Standard Model Higgs Boson Searches at ATLAS

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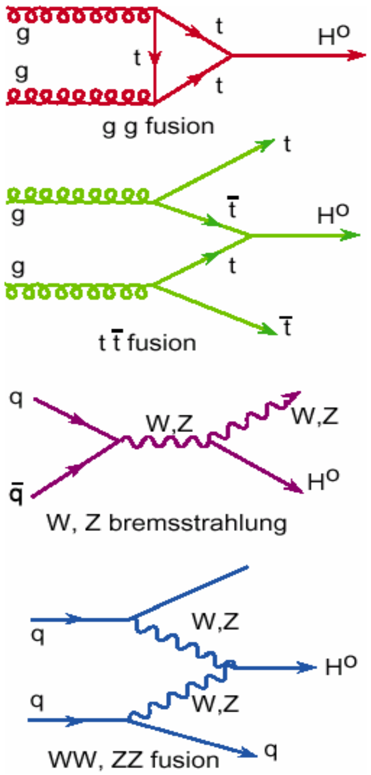
On behalf of the ATLAS collaboration

Outline

- Introduction
  - Higgs phenomenology, production and decay modes at LHC
- The ATLAS experiment
  - Main design characteristics
- Standard Model Higgs Searches (a selection of channels)
  - gg-fusion production
    - $H \to \gamma\gamma$
    - $H \to ZZ^* \to$ 4 leptons
    - $H \to WW \to l\nu l\nu$
  - Vector Boson Fusion production
    - $H \to \tau\tau$
    - $H \to WW$
  - ttH ($H \to bb$)
- Expected significances

