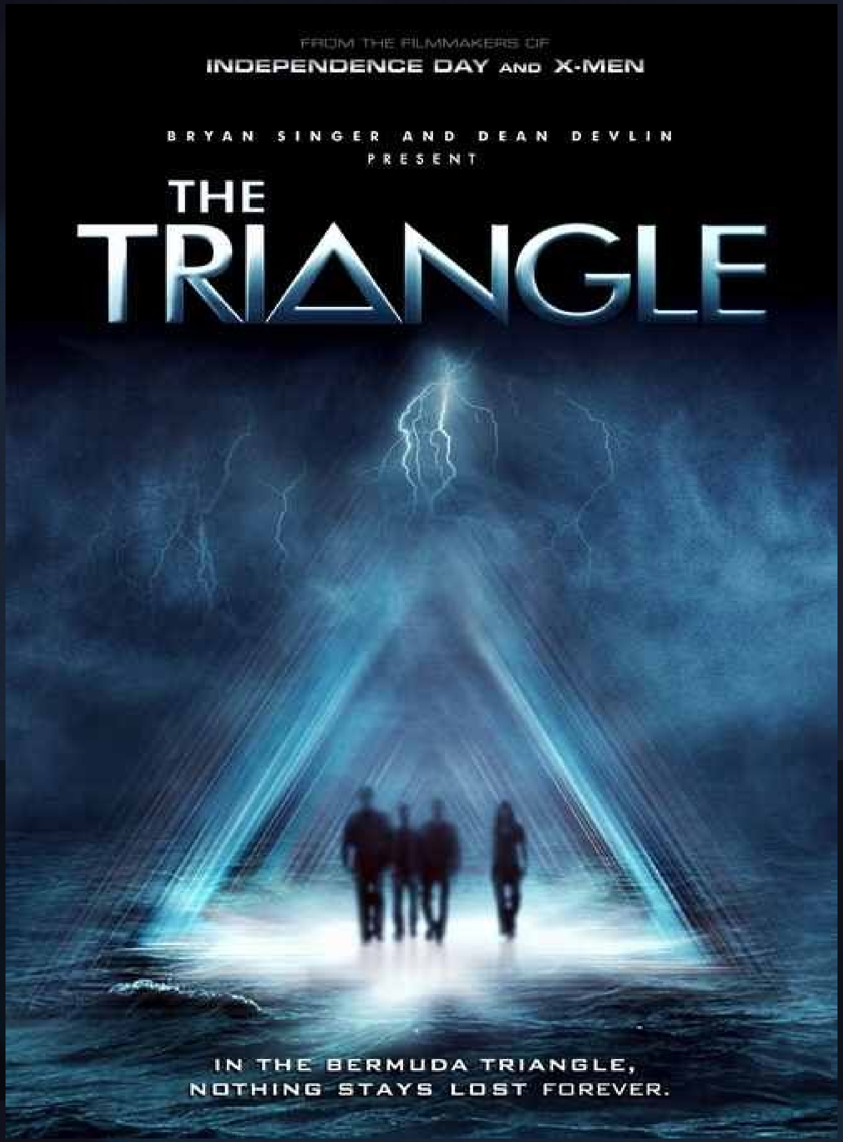
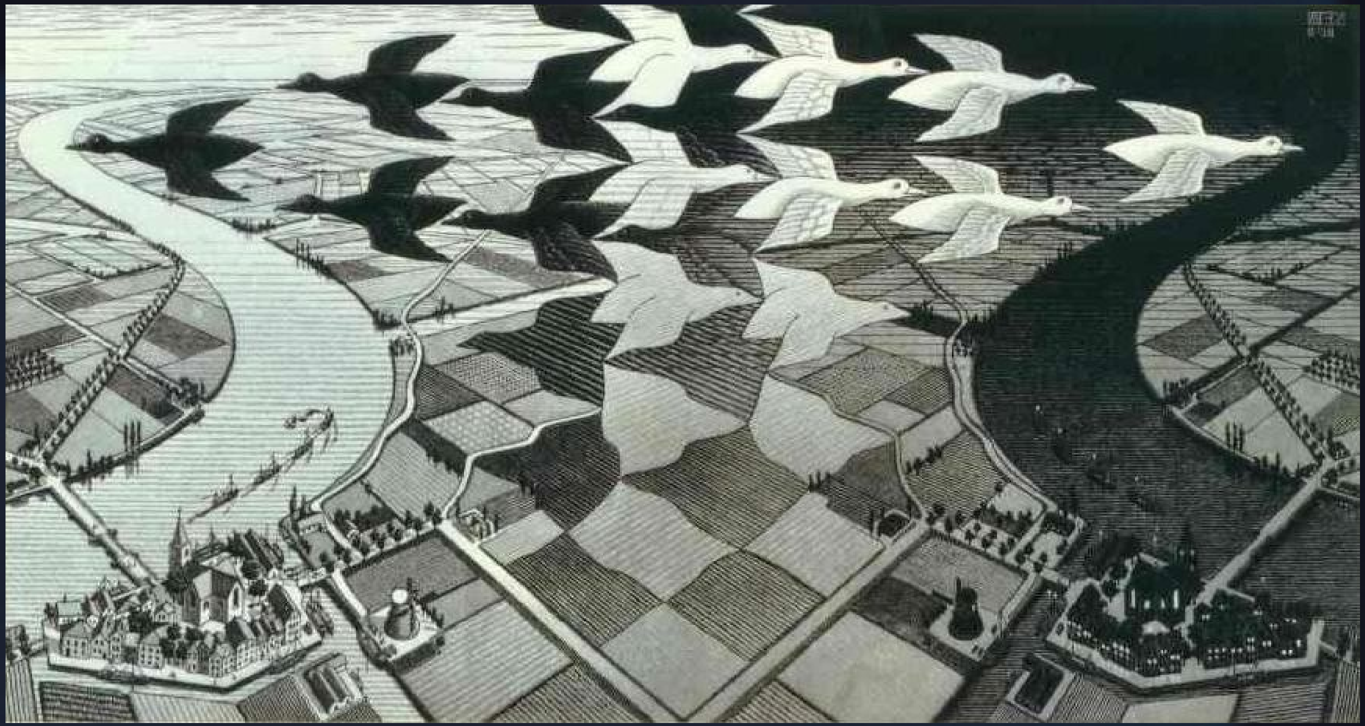


HEP Theory Group Seminar
December 26th, 2006,
Department of Physics, CYCU

Kai-Feng Chen
National Taiwan University

The Belle Collaboration

Measurements on CKM Angles ϕ_1, ϕ_2 & ϕ_3



CP Violation in *B* Physics: A Brief Introduction

Nuclear Physics B193 (1981) 85–108

NOTES ON THE OBSERVABILITY OF *CP* VIOLATIONS IN B DECAYS

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Received 16 June 1981

The time-dependent CP-violation on B-system was proposed 25 years ago.

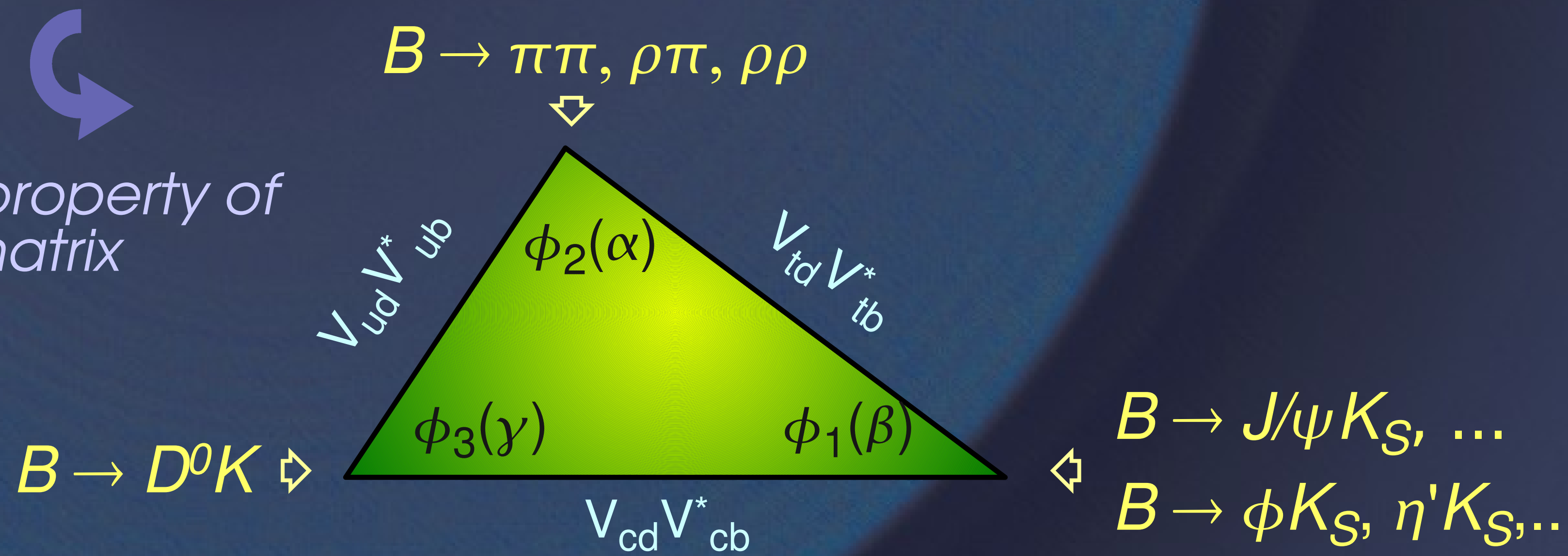
We describe a general method of exposing *CP* violations in on-shell transitions of B mesons. Such *CP* asymmetries can reach values of the order of up to 10% within the Kobayashi–Maskawa model for plausible values of the model parameters. Our discussion focuses on those (mainly non-leptonic) decay modes which carry the promise of exhibiting clean and relatively large *CP* asymmetries at the expense of a reduction in counting rates. Accordingly we address the complexities encountered when performing *CP* tests with a high statistics B meson factory like the Z^0 (and a toponium) resonance.

~~*CP*~~ in the Standard Model

CP symmetry is broken by the complex phase appearing in the quark mixing matrix

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-(\lambda^2/2) & \lambda & A\lambda^3(\rho-\boxed{i\eta}) \\ -\lambda & 1-(\lambda^2/2) & A\lambda^2 \\ A\lambda^3(1-\rho-\boxed{i\eta}) & -A\lambda^2 & 1 \end{pmatrix}$$

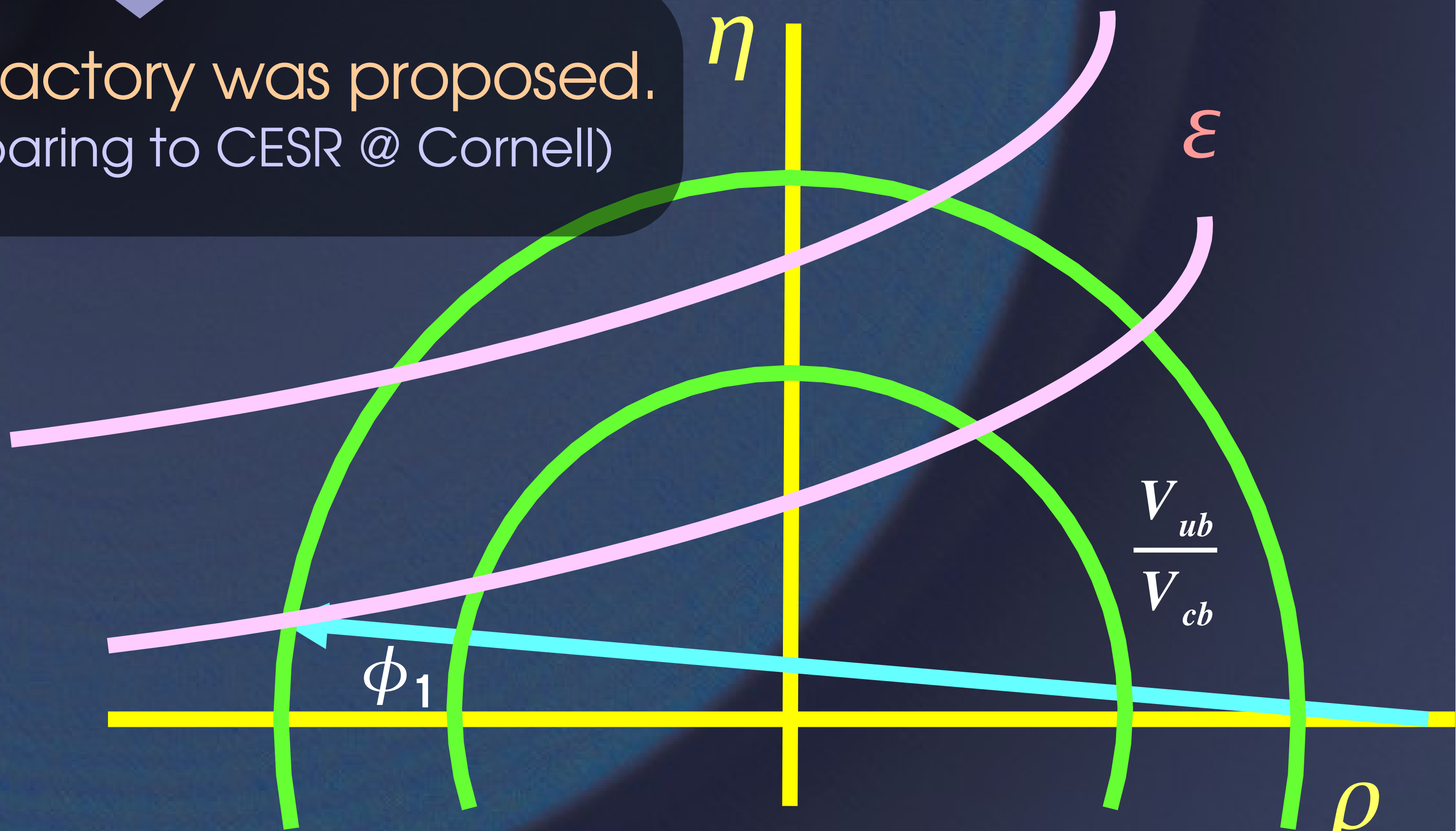
Take the property of unitarity matrix



Unitarity Triangle in 1980's

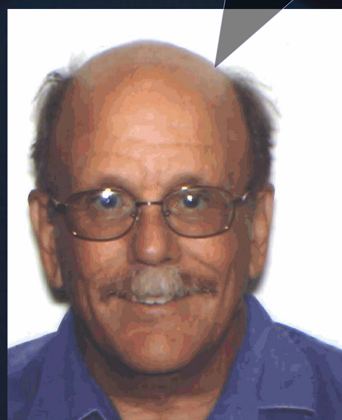
- The "known" minimum *CP* violation in *B* system is 15%.
- A lot of *B* mesons are required to measure the ϕ_1 angle.

A $O(10^{34})$ *B*-factory was proposed.
(~1000x comparing to CESR @ Cornell)

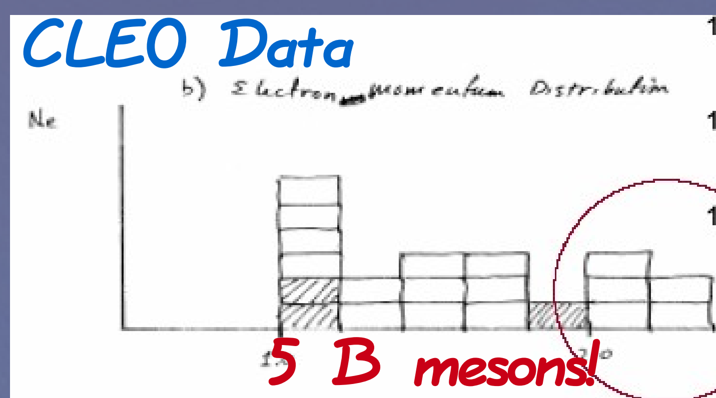


Look! This took us six months!

We need millions of B and use them to search for mixing and CP violation



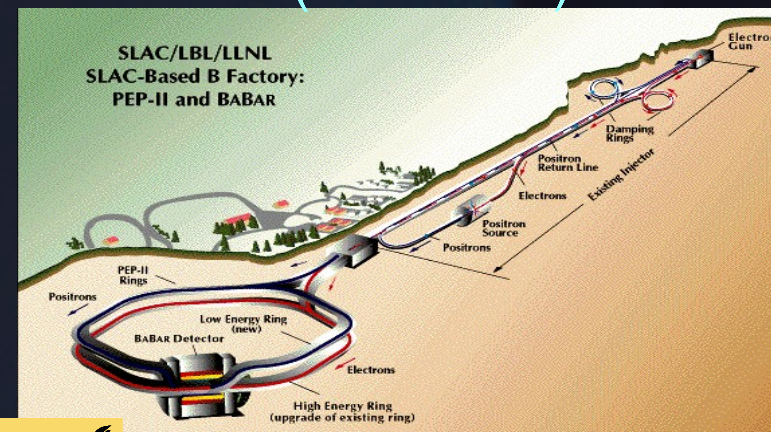
(◁ S.Olsen)



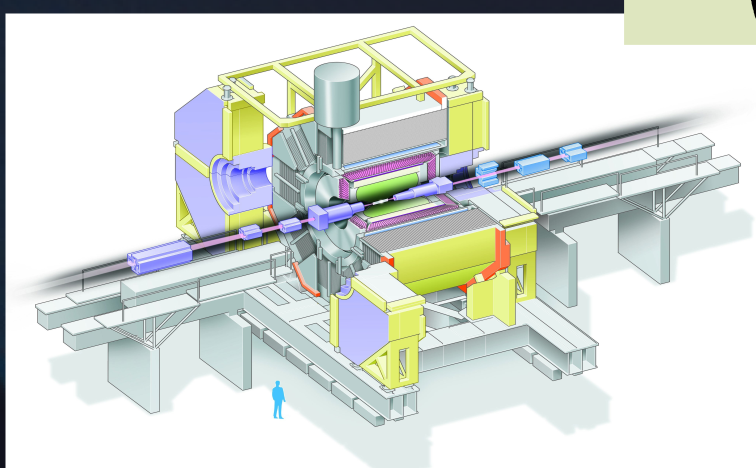
B-Factory Experiments

KEK(Japan)

SLAC(Stanford)

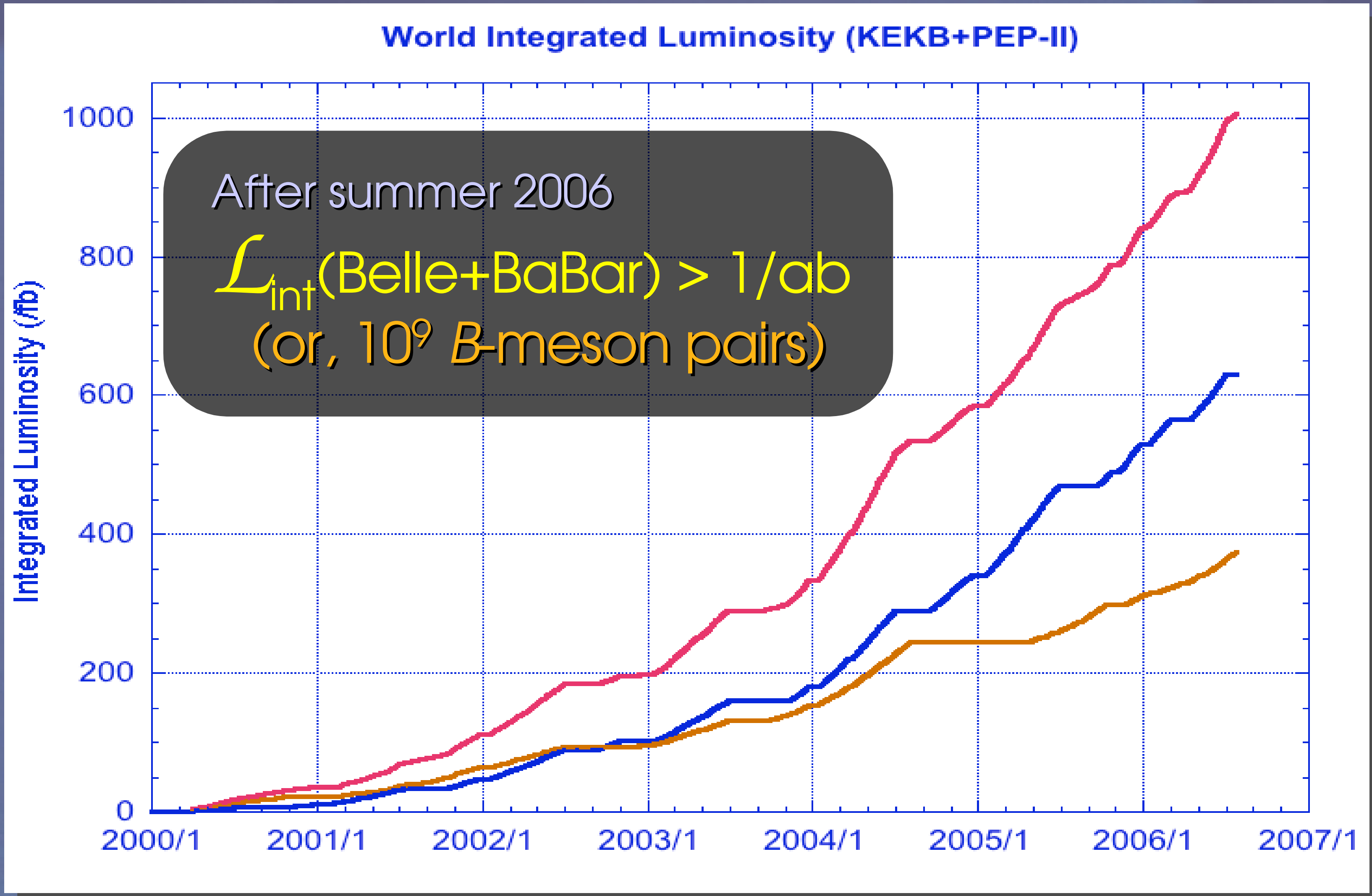


Belle



BaBar

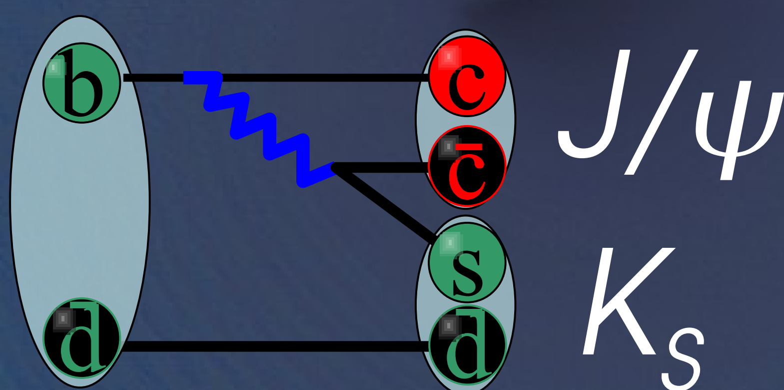
Luminosity Records



Measurement of sin2ϕ_1

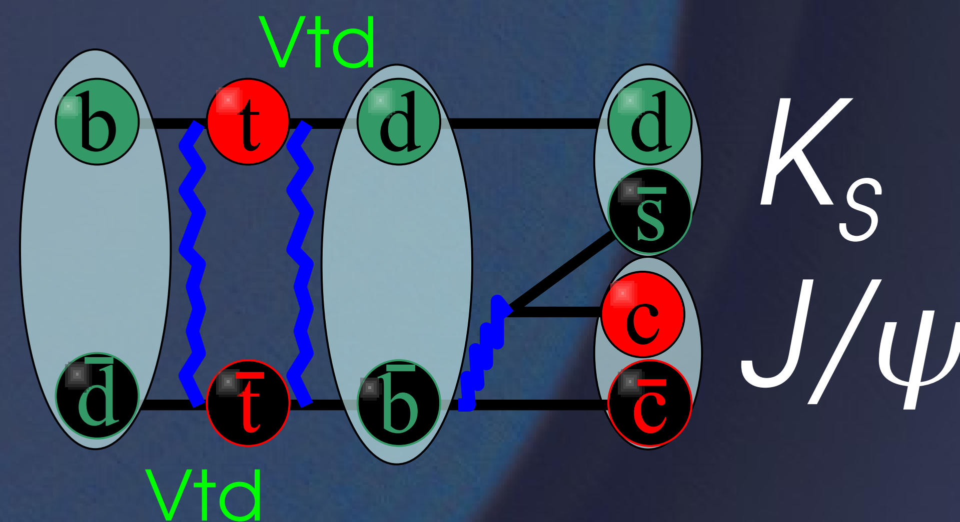
Quantum Interference Between Two Diagrams:

Tree diagram



+

Box diagram + Tree diagram



We have to “wait” (i.e. $\Delta t \neq 0$) to have contributions from the box diagram.

