Combining NLO corrections to production and decay in the WH process

Zurich PhD seminar

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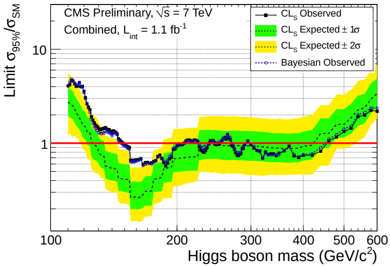
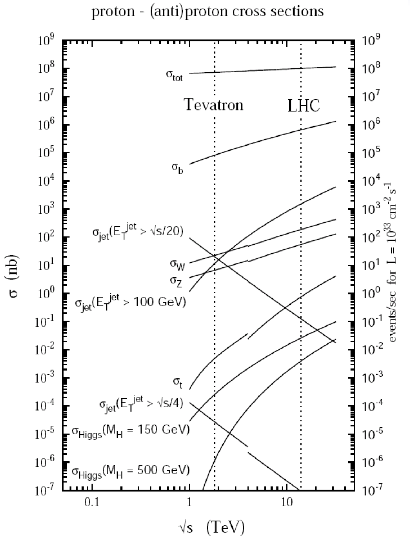
Outline

Why Higgsstrahlung?

- Low mass Higgs boson preferred ⇒ decays mostly to bottom quark pair.
- Issue : huge dijet background ⇒ look for boosted Higgs boson in Higgsstrahlung.





Search strategy

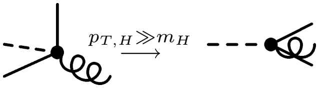
Jet substructure of fat jets

Seymour '94
Butterworth, Cox, Forshaw '08
Butterworth, Davison, Rubin, Salam '08

Boosted Higgs boson ($p_T \gg m_H$) decaying to bottom quark pair:

$$\Delta R_{b\bar{b}} = \sqrt{(\Delta y_{b\bar{b}})^2 + (\Delta\varphi_{b\bar{b}})^2} \simeq \frac{1}{\sqrt{z(1-z)}}\frac{m_H}{p_{T,H}}$$

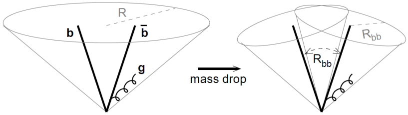
$\Rightarrow$ Higgs decay products end up in one fat jet.



Procedure

1. Apply Cambridge/Aachen jet algorithm with parameter R to recombine protojets $\rightarrow$ jets J.
2. For each jet $j \in J$:
   - 2.1 Decluster : $j \leftarrow (j_1, j_2)$ with $m_{j_1} > m_{j_2}$.
   - 2.2 Selection :

     If Massdrop : $m_{j_1} < \mu m_j$ and
     Symmetric splitting $\min(p_{T,j_1}^2, p_{T,j_2}^2)\Delta R_{j_1 j_2} > y_{cut} m_j^2$,
     Then j is a candidate and exit the loop,
     Else go to step 2.1 with j_1.
3. B-tagging : if j_1 and j_2 have b-tags, set $\Delta R_{b\bar{b}} = \Delta R_{j_1 j_2}$.



In the analysis : $R = 1.2$, $\mu = 0.67$ and $y_{cut} = 0.15$.

Filtering

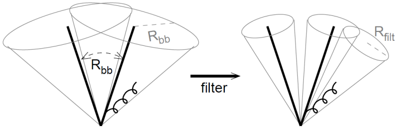
To reduce contamination from underlying event, the following filtering procedure is then applied :

- Redo clustering on the parents protojets of the candidate jet using $R_{filt} < R$: $j'_1, ..., j'_n$ ordered by p_T.

If j'_1 and j'_2 have b-tags,

Then return the invariant mass of the sum of $j'_1 + j'_2(+j'_3)$,

Else return 0.



In the analysis, $R_{filt} = \mathrm{min}(0.3, \Delta R_{b\bar{b}}/2)$.

