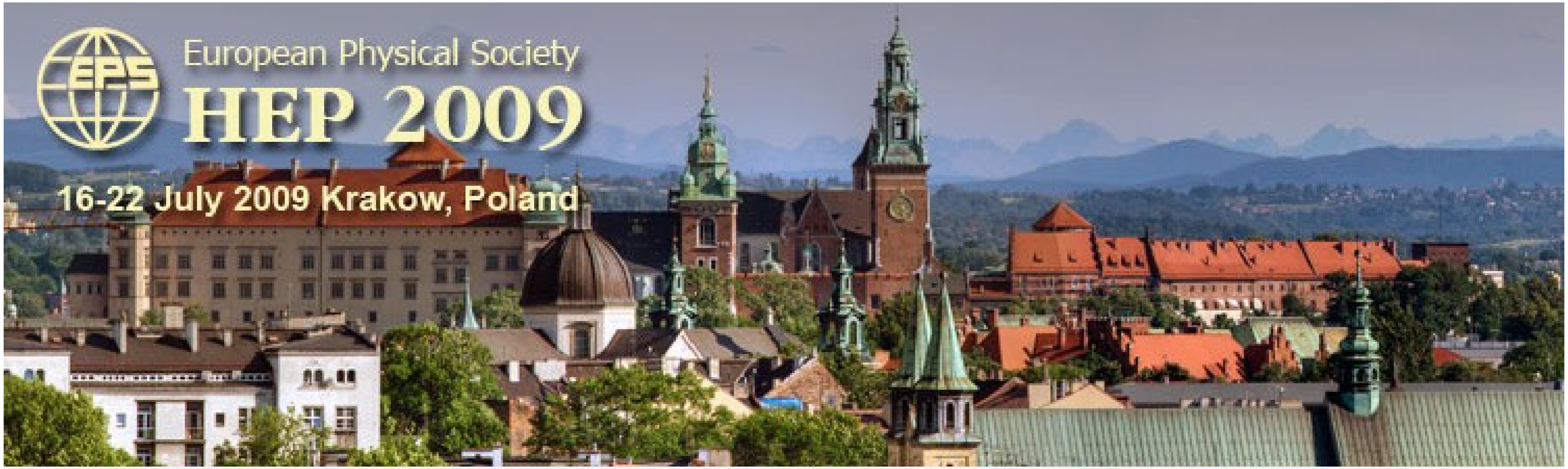

Flavour Physics in the Littlest Higgs Model with T-Parity (LHT)

1. Some Notions about Little Higgs Models

2. Status of Flavour Physics Analysis in LHT

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A brief theoretical introduction…

The Little Hierarchy Problem

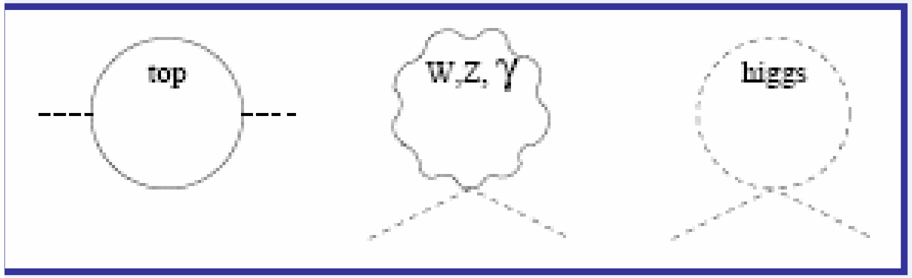
``New Physics (NP) at 1 TeV is expected but its effects are not observed´´

From the instability of the Higgs mass

Parameterizing NP by higher-dimensional operators suppressed by the NP scale Λ:
$(h^\dagger D_\mu h)^2/\Lambda^2$, $(D^2 h^\dagger D^2 h)/\Lambda^2$,…

Ew precision tests yield $\Lambda \geq$5-10TeV

Little Higgs Models with Λ~O(1)TeV can stabilize the Higgs mass without violating the ew bound!



