The discovery of the Higgs boson

How particles acquire mass

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Elementary building blocks of nature

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10^{-15} m
Particles

Quarks
Leptons

Anti-Quarks
Anti-Leptons

Forces

1) Electromagnetism
2) Weak nuclear force
3) Strong nuclear force

Building blocks of protons/neutrons

electron
neutrino
The Standard Model
$SU(2)_L \otimes U(1)_Y \otimes SU(3)_C$

Describes all phenomena and measurement to high precision

Massless (force-)particles ≠ Massive (force-)particles
The Higgs field in the vacuum

“If I’m right there has to be a new scalar particle: the Higgs boson”

“It’s properties depend on it’s mass, … a mass that I cannot predict. Go find it!”

- September 1964 -
The Higgs boson                          Paris Hilton

(In)famous Higgs boson

The Higgs boson                          Paris Hilton

Being famous is not the same as being important
Energy and mass are equivalent → you can create new particles
The Large Hadron Collider (LHC)
CERN, Geneva, Switzerland

2012: center-of-mass energy = 8 TeV

8000 times the proton mass
energy of a flying mosquito
Colliding beams of protons

40 million collisions per second

Was an (unstable) Higgs boson produced?
De Atlas pixel detector

Nikhef technicians at work
The SCT end-cap: constructed at Nikhef (across the street)
Muons produced in a proton-proton collision

Muon is the brother of the electron from the 2nd family

2 muons produced in a proton-proton collision
Higgs $\rightarrow$ ZZ $\rightarrow$ 4µ candidate

Look for specific excess in collisions that contain:
- 2 photons
- 4 muons
- ...
Result of the ATLAS experiment (juli 2012)
Excess (peak) in the collisions where 2-photons or 4-leptons were produced

Probability to observe such an excess given the Standard Model without the Higgs boson $\sim 10^{-9}$ → We discovered something new!
Discovery of a new particle

- The Large Hadron Collider works
- Discovered the Higgs* boson, so we think we understand how particles acquire mass

*well ok, a Higgs-boson like particle

Few ‘tiny’ unresolved issues

- why the large spread in masses?
- Nature of dark matter?
- Where did all the anti-matter go?
- …

Standard Model of elementary particles

Hope to discover new phenomena

Supersymmetry?