Time-Dependent Analysis of $B \to J/\psi K^0_L$ Decays with the BaBar Detector

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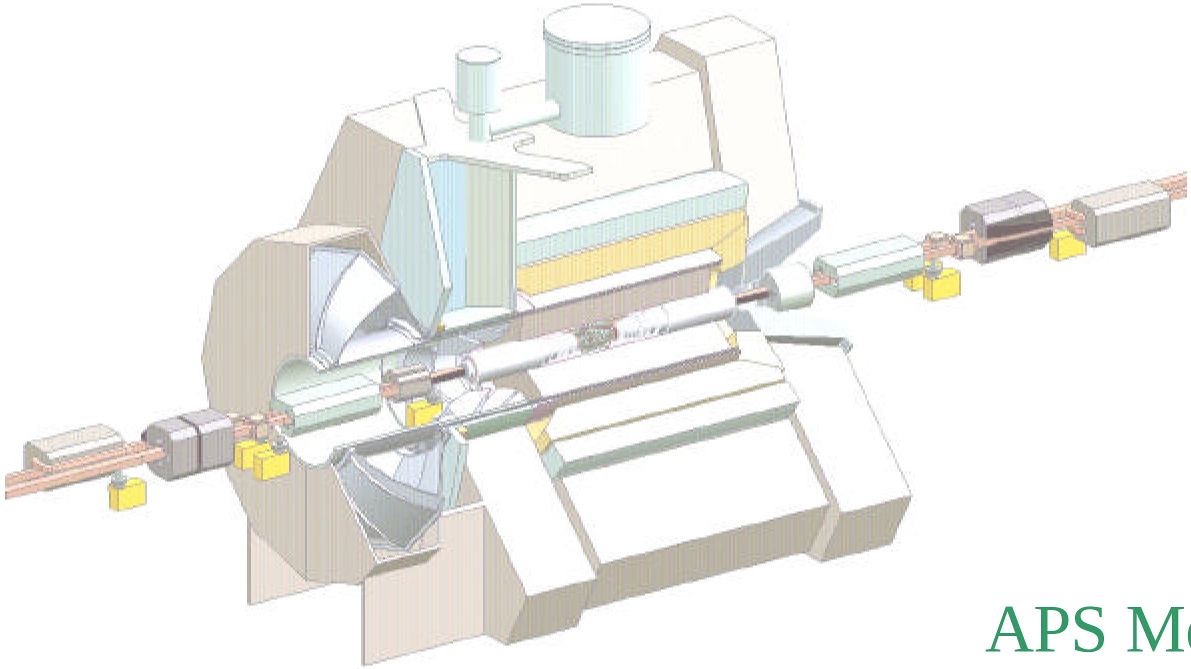
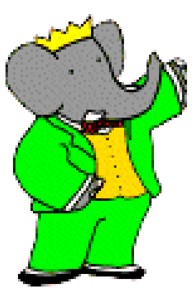


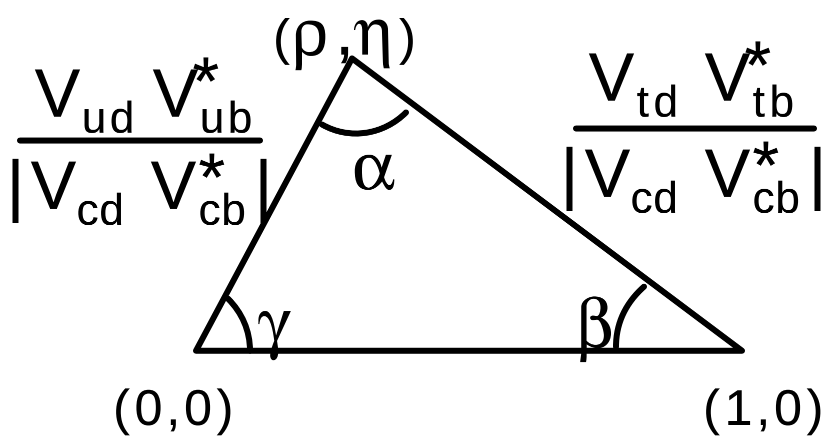


APS Meeting

Albuquerque, 21 April 2002

Why $B \to J/\psi K^0_L$?

- The Standard Model with 3 quark generations predicts CP Violation
  - Complex phase in the quark mixing matrix provides the mechanism for CP Violation
  - Unitarity constraint can be represented graphically in the complex plane

