ATLAS in a nutshell

Visite ACTIF (Association CEA des Thésards d'Ile de Fance), June 14th

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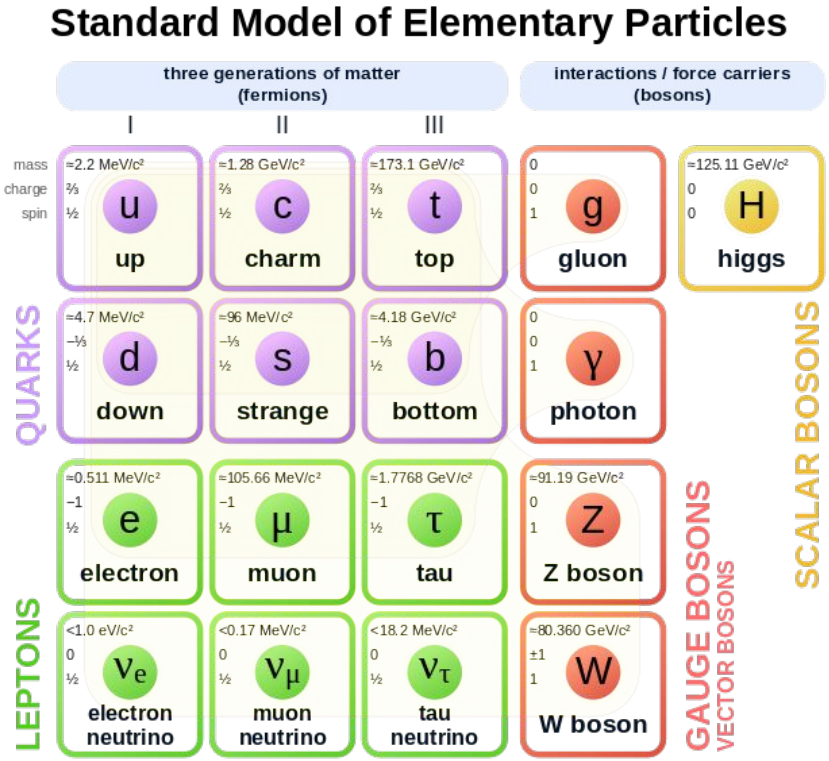
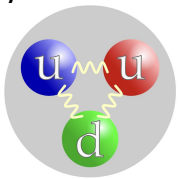
The Standard Model (SM)



- Basic model of fundamental constituents of matter
  - Developed in 2nd half of 20th century
  - Builds on Quantum Field Theory
  - Quarks, leptons and bosons

    ⟶ quarks form the nuclei

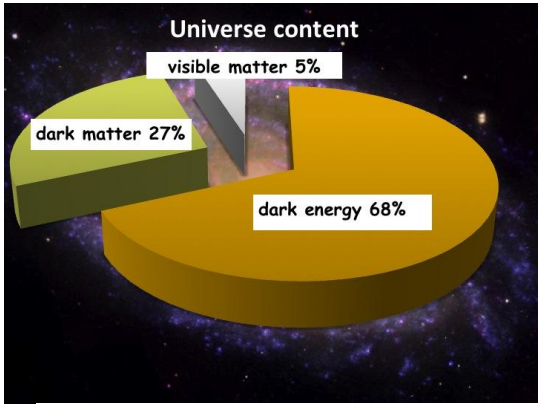


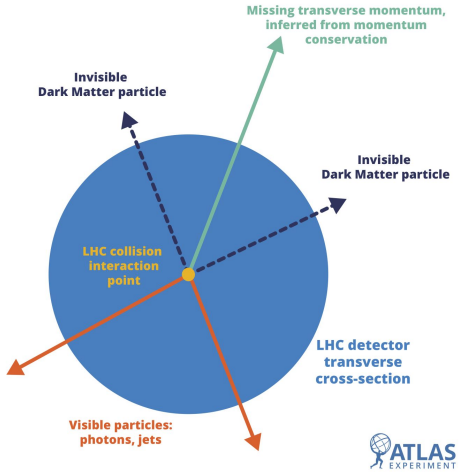
- Electromagnetic force - mediated by massless photon
- Weak interaction - mediated by bosons : Z, W+, W-
- Strong interaction - mediated by 8 gluons
- Higgs boson : confers their mass to other particles via symmetry breaking
  - **Discovered at LHC by ATLAS and CMS in 2012 !**
- Gravity
  - Not described by the SM