Measurement of sin2ϕ_1

Time-dependent *CP* Asymmetries

$$A_{CP}(t)=\frac{\Gamma(\overline{B}^0\to f_{CP};t)-\Gamma(B^0\to f_{CP};t)}{\Gamma(\overline{B}^0\to f_{CP};t)+\Gamma(B^0\to f_{CP};t)}=\boxed{A_f}\cos(\Delta m t)+\boxed{S_f}\sin(\Delta m t)$$

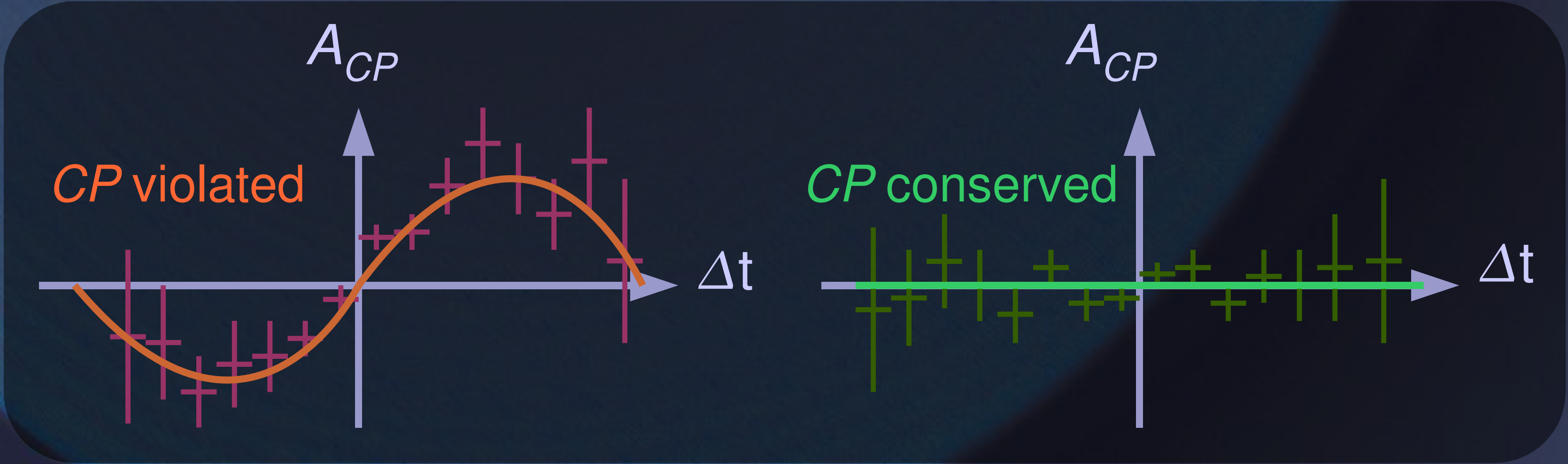
Indicates direct *CP* violation

$A_f = 0$ if $f_{CP} = J/\psi K_S$

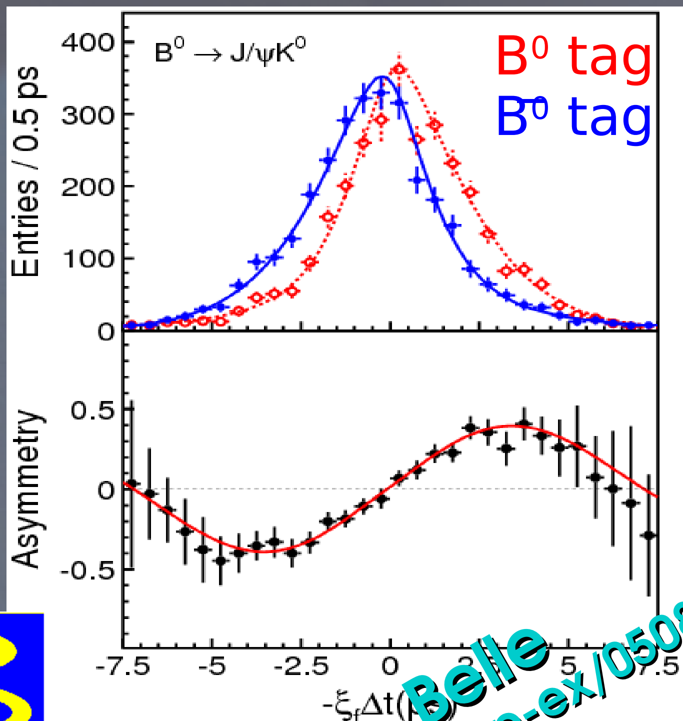
($-A_f = C_f$ in BaBar)

$S_f = \sin 2\phi_1$

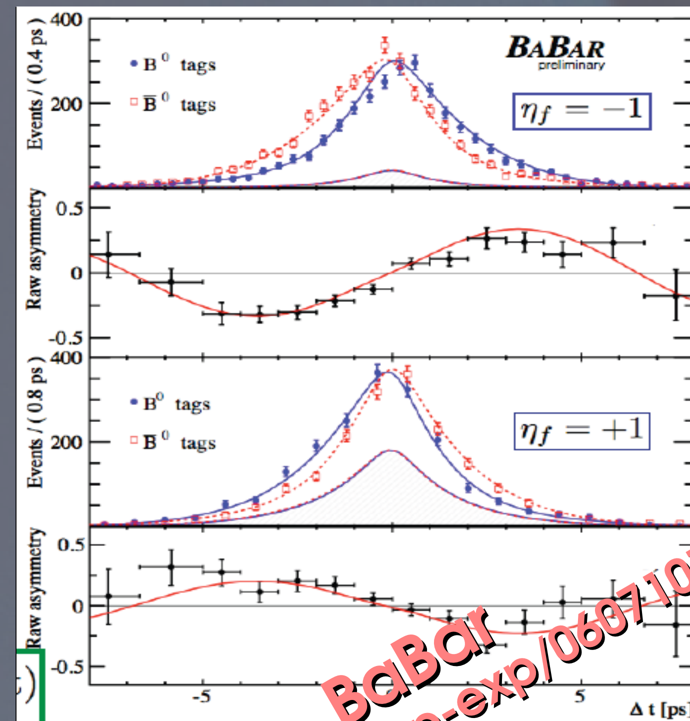
if $f_{CP} = J/\psi K_S$



Measurement of $\sin 2\phi_1$



Belle
hep-ex/0508039



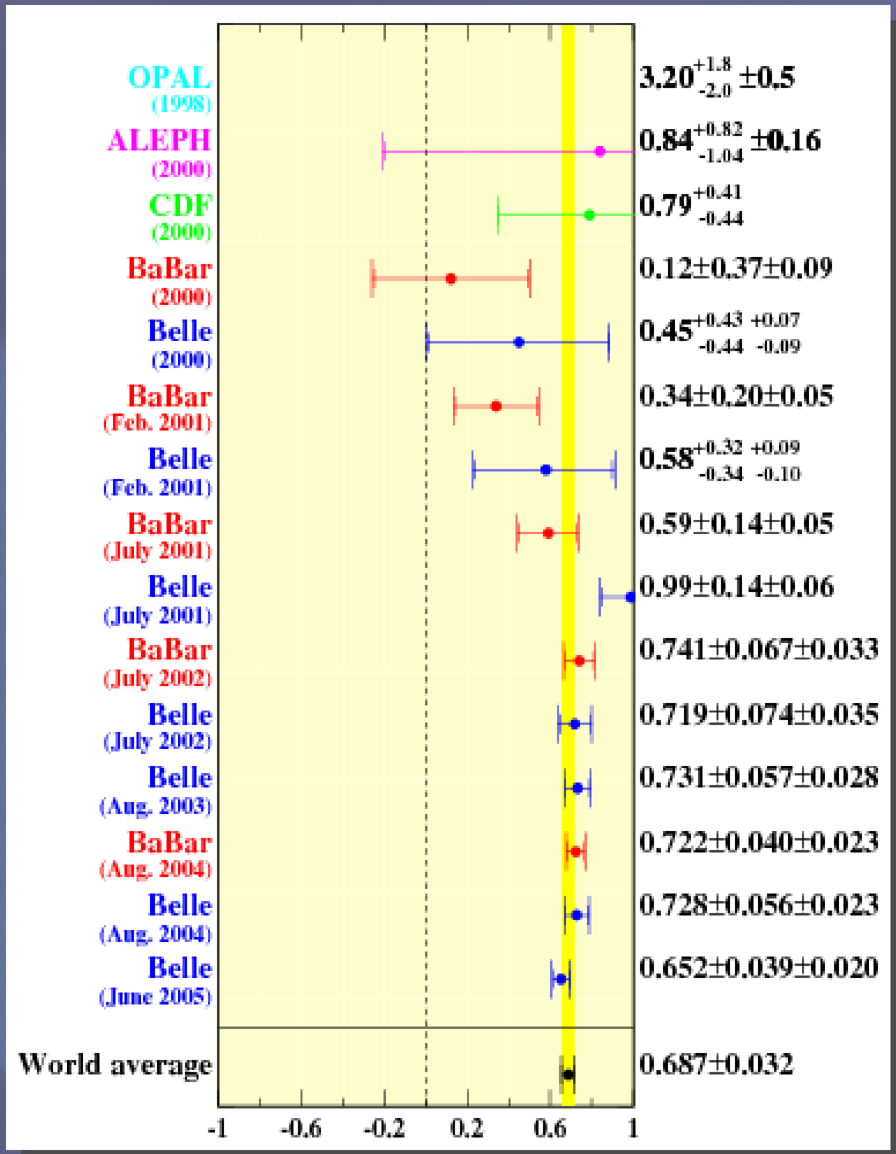
BaBar
hep-exp/0607107

HFAG *(b→ccs)*: $S_{ccs} = 0.674 \pm 0.026$

(A_{ccs} = 0.012 ± 0.022, consists of no *DCPV*)

CP Violation in *B* system is already established within the Standard Model.

Brief History (1998-2005) of sin2ϕ_1:



- Q: What is the main source of CP violation?
- A: The Kobayashi-Maskawa phase IS the dominate source!

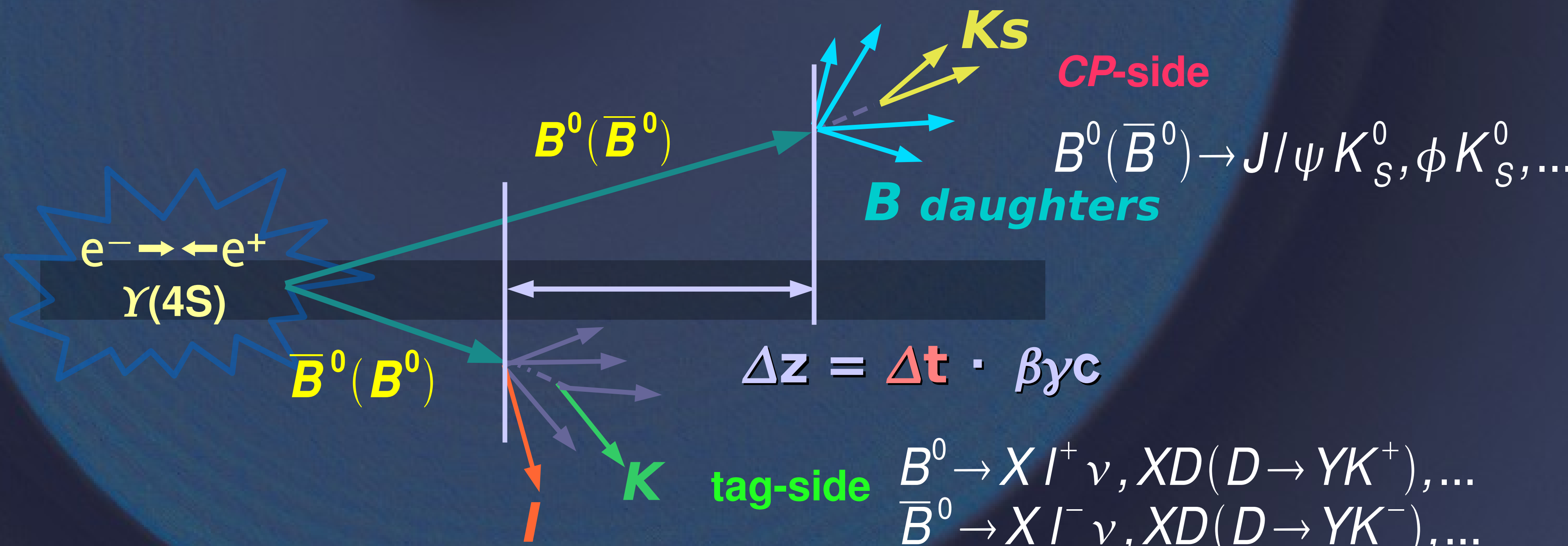
- Q: Is there anything else?
- A: Not clear yet! Two approaches:
  1) Over-constrain the unitary triangle with precise measurements on ϕ_2/ϕ_3 as well.
  2) Compare sin2ϕ_1 in tree and penguin processes.

The Experiment

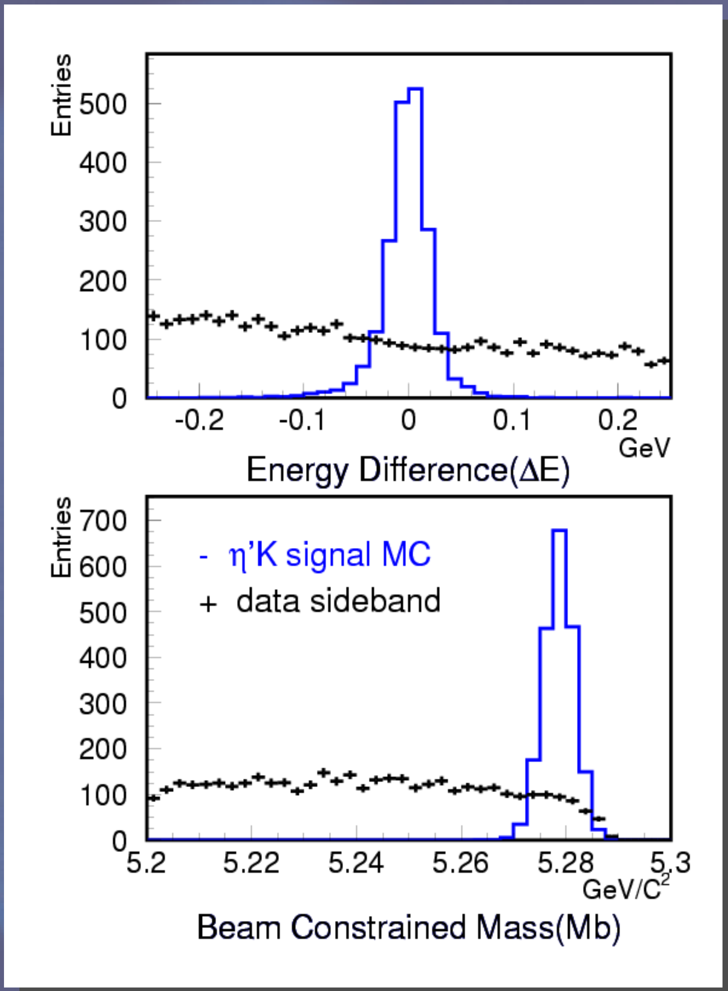
(Mostly about the Belle Analysis)

The Measurements

- The experiments take the advantage of energy-asymmetric collider to produce Lorentz boosted *B* mesons.
- Fully reconstruct a *CP* eigenstate. ⇦ Key point 1
- Tags the *B* flavor from the associated *B* meson. ⇦ Key point 2
- Measures the proper-time difference (Δt), and extract the *CP* asymmetries. ⇦ Key point 3



Event Reconstruction



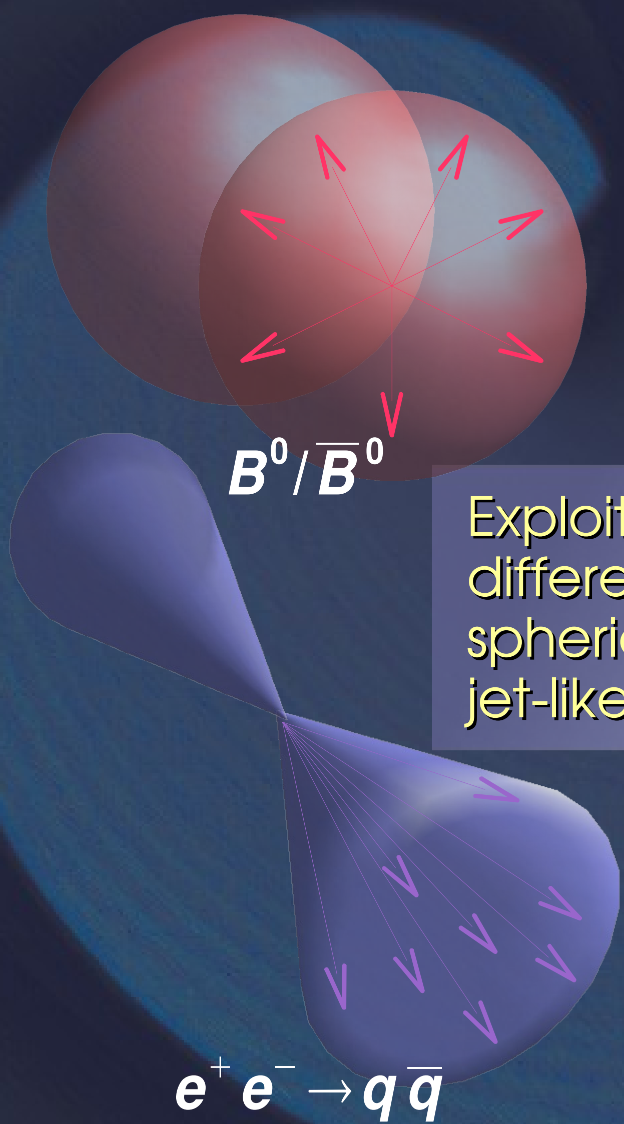
- *B* candidates are identified by the beam constrained mass (M_{bc}), and the energy difference (ΔE):

$$\begin{cases} M_{bc} = \sqrt{E_{beam}^2 - P_B^2} \\ \Delta E = E_B - E_{beam} \end{cases}$$

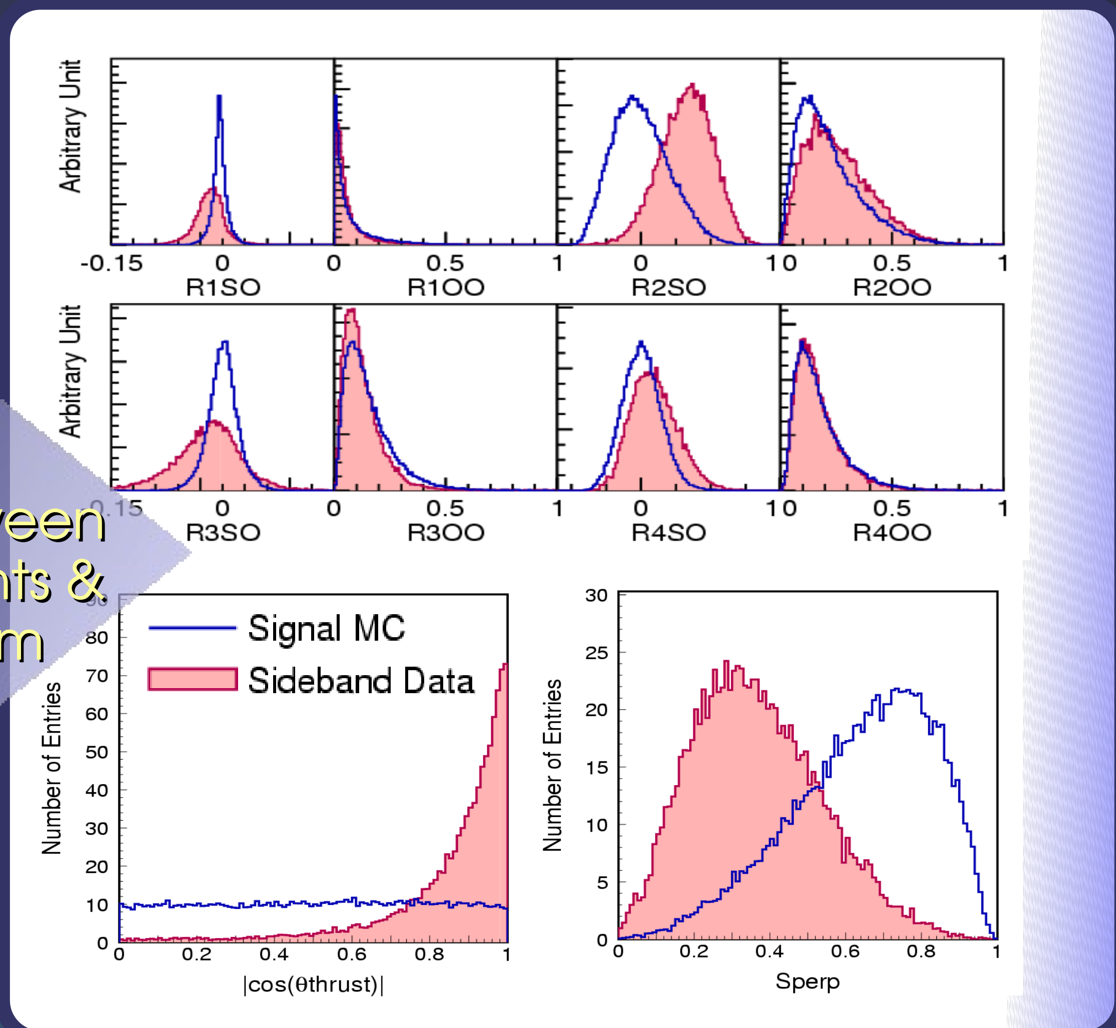
where E_B and P_B are the reconstructed *B* energy and momentum in the cms frame.

- Dominated background events are from **continuum processes** ($e^+ e^- \to q\bar{q}$).

