Calibration of the CMS Hadron Calorimeter using Isolated Muons from Collision Data

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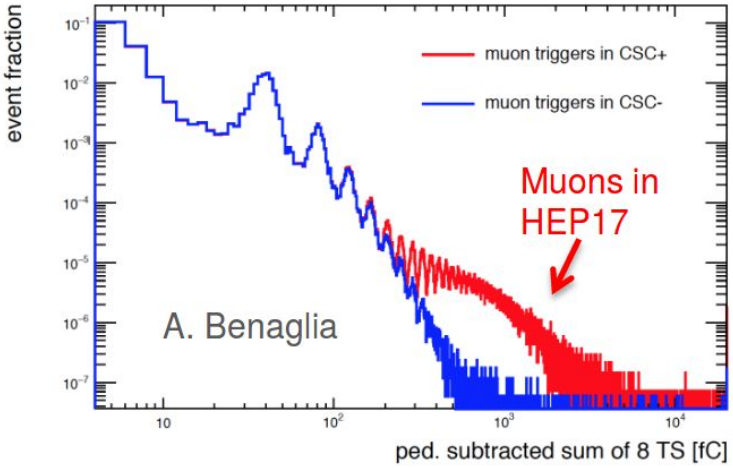
Outline of the talk

- Motivation
- CMS Hadron Calorimeter
- Methodology
- Data Analyzed
- Results
- Summary

Motivation

- Why Muons?
  - Expect the energy deposit in a given depth to depend on the path length of the muon in the scintillator
  - SiPM has much better S/B than HPD and is used (partly) in HE from beginning of 2017

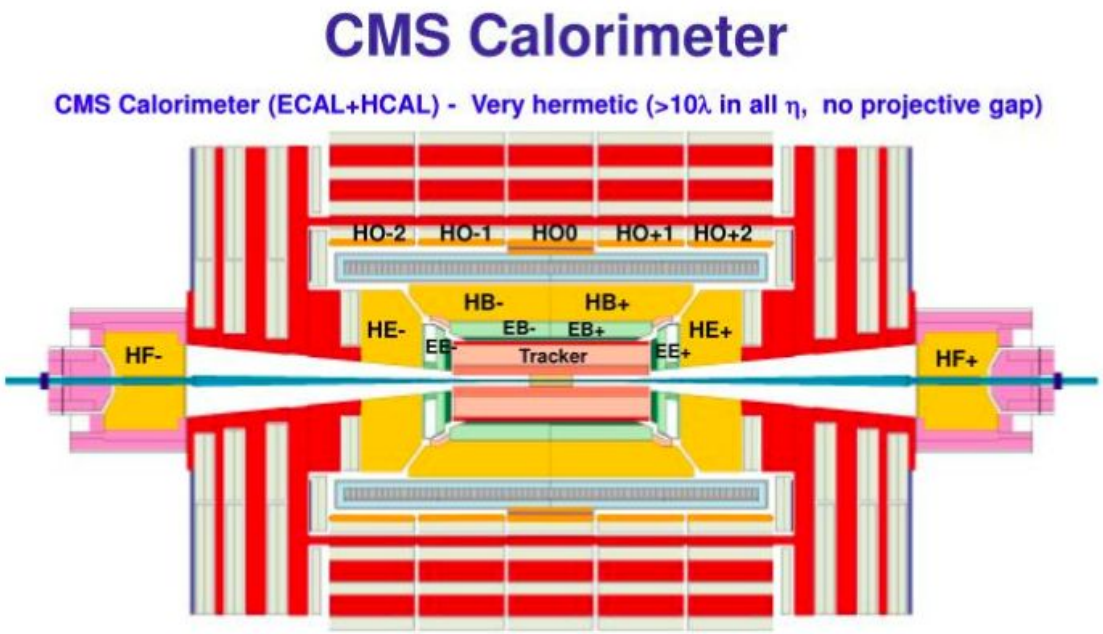


A early illustrative plots on the HEP17 performance with Cosmic muons after the installation in p5

In this study, with muons:

- make depth dependent calibration constants
- look into radiation damage effect by studying the signal in different luminosity blocks

