LATTICE QCD AND NEW PHYSICS: PRESENT & FUTURE

Luca Silvestrini – INFN, Rome

- Introduction (and Past)
- Present:
  - precision flavour physics & bounds on New Physics
  - evidence of New Physics in the flavour sector (?)
- Future:
  - New Physics Lagrangian determination
- Conclusions

See also: Gamiz, Lellouch & parallel session

Special thanks to M. Bona and M. Ciuchini

INTRODUCTION

The Standard Model works beautifully up to a few hundred GeV's, but it must be an effective theory valid up to a scale $\Lambda \sim M_{NP}$:

$$\mathcal{L}(M_W) = \Lambda^2 H^\dagger H + \lambda \left(H^\dagger H\right)^2 + \mathcal{L}_{\rm SM}^{\rm gauge} + \mathcal{L}_{\rm SM}^{\rm Yukawa} + \frac{1}{\Lambda}\mathcal{L}^5 + \frac{1}{\Lambda^2}\mathcal{L}^6 + \ldots$$

EW scale

Has accidental symmetries

Violates accidental symmetries

HOW TO PROBE NEW PHYSICS WITH FLAVOUR

In the SM, three flavours of fermions with same gauge quantum numbers but different mass.

Flavour eigenstates are not weak interaction eigenstates

⇒ weak interactions change flavour

Accidental symmetry of the SM: Neutral current weak interactions conserve flavour!

⇨ quantum corrections computable and sensitive to higher-dim operators

CKM MATRIX AND UT

- All flavour violation from charged current coupling: CKM matrix V

$$V_{CKM} = \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\bar{\rho}-i\bar{\eta}) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

- Top quark exchange dominates FCNC loops: third row (V_{tq}) determines FCNC's $\leftrightarrow \bar{\rho}, \bar{\eta}$

Flavour summarized on the $\rho-\eta$ plane

$BR(b\to cl\nu)$, $BR(B\to D^{(*)}l\nu)$ (LAT)

$BR(b\to ul\nu)$, $BR(B\to \pi l\nu)$ (LAT)

Δm_q (B_q-B_q mass diff.) LAT

$A_{CP}(b\to c\bar{c}s)$ (J/ψ K, ...)

$A_{CP}(b\to s\bar{s}s, d\bar{d}s)$ (ϕ K, πK, ...) HAD

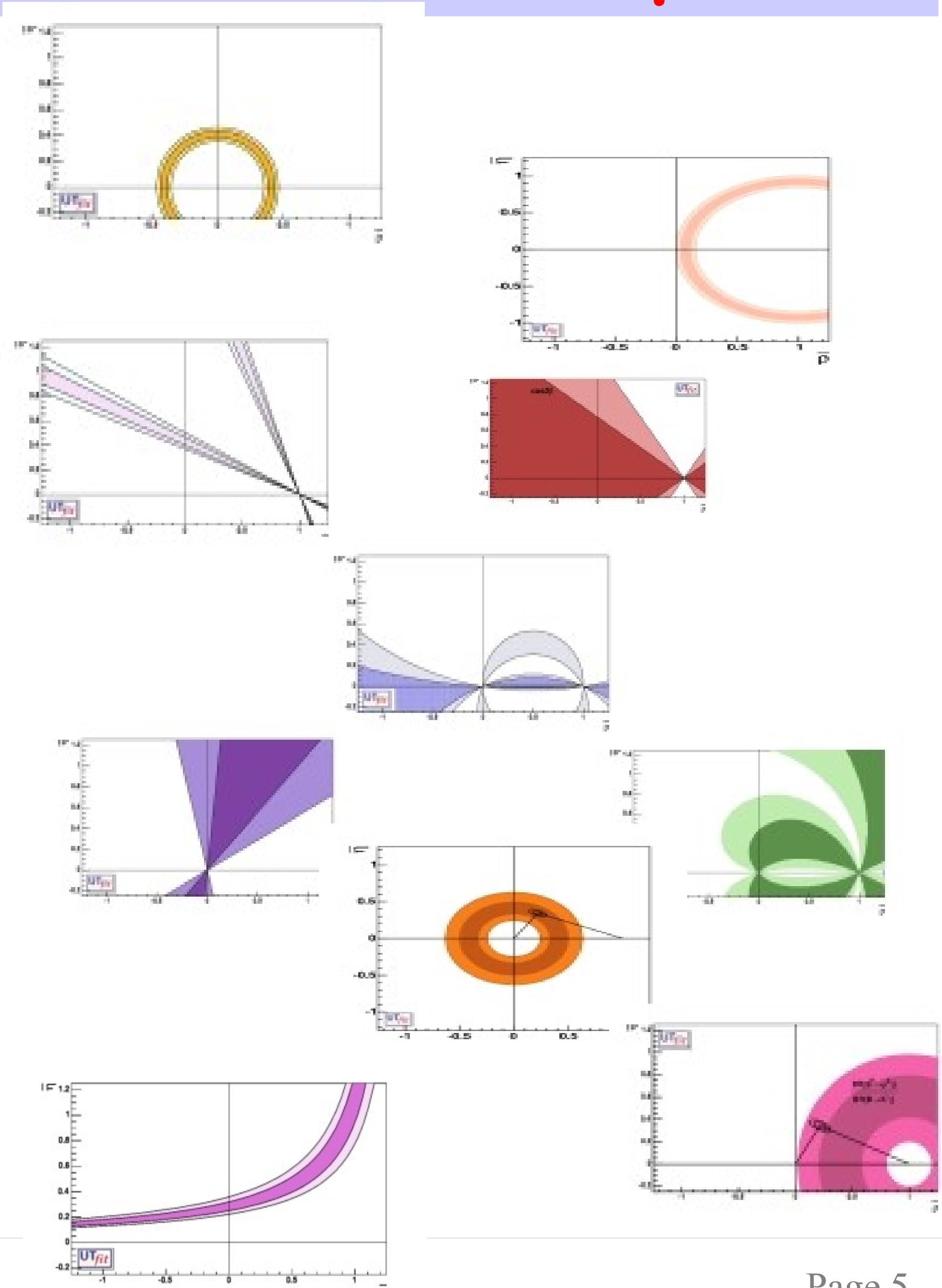
$A_{CP}(b\to d\bar{d}d, u\bar{u}d)$ ($\pi\pi$, $\rho\rho$, ...)

$BR(b\to c\bar{u}d, c\bar{u}s)$ (DK, ...)

$BR(B\to\tau\nu)$ LAT

$BR(B\to\rho\gamma)/BR(B\to K^*\gamma)$ HAD

ε_K (CP violation in K mixing) LAT



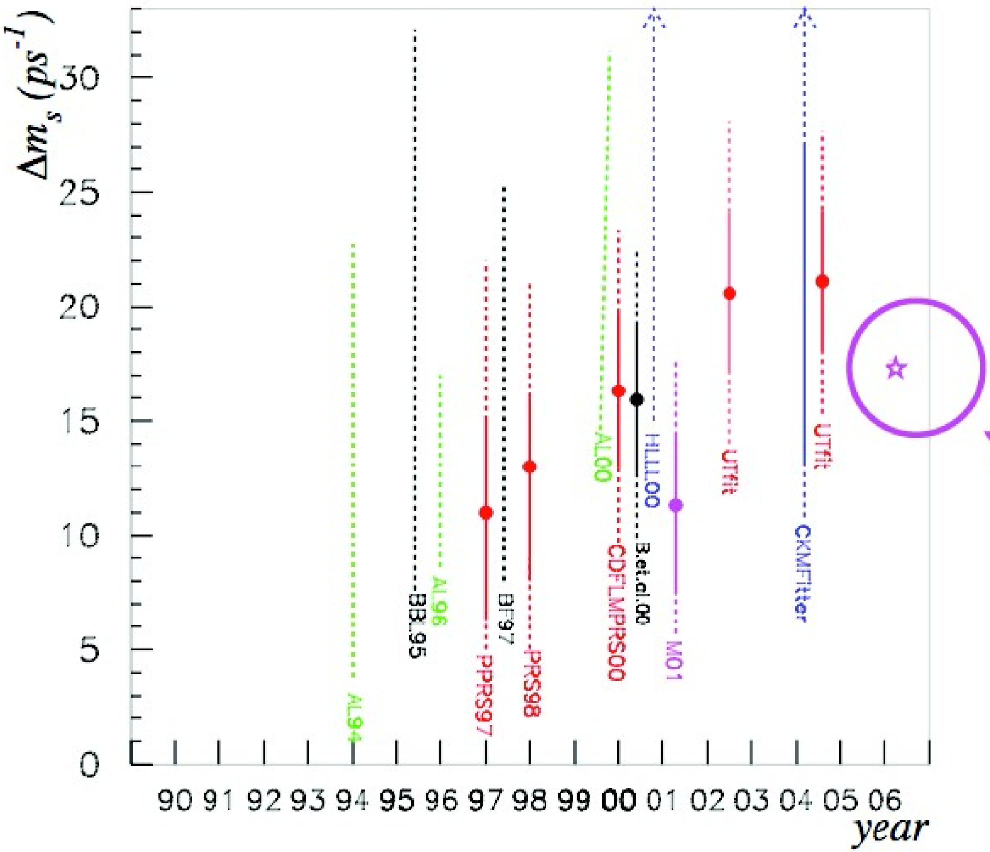
THE PAST: A GREAT SUCCESS OF (QUENCHED) LATTICE QCD

- Using Lattice QCD, two very successful predictions have been made: $\sin 2\beta$ and Δm_s
- $\sin 2\beta_{pred} = 0.65 \pm 0.12$ (Ciuchini et al, 1995)

  $\sin 2\beta_{pred} = 0.70 \pm 0.07$ (Ciuchini et al, 2000)

  $\sin 2\beta_{exp} = 0.668 \pm 0.028$ ($B_d \to J/\psi\, K_S$)

