

High Energy Physics

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Astronomy & Fundamental Physics Unit Day

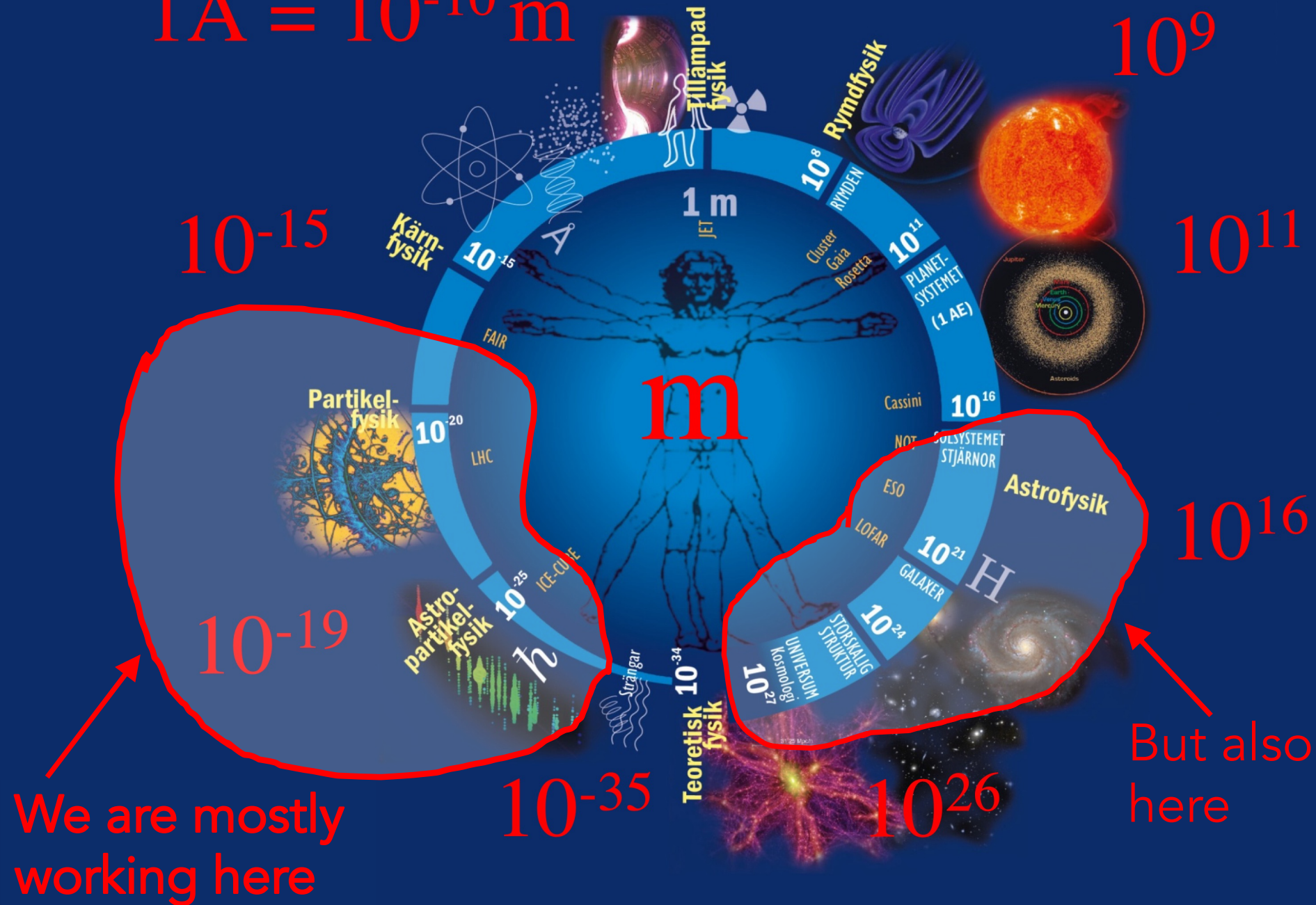
1 October 2026

High Energy Physics

Particle Physics

Astroparticle Physics

$$1\text{\AA} = 10^{-10}\text{ m}$$



The fundamental questions

What are the fundamental constituents of matter and their interactions?

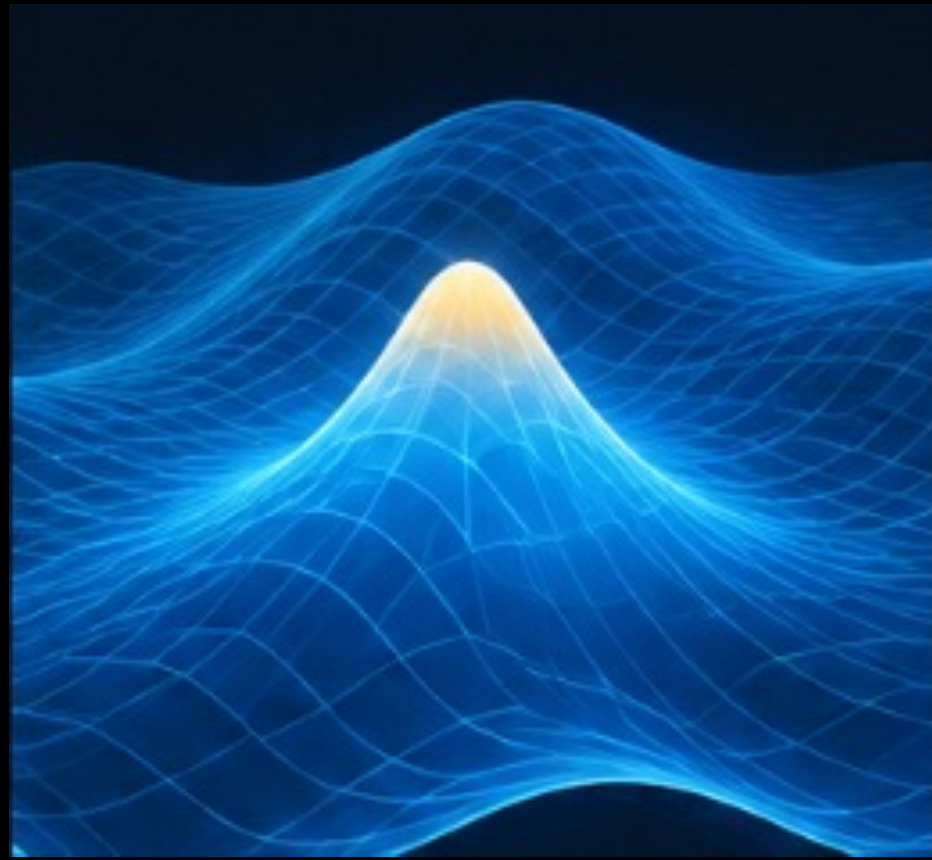
- What are the fundamental degrees of freedom?
- What are their interactions and symmetries?
- I.e., what are the fundamental laws of nature?