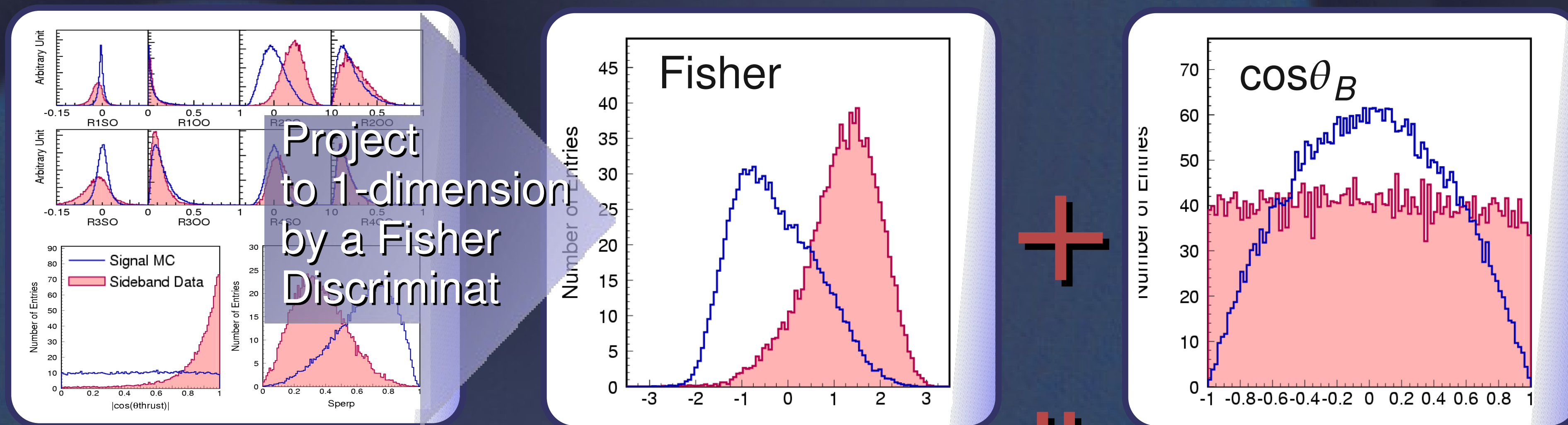
Continuum Suppression



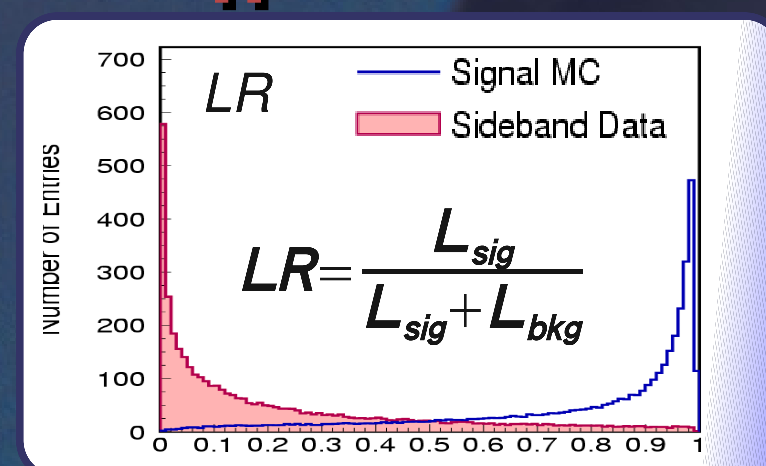
Exploit the difference between spherical *B* events & jet-like continuum



Continuum Suppression



- Naïve error: $\delta S_f \propto 1/\sqrt{N_S} \propto \sqrt{(1+N_B/N_S)}$
- Most of the Belle analysis use a likelihood ratio to combine all the information, while many BaBar analysis use the neural network.
- Selection applied on the final LR/NN.



Flavor Tagging

Information on charged tracks

Slow pion | Lambda | Kaon | Lepton

Select the track with largest *r*

Calculate combined $q \cdot r$

Select the track with largest *r*

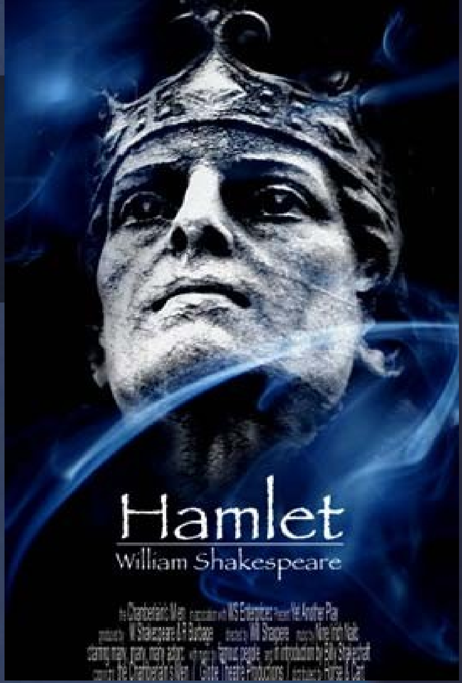
Flavor information ***q*** and ***r***

Event-level look-up table

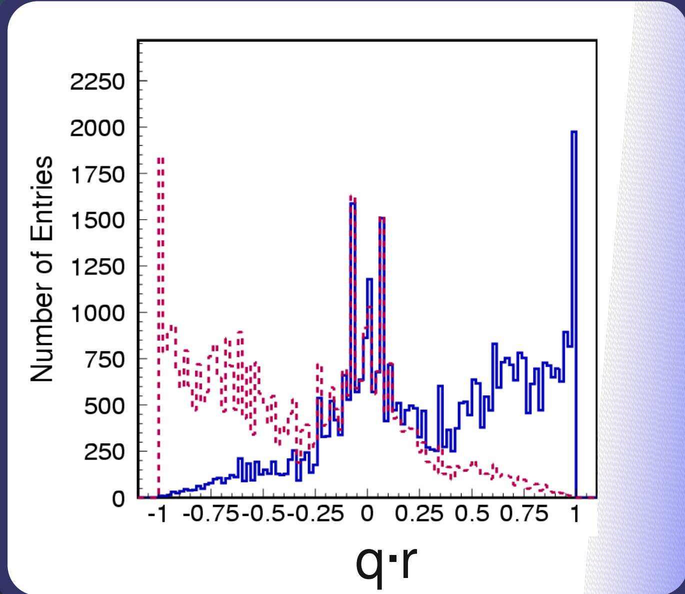
$$q \cdot r = \frac{N(B^0) - N(\bar{B}^0)}{N(B^0) + N(\bar{B}^0)}$$

q: flavor = +1 or -1

r: quality = (0,1]



To **B** or not to **B**, that's a question



Flavor Tagging

Tagging Performance

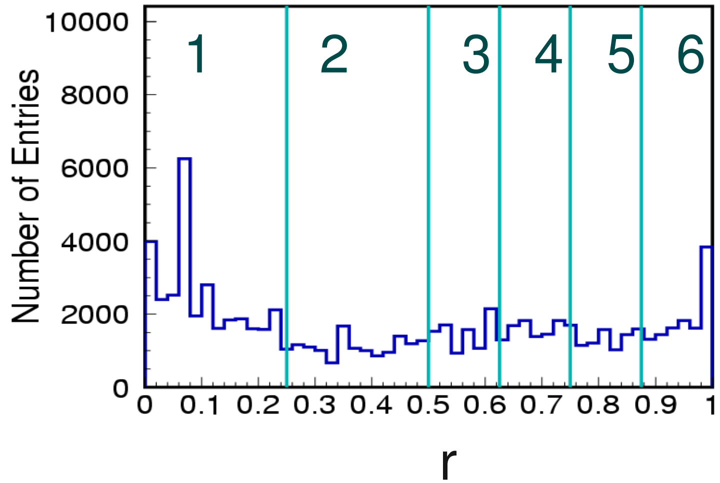
- A replacement for real data:

$$q \cdot r = q(1 - 2\boxed{w_{tag}})$$

wrong-tag fractions

- Wrong-tag fractions are measured by the *B*-mixing study in 6 'r' regions, and the performance is rated by the effective efficiency:

$$\epsilon_{eff} = \sum_l \epsilon (1 - 2w^l_{tag}) \approx 29\%$$



DS-I	r interval	w_l	Δw_l	$\epsilon_{\text{eff},l}$
1	0.000 – 0.250	0.464 ± 0.006	−0.011 ± 0.006	0.002 ± 0.001
2	0.250 – 0.500	0.331 ± 0.008	+0.004 ± 0.010	0.017 ± 0.002
3	0.500 – 0.625	0.231 ± 0.009	−0.011 ± 0.010	0.030 ± 0.002
4	0.625 – 0.750	0.163 ± 0.008	−0.007 ± 0.009	0.055 ± 0.003
5	0.750 – 0.875	0.109 ± 0.007	+0.016 ± 0.009	0.057 ± 0.002
6	0.875 – 1.000	0.020 ± 0.005	+0.003 ± 0.006	0.126 ± 0.003

Understanding the Δt

- Resolution function: describe the smearing due to detector or physics.
- Δt probability density function:

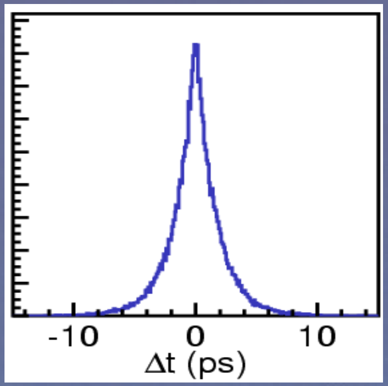
Convolution

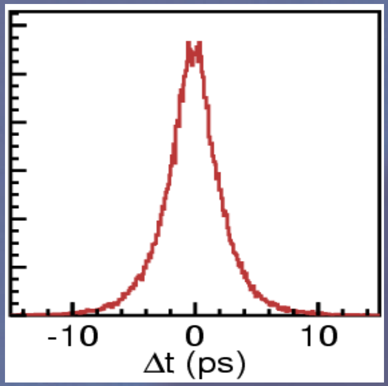
$$P(\Delta t) = \int_{-\infty}^{+\infty} d(\Delta t') \underbrace{P(\Delta t')}_{\text{True } \Delta t \text{ PDF}} R(\Delta t - \Delta t')$$

⇧ Gaussian-based resolution function.

- The resolution is consistent of **three** parts: $R(\Delta t) = R_{det} \otimes R_{np} \otimes R_k$

True Δt



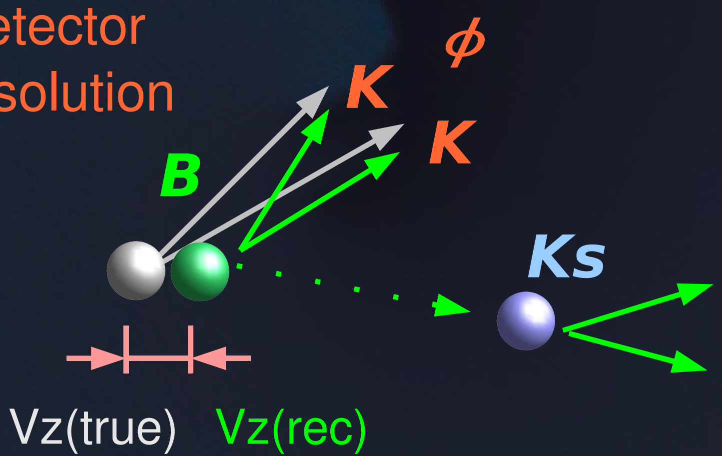


Measured Δt

Understanding the Δt

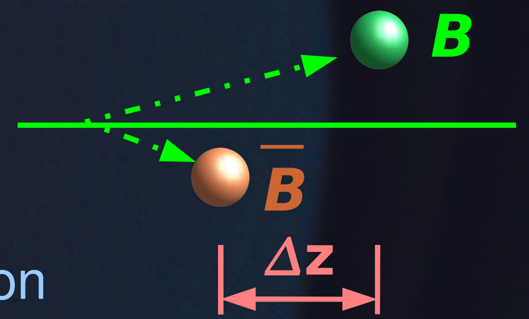
Resolution Function

R_{det} Detector resolution



R_k

Effects of kinematic approximation

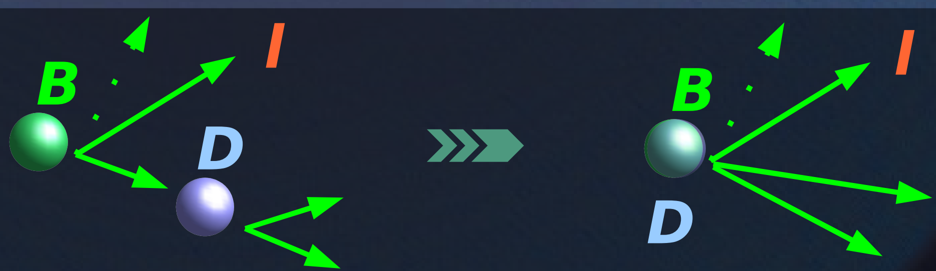


$$\Delta t \approx \Delta z / \beta\gamma c$$

$$\cancel{\Delta t \equiv \Delta z / \beta\gamma c}$$

R_{np}

Smearing due to non-primary tracks of the tag side

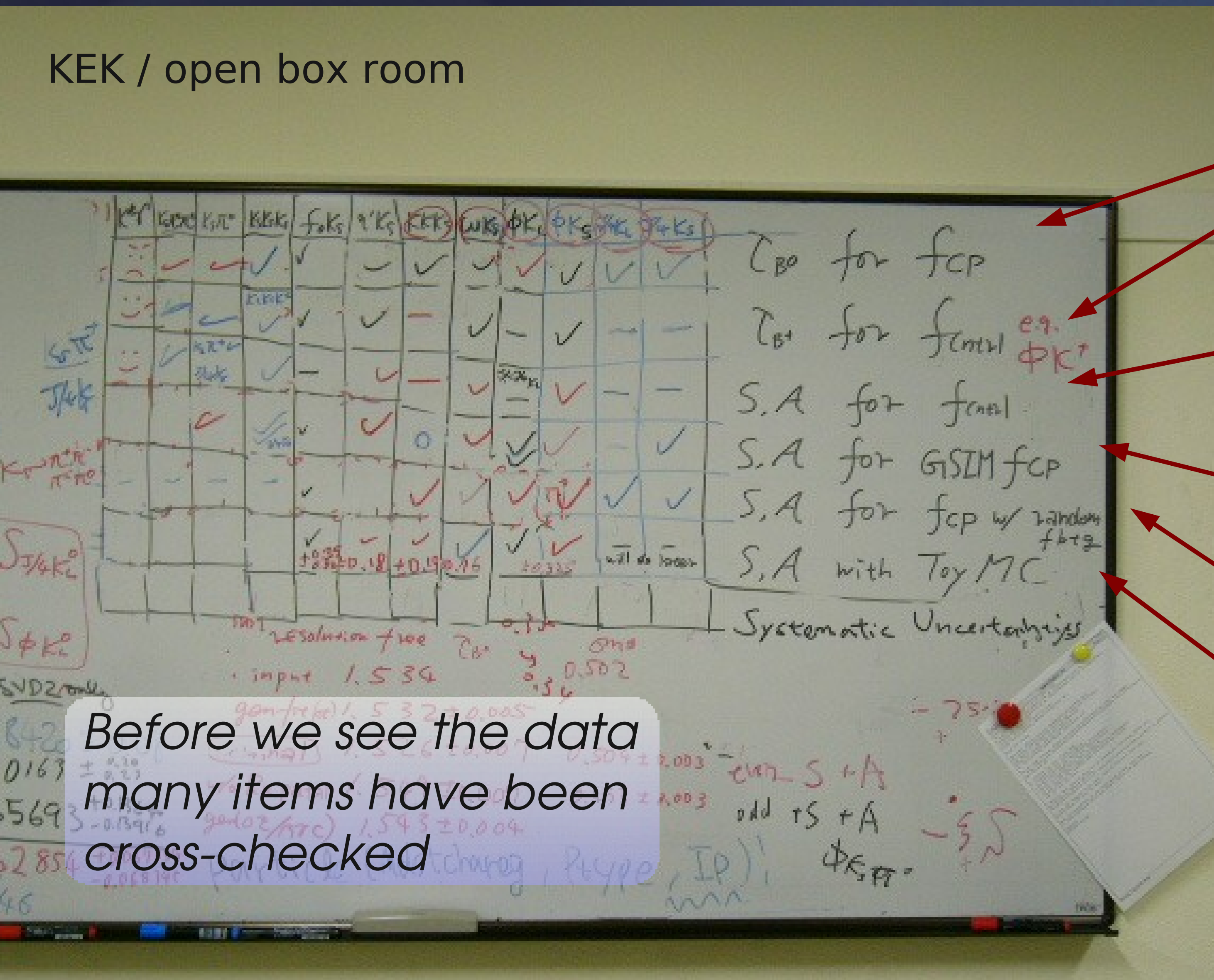


Non-primary tracks

All the tracks are starting from B-vertex

Check List

KEK / open box room



Before we see the data many items have been cross-checked

1) Lifetime of f_{CP}

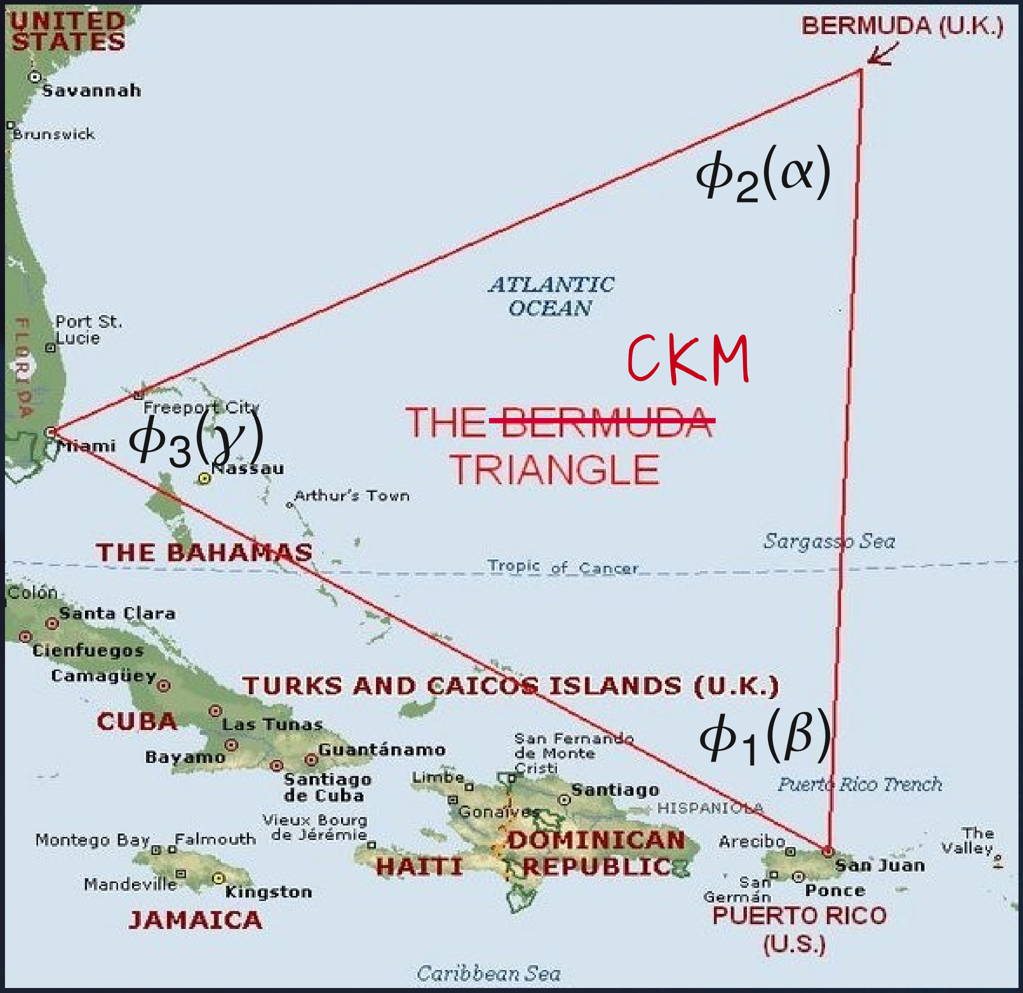
2) Lifetime of control sample

3) *CP*-fit with control sample

4) *CP*-fit with signal MC

5) *CP*-fit w/o flavor

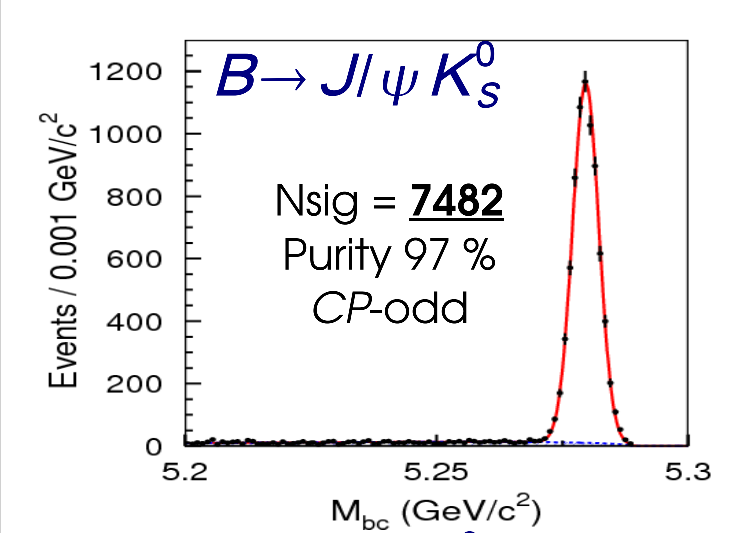
6) *CP*-fit w/ Toy MC

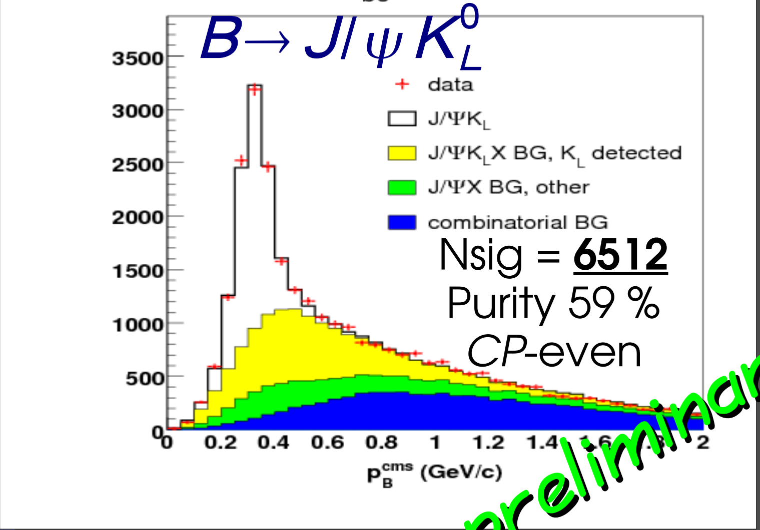


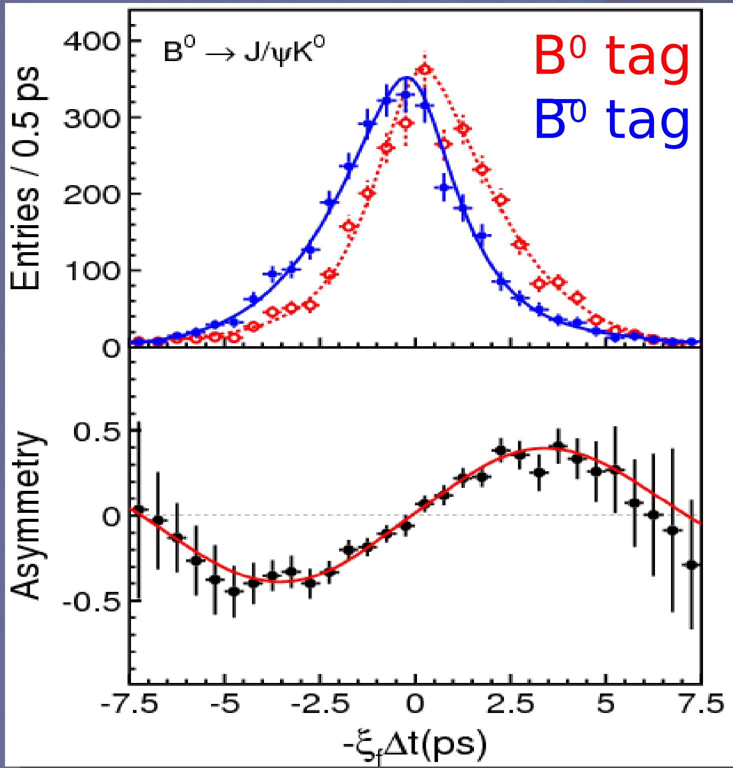
Measurements of the CKM Triangle

Measurement of $\sin 2\phi_1$

535M $B\bar{B}$ pairs





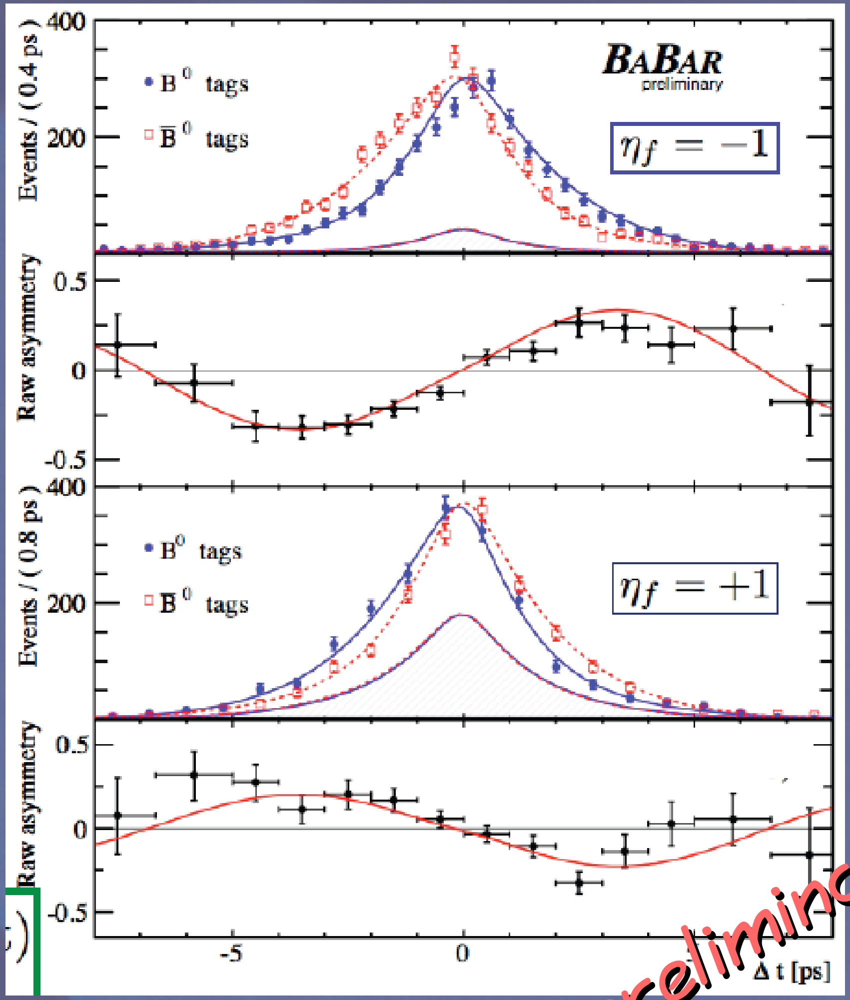


$\sin 2\phi_1 = 0.642 \pm 0.031$ (stat) ± 0.017 (syst)

