



$$m_s^2 \mu_{\text{had}}^4 / m_c^6$$

(vs. m_s^4 / m_c^4)

- $x_D(\text{SM})|_{\text{OPE}}, y_D(\text{SM})|_{\text{OPE}} \sim O(10^{-3})$
- unlikely uncertainties can be reduced
- furthermore central theoretical issue:

does quark-hadron duality hold at the charm scale?

- more averaging in x_D than in y_D
- ➔ duality better in x_D than in y_D

general expectations

- $\Delta\Gamma$: on-shell contributions
 - ➔ ~ insensitive to New Physics
- Δm : virtual intermediate states
 - ➔ sensitive to New Physics
 - $x_D \sim O(\text{few \%})$ conceivable

if $y_D \sim 0.01$ {
for $x_D \leq \text{few} \times 10^{-3}$: $1/m_c$ expansion.
okay!
for $x_D \sim 0.01$: theor. conundrum

sobering lesson:

case for New Physics based on x_D uncertain!

III.3 CP violation

□ *direct* ~~CP~~

① partial width

final state interactions necessary evil

↻ in Cabibbo favoured (CF) modes

possible only with New Physics *

↻ in singly Cabibbo supp. modes (SCS)

possible with SM & KM

benchmark $\sim O(0.001)$

↻ in doubly Cabibbo supp. modes (DCS)

possible only with New Physics *

*: $D^\pm \rightarrow K_{S[L]} \pi^\pm$

interference between

$$D^+ \rightarrow \underset{\text{CF}}{K^0} \pi^+ \quad \text{and} \quad D^+ \rightarrow \underset{\text{DCS}}{K^0} \pi^+$$

in KM only effect from ~~CP~~ in $K^0 - \bar{K}^0$

asymmetry $A_{S,L} \equiv [A]_{S,L} - [A]_{\bar{S},L} \equiv -3.3 \times 10^{-3}$

with NP in DCS amplitude could reach $O(1\%)$

of either sign and $A_S \equiv -A_L$

○ observe direct ~~CP~~ in CF and/or DCS decays

➔ New Physics!

○ observe direct ~~CP~~ ~ 1% in S CS decays

when benchmark ~ $O(0.1 \%)$

➔ New Physics or hadronic enhancement?

no 'smoking gun' case -- had to rely on circumstantial evidence!

necessary condition: analyze host of channels

n

② in final state distributions: Dalitz etc.

e

impact of final state interactions complex

w

little in the public domain!

p

in principle very promising

h

in practise theoretical tools not developed yet

e

n

③ decays of polarized charm baryons

o

novel diagnostic tools for New Physics

m.

source: GIGA-Z-b?

!

- ~~CP~~ involving $D^0 - \bar{D}^0$ oscillations

$$D^0 \rightarrow K_S \phi \quad \text{vs.} \quad \bar{D}^0 \rightarrow K_S \phi$$

$$D^0 \rightarrow K^+ K^- \quad \text{vs.} \quad \bar{D}^0 \rightarrow K^+ K^-$$

$$D^0 \rightarrow \pi^+ \pi^- \quad \text{vs.} \quad \bar{D}^0 \rightarrow \pi^+ \pi^-$$

$$D^0 \rightarrow K^+ \pi^- \quad \text{vs.} \quad \bar{D}^0 \rightarrow K^- \pi^+$$

CP asymmetry given by

$$\sin \Delta m_D t \operatorname{Im} \rho(D \rightarrow f)$$



small [each $\sim O(10^{-3})$]

in

SM

KM

➔ strong case for New Physics!

asymmetry is **linear** in x_D

whereas r_D is **quadratic**

➔ could be first signal of oscillations!

benchmarks to aim at:

○ x_D, y_D down to $O(10^{-3}) \Leftrightarrow r_D \sim O(10^{-6} - 10^{-5})$

○ time dependant CP asymmetries in

$$D^0 \rightarrow K^+K^-, \pi^+\pi^-, K_S \phi$$

down to $O(10^{-4})$;

$$D^0 \rightarrow K^+\pi^-$$

down to $O(10^{-3})$.

○ ~~direct CP~~ in partial widths

$$\text{of } D^\pm \rightarrow K_{S[L]}\pi^\pm$$

down to $O(10^{-3})$;

in a host of SCS channels

down to $O(10^{-3})$.

○ ~~direct CP~~ in the final state distributions:

Dalitz plots, T-odd correlations etc.

down to $O(10^{-3})$.

IV. Outlook

- We have learnt many, many lessons from charm studies
- never mind popular opinion -- charm does not represent a closed chapter
- charm provides a unique portal to New Physics through up-type quark dynamics with many -- though not all -- experimental features favourable
- only now have we begun to enter promising territory

guaranteed experimental activities:

- ❑ FOCUS & SELEX
- ❑ e^+e^- beauty factories

○ promised experimental activities:

- ❑ Compass
- ❑ BTeV
- ❑ (LHC-b)

○ 'glee in the eye' experimental activities:

- ❑ τ -charm factory at Cornell

a considerable amount of significant calibration work (experim. as well as theor.) waits to be done

... and maybe more!

The poor sleeper's impatience

A man wakes up at night,

Sees it is dark outside and falls asleep again.

A short while later he awakes anew,

Notices it still to be dark outside and goes back
to sleep.

This sequence repeats itself a few times

-- waking up, seeing the dark outside and
falling asleep --

Till he cries out in despair:

“Will there never be daylight?”

A bird begins to sing.