WH/ZH Higgs cross section group Workplan and few experimental issues

Stefan Dittmaier (Theory – Freiburg University)

Robert Harlander (Theory – Wuppertal University)

Jim Olsen (CMS - Princeton University)

Giacinto Piacquadio (ATLAS - CERN)

12 April 2010

Freiburg Higgs Cross Section Workshop

Outline

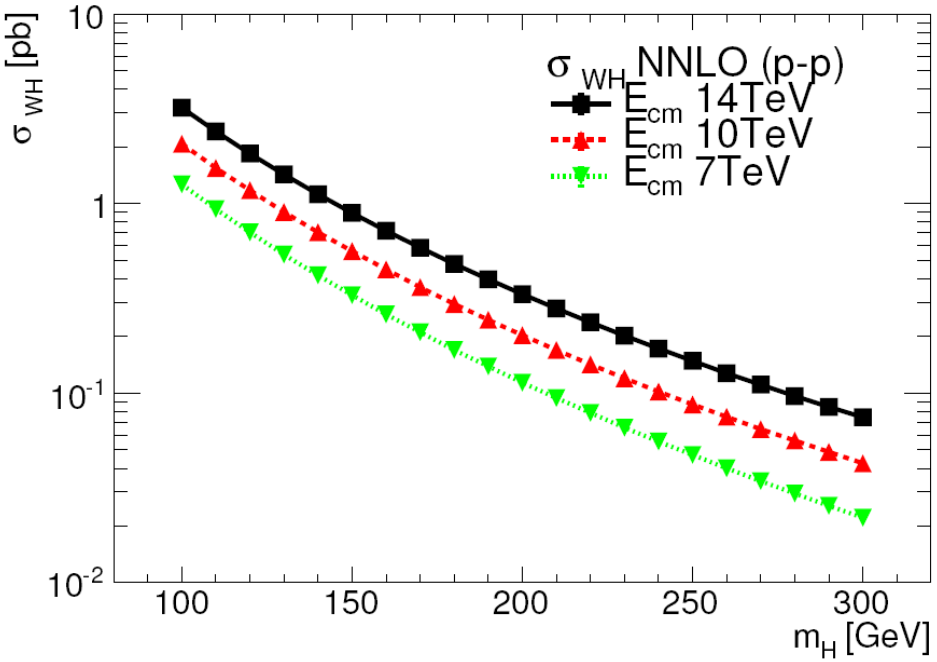
- Summary of actual status
  (previous work done in ATLAS)
- Working group workplan
  (CMS + ATLAS + Theory)
- Involved people

What has been done in ATLAS (before cross section group started)

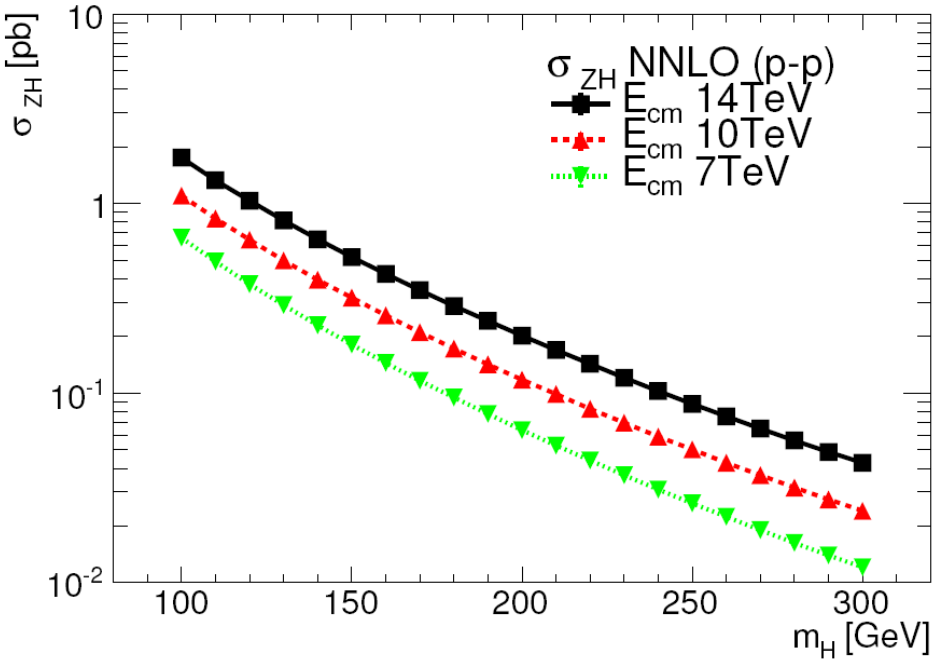
- Inclusive cross sections for WH and ZH production have been computed in collaboration with theorists, by factorizing the NLO EW and NNLO QCD corrections:
  - NNLO QCD [Brein, Djouadi, Harlander]
  - NLO EW [Ciccolini, Dittmaier, Kramer]
- using the formula:
  - $$\sigma = \sigma_0 \cdot (1+\delta^{QCD}) \times (1+\delta^{EW})$$
- Cross section obtained for:
  - $\sqrt{s}$ = 4, 6, 7, 8, 10, 14 TeV
  - m_H = 100 – 300 GeV (10 GeV steps)
- and then extrapolation performed to join these points.

