Search for Higgs Bosons with early data in ATLAS

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on behalf of the ATLAS collaboration

La Thuile, Aosta Valley, Italy
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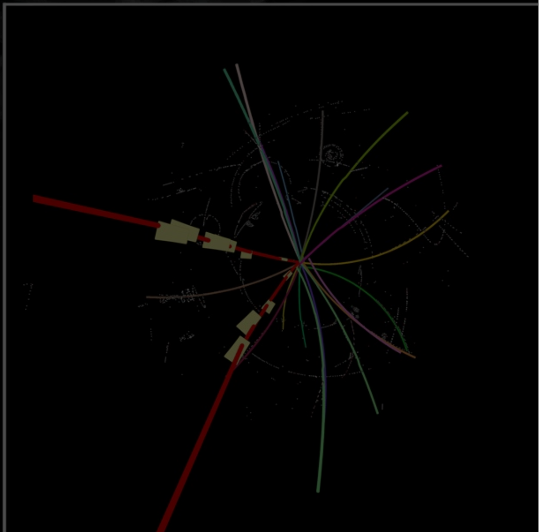
Jet Event at 2.36 TeV Collision Energy
2009-12-14, 04:30 CET, Run 142308, Event 482137
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

Outline

ATLAS EXPERIMENT
2009-12-06, 08:25 CET
Run 141749, Event 133538

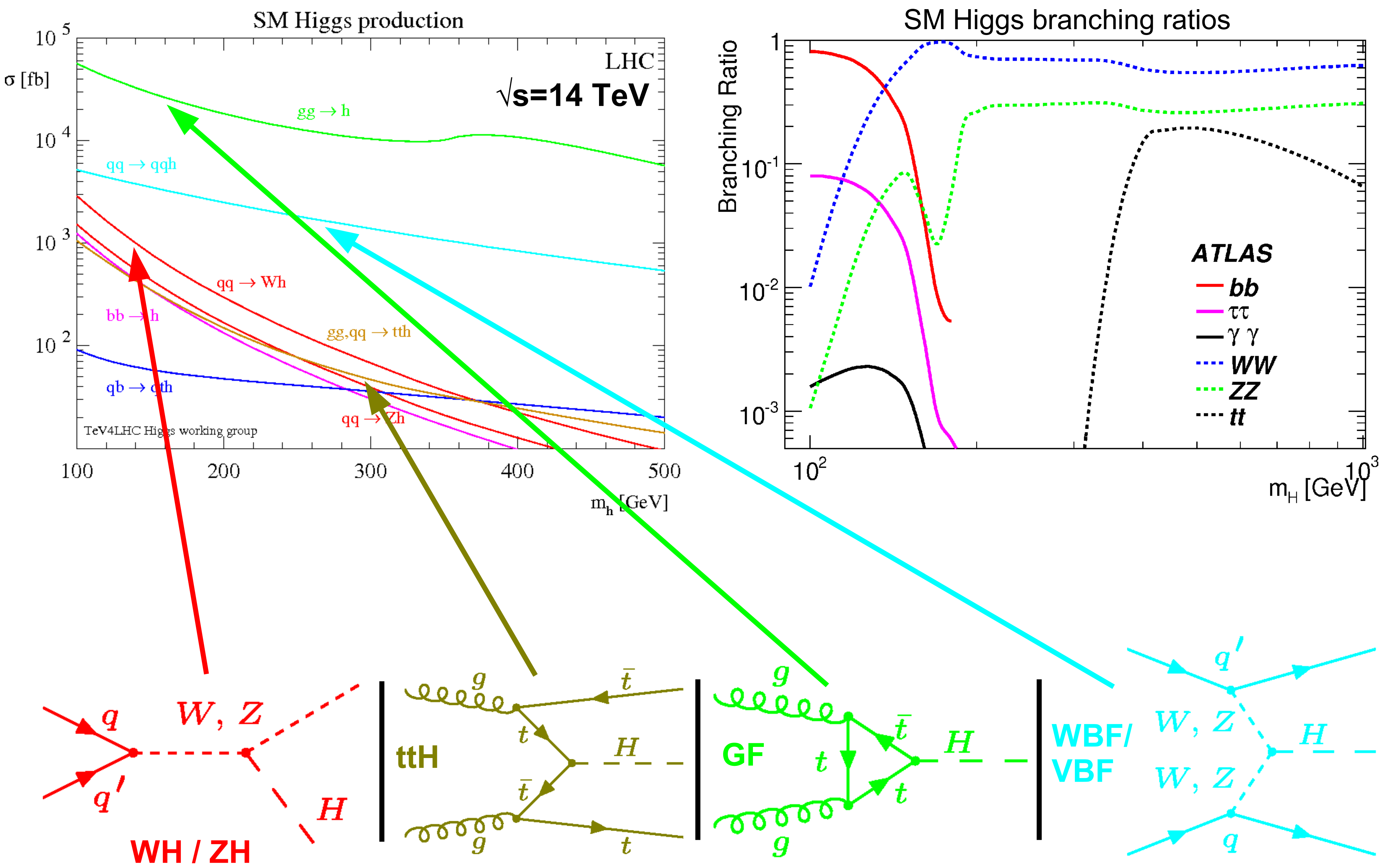
- **Introduction**
- **Detector performance**
- **Higgs with ~ 1 fb^{-1}**
  - H→WW
  - H→ZZ
- **Higgs with ~ 10 fb^{-1}**
  - H→$\gamma\gamma$
  - H→$\tau\tau$
  - H→bb

Reference for most results:
“Expected Performance of the ATLAS Experiment: detector, trigger and physics“
CERN-OPEN-2008-020, http://arxiv.org/pdf/0901.0512



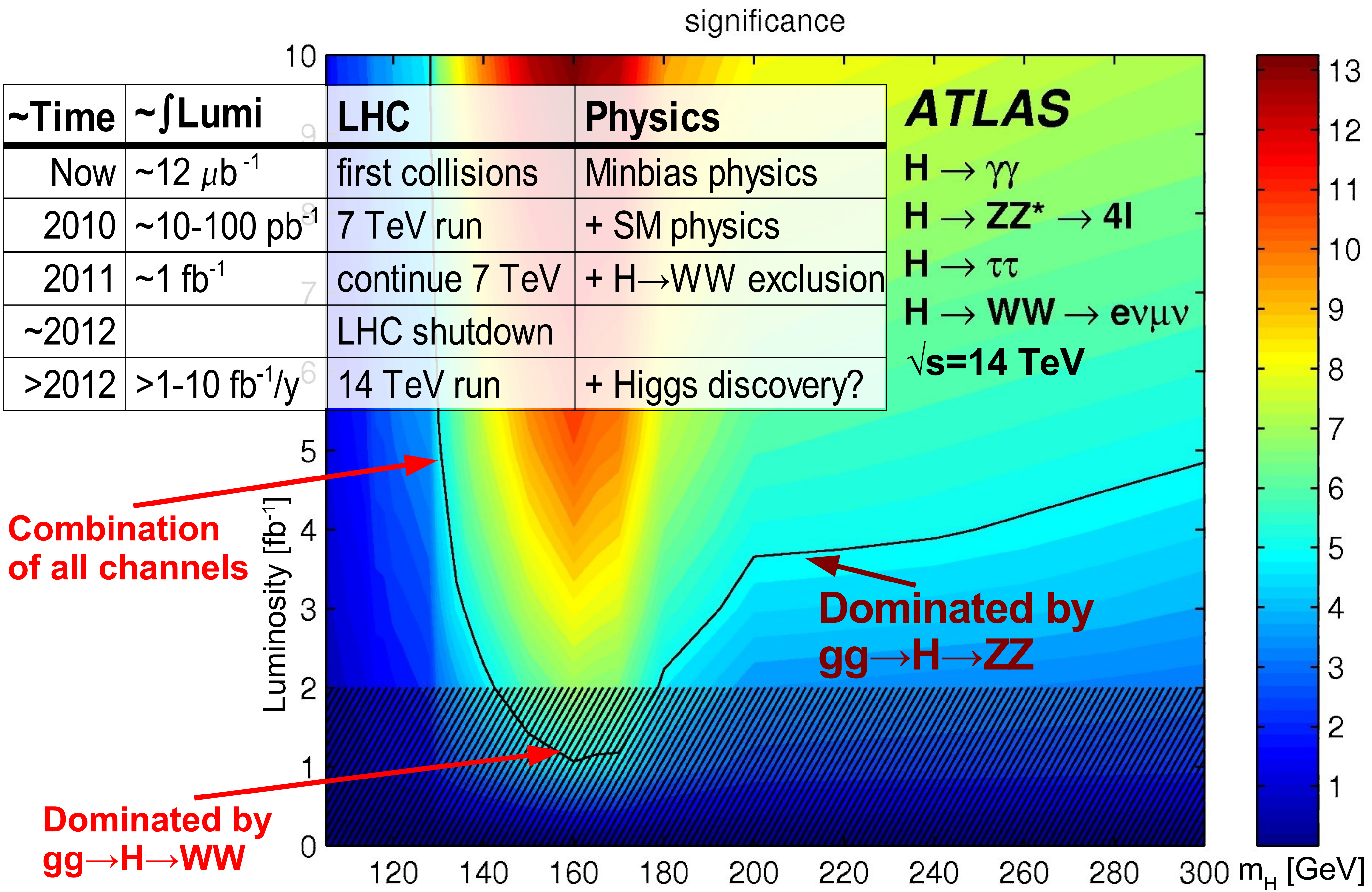
Collision Event with 2 Muon Candidates
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

Standard Model Higgs at the LHC



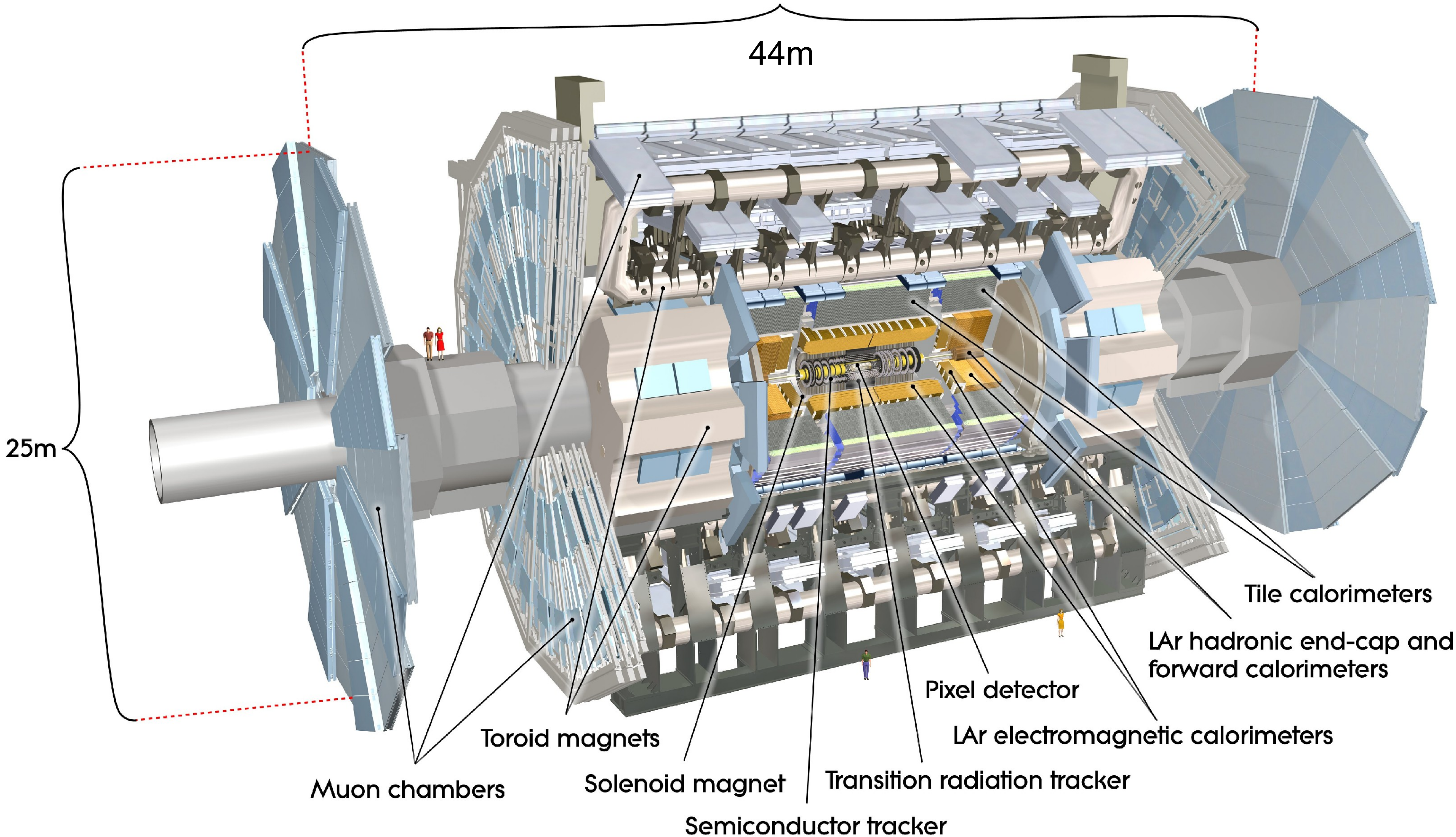
What is early data for Higgs physics

~Time	~∫Lumi	LHC	Physics
Now	~12 μb^{-1}	first collisions	Minbias physics
2010	~10-100 pb^{-1}	7 TeV run	+ SM physics
2011	~1 fb^{-1}	continue 7 TeV	+ H→WW exclusion
~2012		LHC shutdown	
>2012	>1-10 fb^{-1}/y	14 TeV run	+ Higgs discovery?

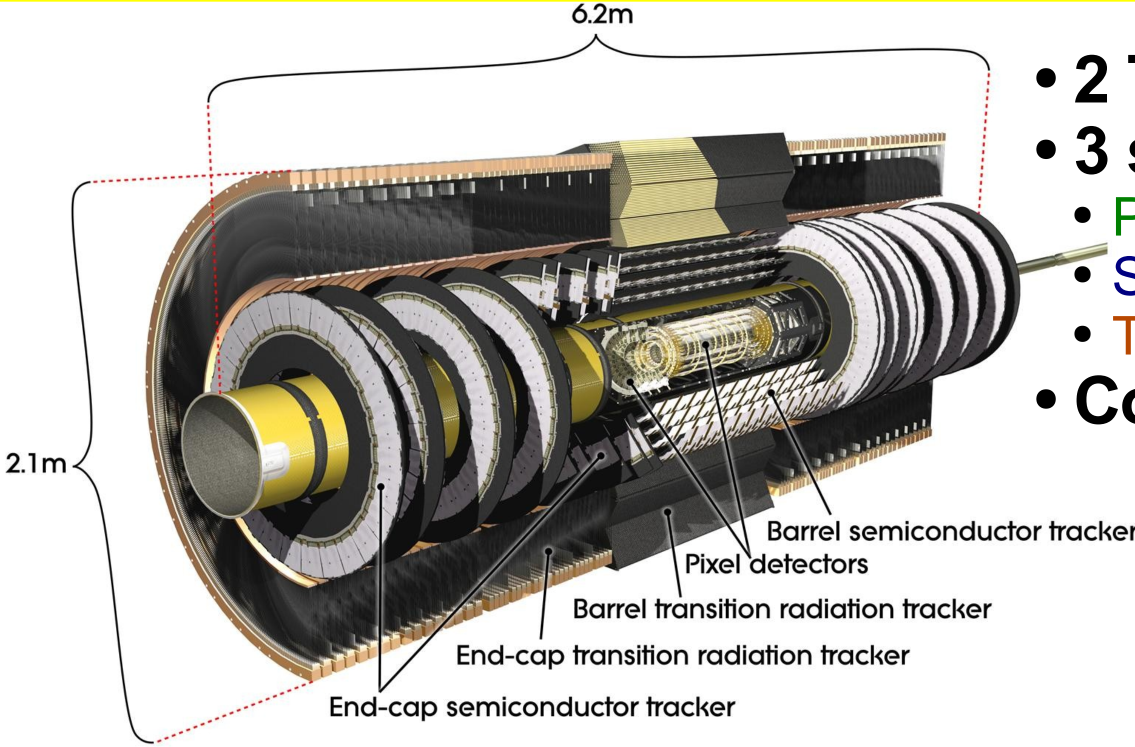


The ATLAS Detector

In parallel to physics with first data:
Detector commissioning and understanding!