Higgs Phenomenology

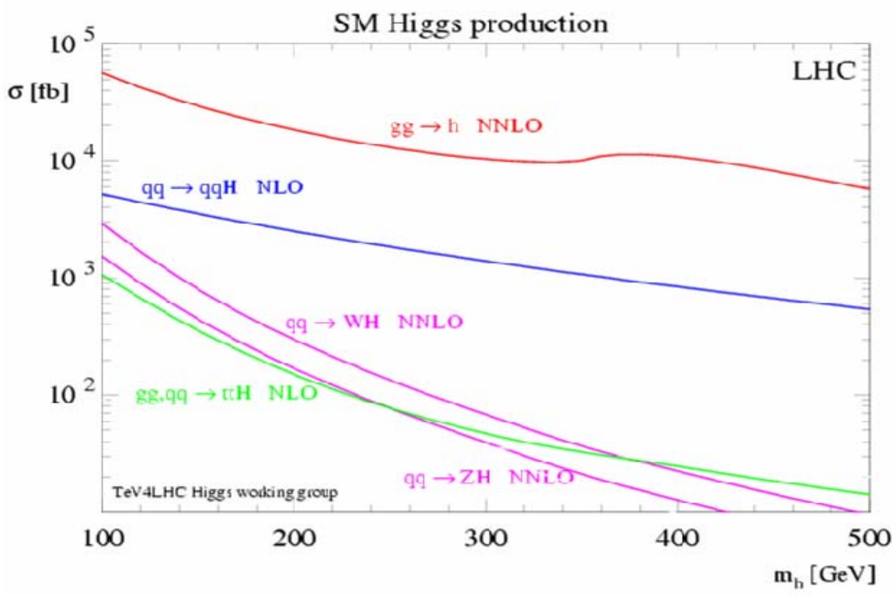


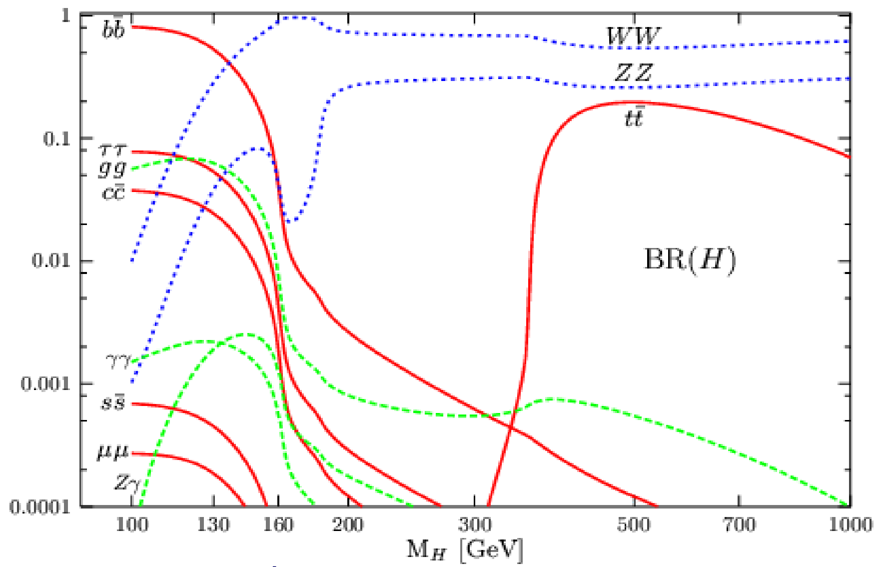
K~2.0

K~1.2

K~1.4

K~1.1





- Production cross sections and K-factors

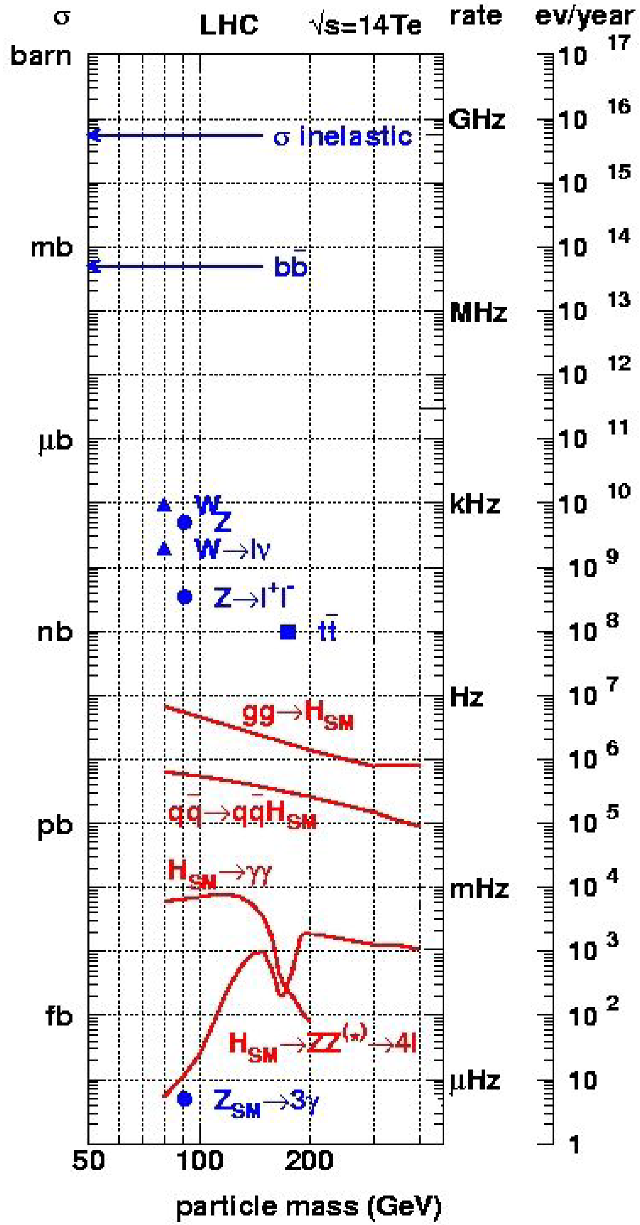
- Decay branching ratios at NLO Few % accuracy

Typical uncertainties

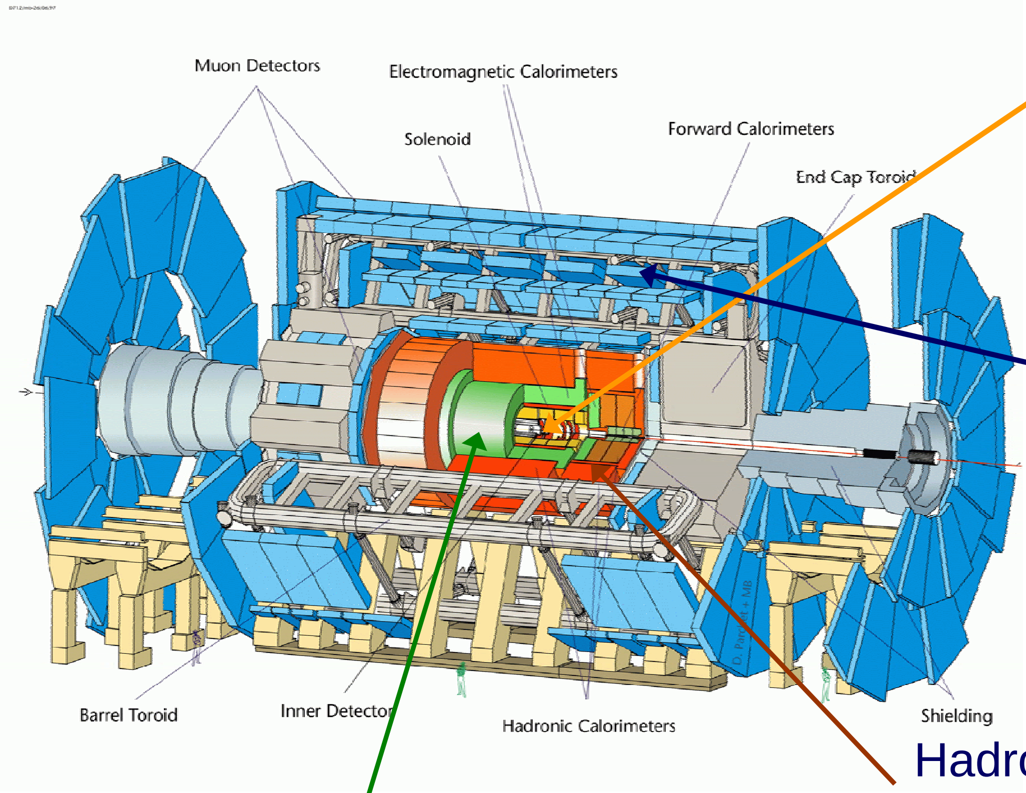
- gg 10-20 % (NNLO)
- VBF ~ 5% (NLO)
- WH,ZH ~< 5% (NNLO)
- ttH 10-20 % (NLO)

