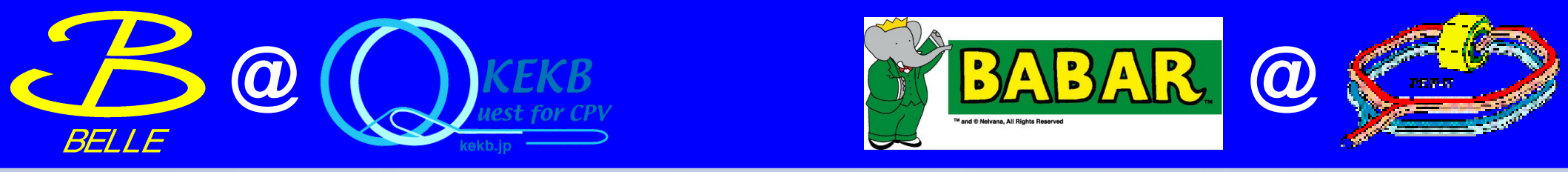

B-Factories: Overview of Recent Results

Marko Bračko

University of Maribor & J. Stefan Institute, Ljubljana, Slovenia

LHC Days 2006, Split, Croatia

2nd — 7th October 2006

B-Factories: Overview of Recent Results

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2nd — 7th October 2006

main Goals of B-Experiments

Step1

Discovery of CPV in B decay ← **2001 summer !**

Step2

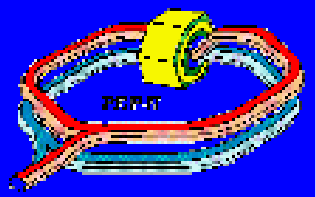
Precise test of KM(CPV) and SM ← Now

Step3

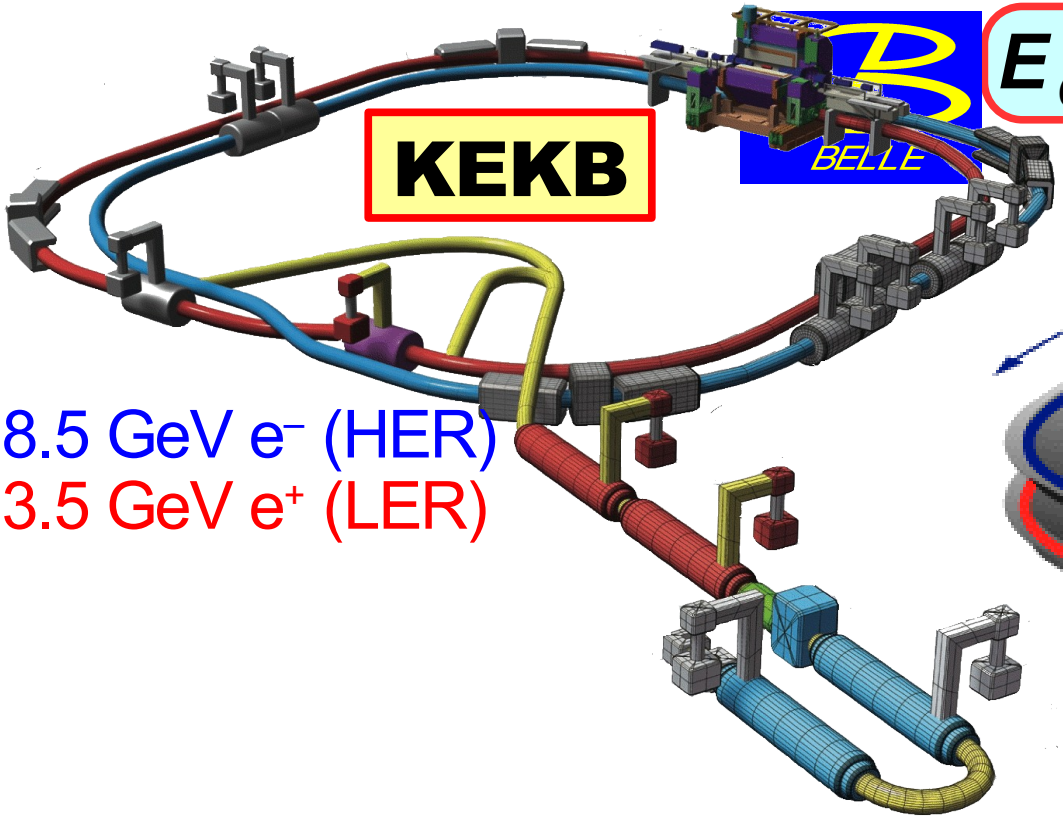
Search/Evidence for New Physics

B decays → QCD/Lattice, New Resonances
Also, excellent τ/charm factory

Asymmetric-Energy e^+e^- Colliders

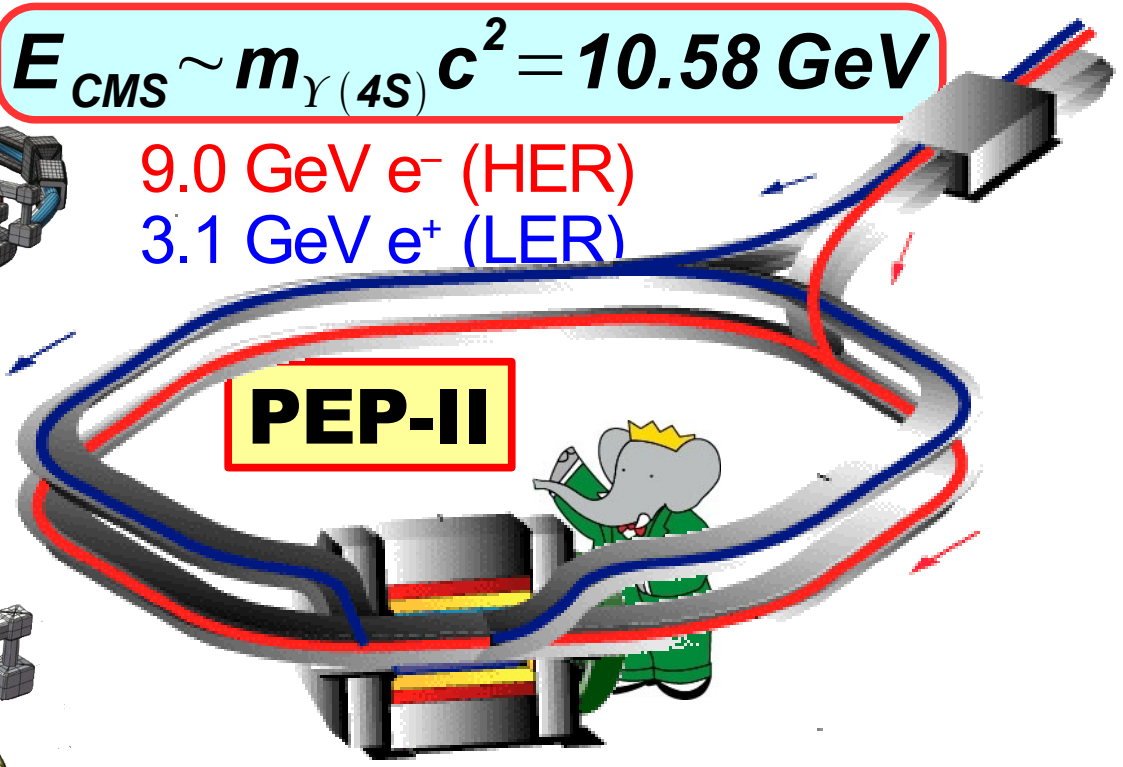


$$E_{CMS} \sim m_{\Upsilon(4S)} c^2 = 10.58\ GeV$$

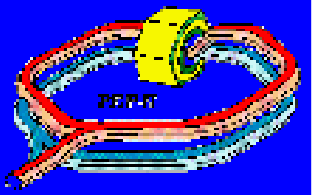


8.5 GeV e^- (HER)
3.5 GeV e^+ (LER)

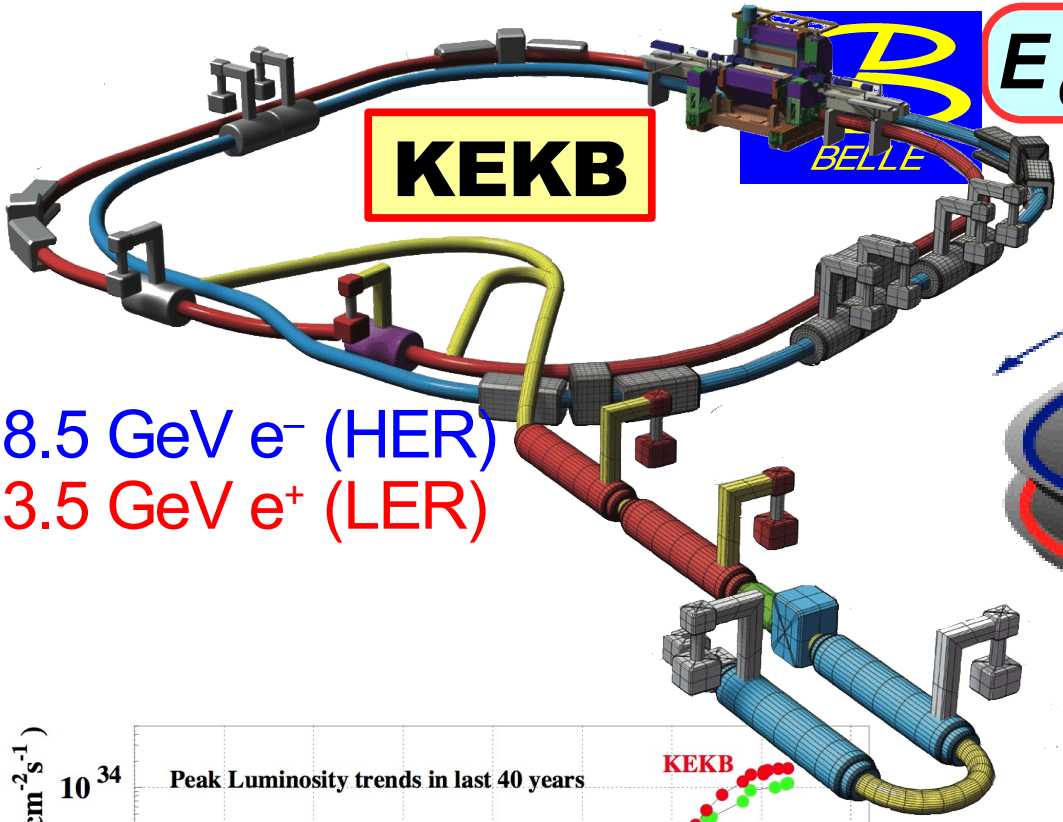
9.0 GeV e^- (HER)
3.1 GeV e^+ (LER)



Asymmetric-Energy e^+e^- Colliders

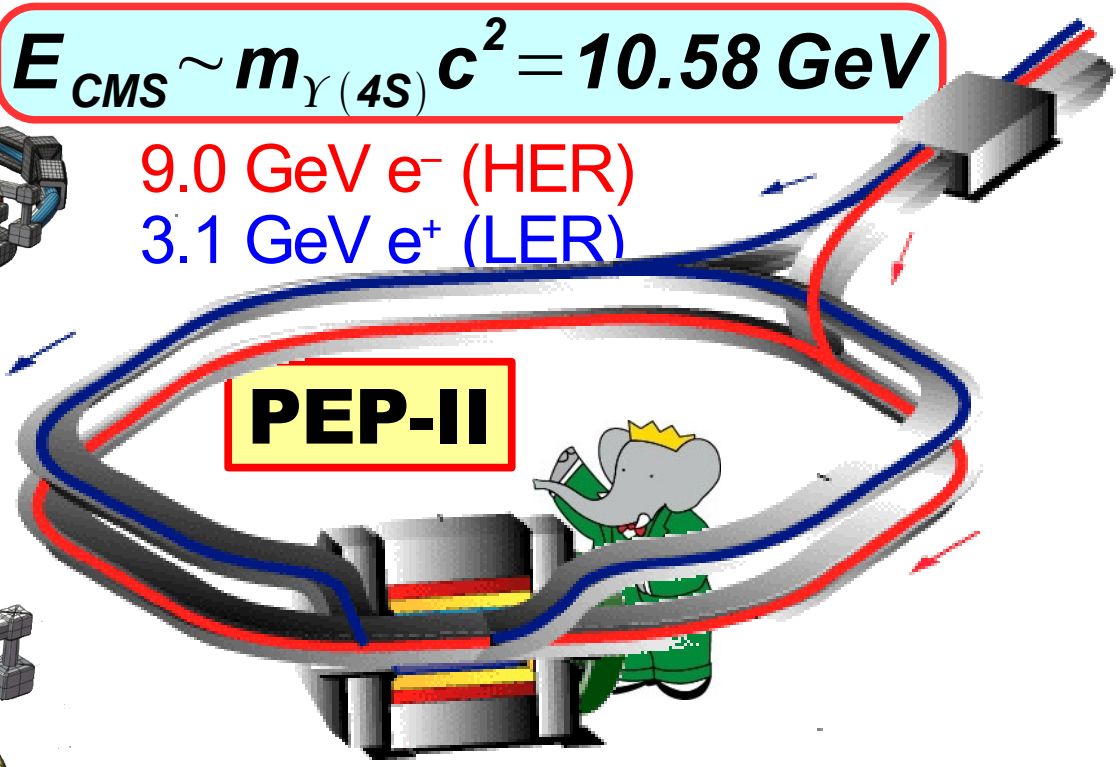


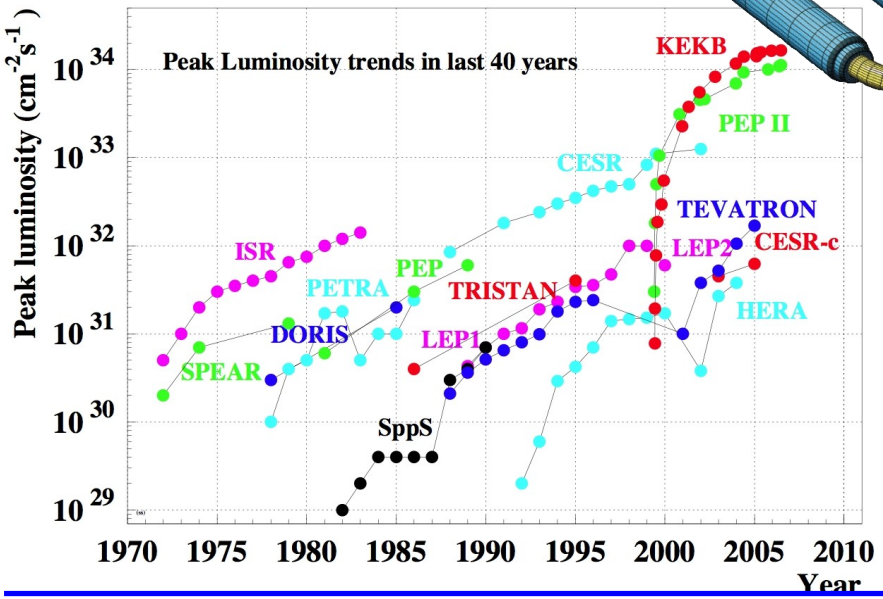
$E_{CMS} \sim m_{\Upsilon(4S)} c^2 = 10.58\ GeV$



8.5 GeV e^- (HER)
3.5 GeV e^+ (LER)

9.0 GeV e^- (HER)
3.1 GeV e^+ (LER)





Asymmetric-Energy e^+e^- Colliders

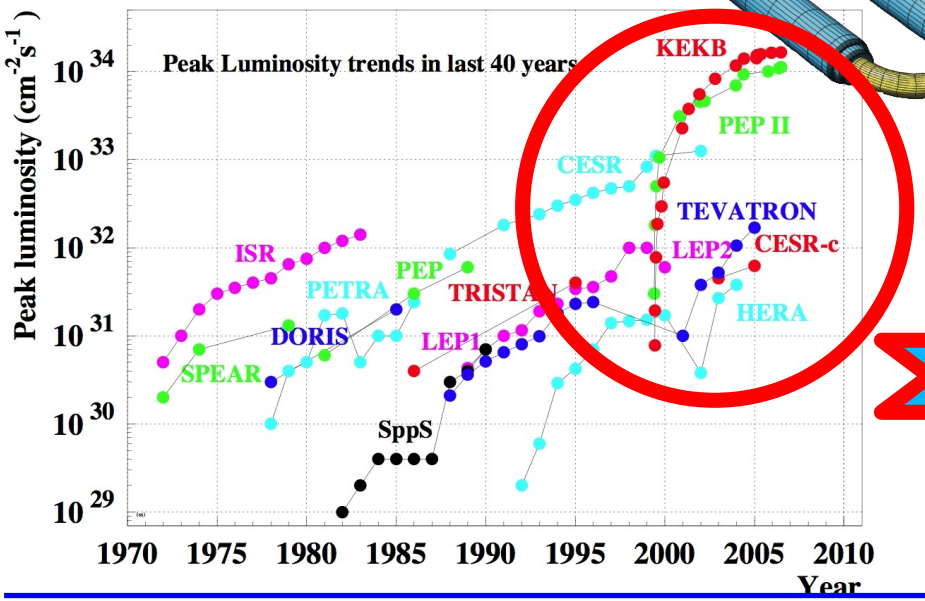
$E_{CMS} \sim m_{\Upsilon(4S)} c^2 = 10.58\ GeV$

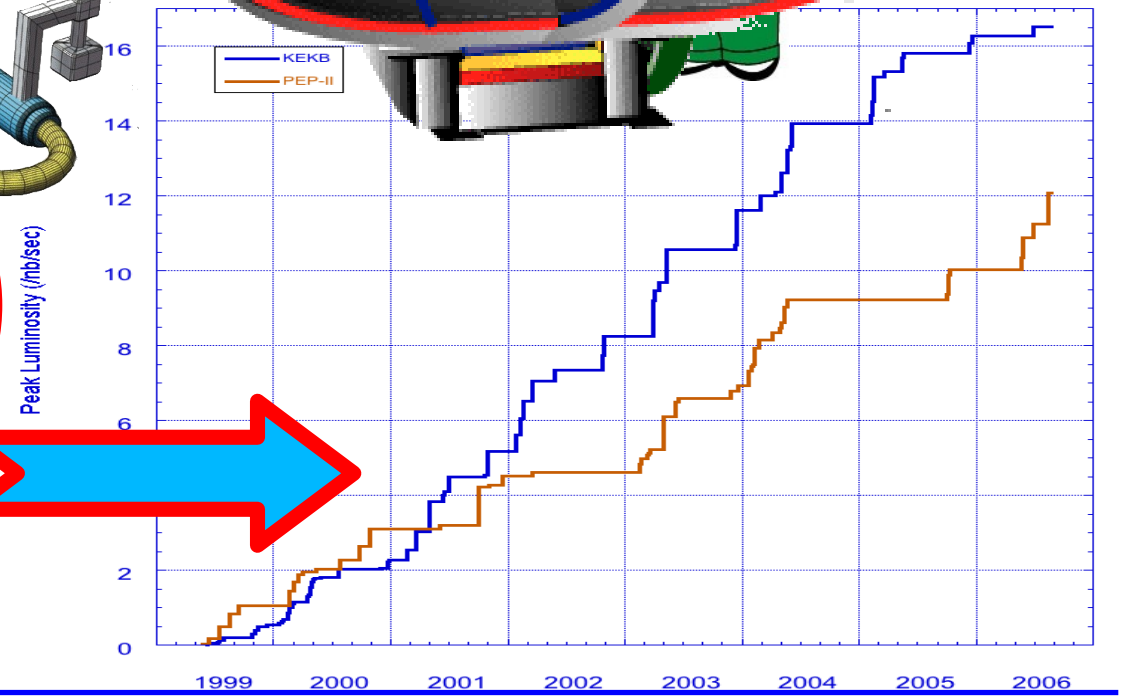
$1.65 \times 10^{34}\ cm^{-2}s^{-1}$ (WR!)

8.5 GeV e^- (HER)
3.5 GeV e^+ (LER)

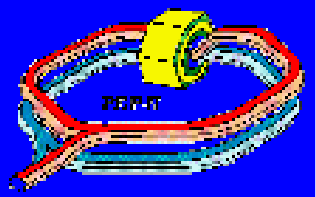
9.0 GeV e^- (HER)
3.1 GeV e^+ (LER)

$1.21 \times 10^{34}\ cm^{-2}s^{-1}$

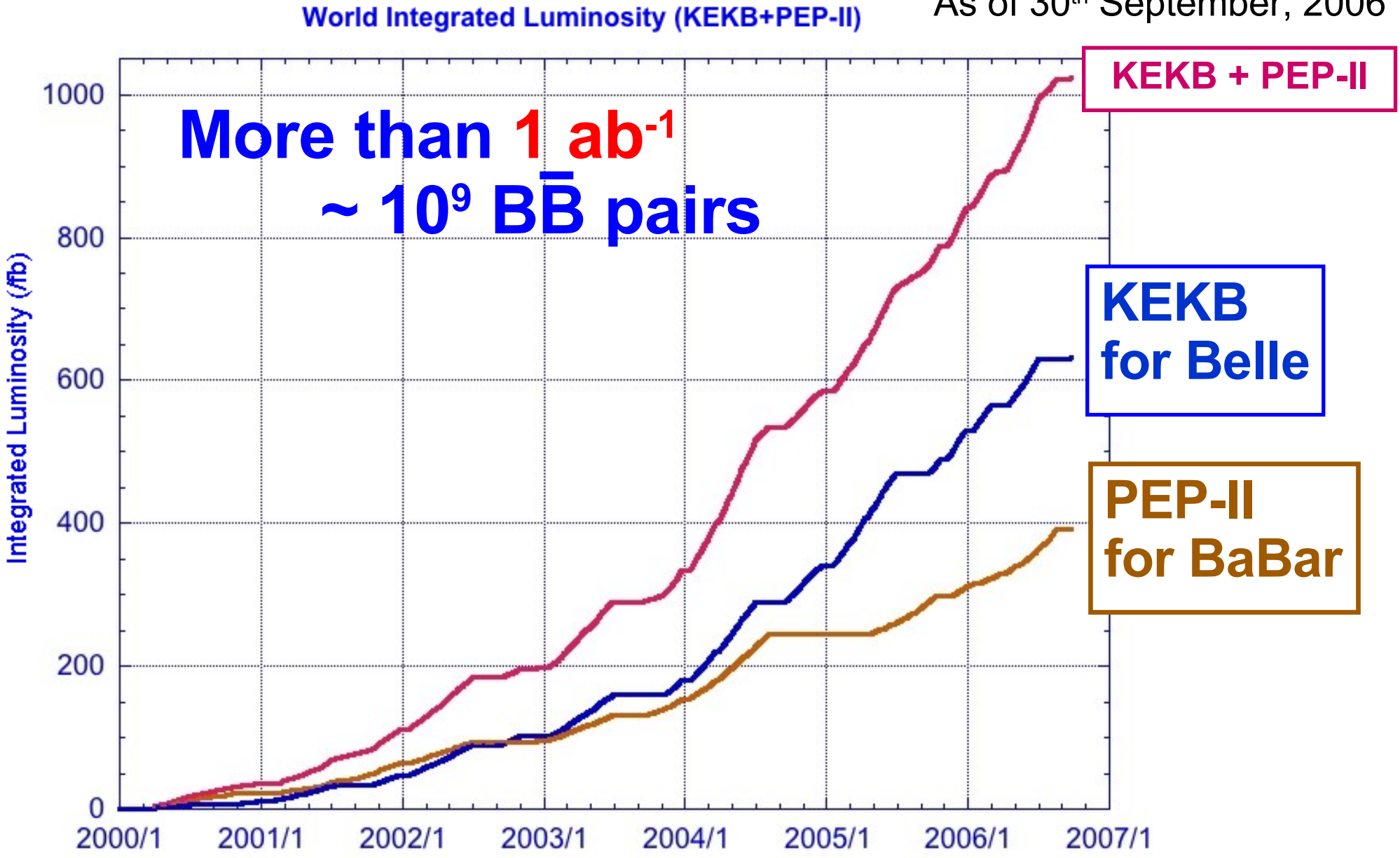




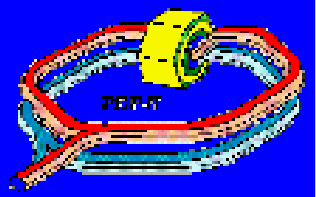
Asymmetric-Energy e^+e^- Colliders



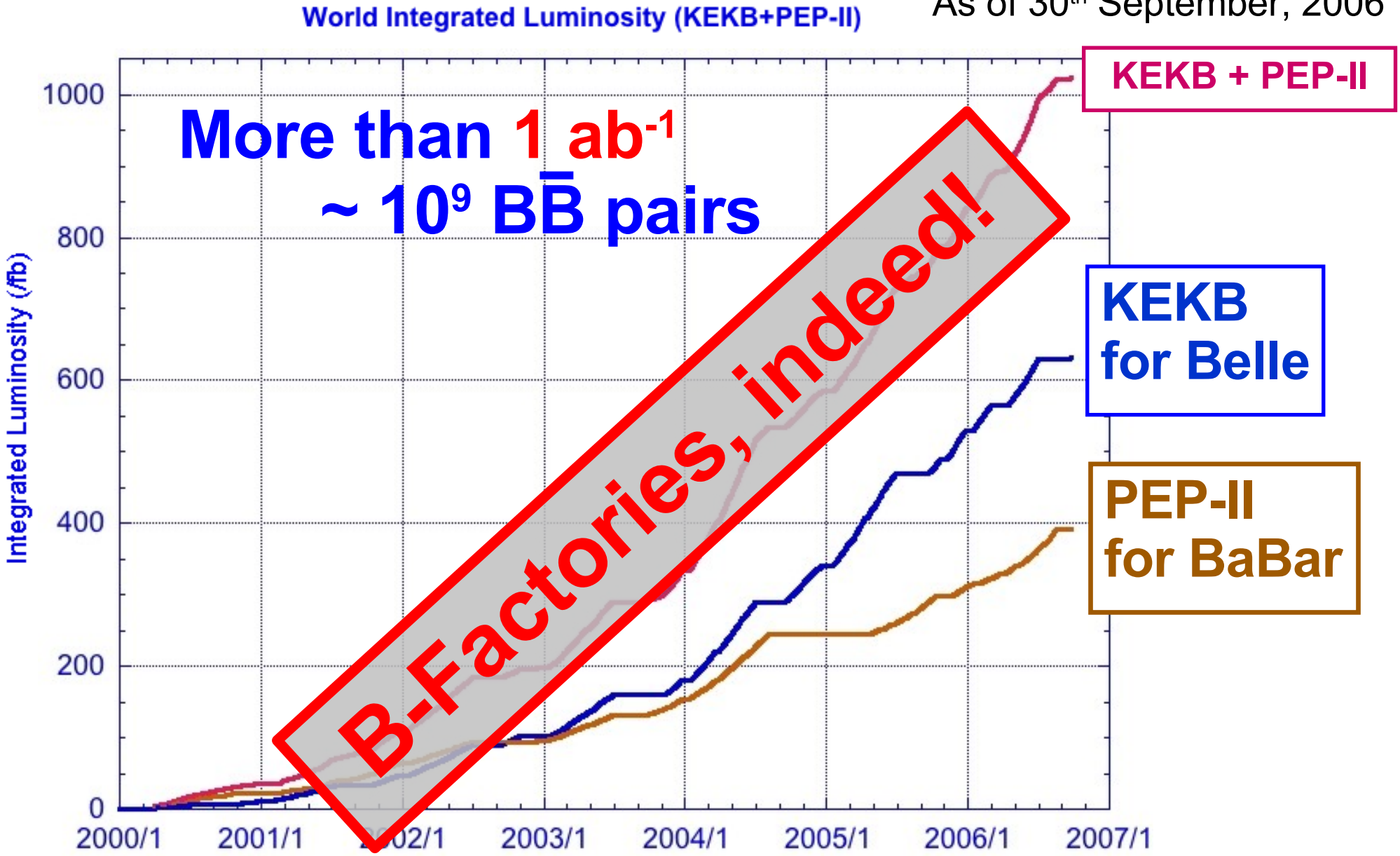
As of 30th September, 2006



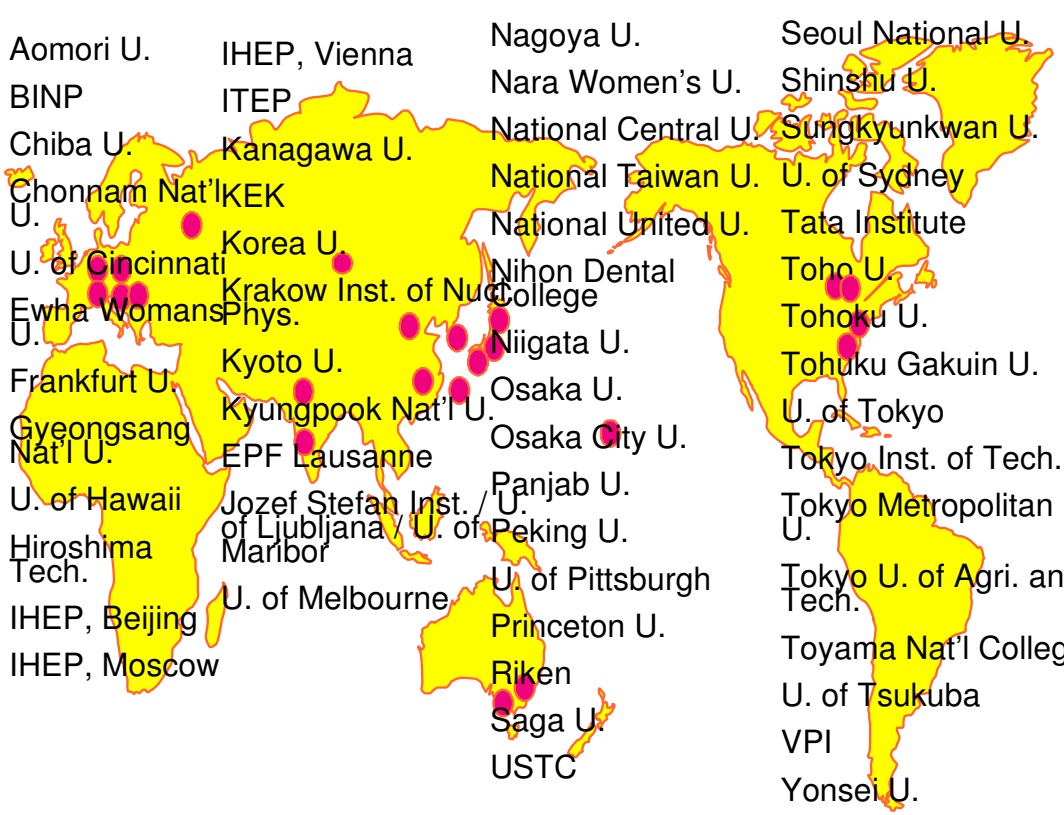
Asymmetric-Energy e^+e^- Colliders



As of 30th September, 2006



Belle & BaBar Collaborations



Aomori U.
BINP
Chiba U.
Chonnam Nat'l U.
U. of Cincinnati
Ewha Womans U.
Frankfurt U.
Gyeongsang Nat'l U.
U. of Hawaii
Hiroshima Tech.
IHEP, Beijing
IHEP, Moscow
IHEP, Vienna
ITEP
Kanagawa U.
KEK
Korea U.
Krakow Inst. of Nucl. Phys.
Kyoto U.
Kyungpook Nat'l U.
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Toho U.
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Tohuku Gakuin U.
U. of Tokyo
Tokyo Inst. of Tech.
Tokyo Metropolitan U.
Tokyo U. of Agri. and Tech.
Toyama Nat'l College
U. of Tsukuba
VPI
Yonsei U.