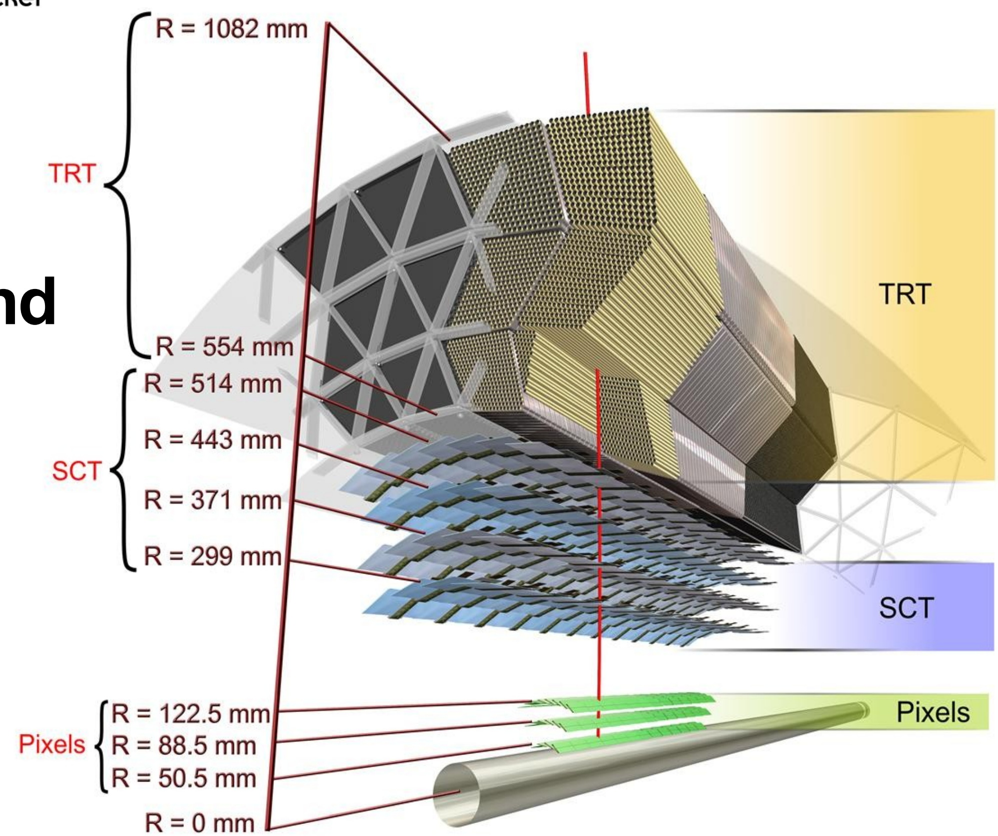
Inner Detector



- **2 Tesla solenoid field**
- **3 sub-detectors: (resolution)**
  - Pixel detector: 10/115 μm
  - Silicon strip detector (SCT): 17/580 μm
  - Transition radiation tracker (TRT): 130 μm
- **Coverage up to |η| < 2.5**

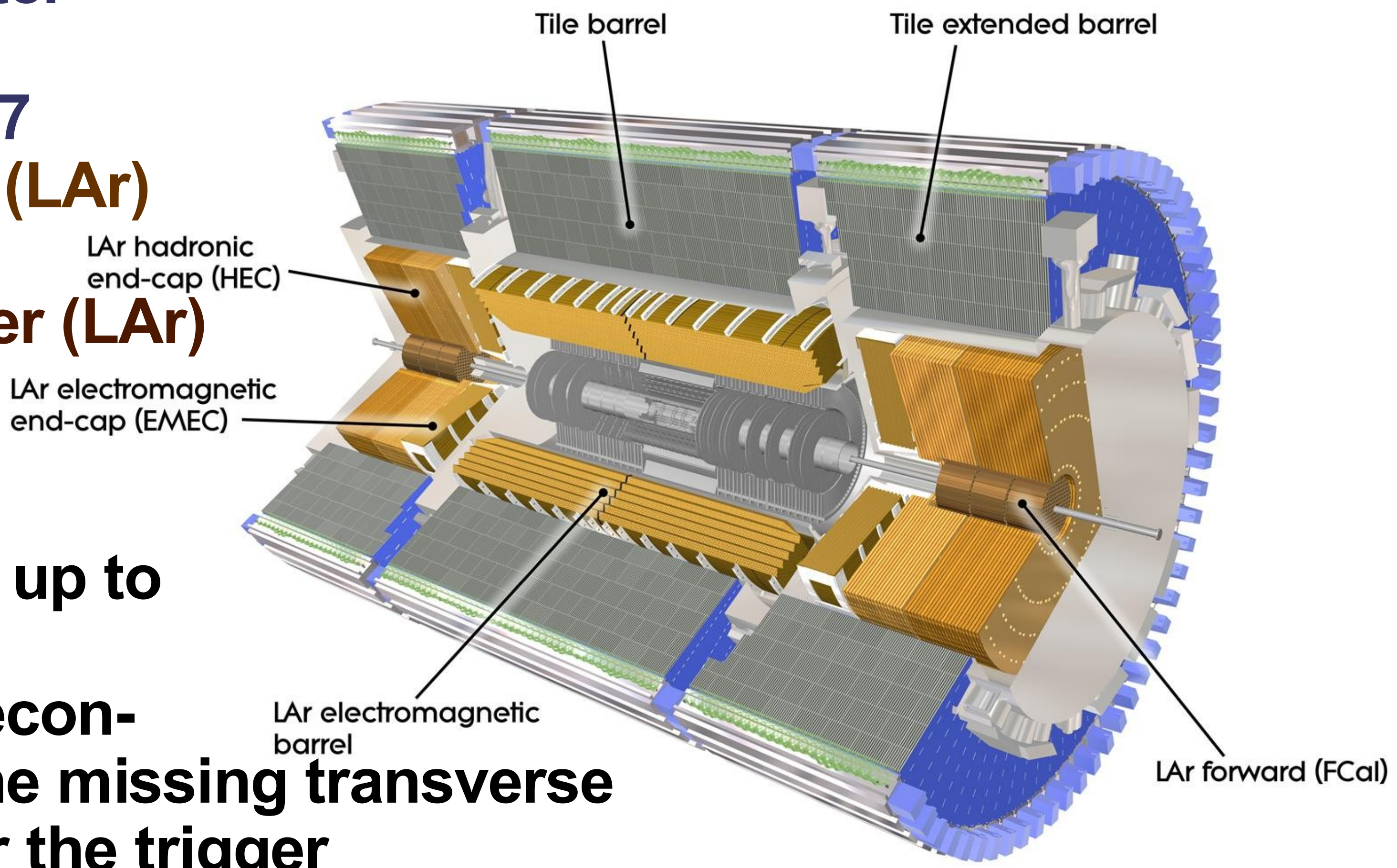
The Inner Detector (ID) gives around
- **3 Pixel**
- **4 SCT pairs**
- **36 TRT**

precision measurements per track and allows for accurate track and vertex reconstruction



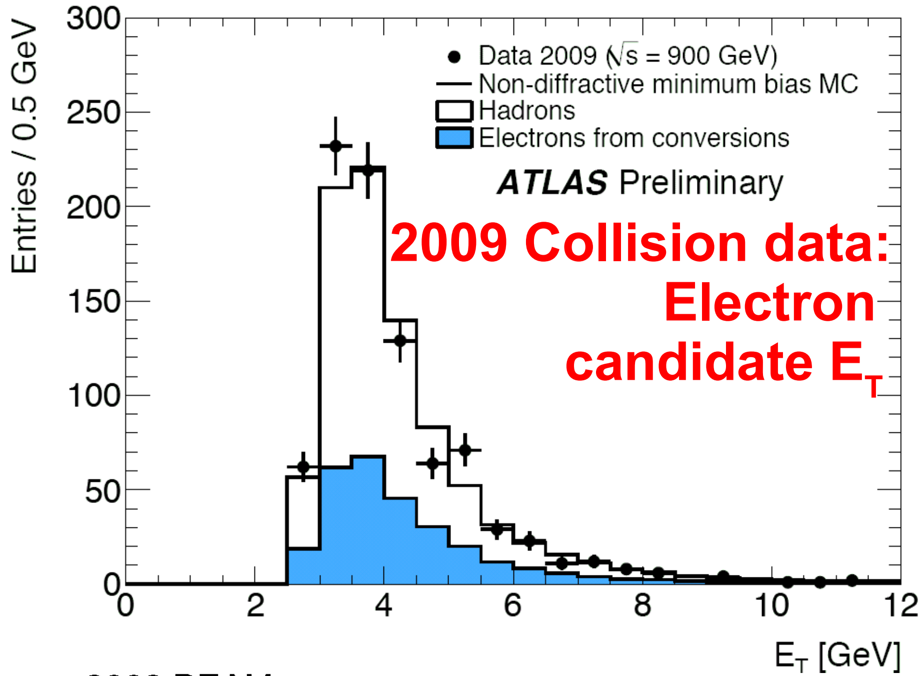
Calorimeter system

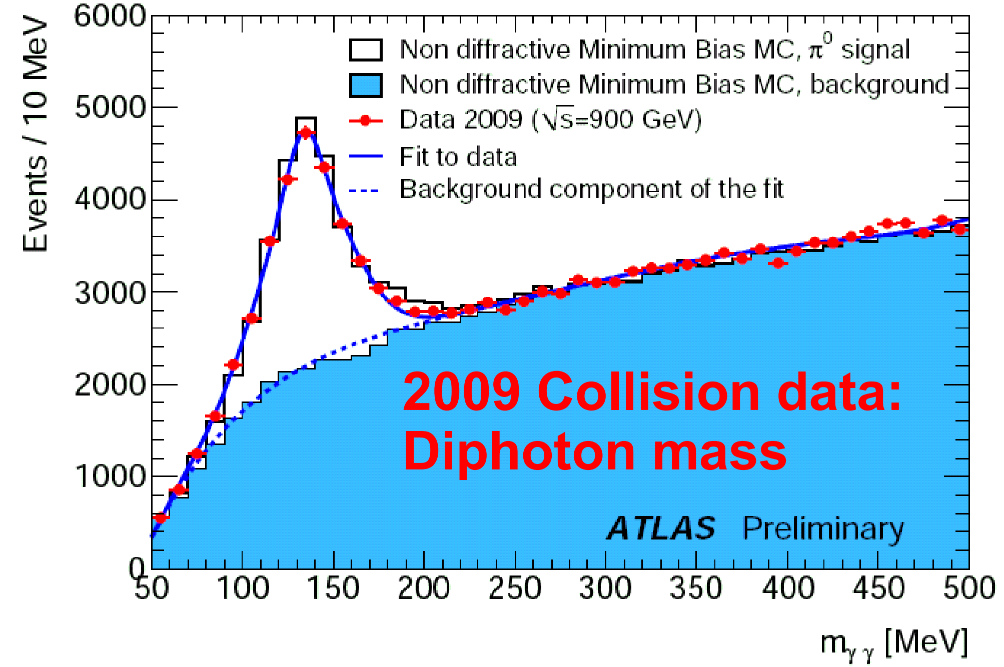
- Electromagnetic accordion calorimeter (LAr)
  - Precision measurement of photons and electrons
  - $|\eta|<3.2$
  - Intrinisic resolution ~10%/$\sqrt{E}$
- Hadronic calorimeter
  - Scintillator Tile calorimeter $|\eta|<1.7$
  - Hadronic endcap (LAr) $1.5<|\eta|<3.2$
- Forward calorimeter (LAr)
  - $3.2<|\eta|<4.9$

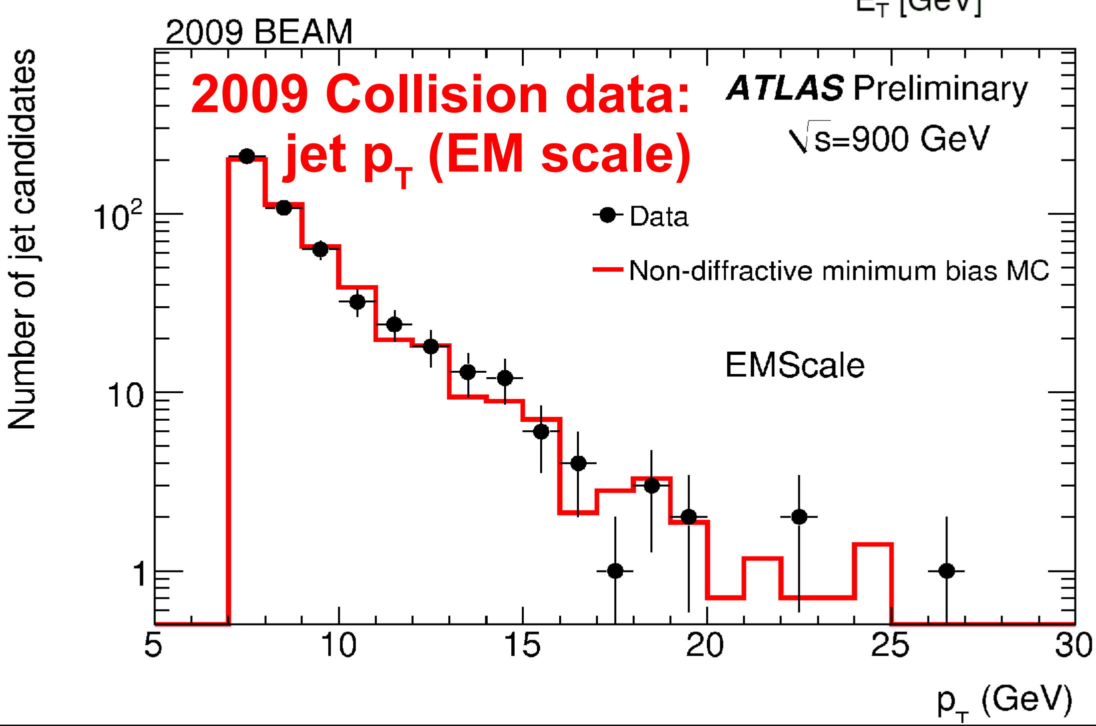


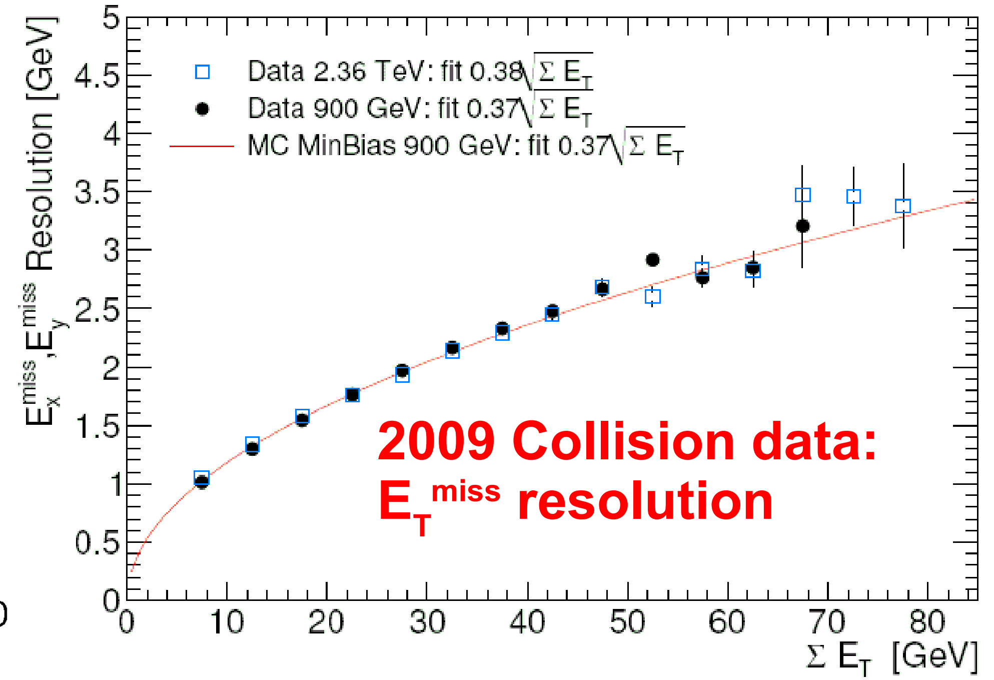
- Altogether gives hermetic coverage up to $|\eta|<4.9$
- Essential for the reconstruction of jets, the missing transverse momentum and for the trigger

