Eur. Phys. J. C (2010) 66: 119–126
DOI 10.1140/epjc/s10052-010-1238-1

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Experimental Physics

The fourth Standard Model family and the competition in Standard Model Higgs boson search at Tevatron and LHC

N. Becerici Schmidt[1,a], **S.A. Çetin**[2,b], **S. Iştin**[1,c], **S. Sultansoy**[3,4,d]

[1]Physics Department, Boğaziçi University, Istanbul, Turkey
[2]Physics Division, Doğuş University, Istanbul, Turkey
[3]Physics Division, TOBB University of Economics and Technology, Ankara, Turkey
[4]Institute of Physics, Academy of Sciences, Baku, Azerbaijan

Received: 22 August 2009 / Revised: 4 December 2009 / Published online: 14 January 2010

Abstract The impact of the fourth Standard Model family on Higgs boson search at Tevatron and LHC is reviewed. The enhancement due to a fourth SM family in the production of Higgs boson via gluon fusion already enables the Tevatron experiments to become sensitive to Higgs masses between 140 and 200 GeV and could increase this sensitivity up to about 300 GeV until the LHC is in shape. The same effect could enable the LHC running even at 7 TeV center of mass energy to scan Higgs masses between 200 and 300 GeV only with a few hundred pb^{-1} of integrated luminosity.

1 Introduction

Recent changes in the schedule of the LHC operation has resulted in an additional two years extension of Tevatron discovery challenges in the search for the Higgs boson (H), the fourth Standard Model family and so on (including SUSY). The fourth family is a natural consequence of the Standard Model (SM) basic principles and the actual patterns of the first three family fermion masses and mixings [1–3] (for reviews see [4–10]). We should once again note that, in contrast to the widespread opinion, electroweak precision data does not exclude the fourth family [11–14]. The fourth family matters were discussed in detail during the topical workshop held in September 2008 at CERN [15] (see [10] for resume of the workshop).

Concerning the Higgs boson, the existence of the fourth Standard Model family has a strong impact on the search strategies of Tevatron and LHC [13, 16–24] mainly due to the essential enhancement of the $gg \to H$ production channel. In this paper, SM-4 (SM-3) denotes Standard Model with 4 (3) families.

2 Fourth SM family effects on the Higgs boson

The crucial contribution of the new heavy quarks to the $gg \to H$ vertex via the triangular loop has been realized many years ago [25]. Additional quark loops introduced by the fourth SM family quarks strengthens the $gg \to H$ vertex by a factor of about 3, hence causing an enhancement in the cross section by about 9. The actual values depend on the mass of the Higgs boson and fourth SM family fermions. Figures 1–5 demonstrate this dependence for different scenarios. As seen from these figures, the choice of infinitely heavy fourth SM family quarks corresponds to the most conservative scenario which will be the assumption in the rest of this work.

The fourth SM family fermions will affect a number of other vertices [13, 16–24, 26, 27] along with $gg \to H$ resulting in new branching ratio values of the Higgs decays. Figure 6 illustrates Higgs decay branching ratios in SM-3 and Fig. 7 in SM-4 with infinitely heavy fourth family. In principle if the neutrino has Majorana nature, ν_4 could be essentially lighter than the other members of the fourth family and the Higgs boson could decay into the fourth family neutrinos; this scenario is considered in [26, 27].

3 The Tevatron perspective

$gg \to H \to WW \to \ell\ell\nu\nu$ (where ℓ denotes e or μ) is the most promising channel in SM-4 case. Figures 8 and 9 show recent results [28, 29] on this channel where we add the

[a] e-mail: neslihanbecerici@gmail.com
[b] e-mail: serkant.cetin@cern.ch
[c] e-mail: istins@gmail.com
[d] e-mail: ssultansoy@etu.edu.tr

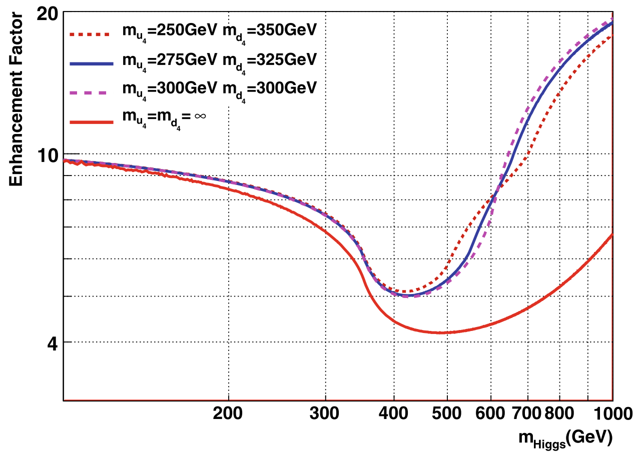

Fig. 1 Enhancement factors for the SM Higgs production via gluon fusion when the fourth SM family quark masses are around 300 GeV. Enhancement factors in the infinite mass limit are also shown for comparison

