BOLOGNA

Analisi generalizzata e scale di Nuova Fisica da transizioni $|\Delta F|=2$

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on behalf of the UTfit Collaboration

http://www.utfit.org

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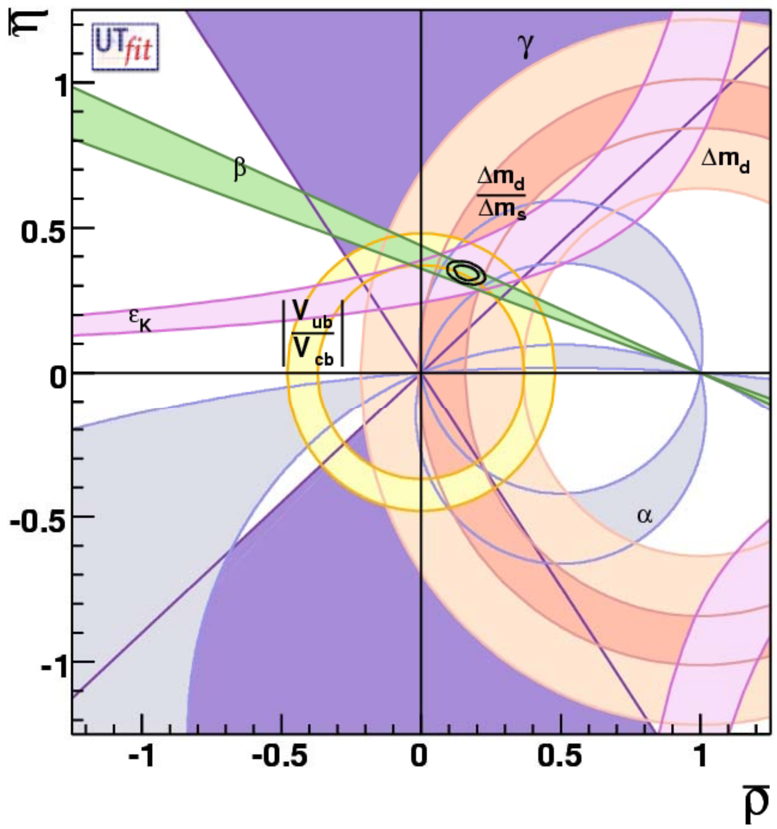
Incontri di Fisica delle Alte Energie 2007

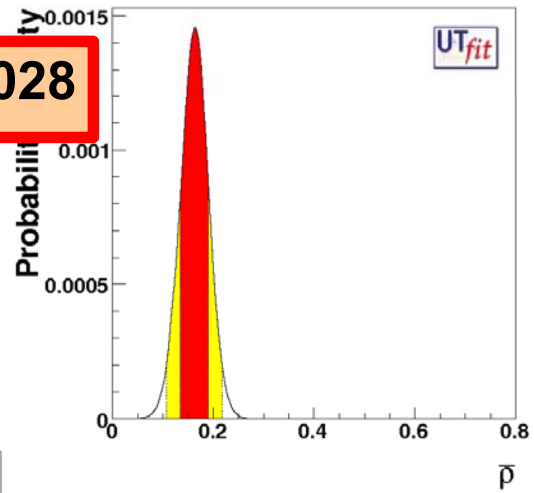
Outline

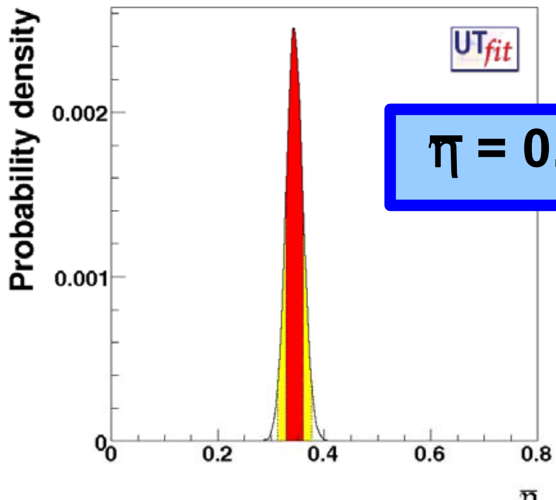
- Standard Model fit (very briefly)
- Un sassolino nella scarpa: α da $B \rightarrow \pi\pi$
- NP generalized fit allowing for $\Delta F=2$ NP transitions
- Effective Hamiltonian for $\Delta F=2$ transitions beyond the SM
- Bounds on Wilson coefficients and NP scales in different NP scenarios
- Comment on perspectives for direct detection of NP at the LHC

