$D^0\overline{D}^0$ Mixing and CP Violation Results from the B Factories

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Outline from 1st Meeting

i. Theory — 11 p.
   1. Brief history
   2. Mixing
   3. CPV
   4. NP

ii. General Exp. Remarks — 5 p.
   1. D* tagging
   2. Decay-t resolution

iii. Decays to CP eigenstates — 6 p.
   1. Method
   2. Results KK/pipi
   3. Results Ksphi + others

iv. Hadronic WS decays — 3 p.
   1. Formalism
   2. Results Kpi

v. t-dependent Dalitz — 10 p.
   1. Kpipi0
   2. Ks h h
   3. Other multibody

vi. Semileptonic — 6 p.
   1. General remarks
   2. comparison of results tagged/un-tagged

vii. t-integrated CPV measurements — 15 p.
   1. Using data to measure eff. asymmetry
   2. Results KK/pipi
   3. Multi-body (KKpi0, pipipi0, KKpipi)
   4. T-odd correlations

viii. t-dependent CPV measurements — 1 p.

ix. Summary — 2 p.

$\Sigma = \sim 60$ p.

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Theory (and Formalism)

i. Theory
  1. Brief history
    - Invention of charm (GIM mechanism)
    - Pais and Treiman, 1975
    - Short range -> x is small
    - Long range (Wolfenstein)
    - Compare w/other neutral systems
    - Uniqueness of charm

  5 p.

  2. Mixing
    - Definitions (x, y, q/p, phi, δ and all <u>t</u>hat)

  3 p.

  3. CPV
    - Mixing, Decay and Interference
    - Define λ_f
  4. NP
    - Best outlined by theorist !

  3 p.

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$$\langle \overline{B}^0 | H_{wk} | B^0 \rangle \propto \sum_{i,j=u,c,t} V_{ib}^* V_{id} V_{jd} V_{jb}^* \mathcal{F}(m_W^2, m_i^2, m_j^2)$$

if $m_i = m_j \Rightarrow$
due to CKM unitarity: no mixing

more explicitly:

$$\langle \overline{D}^0 | H_w^{\Delta C=-2} | D^0 \rangle = \frac{G_F^2}{4\pi^2} V_{cs}^* V_{cd}^* V_{ud} V_{us} \frac{(m_s^2 - m_d^2)^2}{m_c^2}$$

$$\langle \overline{D}^0 | \bar{u}\gamma^\mu (1-\gamma_5) c \bar{u} \gamma_\mu (1-\gamma_5) c | D^0 \rangle$$

this should be at the
level of postgrad student;

i.e. DCS and SU(3) violating

should we continue with LD
estimates (OPE, exclusive approach)?

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General Exp. Remarks

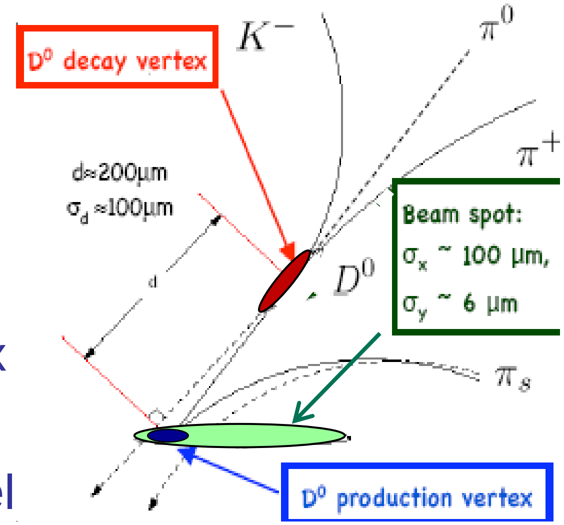
ii. General Experimental Remarks

1. D^* Tagging

2 p.

Usual “cartoon” showing vertices and vertex resolution

Figures illustrating M, ΔM for varous channel



+ Belle equivalent

2. Decay Time Resolution

Resolution for

3 p.

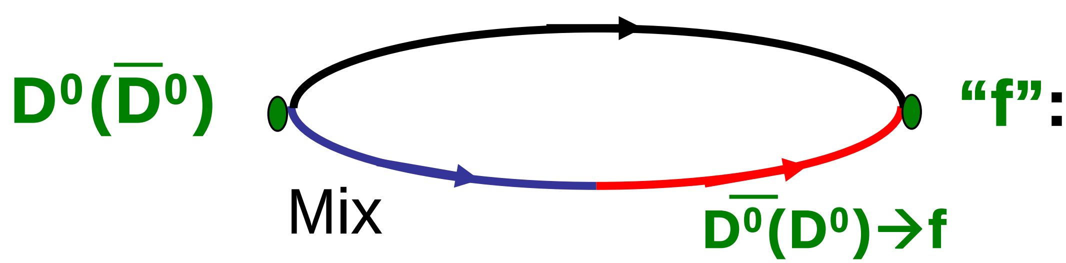
a. $K\pi$

b. $K_s\pi^+\pi^-$ and variation over Dalitz plot

biases?

