Next to Minimal Flavor Violation (NMFV)

Michele Papucci

UC Berkeley, LBNL

Kaustubh Agashe, MP, Gilad Perez & Dan Pirjol hep-ph/0509117.

CERN, Flavor in the era of the LHC, November 7-11 2005

Flavor & the LHC

The real challenge for the LHC

is to tell apart different NP scenarios

$\Rightarrow$ Flavor Physics can help:

- looking for deviations from the SM
- understanding the physics behind them (see Isidori Perez talks)

  Does it come from LL op'? RR?

  Is it due to tree level eschanges? Penguins? Boxes?

MFV $\Rightarrow$ powerful model independent framework to answer if V_{CKM} is the only source of FV & CPV

NMFV

V_{CKM} may not be the only source of Flavor and CP violation.

NMFV $\longrightarrow$ Additional sources of flavor and CP viol':

- $U(2)^3$-symmetric (TeV NP $\leftrightarrow$ 3rd gen.) .
- quasi-aligned with Yukawas

  (mixing matrices hierarchical, CKM-like).

$\Rightarrow$ Many models with NP @ TeV covered!

NMFV

Expect new CPV in

- $\Delta F = 2$

  (see talks of Nir, Perez, Robert, Stocchi)

- $\Delta F = 1$

  (here mainly $b \to s$)

- Possible correlations?

CPV in NMFV

- Focus on the down sector:

	Generic	No LR	Only LL (or RR)
# new CP phases	5	4	2

- $\Delta F = 2 \Leftrightarrow \Delta F = 1$ if LL (RR) dominate.

$$\Downarrow$$

Use correlations to classify/constrain NP!

- LL dominance here

(NP $\leftrightarrow t_L \leftrightarrow b_L$)

Correlations $\Delta F = 1$ - $\Delta F = 2$

Schematically :

$\Delta F = 2$: $\Rightarrow M_{12} = M_{12}^{SM}(1 + h_X e^{2i\sigma_X})$

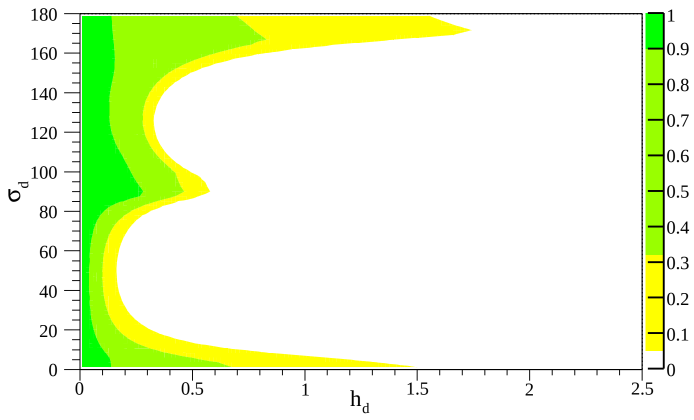
$\Delta F = 1$: $\Rightarrow A = A^{SM,1-loop}(1 + h_X^1 e^{i\sigma_X})$

with $X = b \to d, s$ or $s \to d$.

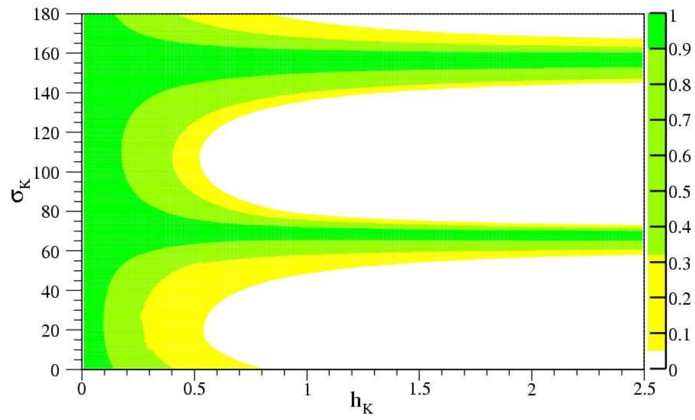
- Different amplitudes
- Same weak phase (up to multiplicity factor)

$\Delta F = 2$ (b⟶s,d & s⟶d)

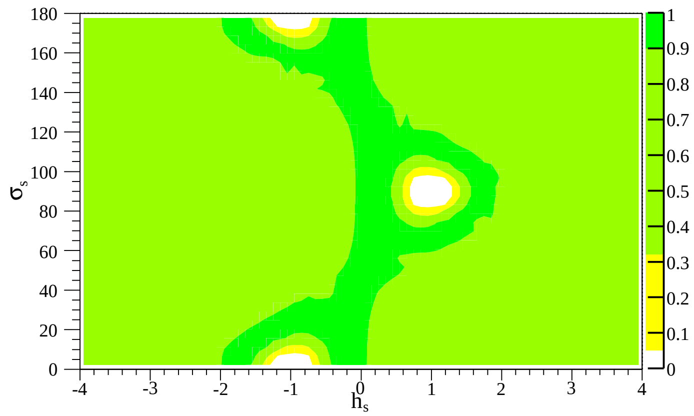
$b \to d$ (h_d, σ_d)