Standard Model fit



$\bar{\rho} = 0.163 \pm 0.028$



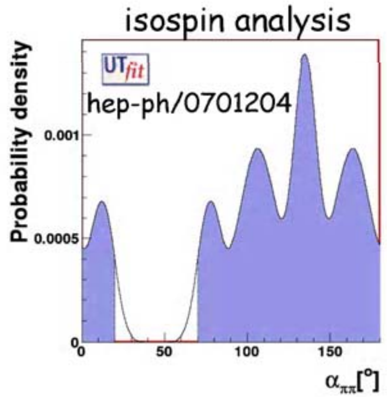


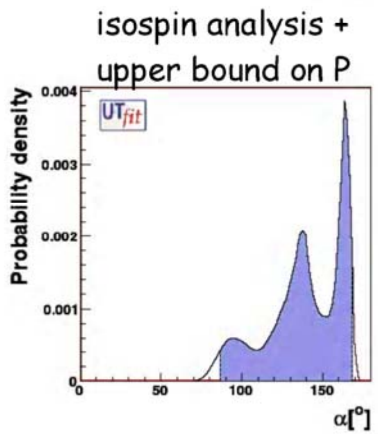
$\bar{\eta} = 0.344 \pm 0.016$

Apart from a slight tension due to V_{ub} inclusive with respect to the rest of the fit (very unlikely to be due to New Physics…) the consistency of the SM fit is just spectacular

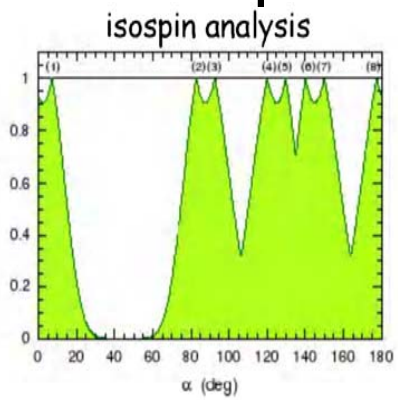
A debated question: α from $B \rightarrow \pi\pi$

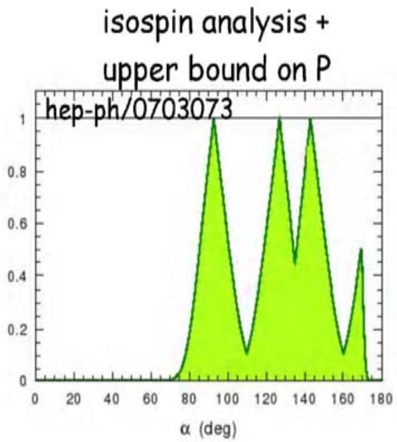
Analisi Bayesiana





Analisi Frequentista





Annoso problema: perché la collaborazione CKMfitter trova una soluzione compatibile con α=0 anche se la violazione di CP in $B \rightarrow \pi^+\pi^-$ è appurata a più di 5σ, mentre per UTfit la soluzione α=0 è soppressa come atteso dal buon senso e dalla fisica?

Risposta CKMfitter: l'analisi UTfit è fortemente influenzata dai prior, il metodo statistico è inattendibile.

