Status of SM Higgs Feasibility Studies at ATLAS

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ATLAS project

PHENO 2008 SYMPOSIUM
LHC Turn On
University of Wisconsin-Madison

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Outline

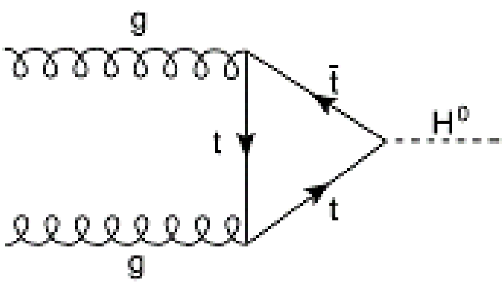
- Introduction
- Most relevant observation channels
  - $H \to \gamma\gamma$
  - $H \to \tau\tau$
  - $H \to ZZ^{(*)} \to 4l$
  - $H \to WW^{(*)} \to ll\nu\nu$
- Summary

Focus on what we can do with 10 fb^{-1} of data

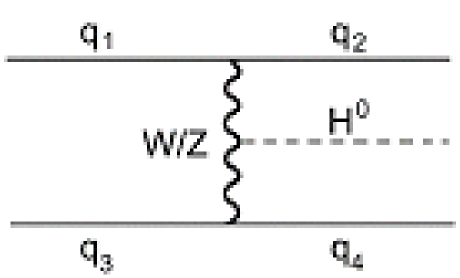
ATLAS will soon release new studies of all relevant channels, including new reconstruction software, MC, analysis techniques

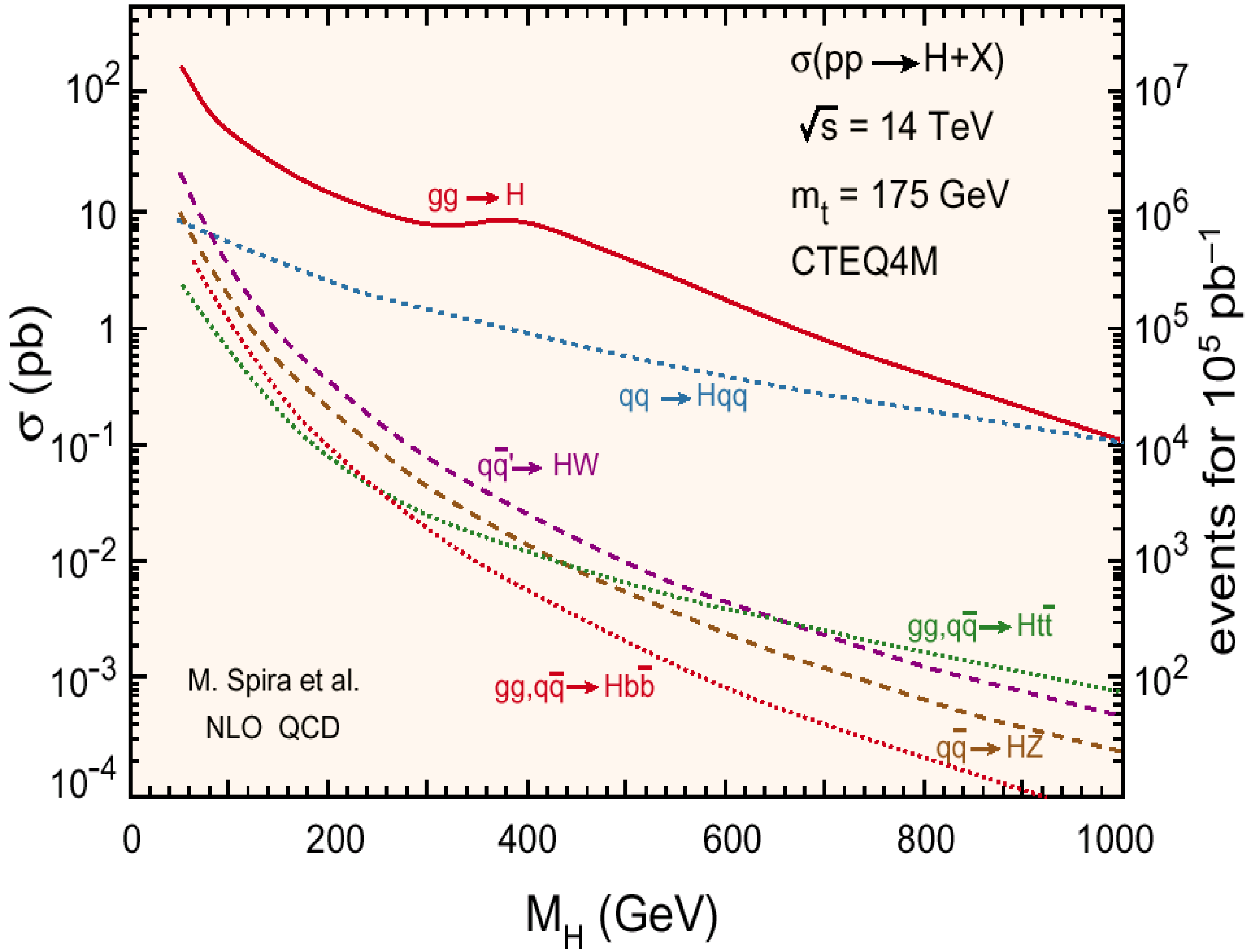
Higgs Production at LHC

Leading Process (gg fusion)