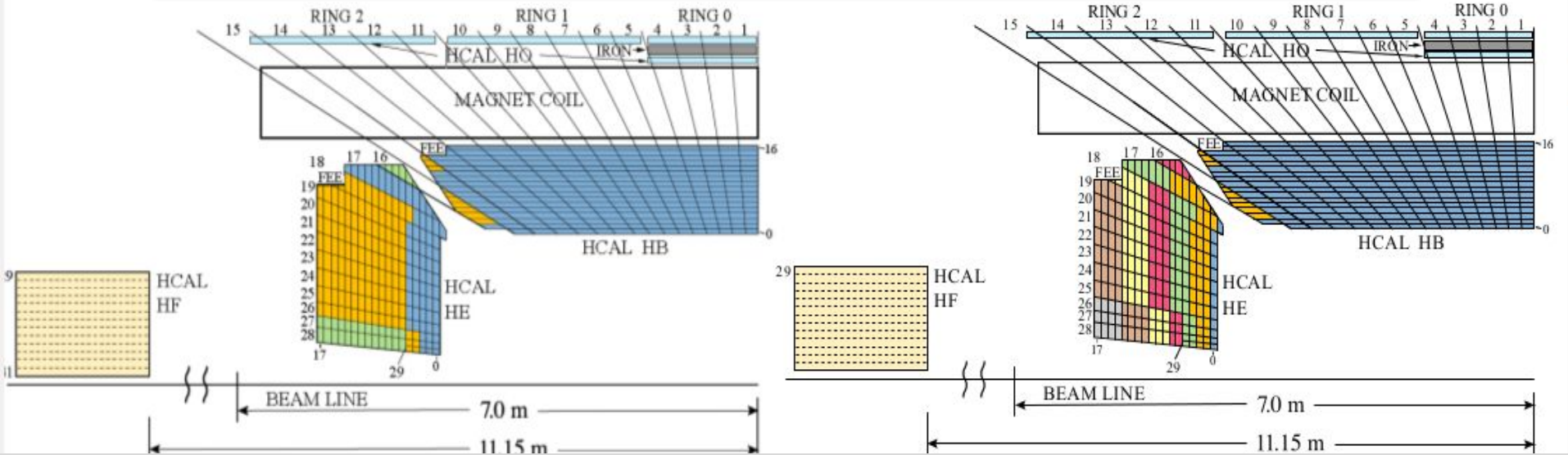
CMS Hadron CALorimeter



- (Layer 0) 9mm Scint/61mm Stainless Steel
- (Layer 1-8) 3.7mm Scint/50.5mm Brass
- (Layer 9-14) 3.7mm Scint/56.5mm Brass
- (Layer 15+16) 3.7mm Scint/75mm Stainless Steel/9mm Scint

- 17 active plastic scintillator tiles for HB and 18 for HE interleaved between the stainless steel and brass absorber plates
- tile size : $\Delta\eta \times \Delta\phi = 0.087 \times 0.087$ unto $|i\eta|$ 20 and increases beyond $|i\eta|$ 21

CMS Hadron CALorimeter

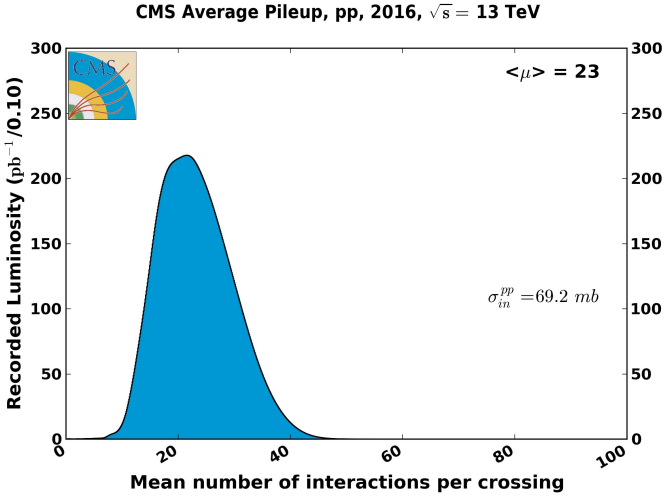


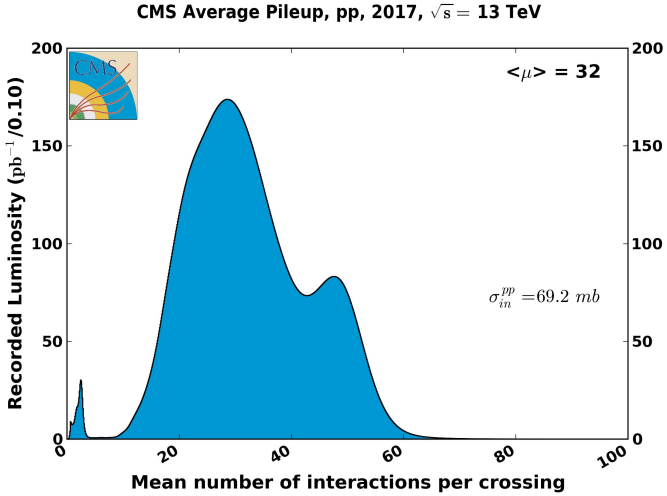
- During 2016, all HB, HE channels are read out using HPD with QIE8 ASIC
- During 2017, one of the readout boxes (HEP17 corresponding to HE +z with iϕ = 63:66) replaced with SiPM photo-transducer and QIE11 ASIC (expanded scale for ADC and also TDC information)
- Number of depth segments increased significantly: 2(5) depth segments for |iη| = 17(18); 6 depth segments for |iη| = 19:25 and 7 depth segments at higher |iη|
- With tracker and muon detector coverage one can access up to |iη| = 26

Data Analyzed

For the Analysis :

- Entire 2016 and 2017 proton-proton Collision data analyzed corresponding to integrated luminosity of ~31 fb^{-1} and ~49 fb^{-1} respectively.