Calorimeter performance



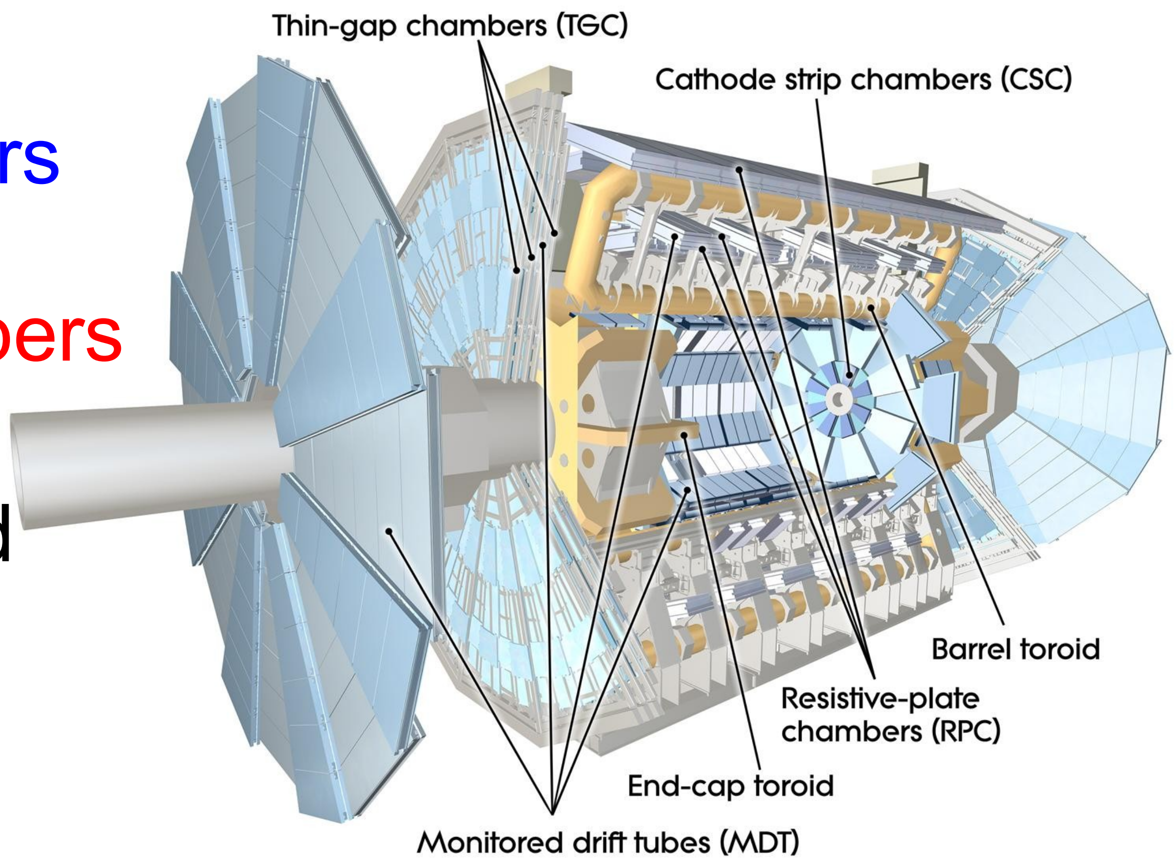




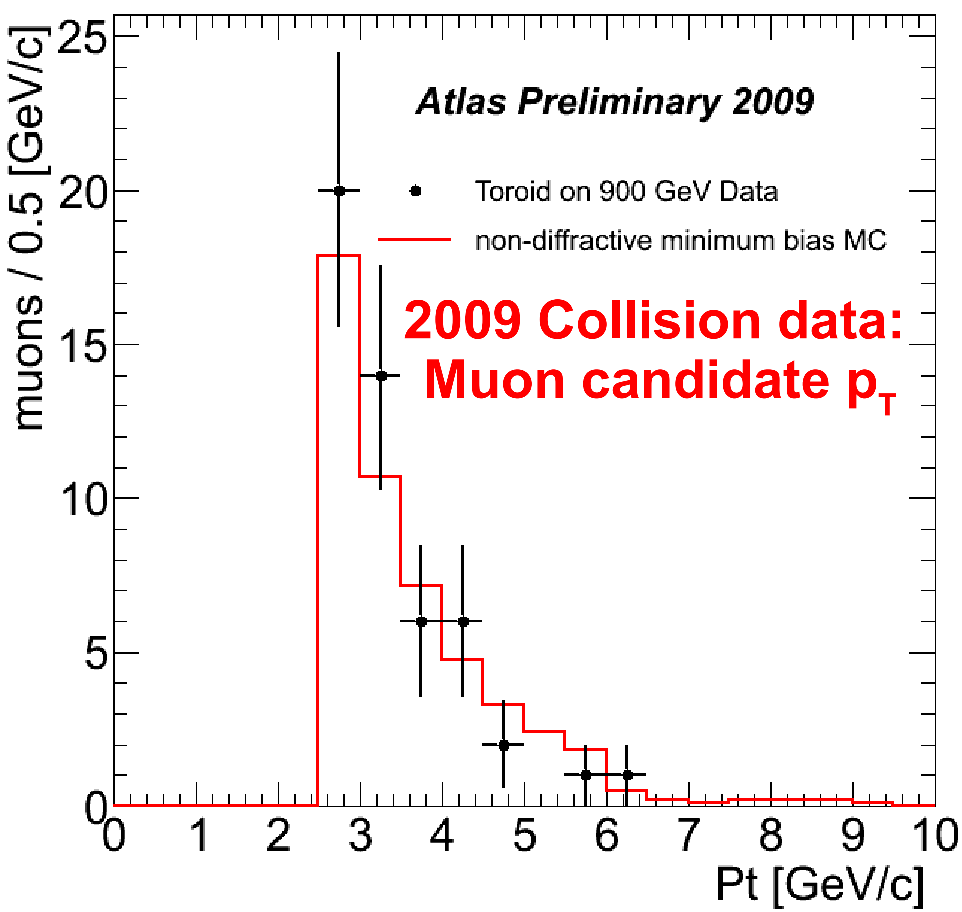


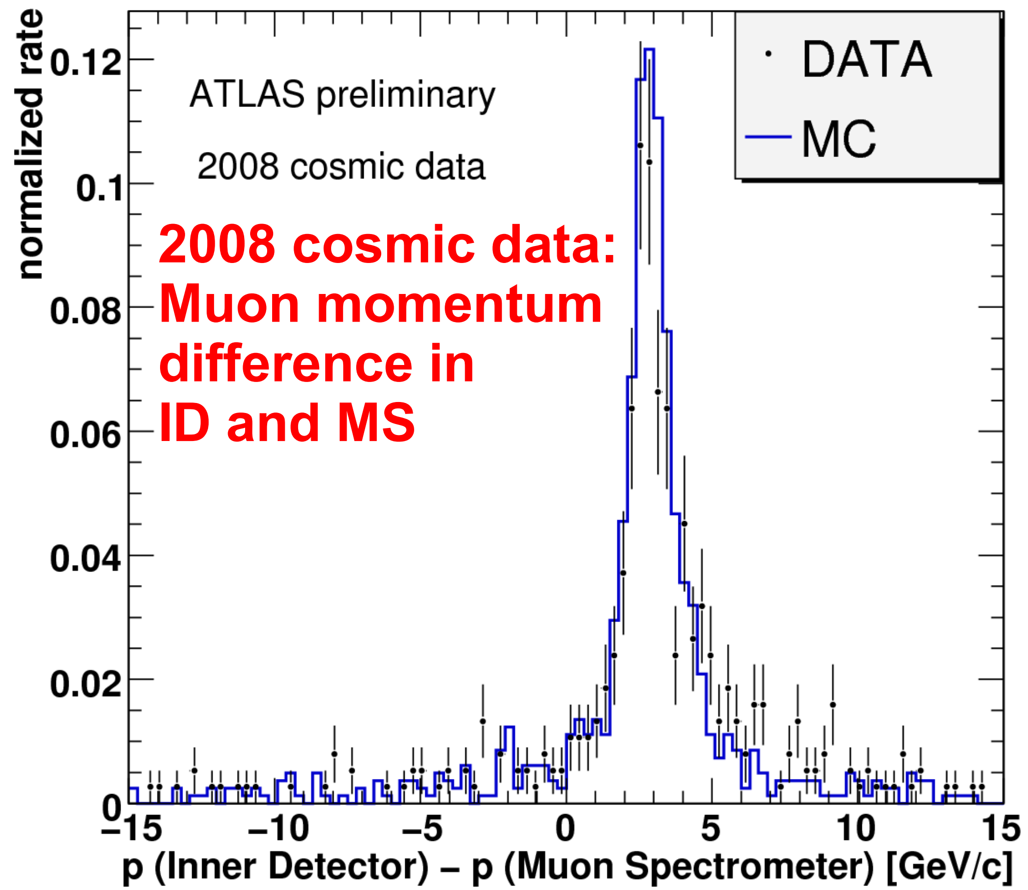
Muon Spectrometer

- Tracking and trigger
- 4 detector types :
  - Monitored drift tubes
  - Cathode drift chambers
  - Thin-gap chambers
  - Resistive plate chambers
- |η| coverage up to 2.7
- Magnetic field produced by 3x8 large coils + End-cap toroids
- Up to 4T magnetic field

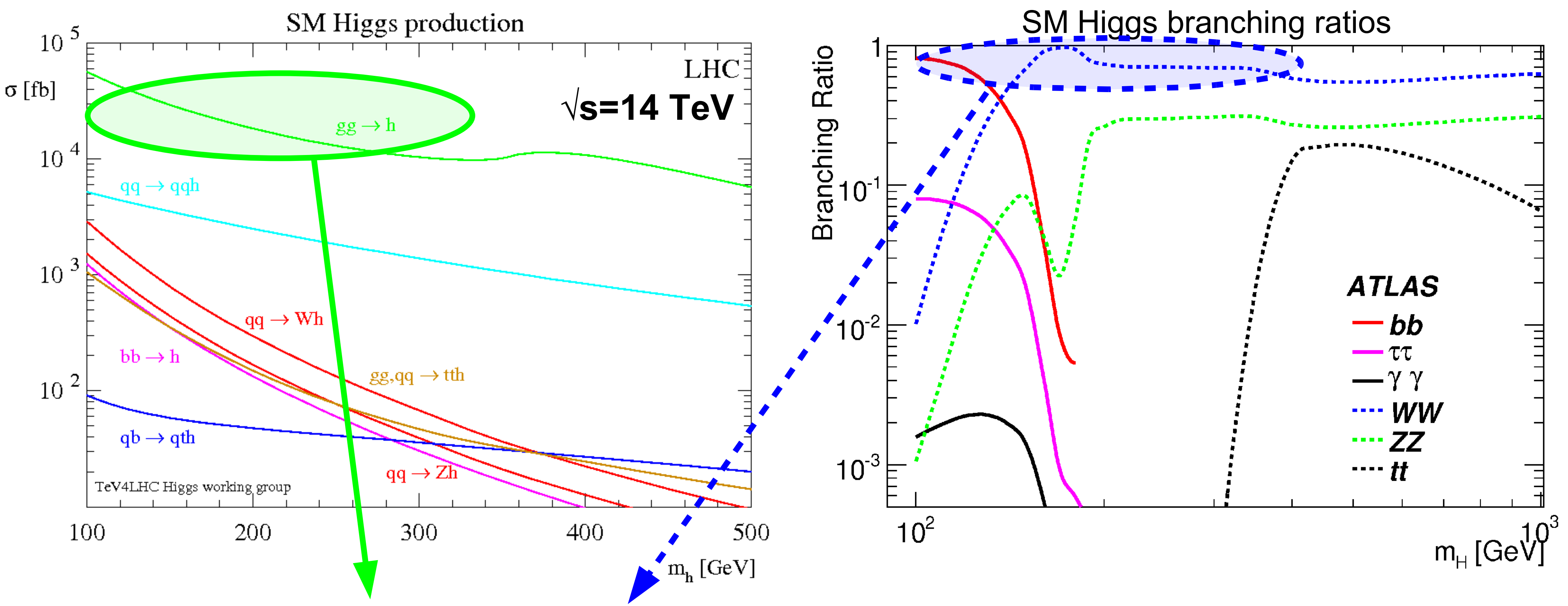


Muon System performance





Higgs Boson physics with ~1 fb^{-1}



(Inclusive) H→WW→lν lν (0 jet analysis)

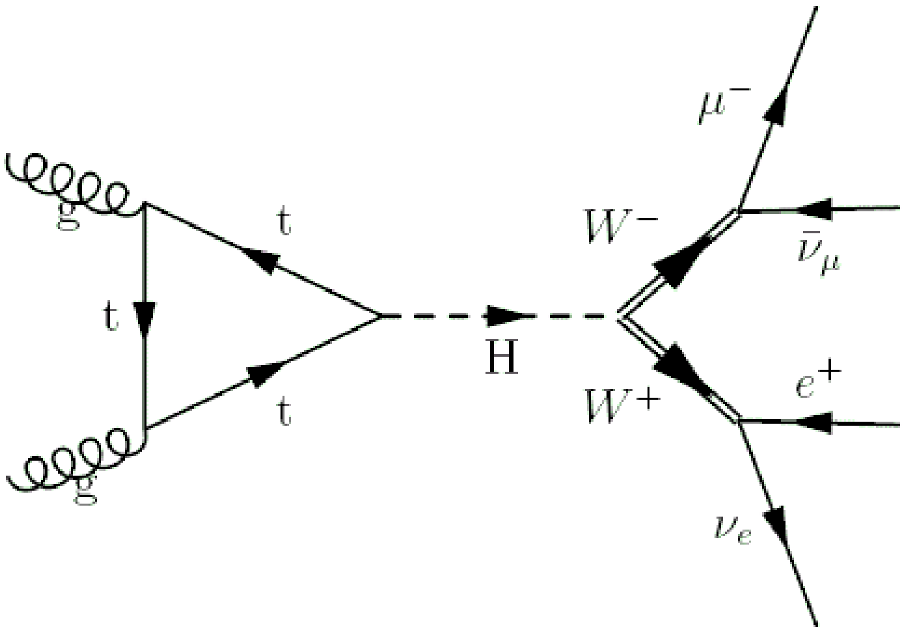
Low event statistics with 1 fb^{-1}: most channels not visible yet

➔ gg→H→WW→lν lν: Most promising channel for a SM Higgs Boson

- Pro: 2 Leptons in the final state → clear signal
- Con: 2 Neutrinos in the final state → no Higgs mass peak → large background systematic

Inclusive $H \to WW \to l\nu\ l\nu$

Dominant signal process
- $gg \to H \to WW \to l\nu\ l\nu$



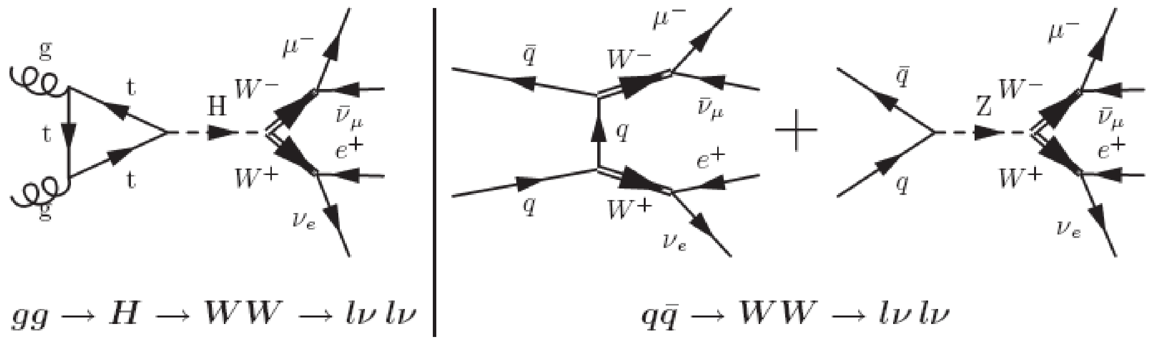
Dominant backgrounds
- WW (including $gg \to WW$)
- tt, Wt
- $Z \to ll$
- W+jets

Basic event selection:	**suppressed background**
• 2 isolated leptons, $p_T > 15$ GeV, $\lvert\eta\rvert < 2.5$	W+jets
• $E_T^{miss} > 30$ GeV	$Z \to ee/\mu\mu$
• 12 GeV $< m_{ll} <$ 300 GeV	cc, bb, Wt, ...
• $\lvert m_{\tau\tau} - m_Z \rvert < 25$ GeV	$Z \to \tau\tau$
• Jet veto: $p_T > 20$ GeV, $\lvert\eta\rvert < 4.8$	tt, Wt
• b-Jet veto $p_T > 15$ GeV	tt, Wt

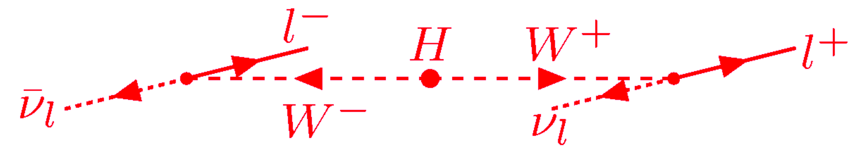
H→WW: Signal discrimination

Two neutrinos in the final state:

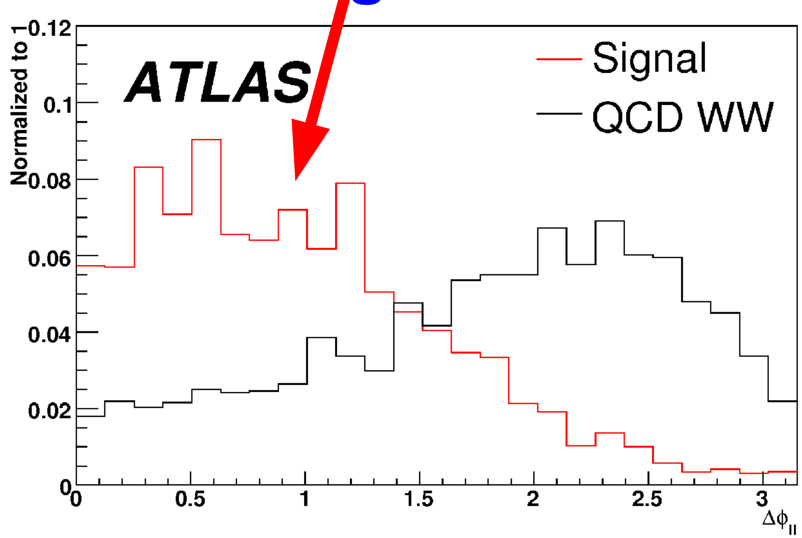
- **no Higgs Boson mass peak can be reconstructed**
- **But: WW pair produced in the decay of the spin 0 Higgs Boson**

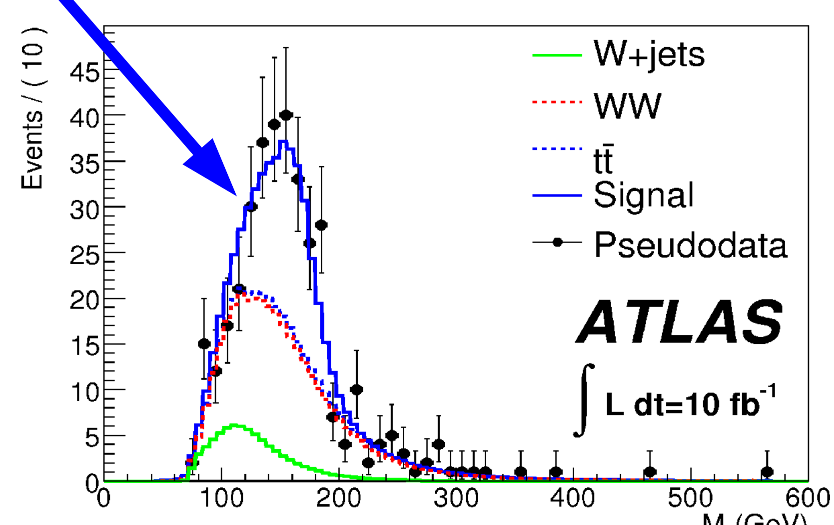


- **The spin correlations in the W decays give a characteristic lepton distribution**