13 countries, 55 institutes, ~400 collaborators

The BABAR Collaboration
11 Countries
80 Institutions
623 Physicists

USA [38/311]
California Institute of Technology
UC, Irvine
UC, Los Angeles
UC, Riverside
UC, San Diego
UC, Santa Barbara
UC, Santa Cruz
U of Cincinnati
U of Colorado
Colorado State
Harvard U
U of Iowa
Iowa State U
LBNL
LLNL
U of Louisville
U of Maryland
U of Massachusetts, Amherst
MIT
U of Mississippi
Mount Holyoke College
SUNY, Albany
U of Notre Dame
Ohio State U
U of Oregon
U of Pennsylvania
Prairie View A&M U
Princeton U
SLAC
U of South Carolina
Stanford U
U of Tennessee
U of Texas at Austin
U of Texas at Dallas
Vanderbilt
U of Wisconsin
Yale

Canada [4/24]
U of British Columbia
McGill U
U de Montréal
U of Victoria

China [1/5]
Inst. of High Energy Physics, Beijing

France [5/53]
LAPP, Annecy
LAL Orsay
LPNHE des Universités Paris VI et VII
Ecole Polytechnique, Laboratoire Leprince-Ringuet
CEA, DAPNIA, CE-Saclay

Germany [5/24]
Ruhr U Bochum
U Dortmund
Technische U Dresden
U Heidelberg
U Rostock

Italy [12/99]
INFN, Bari
INFN, Ferrara
Lab. Nazionali di Frascati dell' INFN
INFN, Genova & Univ
INFN, Milano & Univ
INFN, Napoli & Univ
INFN, Padova & Univ
INFN, Pisa & Univ & Scuola Normale Superiore
INFN, Perugia & Univ
INFN, Roma & Univ "La Sapienza"
INFN, Torino & Univ
INFN, Trieste & Univ

The Netherlands [1/4]
NIKHEF, Amsterdam

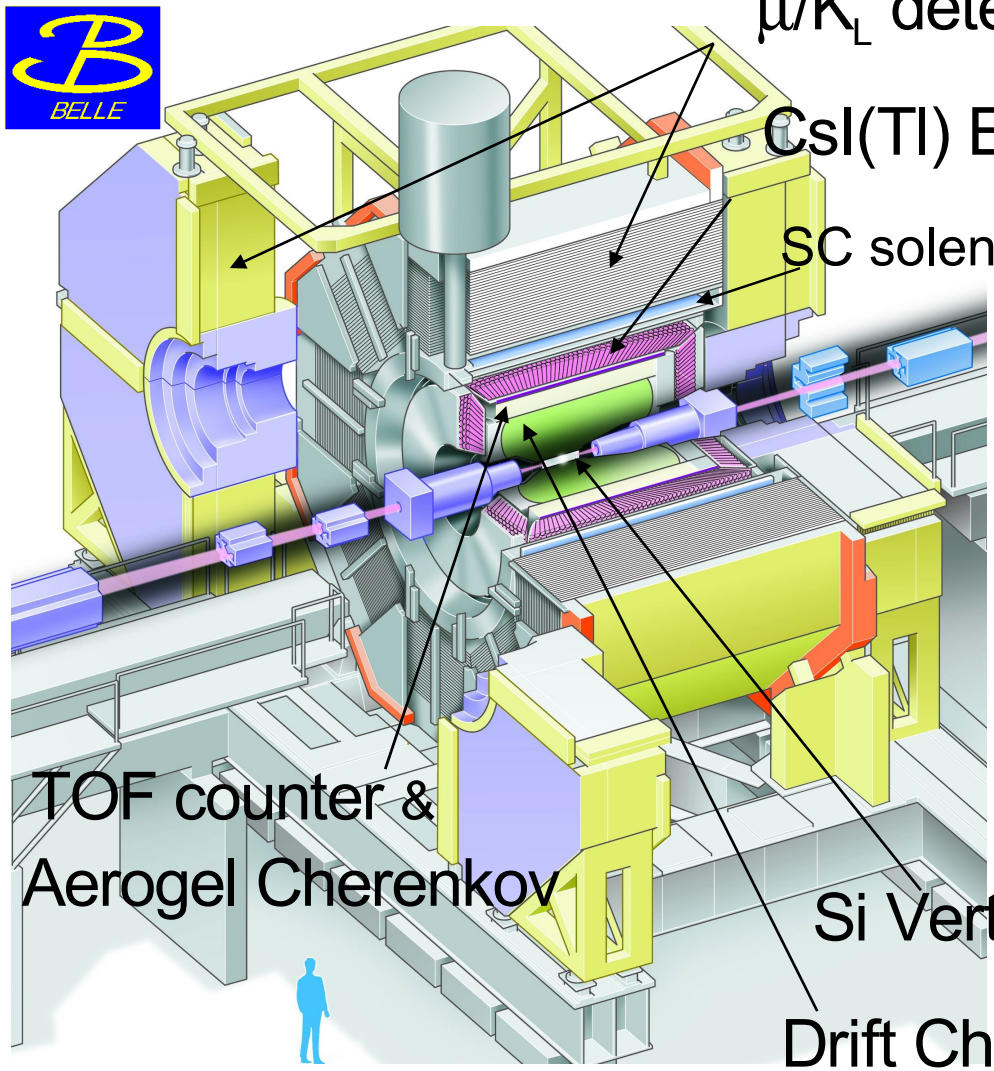
Norway [1/3]
U of Bergen

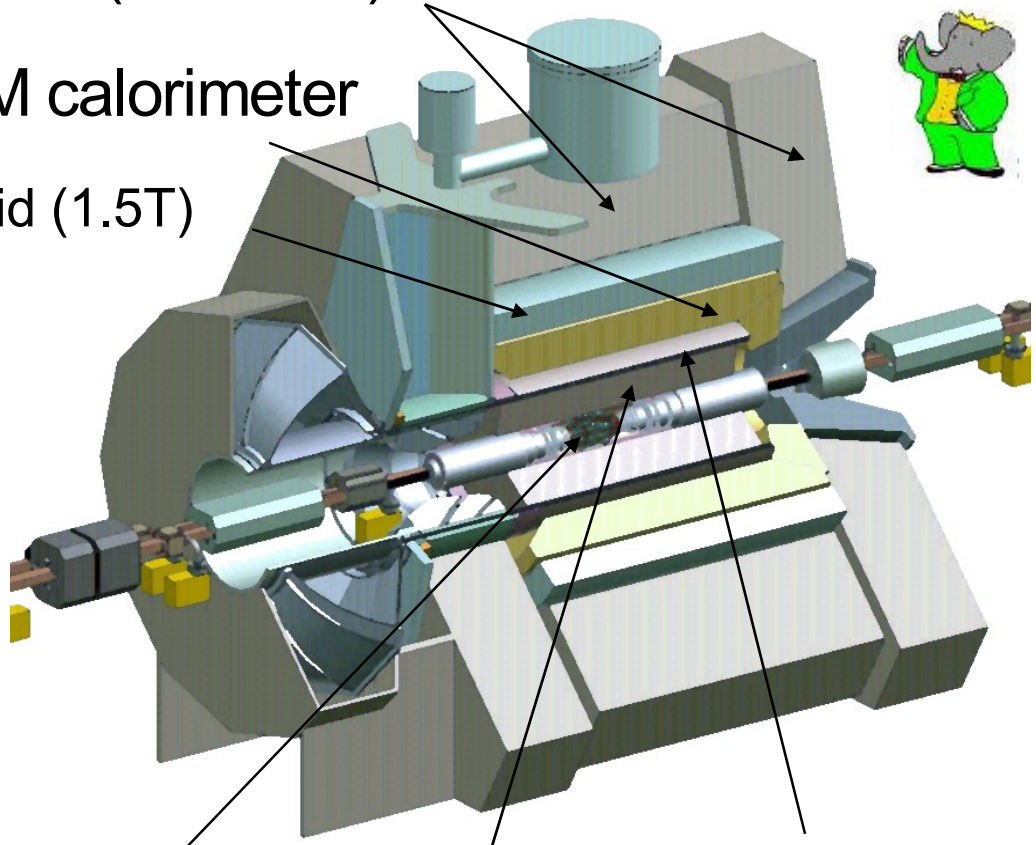
Russia [1/13]
Budker Institute, Novosibirsk

Spain [2/3]
IFAE-Barcelona
IFIC-Valencia

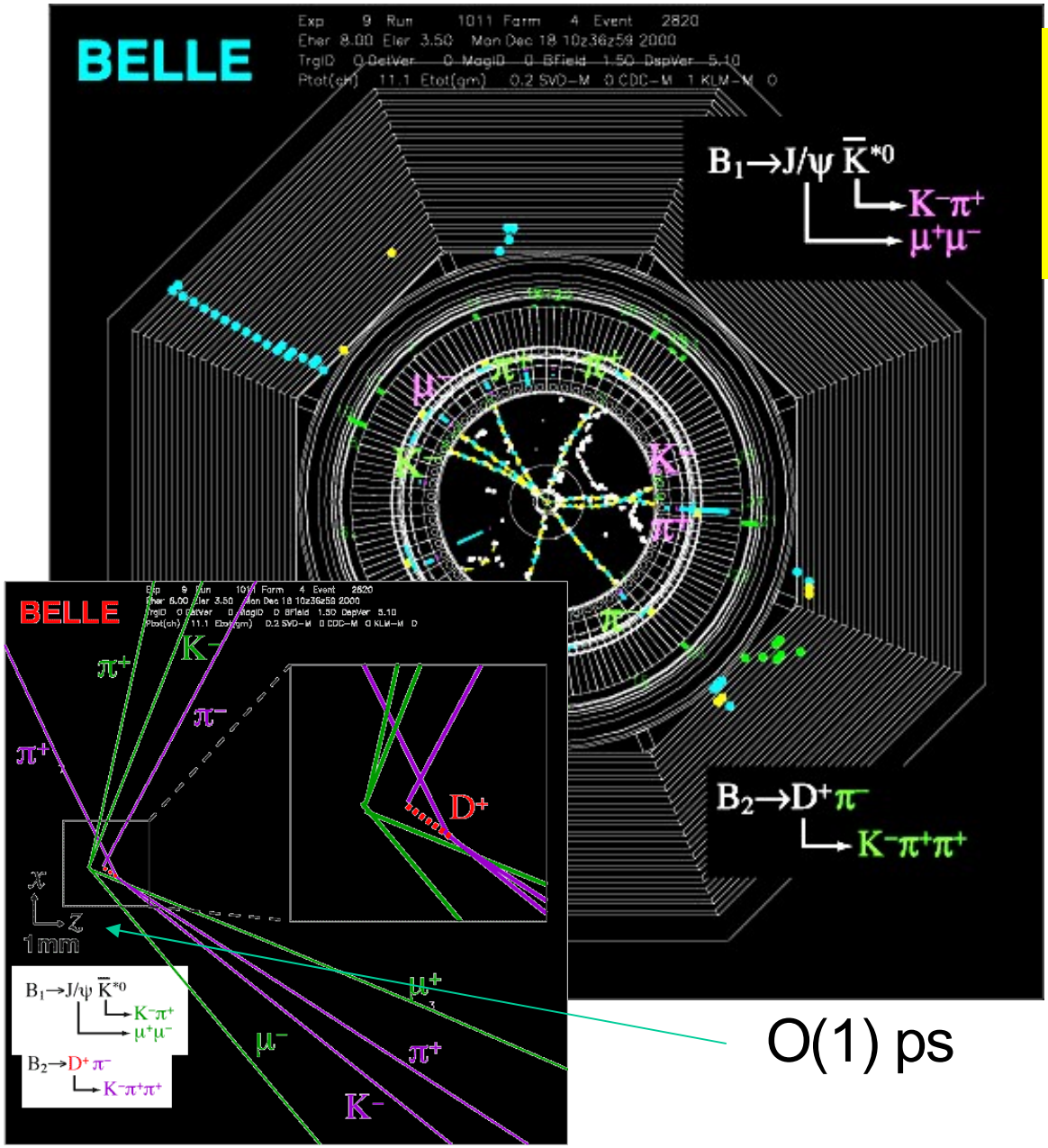
United Kingdom [11/75]
U of Birmingham
U of Bristol
Brunel U
U of Edinburgh
U of Liverpool
Imperial College
Queen Mary , U
U of London, Rc
U of Manchest
Rutherford Ap
U of Warwick

Belle & BaBar Detectors





Detectors' Performance



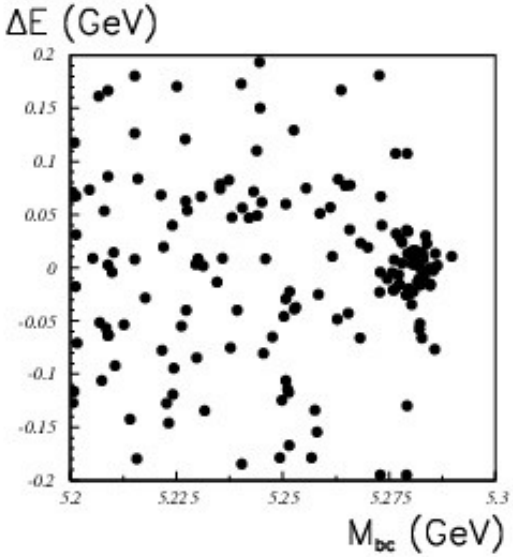
Big "**digital cameras**" that take ~10^8 beautiful pictures/year.

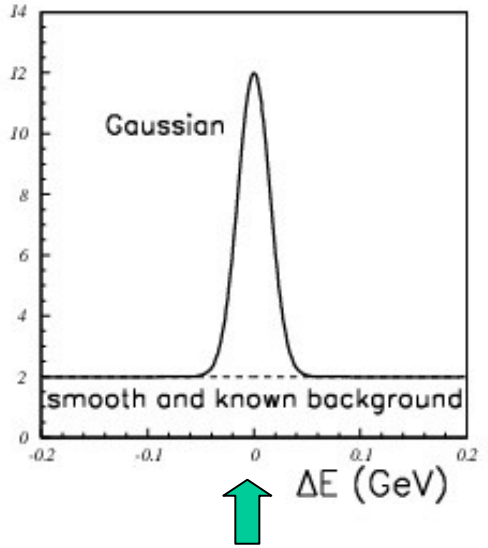
Good Resolutions
- ***Momentum***
- ***Energy (EM)***

Good PID
- ***e, μ, π/K, p, K_L***

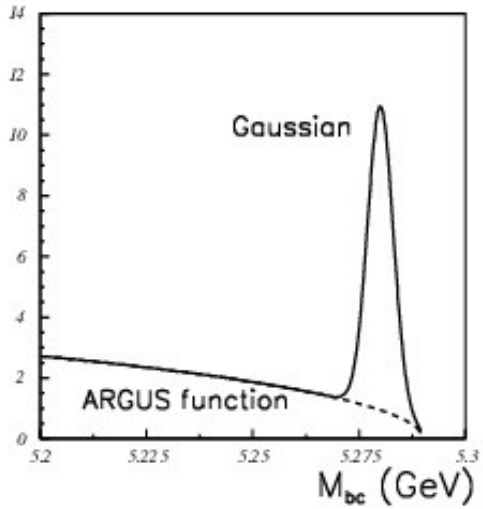
Good Vertexing
- ***(decay point)***

Analysis Tools: B-Meson Selection





Reconstructing B-meson decays at Y(4S):
use two variables,
beam-constrained mass M_{bc}
(energy-substituted mass m_{ES})
and
energy difference ΔE



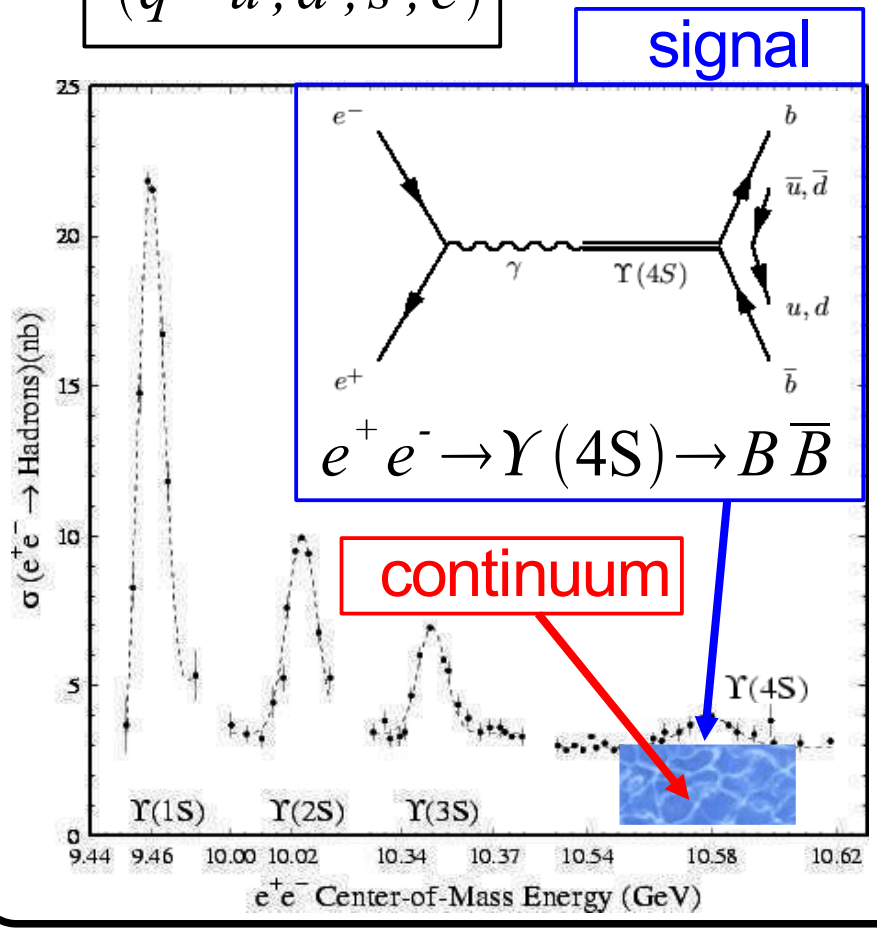
$$\Delta E \equiv \sum E_i - E_{beam}^{CMS}$$

$$M_{bc} = \sqrt{(E_{CM}/2)^2 - (\sum \vec{p}_i)^2}$$

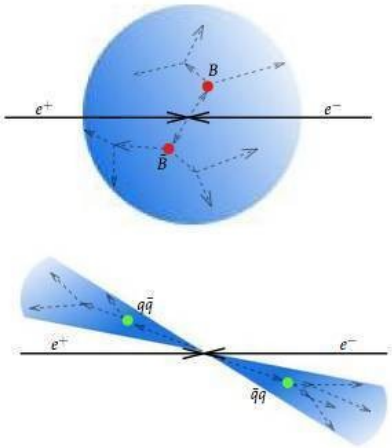
Anal. Tools: Continuum-Background Suppression

- **The background :** ~ 3 x $B\overline{B}$
  "continuum"

$$e^+e^- \to q\bar{q}$$
$$(q = u, d, s, c)$$

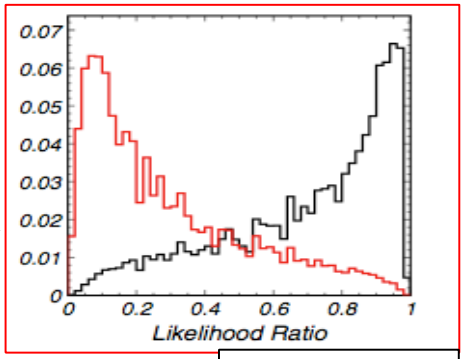


- **The event topology**
  Spherical $B\overline{B}$
  vs
  Jet-like continuum

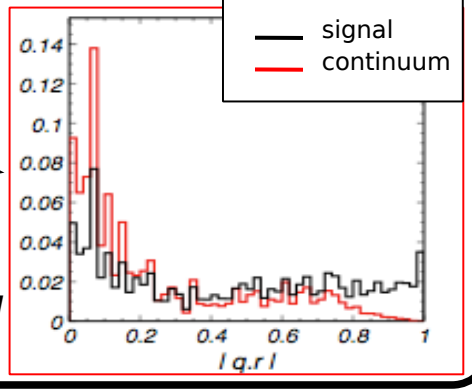


→ Fisher variable

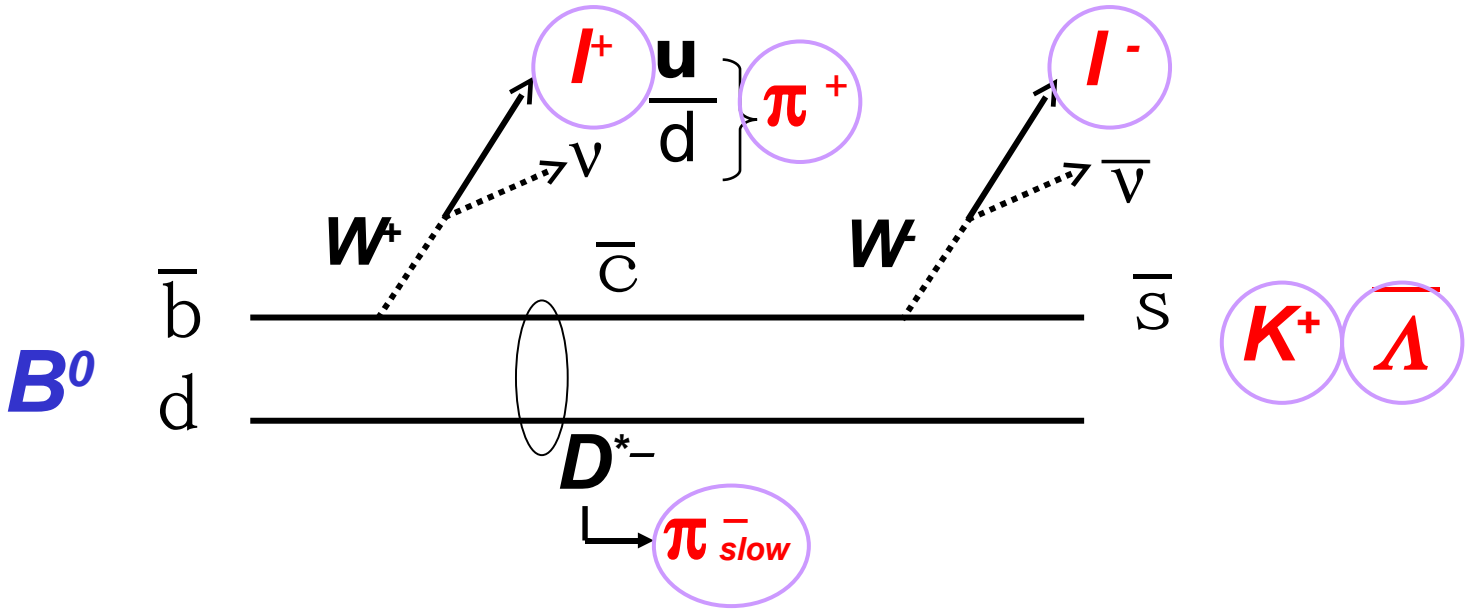
- **B flight direction**
  → $\cos\theta_B$



- **B-flavour tagging**
  → tag-quality parameter ***r***
  (confidence that the other B meson's flavour *q* is correctly tagged)



Analysis Tools: Flavour Tagging

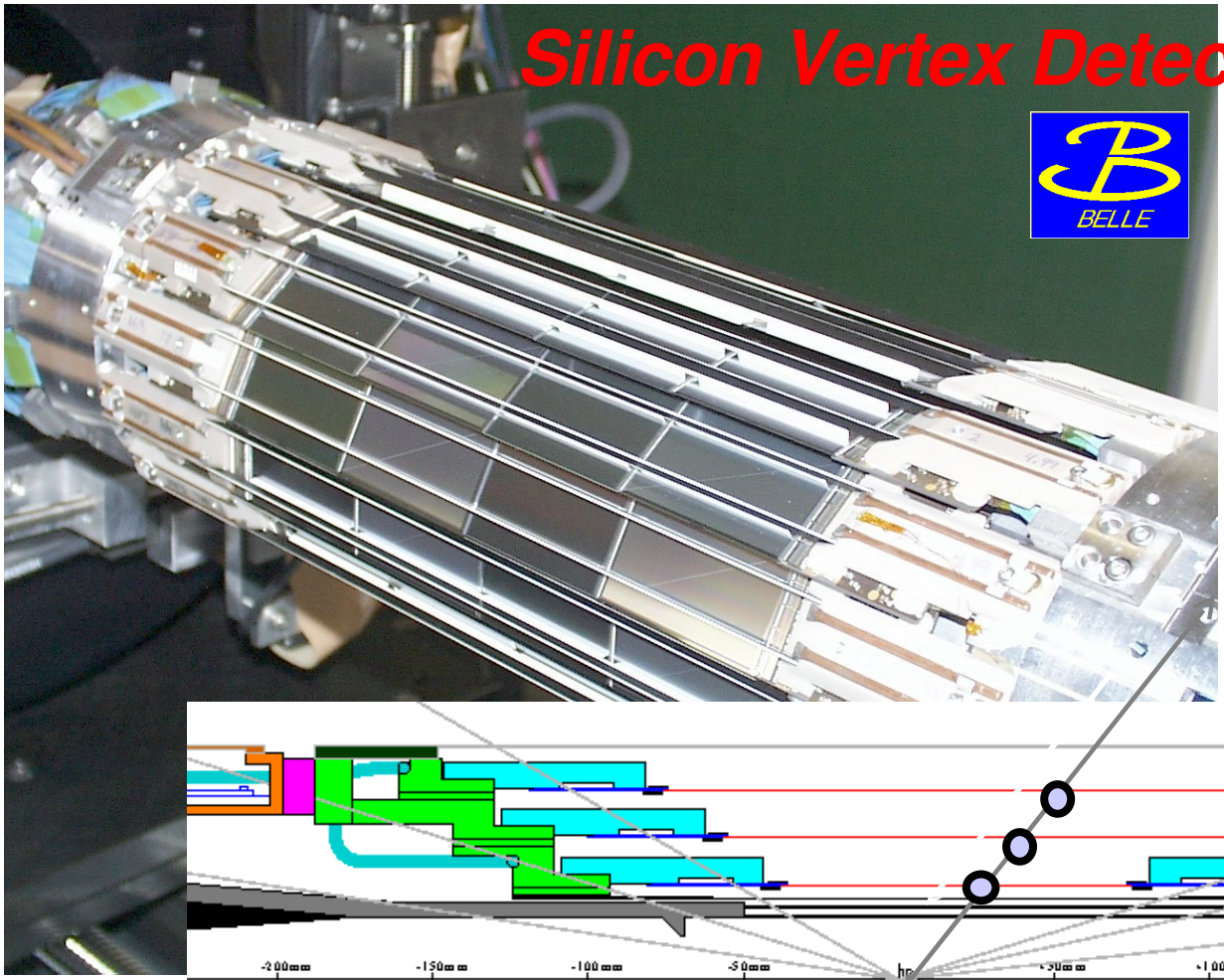


- **High-p** (primary), **low-p** (secondary) **leptons**
- **Strangeness** ($b \to c \to s$)
- **Fast π, slow π**

utilise all available info.

