The Impact of a Higgs Boson on the Standard Model with Four Generations

Motivation for a Fourth Fermion Generation

- The addition of a fourth generation to the standard model (SM4) is a popular new physics extension to the standard model (SM).
- The model adds a fourth generation of fermions including two chiral quarks named t' ($q = +2/3$) and b' ($q = -1/3$).
- The SM is currently indicated to be incomplete and leaves masses of fundamental particles as free parameters.
- The SM4 would have significant effects on the phenomena of electroweak symmetry breaking.
- A heavy 4th quark generation could increase the predicted baryon asymmetry by up to nearly $10^{13} - 10^{15}$ times that found in the SM [1].
- ATLAS and CMS have observed significant excesses above the background only expectation consistent with a Higgs boson at around 126 GeV [2,3].
- Re-interpretation of Higgs results is vital to whether the SM4 is still possible with a simple Higgs sector.

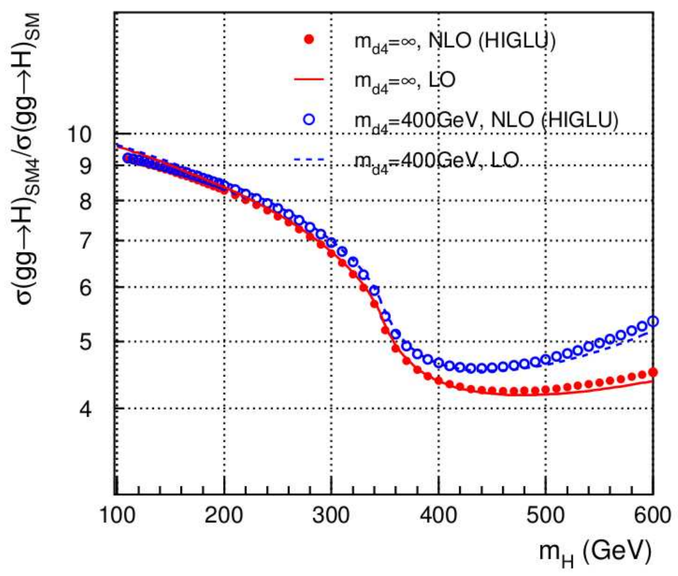

Fig.1 Ratio of SM4 and SM gluon-gluon fusion cross section as a function of Higgs mass for a nominal fermion mass scenario [4].

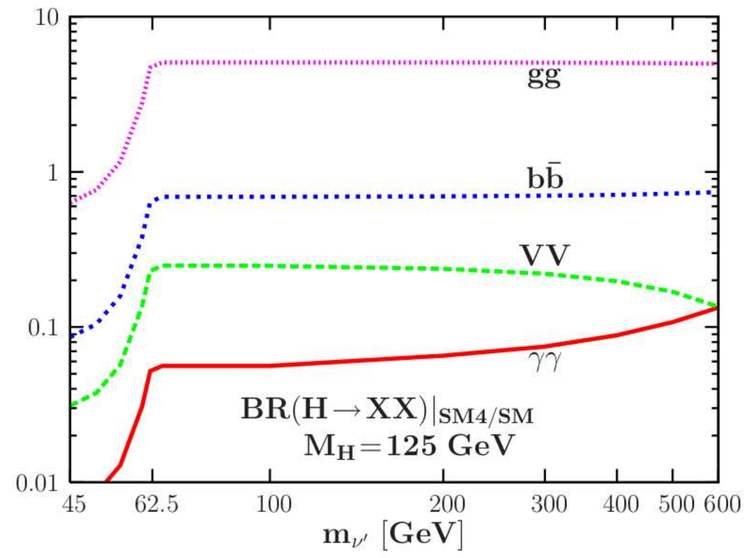

Fig.2 Ratio of SM4 and SM branching ratios as a function of fourth generation neutrino mass m_{ν_4} [5].

Effects of a Fourth Generation on the Higgs Sector

Observed signal strengths (μ_{obs}. Eq 1.) are provided by ATLAS, CMS and the Tevatron experiments.

$$\mu_{obs} = \frac{(\sigma(XX \to H) \cdot BR(H \to YY))_{obs}}{\sigma(XX \to H)_{SM} \cdot BR(H \to YY)_{SM}} \qquad (1)$$

Observed signal strengths can be translated to a SM4 scenario by calculating $\sigma(XX \to H)_{SM4} \cdot BR(H \to YY)_{SM4}$.

$\sigma(gg \to H)_{SM4}$ is increased by a factor ~ 9 with respect to the SM for small m_H values (Fig.1).

Dominant production cross section at Tevatron is associated production: $\sigma_{SM4} \approx \sigma_{SM}$.

Variation of m_{ν_4} allows tuning of $BR(H \to YY)_{SM4}$ but not their hierarchy (Fig.2).

Quantitative Analysis using CKMfitter

Collaboration between Humboldt Universität zu Berlin, The University of Durham and Karlsruher Institut für Technologie.

