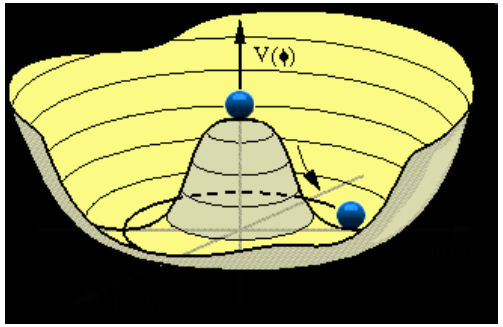
The Higgs
….discovery????

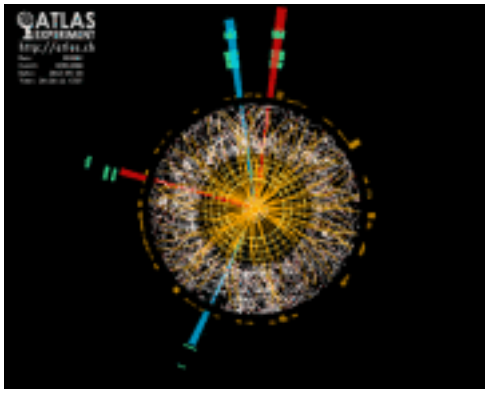
Maybe a Higgs-like particle…..

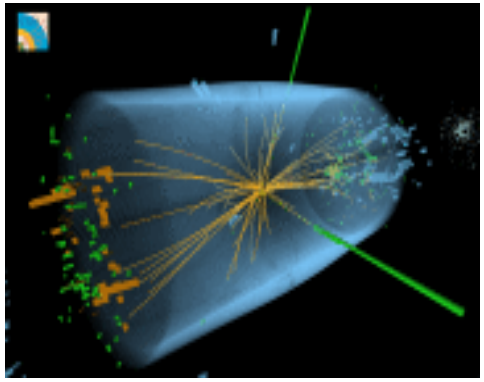
What is it and why should you care?



S. Dawson, BNL

July 25, 2012





New York Times, July 5, 2012

Physicists Find Elusive Particle Seen as Key to Universe

POOL PHOTO BY DENIS BALIBOUSE

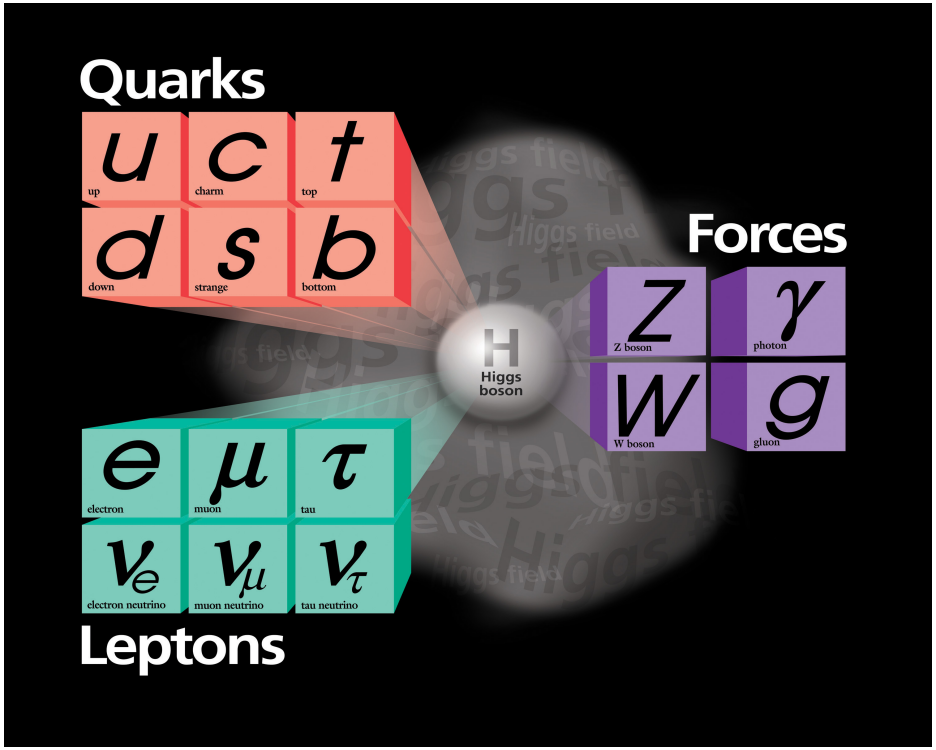
Scientists in Geneva on Wednesday applauded the discovery of a subatomic particle that looks like the Higgs boson.