Theoretical predictions of Δm_s in the years



predictions exist since '97

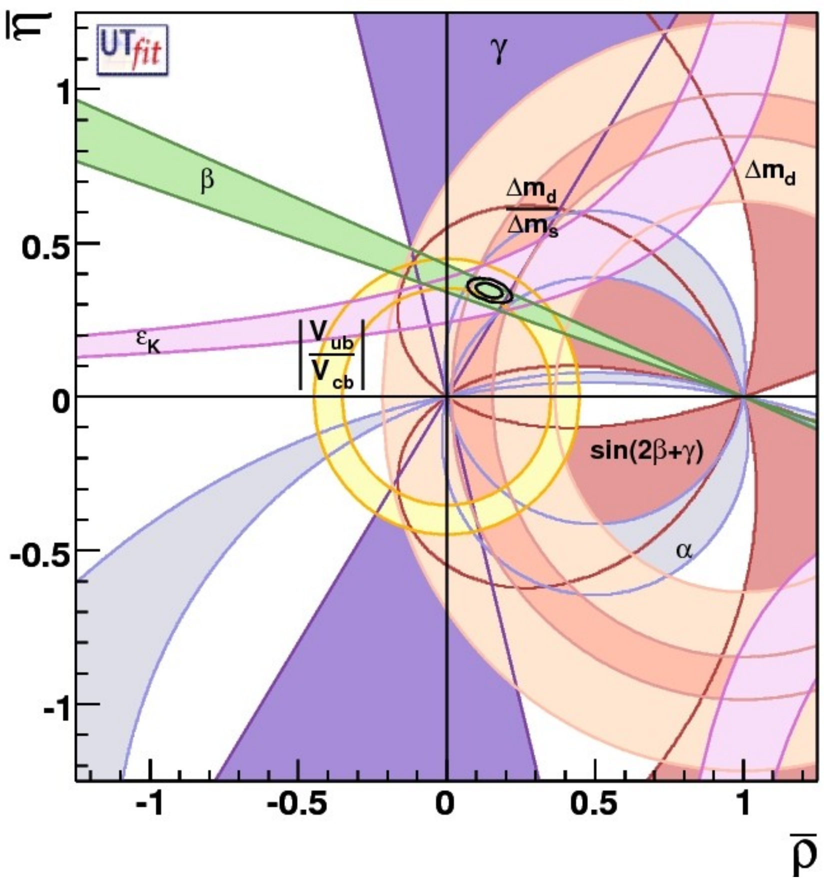
CDF

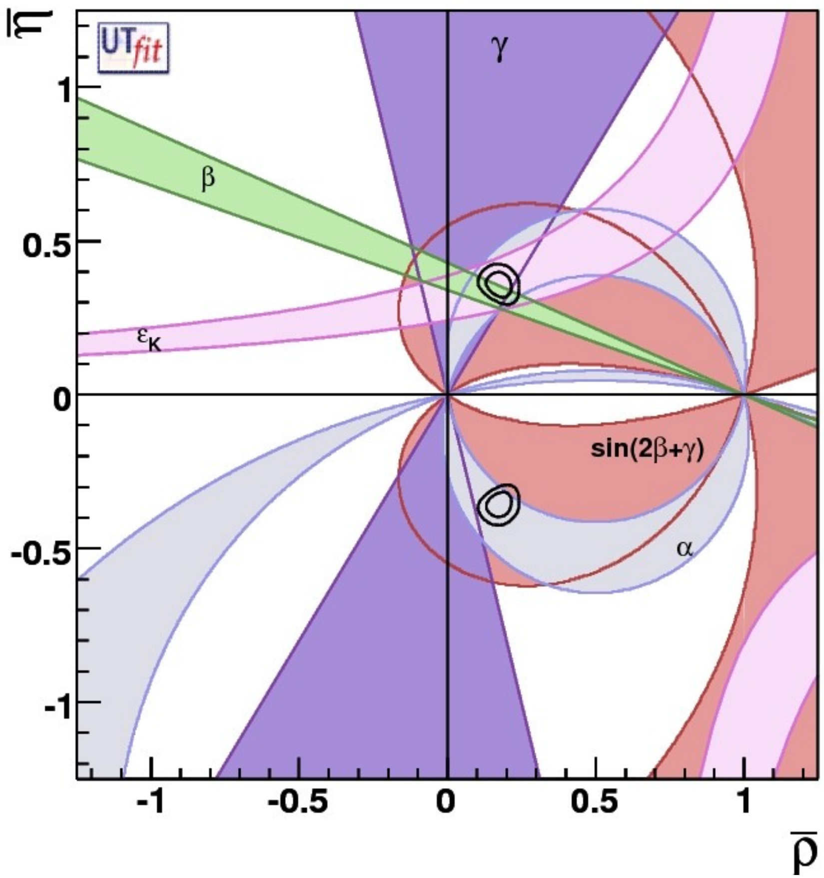
A GREAT SUCCESS OF (QUENCHED) LATTICE QCD CALCULATIONS

G. Martinelli @ CERN 08

PRESENT: THE SM UT ANALYSIS

End of SM parameter determination era, begin of precision test era: redundant determination of the triangle with new measurements from B-factories and Tevatron and test of new physics.





Slight tension between CP-conserving and CP-violating...

THE $\sin 2\beta$-V_{ub} TENSION

- Fit "predictions" vs exp results:
  - $V_{ub}^{UT}=(3.48\pm0.16)\ 10^{-3}$ vs
    $V_{ub}^{excl}=(3.5\pm0.4)\ 10^{-3}$,
    $V_{ub}^{incl}=(4.00\pm0.15\pm0.40)\ 10^{-3}$
  - $\sin 2\beta^{UT}=0.735\pm0.034$ or
    $\sin 2\beta^{UT}_{noVub}=0.75\pm0.09$ vs
    $\sin 2\beta^{J/\Psi Ks}=0.668\pm0.028$

UTfit coll., summer 08

See however Soni & Lunghi, Buras & Guadagnoli

THE ROLE OF LATTICE QCD

- Since the determination of the UT is redundant, can compare the indirect (i.e. from the UT fit) determination of QCD parameters with the Lattice QCD input:

UTfit Coll, hep-ph/0606167
& Summer 08 update

  - $B_K^{UT}=0.75\pm0.07$, $B_K^{LAT}=0.75\pm0.07$
  - $f_{Bs}\sqrt{B_{Bs}}^{UT}=265\pm4$ MeV, $f_{Bs}\sqrt{B_{Bs}}^{LAT}=270\pm30$ MeV
  - $\xi^{UT}=1.25\pm0.06$, $\xi^{LAT}=1.21\pm0.04$

THE UT AND NEW PHYSICS

1. Use the redundancy of the UTA and Lattice QCD to constrain NP in Delta F=2
   - add most general NP to all sectors
   - use all available experimental info
   - fit simultaneously for the CKM and the NP parameters (generalized UT fit)
2. perform an EFT analysis to put bounds on the NP scale
   - consider different choices of the FV and CPV couplings

UTfit Coll., 0707.0636

THE GENERALIZED UTA

- Consider ratios of (SM+NP)/SM amplitudes

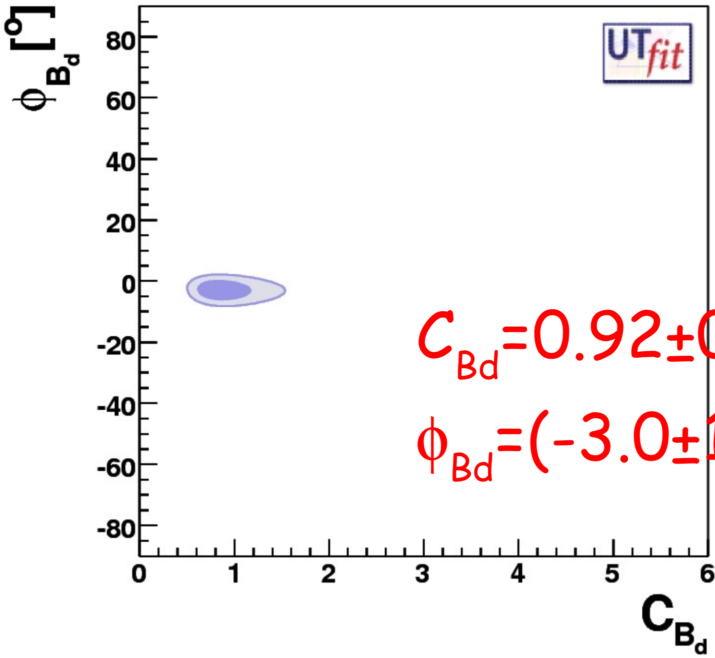
$$C_{B_q}\, e^{2i\phi_{B_q}} = \frac{\langle B_q|H_{\rm eff}^{\rm full}|\bar{B}_q\rangle}{\langle B_q|H_{\rm eff}^{\rm SM}|\bar{B}_q\rangle} = \frac{A_q^{\rm SM} e^{2i\phi_q^{\rm SM}} + A_q^{\rm NP} e^{2i(\phi_q^{\rm SM}+\phi_q^{\rm NP})}}{A_q^{\rm SM} e^{2i\phi_q^{\rm SM}}}$$

$$C_{\epsilon_K} = \frac{{\rm Im}[\langle K^0|H_{\rm eff}^{\rm full}|\bar{K}^0\rangle]}{{\rm Im}[\langle K^0|H_{\rm eff}^{\rm SM}|\bar{K}^0\rangle]}\,, \qquad C_{\Delta m_K} = \frac{{\rm Re}[\langle K^0|H_{\rm eff}^{\rm full}|\bar{K}^0\rangle]}{{\rm Re}[\langle K^0|H_{\rm eff}^{\rm SM}|\bar{K}^0\rangle]}$$

- Determine C's and ϕ's using generalized UT analysis

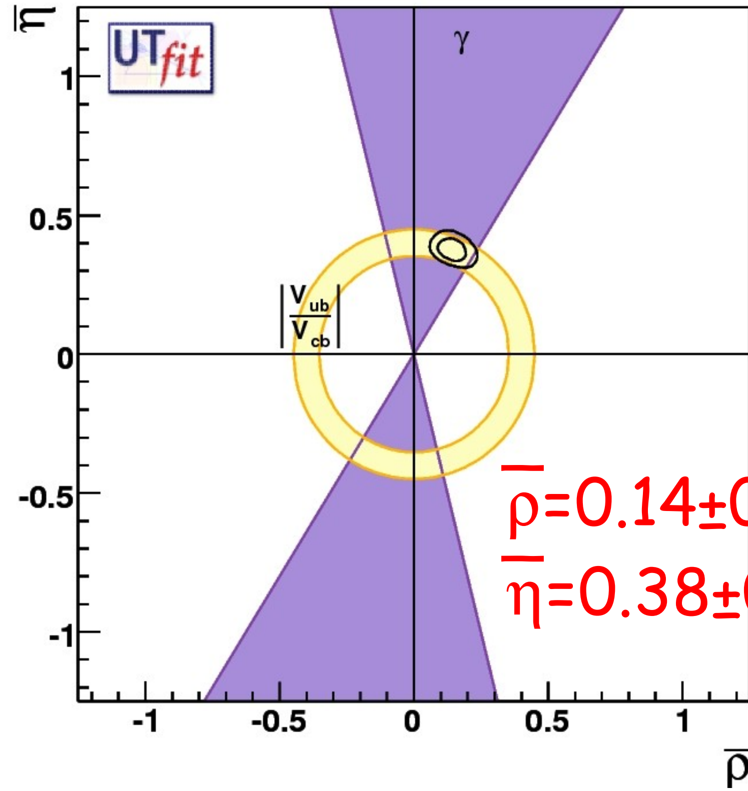
UTfit coll., hep-ph/0605213; Ligeti et al., hep-ph/0604112; Grossman et al, hep-ph/0605028; Ball & Fleischer, hep-ph/0604249; Lenz & Nierste, hep-ph/0612167. Previous attempts: Ciuchini et al., hep-ph/0307195; CKMfitter group, hep-ph/0406184; Ligeti, hep-ph/0408267; Botella et al., hep-ph/0502133; Agashe et al., hep-ph/0509117; UTfit coll., hep-ph/0509219.

