



STATUS REPORT

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OUTLINE

1. Research On Charm Studies

- a) D^0 - \bar{D}^0 Mixing and y_{CP} Measurement
- b) Direct CP Violation in Neutral Charm Meson D^0
- c) Measurement of R_{WS} , R_{DCS}
- d) D^{*+} Width Measurement

2. Radiative Decay $D^0 \rightarrow \Phi\gamma$

3. Future Plans and Status of Analysis



CP Violation Through $D^0 - \bar{D}^0$ Mixing, y_{CP} Measurement

◆ Large $D^0 - \bar{D}^0$ Mixing \Rightarrow Signature of non-SM processes

◆ $y_{CP} \sim y \cos \Phi + x \Delta \sin \Phi$ [5]

where

$$x = \frac{M_1 - M_2}{\Gamma_{av}}, y = \frac{\Gamma_1 - \Gamma_2}{2\Gamma_{av}}$$

$$|D_{1,2}\rangle = p|D^0\rangle \pm q|\bar{D}^0\rangle$$

$$\Phi = \frac{q\mathcal{A}(\bar{D}^0 \rightarrow K^- K^+)}{p\mathcal{A}(D^0 \rightarrow K^- K^+)}$$

$$\Delta = \frac{(|p|^2 - |q|^2)}{(|p|^2 + |q|^2)}$$

◆ $y_{CP} = y = \frac{\tau(K^- \pi^+)}{\tau(K^- K^+)} - 1$ [5]

in the limit of CP conservation

and

assuming equal mix of CP even and odd states in $K^- \pi^+$

◆ $R_{mix} = \frac{1}{2}(x^2 + y^2) = D^0 - \bar{D}^0$ mixing rate $\sim \mathcal{O}(10^{-8} - 10^{-3})$ [6]

Large uncertainty due to intermediate mesons

Cancellation in I.M. states, $R_{mix} \rightarrow 10^{-5}$ level

Non S.M. processes could enhance R_{mix} further



CP Violation Through D^0 - \bar{D}^0 Mixing , y_{CP} Measurement

- ◆ $D^0 - \bar{D}^0$ mixing through on or off-shell intermediate states [1,2,3]
 - GIM cancellation $\rightarrow 10^{-6} - 10^{-2}$ level
 - Non S.M. $|x| > 1\%$ (due to highly massive particles)
 - Signatures of new physics are
 - $|x| \gg |y|$
 - CP violating interference between x and y
 - or
 - x and a direct decay amplitude
- ◆ S.M. prediction $x, y \sim \mathcal{O}(10^{-3})$, non S.M. enhances x and not y [5]
 - Large $y_{CP} \Rightarrow$ no new physics but S.M. effects at 10^{-2} level
 - Large y_{CP} may also come from large CP violation
 - since limits on x are loose and no constraints on Δ
- ◆ FOCUS $y_{CP} = (3.42 \pm 1.39 \pm 0.74)\%$
- ◆ CLEO $y_{CP} = (-1.1 \pm 2.5 \pm 1.4)\%$
- ◆ BELLE $y_{CP} = (-0.5 \pm 1.0_{-0.8}^{+0.7})\%$



Direct CP Violation in D^0 Decays

- ◆ In S.M. direct CP violation is [7]
 - largest in Cabibbo suppressed(CS) decays
 - non existent in (exception $D \rightarrow K_S \eta \pi$)
 - Cabibbo Favoured(CF) and Doubly CS(DCS) decays
- ◆ Previous limits on direct CP violation \rightarrow few % level [1,2,3,4]
- ◆ $A \equiv ae^{i\delta_1} + be^{i\delta_2}$, weak phase + strong phase [7]
 - weak phase changes sign for CP conjugate process
$$A_{CP} \equiv \frac{|A|^2 - |\bar{A}|^2}{|A|^2 + |\bar{A}|^2}, \quad A_{CP} = \frac{\Gamma(D^0 \rightarrow f) - \Gamma(\bar{D}^0 \rightarrow f)}{\Gamma(D^0 \rightarrow f) + \Gamma(\bar{D}^0 \rightarrow f)}$$
- ◆ Results from CLEO for A_{CP} ($D^{*+} \rightarrow D^0 \pi^+$ tag for i and ii) [1,2,3,4]
 - i) $A_{CP}(K^+ K^-) = (0.05 \pm 2.18 \pm 0.84)\%$
 - ii) $A_{CP}(\pi^+ \pi^-) = (1.95 \pm 3.22 \pm 0.84)\%$
 - iii) $A_{CP}(K_S^0 \pi^0) = (0.1 \pm 1.3)\%$
 - iv) $A_{CP}(\pi^0 \pi^0) = (0.1 \pm 4.8)\%$
 - v) $A_{CP}(K_S^0 \pi^0) = (-23 \pm 19)\%$
- ◆ CP violation in D^0 is consistent with 0.



