Once more on extra quark-lepton generations and precision measurements

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plan

- decoupling and nondecoupling
- SM fit
- fits with extra generations
- S, T, U
- higgs properties with extra generations
- conclusions

New Generations?

We know 3 quark-lepton generations - more can exist
IF new quarks, new leptons are heavy (Tevatron, LEPII, Z width).

Higgs mechanism of mass generation, $\eta = 246$ GeV and since Yukawa coupling constant $fHQq$ which equals $f = m_q/\eta$ should not be too large (stability of higgs potential, unitarity of Qq scattering amplitude) quarks of new generation should be reachable at LHC.

Soon we will know if extra generation(s) do exist.

Heavy particles at low energies

Heavy particles contributions to low energy observables:

QED

1. t - quark contribution to α - divergent, nonextractable from data;
2. t - quark contribution to muon anomalous magnetic moment - suppressed as $\alpha^2(m_\mu/m_t)^2$, decouples.

What about QAD ?

3. t - quark contribution to $K-\bar{K}, B-\bar{B}$ amplitudes - $\sim f^4/m_t^2 = G_F^2 m_t^2$ heavy top dominates, nondecoupling.

Z, W properties

Even if new generations mixing with light generations is small (vanishing contributions to $K - \bar{K}, B - \bar{B}$ mixing) they contributes to Z and W polarization operators. Resulting contributions to physical observables are finite and do not decouple.

Considerable part of phase space (masses of new quarks and leptons) is excluded by precision data.

Nevertheless one can find still allowed domains.