Problematic quadratic divergences in m_H^2 are canceled by:
- **Same-statistics heavy partners**
- **With couplings related to the SM couplings by a global symmetry**

More formally, in Little Higgs Models:

[N. Arkani-Hamed, A.G. Cohen, H. Georgi (2001)]

1. The **Higgs** is **light** as it is the **Goldstone boson** of a spontaneously broken **global symmetry** (G)

2. **Gauge and Yukawa couplings** of the Higgs are introduced by **gauging a subgroup of G**

3. ``Dangerous´´ **quadratic corrections** are **avoided at one-loop** through **Collective Symmetry Breaking**
   (the Higgs becomes massive only when two couplings are non-vanishing)

The most economical in matter content: Littlest Higgs (LH)

[N. Arkani-Hamed, A.G. Cohen, E. Katz, A.E. Nelson (2002)]

Global Spontaneous SB:

$SU(5) \longrightarrow SO(5)$

$f \approx O(1 TeV)$

New Heavy Particles (with O(f) masses)

Gauge Bosons: $W^{\pm}_H$, Z^0_H, A^0_H

Fermions: T

Scalars: Φ(triplet)

Electroweak (ew) precision tests

Tree-level heavy gauge boson contributions and the triplet Φ vev make ew precision tests highly constraining

[Han, Logan, McElrath, Wang (2003)]

[Csaki, Hubisz, Kribs, Meade, Terning (2003)]

⇒ **$f \geq$ 2-3 TeV**

The little hierarchy problem is back!

The solution comes from a discrete symmetry:

T-Parity [H.C. Cheng, I. Low (2003)]

T-parity forbids the unwanted contributions:

- **SM particles are T-even,**
- **new particles are T-odd**

(similarly to R-parity in SUSY)

smaller f allowed by ew tests

[Hubisz,Meade,Noble,Perelstein (2005)]

⇓

$f \geq$ 500 GeV

The Littlest Higgs Model with T-Parity (LHT)

Dark Matter candidate

T-even Sector:

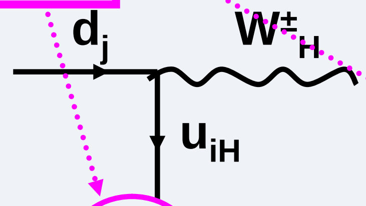
SM Particles + T_+

T-odd Sector:

Gauge Bosons: $W^{\pm}_H$, Z^0_H, A^0_H
Fermions: T_-, Mirror Fermions (f_H)
Scalars: Φ

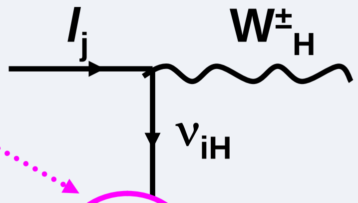
with NEW flavour interactions

New mixing matrices in addition to V_{CKM} and V_{PMNS}



$\sim (V_{Hd})_{ij}\, \gamma_\mu\, (1-\gamma_5)$

Quark Sector



$\sim (V_{Hl})_{ij}\, \gamma_\mu\, (1-\gamma_5)$

Lepton Sector

New parameters of the LHT model:

Global symmetry breaking scale: f ~ 1TeV
1 parameter describing the T_+: x_L
V_{Hd} and V_{Hl}: 3 angles and 3 phases each
3 generations of mirror quarks and leptons (6 masses)

LHT goes beyond Minimal Flavour Violation (MFV)
``visible effects in flavour physics are possible´´

FCNC Processes in LHT: a 2009 Look

0906.5454 [hep-ph]

M. Blanke, A.J. Buras, B. Duling, S. Recksiegel, C.T.

The main news w.r.t to our previous analyses:

- We had **previously overlooked** an $O(v^2/f^2)$ contribution to the Z^0-penguin diagrams, identified by Goto et al. (0809.4753) and Aguila et al. (0811.2891)

- Introducing this contribution the logarithmic **UV-cutoff dependence disappears** at $O(v^2/f^2)$ from our results $\longrightarrow$ the LHT model is **less sensitive** to the physics at the UV-cutoff scale than how one could expect

- We have extended our analysis to **include** the interesting decay $K_L \to \mu^+ \mu^-$

- We have studied the degree of **fine tuning** necessary in LHT to satisfy the constraints from ε_K and $\mu \to e \gamma$

- We have **updated** some experimental and theoretical **inputs**

Numerical Analysis: Quark and Lepton Sectors

•Being interested in pointing out visible LHT effects, we perform a general scan over the LHT parameters

Quark sector

- $f = 1$ TeV (or 500 GeV)
- 300 GeV $\leq m_{Hi} \leq$ 1 TeV
- general scan over V_{Hd}

Lepton sector

- $f = 1$ TeV (or 500 GeV)
- 300 GeV $\leq m^{l}_{Hi} \leq$ 1.5 TeV
- general scan over V_{Hl}

