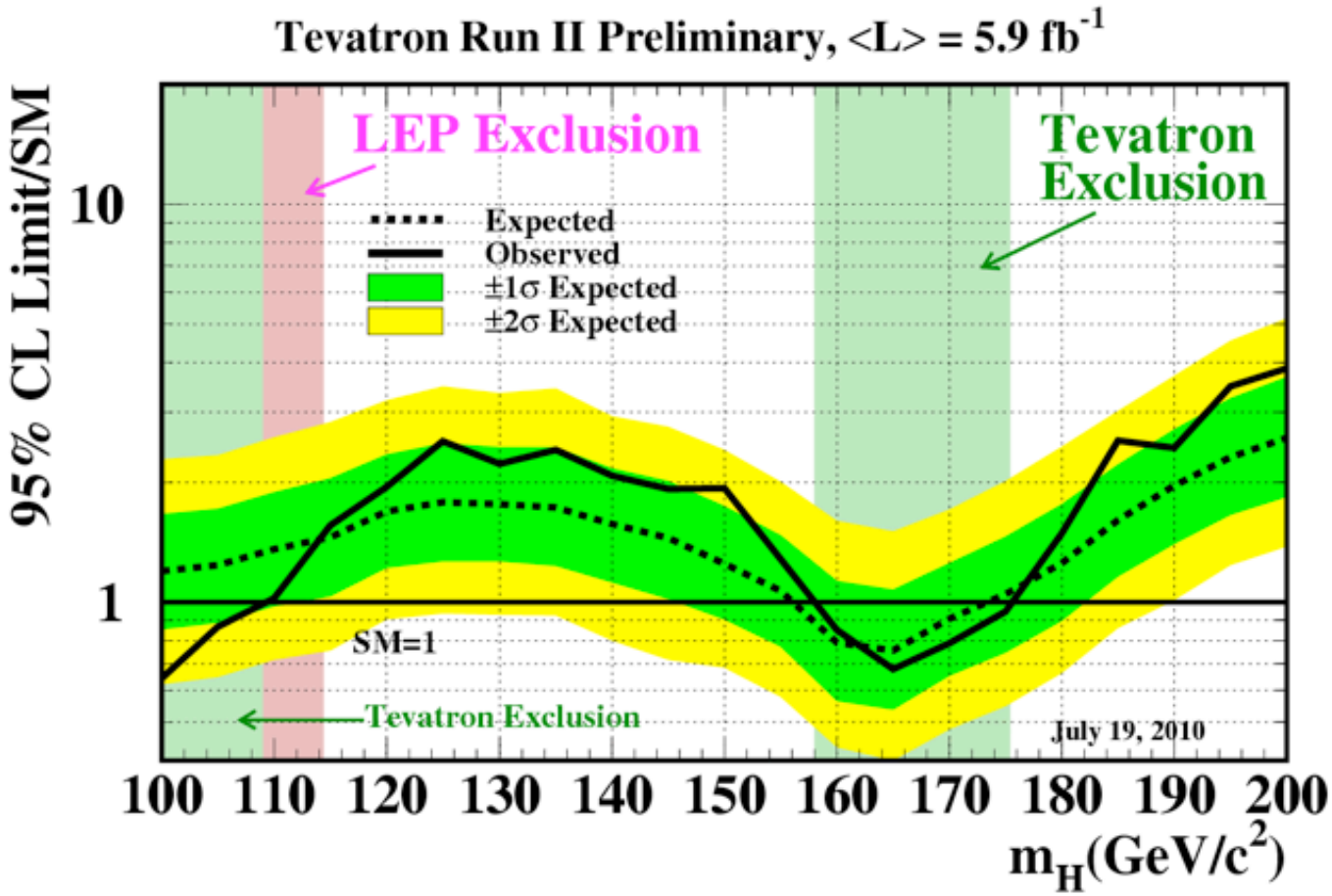
Higgs Prospects at the LHC

with 0.5 to 1 fb^{-1}

Jürgen Kroseberg
(University of Bonn)

on behalf of CMS and ATLAS

Standard-Model Higgs Search Status



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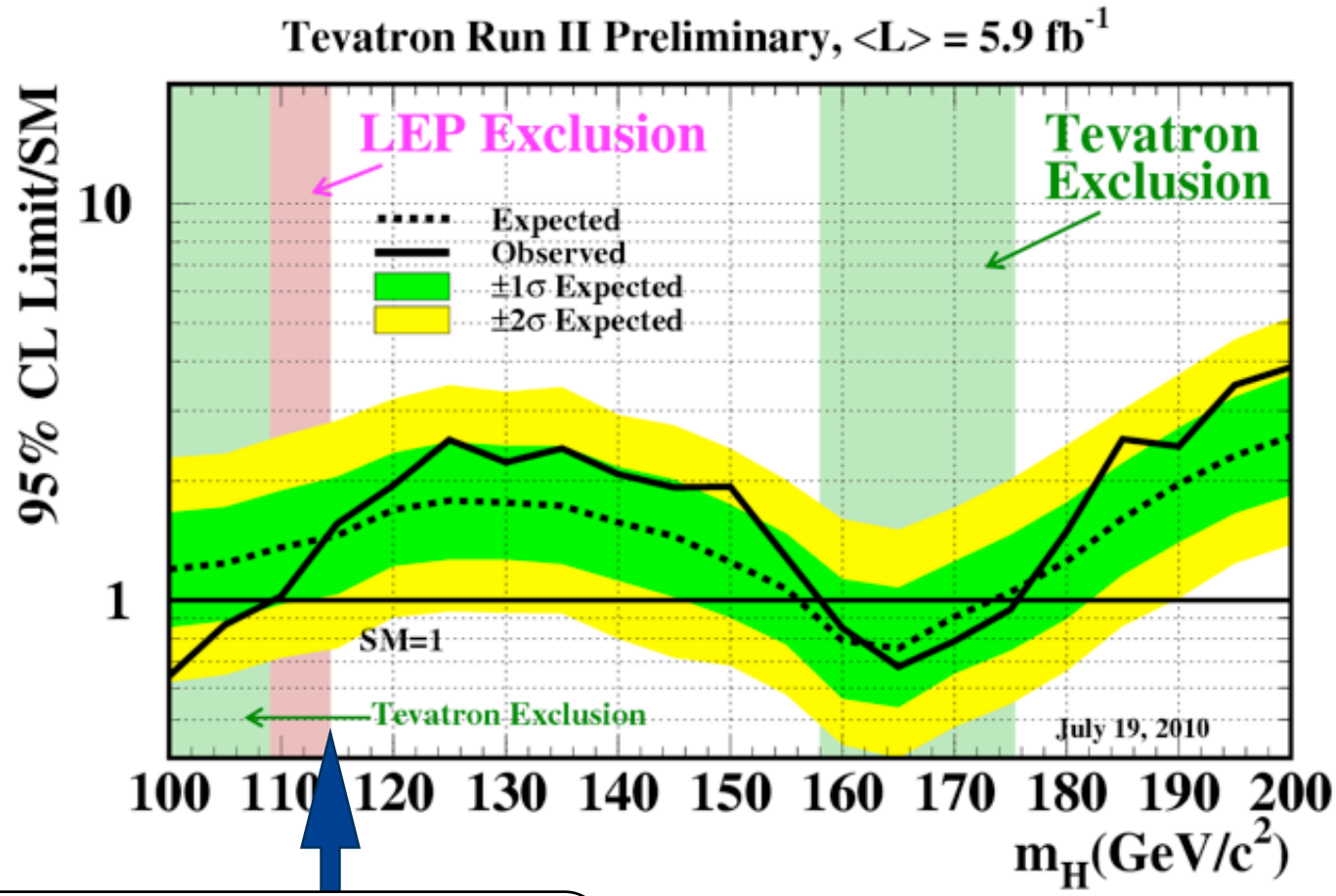

95% CL limits @ 115 GeV

- expected: 1.45 x SM
- observed: 1.56 x SM

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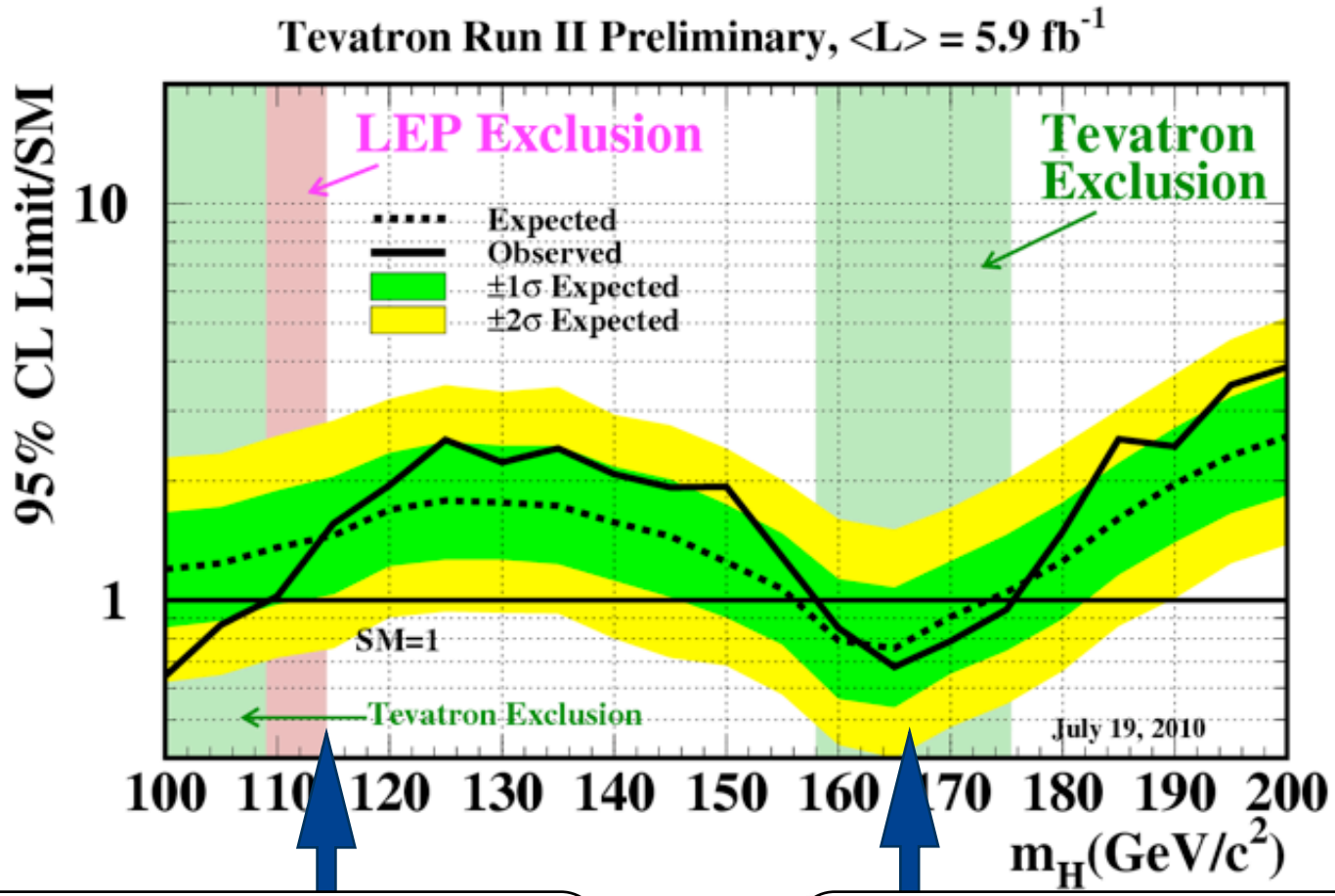


95% CL limits @ 115 GeV

- expected: 1.45 x SM
- observed: 1.56 x SM

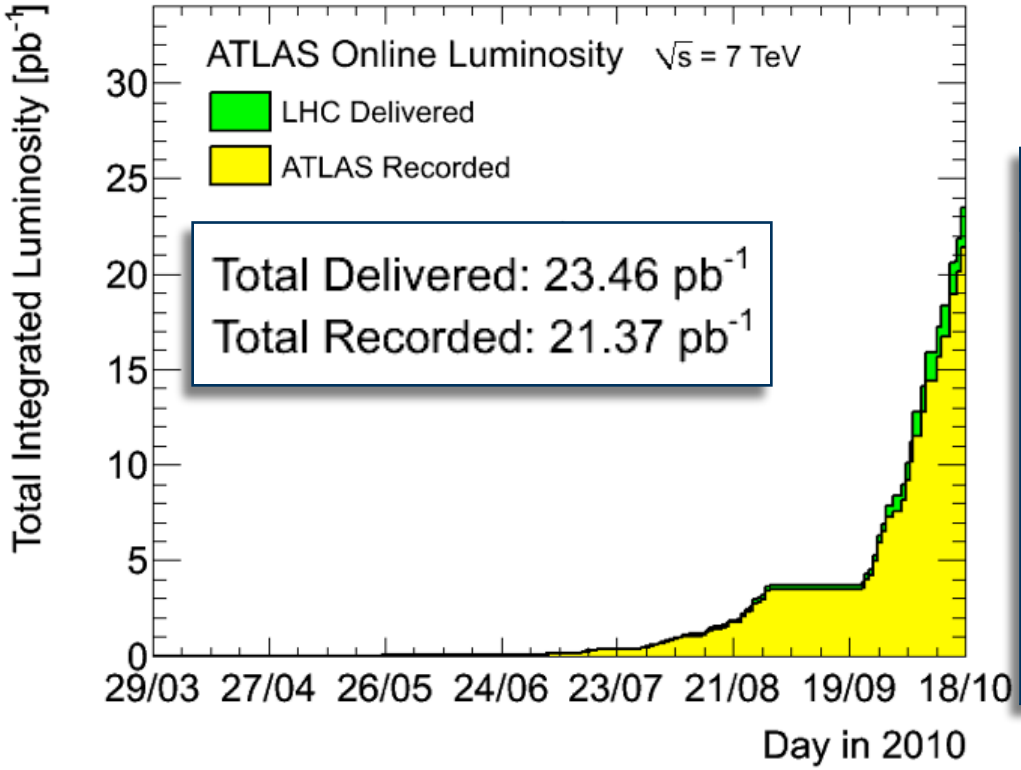
m_H Exclusion Region:

- expected: 156 - 173 GeV
- observed: 158 - 175 GeV

LHC Status & Plans

- ≈ 20 pb^{-1} per experiment to date
- expect $\mathcal{O}(50pb^{-1})$ by the end of this year
- early physics program well underway

S. Myers, ICHEP2010

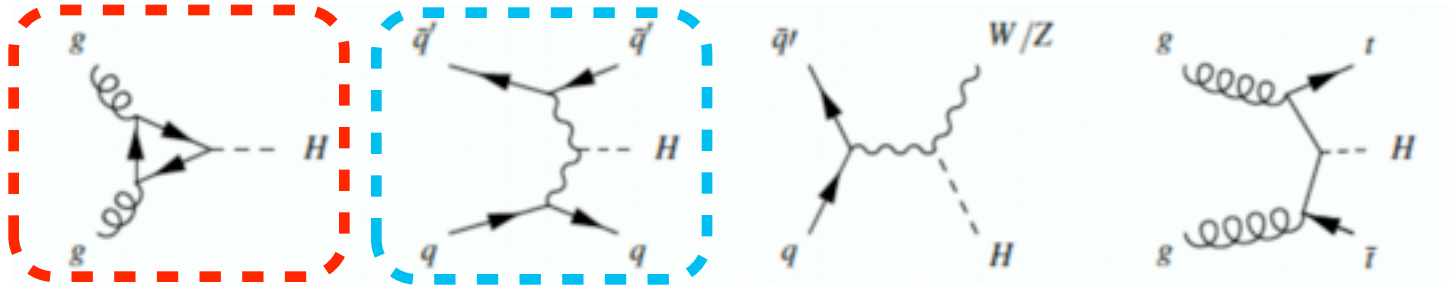


Decided Scenario 2010-2011

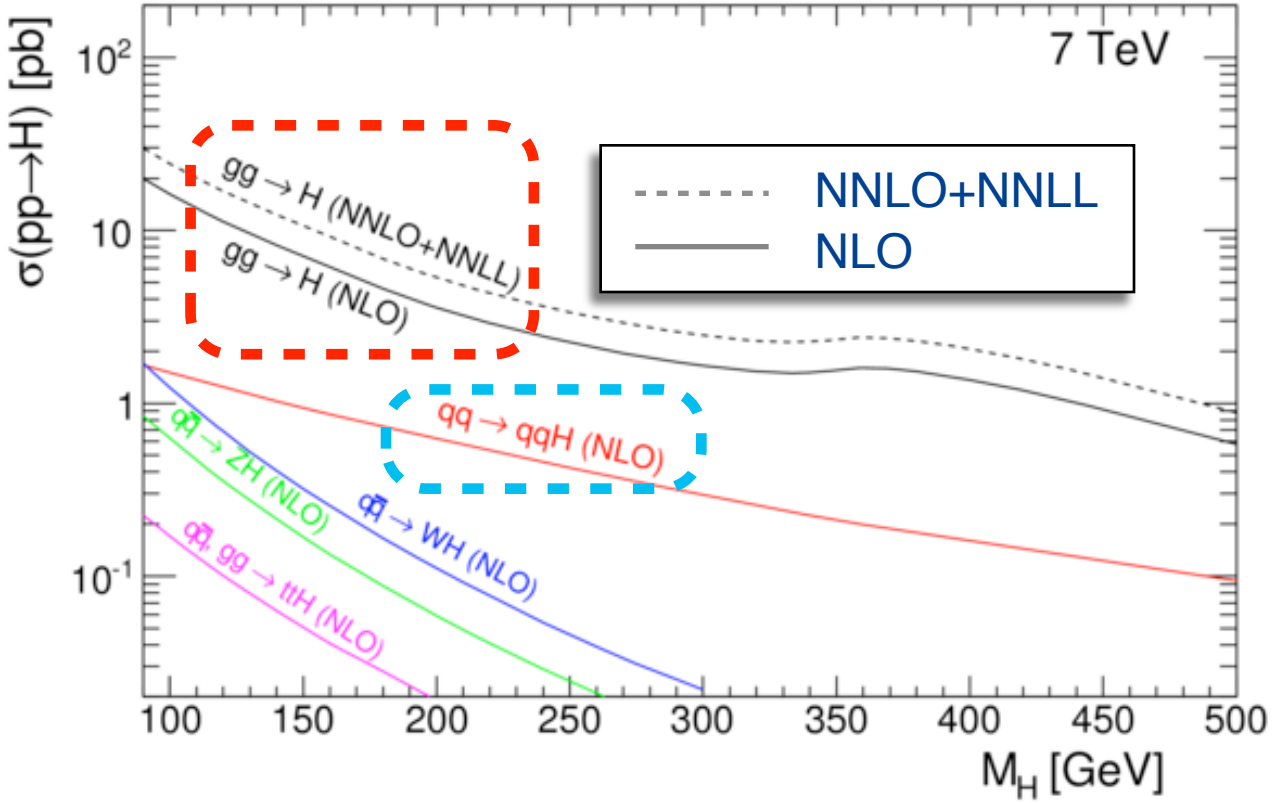
Following the technical discussions in Chamonix (Jan 2010) the CERN management and the LHC experiments decided

- Run at 3.5 TeV/beam up to a integrated luminosity of around $1fb^{-1}$.
- Then consolidate the whole machine for 7TeV/beam (during a shutdown in 2012)
- From 2013 onwards LHC will be capable of maximum energies and luminosities

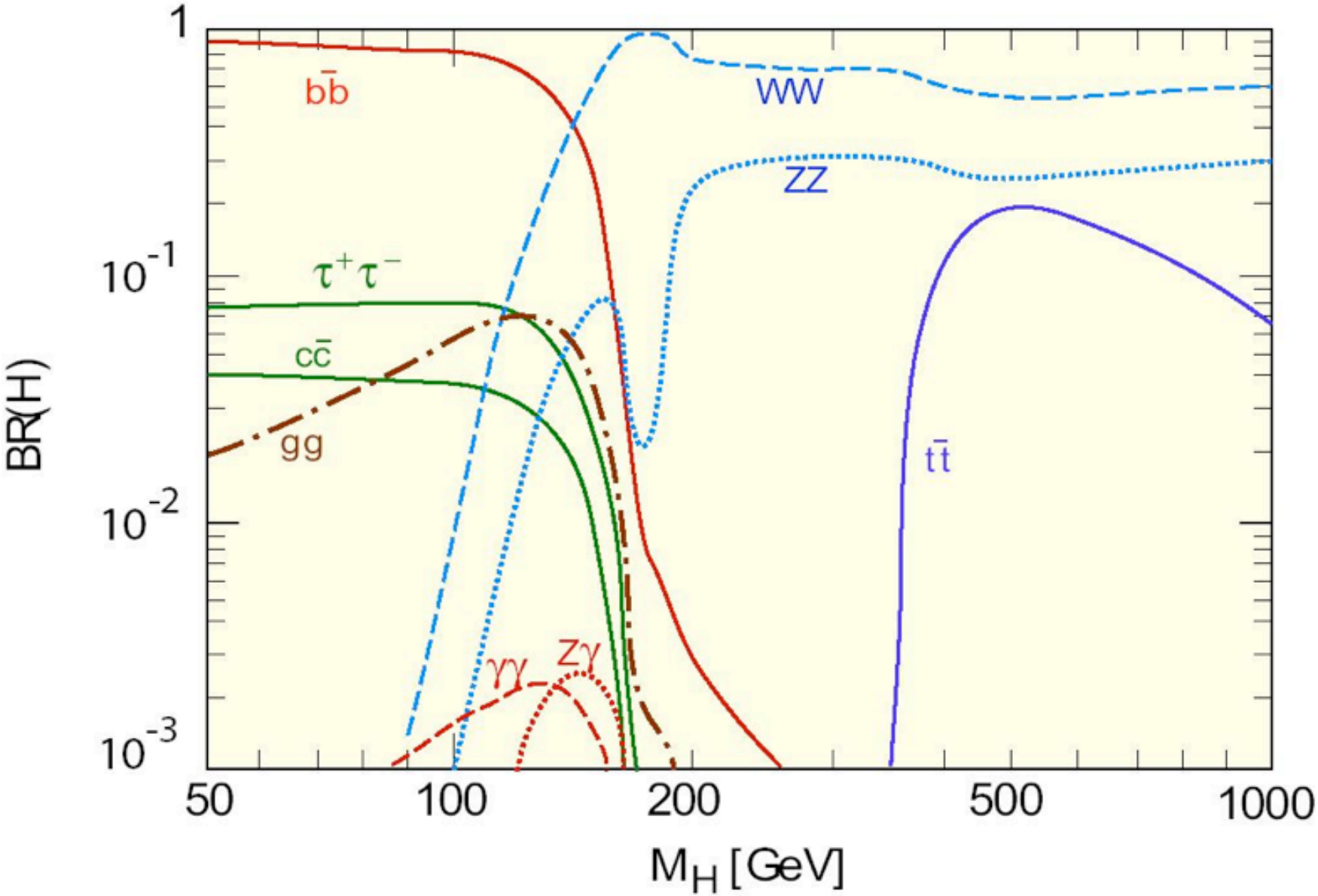
SM Higgs Production at the LHC



gluon-gluon fusion | vector boson fusion | associated production



Higgs Decay Modes



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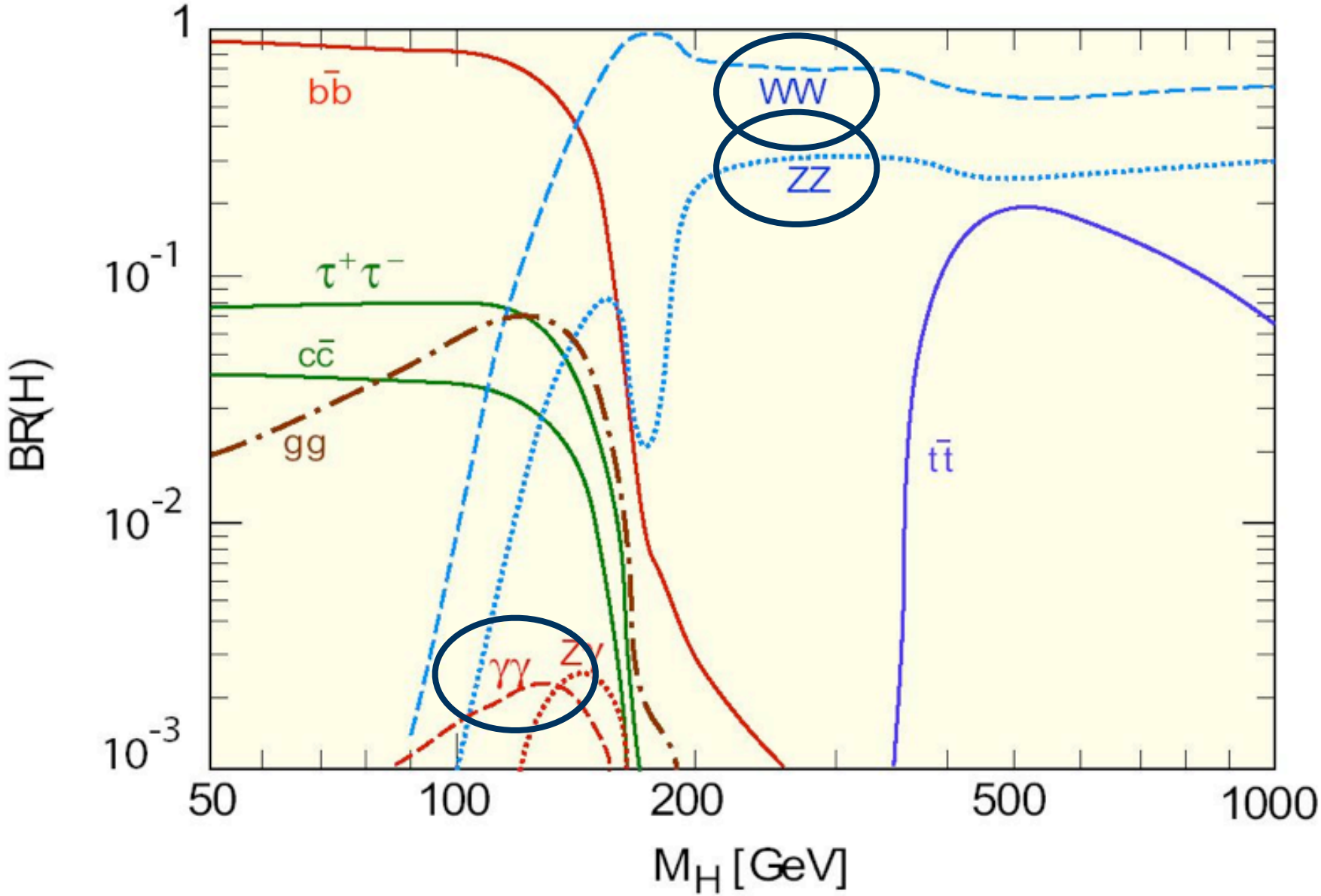

LHC Potential?

Previous Studies

- assuming **large data samples @14 TeV** (or **10 TeV**)
- **purely** based on **simulated samples**
- potentially **important aspects neglected**, e.g. **pile-up events**
- used **LO cross sections**

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Now

- expect **1 fb^{-1}** per experiment @ **7 TeV** by end of 2011
- **actual collision data!**
- study **running conditions** and **background processes** with data
- **improved simulation**
- **beyond LO** cross sections

LHC Potential?