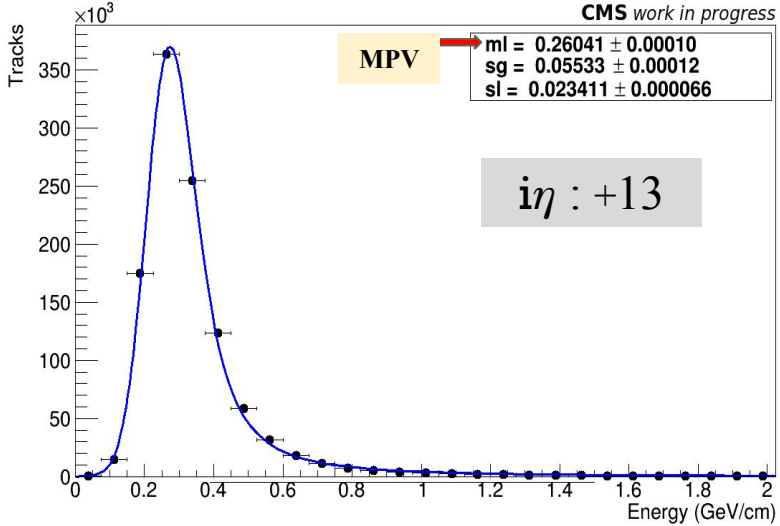


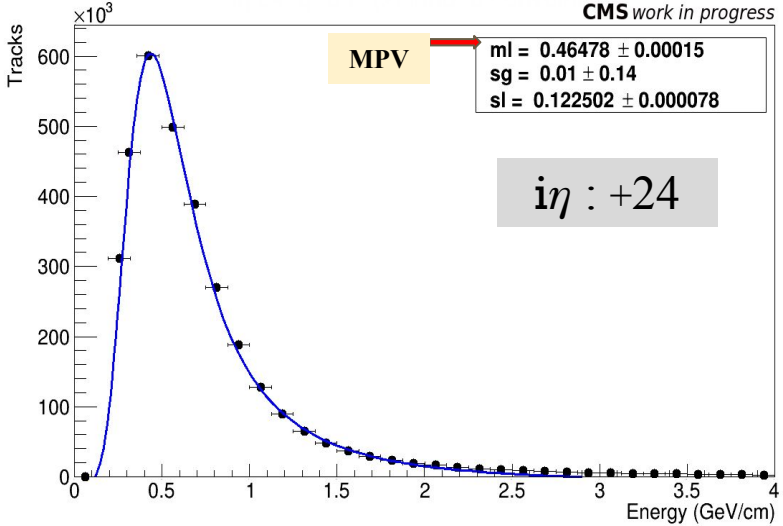
Mean no. of interactions per crossing during 2016 and 2017

Methodology

- Select well measured muons with $p_T > 20$ GeV satisfying medium muon ID
  - It should be a Global or a Tracker muon
  - Consider candidates which satisfy PF muon criterion
  - At least 1 hit in the pixel detector
  - well isolated (< 0.15) using $\Delta\beta$ correction in a cone of size 0.4
- Propagate the track to the surface of ECAL and HCAL
  - track has to cross a given HCAL tower (not shared between towers having different $i\eta$ or $i\phi$)
  - energy in the HCAL tower hit is the highest within a 3x3 matrix surrounding the hit tower
  - check energy in each HCAL hot cell within a 3x3 matrix
- Fit the energy spectrum for a given cell (fixed $i\eta$, $i\phi$, depth) with Gaussian-convoluted Landau function : to calculate Most probable value of energy (MPV)
- For radiation damage studies take away the correction factors applied at reconstruction phase
  - Gain and response correction to get charge in fC

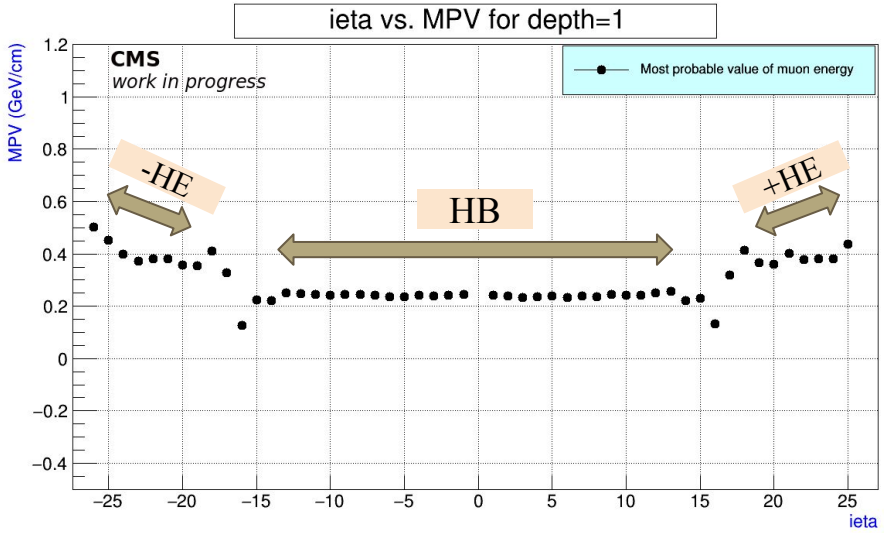
Some fitted distributions of Path length corr. energy from 2016 Data

