Status of HPS-Ecal calibrations and corrections, 2021 run

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Overview

- Energy calibration
- Energy-leakage correction - so called “sampling fraction”

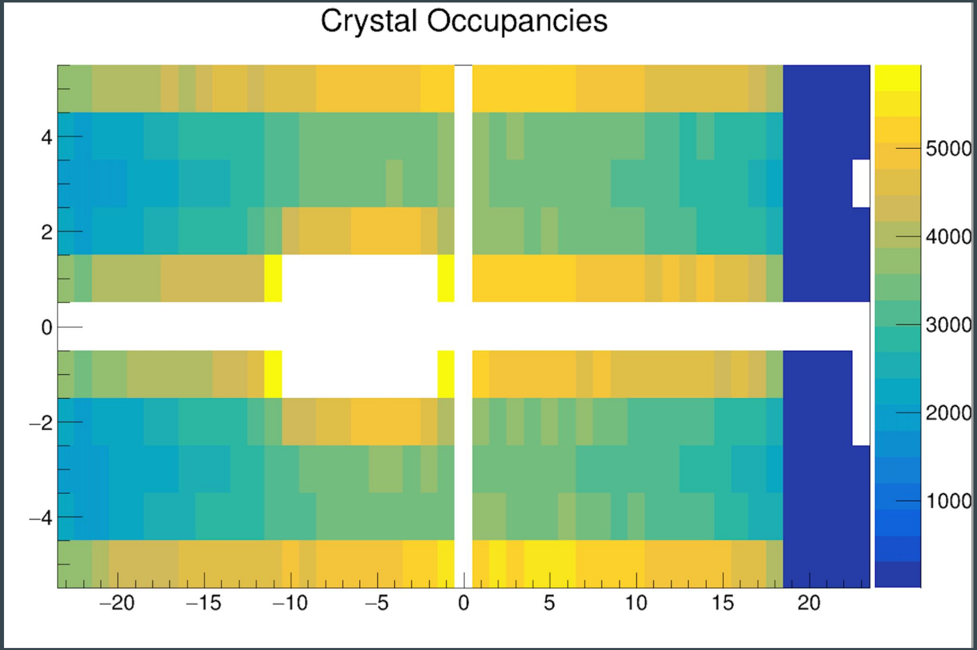
Ecal energy calibration procedure: FEE

- Determine from MC the cluster energy peak position for FEEs for each crystal: E^{FEE}_{MC}
  - For each crystal, consider only events with the seed hit being in that crystal
- Pre-calibrate data using the pre-calibration constant obtained from cosmic rays
- Select FEE events in the data, and determine for each crystal the cluster energy peak position: E^{FEE}_{DATA}
  - As before, for each crystal, consider only events with the seed hit being in that crystal
- Define the correction to the cosmics calibration constant as: $C = E^{FEE}_{MC} / E^{FEE}_{DATA}$
- Since clustering involves multiple crystals, each with its own calibration constant, the procedure needs to be iterated.

FEE Hits distribution in the ECAL - from MC

- 3.714 GeV electrons generated from target covering the SVT acceptance (courtesy of N. Graf)
- Cluster selection:
  - Etot > 2
  - Eseed / Etot > .6
  - At least one cluster with above req.

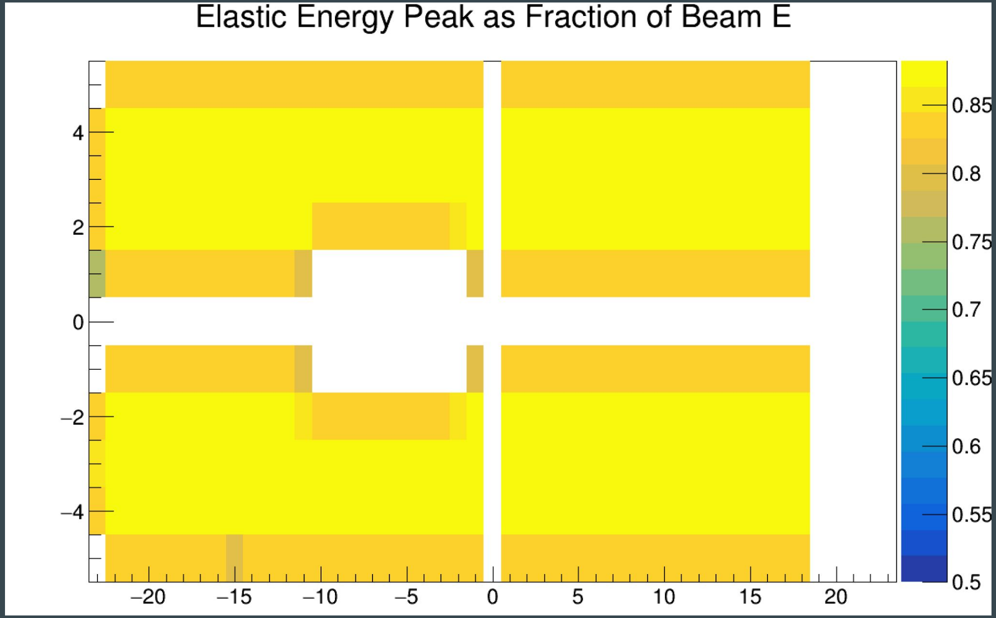
- Apply a 30 MeV hit threshold to each crystal to simulate the 2021 readout threshold in FADCs
  - This is critical for both FEEs gain calibration and WABs sampling fraction
- No coverage for column X=-23 and X=19..23
  - Same result in 2015 / 2016 / 2019



