The Charm of the Littlest Higgs with T-Parity

CP-Violation in $D^0 - \bar{D}^0$ Oscillations

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Workshop on New Physics with SuperB
Warwick, UK
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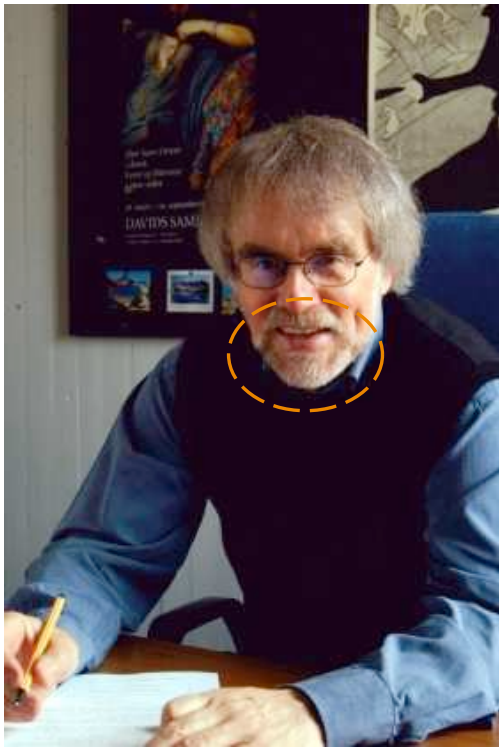
based on: Bigi, MB, Buras, Recksiegel, 0904.1545

Outline

news on K and B physics and LFV in the LHT model:
MB, Buras, Duling, Recksiegel, Tarantino, 0904.soon
talk by Björn Duling, tomorrow morning!

The Bet



Andrzej Buras has authorized me to make the following statement:

He is willing to bet his beard that LHT models would lead to

observable ~~CP~~ in D decays!

The Bet – Part II

Ikaros Bigi has authorized me to make the following statement:

He is willing to grow a beard if ~~CP~~ is not observed in D decays by 2017!

The Judges

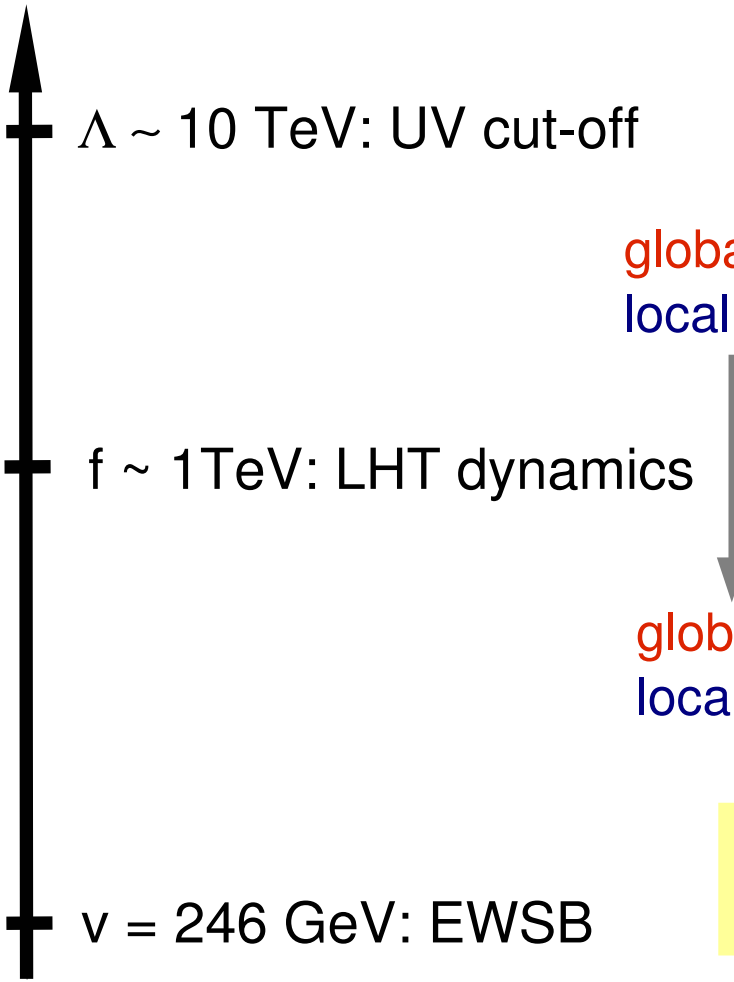
MB

Stefan Recksiegel

➢ foundation of the **BBBR collaboration**

Symmetries in the Littlest Higgs Model with T-Parity

Arkani-Hamed, Cohen, Georgi, hep-th/0104005, hep-ph/0105239
Arkani-Hamed, Cohen, Katz, Nelson, hep-ph/0206021
Cheng, Low, hep-ph/0308199, hep-ph/0405243
Low, hep-ph/0409025



