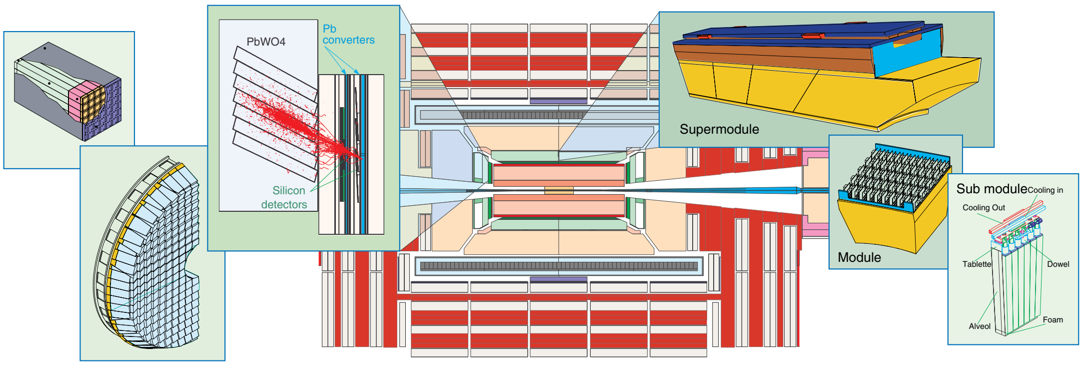
Electromagnetic calorimeter



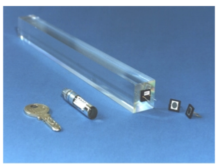
One of the principal CMS design objectives is to construct a very high performance electromagnetic calorimeter. A scintillating crystal calorimeter offers excellent performance for energy resolution since almost all of the energy of electrons and photons is deposited within the crystal volume. CMS has chosen lead tungstate crystals which have high density, a small Molière radius and a short radiation length allowing for a very compact calorimeter system. A high-resolution crystal calorimeter enhances the $H \rightarrow \gamma\gamma$ discovery potential at the initially lower luminosities at the LHC

Lead-Tungstate Crystals

The CMS electromagnetic calorimeter will consist of over 80,000 lead-tungstate ($PbWO_4$) crystals equipped with avalanche photodiodes or vacuum phototriodes and associated electronics operating in a challenging environment: a magnetic field of 4T, a time of 25 ns between bunch crossings, a radiation dose of ≈ 1-2 kGy/year for LHC operation at maximum luminosity, and also difficult access for maintenance

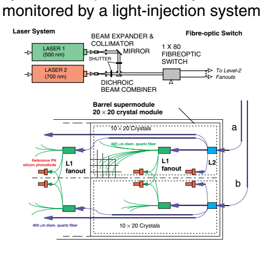
After an intensive R&D program, lead tungstate crystals were chosen because they offer the best prospects of meeting these demanding requirements. The choice was based on the following considerations:

- $PbWO_4$ has a short radiation length and a small Molière radius
- it is a fast scintillator
- it is relatively easy to produce from readily available raw materials and substantial experience and production capacity already exist in China and Russia



The crystals have a front face of about 22x22 mm^2 — which matches well the Molière radius of 22 mm. To limit fluctuations on the longitudinal shower leakage of high-energy electrons and photons, the crystals must have a total thickness of 26 radiation lengths — corresponding to a crystal length of only 23 cm

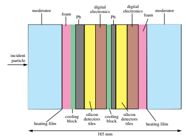
$PbWO_4$ is intrinsically radiation-hard, but non-optimized crystals do suffer from radiation damage. The R&D program of the last few years has led to a better understanding of the damage mechanism. The main conclusion is that radiation affects neither the scintillation mechanism nor the uniformity of the light yield along the crystal. It only affects the transparency of the crystals through the formation of color centers and the transport of light is changed by self-absorption of the crystals. This light loss can be monitored by a light-injection system



