Calibrating Electromagnetic Calorimeter

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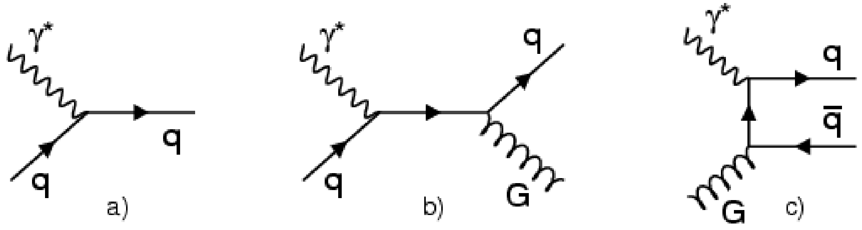
290E SP-18

Purpose of Electromagnetic Calorimeters (EMCals)

- Measuring energy of two special particles
  - Electrons
  - Photons
- Photons and electrons are very common decay products so their energies (and momentum) provides information about the parent
- Examples of particles with photon or electron decay products:
  - Pions, etas
  - Higgs
  - W/Z bosons
- Additionally photons can also come from initial processes just as QCD Compton scattering.

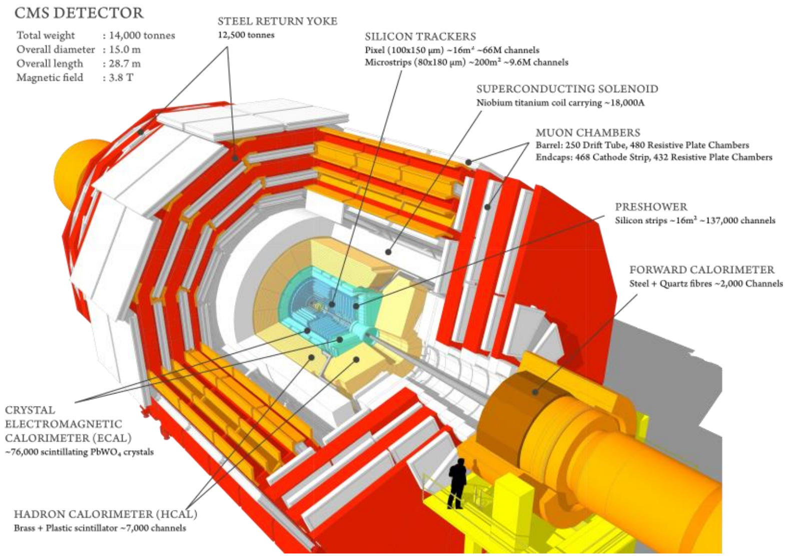
arXiv:1111.0561



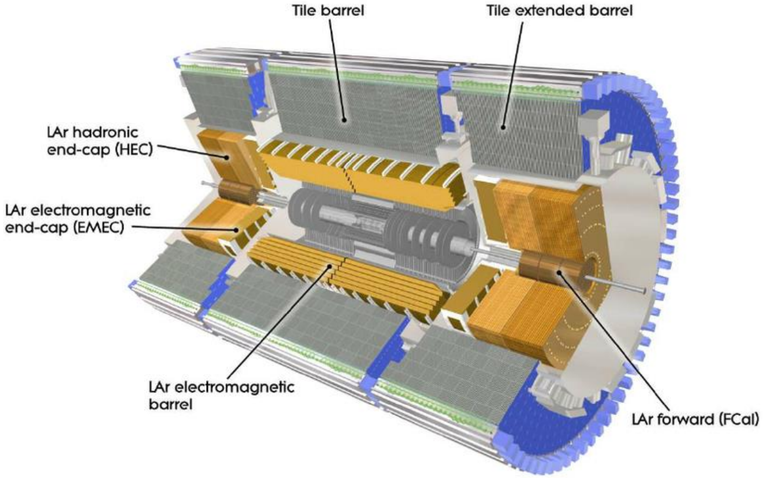
Calorimeters at the LHC

- CMS: $PbWO_4$ Homogenous Calorimeter
- ATLAS: Lead/Liquid Argon Sampling Calorimeter
- ALICE: Lead-Scintillator Sampling Calorimeter