LHC conditions

- First pp collisions at √s=14 TeV from summer 2008
- Foreseen luminosity:
  - For 2008: L < 10^{33} cm^{-2} s^{-1}, Integrated L up to 1 fb^{-1}
  - For 2009: L = 1-2 10^{33} cm^{-2} s^{-1}, Integrated L < 10 fb^{-1} (low-luminosity phase)
    - 30 fb^{-1} between 2008 and 2010/2011
  - ~10^{34} $cm^{-2}s^{-1}$, high-luminosity phase
    - ~300 fb^{-1} by 2014/2015
- Pile-up:
  - ~2 (low luminosity) or 20 (high luminosity) pp minimum bias interactions per bunch crossing (25 ns)
- Experiment trigger to go from 40 MHz bunch crossing to the ~200 Hz to disk for offline analysis



The ATLAS Experiment at LHC



Inner Detector: solenoidal field B=2T , (Pixel+Silicon strips+ transition radiation tracker)

Muon Spectrometer: precision tracking drift chambers and trigger chambers in air core toroid, <B>=0.6T, good standalone performance at high p_T ~10% resolution at 1 TeV

EM calo: Pb Liquid Argon
$\sigma/E \sim 10\%/\sqrt{E}$
e/g identification, angular resolution for vertex association, γ/j γ/π^0 separation

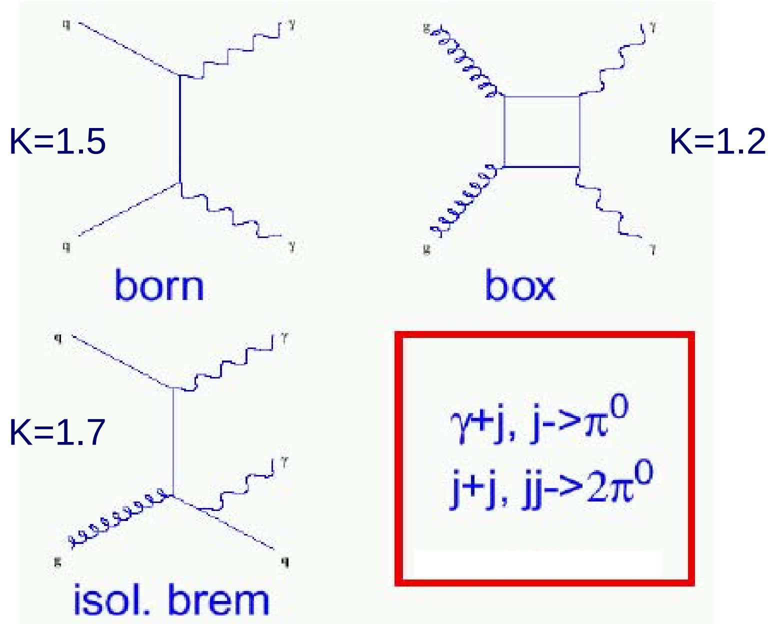
Hadronic calorimeters: (Fe scint Cu-LAr)
$\sigma/E \sim 50\%/\sqrt{E}+0.03$
Jet, ETmiss measurements

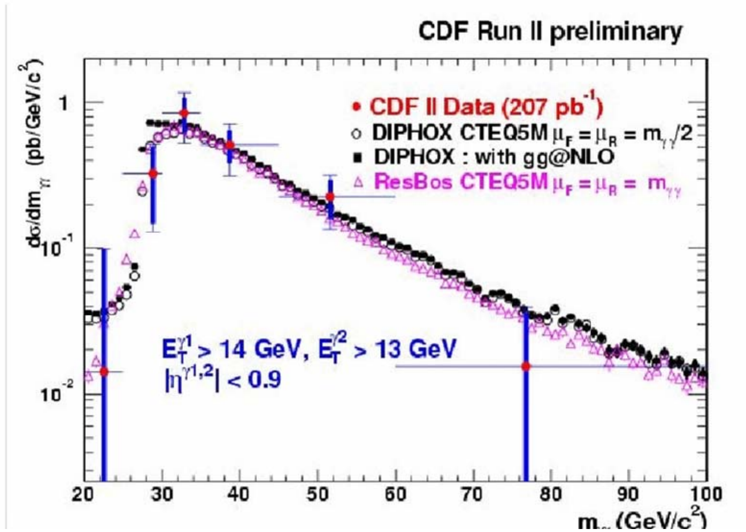
- Performance assessment also from combined test beam data of all subdetectors integrated