FEE MC peak

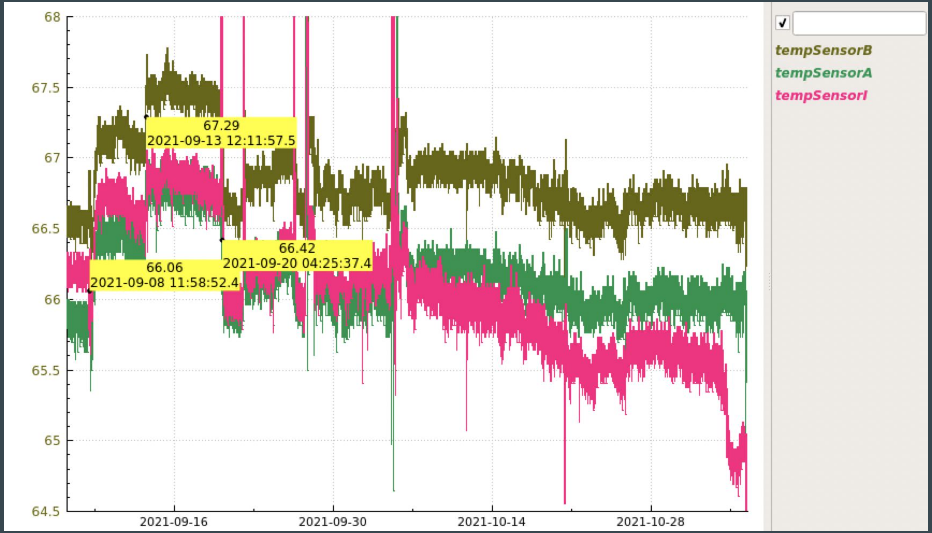
- 3.714 GeV electrons generated from target covering the SVT acceptance (courtesy of N. Graf)
- Cluster selection:
  - Etot > 2
  - Eseed / Etot > .6
  - At least one cluster with above req.

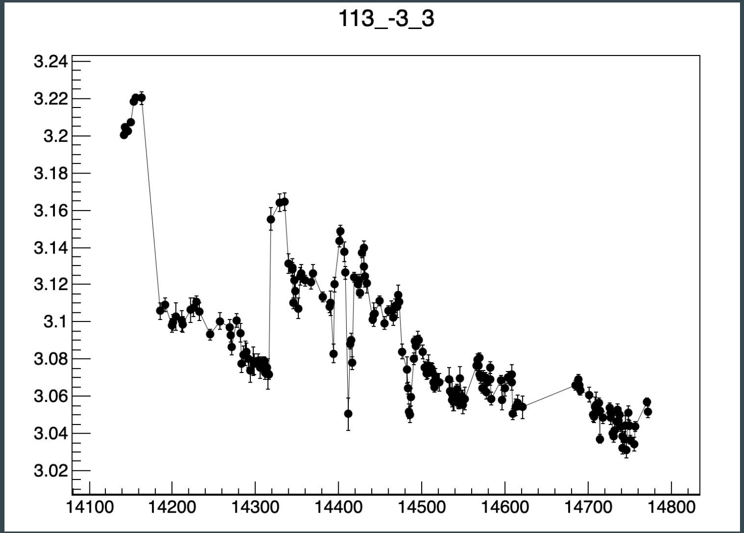
- Apply a 30 MeV hit threshold to each crystal to simulate the 2019 readout threshold in FADCs
- Fit with CB function to determine MC peak position / beam energy ratio



FEE Hits distribution in the ECAL: stability

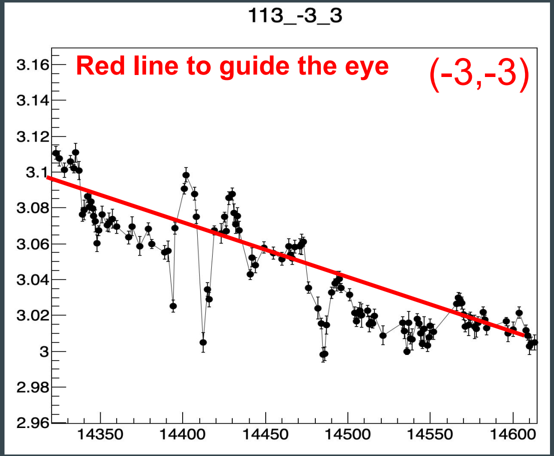
- Generally, temperature stability during the run was good.
- Some variations to the FEE peak position were observed as a function of run number (proxy for time)
- Data was divided into the following periods, that were calibrated independently:
    - Period 1: <= 14163
    - Period 2: 14163 < runN <= 14316 “Golden Period”
    - Period 3: 14316 < run N < 14620
    - Period 4: runN >= 14620

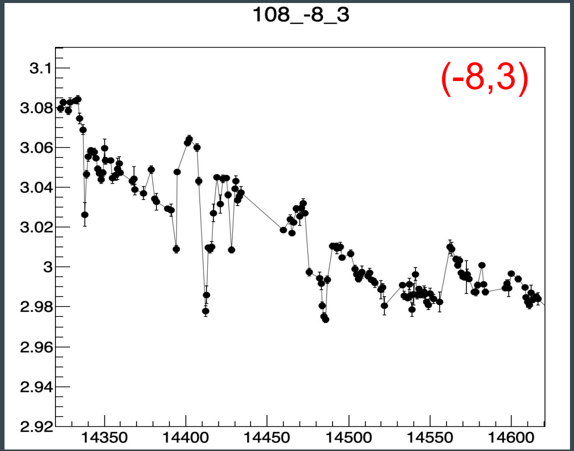


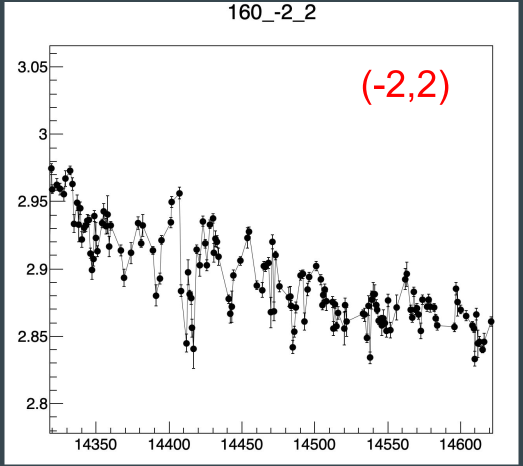


FEE peak position vs run number - golden period

- For each crystal, only runs with > 1000 FEE events were considered.
- The trend is clearly visible also for crystals at significant distance to the beam hole, like (-2,2)
- For crystals at larger distance, low statistics prevent a run-by-run comparison



