EW physics at the LHC in 2010/2011

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Outline

- Drell-Yan at LHC 14 (7) TeV and Tevatron
- $t\bar{t}$
- Higgs production and detection
- W,Z in weak boson fusion
- W W, WZ production

Warnings.

- Assumption: 500 pb^{-1} at 7 TeV in the centre of mass (2010 and 2011, a bit pessimistic now the goal is 1 fb^{-1})
- basically no public study at 7 TeV
- anything with a cross section smaller than 10fb neglected
- (several plots produced just for the seminar... handle with care)
- all presented results for 7 TeV are partonic LO (differential) cross sections

Drell-Yan

- LHC standard candle
- M_W crucial for EW precision test
- NLO and NNLO QCD correction known (NLO implemented in a shower montecarlo)
- NNLL QCD correction known
- residual QCD 1-2 % (smaller on shapes)
- PDF uncertainties (of experimental origin) 5-6 % (substantially smaller on shapes)
- At high invariant dilepton mass $M_{ll'}$ sizable EW corrections.
- $\sigma_W = 16$nb (LHC_7), 36nb (LHC_{14}), 4.2nb $(Tevatron)$ (no cut on leptons)
- $\sigma_Z = 8.2$nb (LHC_7), 15.4nb (LHC_{14}), 2.6nb $(Tevatron)$ (no cut on leptons)

Drell-Yan: PDF (experimental) uncertainties.

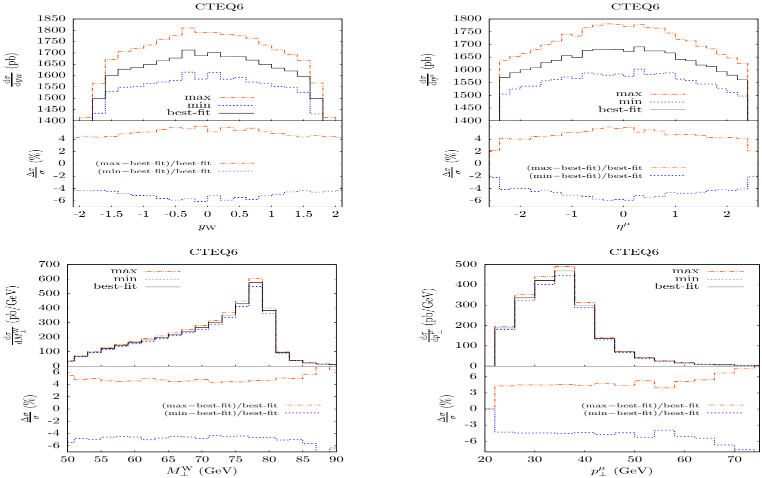

Figure: CTEQ61 PDFs uncertainties for W rapidity and muon pseudorapidity (upper plots), and for the W transverse mass and muon transverse momentum (lower plots). LHC_{14}, G. Balossini et al. JHEP:013, 2010

Drell-Yan: theoretical PQCD uncertainties.

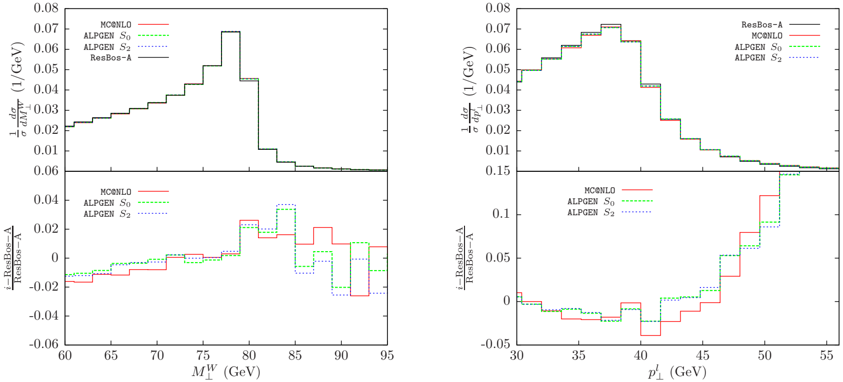

Figure: The W transverse mass (left plot) and muon transverse momentum (right plot) distributions,according to the QCD predictions of ALPGEN, MC@NLO and ResBos. In the lower panel the absolute deviations of each code w.r.t. ResBos are shown. G. Balossini et al. JHEP:013, 2010

Drell-Yan: EW Sudakov logs

- Very high p_T fermions can emit “soft/collinear” W and Z bosons.
- This emissions are logaritmically enhanced: Sudakow EW logs.
- initial state is not an isoweak singlet: KLN cancellation only partial $\Rightarrow$ possible large EW corrections
- EW corrections $\simeq 1$ % around Z, W peak, $\simeq 20$ % at high invariant dilepton mass $M_{ll'}$