- 2-stage Multi-dim. Likelihood-based method (including correlations)
- Neural Network

Analysis Tools: Vertex Reconstruction



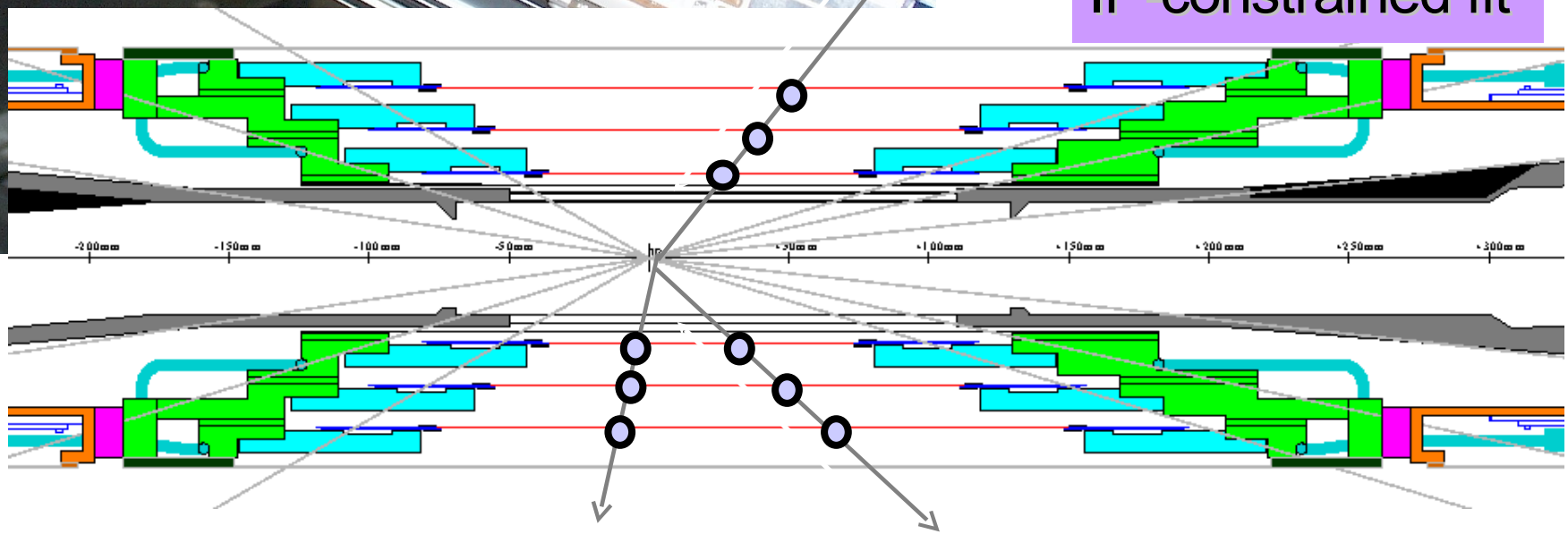
$\beta\gamma$=0.425 (KEKB)
0.56 (PEP-II)

$$\Delta t = \frac{\Delta z}{c(\beta\gamma)_\Upsilon}$$

$\sigma(z_{CP}) \sim 75\mu m$

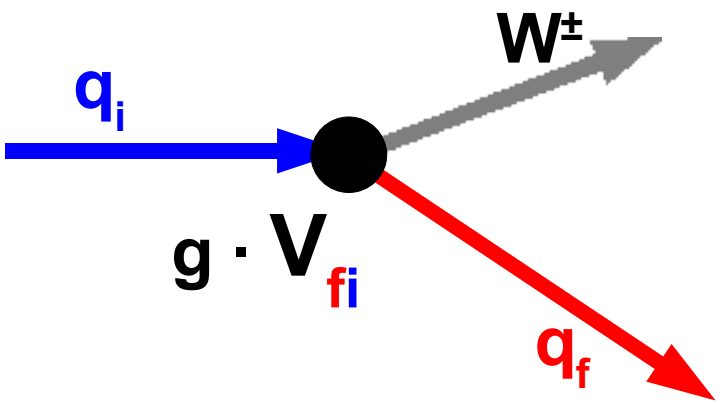
$\sigma(z_{tag}) \sim 140\mu m$

IP-constrained fit



The CKM Matrix

- Quark mixing in the Standard Model (SM) is described by the Cabbibo-Kobayashi-Maskawa matrix:



$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

- Wolfenstein parametrisation :

$$V_{CKM} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

($\lambda = \sin\theta_c$)
θ_c: Cabibbo angle

Unitary matrix: 3 real parameters & 1 irreducible complex phase (CP violation)

The Unitarity Triangle (UT)

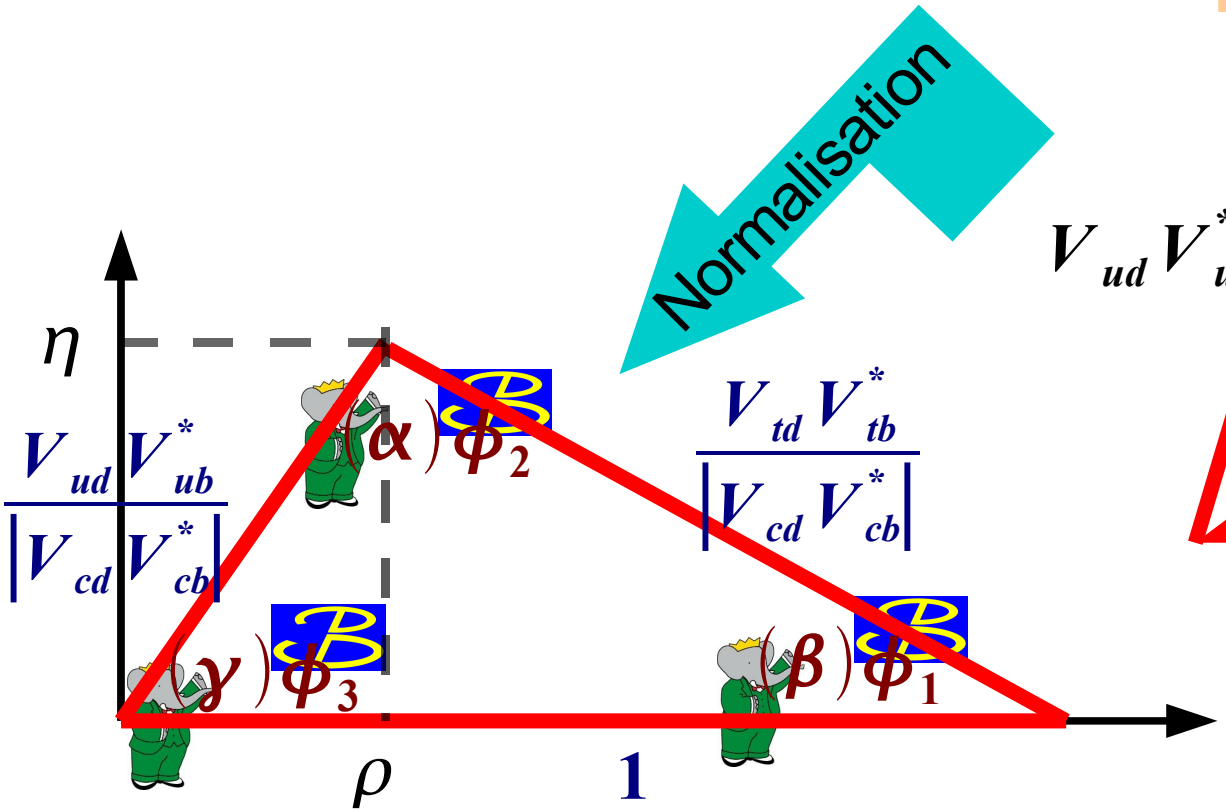
Unitarity constraints for the CKM matrix :

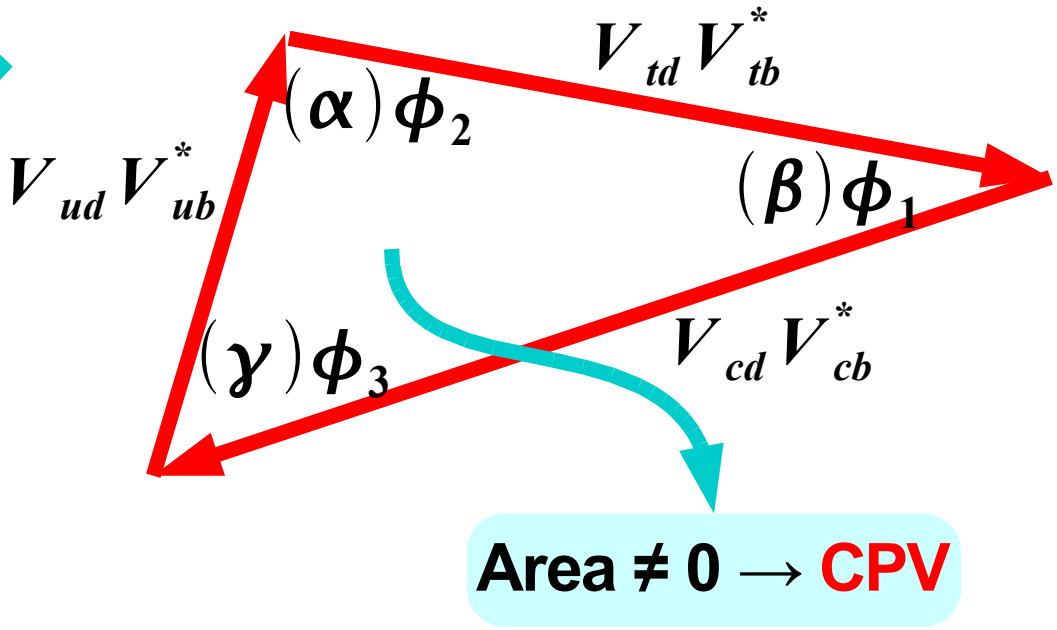
$$V_{CKM}^{\dagger} V_{CKM} = \mathbf{1} \;\Rightarrow\; \sum_{k=1}^{3} V_{ik} V_{jk}^{*} = \delta_{ij} \;\rightarrow$$

6 $i \neq j$ constraints can be shown as triangles in the complex plane

"The Unitarity Triangle" (1st x 3rd column):

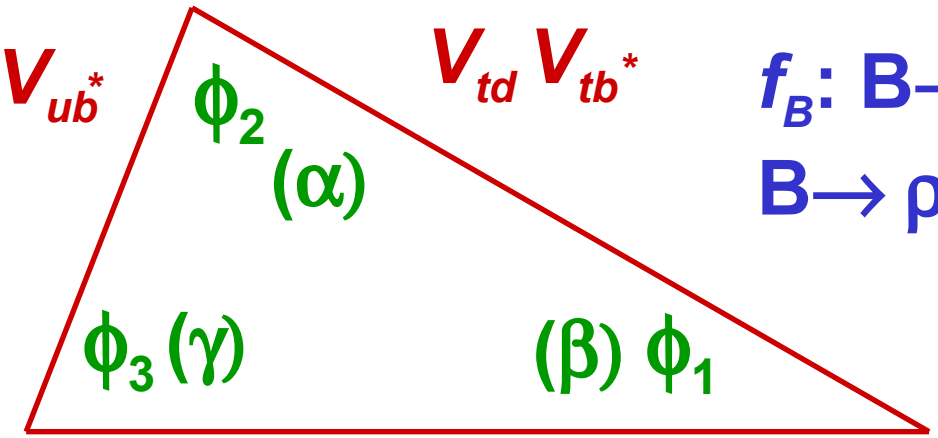
$$V_{ud} V_{ub}^{*} + V_{cd} V_{cb}^{*} + V_{td} V_{tb}^{*} = 0$$





The Determination of UT

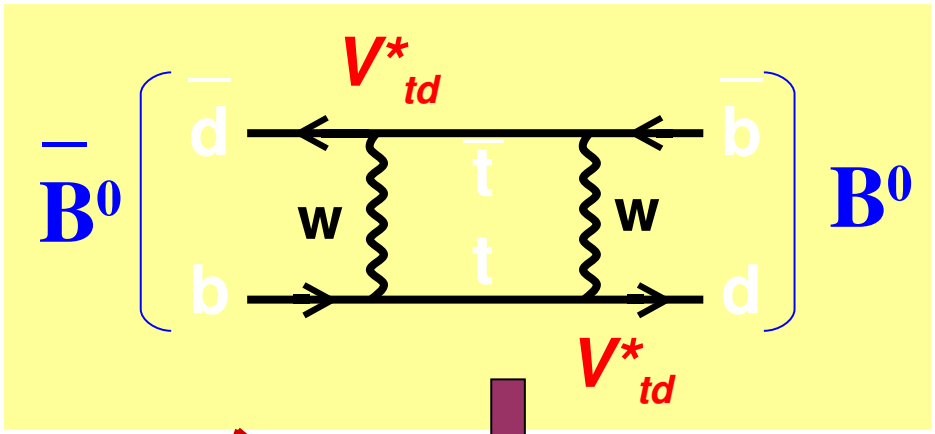
Precise test of KM(CPV) and SM

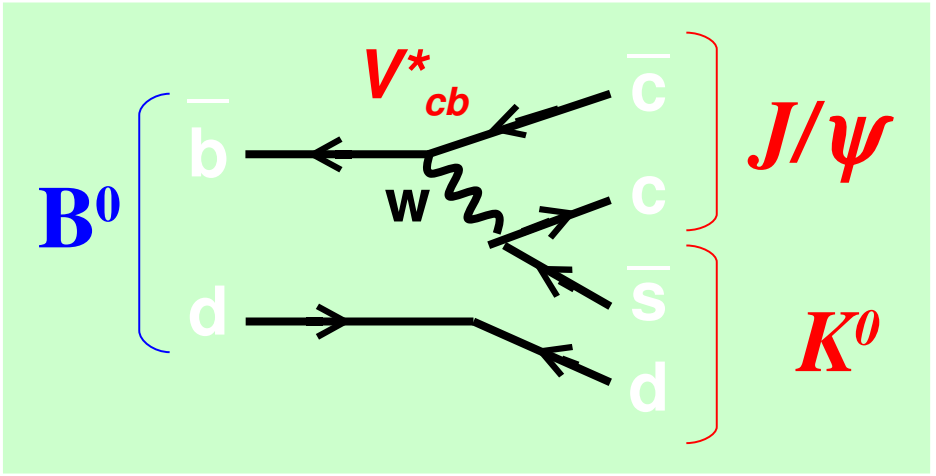


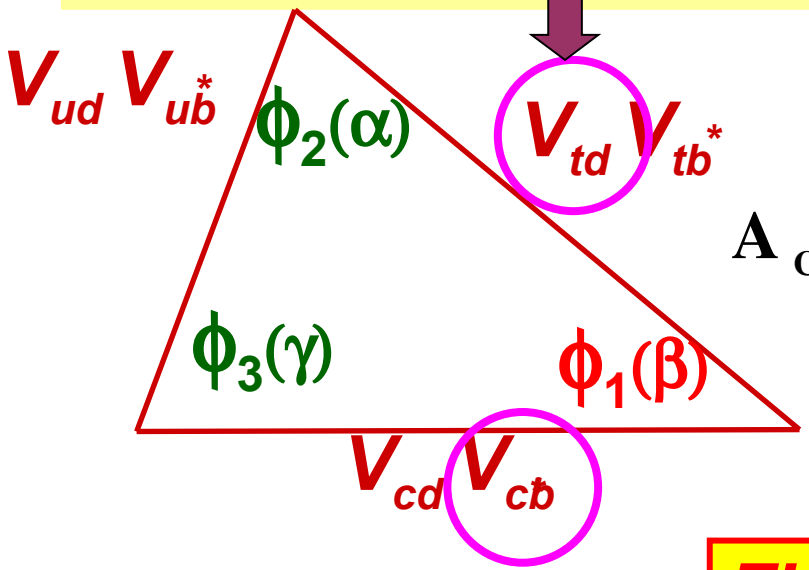
B experiments can provide all measurements !

Measurement of β/ϕ_1

SM: $\sin 2\beta/\sin 2\phi_1$ observable due to interference between direct decays ($B^0 \to f_{CP}$) and mixing decays ($B^0 \to \overline{B}^0 \to f_{CP}$); e.g. the golden mode :







$$A_{CP} = -\xi_{cp}\sin 2\phi_1 \sin(\Delta m \Delta t) + A\cos(\Delta m \Delta t)$$

Mixing induced CPV — Direct CPV

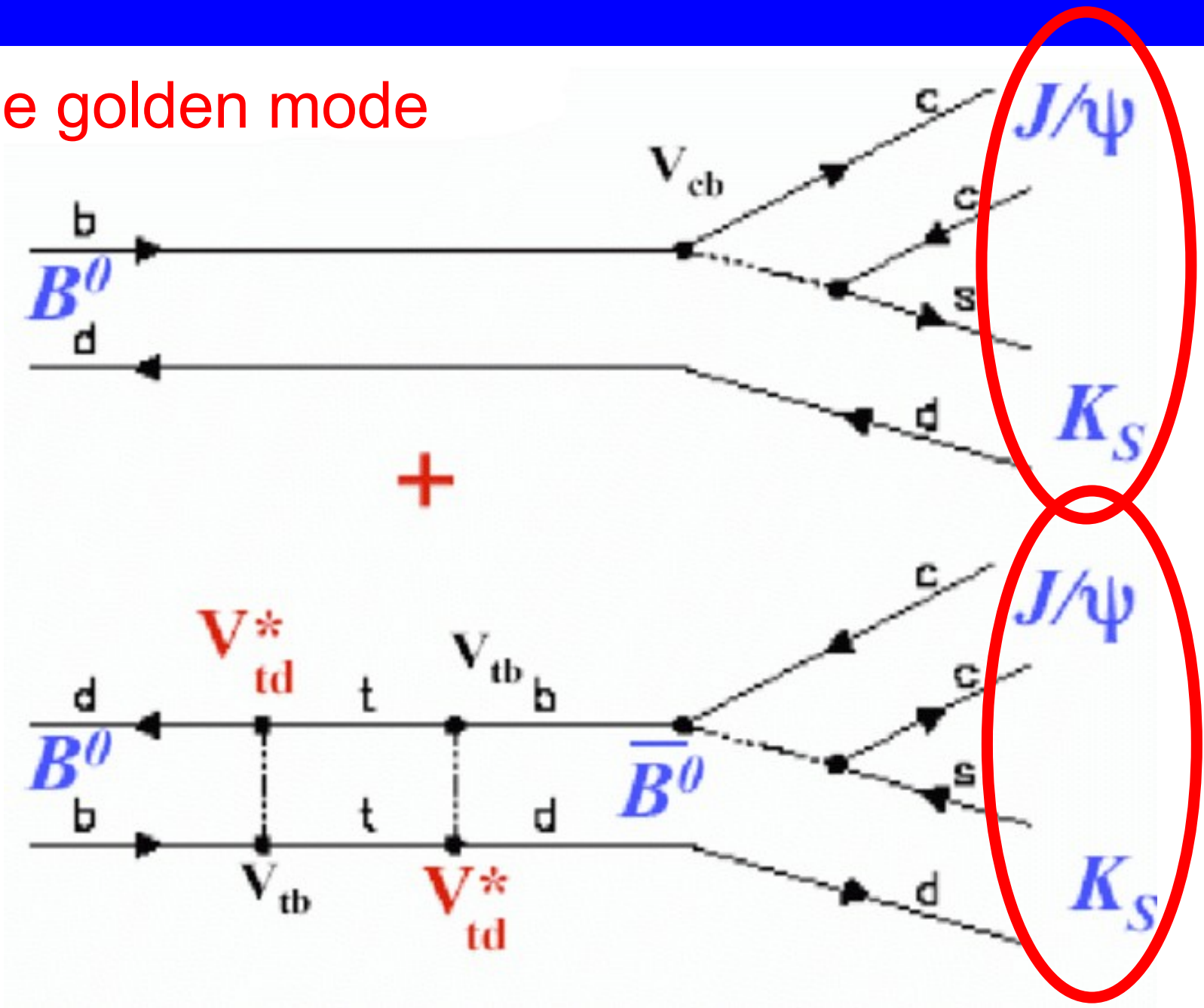
ξ_{CP} : *CP eigenvalue*

$A \cong 0$

First observed CPV in B (2001)

Measurement of sin2β/sin2φ$_1$

The golden mode



$\propto V_{td}^{*2}$

Measurement of sin2β/sin2φ$_1$

- Measure time-dependent CP asymmetries :

$$A(t)=\frac{\Gamma\left(\overline{B}^0\to f_{CP};t\right)-\Gamma\left(B^0\to f_{CP};t\right)}{\Gamma\left(\overline{B}^0\to f_{CP};t\right)+\Gamma\left(B^0\to f_{CP};t\right)}=S_{f_{CP}}\sin\left(\Delta m_d t\right)+A_{f_{CP}}\cos\left(\Delta m_d t\right)$$

$$S_{f_{CP}}\equiv\frac{2\,\Im\left(\lambda_{f_{CP}}\right)}{\left|\lambda_{f_{CP}}\right|^2+1},\qquad A_{f_{CP}}\equiv\frac{\left|\lambda_{f_{CP}}\right|^2-1}{\left|\lambda_{f_{CP}}\right|^2+1}=-C_{f_{CP}},\qquad \lambda_{f_{CP}}=\frac{q}{p}\frac{\overline{Ampl}_{f_{CP}}}{Ampl_{f_{CP}}}$$

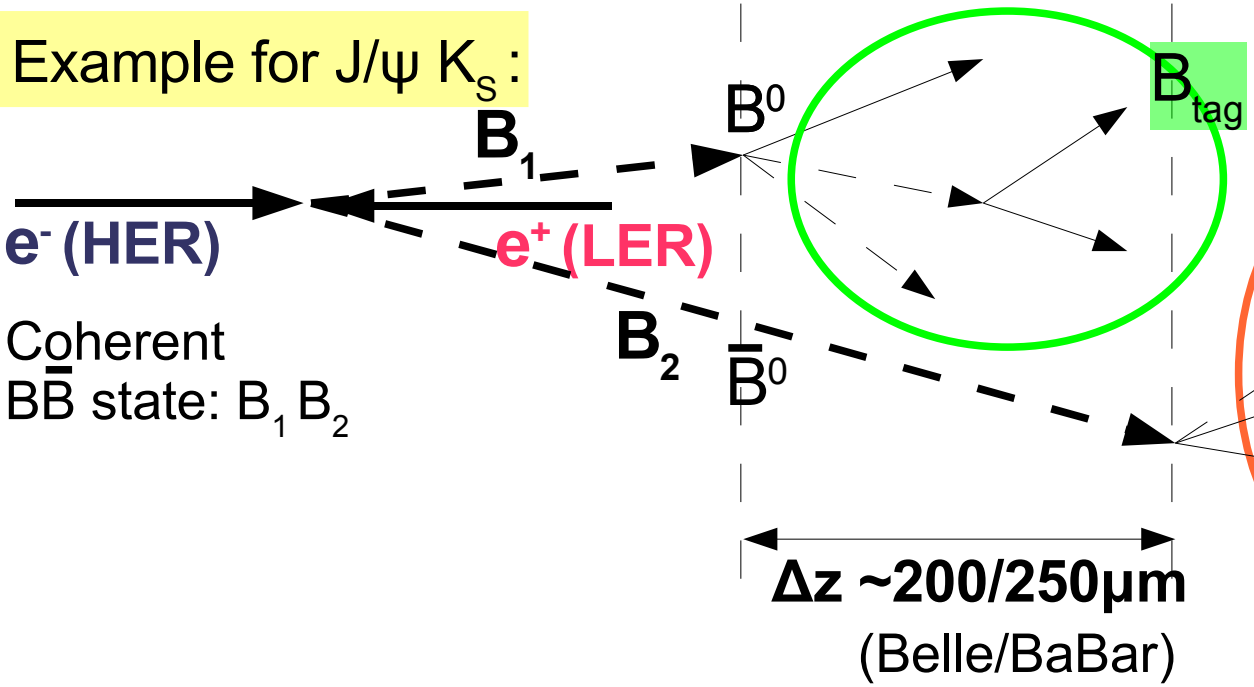
$S_{f_{CP}}=-\eta_{f_{CP}}\sin 2\phi_1$

Direct CP violation term $\left(\left|\overline{Ampl}_{f_{CP}}\right|\neq\left|Ampl_{f_{CP}}\right|\right)$

- mass eigenstates: $\left|B_{L,H}\right\rangle=p\left|B^0\right\rangle\pm q\left|\overline{B}^0\right\rangle;\ \Delta m_d=m_H-m_L$
- $t = t_{rec} - t_{tag}$ (coherent $B\overline{B}$ state: B_{tag} tags flavour at t_{tag} ; B_{rec} decays to f_{CP} at t_{rec})
- For $f_{CP} = (c\bar{c})_{Vector}\ K_S/K_L$:
  - $A = 0$ and $S = -\eta_f \sin 2\varphi_1$
  - CP eigenvalue: $\eta_f = -1/+1$ (K_S/K_L)

Time-Dependent Analysis

Example for J/ψ K_S :



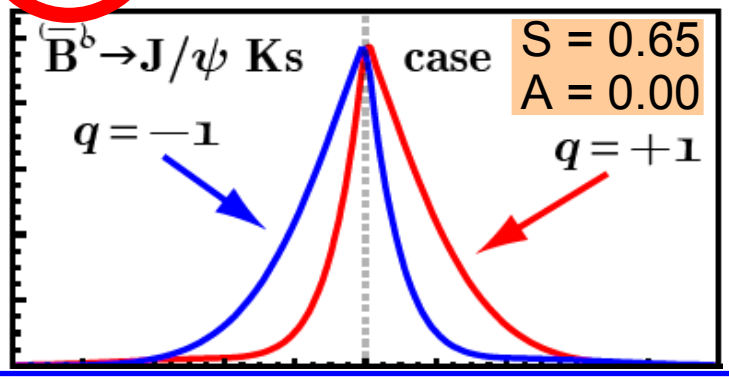
Procedure:
- Reconstruct B_{CP} meson
- Reconstruct 2 vertices
- Tag B meson flavour

Fit proper time distribution

Wrong flavour tag

$$P_{signal}(q,\Delta t) \propto e^{-|\Delta t|/\tau}\left[1-q(1-2w)\left(S_{f_{CP}}\sin(\Delta m_d \Delta t)+A_{f_{CP}}\cos(\Delta m_d \Delta t)\right)\right]$$

Flavour tag:
q = +1 (tagged with $\bar{B}^0$)
-1 (tagged with B^0)

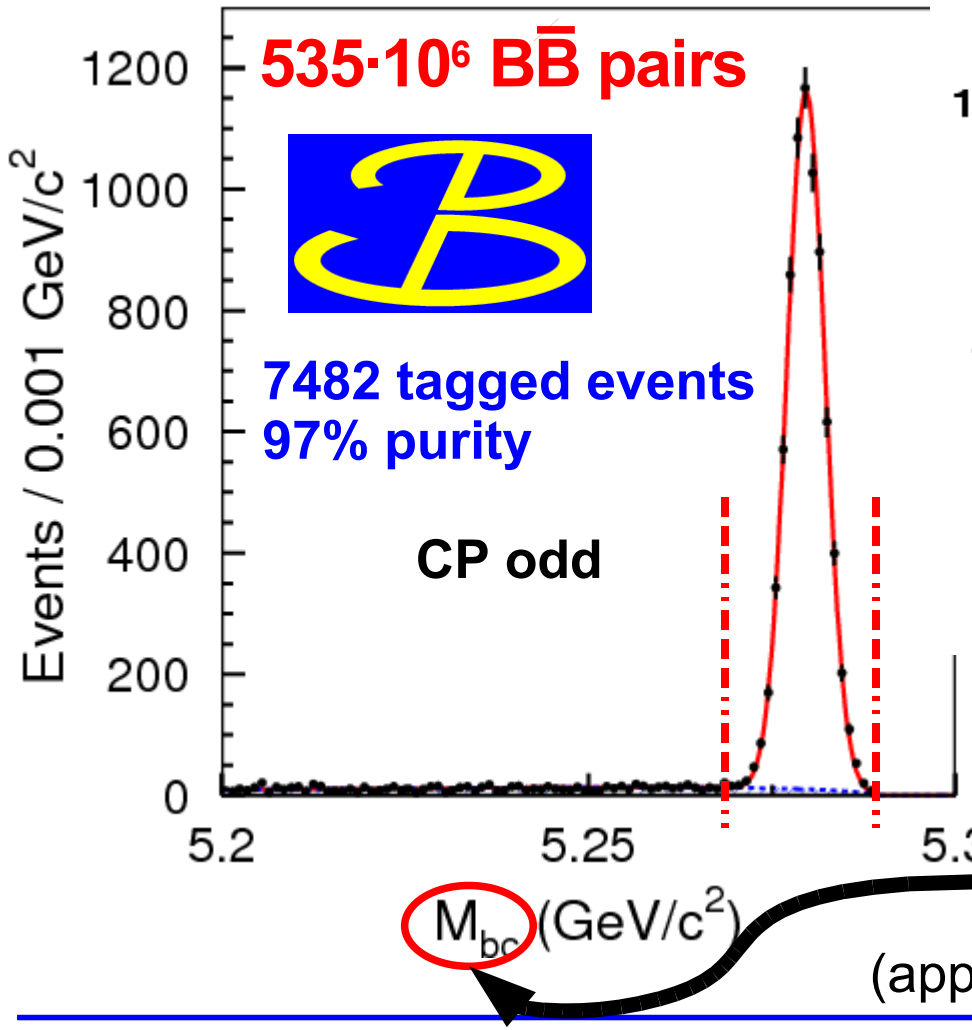


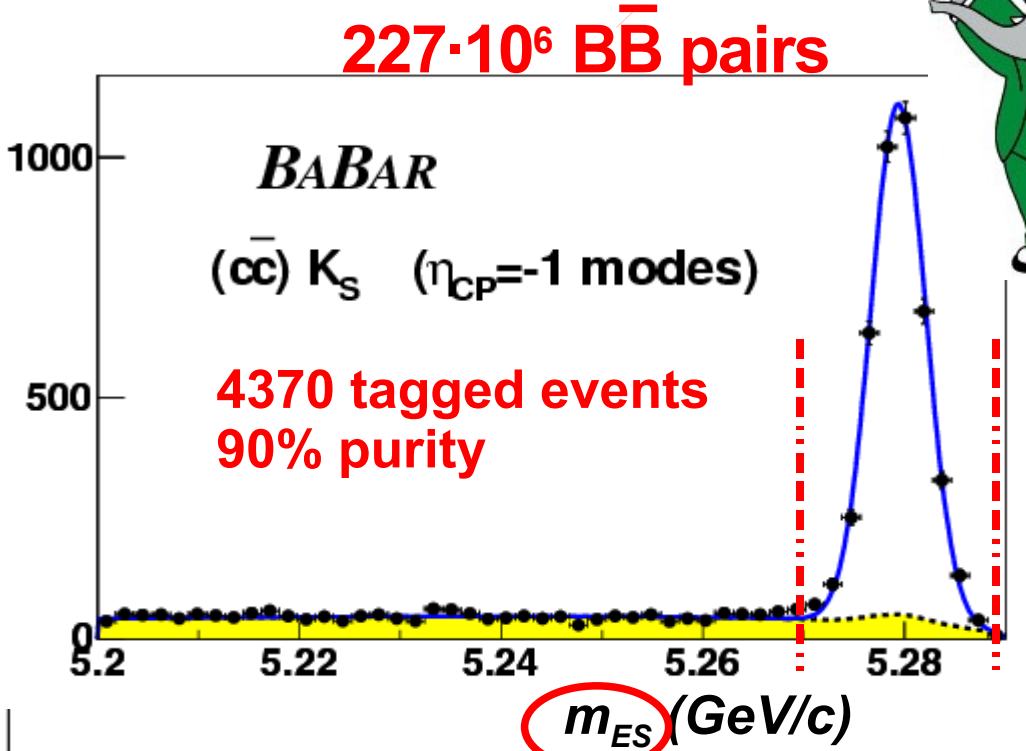
$\times$ *Res. f.*

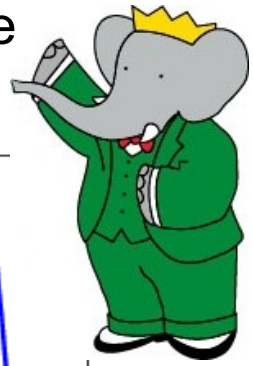
Smearing due to finite resolution

sin2β/sin2φ$_1$ from b→cc̄s decays: $B^0 \to (c\bar{c})K_S$, $(c\bar{c})K_L$

- Tree-dominated decay (+ the same phase in leading penguin correction)
  → Clean extraction of the CKM angle
- Relatively large BR's & low background due to clean experimental signature
  → Experimentally favourable ...