T-parity = discrete symmetry
- SM particles even
- new particles odd

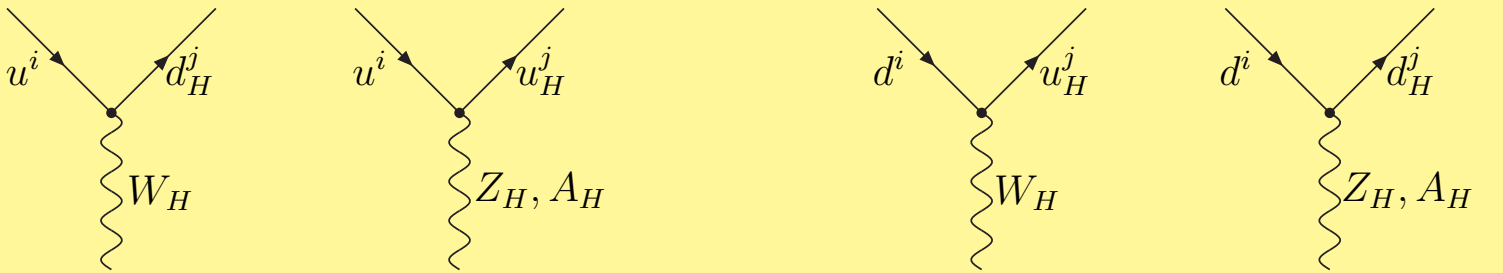
Higgs = Goldstone Boson of SU(5) → SO(5)
collective symmetry breaking

The Who-Is-Who in the LHT Model

	T-even sector	T-odd sector
gauge bosons	$W_L^\pm$, Z_L, A_L	$W_H^\pm$, Z_H, A_H
	gluons	—
fermions	**SM quarks**	**mirror quarks**
	top partner T_+	T_-
	SM leptons	**mirror leptons**
scalars	Higgs doublet H	scalar triplet Φ

Flavour Violation by Mirror Quarks

SM quarks couple to heavy gauge bosons & mirror fermions:



$\sim (V_{Hu})_{ji}\gamma^\mu P_L$ $\sim (V_{Hu})_{ji}\gamma^\mu P_L$ $\sim (V_{Hd})_{ji}\gamma^\mu P_L$ $\sim (V_{Hd})_{ji}\gamma^\mu P_L$

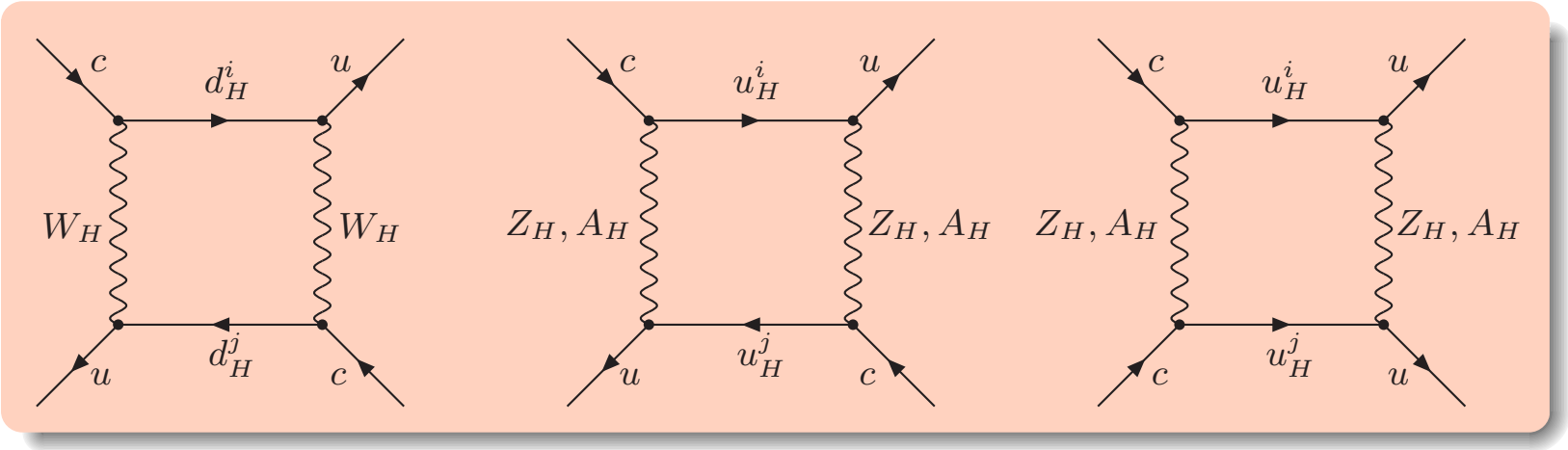
- new FCNC contributions at the **loop level** (T-parity)
- **new sources of flavour and CP-violation** (V_{Hu}, V_{Hd})

