

Old and new flavour Physics

Introduction

Flavour : Physics of diff. q and ℓ
masses, mixings, fu....

Physics of the unknown -
not real guiding principle

Quite some progress

- 3 standard generations $\begin{cases} \text{Quarks} \\ \text{leptons} \end{cases}$
- Establishing CKM matrix with high precision
- Confirmation of SM picture (GIM-controllable FV)
- Precision work in QCD and perturbation theory
 $b \rightarrow s\gamma, K \rightarrow \pi\nu\bar{\nu}, \dots$
Lattice, SCET, perturbation theory
R.G. techniques, multiloop ($\rightarrow h.e.$)
- CP-violation studies

All flavour physics described by unitary CKM-matrix and few masses

The parameters show a structure: small and hierarchical

$$|U| \sim \begin{pmatrix} 1 & \lambda & \lambda^3 \\ \lambda & 1 & \lambda^2 \\ \lambda^3 & \lambda^2 & 1 \end{pmatrix} \quad M_1 : M_2 : M_3 \approx \lambda^4 : \lambda^2 : 1$$
$$\lambda \sim 0.2$$

SM gives no explanation:

- just numbers?
- Explained by new symmetries?
model building

Explanation requires new physics
(new symmetries, new particles....)

- NP at scale $\Lambda \gg M_W$

$$L_{\text{eff}} = \sum_i g_i \frac{O^i}{\Lambda^2} + \dots$$

$O^i \sim (\bar{q}q)(\bar{q}q), \dots$ SM-fields

$\langle f | H_{\text{SM}} + g_i \frac{Q^i}{\Lambda^2} | i \rangle$: bounds on g_i / Λ^2

- If $\Lambda \sim \Lambda_{\text{LHC}}$ then investigate NP in more detail (susy, LH, ...)
 - New era for flavour physics can investigate NP directly
- Interplay of NP in colliders and $B(C)$ decays "new flavour physics"

Continuing precision + phenomenological analysis

- Detailed analysis of (specific) B (C) decays ; leptons
- Precision experiments : $d_n, \mu \rightarrow e\gamma$
- B-factories
- Super-B-factories ($\sim 100 \times$ better)
- Use LHC as B source $\rightarrow B_s$ (Tevatron)
- Theoretical + experimental improvements

* $b \rightarrow s\gamma$: 1996 NLO - 2007 NNLO (almost)

$$\text{TH: } BR (3.15 \pm 0.23) 10^{-4}$$

$\hookrightarrow \frac{1}{2}$

$$\text{EXP: } BR (3.55 \pm 0.30) 10^{-4}$$

$$\hookrightarrow 0.01 \text{ Super B}$$

Strong tool against NP :

CP-asymmetry : $SM=0, SUPB \sim \%$

Calculations in MSSM etc. Detailed work, up to (almost) NLO in many models.

Extensive QCD work (SCET..) :
Endpoint E_ν

- * Exclusive modes $B \rightarrow K^* \gamma \dots$
CP-violation studies at LHCb
- * $b \rightarrow s \ell \ell$
NLO-work, interesting distributions
more and complementary information
to $b \rightarrow s \gamma$
 - $BR(b \rightarrow s \ell \ell) = 1.6 \cdot 10^{-6} (\pm 0.1) \text{ SM}$
 $= 3.2 \cdot 10^{-6} (-C_7)$
 - $\pm (1-2) 10^{-6} \text{ Exp}$
- * Zero in the FB asymmetry ($C_7!$)
Super-B tests CP-violations $\sim \%$
- * Similar possibilities at LHCb, ATLAS
for excl. decays ($B \rightarrow K^{(*)} \ell \ell$)

Strong tests for NP
zero shifts considerably
polarization of K^*
- * $b \rightarrow s \nu \bar{\nu}$
Clear theoretically (relate to $b \rightarrow c \bar{e} \nu$)
 $BR \sim 10^{-6}$
limits; Super-B

- $B \rightarrow \tau\nu$ ($BR \sim 10^{-4}$)

