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THE CALIBRATION OF CMS PRESHOWER DETECTOR DURING LHC RUN 2

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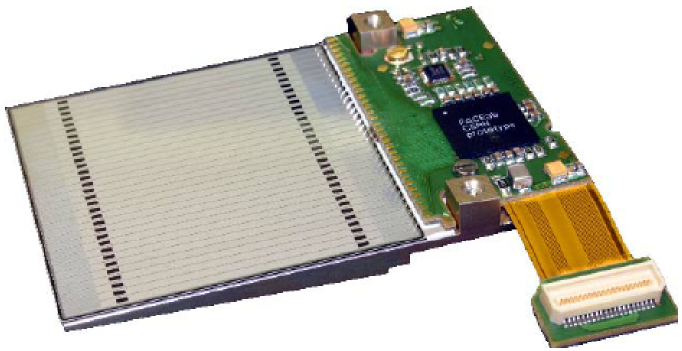
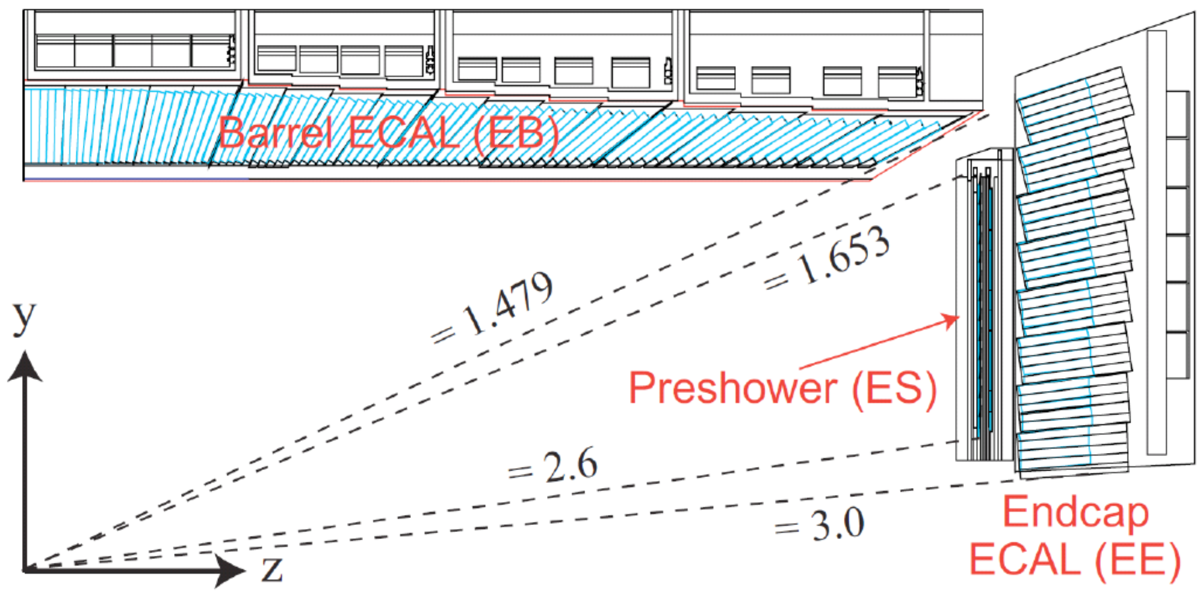
The CMS Preshower detector

- Sampling detector of CMS Electromagnetic Calorimeter (ECAL)
- Cover the region of 1.65 < |η| < 2.60 (Endcap region)
- 2 layers of lead arbsorbers followed by 2 layers of silicon sensors, has 4288 sensors in total.
- Sensor: 32 silicon strip sensors, thickness: 0.32mm
- Has good spatial resolution



