Results from the *B* Factories

Physics At LHC

Cracow, Poland

July 3-8, 2006

BELLE

Rainer Bartoldus

SLAC

STANFORD LINEAR ACCELERATOR CENTER
ESTABLISHED 1962
D.O.E.

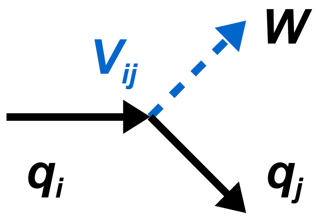
Outline

- The CKM Matrix
- Time Dependent *CP* Asymmetries in *B* Decays
- The *B* Factories: BaBar and Belle
- Unitarity Triangle Measurements:
  - UT Angles: α β γ
  - [*UT Sides:* V_{ub} V_{cb}]
- Rare Decays
- Conclusions

Introduction

Scope of this talk

- The two *B* Factories are primarily flavor factories; they also produce a rich program of:
  - Tau physics, charm physics, two-photon physics, ISR physics (e.g. *R* measurement) and much more
- Disclaimer: I will not cover any of these results
    - For a glimpse of non-*CP* physics, please see Hendryk Palka's talk in the afternoon session on spectroscopy and baryon production
- Regarding the standard *B* physics program I will focus on the most recent measurements
- Stay tuned: A wealth of new results from both experiments is going to appear at ICHEP



The CKM Matrix

Cabibbo
Kobayashi
Maskawa

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

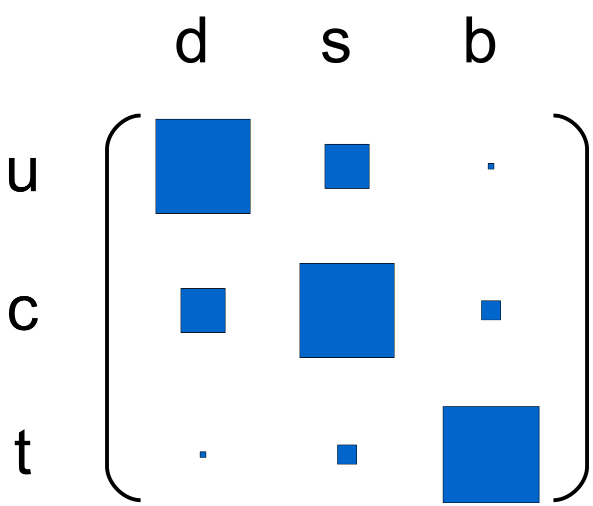
CPT: Unitary:

$$V\,V^{\dagger} = 1$$

Three real parameters plus one irreducible phase (other phases can be absorbed in quark fields)

→ *CP Violation*

Observed hierarchy:



Wolfenstein Parameterization: (expansion in λ)

$\lambda = \sin\theta_c \approx 0.22$

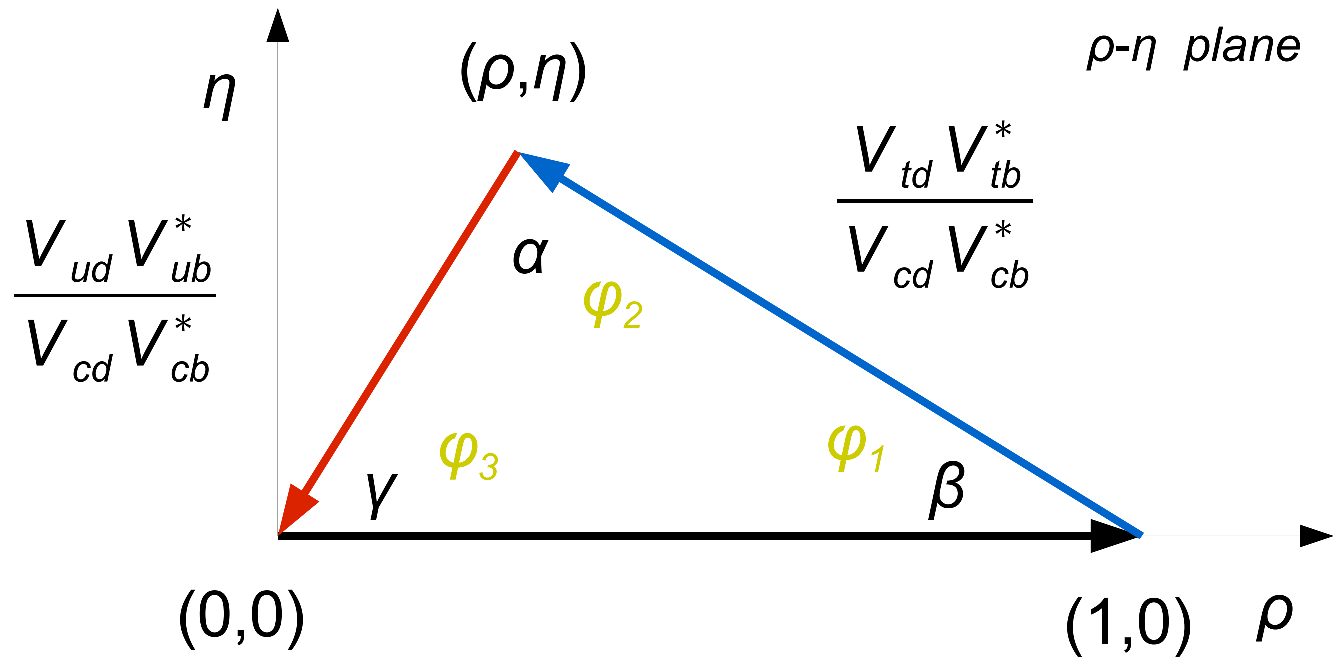
$$\begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

The (B_d) Unitarity Triangle

$V V^{\dagger} = 1 \Rightarrow$ $V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$

CKM unitarity leads to six such triangles

One of them governs the B_d system



$\alpha,\beta,\gamma \neq 0$ implies *CP* Violation

$\beta = \arg(-V_{cd}V_{cb}^* / V_{td}V_{tb}^*)$

$B^0\overline{B}^0$ - Mixing

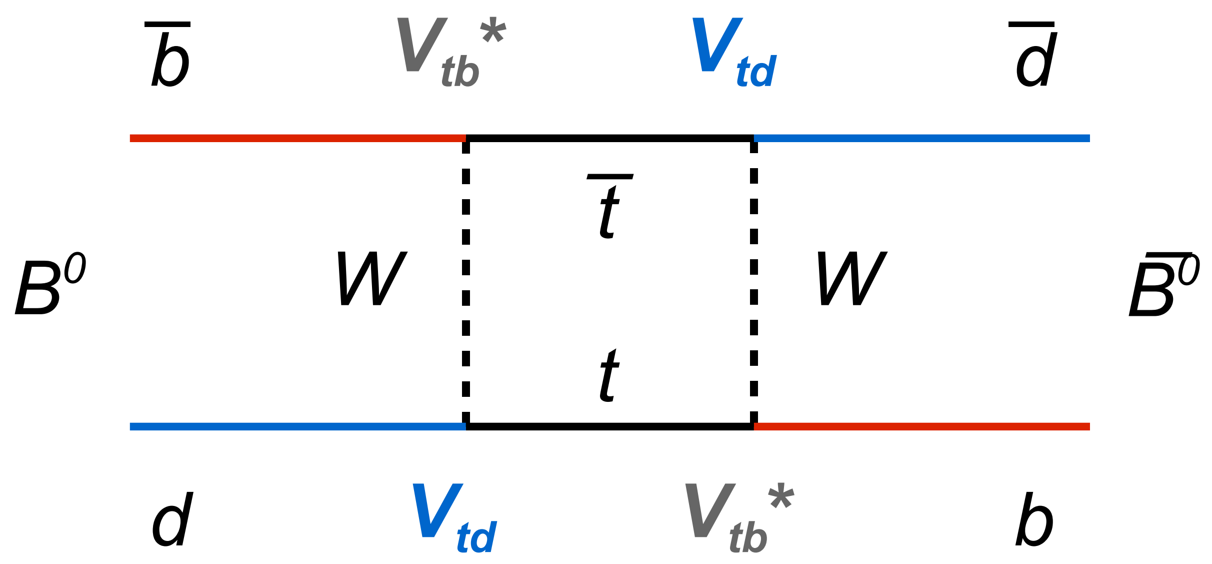
$B_L = p\,|B^0\rangle + q\,|\overline{B}^0\rangle$

$B_H = p\,|B^0\rangle - q\,|\overline{B}^0\rangle$

$\Delta m = m(B_H) - m(B_L)$

mass eigenstates
$\neq$
flavor eigenstates

$B^0\overline{B}^0$ mixing is mediated by a second order weak interaction:
(this plus the same box diagram with W and top exchanged)



$V_{td} \approx |V_{td}| e^{-i\beta}$

Through mixing the $B^0/\overline{B}^0$ picks up a weak phase of:

$$\frac{q}{p} = e^{-2i\beta}$$

Interference between Mixing and Decay

B decay rate as a function of proper time:

$$f_{\pm}(\Delta t) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}}\left[1 \pm S_f \sin(\Delta m_d \Delta t) \mp C_f \cos(\Delta m_d \Delta t)\right]$$

Mixing is observable because of the (unexpectedly) long *B* lifetime:
$1/\tau_B = \Gamma_B \approx 1.5\ \mathrm{ps}^{-1}$
$\Delta m_d \approx 0.5\ \mathrm{ps}^{-1}$

$$S_f = \frac{2\,\mathrm{Im}\,\lambda_f}{1+|\lambda_f^2|} \qquad C_f = \frac{1-|\lambda_f^2|}{1+|\lambda_f^2|}$$

$$\lambda_f = \frac{q}{p}\frac{\bar{A}(\bar{B}\to f_{CP})}{A(B\to f_{CP})}$$

Standard Model: $|\lambda_f| \approx 1$

$$S_f = \mathrm{Im}\,\lambda_f \qquad C_f = 0$$

CP Violation on the Υ(4S)

$B\bar{B}$ are produced in a coherent L=1 state

Three observable interference effects:

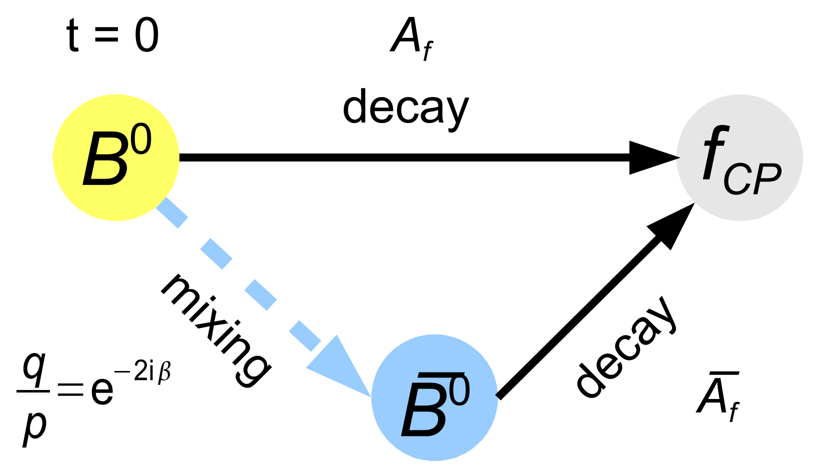
- *CP* violation in mixing:

$$B \to \bar{B} \neq \bar{B} \to B$$

- (direct) *CP* violation in decay:

$$B \to f_{CP} \neq \bar{B} \to f_{CP}$$

- (indirect) *CP* violation in the interference between mixing and decay:



$$A_{CP}(t) \equiv \frac{\Gamma(\bar{B}(t) \to f_{CP}) - \Gamma(B(t) \to f_{CP})}{\Gamma(\bar{B}(t) \to f_{CP}) + \Gamma(B(t) \to f_{CP})}$$

$$= \underbrace{S_{f_{CP}} \sin(\Delta m_d \Delta t)}_{\text{indirect CPV}} - \underbrace{C_{f_{CP}} \cos(\Delta m_d \Delta t)}_{\text{direct CPV}}$$

Coherent Production of $B^0\bar{B}^0$

- Note that in $e^+e^- \rightarrow Y(4S) \rightarrow B^0\bar{B}^0$ there is **at any time**:

  one B^0 and one $\bar{B}^0$ *(flavor eigenstates)*

  one $B_{CP=+1}$ and one $B_{CP=-1}$ *(CP eigenstates)*

  one B_H and one B_L *(mass eigenstates)*

- Measurement of the flavor of one meson determines the flavor of the other meson **at that same proper time**

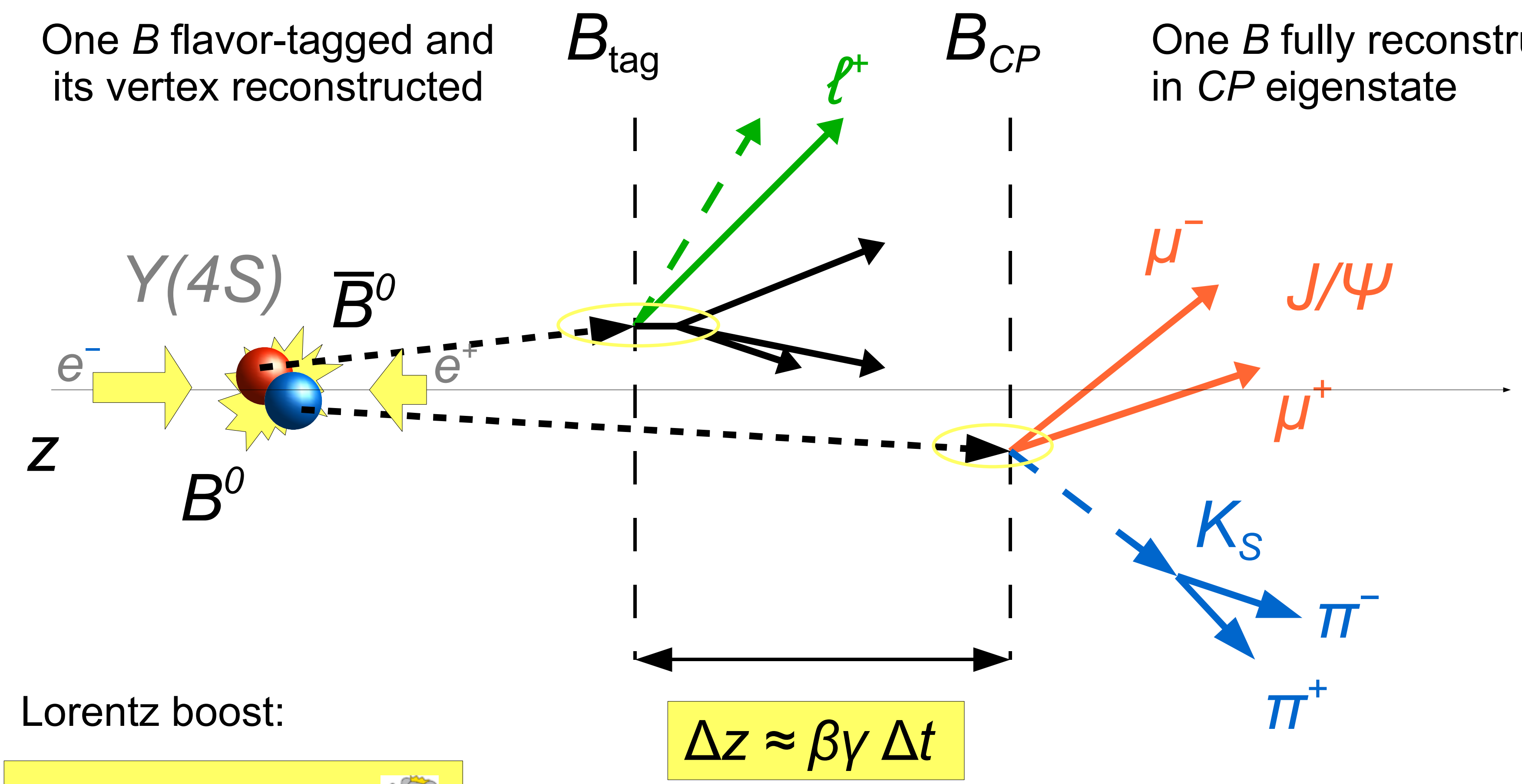
  (Einstein-Podolsky-Rosen phenomenon)

- This property is exploited in the flavor tagging technique

Time-Dependent CP Analysis

One *B* flavor-tagged and its vertex reconstructed

One *B* fully reconstructed in *CP* eigenstate

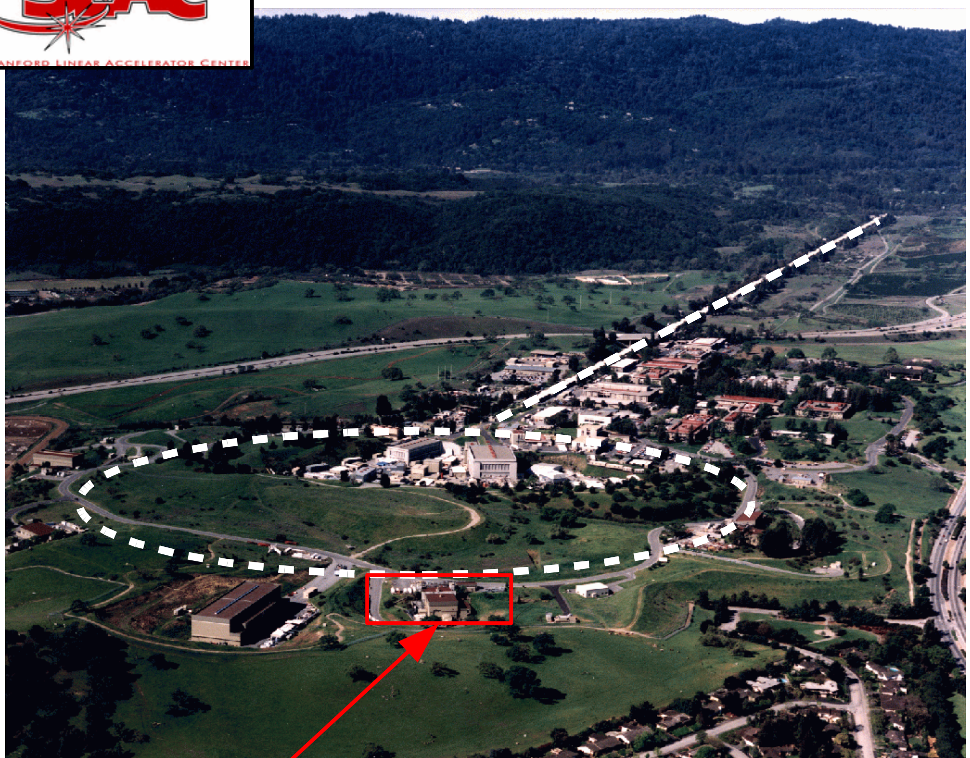


Lorentz boost:

$$\langle\beta\gamma\rangle = \begin{cases} 0.56 \\ 0.43 \end{cases}$$

$\langle\Delta z\rangle \approx$ 200-250 μm

The Asymmetric *B* Factories



PEP-II

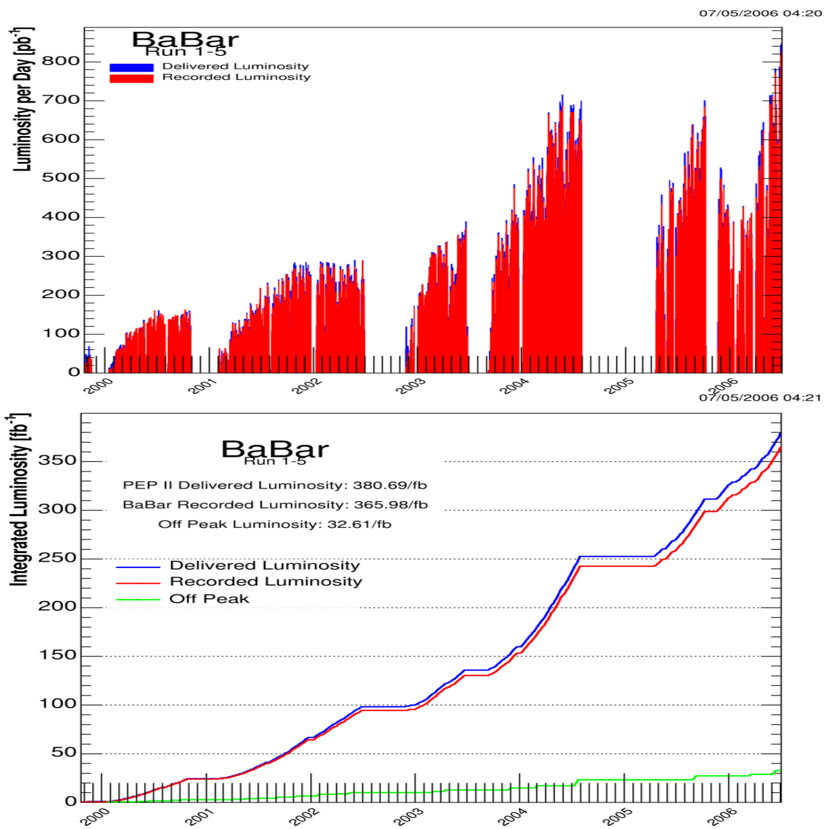
$E(e-) \sim 9.0$ GeV
$E(e+) \sim 3.1$ GeV