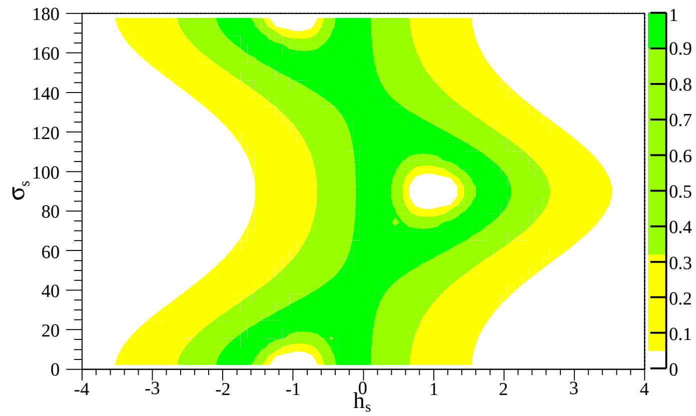
$s \to d$ (h_K, σ_K)



$b \to s$ (h_s, σ_s) (pr.)



$b \to s$ (future)



$\Delta F = 1 \; b \to s$ (h_s^1, σ_s)

1 weak phase.

Many operators, affected differently by NP.

Not enough observables.

$$\Downarrow$$

Model independence?

Various possibilities:

- Focus on a single channel
- Choose a few "templates" covering many models
  e.g. Buchalla, Hiller, Nir, Raz ph/0503151

$\Delta F = 1$ ($b \to s$)

Assume NP aligned with SM Z-penguins:

$$EWP_Z^{SM} * (1 + h_s^1 e^{i\sigma_s})$$

valid in RS1, Little H, Z' models, ...

Analysis of:

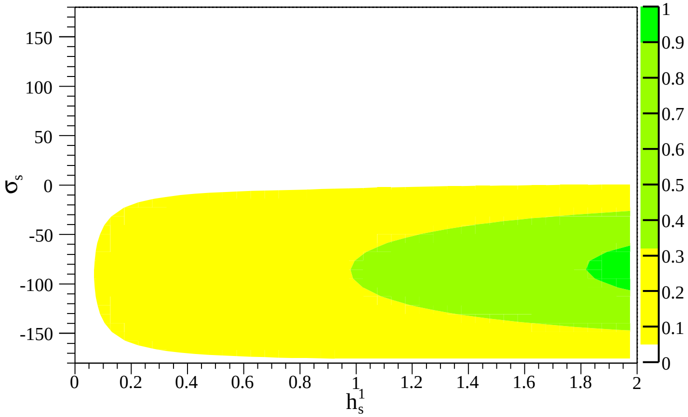
- ϕK_S (CP asym.)
- $\eta' K_S$ (CP asym.)
- πK (CP asym & BR)
- combined results

Theoretical uncertainties?

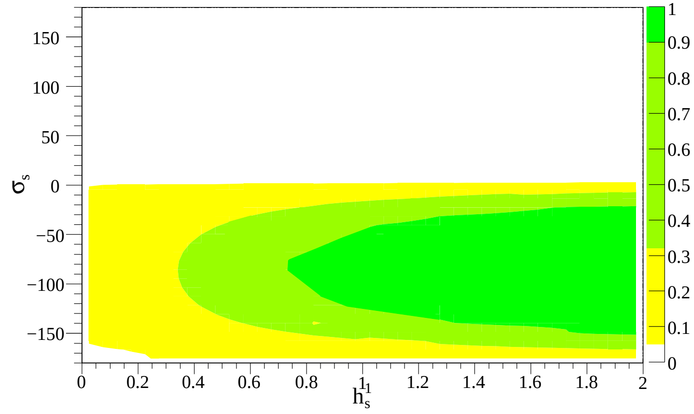
- Scan over unknown theoretical param's.
- Use 2 different factorization schemes and compare
  - ϕK_S, $\eta' K_S$:
    Naive Fact. & QCD Fact.
  - πK:
    QCD Fact. & $SU(3)$ analysis (w/ NP)

ϕK_S, $\eta' K_S$ (h_s^1, σ_s)