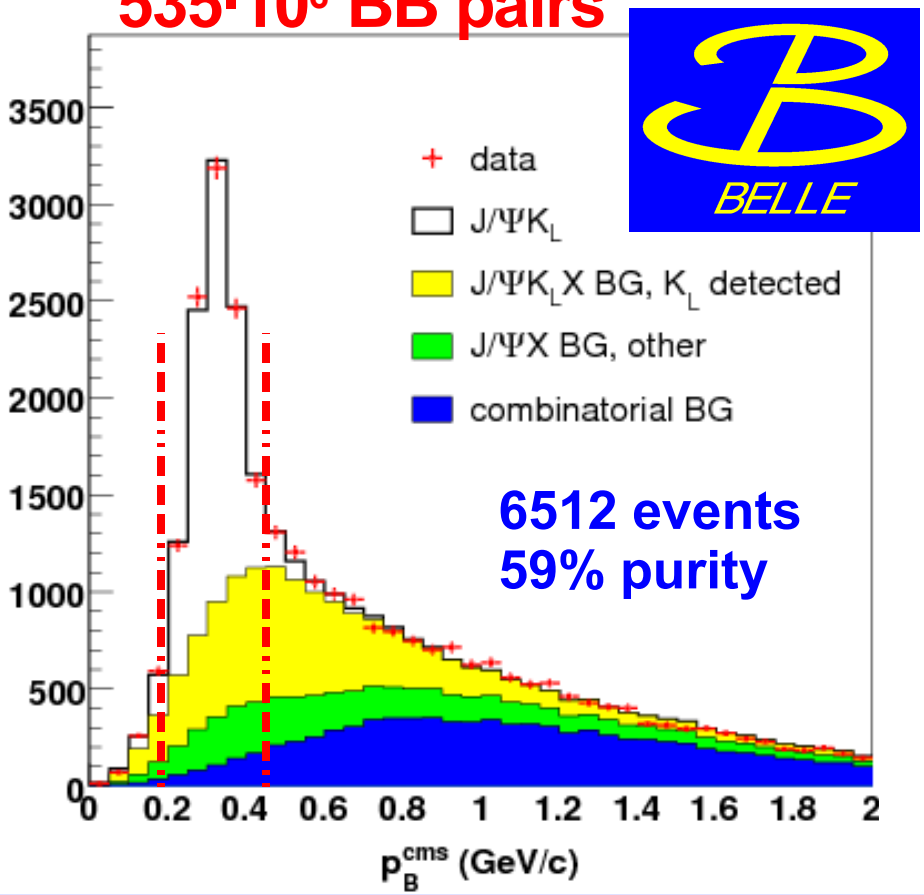
$$M_{bc} = \sqrt{\left(E_{beam}^{CMS}\right)^2 - \left(p_B^{CMS}\right)^2} = m_{ES}$$

(applying kinematic constraints at the Y(4S))

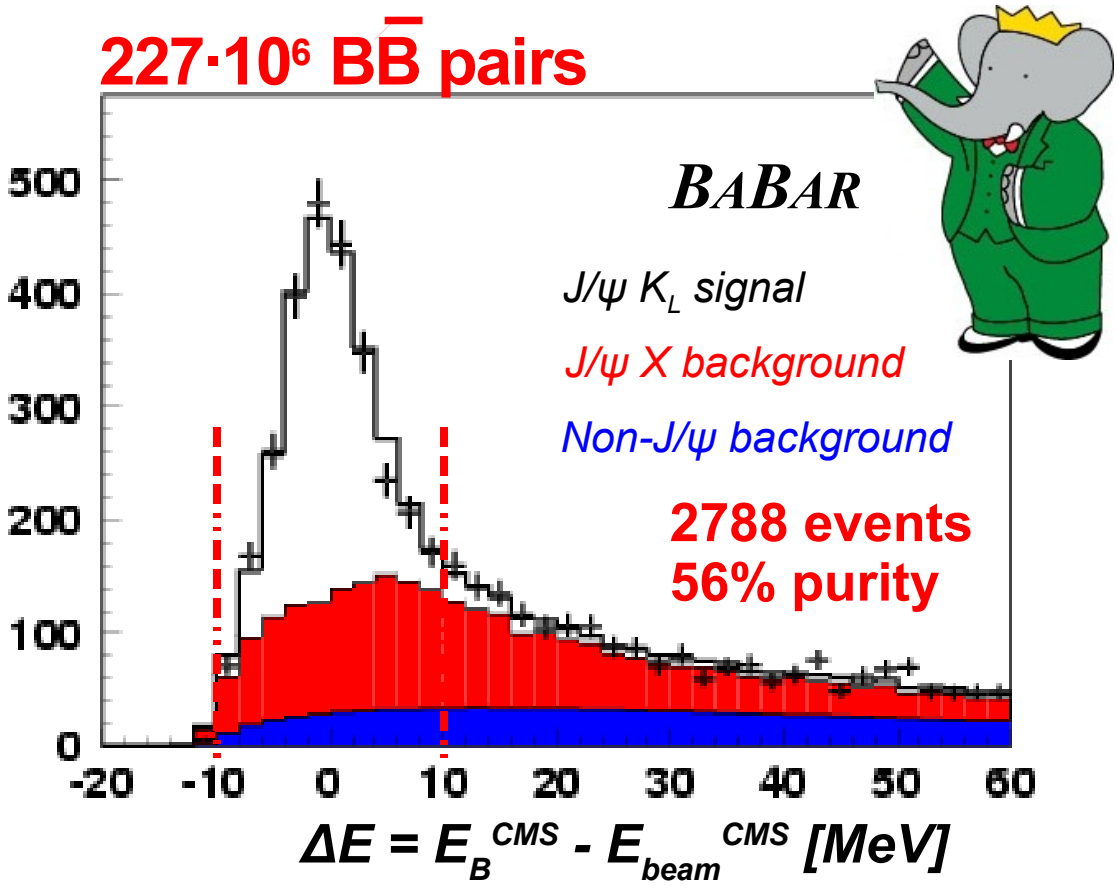
sin2β/sin2φ$_1$ from b→cc̄s decays:B^0→(cc̄)K$_S$,(cc̄)K$_L$

- ... even for the modes with K$_L$'s, where kinematic constraints cannot be fully applied:
  - K$_L$ flight direction (cluster centre) & (cc̄) 4-momentum are measured
  - Requirements: M$_{inv}$(charmonium K$_L$) = m$_B$ (BaBar) ; E$_{rec}$ = E$_{beam}$ (Belle)
    → K$_L$ momentum is calculated → p$_B^{CMS}$ (Belle) ; ΔE (BaBar) for selection

535·10^6 BB̄ pairs

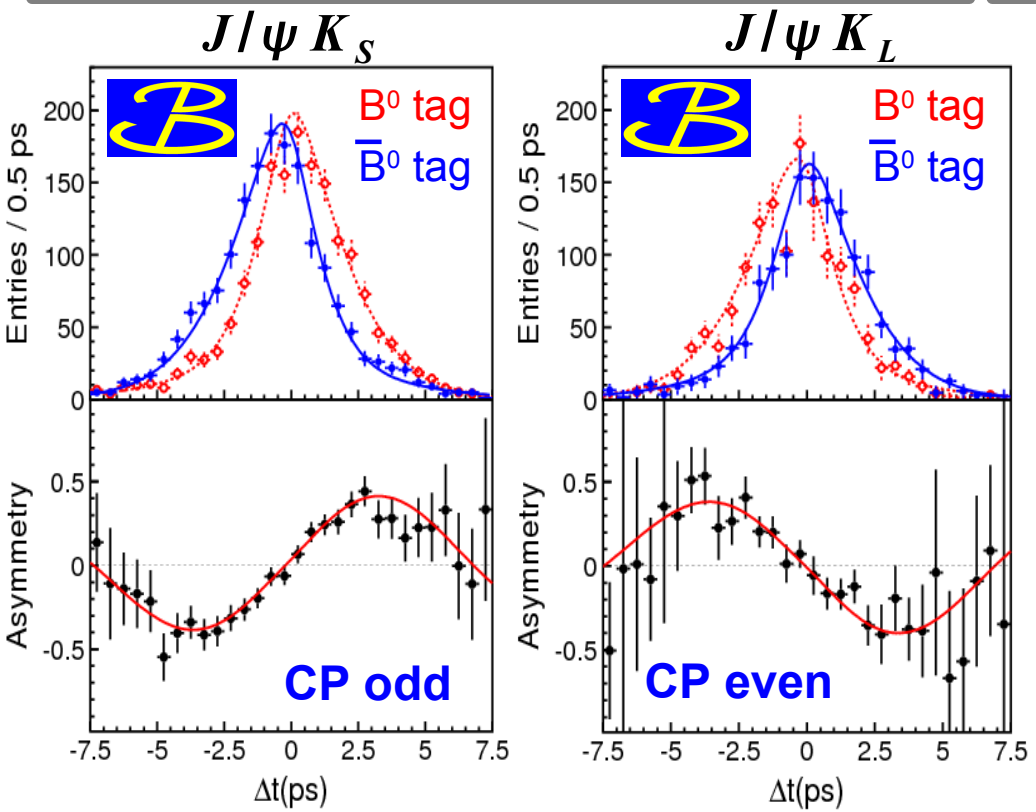


227·10^6 BB̄ pairs



sin2β/sin2φ$_1$ from b→cc̄s decays: Latest Results

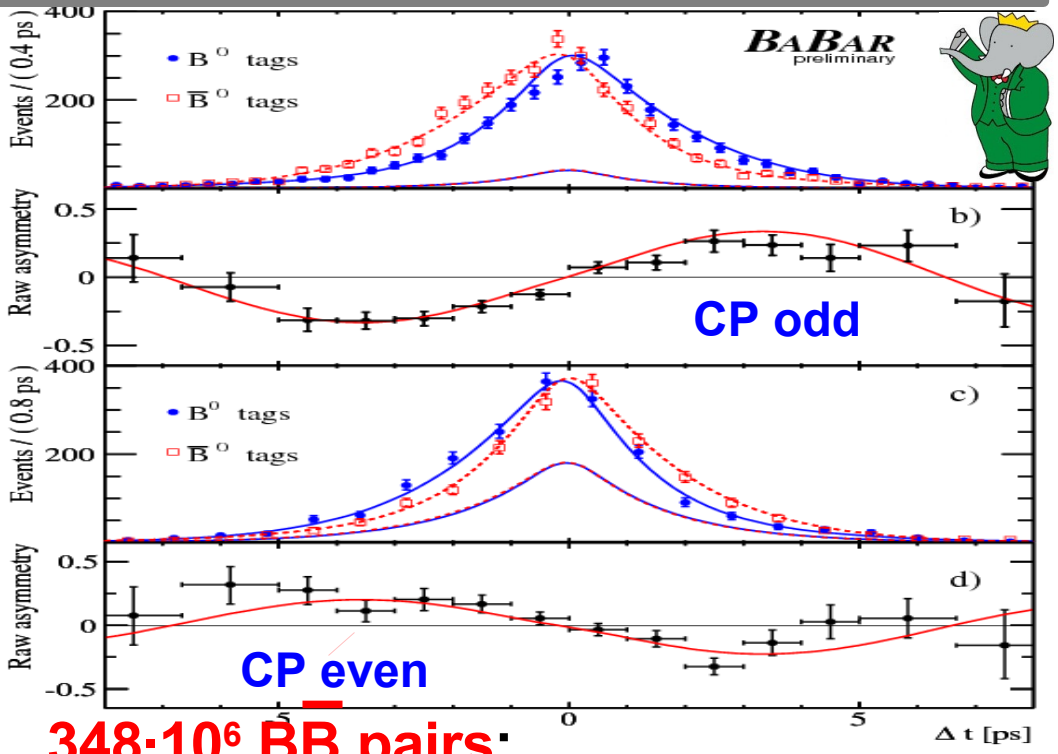
hep-ex/0608039; hep-ex/0507037



535·10^6 BB̄ pairs;

J/ψ K$_S$ & J/ψ K$_L$ combined :

hep-ex/0607107; PRL 94, 161803 (2005)



348·10^6 BB̄ pairs;

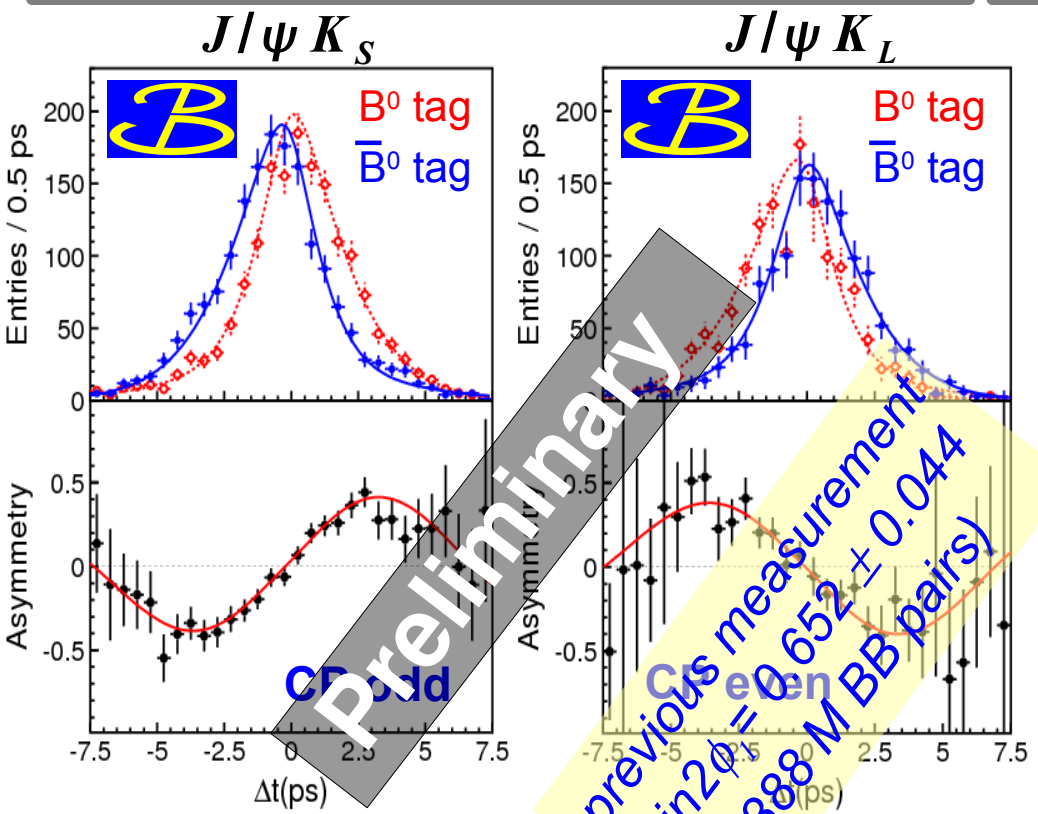
J/ψ K$_S$, ψ(2S) K$_S$, χ$_{c1}$K$_S$, η$_c$ K$_S$,

J/ψ K$_L$ & J/ψ K^{*0}(K^{*0}→K$_S$ π^0)

combined :

sin2β/sin2φ$_1$ from b→cc̄s decays: Latest Results

hep-ex/0608039; hep-ex/0507037

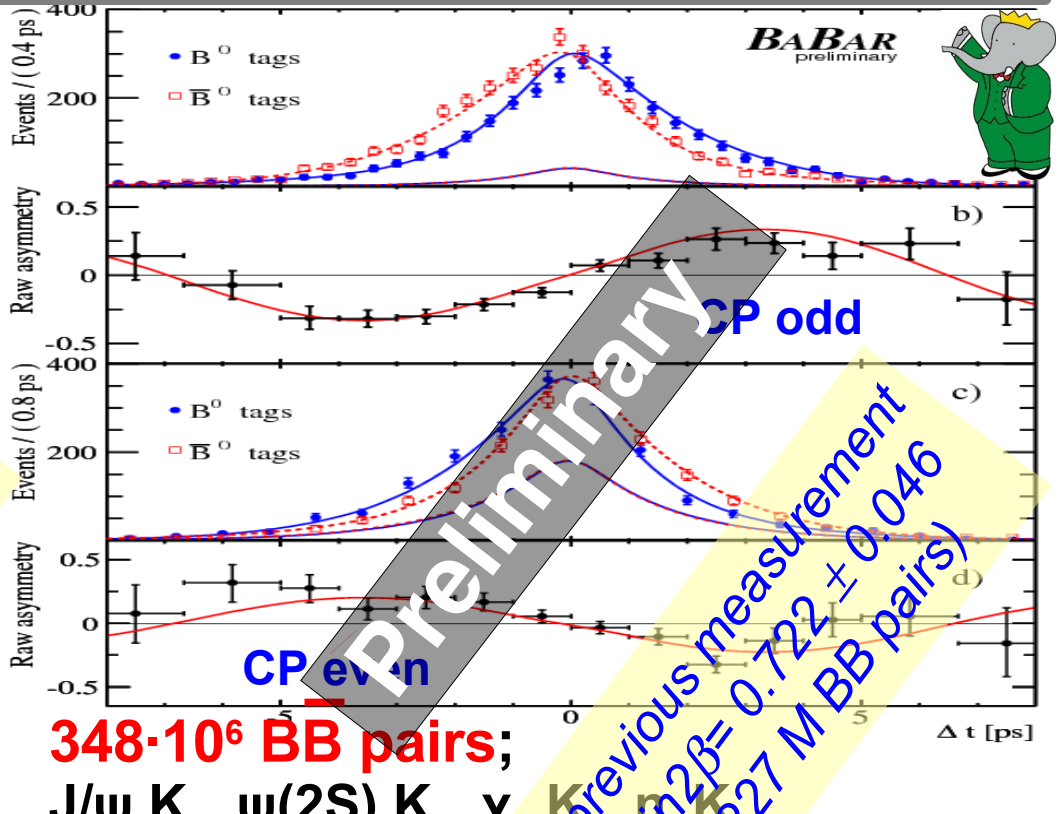


535·10^6 BB̄ pairs;

J/ψ K$_S$ & J/ψ K$_L$ combined :

$$\sin 2\phi_1 = 0.642 \pm 0.031\,(stat) \pm 0.017\,(syst)$$
$$A = (-C) = 0.018 \pm 0.021\,(stat) \pm 0.014\,(syst)$$

hep-ex/0607107; PRL 94, 161803 (2005)



348·10^6 BB pairs;

J/ψ K$_S$, ψ(2S) K$_S$, χ$_{c1}$ K$_S$, η$_c$ K$_S$

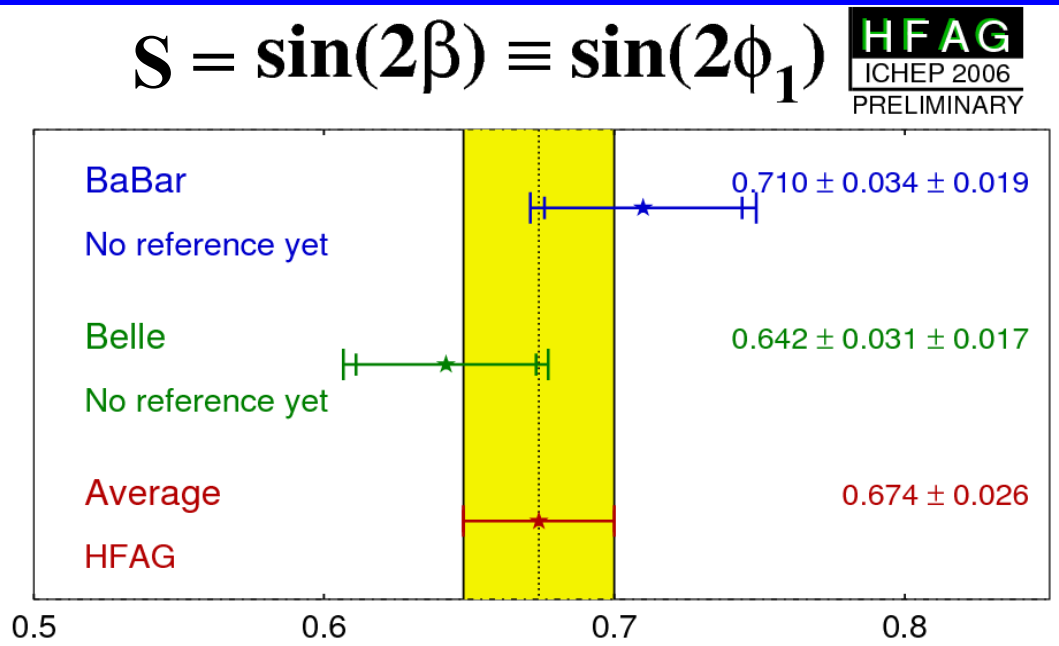
J/ψ K$_L$ & J/ψ K^{*0}(K^{*0}→K$_S$ π^0)

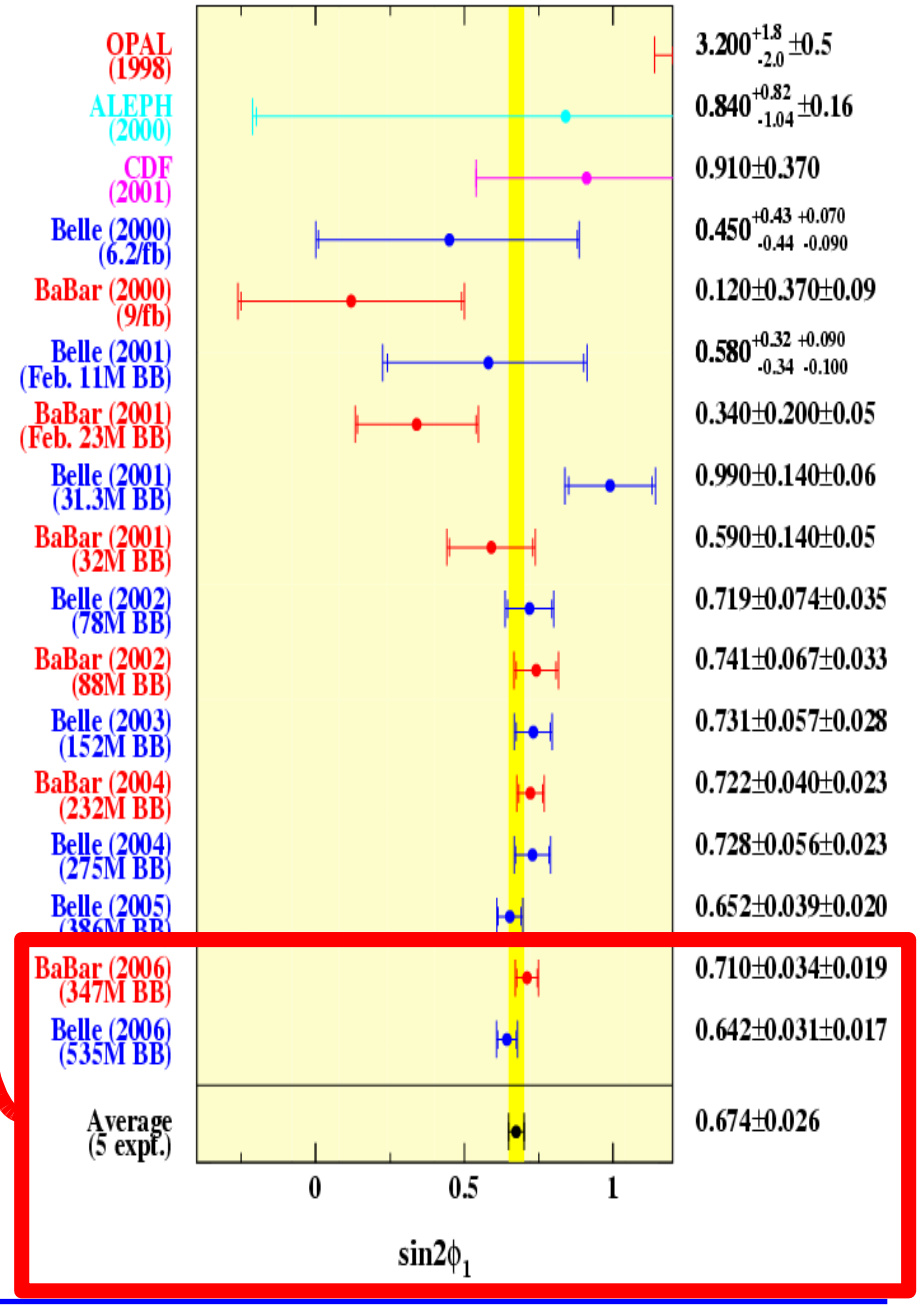
combined :

$$\sin 2\beta = 0.710 \pm 0.034\,(stat) \pm 0.019\,(syst)$$
$$C = (-A) = 0.07 \pm 0.028\,(stat) \pm 0.018\,(syst)$$

sin2β/sin2φ$_1$ from b→ccs̄ decays: ICHEP 2006

$$S = \sin(2\beta) \equiv \sin(2\phi_1)$$



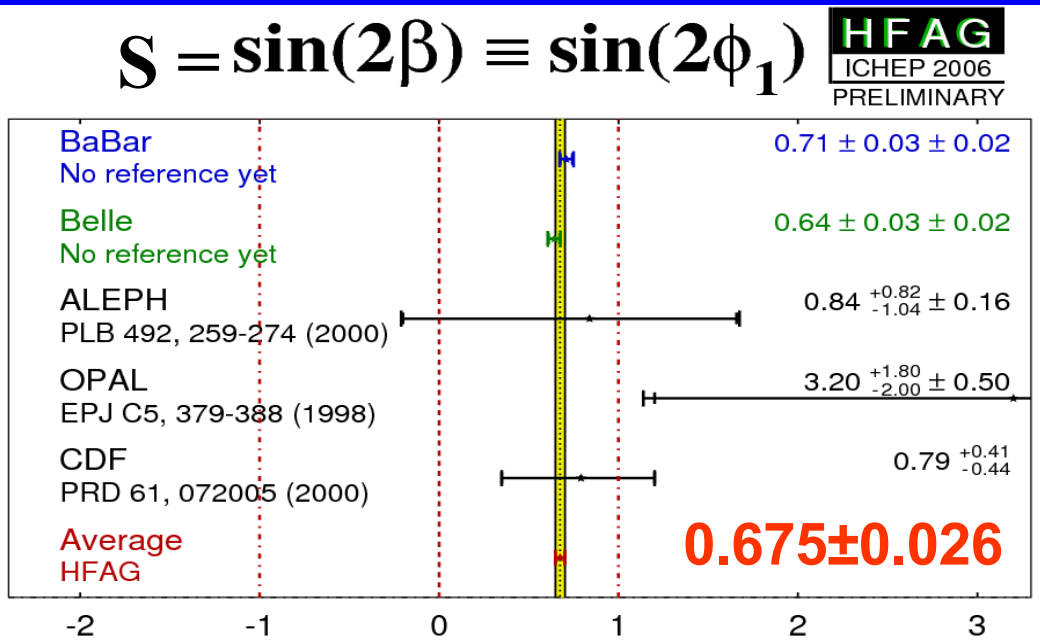


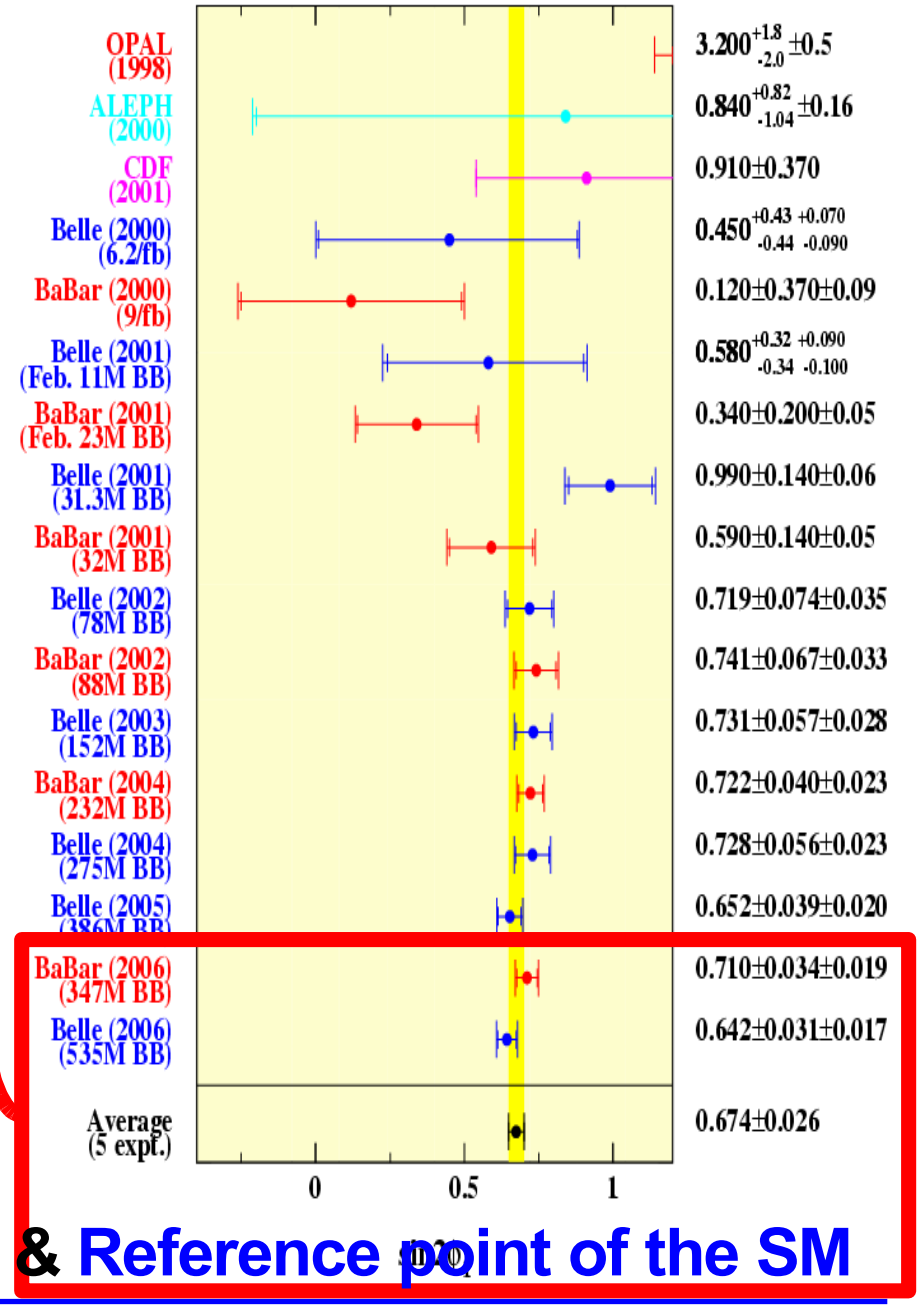
- B-factories average :

$$S = \sin(2\phi_1)/\sin(2\beta) = 0.674 \pm 0.026$$
$$A = (-C) = -0.012 \pm 0.022$$

sin2β/sin2φ$_1$ from b→ccs̄ decays: ICHEP 2006

$$S = \sin(2\beta) \equiv \sin(2\phi_1)$$





- B-factories average :

