Higgs pair production in the bbWW channel

José Francisco Zurita (ITP, Univ. Zürich)

In collaboration with Andreas Papaefstathiou and Li Lin Yang

arXiv: 1206.XXYZ

CERN BSM Institute 2012, 26th June 2012

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PRELIMINARY

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Outline

- Motivation
- Cross sections and BRs
- Results
- Conclusions

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$$V = \frac{1}{2} m_h^2 \, h^2 + \lambda v h^3 + \frac{1}{4} \tilde{\lambda} h^4$$

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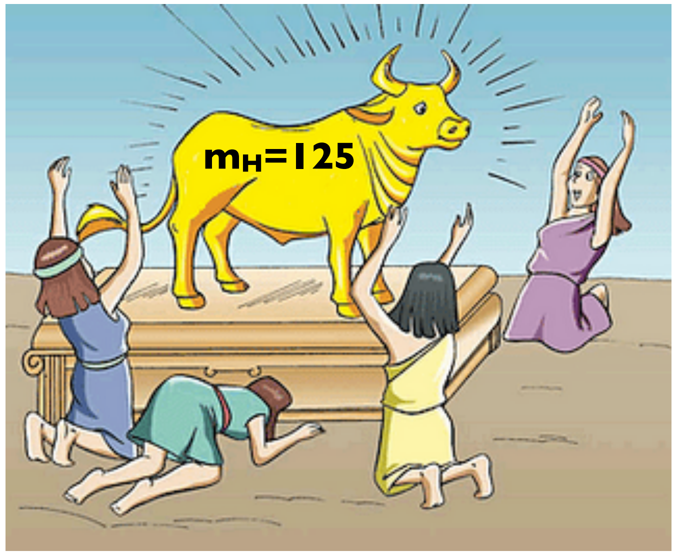
still early... lets not get carried away



A. Martin, PLHC 2012

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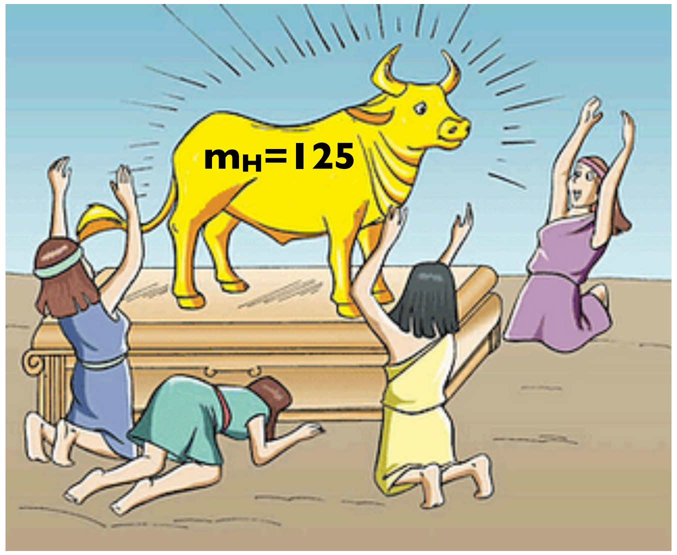

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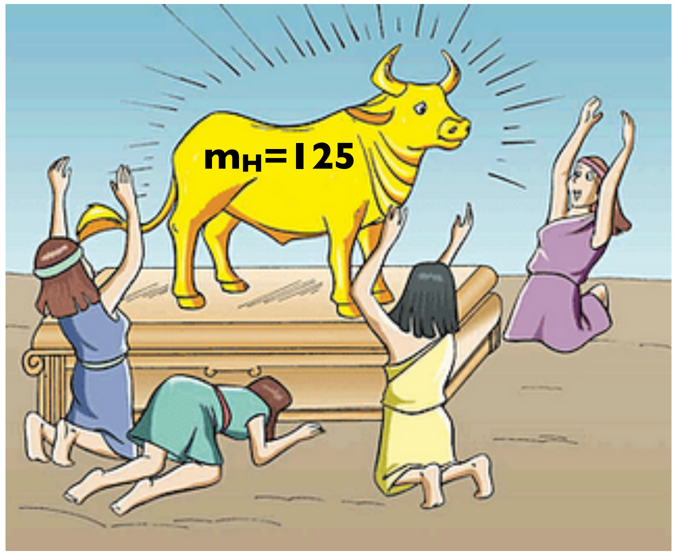