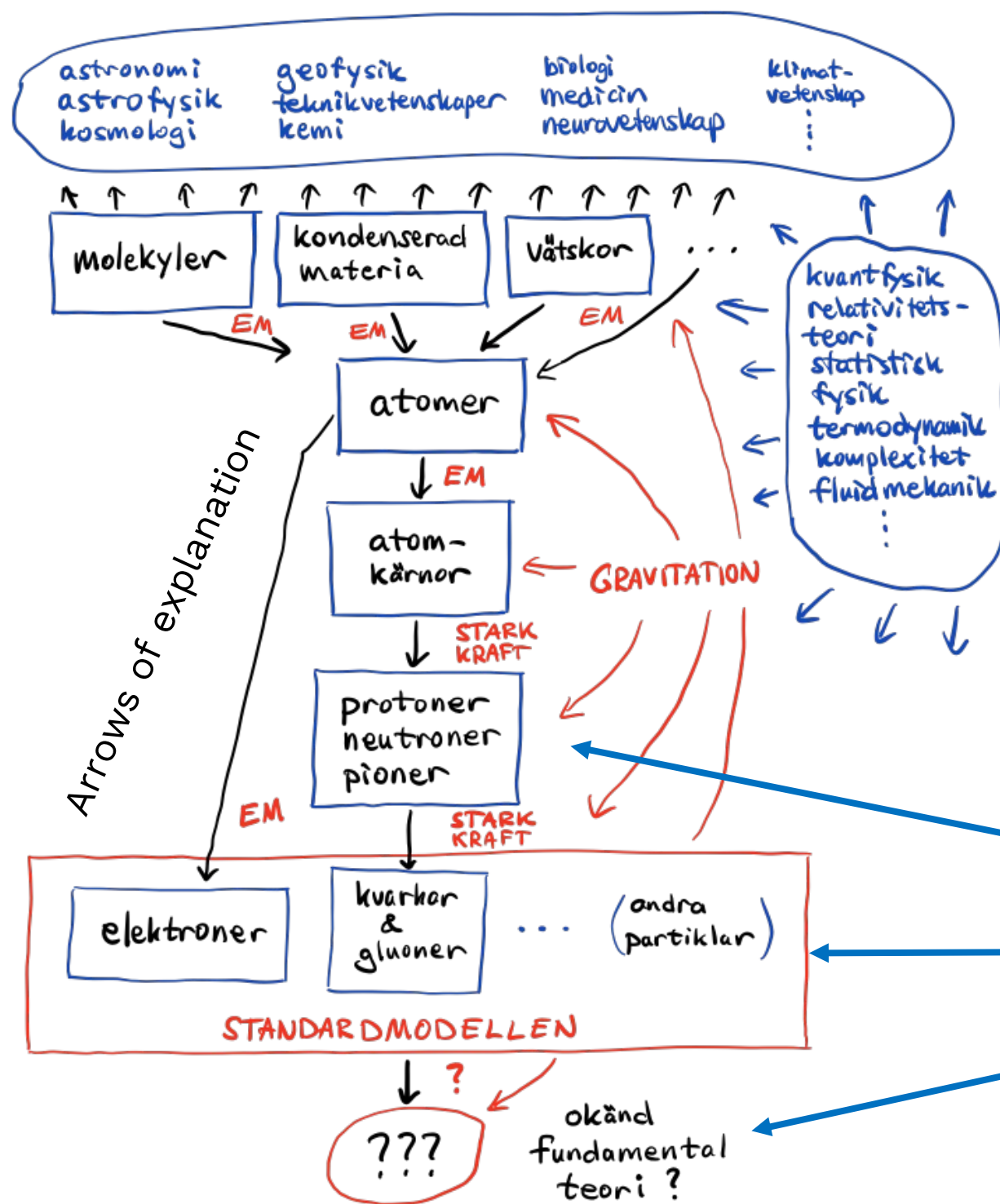
What can we learn about the Universe and astrophysics using particle physics, and vice versa?

The Standard Model

The Standard Model is our current answer to the first question:

- Particles interacting via gauge bosons, and a set of symmetries
- Particles are excitations of quantum fields



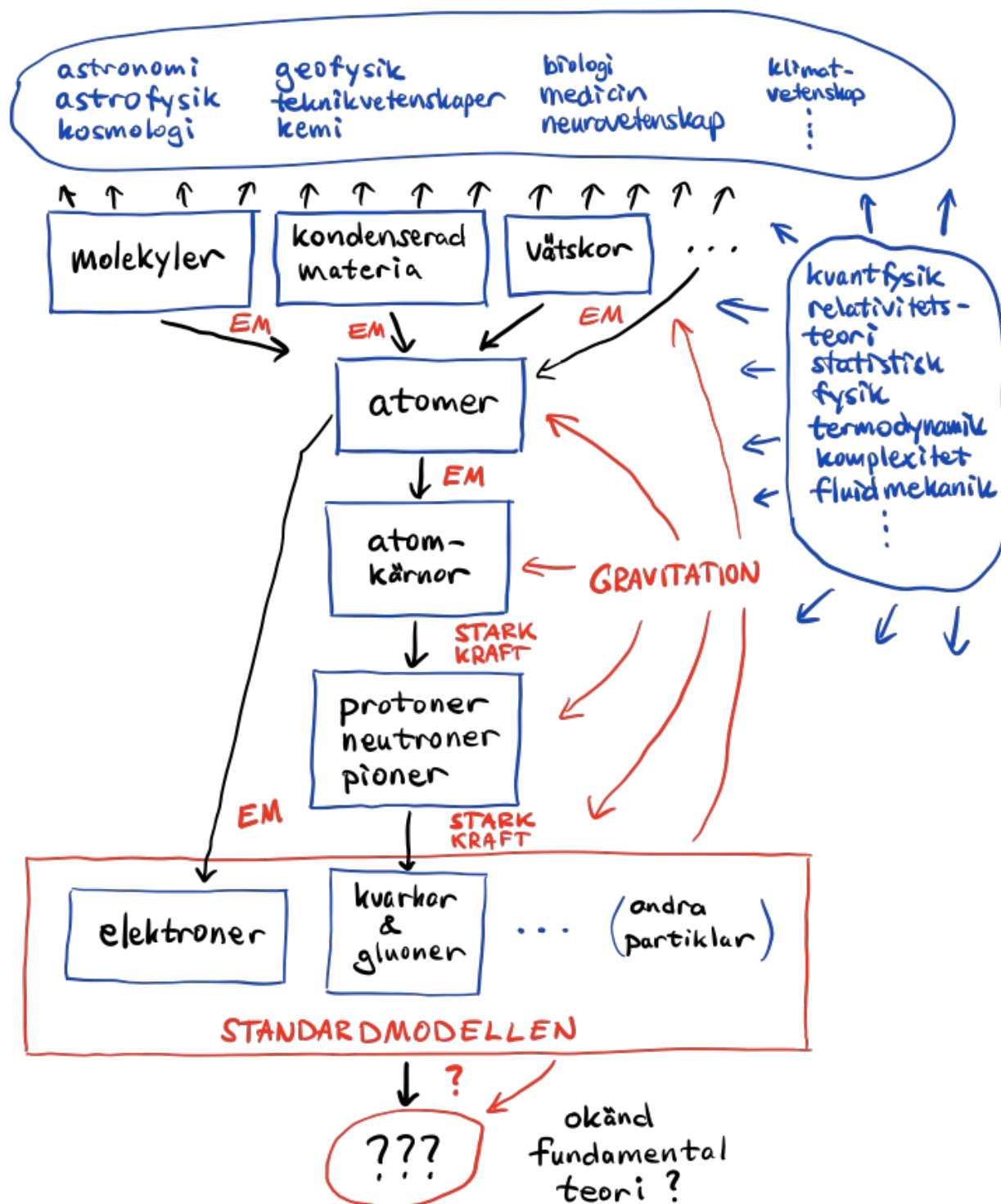


Particle physics underlies natural science

► Different length scales

What we are doing in particle physics

The Standard Model works exceedingly well! (Unfortunately)



There are a lot of phenomena we can't explain in the Standard Model:

Dark matter, dark energy, neutrino masses, matter-antimatter asymmetry, how to add gravity, some astrophysical phenomena, early universe, ...

We don't understand why the SM looks like it does

What else is there?