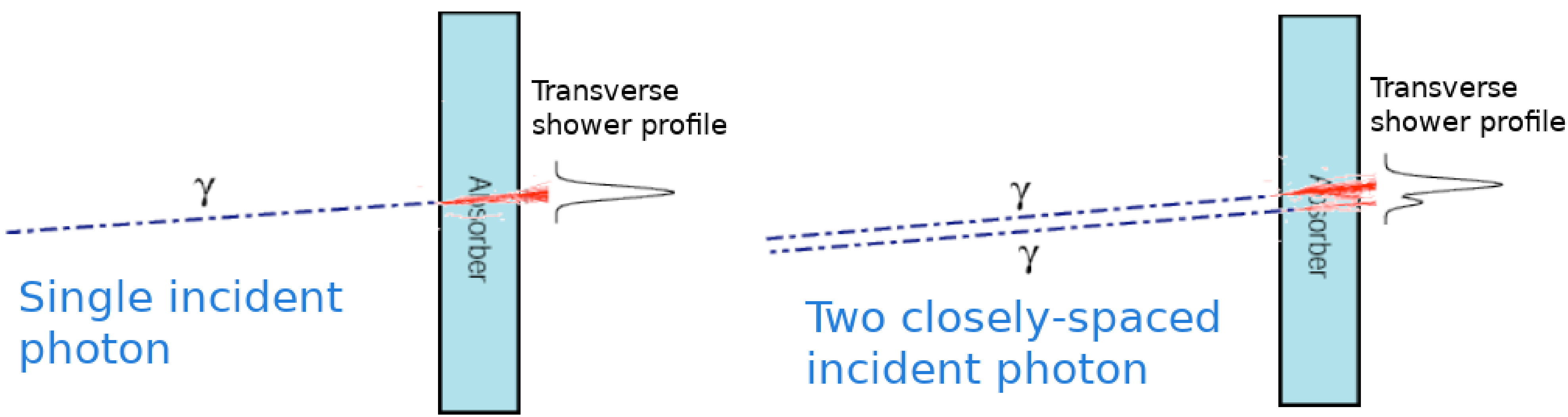
1 sensor contains 32 silicon strips



The schematic view of the CMS ECAL [2] shows the region cover by the Preshower

The CMS Preshower detector (cont)

- In the high η region, closely-spaced photon pairs from π^0 decays mimic the high energy photons from Higgs boson decays.
- The Preshower increases the ability to distinguish between different types of incoming particles (photon pair from pion and photon from Higgs boson) in the endcap region



Why we need to calibrate the Preshower

- Charged particles and photons lose energy when they traverse the Preshower (from 6 to 8% of the energy of the electromagnetic shower is deposited in the Preshower [1])
- The sensors of the Preshower are damaged by radiation → The energy recorded by the Preshower changes over time.
- Calibrating the Preshower help estimate the total energy of the particle -> stabilizes the measured energy
- The calibrations have been done periodically (every 15-20 fb^{-1}) with data taken in 2016, 2017 and 2018
- The calibrations were done at the sensor level

Calibration method

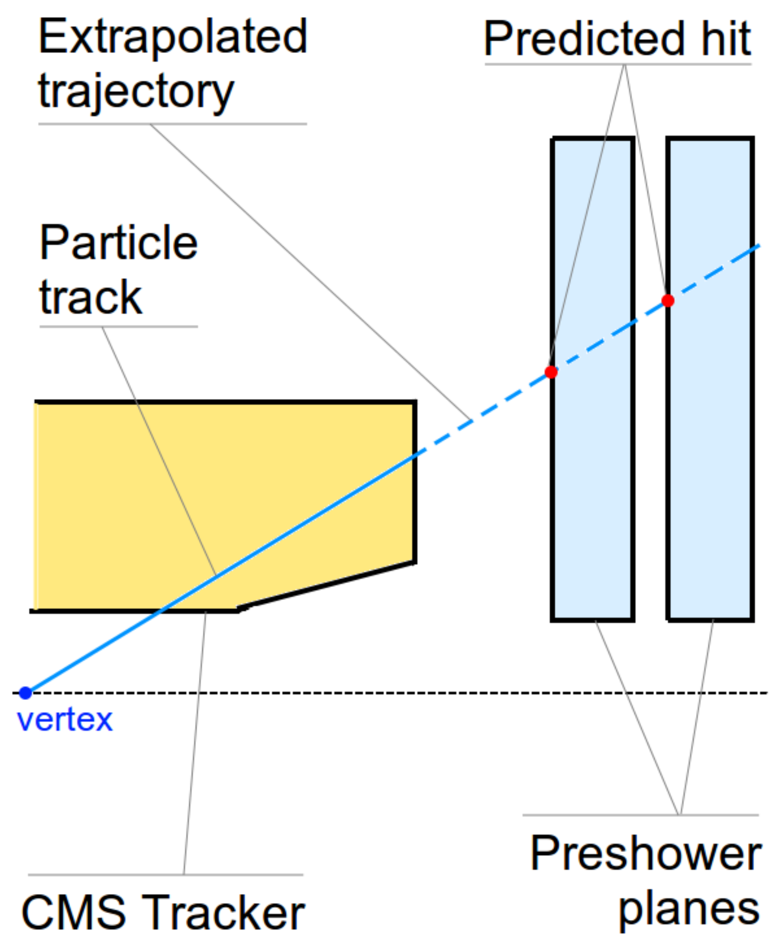
Charged hadrons are used for the calibration.

