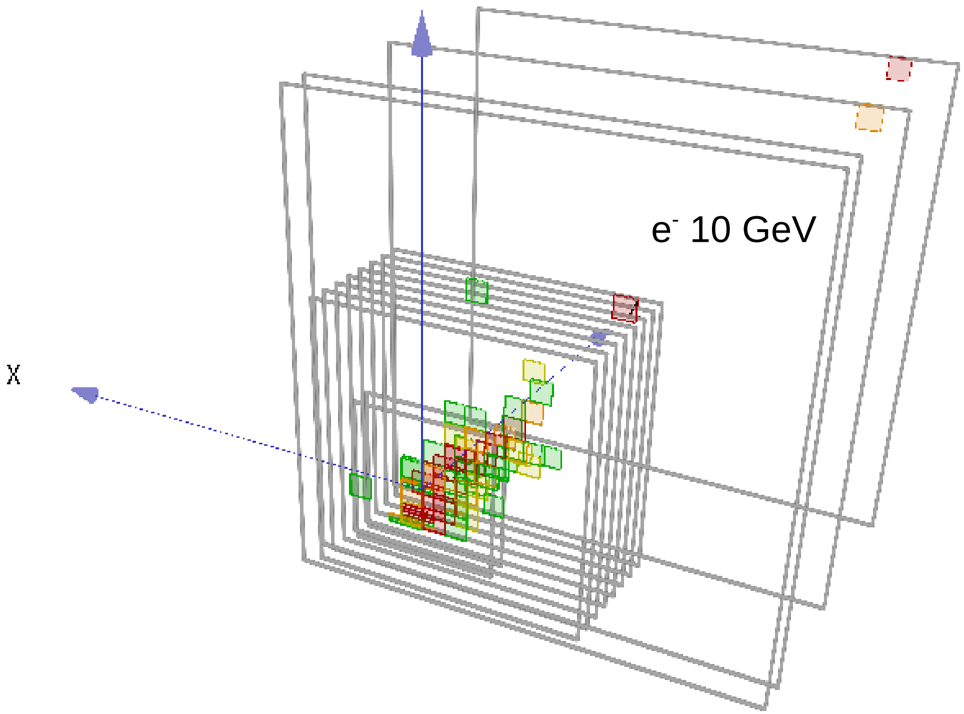
Analysis of July 2015 CERN test beam electron data



Ambra Provenza
For the Calice D-Collaboration
29.03.2017

HELMHOLTZ ASSOCIATION | PIER | Universität Hamburg DER FORSCHUNG | DER LEHRE | DER BILDUNG | CALICE | DESY

Outline

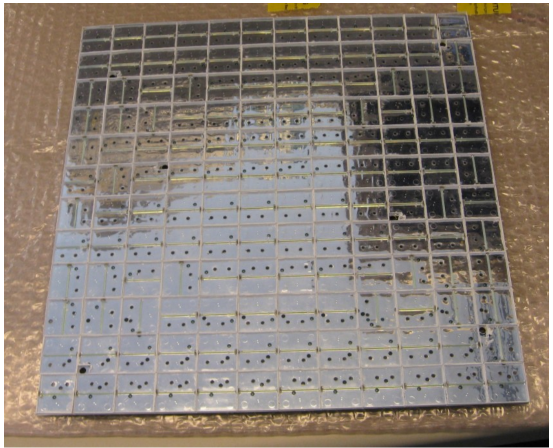
- The Analog Hadronic Calorimeter (AHCAL) & the CERN test beam setup
- Plan & Motivation
- Data selection
- Simulation status
  - Noise
  - Material tuning
  - Cross talk tuning
- Outlook

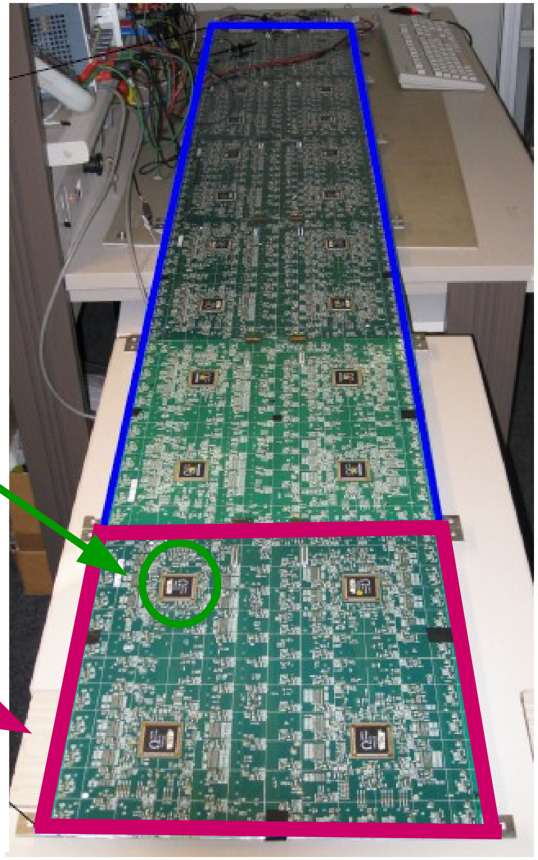
Analog Hadronic Calorimeter (AHCAL)

- The **A**nalog **H**adron **Cal**orimeter **AHCAL**:
  - Sandwich calorimeter:
  - Absorber material: Steel
  - Based on scintillator tiles of 3x3 cm^2
  - Read out using **Si**licon **P**hoto**M**ultiplier (one for each tile) **Read out with chips**
  - **H**cal **B**ase **U**nit (**HBU**)