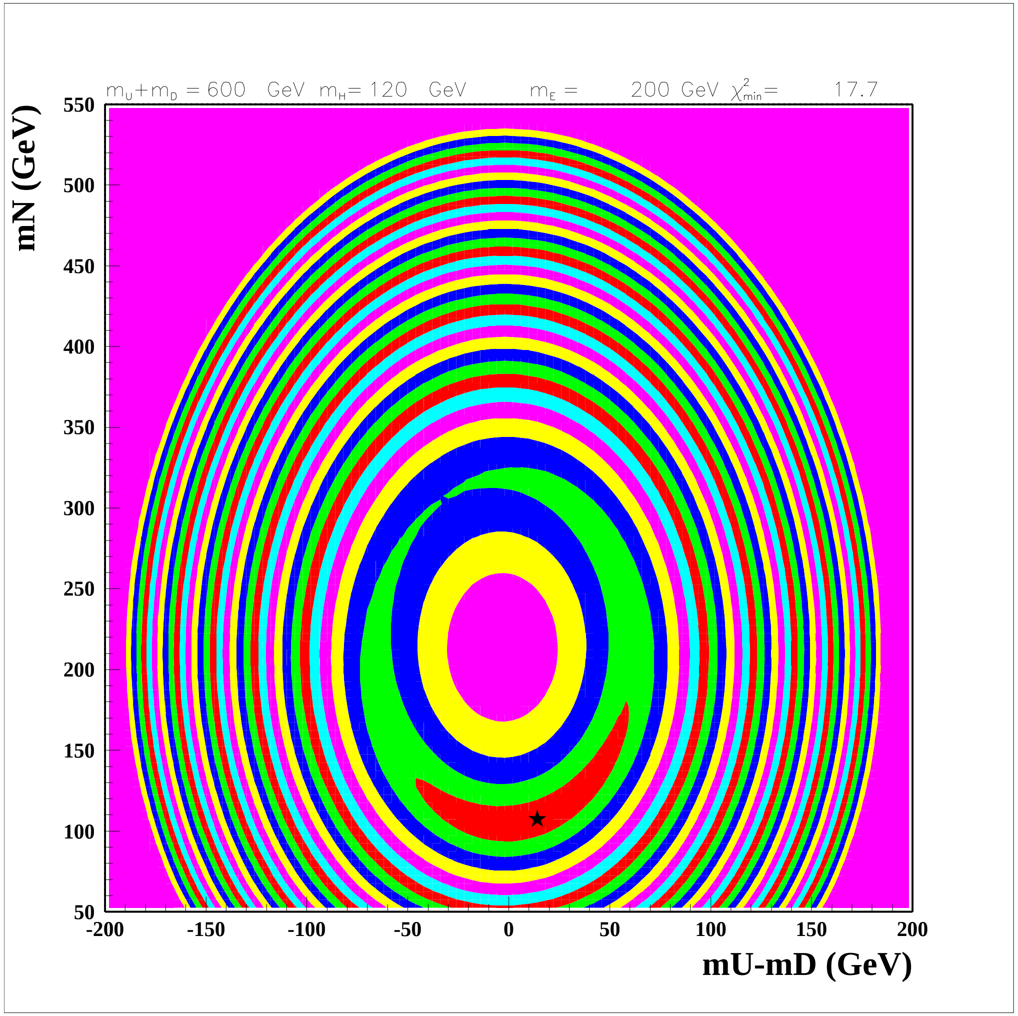
SM fit by LEPTOP, summer 2009

LEPTOP - the approach to ew rc worked out by V.A.Novikov, L.B.Okun, A.N.Rozanov and M.V. in the -90s.

Observable	Exper. data	LEPTOP fit	Pull
Γ_Z, GeV	2.4952(23)	2.4963(15)	-0.5
σ_h, nb	41.540(37)	41.476(14)	1.8
R_l	20.771(25)	20.743(18)	1.1
$A^l_{\rm FB}$	0.0171(10)	0.0164(2)	0.8
A_τ	0.1439(43)	0.1480(11)	-0.9
R_b	0.2163(7)	0.2158(1)	0.7
R_c	0.172(3)	0.1722(1)	-0.0
$A^b_{\rm FB}$	0.0992(16)	0.1037(7)	-2.8
