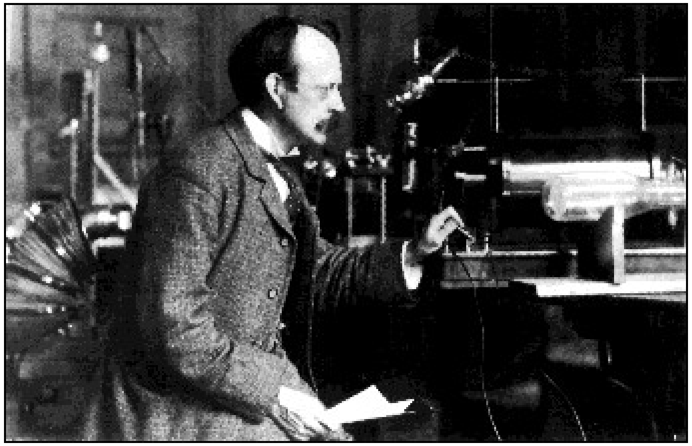
Finding the Higgs Boson

Peter Onyisi

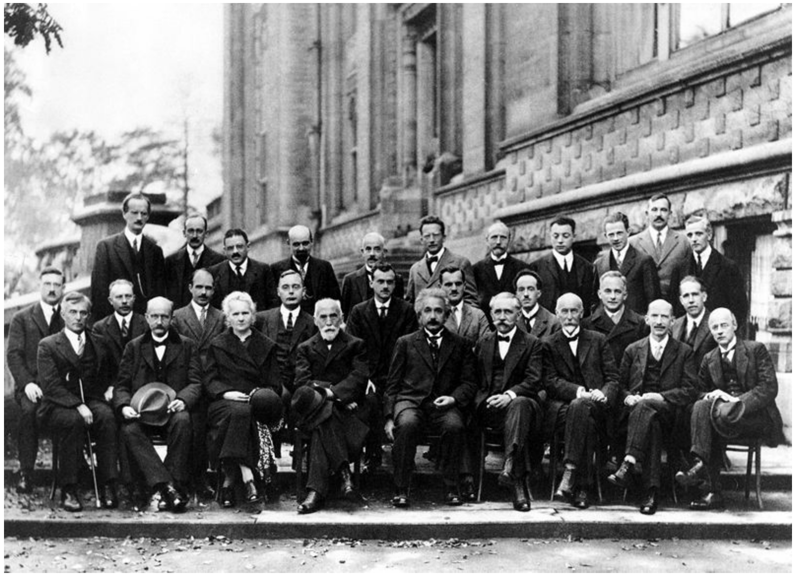
UT Physics Open House, 30 Oct 2012

THE UNIVERSITY OF TEXAS AT AUSTIN

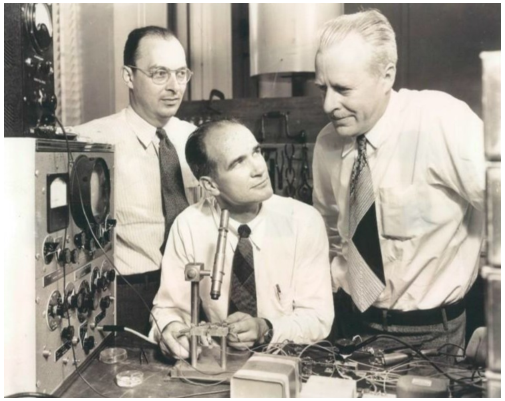
Today's technology is the particle physics of the early 20th century

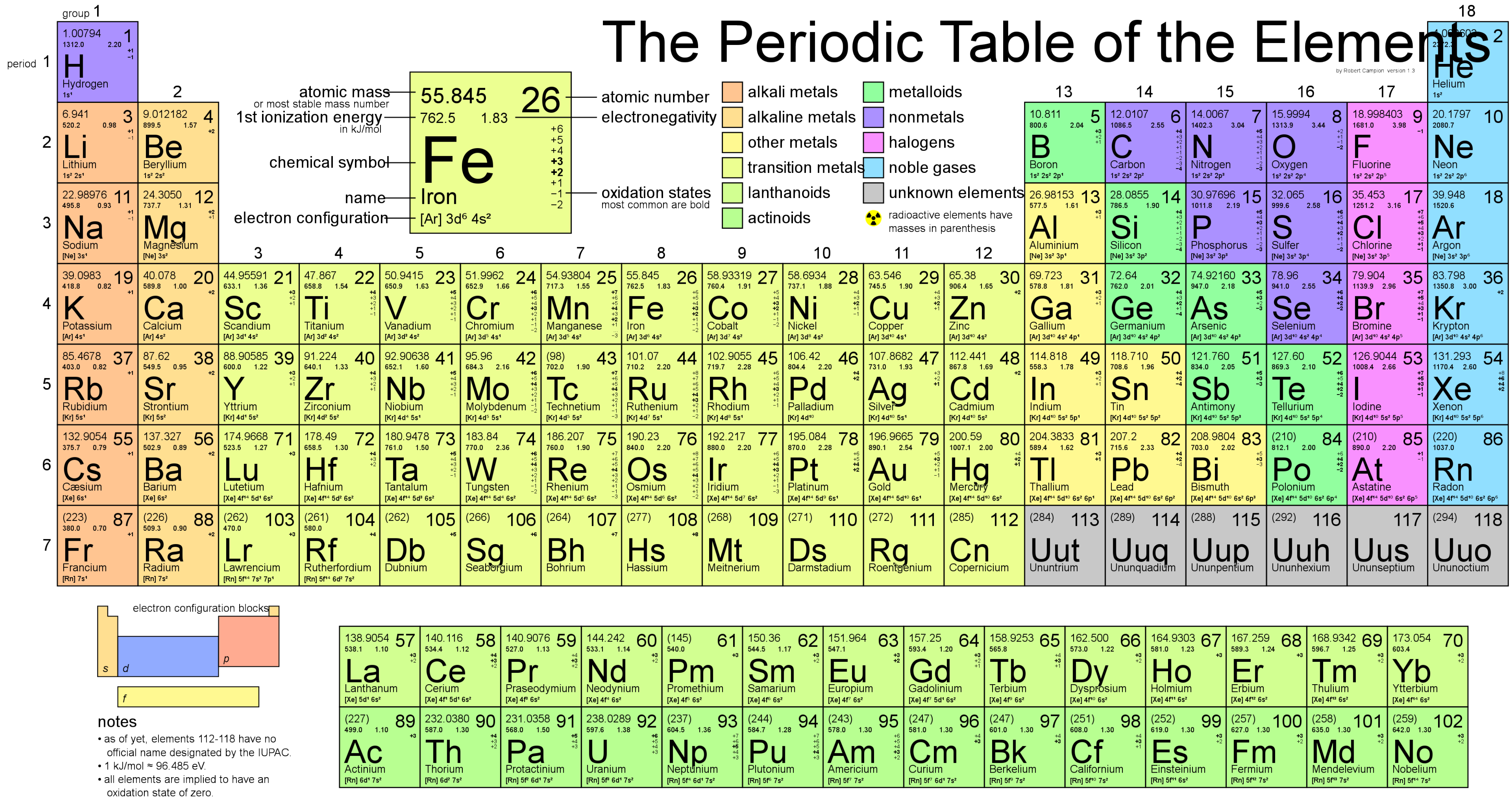


J. J. Thomson & the cathode ray tube: discovery of the electron



1927 Solvay Conference

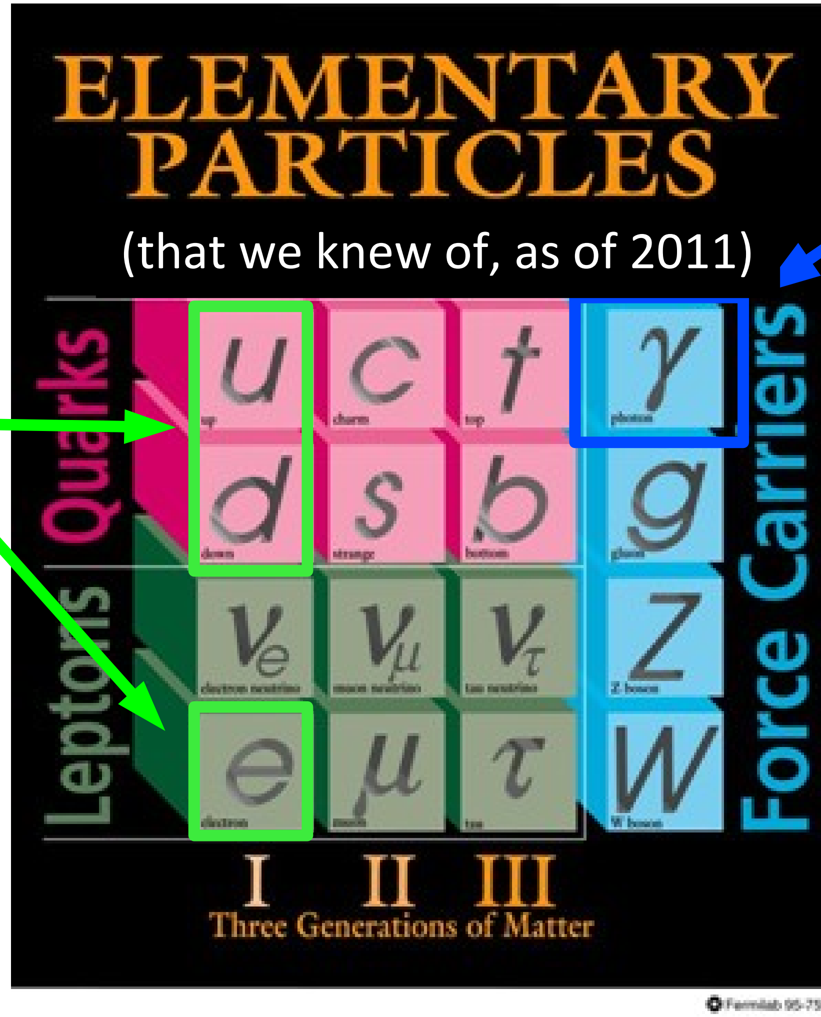




Overwhelming complexity of substances → smaller set of atoms

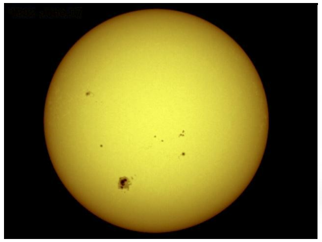
Overwhelming complexity of atoms → electronic structure, nuclei

