The Fourth SM Family at the CLIC

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1. ***Why the Four SM Familiies***

2. ***The Fourth SM Family and the Higgs Boson***

3. ***The Fourth SM Family at hadron colliders***

4. ***The Fourth SM Family at the CLIC***

1. Why The Four SM Families
(two approaches)

First approach – Why not ?

N ≥ 3 from LEP data

N < 9 from asymptotic freedom

“A 4th generation of ordinary fermions is excluded to 99.999% CL on the basis of S parameter alone”

PDG 2006

This conclusion is wrong.

Graham Kribs, CERN Aug 2007

Precision EW data:

2000: the 4th family excluded at 99% CL

***2002: 3 and 4 families have the same status 5 and even 6 families are allowed if* mN ≈ 50 GeV**

2004: 6`th SM family is excluded at 3σ ...

2006: ???

H.J. Su, N. Polonsky and S. Su, Phys. Rev. D 64 (2001) 117701
V.A. Novikov, L.B. Okun, A.N. Rosanov and M.I. Vysotsky, Phys. Lett. B 529 (2002) 111
....

S. Sultansoy, CERN May 16, 2006

Second Approach –

Flavor Democracy favors the Fourth SM Family

Periodic Table of the Elementary* Particles

family	ν	l	u	d
1	< 3 eV	510.99892(4) keV	1.5 to 4 MeV	4 to 8 MeV
2	< 190 keV	105.658369(9) MeV	1.15 to 1.35 GeV	80 to 130 MeV
3	< 18.2 MeV	1.77699(+29-26) GeV	174.3(5.1) GeV	4.1 to 4.4 GeV
4	> 45 GeV	> 100 GeV	> 260 GeV	> 130 GeV

Also, $m_\gamma = 0$ (< $6 \cdot 10^{-17}$ eV) $m_g = 0$ (< few MeV)

$m_W = 80.425(38)$ GeV $m_Z = 91.1876(21)$ GeV

$m_H > 114.4$ GeV

Scale: $\eta \approx 247$ GeV

* *Elementary in the SM framework. At least one more level (preons) should exist.*

Yukawa couplings

In standard approach: $m_f = g_f\eta$ ($\eta \approx 245$ GeV) $g_t / g_e = 0\,(m_t / m_e) \approx 340000$

Moreover, $g_t / g_{\nu e} \approx 1.75\cdot10^{11}$ (if $m_{\nu e} = 1$ eV) compare with $m_{GUT}/m_W \sim 10^{13}$

However, see-saw mechanism …

For same type fermions: $g_t / g_u \approx 35000\div175000$, $g_b / g_d \approx 300\div1500$,

$g_\tau / g_e \approx 3500$

Within third family: $g_t / g_b \approx 40$, $g_t / g_\tau \approx 100$, $g_t / g_{\nu\tau} > 10000$

et cetera **Therefore, 3 family case is unnatural**

Hierarchy: $m_u \ll m_c \ll m_t$ $m_d \ll m_s \ll m_b$ $m_e \ll m_\mu \ll m_\tau$

Why the four SM families (S. Sultansoy, hep-ph/0004271)

Today, the mass and mixing patterns of the fundamental fermions are the most mysterious aspects of the particle physics. Even the number of fermion generations is not fixed by the Standard Model **(N ≥ 3 from LEP, N ≤ 8 from Asymptotic Freedom)**.

The statement of the Flavor Democracy (or, in other words, the Democratic Mass Matrix approach)

H. Harari, H. Haut and J. Weyers, Phys. Lett. B 78 (1978) 459;

H. Fritzch, Nucl. Phys. B 155 (1979) 189; B 184 (1987) 391;

P. Kaus and S. Meshkov, Mod. Phys. Lett. A 3 (1988) 1251;

H. Fritzch and J. Plankl, Phys. Lett. B 237 (1990) 451.

which is quite natural in the SM framework, may be considered as the interesting step in true direction.

It is intriguing, that **Flavor Democracy favors the existence of the fourth SM family**

A. Datta, Pramana 40 (1993) L503.

A. Celikel, A.K. Ciftci and S. Sultansoy, Phys. Lett. B 342 (1995) 257.

Moreover, Democratic Mass Matrix approach provide, in principle the possibility to obtain the small masses for the first three neutrino species without see-saw mechanism

J. L. Silva-Marcos, Phys Rev D 59 (1999) 091301

The fourth family quarks, if exist, will be copiously produced at the LHC.

ATLAS Detector and Physics Performance TDR, CERN/LHCC/99-15 (1999), p. 663-

Then, the fourth family leads to an essential increase of the Higgs boson production cross section via gluon fusion at hadron colliders and this effect may be observed soon at the Tevatron.

Flavor Democracy and the Standard Model

It is useful to consider three different bases:

- Standard Model basis $\{f^0\}$,
- Mass basis $\{f^m\}$ and
- Weak basis $\{f^w\}$.

According to the three family SM, before the spontaneous symmetry breaking quarks are grouped into the following SU(2)×U(1) multiplets:

$$\begin{pmatrix} u_L^0 \\ d_L^0 \end{pmatrix}, u_R^0, d_R^0; \quad \begin{pmatrix} c_L^0 \\ s_L^0 \end{pmatrix}, c_R^0, d_R^0; \quad \begin{pmatrix} t_L^0 \\ b_{Ll}^0 \end{pmatrix}, t_R^0, b_R^0.$$

In **one family** case all bases are equal and, for example, d-quark mass is obtained due to Yukawa interaction

$$L_Y^{(d)} = a_d \left(\bar{u}_L \ \bar{d}_L \right) \begin{pmatrix} \varphi^+ \\ \varphi^0 \end{pmatrix} d_R + h.c. \ \Rightarrow \ L_m^{(d)} = m_d \bar{d} d$$

where $m_d = a_d \eta/\sqrt{2}$, $\eta = \langle\varphi^0\rangle \cong 247$ GeV. In the same manner $m_u = a_u \eta/\sqrt{2}$, $m_e = a_e \eta/\sqrt{2}$ and $m_{\nu e} = a_{\nu e} \eta/\sqrt{2}$ (if neutrino is Dirac particle).

In ***n* family** case

$$L_Y^{(d)} = \sum_{i,j=1}^{n} a_{ij}^d \left(\bar{u}_{Li}^0 \ \bar{d}_{Li}^0 \right) \begin{pmatrix} \varphi^+ \\ \varphi^0 \end{pmatrix} d_{Rj}^0 + h.c. = \sum_{i,j=1}^{n} m_{ij}^d \bar{d}_i^0 d_j^0, \ \ m_{ij}^d = a_{ij}^d \eta/\sqrt{2}$$

where d_1^0 denotes d^0, d_2^0 denotes s^0 etc.

Flavor Democracy assumptions

Before the spontaneous symmetry breaking all quarks are massless and there are no differences between d^0, s^0 and b^0. In other words fermions with the same quantum numbers are indistinguishable. This leads us to the ***first assumption***, namely, **Yukawa couplings are equal within each type of fermions**:

$$a_{ij}^{d} \cong a^{d}, \quad a_{ij}^{u} \cong a^{u}, \quad a_{ij}^{l} \cong a^{l}, \quad a_{ij}^{\nu} \cong a^{\nu}.$$

The first assumption result in *n-1* massless particles and one massive particle with $m = n \cdot a^F \cdot \eta / \sqrt{2}$ (F = u, d, l, ν) *for each type of the SM fermions.*

Because there is only one Higgs doublet which gives Dirac masses to all four types of fermions (up quarks, down quarks, charged leptons and neutrinos), it seems natural to make the ***second assumption***, namely, **Yukawa constants for different types of fermions should be nearly equal**:

$$a^d \approx a^u \approx a^l \approx a^\nu \approx a$$

.

Taking into account the mass values for the third generation

$$m_{\nu_\tau} << m_\tau < m_b << m_t$$

the second assumption leads to the statement that ***according to the flavor democracy the fourth SM family should exist.***

Above arguments, in terms of the mass matrix, mean

$$M^0 = a\eta/\text{v}2 \begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{pmatrix} \Rightarrow M^m = 4a\eta/\text{v}2 \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Now, let us make the ***third assumption***, namely, **$a/\sqrt{2}$ is between $e = g_w \sin\theta_W$ and $g_z = g_w/\cos\theta_W$**. Therefore, the fourth family fermions are almost degenerate, in good agreement with experimental value $\rho = 0.9998 \pm 0.0008$, and their common mass lies between **320 GeV and 730 GeV**. The last value is close to the upper limit on heavy quark masses, $m_Q \leq 700$ GeV, which follows from partial-wave unitarity at high energies

M.S. Chanowitz, M.A. Furlan and I. Hinchliffe, Nucl. Phys. B 153 (1979) 402

It is interesting that with value of $a/\sqrt{2} \approx g_w$ flavor democracy predicts

$$m_4 \approx 8m_W \approx 640 \text{ GeV}.$$

The masses of the first three family fermions, as well as an observable interfamily mixings, are generated due to the small deviations from the full flavor democracy

A. Datta and S. Rayachaudhiri, Phys. Rev. D 49 (1994) 4762.
S. Atag et al., Phys. Rev. D 54 (1996) 5745.
A.K. Ciftci, R. Ciftci and S. Sultansoy, Phys. Rev. D 72 (2005) 053006.

Last parameterization, which gives correct values for fundamental fermion masses, at the same time, **predicts quark and lepton CKM matrices in good agreement with experimental data.**

Arguments against the Fifth SM Family

The **first argument** disfavoring the fifth SM family is the large value of $m_t \approx 175$ GeV. Indeed, partial-wave unitarity leads to $m_Q \leq 700$ GeV $\approx 4\, m_t$ and in general we expect that $m_t << m_4 << m_5$.

Second argument: neutrino counting at LEP results in fact that there are only three "light" ($2m_\nu < m_Z$) non-sterile neutrinos, whereas in the case of five SM families four "light" neutrinos are expected.