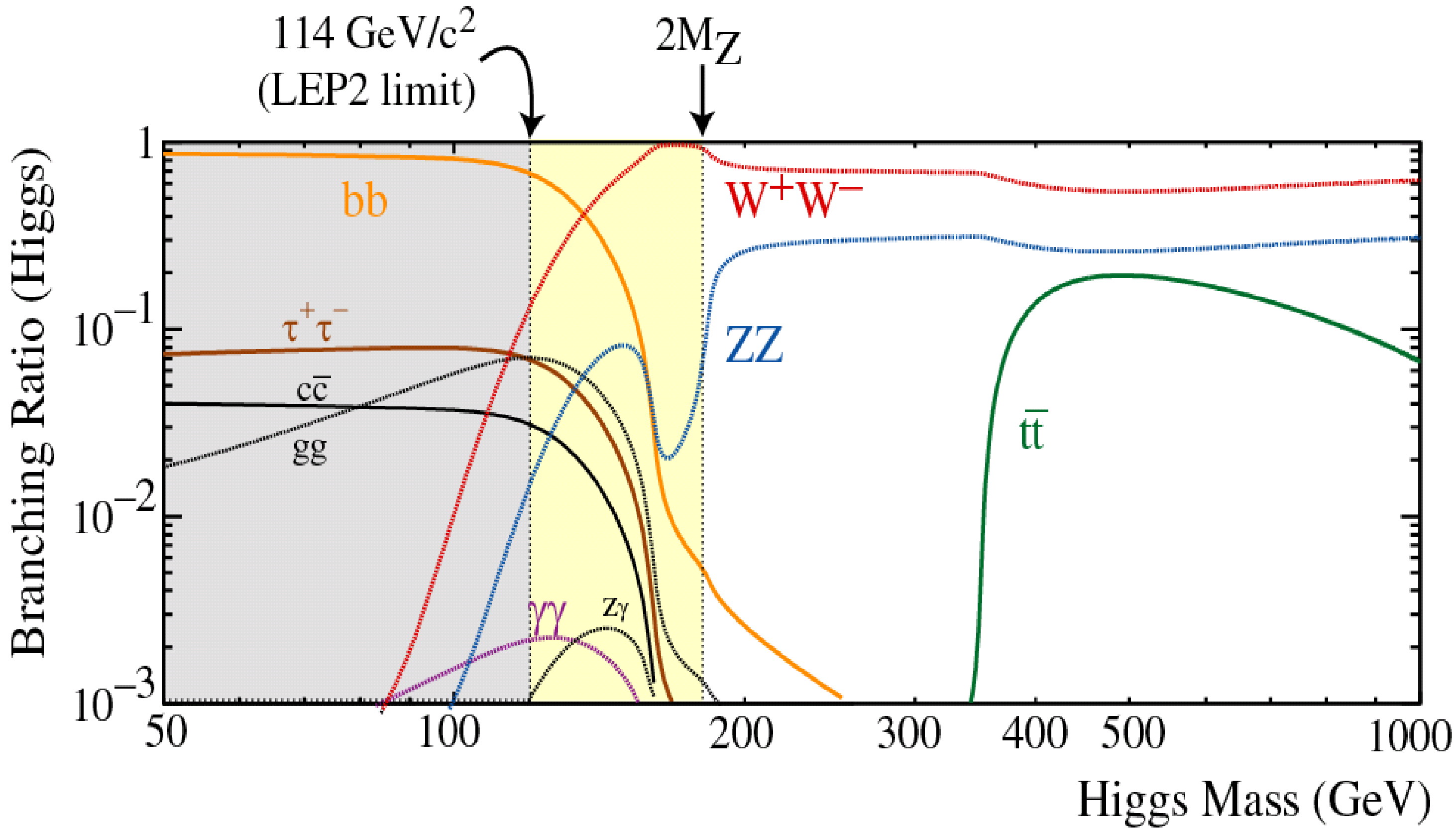


Sub-leading Process (VBF)



