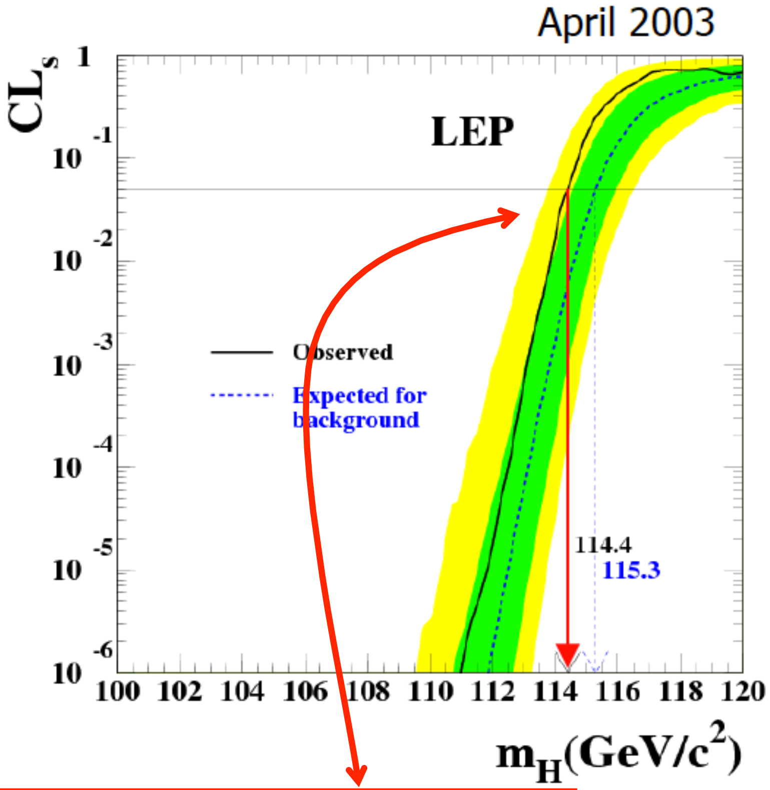
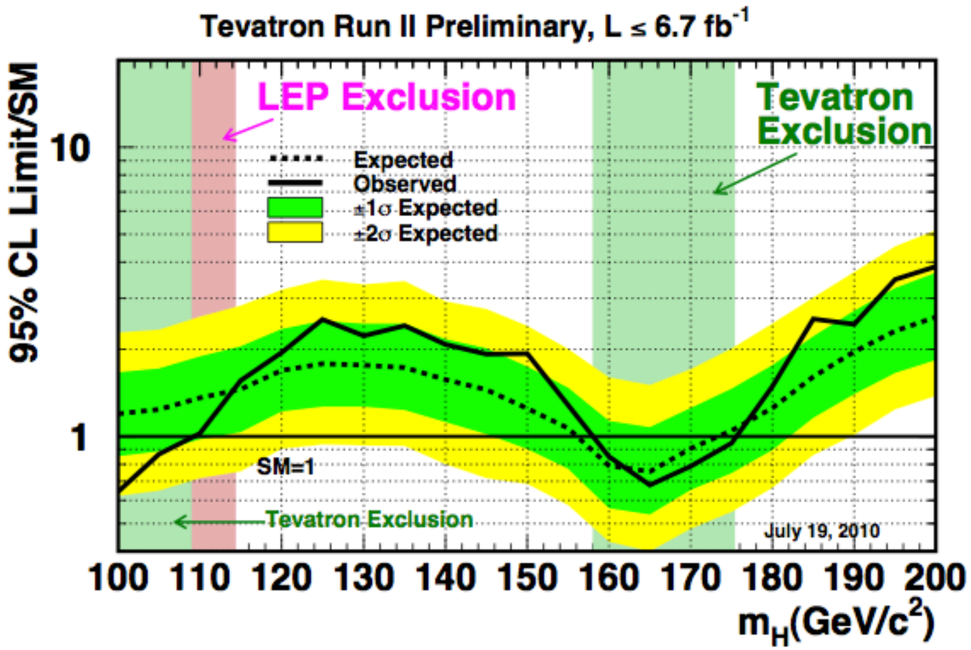
Higgs boson searches

in

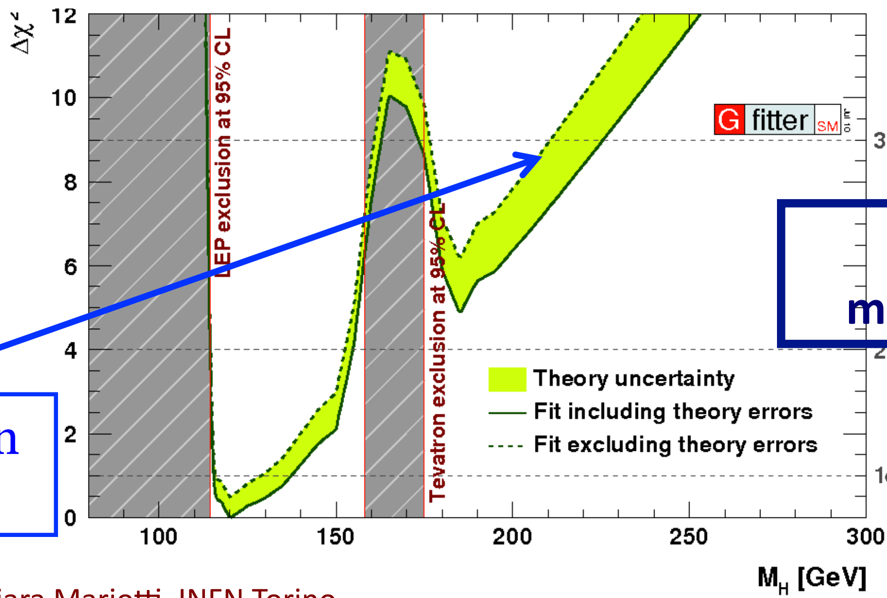
ATLAS and CMS

The Higgs as of today





Direct Search
m(H) ≥ 114.4 GeV/c²
at 95% CL



Theory
m(H) < TeV

EW precision measurements
m(H)= 87 $^{+35}_{-26}$ GeV/c²

Plus Tevatron and LEP DS

The Higgs roadmap at LHC

- LHC experiments have been preparing for discovery

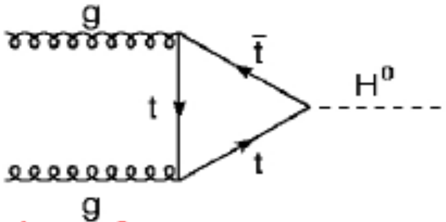
- For the run at **7 TeV** the aim will be the **exclusion over a large range of masses**

  (discovery possible only if 160<MH<170 GeV):

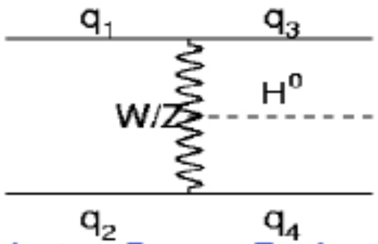
  ATLAS+CMS will revisit all the possible channels in order to combine them to increase the exclusion reach

- For the **14 TeV** run (2013 on) we will switch back to **discovery mode**

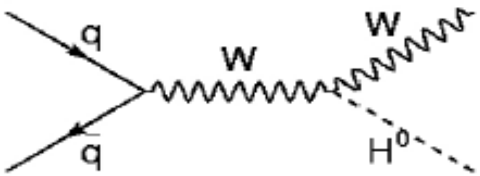
The search for the Higgs a 14 TeV



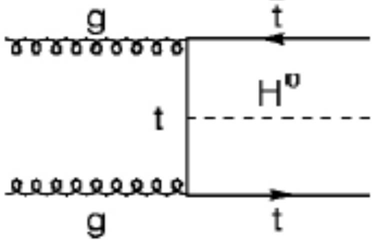
gluon fusion



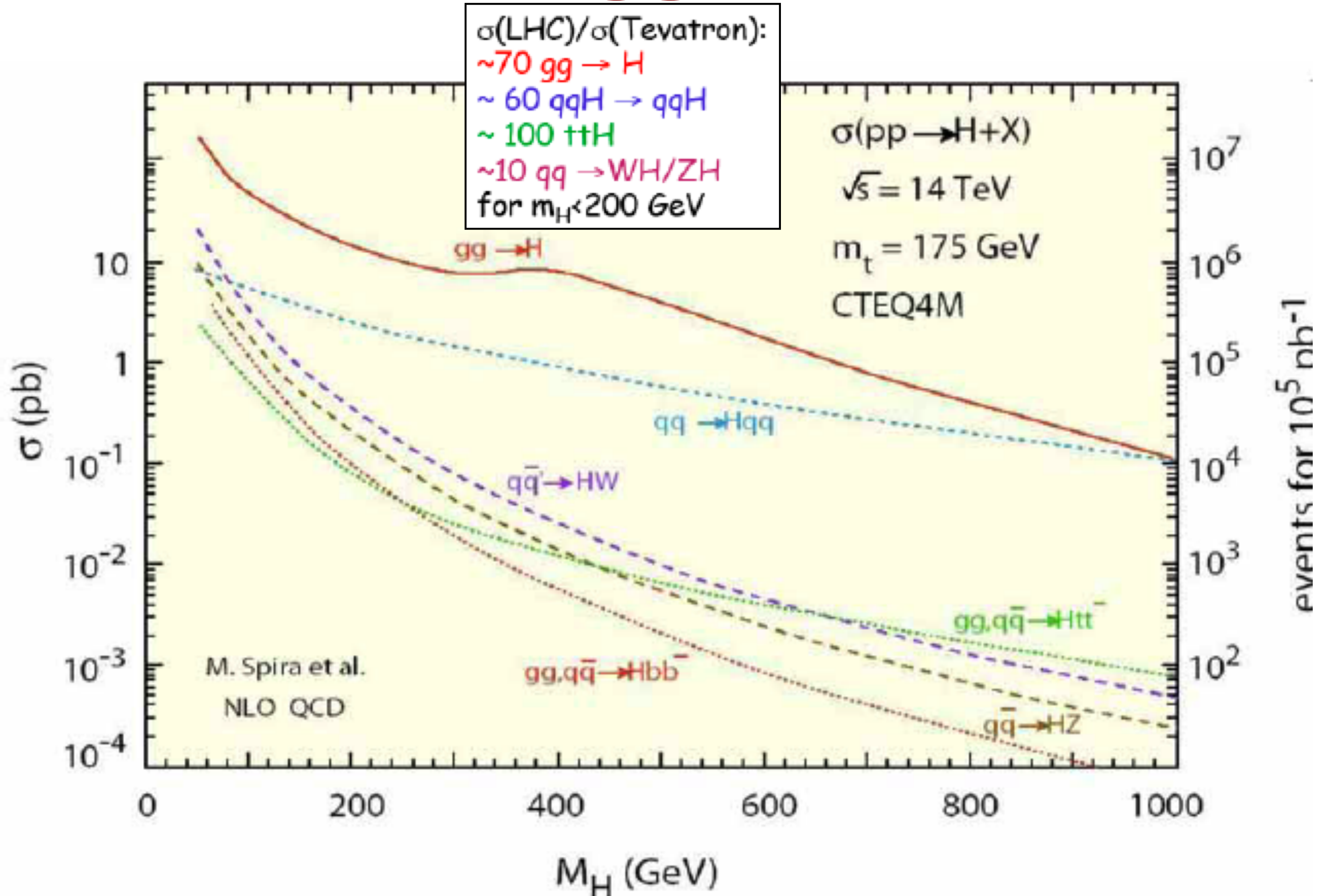
Vector-Boson-Fusion (VBF)



associated production (W, Z)