Risposta UTfit: l'analisi CKMfitter non tiene conto di importanti informazioni di fisica nella soluzione del problema, il metodo statistico non è rilevante. Bayes può dormire sonni tranquilli (semmai si fosse turbato…)

α < 2 implicherebbe P > 30, mentre SU(3) dal BR($B_s \rightarrow K^+K^-$) implica P ~ 1. Una rottura di SU(3) del 3000% è fuori questione. Peraltro, che ne sarebbe di SU(2) in tal caso? La soluzione del problema viene dalla fisica, e non dalla statistica! Lavoro a stampa in arrivo…

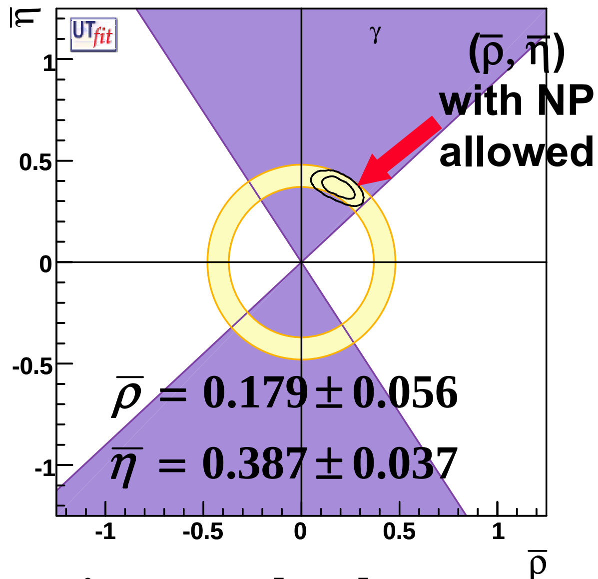
New Physics generalized fit

The mixing processes being characterized by a single amplitude, they can be parametrized in a general way by means of two parameters

$$C_{B_q} e^{2i\phi_{B_q}} = \frac{\langle B_q^0 | H_{eff}^{full} | \overline{B}_q^0 \rangle}{\langle B_q^0 | H_{eff}^{SM} | \overline{B}_q^0 \rangle} \qquad q = d,\, s$$

- H^{SM}_{eff} includes only SM box diagrams while H^{full}_{eff} includes New Physics contributions as well

Summer 2006



Using Tree-level processes assumed to be NP-free

**the effect in the D^0-$\bar{D}^0$ mixing is neglected*

Four “independent” observables

- C_{Bd}, ϕ_{Bd}, C_{Bs}, ϕ_{Bs}
- $C_{Bq}=1$, $\phi_{Bq}=0$ in SM

For the neutral kaon mixing case, it is convenient to use the following two parameters

$$C_{\varepsilon_K} = \frac{\mathrm{Im}\langle K^0 | H_{eff}^{full} | \overline{K}^0 \rangle}{\mathrm{Im}\langle K^0 | H_{eff}^{SM} | \overline{K}^0 \rangle} \qquad C_{\Delta m_K} = \frac{\mathrm{Re}\langle K^0 | H_{eff}^{full} | \overline{K}^0 \rangle}{\mathrm{Re}\langle K^0 | H_{eff}^{SM} | \overline{K}^0 \rangle}$$

The CKM fit determines ρ, η, C_{Bq}, ϕ_{Bq}, $C_{\varepsilon K}$ and $C_{\Delta mK}$ simultaneously

**to be conservative a long-distance contribution between zero and the experimental Δm_K is added to $C_{\Delta mK}$*

Information on the moduli

B_d sector

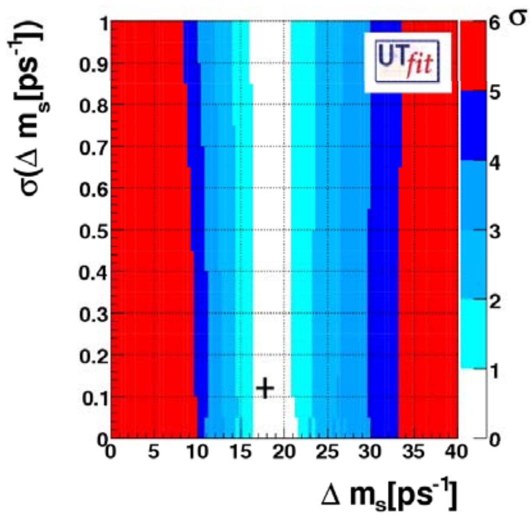
$\Delta m_d = (0.507 \pm 0.005)\ ps^{-1}$

