

Beyond the 3SM generation at the LHC era
Workshop
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CERN

Fourth SM Family and Higgs at Hadron Colliders

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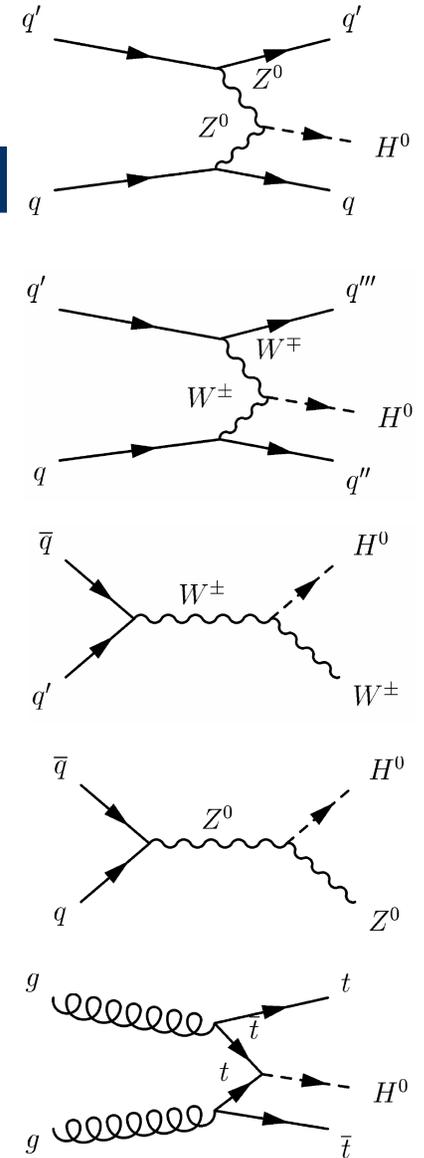
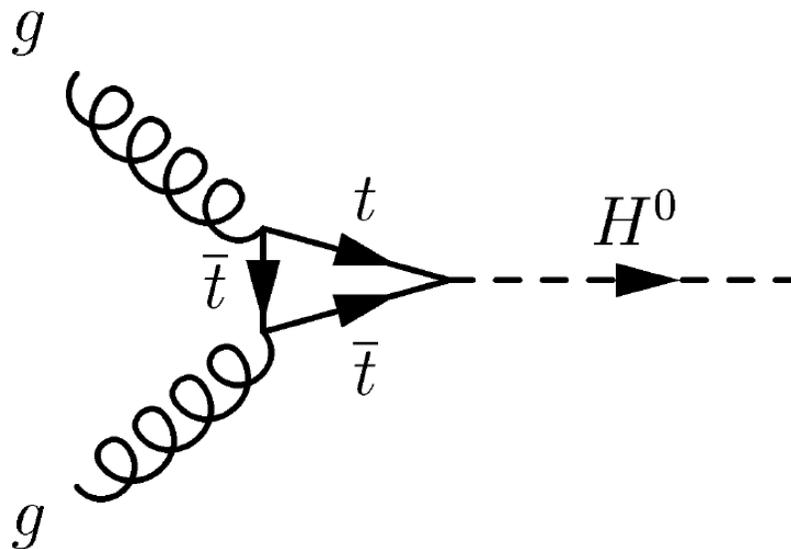
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$$pp \rightarrow ggX \rightarrow hX$$



Higgs production at hadron colliders

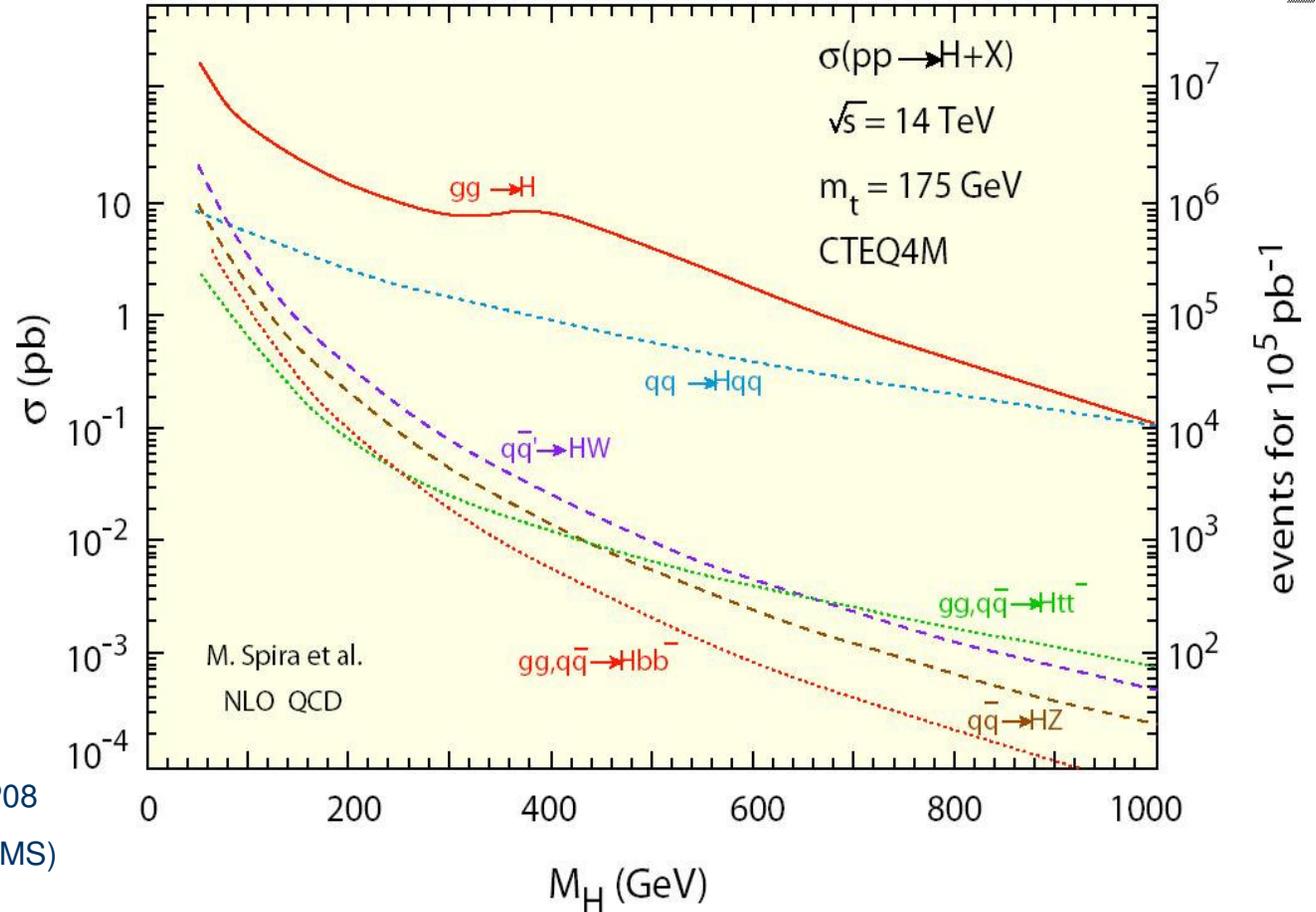
Higgs Boson production at hadron colliders is dominated by **gluon-gluon fusion** process, hence any change in the cross-section of the gluon-gluon fusion will practically result with the same amount of change on the total production cross-section of the Higgs.



$$pp \rightarrow ggX \rightarrow hX$$



Higgs production at LHC



Ricardo Gonalo @ ICHEP08
 (on behalf of ATLAS and CMS)

$$pp \rightarrow ggX \rightarrow hX$$



Enhancement of Higgs production cross section

ATL-PHYS-98-125 / ATLAS physics note

$$\sigma(pp \rightarrow hX) = \sigma_0 \tau_h \int_{\tau_h}^1 \frac{dx}{x} g(x, Q^2) g(\tau_h/x, Q^2)$$

$$\sigma_0(gg \rightarrow h) = \frac{G_F \alpha_s^2(\mu^2)}{288 \sqrt{2} \pi} |I|^2$$

$$I = \sum I_q$$

$$\lambda_q = \left(\frac{m_q}{m_H} \right)^2$$

in 3 SM family case; $q = t, b$

in 4 SM family case; $q = t, b, u_4, d_4$

$$I_q = 3[2\lambda_q + \lambda_q(4\lambda_q - 1)f(\lambda_q)]$$

hence enhancement is given by the ratio of $(I_b + I_t + I_{u4} + I_{d4})$ to $(I_b + I_t)$

$$f(\lambda_q) = \frac{1}{2} \left(\ln \frac{\eta^+}{\eta^-} \right)^2 - \frac{\pi^2}{2} - i\pi \ln \frac{\eta^+}{\eta^-}, \quad \text{for } \lambda_q < \frac{1}{4}$$