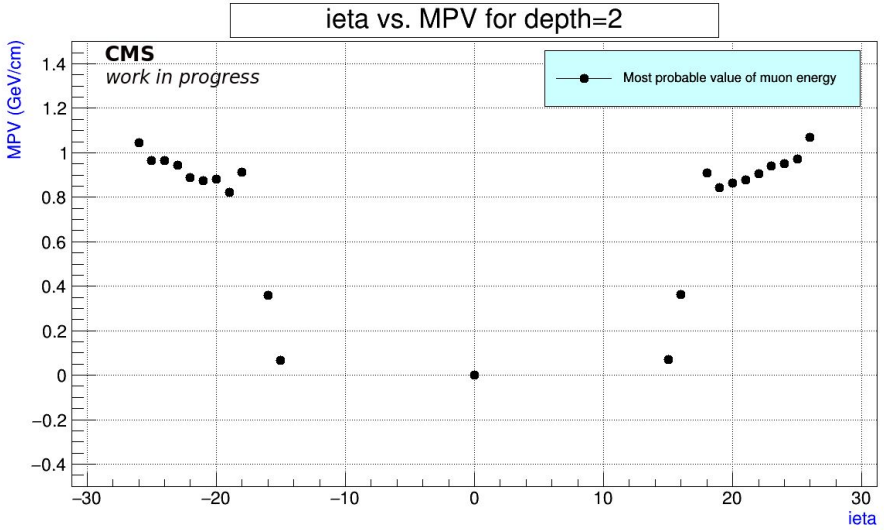




- The path length corrected energy corresponds to the Energy divided by the active length in the cell.
- These are the fitted distributions of energy using Landau function convoluted with a Gaussian.
- The mean of Landau (i.e. ml) gives the most probable value of energy.

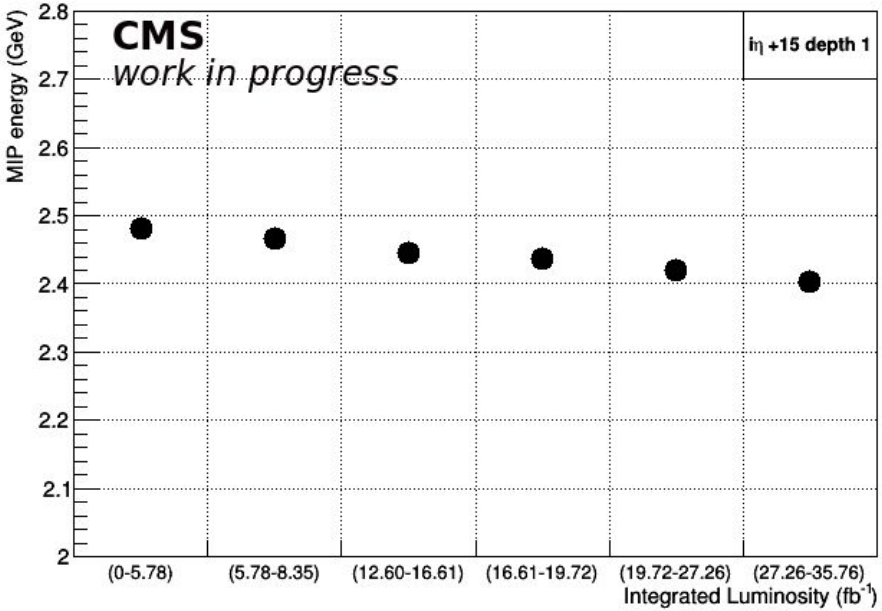
Results from 2016 data

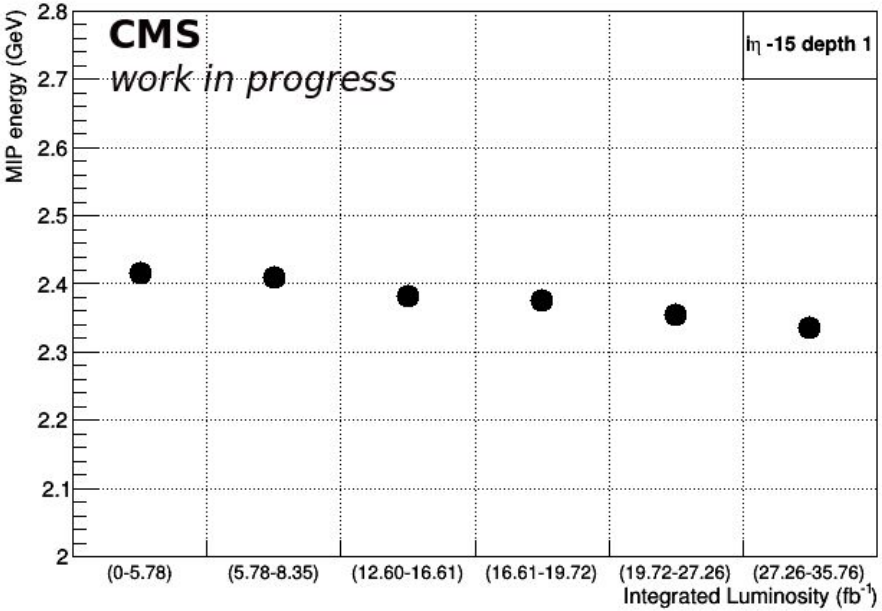




- The MPV of energy is the most probable value of energy divided by active length in the cell
- Flat distribution of path length corrected energy for Barrel but increases with $|i\eta|$ in the endcap

