SM Higgs boson at LHC: recent developments

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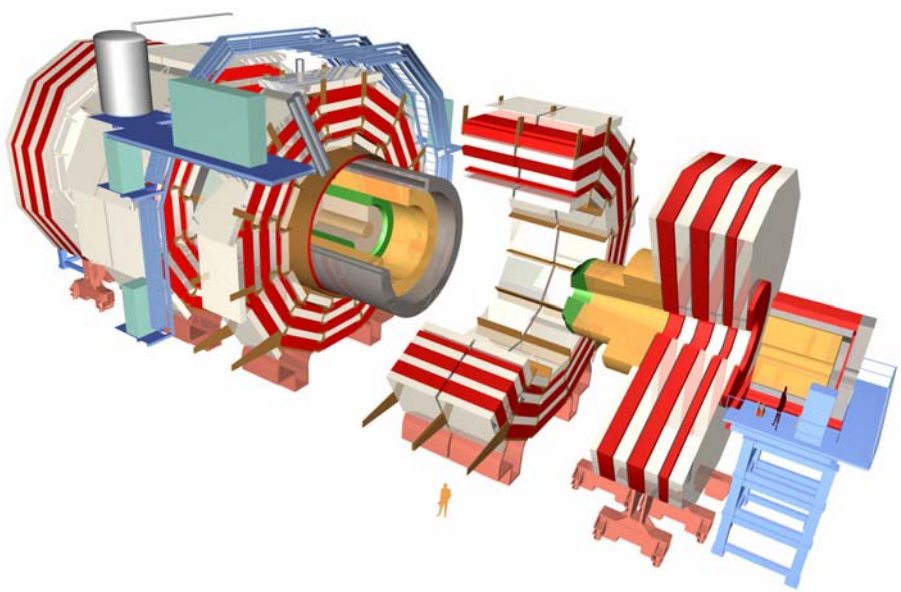
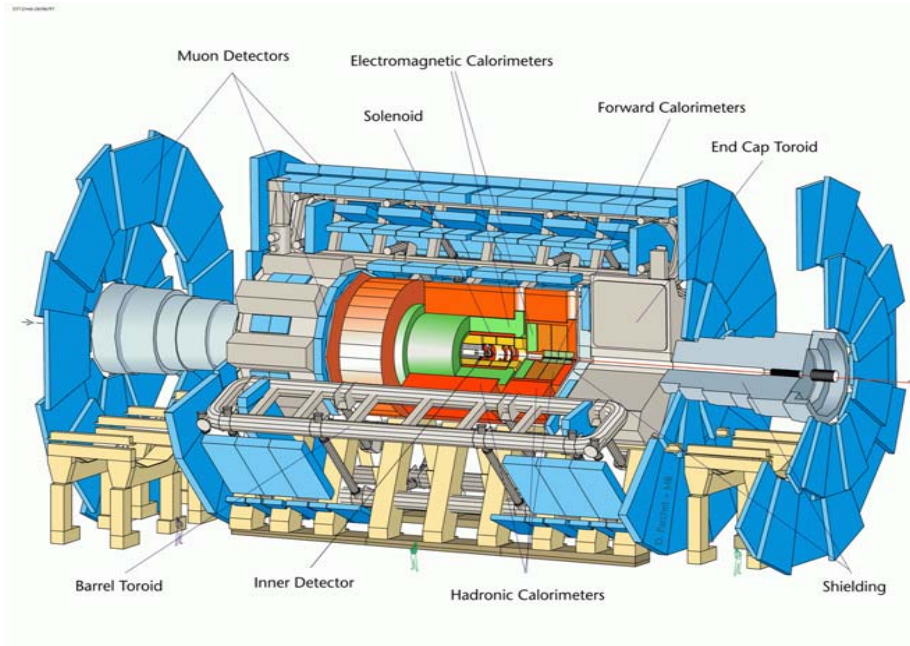
(for CMS and ATLAS collaborations)





working colliders and… not yet working ones…

while some are working hard…

…others trying to walk…

…keeping hopes in mind…

…for all to remember something in the future…

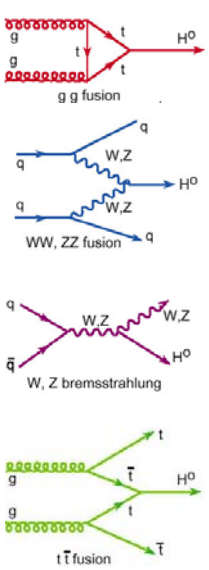
Introduction

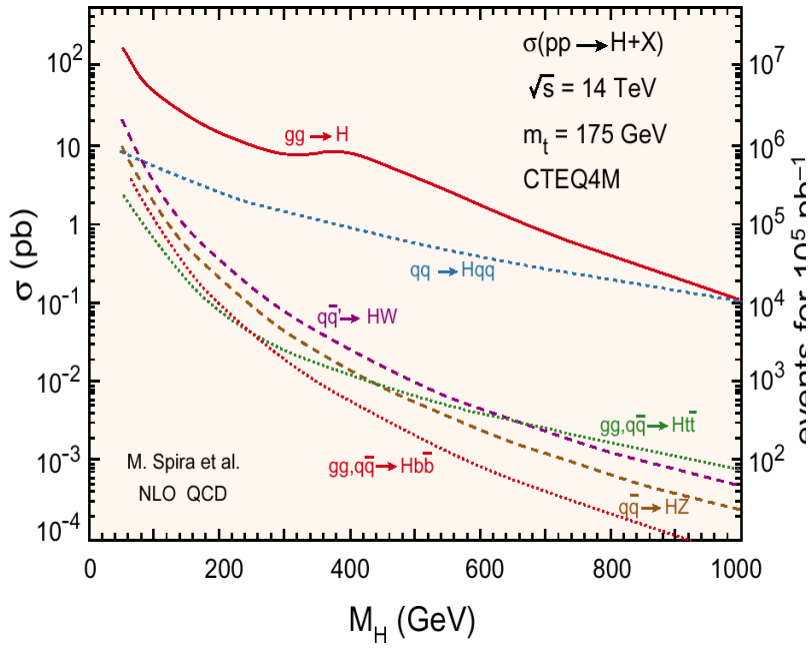
- Focus on recent (published) developments in SM Higgs search at LHC strategies
- Benchmark LHC luminosities
  - 2008: $\int L \sim 0.1 - 1\ fb^{-1}$
  - 2009: $\int L \sim 5\ fb^{-1}$
- Emphasis on "discovery-channels"
  - discovery $\geq 5\sigma$ significance

