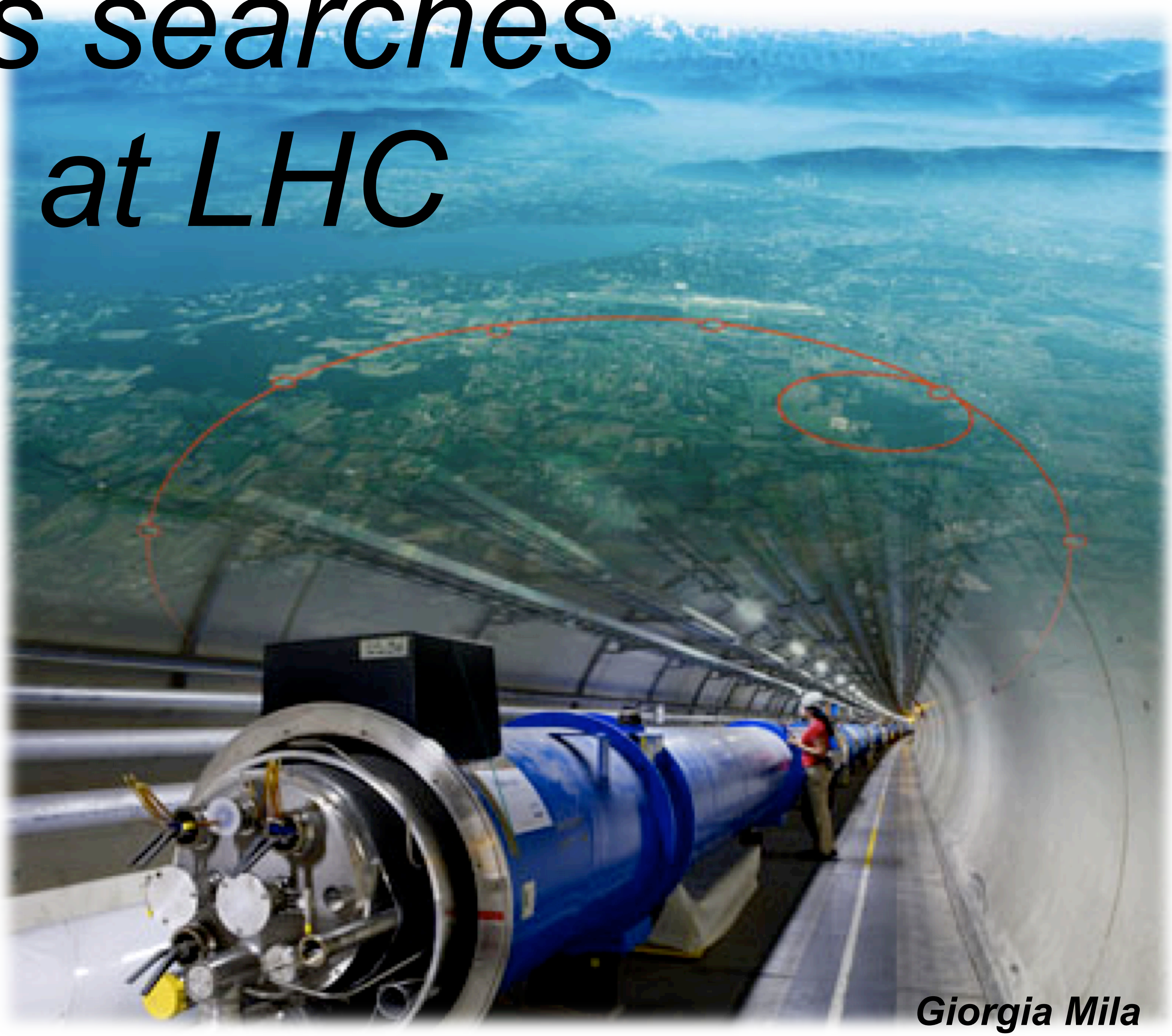
Higgs searches at LHC



Physics in Collision
Perugia, 28-06-08

Giorgia Mila
University of Turin

Outline

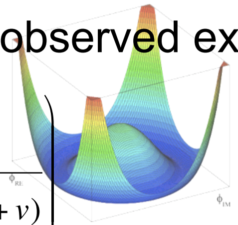
- Overview on the LHC
- Higgs boson production channels
- Higgs decay modes
  - Low masses searches
  - H→VV channels
- Higgs detection strategies
- Higgs discovery potential with the first data

the Higgs boson & LHC

The Higgs boson mass is the only yet unknown free parameter of the SM.