$A = 0.018 \pm 0.021$ (stat) ± 0.014 (syst)

Measurement of sin2ϕ_1

347M *BB* pairs



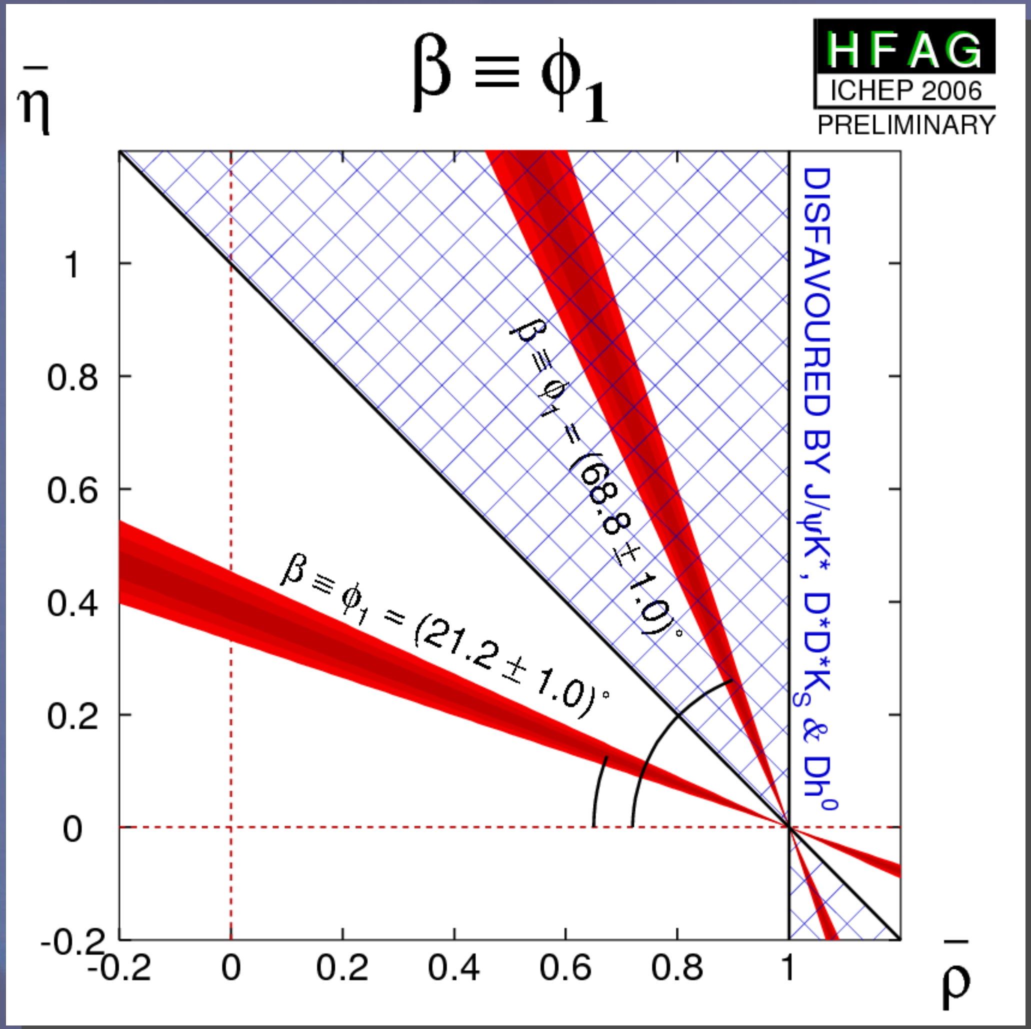
Included decays:

$B \to J/\psi K^0$
$B \to \psi(2S) K_S$
$B \to \eta_c K_S$
$B \to \chi_{c1} K_S$
$B \to J/\psi K^{*0}$

$\sin 2\phi_1 = 0.710 \pm 0.034 \pm 0.019$
$|\lambda| = 0.932 \pm 0.026 \pm 0.017$

$(A = -0.07 \pm 0.026 \pm 0.018)$

Measurement of “ϕ_1”



$\langle\sin 2\phi_1\rangle = 0.674 \pm 0.026$

- Time-dependent Dalitz analysis on $B^0 \to D^* D^* K_S$: $\cos 2\phi_1 > 0$ @ 94% C.L., (model-dependent)

BELLE

- Time-dependent Dalitz analysis on $B^0 \to D^0 h^0$: $\cos 2\phi_1 > 0$
  @ 98.3% C.L., (Belle)
  @ 87% C.L., (BaBar)

TCPV in $b \rightarrow s$ Transitions

- The Standard Model explains almost all observed *CP* asymmetries to date.
- But it is known to be **incomplete**.
- A good place to search for **physics beyond the SM** is provided by measuring the *CP* violation in **$b \rightarrow sqq$ penguin** processes, and compare it with the $b \rightarrow ccs$ decays.

$b \rightarrow c$ Tree

New Physics in the loop diagram!?

$\neq$?

$b \rightarrow s$ Penguins

$b \to s$ Sensitive Decays

ϕK_S / ϕK_L

☑ Smallest theoretical error
☑ Clean (K_S)

$\eta' K_S$ / $\eta' K_L$

☑ Largest BF
☑ Clean ($\eta' \to \eta\pi\pi$)

$K_S K_S K_S$

☒ Require special K_S vertex
☑ Clean, clear *CP* state

$K^+K^-K_S$ / $K^+K^-K_L$

☑ Large BF
☒ Unclear *CP* state

ωK_S

☒ Large theoretical error
☒ Dirty / Small signal

$f_0 K_S$

☒ Unclear f_0 resonance

$\pi^0 K_S$

☒ Require special K_S vertex tech.
☑ Supports $B \to K\pi$ DCPV ($\pi^0 K_S$)

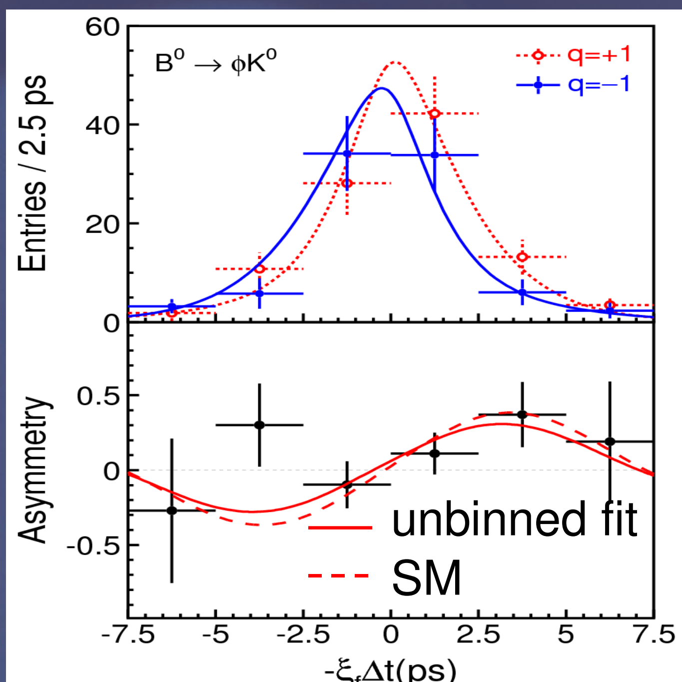
$\pi^0 \pi^0 K_S$

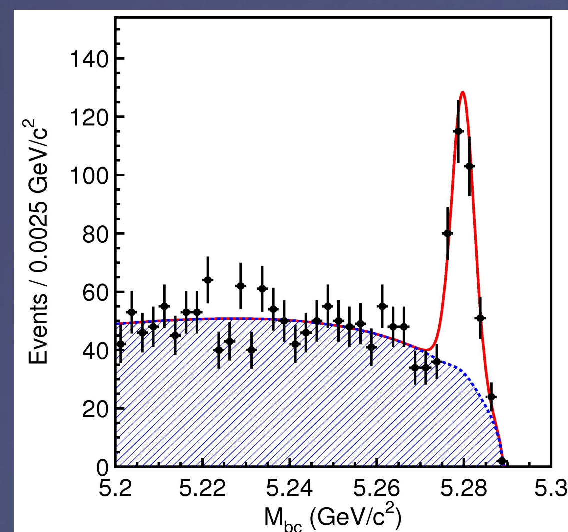
☒ Special K_S vertex tech.
☒ Very Dirty

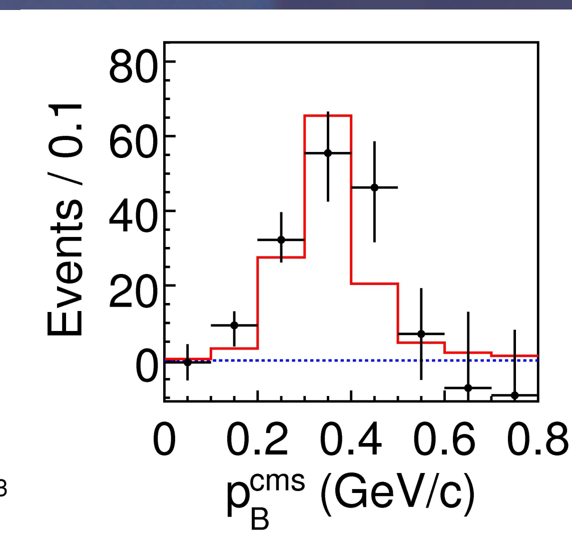
TCPV in $B \to \phi K^0$

535M BB pairs

Good Tags only & bkg. subtracted







$N(\phi K_S) = 307 \pm 21$

$N(\phi K_L) = 114 \pm 17$

"$\sin 2\phi_1$" $= 0.50 \pm 0.21 \pm 0.06$

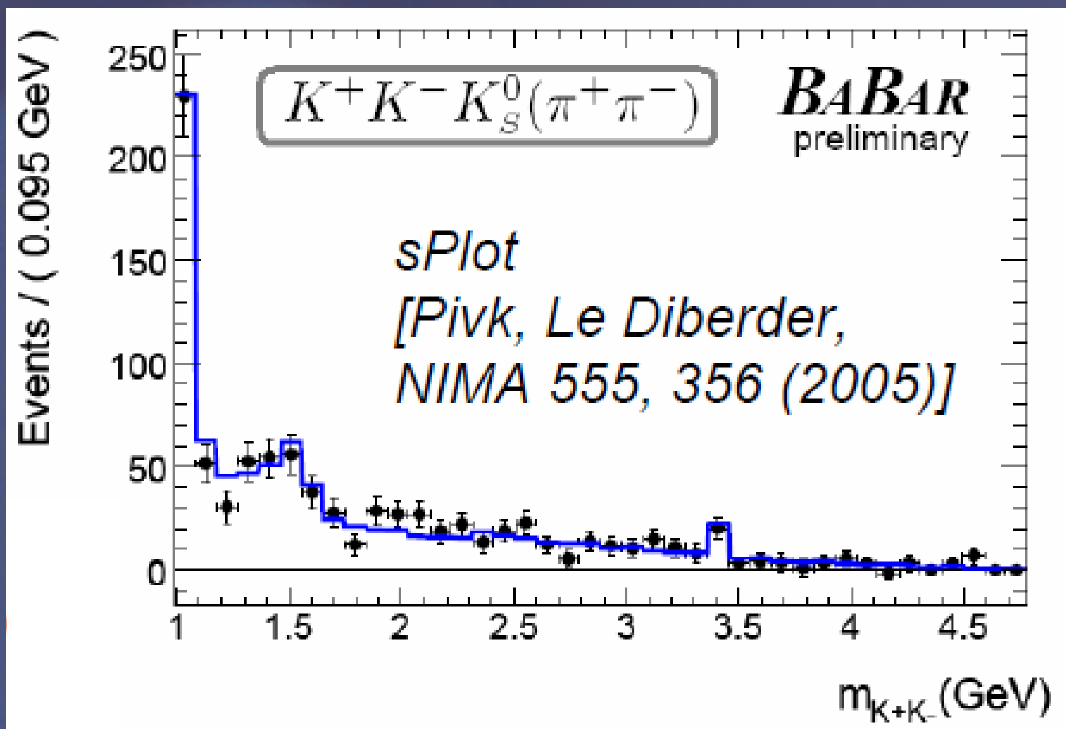
A $= 0.07 \pm 0.15 \pm 0.05$

preliminary

- Consistent with SM prediction (~1σ).
- Consistent with Belle 2005 result *($S = 0.44 \pm 0.27 \pm 0.05$)*

TCPV in $B \to KKK^0$ Dalitz

347M BB pairs



Model=
$\phi(1020)K + f_0(980)K + NR +$
$X_0(1550)K + \chi_{c0}K + DK + D_sK$

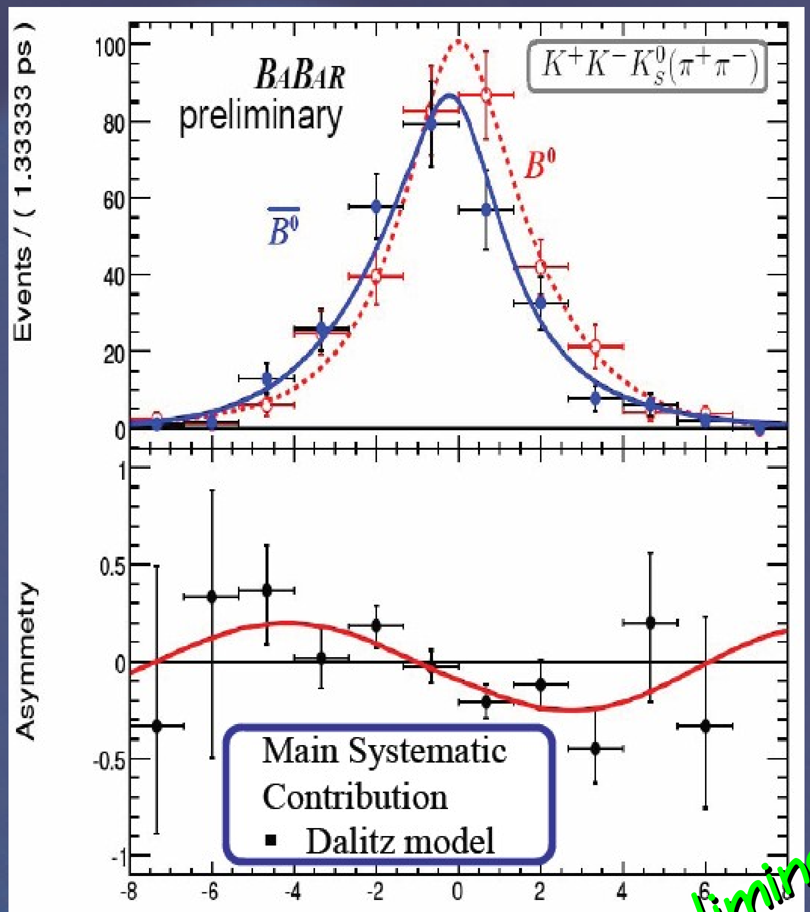
$N(K^+K^-K^0) = 1516 \pm 65$

$$\begin{cases} B^0 \to K^+K^-K^0_S(\pi^+\pi^-) \\ B^0 \to K^+K^-K^0_S(\pi^0\pi^0) \\ B^0 \to K^+K^-K^0_L \end{cases}$$

- Obtain *CP* parameters for 2-body and 3-body modes simultaneously by time-dependent Dalitz fits.
- Fit to the low mass region in order to obtain the CPV parameters for ϕK_S and $f_0(980)K_S$.

TCPV in $B \to KKK^0$ Dalitz

347M BB pairs



preliminary

- Measurement on ϕ_1 (not $\sin 2\phi_1$) w/ full region:

$$Acp = -0.034 \pm 0.079 \pm 0.025$$
$$\phi_1^{eff} = 0.361 \pm 0.079 \pm 0.037$$

- Fits to low mass region:

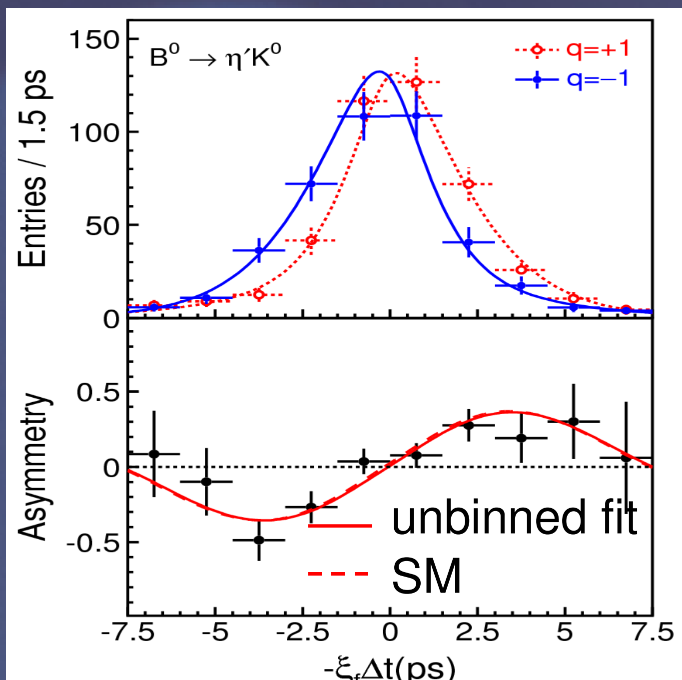
$$Acp(\phi K^0) = -0.18 \pm 0.20 \pm 0.10$$
$$\phi_1^{eff}(\phi K^0) = 0.06 \pm 0.16 \pm 0.05$$
$$Acp(f_0 K^0) = 0.45 \pm 0.28 \pm 0.10$$
$$\phi_1^{eff}(f_0 K^0) = 0.18 \pm 0.19 \pm 0.04$$

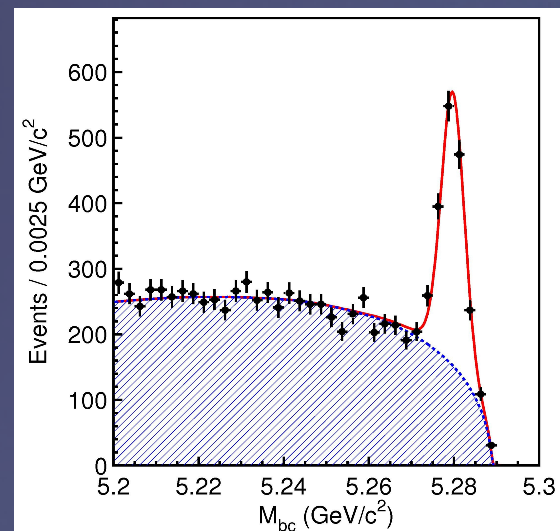
$$\sin 2\phi_1(\phi K^0) = +0.12 \pm 31 \pm 0.10$$

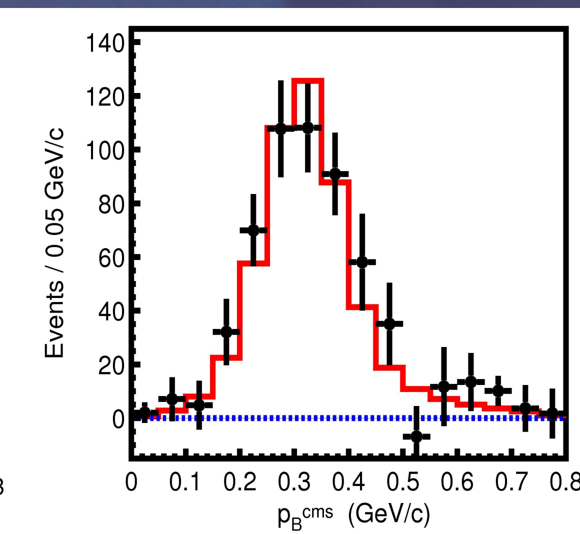
TCPV in $B \to \eta' K^0$

535M $B\bar{B}$ pairs

⇩ Good Tags only & bkg. subtracted







$N(\eta' K_S) = 1421 \pm 46$ $N(\eta' K_L) = 454 \pm 39$

"$\sin 2\phi_1$" $= 0.64 \pm 0.10 \pm 0.04$

$A = -0.01 \pm 0.07 \pm 0.05$

preliminary

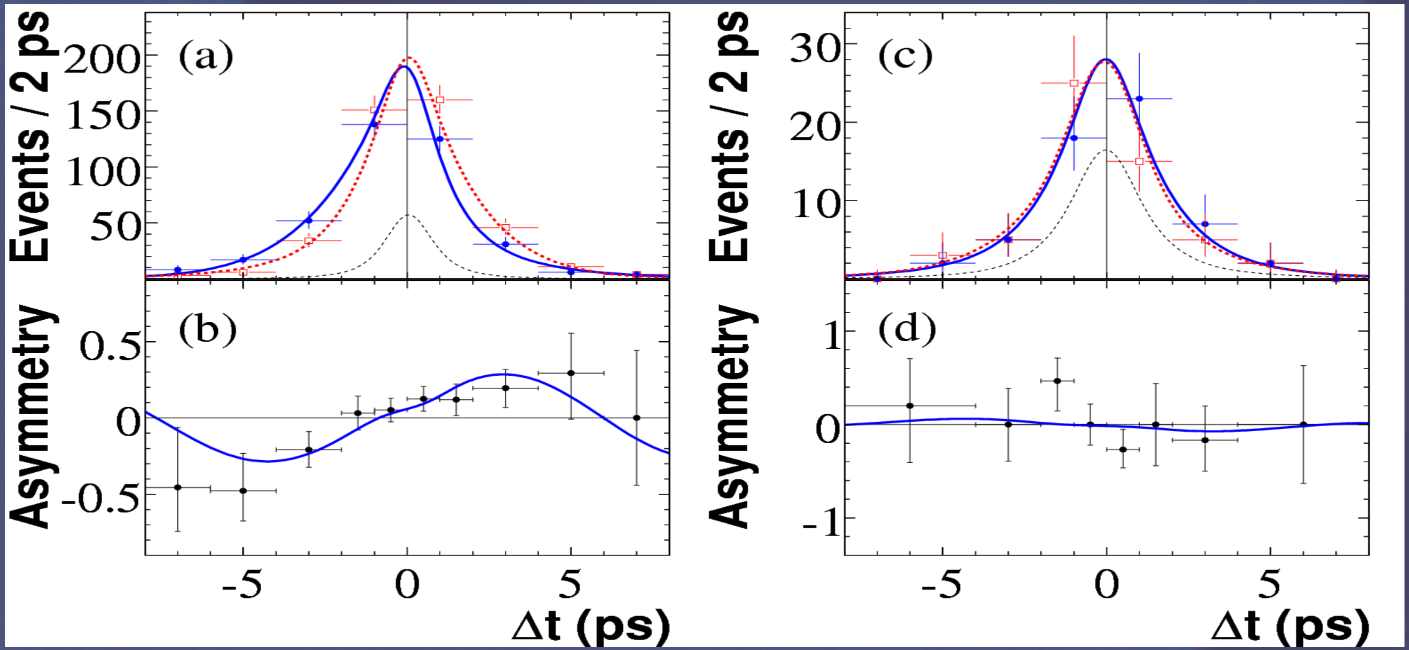
- First observation of TCPV (5.6σ) in a single $b \to s$ decay mode.
- Consistent with SM prediction.