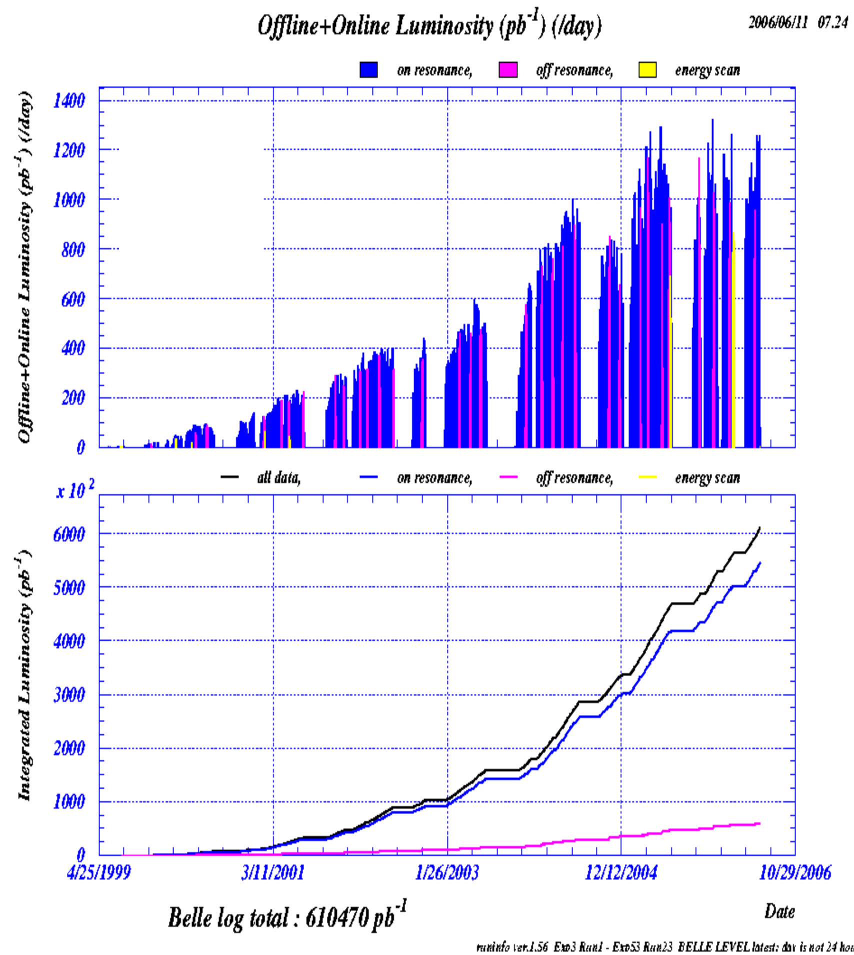
$E(e-) \sim 8.5$ GeV
$E(e+) \sim 3.5$ GeV

KEKB

$\sqrt{s} = m_{\Upsilon(4S)} = 10.58\,\mathrm{GeV}$ $\quad \sigma(B^0\overline{B}^0) \approx 1$ nb ➡ ~1M $B^0\overline{B}^0$ events per 1 fb^{-1} (~1 day !)

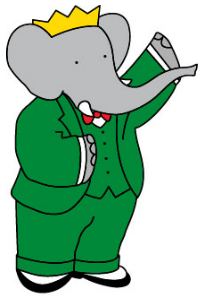
B Factory Performance



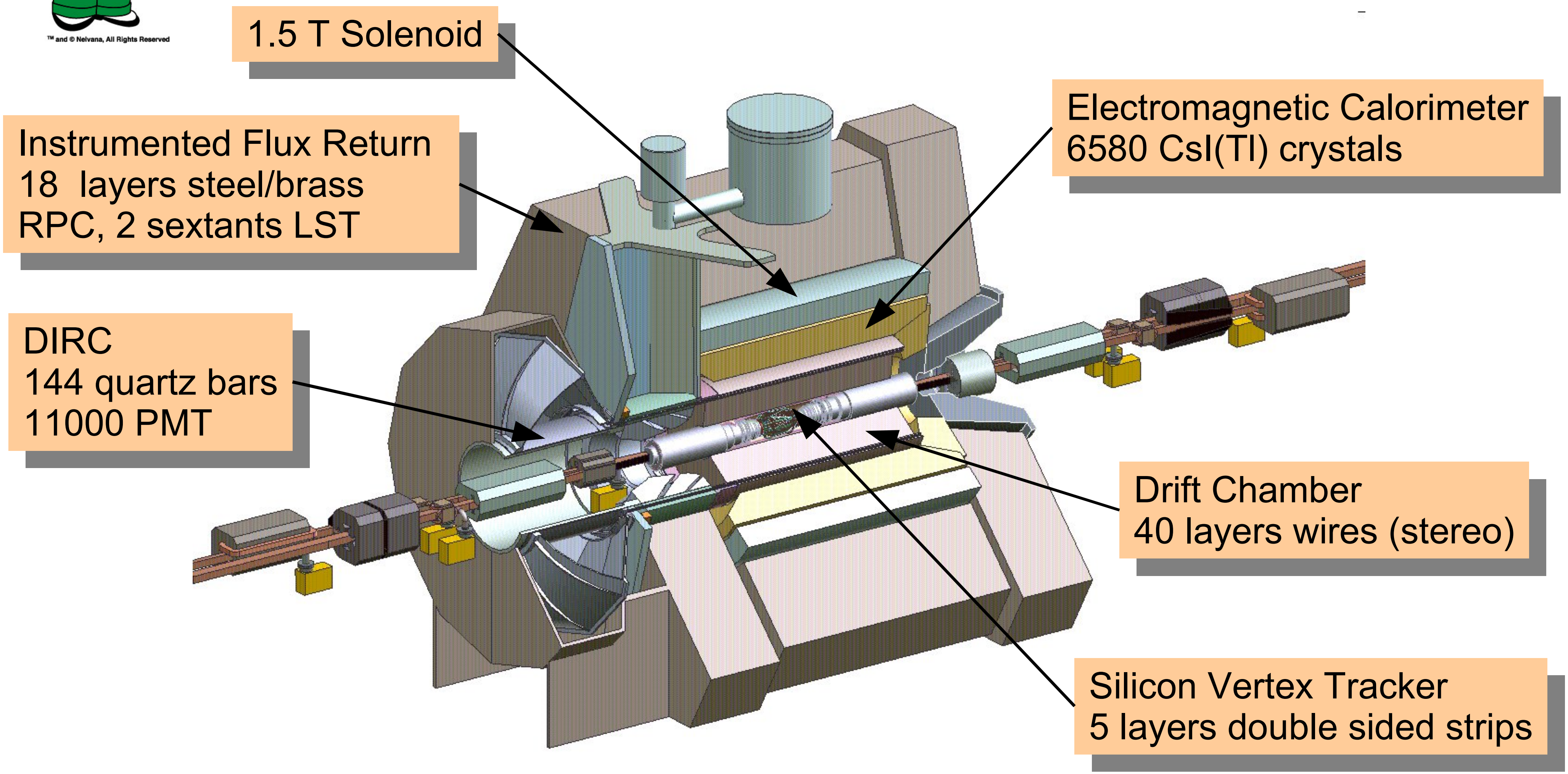


BaBar collected **365 fb^{-1}**
PEP-II peak: **11 · 10^{33} cm^{2}s^{-1}** (Jul 2, 2006)
Avg deadtime ~2%, Best 24h: **~900 pb^{-1}**

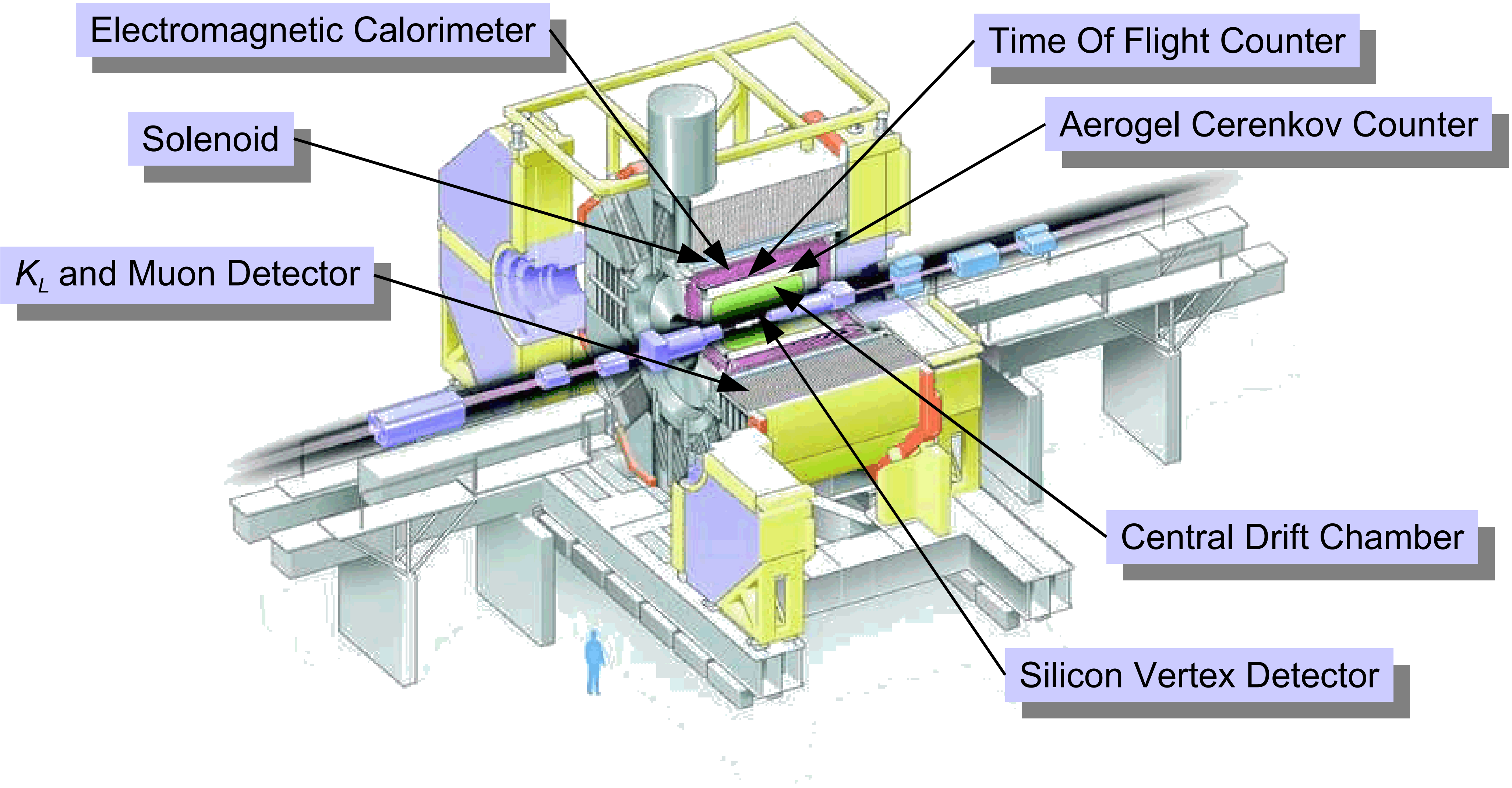
Belle collected **610 fb^{-1}**
KEK-B peak: **16 · 10^{33} cm^{2}s^{-1}** (Jun 29, 2006)
Avg deadtime ~10%, Best 24h: **~1200 pb^{-1}**



BaBar


1.5 T Solenoid
Instrumented Flux Return
18 layers steel/brass
RPC, 2 sextants LST
DIRC
144 quartz bars
11000 PMT
Electromagnetic Calorimeter
6580 CsI(Tl) crystals
Drift Chamber
40 layers wires (stereo)
Silicon Vertex Tracker
5 layers double sided strips

Belle



Electromagnetic Calorimeter
Solenoid
K_L and Muon Detector
Time Of Flight Counter
Aerogel Cerenkov Counter
Central Drift Chamber
Silicon Vertex Detector

B Reconstruction

Exploiting kinematics of $e^+e^- \rightarrow Y(4S) \rightarrow B^0\overline{B}^0$ for signal selection

Beam energy substituted Mass:

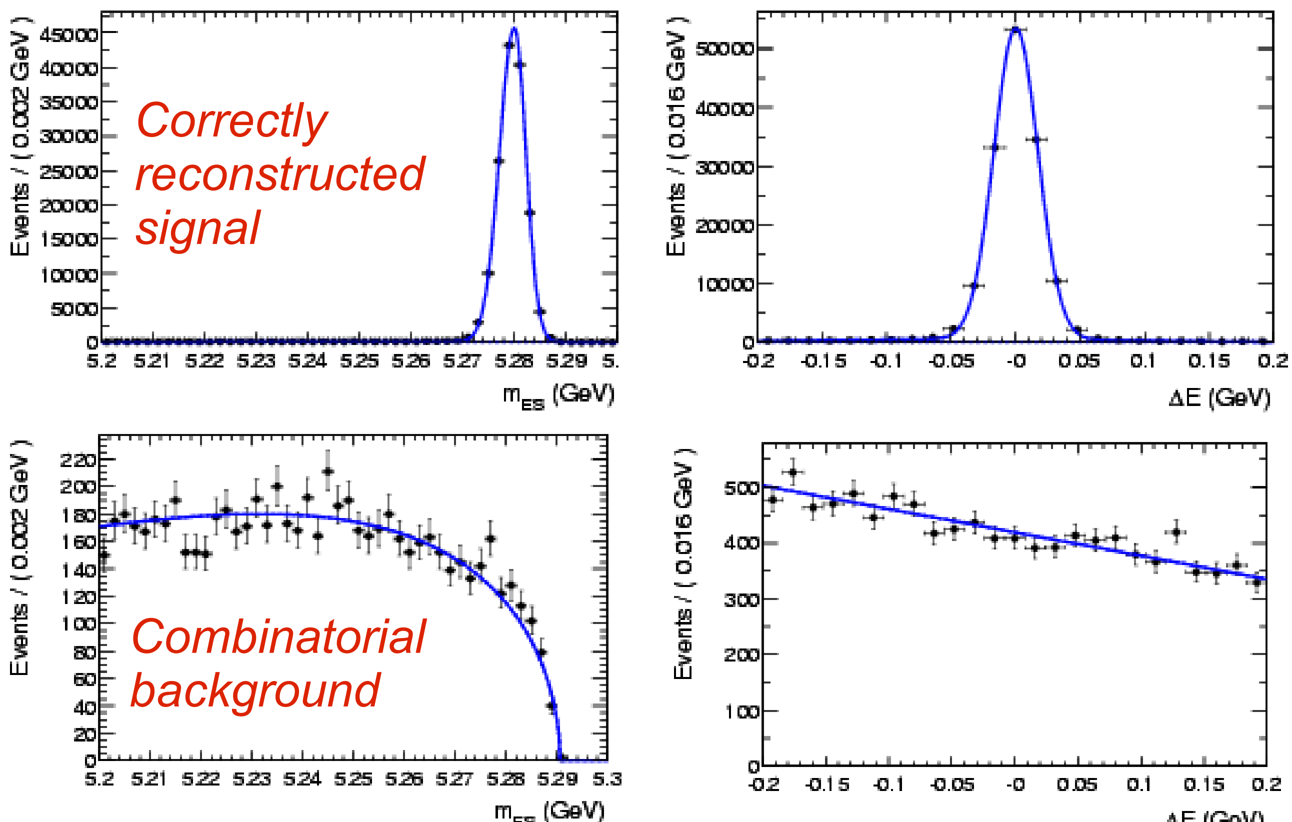
$$m_{ES} \equiv \sqrt{(E_{beam}^{cm})^2 - (p_B^{cm})^2}$$