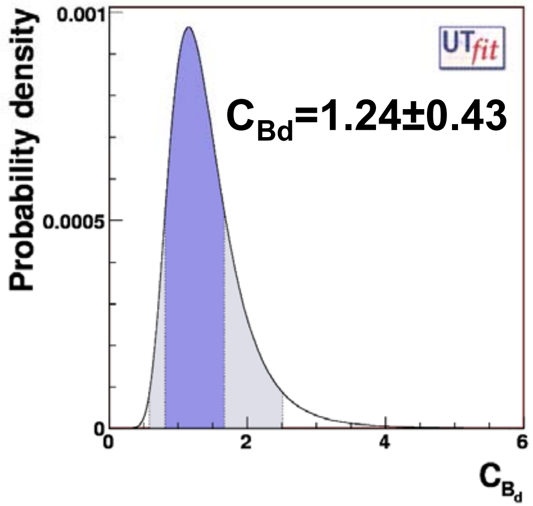
B_s sector

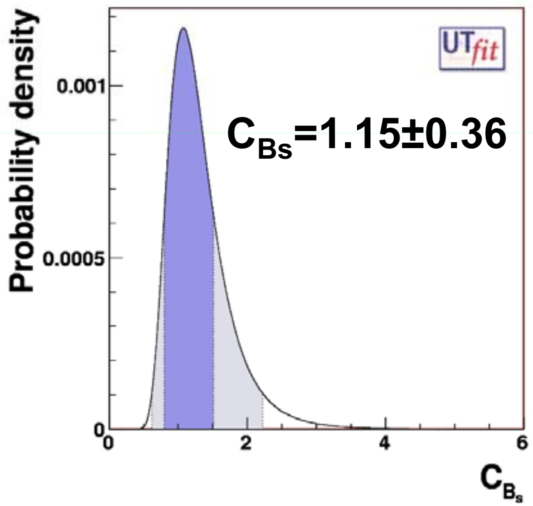
$\Delta m_s = (17.77 \pm 0.10 \pm 0.07)\ ps^{-1}$

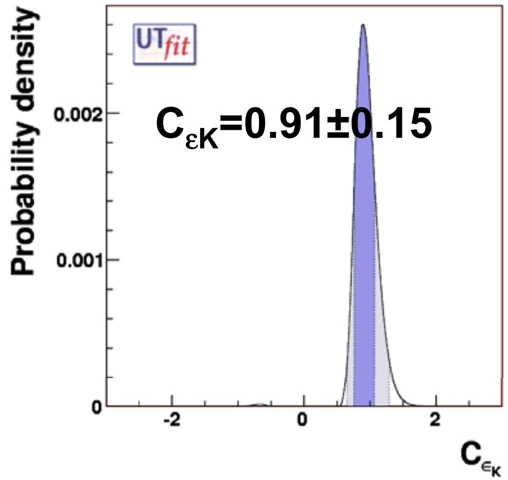
K^0 sector

$\varepsilon_K = (2.280 \pm 0.013) \cdot 10^{-3}\ ps^{-1}$









Information on the B_s mixing phase

Recent measurements from the Tevatron opened the box of the B_s mixing phase

$a_{CH}^{dimuon} = (-9.2 \pm 4.4 \pm 3.2) \times 10^{-3}$ measured by D0

$\Delta\Gamma_s = (0.47^{+0.19}_{-0.24} \pm 0.01)$ ps^{-1} measured by CDF

$A_{SL}^{s} = (24.5 \pm 19.3 \pm 3.5) \times 10^{-3}$ measured by D0

and in addition the time-dependent (untagged) angular analysis of the $B_s \to J/\psi\phi$ decay by D0, yielding a 3-dimensional measurement of $\Delta\Gamma_s$, Γ_s and ϕ_{Bs}