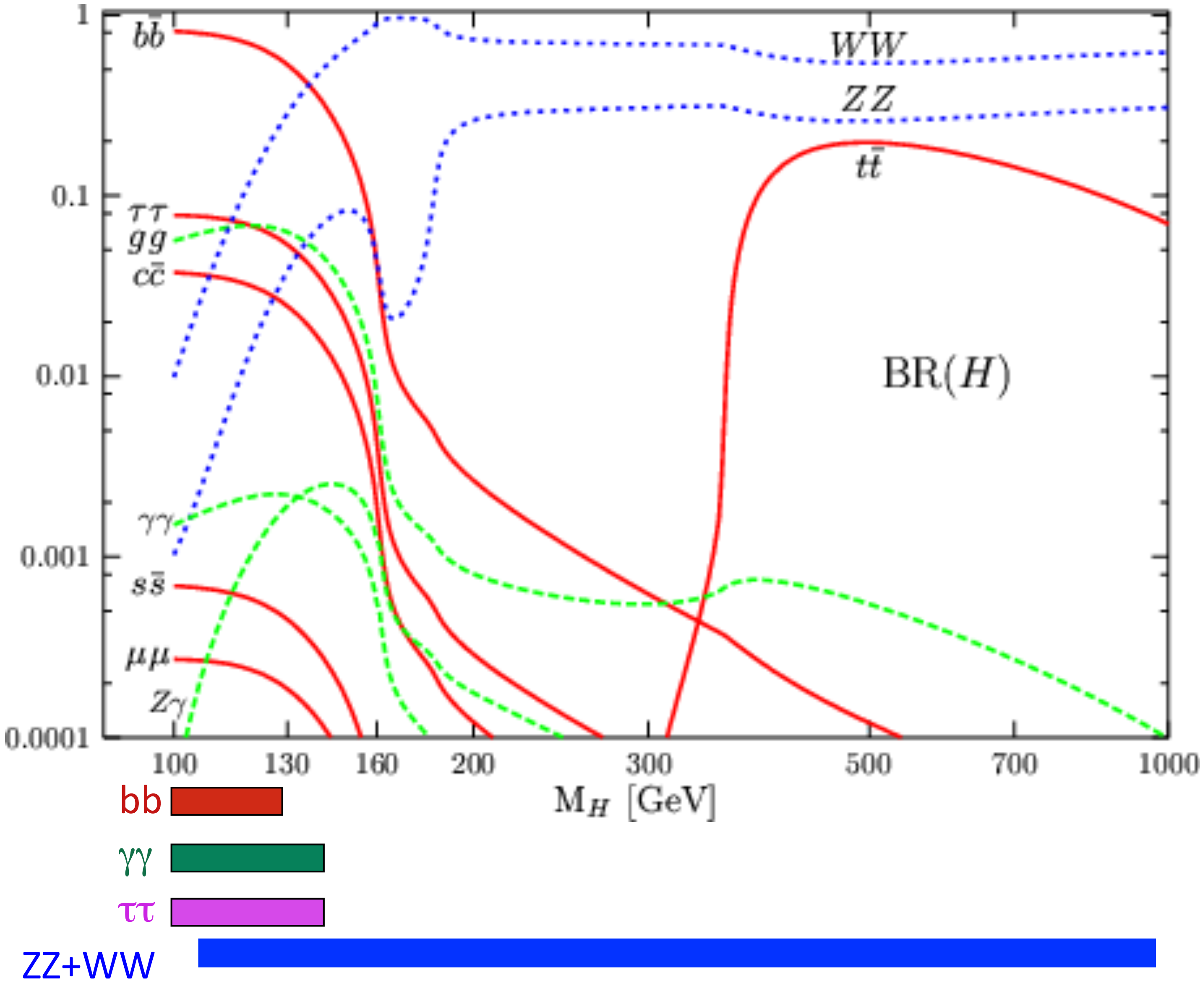
top fusion



Typical uncertainlties on total cross-sections

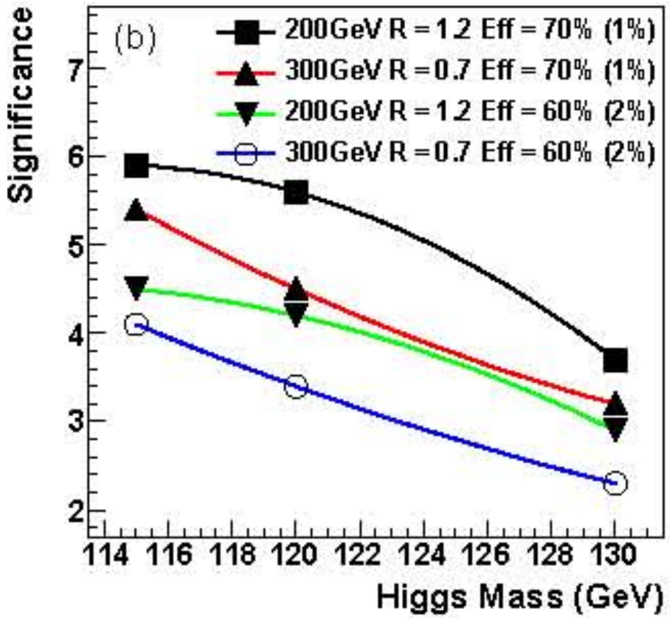
gg	10%	NNnLO
VBF	5%	NNnLO
WH, ZH	5%	NNLO
ttH	15%	NLO

Higgs Branching Ratios



H -> bb

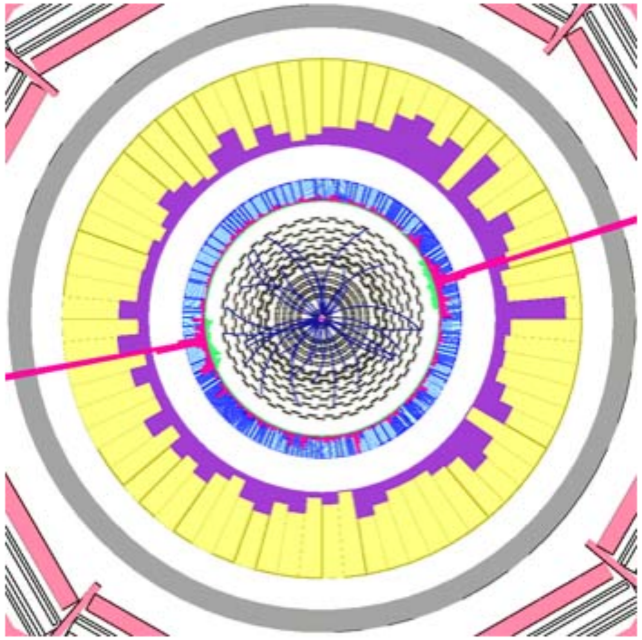
- H->bb : it was studied in tt-associated-production but considered impossible for a discovery. Since then news ideas:



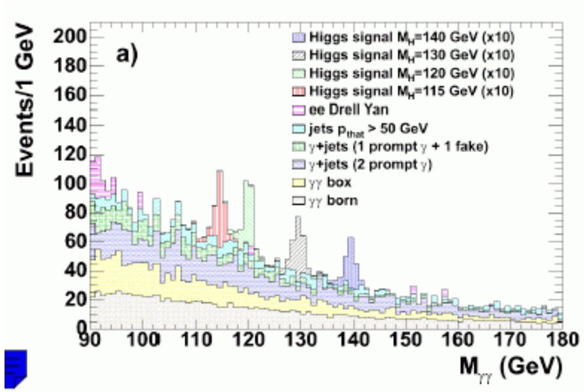
* HV, H->bb with $p_T(H)$ > 200 GeV
L~30fb^{-1} at 14 TeV
(Proposed by J.M.Butterworth et al.)

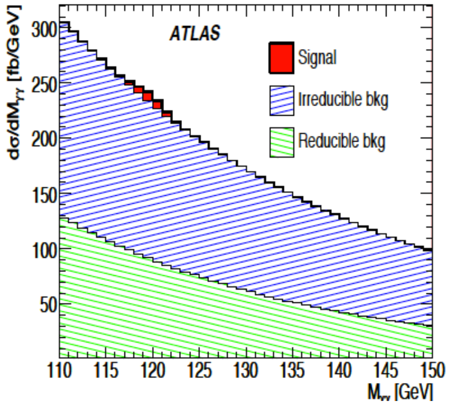
* VBF H , H->bb+γ/W for bb-coupling (L>300fb^{-1})
(Proposed by D. Rainwater , A. Ballestrero et al., Gabrielli et al.)

H -> γγ

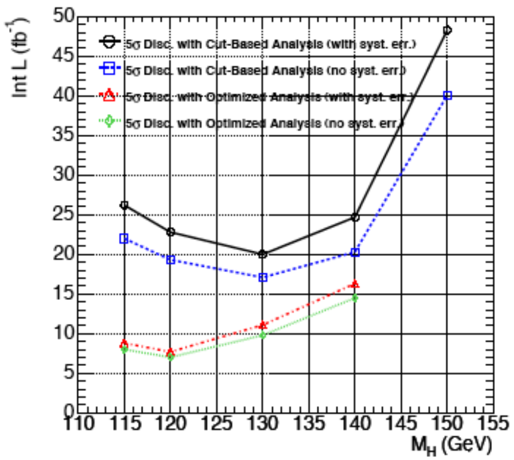


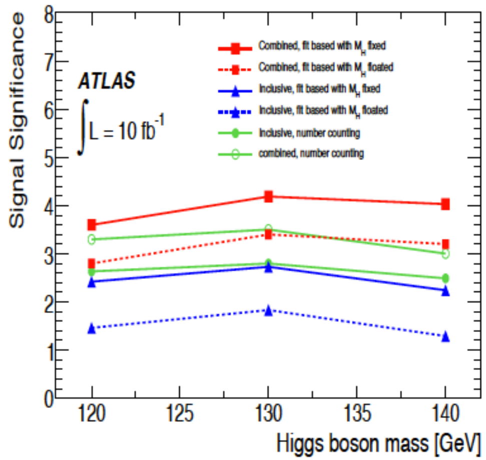
-look for γγ in all the Higgs production mode:
gg, VBF, VH, ttH
-Higgs can be fermiophobic, thus could be seen with low luminosity



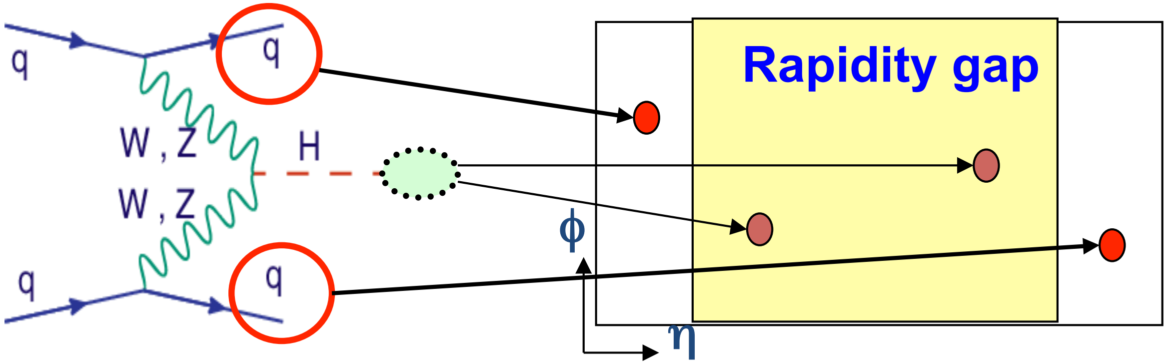


Experimentally challenging, because of the material in front of the EM calorimeter:
20% to 65% of photons convert into e+e- pair before reaching the EM calo





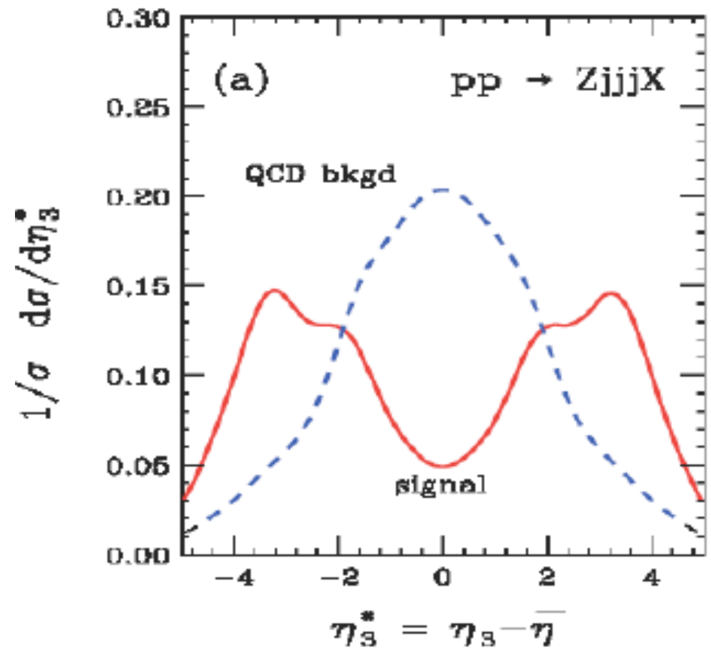
VBF: a peculiar signature



- Energetic jets in the forward/backward direction
  → **TAG JETS**
- Higgs decay products between the tagging jets

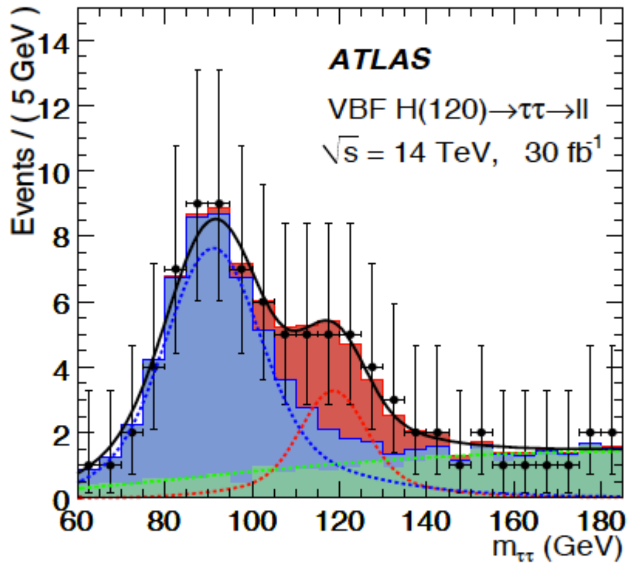
- Sparse gluon radiation in the central-rapidity region due to colorless W/Z exchange
  -> central jet veto