What you're made of



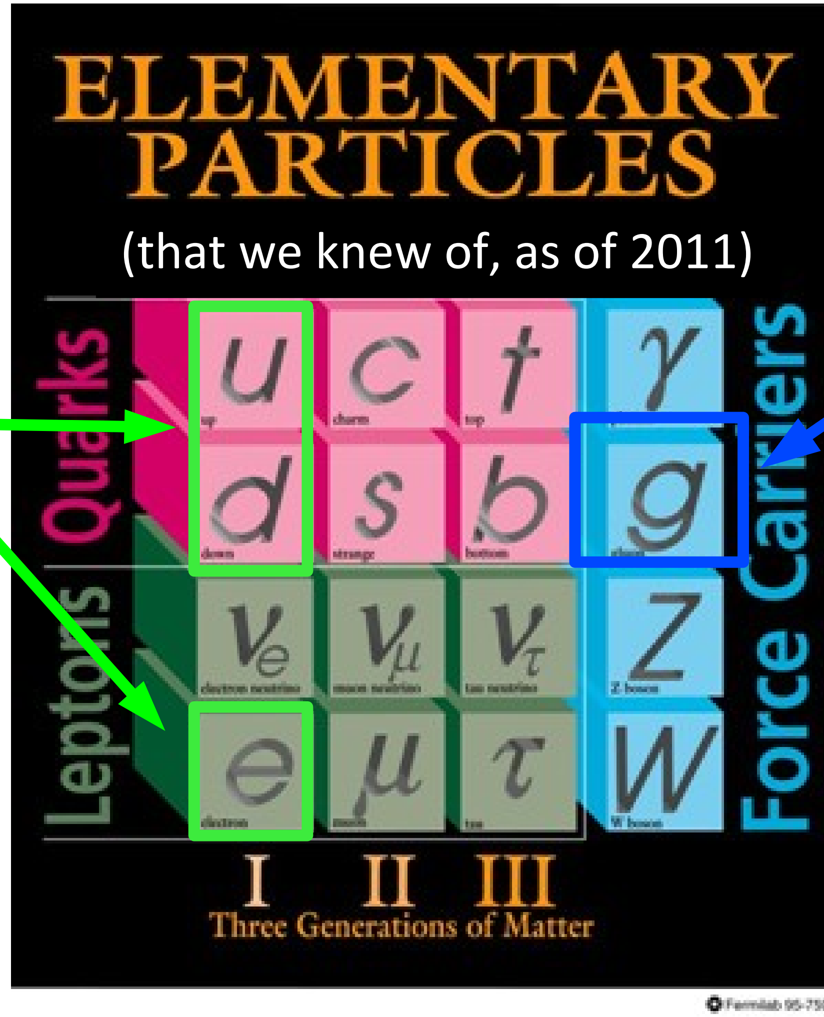
(that we knew of, as of 2011)

Photon
Particle of light



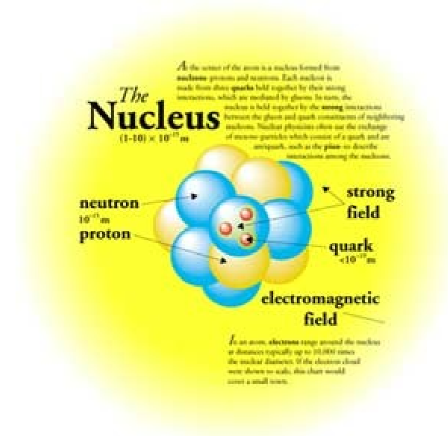

Overwhelming complexity of particles and forces → fundamental particles
“matter” and “forces”: both are particles (different kinds)

What you're made of

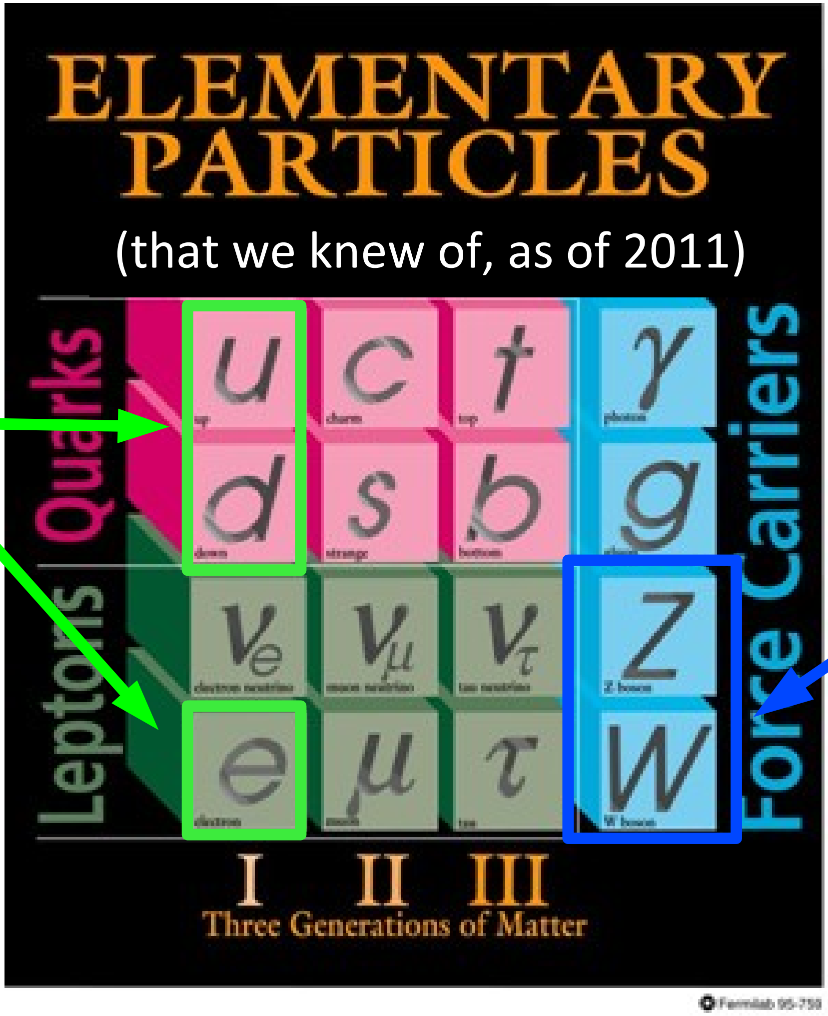


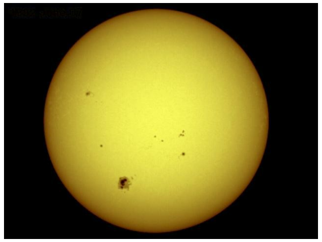
(that we knew of, as of 2011)

Gluon
Particle of the strong nuclear force

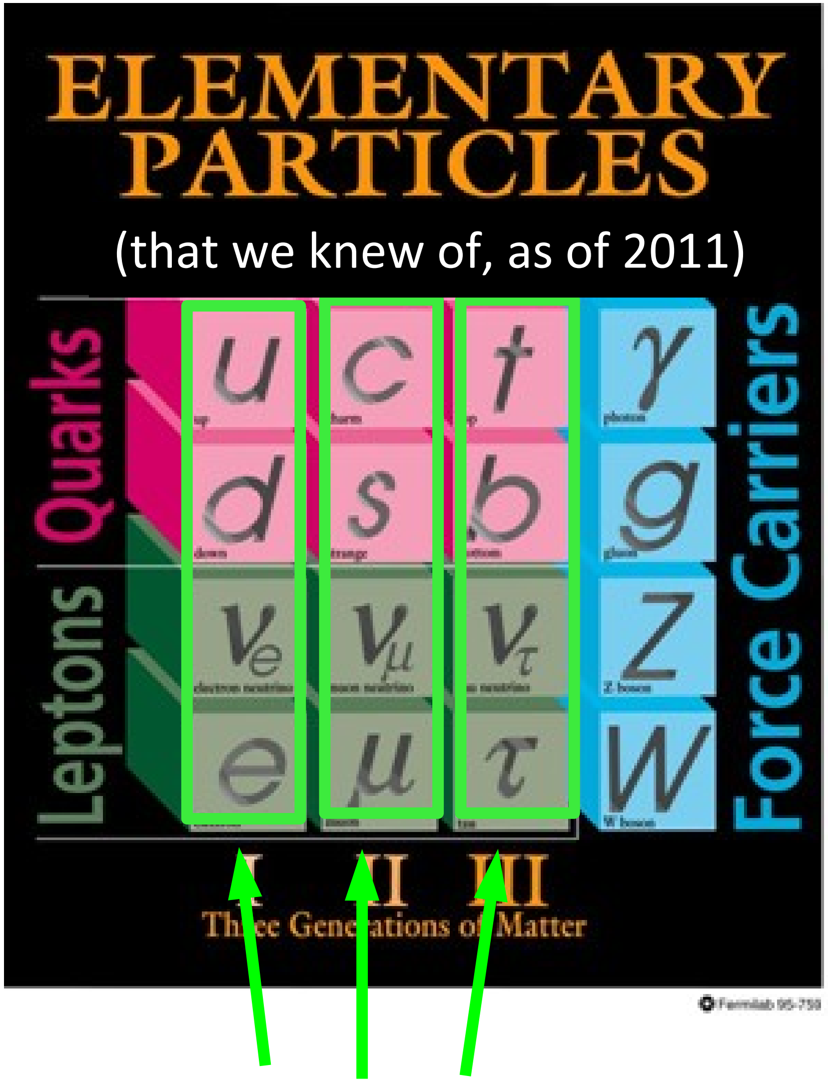


What you're made of





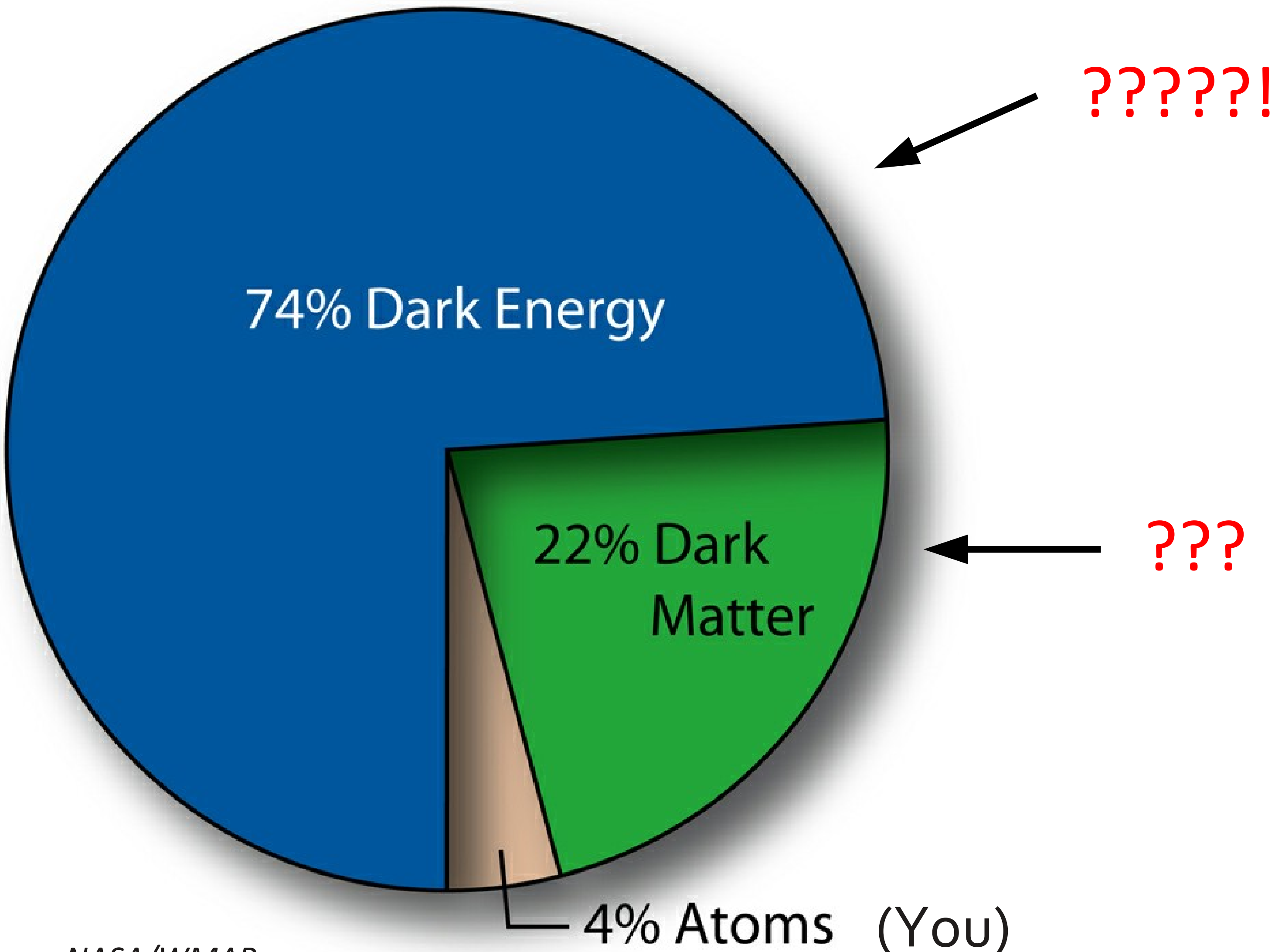
W and Z
Particles of the
weak nuclear force



Three “generations” of matter particles

Units of energy and mass
1 GeV = 1.07 protons
125 GeV ≈ 1 cesium atom

The Modern Universe



NASA/WMAP

What does the Higgs boson do?

