B physics

- BaBar/PEP-II
- Belle/KEK-B
- CDF & D0/Tevatron
- LHCb, ATLAS & CMS/LHC
- Super B Factory/???

ALL RESULTS ARE PRELIMINARY UNLESS PUBLISHED

Apologies

- Due to shortness of time, I will cover only a selection of B physics, and skip entirely many other important results
  - D physics: mixing & rare decays
  - Spectroscopy: observations & interpretations of new states
  - τ physics: new limits on lepton flavour violation
  - ISR physics, γγ physics, spin physics, ...
  - Theoretical developments
- For details see review talks at (ongoing) FPCP

http://fpcp2006.triumf.ca/agenda.php

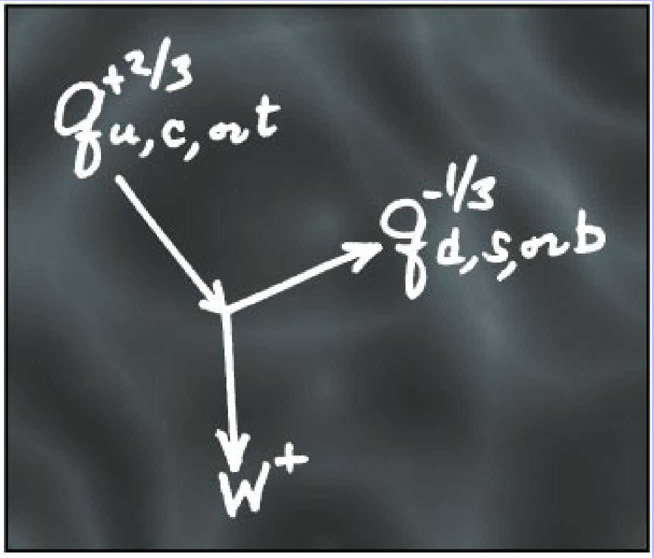
The (SM) physics

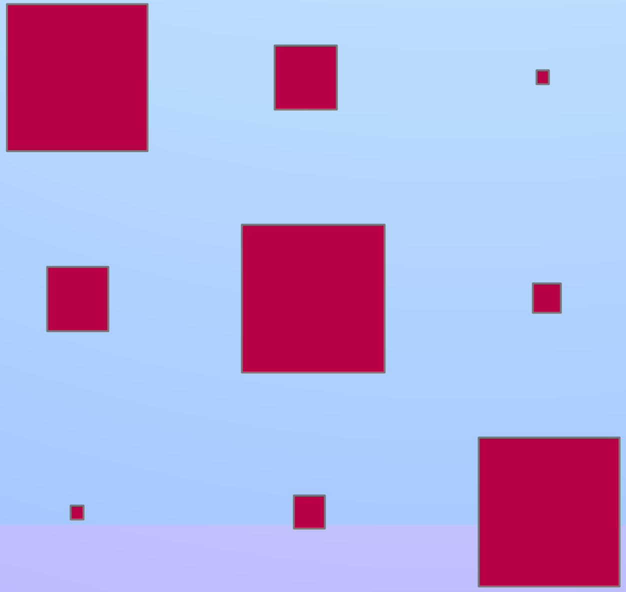
- Electroweak symmetry breaking
  - Higgs field acquires vacuum expectation value
  - diagonalization of quark mass matrix
  - charged current → flavour mixing (CKM)
  - no tree-level flavour changing neutral currents (GIM)
- CKM matrix (3 mixing angles & 1 phase) responsible for <u>all</u> quark mixing & CP violation phenomena

Most of SM free parameters are in flavour sector

CKM matrix

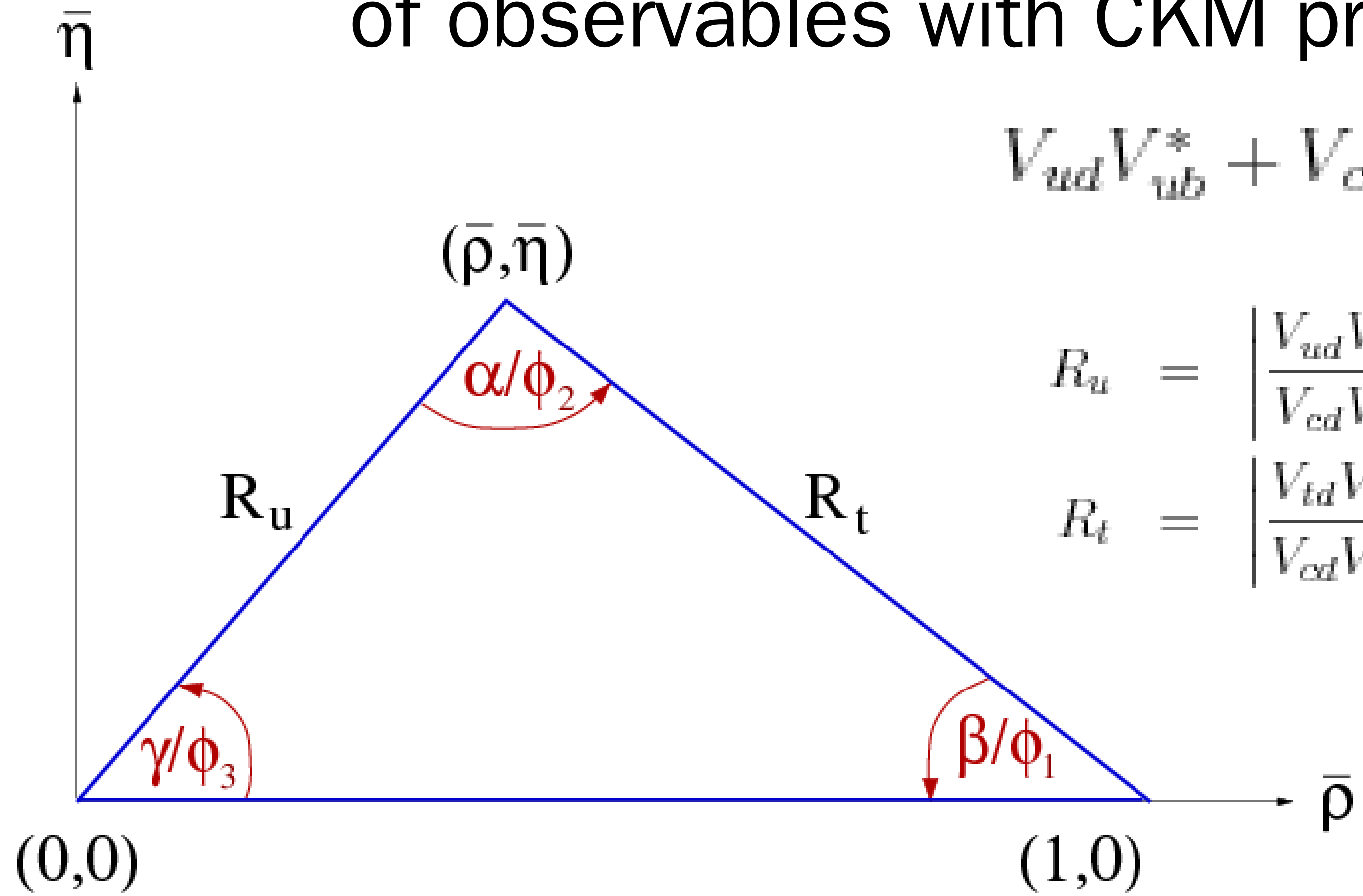
$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$





Unitarity Triangle

Convenient method to illustrate (dis-)agreement of observables with CKM prediction



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

$$R_u = \left|\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right| = \sqrt{\bar{\rho}^2 + \bar{\eta}^2},$$

$$R_t = \left|\frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*}\right| = \sqrt{(1-\bar{\rho})^2 + \bar{\eta}^2}.$$

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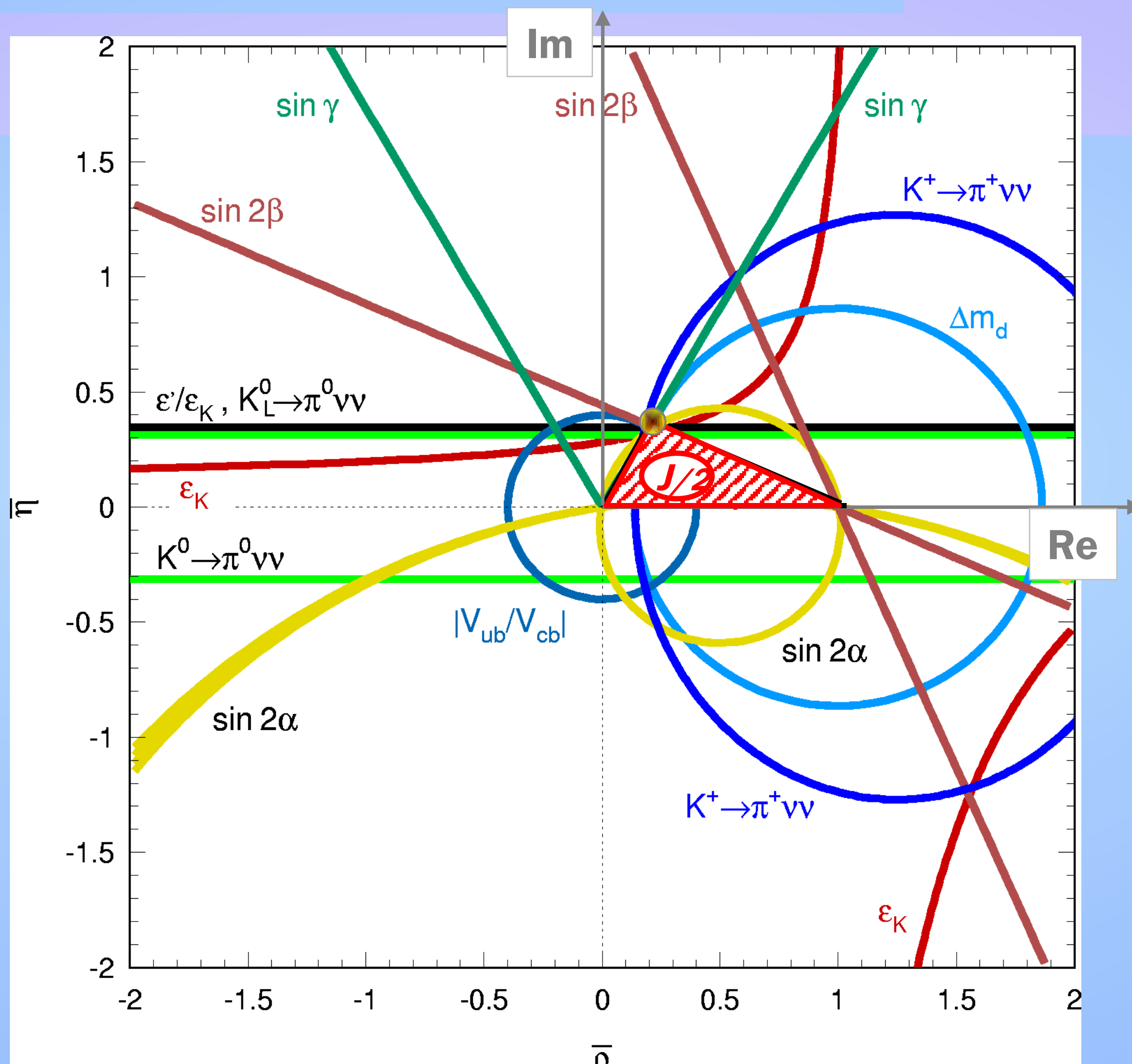
KM Prediction

All measurements must agree



Picture by A.Hoecker

Overconstraining the UT

- Test SM via multiple redundant measurements of UT parameters
  - 3 angles ($(\beta,\alpha,\gamma) = (\varphi_1,\varphi_2,\varphi_3)$) & 2 sides ($R_u$ & R_t)
- β : TDCPV in $B^0 \to J/\psi K_S$, $B^0 \to \phi K_S$, many others
- α : TDCPV in $B^0 \to hh'$ ($h,h' = \pi/\rho/\ldots$)
- γ : DCPV in $B \to hh'$ ($h,h' = \pi/K/\ldots$);
  DCPV in $B \to DK$; TDCPV in $B^0 \to D^*\pi$; and more
- R_u : rates & spectra in $B \to X_u l\nu$; rates of $B^+ \to l^+\nu$
- R_t : mixing ($\Delta m_d/\Delta m_s$); rates of $B \to \rho\gamma$, ...

Direct CP Violation

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$$B \xrightarrow{A} f$$

$$\bar{B} \xrightarrow[\bar{A}]{} \bar{f}$$

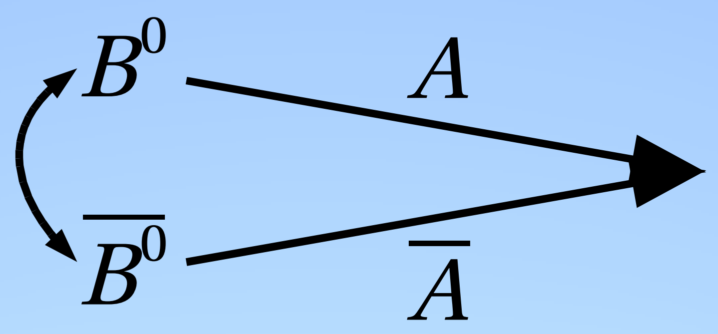
Direct CP violation if $\left|\frac{\bar{A}}{A}\right| \neq 1$

Requires $A = \sum_i A_i = \sum_i |A_i| e^{i(\delta_i + \phi_i)}$

$$i \geq 2 \quad \delta_i \neq \delta_j \quad \phi_i \neq \phi_j$$

Time Dependent CP Violation

$$|B_L\rangle = p|B^0\rangle + q|\overline{B}^0\rangle$$
$$|B_L\rangle = p|B^0\rangle - q|\overline{B}^0\rangle$$
$$\sqrt{|p|^2+|q|^2}=1$$
$$\Delta m = m(B_H) - m(B_L)$$
$$\Delta\Gamma = \Gamma(B_H) - \Gamma(B_L)$$



$$f = (\pm)\bar{f} = f_{CP}$$

CP violation in mixing if $\left|\frac{q}{p}\right| \neq 1$ (*cf.* ϵ_K)

Time-dependent CP violation if $\Im\left(\frac{q}{p}\frac{\overline{A}}{A}\right) \neq 1$
(interference between mixing and decay)

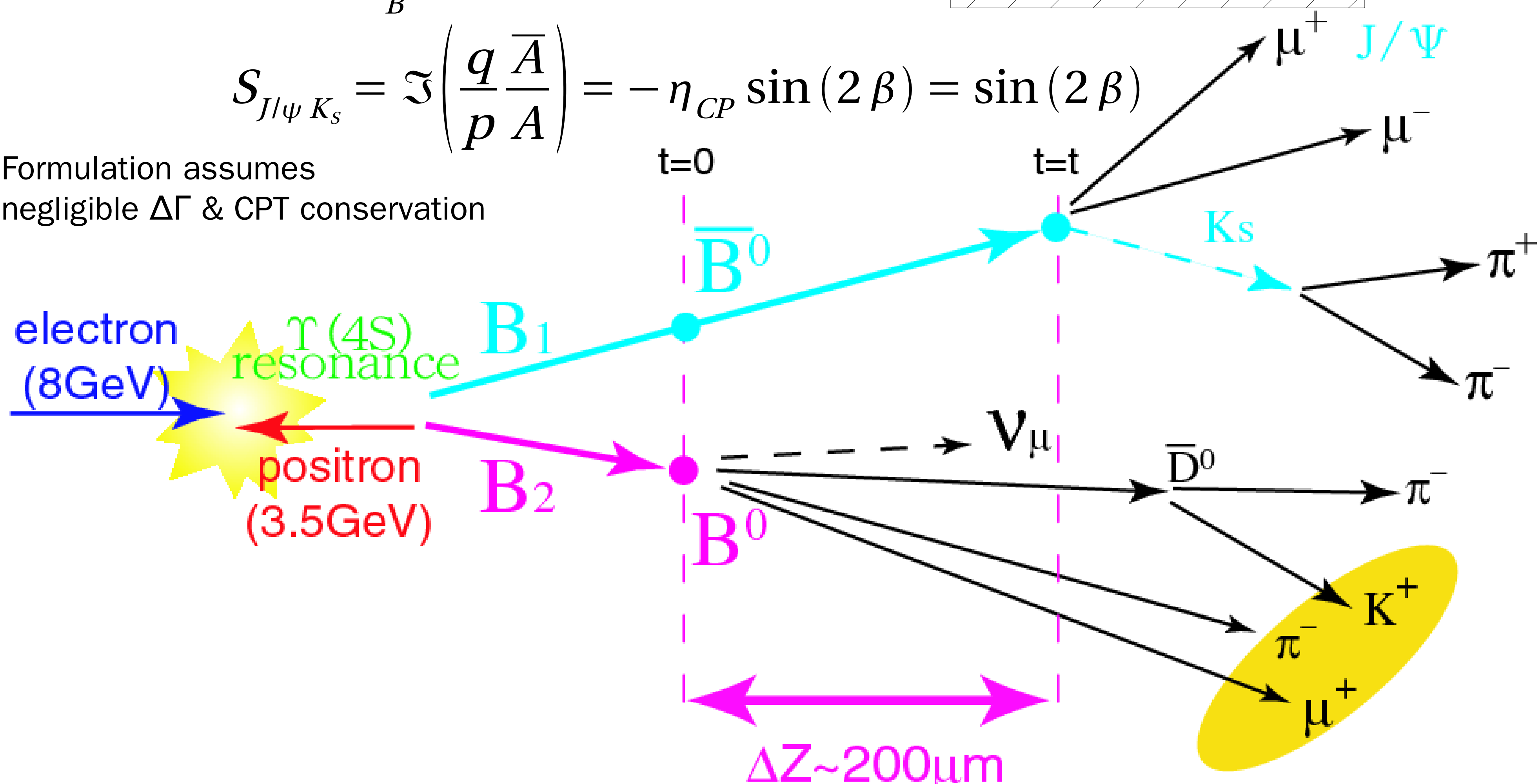
Asymmetric B Factory Concept

Direct CP violation

$$P_{CP}(\Delta t, q_{tag}) = \frac{e^{-|t|/\tau_B}}{4\tau_B}\left(1 \pm q_{tag}\left(S_{CP}\sin(\Delta m \Delta t) - C_{CP}\cos(\Delta m \Delta t)\right)\right)$$

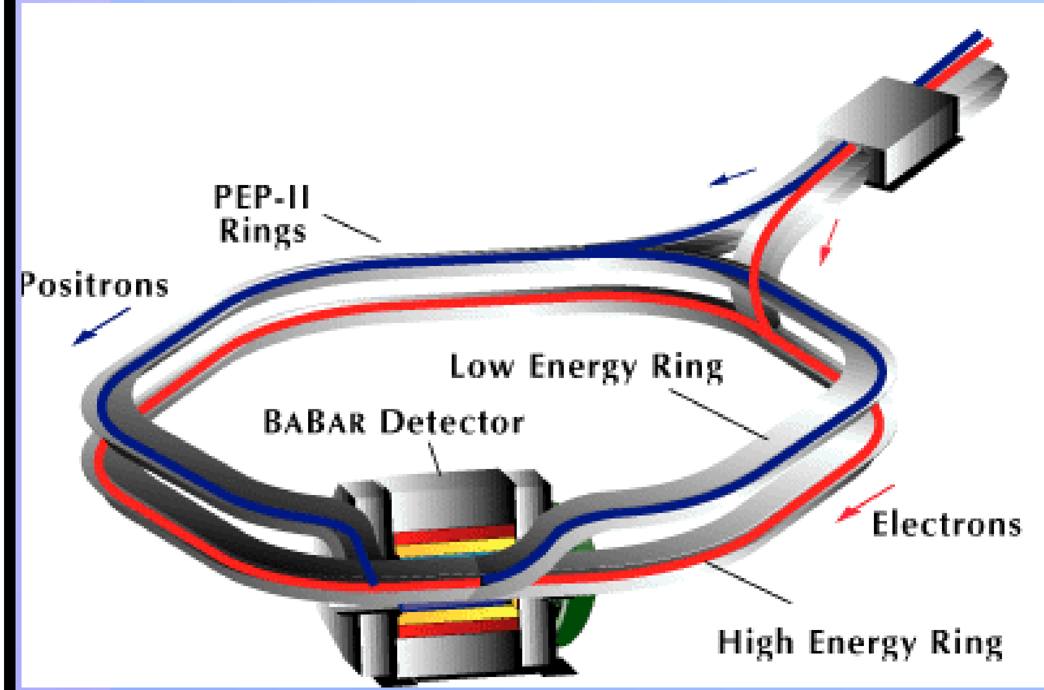
$$S_{J/\psi K_S} = \Im\left(\frac{q}{p}\frac{\overline{A}}{A}\right) = -\eta_{CP}\sin(2\beta) = \sin(2\beta)$$