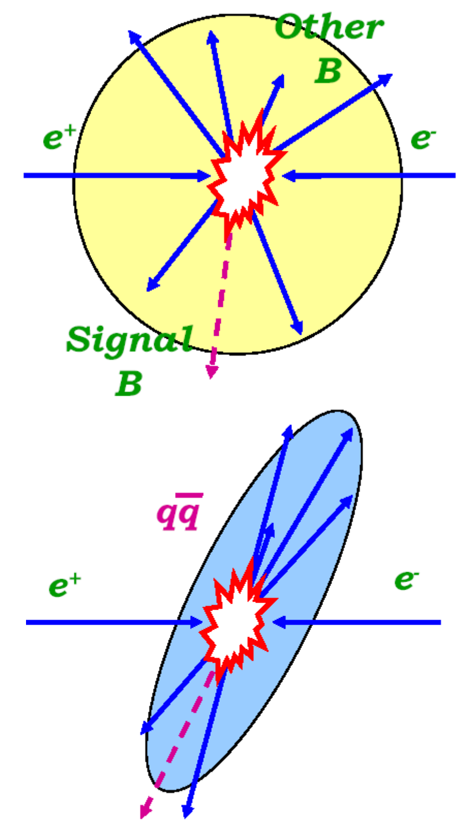
Energy difference:

$$\Delta E \equiv E_B^{cm} - E_{beam}^{cm}$$

Event shape:

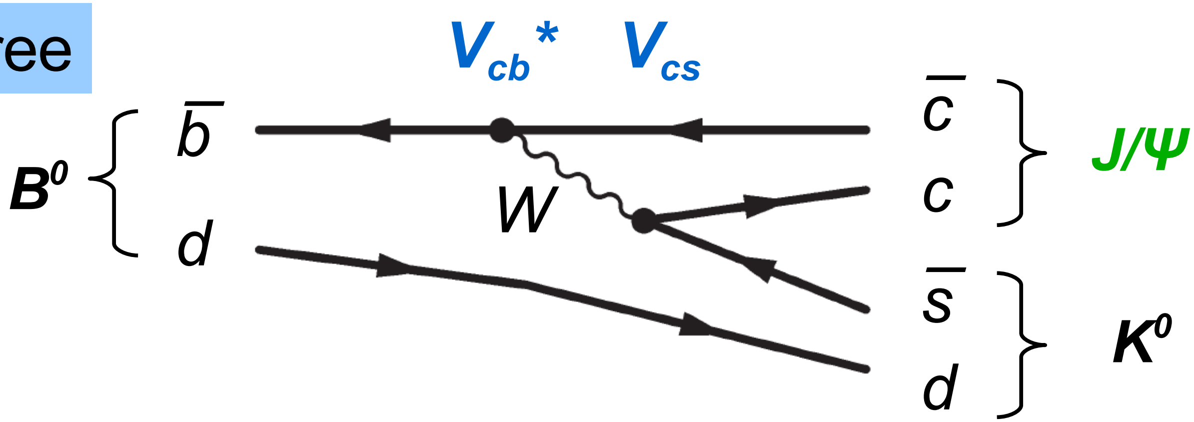
Multivariate techniques



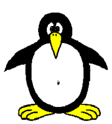


Comparing Trees and Penguins

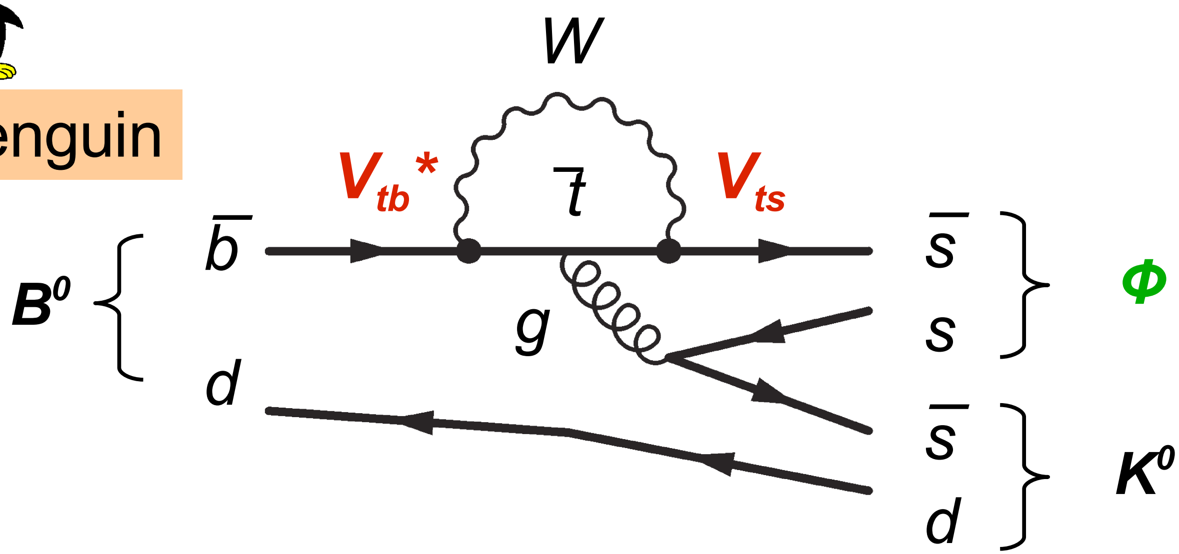
Tree



- $b \rightarrow c\bar{c}s$ are tree and penguin diagrams with equal dominating weak phases
- Theoretically clean (*"Golden Mode"*)



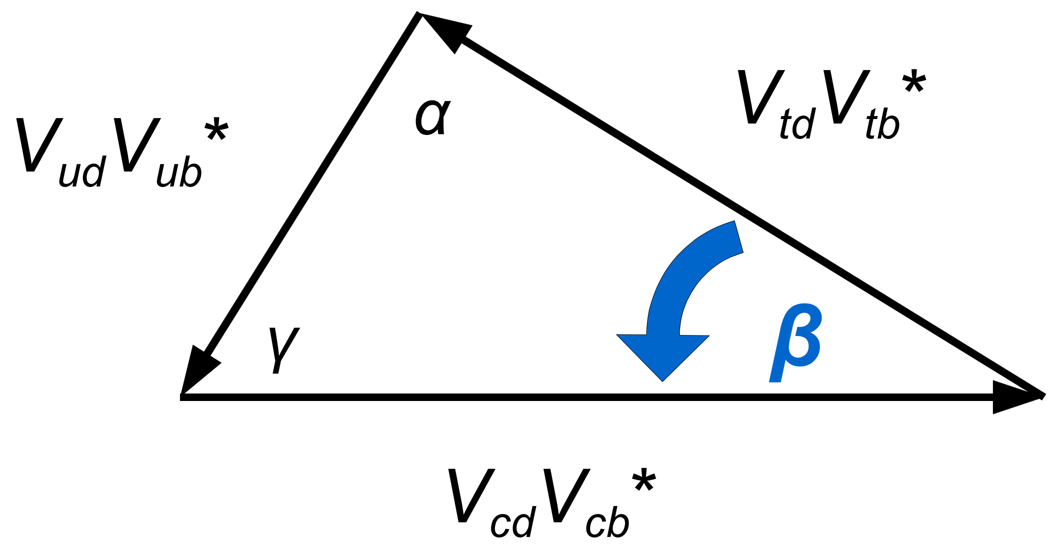
Penguin



- $b \rightarrow s\bar{s}s$ are pure penguin diagrams
- High virtual mass scales involved
- New particles could enter the loop
- Probe for New Physics!

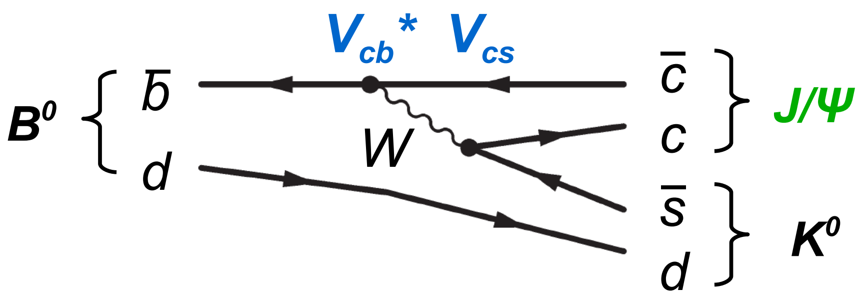
Is sin2β (*s*-penguin) = sin2β (charmonium) ?

CP Measurements: β (φ_1)

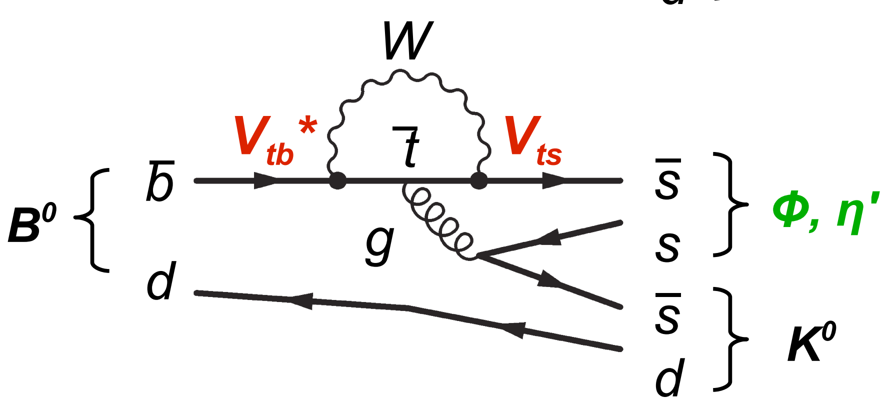


Penguins and New Physics

"Golden" Tree



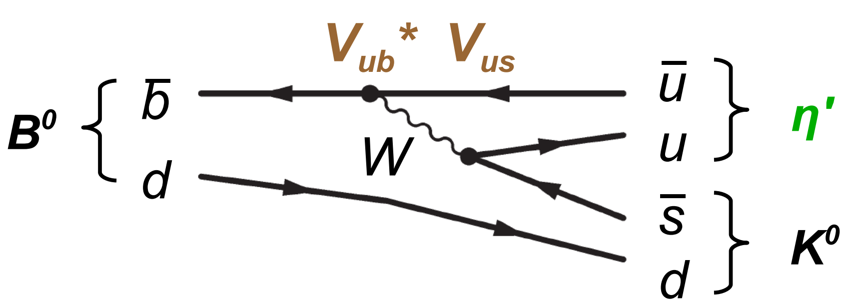
Penguin



Dominating tree or penguin with same (vanishing) weak phase

Add 2 arg(V_{td}) = 2β through mixing

"Nasty" Tree



CKM- and color-suppressed tree with different weak phase: arg(V_{ub})=γ

$S(b\rightarrow c\bar{c}s) \neq S(b\rightarrow q\bar{q}s)$

↑ sin2β ↑ "sin2β_{eff}"

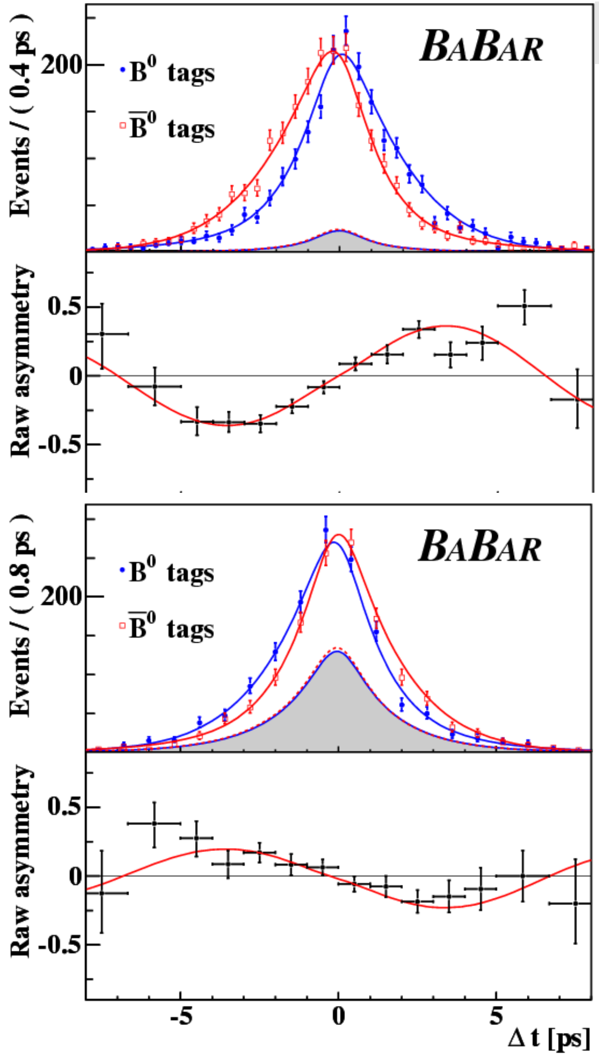
sin2β from $B^0 \to c\bar{c}\, K^0$

227M $B\bar{B}$

386M $B\bar{B}$

PRL **94** (2005) 161803

hep-ex/0507037



CP-even

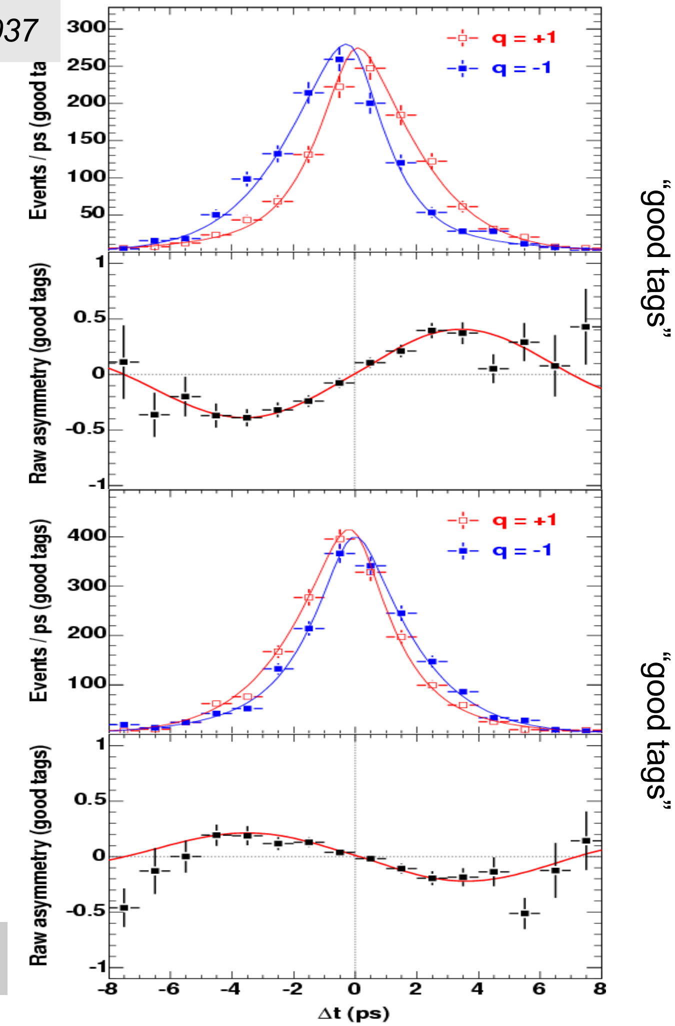
$J/\Psi\ K_S$

$\Psi(2S)\ K_S$
$\chi_{c1}\ K_S$
$\eta_c\ K_S$

CP-odd

$J/\Psi\ K_L$

The "Golden mode"



sin2β = 0.685 ± 0.032

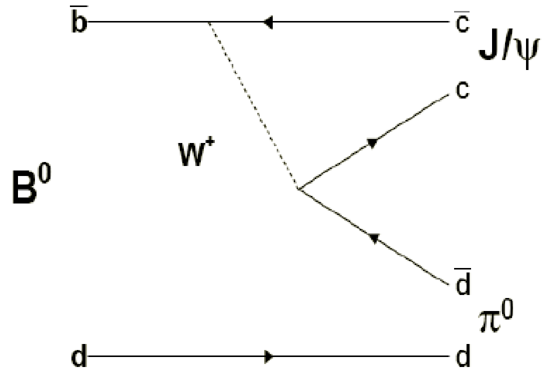
sin2β = 0.722 ± 0.040 ± 0.023

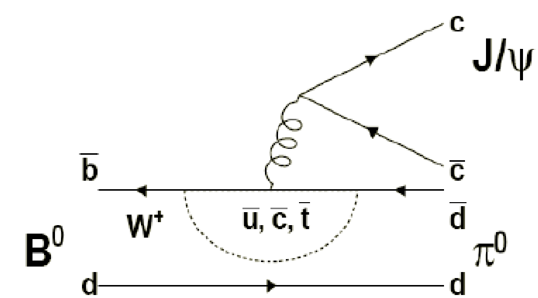
sin2β = 0.652 ± 0.039 ± 0.020

$B^0 \to J/\Psi\ \pi^0$

232M $B\bar{B}$

- Cabibbo-suppressed CP-even $b \to c\bar{c}d$
- Color-suppressed tree gives $\sin 2\beta$
  - same weak phase as CP-odd $b \to c\bar{c}s$
- $b \to d$ penguin pollution

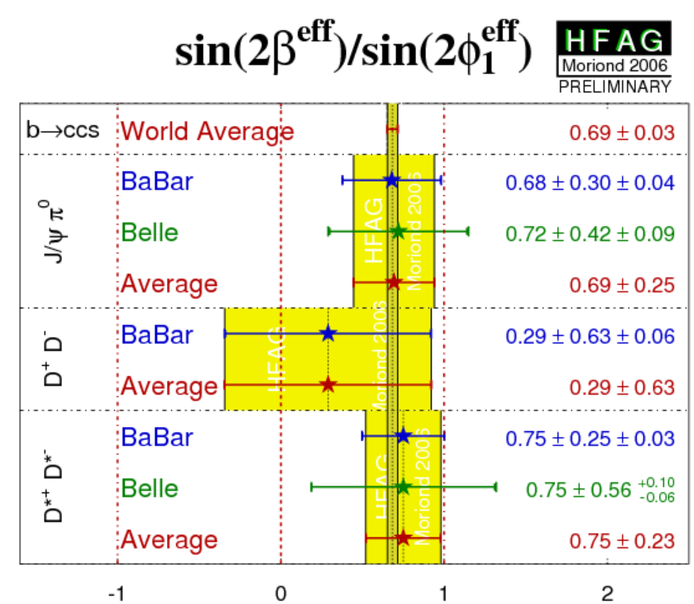




$$S_{J/\Psi\,\pi 0} = -0.68 \pm 0.30 \pm 0.04$$
$$C_{J/\Psi\,\pi 0} = -0.21 \pm 0.26 \pm 0.06$$