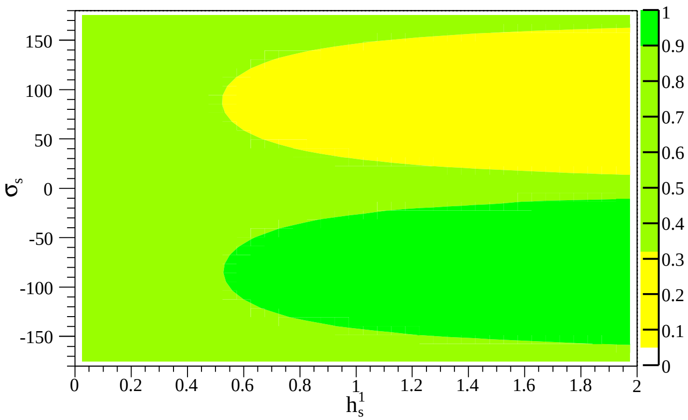
$\eta' K_S$ Naive



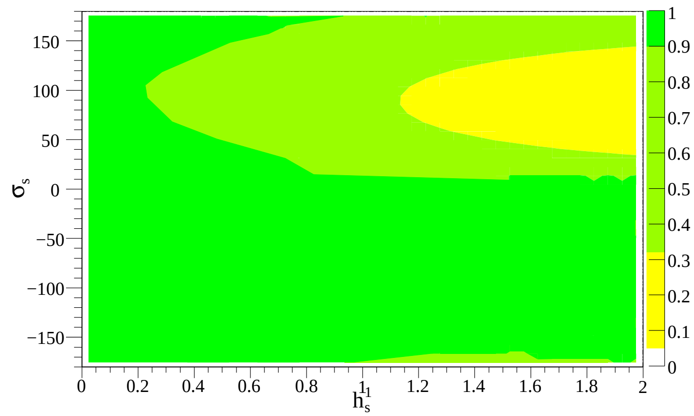
$\eta' K_S$ QCDF



ϕK_S Naive



ϕK_S QCDF



$\pi K\ SU(3)$ analysis

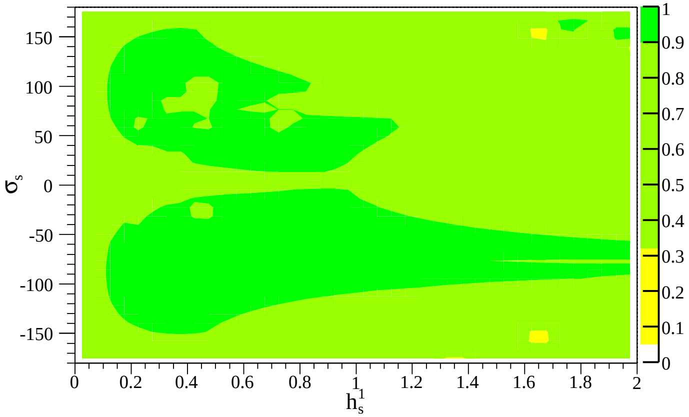
- use $SU(3)$ in amplitudes
- neglect weak annihilations
  (Λ/m_b suppressed)
- neglect $O_{7,8}$
  (good in SM, checked in dyn' models for NP Z-alignment)
- neglect QCDP $\propto V_{ub}V_{us}$
- relate EWP to trees (both SM and NP)
- add a new (complex) parameter for NP contrib' in QCDP (O_3)

$\Rightarrow$ Fit 9 observables with 8 params

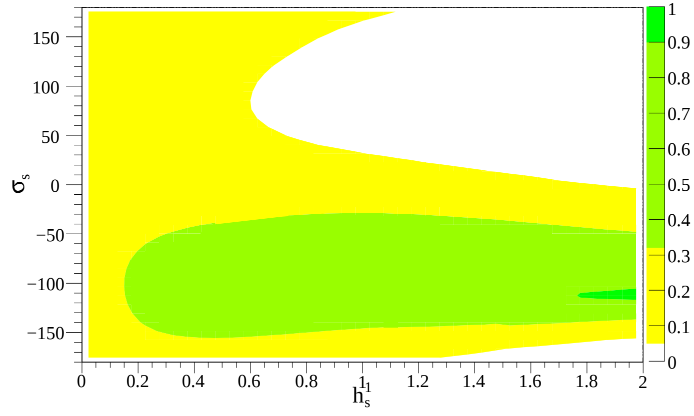
- 4 A_{CP}, 4 BR ratios, $S_{\pi K}$ vs. ε_C, ε_T, p_Z & h_s^1, σ_s
- γ from NP $\rho - \eta$ fit.

πK **results** (h_s^1, σ_s)