TCPV in $B \to \eta' K^0$

384M BB pairs

$N(\eta' K_s) = 1038 \pm 44$ $N(\eta' K_L) = 204 \pm 24$

$\eta' K_S$



$\eta' K_L$

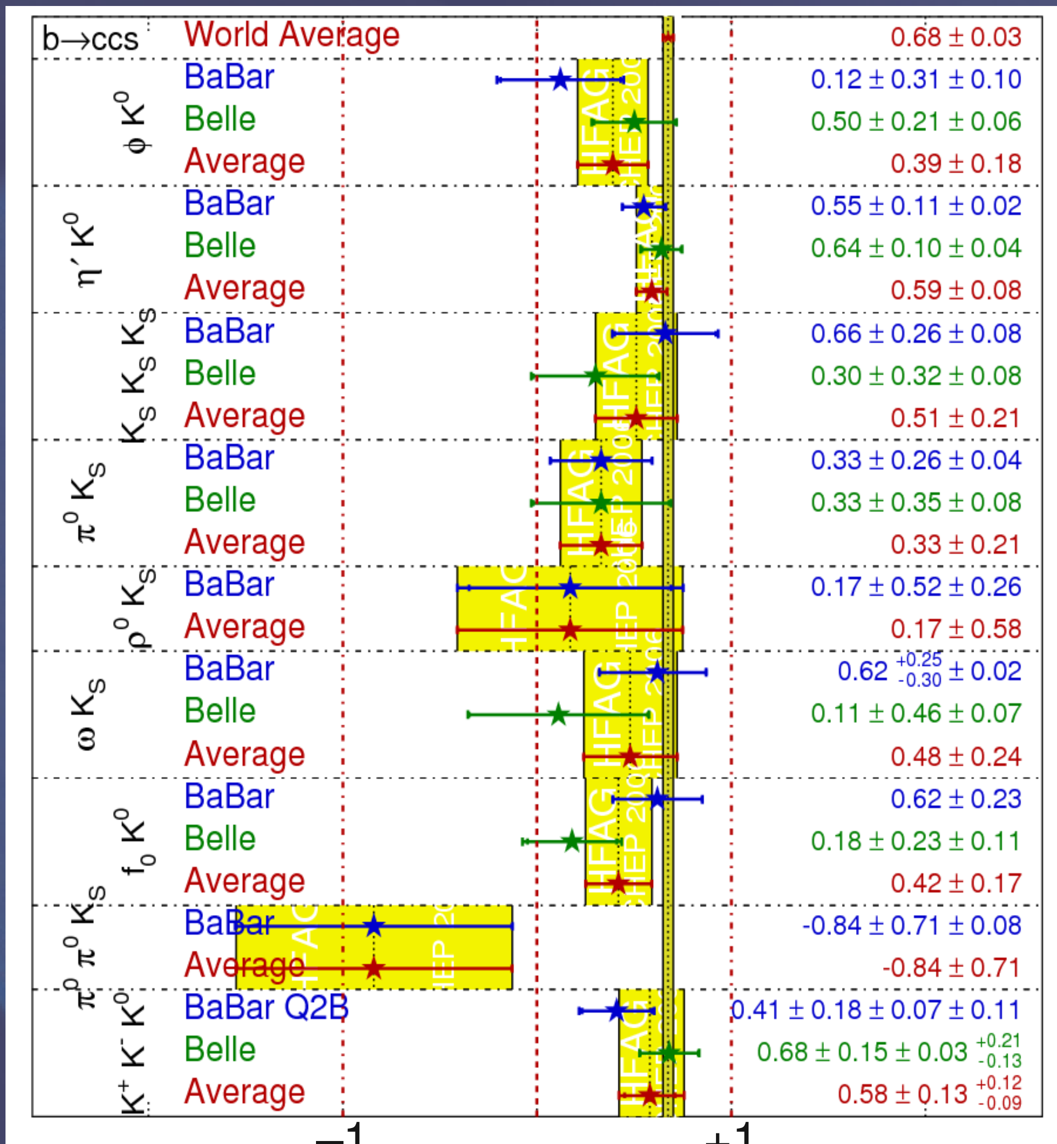
"$\sin 2\phi_1$" = 0.58 ±0.10 ±0.03

A = 0.16 ±0.07 ±0.03

preliminary (2006 September)

- 5.5σ away from zero.
- Consistent with SM prediction.

Other Penguin Modes



HFAG summer 2006 results

All measured values are smaller than the $\sin 2\phi_1$ from $b \to ccs$ decays.

Naïve average:
S(penguins) = 0.52 ± 0.05
(~2.6σ from S(b→ccs))

- The same analysis has been applied to 9 decay modes.
- More statistics are required for mode-by-mode studies.

Signature on δS_f

- Even in the Standard Model, the expectations on S_f are not exactly equal to $\sin 2\phi_1$. e.g. the $b \to u$ penguin is neglected, etc.
- Most of the measurements on δS are negative and small. How about the theory?
  - δS bound from SU(3) relations
    - ➡ use the SU(3) relations to estimate the amplitudes $\propto V_{ub}^* V_{us}$
    - ➡ providing boundaries on δS_f and A_f.
  - Factorization approaches:
    - ➡ annihilation, vertex corrections, final state interactions, etc.
    - ➡ providing model-dependent estimations on δS_f.

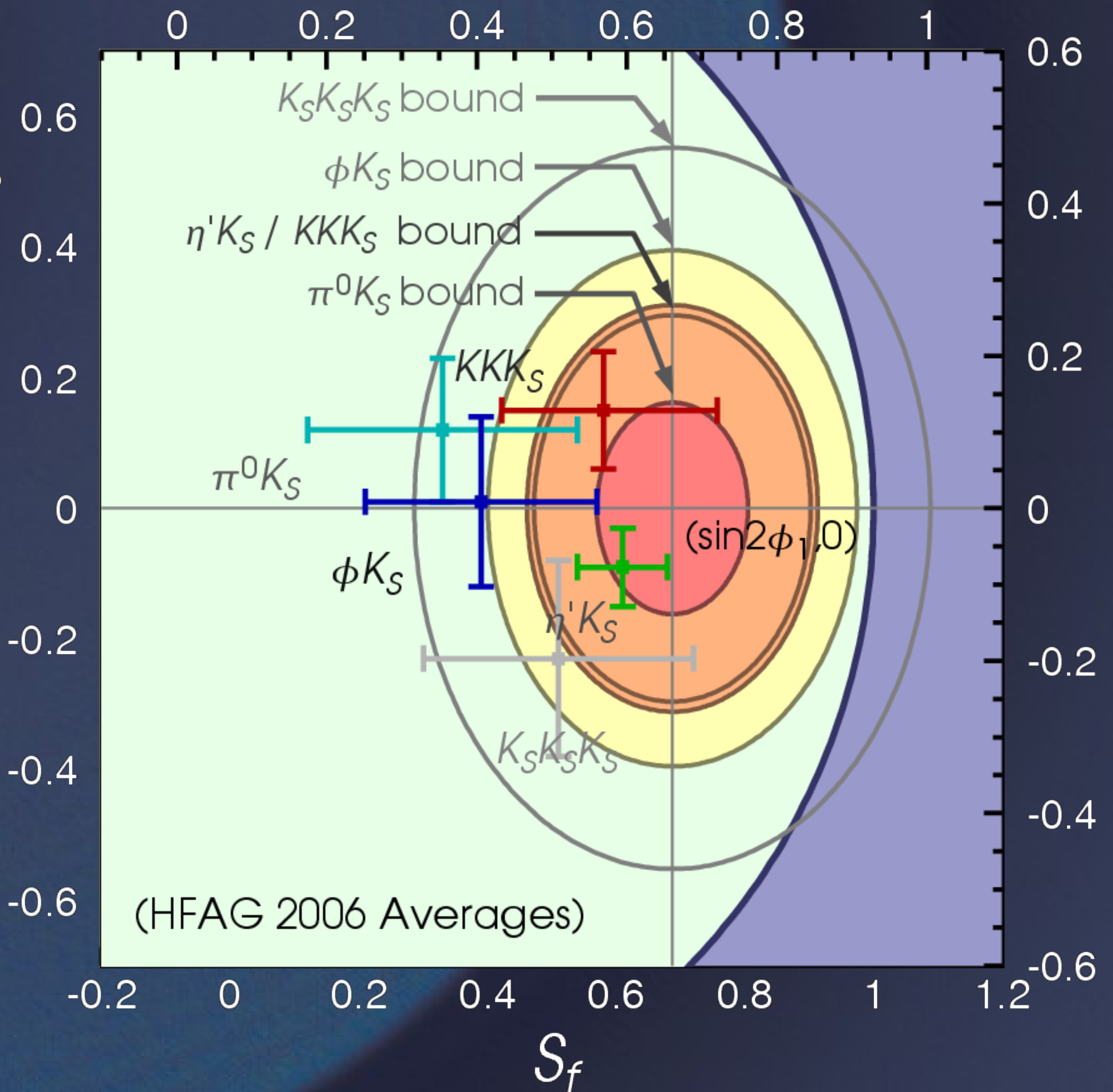
δS_f Bounds from SU(3) Relations

- SU(3) relations based on various charmless branching fractions. *(from HFAG 2006 summer)*.

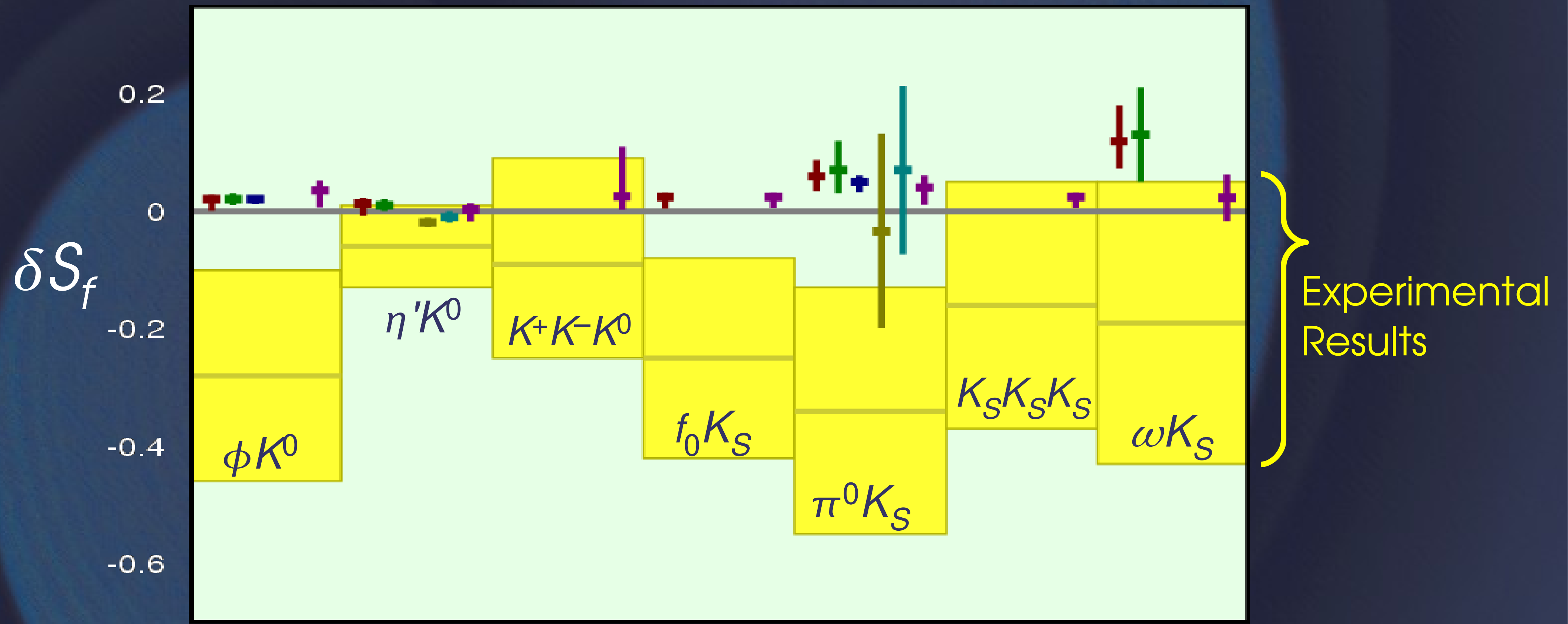
[Grossman, PRD68 (2003),015004]
[Gronau, PLB579 (2004), 331-339]
[Engelhard, PRD72 (2005) 075013]

$$C_f^2+\left[\frac{\eta_f S_f+\sin 2\phi_1}{\cos 2\phi_1}\right]^2=4\sin^2\phi_3|\xi_f|^2$$

$$(\phi_3\approx 63^\circ, \sin 2\phi_1=0.674)$$

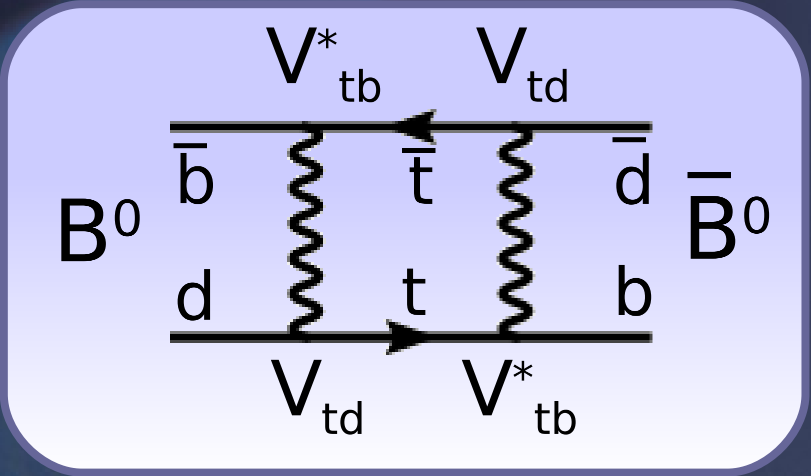


Factorization Approaches



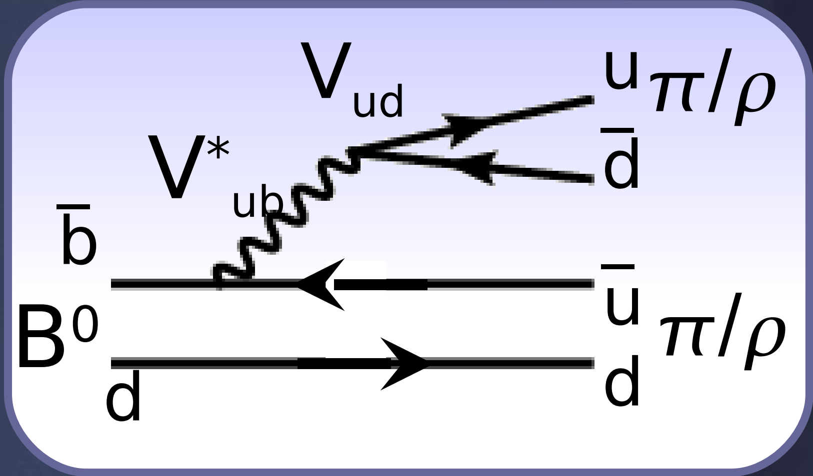
■ QCDF (Cheng-CKC-Soni), ■ QCDF+FSI (Cheng-CKC-Soni)
■ QCDF (Beneke), ■ pQCD (Mishima-Li)
■ SCET (Williamson-Zupan) Solution 1 / ■ Solution 2

Measurement of ϕ_2



Mixing diagram

$\otimes$



Decay diagram (tree)

Probing CKM angle ϕ_2 in three directions:

- $B \to \pi^+\pi^-, \pi^\pm\pi^0, \pi^0\pi^0$ +TCPV & BR
- $B \to \rho^+\rho^-, \rho^\pm\rho^0, \rho^0\rho^0$ +TCPV + Angular Ana.
- $B \to \rho^+\pi^-, \rho^0\pi^0$ +TCPV + Dalitz

TCPV in $B \to \pi^+\pi^-$

Time-dependent CP asymmetry in $B \to \pi^+\pi^-$:

$$A_{CP}(t) = A_{\pi\pi}\cos(\Delta m t) + S_{\pi\pi}\sin(\Delta m t)$$

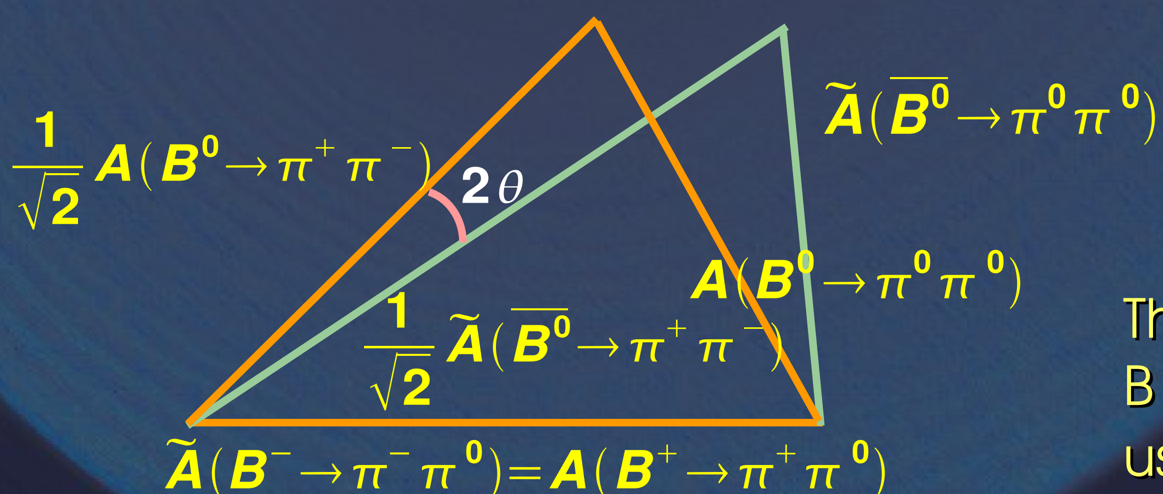
$$\lambda = e^{2i\phi_2}$$
$$A_{\pi\pi} = 0$$
$$S_{\pi\pi} = \sin 2\phi_2$$

Tree only

$$\lambda = e^{2i\phi_2}\frac{1+|P/T|e^{i\delta}e^{i\gamma}}{1+|P/T|e^{i\delta}e^{-i\gamma}}$$
$$A_{\pi\pi} \propto \sin\delta$$
$$S_{\pi\pi} = \sqrt{1-A_{\pi\pi}}\sin 2\phi_2^{eff}$$

Tree + Penguin

Related to ϕ_2
(isospin analysis required)



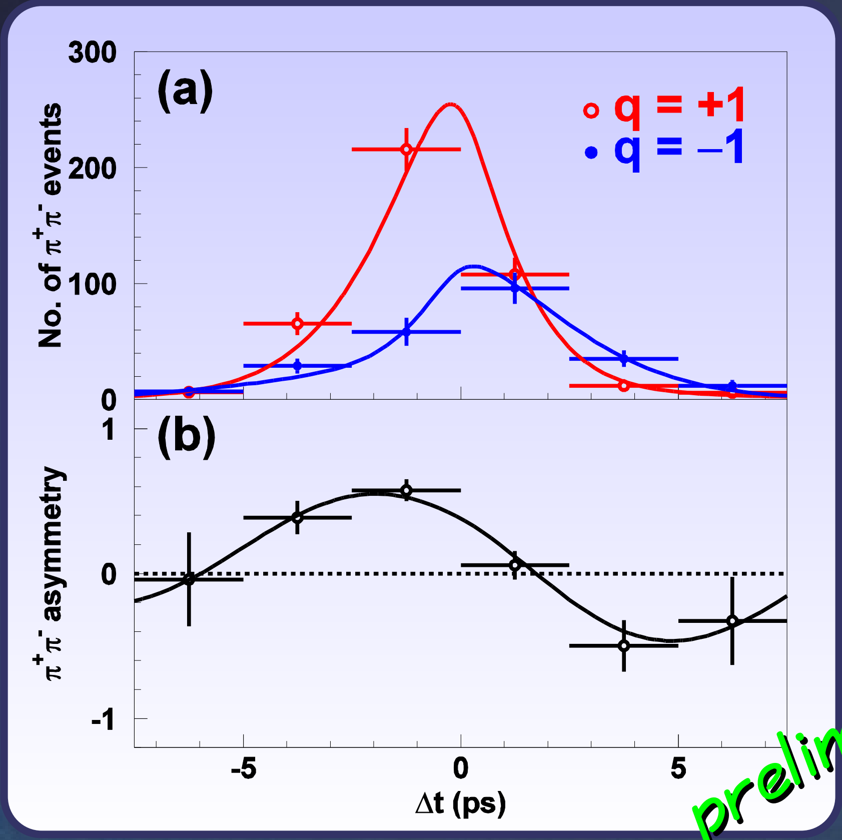
$$\theta = |\phi_2 - \phi_2^{eff}|$$

The branching fractions of $B \to \pi^+\pi^-/\pi^+\pi^0/\pi^0\pi^0$ can be used to constrain ϕ_2

TCPV in $B \to \pi^+\pi^-$

535M *BB* pairs

background subtracted

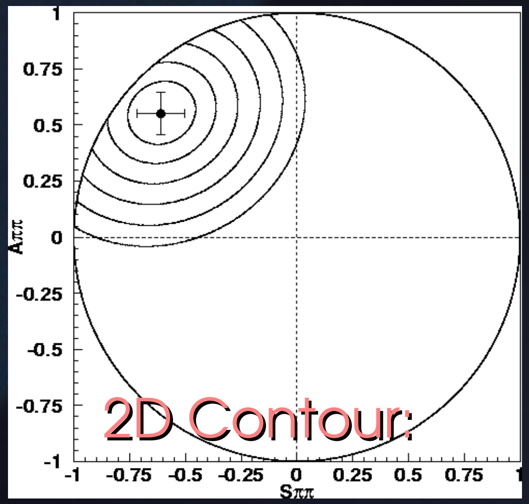


preliminary

$N(B \to \pi^+\pi^-) = 1464 \pm 65$

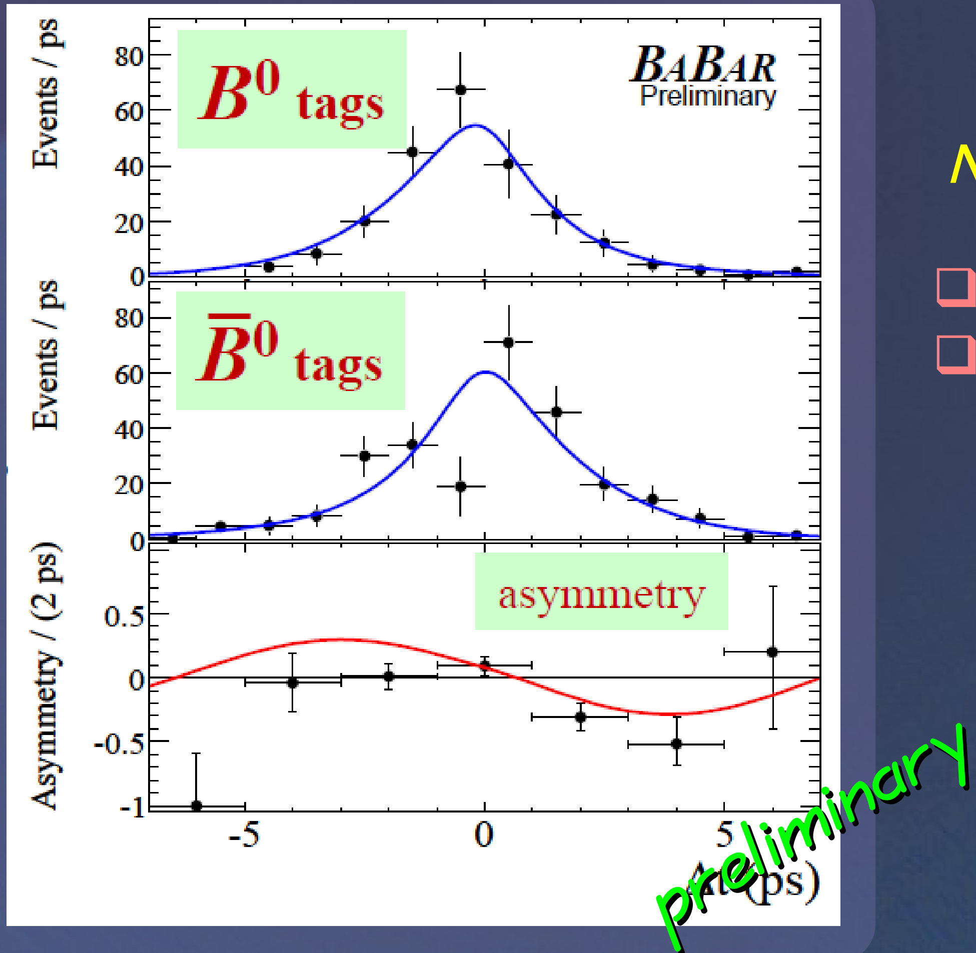
- Large direct *CP* violation (5.5σ).
- Large mixing-induced *CP* violation (5.6σ).