Concerning the BSM Physics, Flavor Democracy:

- **Favors the RS-LSP scenario**
- **Allows relatively “light” isosinglet quarks (E6 predicted)**
- **…**

For details see

S.Sultansoy **“Flavor Democracy in Particle Physics”**

e-Print: **hep-ph/0610279; AIP Conf. Proc. 899, 49-52 (2007)**

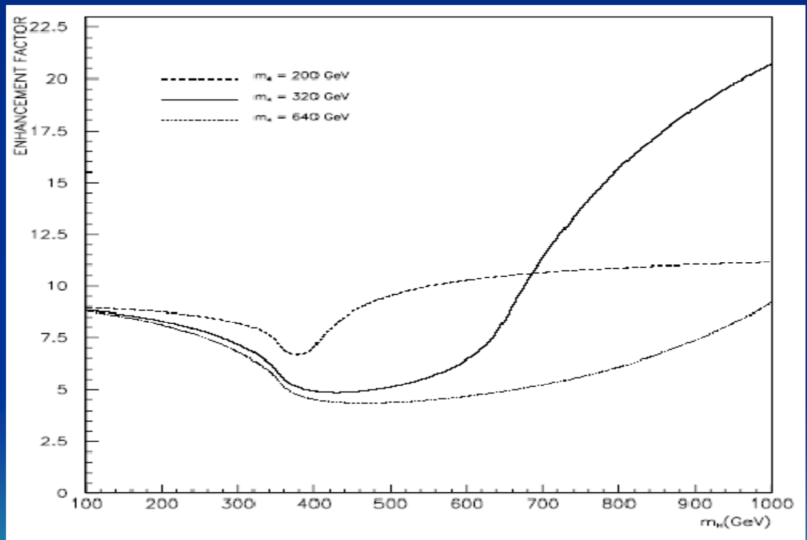
and refferencies therein

2. The Fourth SM Family and the Higgs Boson

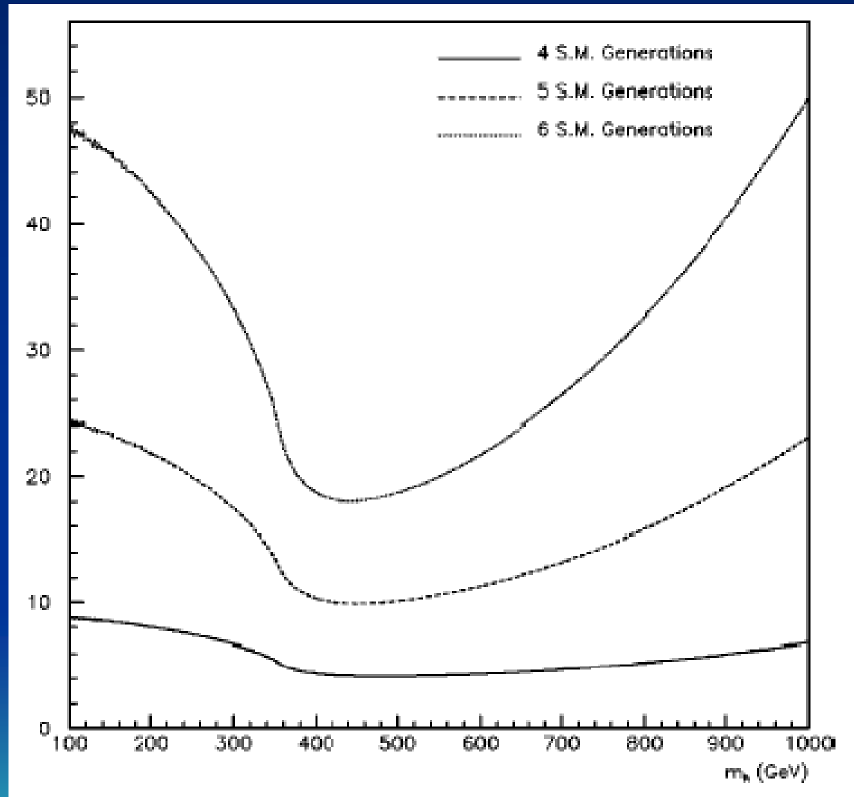
gg → H enhancement factor as a function of Higgs mass:

four SM family case with m_4 = 200; 320 and 640 GeV (upper, mid and lower curves, respectively)

4; 5 and 6 SM families with infinite masses (lower, mid and upper curves)

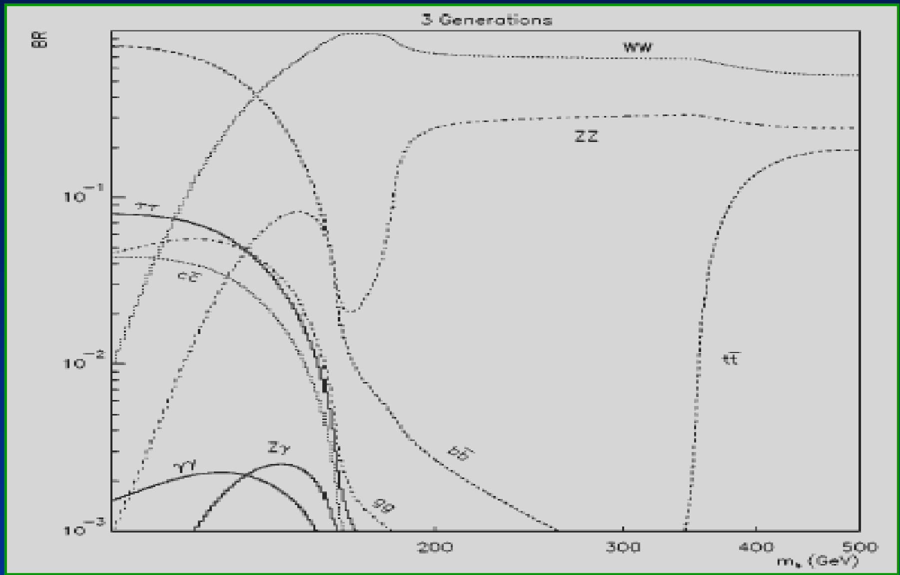


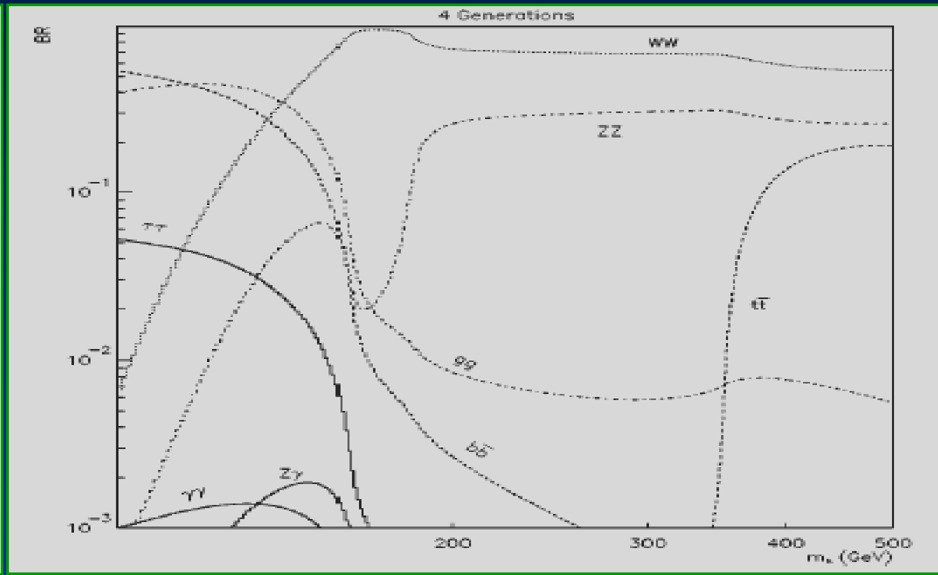
E. Arik et al., Eur Phys J C 26 (2002) 9

