Gluon-induced WW background to Higgs boson searches at the LHC

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in collaboration with
T. Binoth, M. Ciccolini and M. Krämer

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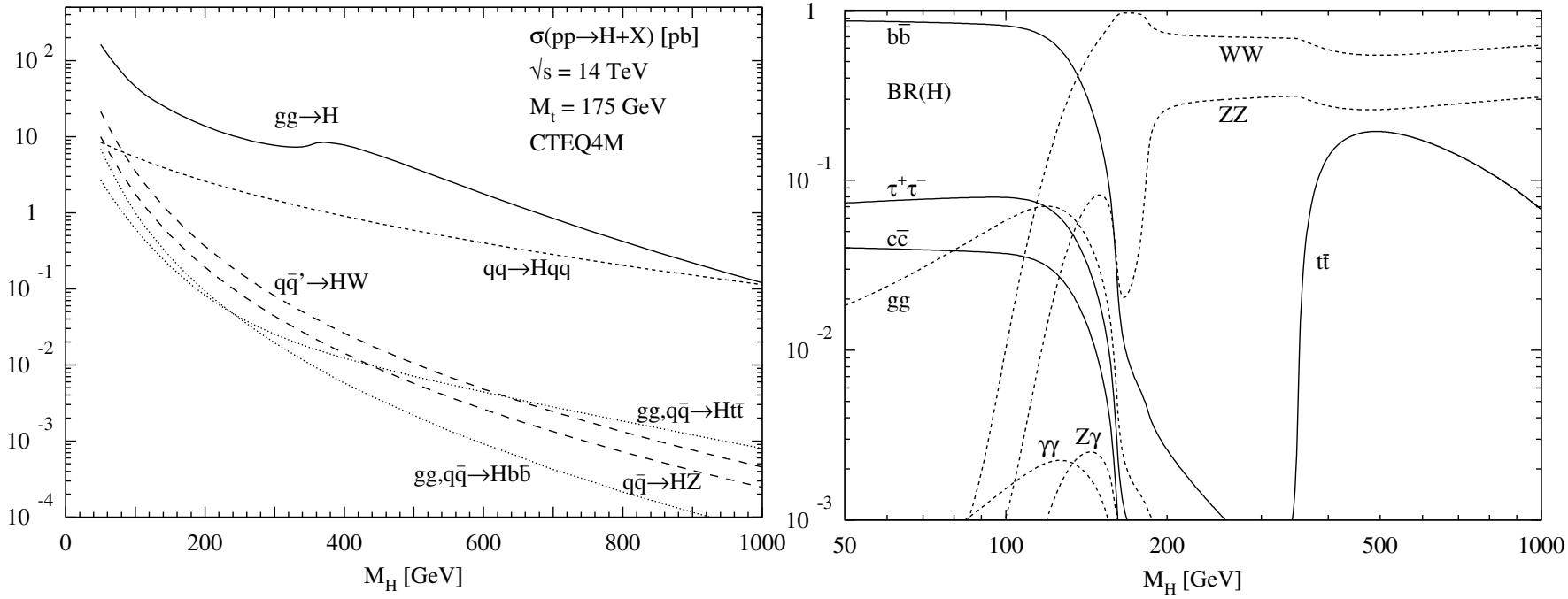
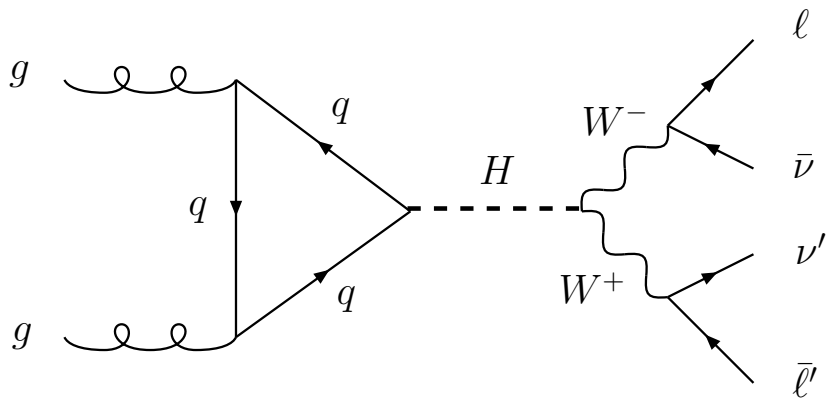
LHC SM Higgs Production and Decay