Common to Each Measurement

- Assume NO CPV – discuss this later
- Measurements mostly come from interference between direct decay and decay through mixing



Accessible to D or D
Kπ (WS),
point on DP,
etc

to 2nd order in x and y:

$$dn/dt \sim e^{-\Gamma t} x \, [r^2 + r\,(y \cos\delta - x \sin\delta)\, t + (x^2+y^2)/4\, t^2] \quad \text{- - - -} \quad (1)$$

Parameters (x, y, r, δ)

Exception: "f" is SL state – only through mixing

- Describe all asymmetries in CPV section

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Decays to CP eigenstates

iii. Decays to CP eigenstates

1. Method

Decay not truly exponential but nearly so - relate to (1) 1 p.

Definitions of y_{CP} = y if no CPV

2. Results KK/pipi 2 p.

Compare D^*-tagged with untagged results

3. Results $K_s\phi$ + others 3 p.

Outline method and results

Comment on $D^0 \rightarrow \pi^+\pi^-\pi^0$ (dominated by I=0 → CP=+1)

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Hadronic WS decays

iv. Hadronic WS decays

1. Formalism

   Refer to Eq. (1)

   - this implies we measure (x'^2, y') and r

   1 p.

2. Results Kpi

   Describe results obtained

   Include some discussion on the confidence level contour plots

   [Project the 68.3% contour onto (x,y) plane ?]

   2 p.

if in decays subsection discussion on DCS decays, then part of the measurement (R_WS) to be described there

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t-dependent Dalitz

v. t-dependent Dalitz

Point out that each "bin" (coordinates (s_1,s_2) in Dalitz plot is analogous to WS $K\pi$ decay – refer to Eq. (1)

3 p. t-dependence for each bin determined by local "$r(s_1,s_2)$" and "$\delta(s_1,s_2)$"

An amplitude model can provide both,

but not the overall phase δ_0 between D^0 and D^0 decays to that point.

1. Kpipi0

3 p. δ_0 is "unknown" (though recently measured by CLEO)

Outline results (only Babar so far).

2. Ks h h

Method pioneered by CLEO (9 fb^{-1})

3 p. δ_0=0 since self-conjugate final state is sum of CP=+/-1 eigenstates

Outline results

Discuss Belle extraction of CPV parameters

3. Other multibody

1 p. Describe Babar phase-space averaged preliminary results

No amplitude models so far.

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Mixing from WS Semileptonic Decays

vi. Semileptonic
1. General remarks

Time-dependence is ~ $(x^2+y^2)\, t^2\, e^{-\Gamma t}$ – refer to Eq. (1)

$R_M=(x^2+y^2)/2 \sim 5 \times 10^{-5}$ [x very small, y ~ 0.01]

→ Too small to have been observed so far.

3 p. Backgrounds need to be kept under control

Missing neutrinos make life difficult

D^* tagging essential

2. comparison of results tagged/un-tagged

Belle chose a D^*-tagged sample

→ Large RS signal and background of ~5000 events

3 p. Babar chose a double tagged sample

→ Small RS signal but low background ~ 3 events

Results are relatively comparable

semileptonic for mixing: different method than for semileptonic decays

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t-integrated CPV measurements

vii. t-integrated CPV measurements

1. Using data to measure eff. Asymmetry
   - Describe - D^*/D ratio same for both charges of π_s
   - 4 p. Point out that this means results should improve with higher luminosity.
2. Results KK/pipi
   - 3 p. Add new $D_{(s)}^+ \rightarrow K_s\, \pi^+(K^+)$ results from Belle
3. Multi-body (KKpi0, pipipi0, KKpipi)
   - 4 p. Point out that CPV probably occurs in some channels but not others
   - Model-dependent vs Model-independent approaches
   - Normalization to total in phase space (Dalitz) plot.
4. T-odd correlations
   - 4 p. Describe
   - New results from Babar on $K^+K^-\pi^+\pi^-$

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viii. t-dependent CPV measurements

Discuss all mixing asymmetries here A_D, A_M, A_τ

1 p.

Belle time-dependent analysis of $K_s\pi^+\pi^-$ Dalitz plot

Any other ??

here or previously

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2 p.