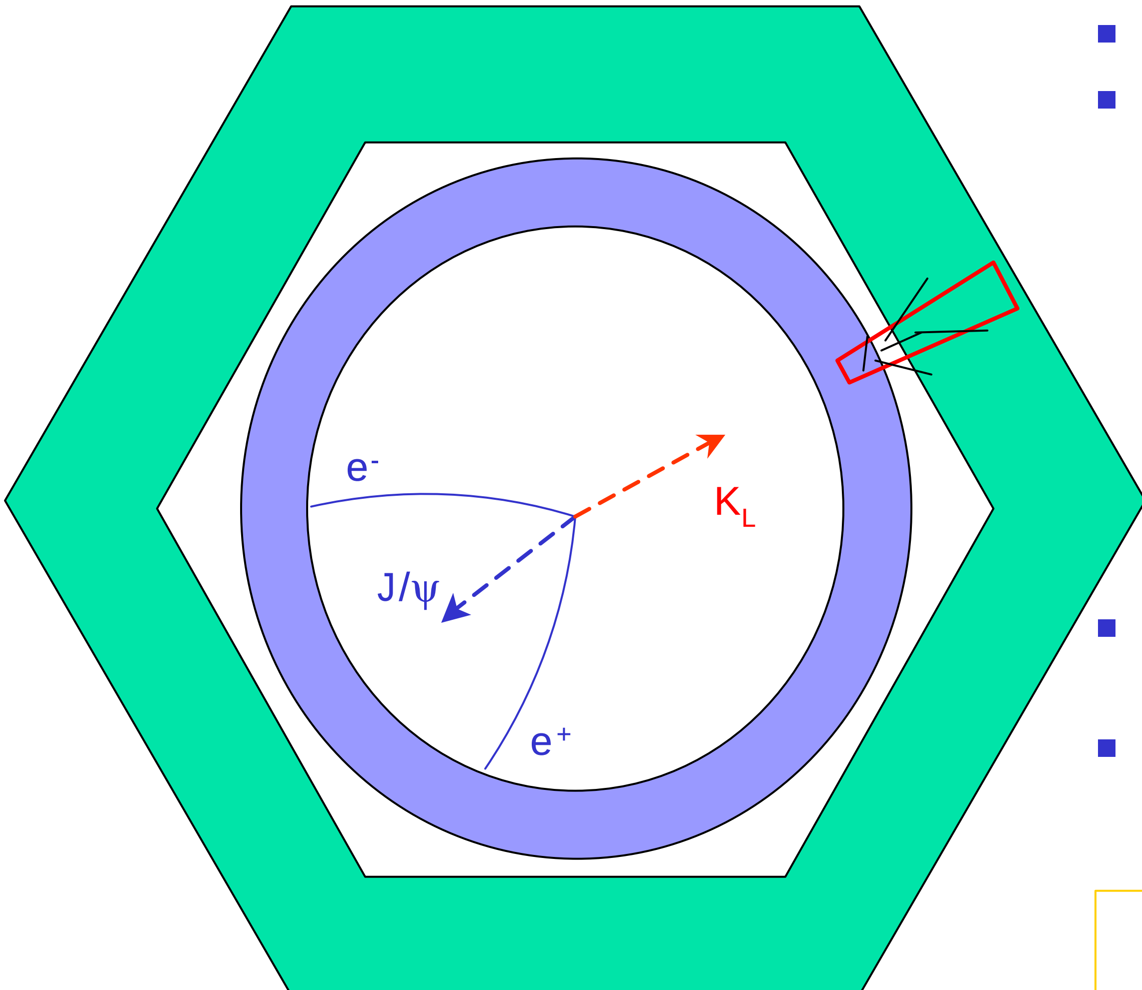


- $B \to J/\psi K^0$ (with K^0 mixing) provides a theoretically clean means of measuring CP violation in the B system:

$$\boxed{A_{CP}(t) = -\eta_{CP} \sin 2\beta \sin(\Delta m \Delta t)}$$

- Advantages of $B \to J/\psi K^0_L$:
  - Most experimentally accessible mode with $\eta_{CP} = 1$
  - $B \to J/\psi K^0_L$ is the 2nd most sensitive measurement of $\sin 2\beta$ after $B \to J/\psi K^0_S$
    - Same branching fraction as $B \to J/\psi K^0_S$
    - Less efficient signal reconstruction

