The research at CERN/ATLAS

http://www.cern.ch

CERN IS OVER 65 YEARS OLD

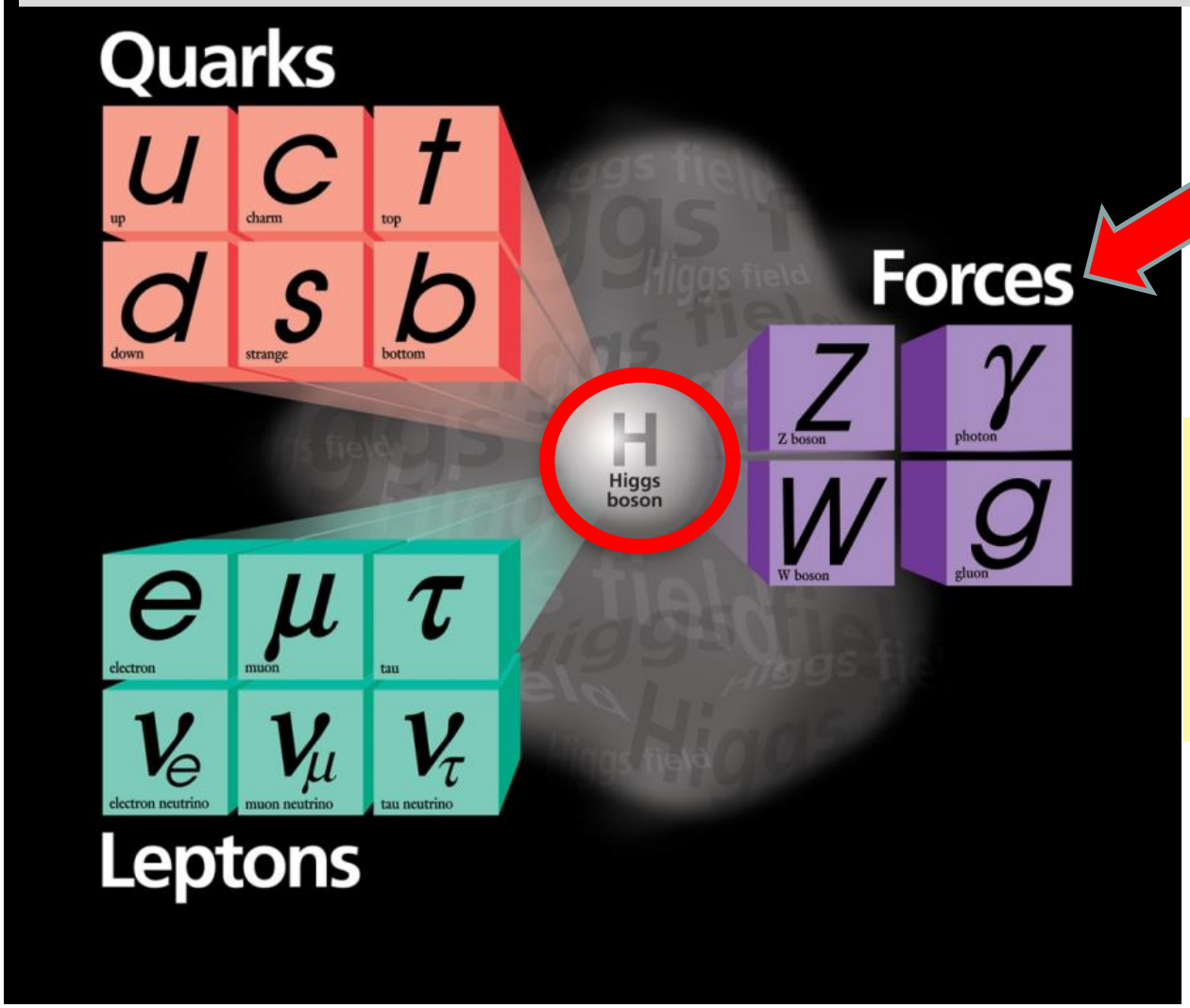
10 years ago it discovered the Higgs Boson!

The last component for the completion of the SM

- Basic research
- 24 members countries, 14,000 researchers from 800 Universities/research centers
- Brings together researchers from all five continents
- Unique facilities in the world (Accelerators and experiments)
- Pushes cutting-edge technology at its limits
- Trains tomorrow's researchers.

Our description of matter: the SM

The elementary particles, the force carriers and **the key component missing for 50 years!!!**



- Strong
- EM
- Weak

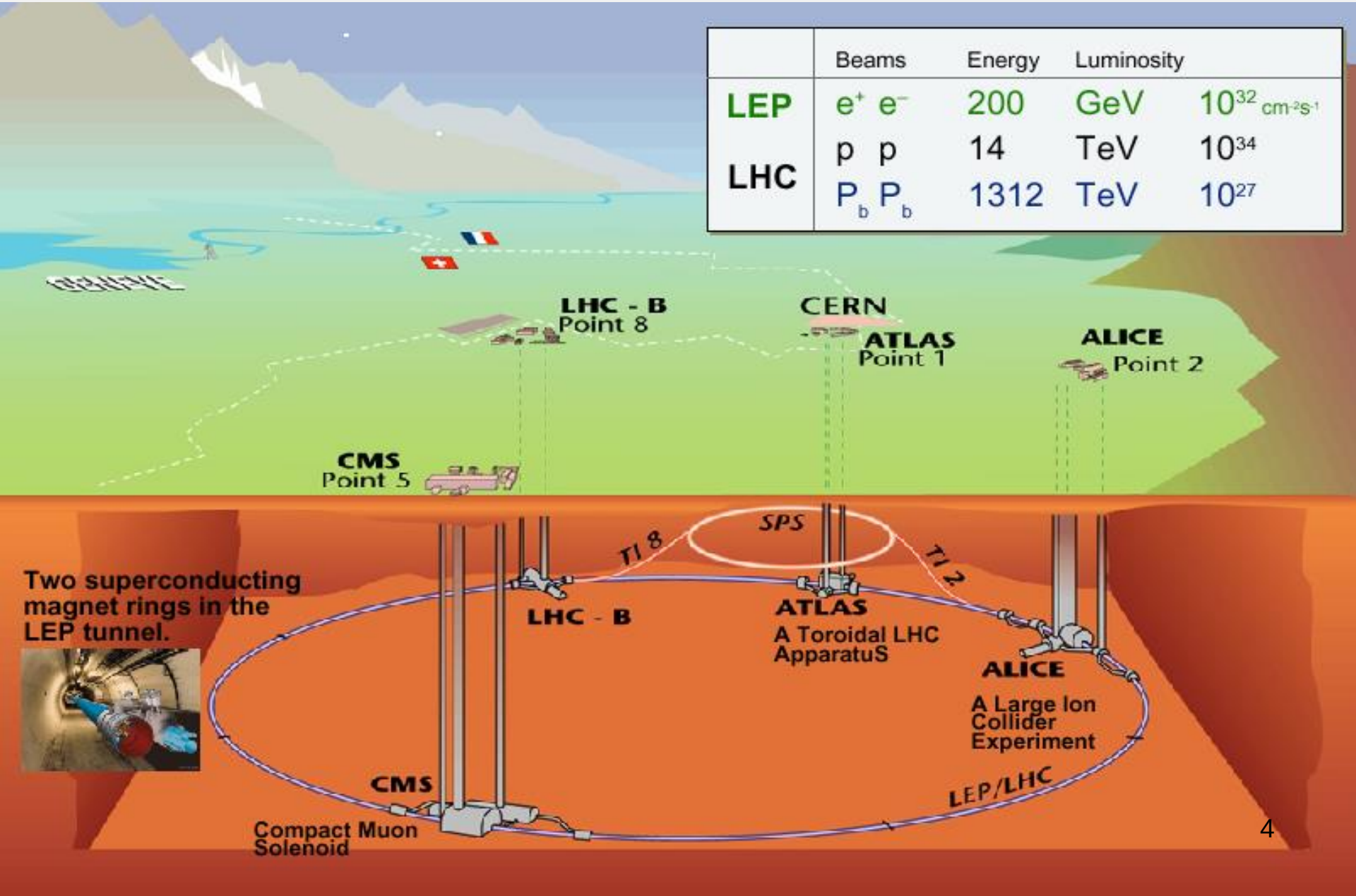
$m_\gamma = 0$

$m_{Z,W} \sim 100$ GeV

Why?