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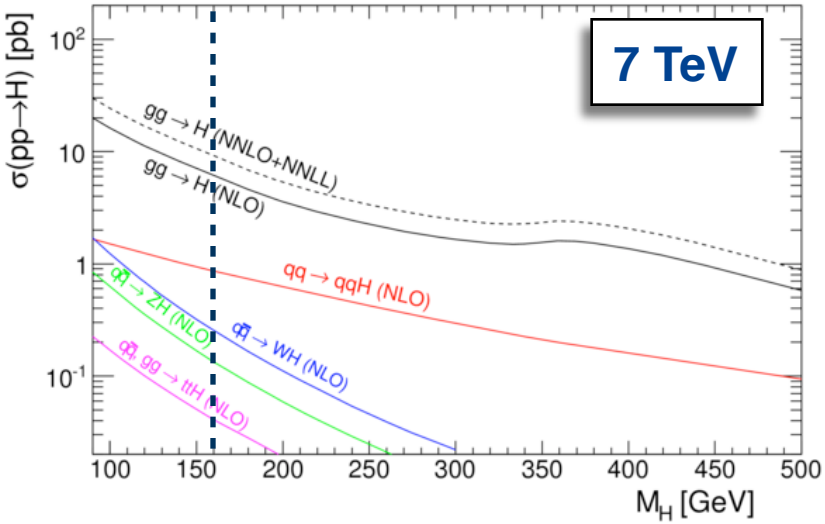
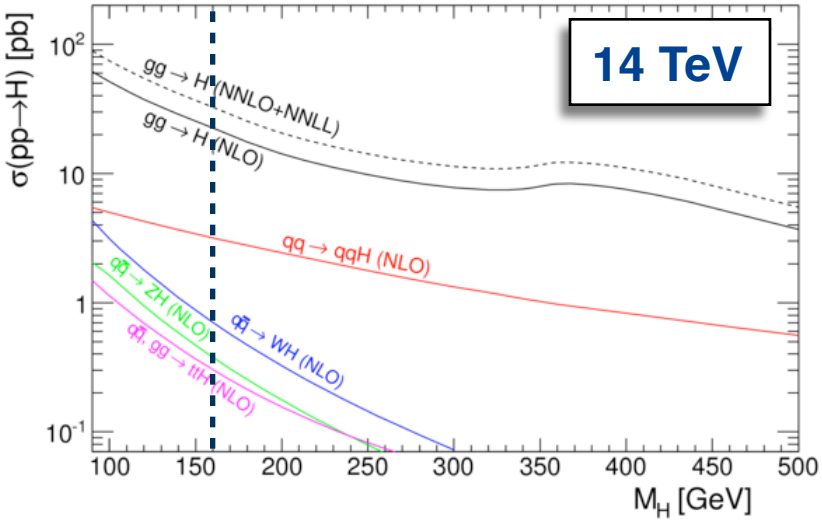
⇒ Need to revisit LHC Higgs Sensitivity

- not a small program; **first steps** have been taken **for selected channels**
- **scale previous results** according to 14(10)/7 TeV cross section ratios; **PDF reweighting** for ATLAS WW and **full 7 TeV simulation** for ATLAS ZZ
- estimate effect on **selected systematic uncertainties**
- use **NLO** production **cross sections**; **CMS** uses **NNLO for gg→H**

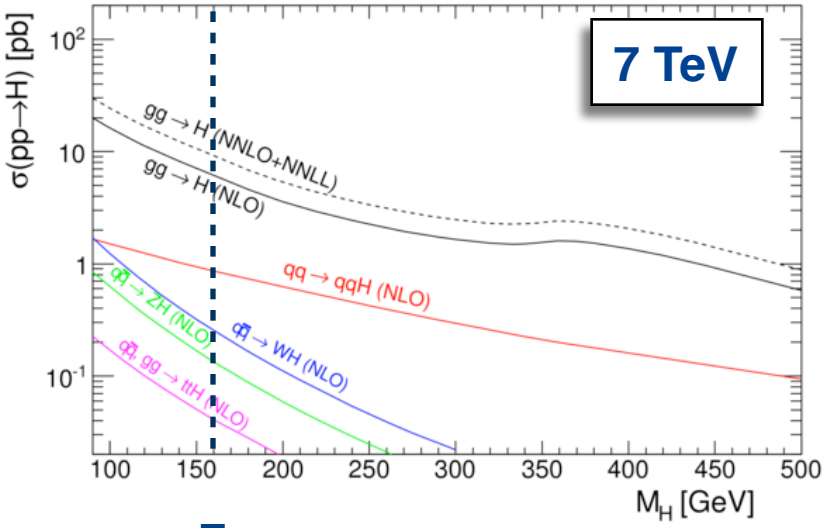
Cross Sections at Different CM Energies

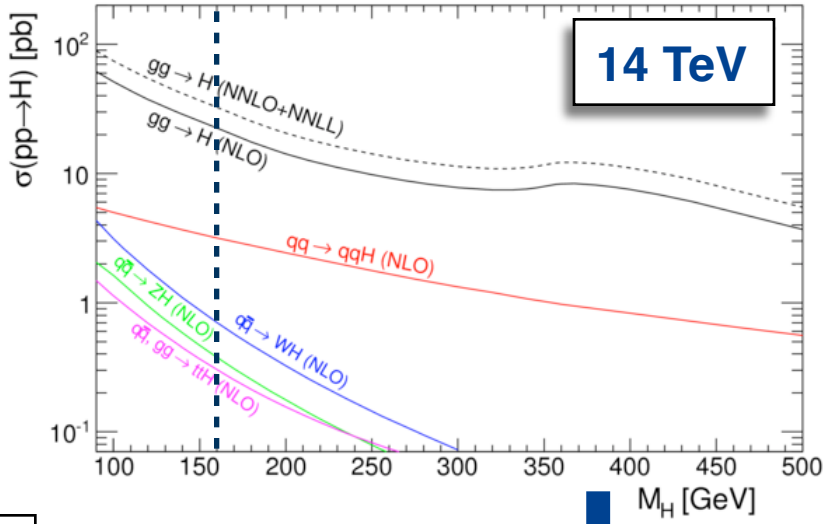


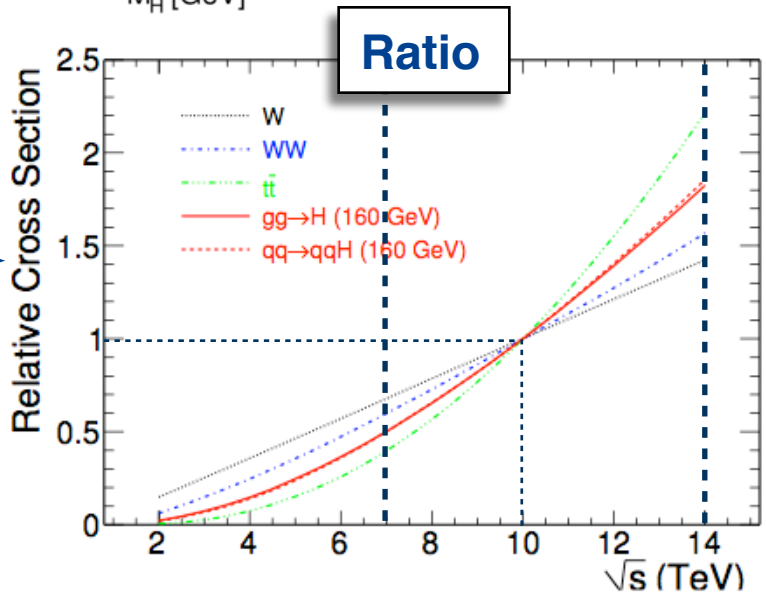


Harlander, Kilgore, Phys.Rev.Lett. 88 (2002) 201801; Ravindram, Smith, van Neerven, Nucl.Phys.B665 (2003) 325; Catani, de Florian, Grazzini, Nason, JEHP 07 (2003) 028; Anastasiou, Melnikov, Nucl.Phys.B646 (2002) 220

Cross Sections at Different CM Energies







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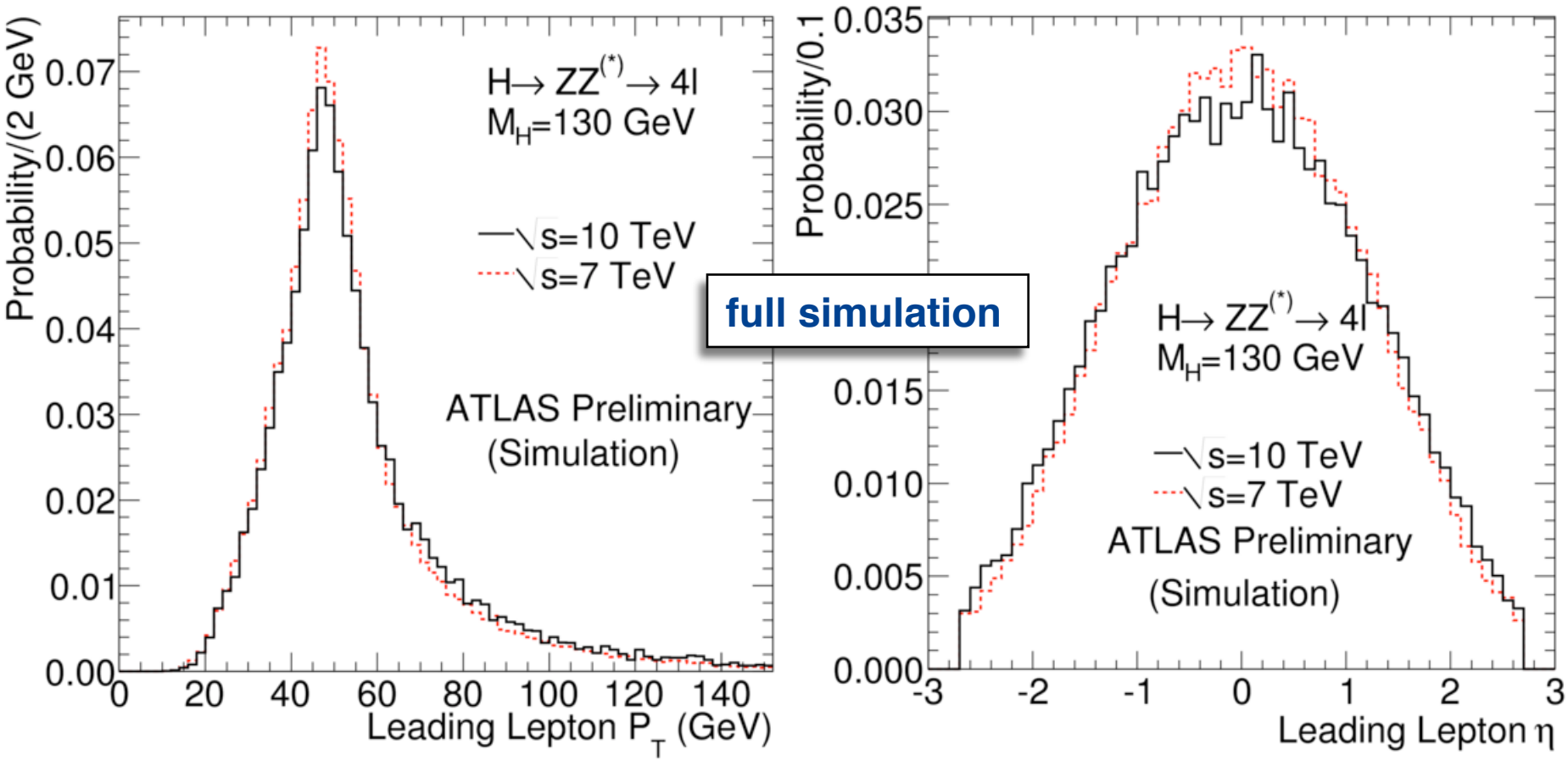
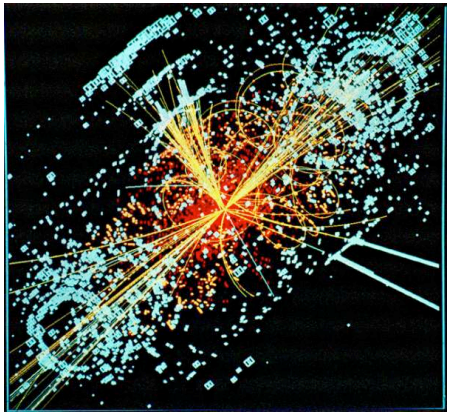
Acceptance at Different CM energies

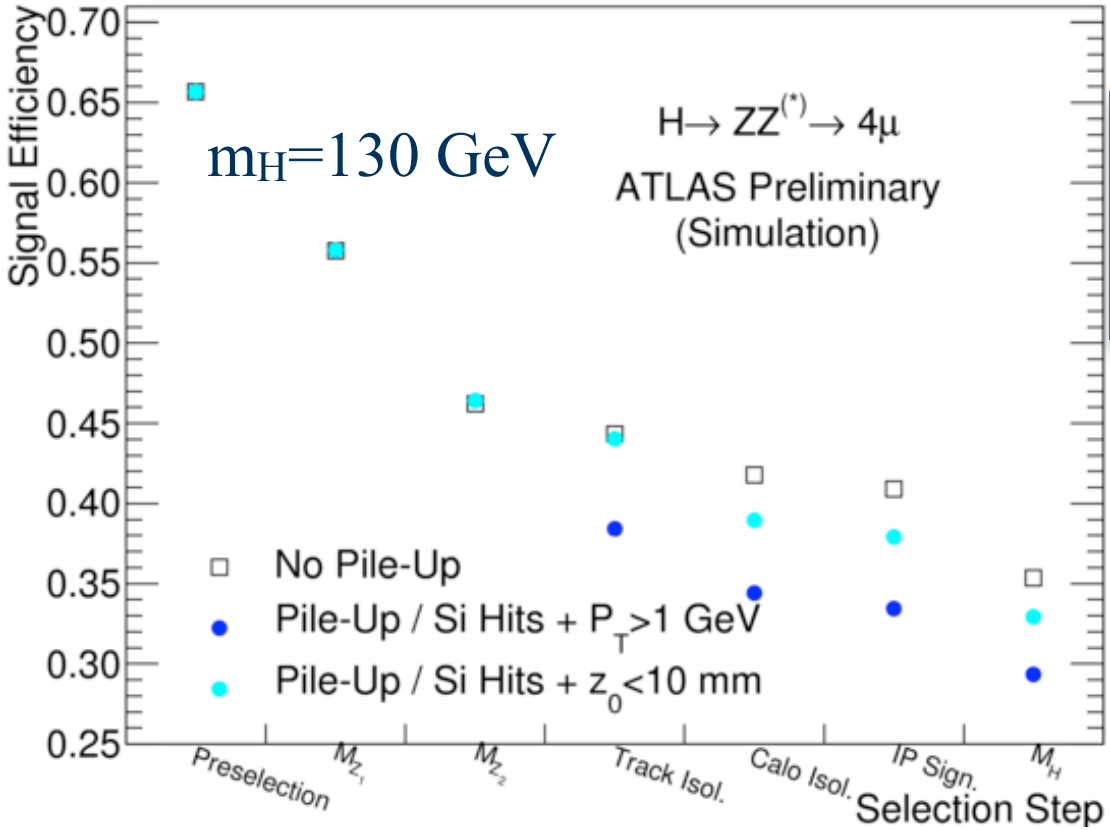
e.g.: 130 GeV SM **H →ZZ(*)→4l**



Effect of Pile-Up Events

Scenario	Luminosity ($cm^{-2}s^{-1}$)	Bunch Crossing Time (ns)	Events/Bunch Crossing
A	$1 \cdot 10^{33}$	75	6.9
B	$2 \cdot 10^{33}$	25	4.6
C	$1 \cdot 10^{32}$	450	4.1