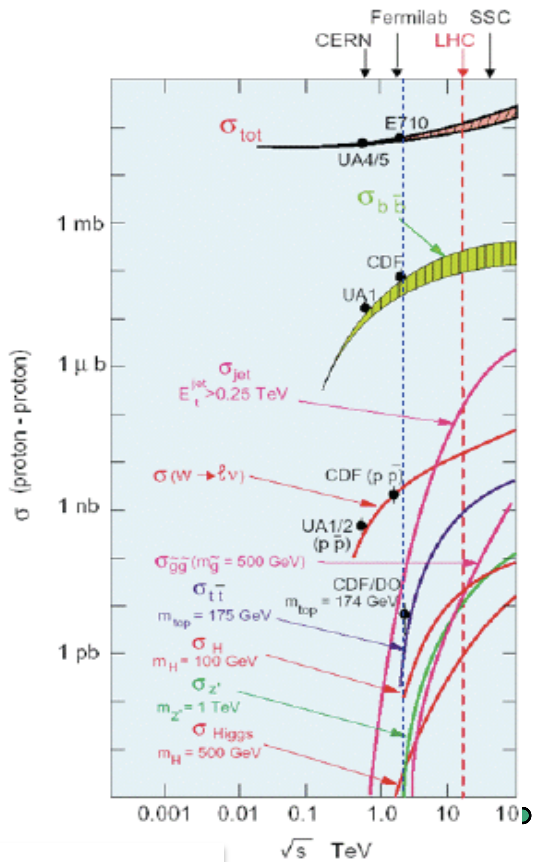
In fact it has never been observed experimentally and its mass cannot be predicted theoretically.

$$\varphi = e^{\frac{i}{v}\xi_a t^a} \begin{pmatrix} 1 \\ \frac{1}{\sqrt{2}}(\lambda + v) \end{pmatrix}$$



If such a particle exists,
LHC will be able to product it.

LHC		
	circumference	27 Km
	luminosity	$10^{33}/10^{34}$ cm^{-2}s^{-1}
	$\sqrt{s}$	14 TeV



Higgs processes xsec:
from **fb** to **pb**

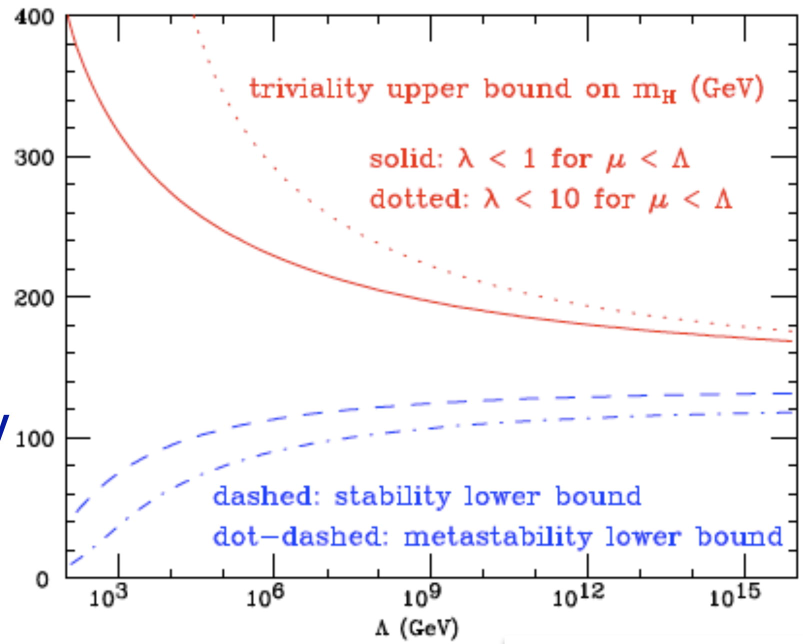
Minimum Bias = $10^{13}\times$sgn

Gain of a factor 40 Vs Tevatron at fixed lumi

Theoretical constraints :