- Using all constraints:



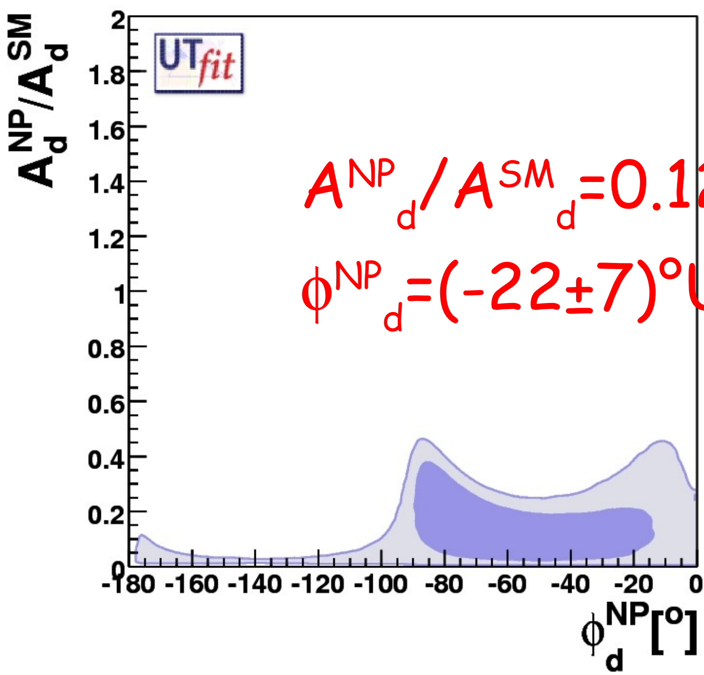
C_{Bd}=0.92±0.20

ϕ_{Bd}=(-3.0±1.9)°



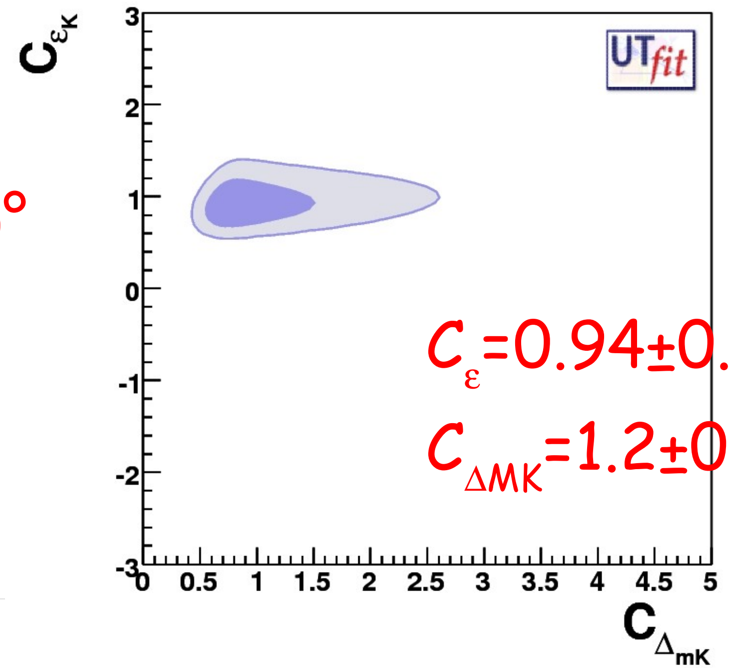
$\bar{\rho}$=0.14±0.04

$\bar{\eta}$=0.38±0.03



$A^{NP}{}_d/A^{SM}{}_d$=0.12±0.09

$\phi^{NP}{}_d$=(-22±7)°U(-68±22)°



C_ε=0.94±0.13

$C_{\Delta MK}$=1.2±0.4

- Determine coefficients of dimension-6 operators:

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

$$\mathcal{H}_{\rm eff}^{D-\bar D} = \sum_{i=1}^{5} C_i\, Q_i^{cu} + \sum_{i=1}^{3} \tilde C_i\, \tilde Q_i^{cu}$$

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

$$\begin{aligned}
Q_1^{q_iq_j} &= \bar q_{jL}^{\alpha}\gamma_\mu q_{iL}^{\alpha}\bar q_{jL}^{\beta}\gamma^\mu q_{iL}^{\beta}\ ,\\
Q_2^{q_iq_j} &= \bar q_{jR}^{\alpha} q_{iL}^{\alpha}\bar q_{jR}^{\beta} q_{iL}^{\beta}\ ,\\
Q_3^{q_iq_j} &= \bar q_{jR}^{\alpha} q_{iL}^{\beta}\bar q_{jR}^{\beta} q_{iL}^{\alpha}\ ,\\
Q_4^{q_iq_j} &= \bar q_{jR}^{\alpha} q_{iL}^{\alpha}\bar q_{jL}^{\beta} q_{iR}^{\beta}\ ,\\
Q_5^{q_iq_j} &= \bar q_{jR}^{\alpha} q_{iL}^{\beta}\bar q_{jL}^{\beta} q_{iR}^{\alpha}\ ,
\end{aligned}$$

- In the SM, only Q_1 is present. Q_{2-5} are RG-enhanced (and chirally-enhanced in K) $\Rightarrow$ NP models w. $C_{2-5}\neq 0$ more constrained

H_{eff} can be recast in terms of the high-scale $C_i(\Lambda)$

- $C_i(\Lambda)$ can be extracted from the data (one by one)
- the associated NP scale Λ can be defined as

$$\Lambda = \sqrt{\frac{L F_i}{C_i(\Lambda)}}$$

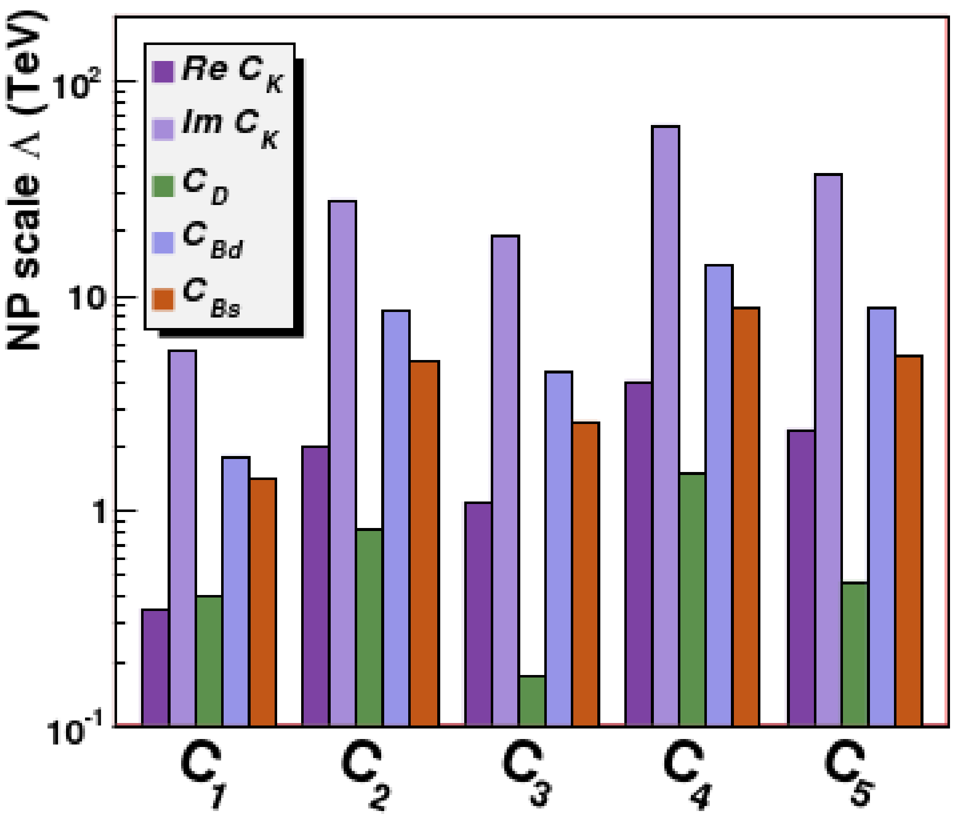
tree/strong interact. NP: $L \sim 1$

perturbative NP: $L \sim \alpha_s^2, \alpha_W^2$

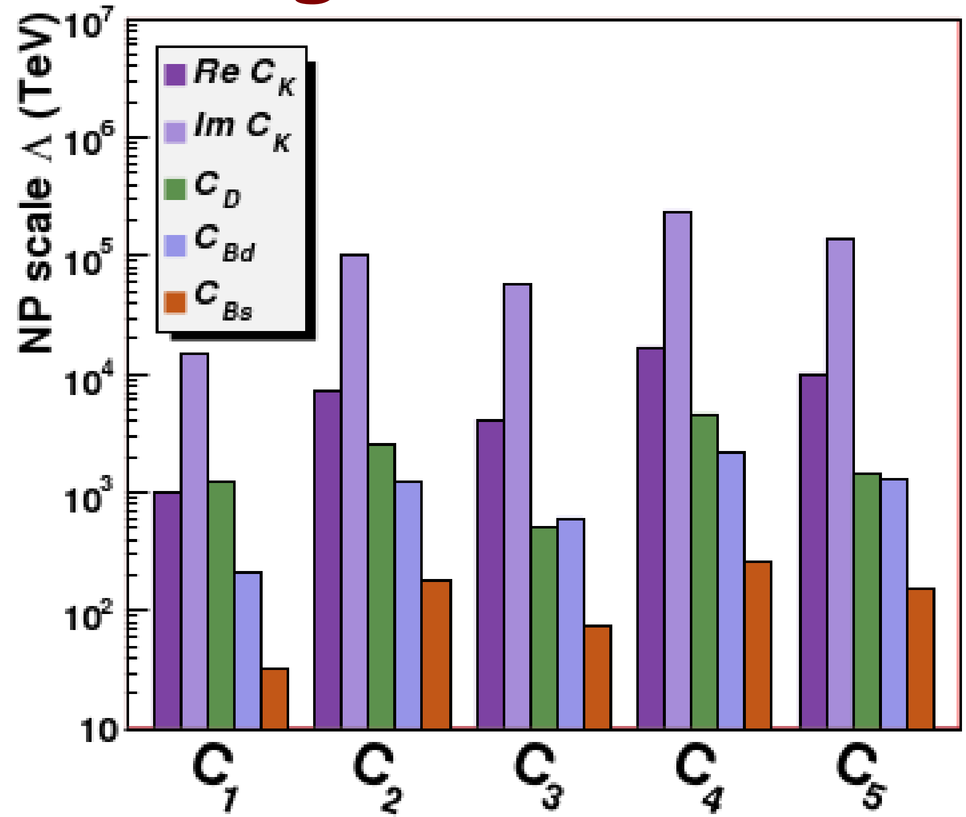
Flavour structures:

MFV	next-to-MFV	generic
- $F_1 = F_{SM} \sim (V_{tq} V_{tb}^*)^2$ - $F_{i\neq 1} = 0$	- $\lvert F_i \rvert \sim F_{SM}$ - arbitrary phases	- $\lvert F_i \rvert \sim 1$ - arbitrary phases

NMFV



generic FV



Contributions of the $\Delta F=2$ operators to the lower bound on the NP scale in the tree/strong interacting case

present lower bound on the NP scale (TeV @95%)

B + K

Scenario	strong/tree	α_s loop	α_W loop
MFV	5.5	0.5	0.2
NMFV	62	6.2	2
General	24000	2400	800

B only

strong/tree	α_s loop	α_W loop
–	–	–
14	1.4	0.4
2200	220	66

* $\Delta F=2$ chirality-flipping operators are RG enhanced and thus probe larger NP scales
* when these operators are allowed, the NP scale is easily pushed beyond the LHC reach (manifestation of the flavour problem)
* suppression of the 1 <-> 2 transitions strongly weakens the lower bound on the NP scale

K and B_d mixings occur at the loop level, thus could receive O(1) NP corrections but effects > ~20% are excluded

common misconception: this result points to MFV (or even establishes MFV)

if NP < 1 TeV

* suppression of flavour-violating couplings required in all sectors *possibly* pointing to MFV
* NP can stabilize the Fermi scale with "mild" fine-tuning

if 1< NP < 10-100 TeV

* suppression of flavour-violating couplings needed in sector 1-2 only. No indication of MFV
* NP can still stabilize the Fermi scale with "moderate" fine-tuning

EVIDENCE FOR FLAVOUR PHYSICS BEYOND THE SM

Great potential of flavour physics to display large deviations from the Standard Model

but not a single evidence in >20 years

EVIDENCE FOR FLAVOUR PHYSICS BEYOND THE SM

Great potential of flavour physics to display large deviations from the Standard Model **but** not a single evidence in >20 years

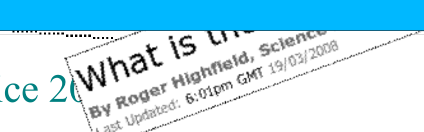
...until March 2008!!!

EVIDENCE FOR FLAVOUR PHYSICS BEYOND THE SM

Great potential of flavour physics to display large deviations from the Standard Model but not a single evidence in >20 years

Three new evidences announced:

* $?.?\sigma$ in the CP asymmetries of $B \to K\pi$
* 3.8σ in leptonic D_s decays
* 3σ in the phase of the B_s mixing amplitude



1. new physics in Kπ CP asymmetries?

$$\mathcal{A}_{K^\pm\pi^\mp} \equiv \frac{N(\bar{B}^0 \to K^-\pi^+) - N(B^0 - K^+\pi^-)}{N(\bar{B}^0 \to K^-\pi^+) + N(B^0 \to K^+\pi^-)} = -0.094 \pm 0.018 \pm 0.008$$

Belle collaboration
Nature 452,2008

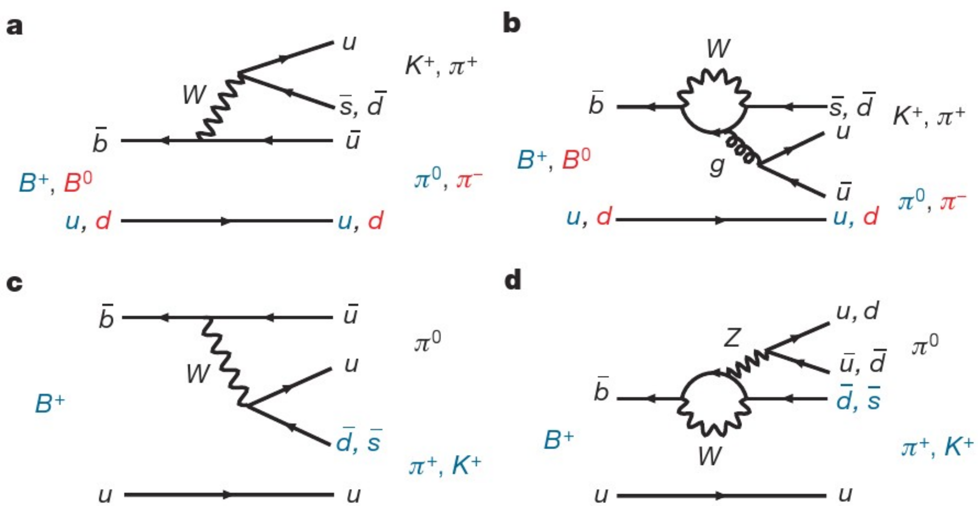
$$\mathcal{A}_{K^\pm\pi^0} = +0.07 \pm 0.03 \pm 0.01$$

$$\Delta\mathcal{A} \equiv \mathcal{A}_{K^\pm\pi^0} - \mathcal{A}_{K^\pm\pi^\mp} = +0.164 \pm 0.037$$

difference: 4.4σ

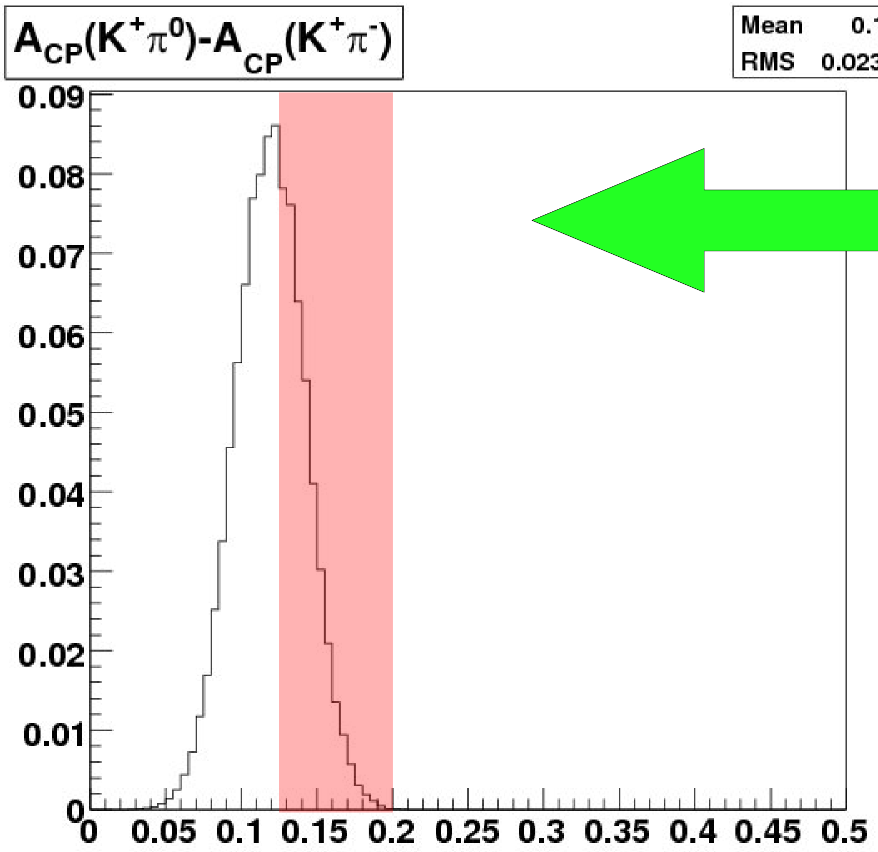
Is this new physics?

It could be but SM predictions depend on hadronic models



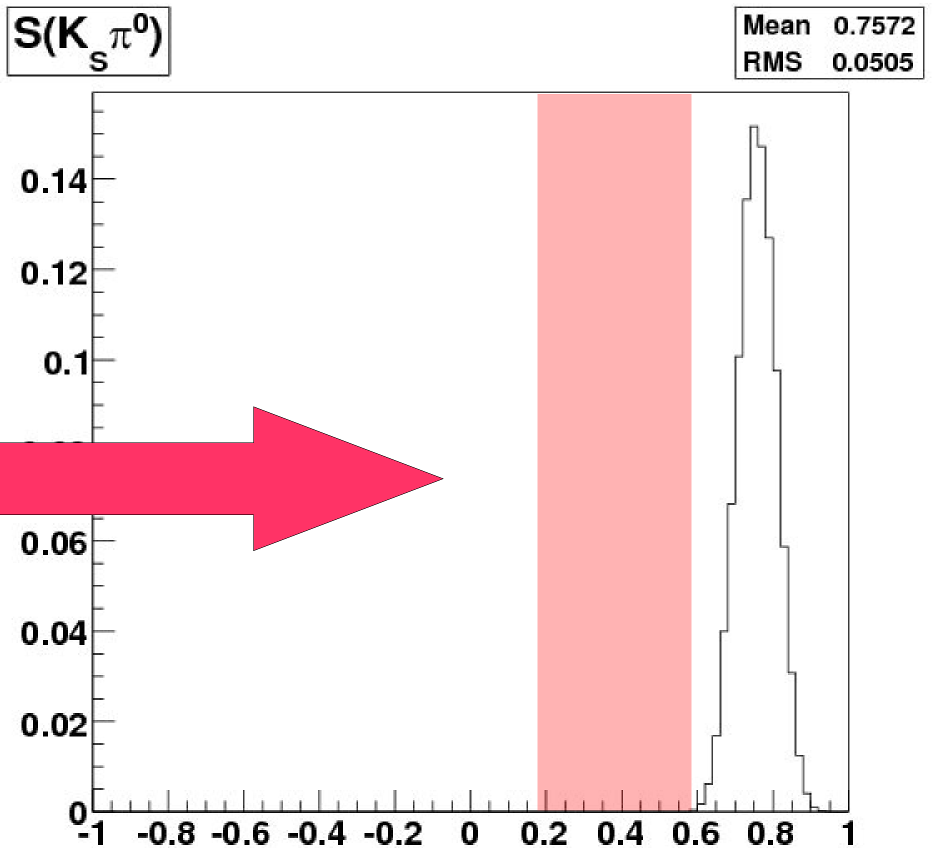
L.S., arXiv:0705.1624

%	QCDF [50]	PQCD [54, 55]	SCET [58]	GP [92]
$A_{CP}(\pi^0 K^-)$	$7.1^{+1.7\,+2.0\,+0.8\,+9.0}_{-1.8\,-2.0\,-0.6\,-9.7}$	-1^{+3}_{-5}	$-11 \pm 9 \pm 11 \pm 2$	3.4 ± 2.4
$A_{CP}(\pi^+ K^-)$	$4.5^{+1.1\,+2.2\,+0.5\,+8.7}_{-1.1\,-2.5\,-0.6\,-9.5}$	-9^{+6}_{-8}	$-6 \pm 5 \pm 6 \pm 2$	-8.9 ± 1.6



preliminary

No clash with the Belle measurement of the *CP* asymmetries



However...