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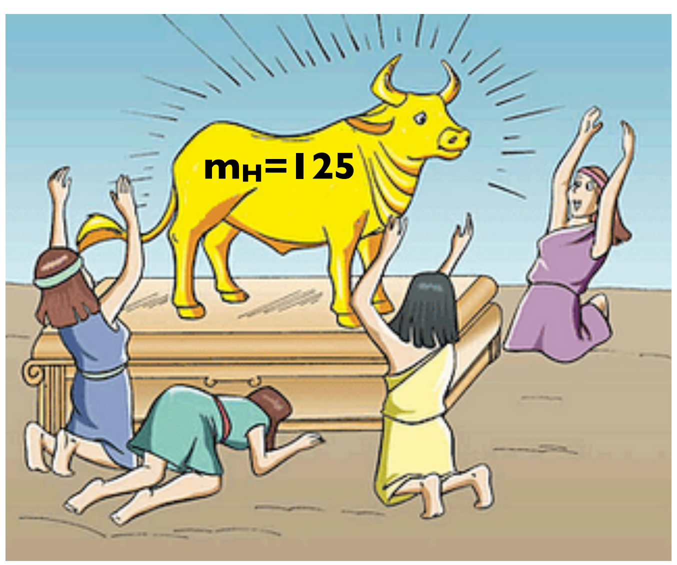

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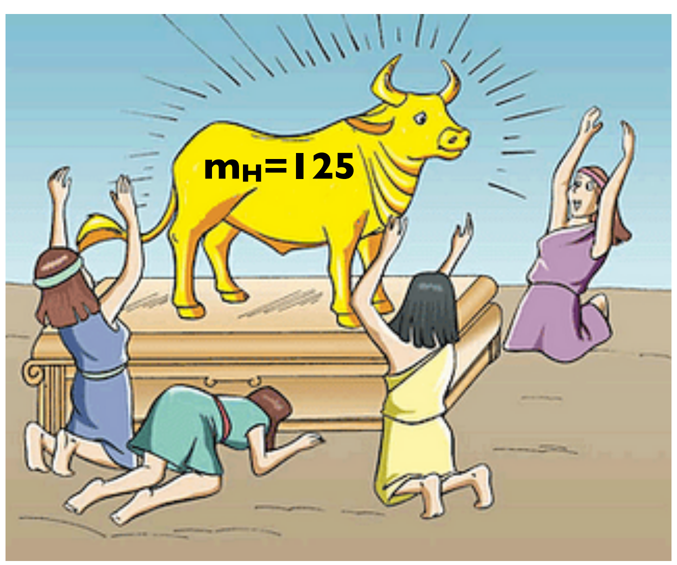