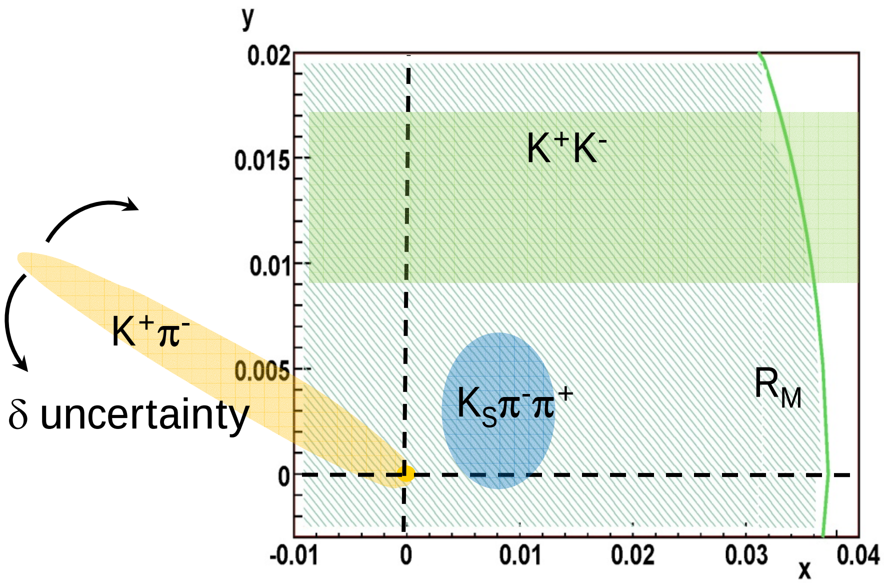
Make average(s) for Babar and Belle
- Either as a group or individually ?
- Compare one with the other ?

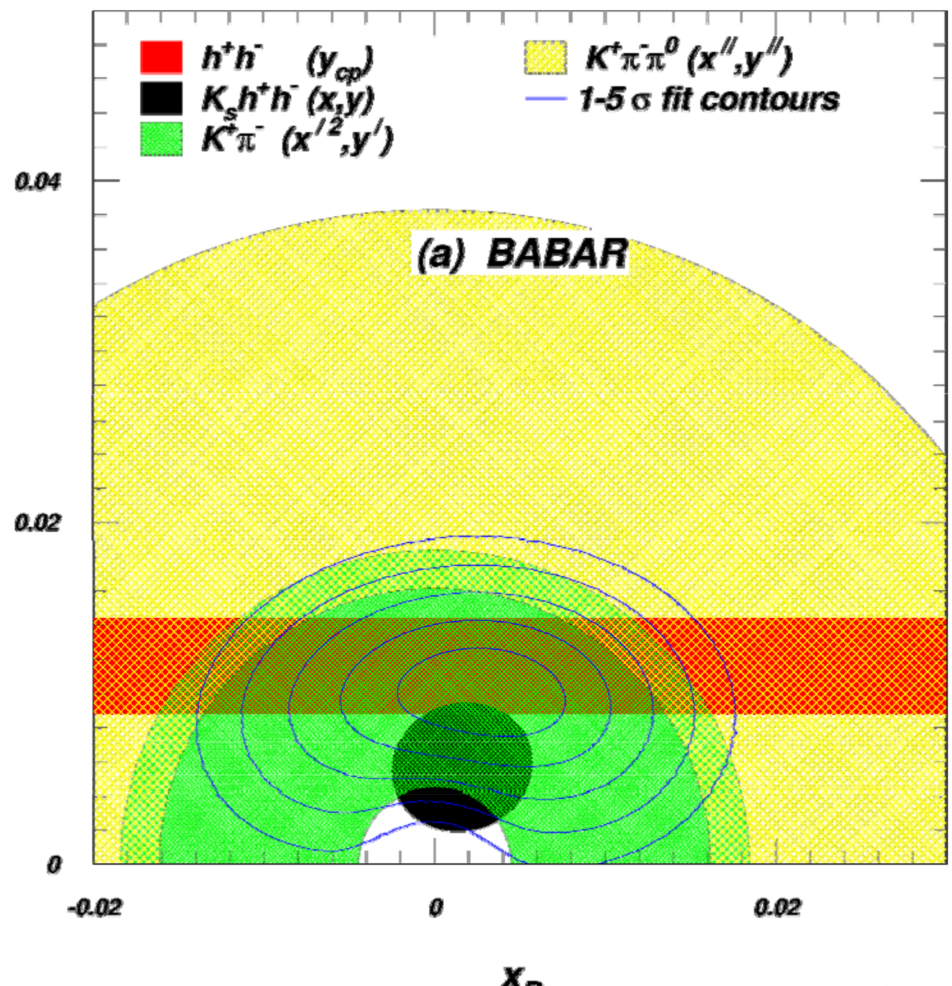
we can compare diff. methods; the main message is to be on the combined knowledge we have, i.e. combination of all results

Given that a principal group of readers is to consist of new students and postdocs working on future flavour experiments, make a projection of our results to these experiments.

in general, we should avoid extensive projections because it may take another book to do those seriously; of course few statements like "at the future … the parameter x will be measured with an accuracy of … once ?? ab^{-1} of data is collected [reference to detailed document]" can be afforded

Summary of Measurements - Babar





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