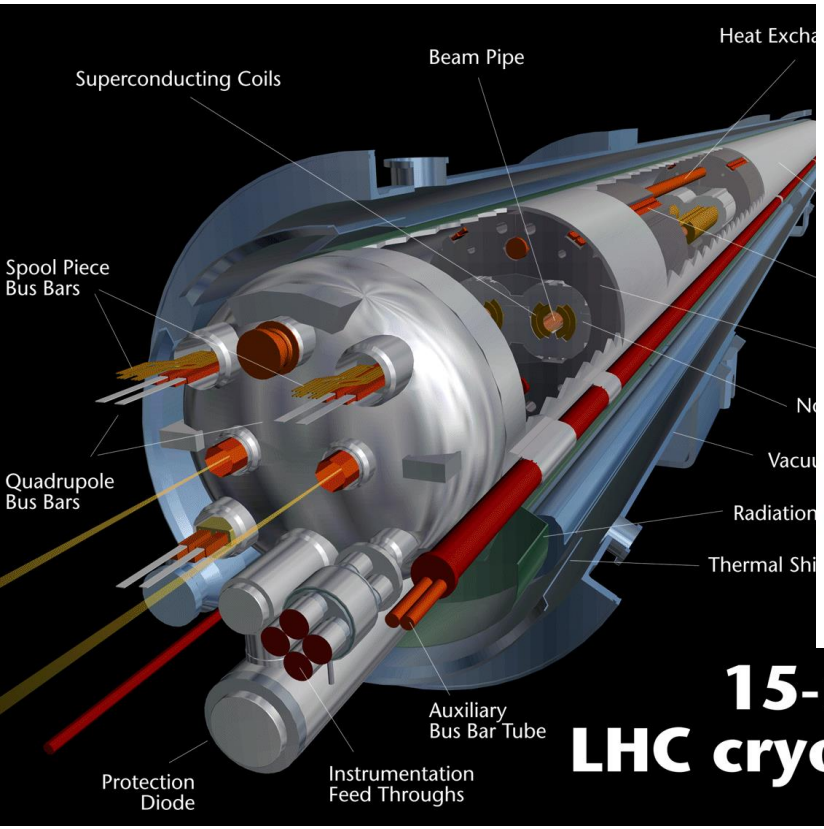
CERN designed and constructed LHC: The challenge was the discovery of the Higgs boson + new physics

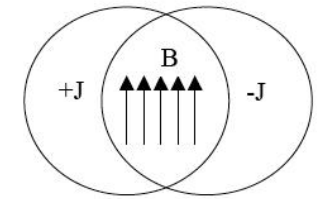
	Beams	Energy	Luminosity	
LEP	e^+ e^-	200	GeV	10^{32} $cm^{-2}s^{-1}$
LHC	p p	14	TeV	10^{34}
	P_b P_b	1312	TeV	10^{27}

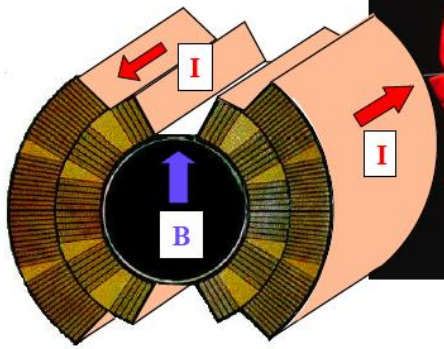


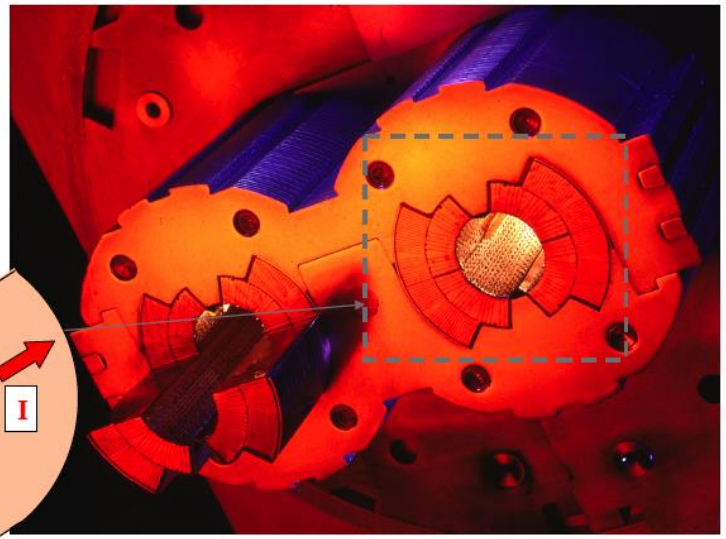
Two superconducting magnet rings in the LEP tunnel.

The challenge was the design and construction of the dipole magnets









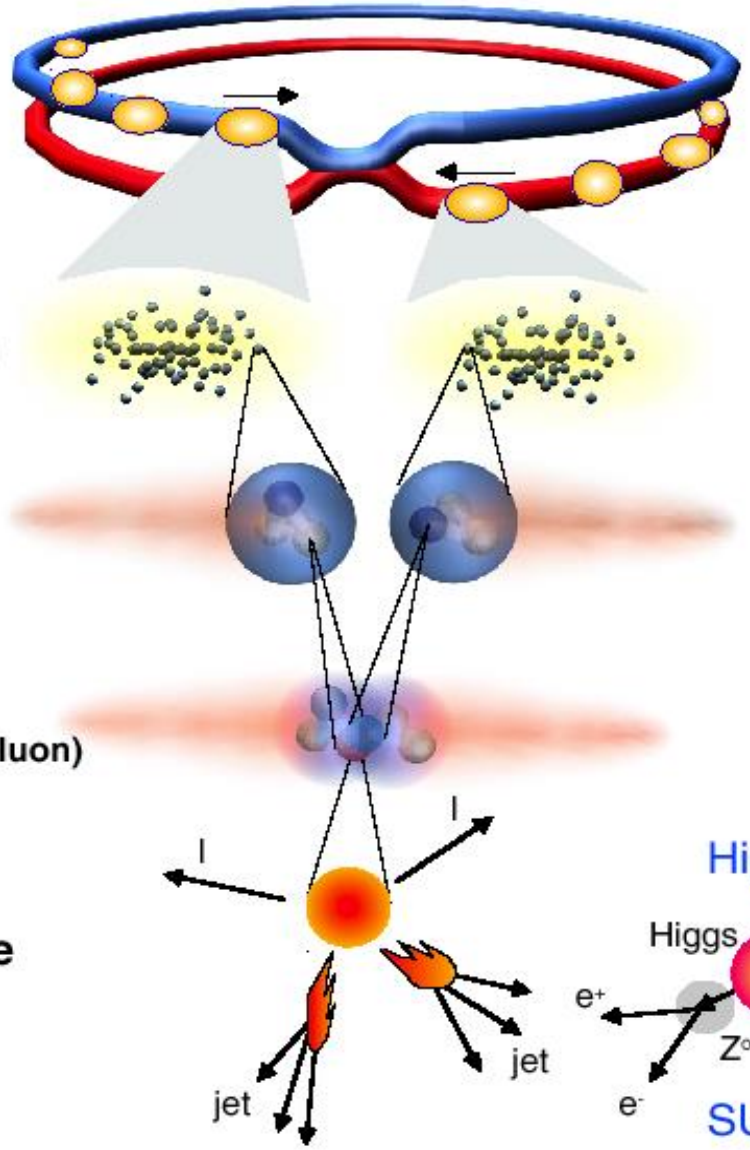
Magnetic Field for Dipoles
p (TeV) = 0.3 B(T) R(km)

1232 magnets, 35 tons each
The coldest ring in the universe ?1.9 K

For p = 7 TeV and R = 4.3 km
⇨ B = 8.4 T
⇨ Current 12 kA

The magnets cool down with liquid Helium under pressure

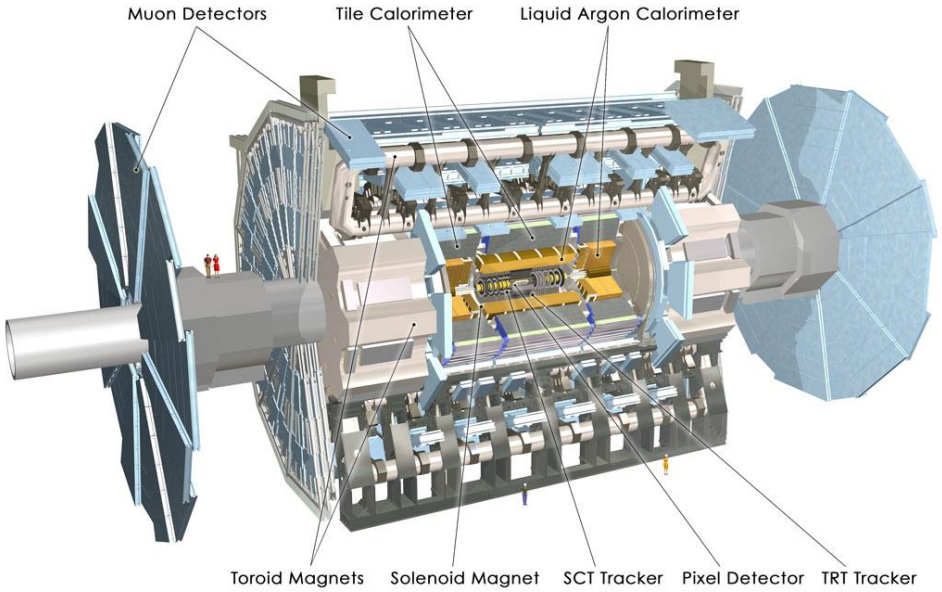
Collisions at LHC



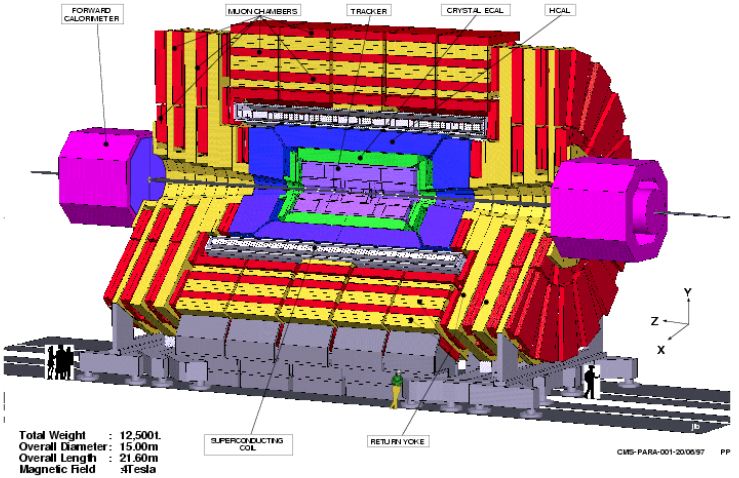
Proton-Proton	2835 bunch/beam
Protons/bunch	10^{11}
Beam energy	7 TeV (7×10^{12} eV)
Luminosity	10^{34} cm^{-2} s^{-1}
Crossing rate	40 MHz
Collisions ≈	10^{7} - 10^{9} Hz