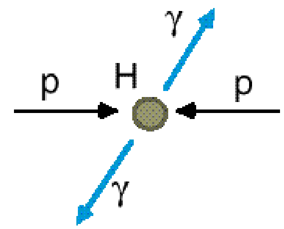


Main Decay Modes

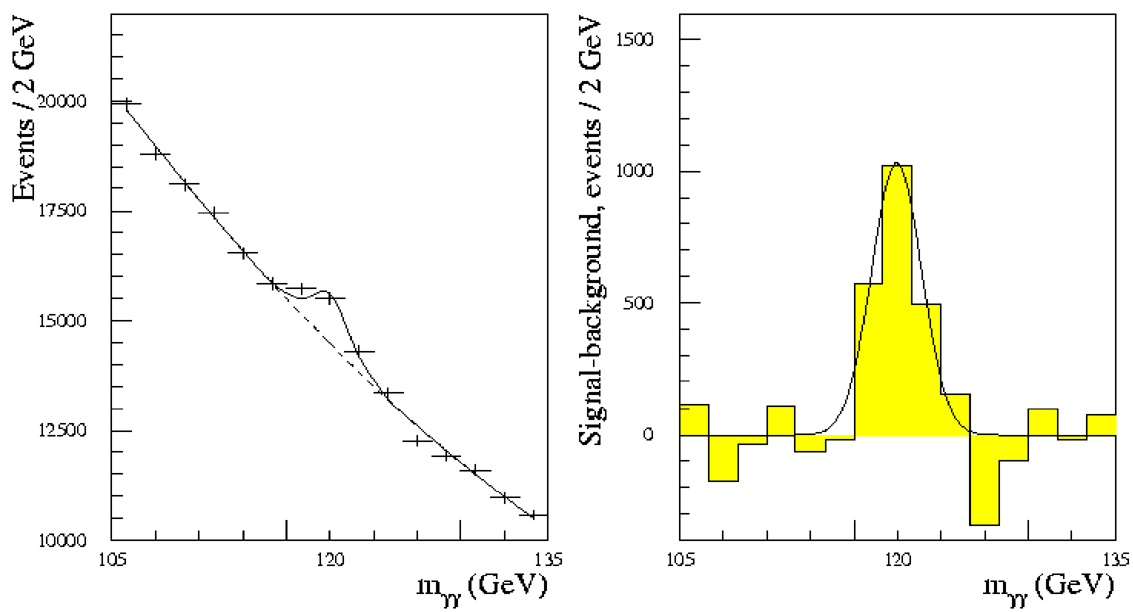


Close to LEP limit:
$H \rightarrow \gamma\gamma, \tau\tau, bb$

For M_H>140 GeV:
$H \rightarrow WW^{(*)}, ZZ^{(*)}$



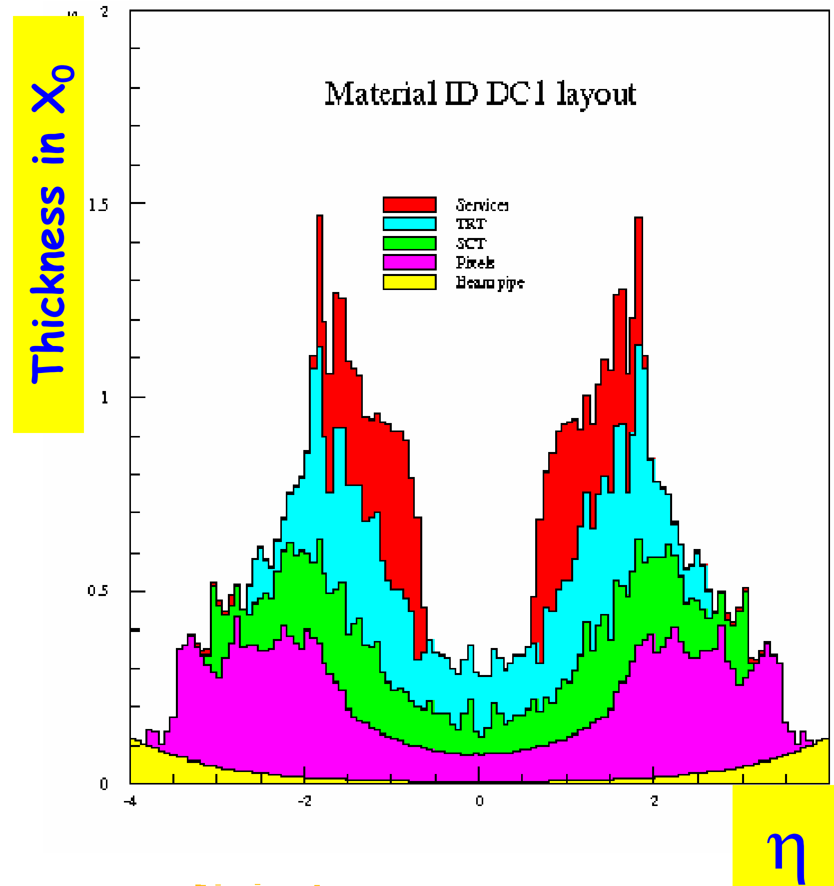
Low Mass SM Higgs: $H\rightarrow\gamma\gamma$



ATLAS TDR (low lumi)

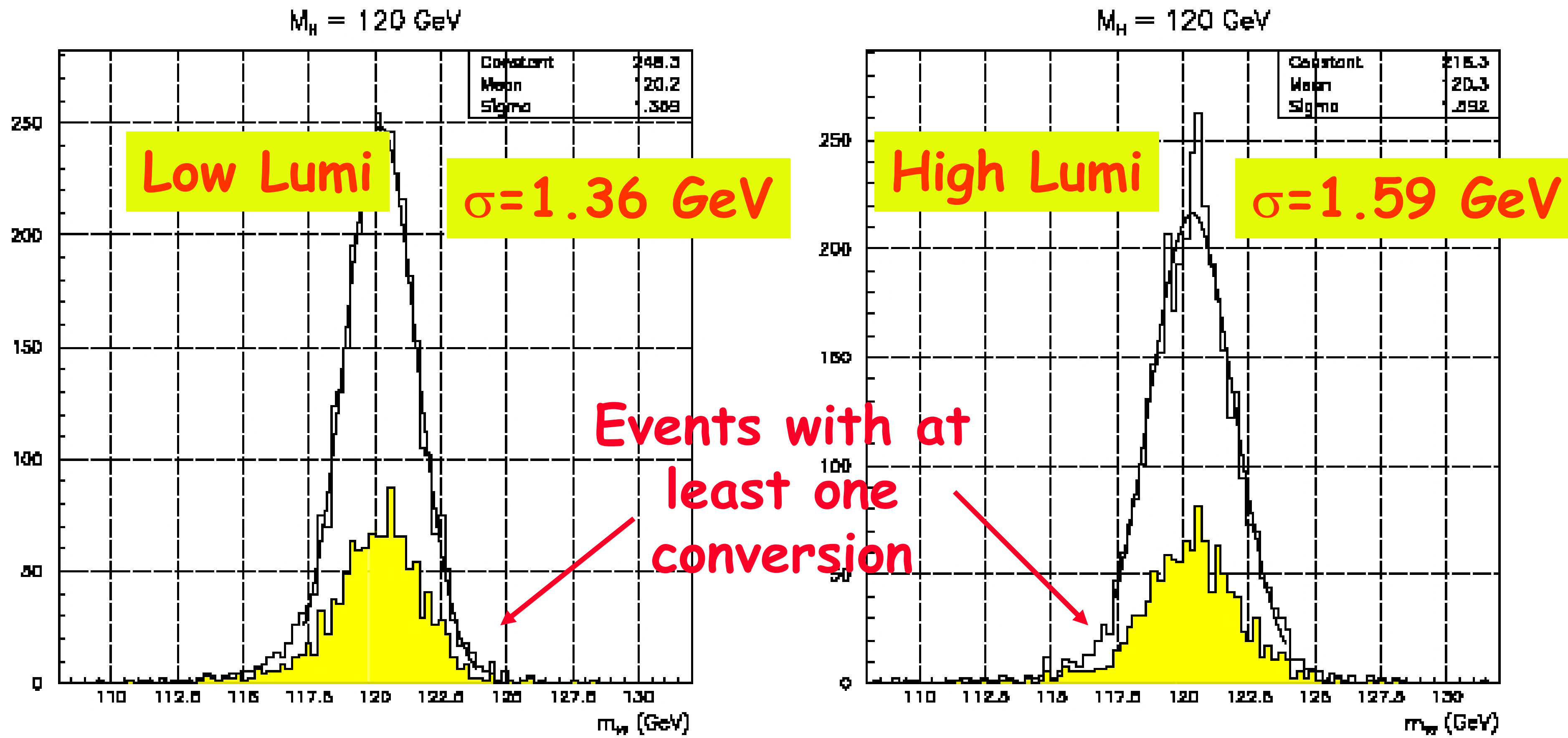
Higgs mass (GeV)	80	90	100	110	120	130	140	150
Cross-section (pb)	38.4	32.4	27.8	24.2	21.2	18.8	17.0	15.4
Branching ratio (%)	0.089	0.119	0.153	0.190	0.219	0.222	0.193	0.138
$\sigma \times$ BR (fb)	34.2	38.6	42.5	46.0	46.4	41.8	32.8	21.2
Acceptance	0.29	0.38	0.44	0.48	0.51	0.53	0.55	0.58
Mass resolution (GeV)	1.11	1.20	1.31	1.37	1.43	1.55	1.66	1.74

- Signal to background for inclusive $H\to\gamma\gamma$ is 3-4% need excellent Higgs mass resolution of about 1%
- Constant term in EM resolution needs to be understood to c_{tot}<0.7%
  - Use cosmics, minimum-bias for first crude look at cell inter-calibration
  - Use $Z\to ee$ for absolute EM scale and refined cell inter-calibration
    - Need $O(10^5)$ events or <1 fb^{-1}
  - Use $Z\to ee\gamma,\mu\mu\gamma$ to study detector response to photons