$A^c_{\rm FB}$	0.0707(35)	0.0741(6)	-1.0
s^2_l ($Q_{\rm FB}$)	0.2324(12)	0.2314(1)	0.8

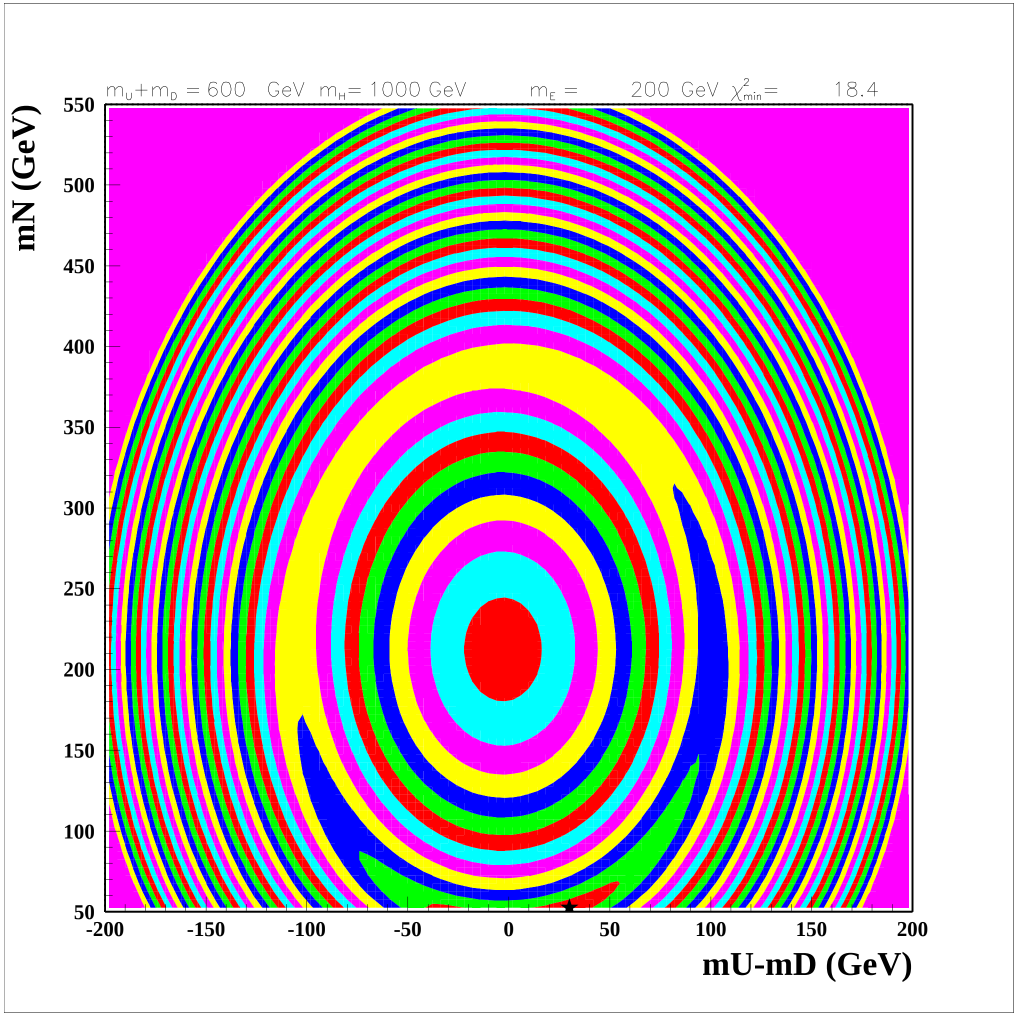
Observable	Exper. data	LEPTOP fit	Pull
$A_{\rm LR}$	0.1513(21)	0.1479(11)	1.6
A_b	0.923(20)	0.9349(1)	-0.6
A_c	0.670(27)	0.6682(5)	0.1
m_W, GeV	80.398(25)	80.377(17)	0.9
m_t, GeV	172.6(1.4)	172.7(1.4)	-0.1
$M_{\rm H}$, GeV		84^{+32}_{-24}	
$\hat{\alpha}_s$		0.1184(27)	
$1/\bar{\alpha}$	128.954(48)	128.940(46)	0.3
$\chi^2/n_{\rm d.o.f.}$		18.1/12	