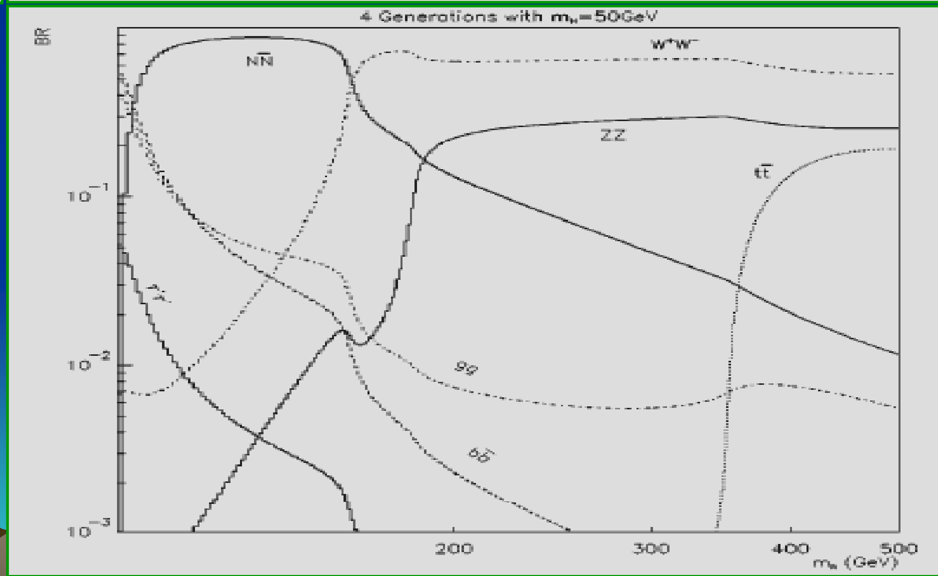


E. Arik et al., Phys Rev D 66 (2002) 033003

Higgs decay branching ratios







E. Arık, O. Çakır, S. A. Çetin, S. Sultansoy, Phys. Rev. D 66, 033003 (2002).

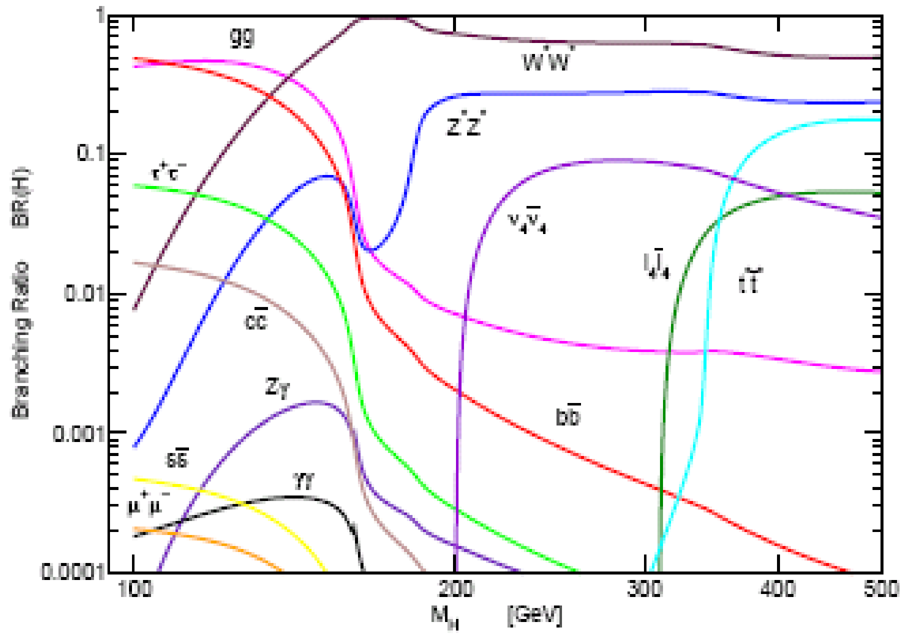


FIG. 3: Branching ratio of the Higgs with fourth–generation effects assuming $m_\nu = 100$ GeV and $m_\ell = 155$ GeV. The loop effects to $H \to gg$ and $H \to \gamma\gamma$ are largely insensitive to the fourth–generation quark masses. For the fourth–generation masses we follow the reference point (b).

Four generations and Higgs physics.
Graham D. Kribs (Oregon U.) , Tilman Plehn (Edinburgh U.) , Michael Spannowsky (ASC, Munich & Munich U.) , Tim M.P. Tait (Argonne) . ANL-HEP-PR-07-39, Jun 2007. 11pp.
e-Print: **arXiv:0706.3718** [hep-ph]

'Silver' mode

S. Sultansoy and G. Ünel e-Print: **arXiv:0707.3266** [hep-ph] Aug 2007

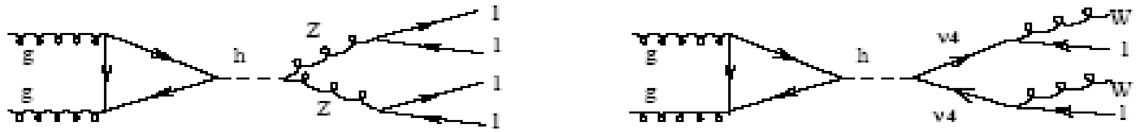


Figure 1: The "golden" (left) and the "silver" (right) modes for heavy Higgs boson discovery.

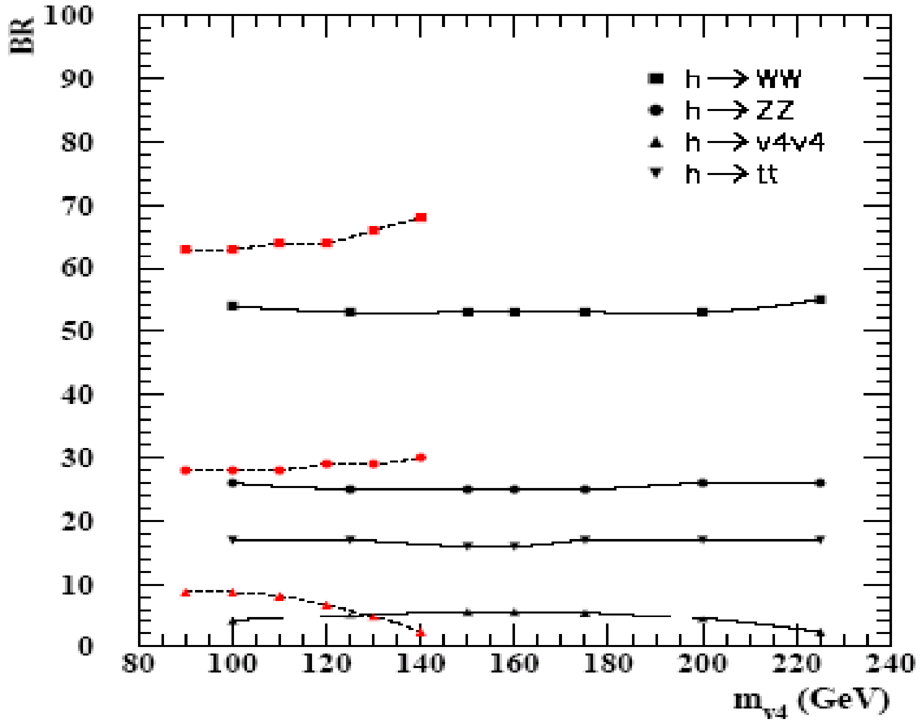


Figure 2: The heavy Higgs branching ratios as a function of the heavy neutrino mass for two example m_h values 300 GeV (dashed lines) and 500 GeV (solid lines)

3. The Fourth SM Family at hadron colliders

3.1. The fourth SM family manifestations at the upgraded Tevatron:

a) Significant enhancement (~8 times) of the Higgs boson production cross section via gluon fusion

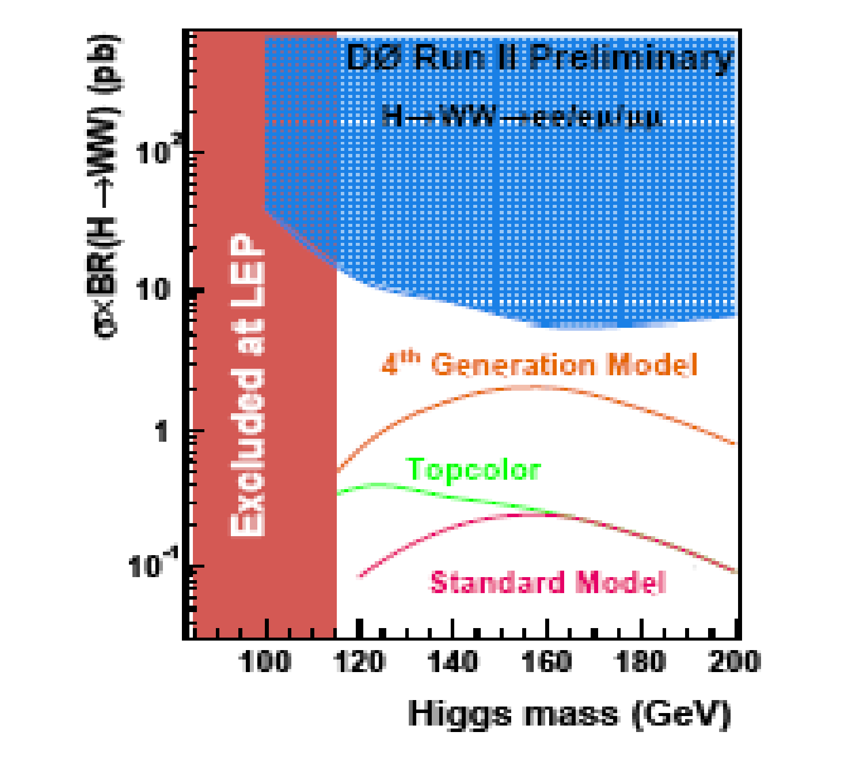
b) Pair production of the fourth family quarks (if m_{d4} and/or m_{u4} < 350 GeV)

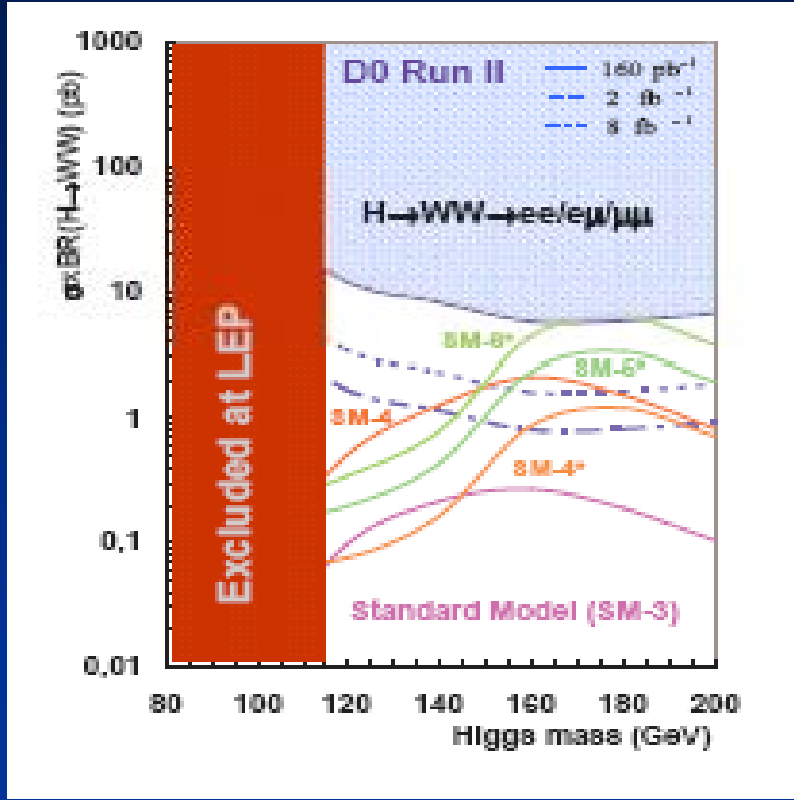
c) Single resonant production of fourth family quarks via the process

