

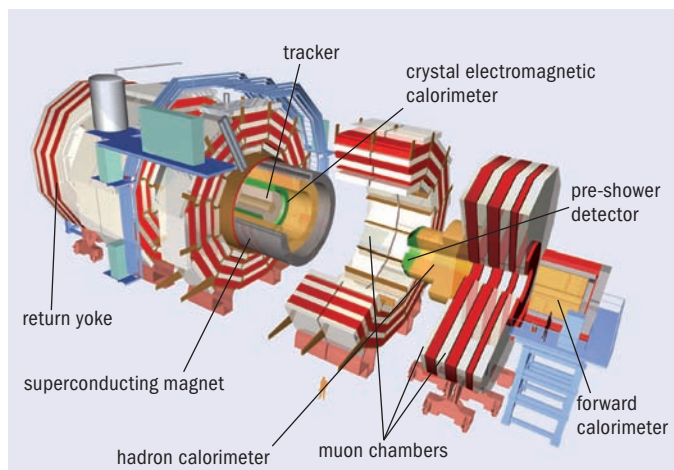
Building on innovation

Tejinder (Jim) Virdee describes concepts and technologies behind the CMS detector.

From the beginning, the CMS collaboration had taken a new approach with the plan to assemble the detector above ground in a spacious surface building while the civil engineering work on the underground cavern was underway. Alain Hervé, who had been Technical Coordinator for the L3 experiment at LEP before taking up the same position with CMS, strongly recommended constructing the detector in slices that would be lowered down the 100 m shaft into the cavern

after extensive commissioning on the surface. This had never been done before for such a large-scale high-energy physics experiment, most experiments being constructed directly in the experimental area. This decision, and the requirement of the ease of maintenance, determined the overall structure of the detector, with slices that could be lowered one by one – 15 heavy pieces in all.

“It is very unusual to do this, but the surface building was made quite large, and we could work on several pieces at the same time because they could easily be moved back and forth. Also the underground civil-engineering work in the caverns would take time, so we started assembling the detector four to five years before the



underground cavern was finished. The fully tested elements were lowered underground between November 2006 and January 2008. The experiment is commissioned and now ready for data-taking. The duration of the lowering operation and commissioning was essentially that foreseen 17 years ago,” explains Jim Virdee, who has been with CMS since the very beginning and spokesperson since 2007. “I know a few future experiments are looking at this way of doing things,” he

adds, “so I think it might catch on. It gives a lot of flexibility, providing ease of maintenance and installation. Even late on we could work on various elements in parallel in the underground cavern.”

The long process from the design phase to final construction encompassed some crucial changes in technology, which allowed savings in time, money and effort. Despite the unexpected challenges that arose, the collaboration remained flexible and creative in solving them. “We needed radiation-hard electronics in our tracker, electromagnetic calorimeter and hadron calorimeters, along with radiation-tolerant muon systems. We did a lot of R&D on this with industries that had produced radiation-hard electronics, usually for



The first ring for the barrel yoke of the CMS superconducting magnet under assembly in 1999 by the manufacturer Deggendorfer Werft und Eisenbau GmbH (DWE) in Germany.

● November 1999 p7.



Two modules of the CMS solenoid at the manufacturers, Ansaldo, in Italy. The lower module was the first travel to CERN from Genova, at the end of January 2004. (Courtesy INFN.)

● March 2004 p6.



On 1 February 2005, the cavern for the CMS detector at CERN was inaugurated in a ceremony attended by many guests, including representatives of the construction companies.

● March 2005 p5.



The first half of the barrel hadron calorimeter was tested in March 2006 using a radioactive source before insertion into the solenoid in early April. The second half was inserted a month later.

● July-August 2006 pp28–29.

space or military applications,” recalls Virdee. The collaboration was ready to launch production of the front-end electronics of the inner tracker when the foundry that was going to produce the electronics moved, and somehow lost its ability to produce electronics with good radiation hardness. “So we were thrown back to the drawing board and had to develop a new way of obtaining radiation-hard electronics,” says Virdee. “We essentially changed all of our on-detector electronics for the tracker and the electromagnetic calorimeter. This was a major issue that we were confronted with in the late 1990s and it’s all worked out very well. A lot of people thought we had left it too late, and I was being advised that we were taking a risk, but it was a risk we had to take.”