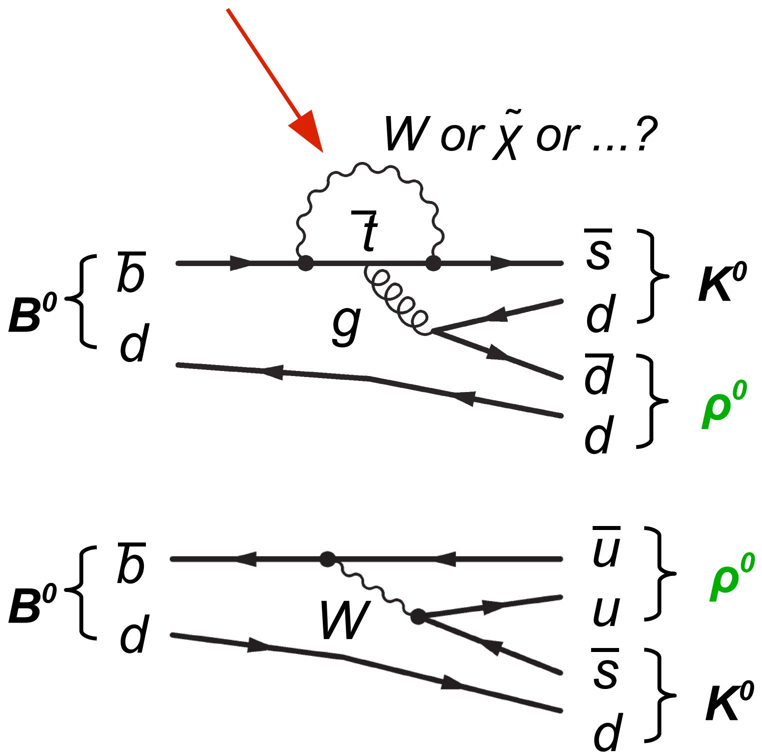
hep-ex/0603021

$$B(B^0 \to J/\Psi\ \pi^0) = (1.94 \pm 0.22 \pm 0.17) \cdot 10^{-5}$$



High sensitivity to New Physics

$B^0 \to \rho^0 K_S$



dominating
$b \to s$ penguin

CKM- and color-suppressed
$b \to d$ tree

Expect: $\Delta\sin 2\beta \approx -0.24\ [-0.56, -0.01]$

Buchalla, Hiller, Nir, Raz: hep-ph/0503151

First Measurement

$B^0 \rightarrow \rho^0 K_S$

227M $B\bar{B}$

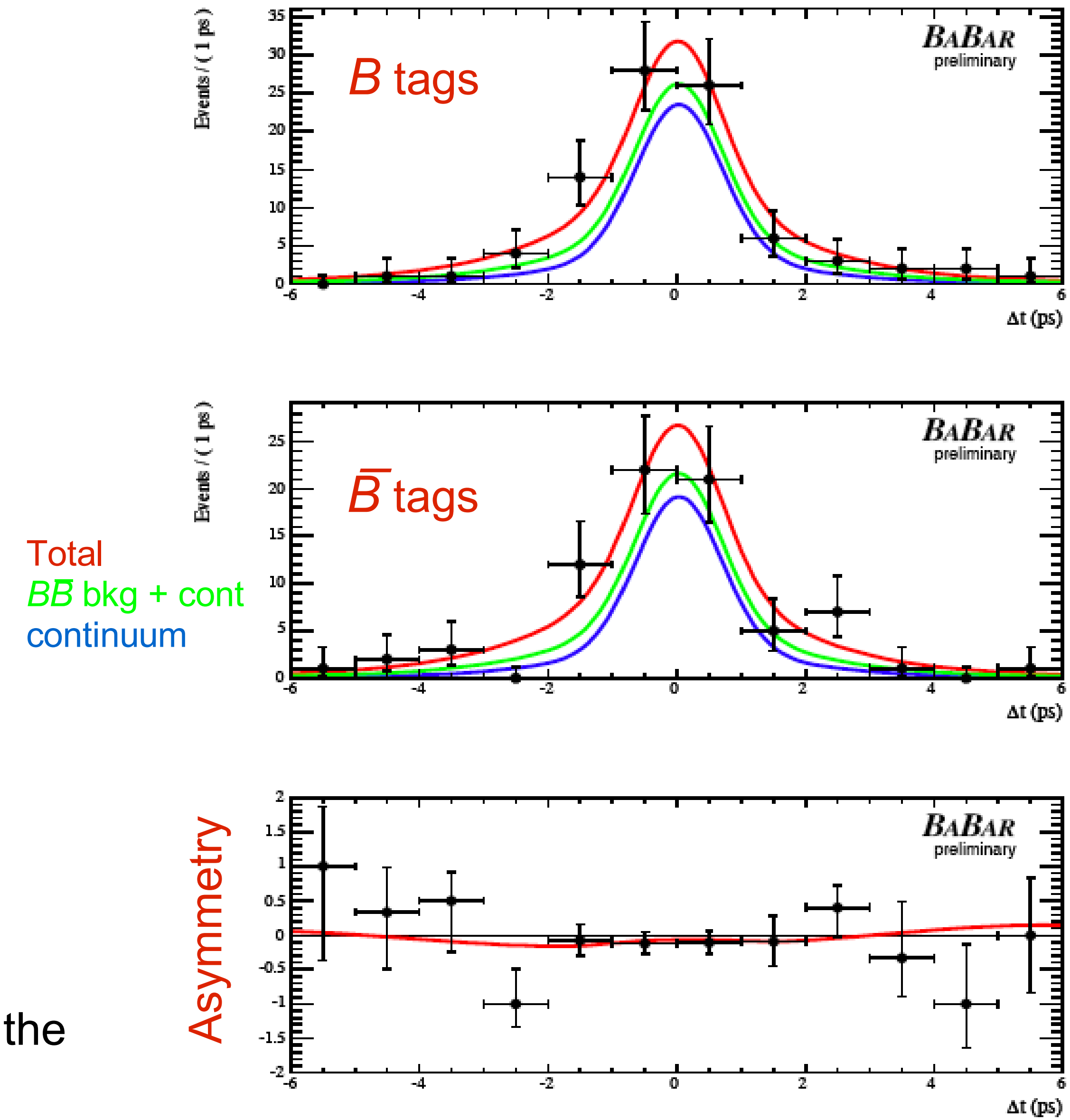
Complicated analysis:

- High $B\bar{B}$ backgrounds
- Need to understand $\pi\pi K$ Dalitz structure
- Large uncertainty from the possible CP-even contribution under the ρ

CP Asymmetry:

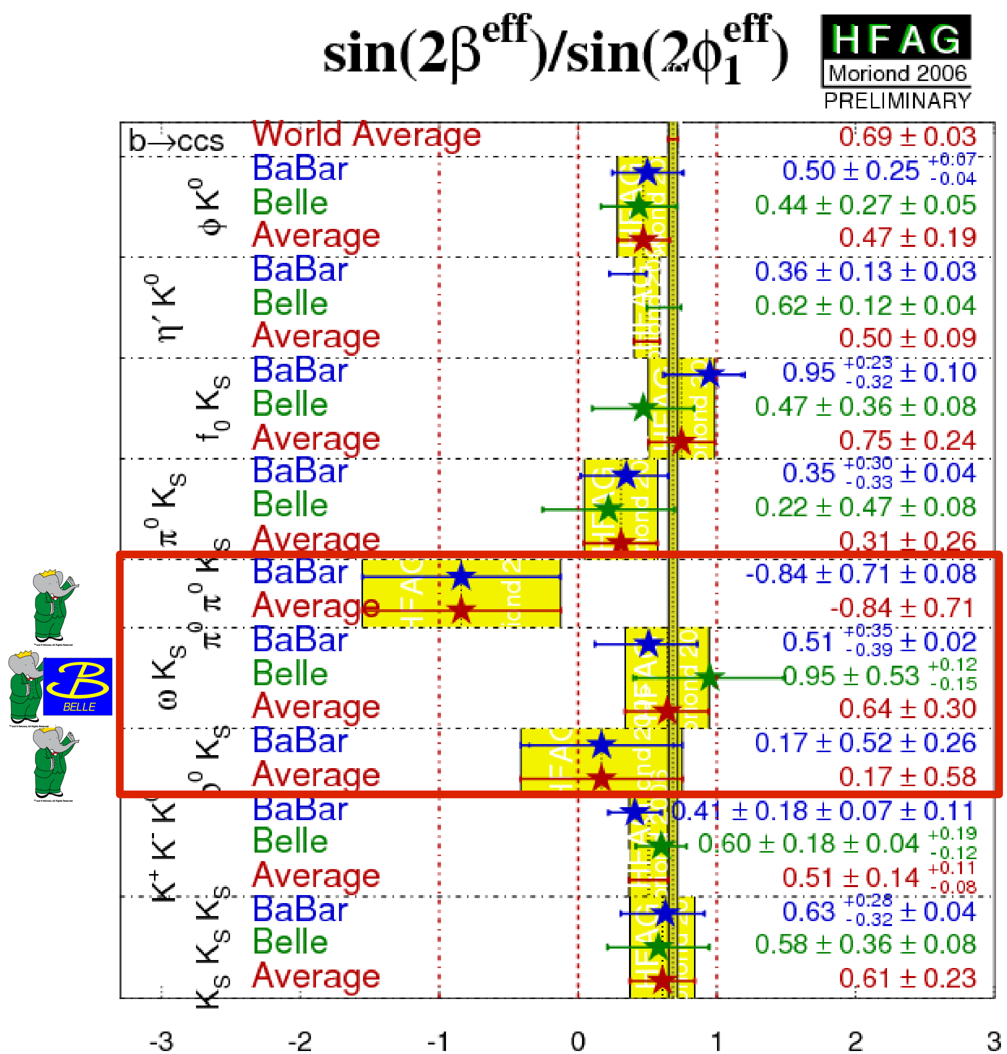
$S_{\rho Ks} = 0.20 \pm 0.52 \pm 0.23$
$C_{\rho Ks} = 0.64 \pm 0.41 \pm 0.23$

(In preparation)

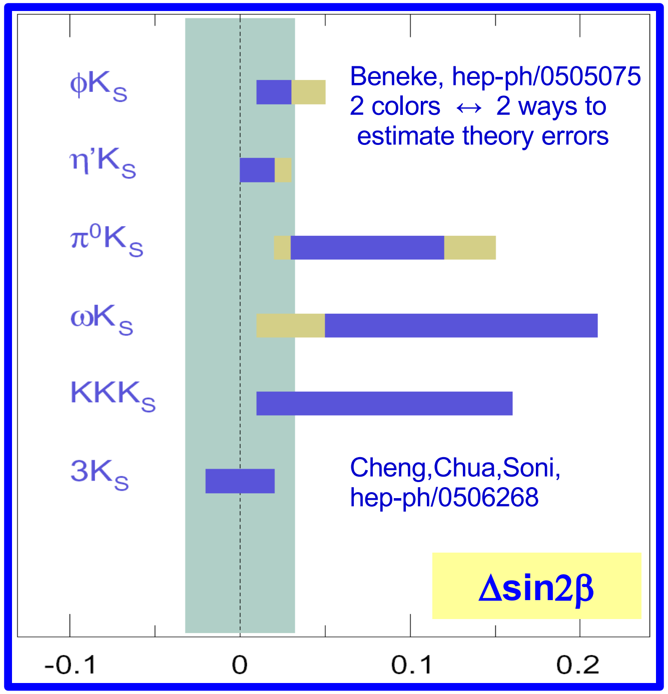


Still large errors, but seem to hint in the direction of the expectation

sin2β from Penguins

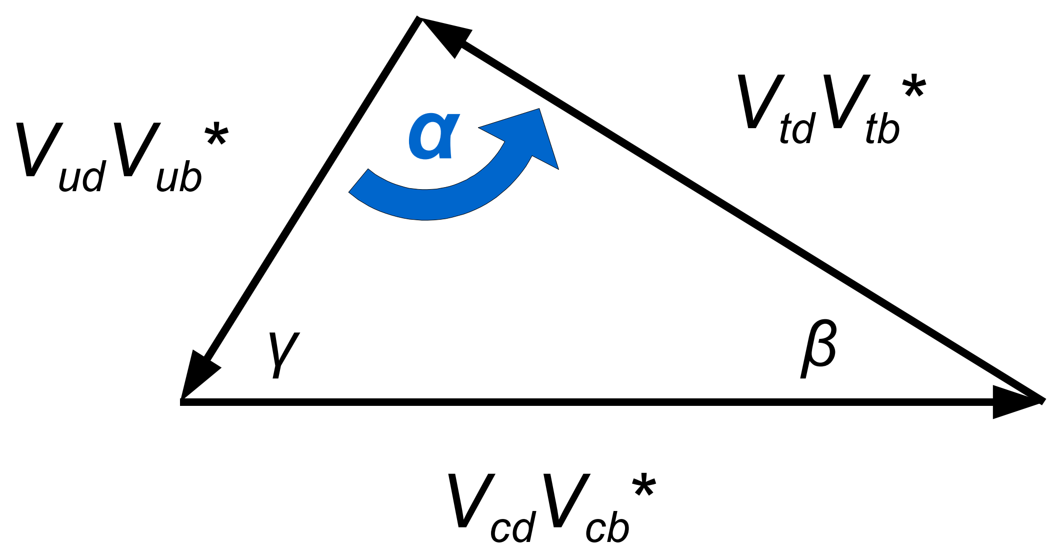


- Two new, one updated mode
- Theory expects positive $\Delta\sin2\beta$ (except for $\rho^0 K_s$)



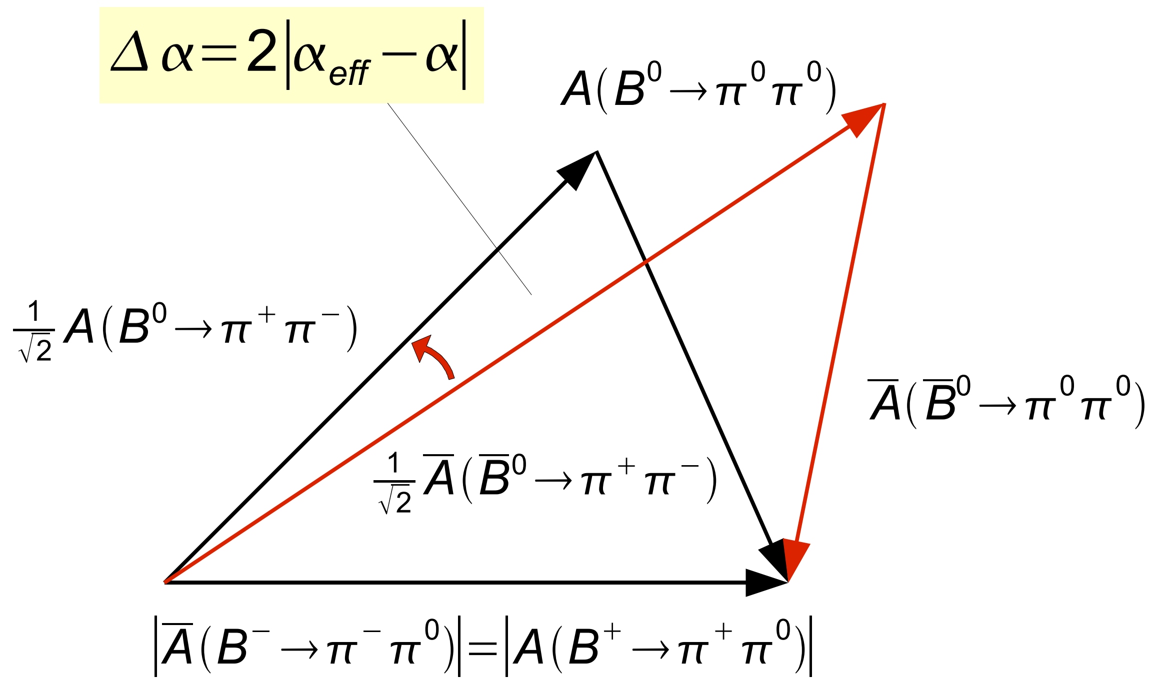
- All but two experimental results low compared to charmonium average (weighted average about ~3σ below SM)

CP Measurements: α (φ_2)



Isospin analysis: $B \to \pi\pi$

- Branching fractions of $\pi^+\pi^-$, $\pi^0\pi^0$, $\pi^\pm\pi^0$ modes related through isospin symmetry
- Ratio of $\pi^0\pi^0$ over $\pi^\pm\pi^0$ gives upper bound on relative strong phase $\Delta\alpha_{\mathrm{eff}}$
- Problem: needs small $B(B^0 \to \pi^0\pi^0)$, but turned out larger than expected

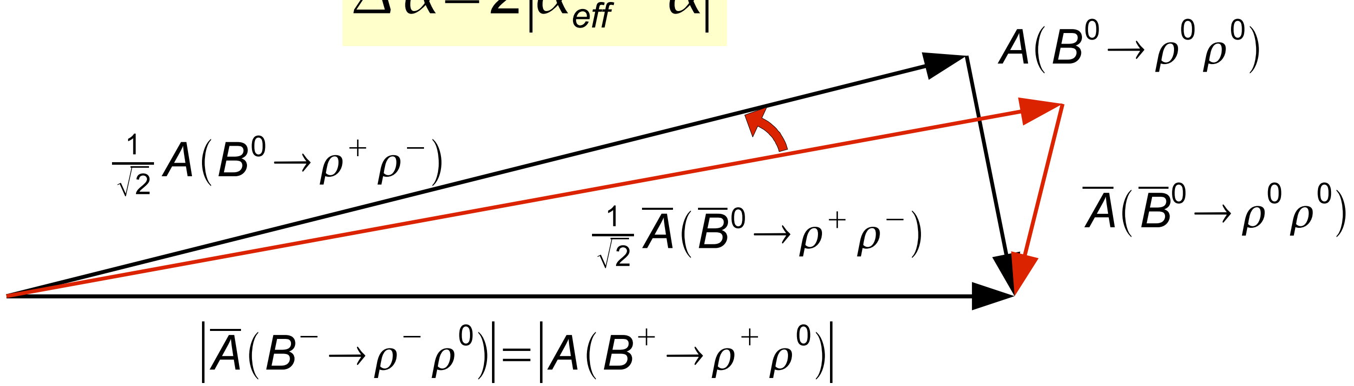


Gronau, London: PRL **65** (1990) 3381

α from $B \to \rho\rho$

- Same isospin analysis as in $B \to \pi\pi$
- $B \to VV$ mode; turned out to be ~100% longitudinally polarized
- Stronger bound since limit on $B^0 \to \rho^0\rho^0$ much lower
- Currently the best mode to measure α
  - But observing signal for $B^0 \to \rho^0\rho^0$ could be bad news for α

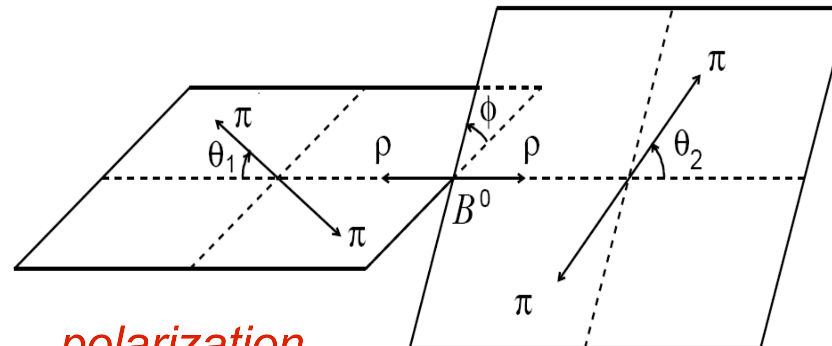
$$\Delta\alpha = 2\left|\alpha_{eff} - \alpha\right|$$