$qg \rightarrow q_4$ *(if anomalous coupling has sufficient strength)*

d) Pair production of the fourth family neutrinos (via Z and/or H)

Tevatron 2004





DØ presentations, for example,

A. Kharchilava, hep-ex/0407010

W.-M. Yao, hep-ex/0411053

V. Buscher, hep-ex/0411063

E. Arik et al., hep-ex/0411053

* means extra SM families with $m_N \approx 50$ GeV

Tevatron 2005 -2006

PRL 96, 011801 (2006) PHYSICAL RE

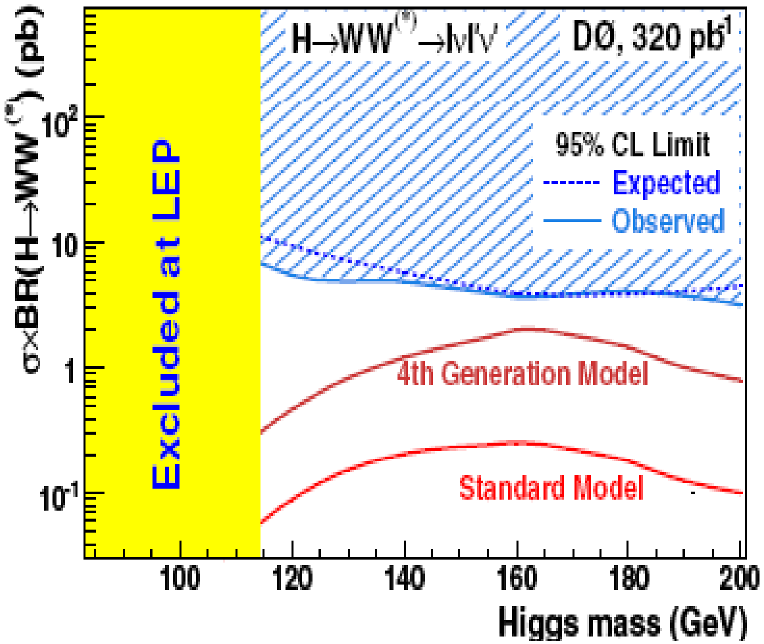
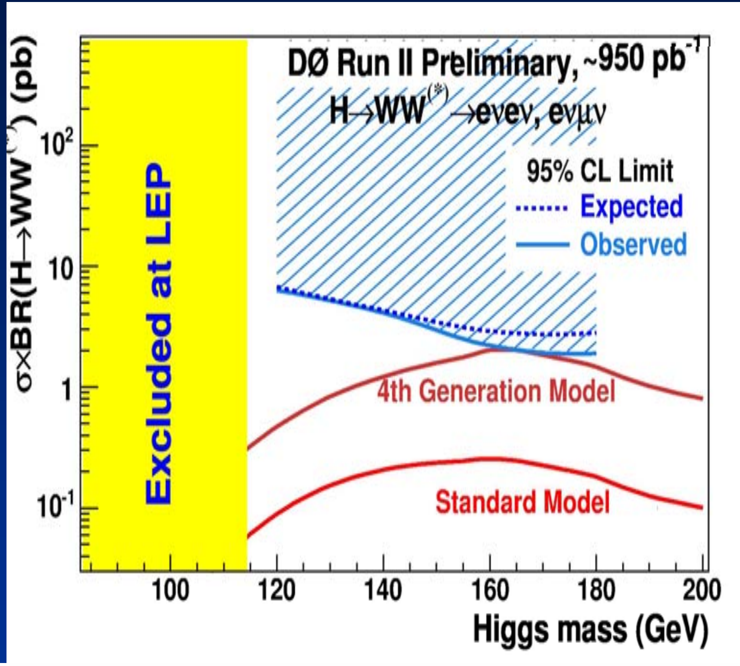
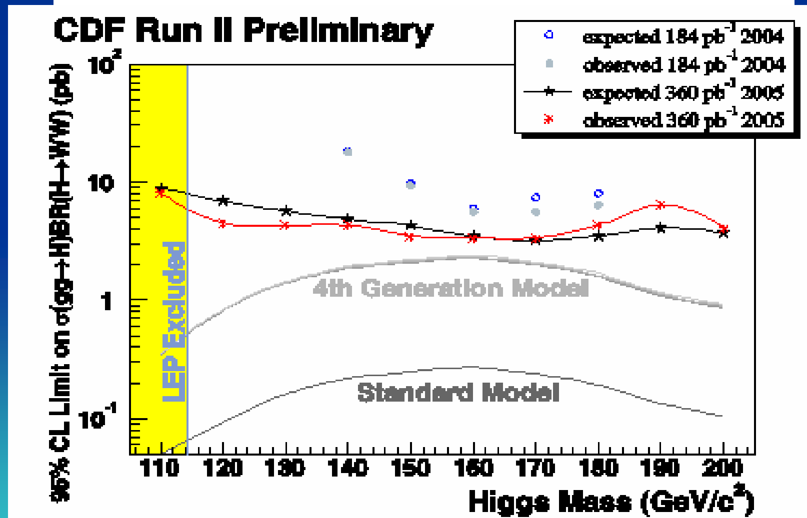


FIG. 2 (color online). Expected and observed upper limits on the cross section times branching ratio $\sigma \times \mathrm{BR}(H \to WW^{(*)})$ at the 95% C.L. together with expectations from standard model Higgs boson production and an alternative model. The LEP limit on the standard model Higgs boson production is taken from [1] and the 4th generation model prediction is described in [6].





Accessible mass range of the Higgs boson at the Tevatron

L_{int}	$2\ fb^{-1}$	$8\ fb^{-1}$
SM-4	$150\ GeV < m_H < 180\ GeV$	$140\ GeV < m_H < 200\ GeV$
SM-5	$135\ GeV < m_H$	$125\ GeV < m_H$
SM-4*	---	$160\ GeV < m_H < 195\ GeV$
SM-5*	$155\ GeV < m_H$	$150\ GeV < m_H$
SM-6*	$150\ GeV < m_H$	$145\ GeV < m_H$

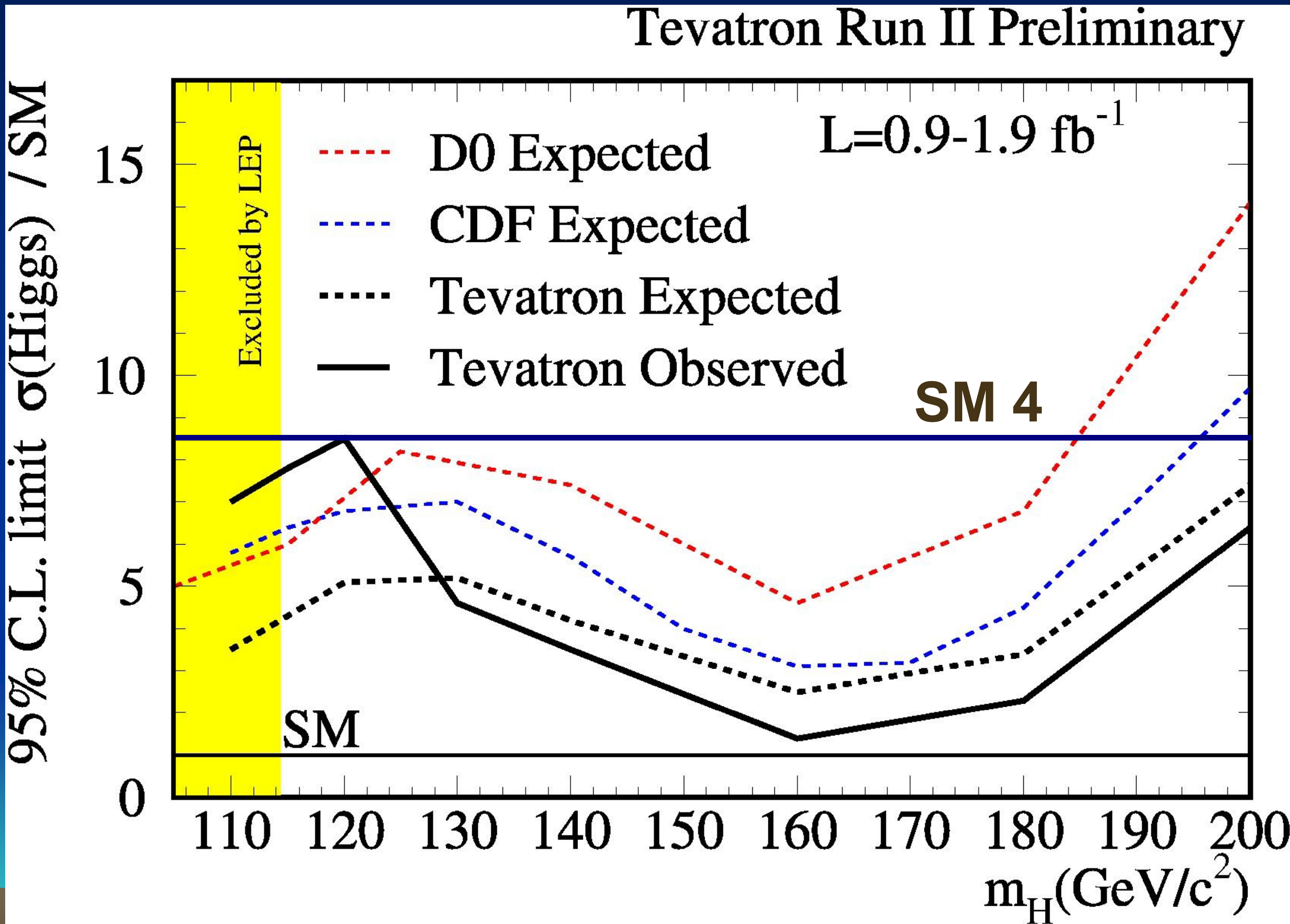
Another opportunity to observe the fourth SM family quarks at the Tevatron is their anomalous production via qg-fusion if anomalous coupling has sufficient strength