ATLAS EXPERIMENT

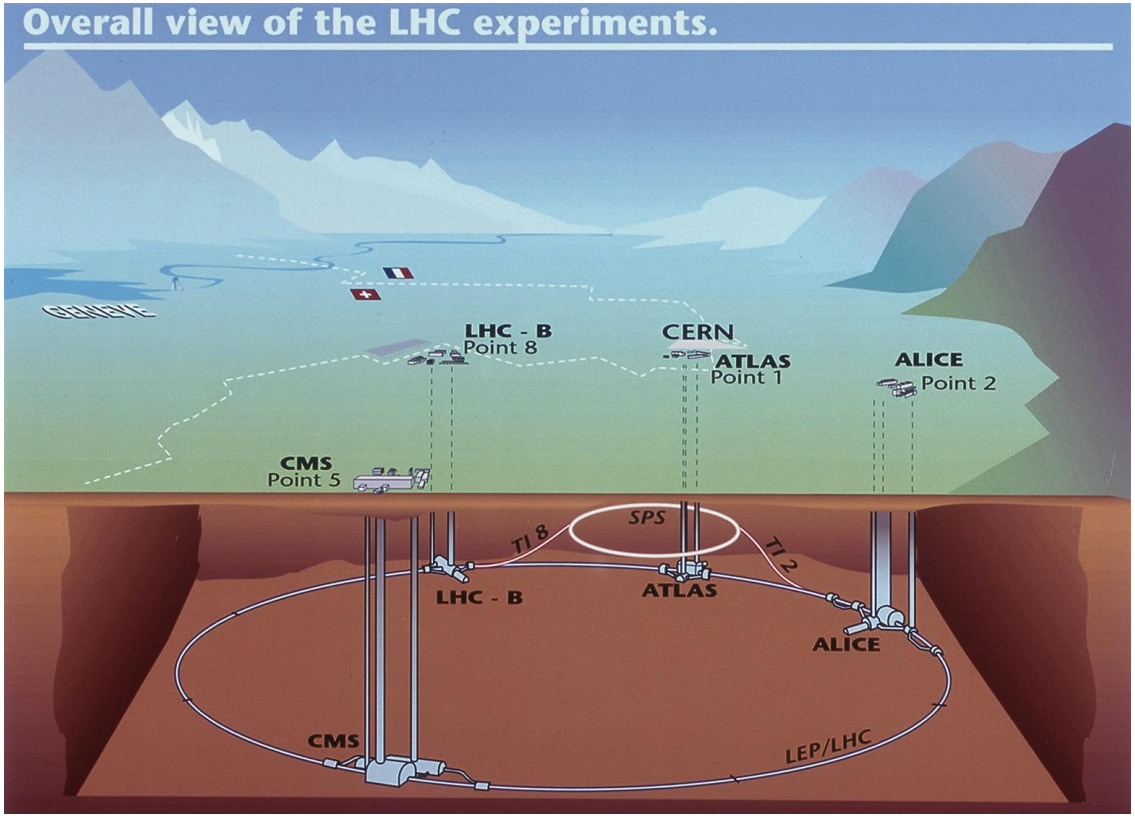
Going beyond the Standard Model

- Several loopholes in the SM
  - No explanation for ~95% of the content of the universe
    - Dark Matter (~25%), Dark Energy (~70%)
  - Some mathematical inelegancies (fine-tuning problems…)
- Several models go beyond the Standard Model to try and solve these
  - e.g. predict new particles constituting Dark Matter
- In LHC experiments, try to produce directly such new particles and detect their signatures
- Other way of finding hints of New Physics is the very precise measurement of known particles properties, and test their values against the SM predictions
  - Higgs couplings to bosons, quarks and leptons
  - top quark mass, W boson mass
  - …
- Measurements and searches are led by analysing high energy collisions at the LHC