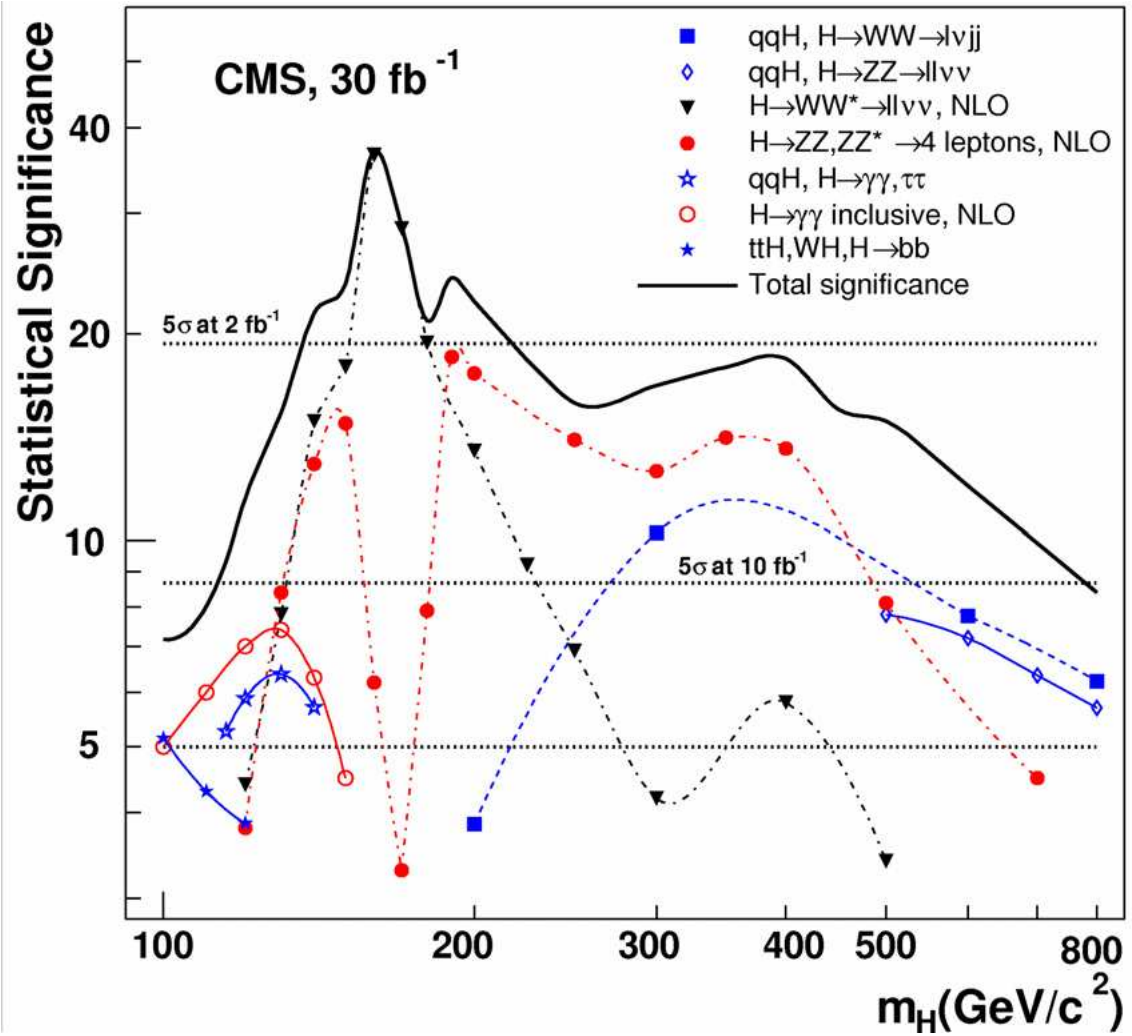
M. Spira

$$gg \to H \to W^-W^+ \to \ell\bar{\nu}\bar{\ell}'\nu'$$

$$140\ \text{GeV} < M_H < 180\ \text{GeV}$$



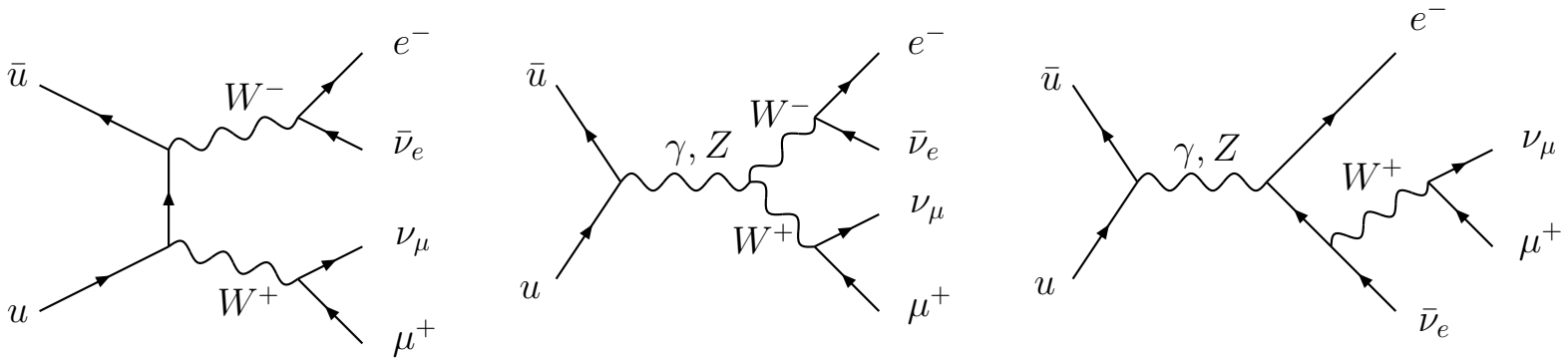
LHC SM Higgs Discovery Potential



CMS-NOTE-2003-033

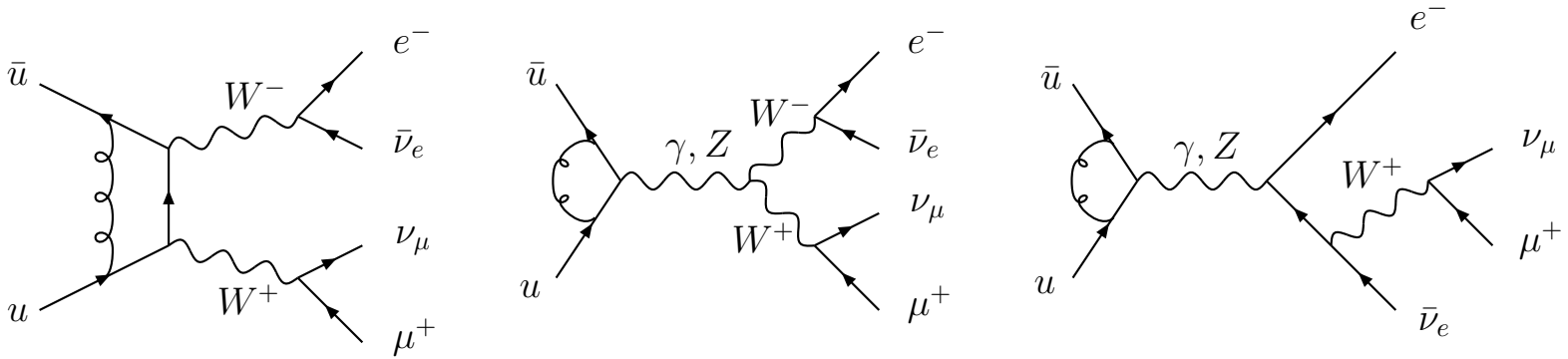