4 generation with 120 GeV higgs



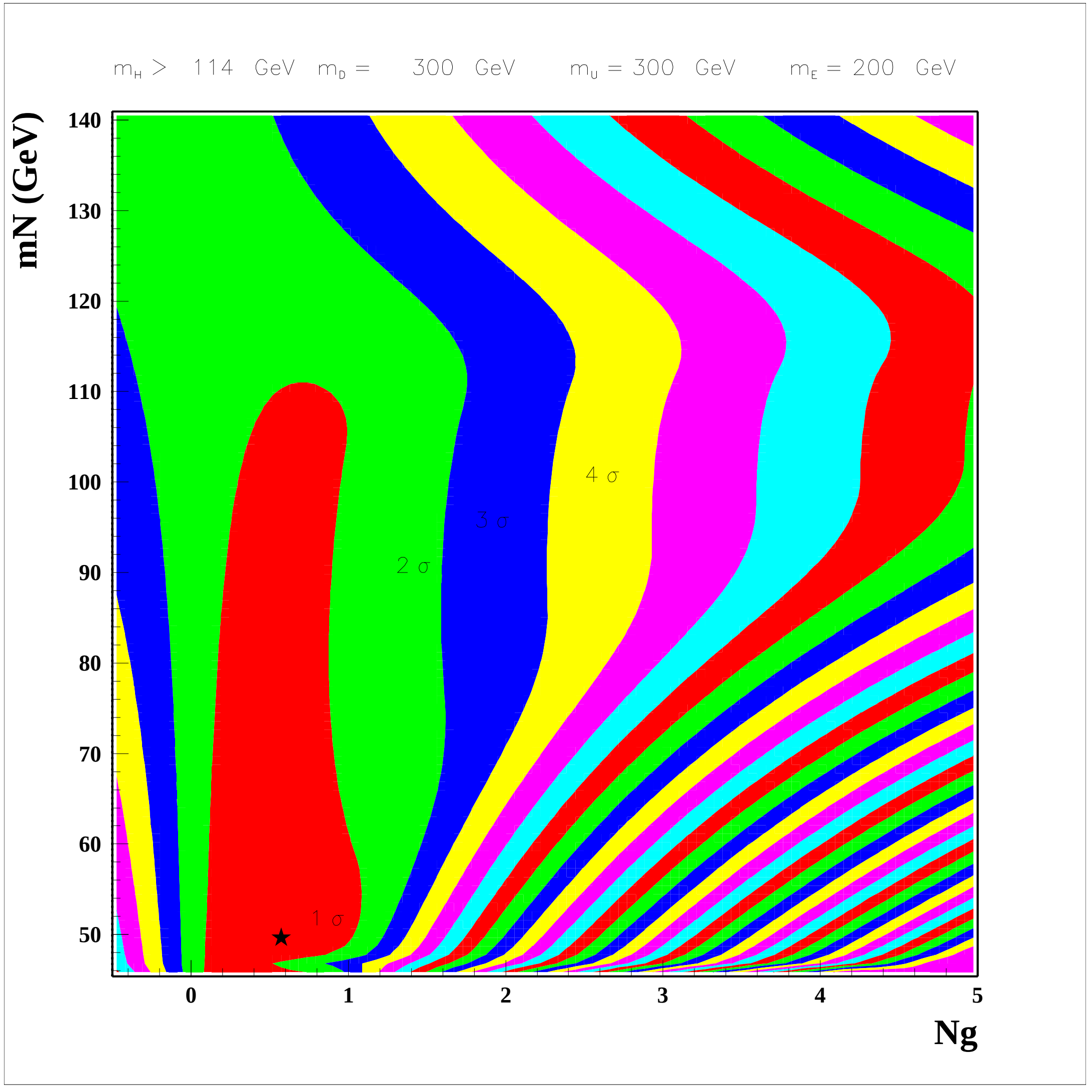
$m_E = 200$GeV, $m_U + m_D = 600$ GeV, $\chi^2/d.o.f. = 17.7/11$, the quality of fit is the same as in SM.