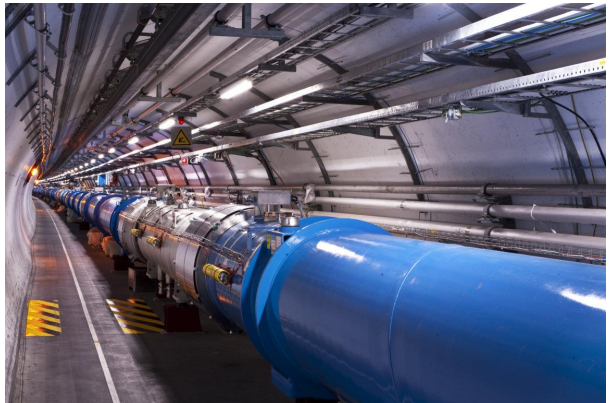
The LHC (Large Hadron Collider)

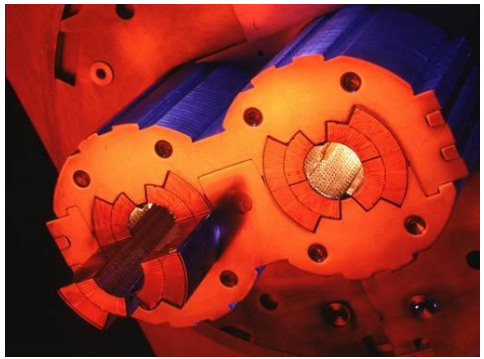


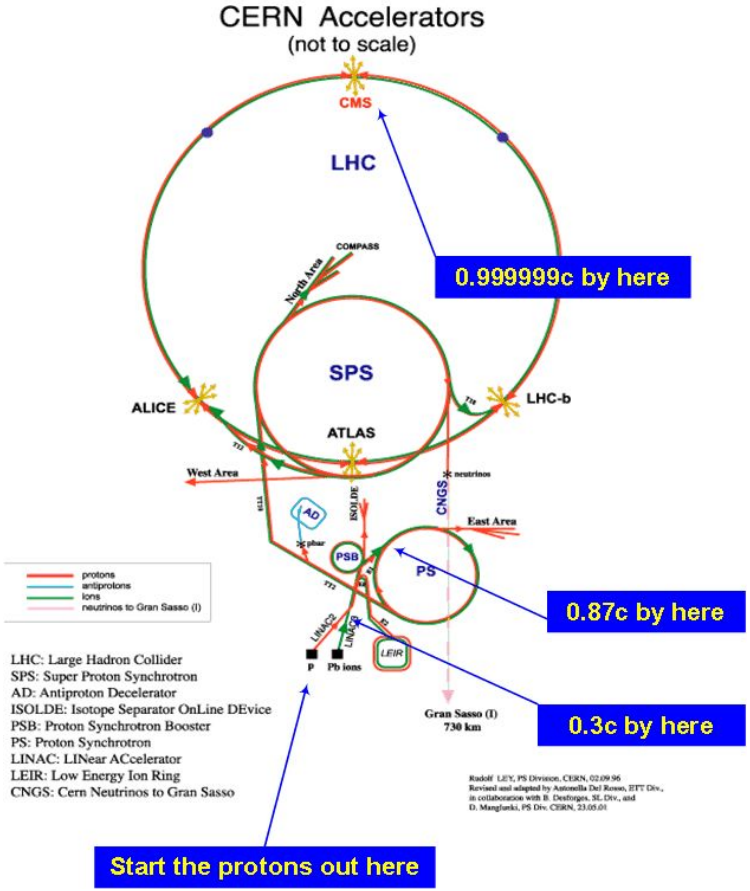
- proton-proton collider, in service since 2009-2010
  - Most energetic: reached an energy 13.6 TeV in the centre of mass since 2022
- 27 km of circumference, many superconducting magnets to bend the proton trajectories
- protons grouped in bunches separated in time by 25ns
- 4 points of collision, where detectors are installed: LHCb, ALICE, CMS, ATLAS

The LHC (Large Hadron Collider)