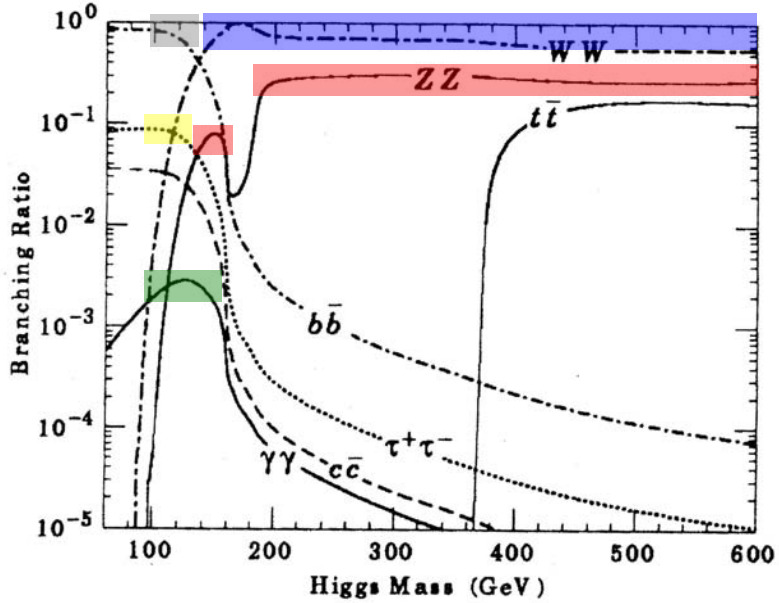
Introduction (2)

- MC Generators:
  - PYTHIA, CompHEP, Alpgen, MadGraph, TopRex, MC@NLO, …
- Cross sections:
  - CMS: NLO K-factors and dynamic event re-weighting used in most analyses
    - for backgrounds: when available
  - ATLAS: mostly LO (often more conservative)
- [Mostly] full detector simulation and reconstruction
- Systematics included for most recent analyses

SM Higgs: discovery signatures at L=30 fb^{-1}



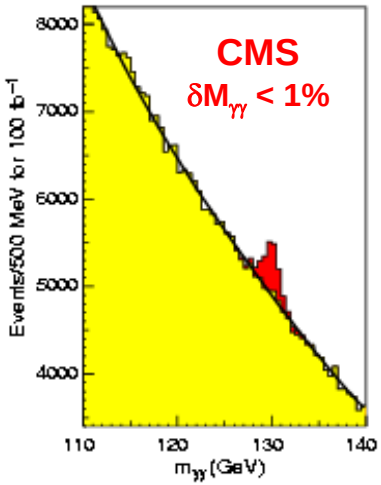




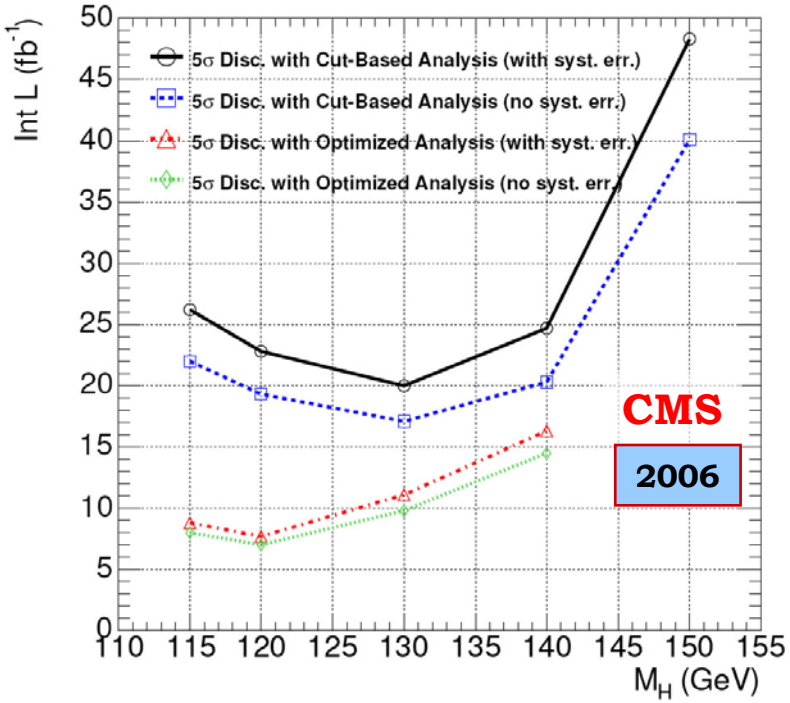
	H→bb	H→ττ	H→γγ	H→WW	H→ZZ
inclusive			YES	YES	YES
qqH		YES		YES	YES
W/Z+H					
ttH					

- filled boxes: detailed analysis available
- YES: sure discovery at $\int L < 30 fb^{-1}$ in the appropriate masses range

- CMS Analysis
  - narrow mass peak
  - K_{NLO}
  - background from side-bands
    - stat. & syst. uncertainties of the fit
  - sort photons into quality categories
    - shower shape
    - η-regions
  - Cut-based analysis
  - NN based analysis
    - background: training on side bands (a la real data)
    - signal: training with MC
    - treating separately each event
  - Discovery M_H<130 at $\int L \leq 10 fb^{-1}$
- ATLAS (2006 update):
  - ResBos NLO MC generator was used for signal and irreducible bckg
  - improved (vs. ATLAS TDR) reach reported