H→γγ

γγ irreducible

- Important channel for M_H<150 GeV
- Irreducible γγ background
  - NLO now computed
- Other backgrounds γ/jet (or jet/jet)
  - Rejection through isolation cuts, π^0 rejection
- Di-photon background now computed at NLO
  - agrees with Tevatron data
- Background normalization from side-bands
- Key points:
  - EM calorimeter resolution and primary vertex determination
  - Jet rejection (>10^3 for 80% γ efficiency)

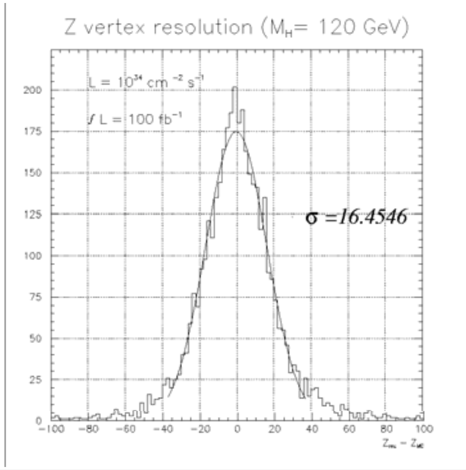


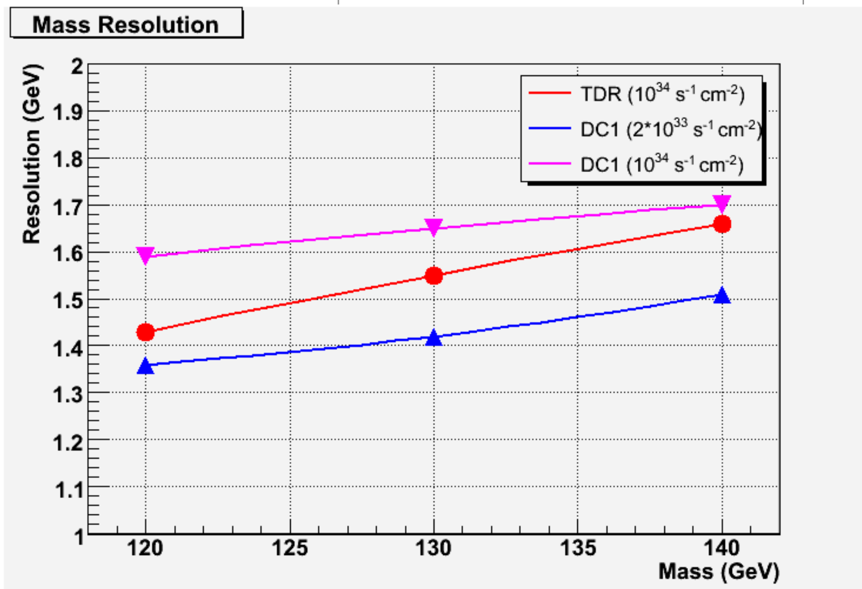


$H \rightarrow \gamma\gamma$

- γ direction from primary vertex position
- Low luminosity ($2 \cdot 10^{33}$ cm^{-2} s^{-1})
  - Z of primary vertex from ID tracks (σ=40 μm)
- High luminosity (10^{34} cm^{-2} s^{-1})
  - Photons direction obtained with calorimeter information alone
- Fine calo segmentation for π^0 rejection
- Recovery of conversions
  - ~30% of photons convert in the tracker

Vertex Z position from calorimeter: σ=1.6 cm at high luminosity





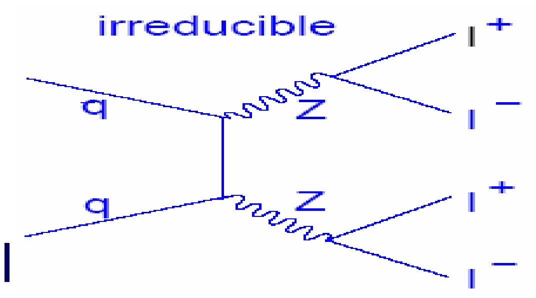
- Exp. Significances (30 fb^{-1}):

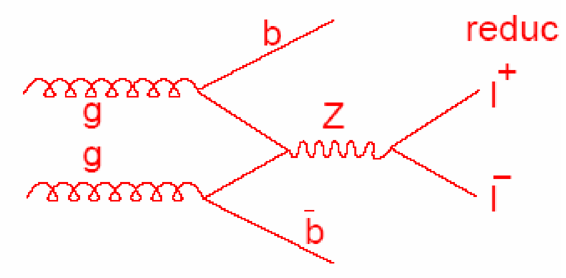
  TDR(LO): 3.9   new(NLO): 6.3

- ~30-40% improvement expected from likelihood analysis (p_T, angular distributions)