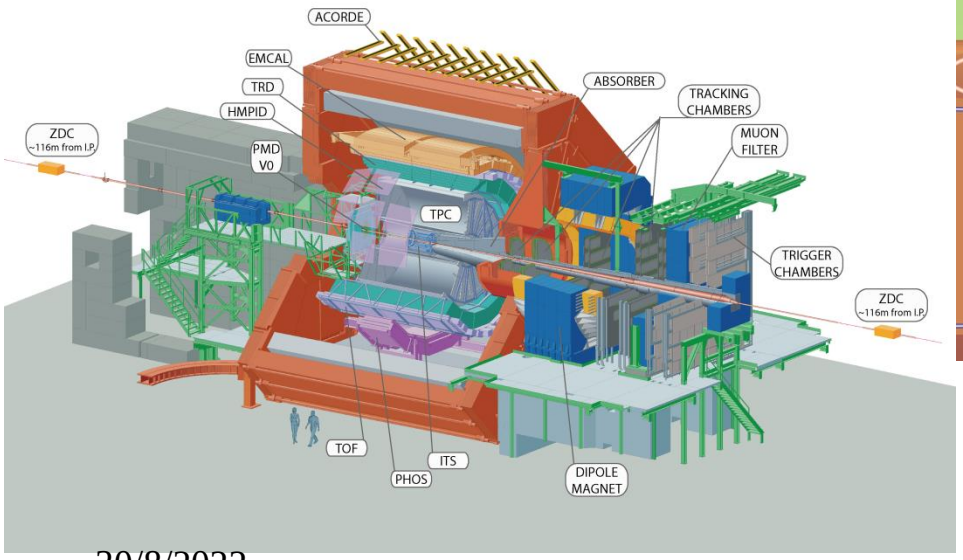
Selection of 1 in 10,000,000,000,000

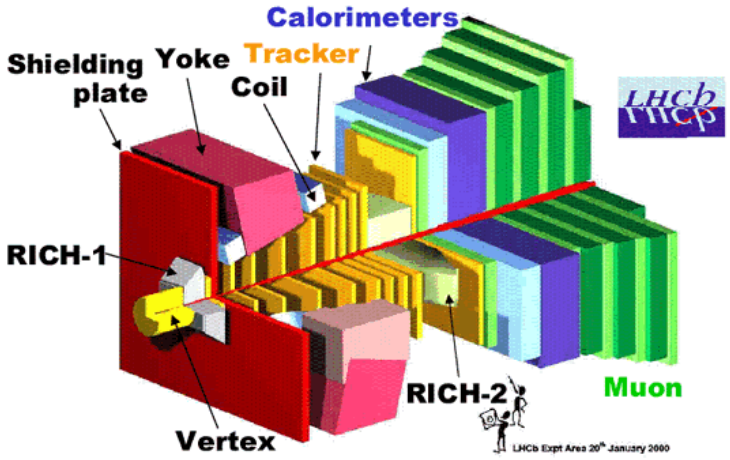
ATLAS



CMS







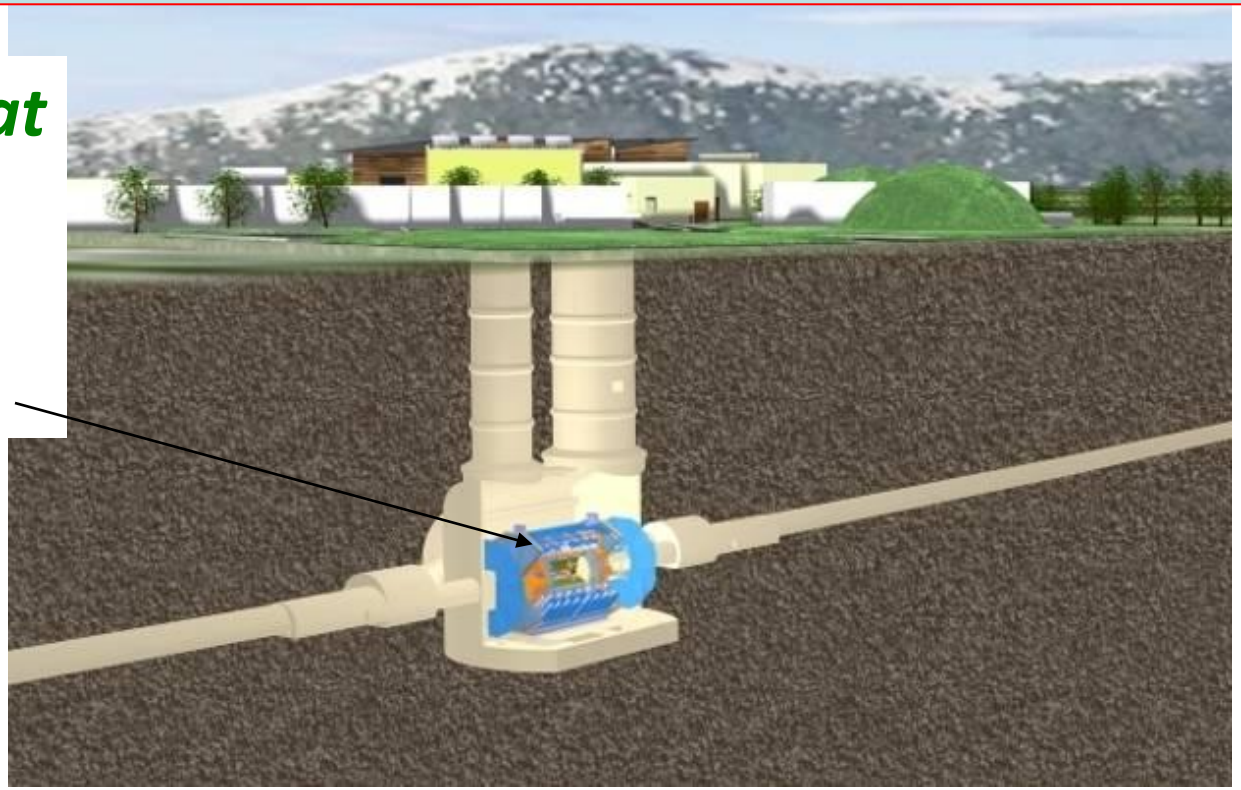
ALICE

LHC-B

ATLAS Challenge:

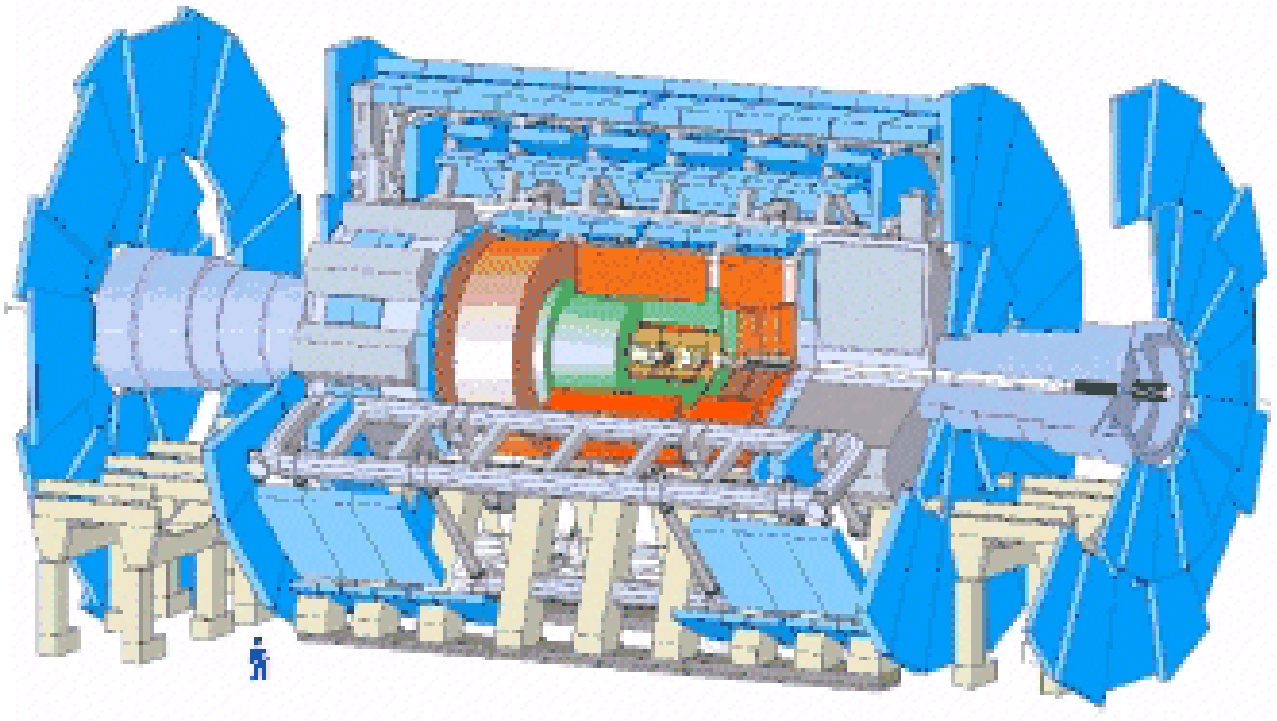
- to explore LHC pp collisions (and heavy ions)
- Reconstruct collisions products with high accuracy in a hostile environment