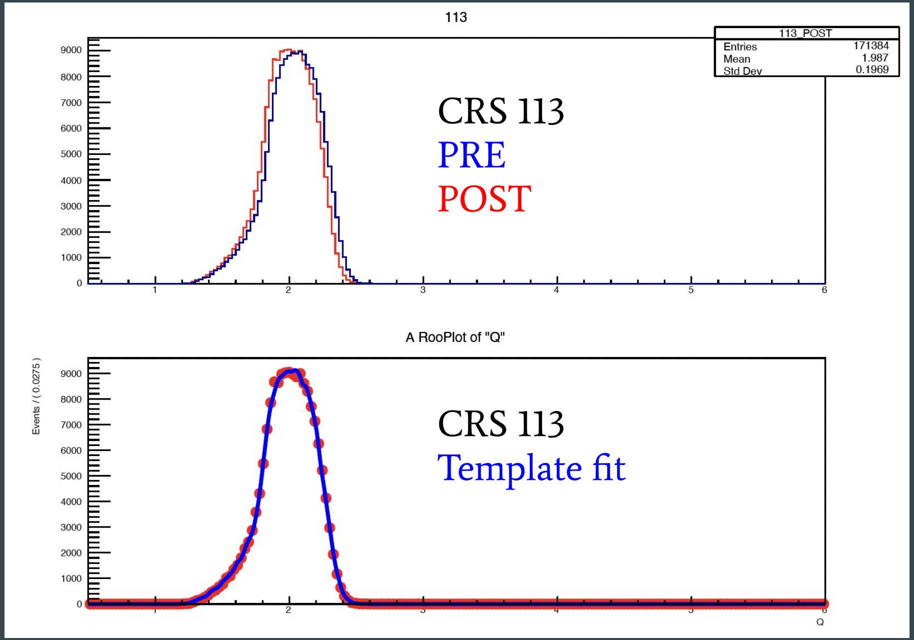




FEE peak position vs run number - golden period

Procedure:

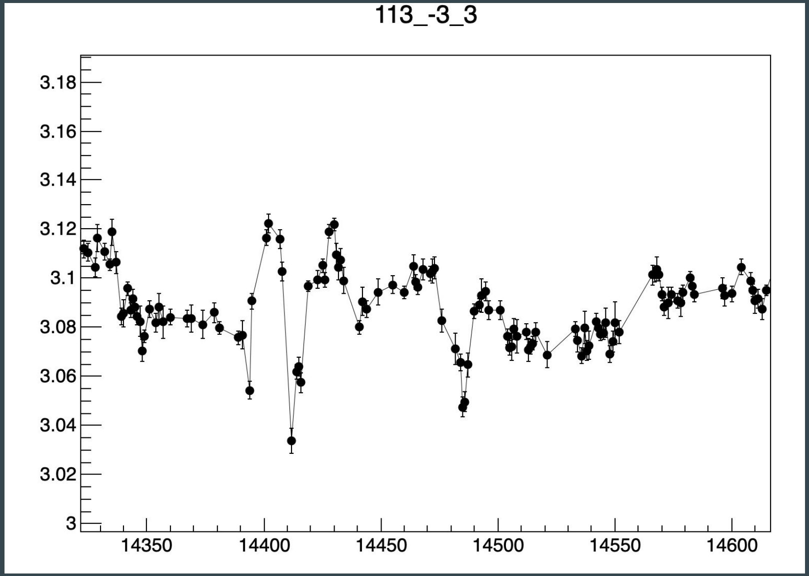
- Assume linear dependence on run number (time proxy)
- Select group of runs for each crystal:
  - 14319-14419 “PRE”
  - 14525-14625 “POST”
- Determine POST/PRE ratio via a template fit to the crystal seed energy
- Convert ratio to gain-dependency slope



FEE peak position vs run number - golden period

After correction:

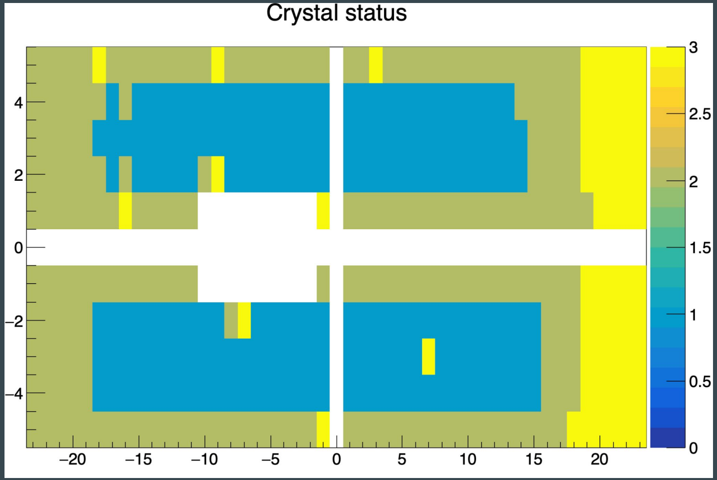
- After the correction, the linear dependency is no longer visible.
- Note that the FEE peak position reported in this plot is for the first gain iteration.