$$V_{Hu} = V_{Hd} V_{\text{CKM}}^\dagger$$

Hubisz, Lee, Paz, hep-ph/0512169
MB, Buras, Poschenrieder, Tarantino, Uhlig, Weiler, hep-ph/0605214
BBPTUW+Recksiegel, hep-ph/0609284

LHT Contributions to $\Delta C = 2$

Hubisz, Lee, Paz, hep-ph/0512169
MB, Buras, Poschenrieder, Tarantino, Uhlig, Weiler, hep-ph/0605214
MB, Buras, Recksiegel, Tarantino, Uhlig, hep-ph/0703254



- **loop contributions** by **heavy gauge bosons & mirror fermions**
- new source of **flavour and CP-violation**
- pure $\boldsymbol{(V-A)\otimes(V-A)}$ structure

$D^0 - \bar{D}^0$: SM Prediction & Experimental Status

$D^0 - \bar{D}^0$ oscillations in the SM

- SD contribution (box diagrams) highly suppressed by GIM
- **dominated by LD contributions**

  ➢ **poorly known**: $|x_D|, |y_D| \lesssim \mathcal{O}(10^{-2})$

  ➢ **no CP-violation!**

experimentally

- **evidence for $D^0 - \bar{D}^0$ mixing** at the 9.8σ level
- CP-conserving data already constraining

  $x_D = \frac{\Delta M_D}{\Gamma_D} = 0.0100^{+0.0024}_{-0.0026}$ $\qquad$ $y_D = \frac{\Delta \Gamma_D}{2\Gamma_D} = 0.0076^{+0.0017}_{-0.0018}$
- still a **lot of room for CP-violation**: $\left|\frac{q}{p}\right| = 0.86^{+0.17}_{-0.15}$

Recipe for the Numerical Analysis

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1. Generate **LHT parameter points that fulfil present K and B physics constraints** ($f = 1\,\text{TeV}$)
2. Evaluate $\mathbf{(M_{12}^D)_{LHT}}$
3. **Determine $(M_{12}^D)_{SM}$, $(\Gamma_{12}^D)_{SM}$** required to fit the data on x_D, y_D
4. Calculate **CP-violating observables in the D system**
5. Study **relation with K and B physics**

●, ● points fulfilling K, B constraints (2 solutions for $(M_{12}^D)_{SM}$, $(\Gamma_{12}^D)_{SM}$)