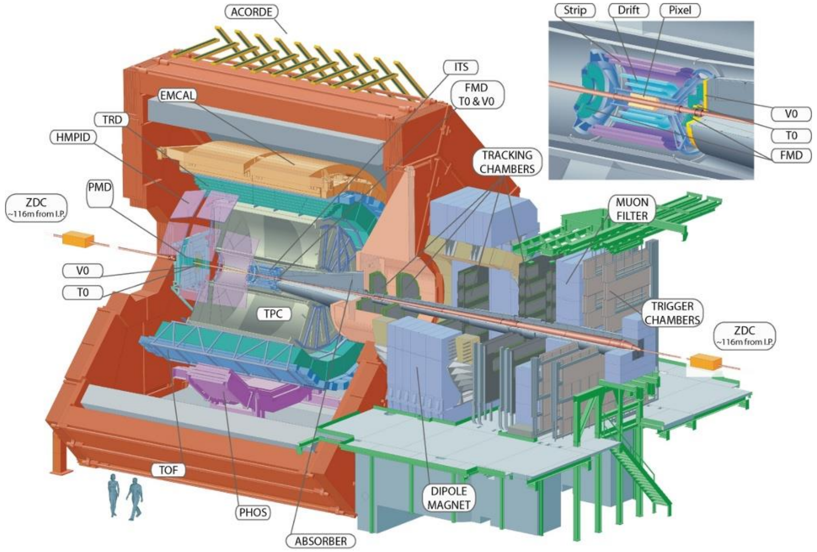
https://www.quantumdiaries.org/2010/10/13/meet-the-alice-electromagnetic-calorimeter/



http://cms.web.cern.ch/news/cms-detector-design



Design and implementation of the Front End Board for the readout of the ATLAS liquid argon calorimeters. Journal of Instrumentation. 3. P03004. 10.1088/1748-0221/3/03/P03004.