- **The transverse mass allows for some additional signal discrimination**

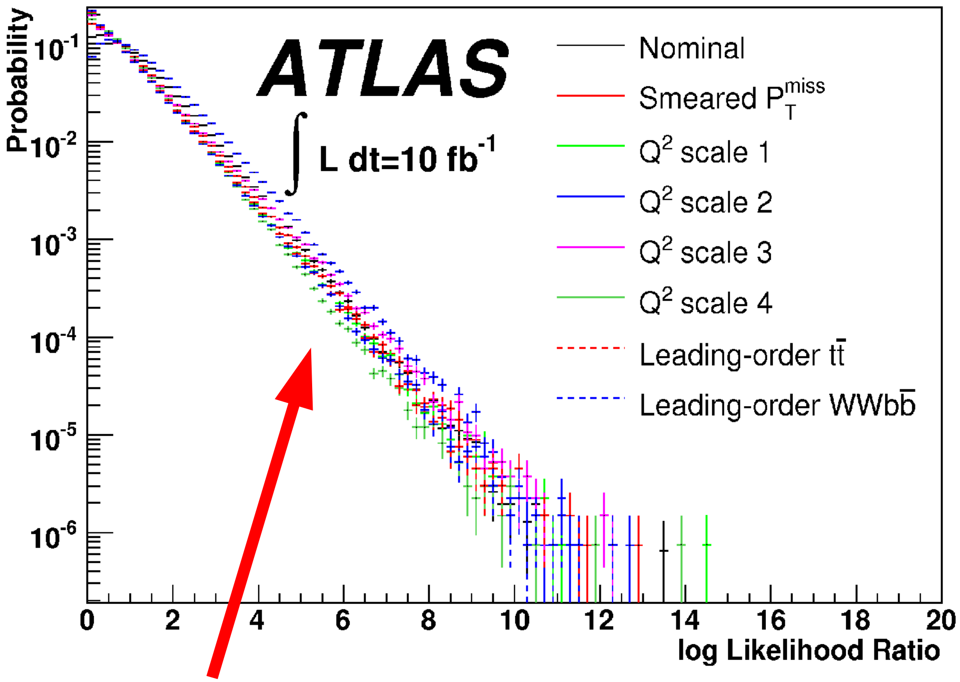




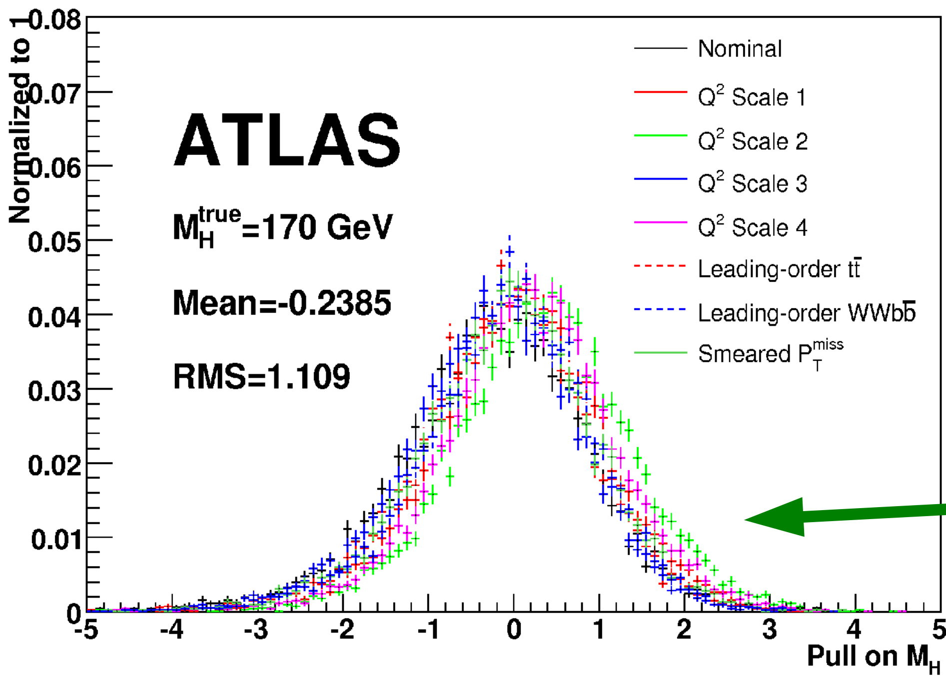
H→WW: Background determination

No clear signal peak:

- Signal and background separated with a fit using flexible template functions and control samples for the backgrounds
- A Likelihood ratio is used for the signal extraction



- Determination of systematic uncertainties is crucial:
  - detector effects
  - uncertainties on background cross sections and shapes

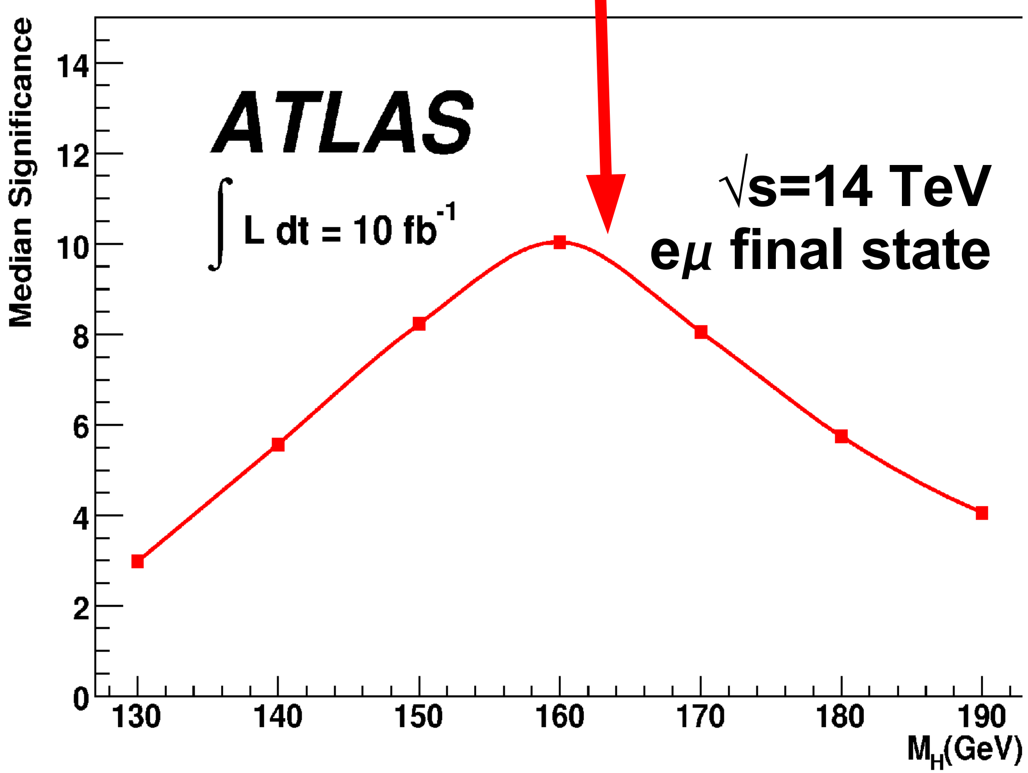


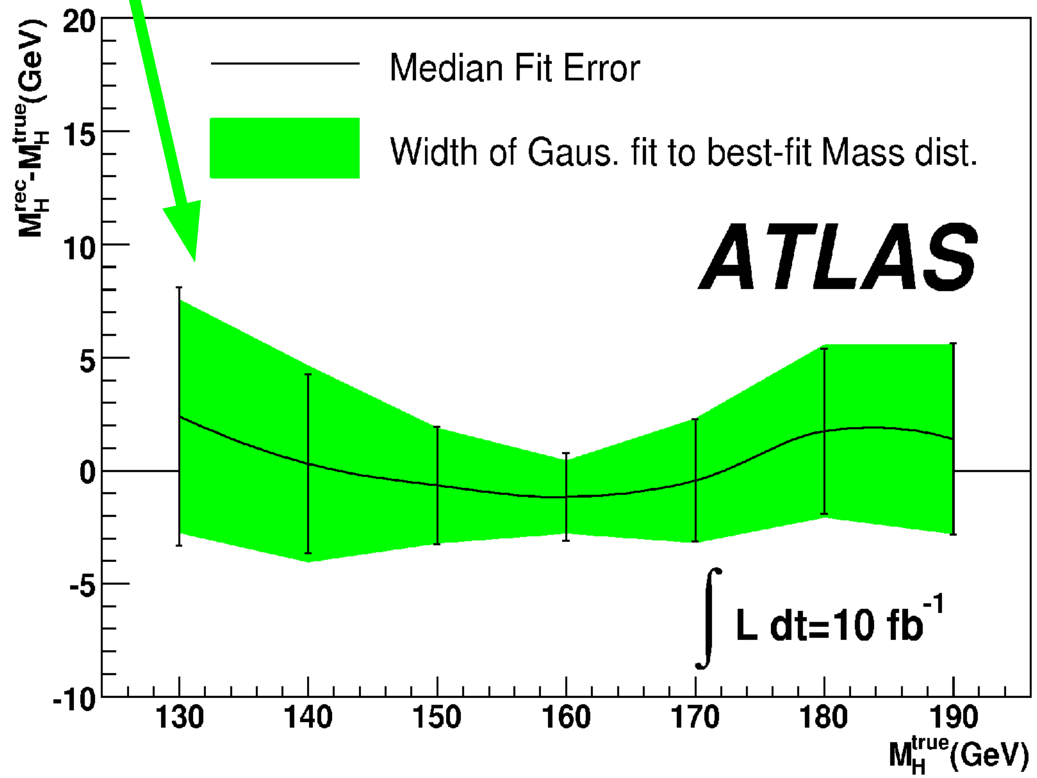
- The Higgs boson mass can be extracted from the best fit signal template function

H→WW significance

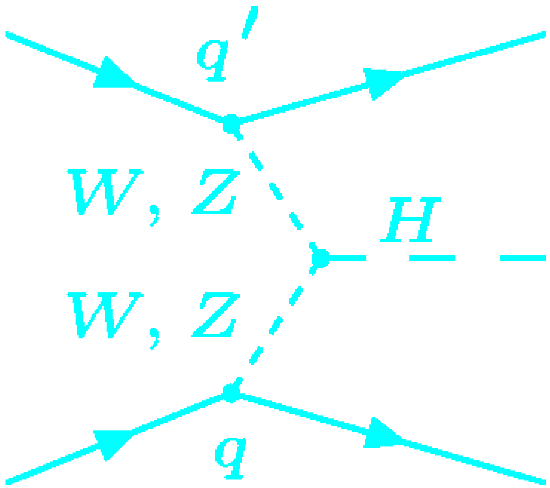
H→WW→eν $\mu\nu$ (0 jet) channel:

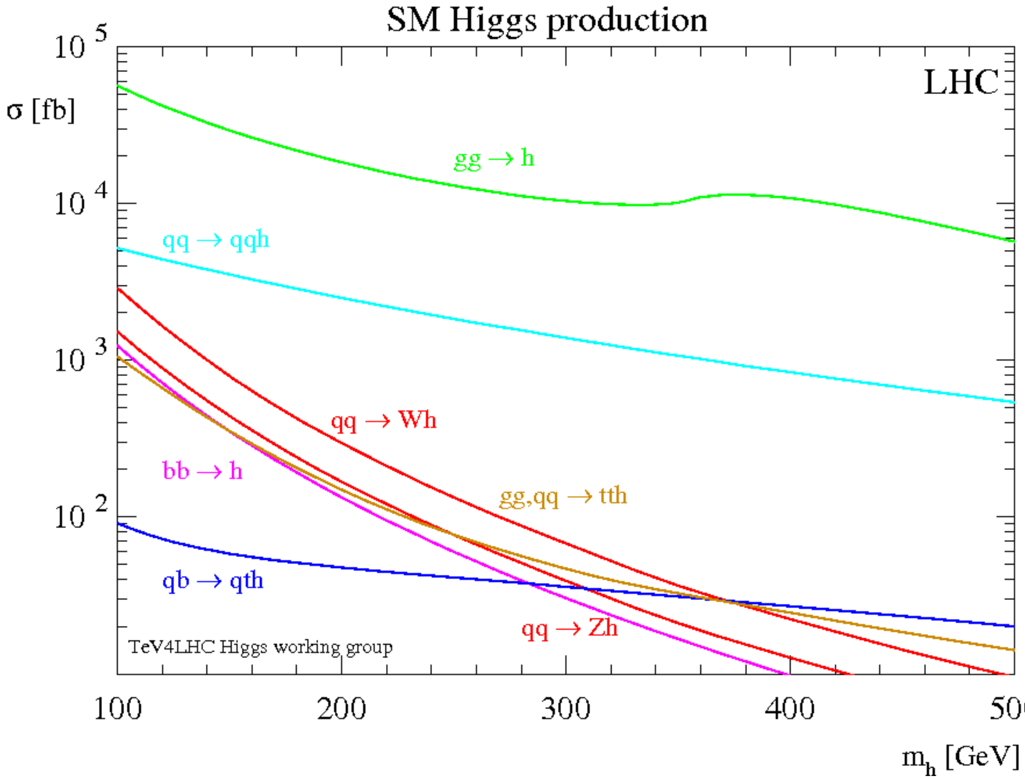
- **5σ discovery potential in the mass range ~140GeV to ~180GeV with 10 fb^{-1}**
- **Higgs boson mass sensitivity even without clear peak**





WBF/VBF H→WW



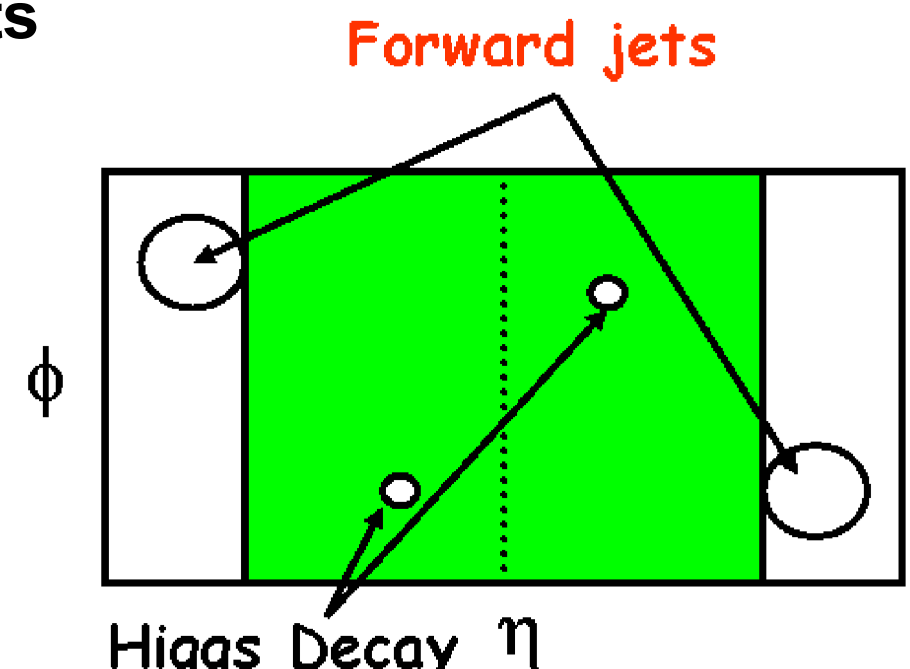


Weak Boson Fusion or Vector Boson Fusion:

- **WBF cross section smaller by a factor ~10 compared to the inclusive cross section**

But: Extra signature

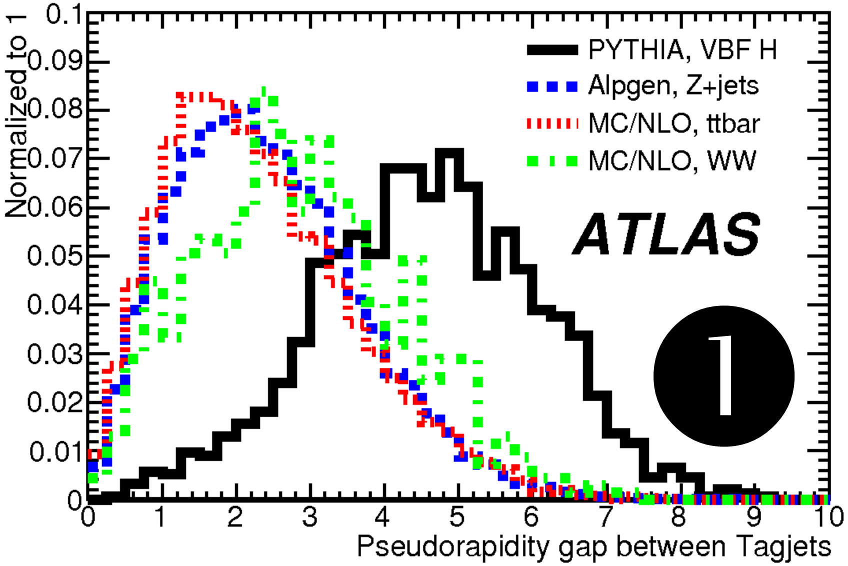
→ **Recoil quarks visible as forward jets**