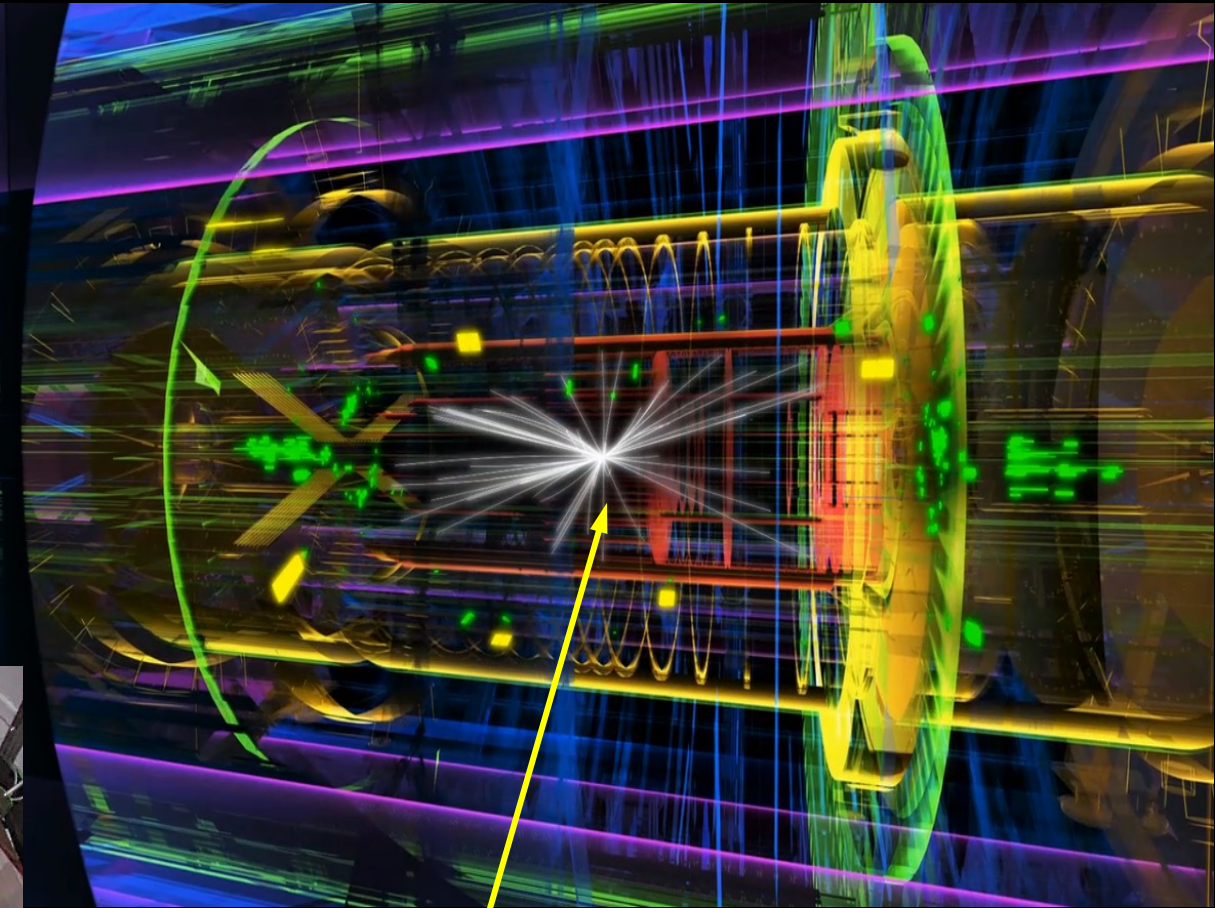
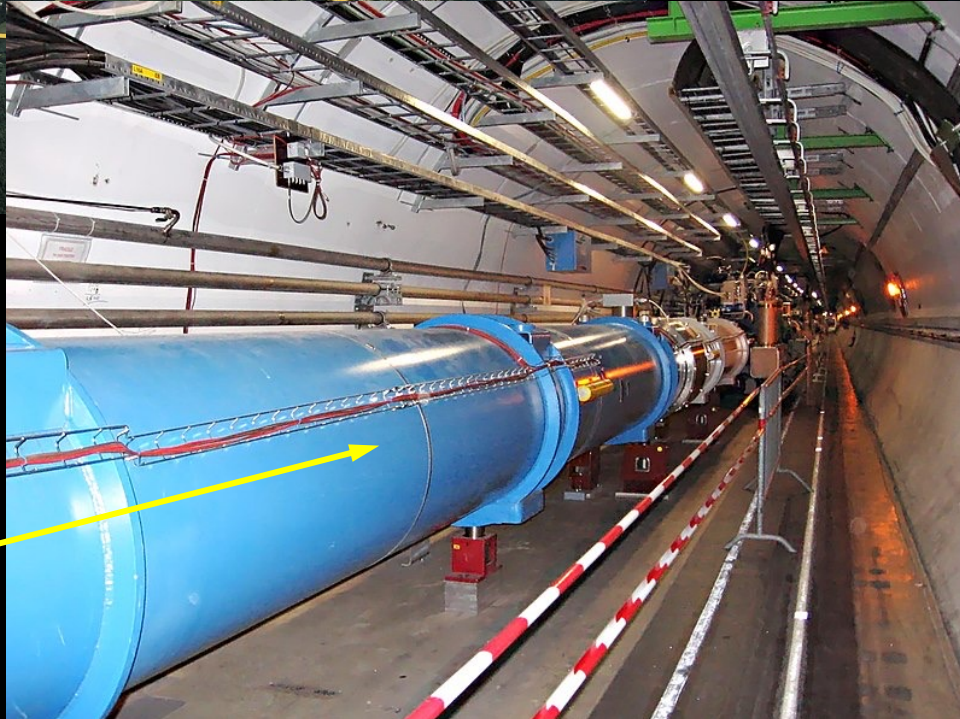
Physics beyond the Standard Model

Particle physics is intimately connected to accelerators/colliders



LHC

27 km tunnel
100 m below
ground



Tracks of particles
created in collision

Bilder från CERN, CC-BY-SA-4.0; samt Julian Herzog
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Astroparticle physics has become the other pillar of the field:

- Gamma Ray Bursts, supernovae, active galactic nuclei (quasars, blazars etc) and other sources emit cosmic rays = particles with extremely high energies
- Particle physics sources like dark matter, monopoles, cosmic strings, etc etc
- ...

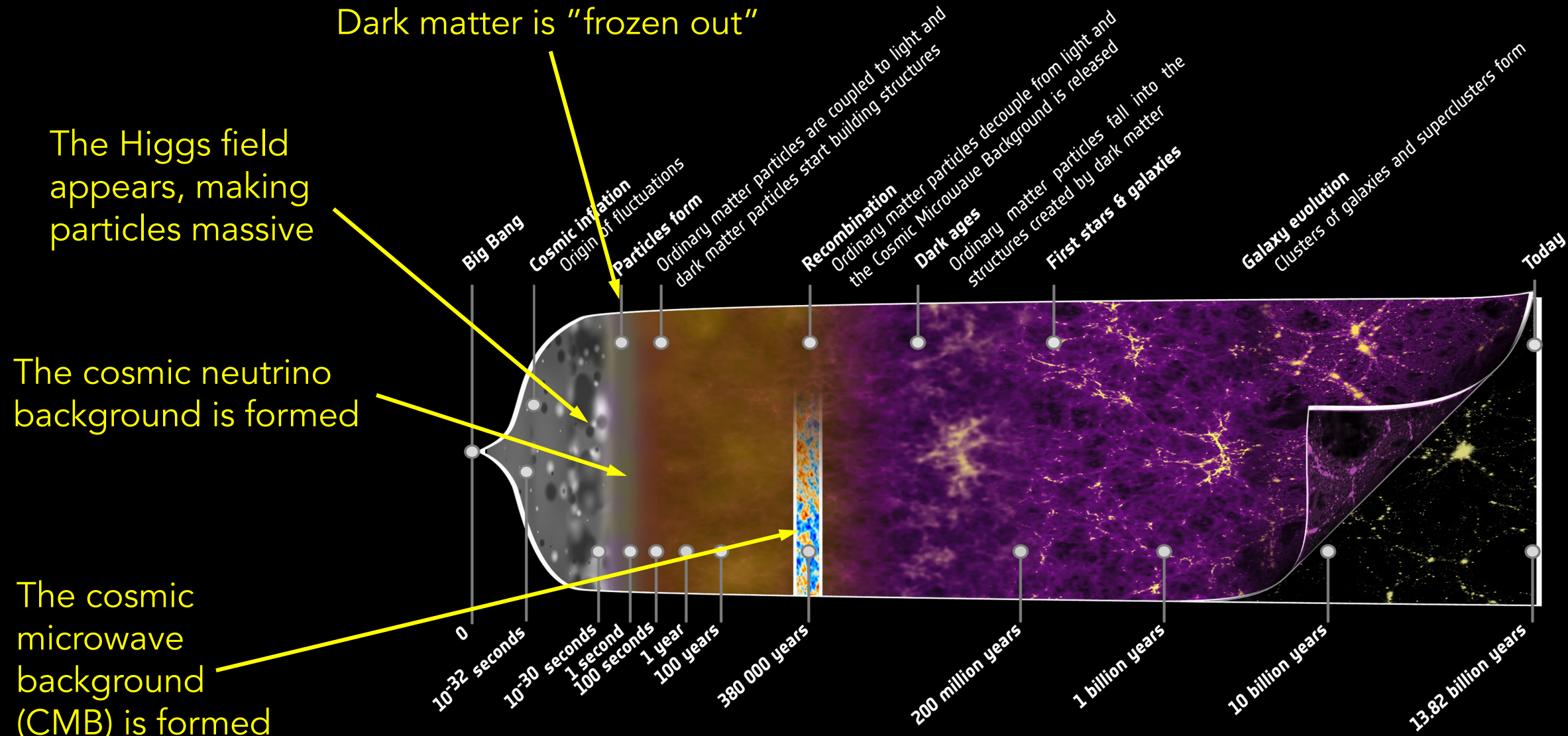


Cosmic rays create showers of particles in the atmosphere
– complement to particle accelerators



Image by Helmholtz Alliance for Astroparticle Physics CC BY-NC 4.0

But also: cosmology in the very early universe is particle physics



Gravitational waves probe black holes and neutron stars
– but also particle physics in the early universe