H→ZZ*→4leptons

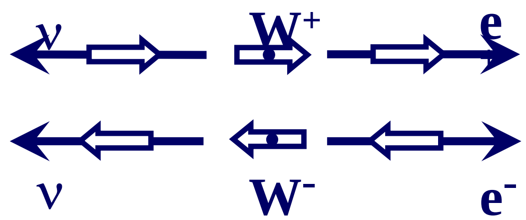
- Key point are good e/μ identification efficiency and energy resolution
- Mass resolution from ~1.6 to ~2.0 GeV
- Irreducible background: ZZ*/γ*→4leptons
  - qq annihilation known to NLO
  - Add ~20% to account for gg→ZZ
- Reducible backgrounds (reject through lepton isol
  - Zbb→4leptons: typical rejection ~O(10^3)
  - tt→4leptons
- ZZ background dominant after selection
- Background shapes from data (reduce PDF and luminosity uncertainties
  - E.g. $\sigma_{ZZ\rightarrow 4l}$ / $\sigma_{Z\rightarrow 2l}$
- Mass peak can be reconstructed:
  - background normalization from sidebands
- Clean channel (but low statistics)



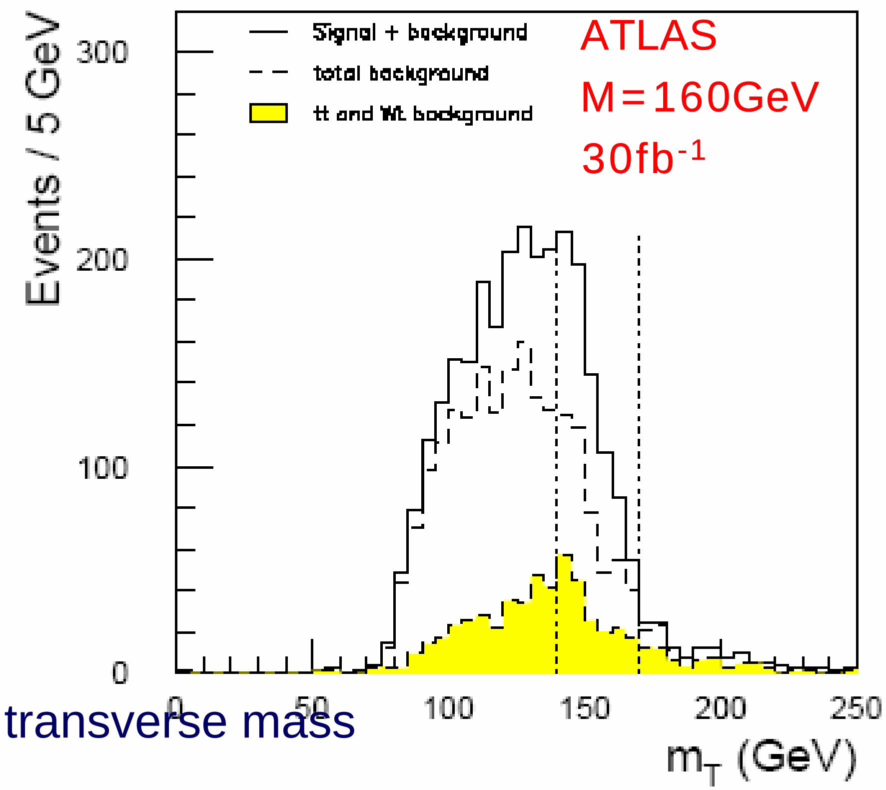


H→WW→lνlν

- Inclusive H→WW
  - No mass peak:
  - background shape knowledge important
  - Leptons spin are anti-correlated
- Backgrounds:
  - tt, tWb: rejected through jet-veto
  - WW,WZ,ZZ: rejected trough reconstruction of the event kinematics
- Main interest is near M_H~160 GeV (BR H→WW 95%)
  - Sensitivity in the lower mass region can be extended looking at VBF production

