Higgs

- Accoppiamento con fermioni e bosoni di gauge
- Rapporti di decadimento
- Ricerca dell'Higgs al Lep
- Ricerca dell'Higgs a LHC
-

Accoppiamento dell’Higgs con W e Z

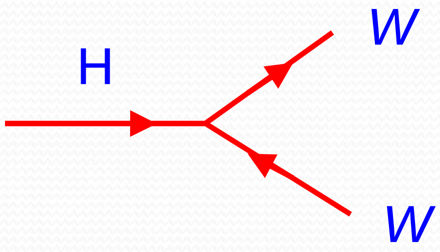
- Lagrangiana elettrodebole invariante per trasformazione di gauge:

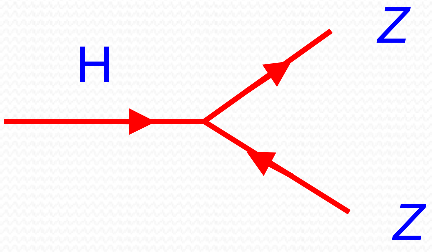
$$\mathcal{L} = \bar{\Psi}_L\gamma^\mu\left[i\partial_\mu - g\vec{I}\cdot\vec{W}_\mu(x) - \frac{g'}{2}Y\cdot B_\mu\right]\Psi_L + \bar{\Psi}_R\gamma^\mu\left[i\partial_\mu - \frac{g'}{2}Y\cdot B_\mu\right]\Psi_R + \mathcal{L}_{free}(\vec{W}, B)$$

- Sostituendo il nuovo campo dopo la rottura spontanea della simmetria

$$\varphi(x) = \frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ v + H(x) \end{pmatrix}$$

si ottengono gli accoppiamenti dell’Higgs con i bosoni di gauge





$$\frac{m_W}{m_Z} = \cos\theta_W$$

$$g_{HWW} = \frac{g^2 v}{2} = \frac{2m_W^2}{v}$$

$$g_{HZZ} = \frac{g^2 v}{4\cos^2\theta_W} = \frac{m_Z^2}{v}$$

$$v = \frac{1}{\sqrt{\left(G\sqrt{2}\right)}} \approx 246\ GeV$$

$$m_W = \frac{1}{2}gv$$

Accoppiamento dell'Higgs con i fermioni

- Dopo la rottura spontanea di simmetria, la Lagrangiana diventa $\longrightarrow$

$$\varphi = \frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ v + H \end{pmatrix}$$

$$\mathscr{L} = -\frac{g_e v}{\sqrt{2}}\left[\bar{e}_R e_L + \bar{e}_L e_R\right] - \frac{g_e}{\sqrt{2}}\left[\bar{e}_R e_L + \bar{e}_L e_R\right] H$$

↑ termine di massa

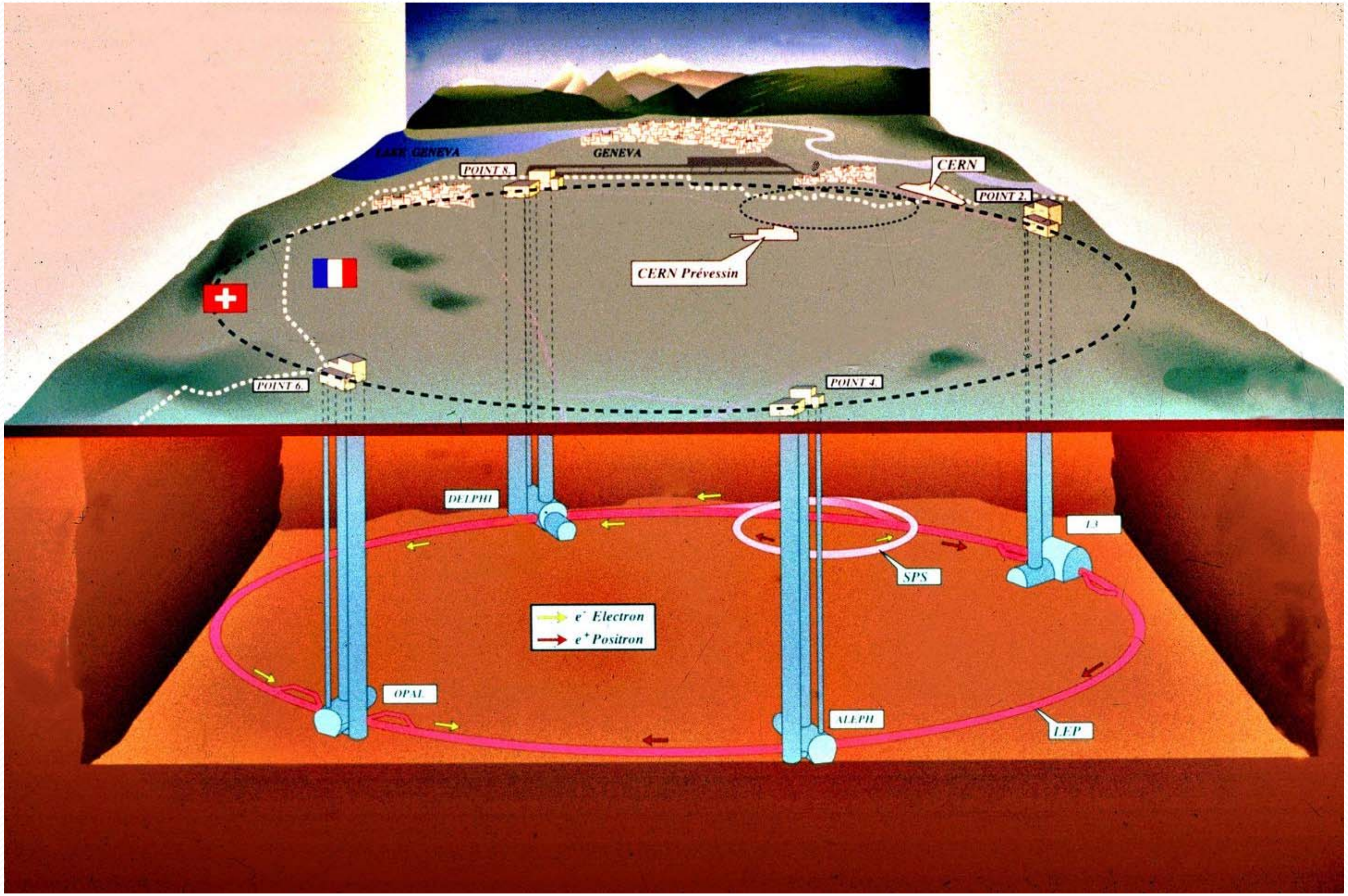
↑ accoppiamento dell'elettrone con il bosone di Higgs

$$\mathrm{m}_e = \frac{g_e \cdot v}{\sqrt{2}}$$

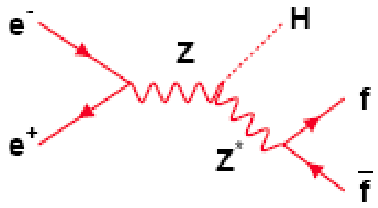
$$\Rightarrow \quad \mathscr{L} = -m_e \bar{e} e - \left(\frac{m_e}{v}\right) \bar{e} e H$$

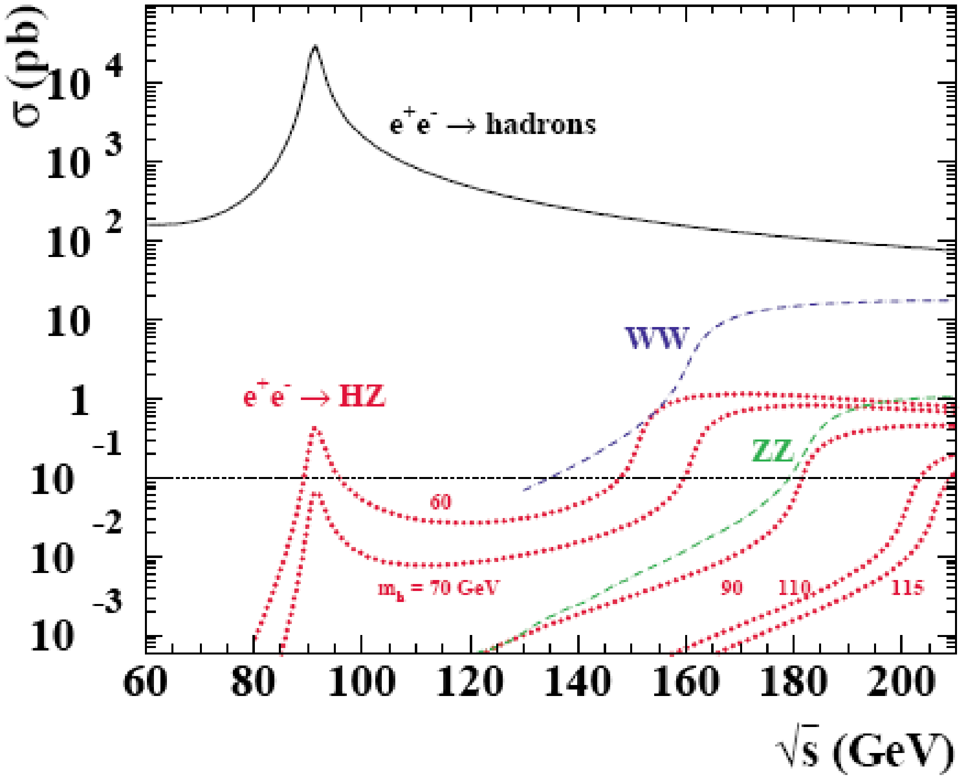
N.B. La costante di accoppiamento è proporzionale alla massa del fermione

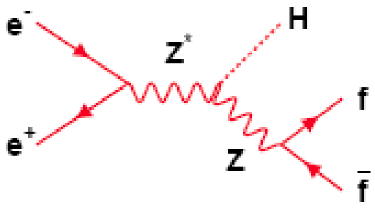
Ricerca del bosone di Higgs al Lep



Higgs production cross-section at LEP





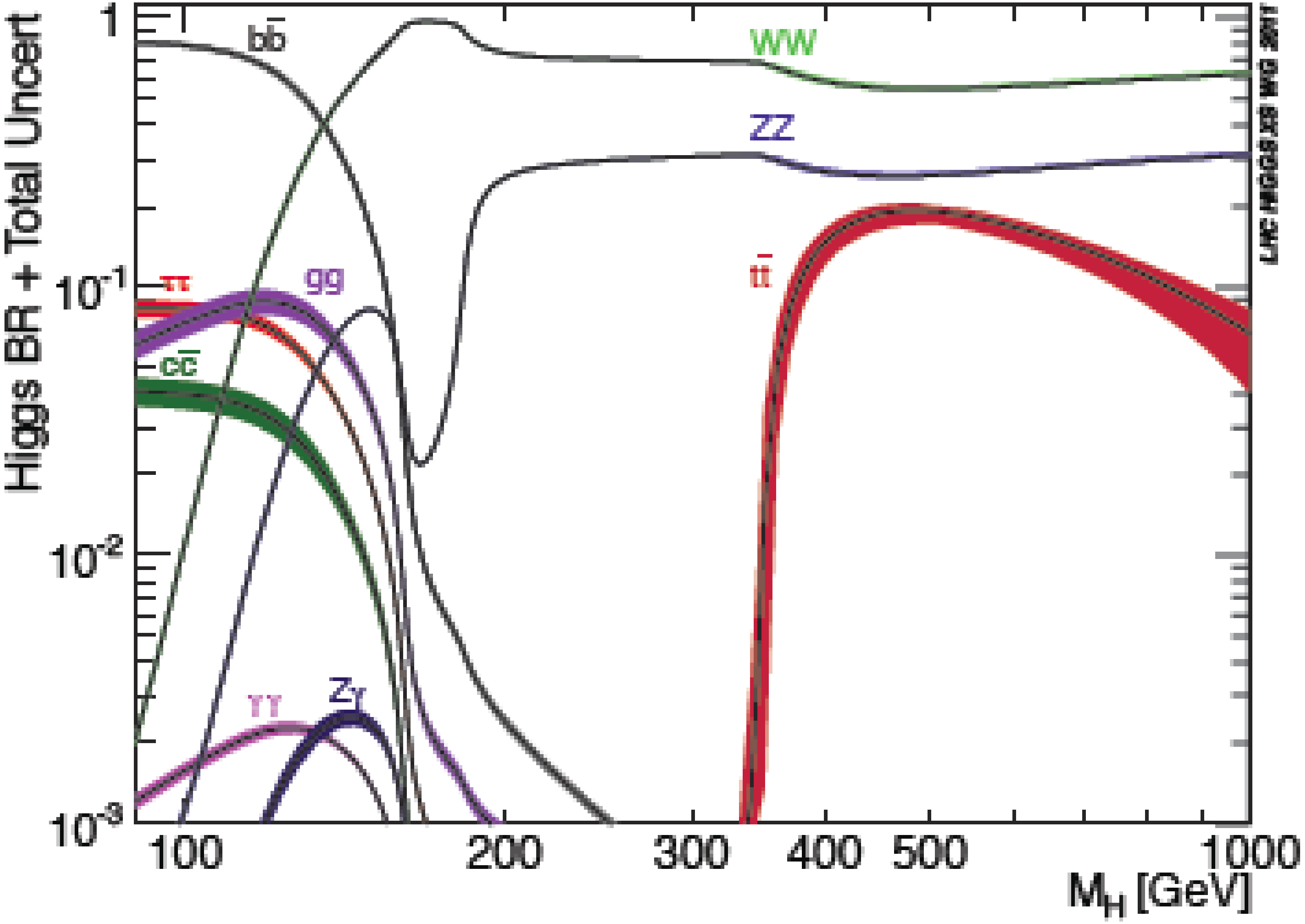


With a luminosity of about 100pb^{-1} and reasonable detection efficiency, sensitive to a cross section of $O(0.1)$ pb.

Need LEP2 to produce $m_H \gtrsim 65$ GeV. Reach $m_H \lesssim \sqrt{s} - M_Z$

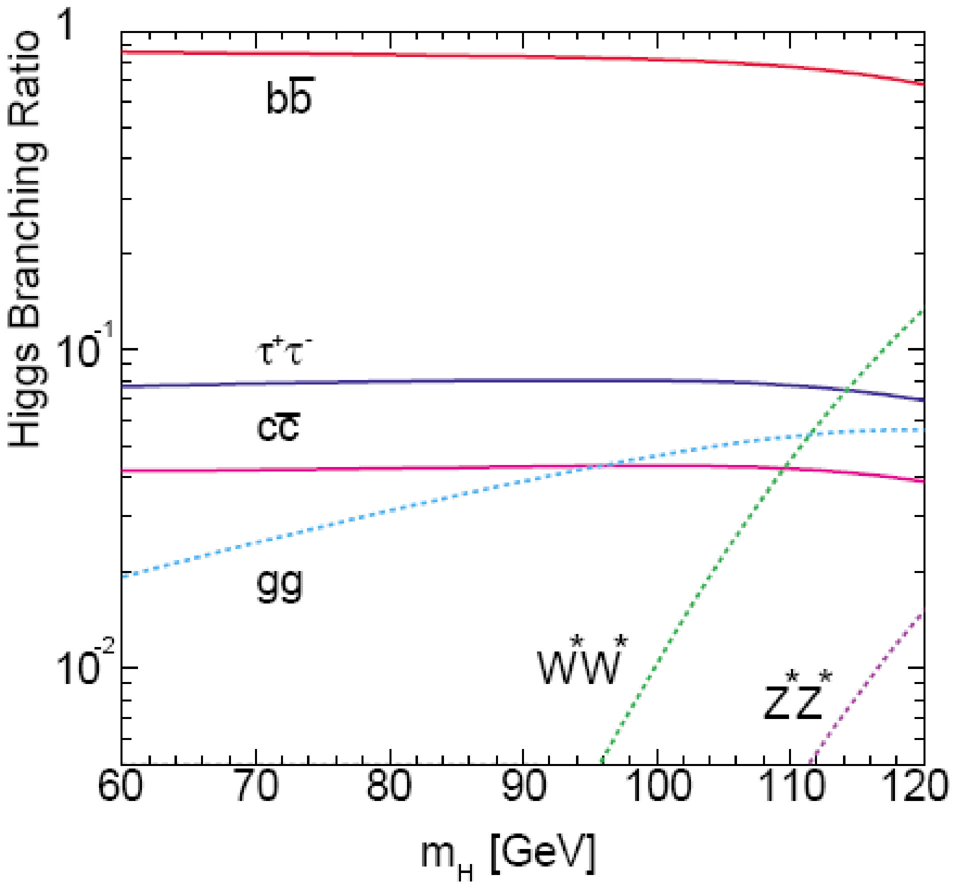
Must take into account many background processes

Higgs Branching Ratios



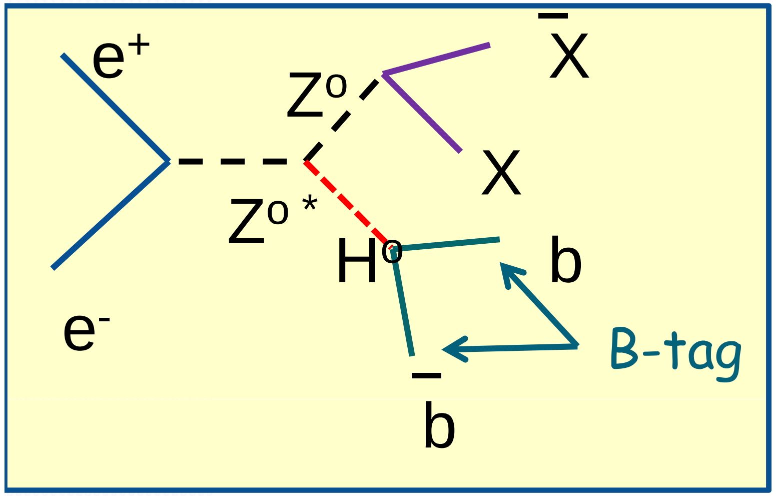
Higgs decay branching ratios

"Higgs couples to mass"



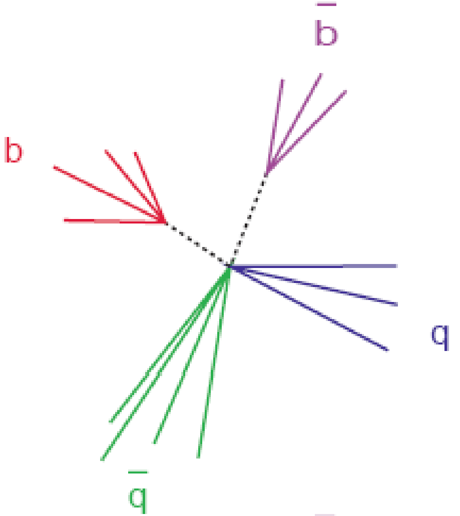
BR(%)	Higgs 115 GeV	Z boson
$q\bar{q}$		70
$b\bar{b}$	74	15
$c\bar{c}$	4	12
gg	6	0
$\ell^+\ell^-$		10
$\tau^+\tau^-$	7	3
$\nu\bar{\nu}$		20
W^*W^*	8	
Z^*Z^*	1	

HZ decays



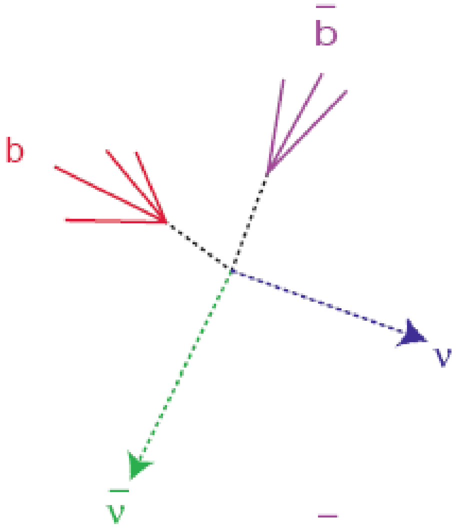
Four jets, 60%

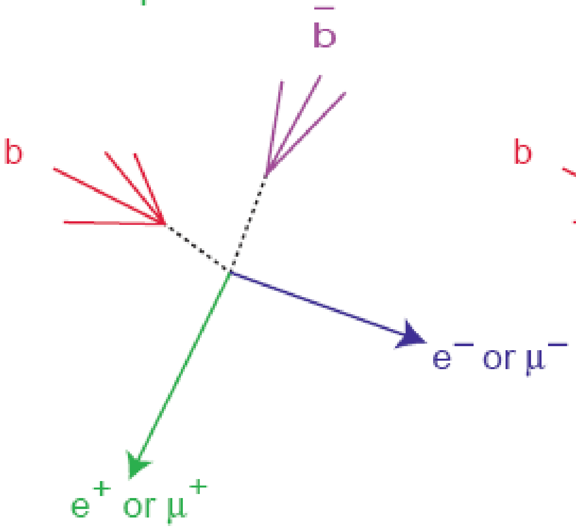
$H \to b\bar{b}\,,\ Z \to q\bar{q}$



Missing energy, 18%

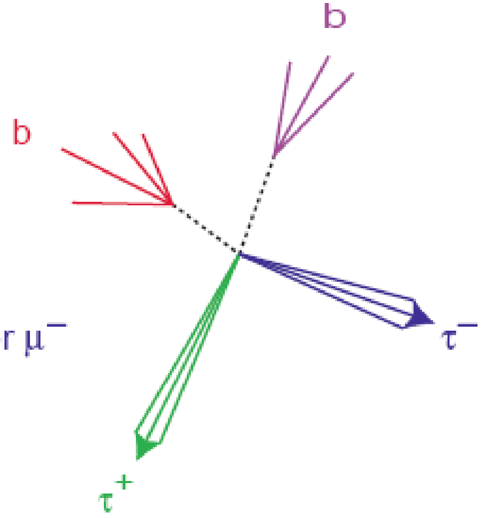
$H \to b\bar{b}\,,\ Z \to \nu\bar{\nu}$





Leptonic, 6%

$H \to b\bar{b}\,,\ Z \to \ell^+\ell^-$



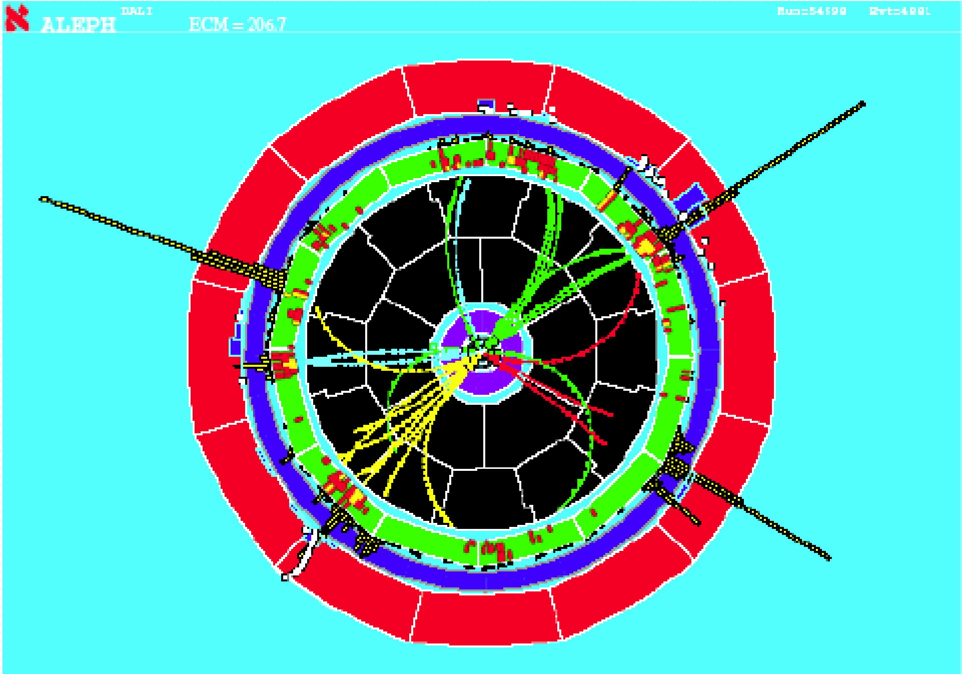
Tau channels, 9%

$H \to b\bar{b}(\tau^+\tau^-)\,,\ Z \to \tau^+\tau^-(q\bar{q})$

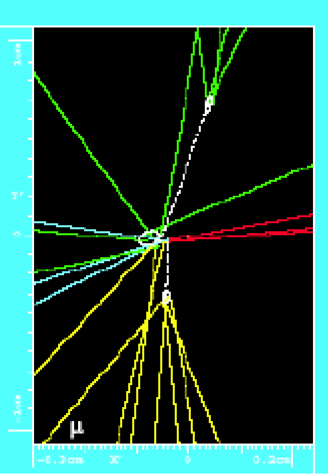
Aleph Higgs events

The Evidence....

