

Dear Santa:
Heavy Flavour Physics at nuMC's --
Theoretical Desires

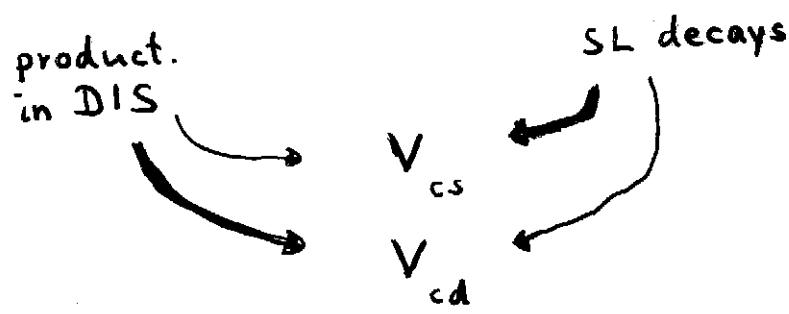
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Which info on HFIPh missing + interesting in 2010?

3 classes

- (more precise) measurements of SM parameters
- calibration of theoretical tools
(control over hadronization)
- probe for NP



future

- $|\Delta V_{cd}|_{pre \nu MC} \sim 10\%$
- $|\Delta V_{cs}| \sim 10\%$
- $|\Delta V_{cb}| \simeq 4\%$
- $|\Delta V_{ub}| \sim 10-15\% \leftarrow \text{not guaranteed!}$

want to do better!

- CKM fundamental quantities related to generation of mass
- very different 'textures' at GUT scales yield not so different CKM at EW scales
- CP asymmetries in B decays:
 - will be measured with few % accuracy
 - are functions of $|V(ub)|, |V(cb)|$

challenge for nuMC

extract $\begin{pmatrix} |V_{cd}| \\ |V_{ub}| \\ |V_{cs}| \\ |V_{cb}| \end{pmatrix}$ with uncertainty $\begin{pmatrix} \mathcal{O}(1\%) \\ \mathcal{O}(1\%) \\ \mathcal{O}(\text{few}\%) \\ \mathcal{O}(\text{few}\%) \end{pmatrix}$

○ appears feasible experimentally

○ theoretical uncertainties?

○ actually measure ratios $|V(cd)/V(ud)|$

uncertainties in PDF's drop out

○ threshold suppression

lab for duality stud

central challenge

involves nonperturb. definit. of quark mass

$\frac{1}{\Gamma}$ “ “ of “ “ in decays

could use $|V(cs)|$ and $|V(cb)|$ as calibrators!

2) f_D

- $D \rightarrow \mu \nu$ f_D
- $D_s \rightarrow \mu \nu$ f_{D_s}

(B) Calibrating our Theoretical Tools

1) Inclusive charm decays

- tool: OPE \rightarrow $1/m_c$ expansion
 quark-hadron duality
 - observables
 - lifetimes of Ω_c or exotic [ccq] baryons
 - absolute ^(SL)BR's $D_s / \Lambda_c^+ / \Xi_c^{+,0} / \Omega_c \rightarrow \ell \nu X$
 - multineutral final states
- SU(3) & duality