E. Arik. O. Cakir and S. Sultansoy, Phys Rev D 67 (2003) 035002

Eur Phys Lett 62 (2003) 332

Eur Phys J C 39 (2005) 499

Wrong approach



Correct approach

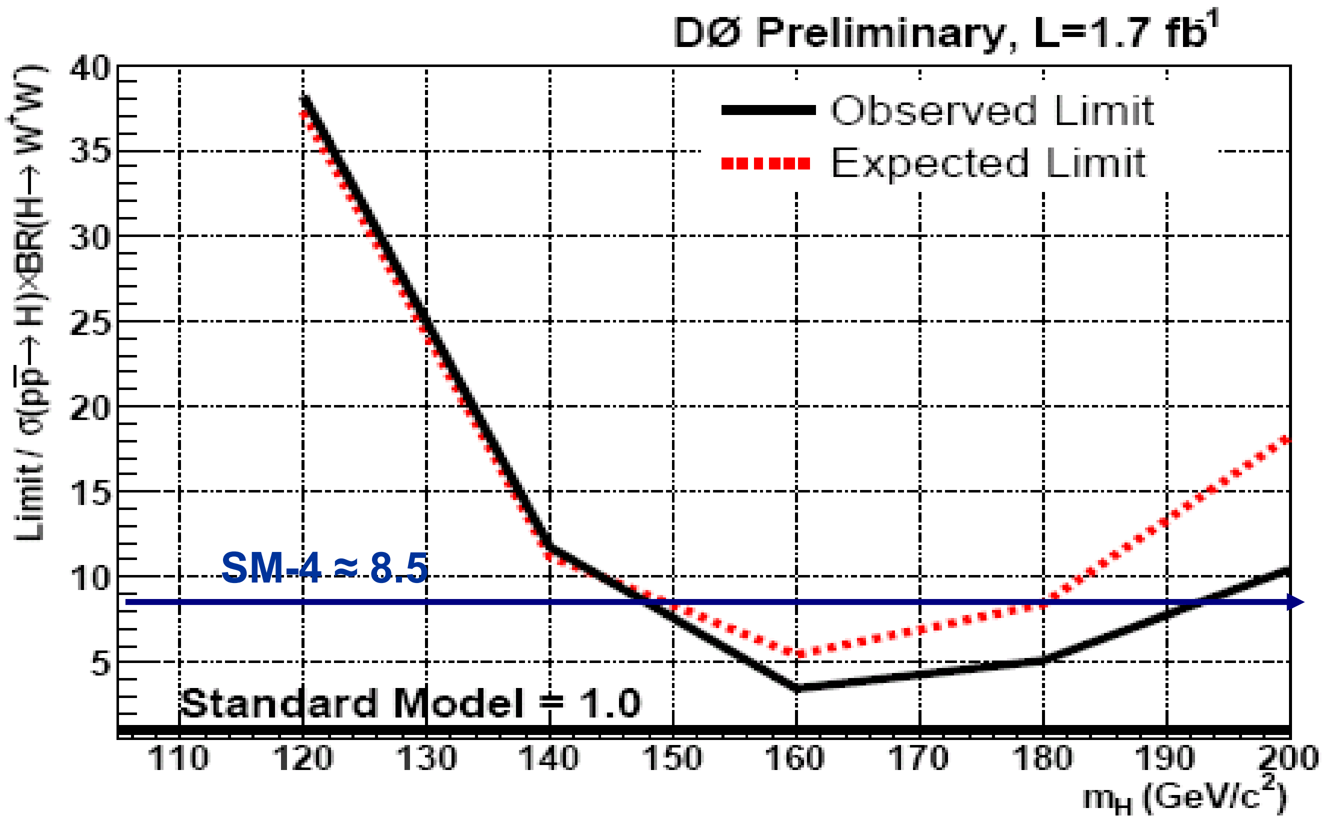


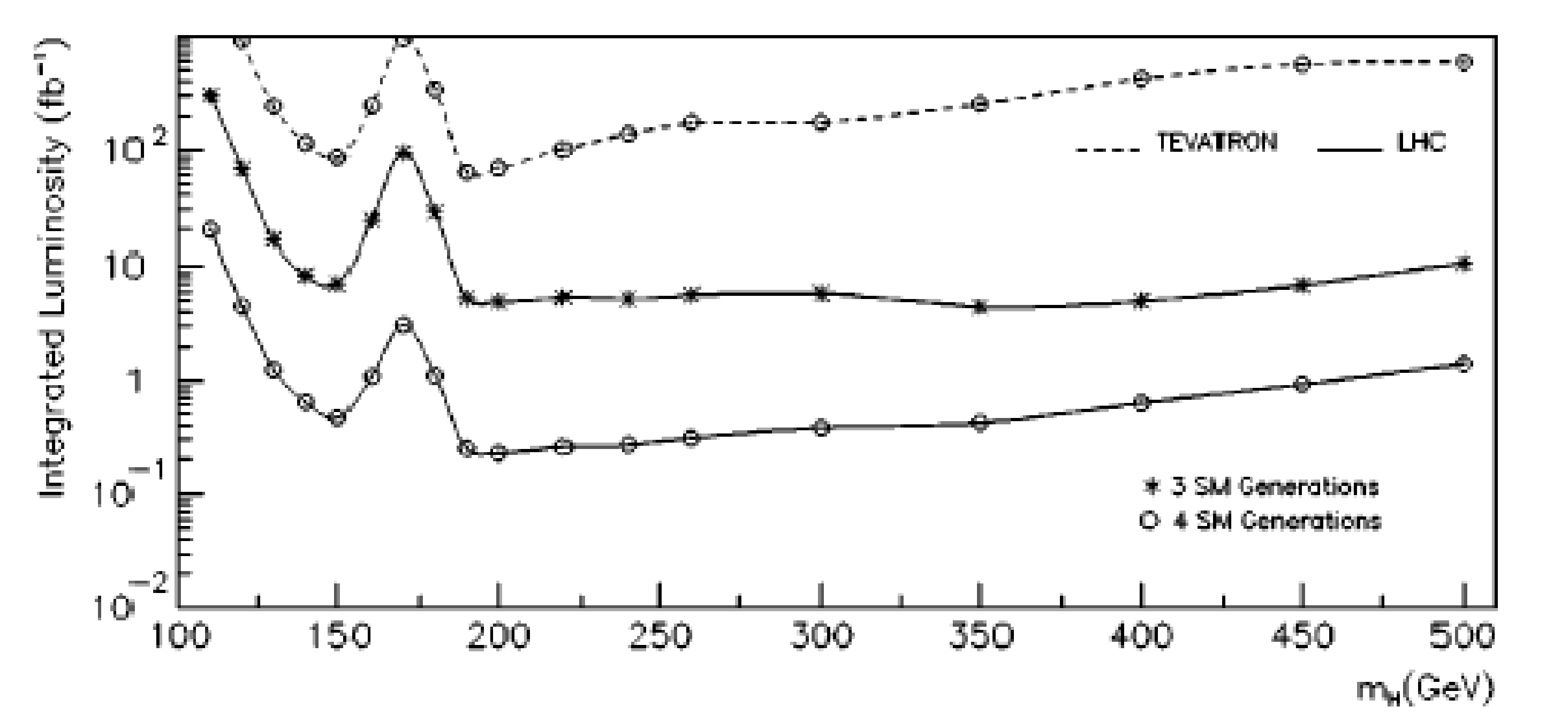
FIG. 4: Expected and observed 95% CL cross section ratio of the combined Run IIa and Run IIb analyses for $H \to WW^*$.

3.2. The Fourth SM Family at the LHC

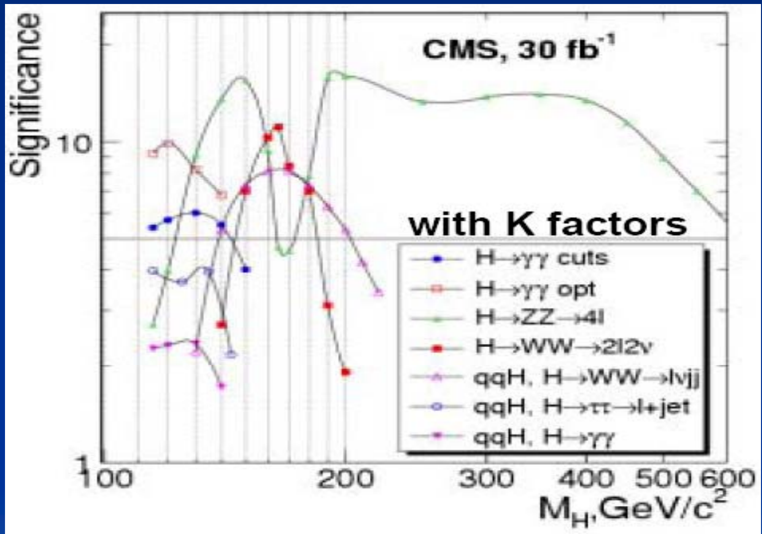
- Higgs – “golden mode”
- Higgs – “silver mode”
- Pair production – fourth family quarks
- Pair production – fourth family neutrinos (via Z and H)

Existence of the fourth SM family can give opportunity for Tevatron to observe the intermediate mass Higgs boson before the LHC.