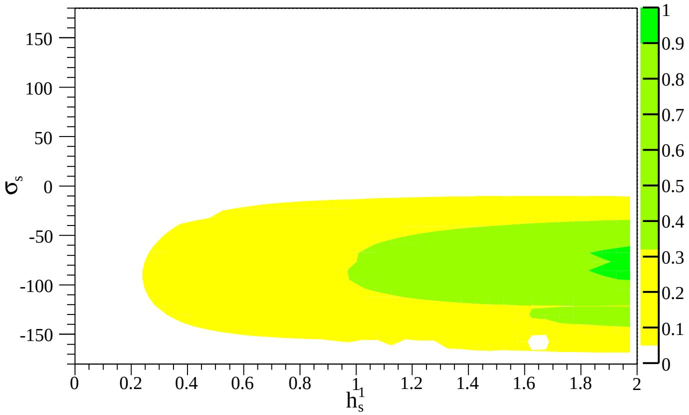
$\pi K\ SU(3)$



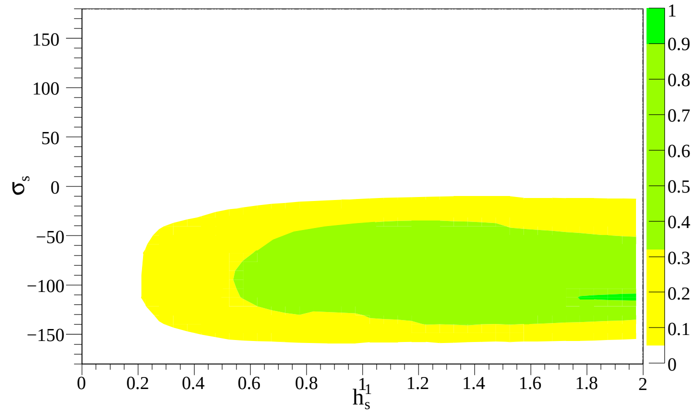
πK QCDF



all NF + $SU(3)$

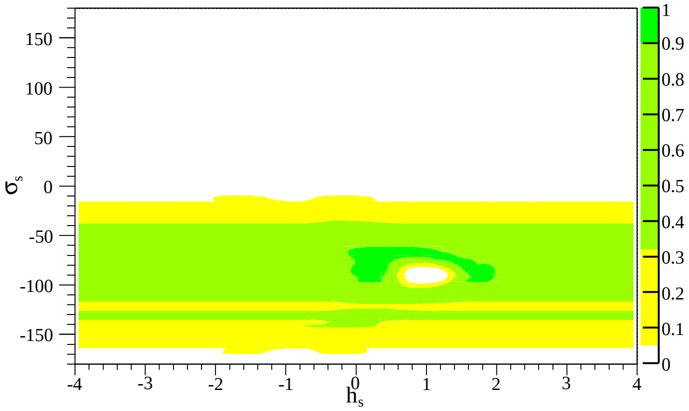


all QCDF

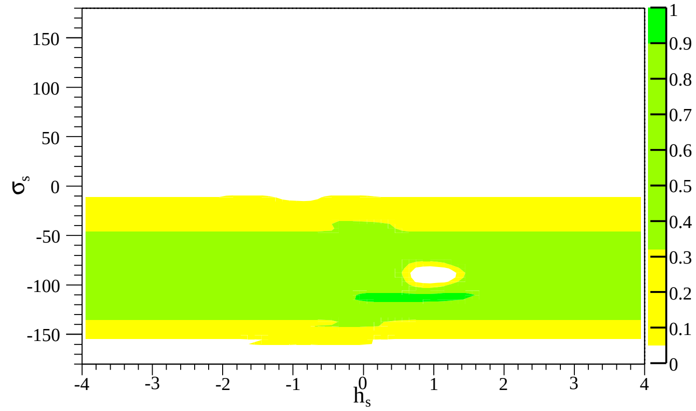


Correlations: $\Delta F = 1$ (all channels) + Δm_S (h_s, σ_s)