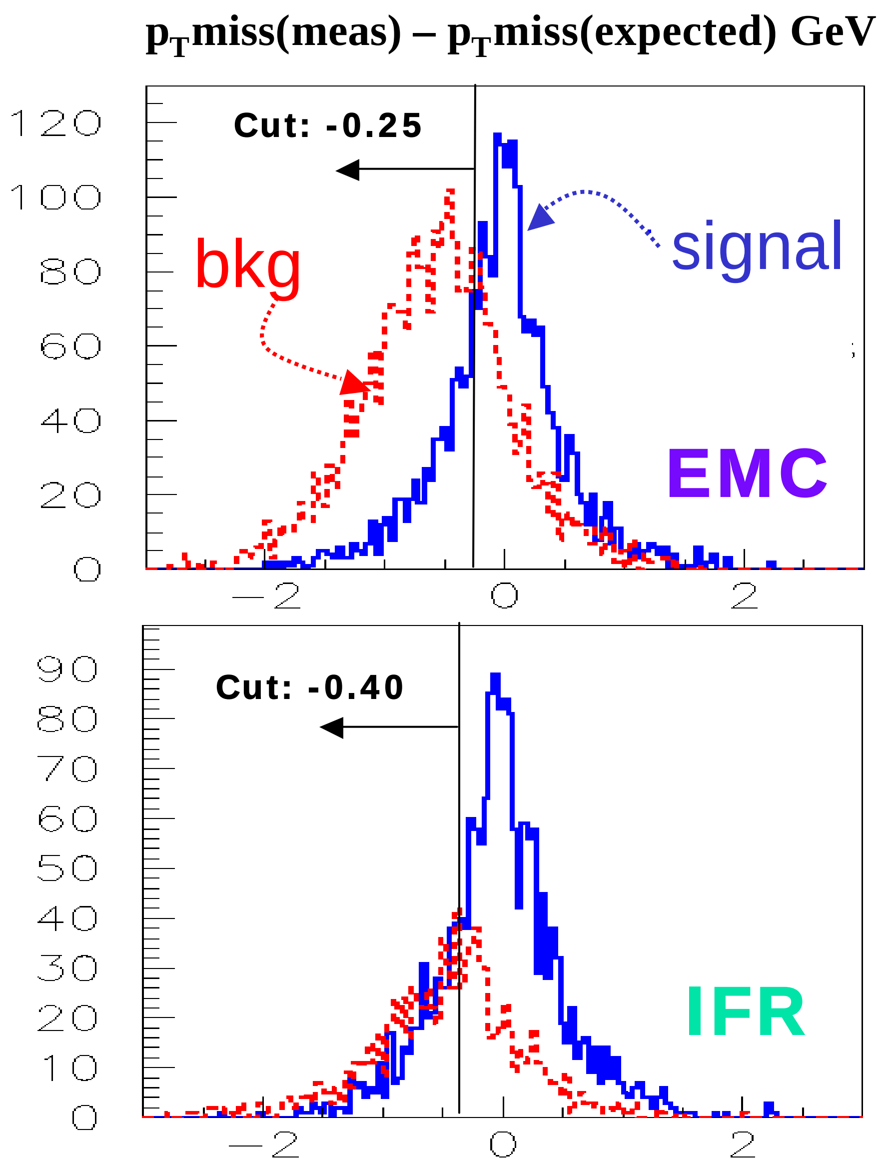
K^0_L reconstruction at BaBar



- Mean life $\tau \sim 52$ nsec
- Look for a hadronic interaction in the detector
  - **ElectroMagentic Calorimeter (EMC)**
    - Significant energy deposit
    - Reject π^0 photons
  - **Instrumented Flux Return (IFR)**
    - At least two layers hit
    - Reject contributions from beam backgrounds
- $E(K_L)$ not measured due to vague K_L signature
- Calculate the K_L momentum from its direction and B-mass constraint

$$m_B^2 = \left(E_{J/\psi} + \sqrt{m_{K_L}^2 + p_{K_L}^2}\right)^2 - \left(\vec{p}_{J/\psi} + p_{K_L}\vec{d}_{K_L}\right)^2$$

