Alignment and detection efficiency of CMS Preshower (ES) detector at CERN LHC

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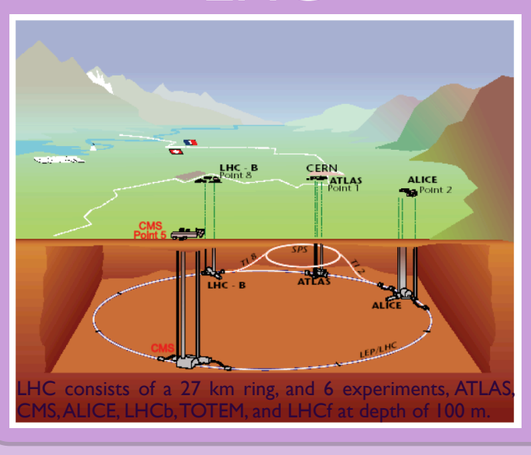
On behalf of the CMS Collaboration

CMS Preshower

LHC



LHC consists of a 27 km ring, and 6 experiments, ATLAS, CMS, ALICE, LHCb, TOTEM, and LHCf at depth of 100 m.

CMS ES detector Introduction

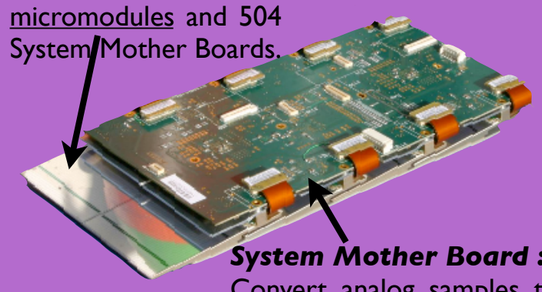
The Preshower detector, as part of the CMS Endcap electromagnetic calorimeter (ECAL), is designed to have good spatial resolution to measure the position of incoming particles and thus aid particle identification in the endcaps [1].

In each endcap there are two orthogonal layers of 1.9mm-pitch silicon sensors, each preceded by thin layers of lead that initiate electromagnetic showers. The silicon layers are known as "ES+F, ES+R, ES-F, ES-R", where the nomenclature reflects the endcap (+ or -) and whether the layer is "Front" or "Rear"

The physics performance of the Preshower relies upon excellent detection efficiency and accurate alignment to the Tracker and the Endcap ECAL crystals. More than 99.8% of Preshower strips are operational, with a detection efficiency better than 99.5%. The alignment is measured with an accuracy of better than 1mm [2].

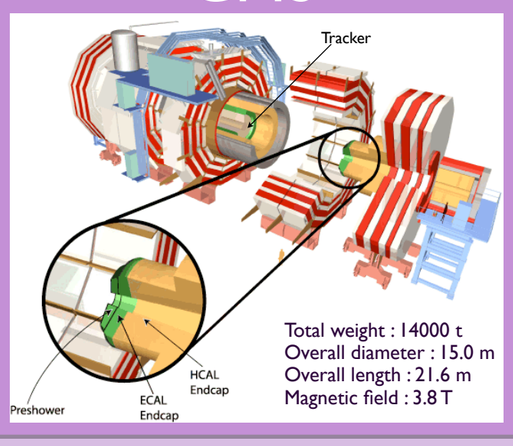
Ladder

ES includes 4288 micromodules and 504 System Mother Boards.

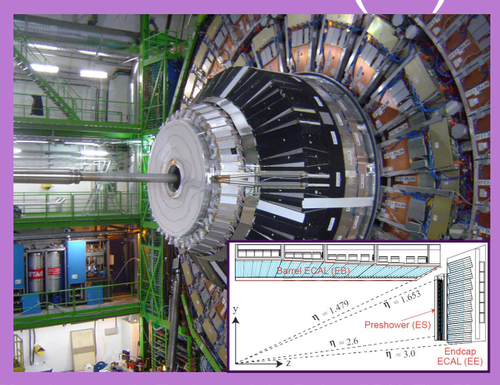


System Mother Board :
Convert analog samples to digital, package data and transfer optically.