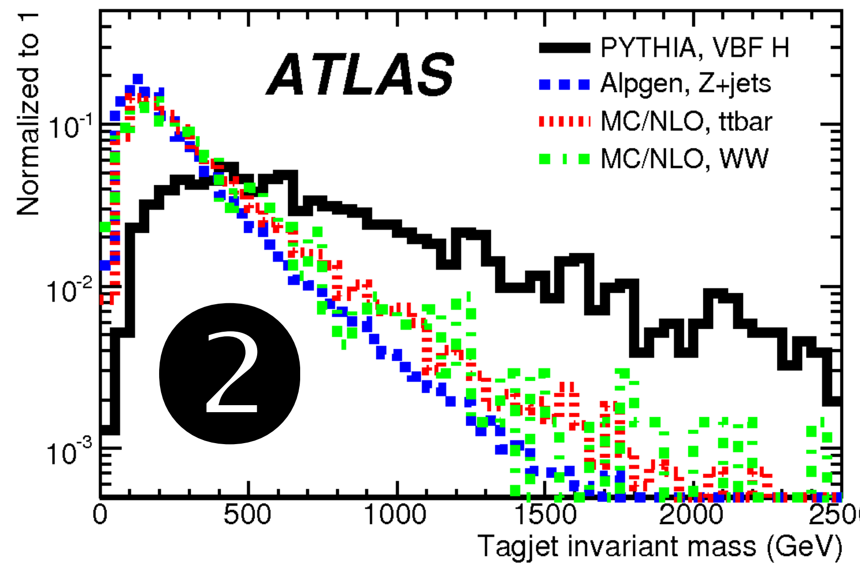


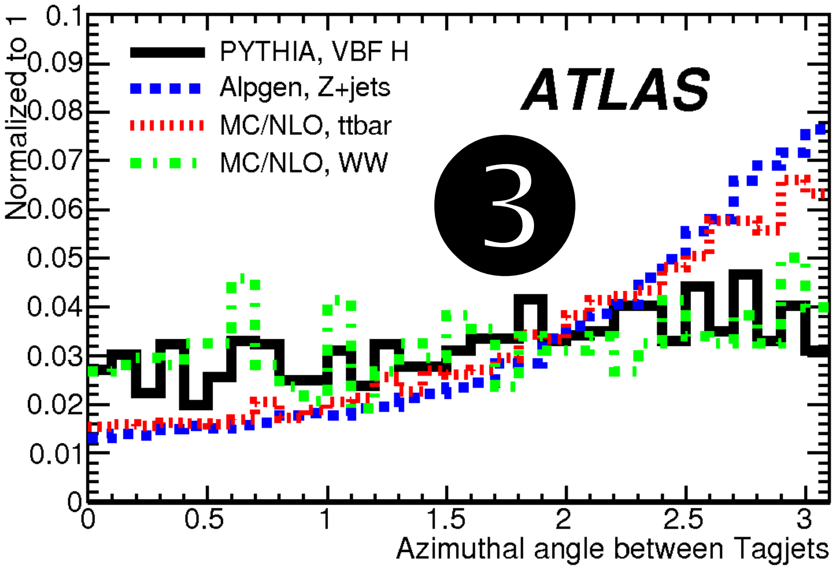
→ **No color connection between the recoil jets → central jet veto**

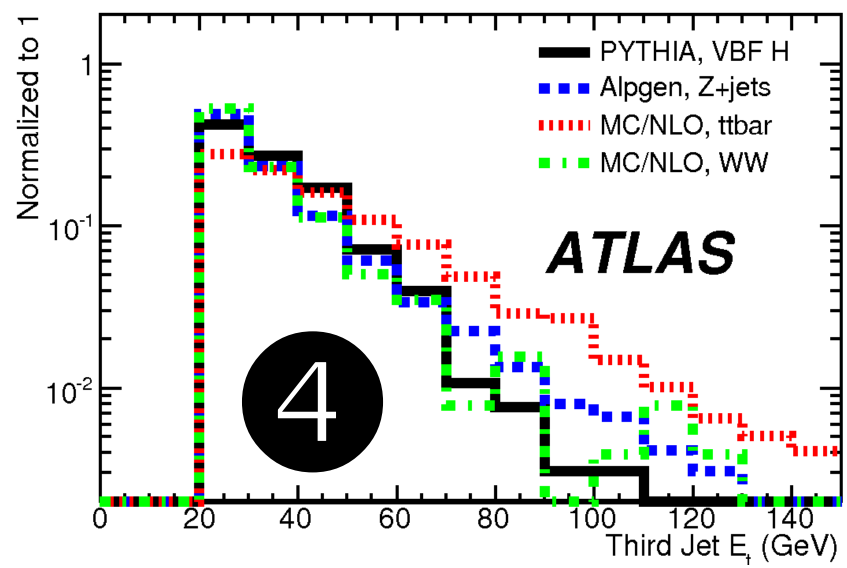
WBF selection

- **Similar final state selection as for the H→WW (0 jet) analysis**
- **Additional selection on forward tag jets (❶, ❷, ❸) and jet veto (❹)**





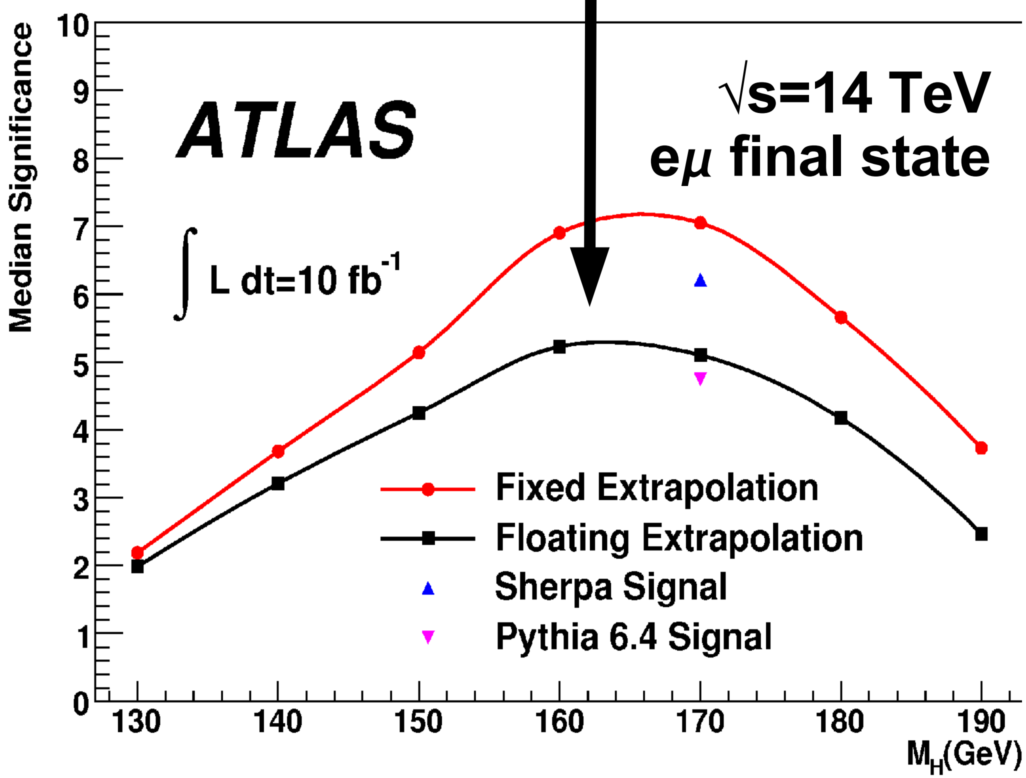


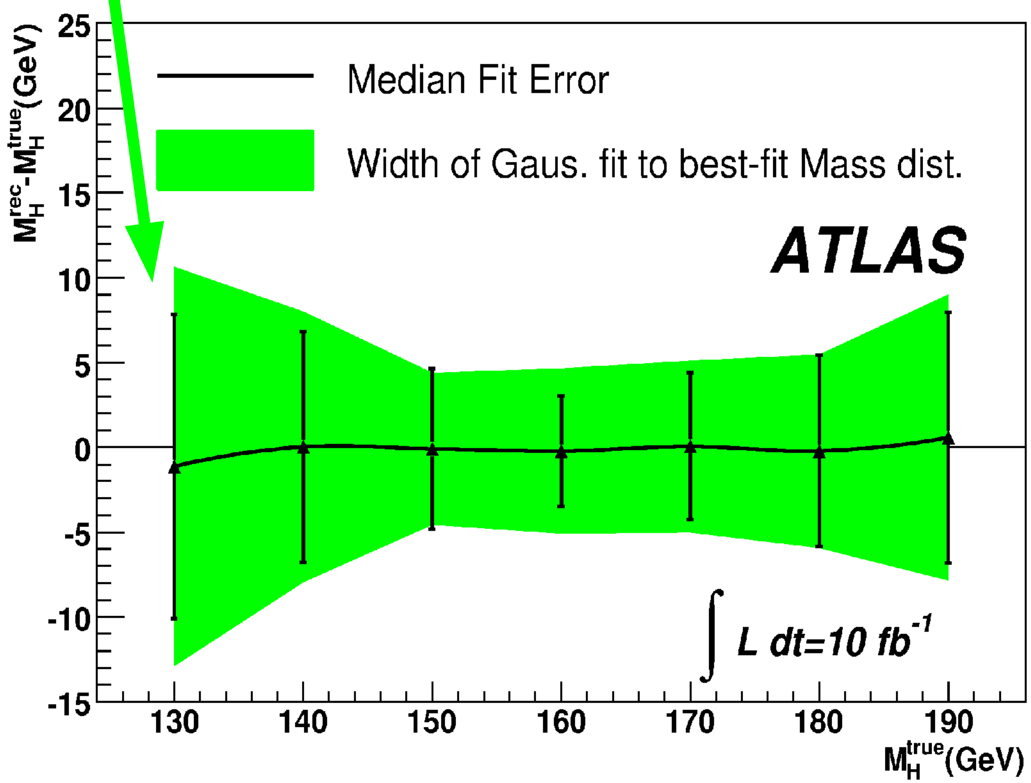


WBF H→WW significance

WBF H→WW→eν $\mu\nu$ channel:

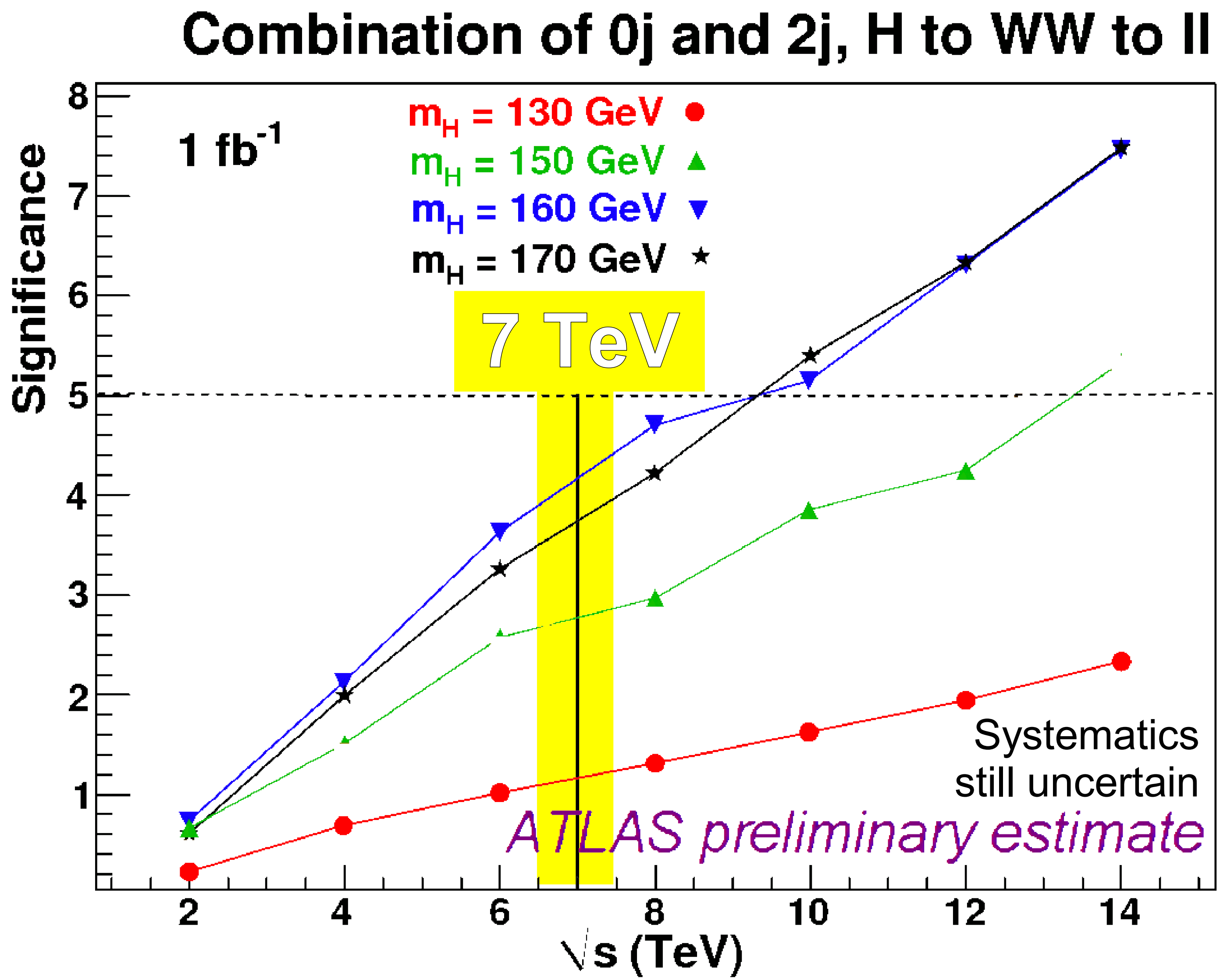
- Conservative 5σ discovery potential in the mass range ~160GeV to ~170GeV with 10 fb^{-1}
- Higgs boson mass sensitivity even without clear peak



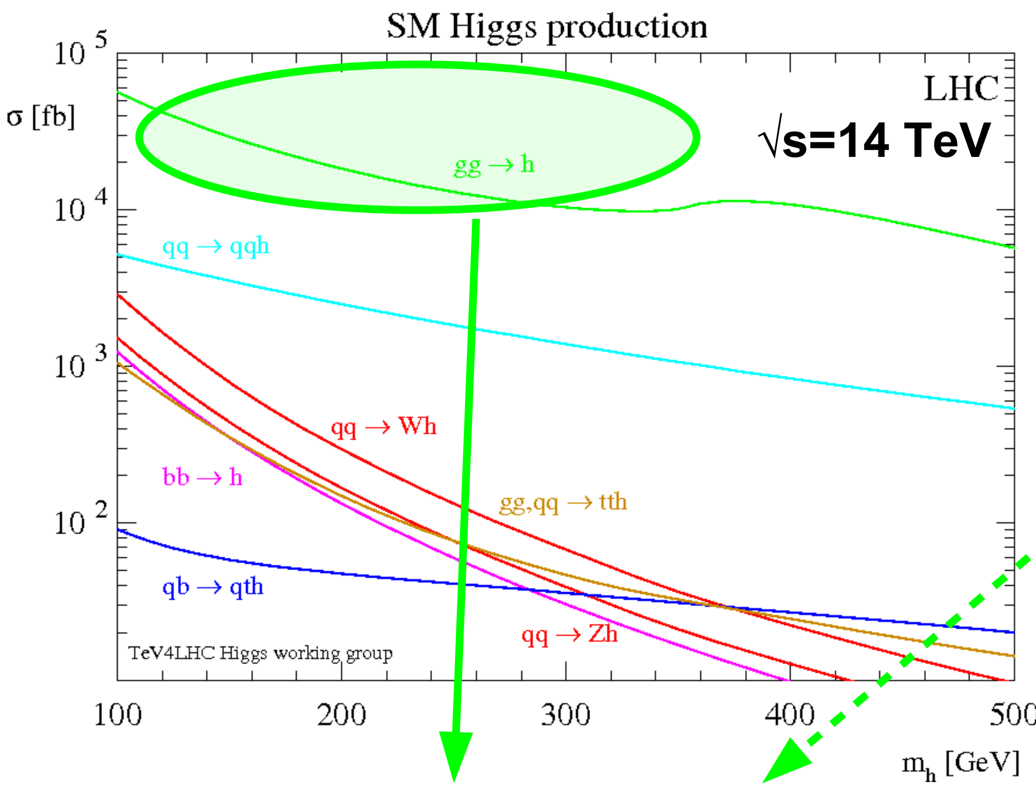


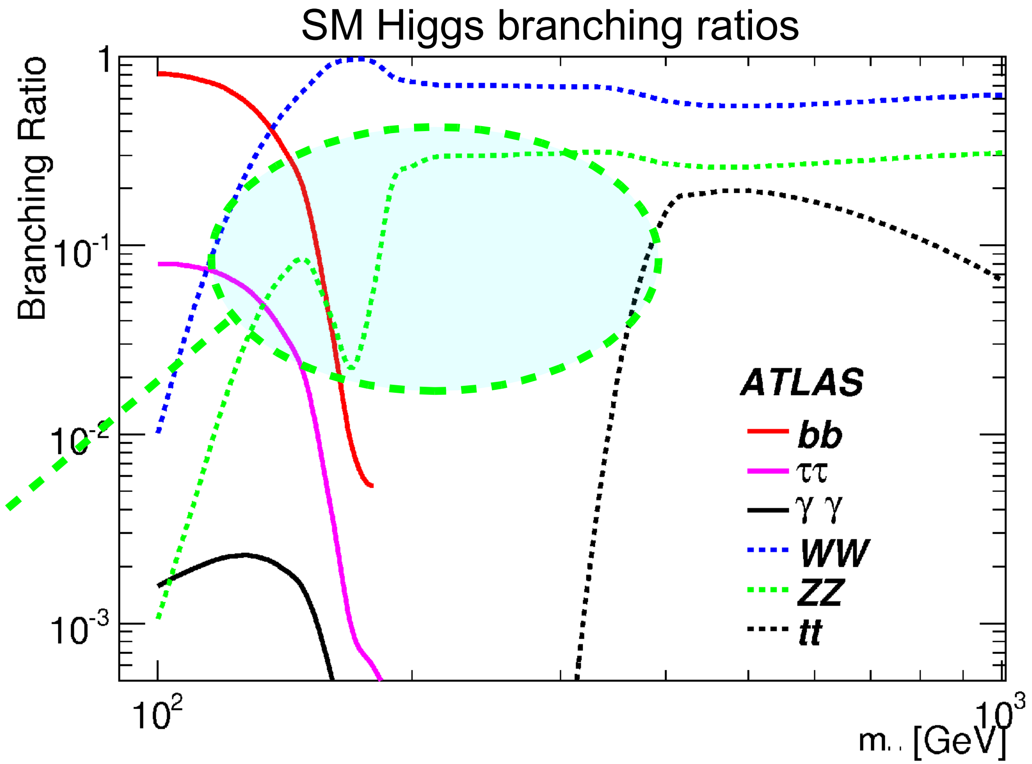
Combined 1 fb^{-1} H→WW significance

- Significance extrapolated from the 14 TeV studies
- ~4σ discovery potential possible with 1 fb^{-1} at 7 TeV