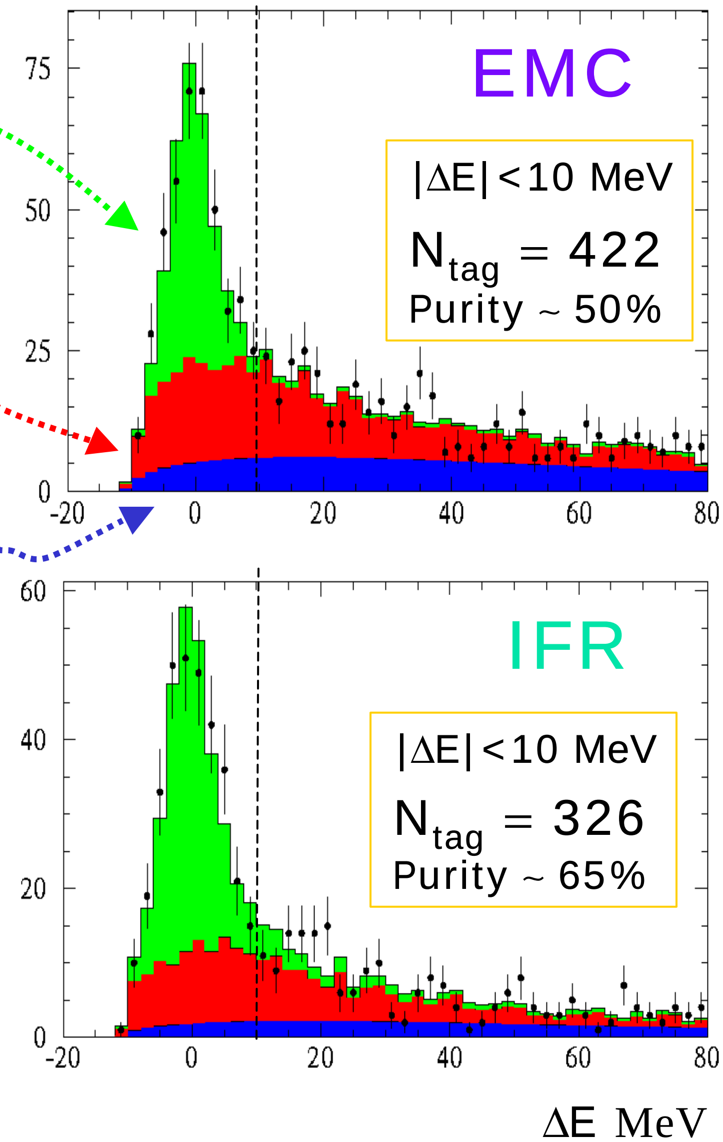
Backgrounds in $B \to J/\psi K_L$



- Background from
  - Photons (in the calorimeter)
  - K_L from $B \to J/\psi X$ modes
- Reject background events with a missing momentum requirement
  - **Calculate** missing transverse momentum in the event
  - **Project** along K_L direction
  - **Subtract** K_L transverse momentum calculated assuming $B \to J/\psi K_L$ kinematics
- Background events have lower missing momentum than signal events
- Photon background mostly eliminated
- Cut has been optimized for minimal statistical error on $\sin 2\beta$

Event Selection Summary

- Maximum likelihood fit to data
  - Signal and Inclusive J/ψ shapes taken from Monte Carlo
  - Non-ψ background shape and normalization taken from J/ψ mass sidebands
- Data is broken up into blocks of different purity to increase signal sensitivity
- Reject some specific $B \to J/\psi X$ modes
- 56 fb^{-1} in sin2β sample
  - Reconstruct nearly 12 $J/\psi K_L$ events/fb^{-1} (6 in the EMC, 6 in the IFR)
- Most background from real K_L from $B \to J/\psi X$ decays



Fitting for sin2β in $B \to J/\psi K_L$

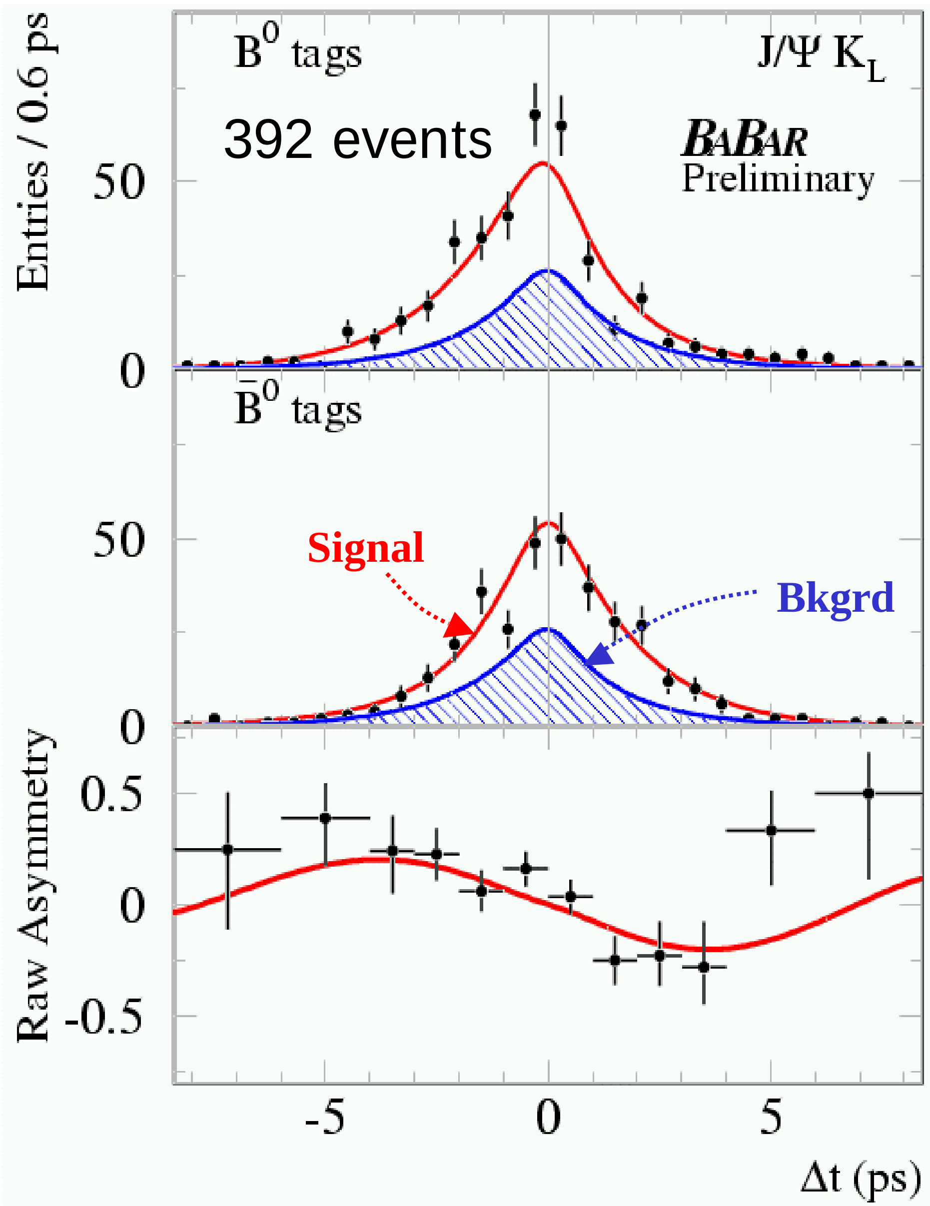
- The $B \to J/\psi K_L$ decay mode has non-negligible backgrounds
- The sin2β analysis for $B \to J/\psi K_L$ must properly model the Δt and CP properties of the background
  - Itemize the background components
    - Inclusive J/ψ events : separate the largest contributors
    - Fake J/ψ events
  - Include a term for each in the likelihood fit
    - Tagging dilutions and Δt distribution taken from Monte Carlo and data sidebands
  - Monte Carlo used to validate assumptions