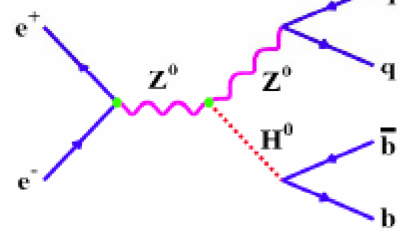
4 Possible $e^+e^- \rightarrow Z^0H^0$ events observed in the final year of LEP operation. *e.g.*



4-jet event; 2 b-jet

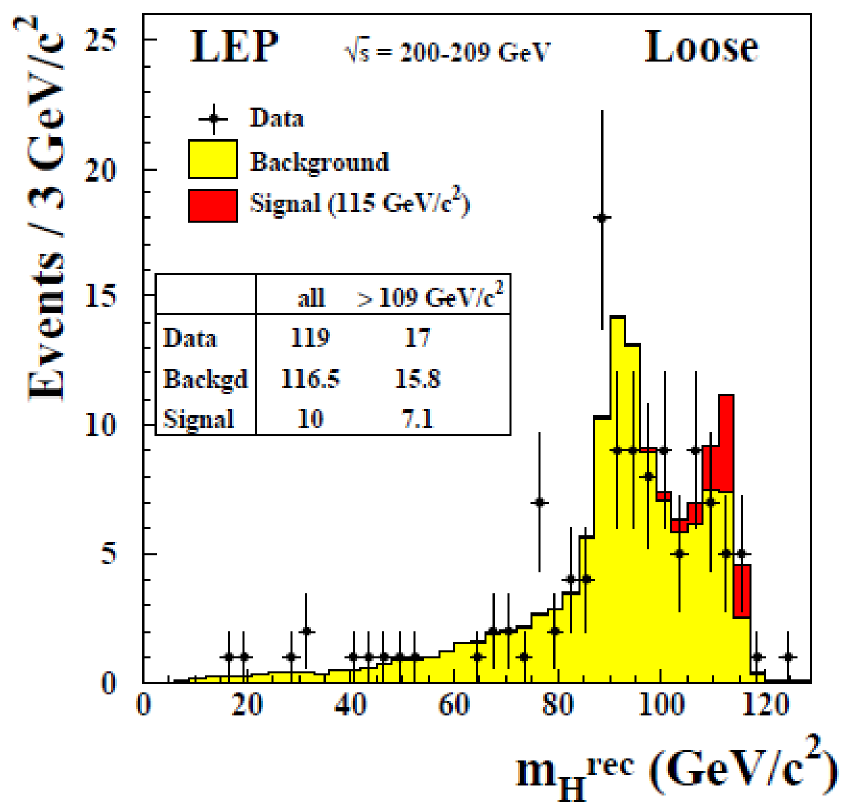


Consistent with

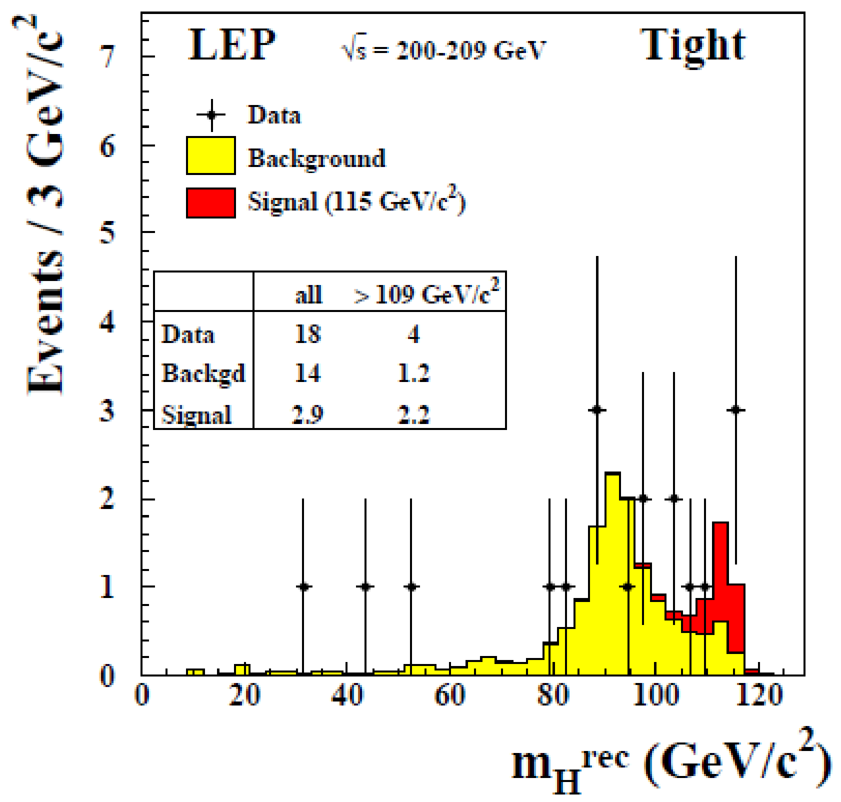


$$m_{H^0} = 115\ \text{GeV}$$

Il “segnale” visto dal LEP



	all	> 109 GeV/c^2
Data	119	17
Backgd	116.5	15.8
Signal	10	7.1



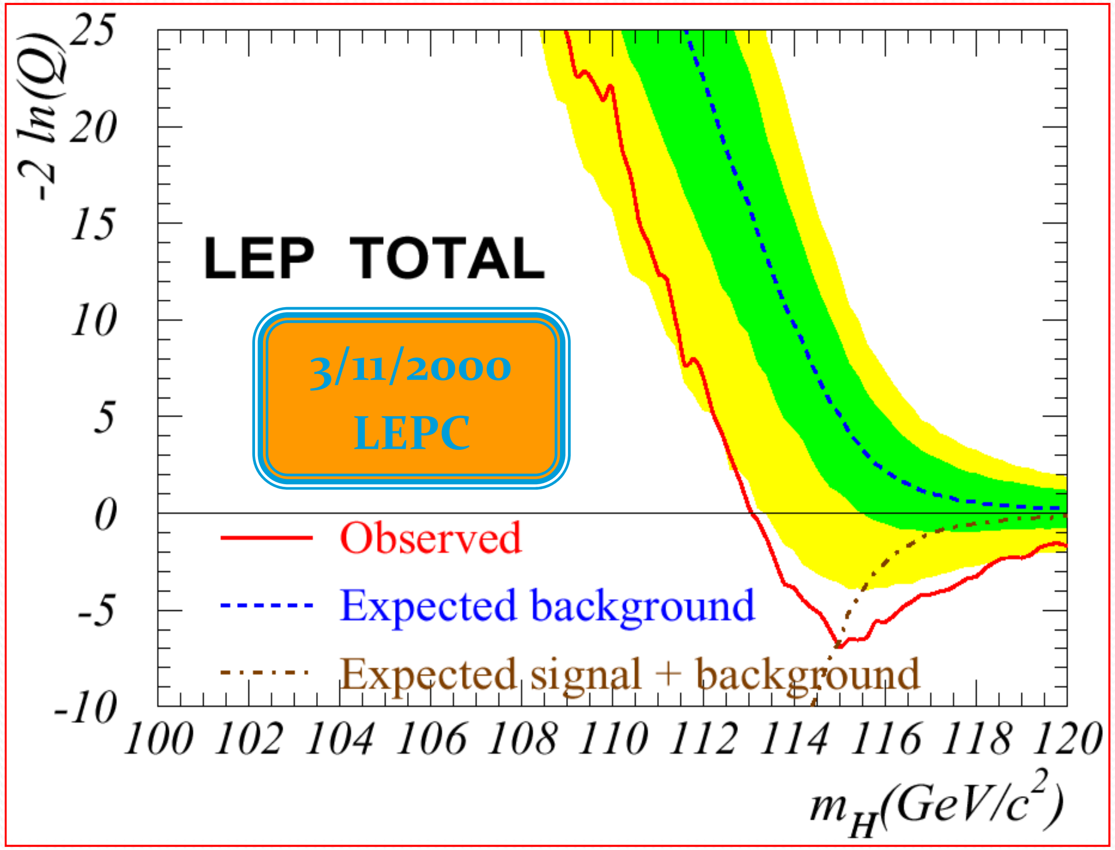
	all	> 109 GeV/c^2
Data	18	4
Backgd	14	1.2
Signal	2.9	2.2

risultati finali – LEPC, 3/11/2000

$Q = L_{s+b}/L_b$ Likelihood con ipotesi di segnale + background
Likelihood con ipotesi di solo segnale

- $m_H = 115^{+1.3}_{-0.9}$ GeV;
- $-2\ell nQ|_{\text{eventi reali}} = -7$;
- $1-CL_b = 4.2\ \ 10^{-3}$;
- "2.9 σ"; (poi 2.1 σ);
- $m_H > 113.5$ GeV
  @ 95%CL

Segnale di un Higgs di 115 GeV



Grande eccitazione all'epoca tra i fisici di Lep

Run LEP in 2001?

Evidence was consistent with a hint of Higgs production at 115 GeV

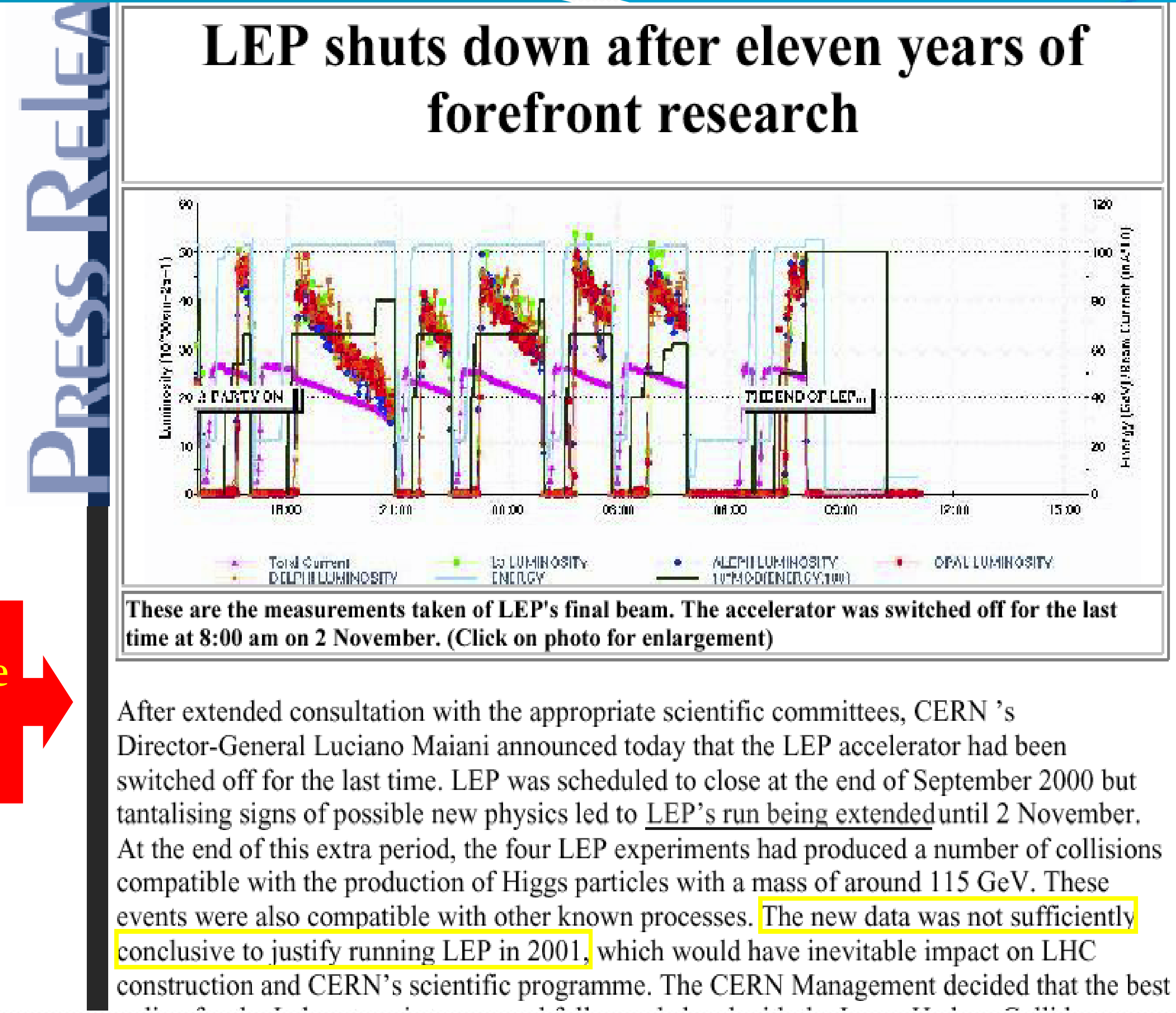
- 3/4 experiments somewhat more “s+b” than “b”
- Two channels more “s+b” than “b”
- Spread of s/b and m_H^{rec} for significant candidates consistent with Higgs

BUT

- Evidence still weak ($< 3\sigma$ - a “discovery” is usually considered to be 5σ. Fluctuations happen.)
- No guarantee that extra running would confirm a discovery
- Big impact on LHC schedule and resources (civil engineering directly delayed by LEP extension)
- LHC could see this Higgs boson, and if it’s a light SUSY Higgs could simultaneously investigate other SUSY particles...

LEP SHUTDOWN DEFINITIVELY AT THE END OF 2000

press release
8/11/2000



LEP shuts down after eleven years of forefront research

These are the measurements taken of LEP's final beam. The accelerator was switched off for the last time at 8:00 am on 2 November. (Click on photo for enlargement)

After extended consultation with the appropriate scientific committees, CERN 's Director-General Luciano Maiani announced today that the LEP accelerator had been switched off for the last time. LEP was scheduled to close at the end of September 2000 but tantalising signs of possible new physics led to LEP's run being extended until 2 November. At the end of this extra period, the four LEP experiments had produced a number of collisions compatible with the production of Higgs particles with a mass of around 115 GeV. These events were also compatible with other known processes. The new data was not sufficiently conclusive to justify running LEP in 2001, which would have inevitable impact on LHC construction and CERN's scientific programme. The CERN Management decided that the best

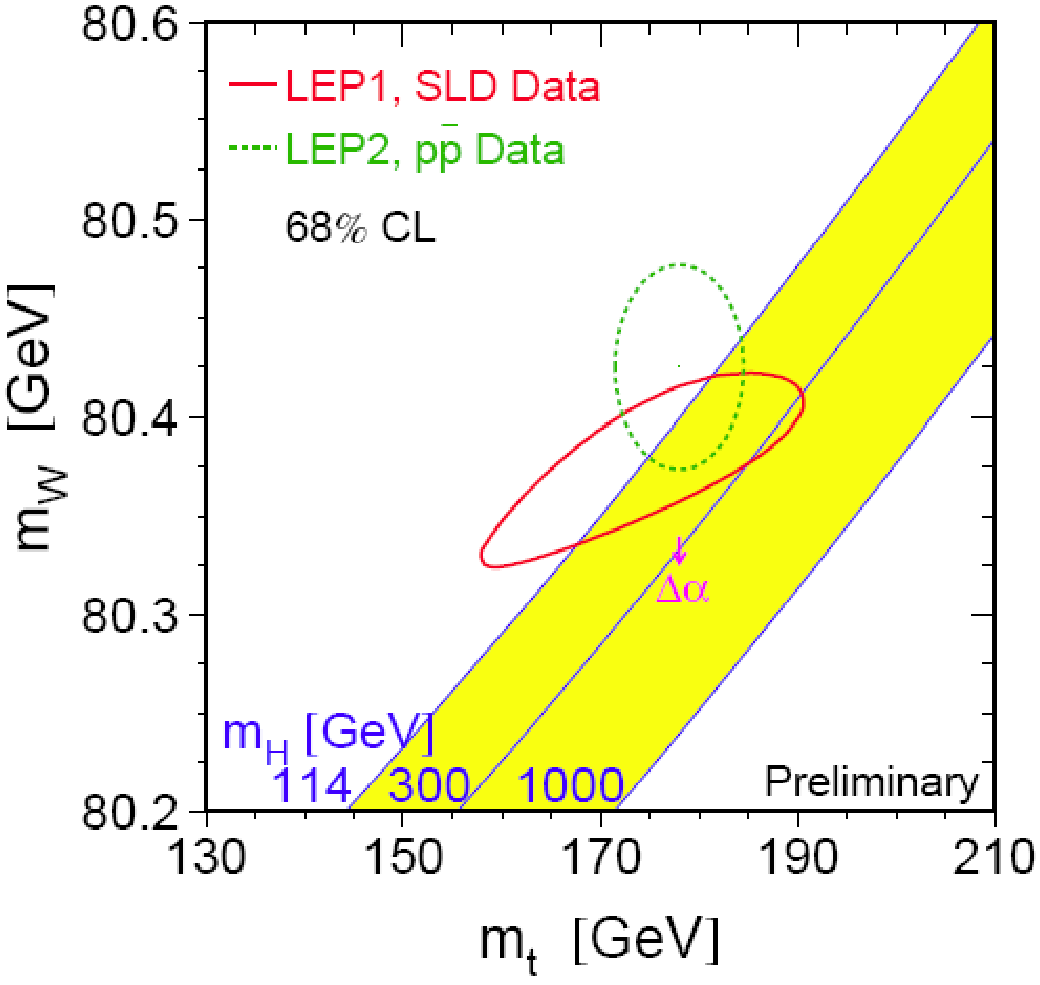
Global electroweak fits and Higgs Mass

Fit to data from LEP, SLD, Tevatron...

Electroweak variables depend on m_t^2 and $\log m_H$ through radiative corrections

Consistency between predicted top and W mass (Z pole) and direct measurements

Preference for low Higgs mass.



Constraints on Higgs mass

Electroweak fits

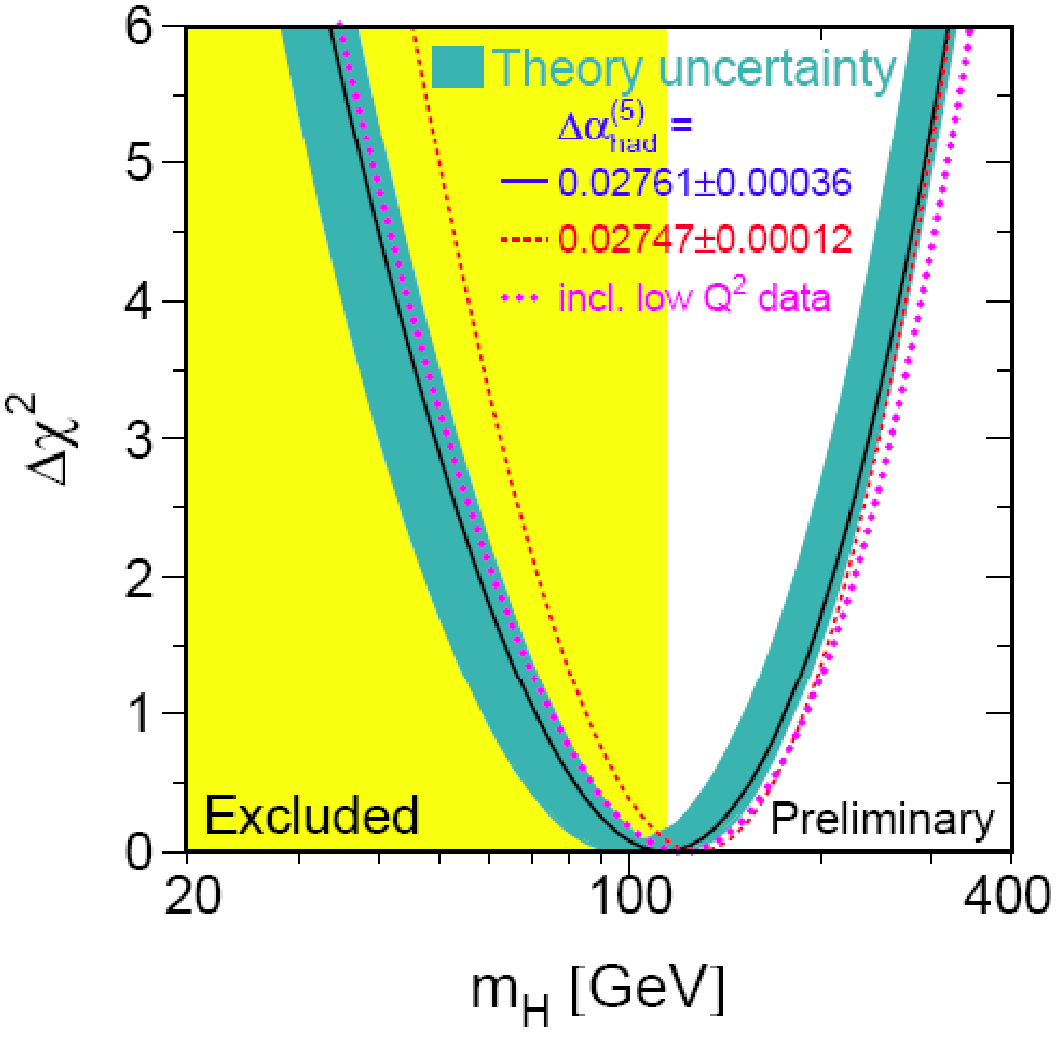
$m_H < 237$ GeV (95% CL)