H→ZZ→4l

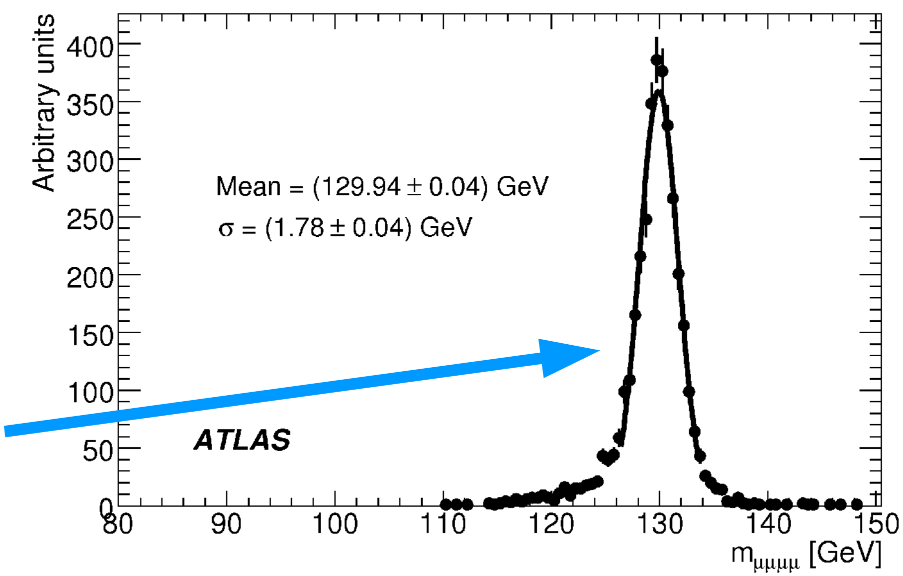




(Inclusive) H→ZZ→ll ll

Compared to H→WW→lν lν

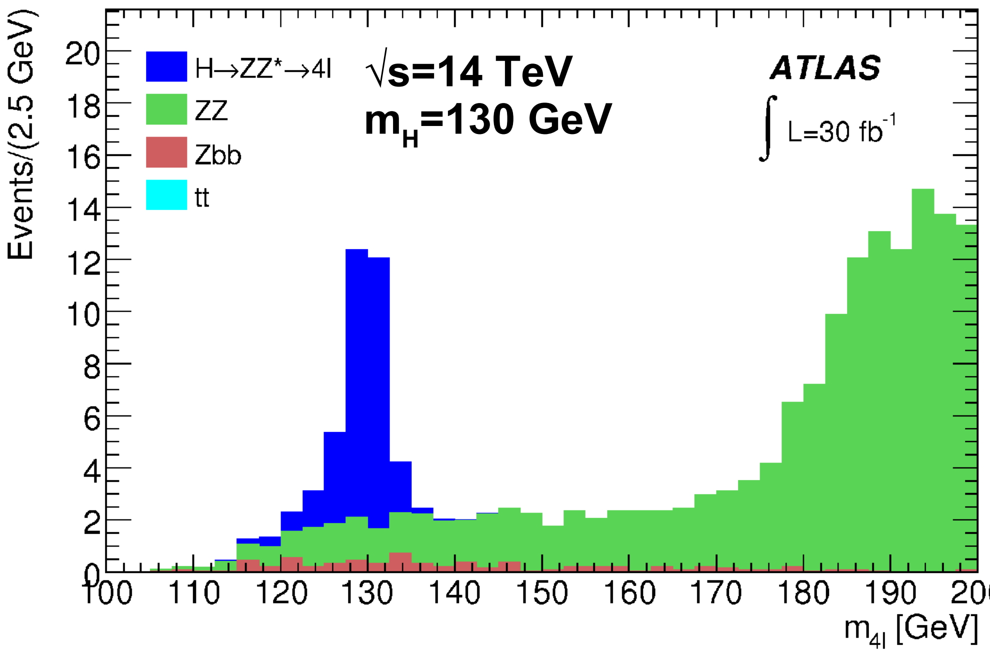
- smaller branching ratios H→ZZ and Z→ll
- **But:** Higgs mass can be reconstructed! Very clear signature!

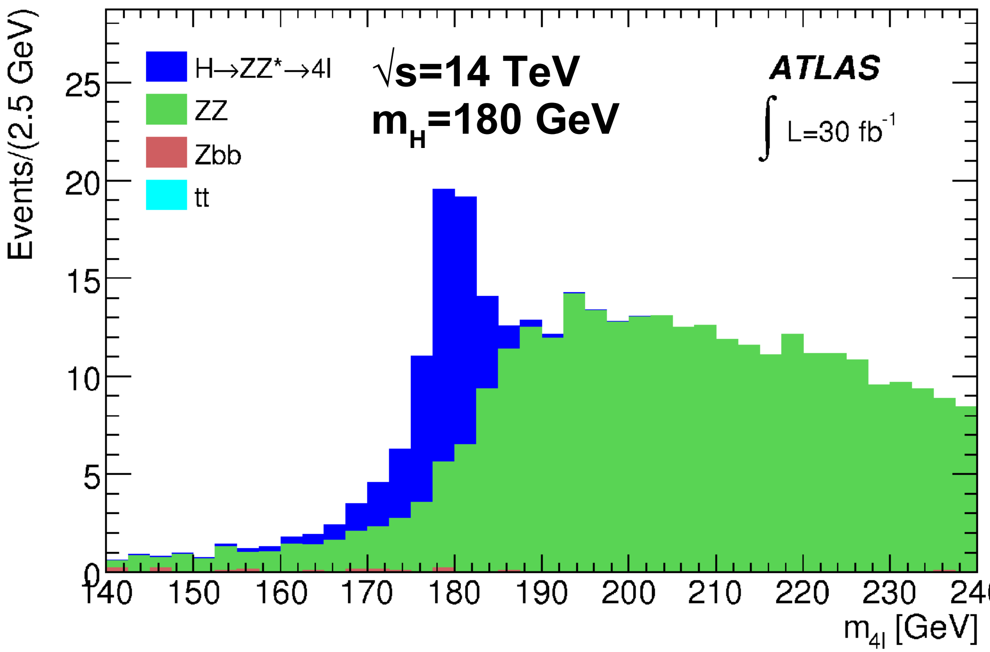


H→ZZ→4l selection

- 4 good quality leptons
- Lepton calorimeter and track isolation (reduce tt, Zbb background)
- Veto against leptons with large impact parameter (reduce tt, Zbb)
- Lepton flavours, charges and dilepton masses compatible with 2*Z→ll

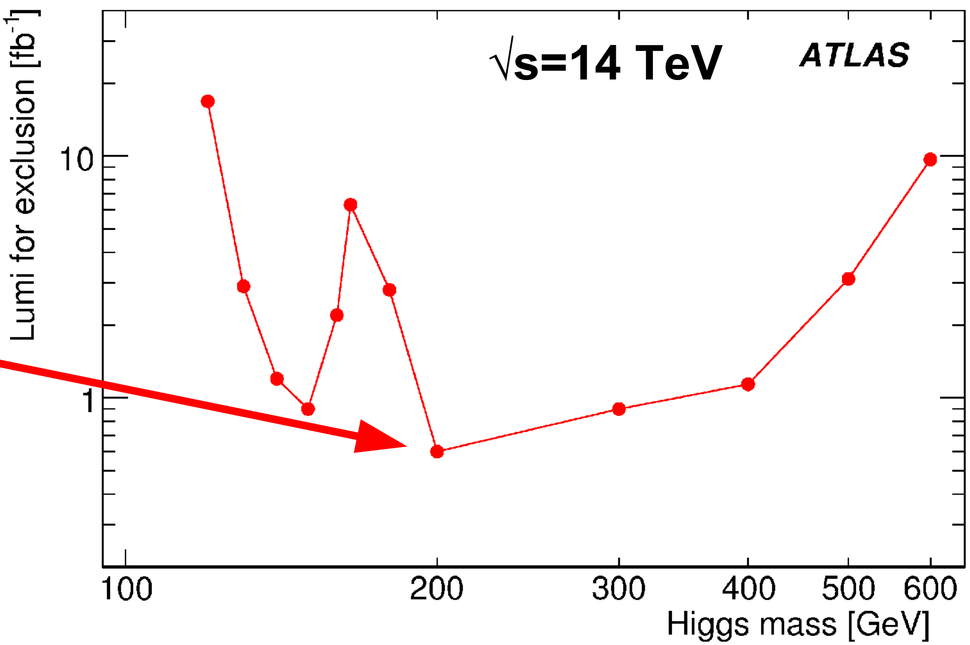
➔**Signal peak visible above continuous background**

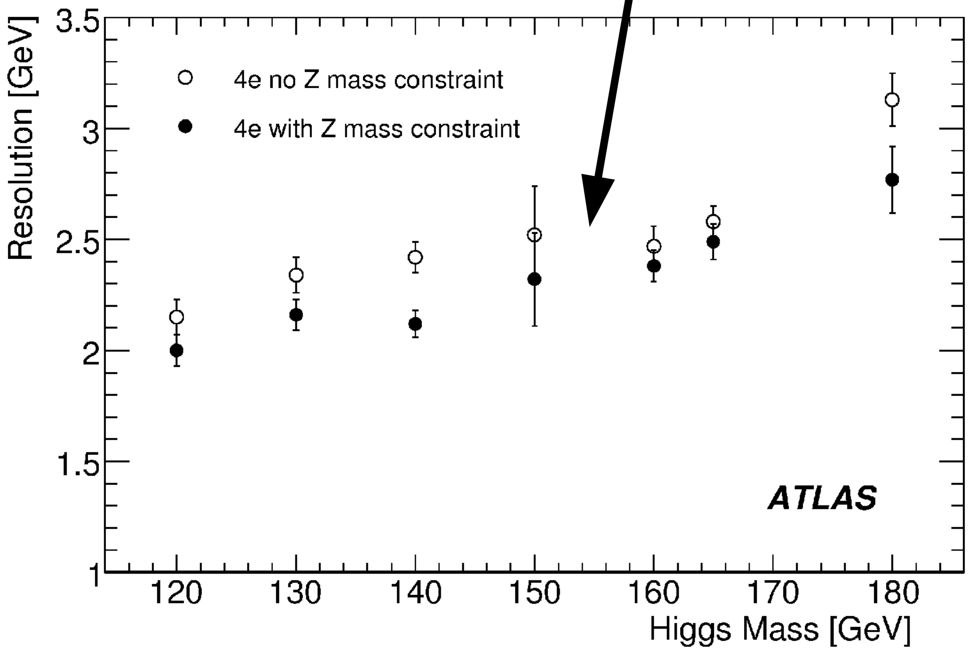


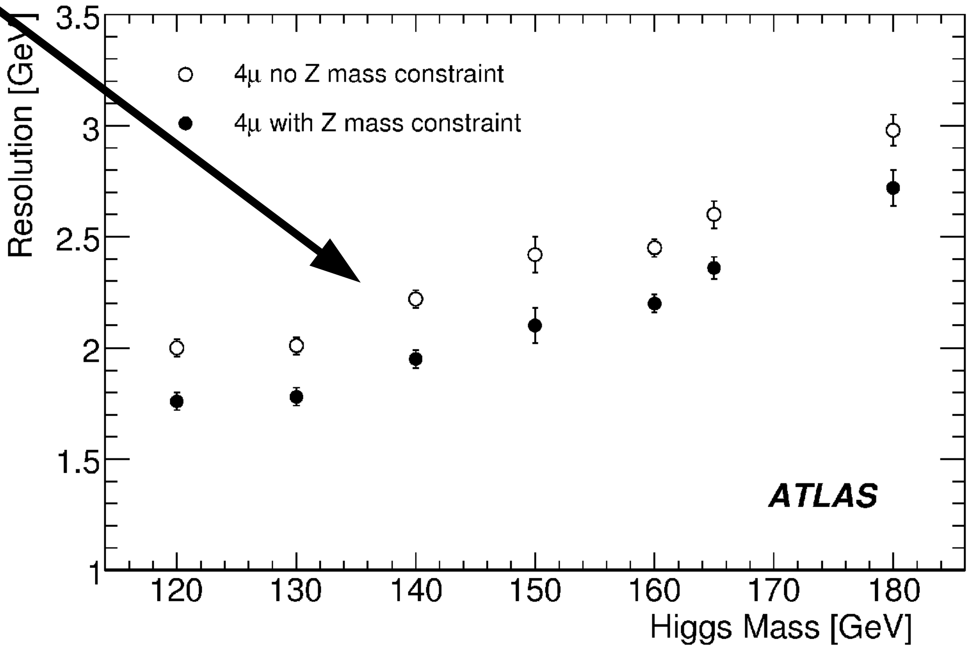


H→ZZ→4l results

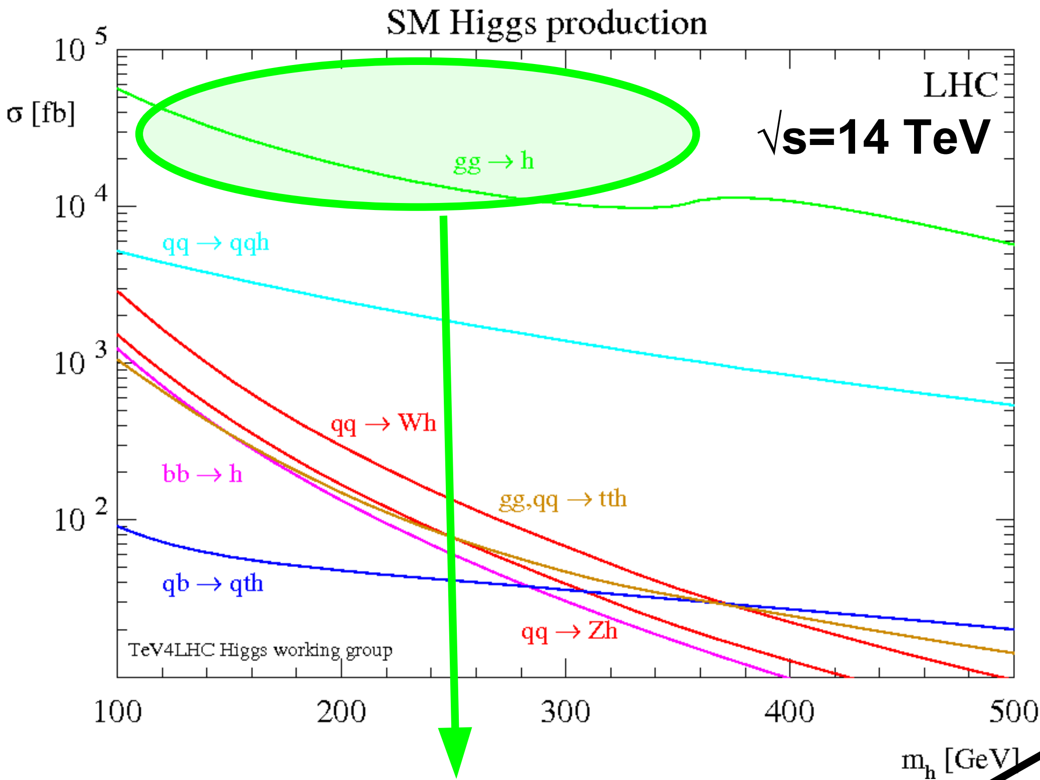
- Statistically less significant than the H→WW channel
- 2σ exclusion possible with ~1fb^{-1} at 14 TeV between m_H~200GeV and m_H~400GeV
- Mass resolution ~2 GeV in all final states (for small intrinsic H width)

