Did LEP find the Higgs boson? Will the LHC?

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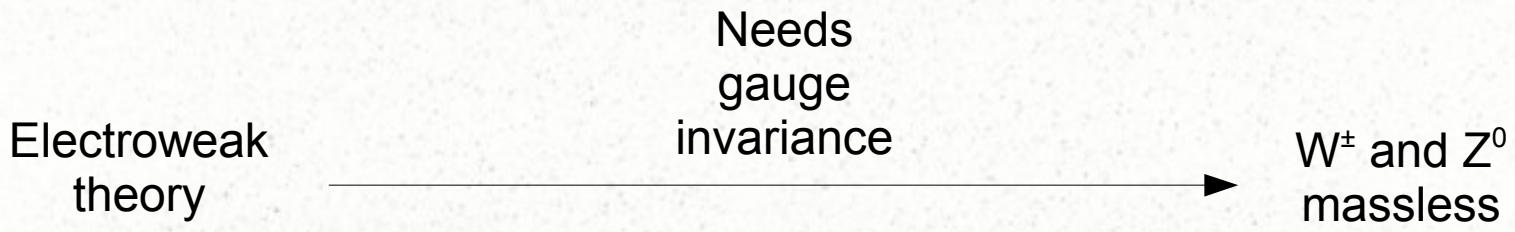
Outline

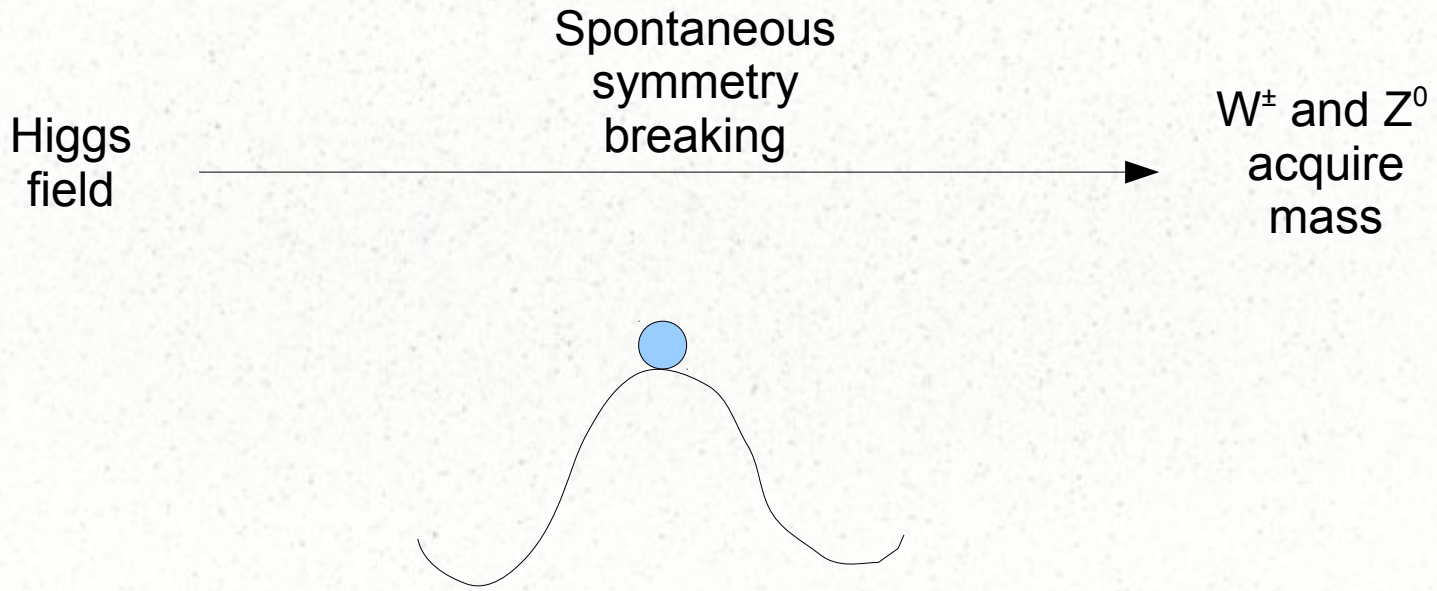
- Where does the Higgs boson come from?
- Some properties
- Searching for H^0
  - LEP
  - LHC
- Alternatives

Where does the Higgs boson come from?



But they have mass indeed!

Where does the Higgs boson come from? (II)