Radiation damage effect from 2016 data

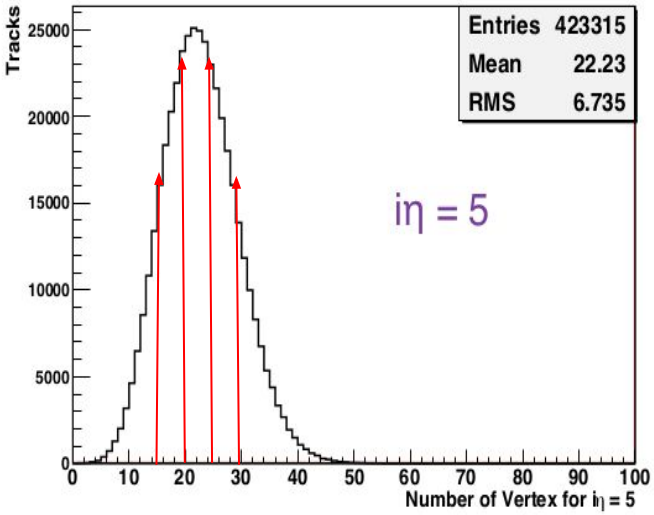


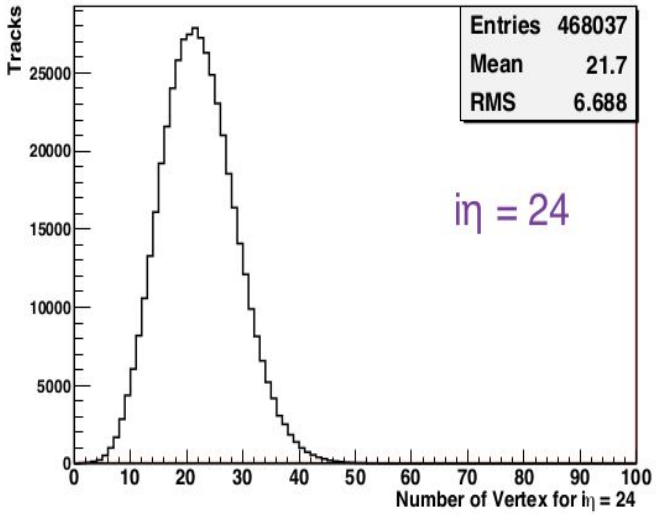


- The energy is uncorrected from the effect of response corrections (undoing radiation damage corrections)
- The MIP energy decreases with increase in integrated luminosity

Analysis with 2017 data

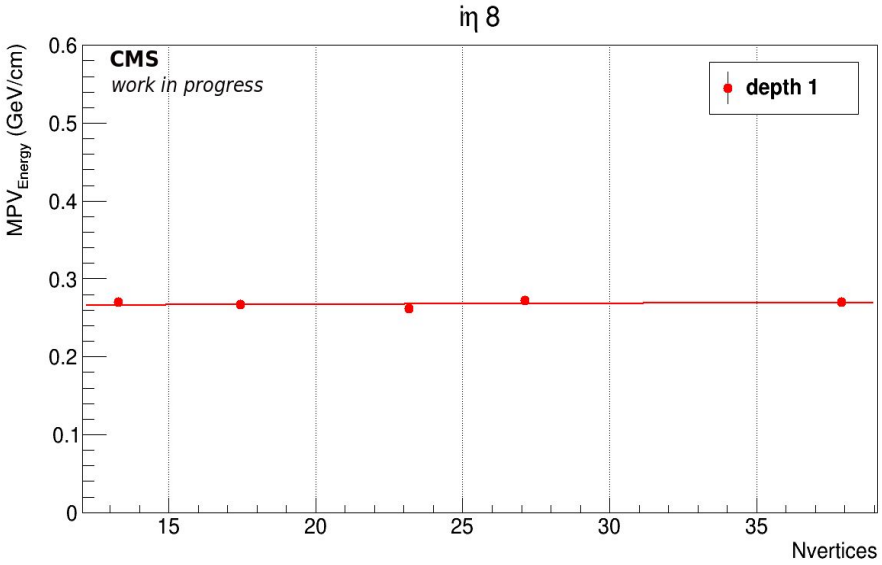
- Look at energy deposit in HB, HE by well measured isolated muons from collision data
- To see the effect of pile-up on MPV in the barrel and end-cap
- To see the effect in HEP17 (SiPMs) and HEM17 (HPDs)
- To study the radiation damage effect with 2017 collision data