Overlapping γ From π^0 fake K_L.

Jumble of modes each < 2 %.

	EMC K_L	IFR K_L	h_{cp}
Signal	**50 ± 4 %**	**65 ± 4 %**	+ 1
J/y K^{*+} ($K_L p^+$)	11 %	12 %	0
J/y K^{*0} ($K_L p^0$)	8 %	7 %	-0.68 ± 0.07
J/y K_S ($p^0 p^0$)	3 %	1 %	- 1
Other J/y	17 %	9 %	0 ± 0.25
Non-J/y	11 %	6 %	0 ± 0.25

CP Asymmetry in $B \to J/\psi K^0_L$



- Time-Dependent CP Asymmetry given by

$$A_{CP} = \frac{N(B^0 \to f_{cp}) - N(\overline{B^0} \to f_{cp})}{N(B^0 \to f_{cp}) + N(\overline{B^0} \to f_{cp})}$$

$$A_{CP}(t) = -\eta_{cp} \cdot \sin 2\beta \cdot \sin(\Delta m \Delta t)$$

- Preliminary Result

sin2b = 0.72 ± **0.19(stat)** ± **0.06(syst)**

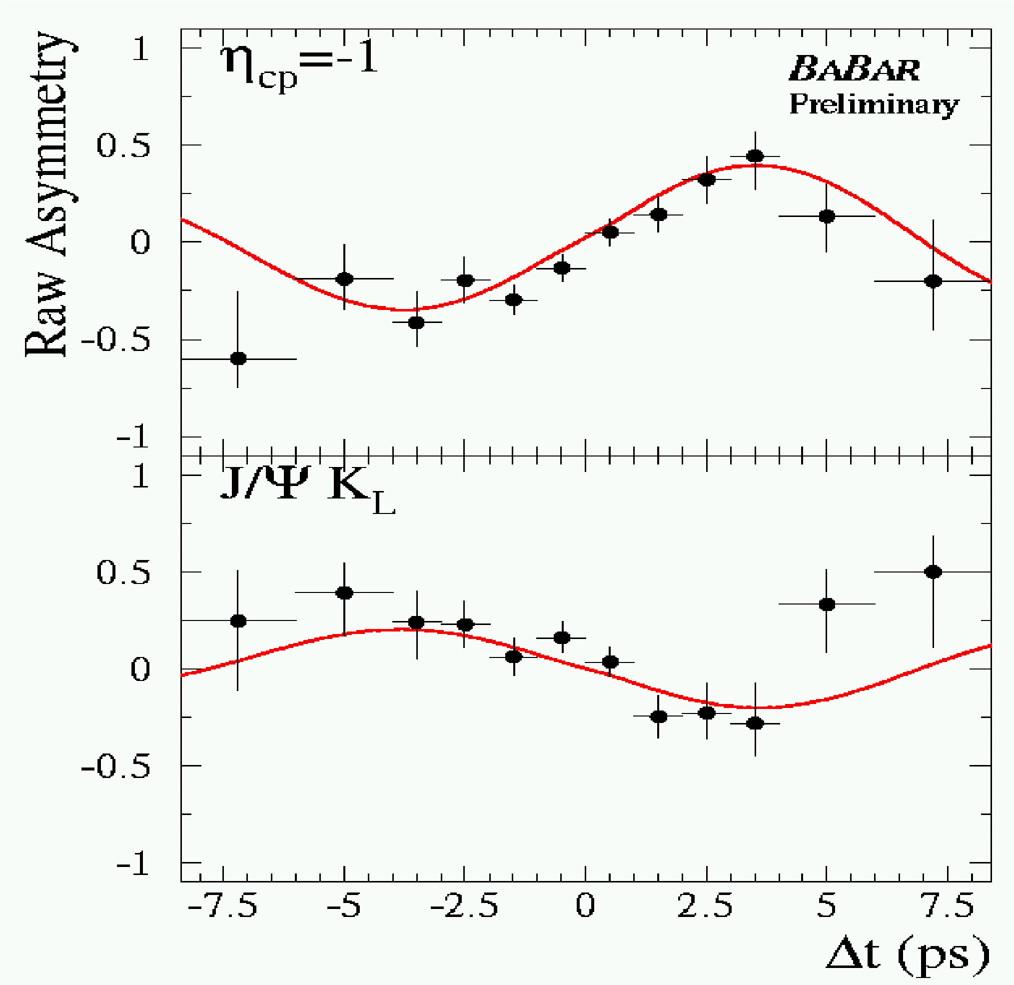
- Our measurement is still dominated by statistics

