STATUS REPORT

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(5th May 2004)

OUTLINE

1. Research On Charm Studies
   a) $D^0$-$\bar{D}^0$ Mixing and $\gamma_{CP}$ 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

- $y_{CP} \sim y \cos \Phi + x \Delta \sin \Phi$ \hspace{1cm} [5]

  where

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

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

  $\Phi = \frac{qA(D^0 \rightarrow K^- K^+)}{pA(D^0 \rightarrow K^- K^+)}$

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

- $y_{CP} = y = \frac{\tau(K^- \pi^+)}{\tau(K^- K^+)} - 1$ \hspace{1cm} [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 $\sim \mathcal{O}(10^{-8} - 10^{-3})$ \hspace{1cm} [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  
  $|x| >> |y|$  
  CP violating interference between x and y 
  or  
  x and a direct decay amplitude

- S.M. prediction $x, y \sim O(10^{-3})$, 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 $\Delta$

- FOCUS $y_{CP} = (3.42 \pm 1.39 \pm 0.74)\%$

- CLEO $y_{CP} = (-1.1 \pm 2.5 \pm 1.4)\%$

- BELLE $y_{CP} = (-0.5 \pm 1.0^{+0.7}_{-0.8})\%$
Direct CP Violation in $D^0$ Decays

- In S.M., direct CP violation is \cite{7} largest in Cabibbo suppressed (CS) decays 
  non existent in (exception $D \to K_S \eta \pi$) 
  Cabibbo Favoured (CF) and Doubly CS (DCS) decays

- Previous limits on direct CP violation $\rightarrow$ few \% level \cite{1,2,3,4}

- $A \equiv a e^{i \delta_1} + b e^{i \delta_2}$, weak phase + strong phase \cite{7}
  weak phase changes sign for CP conjugate process

$$A_{CP} \equiv \frac{|A|^2 - |\bar{A}|^2}{|A|^2 + |\bar{A}|^2}, \quad A_{CP} = \frac{\Gamma(D^0 \to f) - \Gamma(D^0 \to f)}{\Gamma(D^0 \to f) + \Gamma(D^0 \to f)}$$

- Results from CLEO for $A_{CP}$ ($D^{*+} \to D^0 \pi^+$ tag for i and ii) \cite{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 \cite{1,2,3,6}
  wrong sign decays (like $D^0 \to K^+\pi^-\pi^0$, $K^+\pi^-$) 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 \cite{6}
  
  $R_{DCS} \sim \tan^4 \theta_c \simeq 0.25\%$ (S.M. prediction)

- CLEO $R_{WS}(K^+\pi^-\pi^0) = (0.43^{+0.11}_{-0.10} \pm 0.07(syst))\%$, 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 \[ \text{[1]} \]
- 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) \cite{8}
- **BELLE**
  \[ \mathcal{B}(D^0 \rightarrow \Phi\gamma) = [2.60^{+0.70}_{-0.61}(stat)^{+0.15}_{-0.17}(syst)] \times 10^{-5} \]
  \[ \mathcal{B}(D^0 \rightarrow \Phi\pi^0) = [8.01 \pm 0.26(stat) \pm 0.47(syst)] \times 10^{-4} \]
  \[ \mathcal{B}(D^0 \rightarrow \Phi\eta) = [1.48 \pm 0.47(stat) \pm 0.09(syst)] \times 10^{-4} \]

- Thoroughly read and discussed with Leo, NOT discussing today
- Observation of CS decay $B \rightarrow D^{(*)}K^-$ at Belle, NOT discussing \cite{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 $D^0 \rightarrow K_S^0\pi^0, D^0 \rightarrow \pi^0\pi^0, D^0 \rightarrow K_S^0K_S^0$ Decays”

- ref5  hep-ex/0111026 v3 15 Mar 2002
  “A Measurement of Lifetime Difference in $D^0$ Meson Decays”

- ref6  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 $B \rightarrow D^{(*)}K^- \rightarrow D^{(*)}K^- \rightarrow \pi \pi \pi$”