The Higgs *field* fills all of space. It's like a gravitational or electric field, but it doesn't need a source to exist; it's just there.

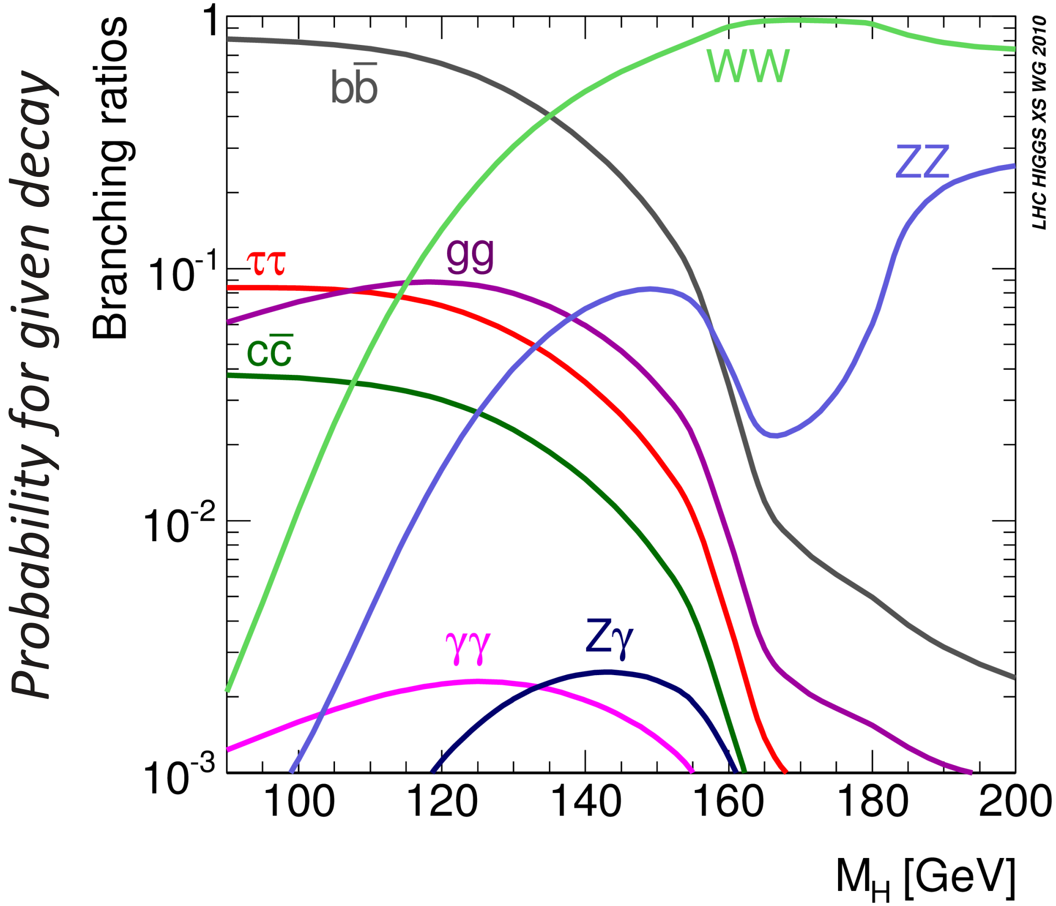
It gives masses to all the fundamental particles that we know of, essentially by sticking to them.

How can we see it? By shaking the field a bit and seeing the wobbles.


Higgs Field
Higgs Bosons

Theoretically well understood

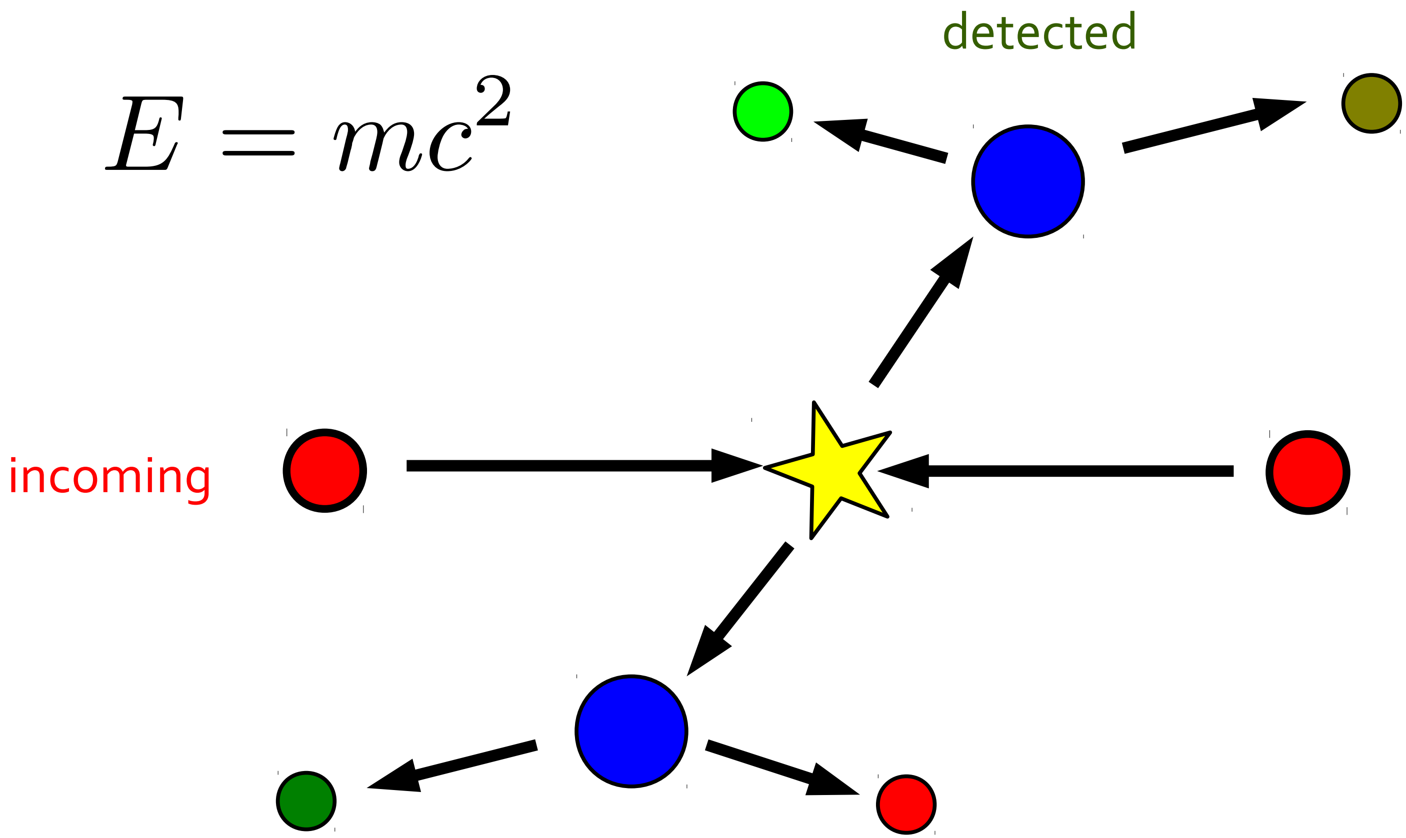
LHC Higgs WG



We knew exactly what to look for (except how heavy it was!)

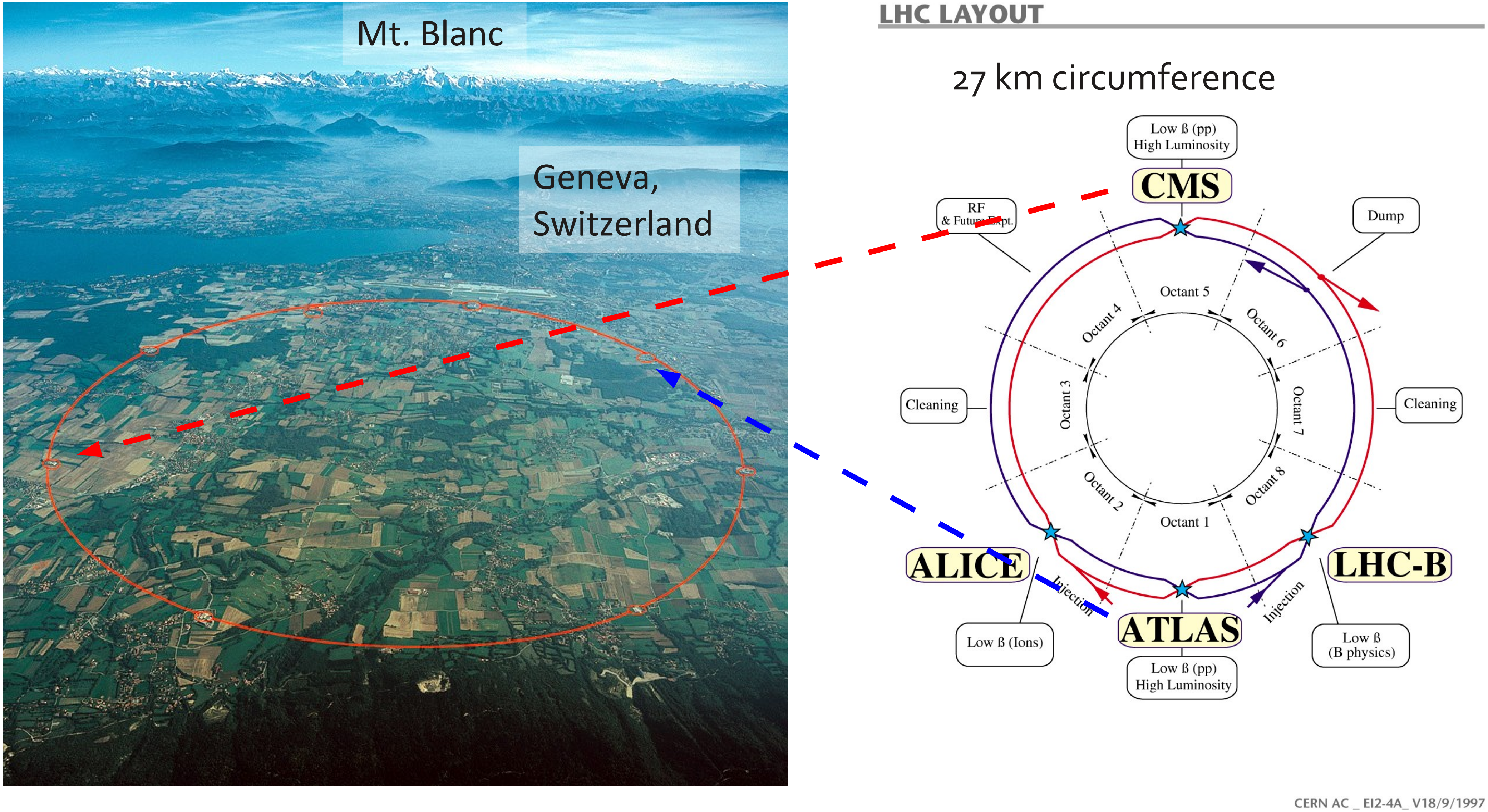
How do we look for new particles?