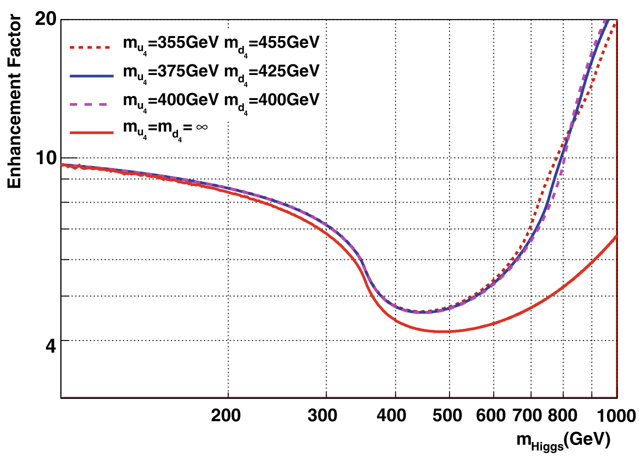

Fig. 2 The same as Fig. 1 but for fourth SM family quark masses around 400 GeV

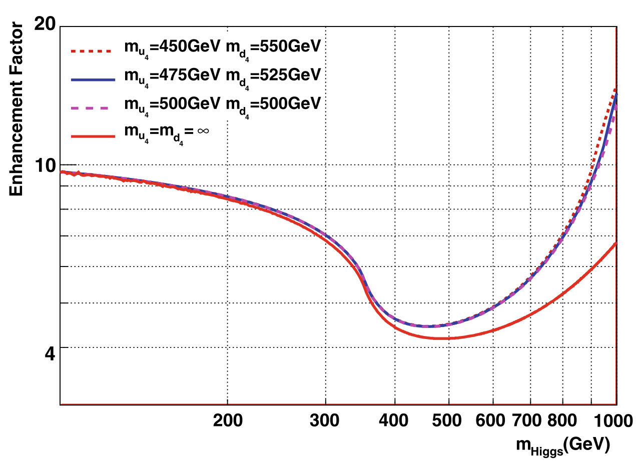

Fig. 3 The same as Fig. 1 but for fourth SM family quark masses around 500 GeV

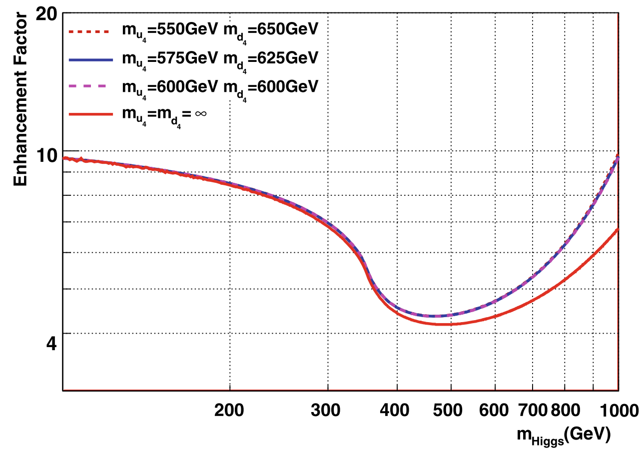

Fig. 4 The same as Fig. 1 but for fourth SM family quark masses around 600 GeV

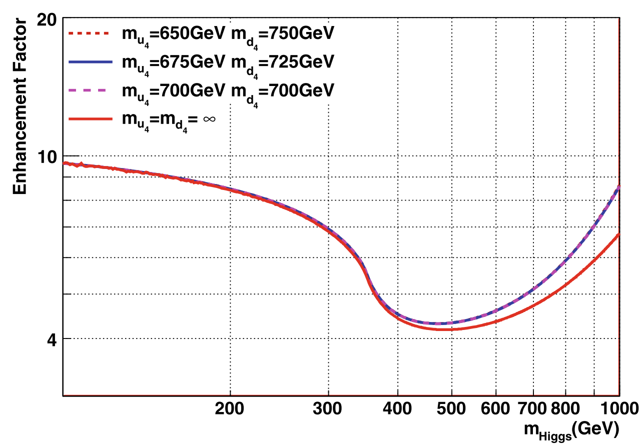

Fig. 5 The same as Fig. 1 but for fourth SM family quark masses around 700 GeV

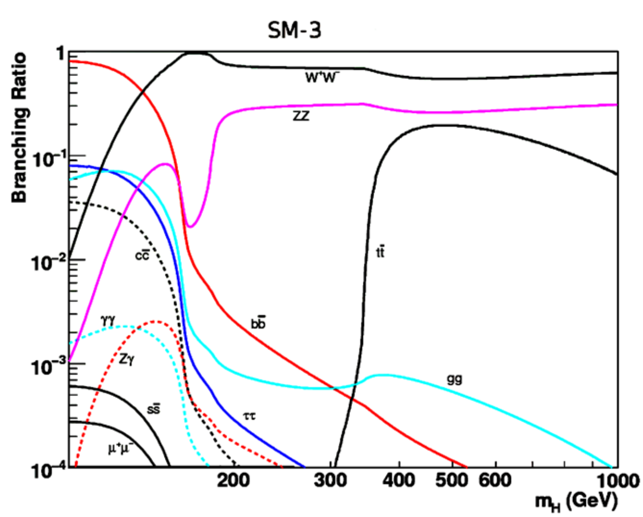

Fig. 6 Higgs branching ratios in SM-3

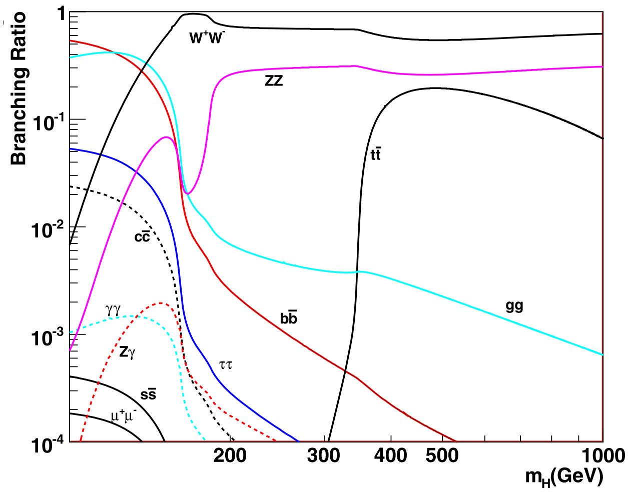

Fig. 7 Higgs branching ratios in SM-4 where fourth family fermions are assumed to be infinitely heavy