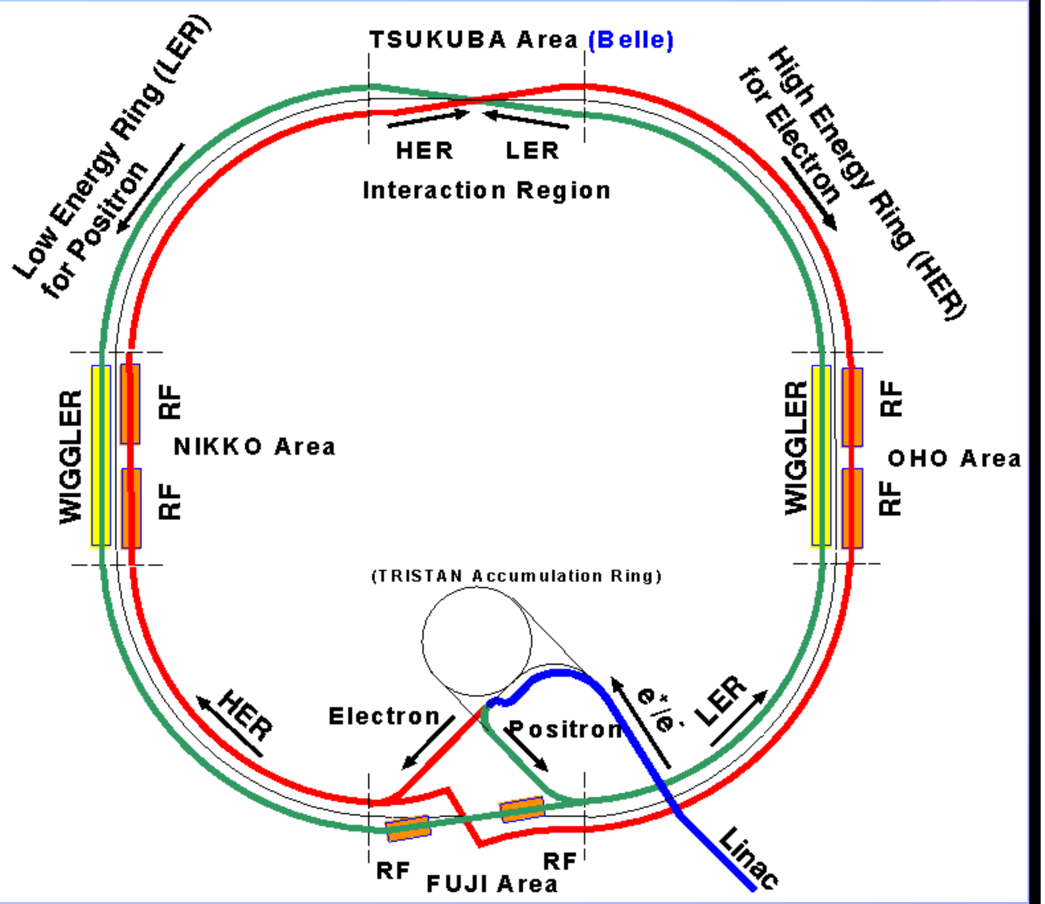
Formulation assumes
negligible ΔΓ & CPT conservation



Asymmetric B Factories

PEPII at SLAC	KEKB at KEK
9.0 GeV e^- on 3.1 GeV e^+	8.0 GeV e^- on 3.5 GeV e^+



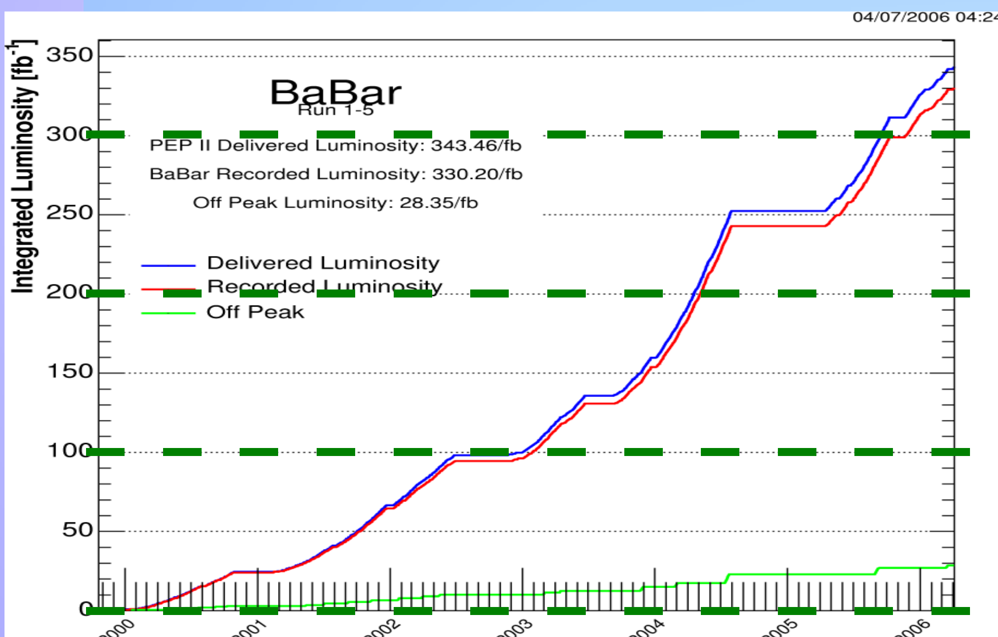


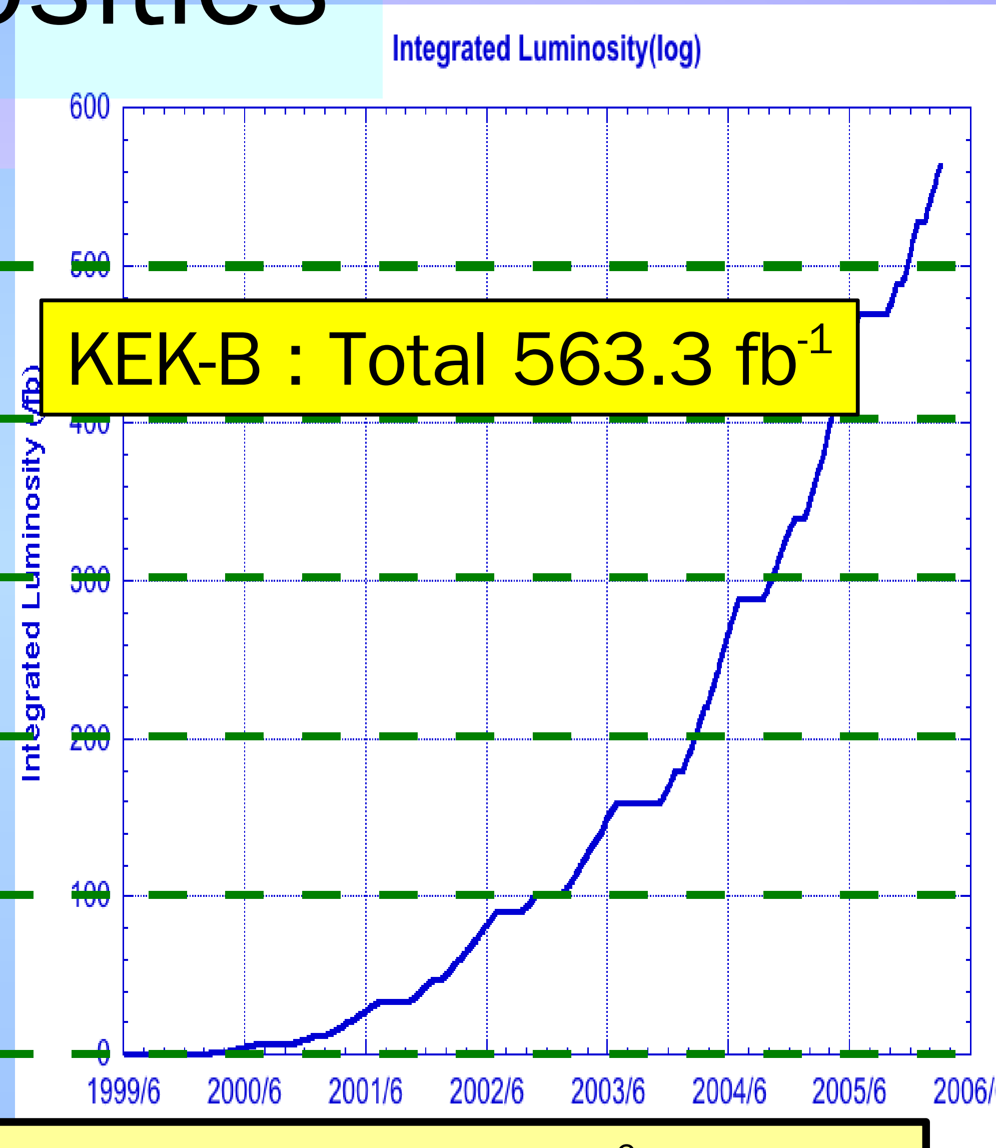
B factory Luminosities

$0.5\ ab^{-1}$

PEP-II : Total 330.2 fb^{-1}

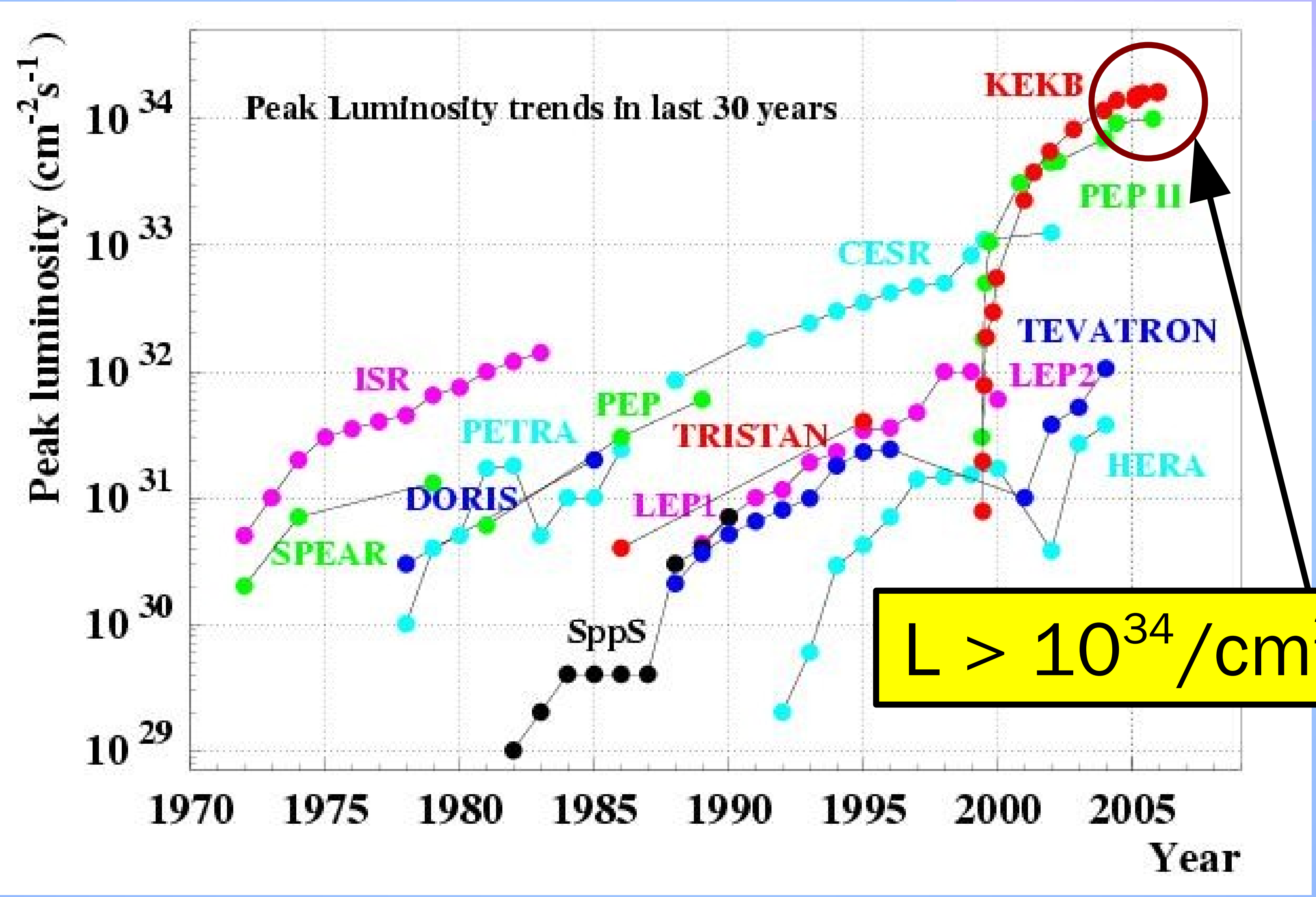
KEK-B : Total 563.3 fb^{-1}





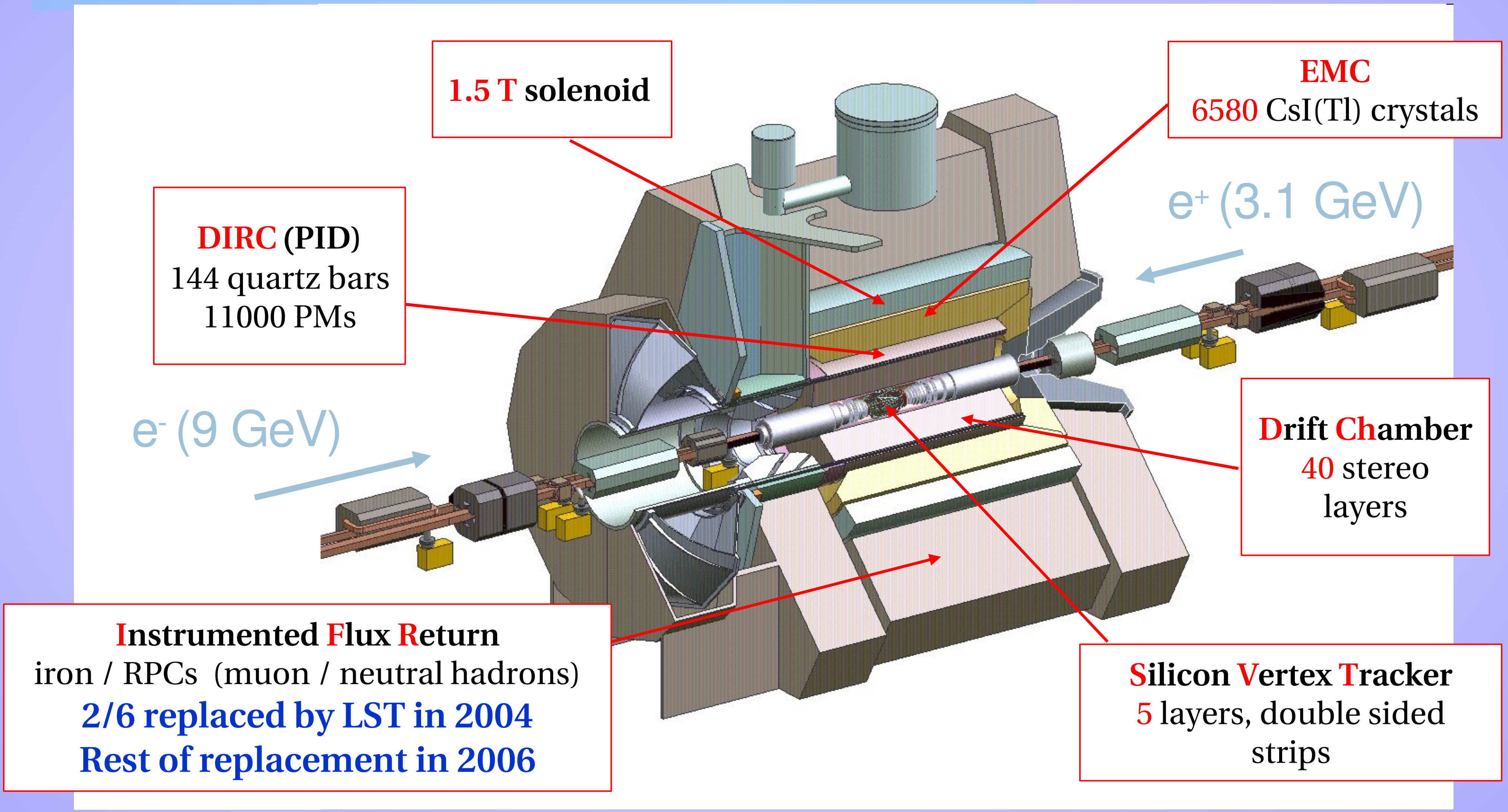
~220 x 10^6 BB pairs TODAYS RESULTS ~385 x 10^6 BB pairs