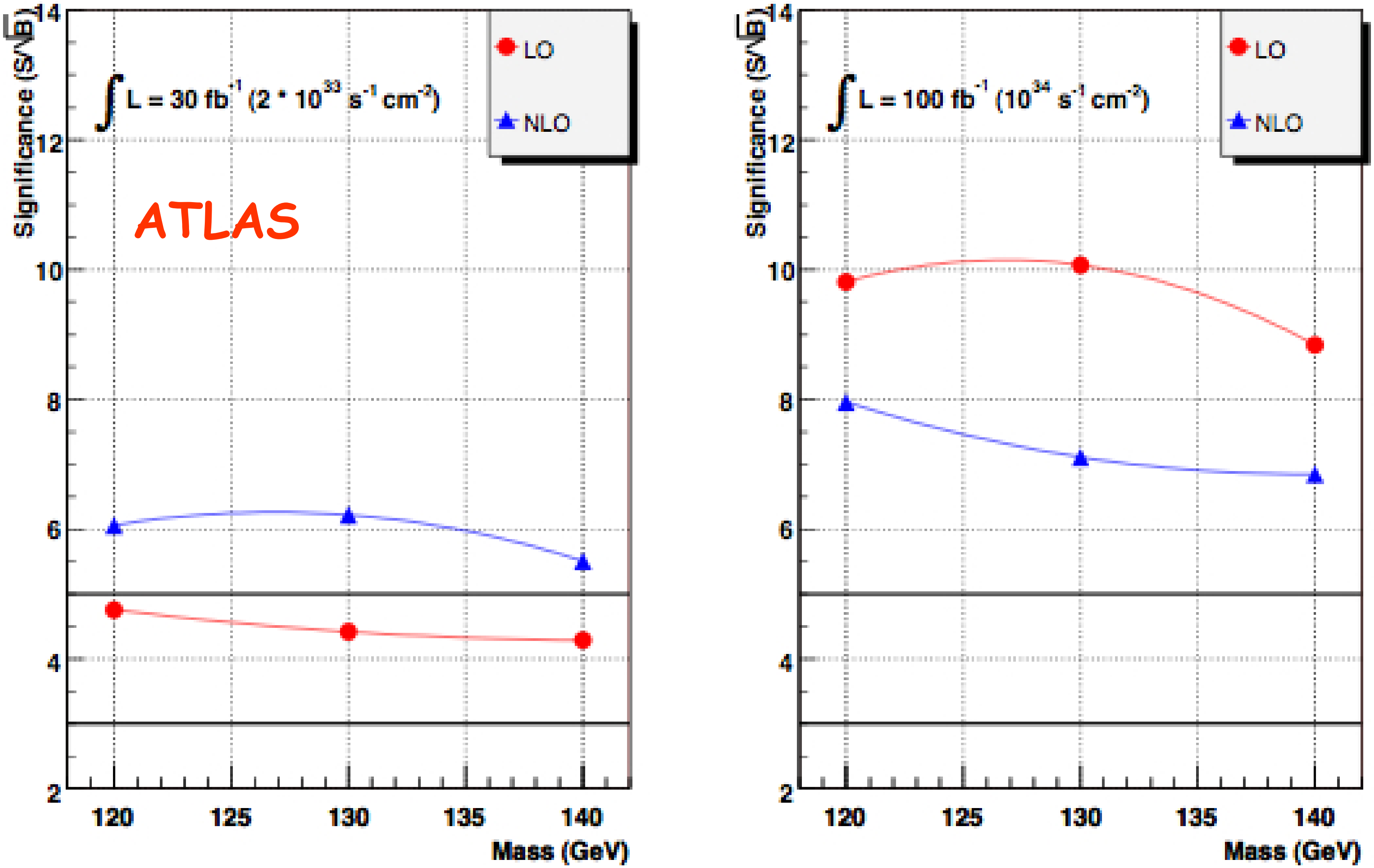


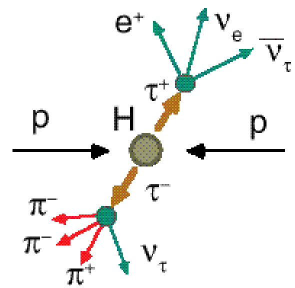
Higgs Mass Reconstruction

- Expect about 50% of events to have at least one converted photon, but can achieve <1.2% mass resolution