Strong tests for charged Higgs / $\tan\beta$

\rightarrow several hundred GeV for m^+

$B \rightarrow \mu\nu$ at Super-B

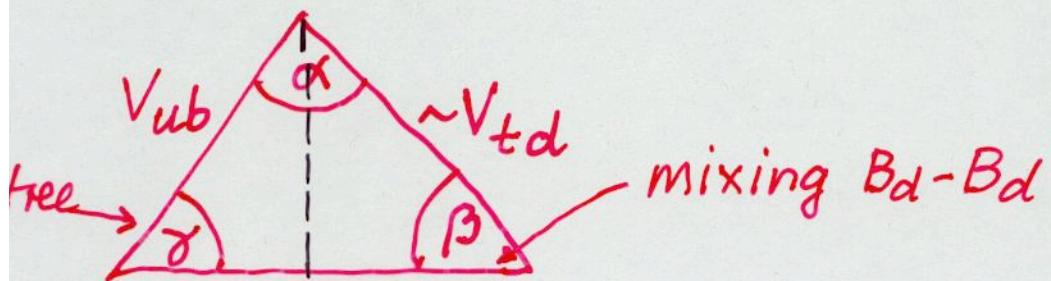
- $B \rightarrow l^+l^-$ ($BR \sim 10^{-7} - 10^{-15}$)

Central focus at LHC

SM within reach for $B_s \rightarrow \mu\mu$ (10^{-9})

Angles of UT; CP-violation

UT fits $(\alpha, \beta, \gamma) \sim (90 \pm 7, 22 \pm 1, 66 \pm 7^\circ)$



β : mixing (Loop) may have NP contrib.

clean ($\sim \%$) theoretically
measurable in many decays

$b \rightarrow ccs, b \rightarrow sss, B \rightarrow D\pi \dots$

Puzzles in $b \rightarrow sss$
all values smaller } \rightarrow NP

Super-B : # 0.01

γ : question of time

Super-B, LHCb $1-2^\circ$

$B_d \rightarrow DK, B_s \rightarrow D_s K \dots$

α : Can reach $\sim 1-2^\circ$

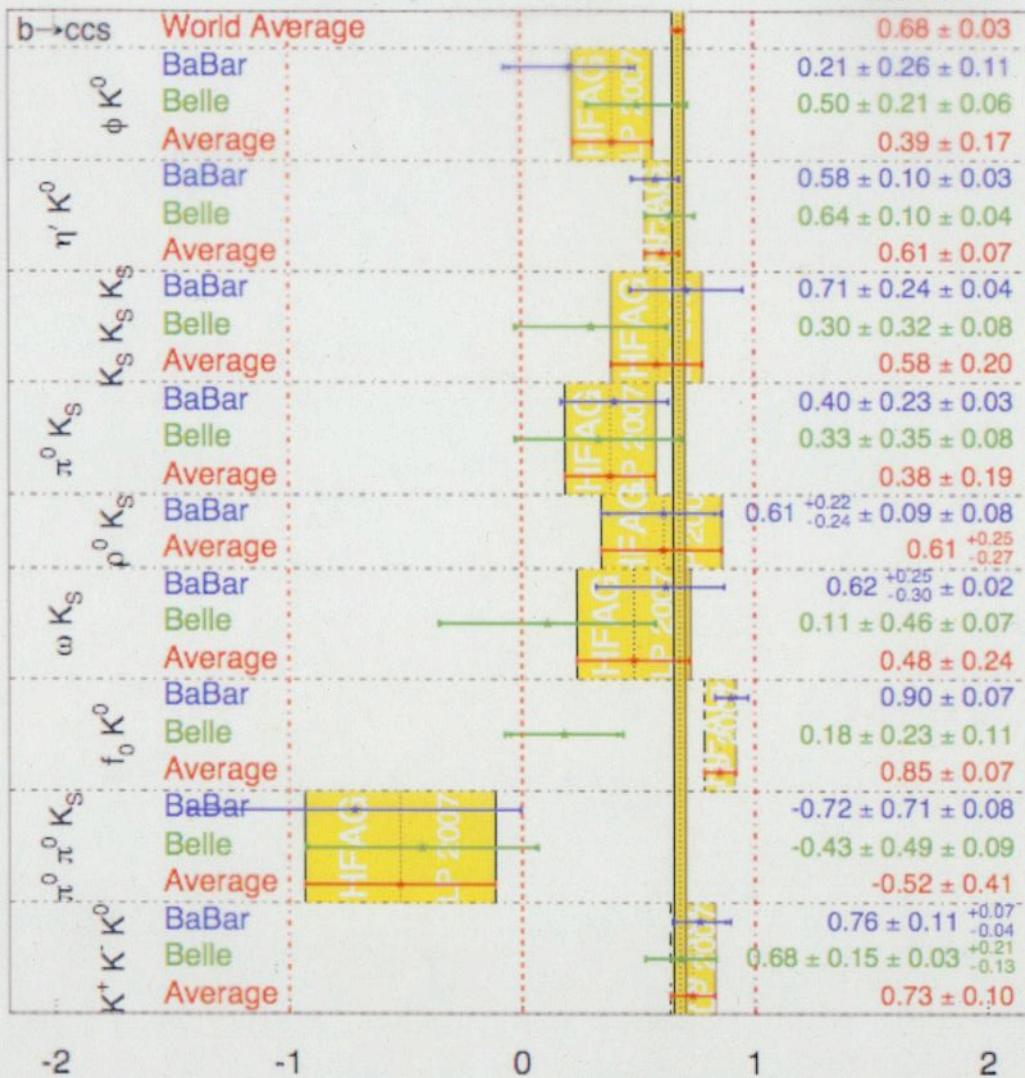
' β ' from $\gamma, |V_{ub}/V_{cb}|$ exact β