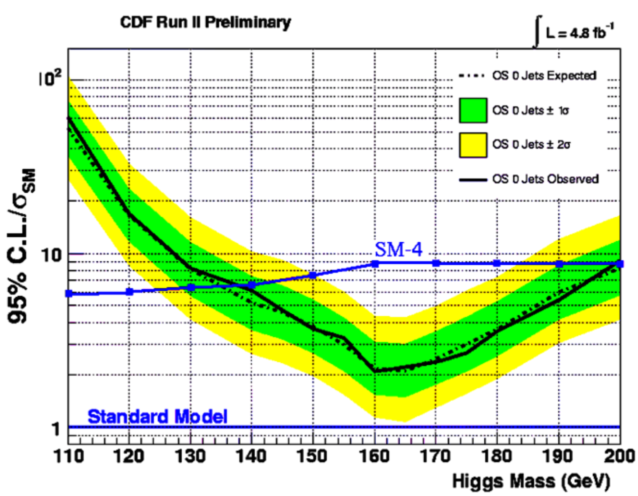

Fig. 8 Exclusion plot from CDF [28] experiment

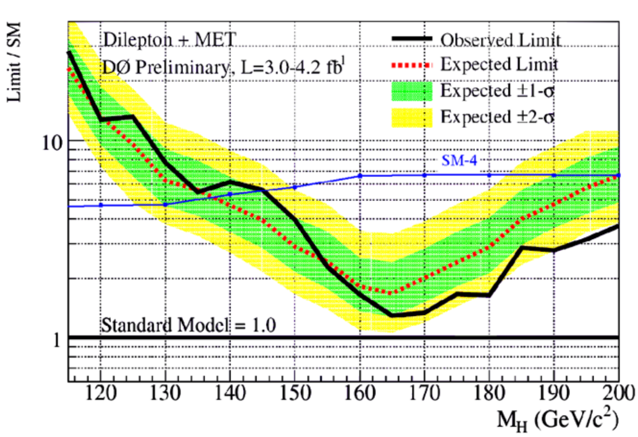

Fig. 9 Exclusion plot from D0 [29] experiment

curves corresponding to SM-4. It is clear that Higgs boson with mass 140–200 GeV is excluded if a fourth SM family exists while only the 160–170 GeV region is excluded in the SM-3 case. As seen from Fig. 9, D0 actually excludes even higher Higgs masses (presumably up to 240 GeV) in SM-4, however the analysis ends at 200 GeV.

Although the contribution from WH, ZH and VBF processes is about one fourth of the total production cross section, the zero jet final state results of CDF presented in Fig. 8 can practically be assumed to be composed of the $gg \to H \to WW$ channel. The DO analysis, however, does not eliminate the jet events, hence in Fig. 9 the SM-4 approximation is calculated accordingly.

Taking into account the fact that nature could prefer the SM-4 case, both D0 and CDF should extend the horizontal axis up to 300 GeV and, moreover, combine their results on the WW channel. Furthermore, combined analysis of all channels and both experiments done for SM-3 should be repeated for SM-4. Examples of proper approach are [30–39].

4 The LHC perspective

As an example for the LHC perspectives, we restrict ourselves to a detailed consideration of the *Golden Mode* at the ATLAS experiment [40, 41]. A similar analysis can be carried out for CMS as well. Moreover, a combined analysis of both LHC experiments could be useful.

The design center of mass energy of 14 TeV is the basic scenario, in addition, we also consider 10 TeV and 7 TeV cases for early phase operation. As input parameters, we use the most recent ATLAS simulation results for 14 TeV published in [41]. The analysis for 10 and 7 TeV cases is performed using the Higgs production cross section ratio given in Fig. 10a (calculations are performed using HIGLU [42]). The backgrounds considered in [41] are rescaled using the calculations performed in COMPHEP [43, 44] in a similar manner. It is recently shown in [45] that the theoretical uncertainties on the SM background via two weak boson production is around 5–20%. This uncertainty merely effects the significance results presented in this section.