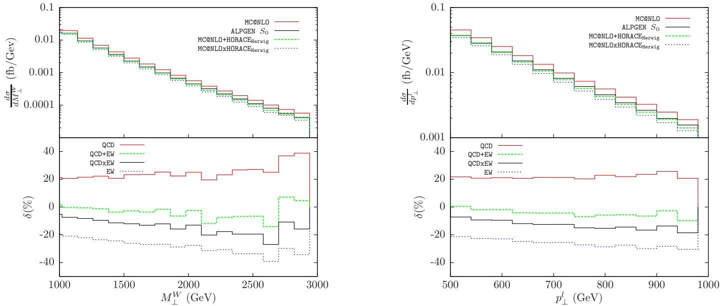

Figure: Transverse mass (left plot) and lepton transverse momentum (right plot) distributions in the high $M_{\perp W}$ tails, at the LHC$_{14}$. JHEP:013, 2010

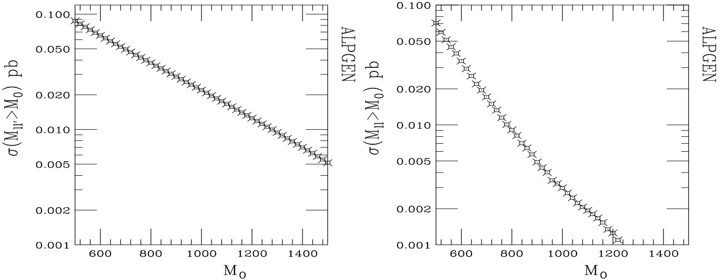

Figure: DY cross section as a function of a cut on transverse “W” mass (left) and “Z” mass (right). No cut on leptons. Muon and electron summed

small cross section hard to detect $\sim$ 10-20 % effects

$t\bar{t}$

- $\sigma_{t\bar{t}} = 74$pb (LHC_7), 433pb (LHC_{14}), 5.1pb $(Tevatron)$. N.B. LO calculation, K factor $\sim 1.5 \div 2$
- m_t important for EW precision physics N.B. pole mass, $\overline{MS}$ mass or any pertubatively well defined quantity should be measured
- verify $V - A$ couplings of t, W and b
  1. requires the measurment of decay products (jets) angular correlations.
  2. Challenging but measurments already performed at TEVATRON.

Higgs production

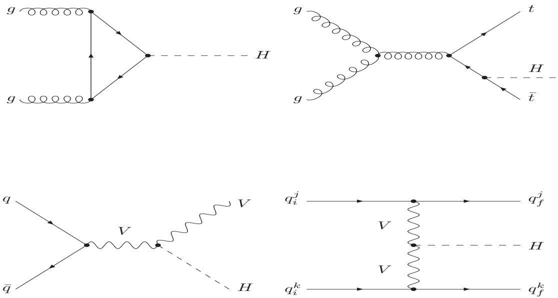

Figure: Higgs boson production: gluon fusion (upper left), associate $t\bar{t}H$ production (upper right), associate VH production (lower left), Weak Boson Fusion (lower right)

Higgs production: gluon fusion

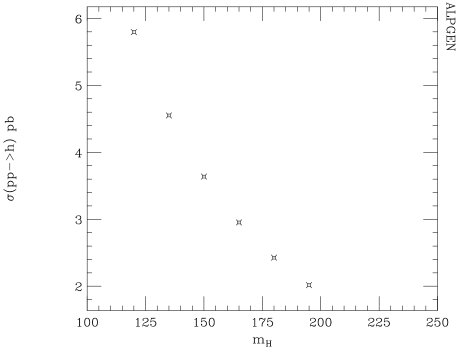

Figure: Cross Section for higgs boson production in gluon fusion channel as a function of higgs mass

LHC$_{14}$: $\sigma(m_H = 120) = 21$pb, $\sigma(m_H = 200) = 8.3$pb; $\sim 1/4$
Tevatron: $\sigma(m_H = 120) = 0.31$pb, $\sigma(m_H = 200) = 0.056$pb; ~ 20