Inclusive H→γγ

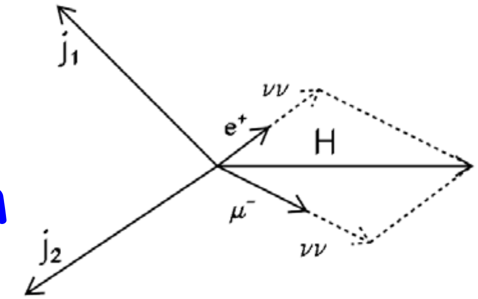




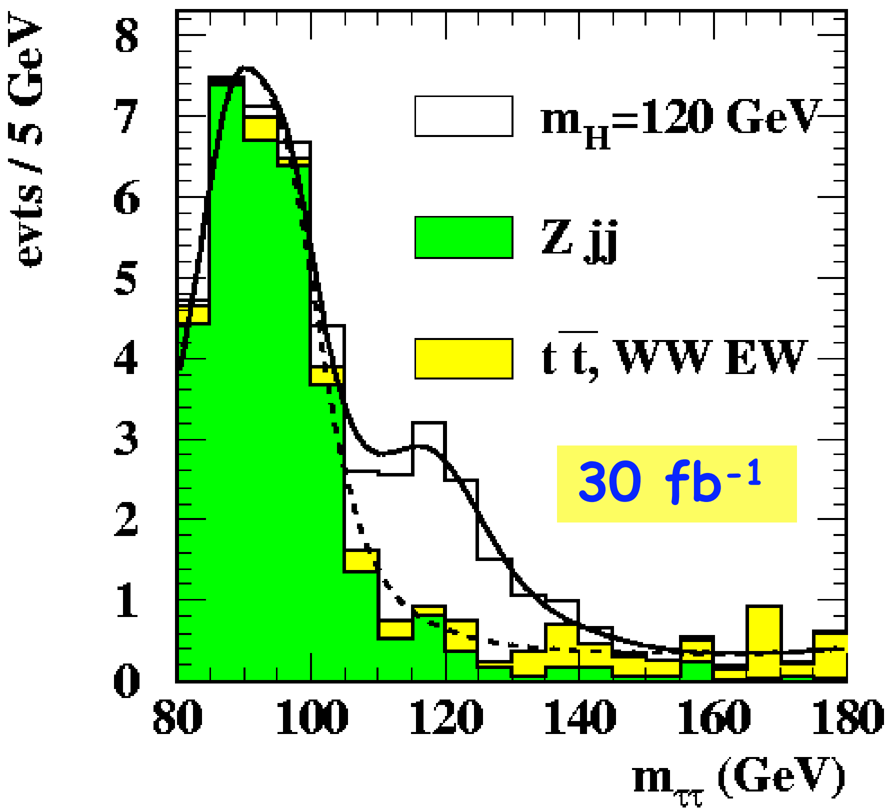
Low Mass SM $H \rightarrow \tau\tau$

Low Mass SM H→ττ+jets

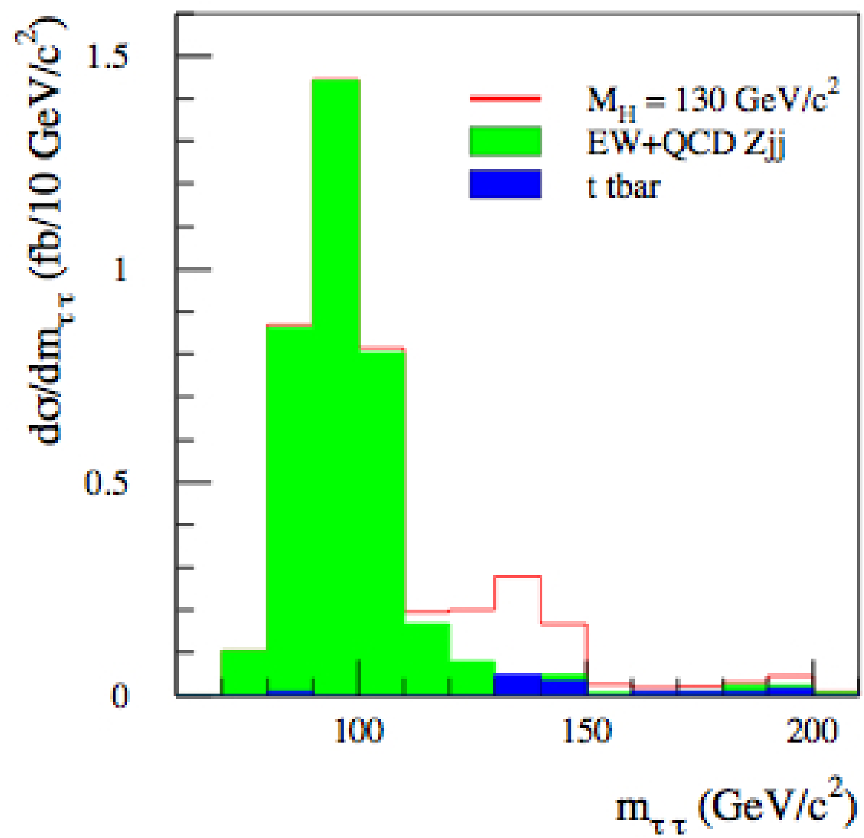
- Reconstruct Higgs mass with collinear approxim



H(→ττ→ll) +≥2jets (VBF)

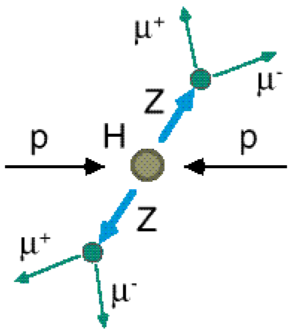


H(→ττ→lh) +≥2jets (VBF)

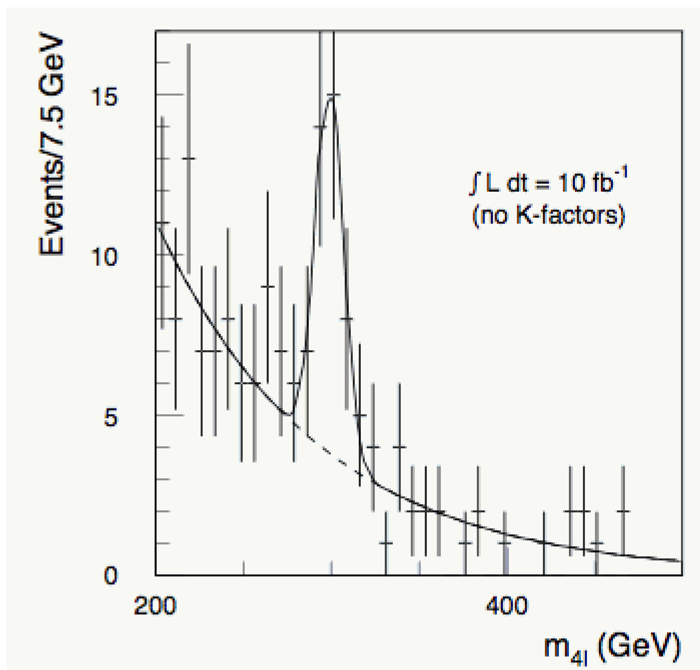


Main Detector Requirements

- Missing E_T reconstruction is a challenge (even with MC!)
- Missing E_T is crucial to reconstruct Higgs mass
  - Require mass resolution of <10%
  - Hadronic calibration with data: combination of
    - Minimum bias (low P_T depositions)
    - di-jets, $Z \rightarrow ll$+jets (γ-jet) events, $W \rightarrow \tau\nu$ for high P_T depositions.
    - Enough data with 1 fb^{-1} to cover necessary phase space to calibrate detector for Higgs discovery
- In order to suppress fake leptons (QCD background) to a level <10% of the irreducible background we need to achieve combined 10^7 rejection with lepton ID
  - May be achieved for $H \rightarrow \tau\tau \rightarrow ll$ ($l=e,\mu$)
    - May achieve $>10^4$ per lepton
  - Checking TDR QCD rejection estimates for $H \rightarrow \tau\tau \rightarrow lh$

