# PF Hadron Cluster Calibration for 12_0_0 ( MC for Run 3)

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# Outline

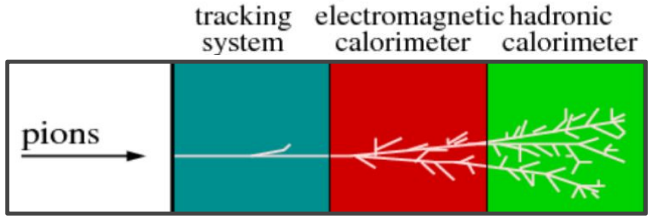
- **Technical Details**
- **Calibration Procedure**
  - **Energy dependent corrections**
  - **Eta dependent corrections**
- **Comparisons between old calibration parameters and new parameters.**
  - **1D response plots**
  - **Summary response plots**
- **Summary**

# Technical Details:

- Centrally generated and reconstructed Single Pion samples
  - In CMSSW version: **CMSSW_12_0_0**
  - GT: 120X_mcRun3_2021_realistic_v6
  - Energy range: 2 - 500 GeV  (using FlatRandomEGunProducer)
  - $|\eta| < 3.0$,  $|\varphi| < 3.14$
  - Particle ID: -211 (charged hadron: $\pi^-$)
  - It is referred as **“Run3”** sample in this presentation.
  - Das link : link

# Motivation for offline calibration

**Simple block diagram**




**E = 0 to 500 GeV**

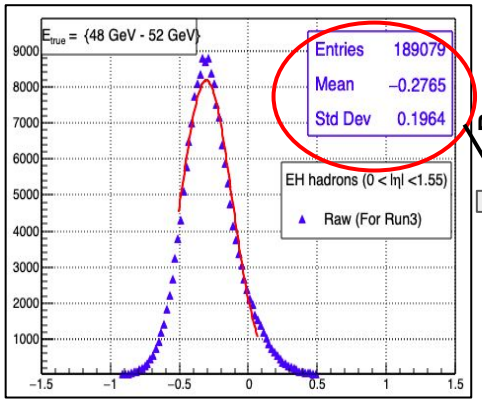
**EH hadrons : hadrons which start showering in ECAL.**

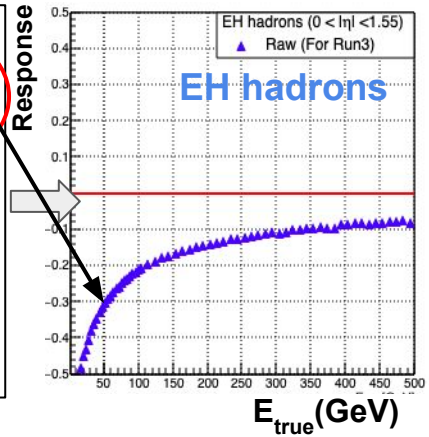
**H hadrons : hadrons which start showering in HCAL**

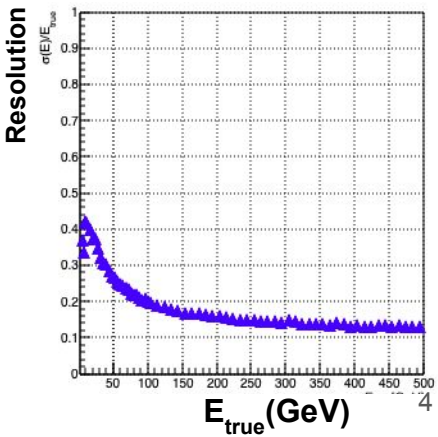
- The total raw energy deposited by hadron : $E_{total} = E_{RawEcal} + E_{RawHcal}$
- Energy response = $(E_{total} - E_{true})/E_{true}$ & resolution = $\sigma(E)/E$
- Plot 1D response distribution and obtain gaus mean & sigma
- Using above mean & sigma , plot response & resolution as a function of true energy

**Response is non-linear**

**1D-response**



# Energy dependent calibrations

- For EH Hadrons:

  $E_{corrected} = a(E_t) * E_{rawEcal} + b(E_t) * E_{rawHcal} + o_{EH}$

- For H Hadrons:

  $E_{corrected} = c(E_t) * E_{rawHcal} + o_{H}$

- $o_{EH}$ & $o_{H}$ : offsets

  $o_{EH}$ = 3.5 GeV

  $o_{H}$ = 2.5 GeV

- These parameters are derived separately for Barrel region (|η| < 1.5), and EndCap region(1.5 < |η| < 3.0)

- **$a(E_{true})$**, **$b(E_{true})$** & **$c(E_{true})$** curves are then parameterized as **$f(E_{true})$**.

- Then we recalculate the **$a(E_{true})$**, **$b(E_{true})$** & **$c(E_{true})$** values using parameterization formula.

- Apply these corrections on the raw ECAL & HCAL energies

To get *a* & *b* parameter

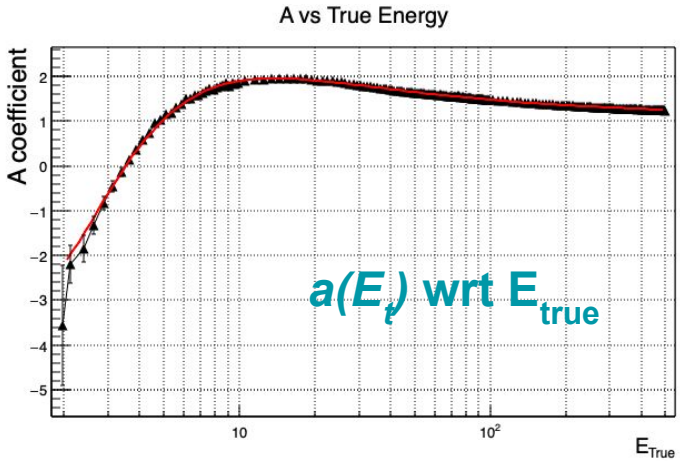
$\chi^2$ minimization for EH hadrons

$$\chi^2_{EH} = \sum_{hadrons} \left[ \frac{E_{true} - E_{corr}}{\sigma(E_e + E_h)} \right]^2$$

