CMS Electromagnetic Calorimeter

Design and Upgrade for HLLHC

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Introduction

The LHC

Figure 1: inserire didascalia

CMS

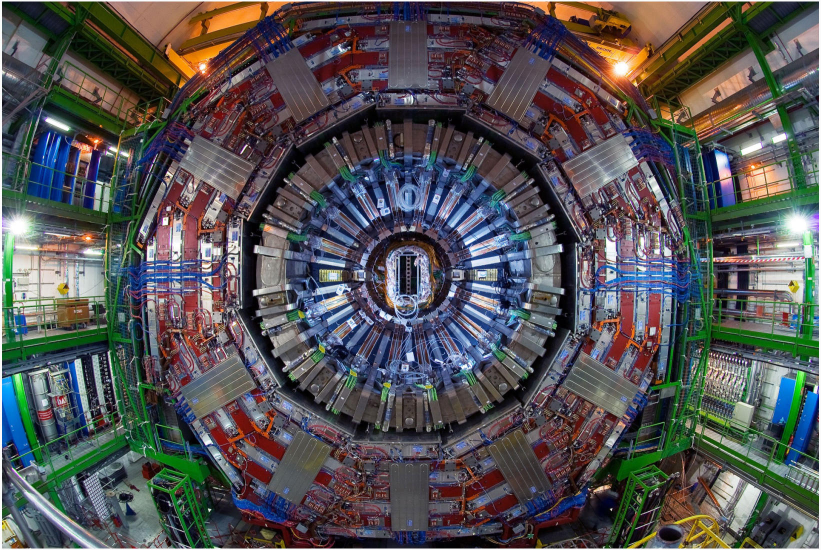


Figure 2: CMS experiment section view

CMS

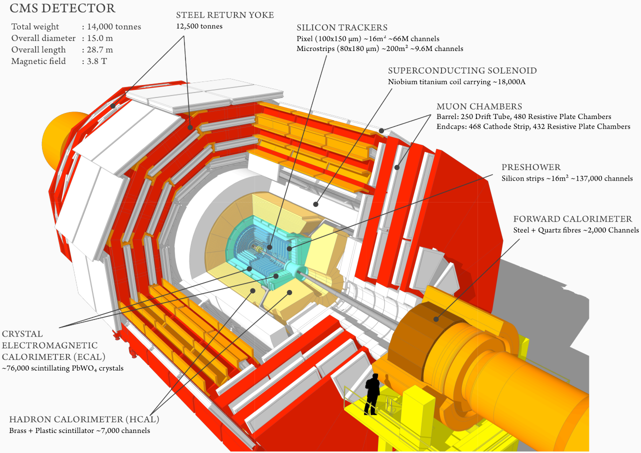


Figure 3: CMS experiment scheme

EM Calorimeter

EM Calorimeter

Barrel ECAL

- covering $|\eta| \leq 1.479$ range
- 61200 crystals organized in 5×5 modules and 36 supermodules
- 360-fold in ϕ (2×85)-fold in η
- crystal lenght: 230 mm corresponding to 25.8 X_0

Endcap ECAL

- $1.479 \leq |\eta| \leq 3.0$
- Each endcap divided in 2 "Dees", each with 3662 crystals organized in 5×5 supercrystals
- crystal lenght: 220 mm corresponding to 24.7 X_0

Design

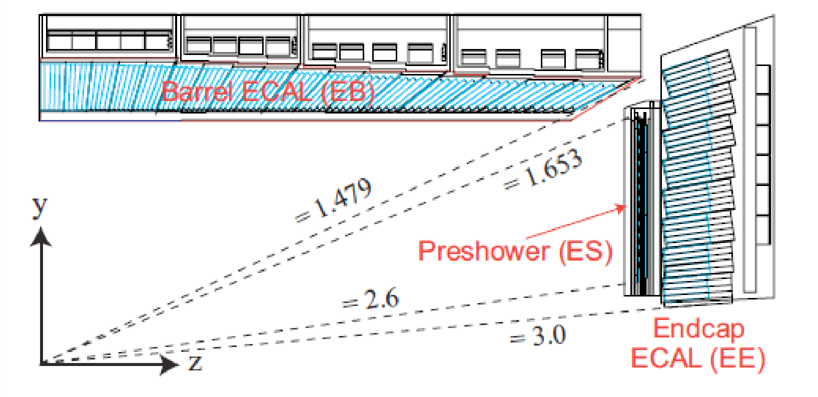


Figure 4: emcal scheme

EM Calorimeter

non mi piace molto questa foto, vedi se ne trovi una migliore...