A Higgs particle predicted in 1964

Peter Higgs in the LHC tunnel in 2012

Standard Model

- Particle physics has a "Standard Model" of particles and their interactions

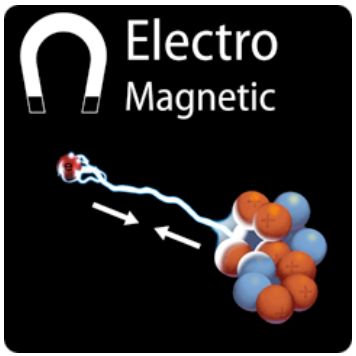


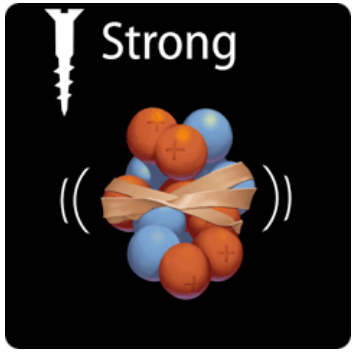
Pointlike particles

Force carriers communicate between particles

Understanding Forces

- Electromagnetism explains electricity and magnetism
- Weak force explains radioactivity
- Strong force explains why quarks are bound in protons
- Gravity seems simple…..





Forces associated with particles

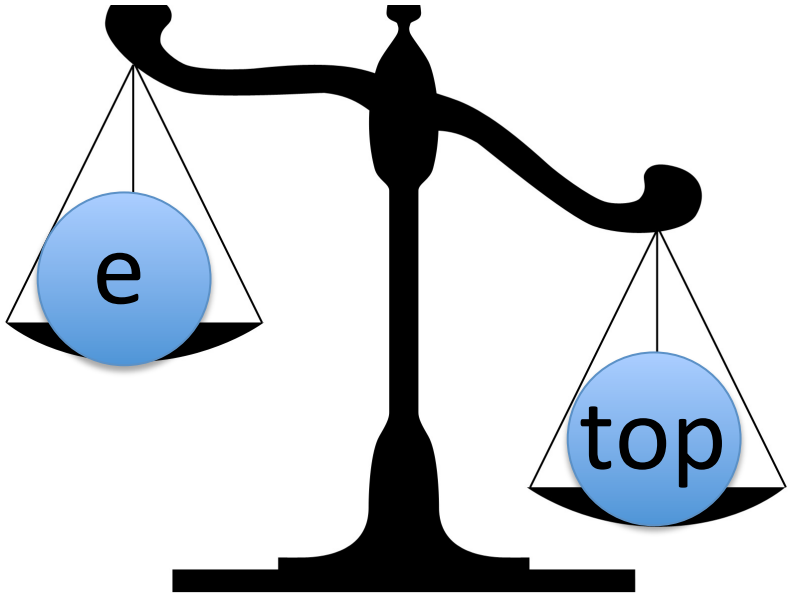
- Force carriers: gluon, W/Z bosons, photon
- Gluon and photon are massless
- W/Z are very heavy…..***WHY?????***
- We say that the symmetry is broken

The Higgs boson was invented to explain why the W and Z boson are heavy

What is this thing?????

- A particle (The Higgs boson)
  - All of its properties except for its mass are predicted
  - It is a real particle which we can study
- A field (The Higgs field)
  - When other particles (like the W and Z bosons) interact with the Higgs field they become massive

