Standard Model Higgs Boson Search in the ATLAS Experiment

Daniele Zanzi, NBI

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Outline:

The Standard Model and the SM Higgs boson

Direct and indirect searches

SM Higgs boson searches in ATLAS

The low mass range

gg+VBF→H→ττ

Results

Improvements

The Standard Model and the SM Higgs boson

Introducing a *doublet of scalar fields* in the SM Lagrangian is possible to achieve at the same time:

- ✓ The Electro-Weak Symmetry breaking (gauge couplings, VEV≠0)
- ✓ The generation of the fermion masses (Yukawa couplings)

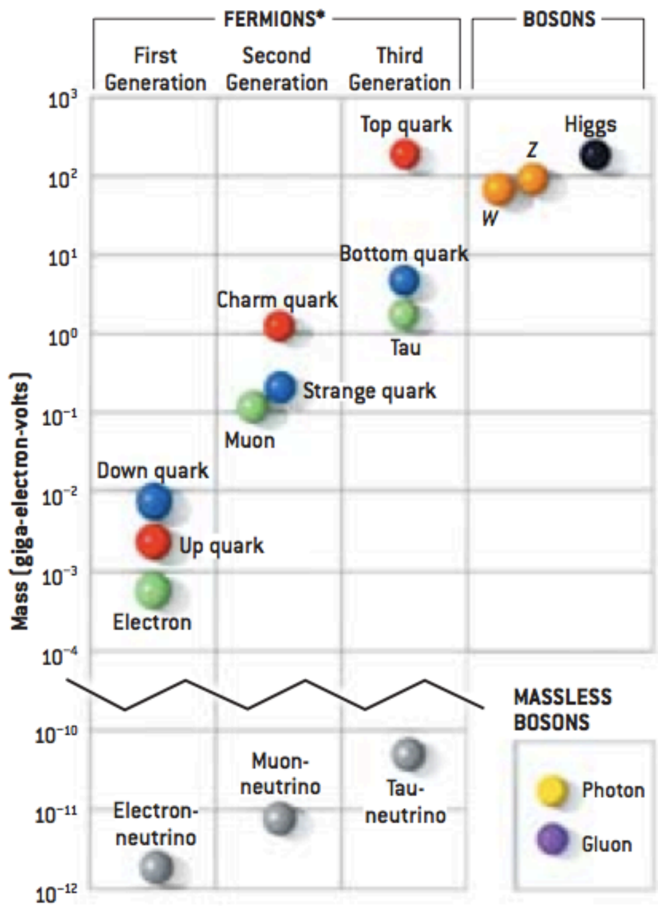
The SM Higgs boson is a CP-even *scalar neutral* particle.

All the parameters in the Higgs sector of the SM Lagrangian can be fixed choosing the *mass* of the Higgs boson!

SM Higgs boson couplings:

a)~ M^2 for W,Z

b)~ M for fermions



Indirect searches:

Theoretical constraints:

a) Unitarity ($V_L V_L \rightarrow V_L V_L$)

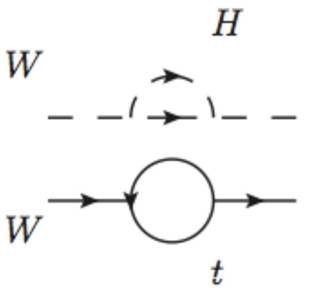
b) Triviality (self-coupling)

c) Vacuum stability (ground state)

Theoretical arguments are valid as long as new physics occurs.

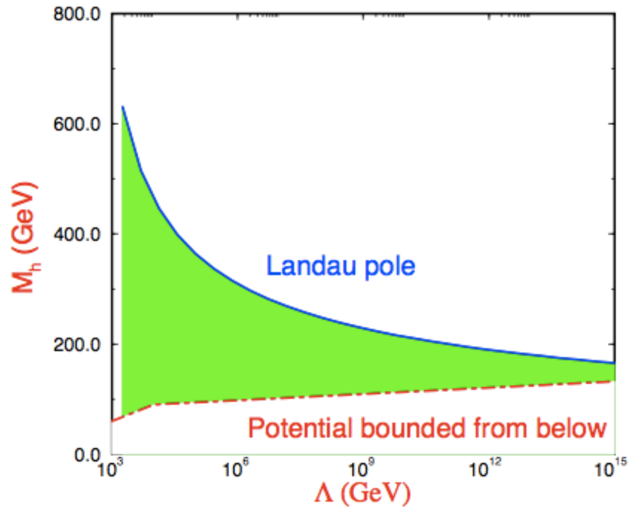
ElectroWeak Precision Observables are sensitive to the Higgs boson through virtual effects, but only with a logarithmic dependence on M_H.