Luminosity trends

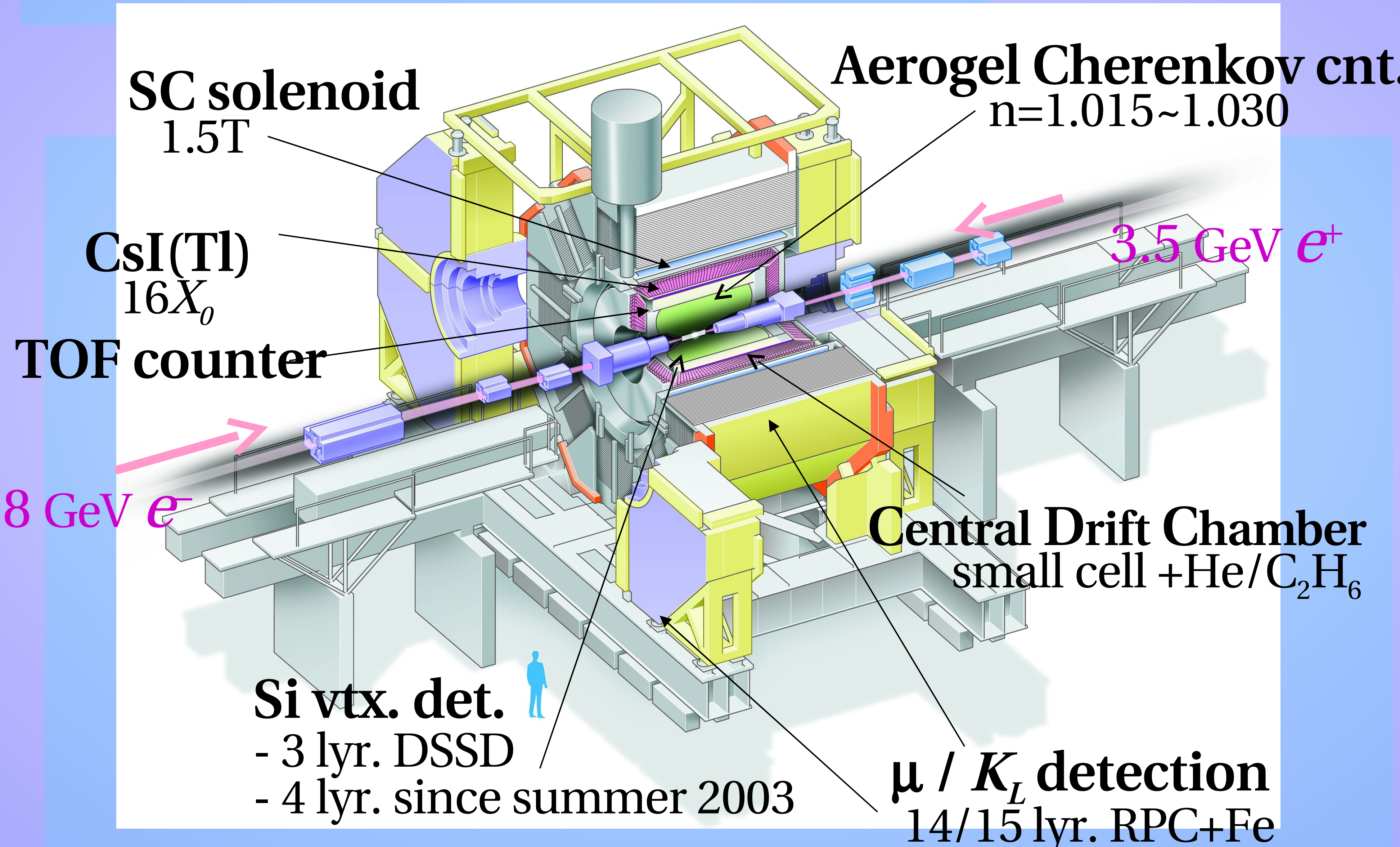


$L > 10^{34}/cm^2/s$

BaBar Detector



Belle Detector



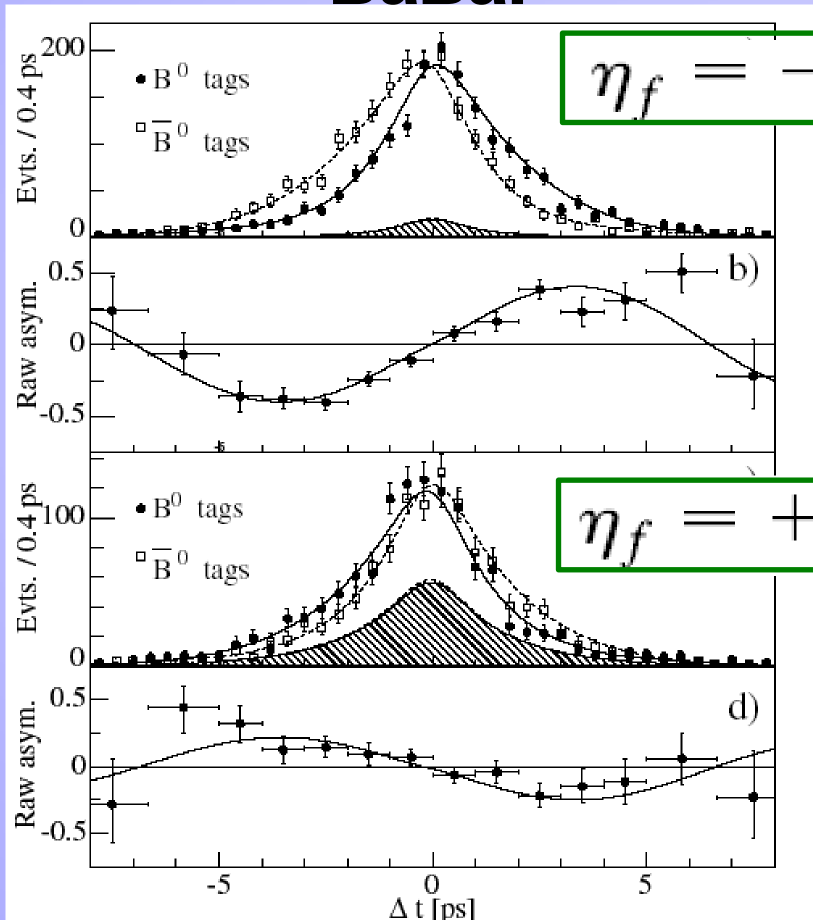
The Golden Mode

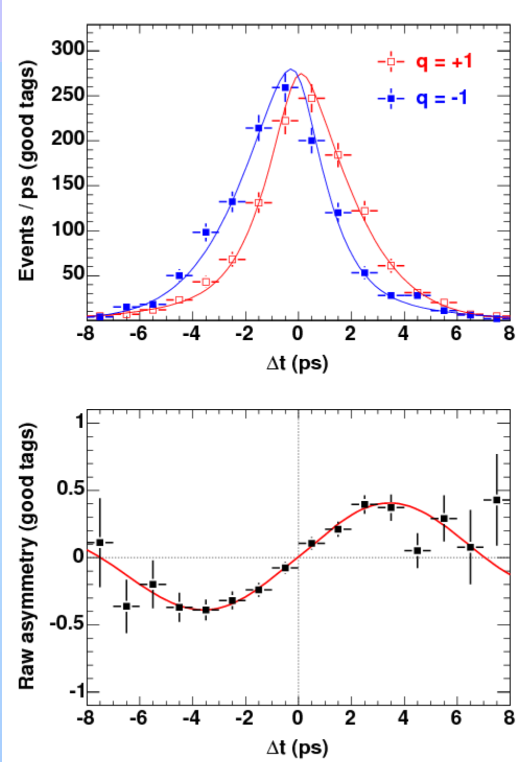
$$B^0 \to J/\psi K^0$$

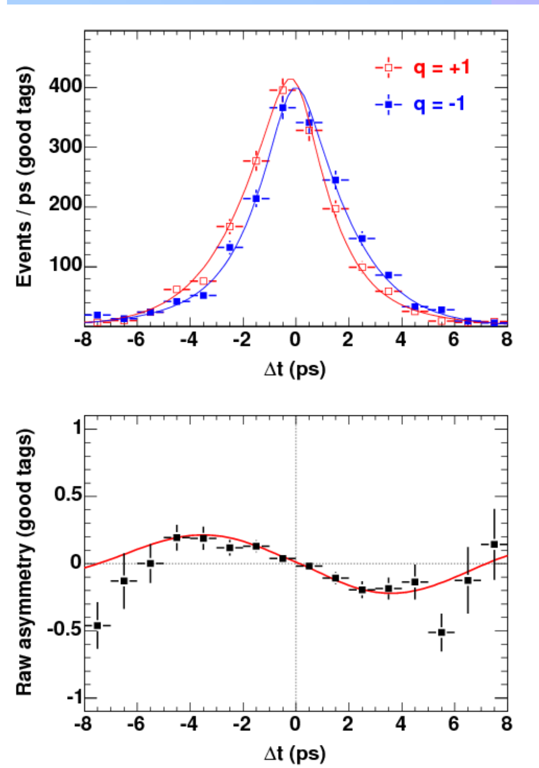
BaBar

$\eta_f = -1$

$\eta_f = +1$



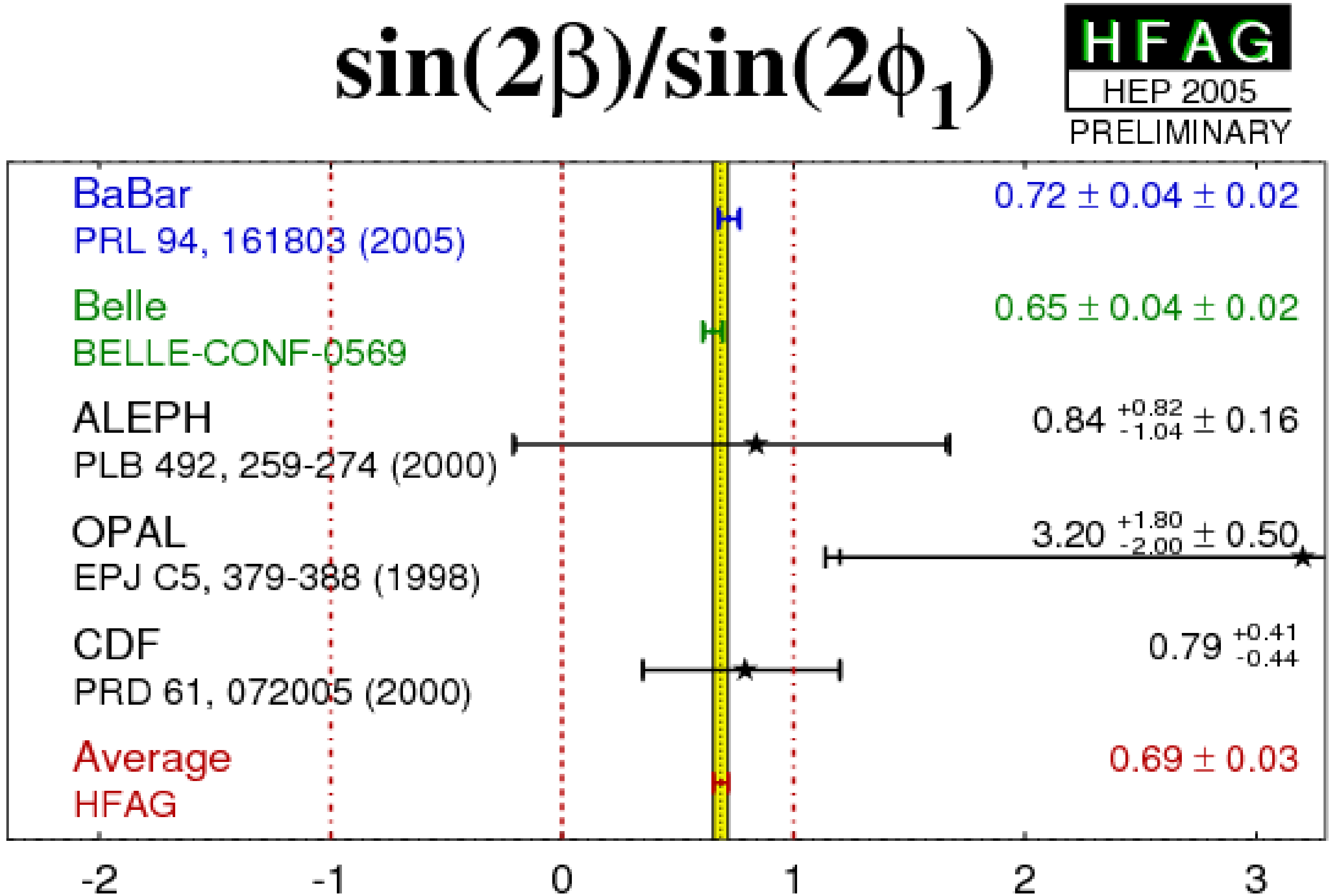




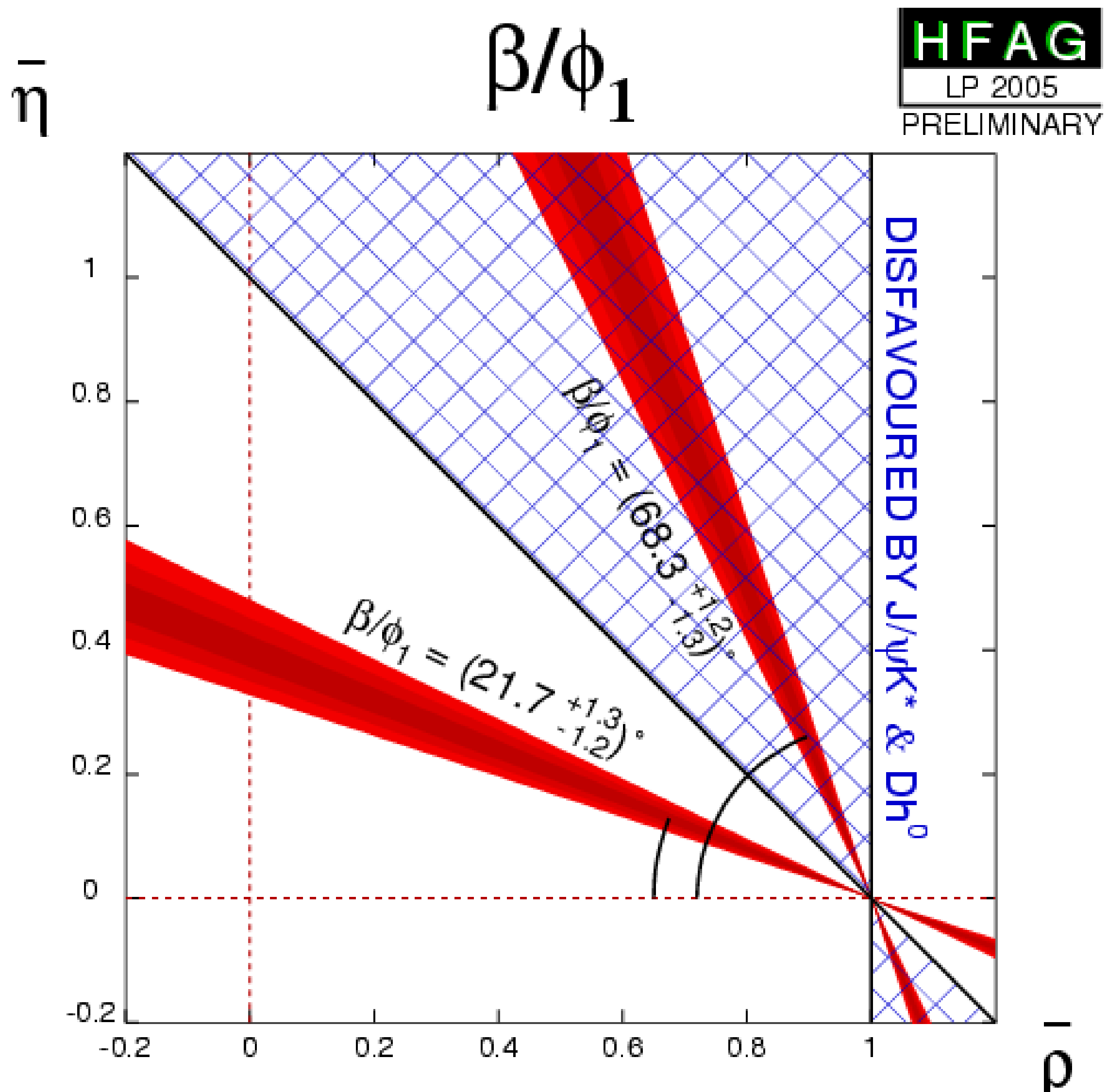
PRL 94, 161803 (2005)

BELLE-CONF-0569

Compilation of Results



Constraint from β



Other modes for β

- $B^0 \to J/\psi\ K^*$ time-dependent angular analysis
  - determine sign of cos(2β)
- $B^0 \to D^{(*)+}D^{(*)-}K_s$ time-dependent (amplitude) analysis
  - determine sign of cos(2β) (eventually)
- $B^0 \to J/\psi\ \pi^0$, $D^{(*)+}D^{(*)-}$ TDCPV
  - $\beta(b \to c\bar{c}d) = \beta(b \to c\bar{c}s)$?
- $B^0 \to D\pi^0$, etc. time-dependent amplitude analysis
  - $\beta(b \to cud) = \beta(b \to c\bar{c}s)$?
  - with $D \to K_s\pi^+\pi^-$, determine sign of cos(2β)
- $B^0 \to \phi K_S$, etc. time-dependent analysis
  - $\beta(b \to sqq) = \beta(b \to c\bar{c}s)$? more later ...

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Other modes for β

- $B^0 \to J/\psi\, K^*$ time-dependent angular analysis
  - determine sign of $\cos(2\beta)$
- $B^0 \to D^{(*)+}D^{(*)-}K_S$ time-dependent (amplitude
  - determine sign of $\cos(2\beta)$ (eventual
- $B^0 \to J/\psi\, \pi^0$, $D^{(*)+}D^{(*)-}$ TDCPV
  - $\beta(b \to ccd) = \beta(b \to ccs)$?
- $B^0 \to D\pi^0$, etc. time-dependent amplitude
  - $\beta(b \to cud) = \beta(b \to ccs)$?
  - with $D \to K_S\pi^+\pi^-$, determine sign o
- $B^0 \to \varphi K_S$, etc. time-dependent analysis
  - $\beta(b \to sqq) = \beta(b \to ccs)$? more later …

NEW results from BaBar

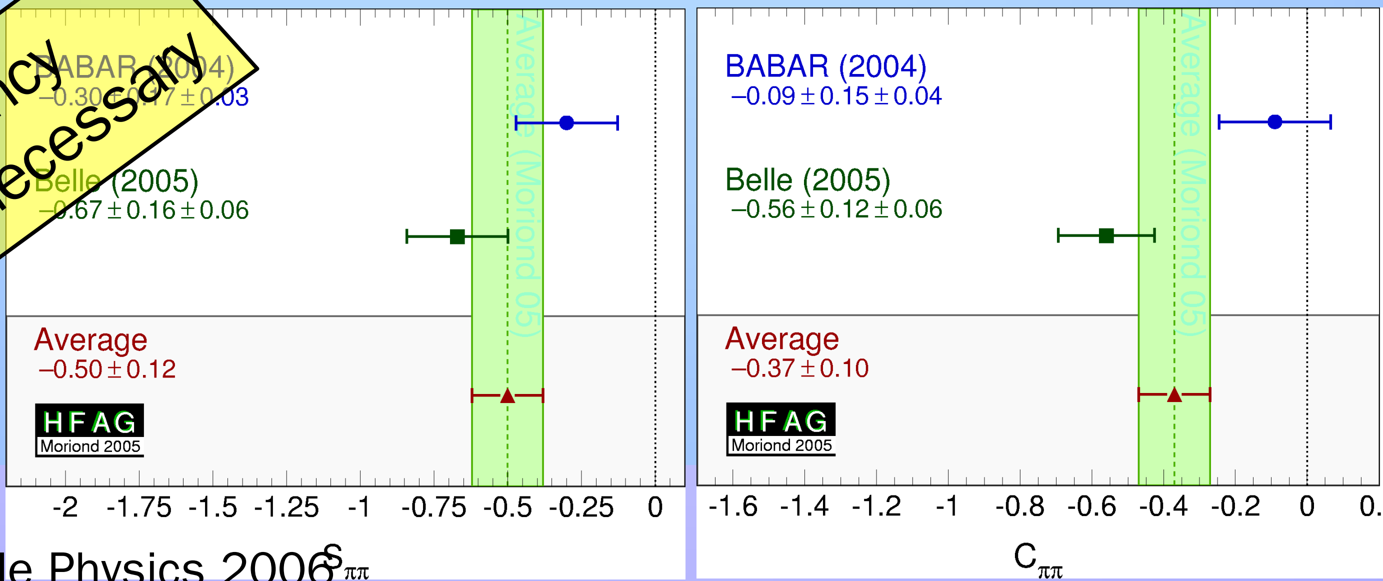
NEW results from Belle

Measurement of α

- $B^0 \to \pi^+\pi^-$
  - both tree and penguin contributions
  - large possible DCPV & $S_{\pi^+\pi^-} \neq -\sin(2\alpha)$
  - isospin ⇒ Grossman-Quinn type bounds

$$\left(S_{\pi^+\pi^-} - \left[-\sin(2\alpha)\right]\right)_{max} \longleftrightarrow B(B^0 \to \pi^0\pi^0)$$

Some discrepancy
Updated results necessary



Measurement of α

- $B^0 \to \pi^+\pi^-\pi^0$
  - decays mainly via intermediate ρ resonances
  - time-dependent Dalitz plot analysis

    $\Rightarrow$ separate penguin from tree contribution
- $B^0 \to \rho^+\rho^-$
  - almost 100% longitudinal polarization (CP even)
  - small penguin contribution $S_{\rho^+\rho^-} \simeq -\sin(2\alpha)$
  - accuracy on α still limited by (lack of) knowledge of $B^0 \to \rho^0\rho^0$ and $B^+ \to \rho^+\rho^0$

Measurement of α

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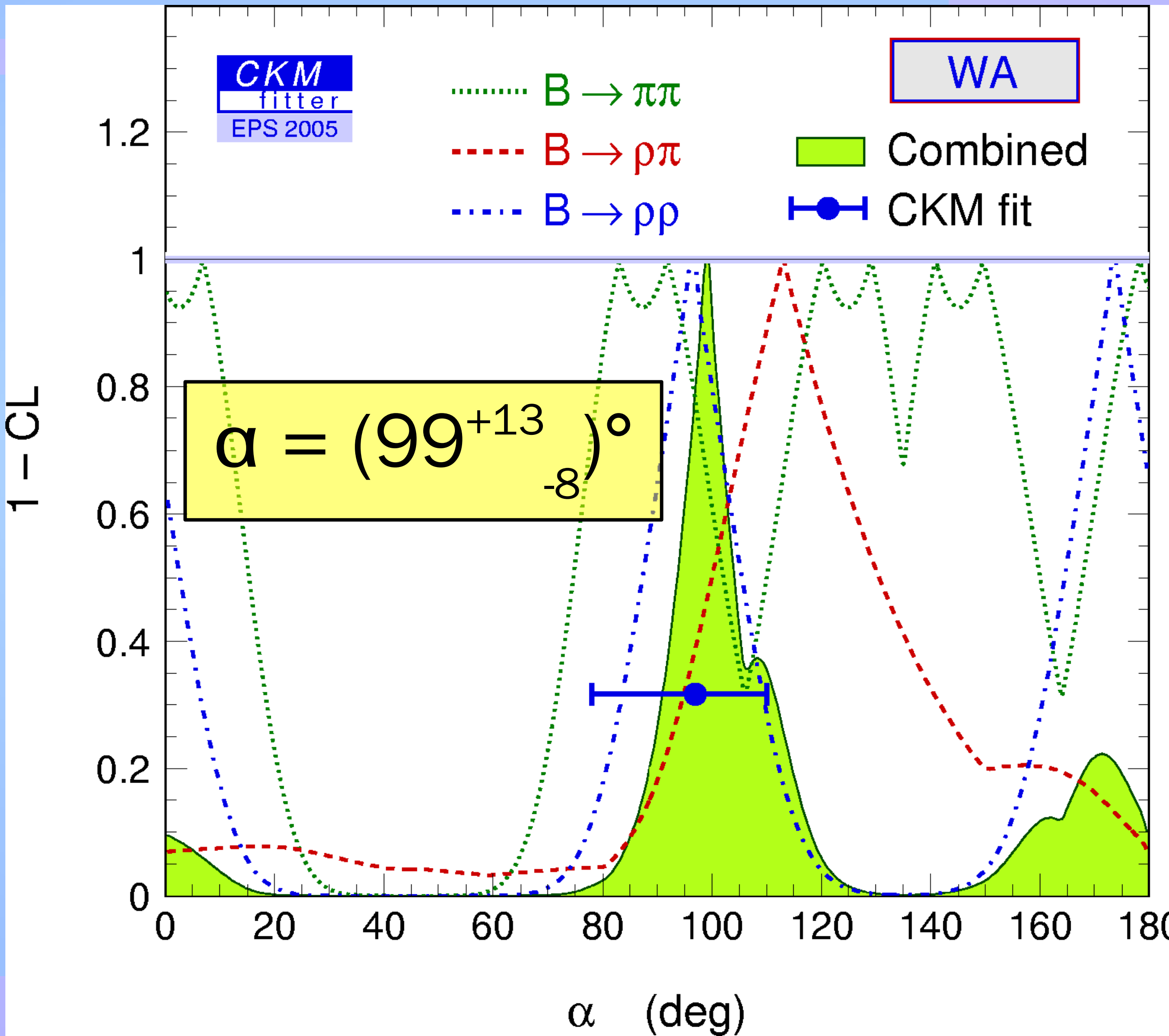
NEW results from BaBar

Constraint on α



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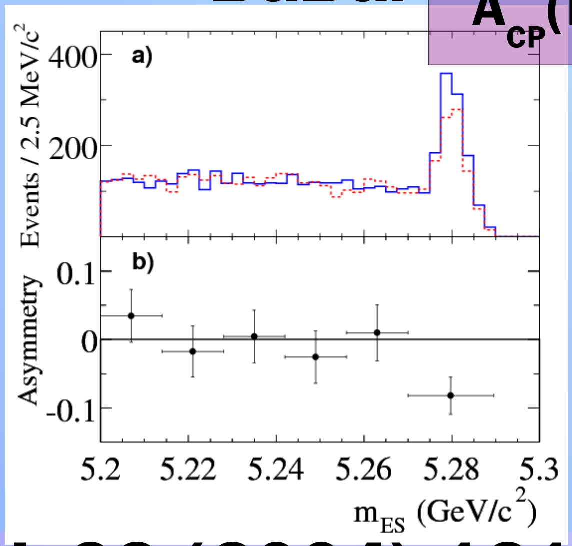
DCPV in B decay