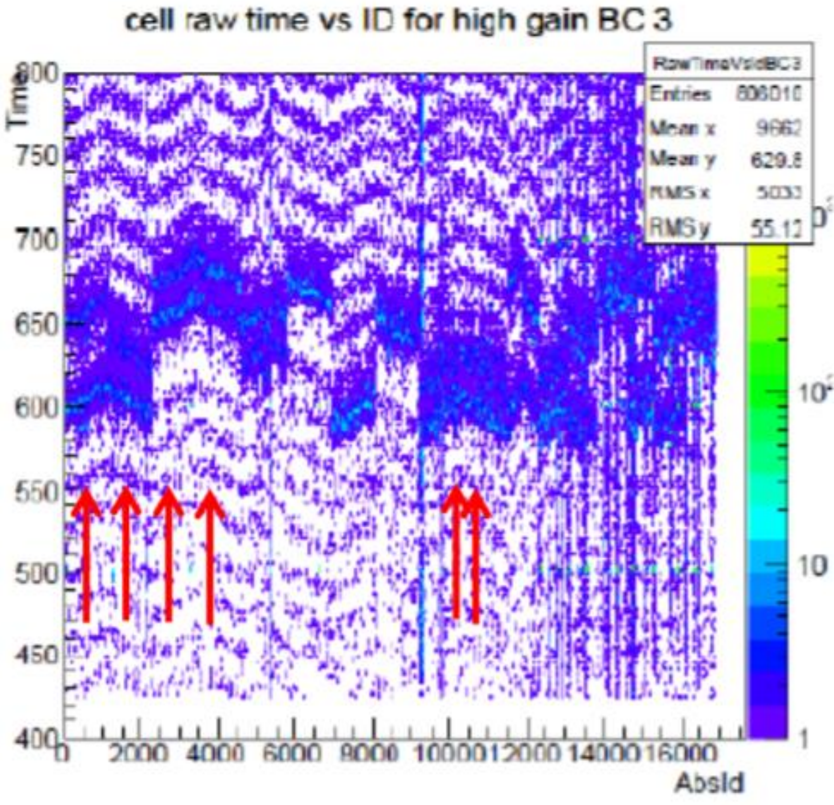


Different Calibrations

- When we think calibrations of EMCals, we think about energy calibrations
- There is more than the just energy which needs to be corrected
- Other calibrations:
  - Timing Calibration
  - Temperature Calibration

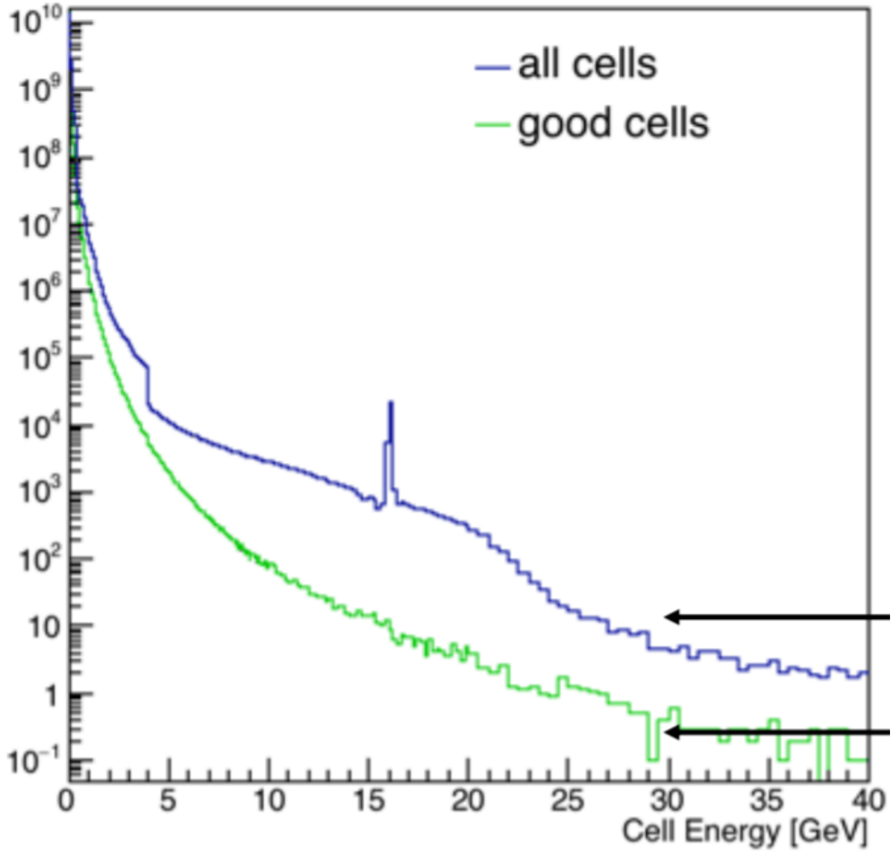
Timing Calibration

- Purpose: To correct cell time information by the average cell time over a period
- While an entire event is read in simultaneously, each cell is read out individually
- Due to this, we can cell-to-cell offsets, which need to be corrected.
- How to correct:
  - Use a recursive method: find phases between each cell on a run by run bases
  - Create coefficients from those phases to correct for the offests



Energy Calibrations

- Absolute calibrations: We know the deposited energy and we correct accordingly
  - Mass peak reconstruction
  - Calibrations using a test beam
- Relative calibrations: We have some cells which are mis calibrated, so we adjust their spectrum according to the "good" cells.