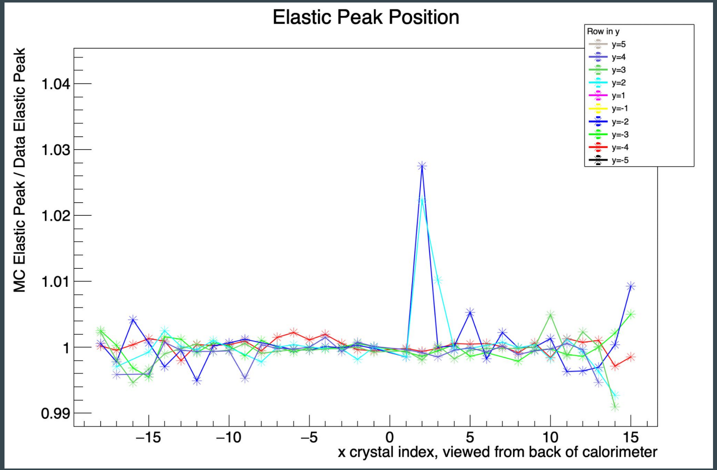


Results after calibration - golden period

Calibration status after 4 iterations:

- Crystals in the centermost region of ECAL are properly calibrated (blue)
- Crystals in the lateral regions are not calibrated (brown /yellow)
    - I decided to ignore crystals with Y=-5, Y=5, Y=-1, and Y=1 since the FEE peak was not visible
    - The following crystals were found to be dead, gain set to zero in both data and MC: (-1,-5) (7,-3) (-7,-2) (-16,1) (-1,1) (-9,2) (-18,5) (-9,5) (3,5)
- After calibration, the ratio E^{FEE}_{MC} / E^{FEE}_{DATA} is close to 1 for all crystals



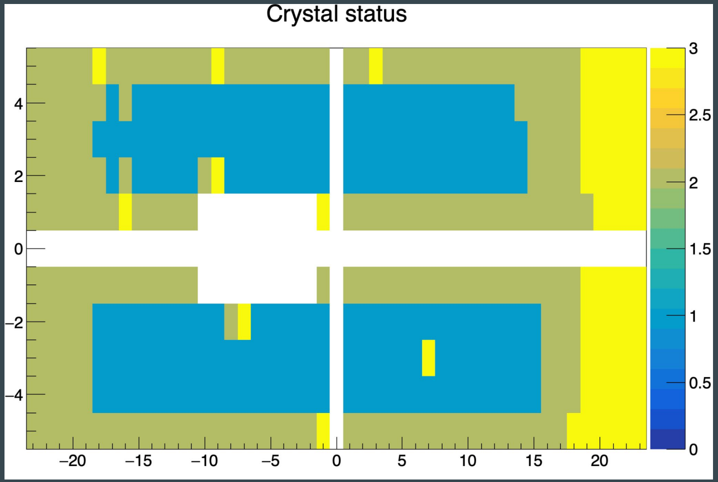


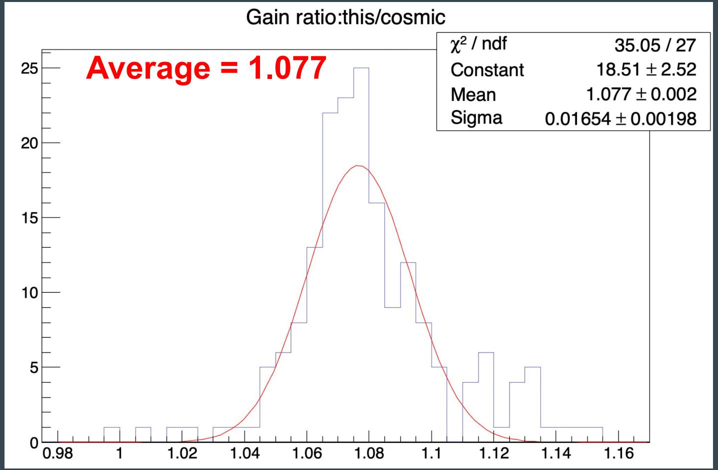
Results after calibration - golden period

For crystals not calibrated with the FEE method:

- CosmicsGain = 18.3 MeV / $Q_{cosmics}$
- FeeGain = $E^{FEE}_{MC}/E^{FEE}_{Data}$ * CosmicGain = E^{FEE}_{MC} / Q^{FEE}
  - Simplifying the iterative procedure to a single iteration
- Ratio = FeeG/CosmicsG = $E^{FEE}_{MC}/E^{FEE}_{Data}$ = (E^{FEE}_{MC} / 18.3 MeV) * ($Q_{cosmics}$ / Q^{FEE})

- For those crystals fixed to the cosmic gain, I force them to:
  GAIN = CosmicsGain * 1.077