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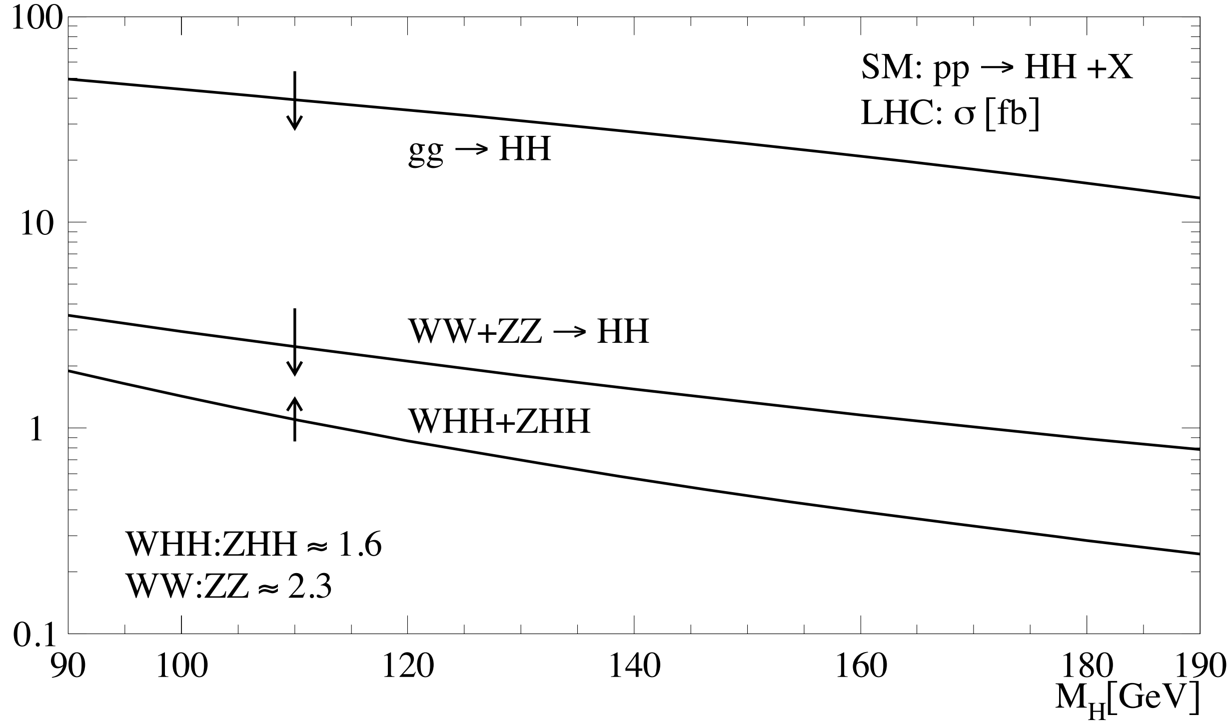
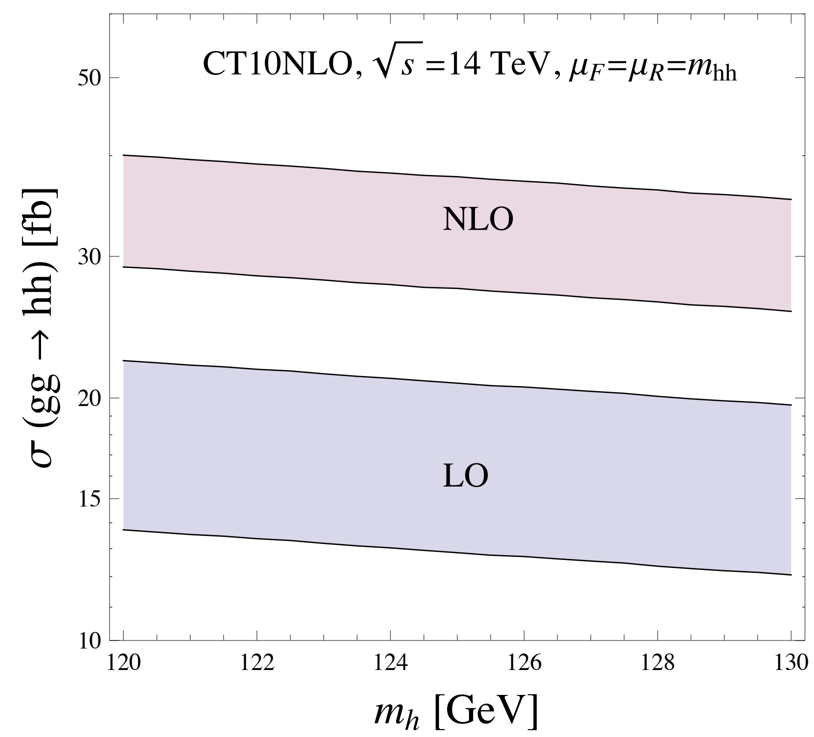
Cross sections and branching ratios

Cross sections @ LHC 14 TeV



Gianotti et al, Eur. Phys. J. C 39, 293 (2005) [hep-ph/0204087]



A. Papaefstathiou, L. L. Yang, JZ (in preparation)

Gluon fusion is dominant over the whole mass range.

Glover, van der Bij, Nucl. Phys. B **309**, 282 (1988); Plehn, Spira and Zerwas, Nucl. Phys. B **479**, 46 (1996), [Erratum-ibid. B **531**, 655 (1998)