    36 x 36 cm^2

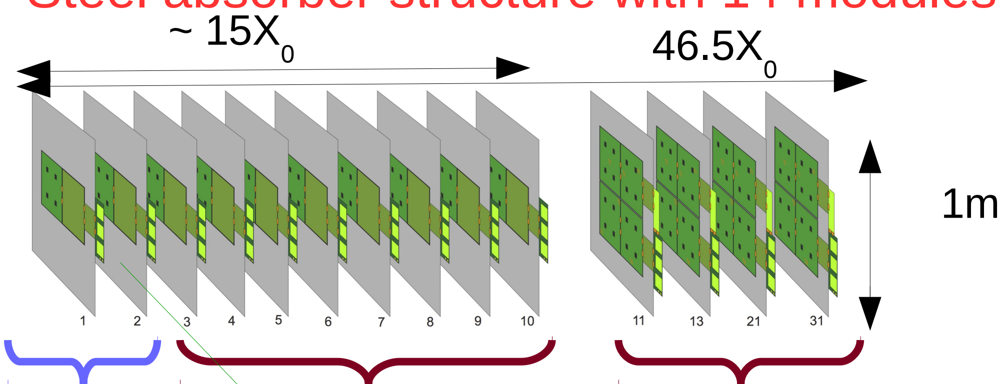
    144 scintillating tiles

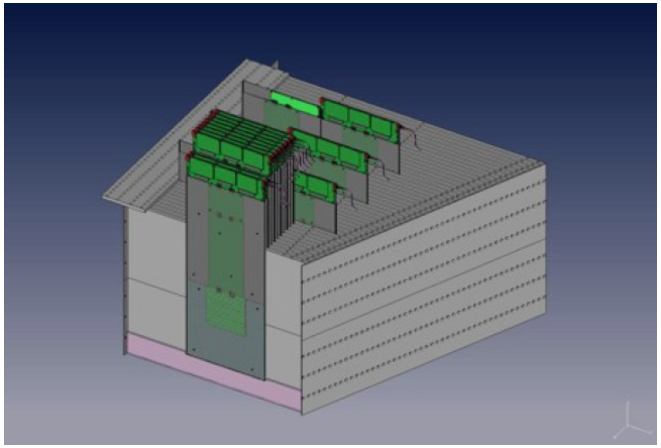




CERN Test Beam configuration

- 2 weeks of Test Beam at Cern in July & August 2015
- Steel absorber structure with 14 modules (Tungsten, 15 modules)





2 EBU
(Ecal Base Unit)
144 scintillating strips
($18x18\ cm^2$)

8 HBUs
$36 \times 36\ cm^2$

4 2x2 HBUs
$72 \times 72\ cm^2$

August: one more EBU

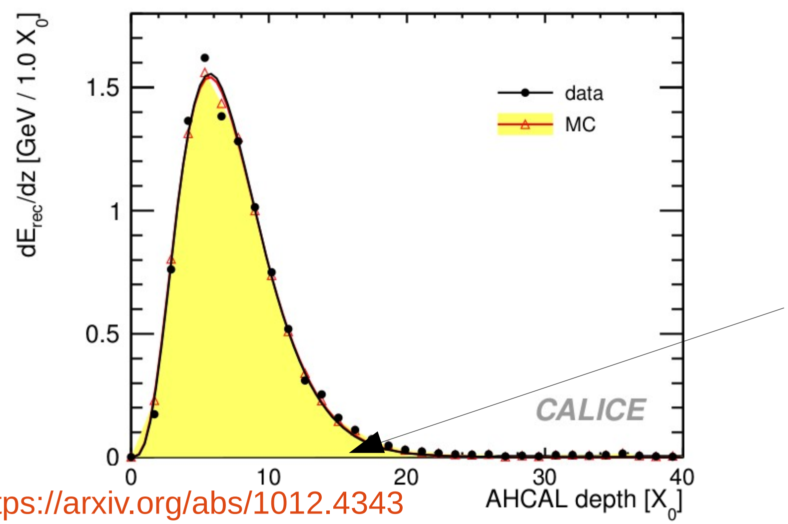
- Goals:
  - Muon beam to calibrate the detector
  - Electron beam (10-50 GeV) for studying electromagnetic response
  - Pion beam (10-90 GeV) for studying shower evolution with time

Plan

> Goal: study electromagnetic response of AHCAL Technological Prototype with July 2015 electrons data

> Why:

- Mandatory step before pion analysis can be started
- Well understood physics process → allow to understand the performance of the detector and validate the Monte Carlo simulation
- High density of energy deposition → study saturation effect and validate calibration
- Em shower contained in the prototype → check energy reconstruction and calorimeter response



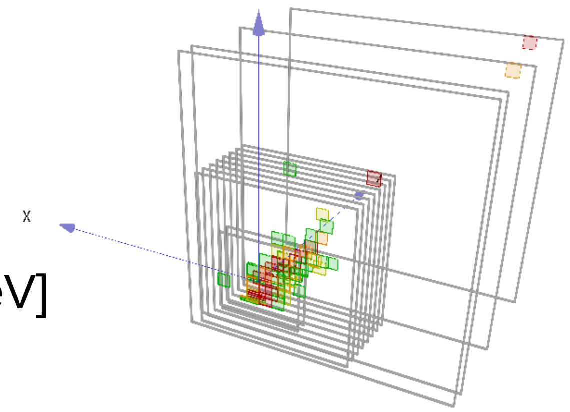
https://arxiv.org/abs/1012.4343

Longitudinal Profile of 10 GeV positron

In Fe: X_0 = 1.757 cm (λ = 16.77 cm)

Fully equipped part of the prototype ~ 15 X_0 (~26 cm of steel)

Data



> Data: Electrons from July 2015 Cern test beam.