2) Absolute charm BR's

{ engineering input } to B studies
{ experim. bottleneck }

3) $B_d \rightarrow \pi^0 \pi^0$

unfolding Penguins

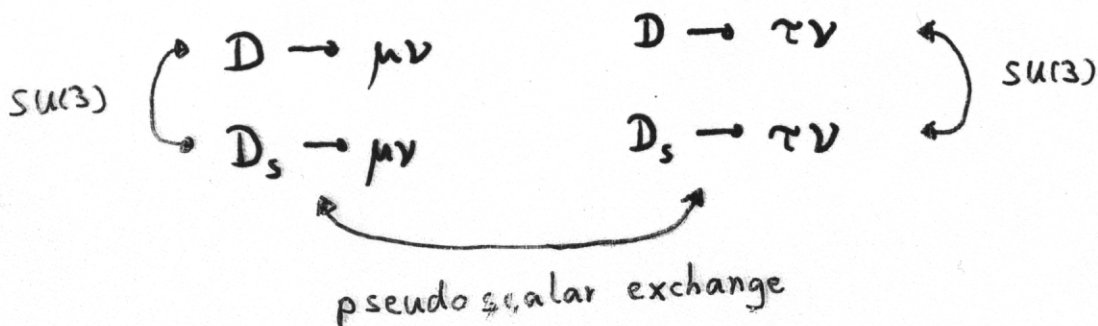
4) $D^0 - \bar{D}^0$ oscillations

$\Delta \Gamma_D$ vs. ΔM_D

see below

(C) Probe for New Physics

(1) $D \rightarrow \mu \nu$ vs. $D \rightarrow \tau \nu$



2) $D^0 - \bar{D}^0$ oscillations

• basic quantities

$$x_D = \frac{\Delta M_D}{\Gamma_D}$$

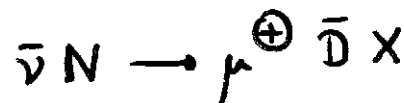
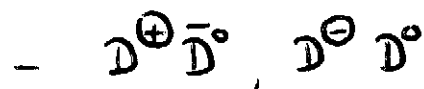
↑
sensitive
to NP

$$y_D = \frac{\Delta \Gamma_D}{2\Gamma_D}$$

↑
hardly sensitive
to NP

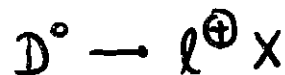
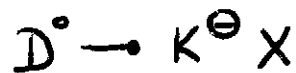
• flavour tag

initial state



νMC $\Delta C = -\Delta Q_l$ rule

final state

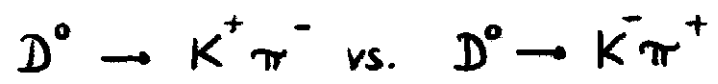


SM backgrd: DCSD

" " none - but
check

• experim. landscape

$$\tau_D = \frac{\Gamma(D^0 \rightarrow \ell^- X)}{\Gamma(D^0 \rightarrow \ell^+ X)} \approx \frac{1}{2} (x_D^2 + y_D^2)$$



$$y'_D = y_D \cos \delta_{K\pi} - x_D \sin \delta_{K\pi}$$

$$\tau_D \leq 5 \times 10^{-4} \quad 95\% \text{ C.L. CLEO}$$

$$-0.04 \leq y_D \leq 0.06 \quad 90\% \text{ C.L. E791}$$

$$-0.058 \leq y'_D \leq 0.01 \quad 95\% \text{ C.L. CLEO}$$

$$y_D = 0.0342 \pm 0.0139 \pm 0.0074 \quad \text{FOCUS}$$

• theoret. landscape

folklore

$$y_D, x_D \sim 10^{-4} - 10^{-3} \quad \text{dominated by LDD}$$

my (& Urattsev's) opinion

$$y_D, x_D \sim \mathcal{O}(10^{-3}) \quad \text{can be obtained from OPE}$$

9
if FOCUS has seen signal for $\Delta\Gamma_D$

↳ ΔM_D 'just around corner'
↳ bad news for NP hunters

NP \neq big game $\hat{=}$ "if encounter it,
can't miss it!"

future

CLEO, BELLE, BABAR, (FOCUS)

τ_D down to few $\times 10^{-4}$

not just game of statistics!

$$\Gamma(D^0(t) \rightarrow \ell^- X) \approx e^{-\Gamma_D t}$$

$$= \left[\left(\frac{x_D}{2}\right)^2 \left(\frac{t}{\tau_D}\right)^2 + y_D \frac{t}{\tau_D} \operatorname{Re} \frac{P}{q} \hat{S}_{\text{wrong}} + \left(1 - y_D \frac{t}{\tau_D}\right) |\hat{S}_{\text{wrong}}|^2 \right]$$

$$\hat{S}_{\text{wrong}} = \frac{\Gamma(D^0 \rightarrow \ell^- X)}{\Gamma(D^0 \rightarrow \ell^+ X)} \quad [\equiv 0 \text{ in SM }]$$

might still be open issue in 2010

" " " systematics limited in 2010

↳ vMC might play decisive role!