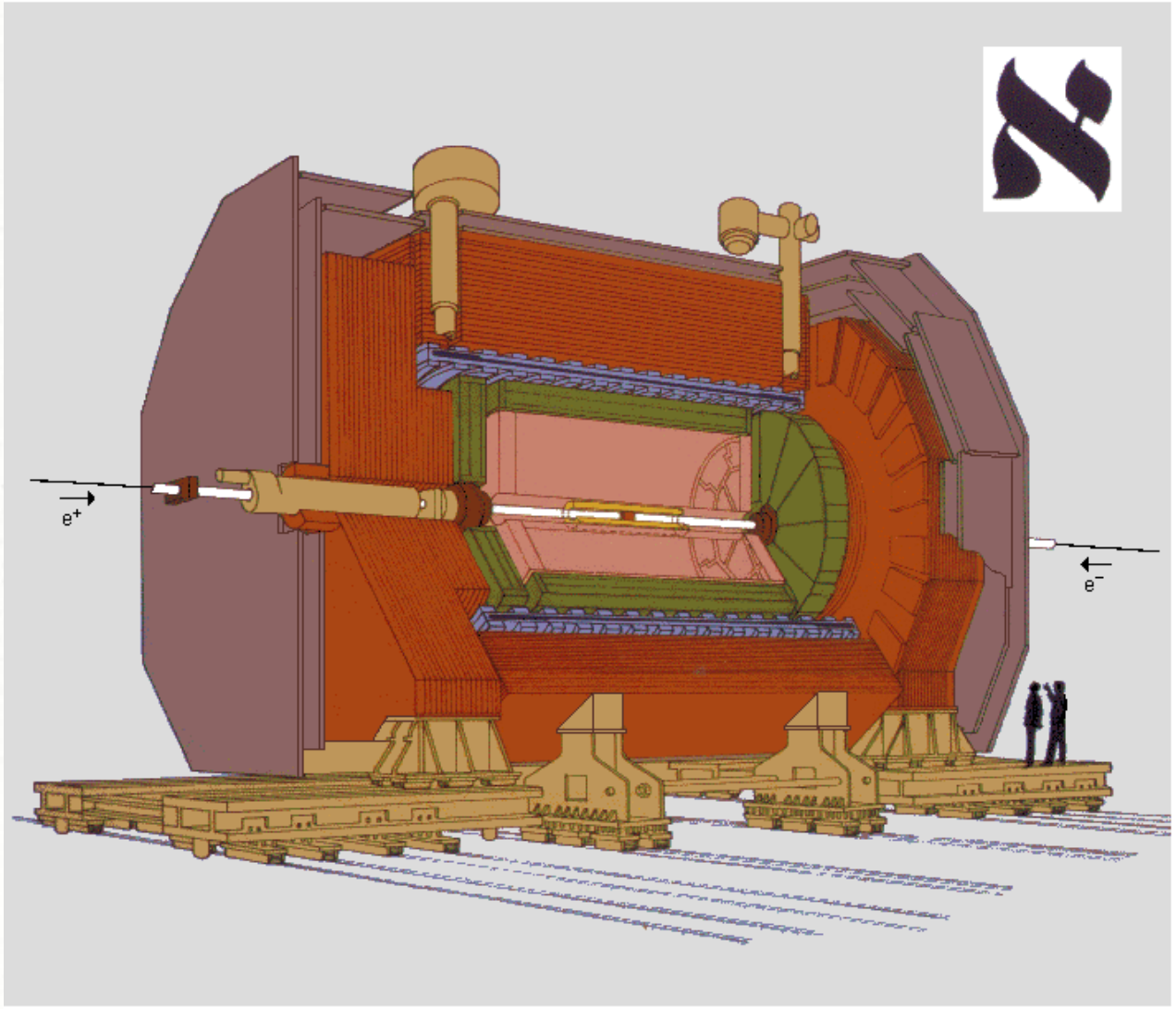
The Higgs boson H^0

- Charge = 0
- Spin = 0
- M_H = ??

  Not predicted by the Standard Model.
  But fine measurements EW processes:
  $28 < M_H < 193$ GeV (95% confidence)
- Coupling proportional to the mass

Large Electron Positron Collider

- Electron-positron collider
- 27 km circumference
- Operated from 1989 to 2000
- Energies up to 209 GeV
- 4 detectors: ALEPH, DELPHI, OPAL and L3