- Energy [10GeV, 15GeV, 20GeV, 30GeV, 40GeV, 50GeV]

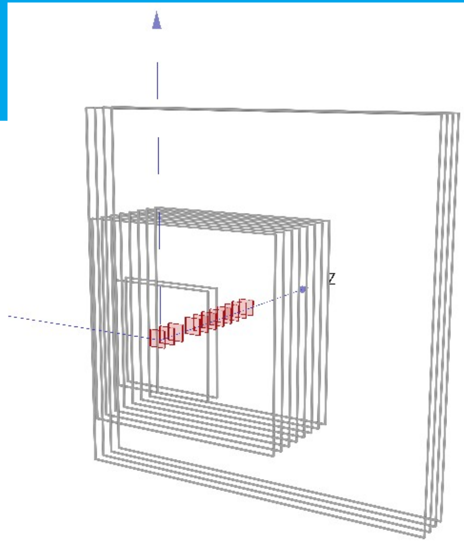
> Event Selection

- Trigger signal (T0) directly fed to the chip as a normal channel: nT0 > 2 to reject noise
- Cherenkov signal required
- nhits > 15 to remove noise and contaminations
- Energy sum last 2 modules < 1% to reject muons (modules at ~ $31X_0$ and ~ $46X_0$)
- Transverse center of gravity of the shower close to the beam axis ((-45,45) mm)

Simulation

- Simulation status:
  - Noise implemented
  - Cross Talk:
    - Fraction of the scintillation light generated by a particle in one cell might propagate in adjacent scintillator tiles adding energy to the measured energy in the neighboring cell.
      It has to be tuned
  - Saturated
    - Saturation due to limited number of pixel of the SiPM. Correction function should be applied to the data, but the number of effective pixel still has to be tuned, so it has been decided for the moment to keep the data like they are and apply a saturation function to the simulation

Noise extraction

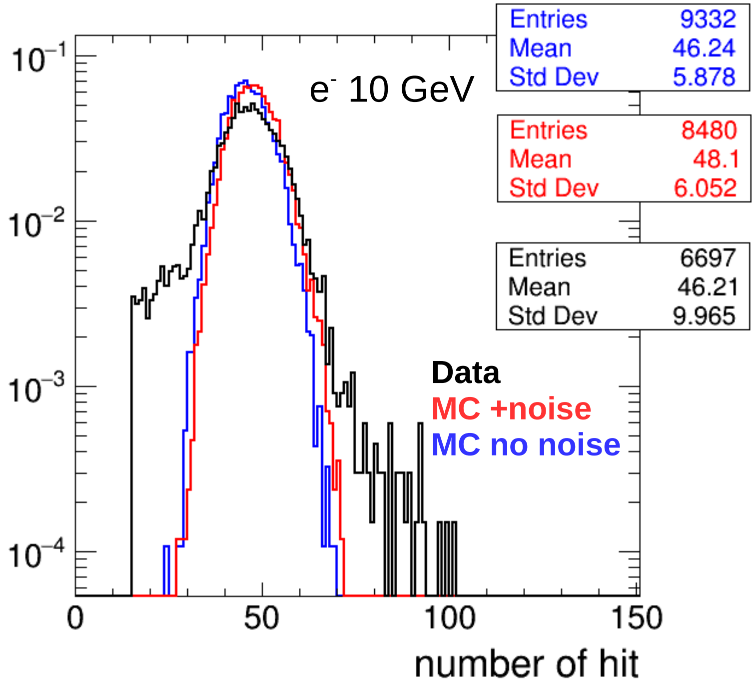


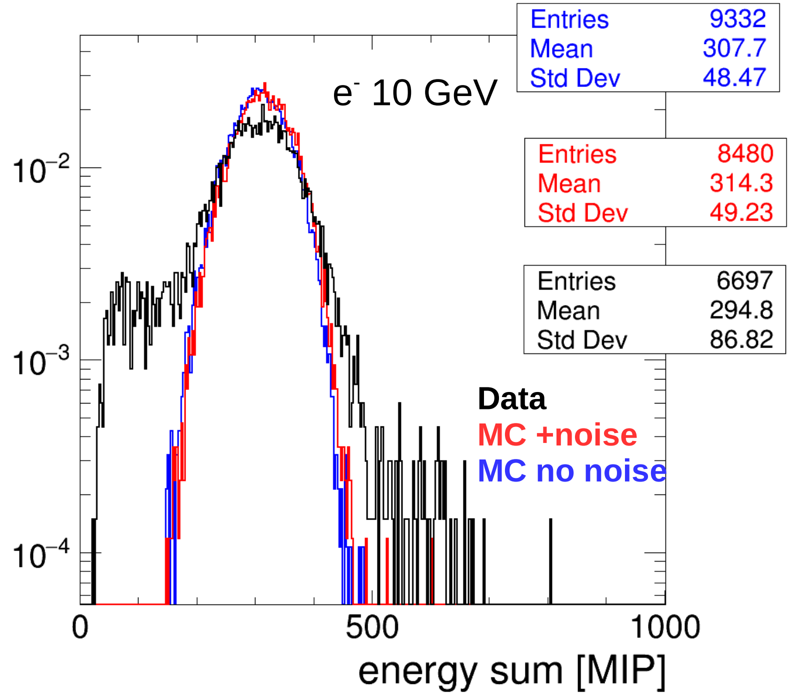
> Muon runs used

> Muon track identified with the track finder:

- nhits per track >= 8 hits
- If $nHits_{layer}$ >2 full event rejected → to reject pion