To get *c* parameter

$\chi^2$ minimization for H hadrons

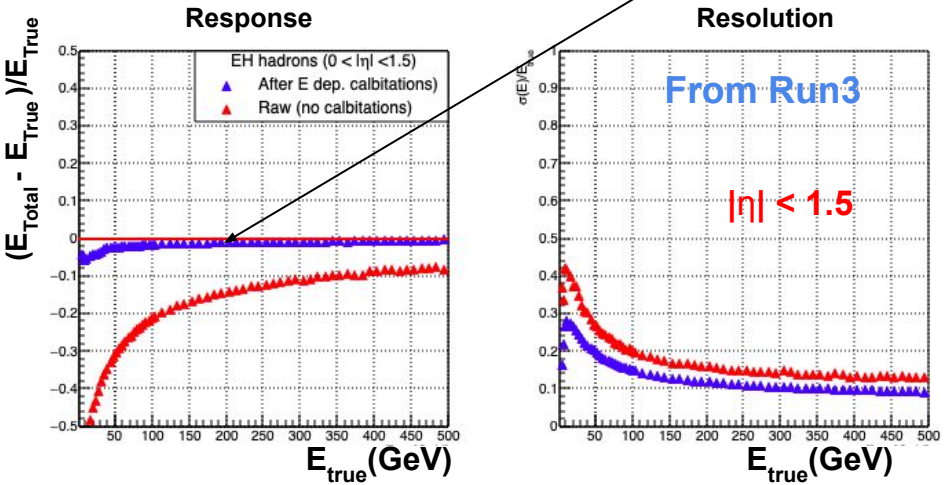
$$\chi^2_{H} = \sum_{hadrons} \left[ \frac{E_{true} - E_{corr}}{\sigma(E_h)} \right]^2$$



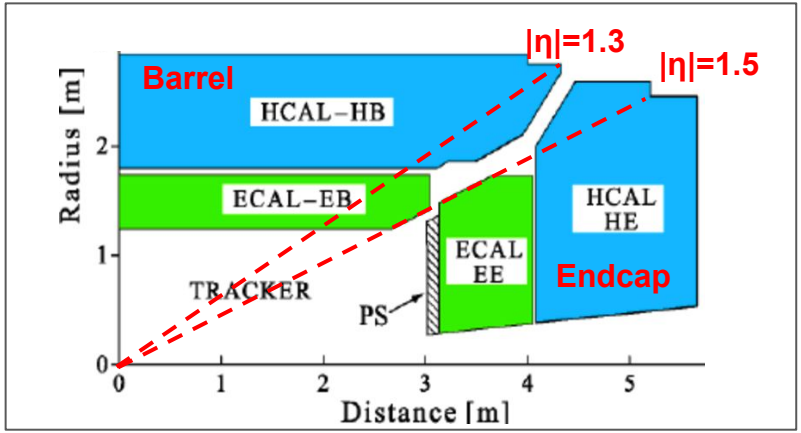
# Need for Pseudorapidity dependent Calibration

- After Energy correction, response linearity is restored but still it was reasonably off from zero response or having incomplete closure.
- There will be residual eta dependency in the response after applying energy dependent corrections which is due to non-uniform detector response in η. (next slide)
- We have divided calibrations into three categories : Barrel(|η| < 1.5), endcap within tracker(1.5<|η| < 2.5) & endcap outside tracker (2.5<|η| < 2.75) regions.

Restored response linearity but incomplete closure




**Longitudinal view of CMS**



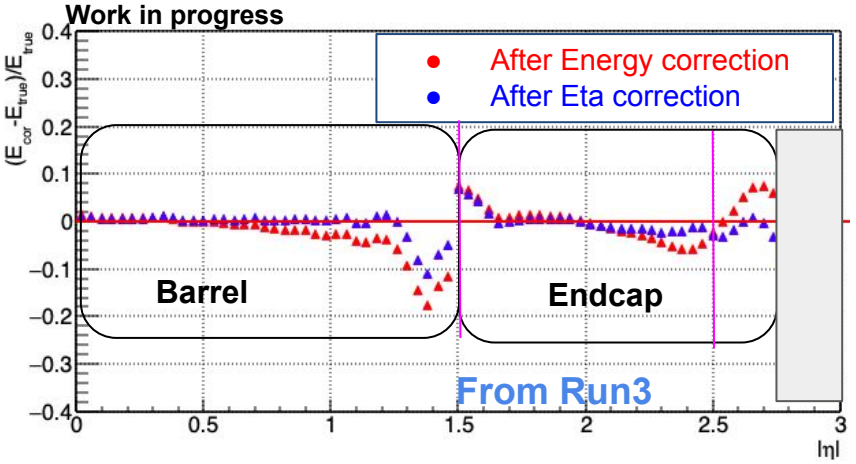
# Pseudorapidity dependent Calibrations

- Separately parametrize the eta dependence for barrel, encap (inside & outside tracker regions).
- **For example**, for EH hadrons in barrel,

$$E^{\eta}_{corr} = (1 + \alpha(E_t) + \beta(E_t) * f(|\eta|)) * E^{Ecal}_{E\text{-}corr} + E^{Hcal}_{E\text{-}corr}$$