Relative Efficiency	Luminosity Scenario A	B	C
$H \rightarrow 4\mu$	-5.2%	-6.0%	-3.0%

- **significant effect on** signal selection **efficiency**
- **can be** largely **recovered** (here: tighter lepton track selection; PV constraint)

Standard Model

- $H \rightarrow WW \rightarrow 2l2\nu$
- $H \rightarrow \gamma\gamma$
- $H \rightarrow ZZ^{(*)} \rightarrow 4l$

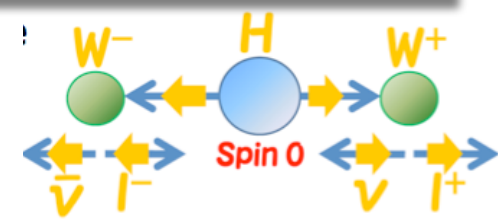
H → WW → 2l2ν

- two **isolated leptons** (ee, μμ, eμ)
- missing transverse energy (**MET**) **+ 0,1,2 jets**
- 2 ν ⇒ **no mass peak** reconstructed

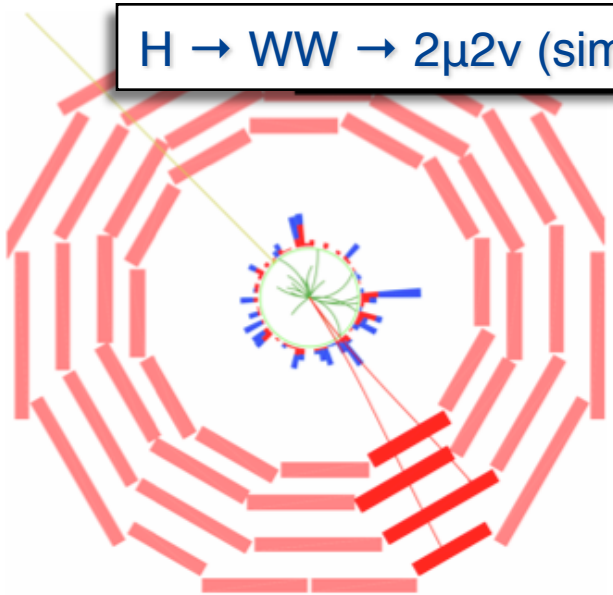
$$M_T = \sqrt{(E_T^{ll} + E_T^{miss})^2 - (P_T^{ll} + E_T^{miss})^2} < M_H$$

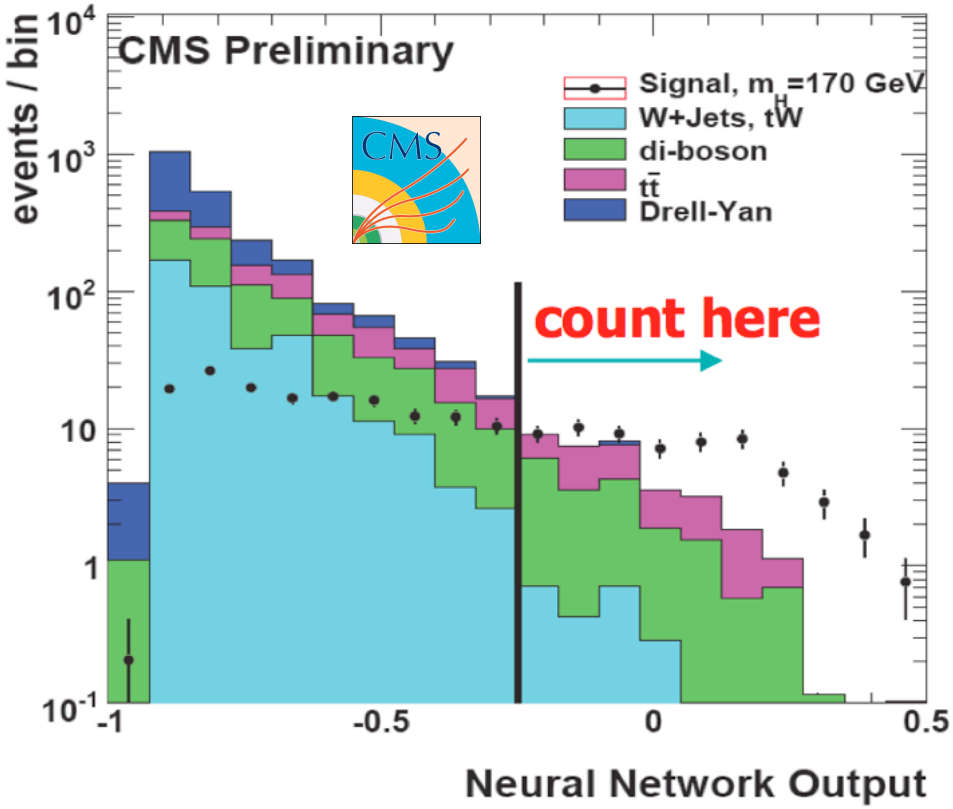
$$E_T^{ll} = \sqrt{(P_T^{ll})^2 + m_{ll}^2}$$

can exploit spin correlations:

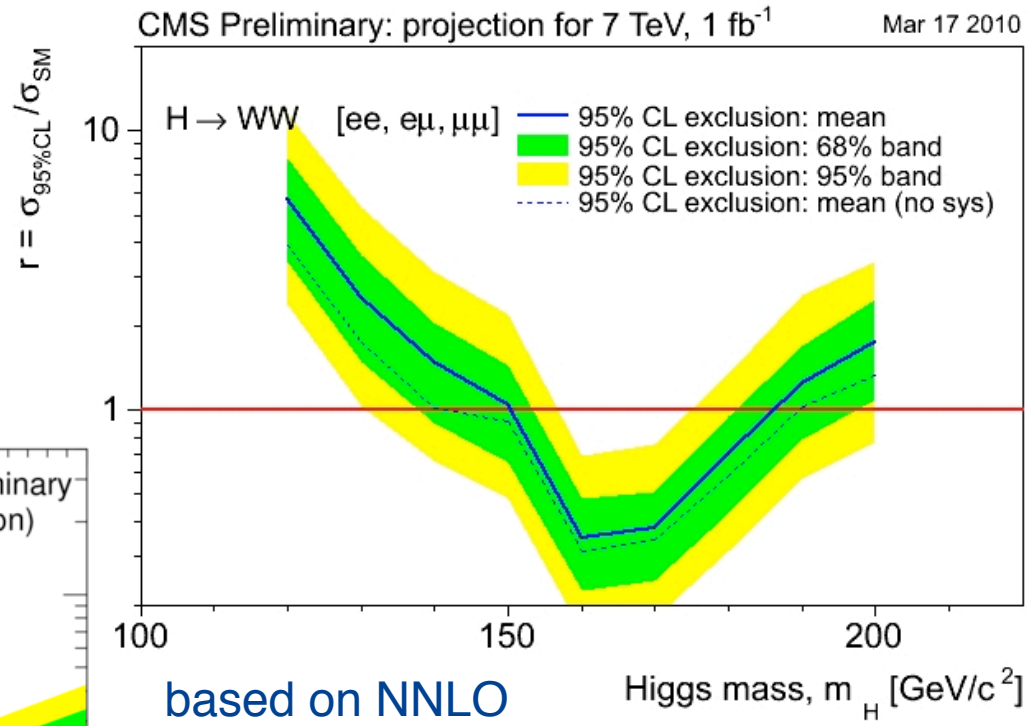


H → WW → 2μ2ν (simulation)