> Track removed from the event and the rest is added to the simulation

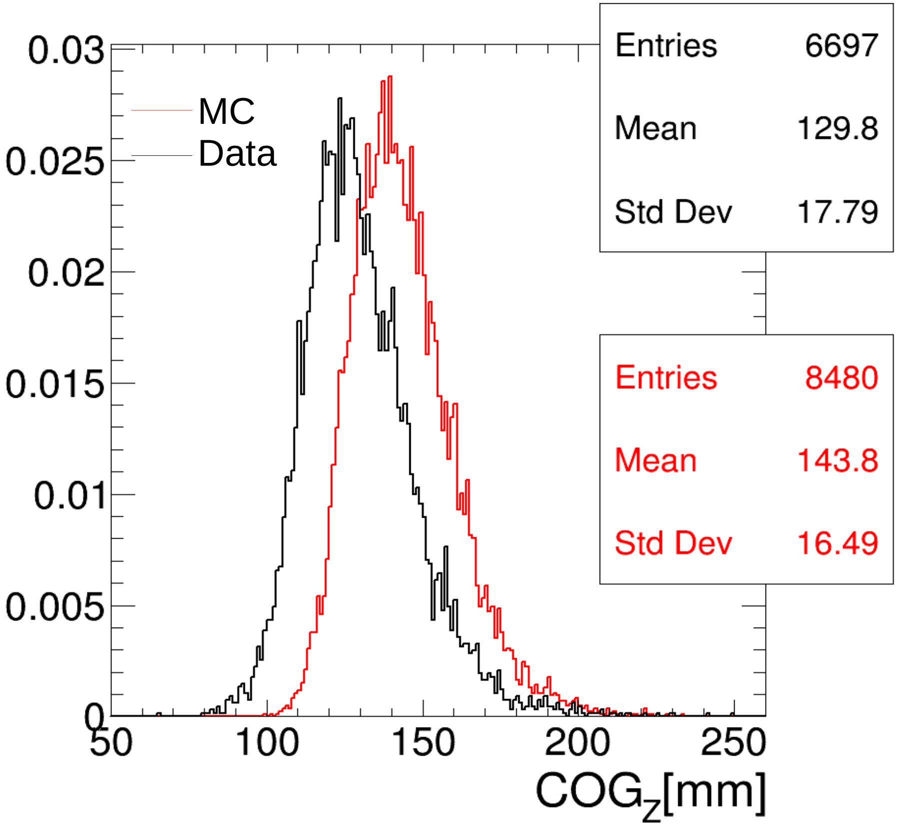




Effect of noise small

Material Tuning in the simulation

- Looking at the center of gravity distribution is Z, a shift between **data** and **simulation** has been observed



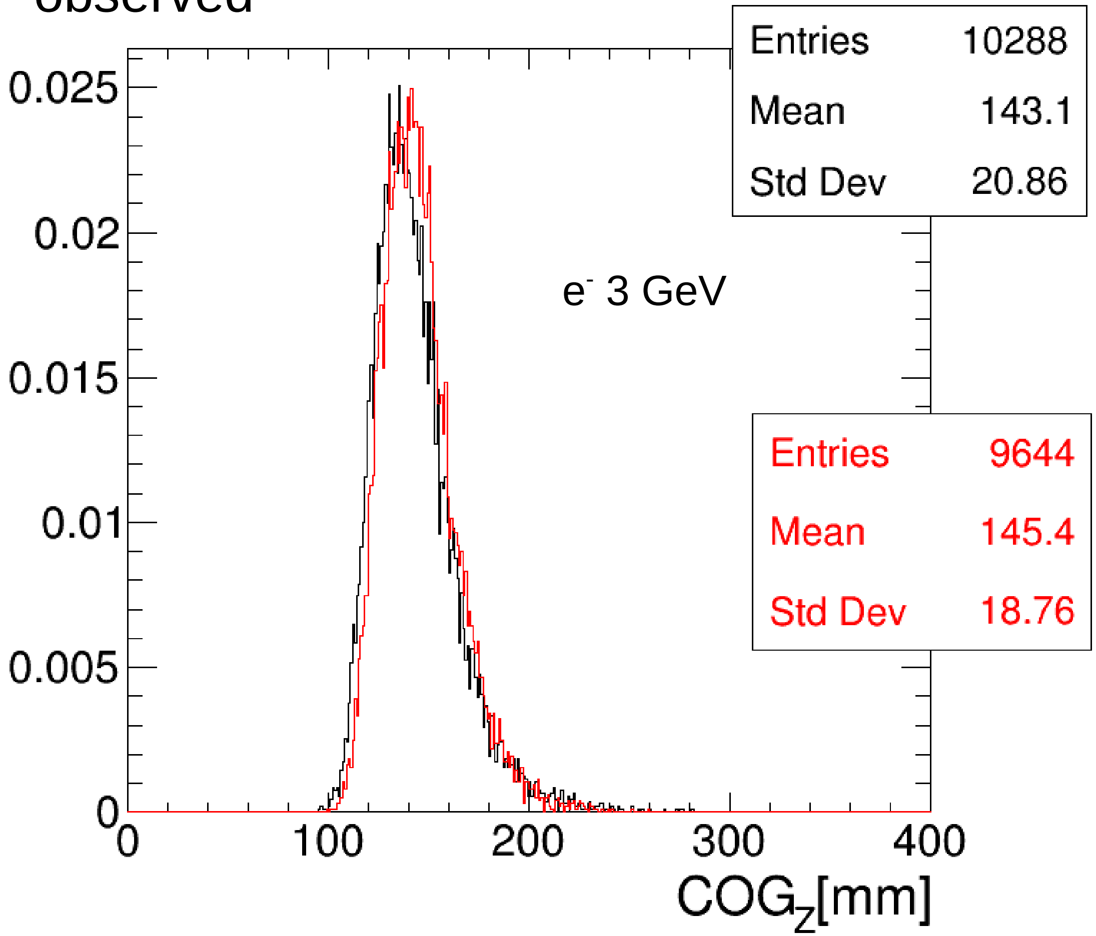
Looks like MC start to shower later.