$B^+ \to \rho^+\rho^0$

227M $B\overline{B}$

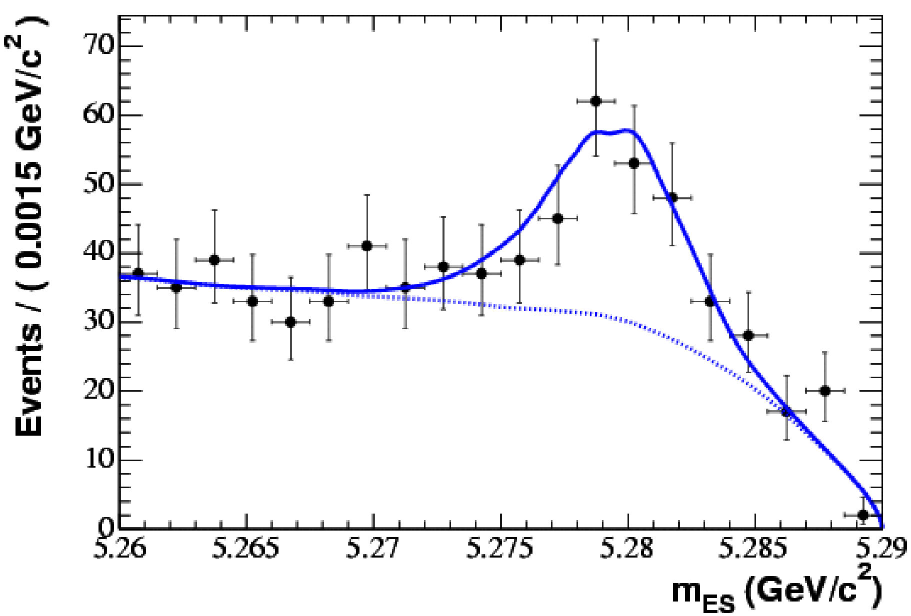
New measurement



polarization

$$\frac{1}{\Gamma}\frac{d^2\Gamma}{d\cos\theta_1\, d\cos\theta_2} \propto f_L \cos^2\theta_1 \cos^2\theta_2 + \frac{1}{4}(1-f_L)\sin^2\theta_1 \sin^2\theta_2$$

longitudinal *transverse*



$B(B^+ \to \rho^+\rho^0) = (17.2 \pm 2.5 \pm 2.8) \cdot 10^{-6}$

$f_L(B^+ \to \rho^+\rho^0) = 0.96 \pm 0.04 \pm 0.05$

$A_{CP}(B^+ \to \rho^+\rho^0) = 0.10 \pm 0.14 \pm 0.09$

(In preparation)

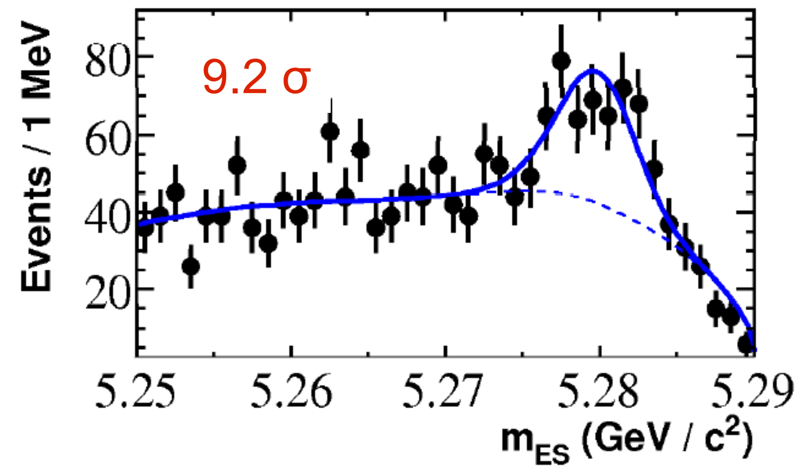
218M $B\bar{B}$

α from $B^0 \rightarrow a_1(1260)^+ \pi^-$?

Observation

Observation of $B^0 \rightarrow a_1(1260)^+ \pi^-$

- Motivated by $B \rightarrow \rho\rho$
  - One of the backgrounds
  - Another mode for measuring α
- Little known about the a_1
- Tests factorization

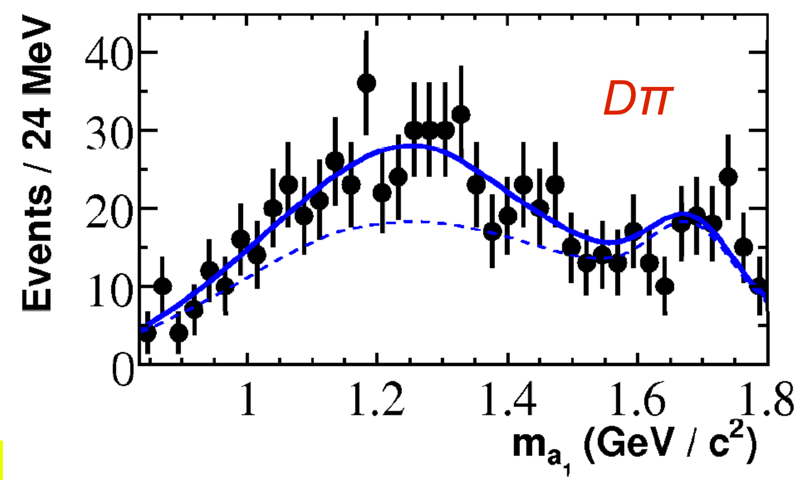


$B(B^0 \rightarrow a_1(1260)^+ \pi^-) = (16.6 \pm 1.9 \pm 1.5) \cdot 10^{-6}$

hep-ex/0603050

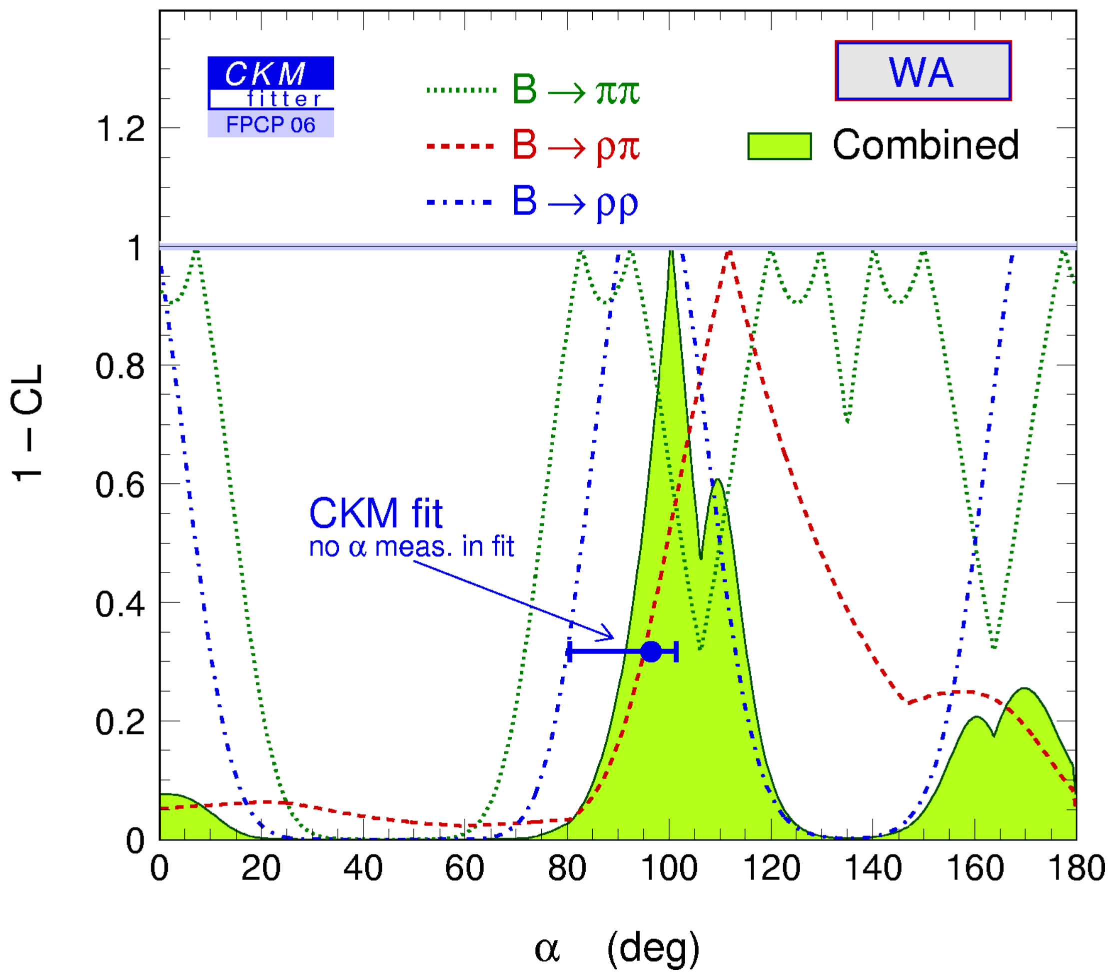
Search for $B^0 \rightarrow a_1^+(1260)\,\rho^-$

- Background to $\rho\rho$
- (in principle) sensitive to α

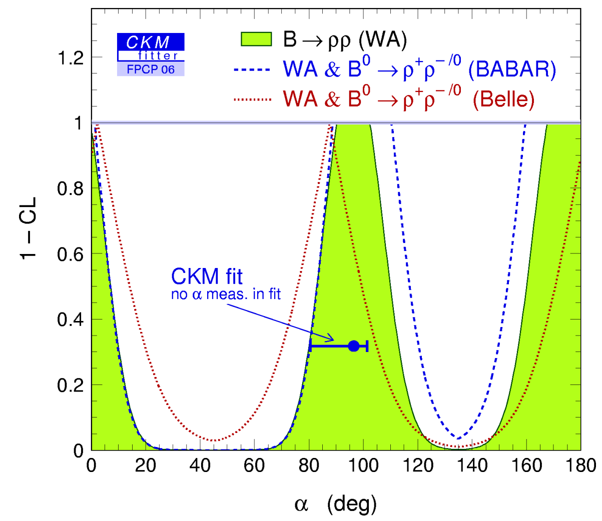


$B(B^0 \rightarrow a_1^+ \rho^-) \cdot B(a_1^+ \rightarrow (3\pi)^+) < 61 \cdot 10^{-6}$ (90% C.L.)

Constraints on α

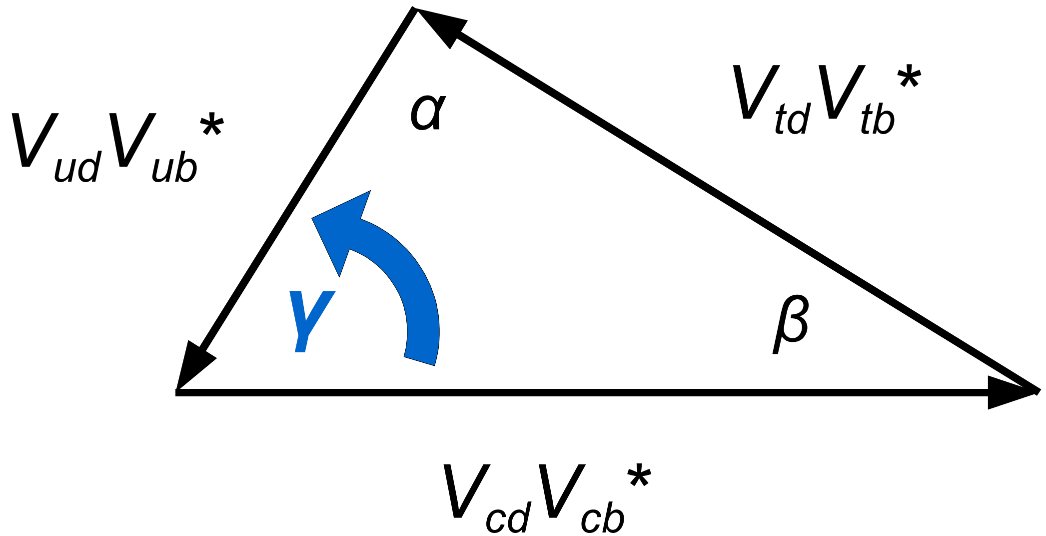


Highest sensitivity from
B → ρρ



$\alpha = (100.2 \ {+15.0}\ {-8.8})$ deg

CP Measurements: γ (φ_3)



γ from $B \rightarrow DK$

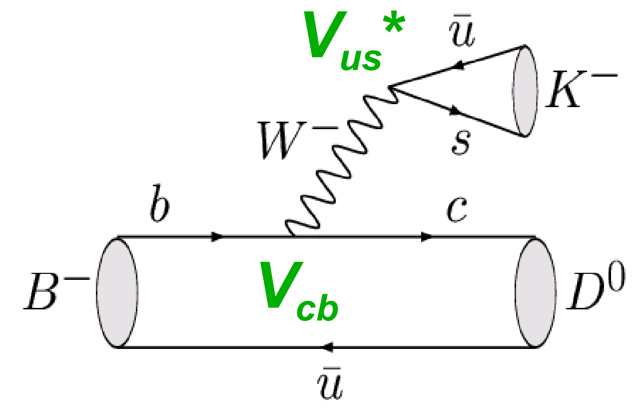
- In general need ≥ 2 amplitudes with different weak and strong phases leading to the same final state *f*
- Choose decays where $D, \bar{D} \rightarrow f$

$$A_{CP} \equiv \frac{\Gamma(B^- \rightarrow D^0 K^-) - \Gamma(B^+ \rightarrow D^0 K^+)}{\Gamma(B^- \rightarrow D^0 K^-) + \Gamma(B^+ \rightarrow D^0 K^+)}$$

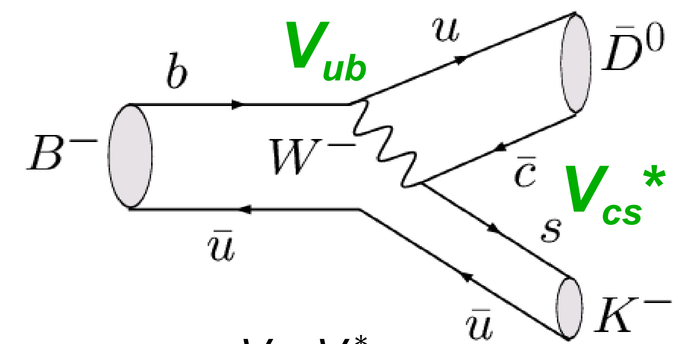
$$\propto r_B \sin(\gamma) \sin(\delta_B)$$

- Critical parameter: $r_B \equiv \frac{A(b \rightarrow u)}{A(b \rightarrow c)}$
- Use additional observables in D decay to measure r_B γ δ_B simultaneously
- Three methods in use:

  GLW, ADS, *D* Dalitz (GGSZ)



relative amplitude r_B
weak phase γ
strong phase δ_B



$$\gamma \equiv arg[-\frac{V_{ud} V_{ub}^*}{V_{cd} V_{cb}^*}]$$

232M $B\bar{B}$

New Results for the GLW Method ($D \rightarrow f_{CP}$)

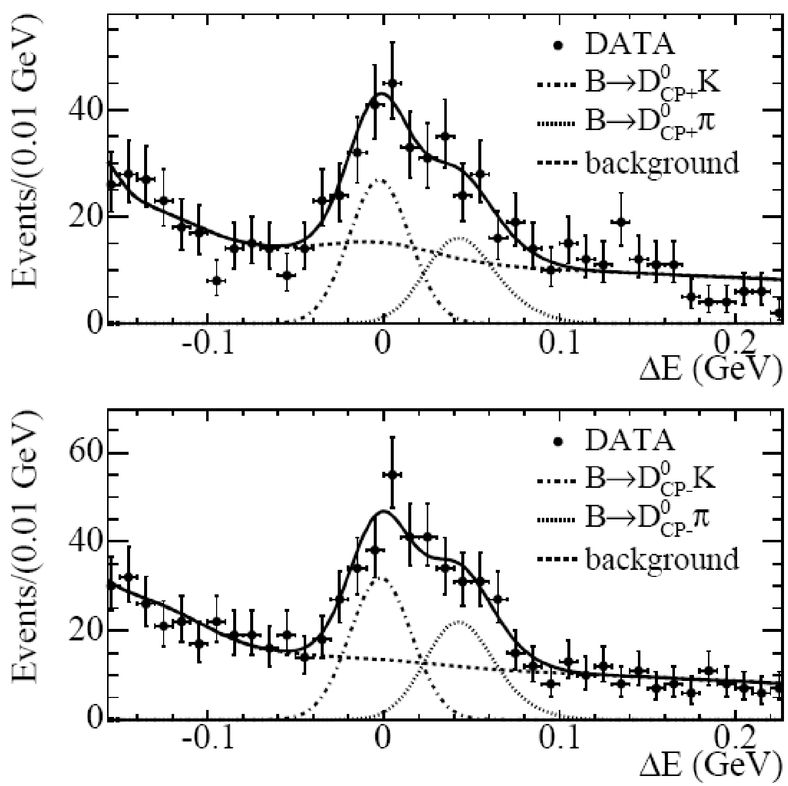
$$A_{CP} \equiv \frac{\Gamma(B^- \to D_{CP} K^-) - \Gamma(B^+ \to D_{CP} K^+)}{\Gamma(B^- \to D_{CP} K^-) + \Gamma(B^+ \to D_{CP} K^+)} = \frac{\pm 2 r_B \sin\gamma \sin\delta_B}{R_{CP}}$$

$$R_{CP} \equiv \frac{\Gamma(B^- \to D_{CP} K^-) + \Gamma(B^+ \to D_{CP} K^+)}{(\Gamma(B^- \to D^0 K^-) + \Gamma(B^+ \to \overline{D}^0 K^+))/2} = 1 + r_B^2 \pm 2 r_B \cos\gamma \cos\delta_B$$