The light monitoring system, shown on the left, is designed to inject light pulses into each crystal to measure the optical transmission. The pulses are distributed via an optical-fibre system. The system is designed to continuously monitor the calorimete

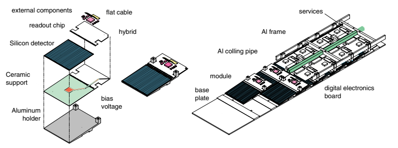
Preshower Detector

CMS will utilize a preshower detector in the endcap region (rapidity range 1.65 < |η| < 2.6). Its main function is to provide γ–π^0 separation



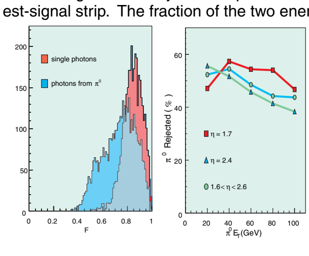
The preshower detector contains two thin lead converters followed by silicon strip detector planes placed in front of the ECAL.

The measurement of the energy deposition in the ~2 mm pitch silicon strips allows the determination of the impact position of the electromagnetic shower by a charge-weighted-average algorithm with very good accuracy (~300μm at 50 GeV). The fine granularity of the detector enables the separation of single showers from overlaps of two close showers due to the photons from π^0 decays



The active planes of silicon detectors are built from a large number of identical modules each of which contains an individual detector, as shown above. A module contains an aluminum tile ('holder') onto which a ceramic support is glued. A silicon detector, subdivided into 32 strips at 1.9 mm pitch, is then glued and bonded to the ceramic. The hybrid containing the analog front-end electronics is also glued and bonded to the ceramic. The modules are then assembled on long ladders which contain two columns of adjacent detectors

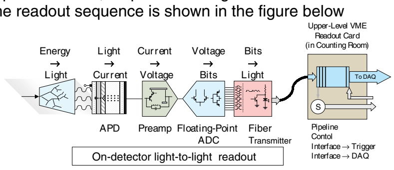
The π^0 rejection algorithm using the preshower compares the highest signal (summed in 1, 2 or 3 adjacent strips) with the total signal in 21 adjacent strips centered on the highest-signal strip. The fraction of the two energies, F, is then used to select photons (and reject π^0's)



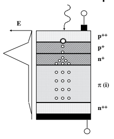
The rejection obtained with this simple algorithm approaches a factor of 3 and is fairly independent of E_T.

Readout

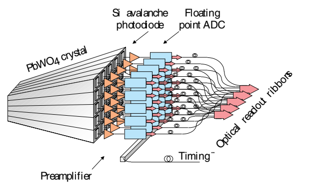
The scintillation light from the crystals must be captured by a photodetector, amplified and digitized. A schematic of the readout sequence is shown in the figure below



The first element is the $PbWO_4$ crystal which converts energy into light. The light is converted into a photocurrent by the photodetector. The relatively low light yield of the crystal necessitates a preamplifier in order to convert the photocurrent into a voltage waveform. The signal is then acquired and digitized. The resulting data are transported off the detector via optical fibre to the upper-level readout



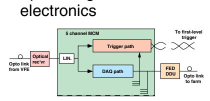
Photodetector (Avalanche Photodiode) principle: Photons convert in the p^{++} layer. Photoelectrons drift towards the abrupt p-n junction where ionization starts and avalanche breakdown occurs. The avalanche breakdown results in impact electron multiplication.



To avoid the design and construction of a very large quantity of radiation-hard electronics, the data are transported, immediately after the digitization step, to the counting room by fibreoptic links

The upper level readout has four main functions:

- formation of trigger tower energy sums
- pipelining (storing the data until receipt of a Level-1 trigger decision)
- transmission of the data from the triggered event to the Data Acquisition System
- providing interface functions for the on-detector electronics



Layout of the upper-level readout. The optical receiver deserializes the data from the Very Front-Ends. The linearizer transforms the incoming data to a representation which facilitates analysis by the trigger (e.g. formation of energy sums) without further conversions