for $\Lambda \approx 1$TeV, M_H up to 700GeV

➔LHC designed for Higgs searches up to masses of ≈ 1TeV



M_H experimental constraints

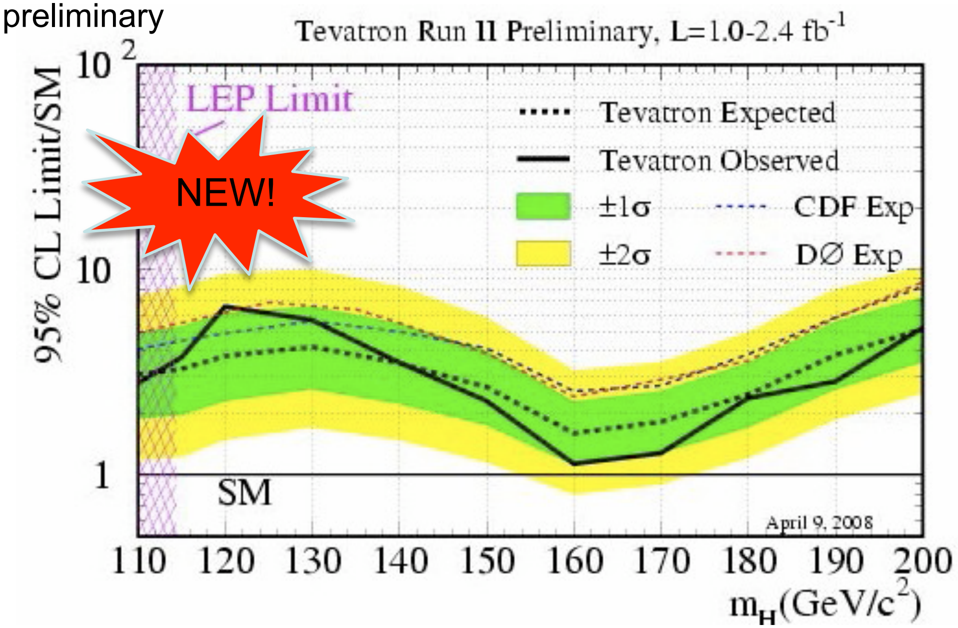
from **LEP** direct searches :

$$M_H > 114.4 GeV/c^2 \quad \text{(at 95\%C.L.)}$$

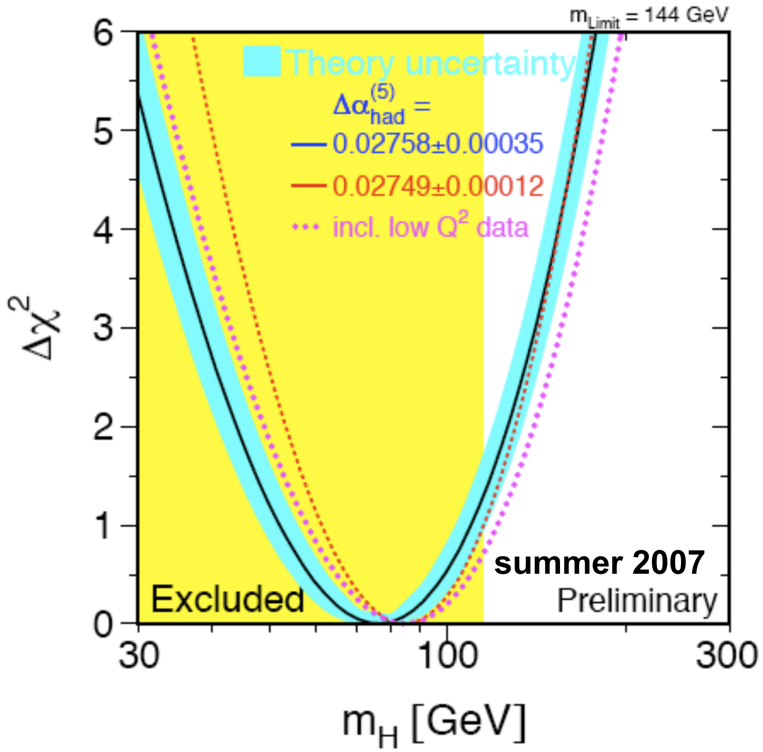
from indirected searches (**SLD,CDF,D0**) :

$$M_H = 76^{+33}_{-24} GeV/c^2 \quad \text{(at 68\%C.L.)}$$

winter 2008
preliminary

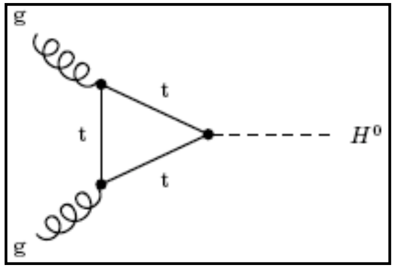


[from Gregorio Bernardi talk at the CMS Higgs WG meeting (may-08)]