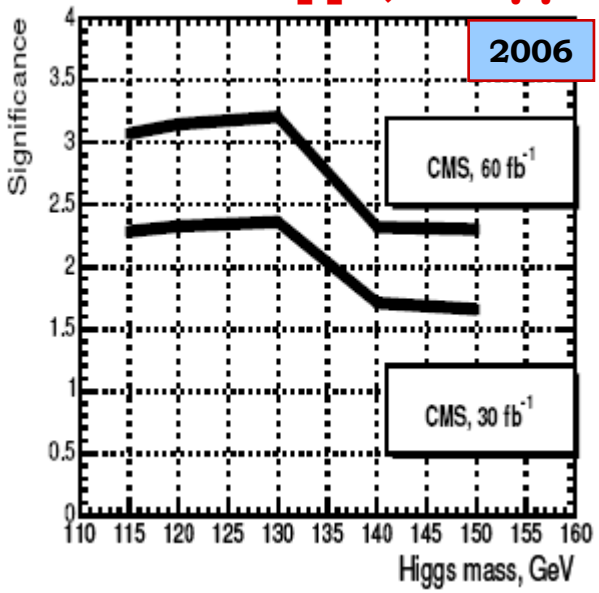
- Results



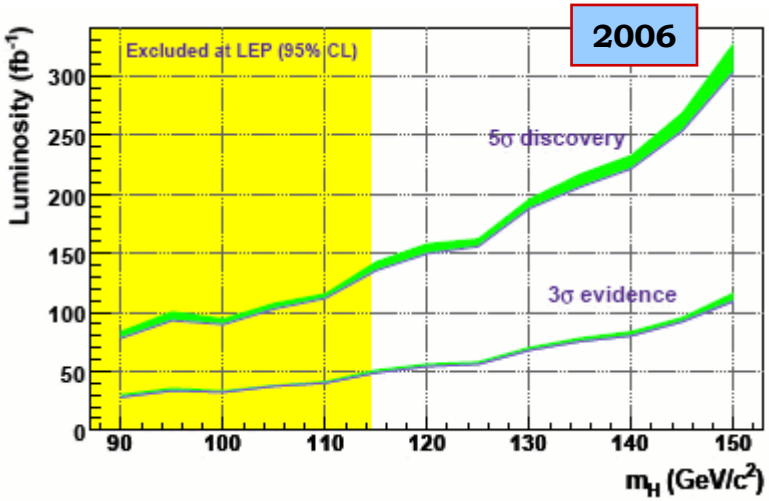
qqH, ttH, W/Z+H with H→γγ

- CMS Analyses
  - photon fakes rejection
    - NN usage (for π^0 rejection)
  - overall improvements vs. previous ATLAS/CMS studies
- Results
  - ~3σ qqH, H→γγ for 60fb^{-1}
  - ~3σ W/Z+H, H→γγ for 60fb^{-1}
  - ~3σ ttH, H→γγ for 100fb^{-1}
  - …all behind inclusive H→γγ, but important for coupling measurements

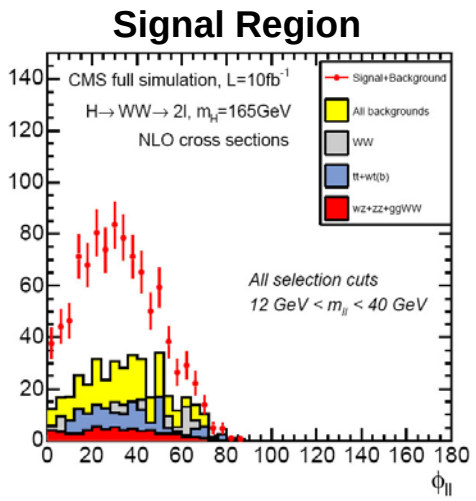
CMS: qqH, H→γγ

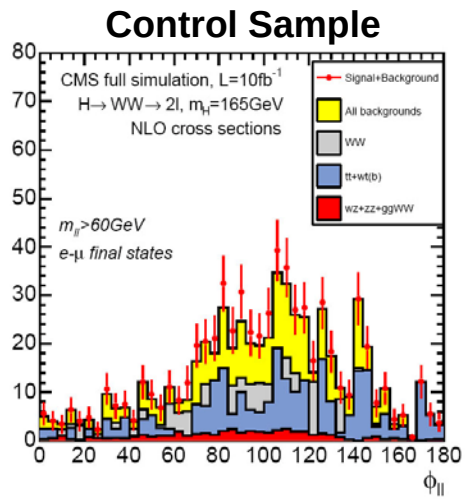


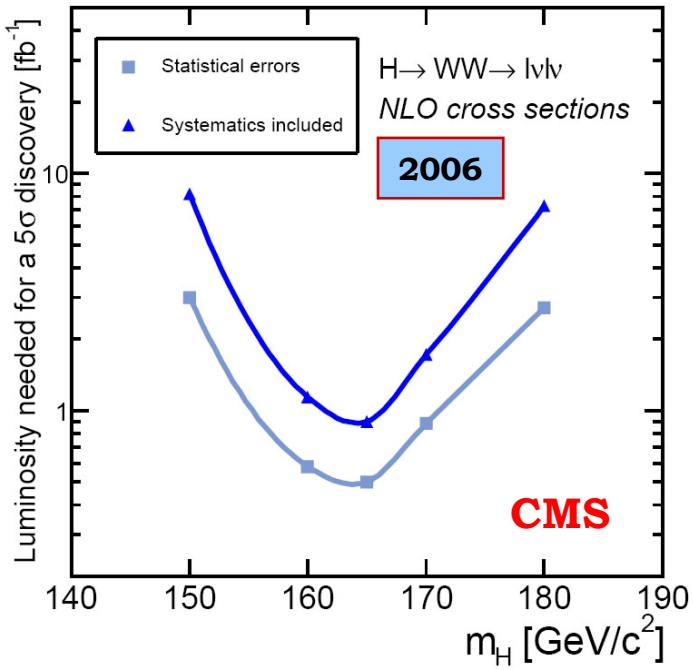
CMS: W/Z+H, H→γγ



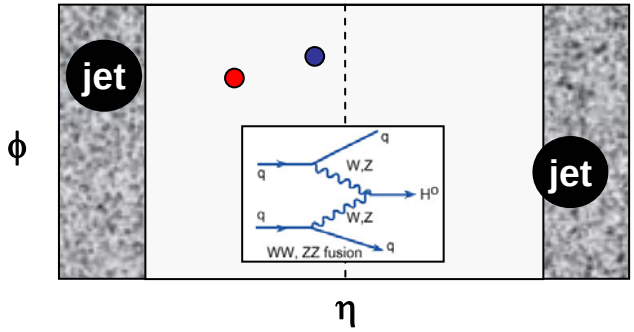
- CMS Analysis
  - counting experiment (no mass peak)
  - special treatment of low E_T jet fakes from W+jets
  - background normalization (mostly) from data
    - systematic uncertainty ↓
    - statistical error penalty ↑
  - special treatment in 2e2ν analysis for low M_H<160 GeV
    - improvements in e-reco (➔better W+jets rejection)
  - 2μ2ν analysis
  - $K_{NLO}(p_T^{WW})$ events re-weighting
    - signal and WW background
- Discovery:
  - 1fb → M_H~165 GeV
  - 10fb → M_H~150..180 GeV