- γ is the relative weak phase between tree and penguin amplitudes in charmless B decays
- DCPV in, eg., $B^0 \rightarrow K^+\pi^-$ sensitive to γ

hadronic uncertainties ⇔ (only) model-dependent constraints

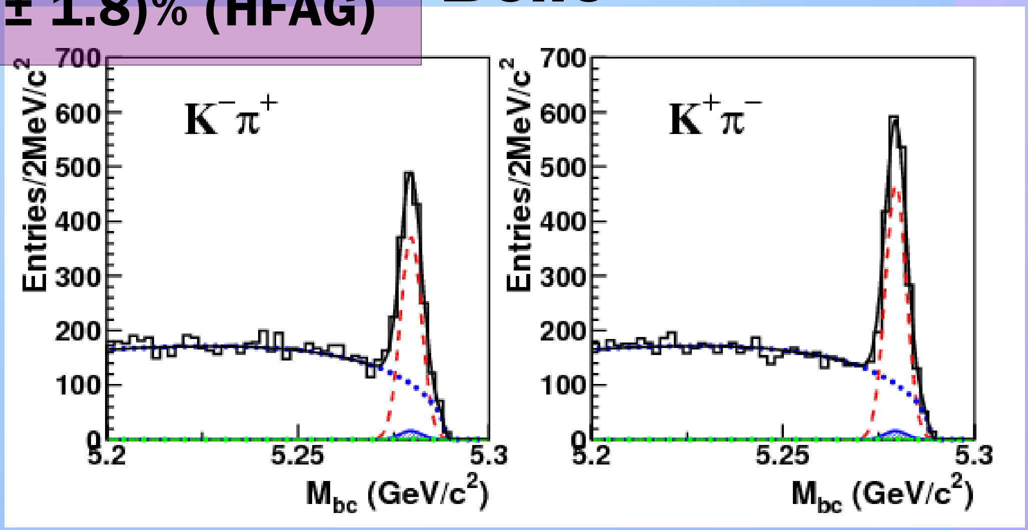
$A_{CP}(K^-\pi^+) = (-11.5 \pm 1.8)\%$ (HFAG)

BaBar



PRL 93 (2004) 131801

Belle



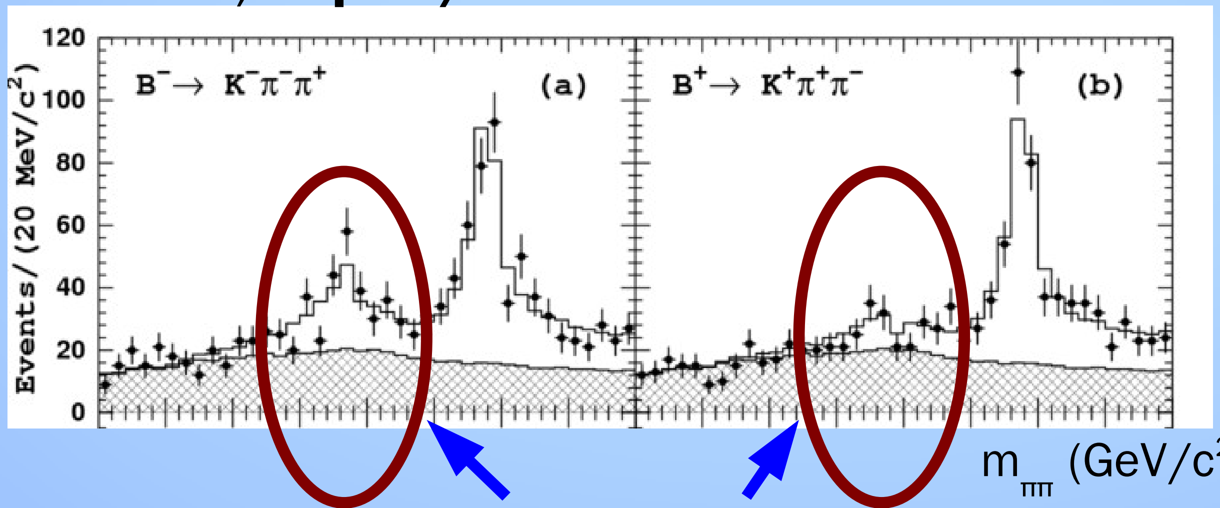
BELLE-CONF-0523

CDF result not shown here – will be competitive soon

DCPV in 3 body B decay

- Dalitz analysis → measure hadronic parameters
- Search for DCPV in $B^+ \to K^+\pi^+\pi^-$

Belle, hep-ex/0512066



Clear asymmetry in the ρ region

Dalitz analysis → enhanced sensitivity to CPV

$A_{CP}(\rho K^+) = (30 \pm 11 \pm 2\ ^{+11}_{-4})\%$ 3.9σ significance

first evidence for CPV in any charged particle!

BaBar result not shown here

CP violation in the B system

- Time-dependent CP violation
  - Observed (>5σ)
    - $J/\psi K^0$ (BaBar,Belle); $\pi^+\pi^-$ (Belle); $\eta' K^0$ (BaBar,Belle combined)
  - Evidence (>3σ)
    - $D^{*+}\pi^-$ [$D^{*+}D^-$, $K^+K^-K^0$, f_0K_S] (BaBar,Belle combined)
- Direct CP violation
  - Observed (>5σ)
    - $K^+\pi^-$ (BaBar,Belle combined)
  - Evidence (>3σ)
    - $\pi^+\pi^-$ (Belle); ρ^-K^+ (Belle); $\rho^+\pi^-$ (BaBar, Belle combined)
- Kaon system: $\pi^+\pi^-$, $\pi^0\pi^0$, $\pi^+\mu^-\nu$, $\pi^+e^-\nu$, $\pi^+\pi^-e^+e^-$, ϵ'/ϵ

Clean measurement of γ

- A theoretically clean measurement of γ can be made using B → DK decays
- Reconstruct neutral D mesons in states accessible to both flavour eigenstates

$$B^- \to D^0 K^- \quad (b \to c\,\bar{u}\,s) \qquad B^- \to \overline{D^0} K^- \quad (b \to u\,\bar{c}\,s)$$

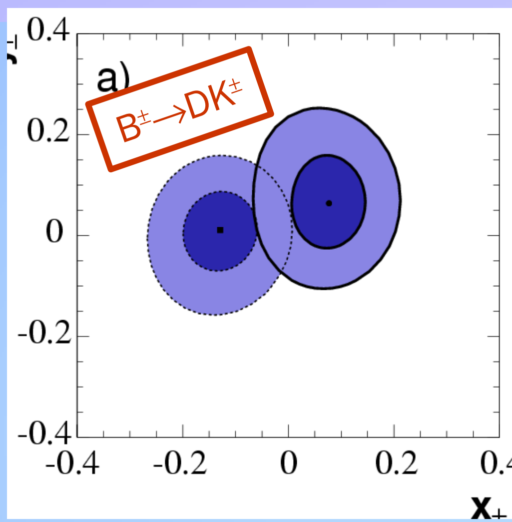
  - relative weak phase is γ (strong phase δ)
  - relative magnitude is r_B
  - various different B & D decays utilized
  - current most accurate: $D \to K_S \pi^+ \pi^-$

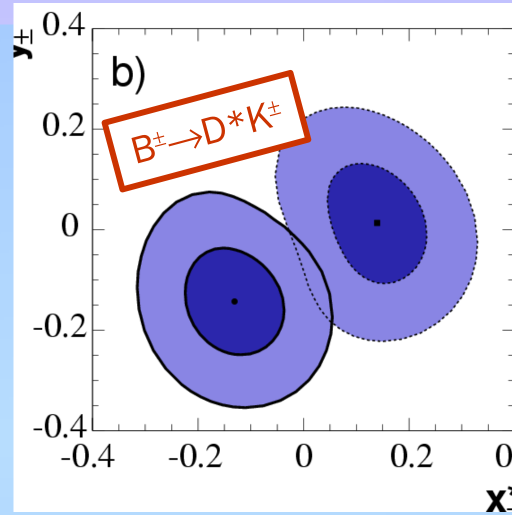
NEW results from Belle

Fit results:

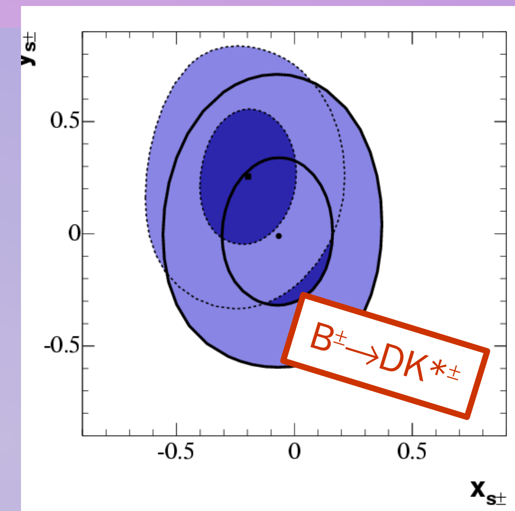
$(x_\pm, y_\pm) = (\mathrm{Re}(r_B e^{i(\delta\pm\gamma)}), \mathrm{Im}(r_B e^{i(\delta\pm\gamma)}))$

BaBar $\gamma = (67 \pm 28 \pm 13 \pm 11)^\circ$



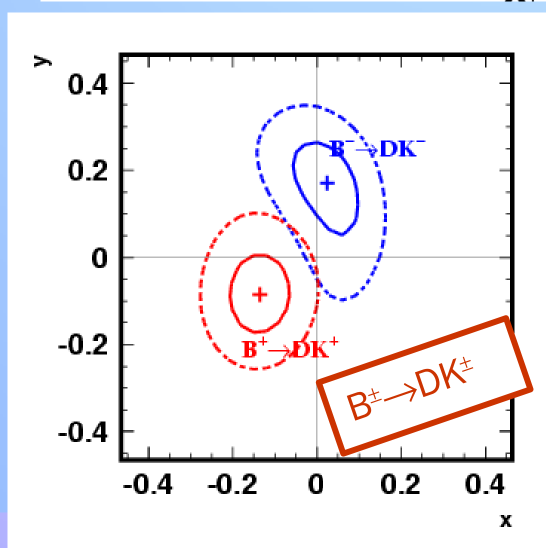


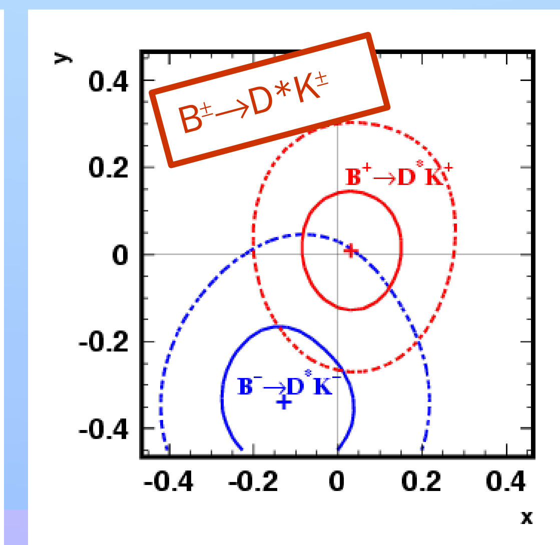
Warning: Different scale

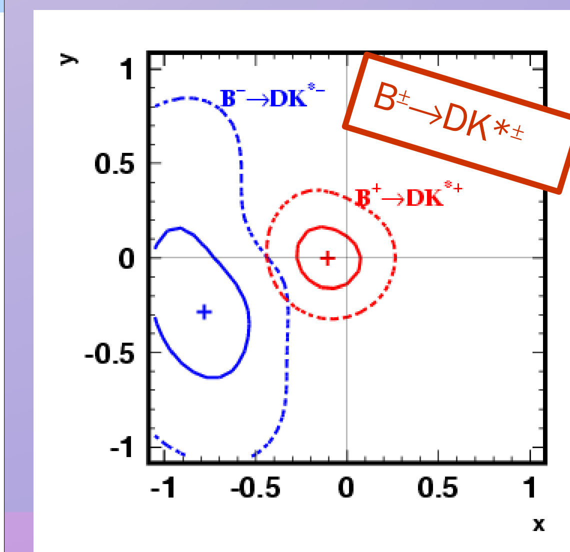


BABAR-CONF-05/018

Belle $\phi_3 = (53^{+15}_{-18} \pm 3 \pm 9)^\circ$

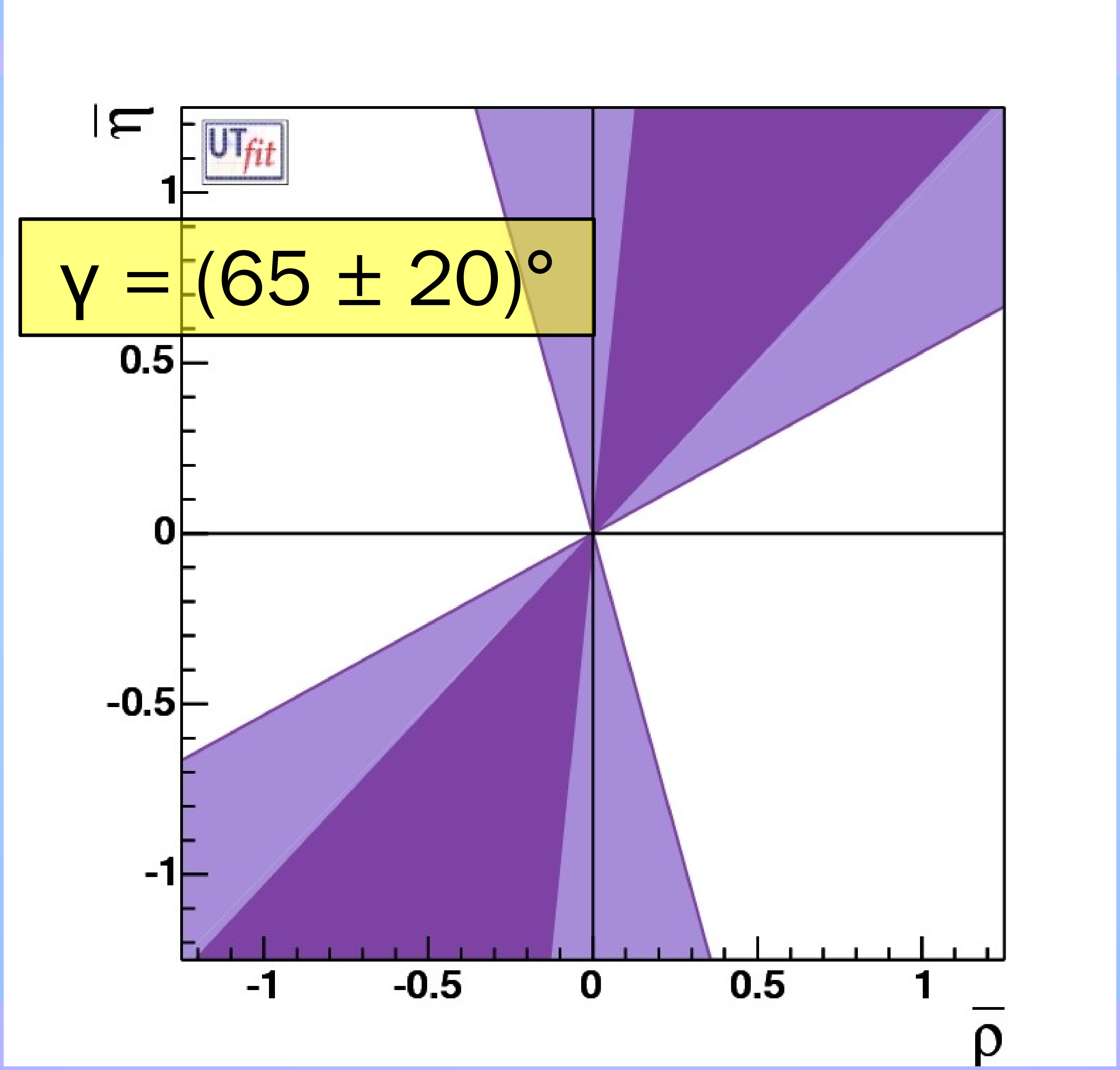






IN PREPARATION

Constraint on γ

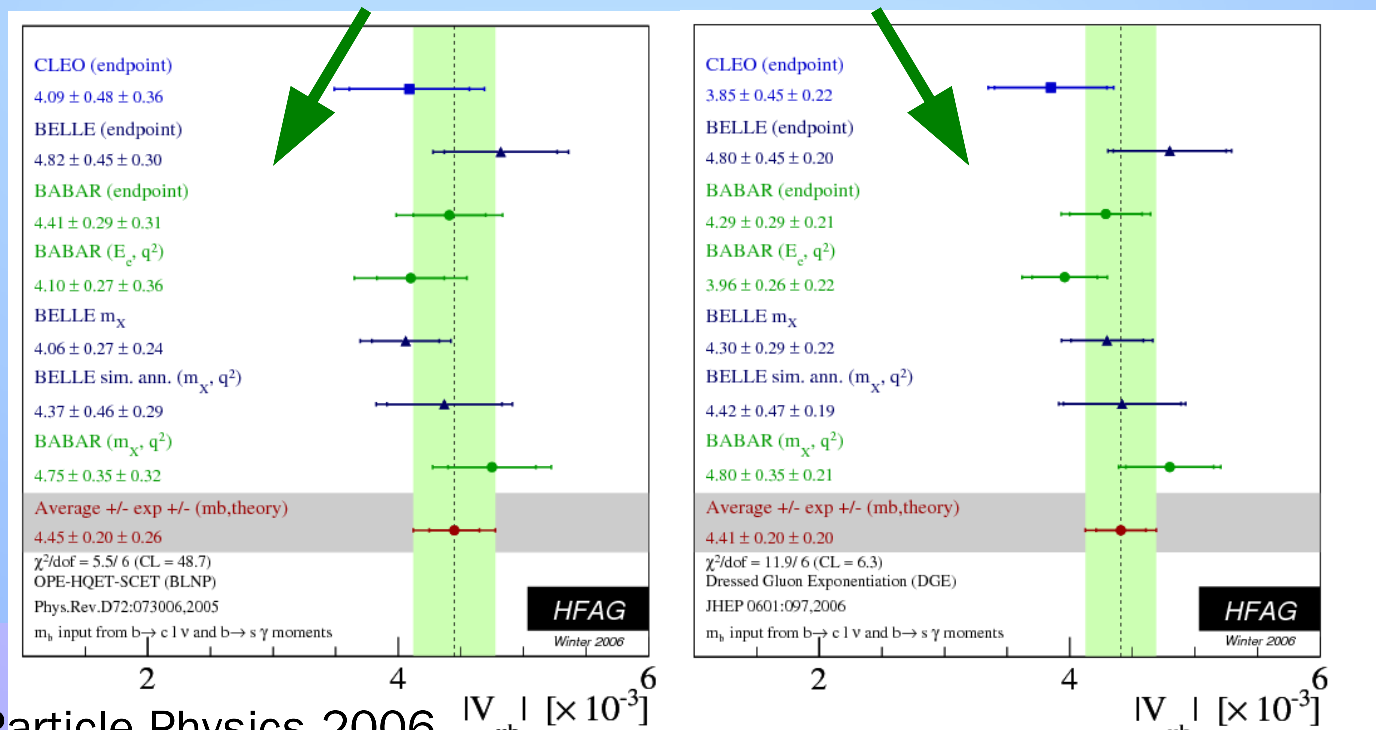


$\gamma = (65 \pm 20)°$

Measurement of R_u

- Require measurement of $|V_{ub}|$
  - both experimentally and theoretically challenging
- Two main approaches: <u>inclusive</u> & exclusive $B \to X_u l\nu$

Different theoretical treatment



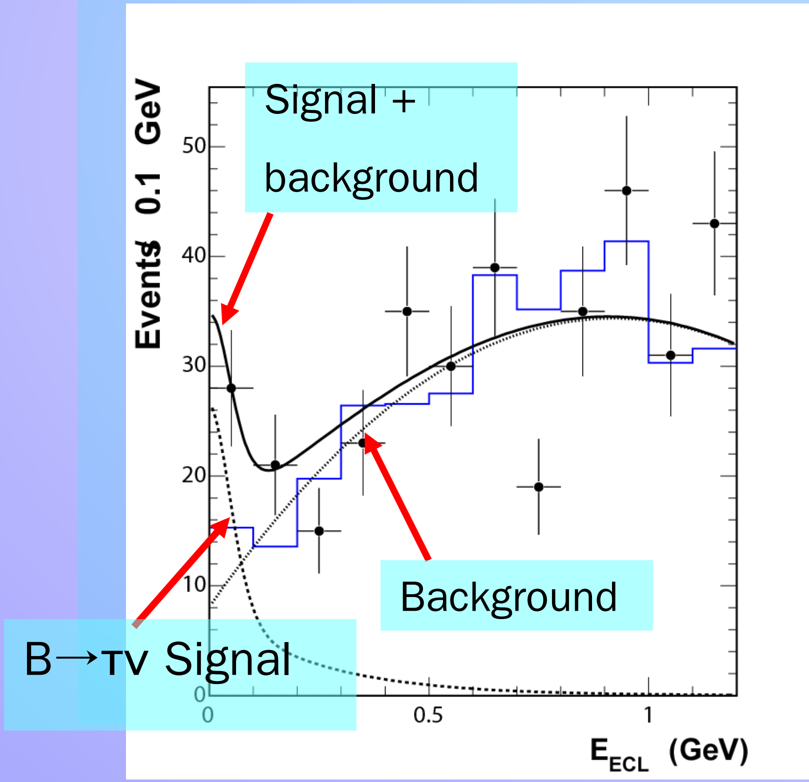
Alternative approach to $|V_{ub}|$

- Leptonic decays:

decay constant ⇔ lattice QCD

$$\Gamma(B^+ \to l^+ \nu_l) = \frac{G_F m_B m_l^2}{8\pi}\left(1 - \frac{m_l^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2$$

NEW results from Belle



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

hep-ex/0604018

$21.2^{+6.7}_{-5.7}$ signal events (4.2σ)

[cf. CLEO-c $D^+ \to \mu^+ \nu$; BaBar $D_s^+ \to \mu^+ \nu$]