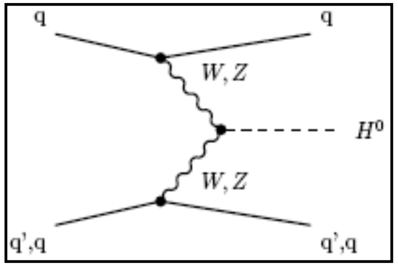
- Collected >3 fb^{-1}, expected 6 or 7 fb^{-1} by the end of 2009
- With 1.9 fb^{-1} analysis close to exclude wide mass range ($M_H \approx 160 GeV/c^2$)

Higgs production channels



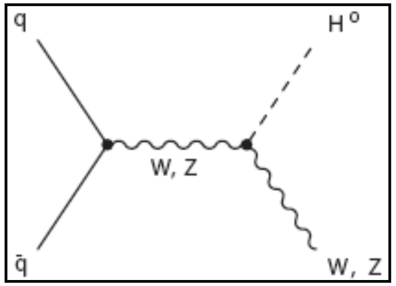
gluon-gluon fusion

- large NLO QCD corrections ($\sigma_{NLO} \approx 2\sigma_{LO}$)
  - ? gluon structure function
  - ? fourth quark generation



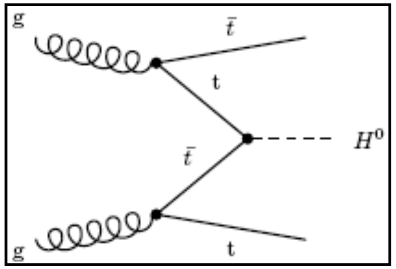
VV fusion

- clear exp. signature
- cross section well known
- small QCD corrections



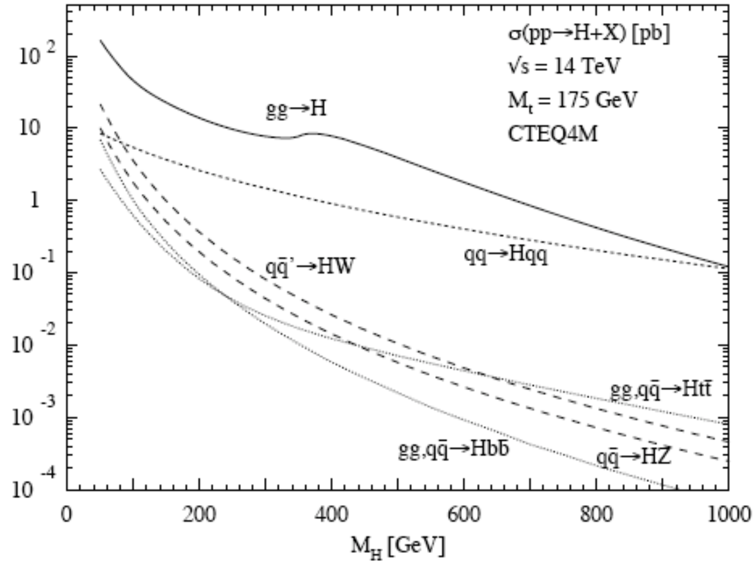
Higgsstrahlung

- quite large QCD corrections ($\sigma_{NLO} \approx 1.3\sigma_{LO}$)