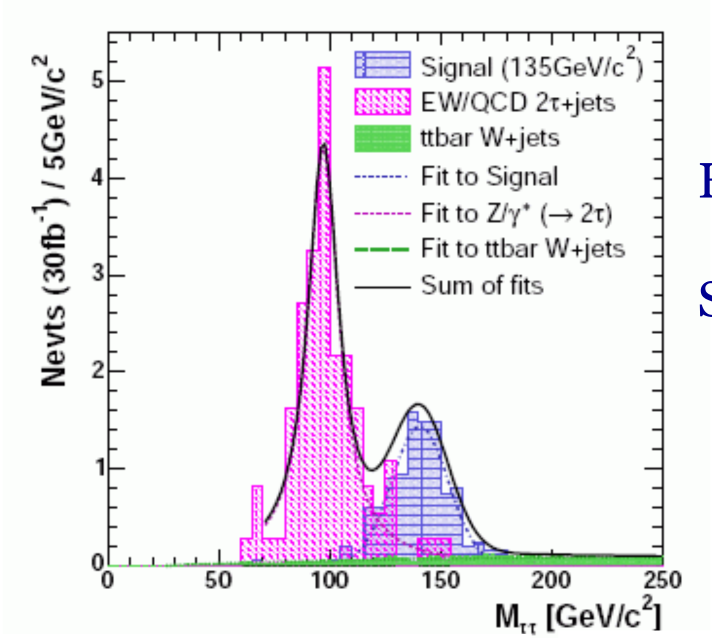
$$\eta_3^* = \eta_3 - \bar{\eta} = \eta_3 - \frac{\eta_j^{tag1} + \eta_j^{tag2}}{2}$$



born level distribution for Z + 3 jets
D. Zeppenfeld et al. (96)

VBF: H->ττ->l+jet



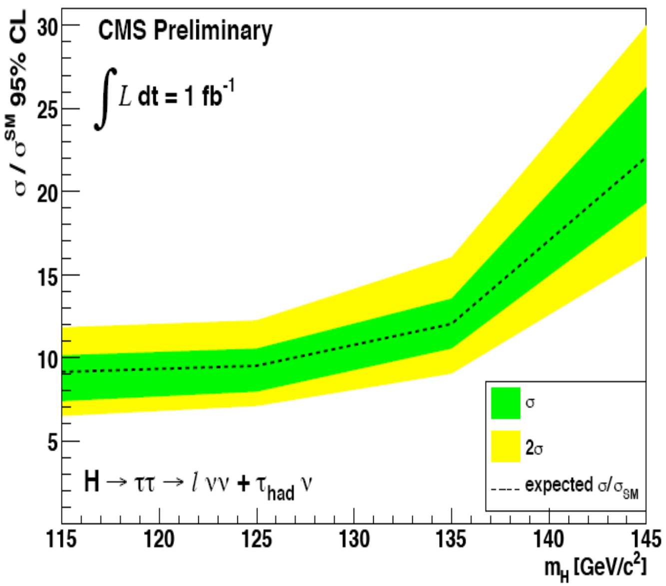


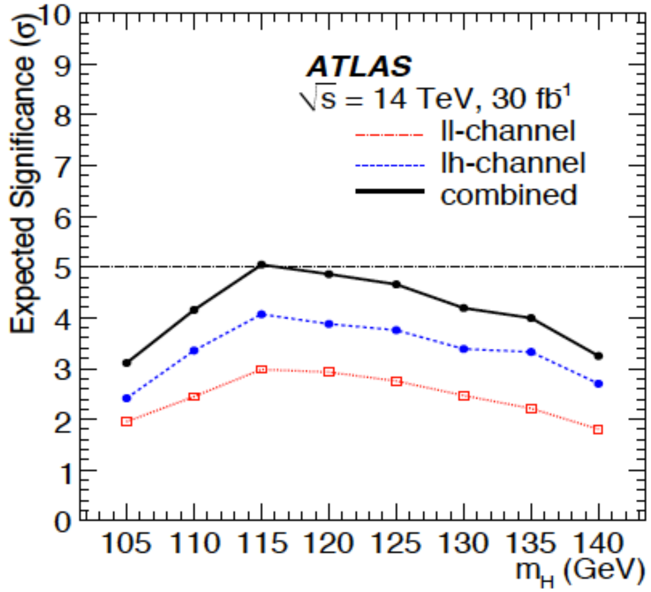
Higgs mass reconstruction possible.

Stringent cuts to suppress background

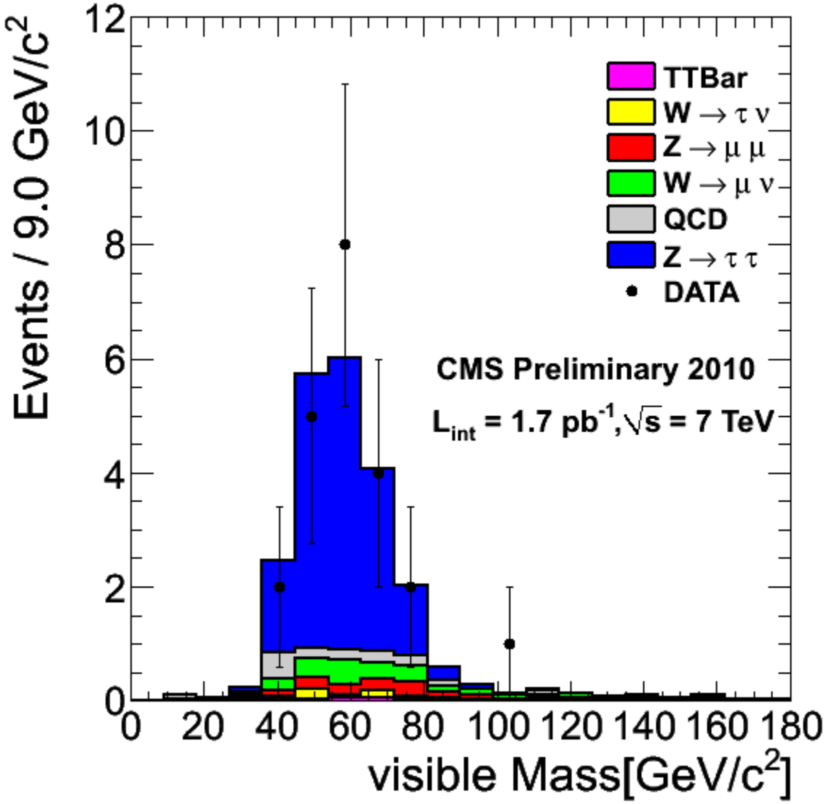
Luminosity is needed

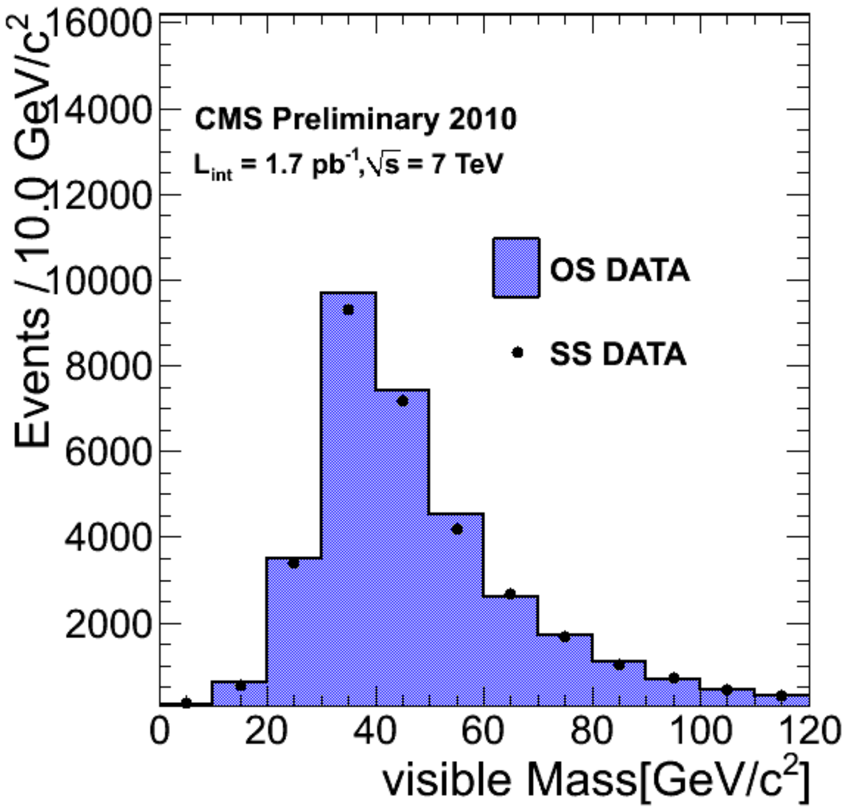
Important channel for the low mass region





Some data results on tau!





- **Mu Pt > 15 GeV/c**
- **Isolation**
- **Tau Pt > 20 GeV/c**

Measured:

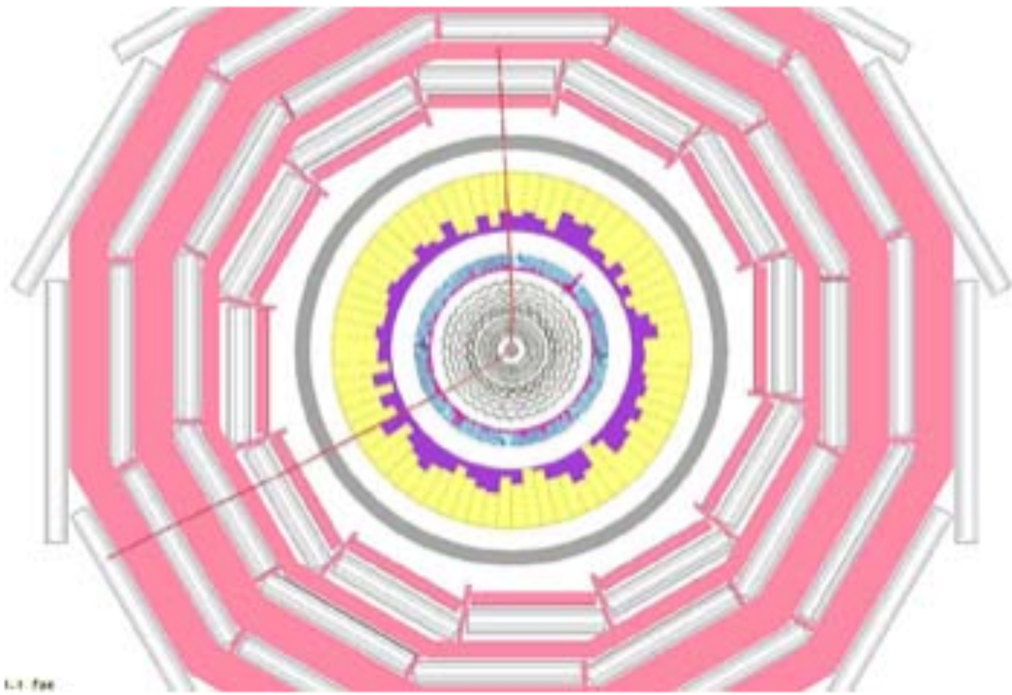
OS/SS = 1.03 +- 0.01(stat)

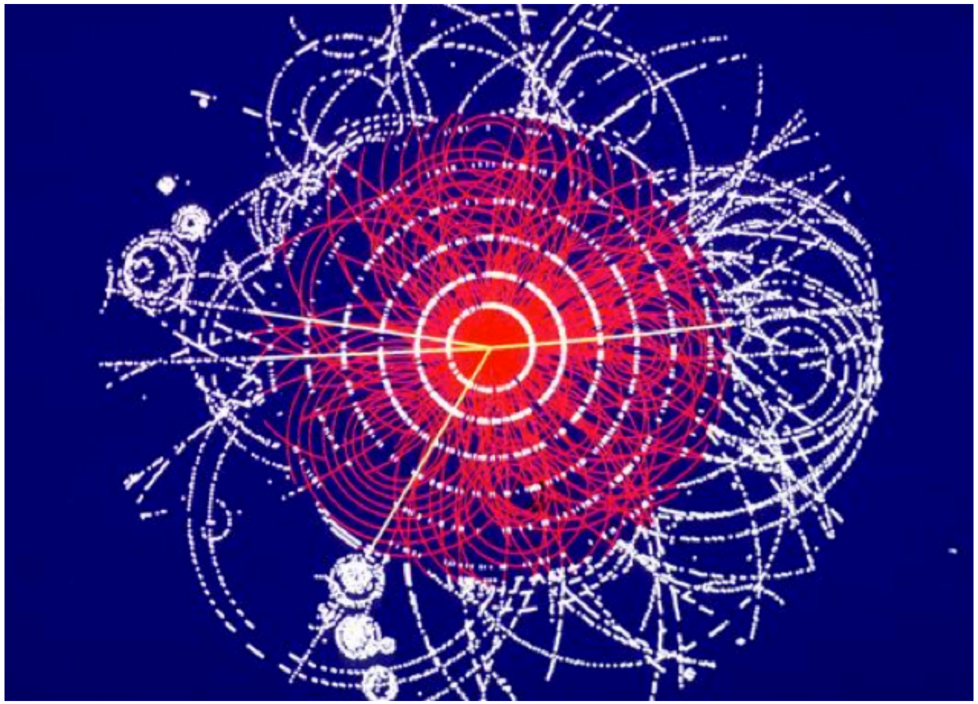
QCD MC expected value:

OS/SS = 1.036 +-0.002

Higgs: ZZ and WW final state

- WW and ZZ decays will cover basically the full range (production via gg and VBF)
- H->WW: higher cross section and first channel at LHC!
- H->ZZ : very clean and very good mass resolution