$$\sin(2\beta^{\text{eff}}) \equiv \sin(2\phi_1^{\text{eff}})$$

HFAG

LP 2007

PRELIMINARY



-2

-1

0

1

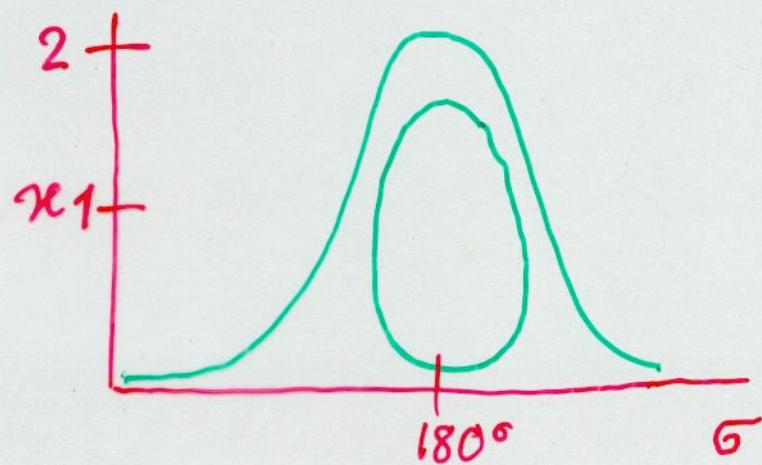
2

New options at LHCb

B_s -physics (continuing Tevation)

- New physics in Δm_s

$$\Delta m_s = \Delta m_s^{\text{SM}} (1 + \alpha e^{i\phi})$$



recent analysis (includes A_{SL} , $A_{SL}^{\mu\mu}$, τ_{B_s} , $B_s \rightarrow J/\psi \phi$ → large effect: $\phi \sim 50^\circ$!)

- Rare decays $B_s \rightarrow \mu\mu \dots$
comparisons with $b \rightarrow s \mu\mu$
 $B_s \rightarrow \phi\phi$ ($b \rightarrow sss$)
- angle γ from $B_s \rightarrow K\bar{K}$, etc.