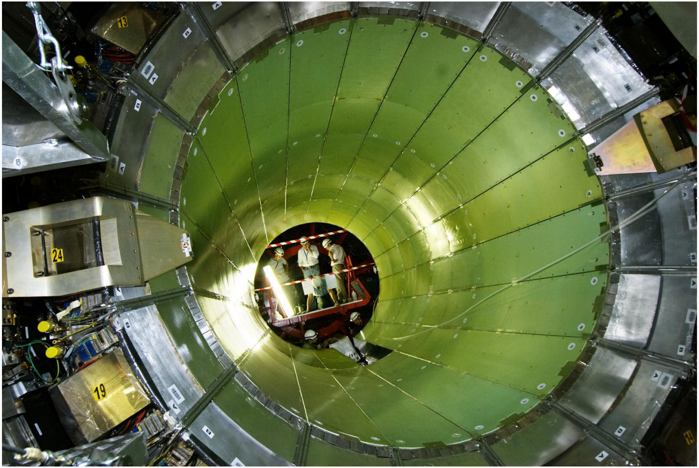


Figure 5: inserire didascalia

Frame Title

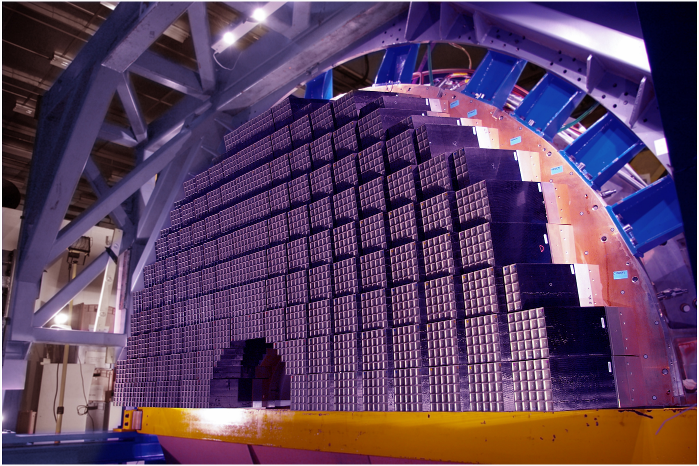


Figure 6: One of the four "Dees" of the endcap EmCal

Design

non mi piace molto questa immagine.. ma è un supermodulo del barrel

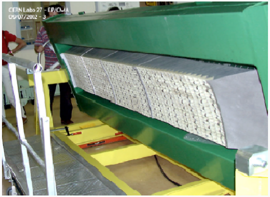
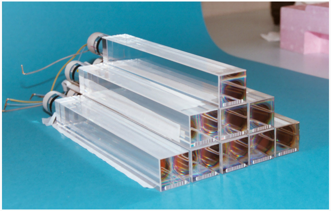


Figure 7: EmCal module

Lead Tungstate ($PbWO_4$) Crystals



- $\rho = 8.3\,\mathrm{g/cm^3}$
- $X_0 = 0.89\,\mathrm{cm}$
- Moliere Radius $= 2.2\,\mathrm{cm}$
- Light Output: 4.5 ph/MeV
- Green-Blue light, max @ 420 nm
- Polished for internal reflection

High radiation levels throughout the duration of the experiment $\rightarrow$ wavelength dependent loss of light transmission without changes to the scintillation mechanism.

Radiation hardness properties are required: the induced light attenuation length must be always greater than $3\times$ crystal length.

Damage is tracked and corrected by a laser light monitoring system.