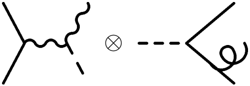
Motivation

- So far only checked with LO shower MC and MC@NLO for initial state radiation.
- Hard initial state QCD radiation effects in NNLO WH production for Higgs decay into bottom quarks at LO can be studied.
  Ferrera, Grazzini, Tramontano '11
- What about stability against final state radiation?

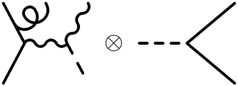
$\Rightarrow$ we study production and decay at NLO.

NLO Monte-Carlo

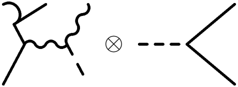
- The calculation is split in the channels:
  - LO production ⊗ LO+NLO decay



  - NLO qq production ⊗ LO decay



  - NLO qg production ⊗ LO decay



Virtual

- Dimensional regularization : $d = 4 - 2\varepsilon$
- Reduction to master integrals
- Evaluation of master integrals through Feynman parametrization and Wick rotation
- $\Rightarrow$ Laurent series in ε

Real

- Phase space parametrization to factorize singular propagators

$$\omega = \frac{\sqrt{s_{12}}}{2}(1-z) \qquad \lambda = \frac{1-\cos\vartheta}{2}$$

$$\to |\mathcal{M}|^2 d\Phi \sim \frac{F(z,\lambda)}{(1-z)^{1-2\varepsilon}\lambda^{1+\varepsilon}(1-\lambda)^{1+\varepsilon}}$$

- Partial fractioning
- Expansion in +-distributions

$$\frac{1}{x^{1+\varepsilon}} = -\frac{1}{\varepsilon}\delta(x) + \left(\frac{x^{-\varepsilon}}{x}\right)_+$$

$$\int_0^1 dx \left(\frac{x^{-\varepsilon}}{x}\right)_+ f(x) = \int_0^1 dx\, x^{-\varepsilon}\frac{f(x)-f(0)}{x}$$

- $\Rightarrow$ Laurent series in ε

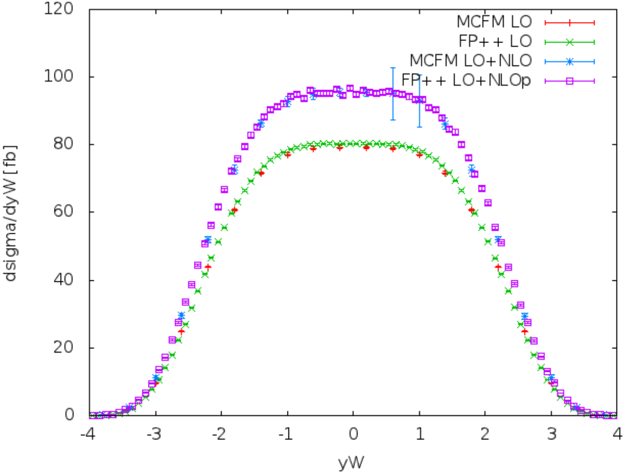
- Local substraction of singularities
- ⇒ Fully exclusive NLO MC (with stable W)
- Checked against inclusive WH NLO production cross section