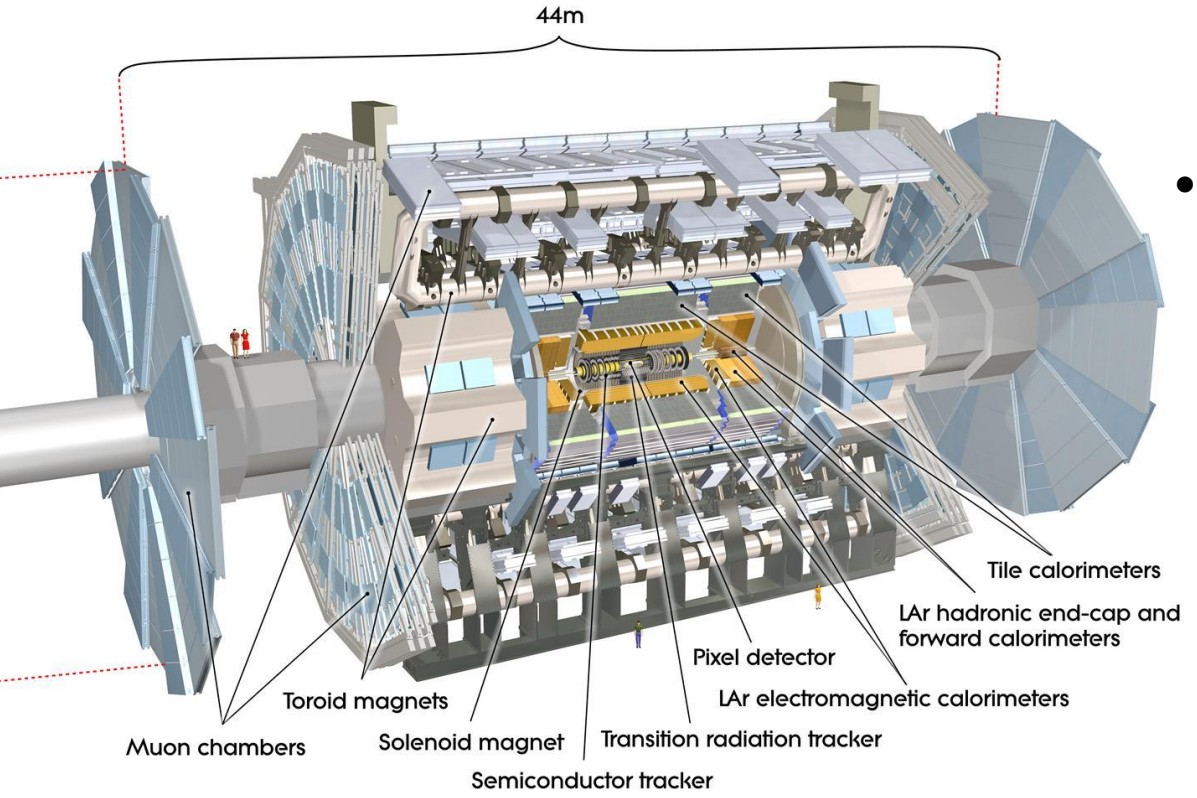
- Before they reach the LHC, the particles are sped up in a series of interconnected linear and circular accelerators
- LHC further accelerates and focuses the proton beams for them to collide at each interaction point
  - 1232 dipole magnets, 15 metres in length, which bend the beams
  - 392 quadrupole magnets, each 5–7 metres long, which focus the beams





