High precision, low disturbance calibration of the HV system of the CMS Barrel ECAL

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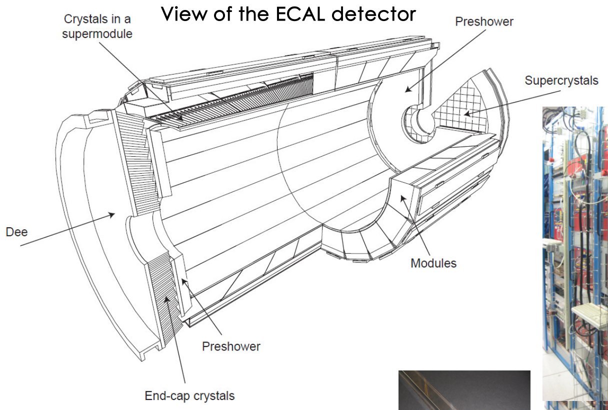
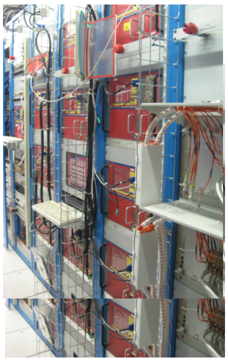
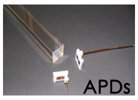
The barrel part of the CMS electromagnetic calorimeter (ECAL) is made of 61200 scintillating lead tungstate crystals. The scintillating light is read by avalanche photodiodes (APDs) in the barrel. The APDs are silicon photon sensors with an internal gain. They are typically operated at a gain of 50, achieved with a high voltage (HV) bias of 380 V. The gain stability requirement implies a supply voltage stability better than 60 mV per month.
The high voltage is provided to the detector through 120 meters cables. Sense lines are used to compensate for the voltage drop across the cables. In this poster, a new calibration system deployed at the end of 2015 is presented.

The CMS ECAL:

The **energy resolution** of the ECAL is parametrized as $\frac{\sigma_E}{E}=\sqrt{\frac{a^2}{E}+\frac{b^2}{E^2}+c^2}$
The APD contribute to all of the three terms:
a → Fano factor & quantum efficiency ~ 3%
b → Capacitance & Dark current ~ 200 MeV
c → HV + temperature stability ~ 0.5 %

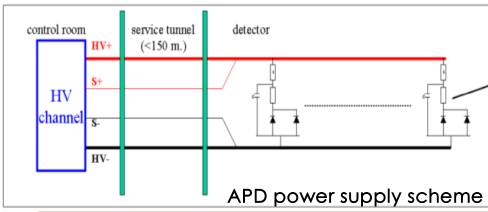




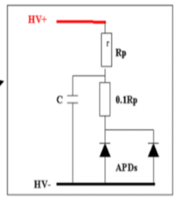


The HV system:

A dedicated power supply is used to bias the APDs
It was developed by **INFN-Roma** in collaboration with **CAEN**
It is installed in 6 racks in the CMS Service Cavern
It is composed of **18 CAEN SY4527 Mainframes**
Each mainframe hosts **8 CAEN A1520PE** 9-channels modules
Each channel is used to bias 100 APDs (50 crystals)

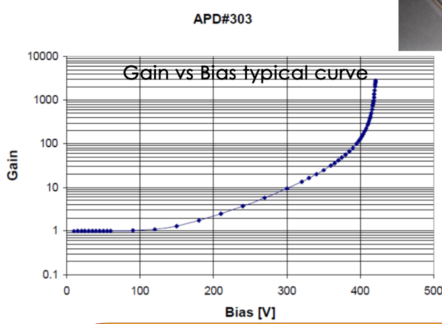


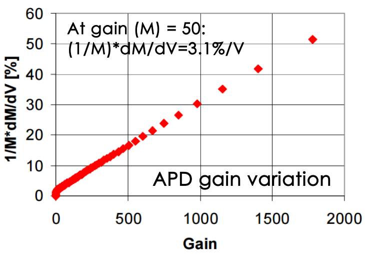
APD power supply scheme



Required stability:

The APD gain is sensitive to small fluctuations of the HV bias
The **APD gain variation** is ~ **3.1%/V** at gain 50
The bias stability has hence a **direct effect on the energy resolution**
The impact on the constant term is required to be less than 0.2%
This in turn implies an **HV stability** at the level of **60 mV per month**
Variations on longer time scale can be corrected by the detector calibration using physics events





APD characteristics

Parameter	
Maximum operating voltage	500 V
Minimum operating voltage	200 V
Leakage current (start of experiment)	$< 0.01\,\mu A$
Leakage current (after 10 years)	$< 20\,\mu A$
dM/dV gain sensitivity (at gain M = 50)	3.1%/V
APDs used in the ECAL barrel	122400

HV channel electrical characteristics

Parameters	
Output voltage range	0–500 V
Programmable setting step	20 mV
DC regulation at load	$< \pm 20$ mV
DC stability at load (over 90 days)	$< \pm 20$ mV
Low freq. noise at load (f < 100 kHz)	$< \pm 20$ mV
High freq. noise at load (f > 100 kHz)	$< \pm 20$ mV
Operating temperature at supply	$15 \div 40$°C
Current limit	15 mA
On and off maximum ramp rate	50 V/sec.
External calibration	$< \pm 20$ mV

→ picture of the **multiboxes** used in the HV apparatus

Calibration of the HV system:

In order to avoid inducing noise on the calorimeter signal measurement, the HV system was not equipped with a continuos monitoring system. **Periodic** monitoring and **calibration campaigns are** hence **perfomed**.

Old method:

Until 2015 the calibration was done **manually uncabling** the system in the CMS service cavern and calibrating one by one the HV boards with a precision multimeter.
Due to the **long time required** and to reduce mechanical stress on cables and connectors, the calibration was done **once per year** during the LHC winter shutdown.

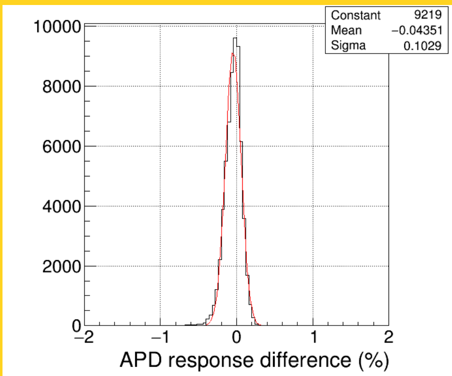
New method:

A new calibration system was deployed at the **end of 2015**.
It consists of **mechanical switches** connecting the HV cables to the calibration system, guaranteeing that no additional noise is introduced.
Calibration cables draw the bias to a precision multimeter through a set of multiplexers. The calibration **program cycles through all the channels** allowing both to measure the voltage and to recalibrate the channels one by one.

One complete calibration with the old system required about 1 month, while the new method, after the commissioning, will require about 1 week with half manpower

Performances:

To commission the new calibration system In 2016 the ECAL Barrel HV system was calibrated **both** with the **old and new calibration** apparatus.
The plot shows the **relative difference** of the laser monitoring signal in the ECAL Barrel crystals when the HV was calibrated with the new and with the old calibration system.



The distribution is fitted with a gaussian function.
The sigma is 0.1%.
The mean is slightly shifted from zero, due to the use of two different multimeters in the two HV calibration systems, whose calibration is compatible at 30 mV level, which reflects in a 0.1% syst. error on the APD gain.
There are **more than 99.4% channels within +- 0.5%.**
The few channels with large shift are understood to be due to the fact that half of the channels were calibrated without load, because the resistor which had been employed was not suitable for high load. In the next campaign a new resistor will be used, which allows better heat dissipation.