The underground pit at Point 1 where the ATLAS experiment is installed (since 2008)

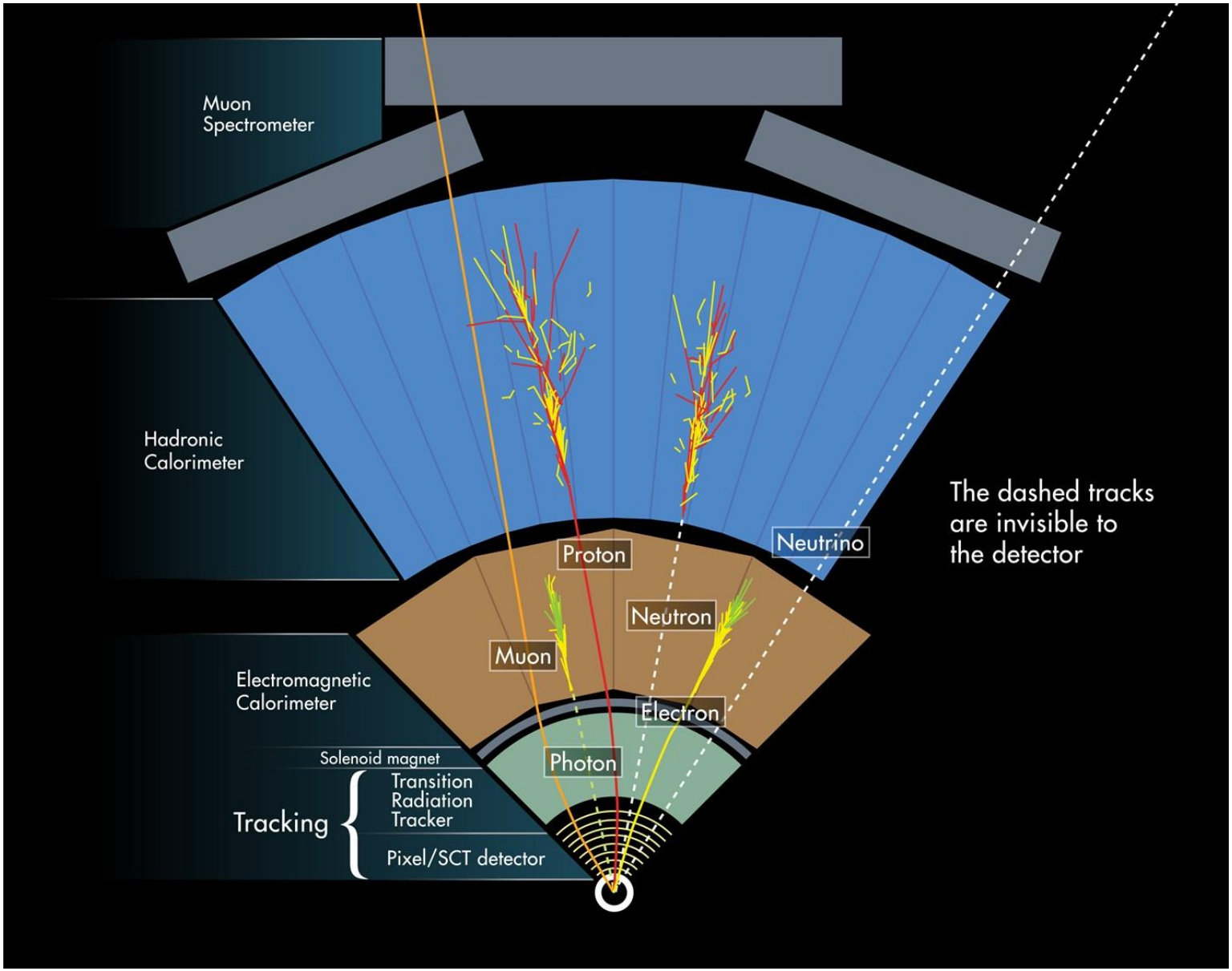


Length = 55 m
Width = 32 m
Height = 35 m

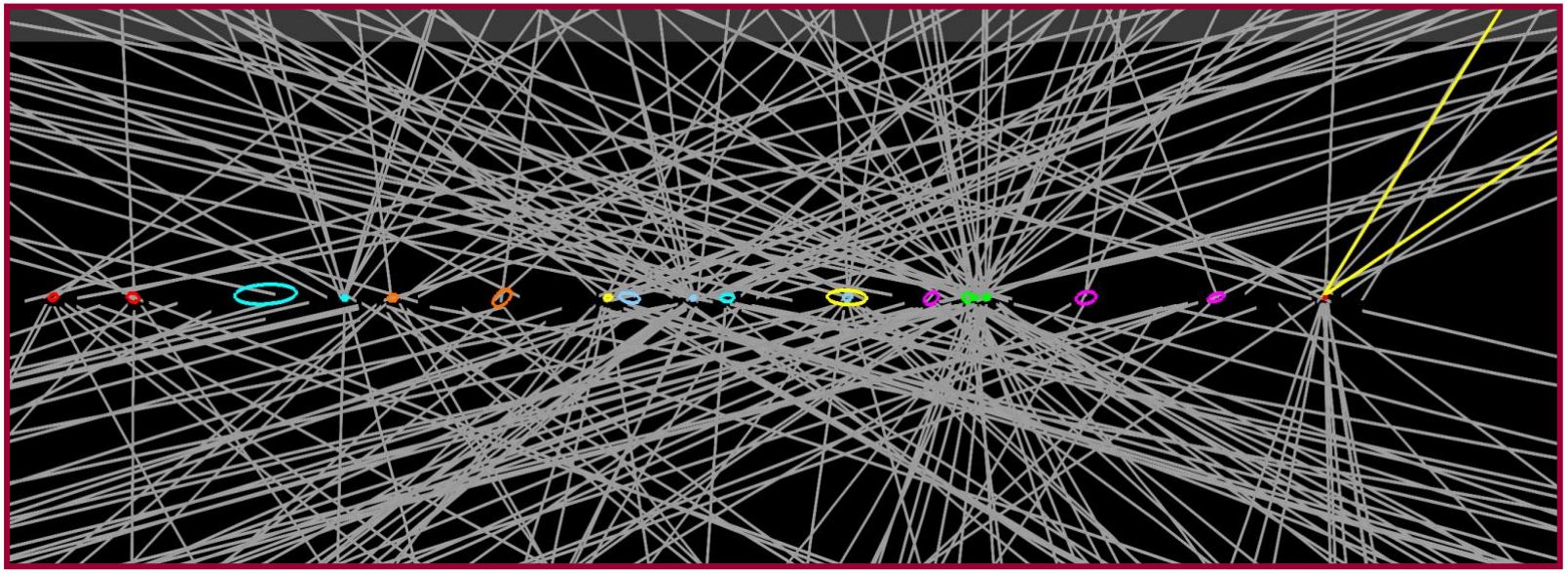
Different parts of the detector (subdetectors) identify/measure different particles