Measurement of R_t

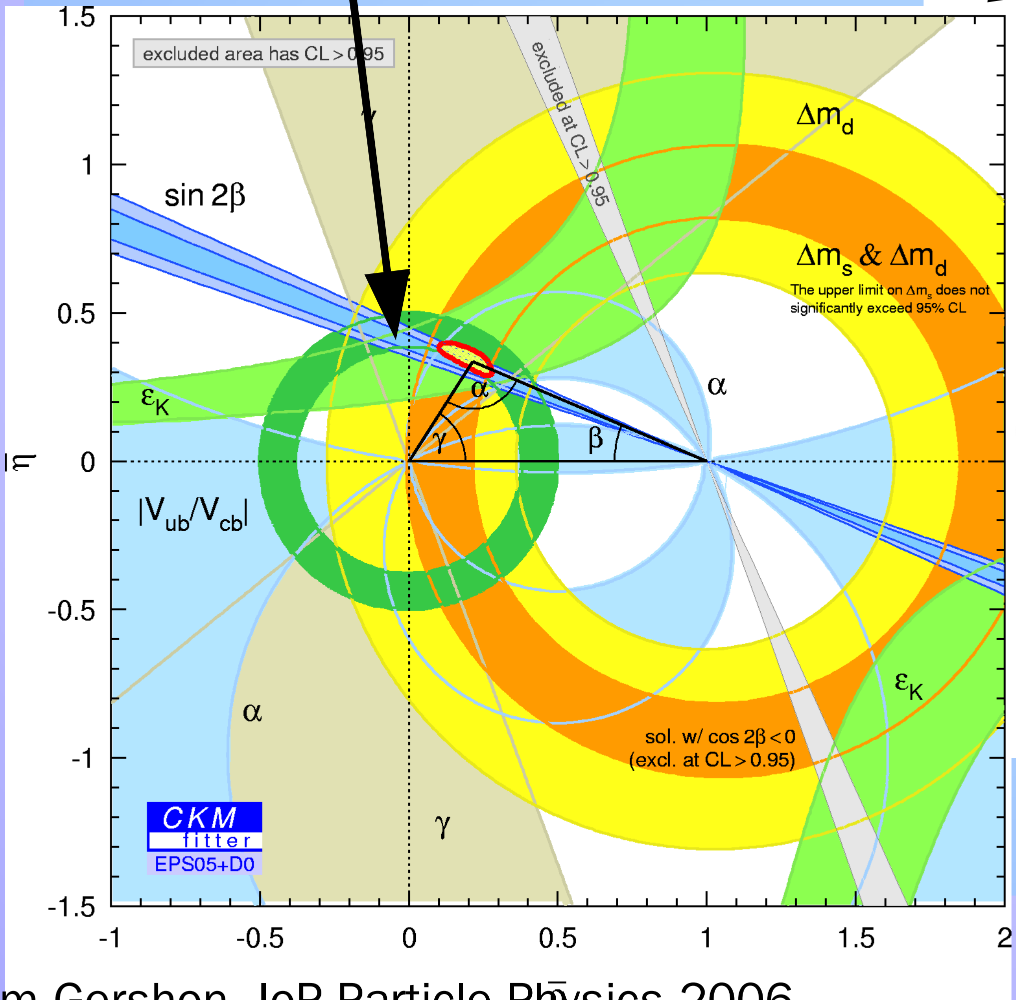
- In principle, Δm_d measures R_t
  - large theoretical uncertainty
  - can be controlled in the ratio $\Delta m_d / \Delta m_s$

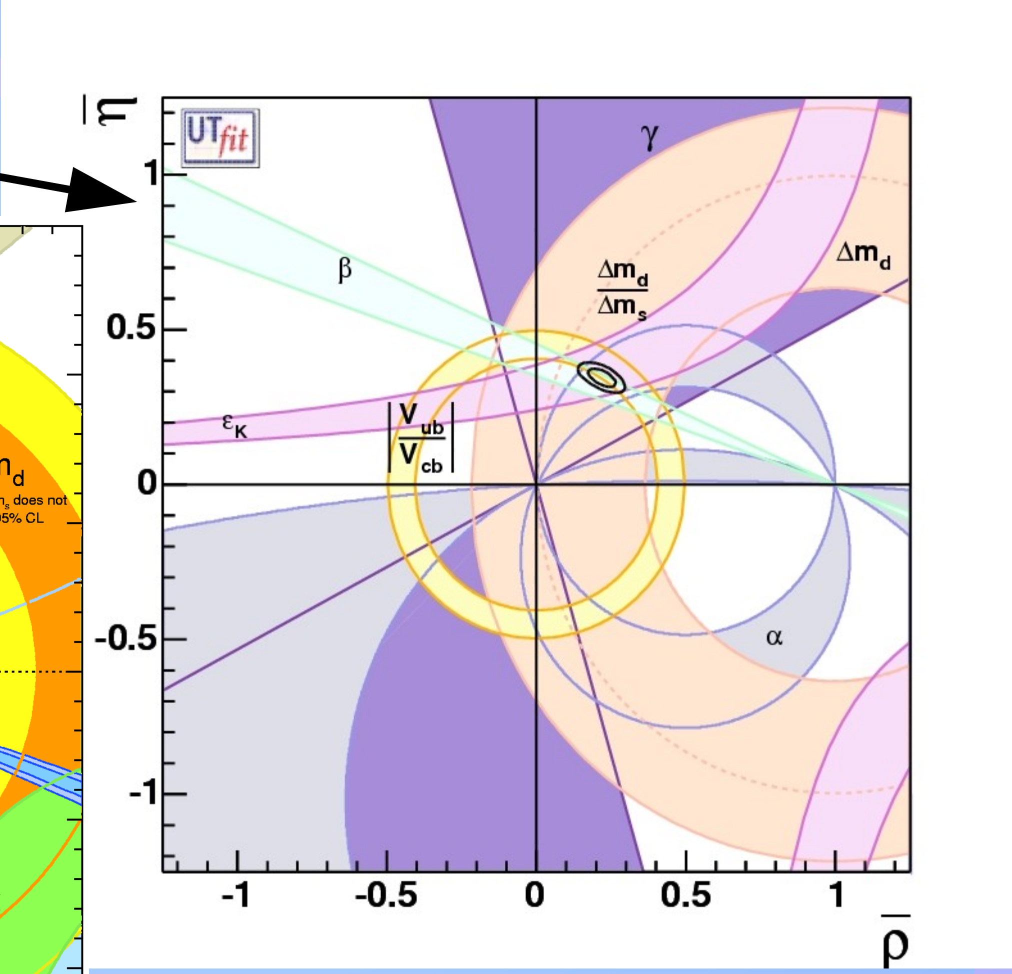
$$\frac{\Delta m_d}{\Delta m_s} = \frac{m_{B_d} f_{B_d}^2 \hat{B}_{B_d}}{m_{B_s} f_{B_s}^2 \hat{B}_{B_s}} \left| \frac{V_{td}}{V_{ts}} \right|^2$$

NEW results from D0

All UT Constraints

Different statistical approaches





Beyond the UT

- Now have measurements of all three angles and two sides of UT
  - highly constraining values of β and R_u
    - slight tension between these constraints
  - interpretation of this & other possible NP hints obscured by hadronic uncertainties
- Beyond overconstraining the UT, $\exists$ numerous additional possible NP signatures in B physics
  - loop diagrams (FCNCs) probe *very* high mass scales through virtual particles

Historically, extremely successful for both NP discovery and quantification

The FCNC Matrix

th. error $\lesssim 10\%$
= exp. error $\lesssim 10\%$
= exp. error $\sim 30\%$

FLAVOUR COUPLING:

ELECTROWEAK STRUCTURE

	$b \to s\ (\sim\lambda^2)$	$b \to d\ (\sim\lambda^3)$	$s \to d\ (\sim\lambda^5)$
$\Delta F=2$ box	ΔM_{Bs}, $A_{CP}(B_s \to \psi\phi)$	ΔM_{Bd}, $A_{CP}(B_d \to \psi K)$	ΔM_K, ε_K
$\Delta F=1$ 4-quark box	$B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to \pi\pi$, $B_d \to \rho\pi$, ...	ε'/ε, $K \to 3\pi$, ...
gluon penguin	$B_d \to X_s \gamma$, $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d \gamma$, $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, ...
γ penguin	$B_d \to X_s l^+ l^-$, $B_d \to X_s \gamma$, $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d l^+ l^-$, $B_d \to X_d \gamma$, $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, ...
Z^0 penguin	$B_d \to X_s l^+ l^-$, $B_s \to \mu\mu$, $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d l^+ l^-$, $B_d \to \mu\mu$, $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, $K \to \pi\nu\nu$, $K \to \mu\mu$, ...
H^0 penguin	$B_s \to \mu\mu$	$B_d \to \mu\mu$	$K_{L,S} \to \mu\mu$

From G.Isidori, via O.Schneider

The FCNC Matrix

th. error $\lesssim 10\%$

(grey filled oval) = exp. error $\lesssim 10\%$

(open oval) = exp. error $\sim 30\%$

FLAVOUR COUPLING:

ELECTROWEAK STRUCTURE	$b \to s$ $(\sim\lambda^2)$	$b \to d$ $(\sim\lambda^3)$	$s \to d$ $(\sim\lambda^5)$
$\Delta F=2$ box	ΔM_{Bs}, $A_{CP}(B_s \to \psi\phi)$	ΔM_{Bd}, $A_{CP}(B_d \to \psi K)$	ΔM_K, ε_K
$\Delta F=1$ 4-quark box	$B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to \pi\pi$, $B_d \to \rho\pi$, ...	ε'/ε, $K \to 3\pi$, ...
gluon penguin	$B_d \to X_s \gamma$, $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d \gamma$, $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, ...
γ penguin	$B_d \to X_s l^+ l^-$, $B_d \to X_s \gamma$, $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d l^+ l^-$, $B_d \to X_d \gamma$, $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, ...
Z^0 penguin	$B_d \to X_s l^+ l^-$, $B_s \to \mu\mu$, $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d l^+ l^-$, $B_d \to \mu\mu$, $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, $K \to \pi\nu\nu$, $K \to \mu\mu$, ...
H^0 penguin	$B_s \to \mu\mu$	$B_d \to \mu\mu$	$K_{L,S} \to \mu\mu$

From G.Isidori, via O.Schneider

kaon physics

FCNC Matrix phenomenology

- Generic NP can effect each loop independently
  - particular models ⇔ correlations

    also with other observables (eg. τ LFV, CPV, EDMs, ...)

probing for new physics in the flavour sector

↕ *NP discovery* ↕

probing the flavour sector of the new physics

- Flavour physics is essential to understand NP at the TeV scale (or higher)

Key measurements

- $\Delta F = 2$:

  Δm_s, $A_{CP}(B_s \to J/\psi\ \varphi)$, ϵ_{Bd}, ϵ_{Bs}

- gluon penguin

  $A_{CP}(B_s \to \varphi\varphi)$, $A_{CP}(B_d \to \varphi K_S)$, *etc.*

- γ penguin

  [Γ, A_{CP}, polarisation] $B_s \to \varphi\gamma$, $B_d \to X_s\gamma$, $B_d \to X_d\gamma$

- Z^0 penguin

  [Γ, A_{FB}, A_{CP}] $B_s \to \varphi l^+l^-$, $B_{u,d} \to K^*ll$, $B_{u,d} \to X_s l^+l^-$, $B_{u,d} \to X_d l^+l^-$

- H^0 penguin

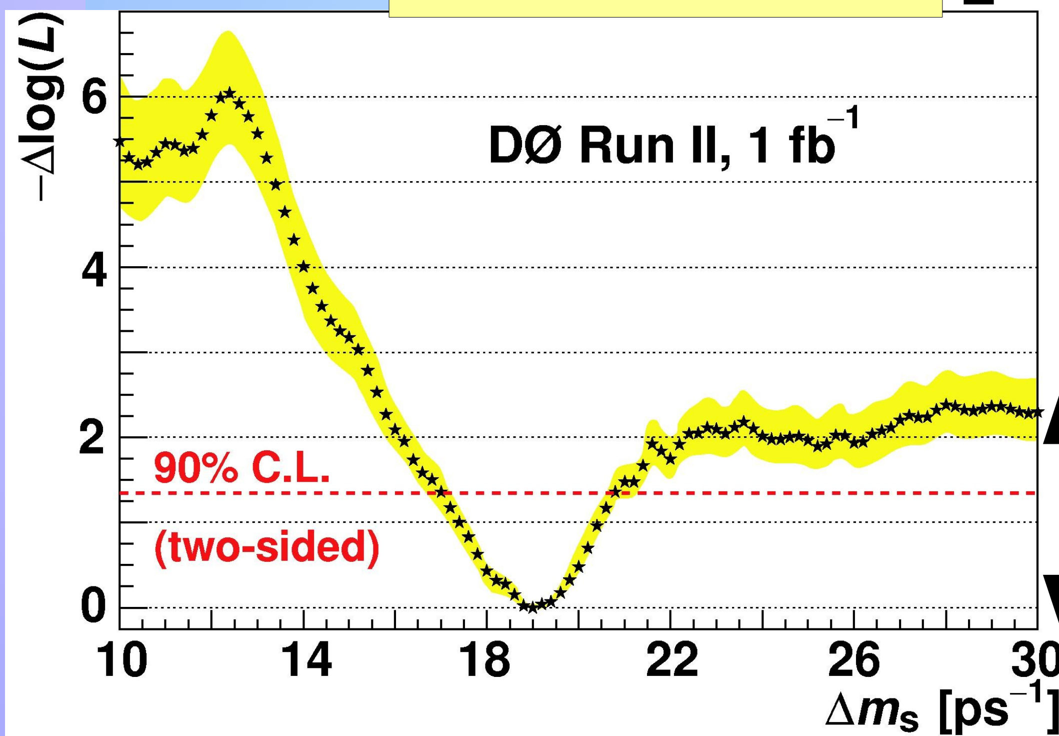
  $B_{s,d} \to \mu^+\mu^-$, $B_d \to \tau^+\tau^-$

D0 Δm_s result

hep-ex/0603029

$17/\text{ps} < \Delta m_s < 21/\text{ps}$

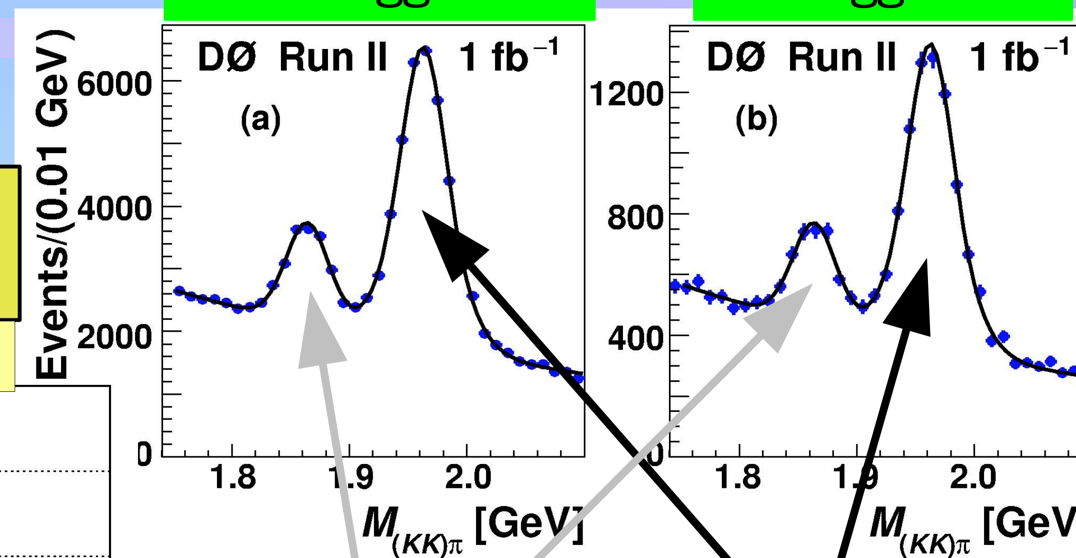
assumes Gaussian errors



SIGNIFICANCE

untagged

tagged



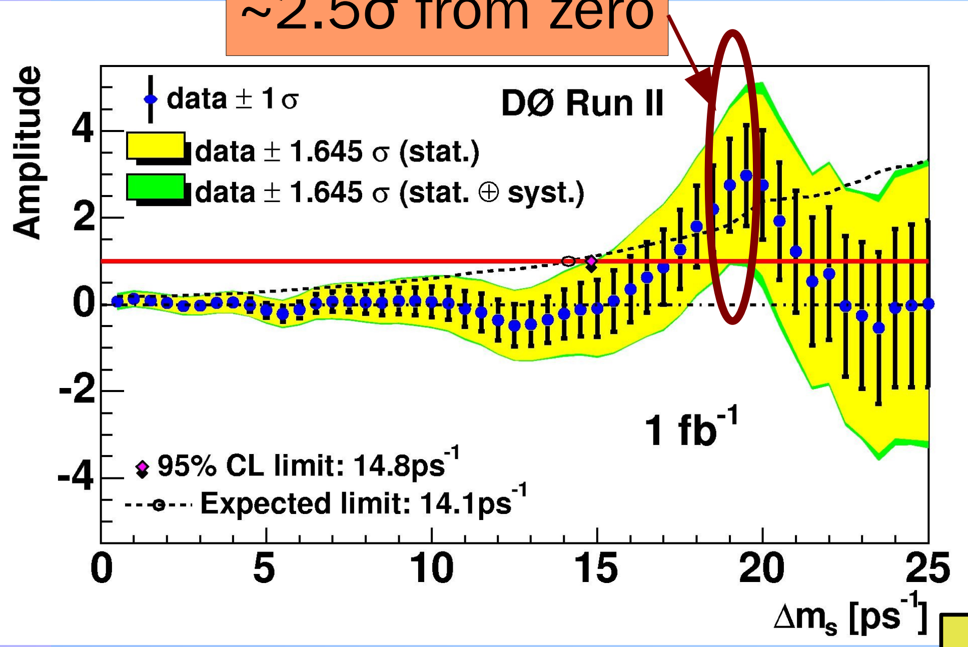
$B_d \rightarrow D^- \mu^+ X$

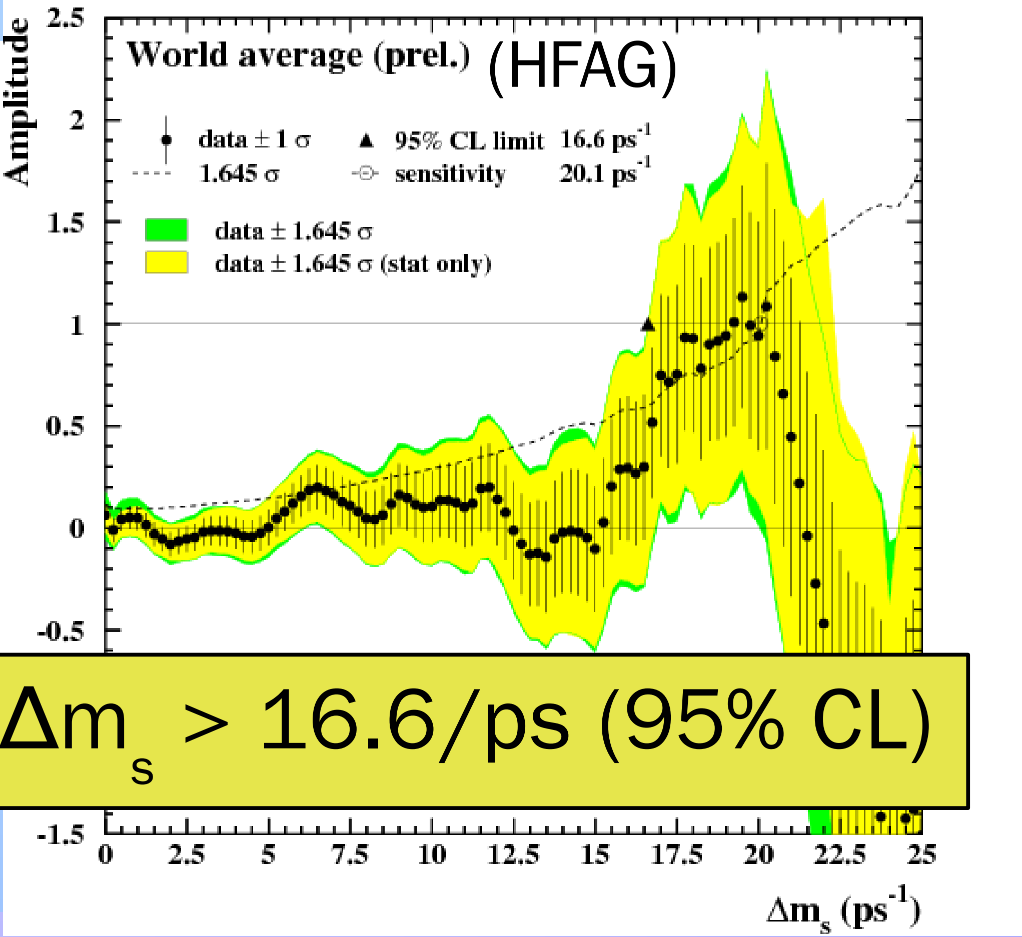
$B_s \rightarrow D_s^- \mu^+ X$

Δm_s World Average

Results presented as amplitude scans

~2.5σ from zero





Δm_s > 16.6/ps (95% CL)