4 generation with 1000 GeV higgs



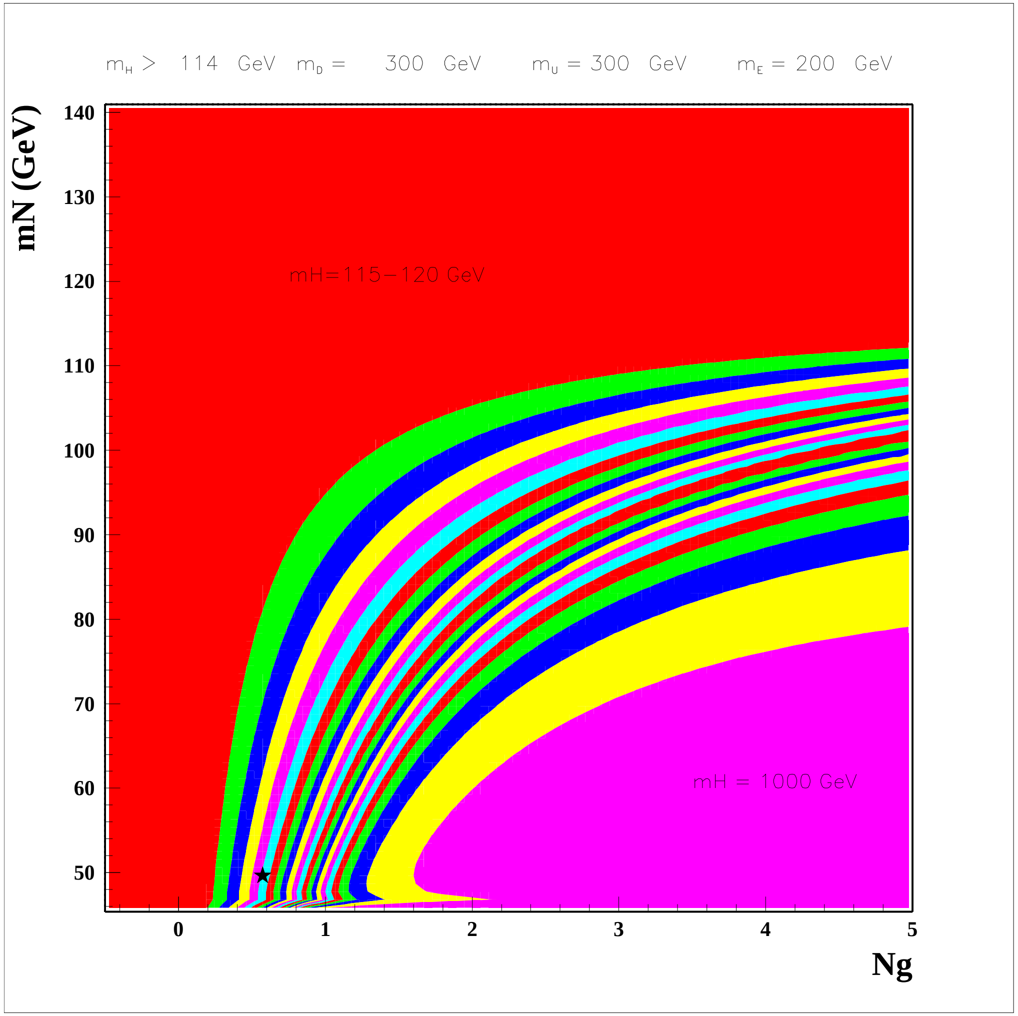
$m_E = 200$GeV, $m_U + m_D = 600$ GeV, $\chi^2/d.o.f. = 18.4/11$, the quality of the fit is the same as in SM.

