Search for the Higgs boson produced in vector boson fusion processes at the LHC

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Rencontres de Moriond
QCD and Hadronic Interactions
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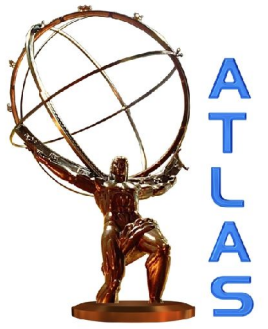
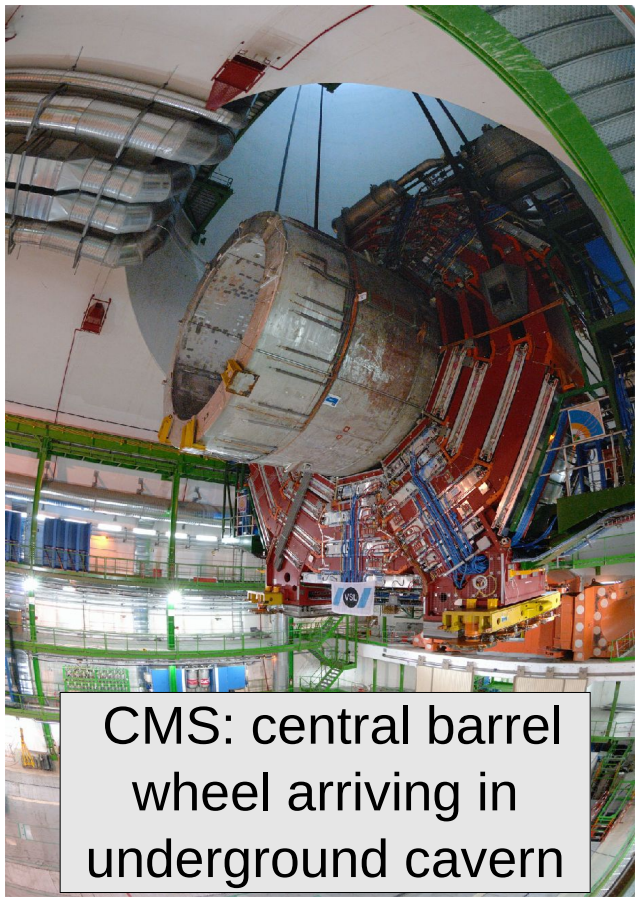


LHC, ATLAS & CMS

LHC: First collisions 12/2007 (E_{CM} =900 GeV)
14 TeV in 2008
Initial luminosity: $2 \cdot 10^{33}/(cm^2 s) \Rightarrow 10 fb^{-1}$/year
Design luminosity: $10^{34}/(cm^2 s) \Rightarrow 100 fb^{-1}$/year

Not studied for VBF so far !


CMS: central barrel wheel arriving in underground cavern

Two multipurpose-experiments for wide physics range:

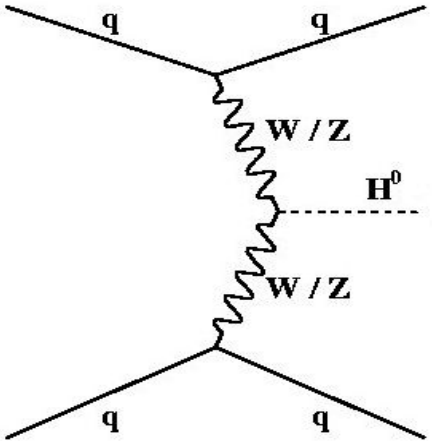
ATLAS: All components completed
Installation in cavern well progressed

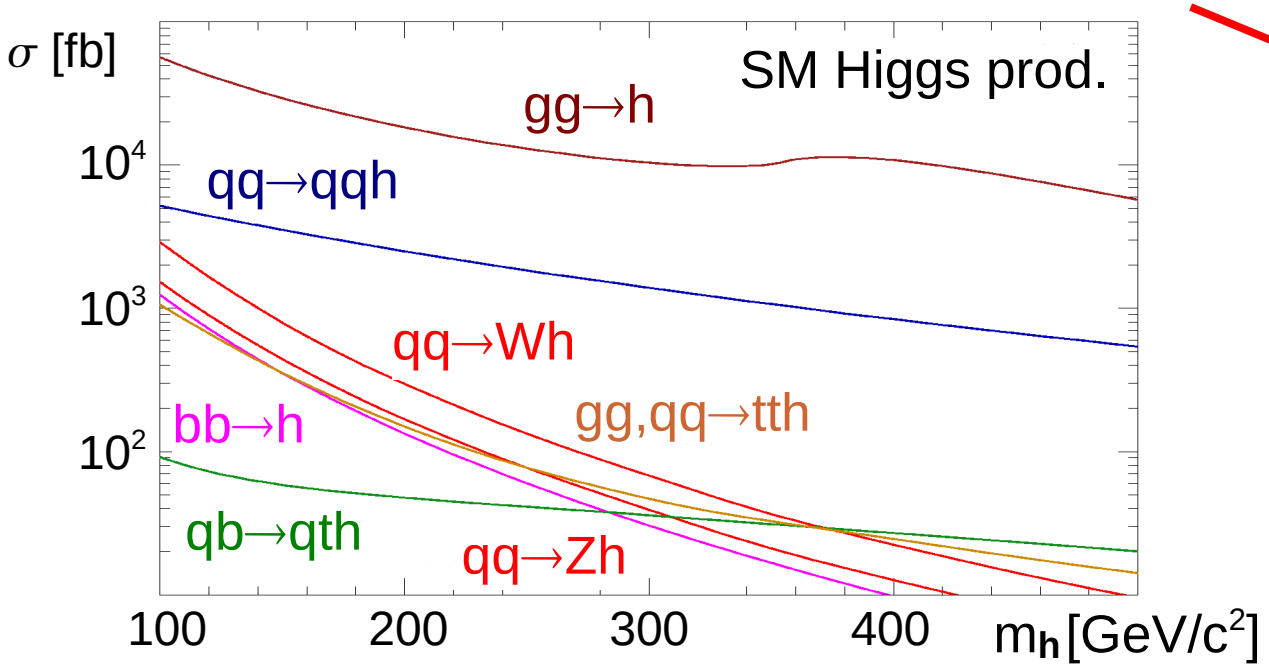
CMS: Installation on surface completed
Lowering into cavern ongoing

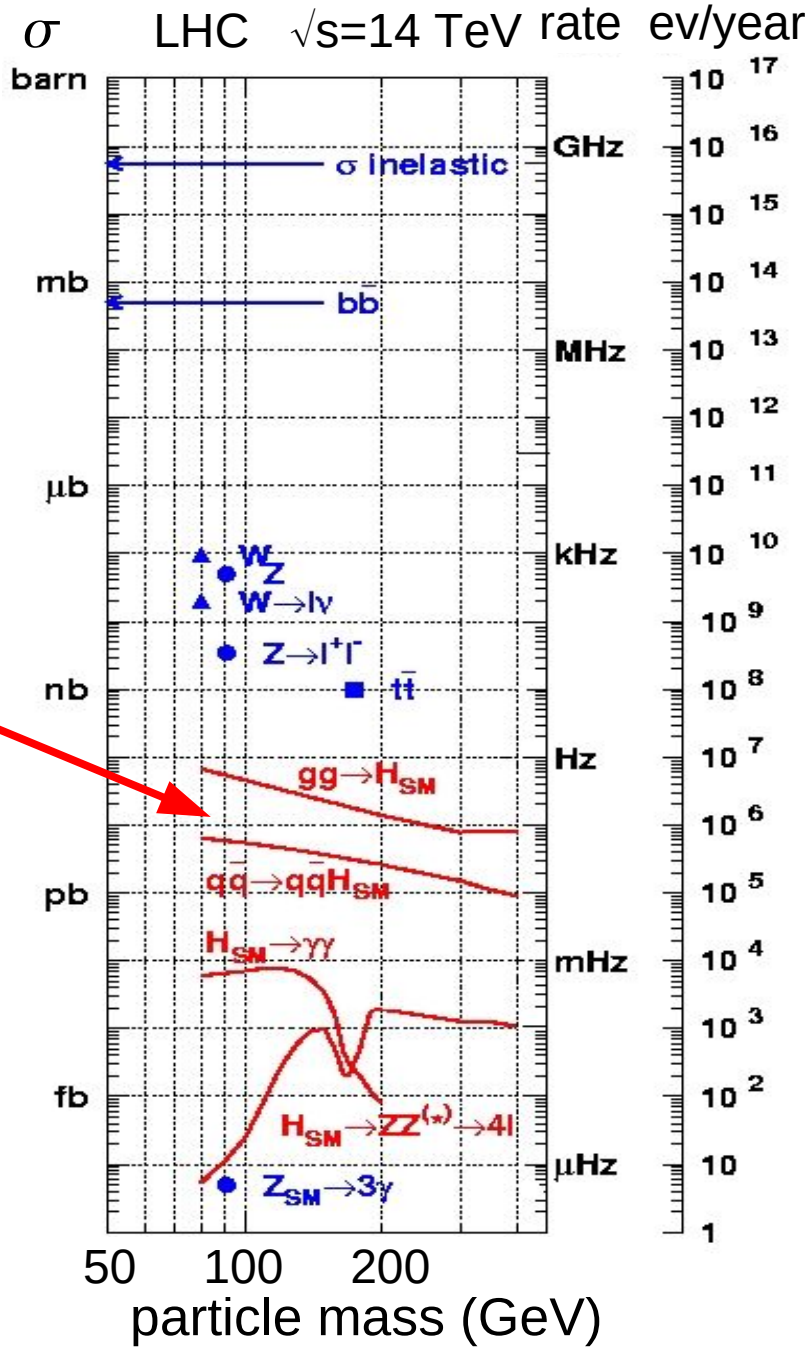
Both experiments will be ready for first collisions on time !