4-fold ambiguity $(\phi_{Bs}, \cos\delta_{1,2}) \leftrightarrow (-\phi_{Bs}, -\cos\delta_{1,2})$, $(\phi_{Bs}, \Delta\Gamma_s) \leftrightarrow (\pi+\phi_{Bs}, -\Delta\Gamma_s)$

For extreme precision measurements of ϕ_s we have to wait LHCb in a couple of years

Bounds on the mixing phases

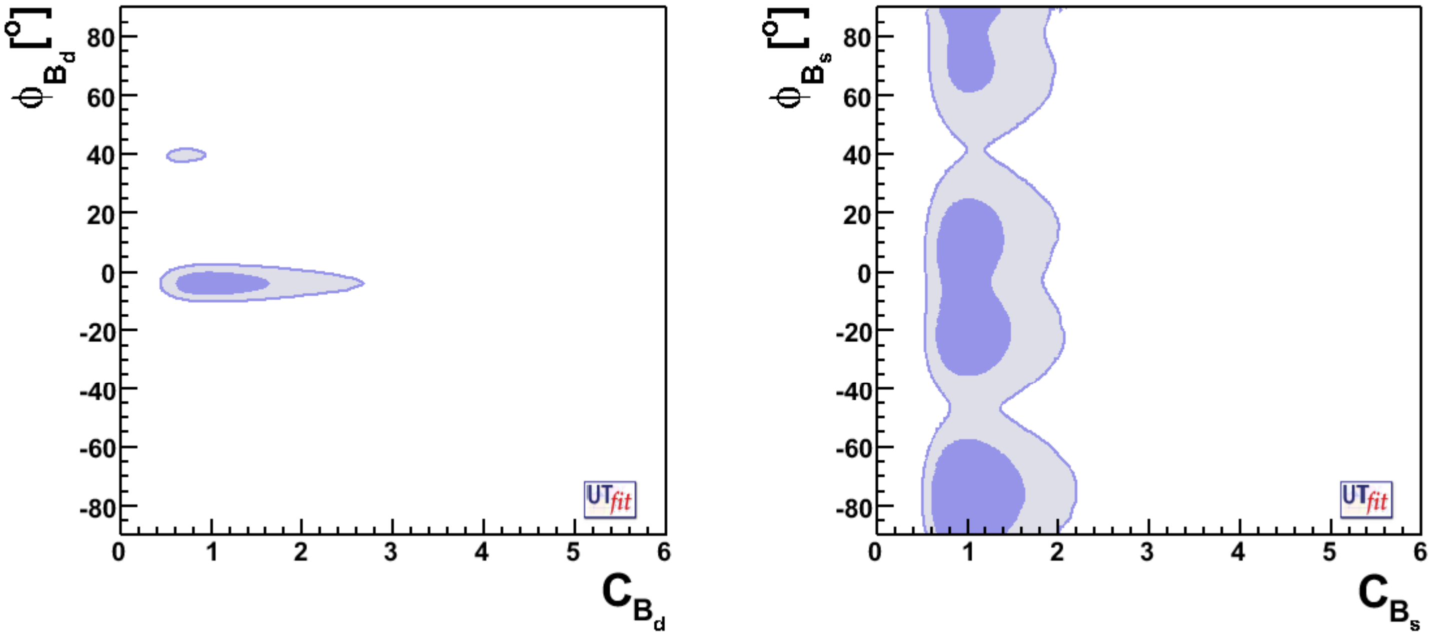
B_d mixing:

$\phi_{Bd} = (-4 \pm 2)^o$

B_d mixing phase very well contrained but still ample room for a large B_s phase

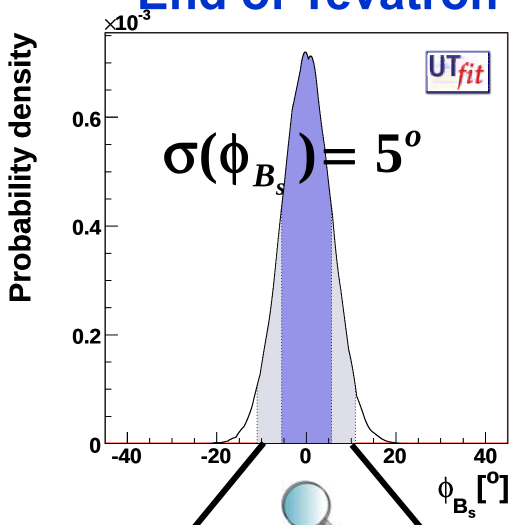
B_s mixing:

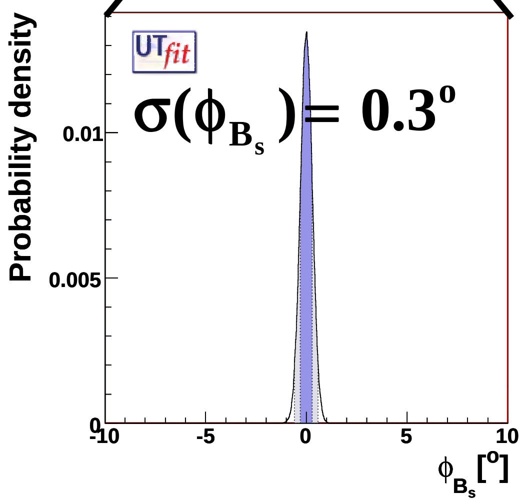
$\phi_{Bs} = (-75 \pm 14)^o \cup (-19 \pm 11)^o \cup (9 \pm 10)^o \cup (102 \pm 16)^o$



Perspectives in the (not-so-far) future

End of Tevatron



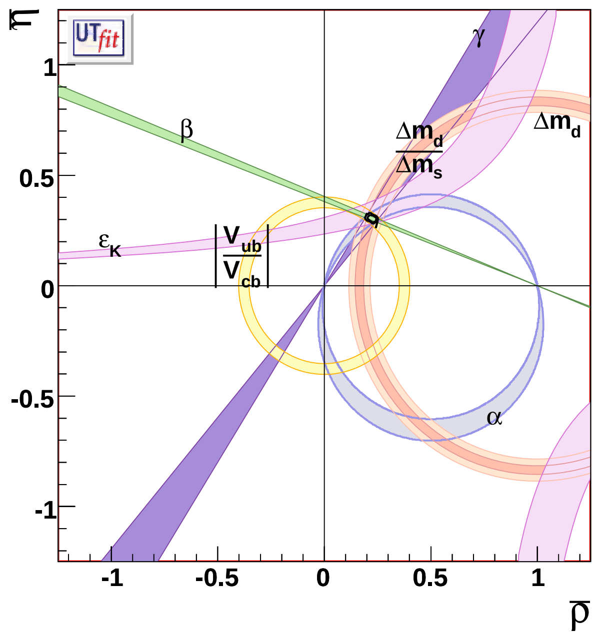


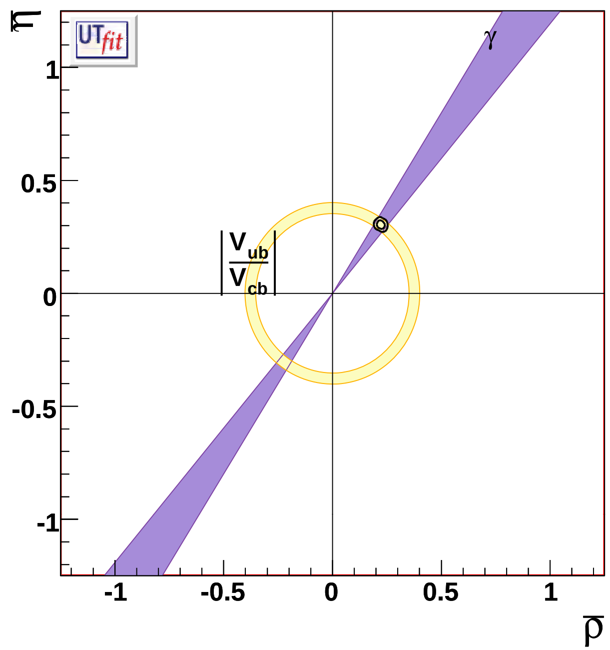
Relevant impact of LHCb on the B_s mixing phase and on γ