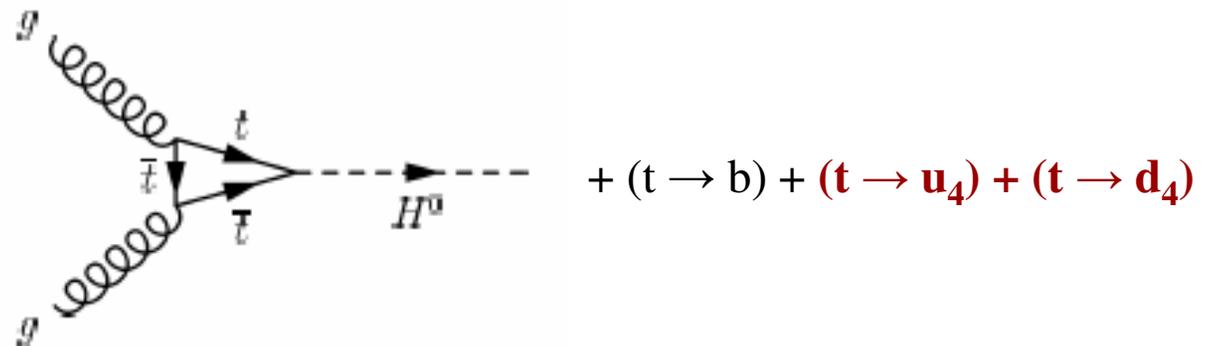
$$f(\lambda_q) = -2 \left(\arcsin \frac{1}{2\sqrt{\lambda_q}} \right)^2, \quad \text{for } \lambda_q > \frac{1}{4}$$

$$pp \rightarrow ggX \rightarrow hX$$



Enhancement of Higgs production cross section

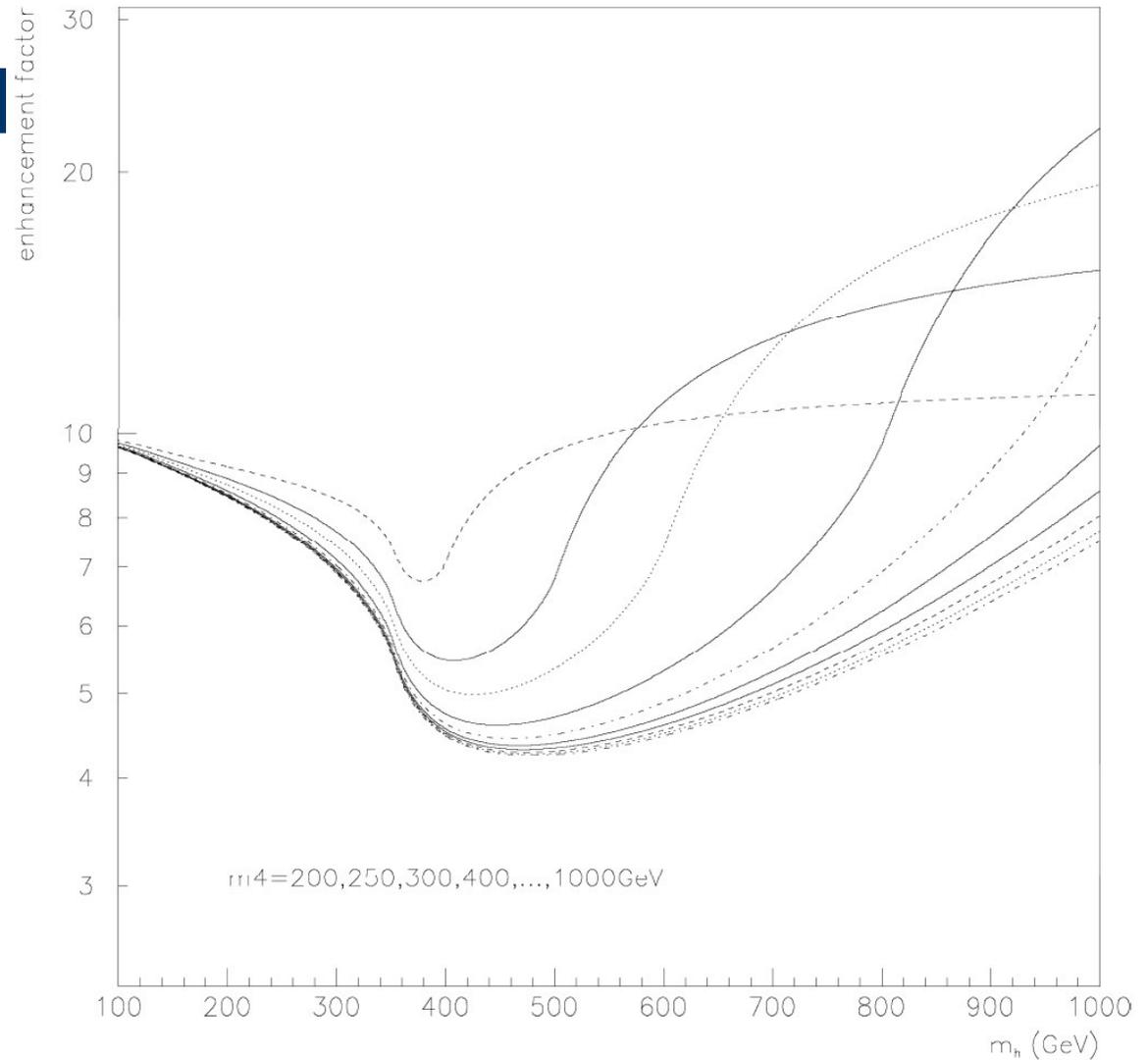
Existence of the extra SM generations leads to an essential increase of the Higgs boson production cross section via gluon gluon fusion at hadron colliders





Enhancement of Higgs production cross section

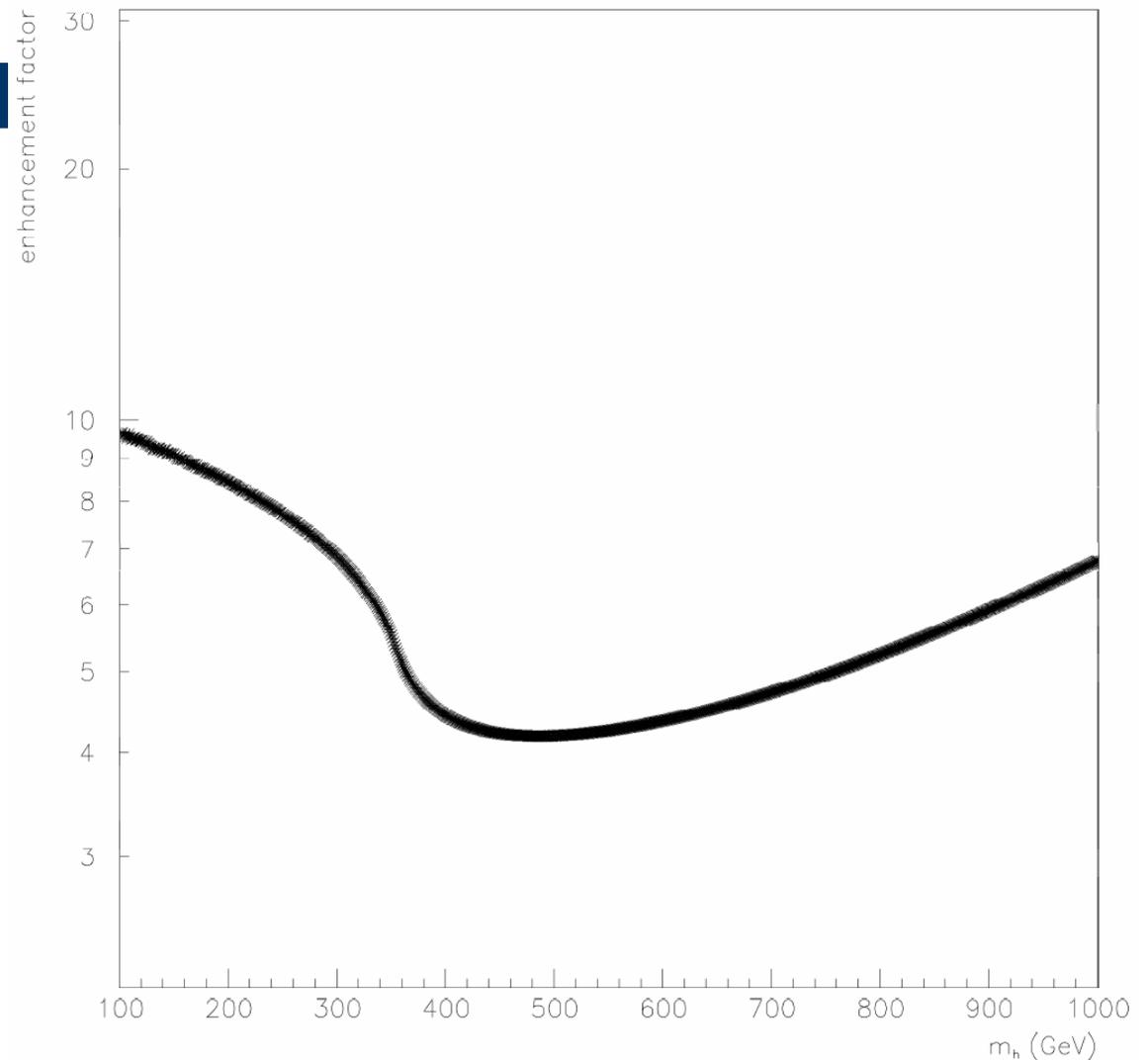
- enhancement factor as a function of the Higgs boson mass for various 4th family quark masses