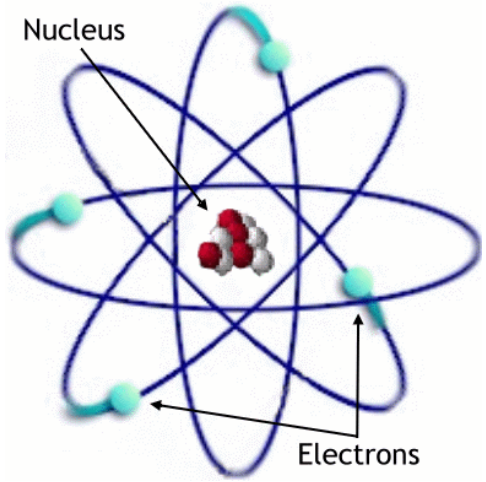
Masses for particles



The more a particle interacts with the Higgs boson, the heavier it is

If there were no Higgs Boson

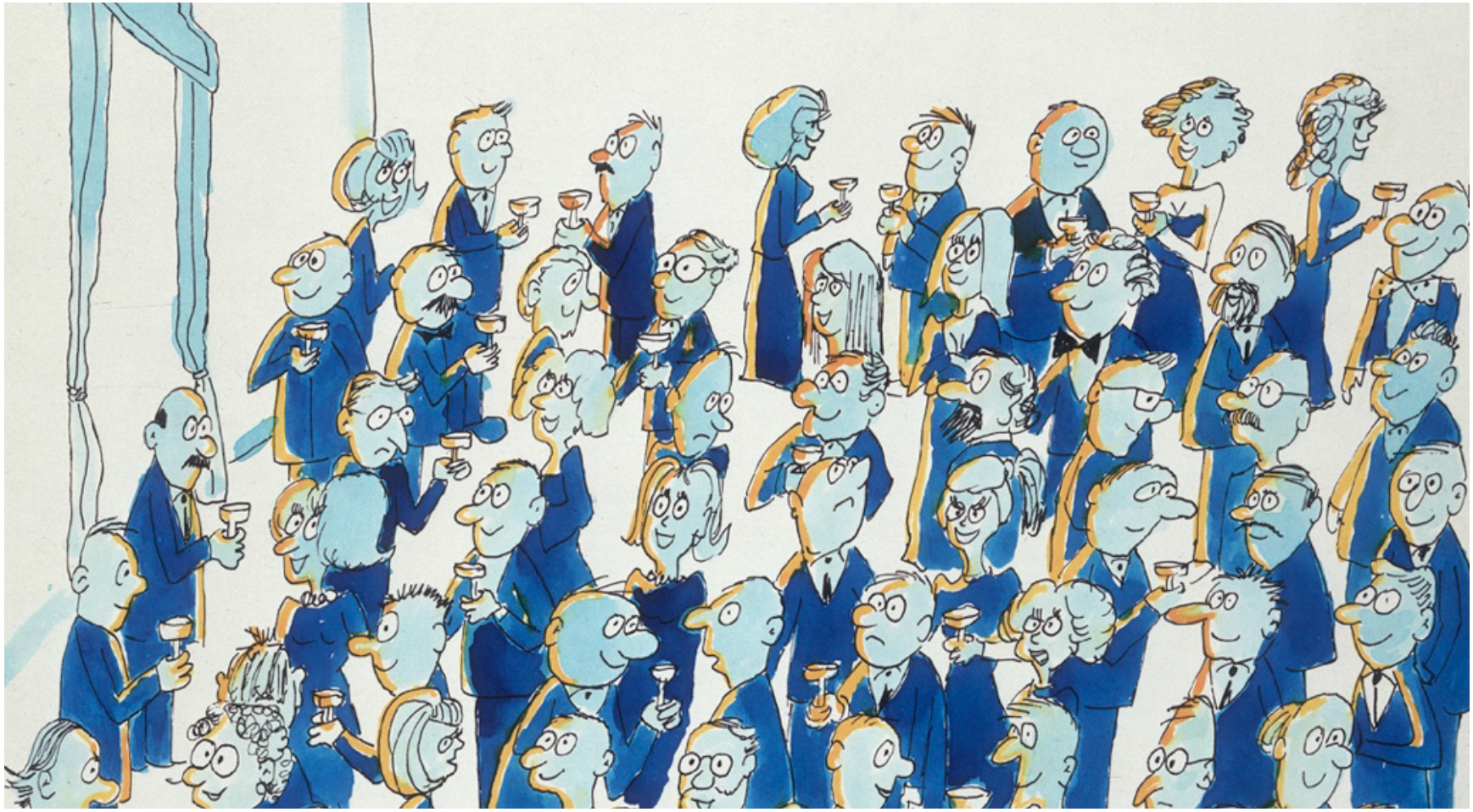
- Higgs boson explains why electron has mass
- Radius of nuclei depend on electron mass