4 Observables ($A_{CP\pm}$, $R_{CP\pm}$) to measure r_B γ δ_B

- Theoretically clean
- $B \rightarrow D\pi$ background
- Limited statistics

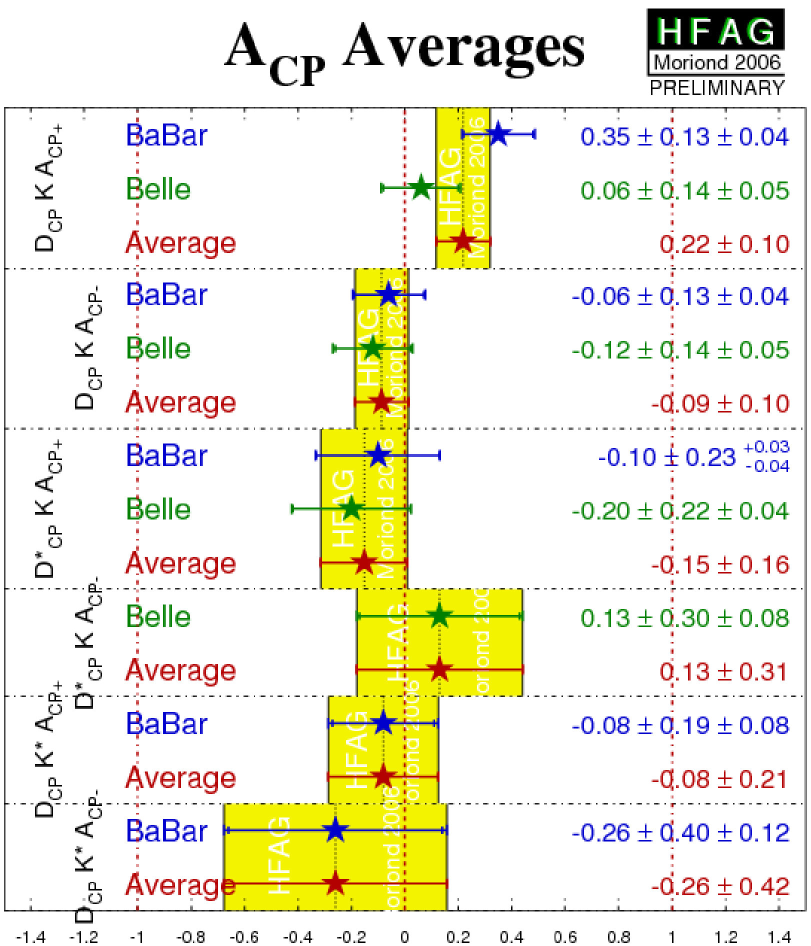
New from BaBar:
$D \rightarrow \omega K_S$, $D \rightarrow \varphi K_S$

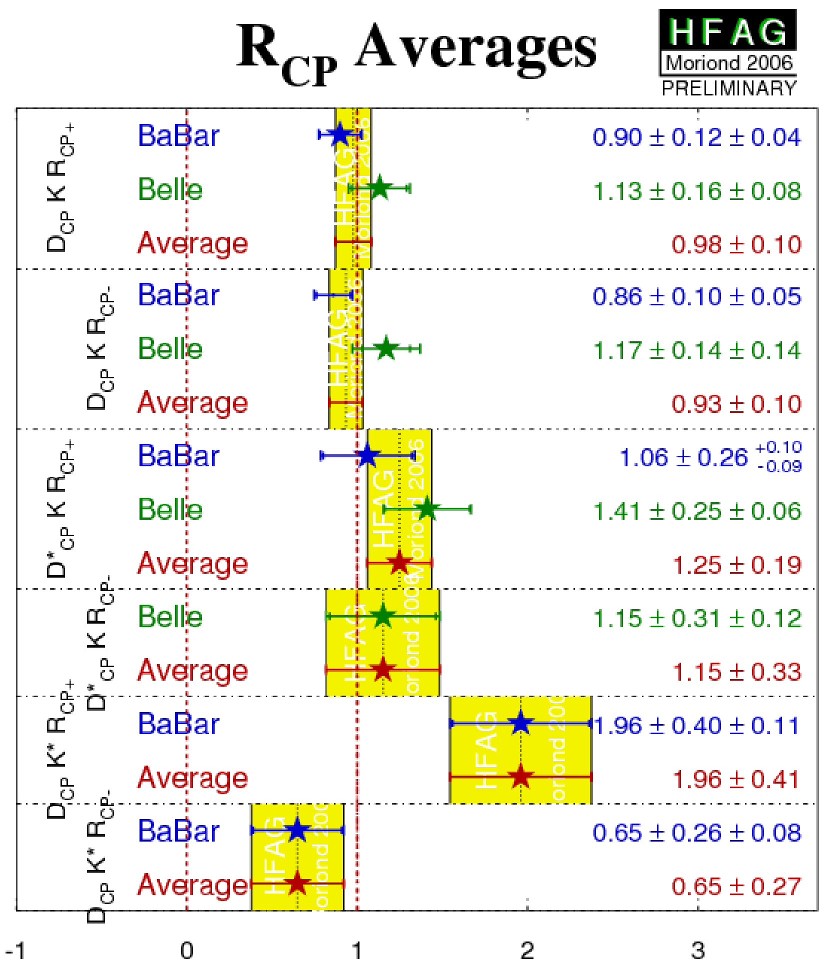


D_{CP} K

R_{CP+} =	0.90 ± 0.12 ± 0.04
R_{CP-} =	0.86 ± 0.10 ± 0.05
A_{CP+} =	0.35 ± 0.13 ± 0.04
A_{CP-} =	−0.06 ± 0.13 ± 0.04

GLW Method ($D \to f_{CP}$) Summary



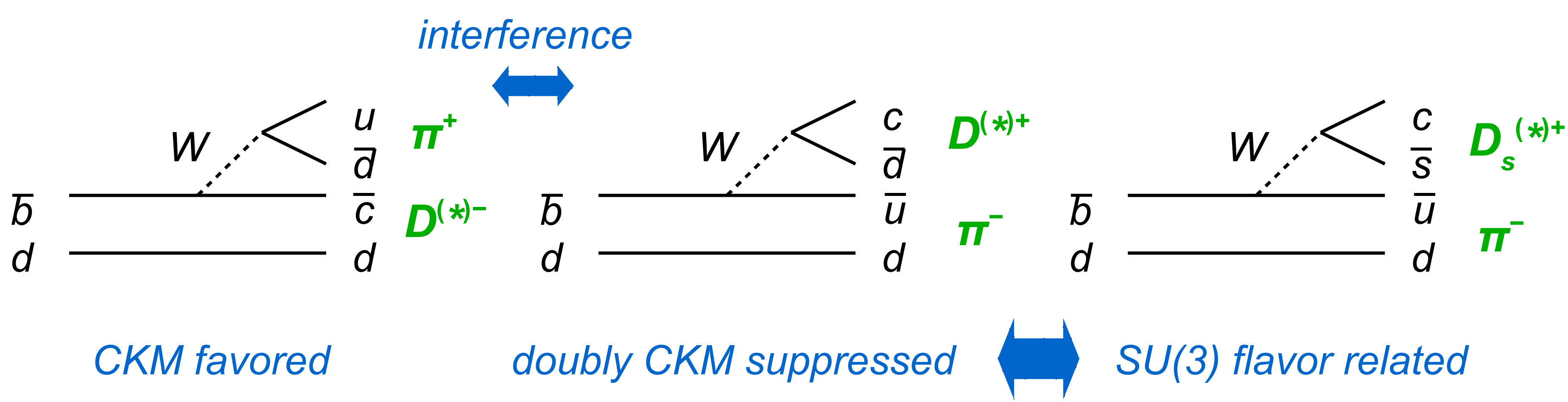


r_B from $B^0 \to D_s^{(*)}\pi/K$ and SU(3)

- Branching fraction $B^0 \to D^{(*)+}\pi^-$ overwhelmed by $\bar{B}^0$ background
- SU(3) relates $D\pi$ and $D_s\pi$

$$r_{D^{(*)}\pi} \approx \frac{|V_{cd}|}{|V_{cs}|}\frac{f_{D^{(*)}}}{f_{D_s^{(*)}}}\sqrt{\frac{B(B^0 \to D_s^{(*)+}\pi^-)}{B(B^0 \to D^{(*)-}\pi^+)}}$$

- Estimate 30% theoretical error on r
  - assuming W exchange diagrams strongly suppressed
  - SU(3) breaking effects factorize to ratio of D decay constants



230M $B\bar{B}$

$B^0 \rightarrow D_s^{(*)} \pi/K$

First Observation of

$B^0 \rightarrow D_s^{(*)+} \pi^-$

$B^0 \rightarrow D_s^{(*)-} K^+$

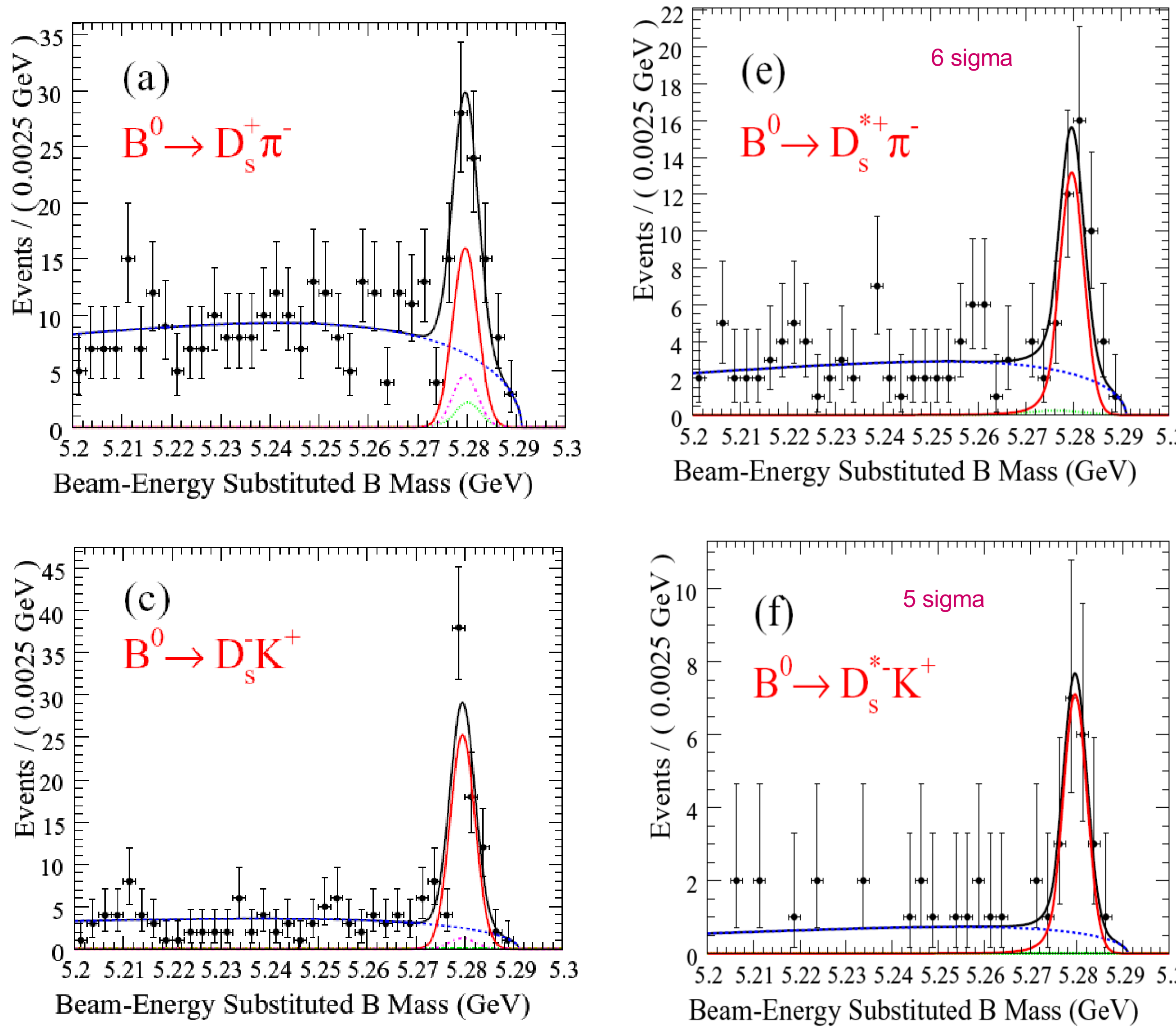
hep-ex/0604012

$B(B^0 \rightarrow D_s^+ \pi^-) =$
$(1.3 \pm 0.3 \pm 0.2) \cdot 10^{-5}$

$B(B^0 \rightarrow D_s^- K^+) =$
$(2.5 \pm 0.4 \pm 0.4) \cdot 10^{-5}$

$B(B^0 \rightarrow D_s^{*+} \pi^-) =$
$(2.8 \pm 0.6 \pm 0.5) \cdot 10^{-5}$

$B(B^0 \rightarrow D_s^{*-} K^+) =$
$(2.0 \pm 0.5 \pm 0.4) \cdot 10^{-5}$



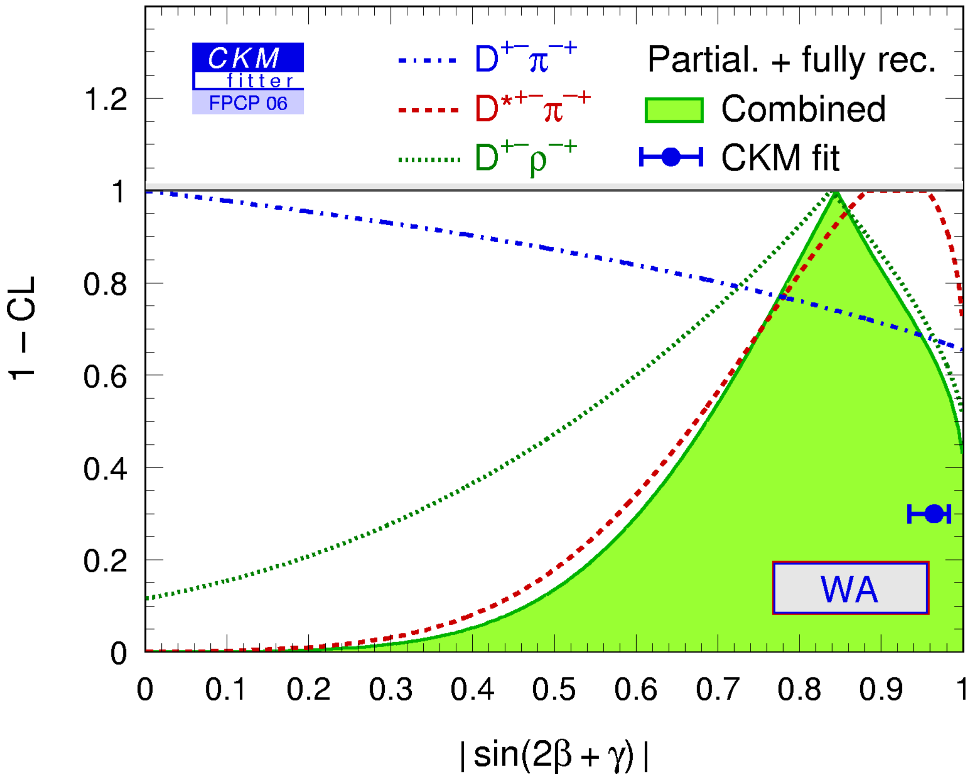
$\sin(2\beta+\gamma)$ from $B^0 \to D^{(*)}\pi, D\rho$

- Result from $B^0 \to D^{(*)}\pi$

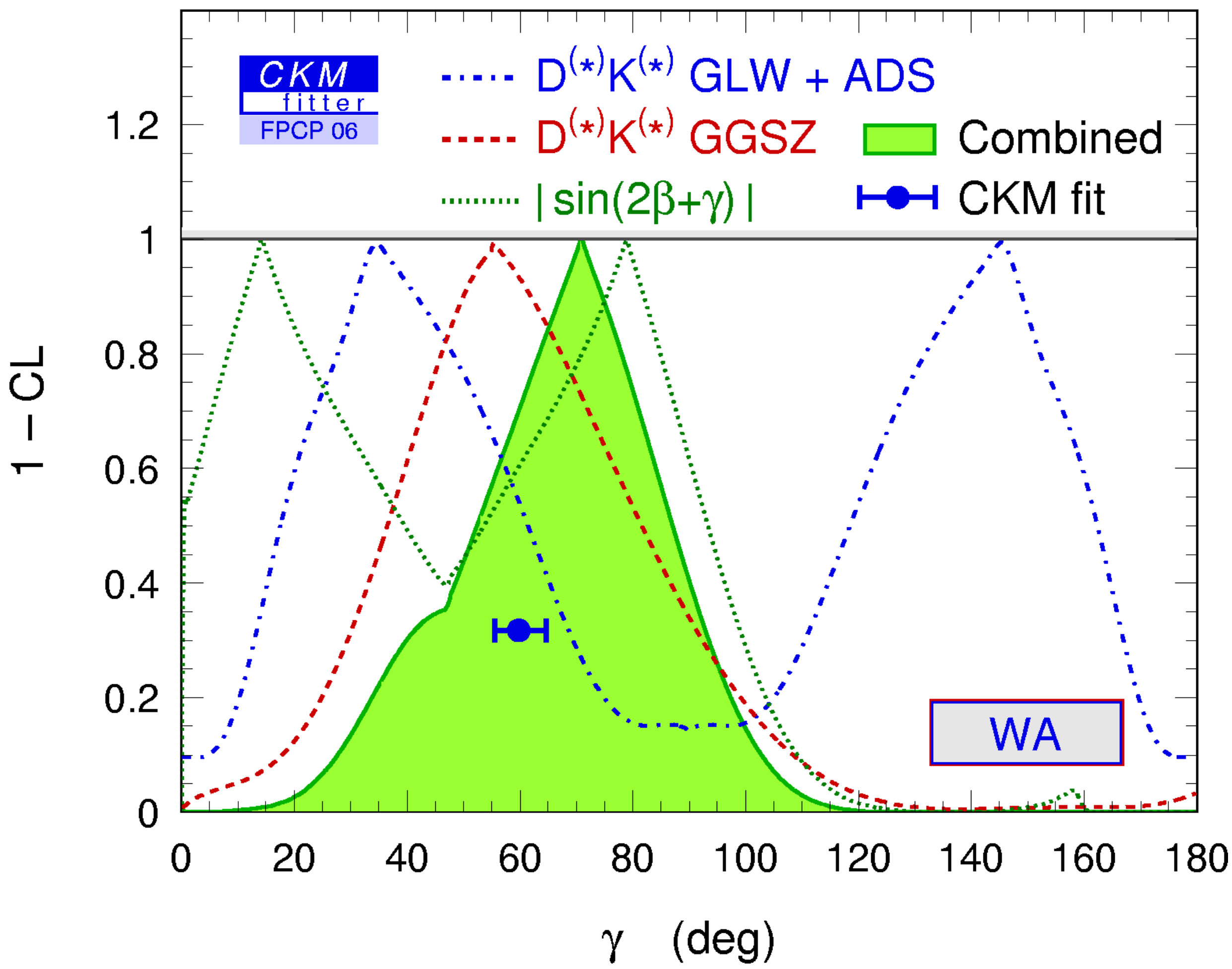
$r(D\pi) = 0.013 \pm 0.002 \pm 0.001$
$r(D^*\pi) = 0.019 \pm 0.002 \pm 0.002$

- Small r values imply small CP asymmetries in $B^0 \to D^{(*)}\pi$
  - Need bigger r !
- Set upper limit

$\sin(2\beta+\gamma) > 0.64$ (68% C.L.)
$\sin(2\beta+\gamma) > 0.42$ (90% C.L.)