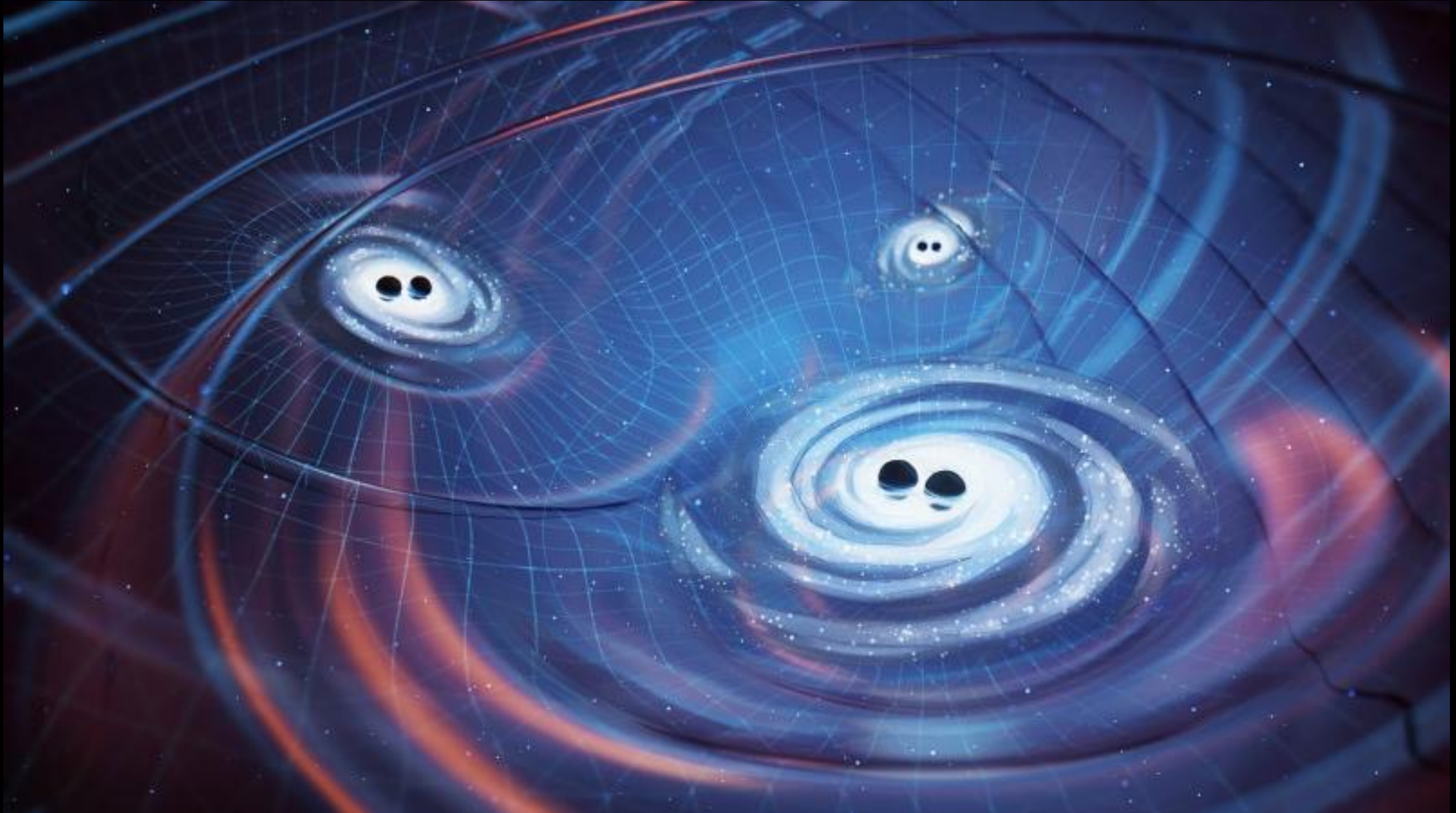
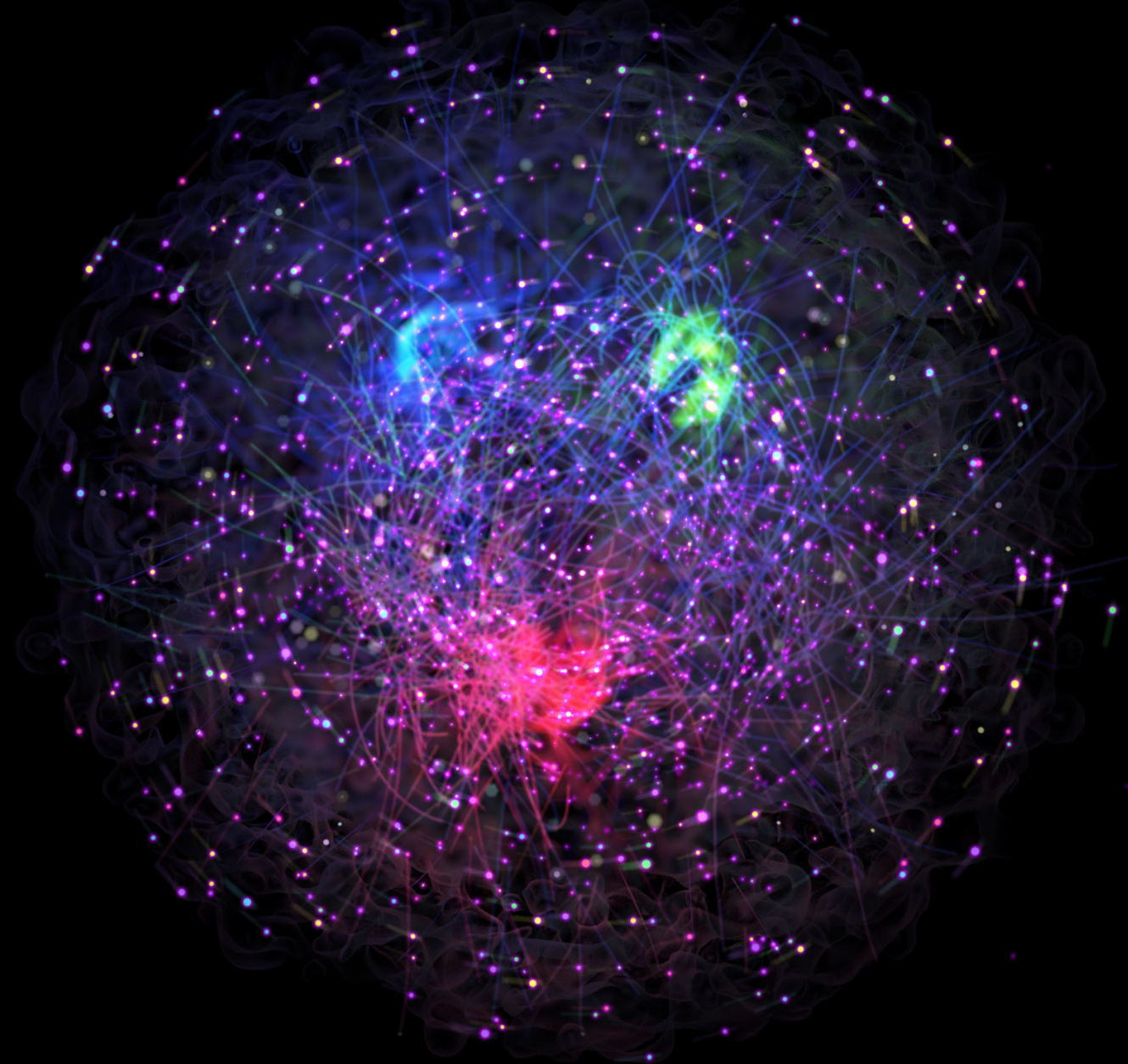
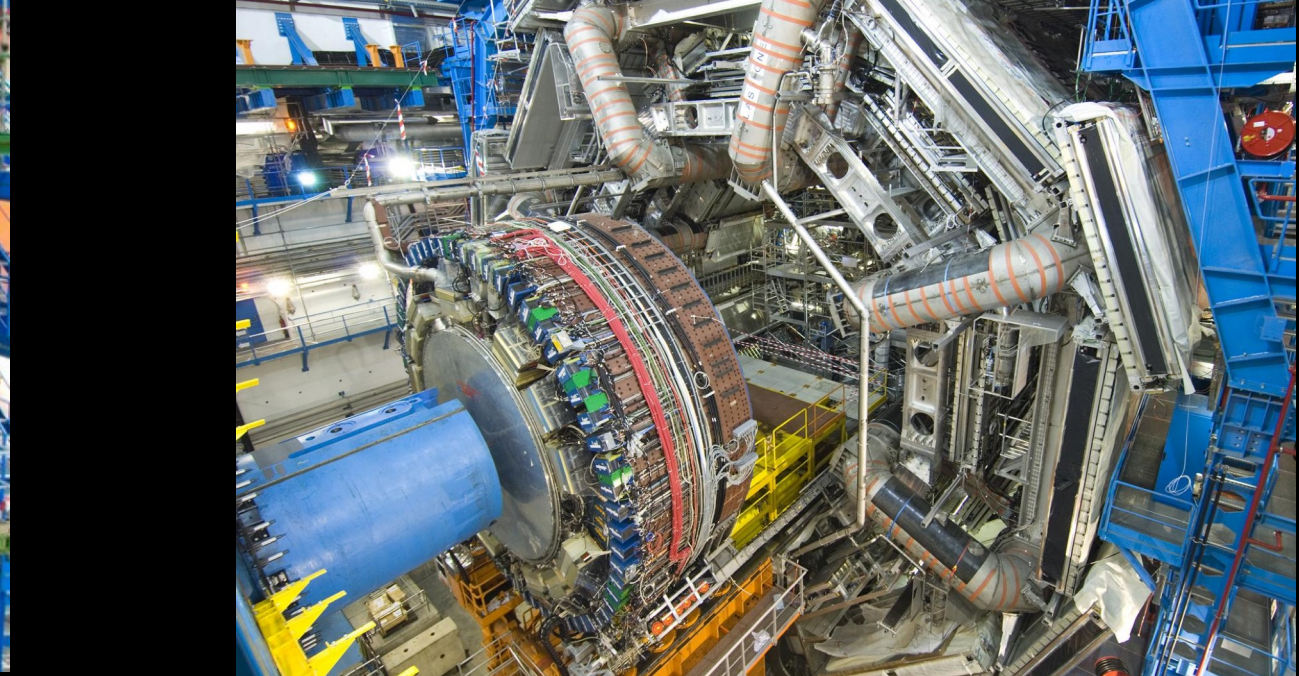