Vertex Detector

Inner Tracking Chamber

Time Projection Chamber

Electromagnetic Calorimeter

Superconducting Magnet Coil

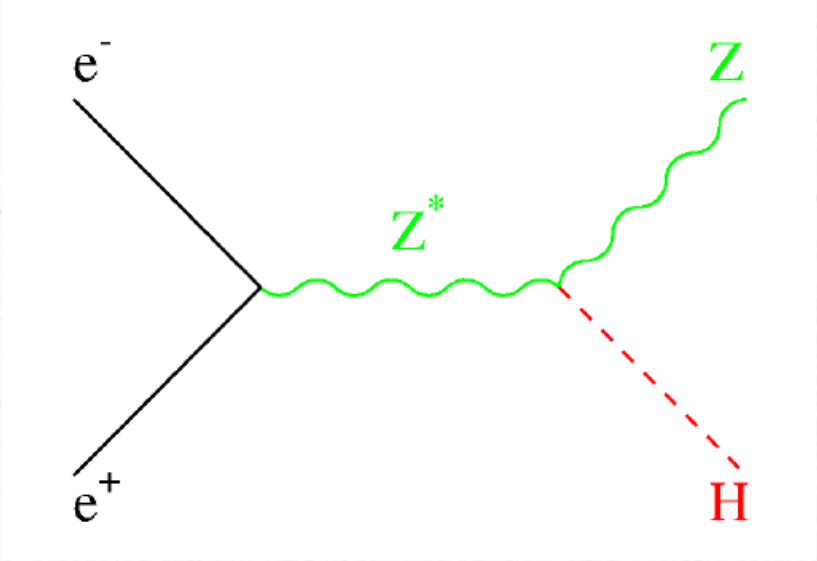
Hadron Calorimeter

Muon Chambers

Luminosity Monitors

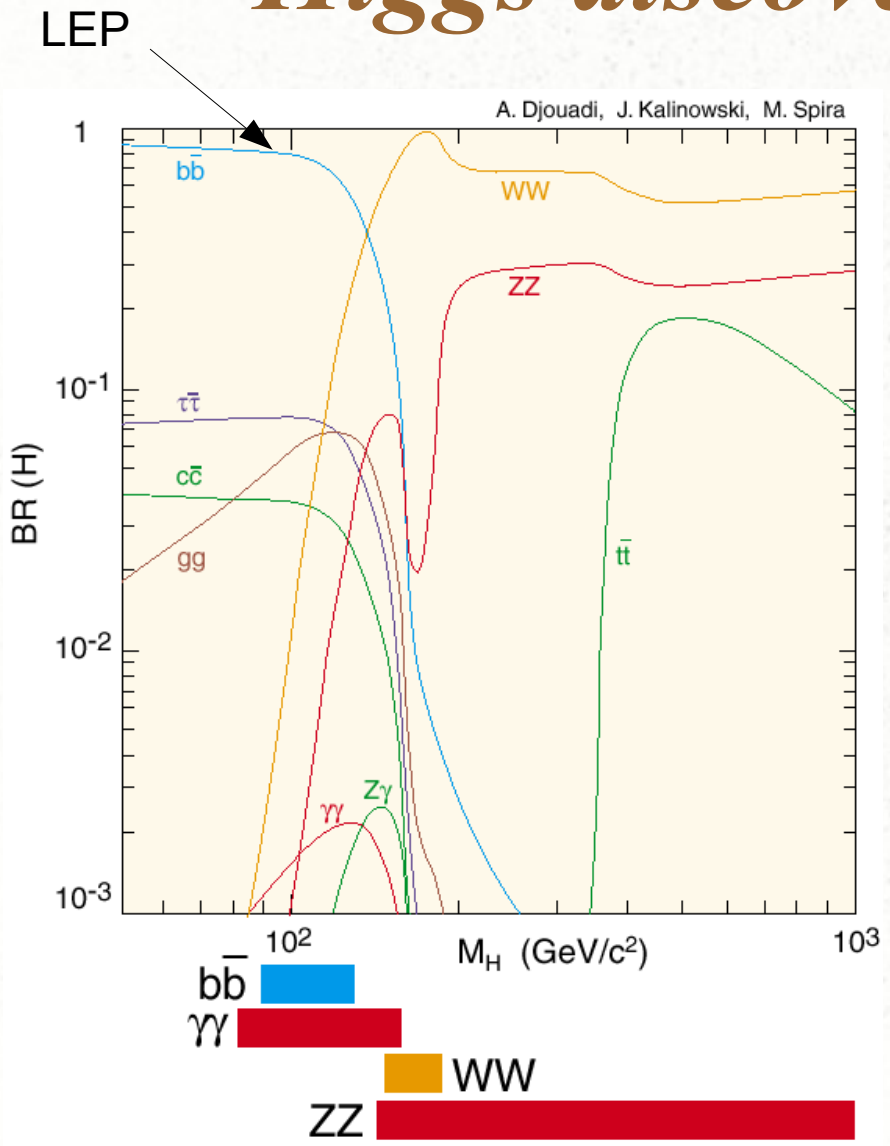
The ALEPH Detector

Higgs production at LEP

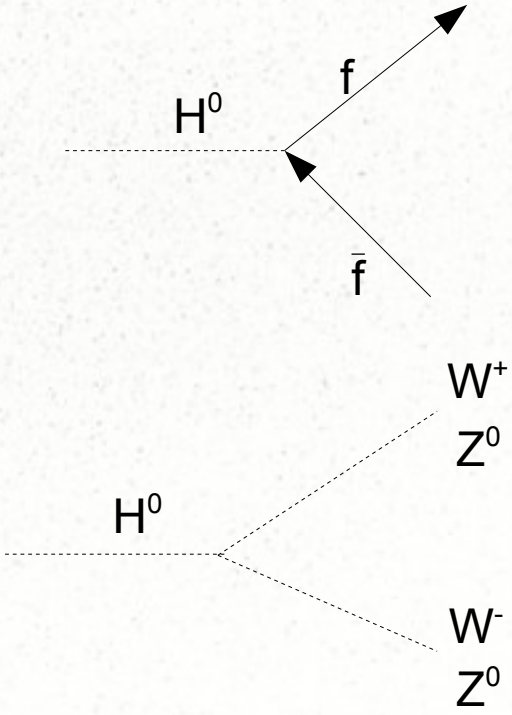


Higgsstrahlung

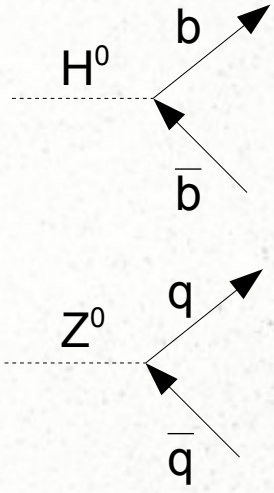
Higgs discovery channels



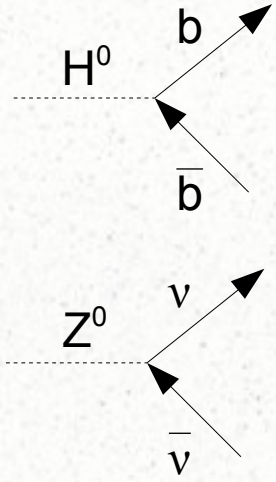
Decays to the heaviest particle-antiparticle pair allowed by energy conservation.