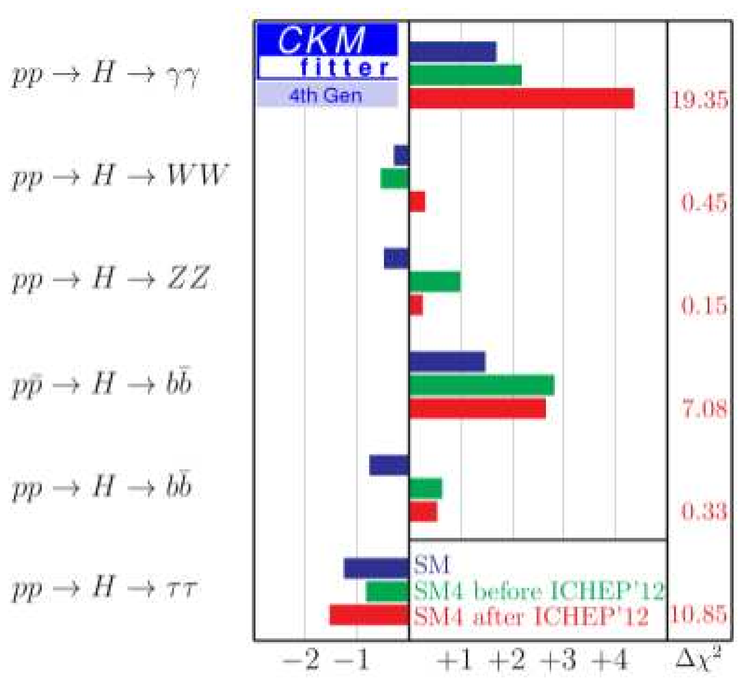

Fig.3 Pulls and χ^2 values of μ_{obs} for each channel in both the SM and the SM.

Technical Implementation in CKMfitter:

- CKMfitter linked to Zfitter for SM electro-weak precision observables (EWPOs).
- SM4 corrections to EWPOs coded in CKMfitter.
- SM4 CKM matrix mixing included in CKMfitter.
- Higgs observed signal strengths translated into an SM4 scenario using HDECAY [6].

$$\sigma(XX \to H)_{SM4} = \sigma(XX \to H)_{SM} \cdot \frac{\Gamma(H \to XX)_{SM4}}{\Gamma(H \to XX)_{SM}}$$

$$\mu_{obs}^{SM4} = \mu_{obs}^{SM} \cdot \frac{\sigma(XX \to H)_{SM} \cdot BR(H \to YY)_{SM}}{\sigma(XX \to H)_{SM4} \cdot BR(H \to YY)_{SM4}}$$

Results (See Publications)

- Pulls: $((\mu_{exp} - \mu_{fit})/\Delta\mu_{exp})$ quantify and highlight tensions in observed signal strengths.
- Pulls (Fig.3) indicate that the SM4 scenario is disfavoured when compared with the SM.
- Significance of tensions is calculated with Monte Carlo techniques using *my*Fitter [7].

Conclusion: SM4 excluded at 5.3σ.

Charged Higgs Analysis in ATLAS

- Fourth Generation not excluded in Two Higgs Doublet Model
- Recent LHC results consistent with (but not constraining to) a minimal SM Higgs sector.
- Two Higgs Doublet Model introduces a second Higgs doublet allowing two charged Higgs bosons; $H^{\pm}$.
- Dominant decay channel of heavy charged Higgs is $H^+ \to t\bar{b}$
- Boosted Top Taggers could give higher sensitivity to heavy charged Higgs decays.

Plan: Feasibility study of $H^+ \to t\bar{b}$ searches using TopTagging methods.

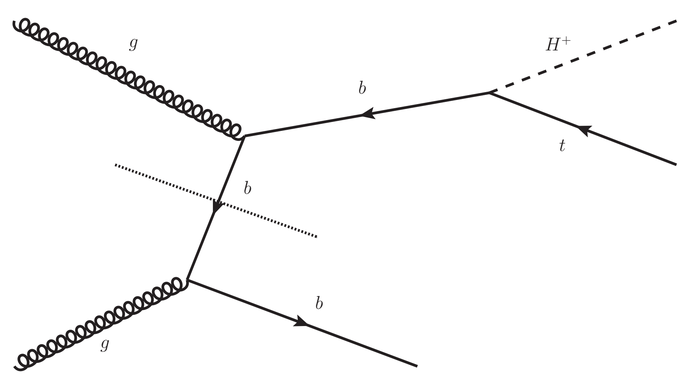

Fig.3 Feynmann diagram(s) of dominant production method(s) of a heavy H^+ at the LHC.

Profit from the GK

- Attended three GK Block Courses
- Shared knowledge and expertise amongst phd students
- Travel Allowance facilitated research stays.
- Second supervisor

References

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2) ATLAS Collaboration. Phys. Lett. B 716 (2012)
3) CMS Collaboration. Phys. Lett. B 716 (2012)
4) X. Raun and Z. Zhang. arXiv:1105.1634
5) A. Djouadi and A. Lenz. Phys.Lett. B 715 (2012)
6) A. Djouadi *et al.* HDECAY. Comput.Phys.Commun. 108 (1998)
7) M. Wiebusch. *my*Fitter. arXiv:1207.1446

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Publications

- Joint analysis of Higgs decays and electroweak precision observables in the Standard Model with a sequential fourth generation. $(*)$. Phys. Rev. D 86, 013011 (2012).
- Impact of a Higgs boson at a mass of 126 GeV on the standard model with three and four fermion generations. $(*)$. Phys. Rev. Lett. 109, 241802 (2012).

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