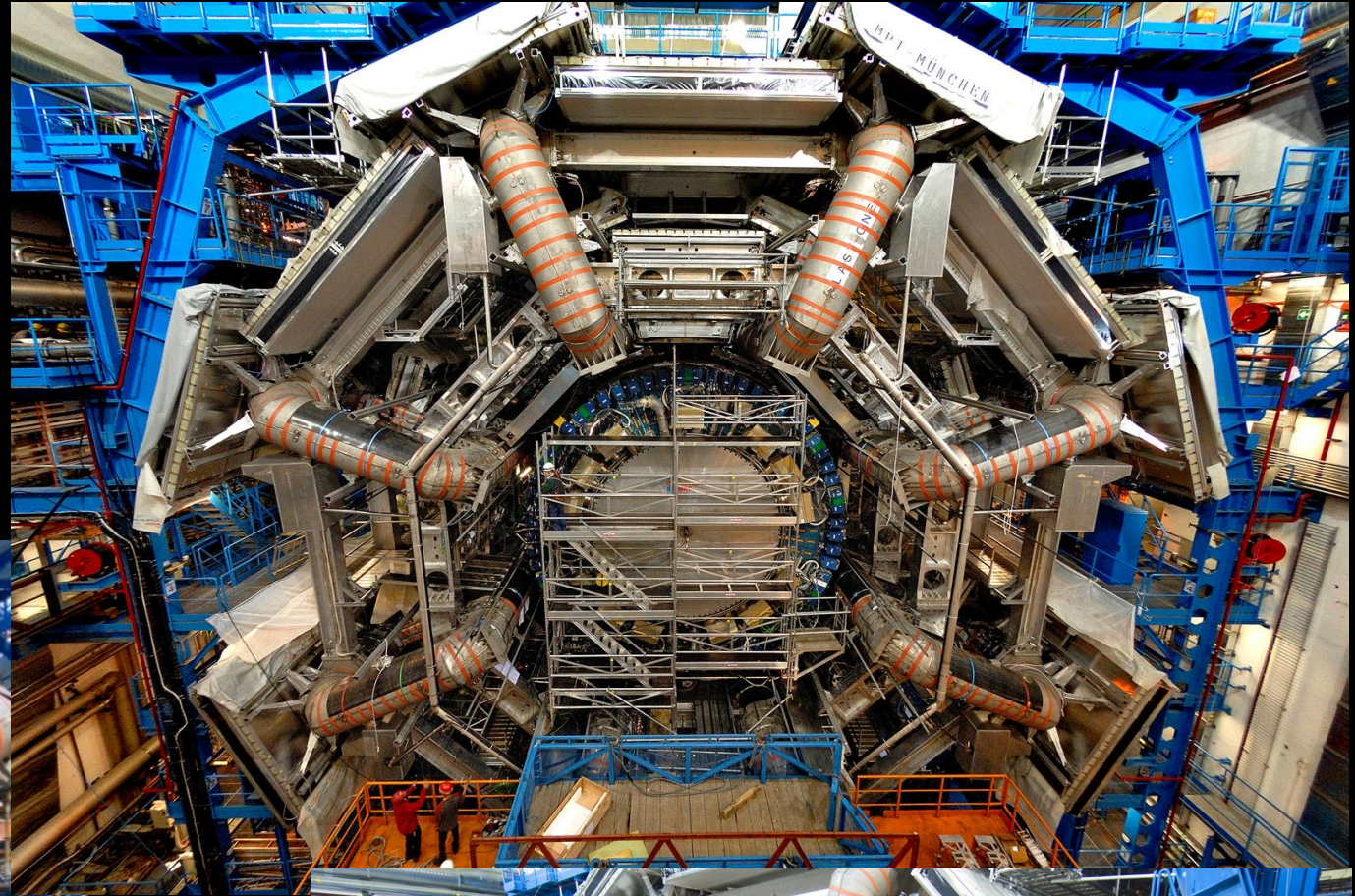
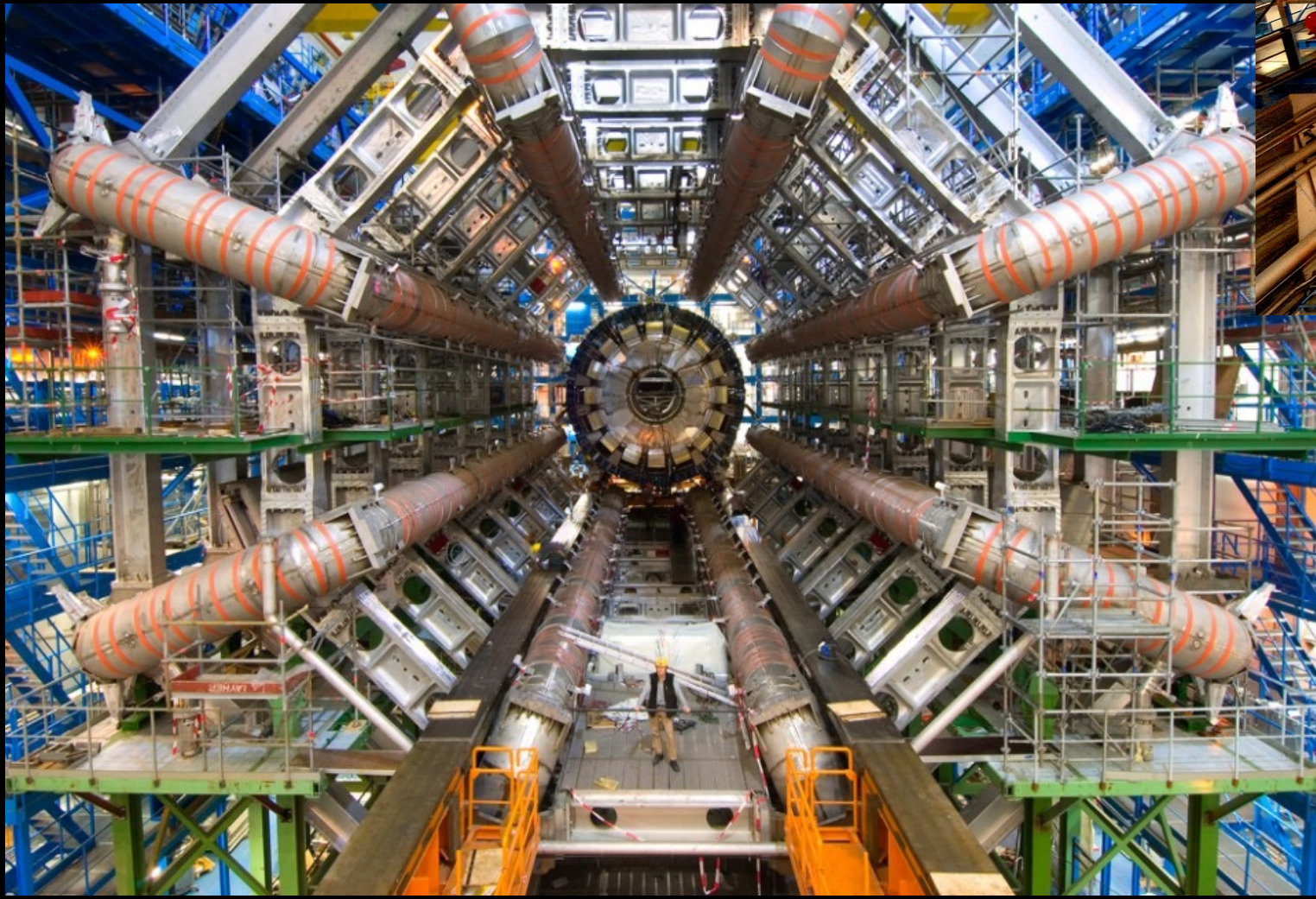


