CP Violation and angles of the Unitarity Triangle: the measurement of α using $B \to \rho\rho$

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THE UNIVERSITY of LIVERPOOL

Imperial College seminar, 16 June 2004

BABAR™

Objective: UT angles

- Personal interest and main axis for Liverpool@BABAR
- Were involved with β
- Started on α few years ago
- Involved in $\pi^0\pi^0$ (with Imperial group)
- Found $\pi^0\pi^0$; killed prospects of α with $\pi^+\pi^-$

- Sept. '02 (BABAR@Imperial): launched $\rho^+\rho^-$ TD analysis (Liverpool-Saclay)

- Moriond 2004: presented $\alpha = 96^\circ \pm 10^\circ_{stat} \pm 4^\circ_{syst} \pm 13^\circ_{penguin}$

- New paradigm for α measurements established!

Outline of the talk

- Flavor and CP violation measurements
  - Motivation
  - Unitarity Triangle and angles
  - The SLAC B Factory
- Status of the angle β
- The angle α:
  - Trees and Penguins
  - The $\pi\pi$ system
    - the $\rho\rho$ system

MOTIVATION

WHY AM I DOING CP MEASUREMENTS IN A B FACTORY?

WHY SHOULD YOU CARE ABOUT ALL THIS?

A NUMBER OF FACTS

AND SOME BOLD STATEMENTS

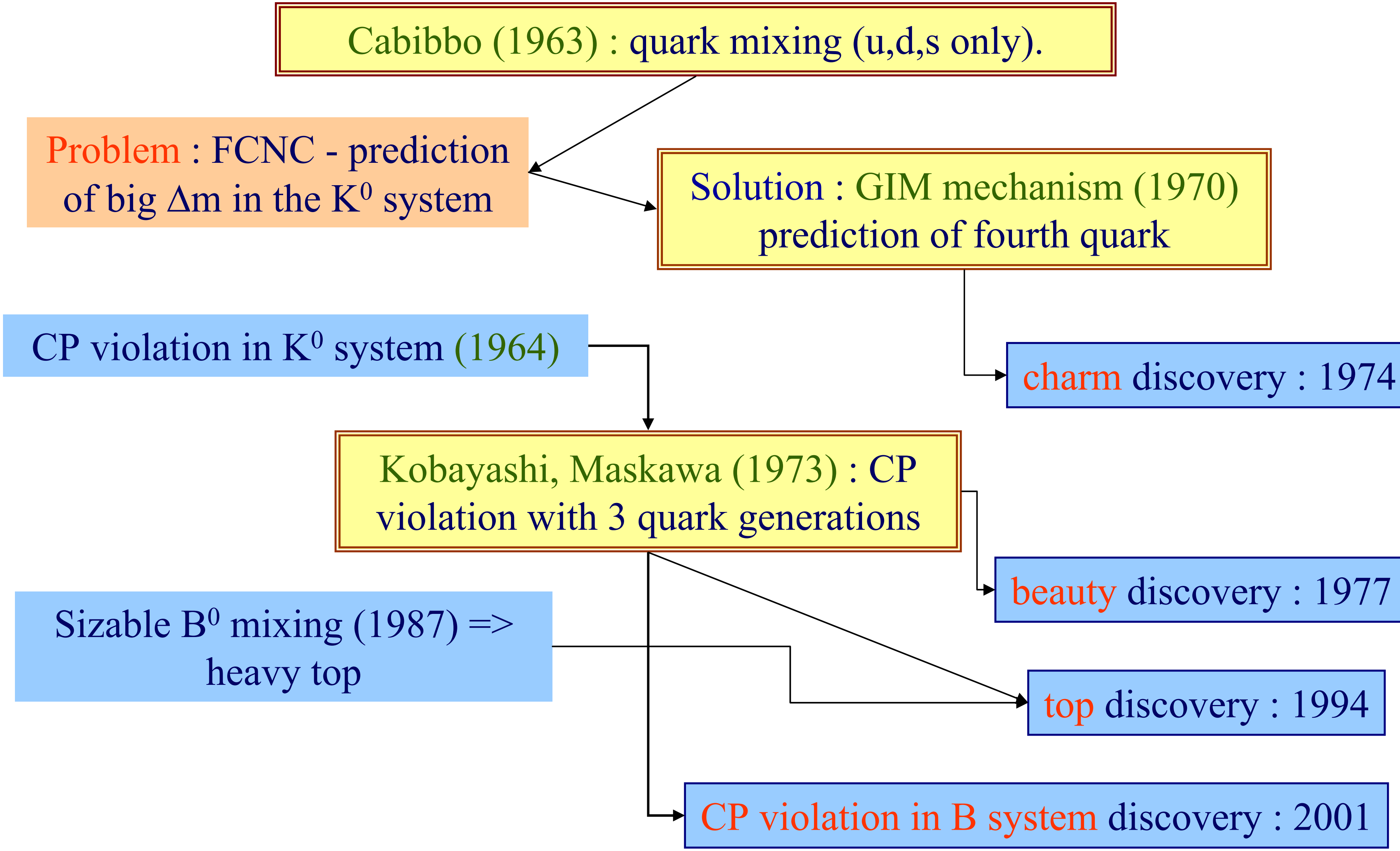
IN FEW PAGES

Motivation

- CP Violation and Flavor physics:
  - Historically important for development of SM
  - Precision measurements of fundamental symmetries
  - High sensitivity to higher energy scales through interference effects
  - Cosmology (matter dominance; Sakharov conditions)
  - Most of SM free parameters are flavor parameters: pin them down
  - Search for NP (heavy particles) in loops
- B Factories: known CPV is due to CKM phase
  - But:
    - 10^{10} too small for cosmology
    - Relationship to neutrino mixing: leptogenesis vs baryogenesis?
    - Mass, couplings hierarchy; relationship to lepton sector?

By confirming the SM model of CPV, the B factories have established that there is more to flavor and CPV than what we know today!

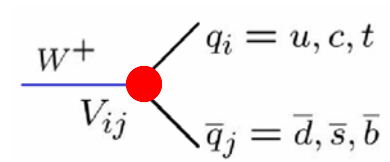
Intuition based on history:
Neutral mesons, CP violation and quark families

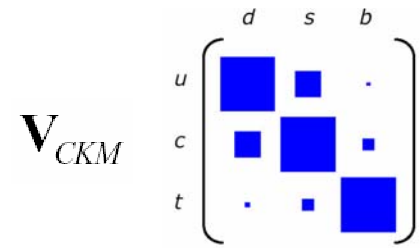


CPV and Flavor in the Standard Model

- Flavor structure of quark sector:
  - Mass origin = Yukawa couplings to Higgs ⇒ non-diagonal fermion mass terms:
    - Mass eigenstates ≠ Weak eigenstates
    - Flavor mixing in CCWI : description in CKM quark-mixing matrix

- Measure CKM elements:
  - Phases?
  - CKM matrix unitarity?
  - Magnitude hierarchy?
  - Link to mass hierarchy?





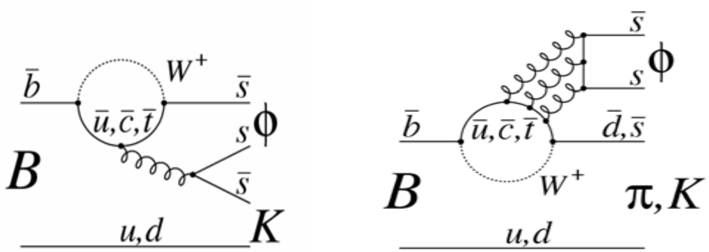
Relative magnitudes

- Complications from Strong Interaction effects:
  - Need SI input (HQET, Factorization, SCET, Lattice,…) to extract "pure" CKM elements
  - Provide input and validate SI theory/phenomenology/calculations by measuring many related B decays

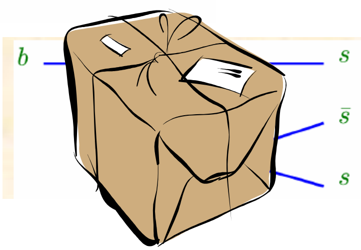
> Precision measurements in the B meson system:
> - direct determination of not-well-known SM parameters
> - stringent SM tests through redundant measurements
> - input and validation for SI models

CPV and Flavor beyond the Standard Model

- SUSY, extra dimensions, you name it … many new physics scenarios affect flavor transitions … and many do not
- B measurements (e.g. $b \rightarrow s\gamma$) already constrain certain models
- New particles in loops can modify SM-predicted patterns
- Some indications already: wait for more data before queuing for Stockholm!

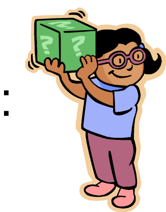


ϕK_S from SM

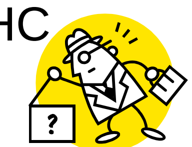


possible ϕK_S from NP

What's in the box?



- Indirect method (flavor studies): "rattle the box and listen"
- Direct (brute force) approach: LHC "open the box and look"



- Even after NP appears at LHC, indirect measurements may help decide "which NP?"

> Part of the fascination of flavor is precisely that the chiral and CKM and PMNS structure may thus originate from the GUT or string scale.

Edward Witten
Beauty 2003

INTRODUCTION

CKM matrix,

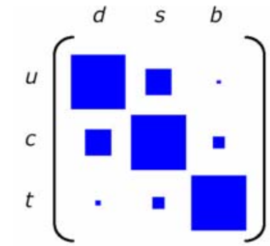
Unitarity Triangle,

Angles

The CKM matrix

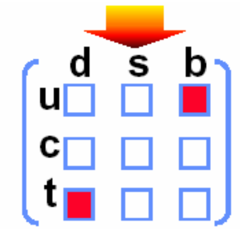
$$V_{CKM} = \begin{bmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{bmatrix}$$

3x3 unitary matrix:
3 real parameters,
1 phase: only source of CPV in SM



Relative magnitudes

usual phase convention: assign phase to smallest elements



Wolfenstein parametrisation
(motivated by experimentaly observed hierarchy):

$$A \approx 0.83, \quad \lambda \approx 0.22, \quad \rho, \eta: ??$$

$$V_{CKM} \approx \begin{bmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{bmatrix}$$

CP flips phase sign

phase convention:

- β: phase of V_{td}
- γ: phase of V_{ub}

measuring (β,γ) is equivalent to measuring (ρ,η)

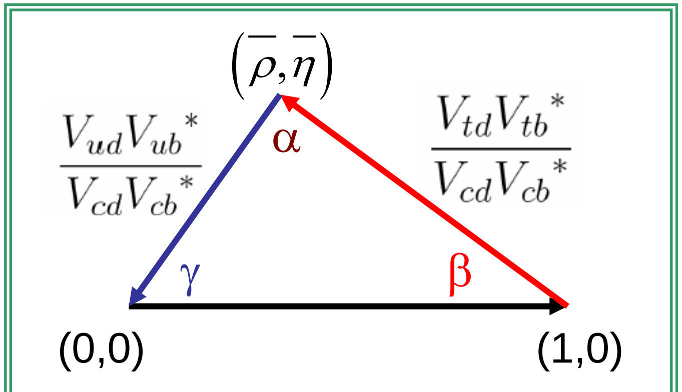
The Unitarity Triangle

$$V_{CKM} \approx \begin{bmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{bmatrix}$$