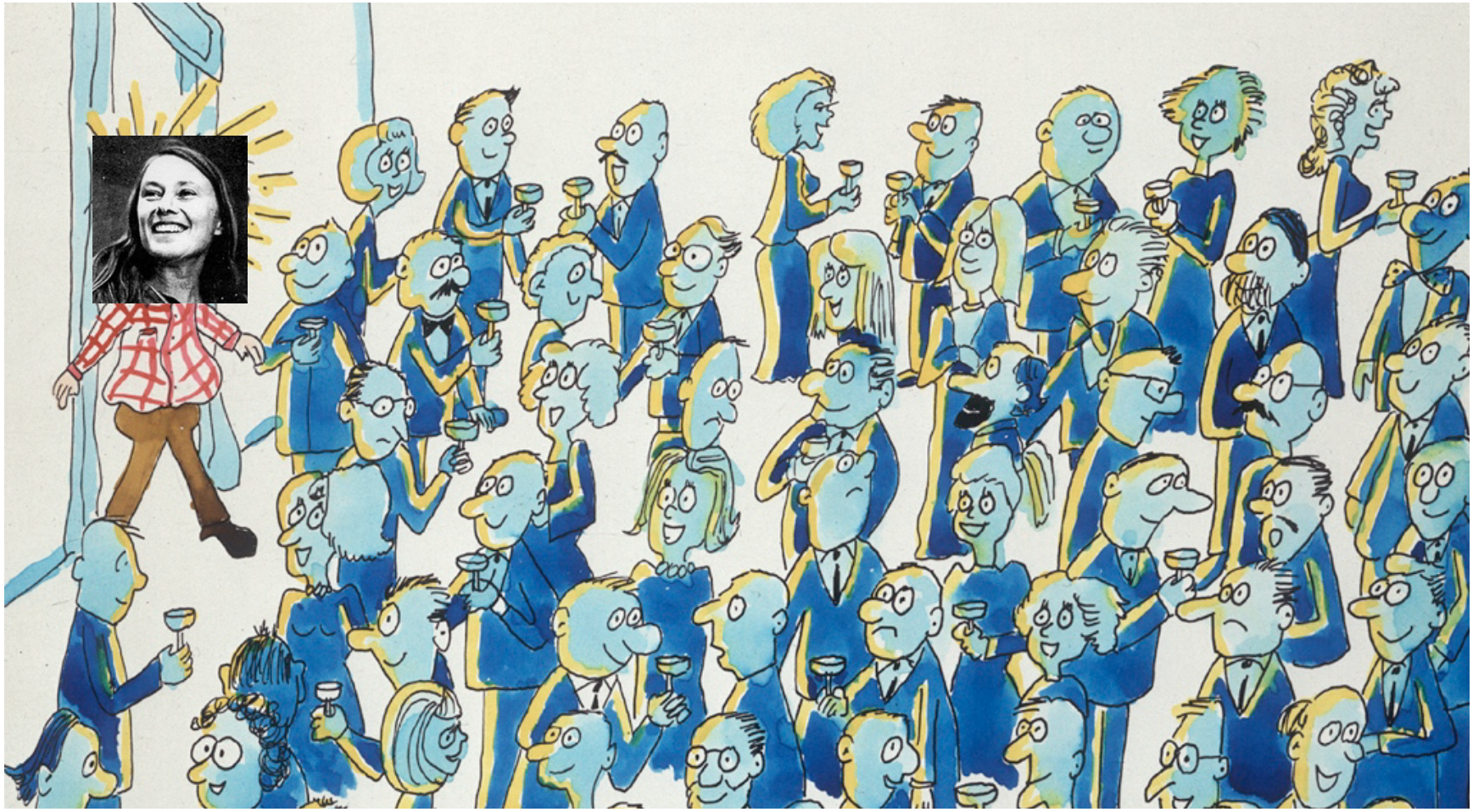
Radius is proportional to 1/mass(electron)

- Atoms wouldn't form without the Higgs boson!