•Input parameters flatly extracted in 1σ ranges
•Flavour observables required to lie within experimental 1σ ranges or to satisfy experimental bounds

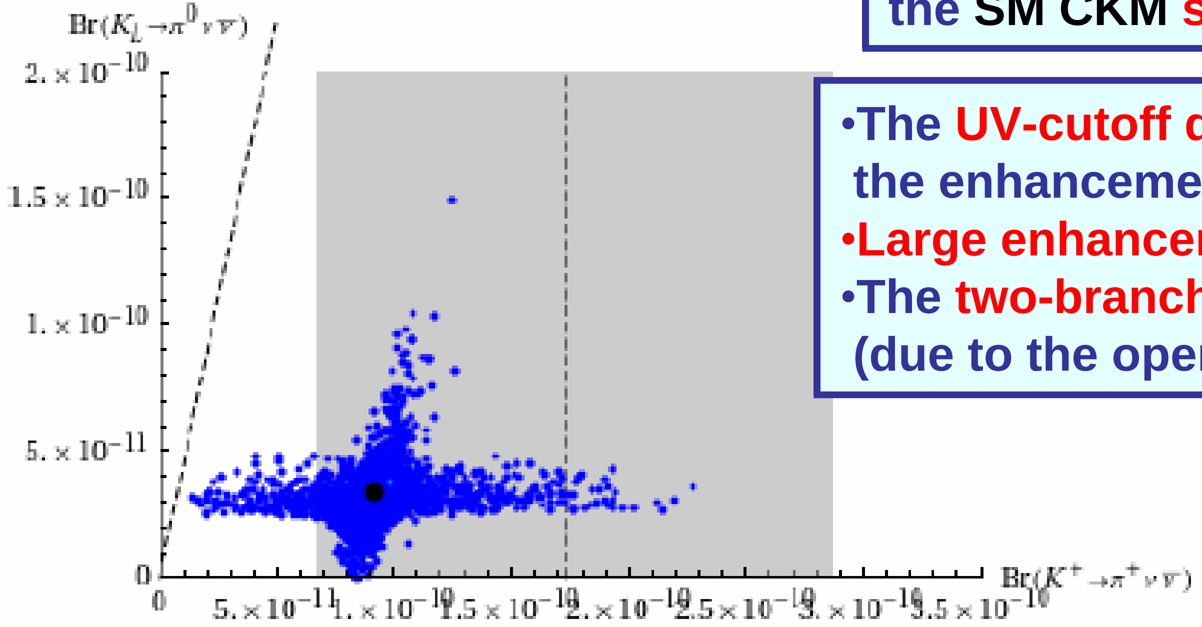
•In studying fine-tuning we use the Barbieri-Giudice definition (Nucl.Phys.B306 (1988))

$$\Delta_{\rm BG}(O) = \max_{j=1,\ldots,m} \{\Delta_{\rm BG}(O, p_j)\}\,,$$

$$\Delta_{\rm BG}(O, p_j) = \left|\frac{p_j}{O}\frac{\partial O}{\partial p_j}\right|\,,$$