However, LHC will cover whole region via golden mode during the first year of operation. E. Arik et al., Phys. Rev. D 66 (2002) 033003



Kribs et al , Jun 2007



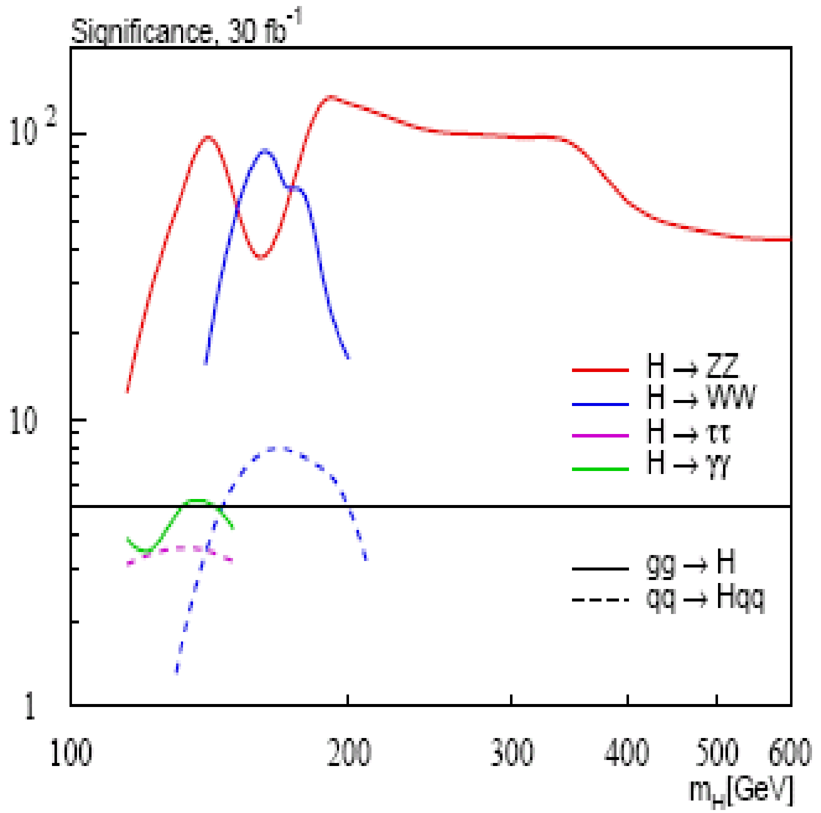
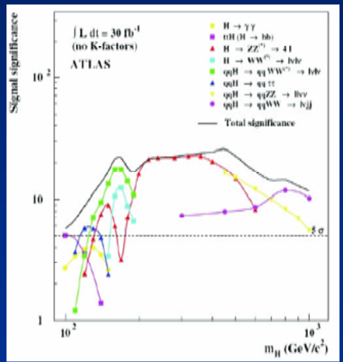


FIG. 4: Scaled LHC discovery contours for the fourth-generation model. All channels studies by CMS are included. The significances have naively been scaled to the modified production rates and branching rations using the fourth-generation parameters of reference point (b).

E.Arık, S.A. Çetin, S. Sultansoy e-Print: **arXiv:0708.0241** [hep-ph] Aug 2007



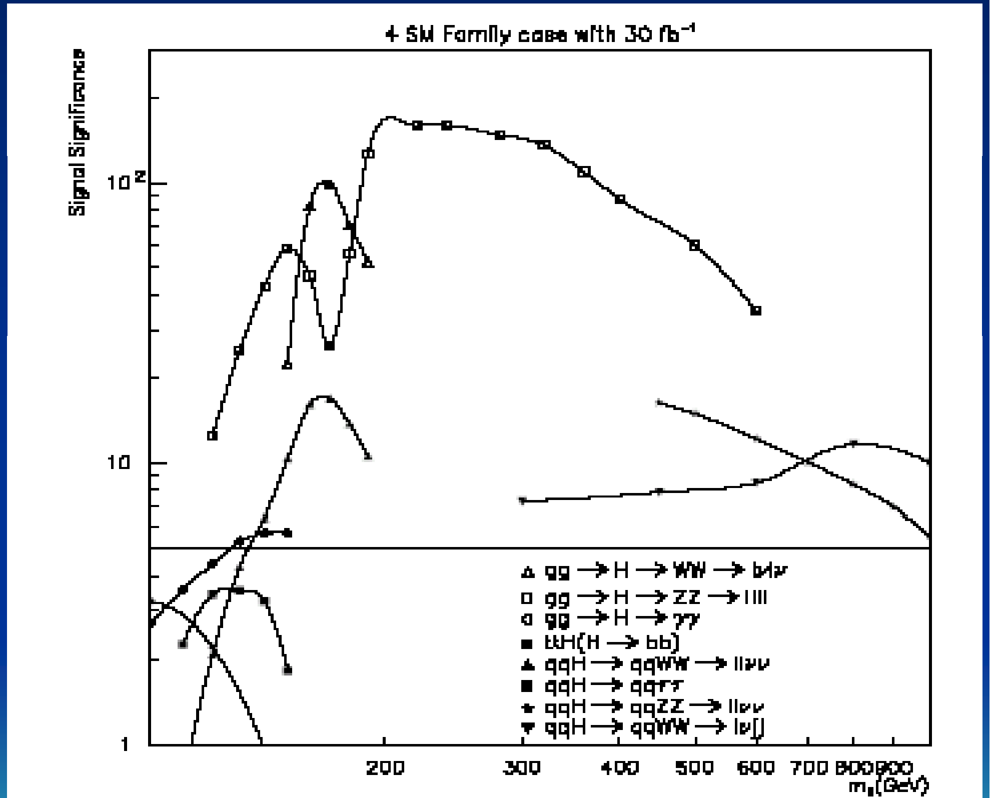


Fig. 2: ATLAS sensitivity for the discovery of the SM Higgs boson in the 4 SM family case with an integrated luminosity of 30 fb^{-1}.

SM-4 with 10 fb(-1) SM-4 with 3 fb(-1) SM-4 with 1 fb(-1)

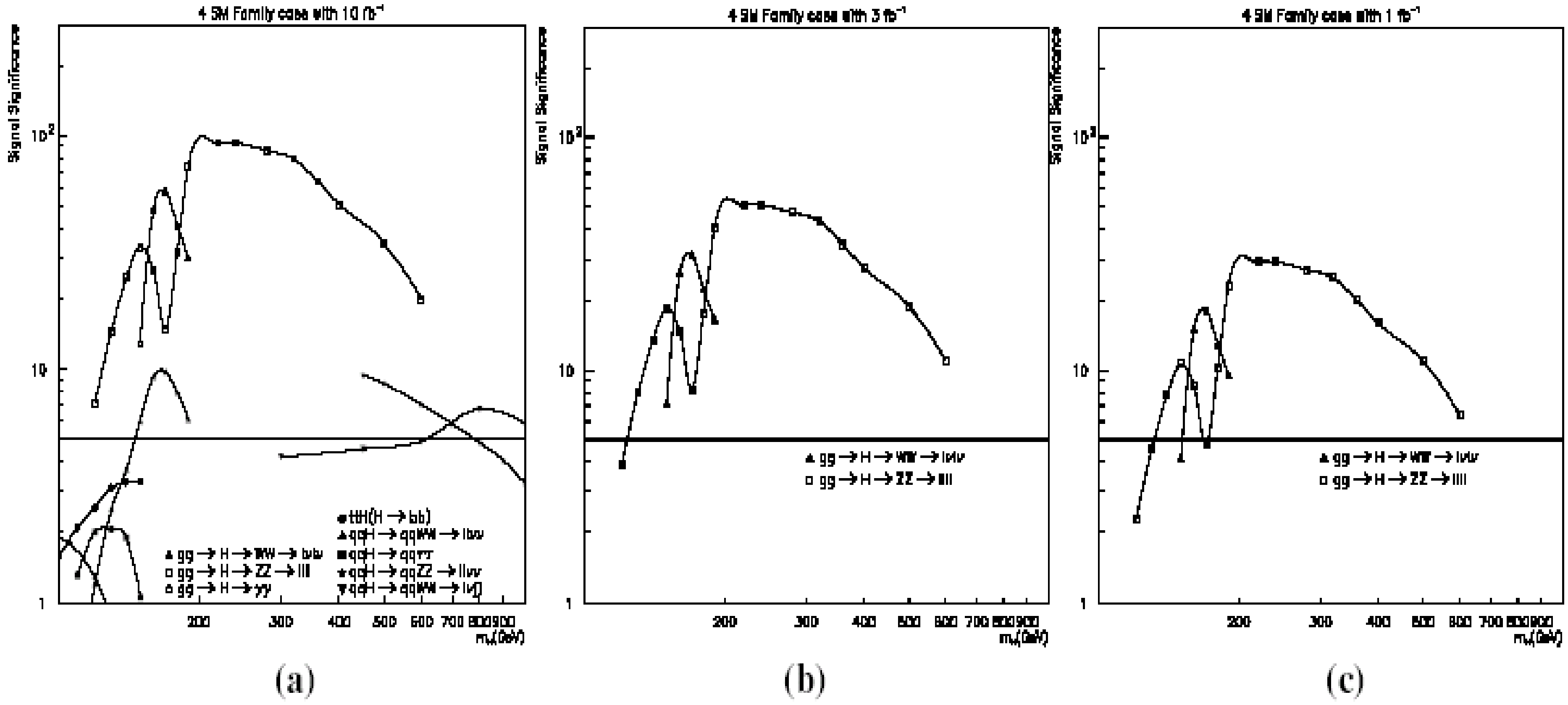


Fig. 3: ATLAS sensitivity for the discovery of the SM Higgs boson in the 4 SM family case with an integrated luminosity of (a) 10 fb^{-1}, (b) 3 fb^{-1} and (c) 1 fb^{-1} .