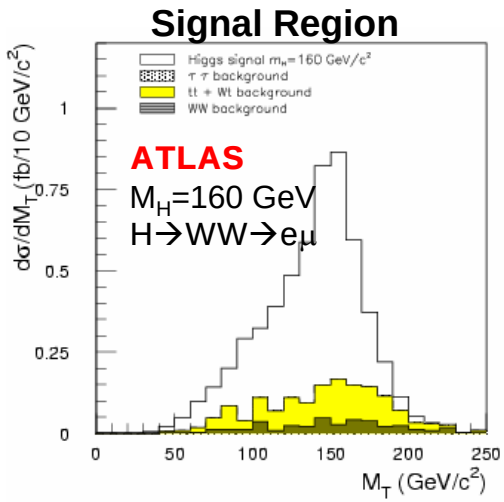


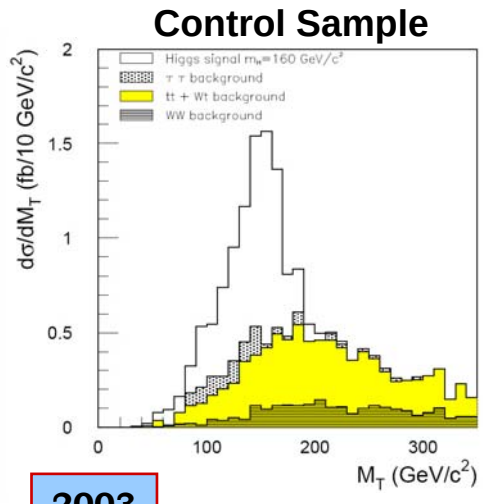




qqH, H→WW/ττ→ll/lj(j)

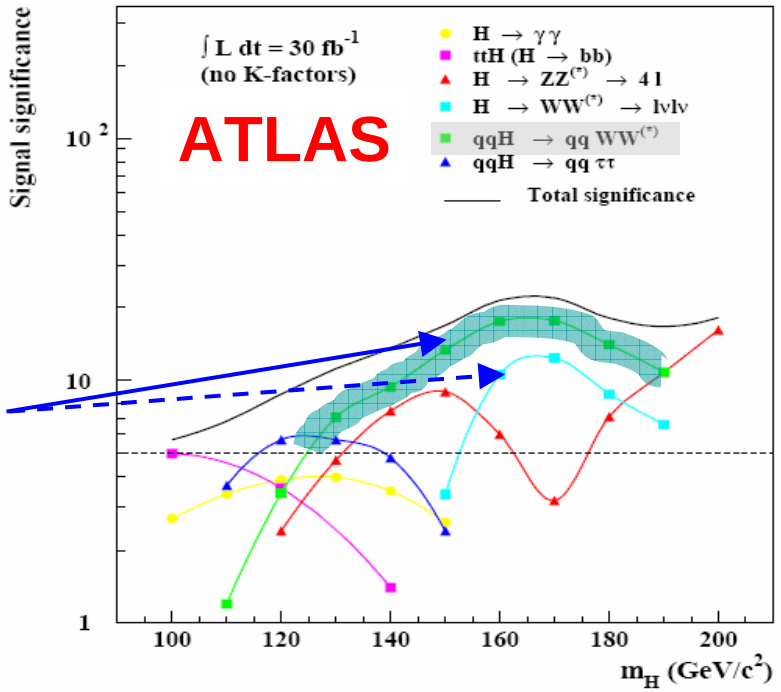






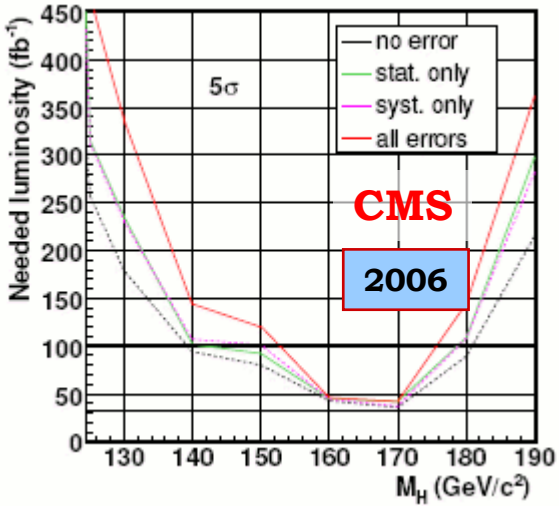
- ATLAS Analysis
  - forward jet tagging, lepton(s)
  - central jet and b-tag veto, MET
  - counting experiment
  - background from control sample
    - signal: $12<m_{ll}<40$ GeV
    - control sample: $m_{e\mu}>60$ GeV
- Features
  - qqH→qqWW is better than inclusive H→WW
    - CMS: m_H=150..180 inclusive is better than qq
  - CMS: longer list of investigated backgrounds (+dedicated generators) and systematic uncertainties, plus full simulation/reconstruction is used

2003



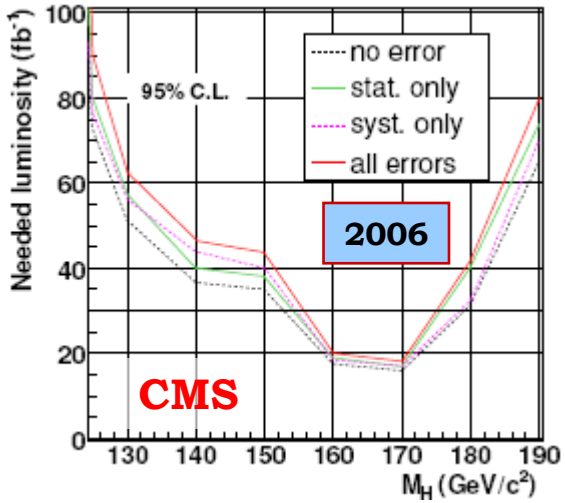
CMS Analysis

- selection
  - 3 isolated leptons
  - (b-)jet veto
  - Z veto (M(ll)-M_Z > 25 GeV/c^2)
  - angular cuts (against WWW continuum)
  - more topological cuts
- background from data