$$E = mc^2$$



convert kinetic energy to mass energy of new particles

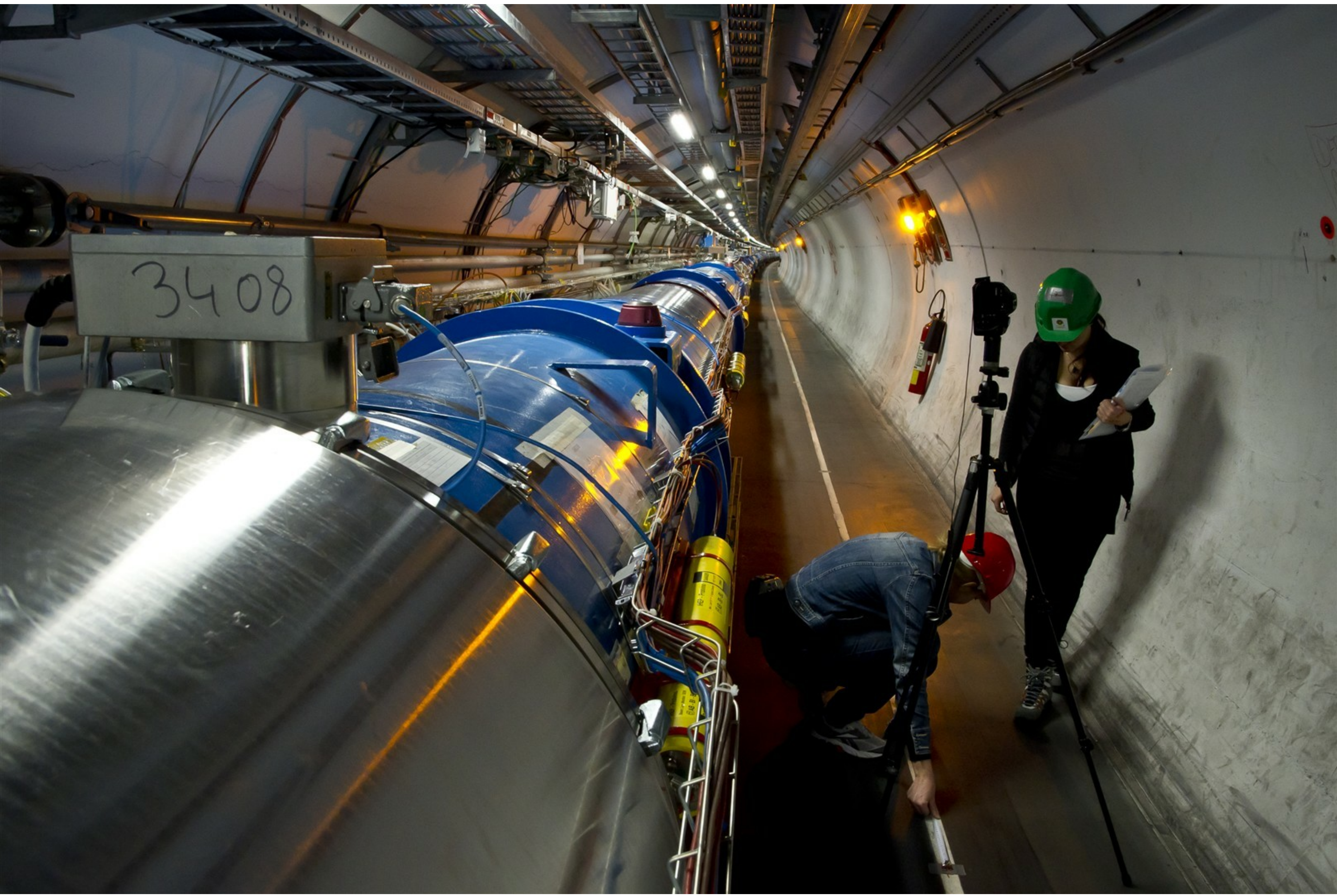
the particles you can make are determined by the forces they feel



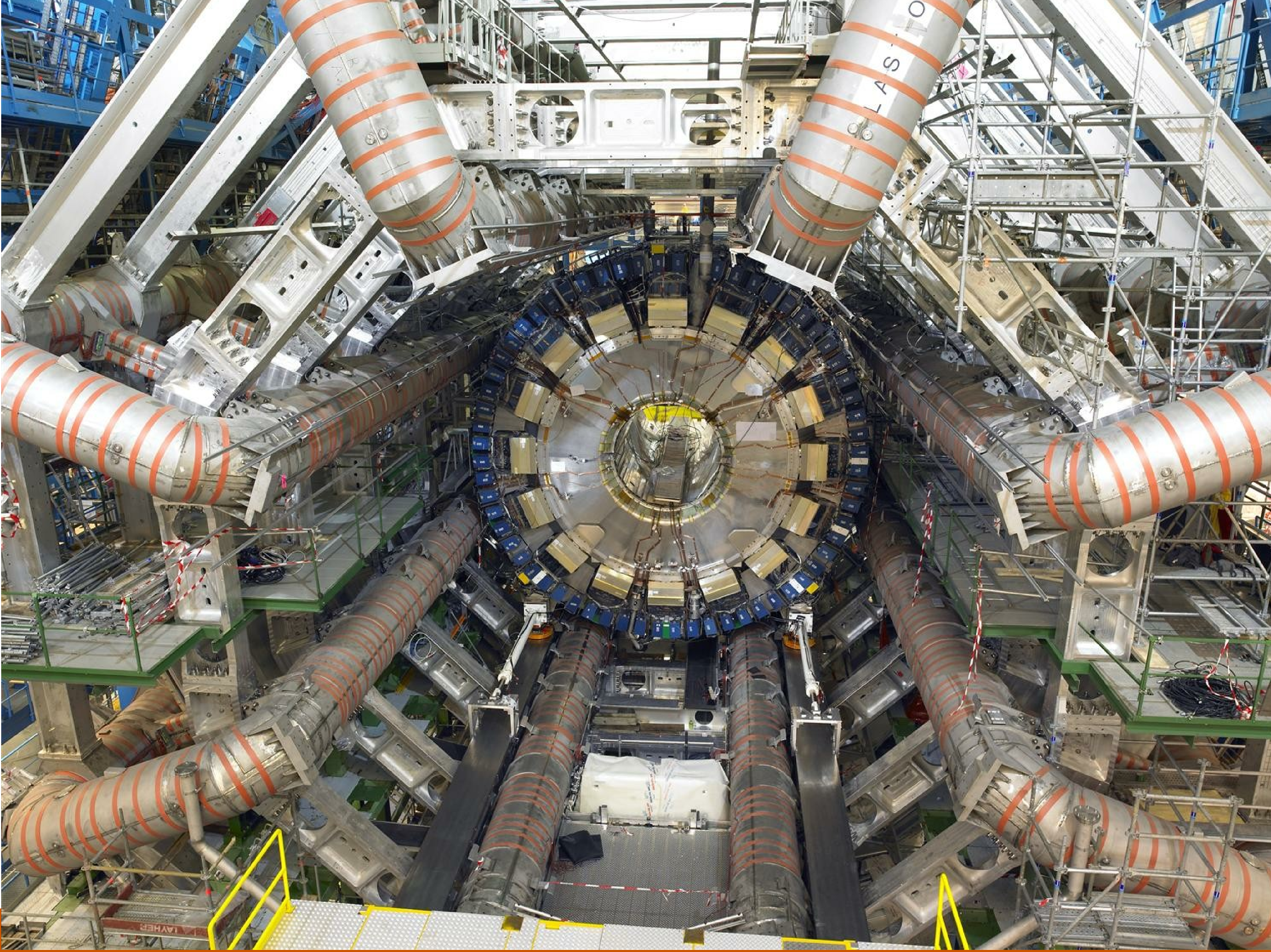
CERN: the European laboratory for particle physics

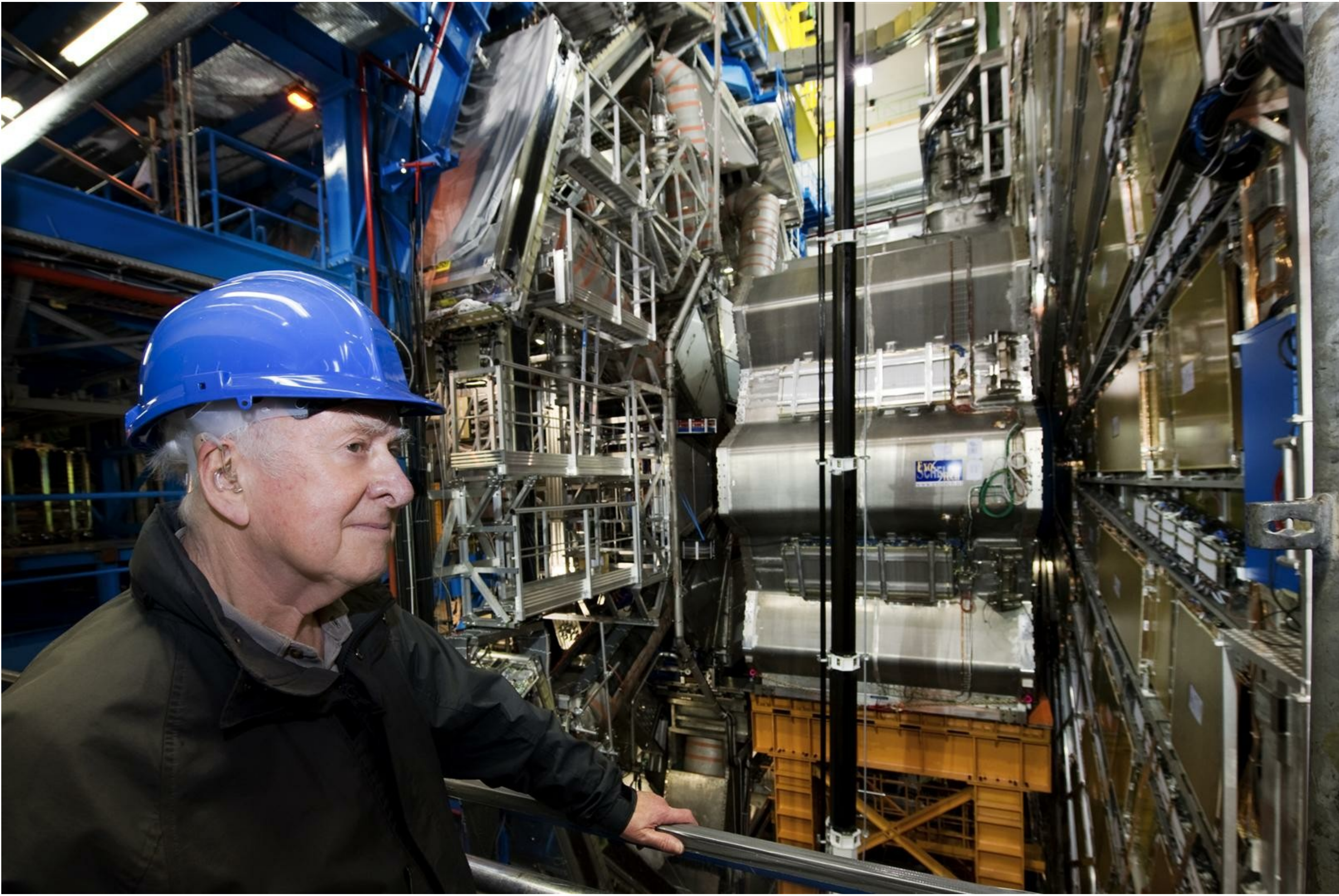
LHC: collides protons with kinetic energy > 4000 times their rest mass where it all begins