$$S = \sin(2\phi_1)/\sin(2\beta) = 0.674 \pm 0.026$$
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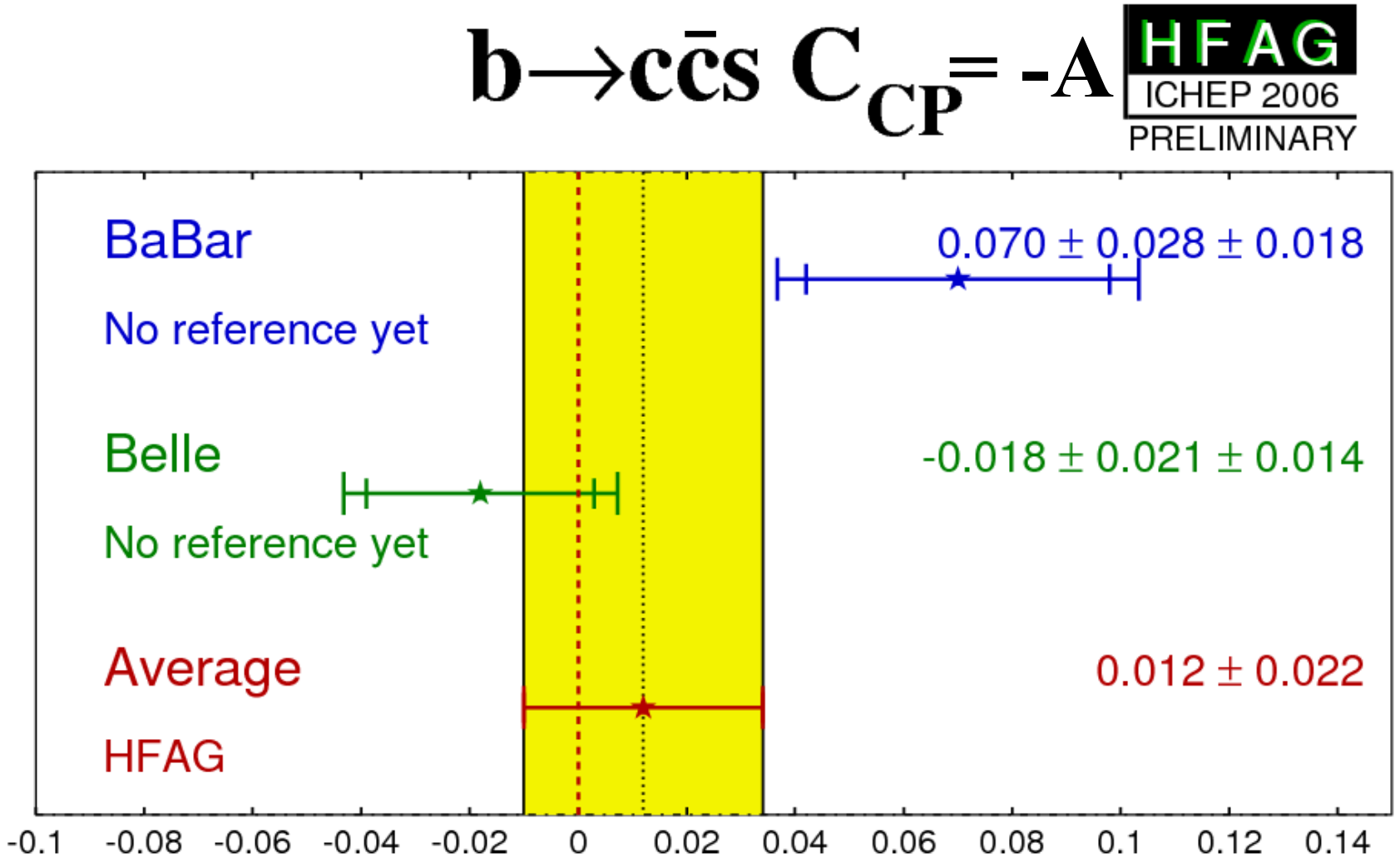
- World average :

$$S = \sin 2\phi_1 / \sin 2\beta = 0.675 \pm 0.026$$

- **Precision measurement (< 4% error) & Reference point of the SM**

sin2β/sin2φ$_1$ from b→ccs̄ decays: ICHEP 2006



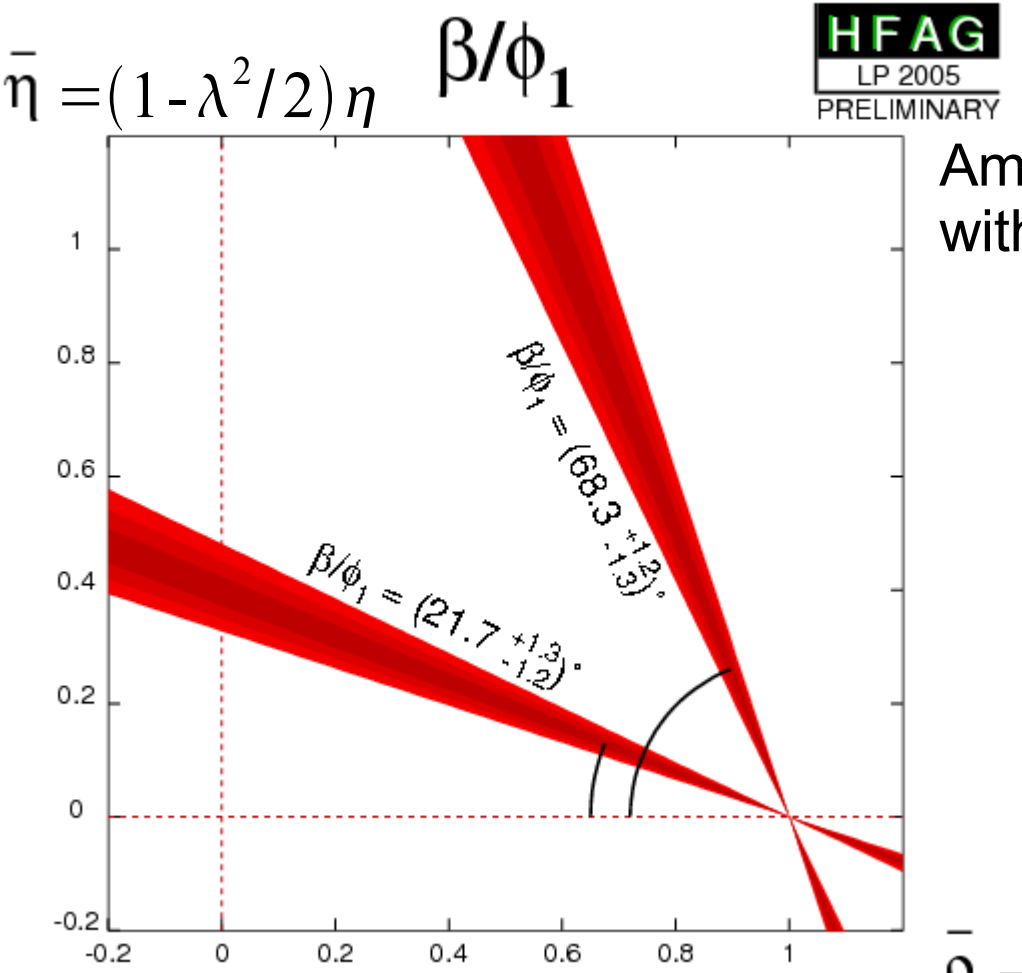
- There is no direct CPV in the SM ...
  but ~2σ difference between the two B factories ...
  ➔We have to wait for more data again ...

β/ϕ_1 Constraints from $b \to c\bar{c}s$ Modes

- World average:

$$S = \sin 2\phi_1 / \sin 2\beta = 0.675 \pm 0.026$$

$\beta \equiv \phi_1 = (21.2 \pm 1.0)°$
or
$\beta \equiv \phi_1 = (68.8 \pm 1.0)°$



Ambiguity has to be solved with additional measurements

β/ϕ_1 Constraints from $b\to c\bar{c}s$ Modes

- World average:

$$S = \sin 2\phi_1 / \sin 2\beta = 0.675 \pm 0.026$$

$$\beta \equiv \phi_1 = (21.2 \pm 1.0)^\circ$$
or
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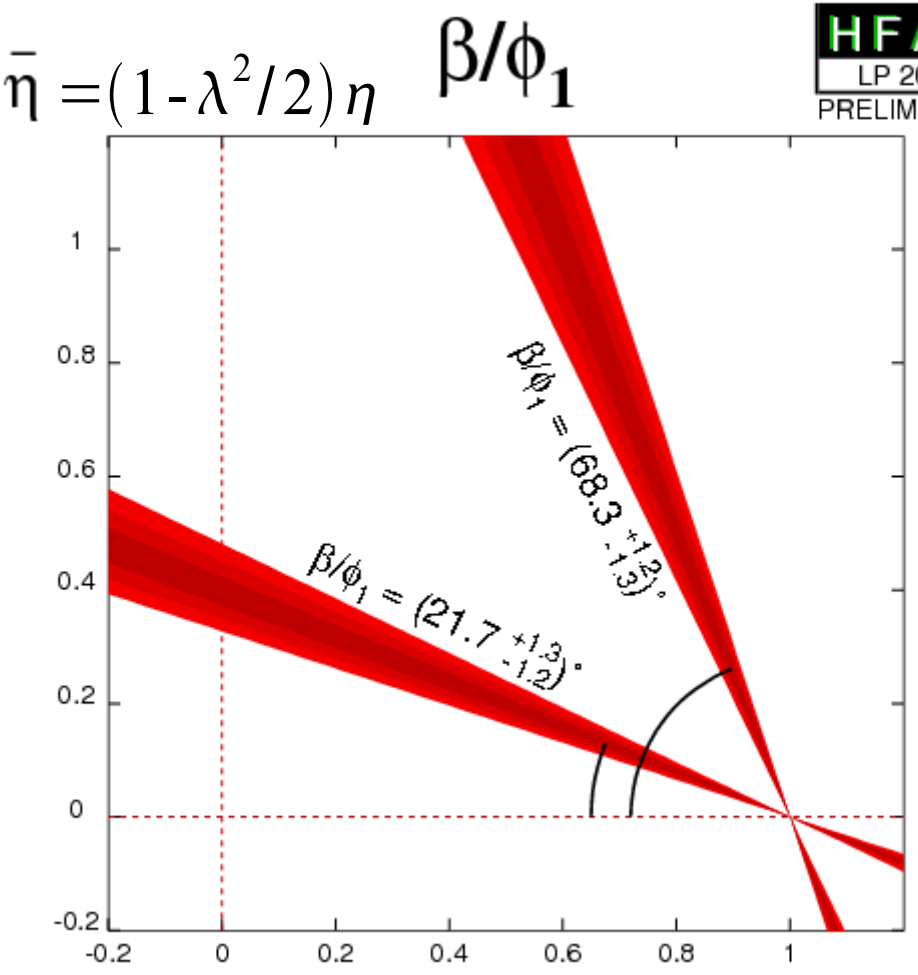


Ambiguity has to be solved with additional measurements, e.g. :

- Time-dependent Dalitz analysis for
  $B^0 \to D^{0(*)}h^0$ ($b\to c\bar{u}d$)
  ($D^{0(*)}\to K_S\pi^+\pi^-$; h=ω,η,π)

$$\sin 2\phi_1 = 0.78 \pm 0.44 \pm 0.22$$
$$\cos 2\phi_1 = 1.87\ ^{+0.40\ +0.22}_{-0.53\ -0.32}$$

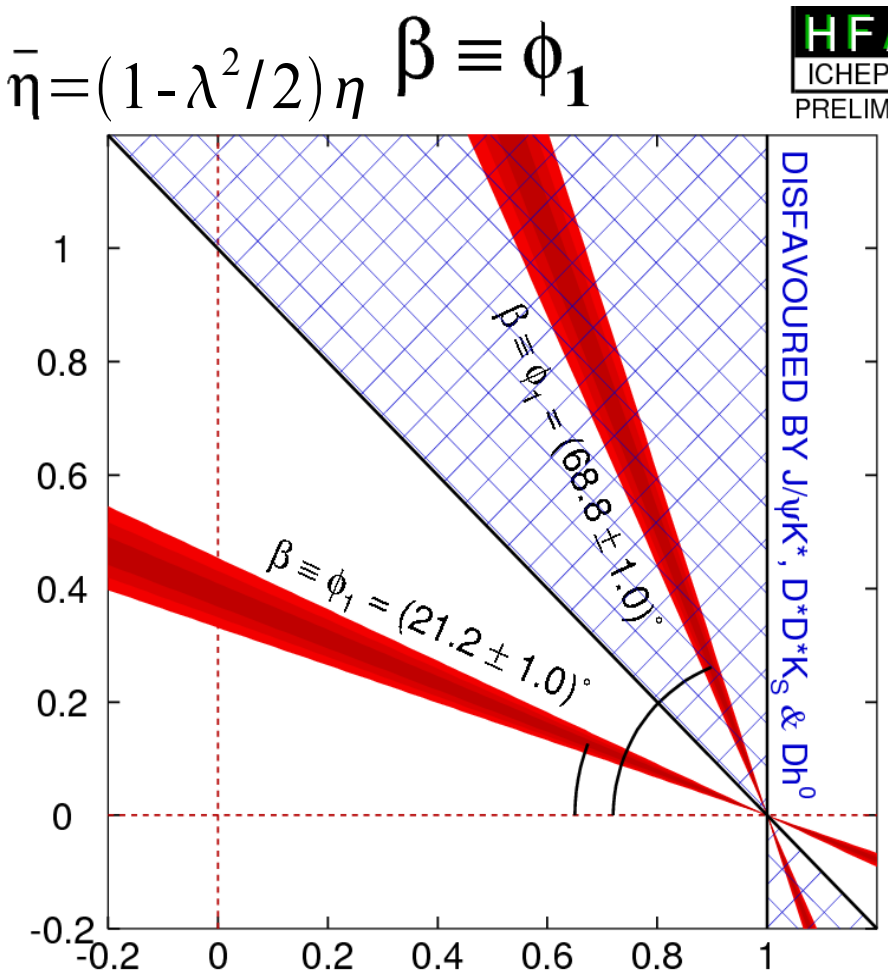
hep-ex/0605023
(PRL submitted)

β/ϕ_1 Constraints from $b\to c\bar{c}s$ Modes

- World average:

$$S = \sin 2\phi_1 / \sin 2\beta = 0.675 \pm 0.026$$

$$\beta \equiv \phi_1 = (21.2 \pm 1.0)^\circ$$
or
$$\beta \equiv \phi_1 = (68.8 \pm 1.0)^\circ$$



Ambiguity has to be solved with additional measurements, e.g. :

- Time-dependent Dalitz analysis for
  $B^0 \to D^{0(*)} h^0$ ($b\to c\bar{u}d$)
  ($D^{0(*)} \to K_S\pi^+\pi^-$; $h=\omega,\eta,\pi$)

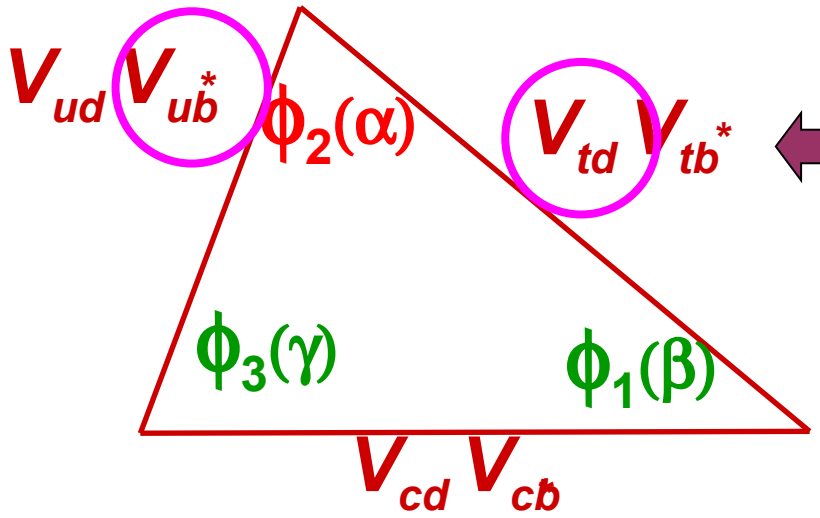
$$\sin 2\phi_1 = 0.78 \pm 0.44 \pm 0.22$$
$$\cos 2\phi_1 = 1.87^{+0.40\ +0.22}_{-0.53\ -0.32}$$

hep-ex/0605023 (PRL submitted)

- Consistent with $\cos\phi_1$ from $B0\to J/\psi\, K^*$ (time-dependent angular analysis)

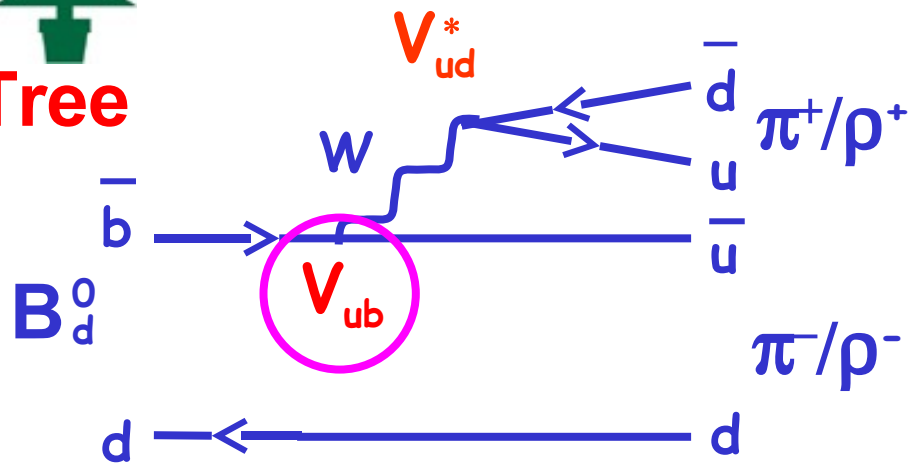
PRL95,091601(2005) **PRD71,032005(2005)**

Measurements of α/φ_2

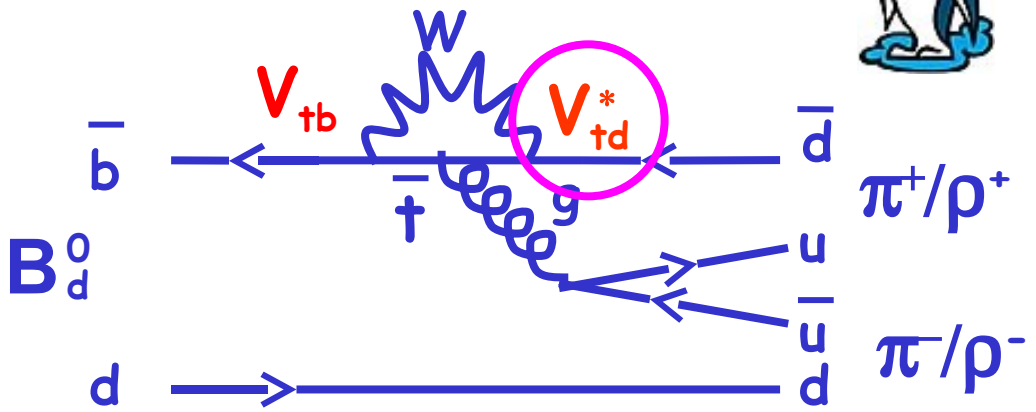


mixing

Tree



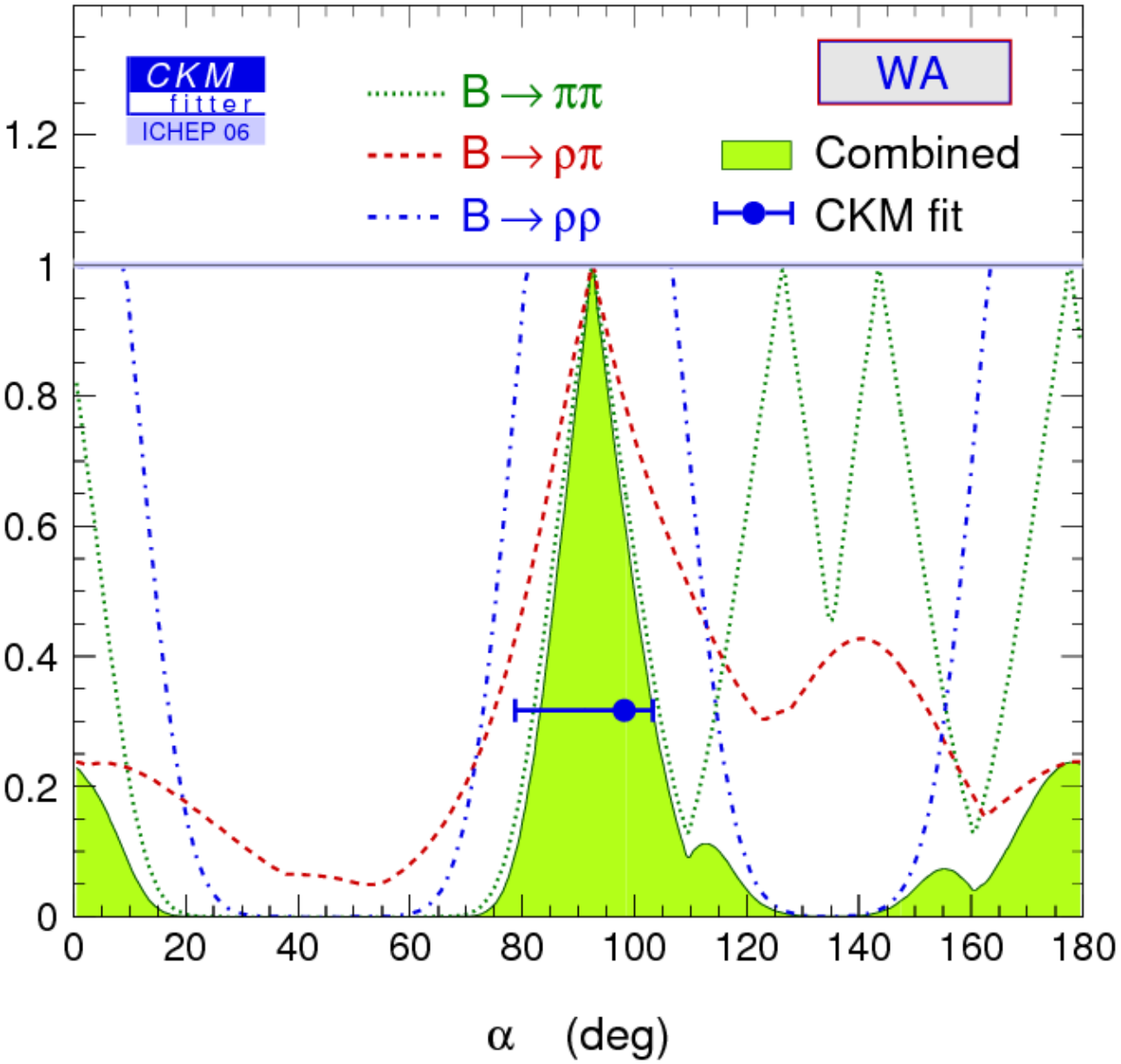
Penguin



$S \neq \xi \sin\phi_2$

Need Isospin Analysis for P/T contrib.

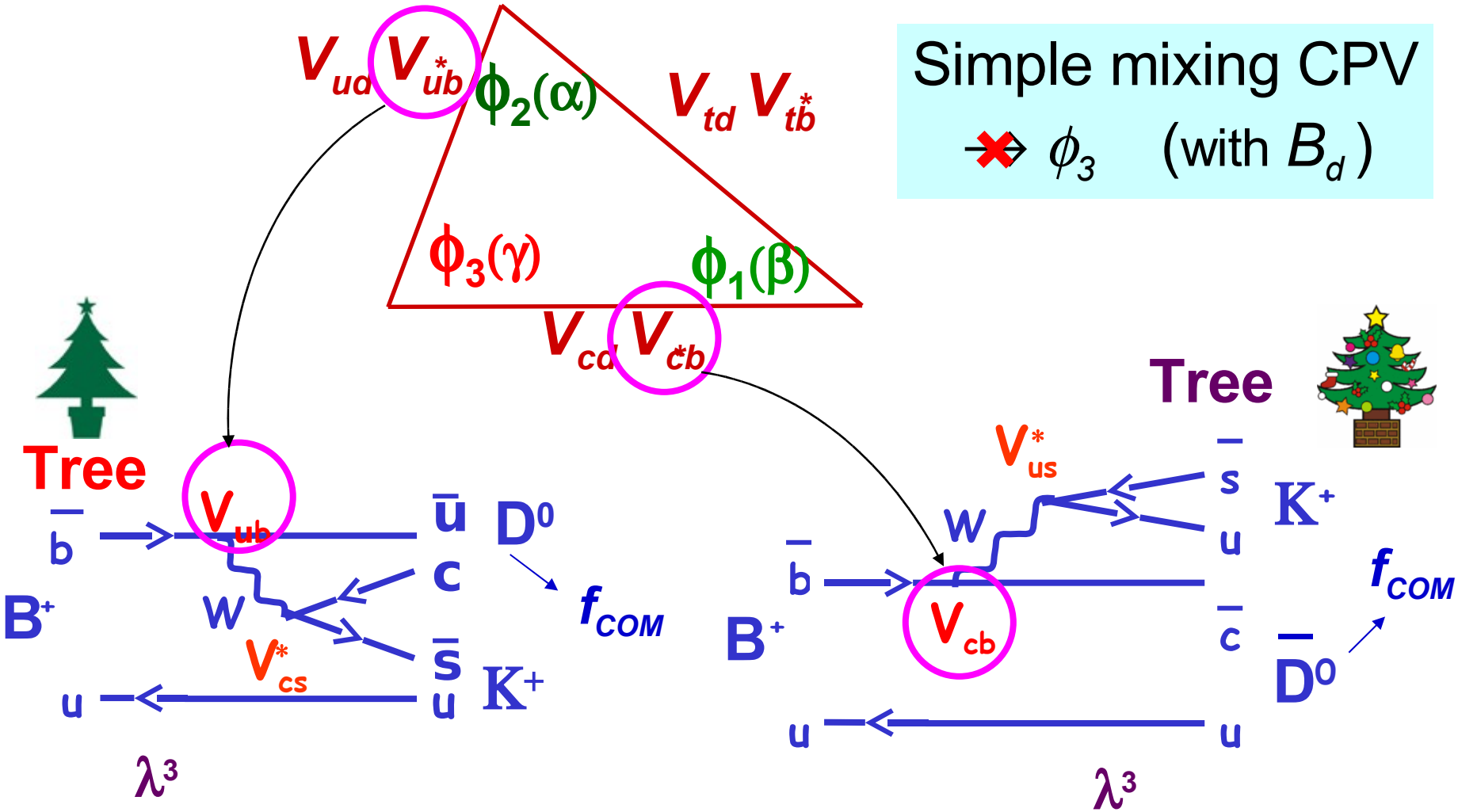
Summary of α/φ_2 Measurements



$\alpha/\phi_2 = [93\ ^{+11}_{-9}]^\circ$

It turned out
to be more difficult
than expected
two years ago...