Brein, Djouadi, Harlander '03

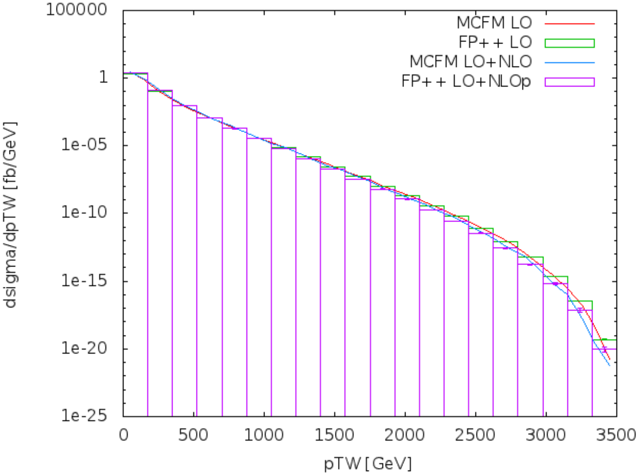
Analysis details

- Preliminary!
- Collider : LHC at $\sqrt{s} = 7\,\text{TeV}$
- PDFs : CTEQ6M, no PDF uncertainty
- Numerical integration : VEGAS from CUBA library Hahn '05
- Scales : $m_H = 120\,\text{GeV}$, $m_b = 4.24\,\text{GeV}$, $\mu_R^P = \mu_F^P = m_W + m_H$, $\mu_R^D = m_H$.
- W boson stable
- Interfaced with FastJet Cacciari, Salam, Soyez '06

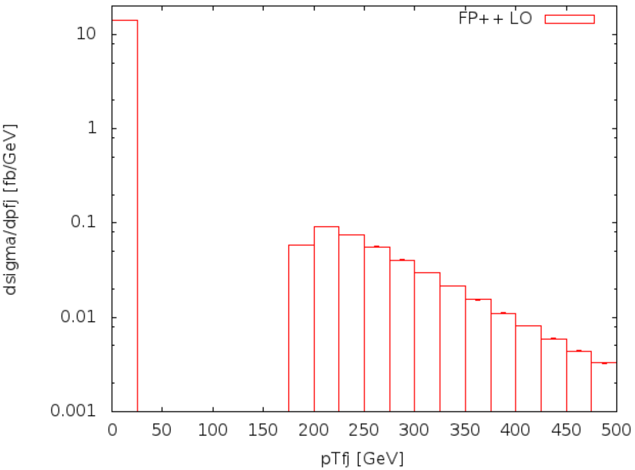
Control distribution : W rapidity (inclusive)



Control distribution : W transverse momentum (inclusive)



Higgs candidate transverse momentum (inclusive)



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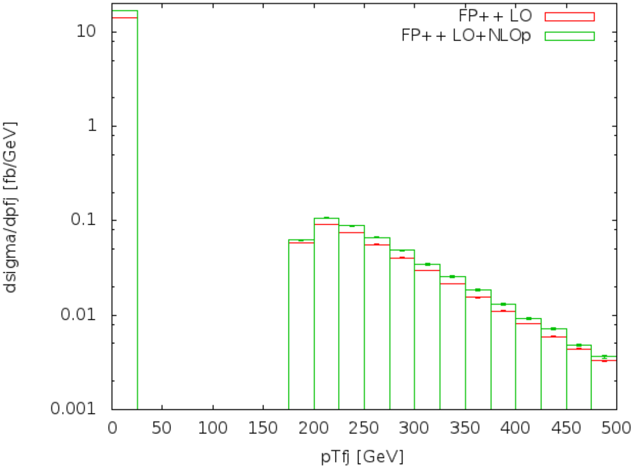