'Silver' mode

S. Sultansoy and G. Ünel e-Print: **arXiv:0707.3266** [hep-ph] Aug 2007

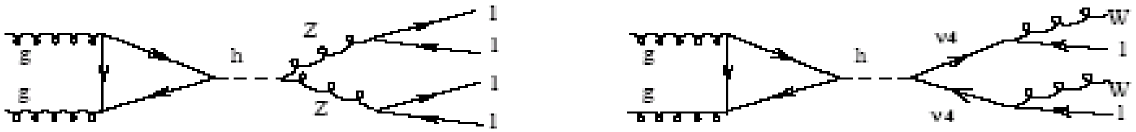


Figure 1: The "golden" (left) and the "silver" (right) modes for heavy Higgs boson discovery.

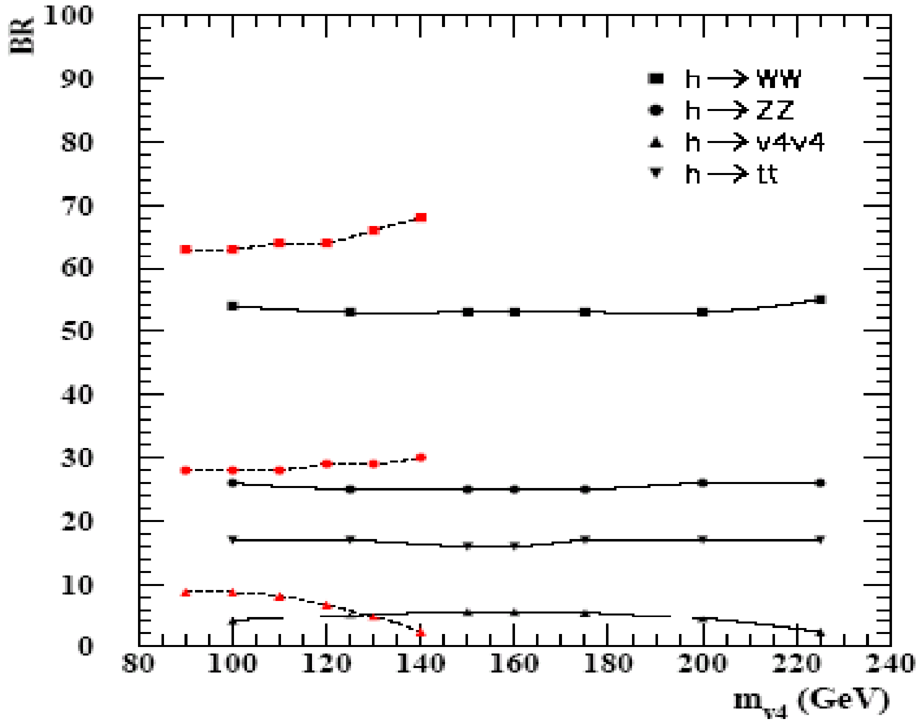


Figure 2: The heavy Higgs branching ratios as a function of the heavy neutrino mass for two example m_h values 300 GeV (dashed lines) and 500 GeV (solid lines)

The fourth family neutrino, ν_4, couples to the Higgs boson with a vertex coefficient proportional to its mass providing a new decay channel. The branching ratios as a function of the ν_4 mass for two Higgs mass values, 300 and 500 GeV, are presented in Fig. 2. As seen $Br(h \to \nu_4 \bar{\nu}_4)$ is maximized between 90 and 100 GeV as 8.8% for m_h =300 GeV and between 150 and 160 GeV as 5.7% for m_h =500 GeV. Below we compare the "golden" and "silver" modes in these mass ranges.

The decays of the ν_4 are governed by the leptonic 4x4 CKM matrix. For numerical calculations, we consider the parameterization in [6] which is compatible with the experimental data on the masses and the mixings in the SM leptonic sector. In this case, the $Br(\nu_4 \to \mu W) \simeq 0.68$ and $Br(\nu_4 \to \tau W) \simeq 0.32$ which imposes the main discovery signal as two muons and four jets considering the hadronic decays of the W bosons in the final state. Note that the "silver" mode contains only muons compared to both electrons and muons of the "golden" mode. This scenario with $m_h = 300$ GeV, leads to $Br(h \to \nu_4 \bar{\nu}_4 \to \mu^+ \mu^- jjjj)$=$1.22 \times 10^{-2}$ which should be compared to the "golden" mode branching ratio of 1.12×10^{-3}, giving an enhancement factor about 11. Corresponding numbers for $m_h = 500$ GeV are 1.88×10^{-2} and 1.25×10^{-3} respectively, yielding an enhancement of about 15 times. We believe that an order of magnitude higher statistics would compensate the possible inefficiencies associated with jet detection and hadronic W reconstruction.

An associated channel to the "silver" mode is the case where one of the W boson decays leptonically: $W \to \ell \nu$ ($\ell = \mu, e$). The final state in this case will be $\mu^+\mu^-\ell jj\not{E}_T$. The number of such events is 63% of the "silver" mode discussed above, bringing the total enhancement factor up to 24 (18) compared to the "golden" mode for a Higgs boson of m_h=500 (300) GeV.

If the fourth family neutrino is of Majorana nature, an experimentally clear signature would be available, namely same sign muons as decay products of ν_4s. Although in this case, the number of expected signal events is halved, the SM background is practically negligible making this mode deserve the name "platinum" mode.

3 Conclusion

If Nature allows, a double discovery in the first year of the LHC start up is in the realm of the possible: the fourth family neutrino and a heavy ($m_h > 300$ GeV) Higgs boson. For $m_h = 300$ (500) GeV the fourth family quarks increase the Higgs production cross section to 7×10^4 (2.5×10^4) fb compared to 10^4 (5×10^3) fb in the 3 family SM case [7]. Consequently, the so called "silver" mode allows about 850 (470) Higgs bosons (and obviously twice as many ν_4) to be reconstructed with 1fb^{-1} luminosity for m_h =300 (500) GeV and m_{ν_4} =100 (150) GeV. The Monte Carlo simulation to verify this statement is under progress.

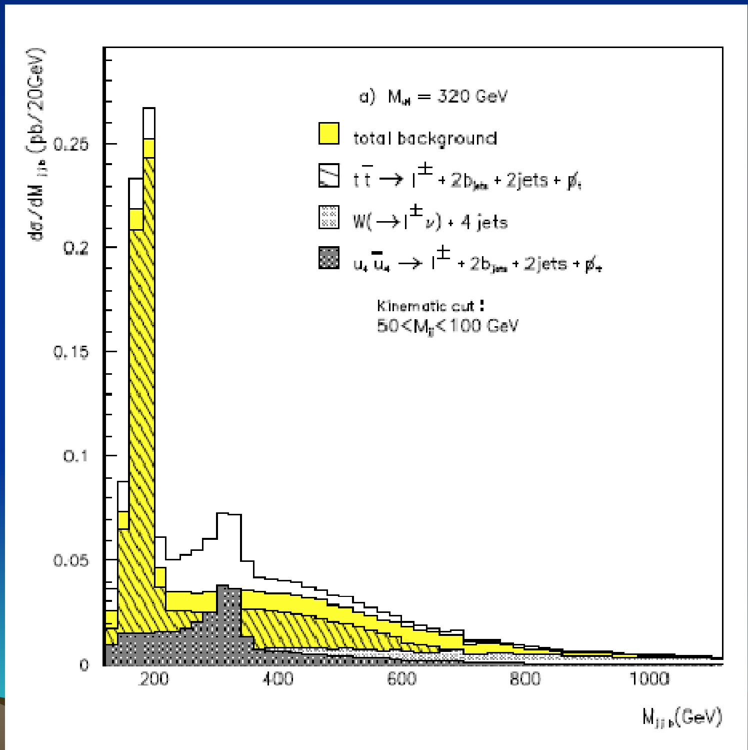
Pair production LHC, 100 fb-1

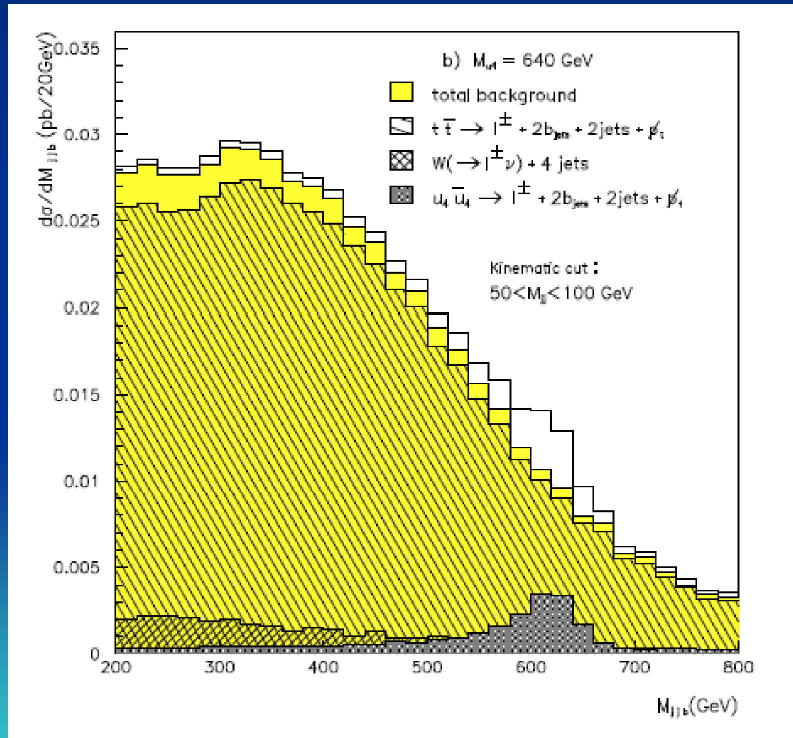
E. Arik et al., Phys. Rev. D 58 (1998) 117701

$$pp \to u_4\bar{u}_4 \to b\bar{b}\ W^+W^-$$

$$u_4\bar{u}_4 \to l^{\pm} + 2j + 2b_{jet} + \not{p}_t,$$

M_{u_4}	320 GeV	640 GeV
$t\bar{t}$	19320	8930
$W+4j$	760	327
$WW+2j$	113	48
$ZZ+2j$	17	6
Background	20210	9311
Signal	10600	1591
$\frac{S}{\sqrt{B}}$	74.5	16.6





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t' at the LHC: the physics of discovery

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ABSTRACT: A search for a fourth family at the LHC is presently a low priority, but we argue that an effective search can be conducted early with only a few inverse femtobarns of data. We discuss a method based on invariant masses of single jets for identifying the W's originating from heavy quark decays. This can significantly increase signal to background in the reconstruction of the t' mass. We also study the various types of physics that can impact the background estimate, most notably higher order effects, initial state radiation, and models of the underlying event.