N_g



$m_E = 200$GeV,
$m_U = m_D = 300$ GeV, fitted $M_h > 114$ GeV, χ^2 levels.

$N_g M_h$



$m_E = 200$ GeV, $m_U = m_D = 300$ GeV, fitted M_h levels.

S, T, U

Review of Particle Physics, J.Erler, P.Langacker:
"extra generation is excluded at the 6σ C.L....at 99% C.L...."

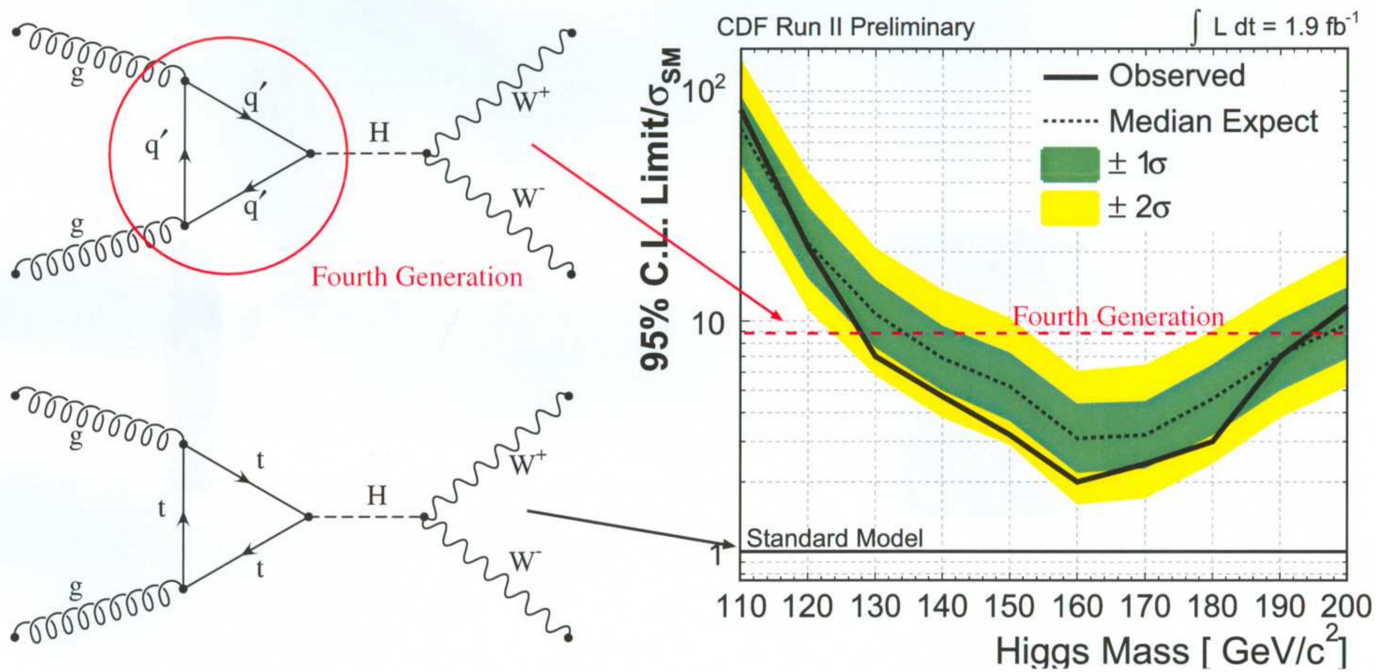
m_H		T_i	T	S_i	S	U_i
120	$m_U = 310$, $m_D = 290$	0.02	0.02	0.15	0.15	0
	$m_N = 120$, $m_E = 200$	0.11	0.11	-0.01	-0.01	0.02
1000	$m_U = 315$, $m_D = 285$	0.05	0.05	0.15	0.15	0
	$m_N = 53$, $m_E = 200$	0.27	0.36	-0.19	-0.13	0.16

Quark and lepton contributions to S, T, U and S_i, T_i, U_i at the points of χ^2 minimum. All masses are in GeV.