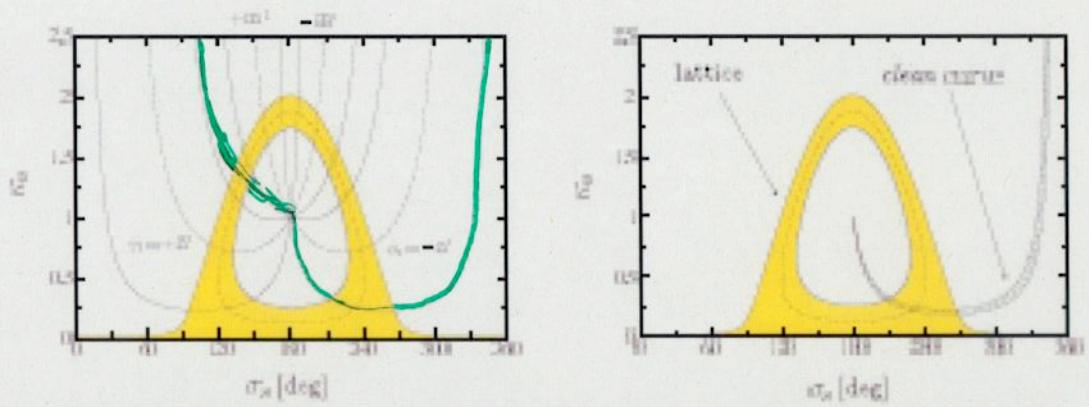
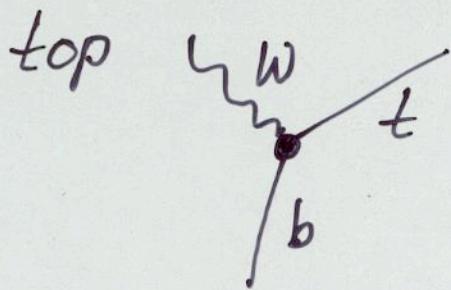


Figure 2: Impact of the measurement of CP violation in $B_s^0 \rightarrow J/\psi\phi$: current D0 data [left panel], and a NP scenario with $(\sin \phi_s)_{\text{exp}} = -0.20 \pm 0.02$ [right panel].

*Typical progress in coming years on constraining
NP (Fleischer)*

New flavour physics

10



(Wtb) -operators

- Constraints from

$$g_{Wtb} < 0.02 - 0.05$$

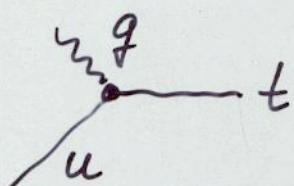
- Anomalous couplings from t -decays
(correlations, polarizations)

$$g_{Wtb} < 0.01 - 0.1$$

- V_{tb} in single top production
(without unitarity)
example: $|V_{tb}| \gtrsim 0.5$

- Effective approach

$$\dots O \sim \frac{1}{\Lambda} (\bar{u} G_F t)$$



Correlations production-decays $t \rightarrow ug$

- Rare decays: $t \rightarrow qZ, \dots$

$$10^{-14} \rightarrow 10^{-7} \rightarrow 10^{-5} \rightarrow 10^{-4} \dots$$

- Many effects (SUSY, extra dimensions) considered

Flavour + NP

Flavour - Higgs - Gauge SM
q's, e's

some q-e connection (GUT)

sflavour shiggs sgauge SUSY
more FV couplings

Study rare (FV) of $\tilde{q}, \tilde{e}, \dots$

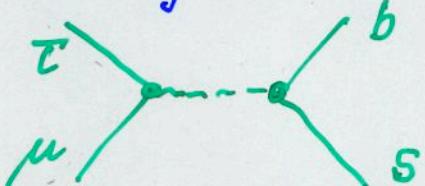
Next step ?

Higgs - flavours ?

$\{H_1\}, \{H_2\}, \{H_3\} \dots$

more general flavour notion
model building

- $\{H_i\} \rightarrow \{H_j\} + \dots$
- $q_i \leftrightarrow e_j$ connection



Absence of large FV

$$SM: \mathcal{L} = i\bar{\psi}\not{D}\psi + \sum L_i \Gamma_{ik} R_k \phi \dots$$

- Flavour only in Γ
- automatic GIM ("accidental")

Could be different with flavour-Higgs

$$NP: \sum \frac{1}{\Lambda^n} O^{cn} \quad \Lambda \geq 1 \text{ TeV}$$

various limits $1 \text{ TeV} - 10^4 \dots \text{TeV}$

($b s \bar{s} s$)-operator $\Lambda > 10^4 \text{ TeV}$

not so interesting

Needs some structure:

- Flavour blind
 - Minimal flavour violation (only Γ)
- :

(MFV) leads to definite predictions

- MFV and GUT may clash
- Difficult to find "reason"

Message

- Much more standard flavour physics ahead (interesting)
- Not clear where it points
- "New flavour" physics (production)
(anomal. productions, rare decays..)
- Work on leptons, charm?

Could end up with nothing -
or deep insights