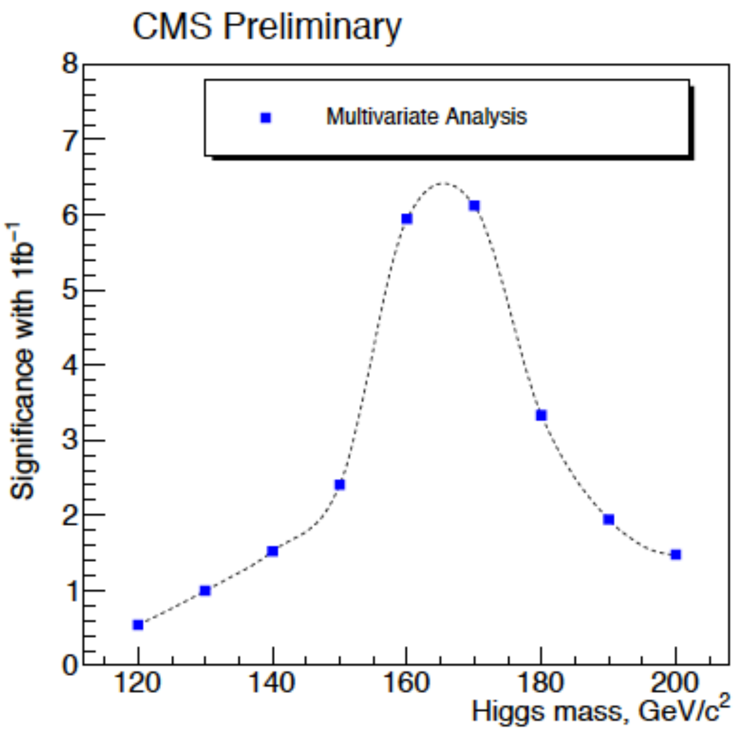


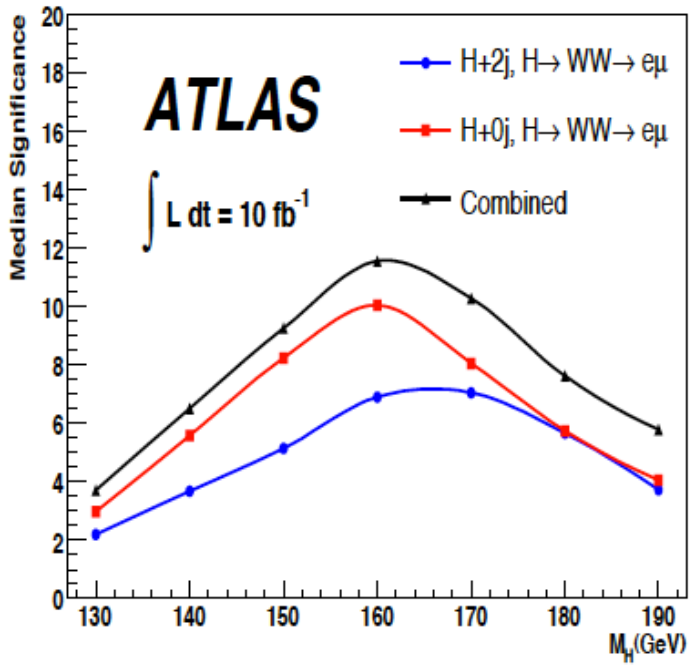
H→WW: Significance for 14 TeV

- H->WW->llνν : no mass peak
- The control of the background (QCD, tt, WW, W+jet, DY) is essential!

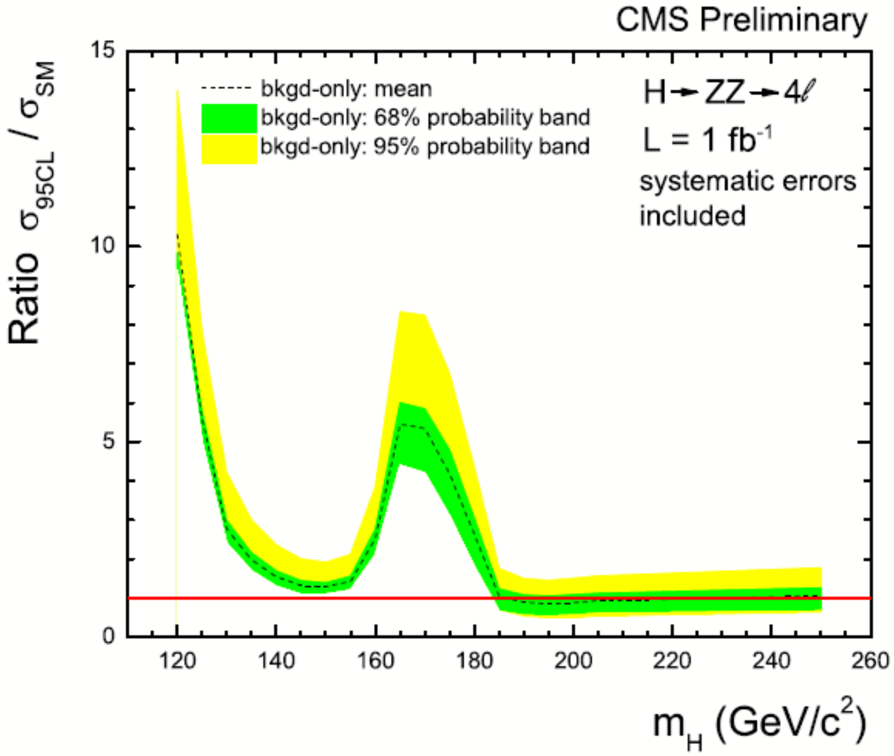
Experiments developed data driven methods to control the background

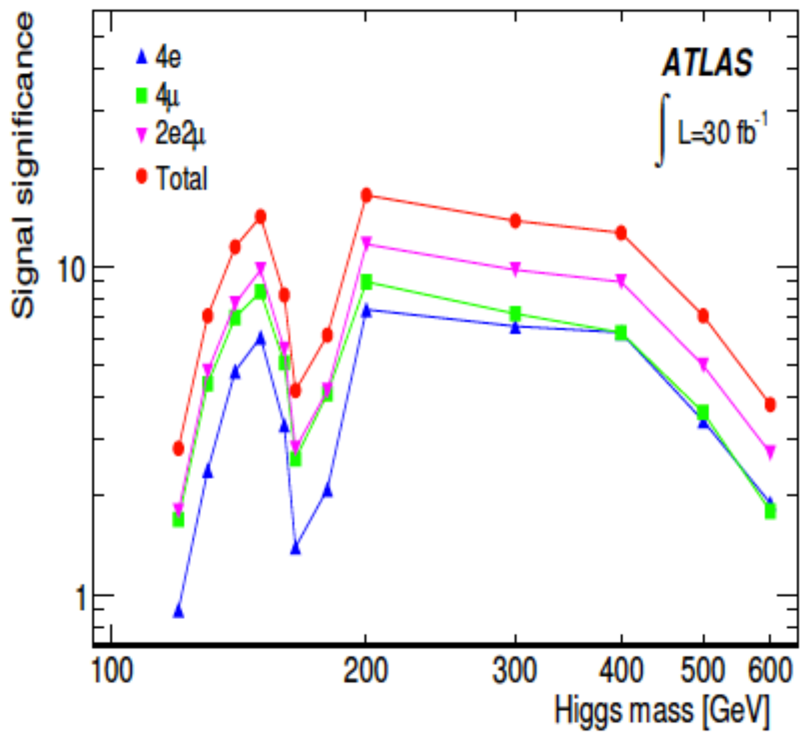
- Large cross section, so first exclusion/discovery channel!





H→ZZ→4l : the performance

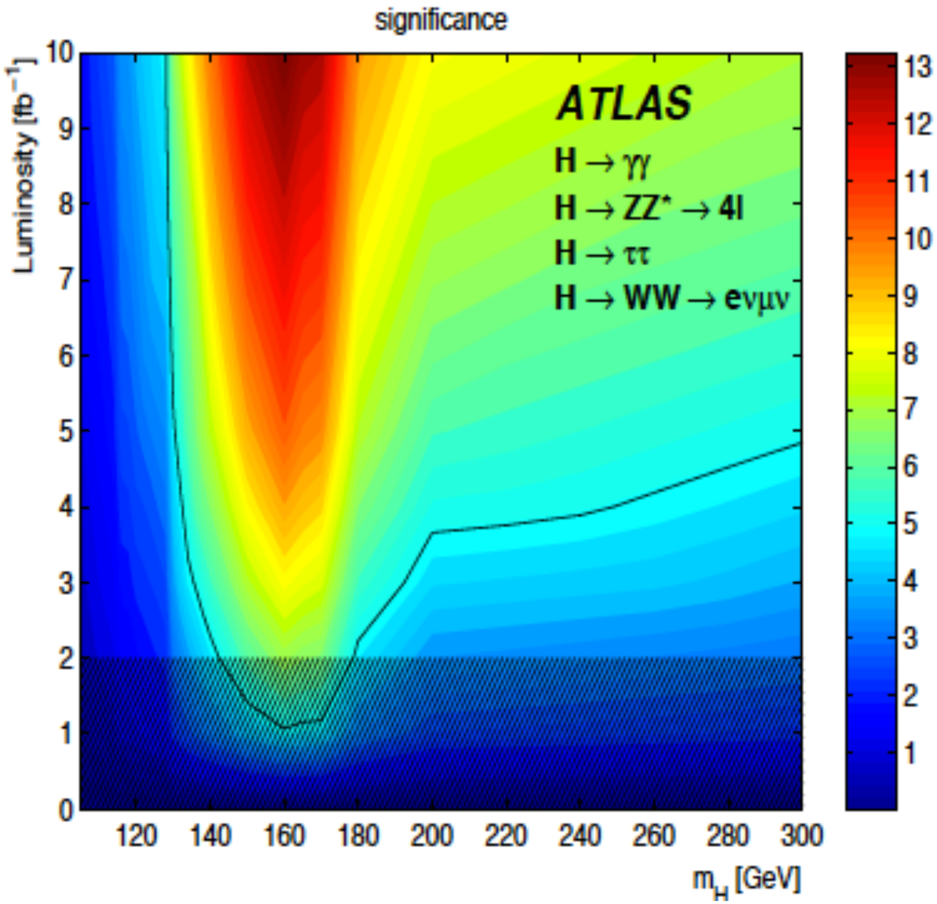


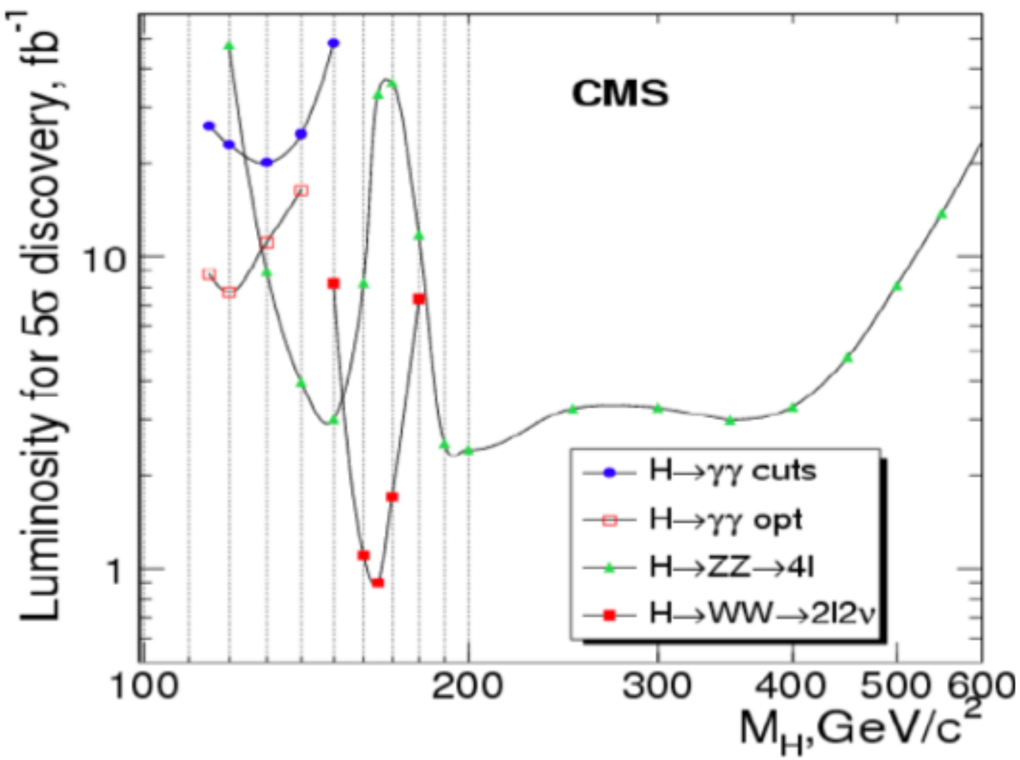


- Cross section limits for low luminosity: 5-10 events for mh=150-200 GeV with L=1fb^{-1} at 14 TeV

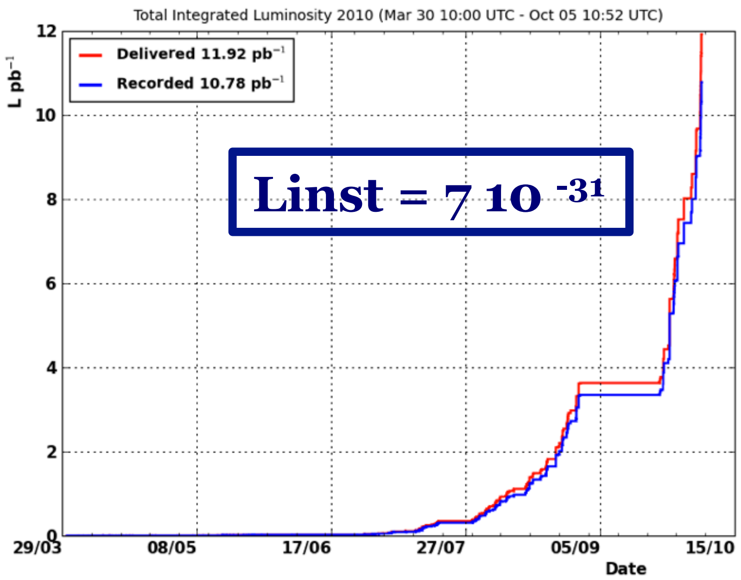
- For high luminosity a good discovery power over the full mass spectra