Data is taken in "**High Gain**" (HG) mode of the Preshower

Particle energy is close to Minimum Ionizing (MIP)

The procedure consists of 2 steps:

1. Select the hits close to the position predicted by the track trajectory measured in the Tracker to obtain the deposited energy spectrum for each sensor.
2. Fit the spectra with Landau distribution convoluted by a Gaussian to estimate the most probable energy value.

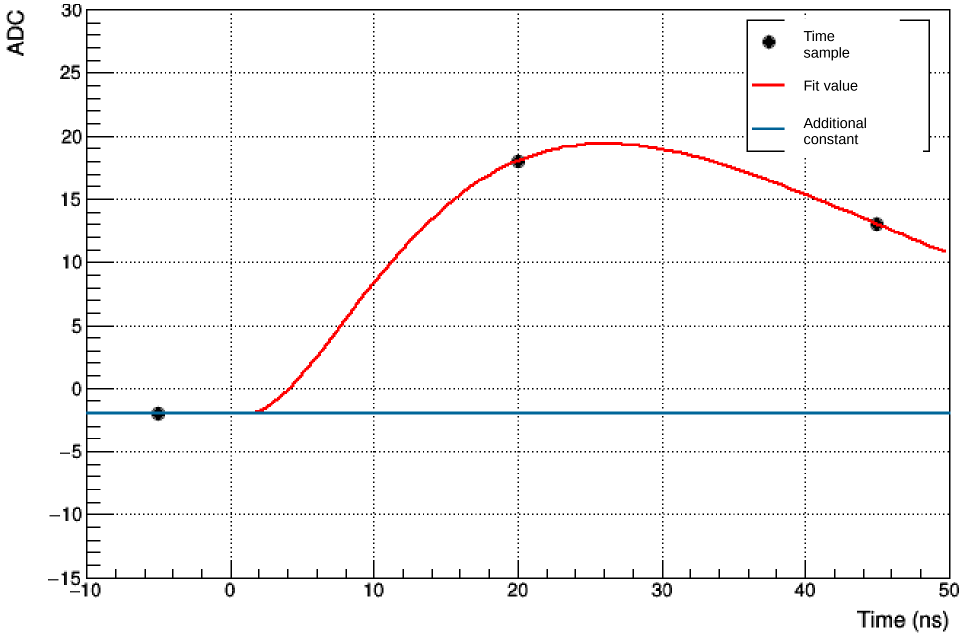


Calibration method (cont)

Track selection: Track P_T > 1.0 GeV

Rechit selection

- Close to track pointing
- Rechit isolation: we require no other hit within 3 strips around the selected hit to prevent pile-up effect.



Rechit energy reconstruction:

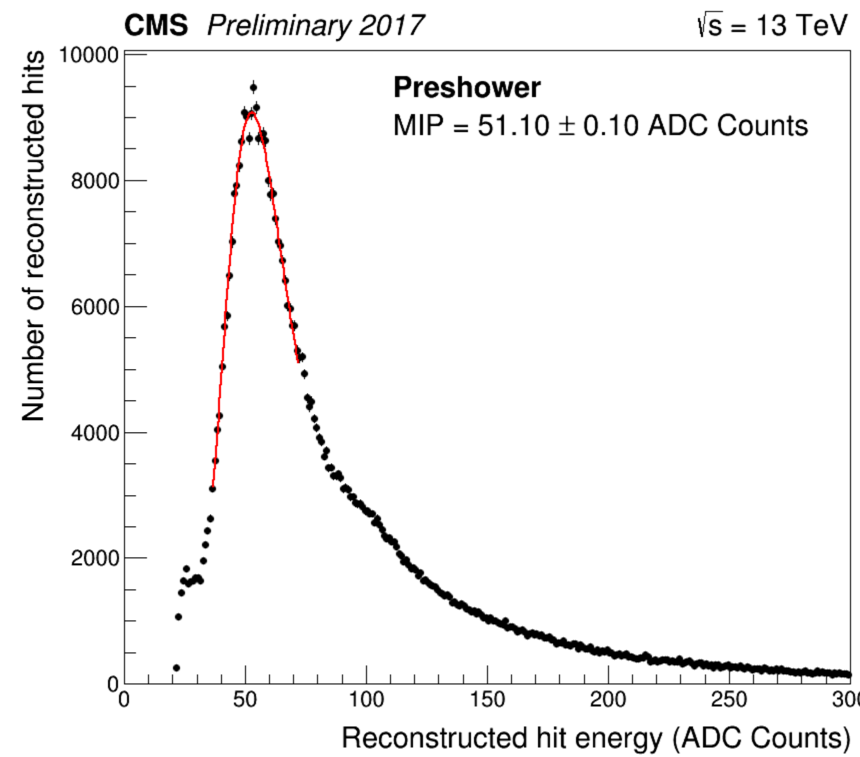
- Reconstruct pulse from 3-time sample
- Fit function: $A(t) = A_0 \left(\frac{\omega}{n}(t - t_0)\right) e^{(n - \omega(t - t_0))} + Additional\ constant$
- Empirical value: n = 2.016; ω = 0.08373; The obtained amplitude is the rechit energy.