Measurements of γ/φ_3

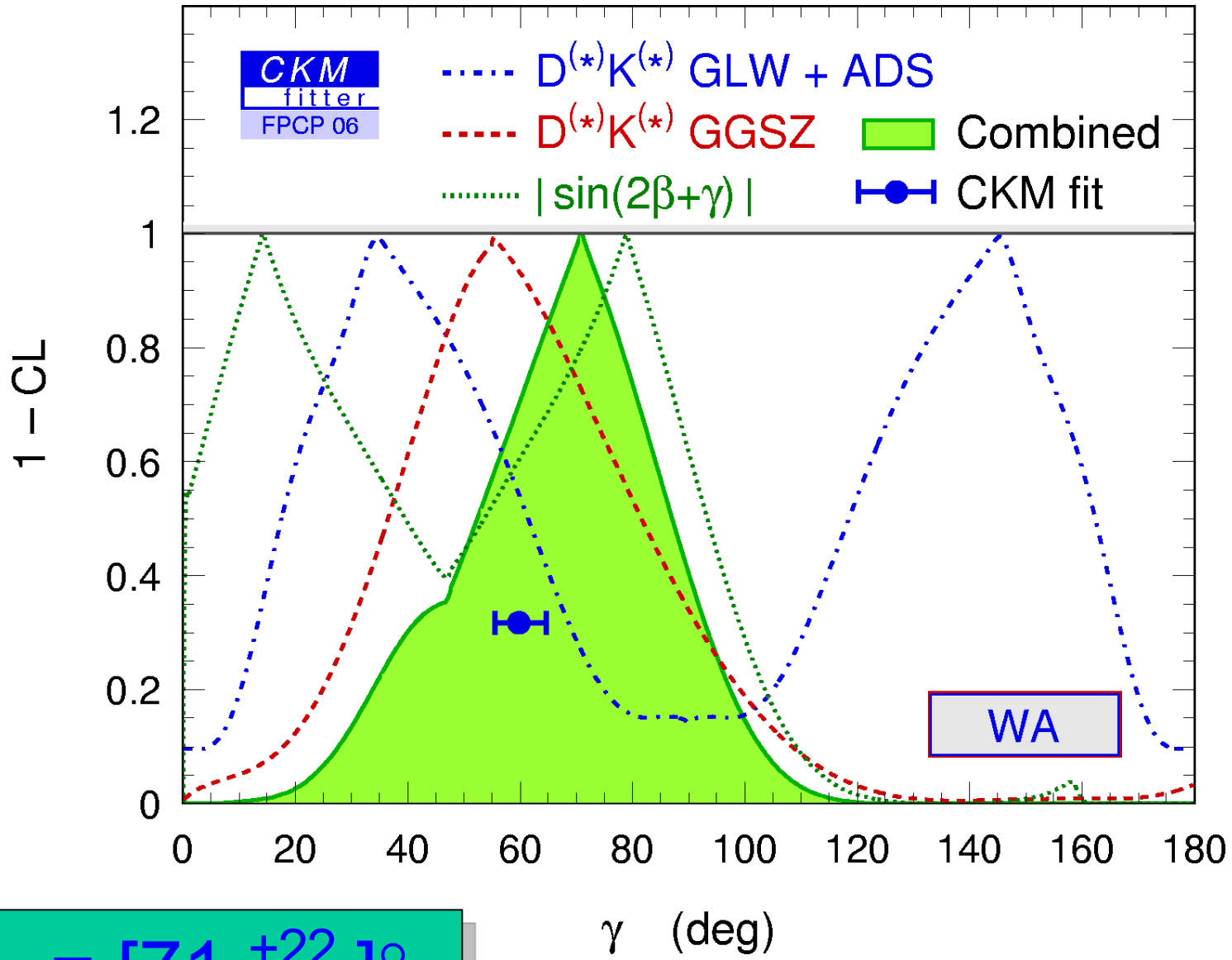


Simple mixing CPV

ϕ_3 (with B_d)

interference gives $\delta \pm \varphi_3(B^\pm)$

Summary of γ/ϕ_3 Measurements



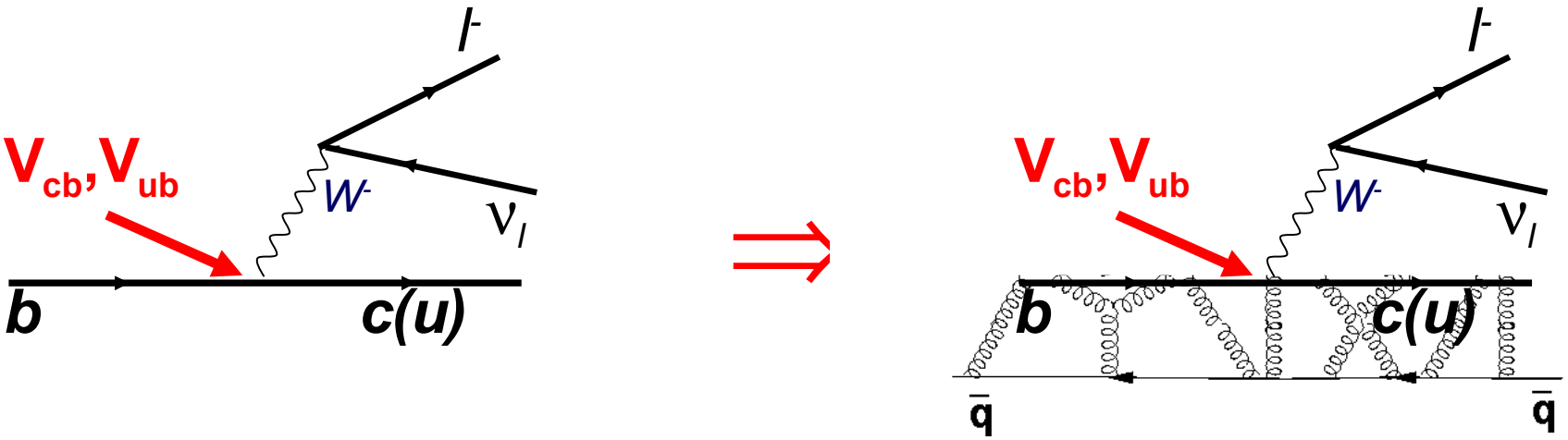
$$\gamma/\phi_3 = [71\ ^{+22}_{-30}]^\circ$$

Measurements of $|V_{cb}|$ and $|V_{ub}|$

Semileptonic B decays - reasonably good theoretical understanding

two ways:

- exclusive final states
- inclusive final states

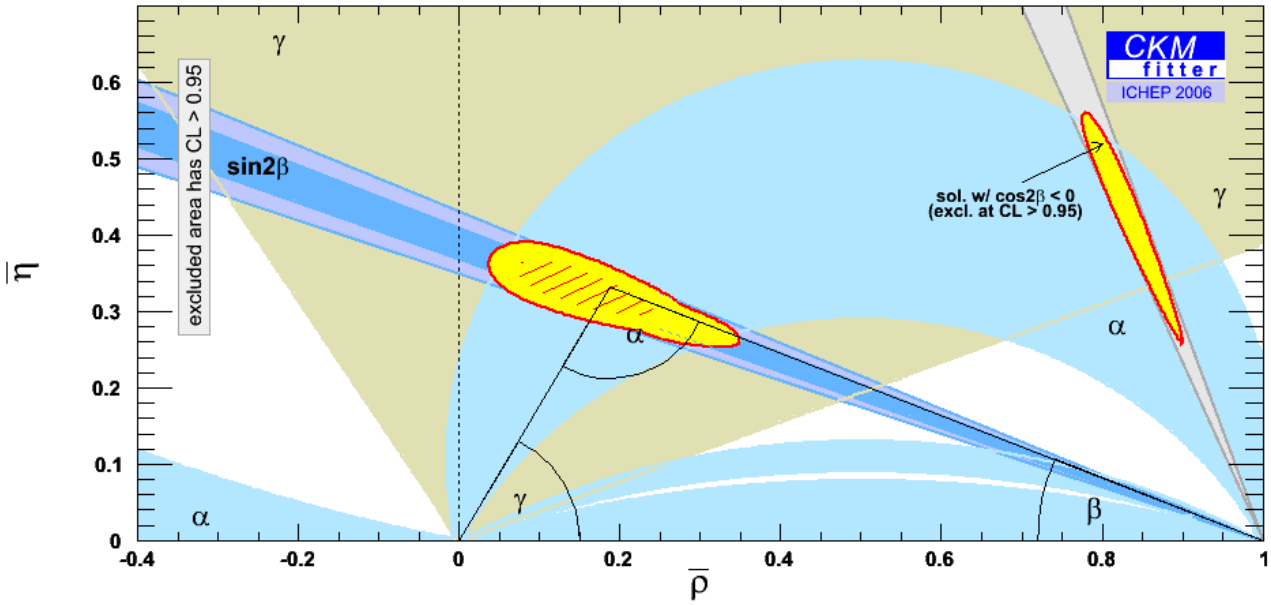


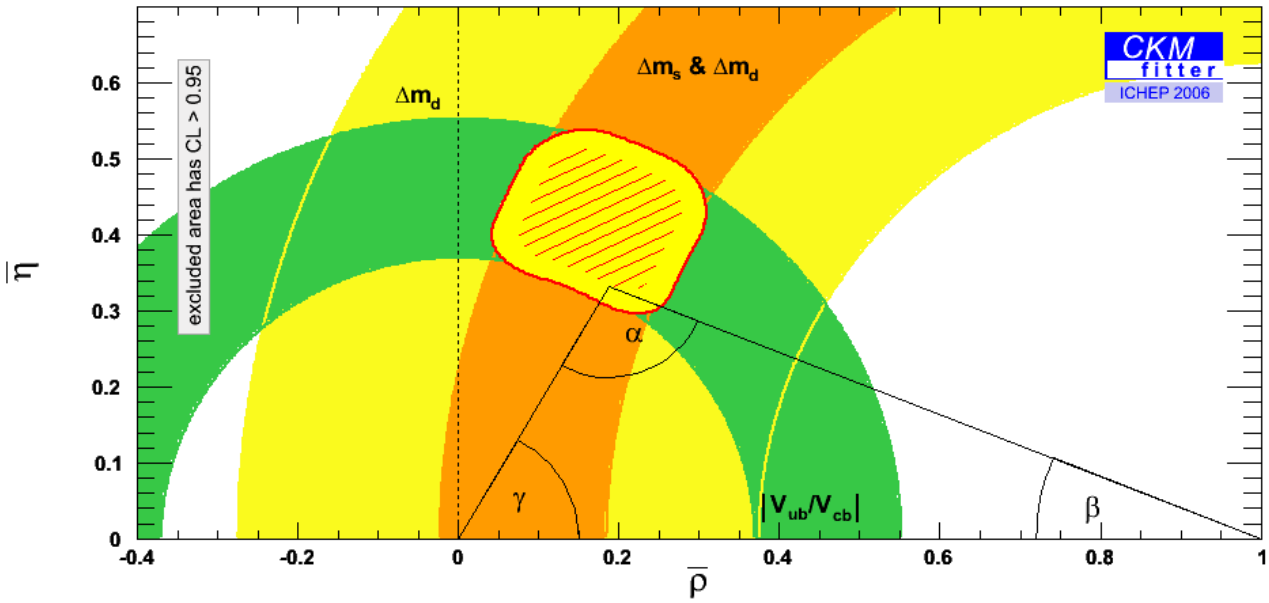
$\Delta|V_{cb}| < 2\%$

$\Delta|V_{ub}| \sim 7\%$

SEVERAL THEORETICAL APPROACHES TO HANDLE HADRONIC EFFECTS

Summary of Measurements of UT angles/sides





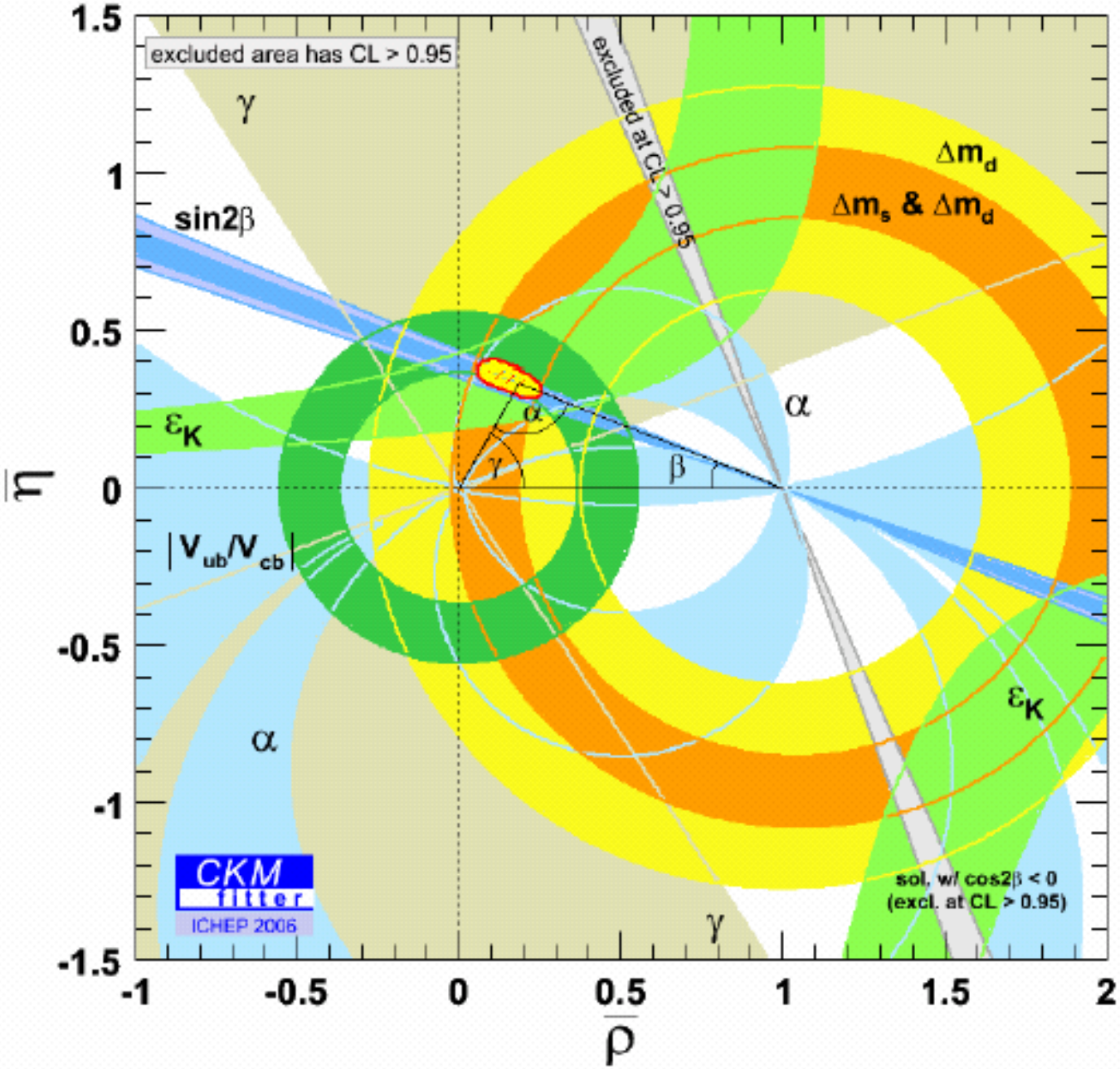
$\alpha/\phi_2 = [93\ ^{+11}_{-9}]^\circ$

$\gamma/\phi_3 = [71\ ^{+22}_{-30}]^\circ$

$\Delta|V_{ub}/V_{cb}| \sim 7\%$

$\Delta|V_{td}/V_{ts}| \sim 4\%$

Summary of CKM/UT Measurements



KM-phase = source for CPV ~ Established !

Precise Test of SM (& search for NP effect) ~ in progress (Need more Data)

Search for New Physics

In spite of Great Success of SM, there must be New Physics beyond it at High Energy scale

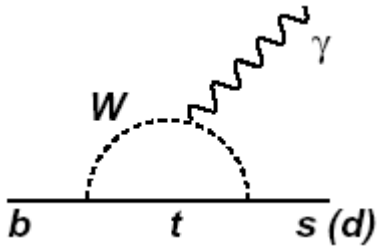
CPV in B decays a powerful tool to search for NP (**New Phase**)

Rare B decays excellent opportunities for NP search

Loop diagram Penguins [$b \to s(d)\,\gamma$, $b \to s(d)\,l^+l^-$]

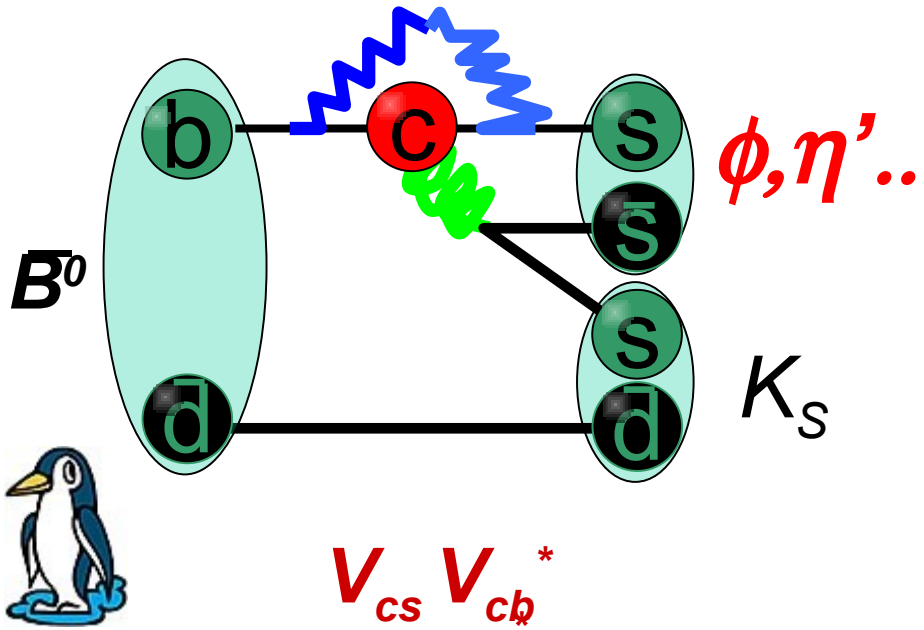
Key

Decays involving τ ($\leftrightarrow H^{\pm}$)



τ Decays (Lepton-Flavor Violation = NP) : B-factory = τ-factory

$\sin 2\beta^{eff}/\sin 2\varphi_1^{eff}$ from b→s Penguin Decays

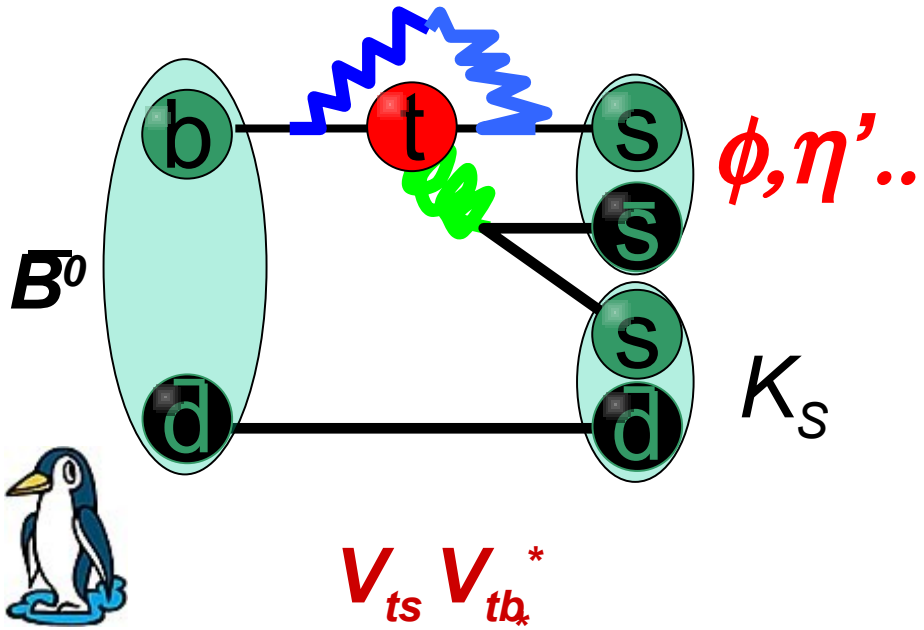


SM scenario :

$S_{ccs} = S_{sss} = \sin 2\beta/\sin 2\varphi_1$

$A_{ccs} = A_{sss} = 0$

$\sin2\beta^{eff}/\sin2\varphi_1^{eff}$ from b→s Penguin Decays

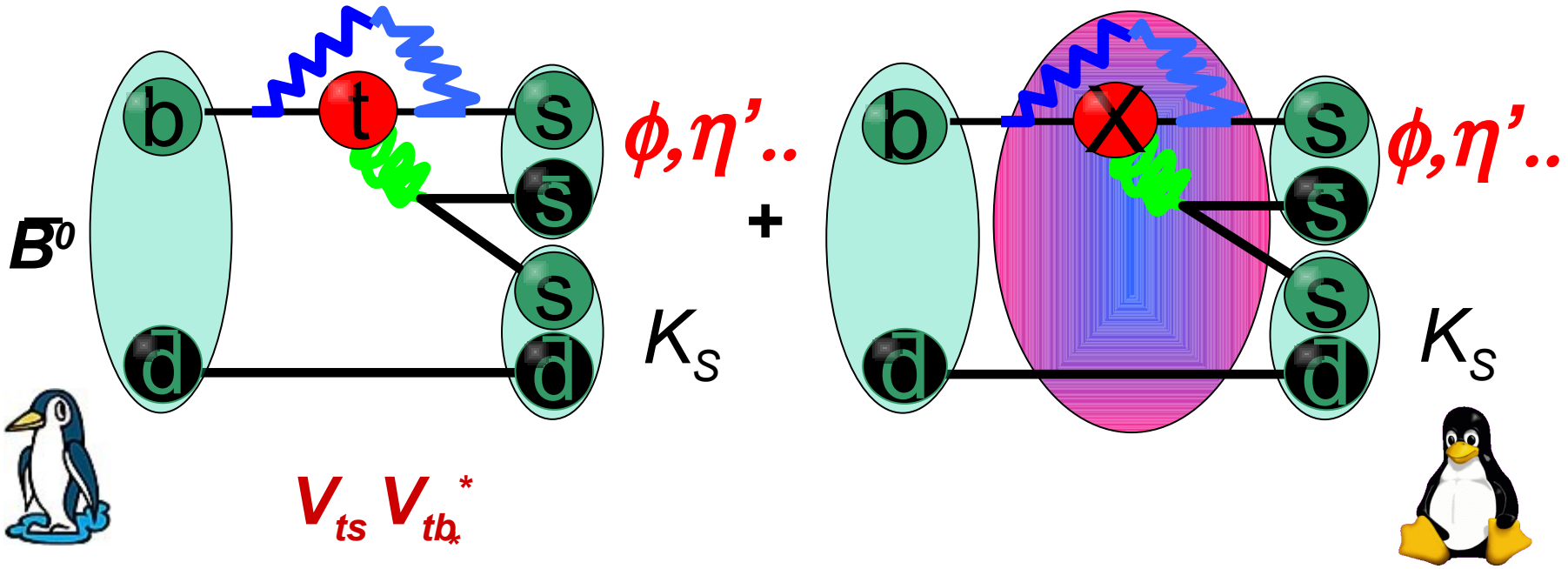


SM scenario :

$$S_{ccs} = S_{sss} + \Delta S_{SM} = \sin2\beta/\sin2\varphi_1$$

$$A_{ccs} \sim A_{sss} \sim 0$$

$\sin2\beta^{eff}/\sin2\varphi_1^{eff}$ from $b\to s$ Penguin Decays



SM scenario :

$S_{ccs} = S_{sss} + \Delta S_{SM} = \sin2\beta/\sin2\varphi_1$

$A_{ccs} \sim A_{sss} \sim 0$

Scenario with New Physics :

$S_{ccs} \neq \Delta S_{SM} + S_{sss}$

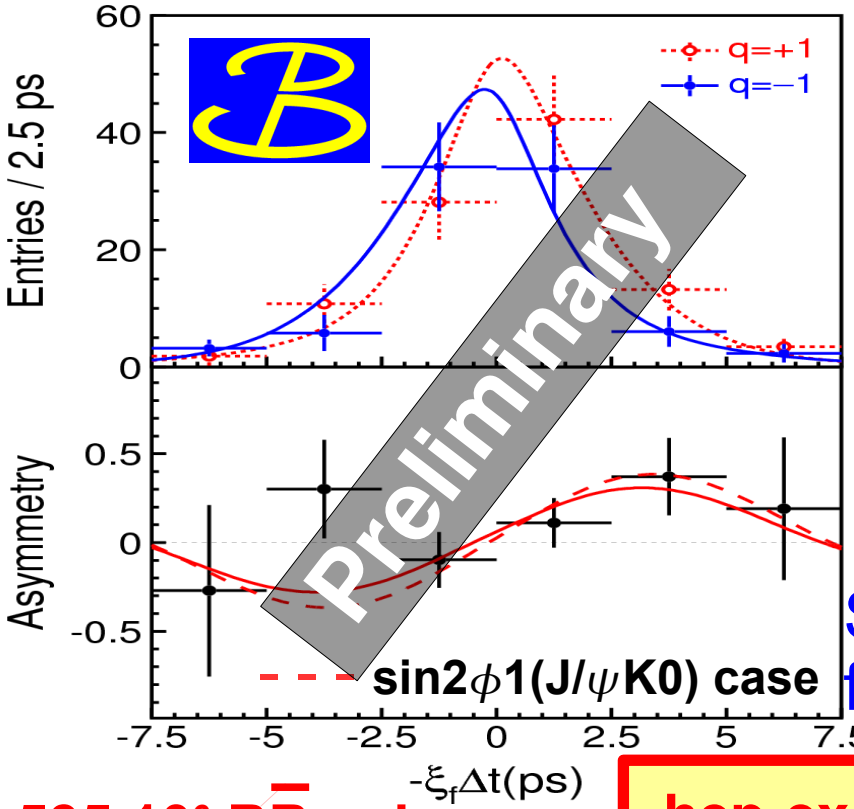
$A_{ccs} \neq A_{sss}$

Theoretical evaluation for ΔS_{SM} are crucial for each $s\bar{q}q$ mode !

"$b \to c\bar{c}s$: $\sin2\phi_1$" (SM reference) ⇒ **deviation(?)**

b→s Penguin Decays: $B^0 \to \phi K^0$

- **Almost pure penguin ("golden" mode)**
- **$|\Delta S_{SM}| \leqslant 0.04$ (CPV phase beyond SM?)**
- ϕ clean to reconstruct; but BR~9×10^{-6}

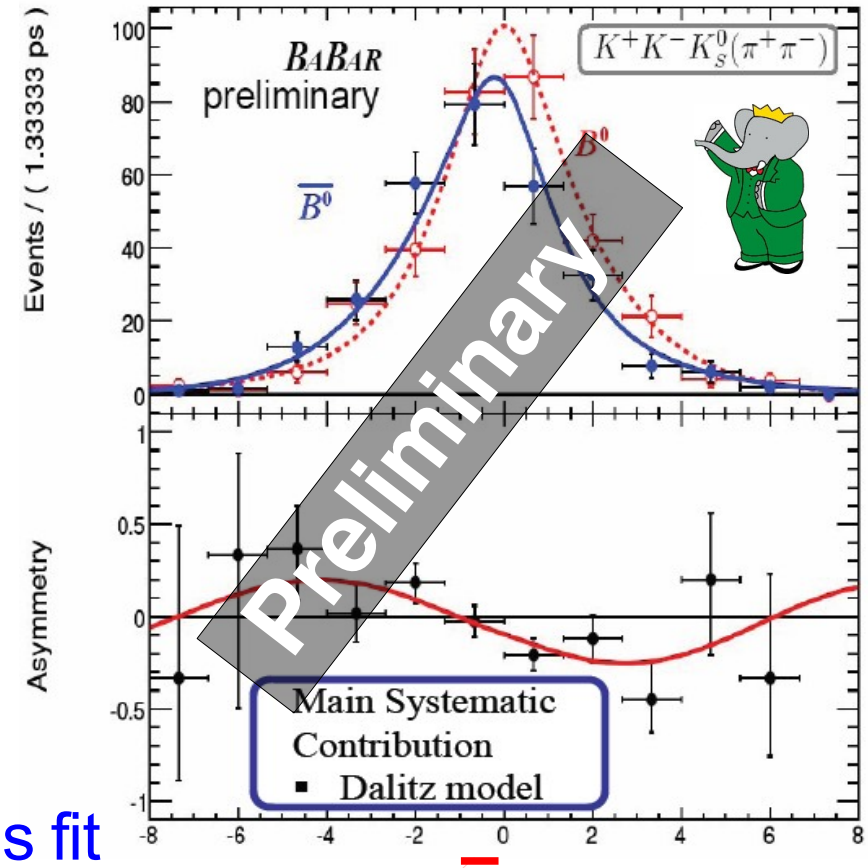


535·10⁶ $B\bar{B}$ pairs

hep-ex/0608039

$$S = \sin 2\phi_1^{eff} = 0.50 \pm 0.21 \pm 0.05$$
$$A = (-C) = 0.07 \pm 0.15 \pm 0.06$$

Simultaneous fit for K_s &K_L sample



347·10⁶ $B\bar{B}$ pairs

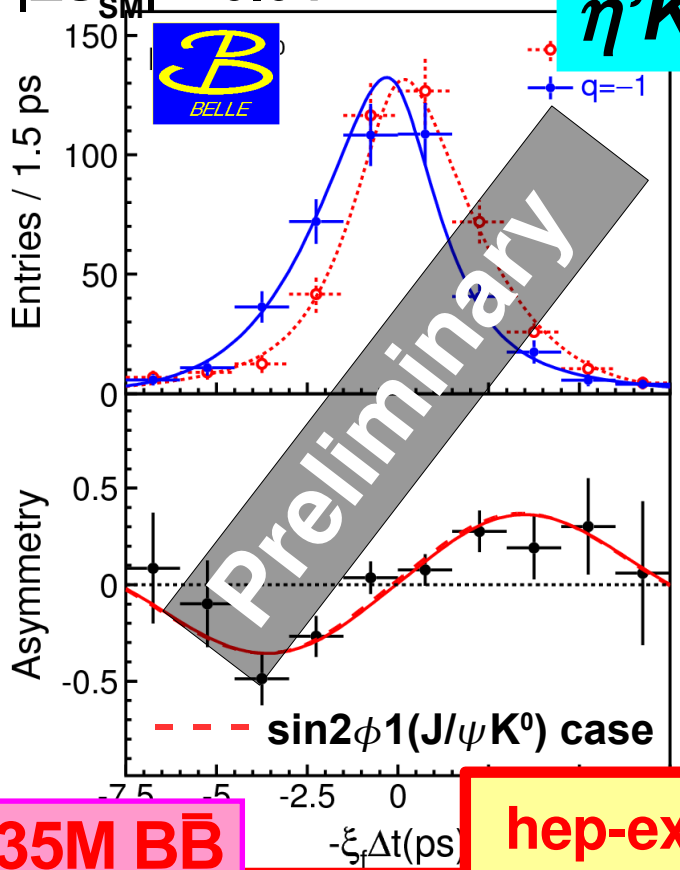
hep-ex/0607112

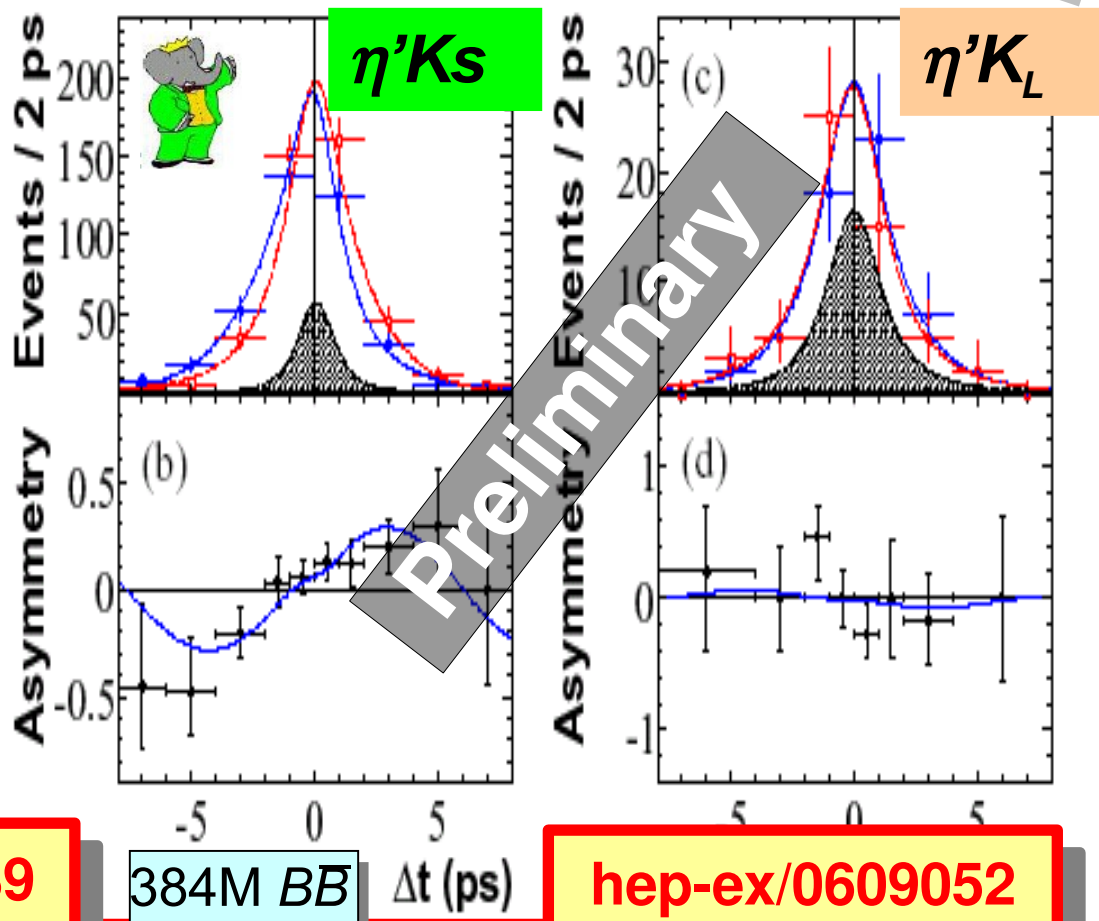
$$S = \sin 2\beta^{eff} = 0.12 \pm 0.31 \pm 0.10$$
$$C = (-A) = 0.18 \pm 0.20 \pm 0.10$$

b→s Penguin Decays: $B^0 \to \eta' K^0$

1st observation of b → s mode TCPV!