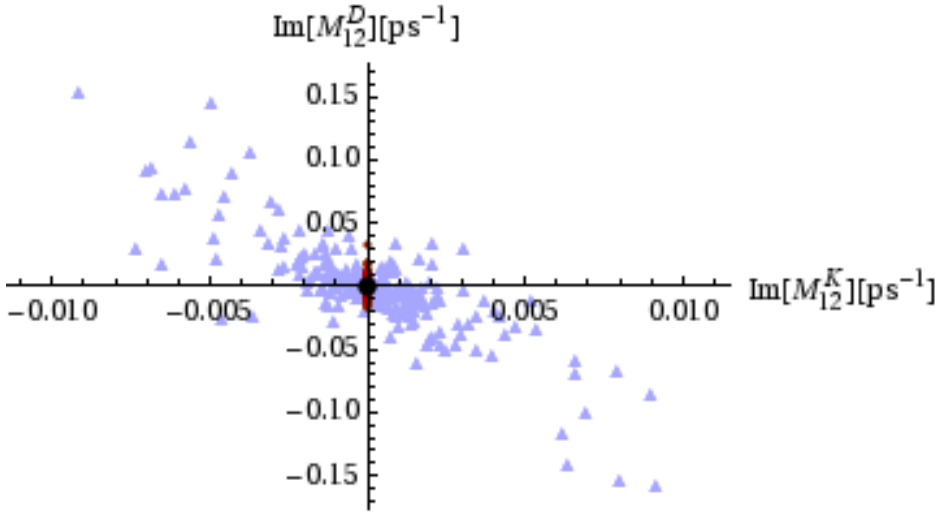
▲ points *not* fulfilling ε_K

Connection to $K^0 - \bar{K}^0$ Mixing

in LHT only left-handed FCNCs

- K **and** D systems **strongly correlated** ($SU(2)_L$ symmetry)
- **violation** of correlation through **CKM misalignment**
- **corrections suppressed** by Cabibbo angle λ

$$\overbrace{\xi_i^{(D)}}^{D\text{ system}} = \overbrace{\xi_i^{(K)*}}^{K\text{ system}} + \lambda\left(|V_{Hd}^{is}|^2 - |V_{Hd}^{id}|^2\right) + \mathcal{O}(\lambda^2)$$



Blum, Grossman, Nir, Perez, 0903.2118; BBBR

Constraint in the Complex M_{12}^D Plane

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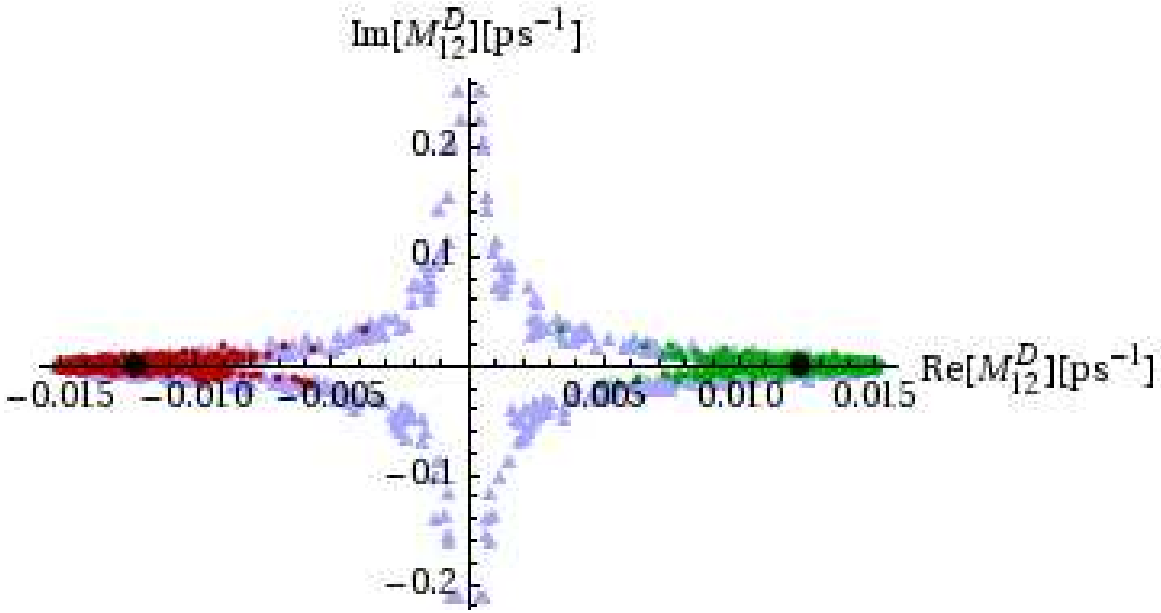
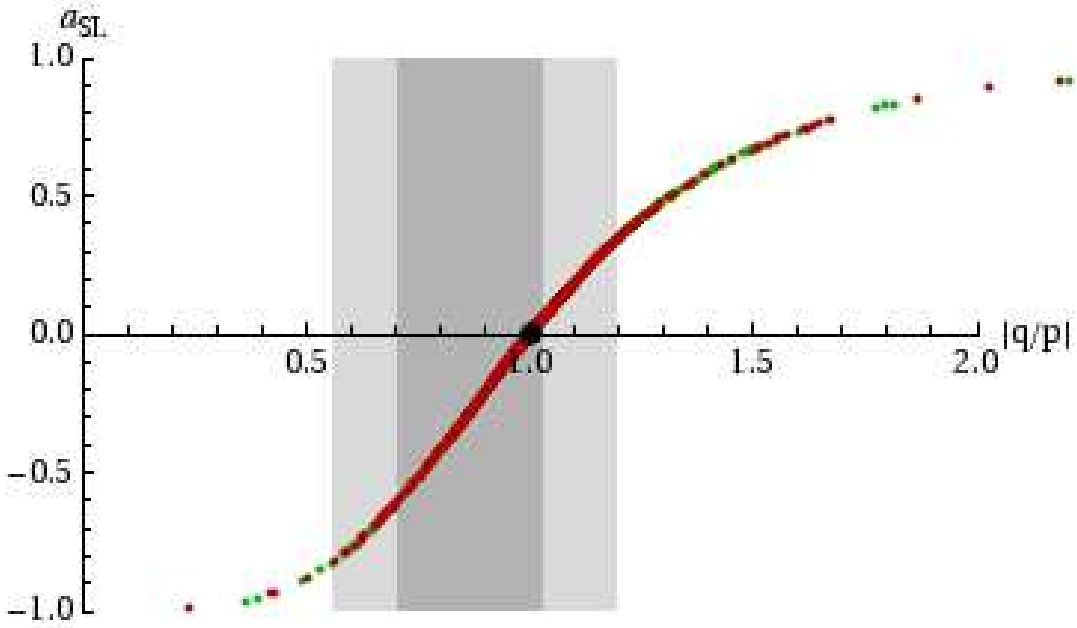