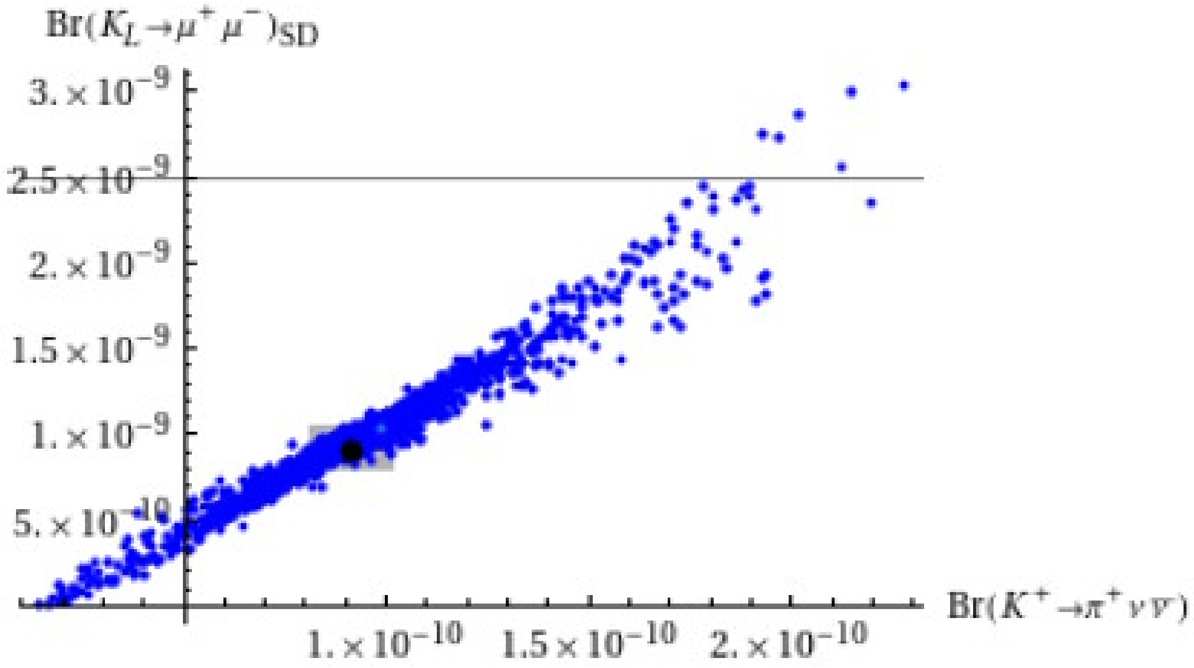
Kaon Sector

A **privileged sector** to look for **NP** due to the **SM CKM suppression factor** $\lambda_t^{(s)} \approx O(10^{-4})$

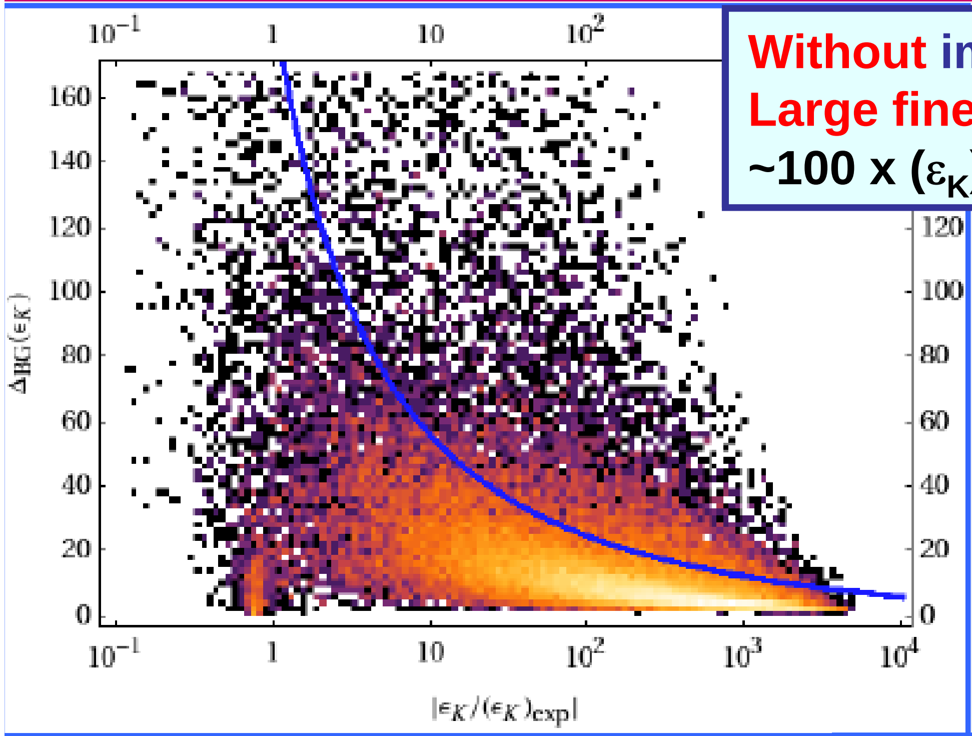


- The **UV-cutoff divergence removal reduces** the enhancements by **~2-3**
- **Large enhancements** w.r.t the SM are **allowed**
- The **two-branches correlation** is still satisfied (due to the operator structure)

- **Strong correlation** between the two decays, due to **left-handed** mediation of $K_L \to \mu^+ \mu^-$ (inverse of the correlation in the custodially protected RS model, see talk by Monika)