Vector Boson Fusion (qq→qqH)

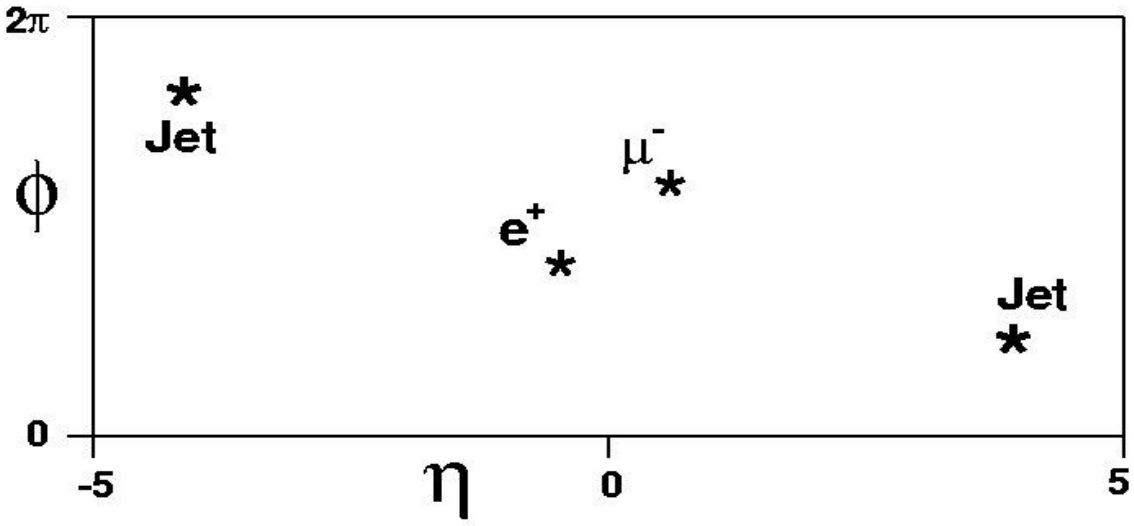
- Second largest Higgs boson production channel at the LHC
- Promising for discovery (clean signature)
- Contribute to coupling measurement

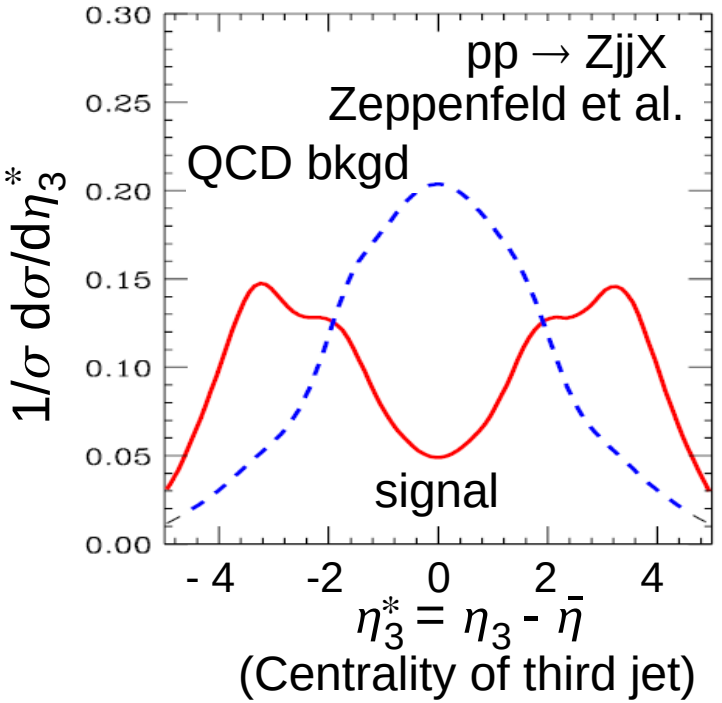






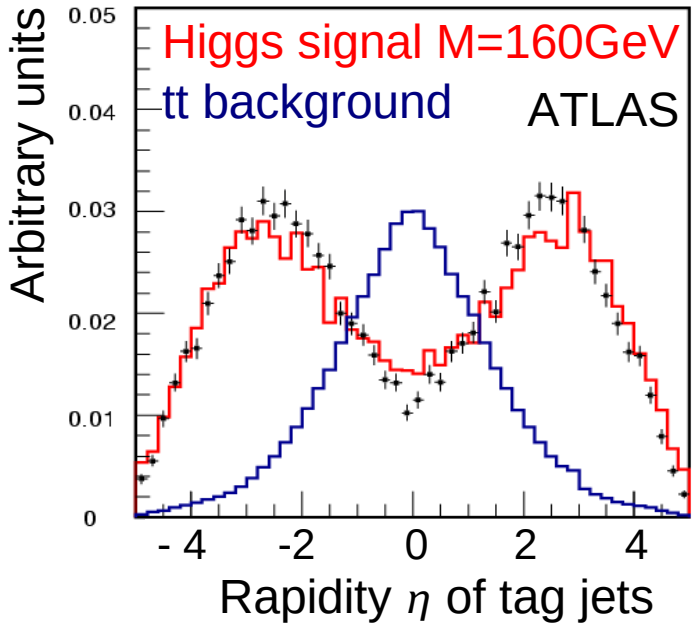
VBF Signature





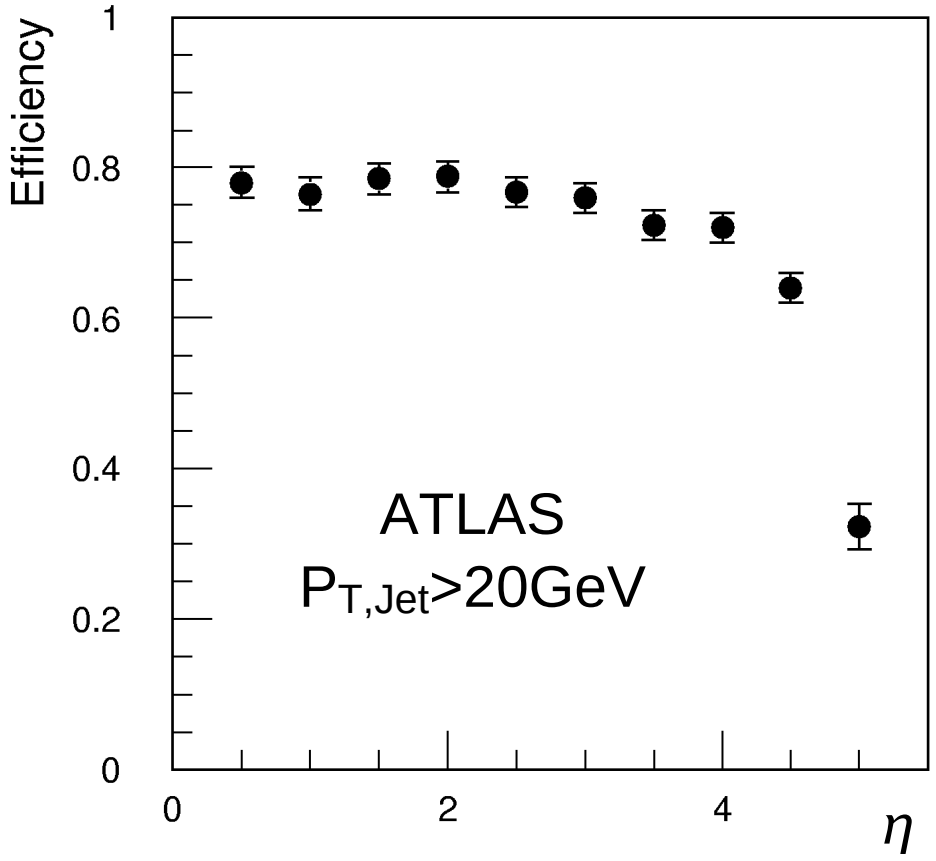
- **Two tag jets in forward region**
  - ⇒ To be found up to 1° to beam pipe (Jets partially in beam pipe)
  - ⇒ Pile-up & underlying event effects?
- No color flow between quark lines ⇒ **Central jet veto**
  - ⇒ Pile-up & underlying effects?
- **Higgs boson decay products in central region**

Significant background suppression!