Future updates (CDF, D0) keenly anticipated

Measurement of ϵ_{Bd}

- **Belle (hep-ex/0505017)**

  $|q/p|-1 = 0.0005 \pm 0.0040 \pm 0.0043$

- **BaBar (hep-ex/0603053)**

  $|q/p|-1 = -0.0008 \pm 0.0027 \pm 0.0019$

- **D0 (D0note-5042-CONF)**

  WARNING: ADMIXTURE OF B_d & B_s

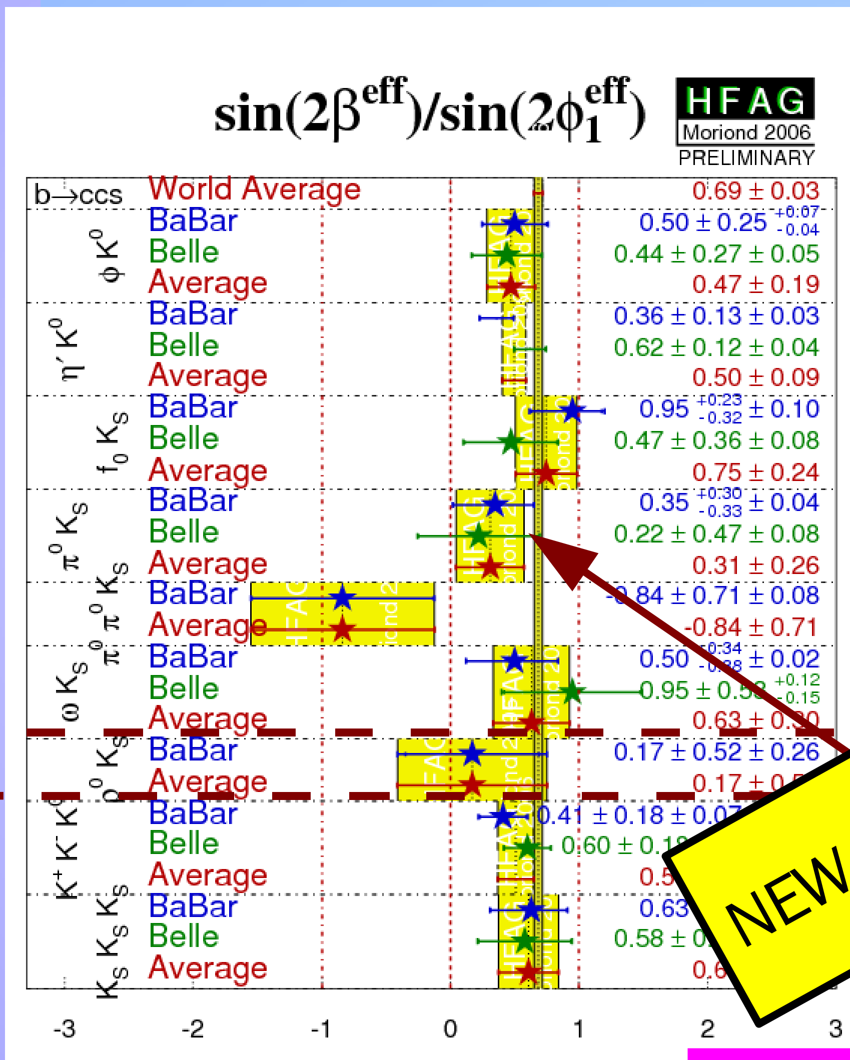
  "$|q/p|-1$" $= 0.0022 \pm 0.0020 \pm 0.0014$

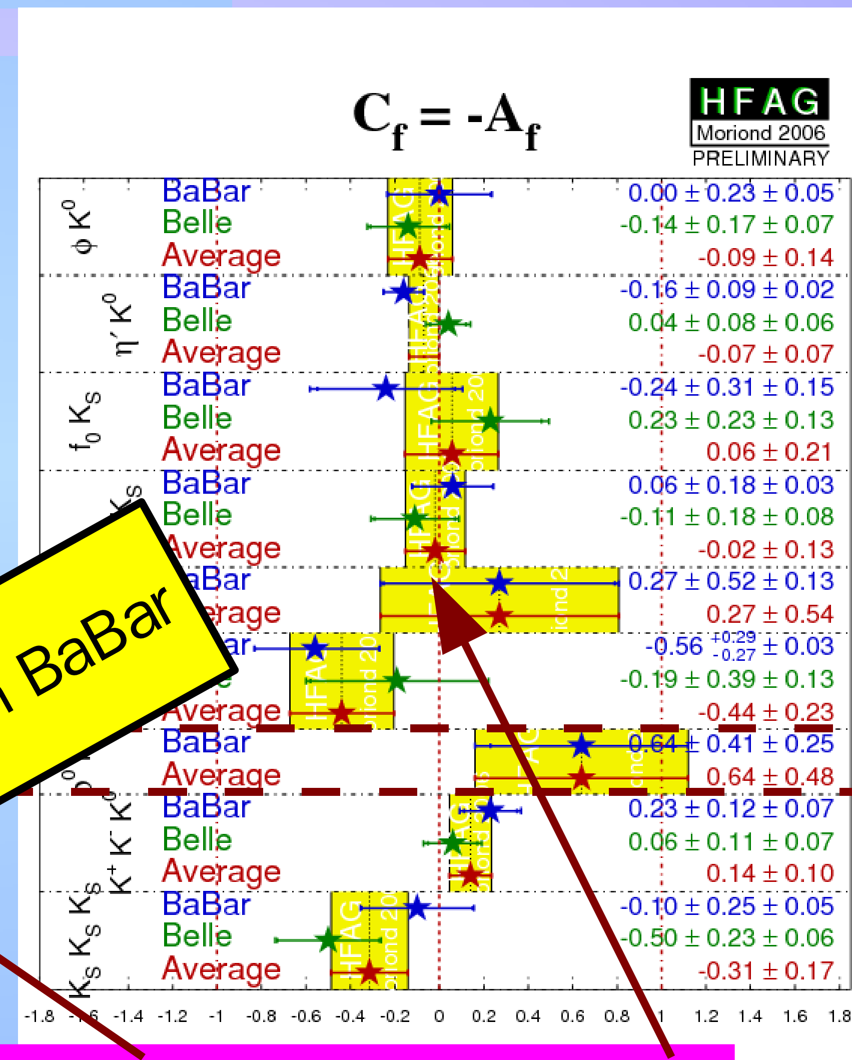
NEW results from BaBar

NEW results from D0

Challenging control of systematic errors at sub % level

Measurement of $A_{CP}(B_d \to \phi K_S)$, *etc.*



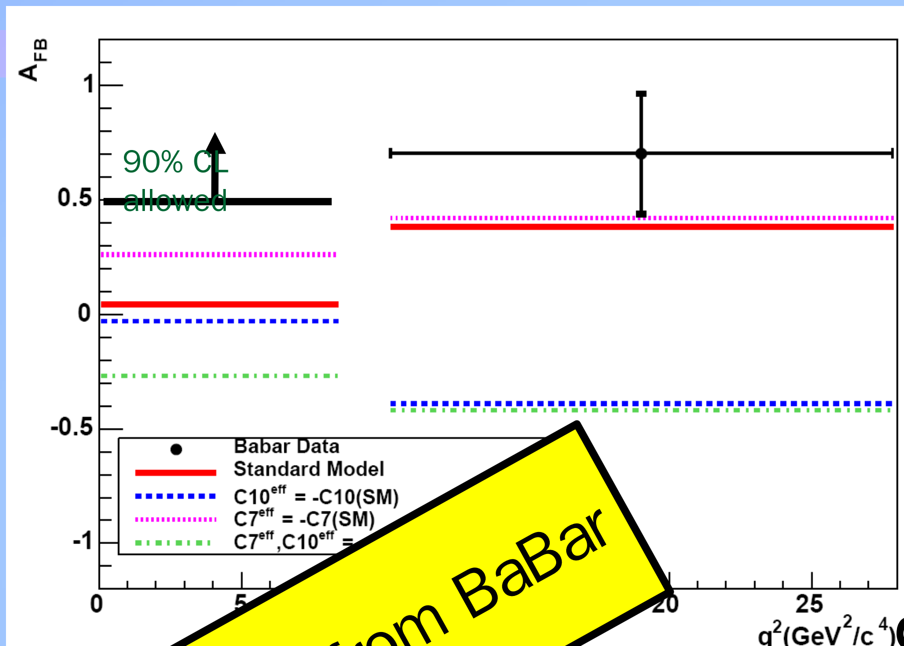


NEW results from BaBar

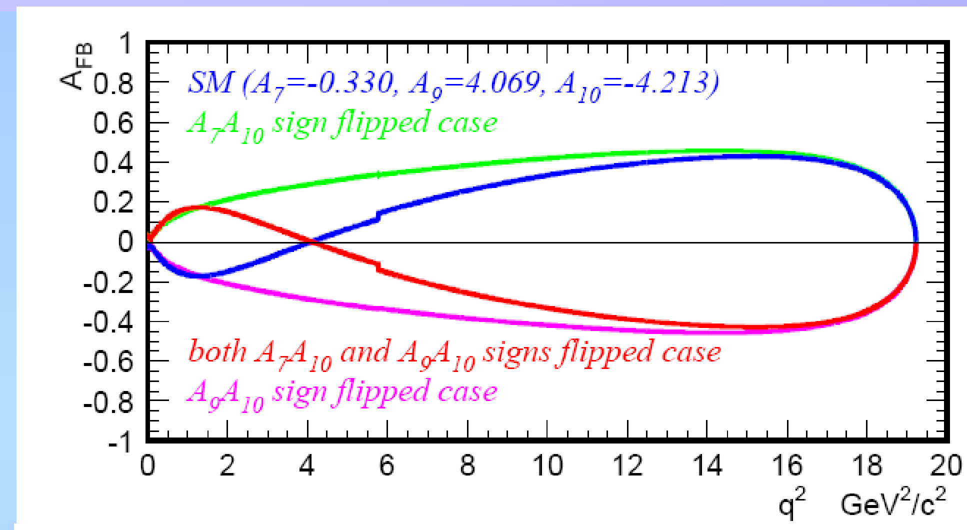
SM expectations : ~same as $B^0 \to J/\psi\, K_S$ ~0

Studies of $B_{u,d} \rightarrow K^{(*)}l^+l^-$

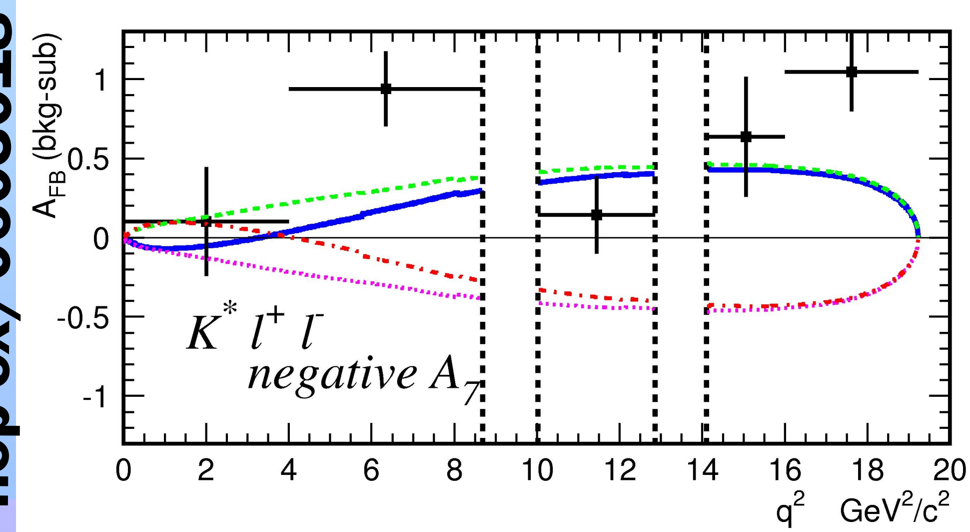
hep-ex/0604007



NEW results from BaBar



Belle hep-ex/0603018



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Measurement of $B_{s,d} \to \mu^+\mu^-$

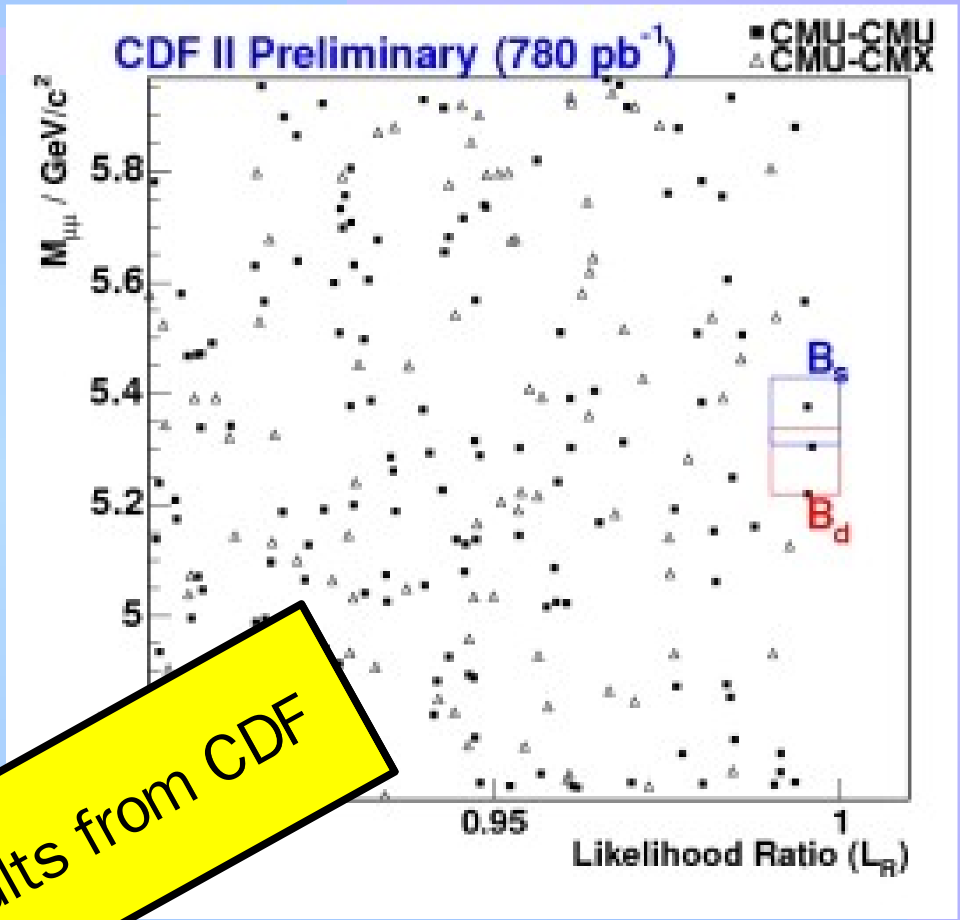
$BR(B_s \to \mu^+\mu^-) < 1.0 \times 10^{-7}$ @95% CL

$BR(B_d \to \mu^+\mu^-) < 3.0 \times 10^{-8}$ @95% CL

SM predictions: $O(10^{-9})$ & $O(10^{-10})$

$B_d \to e^+e^-$ limits from BaBar

$B_d \to \tau^+\tau^-$ limits from BaBar



NEW results from CDF

CDF Public note 8176

Probing the FCNC Matrix

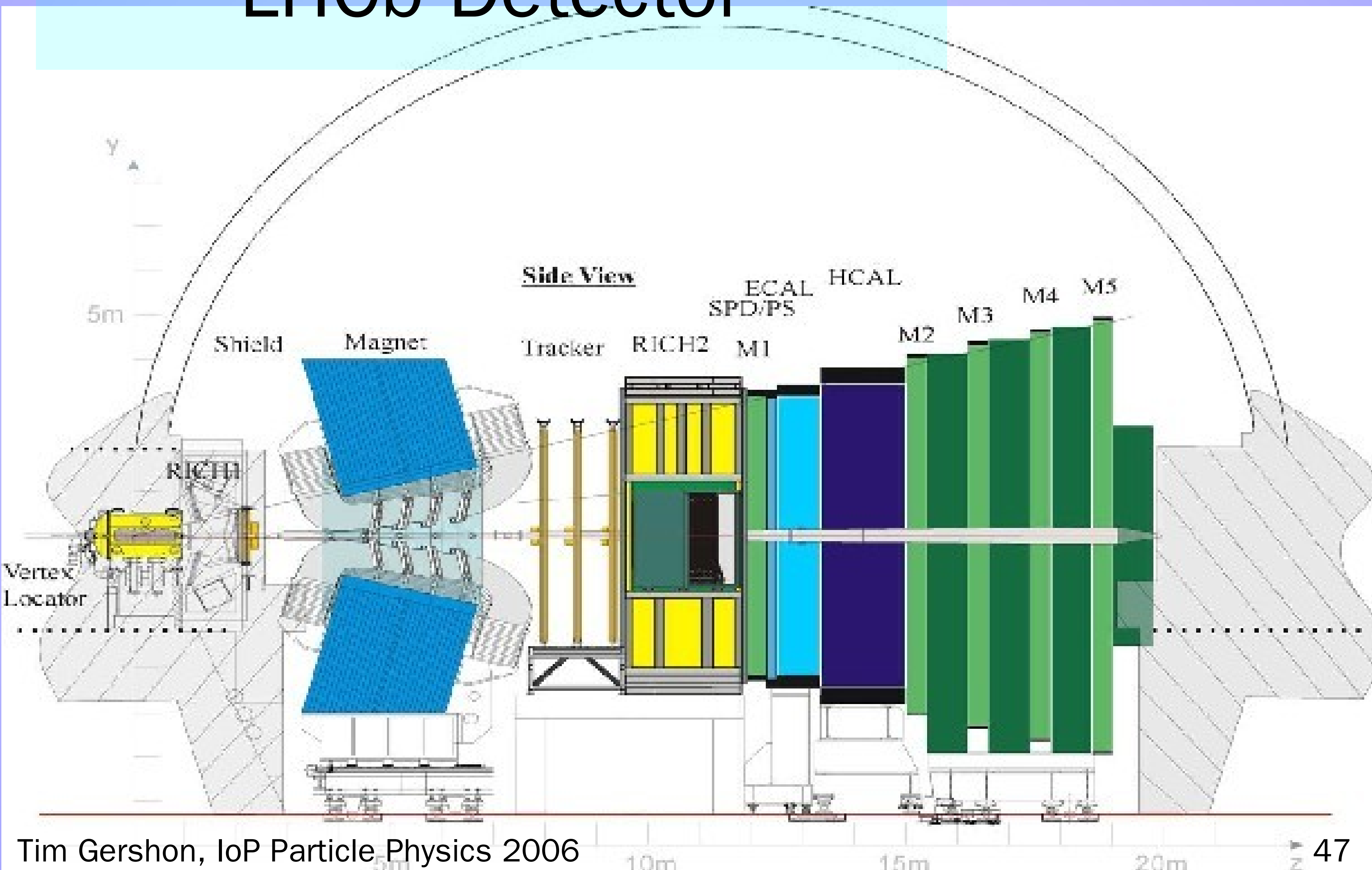
- Good constraints in some corners, but mostly still only loose bounds on possible NP contributions
- LHC will provide copious b production
  - but also copious backgrounds
- ATLAS/CMS can measure SM $B_{s,d} \to \mu^+\mu^-$
- Dedicated experiment necessary for most other modes

  $\Rightarrow$ LHCb
  - Excellent sensitivity for (among others):

$$\Delta m_s,\ A_{CP}(B_s \to J/\psi\ \varphi),\ B_s \to \varphi\gamma,\ B_{u,d} \to K^*\gamma,$$

$$B_s \to \varphi l^+l^-,\ B_{u,d} \to K^*ll,\ \gamma(B_s \to D_sK),\ \gamma(B_{u,d} \to DK),\ \ldots$$

LHCb Detector



Motivation for Super B Factory

- How to beat theoretical (hadronic) uncertainties?
  - Measure ratios, asymmetries, *etc.*
  - Exploit flavour symmetries (isospin, U-spin, SU(3))
    - these approaches key to LHCb program
  - Avoid hadrons in the final state
    - neutrinos ← impossible in hadronic environment
    - photons ← difficult in hadronic environment
    - charged leptons
      - e, μ, τ ← e difficult, τ impossible
  - Use inclusive final states
    - X_s, X_d ← impossible in hadronic environment

Pros and Cons

LHCb	Super B Factory
Huge b cross-section	Use "simple" hadronic trigger
All b hadrons produced	Only B_u & B_d at Υ(4S) (other E_{CM} possible)
Large boost	Reconstruct "any" decay
Measure production vtx	Coherent production at Υ(4S)

Together, provide complete coverage of B sector

Super B Factory design

Requirements:

- Extremely high luminosity
- Low backgrounds
- Small beam energy spread ($< \Gamma(\Upsilon(4S))$)
- Boost + vertexing
- Hermiticity
- Timeliness
- Affordability! (construction & operation)

Daresbury Laboratory, April 26-27

Possible designs:

- SuperKEKB — upgrade of conventional B factory
- "linear" SuperB — use ILC technology (damping rings, compressor, final focus, SC-cavities(?))