Irreducible WW Background

$$q\bar{q} \to W^-W^+ \to e^-\bar{\nu}_e\ \mu^+\nu_\mu \text{ (LO)}$$



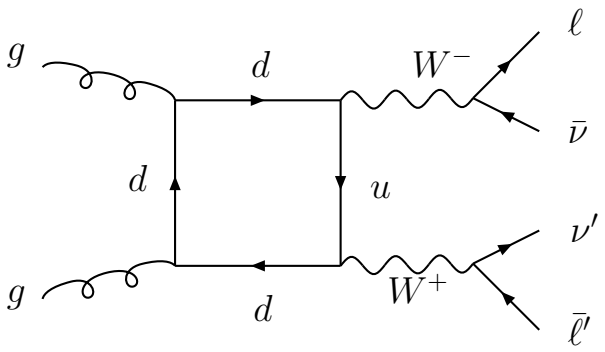
J.M. Campbell, R.K. Ellis

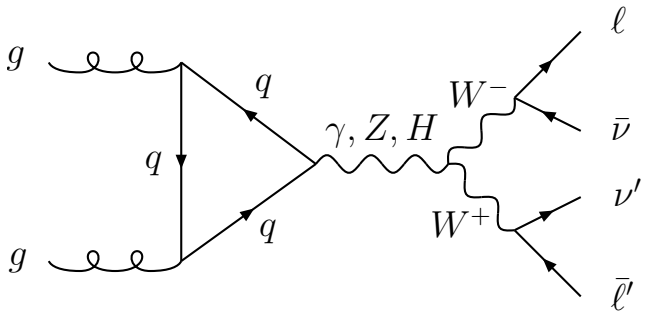
$$q\bar{q} \to W^-W^+ \to e^-\bar{\nu}_e\ \mu^+\nu_\mu \text{ (NLO)}$$