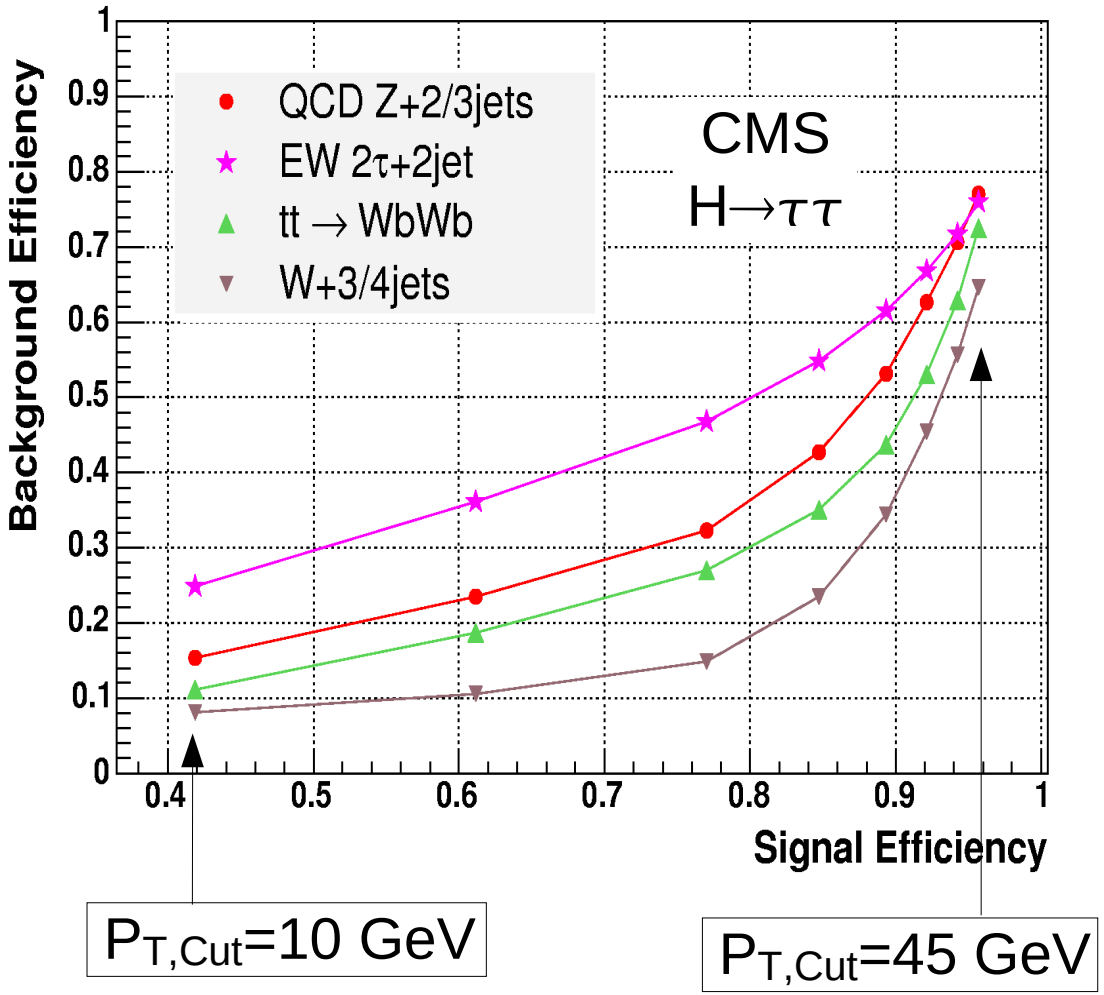


Experimental Performance

Jet Tagging Efficiency

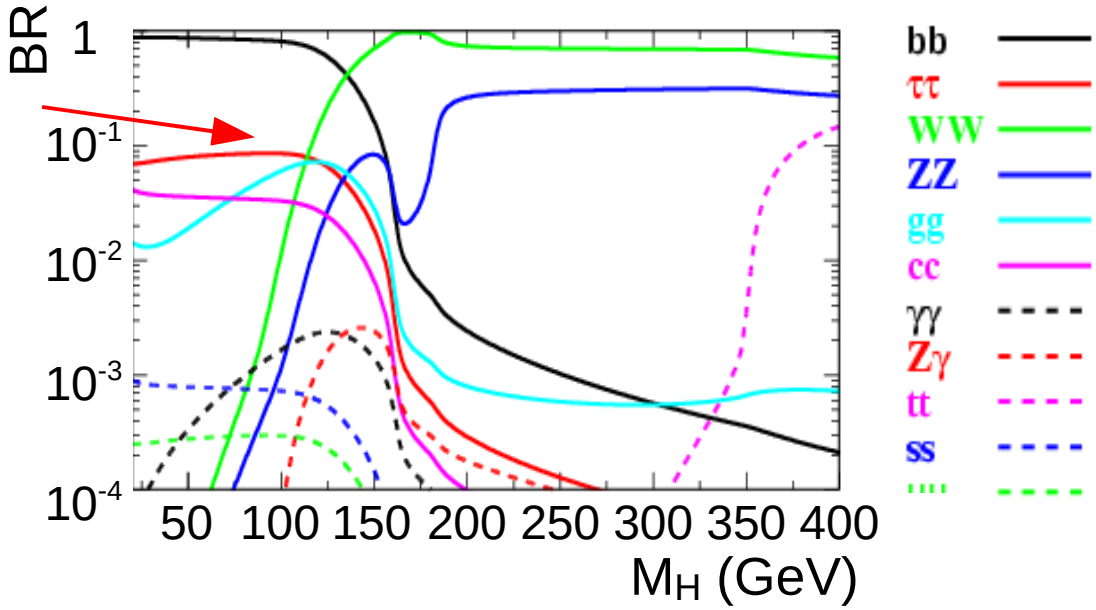


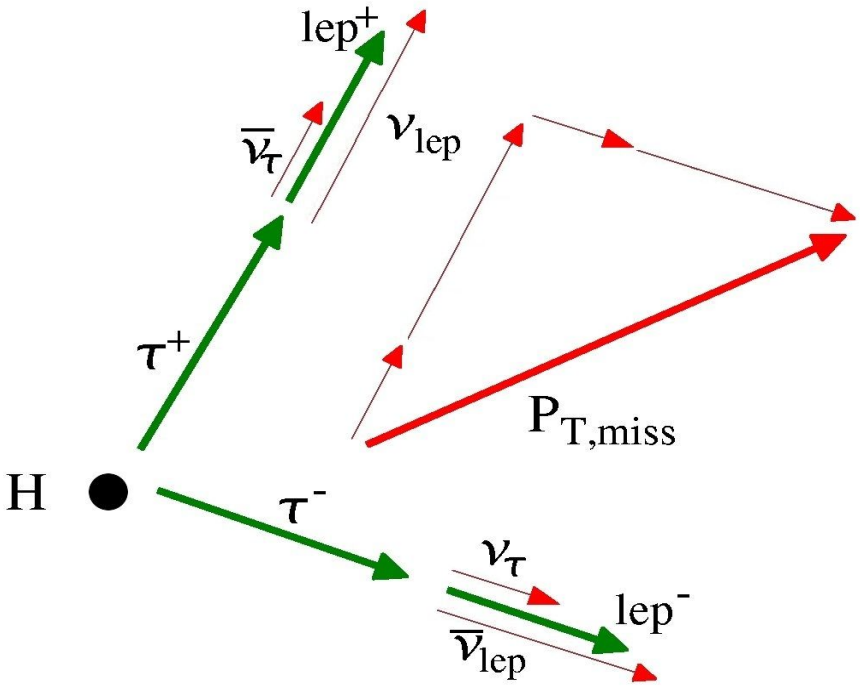
Central Jet Veto



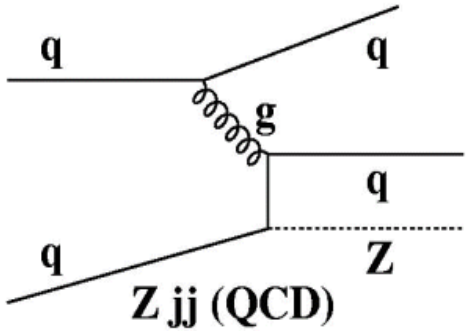
qq→qqH, H→ττ→lh+3ν / ll+4ν

- Low Higgs boson masses important
- Higgs boson – fermion coupling
- Final state lepton for triggering
- Mass reconstruction despite neutrinos in final state ("C*ollinear approximation*")

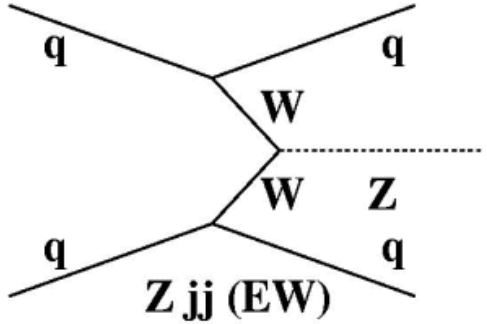




Main backgrounds:



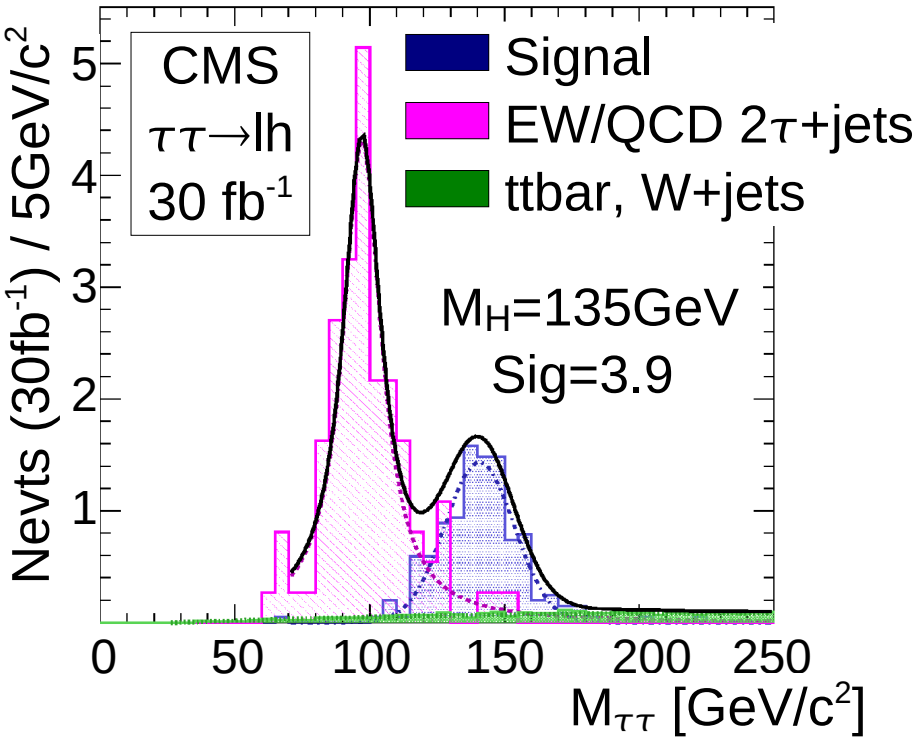
reduced by jet veto

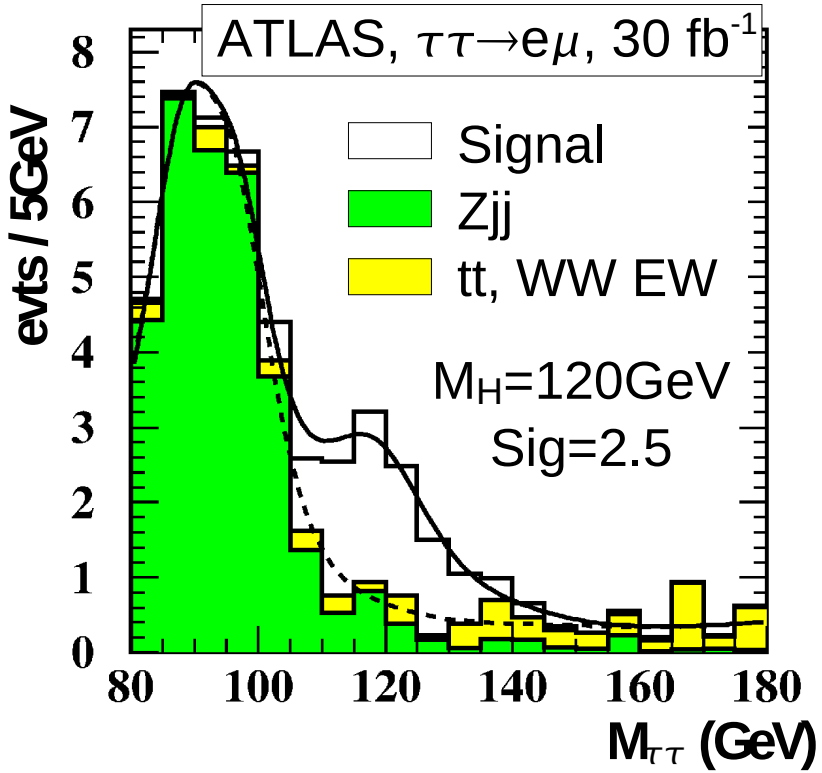


reduced by mass reconstruction

qq→qqH, H→ττ→lh+3ν / ll+4ν

- Signal peak near Z-peak:





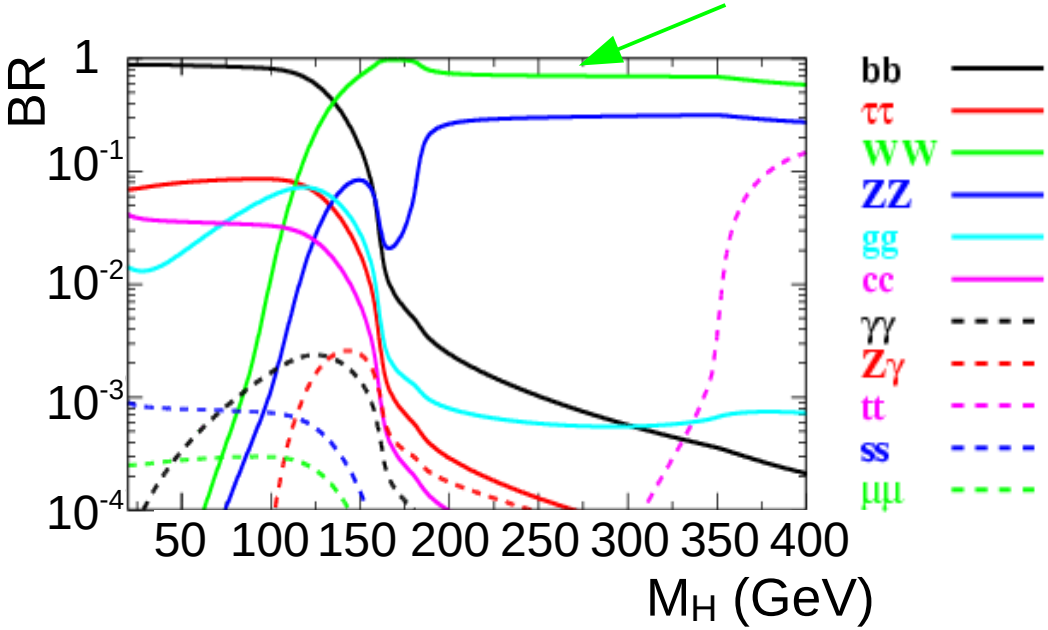
- Mass resolution (~9-10%) dominated by P_{Tmiss}-resolution
- Significances at 30 fb^{-1}:

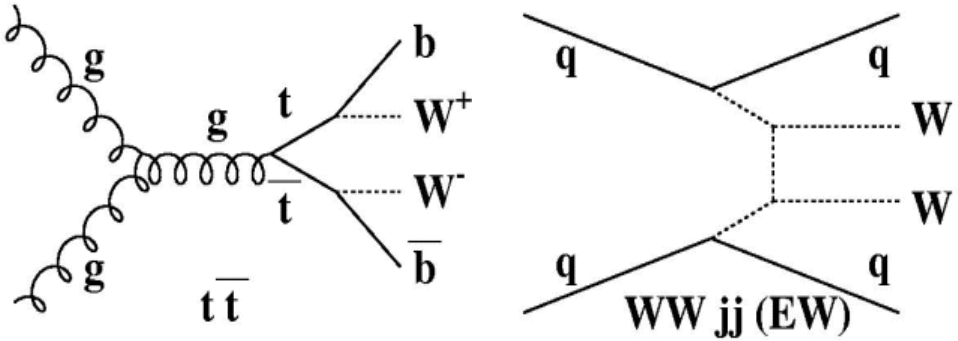
CMS :	**ττ→lh**, M_H=135 GeV	⇒	**Sig = 3.9**
	ττ→eμ, M_H=125 GeV	⇒	**Sig = 4.0**
ATLAS :	**ττ→lh**, M_H=130 GeV	⇒	**Sig = 4.4**
	ττ→lh+ττ→ll, M_H=130 GeV	⇒	**Sig = 5.7**

background uncertainty 7-10%

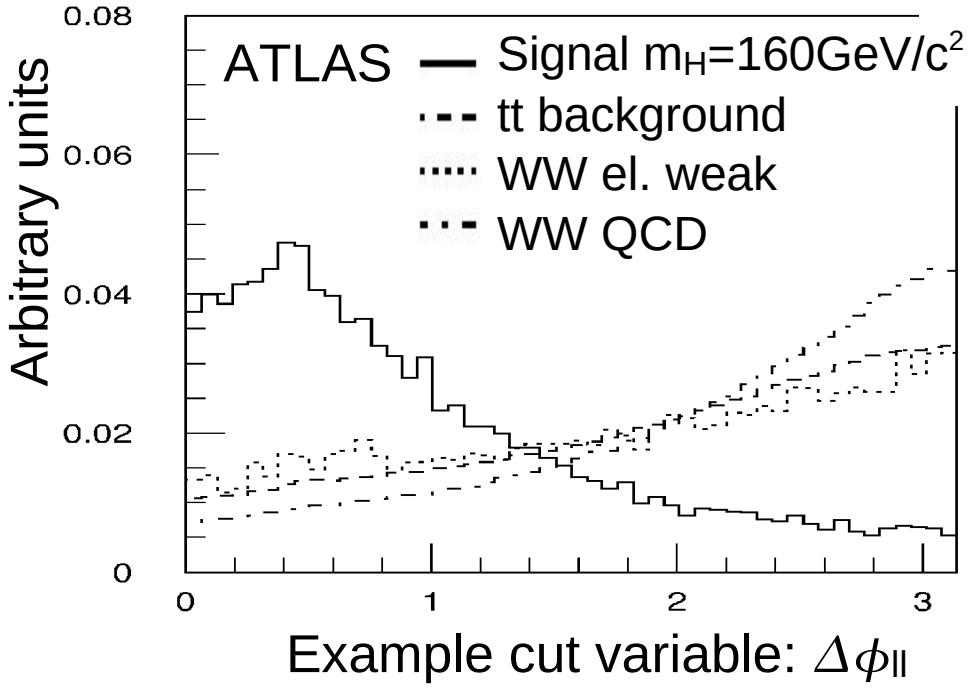
qq→qqH, H→WW

- W off-shell or on-shell
- Higgs boson mass close to production threshold ⇒ W-bosons have low P_T
- Many & large background processes *(tt+jets, W+jets, Z+jets, WW+jets, ZZ+jets, QCD multijets...)*
- Clean access to Higgs-W-W-coupling





Example background processes

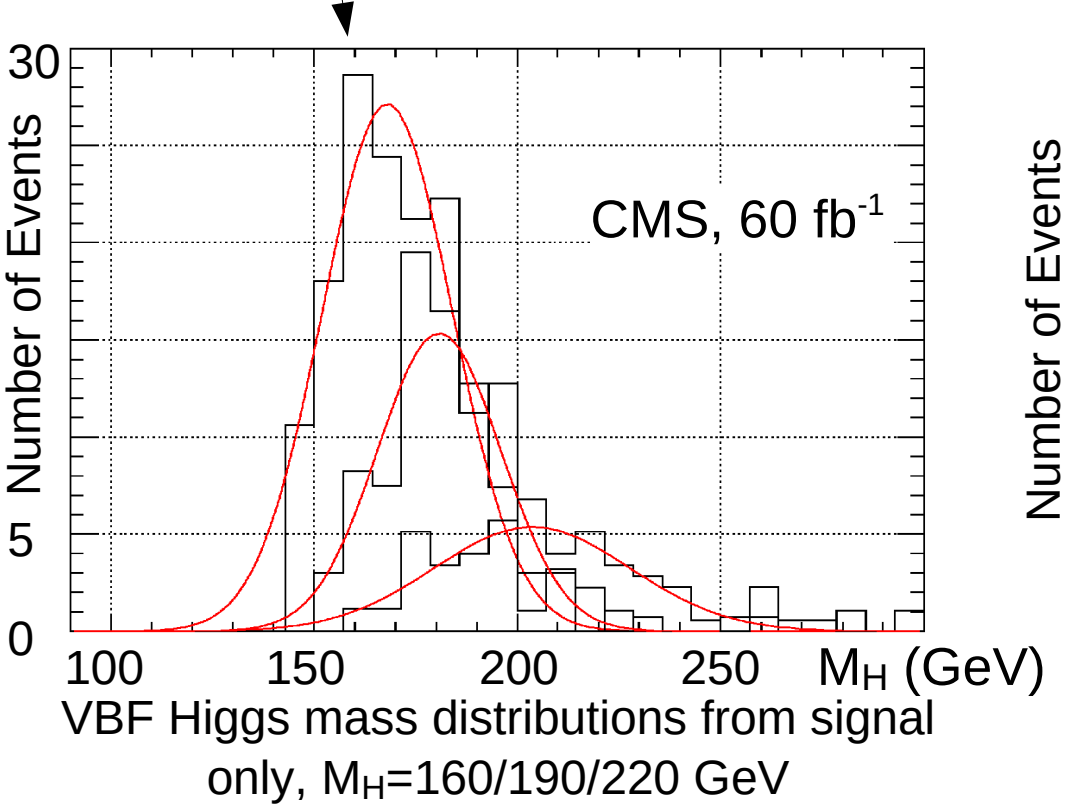


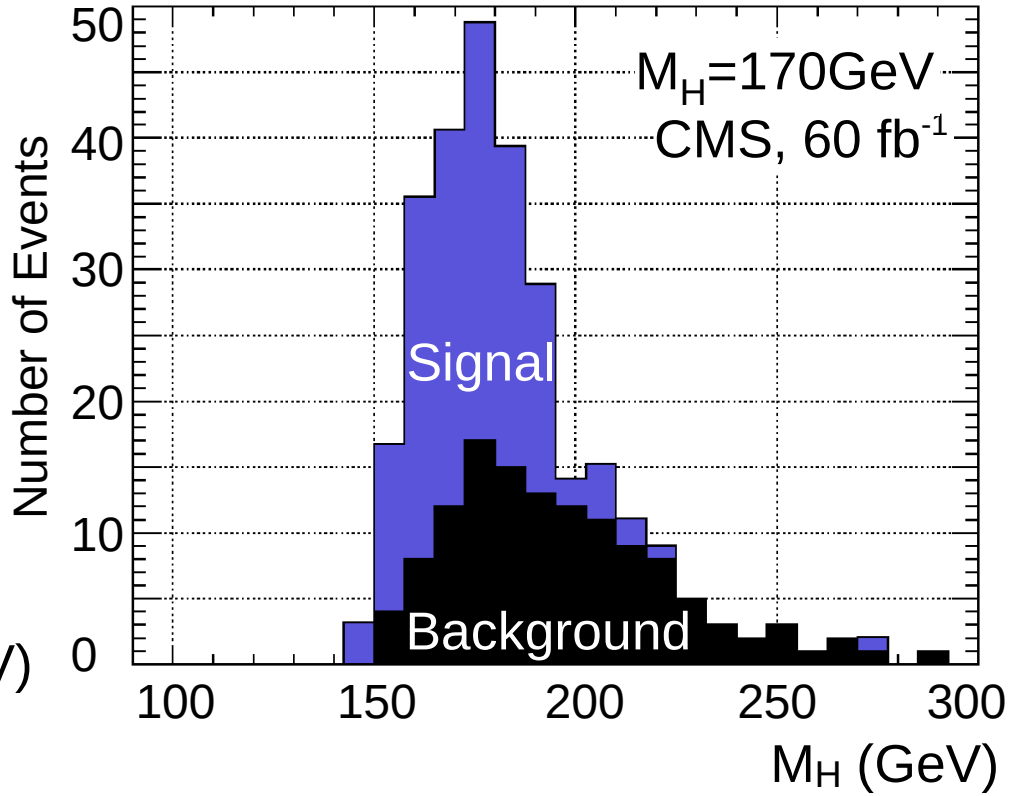
qq→qqH, H→WW→lνjj

- Significances:
  - CMS: Sig>5.0 for $M_H \approx 140\text{-}200$ GeV at 30 fb^{-1}
  - ATLAS: Sig=4.6 for $M_H=160$ GeV at 30 fb^{-1}