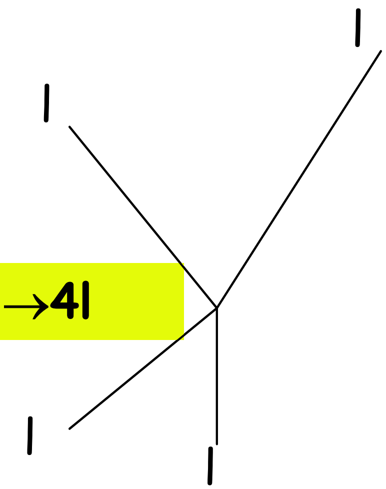


SM Higgs: $H \rightarrow ZZ^{(*)} \rightarrow 4l$



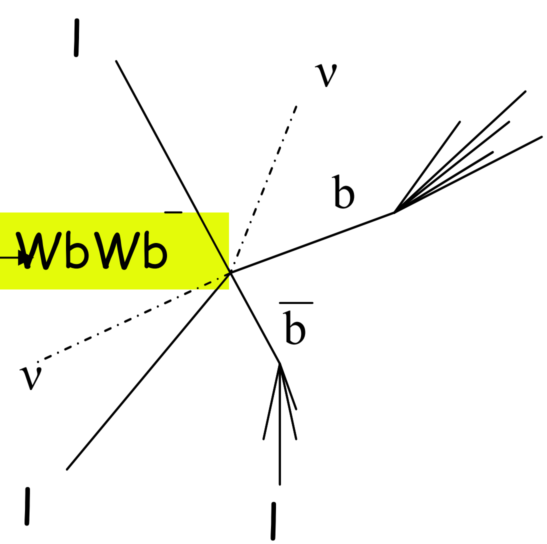
Backgrounds Higgs→$ZZ^{(*)}$→4l (l=eμ)