consumption per day
≈ 2 nanograms

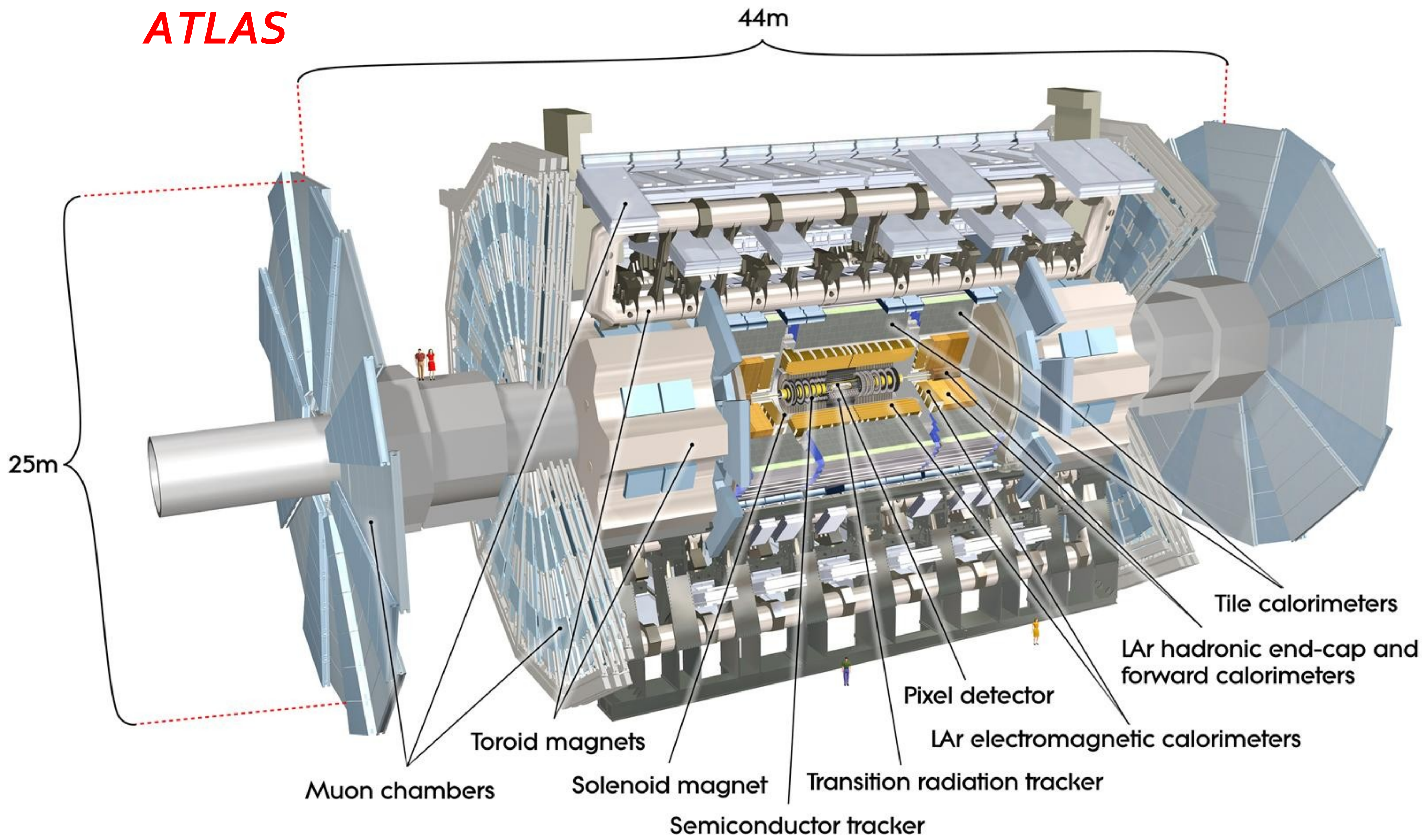


Inside the LHC tunnel



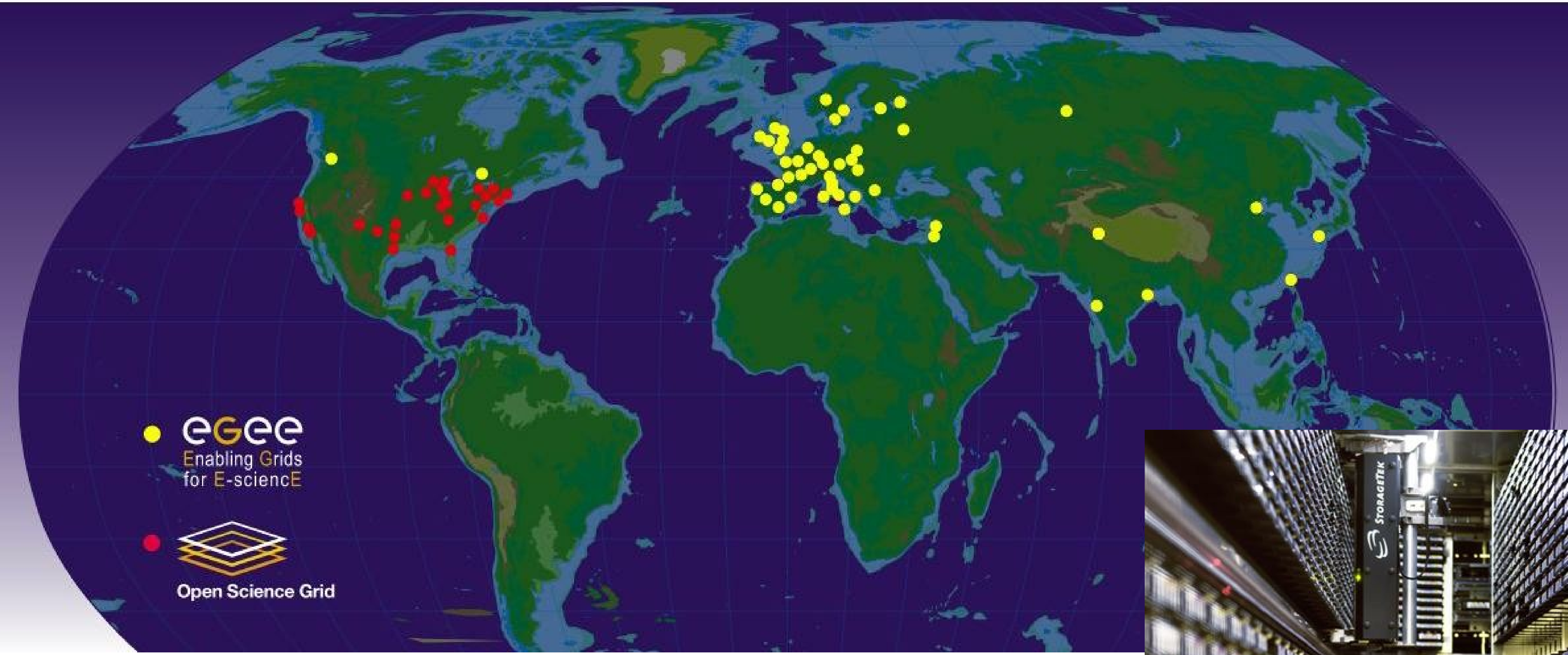


ATLAS



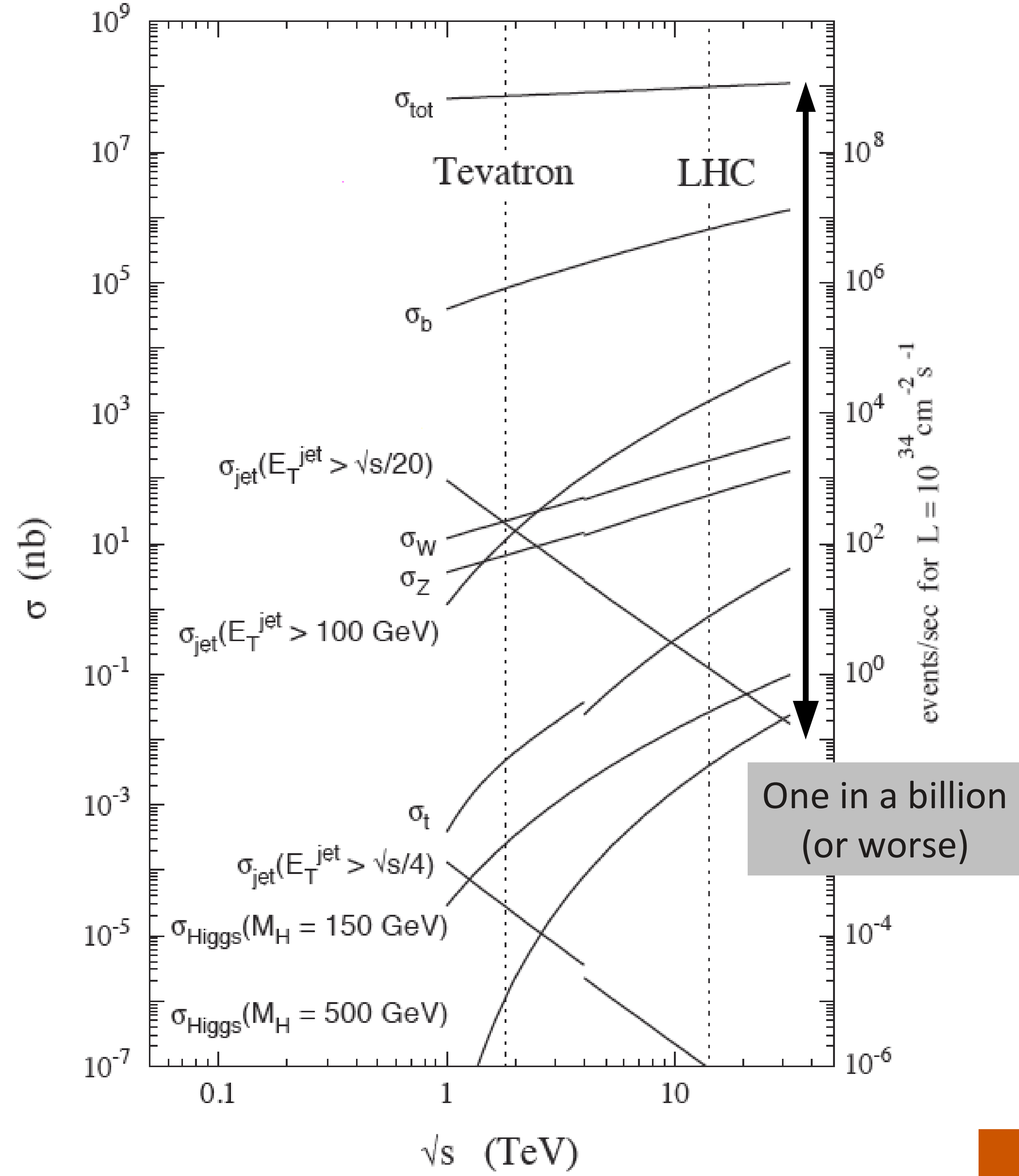
How ATLAS detects particles

Over 3000 people work on ATLAS… here are a few (at the Higgs party!)