Two possibilities:

(1) Geometry not well implemented in the simulation
(2) Something missing in the beam line

Electrons 3 GeV DESY 2015 test beam:center of gravity in Z

- To verify the geometry is well implemented in the simulation, June 2015 DESY test beam electron data has been looked (same test beam setup)
- If there is a problem in the simulation the same behaviour should be observed

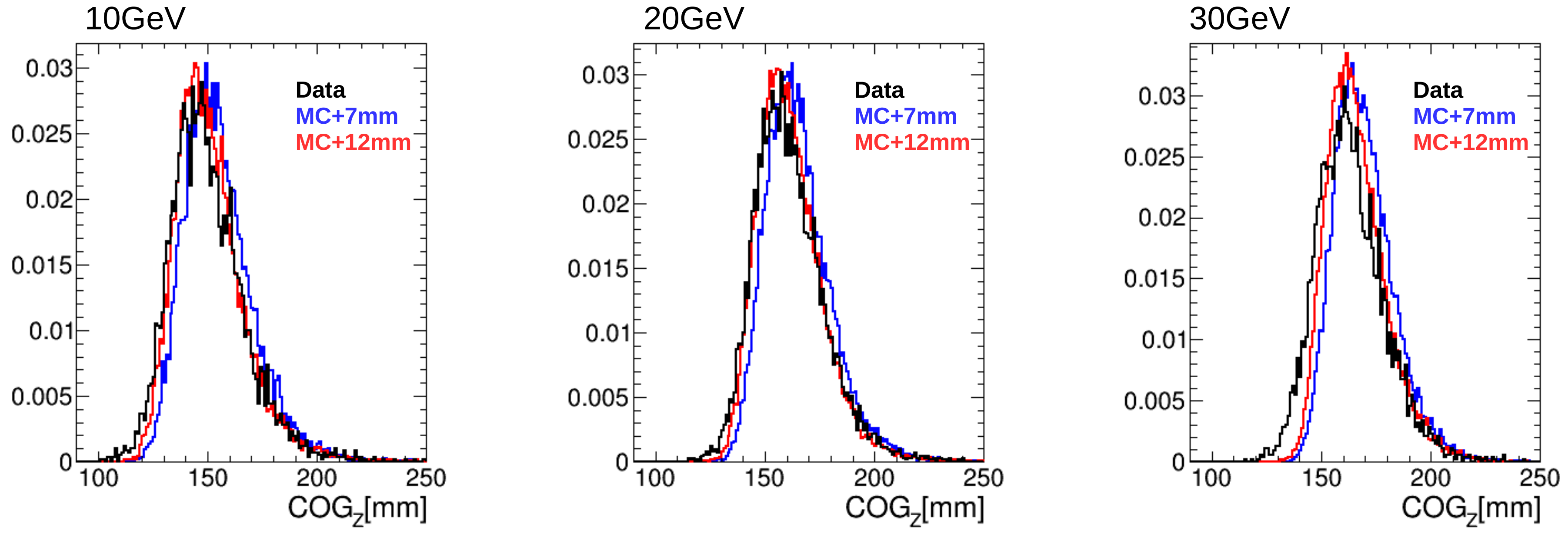


Clear hint there is something not understood in the beam line, but geometry of the detector in the simulation well done

Material Tuning in the simulation

- Beam line at CERN SPS very complex (several 100 m of beam line with magnets, cherenkov, wire chamber.. e^- produced as tertiary beam from secondary p)
  - Some simplifications in the simulation have been done
    - Cherenkov detector added in the simulation
    - Additional upstream material simulated by few mm of Steel

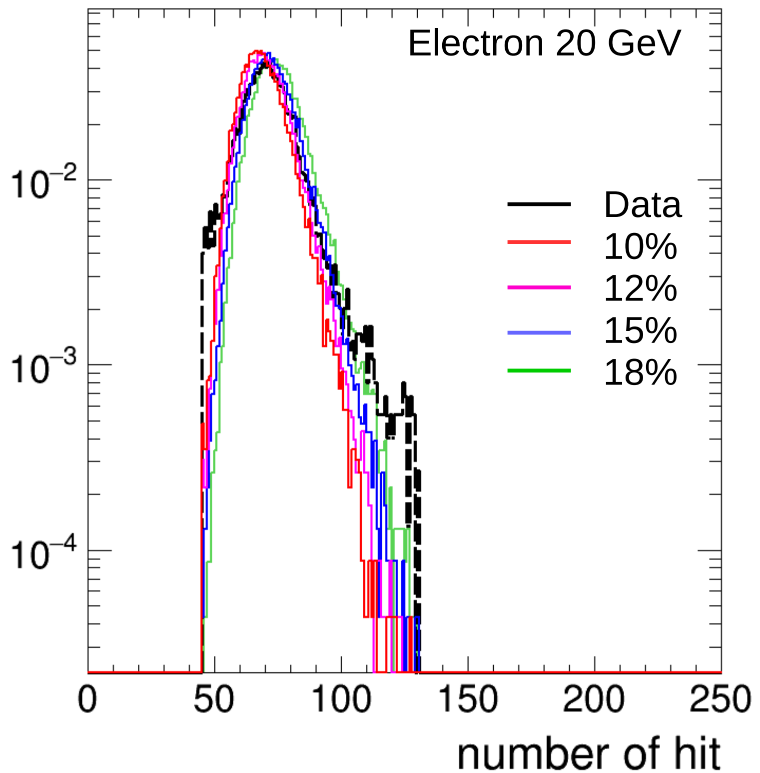
Obtained looking at the comparison of the center of gravity in Z between data and MC for all the energies: 12 mm chosen