ALICE EMCAL workshop March 2018

Energy Calibrations

- Due to various reasons (radiation exposure, weird electronics, individual cell responses, etc) cells will measure a different energy than the truth.
- Thus, the measured energy will not be correct, and be off by some factor

$$E_{measured} = \frac{E_{truth}}{a}$$

- What we need to do find the calibration coefficient (a), so that if we multiple by both sides by a, we get the true energy.

Test Beam Calibrations

- Take the detector to a test beam facility
- Shoot electrons at it
- The beam will be coming in with a certain energy
- We look at the energy we measured, and compare it with the expected energy and adjust coefficients accordingly
- This is nice, but once the calorimeter is installed for a long period, it is not practice to remove it and bring it to test beam before every run year.

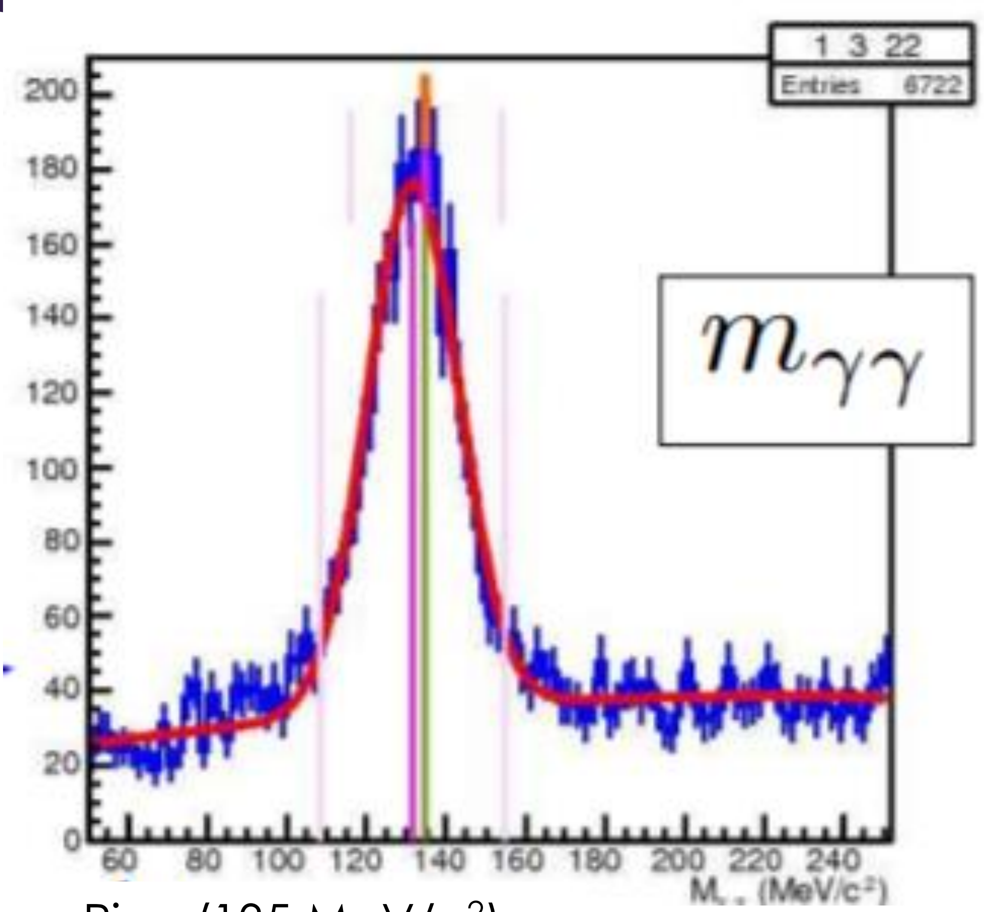
Calibrating using a mass peak

- The mass of many hadron is known very well, and to a very precision.
  - Neutral pion mass: 134.976 6 ± 0.000 6 MeV/c^2
  - Eta mass: 547.862 ± 0.018 MeV/c^2
- Since these hadrons decay into photons, we can combine the photon energies to obtain the invariant mass of the pion and the eta.

