Higgs production by Gluon initiated Weak Boson Fusion

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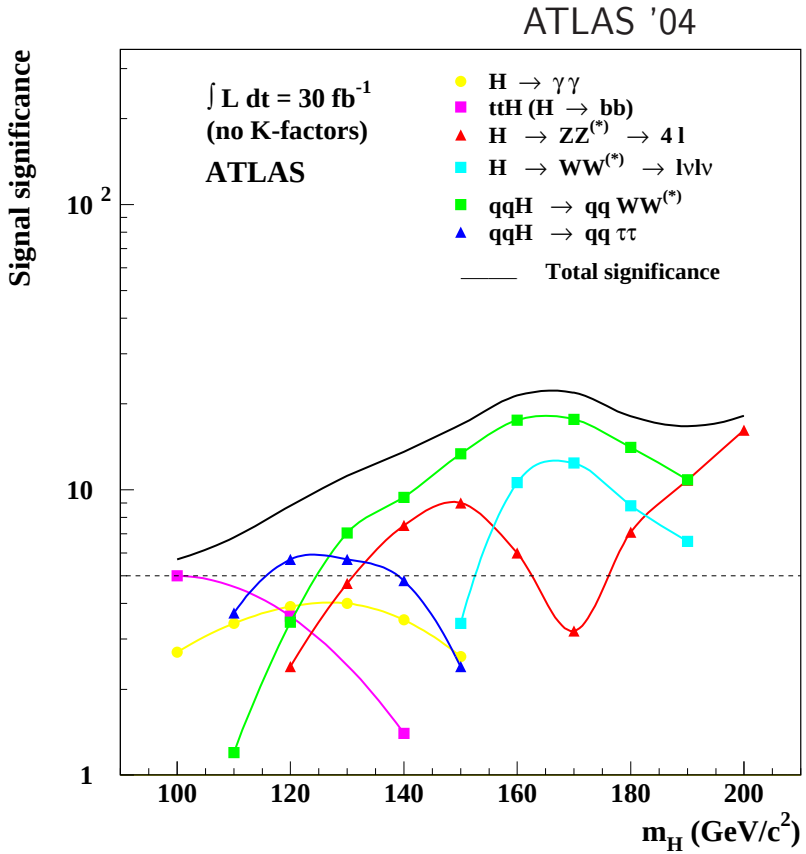
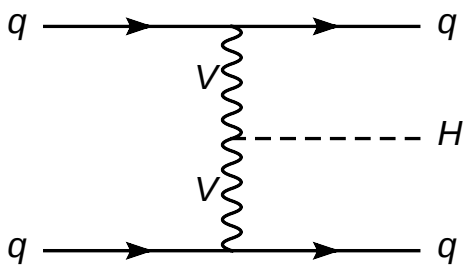
Higgs discovery at LHC



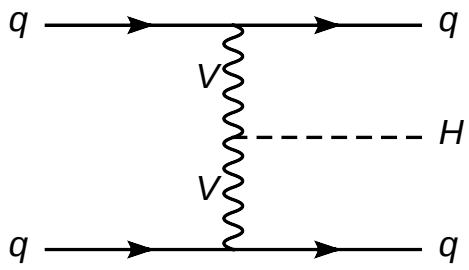
Weak Boson Fusion: $\mathbf{qq' \to qq'H}$