$ZZ^*/\gamma^* \rightarrow 4l$



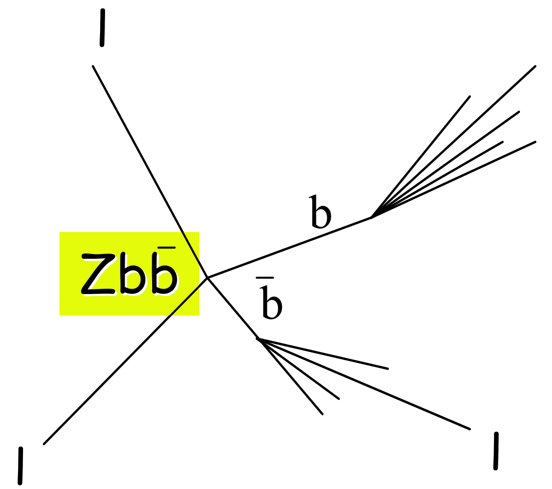
Continuum Irreducible

$t\bar{t} \rightarrow WbW\bar{b}$



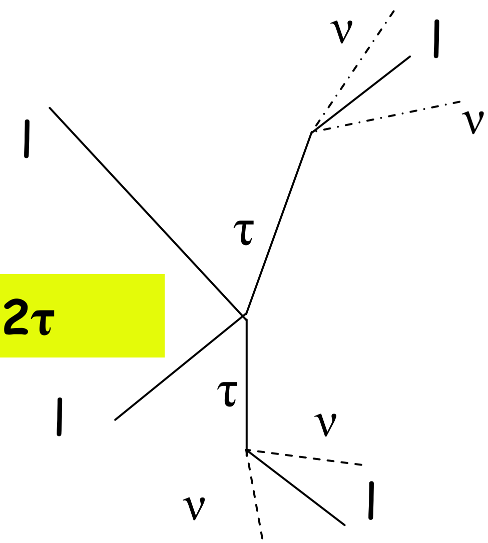
Non-Resonant reducible

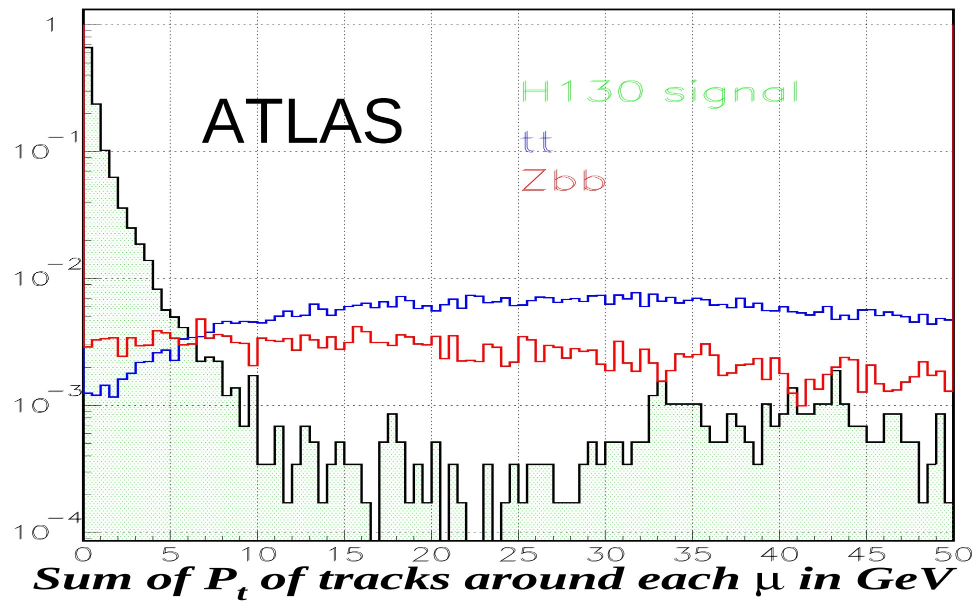
$Zb\bar{b}$

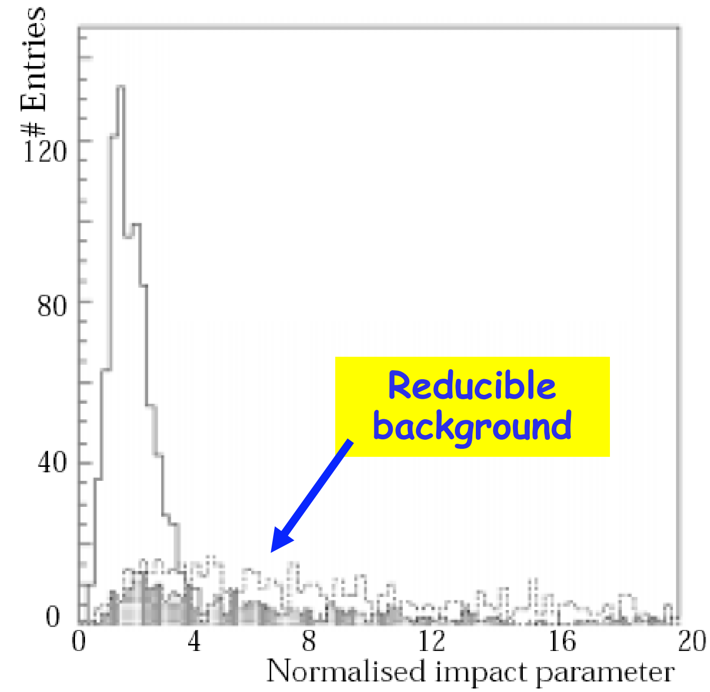


Resonant reducible

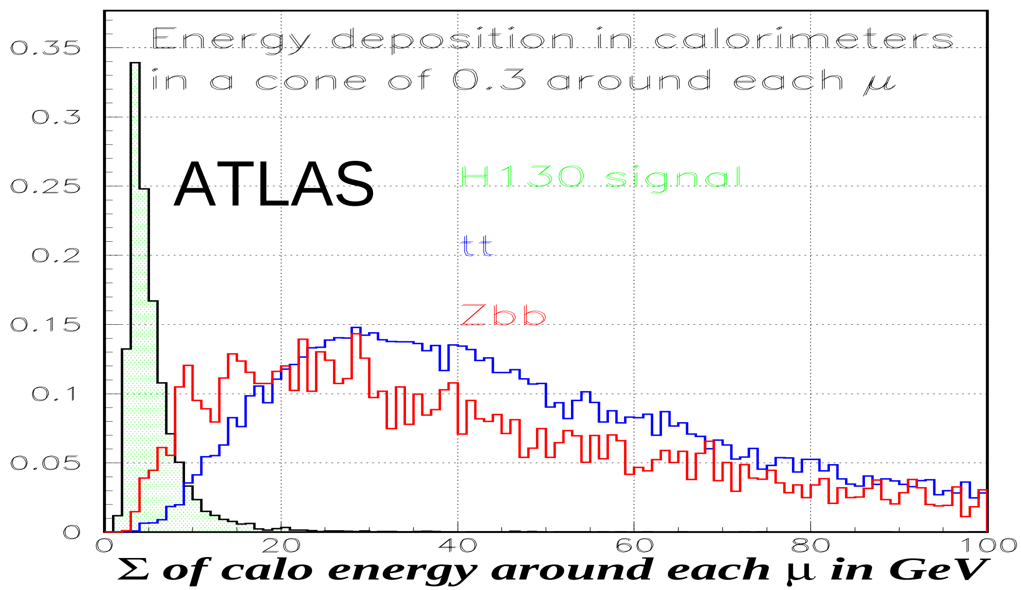
$ZZ^*/\gamma^* \rightarrow 2l\ 2\tau$

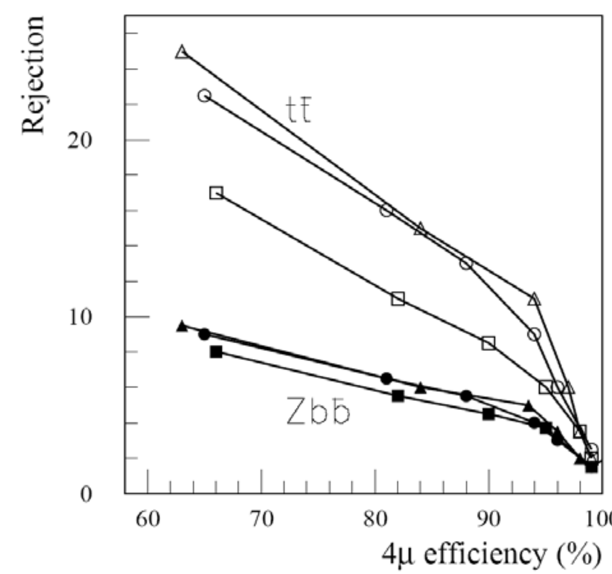






ATLAS TDR



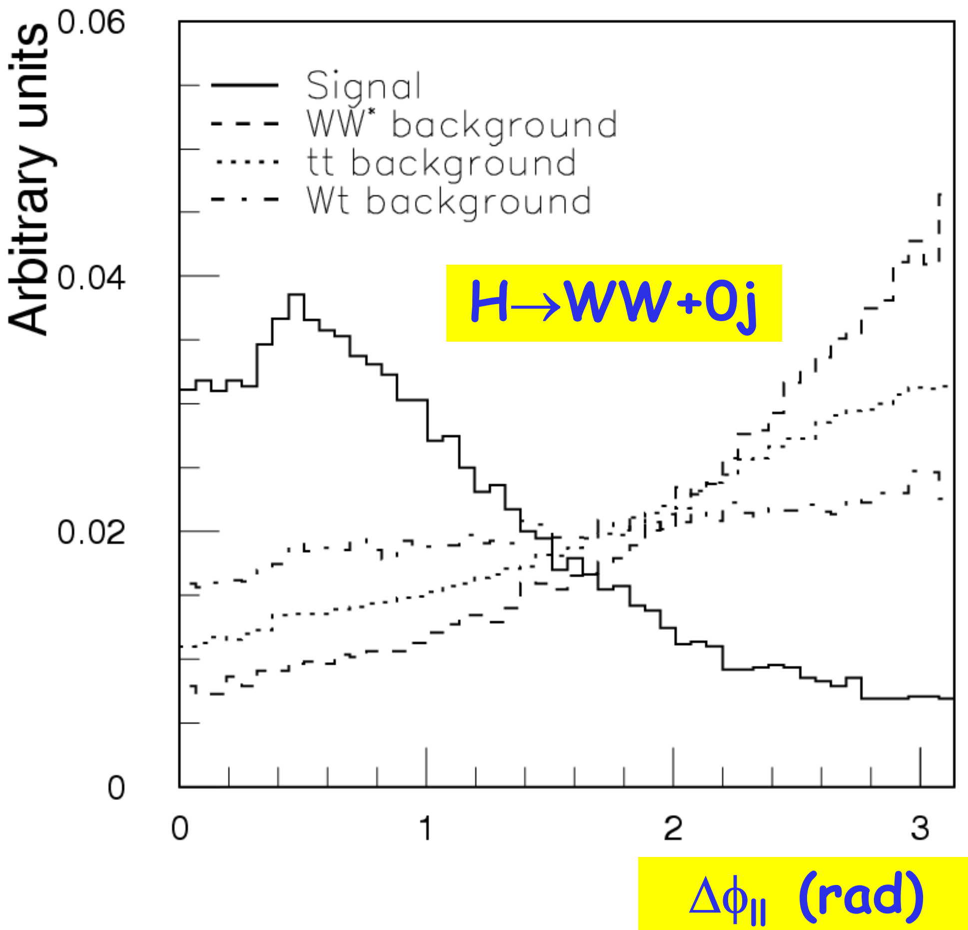


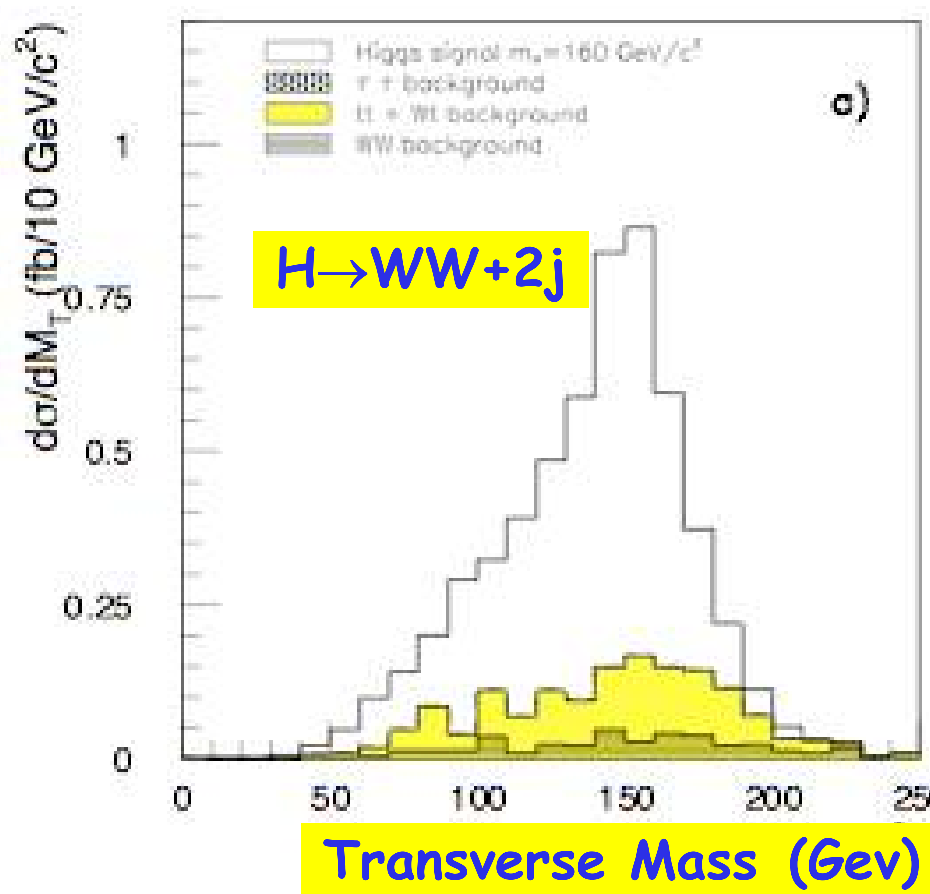
ATLAS TDR

SM Higgs: $H \to WW^{(*)} \to 2l2\nu$

SM Higgs $H \to WW^{(*)} \to 2l2\nu$

- Strong potential due to large signal yield, but no narrow resonance. Left basically with event counting experiment



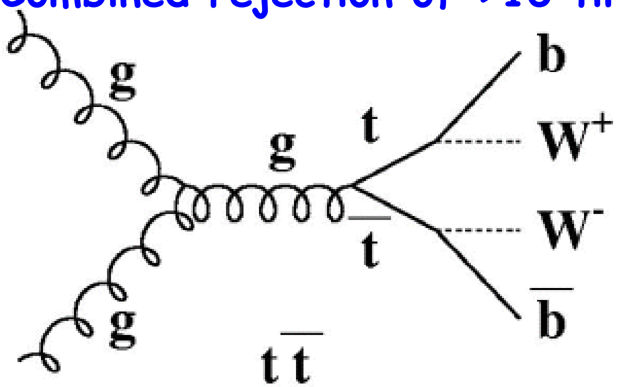


Background Suppression and Extraction

- Not able to use side-bands to subtract background. This makes signal extraction more challenging. Need to rely on data rather than on theoretical predictions
- Definition & understanding of control samples is crucial

ttbar suppression