LHC experiments record billions of collisions, tens of petabytes of data per year

Need to search through them with computers throughout the globe



Quantum mechanics:
We only have *probabilities*

Every collision is a *random occurrence*

We're looking for things happening less often than once in a trillion collisions

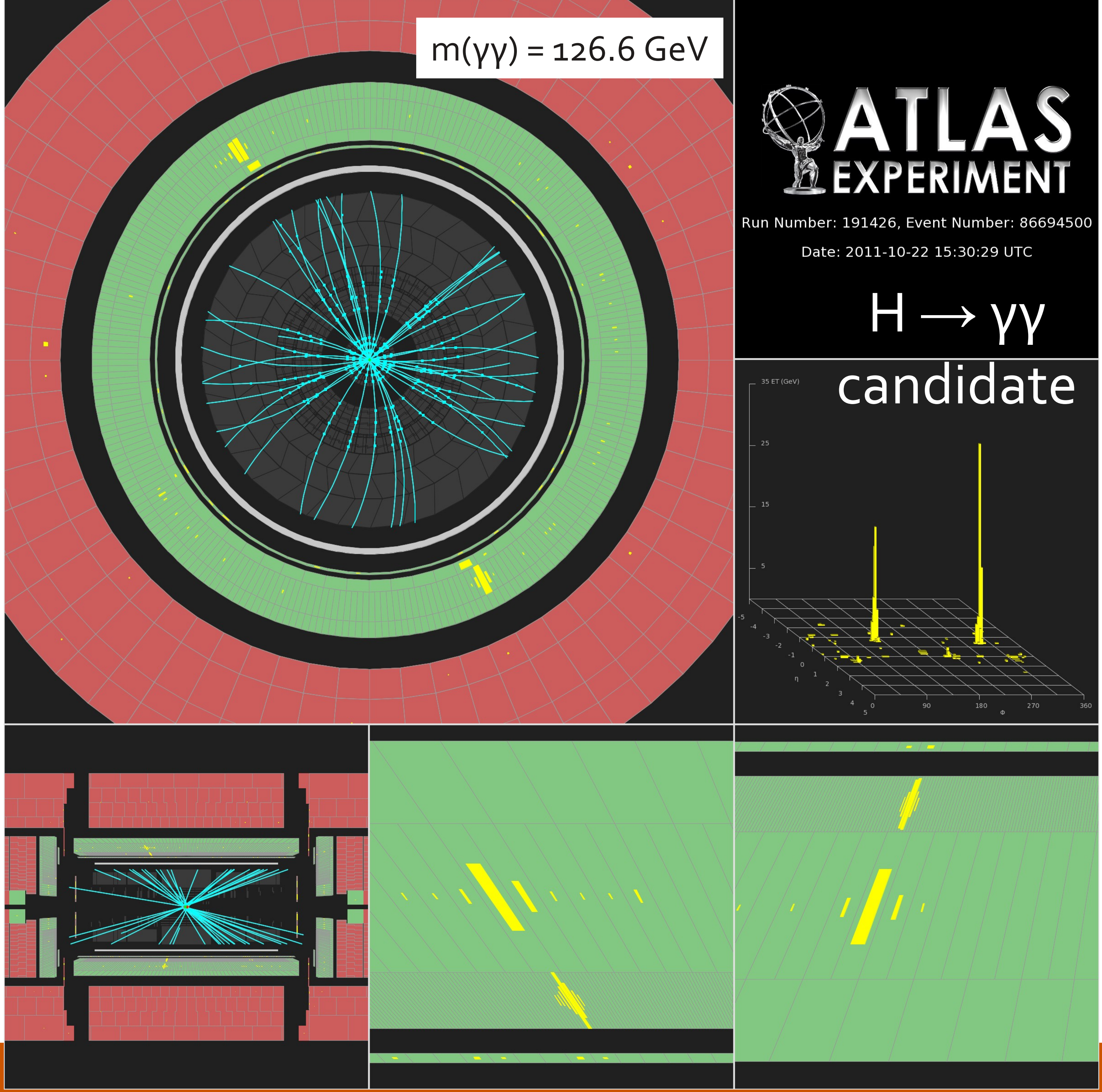
The Pace of Higgses

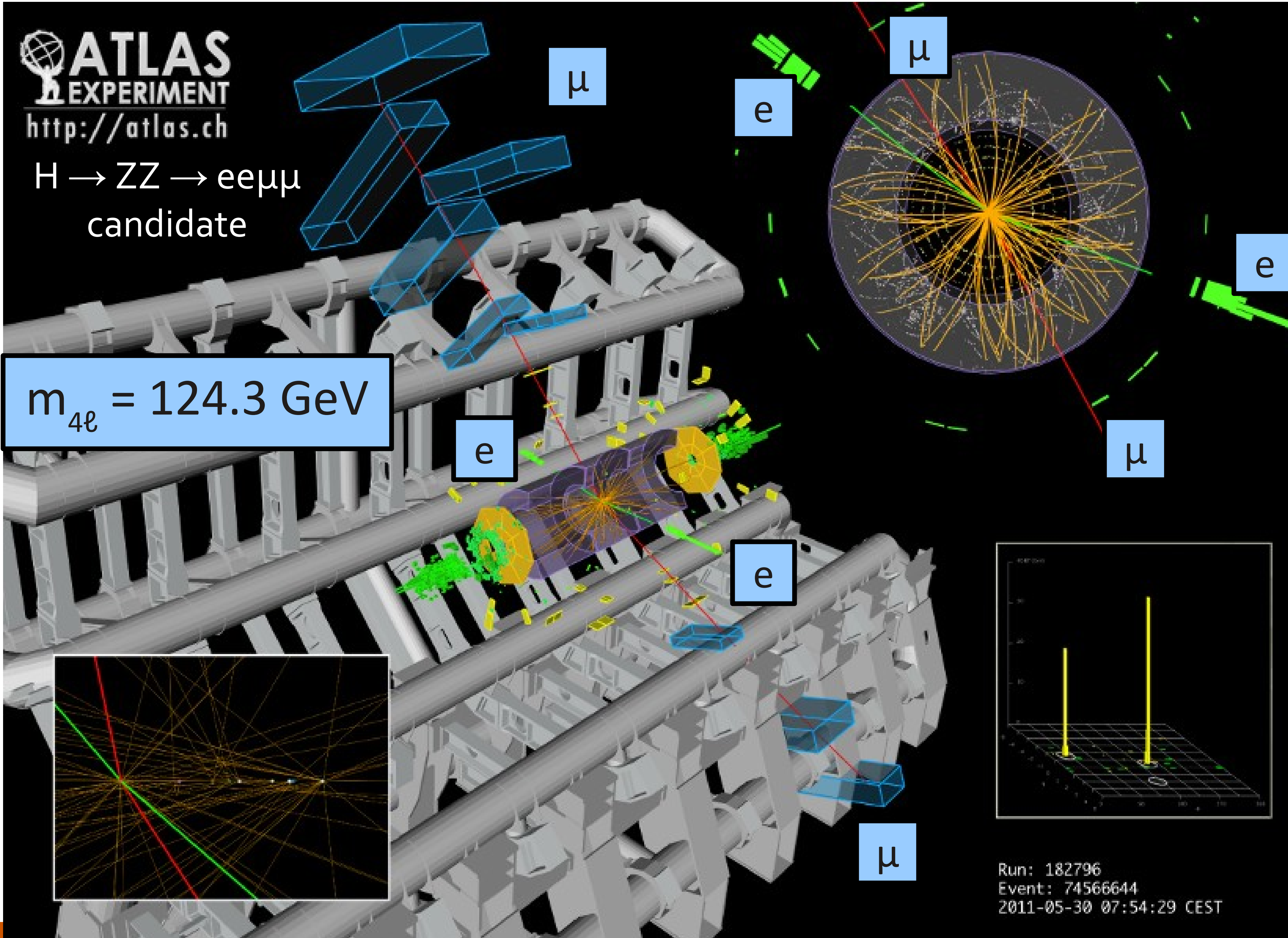
The collisions produce

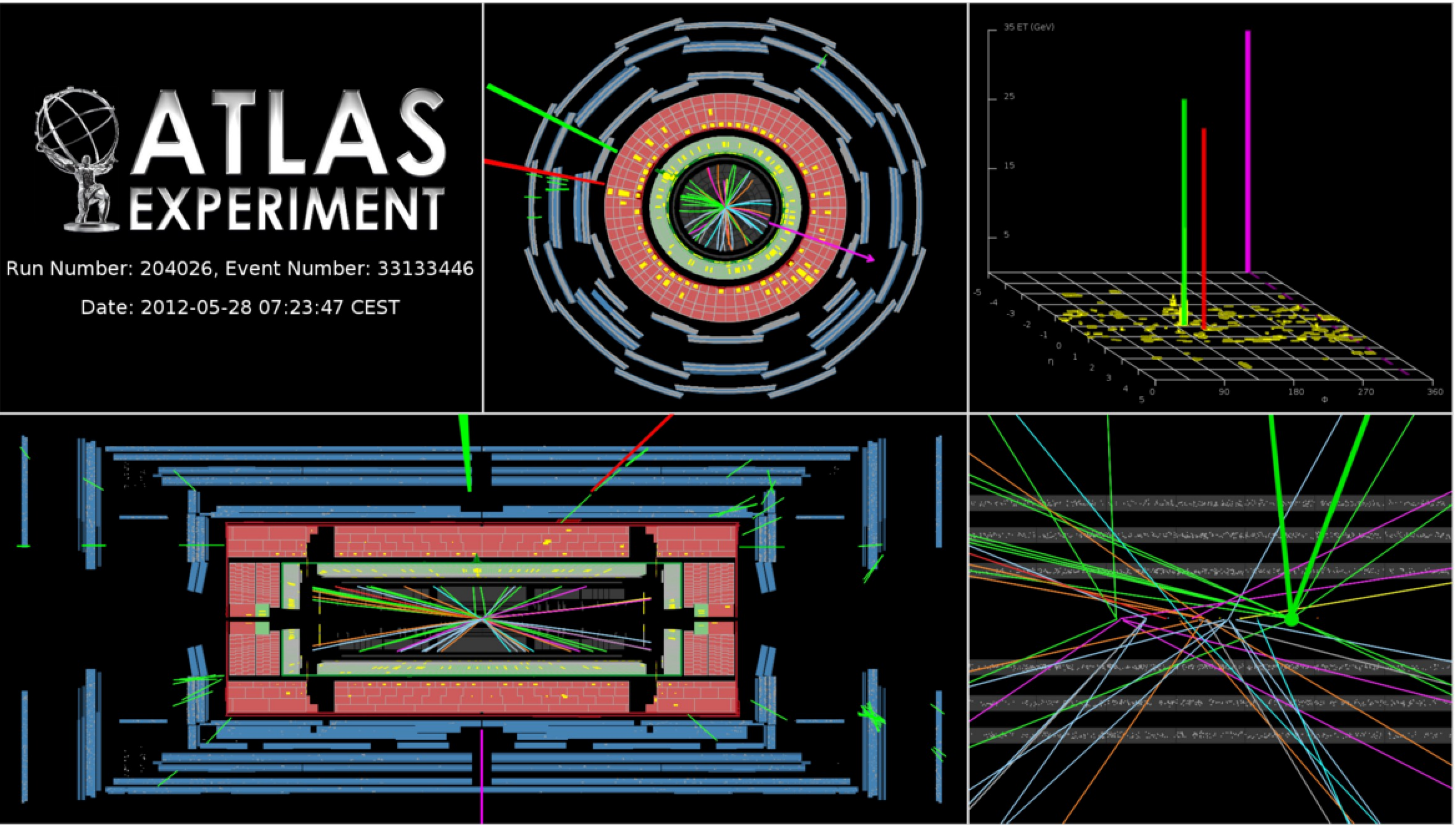
- a $H \to WW \to \ell\nu\ell\nu$ event every 20 minutes
- a $H \to \gamma\gamma$ event every 45 minutes
- a $H \to ZZ \to 4\ell$ event every 13 hours

We're not 100% efficient at catching them, and we need a lot to separate them from other processes

In short, it takes a long time to accumulate data.