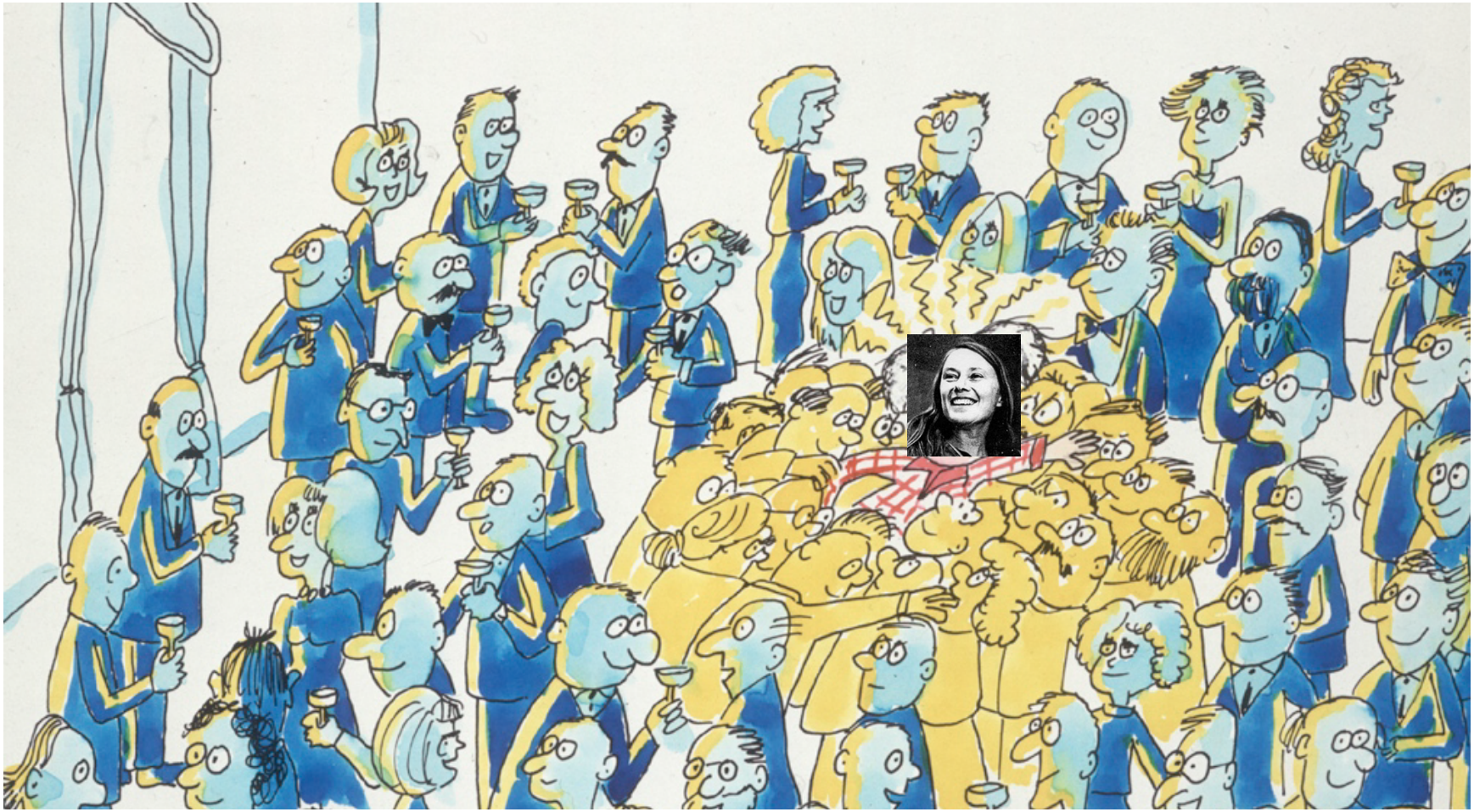
Imagine that a room filled with physicists is like space filled with the Higgs Field



A well known physicist walks in, creating a disturbance as she moves across the room, and attracts a cluster of admirers with each step



.. . this increases her resistance to movement, in other words, she acquires mass, just like a particle moving through the Higgs field . ..