4.1 $\sqrt{s} = 14$ TeV case

The ATLAS simulation results for the $gg \to H \to ZZ^{(*)} \to 4\ell$ signature are presented in column 2 and 4 of Table 1 where we add the SM-4 case in column 3. Using these foreseen reconstructed signal and background cross sections and the statistical significance (SS) formula [46]

$$\sqrt{2(s+b)\ln(1+s/b) - 2s}$$

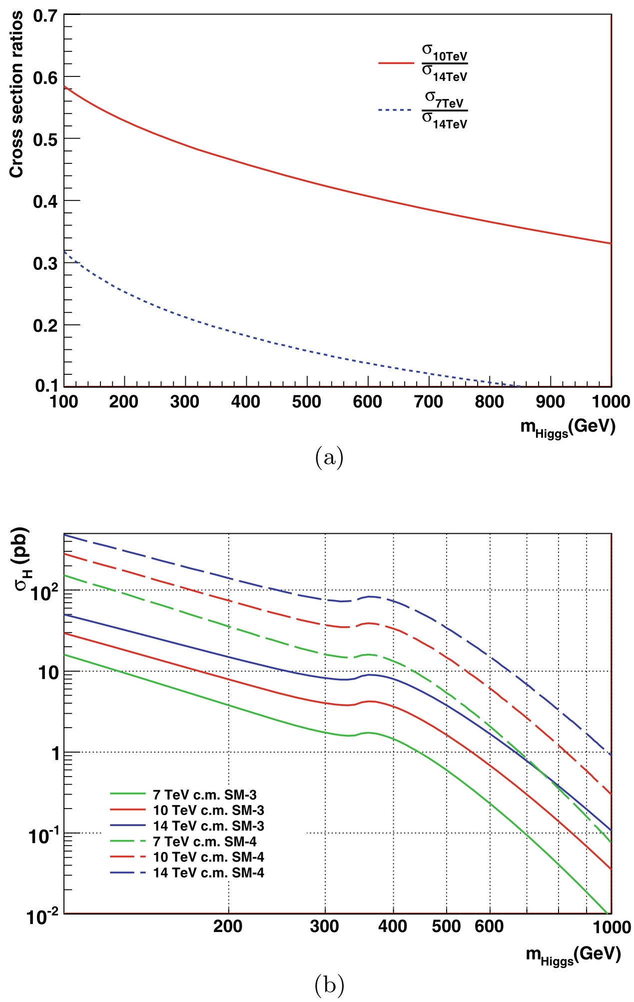

Fig. 10 (**a**) Ratios of the Higgs production cross sections via gluon fusion at 10 and 7 TeV center of mass energies to 14 TeV center of mass energy; (**b**) Higgs production cross section via gluon fusion at different center of mass energies for SM-3 and SM-4 cases

we calculate SS for different integrated luminosities (L_{int}) as shown in Table 2. The necessary L_{int} values to achieve 3σ and 5σ significance are also shown in Table 3 and plotted in Fig. 11.

It is clear that with only 500 pb^{-1} Higgs boson will be observed at 3σ level in the golden mode for the SM-4 case if the mass of the Higgs is between 130–500 GeV. An integrated luminosity of 100 pb^{-1} will be more than enough to scan 200–300 GeV Higgs at 3σ level. One should note that 130–200 GeV Higgs in SM-4 is already excluded by Tevatron.

4.2 $\sqrt{s} = 10$ TeV case

Table 4 shows expected cross sections after reconstruction of $gg \to H \to ZZ^{(*)} \to 4\ell$ channel and its backgrounds. Corresponding statistical significance for various integrated luminosities are shown in Table 5 and L_{int} needed for 3σ and 5σ significance are given in Table 6 and plotted in Fig. 12.

It is seen that 200–250 GeV Higgs will be covered by 100 pb^{-1} and an additional 100 pb^{-1} will increase the reach up to 350 GeV.

Table 1 Expected cross sections of the reconstructed $gg \to H \to ZZ^{(*)} \to 4\ell$ channel and its total background at 14 TeV

$gg \to H \to ZZ^{(*)} \to 4\ell$ at 14 TeV

m_H (GeV)	Cross section (fb)		
	Signal		Background
	SM-3	SM-4	SM-3 & SM-4
120	0.281	1.658	0.198
130	0.816	4.902	0.197
140	1.511	9.885	0.189
150	1.94	14.214	0.172
160	1.03	8.692	0.223
165	0.484	4.197	0.253
180	1.32	11.339	0.951
200	6.68	55.935	3.09
300	4.21	28.697	1.65
400	3.34	14.747	1.21
500	1.66	6.937	1.14
600	0.76	3.308	0.914

Table 2 Expected statistical significance for various integrated luminosity values at 14 TeV

$gg \to H \to ZZ^{(*)} \to 4\ell$ at 14 TeV

m_H (GeV)	0.3 fb^{-1}		1 fb^{-1}		3 fb^{-1}		10 fb^{-1}	
	SM-3	SM-4	SM-3	SM-4	SM-3	SM-4	SM-3	SM-4
120	0.29	1.22	0.53	2.23	0.92	3.87	1.68	7.07
130	0.71	2.65	1.29	4.83	2.24	8.37	4.10	15.29
140	1.15	4.25	2.10	7.77	3.65	13.45	6.66	24.56
150	1.42	5.45	2.59	9.95	4.48	17.23	8.19	31.45
160	0.82	3.81	1.50	6.95	2.60	12.05	4.76	21.99
165	0.42	2.27	0.78	4.14	1.35	7.17	2.46	13.08
180	0.62	3.47	1.14	6.34	1.98	10.98	3.62	20.06
200	1.65	8.42	3.02	15.37	5.23	26.63	9.55	48.61
300	1.39	5.98	2.53	10.92	4.39	18.92	8.02	34.55
400	1.27	3.98	2.31	7.27	4.01	12.59	7.33	22.98
500	0.71	2.31	1.30	4.21	2.26	7.30	4.13	13.32
600	0.39	1.15	0.71	2.51	1.23	4.35	2.25	7.94