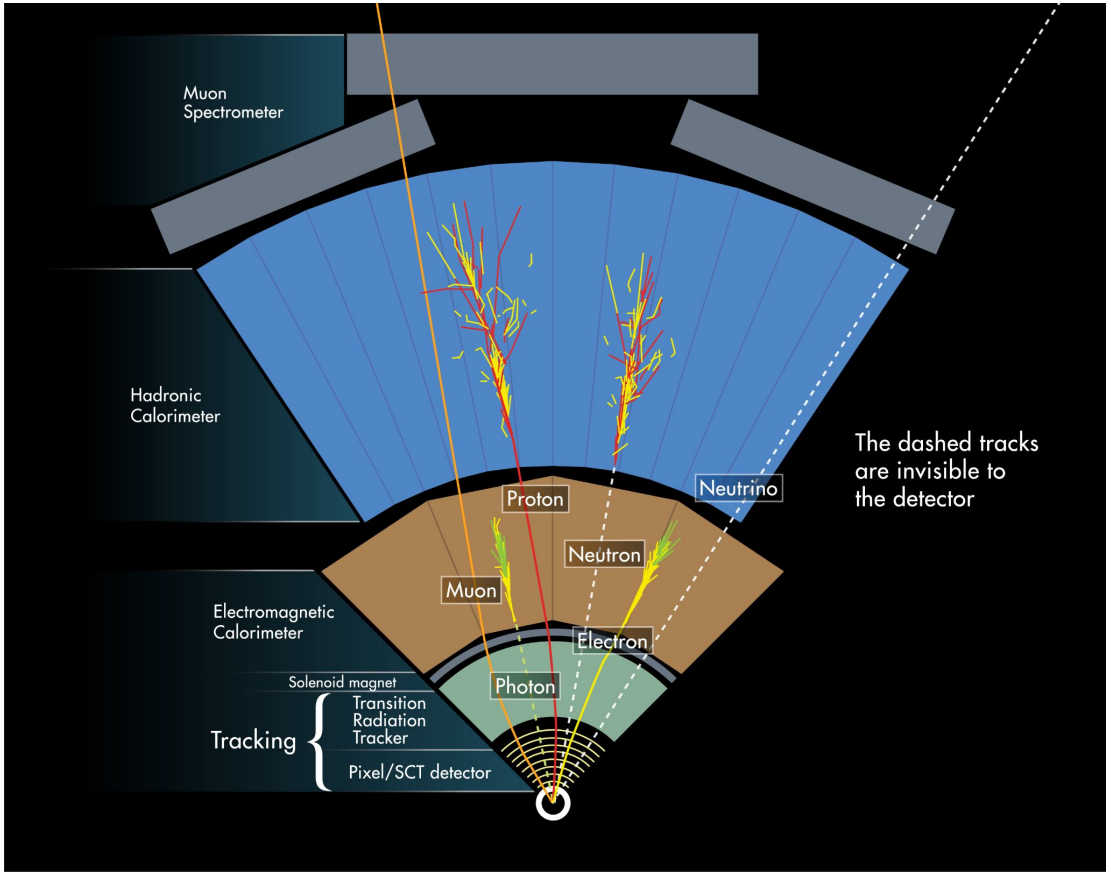


The ATLAS detector: A Toroidal LHC ApparatuS



- ATLAS has the dimensions of a cylinder, 46m long, 25m in diameter, weighs 7000 tons and sits in a cavern 100m below ground.
- Main subsystems:
  - Inner Tracking system: charged particles, interaction vertex, secondary vertices
  - Electromagnetic calorimeter : electrons, photons
  - Hadronic calorimeter: ‘jets’ (quarks and gluons signatures)
  - Muon spectrometer: within a toroidal magnetic field