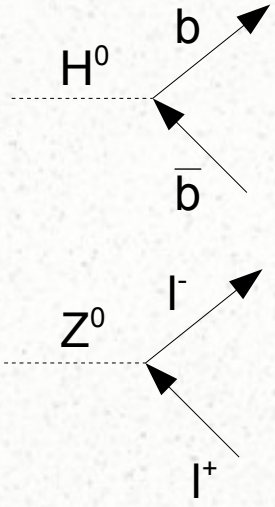
Decays studied in LEP



four-jet

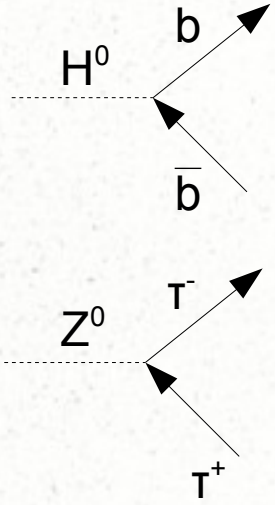


missing-energy



leptonic

l = electron or muon



tauonic

Reduce background, e.g. eliminating two-photon processes and by b-tagging

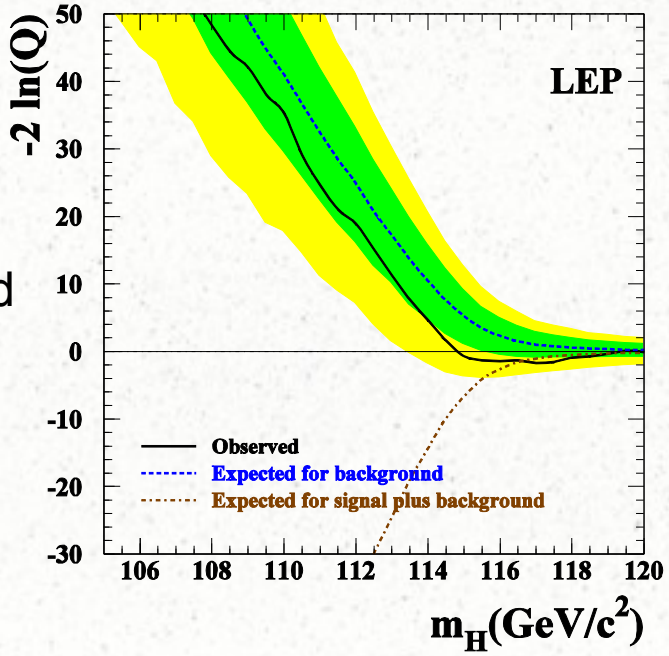
Hypothesis testing

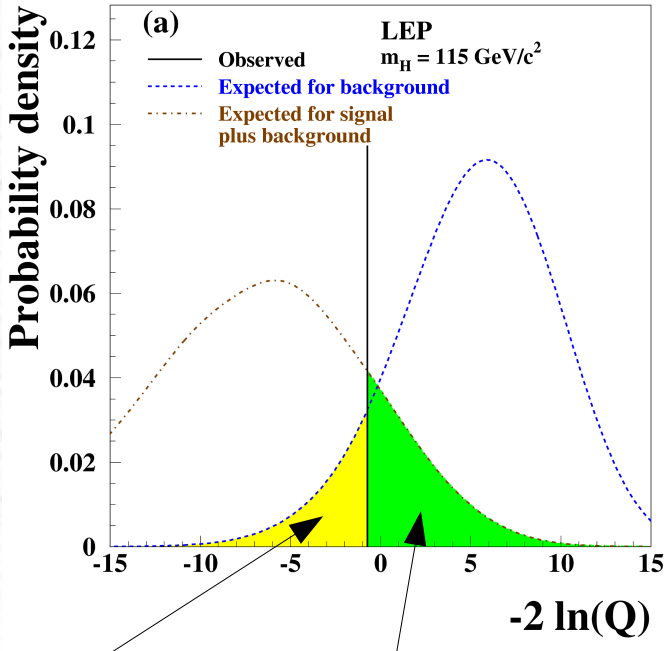
- Differentiate background (b) from signal+background ($s+b$)
- For each way to detect the boson (channel), calculate theoretical b and $s+b$ expectations
- For each channel and hypothetical mass, calculate the probability (likelihood) of experimental results to be b and $s+b$