Table 3 Integrated luminosity needed for 3σ and 5σ significance at 14 TeV

$gg \to H \to ZZ^{(*)} \to 4\ell$ at 14 TeV				
m_H (GeV)	Luminosity (fb^{-1})			
	for 3σ		for 5σ	
	SM-3 (14 TeV)	SM-4 (14 TeV)	SM-3 (14 TeV)	SM-4 (14 TeV)
120	31.65	1.80	87.92	5.00
130	5.34	0.38	14.83	1.06
140	2.02	0.15	5.62	0.41
150	1.34	0.01	3.72	0.25
160	3.97	0.19	11.03	0.52
165	14.80	0.52	41.11	1.46
180	6.85	0.22	19.03	0.62
200	0.98	0.04	2.73	0.10
300	1.39	0.07	3.88	0.21
400	1.67	0.17	4.65	0.47
500	5.25	0.51	14.60	1.41
600	17.78	1.42	49.40	3.97

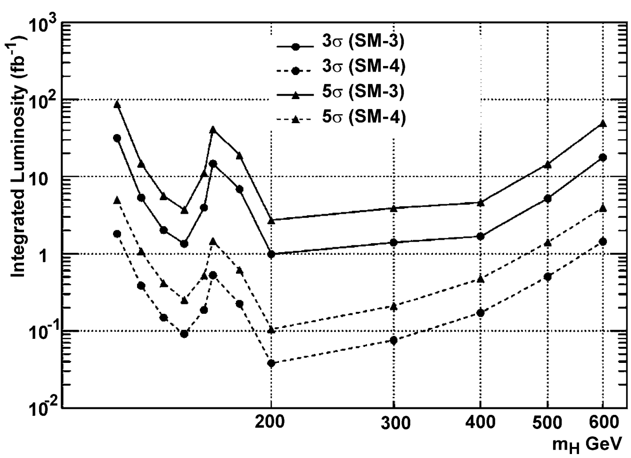

Fig. 11 Integrated luminosity needed at 14 TeV for 3σ and 5σ for $gg \to H \to ZZ^{(*)} \to 4\ell$ channel considering SM-3 and SM-4 cases

4.3 $\sqrt{s} = 7$ TeV case

Table 7 shows expected cross sections after reconstruction of $gg \to H \to ZZ^{(*)} \to 4\ell$ channel and its backgrounds. Corresponding statistical significance for various integrated luminosities are shown in Table 8 and L_{int} needed for 3σ and 5σ significance are given in Table 9 and plotted in Fig. 13. 200 pb^{-1} will scan 200–250 GeV Higgs whereas an additional 200 pb^{-1} will scan up to 300 GeV.

Table 4 Expected cross sections of the reconstructed $gg \to H \to ZZ^{(*)} \to 4\ell$ channel and its total background at 10 TeV

$gg \to H \to ZZ^{(*)} \to 4\ell$ at 10 TeV			
m_H (GeV)	Cross section (fb)		
	Signal		Background
	SM-3 (10 TeV)	SM-4 (10 TeV)	SM-3 & SM-4 (10 TeV)
120	0.160	0.948	0.100
130	0.460	2.763	0.100
140	0.844	5.521	0.096
150	1.07	7.840	0.087
160	0.56	4.726	0.113
165	0.263	2.280	0.128
180	0.71	6.099	0.484
200	3.52	29.475	1.572
300	2.05	13.974	0.839
400	1.53	6.755	0.615
500	0.71	2.967	0.580
600	0.31	1.349	0.465

Table 5 Expected statistical significance for various integrated luminosity values at 10 TeV

$gg \to H \to ZZ^{(*)} \to 4\ell$ at 10 TeV								
m_H (GeV)	0.1 fb^{-1}		0.2 fb^{-1}		0.3 fb^{-1}		0.5 fb^{-1}	
	SM-3	SM-4	SM-3	SM-4	SM-3	SM-4	SM-3	SM-4
120	0.13	0.55	0.19	0.78	0.23	0.95	0.30	1.23
130	0.31	1.17	0.45	1.65	0.55	2.02	0.71	2.61
140	0.51	1.86	0.72	2.63	0.88	3.22	1.14	4.16
150	0.62	2.36	0.88	3.34	1.07	4.09	1.39	5.28
160	0.35	1.64	0.50	2.32	0.62	2.84	0.80	3.67
165	0.18	0.98	0.26	1.38	0.32	1.69	0.42	2.18
180	0.27	1.49	0.38	2.10	0.47	2.57	0.61	3.32
200	0.70	3.55	0.99	5.02	1.21	6.15	1.57	7.94
300	0.55	2.39	0.78	3.37	0.95	4.13	1.23	5.34
400	0.48	1.52	0.68	2.15	0.83	2.63	1.07	3.39
500	0.25	0.83	0.36	1.17	0.44	1.43	0.57	1.85
600	0.13	0.47	0.18	0.67	0.23	0.81	0.29	1.05

4.4 300 GeV Higgs with 500 GeV fourth family

If the common Yukawa coupling constant is equal to SU(2) gauge coupling g_w then flavour democracy predicts the mass value about 500 GeV for fourth family quarks. It is interest-