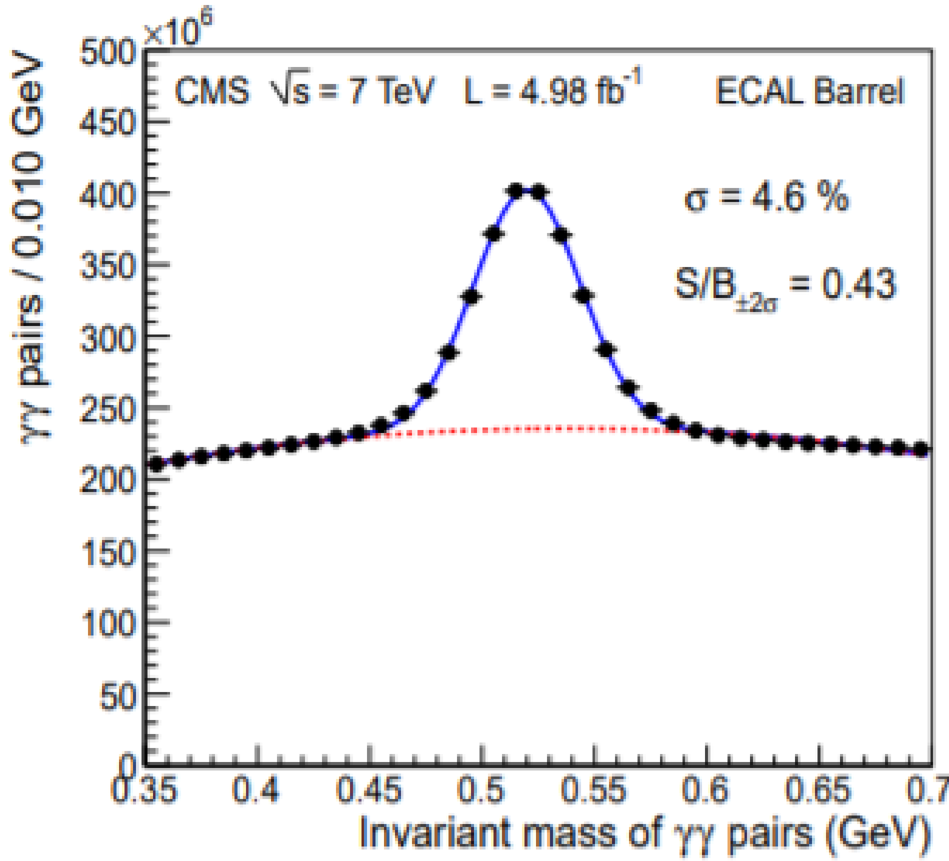
$$m_{\gamma\gamma} = \sqrt{2E1E2(1 - \cos\theta)}$$

- To ensure it is a photon, we look at clusters in the EMCal and reject thoses with associated tracks. Then we pair all photons with each other to create a mass peak.

Mass Peak



Pion (135 MeV/c^2)
Mass peak



Eta (0.547 GeV/c^2)
Mass peak

Relative Calibrations

- If we have known well calibrated cells, then we can compare the energy spectrum of those with uncalibrated cells, and find the calibration coefficient from that.
- Procedure (How I do it for ALICE):
  - Sum energy spectrum of good cells
  - Fit a power law ($y = ax^g$) spectrum to it within (1.5-5 GeV) to find g
  - Apply that to the uncalibrated cells to find a.

Summary

- Electromagnetic calorimeters are important detector in particle physics experiments.
- In order to be able to use them reliably, they need to be well calibrated.
- There are many different calibrations such as energy, temperature, and time.

References

- Energy calibration and resolution of the CMS electromagnetic calorimeter in pp collisions at $\sqrt{s} = 7$ TeV (arXiv:1306.2016)
- Calibration of the ATLAS electromagnetic calorimeter using calibration hits (CDS:1046248)
- ALICE EMCAL Workshop March 2018