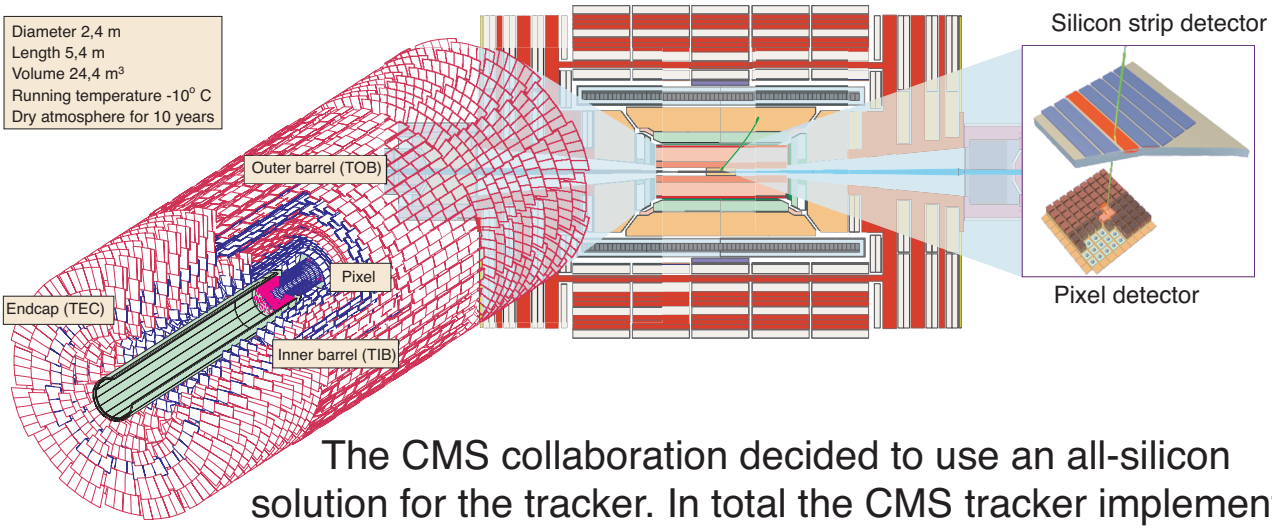
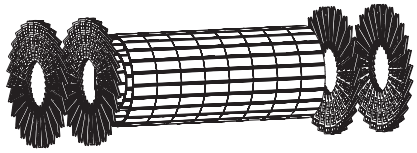
Tracking detectors



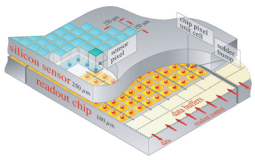
The CMS collaboration decided to use an all-silicon solution for the tracker. In total the CMS tracker implements 25000 silicon strip sensors covering an area of 210 m^2. Connected to 75000 APV chips, one has to control 9600000 electronic readout channels, needing about 26 million microbonds. This large detector system will be realized, applying industrialized methods in production and quality assurance.

Pixel Detectors

At the smallest radii from the beam line (at 4 and 7 cm at low luminosity and at 7 and 11 cm at high luminosity) the interaction region is surrounded by two barrel layers of Silicon Pixel detectors. Two endcap disks cover radii from 6cm to 15cm.

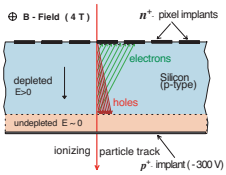


The pixel layers are composed of modular detector units. Each module consists of a thin, segmented sensor plate with highly integrated readout chips connected to them using the bump bonding technique, as shown below.



Schematic view of a pixel detector element. Each sensor pixel is connected via a solder bump to a pixel unit on the readout chip, where the signal is amplified. The hit data are stored on the edge of the chip where they wait for the trigger information.