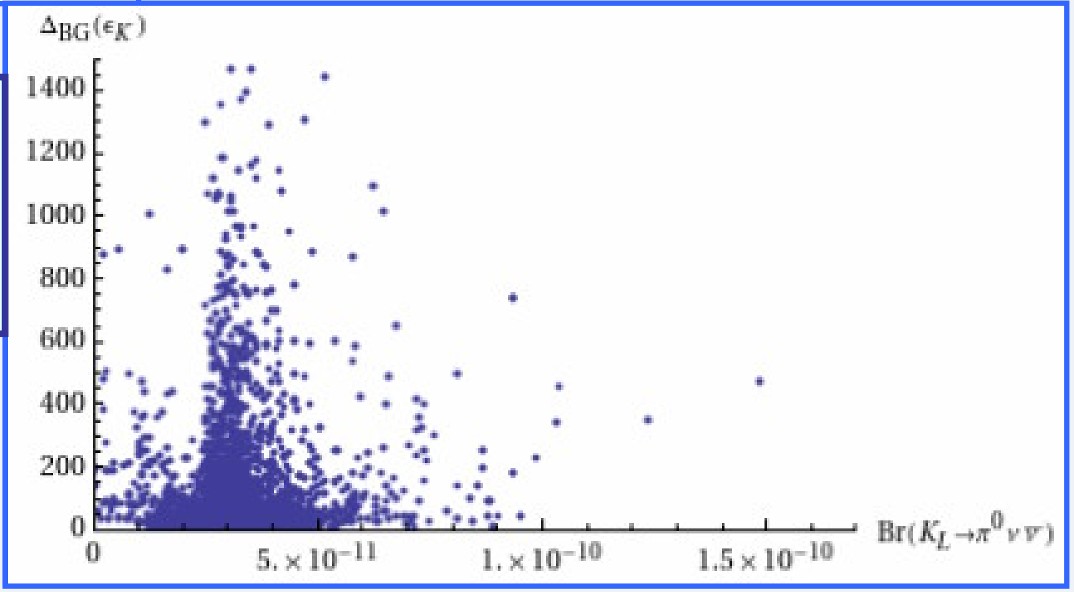


Fine tuning to satisfy the experimental value of ε_K

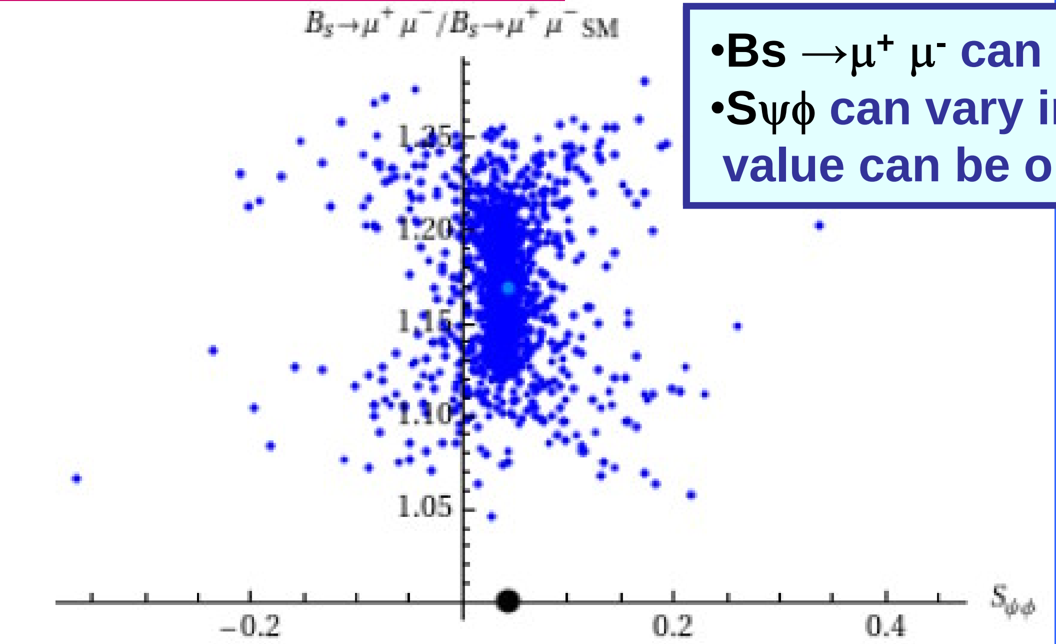


Without imposing any available **flavour constraint**:
Large fine-tuning →LHT would naturally predict ~100 x $(\varepsilon_K)_{exp}$