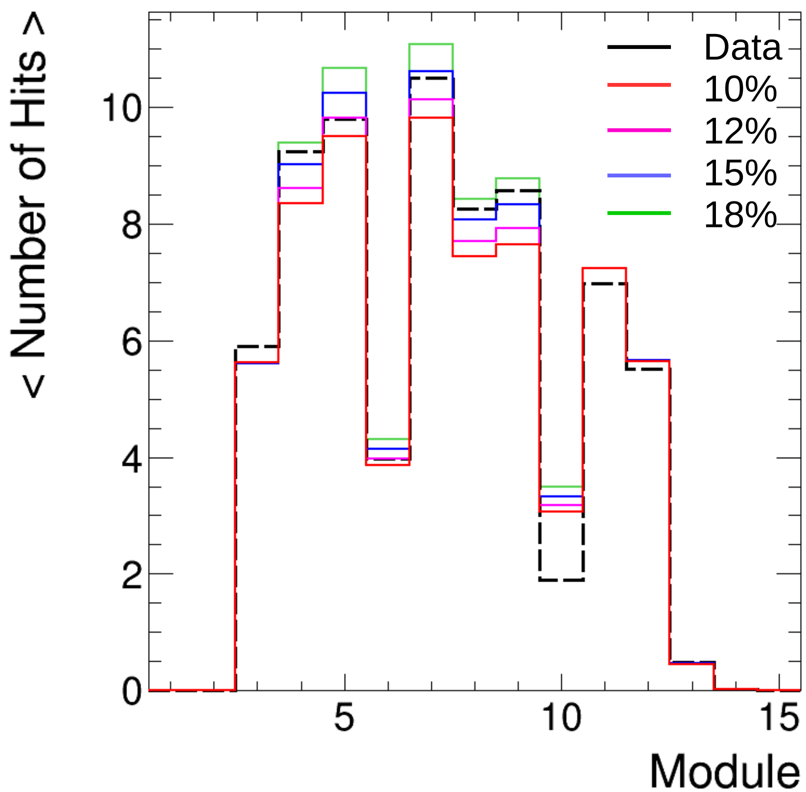


Simulation: cross talk tuning

> For each energy the hits distribution has been considered, using different cross talk values in the simulation
> 10%, 12%, 15%, 18%

> A cut on the number if hits per event has been applied → interested on the mean

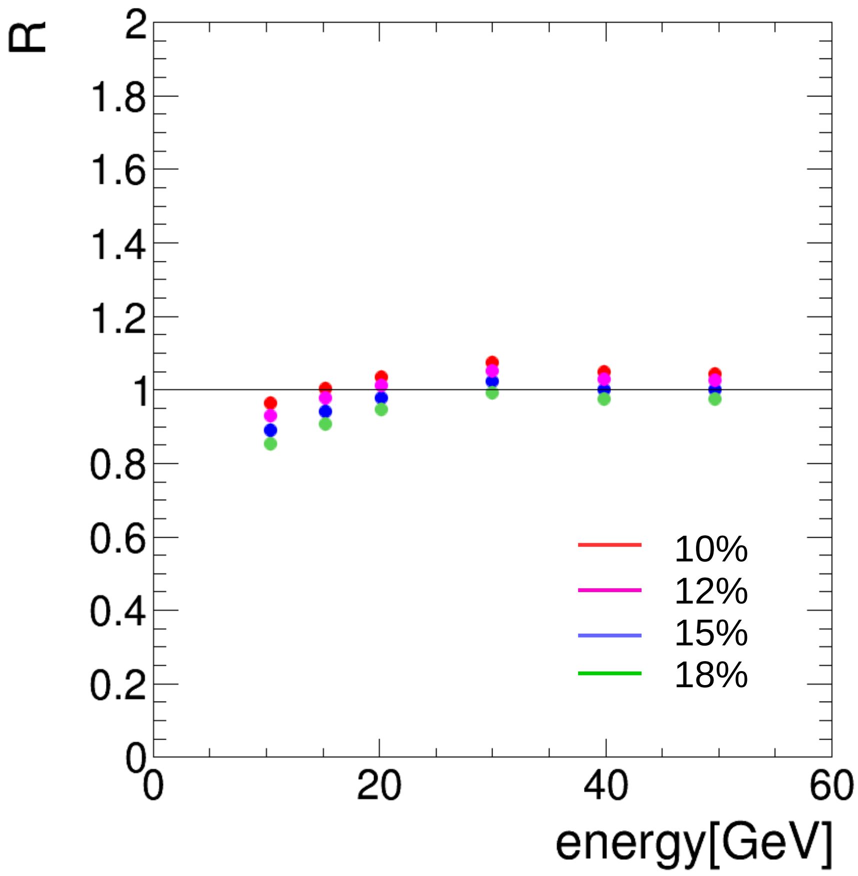




Simulation: cross talk tuning

- The mean of the distribution is plotted for all the energies and for different cross talk values
- The ratio R has been considered