The Higgs potential at 14 TeV

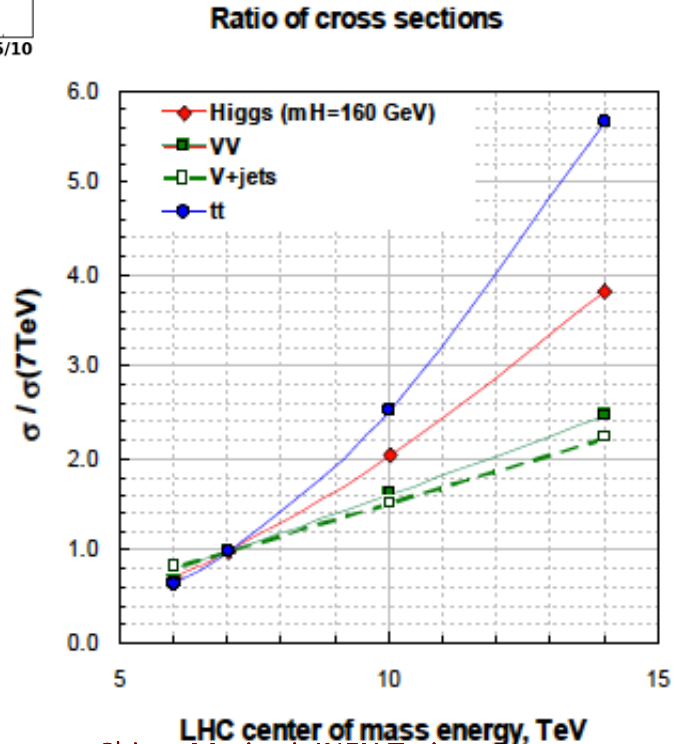




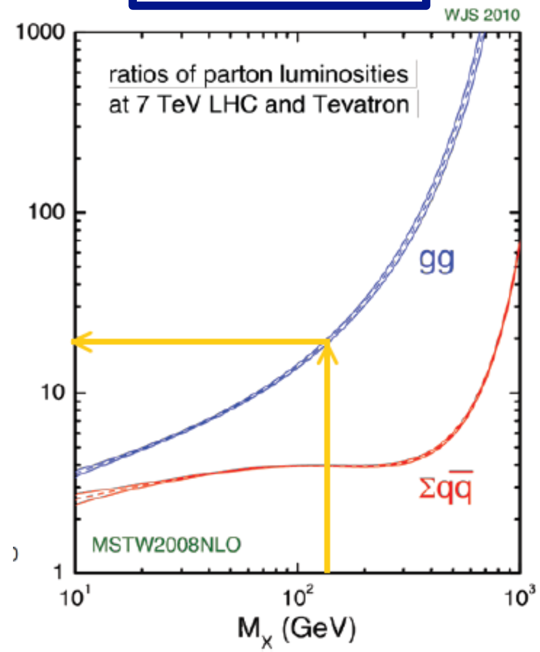
The 7 TeV run



14 vs 7 TeV



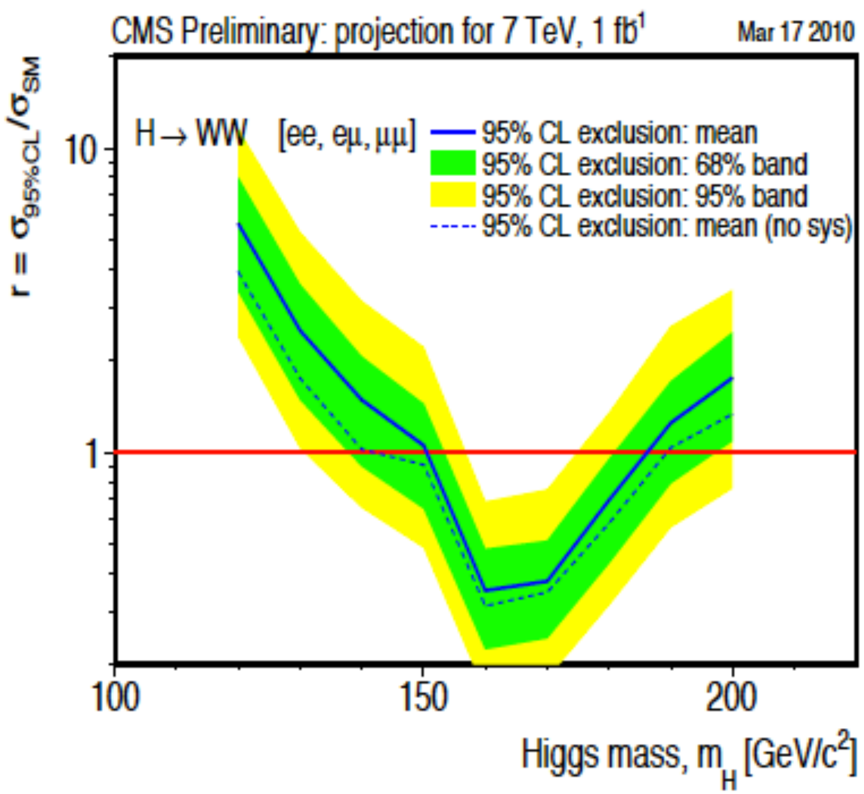
7 vs 2 TeV

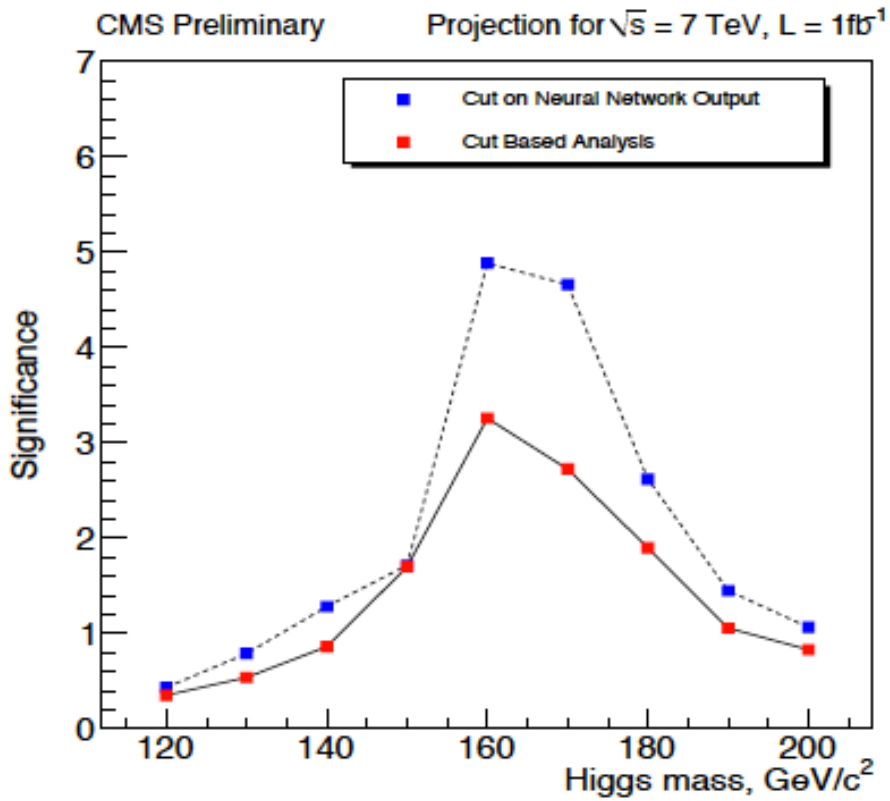


Projection for the 7 TeV run

- Projections obtained scaling the 14 TeV results to 7 TeV by the ratio of the cross sections. L= 1 fb^{-1}
- Efficiency is higher at 7 TeV, but maybe systematic will be higher too.

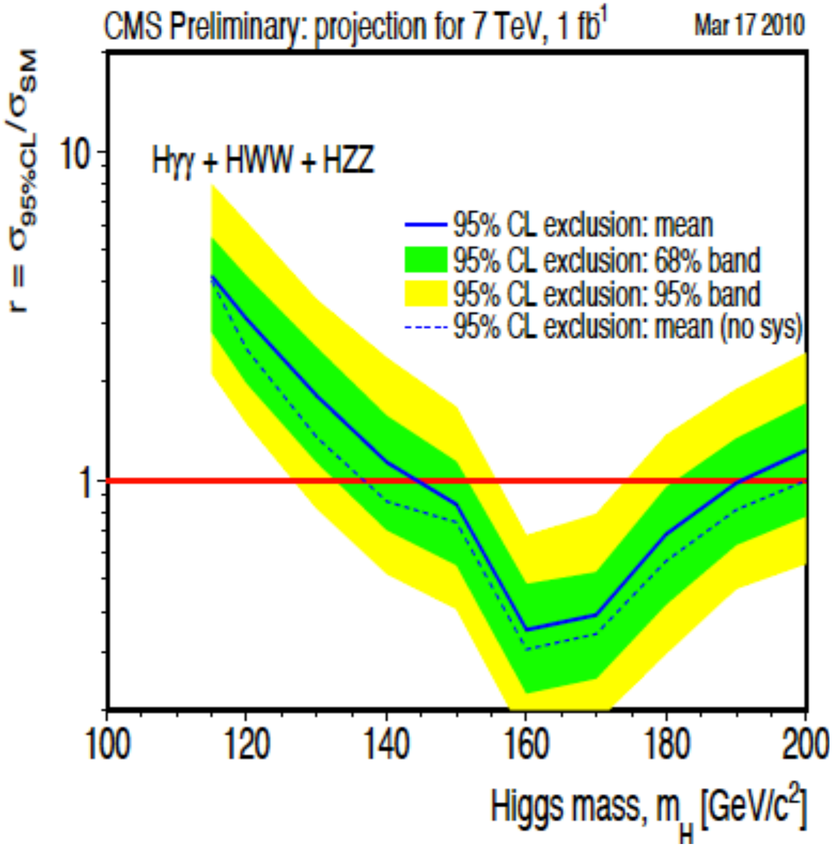
NNLO σ for the Higgs signal!

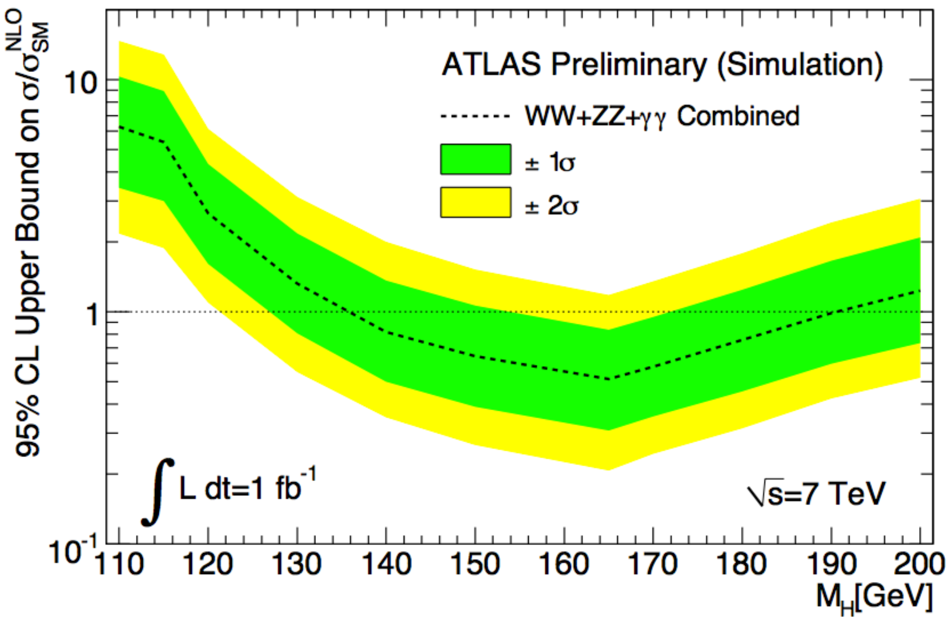




Atlas and Cms at 7 TeV

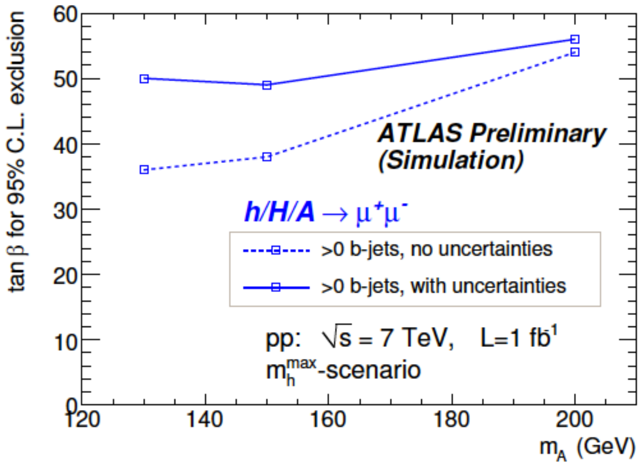
- SM Discovery reach sensitivity: 160-170 GeV
- SM Exclusion sensitivity ATLAS+CMS: 130-200 GeV