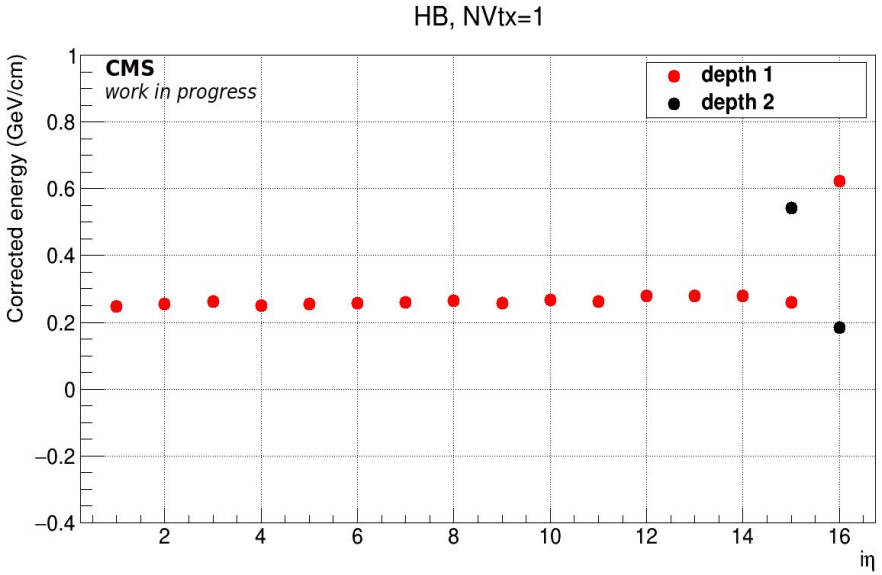




- The distributions are divided into #vtx bins as 0-15, 15-20, 20-25, 25-30, 30-100 for all iη's and depths and examine the energy (charge) distribution there
- For the radiation damage studies, the #vtx bin 25-30 chosen because of less variation in its mean value over the periods.

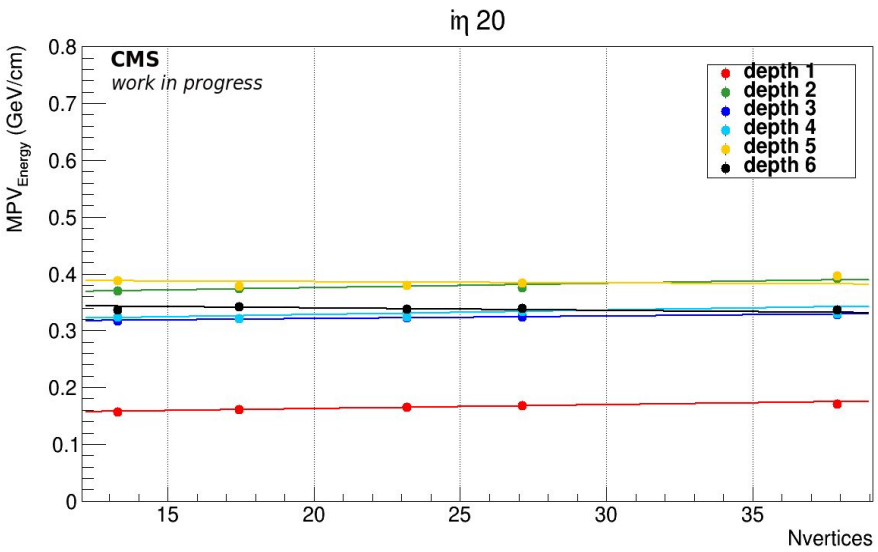
Path-length corrected energy vs. Nvtx for HB: RBX17

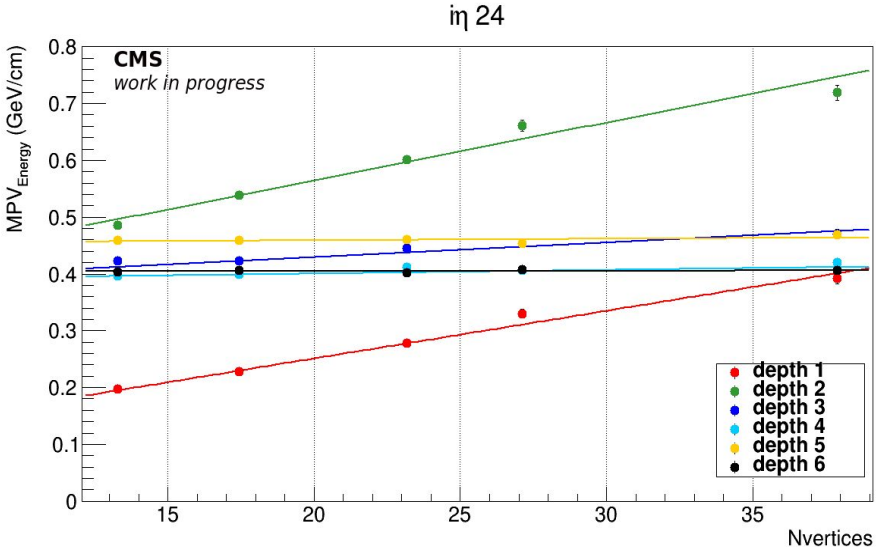




- Extrapolate the MPV's to NVtx = 1 and examine the MPV's after PU correction
- The iη's in barrel does not show increase in MPV of energy w.r.t increase in |iη|

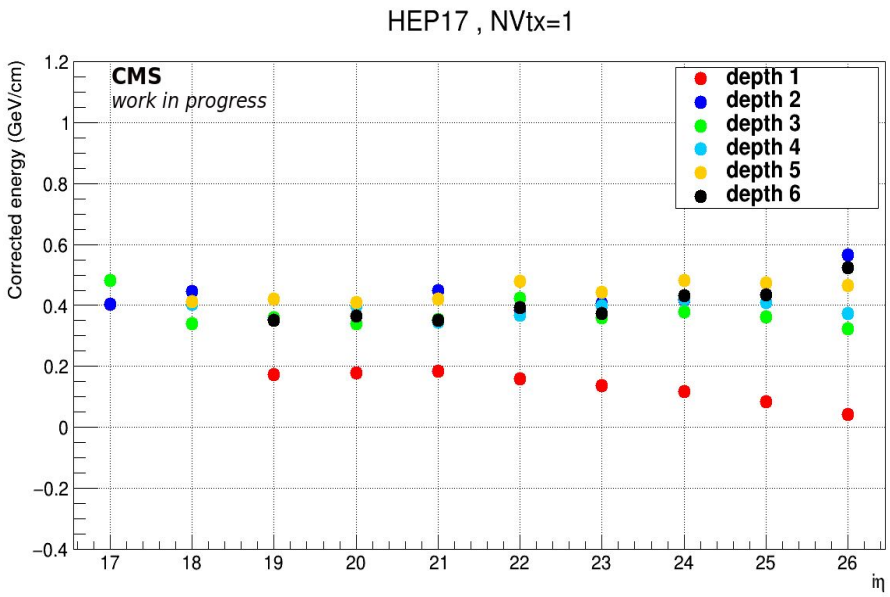
Path-length corrected energy vs. Nvtx for HEP17