- can bring down the sensitivity to the NP contribution ϕ_{Bs} from 5° at the end of the Tevatron to 0.3°
- γ will be known at about 2°

With LHCb at $L=10\ fb^{-1}$ (around 2014)

Significant improvements in the B_d sector expected at a SuperB-Factory





Effective Hamiltonian for ΔF=2 transitions beyond the SM

Most general form of the effective Hamiltonian for ΔF=2 processes

$$\mathcal{H}_{\rm eff}^{K-\bar{K}} = \sum_{i=1}^{5} C_i\, Q_i^{sd} + \sum_{i=1}^{3} \tilde{C}_i\, \tilde{Q}_i^{sd}$$

$$\mathcal{H}_{\rm eff}^{B_q-\bar{B}_q} = \sum_{i=1}^{5} C_i\, Q_i^{bq} + \sum_{i=1}^{3} \tilde{C}_i\, \tilde{Q}_i^{bq}$$

The Wilson coefficients C_i have in general the form

$$C_i(\Lambda) = F_i \frac{L_i}{\Lambda^2}$$

- **F_i: function of the NP flavour couplings**
- **L_i: loop factor (in NP models with no tree-level FCNC)**
- **Λ: NP scale (typical mass of new particles mediating ΔF=2 transitions)**

Putting bounds on the Wilson coefficients give insights into the NP scale, in different NP scenarios which enter through F_i and L_i

Different NP scenarios

The connection between Ci(Λ) and the NP scale Λ depends on the specific NP model under consideration

Assuming that new particles interact strongly and/or enter at tree-level we can set L_i~1, thus $\Lambda = \sqrt{F_i / C_i}$

Let's make four relevant cases:

- Minimal Flavour Violation with one Higgs or two Higgs doublets with small or moderate tanβ
  - $F_1 = F_{SM}$, $F_{i\neq 1} = 0$, where F_{SM} are CKM matrix elements in the top-quark mediated SM mixing amplitudes
- Minimal Flavour Violation at large tanβ
  - Additional contribution in B_q mixing by C_4 which differentiates B-meson mixing from Kaon mixing
- Next-to-Minimal Flavour Violation
  - $|Fi| = F_{SM}$ with arbitrary phases
- Arbitrary flavour structure, i.e. no CKM suppression in NP transitions
  - $|Fi| \sim 1$

Other interesting cases are from loop-mediated NP processes, and L_i would be proportional to α_s^2 and α_W^2

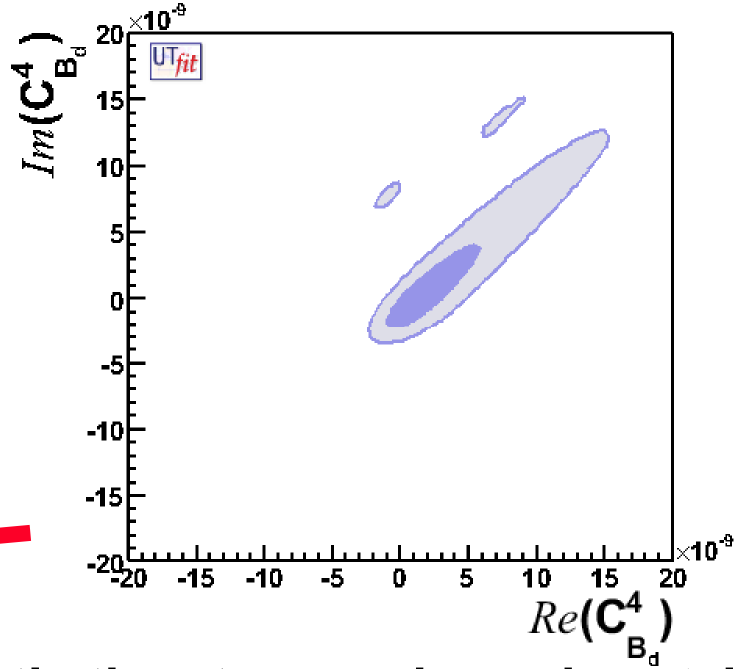
Λ is reduced by a factor ~0.1 and ~0.03 respectively