Enhancement of Higgs production cross section

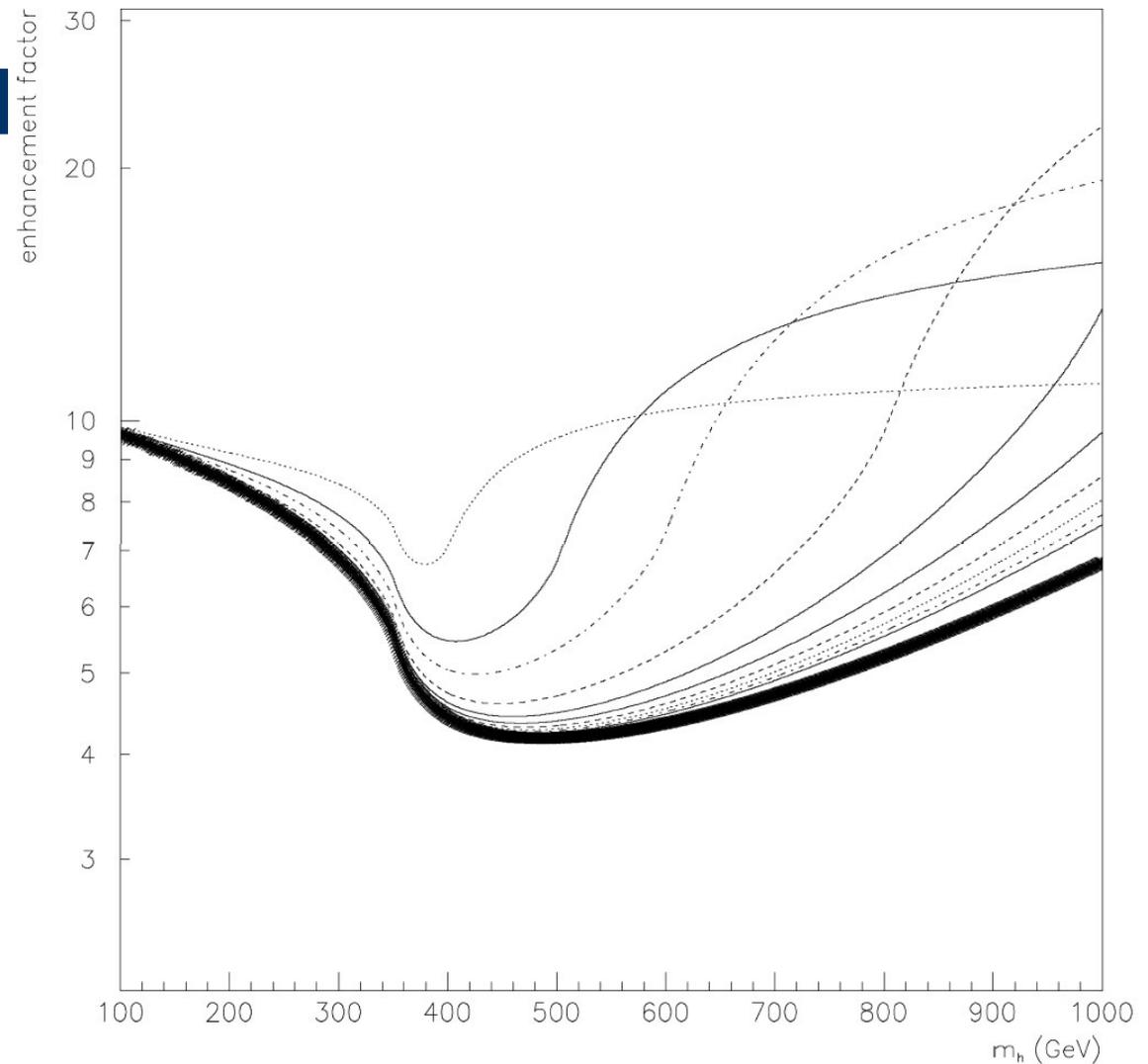
- enhancement factor as a function of the Higgs boson mass for infinitely heavy 4th family quark mass (pessimistic case)





Enhancement of Higgs production cross section

- enhancement factor as a function of the Higgs boson mass for various finite 4th family quark masses compared to infinitely heavy 4th family quark mass (pessimistic case)



Decays of the Higgs Boson

$$\Gamma(H \rightarrow \gamma\gamma) = \frac{G_F m_H^3}{8\sqrt{2}\pi} \left(\frac{\alpha}{\pi}\right)^2 |I|^2,$$

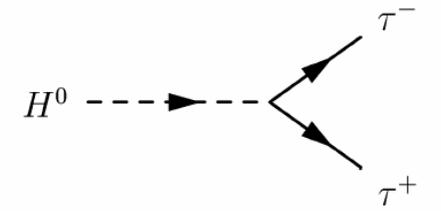
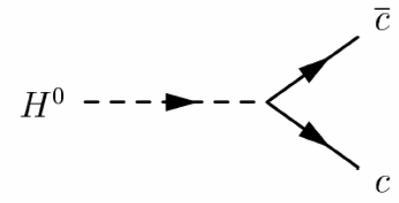
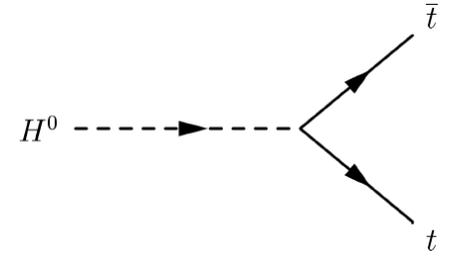
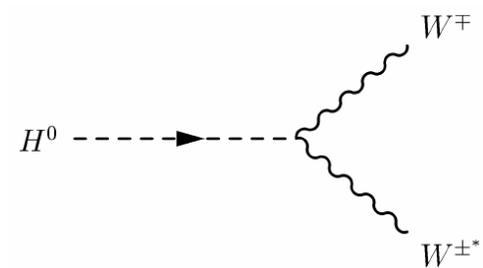
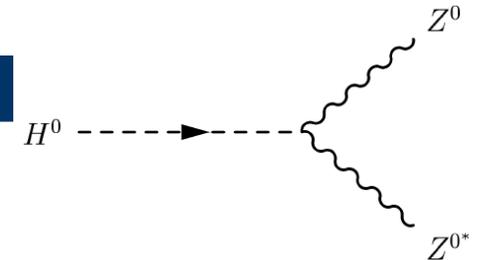
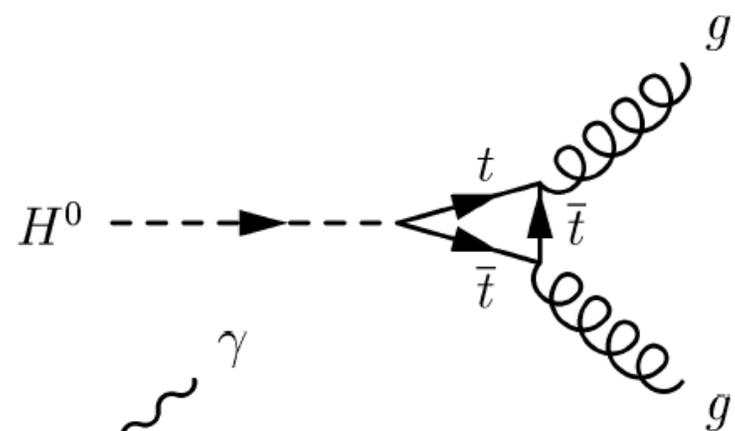
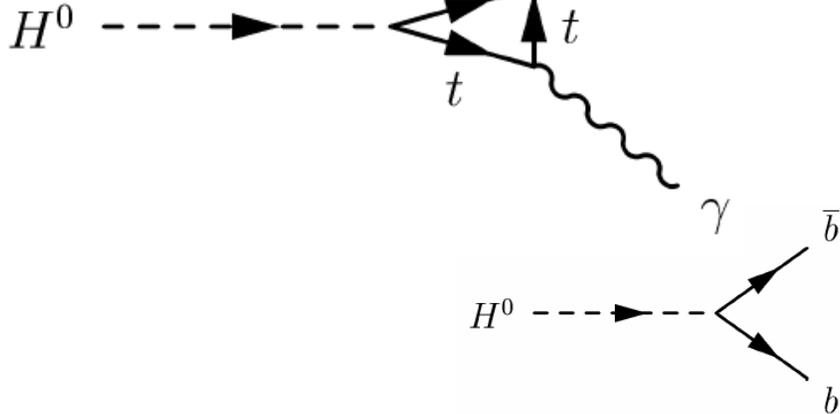
$$I = \Sigma_q Q_q^2 I_q + \Sigma_l Q_l^2 I_l + I_W + I_S,$$

