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

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Outline of the talk

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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. Benaglia

Muons in HEP17

event fraction

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 $|i\eta| 21$
- 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 $i\phi = 63:66$) 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 $|i\eta| = 17(18)$; 6 depth segments for $|i\eta| = 19:25$ and 7 depth segments at higher $|i\eta|$.
- With tracker and muon detector coverage one can access up to $|i\eta| = 26$. 
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.
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
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.
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 $|\eta|$ in the endcap.
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 |\eta|'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.
Extrapolate the MPV's to NVtx = 1 and examine the MPV's after PU correction.

The $\eta$'s in barrel does not show increase in MPV of energy w.r.t increase in $|\eta|$. 
Lower $\eta$'s do not show much dependence of MPV as a function of NVtx but there is significant NVtx dependence for higher $\eta$'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 $\eta$ but this behavior is not seen in case of HPD’s
- 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.
The MIP charge decreases with increase in integrated luminosity for higher \( \eta \)s 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