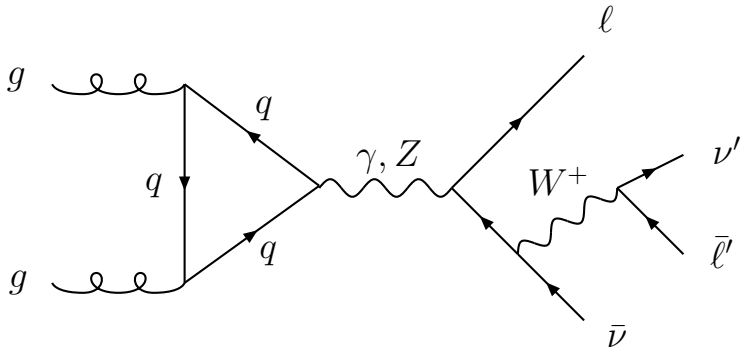


L. Dixon, Z. Kunszt, A. Signer; S. Frixione; J. Ohnemus; J.M. Campbell, R.K. Ellis

$$gg \to W^{-*}W^{+*} \to \ell\bar{\nu}\bar{\ell}'\nu' \text{ (LO)}$$







without W decays: J.J. van der Bij, E.W.N. Glover; C. Kao, D.A. Dicus

Calculation

- External fermions massless
- Internal fermions massless (but t-b loop)
- Single-resonant contributions
- Gauge-invariant off-shell calculation
- Binoth *et al.* and Passarino-Veltman reduction
- Gram determ. singularities inside phase space

Experimental cuts enhance gluon-scattering (signal!):

$$\Delta\phi_{ll} < 45^\circ \text{ and } m_{ll} < 35 \text{ GeV}$$

$$\text{jet veto: } p_{Tj} > 20 \text{ GeV and } |\eta_j| < 3$$

$$35 \text{ GeV} < p_{Tl,\text{max}} < 50 \text{ GeV and } 25 \text{ GeV} < p_{Tl,\text{min}}$$