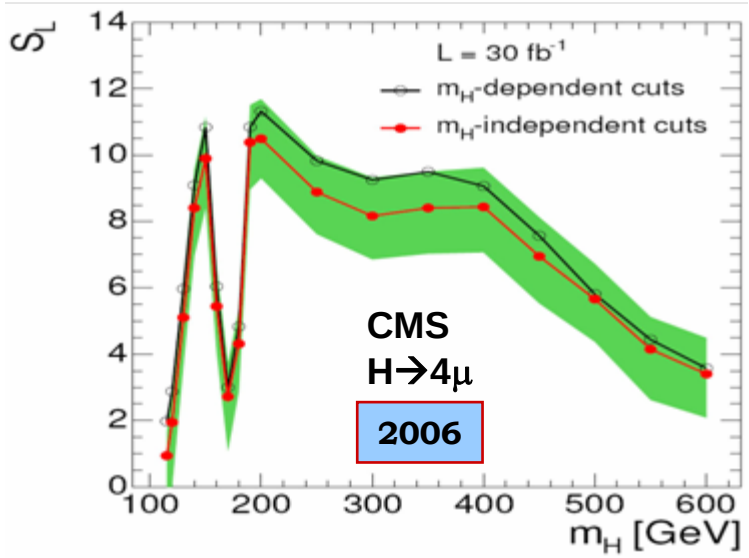


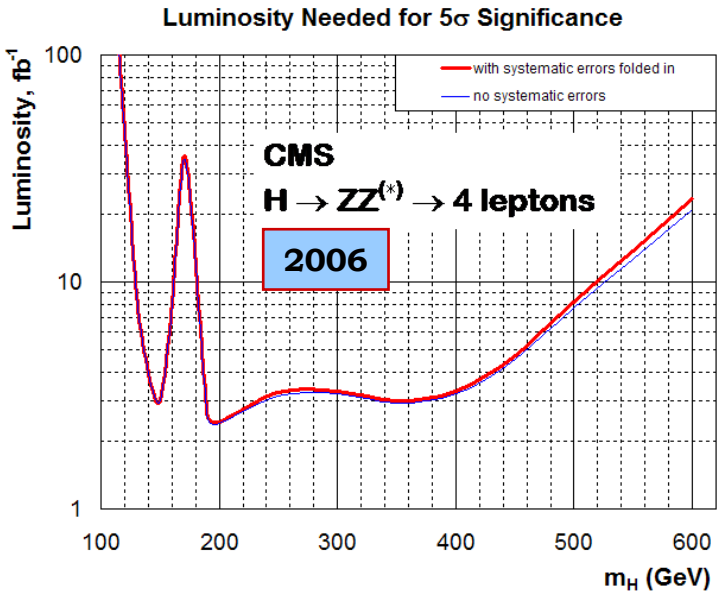
Results

- 5σ discovery with 100fb^{-1} in m_H=155..175 GeV
- (WH coupling)^2 measurements
- one more motivation for this [relatively low significance] channel is to check for a fermiophobic Higgs boson model for which 95% C.L. is possible with <30fb^{-1} for the whole region: from LEP exclusion (114 GeV) to 175 GeV



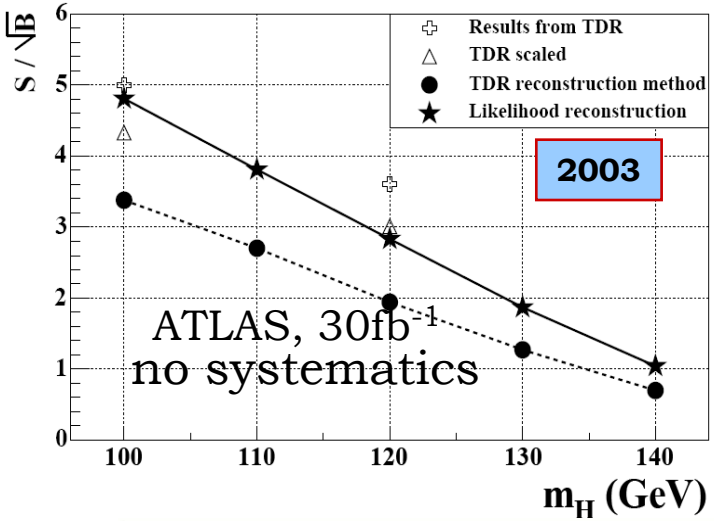
- CMS Analysis
  - $K_{NLO}(M_{4l})$
  - cuts
    - M_{4l}-mass dependent and "flat" cuts
  - ZZ is the only significant background ($Z=Z,Z^*,\gamma^*$)
    - long list of considered backgrounds
  - control samples
    - side bands (penalty: low statistics, complicated background shape)
    - Z-peak (Z- and ZZ-production are similar, Z-production is much used as a reference process)
  - muon reconstruction and isolation efficiencies will be measured from data (Z-production)
  - full treatment of systematic errors