$t\bar{t}$ associated production

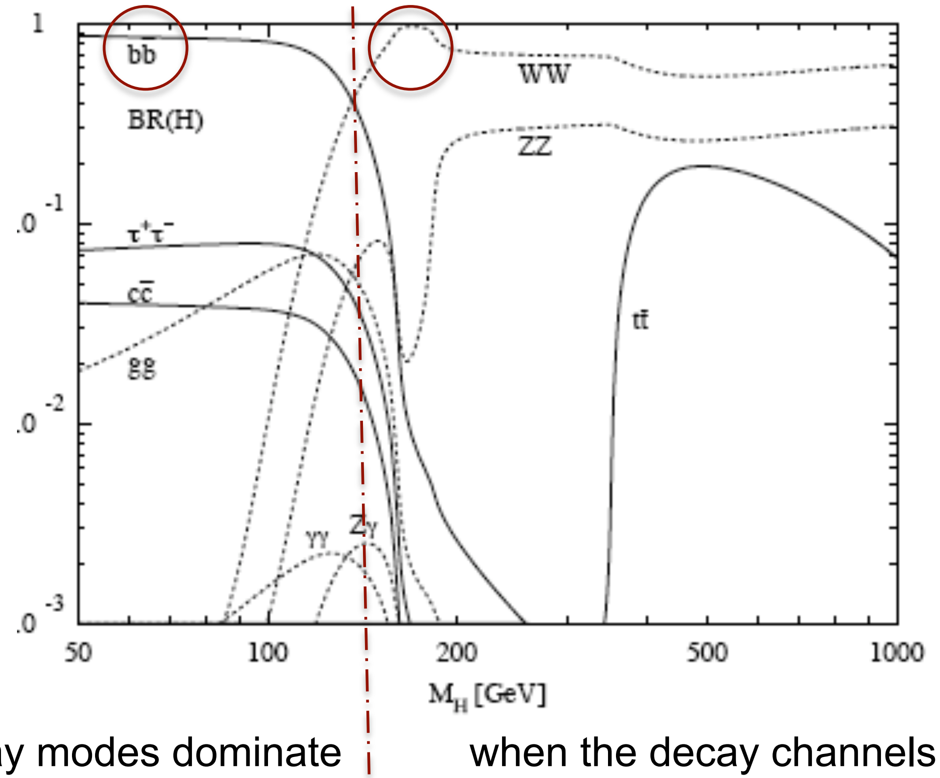
- good exp. signature
- quite large QCD corrections ($\sigma_{NLO} \approx 1.2\sigma_{LO}$)



Higgs decay modes

Higgs boson decay channels branching ratio Vs Higgs mass

note!
high BR decays are not always the most promising discovery channels
(they need also of clear signature - high S/B)



fermionic decay modes dominate the BR ratio for M_H<150GeV/c^2

when the decay channels into VB pairs open up, they quickly dominate

different analysis strategies for different Higgs mass range

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low masses searches

- Low Higgs mass favored by EW precision measurements

- **Experimentally, most difficult mass region:**

  - with M_H<130 GeV the most promising decay channels are **H→γγ/ττ** (σ ≈ 50/100 fb)
    - very high background rate, also from fakes (for ex. $\sigma_{\gamma j} \approx 10^3 \sigma_{\gamma\gamma}$, $\sigma_{jj} \approx 10^6 \sigma_{\gamma\gamma}$)
    - VBF production channel gives the best s/b ratio
  - at low mass **BR(H→bb) ≈ 70%** but it cannot be a low lumi discovery channel:
    - huge QCD background
      - ➢ associated production ttH ($\sigma \approx 10^6\ \sigma_{bb}$)
    - very complex final state, many systematics involved
    - NEW!! VBF Higgs with H→bb + request of a **high p_T central photon**

      pioneer parton level study shows that s/b increases of more than one order of magnitude (destructive interference in central γ emission in QCD bbjj):

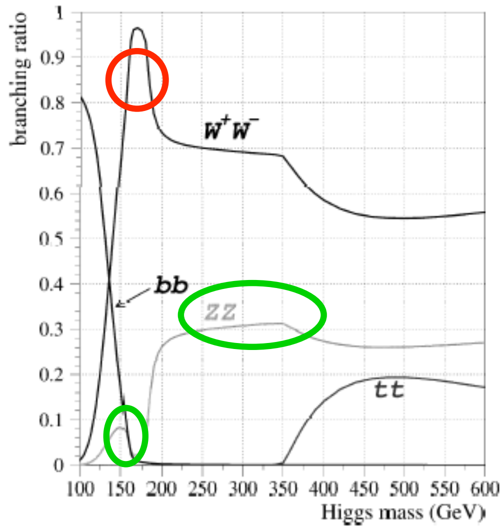
      E.Gabrielli, F.Maltoni, B.Mele, M.Moretti, F.Piccinini and R.Pittau, [hep-ph/0702119]

more details in back-up slides!