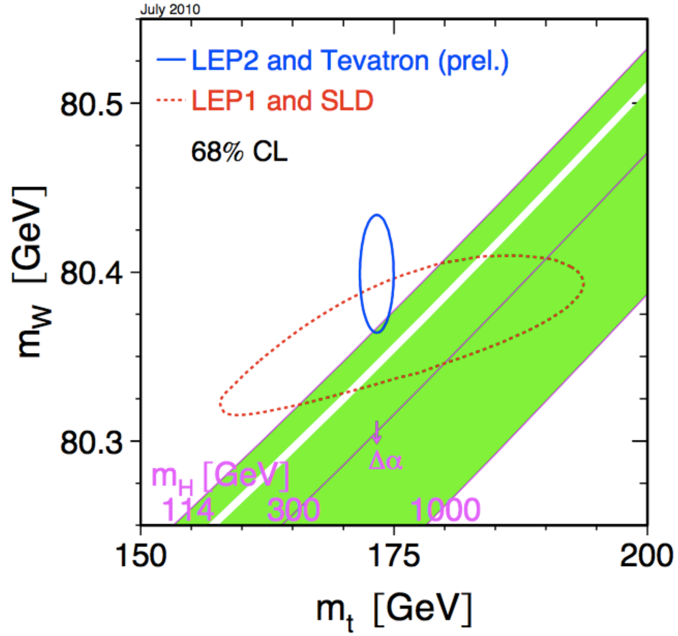
$\Delta m_W \sim$



$\sim \ln m_H$

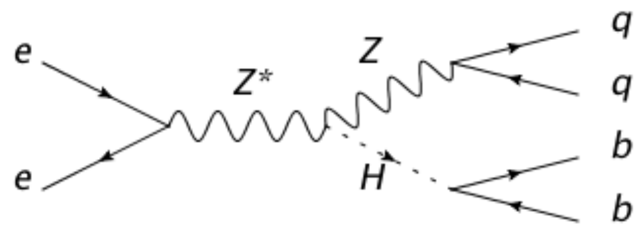
$\sim m_t^2$

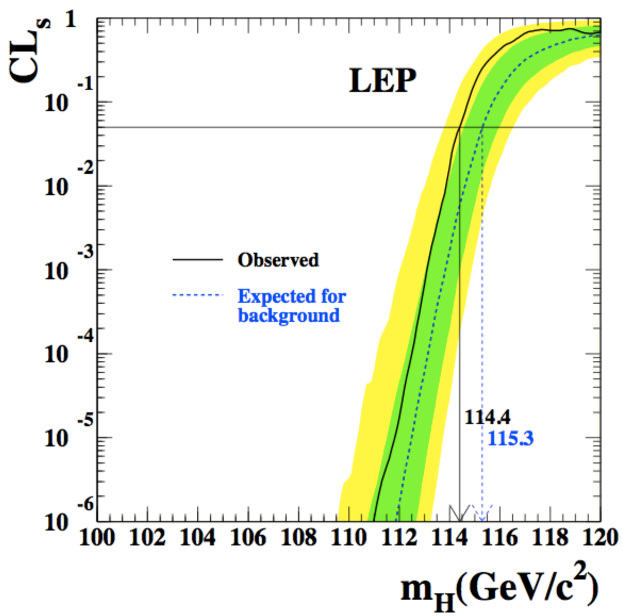


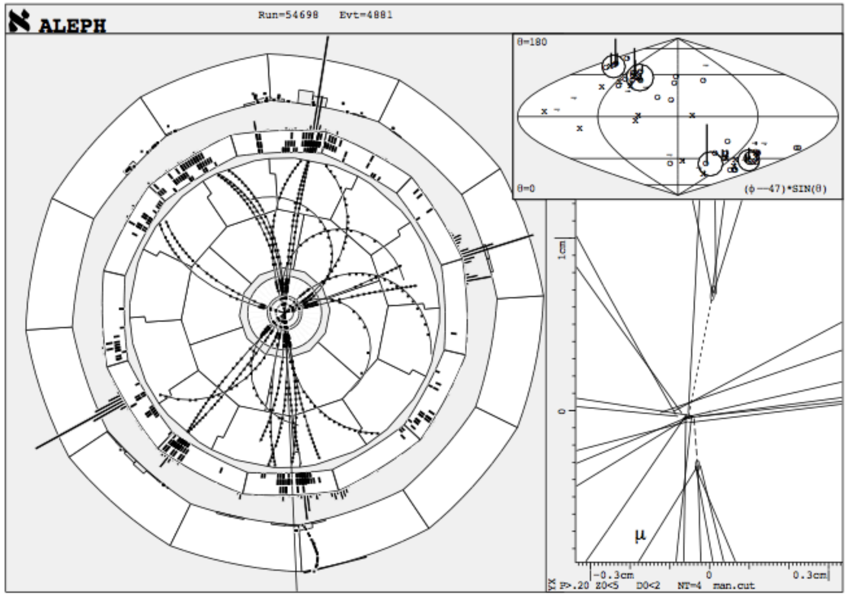


Direct searches: LEPII

- e^+e^- collider at the center of mass energy <209 GeV (LEPII);
- Higgs boson production channel: *Higgs-strahlung*;
- Little signal excess at 115 GeV
- 95% CL exclusion limit for SM Higgs below 114.4 GeV