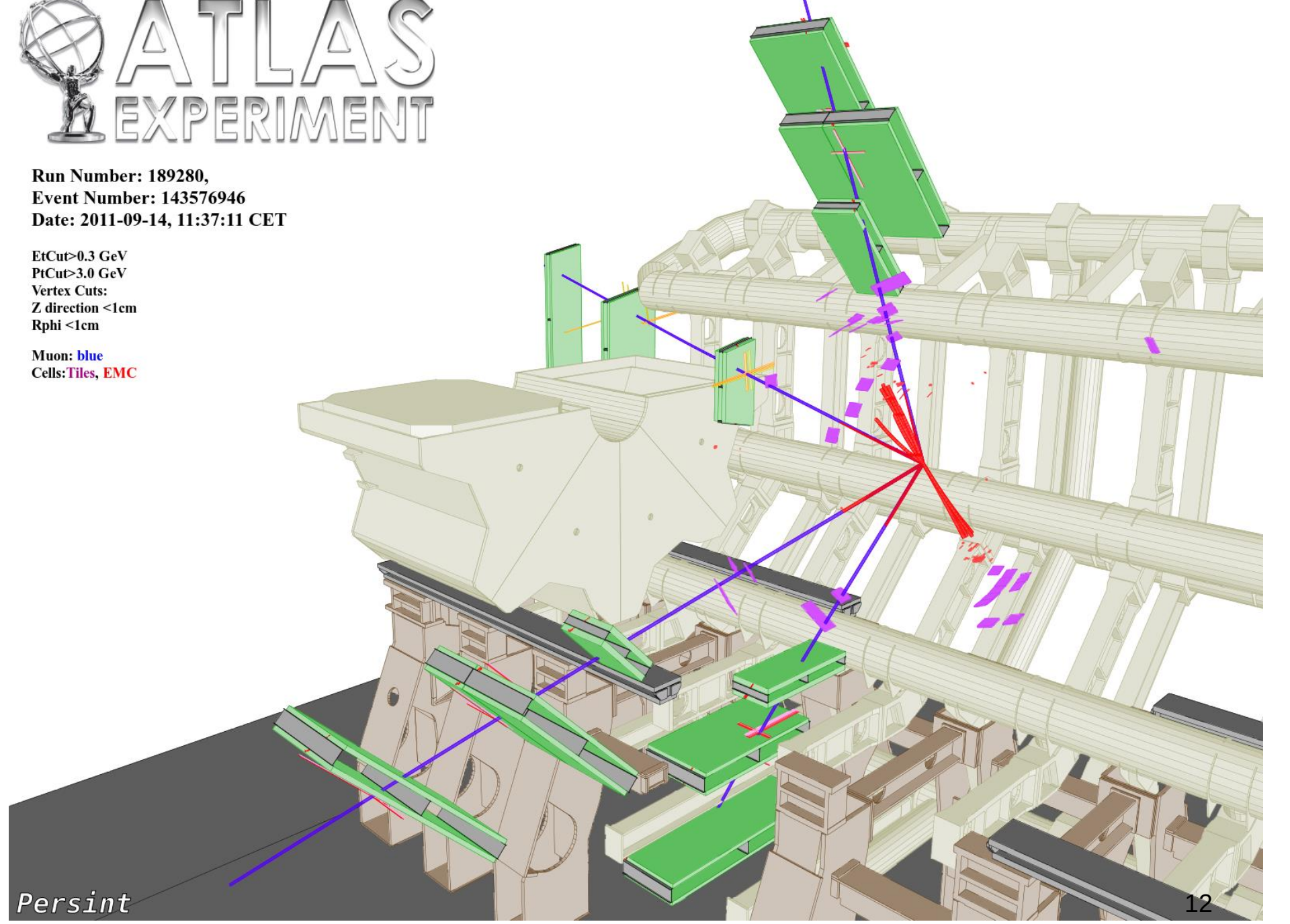


The requirements: Subdetectors

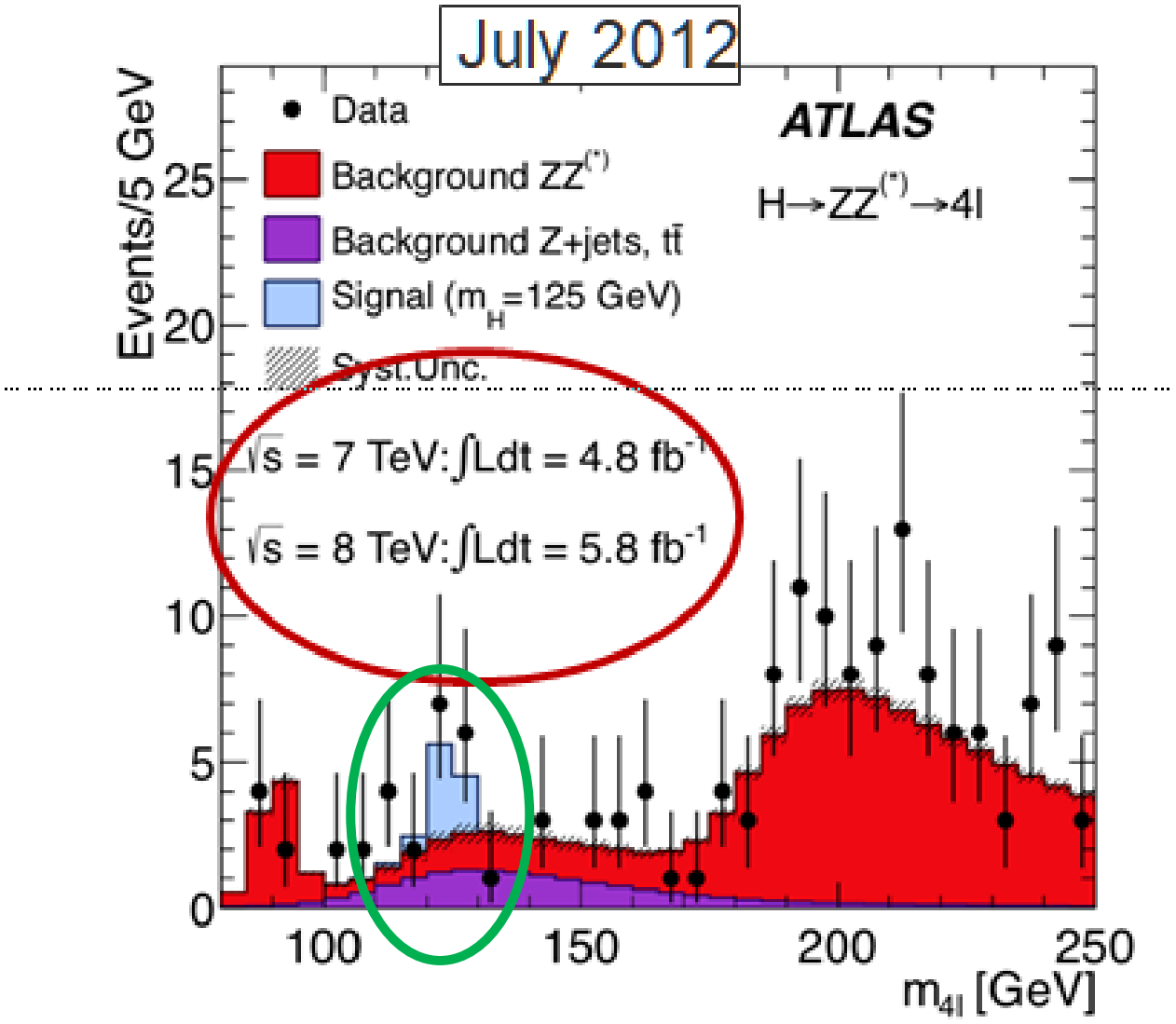


Very complex reconstruction of interaction vertices at the LHC




ATLAS
EXPERIMENT
Run Number: 189280,
Event Number: 143576946
Date: 2011-09-14, 11:37:11 CET
EtCut>0.3 GeV
PtCut>3.0 GeV
Vertex Cuts:
Z direction <1cm
Rphi <1cm
Muon: blue
Cells:Tiles, EMC
Persint