Photodetectors

Barrel EMCal

- Reverse structure avalanche photodiodes (APDs)
- Glued to the back of the crystals
- High quantum efficiency ($\sim 75\,\%$) with mean gain of 50

Endcap EMCal

- Vacuum Phototriodes
- Essentially photomultipliers, with a single gain stage
- Specially designed to withstand the 4 T magnetic field
- 22 % quantum efficiency with mean gain of 10.2 at 0 T

Pre-shower Detector

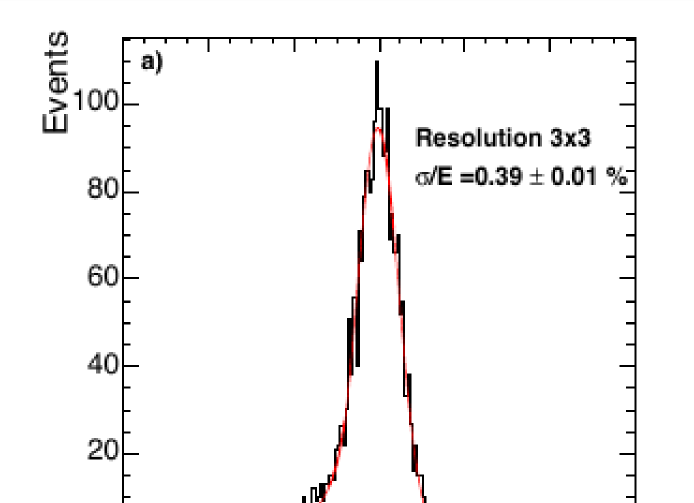
fare il preshower, non so quanto approfondirlo, vediamo alla fine se ci sta

Elettronica e Segnale

voglio dire qualcosa di elettronica ed elaborazione del segnale? è necessario?

Energy Resolution

Showers in EMCal are reconstructed by building *clusters* of crystals. Best performance is obtained using a simple 3x3 (or 5x5) sliding window centered in the crystal having the maximum energy deposition.



Energy Resolution

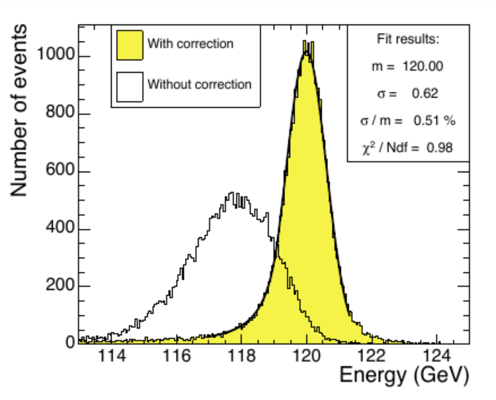


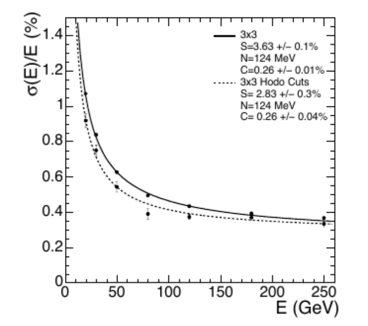
Figure 9: Energy distribution reconstructed during the test beam (pointed to a *corner* of the supermodule). A single correction function, parametrized from the data, was applied to all regions of the supermodule to take into account variations in shower containment.

Energy Resolution

Energy Resolution can be parametrized as a function of energy

$$\left(\frac{\sigma}{E}\right)^2 = \left(\frac{S}{\sqrt{E}}\right)^2 + \left(\frac{N}{E}\right)^2 + C^2, \tag{1}$$

- S is the **stochastic** term
- N is the **noise**
- C is a **constant** term



Calibration

It is a *severe technical challenge*. Naturally divided in two parts:

- **Absolute energy scale**
- **Inter-calibration**

The final energy measurement is given by

$$E_{e,\gamma} = G \times \mathcal{F} \times \sum_i c_i \times A_i \qquad (2)$$

where

- G is a *global absolute scale*
- $\mathcal{F}$ is a *correction function* depending on particle type, position, momentum...
- c_i are the *inter-calibration coefficients*
- A_i are the *signal amplitudes* summed over the cluster of crystals

HL-LHC Upgrade

Conclusion

- one
- two