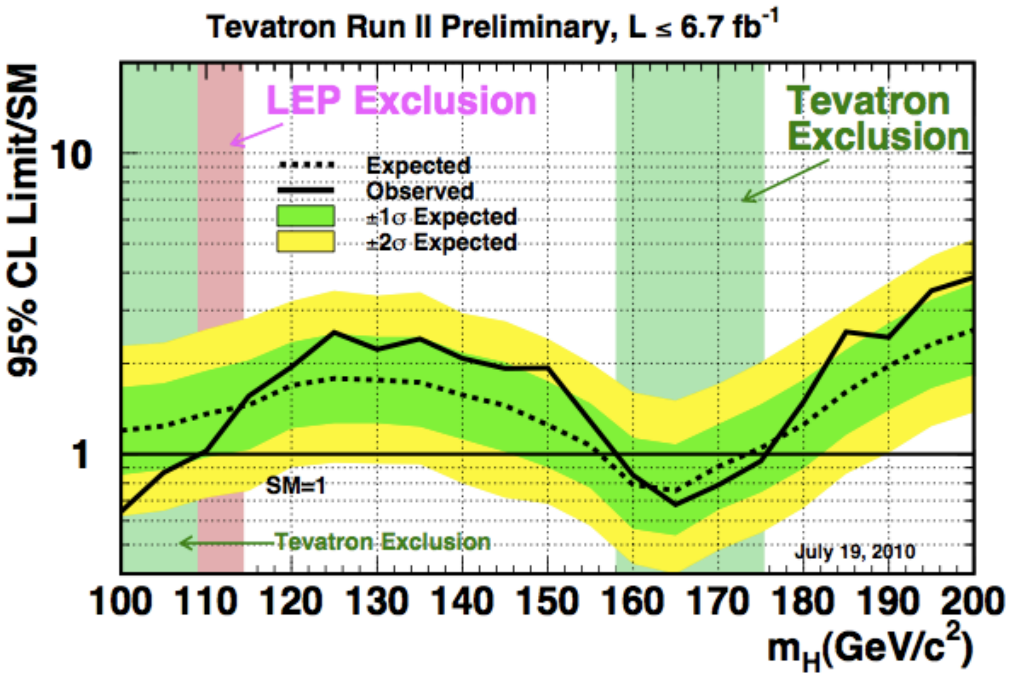




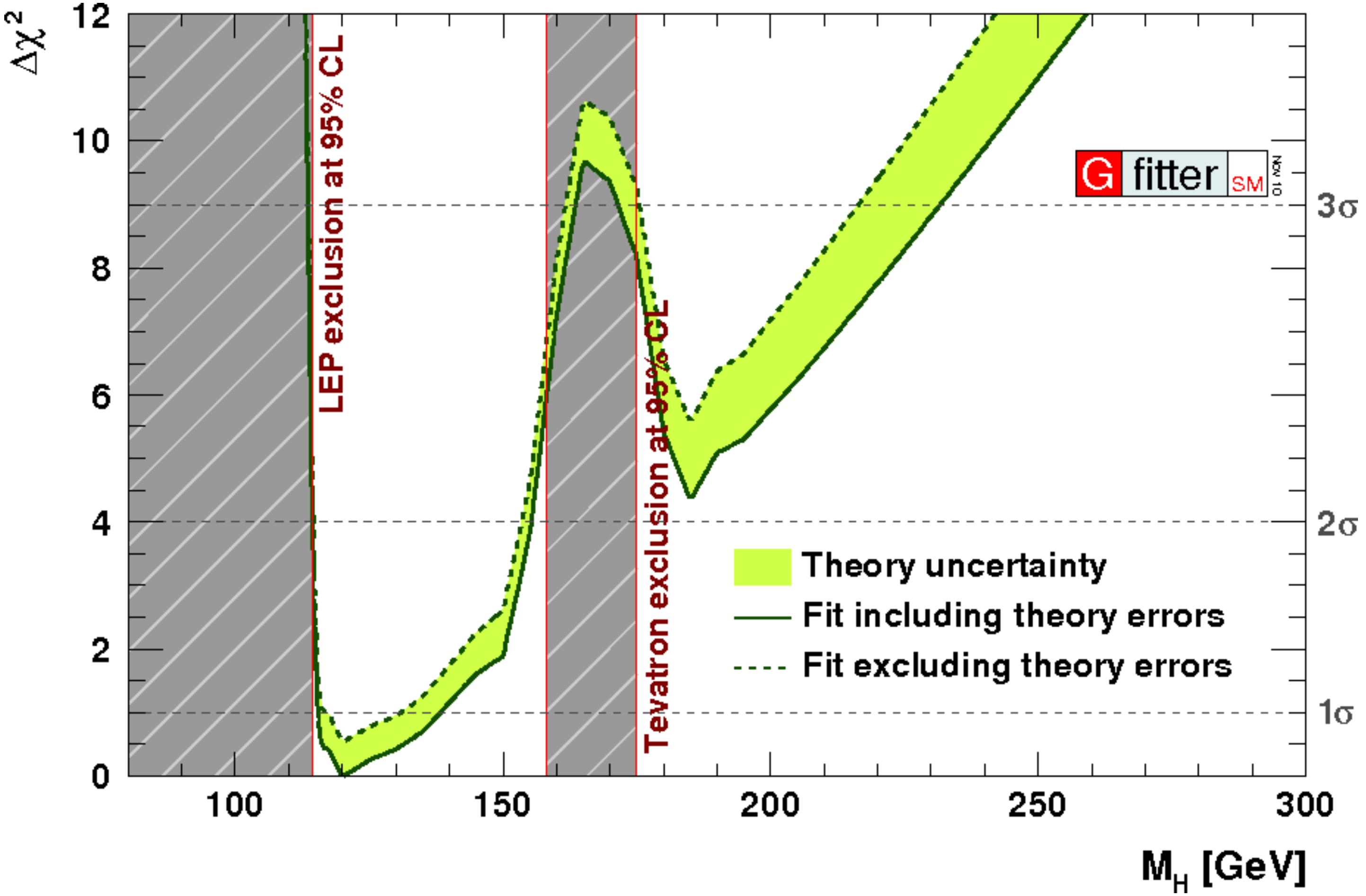


Direct searches: Tevatron

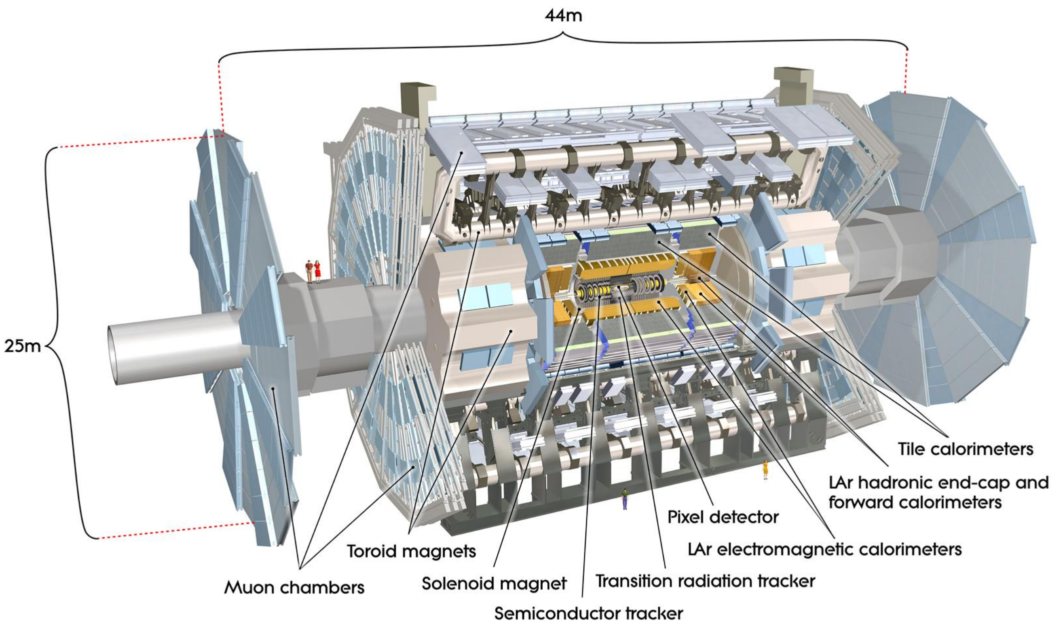