$$I_q = 3[2\lambda_q + \lambda_q(4\lambda_q - 1)f(\lambda_q)],$$

$$I_l = 2\lambda_l + \lambda_l(4\lambda_l - 1)f(\lambda_l),$$

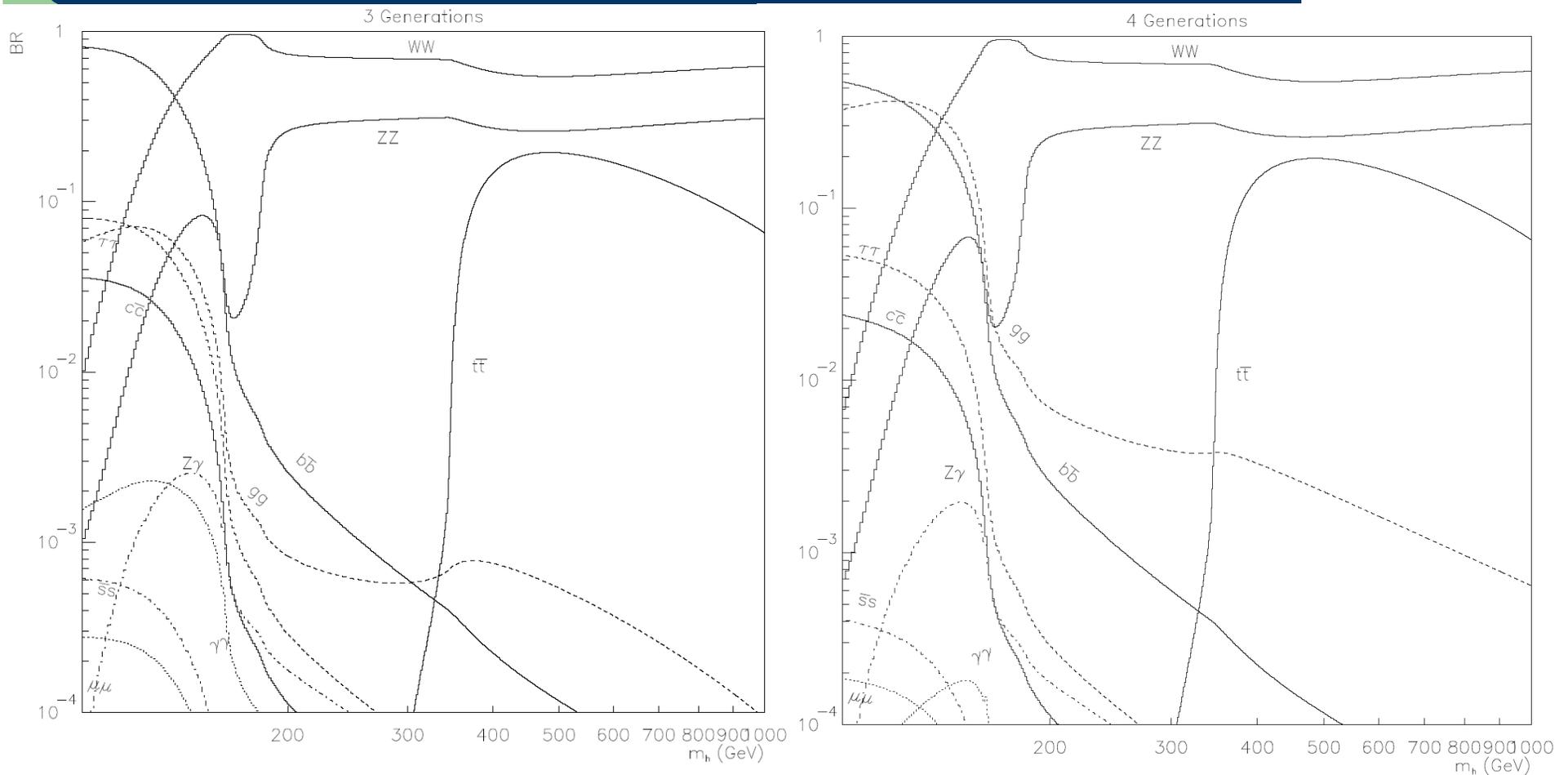
$$I_W = 3\lambda_W(1 - 2\lambda_W)f(\lambda_W) - 3\lambda_W - \frac{1}{2},$$