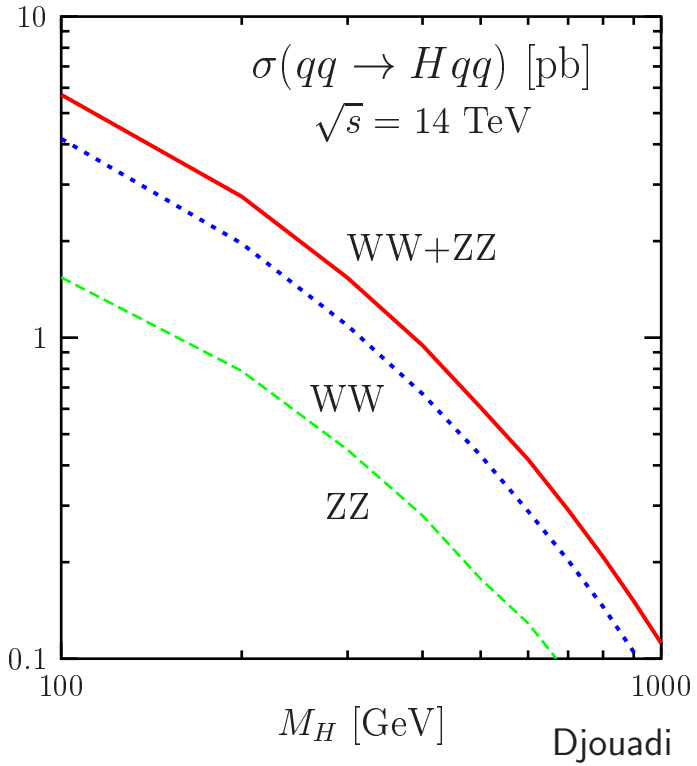
- important Higgs discovery mode at LHC
- allows measurement of HVV couplings

$\longrightarrow$ precise predictions for WBF necessary

Weak Boson Fusion



leading order cross section at LHC



WBF characteristics

- t-channel W/Z exchange
  $\longrightarrow$2 jets at high rapidities
- no color exchange
  no central hadronic activity
- H decay products at low rapidities

QCD background

- much jet activity in central detector region

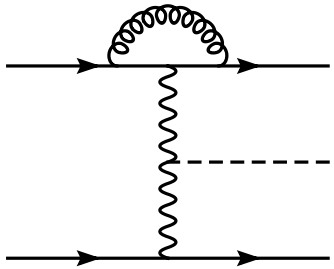
$\longrightarrow$ suppression of WBF background possible

Weak Boson Fusion at NLO

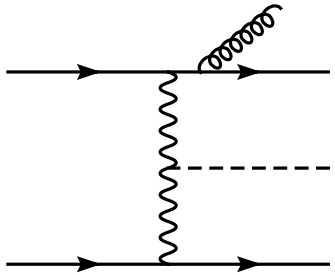
QCD corrections

- total rates [Han, Valencia, Willenbrock '92] [Djouadi, Spira '00]
- distributions [Figy, Oleari, Zeppenfeld '03] [Barger, Campbell '04]

virtual corrections



real corrections

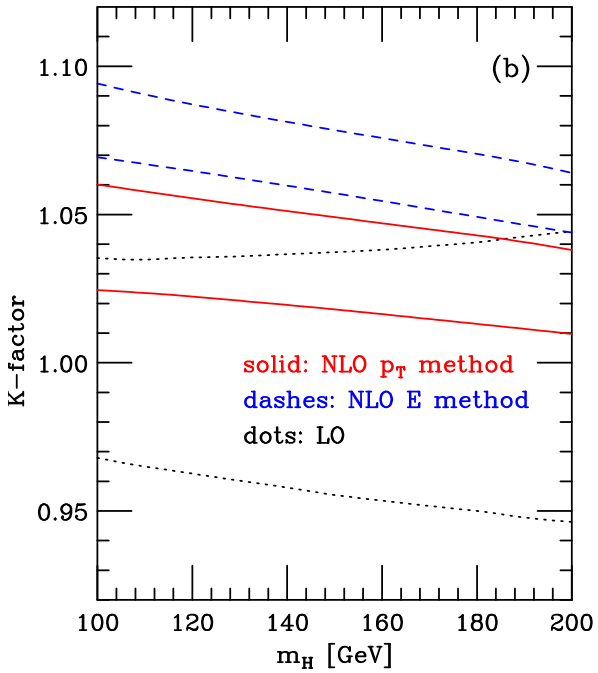


- no color exchange
  - $\longrightarrow$ only corrections to structure functions
  - $\longrightarrow$ read radiation in forward/backward region