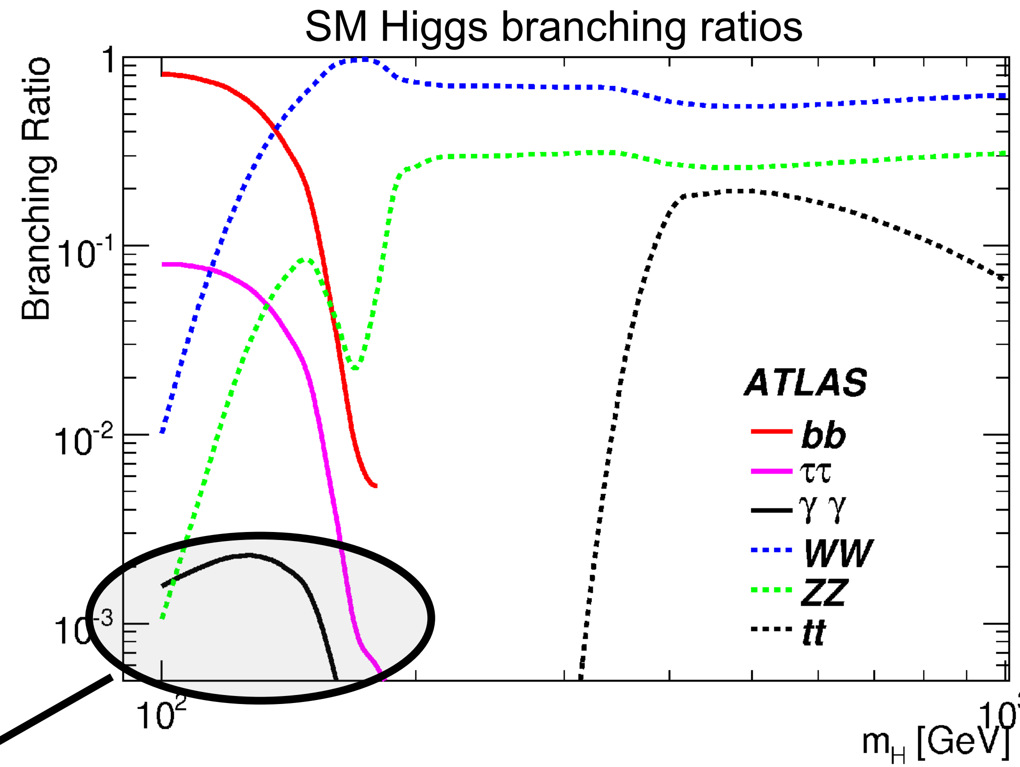






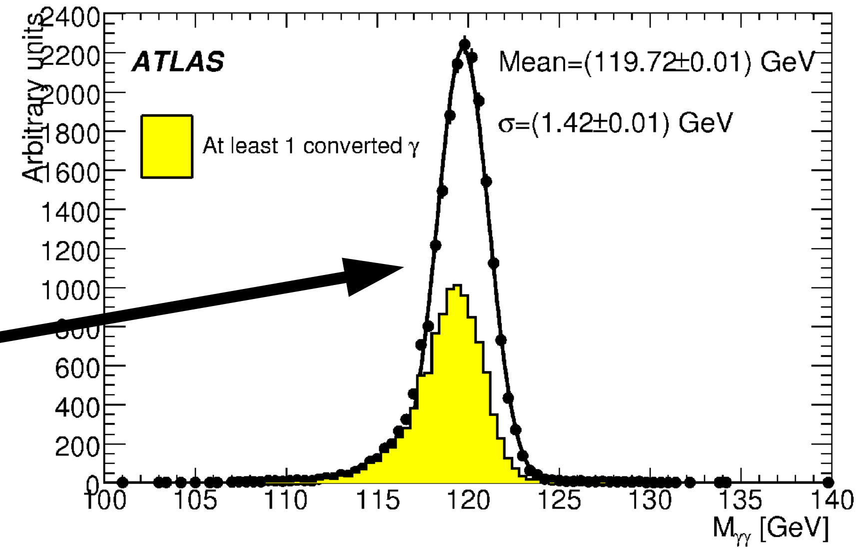
H→$\gamma\gamma$



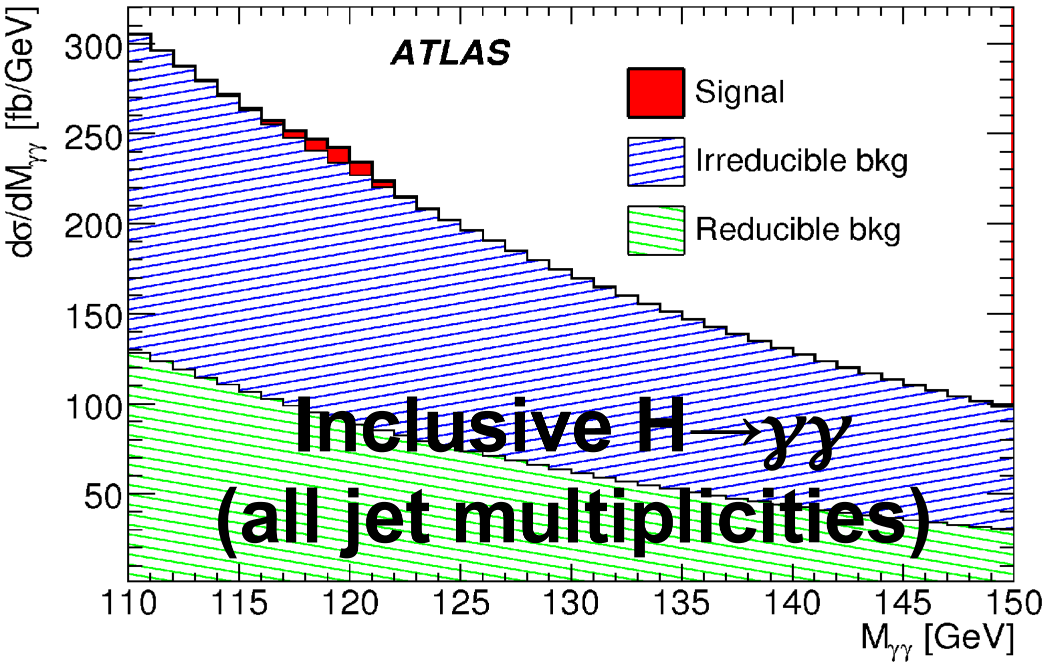


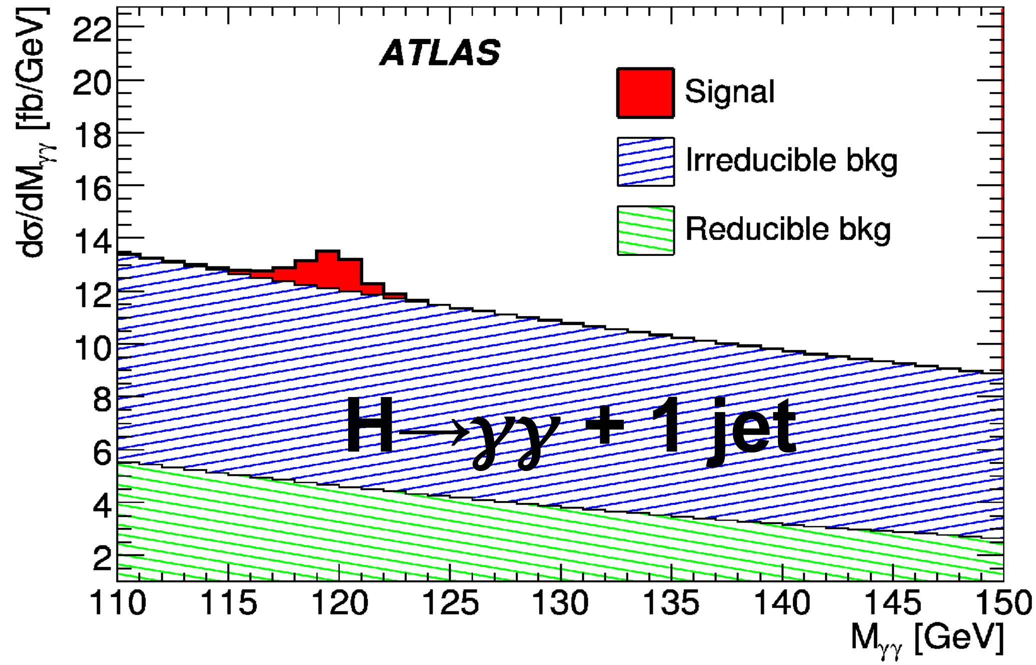
(Inclusive) H→$\gamma\gamma$

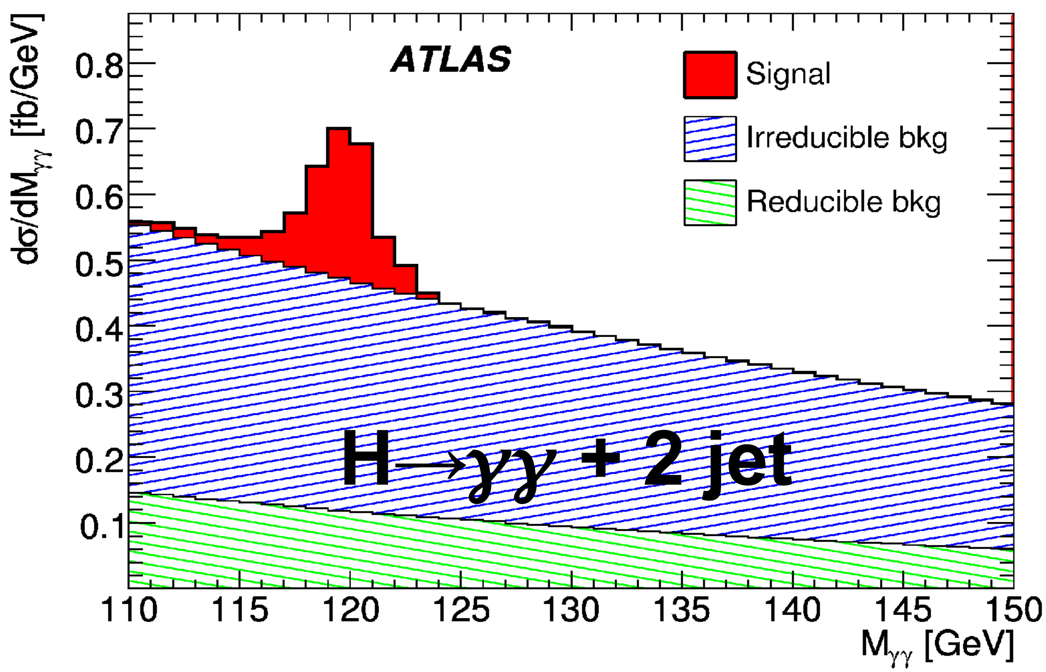
- Very smaller branching ratios H→$\gamma\gamma$
- **But:**
  Higgs mass can be reconstructed!
  Very clear signature!

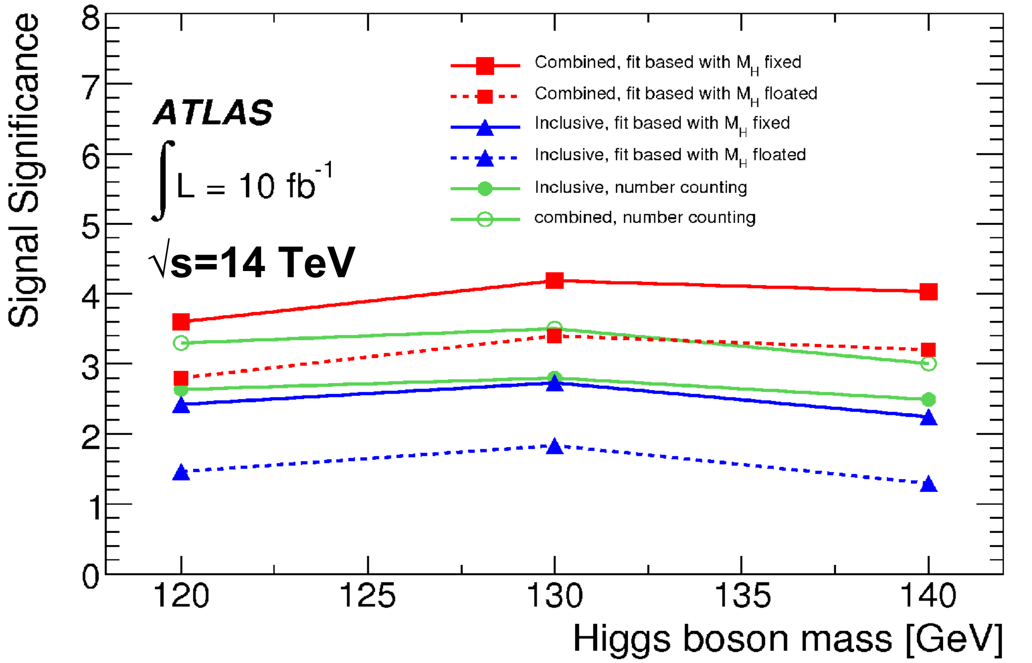


$H \to \gamma\gamma$ results

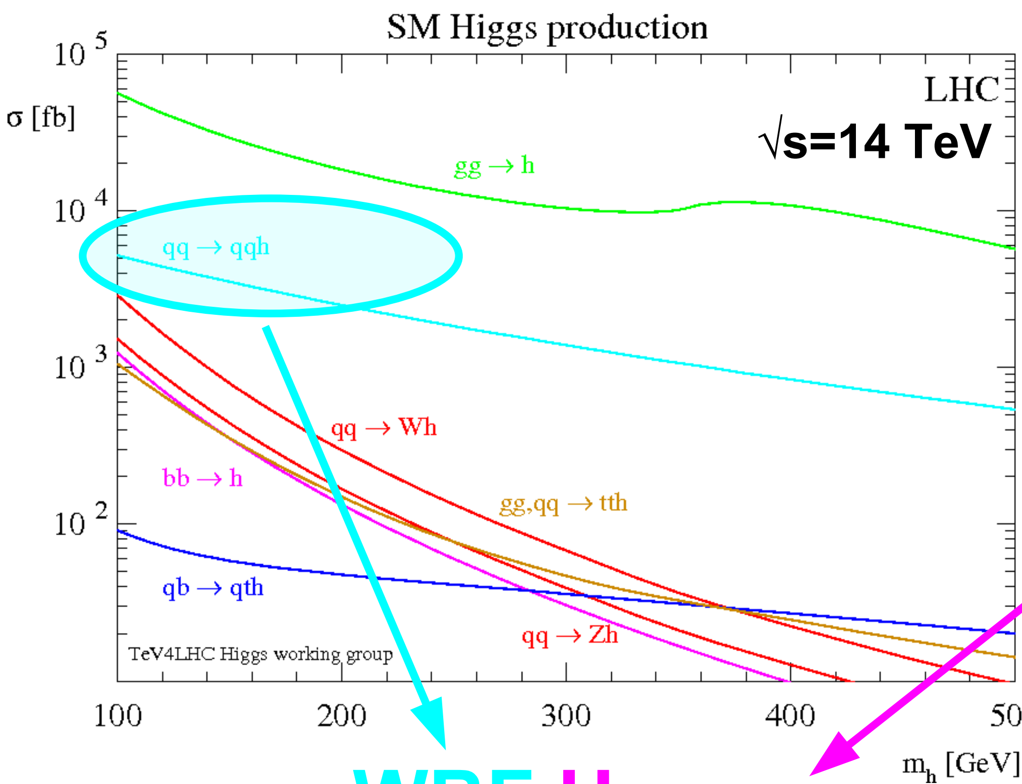


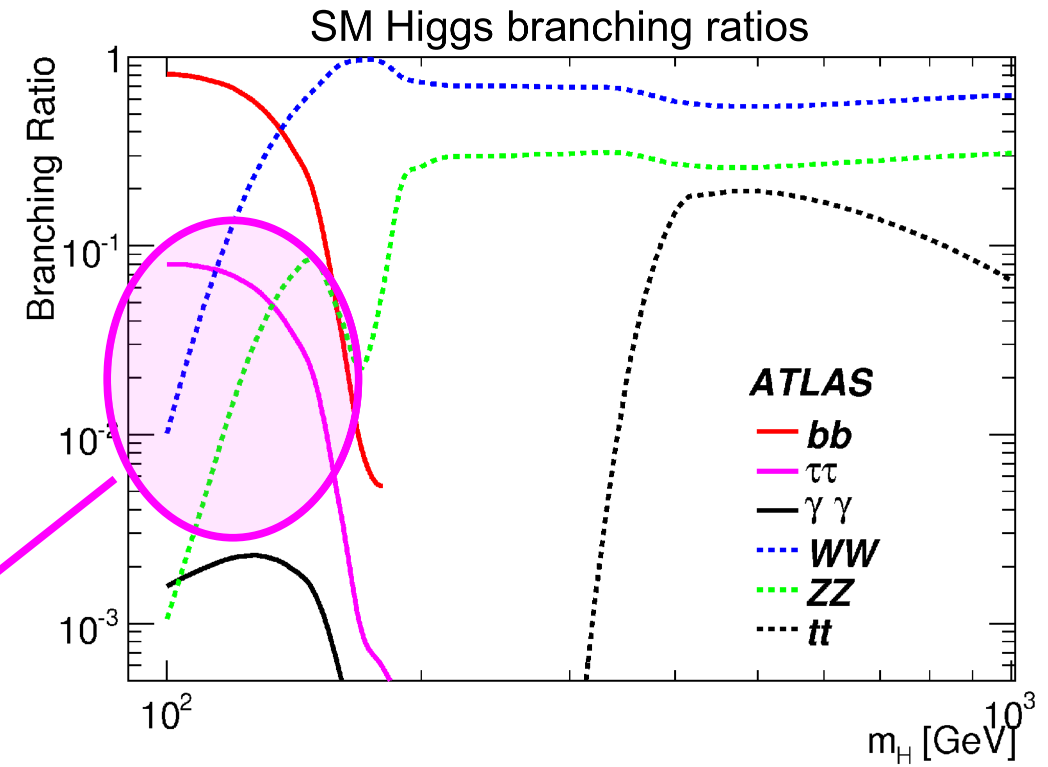






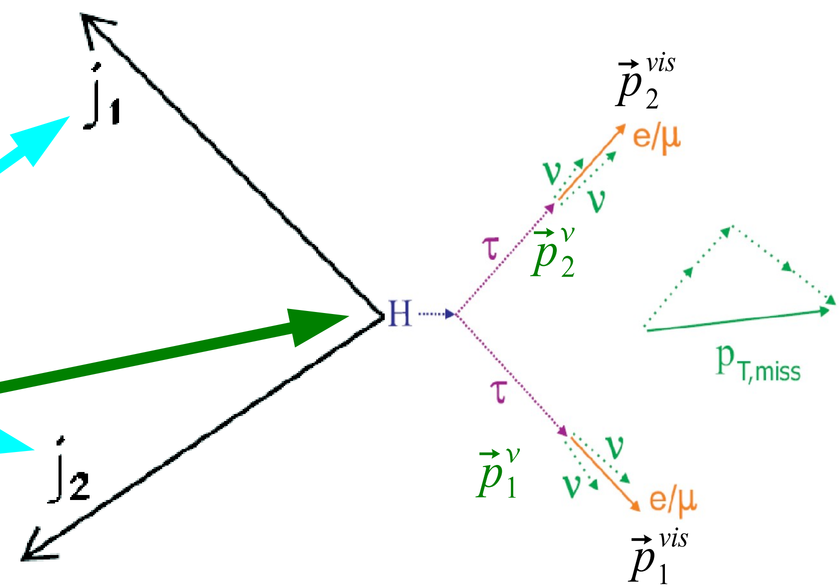
WBF H→ττ





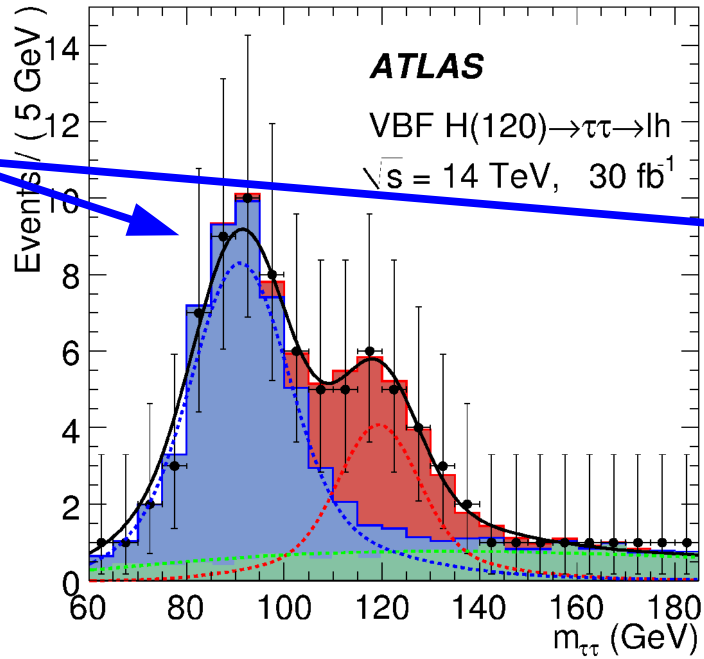
WBF H→ττ

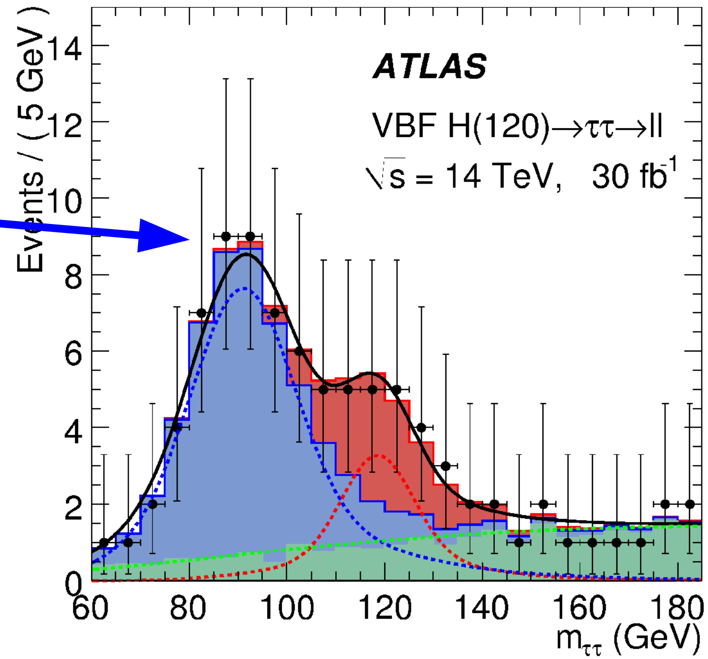
- Relatively small cross section and branching ratio
- Complicated channel
- **But:**
  Clear signature from WBF
  Higgs mass can be reconstructed in collinear approximation