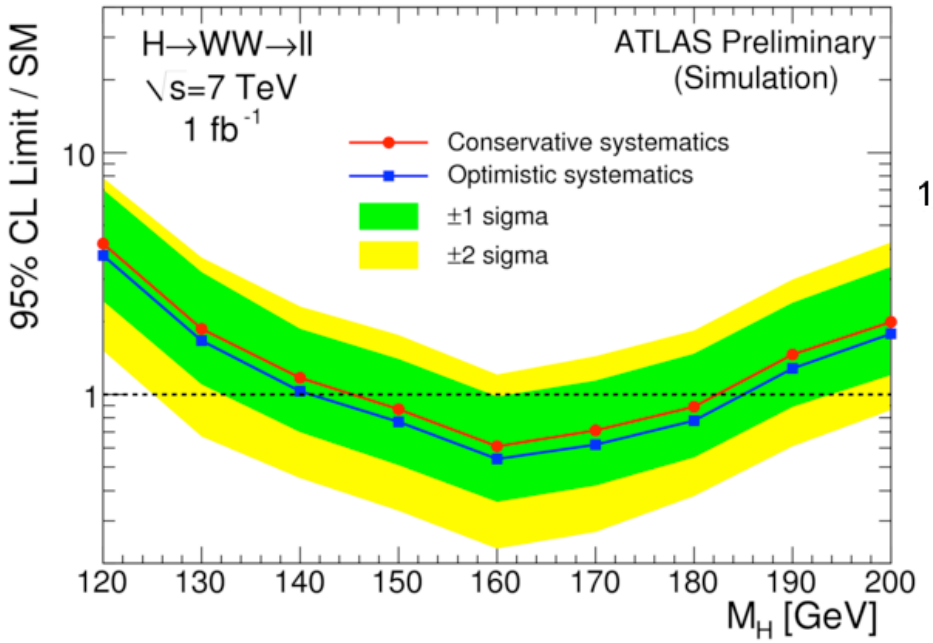




H → WW → 2l2ν : Exclusion

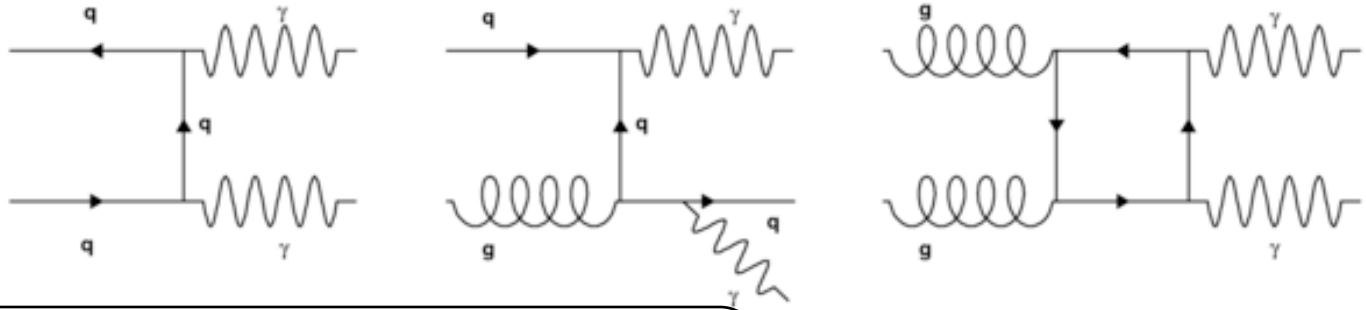


based on NLO

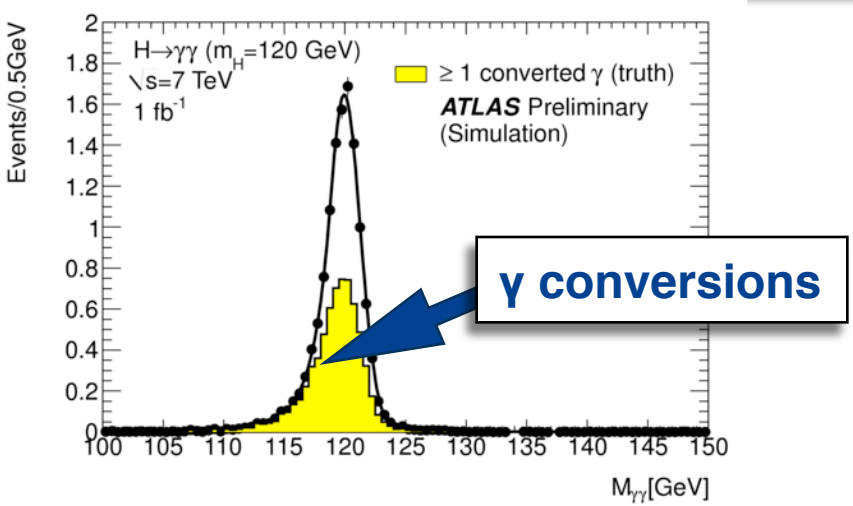


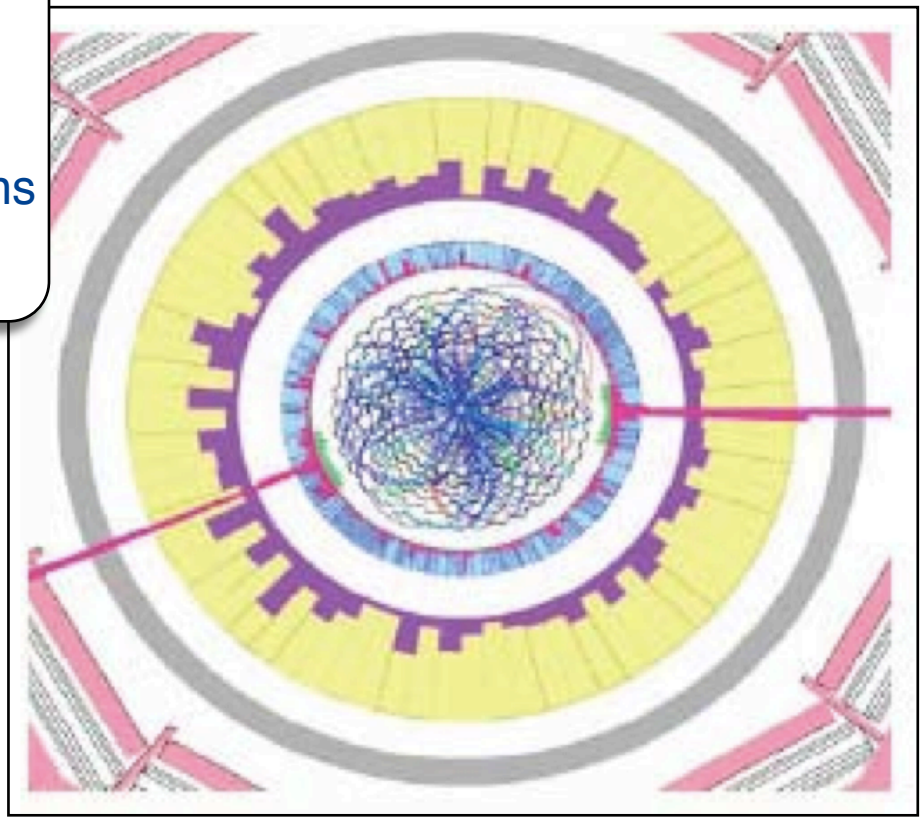
based on NNLO

$H \rightarrow \gamma\gamma$

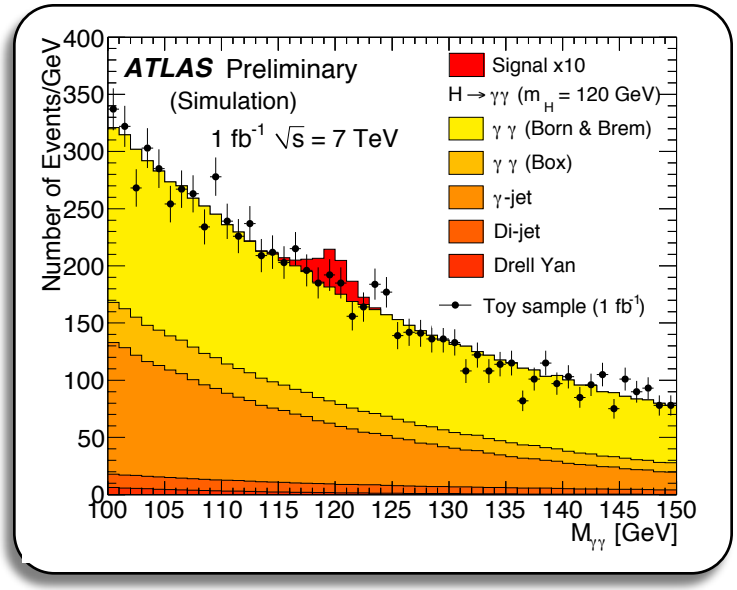


- search for narrow **di-photon resonance**
- quality and control of **photon ID** and **energy resolution** crucial
- background estimated from control regions (mass sidebands and or shower shape)





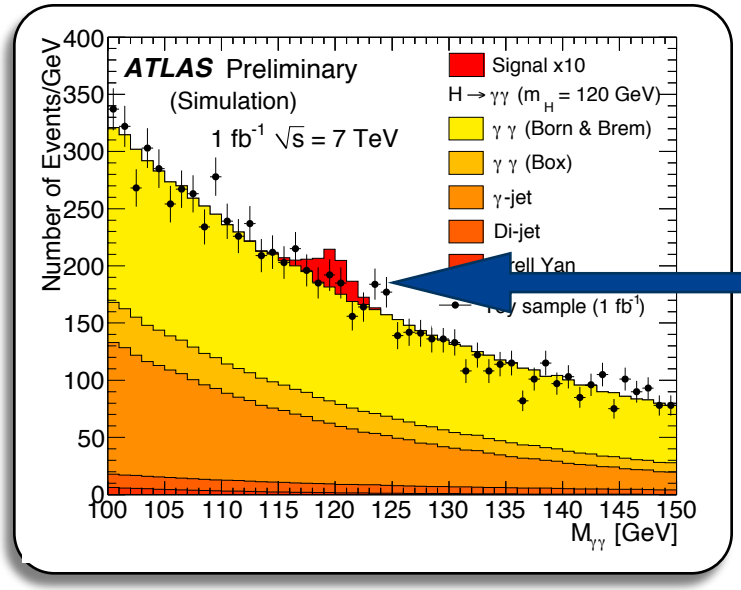
$H \rightarrow \gamma\gamma$: Expected Signal / Exclusion



based on NLO

based on NNLO

$H \rightarrow \gamma\gamma$: Expected Signal / Exclusion

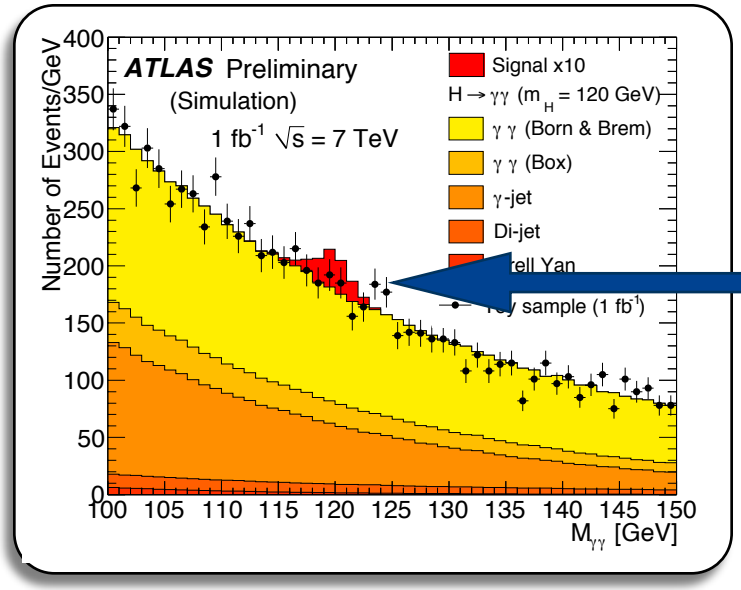


signal x 10

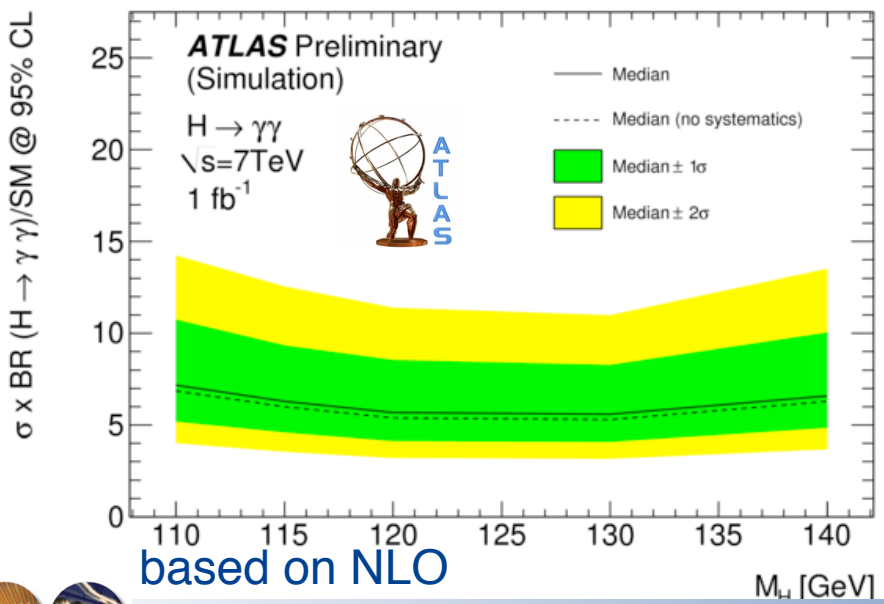
based on NLO

based on NNLO

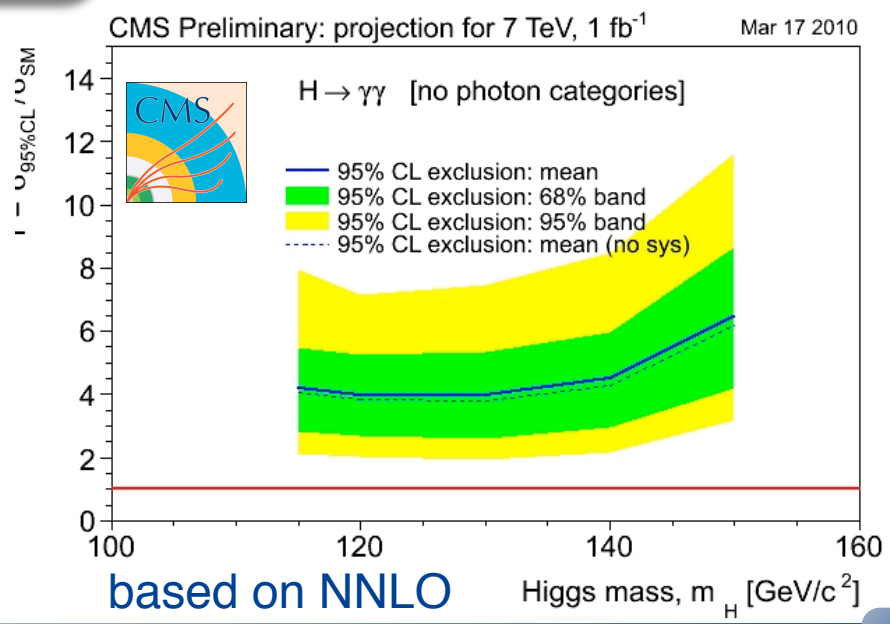
H → γγ : Expected Signal / Exclusion



signal x 10

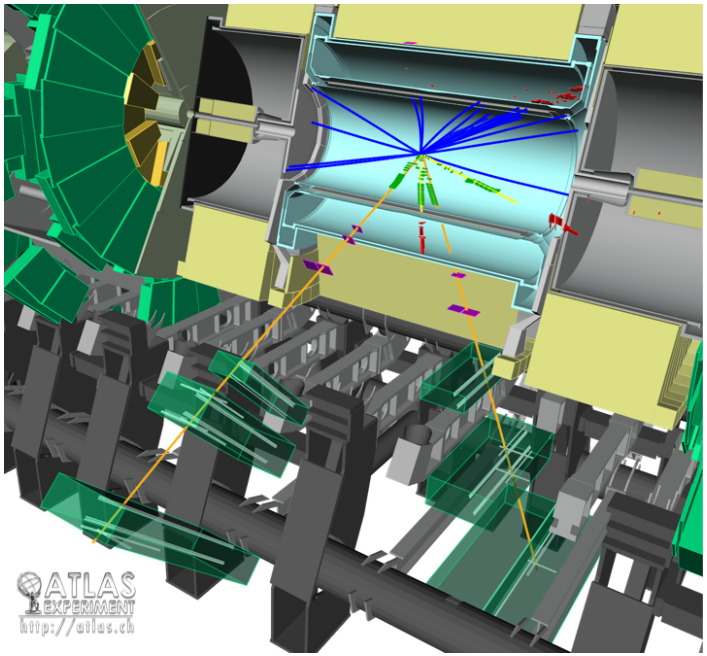


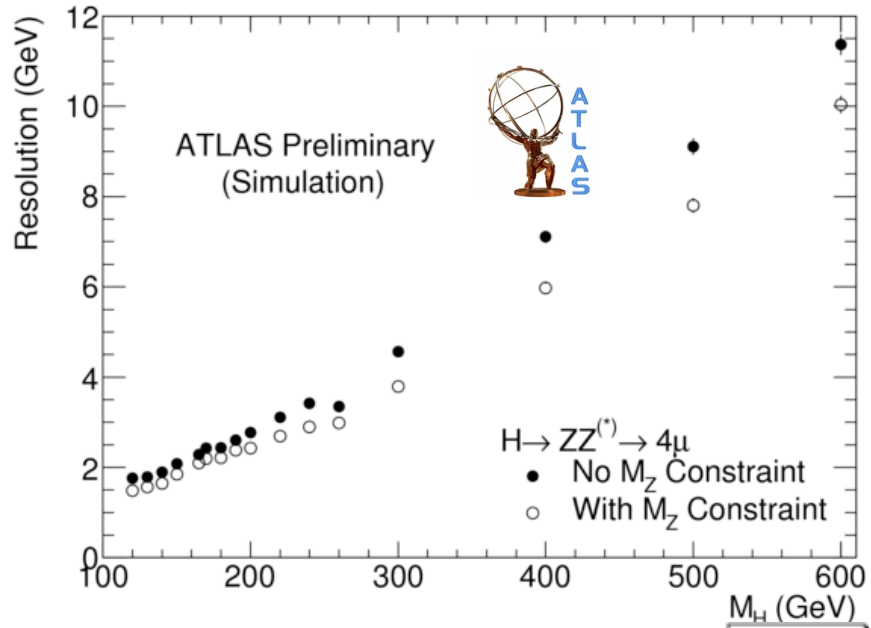
based on NLO



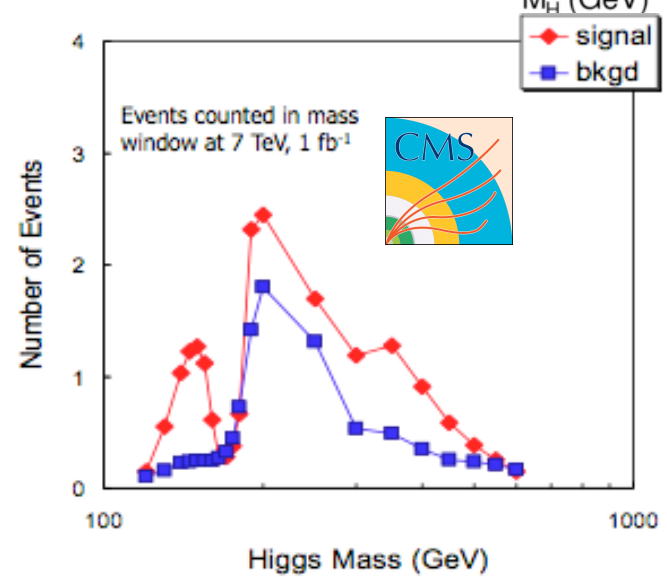
based on NNLO

$H \rightarrow ZZ \rightarrow 4l$





- four **isolated leptons**
- lepton efficiency crucial
- improve mass resolution by **Z mass constraint**
- search by, e.g., counting events in sliding mass window