M. Dittmar, H. Dreiner, G. Davatz, G. Dissertori, M. Grazzini, F. Pauss

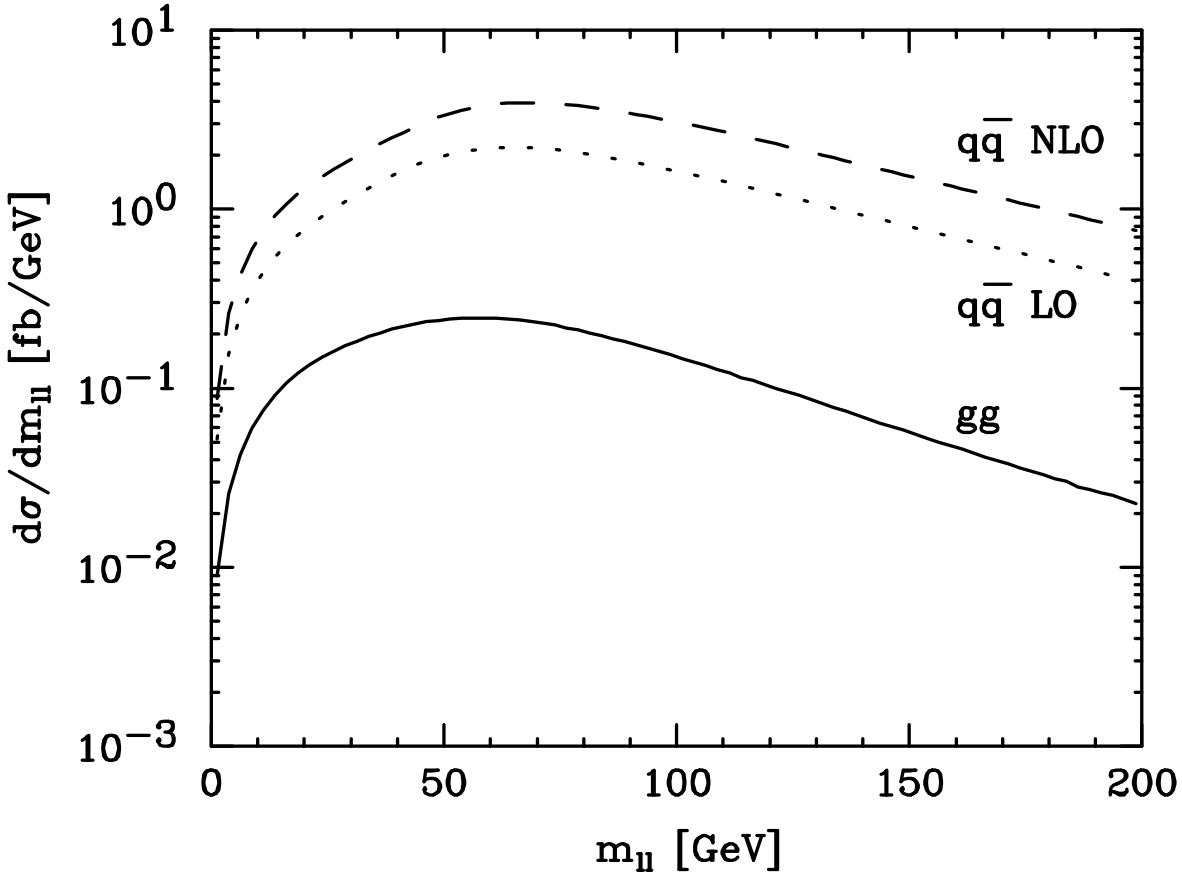
Results

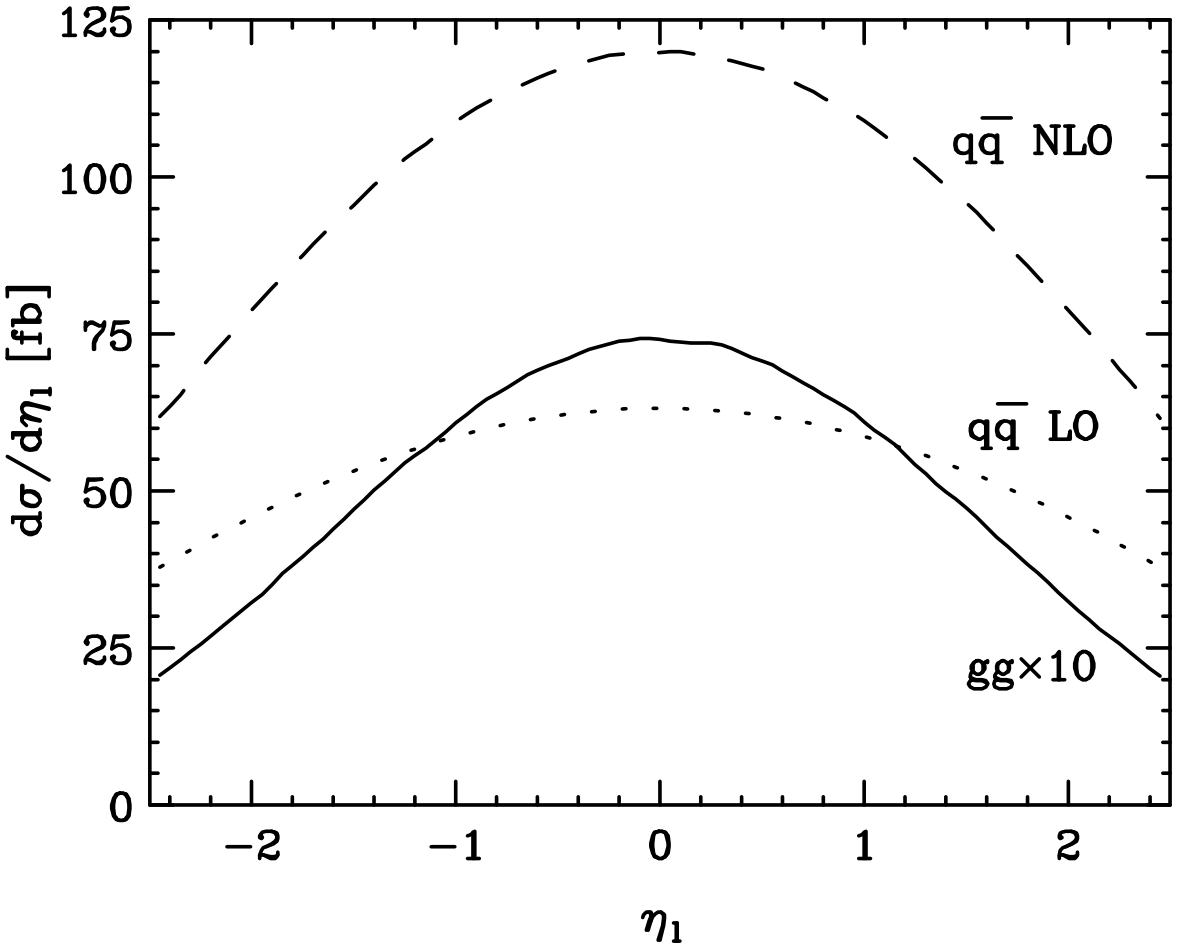
$$pp \to W^*W^* \to \ell\bar{\nu}\bar{\ell}'\nu' \ (\sqrt{s} = 14 \text{ TeV})$$