Theory: self consistency of SM to GUT scale $\approx 10^{16}$ GeV

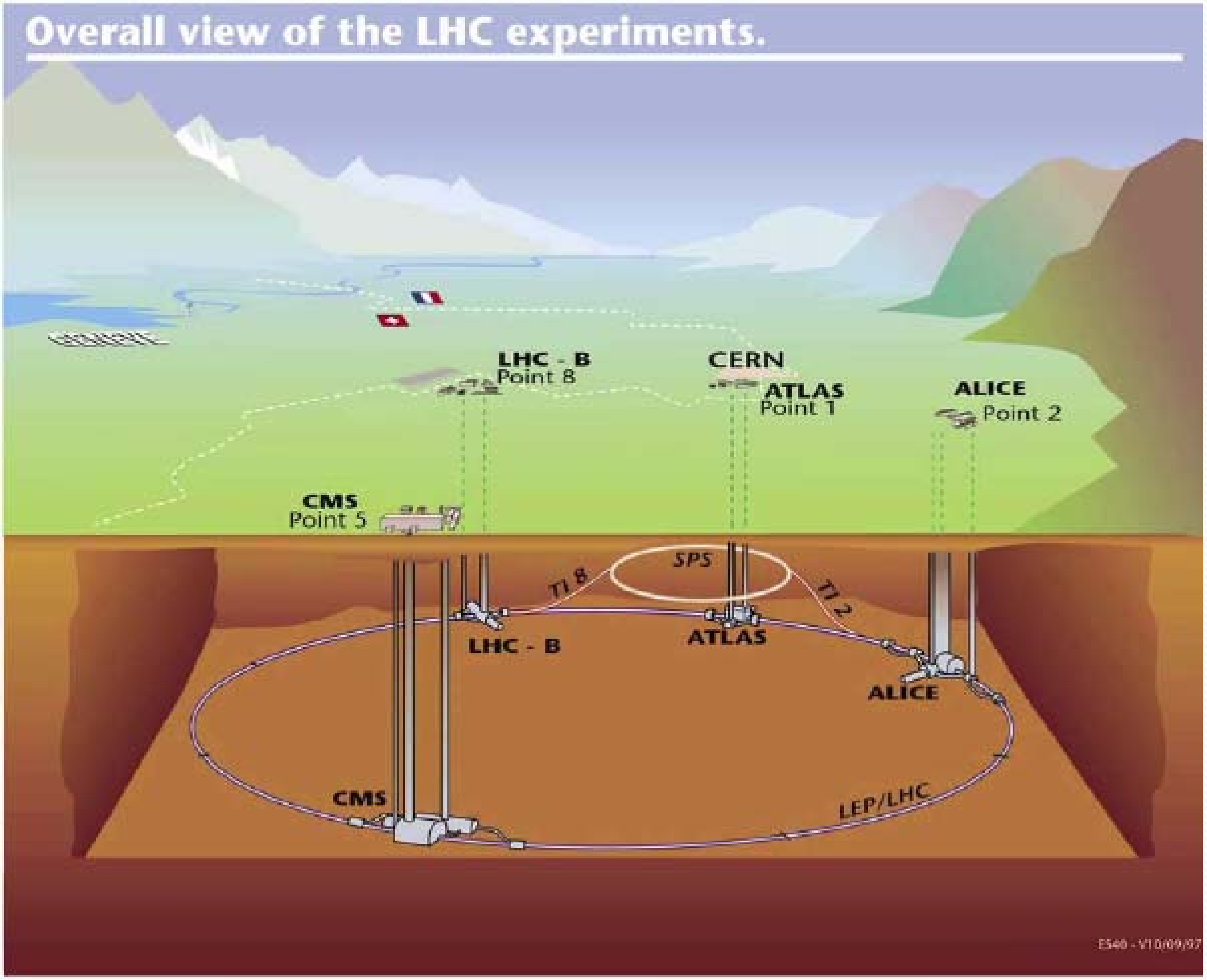
$130 < m_H < 190$ GeV.

m_H higher - theory non-perturbative,

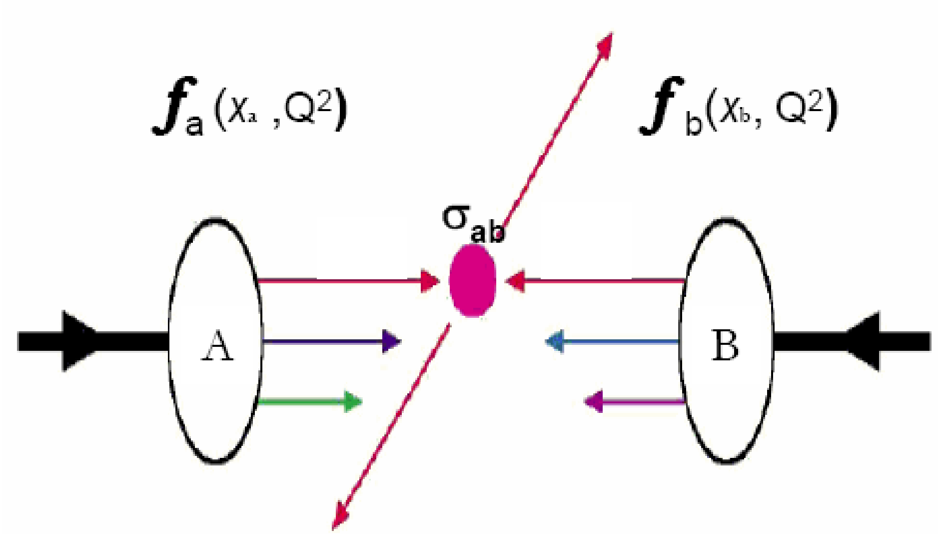
m_H lower - vacuum unstable.



La staffetta passa a LHC



Parton-Parton interactions



hadron collision

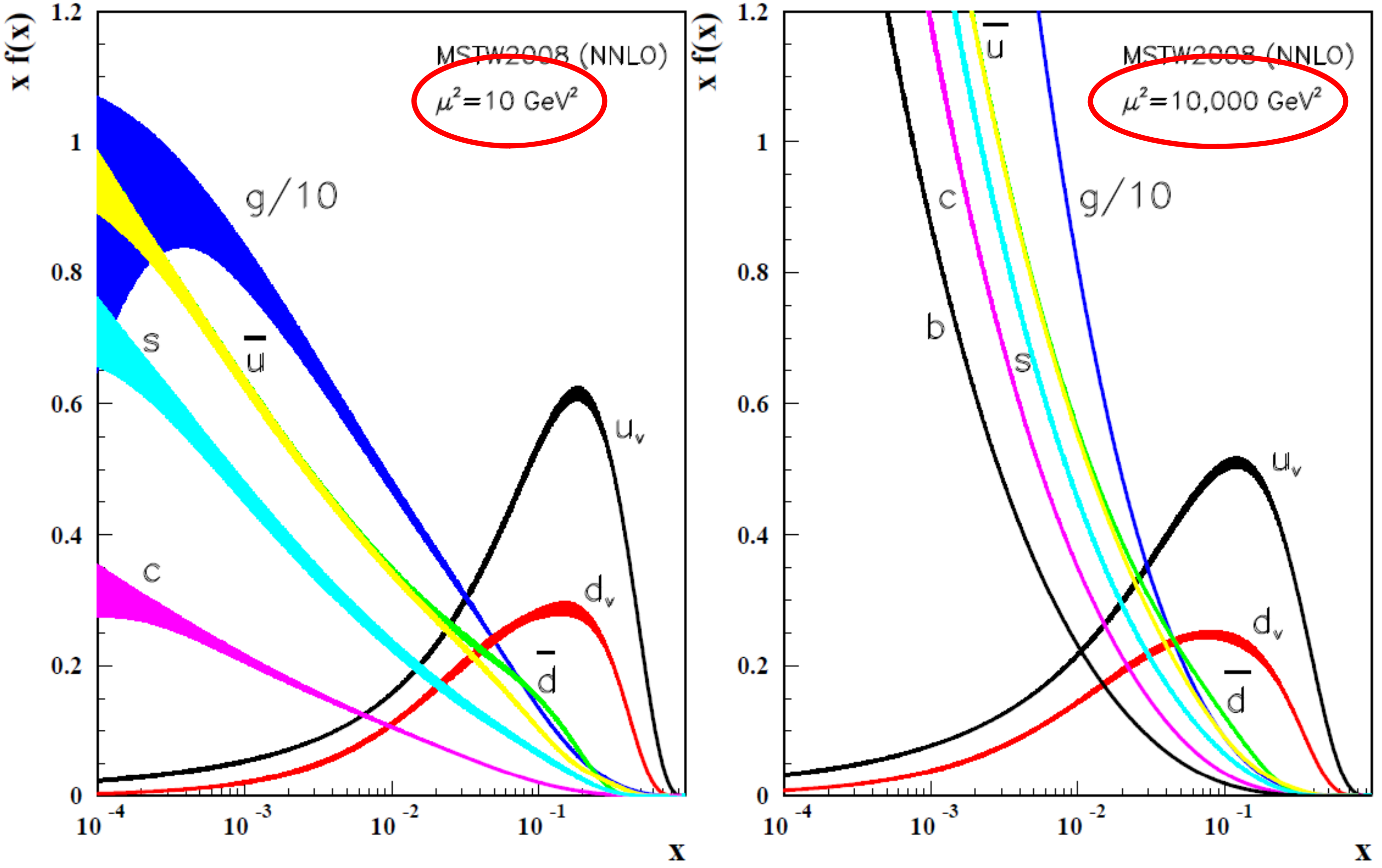
interaction between the partons which constitute the hadrons:
not well defined parton energy
but energy distribution

At LHC pp collision

PDFs are parameterizations of the partonic content of the proton;
at Hadron Colliders cross-section calculation is a convolution of the cross-section at parton level and PDFs:

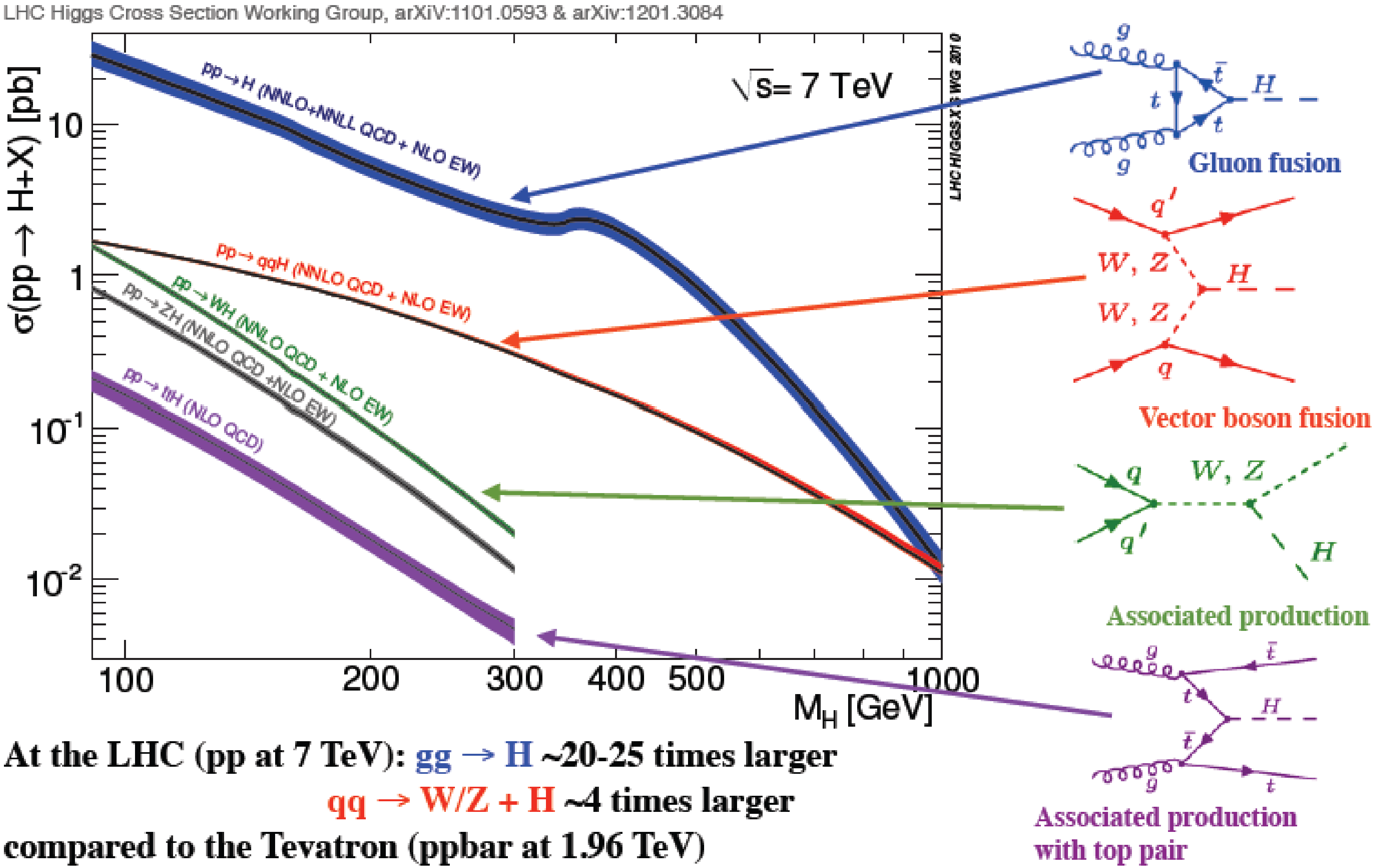
$$\sigma_X = \underbrace{\sum_{a,b}}_{\text{Sum over initial partonic states a,b}} \int_0^1 dx_a dx_b \underbrace{f(x_a, flav_a, Q^2) f(x_b, flav_b, Q^2)}_{\text{Parton Density Function}} \cdot \underbrace{\sigma_{ab\to X}(x_a, x_b, Q^2)}_{\text{hard scattering cross-section}}.$$

Parton Density Function del protone



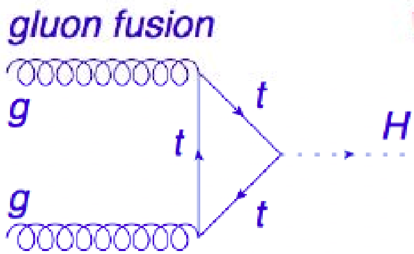
LHC e’ una macchina di gluoni

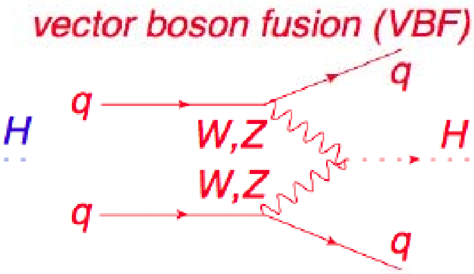
Higgs Boson Production at LHC

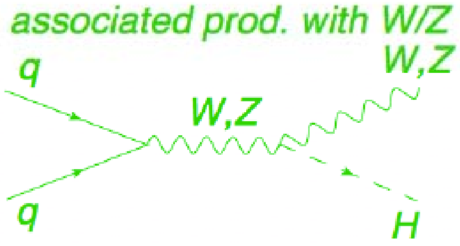

LHC Higgs Cross Section Working Group, arXiV:1101.0593 & arXiV:1201.3084

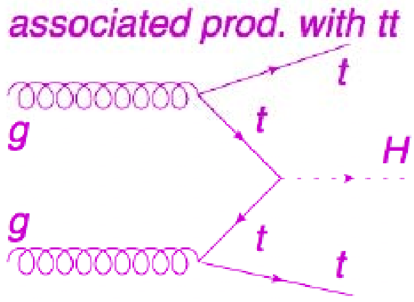
At the LHC (pp at 7 TeV): gg → H ~20-25 times larger
qq → W/Z + H ~4 times larger
compared to the Tevatron (ppbar at 1.96 TeV)

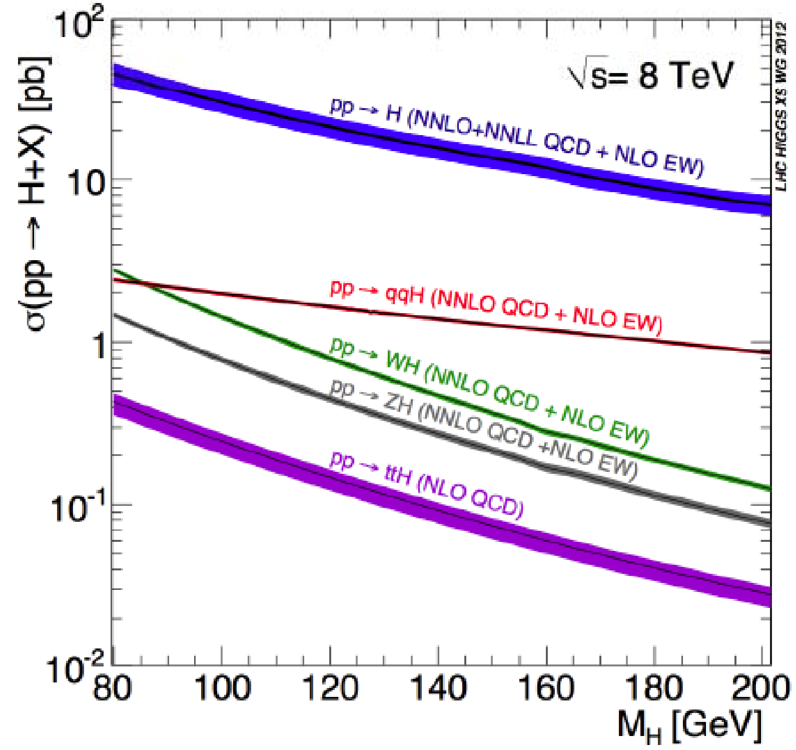
Higgs production







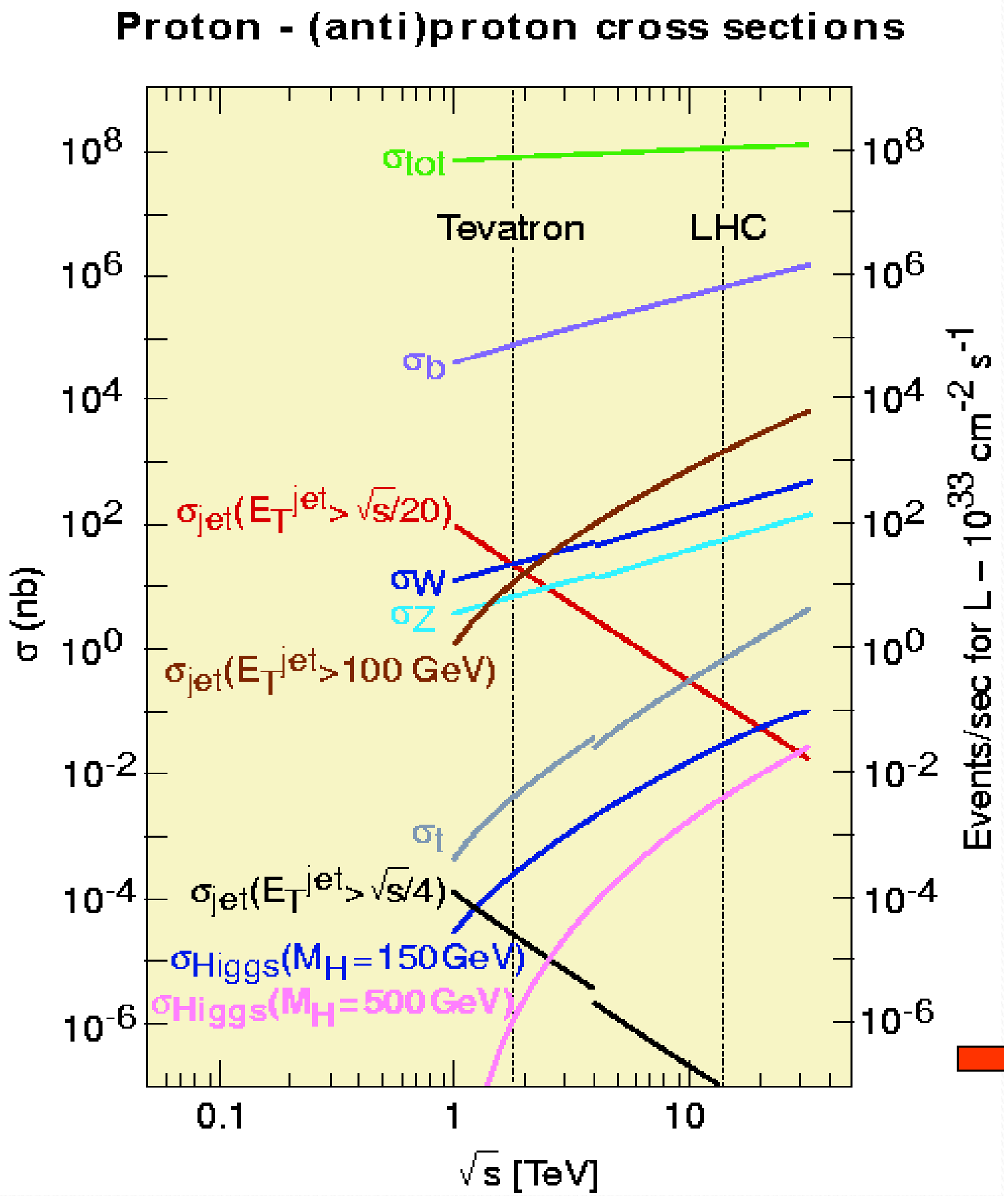




Main production mode via loops. Theory uncertainty O(10%)

Access to top-quark, W and Z couplings via production cross section

Cross-sections and rates



- huge range of cross-section values and rate

  -listed for $10^{34}\text{ cm}^{-2}\text{ s}^{-1}$

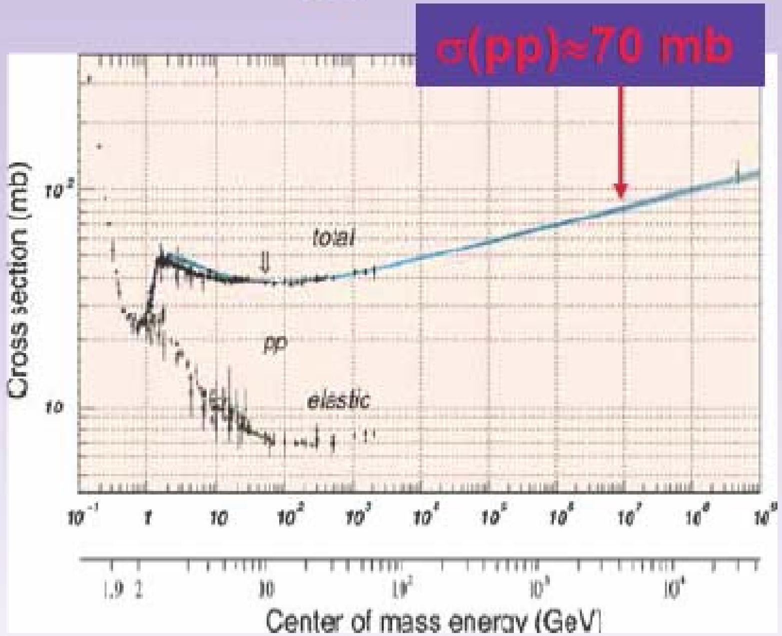
  - total
    - $\sigma \approx 100$ mb (${10^9}$ Hz)
  - b production
    - $\sigma \approx 0.7$ mb ($7*10^6$ Hz)
  - W/Z production
    - $\sigma \approx 200/60$ nb (2/0.6 kHz)
  - Top production
    - $\sigma \approx 0.8$ nb (80 Hz)
  - SM Higgs ($m_H = 150$ GeV)
    - $\sigma \approx 30$ pb (3 Hz)

- With branching ratios included
  - W → eν 150 Hz
  - Z → ee 15 Hz
  - H → γγ 0.003 Hz

Sezione d'urto pp e min. bias

Challenge 1

- # di interazioni /bunch crossing:
  - Interazioni/s:
    - Lum = 10^{34} $cm^{-2}s^{-1}$=$10^{7}mb^{-1}Hz$
      σ(pp) = 70 mb
    - Rate di interazione, R = $7x10^{8}$ Hz
  - Eventi/bunch crossing:
      Δt = 25 ns = $2.5x10^{-8}$ s
    - Interazioni/crossing=17.5
  - Non tutti i bunches sono "pieni"
    - 2835 out of 3564 only
    - Interazioni/"active" crossing = 17.5 x 3564/2835 = 23



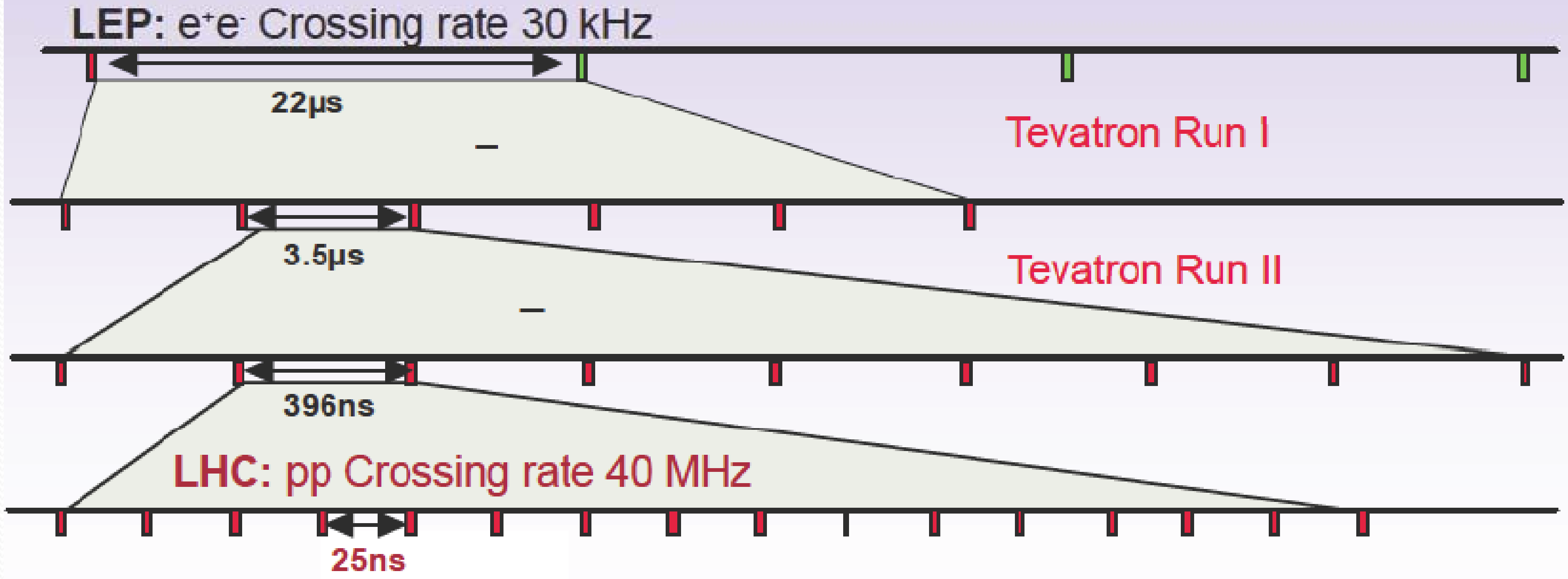
Un "buon" evento contiene un decadimento di scoperta + ≈ 25 extra (minimum bias)

- **Obiettivo limitare la quantita' di dati alla frazione interessante**

  event size: 1-2 Mbytes.