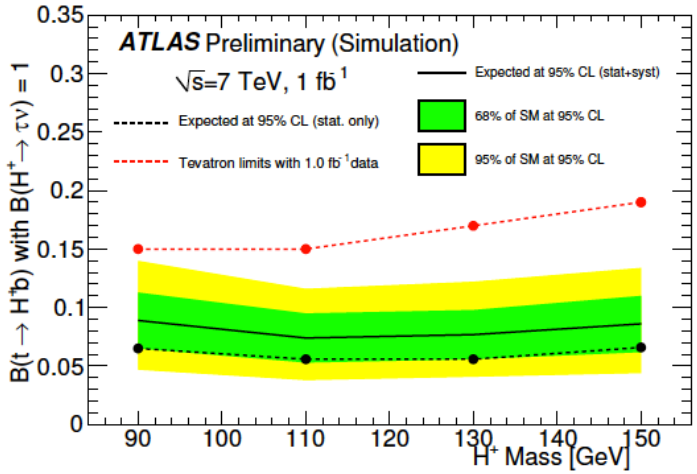


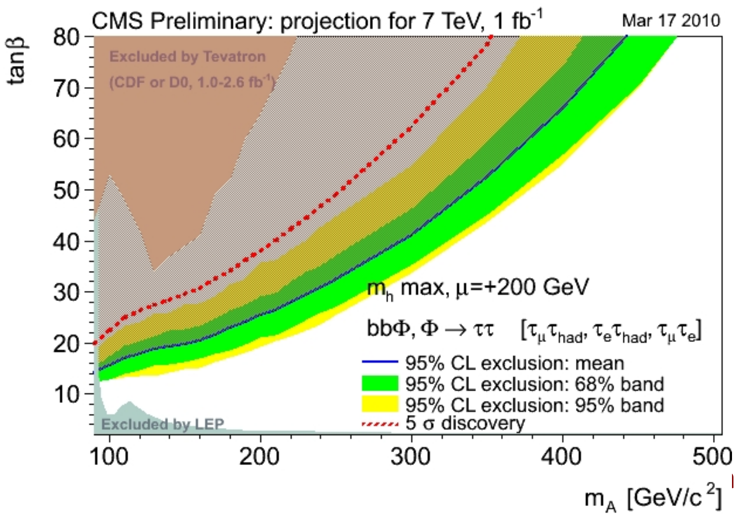


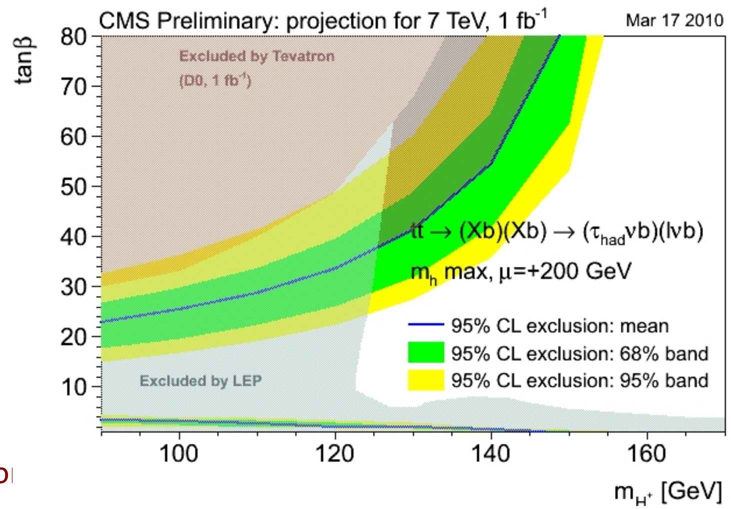
MSSM Higgs at 7 TeV

- MSSM neutral Higgs discovery reach: down to tanβ~20 at low m_A
- MSSM neutral Higgs exclusion reach: down to tanβ~15 at low m_A
- MSSM light charged Higgs: production rate is quite hig…
- Beyond SM/MSSM : a number of opportunities open…

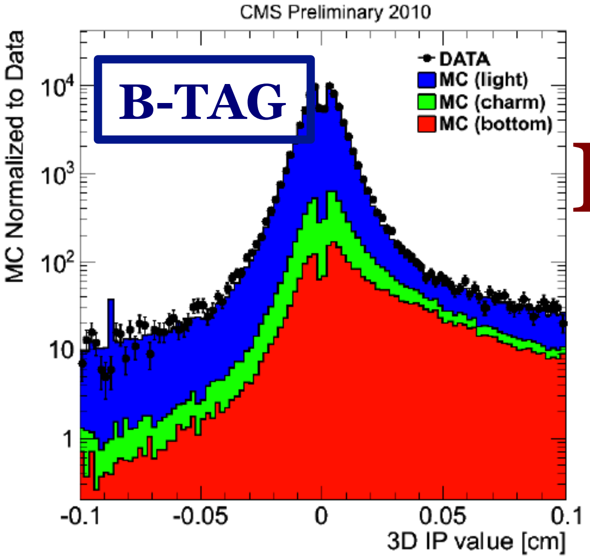


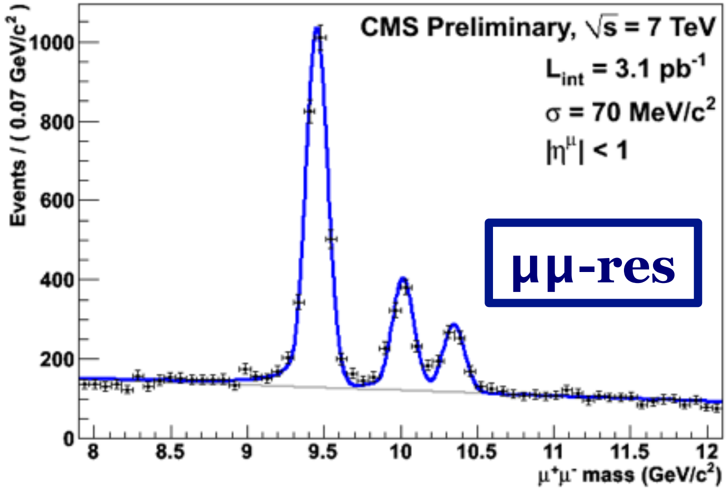


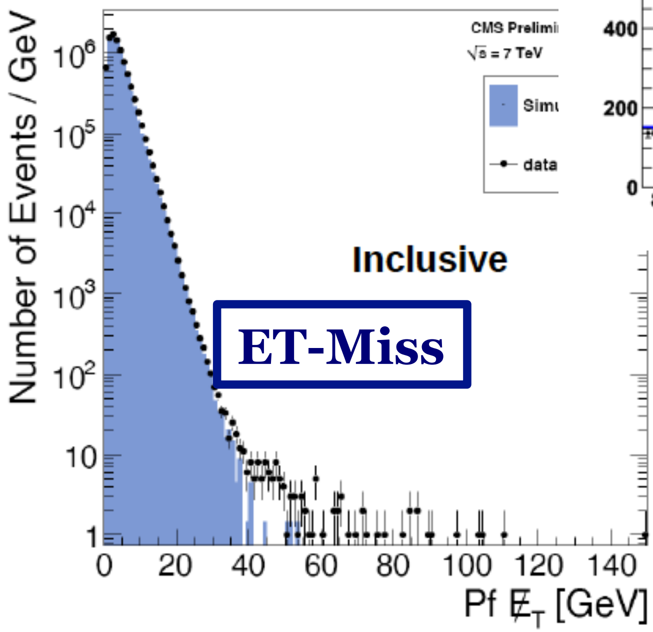


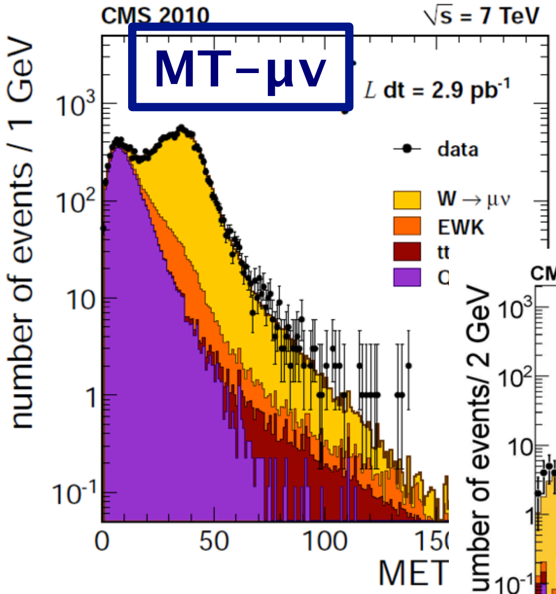


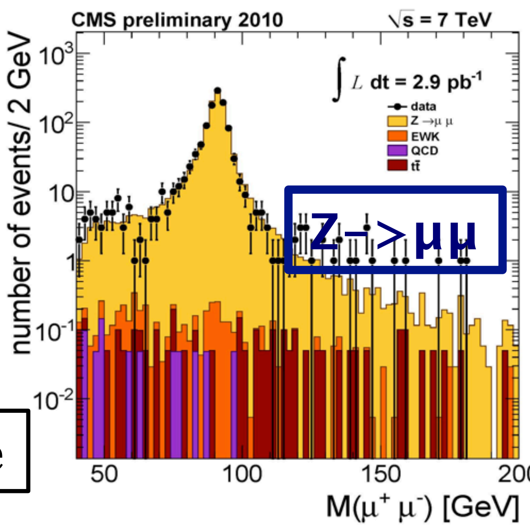
Excellent Performance

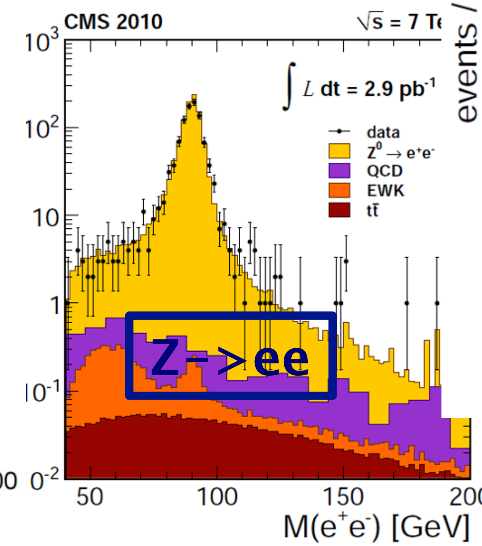


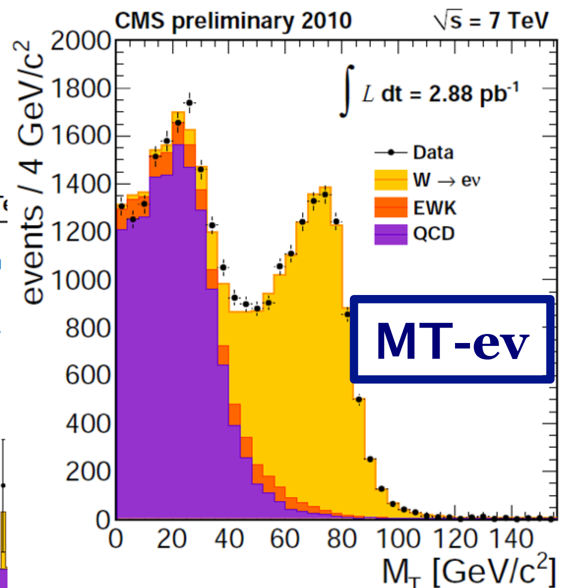






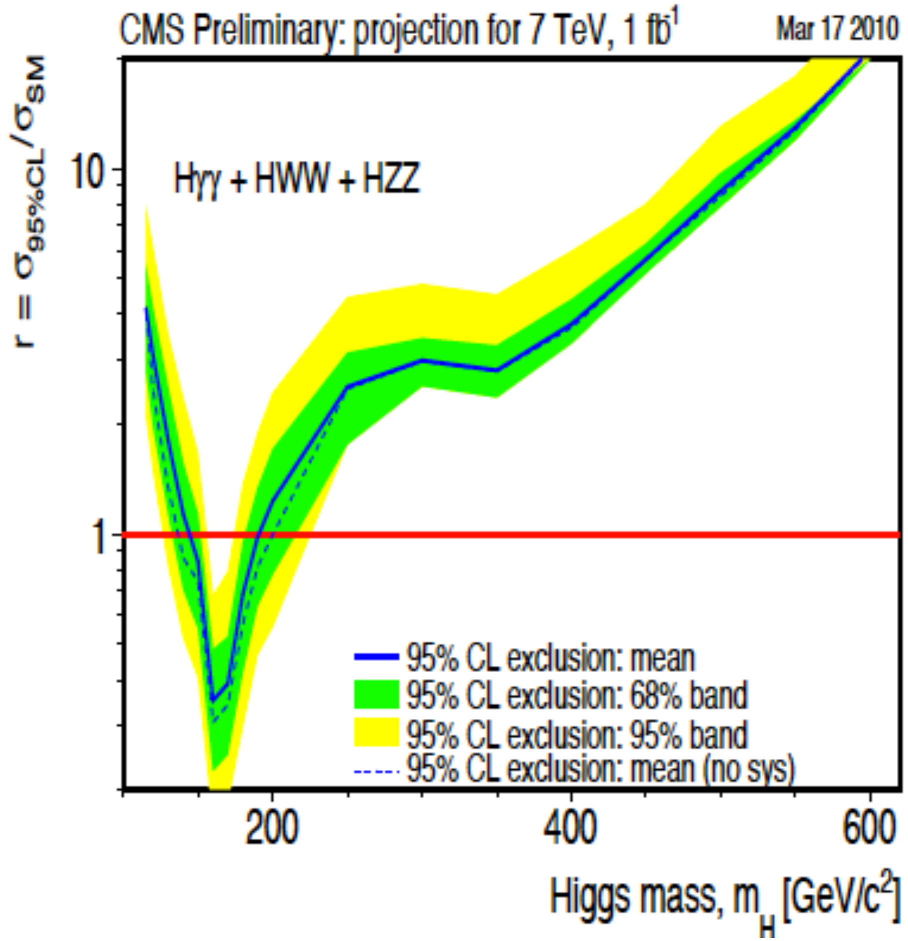






CMS as an example

Thus we can do better!