By imposing available **flavour constraints** one sees that: there are **parameter regions** where **fine-tuning is small**

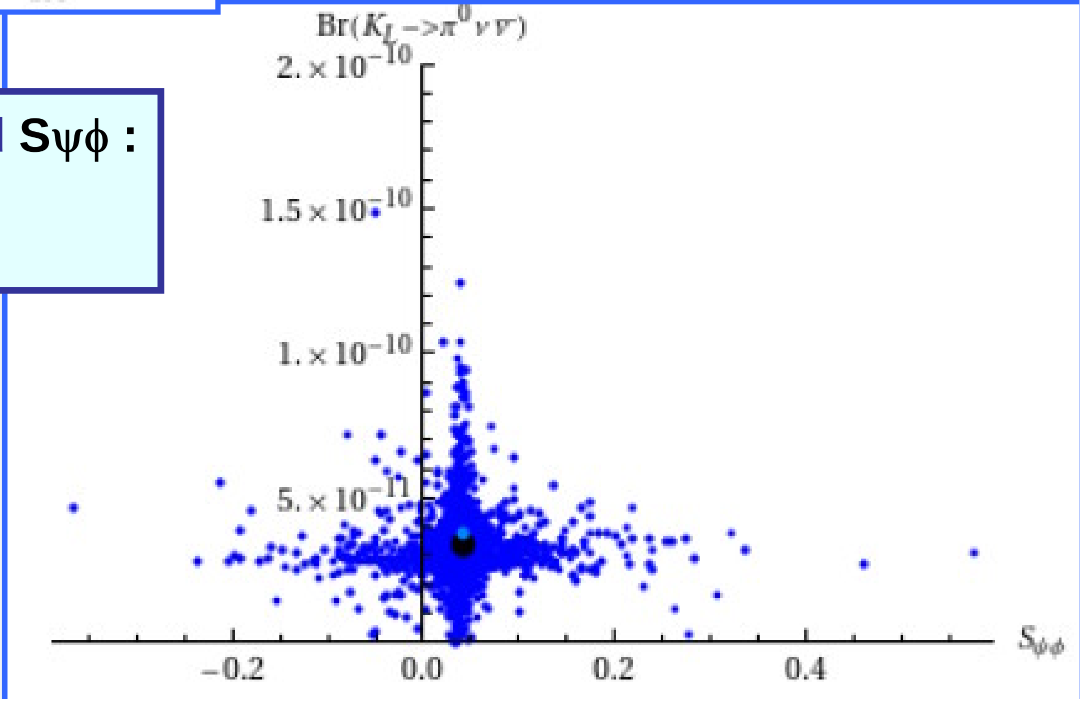


B_s and K Sectors



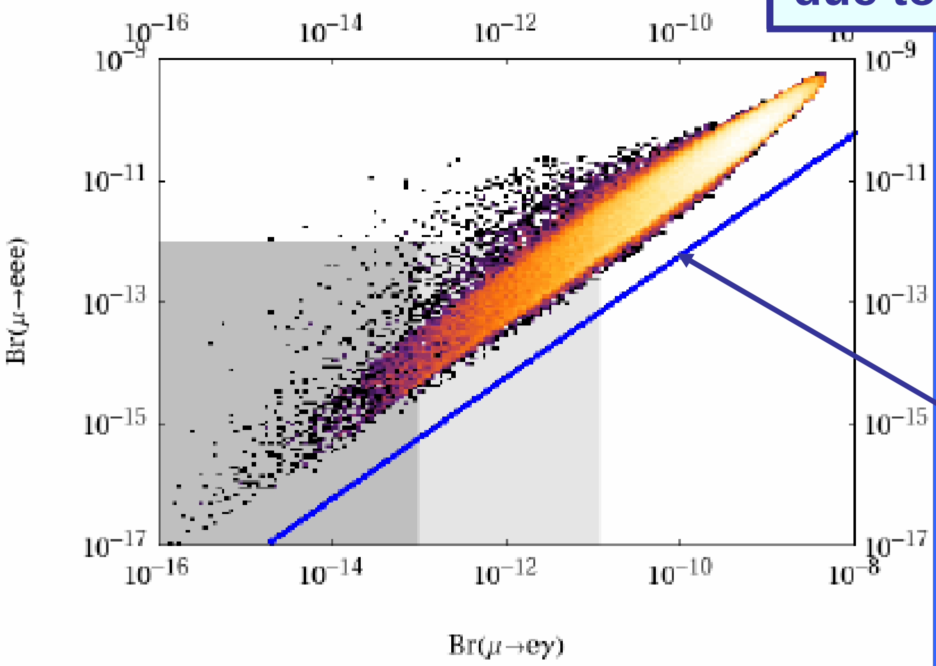
- Bs $\to \mu^+ \mu^-$ can be enhanced by at most 30%
- S$\psi\phi$ can vary in [-0.4,+0.5] (the CDF+D0 exp. value can be obtained with some parameter tuning)