Systematic Errors in $B \to J/\psi K_L$

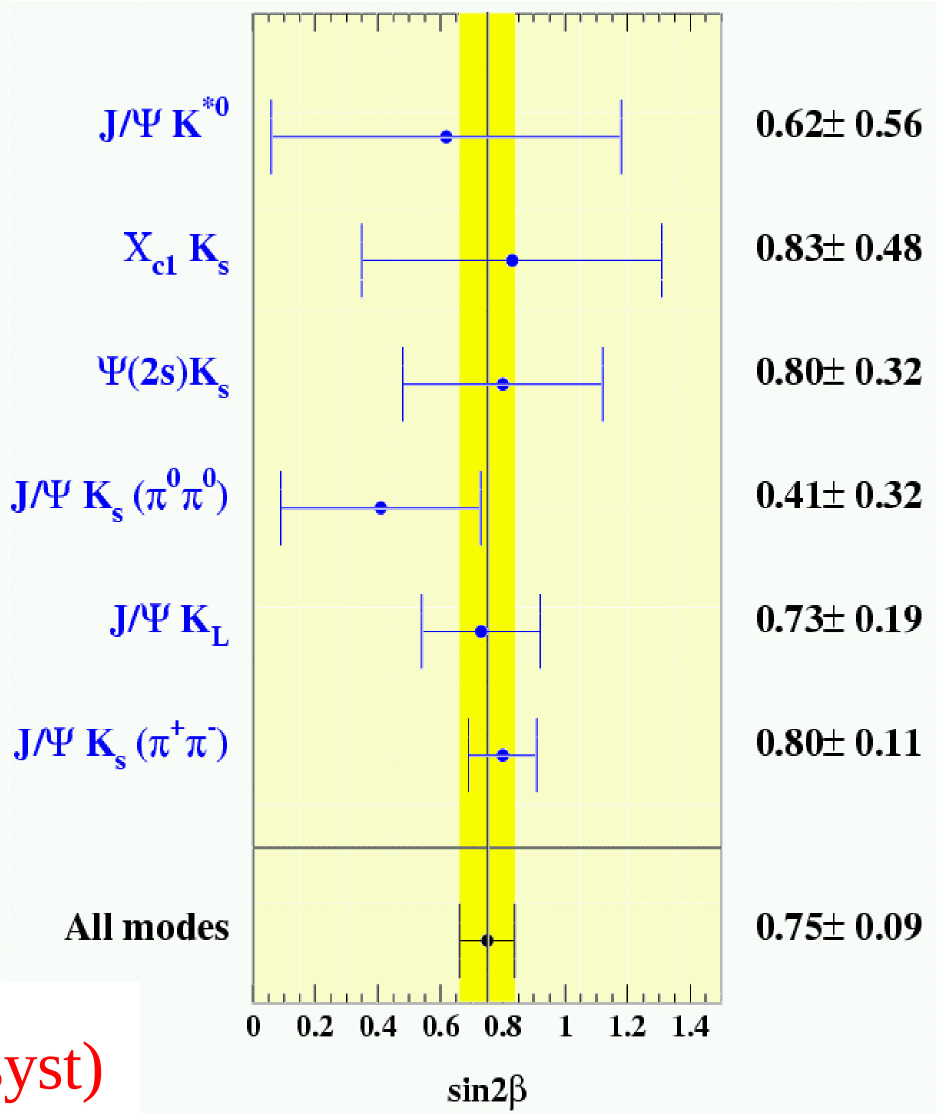
- Systematic error for the $\sin 2\beta$ fit calculated for
  - $B \to J/\psi K_L$ events only
  - K_L + all other modes (Global fit)
- Systematic errors are also limited by statistics
- Expect systematic errors to drop as more data is accumulated

Source	**K_L Only**	**Global**
Sample Composition	0.037	0.008
$J/\psi X$ fractions	0.033	0.007
MC corrections	0.026	0.006
Assumed CP of background	0.014	0.003
Δm_d and τ_B (PDG 2000)	0.014	-
Non-ψ BG Δt	0.002	0.0004
Total	**0.059**	**0.013**

