To understand the subatomic processes unfolding at the center of powerful particle collisions, scientists design and build huge, massive detectors. The Compact Muon Solenoid (CMS) detector, currently under construction, will record high-energy proton-proton collisions produced by the Large Hadron Collider at the European laboratory CERN. Building this detector, which will stand more than 50 feet tall, requires one of the largest international scientific collaborations in history.

Pieces from forty countries

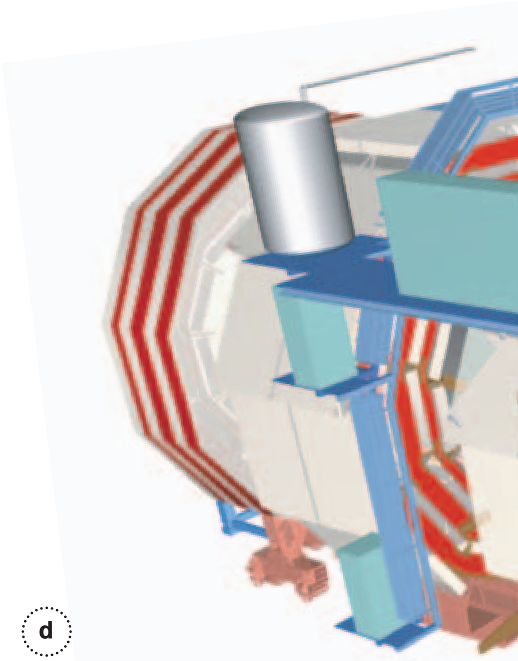
The CMS detector relies on an array of particle detection subsystems to record and identify the plethora of particles emerging from a single proton-proton collision. More than 2000 scientists and engineers from almost 40 countries have helped to design, build, and test components, shipping the finished pieces to CERN. The final assembly happens in a cavern about 300 feet underground in Cessy, France, near the Swiss border. Each piece of US equipment arrives with a "traveler," a document that specifies the construction details, the tests performed, as well as the maintenance and safety instructions.

Text: Kurt Riesselmann
Graphic: CMS Collaboration

a

The largest superconducting magnet in the world

Many of the CMS subsystems fit inside a cylindrical, superconducting magnet, about 40 feet long and 20 feet wide. This compact design led to the detector's name. Several companies contributed to the construction of the powerful magnet, the largest of its type ever built. The superconducting wire came from Finland and Japan, and was made into coils in Italy. Scientists need the magnet to bend the paths of charged particles, providing information on each particle's charge, mass, and speed.



c

Glass made of metal

The intermediate set of the CMS detector subsystems is the calorimeter, which determines the energy of the particles escaping each proton-proton collision. The electromagnetic calorimeter (green) is based on 80,000 crystals, each about ten inches long and one inch wide. Grown in China and Russia using a lead tungstate compound, the crystals consist almost entirely of metal (98 percent by weight), yet they are as transparent as glass. Electrons and photons crossing the crystals produce light, giving a measure of their energy. The light escapes the crystals and is recorded by sensors attached to them.