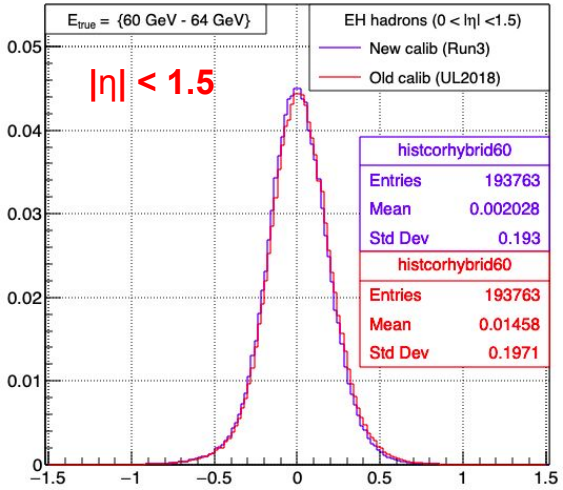
**Where,** $f(|\eta|) = p_3 * (|\eta| - p_0)^{p_1} + p_2$ **, that made PF hadron calibration much easier for Ultra legacy.** link

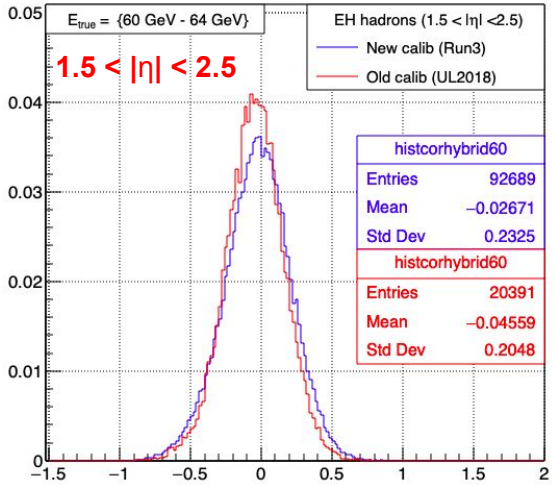
- Then use same chi square minimisation strategy for ***α(E$_t$)*** ***& β(E$_t$).***
- Apply these corrections on the top of Energy corrections
- **We follow the same procedure as used in UL rounds. (**UL2016, UL2017 & UL2018**)**

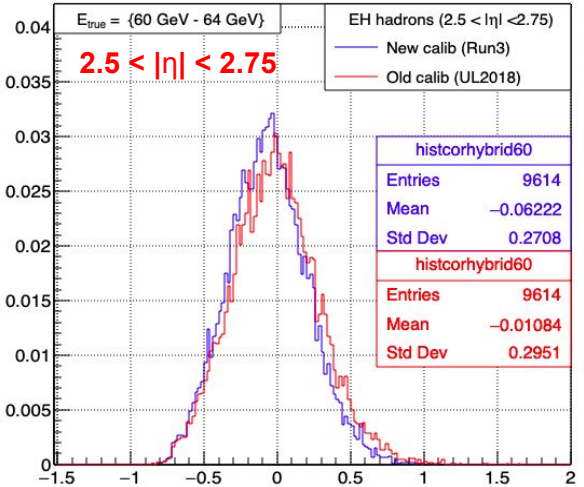



We restrict ourself to |η| < 2.75, don't correct after that because we start losing clusters outside ECAL/HCAL boundaries and don't want to over-correct it.

# 1D Response: EH-hadrons



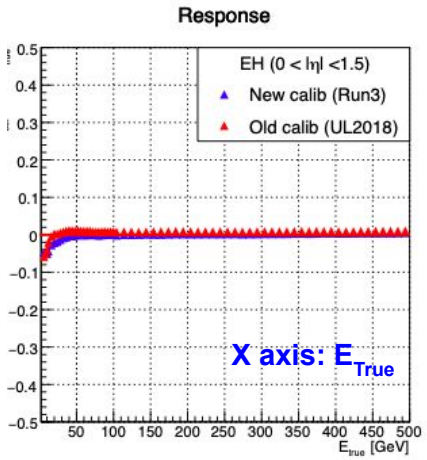

**X axis: $(E_{Total} - E_{True})/E_{True}$**

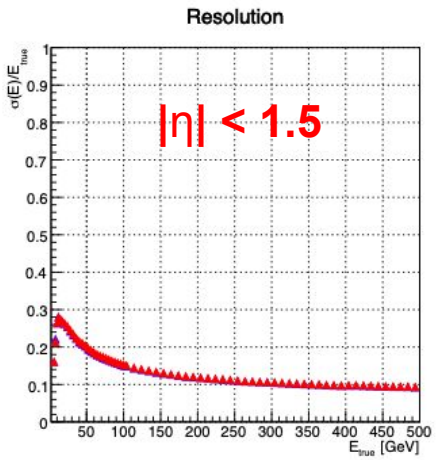
**Response (Mean) is getting improved**

**Red - Using Old calib parameters**
**Blue - Using New calib parameters**

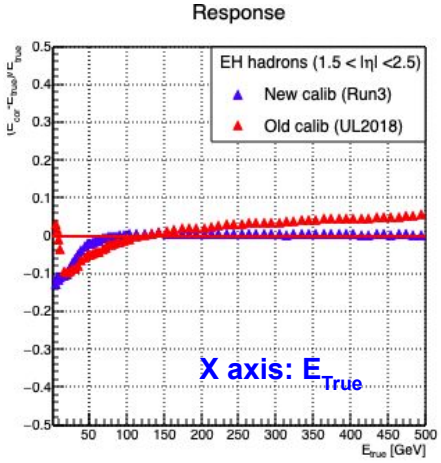
- Most probable value closer to zero residual.
- To get summary plot, Gaussian fit is used (which doesn't always work).
- For more details : barrel (link), endcap in tracker (link) & endcap out tracker (link)

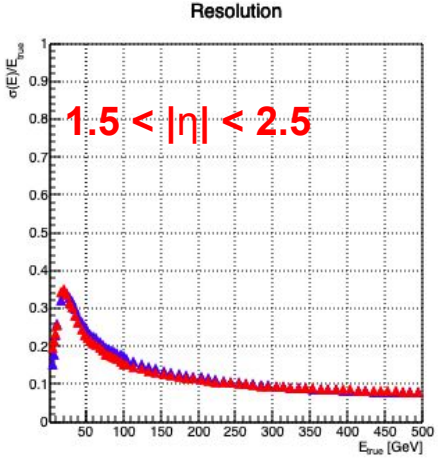
# EH-hadrons (Response as a function of $E_{true}$ )