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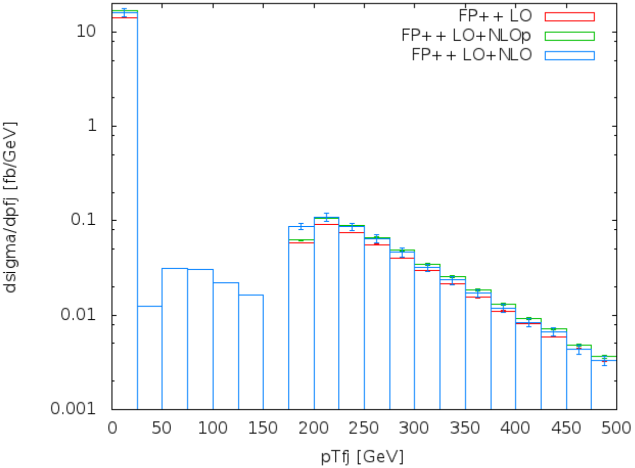
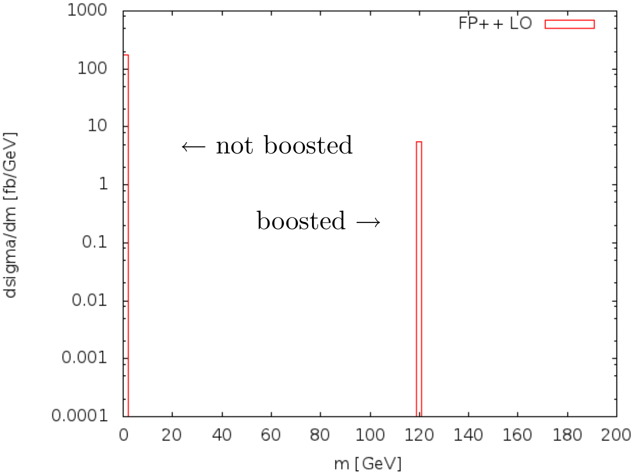


Higgs candidate invariant mass (inclusive)



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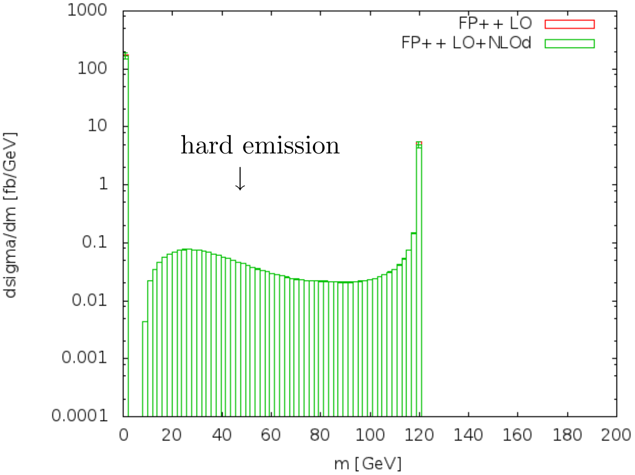

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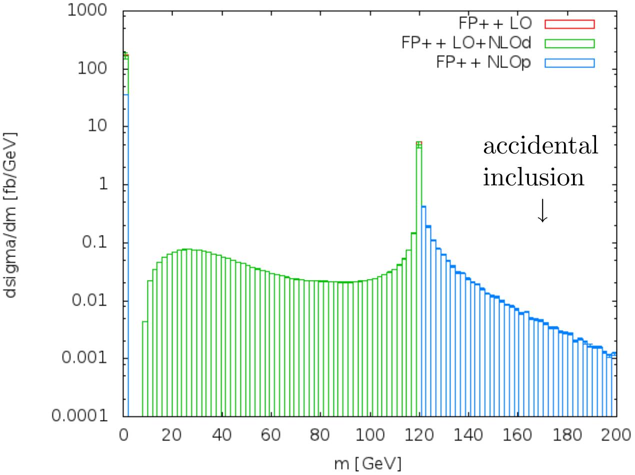