$A\pi\pi$ = 0.55 ±0.08(stat) ±0.05(syst.)
$S\pi\pi$ = –0.61 ±0.10(stat) ±0.04(syst.)



TCPV in $B \to \pi^+\pi^-$

347M BB pairs

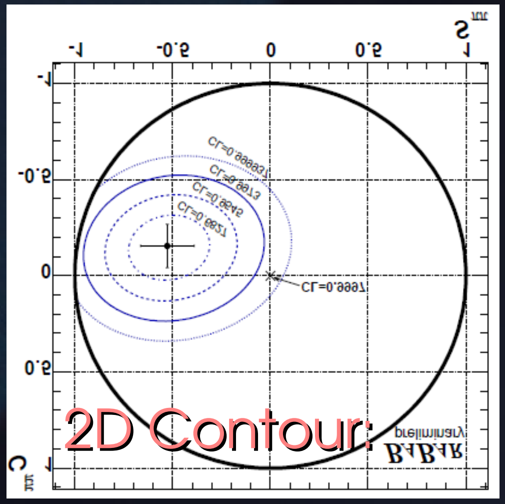


$N(B \to \pi^+\pi^-) = 675 \pm 42$

- Evidence for *CP* violation (3.6σ).
- No direct CP violation.

$A\pi\pi = 0.16 \pm 0.11(\text{stat}) \pm 0.03(\text{syst.})$

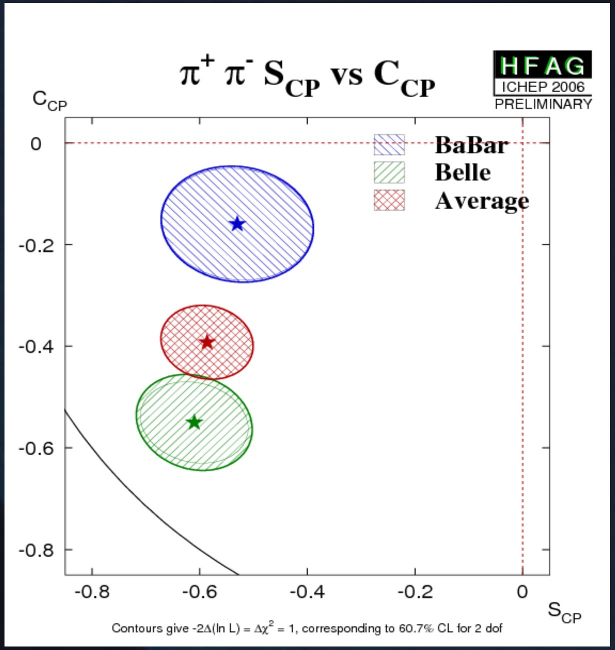
$S\pi\pi = -0.53 \pm 0.14(\text{stat}) \pm 0.02(\text{syst.})$

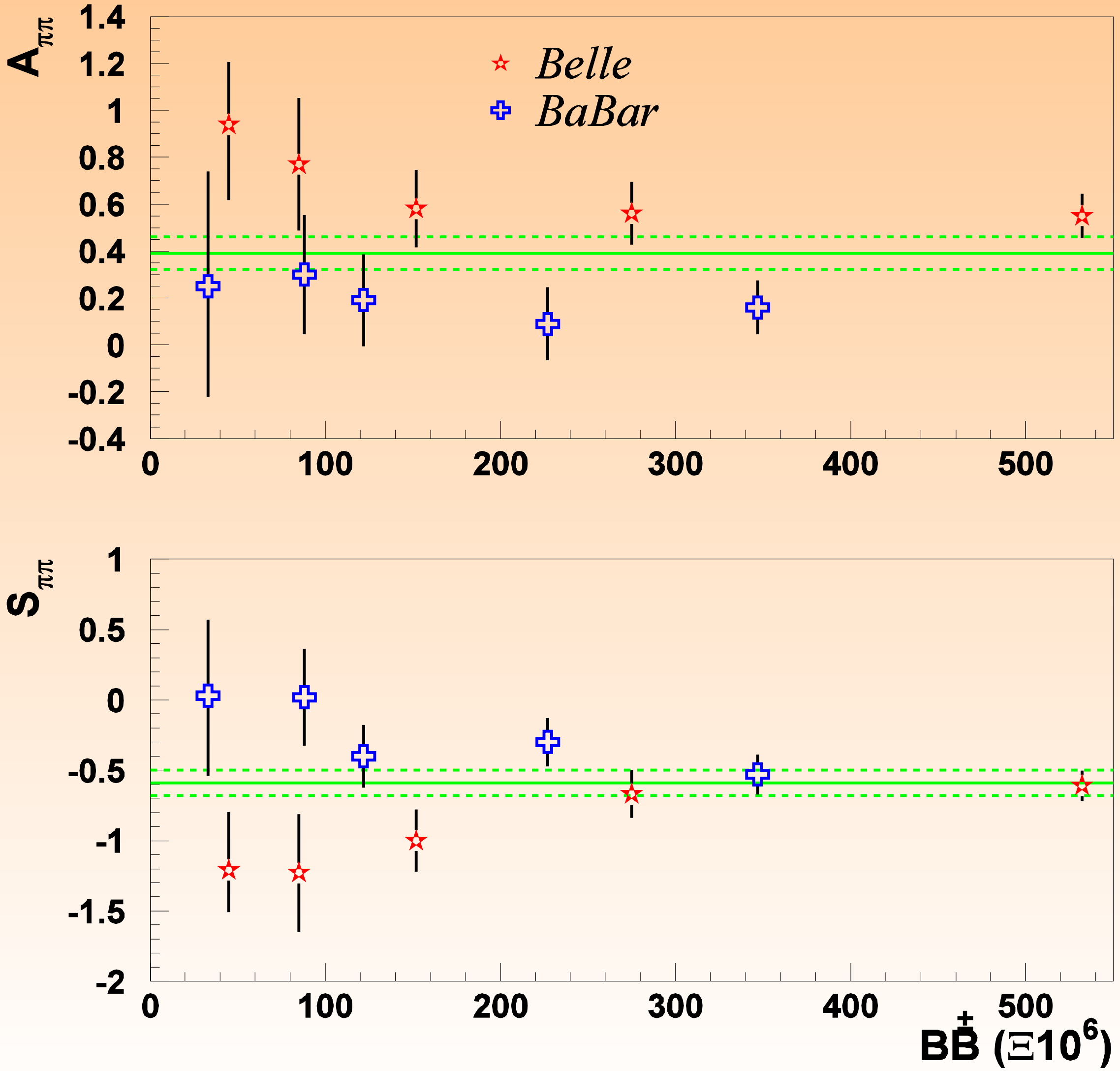


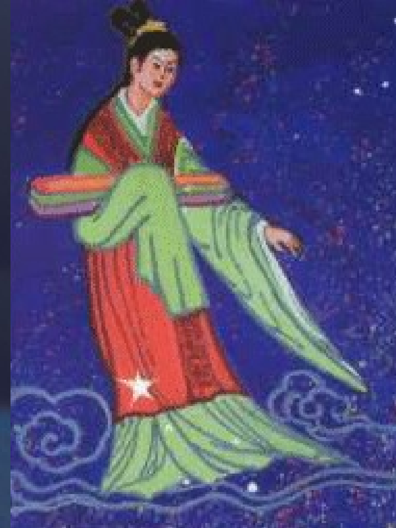
TCPV in $B \to \pi^+\pi^-$

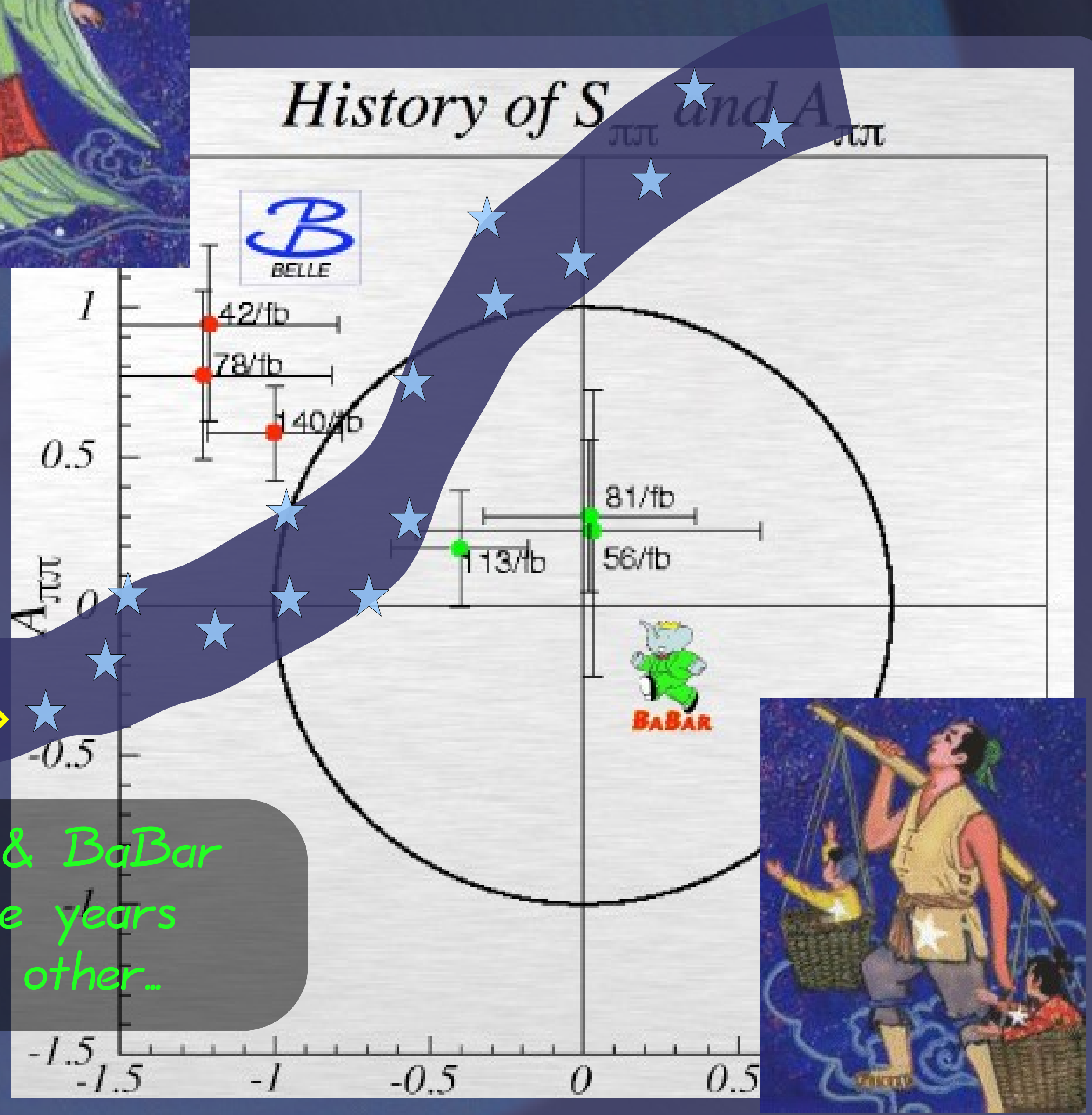
- Brief history of Belle & Babar measurements:

2.3σ difference between Belle & BaBar





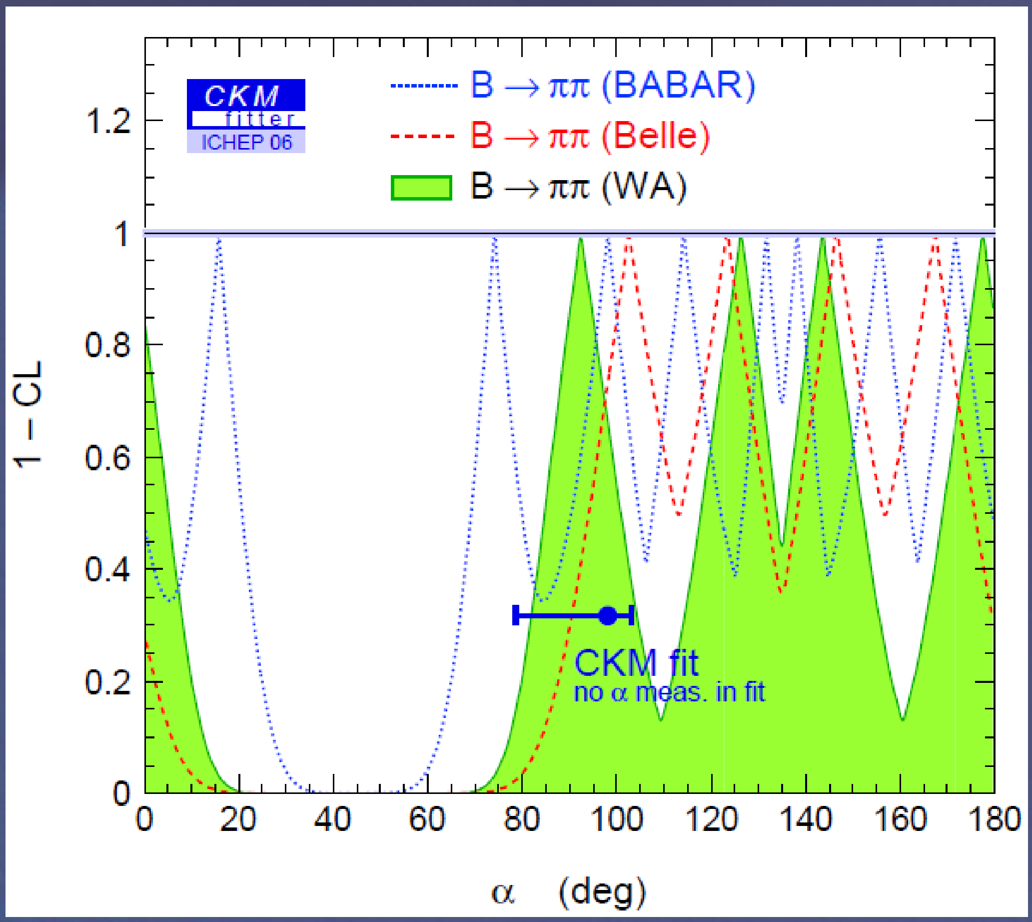




The Milky Way ⇨

Probably, Belle & BaBar
need few more years
to meet each other...

Measurement of ϕ_2



Inputs:

$BR(B\to\pi^+\pi^0)=5.75\pm0.42\times10^{-6}$

$BR(B\to\pi^+\pi^-)=5.20\pm0.25\times10^{-6}$

$BR(B\to\pi^0\pi^0)=1.30\pm0.21\times10^{-6}$

$A_{CP}(B\to\pi^0\pi^0)=+0.35\pm0.33$

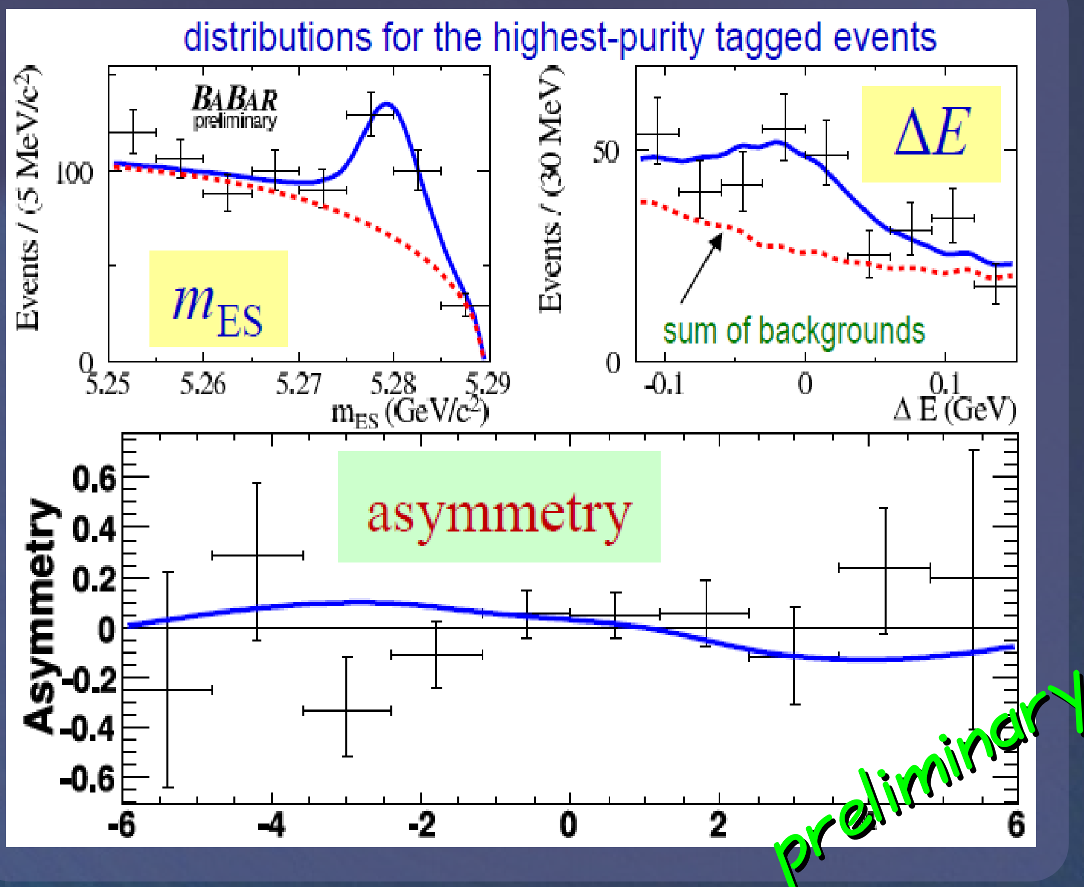
$S(B\to\pi^+\pi^-)=-0.59\pm0.09$

$A(B\to\pi^+\pi^-)=+0.39\pm0.07$

- No stringent constraint obtained (many solutions!)
  - require $\rho\pi/\rho\rho$ systems to solve it.

TCPV in $B \to \rho^+\rho^-$

347M *BB* pairs



$N(B \to \rho^+\rho^-) = 615 \pm 57$

- BR($\rho^+\rho^-$) > BR($\pi^+\pi^-$).
- BR($\rho^0\rho^0$) < BR($\pi^0\pi^0$) (i.e. smaller penguin!)
- $f_L = 0.977 \pm 0.024$ (i.e. ~ pure *CP*-even state, no needs of time-dependent angular analysis!)

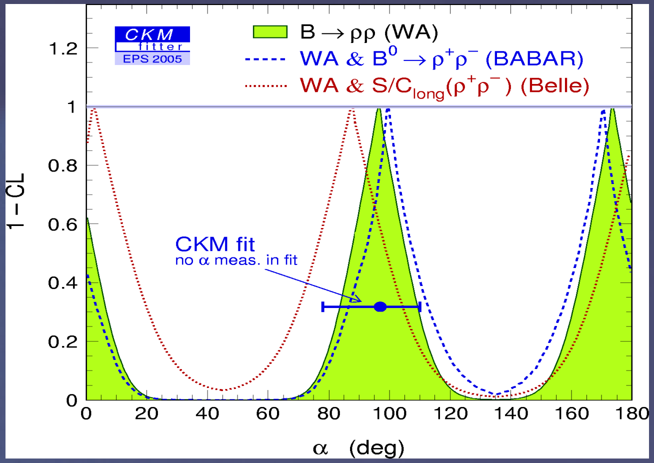
$S_{Long} = -0.19 \pm 0.21(\text{stat}) {}^{+0.05}_{-0.07}(\text{syst.})$
$C_{Long} = -0.07 \pm 0.15(\text{stat}) \pm 0.06(\text{syst.})$

BELLE 275M Result:

$S_{Long} = 0.08 \pm 0.41 \pm 0.09$
$C_{Long} = 0.00 \pm 0.30 \pm 0.09$

Measurement of ϕ_2

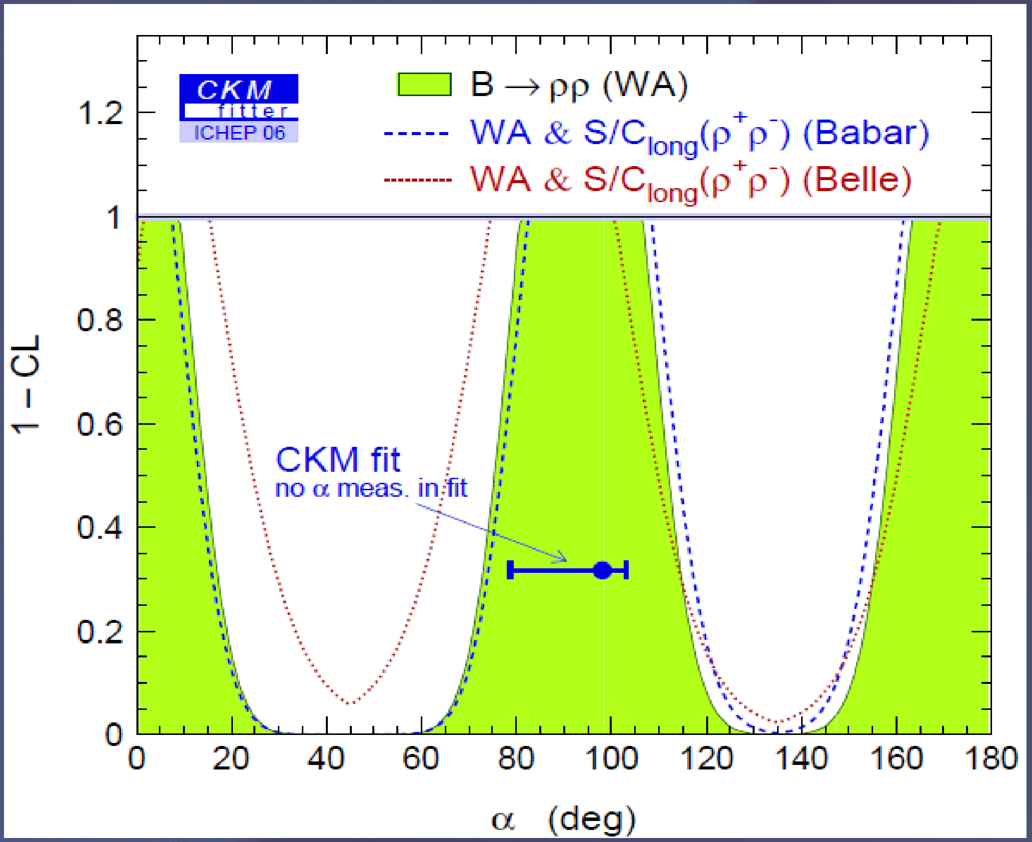
EPS'2005 Result



The constraint become less stringent.