Since a particle does not hit the sensor perpendicularly in general, we apply an angle correction by multiplying the rechit energy with the cosine of the incident angle of the hits

Calibration method (cont)

MIP estimation:

- From the reconstructed rechit energy, obtain the rechit energy distribution for each sensor
- Fit the spectrum by a Landau function convoluted with a Gaussian. The Gaussian describes the energy smearing effect occurs when a particle goes through a thin sensor [3].
- Fit range is constrained around the peak of the spectrum to avoid the disturbance from other sources (pedestal, coincident hits).
- The fit returns the Most Probable Value (MPV) of the Landau distribution, which is the MIP value.



Fit function = Landau × Gaussian

Recorded energy	Energy loss	Energy spreading

Result

1) As the responses of the sensors are affected by radiation, the fit results are used to study the change of MIP response as a function of integrated luminosity w.r.t 2017 calibration (with eta taken into account):

- 2017 calibration: MIP = 1
- Average ratio: ‹ nth MIP › / ‹ 2017 MIP › for each η. (η range = 0.2)
- (nth MIP: 2017A, 2017E...)

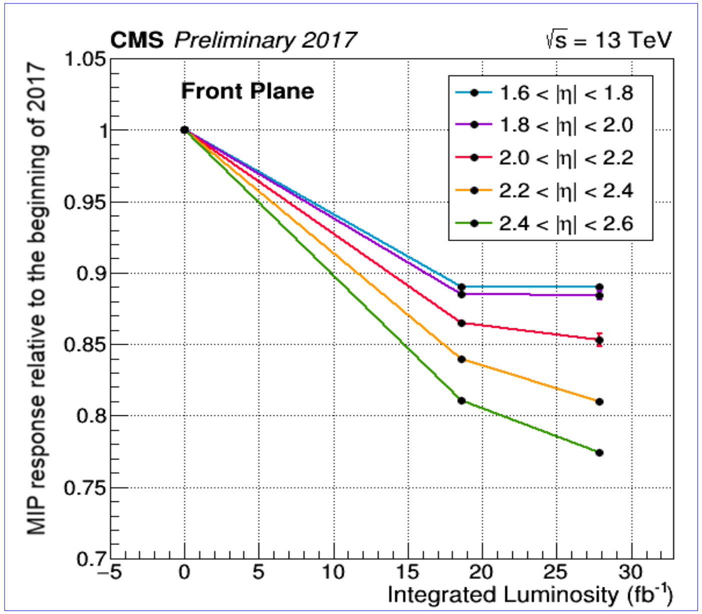
Result – Changes of MIP responses by luminosity

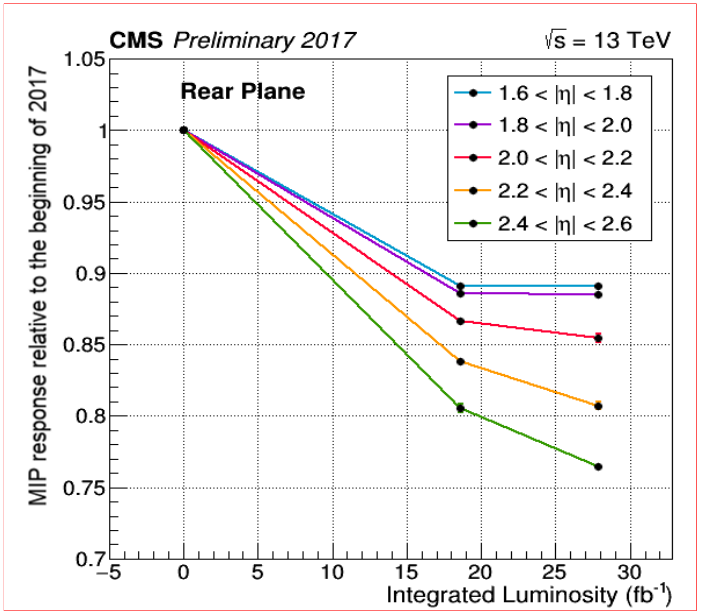
The 2D plots show that: the change of MIP response depends on luminosity and pseudorapidity (η)

The MIPs decrease in general!