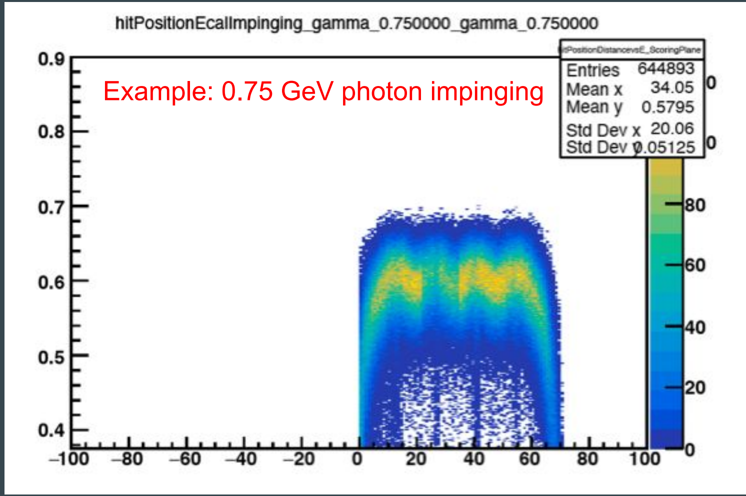


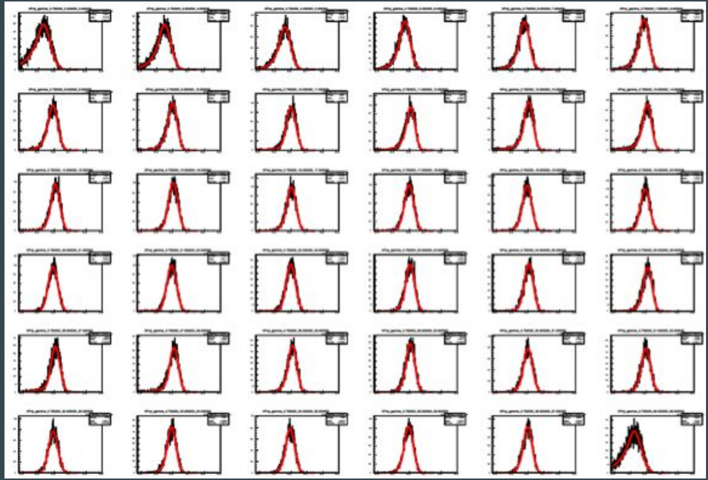


MC SF 2021

Procedure:

- Generate and simulate single particle MC files, at fixed energy, impinging on the ECAL from the target.
  - Critical: use 30 MeV hit threshold to consider real data readout threshold.
- Construct 2D histogram of measured cluster energy in the ECAL vs vertical distance from the edge - using 2015 definition of “distance from the edge”, to account for the presence of the beam gap for some columns. X-axis: distance, Y-axis: energy
- Slice the 2D histogram along x and for each slice plot the energy distribution. Do a fit to the energy distribution with a CB function and determine the gaussian mean. From this, extract the sampling fraction at this energy: SF(E,y,PID)





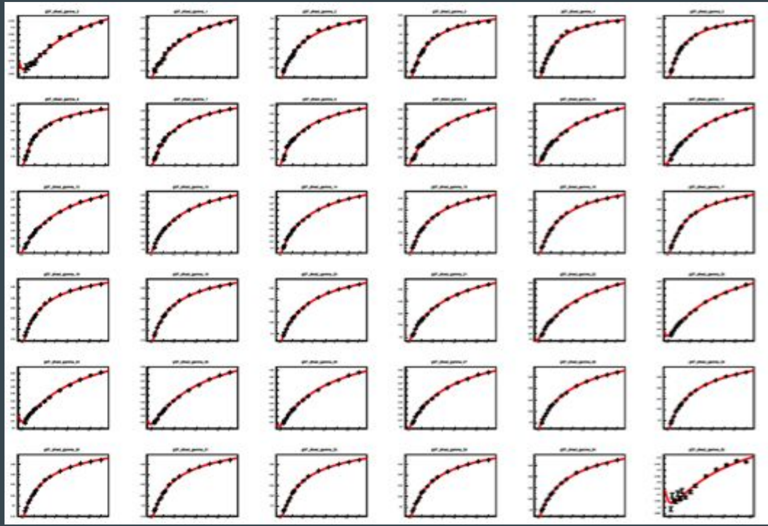
MC SF 2021

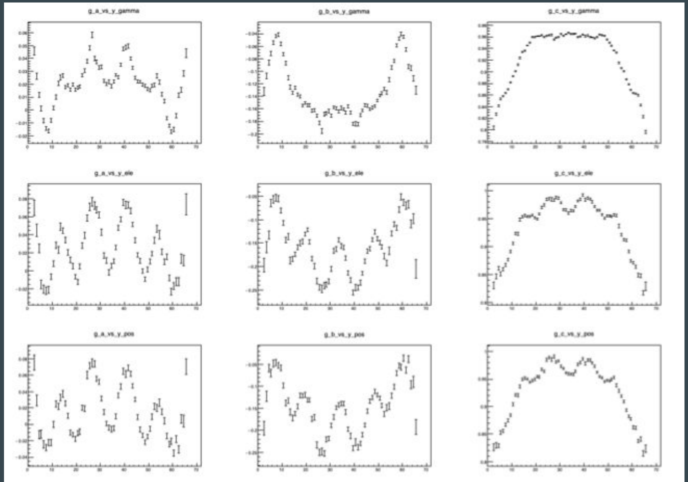
Procedure:

- Repeat the procedure for different energies. Plot, at fixed distance from the edge, the SF(E,y,PID) vs E.
- Perform a fit to each SF(E,y,PID) dataset with the function: A/E+B/sqrt(E)+C, with "A", "B", "C" free parameters.
- Determine A, B, and C for each 'y' and for each PID

A specific code was implemented in HPS-JAVA to retrieve, for a given cluster at given distance from the edge and given PID, the SF. Splines were used to interpolate the A, B, and C datasets.

"Oscillations" in the A, B, and C parameters are related to the high hit threshold (30 MeV) - this was already seen in 2019.