Result for $\sqrt{s}$ = 14 TeV

- Work done by Huaqiao Zhang in ATLAS in collaboration with the theorists (use of private code).



(a) WH 14 TeV



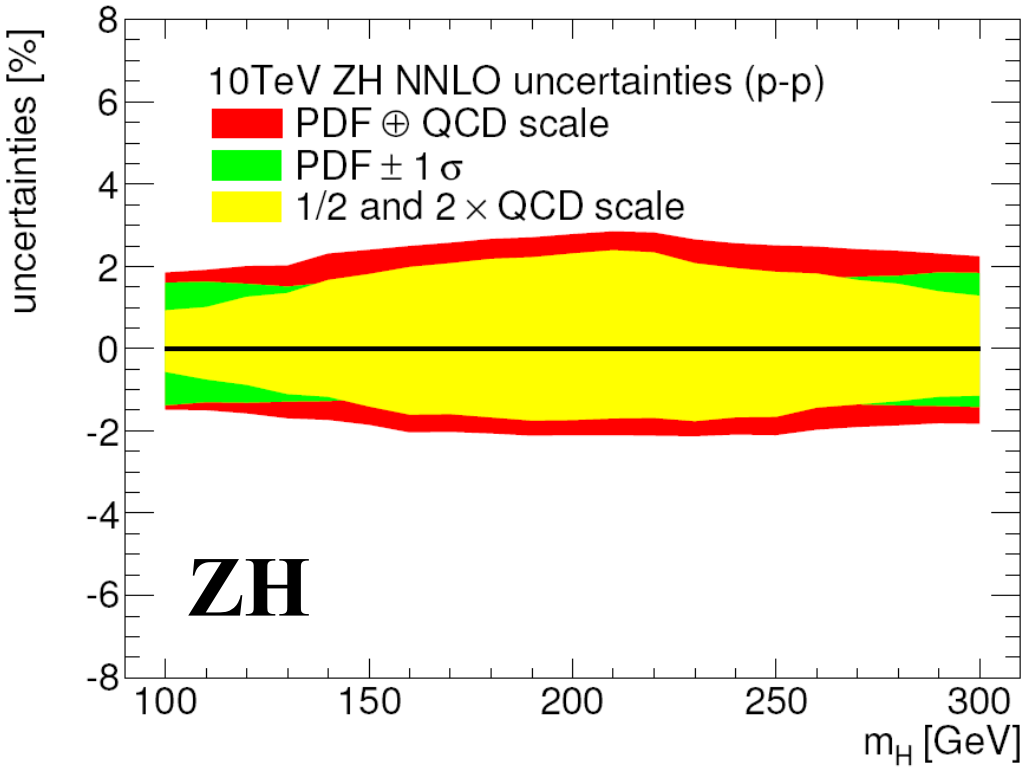
(b) ZH 14 TeV

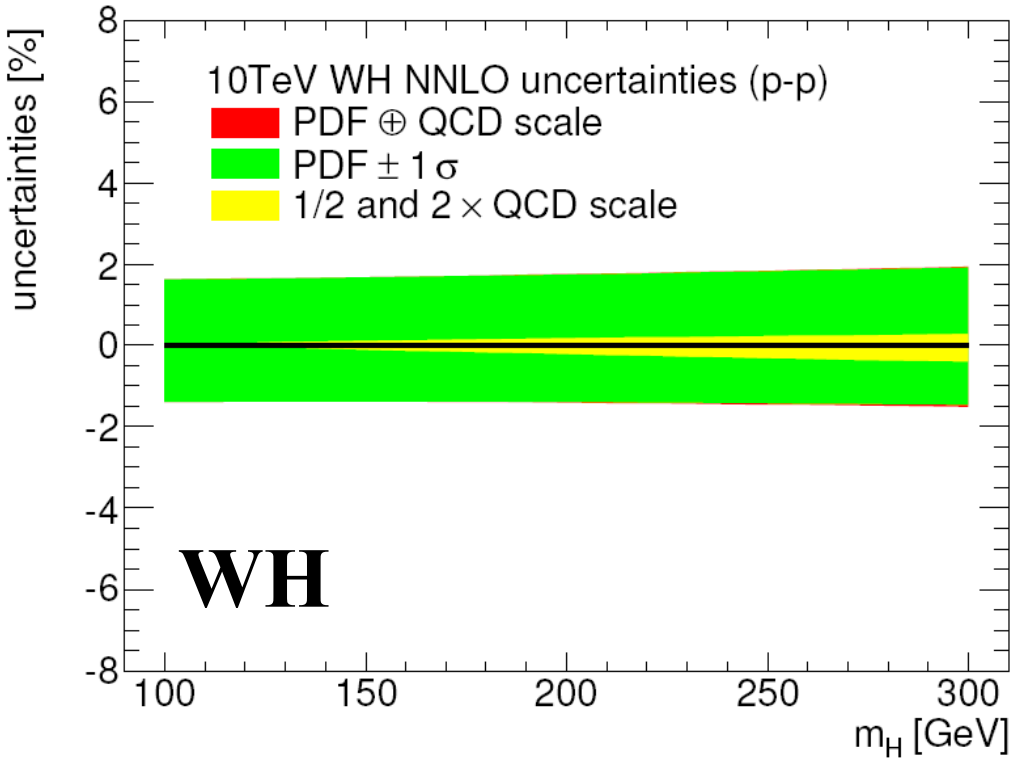
+ the same for different center of mass energies.

Parameters used

- PDF sets:
  - MTSW2008 for NNLO QCD
  - MRST2004QED for NLO EW
- Scale variation uncertainty:
  - Evaluated by varying by ½ and 2 the QCD renormaliz. and factoriz. scales ($\mu=m_{WZ}$),
- Result:
  - PDF uncertainty dominates for WH, while for ZH the scale var. uncert. dominates (in both cases uncert. ~ 2%)