Measurement of R_{WS} and R_{DCS}

- ◆ $R_{WS} \equiv$ Rate of wrong sign decay [1,2,3,6]
wrong sign decays (like $D^0 \rightarrow K^+ \pi^- \pi^0$, $K^+ \pi^-$) can proceed
i) directly as a DCS decay
or
ii) through $D^0 \bar{D}^0$ mixing followed by CF decay
- ◆ $R_{DCS} \equiv$ Rate of DCS decay relative to CF decay [6]
 $R_{DCS} \sim \tan^4 \theta_c \simeq 0.25\%$ (S.M. prediction)
- ◆ CLEO $R_{WS}(K^+ \pi^- \pi^0) = (0.43_{-0.10}^{+0.11} \pm 0.07(\text{syst}))\%$, first measurement
- ◆ FOCUS sets a limit for R_{DCS} , $0.43\% < R_{DCS} < 1.73\%$



D^{*+} Width Measurement

- ◆ $\Gamma(D^{*+}) \rightarrow$ window to non-perturbative heavy quark physics [1]
- ◆ Width prediction is uncertain with a range from 15 KeV to 150 KeV
- ◆ Lack of calibration modes (modes with small width, large cross section and similar kinematics)
- ◆ $\Gamma(D^0) \ll \Gamma(D^{*+})$ is assumed for the tagging decay $D^{*+} \rightarrow D^0 \pi^+$
- ◆ CLEO Measurement $\Gamma(D^{*+}) = 96 \pm 4(stat) \pm 22(syst)$ KeV



Radiative Decay $D^0 \rightarrow \Phi\gamma$ and Other Studies

- ◆ Paper by O.Tajima san (27 Jan 2004) [8]
- ◆ BELLE $\mathcal{B}(D^0 \rightarrow \Phi\gamma) = [2.60_{-0.61}^{+0.70}(stat)_{-0.17}^{+0.15}(syst)] \times 10^{-5}$
 $\mathcal{B}(D^0 \rightarrow \Phi\pi^0) = [8.01 \pm 0.26(stat) \pm 0.47(syst)] \times 10^{-4}$
 $\mathcal{B}(D^0 \rightarrow \Phi\eta) = [1.48 \pm 0.47(stat) \pm 0.09(syst)] \times 10^{-4}$
- ◆ Thoroughly read and discussed with Leo, NOT discussing today
- ◆ Observation of CS decay $B \rightarrow D^{(*)}K^-$ at Belle, NOT discussing [9]



Future Plan of Action

- ◆ Monte Carlo study of $D^0 \rightarrow K_L^0 \pi^0$ and $D^0 \rightarrow K_S^0 \pi^0$ as summer assignment
- ◆ Restart stalled analysis as necessitated by above study (rather than as a stand alone study)
- ◆ Few significant errors spotted in reconstruction code and corrected (No plots to show now)



References

- ◆ ref1 hep-ex/0104008 v1 3 Apr 2001
“Recent Results from CLEO on $D^0 - \bar{D}^0$ Mixing, CP Violation in D^0 Decays and D^{*+} Width”
- ◆ ref2 hep-ex/0105013 v1 8 May 2001
“Neutral Charm Decays at CLEO :Searches for CP Violation and Mixing”
- ◆ ref3 hep-ex/0102006 v1 5 Feb 2001
“Mixing and CP Violation in the Decay of Neutral D Mesons at CLEO”
- ◆ ref4 Physical Review D, Volume 63, 071101(R)
“Search for CP Violation in $D^0 \rightarrow K_S^0 \pi^0, D^0 \rightarrow \pi^0 \pi^0, D^0 \rightarrow K_S^0 K_S^0$ Decays”
- ◆ ref 5 hep-ex/0111026 v3 15 Mar 2002
“A Measurement of Lifetime Difference in D^0 Meson Decays”
- ◆ ref 6 hep-ex/0106093 v1 26 Jan 2001
“ $D^0 - \bar{D}^0$ Mixing in FOCUS”



References

- ◆ ref 7 hep-ex/0011055 v2 29 Nov 2000
“New FOCUS Results on Charm Mixing and CP Violation”
- ◆ ref 8 hep-ex/0308037 v3 27 Jan 2004
“Observation of the Radiative Decay $D^0 \rightarrow \Phi\gamma$ ”
- ◆ ref 9 hep-ex/0104051 v1 28 Apr 2001
“Observation of the Cabibbo suppressed $B \rightarrow D^{(*)}K^-$ Decays at Belle”