Constraints on γ



$\gamma = (71\ {+22}\ {-30})$ deg

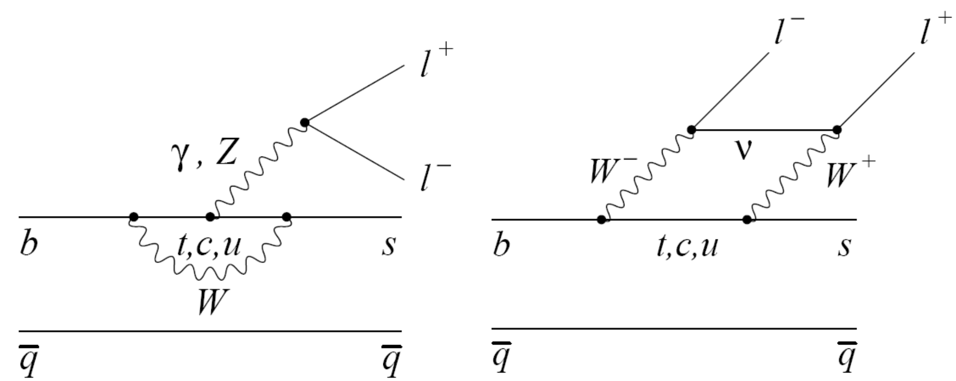
Rare Decays

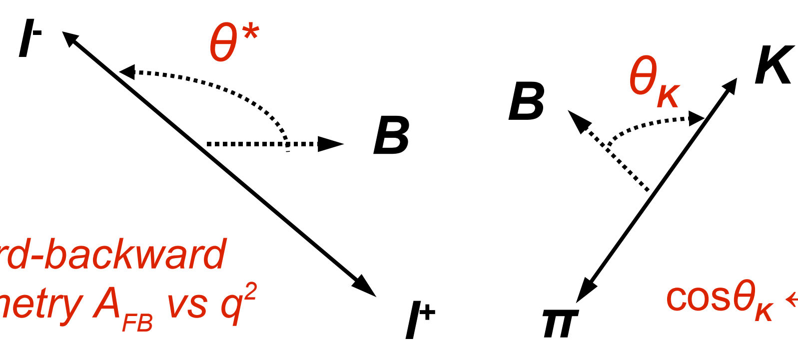
Allowed	***Rare***	***Forbidden***
		

$B^0 \to K^{(*)}\, l^+ l^-$

"Rare or medium rare?"

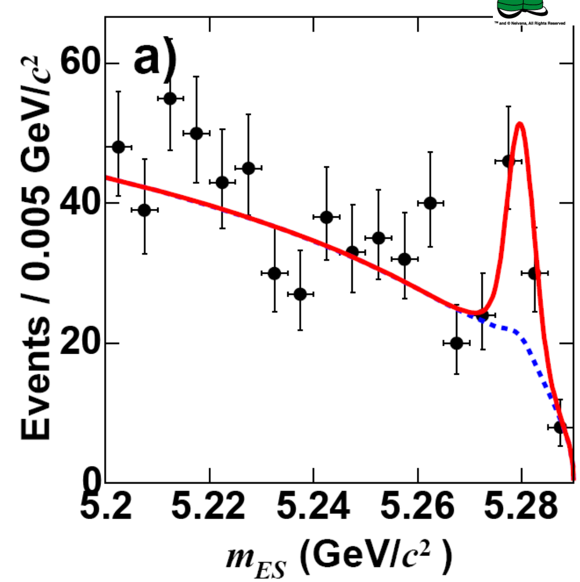
- Rates well measured
- Start to investigate angular distributions and asymmetries





Forward-backward asymmetry A_{FB} vs q^2

$\cos\theta_K \leftrightarrow K^*$ polarization



$b \to sll$ transition described by three (effective) Wilson coefficients:

C_7 photon (constrained from $b \to s\gamma$)

C_9 vector EW

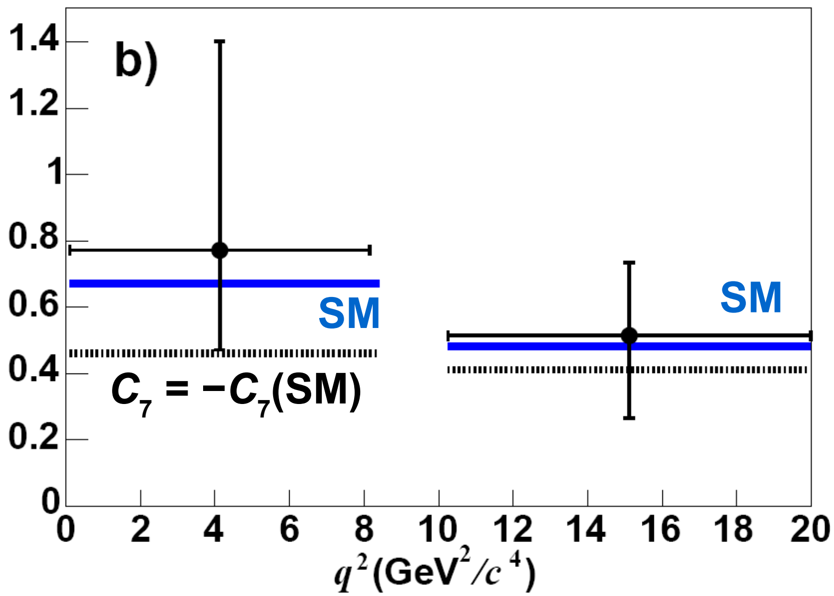
C_{10} axial-vector EW

Angular analysis of $B^0 \to K^{(*)} l^+ l^-$

229M $B\bar{B}$

hep-ex/0604007

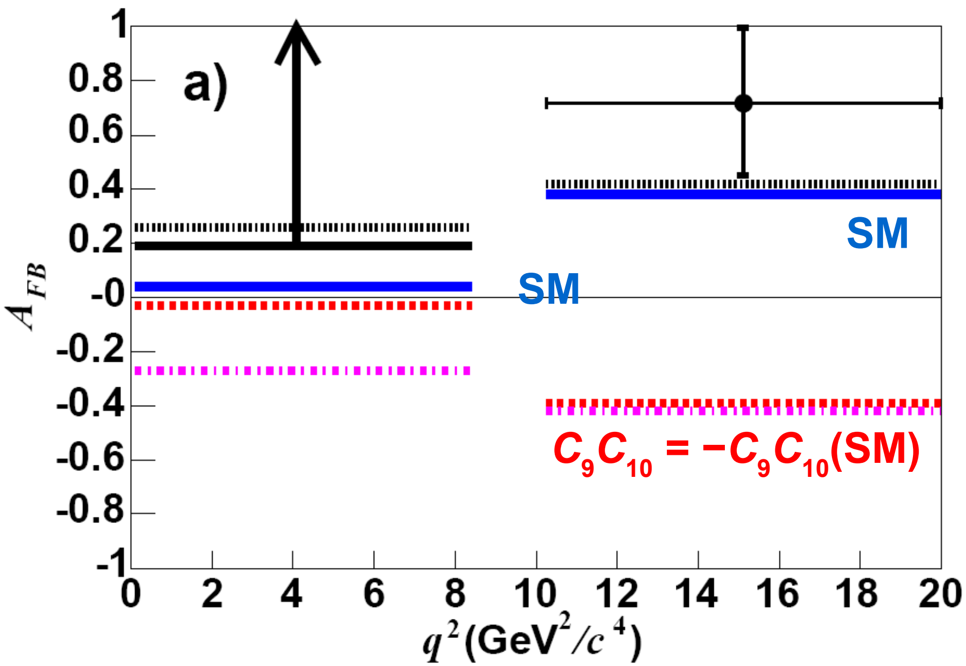
K^* polarization F_L



K^* polarization consistent with SM

Should be possible to exclude $C_7 = -C_7$(SM) with 1 ab^{-1}

Forward-backward asymmetry A_{FB} vs q^2



Low q^2 limit excludes SM at 98% C.L. (2.1σ)

A_{FB} = 0.19 (at 95% C.L.)
A_{FB}(SM)= 0.03

Wrong-sign C_9C_{10} excluded at >3σ

Angular analysis of $B^0 \to K^{(*)} l^+l^-$ (cont.)

386M $B\bar{B}$

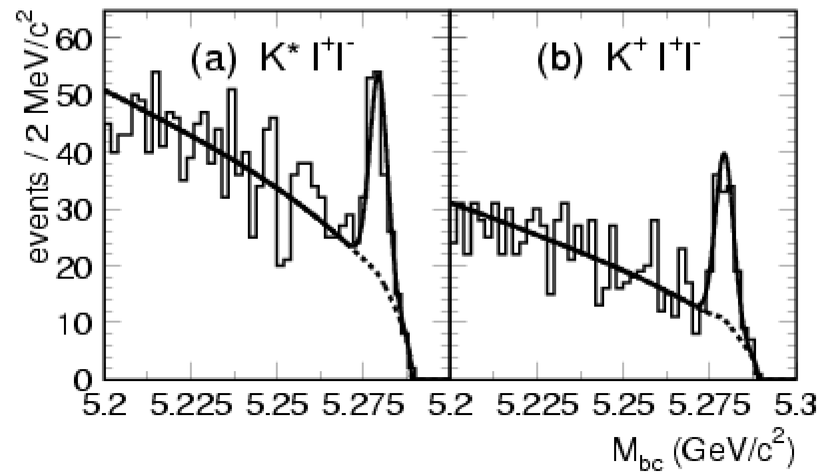
Forward-backward asymmetry A_{FB} vs q^2

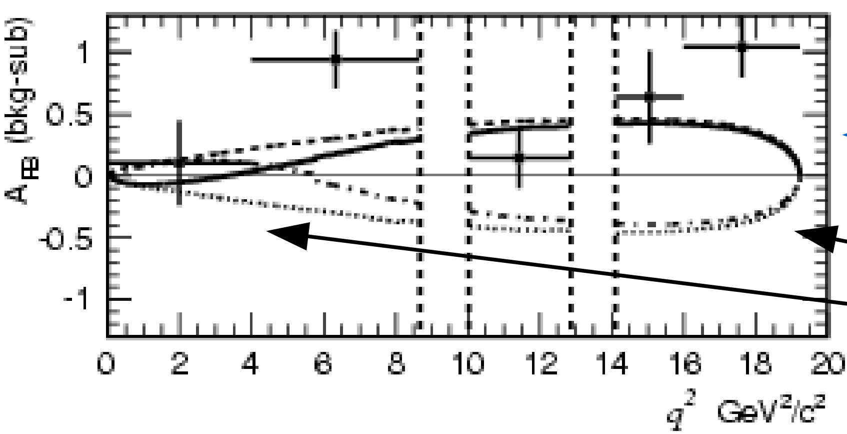
$A_{FB}\,(B \to K^*\, l^+l^-) =\ 0.50 \pm 0.15 \pm 0.02$

$A_{FB}\,(B^+ \to K^+\, l^+l^-) =\ 0.10 \pm 0.14 \pm 0.01$

Large integrated $K^*\, l^+l^-$ asymmetry at 3.4 σ
Asymmetry of $K^+\ l^+l^-$ consistent with 0

hep-ex/0603018





A_{FB} vs q^2

$C_7C_9C_{10}$ (SM)

$C_9C_{10} = -C_9C_{10}$ (SM)

$C_7 = -C_7$ (SM)

$B \to \tau\nu$

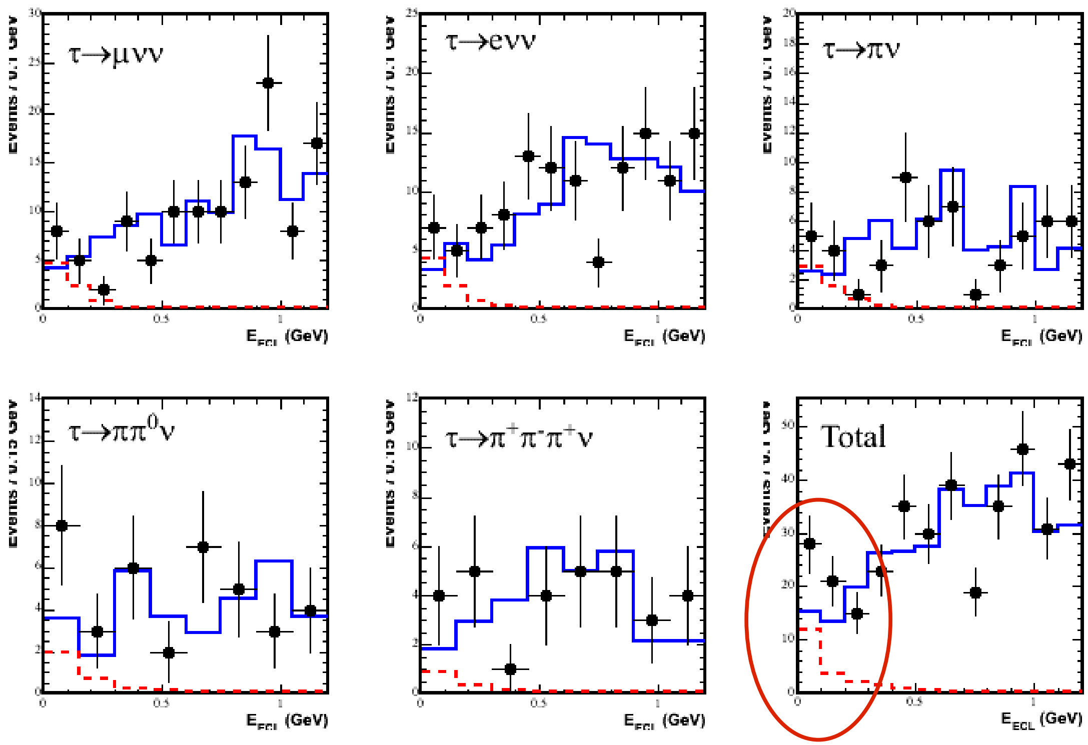
447M $B\bar{B}$

τ lepton least helicity suppressed

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

Direct measure of B decay constant f_B

Experimentally challenging: at least two neutrinos in the event



Identify 5 tau decay modes (81% of all tau)

Fully reconstruct tag *B*, reconstruct tau daughters

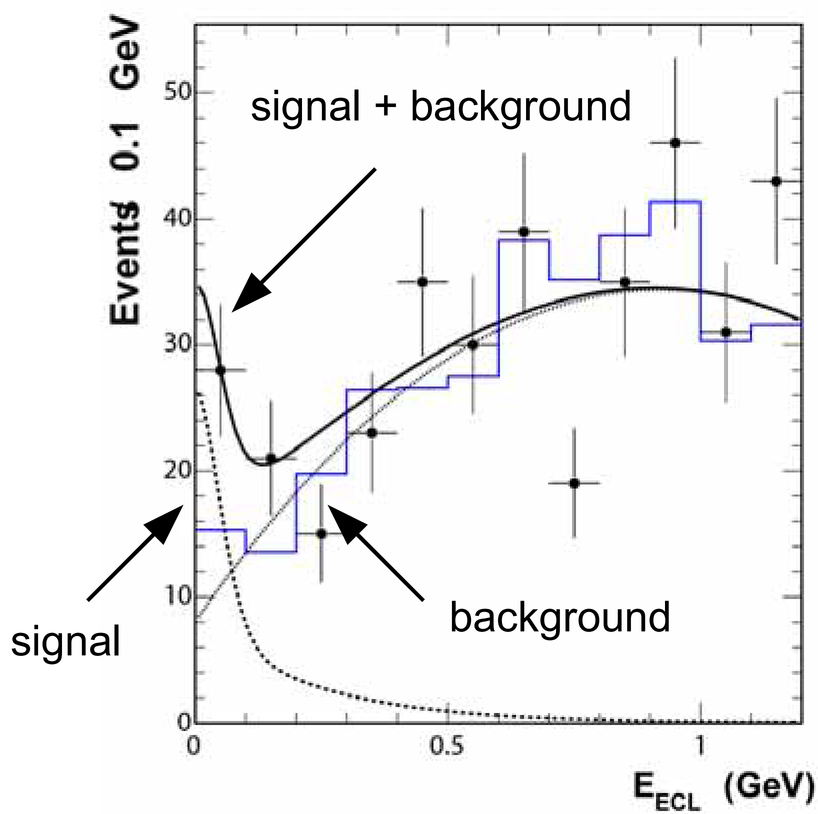
Look at **extra neutral energy in calorimeter E_{ECL}** not associated with tag *B* (or $\tau \to \pi\pi^0\nu$)

Signal peaks at zero

First Observation

$B \to \tau\nu$

447M $B\bar{B}$



	N_{obs}	N_s	N_b	Σ
$\mu^- \bar{\nu}_\mu \nu_\tau$	13	$5.4^{+3.2}_{-2.2}$	$9.1^{+0.2}_{-0.1}$	2.3σ
$e^- \bar{\nu}_e \nu_\tau$	12	$3.9^{+3.5}_{-2.5}$	$9.2^{+0.2}_{-0.2}$	1.5σ
$\pi^- \nu_\tau$	9	$3.4^{+2.6}_{-1.6}$	$4.0^{+0.2}_{-0.1}$	1.9σ
$\pi^- \pi^0 \nu_\tau$	11	$6.2^{+3.9}_{-2.7}$	$4.2^{+0.3}_{-0.3}$	2.6σ
$\pi^- \pi^+ \pi^- \nu_\tau$	9	$3.1^{+3.1}_{-2.6}$	$3.7^{+0.3}_{-0.2}$	1.2σ
Combined	54	$21.2^{+6.7}_{-5.7}$	$30.2^{+0.5}_{-0.4}$	4.2σ