- p/p collider at the center of mass energy of 1.96 TeV;
- Higgs boson production processes:
  a) Low mass range: Higgs-strahlung q/q → (H>b/b)+W/Z;
  b) Higgs mass range: gluon fusion gg→ H→ WW

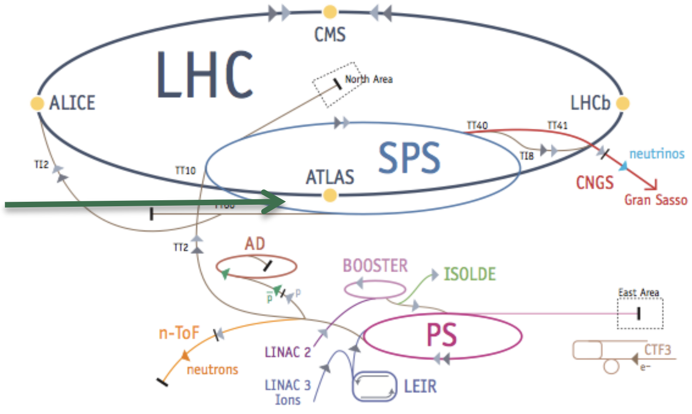


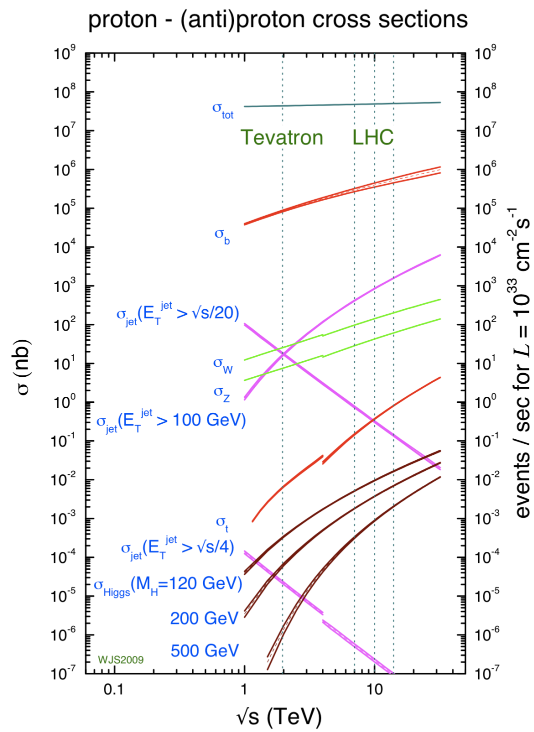
Direct and indirect searches:



The ATLAS Experiment:







- Multi-purpose experiment
- pp scatterings at the center of mass energy of 7 TeV (2010)
- Integrated luminosity of 45 pb^{-1}

Higgs production and BR at LHC:

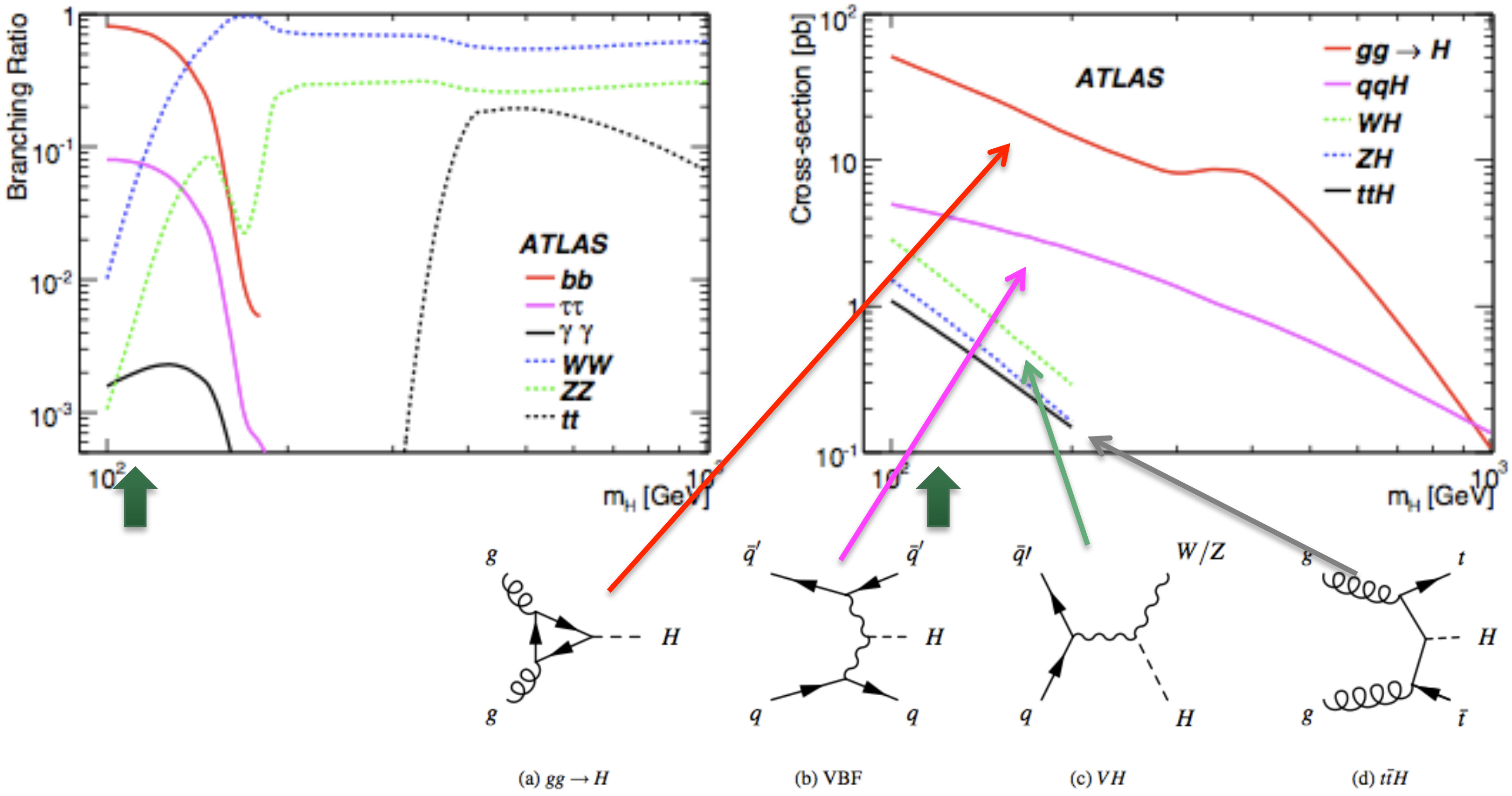


Figure 1: Representative leading order diagrams of the Standard Model Higgs boson production.