- non-trivial constraint from $D^0 - \bar{D}^0$ data
- LHT: additional strong constraint from ε_K
- **arg(M_{12}^D) essentially unconstrained**

CP-Violation in $D^0 - \bar{D}^0$ Oscillations

- $\left|\frac{q}{p}\right| \neq 1$ **measures CP-violation** in $D^0 - \bar{D}^0$ mixing
- exp. signature: **asymmetry in "wrong sign" leptons**

$$a_{\text{SL}} = \frac{\Gamma(D^0 \to \ell^- \bar{\nu} K^{+(*)}) - \Gamma(\bar{D}^0 \to \ell^+ \nu K^{-(*)})}{\Gamma(D^0 \to \ell^- \bar{\nu} K^{+(*)}) + \Gamma(\bar{D}^0 \to \ell^+ \nu K^{-(*)})}$$



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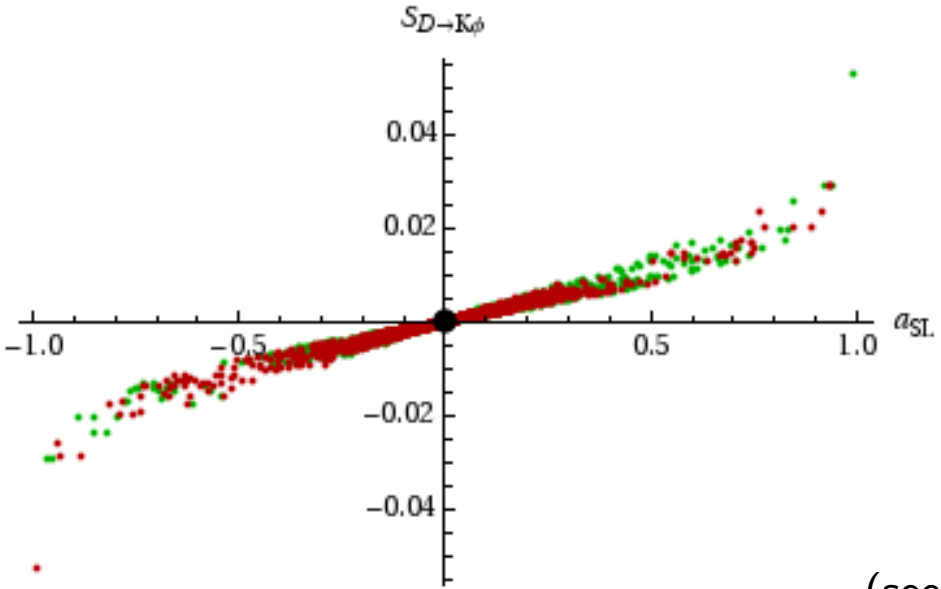
Correlation between various CP-Asymmetries

example: **time-dependent CP-asymmetry in $D \to K_S\phi$**

$$\frac{\Gamma(D^0(t) \to K_S\phi) - \Gamma(\bar{D}^0(t) \to K_S\phi)}{\Gamma(D^0(t) \to K_S\phi) + \Gamma(\bar{D}^0(t) \to K_S\phi)} \equiv S_{D\to K_S\phi}\frac{t}{2\tau_D}$$