Table 6 Integrated luminosity needed for 3σ and 5σ significance at 10 TeV

$gg \to H \to ZZ^{(*)} \to 4\ell$ at 10 TeV				
m_H (GeV)	Luminosity (fb^{-1})			
	for 3σ		for 5σ	
	SM-3 (10 TeV)	SM-4 (10 TeV)	SM-3 (10 TeV)	SM-4 (10 TeV)
120	50.88	2.97	141.35	8.26
130	8.91	0.65	24.76	1.83
140	3.46	0.26	9.61	0.72
150	2.33	0.16	6.49	0.45
160	7.02	0.33	19.50	0.93
165	25.91	0.94	72.00	2.61
180	12.22	0.40	33.95	1.13
200	1.82	0.07	5.07	0.20
300	2.95	0.16	8.21	0.44
400	3.91	0.38	10.87	1.08
500	14.01	1.30	38.91	3.62
600	52.39	4.01	145.53	11.15

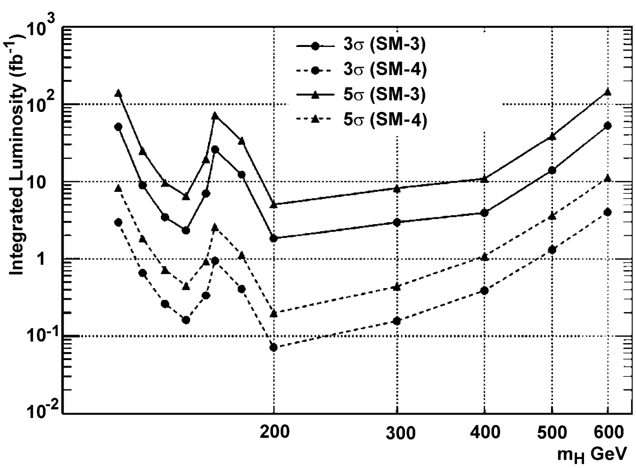

Fig. 12 Integrated luminosity needed at 10 TeV for 3σ and 5σ for $gg \to H \to ZZ^{(*)} \to 4\ell$ channel considering SM-3 and SM-4 cases

ing to note that this mass value also allows to explain several "anomalies" in B, B_s mixings and decays involving CP observables [47, 48]. If one considers the quartic coupling constant of the Higgs self interaction also to be equal to g_w, the Higgs boson mass is predicted to be around 300 GeV. In such a case the enhancement factor in $gg \to H$ production is 7 (Fig. 3) and the $H \to ZZ$ branching ratio is 0.3 (Fig. 7). The integrated luminosity to achieve 3σ and 5σ significance in such a situation at different center of mass energies are shown in Table 10.

Table 7 Expected cross sections of the reconstructed $gg \to H \to ZZ^{(*)} \to 4\ell$ channel and its total background at 7 TeV

$gg \to H \to ZZ^{(*)} \to 4\ell$ at 7 TeV			
m_H (GeV)	Cross section (fb)		
	Signal		Background
	SM-3	SM-4	SM-3 & SM-4
120	0.085	0.502	0.053
130	0.240	1.44	0.053
140	0.434	2.84	0.051
150	0.544	3.99	0.046
160	0.282	2.39	0.060
165	0.131	1.14	0.068
180	0.347	2.99	0.255
200	1.689	14.14	0.830
300	0.892	6.08	0.443
400	0.608	2.69	0.325
500	0.262	1.096	0.306
600	0.105	0.457	0.245

Table 8 Expected statistical significance for various integrated luminosity values at 7 TeV

$gg \to H \to ZZ^{(*)} \to 4\ell$ at 7 TeV								
m_H (GeV)	0.1 fb^{-1}		0.2 fb^{-1}		0.3 fb^{-1}		0.5 fb^{-1}	
	SM-3	SM-4	SM-3	SM-4	SM-3	SM-4	SM-3	SM-4
120	0.097	0.400	0.137	0.566	0.167	0.693	0.216	0.894
130	0.229	0.843	0.323	1.192	0.396	1.460	0.511	1.885
140	0.363	1.330	0.514	1.880	0.629	2.303	0.812	2.974
150	0.438	1.677	0.620	2.371	0.759	2.904	0.980	3.749
160	0.251	1.157	0.355	1.637	0.435	2.004	0.561	2.587
165	0.129	0.684	0.182	0.967	0.223	1.184	0.288	1.529
180	0.184	1.024	0.261	1.449	0.320	1.774	0.413	2.291
200	0.471	2.416	0.666	3.417	0.815	4.184	1.053	5.402
300	0.341	1.514	0.482	2.141	0.590	2.623	0.762	3.386
400	0.274	0.897	0.388	1.268	0.475	1.553	0.614	2.005
500	0.134	0.455	0.189	0.644	0.232	0.789	0.299	1.019
600	0.063	0.237	0.089	0.335	0.109	0.411	0.141	0.530

5 Conclusions

Assuming that nature prefers the SM-4 case, Fermilab already excludes Higgs masses up to 200 GeV. In contrast to SM-3, in SM-4 case electroweak precision data favors a heavier Higgs [13]. Hence, during the next couple of

Table 9 Integrated luminosity needed for 3σ and 5σ significance at 7 TeV

$gg \to H \to ZZ^{(*)} \to 4\ell$ at 7 TeV				
m_H (GeV)	Luminosity (fb^{-1})			
	for 3σ		for 5σ	
	SM-3	SM-4	SM-3	SM-4
120	96.4	5.62	268	15.6
130	17.2	1.27	47.8	3.52
140	6.82	0.51	18.9	1.41
150	4.68	0.32	13.0	0.89
160	14.3	0.67	39.7	1.87
165	54.0	1.92	150	5.35
180	26.4	0.86	73.4	2.38
200	4.06	0.15	11.3	0.43
300	7.75	0.39	21.5	1.09
400	11.9	1.12	33.2	3.11
500	50.3	4.34	140	12.1
600	227	16.0	632	44.4