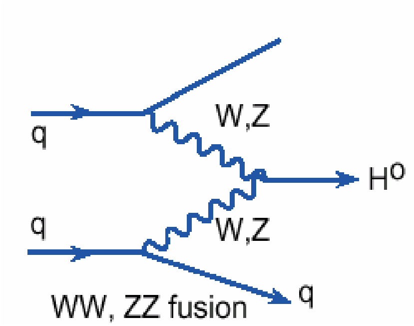


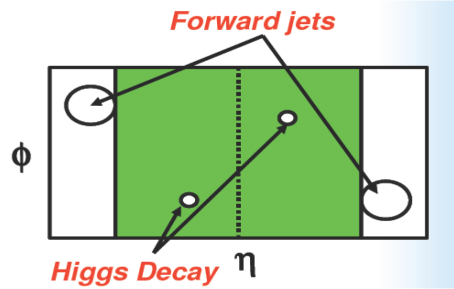
Higgs
Spin 0



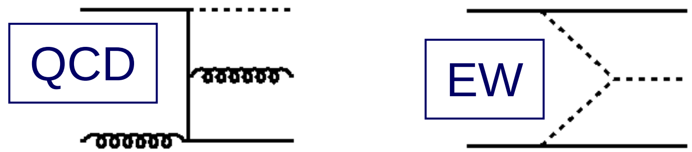
transverse mass

Vector Boson Fusion



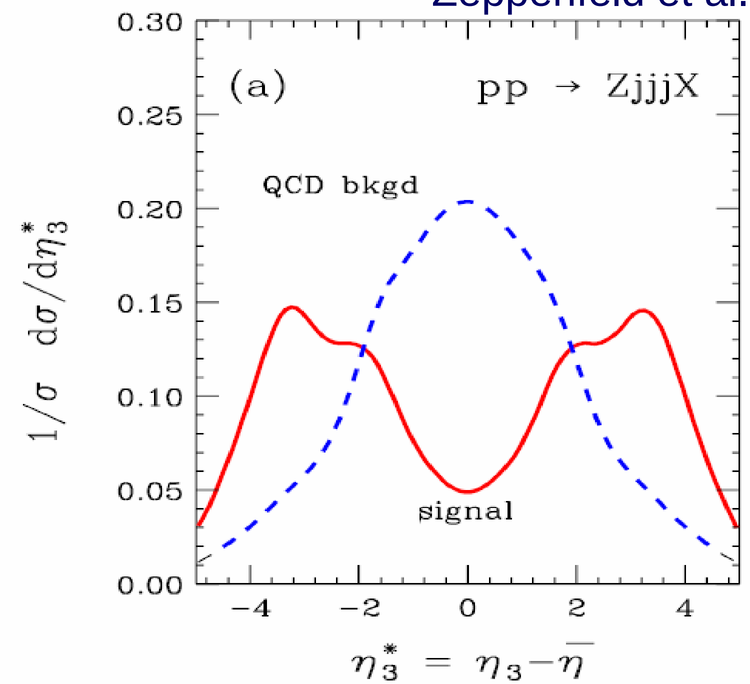


- Second largest production channel (σ~20% of gg-fusion)



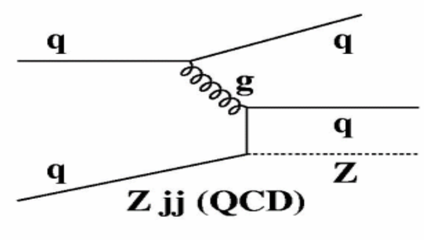
- Two tagging jets in the forward region
  - large separation in η
  - jets down to 1^o from the beampipe
- No color exchange between quarks
  - no jet radiation in central region
- Higgs decay products in the central region
- Powerful background suppression
- Smaller K-factors than for gg-fusion

Zeppenfeld et al.

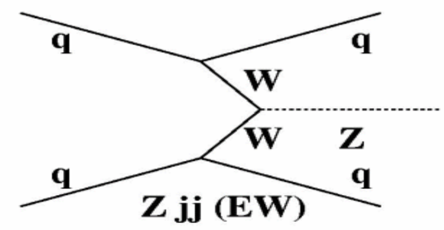


VBF, H→ττ

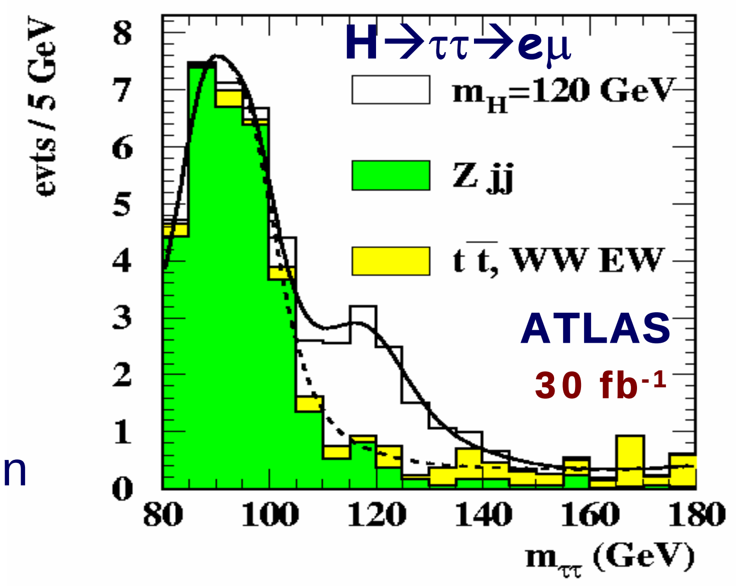
- H→ττ→ll4ν (o l had 3ν)
- Main background Zjj:



Rej. by central Jet Veto

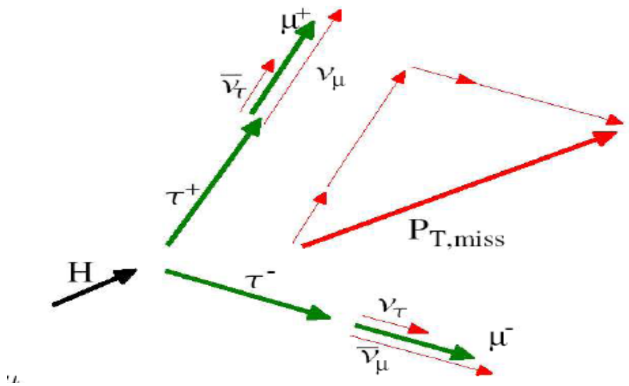


Rej. by ττ mass reconstruction



- mass resolution ~ 10%
- dominated by E_{Tmiss}

- Mass reconstruction: collinear approximation



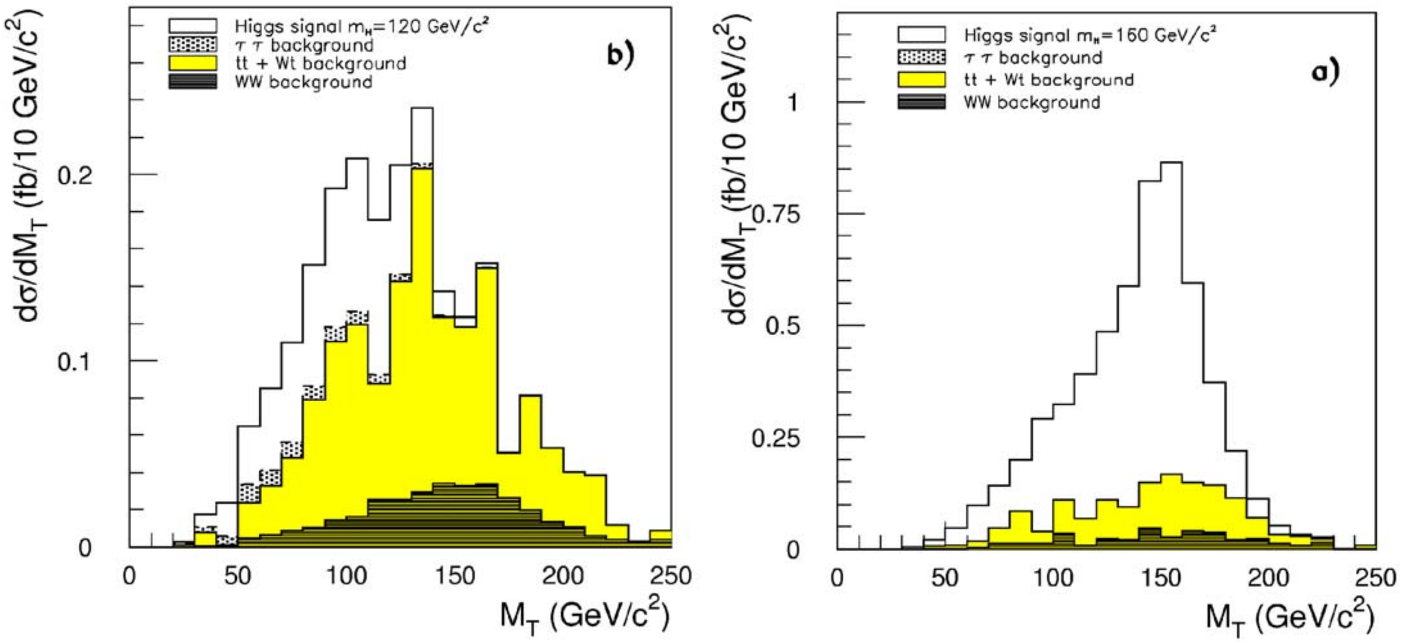
ATLAS significances for 30 fb^{-1}

- ττ→lh M_H=130 GeV , Sign. 4.4
- ττ→lh+ ττ→ll M_H=130 GeV Sign. 5.7

VBF, H→WW

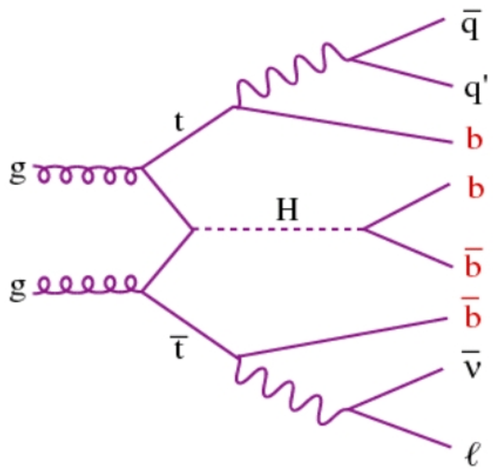
- Relevant for MH from ~130 GeV to ~190 GeV
- Main backgrounds tt+jets, W(Z)+jets, WW(ZZ)+jets, QCD
- WW→lνjj
  - Significance 4.6 at M_H=160 GeV for 30 fb^{-1}
- WW→lνlν : no mass peak
  - Transverse mass: $m_T = \sqrt{2\ P_T{}^{\ell\ell} \not{E}_T\ (1 - \cos\Delta\varphi)}$
  - Significance > 5 for MH 125-190 GeV for 30 fb^{-1}