The discovery of H->ZZ(*)->4l



The Nobel Prize in Physics 2013

François Englert, Peter Higgs

The Nobel Prize in Physics 2013

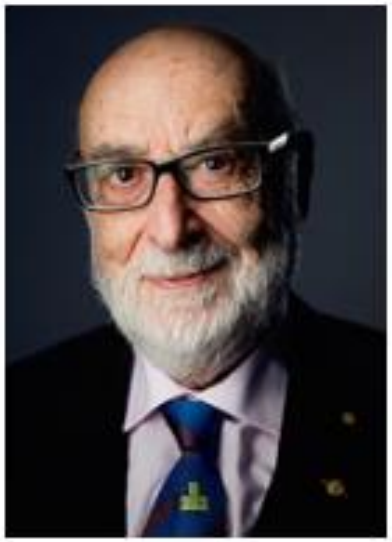


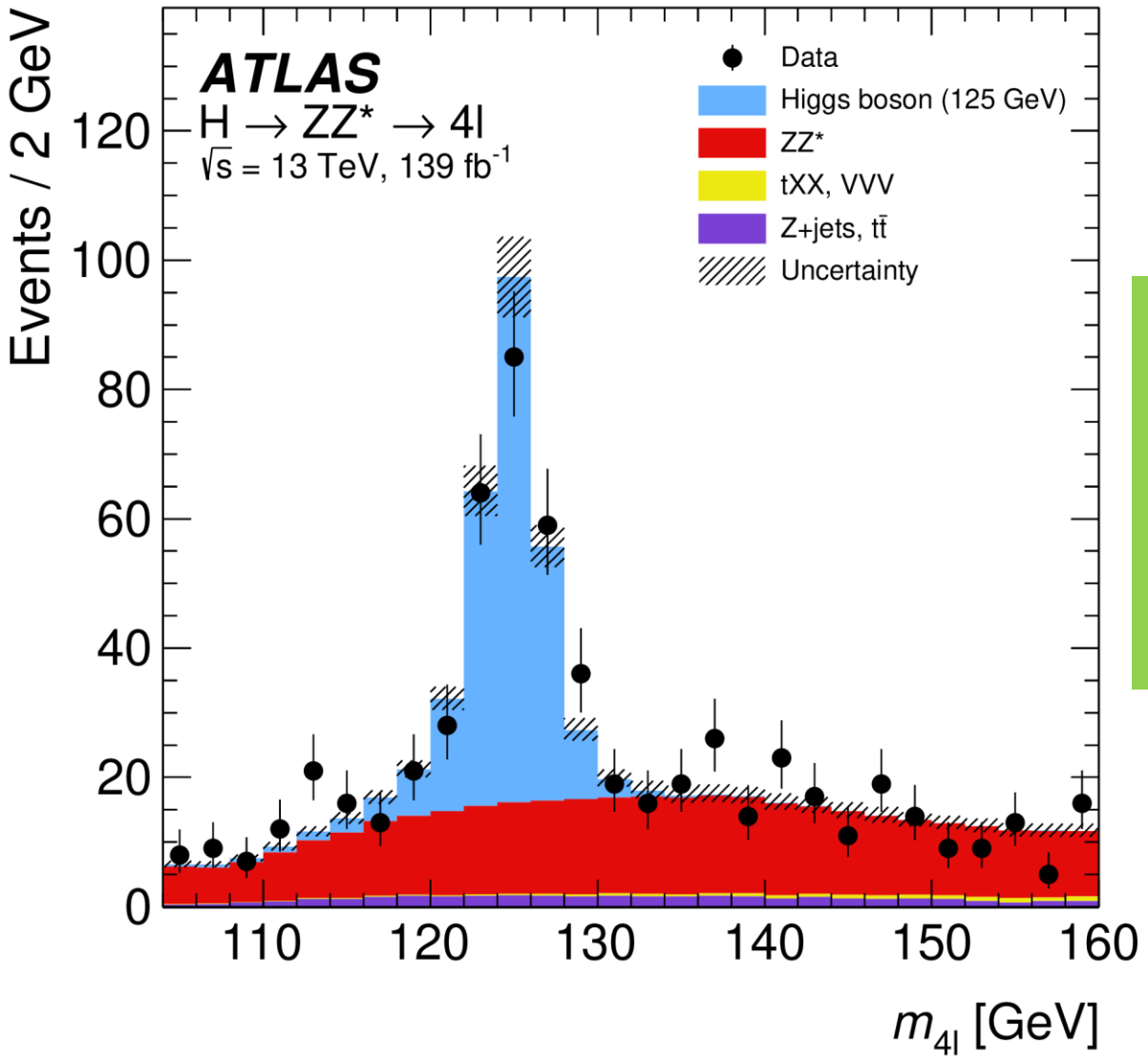
Photo: A. Mahmoud

François Englert

Photo: A. Mahmoud

Peter W. Higgs

Run II (2015-2018) H->ZZ$^{(*)}$->4l

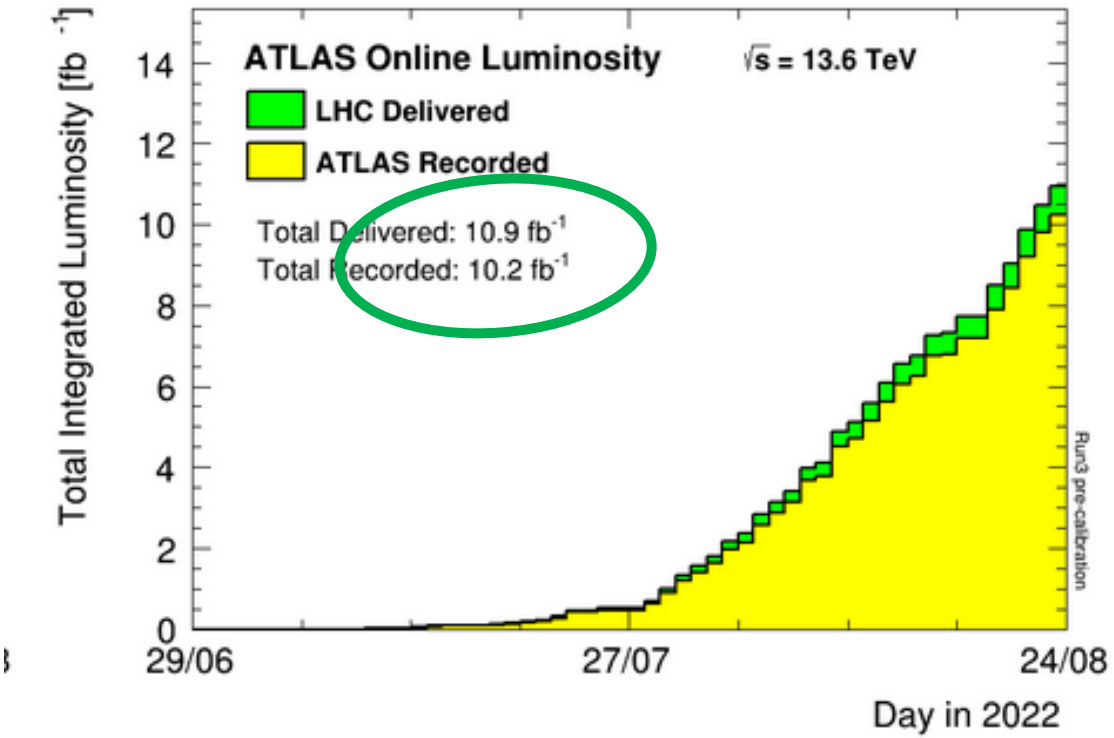


Note the vertical scale
Discovery plot of 2012:
Higgs peak@5 events
(with x2.5 wider bins)
>50x more events!!

- The LHC experiments collected data during Run I and Run II (2009-2018)
- At the end of 2018 LHC stopped for major upgrades (both for the accelerator and experiments)
- On **5th of July 2022** Run III started with beam collision energy of **6.8 TeV** (record)

Running since the **5th of July 2022 @ 6.8 TeV/beam**

Total Luminosity



A RF failure
Made necessary a stop for ~4 weeks

[Log Scale]

The SM is very successful in predicting experimental results BUT leaves unanswered questions:

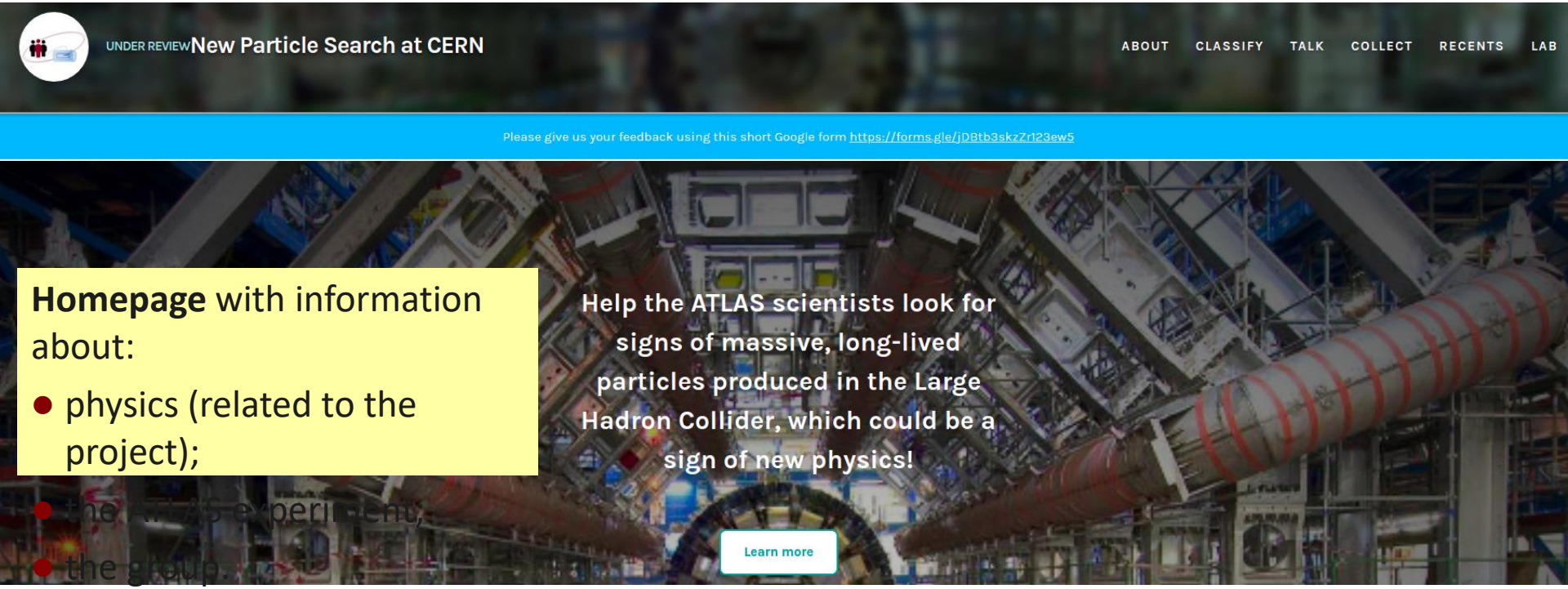
- **What is the dark mass and energy?**
- **Why there is more matter that antimatter?**
- **How the theory of gravity fits to the SM?**
- **Are the quarks and leptons elementary ?**
- **Why are there three quark and lepton families?**

Theories BSM (such as supersymmetry) predict the existence of long-lived particles

Search-for-new-particles-at-CERN demonstrator

The Project on ZOONIVERSE

https://www.zooniverse.org/projects/reinforce/new-particle-search-at-cern



Homepage with information about:

- physics (related to the project);
- the ATLAS experiment;
- the group.