Table 10 Integrated Luminosities (in fb^{-1}) needed to achieve 3 or 5 σ significance at different center of mass energies

Energy	L_{int} (fb^{-1}) for 3σ	L_{int} (fb^{-1}) for 5σ
14 TeV	0.07	0.21
10 TeV	0.16	0.44
7 TeV	0.39	1.09

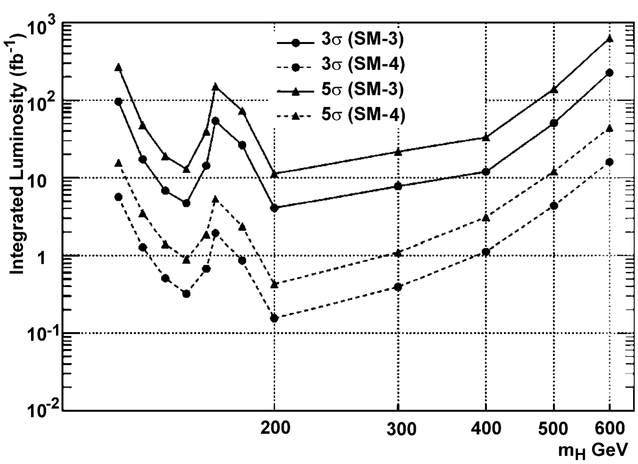

Fig. 13 Integrated luminosity needed at 7 TeV for 3σ and 5σ for $gg \to H \to ZZ^{(*)} \to 4\ell$ channel considering SM-3 and SM-4 cases

years we will experience tough competition between the two hadron colliders: running Tevatron and soon to run LHC. In our opinion, corresponding experiments at both machines should seriously consider SM-4 predictions.

Acknowledgements We are grateful to V.N. Şenoguz and G. Ünel for useful discussion and crucial remarks. This work is supported in part by the Turkish Atomic Energy Authority (TAEK).

References

1. H. Fritzsch, Light neutrinos, nonuniversality of leptonic weak interaction and a fourth massive generation. Phys. Lett. B **289**, 92 (1992). MPI-PH-92-42
2. A. Datta, Flavor democracy calls for the fourth generation. Pramana **40**, L503 (1993). hep-ph/9207248. PRINT-92-0285 (JADAVPUR), IC-92-164
3. A. Celikel, A.K. Ciftci, S. Sultansoy, A search for fourth SM family. Phys. Lett. B **342**, 257 (1995). AU-HEP-94-12
4. S. Sultansoy, Four ways to TeV scale. Turk. J. Phys. **22**, 575 (1998). AU-HEP-97-04
5. S. Sultansoy, Four remarks on physics at LHC. Invited talk given at the ATLAS week, Geneva, Switzerland. AU-HEP-97-05
6. P.H. Frampton, P.Q. Hung, M. Sher, Quarks and leptons beyond the third generation. Phys. Rep. **330**, 263 (2000). hep-ph/9903387. IFP-759-UNCA, WM-99-104
7. S. Sultansoy, Why the four SM families (2000). hep-ph/0004271. AU-HEP-00-04
8. S. Sultansoy, Flavor democracy in particle physics. AIP Conf. Proc. **899**, 49 (2007). hep-ph/0610279
9. S. Sultansoy, The naturalness of the fourth SM family (2009). arXiv:0905.2874 [hep-ph]
10. B. Holdom et al., Four statements about the fourth generation (2009). arXiv:0904.4698 [hep-ph]
11. H.-J. He, N. Polonsky, S. Su, Extra families, Higgs spectrum and oblique corrections. Phys. Rev. D **64**, 053004 (2001). arXiv:hep-ph/0102144. CALT-68-2313, MIT–CTP–3080, UT-HEP-01-018
12. V.A. Novikov et al., Extra generations and discrepancies of electroweak precision data. Phys. Lett. B **529**, 111 (2002). arXiv:hep-ph/0111028
13. G.D. Kribs et al., Four generations and Higgs physics. Phys. Rev. D **76**, 075016 (2007). arXiv:0706.3718 [hep-ph]. ANL-HEP-PR-07-39
14. V.E. Ozcan, S. Sultansoy, G. Unel, Possible discovery channel for new charged leptons at the LHC. J. Phys. G **36**, 095002 (2009). arXiv:0903.3177
15. CERN, Beyond the 3SM generation at the LHC era workshop, 04-05 September 2003. http://indico.cern.ch/conferenceDisplay.py?confId=33285
16. E. Arık et al., Enhancement of the Standard Model Higgs boson production crosssection with the fourth Standard Model family quarks (1998). ATLAS Internal Note ATL-PHYS-98-125
17. ATLAS Collaboration, ATLAS TDR, vol. 2, Chap. 18 (1999). CERN/LHCC/99-15
18. I.F. Ginzburg, I.P. Ivanov, A. Schiller, Search for fourth generation quarks and leptons at the Fermilab Tevatron and CERN Large Hadron Collider. Phys. Rev. D **60**, 095001 (1999). hep-ph/9802364. UL-NTZ-03-98
19. S. Sultansoy, The 'Golden mode' at the upgraded Tevatron? (2000). hep-ex/0010037
20. E. Arık et al., With four standard model families, the LHC could discover the Higgs boson with a few fb^{-1}. Eur. Phys. J. C **26**, 9 (2002). hep-ph/0109037. ATLAS Scientific Note SN-ATLAS-2001-005
21. O. Çakır, S. Sultansoy, The Fourth SM family enhancement to the golden mode at the upgraded Tevatron. Phys. Rev. D **65**, 013009 (2002). hep-ph/0106312