In Fig. 10.4 of E - L review one can see that both Standard Model point $S = T = 0$ and just described new physics points are on the border of the allowed 1σ domains.

higgs properties with 4 generation

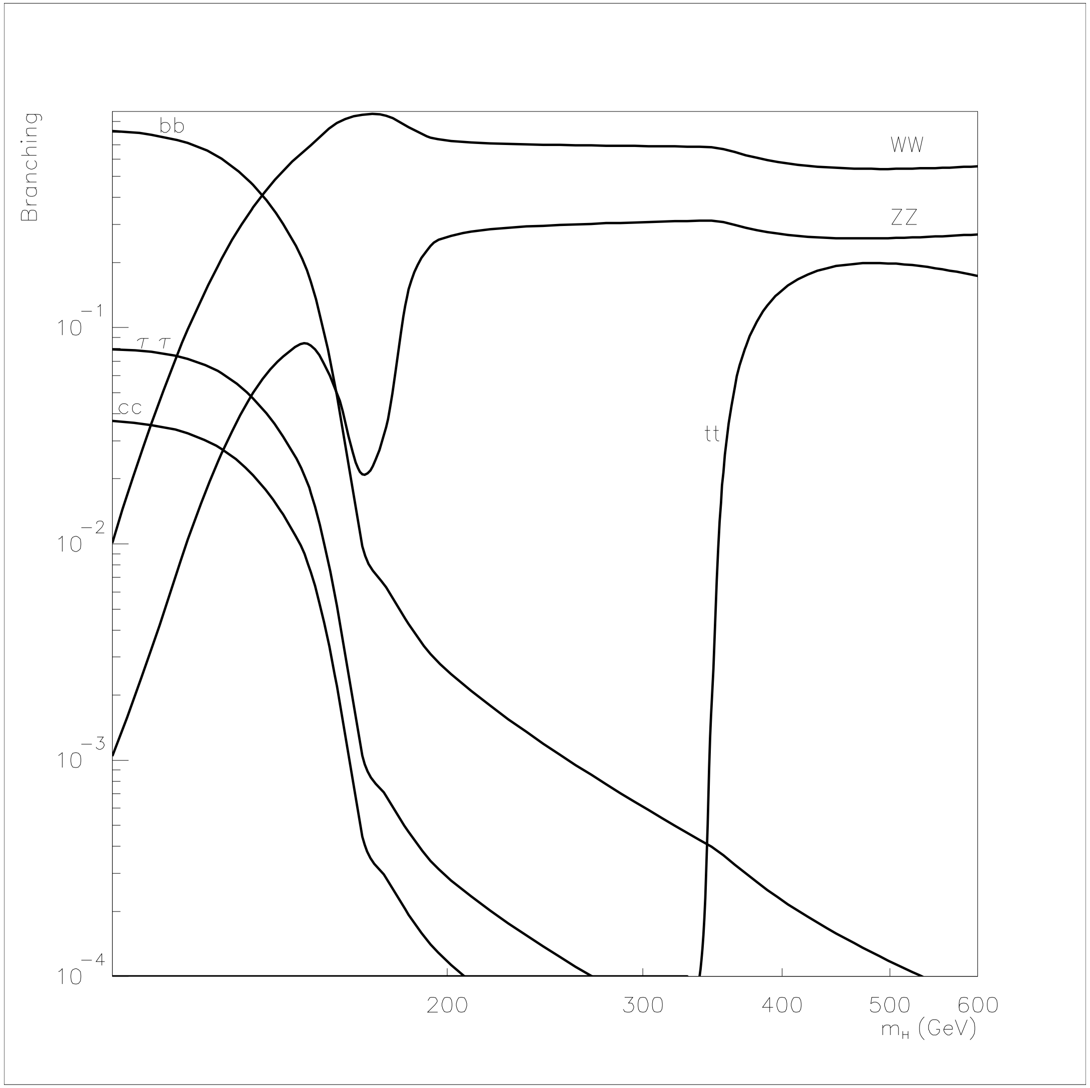
CDF Fourth Generation and Higgs



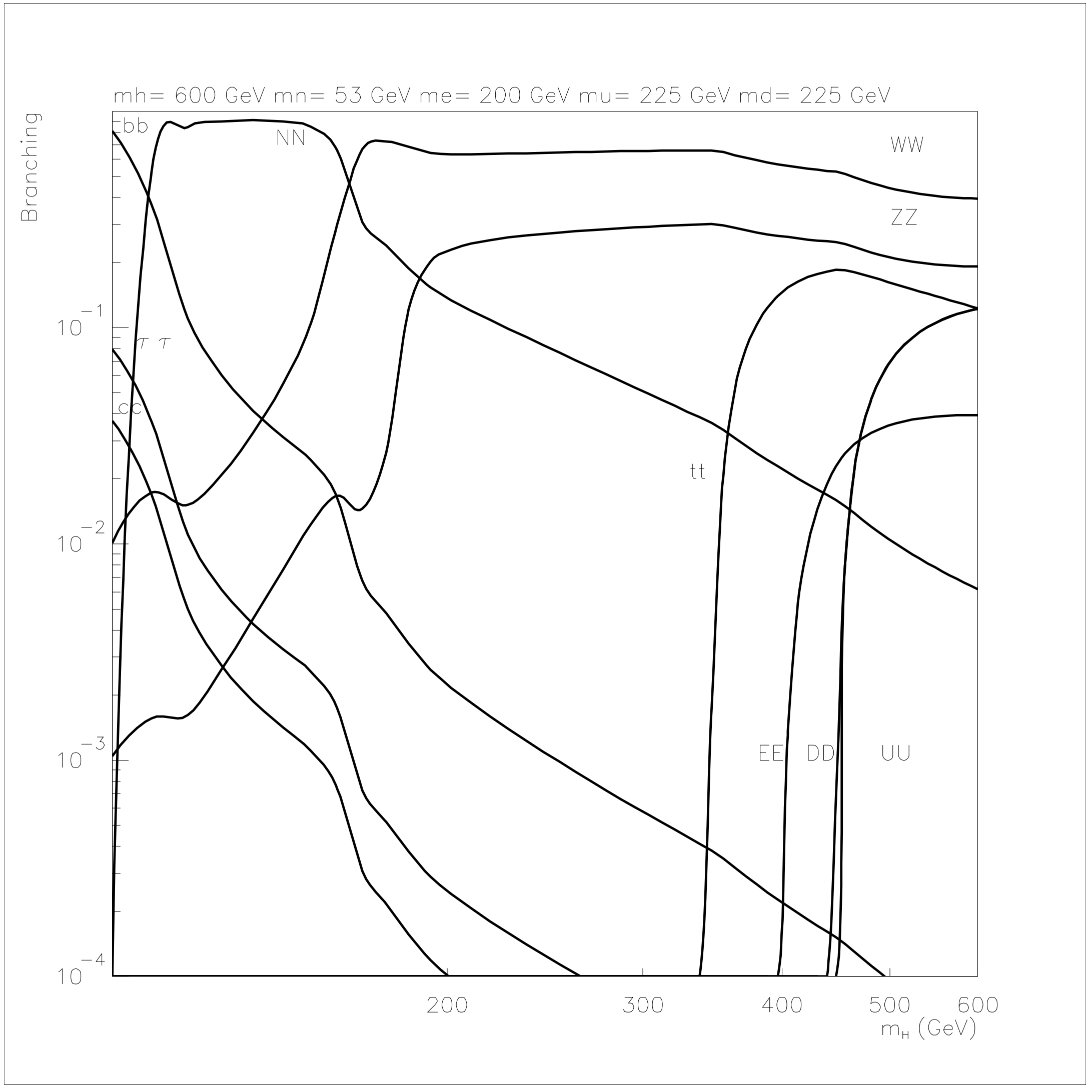
- Interpret SM $H \rightarrow WW$ Higgs limit in context of a fourth generation.
- Production cross-section larger due to additional quarks with large mass.
- Result: 130 GeV $< m_H <$ 195 GeV excluded at 95% CL.