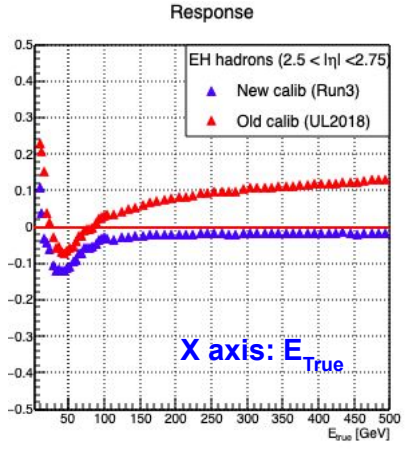


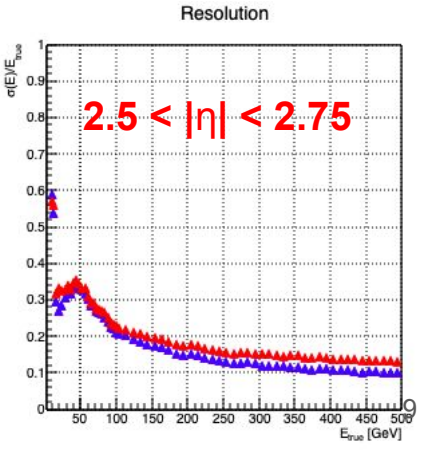




y-axis = $(E_{corr} - E_{true})/E_{true}$



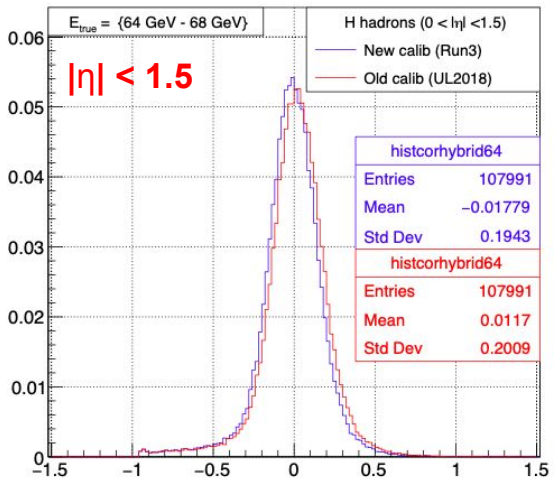



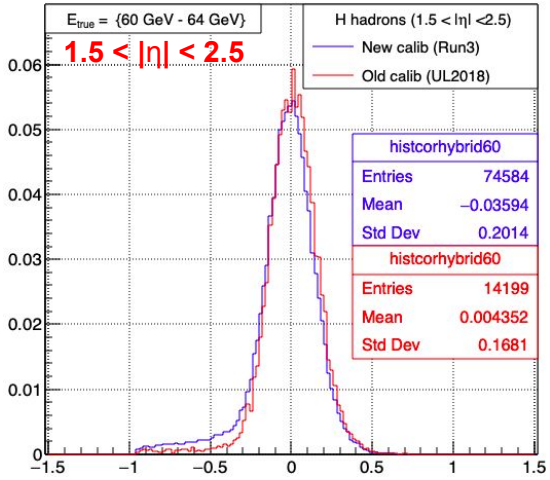

Improvements for EH Hadrons

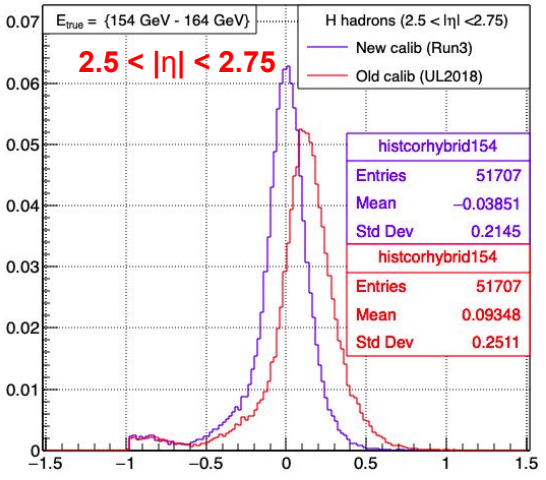
Red - old calibration parameters (UL2018)

Blue - New calibration parameters (Run 3)