ATLAS EXPERIMENT

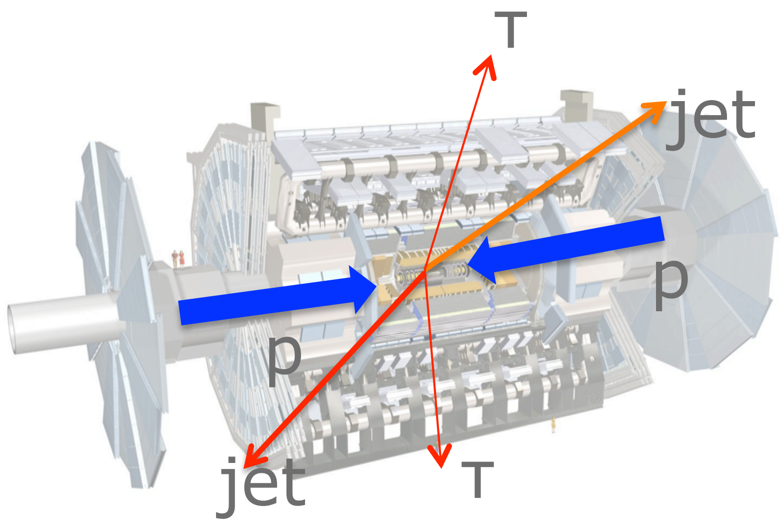
Higgs search in the low mass range:

Production: gg, VBF

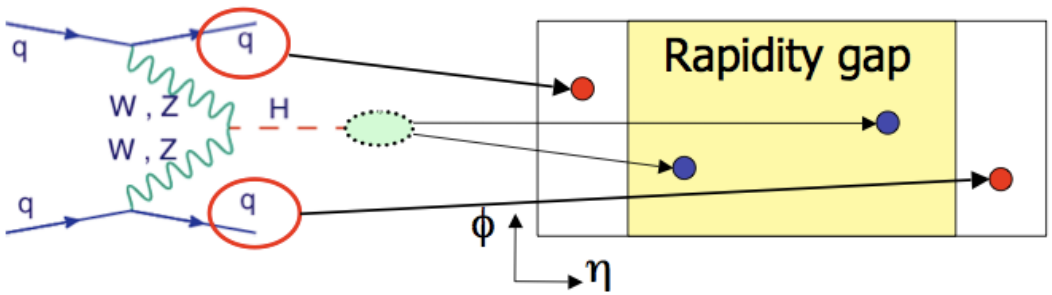
Decay: ττ, γγ

The VBF H→ ττ:

- peculiar topology;
- two forward jets and two central taus;
- Central Jet Veto



VBF baseline analysis considers only the VBF as production process and only the full leptonic and semi leptonic channels



An alternative study: gg+VBF→H→ττ

Aims:

a) explore the possibility of a gg+VBF analysis in tau pair final states that can be combined to the VBF study
b) prove that the full hadronic channel can improve the total sensitivity

The analysis:

a) gg+VBF → H(120 GeV)+jets → ττ+jets at cme 10 TeV
b) Tau decay channels: ll, lh, hh
c) Backgrounds: W/Z+jets, qcd multijets, top pairs
d) Cut-based event selection

Table 1: Total inclusive cross sections for Higgs production in proton-proton collisions.

m_H = 120 GeV	$\sqrt{s}$=7 TeV	$\sqrt{s}$=10 TeV	$\sqrt{s}$=14 TeV
GF: $\sigma_{NNLO}(gg \to H)$	16.69 pb	31.03 pb	53.50 pb
VBF: $\sigma_{NLO}(gg \to ggH)$ (t+u)	1.24 pb	2.40 pb	4.26 pb
VBF: $\sigma_{NLO}(gg \to ggH)$ (t+u+s)	1.84 pb	3.41 pb	5.84 pb