Michael Mulhearn, Moriond QCD 2008

Higgs decays, 3 gen



Higgs decays, 4 gen



J.M.Frere, A.N.Rozanov, M.V. (2006)

Conclusions

- One extra quark-lepton generation is not excluded by ew precision data while 3 extra generations are excluded with high probability;
- The quality of fit for one extra generation is the same as that for SM for certain values of new particle masses;
- In case of 4^{th} generation the upper bound on higgs mass from SM fit is removed;
- higgs production crossection is enhanced while decay branching ratios modify in case of extra generations

backup slides

Letters B 374 (1996) 127–130

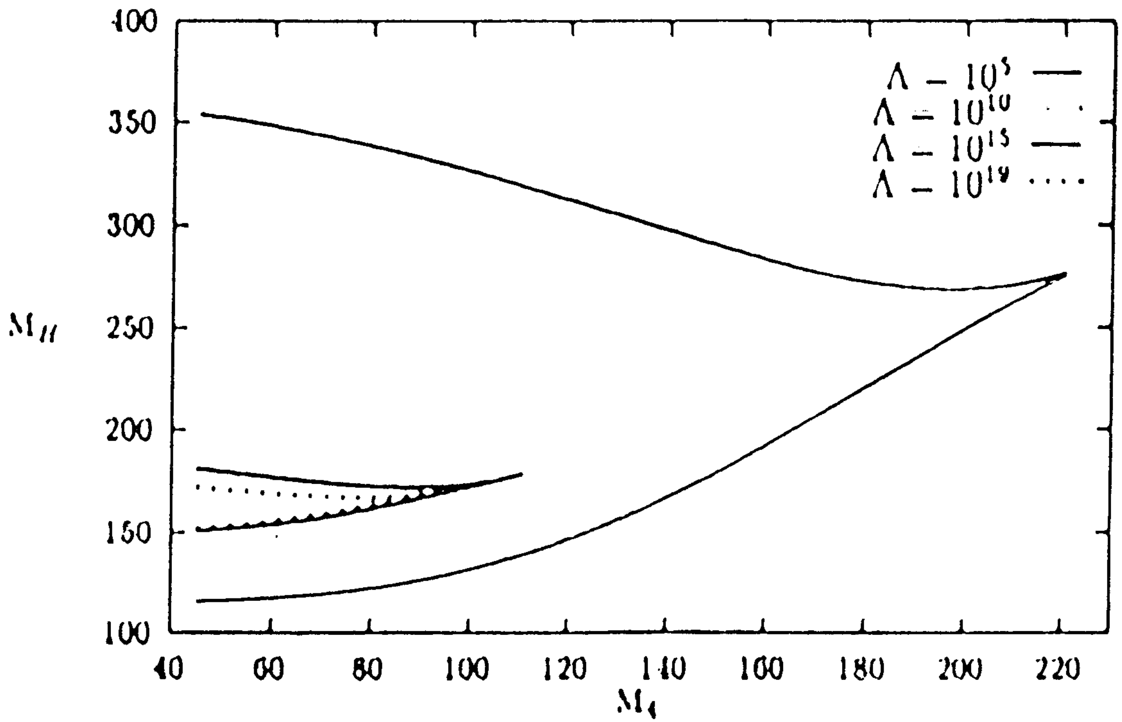


Fig. 1. Allowed values of M_H and M_4 lie between two curves: a. solid for $\Lambda = 10^5$ GeV; b. thin dotted for $\Lambda = 10^{10}$ GeV; c. thick solid for $\Lambda = 10^{15}$ GeV; d. thick dotted for $\Lambda = 10^{19}$ GeV.

H.B. Nielsen, A.V. Novikov, V.A. Novikov, M.V. (1996)

C versus DCPV puzzle

$$A_{CP}(K^+\pi^-) = A_{CP}(K^+\pi^0) + A_{CP}(K^0\pi^0) \quad ,$$

$$A_{CP}(K^0\pi^0) = \frac{\Gamma(B_d \to \pi^0\pi^0) + \Gamma(\bar{B}_d \to \pi^0\pi^0)}{\Gamma(B_d \to K^0\pi^0) + \Gamma(\bar{B}_d \to \bar{K}^0\pi^0)} *$$

$$* \left| \frac{V_{us}V_{ts}}{V_{td}} \right| \frac{\sin\gamma}{\sin\alpha} C_{00} \quad ,$$

where C_{00} is direct CP asymmetry in $B_d(\bar{B}_d) \to \pi_0\pi_0$ decay.

$$C_{00} \approx -0.6 \;\; (Kaidalov, M.V., Phys.Lett.\mathbf{B652}(2007)203),$$

$$-0.094 \pm 0.02 = (0.05 \pm 0.03) + (-0.07 \pm 0.02) \;\; -$$

2 sigma instead of 4.5 sigma discrepancy (which can be a statistical fluctuation).