LEP combined results

likely background

likely signal+b



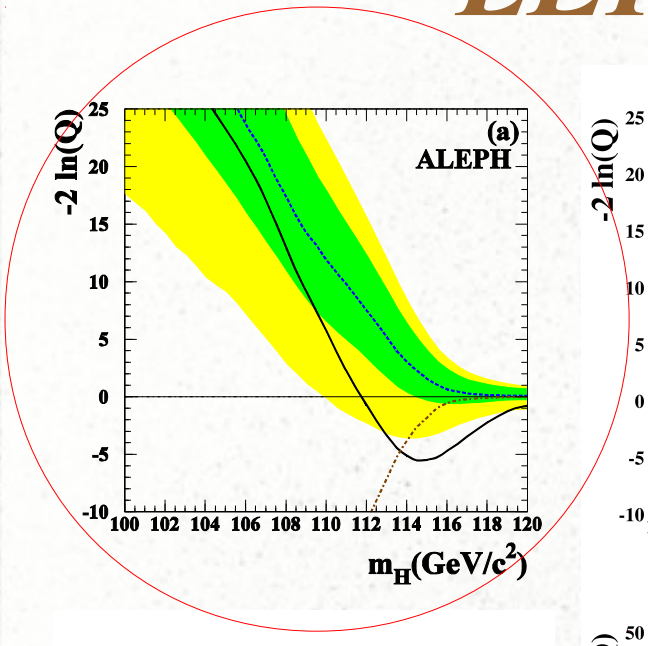


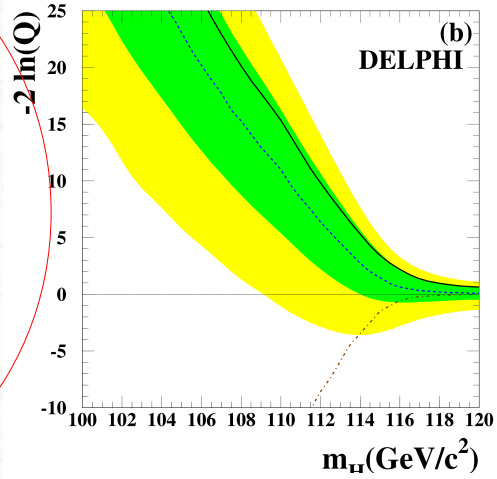
Probability of erroneously detecting *s+b*

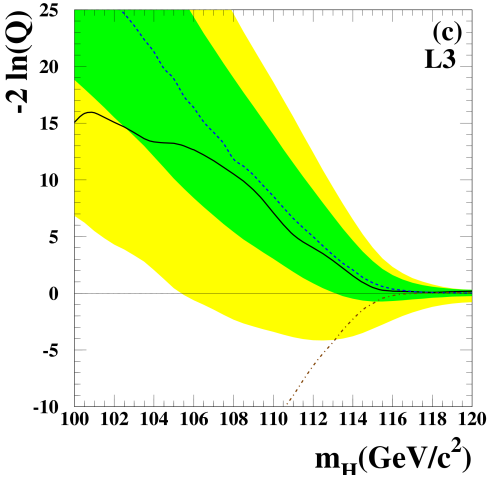
Probability of correctly detecting *s+b*

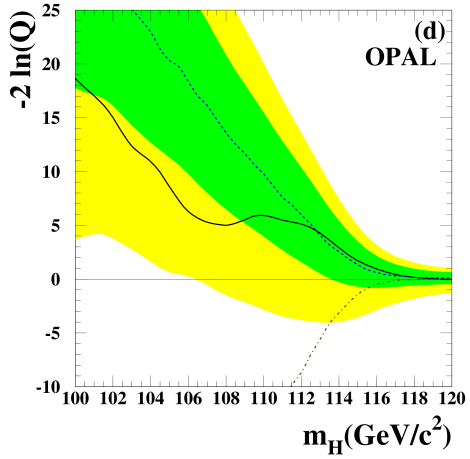
Likelihood ratio $Q = \frac{L_{s+b}}{L_b}$