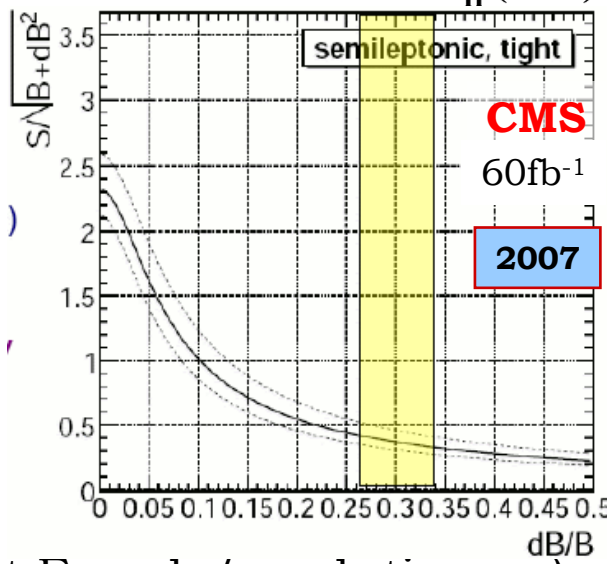




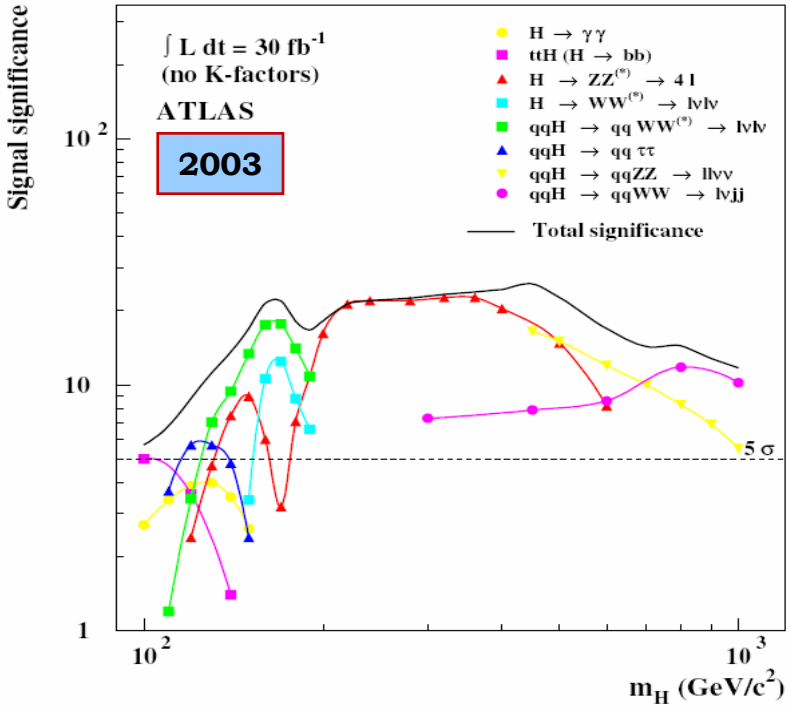
ttH, H→bb

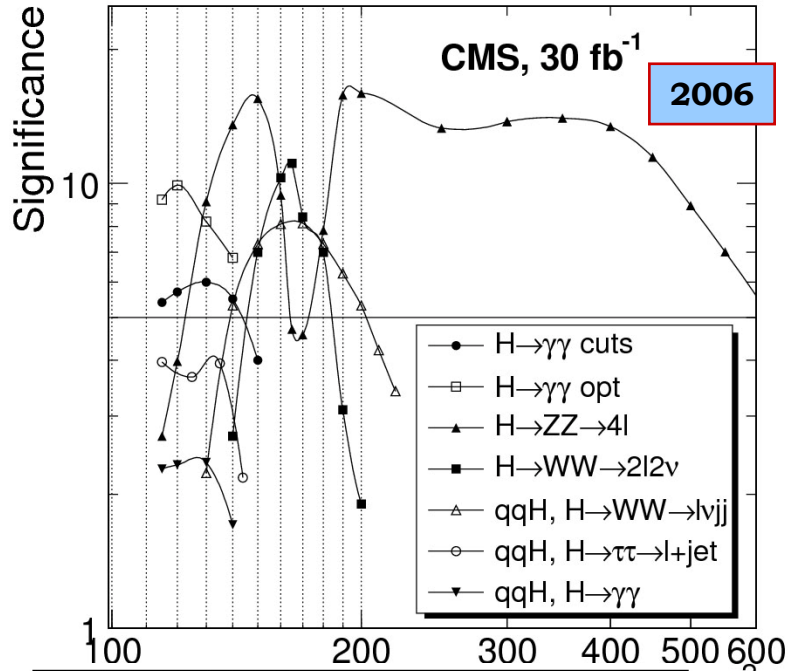
- bb is dominant decay mode up to M_H=135 GeV
  - direct H→bb is hopeless (QCD)
  - ttH, H→bb investigated
- Analysis, ATLAS:
  - semi-leptonic mode considered
  - backgrounds considered:
    - ttbb, ttjj, ttZ
  - systematic uncertainty estimated 10%
  - TDR vs. 2003 paper (changes in significance, S)
    - more realistic backgrounds generation, S↓
    - collinear approximation, S↑
    - likelihood methods, S↑
    - …"restored" TDR level performance
- CMS (2006):
  - combined all channels: e/μ/ll/hadronic
  - larger list of systematics
  - **full(!) simulation+reconstruction** (b-tagging, jet E-scale/resolution, …)
  - **no way to control systematic errors found**