- Another "golden" mode:
  - Largest branching ratio among the b→s penguin modes (BR ~ 6×10^{-5})
  - $|\Delta S_{SM}| < 0.04$





535M BB̄

hep-ex/0608039

"$\sin2\phi_1$" = +0.64 ± 0.10 ± 0.04

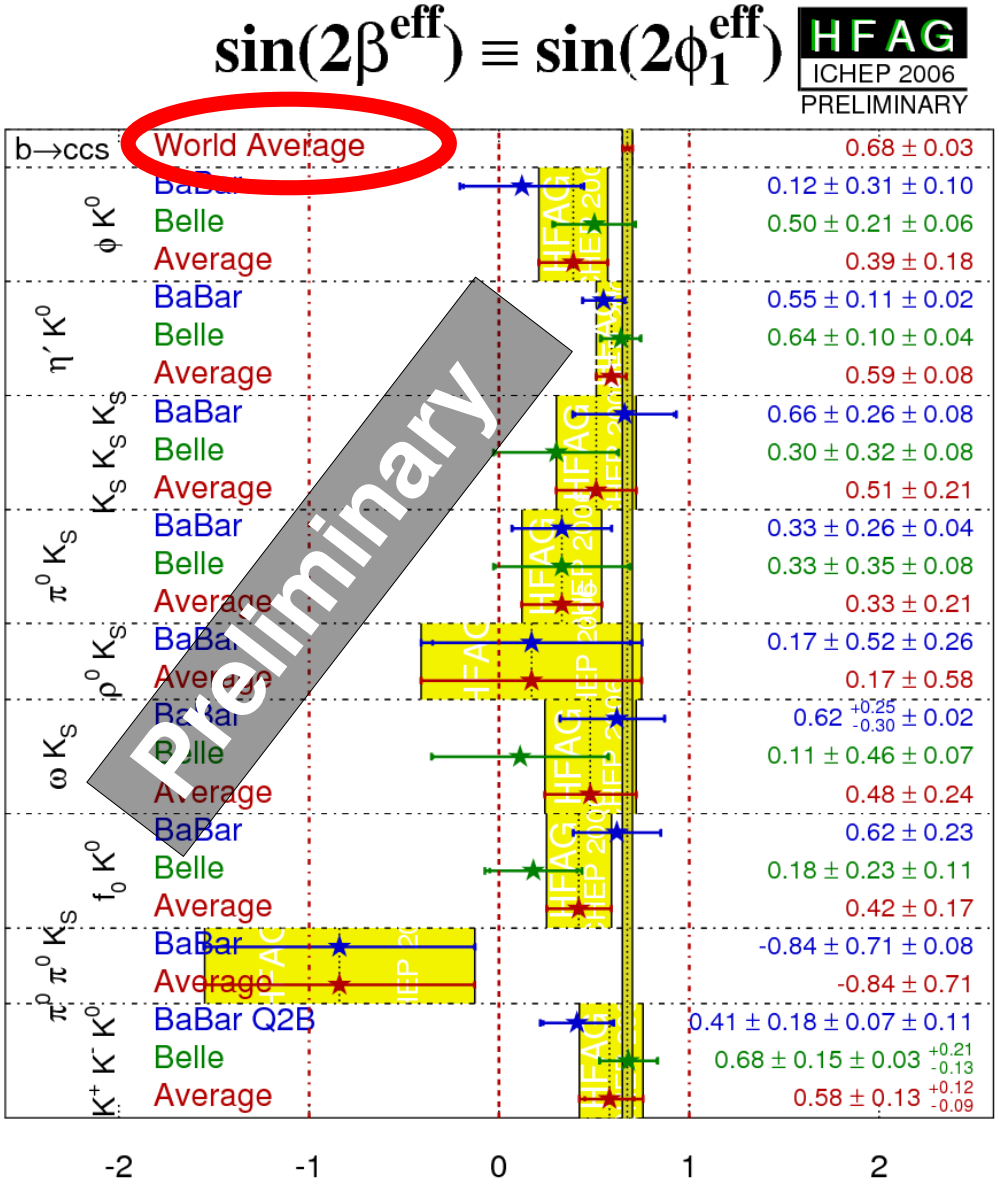
5.6σ A = +0.01 ± 0.07 ±0.05

hep-ex/0609052

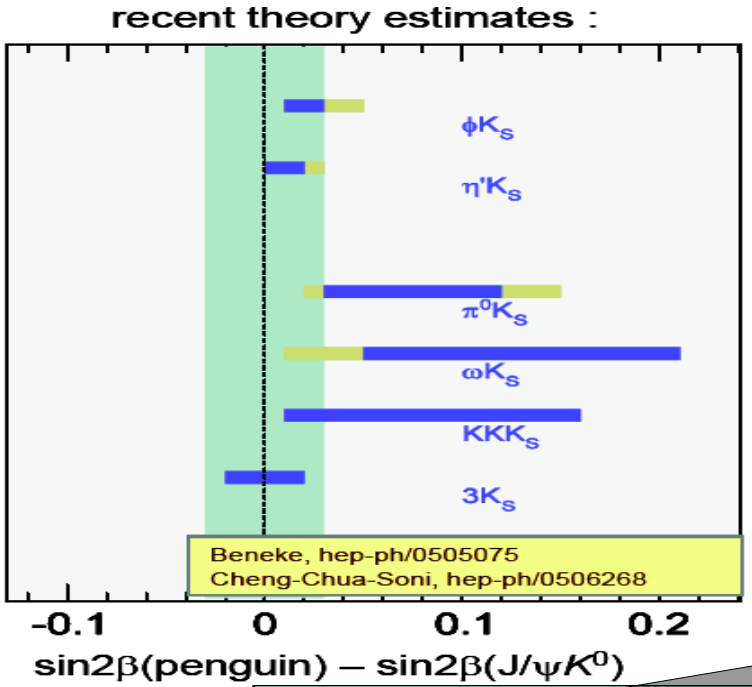
"$\sin2\phi_1$" = +0.58 ± 0.10 ± 0.03

5.5σ A = +0.16 ± 0.07 ± 0.03

Summary for b→s Penguins in 2006



Smaller than b→cc̄s in all 9 modes ...



Theory : tends to positive shifts ...

Naïve average of all modes :

$\sin 2\beta^{eff} = 0.52 \pm 0.05$

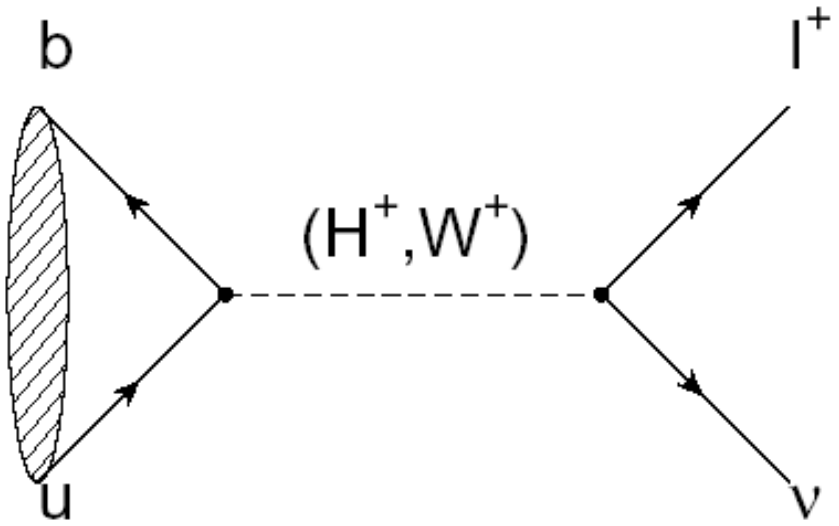
2.6 σ deviation

Use with caution!

Need more data for conclusive assumptions!

Decays with "Missing Energy" (≥ 2 neutrinos)

$B^{\pm} \to \tau^{\pm} \nu$



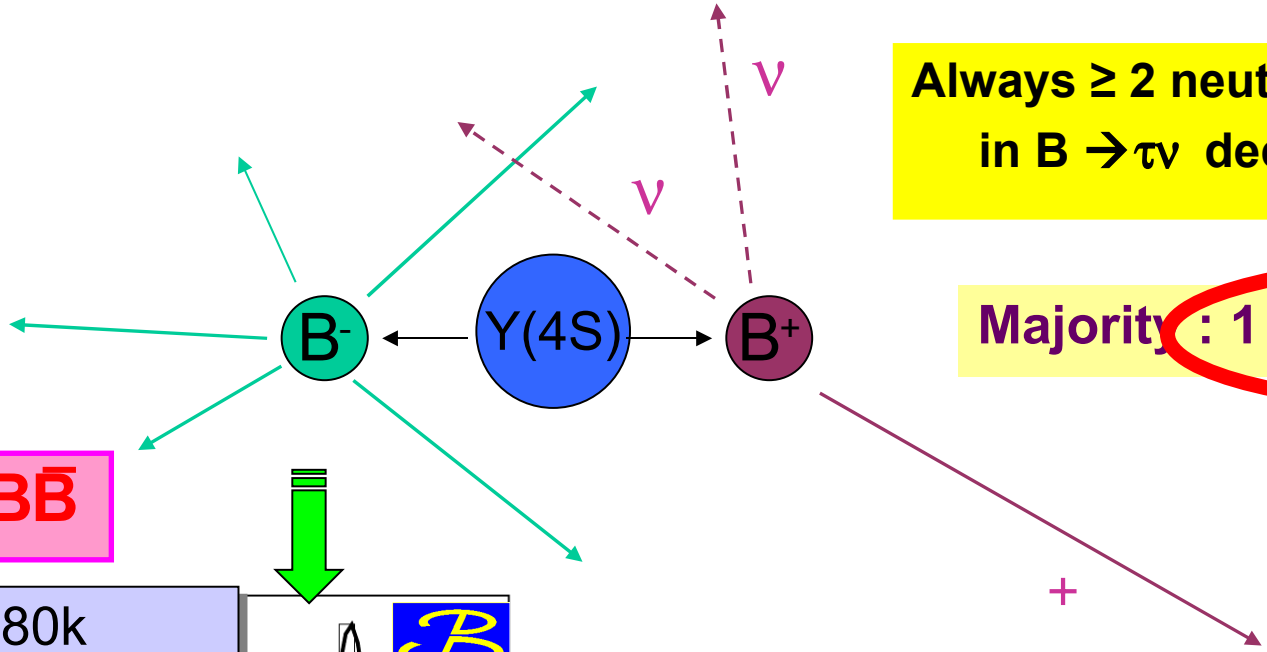
SM :

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

B decay constant ↔ Lattice QCD

BSM : sensitive to New Physics from $H^{\pm}$

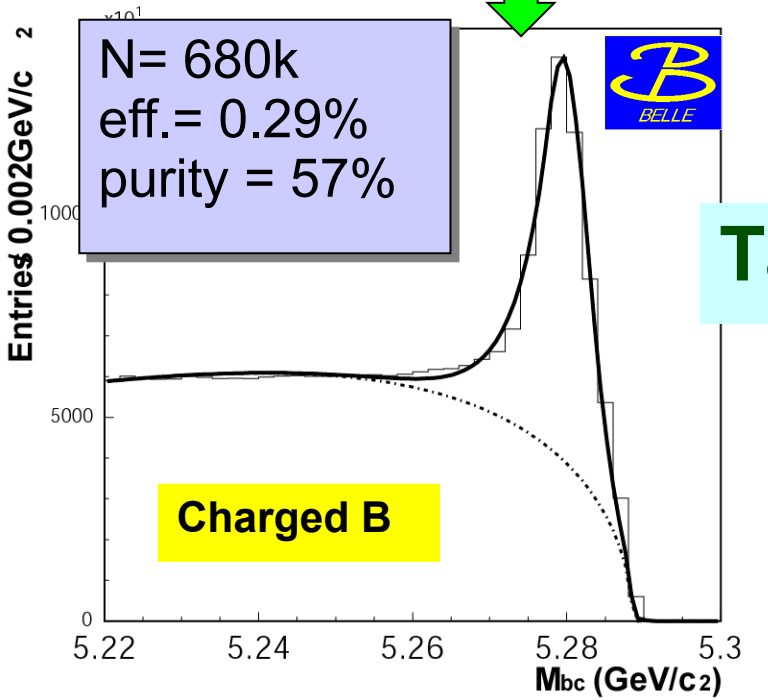
$B \to \tau\nu$: Experimental Challenge



Always ≥ 2 neutrinos appear in B → τν decay

Majority : 1 track + invisible

449M $B\bar{B}$



Tag-side: Full reconstruction

$$B^+ \to \bar{D}^{(*)0} + p^+ / r^+ / a_1^+ / D_S^{(*)+}$$
$$\bar{D}^0 \to \bar{D}^0 p^0 / \bar{D}^0 g \qquad D_S^{(*)+} \to D_s^+ g$$

$B \to \tau\nu$: Candidate Example

$B^+ \to \overline{D^0}\,\pi^+$

$\hookrightarrow K^+\,\pi^-\,\pi^+\,\pi^-$

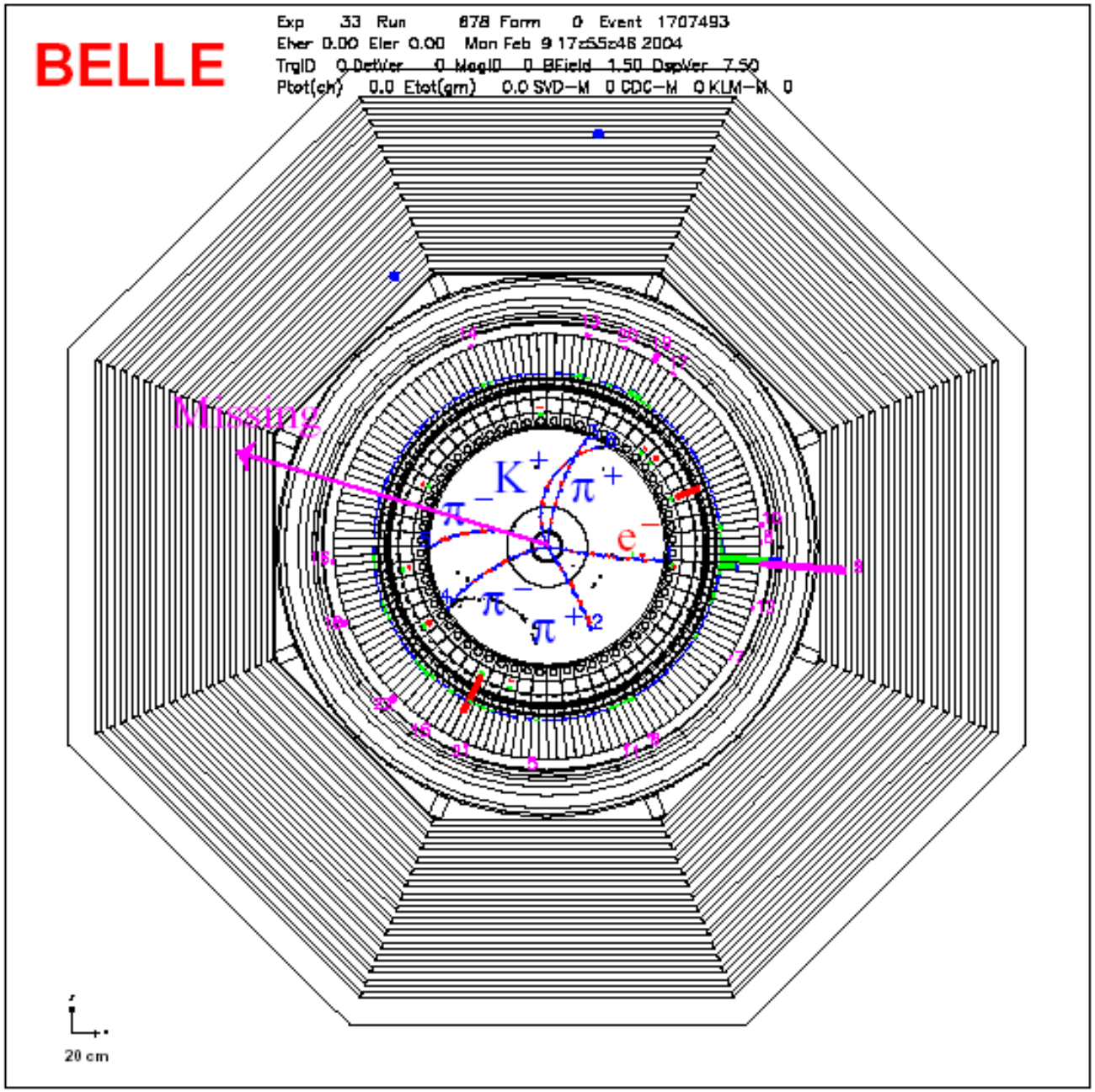
$B^- \to \tau^-\,\nu$

$\hookrightarrow e^-\nu\nu$

Signature:
Remove Tag-side

1 track + nothing

No extra tracks
$E_{ECL} \sim 0$

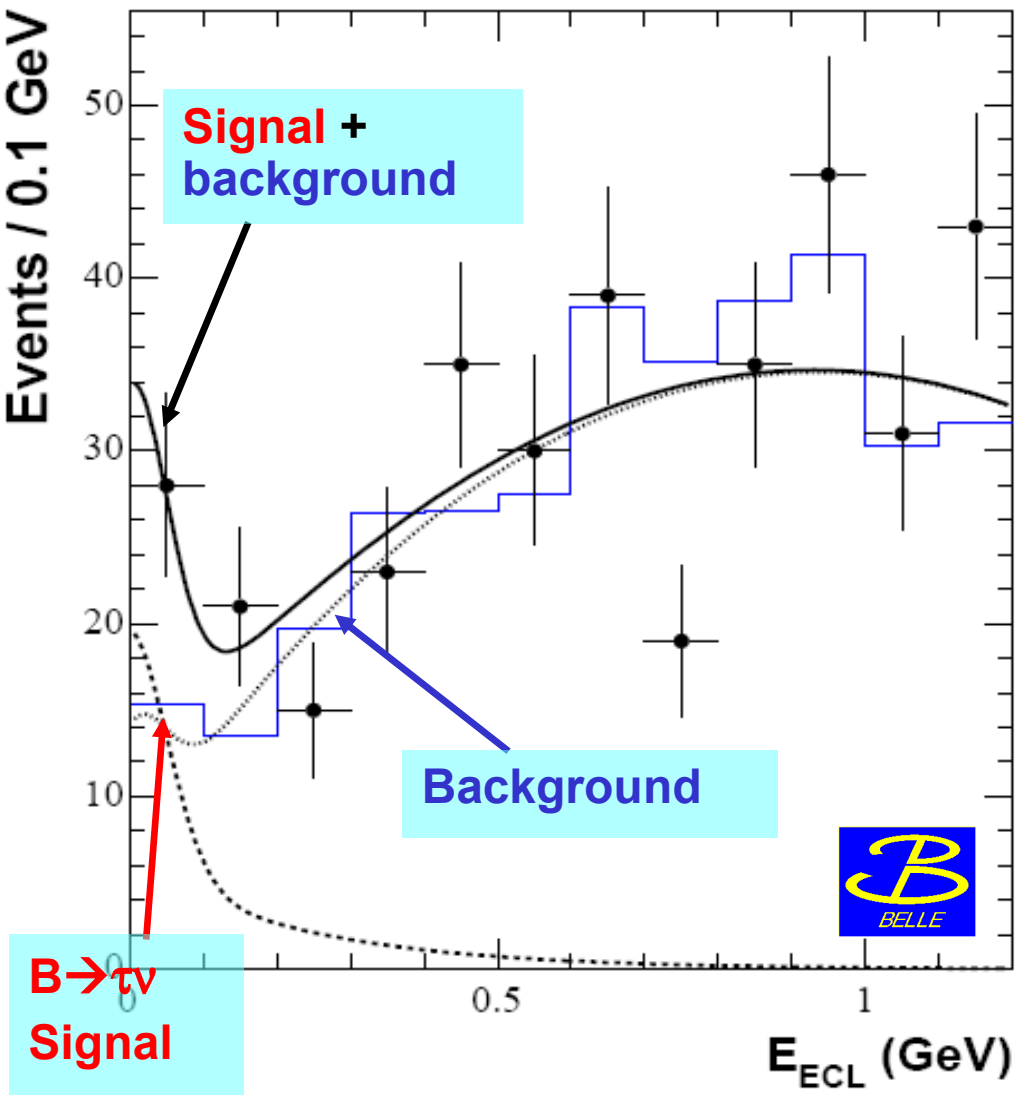


$B \to \tau\nu$: Signal Extraction

E_{ECL} : extra neutral energy

449M $B\bar{B}$

hep-ex/0604018
submitted to PRL



5 τ decay modes

Observe $17.2^{+4.3}_{-5.7}$ events

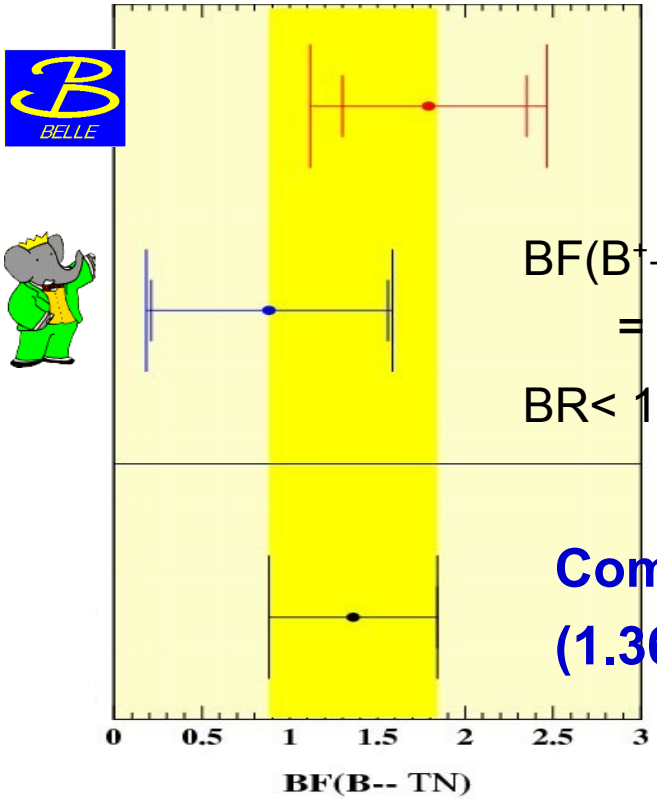
significance = 3.5σ

$$\mathcal{B}(B^+ \to \tau^+\nu) = (1.79 \pm {}^{0.56}_{0.49} \pm {}^{0.39}_{0.46}) \times 10^{-4}$$

1st Evidence of B decay with ≥ 2 ν !!

Big step for the future of hunting for NP

$B \to \tau\nu$: Average results

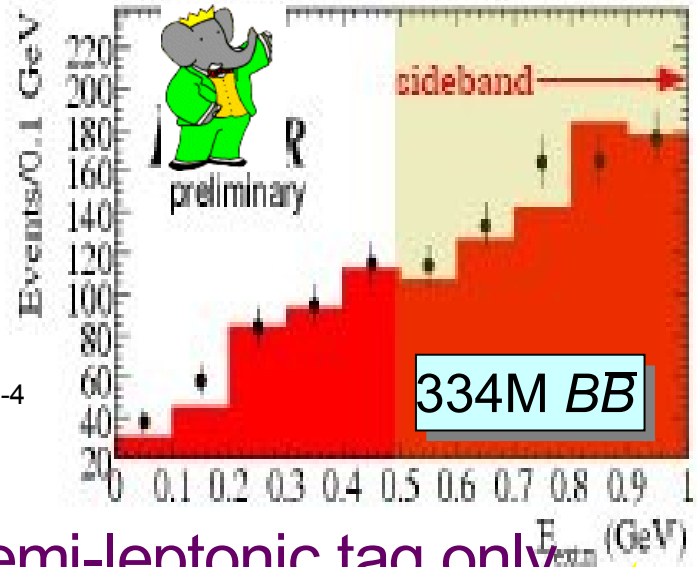


$BF(B^+ \to \tau^+ \nu_\tau) = (0.88\ ^{+0.68}_{-0.67} \pm 0.11) \times 10^{-4}$

$BR < 1.80\ 10^{-4}$ @ 90%CL

Combined

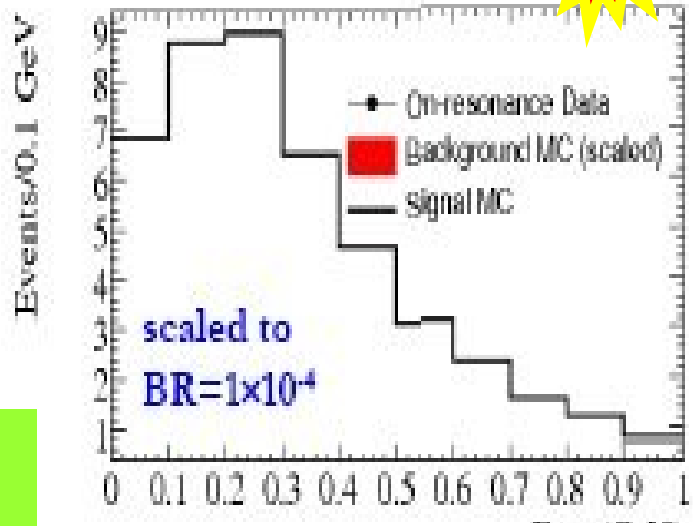
$(1.36 \pm 0.48) \times 10^{-4}$



Semi-leptonic tag only

[hep-ex/0608019]

New !



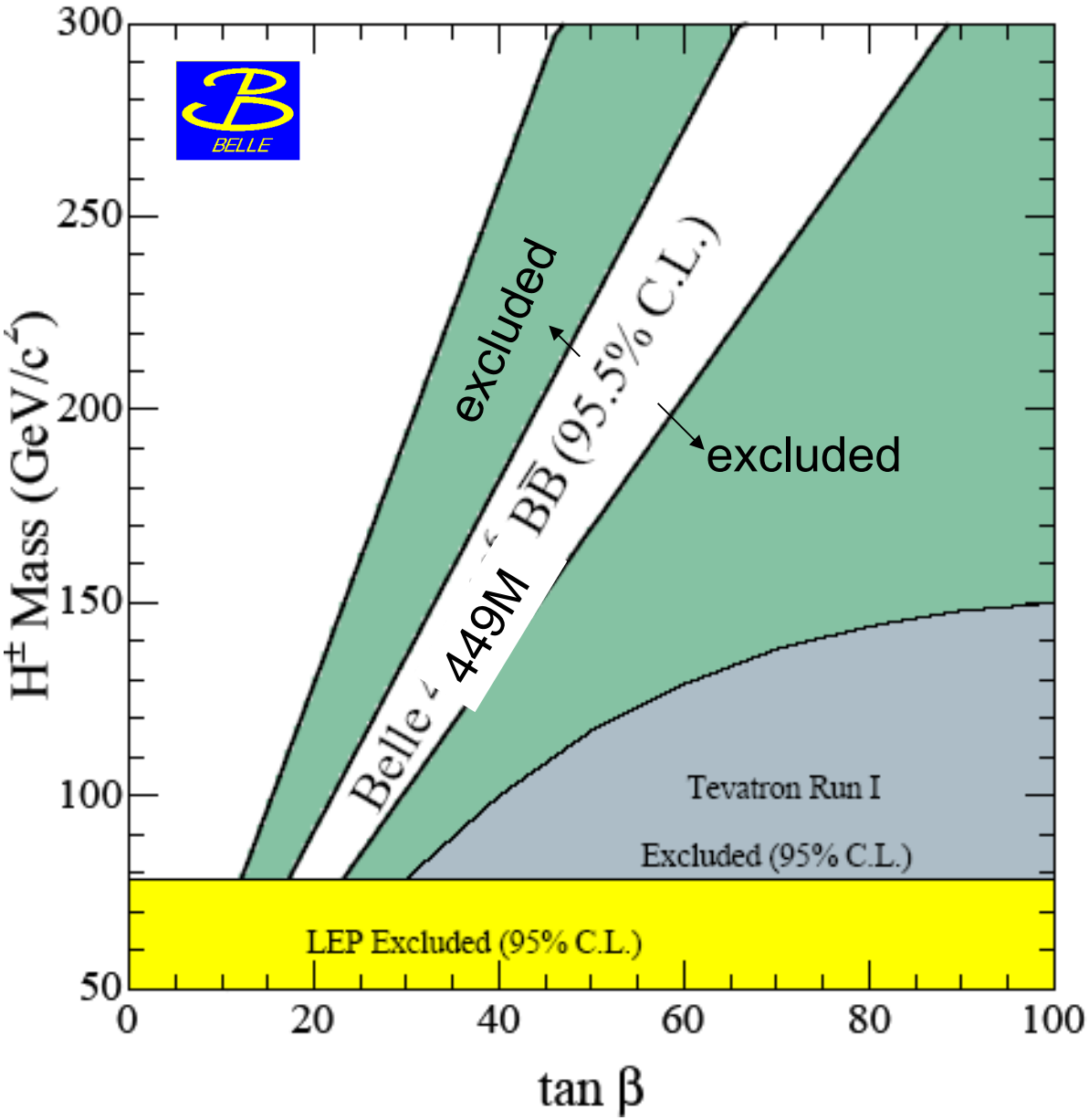
- **$|V_{ub}| = (4.39 \pm 0.33) \times 10^{-3}$ (HFAG)**

$f_B = 0.200 \pm 0.038$ GeV

$f_B = 0.216 \pm 0.022$ GeV (HPQCD)

PRL 95, 212001 (2005)

Constraints on $H^{\pm}$ Mass

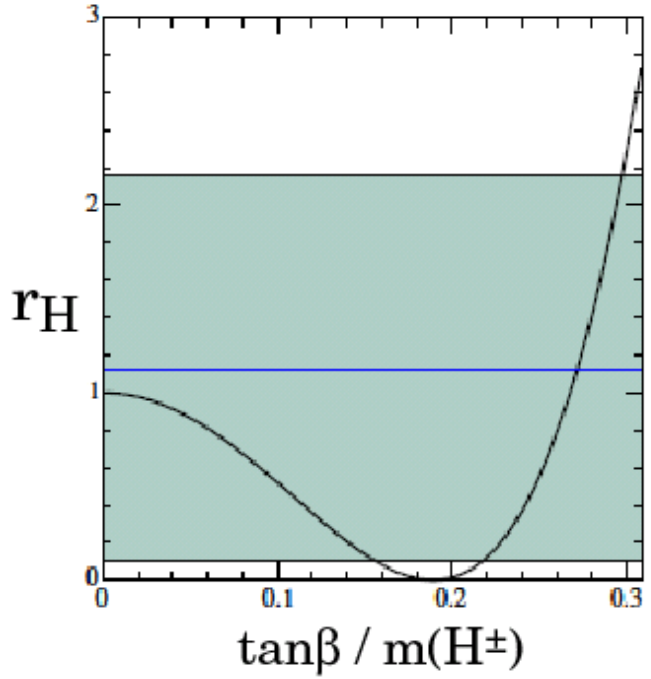


Use known f_B and $|V_{ub}|$

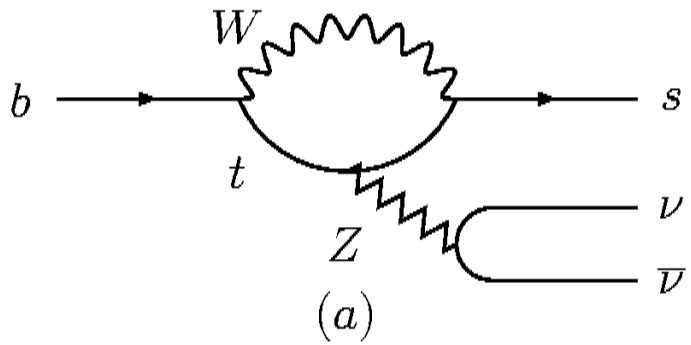
Ratio to the SM BF.