background uncertainty 10-16%

- Mass resolution (CMS) ~14-24 GeV





$qq \rightarrow qqH,\ H \rightarrow WW \rightarrow l\nu l\nu$

- No mass peak can be reconstructed ⇒ transverse mass

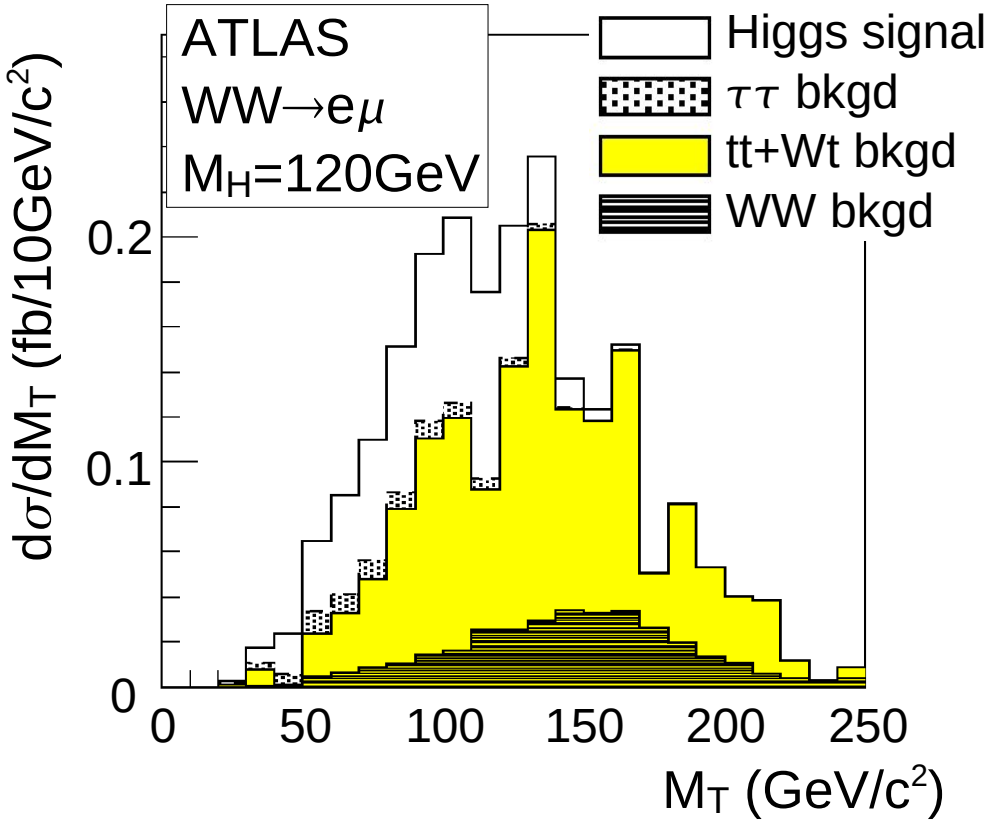
$$M_T = \sqrt{2 \cdot P_T^{ll} \cdot E_{Tmiss} \cdot (1 - \cos\Delta\phi)}$$

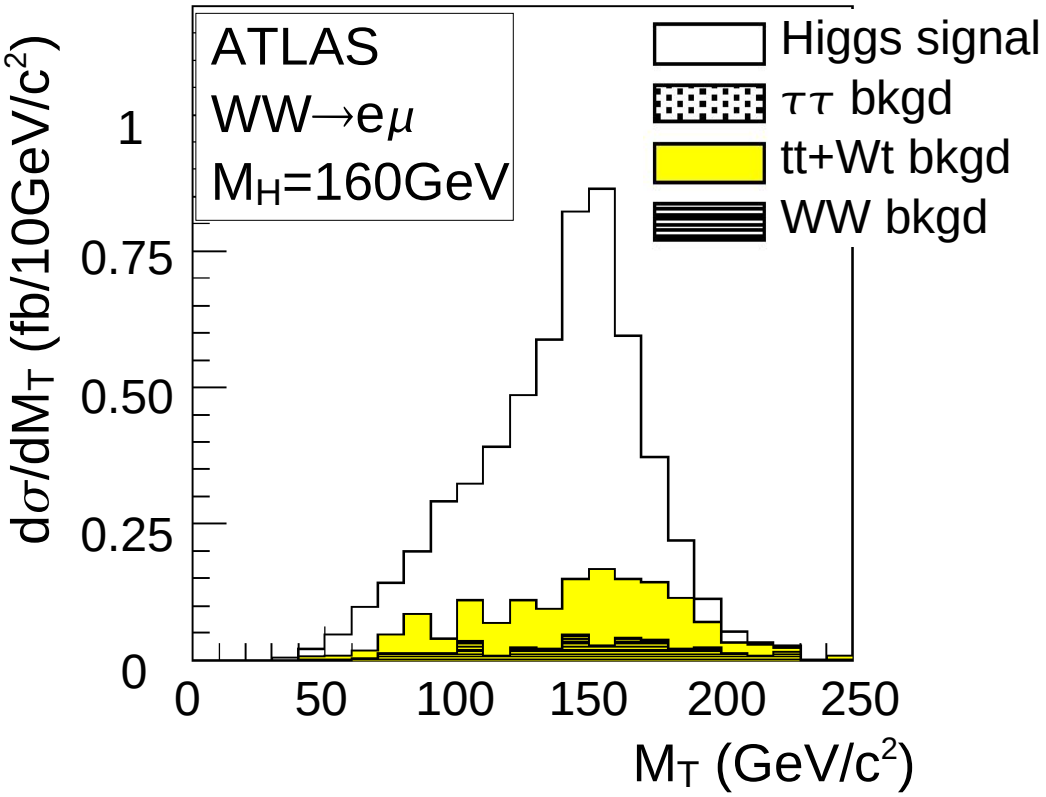
- Significances:

CMS: Sig>5.0 for $M_H \approx 140\text{-}190$ GeV at 30 fb^{-1}

ATLAS: Sig>5.0 for $M_H \approx 125\text{-}190$ GeV at 30 fb^{-1}

background uncertainty 7-10%



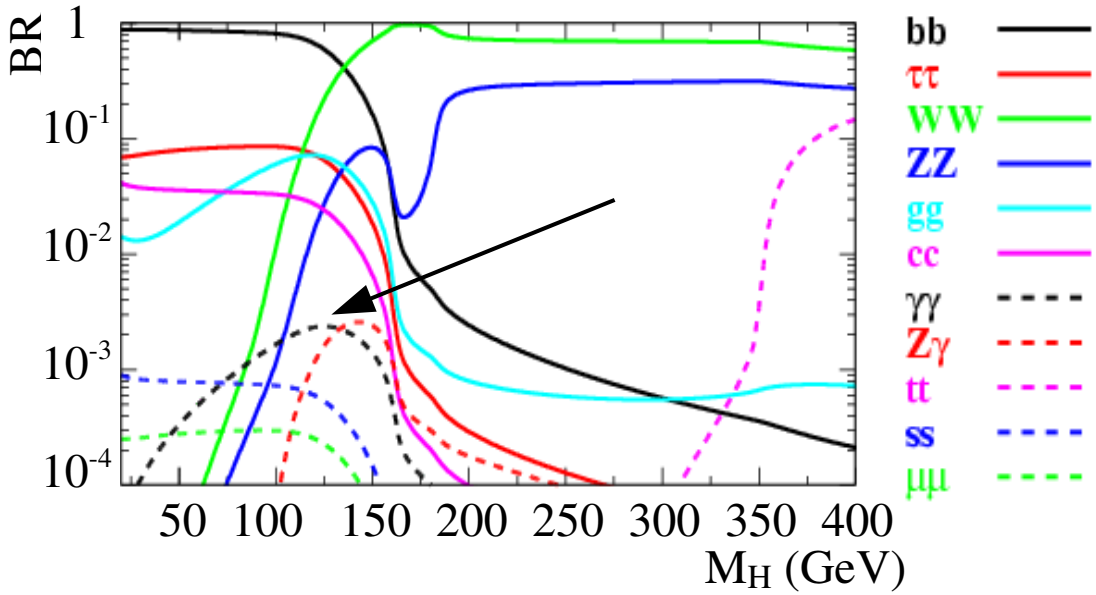


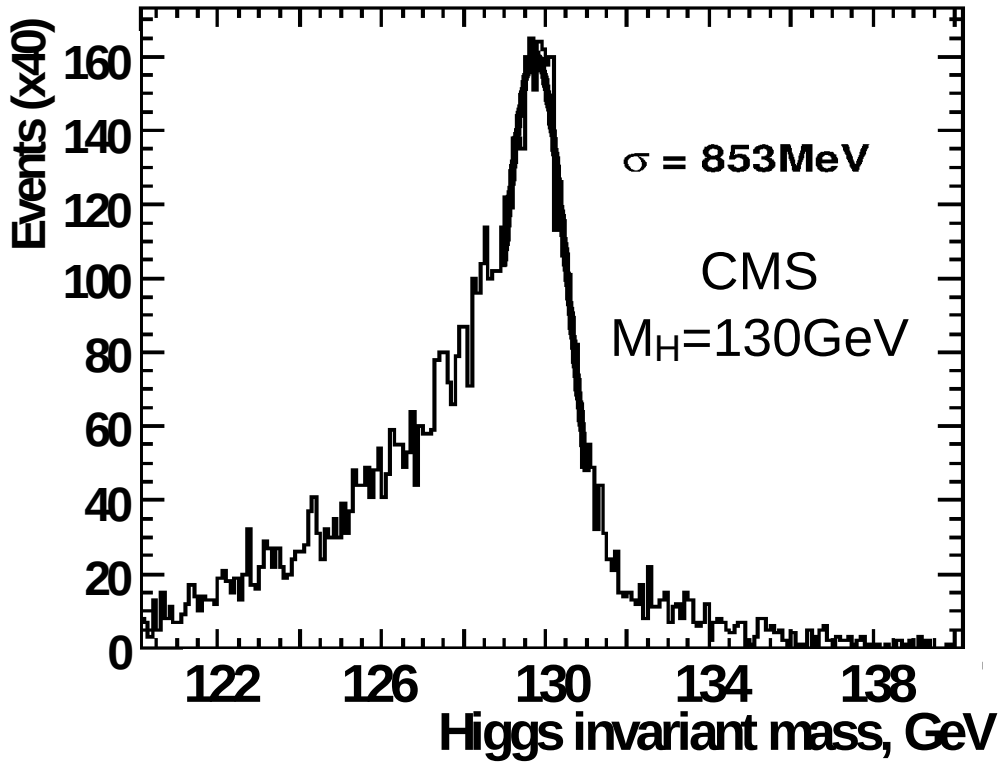
qq→qqH, H→γγ

- Low branching ratio, clean signal
- Background processes:
  γγ+jets, Z→ee, QCD jets, ...
- Photon Id. & isolation crucial
  ⇒ Realistic fake rates needed
- Narrow mass state ($\sigma_{res} \approx 0.7\%$)
  ⇒ reconstruct Higgs boson vertex