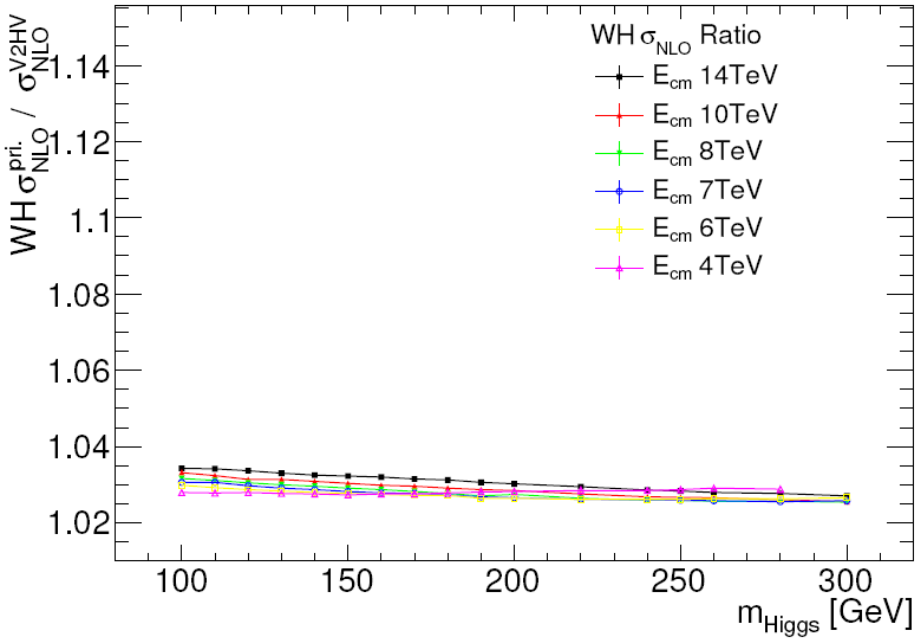
Giacinto Piacquadio
CERN



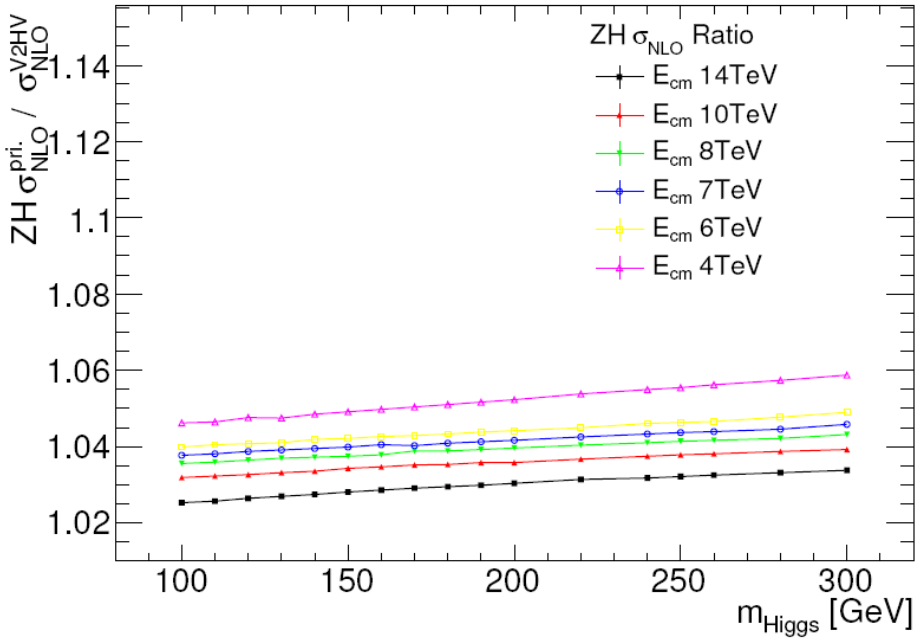


Comparison with other codes

- Comparison with V2HV NLO code [Spira, Han, Willenbrock] gives sufficiently consistent results (+3 % ~flat in m_H and $\sqrt{s}$)



(a) WH



(b) ZH

- Result should agree exactly, suggestion by Stefan D. to look for source of discrepancy
- MCFM NLO code also available [Campbell,Ellis] (plan to use as cross-check)

Assessment of state of the art of theory computation (I)

- Starting from ATLAS result, re-assess situation in collaboration with CMS and theorists and update the inclusive results, also wrt input parameters
- Looking forward for public releases of NNLO QCD and NLO QCD+EW codes:
  - Robert H.: plan to make the code public in few months / half a year
  - Stefan D.: plan to make the code public in HAWK v. 2
- But:
  - this should not prevent work to be based on the actual private code
- PDF, scale variation and α_s uncertainties to be re-estimated according to Higgs cross section group prescriptions
- + cross-check NLO QCD computation with other NLO codes (MCFM, V2HV)

Assessment of state of the art of theory computation (II)

- Go beyond inclusive predictions and assess differential distributions + uncertainties for following variables:

• p_T(Higgs)	• p_T(add. jet)	• m(WH)
• pT(W)	• eta(add. jet)	
• eta(Higgs)	• $\Delta\phi$(W,Higgs)	
• eta(W)	• $\Delta\eta$(W,Higgs)	