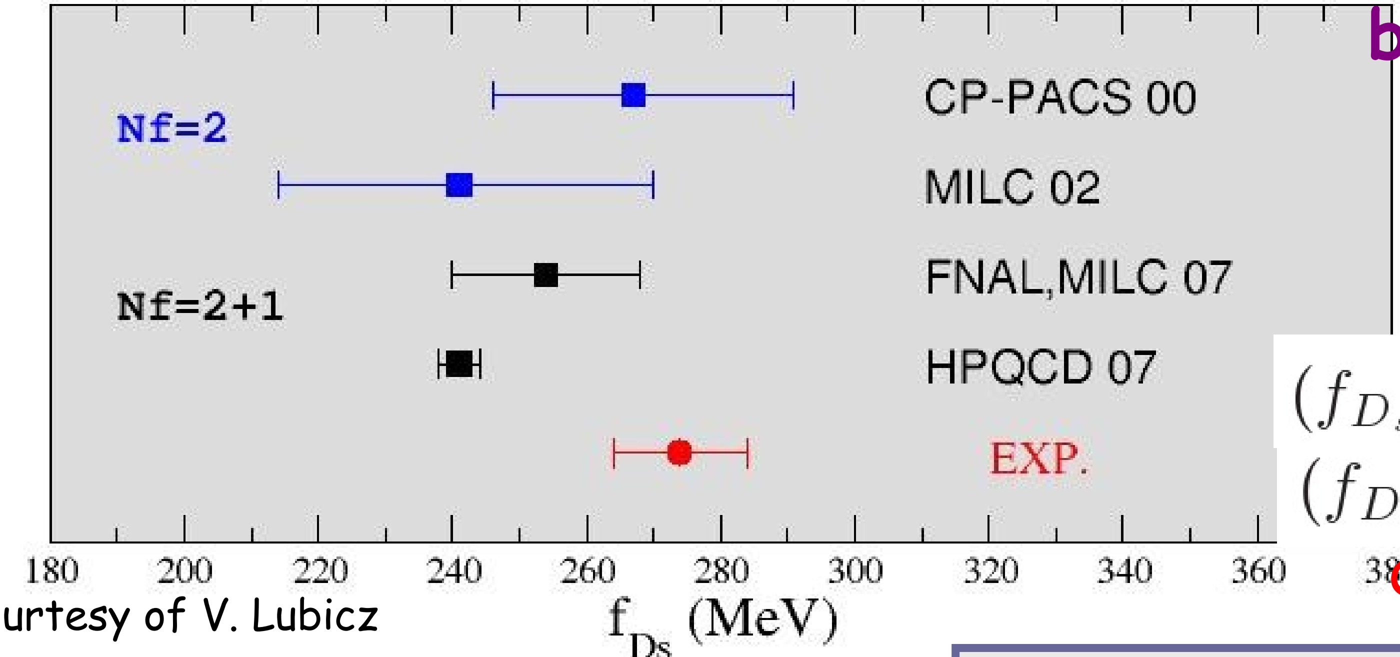
$S(K_S\pi^0)_{exp}$=0.38 ± 0.19

Ciuchini et al.

2. Evidence for non-standard leptonic decays of D_s mesons

Dobrescu, Kronfeld
arXiv:0803.0512

$$B(D_s \to \ell\nu) = \frac{m_{D_s}}{8\pi}\tau_{D_s} f_{D_s}^2 \left|G_F V_{cs}^* m_\ell\right|^2 \left(1 - \frac{m_\ell^2}{m_{D_s}^2}\right)^2$$



courtesy of V. Lubicz

based on the latest lattice result only

Follana et al.
arXiv:0706.1726

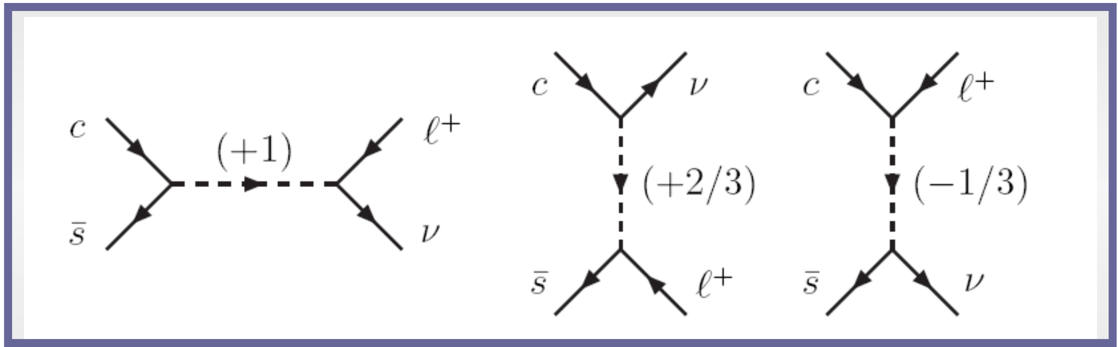
$$(f_{D_s})_{\rm QCD} = 241 \pm 3 \text{ MeV}$$

$$(f_{D_s})_{\rm expt} = 277 \pm 9 \text{ MeV}$$

difference: 3.8σ

"exotic" new physics:

- leptoquarks
- exotic charged Higgs



3. NEW PHYSICS IN B_s MIXING

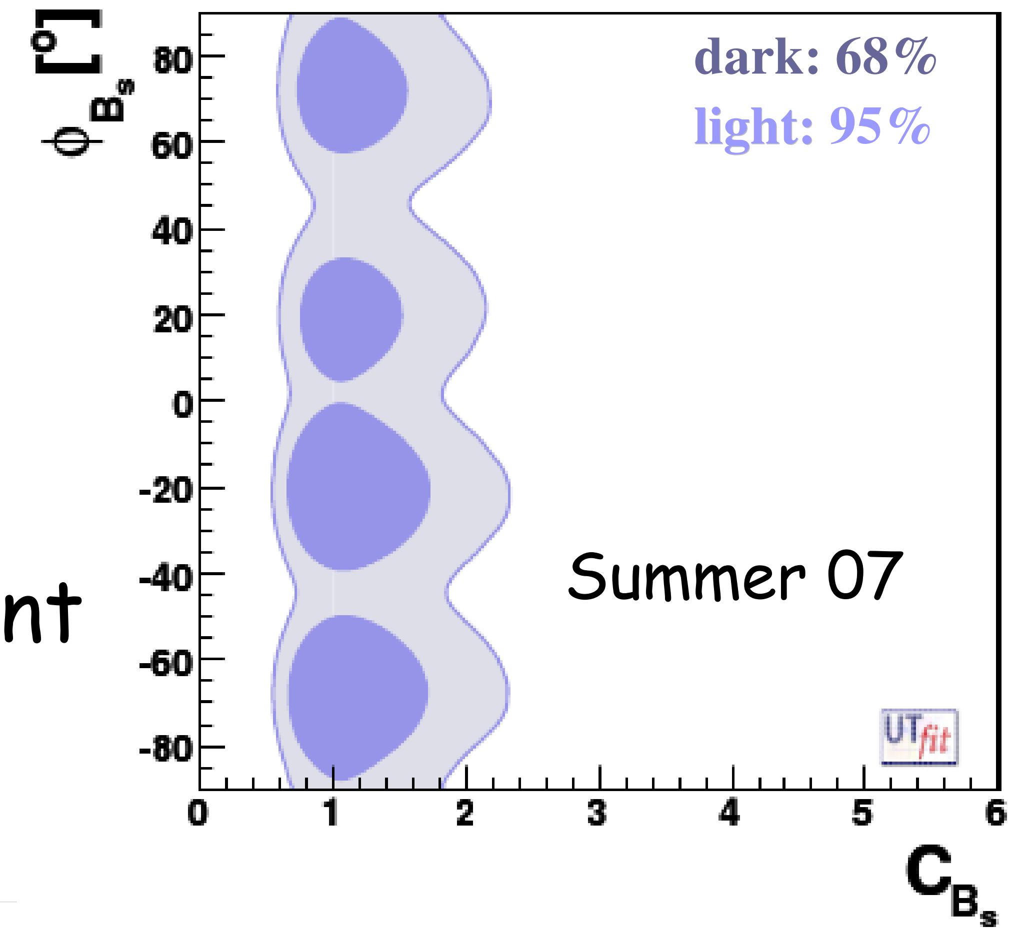
the TeVatron realm

$C_{B_s} = 1.11 \pm 0.32$

$\phi_{B_s} = (-69\pm14)° \cup (-20\pm14)° \cup (20\pm5)° \cup (72\pm8)°$

* Δm_s
* $\tau_{B_s}^{FS} = \frac{1}{\Gamma_s} \frac{1+\left(\frac{\Delta\Gamma_s}{2\Gamma_s}\right)^2}{1-\left(\frac{\Delta\Gamma_s}{2\Gamma_s}\right)^2}$
* A_{SL}^s
* $A_{\mathrm{SL}}^{\mu\mu} = \frac{f_d \chi_{d0} A_{\mathrm{SL}}^d + f_s \chi_{s0} A_{\mathrm{SL}}^s}{f_d \chi_{d0} + f_s \chi_{s0}}$
* $\Delta\Gamma_s$ and ϕ_s from the untagged time-dependent angular analysis of

$B_s \to J/\Psi\ \phi$



Recently both CDF and DØ published the tagged time-dependent angular analysis of $B_s \to J/\Psi\ \phi$