KEYWORDS: Hadron-Hadron Scattering.

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ATLAS Exotics WG

Update on Search for 4^{th} Family Sequential Quarks

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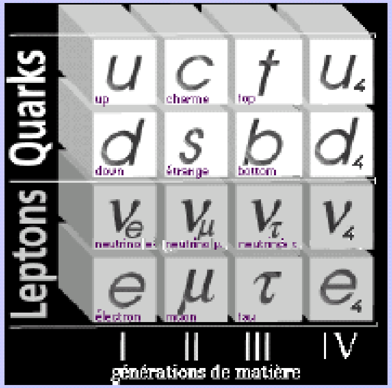
Fourth generation of quarks : u_4 --> b + W



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Update on Fourth Family Quarks at ATLAS

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ATLAS Trigger & Physics Week

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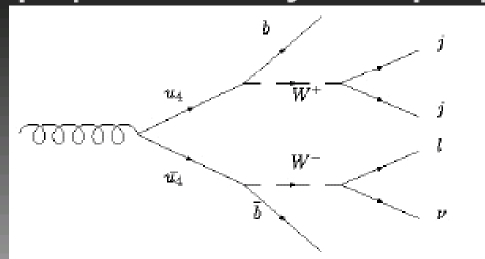
4^{th} up quark decay and property



Democratic model : simple extension of standard model.

$|Mu_4\text{-}Md_4| \sim 1$ GeV

$Mu_4 > 190$ GeV

$u_4 \rightarrow W + b$

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4. The Fourth SM Family at the CLIC

m_{u4} > 260 GeV !!

CDF 760 pb^{-1}

$m_{d4} > m_{u4}$

$m_{l4} \approx m_{d4}$

$m_{\nu4}$ (D) $\approx m_{u4}$

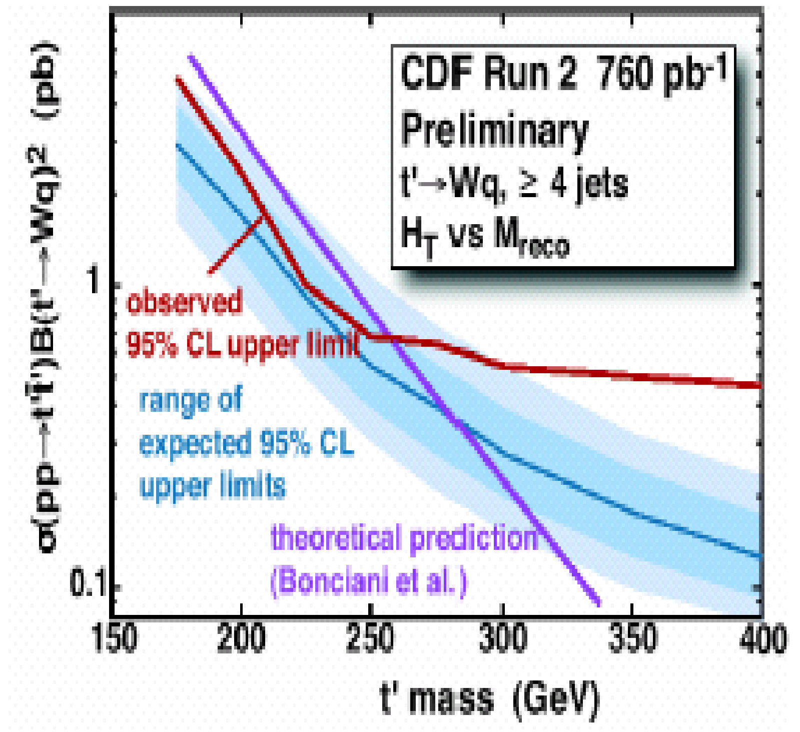

FIGURE 3. 95% CL upper limits for the cross section for t' production.

Yellow Report CERN-2004-005, hep-ph/0412251

Table 6.11: Cross sections and event numbers per year for pair production of the fourth-SM-family fermions with mass 320 GeV at CLIC ($\sqrt{s_{ee}}$ = 1 TeV, $L_{ee} = 2.7 \times 10^{34}$cm^{-2}s^{-1} and $L_{\gamma\gamma} = 10^{34}$cm^{-2}s^{-1})

		$u_4\overline{u_4}$	$d_4\overline{d_4}$	$l_4\overline{l_4}$	$\nu_4\overline{\nu_4}$
e^+e^- option	σ (fb)	130	60	86	15
	N_{ev}/year	35 000	16 000	23 000	4100
$\gamma\gamma$ option	σ (fb)	34	2	58	–
	N_{ev}/year	3400	200	5700	–

Table 6.12: Cross sections and event numbers per year for pair production of the fourth-SM-family fermions with mass 640 GeV at CLIC ($\sqrt{s_{ee}}$ = 3 TeV, $L_{ee} = 1 \times 10^{35}$cm^{-2}s^{-1} and $L_{\gamma\gamma} = 3 \times 10^{34}$cm^{-2}s^{-1})

		$u_4\overline{u_4}$	$d_4\overline{d_4}$	$l_4\overline{l_4}$	$\nu_4\overline{\nu_4}$
e^+e^- option	σ (fb)	16	8	10	2
	N_{ev}/year	16 000	8000	10 000	2000
$\gamma\gamma$ option	σ (fb)	27	2	46	–
	N_{ev}/year	8100	600	14 000	–

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Table 6.14: The production event numbers per year for the fourth-SM-family ψ_4 quarkonia at a CLIC 1 TeV option with $m_{\psi_4} \simeq 1$ TeV

	$(u_4\overline{u_4})$	$(d_4\overline{d_4})$
$e^+e^- \to \psi_4$	26 600	10 400
$e^+e^- \to \psi_4 \to \gamma H$	510	50
$e^+e^- \to \psi_4 \to ZH$	60	80

Table 6.13: Decay widths for main decay modes of ψ_4 for m_H = 150 GeV with $m_{\psi_4} \simeq 1$ TeV

	$(u_4\overline{u_4})$	$(d_4\overline{d_4})$
$\Gamma(\psi_4 \to \ell^+\ell^-)$, 10^{-3} MeV	18.9	7.3
$\Gamma(\psi_4 \to u\overline{u})$, 10^{-2} MeV	3.2	1.9
$\Gamma(\psi_4 \to d\overline{d})$, 10^{-2} MeV	1.4	1.7
$\Gamma(\psi_4 \to Z\gamma)$, 10^{-1} MeV	15	3.7
$\Gamma(\psi_4 \to ZZ)$, 10^{-1} MeV	1.7	5.4
$\Gamma(\psi_4 \to ZH)$, 10^{-1} MeV	1.7	5.5
$\Gamma(\psi_4 \to \gamma H)$, 10^{-1} MeV	14.4	3.6
$\Gamma(\psi_4 \to W^+W^-)$, MeV	70.8	71.2

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Fourth standard model family neutrino at future linear colliders

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It is known that flavor democracy favors the existence of the fourth standard model (SM) family. In order to give nonzero masses for the first three-family fermions flavor democracy has to be slightly broken. A parametrization for democracy breaking, which gives the correct values for fundamental fermion masses and, at the same time, predicts quark and lepton Cabibbo-Kobayashi-Maskawa (CKM) matrices in a good agreement with the experimental data, is proposed. The pair productions of the fourth SM family Dirac (ν_4) and Majorana (N_1) neutrinos at future linear colliders with $\sqrt{s} = 500$ GeV, 1 TeV, and 3 TeV are considered. The cross section for the process $e^+e^- \to \nu_4\overline{\nu}_4(N_1N_1)$ and the branching ratios for possible decay modes of the both neutrinos are determined. The decays of the fourth family neutrinos into muon channels ($\nu_4(N_1) \to \mu^\pm W^\mp$) provide cleanest signature at e^+e^- colliders. Meanwhile, in our parametrization this channel is dominant. W bosons produced in decays of the fourth family neutrinos will be seen in detector as either di-jets or isolated leptons. As an example, we consider the production of 200 GeV mass fourth family neutrinos at $\sqrt{s} = 500$ GeV linear colliders by taking into account di-muon plus four jet events as signatures.

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Single Production of Heavy Charged Leptons at the ILC

Authors: Erin De Pree, Marc Sher (William and Mary)

(Submitted on 20 Sep 2007)

Abstract: A sequential fourth generation of quarks and leptons is allowed by precision electroweak constraints if the mass splitting between the heavy quarks is between 50 and 80 GeV. Although heavy quarks can be easily detected at the LHC, it is very difficult to detect a sequential heavy charged lepton, L, due to large backgrounds. Should the L mass be above 250 GeV, it can not be pair-produced at a 500 GeV ILC. We calculate the cross section for e^+e^-\to L\tau, which occurs through a loop, and find that the L can be detected through this process over a wide range of parameter space. We also consider contributions to the cross section in the two Higgs doublet model and in the Randall-Sundrum model

Subjects: High Energy Physics - Phenomenology (hep-ph)

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Future Studies

- Detailed study of pair production of the 4-th family leptons
- Impact of beam dynamics on the 4-th family quarkonia
- Anomalous production and decays of the 4-th family quarks and leptons
- $u_4 u_4 H$ and $d_4 d_4 H$ final states
- Identification: d_4 vs isosinglet D (E_6)
- Identification: u_4 vs isosinglet T (Little Higgs)
- ...

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