In the low mass region: VH, H->bb + VBF H, H->tau tau can be added
In the high mass region: H->ZZ->llbb, llvv + VBF H, H->WW can be added

allowing LHC to be able to probe a much larger mass range.

We should do it correctly!

The LHC Cross Section WG

- Access the best theory predictions for the Higgs Cross Section and Branching Ratio

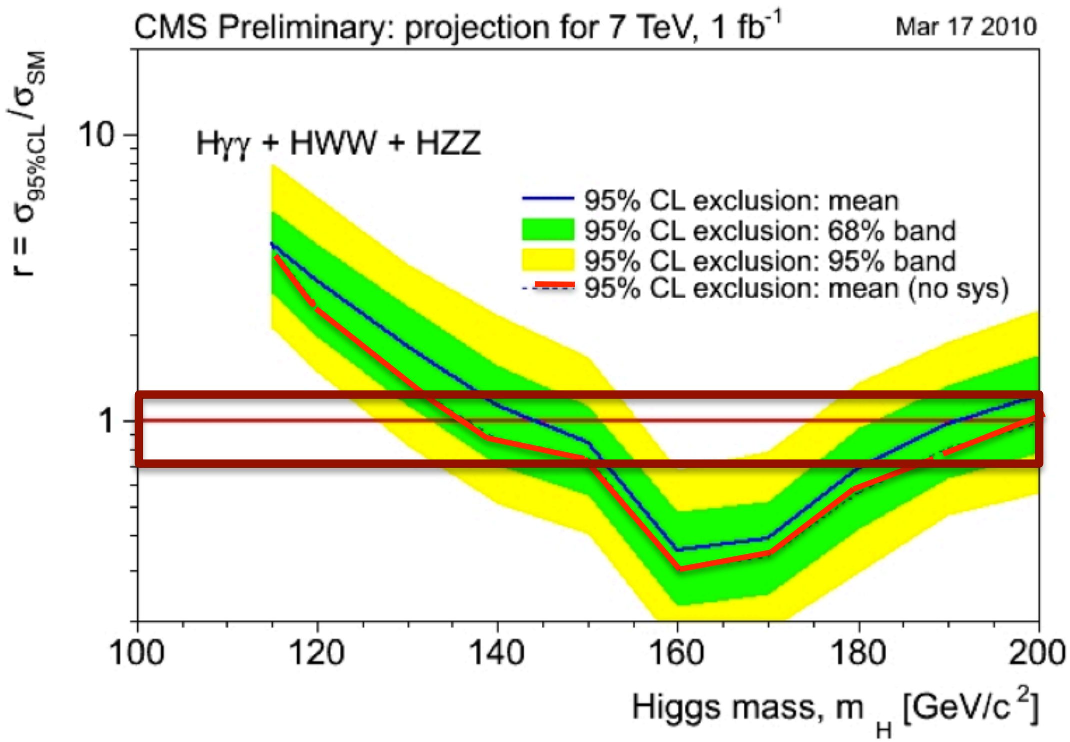
- Experiments will coherently use the common inputs based on the interaction with the theory to facilitate the combination of the individual results

Task: SM and MSSM Higgs Cross Section and BRs

- Use the same Standard Model input parameters
- Strategy on uncertainties (scale, α_s, PDF, etc.)
- Monte Carlo at NLO for the signal
- Define pseudo-observables
- Cross sections of background in Higgs region

Uncertainties

- The **experimental uncertainties** will determine the blue/red lines + the green/yellow band
- The **theoretical uncertainties** on the signal will determine where is the horizontal line. The theoretical uncertainties on the background will contribute to the red/blue line +green/yellow band

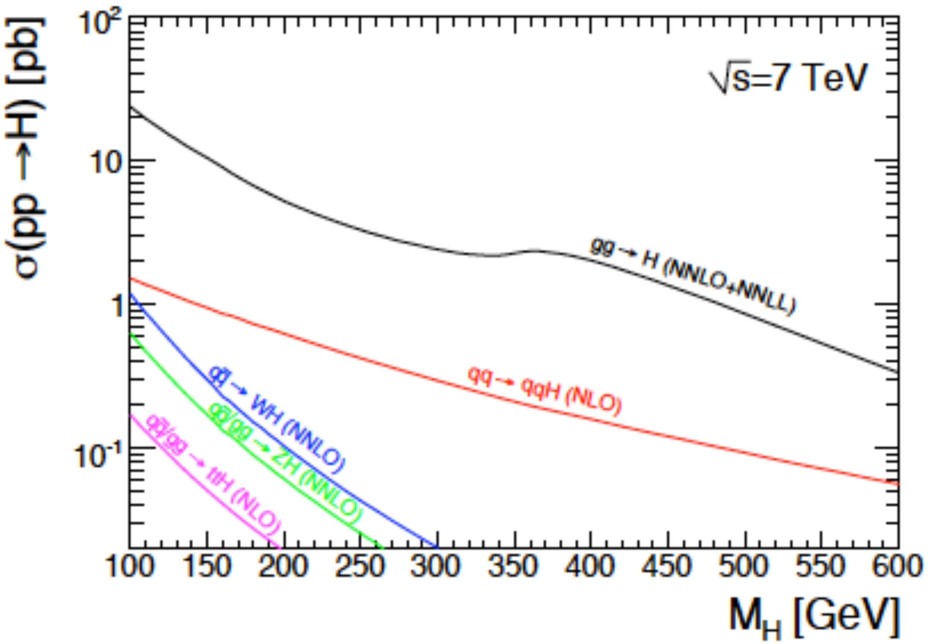


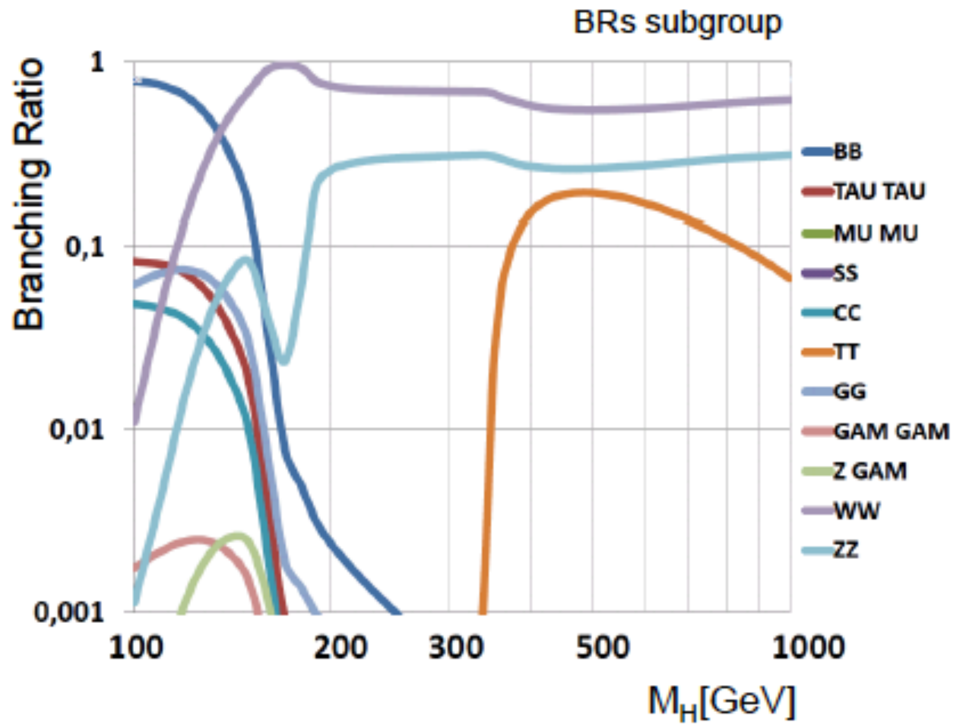
PDF: the groups followed the PDF4LHC prescription.

α_S: added in quadrature to the PDF variation. Still debate on the total uncertainty:
$\delta\alpha_S$ = 0.0007 – 0.002 0.0044 ?

QCD scale: it gives the largest of the effect. It has been varied with reasonable criteria in order to cover the "unknowns"

The cross section and BR





Process	order	QCD scale	PDF+α_s	Higgs mass range
ggF	NNLO	±8-6%	±4-6%	MH=[100,600]GeV
VBF	(N)NLO	±(2) 4-9%	±2.0-2.5%	MH=[100,600]GeV
WH	NNLO	±0.1-0.6%	±1.8-2.2%	MH=[100,300]GeV
ZH	NNLO	±0.8-2.0%	±1.8-2.2%	MH=[100,300]GeV
ttH	NLO	+4-10%	±3.2-3.9%	MH=[100,300]GeV

From the LHC Higgs XS W.G.

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CrossSections

Proposal of future work

- To compute cross section within acceptance:
  establish a common ATLAS and CMS
  "MInimal but ReAlistiC AnaLysis Setup" for first analysis in each channel group.

- Study and provide guidelines for TH uncertainties

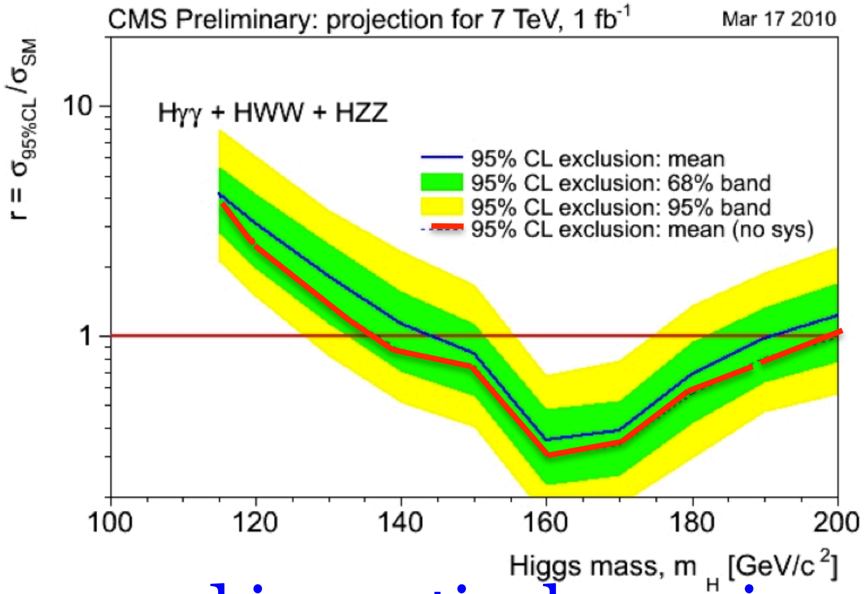
- Identify the **background** of a given "production * decay" channel

- TH uncertainties on the background, and then use the data to validate/tune the background MC estimations.

- Start addressing more advance question: are there ways to use data to validate the signal MC?

The experimental side

- The first step is "exclusion". This mean background understanding. In case of no Higgs signal, what we observe is "background only".



- BUT background in particular region of the parameters.
- Experiments should validate the MC in these regions and in the "control regions" , where the experiments control the background with "data driven methods"

Summary

- The 7 TeV run will allow the LHC to eventually exclude the SM Higgs mass in a very wide range, and to access new regions of the MSSM

- The 14 TeV run will allow the discovery of the Higgs and with higher luminosity the study of its properties

- A large theoretical and experimental community is active to precisely prepare for the Higgs physic era and to facilitate the combination of the results.

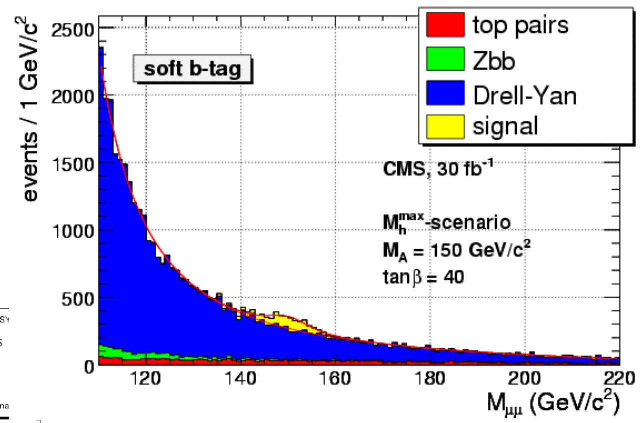
Backup

Higgs: Low Mass (M<130)

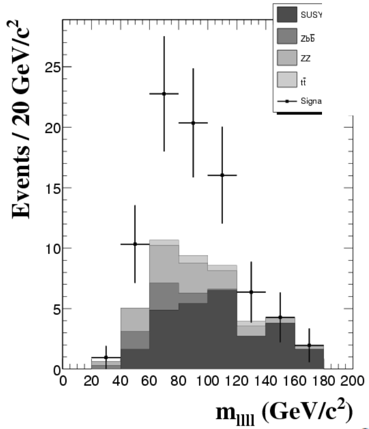
- The highest BR is into b-quarks
- Gamma-gamma has low BR, but is clean, provided a very good mass resolution
- WW and ZZ have much-lower BR but they will contribute!