Another significant challenge concerned the production of 75 000 lead-tungstate crystals in Russia and China. These were chosen for their compactness, owing to their short radiation length, and high radiation hardness, but early tests revealed problems when using silicon photodiodes, with the scintillation light being drowned out by unwanted signals arising from charged particles at the end of the shower passing through the photodiodes. A solution was discovered using silicon-avalanche photodiodes, which could work in a magnetic field. Working with the crystal supplier in Russia also proved interesting. “The economic conditions in Russia have changed a lot since we started producing the crystals,” says Virdee, “so much so that we had to place the last few orders in roubles, not in dollars any longer because the rouble was considered by the manufacturer to be a more stable and stronger currency!”

In 1999 the CMS collaboration made a major decision to change the design of their inner tracker. Originally, they had included both microstrip gas chambers (MSGCs) and silicon sensors after performing much R&D on various technological options. The cost-per-square-centimetre of silicon detectors in the early 1990s was high, so the plan was to use silicon detectors close to the interaction point and use MSGCs further away. “This technology required some development to make it suitable for use in the LHC, and essentially we succeeded in doing that,” says Virdee. However, development of silicon detectors continued during the decade. Larger wafers were becoming available at a competitive

cost and with improved performance. Furthermore, automation – employed in the electronics industry – allowed rapid and reliable production of the 17 000 silicon modules needed for the tracker.

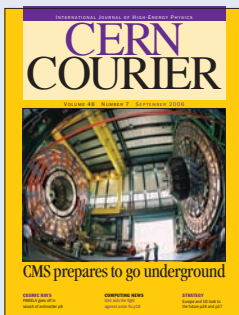
At the beginning of 1999, when it was clear that silicon had reached a competitive state with the MSGCs, the collaboration took the bold decision based on practical aspects to use only silicon. “We were pressed for time, and having two different technologies required us to have two different systems doing similar work. At the time we had not invested as much effort in the systems issues as we would have wished for,” Virdee explains. “So one of the key issues that arose was: can we come up with a single design to simplify the work and save time? The basic issue was that the silicon detectors were of high quality, and were mass-produced by industry, so we could just buy them while high-rate production lines for MSGCs had still to be commissioned.”

Once the LHC starts, the CMS physicists, some of whom have spent most of their working lives building the large and complex subdetectors, will have the long-awaited chance for discoveries. “However, before we do that we need to verify that the subdetectors perform as designed. Currently, we are doing that by running with cosmic rays. As far as we can tell the detector is working as expected and this is very encouraging. The moment of truth, however, will be when we record collision data,” says Virdee. “This start-up is very exciting because we are making a big leap up in energy and entering a new regime. All indications are that there is something special about this energy range.”

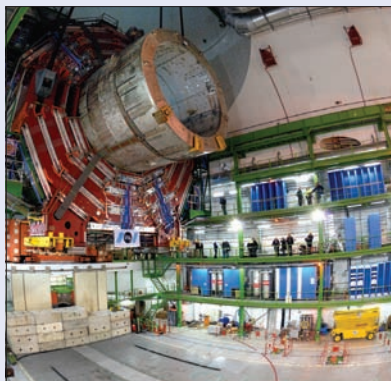
Résumé

La collaboration CMS a choisi une méthode de construction inédite : assembler le détecteur en surface avant de descendre les différentes sections dans la caverne. CMS a accompli d'autres prouesses techniques : la production de 75 000 cristaux de tungstate de plomb pour le calorimètre électromagnétique et l'utilisation du silicium pour la totalité du trajectographe.

Jim Virdee talked to Carolyn Lee, CERN.



On 24 July 2006 the massive CMS magnet yoke was closed for the first time for tests of much of the detector while still on the surface, before the lowering began.
● September 2006 p7.



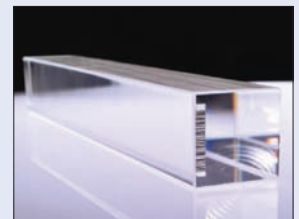
On 28 February 2007 the heaviest section of CMS, containing the complete solenoid, made the 100 m descent into the cavern, descending at a rate of about 10 m an hour.

● April 2007 p6.



The silicon strip tracking detector reached its final resting place in the CMS experiment on 13 December 2007. It is the largest detector of its kind ever constructed.

● January/February 2008 p6.



The final crystals for the electromagnetic calorimeter arrived at CERN from China and Russia in March 2008, completing a mammoth production process nearly 10 years after the delivery of the first production crystal in September 1998.

● June 2008 p6.

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