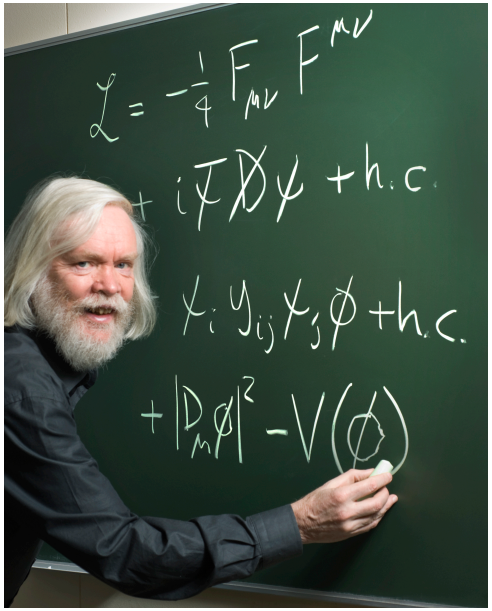
Explaining Mass

95% of the mass of the universe is dark matter and dark energy which is not explained by the Higgs boson

What is a theory????

- We have the "Standard Model"
  - Calculate and make predictions
- Without something like a Higgs boson, results are infinite
- Predict: M_W=82 GeV + infinity

  OOPS!



- Better:

M_W=82 GeV + logarithm (M_{Higgs}) +....

30 Years of Experiments

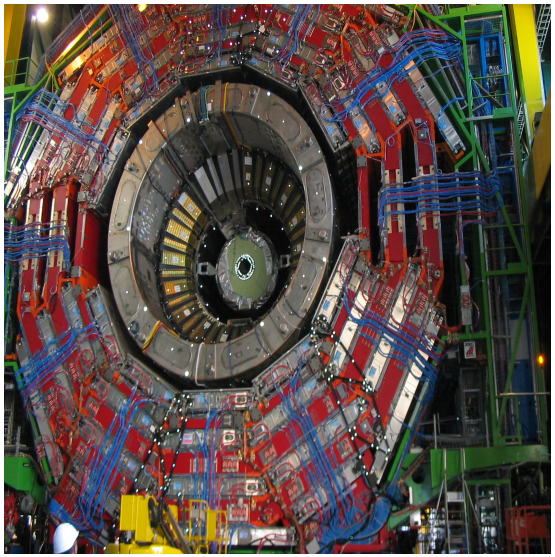
- If….the Standard Model with a Higgs boson is the whole story….
- We infer from many measurements:

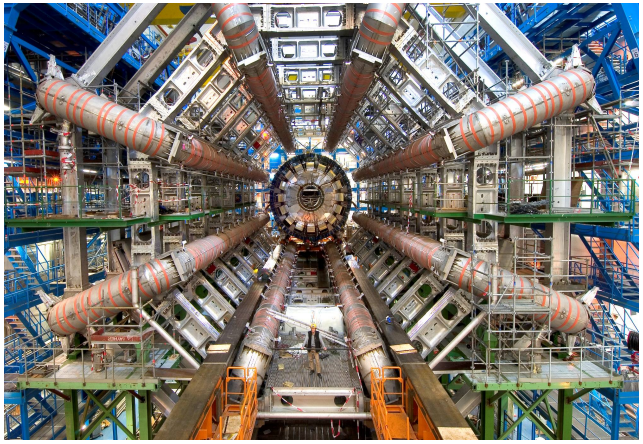
$$\mathbf{M_H < 145\ GeV}$$

  – *Discovery of a 125 GeV Higgs boson is consistent with our Standard Model expectations*

How to find the Higgs

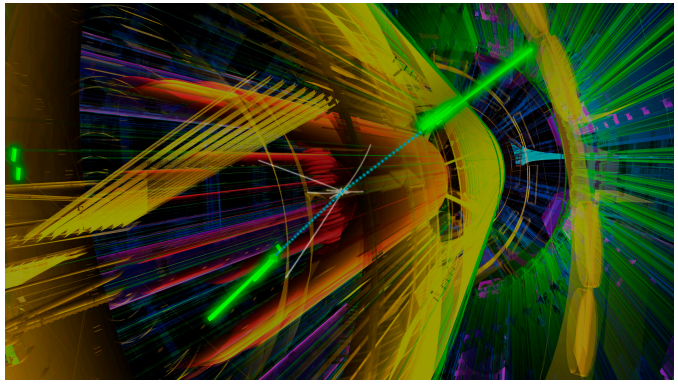
- Need the tools
  - Accelerator: Large Hadron Collider at CERN
  - Detectors: ATLAS and CMS
  - Theory: pointing the way to look