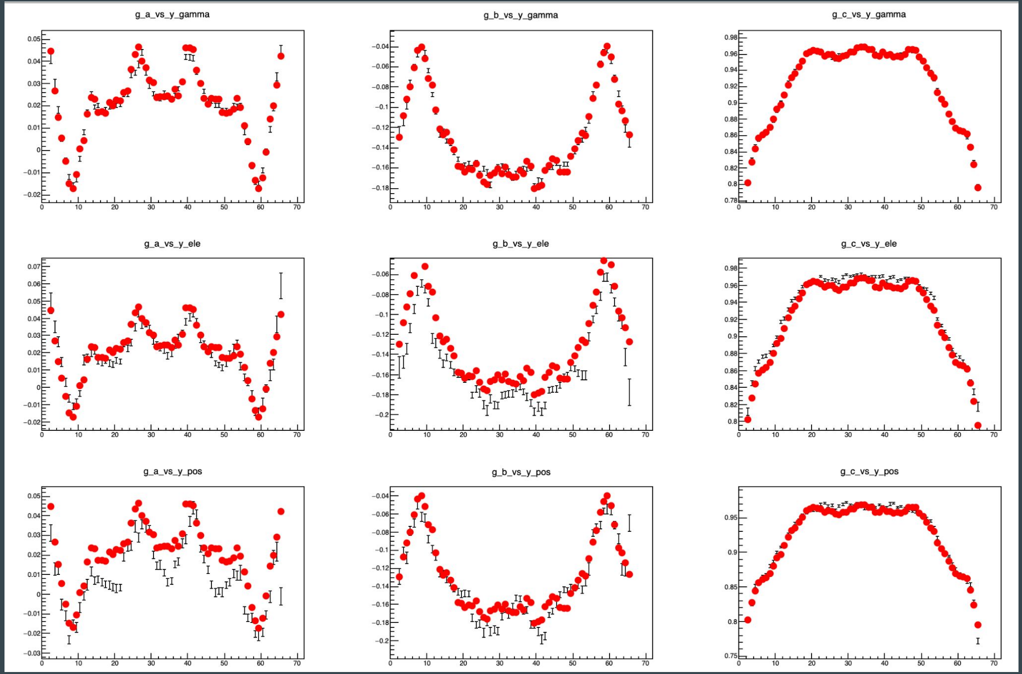


MC SF 2021

Comparison with 2019:

Comparison between 2019 (red) and 2021 (black) shows a very good agreement for photons, and a small differenc for electrons and positrons

- Same ECAL hit energy threshold (30 MeV)
- Different magnetic field strength: for fixed energy, e^+ and e^- impinge on ECAL at slightly different angle.



DATA SF 2021

From 2015/2016/2019 analysis, it is known that MC-derived SF needs to be corrected for data: use WAB events

Ebeam = 3.74 GeV or 3.714 GeV?

WAB events satisfy:

$$\frac{E_\gamma}{SF_\gamma(E_\gamma,y_\gamma)} + \frac{E_e}{SF_e(E_e,y_e)} = E_{beam}$$

Make the assumption that "data" SF and "MC" SF are different by a common scale factor:

$$\frac{SF_\gamma(E,y)}{SF_\gamma^{MC}(E,y)} = \frac{SF_e(E,y)}{SF_e^{MC}(E,y)}$$

The WAB constraint becomes:

$$\frac{E_\gamma}{SF_e(E_\gamma,y_\gamma)R(E_\gamma,y_\gamma)} + \frac{E_e}{SF_e(E_e,y_e)} = E_{beam}$$

with

$$R = \frac{SF_\gamma^{MC}}{SF_e^{MC}}$$

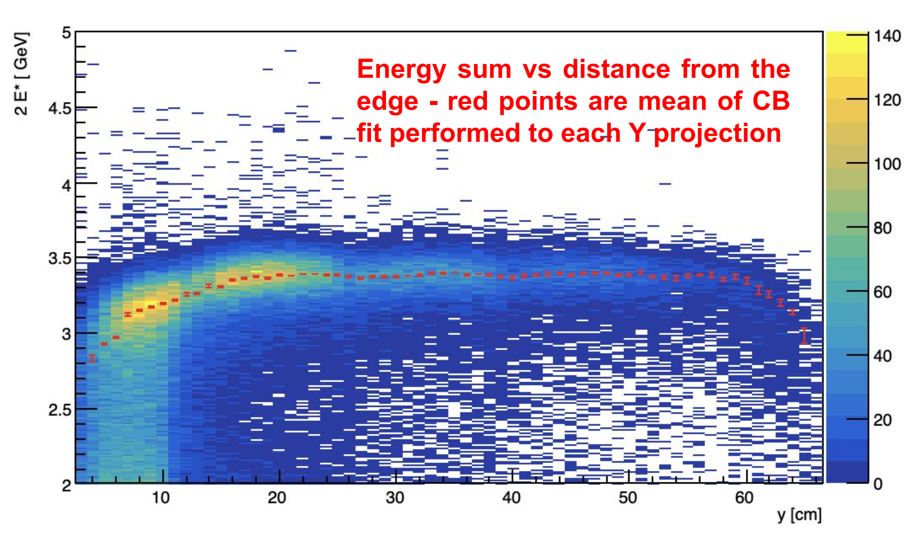
Symmetric WAB events, with $E_e=E_g=E^*$, and same distance y from the edge,

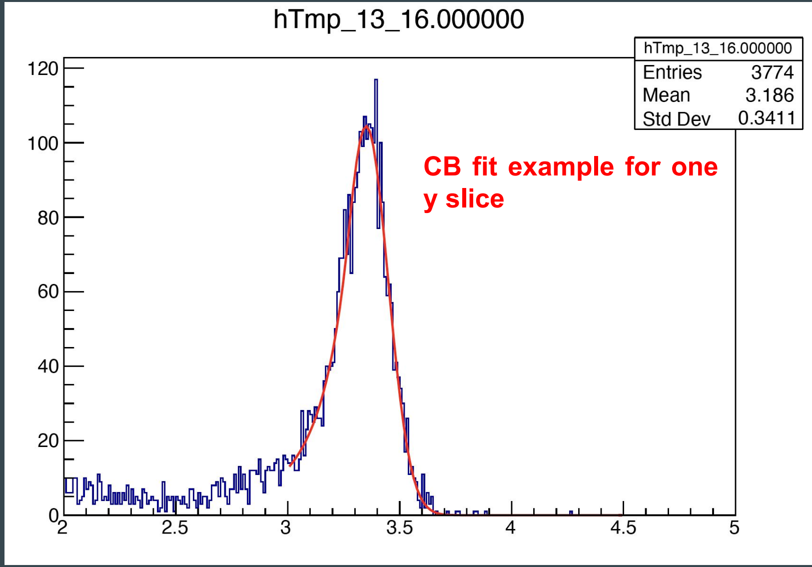
$$\frac{E^*}{SF_e(E^*,y)R(E^*,y)} + \frac{E^*}{SF_e(E^*,y)} = E_{beam}$$

From the knowledge of "E*" the electrons SF at that energy for data can be extracted.