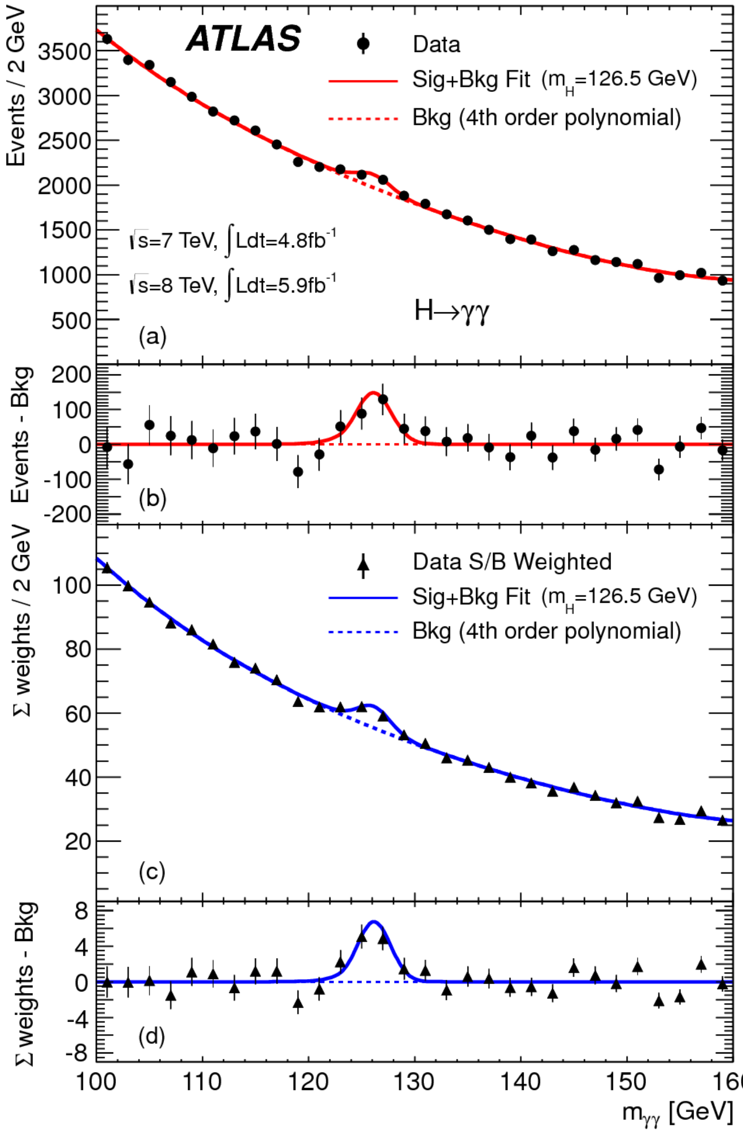

m(γγ) = 126.6 GeV
ATLAS EXPERIMENT
Run Number: 191426, Event Number: 86694500
Date: 2011-10-22 15:30:29 UTC
H ⟶ γγ
candidate
35 ET (GeV)
25
15
5
η
0
90
180
270
360
Φ

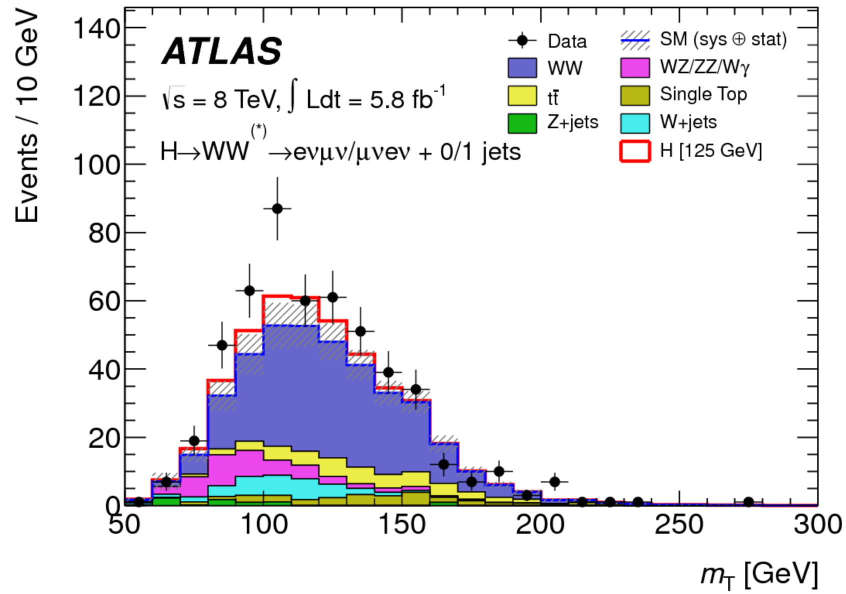

ATLAS EXPERIMENT
http://atlas.ch
H → ZZ → eeμμ candidate
m4ℓ = 124.3 GeV
μ
e
μ
e
e
μ
e
μ
Run: 182796
Event: 74566644
2011-05-30 07:54:29 CEST