$$I_S = -\lambda_S[1 + 2\lambda_S f(\lambda_S)],$$



Branching Ratios in 3 & 4* SM family cases

* infinitely heavy degenerate masses

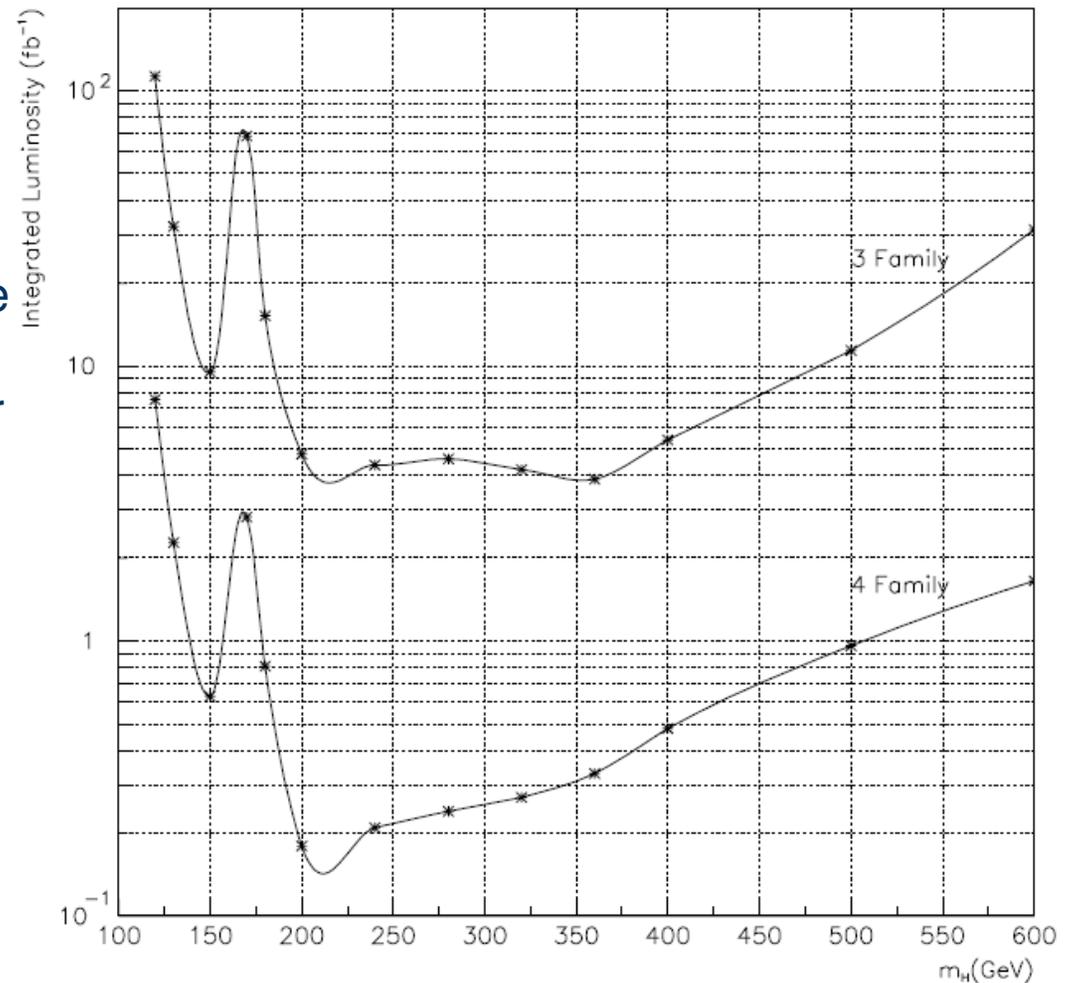




Golden mode and a few fb^{-1} is just enough for ATLAS

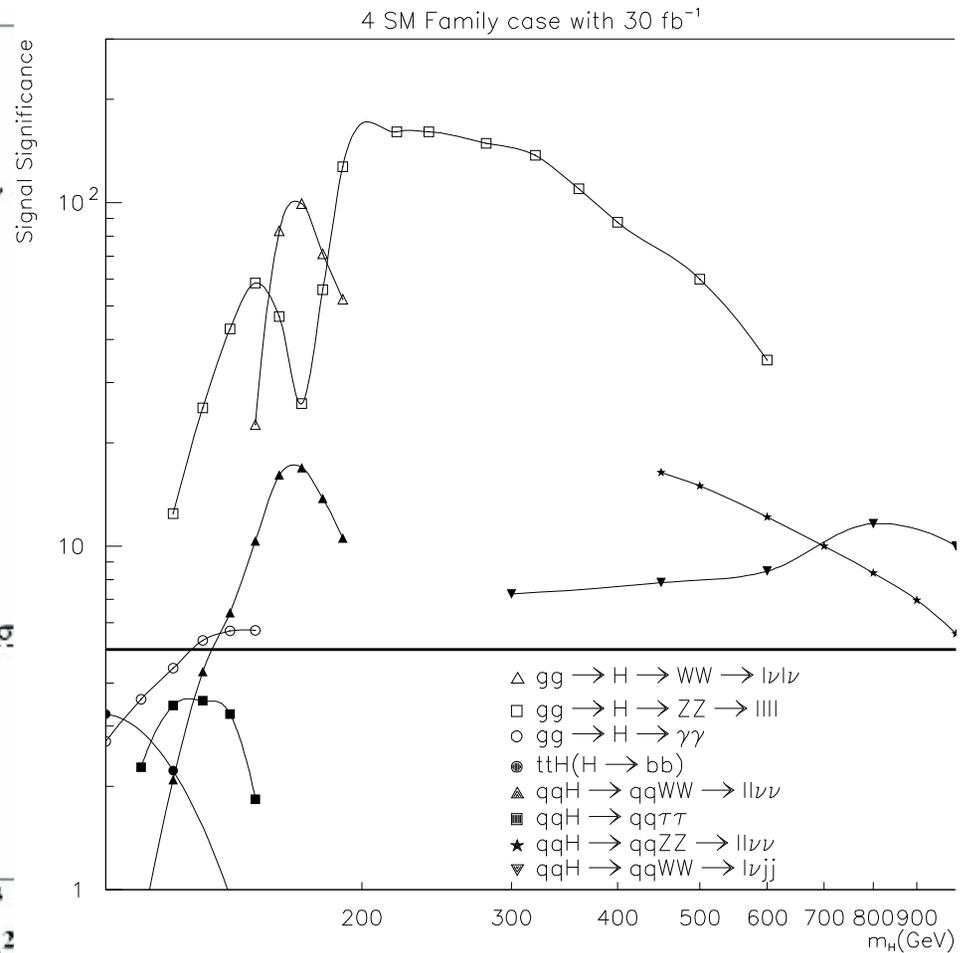
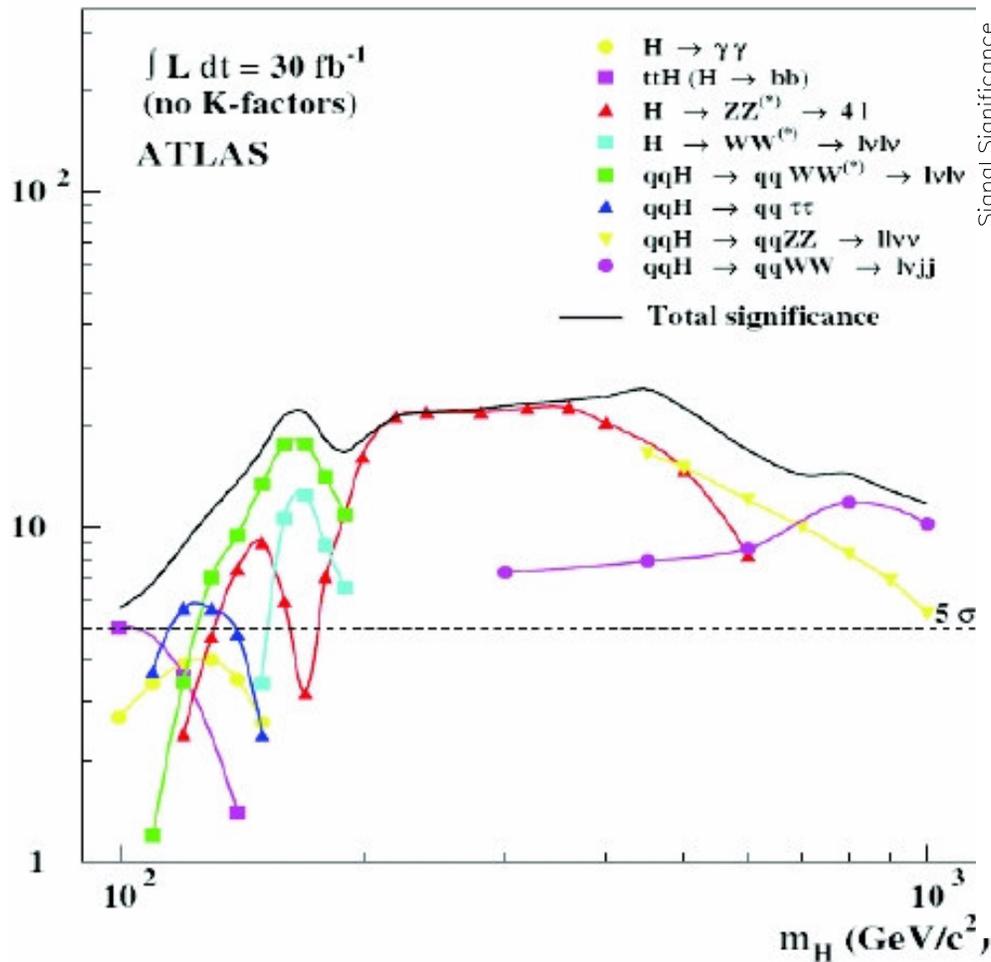
SN-ATLAS-2001-006 / EPJ-C 26 (2002) 9-11

LHC luminosity values corresponding to 5σ significance level of the golden mode ($H \rightarrow ZZ \rightarrow 4l$) signal at ATLAS for 3* and 4 family cases



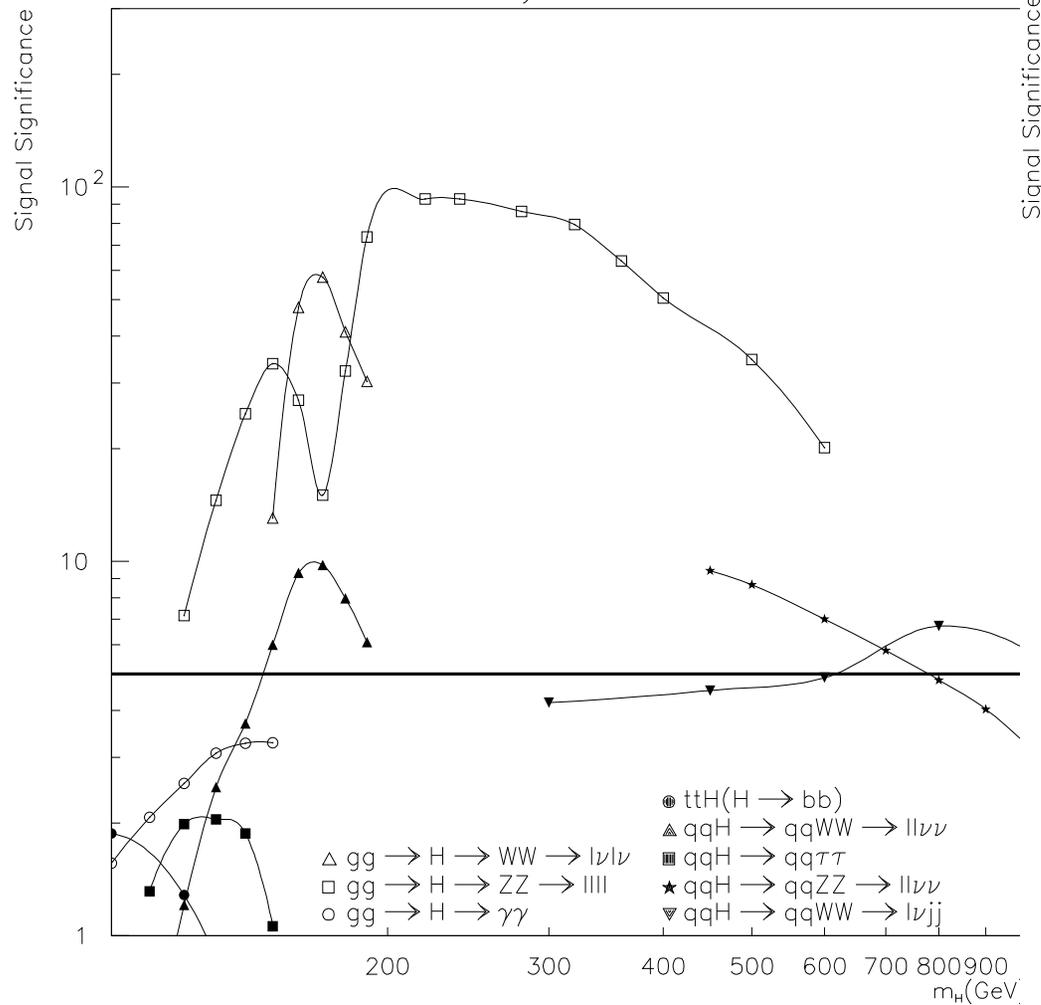
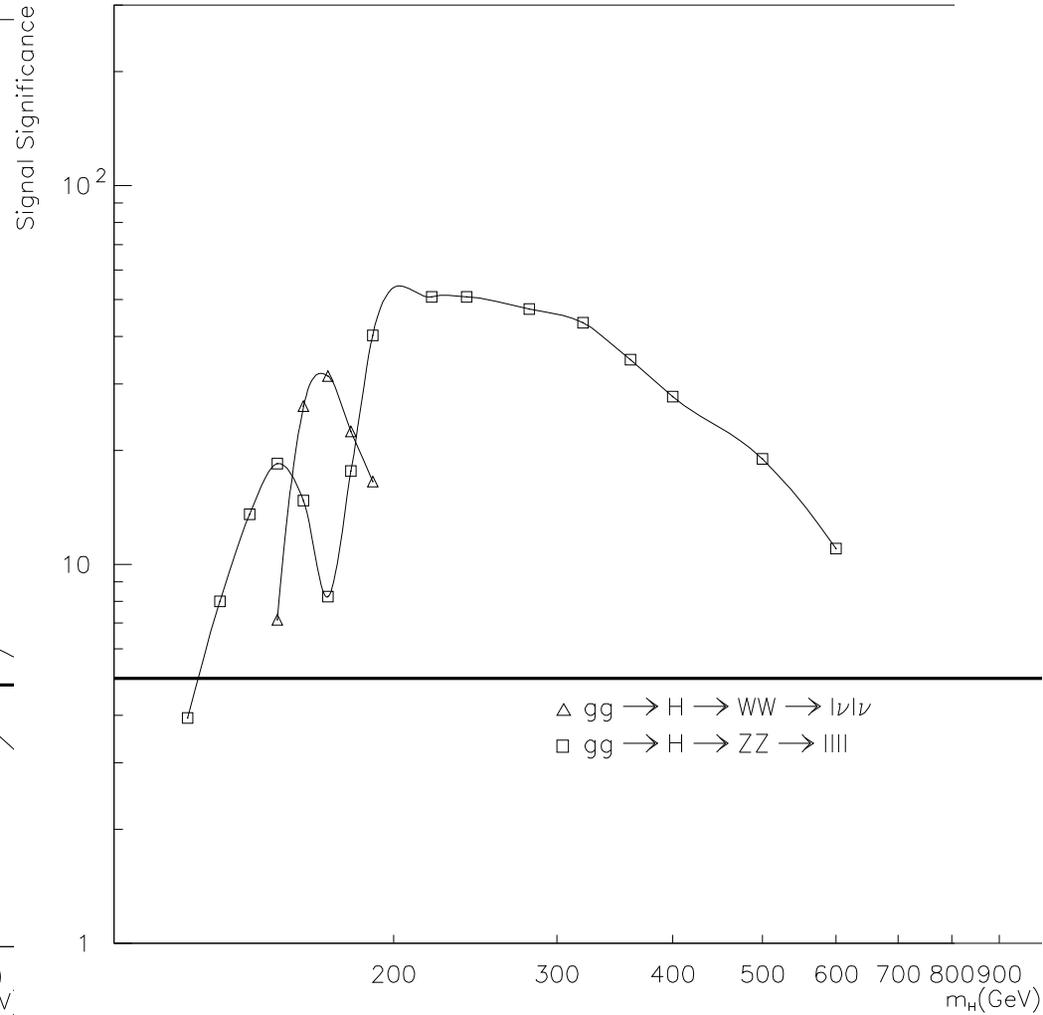