d

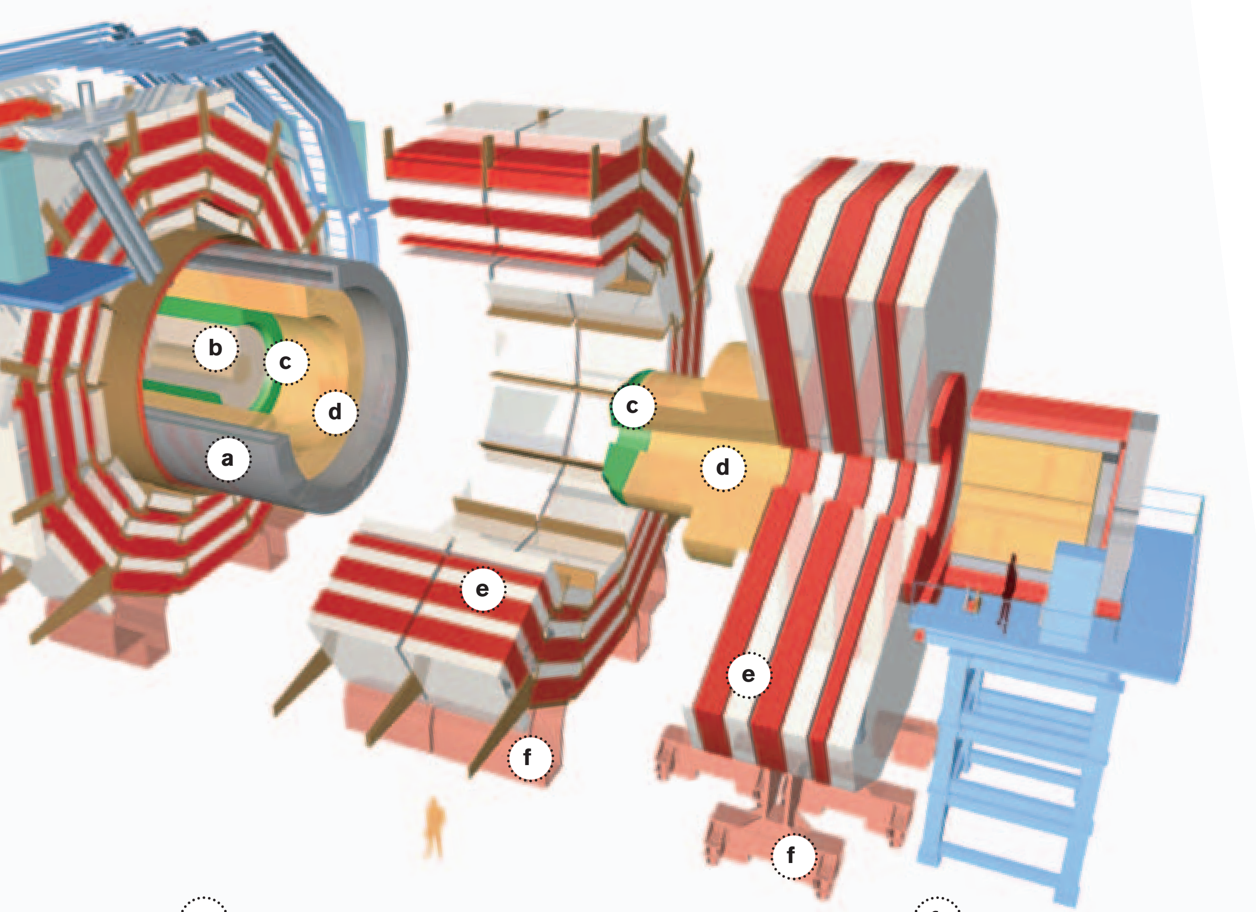
Swords to plowshares

The CMS hadronic calorimeter is a massive brass structure interspersed with scintillating plastic. It slows down quark-containing particles, absorbing their energy. Sensors attached to the plastic measure the light produced in this process. The end caps contain brass recovered from Russian artillery shells. The central part consists of two 500-ton barrels with brass plates held together by 80,000 bolts. Each barrel is twice as heavy as the Statue of Liberty. Designed at Fermilab and manufactured in Spain, the barrels will slide inside the CMS magnet for a snug fit, a daunting task as brass tends to sag.

b

Concentric layers like a tree trunk

Collider detectors contain three main types of detection systems. They surround the collision point like the cylindrical layers of a tree trunk, with end caps that have openings for the incoming particle beams. The tracker, the system at the core, records particle tracks with ultrahigh precision so that scientists can trace the particles back to their origins. The CMS tracker relies on silicon technology and can determine the exact coordinates of a particle track to within the width of a human hair. Universities and laboratories in 13 countries, including the United States, are participating in assembling and testing the individual silicon subsystems in cleanrooms. Spreading out all CMS silicon layers would cover an area about the size of a 25-meter swimming pool.



e

Catching tell-tale signs

The outermost devices of a collider detector identify muons, heavy electron-like particles that can travel long distances through matter. Muons are the only charged particles that regularly "survive" a trip through the inner detector unscathed. They are tell-tale signs of many interesting subatomic processes that take place at the core of a proton-proton collision. The CMS detector uses three different muon detection systems (white). They are interleaved with layers of steel (red), which close the magnetic circuit of the solenoid. Thirteen countries contributed to building and testing the muon detectors.

f

Solid foundation

The entire CMS detector rests on massive feet made of steel. They carry the weight of the entire detector with all its subsystems, a total of almost 14,000 tons. The feet were produced in Pakistan and China. They were shipped to Geneva by boat and rail.