Higgs production: gluon fusion II

- ~ 500 pb^{-1} $\Rightarrow 1000 \div 3000$ higgs bosons
- $H \to b\bar{b}$ dominant channel for light ($m_H < 150$) GeV but large $b\bar{b}$ QCD background hopeless
- $H \to WW(W^*)$, small branching ratio ($< 5\%$ in four lepton channel, hard to detect in other channels for large Drell-Yan, QCD background). Need to reject $t\bar{t}$ background and WW background. Challenging
    1. $m_H > 150$ GeV $\Rightarrow \sigma < 3$ pb, $20 \div 60$ events (500 pb^{-1}, B.R. $< 5\%$) *before acceptance cuts and with 100% efficency*
    2. $\sigma_{\bar{t}t} \simeq 70$ pb (1 and 5 pb rejecting events with at least one bottom with $p_T > 20$ and 30 GeV respectivley.)
    3. $\sigma_{WW} \simeq 15$pb
    4. Best prospects from leptons angular correlation, but small number of events ...
- $H \to \gamma\gamma$, small branching: $2 \cdot 10^{-3}$ negligible rate ($\neq 0 \Rightarrow$ BSM)
- $H \to ZZ \to 4$ leptons small branching: $< 10^{-3}$ negligible rate

Higgs production: weak boson fusion (VBF) channel

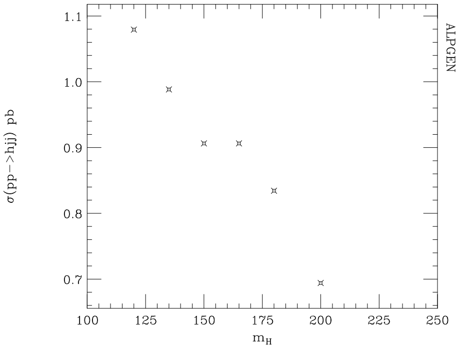

Figure: Cross Section for higgs boson production in Weak boson fusion channel, as a function of higgs mass. $gg \to Hjj$ *not included*.

LHC$_{14}$: $\sigma(m_H = 120) = 2.5$pb, $\sigma(m_H = 200) = 1.8$pb; $\sim 1/2$
Tevatron: $\sigma(m_H = 120) = 0.17$pb, $\sigma(m_H = 200) = 0.060$pb; ~ 7

Higgs production: weak boson fusion (VBF) channel II

- Mild dependence on higgs mass
- $350 \div 500$ events (500 pb^{-1})
- Low higgs mass (< 150) major decay mode $b\bar{b}$, plagued by a very large QCD background . *Other channels: negligible*
- High higgs mass (> 150), major decay mode $WW(W^*)$.
  1. cleanest channel: $WW(W^*) \to ll'\nu_l\nu_{l'}$. $B.R. \sim 5\%$
  2. large $t\bar{t}$ background $\Rightarrow$ need to exploit VBF feature: high dijet invariant mass, jet veto.
  3. lepton angular correlation important, but small number of events
  4. Challenging, but $S/B > 1$ might be achievable
- $WW(W^*) \to l\nu_l qq'$. $B.R. \sim 30\%$, huge Drell-Yan background

Higgs production: weak boson fusion (VBF) channel III

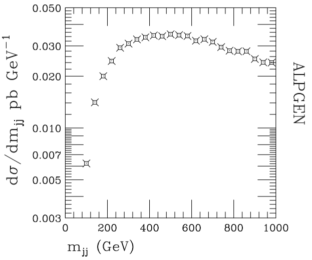

Figure: Cross Section for higgs boson production in weak boson fusion channel as a function of dijet m_{jj} mass. Left: differential cross section; Right: cross section for $m_{jj} > m_0$. Plots: hjj, dashes $t\bar{t}$

Higgs production: associate WH production

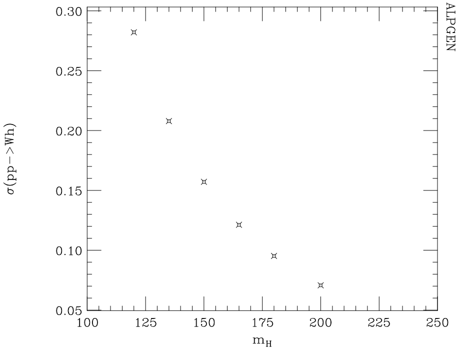

Figure: Cross Section for associate W and higgs boson production as a function of higgs mass

LHC$_{14}$: $\sigma(m_H = 120) = 0.36$pb, $\sigma(m_H = 200) = 0.10$pb; ~ 1
Tevatron: $\sigma(m_H = 120) = 0.096$pb, $\sigma(m_H = 200) = 0.015$pb; ~ 3

Higgs production: associate WH production II

- At most $75 \div 150$ events for light higgs $m_H < 150$ GeV
- only chance $H \to \bar{b}b$, $W \to l\nu_l$: branching ratio, b tagging acceptance: at least a factor 10 reduction
- large $\bar{t}t$ background
  1. need to veto events: an extra hadronic or leptonic W is produced
  2. need to exploit the invariant $b\bar{b}$ mass
- $Wb\bar{b}$ $0.4pb$, manageable.
- Very Challenging, it might be worth trying...