(3) ~~CP~~

• $\Gamma(D^0(t) \rightarrow K^+\pi^-) \propto e^{-\Gamma_D t} \text{tg}^4 \theta_c |\hat{S}_{K\pi}|^2$

$$\left[1 - \frac{1}{2} \Delta\Gamma_D t + \frac{(\Delta m_D t)^2}{4 \text{tg}^4 \theta_c |\hat{S}_{K\pi}|^2} + \frac{\Delta\Gamma_D t}{2 \text{tg}^2 \theta_c |\hat{S}_{K\pi}|} \text{Re} \frac{\hat{P}_{K\pi}}{|\hat{S}_{K\pi}|} - \frac{\Delta m_D t}{\text{tg}^2 \theta_c |\hat{S}_{K\pi}|} \text{Im} \frac{\hat{P}_{K\pi}}{|\hat{S}_{K\pi}|} \right]$$

$$\text{tg}^2 \theta_c \hat{S}_{K\pi} \equiv \frac{T(D^0 \rightarrow K^+\pi^-)}{T(D^0 \rightarrow K^-\pi^+)}$$

↑
CP asym.

$\Gamma(\bar{D}^0(t) \rightarrow K^-\pi^+) \propto e^{-\Gamma_D t} \text{tg}^4 \theta_c |\hat{S}_{K\pi}|^2$

$$\left[\left\{ \hat{S}_{K\pi} \rightarrow \hat{S}_{K\pi} \right\} + \frac{\Delta m_D t}{\text{tg}^2 \theta_c |\hat{S}_{K\pi}|} \text{Im} \frac{\hat{P}_{K\pi}}{|\hat{S}_{K\pi}|} \right]$$

observable CP asymm. $\propto \frac{x_D}{\text{tg}^2 \theta_c}$

e.g.:

if $x_D = 10^{-2}$ $\left\{ \begin{array}{l} \tau_D \approx \frac{1}{2} (x_D^2 + y_D^2) \sim 10^{-4} \\ \frac{x_D}{\text{tg}^2 \theta_c} \sim 0.2 \quad ! \end{array} \right.$

i.e.: could be CP asymm. as large as 10%
without $D^0 - \bar{D}^0$ oscill. exceeding $\tau_D = 10^{-4}$!

will be searched for at beauty factories

superior systematics at ν MC ?

• direct \mathcal{CP}

within KM only in Cabibbo suppr. modes
"typical" expectations $\lesssim O(10^{-3})$

exotic exception: $D^+ \rightarrow K_S \pi^+$ vs. $D^- \rightarrow K_S \pi^-$

2 classes of effects

- partial width differences

$$\Gamma(D \rightarrow f) \neq \Gamma(\bar{D} \rightarrow \bar{f})$$

- asymm. in final state distributions: Dalitz plots etc.

highly desirable to analyze multi-neutral final states

(i) more places to search / self-consistency checks

(ii) great benefit for proper interpretation

? is it KM or is it NP?

superior ~~statistics~~ systematics at ν MC?

special case of direct \mathcal{CP}

T odd correlation in

$$\nu N \rightarrow \Lambda_c X$$
$$\hookrightarrow \ell^+ \nu \Lambda$$

$$C_{T\text{odd}} \equiv \langle \vec{G}_\Lambda \cdot (\vec{p}_\Lambda + \vec{p}_\ell) \rangle \stackrel{?}{\neq} 0 \quad \text{no FSI!}$$

similar to P_\perp in $K^+ \rightarrow \mu^+ \nu \pi^0$

FABULA DOCET

- many important questions in charm & beauty decays (mainly - but not only - quantitative ones) will still await a definitive answer in 2010.
- the urgency of some of them might actually be enhanced by then

$\Delta \mathcal{B}(B) \Big _{\text{exp}} \sim 2\%$	\longleftrightarrow	$\Delta \mathcal{B}(B) \Big _{\text{KM}} ?$
$\mathcal{B}(D) \sim \mathcal{O}(10^{-3})$	\longleftrightarrow	NP ?
$x_D, y_D \sim 0.01$	\longleftrightarrow	NP ?

- ν MC might represent a powerful answer to these challenges due to novel and superior (?) systematics
 - better extraction of $|V_{cd}|, |V_{cb}|, \dots$
 - better calibration of theoret. tools
 - f_D, f_{D_s} ; multi-neutral final states
 - searches for NP
 - $D^0 - \bar{D}^0$ oscill.

\mathcal{B}