# 1D Response: H-hadrons




X axis: $(E_{Total} - E_{True})/E_{True}$

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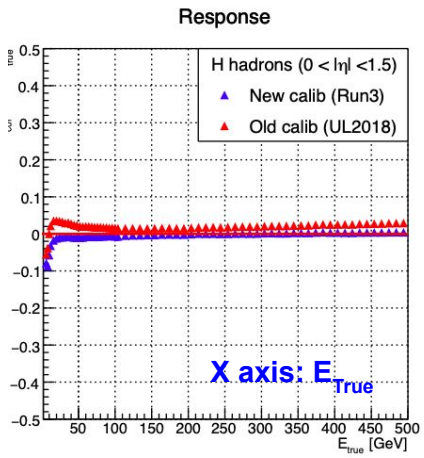
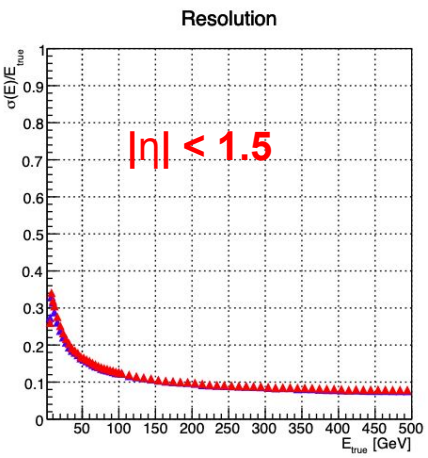
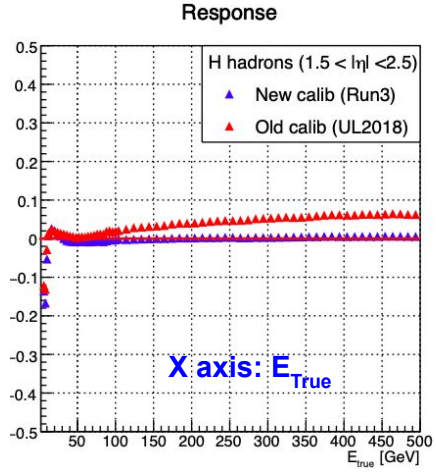
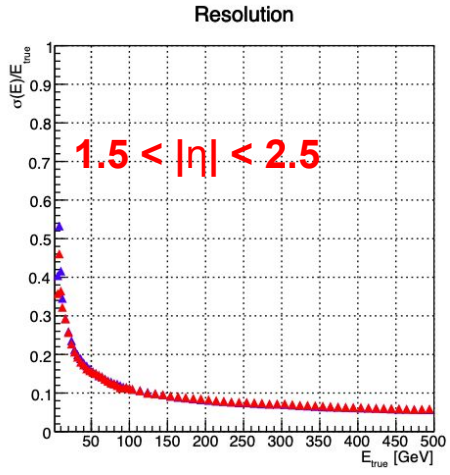
# H-hadrons (Response as a function of $E_{true}$ )

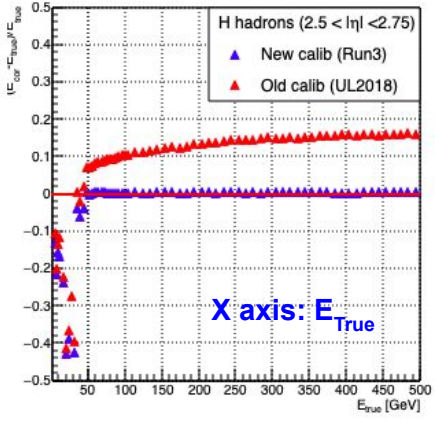


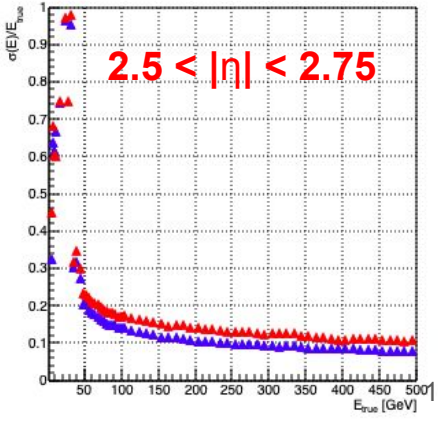




y-axis = $(E_{corr} - E_{true})/E_{true}$



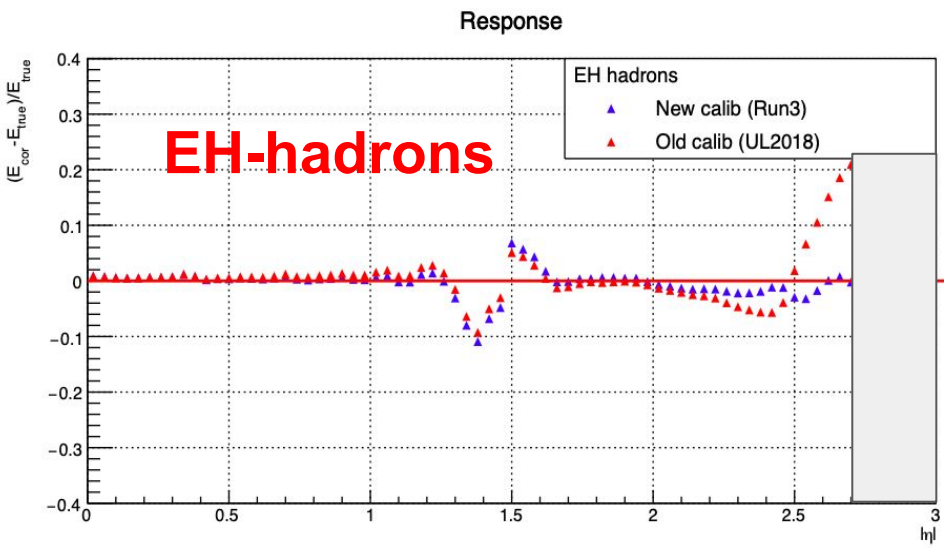



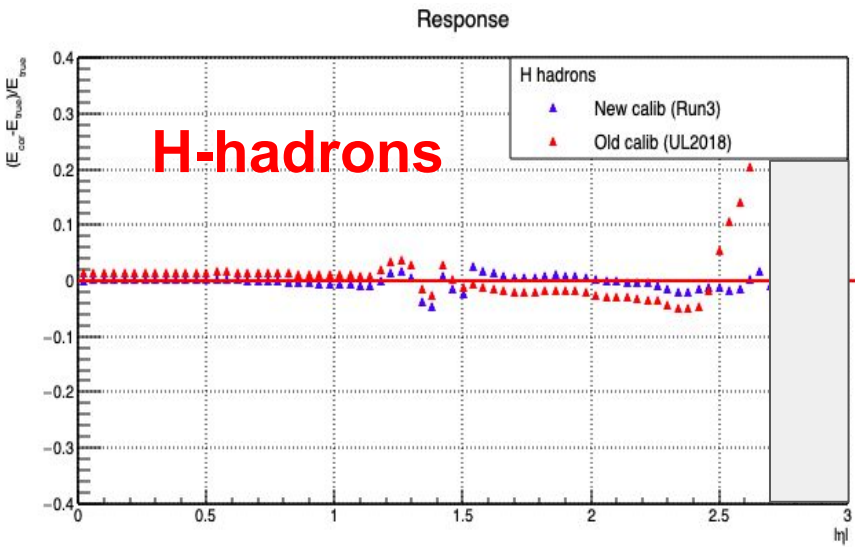

## Improvements for H Hadrons

Red - old calibration parameters (UL2018)