Beam crossings: LEP, Tevatron & LHC

- LHC ha ~3600 bunches
  - Stessa lunghezza di LEP (27 km)
  - Distanza fra bunches: 27km/3600=7.5m
  - Distanza tra bunches in tempo: 7.5m/c=25ns



Experimental conditions at LHC

Le piccole sezioni d’urto dei processi interessanti richiedono una grande luminosità.

Questo implica delle difficoltà costruttive notevoli per i rivelatori.

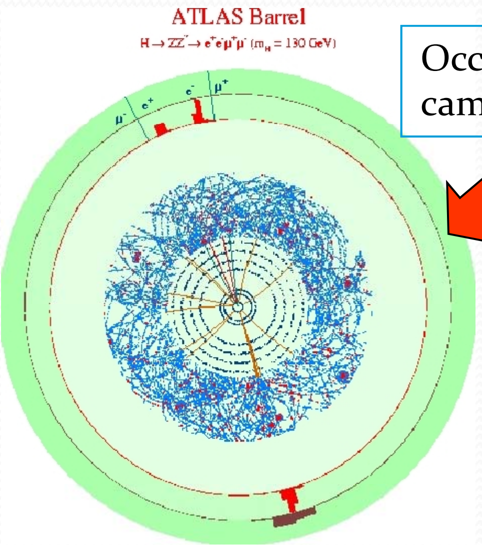
- Very small bunch crossing separation: T=25 ns (40 MHz frequency)
- Multiple interaction per bunch crossing (~ 20 at $L = 10^{34}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$)
  - → fast, high granularity detectors, fast level 1 trigger
- High radiation level in the hall (neutrons, photons and charge particles)
  - → radiation hard electronics
  - → high rate capability of the detectors
  - → careful study of detectors ageing
  - → high occupancy of tracking detectors (reduced efficiency and spurious hits)

Detector performance requirements

- Mass resolution (m <200 GeV) :

  ≈ 2 % (H $\rightarrow \gamma\gamma$, 4) ≈ 10 % (W $\rightarrow$ jj, H $\rightarrow$ bb)

- Particle identification : μ,e, γ, τ, b
- Lepton measurement: p_T from few GeV $\rightarrow$ 3 TeV (W'/Z')
- Calorimeter coverage : $|\eta| < 5$ (E_T^{miss}, forward jet tag)



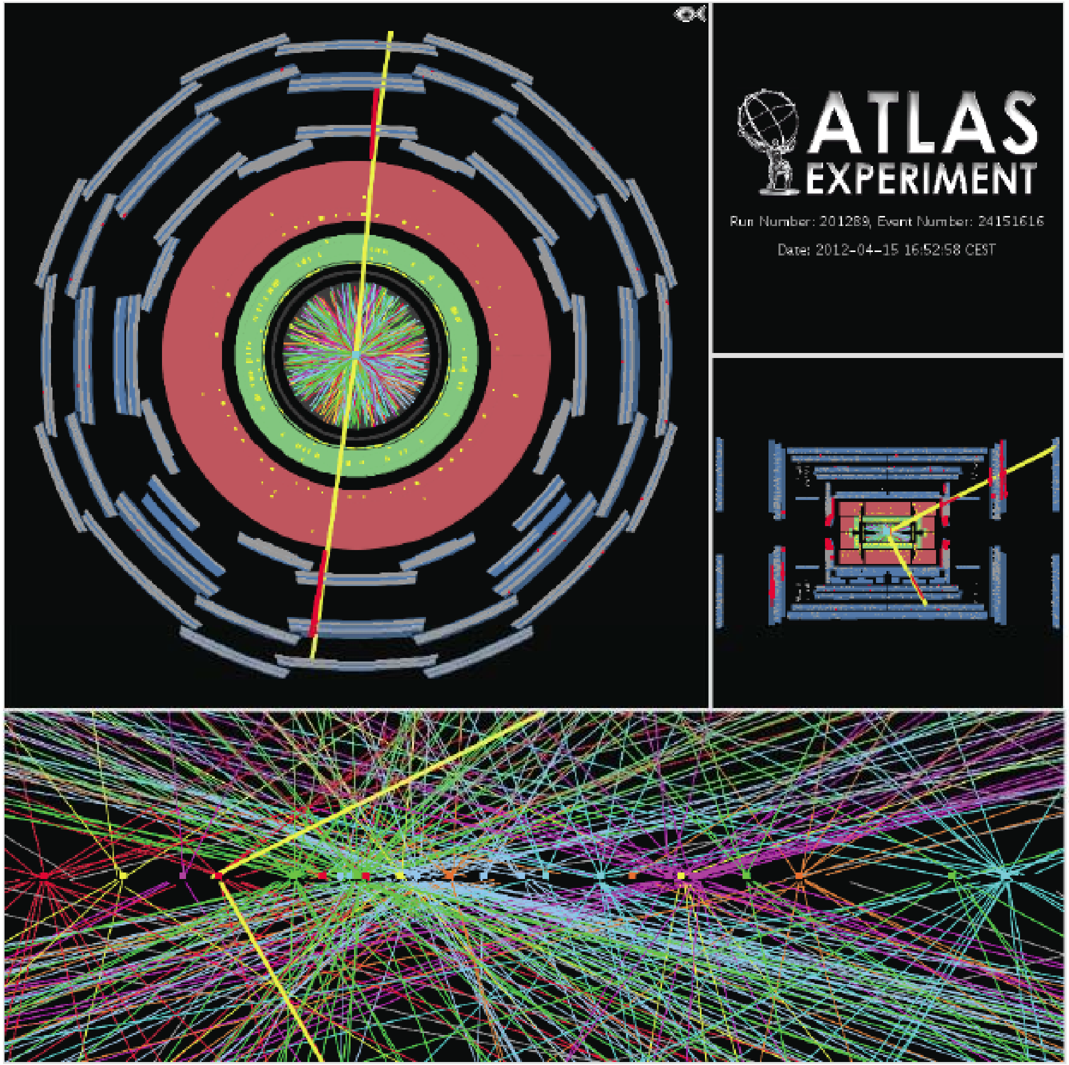
Occupazione della camera centrale

(Motivazione storica)

Muon spectrometer

- **Stand-alone**
- **Accurate muon momentum measurement;**
- **Robust and flexible level-1 muon trigger**

Pileup

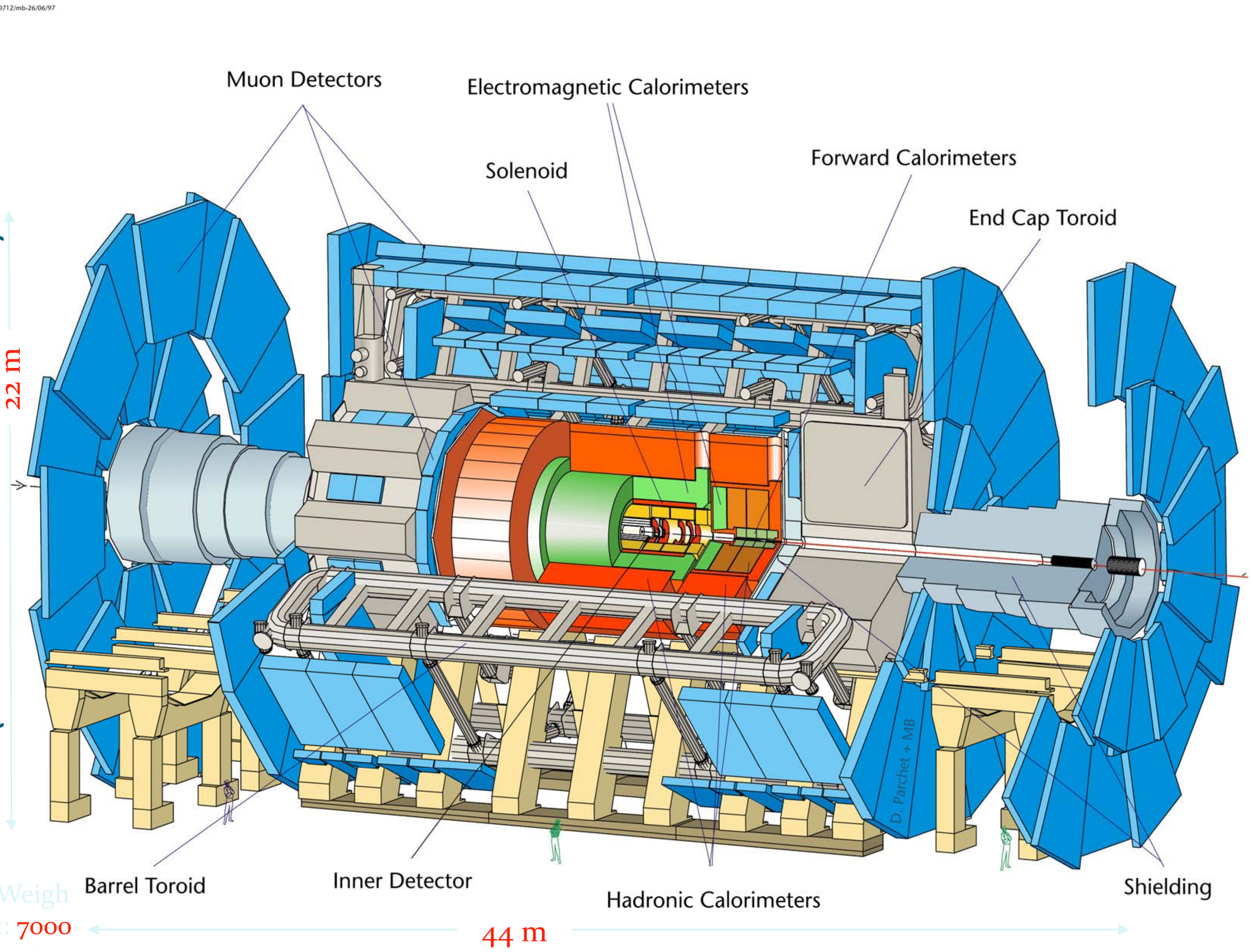


Continuously improve triggering, reconstruction and identification algorithms to cope with this challenging environment

Main impact on jets, missing E_T and tau reconstruction (as well as on trigger rates and computing)

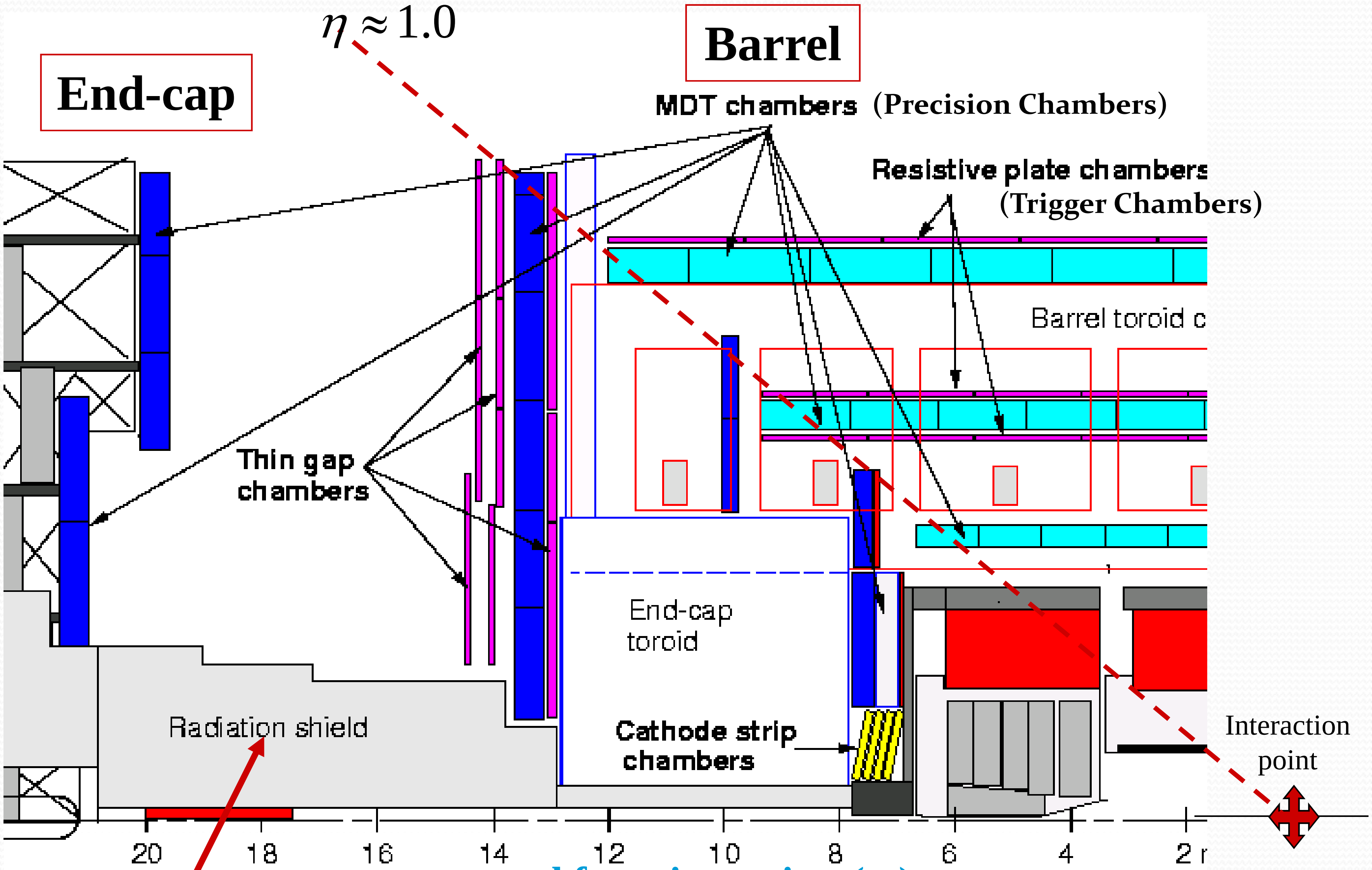
Z → μμ event with 25 reconstructed vertices

ATLAS (A Toroidal Lhc ApparatuS)



Weight: 7000 t

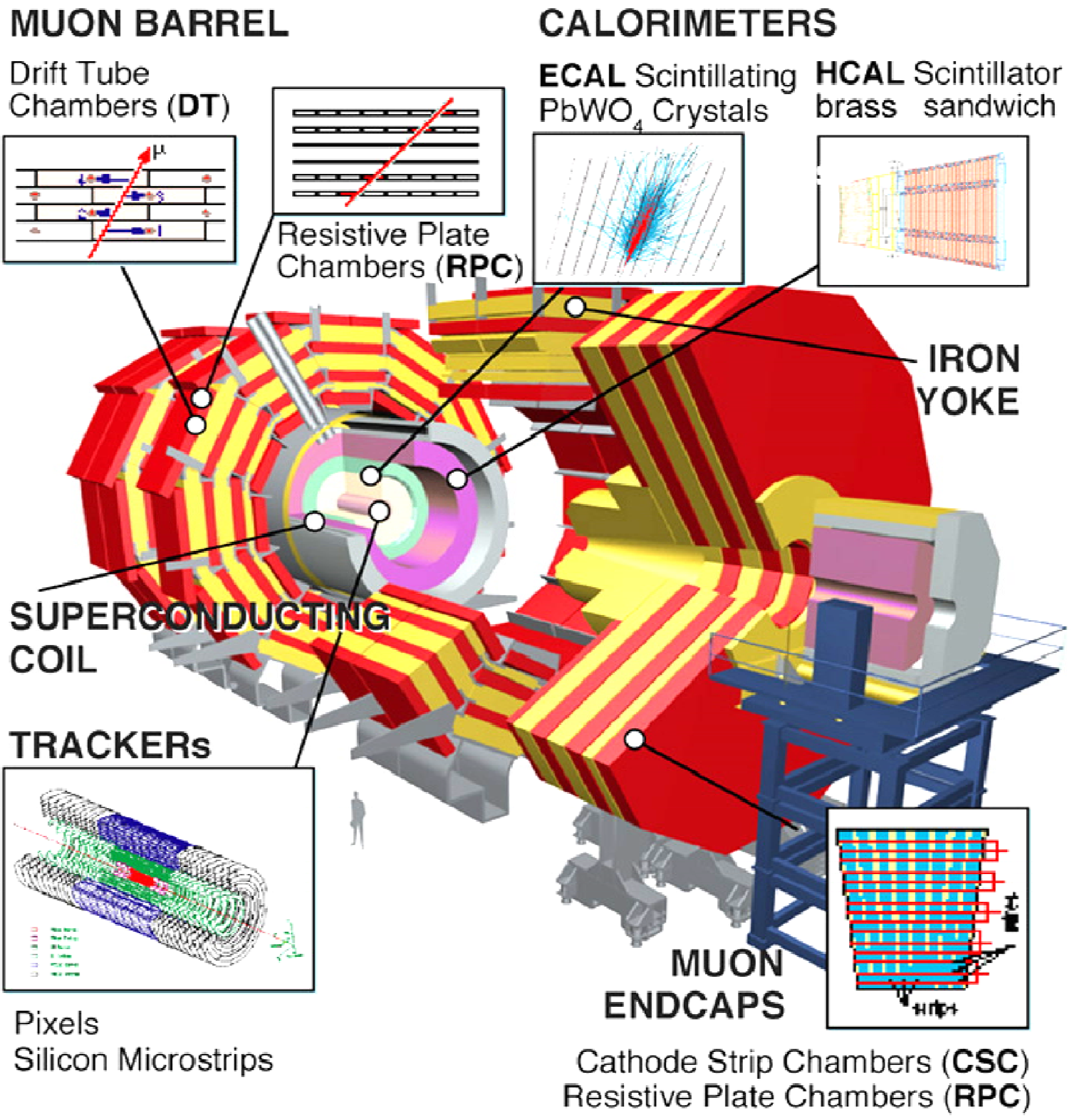
The ATLAS muon Spectrometer-Side view



d from int. point (m)

Reduce hall background

CMS (Compact Muon Solenoid)



MUON BARREL

Drift Tube Chambers (**DT**)

Resistive Plate Chambers (**RPC**)

CALORIMETERS

ECAL Scintillating $PbWO_4$ Crystals

HCAL Scintillator brass sandwich

IRON YOKE

SUPERCONDUCTING COIL

TRACKERs

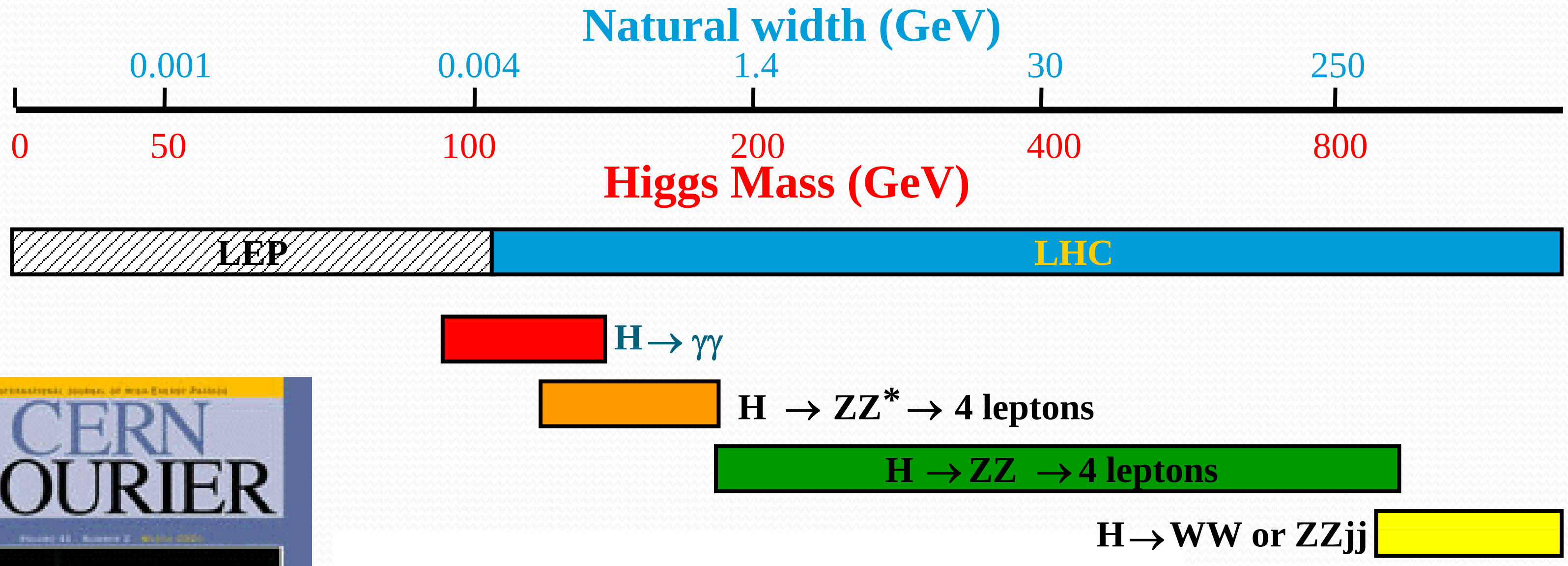
Pixels
Silicon Microstrips

MUON ENDCAPS

Cathode Strip Chambers (**CSC**)
Resistive Plate Chambers (**RPC**)

Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

Bosone di Higgs a LHC



Natural width (GeV)

0.001 0.004 1.4 30 250

0 50 100 200 400 800

Higgs Mass (GeV)

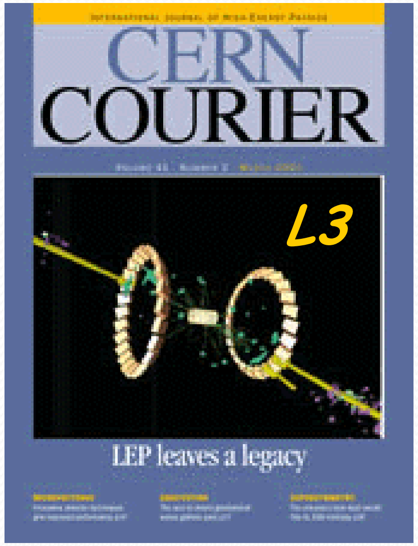
LEP **LHC**

H → γγ

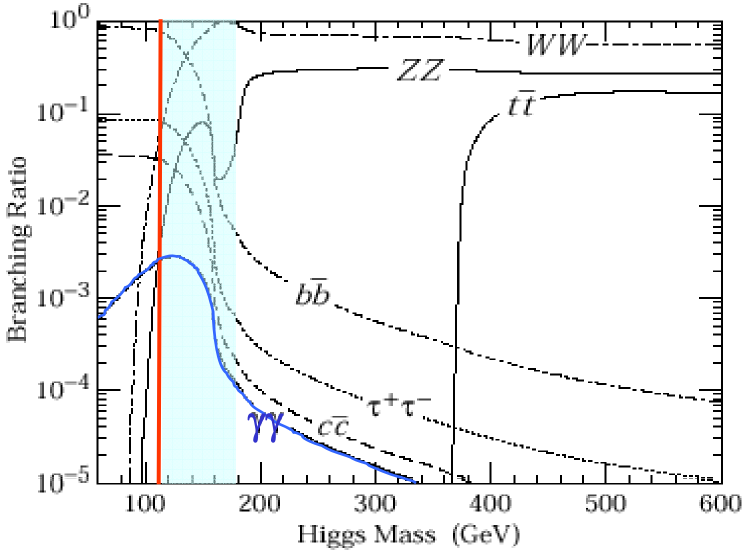
H → ZZ* → 4 leptons

H → ZZ → 4 leptons

H → WW or ZZjj



LEP: osservato un eccesso di eventi a 115 GeV



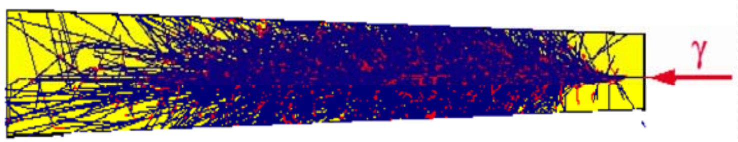
Decadimenti in γγ: rari, ma estremamente "puliti" se si "guarda" con un calorimetro eccellente

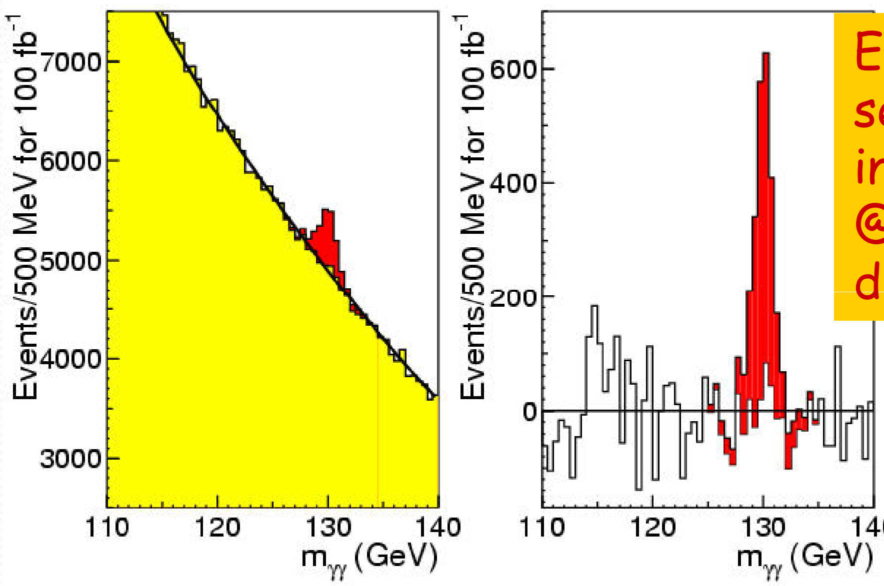
Rivelazion

Termine costante cruciale:
dipende dalla intercalibrazione e dal
suo controllo durante l'esperimento

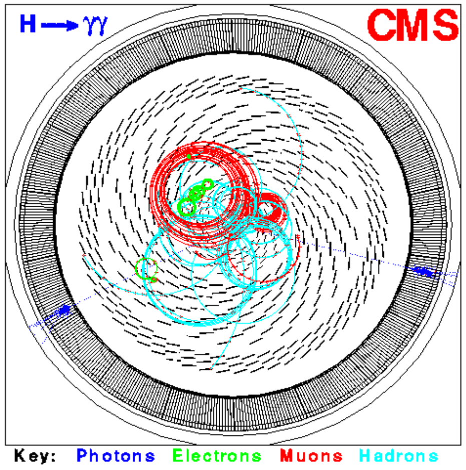
C

$$\frac{\sigma}{E} = \frac{2.7\%}{\sqrt{E}} \oplus 0.5\% \oplus \frac{150\,MeV}{E}$$

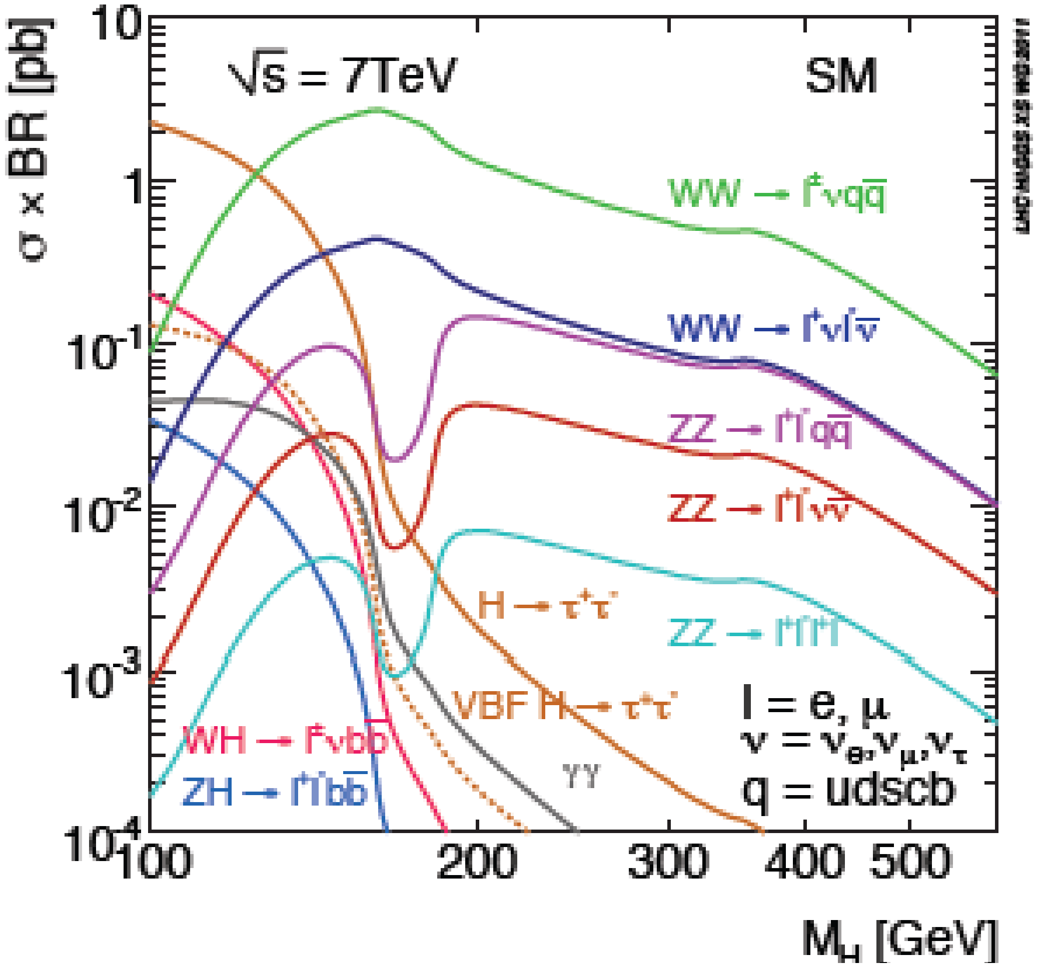




Evidenza del
segnale H →γγ
in ECAL CMS
@ risoluzione
di progetto



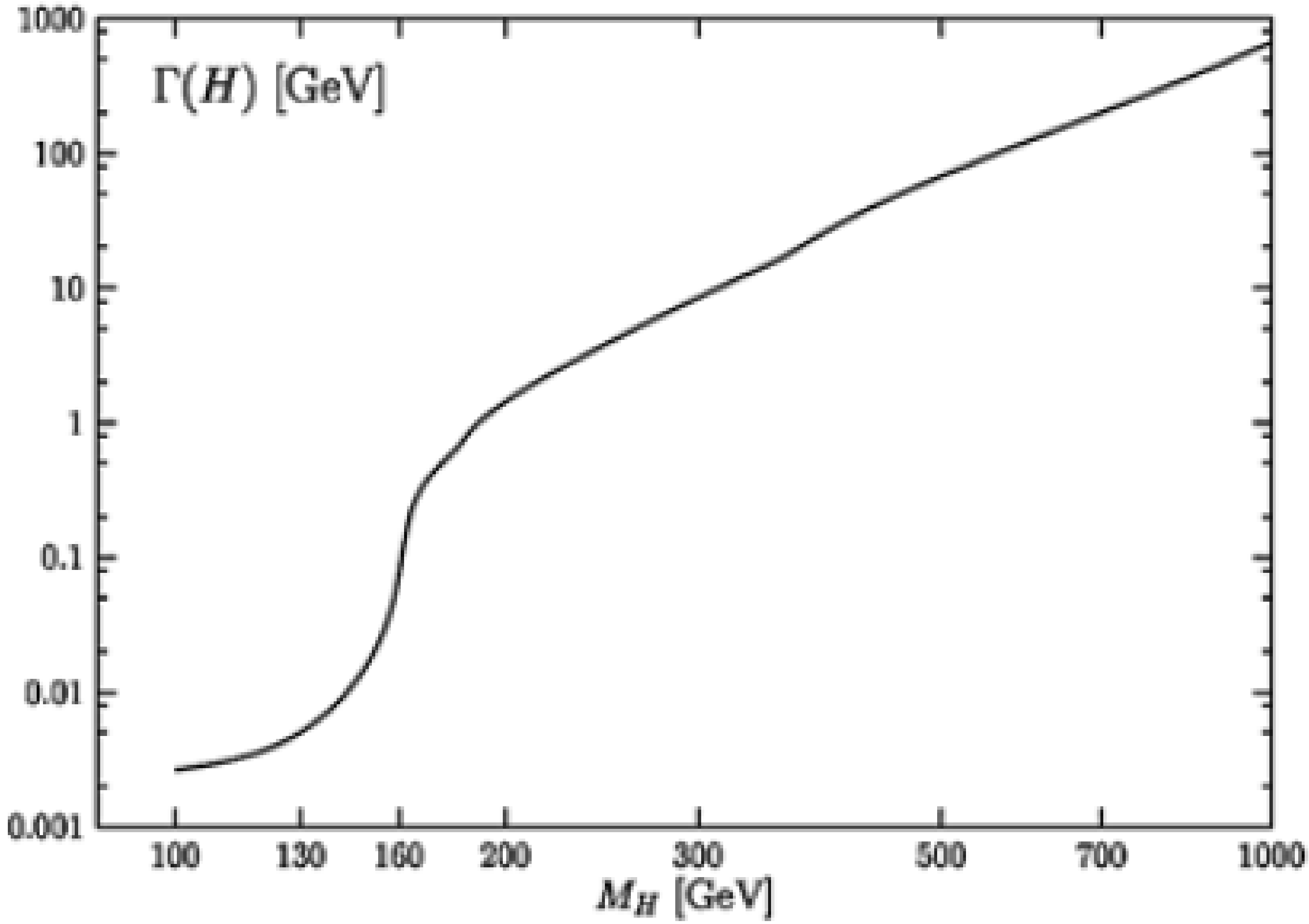
SM Higgs decay channel at LHC



- At high mass (>135 GeV):
  - Decay to H→WW and H→ZZ dominates

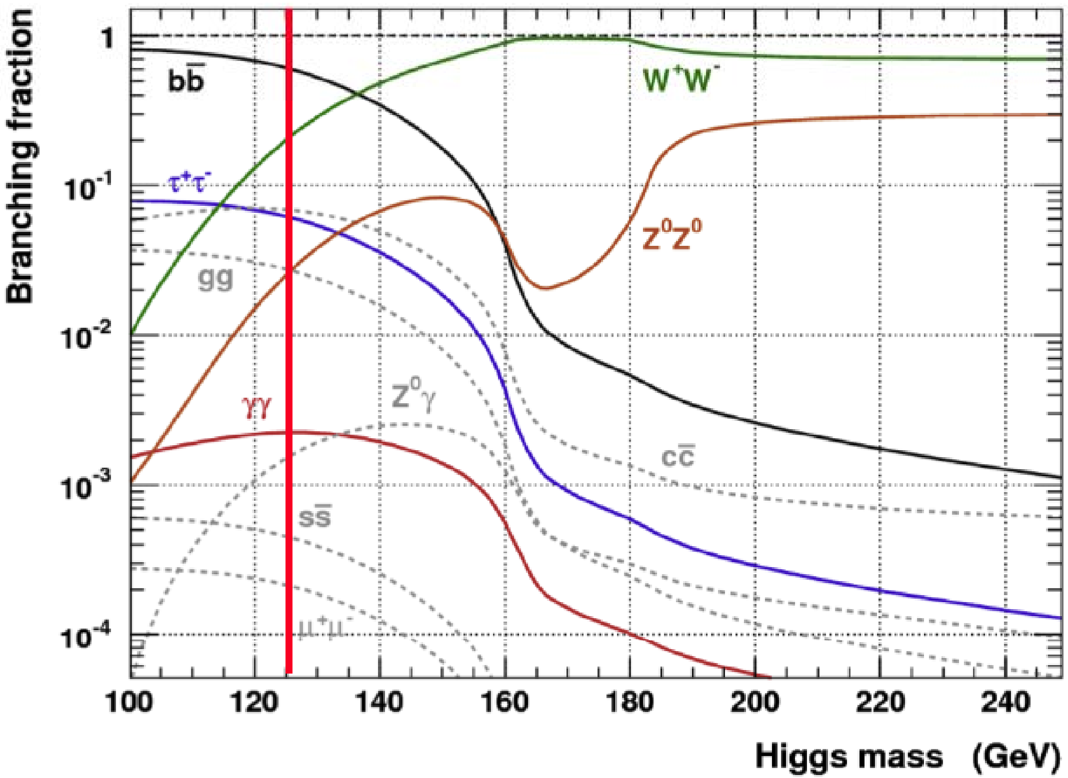
- At low mass (<135 GeV):
  - Dominant decay modes are into pairs of b-quarks and taus
  - H→γγ tiny branching ratio but distinct signature

Higgs Width vs M_{Higgs}



- A basse masse (MH<300-400 GeV) la sua larghezza è “strumentale”
- Per masse più grandi la sua larghezza intrinseca è prevalente
- Intorno ad 1 TeV la larghezza è quasi uguale alla massa

Higgs decays



Γ_H = 4 MeV not directly measurable at LHC

Best experimental mass resolution for $\gamma\gamma$ and 4ℓ decays

Tree level couplings → decay ττ/bb (fermions) WW/ZZ (bosons)

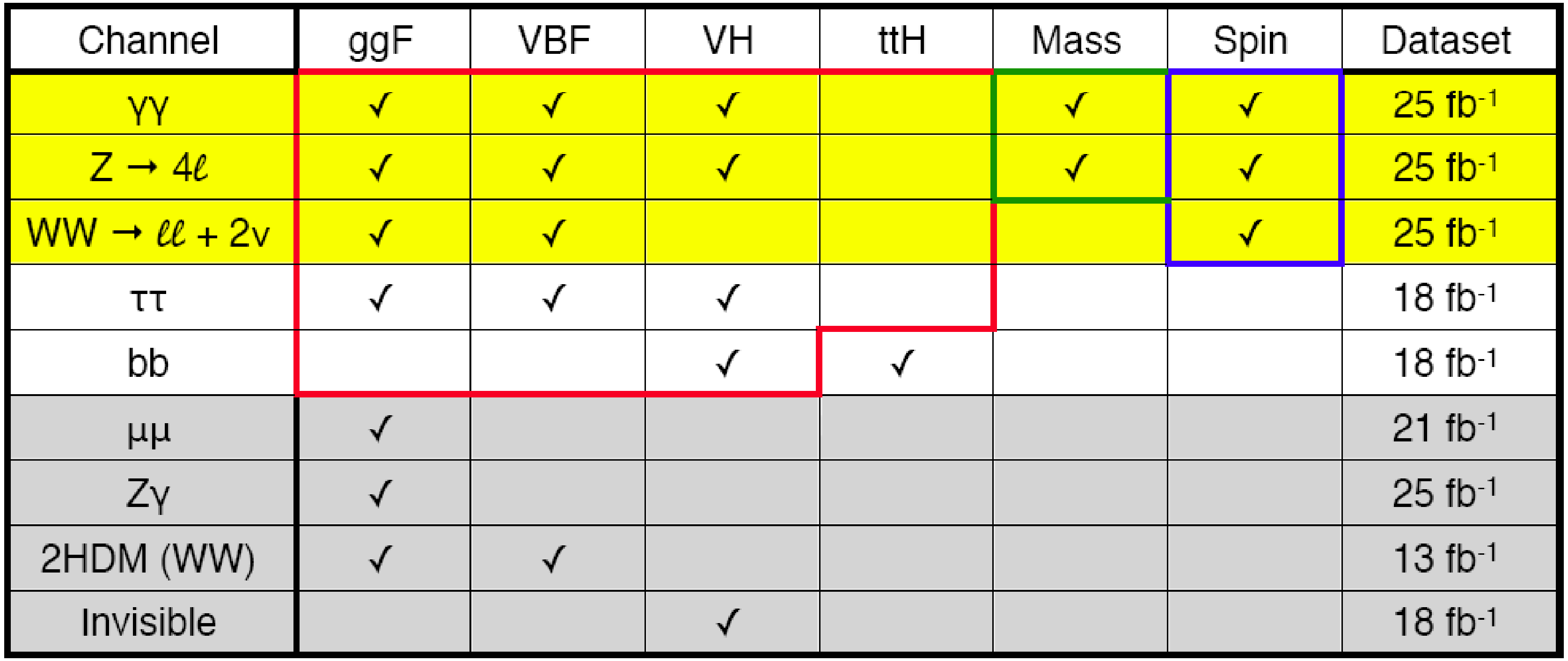
Loop couplings γγ → sensitive to BSM

Overall experimental strategy (ATLAS)

Investigate a large number of final states, with sub-channels to separate different production mechanisms (and to increase overall significance)

Probe Lagrangian structure. Measure mass, spin and CP properties

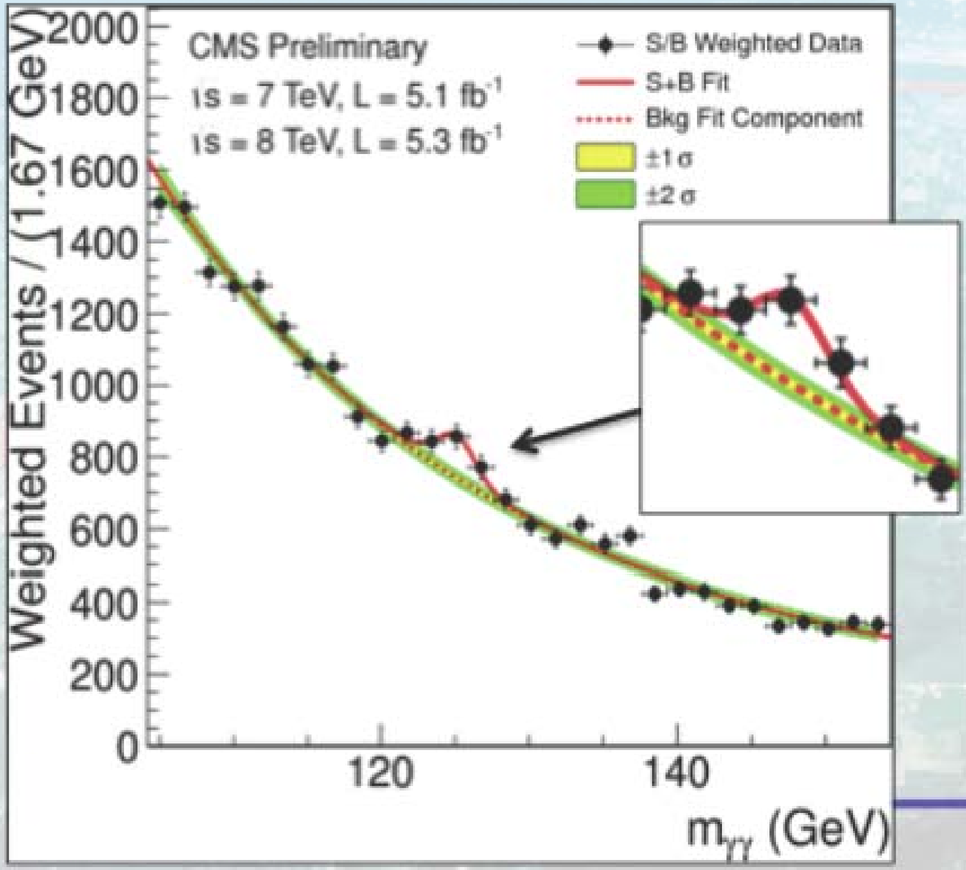
Continue to search for additional Higgs bosons