Allowed ranges for Wilson coefficients: an example

Upper and lower bounds on $|C_i(\Lambda)|$ and Λ for NMFV models

Parameter	95% Upper Limit	Lower limit on Λ (TeV)
	K Sector	
$\lvert C_K^1 \rvert$	$4.3 \cdot 10^{-6}$	0.5
$\lvert C_K^2 \rvert$	$7.6 \cdot 10^{-8}$	3.6
$\lvert C_K^3 \rvert$	$2.8 \cdot 10^{-7}$	1.9
$\lvert C_K^4 \rvert$	$1.9 \cdot 10^{-8}$	7.3
$\lvert C_K^5 \rvert$	$5.4 \cdot 10^{-8}$	4.3
	B_d Sector	
$\lvert C_{B_d}^1 \rvert$	$3.6 \cdot 10^{-8}$	5.3
$\lvert C_{B_d}^2 \rvert$	$2.0 \cdot 10^{-8}$	7.1
$\lvert C_{B_d}^3 \rvert$	$7.2 \cdot 10^{-8}$	3.6
$\lvert C_{B_d}^4 \rvert$	$6.8 \cdot 10^{-9}$	12
$\lvert C_{B_d}^5 \rvert$	$1.7 \cdot 10^{-8}$	7.7
	B_s Sector	
$\lvert C_{B_s}^1 \rvert$	$4.8 \cdot 10^{-8}$	3.5
$\lvert C_{B_s}^2 \rvert$	$5.6 \cdot 10^{-8}$	4.3
$\lvert C_{B_s}^3 \rvert$	$2.1 \cdot 10^{-7}$	2.2
$\lvert C_{B_s}^4 \rvert$	$2.1 \cdot 10^{-8}$	6.9
$\lvert C_{B_s}^5 \rvert$	$5.3 \cdot 10^{-8}$	4.3

Leave the (complex) C_i coefficients as free parameters to be determined by the fit



Currently the stronger bound on Λ in NMFV scenarios come from C_4 bound in the B_d sector

Λ > 12 TeV

New Physics scales (lower bounds) Perspectives for detection at LHC

	strong/tree	α_s loop	α_W loop
MFV (small $\tan\beta$)	5.5 TeV	0.5 TeV	0.2 TeV
MFV (large $\tan\beta$)	5.1 TeV	0.5 TeV	0.2 TeV
NMFV	12 TeV	1.2 TeV	0.4 TeV
General	2600 TeV	260 TeV	90 TeV

The direct detection of NP in case of an arbitrary flavour structure is clearly far beyond the reach of LHC, even in case of loop suppression

For MFV models, α_s (or α_W) loop-suppression is needed for a detection at LHC

In case of NMFV, α_s loop-suppression might not be sufficient, α_W would be needed

Conclusions

Any model with strongly interacting NP and/or tree-level contributions is beyond the reach of the LHC, while weakly-interacting NP models can be accessible at the LHC provided that they enjoy at least a NMFV-like suppression of $\Delta F = 2$ processes

In the worst scenario, direct detection of NP at LHC might not happen

Low energy measurements could remain the only way to probe the frontiers of HEP for a while

Actually a strong physics case for the forthcoming LHCb and for the (hopefully not so far) SBF

The End