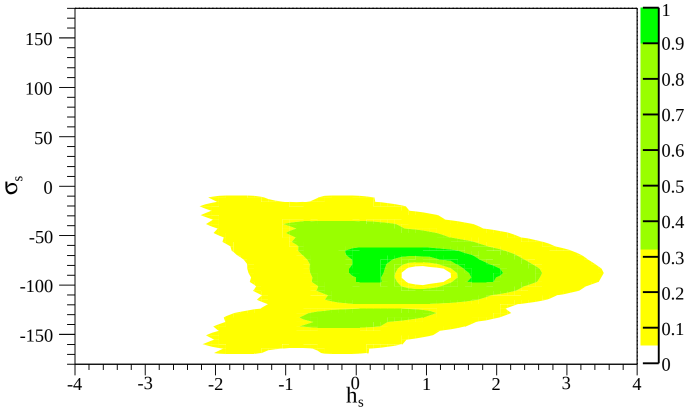
NF+$SU(3)$ present



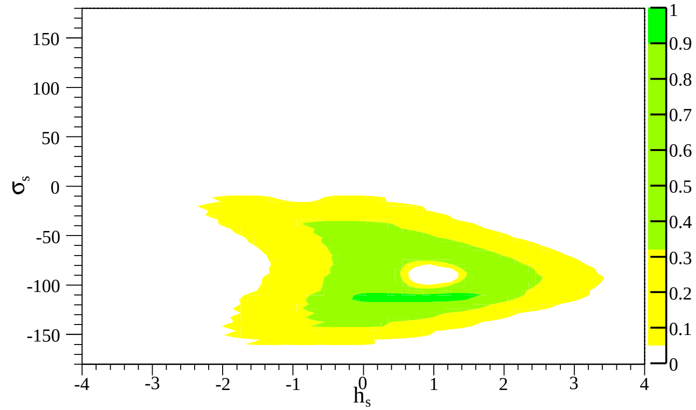
QCDF present



NF+$SU(3)$ future

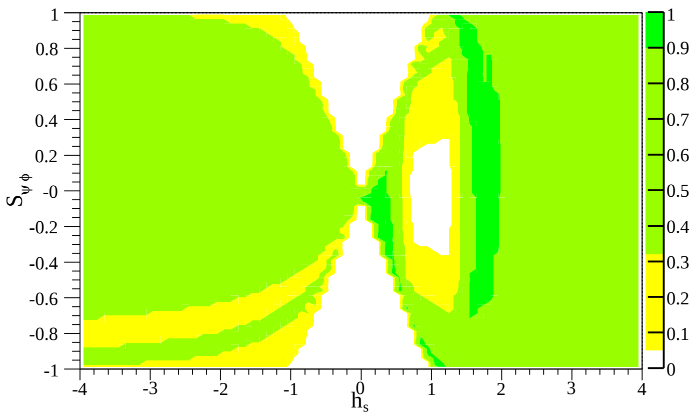


QCDF future

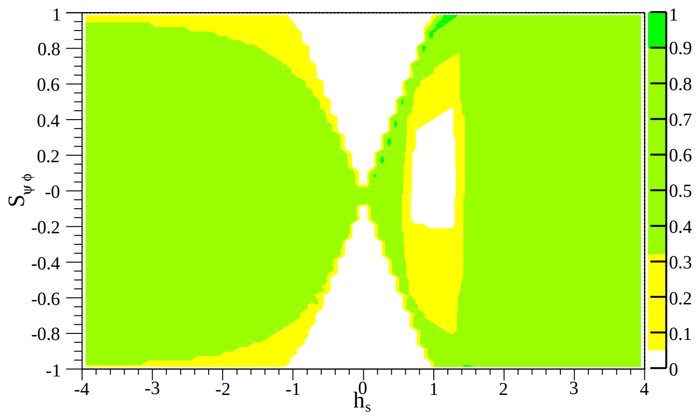


Correlations: $\Delta F = 1$ (all channels) + Δm_S + $S_{\psi\phi}$ $(h_s, S_{\psi\phi})$

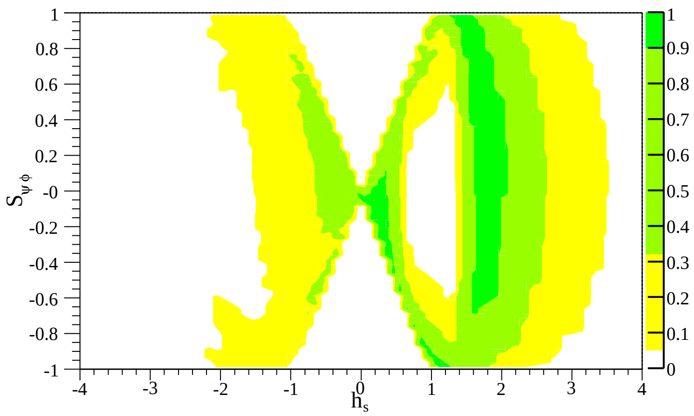
NF+$SU(3)$ present



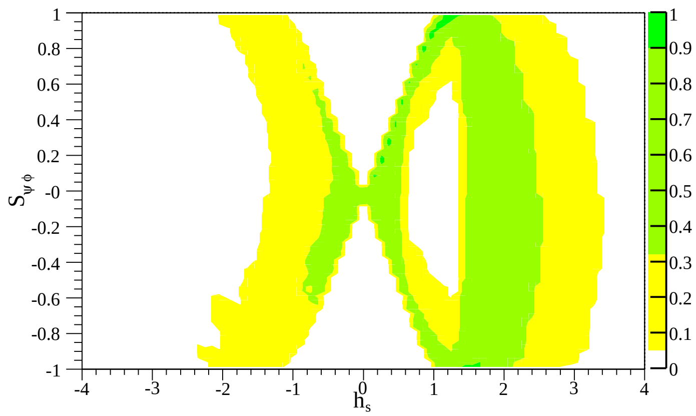
QCDF present



NF+$SU(3)$ future



QCDF future



NMFV wishlist

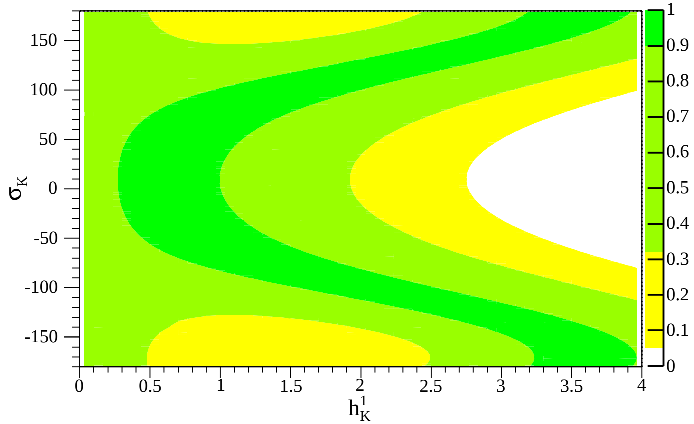
- RR dominance? Degeneracies?
- Other observables
  B_s decays? Leptonic B decays?
- Up sector? Top FCNC?
- NP $\Delta F = 1$ $b \to d$ transitions?
- Correlations among different flavor transitions?
  ($b \to s$ vs. $b \to d$ vs. $s \to d$)
- Origin of the NP contributions?
  (tree vs. penguins vs. boxes, . . .)
- . . .