$\Rightarrow$ distinctive kinematics not changed at NLO

- size: $+5 \ldots 10\%$
- scale uncertainty $\sim 2\%$

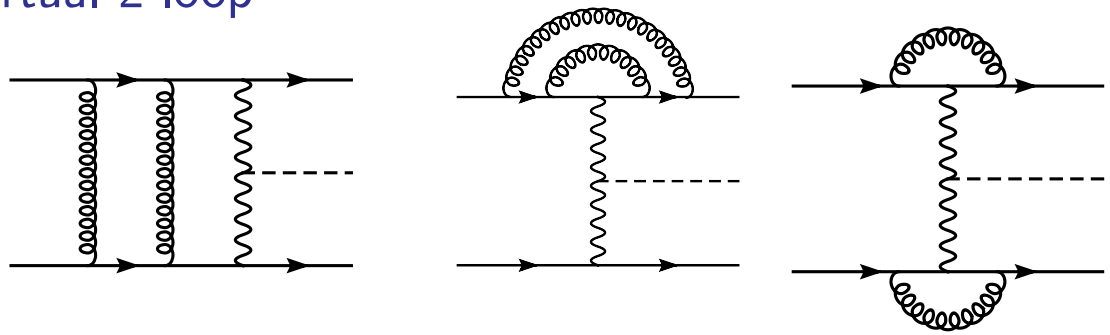
NLO K-factor at LHC



Figy,Oleari, Zeppenfeld

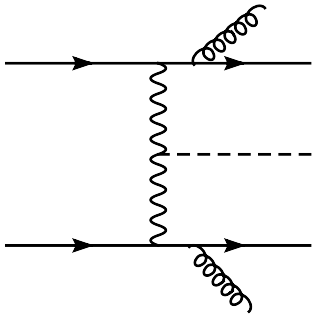
Weak Boson Fusion at NNLO

virtual 2-loop



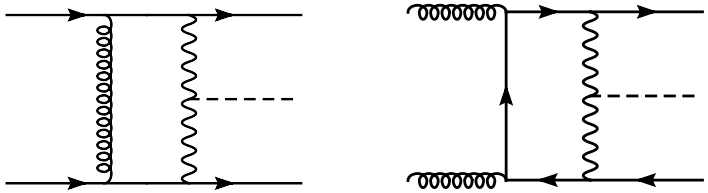
vertex corrections

real radiation



$\longrightarrow$ no color exchange

$(\text{1-loop})^2$



$\longrightarrow$ color exchange

gluon induced processes $gg \longrightarrow q\bar{q}H$

leading order, loop induced

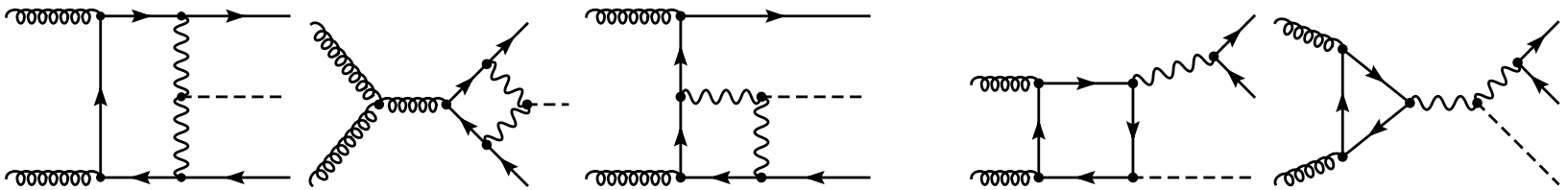
finite, gauge invariant

$\longrightarrow$ this talk

$gg \to q\bar{q}H$

consider: $gg \to q\bar{q}H$ and crossed processes ($q\bar{q} \to ggH$ and $qg \to qgH$)

sample diagrams for $gg \to q\bar{q}H$



non-resonant

resonant Z

external quarks: sum over 5 light flavours, taken as massless

diagrams with resonant Z boson

- resonant and nonresonant diagram sets separately gauge invariant
- resonant diagrams: $gg \to HZ^* \to Hq\bar{q}$
  $\to$ NNLO corrections to Higgsstrahlung
  suppressed by WBF cuts on invariant jet-jet mass
  $\to$ exclude, use only non-resonant diagrams

initial state radiation diagrams

amplitude diverges for soft or collinear final state quarks
$\to$ real corrections to $\bar{q}g \to \bar{q}H$
require 2 non-collinear well separated hard jets using cuts $\to$ finite cross section