2D likelihood ratio for $\Delta\Gamma$ and ϕ_s

2-fold ambiguity present, no assumption on the strong phases

arXiv:0712.2397

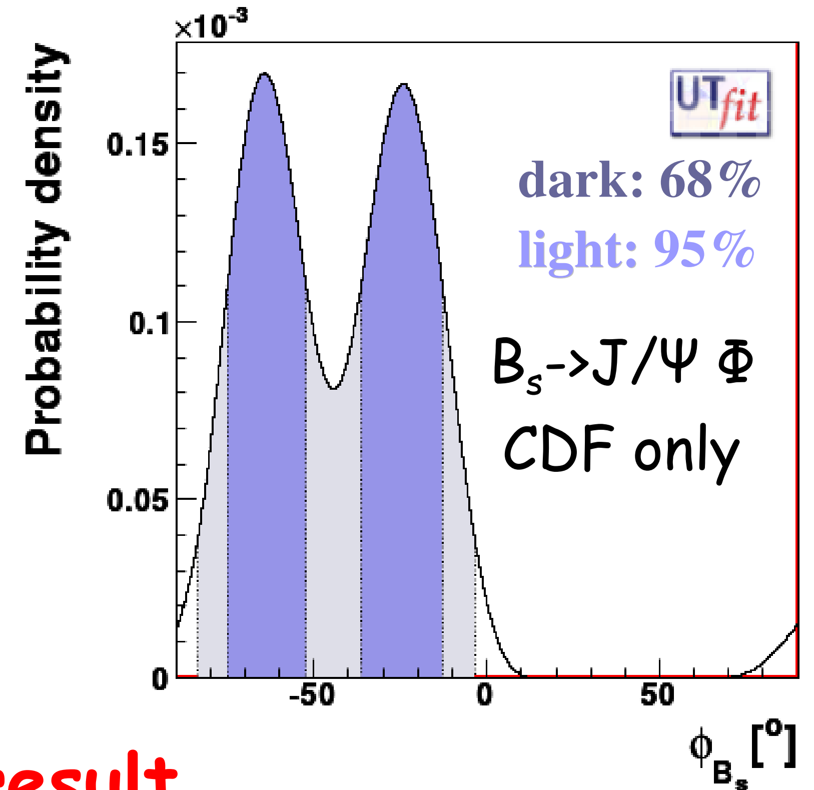
7-parameter fit + correlation matrix or 1D likelihood profiles of $\Delta\Gamma$ and ϕ_s

2-fold ambiguity removed using strong phases from $B \to J/\Psi\ K^*$ + SU(3) + ?

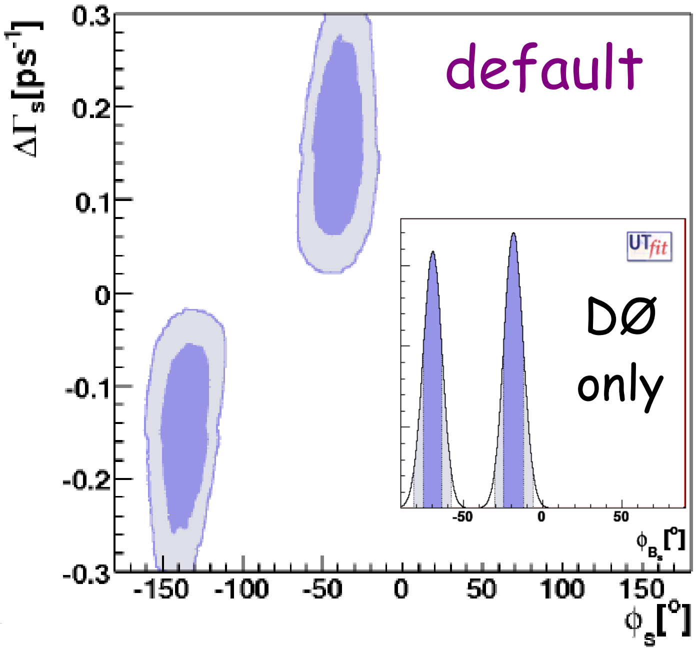
arXiv:0802.2255

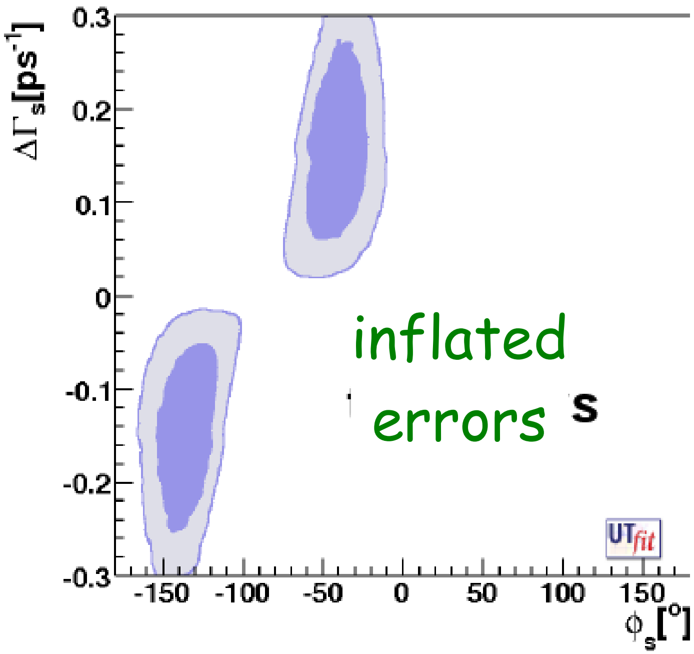
Combining the two measurements requires some gymnastic with the DØ results...

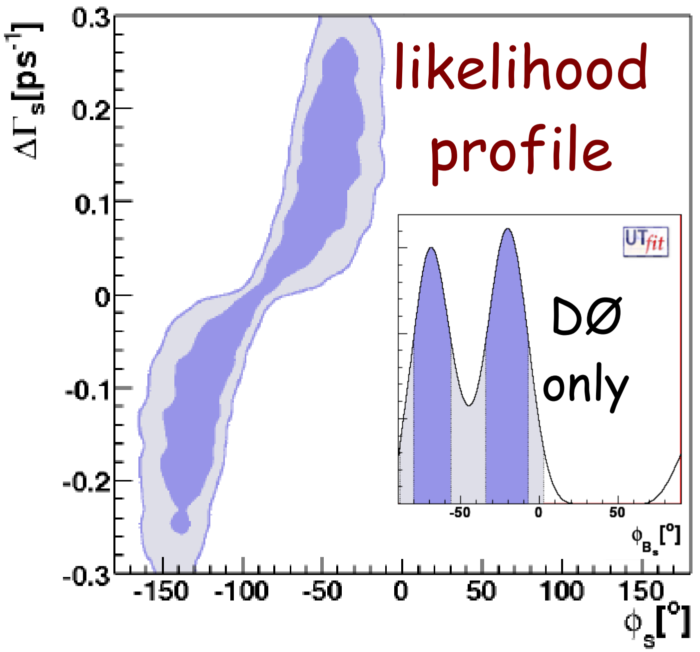
* default: CDF likelihood+Gaussian DØ result with 2x2 corr. matrix
* inflated error: as above, but with error inflated to reproduce the 2σ range computed by DØ
* likelihood profile: using the 1D likelihood profiles for ϕ_s and $\Delta\Gamma_s$