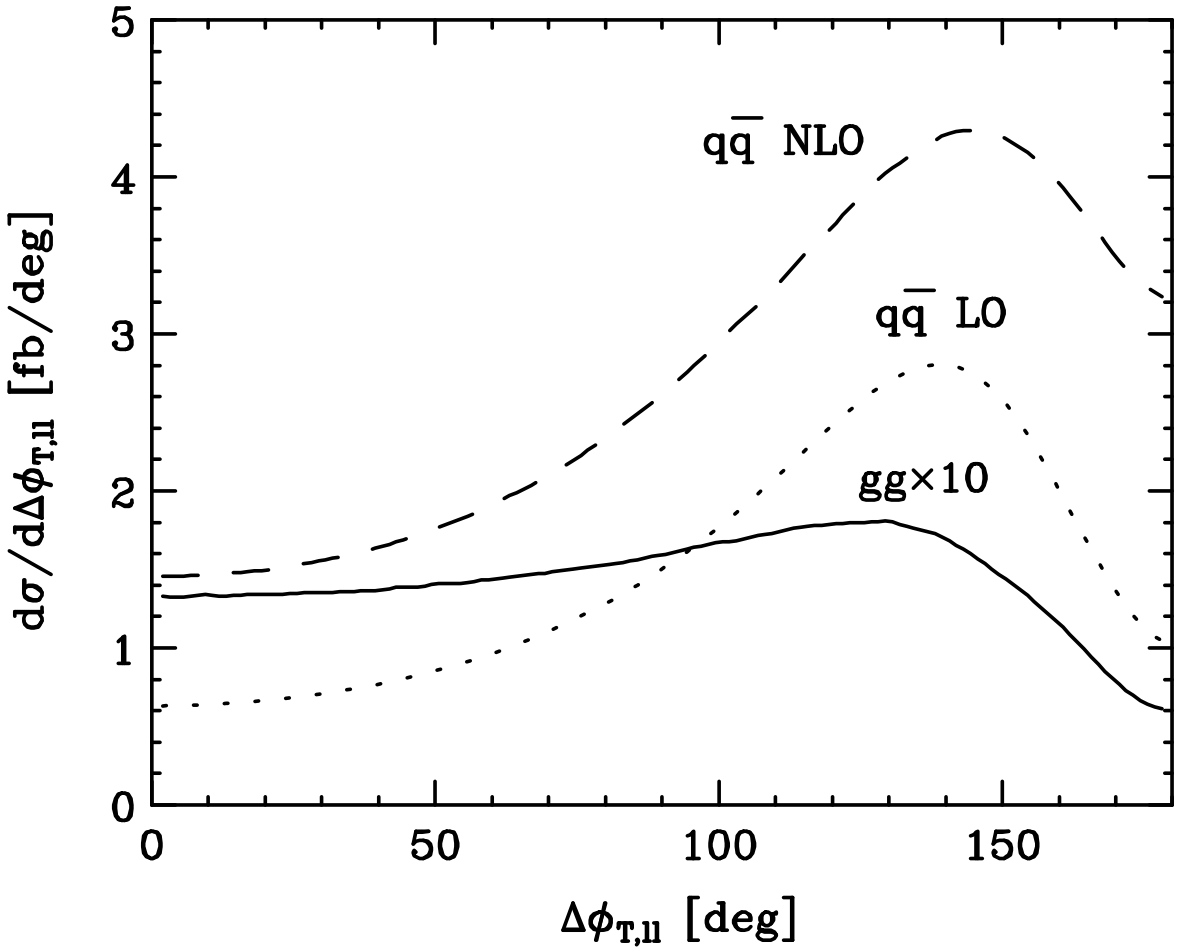
	$\sigma(pp \to W^*W^* \to \ell\bar{\nu}\bar{\ell}'\nu')$ [fb]				
	gg	$q\bar{q}$		$\frac{\sigma_{\rm NLO}}{\sigma_{\rm LO}}$	$\frac{\sigma_{\rm NLO+gg}}{\sigma_{\rm NLO}}$
		LO	NLO		
σ_{tot}	$53.61(2)^{+14.0}_{-10.8}$	$875.8(1)^{+54.9}_{-67.5}$	$1373(1)^{+71}_{-79}$	1.57	1.04
σ_{std}	$25.89(1)^{+6.85}_{-5.29}$	$270.5(1)^{+20.0}_{-23.8}$	$491.8(1)^{+27.5}_{-32.7}$	1.82	1.05
σ_{bkg}	$1.385(1)^{+0.40}_{-0.31}$	$4.583(2)^{+0.42}_{-0.48}$	$4.79(3)^{+0.01}_{-0.13}$	1.05	1.29