β : phase of V_{td}

γ : phase of V_{ub}

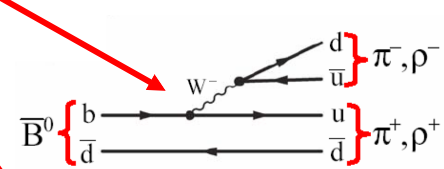
$a = \pi - \beta - \gamma$

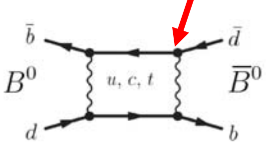


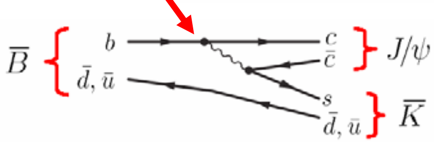
The rescaled UT

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

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







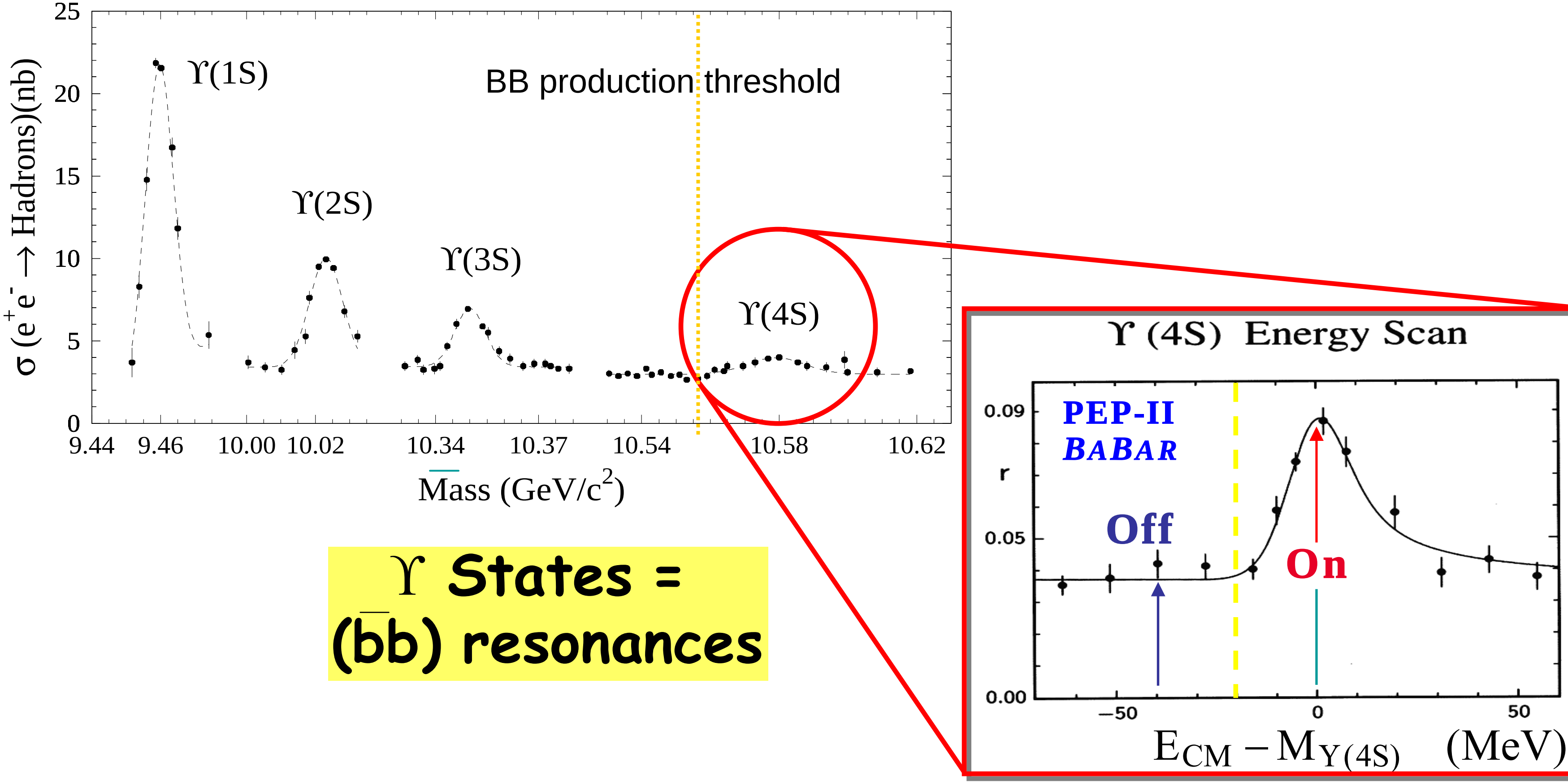
Measuring the angles through CP Violation:

- interference of mixing (β) and zero-weak-phase decay amplitude: β
- interference of mixing (β) and b→u decay amplitude (γ): α

Experimental method:
The B Factory

Production of large B Meson samples

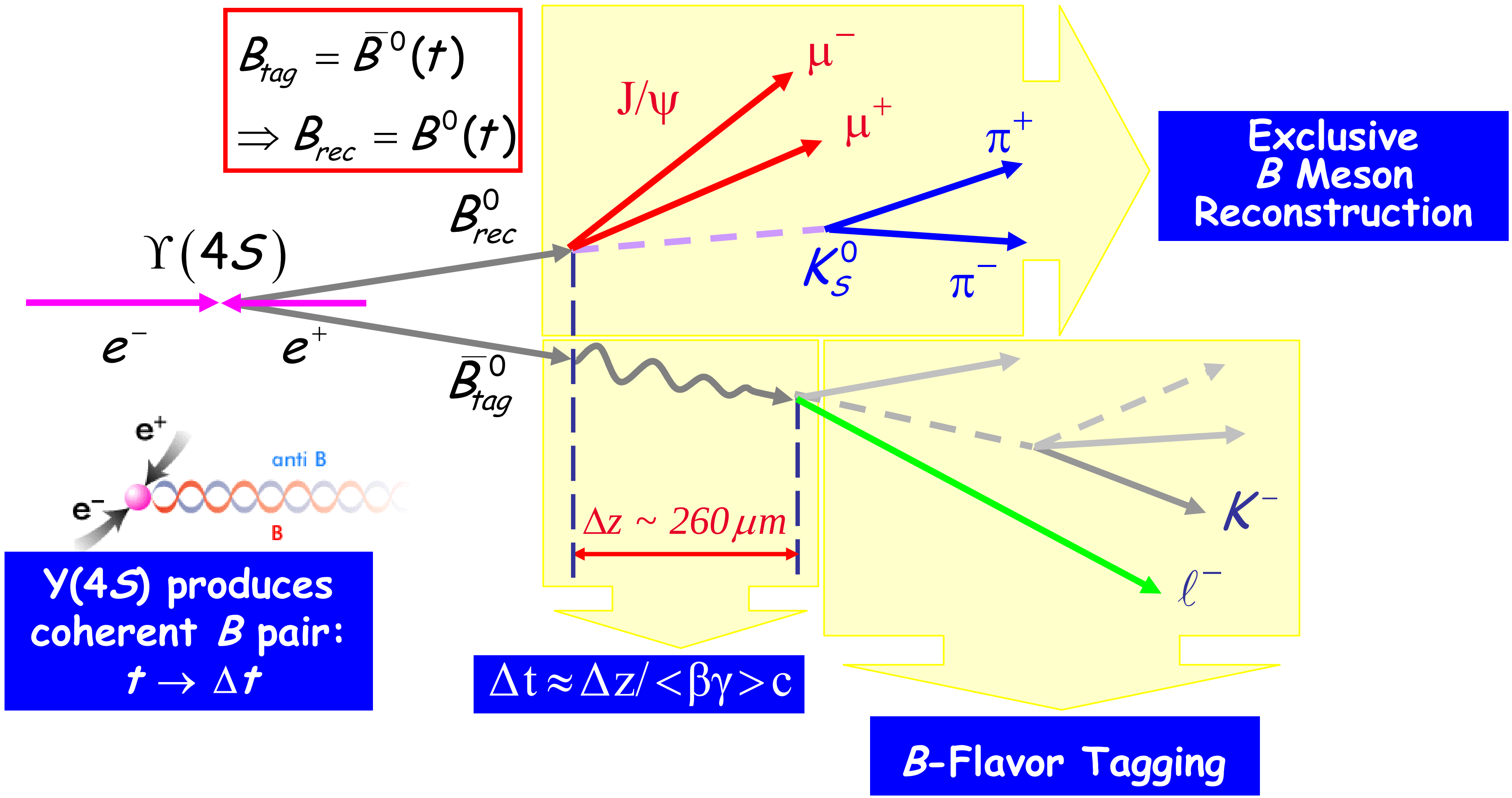
$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\bar{B}$



Υ States = $(b\bar{b})$ resonances

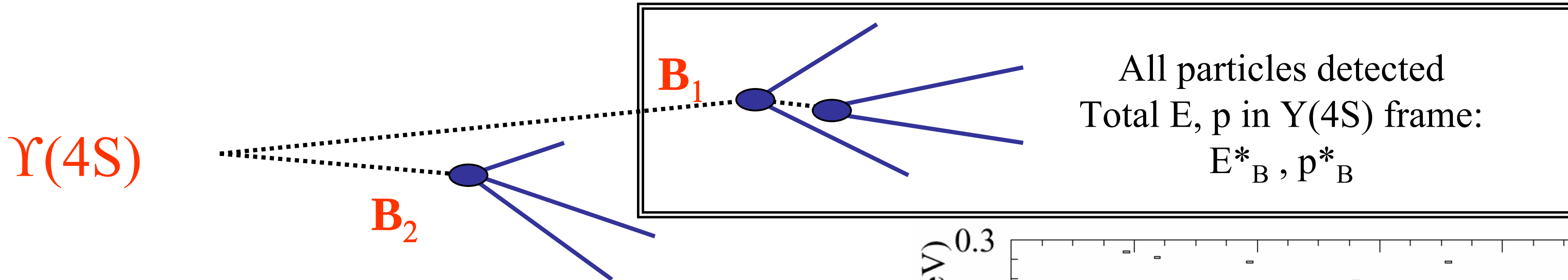
[1nb] DESIGN: $\mathcal{L} = 3\times10^{33}\,cm^{-2}s^{-1}$: 3×10^{7} $B\bar{B}$ pairs/year

Pier Oddone's Idea (1987): asymmetric energy beams



$B^0_{rec} = B^0_{CP}$ (CP eigenstates) ➡ time dependent CP analysis

Exclusive B reconstruction

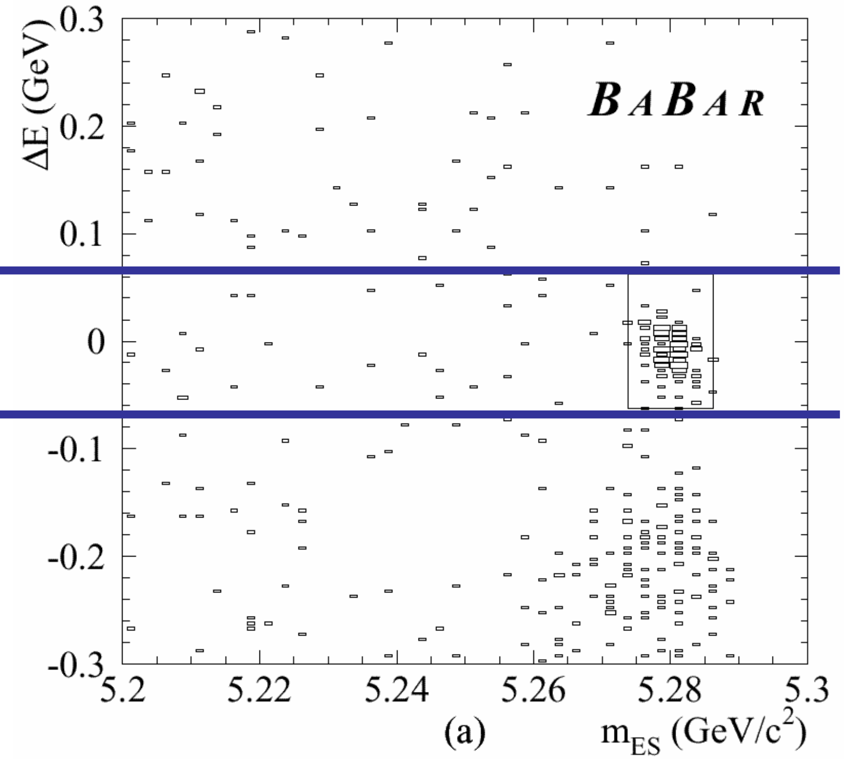


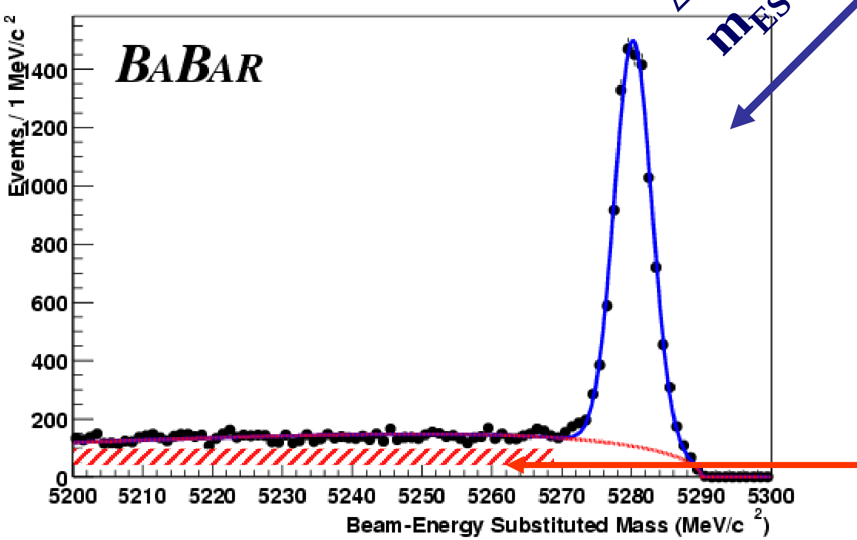
Kinematic variables:

$\Delta E = E^*_B - \sqrt{s}/2$

$m_{ES} = \sqrt{(s/4 - p^{*2}_B)}$

ΔE : $\sigma \sim 15$ MeV
m_{ES} : $\sigma \sim 3$MeV

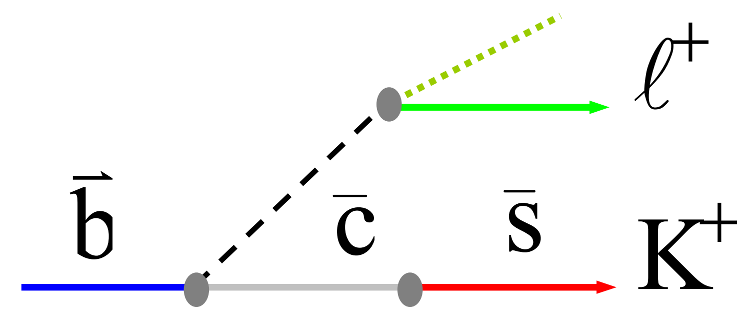




Extraction of background characteristics

B Flavor Tagging

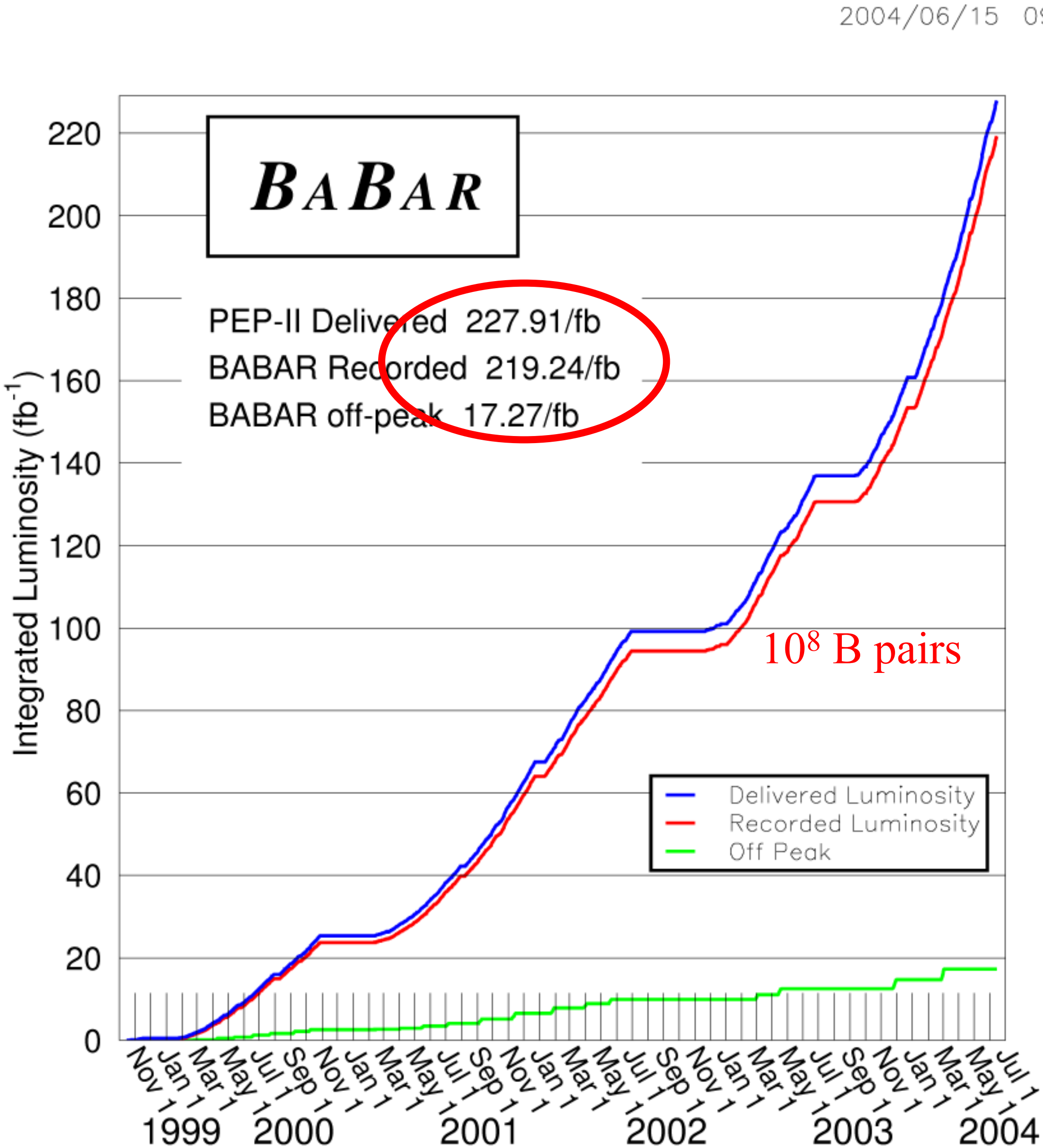
- Neural network:
  - Particle Identification
  - Kinematics



- Underlying physics processes
  - Primary lepton $B^0 \to D^{*-}\ell^+\nu$
  - Kaon(s) $B^0 \to \bar{D}X, \bar{D} \to K^+X$
  - Soft pions (D*) $B^0 \to D^{*-}X^+, D^{*-} \to \bar{D}^0\pi_s^-$
- 4 exclusive categories
  - "Lepton", "Kaon I" (more likely), "Kaon II" (less likely), "Inclusive"

Tagging category	Q = $\varepsilon\,(1-2w)^2$ (%)
Lepton	7.9 ± 0.3
Kaon I	10.7 ± 0.4
Kaon II	6.7 ± 0.4
Inclusive	0.9 ± 0.2
ALL	28.1 ± 0.7

SLAC B factory performance



- PEP-II top lumi: $9.2 \times 10^{33} cm^{-2} s^{-1}$ (design 3.0×10^{33})
- Top recorded 24h L: 700/pb (design 135)

Measurement of UT angles through Time Dependent CP violation analyses:

sin(2β)

Time dependent CP asymmetries

$$A_{CP}(f;t) = \frac{N\left(\overline{B}^0(t) \to f\right) - N\left(B^0(t) \to f\right)}{N\left(\overline{B}^0(t) \to f\right) + N\left(B^0(t) \to f\right)}$$

Need to know initial flavor (at t=0) of B (flavor tagging).

$$A_{CP}(f;t) = \underbrace{\frac{2\,\mathrm{Im}\lambda_f}{1+|\lambda_f|^2}}_{S} \sin \Delta m_d t - \underbrace{\frac{1-|\lambda_f|^2}{1+|\lambda_f|^2}}_{C} \cos \Delta m_d t$$

Fit flavor-tagged time distributions for S and C.

$$\lambda_f = \frac{q}{p}\frac{A(\overline{B}^0 \to f)}{A(B^0 \to f)} = e^{-i2\beta}\frac{\overline{A}_f}{A_f}$$

Phase convention *independent* complex number.

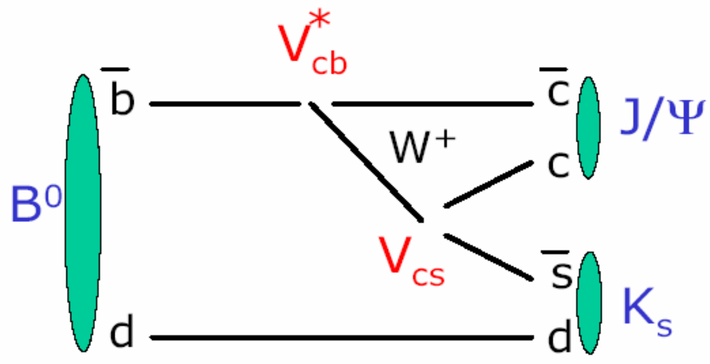
$$|B_\pm\rangle = q|B^0\rangle \pm p|\overline{B}^0\rangle$$

sin2β golden modes: $b \to c\bar{c}s$

- CP eigenstate with only one decay amplitude.

$$\overline{A}_{J/\psi K_s} = -1\, A_{J/\psi K_s}$$

$$\lambda_{J/\psi K_s} = e^{-i2\beta} \frac{\overline{A}_{J/\psi K_s}}{A_{J/\psi K_s}} = -1\, e^{-i2\beta}$$

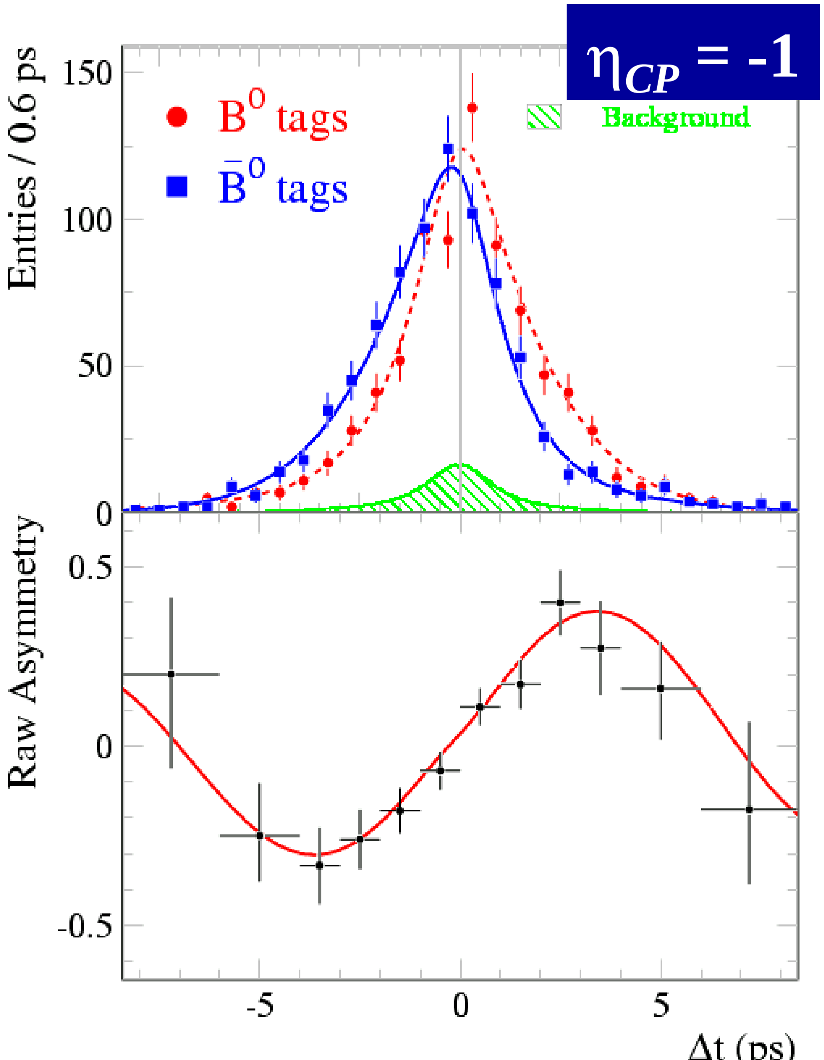


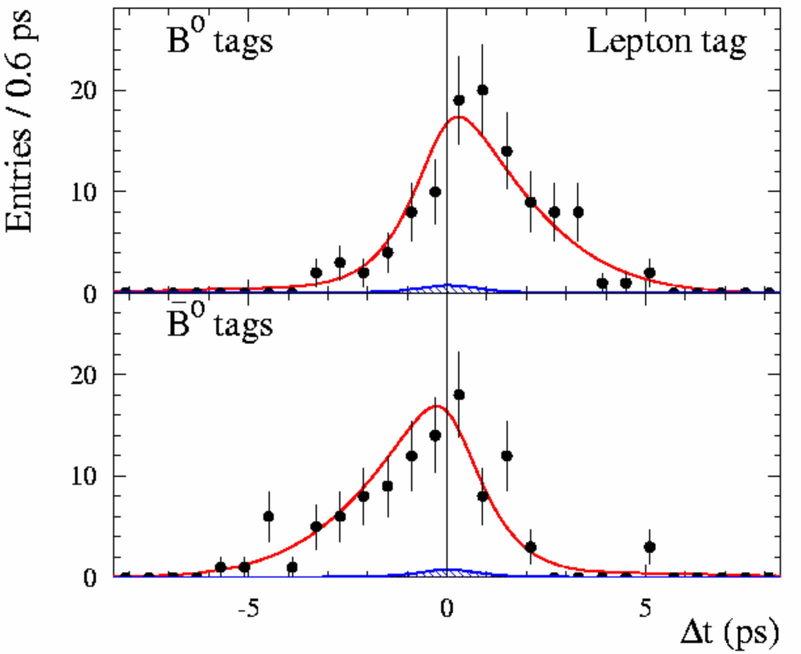
- Time dependence directly measures sin2β