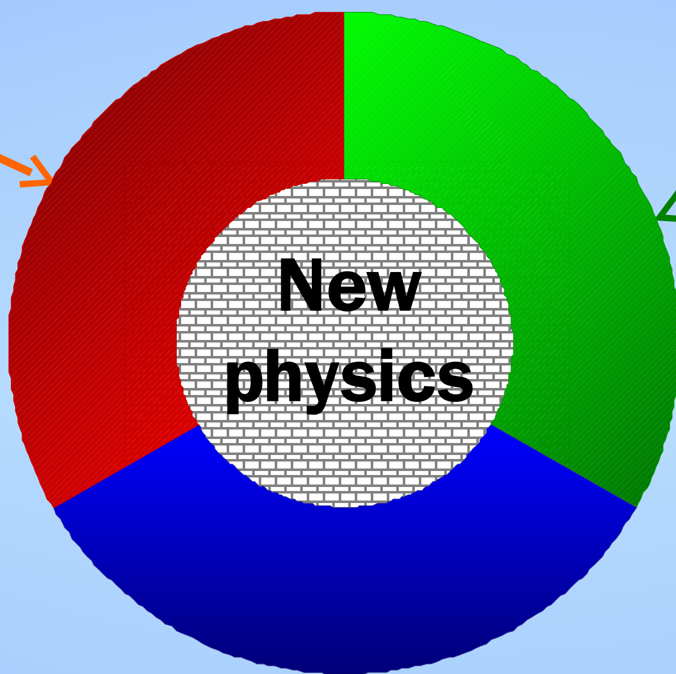
“Unified and Unbiased Attack on New Physics”

LHC, ILC

mass spectrum
interactions

ν experiments,
g_μ–2, $\mu \to e\gamma$, EDM, …

ν mass and mixing
CPV and LFV



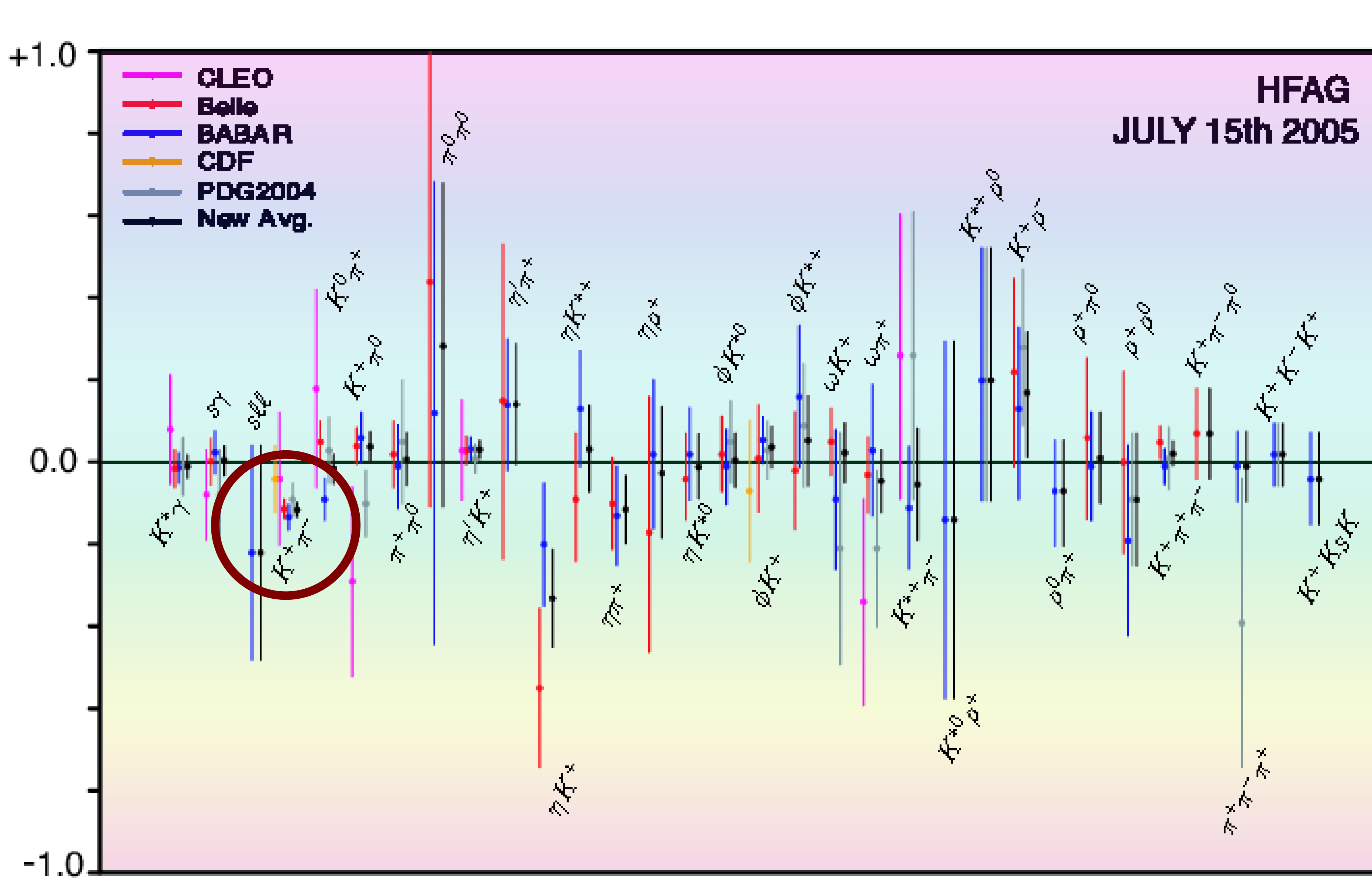
τ LFV
τ CPV

flavour mixing
CPV phases

Super B factory, LHCb, *K* experiments ⋯

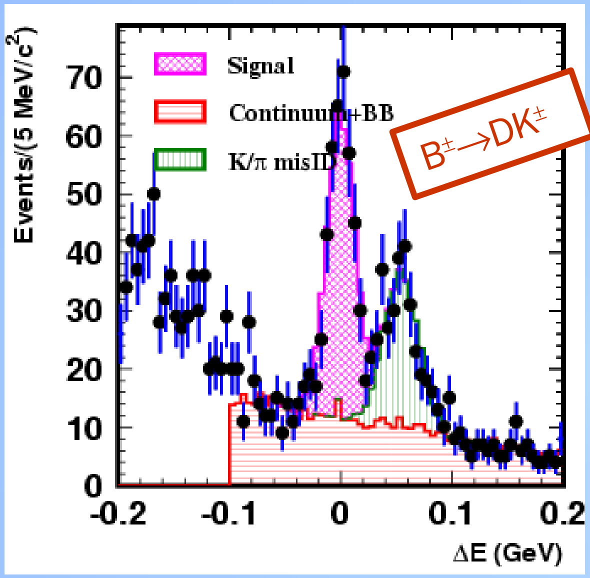
BACK UP MATERIAL

CP Asymmetry in Charmless B Decays

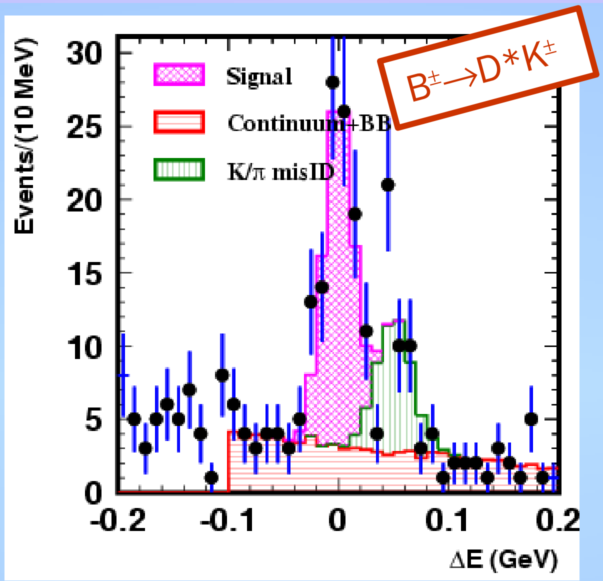


Belle DK Dalitz Result

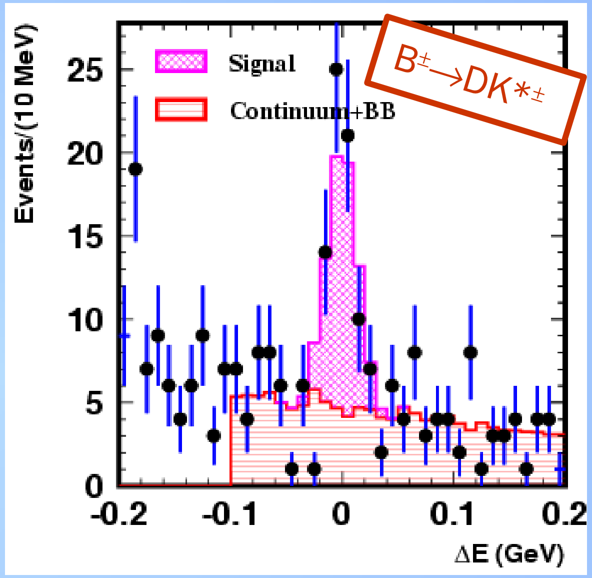
PRD journal submission in preparation



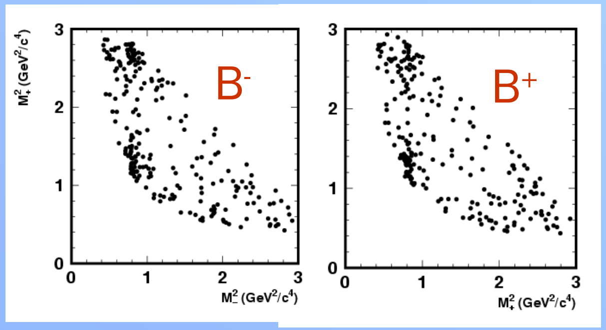
331±17 events

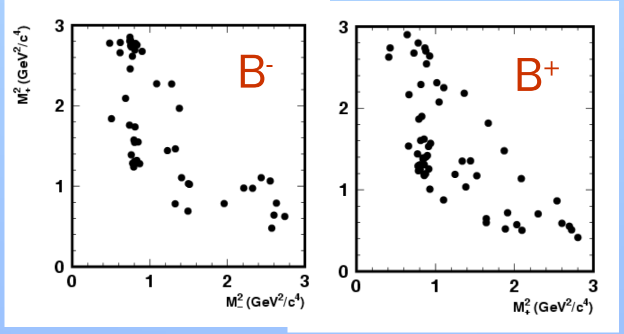


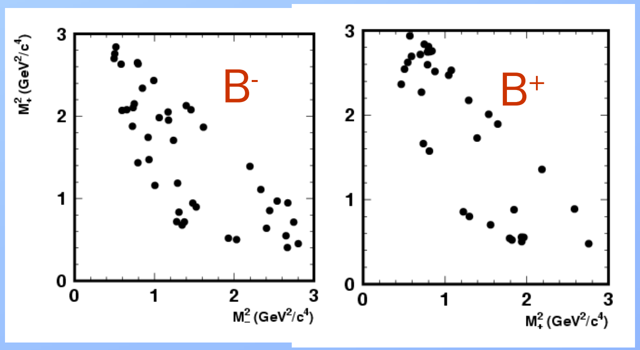
81±8 events



54±8 events







$|V_{ub}|$ from exclusive modes

Current best measurement: PRD 72, 051102 (2005)

$B^0 \to \pi^- l^+ \nu$ $B^0 \to \rho^- l^+ \nu$

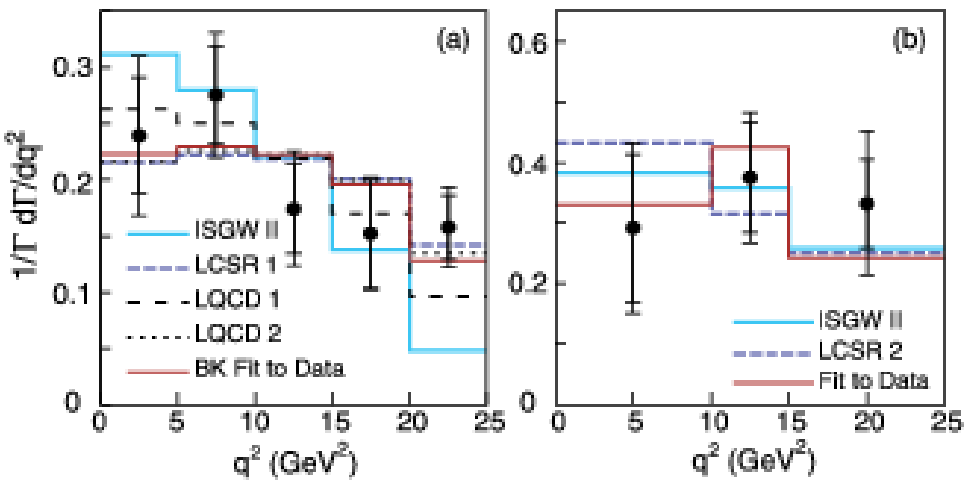
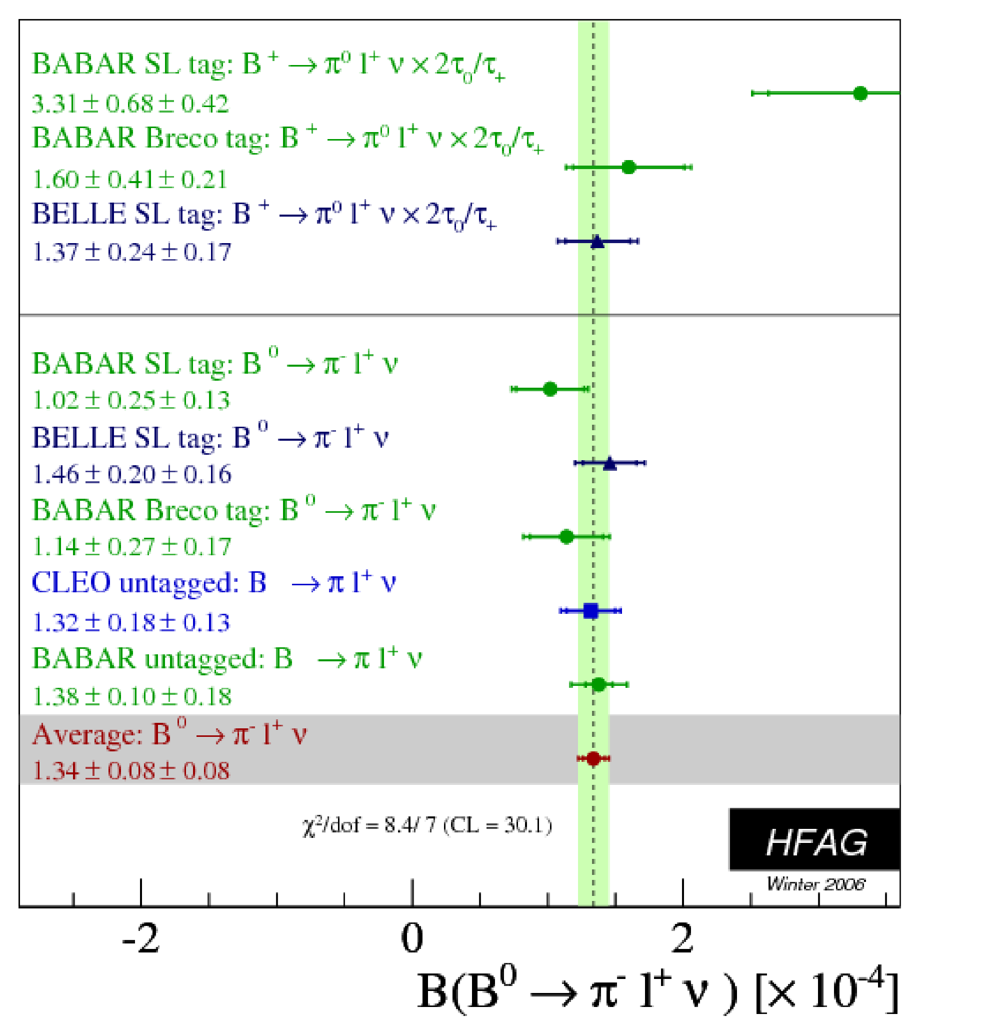
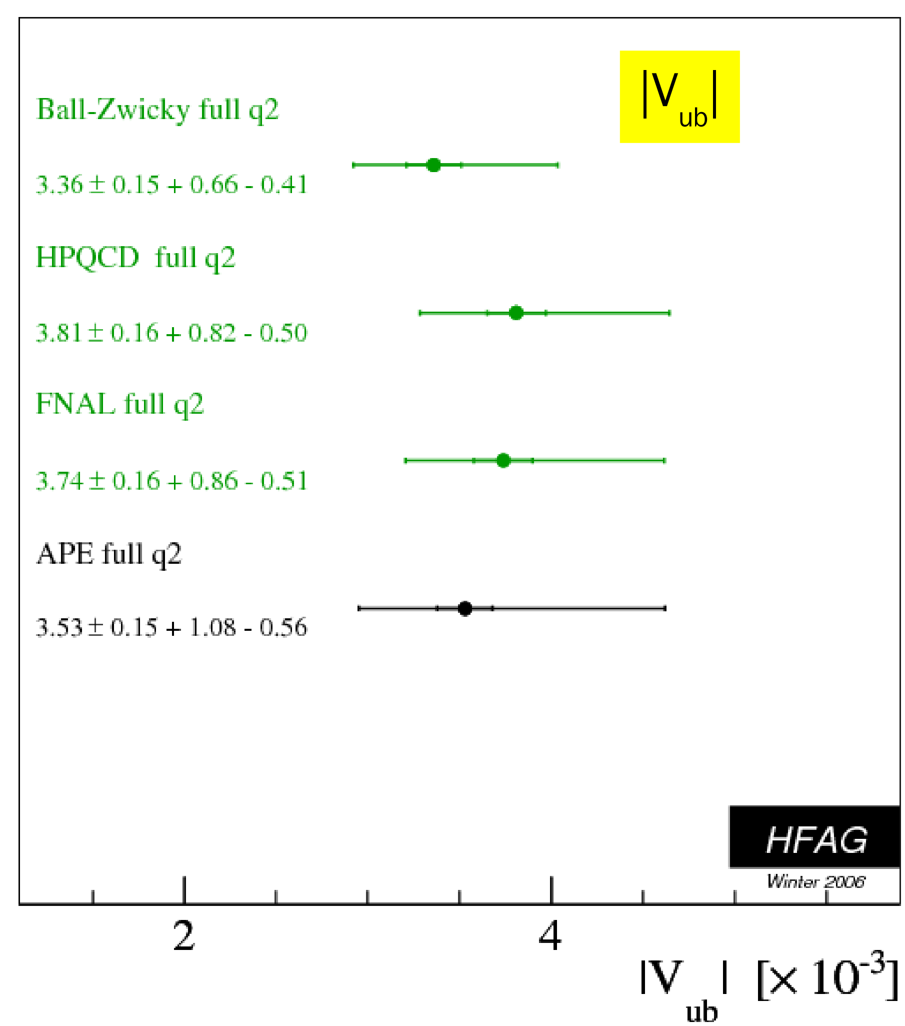


FIG. 3: (color online) Comparison of the differential decay rates as functions of q^2 for $B \to \pi\ell\nu$ (a) and $B \to \rho\ell\nu$ (b) with various form-factor predictions. The data are background subtracted and corrected for efficiency and radiative effects. The error bars are statistical (inner) and statistical plus systematic (outer).

$$\mathcal{B}(B^0 \to \pi^- \ell^+ \nu) = (1.38 \pm 0.10 \pm 0.16 \pm 0.08) \times 10^{-4},$$
$$\mathcal{B}(B^0 \to \rho^- \ell^+ \nu) = (2.14 \pm 0.21 \pm 0.48 \pm 0.28) \times 10^{-4},$$

$|V_{ub}|$ from exclusive modes





Different theoretical approaches

D0 Δm_s : Dilution Calibration Using $B_d \rightarrow D^{*\pm}\mu\nu X$

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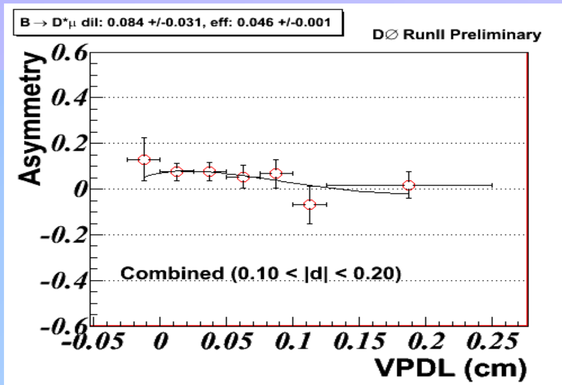
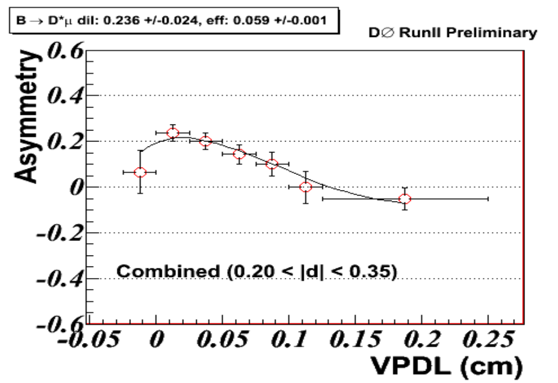
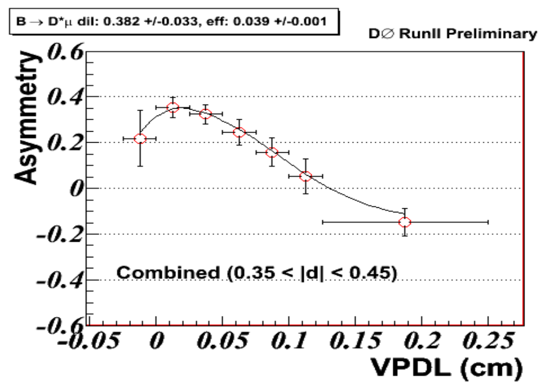
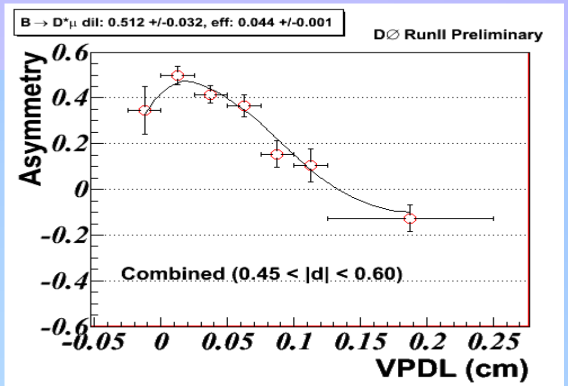
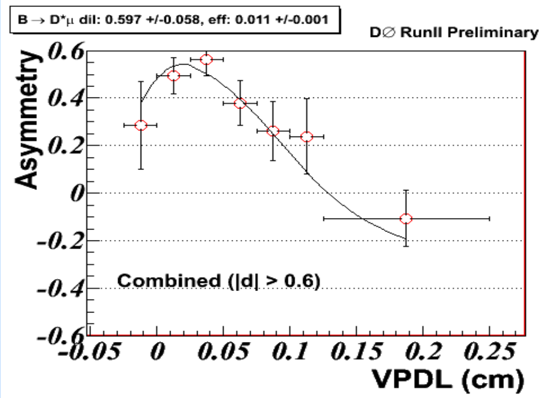
Increasing dilution