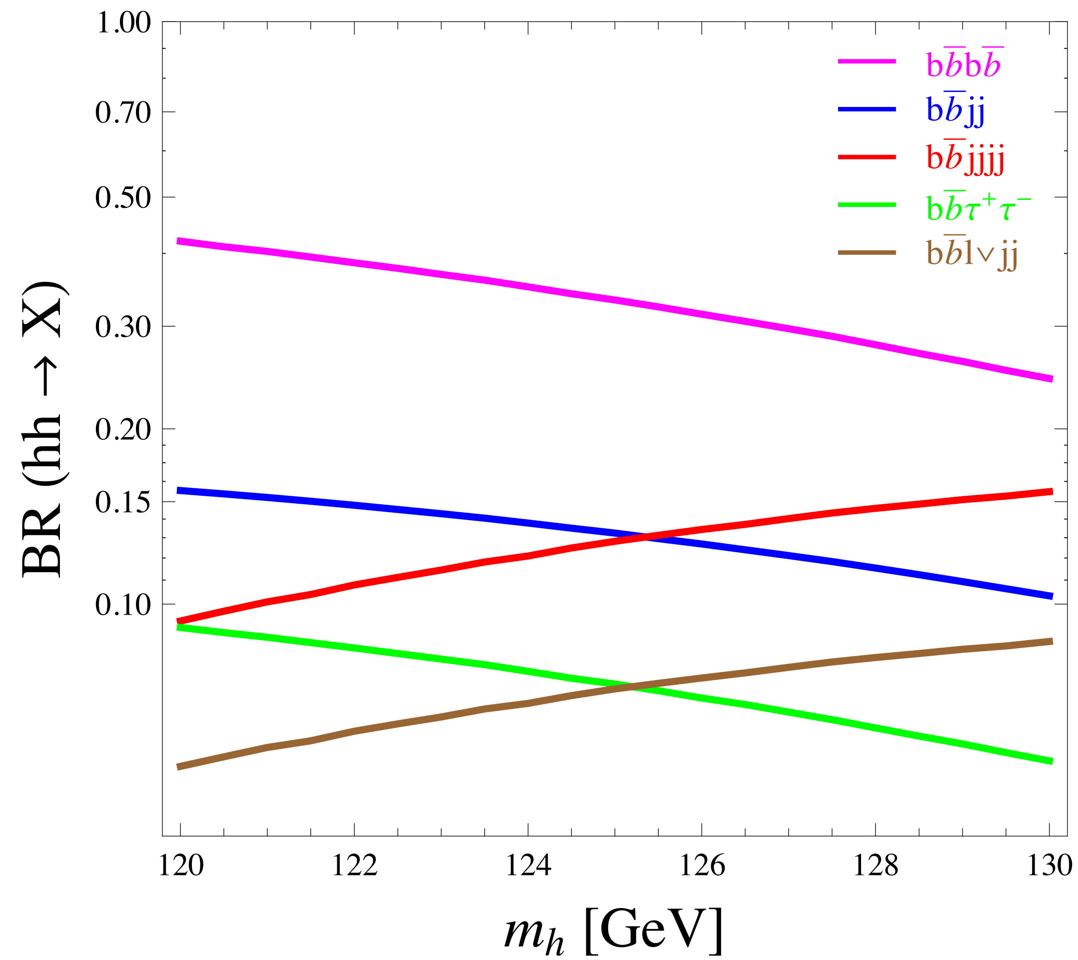
Focus in 120-130 GeV: other modes are 10% of GGF.