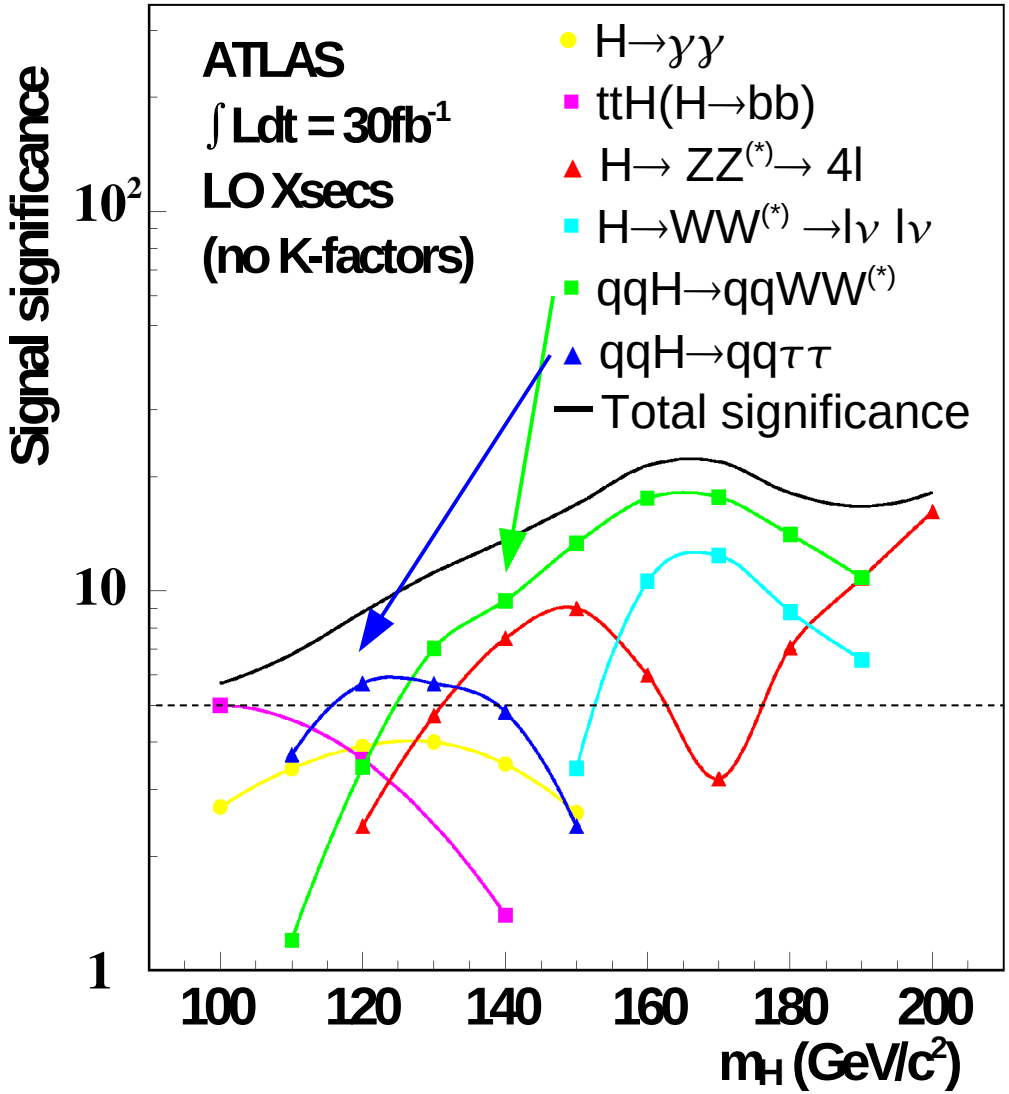
⇒ Sig≈1.5-2.5 (30 fb^{-1})

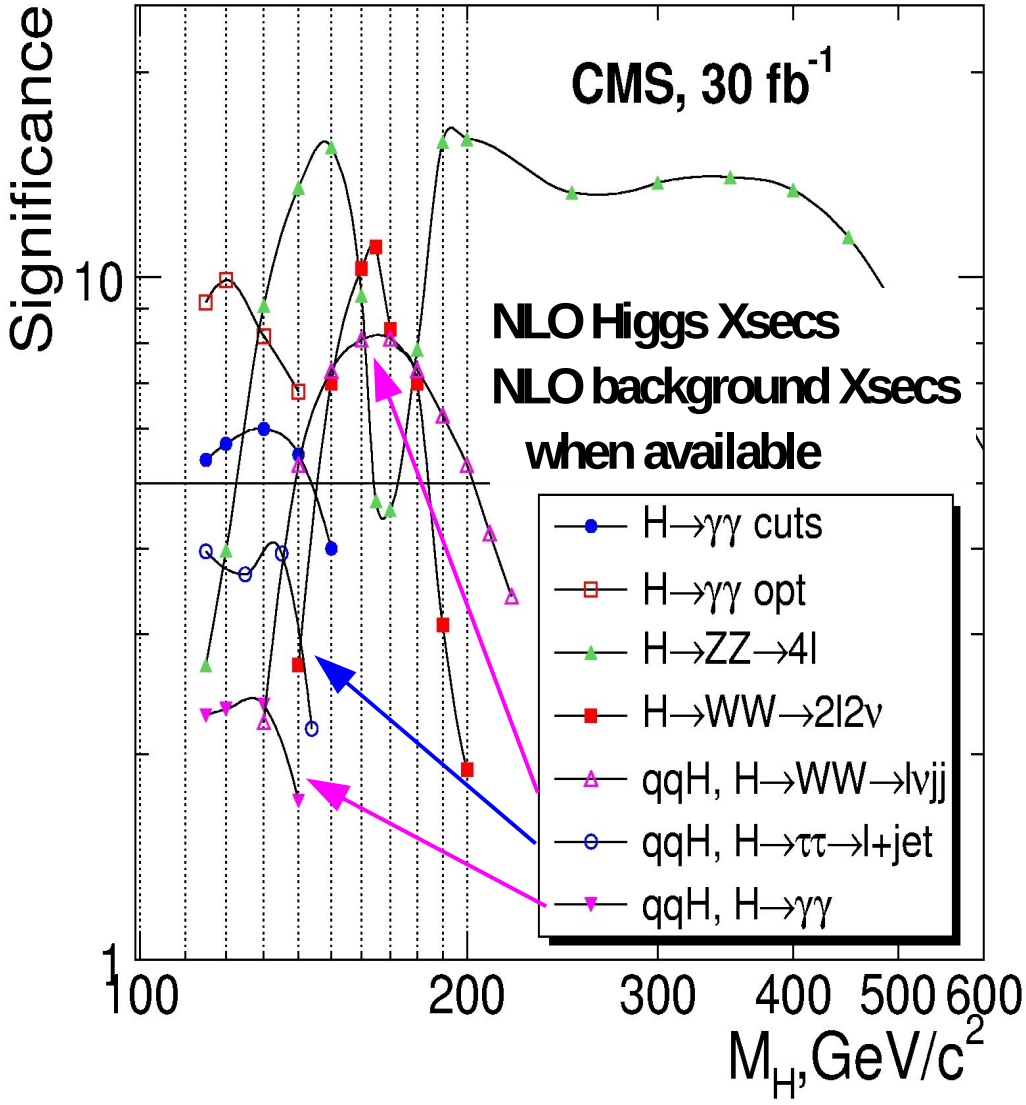
(Higher significances reached for inclusive H→γγ)