$H \rightarrow VV$ decay channels

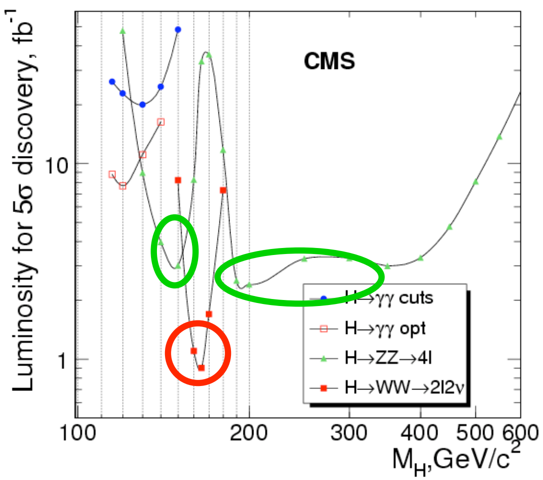
For M_H >150 GeV, $H \rightarrow VV$ most promising channels.

Effectiveness of ZZ and WW channels follow closely the BR shape



Focus on:

- $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$
  no mass peak – analysis on Φ(ll)
- $H \rightarrow ZZ^{(*)} \rightarrow 4l$
  the "golden channel" : - clear signature
  - high S/B ratio



VBF $VV \rightarrow VV$ interesting for its clear signature
(presence of 2q "tag" with high energy and pseudorapidity)

but also for studies on the EWSB mechanism.

- Higgs in s-channel ➔ mass peak
- no Higgs ➔ SM unitarity violation at about 1÷1.5 TeV

The measurement of the cross section at large M(VV) could provide information on the existence of the Higgs indipendentely of its direct observation.

more in back-up slides!

detection strategies

CMS & ATLAS : *"no particle of interest should escape unseen"*

Physics environment :

- adronic collisions: **look for final states with high energy leptons to trigger on signal evt**
- particles produced over all the solid angle (need to cover at least |η|<2.5)
- important for μ/e/γ
  - efficient identification + excellent purity + good accurancy of p_t measurement

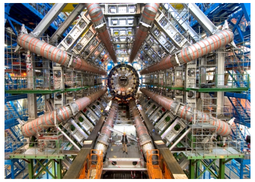
CMS & ATLAS decided to answer to these needs starting from two different magnet systems

(they have shaped the experiments in a major way – **goal**: maximize the factor BL^2)

CMS

4T solenoid magnet in the tkr volume and high enough return flux for $p_T(\mu)$ measurement