$$A_{CP}(f;t) = \frac{2\,\mathrm{Im}\lambda_f}{1+|\lambda_f|^2} \sin\Delta m_d t - \frac{1-|\lambda_f|^2}{1+|\lambda_f|^2} \cos\Delta m_d t$$

$$A_{CP}(J/\psi K_s;t) = \sin 2\beta \, \sin\Delta m_d t$$

BABAR Result for sin2β



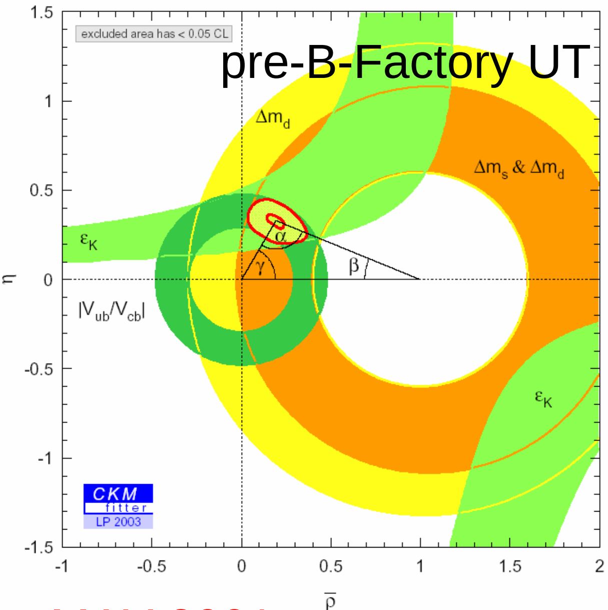


Lepton tags only

98% purity
3.3% mistag rate
20% better Δt resolution

$$\sin 2\beta = 0.741 \pm 0.067_{(stat)} \pm 0.033_{(syst)}$$

88M BB pairs, PRL 89, 201802 (2002)



MAY 2001

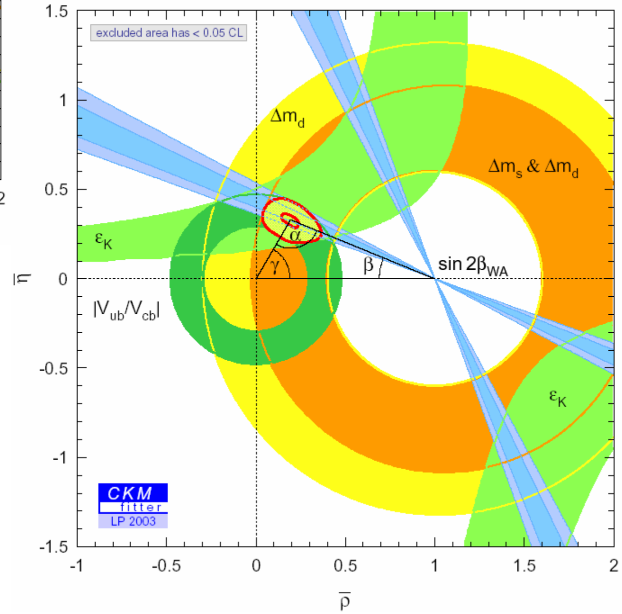
$$\sin 2\beta_{\text{indirect}} = 0.715 \pm 0.055$$

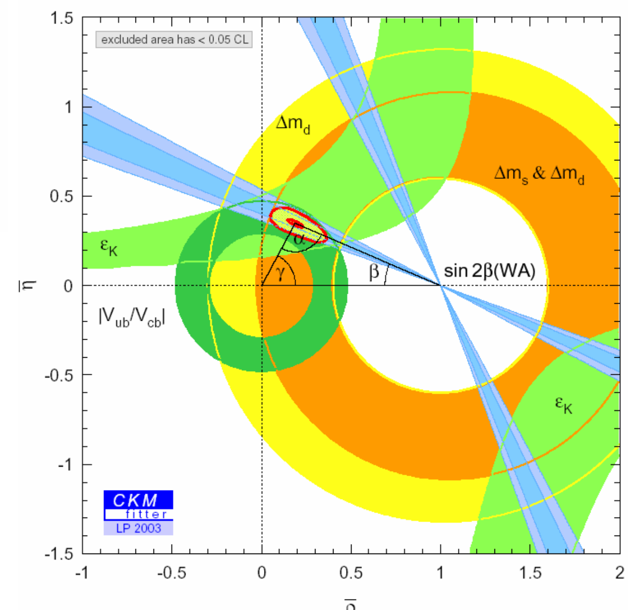
Direct measurements (overlayed)

World average (*BABAR*+Belle+...)

$$\sin 2\beta \;=\; 0.739 \pm 0.048$$

Heavy **F**lavor **A**veraging **G**roup LP 2003

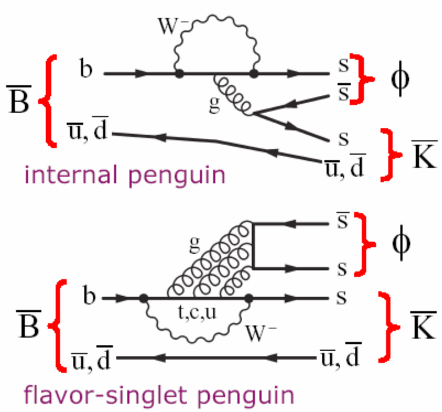




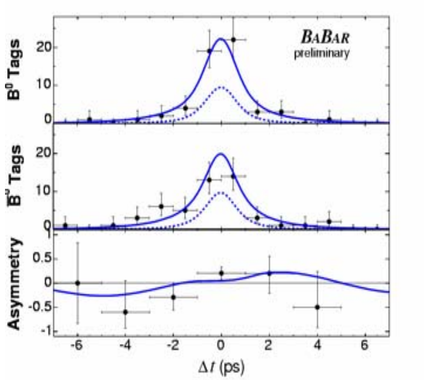
AUGUST 2003

The hunt for New Physics

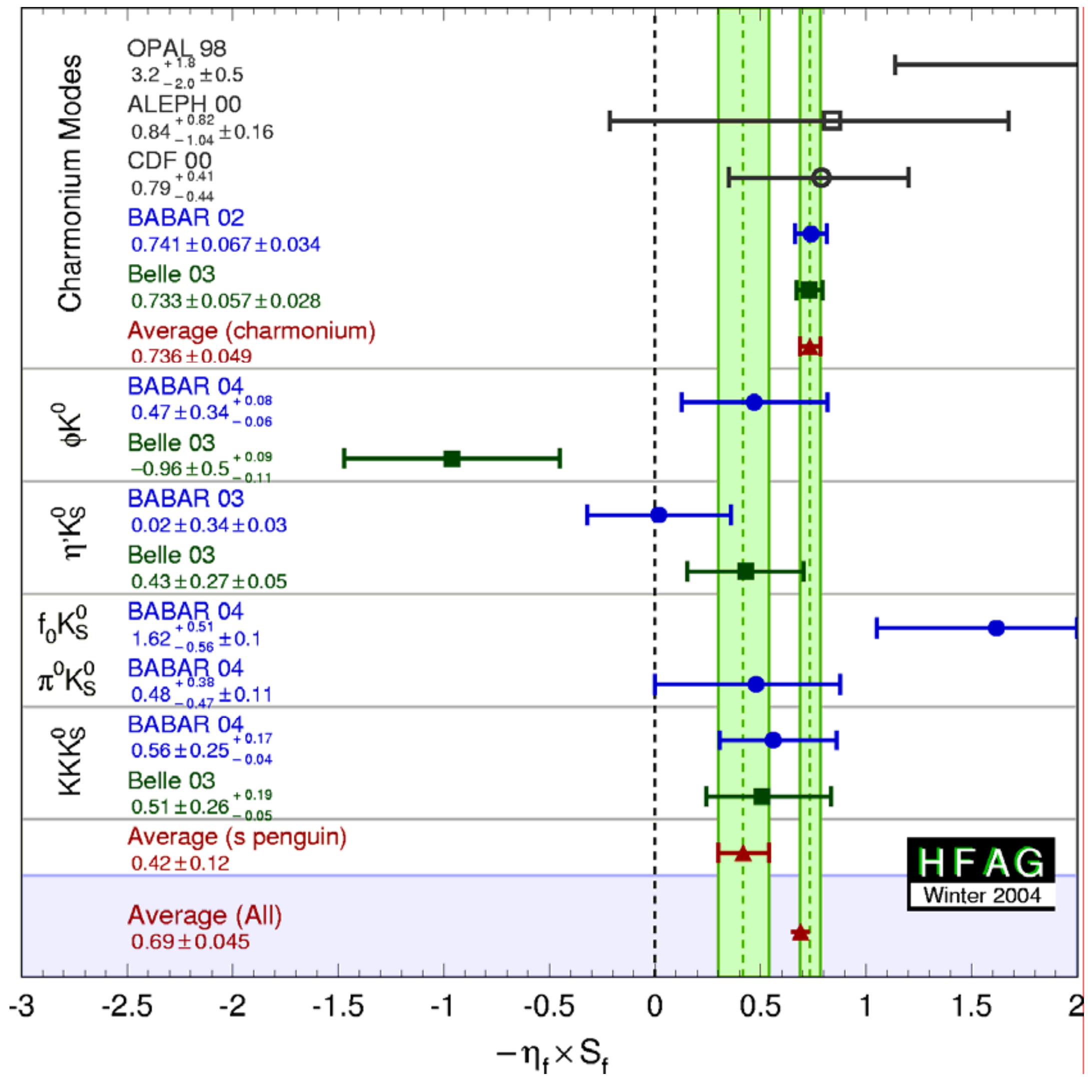
$$b \rightarrow s\,\bar{s}\,s$$



SM: pure penguin ⇒ measures sin(2β)



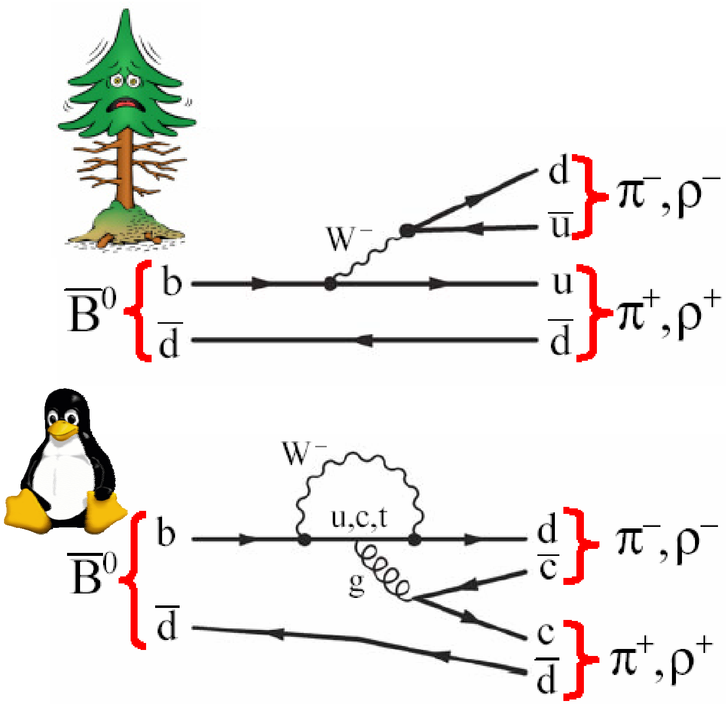
- Many penguin-dominated modes can help!
- Small BFs! Already some hints?