Vector boson production in WBF

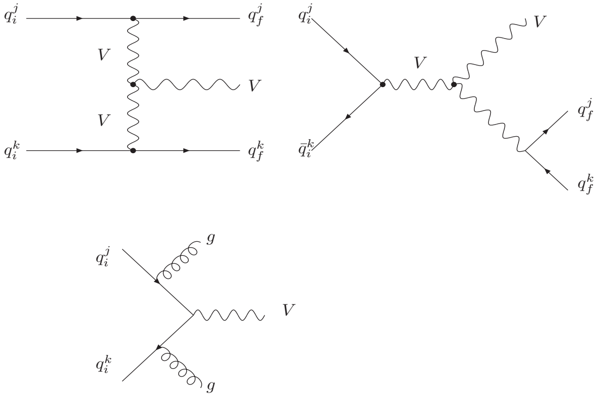

Figure: W boson production in Weak Boson Fusion

W production in weak boson fusion

Pure EW contribution to Wjj production important:

1. Anomalous gauge bosons self couplings.
2. Check of WBF higgs production

$\sigma \sim 16$pb, but background 10^2 larger, standard WBF cuts non sufficient.

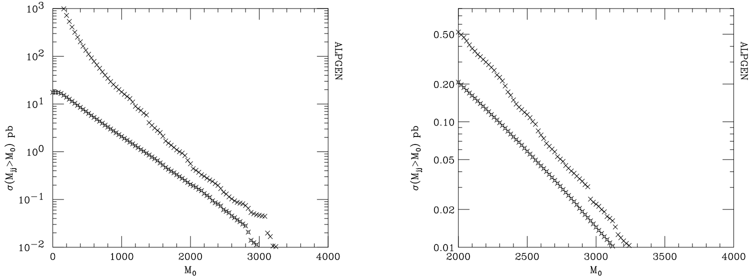

Figure: Cross Section for associate Wjj production as a function of dijet m_{jj} invariant mass. Fancy Box: pure EW contribution ($\alpha_S = 0$). Crosses: Drell Yan.

W pair production

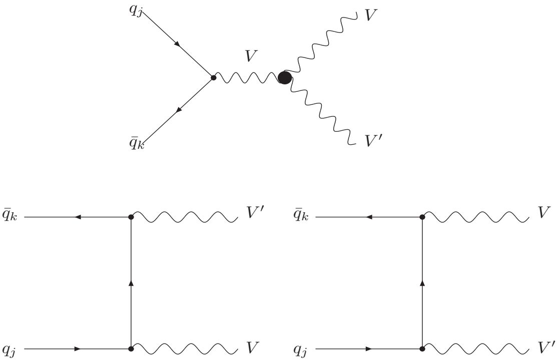

Figure: W pair production

W pair production

- Relevant for the study of gauge bosons self couplings
  1. sensitivity to anomalous couplings grows like m^2_{WW}/m^2_W up to cut-off scale
- $\sigma \sim 16$pb ($m_H = 120$); ~ 8000 events for 500 pb^{-1}
- $WW \to\to ll'\nu_l\nu_{l'}$, cleaner, $B.R. \sim 5\%$
  1. large $t\bar{t}$ background
  2. vetoing extra jets with $p_T > 30(20)$ GeV $\sigma_{t\bar{t}} \to 34(17)$ pb
  3. m_{WW} steeper for $t\bar{t}$
  4. LEP has collected ~ 10000 W pair, but $M_{WW} < 210$ GeV
  5. Most Tevatron events nearly at thresholds
  6. room to be competitive at high ($\sim 600 \div 800$ GeV) m_{WW}
- $WW \to\to l\nu_l qq'$. $B.R. \sim 30\%$, huge Drell-Yan background,

W pair production II

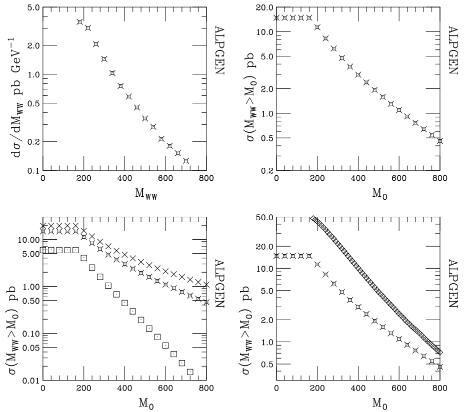

Figure: Cross Section for associate W pair production as a function of M_{WW} (upper left) and as a function of a cut $M_{WW} > M_0$. Fancy Box: LHC_7, Crosses: LHC_{14}, Boxes: Tevatron, Diamonds: $t\bar{t}$