	Tevatron Main Search Channels	LHC Main Search Channels	Luminosity for discovery at LHC
High BR	WH → lvbb ZH → vvbb, llbb	H→γγ qqH →qqττ WH → lvbb , high pT Higgs ttH →lvqqbbbb	~ 10 fb-1 ~ 30 fb-1 ~ 30 fb-1 ?
Lower BR		H→WW→lvlv H→ZZ*→4l qqH →qqWW→qqlvlv	> 30 fb-1 > 30 fb-1 >> 30 fb-1

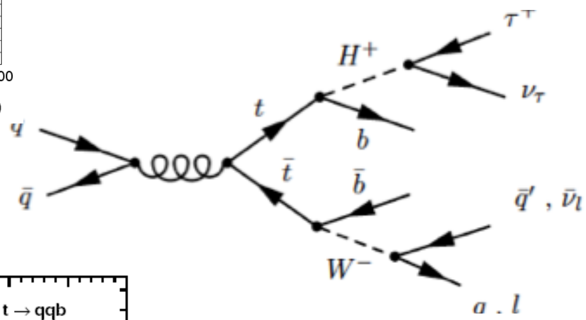
SUSY Higgs



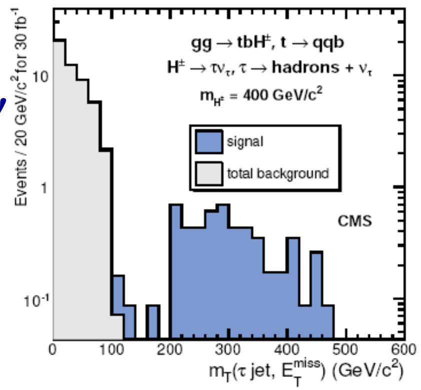
- Neutral ϕ=h,H,A:
  large tanβ --> bbϕ, ϕ -> $\mu\mu$, $\tau\tau$
  low tanβ --> A->Zh, Z->ll, h->bb



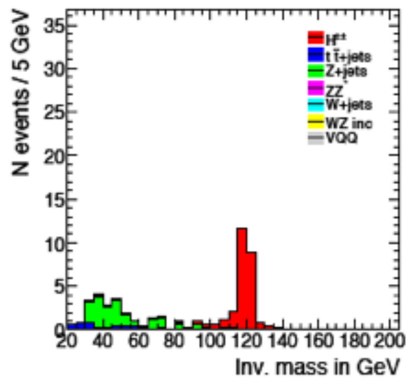
- A/H -> $\chi_2^o\chi_2^o$ ->4l +E_t^{miss}



- Light Charged Higgs: pp->tt->WbH$^+$b, H-> $\tau\nu$

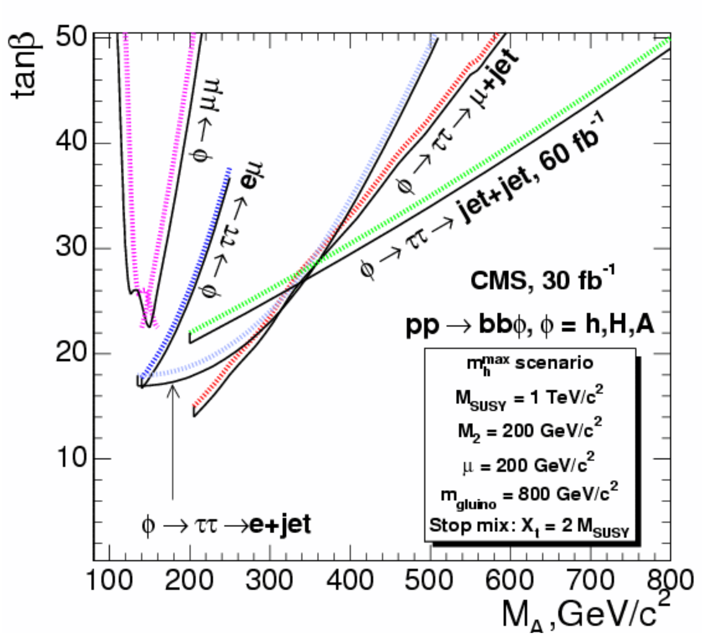


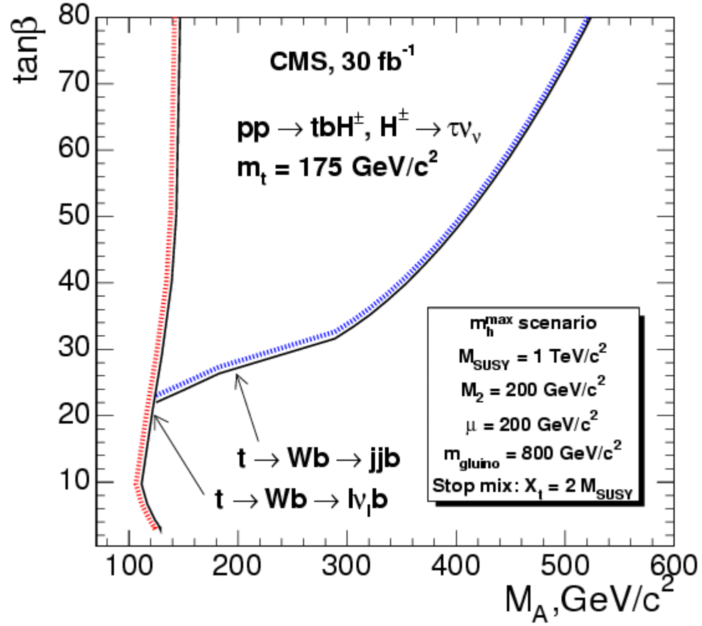
- Heavy Charged Higgs: pp->tH$^+$, H$^+$->$\tau\nu$

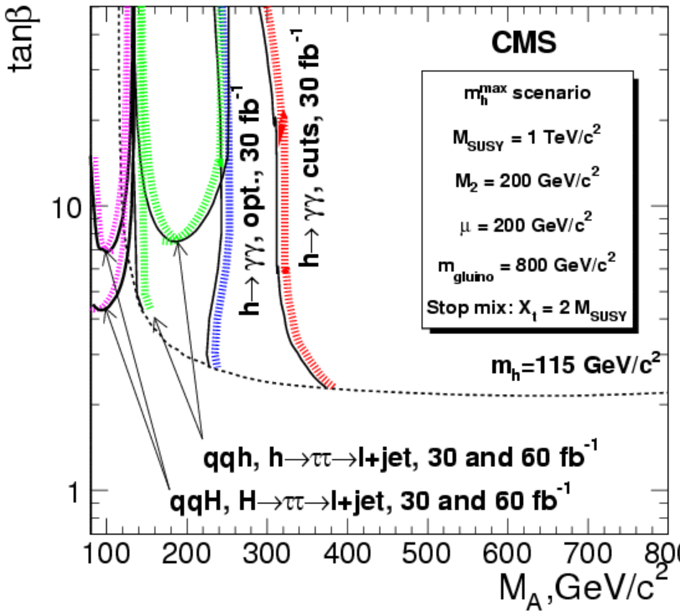


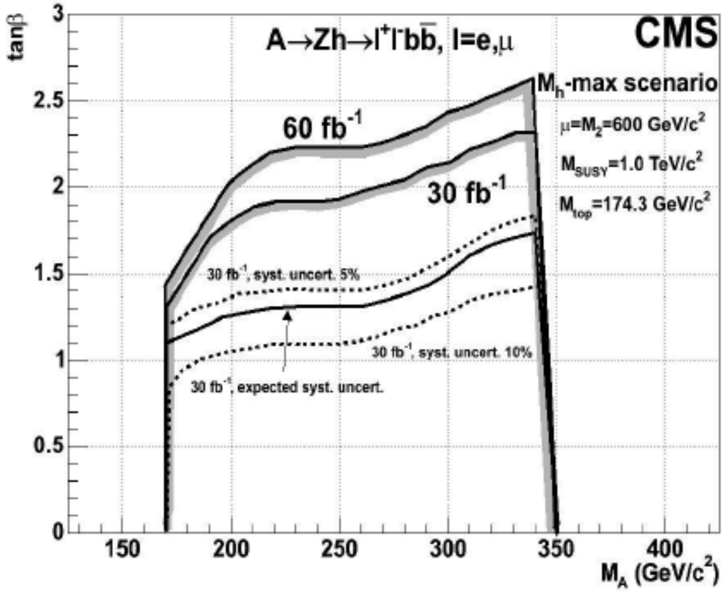
- Double charged: H^{++}H^{--}-> 4l ->e$^+\mu^+\tau^-$e$^-$

The CMS reach in M_A-tanβ at 14 TeV

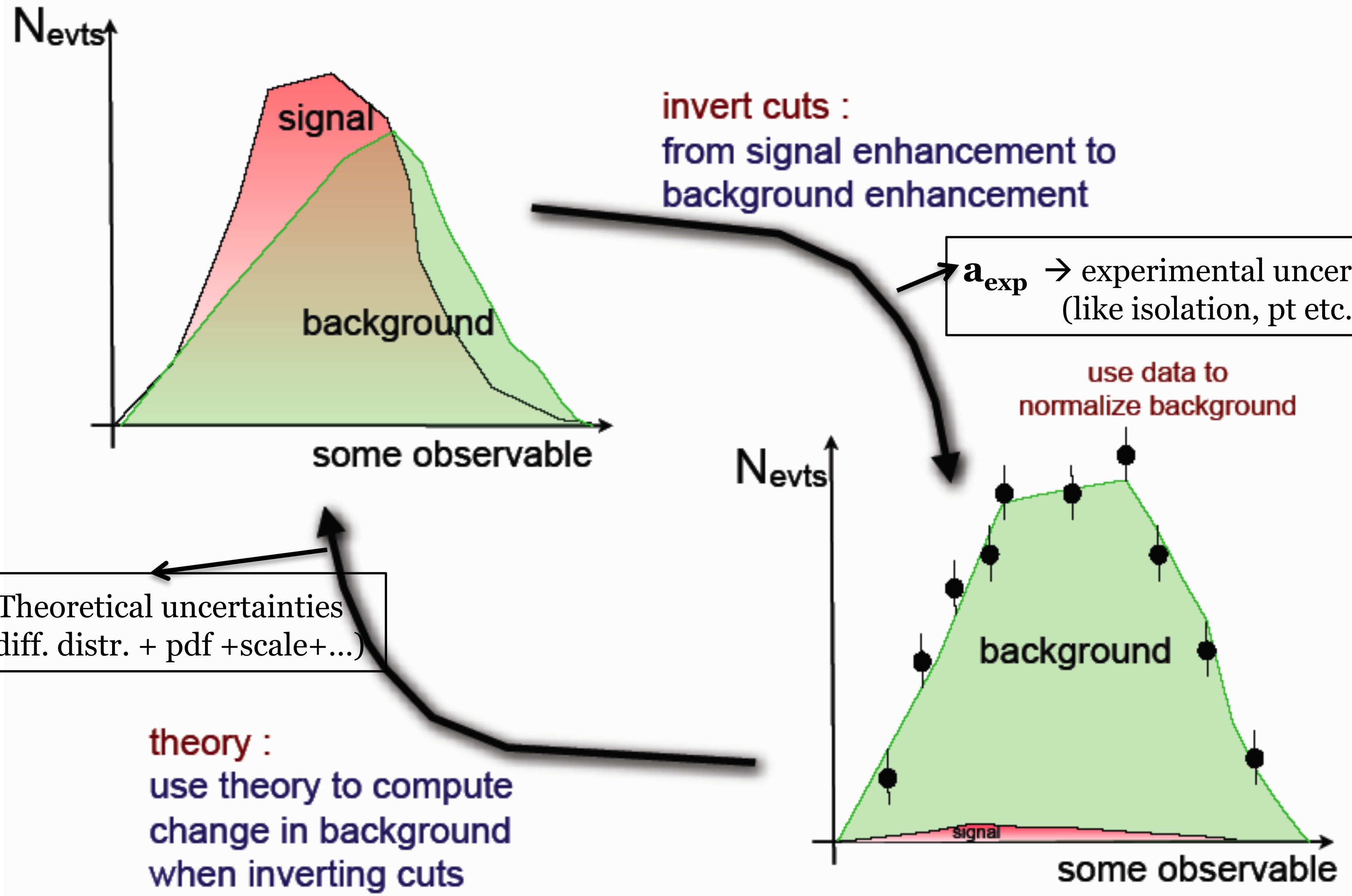








The control of the background



a_{exp} → experimental uncertainties (like isolation, pt etc…)

a_{TH} → Theoretical uncertainties (diff. distr. + pdf +scale+…)

$N^B_{(signal\ region)} = a_{exp} * a_{TH} * N^B_{control\ region}$

a_{exp} - uncorr between exp
a_{TH} - 100% correlated

Pseudo Observables

- What the experiments observe in the final state is not always directly connected to the theoretical variable.
  In between there is
  - the acceptance of the detector (cuts),
  - the interference of signal and background
  - and "approximations"
    (like production x decay)

- A corrected definition of the Higgs mass and width, i.e. of all the "pseudo-observables" is needed.

- Ex: The mass is the real part of the complex p of the propagator → is this correct definition in the MC generators?