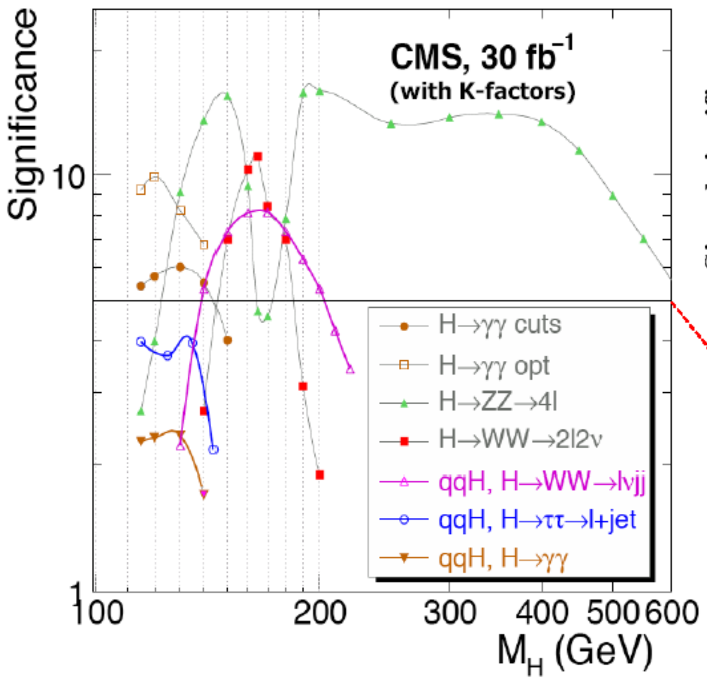
ATLAS

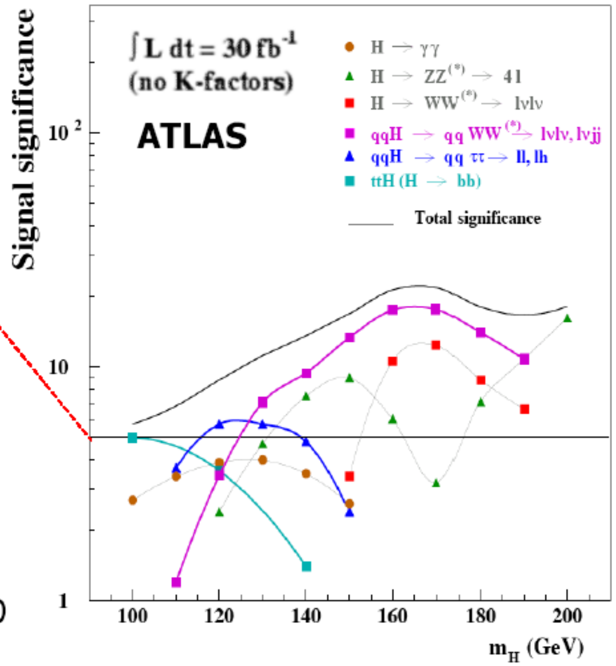


- 2T solenoid magnet integrated in the barrel cryostat of the elm calorimeter
- 3T×m toroidal magnet in the μ spectrometer
- two 6T×m toroidal Endcap magnets positioned at both ends of the Solenoid

more in back-up slides!

discovery channels - summary

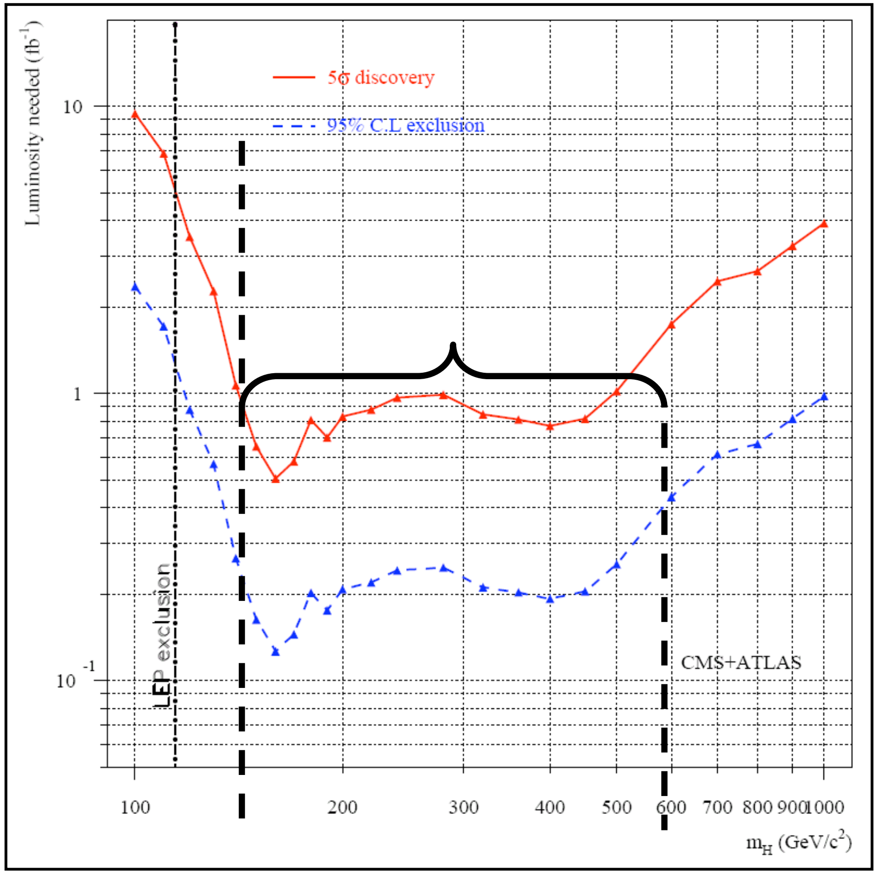




✓ M_H<130GeV CMS : H→γγ [better than ATLAS due to its excellent elm calorimeter system]
ATLAS : qqH→ qqττ [better than CMS in jets&$(E_t)_{mis}$ thanks to its good had calo]

✓ M_H>130GeV ATLAS&CMS : H→WW, H→ZZ
[CMS better than ATLAS in lept decay thanks to its high performant tracker]

start-up time : simulation of combined results



- For M_H>140 GeV, ~1 fb^{-1} might be sufficient
- For low higgs mass (< 140 GeV) situation more complex: ~ 5 fb^{-1} needed and several channels must be combined

- These are fb^{-1} of **well understood data!!**
  - good comprehension of the detector (commissioning & integration)
  - control of the systematics from std candles
  - MC tools well undestood
  - measurement bkg (norm.+shape) from data

Plot from: J.J.Blaising, A.De Roeck, J.Ellis, F.Gianotti, P.Janot, G.Rolandi and D.Schlatter "Potential LHC contributions to Europe's Future Strategy at the High Energy Frontier"