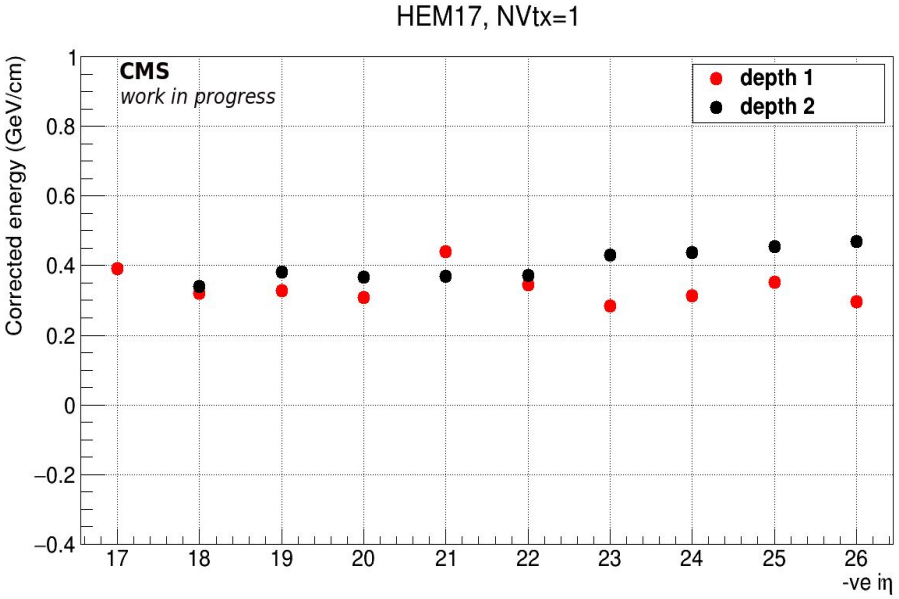




- Lower iη's do not show much dependence of MPV as a function of NVtx but there is significant NVtx dependence for higher iη's and smaller depths
- Extrapolate the MPV's to NVtx = 1 and examine the MPV's after PU correction

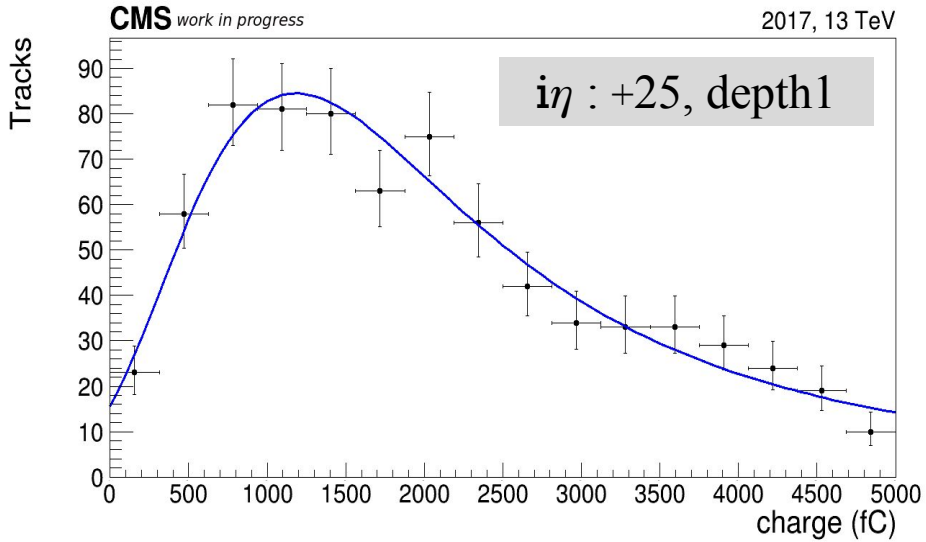
Corrected Energy for NVtx =1 in HEP17(SiPM) & HEM17(HPD)