Combined fit to sin2β



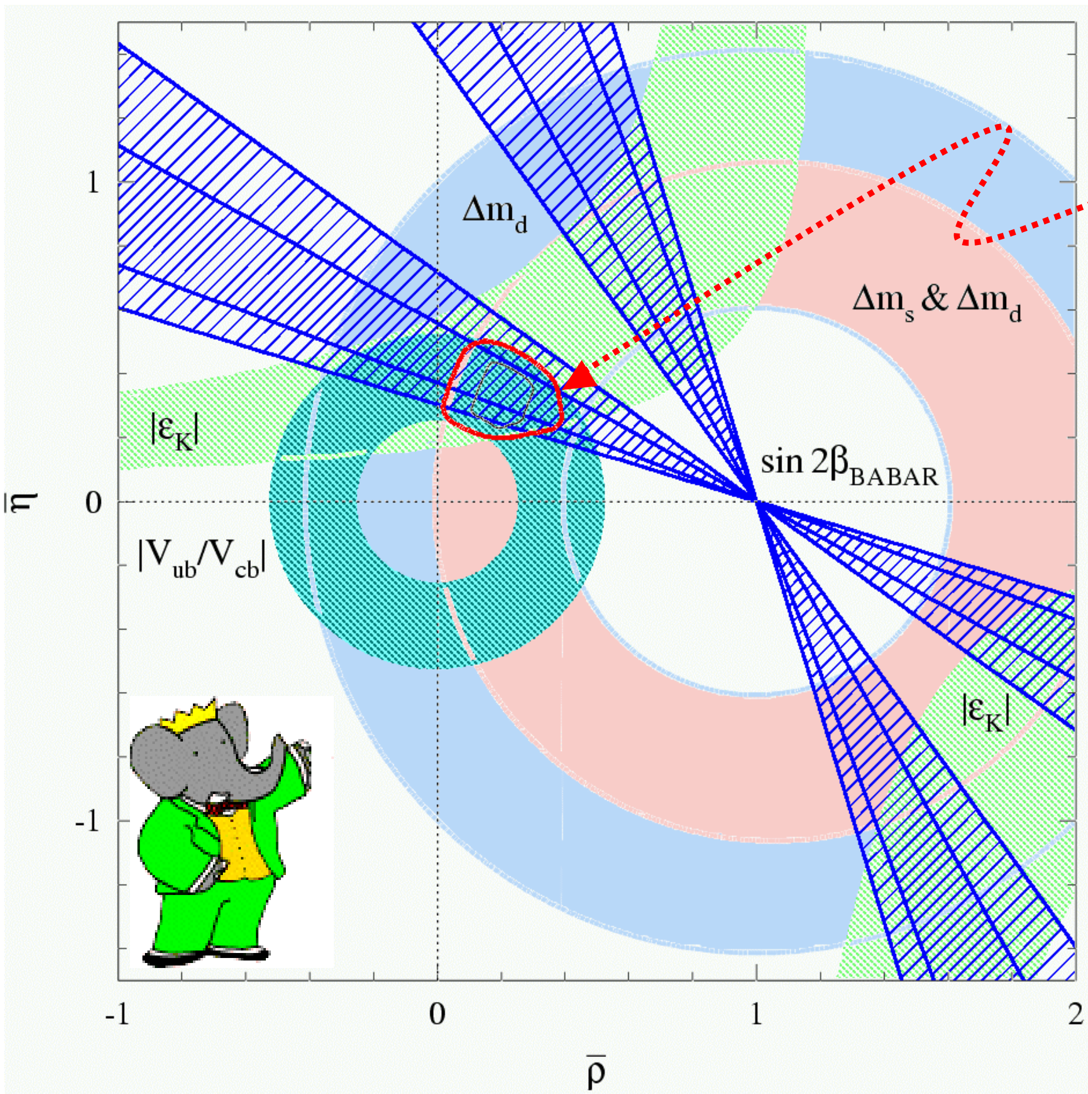
sin2b by decay mode



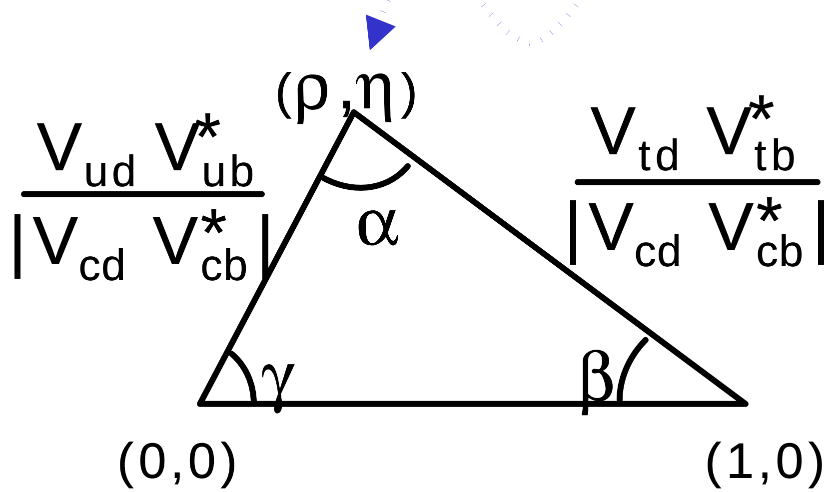
Combined Result (preliminary):

