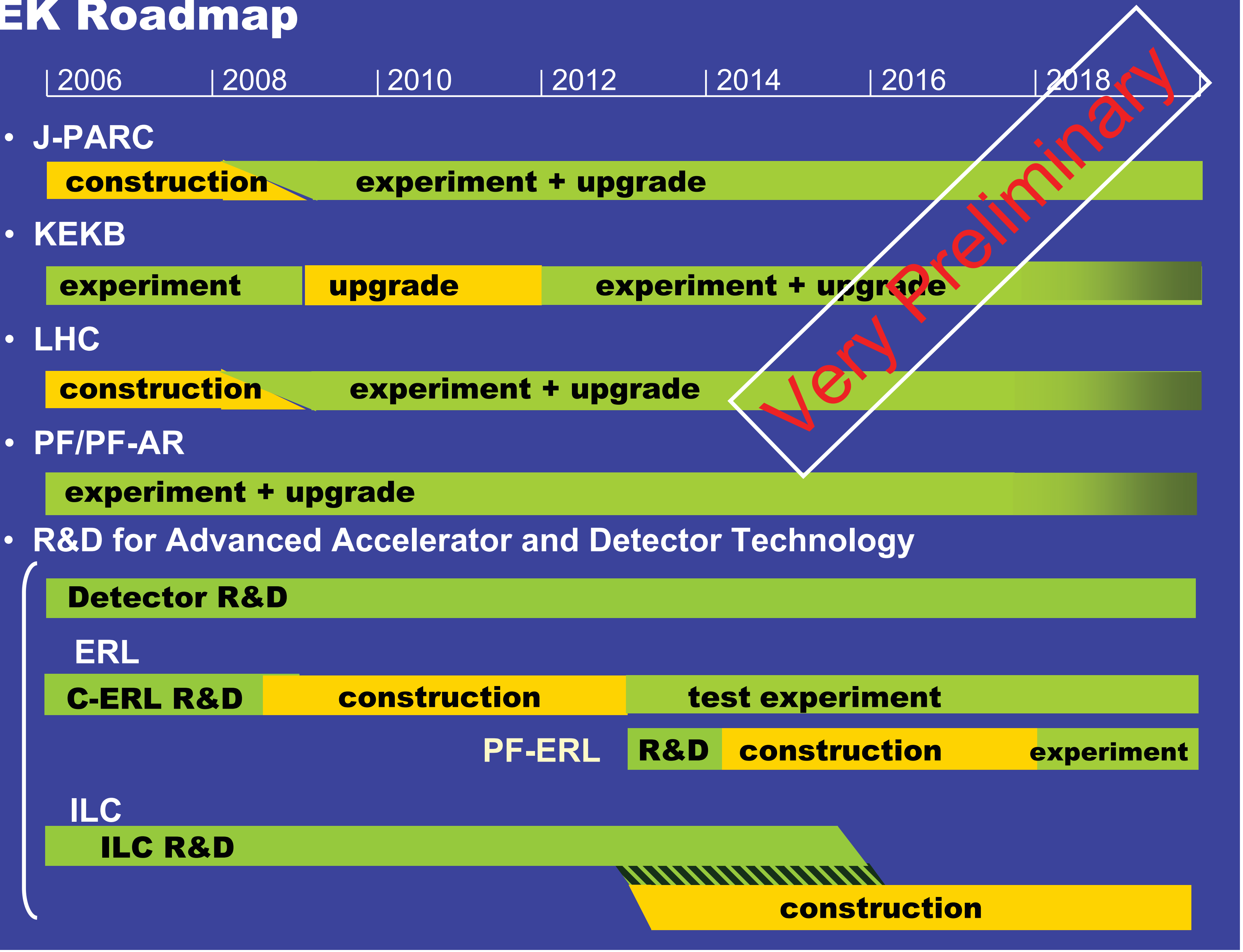
KEK's Super B Becoming Reality

- Official report released on January 4, 2008 by KEK director A. Suzuki and KEK management: KEKB's upgrade to 2x10^{35} /cm^2/sec in 3+x years is the central element in particle physics (although KEK funding is limited)

Favorably reviewed by the Roadmap Review Committee, March 9-10, 2008 (Young Kee Kim, John Ellis, Rolf Heuer, Andrew Hutton, Jon Rosner, H. Takeda and reviewers from other fields)

- Final goal is **L= 8 x 10^{35} /cm^2/sec** and an integrated luminosity of **50 ab^{-1}**
- Super Belle (and Super KEKB) is an **open international project** that covers the next two orders of magnitudes at the luminosity frontier
- An opportunity for a **new high impact international collaboration**

KEK Roadmap



Very Preliminary

2006 2008 2010 2012 2014 2016 2018

- J-PARC
  - construction
  - experiment + upgrade
- KEKB
  - experiment
  - upgrade
  - experiment + upgrade
- LHC
  - construction
  - experiment + upgrade
- PF/PF-AR
  - experiment + upgrade
- R&D for Advanced Accelerator and Detector Technology
  - Detector R&D
  - ERL
    - C-ERL R&D
    - construction
    - test experiment
    - PF-ERL
      - R&D
      - construction
      - experiment
  - ILC
    - ILC R&D
    - construction

Summary and Future Prospects

Summary and Future Prospects

- Big success of both B factories
  - Detailed studies of the SM CPV mechanism in the decays of B mesons
  - Unexpected SM Phenomenology Discovered
- Hints of NP
  - $B \rightarrow hh$ Branching Ratios and A_{CP}
  - Gluonic and radiative penguins
  - $\sin 2\phi_{1S}$ ($\sin 2\beta_S$)
  - D^0 mixing, etc...
- More data needed for further clarification
  - A Super B Factory proposed, KEK making important steps towards its realization
  - Eagerly expecting results from LHC