Next UT angle measurement:

$\sin(2\alpha)$

$u\bar{u}d$, α, trees, penguins



- interference of tree and mixing: α
- shift from penguins: α_{eff}

$$f_{B^0(\bar{B}^0)}(\Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau}(1 \pm S\sin(\Delta m \Delta t) \mp C\cos(\Delta m \Delta t))$$

$$S = \sqrt{1-C^2}\sin(2\alpha_{eff})$$

$$\Delta a = \left| a - a_{eff} \right|$$

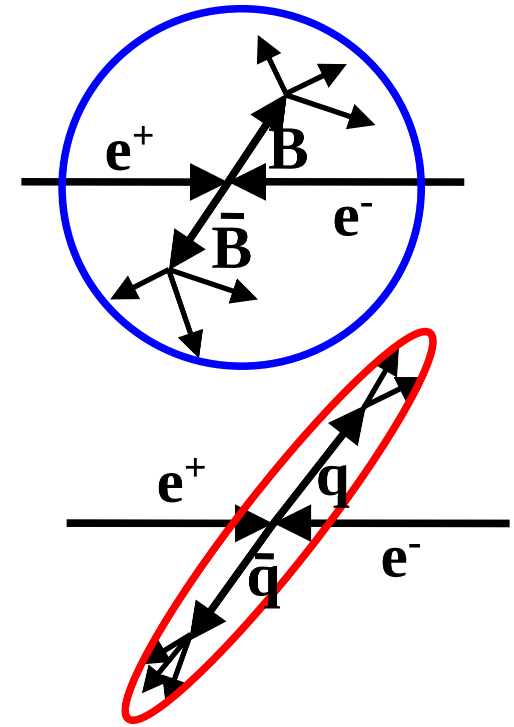
- choice of final states: ππ, ρπ, ρρ, $\alpha_1\pi$
- challenge: measure or limit Δα

Experimental issues

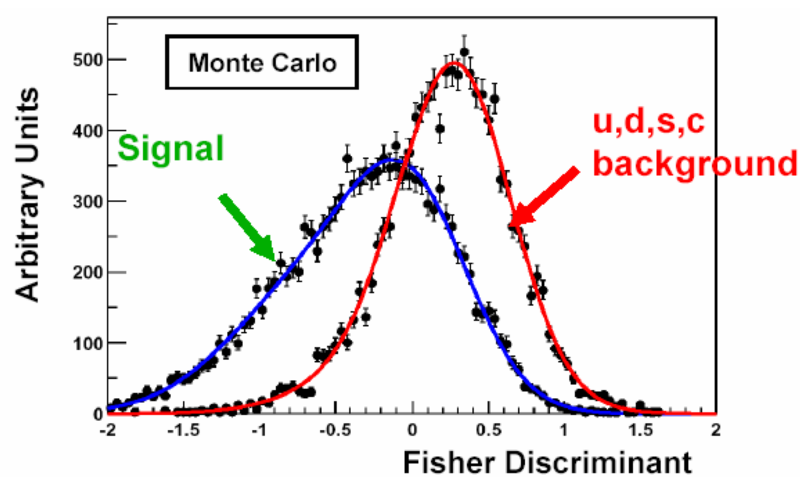
- BFs ~ 10^{-6} to few 10^{-5}
- Huge background from light quark continuum events
- Complex maximum likelihood analyses to isolate signal
- Even more complex fits including time dependence

Continuum suppression:

- spherical B events vs jet-like continuum
- several techniques exploiting event topology or angular distribution
- selection cuts on:
  - Fox-Wolfram moments
  - sphericity, cos θ_S
  - B direction (cos θ_B)
- NN or Fisher:
  - included in the maximum likelihood fit



angle between the sphericity axis of the B and the sphericity axis of the rest of the event



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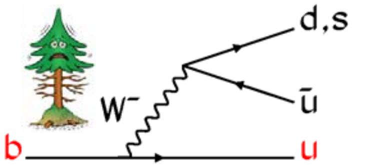
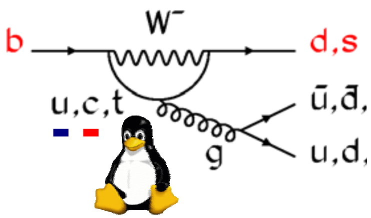
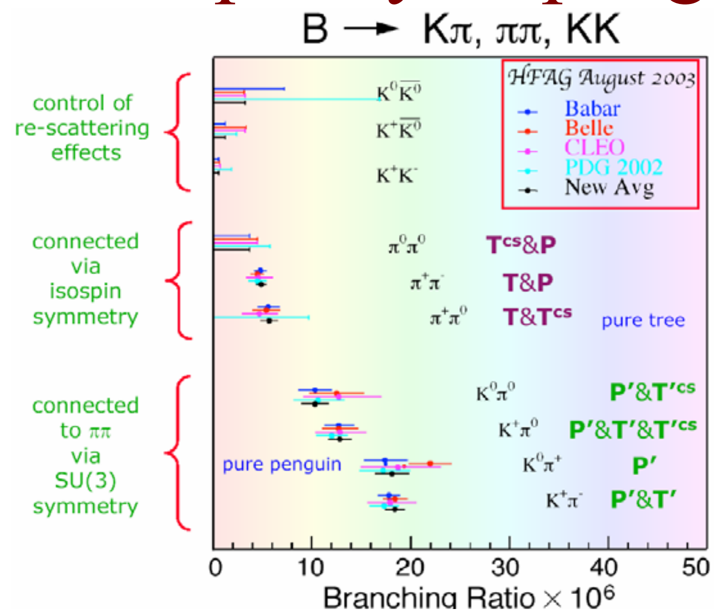
Looking for trees, found plenty of penguins!







Without penguins, expect:

$$\frac{\mathrm{Br}(B \to K\pi)}{\mathrm{Br}(B \to \pi\pi)} \approx \left|\frac{V_{us}}{V_{ud}}\right|^2 \sim 5\%$$

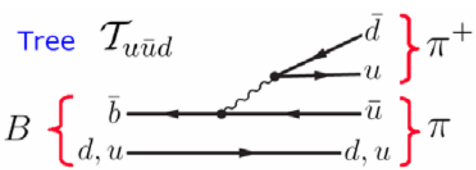
Measurements show:

$$\frac{\mathrm{Br}(B \to K\pi)}{\mathrm{Br}(B \to \pi\pi)} \sim 4 \quad !!$$

penguins cannot be neglected

Use Kπ & SU(3) to estimate penguin pollution in ππ

Tree $\mathcal{T}_{u\bar{u}d}$

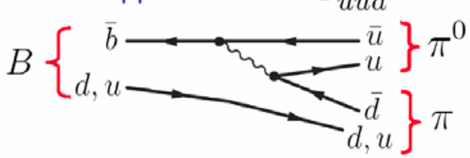


$V_{ud}V_{ub}^*$

contributes to
$B^0 \to \pi^+\pi^-$
$B^+ \to \pi^+\pi^0$

$T(\lambda^3)$

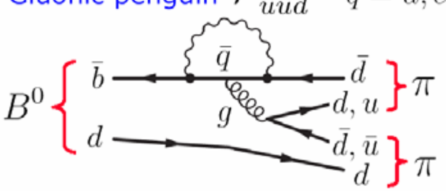
Color-suppressed tree $\mathcal{T}^{CS}_{u\bar{u}d}$



$V_{ud}V_{ub}^*$

contributes to
$B^0 \to \pi^0\pi^0$
$B^+ \to \pi^+\pi^0$

Gluonic penguin $\mathcal{P}^q_{u\bar{u}d}$ $q = u, c, t$

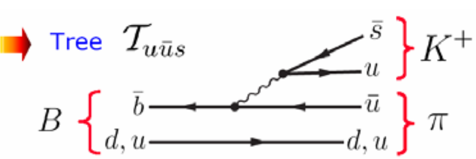


contributes to
$B^0 \to \pi^0\pi^0$
$B^0 \to \pi^+\pi^-$

$V_{qd}V_{qb}^*$

$P_c(\lambda^3)$ $P_u(\lambda^3)$

Tree $\mathcal{T}_{u\bar{u}s}$

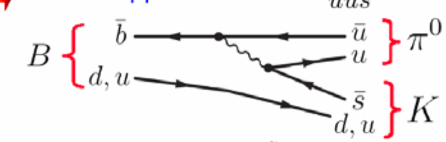


$V_{us}V_{ub}^*$

contributes to
$B^0 \to K^+\pi^-$
$B^+ \to K^+\pi^0$

$T(\lambda^4)$

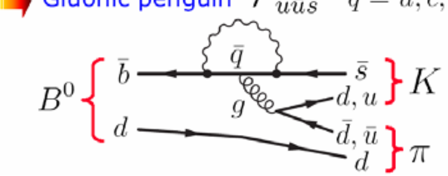
Color-suppressed tree $\mathcal{T}^{CS}_{u\bar{u}s}$



$V_{us}V_{ub}^*$

contributes to
$B^0 \to K^0\pi^0$
$B^+ \to K^+\pi^0$

Gluonic penguin $\mathcal{P}^q_{u\bar{u}s}$ $q = u, c, t$



$V_{qs}V_{qb}^*$

contributes to
$B^0 \to K^+\pi^-$
$B^0 \to K^0\pi^0$
$B^+ \to K^+\pi^0$
$B^+ \to K^0\pi^+$

$P_c(\lambda^2)$

Taming the Penguins: Isospin Analysis

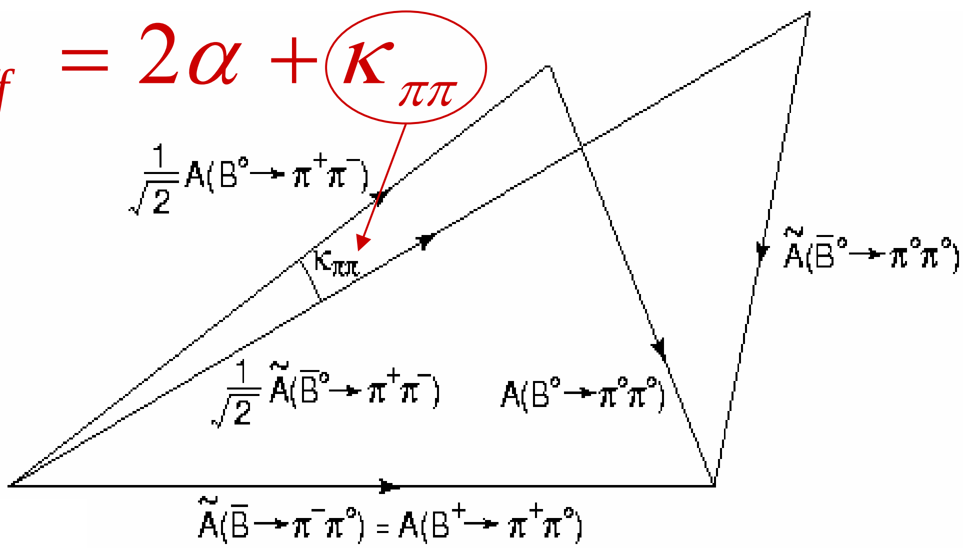
Gronau and London, Phys. Rev. Lett. 65, 3381 (1991)

- The decays $B \to \pi^+\pi^-$, $\pi^+\pi^0$, $\pi^0\pi^0$ are related by isospin
- Central observation is that $\pi\pi$ states can have I = 2 or 0
  - (gluonic) penguins only contribute to I = 0 ($\Delta I = 1/2$)
  - $\pi^+\pi^0$ is pure I = 2 ($\Delta I = 1/2$) so has only tree amplitude

  $\to (|A^{+0}| = |A^{-0}|)$
- Triangle relations allow determination of penguin-induced shift in α

Need branching fractions for all three decay modes, and for B^0 and $\overline{B}^0$ separately

$$2\alpha_{eff} = 2\alpha + \kappa_{\pi\pi}$$



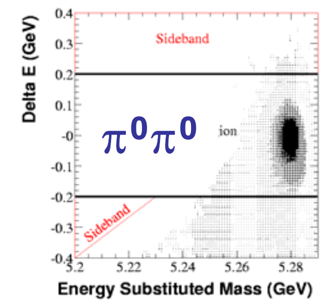
Grossmann-Quinn bound (useful only if $BF(\pi^0\pi^0)$ really small

$$\cos(2\alpha - 2\alpha_{eff}) \geq \frac{1 - 2B^{00}/B^{+0}}{\sqrt{1 - C_{\pi\pi}^2}}$$

Looking for $\pi^0\pi^0$

- *Very small* branching fraction: a few x 10^{-6}
- Primary background from *continuum* events.
  - Combine a π^0 from each quark jet.
  - Fight continuum with
    - event shape information
    - neural network with rest of event as input (leptons, kaons).