CMS

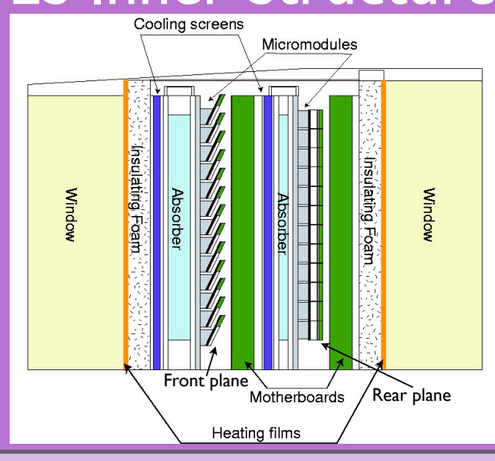


Preshower (ES)



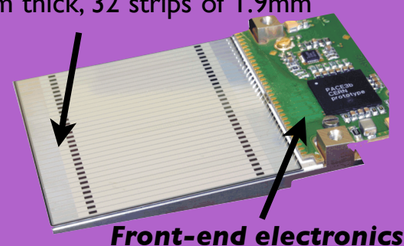
ES sit between the Tracker and the Endcap ECAL. The ES are 2.5m diameter 20cm-thick discs covering $1.653<|\eta|<2.6$

ES Inner Structure



Micromodule

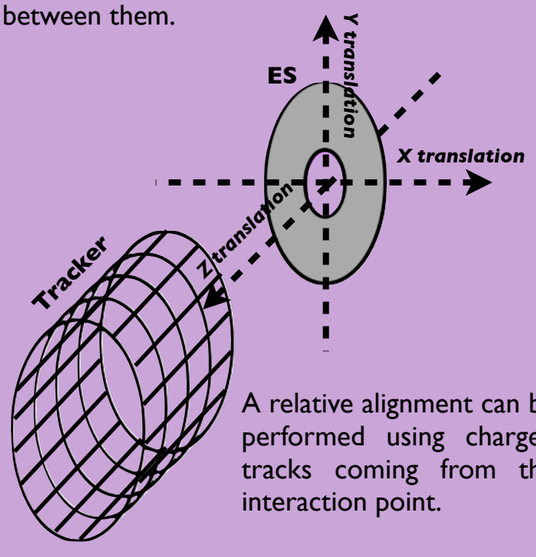
Si-sensor :
Sensor active area is $61\times61mm^2$, 310 μm thick, 32 strips of 1.9mm pitch



Front-end electronics :
Pre-amp, shaping, 25ns sampling and storage until reception of trigger

Alignment with respect to Tracker

As the tracker and endcap disks (supporting the EE and ES) are independent objects there is a non-negligible probability of mis-alignment between them.



A relative alignment can be performed using charged tracks coming from the interaction point.

Selection Criteria :
1). Track selection : High-purity, p_T>1.5 GeV/c, N(valid hits)≥10 (including 1-hit in the outermost layer), 1.7< |η| < 2.3, 1-hit on each ES plane matching the extrapolated track.

2). Prediction selection : 60< Radius <110cm on ES, an extrapolation error < 1cm.

3). Matching selection : Closest reconstructed hit on ES within a search window 30 mm, veto bad sensors.

Obtain the 3 alignment parameters :
Minimizing χ^2 iteratively by calculating all selected tracks in all events

$$\chi^2 = \sum_i \varepsilon_i^T \mathbf{V}_i^{-1} \varepsilon_i \quad => \sum_i \frac{(\Delta x_i)^2}{(\sigma^2_{x\,\text{predicted}})_i + \sigma^2_{x\,\text{measured}}} + \frac{(\Delta y_i)^2}{(\sigma^2_{y\,\text{predicted}})_i + \sigma^2_{y\,\text{measured}}}$$