ATLAS sensitivity for the discovery of the SM Higgs boson (30 fb⁻¹)



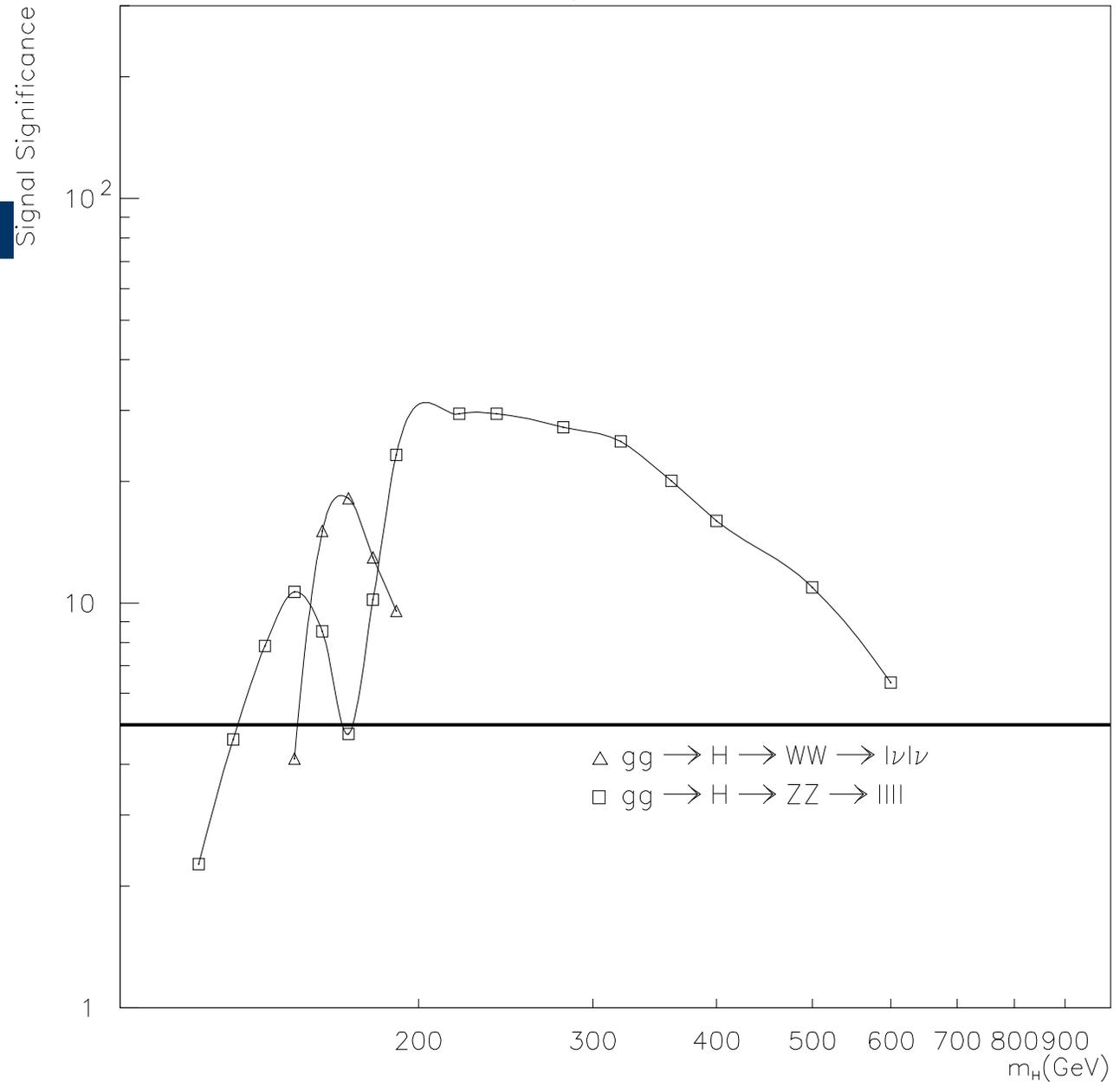


ATLAS sensitivity for the discovery of the SM Higgs boson (10 & 3 fb⁻¹)

4 SM Family case with 10 fb⁻¹4 SM Family case with 3 fb⁻¹

4 SM Family case with 1 fb^{-1}

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



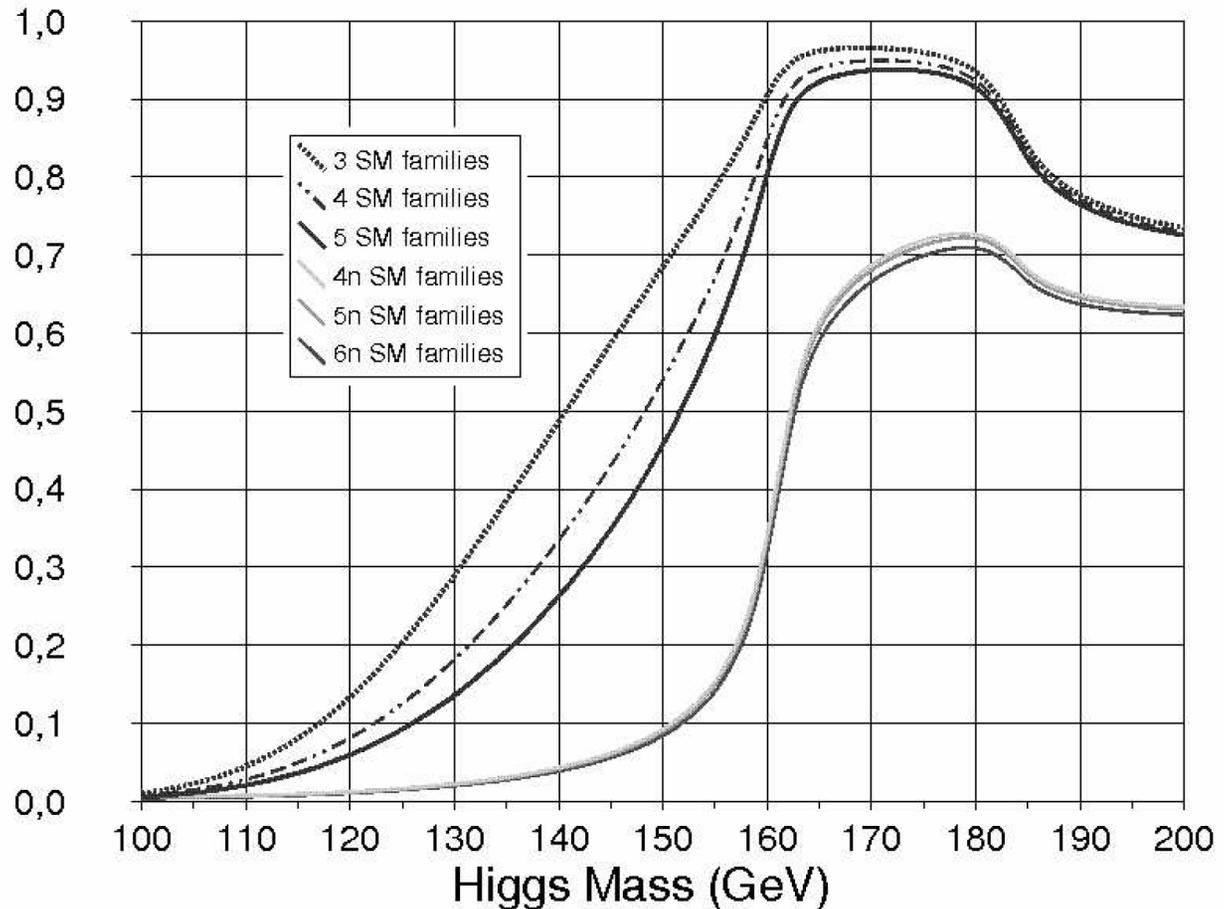


4th family effects on Higgs at the Tevatron

($H \rightarrow WW^{(*)}$ upto 200GeV)

Acta Phys.Polon.B37:2839-2850,2006

Branching Ratio of $H \rightarrow WW$ in different scenarios.