- Correlation between $K_L \to \pi^0 \nu \bar{\nu}$ and S$\psi\phi$:
- Simultaneous enhancements are disfavoured but possible

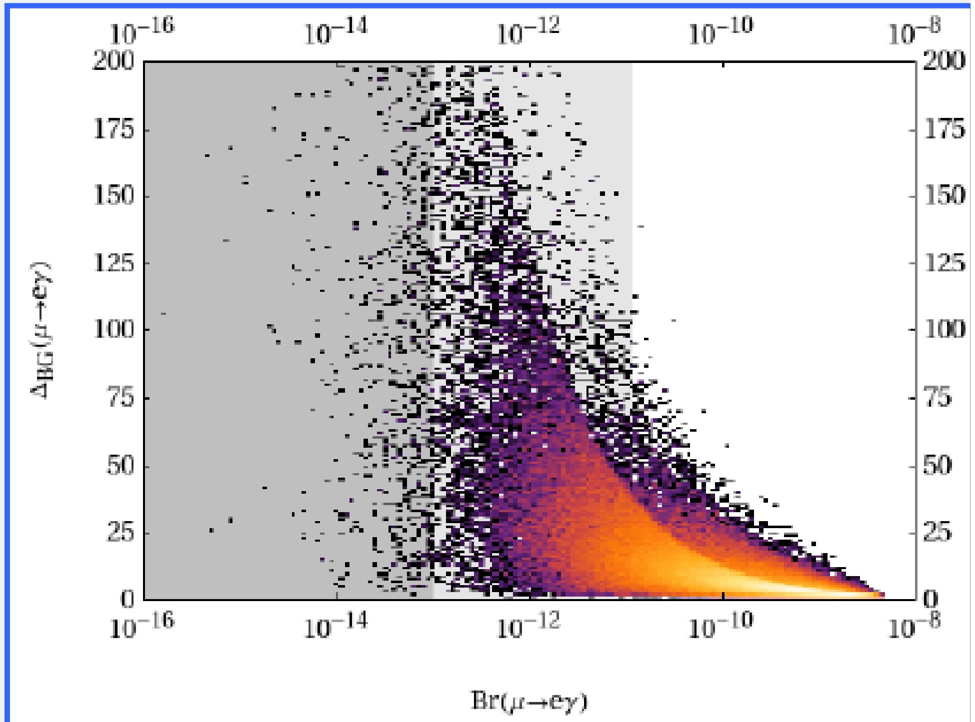


Lepton Sector

LFV decays are **strongly suppressed** in the **SM**, due to **tiny neutrino masses**



- V_{Hl} must be **very hierarchical** to satisfy the exp. bound on $\mu \to e\,\gamma$
- **Strong correlation** between $\mu \to e\,\gamma$ and $\mu \to e\,e\,e$ due to common V_{Hl} elements
- The **LHT** structure of $\mu \to e\,e\,e$ is **significantly different** from **MSSM** (dominated by the dipole operator)



- With the **present exp. bound** on $\mu \to e\,\gamma$ the required **fine tuning is small** (<25)
- If the **MEG** experiment pushes the bound down to $\sim 10^{-13}$ the **LHT** could have **problems to accomodate data**