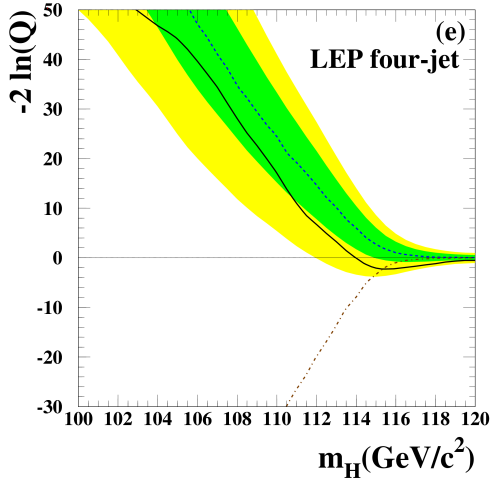
LEP partial results

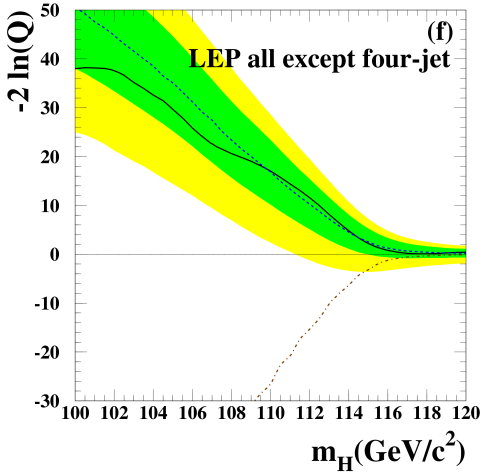












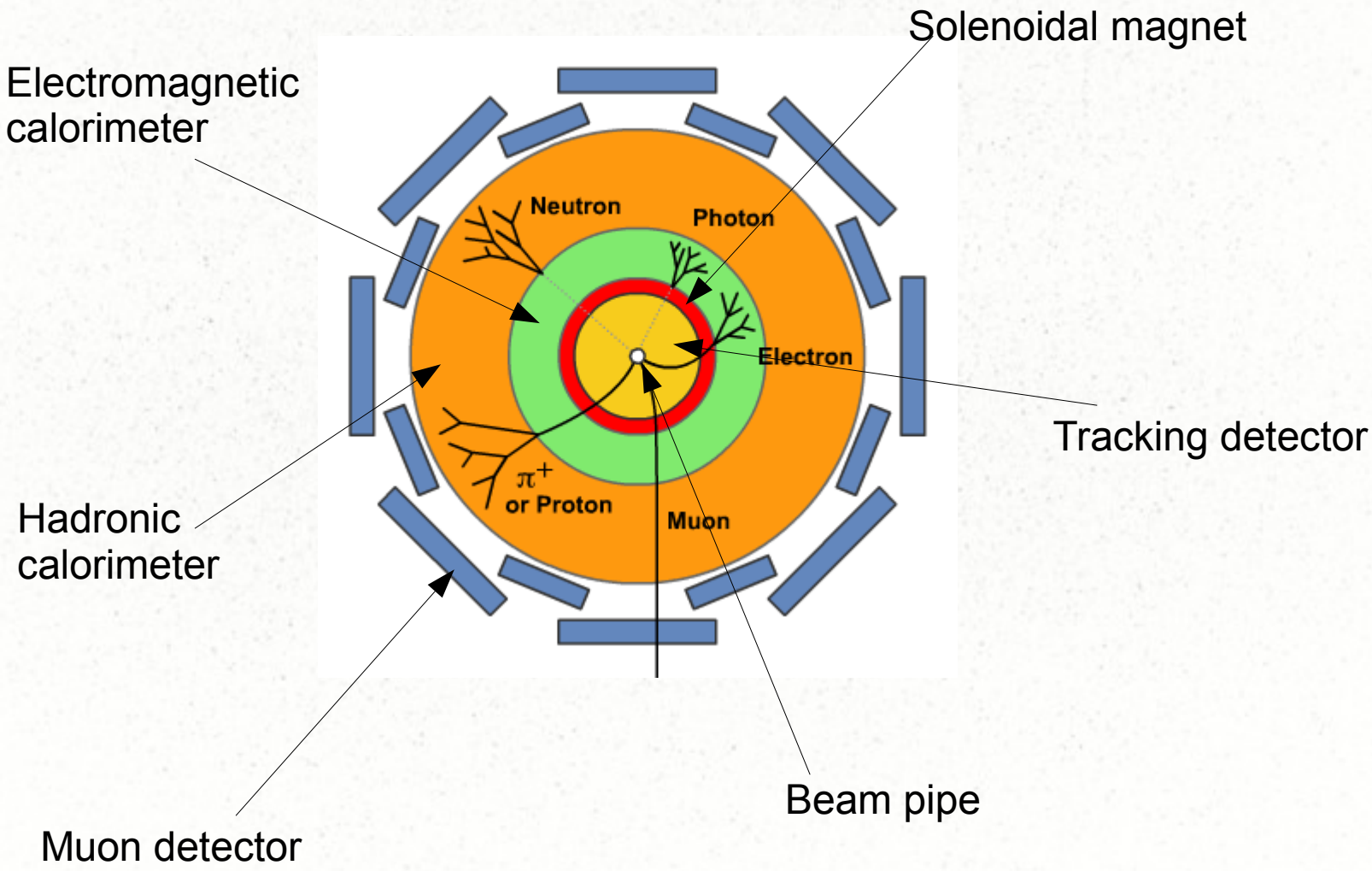
Results summary

- $M_H < 114.4$ GeV/c^2 with 95% confidence
- At $M_H = 115$ GeV/c^2 :
  - Prob(background) = 0.09
  - Prob(signal+background) = 0.15