Backup slides:

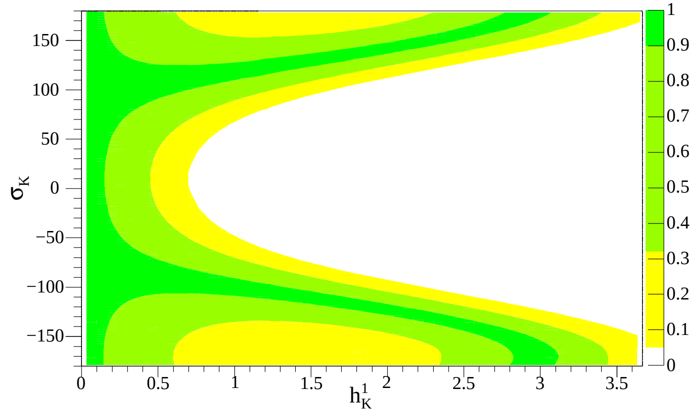
$\Delta F = 1 \; s \to d$ transitions

NP in $K^+ \to \pi^+ \nu \bar{\nu}$ $X_t \to X_t(1 + h_K^1 e^{i\sigma_K})$

present



future $BR = (8 \pm 3)10^{-11}$



And then correlate with ϵ_K . . .

$b \to s$ vs. $s \to d$

Is NP FV entering in a "factorizable" way?

$$\Delta F = 2 : \quad \propto \quad J_{FV} \cdot J_{FV}$$
$$\Delta F = 1 : \quad \propto \quad J_{FV} \cdot J_{FP}$$

e.g. tree level exch., penguins, ...
$\Rightarrow$ Test by correlating different flavor transitions.

$$\sqrt{\frac{h_s}{h_K} \frac{h_K^1}{h_s^1}} = k$$

e.g. $k = c^Z_{\nu\nu}/c^Z_{ss}$ if h_s^1 from ϕK_S
or $k = c^Z_{\nu\nu}/c^Z_{ll}$ if h_s^1 from leptonic B_S

Backup slides:

NP parameterization in $\Delta F = 2$

NP in $\Delta F = 2$

$$
\begin{aligned}
\Delta m_d &= \left|1 + h_d e^{2i\sigma_d}\right| \Delta m_d^{\rm SM} \,, \\
S_{\psi K} &= \sin\left[2\beta + \arg\left(1 + h_d e^{2i\sigma_d}\right)\right] \,, \\
\Delta m_s &= \left|1 + h_s e^{2i\sigma_s}\right| \Delta m_s^{\rm SM} \,, \\
S_{\psi\phi} &= \sin\left[2\beta_s + \arg\left(1 + h_s e^{2i\sigma_s}\right)\right] \,, \\
A_{\rm SL} &= Im\left[\frac{\Gamma_{12}^d}{M_{12}^d\left(1 + h_d e^{2i\sigma_d}\right)}\right] \,,, \\
M_{12}^{\rm K} &\propto \left[\lambda_t^{*2}\eta_2 S_0\left(1 + h_K e^{2i\sigma_K}\right) + \ldots\right]
\end{aligned}
$$

Backup slides:

πK amplitudes

$\pi\ K$ amplitudes

$$A(B^- \to \pi^- \bar{K}^0) = P(1 + h_s^1 e^{i\sigma_s} p_Z e^{i\phi_Z})$$

$$\sqrt{2}A(B^- \to \pi^0 K^-) =$$
$$-P(1 - \delta_{EW}\varepsilon e^{i\phi} + e^{-i\gamma}\varepsilon e^{i\phi} + h_s^1 e^{i\sigma_s}[p_Z e^{i\phi_Z} - \delta_{EW}^Z \varepsilon e^{i\phi}])$$

$$A(\bar{B}^0 \to \pi^+ K^-) = -P(1 - \delta_{EW}\varepsilon_C e^{i\phi_C}$$
$$+e^{-i\gamma}\varepsilon_T e^{i\phi_T} + h_s^1 e^{i\sigma_s}[p_Z e^{i\phi_Z} - \delta_{EW}^Z \varepsilon_C e^{i\phi_C}])$$

$$\sqrt{2}A(\bar{B}^0 \to \pi^0 \bar{K}^0) = P(1 + \delta_{EW}\varepsilon_T e^{i\phi_T}$$
$$-e^{-i\gamma}\varepsilon_C e^{i\phi_C} + h_s^1 e^{i\sigma_s}[p_Z e^{i\phi_Z} + \delta_{EW}^Z \varepsilon_T e^{i\phi_T}])$$