The cell size in the Pixel detectors is 150x150 μm^2. The pixels used are n-on-n devices so that, in the barrel, their response is strongly affected by the 34° Lorentz angle of the drift of electrons. The barrel Pixel geometry is deliberately arranged so that this large Lorentz angle induces significant sharing of charge across neighboring cells and this results in spatial resolutions of ≈ 10 and 15 μm in the ϕ and z coordinates respectively.



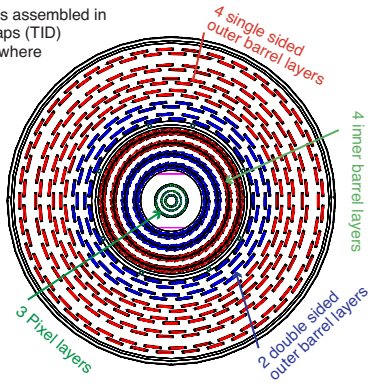
Charge sharing induced by the Lorentz drift. The sensor material is silicon in which the electron drift angle is three times larger than for holes. Therefore, n-type pixels, which collect electrons, will be used. When the electrons arrive at the pixel surface, they are spread over an rϕ distance of ≈ (detector thickness) x tan(34°).

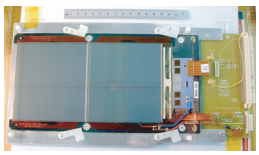
Silicon Strip Detectors

The layout for the silicon strip detector has four inner barrel (TIB) layers assembled in shells, layers 1&2 are double sided , complemented by two inner endcaps (TID) each composed of three small discs. The outer barrel (TOB) structure, where the modules are assembled in six concentric layers (layers 1&2 double sided), closes the tracker towards the calorimeter.

Two endcaps (TEC) ensure a pseudorapidity coverage of η = 2.5. The endcap modules are mounted in 7 rings on 2x9 discs consisting of wedge shaped petals, each covering 1/16 of 2 π. The detectors of ring 1,2,5 are made of double sided modules. Each one is composed out of two single sided sensors mounted back to back, one tilted by an angle of 100 mrad with respect to the other sensor giving the phi coordinate.

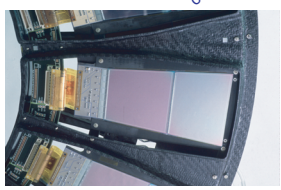
Silicon sensors are highly suited for high occupancy and high resolution experiments, due to their fast response and small pitches, ranging from 80 to 205 μm. In the outer regions, higher noise due to "long" strips is compensated by larger signal height using 500 μm thick sensors instead of 300 μm. 6 inch wafer technology made this huge construction at a reasonable prize and effort possible.



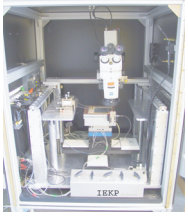


First assembled TOB module

A detector module is the basic functional sub-unit of the silicon tracking system. Each module consists of three elements: a set of single sided sensors, a mechanical support structure and the readout hybrid.

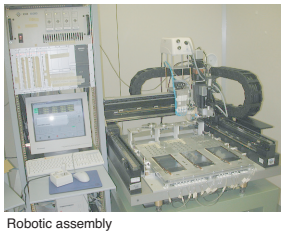


TEC wedge shape module



Fully automatic probe station

Quality assurance, assembly and bonding will be realized under quasi industrial conditions with high multiplicity : 4 centers are surveilling the overall sensor quality using fully automatic probe stations, 3 centers are monitoring the process quality and finally 2 centers are checking the radiation hardness. Assembly robots in 7 centers plus industrial bonding machines in 12 places ensure high quality and reliability over the long construction period. All parameters and logistics are monitored using a special global database.



Robotic assembly

How to survive 10 years in the harsh LHC environment!
- To compensate interstrip capacitance increase, resulting in higher noise, CMS uses silicon with <100> crystal orientation, which is less affected by irradiation.
- Low resistivity silicon in the inner region starts with a higher depletion voltage but ending with lower depletion voltage after type inversion and 10 years of LHC operation. New strip layout optimizes the field configuration, avoiding strip breakdown at high voltage.