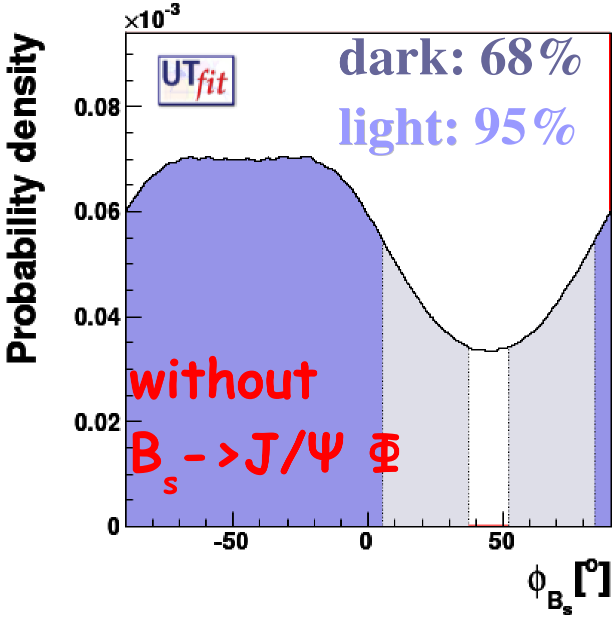


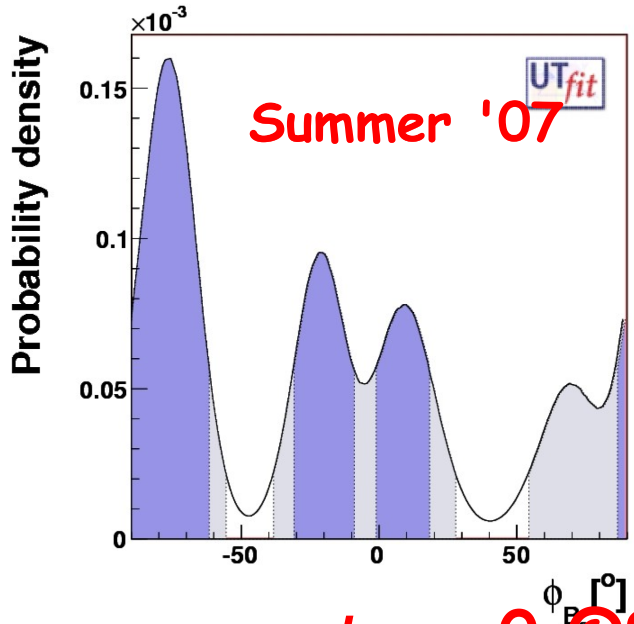
ambiguity reintroduced in the DØ result

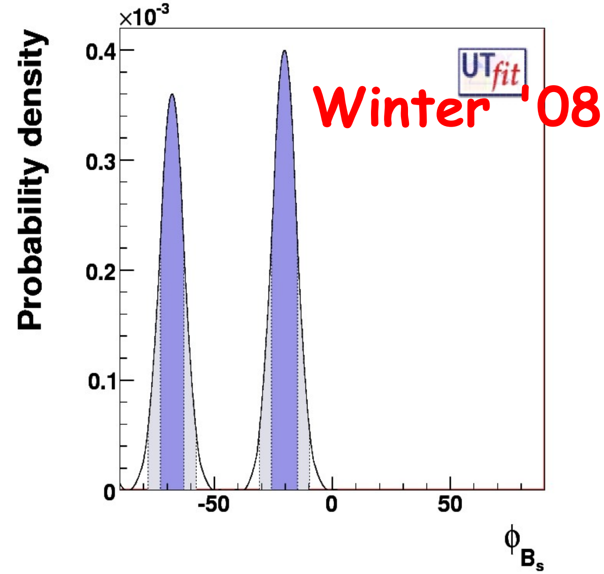




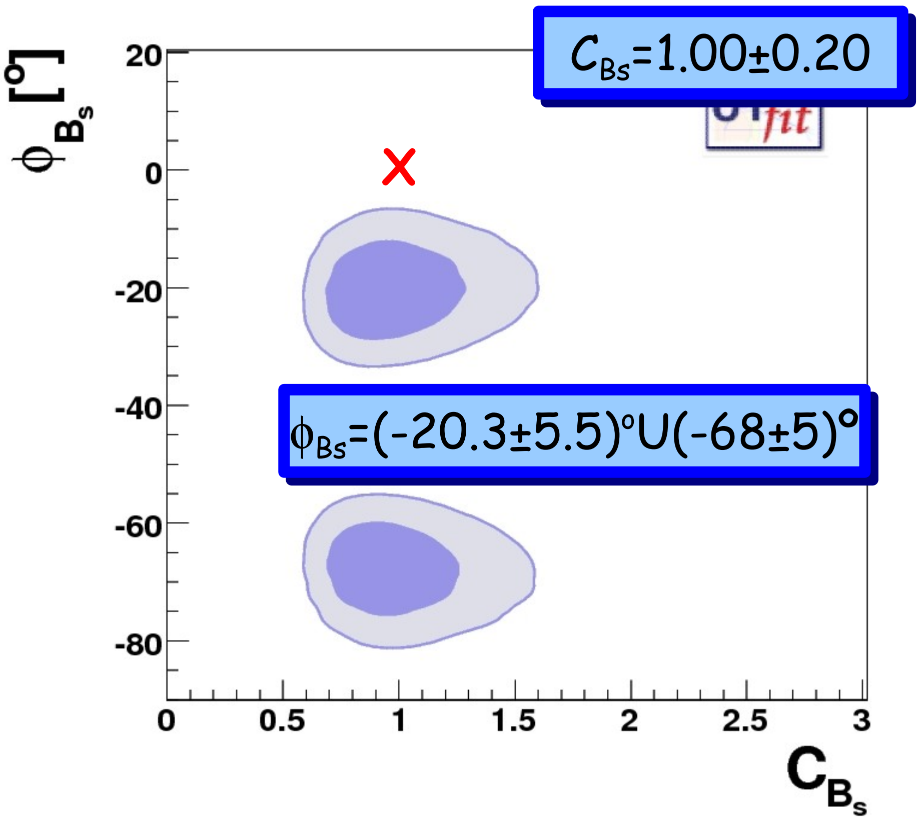




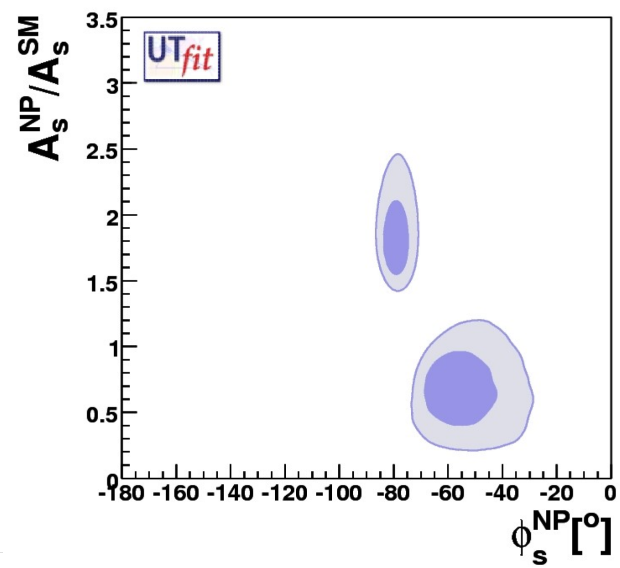




ϕ_{Bs} < 0 @99.7% probability (equivalent to the Gaussian 3σ level) for any treatment of the DØ data



UTfit collaboration
arXiv:0803.0659



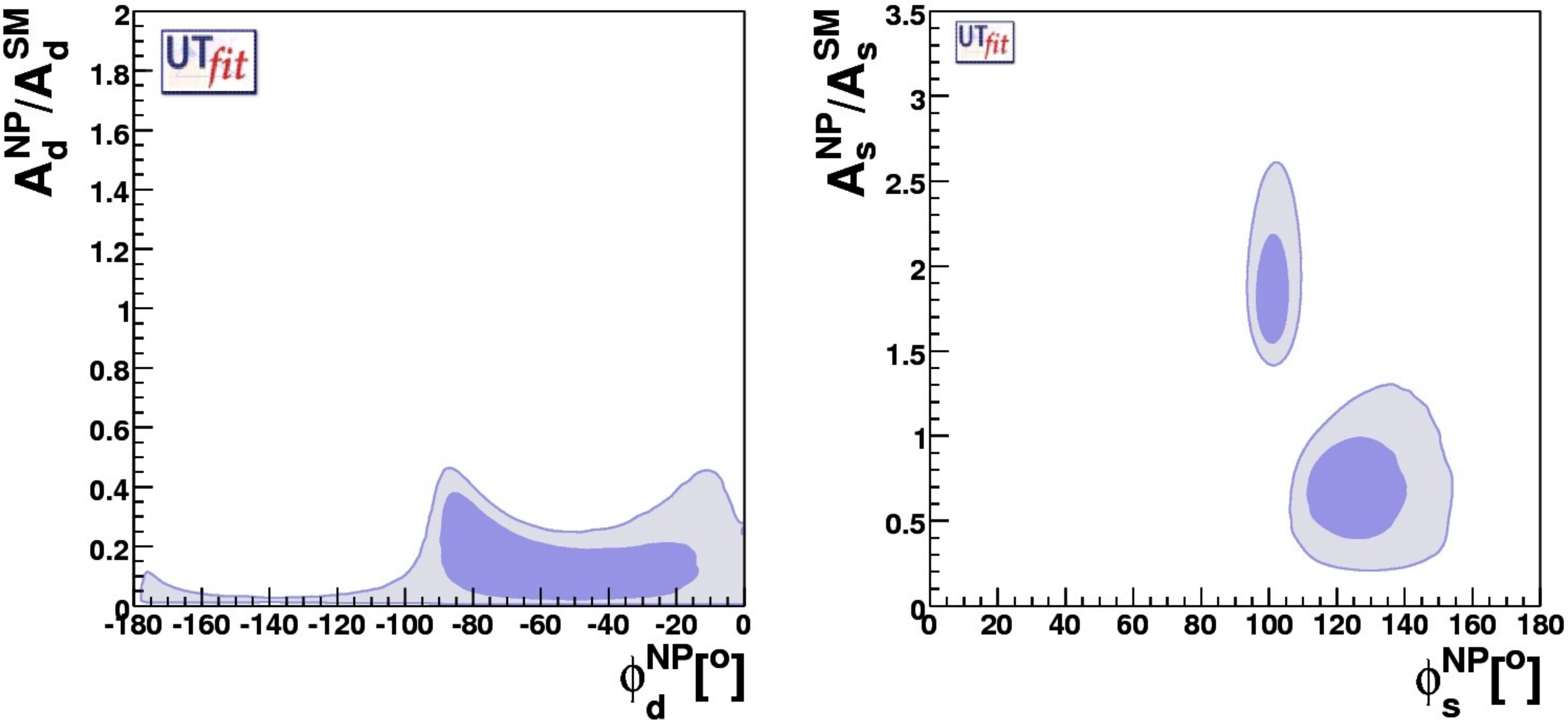
- Lower bounds on NP scale from K and B_d physics: (in TeV at 95% probability)

Scenario	strong/tree	α_s loop	α_W loop
MFV	5.5	0.5	0.2
NMFV	62	6.2	2
General	24000	2400	800

- Upper bounds on NP scale from ϕ_s:

Scenario	strong/tree	α_s loop	α_W loop
NMFV	35	4	2
General	800	80	30

- Need a flavour structure, but not NMFV!



$A^{NP}_d/A^{SM}_d \sim 0.1$ and $A^{NP}_s/A^{SM}_s \sim 0.7$ correspond to $A^{NP}_d/A^{NP}_s \sim \lambda^2$ i.e. to an additional λ suppression.

IMPLICATIONS ON NP

- Large NP contributions to b $\leftrightarrow$ s transitions are natural in nonabelian flavour models, given the large breaking of flavour SU(3) due to the top quark mass

  Pomarol, Tommasini; Barbieri, Dvali, Hall; Barbieri, Hall; Barbieri, Hall, Romanino; Berezhiani, Rossi; Masiero et al; …

- GUTs can naturally connect the large mixing in ν oscillations with a large b $\leftrightarrow$ s mixing

  Baek et al.; Moroi; Akama et al.; Chang, Masiero, Murayama; Hisano, Shimizu; Goto et al.; …

- 4th generation interesting possibility, check carefully other constraints (EW, b $\rightarrow s\gamma$, ...)