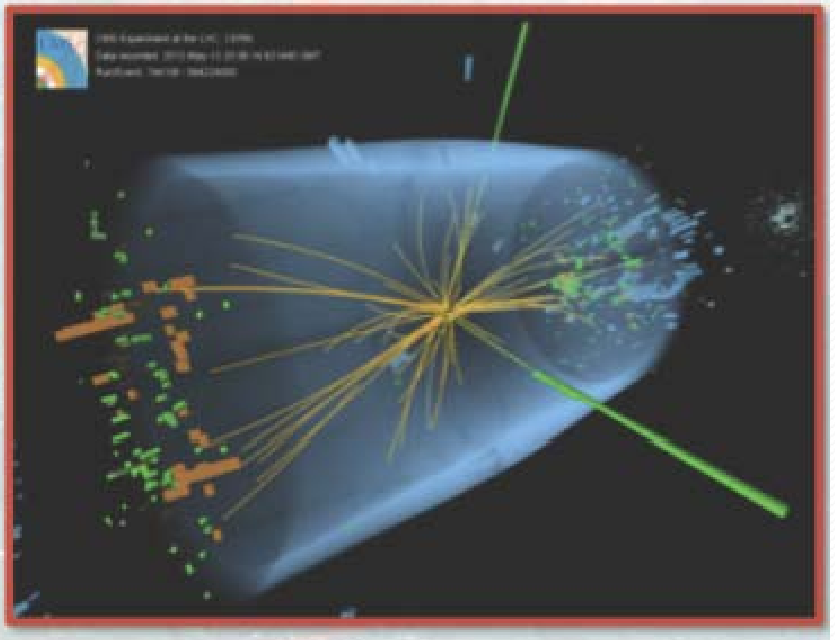


Channel	ggF	VBF	VH	ttH	Mass	Spin	Dataset
$\gamma\gamma$	✓	✓	✓		✓	✓	25 fb^{-1}
$Z \rightarrow 4\ell$	✓	✓	✓		✓	✓	25 fb^{-1}
$WW \rightarrow \ell\ell + 2\nu$	✓	✓				✓	25 fb^{-1}
$\tau\tau$	✓	✓	✓				18 fb^{-1}
bb			✓	✓			18 fb^{-1}
$\mu\mu$	✓						21 fb^{-1}
$Z\gamma$	✓						25 fb^{-1}
2HDM (WW)	✓	✓					13 fb^{-1}
Invisible			✓				18 fb^{-1}

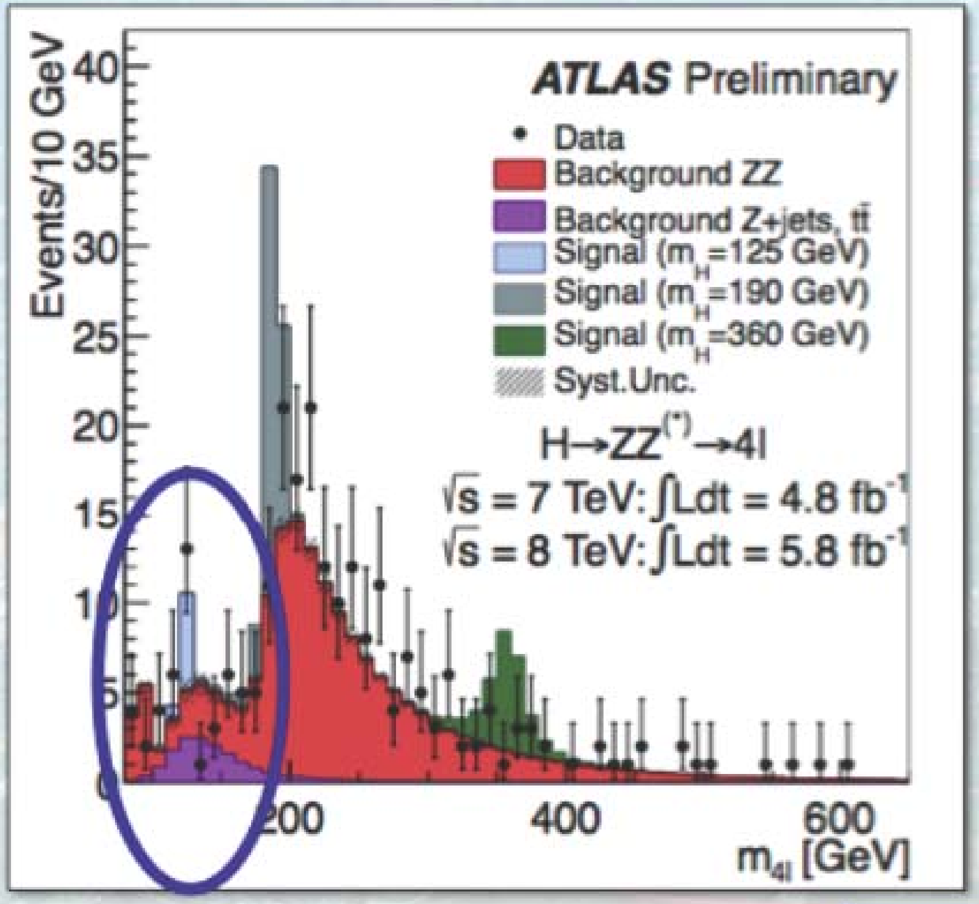
July 4, 2012

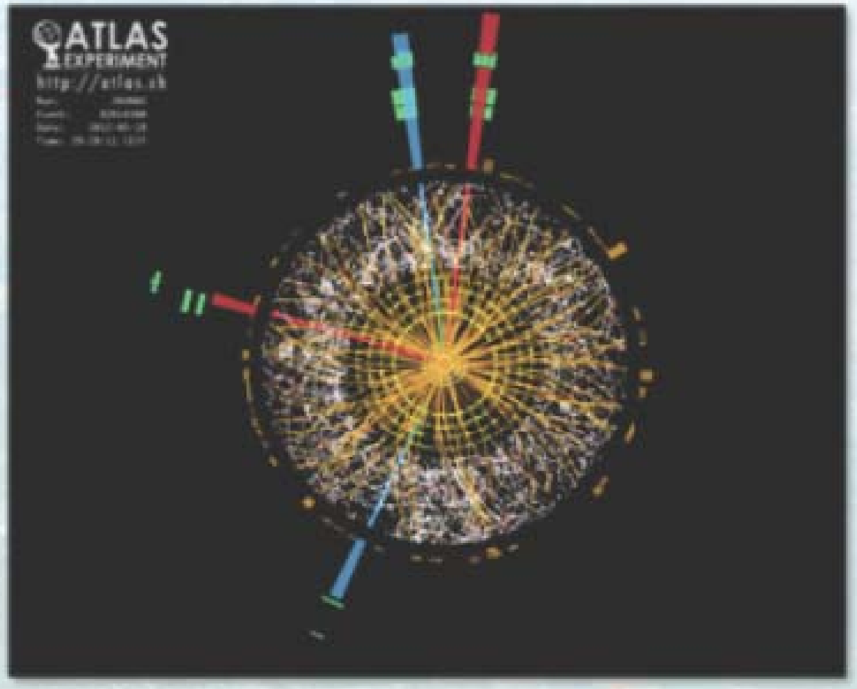
I due esperimenti ATLAS e CMS hanno presentato risultati preliminari sulla ricerca del Bosone di Higgs dai dati accumulati nel 2011 e nel 2012





CERN 4 luglio 2012:
Entrambi gli esperimenti presentano un significativo eccesso di eventi a circa 125 GeV nel plot di massa in diversi canali di decadimento



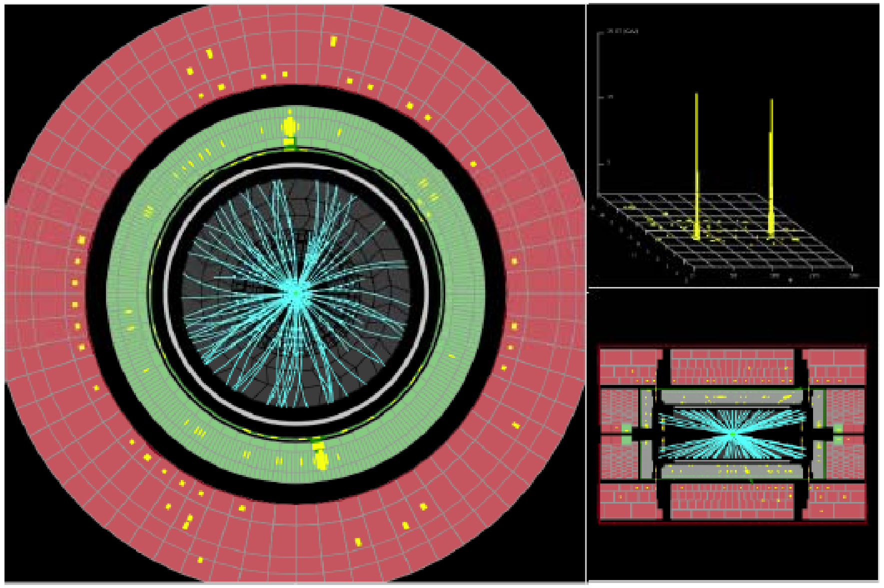


H → γγ

Select events with two isolated high pT photons (40/30 GeV)

Separate events into categories with different S/B, resolutions and different relative contributions of signal production modes

Quantify excess in steeply falling diphoton mass spectrum



Main improvements:
(Since December result)

New / improved categories for VBF and VH signal

Fiducial cross section

Reduced systematic uncertainties

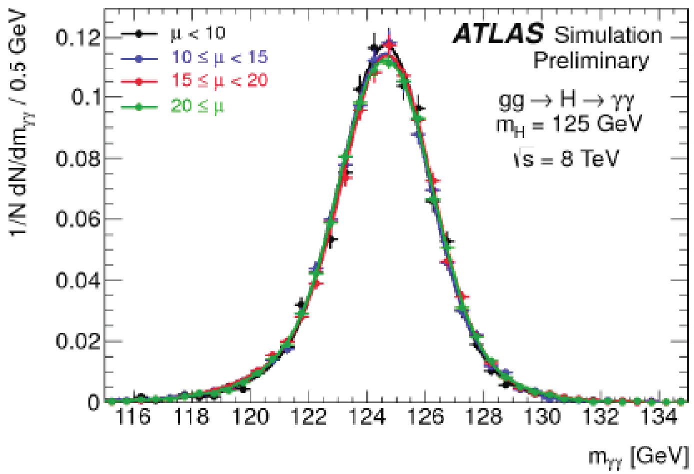
Dataset	Production modes	Exp. signal yield	S/B
25/fb	ggF, VH, VBF	~450	~3%

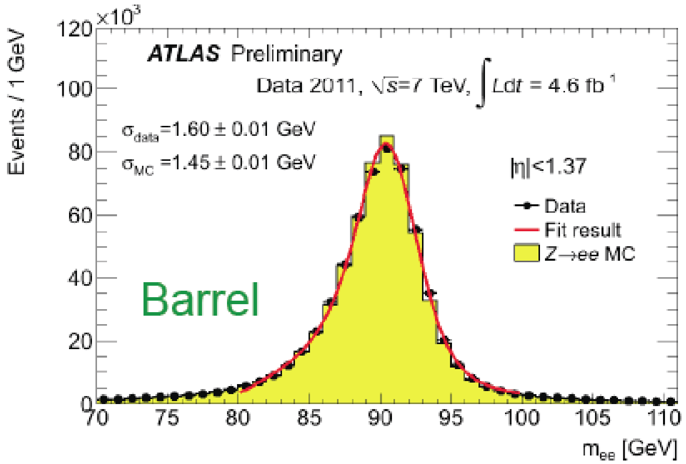
Di-photon mass resolution

Improved and pileup stable mass resolution by relying on calorimeter pointing for the photon direction measurement

Calorimeter resolution corrections derived from Z decay to electrons

- Add effective constant term to perfect MC resolutions through smearing
- 1% in barrel, 1.5 − 2.5% in endcap

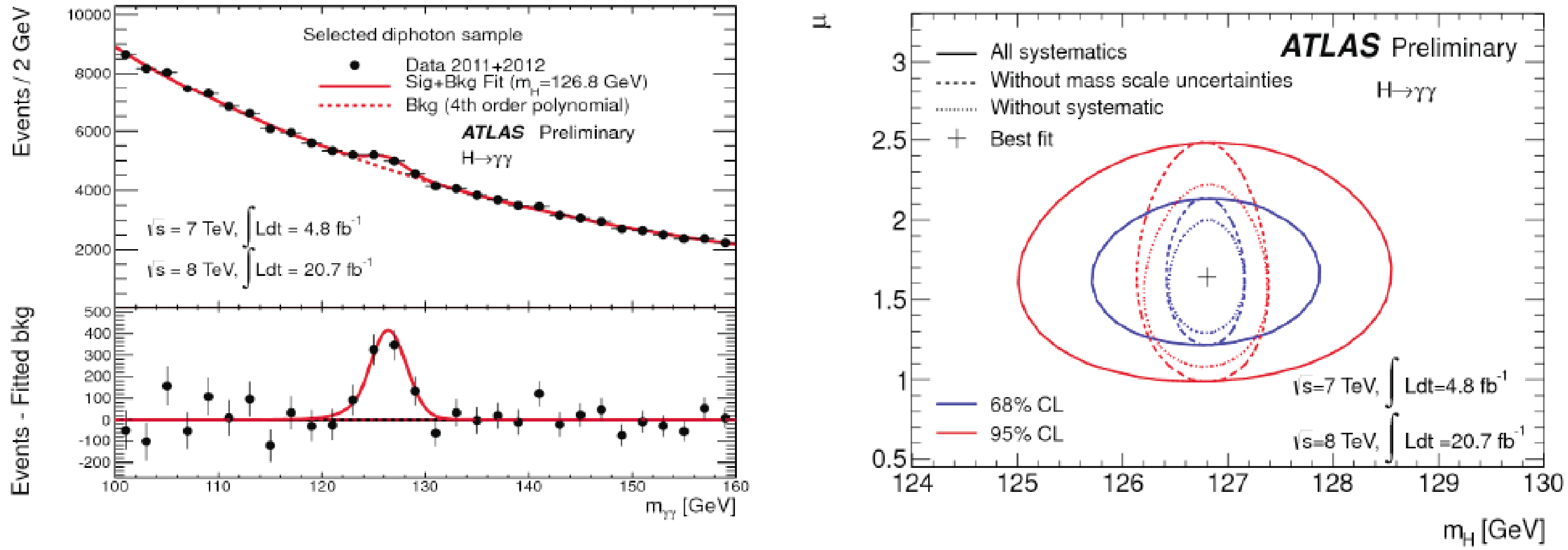




Uncertainty on photon energy resolution (14 − 23%):

Sampling term (from test-beam), 'effective' constant term and e→γ extrapolation (material upstream calorimeter)

Signal strength



Observed significance 7.4σ (expected 4.1σ), consistent result w/o categories

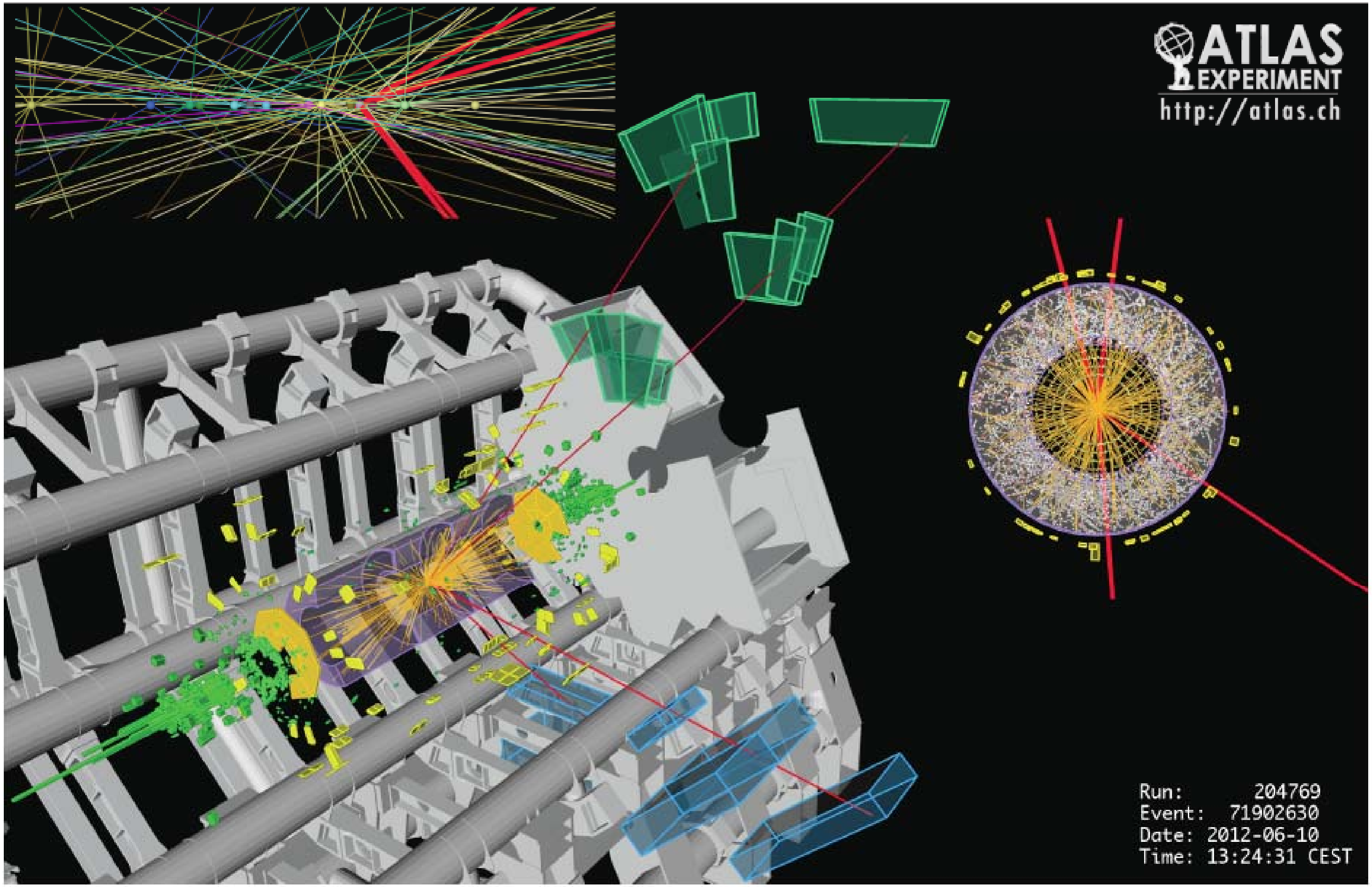
Mass: m_H =126.8 ± 0.2(stat) ± 0.7(syst) GeV

Signal strength: μ = 1.65 ± 0.24(stat) ± 0.22(syst) [2.3σ compatibility with SM]

Fit prefers narrower than nominal mass resolution by 1.8σ. This is better than with a perfectly uniform calorimeter, likely due to background fluctuation

Fitting without resolution constraint gives a ~10% lower signal strength

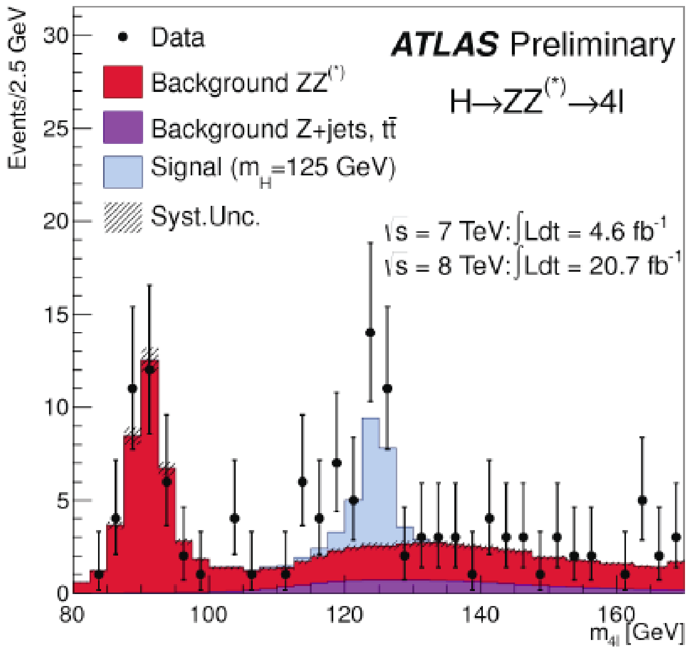
$H \to ZZ^* \to 4\ell$

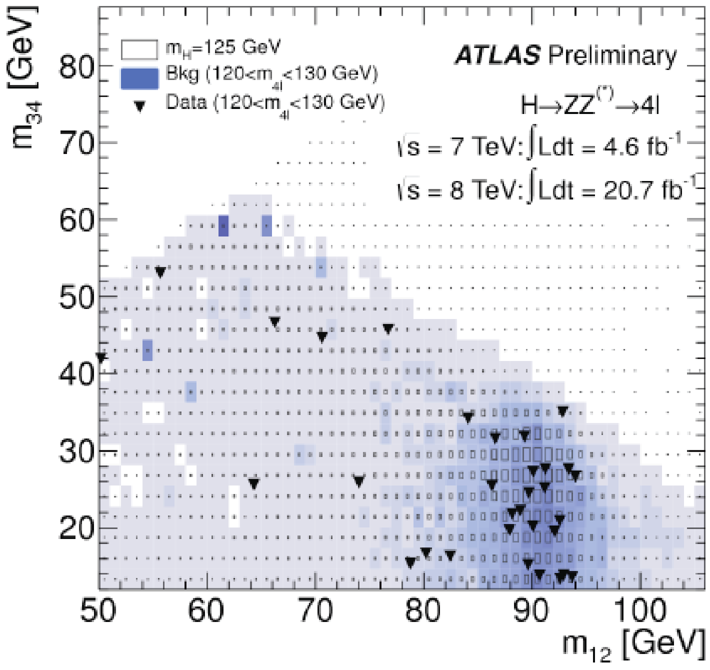


2 same flavour, opposite charge lepton pairs (one) consistent with Z mass

$H \to ZZ^* \to 4\ell$

Look for a clustering of events in the 4-lepton invariant mass distribution

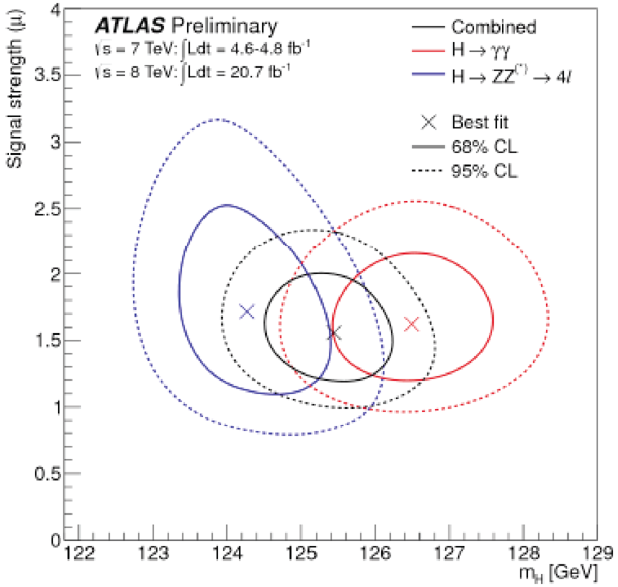


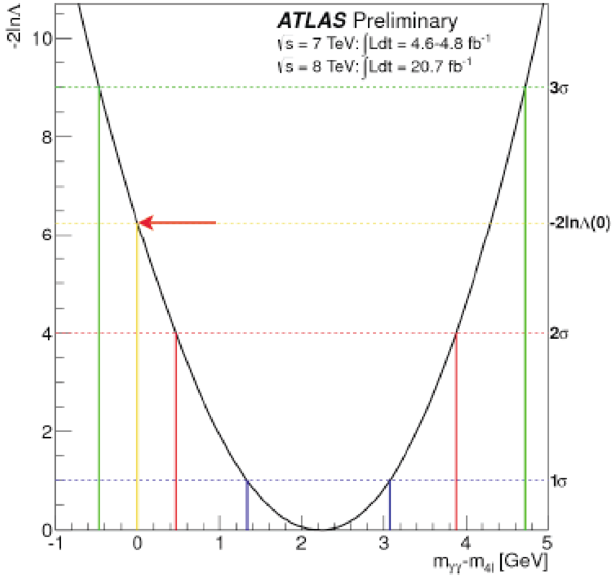


Main backgrounds:

- SM *ZZ** production, irreducible (estimated from MC)
- Top, *Z*+bb, *Z*+jj (data driven estimation)
  - Minimise with isolation and small impact parameter requirements

$H \rightarrow \gamma\gamma$ and $H \rightarrow 4\ell$ mass combination





Combined mass measurement m_H = 125.5 ± 0.2 (stat) ± 0.6 (syst) GeV

The mass difference is reduced by 700 MeV compared to the December result

Taking mass scale systematic uncertainties and their correlations into account the compatibility of the two measurements is at the 1.5% (2.4σ level)

With an alternative treatment of systematic uncertainties this increases to 8%

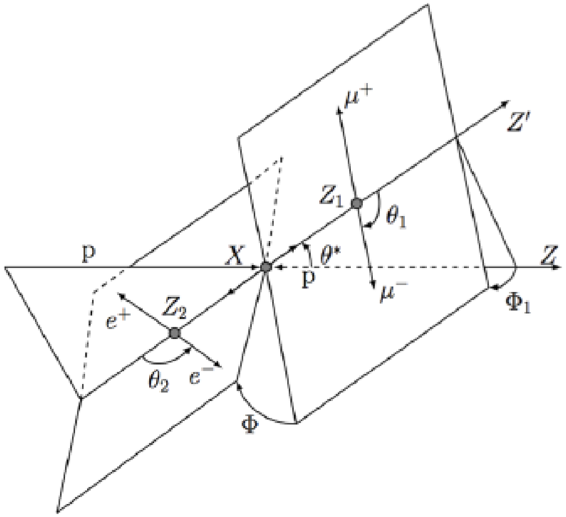
Argomenti “dopo” il 4 luglio.