The ATLAS detector: How we “see” particles



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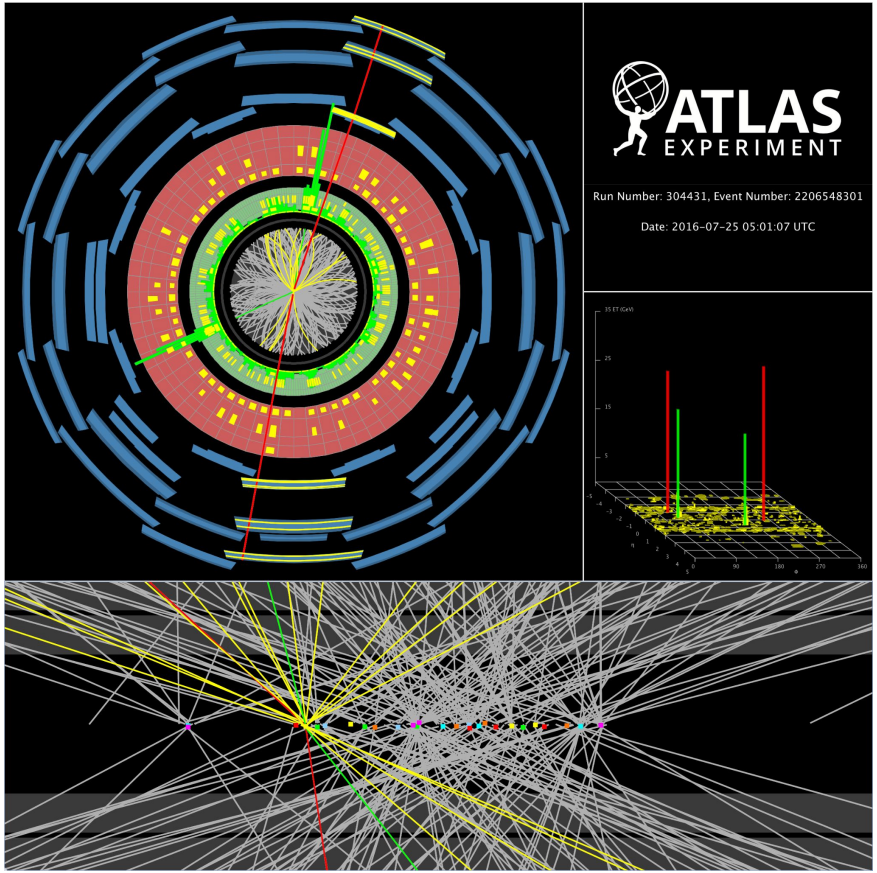
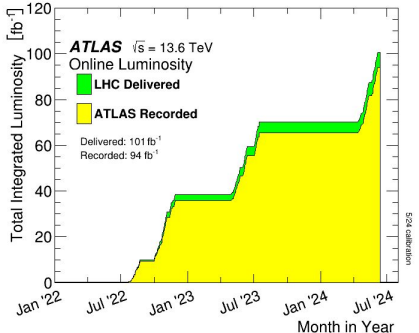
An actual collision seen by ATLAS



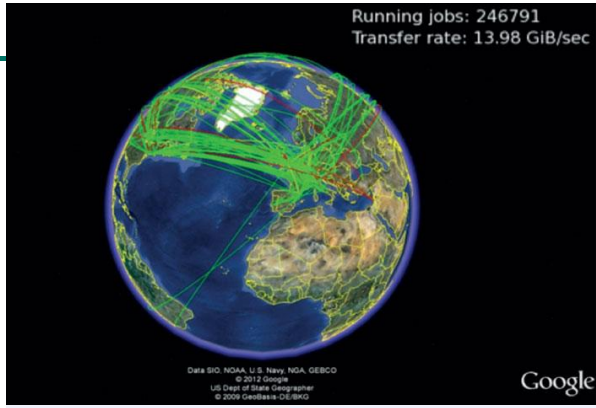
- This is what a Higgs boson looks like in ATLAS
- pp -> H -> ZZ* -> 2 electrons + 2 muons
- “pile-up”: due to the high luminosity, when two proton bunches cross, many other collisions occur (in this case, 25 other collisions)

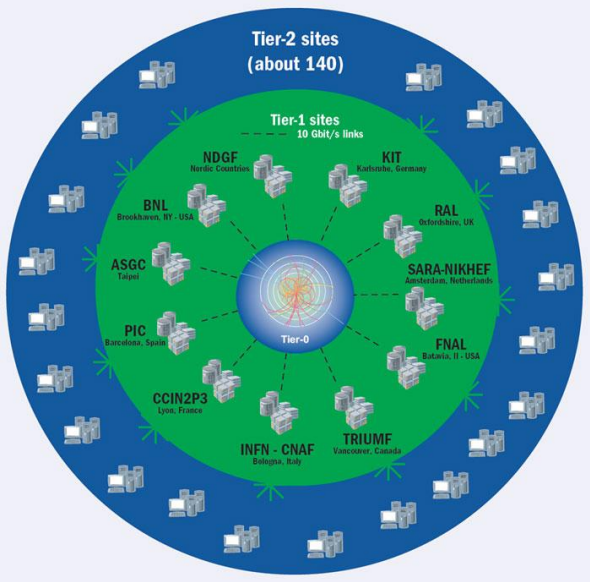
The ATLAS data taking

- ATLAS records data from colliding proton bunches
  - Bunches collide at a frequency of ~40 MHz
  - Needs to record only the interesting collisions, a.k.a those that produce rare physics process
  - Dedicated and complex trigger system in all detector components, reducing recording rate to ~1kHz
    i. ATLAS records >10 000 Tb of data per year
  - Detector operation requires a lot of care → reach ~95% recording efficiency