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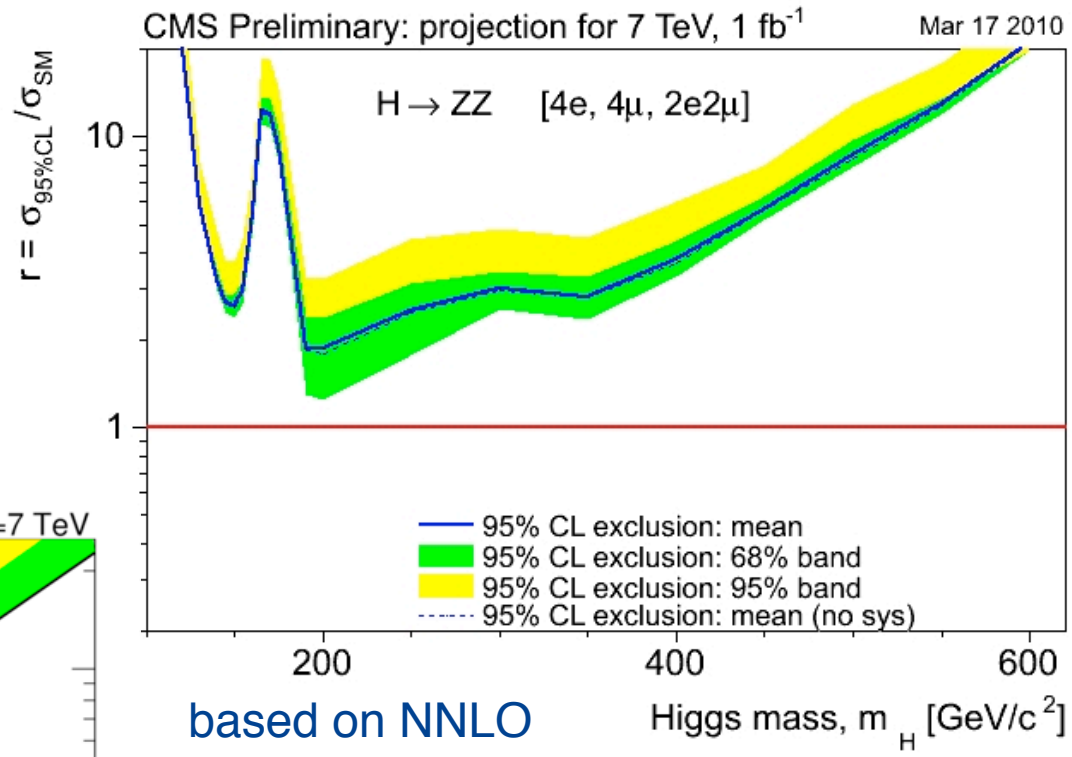
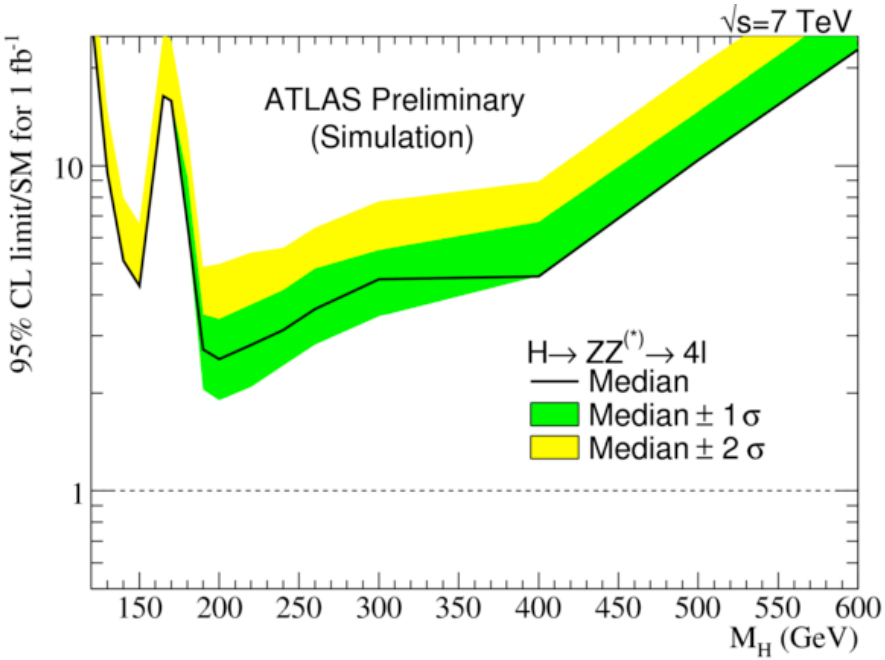
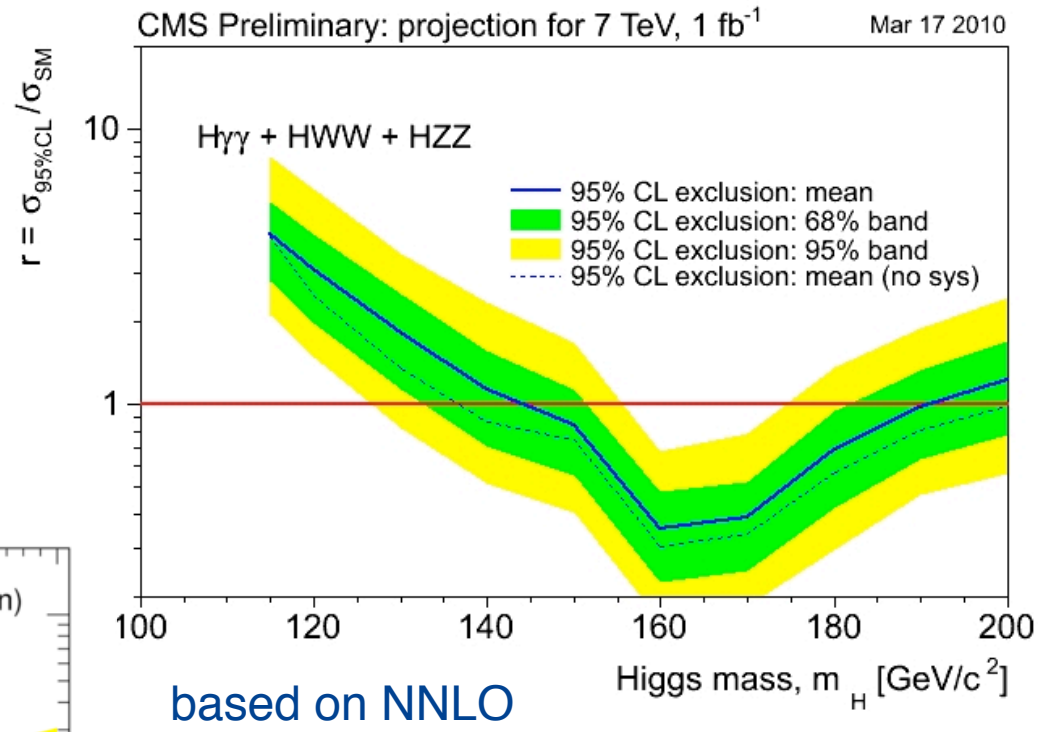


based on NNLO

based on NLO



Combination (WW, γγ, ZZ only!)



based on NNLO

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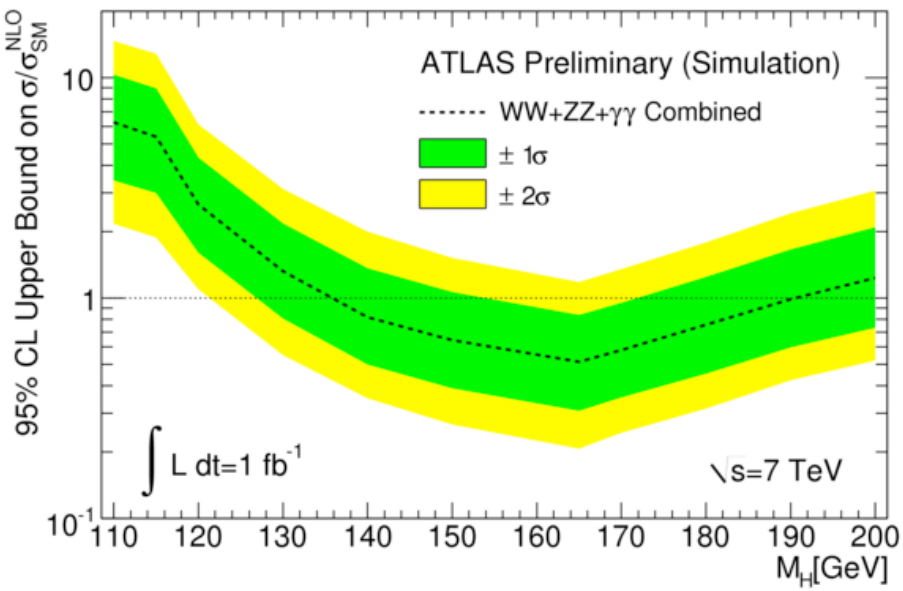


MSSM

- $pp \rightarrow bb\Phi \rightarrow bb\tau\tau$
- $H^+ \rightarrow cs, \tau\nu$
- [+ $\mu\mu$ analysis ; not covered in this talk]

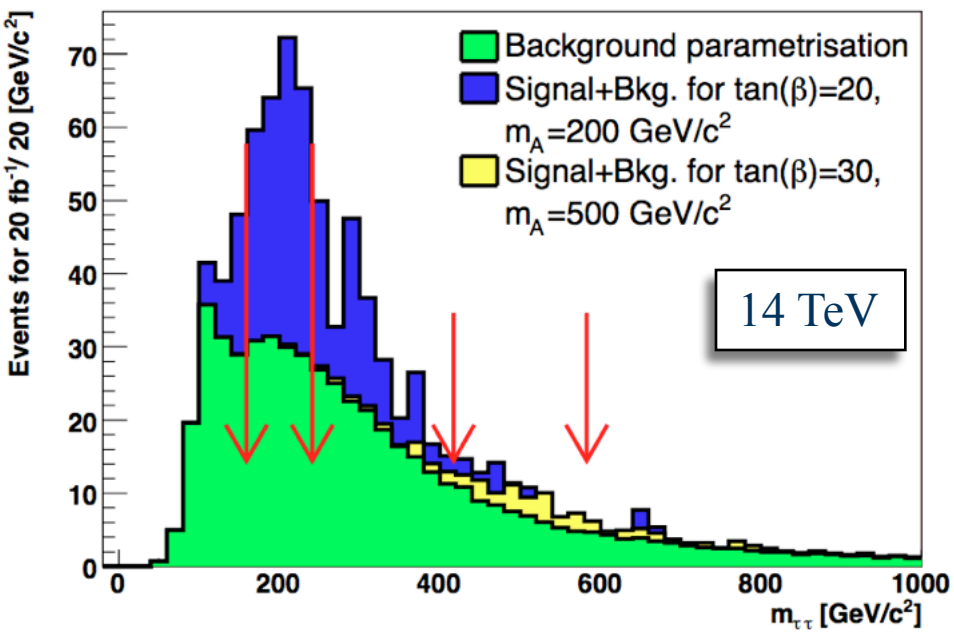
$pp \to b\bar{b}\Phi\,;\,\Phi \to \tau\tau$

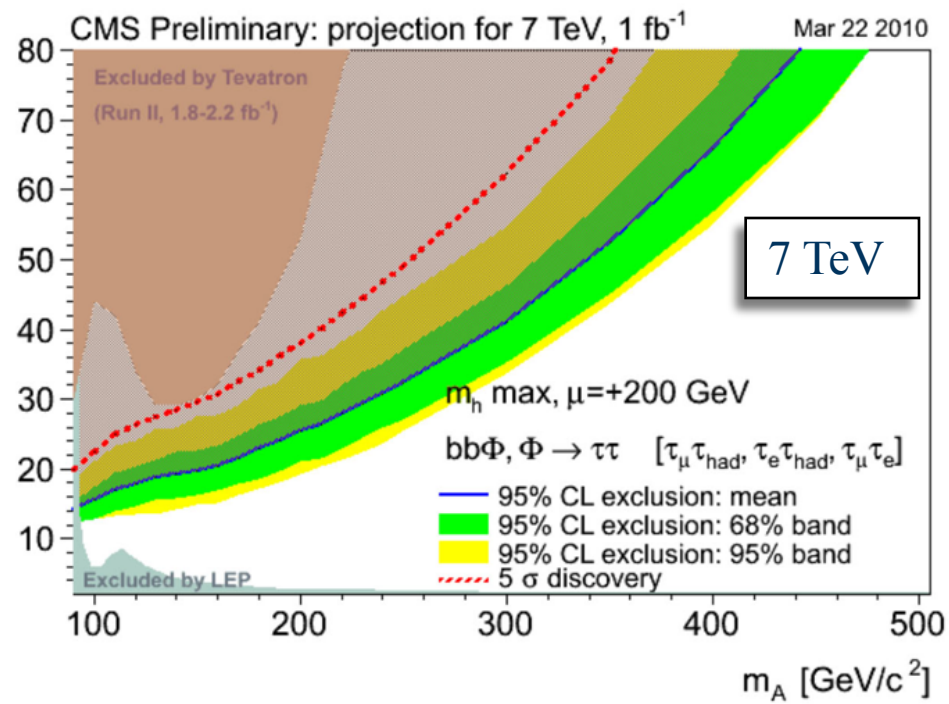
- select events with **MET**, **b-jet** , and **τ pair** (had-e, had-μ, eμ)
- **reconstruct ττ** invariant mass (collinear approximation, i.e. assume ν ll τ) and count events in sliding mass window
- **backgrounds** (top pairs, Z + heavy quark pairs) **to be determined from data**

discovery

exclusion

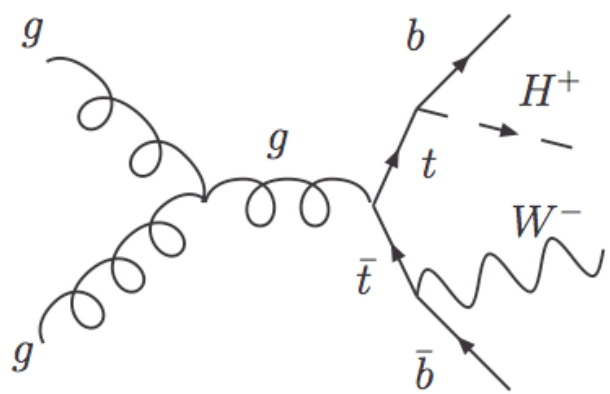
Reconstructed Higgs boson mass.