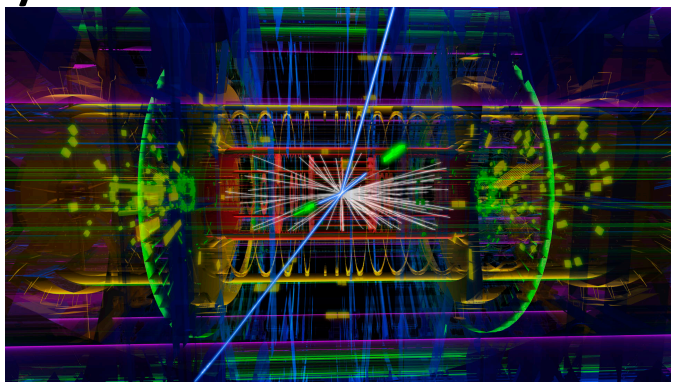


Making a Higgs boson

- At the LHC, protons collide at 99% of the speed of light
  - Most of the time no Higgs boson is made
  - Very (!) rarely, out comes a Higgs boson which decays in 10^{-22} seconds
  - We can calculate how many Higgs bosons are made and what they decay to



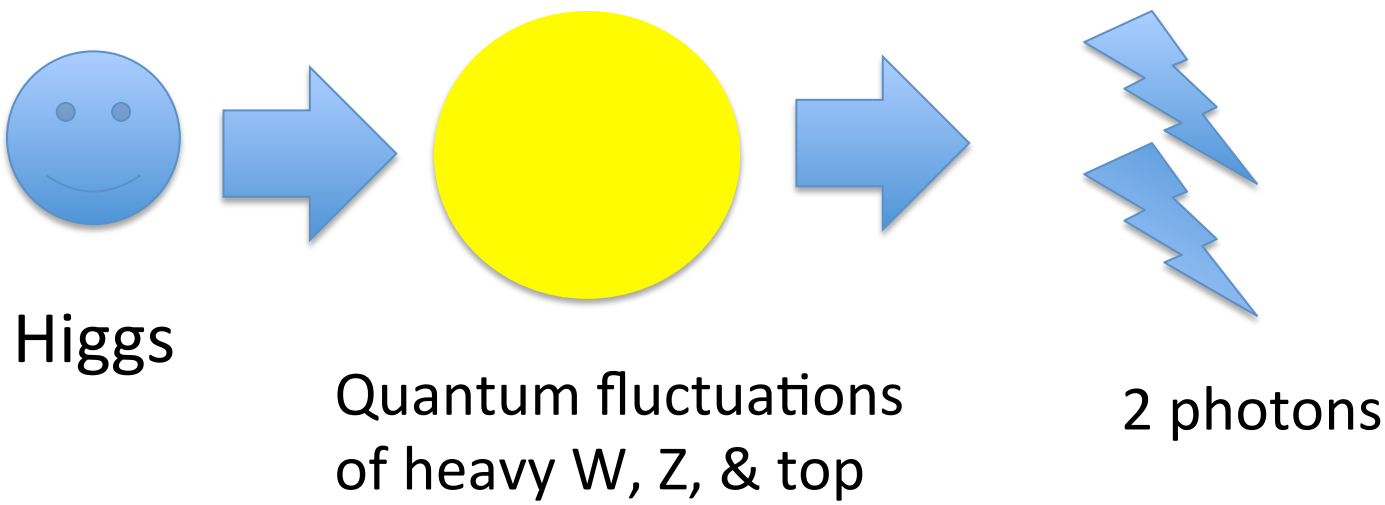
Higgs decaying to two photons



Higgs decaying to 2 electrons and 2 muons

Wait a minute

- Question: How does the Higgs interact with a massless photon?
- Answer: Indirectly