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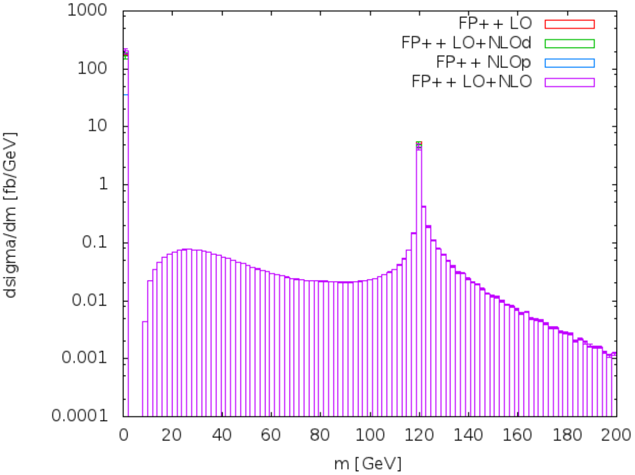
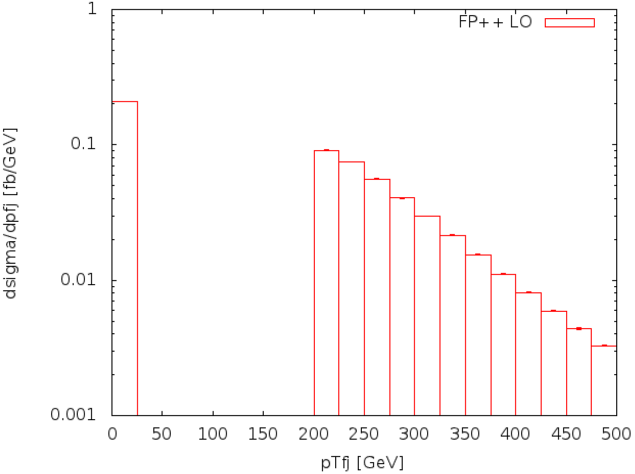


Higgs candidate transverse momentum ($p_T(W) \geq 200$ GeV)



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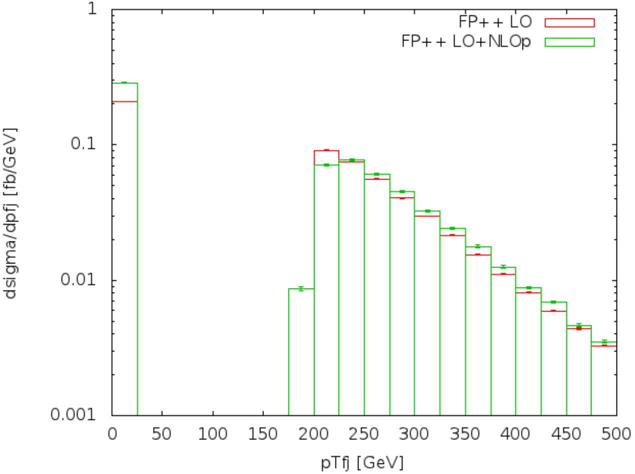

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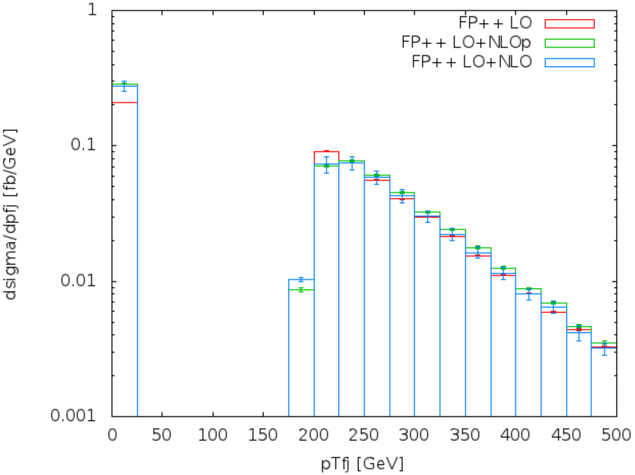

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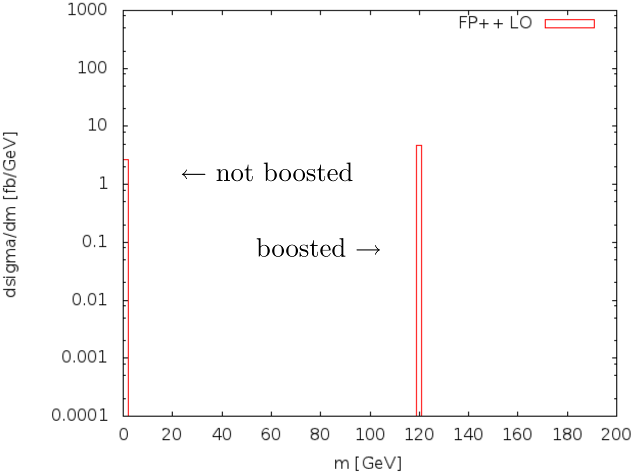