Image by Olena Shmahalo/NANOGrav experiment

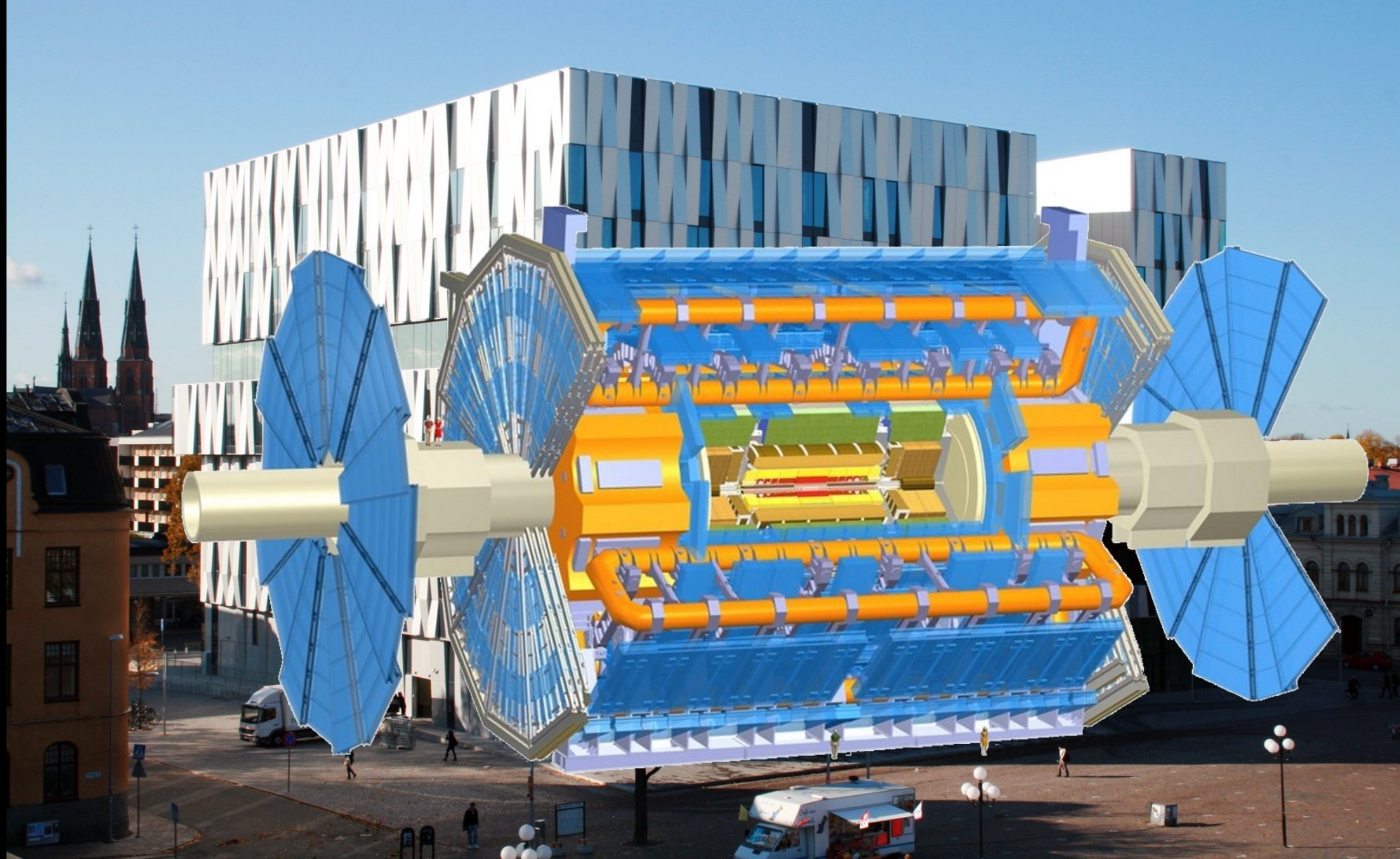
Important to understand the structure of the proton
– not just quarks but also a lot of gluons