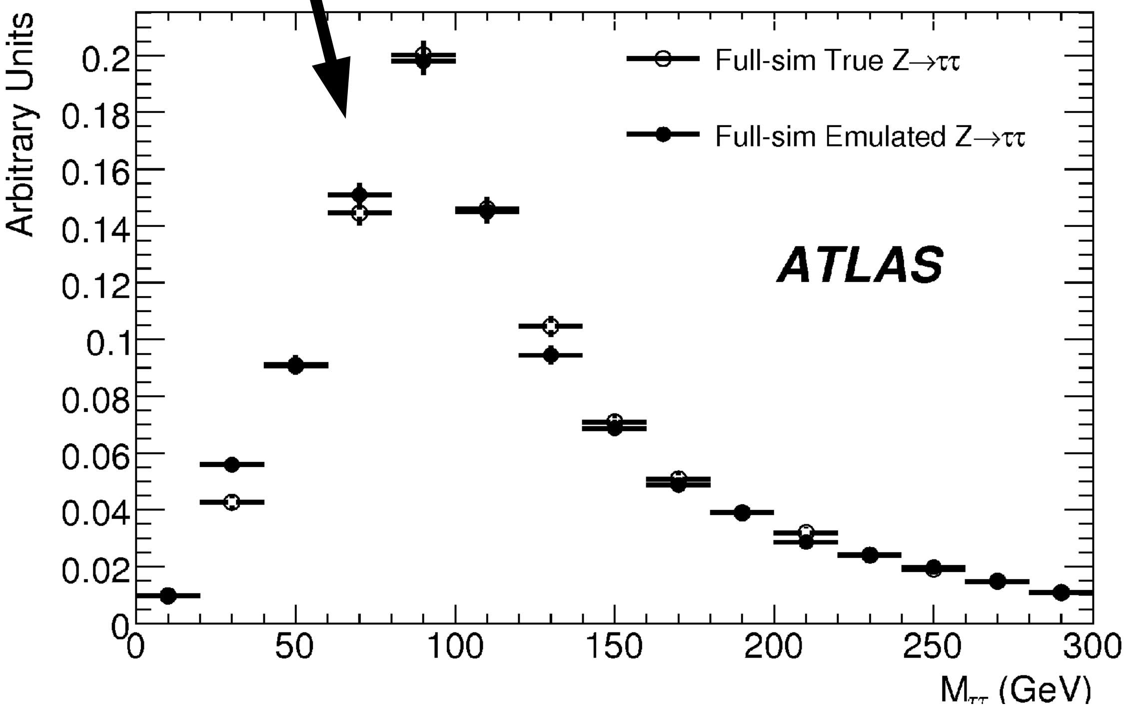


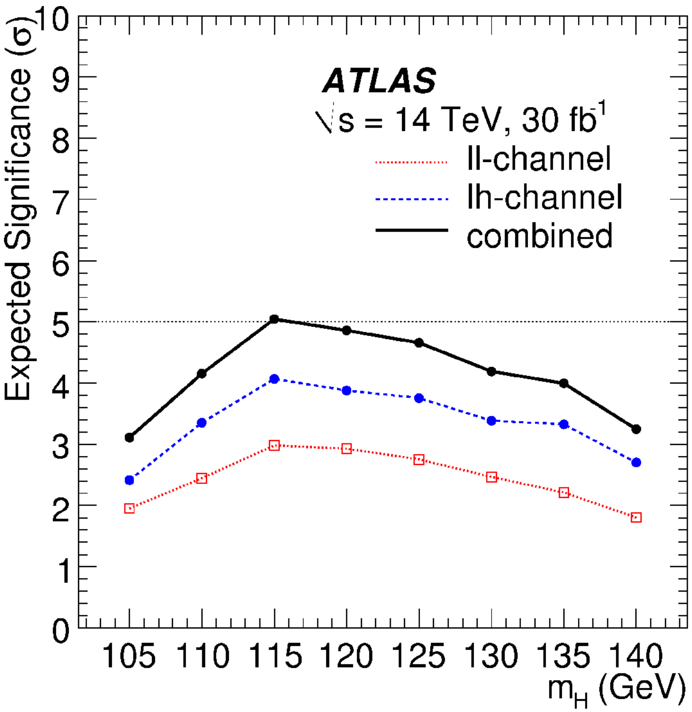
WBF H→ττ results

- **Exact knowledge of the Z→ττ bg. is crucial**
- Can be determined from measured Z→μμ events and replacing the μ by MC τ leptons.

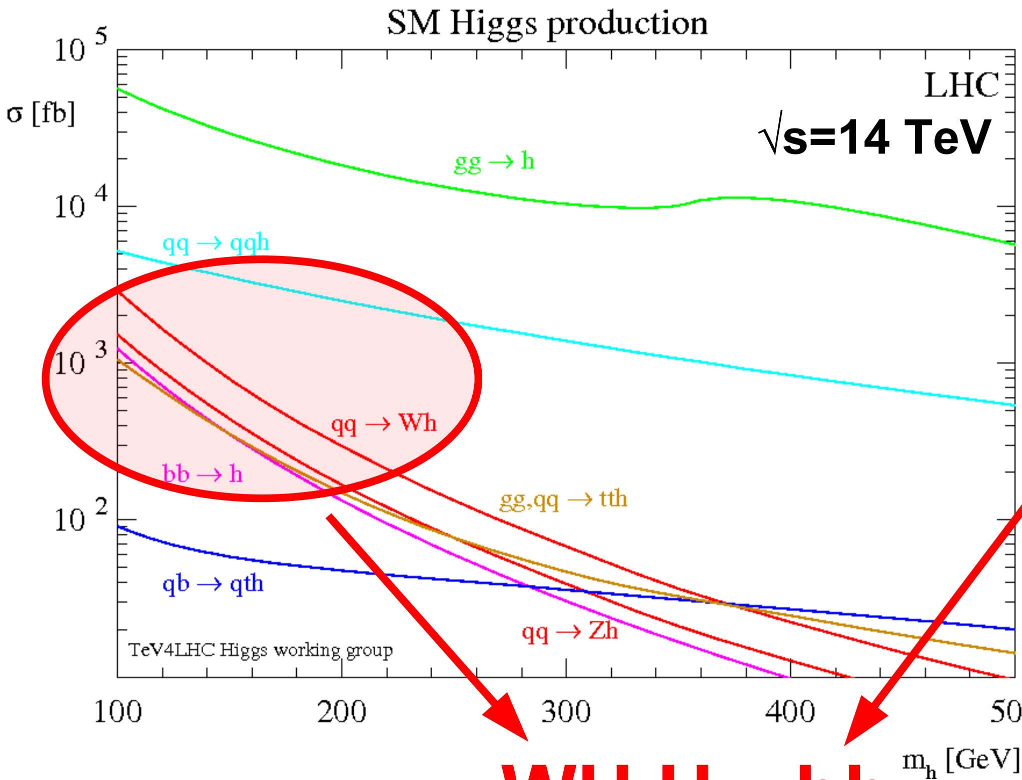


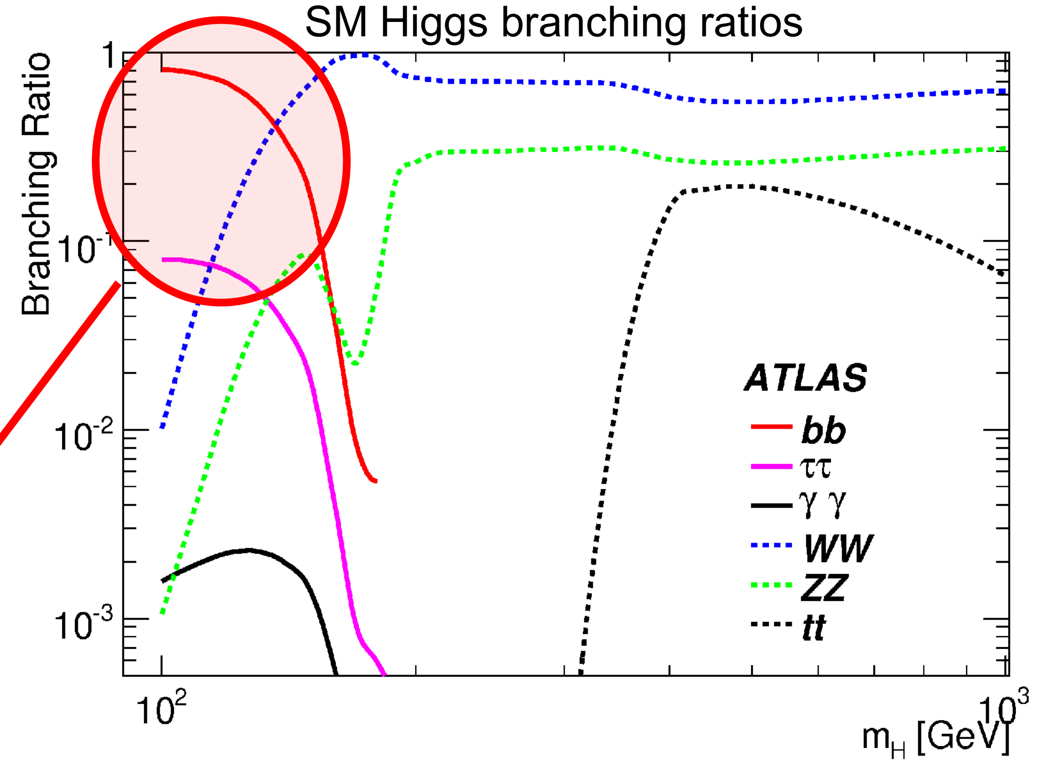






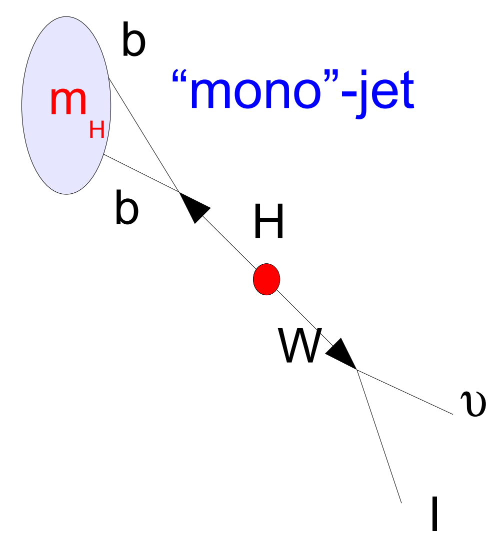
WH H→bb





WH H→bb

- Small cross section, large branching ratio
- Follow idea of J. Butterworth et al. [PRL 100:242001,2008]
- Select events (≈5% of xsec), in which H and W bosons have p_T > 200 GeV
- Select the b-quarks in the fat mono-jet



WH H→bb

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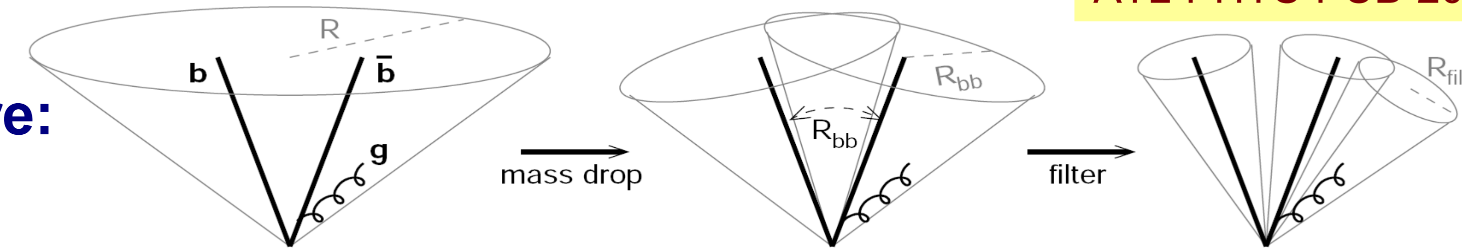
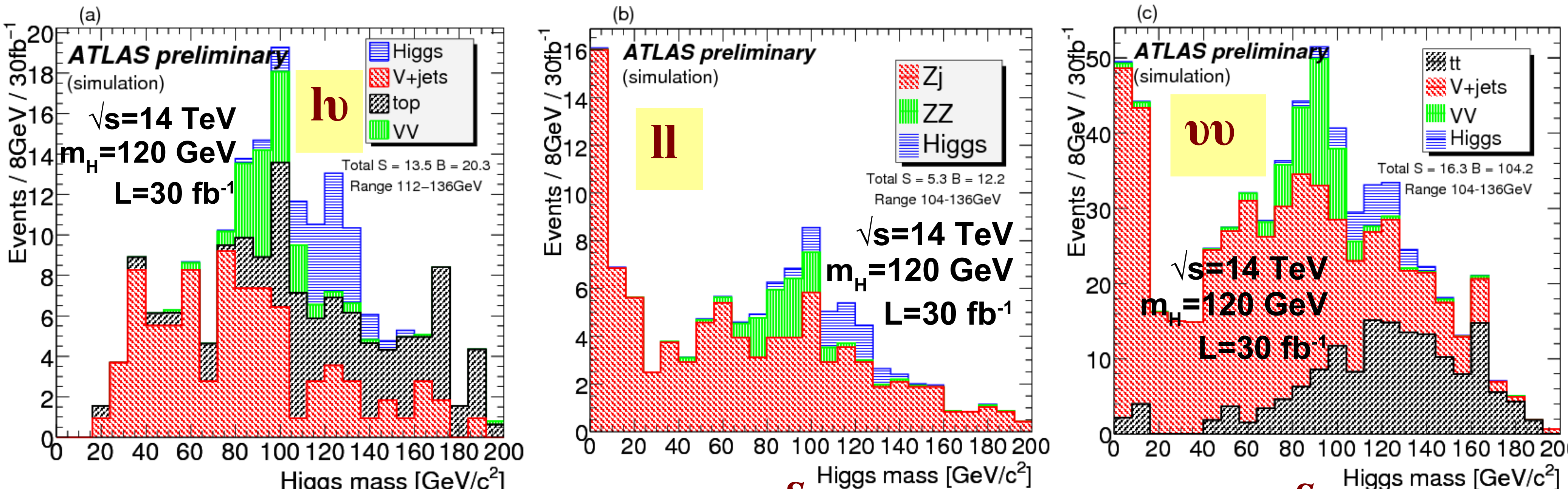
Analyse jet substructure:





$L^{int.} = 30\ fb^{-1} : \frac{S}{\sqrt{B}} = 3.0$ $\qquad \frac{S}{\sqrt{B}} = 1.5$ $\qquad \frac{S}{\sqrt{B}} = 1.6$

Combined: $\frac{S}{\sqrt{B}} = 3.7$

(Pile-Up not yet included)

- S/B much better than for ttH H→bb
- Different backgrounds for different channels
- Still good sensitivity including systematics

  (e.g. S/√B = 3.0 for 15% uncertainty on all backgrounds)

Conclusion: discovery and exclusion

- With 2 fb^{-1} at $\sqrt{s}$=14 TeV a Standard Model Higgs Boson discovery is possible in the range ~140 < m_H < ~180 GeV
- A 2σ exclusion is possible for m_H>115 GeV
- One can expect that the **H→WW** and **H→ZZ** channels are sensitive to a Higgs Boson exclusion already with ~1 fb^{-1} at $\sqrt{s}$=7 TeV.
- In the SM, the **H→$\tau\tau$**, **H→$\gamma\gamma$** and **H→bb** channels need more than 1 fb^{-1}