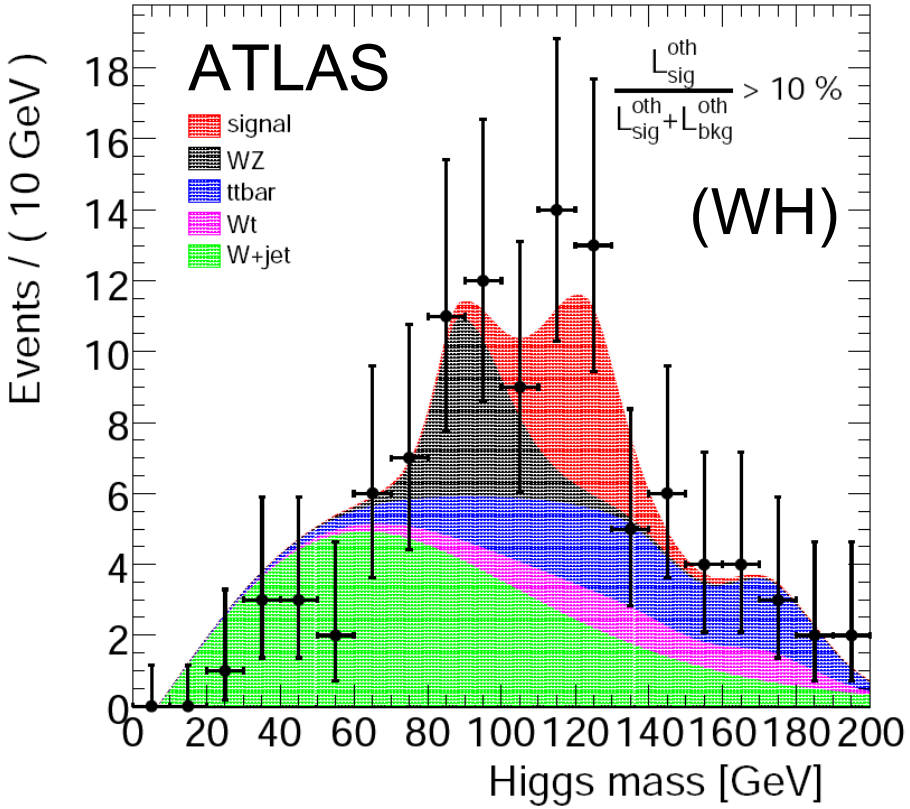
- NNLO QCD computation doesn't provide different predictions (but we could use factorization ($pp \to W^* \to WH$) and NNLO Drell-Yan differential result to get a hint of effect on distributions)
- Plan is to obtain NLO QCD+EW predictions
- Compare differential result with remaining NLO codes.

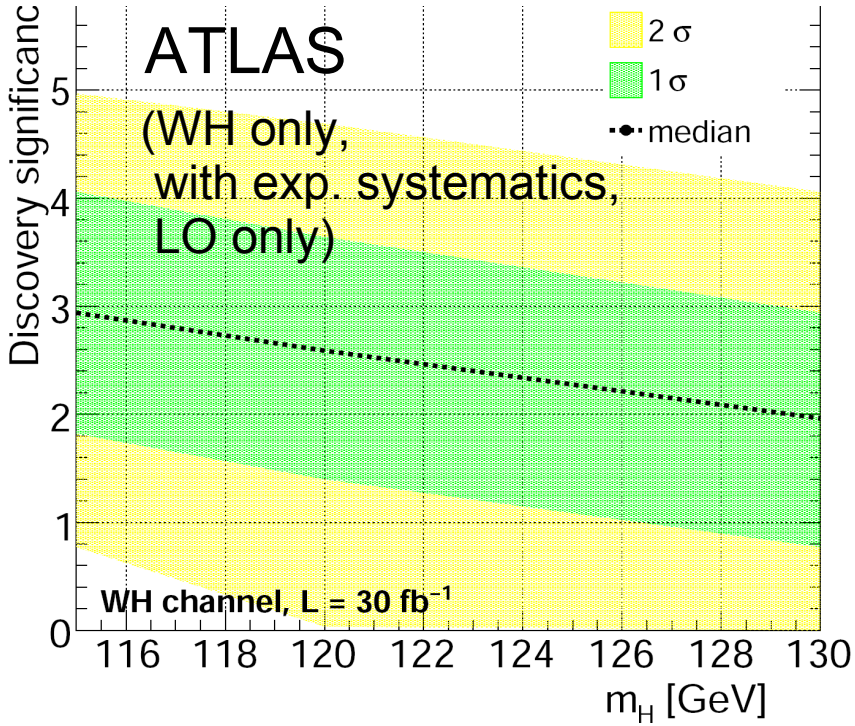
Comparison with parton-shower Monte Carlo