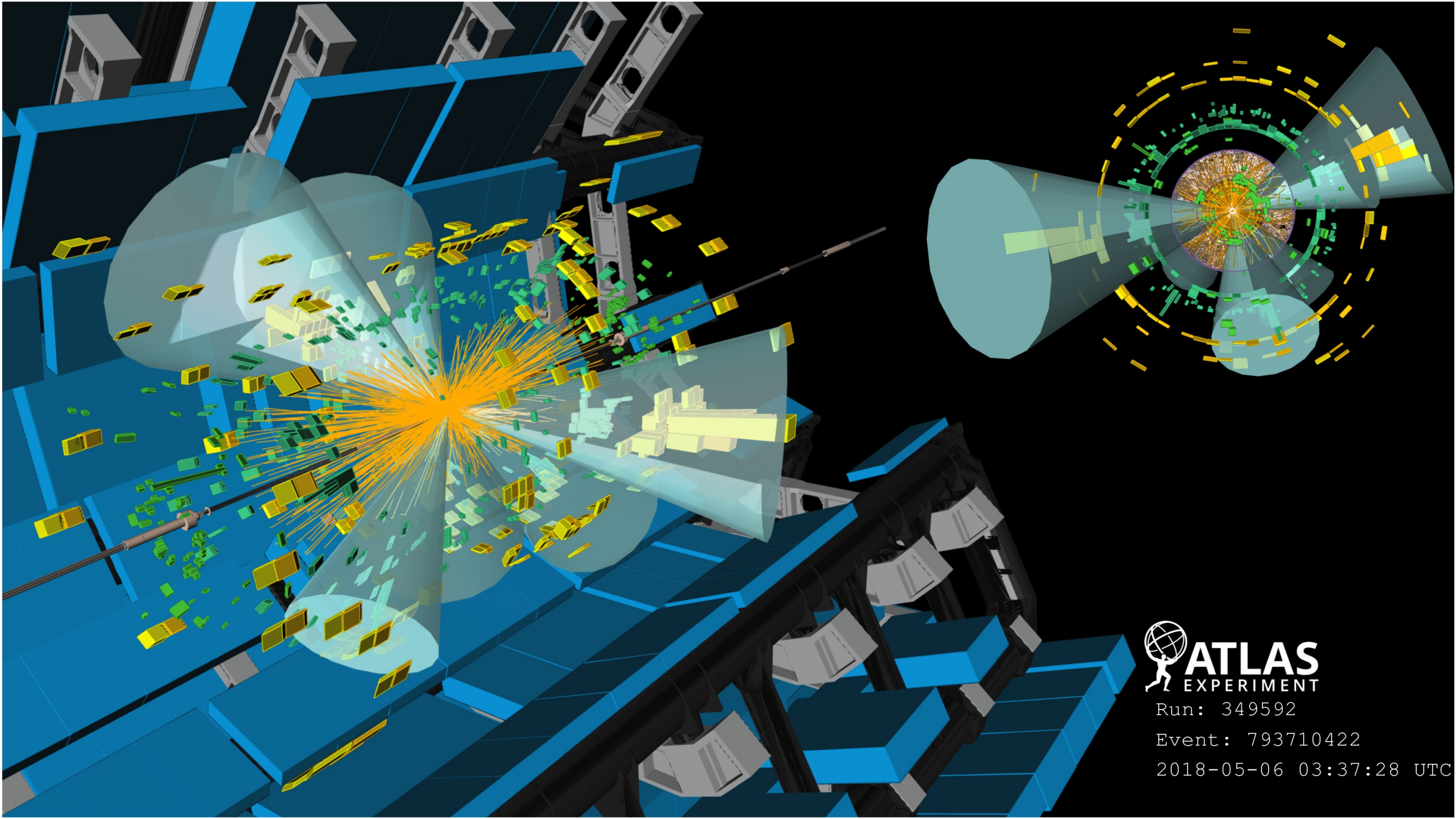


The ATLAS experiment at LHC









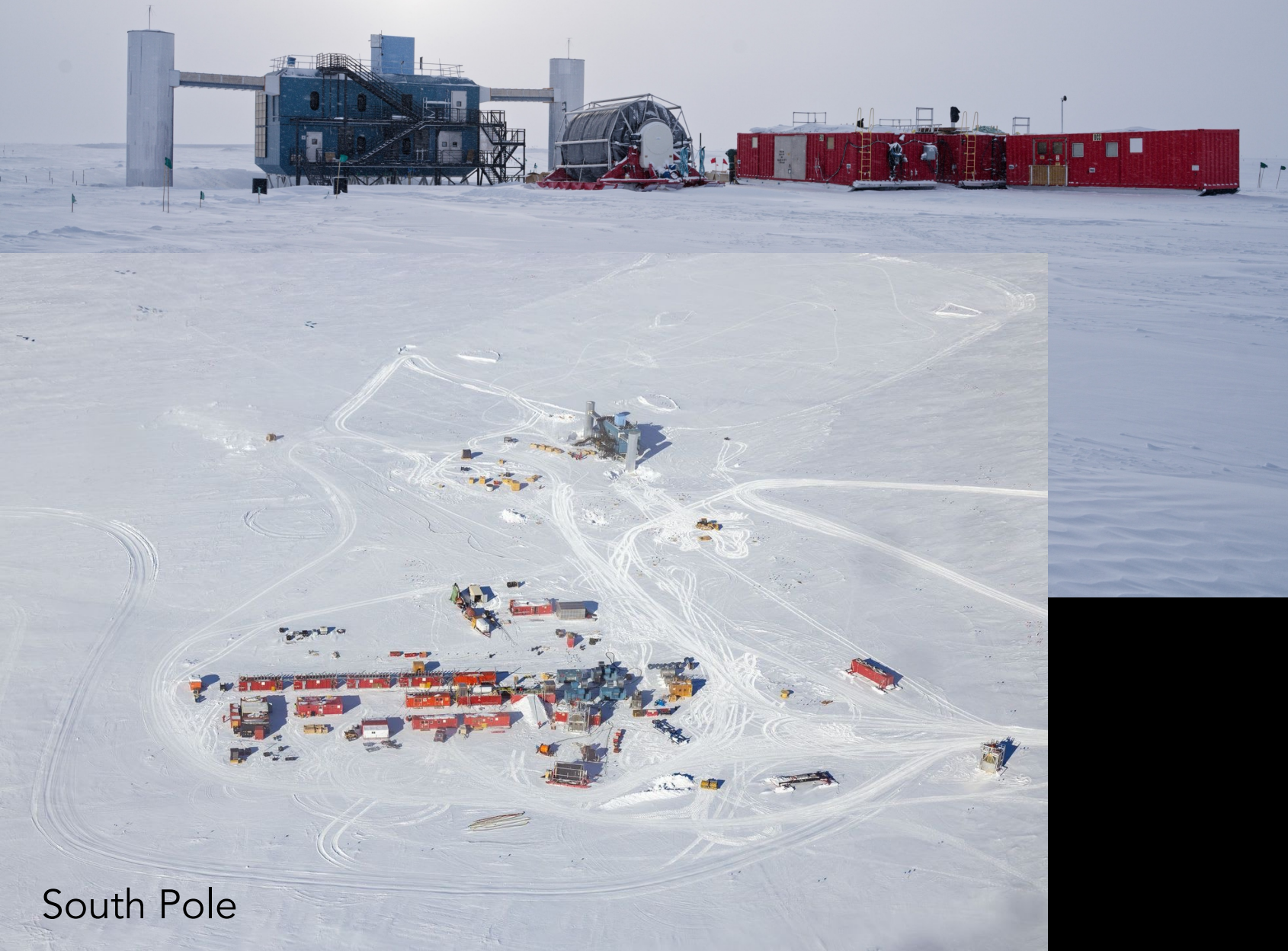
 **ATLAS**
EXPERIMENT

Run: 349592

Event: 793710422

2018-05-06 03:37:28 UTC

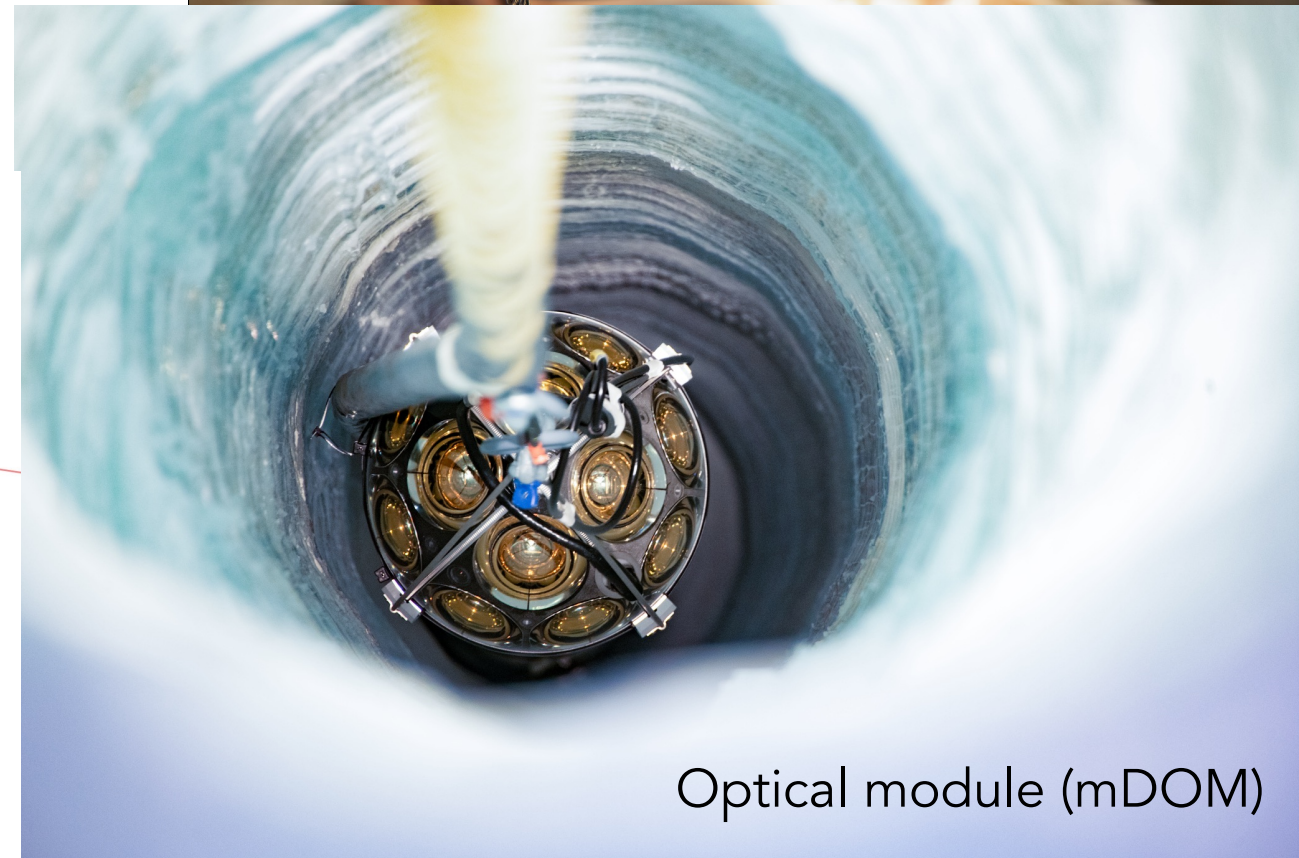
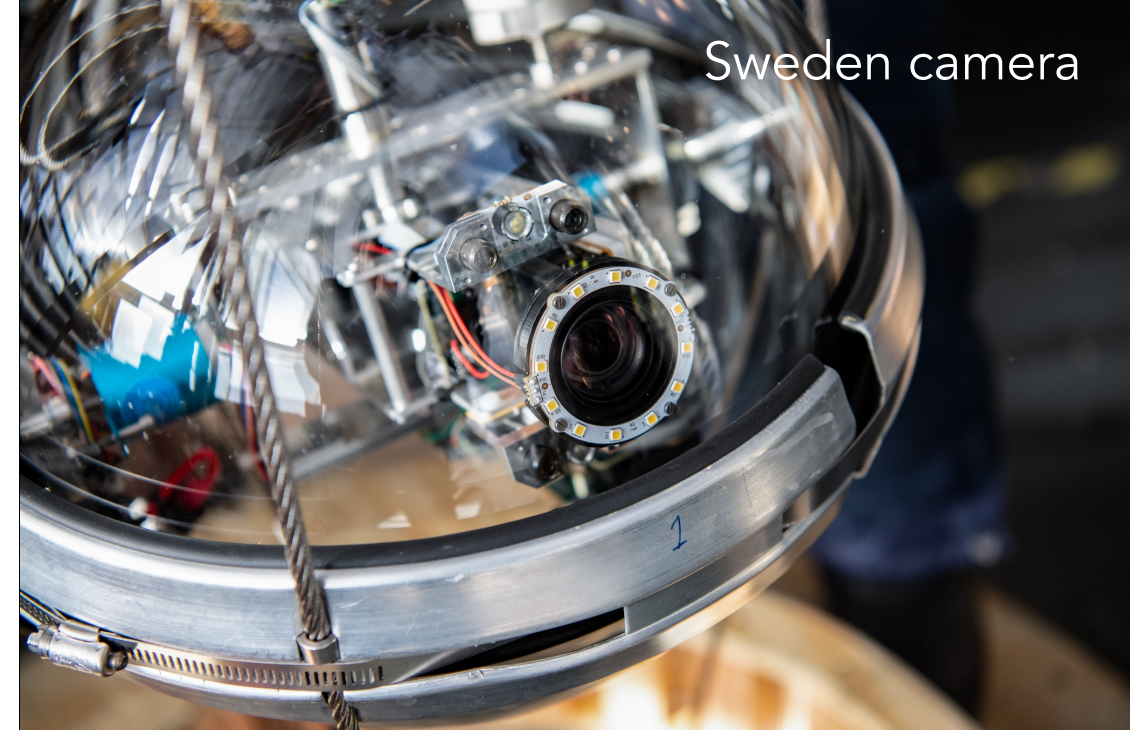
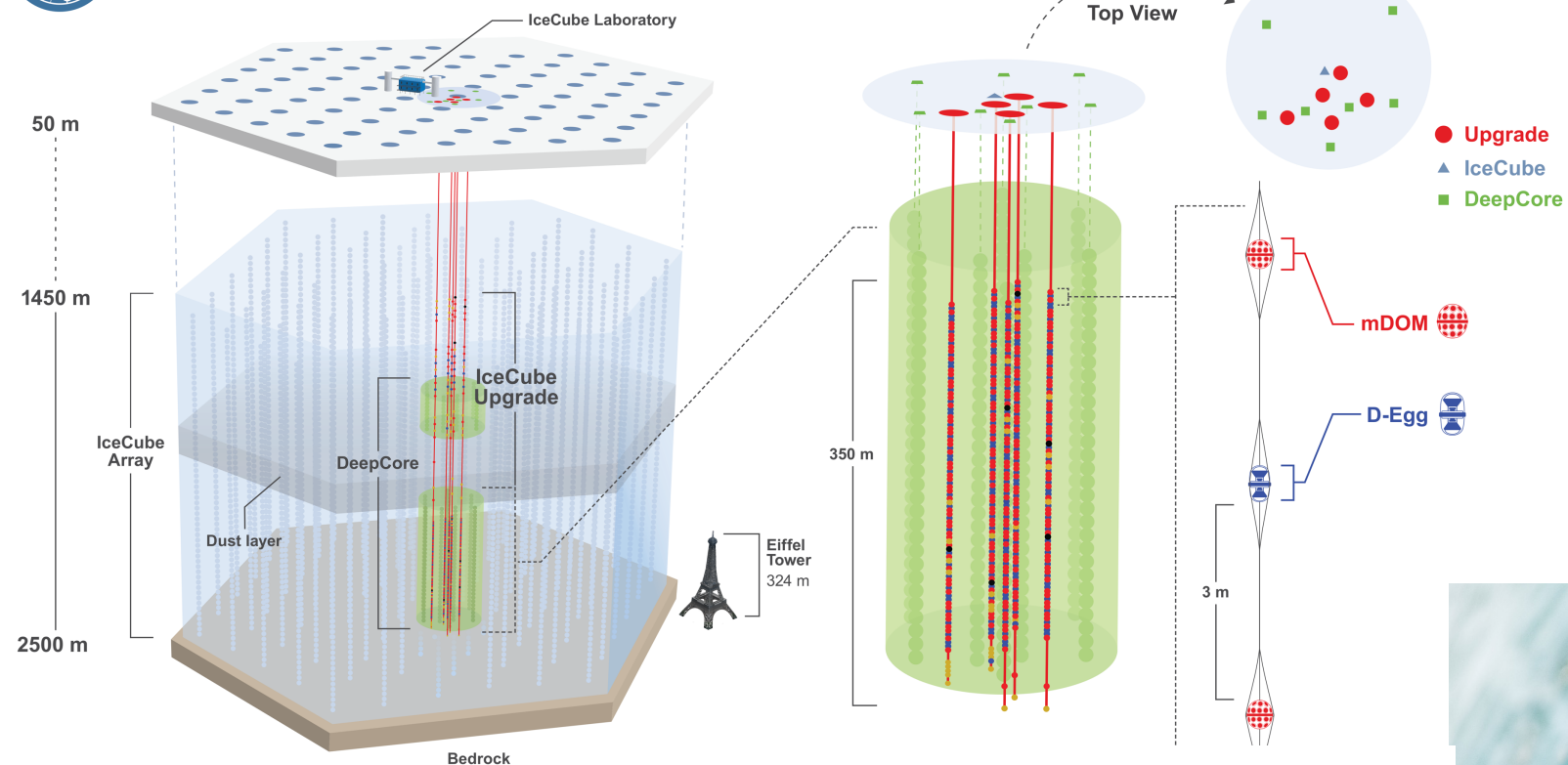
And now for something even larger: the IceCube Neutrino Observatory



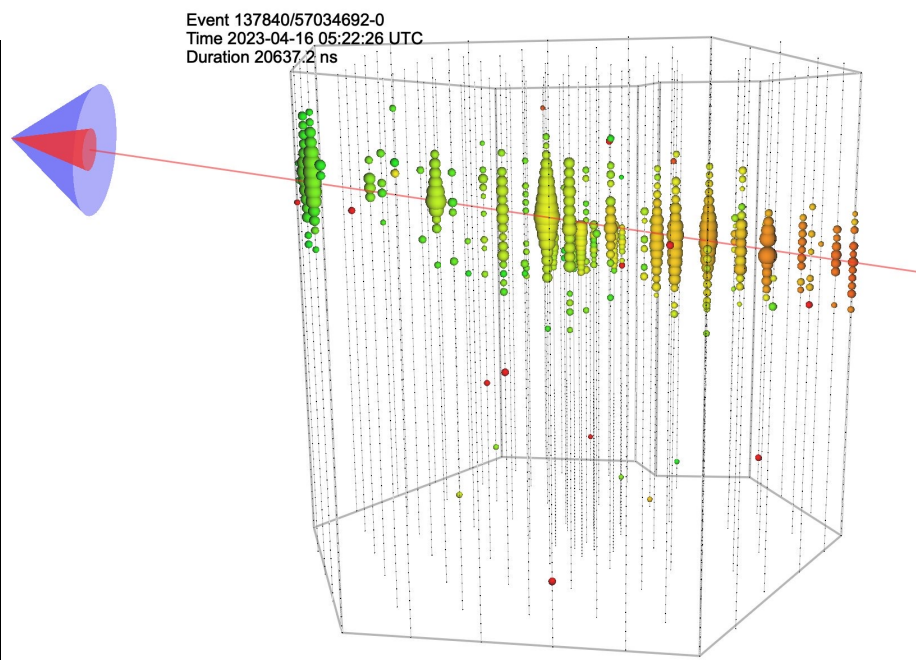
South Pole

Cables on skis
(cables made in Sweden!)





High energy
neutrino event,
showing which
optical modules
saw Cherenkov
light



We can't answer the questions of particle physics with one type of experiment – we have to use all available venues:

- Collider experiments at the energy frontier and the precision frontier
- Astroparticle experiments
- Cosmological observations
- Gravitational waves
- Theory
- ...
- Future experiments!