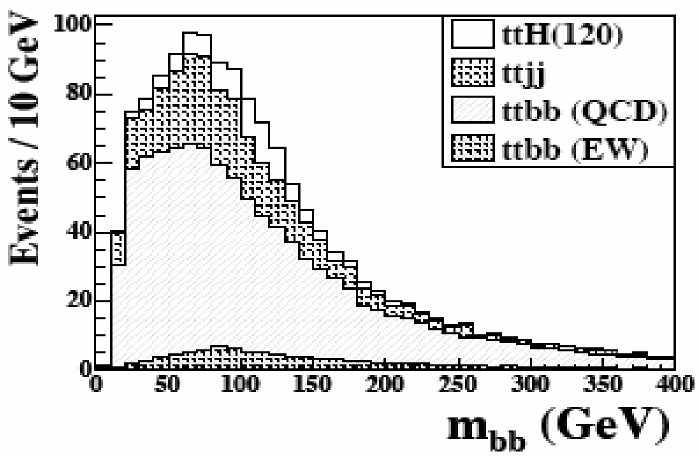
- background uncertainties:
  10-16% (lνjj)
  7-10% (lνlν)



ttH, H→bb

- Potential discovery channel for light Higgs
- Look at semileptonic final states (trigger)
  - ≥6 Jets, ≥4 Jets, b-tagging
  - Isolated lepton
  - Missing energy
- Reducible background
  - tt (+jj)
    - Larger background
    - Relies strongly on b-tagging
  - WWbbjj, W+6j
    - Reconstruct tt
- Irreducible background
  - ttbb
    - Different kinematics w.r.t. signal
    - Multivariate analysis for discrimination



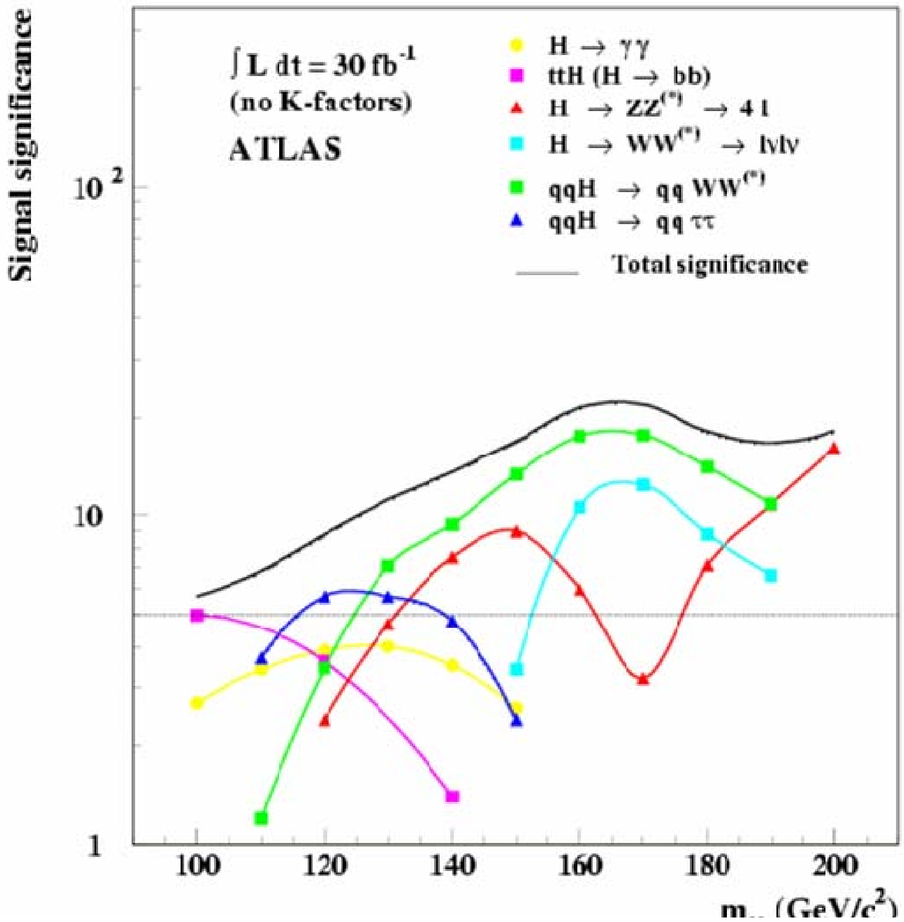


m_H = 120 GeV, L = 30 fb^{-1}

$S/\sqrt{B}$ = 2.8

LO cross sections

Expected significances



- Using LO cross sections
- For M_H just above the LEP exclusion limit several channels can be combined
- In principle, already a good discovery potential with 10 fb^{-1}
- Provided detector performance and background systematics are under control
- For M_H>200 GeV H→ZZ→4l is the "golden" channel

Conclusions

- Many channels sensitive to SM Higgs discovery have been studied in detail
- Sensitivity to the SM Higgs already good with 10 fb-1
- Good understanding of the detector necessary to assess performance from data
- Understand background shapes
- Early discoveries could be possible in H→VV at high mass
- Low mass region more challenging
  - H→gg, ttH, VBF, H→ZZ* are the main channels in the low mass region
- Work in progress right now:
  - Simulation of detector as-installed: including complete material description, misalignments, miscalibrations