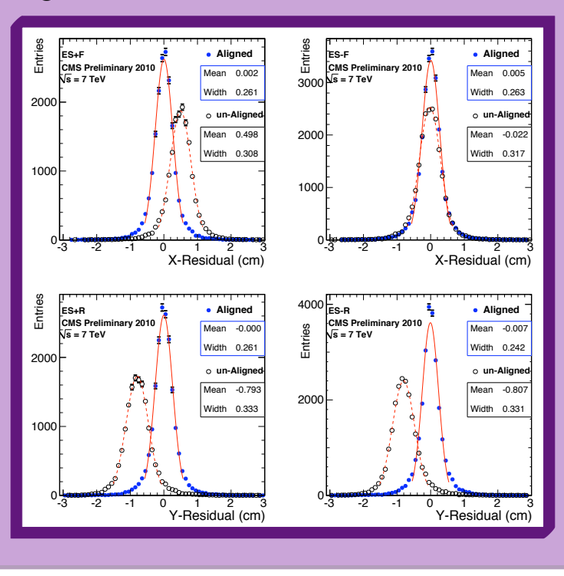
Residual vector :

$$\varepsilon_i = \begin{bmatrix} X_{i,\text{predicted}} - X_{\text{alignment}} - X_{i,\text{reconstructed}} \\ Y_{i,\text{predicted}} - Y_{\text{alignment}} - Y_{i,\text{reconstructed}} \end{bmatrix}$$

Prediction error & resolution :

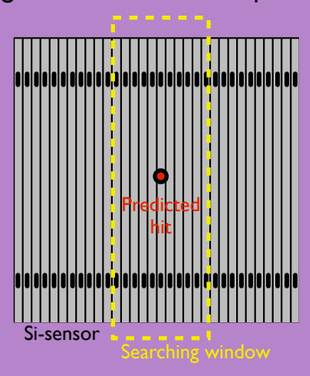
$$V_i = \begin{bmatrix} \sigma_{xx} & \sigma_{xy} \\ \sigma_{xy} & \sigma_{yy} \end{bmatrix}_{\text{prediction}} + \begin{bmatrix} \sigma_{xx} & \sigma_{xy} \\ \sigma_{xy} & \sigma_{yy} \end{bmatrix}_{\text{measurement}}$$

Results :
The below plot shows the residuals for each ES plane, both before and after software alignment.



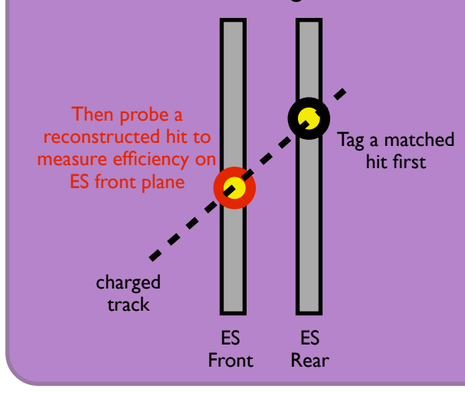
Tracker-ES hit-matching efficiency

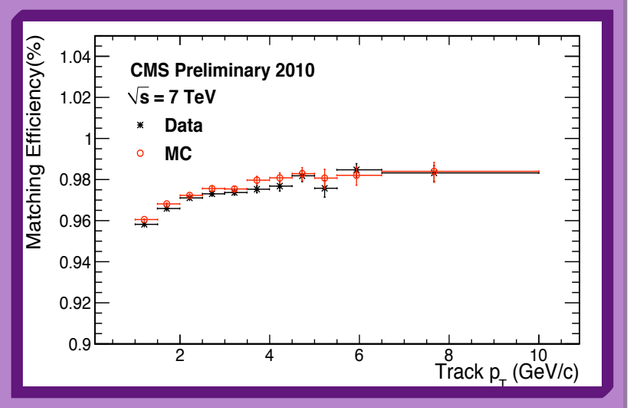
Hit-matching efficiency :
Defined as the probability of finding a hit in the ES within a window around extrapolations of charged tracks from the primary vertex.



Results :
The below plot shows this efficiency, averaged over all four ES planes, as a function of track p_T for 7 TeV minimum bias collision data and simulation (MC). The p_T dependence is due to impurity of the track reconstruction algorithm, mainly fake tracks like the multiple scattering ...etc. The real ES efficiency for p_T > 7 GeV is, in the simulation (MC), 100%. The agreement between data and simulation (MC) demonstrates that the plateau below 100% in below plot is indeed due to inefficiencies in the track extrapolation.