Blue - New calibration parameters (Run 3)

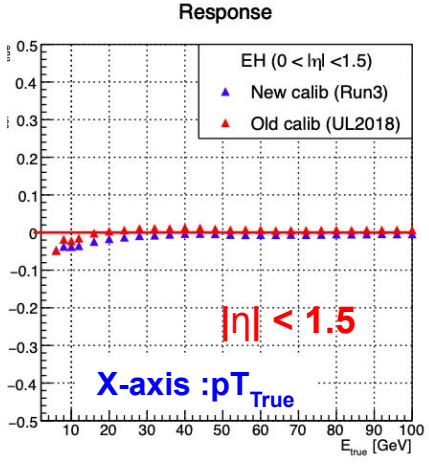
# Response as a function of |η|

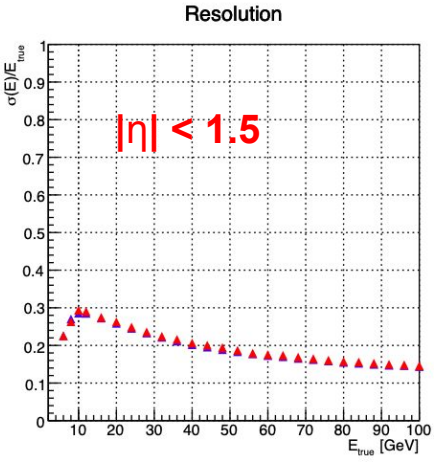


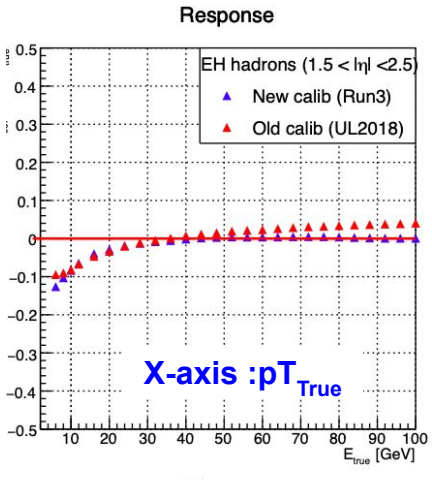

Improvements for EH & H Hadrons in encap region (within few %).

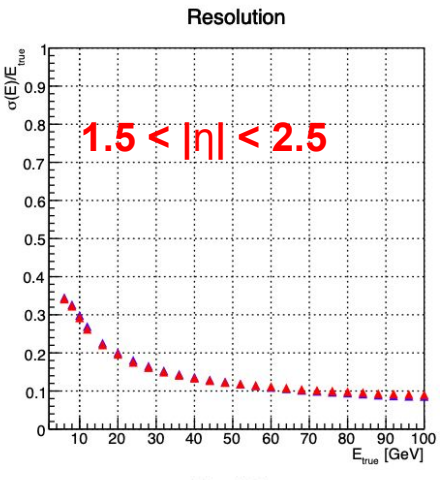
# EH-hadrons (Response as a function of $pT_{true}$)

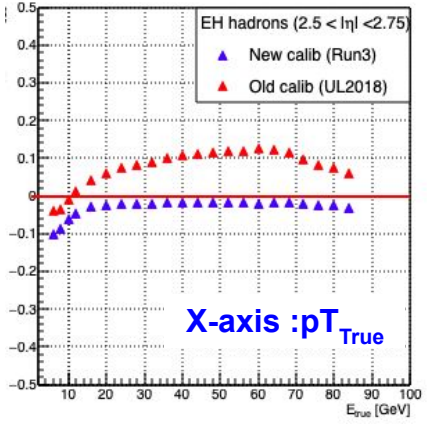


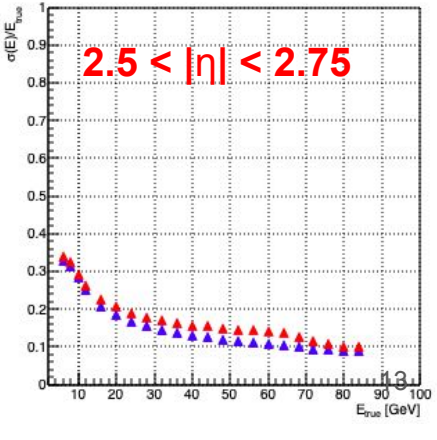




y-axis = $(E_{corr} - E_{true})/E_{true}$

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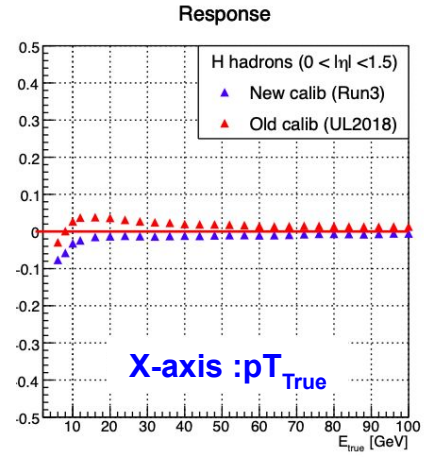
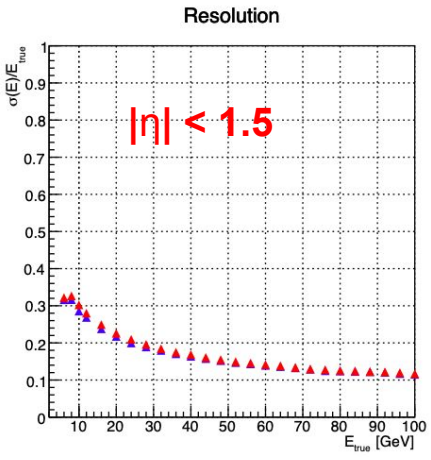
# H-hadrons (Response as a function of $pT_{true}$ )