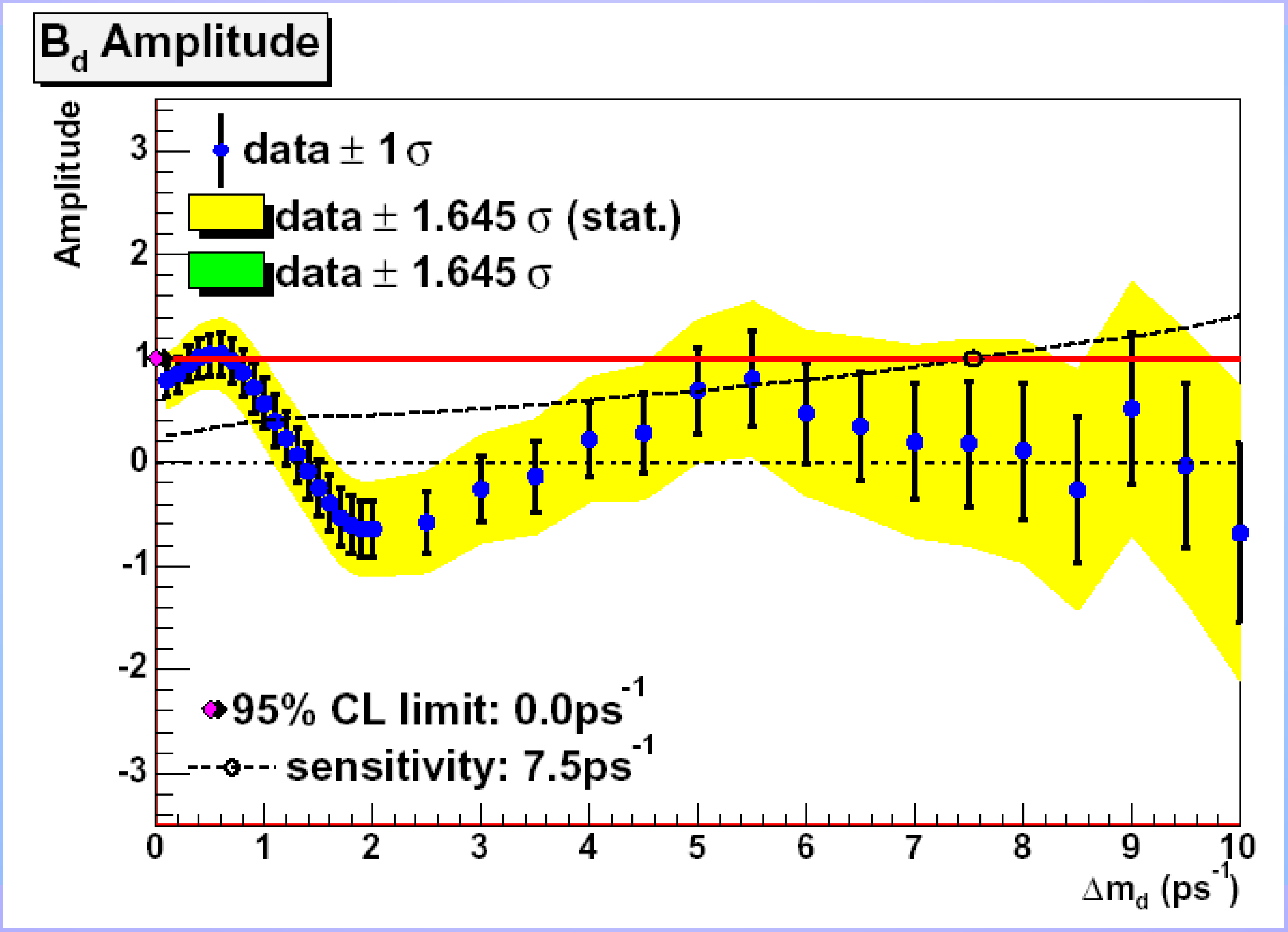


Increasing dilution

$$\Delta m = 0.506 \pm 0.020\ (stat.)\ ps^{-1}$$
$$\varepsilon D^2 = (2.48 \pm 0.21)\ (\%)\ (stat.)$$
$$\varepsilon = (19.9 \pm 0.2)\ (\%)\ (stat.)$$

$$\Delta m_{HFAG} = 0.507 \pm 0.004\ ps^{-1}$$

D0 Δm_s : Amplitude Scan for Δm_d (using $B_d \rightarrow D^{\pm}\mu\nu X$)

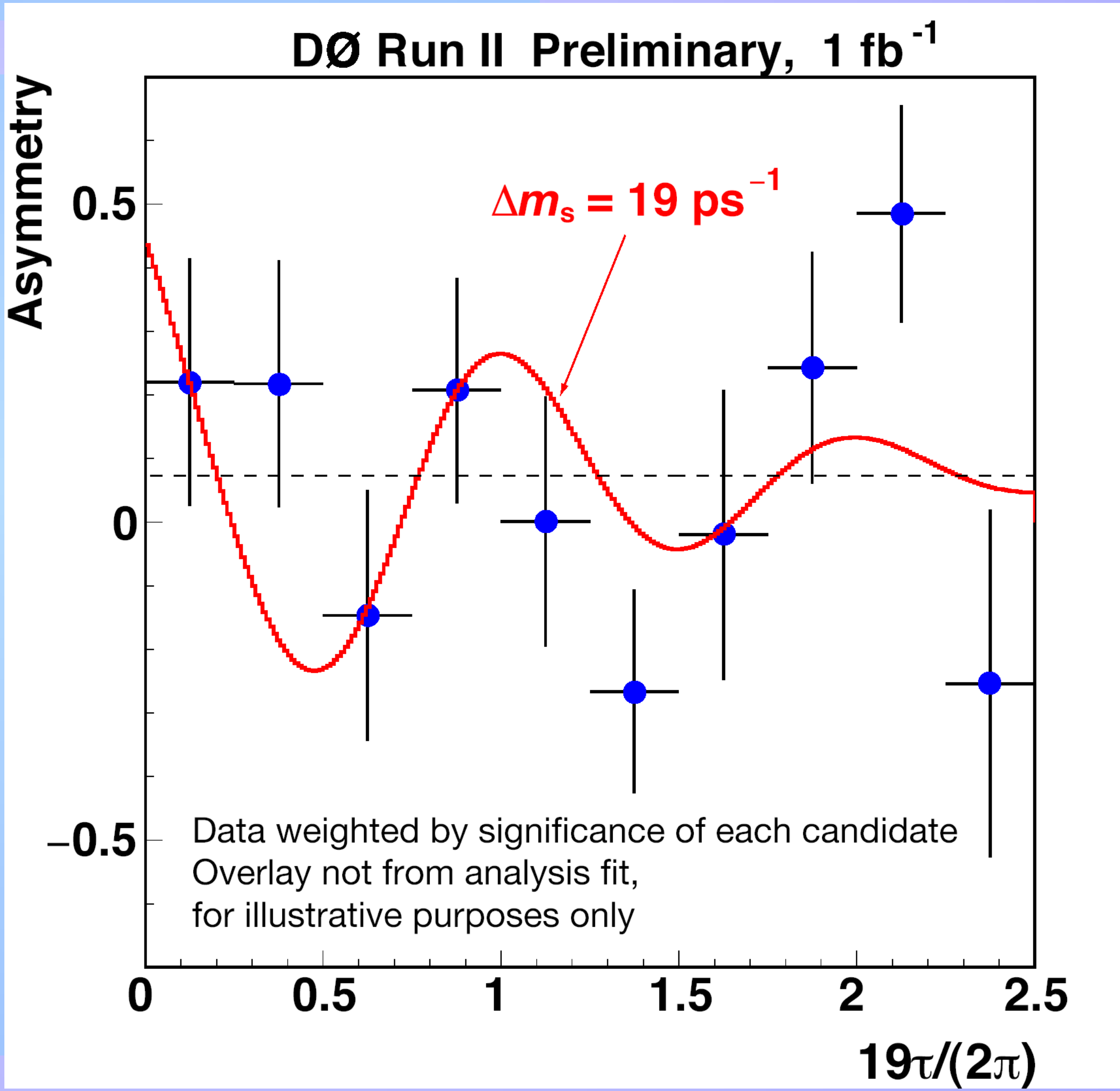


D0 Δm_s : Asymmetry plot

Weighted asymmetry

Does not represent full statistical power

Indication of oscillation clear

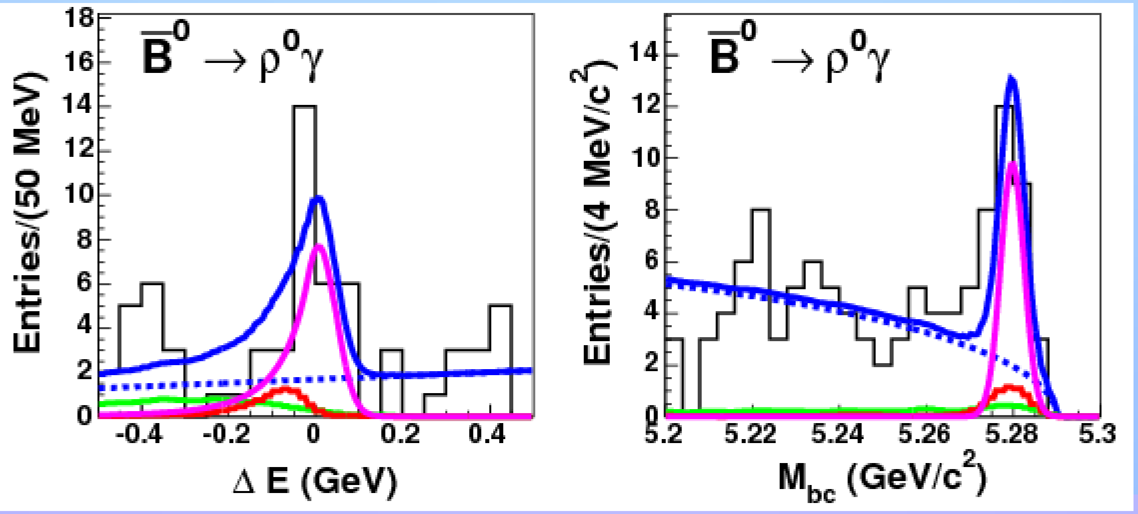


Alternate probe of R_t

- Access $|V_{tb}V_{td}^*|$ through $b \rightarrow d$ penguins
  - hadronization ⇔ theoretical uncertainty
  - cleanest measurement with exclusive modes:

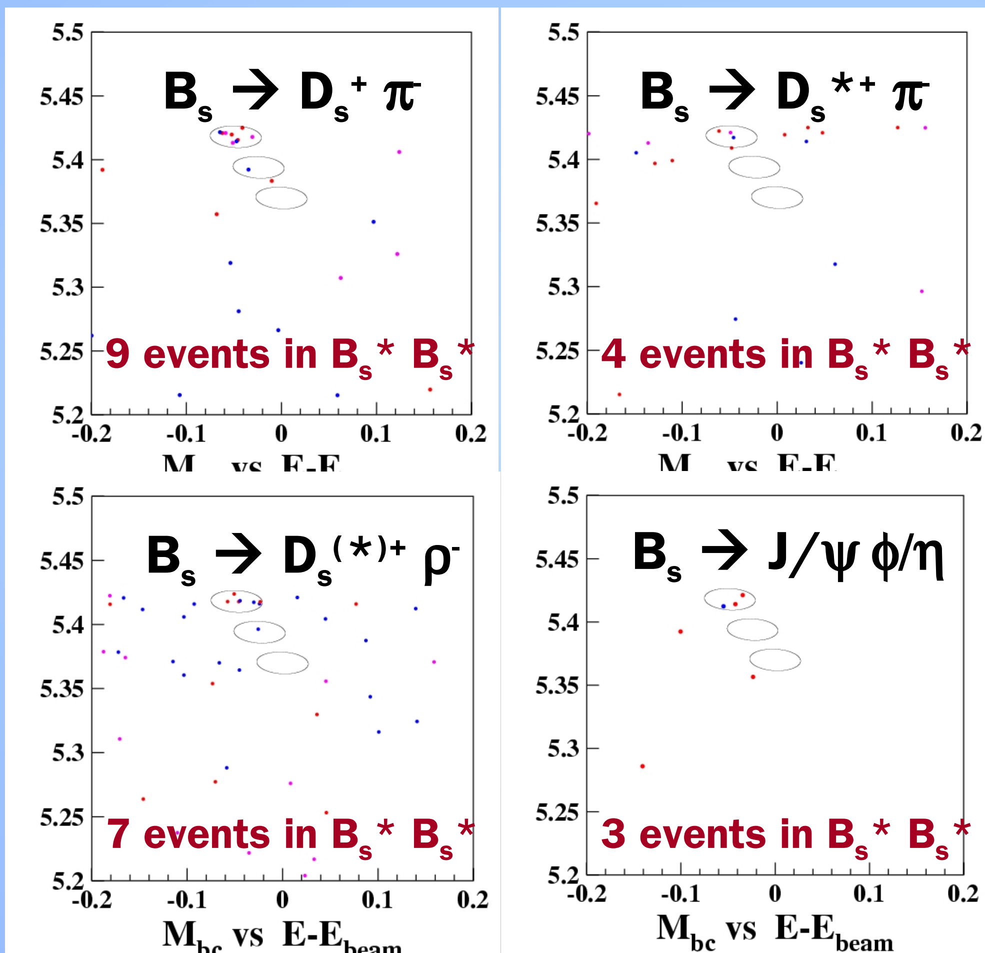
$$B(B^0 \rightarrow \rho^0\gamma)/B(B^0 \rightarrow K^{*0}\gamma)$$

Belle
hep-ex/0506079

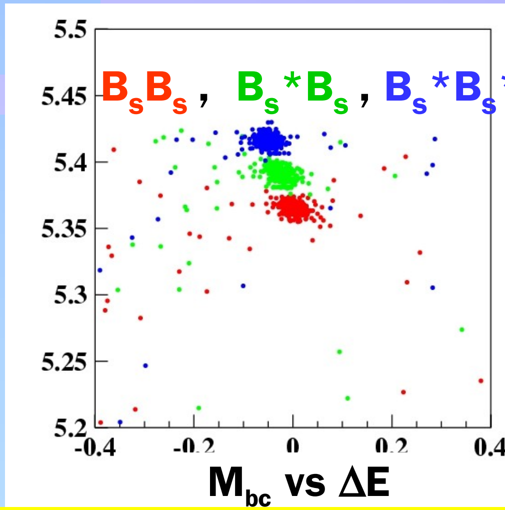


KEK-B Υ(5S) Engineering Run

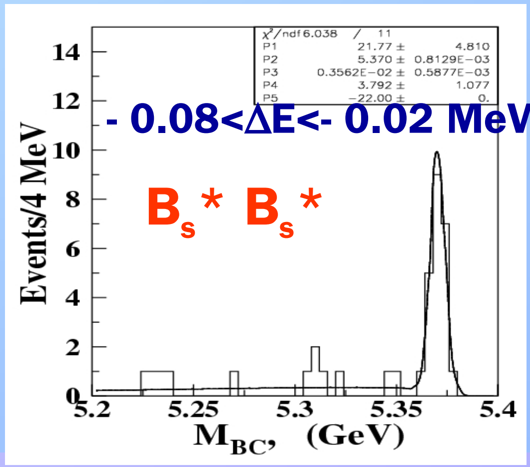
- B_s signals are identified with M_{bc} and ΔE



Clear B_s signals seen in $B_s^*B_s^*$ region

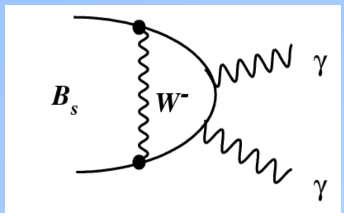


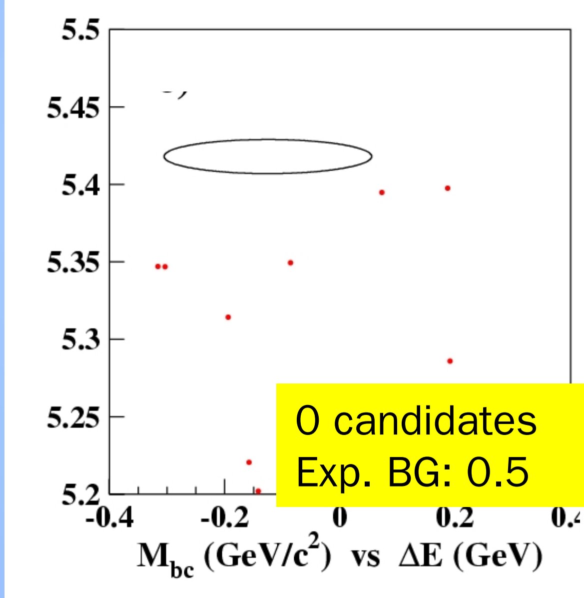
B_sB_s, $B_s^*B_s$, $B_s^*B_s^*$ signals can be separated well



KEK-B Υ(5S) Engineering Run

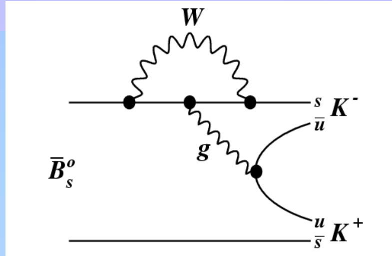
- $B_s \to \gamma\gamma$

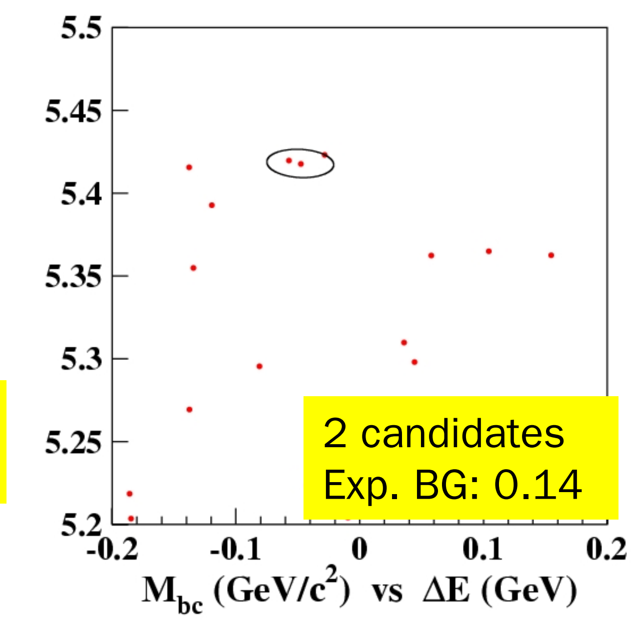




$B(B_s \to \gamma\gamma) < 0.56 \times 10^{-4}$ (90% CL)
PDG :$< 1.48 \times 10^{-4}$
SM: 0.5-1.0x10^{-}

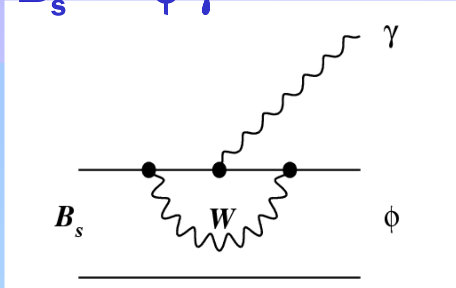
- $B_s \to K^+ K^-$

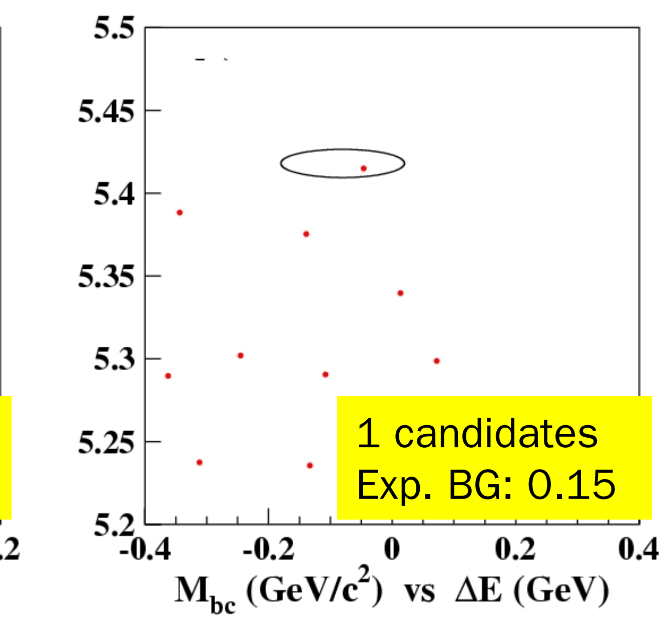




$B(B_s \to K^+K^-) < 3.4 \times 10^{-4}$ (90% CL)
PDG :$< 0.59 \times 10^{-4}$

- $B_s \to \phi\gamma$





$B(B_s \to \phi\gamma) < 4.1 \times 10^{-4}$ (90% CL)
PDG :$< 1.2 \times 10^{-4}$