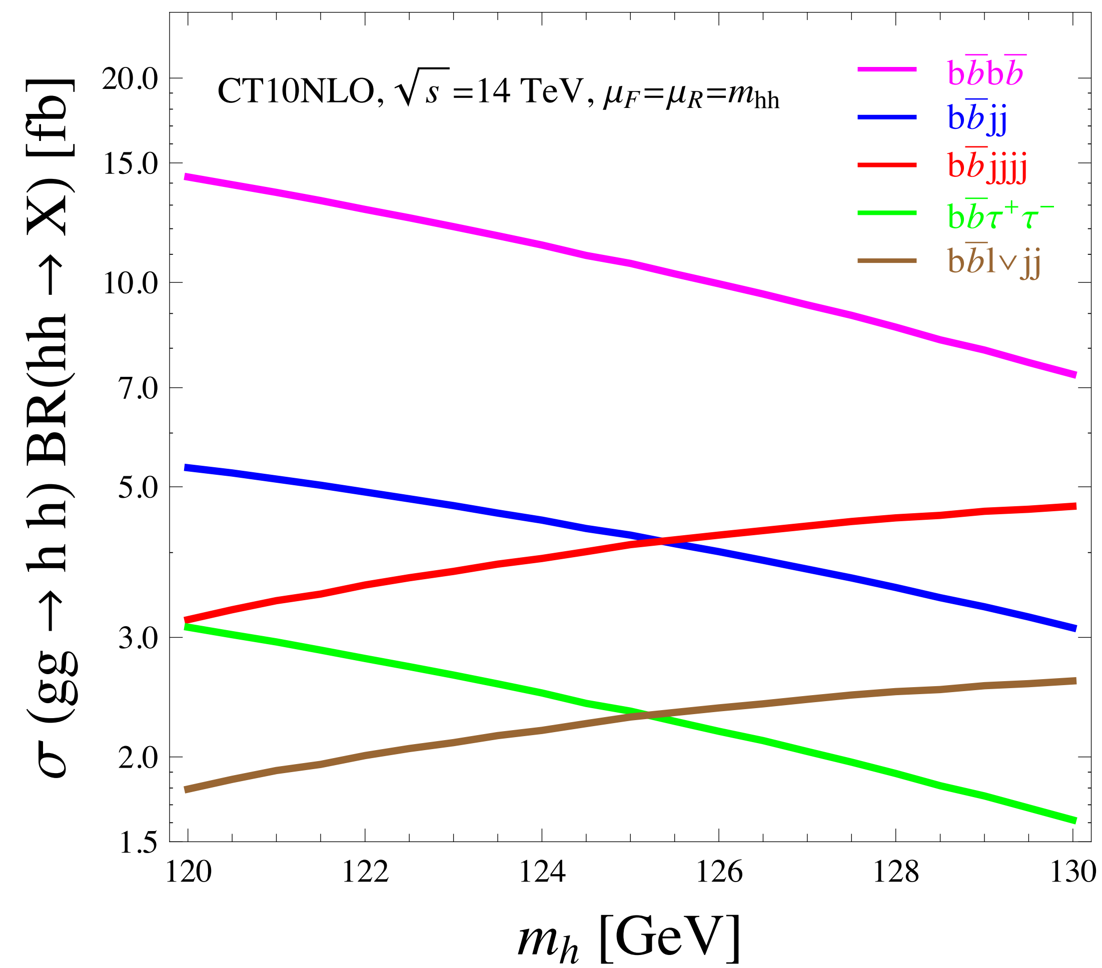
K-factor ~2 ; scale variation @ LO (NLO) 30 (20) %

Dawson, Dittmaier and Spira, Phys. Rev. D**58**, 115012 (1998)

Cross section computed with HPAIR (http://people.web.psi.ch/spira/hpair/)

Branching ratios and rates





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Hadronic decays dominate: semileptonic mode 7.5% @ 125 GeV

Total rate for $gg \to hh \to b\bar{b}W^+W^- \to b\bar{b}l\nu jj$ (before any cuts) 2.5 fb

If $b\bar{b}\tau^+\tau^-$ also feasible (as suggested by Dolan, Englert, Spannowsky) ~ 5 fb.

$b\bar{b}\gamma\gamma$ "most promising channel" S=6, B=11-14 with 600/fb.

Baur, Plehn, Rainwater PRD **69**, 053004 (2004)

Anatomy of the cross section

2 topologies, each with 2 Lorentz structures (1 and 2):

$$\sigma_{LO} = |\alpha_1 C_{tri}^{(1)} + \beta_1 C_{box}^{(1)}|^2 + \gamma_1^2 |C_{box}^{(2)}|^2$$

Our fit: $\sigma_{LO}[\mathrm{fb}] = \alpha_1^2\ 4.73 - \alpha_1\beta_1\ 22.93 + \beta_1^2\ 33.89 + \gamma_1^2\ 0.57.$ $\quad(\mathrm{SM}:\ 16.26)$

$$\sigma_{NLO}[\mathrm{fb}] = \alpha_1^2\ 9.19 - \alpha_1\beta_1\ 44.30 + \beta_1^2\ 65.95 + \gamma_1^2\ 1.17. \quad (\mathrm{SM}:\ 32.01)$$

NLO QCD can be reproduced by LO * K-factor (to an accuracy of 1%).

Desirable: BSM models that mitigate the box-triangle interference.