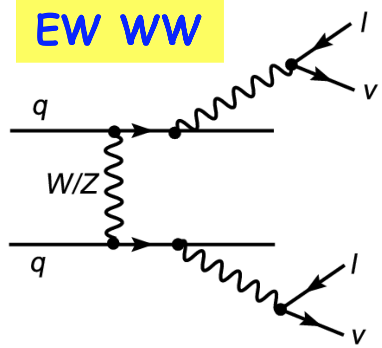
- Jet veto (understand low P_T jets)
- Semi-inclusive b-tagging or "top killing" algorithm
- Combined rejection of >10 times



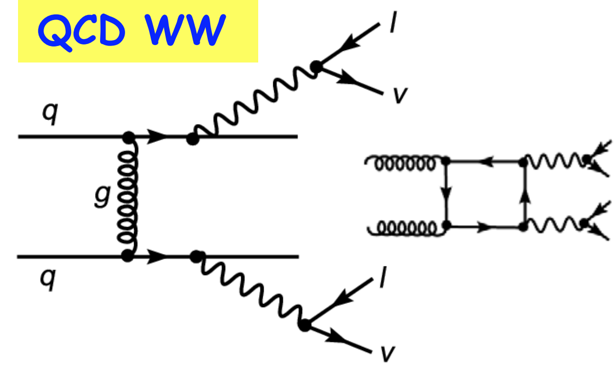
Non-resonant WW suppression

- $\Delta\phi_{ll}$ and $M_{ll,}$ very important variables
- Transverse momentum of WW system
  - Higgs production is harder
  - Missing E_T reconstruction plays a role

EW WW



QCD WW



Summary and Outlook

- Early discovery of low mass Higgs is challenging. Combination of multiple independent channels adds sensitivity and robustness to search
  - One fb^{-1} of usable data (or less) will be needed for calibration and understanding of backgrounds
  - Will need ~10 fb^{-1} to achieve 5σ for mass range
- Data-driven methods for the extraction of background are well defined for Higgs searches
- ATLAS will soon report on re-analysis of sensitivity to observation of SM Higgs.
  - Using new reconstruction software, calibration and background extraction techniques, analysis techniques, Monte Carlos and QCD corrections on signal and backgrounds