Significance with systematics

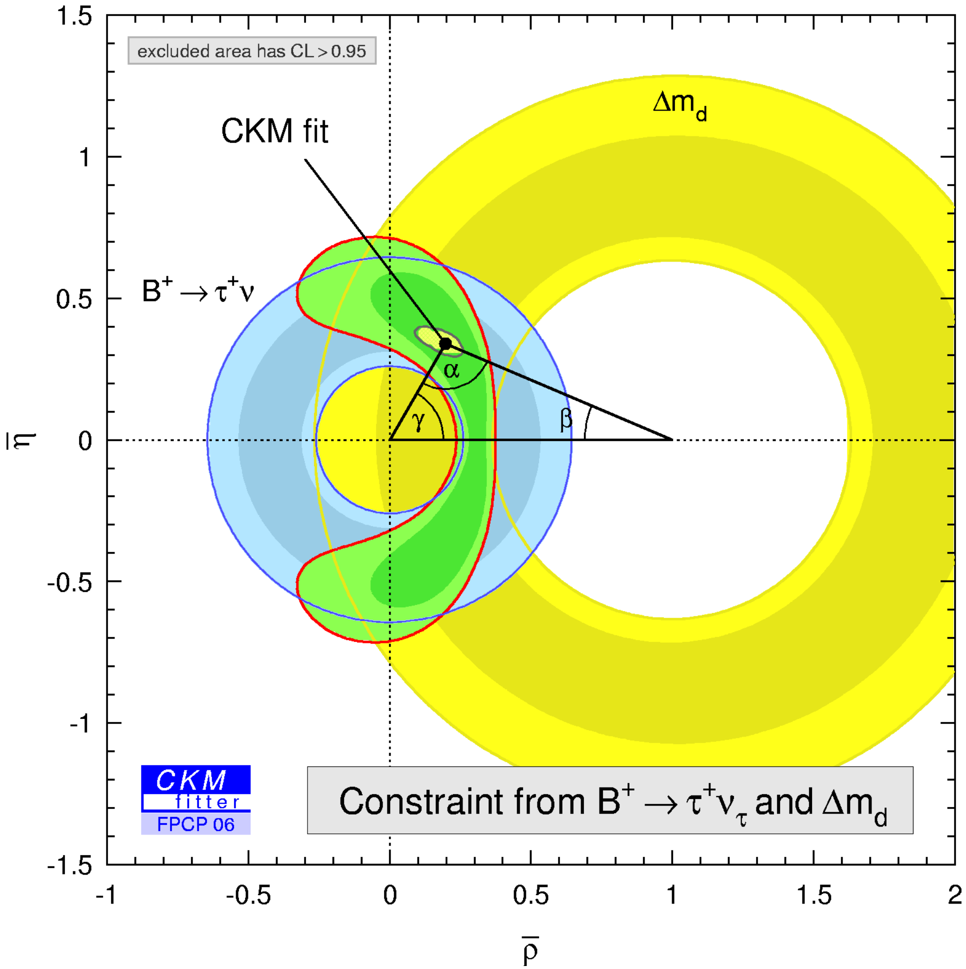
Unbinned likelihood fit to extra calorimeter energy

Observe $21.2^{+6.7}_{-5.7}$ events with a significance of $4.2\ \sigma$

hep-ex/0603018

Signal shape: Gauss + exponential
Background shape: 2nd order polynomial

CKM Constraints from $B \rightarrow \tau\nu$



Measured branching fraction

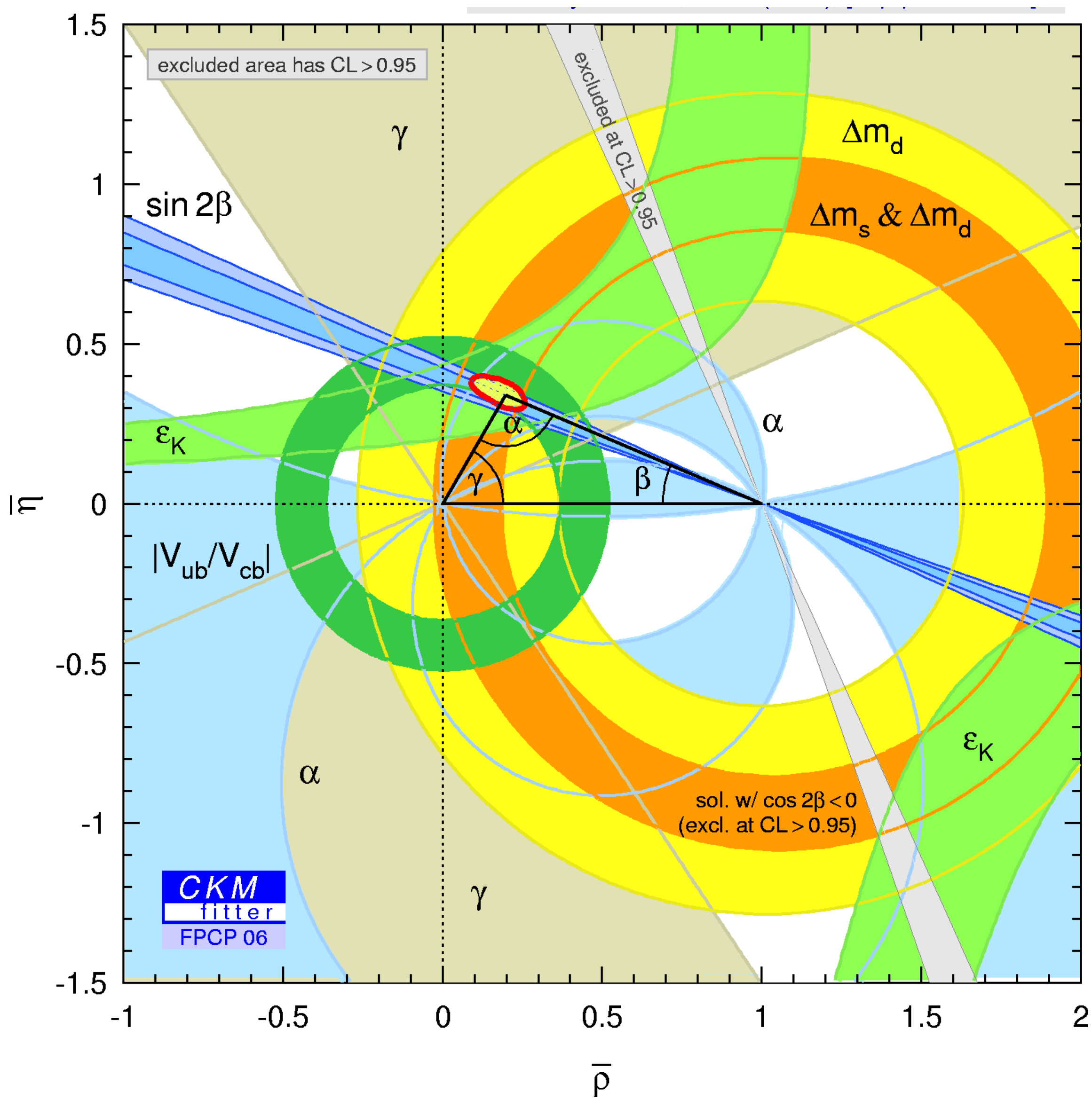
$$\mathcal{B}(B \rightarrow \tau\nu) = 1.06\ ^{+0.34}_{-0.28}\ ^{+0.18}_{-0.16} \cdot 10^{-4}$$

***B* decay constant**

Using $|V_{ub}| = 4.38 \pm 0.33 \cdot 10^{-3}$ from HFAG

$$f_B = 0.176\ ^{+0.028}_{-0.023}\ ^{+0.020}_{-0.018}\ \text{GeV}$$

Summary of CKM Constraints



- Unitarity Triangle (UT) measurements in remarkable agreement with one another
- Provides evidence that CKM mechanism is main source of CP violation
- But is it the only one?

$$\bar{\rho} = \rho\left(1 - \frac{\lambda^2}{2}\right)$$
$$\bar{\eta} = \eta\left(1 - \frac{\lambda^2}{2}\right)$$

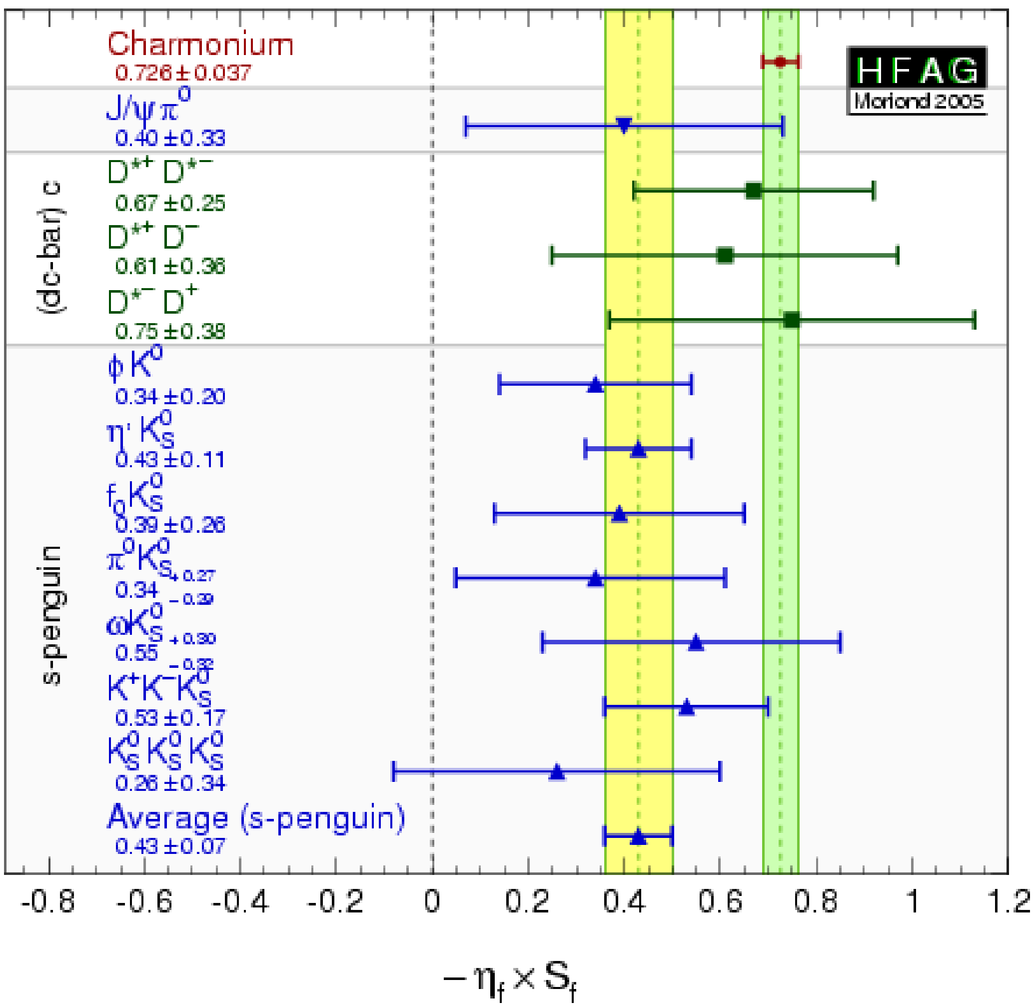
Includes $O(\lambda^5)$ corrections

Conclusions

- The *B* Factories are running at full steam
- sin2β has developed from a discovery into a precision measurement (with 5% combined error); there were recent breakthroughs in the other two angles α and γ, both experimentally and theoretically
- To this day the complex phase in the Standard Model CKM matrix correctly describes CP violation in the *B* system
  - But we know this is not enough
- There may be hints (of NP) in the penguin decays
- Both BaBar+Belle expect to ~double their datasets in the next two years
- There is more to come from CDF/D0 and LHCb

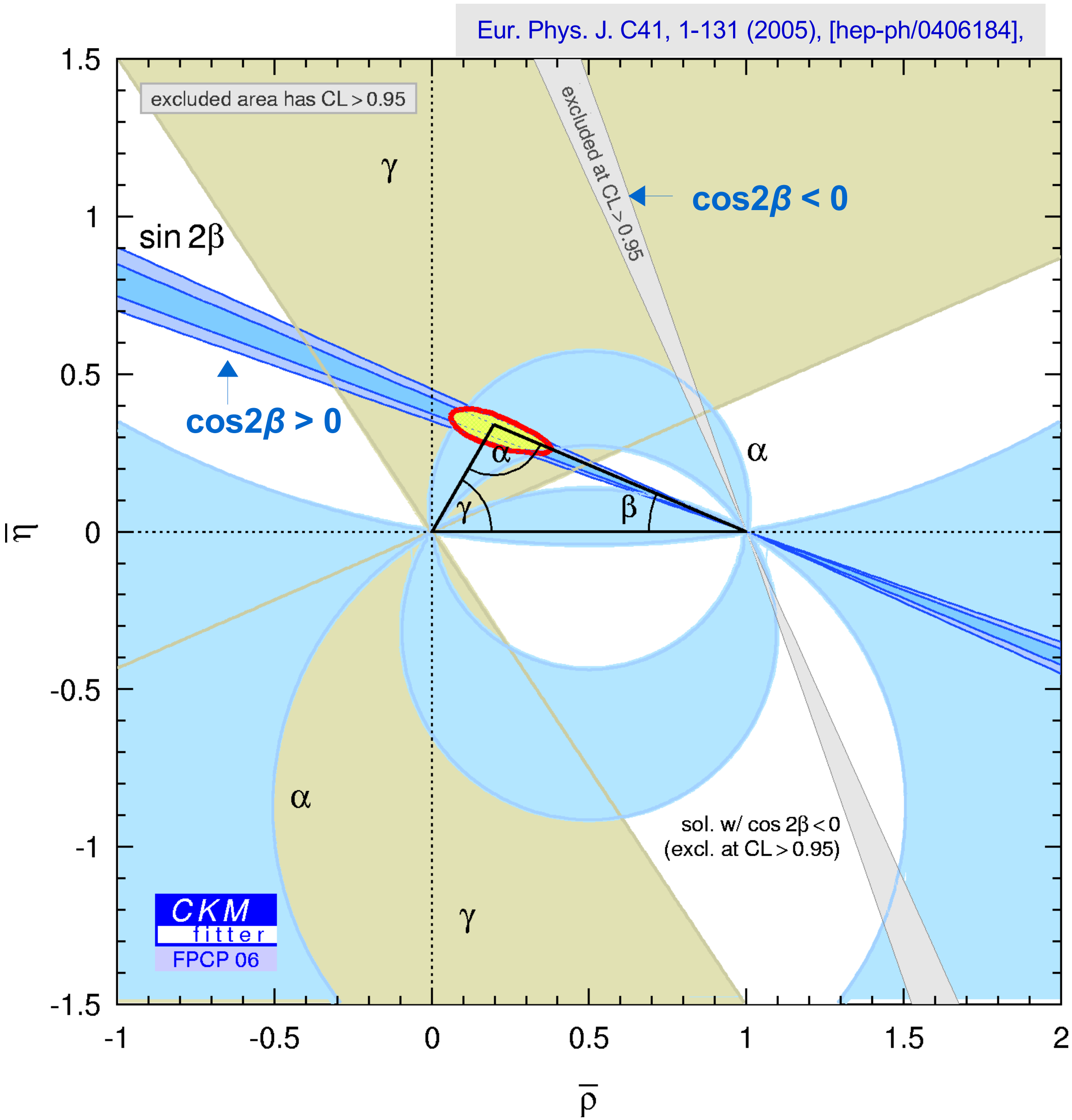
Backup Slides

$b \to s$ penguin Averages as of Moriond 2005



- Both experiments combined
- "Naïve" average over all *s*-penguin modes
- Appears to come out 3.7σ low compared to charmonium modes
- Note different theoretical uncertainties across modes
- Must be cautious with this!
- Still, most intriguing...
- There is more data now

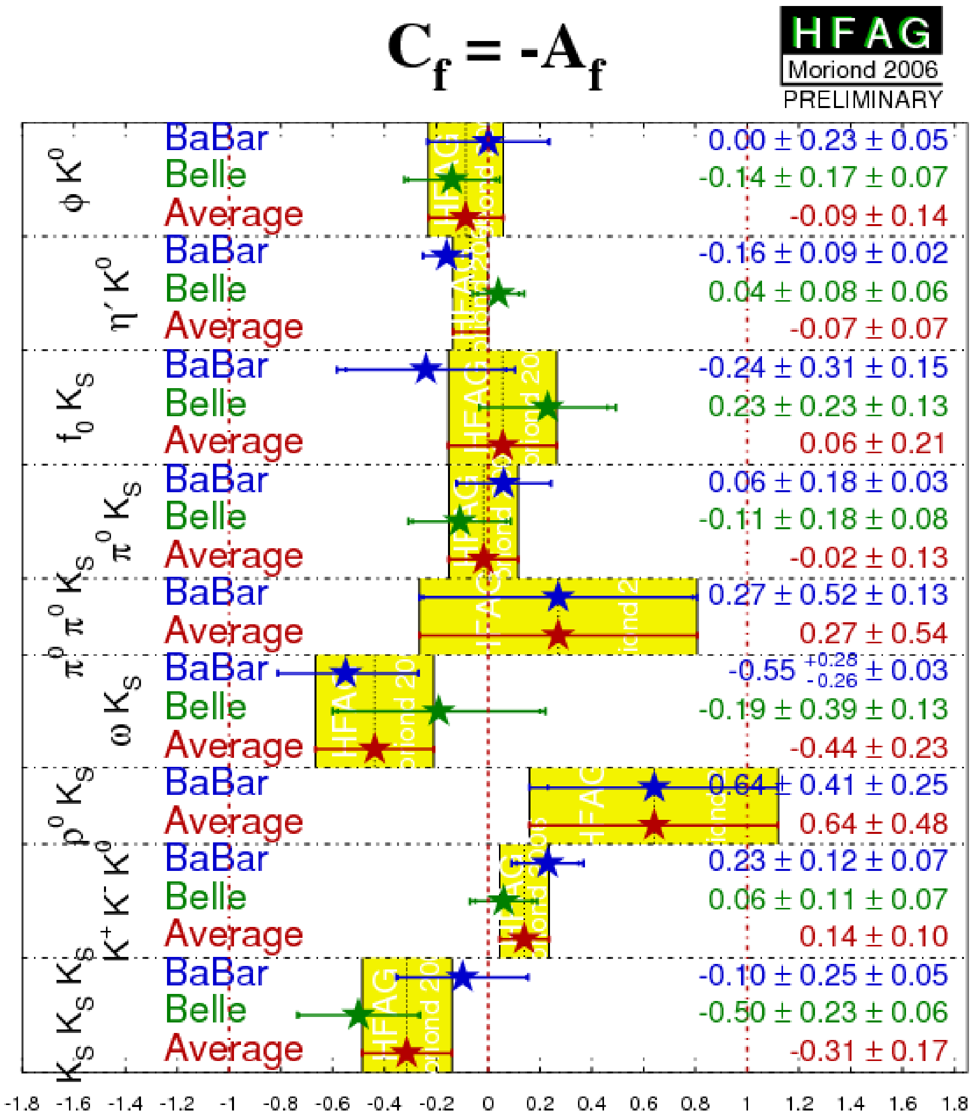
UT Constraints from Angles alone



- Most of the constraint now comes from the angles *α*, *β*, *γ* alone
  - First+foremost *β*
- Milestone for the *B* Factories!
- sin2*β* is first UT input not limited by theory uncertainties
- Provides a firm reference for SM tests

Direct *CP* Violation

- All *CP* asymmetry measurements also fit for cosine term coefficient C_f
- $C_f \neq 0$ would indicate direct *CP* violation (*CP* violation in the decay)
- No hint of that



Semileptonic Decays: V_{ub} and V_{cb}