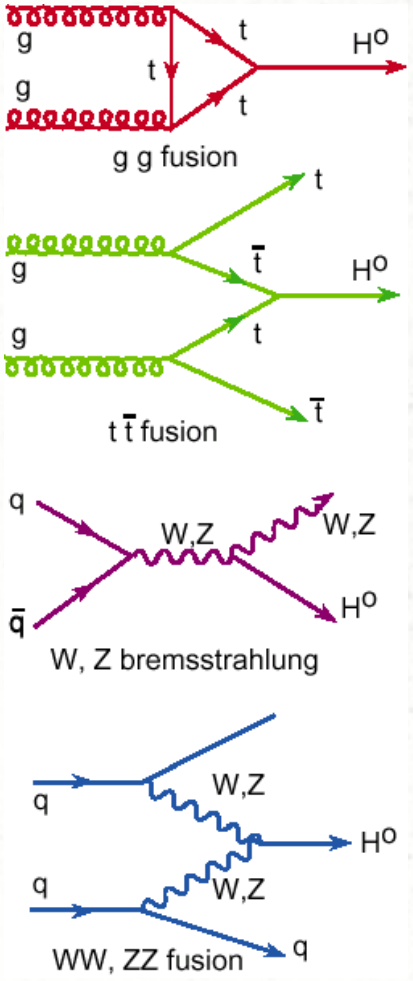
Large Hadron Collider

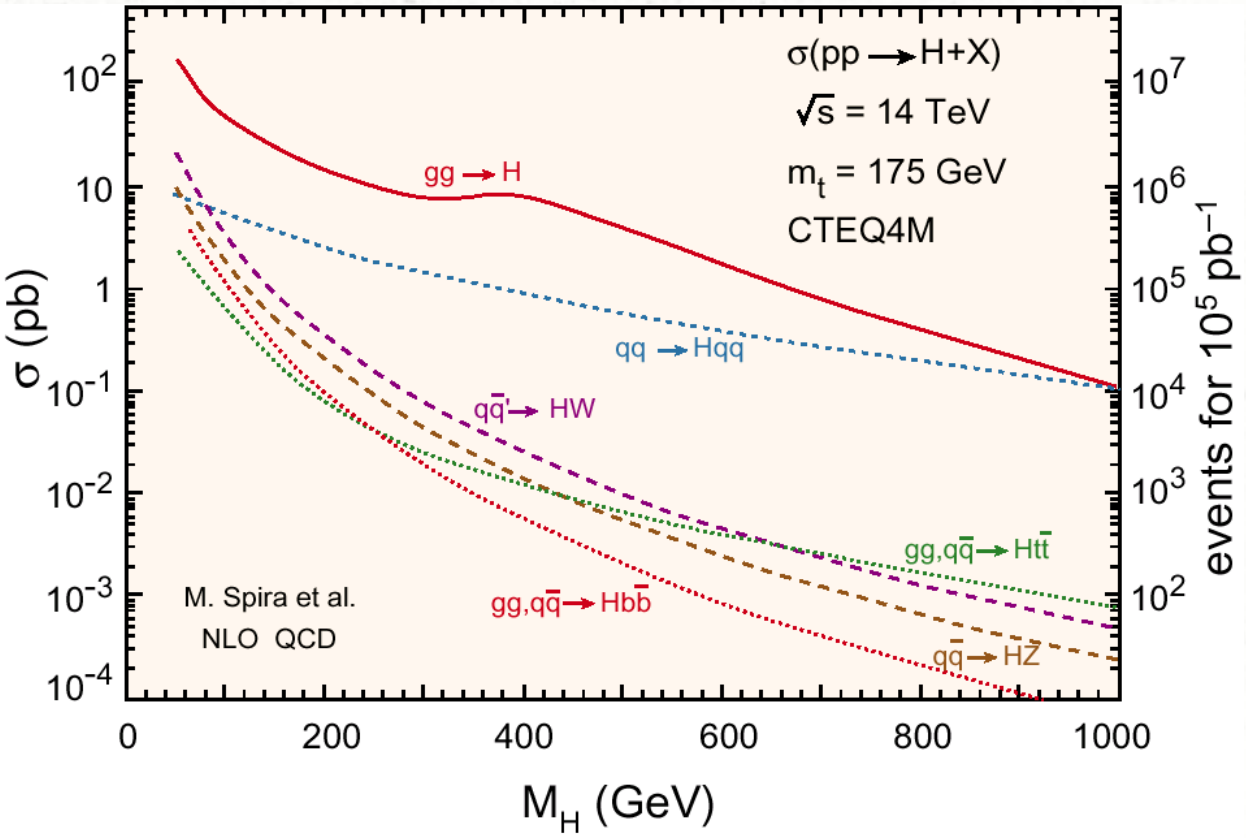
- Proton-proton collider
- 27 km circumference
- 7 TeV per particle
- Start colliding at 7 TeV at 1st quarter 2010
- Expect 3 years collecting data to distinguish the Higgs boson unambiguously
- 4 main detectors: ATLAS, CMS, ALICE and LHCb

ATLAS


Solenoidal magnet
Electromagnetic calorimeter
Neutron
Photon
Electron
Tracking detector
Hadronic calorimeter
π^+ or Proton
Muon
Beam pipe
Muon detector

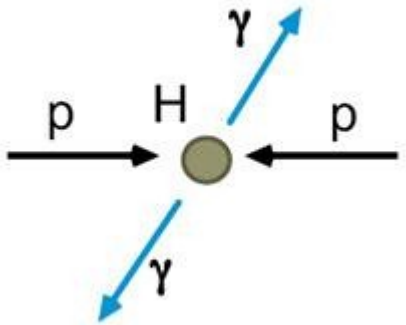
Higgs production and cross section at LHC