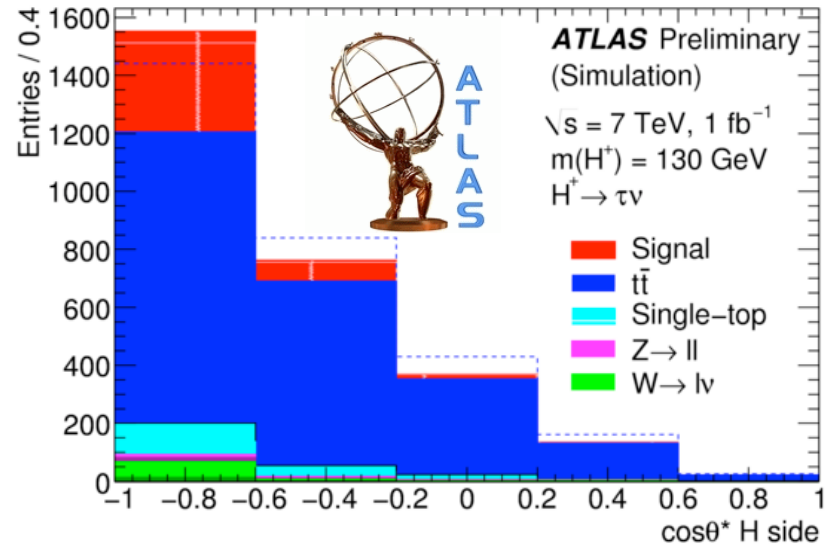


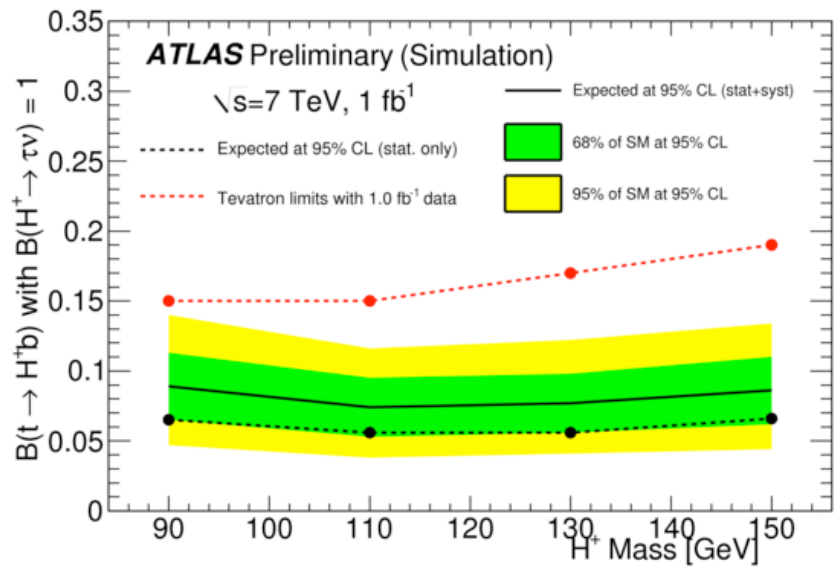
$H^+ \to \tau\nu$

Search for light (<m_{top}) charged Higgs in di-lepton top decays:

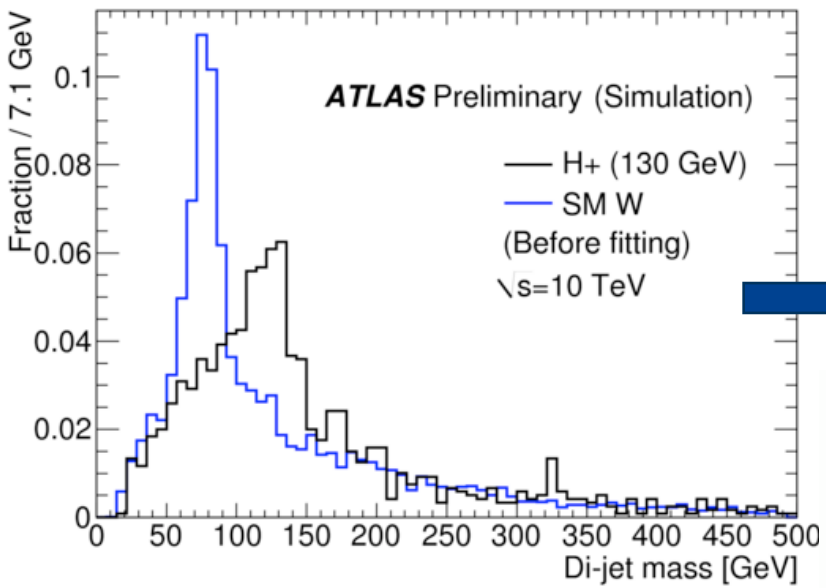


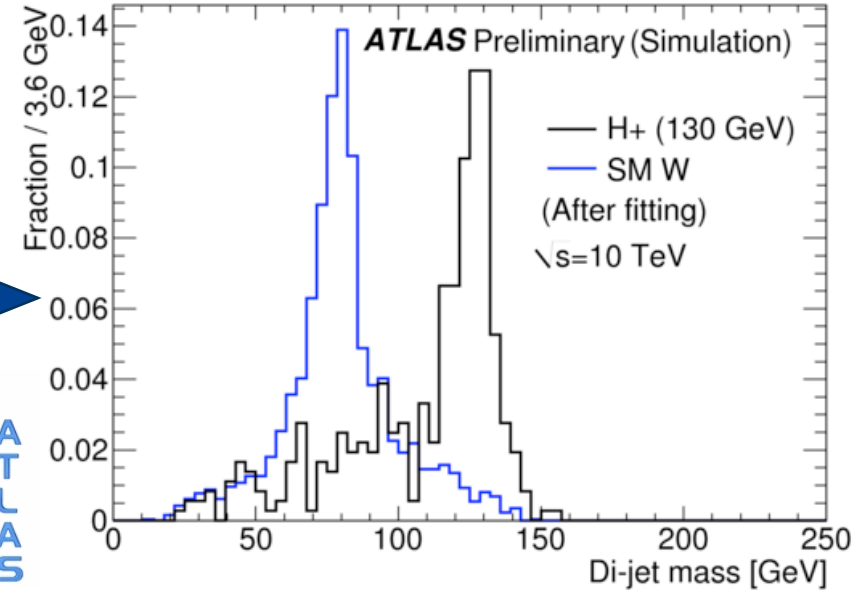
- 2 **leptons** + **MET** + 2 **b-jets**
- reconstruct $H^+ \to \tau\nu$
- **extract signal from** lepton **helicity** angle
- expect **future improvements** from use of additional quantities





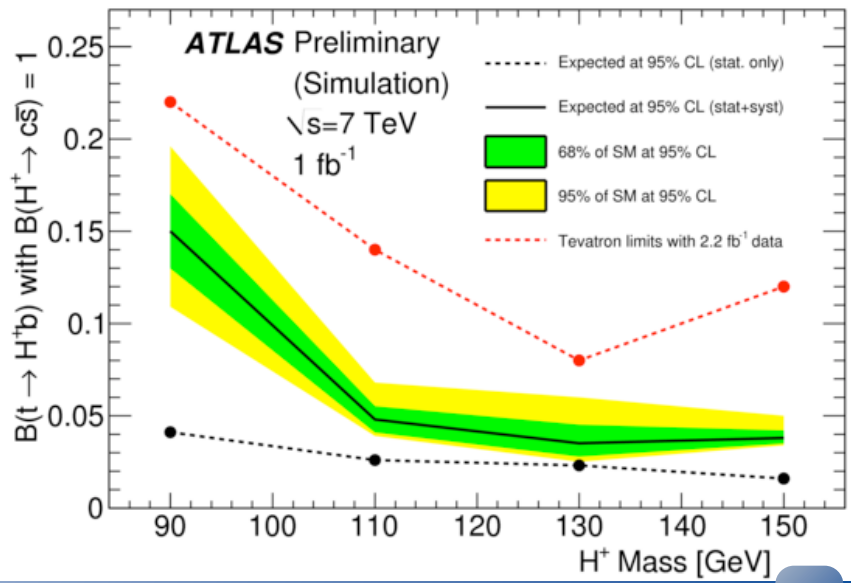
$H^+ \rightarrow c\bar{s}$





Search for light (<m_{top}) charged Higgs in semi-leptonic top decays:

- **lepton** + **MET** + 2 **jets** + 2 **b-jets**
- **reconstruct** $H^+ \rightarrow$ jet jet **di-jet mass**
- **m_H resolution improved** with $W \rightarrow l\nu$ and top **mass constraints**

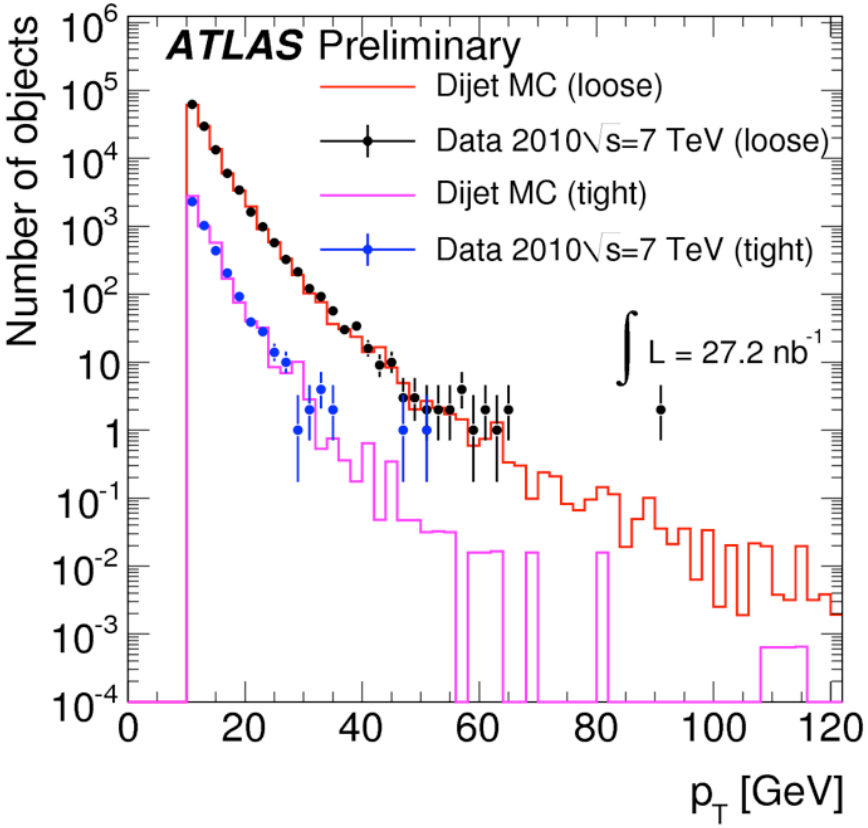


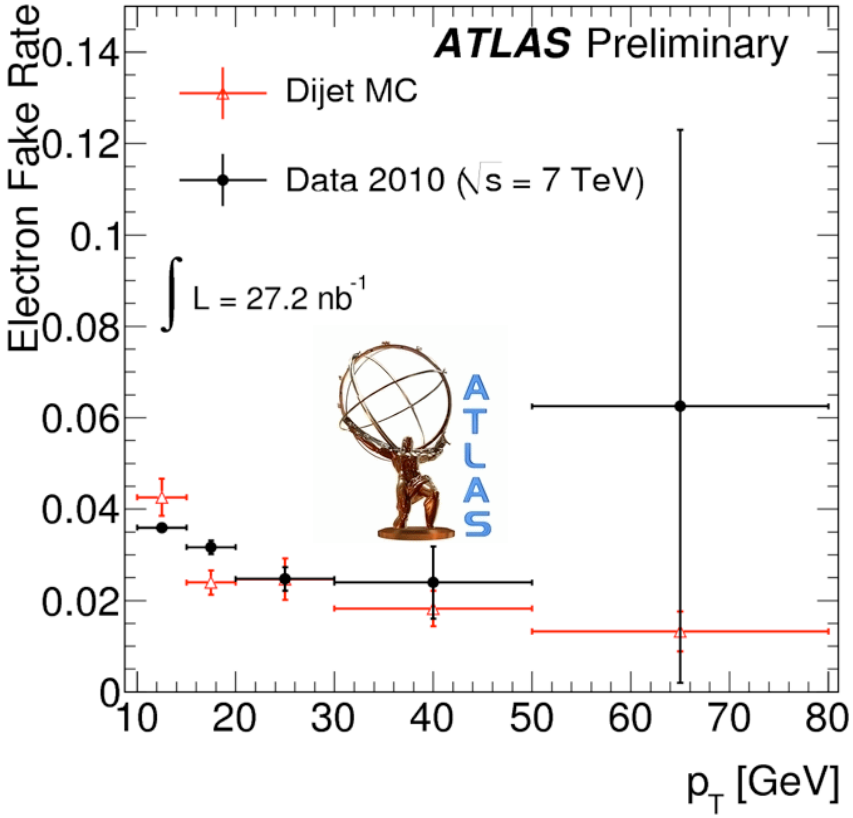
Higgs Backgrounds from early 7 TeV Data

- select 1 “good” + 1 “fake” lepton + MET (27 nb^{-1})
  ⇒ **W + jets background to SM H →WW search**

- select hadronically decaying τ + e or μ + MET (310 nb^{-1})
  ⇒ **backgrounds to (MS)SM H →ττ searches**