- La nuova particella scoperta e’ veramente il bosone di Higgs?
  - ricerca degli altri canali di decadimento
  - misura dello spin
  - misura del “signal strength” $\mu = \sigma/\sigma_{SM}$ (la sezione d’urto e’ funzione di m_H)
- Misura della massa della nuova particella
- Misura dei suoi accoppiamenti
- Ricerca di nuove particelle, ad esempio un bosone di higgs piu’ “pesante”.

Overview

Spin studies in three different decay modes

- H → γγ: fully reconstructed, however only production angle θ* available
- H → WW: direct calculation of decay angles not possible, use other kinematic distributions
- H → ZZ: fully reconstructed, decay of Z bosons provides information on the Z decay planes

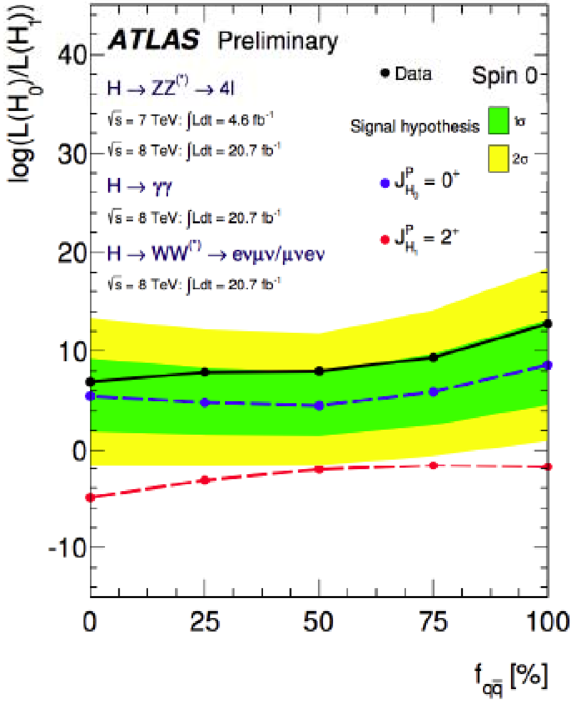


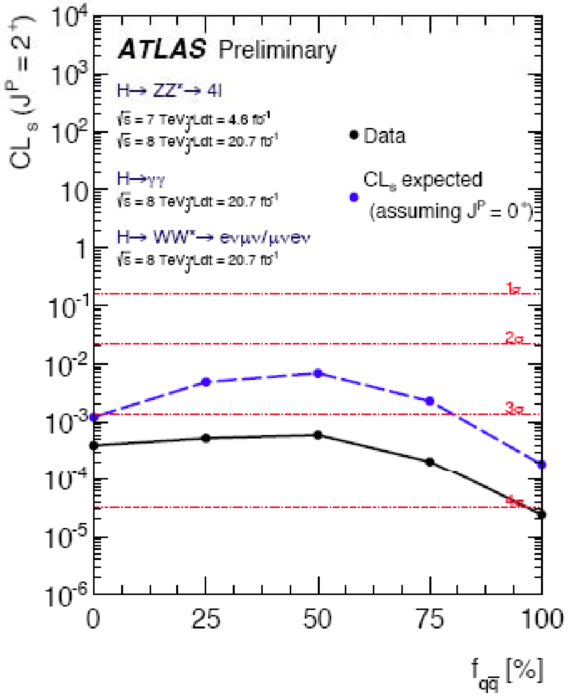
Spin 1 hypothesis strongly disfavoured by Landau-Yang theorem, main interest is to test the SM 0^+ hypothesis against spin 2^+: start with spin 2 tensor with minimal couplings to SM particles (2^+_m)

Spin 2^+_m discrimination is tested for possible mixtures of gluon and quark initiated production

H → ZZ analysis is also testing other spin parity states, as 0^+ vs 0^- etc. with gluon-fusion production

Spin results





New

Will appear as:
ATLAS-CONF-2013-040

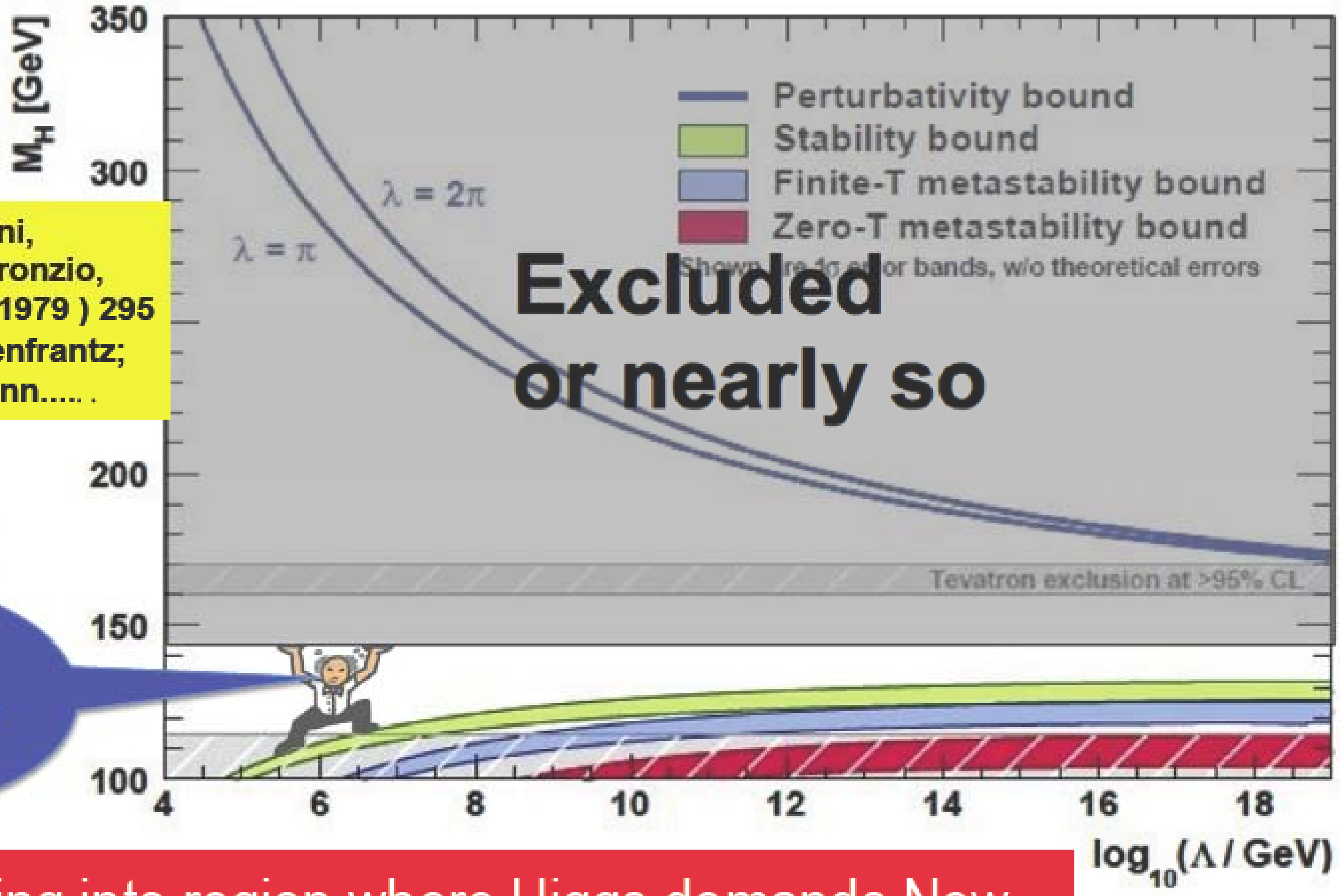
In combination, the 3 channels exclude the 2^+_m model at the 99.9% CL

- Main sensitivity from WW (and γγ for pure ggF production)
- Complementary sensitivity of channels for the different qq production fractions

The ZZ analysis excludes the 0^-, 1^+ and (1^-) hypotheses at the >95% (94%) CL

Higgs Stability

N. Cabibbo, L. Maiani,
G. Parisi and R.Petronzio,
Nucl. Phys. B 158 (1979) 295
Sher; Lindner; Hasenfrantz;
Hambey, Riesselmann..... .



Excluded or nearly so

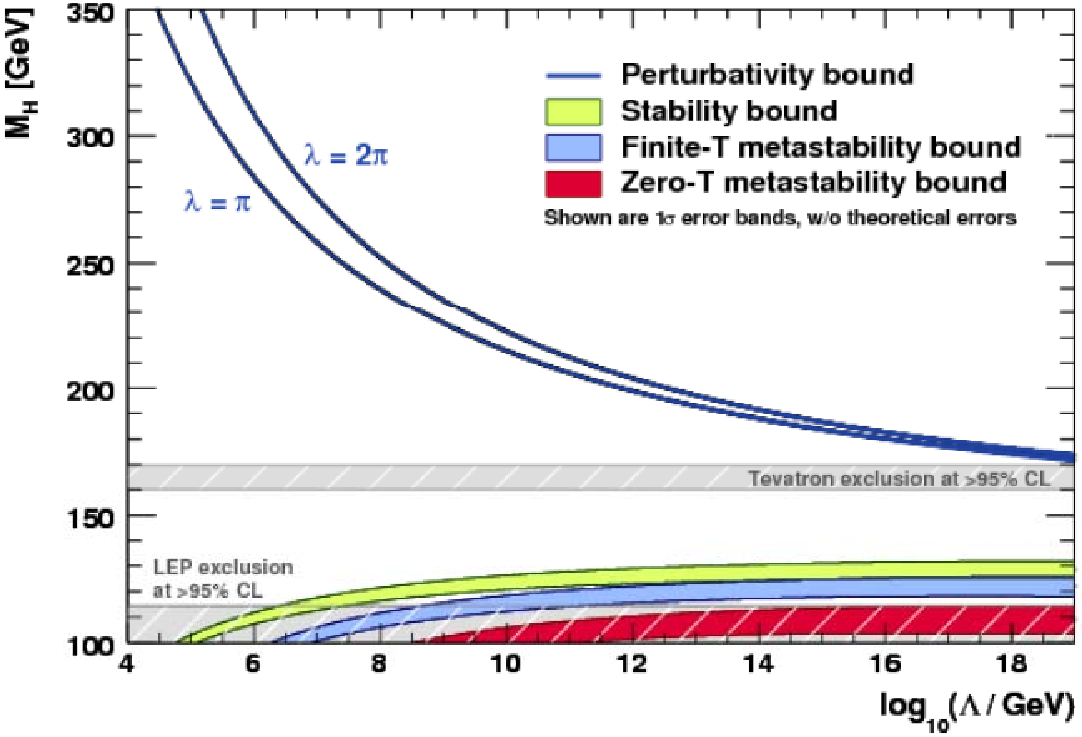
Pretty tight stable region, isn't it ?!

Are we heading into region where Higgs demands New Physics ?

We will know very soon !!

Question: which values of the Higgs mass ensure vacuum stability and perburbativity up to the Planck scale ?

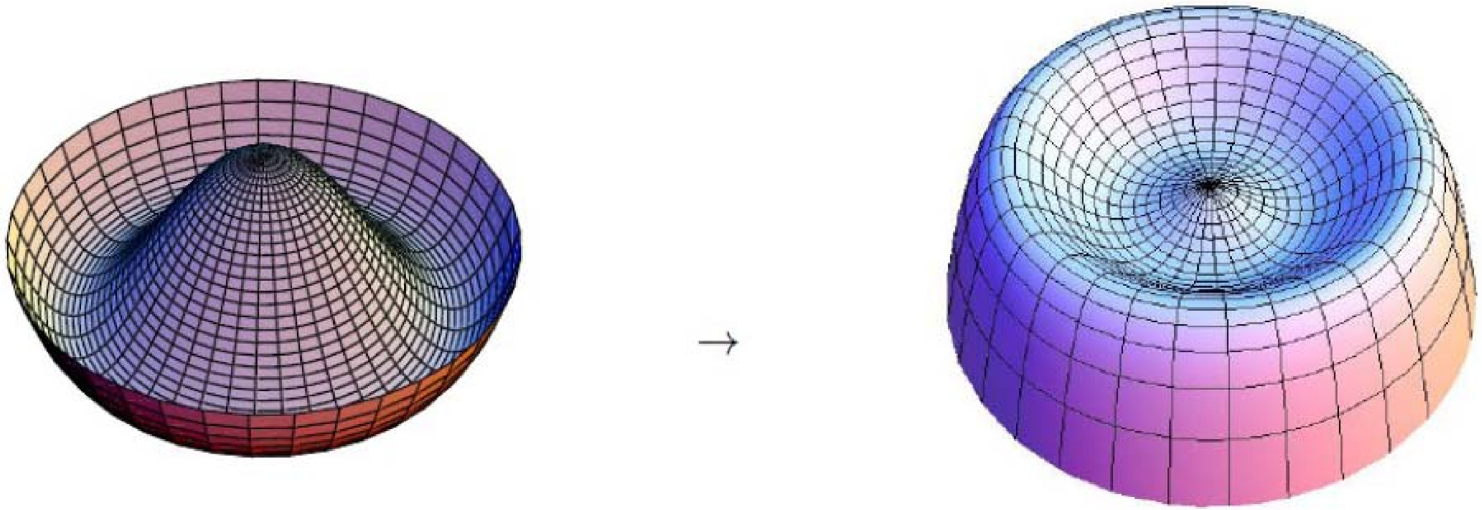
Answer: find when $\lambda = 0$ (~ $V_{eff} = 0$) or when λ becomes large given the initial values for the couplings obtained form the experimental results ($M_t = 173.2 \rightarrow Y_t(M_t)$....)



Ellis et al. 09

M_H ~ 125-126 GeV: $-Y_t^4$ wins: $\lambda(M_t)$ ~ 0.14 runs towards smaller values and can eventually become negative. If so the potential is either unbounded from below or can develop a second (deeper) minimun at large field values

Illustrative



If your mexican hat turns out to be a dog bowl you have a problem…

from A. Strumia

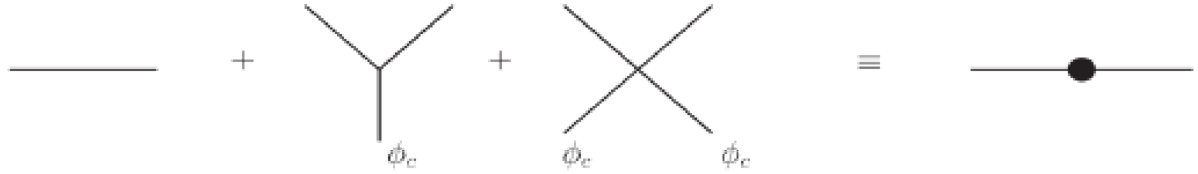
The effective potential

Single real field: $$\mathcal{L} = \frac{1}{2}\partial^\mu\phi\partial_\mu\phi - V(\phi), \qquad V(\phi) = \frac{m^2}{2}\phi^2 + \frac{\lambda}{4}\phi^4$$

The minimum of V(Φ) gives the vacuum expectation value (vev) of Φ “at the classical level” (the state of lowest energy)

V(Φ) gives the lowest-order interactions (proper vertices, 1PI Green's functions at $p^2 = 0$) after SSB and shifting the field by the vev

$V(\phi)$



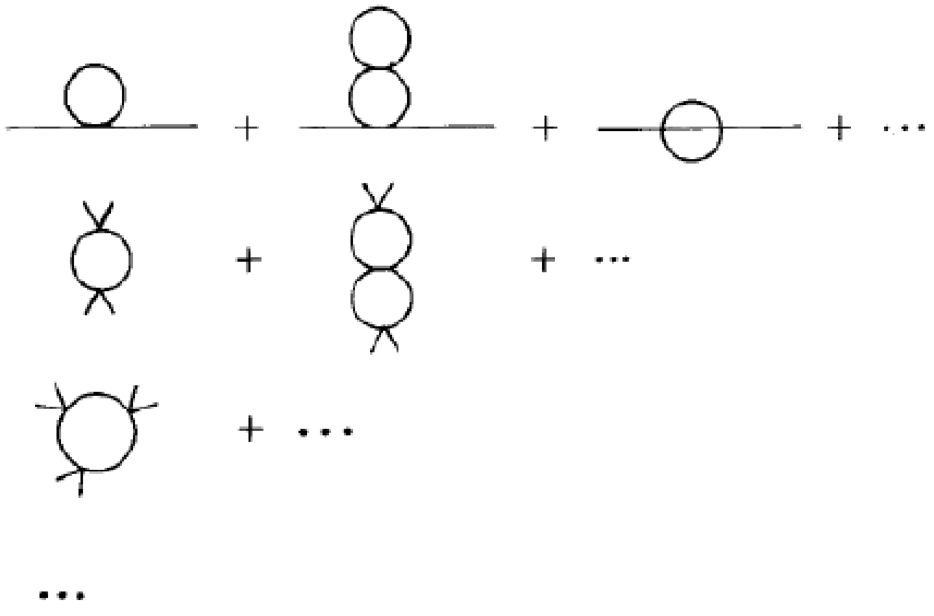
Quantum corrections will create new interactions . We are going to get interactions with 5,6,... external fields and the structure of the potential will be modified.

The vev of Φ including quantum corrections will be given by a new function, Veff (Φ_c), the effective potential that will agree with the classical potential energy to lowest order in perturbation theory

$$V_{eff}(\phi_c) = V(\phi_c) + V^{rad.}(\phi_c)$$

Infinite sum of Feynman diagrams

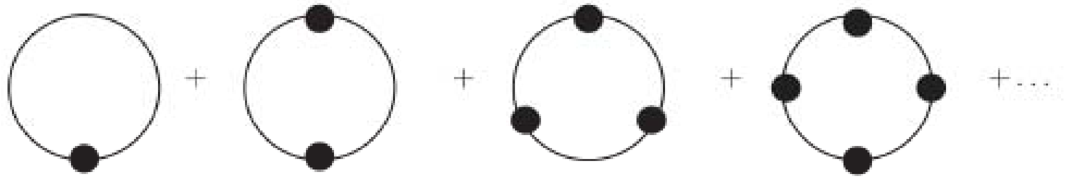
$$V(\phi_c) = \lambda \frac{\phi_c^n}{n!}$$



$$i\int \frac{d^4k}{(2\pi)^4}\frac{1}{2r}\left(\frac{\lambda\phi_c^{n-2}}{(n-2)!}\frac{1}{k^2+i\epsilon}\right)^r$$

n=4, r=3

$$V_{eff}(\phi_c) = \lambda\frac{\phi_c^n}{n!} + i\int\frac{d^4k}{(2\pi)^4}\sum_{r=1}^{\infty}\frac{1}{2r}\left(\frac{\lambda\phi_c^{n-2}}{(n-2)!}\frac{1}{k^2+i\epsilon}\right)^r = \lambda\frac{\phi_c^n}{n!} + \frac{1}{2}\int\frac{d^4k}{(2\pi)^4}\ln\left(1+\frac{\lambda\phi_c^{n-2}}{(n-2)!\,k^2}\right)$$



$$V_{eff}(\phi_c) = V(\phi_c) + \frac{1}{2}\int^{\Lambda}\frac{d^4k}{(2\pi)^4}\ln\left(1+\frac{V''(\phi_c)}{k^2}\right) = V(\phi_c) + \frac{\Lambda^2}{32\pi^2}V'' + \frac{(V'')^2}{64\pi^2}\left[\ln\left(\frac{V''}{\Lambda^2}\right)-\frac{1}{2}\right]$$

$$V(\phi) = \frac{m^2}{2}\phi^2 + \frac{\lambda}{4}\phi^4$$

$$V_{eff}(\phi) = \frac{m^2}{2}\phi_c^2 + \frac{\lambda}{4}\phi_c^4 + \frac{(m^2+3\lambda\phi_c^2)^2}{64\pi^2}\ln(m^2+3\lambda\phi_c^2) + A(\Lambda)\phi_c^2 + B(\Lambda)\phi_c^4$$

Divergent factors, A, B, can be reabsorbed in the definition of the renormalized parameters, m^2_R, λ_R. The result will depend on the scale of the subtraction point, μ, (or in dimensional regularization on 't Hooft mass)

$$V_{eff}(\phi) = \frac{m^2}{2}\phi_c^2 + \frac{\lambda}{4}\phi_c^4 + \frac{(m^2+3\lambda\phi_c^2)^2}{64\pi^2}\ln\frac{m^2+3\lambda\phi_c^2}{\mu^2}$$