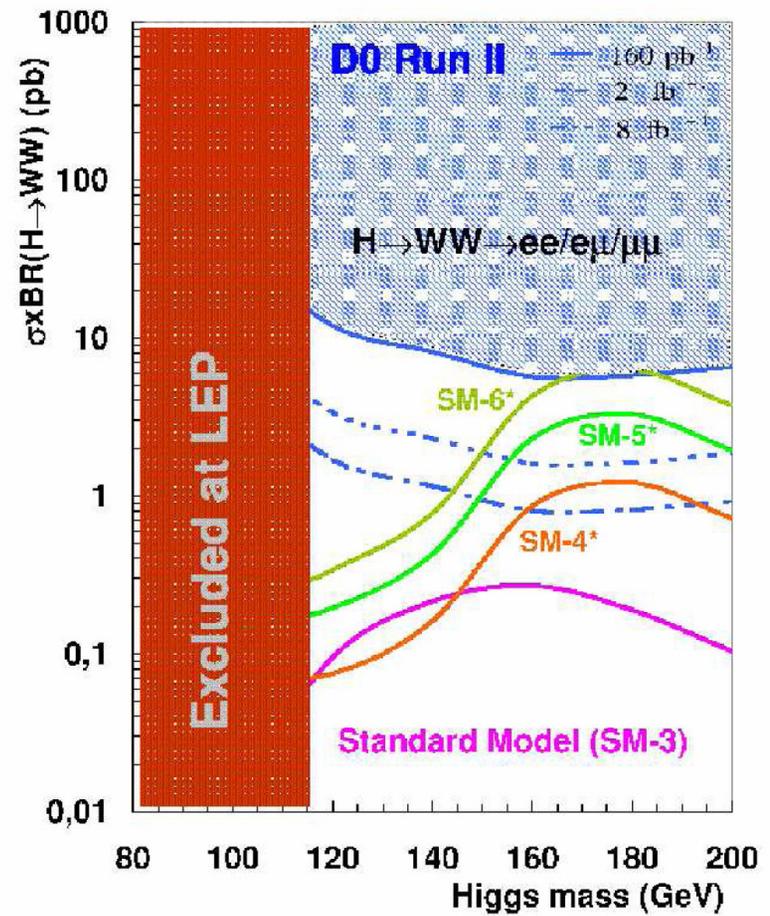
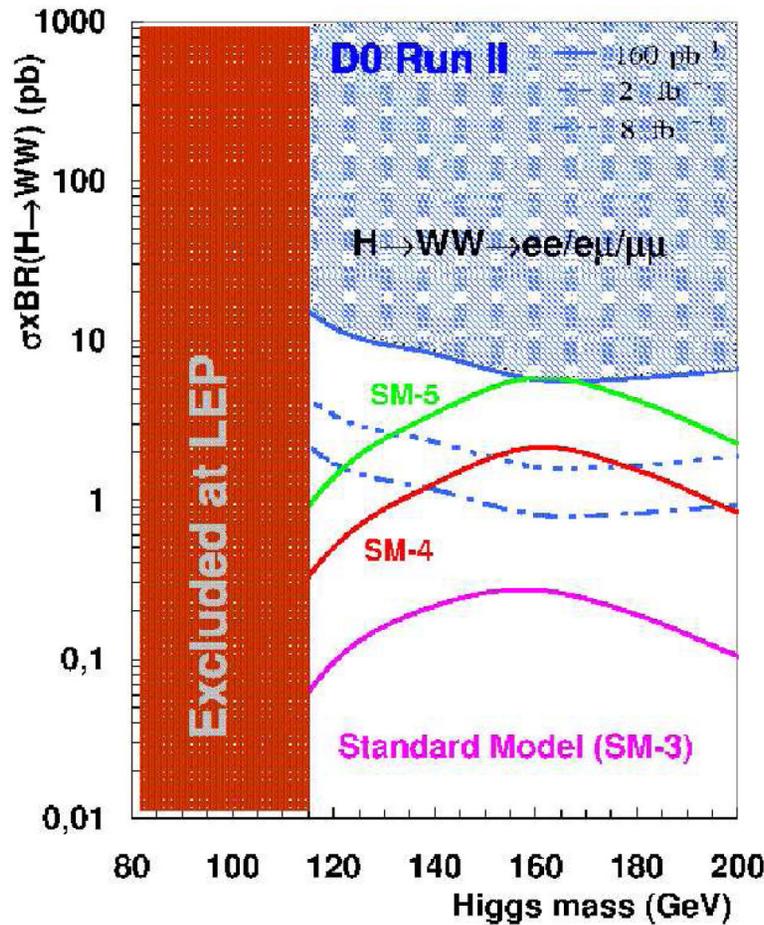




4th family effects on Higgs at the Tevatron

($H \rightarrow WW^{(*)}$ upto 200GeV)

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4th family limits at the Tevatron

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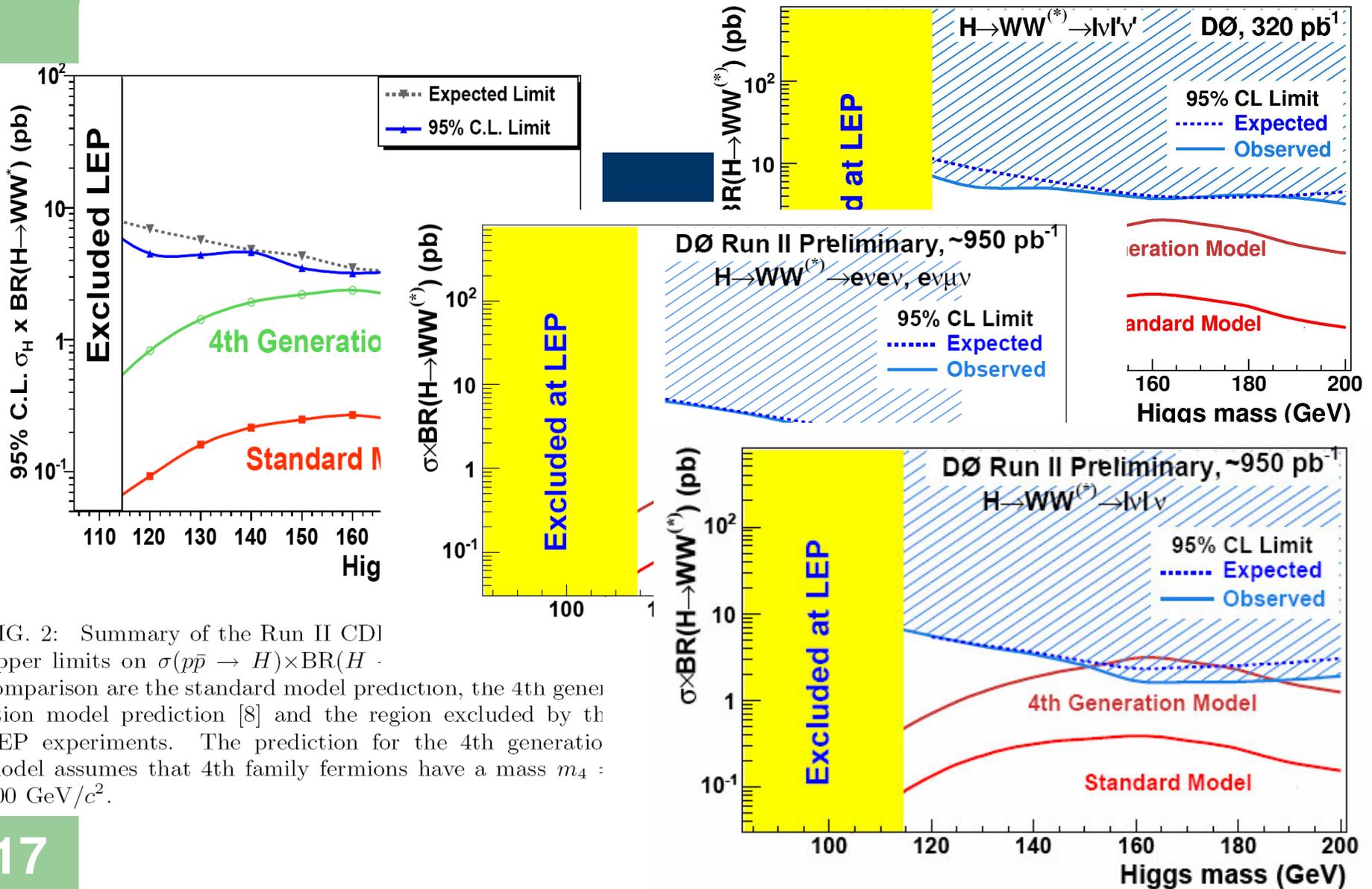
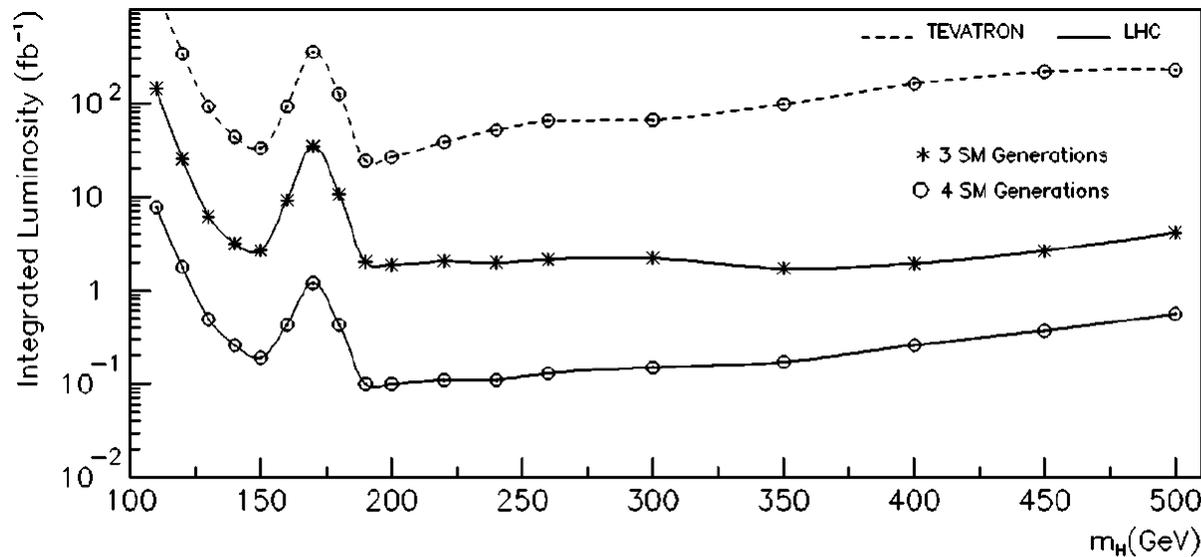