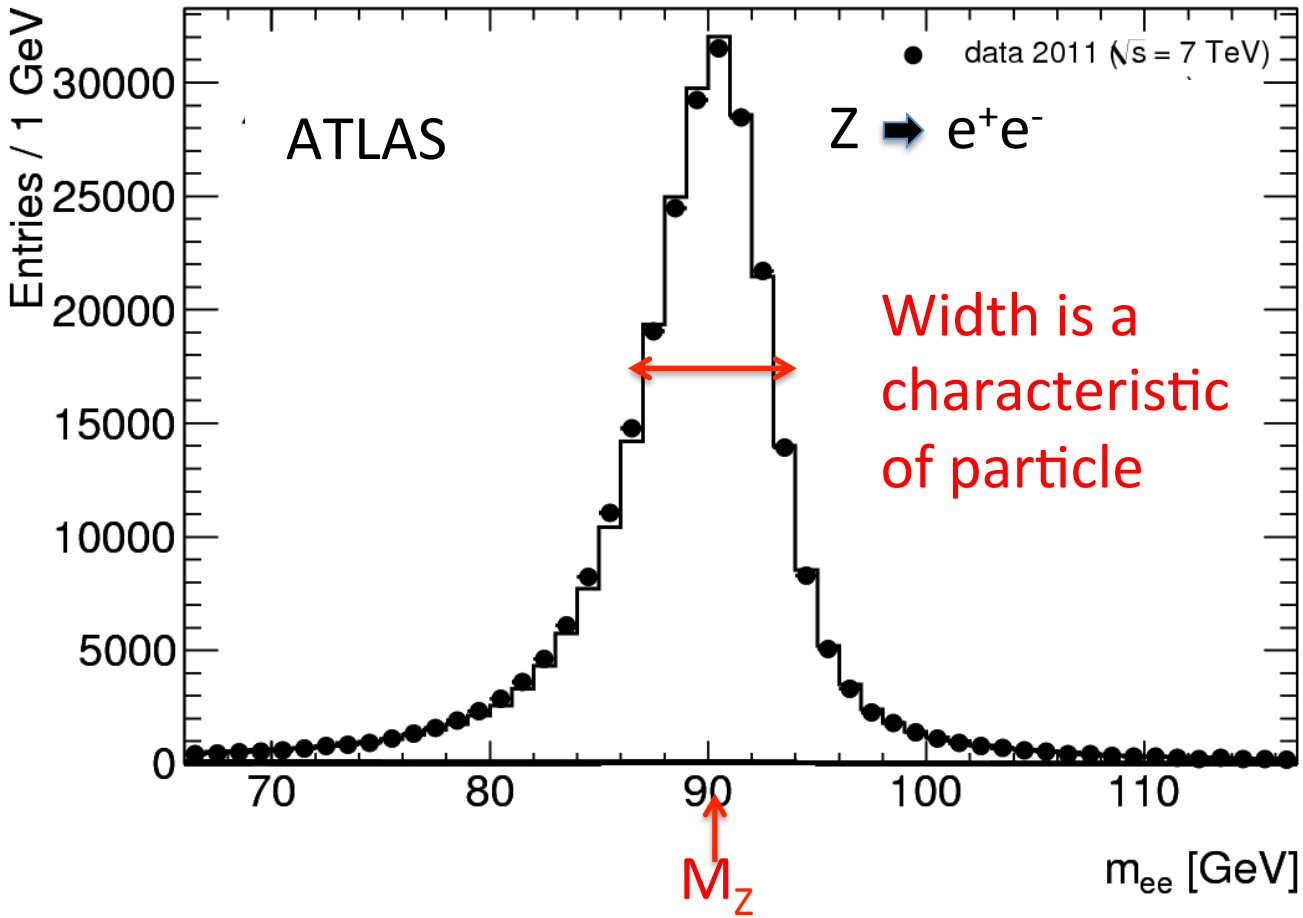


Predictions if M_H=125 GeV

- 174,000 Higgs made
  - 397 decayed to 2γ
  - 10 decayed to 2 Z's which then decayed to $e^+e^-\mu^+\mu^-$ pairs
  - 60% of the Higgs bosons decay to bottom quarks

"Always the last place you look"

Bump Hunting



$$(Mc^2)^2=(E_+ + E_-)^2-(p_+ + p_-)^2c^2$$

Bump Hunting and the Higgs

- Higgs bump narrow in $H \rightarrow \gamma\gamma$
- Large number of 2 photons from other sources

The Detective Story

- Finding a Higgs-like particle is just the beginning
- We need to measure all its properties
- Many unanswered questions
  - What is dark matter?
  - Why are some particles so much heavier than others?
  - We are just beginning the exploration

Pure science at its best!