Calculation

- 't Hooft-Feynman gauge
- generation by FeynArts
- evaluation using Mathematica / FormCalc
  $\longrightarrow$ standard matrix elements and coefficients containing tensor loop integrals
  $\longrightarrow$ translation to C++ code for numerical evaluation
- tensor loop integrals
  3/4 point integrals: Passarino-Veltman reduction
  5 point integrals:
  numerical instabilities from inverse Gram determinants in tensor reduction
  $\longrightarrow$ alternative reduction avoiding leading inverse Gram determinants
  [Denner, Dittmaier '02]
  already used in: $e^+e^- \to \nu\bar{\nu}H$, $e^+e^- \to t\bar{t}H$, $e^+e^- \to 4f$,
  $H \to 4f$, $pp \to t\bar{t}j$
  using loop integral library by A. Denner
- phase space integration: VEGAS
  distributions possible

Checks and Cuts

checks of the calculation

- finiteness

  no UV,IR,collinear divergences in full amplitude

- gauge invariance

  matrix element: $\mathcal{M} = \epsilon_\mu(k_1)\epsilon_\nu(k_2)\mathcal{M}^{\mu\nu}$

  gauge invariance requires:

$$k_{1\mu}\epsilon_\nu(k_2)\mathcal{M}^{\mu\nu} = \epsilon_\mu(k_1)k_{2\nu}\mathcal{M}^{\mu\nu} = 0$$