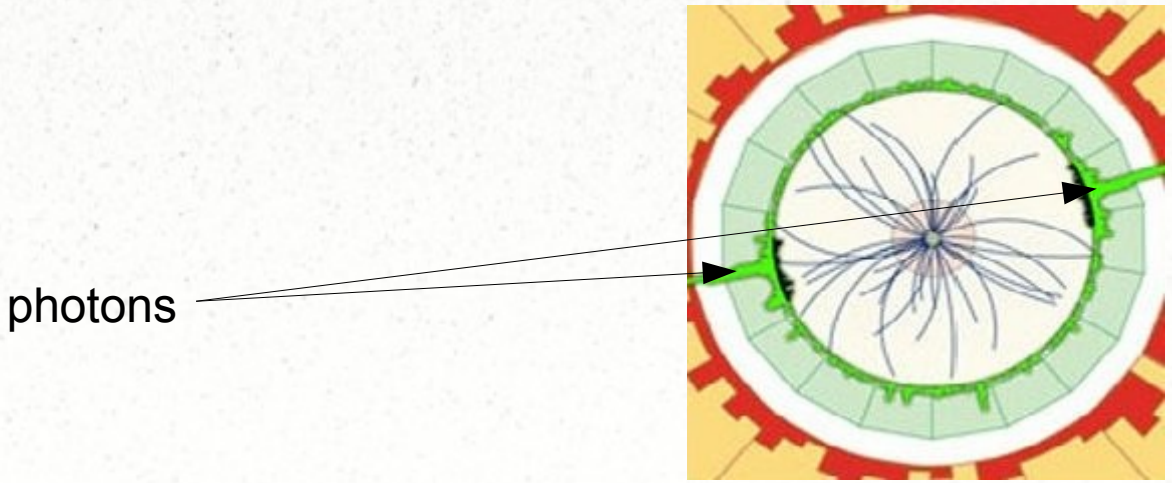




Identifying Higgs at LHC two-photons

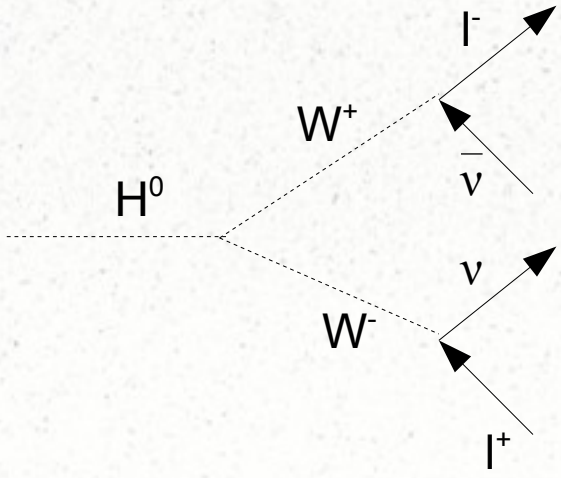
- Valid for M_H<140 GeV
- Low branching ratio (10^{-3})
- But less background!



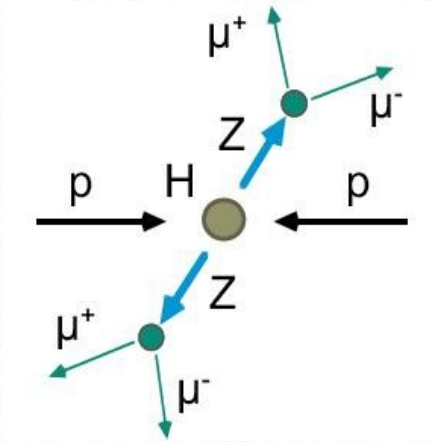


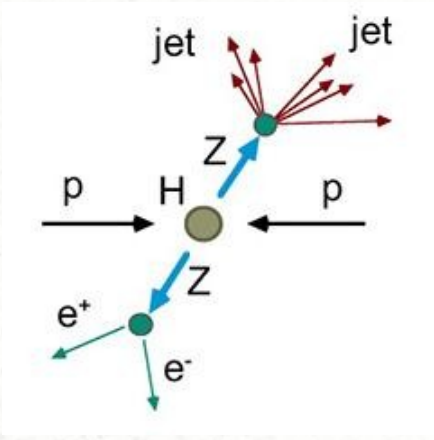
Identifying Higgs at LHC
W-bosons

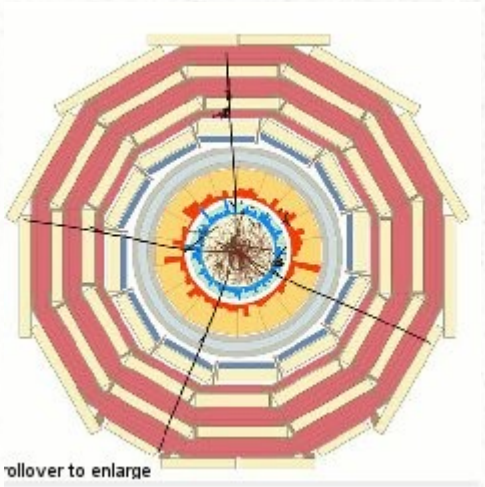
- $150 < M_H < 180$ GeV
- Decay to two W bosons, which then decay into two leptons and two neutrinos

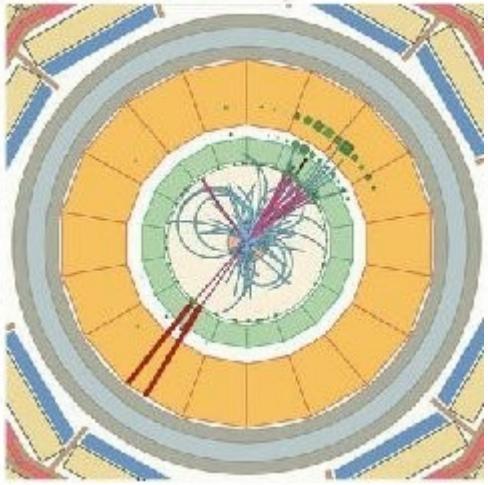


Identifying Higgs at LHC
Z-bosons









$140 < M_H < 600$ GeV

$500\ \text{GeV} < M_H$

Alternatives

- The Particle Standard Model stop working at very high energies.
- Technicolor – new gauge interactions to break gauge symmetry
- Supersymmetry – each boson has an associated fermion, solving the called “hierarchy problem”

Bibliography

- Wikipedia :)
- Physics of the Higgs boson(s) at the LHC, by Mogens Dam
  (http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/Conferences/2003/aspen-03_dam.ppt)
- Particle Physics, by Martin and Shaw
- The LEP working group for Higgs boson searches. “Final LEP publication on the Search for the SM Higgs boson.”
- CERN-related LHC webpages.