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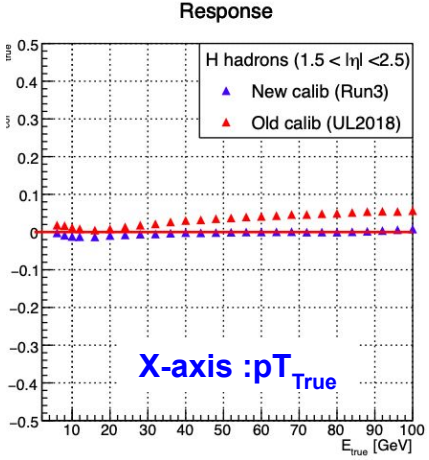


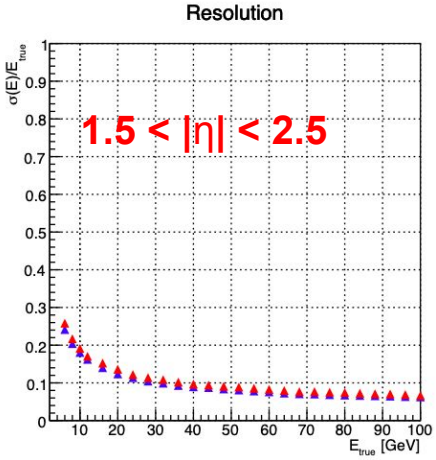


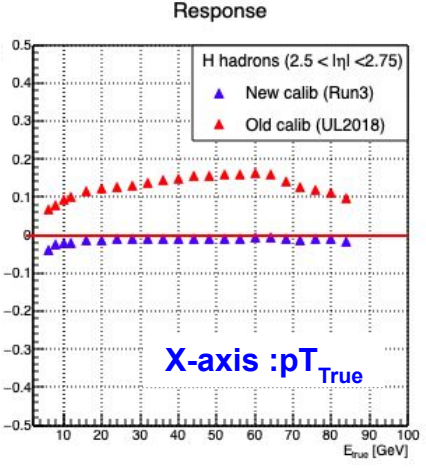


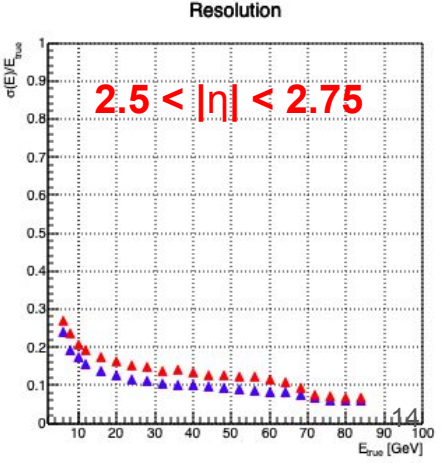


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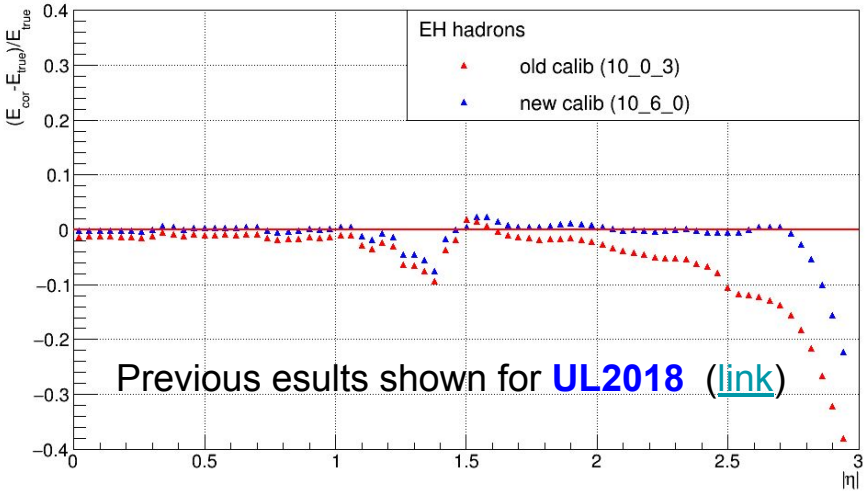
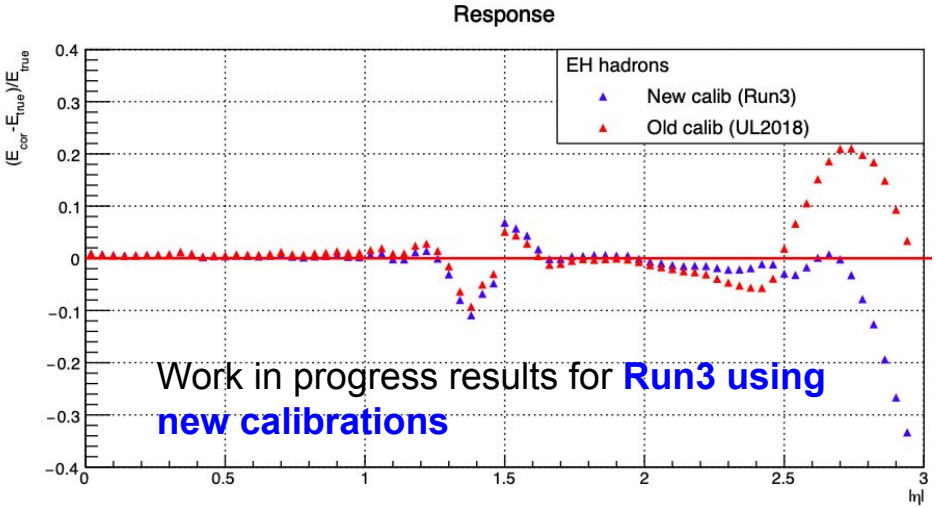
# Summary