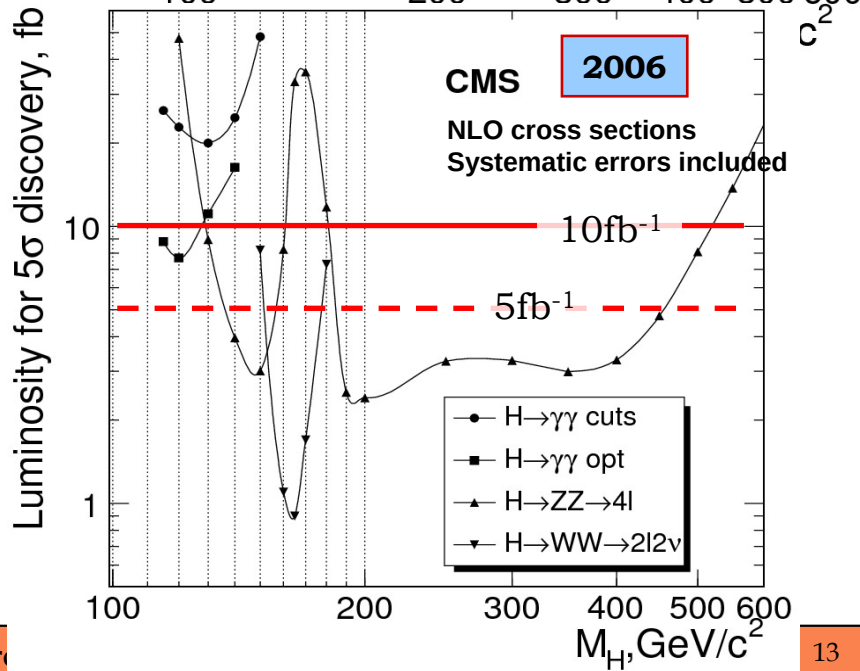




Summary on discovery reach



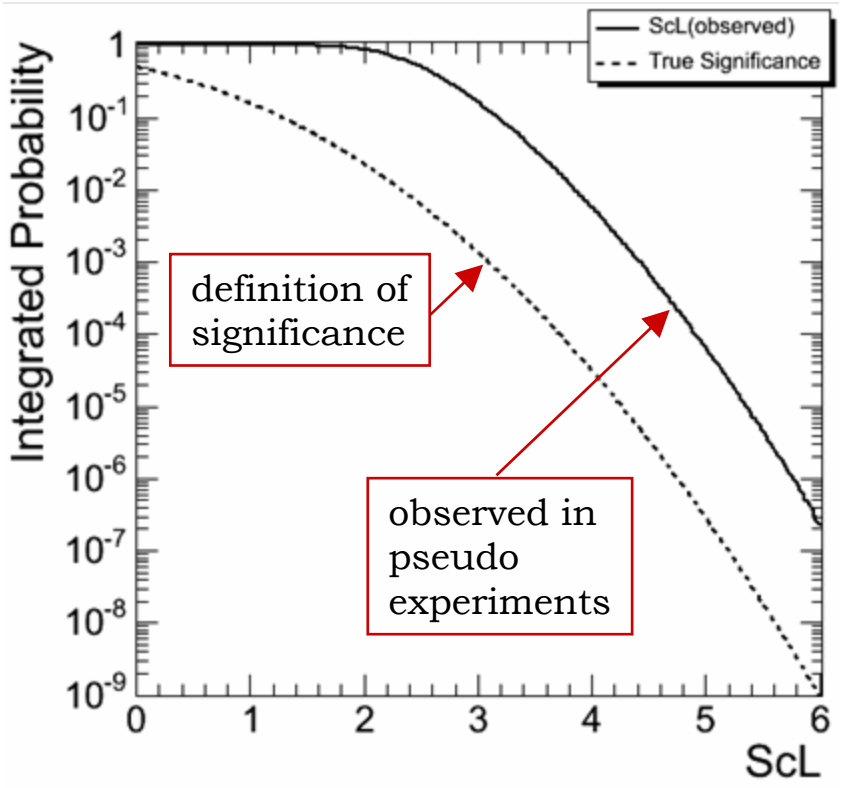


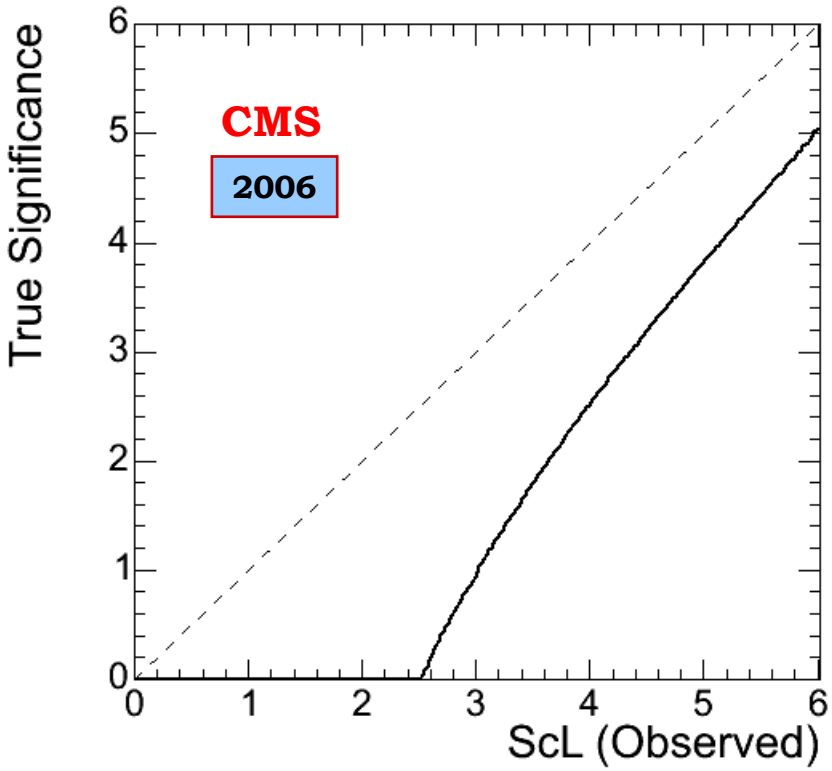


- **Benchmark luminosities:**
  - **0.2 fb^{-1}**: exclusion limits will start carving into SM Higgs x-section
  - **1 fb^{-1}**: discoveries become possible if M_H~170 GeV
  - **10 fb^{-1}**: SM Higgs is discovered (or excluded) in full range

Words of caution: Significance re-weighting

- Significance of n×σ discovery should be re-evaluated (degraded) when a "sliding hypothesis" is used
- The larger the range and narrower the peak, the greater effect is
- Results for SM H→ZZ→4l search in M_H=115..600 GeV range
  - (NOTE: don't depend on background shape or integral number of background events)

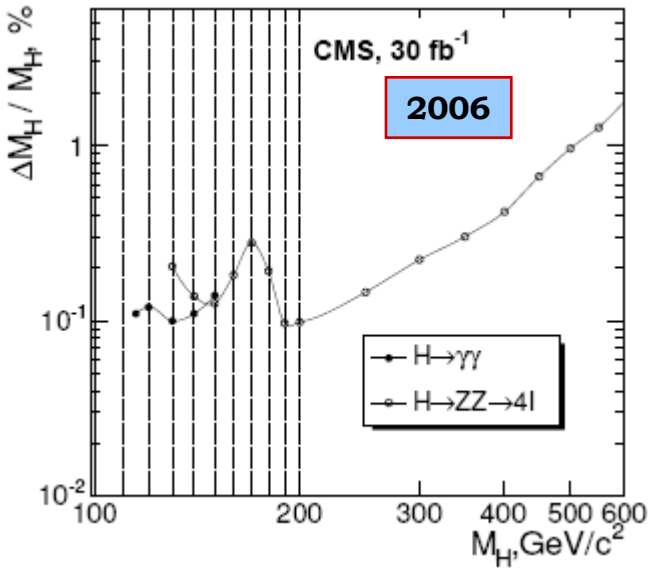


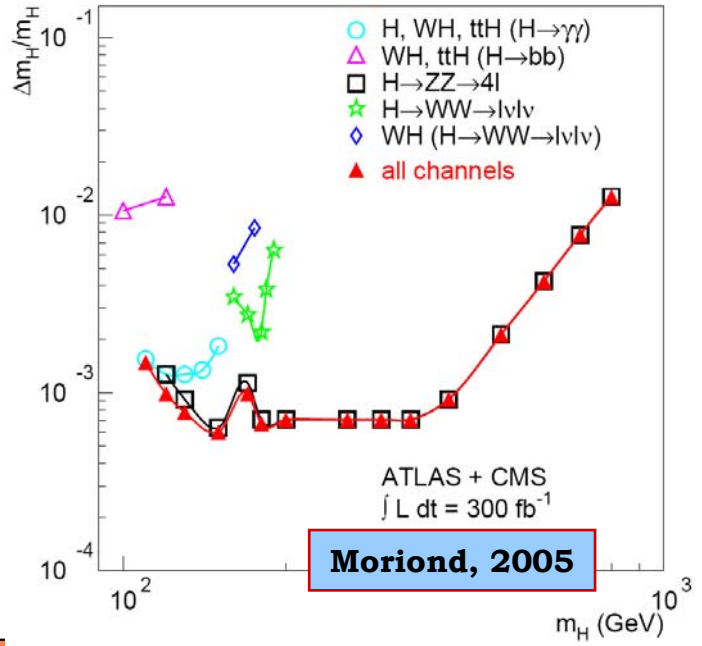


Higgs mass, width, and production cross section

- H→γγ
  - measurements of mass: 0.1-0.2% for 30fb^{-1}
- results for H→ZZ→4μ
  - mass measurements: ~0.1-5% for 30fb^{-1}