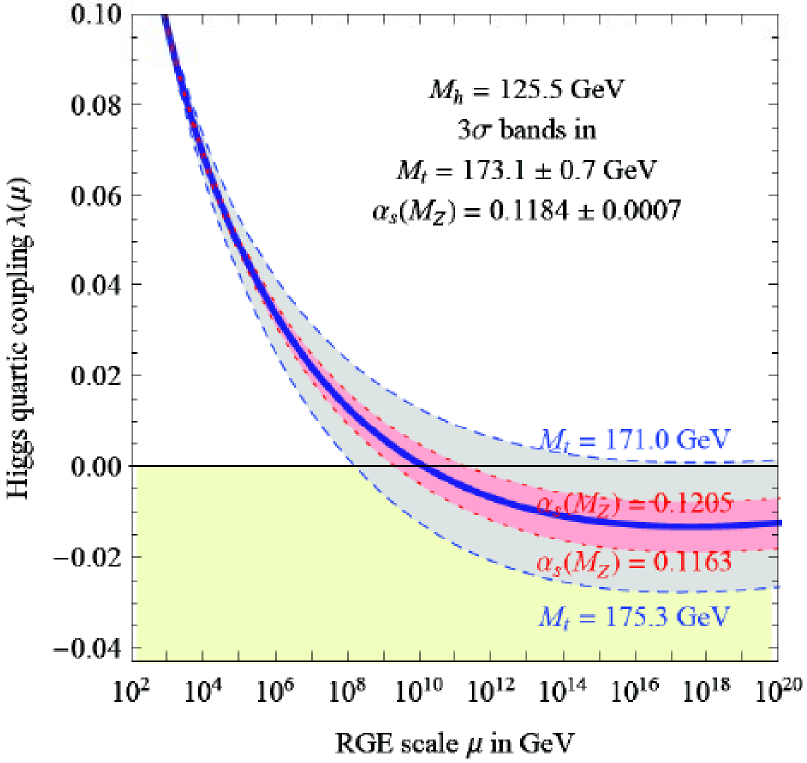
$m^2 = 0$

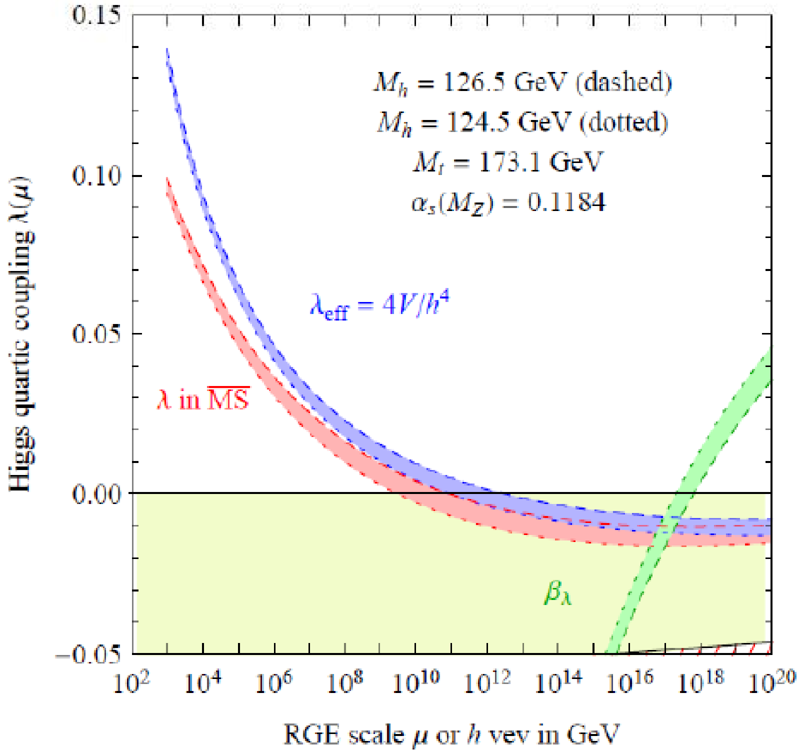
$$V(\phi) \;=\; \frac{\lambda}{4}\phi^4, \qquad \phi = 0 \;\; min$$

$$V_{eff}(\phi_c) \;=\; \frac{\lambda}{4}\phi_c^4 + \frac{9\lambda^2\phi_c^4}{64\pi^2}\ln\frac{\phi_c^2}{\mu^2},, \qquad \frac{dV_{eff}}{d\phi_c} = 0, \;\; \phi = 0 \;\; max, \; \lambda\ln\frac{\phi_c}{\mu} \sim -\frac{8}{9}\pi^2 \rightarrow \; min$$

Minimum occurs when $\lambda\ln\frac{\phi_c}{\mu} \sim \mathcal{O}(1)$ but higher loops contribute to V_{eff} as

$\lambda\left(\lambda\ln\frac{\phi_c}{\mu}\right)^n$ We have to resum the logs using the RGE.



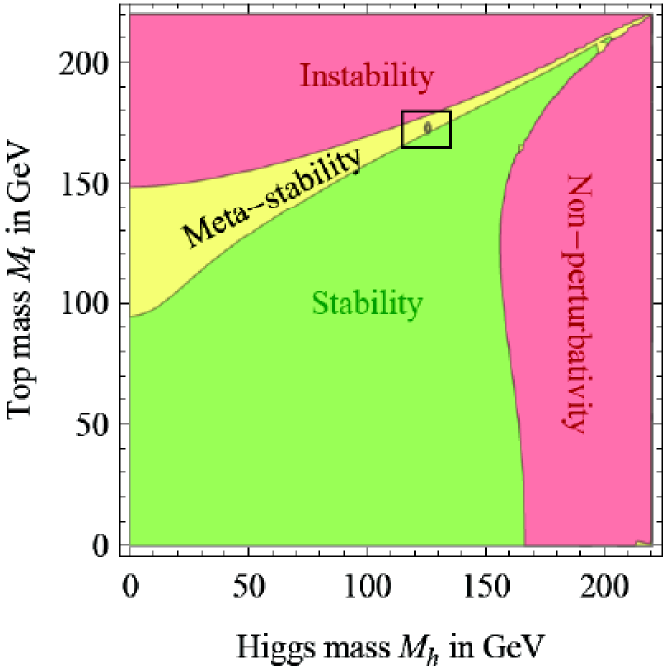


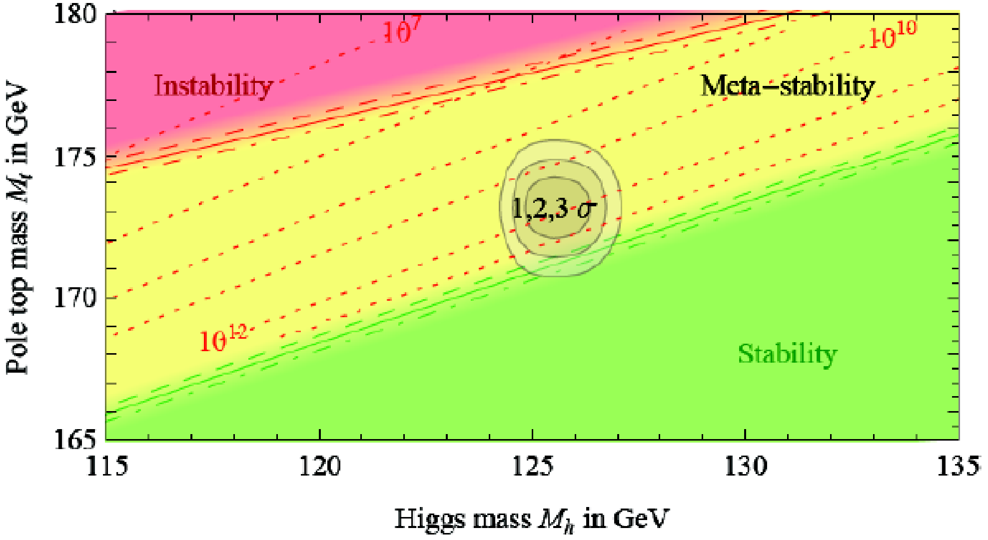
Full stability is lost at $\Lambda \sim 10^{11}$ GeV. but λ never becomes too negative

$$\lambda(M_{Pl.}) = -0.0144 + 0.0028\left(\frac{M_h}{\text{GeV}} - 125\right) \pm 0.0047_{M_t} \pm 0.0018_{\alpha_s(M_Z)} \pm 0.0028_{\text{th}}$$

Both λ and β_λ are very close to zero around the Planck mass

Are they vanishing there?





$$M_h\,[\text{GeV}] > 129.4 + 1.4\left(\frac{M_t\,[\text{GeV}] - 173.1}{0.7}\right) - 0.5\left(\frac{\alpha_s(M_Z) - 0.1184}{0.0007}\right) \pm 1.0_{\text{th}}$$

We live in a metastable universe close to the border with the stability region.
If the top pole mass would be ~ 171 GeV we were in the stable region.
Is the Tevatron number really the "pole" (what is?) mass?
Monte Carlo are used to reconstruct the top pole mass form its decays products that contain jets, missing energy and initial state radiation.

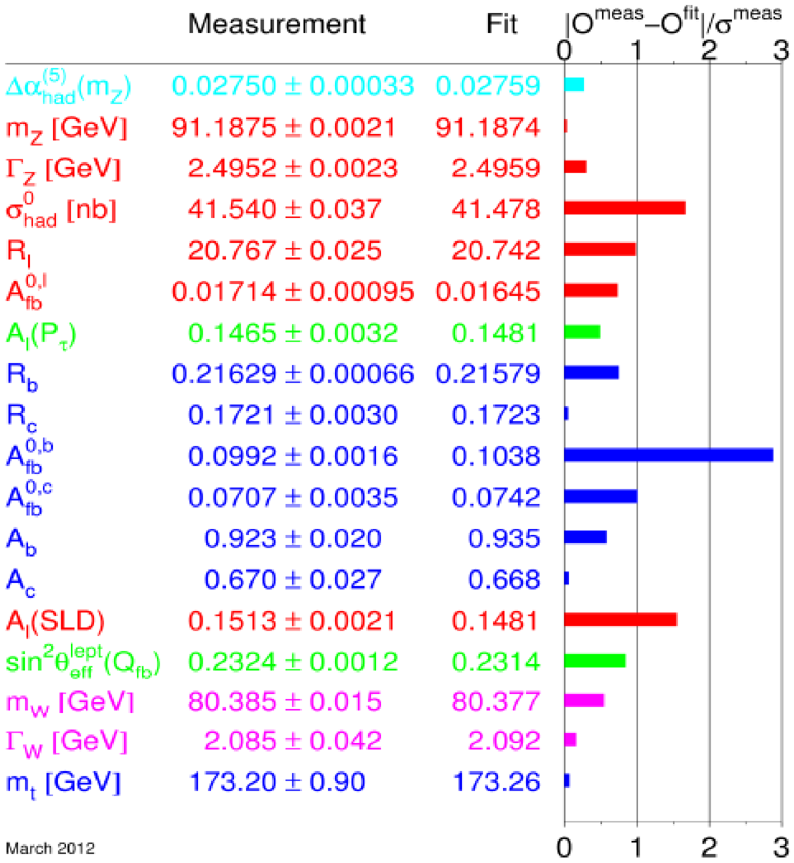
$M_t^{\overline{MS}}$ can be extracted form total production cross section and the corresponding pole mass is consistent with the standard value albeit with a larger error

DOMANDA:

C’e’ ancora spazio per “nuova fisica?”

SM Fit

One can make a global fit including “all” possible measurements and using the radiatively corrected predictions for the various observable. The latter, besides α, G_{μ}, M_Z and lepton masses depend upon: $m_t,\ \Delta\alpha^{(5)}_{had},\ \alpha_s(M_Z),\ M_H$

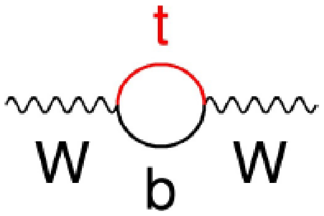


	Measurement	Fit
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02750 ± 0.00033	0.02759
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4959
σ^0_{had} [nb]	41.540 ± 0.037	41.478
R_l	20.767 ± 0.025	20.742
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01645
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1481
R_b	0.21629 ± 0.00066	0.21579
R_c	0.1721 ± 0.0030	0.1723
$A^{0,b}_{fb}$	0.0992 ± 0.0016	0.1038
$A^{0,c}_{fb}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1481
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.385 ± 0.015	80.377
Γ_W [GeV]	2.085 ± 0.042	2.092
m_t [GeV]	173.20 ± 0.90	173.26

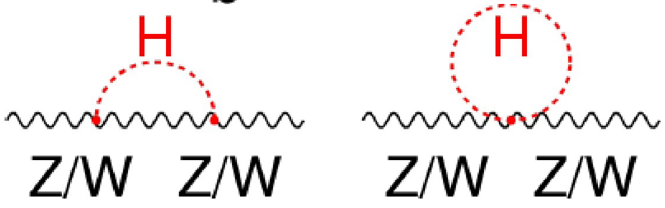
March 2012

Precision $5-1\times10^{-3}$ or better

Sensitivity to quantum effects
Predictions for M_t, M_W, M_H



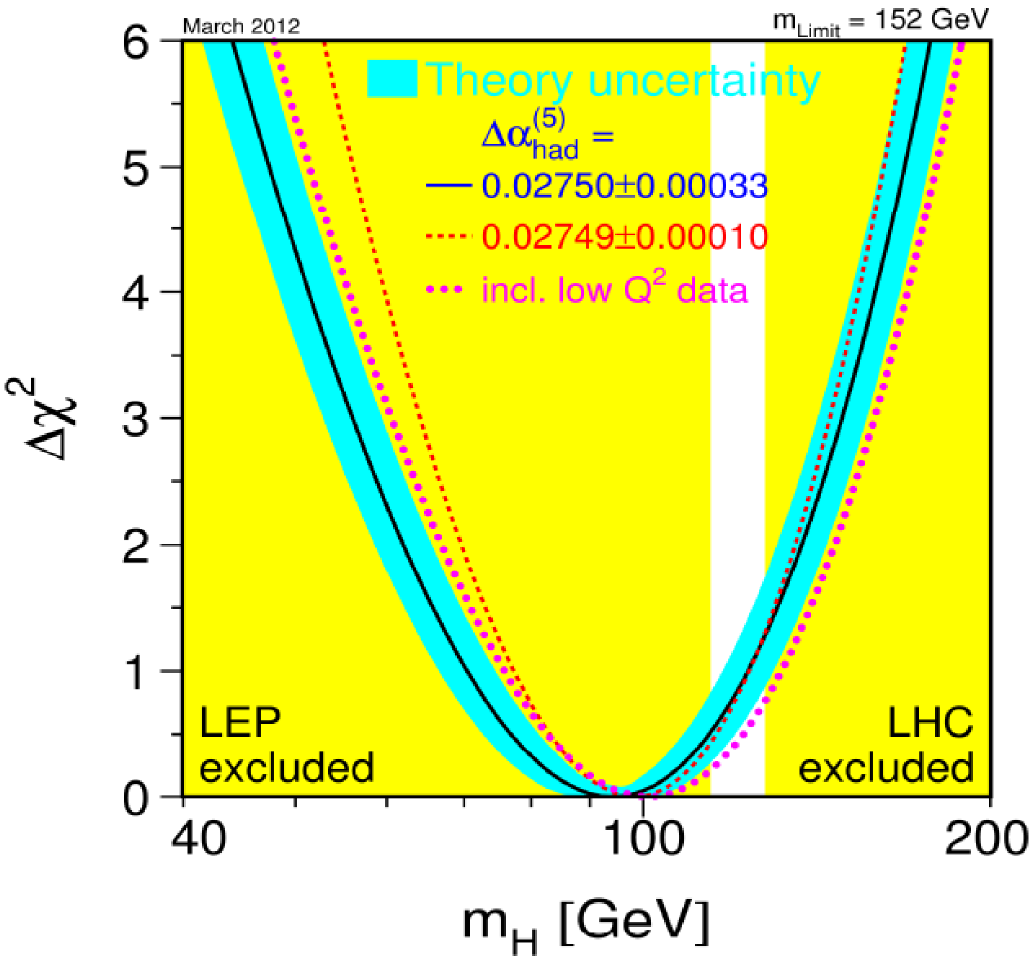
$$\sim \alpha\frac{M_t^2}{M_W^2}$$



$$\sim \alpha\log\frac{M_h^2}{M_Z^2}$$

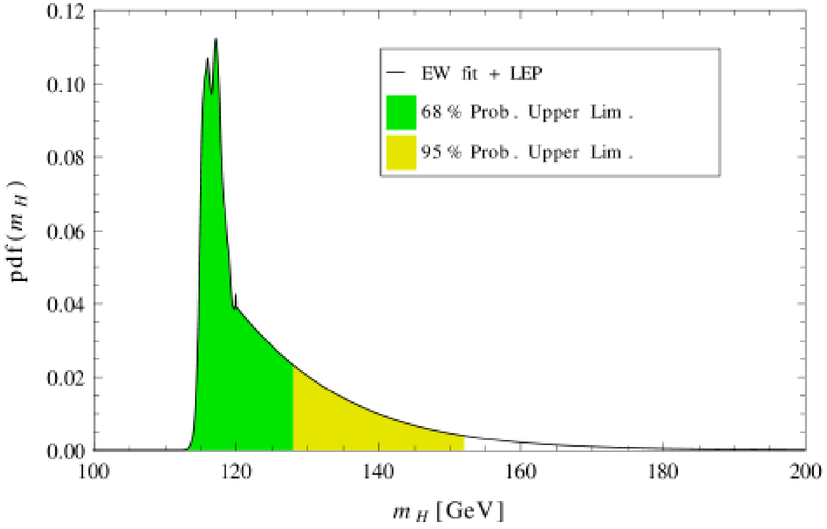
Very weak sensitivity to M_H, without the Value of M_t we cannot predict it.

Global fit to M_H

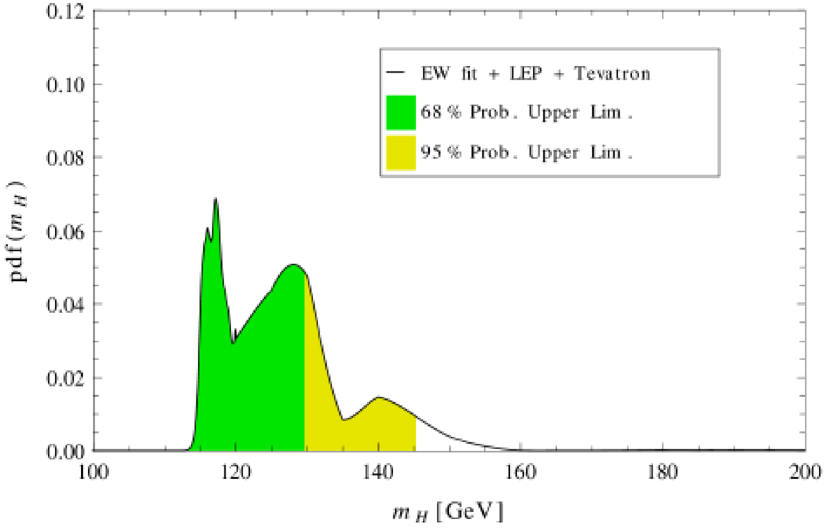


Combining direct and indirect information:

LEP

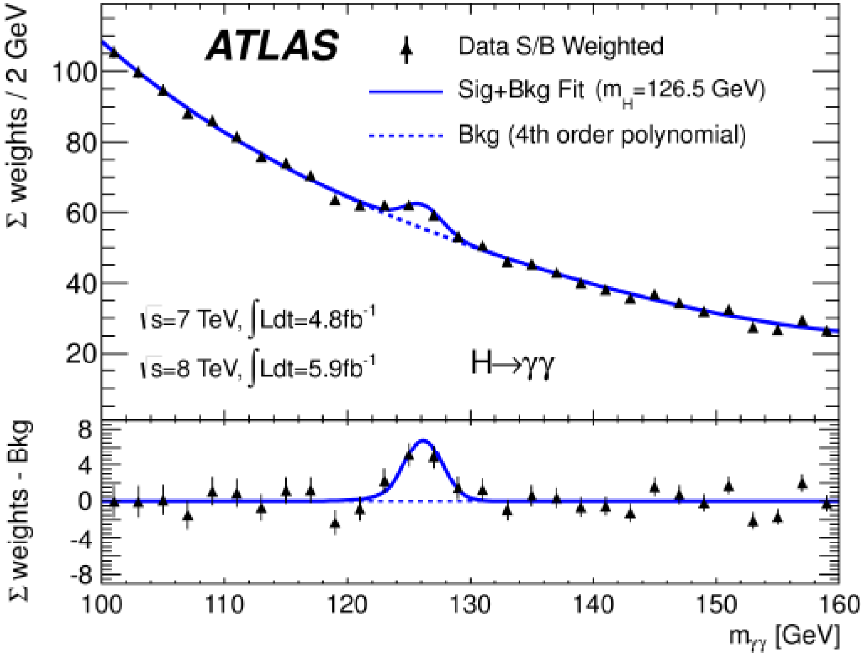


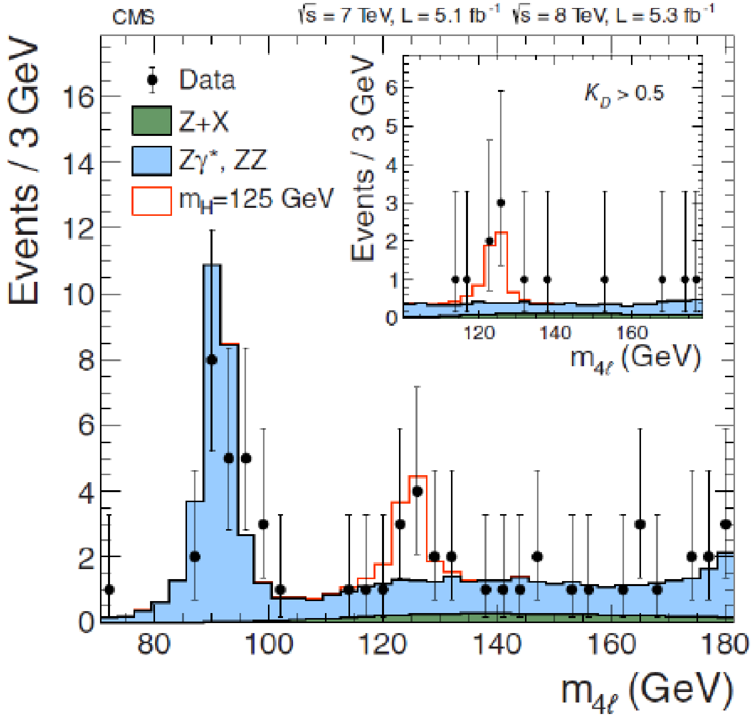
LEP+ TEVATRON



SM: M_H between 114 and 160 GeV with 95% probability below 145 GeV

The Higgs sector: LHC
4th of July 2012





Clear evidence of a new particle
with properties compatible with those of the SM Higgs boson

It is where the SM predicts it should be

Before the discovery of the Higgs one could envisage a situation in which NP contributions were going to mask the effect of a heavy Higgs (“conspiracy”).

Simple explanation:

$$\begin{aligned} \hat{\rho} &= \rho_0 + \delta\rho \; (\rho_0^{\rm SM} = 1, \delta\rho \leftrightarrow T) \\ \Delta\hat{r}_W &\leftrightarrow S \end{aligned}$$

$$\begin{aligned} \sin^2\theta_{eff}^{lept} &\sim \frac{1}{2}\left\{1 - \left[1 - \frac{4A^2}{M_Z^2\,\hat{\rho}\,(1-\Delta\hat{r}_W)}\right]^{1/2}\right\} \\ &\sim (\sin^2\theta_{eff}^{lept})^{\circ} + c_1\,\ln\left(\frac{M_H}{M_H^{\circ}}\right) + c_2\left[\frac{(\Delta\alpha)_h}{(\Delta\alpha)_h^{\circ}} - 1\right] - c_3\left[\left(\frac{m_t}{m_t^{\circ}}\right)^2 - 1\right] + \ldots \end{aligned}$$

$c_i > 0$

To increase the fitted M_H:

$$\left\{ \begin{array}{l} \hat{\rho} > 1 \rightarrow \quad \left\{ \begin{array}{l} \rho_0 > 1 \\ \delta\rho > 0 \end{array} \right. \\ \Delta\hat{r}_W < 0 \end{array} \right.$$

NP better to be of the decoupling type