- Updated the PF hadron calibration parameters for Run 3.
  - Parameter plots : https://bkansal.web.cern.ch/bkansal/Run3/param/
- Payload can be provided as soon as possible.
- Run2 UL presentations:
  - 2016 (link)
  - 2017 (link)
  - 2018 (link)

# Back up

# EH-hadrons (Response as a function of |η| )



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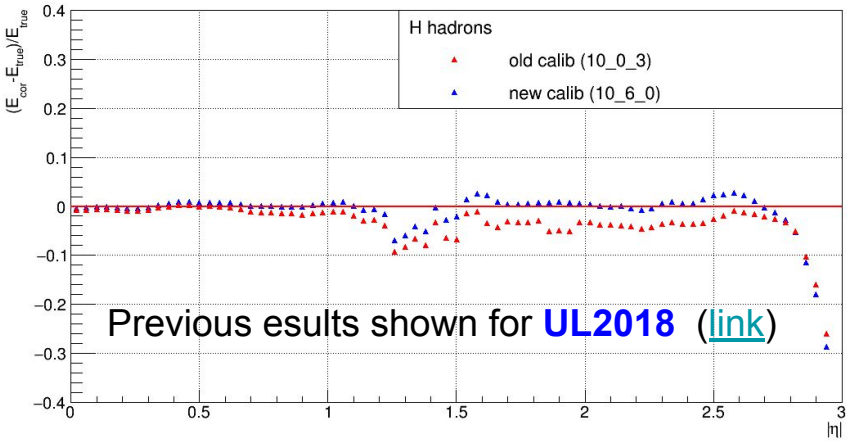


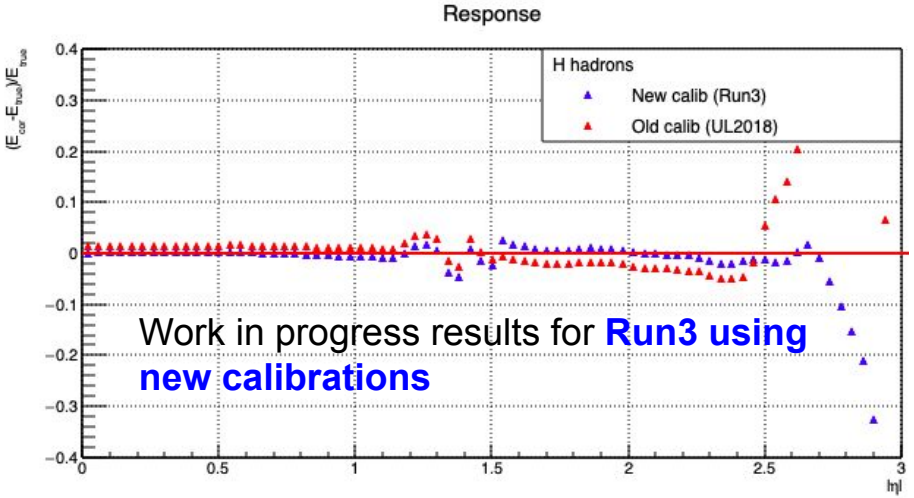

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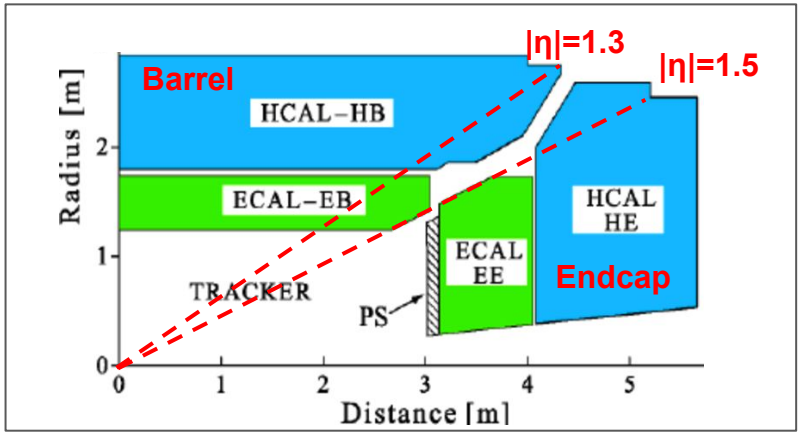


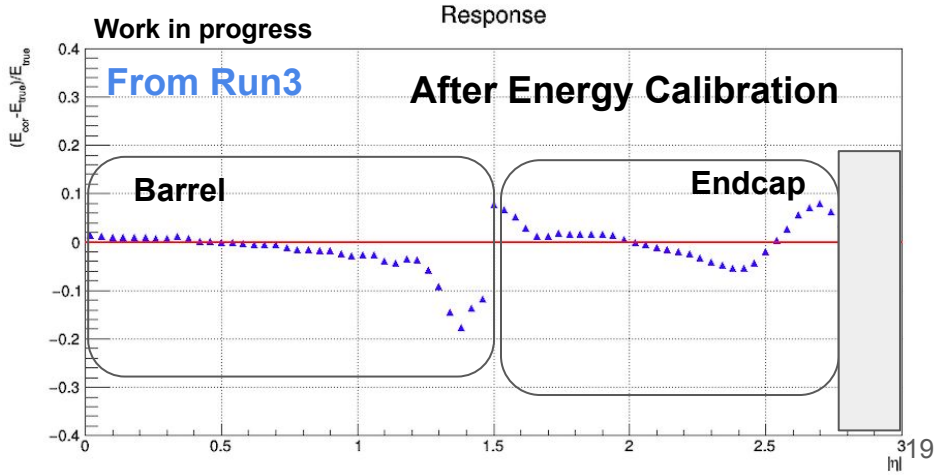

# Calibration parameters in encap for H hadrons

X axis is extended to 1000 GeV

Parameters are constant in higher energy region