DATA SF 2021

Symmetric WAB events





DATA SF 2021

Symmetric WAB events

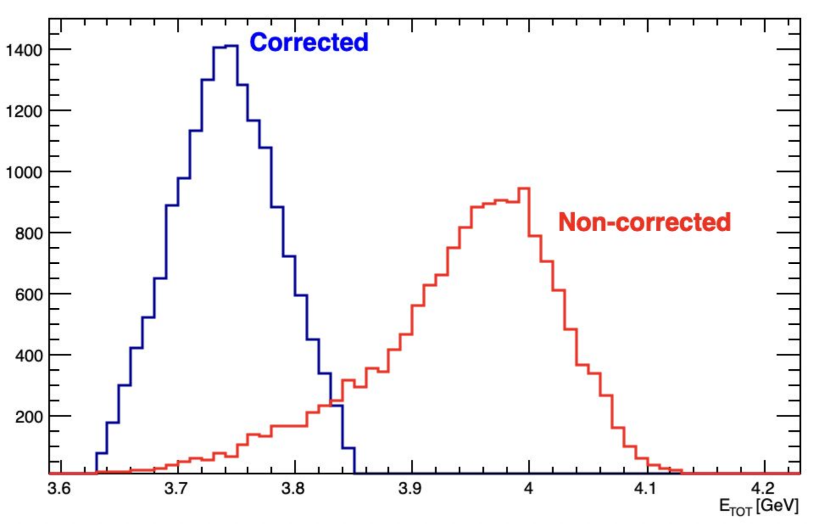
From symmetric WAB events, extract E*(y), and then $SF_e(E^*(y),y)$ and $SF_g(E^*(y),y)$.

$$SF_e(E^*(y),y) = \frac{E^*(y)}{E_{beam}}\left(1 + \frac{1}{R(E^*(y),y)}\right)$$

$$SF_\gamma(E^*(y),y) = R \cdot SF_e(E^*(y),y)$$

From these equations, I can now determine the SF at all y, but only for E*(y).

Energy sum for events when $E_e = E^*_e(y_e)$ and $E_g = E^*_g(y_g)$



DATA SF 2021

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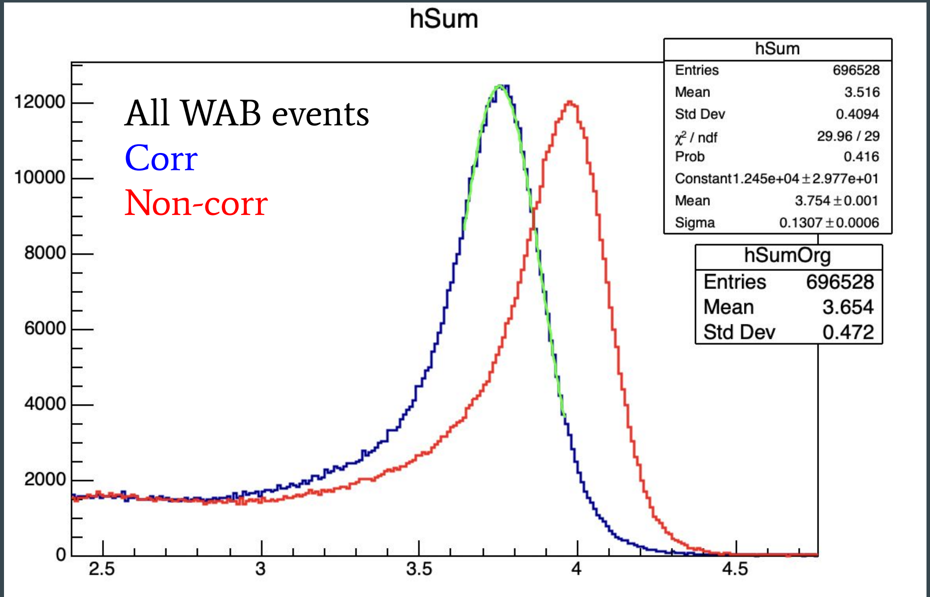


Additional assumption #1: ratio is independent from energy

$$\frac{SF_\gamma(E,y)}{SF_\gamma^{MC}(E,y)} = \frac{SF_e(E,y)}{SF_e^{MC}(E,y)} = C(y)$$

DATA SF 2021

By using the assumption:

$$\frac{SF_\gamma(E,y)}{SF_\gamma^{MC}(E,y)} = \frac{SF_e(E,y)}{SF_e^{MC}(E,y)} = C(y)$$

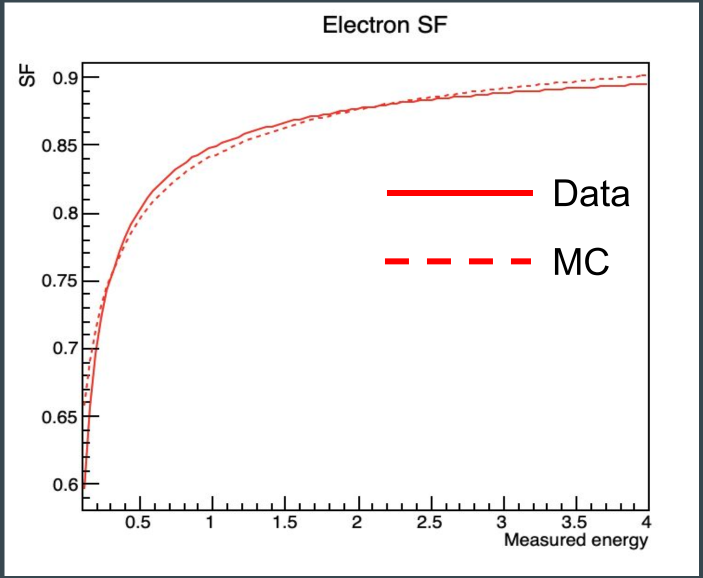
the FEE peak position in the data is modified! Calibration constants were derived assuming C(y) = 1, and embedding any difference between data and MC in the calibration constants.