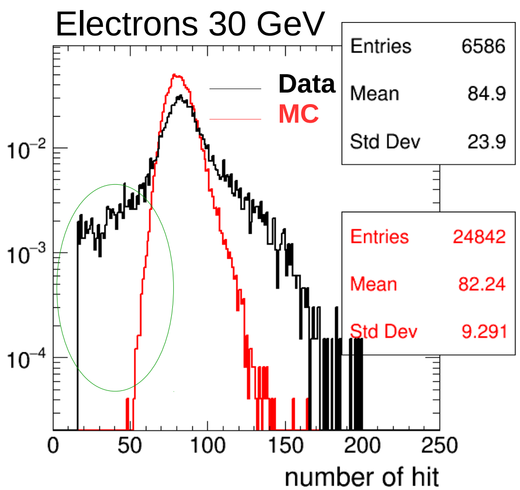
$$R = \frac{\overline{number\ of\ hits_{Data}}}{\overline{number\ of\ hits_{MC}}}$$



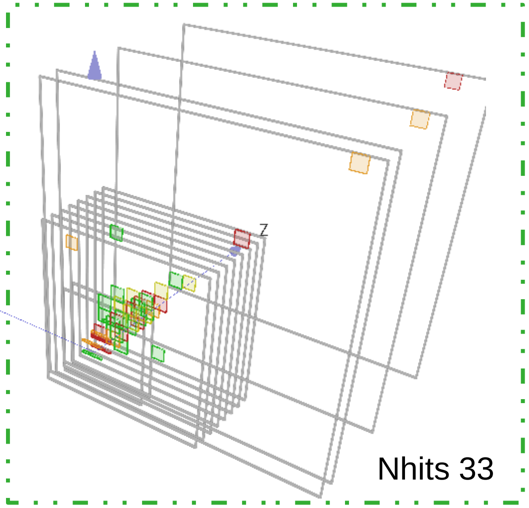
- 15% & 18% clearly too high for low energy electrons
  - 12% of cross talk per tile has been chosen

Event selection

> Looking at the number of hits distribution left tail can been observed

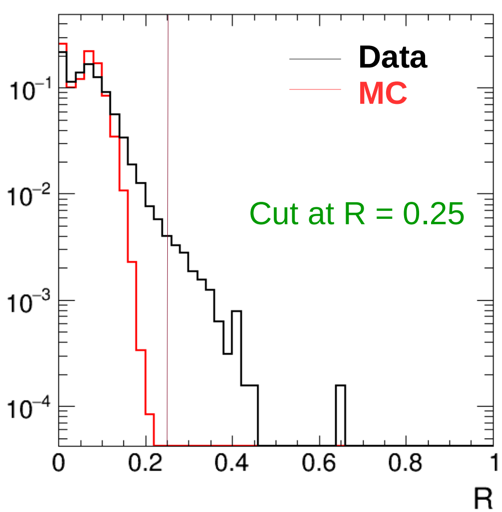


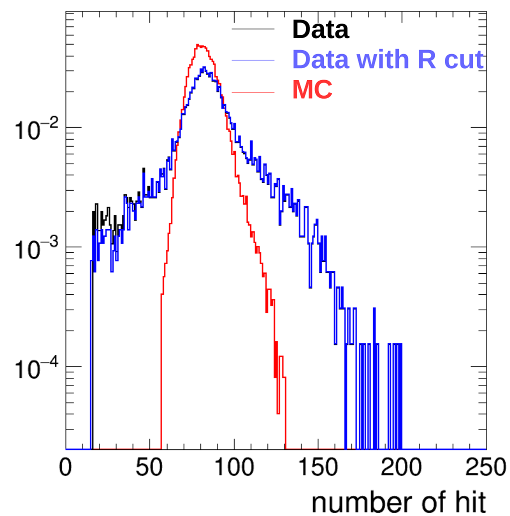
Most likely low energy electrons:
several focusing magnets present in the beam line



> Try to reject these events looking at the ratio R between the energy sum in the first AHCAL module and the total energy sum

$$R = \frac{\sum E_{firstModule}}{\sum E_{tot}}$$





Not as efficient as expected:
Cut on the number of hits will be applied

Summary / Outlook

- Analysis of electrons data from 2015 July Test Beam data is on going
- Data:
  - Event selection is good enough to look into the data
  - There are still few % of event we would like to reject
  - Because there is no chance to simulate them, and the analysis goal is be sure to understand the simulation, a hits cut will be applied
- Simulation
  - Noise implemented
  - Cross Talk tuned
  - Beam Line simulated
- To Do
  - Tuning of the number of effective pixels for saturation corrections
  - Start Pion Analysis