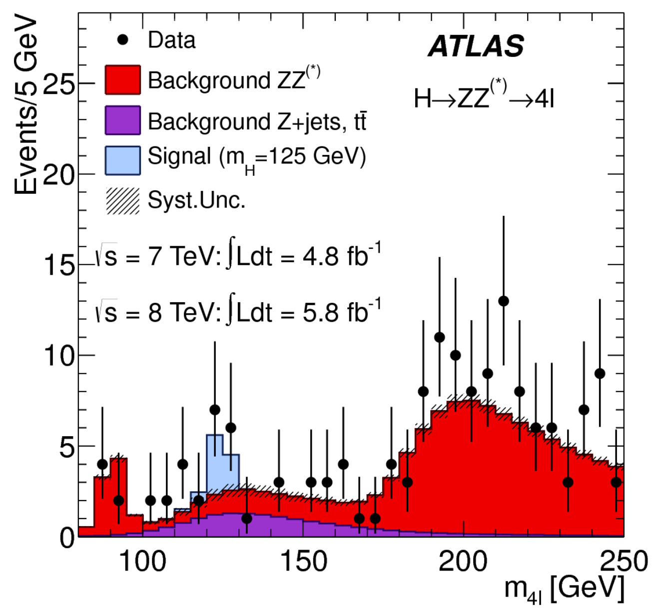


H ⟶ WW ⟶ eνμν candidate

The Discovery Plots



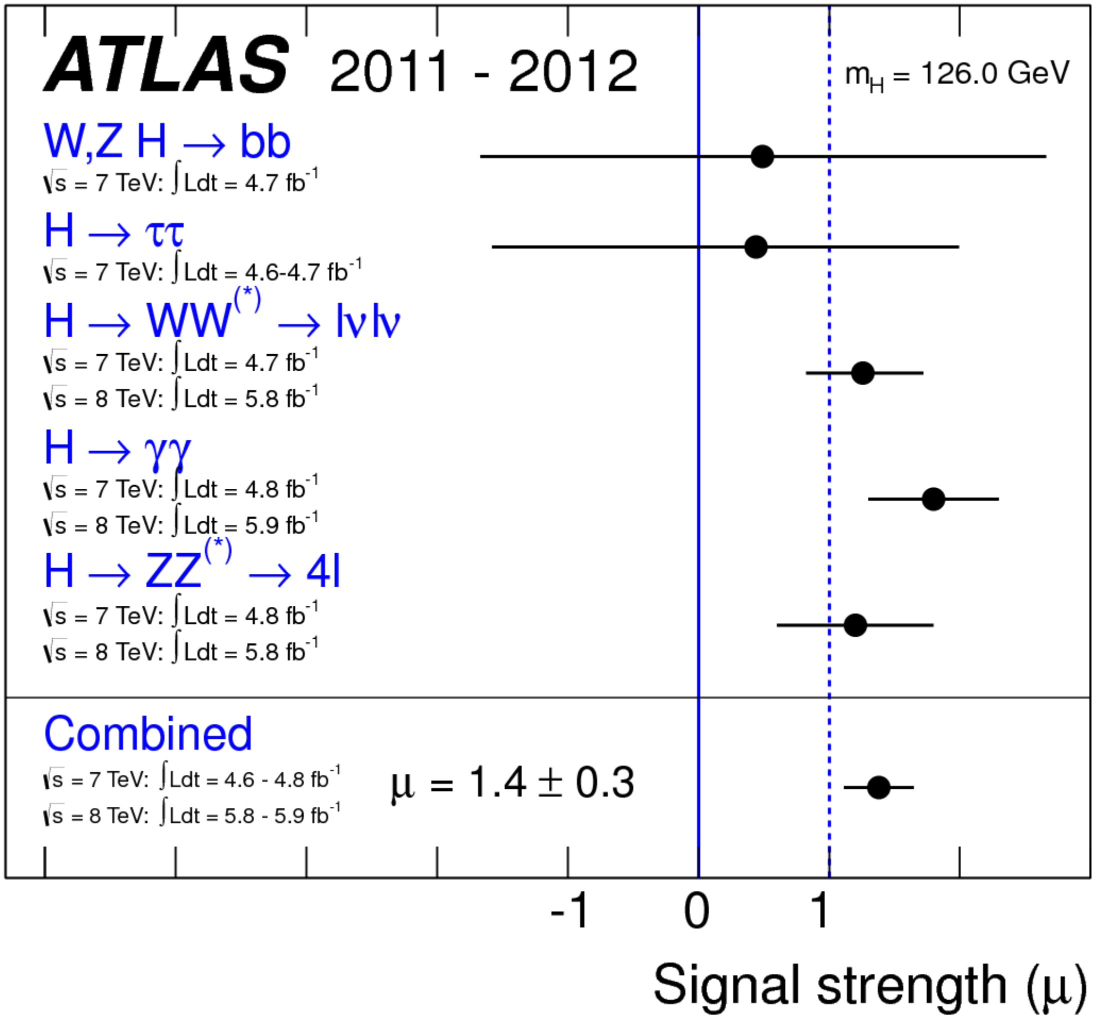


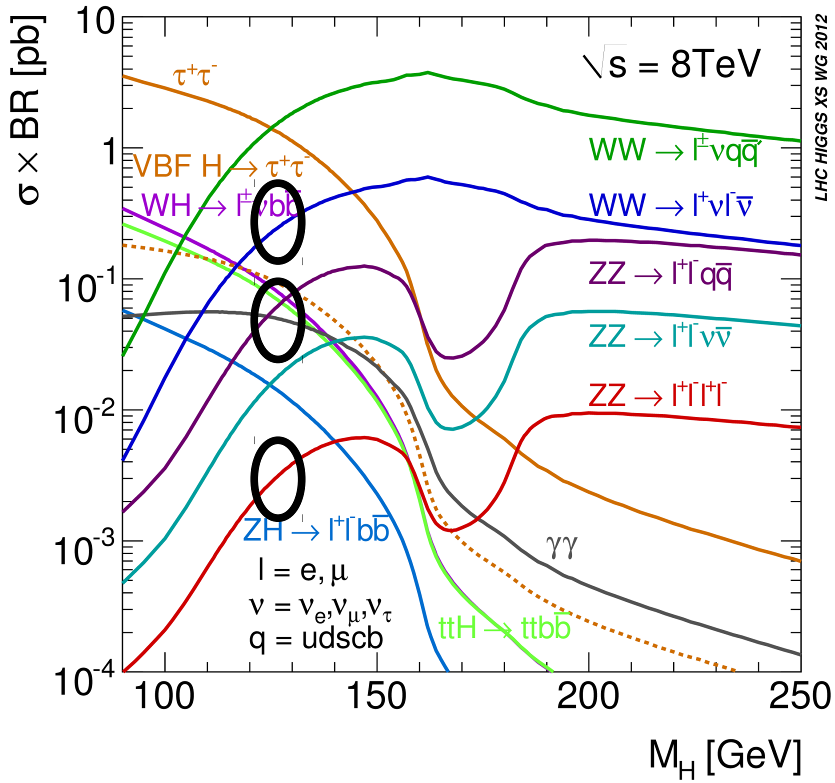


+ equivalent plots from our competitors, CMS

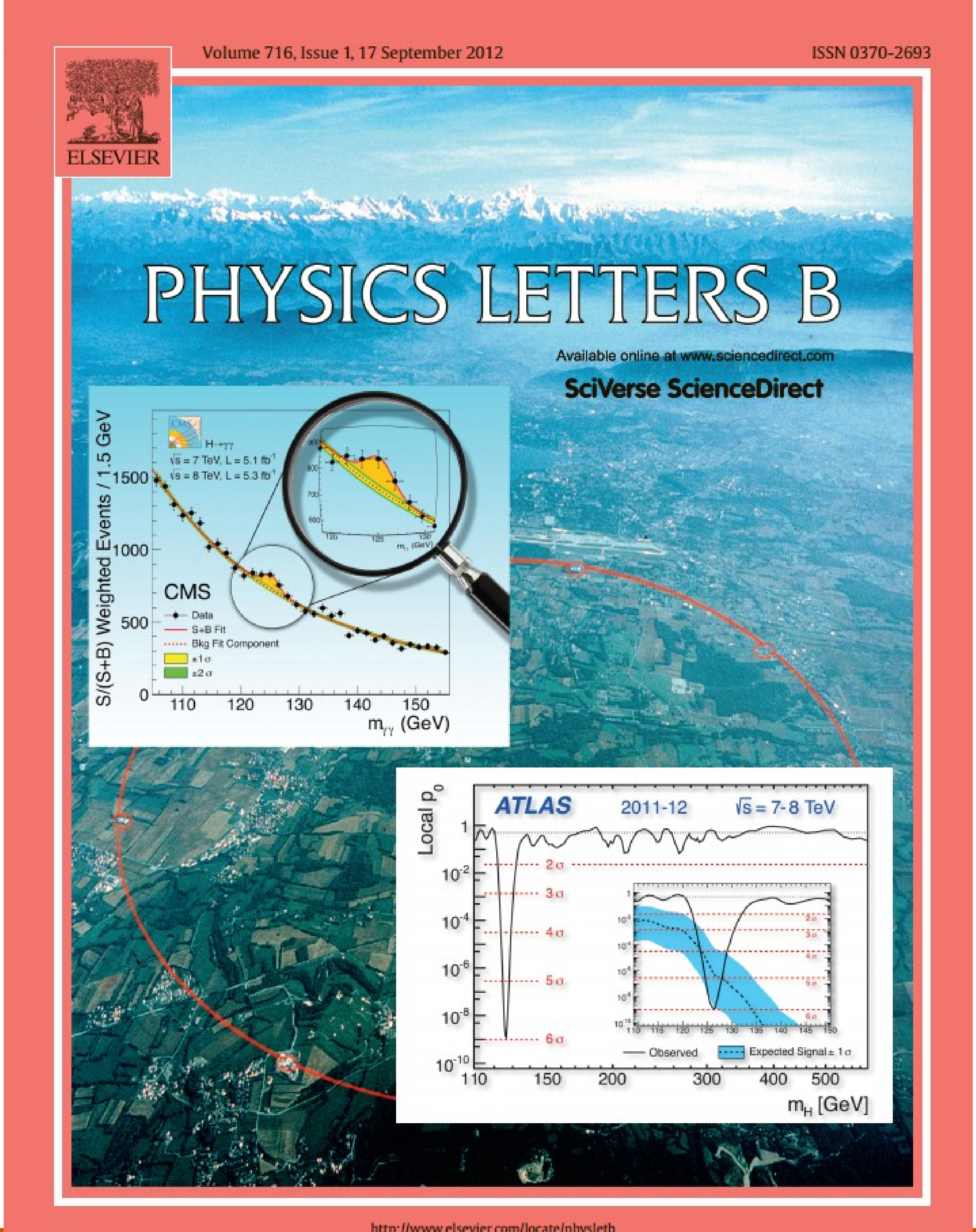
"5.9σ":
probability of fluctuation is 1.7 x 10^{-9}

Is it what we expect?





Signal strength = observed/expected rate

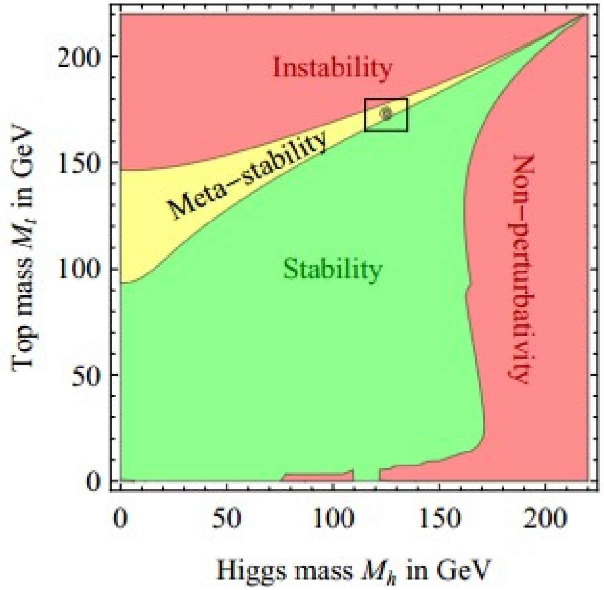

Volume 716, Issue 1, 17 September 2012
ISSN 0370-2693
ELSEVIER
PHYSICS LETTERS B
Available online at www.sciencedirect.com
SciVerse ScienceDirect
CMS
S/(S+B) Weighted Events / 1.5 GeV
Data
S+B Fit
Bkg Fit Component
m_γγ (GeV)
ATLAS
2011-12
√s = 7-8 TeV
Local p_0
Observed
Expected Signal ± 1 σ
m_H [GeV]
http://www.elsevier.com/locate/physletb

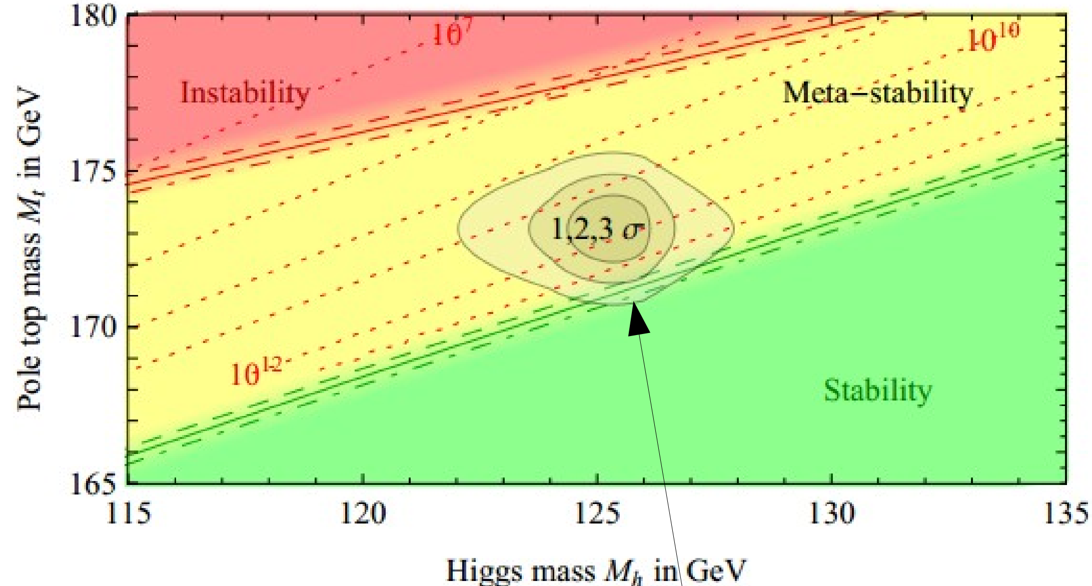
Towards the Future

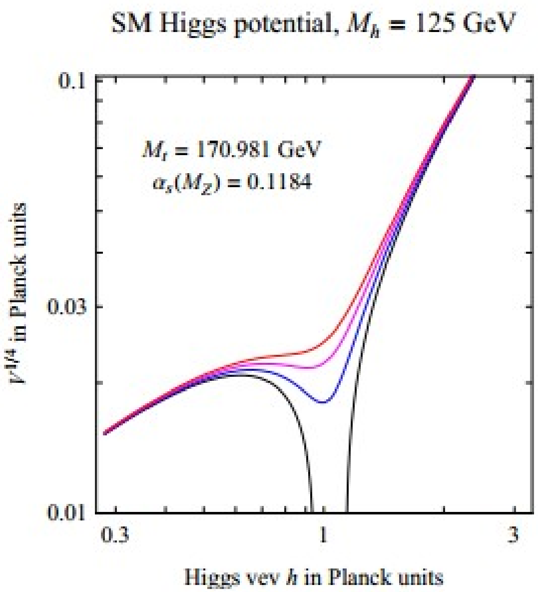
What else do we need to study about the Higgs?

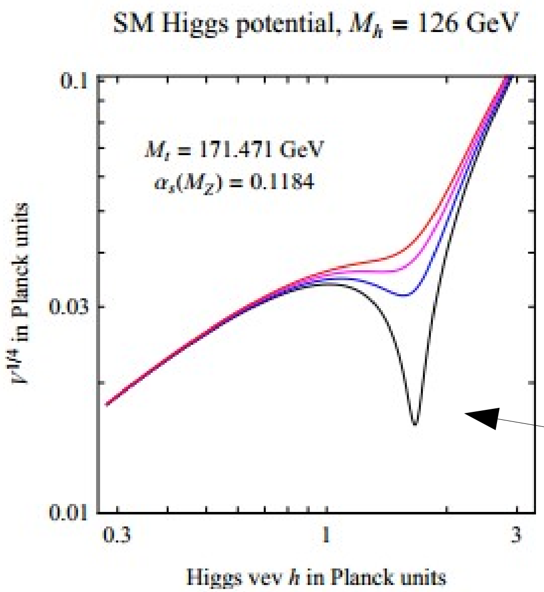
- Is it "the" Higgs, or something that just looks like it? Study its behavior!
- Does it have partners? Many theories predict so!
- What, precisely, is its own mass? Is our picture of how the Higgs field comes to be correct?
- Does it have implications for the evolution of the universe?

Is our vacuum stable?









Perhaps we are not in the true minimum of the Higgs potential?

Could the SM Higgs drive primordial inflation?

Degrassi et al, arxiv:1205.6497

Unsolved Mysteries

There are questions that may be related to new forces and matter particles with mass around the TeV scale.

- What about dark matter?
- The Higgs mass is "unstable" in the Standard Model (very sensitive to initial theoretical parameters) – does something stabilize it? (e.g. "supersymmetry", "composite Higgs")
- Are there differences between matter and antimatter beyond those in the Standard Model?

Also, keep our eyes open for something unexpected!

HIGGS BOSON
H
The HIGGS BOSON is the theoretical particle of the Higgs mechanism, which physicists believe will reveal how all matter in the universe gets its mass. Many scientists hope that the Large Hadron Collider in Geneva, Switzerland, which collides particles at 99.99% the speed of light, will detect the elusive Higgs Boson
Higgs boson
$10.49 PLUS SHIPPING
LIGHT
HEAVY
Wool felt, fleece with gravel fill for maximum mass. MADE IN CHINA.
HIGGS BOSON
The PARTICLE ZOO