FIG. 2: Summary of the Run II CDL upper limits on $\sigma(pp \rightarrow H) \times BR(H \rightarrow WW^{(*)})$ (pb) versus Higgs mass (GeV). Comparison are the standard model prediction, the 4th generation model prediction [8] and the region excluded by the LEP experiments. The prediction for the 4th generation model assumes that 4th family fermions have a mass $m_4 = 200 \text{ GeV}/c^2$.

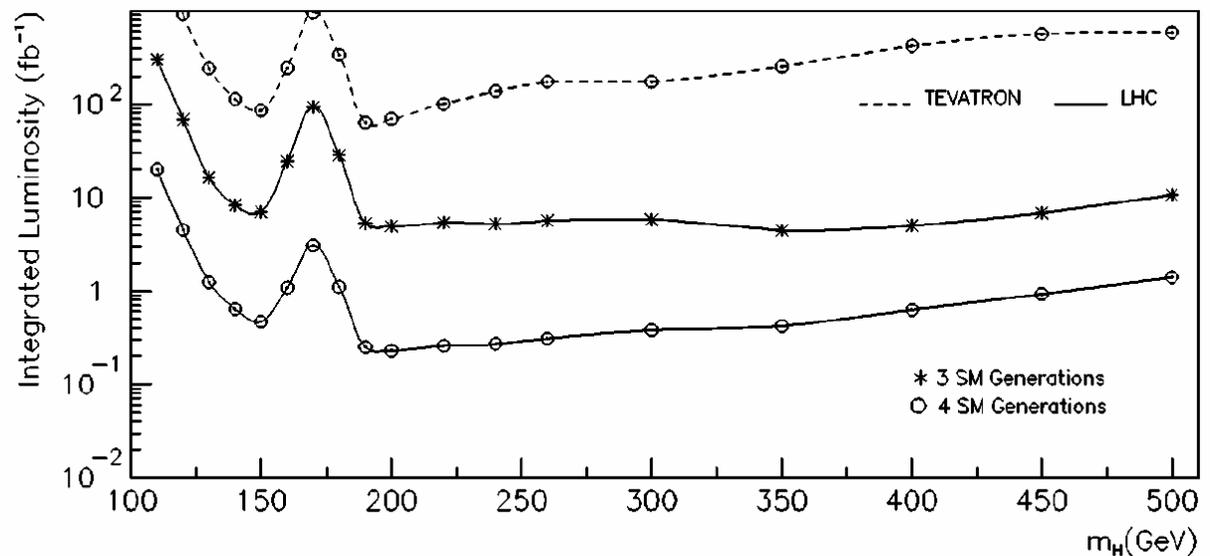


Comparing LHC with Tevatron in the golden mode

Luminosity needed to achieve 3σ significance for the golden mode



Luminosity needed to achieve 5σ significance for the golden mode





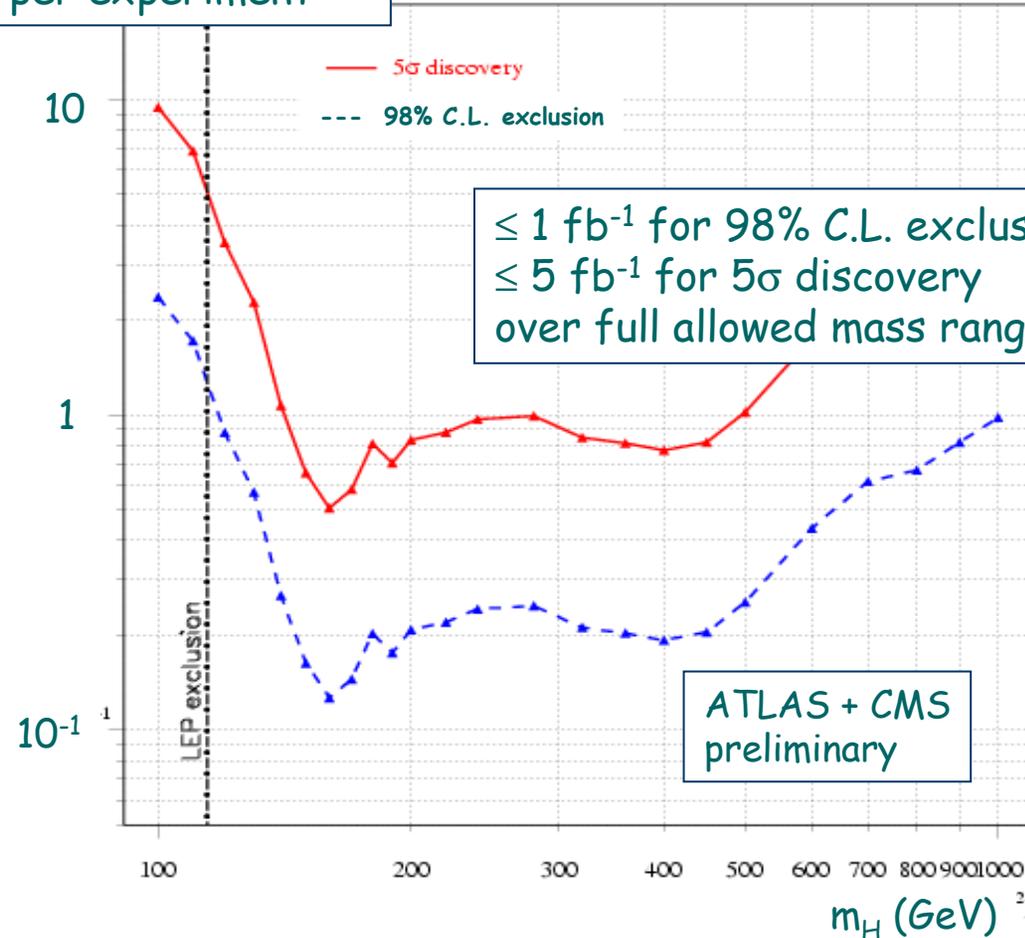
Combined analysis efforts at the LHC

F.Gianotti/ICHEP06 – A.Ball/ICHEP08

LHC must be ready to address any early discovery:

ratio of the two lines compare with consequence of a fourth family

Needed $\int L dt$ (fb^{-1}) per experiment





Conclusions

- Even with **a few fb^{-1}** , the golden mode covers almost all of the Higgs mass region at levels higher than **5σ** . This can result in a **double discovery** or fourth family **exclusion** cases for corresponding higgs mass regions.
- Whichever happens, it happens much earlier than any higgs signal we might see in the SM-3 case, and will become the one of the **first discovery/exclusion result** of the LHC.
- It is also an opportunity for the Tevatron to have the possibility of accessing Higgs masses otherwise not accessible.
- LHC experiments must be ready to address any early Higgs discovery