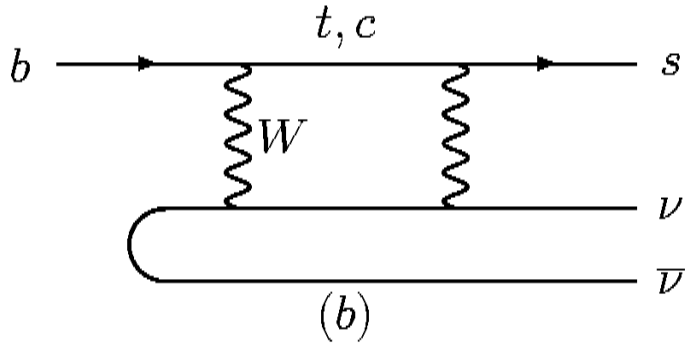
$$r_H = (1 - \frac{m_B^2}{m_H^2} \tan^2 b)$$

$r_H = 1.13 \pm 0.51$



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





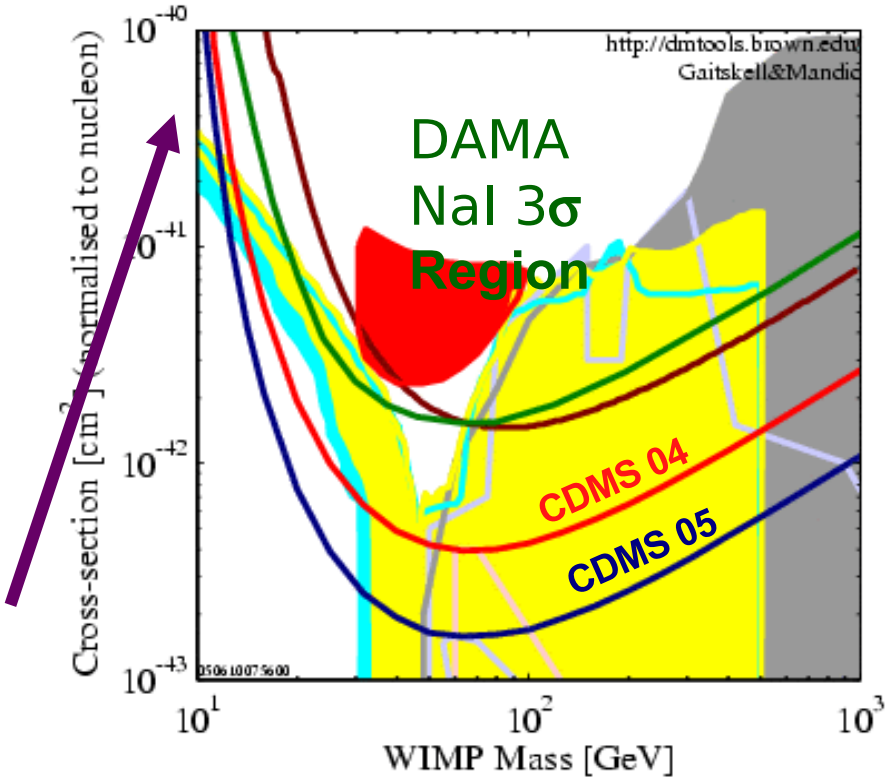
b → s with 2 neutrinos

SM: BR(B→K* $\nu\bar{\nu}$) ~1.3 x 10^{-5}
BR(B→K $\nu\bar{\nu}$) ~4 x 10^{-6}
(Buchalla, Hiller, Isidori)

PRD 63, 014015

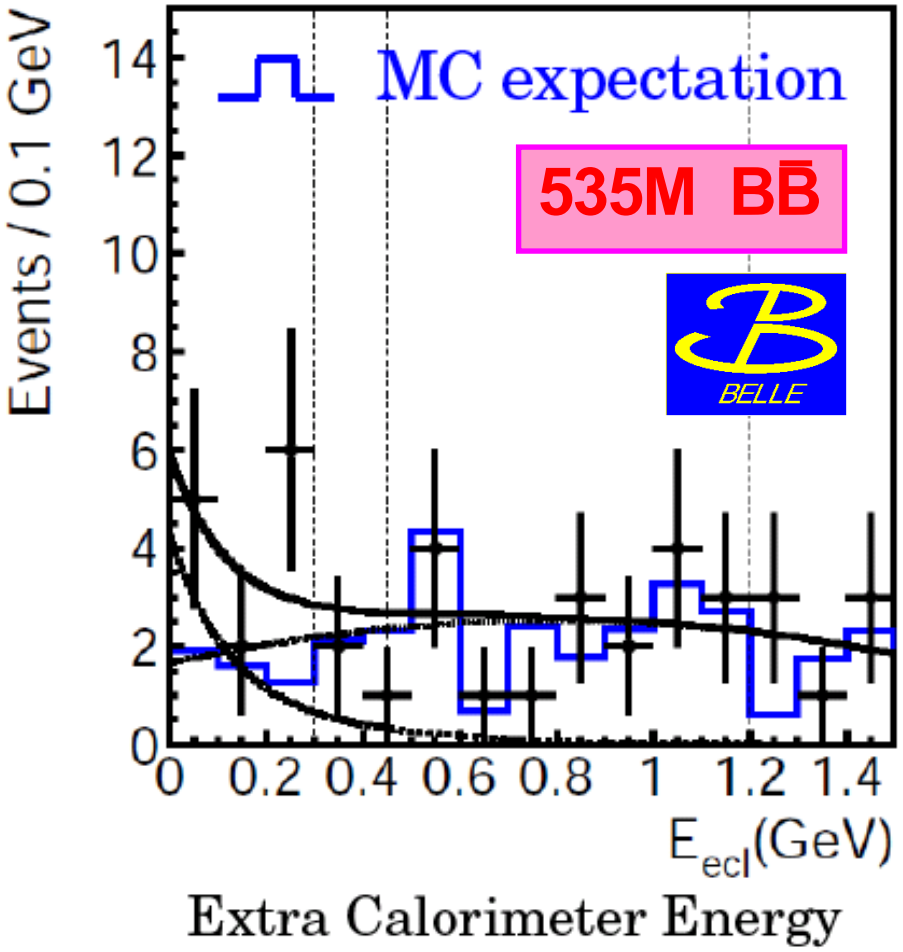
- **New Physics in Loop**
- **Light Dark Mater (M~1GeV)**

No sensitivity in Direct search



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

[hep-ex/0608047]



Similar exp. technique as $B \to \tau^+\nu$

Full-rec. tag & K + nothing

460K tags

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

New !

(1.7σ stat. significance)

Sideband = 19
MC expectation = 18.7±3.3

$$B(B^0 \to K^{*0}\nu\bar{\nu}) < 3.6 \times 10^{-4}$$

(90% C.L.)

cf: BaBar 85M $B\bar{B}$

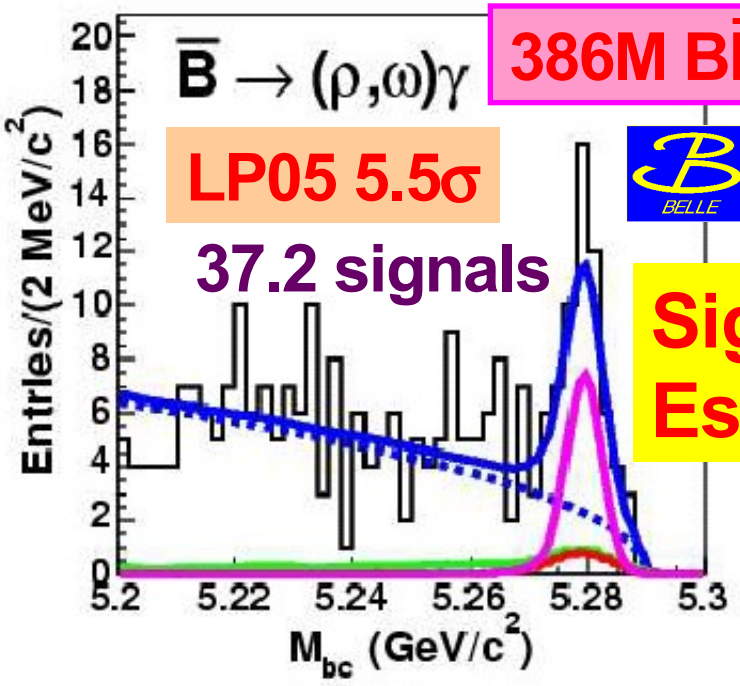
$B(B^+ \to K^+\nu\bar{\nu}) < 5.2 \times 10^{-5}$

[PRL 94,101801(05)]

Hope to see Signal in the (near?) Future ...

b → d Penguins : b → d γ

[PRL96,221601(06)]



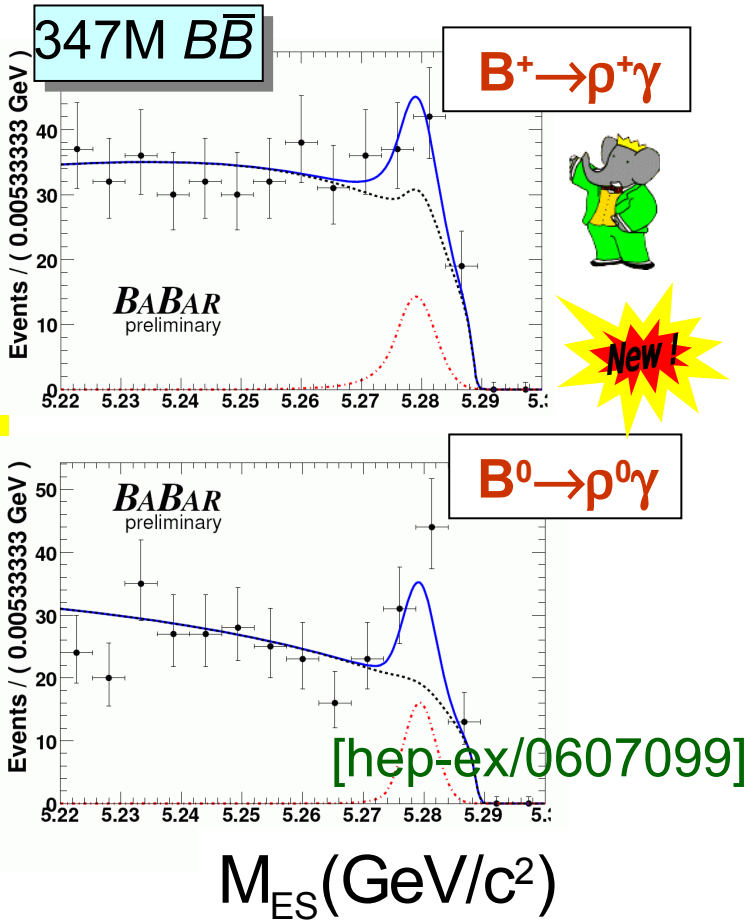
386M BB̄

LP05 5.5σ

37.2 signals

Signals Established !

$BR \times 10^{-6}$	*BaBar*	*Belle*
$B^+ \to \rho^+\gamma$	$1.06^{+0.35}_{-0.31} \pm 0.07$	$0.55^{+0.43+0.12}_{-0.37-0.11}$
$B^0 \to \rho^0\gamma$	$0.77^{+0.21}_{-0.19} \pm 0.07$	$1.17^{+0.35+0.09}_{-0.31-0.08}$
$B^0 \to \omega\gamma$	< 0.84	$0.58^{+0.34+0.14}_{-0.31-0.10}$

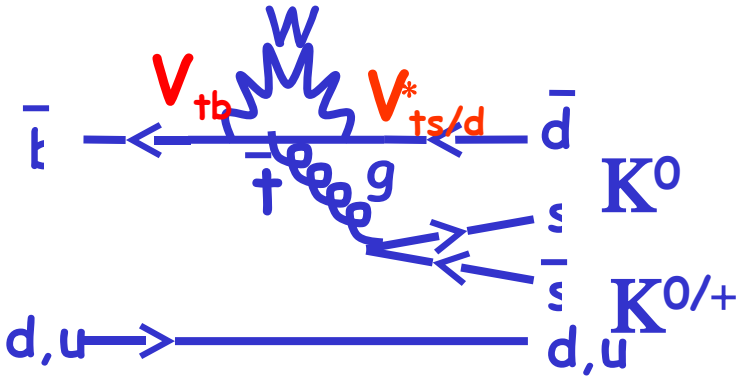


[hep-ex/0607099]

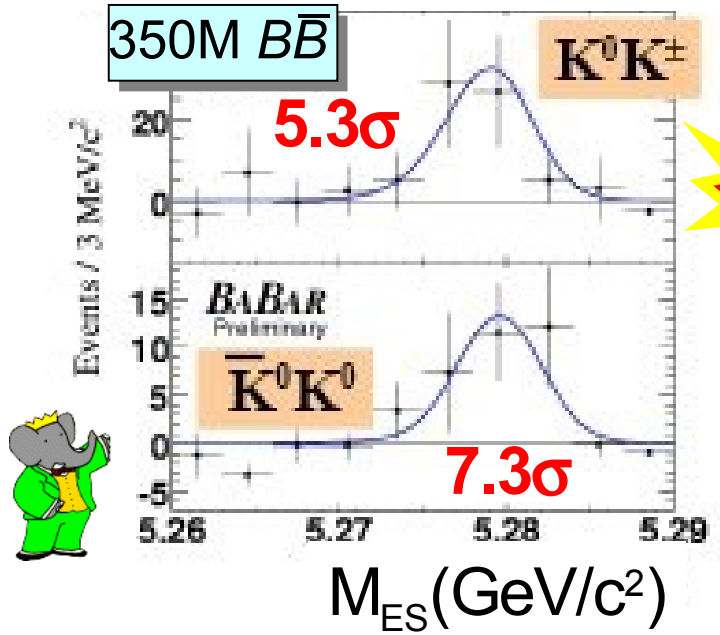
V_{td}/V_{ts}

New Physics !

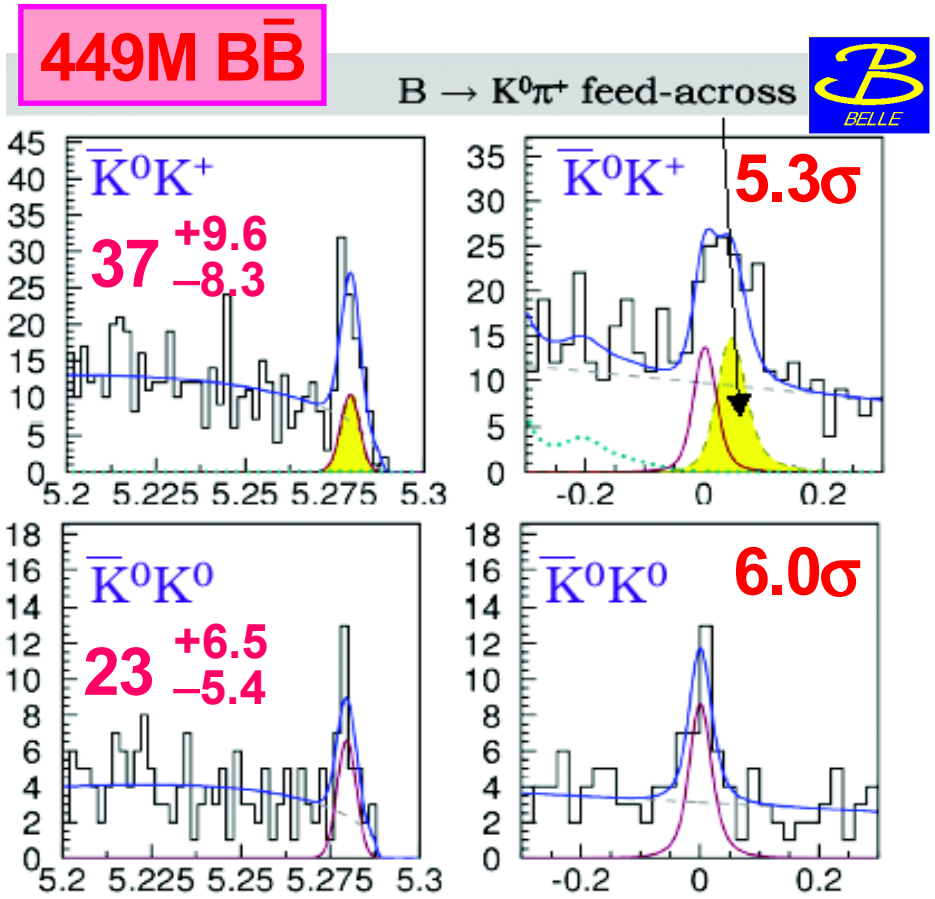
b → d Penguins : B → KK



2004/5 Evidence ⇒ **Observation !**



New !



[hep-ex/0608036]

[hep-ex/0608049]

Summary and Conclusions

Excellent performance of B factories
Belle + BaBar : > 1000 fb^{-1} data !

- **CPV in B decays**: **KM phase = source of CPV (~Established)**

- **CKM/SM tests**:
  Precision measurements of sin2β/sin2φ$_1$ via b → c$\bar{c}$s decays :

$$S = \sin 2\phi_1 / \sin 2\beta = 0.675 \pm 0.026$$

Precision: < 4%(1°)

  Other CKM parameters' precision: φ$_2$, φ$_3$ ~ 10° – 30° ; |V$_{ub}$| ~ 7%

- **NP Searches**:
  ☞Measurements of sin2β^{eff}/sin2φ$_1^{eff}$ via several b → s$\bar{q}$q modes
  (B → ΦK^0, K$^+$ K$^-$ KS, η´K^0, K$_S$K$_S$K$_S$, K$_s$π , f$_0$(980) K$_S$, ω K$_S$ etc.)

  Strong hints of Δsin2β < 0 (between b → c$\bar{c}$s and b → s$\bar{q}$q)

Summary and Conclusions

☞**First evidence of B decay with ≥ 2 neutrinos**
☞**b→d/s;EW;radiative penguins** ...

- I did not have time to mention exciting results in hadron spectroscopy ...
  ... charm baryons ...
  ... strange charm mesons ...
  ... discoveries of unknown new resonances (X, Y, Z)
  and measurement of their properties ...

- D^0-$\bar{D}^0$ mixing: New upper limits

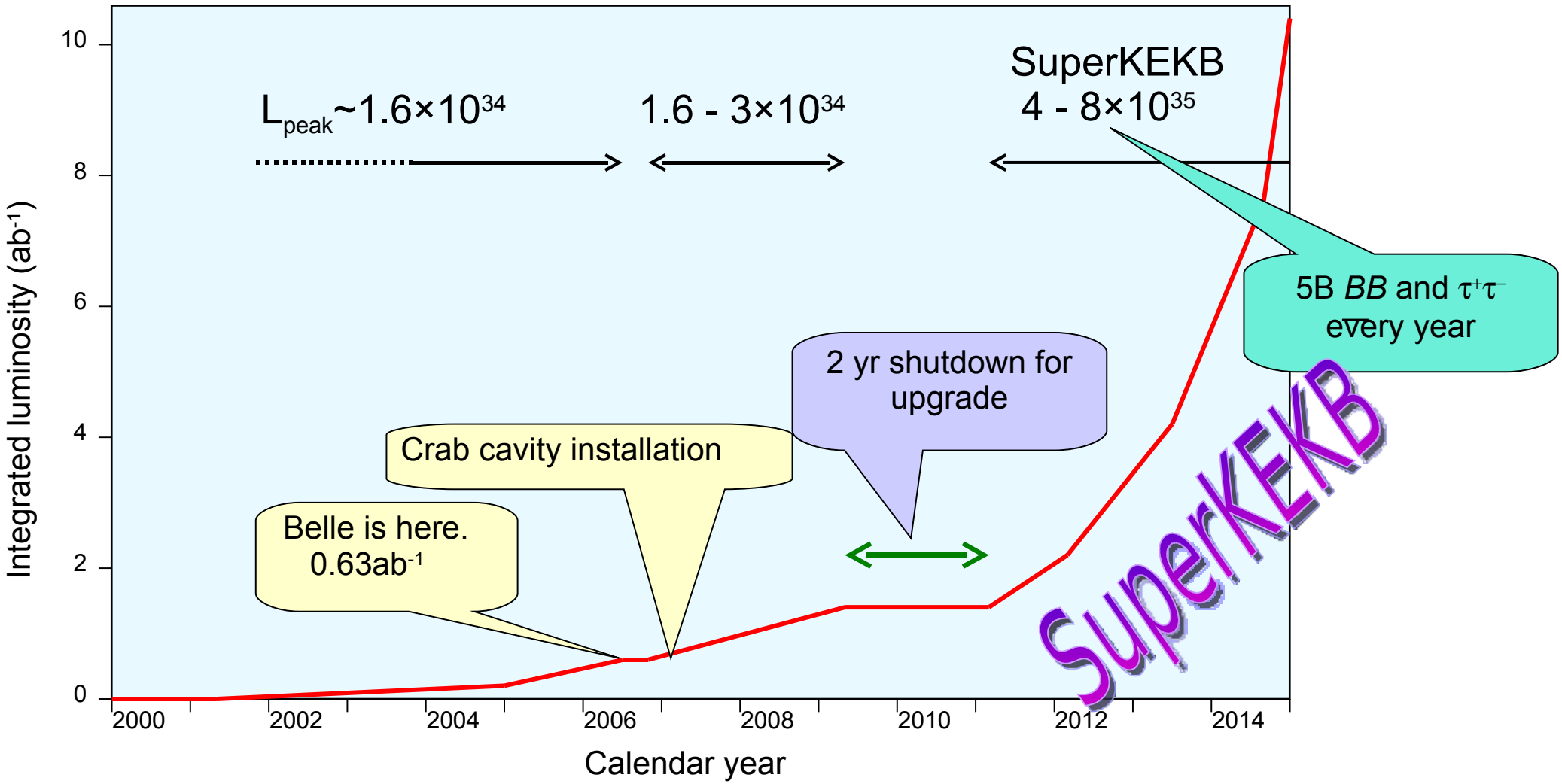
... Would definitely require another talk ...

Many new results still to come with more data!

Supplementary Material

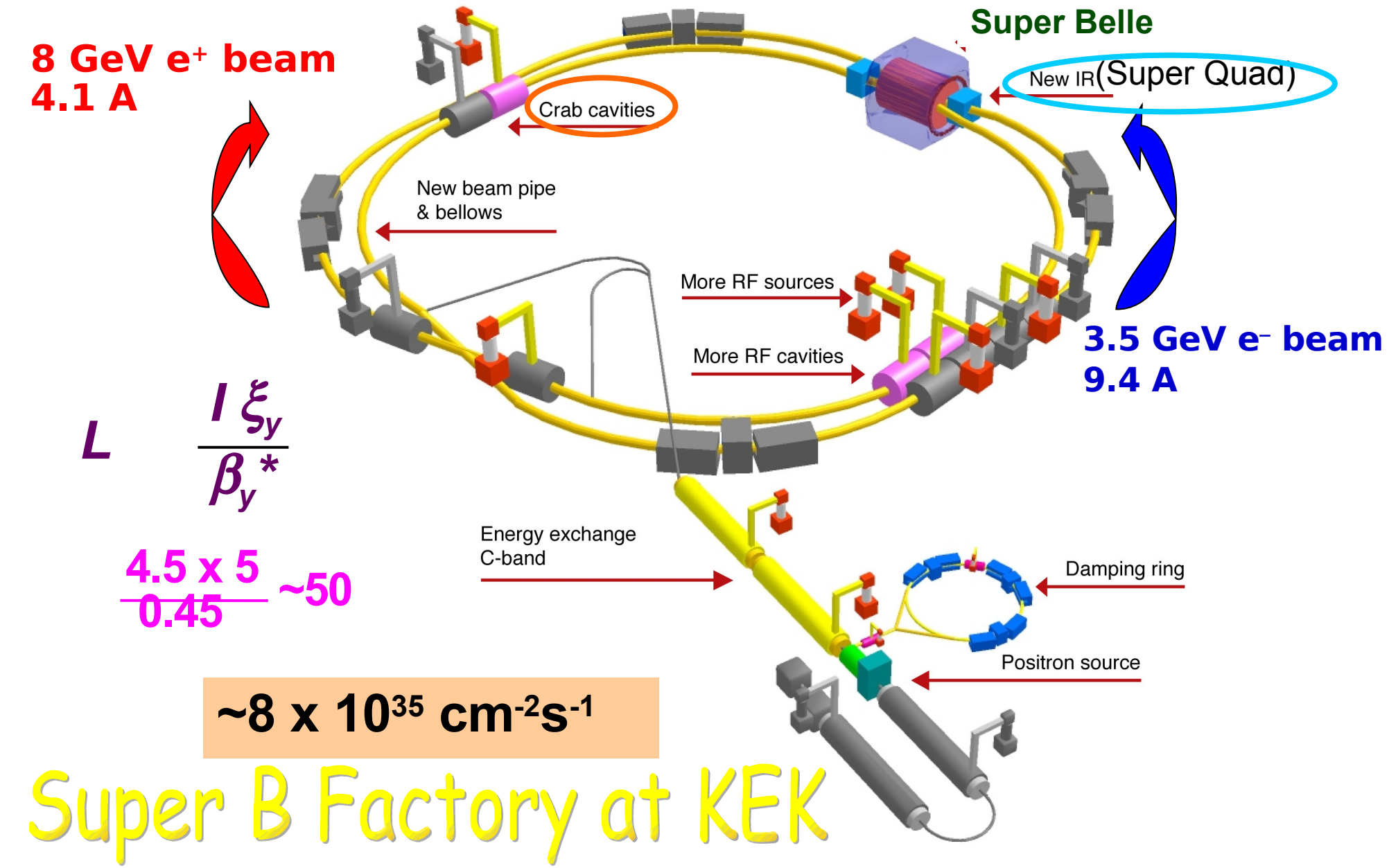
Future Plans: SuperKEKB

Super KEKB Proposed Schedule



[ILC inspired Super B-factory (INFN/SLAC) L_{peak}~10^{36}]

SuperKEKB Schematics



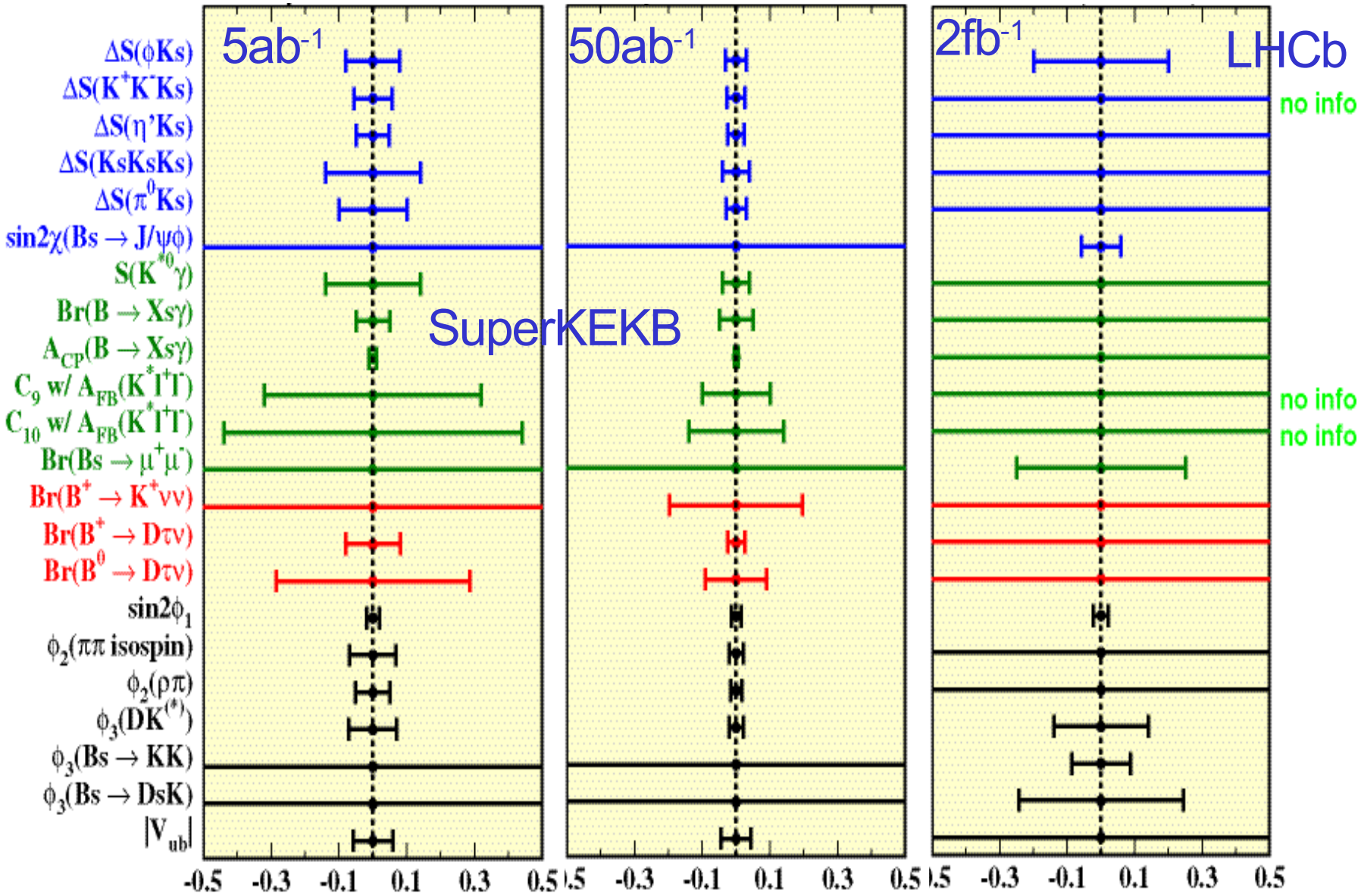
$$L \propto \frac{I\,\xi_y}{\beta_y^*}$$

$$\frac{4.5 \times 5}{0.45} \sim 50$$

~8 x 10^{35} $cm^{-2}s^{-1}$

Super B Factory at KEK

SuperKEKB: Physics Reach



Physics at Super B Factory (hep-ex/0406071)