(The isospin triangle now closed with new $\rho^+\rho^0$ branching fraction.)

ICHEP'2006 Result



New Inputs:

$$BR(B\to\rho^+\rho^-)=23.1^{+3.1}_{-3.2}\times10^{-6}$$

$$BR(B\to\rho^+\rho^0)=18.2\pm3.0\times10^{-6}$$

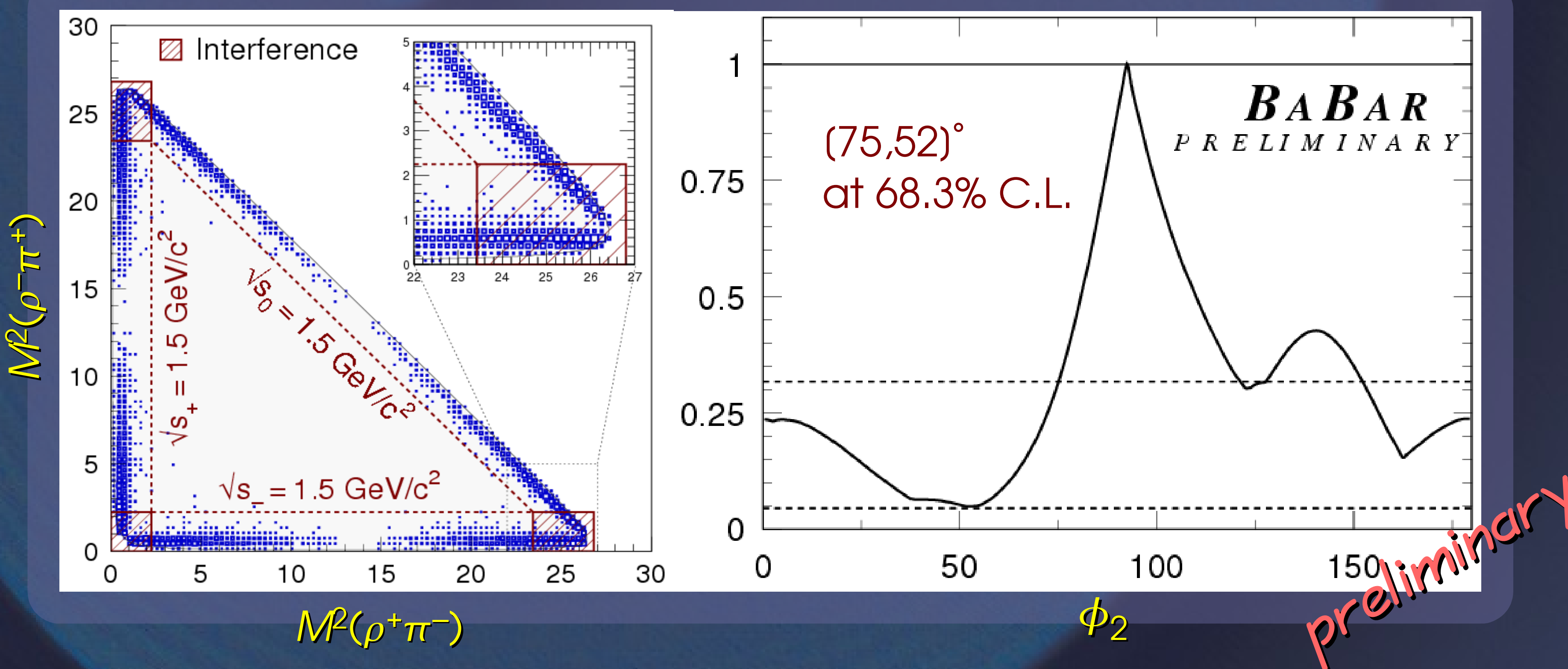
$$A_{CP}(B\to\rho^+\rho^0)=-0.08\pm0.13$$

$$BR(B\to\rho^0\rho^0)=1.2\pm0.5\times10^{-6}$$

TCPV + Dalitz in $B \to \rho\pi$

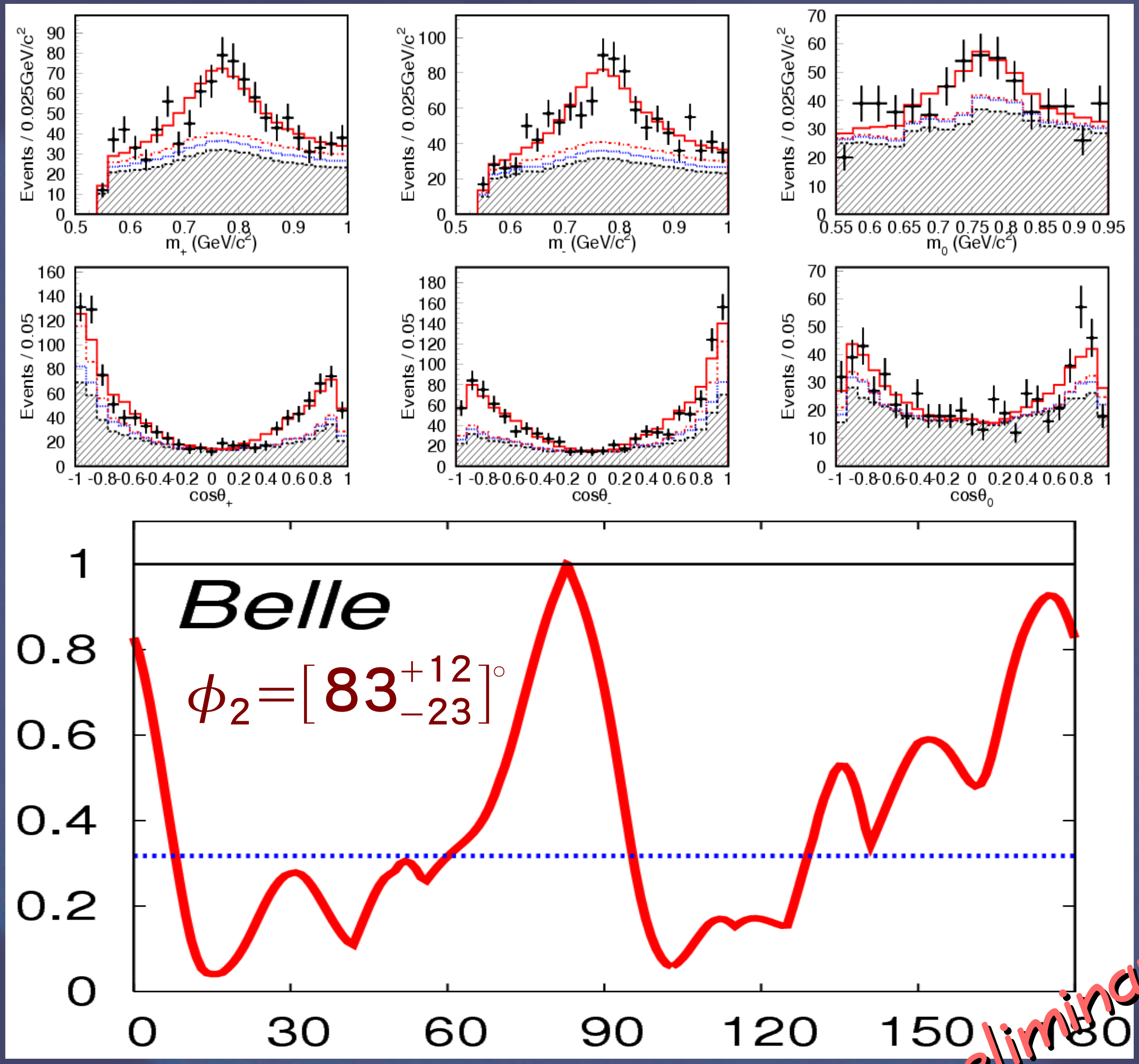
347M BB pairs

Time-dependent Dalitz-plot analysis assuming isospin symmetry, measureing 26 coefficients of the bilinear form factors
(A.Snyder, H. Quinn, Phys. Rev. D, 48, 2139 (1993))

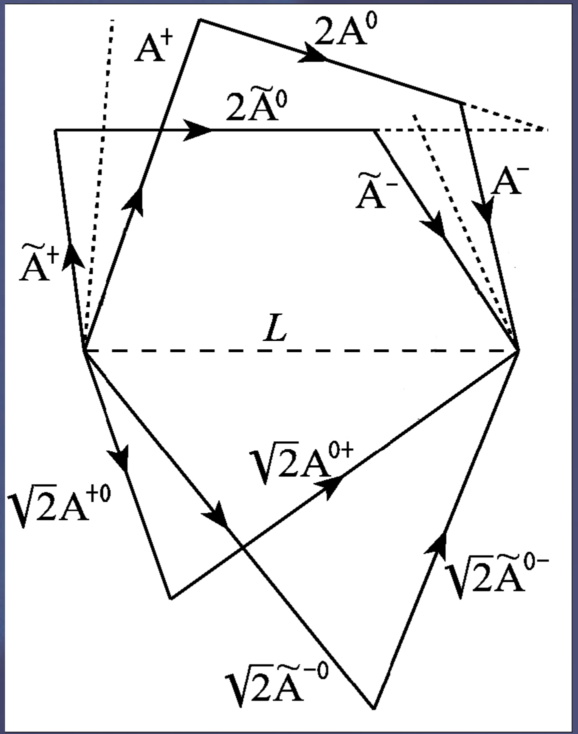


TCPV + Dalitz in $B \to \rho\pi$

447M BB pairs



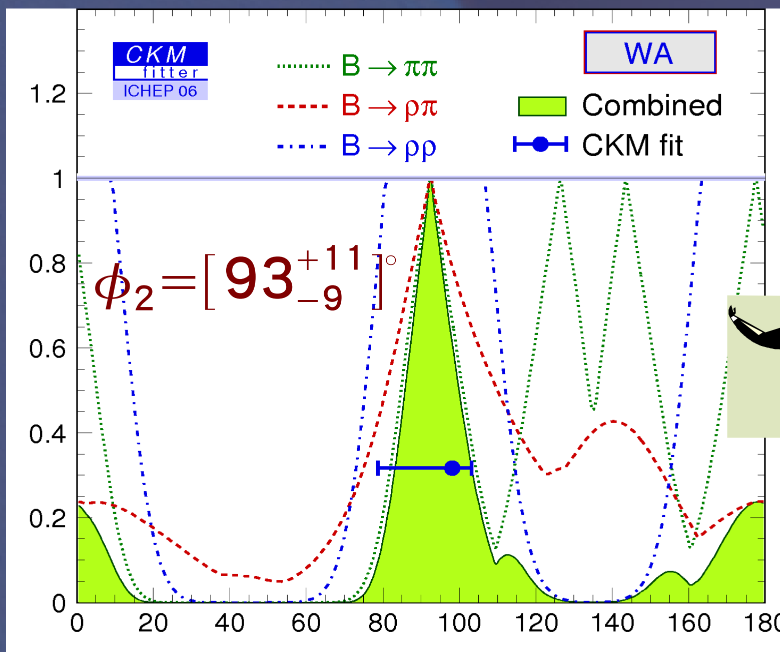
- Time-dependent Dalitz analysis + isospin (pentagon) analysis ⇩



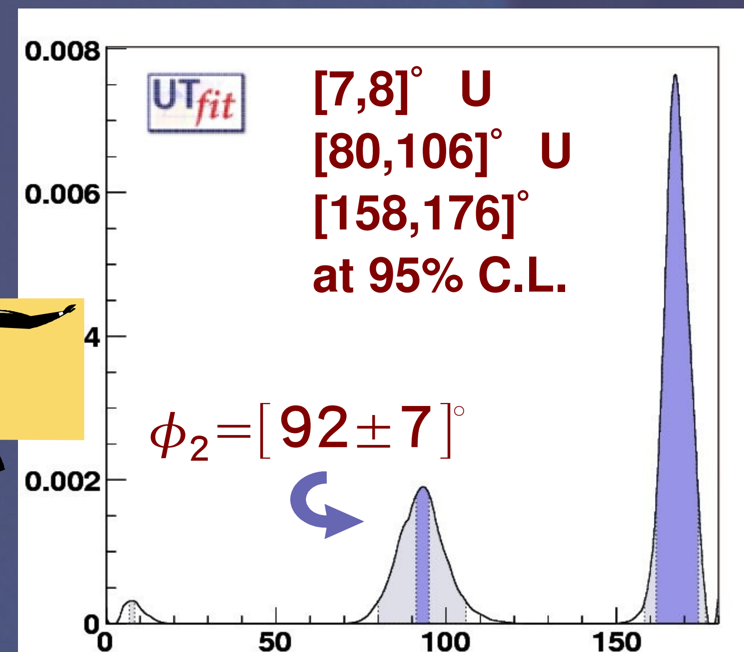
ϕ_2 World Average

Averages from BaBar's $\pi\pi/\rho\rho/\rho\pi$ and Belle's $\pi\pi/\rho\rho[/\rho\pi]$:

CKMFitter



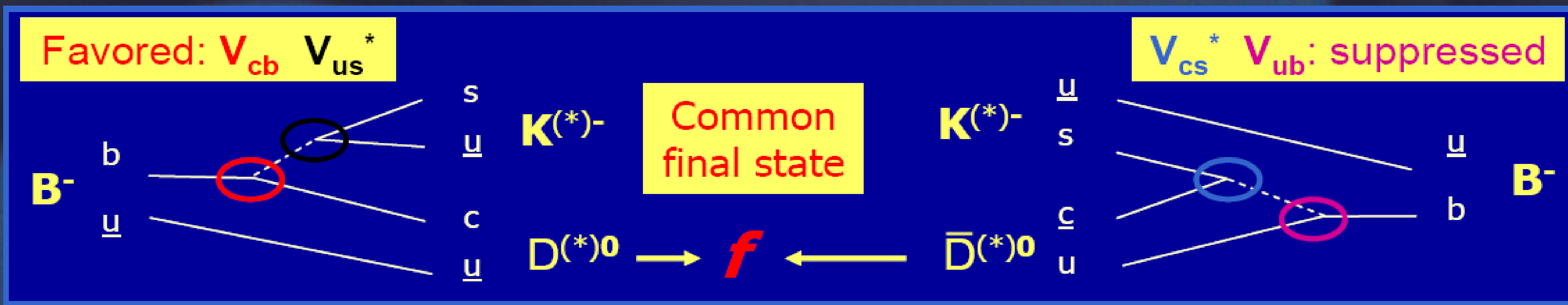
UTFit



- ❑ Unmatched CKMFitter & UTFit results.
- ❑ Ambiguity @ 90 or 180 degrees ($\rho\pi$ is sensitive to this issue).
- ❑ Need to include Belle's $\rho\pi$ result for CKMFitter.

Measurement of ϕ_3

Interference between $B \to DK$ and $B \to \bar{D}K$:



$$A\left(\frac{B^- \to \bar{D}^0 K^-}{B^- \to D^0 K^-}\right) = \boxed{r_B} \cdot \exp(i\,\boxed{\delta_B}) \cdot \exp(-i\,\boxed{\phi_3})$$

Mode-by-mode para. Common CKM angle

Three methods for exploiting interference (choice of D^0 decay modes):

- Gronau, London, Wyler (GLW): Use CP eigenstates of $D^{(*)0}$ decay, e.g. $D^0 \to K_s\pi^0$, $D^0 \to \pi^+\pi^-$
- Atwood, Dunietz, Soni (ADS): Use doubly Cabibbo-suppressed decays, e.g. $D^0 \to K^+\pi^-$
- Giri, Grossman, Soffer, Zupan (GGSZ) / Belle: Use Dalitz plot analysis of 3-body D^0 decays, e.g. $K_s\pi^+\pi^-$

Updated on ICHEP'06

Dalitz Analysis

- Measure the B^+/B^- asymmetry across the Dalitz plot.
- Extract the CKM angle ϕ_3 from the interference term:

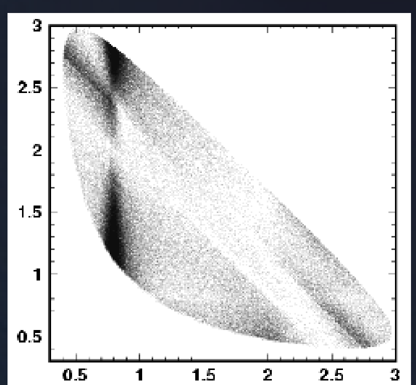
Decay:

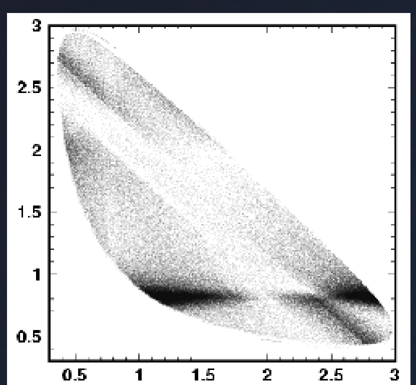
$$B^\pm \to \left[K_S \pi^+ \pi^-\right]_D K^\pm$$

Amplitudes:

$$A^\pm = f\left(m_+^2, m_-^2\right) + r_B \exp\left(\pm i\phi_3\right)\exp\left(i\delta_B\right) f\left(m_-^2, m_+^2\right)$$

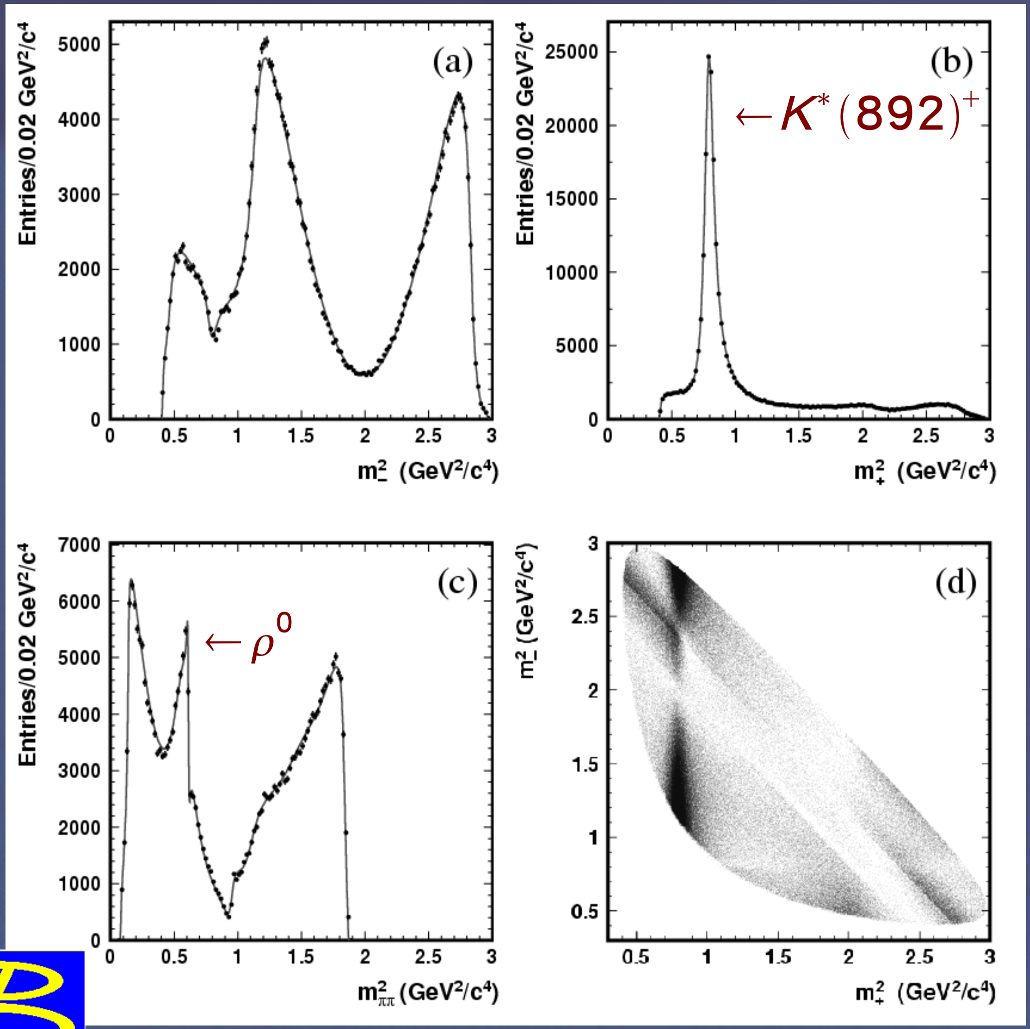
$$\left[m_\pm = m(K_S, \pi^\pm)\right]$$





- Also covers GLW ($D^0 \to K_S\, \rho^0$, CP-eigenstate) and ADS($D^0 \to K^{*+}\, \pi^-$, DCS 2-body decay) regions.
- A 2-fold ambiguity on ϕ_3: $(\phi_3, \delta) \to (\phi_3+\pi, \delta+\pi)$

Dalitz Modeling



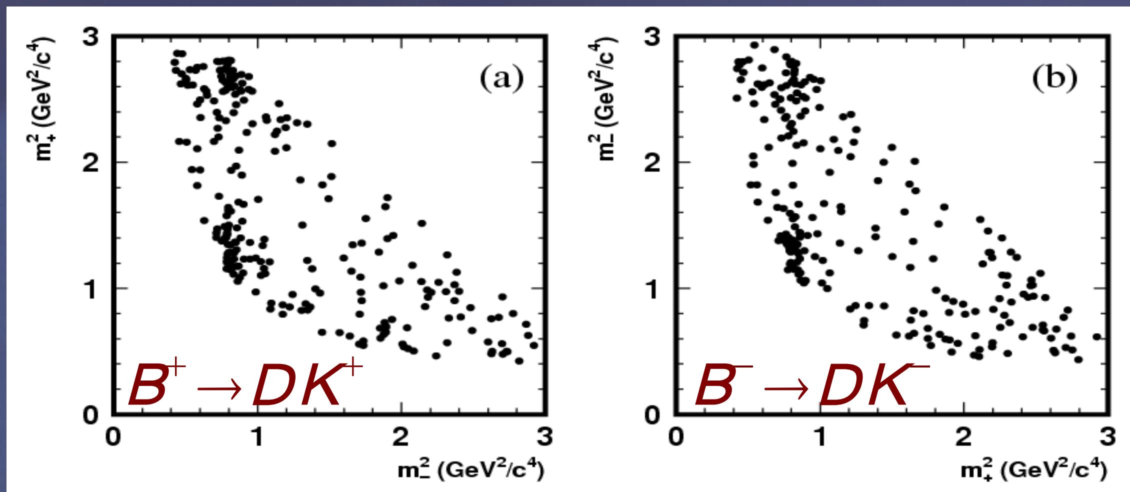
- Select $D^{*+} \to [K_S\,\pi^+\pi^-]\pi^+$ events.
- Fit to a set of 18 2-body amplitudes and a non-resonant component:

$$f\left(m_+^2, m_-^2\right) = \sum_{j=1}^{N} a_j e^{i\alpha_j} A_j\left(m_+^2, m_-^2\right) + b\,e^{i\beta}$$