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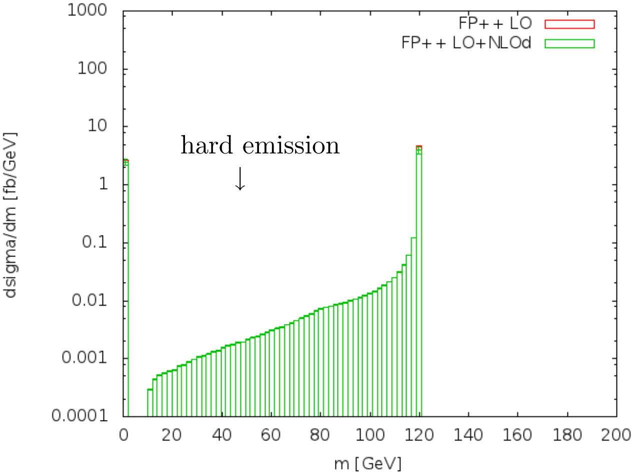

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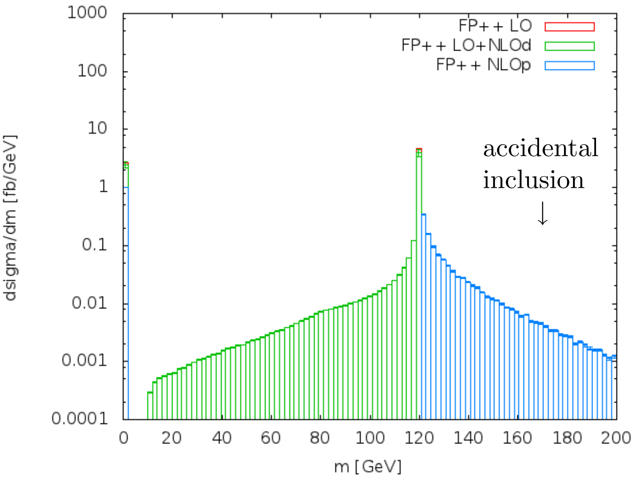

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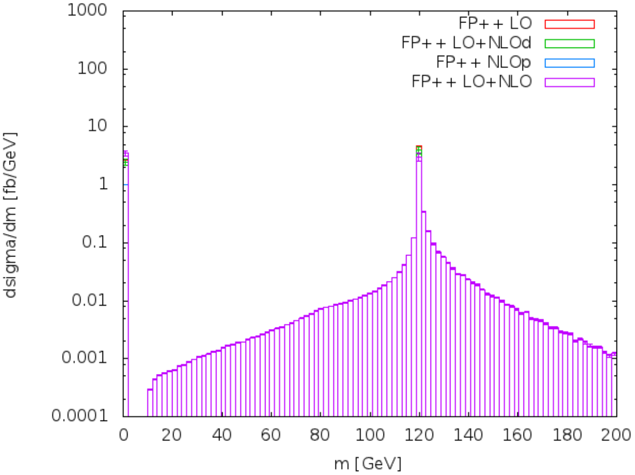

- Preliminary study of the effect of initial and final state radiation on the boosted jet analysis at NLO for the WH process with decay to bottom quarks : Procedure is stable against NLO corrections.
- Perspectives :
  - Include leptonic decay of the W boson and realistic cuts
  - Include ZH channel with charged-lepton decay and cuts
- Program structure adapted for extensions :
  - Interface with parton shower
  - Hadronic decay of W and Z bosons
  - Inclusion of NNLO Higgstrahlung production
  - Inclusion of NNLO Higgs boson decay