Signals of 4th Generation Quarks @ the LHC; a 2HDM Framework

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Motivation:

Heavy fourth generation of fermions is a simple extension of the SM, that has non-trivial far reaching implications:

1. Heavy right hand neutrinos- might be a **dark matter candidate** (requires further "construction").
2. **CP violation**- additional phases in CKM matrix →explaining puzzles in B decays, and a chance to account for nucleosynthesis.
3. Underlying framework for **TeV scale compositeness**- 4th gen. bound states.

The Model - Intro

Motivation for considering 4th generation within a specific 2hdm framework (4G2HDM):

1. Naturally accommodate the new heavy fermionic states.
2. A possible low-energy effective realization of Dynamical EWSB- driven by the fourth generation condensates.

Details- New Particles

Fourth Generation

Quarks:

- t', b' – excluded up to ~300 GeV.
- τ', v' – heavier than about 100 GeV.

4G2HDM

2 higgs doublets:

- Φ_h couples to the 4th generation doublet.
- Φ_l couples to the rest.

The higgs potential is the usual 2hdm one with:

$$tan\,\beta \triangleq \frac{v_h}{v_l} \geq 1$$

Symmetry Breaking

Higgs Scalars

- 3 neutral scalars- h,H (CP even) and A (CP odd).
  - FCNC couplings: htt',hbb'.
- Charged scalar H±
  - Charged current (H±tb, H±t'b, H±t'b',H±tb').

Decay Channels

t'(b') decay channels

1. **t'→ht** (b'→hb).
2. **t'→H⁺b** (b'→H- t).
3. **t'→Wb** (b'→Wt) and **t'→Wb'** (b'→Wt') (SM4- like).

h decay channels (light h with 100 GeV<m_h<250 GeV)

1. **h→bb.**
2. **h→WW,ZZ**: **Can be suppressed with respect to SM4**.
3. **h→gg, h→ ϒϒ** by loop processes: can be either enhanced or suppressed in our **4G2HDM** (Not considered in the present work).
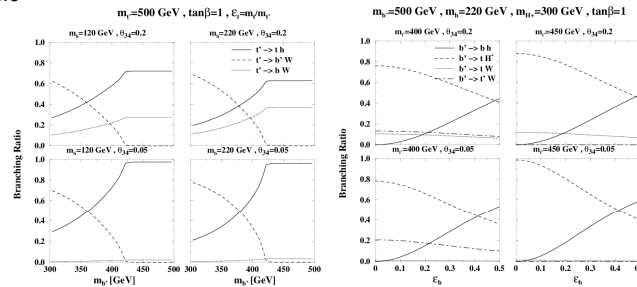

Fig. 1: Branching ratio of t' (left) and b' (right) for different choices of parameters (ϑ_{34}=V$_{t'b}$=V$_{tb'}$)

New Search Strategies (Work in Progress)

In this work we present new search strategies for t', assuming two different decay patterns:

1. **t'→ht, h→bb: 6b+W(leptonic)+W(hadronic)** signature;
2. **t'→ht, h→WW: 2b+5W(hadronic)+W(leptonic)** signature;

We use the following series of cuts:

1. H_T >400GeV.
2. **Number of jets**>6(11) for the first (second) signature.
3. **Number of b-jets**>4(1) for the first (second) signature.

Relevance to Current Searches

t' signals

The dominant t' channel is **pp →t't' →2W+6b** (t'→ht→tbb) or **pp →t't' →6W+2b** (t'→ht→tWW).

The search strategies for the SM4 single lepton signature (1Lepton+jets+missing ET) from **pp →t't' →2W+2b** (t'→Wb) **FAILS**.

b' signals

If **b'→hb** and h→bb, we get a 6b signature, without any leptons and with enormous multijet background- **impossible to discover** .

Full Simulation Results

We use MadGraph+Pythia+PGS for the generation of the background and signal (t't'~) events for 7 TeV @ the LHC. We use BRIDGE for the subsequent decays of the new particles. We generate tt+jets and W+jets background. We use K-factors of 1.5 for the signal and the top pair production, and 1 for W+jets.
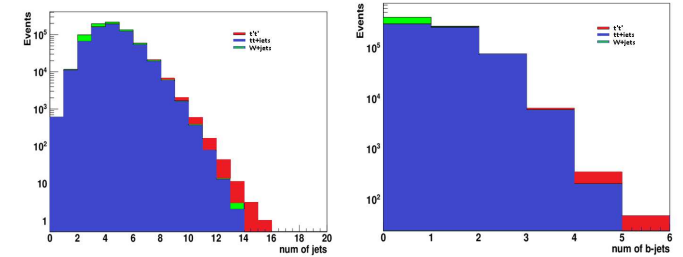

Fig. 2: Number of jets in the signal and background events for the 6W+2b signature (left), number of b-jets in signal and background events for the 2W+6b signature (right). In both cases one W decays to leptons and the others decay to quarks .
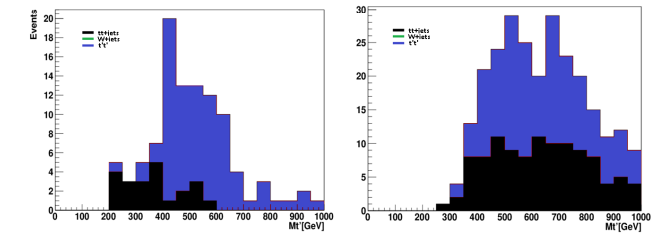

Fig. 3: Reconstructed t' mass for the 6b+2W signature (left) and 6W+2b signature (right) after the cuts (M$_t$=450GeV). In both cases one W decays to leptons and the others decay to quarks .

Conclusions:

1. The phenomenology of 4th generation fermions embedded in the **new 4G2HDM** setup can be drastically altered with respect to the simpler SM4 framework.
2. For the new decay patterns of t', we find higher **jet multiplicity** and a higher number of **b-jets** compared to SM background.
3. In 2 different cases it is possible to discover t' @ 7 TeV LHC, using cuts based on the **hardness**, **high jet multiplicity** and a high number of **b-jets** in the signal.

Future Work:

1. Perform the same analysis for other channels, including the loop processes.
2. Perform the same analysis for b' and the new leptons.