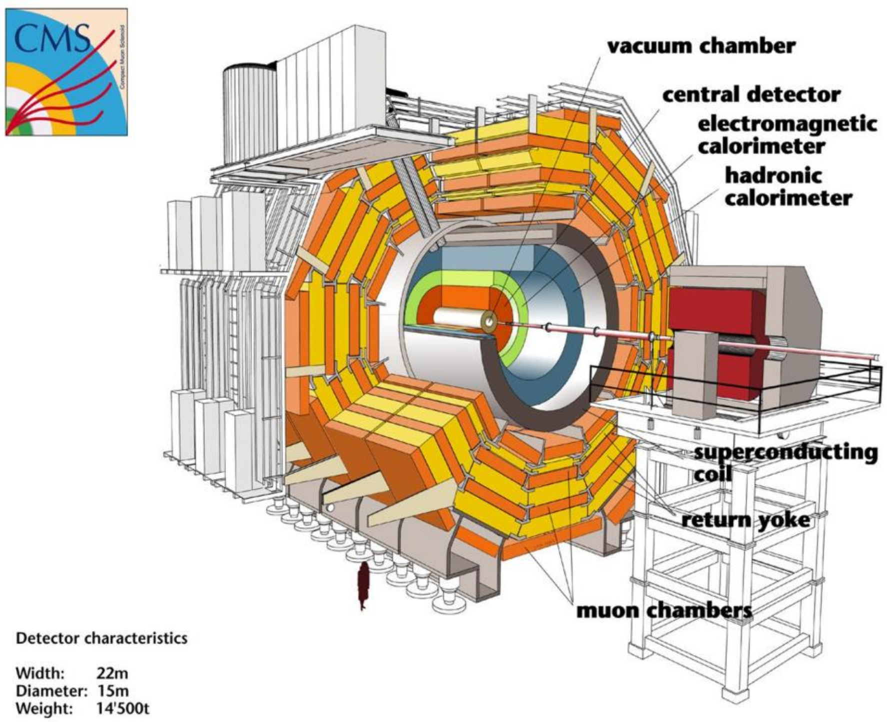
Behind the Scenes of an Experiment

A particle detector produces large amounts of data for each collision observed. Let's see how this complex object works and what becomes of the data collected, from their recording to their analysis.

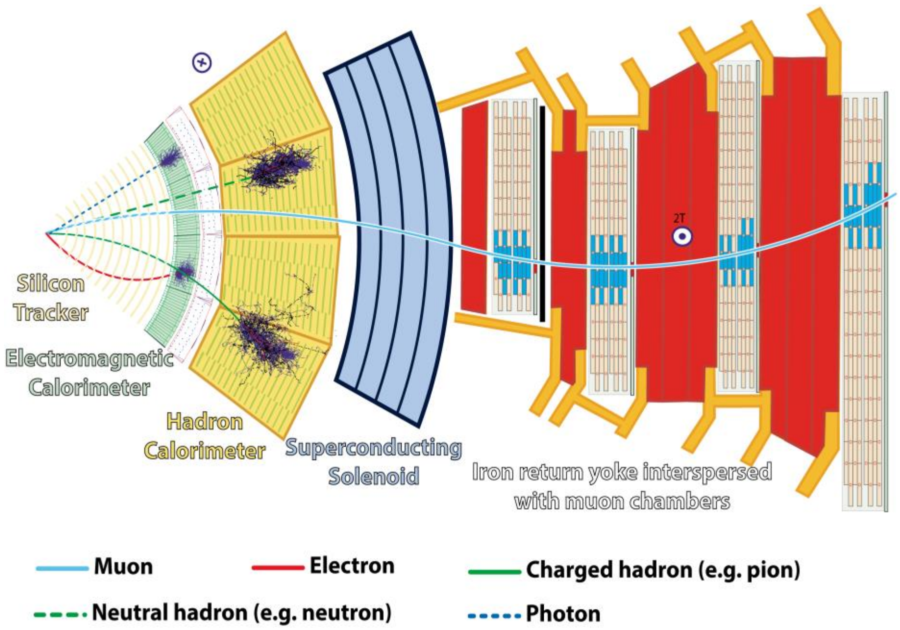


Credit: CERN AC

Layout of the CMS detector

Detectors are assemblies of independent instruments that provide different and complementary pieces of information on the particles passing through them. The collisions generally occur at the centre of the detector. Going outwards, the detector consists of a trajectograph (used to reconstruct the particles' paths from the spot they were created), calorimeters (measuring the particles' energies), and detectors specially designed for observing muons, which are abundantly produced during collisions but travel through the internal instruments in trackless jets.

A particle physics detector carries out various tasks: it identifies the particles produced by collisions, measures their properties (mass, speed, energy), and tracks the chain decays that have occurred. Each collected information comes from the interaction between a particle and an element in the detector, usually an energy deposit that leaves a measurable track. The track is recorded by a sensor and converted into an electrical impulse. All these signals are eventually collected and processed by a series of electronic circuits.



Credit: D. Barney/CERN

Cross-section of a detector

Paths of different types of particles in a section of the CMS detector. The trajectories of the charged particles are bent by a powerful magnetic field (4 Teslas, 100,000 times higher than the Earth's magnetic field) that is generated by a supraconducting solenoid perpendicularly to the cross-section plane. Depending on their type, particles penetrate the detector with various depths and leave different tracks, enabling physicists to identify them and measure their properties.

A tremendous amount of data becomes available. Indeed, a detector comprises several independent systems, or 'sub-detectors', that perform specific measurements – for instance, a calorimeter measures the particles' energies, and a trajectograph tracks their paths. Their precision and performance rely on their segmentation: a sub-detector often contains ten, even hundred thousand independent channels, each observing a small fraction of the measured section.

It is impossible to store or in fact merely read all the produced data. A strict filtering is therefore required: this is the role of the trigger, which selects the rare interesting events. When a collision occurs, the detector is 'studied' at several levels of details. At every step a decision is rapidly made – in a few ten nanoseconds at the start of the process, in a few milliseconds at the end. Either the event is uninteresting and is dismissed, or it is sufficiently promising for the physicists to want to know more, and additional information is collected to continue the analysis. The amount of data thus drastically decreases, filter after filter, until the final sample is recorded.

A performant trigger is very effective in searching signals while filtering out most of the background noise. Its quality is ensured by algorithms run at every event. They sort the pieces of information received, select the relevant ones, and assemble them in a coherent whole.

After interesting events are selected in real time, they are thoroughly reconstructed on a global network of computers, the computing grid. This process brings data to life: a long list of electronic signals are turned into real particles. Physicists can thus study their decays and compare experimental results with theoretical predictions.

Translated from 'Les coulisses d'une expérience',* Passeport pour les deux infinis*, IN2P3/Dunod, https://pass2i.ijclab.in2p3.fr/ (French); updated with ICHEP2024 conference (https://ichep2024.org) for IPPOG