std: $p_{T,\ell} > 20$ GeV, $|\eta_\ell| < 2.5$, $\not{p}_T > 25$ GeV

$$M_W/2 \leq \mu_{\rm ren,fac} \leq 2M_W$$

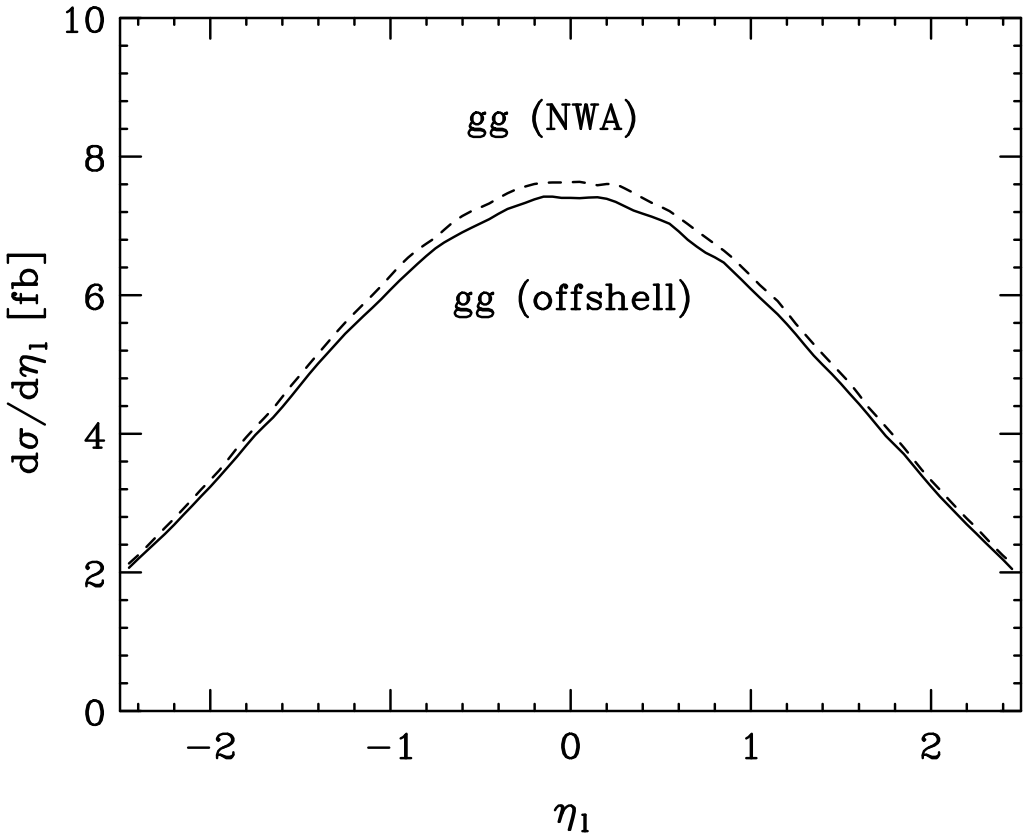

10^1
10^0
10^{-1}
10^{-2}
10^{-3}
$d\sigma/dm_{ll}$ [fb/GeV]
0
50
100
150
200
m_{ll} [GeV]
$q\bar{q}$ NLO
$q\bar{q}$ LO
gg