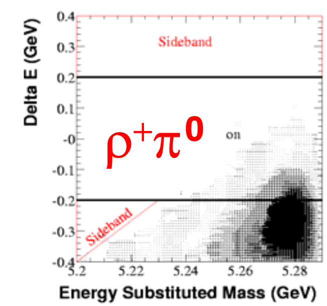
$$e^+e^- \to q\bar{q} \ (q = u, d, c, s)$$



- $B^+ \to \rho^+\pi^0$,($\rho^+ \to \pi^+\pi^0$) also a background
  - Some overlap if π^+ at rest in B frame
  - We measured the branching fraction

Babar hep-ex/0307087

$$\mathcal{B}(\rho^+\pi^0) = (11.0 \pm 1.9 \pm 1.9) \times 10^{-6}$$

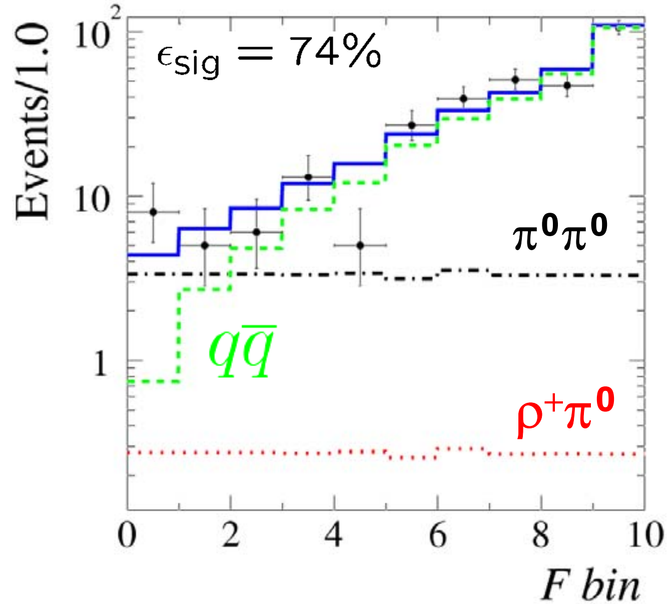


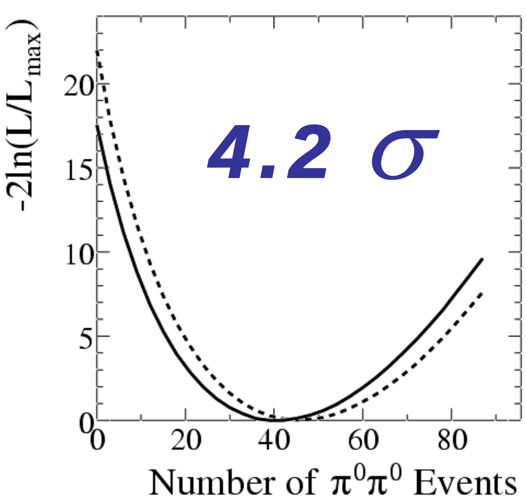
Looking for $\pi^0\pi^0$ – we found it!

$$N_{\text{sig}} = 46 \pm 13 \pm 3$$
$$\mathcal{B}(\pi^0\pi^0) = (2.1 \pm 0.6 \pm 0.3) \times 10^{-6}$$

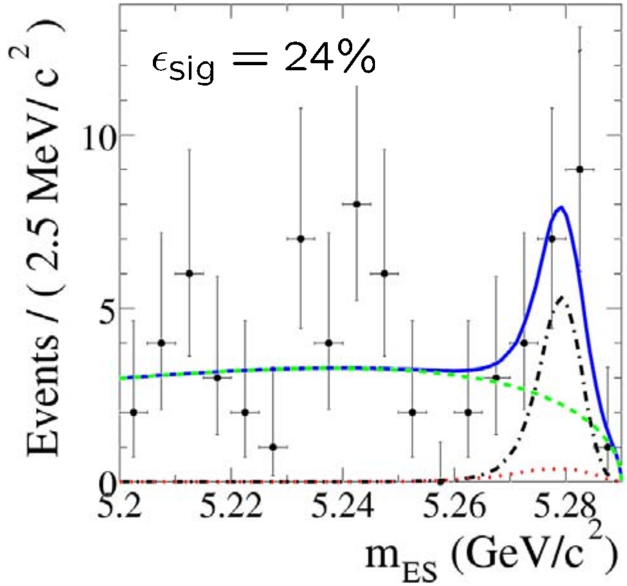
hep-ex/0308012

Plots are after cut on signal probability ratio not including variable shown, optimized with $S/\sqrt{S+B}$

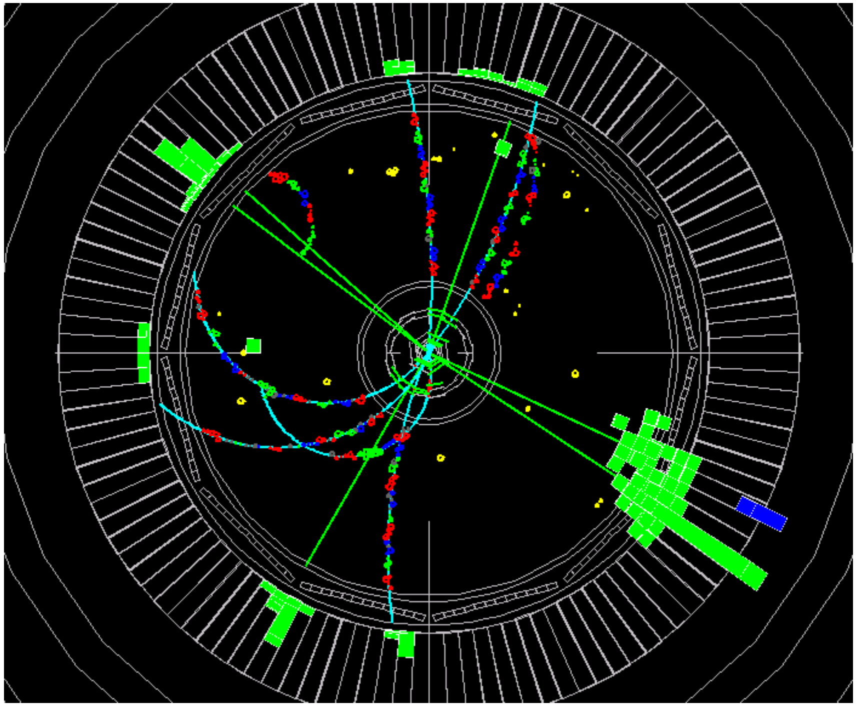


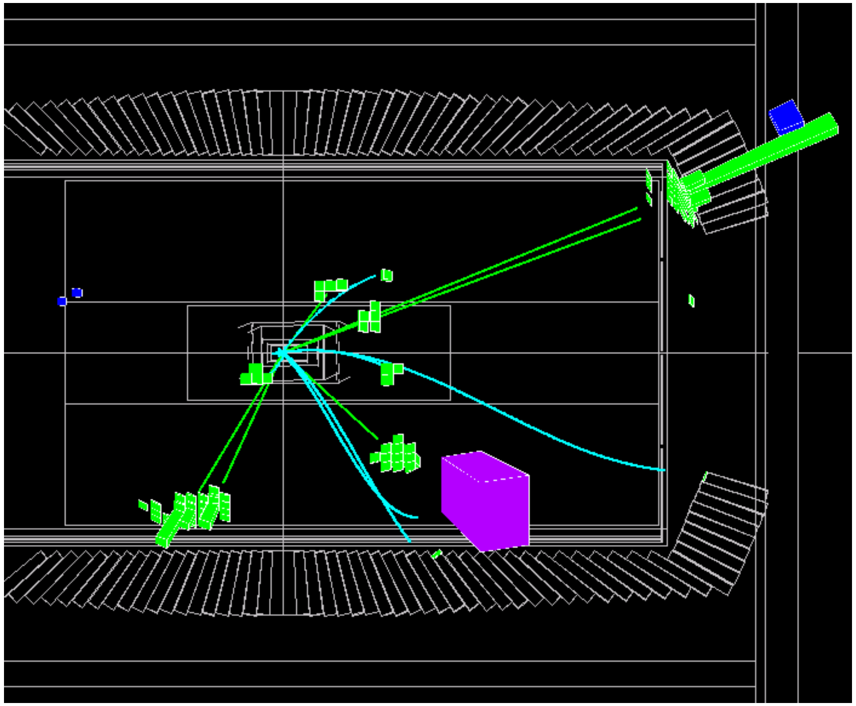


Belle also sees it.
hep-ex/0308040
$(1.7 \pm 0.6 \pm 0.2) \times 10^{-6}$
(3.4 σ)



A real $B^0 \to \pi^0 \pi^0$ candidate event



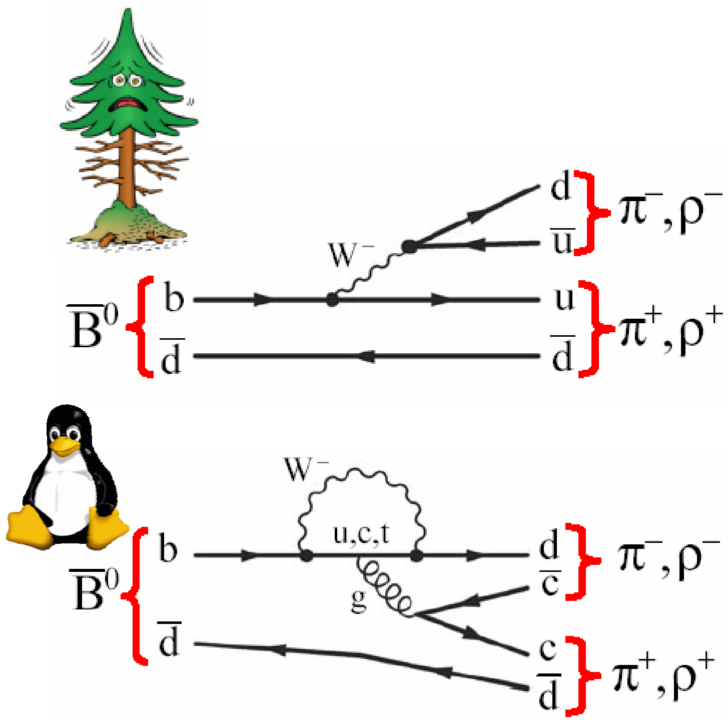


End of the road for 2-pion system for α?

- Grossmann-Quinn bound: $|\alpha - \alpha_{eff}| < 48^\circ \quad (90\%CL)$
- We have to measure separately BF of $\bar{B}(B^0) \rightarrow \pi^0\pi^0$
- With an average BF~$2x10^{-6}$ there is not enough statistics this side of a Super-B factory (10/ab)
- Hadronic experiments (LHCb, BTEV) cannot measure $\pi^0\pi^0$.