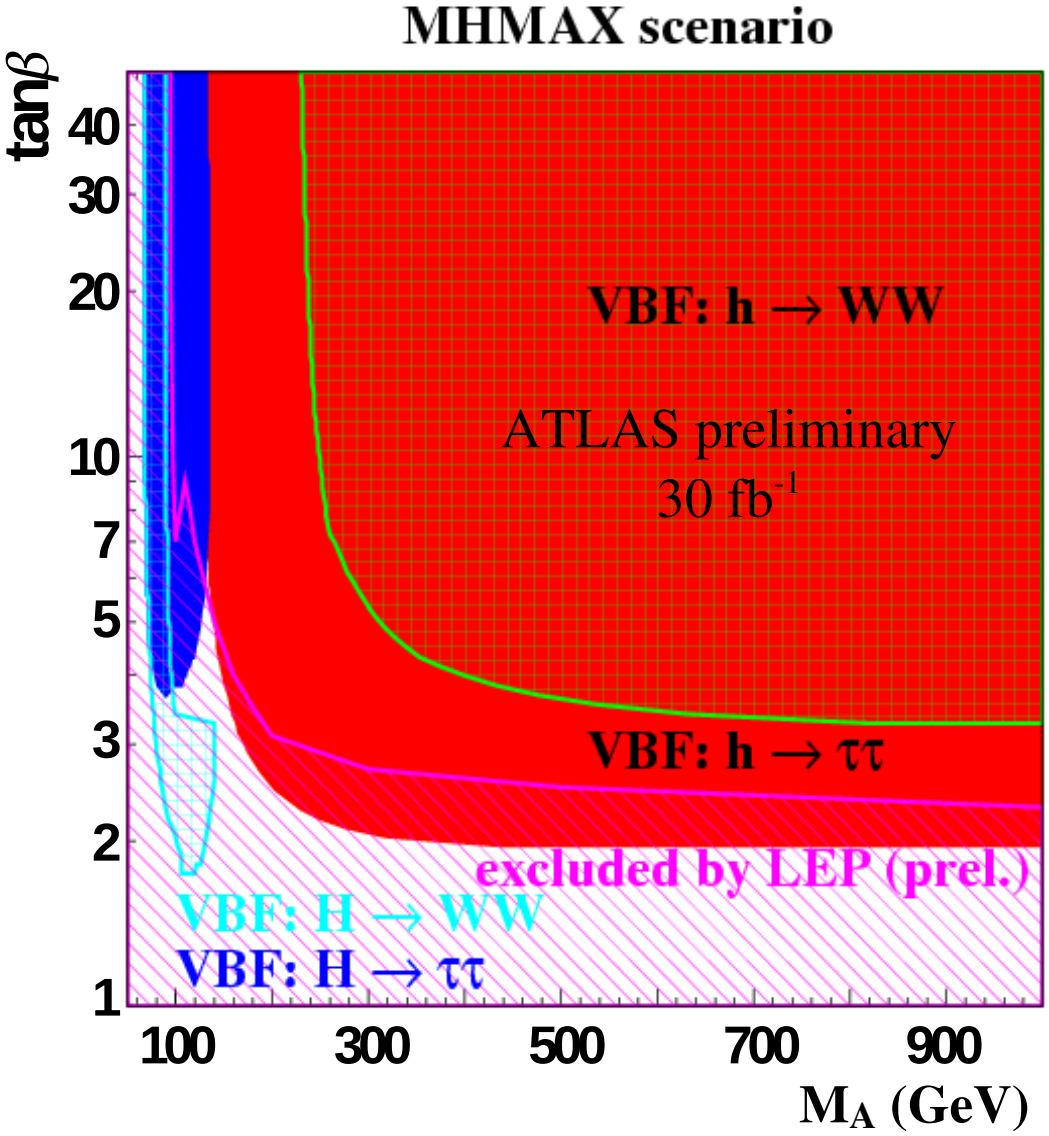


Overall Discovery Potential





VBF & MSSM



- One neutral, CP-even Higgs boson (h, H) observable with VBF at 30fb^{-1} in many benchmark scenarios

VBF has good chances for discovering a supersymmetric Higgs boson! (if it exists)

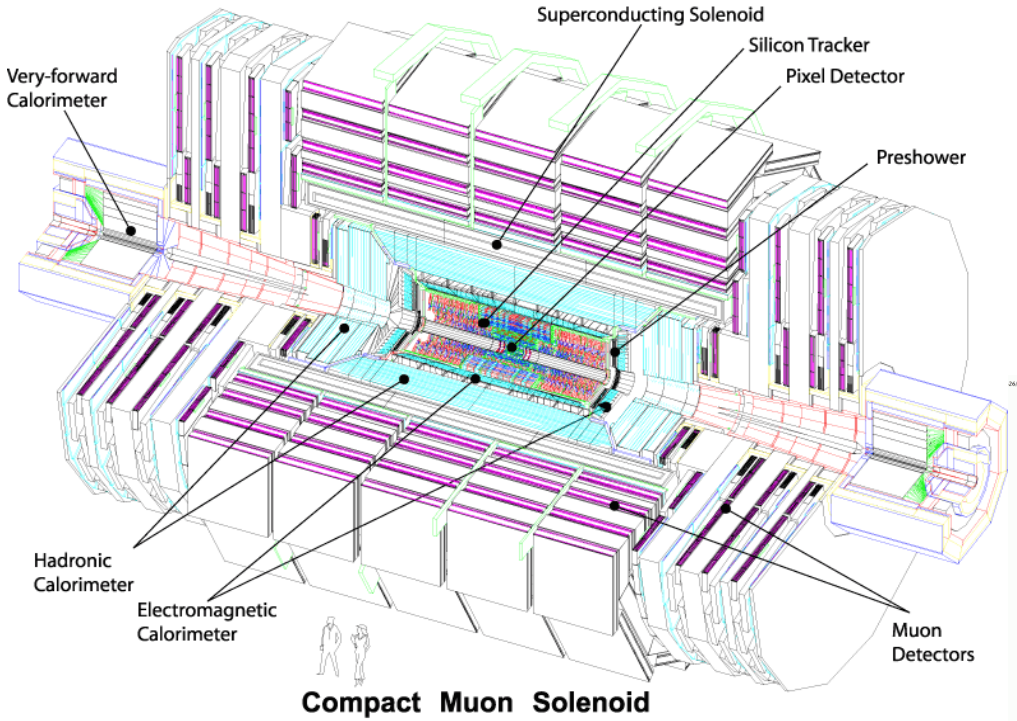
Summary & Conclusions

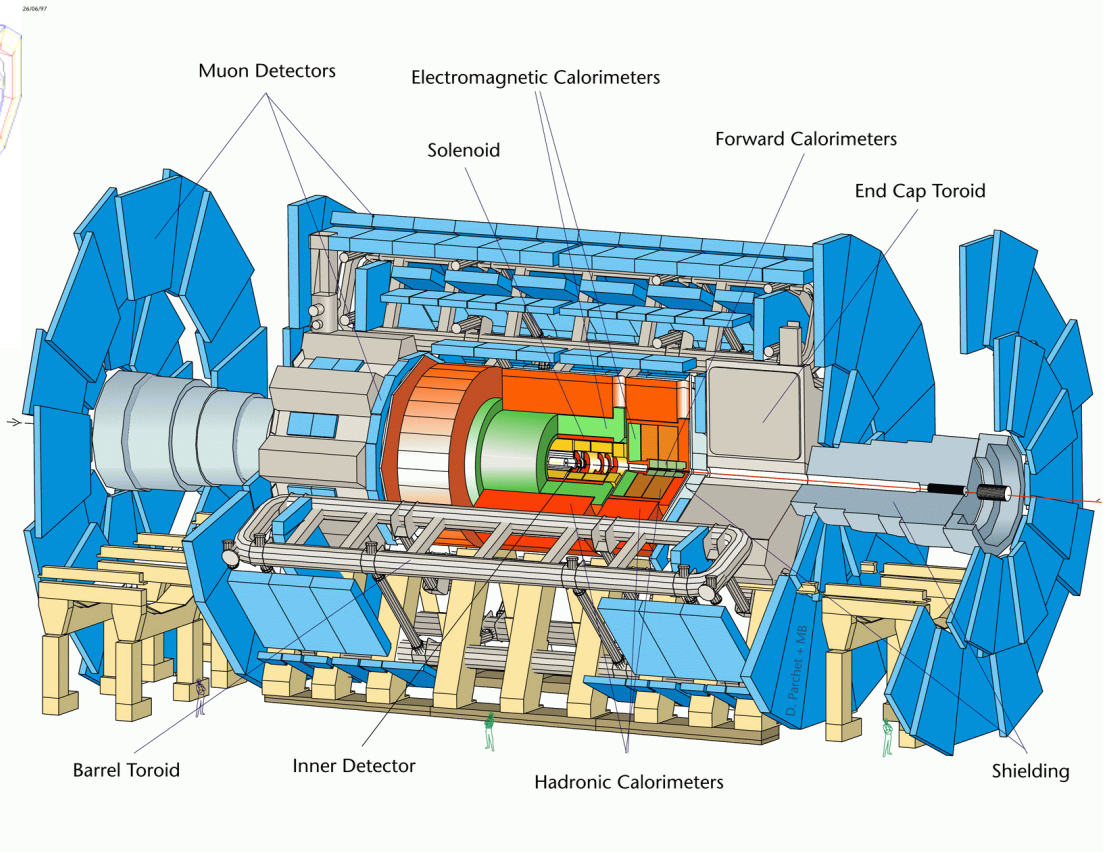
- VBF important Higgs boson discovery channel at LHC
- Prospects well evaluated by CMS & ATLAS collaborations
- Experimental challenges:
  - Forward jet reconstruction
  - Central jet veto
  - Higgs mass resolution (E_{Tmiss}, Jet-P_T, vertex reconstruction, ...)
- Important decay channels:
  - $H \rightarrow \tau\tau$ promising for 5σ discovery for ~120-135 GeV
  - $H \rightarrow WW$ promising for 5σ discovery ~125-190 GeV
  - $H \rightarrow \gamma\gamma$: evidence possible at 2-3σ level
- VBF processes cover tanβ-M_A plane well for many MSSM-scenarios