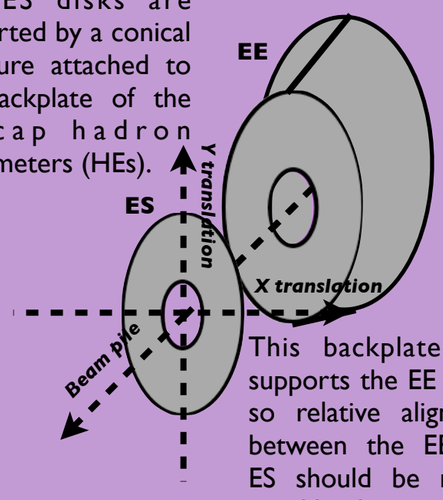
Measured efficiency :
Actually a convolution of the efficiencies of the tracking, the extrapolation to the ES and the ES itself with "Tag & Probe" method.





Alignment with respect to EE

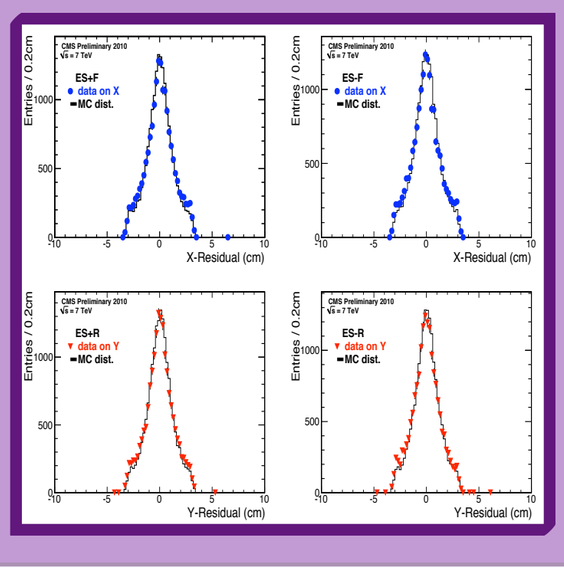
The ES disks are supported by a conical structure attached to the backplate of the endcap hadron calorimeters (HEs).



This backplate also supports the EE Dees, so relative alignment between the EE and ES should be rather good by design.

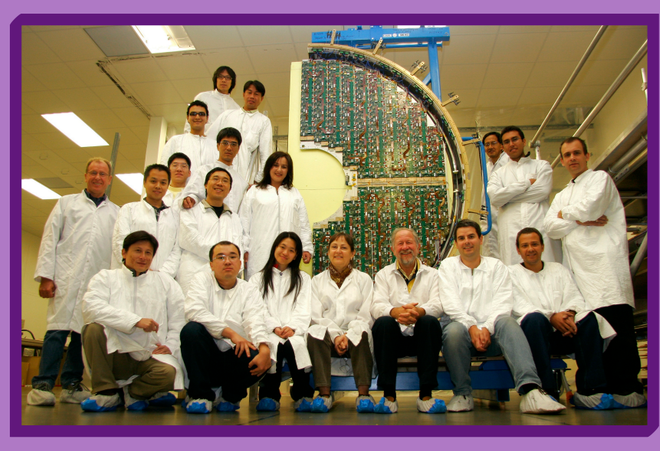
Selection Criteria :
EE clusters with E_T > 2 GeV, without isolation or e/γ identification requirements, were used as the source of this study, with position measurements being made in the EE and the ES.

Results :
The below plot shows the alignment between the EE and ES. The "out of the box" mis-alignment is less than half a millimeter in all planes.



Summary

There is a relative mis-alignment in the vertical positions of the Tracker with respect of both ES endcaps of about 8mm and a horizontal mis-alignment between the Tracker and the positive ES endcap of about 5 mm. The mis-alignment between the EE and ES is less than half a millimeter in all planes. The ES hit-matching efficiency in 7 TeV data is over 98%, consistent with that expected from simulation (MC).



References

[1] "*The CMS Experiment at the CERN LHC*", *2008 JINST 3 S08004*
[2] "*Electromagnetic calorimeter commissioning and first results with 7 TeV data*", *CMS NOTE-2010/012*