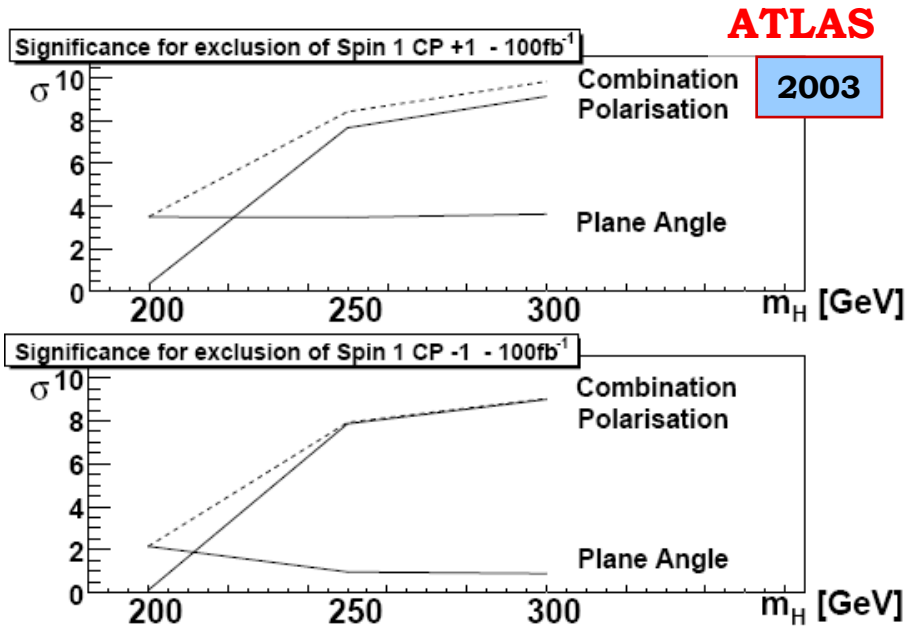
  in the full range
  - direct width measurement for large M_H
    - M_H>190 GeV, ~35% precision

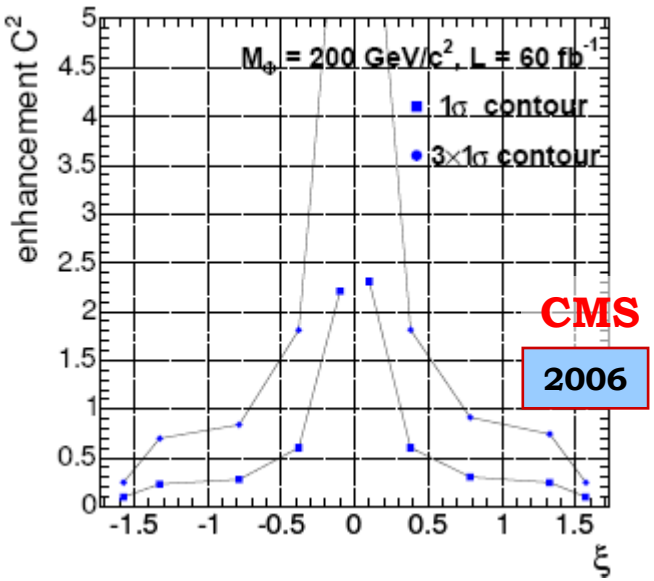




Higgs parameters measurements: CP

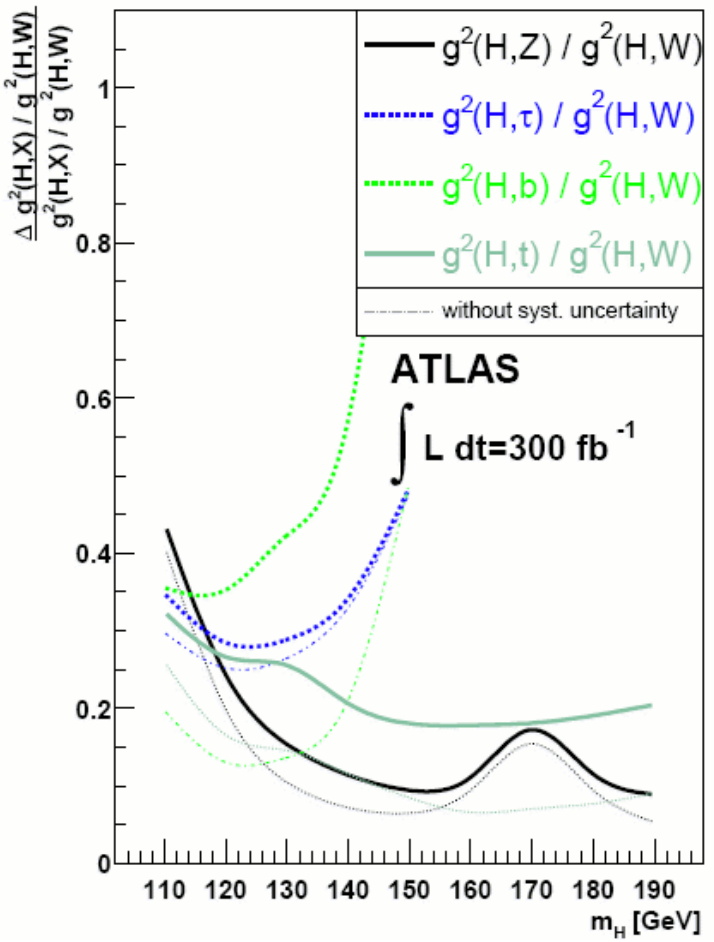
- ATLAS (2003):
  - 1^+, 1^- can be ruled out for 100fb^{-1} for masses >230 GeV
- CMS (2006)
  - 0^- might be ruled out with ~60fb^{-1} for masses >200 GeV depending on mixing parameter value





Higgs parameters measurements: couplings

- Couplings, ATLAS (2003):
  - (assuming only the known SM particles couple to the Higgs boson)
  - $g^2(H,t)/g^2(H,W)$ precision is ~15-30% for 300fb^{-1} (~20-70% for 30fb^{-1})



Summary

- Standard Model Higgs at LHC:
  - discoveries may be *expected* already at L~1 fb^{-1}
  - SM Higgs, if that's all we have, is *expected* to be discovered by the time we reach L~10 fb^{-1}
  - should be able to measure Higgs with L~30 fb^{-1}
    - mass with ~0.1% precision
    - width with ~30% (M_H > 190 GeV) precision
  - should be able to establish spin/CP quantum numbers for M_H>200 GeV with L~100 fb^{-1}
  - should be able to measure couplings with 5-20% percents precision starting with L~300 fb^{-1}

Backup slides

Backgrounds considered

- CMS, H→γγ:
  - pp→γγ: born and box
  - pp→γ+jet: (2 prompt) and (1 prompt + 1 fake)
  - pp→jets (di-jet events)
- CMS: H→WW→2l2ν
  - WW, tt, Wt(b), WZ, ZZ, gg→WW (box, dedicated generator)
- CMS: H→ZZ→4l
  - ZZ, tt, Zbb
  - +gen. level estimations for: single-top, multi-boson, bbbb, bbcc, cccc, Zcc
- ATLAS: qqH, H→WW→2l2ν
  - tt, WWjj, Wt
- ATLAS: qqH, H→ττ
  - Zjj, tt
  - CMS: QCD 2τ+2/3jets, EW 2τ+2jets, W+jets, tt
- ATLAS: ttH, H→bb
  - ttjj, ttbb
  - CMS: ttbb, tt+1/2/3/4jets, ttZ, QCD (120-170, >170 GeV p_T^{hat} bins)