  $\longrightarrow$ checked numerically

phase space cuts

minimal cuts

$$p_{Tj} > 20\,\text{GeV}, \quad |\eta_j| < 5, \quad R > 0.6$$

$$R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$$

$\longrightarrow$ 2 well separated hard jets

additional WBF cuts

$$|\Delta\eta| > 4.2, \quad \eta_1 \cdot \eta_2 < 0$$

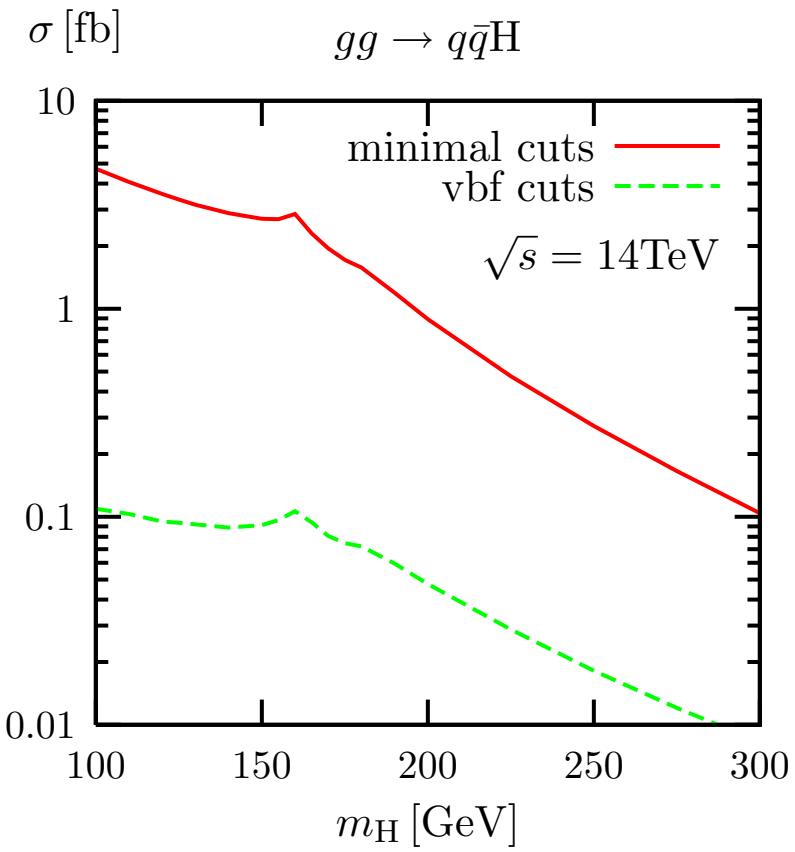
$$m_{jj} > 600\,\text{GeV}$$

$\longrightarrow$ separation of WBF process from background

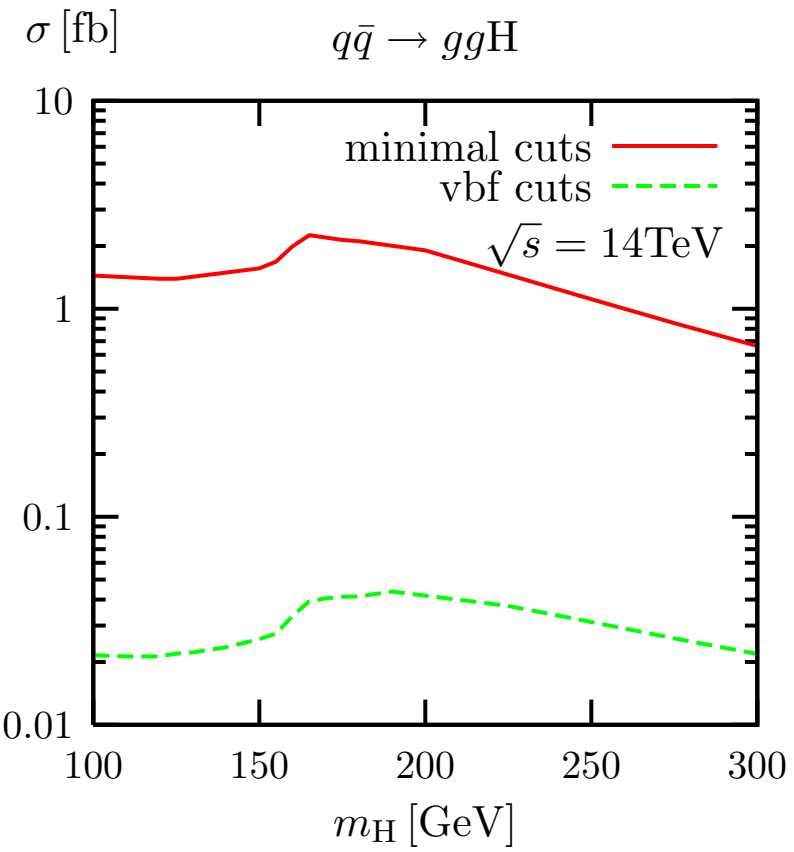
Results for LHC: total cross section

parton densities: MRST nnlo

$gg \to q\bar{q}H$



$q\bar{q} \to ggH$

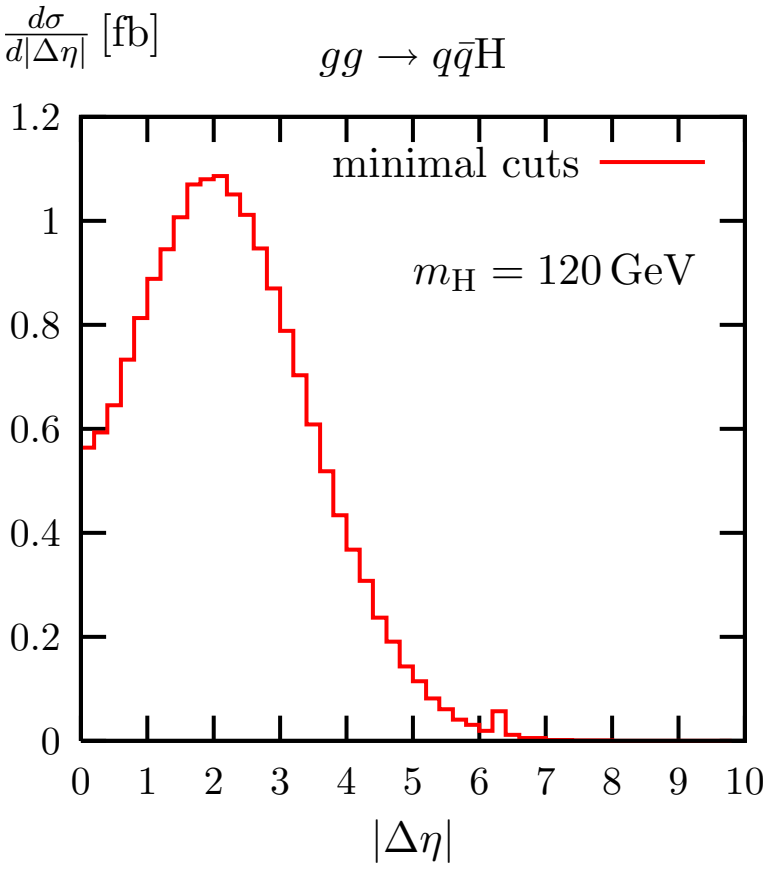


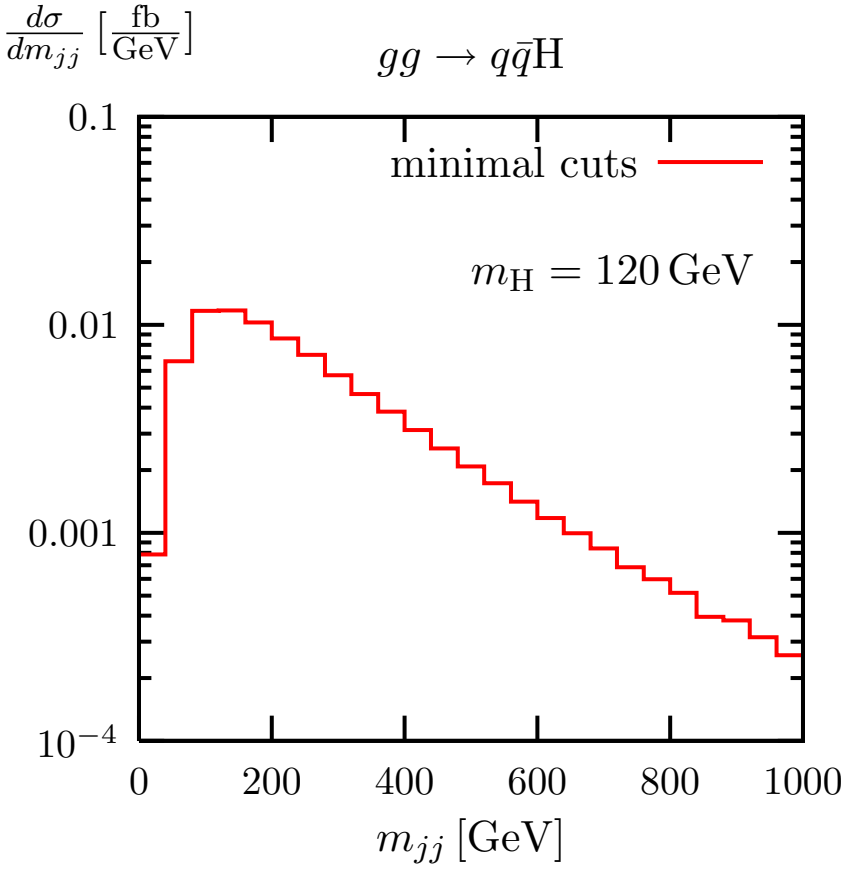
WBF LO: $\sigma \approx 1$ pb with wbf cuts

- W threshold in loops visible
- WBF cuts: strong suppression

Results for LHC: distributions

$m_H = 120\,\text{GeV}$, **minimal cuts**





- rapdity gap: smaller than for weak boson fusion (peak at $\Delta\eta \approx 4..5$)
- dijet invariant mass: rapid falloff

Conclusions

- weak boson fusion important Higgs production channel at LHC
- no color exchange at LO and NLO
  color exchange contributions only at NNLO
- $gg \to q\bar{q}H$ and crossed processes
  finite, gauge invariant subset of NNLO corrections
  with color exchange
- $\sigma \sim 5\,\text{fb}$ for $100\,\text{GeV}$ Higgs with minimal cuts
  strong suppression by additional WBF cuts