Results

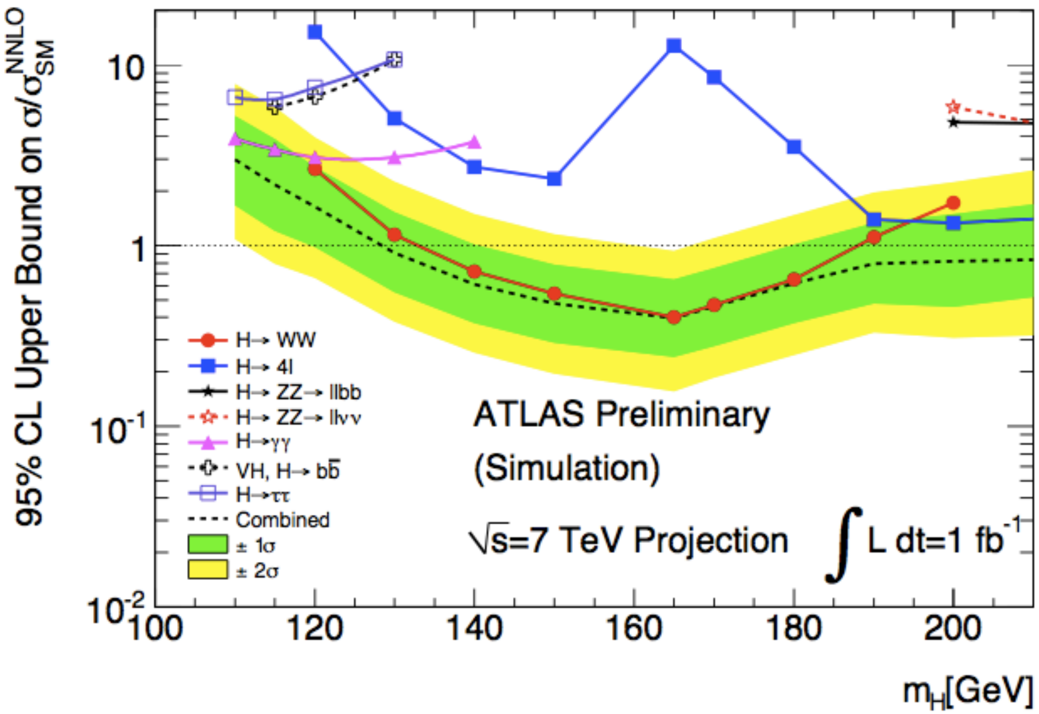
Energy	Signal [fb]	Total Bg [fb]	$s/\sqrt{b}$ 30 fb^{-1}	σ (10% syst on bg) 30 fb^{-1}
10 TeV	1.20±0.05	2.6±0.7	4.6	3.6
14 TeV	2.20±0.10	4.4±1.1	6.0	4.6
7 TeV	0.67±0.03	1.5±0.5	3.3	2.6

a)The sensitivity is comparable with the VBF baseline analysis

b)Although half of the signal is produced by VBF, this event selection is *orthogonal* to the one used in the VBF analysis. This means that the two analyses can be *combined*

c)Trigger and *pileup* studies have been performed

ATLAS sensitivity



○The mass region below 120 GeV is the most difficult to explore for ATLAS. At the end of 2011 Tevatron can reach the sensitivity of 3σ in this range

○This analysis proves that the sensitivity of the H→ττ channel is underestimated and it can be improved with the inclusion of the full hadronic final state and of new production processes

“To-do” list

Improvements of the selection strategy:

a) better MC simulations, inclusion of additional signal channels

b) design of multivariate methods to select a higher fraction of gluon fusion events

c) study of tau polarization effects and new methods for the reconstruction of the Higgs boson mass which don’t have the limitations of the collinear mass approximations

d) optimization of the event selection, maybe in jet multiplicity and tau tracks bins

Background estimations on 2011/2012 data:

a) Design of data-driven background estimations

b) Study of background shape and normalization for W+jets, QCD multijets, Z+jets and top pairs especially for the hadronic channel

Outlook

At the end of 2011 it might be possible to exclude the SM Higgs boson in all the mass region between the LEP and the Tevatron exclusion limits

In the low mass range, where the SM Higgs boson is likely to be, ATLAS has the worst sensitivity, but the $H \rightarrow \tau\tau$ can be significantly improved

It is necessary to optimize this search in order to be ready to set new limits at the end of this year

For more details: ATL-COM-PHYS-2011-036 (ATLAS Internal Communication, http://cdsweb.cern.ch/record/1323075)