Get started

The project consists of three stages, intended to be completed in the given order. In Stage 1, you will identify Displaced Vertices, which are the signatures of long-lived particles. In Stage 2, you will identify the signatures of known particles (electrons, muons, photons) in the ATLAS detector. In Stage 3 you will: a) search for Higgs boson decays to a pair of photons and b) look for long-lived particles decaying far from the beam collision point.

Stage 1 — Stage 1 - Displaced Vertex Identification

Stage 2 — Stage 2 - Particle Identification

Stage 3a — Stage 3a - Study of Higgs Bosons

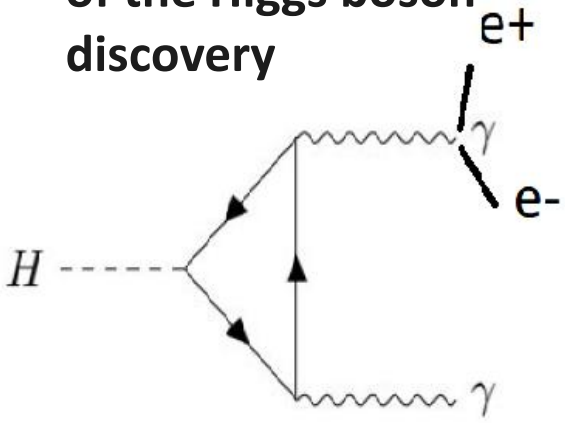
Stage 3b — Stage 3b - Discovery of Long Lived Particles

Each button loads the respective stage.

The “discovery” path given to Citizen Scientists

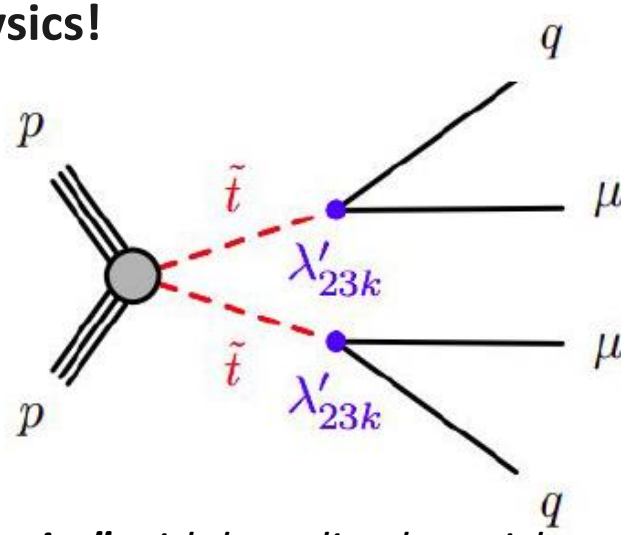
Citizen scientists **visually inspect** collision events in searches of **displaced vertices (DVs)**, i.e. origins of two or more tracks, located away from the main pp point,

to enhance their understanding of the Higgs boson discovery



Higgs→γγ with one converted photon

and identify signs of New Physics!

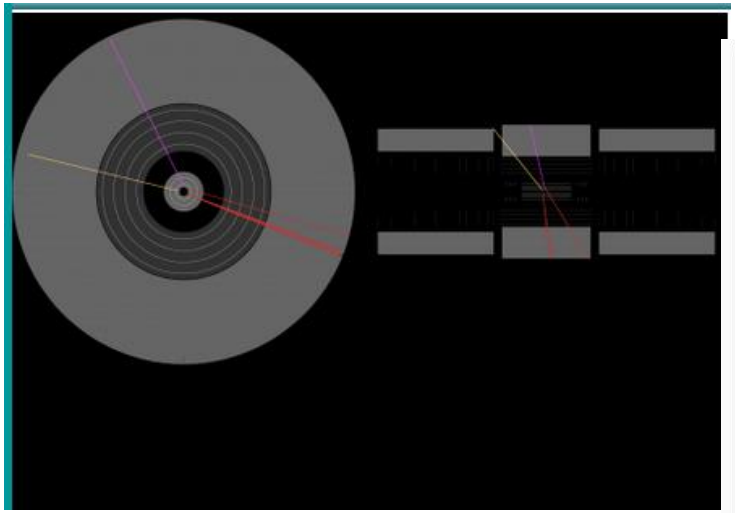


*Scenaria of **“New Physics”** with long-lived particles (ex RPV) **These could give answers to some open questions***

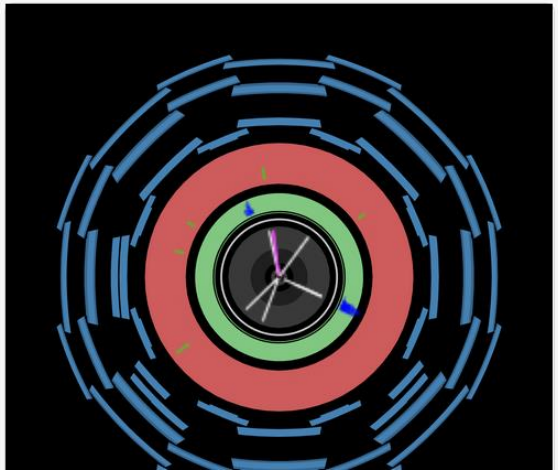
The citizen’s workpath is split in three stages

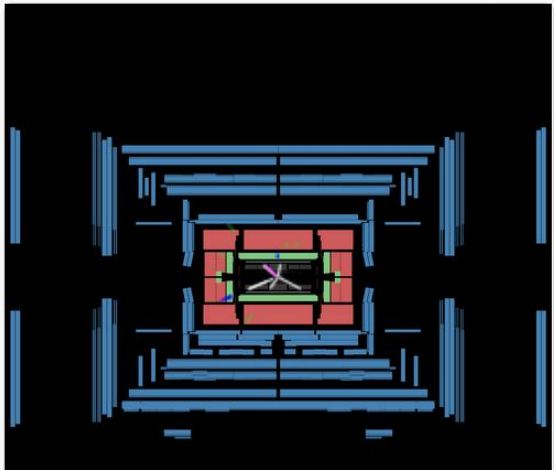
- Special event **visualization tools** had to be developed. In addition to studying stationary images , citizens **interact with HYPATIA event display** .
- **Automated algorithms have been** developed to get quantitative results on the citizens' performance on the simulated datasets.