H → WW : Lepton Fake Rates

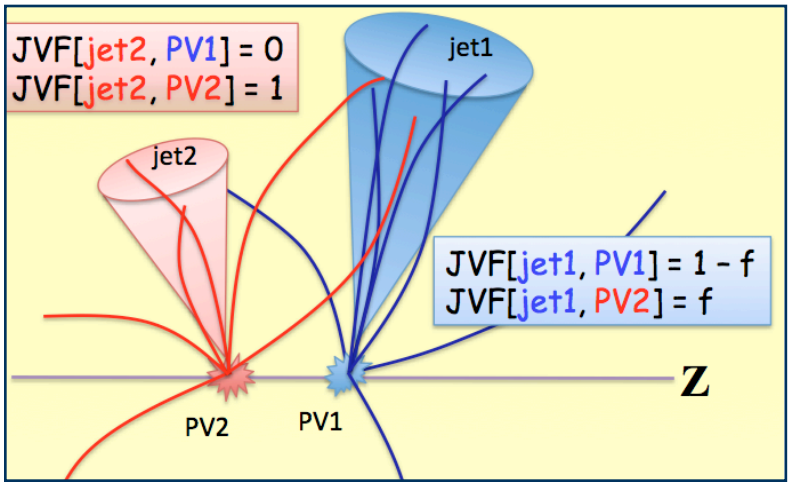


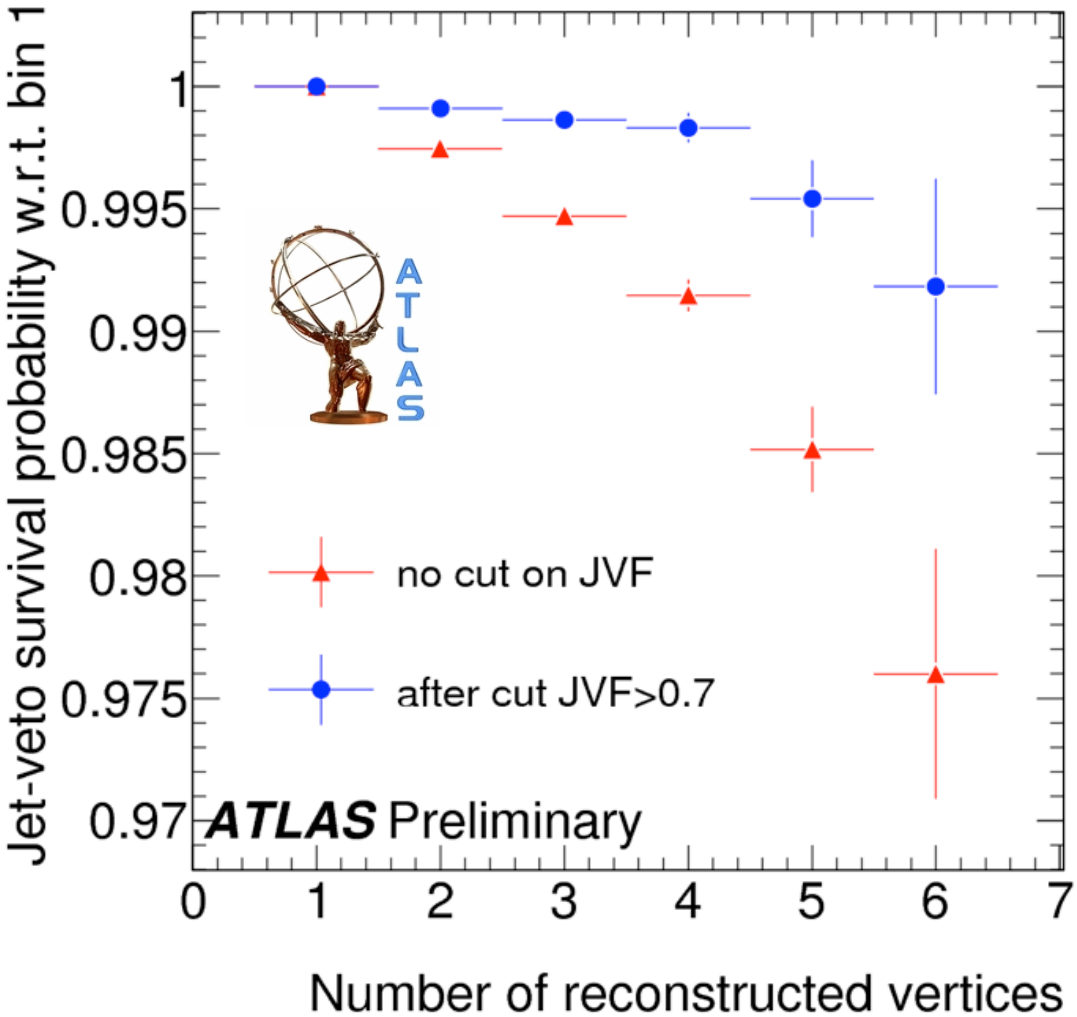


- measure **fraction of jets faking leptons** (needed for W+jets background estimate)
- use **dijet sample** (after W/Z veto); two **different lepton selections** ("loose","tight")
- will **replace simulation-based modelling in future analysis**

H → WW : Jet Veto and Pileup

- select **dijet events**
- check for **presence of third jet**
- **compare pile-up with no pile-up** case (using number of reconstructed vertices)
- **can** largely **compensate** using track information (“jet vertex fraction” JVF)

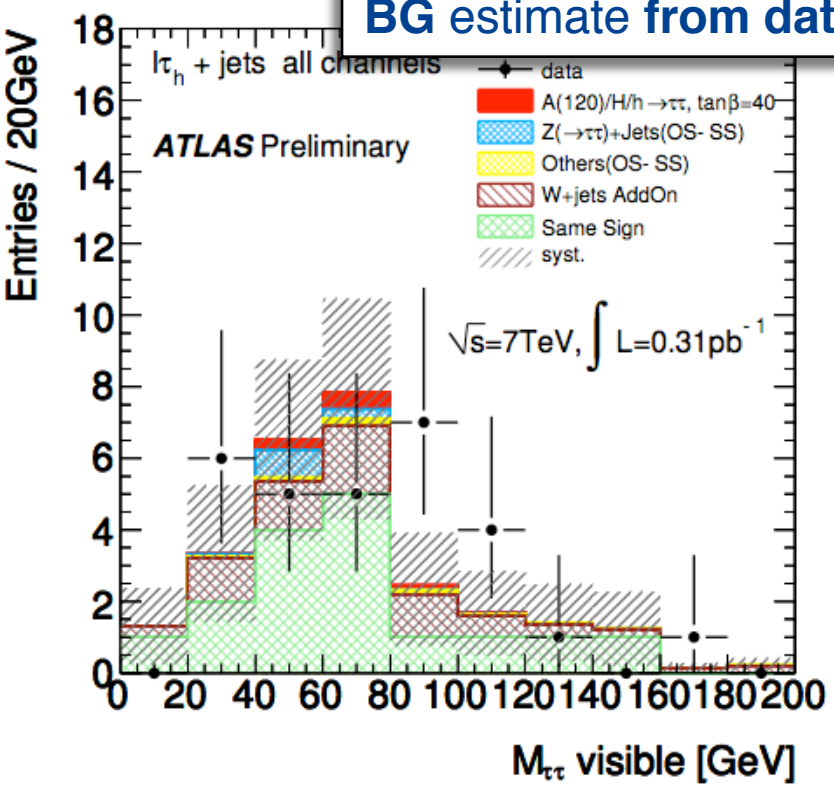




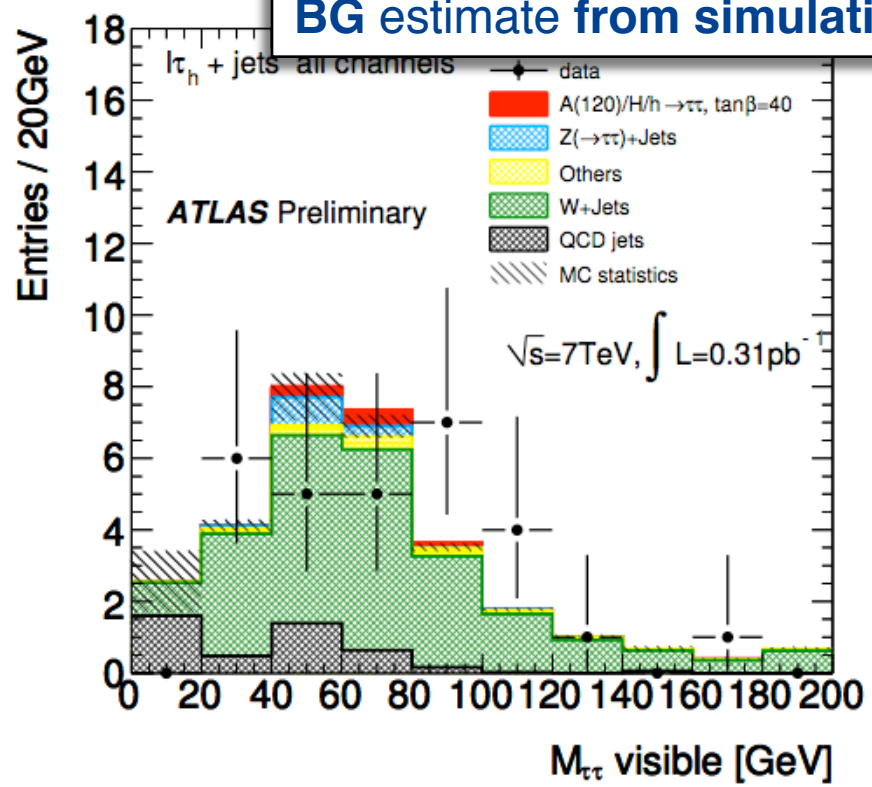
$H \rightarrow \tau\tau$: Data-Driven BG Estimate

- found **29 τ_h + lepton events** with MET > 20 GeV (12e+ 17μ) **in 310 nb^{-1} of data**
- **expect 25±9** from **data-driven** background estimate
- **$m_{\tau\tau}$ mass shape agrees** with data estimate and MC simulation (within large uncertainties)

BG estimate **from data**



BG estimate **from simulation**



Conclusions

- **CMS and ATLAS** will competitively **enter** the SM and BSM **Higgs searches in 2011**
- Estimated **SM Higgs mass exclusion with 1 fb^{-1}** using $H \rightarrow WW \rightarrow 2l2\nu$, $H \rightarrow ZZ \rightarrow 4l$, and $H \rightarrow \gamma\gamma$:
  - CMS : [145,190] GeV
  - ATLAS : [135,188] GeV
- **Expected to improve** (add channels, combine ATLAS&CMS)
- **First successful steps in** validating **data-driven background estimation** with 7 TeV collision data

References (+ References Therein)

CMS-NOTE 2010/008

Available on CMS information serve

The Compact Muon Solenoid Experiment

CMS Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

5th May 2010; updated July 20th, 2010

The CMS physics reach for searches at 7 TeV

The CMS Collaboration

ATLAS-PHYS-PUB-2010-009

ATLAS NOTE

ATLAS Public Note

July 15, 2010

ATLAS Sensitivity Prospects for Higgs Boson Production at the LHC Running at 7 TeV

ATLAS Collaboration

ATLAS-CONF-2010-092

ATLAS NOTE

ATLAS-CONF-2010-092

September 20, 2010

Observation of the Background from W+jets to the $H \to WW^{(*)} \to \ell\nu\ell\nu$ Search with the ATLAS detector at $\sqrt{s} = 7$ TeV

The ATLAS Collaboration

ATLAS-CONF-2010-096

ATLAS NOTE

ATLAS-CONF-2010-096

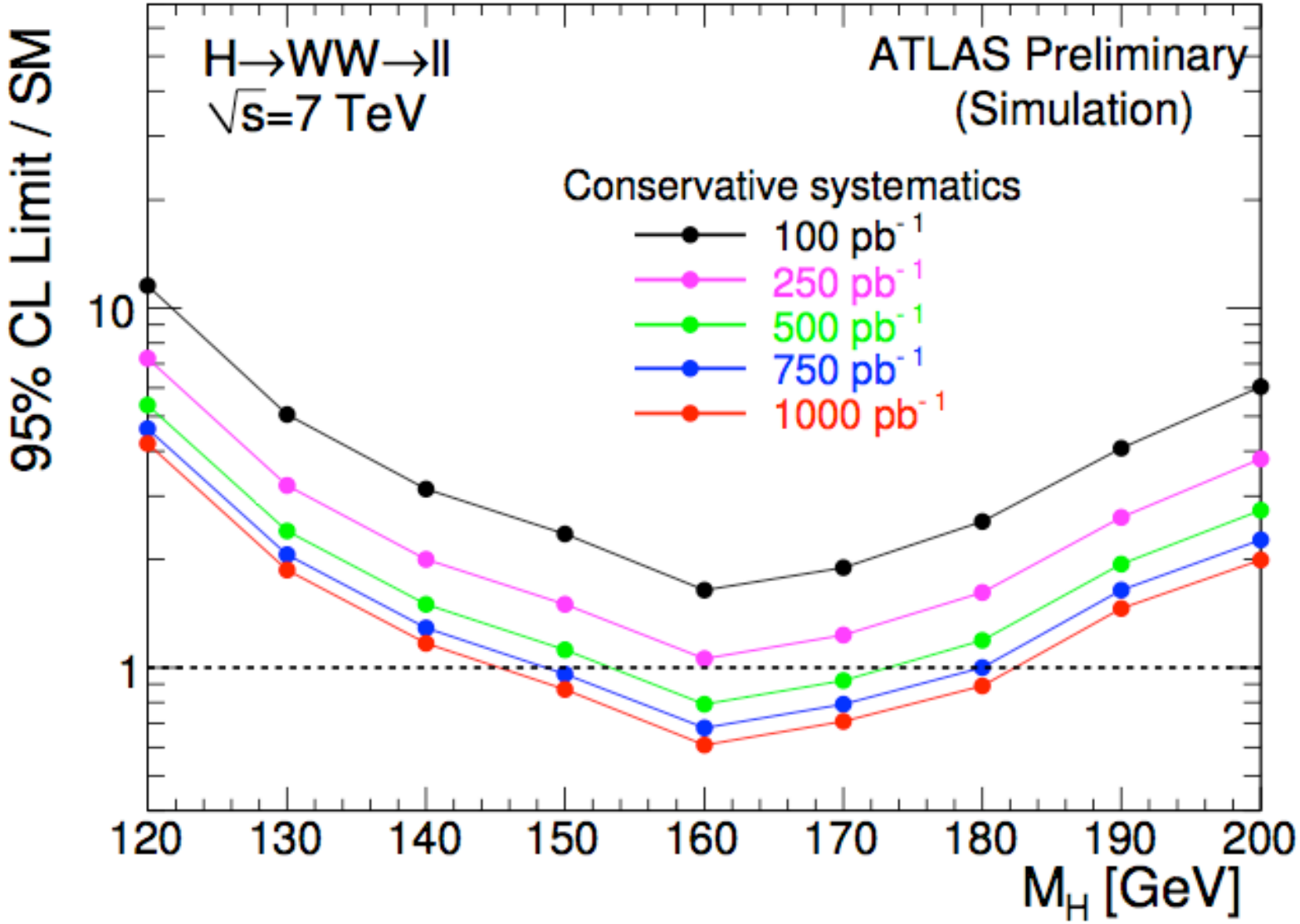
October 15, 2010

Data-driven background estimation for the $H \to \tau^+\tau^- \to \ell\tau_h$ search at $\sqrt{s} = 7$ TeV with the ATLAS detector

The ATLAS Collaboration

Additional Material

H → WW Exclusion vs. Luminosity



PDF Reweighting