Results

Event generation

- Signal: MG5 (private model from R. Frederix)
- PDFs: CTEQ6L1 (LO) and CT10 (NLO)
- Shower and hadronization: HERWIG++
- Backgrounds: $t\bar{t}$ (HERWIG++) and W+ jets (ALPGEN)
- NLO Cross Section $t\bar{t}$: 890 pb, uncertainty 10%

Process	Initial cross section (fb)
$HH \to (b\bar{b})(\ell\nu_\ell q\bar{q}')$	2.516
$t\bar{t} \to (\ell\nu_\ell b)(q\bar{q}'b)$	258×10^3
$W(\to \ell\nu_\ell) + 3j$	$(277 \pm 28) \times 10^3$
$W(\to \ell\nu_\ell) + 4j$	$(368 \pm 2) \times 10^3$
$W(\to \ell\nu_\ell) + b\bar{b} + j$	$(0.83 \pm 0.06) \times 10^3$
$W(\to \ell\nu_\ell) + b\bar{b} + 2j$	$(0.41 \pm 0.05) \times 10^3$
$W(\to \ell\nu_\ell) + c + 2j$	$(67 \pm 5) \times 10^3$
$W(\to \ell\nu_\ell) + c + 3j$	$(17 \pm 3) \times 10^3$
$H + 2j$	$(1.31 \pm 0.01) \times 10^3$
$Hb\bar{b}$	(98.7 ± 0.1)
HWW	(145 ± 9)

light (charm) jet faking b-jet < 1 (10) %

b-tagging efficiency: 0.6

Main background: semileptonic $t\bar{t}$

Analysis

BDRS: Butterworth, Davison, Rubin, Salam, **Phys.Rev.Lett. 100 (2008) 242001**

- Fat jet: CA with $R = 1.2,\ p_{Tj} > 40$ GeV and $\mu = 0.667,\ y_{\rm cut} > 0.09$
- Filtering with $R_{filt} = \min(0.3, R_{b\bar{b}})$

Additional cuts

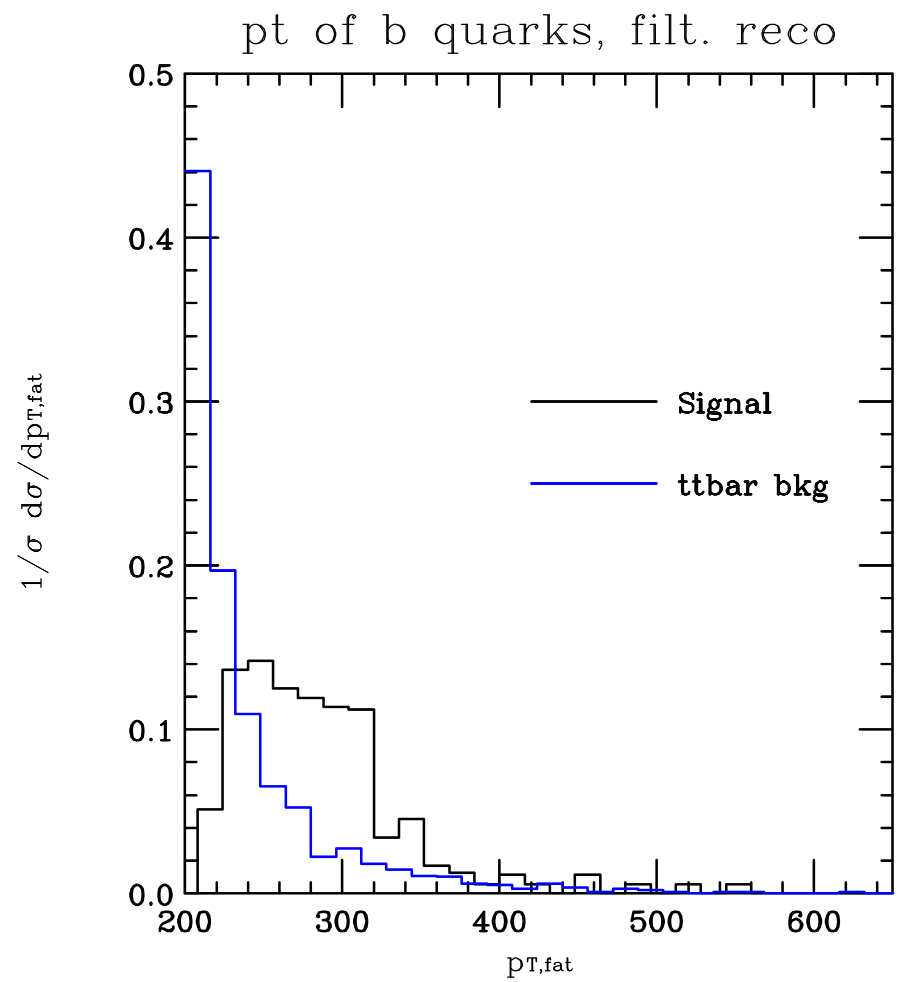
$p_T^l > 15$ GeV, at $R \geq \pi/2$ from the fat jet