Stage 1



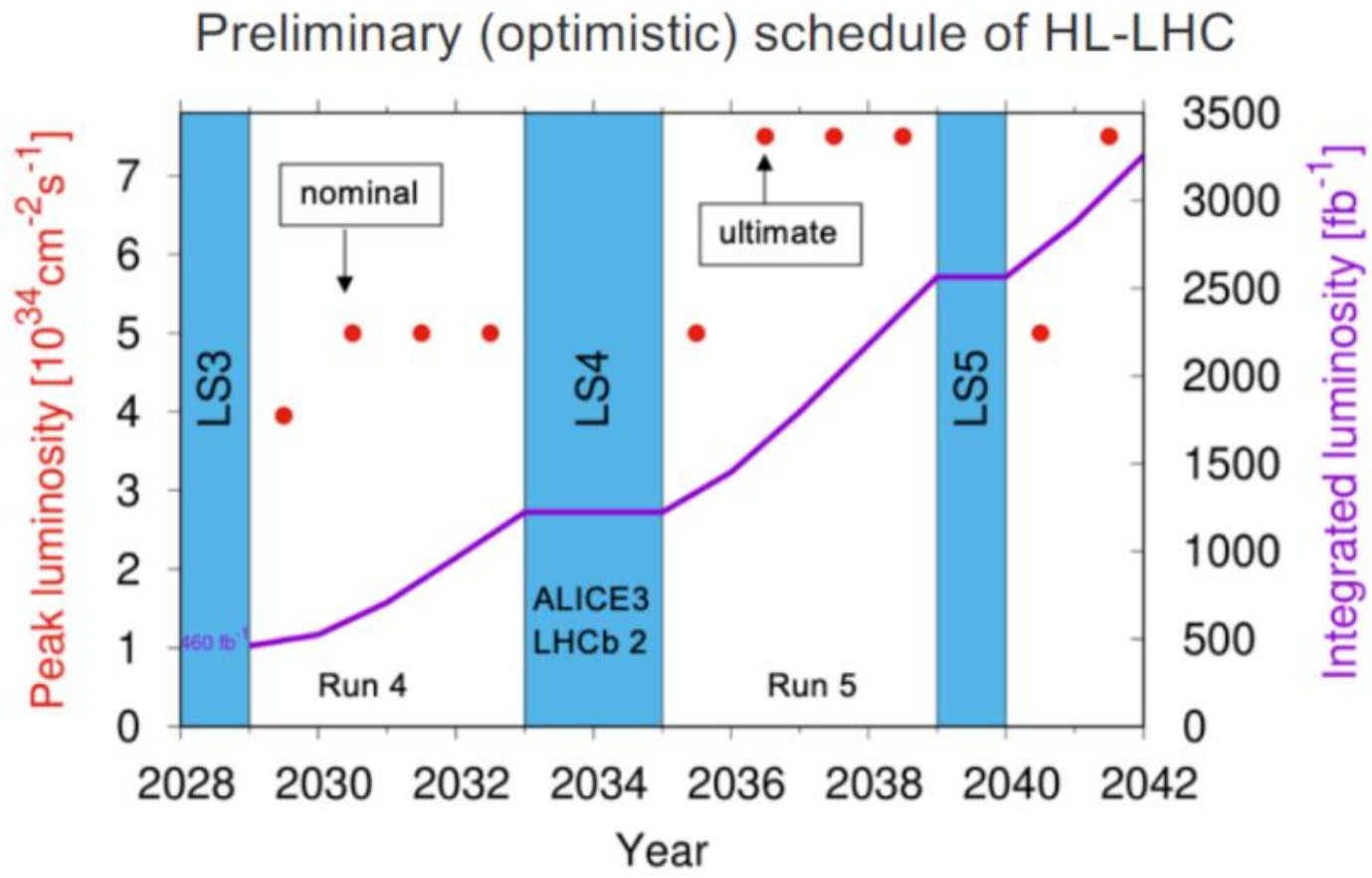
Stage 2 and 3 INTERACTIVE





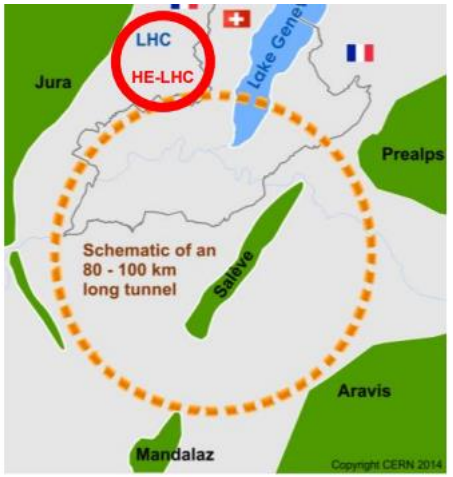
A look to the future

LHC will run for another 15 years (present schedule up to 2040-2042) .....



After that: FCC (Future Circular Collider) e+e-, pp (100km ring, under the lake)?

	√s	L /IP ($cm^{-2} s^{-1}$)	Int. L /IP(ab^{-1})	Comments
e^+e^- FCC-ee	~90 GeV Z 160 WW 240 H ~365 top	230 x10^{34} 28 8.5 1.5	75 ab^{-1} 5 2.5 0.8	2 experiments Total ~ 15 years of operation
pp FCC-hh	100 TeV	5 x 10^{34} 30	2.5 ab^{-1} 15	2+2 experiments Total ~ 25 years of operation
PbPb FCC-hh	$\sqrt{s_{NN}}$ = 39 TeV	3 x 10^{29}	65 nb^{-1}/run	1 run = 1 month operation
ep Fcc-eh	3.5 TeV	1.5 10^{34}	2 ab^{-1}	60 GeV e- from ERL Concurrent operation with pp for ~ 20 years
e-Pb Fcc-eh	$\sqrt{s_{eN}}$ = 2.2 TeV	0.5 10^{34}	1 fb^{-1}	60 GeV e- from ERL Concurrent operation with PbPb



FCC-ee could start 27 years from now!!!

REINFORCE
REsearch INfrastructures FOR Citizens in Europe

Thank you

This project has received funding from the European Union's Horizon 2020 research and innovation programme under `grant agreement No 872859.

Back-up

Medical Applications

CAT, MRI, PET, Hadron therapy

Technological Applications

Biology

Crystallography

Automatic controls

Electronics

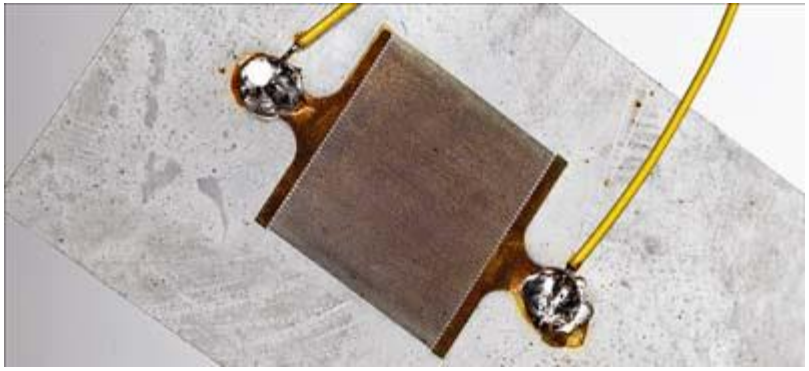
Lithography

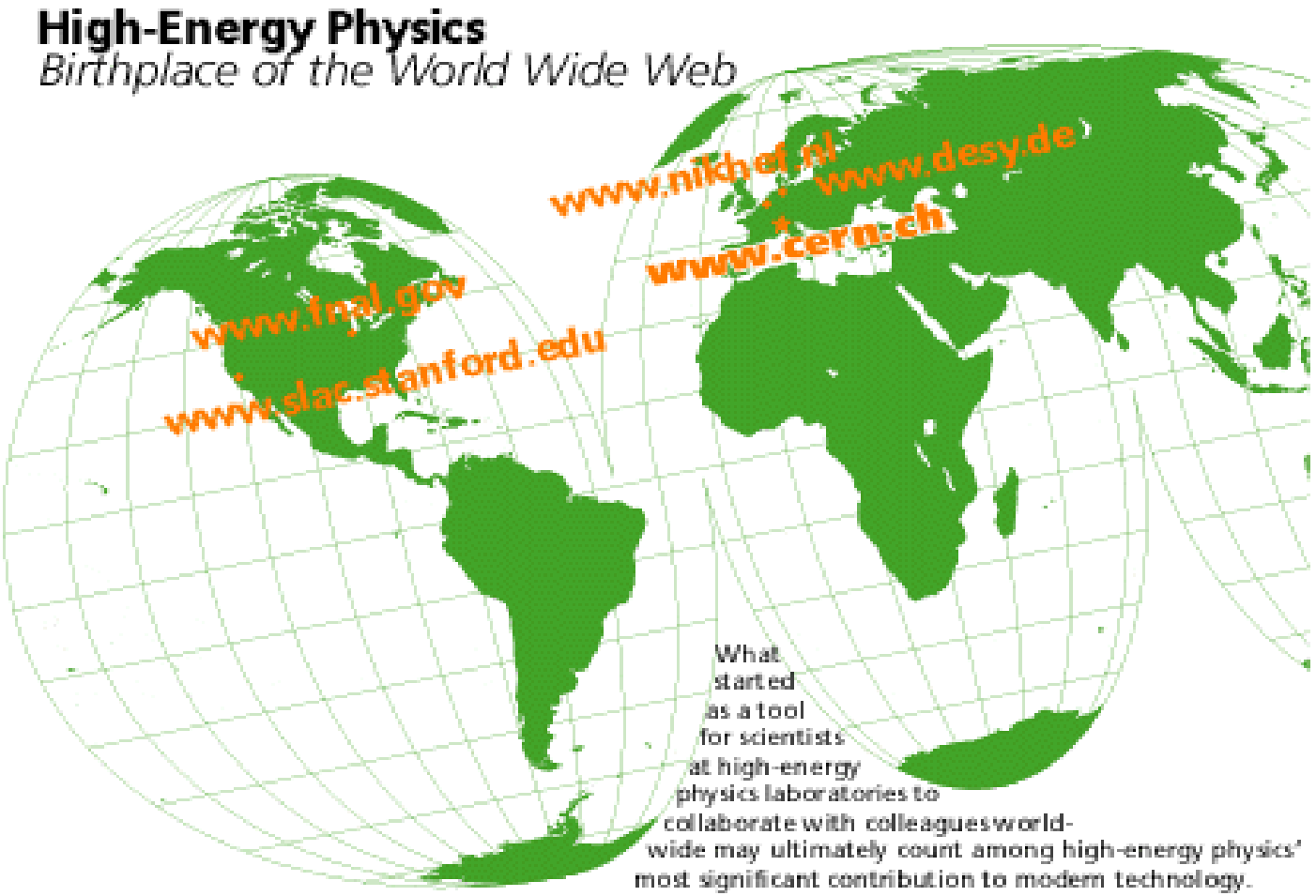
Superconductivity

Computing

Touch screen

The SPS control room in 1977.
The desk, **with its touch screens**;





The WWW was born at CERN !

The GRID

(the technology of the computing grid)