- Main contributions from:

$$D \to K^*(892)^+ \pi^-$$
$$D \to K^*(1430)^+ \pi^-$$
$$D \to K_S \rho^0$$

Dalitz Plots from $B \to DK$



$N(B^\pm \to D^0 K^\pm) = 331 \pm 23$

$N(B^\pm \to D^{*0} K^\pm) = 81 \pm 11$

$N(B^\pm \to D^0 K^{*\pm}) = 54 \pm 8$

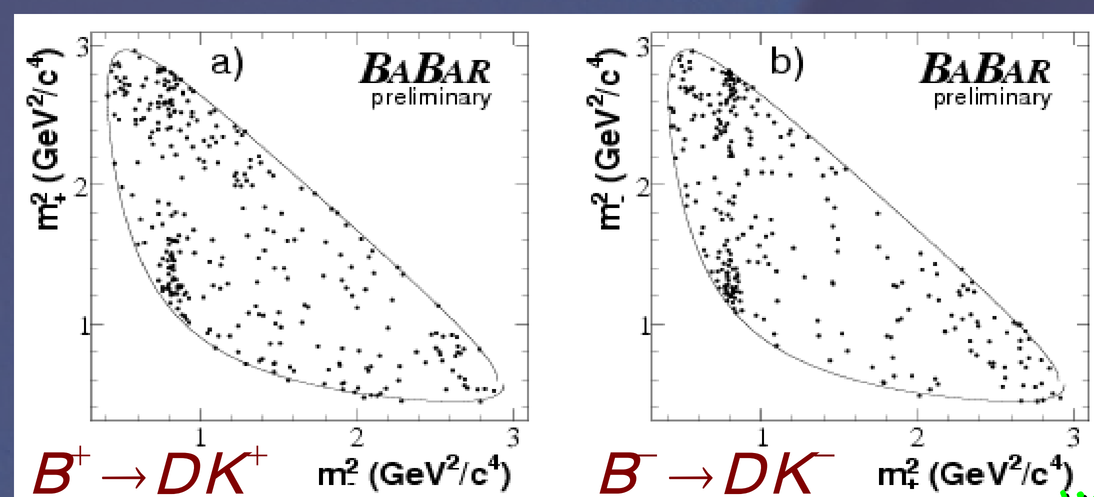
386M BB

347M BB

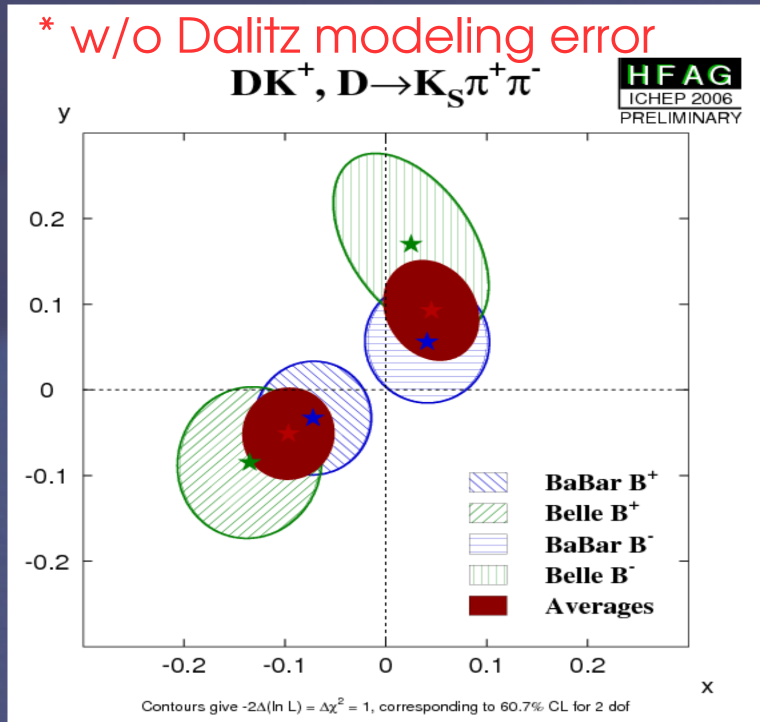
$N(B^\pm \to D^0 K^\pm) = 398 \pm 23$

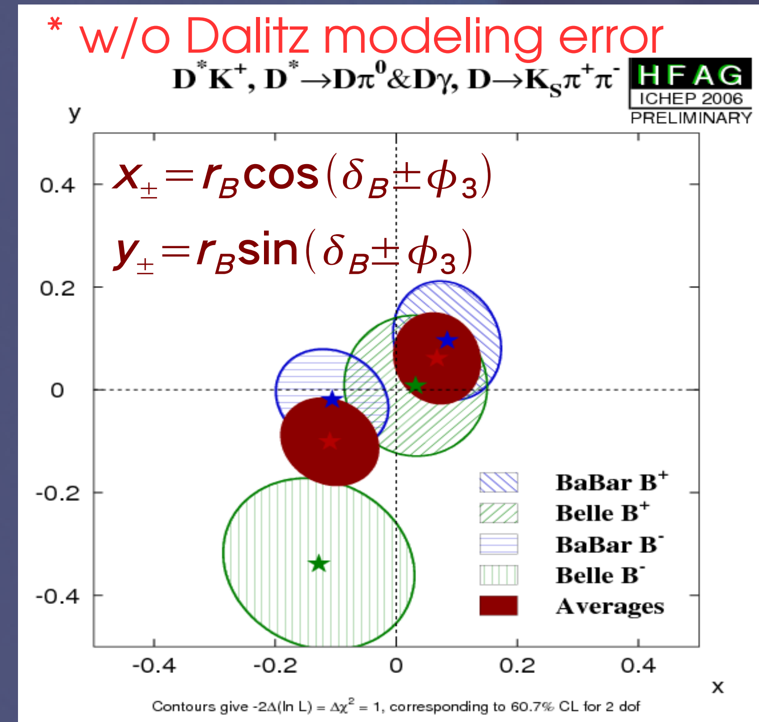
$N(B^\pm \to D^{*0} K^\pm) = 190 \pm 18$

$(D^{*0} \to D^0 \pi^0, D^0 \gamma)$



preliminary





- Measurement on ϕ_3:

BELLE: $\phi_3 = (53^{+15}_{-18} \pm 3 \pm 9)^\circ$
$(B^\pm \to D^0K^\pm, D^{*0}K^\pm, D^0K^{*\pm})$

BaBar: $\phi_3 = (92 \pm 41 \pm 11 \pm 12)^\circ$
$(B^\pm \to D^0K^\pm, D^{*0}K^\pm)$ preliminary

(The result which is consistent with SM fit is quoted here.)

CKMFitter or UTFit is required for Belle/BaBar average.

Summary

ϕ_1/β

- The standard "sin2ϕ_1" has been measured very well.
- New target – "sin2ϕ_1" with $b \to s$ penguins will be examined with more data.

ϕ_2/α

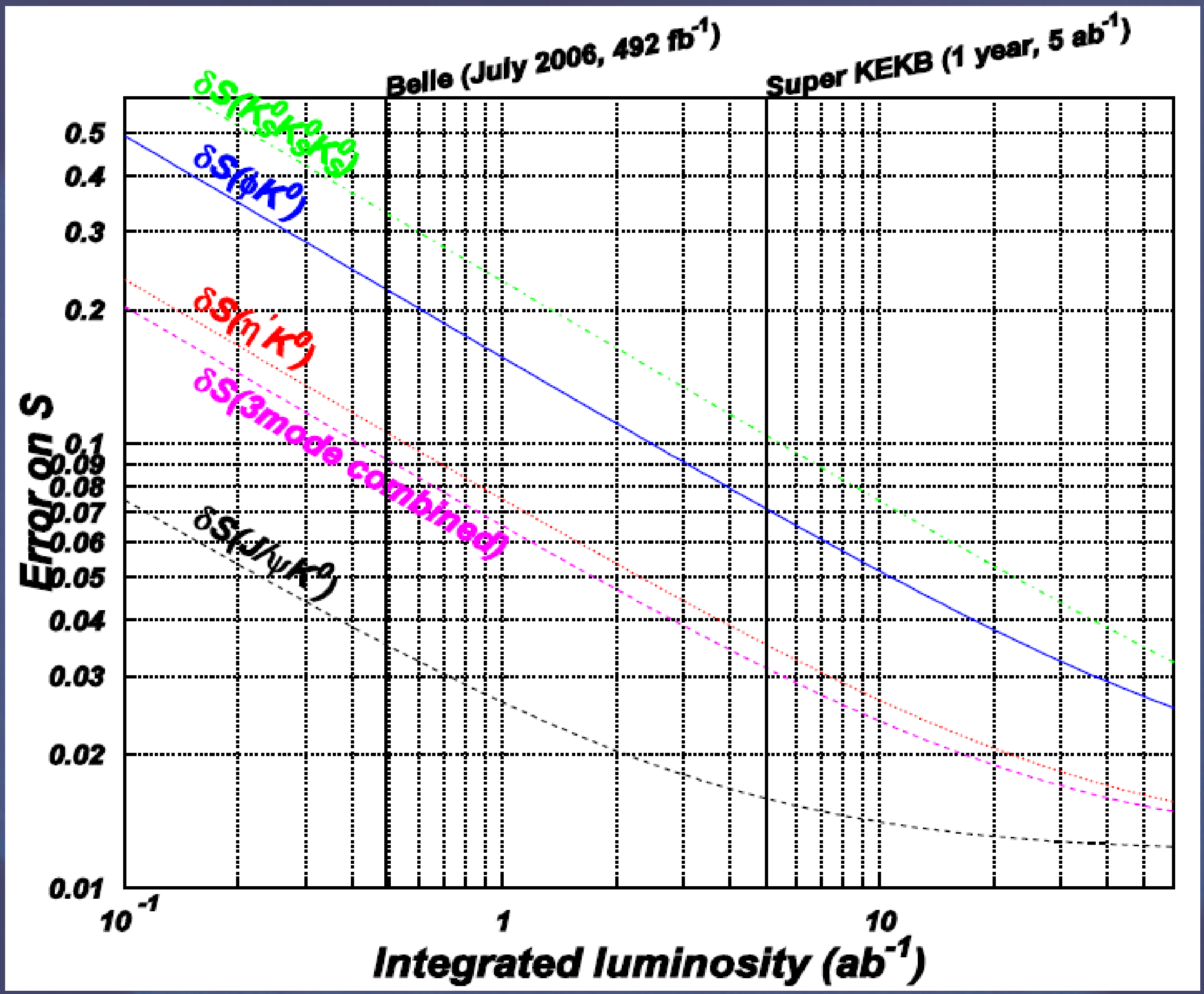
- The angle has been measured with several decay modes.
- The discrepancy between 2 experiments has not been 100% solved – more data is required.
- Need to understand how to include the $\rho\pi$ data in the UT/CKM fitters.

ϕ_3/γ

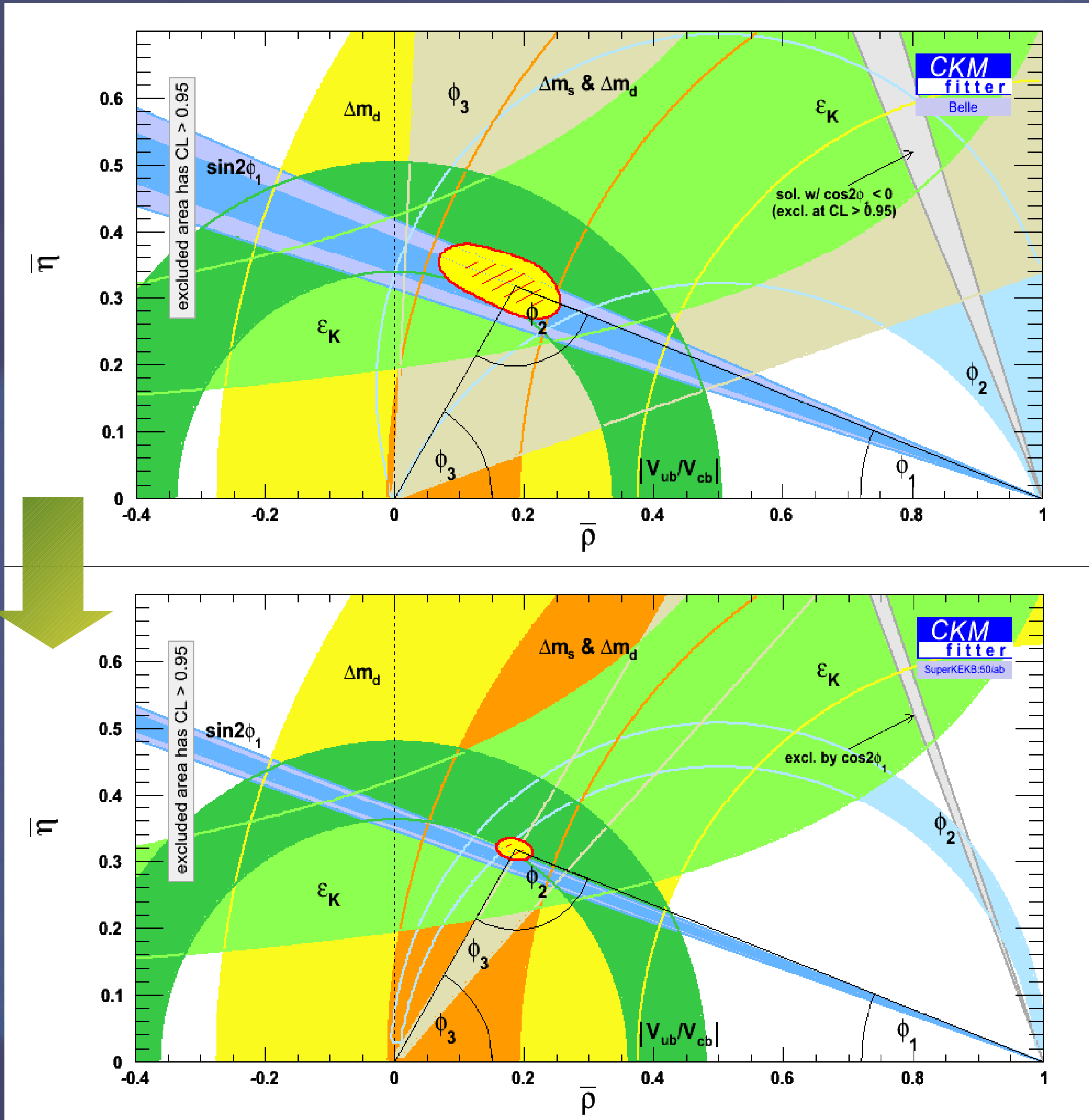
- The ϕ_3 angle is measured by 2 groups with different assumptions.
- No average result can be made unless an unification of analysis methods being made.

⇨ A little bit on the future prospects?

Prospects on δS



- Expected error on $\sin 2\phi_1$:
  0.016 @ 5/ab
  0.012 @ 50/ab
- Limited by vertexing systematic errors



Belle w/ 0.5/ab
(current data)

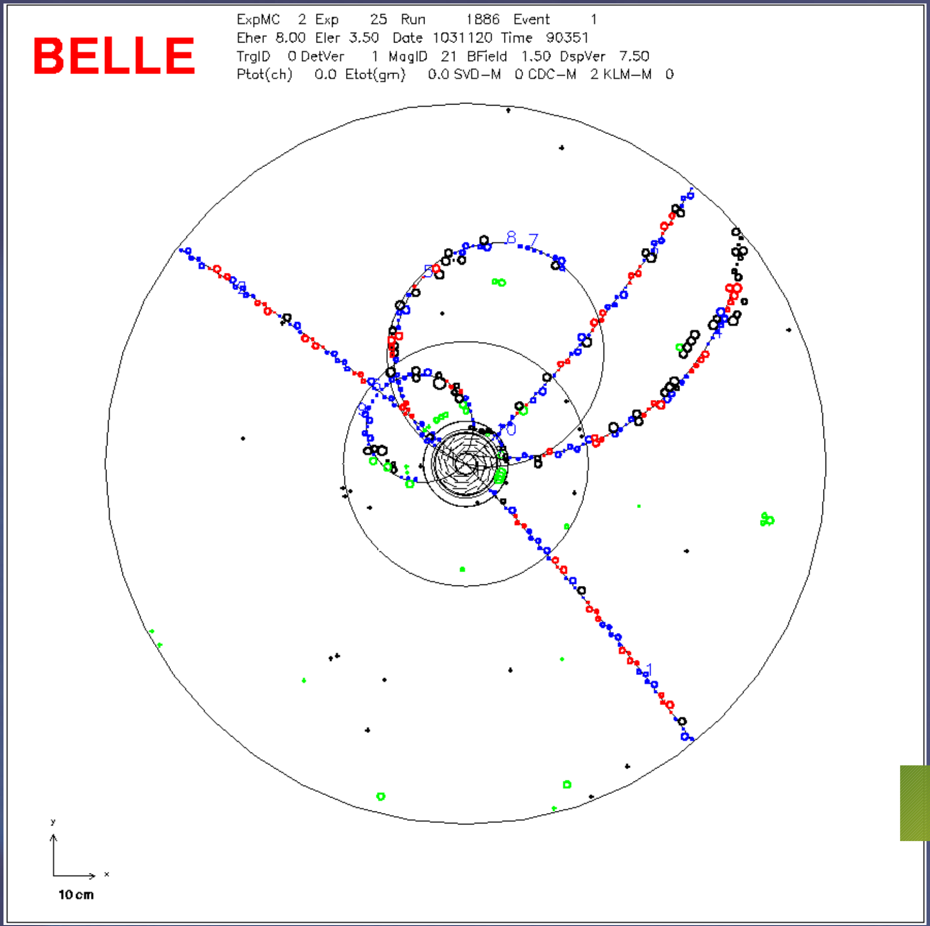
$\delta\phi_2 \sim 11°$

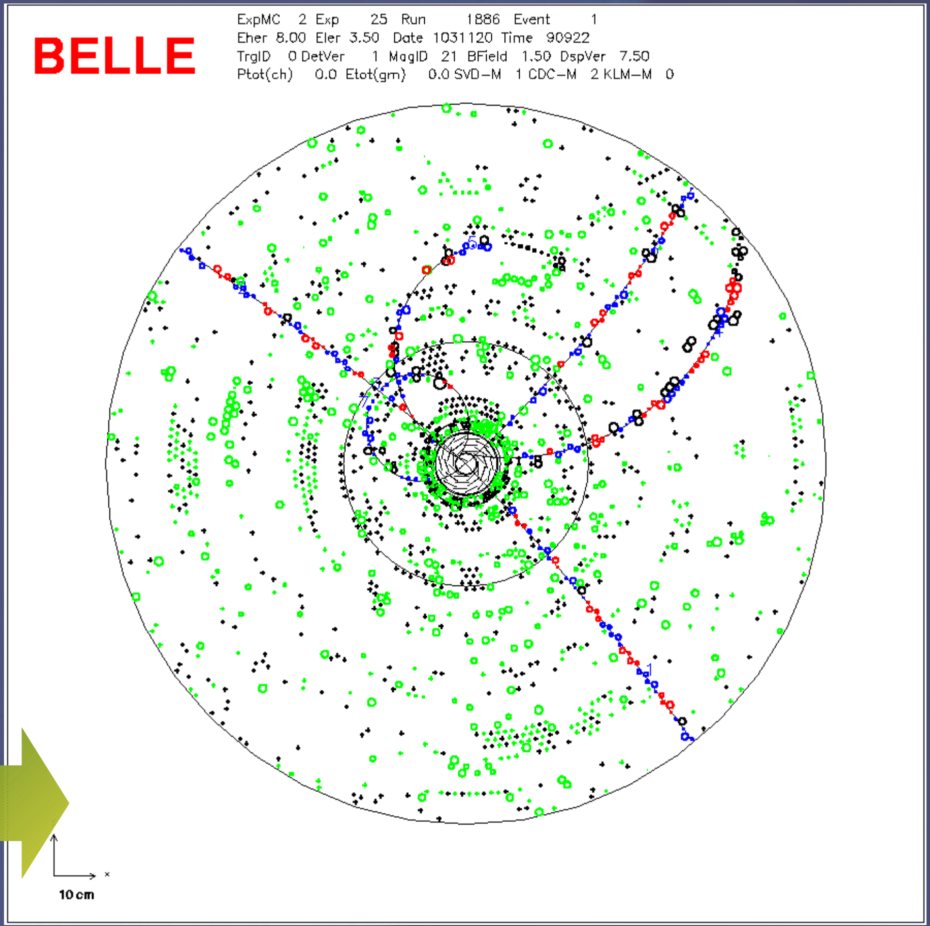
$\delta\phi_3 \sim 15°$

Belle w/ 50/ab

$\delta\phi_2 \sim 2°$

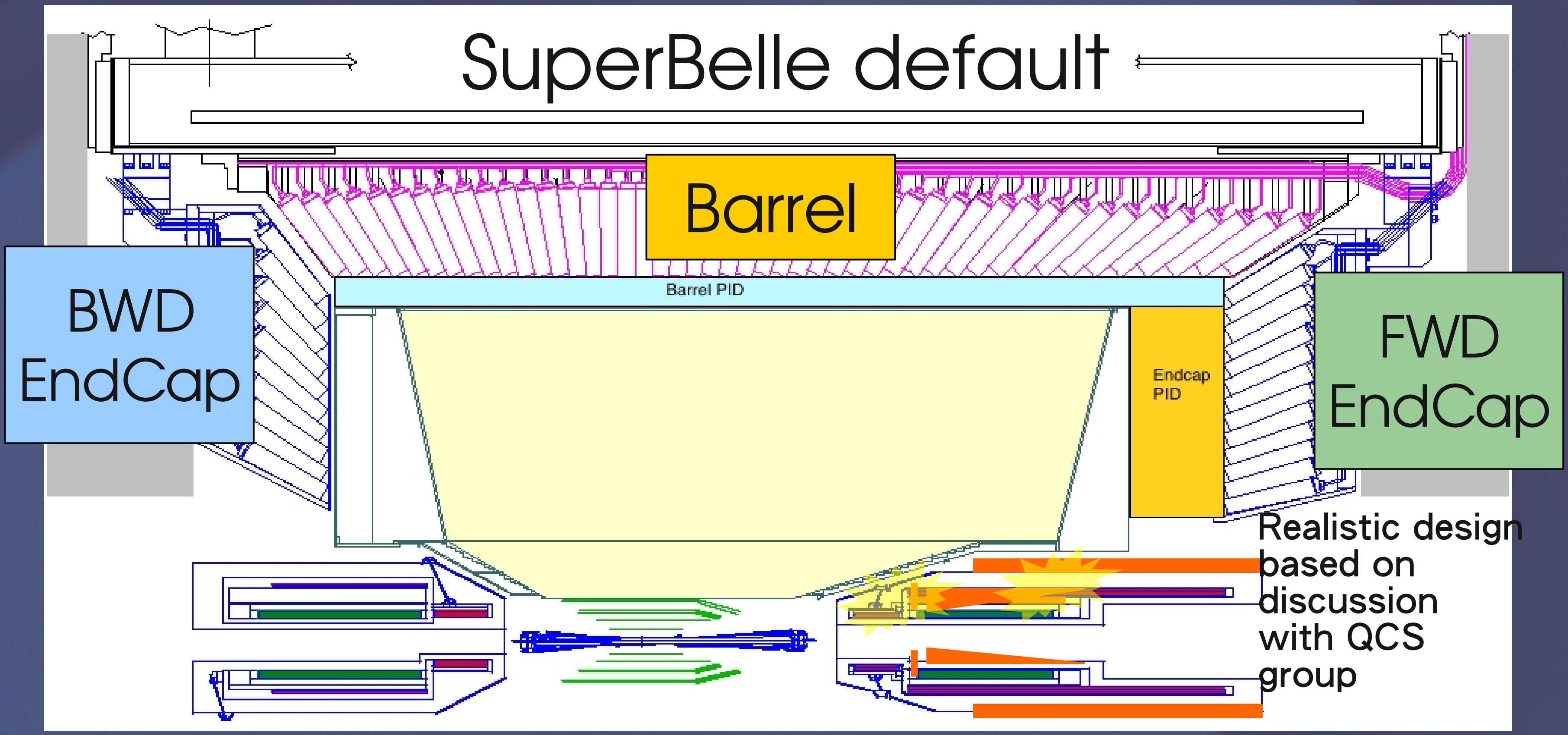
Challenge for the Exp.





The expected beam background will be also 20x larger!

Super *B* Detector



Vertex: Si striplet inner-most and Si strip tracker
Tracker:Drift chamber r>15cm
PID: w/TOP and AC-RICH (endcap)
ECAL:CsI (Tl) +wave from (barrel) pure CsI+PMT (endcap)

Tsukuba?

Super *B* Return?

Frascati?