LHT upper bounds for LFV decays

- The removal of the UV-cutoff divergence lowers the Br's for τ decays in 3 leptons by almost an order of magnitude
- However, for f<1 TeV LFV decays can be seen at a SuperB factory

decay	$f = 1000\,\text{GeV}$	$f = 500\,\text{GeV}$	SuperB sensitivity
$\tau \to e\gamma$	$8 \cdot 10^{-10}$	$2 \cdot 10^{-8}$	$2 \cdot 10^{-9}$
$\tau \to \mu\gamma$	$8 \cdot 10^{-10}$	$2 \cdot 10^{-8}$	$2 \cdot 10^{-9}$
$\tau^- \to e^-e^+e^-$	$1 \cdot 10^{-10}$	$2 \cdot 10^{-8}$	$2 \cdot 10^{-10}$
$\tau^- \to \mu^-\mu^+\mu^-$	$1 \cdot 10^{-10}$	$2 \cdot 10^{-8}$	$2 \cdot 10^{-10}$
$\tau^- \to e^-\mu^+\mu^-$	$1 \cdot 10^{-10}$	$2 \cdot 10^{-8}$	
$\tau^- \to \mu^-e^+e^-$	$1 \cdot 10^{-10}$	$2 \cdot 10^{-8}$	
$\tau^- \to \mu^-e^+\mu^-$	$6 \cdot 10^{-14}$	$1 \cdot 10^{-13}$	
$\tau^- \to e^-\mu^+e^-$	$6 \cdot 10^{-14}$	$1 \cdot 10^{-13}$	
$\tau \to \mu\pi$	$4 \cdot 10^{-10}$	$5 \cdot 10^{-8}$	
$\tau \to e\pi$	$4 \cdot 10^{-10}$	$5 \cdot 10^{-8}$	
$\tau \to \mu\eta$	$2 \cdot 10^{-10}$	$2 \cdot 10^{-8}$	$4 \cdot 10^{-10}$
$\tau \to e\eta$	$2 \cdot 10^{-10}$	$2 \cdot 10^{-8}$	$6 \cdot 10^{-10}$
$\tau \to \mu\eta'$	$1 \cdot 10^{-10}$	$2 \cdot 10^{-8}$	
$\tau \to e\eta'$	$1 \cdot 10^{-10}$	$2 \cdot 10^{-8}$	

Correlations: visible differences between LHT and MSSM

- Correlations are less parameter-dependent
- Different pattern in $l_i \to l_j l_k^+ l_k^-$ between LHT (dominated by Z^0-penguin and box diagram) and MSSM (dominated by dipole operator)

ratio	LHT	MSSM (dipole)	MSSM (Higgs)
$\frac{Br(\mu^-\to e^-e^+e^-)}{Br(\mu\to e\gamma)}$	$0.02\ldots1$	$\sim 6\cdot10^{-3}$	$\sim 6\cdot10^{-3}$
$\frac{Br(\tau^-\to e^-e^+e^-)}{Br(\tau\to e\gamma)}$	$0.04\ldots0.4$	$\sim 1\cdot10^{-2}$	$\sim 1\cdot10^{-2}$
$\frac{Br(\tau^-\to \mu^-\mu^+\mu^-)}{Br(\tau\to \mu\gamma)}$	$0.04\ldots0.4$	$\sim 2\cdot10^{-3}$	$0.06\ldots0.1$
$\frac{Br(\tau^-\to e^-\mu^+\mu^-)}{Br(\tau\to e\gamma)}$	$0.04\ldots0.3$	$\sim 2\cdot10^{-3}$	$0.02\ldots0.04$
$\frac{Br(\tau^-\to \mu^-e^+e^-)}{Br(\tau\to \mu\gamma)}$	$0.04\ldots0.3$	$\sim 1\cdot10^{-2}$	$\sim 1\cdot10^{-2}$
$\frac{Br(\tau^-\to e^-e^+e^-)}{Br(\tau^-\to e^-\mu^+\mu^-)}$	$0.8\ldots2.0$	~ 5	$0.3\ldots0.5$
$\frac{Br(\tau^-\to \mu^-\mu^+\mu^-)}{Br(\tau^-\to \mu^-e^+e^-)}$	$0.7\ldots1.6$	~ 0.2	$5\ldots10$
$\frac{R(\mu\mathrm{Ti}\to e\mathrm{Ti})}{Br(\mu\to e\gamma)}$	$10^{-3}\ldots10^{2}$	$\sim 5\cdot10^{-3}$	$0.08\ldots0.15$

Conclusions

The Littlest Higgs Model with T-parity

- **solves the little hierarchy problem**
- **is compatible with ew precision tests**
- **introduces new flavour violating interactions**
- **can yield large effects in Flavour Physics:**
  in particular in the Kaon sector and in
  Lepton Flavour Violating decays

Correlations of Br´s could provide a clear distinction between LHT and other NP models (custodial RS, MSSM) !!


THANKS!