  Hou et al.; Lunghi & Soni

IMPLICATIONS ON NP - II

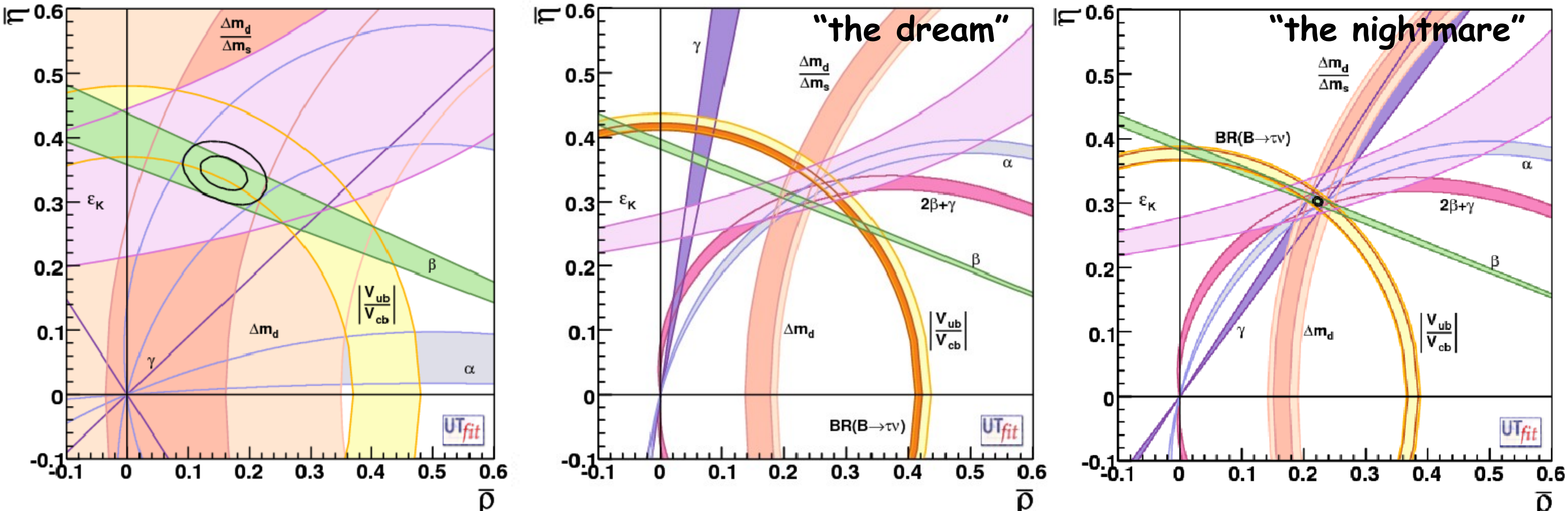
- In a given model expect correlation between b $\leftrightarrow$ s (B_s mixing) and b $\rightarrow$ s (penguin decays) transitions
- This correlation is welcome given the large room for NP in b $\rightarrow$ s hadronic penguins (S_{peng}, $A_{K\pi}$, ...)

Beneke; Buchalla et al.; Buras et al.; London et al.; Hou et al.; Lunghi & Soni; Feldmann et al.; ...

- The correlation is however affected by large hadronic uncertainties

FLAVOUR PHYSICS IN 2015

Today	With a SuperB in 2015



Generalized UT fits:

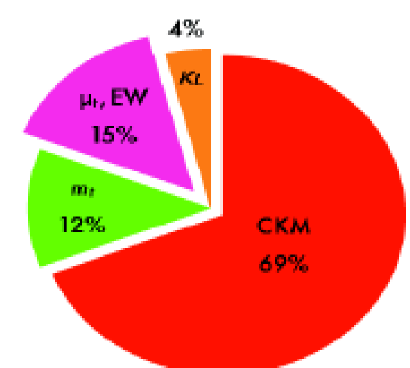
CKM at 1% in the presence of NP!

	today	SuperB
$\bar{\rho}$	0.187±0.056	±0.005
$\bar{\eta}$	0.370±0.036	±0.005

- crucial for many NP searches with flavour (not only for B decays!)

$K_L \to \pi^0 \nu \bar{\nu}$

error budget



U. Haisch, Kaon '07

RECONSTRUCTING L_{NP}

- LHC high-pt experiments will be able to detect new particles up to the TeV scale
- This will give us (part of) the NP spectrum
- LHCb and SuperB will be crucial to study the NP flavour couplings and to
- detect virtual effects of NP particles heavier than the LHC high-pt reach

THE SUSY EXAMPLE

Parameters	MSSM		SM	
gauge+Higgs	14		6	
masses	30	(36)	9	(12)
mixing angles	39	(54)	3	(6)
phases	41	(56)	1	(2)
Total	124	(160)	19	(26)

SM parameters match: FC vs FV&CPV 17-9

MSSM parameters match: FC vs FV&CPV 50-110

* fast increase of the # of FV&CPV parameters
* FV&CPV are related to basic properties of the NP Lagrangian (e.g. SUSY breaking in the MSSM)

SQUARK MASSES

Flavour physics

LHC high-pt

$$m^2_{\tilde d} = \begin{pmatrix} (m^2_{11})_{LL} & (\Delta^d_{12})_{LL} & (\Delta^d_{13})_{LL} & (\Delta^d_{11})_{LR} & (\Delta^d_{12})_{LR} & (\Delta^d_{13})_{LR} \\ * & (m^2_{22})_{LL} & (\Delta^d_{23})_{LL} & (\Delta^d_{21})_{LR} & (\Delta^d_{22})_{LR} & (\Delta^d_{23})_{LR} \\ * & * & (m^2_{33})_{LL} & (\Delta^d_{31})_{LR} & (\Delta^d_{32})_{LR} & (\Delta^d_{33})_{LR} \\ * & * & * & (m^2_{11})_{RR} & (\Delta^d_{12})_{RR} & (\Delta^d_{13})_{RR} \\ * & * & * & * & (m^2_{22})_{RR} & (\Delta^d_{23})_{RR} \\ * & * & * & * & * & (m^2_{33})_{RR} \end{pmatrix}$$

Mass Insertions

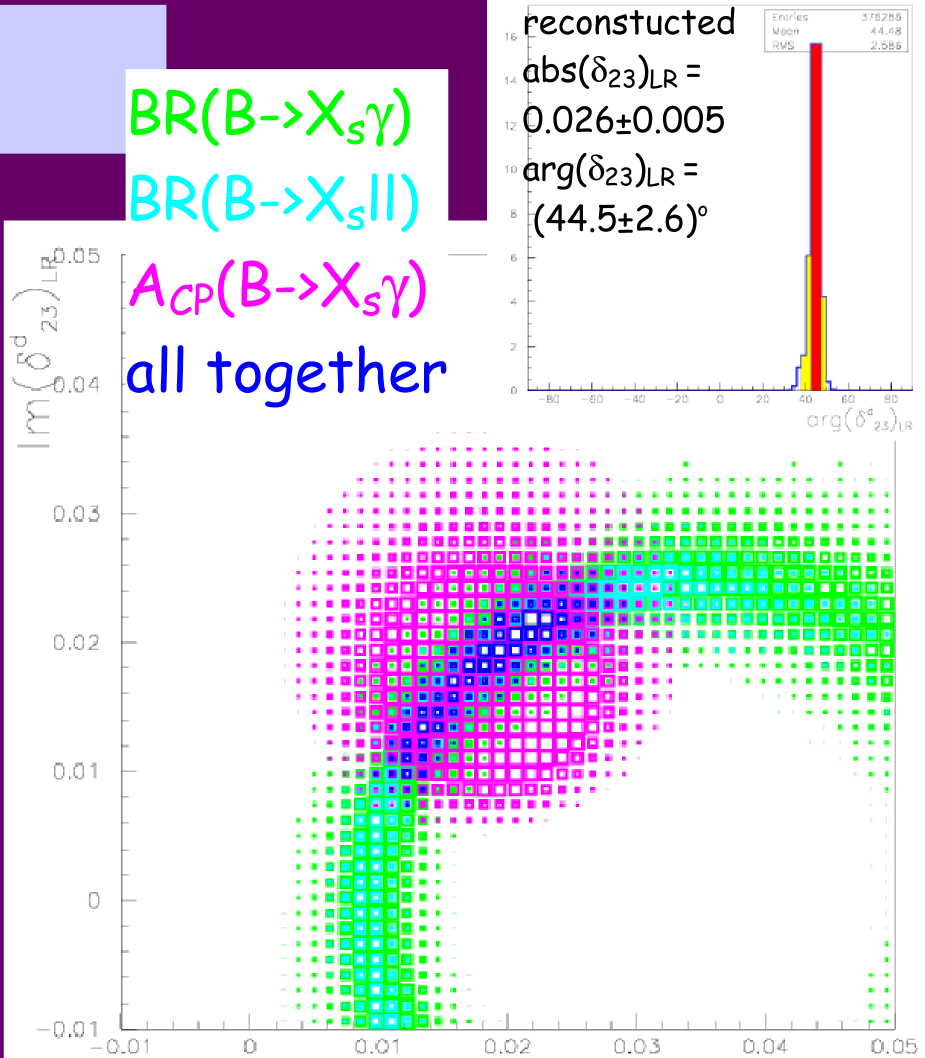
$(\delta^d_{ij})_{AB} = (\Delta^d_{ij})_{AB}/m_{\tilde q}^2$

3σ from 0 sensitivity from SuperB:

i) sensitive to Λ<20 TeV for δ~1

ii) sensitive to $|(\delta^d_{23})_{LR}|>10^{-2}$ for Λ ~ 1 TeV

SuperB CDR & SuperB workshops



$Im(\delta^d_{23})_{LR}$ vs $Re(\delta^d_{23})_{LR}$

Reconstruction of $(\delta^d_{23})_{LR}=0.028\ e^{i\pi/4}$ for $\Lambda = m_{\tilde g} = m_{\tilde q} =$ 1 TeV

THEORY MUST KEEP UP WITH EXP...

- lattice QCD can reach the O(1%) precision goal
- some progress for inclusive techniques for SL B decays
- non-leptonic B decays more problematic...

Measurement	Hadronic Parameter	Present Error	6 TFlops	60 TFlops	1-10 PFlops (Year 2015)
$K \to \pi l \nu$	$f_+^{K\pi}(0)$	0.9 %	0.7 %	0.4 %	$<$ 0.1 %
ε_K	$\hat{B}_K$	11 %	5 %	3 %	1 %
$B \to l \nu$	f_B	14 %	3.5-4.5 %	2.5-4.0 %	1.0-1.5 %
Δm_d	$f_{Bs}\sqrt{B_{B_s}}$	13 %	4-5 %	3-4 %	1-1.5 %
$\Delta m_d / \Delta m_s$	ξ	5 %	3 %	1.5-2 %	0.5-0.8 %
$B \to D/D^* l \nu$	$\mathcal{F}_{B \to D/D^*}$	4 %	2 %	1.2 %	0.5 %
$B \to \pi/\rho\, l \nu$	$f_+^{B\pi}, \ldots$	11 %	5.5-6.5 %	4-5 %	2-3 %
$B \to K^*/\rho\,(\gamma, l^+ l^-)$	$T_1^{B \to K^*/\rho}$	13 %	——	——	3-4 %

V. Lubicz, 4th SuperB Workshop and SuperB CDR

CONCLUSIONS

- Lattice QCD has been very successful in the UT analysis
- Several hints of NP, with solid indications of nonstandard CP violation in B_s mixing
- pointing to NP visible at LHC with a nontrivial flavour structure
- combination of high-pt and flavour data crucial to reconstruct the NP Lagrangian

CONCLUSIONS II

- Lattice QCD will play a crucial role in studying the NP flavour properties
- Improvements to the 1-2% level needed to keep up with future experimental results
- If NP has a nontrivial flavour structure, results will be needed for new operators: $\Delta F=2$, (chromo)electric dipoles, ...
- Exciting times ahead!