- A realistic physics study can only be based on a realistic Monte Carlo simulation: need to rely on parton-shower based Monte Carlo
- Two matched NLO+LL parton shower codes available:
  - MC@NLO [Frixione, Webber]
  - POWHEG (Higgs processes by Hamilton,Richardson,Tully)
- Plan:
  - Compare parton shower based distributions with parton level differential computation
  - Add comparison to LO parton shower codes
  - Run jet clustering on the partons after showering and before hadronization, switching underlying event off
  - Understand/compare NLO/ LO / LL effects on distributions (motivate/demotivate K factors?).

WH/ZH analysis at high p_T

- A lot of interest in the cross-section predictions for the high p_T region:
  - Combined sensitivity to Higgs boson of WH/ZH analysis with H→bbbar has being studied in both ATLAS and CMS, with promising results (>3σ at $\sqrt{s}$=14 TeV with 30 fb^{-1})
- Particularly important:
  - to estimate EW corrections at high p_T(Higgs), which might be large





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WH/ZH analysis at high p_T (ll)

- Will evaluate same differential distributions but in relevant phase of space region of high p_T analysis:

• p_T(W/Z)>200 GeV	• $\|\eta$(W/Z)$\|$<2.5
• p_T(b)>20 GeV	• $\|\eta$(b)$\|$<2.5
• p_T(bb)>200 GeV	
• DR(bb)<1.2	
• pT(add.jet)<60 GeV	• $\|\eta$(jet)$\|$<5

- Use k_T algorithm with size 0.3 and E-invariant scheme
  (to resolve part of jet substructure)
- Analogous to Les Houches 2009 study for W+bbbar
  (L. Reina, D. Wackeroth, F. Febres Cordero, G.P)

Jet veto in WH/ZH (with H → bbbar)

- Important experimental handle to significantly enhance signal to bkg ratio
- e.g. WH → lνbbbar:
  - Strongly reduces ttbar background
  - Reduces Wbbbar + 1 jet contribution (qg → WbBj)
    (which is enhanced at LHC due to the gluon luminosity)
- For the jet veto, it would be desirable to have either:
  - Fully differential result @ NNLO for pp → WH
  - Or (easier) pp → WH + 1 jet @ NLO

WH/ZH at LO and interference term

- Plan is to cross-check interference term between different channels (e.g. WH and WZ)
- For the specific case of H → bbbar:
  - Consider effect of non-resonant diagrams, considering all diagrams giving rise to lνbbbar, llbbbar or ννbbbar
  - Could produce already proposed distributions with MadGraph or CompHep
    - e.g. for lνbbbar
      - ~300 diagrams, ~40 of each with intermediate Higgs
      - Alexander Cheplakov and a student (working on this channel for angular correlation studies) could easily produce these distributions

Interest from LHCb?

- Clara Matteuzzi is the contact person for LHCb
- Very specific region of phase space:
  - Look for H → bbbar (excellent b-tagging performance)
  - $1.9 < \eta < 4.9$
  - Trigger on lepton with p_T>12-15 GeV
- Estimate WH cross section @ NLO QCD (+EW?) in this region of phase space

People involved / interested

- CMS
  - Jim Olsen (contact person)
  - David Lopes Pegna
- ATLAS
  - Giacinto Piacquadio (contact person)
  - Alexander Cheplakov
- LHCb
  - Clara Matteuzzi (contact person)
- Theory
  - Stefan Dittmaier (contact person)
  - Robert Harlander (contact person)
  - Michael Kraemer

Manpower sufficient only for few main points, plenty of room for other people to contribute!