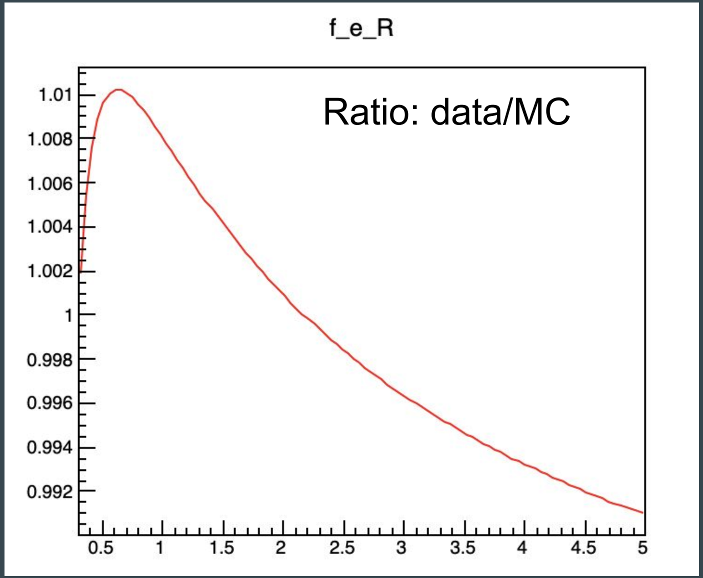
Looking back at 2015 analysis:

Result for electrons

- C is close to 1
- Smooth dependency on energy

Similar trend for photons and positrons.



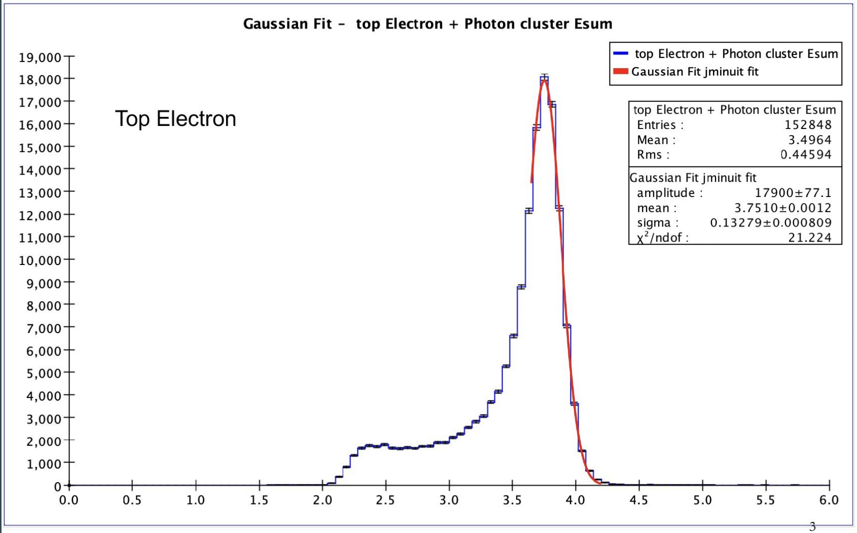


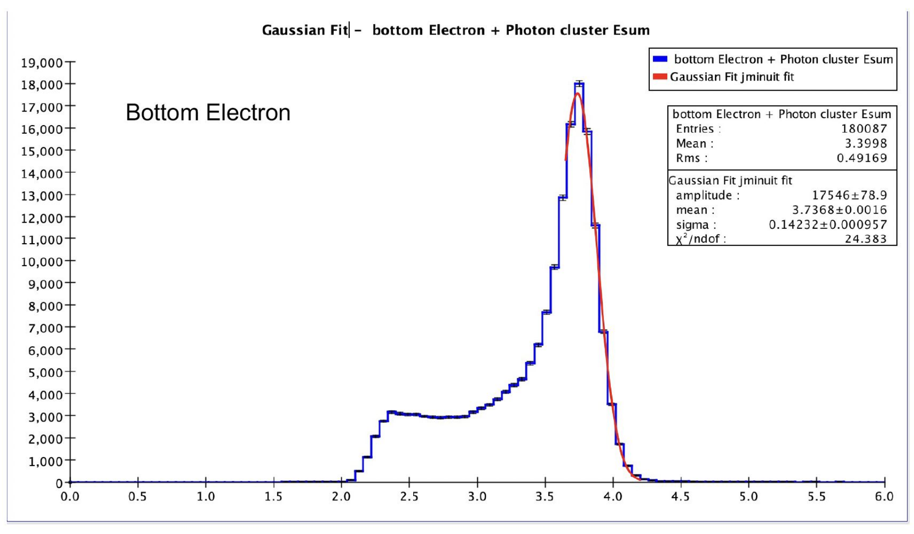
DATA SF 2021

This suggests to use a different assumption:

$$\frac{SF_\gamma(E,y)}{SF_\gamma^{MC}(E,y)} = \frac{SF_e(E,y)}{SF_e^{MC}(E,y)} = 1 + C(y)(E^*_{beam} - E)$$

where $E^*_{beam}(y)$ is the **measured** FEE energy (obtained from the FEE analysis)
Results from HPS-JAVA on all WAB events (thanks Normann!)





Conclusions

Calibrations and corrections for HPS-ECAL, 2021 run, are almost completed

- Energy calibration
  - All crystals were pre-calibrated with cosmic rays
  - FEE-based calibration was used to determine calibration point for centermost crystals
- SF correction
  - MC-based SF was fine-tuned using WABs
  - Need to check beam energy
- Position correction:
  - Still to be done