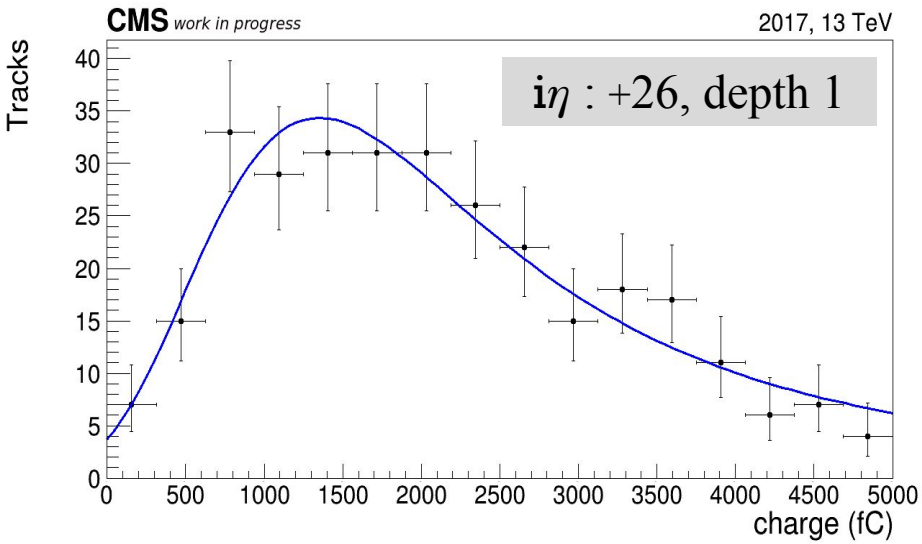




- MPV of energy in case of Depth 1 for HEP17 show some decrease with increase in iη but this behavior is not seen in case of HPD's

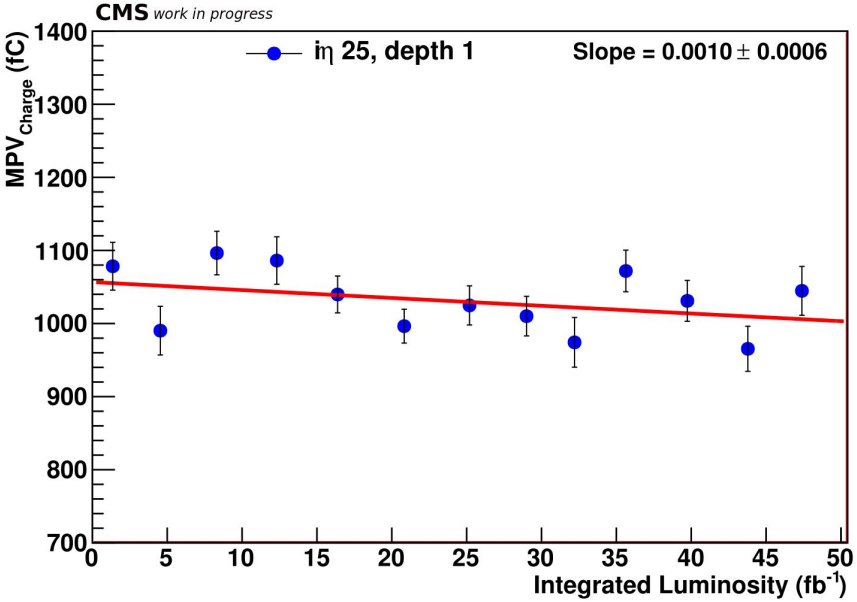
Some fitted distributions of measured charge from 2017 data

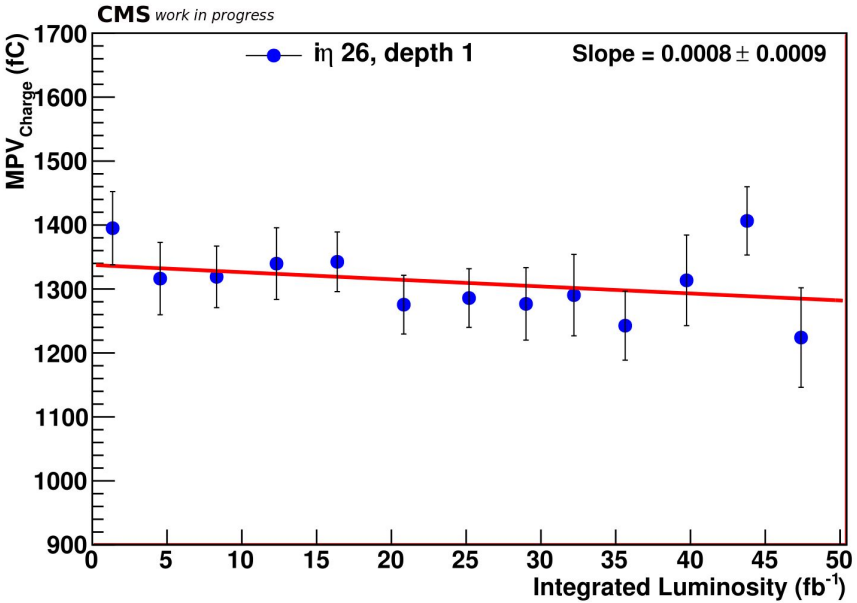




- These are the fitted distributions of charge using Landau function convoluted with a Gaussian.
- Gain and response corrections were taken out to get the charge in fC.
- Calculated the MPV of charge for entire 2017 data divided in 13 luminosity blocks to see the trend in MPV.

Radiation damage effect from 2017 data





- The MIP charge decreases with increase in integrated luminosity for higher iηs although slopes are not much large.

Summary

- From the 2016 data analysis, the MPV decreases with the increase in the integrated luminosity and the calibration constants are updated accordingly.
- From the 2017 data analysis, the behavior of HPDs and SiPMs is consistent to each other.
- Radiation damage studies have been performed with 2017 data as well.

Thank You