- Data is then sent worldwide to the computing GRID (>130 computing centres)
- Then physics objects (electrons, muons, etc…) are reconstructed via algorithms developed by the collaboration → ready for physics analysis





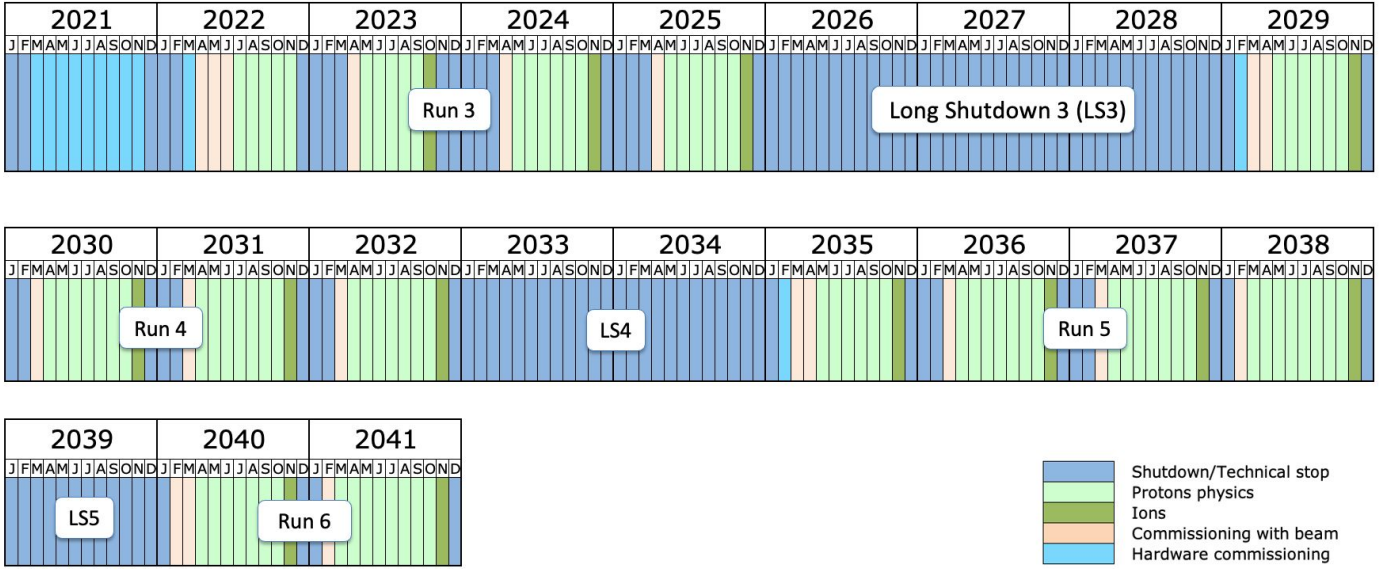
The ATLAS Collaboration

- International collaboration
- ~6000 collaborators, among which ~3000 authors
  - ~1200 PhD students
- More than 1200 papers
- Effort to make data public: https://atlas.cern/Resources/Opendata
- Career opportunities: https://atlas.cern/Discover/Collaboration/Jobs

ATLAS EXPERIMENT

Summary - outlooks

- Planning for the coming years
  - Finishing Run3 end of 2025
  - Then entering long technical shutdown (LS3), opportunity to upgrade several parts of the detector
  - HL-LHC era will start with Run4 and beyond, plan to record ~10x more data, with much higher bunch crossing rate



Summary - outlooks

- Many areas to contribute
  - engineering : detector upgrade
  - computing: data storage and processing, new machine-learning applications to data simulation, etc.
  - detector operations
  - object reconstruction and physics studies
- Thanks for your attention!