The responses of the sensors decrease faster in high η region, around 23% for 2.4<|η|<2.6, compared to ~10% in 1.6<|η|<1.8, after ~30fb^{-1} of pp collision with regard to the first 2017 calibration

The behaviour of the MIPs is similar in both front and rear planes





Result (cont)

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- 2017 calibration: MIP = 1
- Average ratio: ‹ nth MIP › / ‹ 2017 MIP › for each eta. (eta range = 0.2)
- (nth MIP: 2017A, 2017E, ...)

2) **Since the MIP response varies with luminosity, we correct the energy by using the electrons from Z → ee**

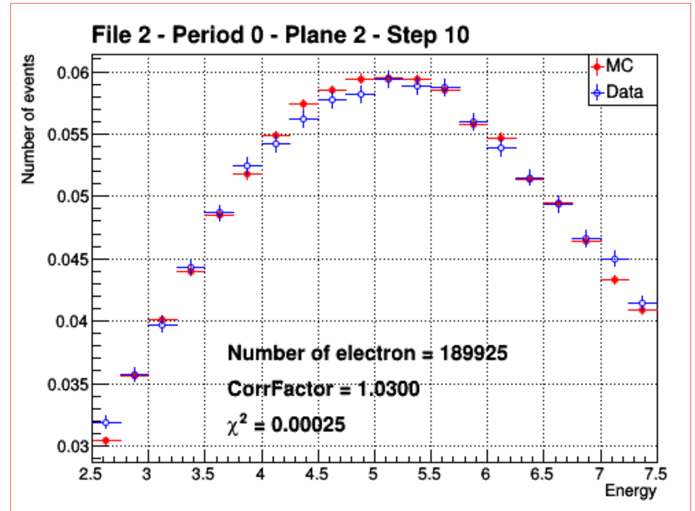
Result – Energy correction

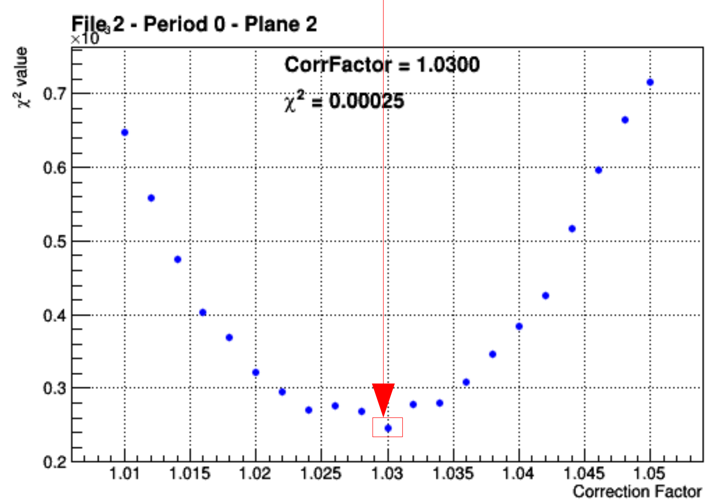
<u>Event selection:</u>

- Electron p_T > 25 GeV (leading) and 15 GeV (trailing)
- 60 GeV < m_{ee} < 120 GeV
- Loose electron ID
- 1.7 < $|\eta_{electron}|$ < 2.5