πK amplitudes

Effects of $O_{7,8}$:

$$EW_T^Z + \frac{3}{2} EW_C^Z = \frac{3}{2}\kappa_+^Z (T+C) + \frac{3}{2}\Delta_1 (T+C)$$

$$EW_C^Z = \frac{1}{2}\kappa_+^Z (T+C) + \frac{1}{2}\kappa_-^Z (C-T) + \Delta_2 (T+C)$$

$$EW_P^Z = \kappa^Z P_u + \Delta_3 \,.$$

$$\kappa_\pm^Z \equiv \frac{C_9^Z \pm C_{10}^Z}{C_1 \pm C_2}$$

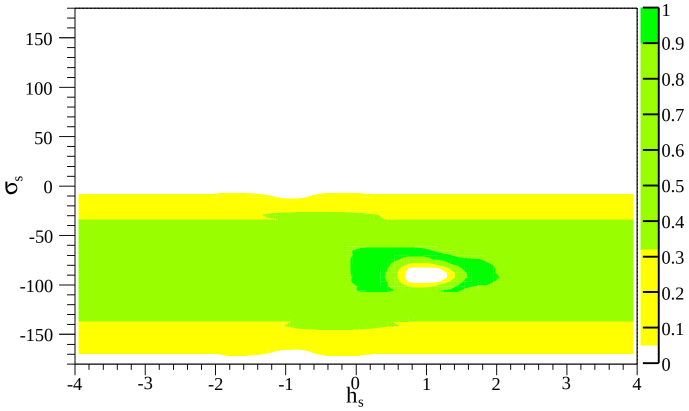
In QCDF Δ_1 is small ($\sim 6\%$).
Δ_2 is not small ($\sim 40\%$) but present mainly in charged modes, where NP effects are small.
Overall effect from Δ_i's $\sim 1\%$.

Backup slides:

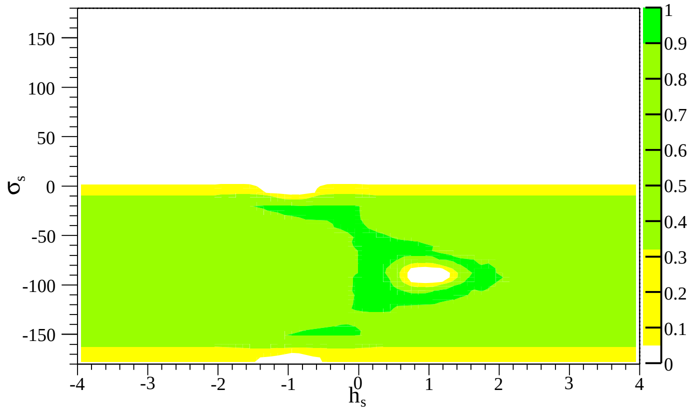
Additional Plots

Correlations: $\Delta F = 1$ ($\eta' K_S$ & ϕK_S only) + Δm_S

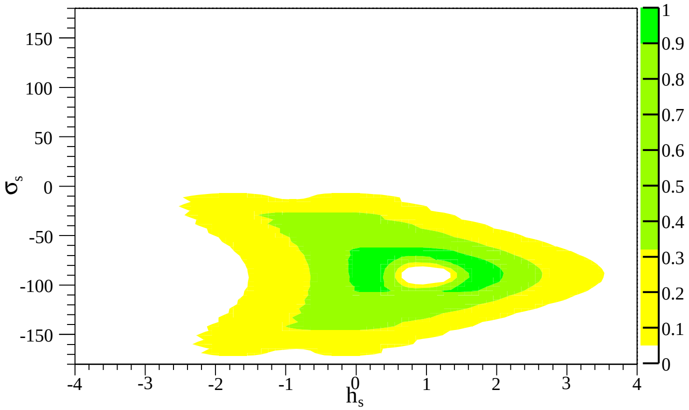
NF present



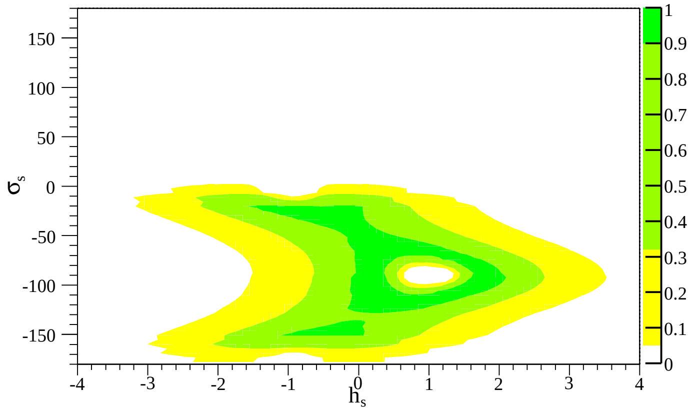
QCDF present



NF future

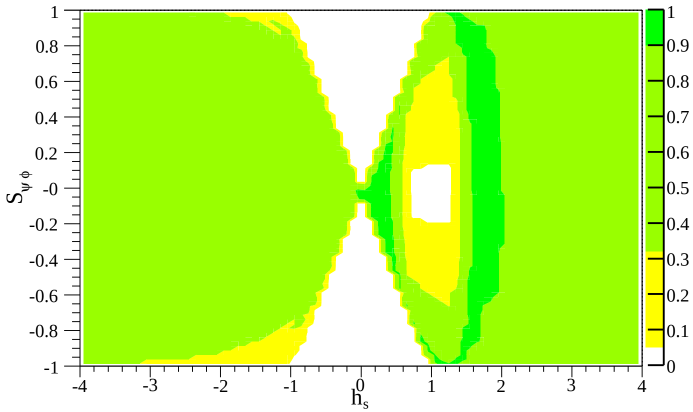


QCDF future

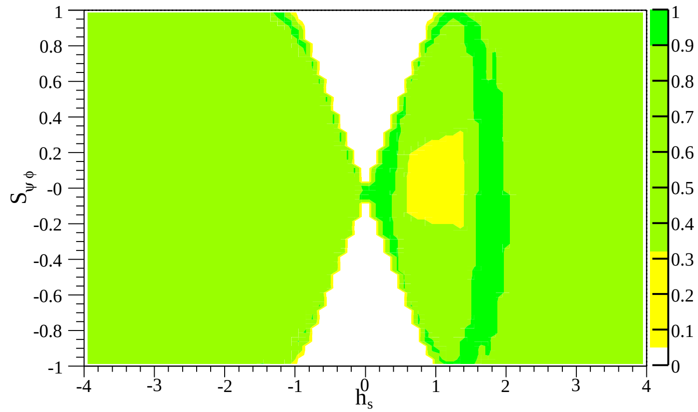


Correlations: $\Delta F = 1$ ($\eta' K_S$ & ϕK_S only)+ Δm_S + $S_{\psi\phi}$

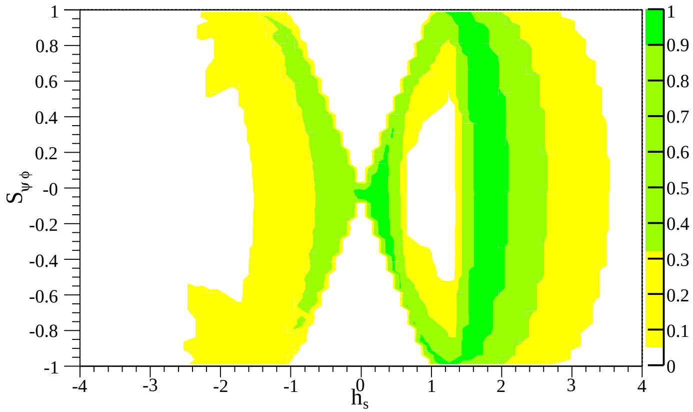
NF+$SU(3)$ present



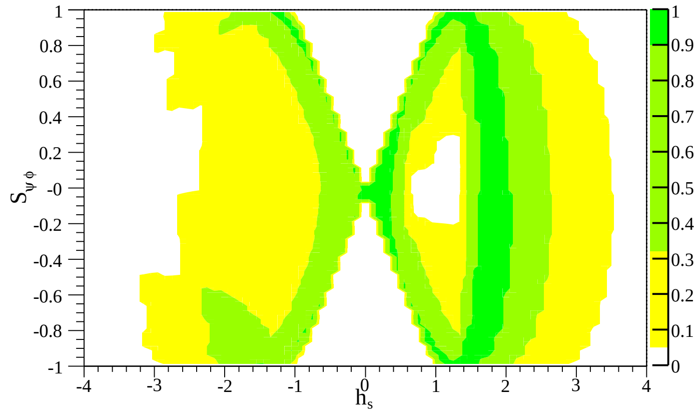
QCDF present



NF+$SU(3)$ future

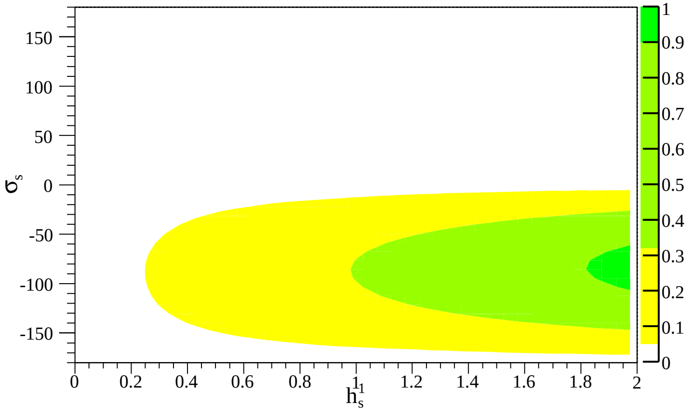


QCDF future

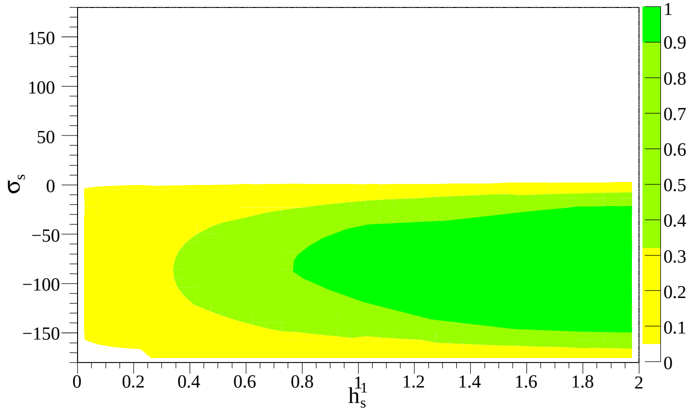


Combined ϕK_S, $\eta' K_S$

$\eta' K_S$ Naive



$\eta' K_S$ QCDF



πK in QCDF with no BR's