$$S_{D\to K_S\phi} \simeq \frac{x_D^2 + y_D^2}{y_D} a_{\mathsf{SL}}$$

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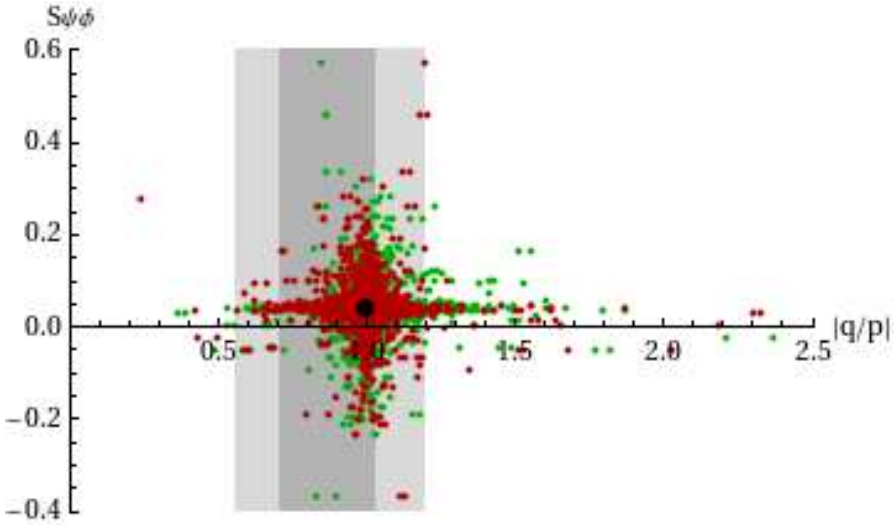
(see also Grossman, Nir, Perez, 0904.0305)

- **strong correlation with a_{SL}**
- its **violation** would **signal direct CP-violation**

Relation to B and K Physics



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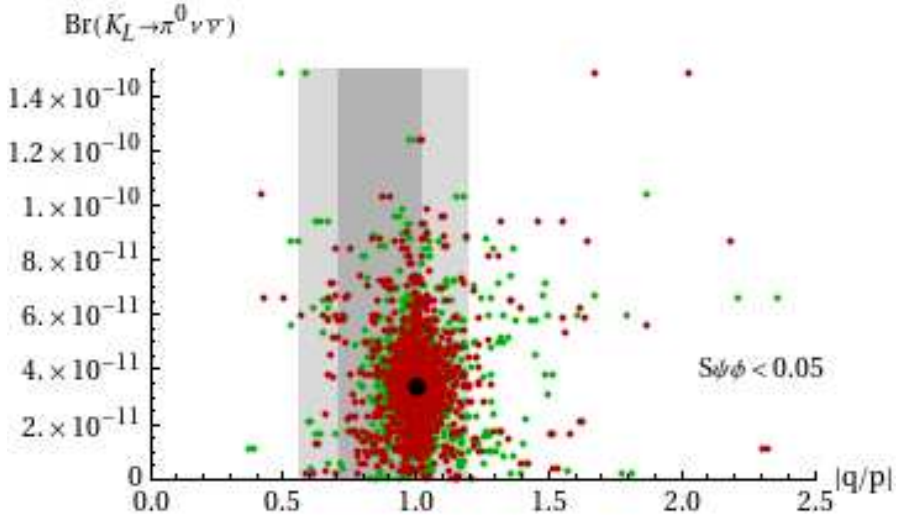
large CP-violating effects in both $B_s - \bar{B}_s$ and $D^0 - \bar{D}^0$ unlikely

simultaneous large CP-violating effects in both $D^0 - \bar{D}^0$ and rare K_L decays possible



Main Messages from LHT Charm Physics

1. LHT dynamics can lead to **sizable CP-violating effects in $D^0 - \bar{D}^0$ mixing**, although constrained from ε_K data
2. **$\Delta C = 2$ CP-violating observables** are strongly **correlated** among each other
3. **correlation with K and B physics** observables:

large CP-violating effects in $D^0 - \bar{D}^0$

- **unlikely if $S_{\psi\phi} \gg (S_{\psi\phi})_{\text{SM}}$**
- **possible together with large $Br(K_L \to \pi^0 \nu\bar{\nu})$**