$\sin 2\beta = 0.75 \pm 0.09(\text{stat}) \pm 0.04(\text{syst})$

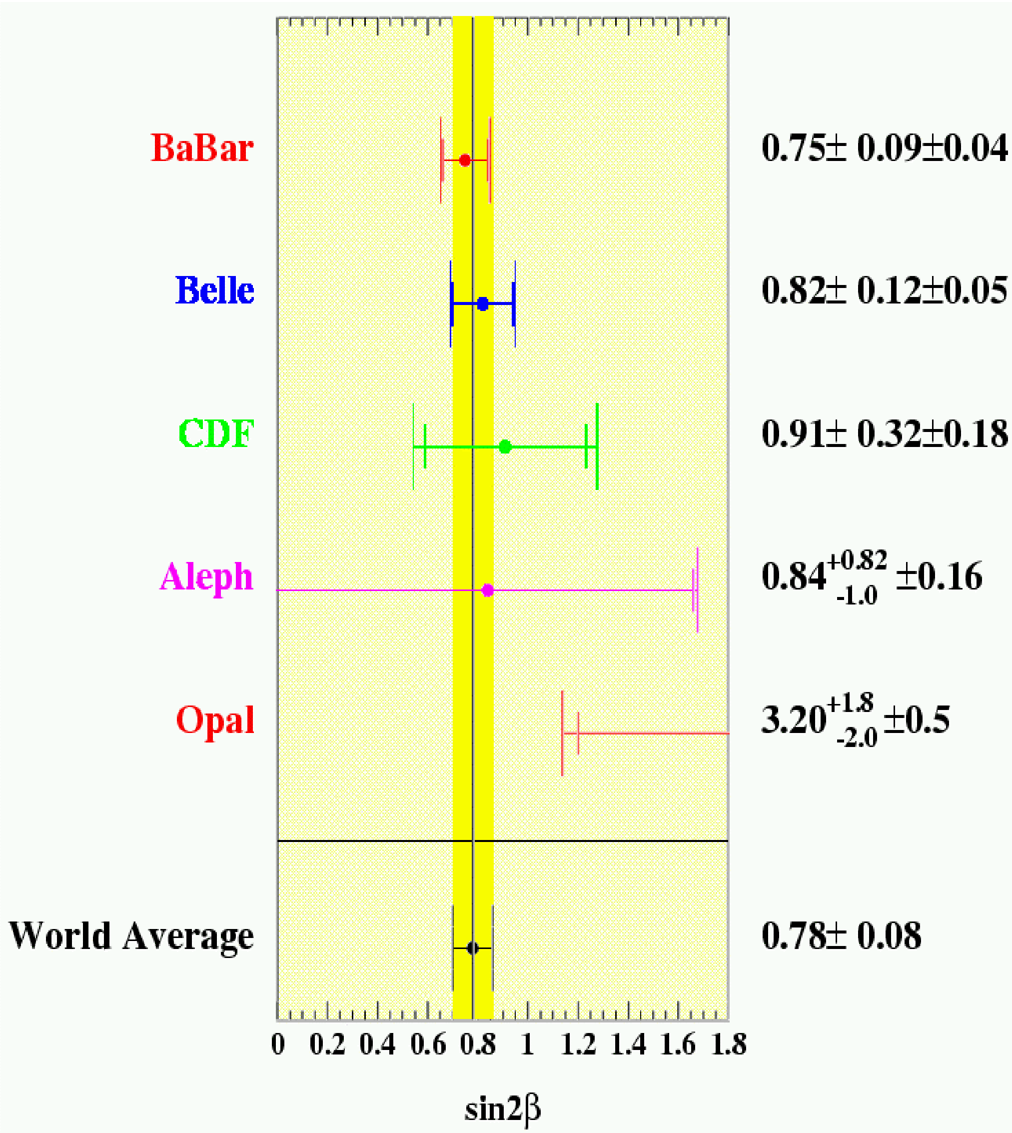
sin2β at BaBar



One solution for b **is consistent with other measurements which constrain the value of** r **and** h



Where do we go from here?



- These results refine the initial observation of CP Violation in the B system
- Sin2β measured at BaBar (hep-ex/0203007)

PRELIMINARY

$\sin 2\beta\ (\eta_{CP} = -1) = 0.76 \pm 0.10 \pm 0.04$

$\sin 2\beta\ (K_L) = 0.72 \pm 0.19 \pm 0.06$

$\sin 2\beta\ (\text{all}) = 0.75 \pm 0.09 \pm 0.04$

- K_L is the 2nd most significant mode at BaBar
- Expect 100 fb^{-1} for summer 2002
  - $\eta_{CP} = -1$ modes : $0.10 \rightarrow 0.07$
  - K_L : $0.19 \rightarrow 0.14$