22. E. Arık et al., Consequences of the extra SM families on the Higgs boson production at Tevatron and CERN LHC. Phys. Rev. D **66**, 033003 (2002). hep-ph/0203257
23. E. Arık et al., Observability of the Higgs boson and extra SM families at the Tevatron. Acta Phys. Pol. B **37**, 2839 (2006). hep-ph/0502050
24. E. Arık, S.A. Çetin, S. Sultansoy, The impact of the fourth SM family on the Higgs observability at the LHC. Balk. Phys. Lett. **15**(4), 1 (2007). arXiv:0708.0241 [hep-ph]
25. V.D. Barger, R.J. Phillips, *Collider Physics* (Addison-Wesley, Reading, 1987)
26. S. Sultansoy, G. Ünel, 'Silver' mode for the heavy Higgs search in the presence of a fourth SM family. Turk. J. Phys. **31**, 295 (2007). arXiv:0707.3266 [hep-ph]
27. T. Çuhadar-Donszelmann et al., Fourth family neutrinos and the Higgs boson. J. High Energy Phys. **0810**, 074 (2008). arXiv:0806.4003 [hep-ph]
28. CDF Collaboration, CDF search for Higgs to WW^* production using a combined matrix element and neural network technique (2009). http://www-cdf.fnal.gov/physics/new/hdg/results/hwwmenn_090710/
29. D0 Collaboration, Search for Higgs boson production in dilepton plus missing transverse energy final states with 3.0–4.2 fb^{-1} of pp collisions at $ps = 1{:}96$ TeV (2009). D0 Note 5871-CONF
30. W.M. Yao for the CDF and D0 Collaborations, Neutral Higgs boson search at Tevatron, in *Beijing ICHEP 2004*, vol. 2, 1228 (2004). hep-ex/0411053. FERMILAB-CONF-04-307-E
31. V. Buescher, Searches for Higgs bosons and supersymmetry at the Tevatron, in *Tsukuba 2004, Supersymmetry and unification of fundamental interactions*, pp. 17–32 (2004). hep-ex/0411063. FERMILAB-CONF-04-356-E
32. W.M. Yao, Top quark and Higgs physics at the Tevatron (2004). LBNL-56547
33. V. Buescher, K. Jakobs, Higgs boson searches at hadron colliders. Int. J. Mod. Phys. A **20**, 2523 (2005). hep-ph/0504099
34. V.M. Abazov et al., by the D0 Collaboration, Search for the Higgs boson in $H \to WW^{(*)}$ decays in p anti-p collisions at $\sqrt{s} = 1.96$ TeV. Phys. Rev. Lett. **96**, 011801 (2006). hep-ex/0508054. FERMILAB-PUB-05-377-E
35. A. Abulencia et al., by the CDF Collaboration, Search for a neutral Higgs boson decaying to a W boson pair in p anti-p collisions at $\sqrt{s} = 1.96$ TeV. Phys. Rev. Lett. **97**, 081802 (2006). hep-ex/0605124. FERMILAB-PUB-06-154-E
36. A. Soha for the CDF Collaboration, New phenomena searches at CDF (2006). FERMILAB-CONF-06-157-E
37. A. Meyer, Searches for new phenomena at the Tevatron and at HERA (2006). hep-ex/0610001. FERMILAB-CONF-06-404-E
38. G. Bernardi for the D0 Collaboration, Searches and Prospects for the Standard Model Higgs boson at the Tevatron (2006). hep-ex/0612046. ICHEP 06
39. T. Nunnemann for the D0 and CDF Collaborations, Searches for the Higgs boson and supersymmetry at the Tevatron. Frascati Phys. Ser. **44**, 475 (2007). arXiv:0710.0248 [hep-ex]
40. ATLAS Collaboration, The ATLAS experiment at the CERN large hadron collider. J. Instrum. **3**, S08003 (1999)
41. ATLAS Collaboration, Expected performance of the ATLAS experiment—detector, trigger and physics (2009). arXiv:0901.0512 [hep-ex]
42. M. Spira, HIGLU (1995). hep-ph/9510347. DESY-T-95-05
43. CompHEP Collaboration, Automatic computations from Lagrangians to events. Nucl. Instrum. Meth. A **534**, 250 (2004). arXiv:hep-ph/0403113
44. A. Pukhov et al., CompHEP—a package for evaluation of Feynman diagrams and integration over multi-particle phase space. INP MSU report 98-41/542 (1998). arXiv:hep-ph/9908288
45. J.M. Campbell et al., Normalizing weak boson pair production at the large hadron collider (2009). arXiv:0906.2500
46. CMS Collaboration 2007, J. Phys. G: Nucl. Part. Phys. **34**, 995 (2007). CMS Technical Design Report, Volume II: Physics Performance
47. A. Soni et al., The fourth family: A natural explanation for the observed pattern of anomalies in B-CP asymmetries (2008). arXiv:0807.1971
48. A. Soni, The '4th generation', B-CP anomalies and the LHC (2009). arXiv:0907.2057