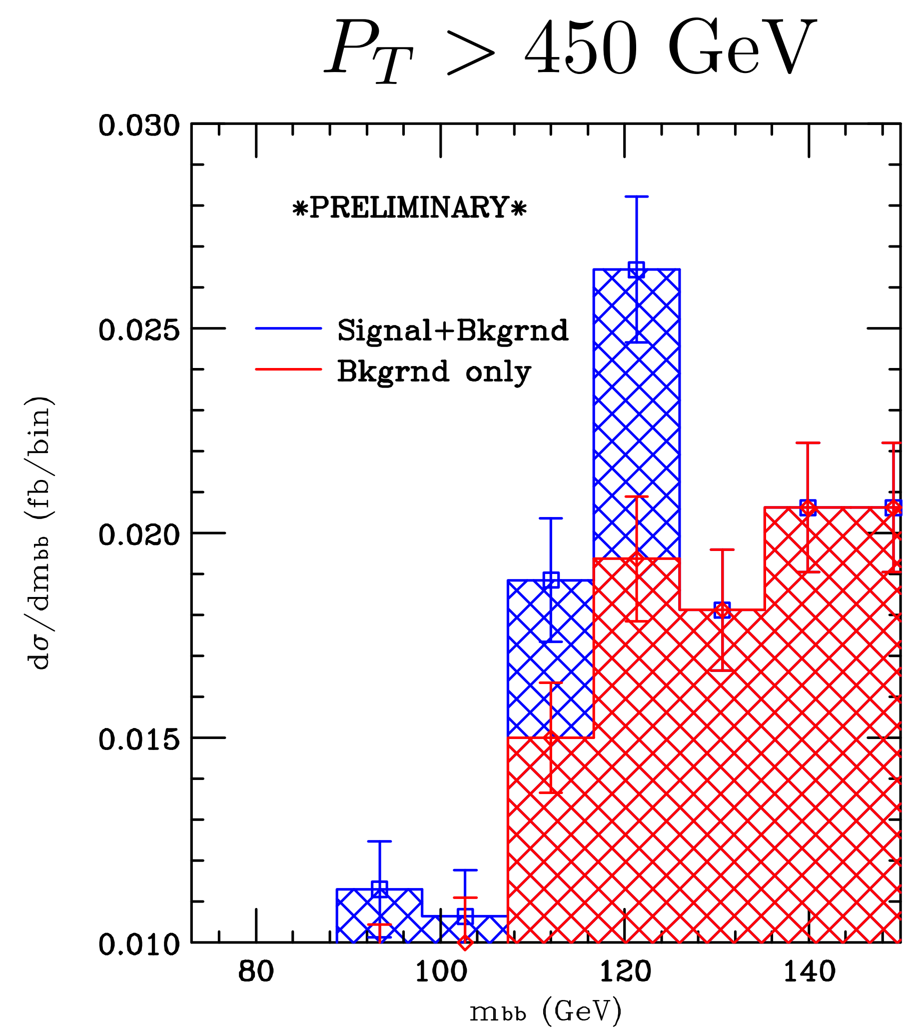
$\not{E}_T > 20$ GeV in $|\eta| < 5.0$

$\Delta R_{bb} \in (0.1, 0.8)$

$p_{T,\mathrm{fat}_1} > 450$ GeV, $p_{T,\mathrm{fat}_2} > 50$ GeV

Taming the tt background





A large cut (250-450) GeV reduces considerably the background.

Mbb mass window (115-135 GeV): 0.7 (signal), 0.14 (background).

We are still far from the optimal situation! (in 600/fb, S=4, B=10).

Conclusions

- We have studied the 14 TeV LHC reach of $gg \to hh \to b\bar{b}W^+W^- \to b\bar{b}l\nu jj$.

- This channel was discarded in previous studies due to large tt background.

- We obtain a significance of 2.8 with 3000 /fb of integrated luminosity.

  (compare to 3.6 in $b\bar{b}\gamma\gamma$)

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- Further improvements might be obtained combining several search channels (like $b\bar{b}\gamma\gamma, b\bar{b}\tau^+\tau^-$).

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