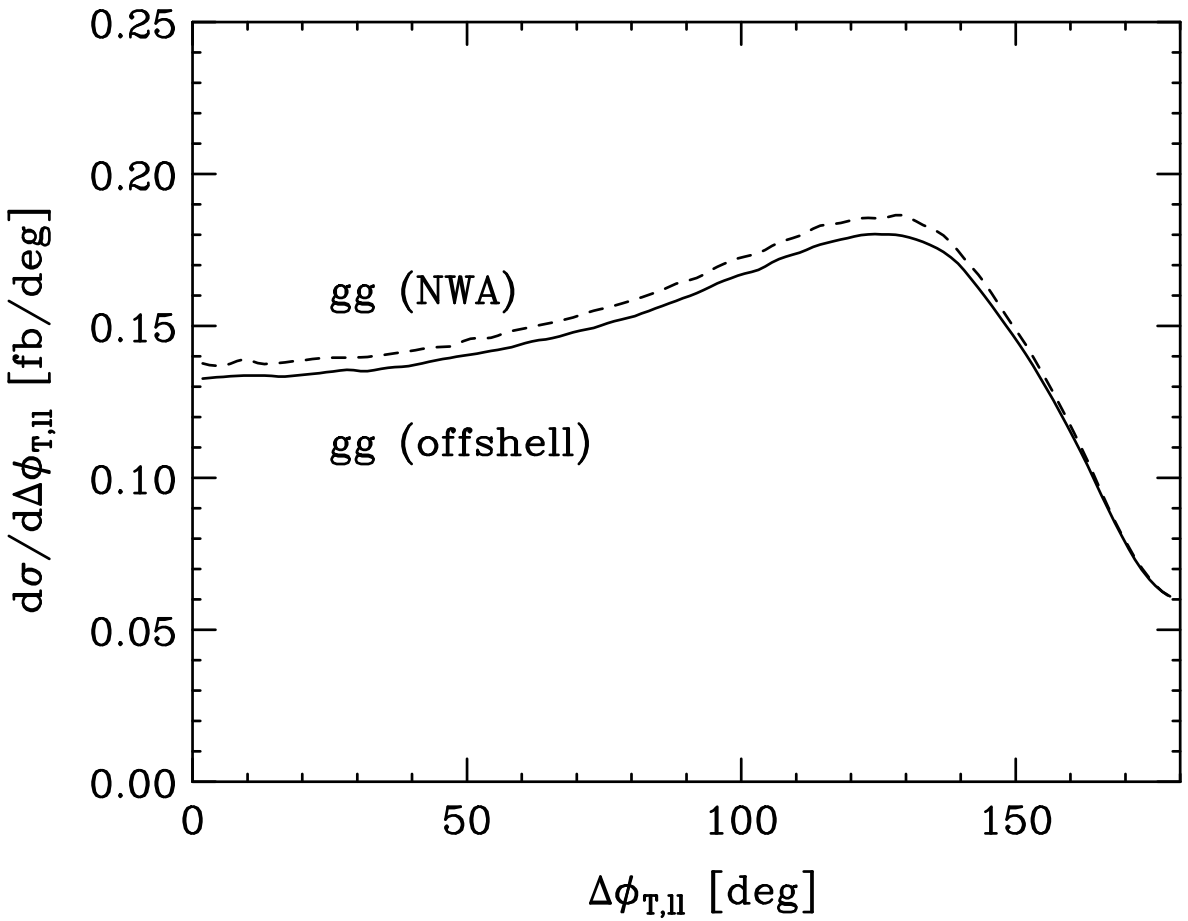

125
100
75
50
25
0
−2
−1
0
1
2
η_1
$d\sigma/d\eta_1$ [fb]
$q\bar{q}$ NLO
$q\bar{q}$ LO
gg×10


5
4
3
2
1
0
0
50
100
150
$q\bar{q}$ NLO
$q\bar{q}$ LO
gg×10
$d\sigma/d\Delta\phi_{T,ll}$ [fb/deg]
$\Delta\phi_{T,ll}$ [deg]

Offshell Effects

$\sigma_{\text{offshell}} = 0.97\ \sigma_{\text{NWA}}$, (selection cuts dependent!)




0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
gg (NWA)
gg (offshell)
dσ/dΔφ_T,ll [fb/deg]
Δφ_T,ll [deg]

Public Parton-Level Program/Event Generator

- MC program with full spin correlations and off-shell effects
- generate weighted and unweighted events
- events in LHA format, compatible with PYTHIA etc.
- LHAPDF interface
- user-friendly specification of selection cuts and histograms
- adaptive MC integration (Dvegas)
- OmniComp-based parallel mode (incl. histogram filling)
- amplitude evaluation in double and quadruple precision

Summary

- calculation for loop-induced $gg \to W^*W^* \to \ell\bar{\nu}\bar{\ell}'\nu'$
- including full spin correlations and off-shell effects
- important background to $H \to WW$ searches at LHC
- $\mathcal{O}(\alpha_s^2)$, but enhanced by Higgs search cuts and $g\ \mathcal{L}$
- without cuts only 5% correction to known WW background
- but **30%** with realistic experimental cuts
- dominant higher-order correction to LO WW background!
- parton-level program/event generator available