□ α: and now what ??

angle α, *THE METHOD*: $\rho\rho$



- Same idea as $\pi\pi$, $\rho\pi$
- Less amplitudes than $\rho\pi$
- Two vectors in final state
- Large ρ width
- Slow pions (charged, neutral)

The complications in a VV final state

- three partial waves:
  - S (L=0, CP even)
  - P (L=1, CP odd)
  - D (L=2, CP even)

OR

- three helicity amplitudes:

$$A_0 = -\frac{1}{\sqrt{3}} S + \sqrt{\frac{2}{3}} D \quad (\lambda = 0\ ,\ CP-even)$$

Longitudinal polarization

$$A_{+1} = -\frac{1}{\sqrt{3}} S + \frac{1}{\sqrt{6}} D + \frac{1}{\sqrt{2}} P \quad (\lambda = +1\ ,\ CP-mixed)$$

$$A_{-1} = -\frac{1}{\sqrt{3}} S + \frac{1}{\sqrt{6}} D - \frac{1}{\sqrt{2}} P \quad (\lambda = -1\ ,\ CP-mixed)$$

Transverse polarization

THE UNIVERSITY of LIVERPOOL

Extracting CP in a VV state

- three transversity amplitudes:

$$A_0 = -\frac{1}{\sqrt{3}}S + \sqrt{\frac{2}{3}}D \quad (CP-even\ longitudinal)$$

$$A_\parallel = \sqrt{\frac{2}{3}}S + \frac{1}{3}D \quad (CP-even\ transverse)$$

$$A_\perp = P \quad (CP-odd\ transverse)$$

- measure $R_\perp$ and use as dilution ($J/\psi K^*$ in $\sin 2\beta$)

  OR

- combined Angular and Time Dependent analysis

Longitudinal polarization dominance in $\rho\rho$

- predicted in some factorization approaches
  - G.Kramer, W.F.Palmer, PRD 45, 193 (1992)
  - R.Aleksan *et al.*, PLB 356, 95 (1995)

- simplifies the measurement of α_{eff}

- allows to limit penguin pollution using Grossman-Quinn bound on longitudinal amplitudes

- Experimental measurements:
  - $\rho^+\rho^0$ $f_L = (97 \pm 3(7) \pm 4)\%$ (BABAR)
  - $\rho^+\rho^0$ $f_L = (95 \pm 11 \pm 2)\%$ (BELLE)
  - $\rho^+\rho^-$ $f_L = (99 \pm 3 \pm 3)\%$ (BABAR)

Babar hep-ex/0307026

Belle hep-ex/0306007

Small penguin pollution in ρρ

- predicted much smaller than in ππ system
  - R.Aleksan *et al.*, PLB 356, 95 (1995)
- minimizes $\Delta\alpha = |\alpha - \alpha_{eff}|$
- Experimental measurements:
  - $\rho^+\rho^0$ BF = (22.5 ± 5.6 ± 5.8)10^{-6} (BABAR)
  - $\rho^+\rho^0$ BF = (31.7 ± 7.1 ± 6.0) 10^{-6} (BELLE)
  - $\rho^0\rho^0$ BF < 2.1x10^{-6} (90% UL, BABAR)

  (26.4 ± 6.4)10^{-6} [HFAG]
- Grossman-Quinn bound (assuming all fully long.):

$$\sin^2(\alpha_{eff}^{\rho\rho} - \alpha)_L \le \frac{Br\left(B^0 \to \rho^0\rho^0\right)_L}{Br\left(B^+ \to \rho^+\rho^0\right)_L}$$

$$\left|\alpha_{eff} - \alpha\right| \le 17.0° \quad (90\%\ CL)$$

$$\left|\alpha_{eff} - \alpha\right| \le 12.9° \quad (68\%\ CL)$$

ρρ: the α "golden" channel

- good rate and efficiency: ~3events/fb^{-1}
- minimum penguin pollution: $\alpha = \alpha_{eff} \pm 13^{o}$ [82/fb]
- ~100% longitudinal polarization
- 2 tracks for vertex (Time Dependent measurement)
- same statistical precision on S and C as for ππ (from the same data sample)

Analysis Strategy

Simultaneous TD fit: signal yield, polarization, C_{long} and S_{long}.

Maximum Likelihood fit: True-signal, Self-cross-feed signal (42% long., 15% trans.), Continuum and 17 B-background modes.

B-background: 209 decay modes simulated. Dominant modes:

$$B \to charm \ , \quad B \to a_1 \rho, \ B \to a_1 \pi \, ,$$

$$B^+ \to \rho^+ \pi^0, \quad B^+ \to \rho^+ \rho^0$$

Simple assumptions (checking for summer update):

§ Neglect interference with other $\pi^+\pi^-\pi^0\pi^0$ final states (includes non-resonant contributions).

§ I=1 decay amplitudes also neglected. I=1 absent due to Bose statistics but reintroduced by the finite Γ_{ρ}.
(Falk, Ligeti, Nir, Quinn, Phys. Rev. D69:011502,2004)

B→ρρ Signal Selection

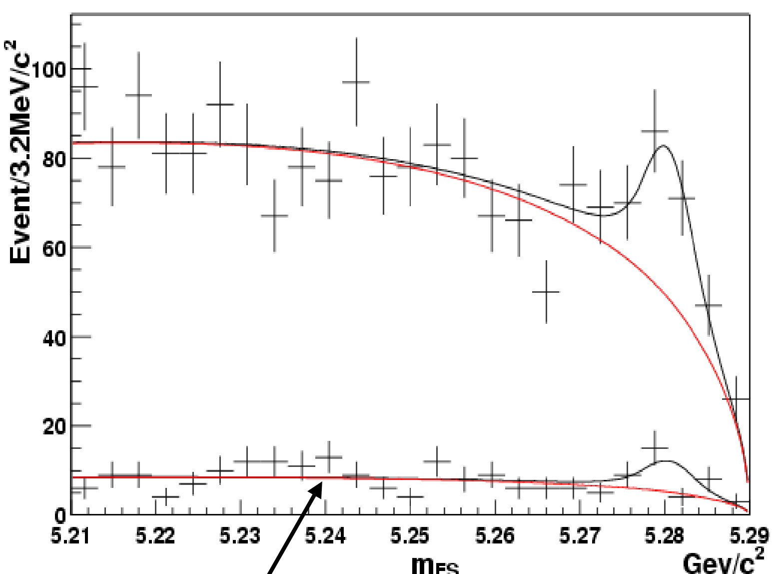
B-decay: isotropic
Continuum $q\bar{q}$: jet-like

} Combine event shape variables into a Neural Network.

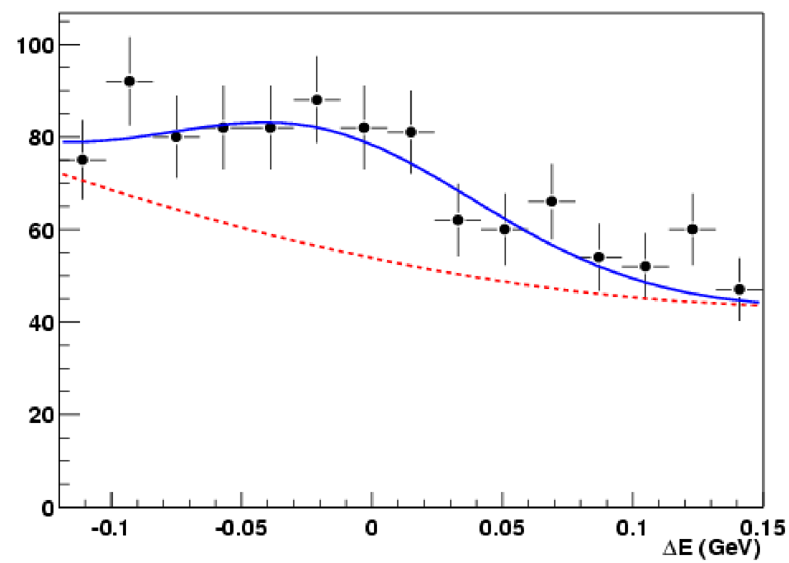
Use ρ-mass and ρ-decay angle (helicity)

B-mass: $m_{ES} = \sqrt{E^{*2}_{\text{beam}} - p^{*2}_{B}}$

Missing energy: $\Delta E = E^{*}_{B} - E^{*}_{\text{beam}}$



Events with clean tags.



Full likelihood
Background
Data

Results:

Babar result from 81fb^{-1} of data (taken between 1999-2001)

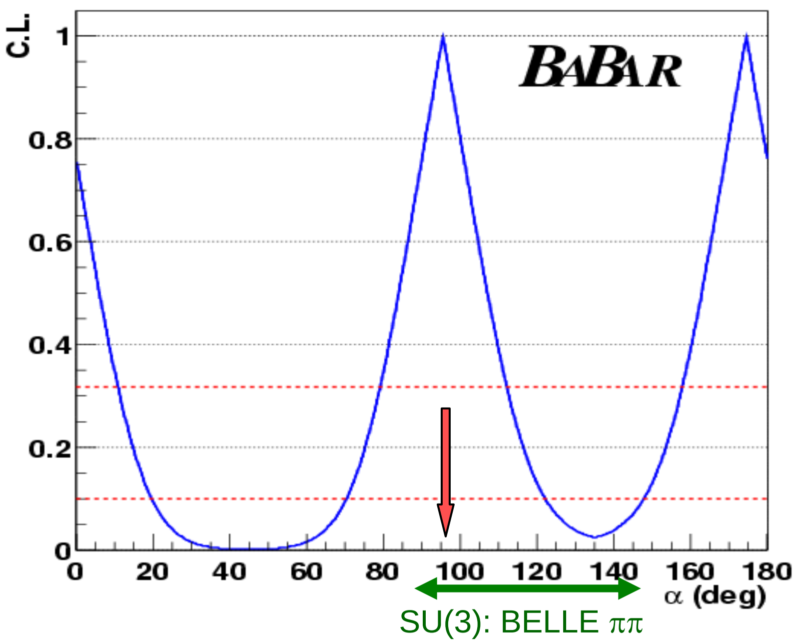
$$S_{long} = -0.42 \pm 0.42(stat) \pm 0.14(syst)$$
$$C_{long} = -0.17 \pm 0.27(stat) \pm 0.14(syst)$$

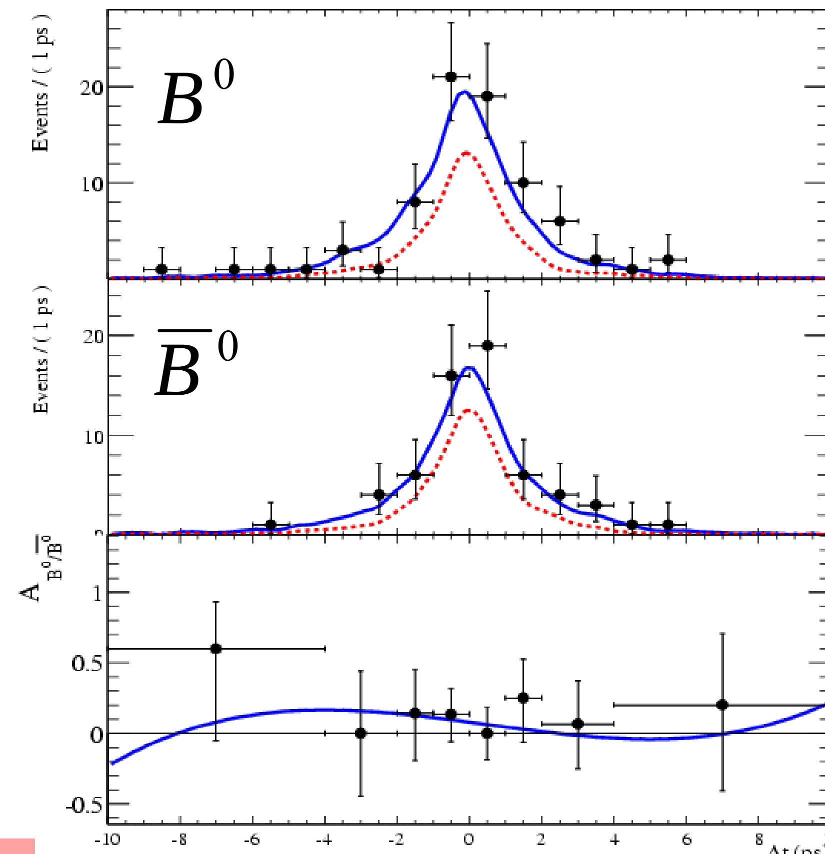
Submitted to PRL

hep-ex/0404029

Preliminary Babar (113fb^{-1}, Moriond EW):

$$S_{long} = -0.19 \pm 0.33(stat) \pm 0.11(syst)$$
$$C_{long} = -0.23 \pm 0.24(stat) \pm 0.14(syst)$$