<u>Electron selection:</u>

- ES Energy P1 & ES Energy P2 > 1GeV





<u>Correction factor estimation:</u>

(1) Multiply electron energy from data with a scale factor

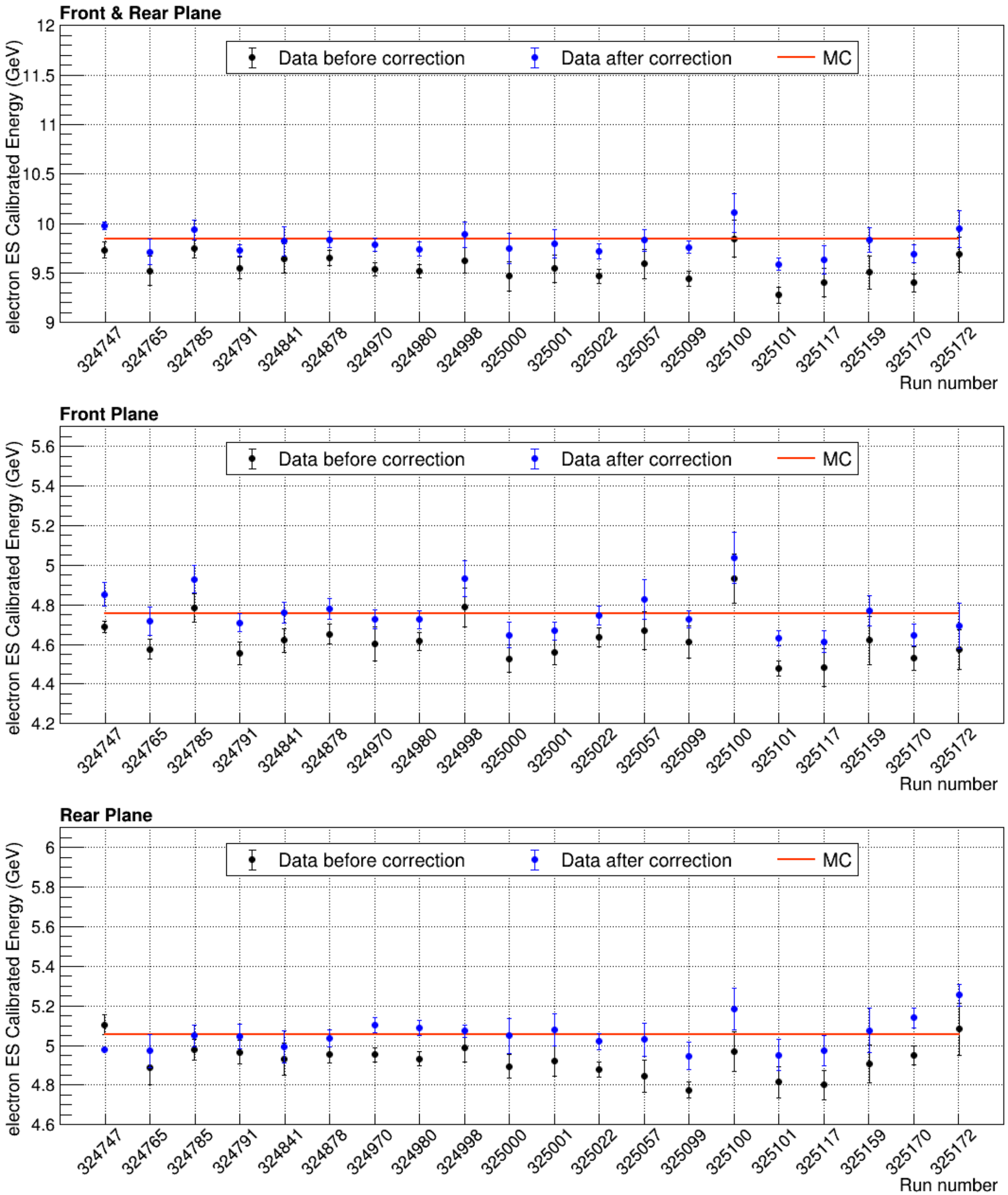
(2) Compare the result with energy from simulation by using the χ^2 value between 2 distributions

(3) Vary the scale factor in (1). The factor correspondent to minimum χ^2 is the correction factor

Correction factors are computed for the whole plane.

Result – Energy correction

After applying the correction, the energy the electrons deposit on the preshower becomes flat and agrees better with MC.



Summary

Conclusion

- MIP calibrations have been produced periodically for Run 2 (2016, 2017, 2018), integrated luminosity ~ 140 fb^{-1}
- The MIP response decreases as a function of luminosity
- The change of the MIP response depends on η due to the larger radiation damage to the sensors in higher η region
- After applying higher voltage to the the silicon sensors, the MIP response increased as expected

References

[1] CMS Collaboration, *"Energy calibration and resolution of the CMS electromagnetic calorimeter in pp collisions at $\sqrt{s}$ = 7 TeV"*, JINST 8, P09009 (2013)

[2] CMS Collaboration, "*The CMS ECAL performance with examples*", JINST 9, C02008 (2014)

[3] S. Meroli et al., "*Energy loss measurement for charged particles in very thin silicon layers*", JINST 6, P06013 (2011)