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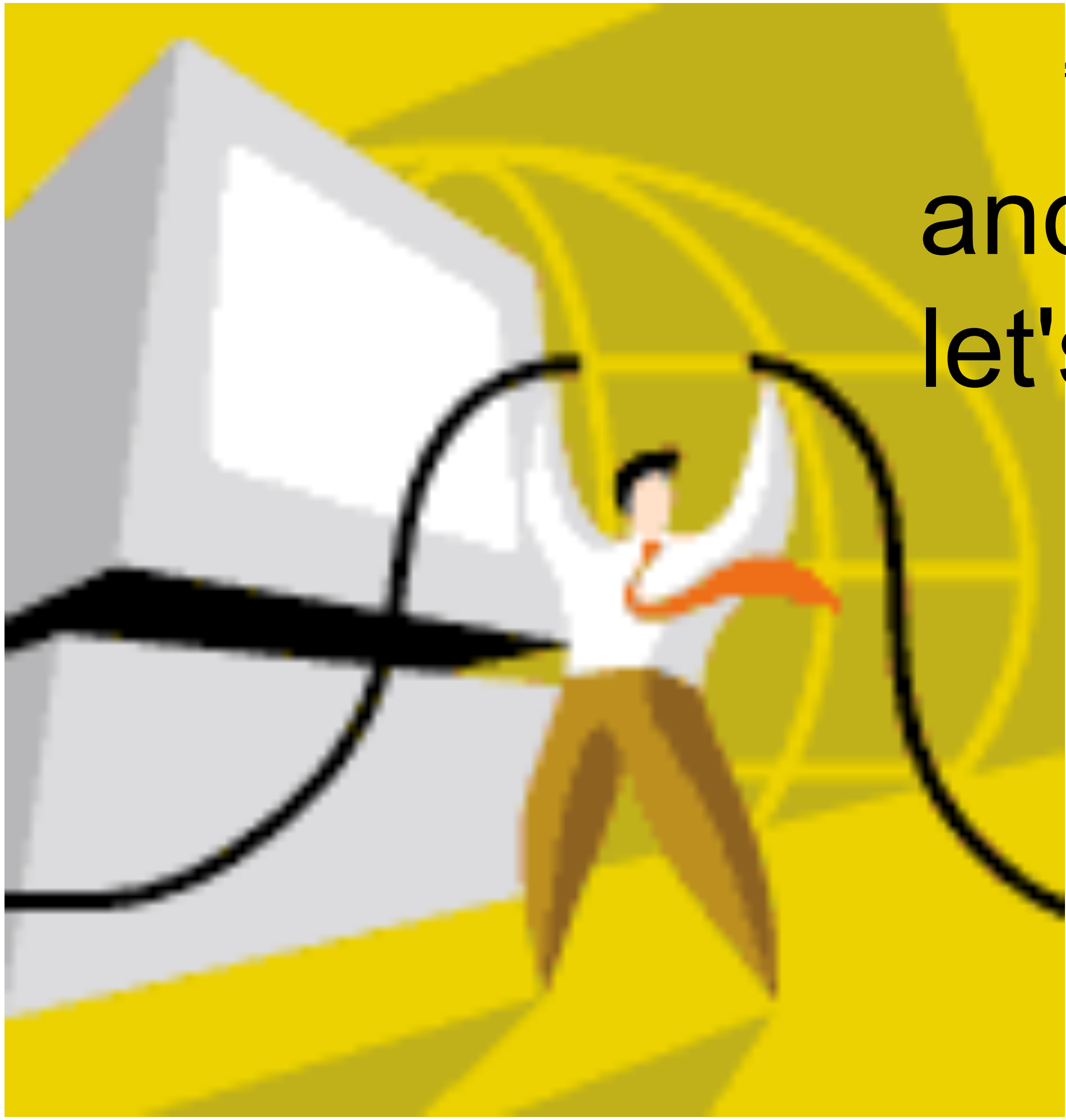

and now?
let's switch on!

Special thanks to :
Chiara Mariotti and Sara Bolognesi

References :

- **Higgs@LHC** – S.Bolognesi, A. Di Simone
V Italian workshop on the p-p physics at LHC, Perugia 30-01-08
- **SM Higgs @CMS Vs SM Higgs @ATLAS –**
C.Botta, N.De Filippis
CMS Italia, Bari 15-16-08