Main Sources:
SN-ATLAS-2003-024
CMS-TDR-008-2 + cited papers

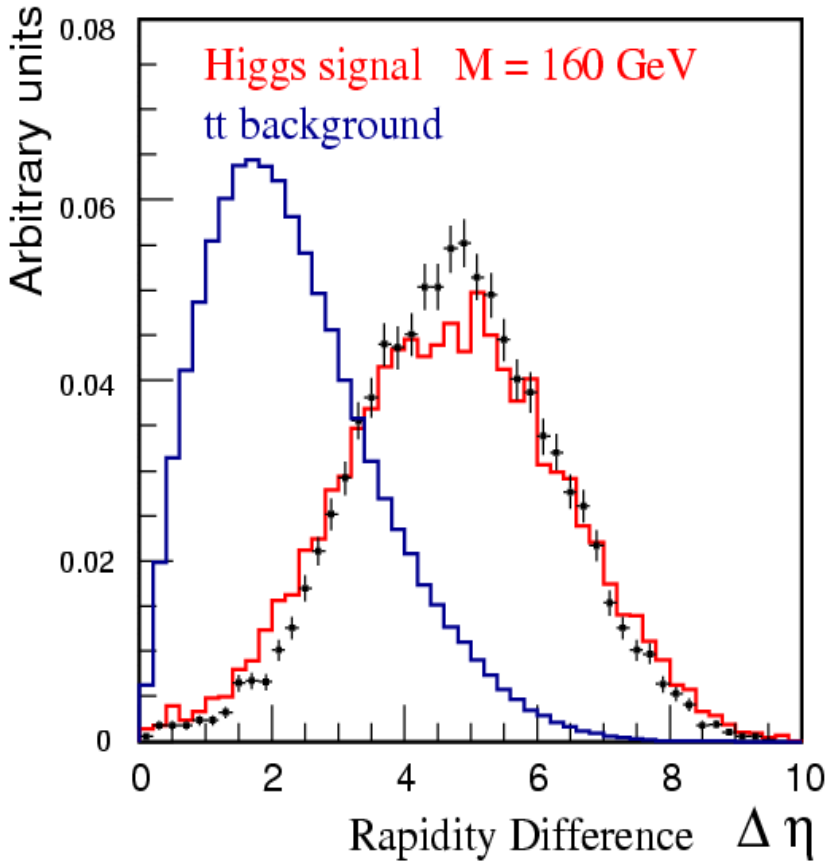
BACKUP SLIDES

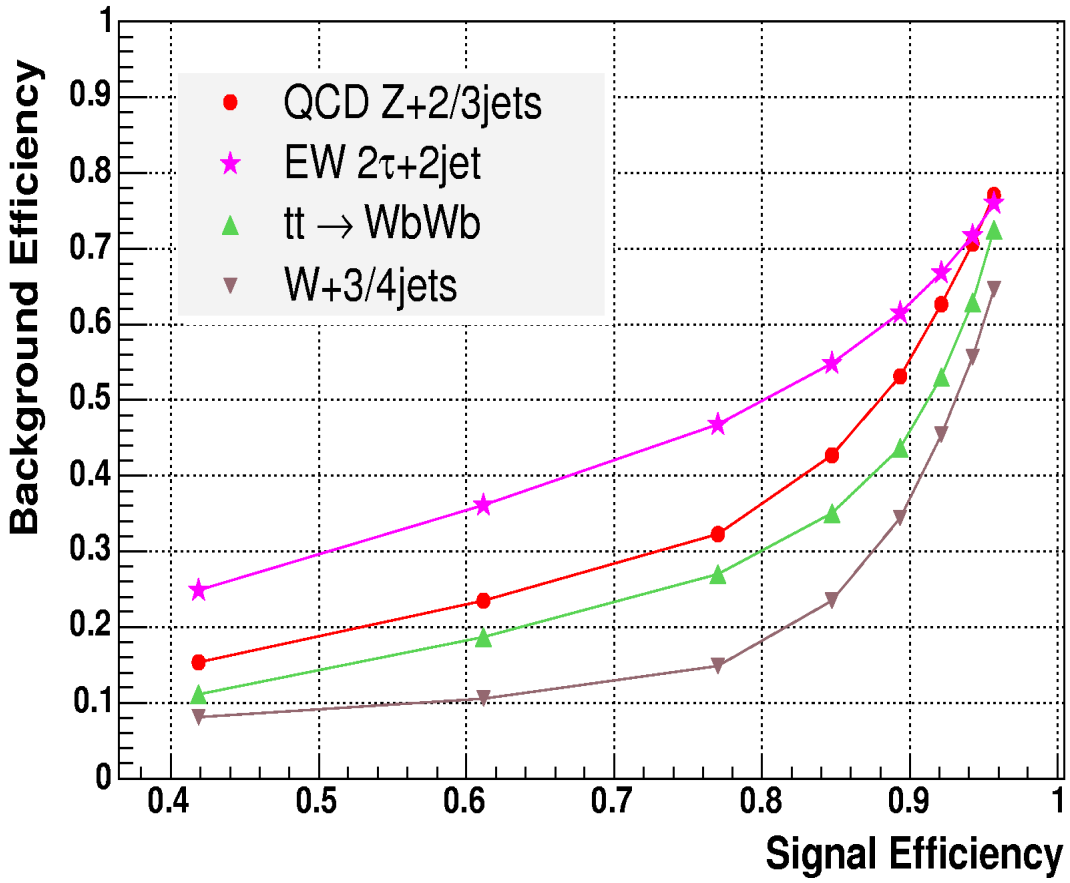
CMS + ATLAS detectors



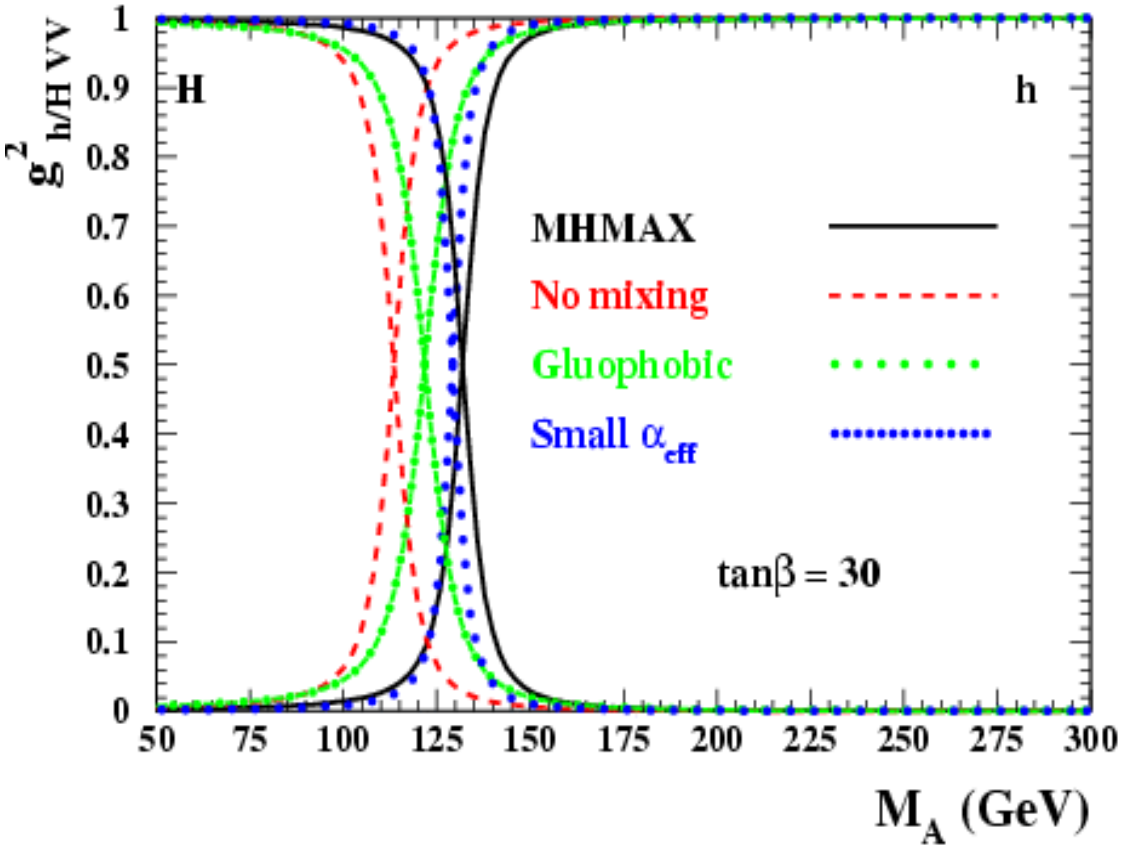


Central Jet Veto + Tagging jets

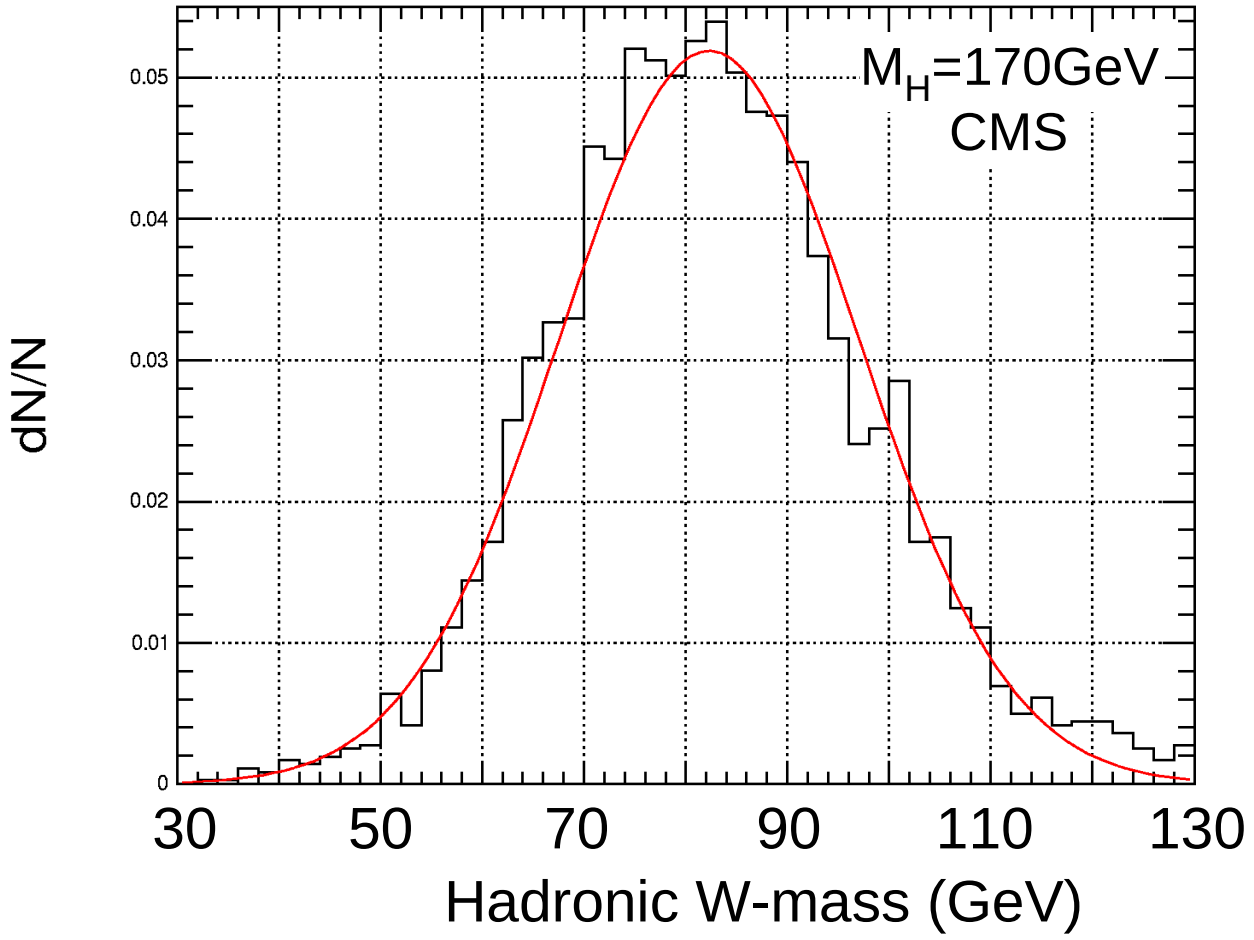




MSSM couplings



Hadronic W-mass reconstruction



σ =14.8 GeV