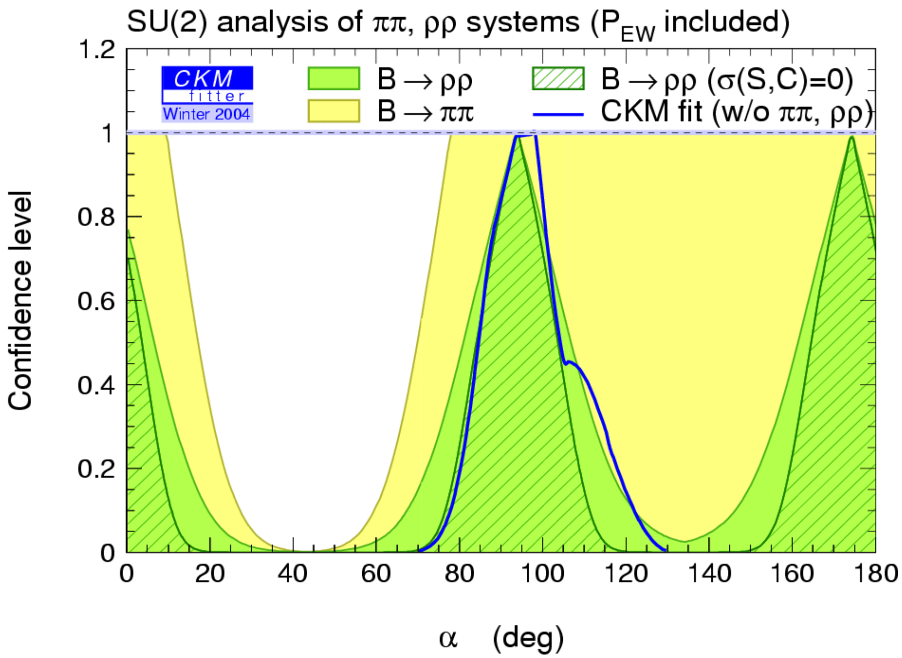


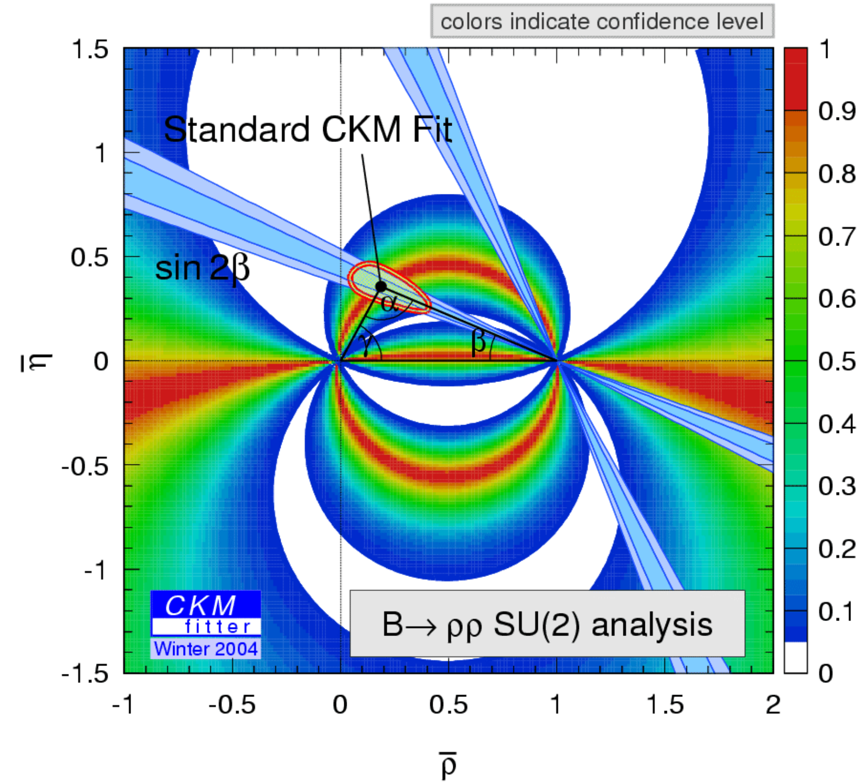


$$\alpha = 96^\circ \pm 10^\circ_{stat} \pm 4^\circ_{syst} \pm 13^\circ_{penguin}$$

Global CKM Fits

More plots at: *http://ckmfitter.in2p3.fr*





Includes the Belle B→ππ result.
Can't exclude a large α region with ππ.

The B→ρρ system provides the most stringent constraint on α!

Other B→ρρ used in the SU(2) analysis.

$$BR(B^+ \to \rho^+\rho^0) = 26.4^{+6.1}_{-6.4}$$

$$f_L(B^+ \to \rho^+\rho^0) = 0.96^{+0.05}_{-0.07}$$

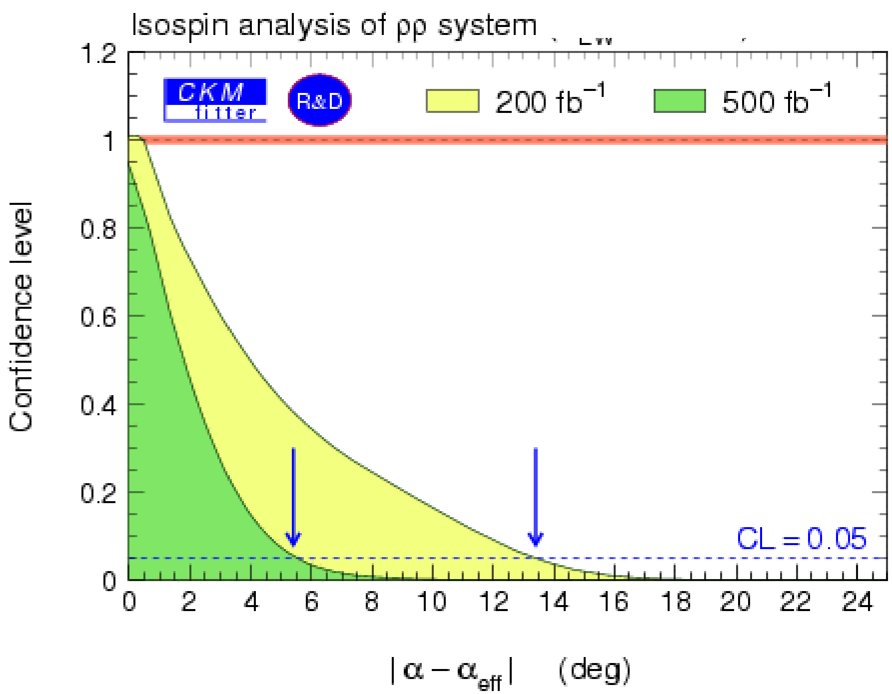
Includes Belle

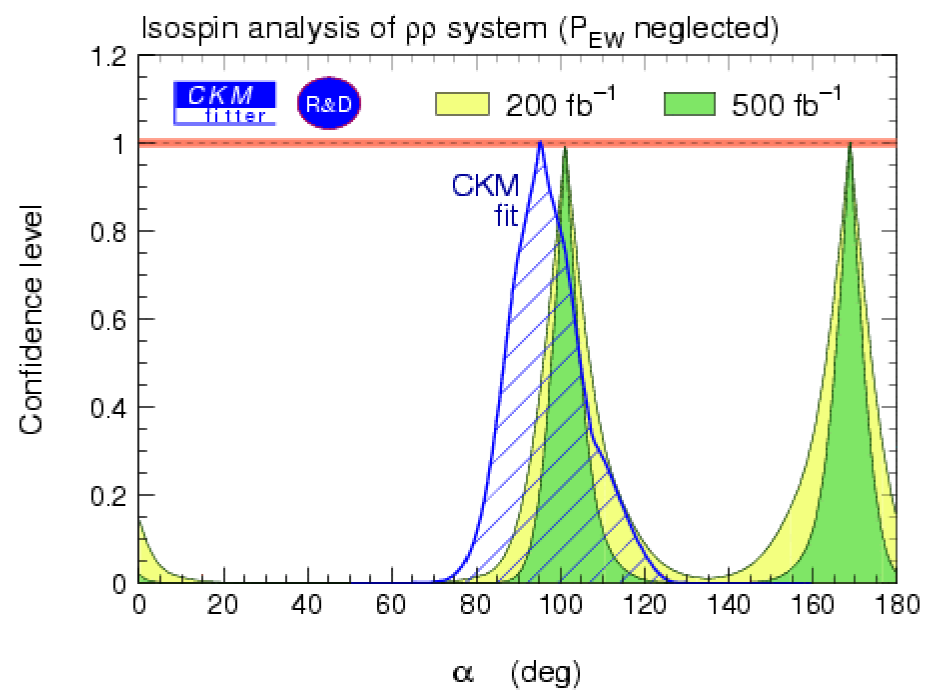
$$BR(B^0 \to \rho^0\rho^0) = 0.6^{+0.8}_{-0.6}$$

$$f_L(B^+ \to \rho^+\rho^0) = 1.0 \text{ (assumed)}$$

Outlook for $\Delta\alpha$: Isospin analysis

Assuming current central values





Already at 200/fb:

assuming BF($\rho^0\rho^0$) is 0.6×10^{-6} :

$\sigma_\alpha(\alpha=90^0) < 10^0$

(plus fourfold ambiguity)

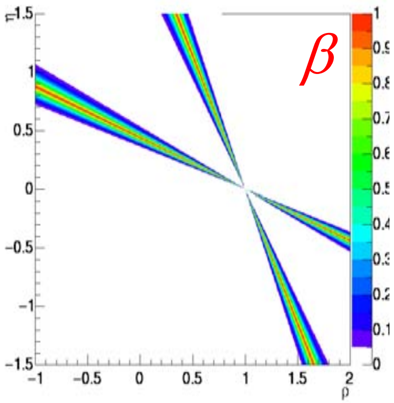
Summary

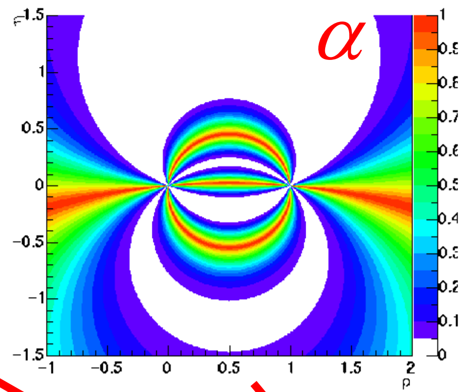
- Great ongoing progress in measuring UT angles in B factories

- Large penguins don't allow measurement of α from $\pi\pi$ decays
- First α measurement from $\rho\rho$
- Can measure α to ~5^0 in BABAR

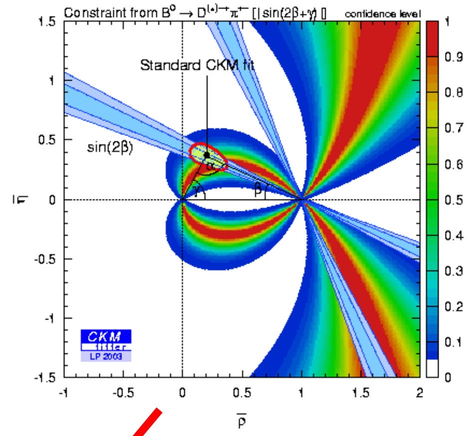
- PEP-II and BABAR outlook:
- Data taking 9-10 months per year to 2009.
- Aggressive hardware upgrade to PEP-II to get to a luminosity of 2 to 3 x 10^{34} by FY2006-2007.
- **Aiming at total of 500 fb^{-1} by 2006.**

Knowledge of η,ρ from direct measurements





$\sin(2\beta+\gamma)$



Constraints from:

$b \rightarrow c\bar{c}s$

$B \rightarrow \rho\rho$

$B \rightarrow D^{(*)}\pi$

$B \rightarrow J/\psi K^*$