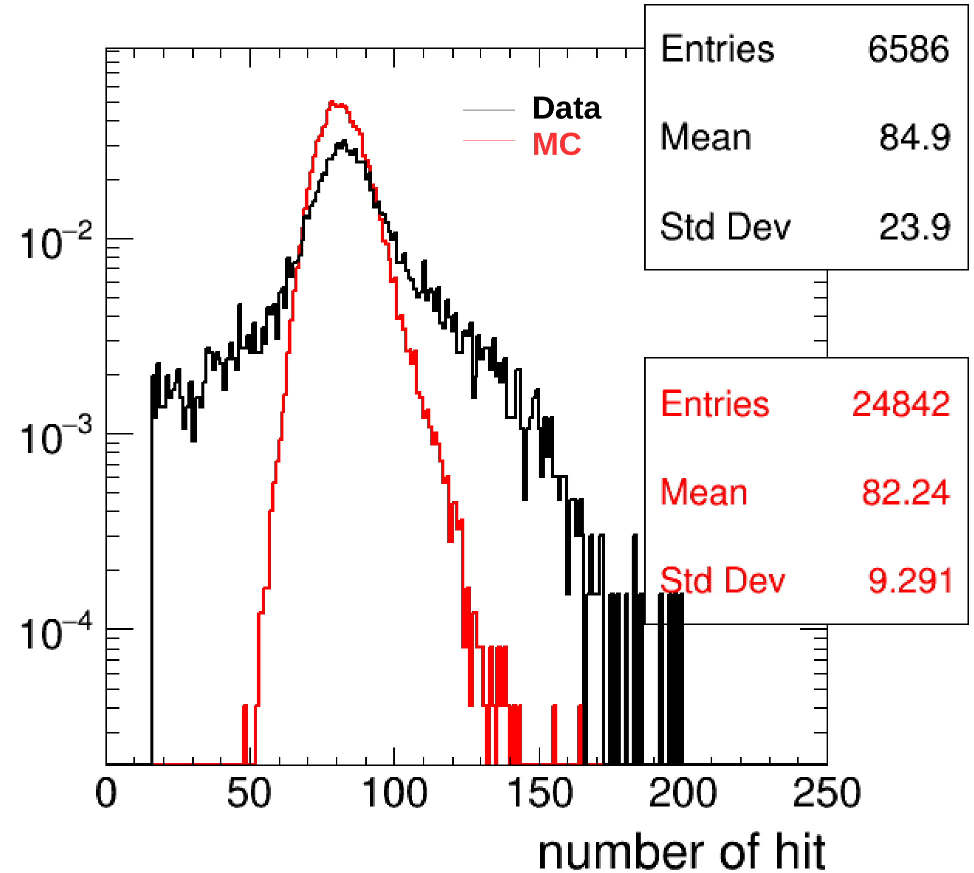
Backup

Event selection

> Looking at the number of hits distribution left tail can been observed

Most likely low energy electrons
(several focusing magnets present in the beam line)

Electrons 30 GeV

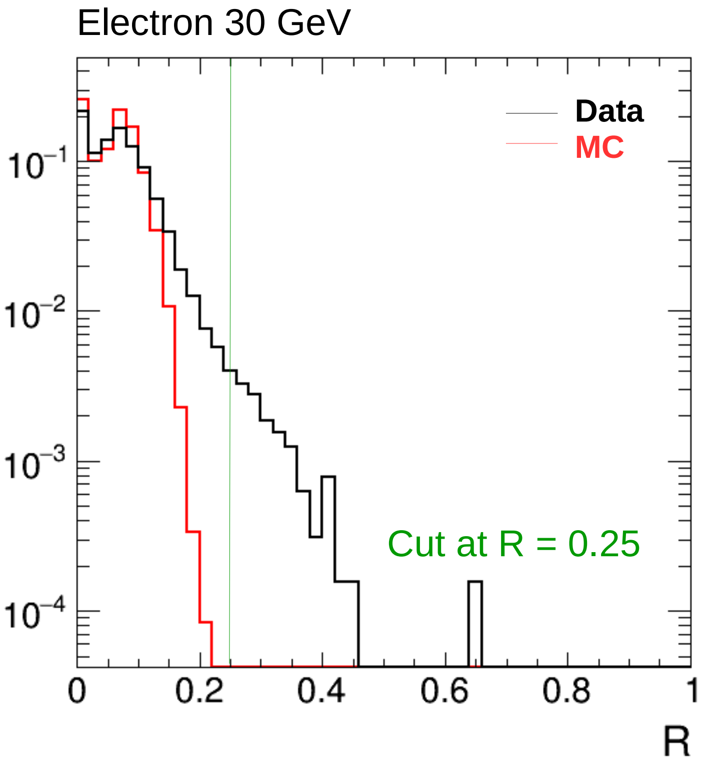


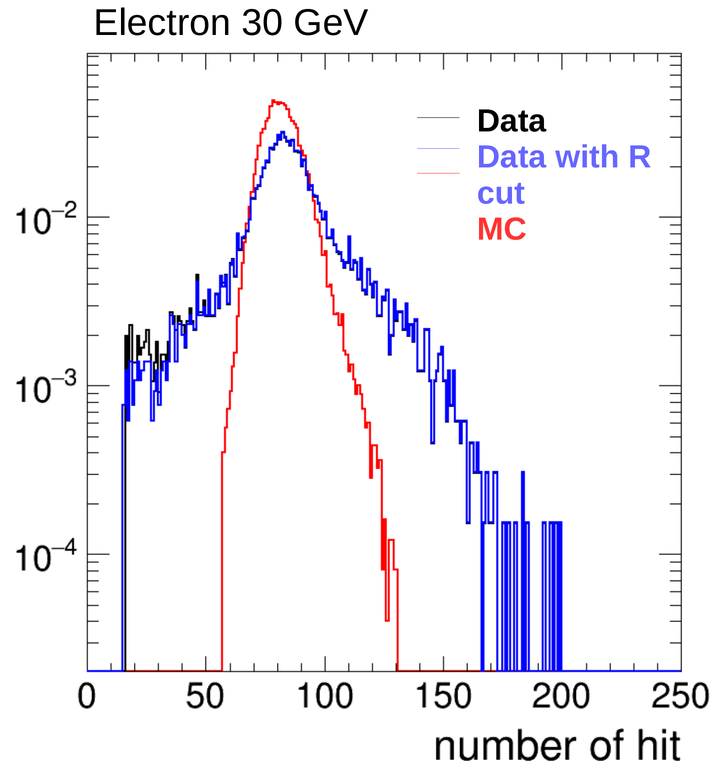
Event selection

- > Try to reject these events looking at the ratio R between the energy sum in the first AHCAL module and the total energy sum

$$R = \frac{\sum E_{firstModule}}{\sum E_{tot}}$$

- > Not as efficient as expected
  - A cut on the number of hits will be then applied

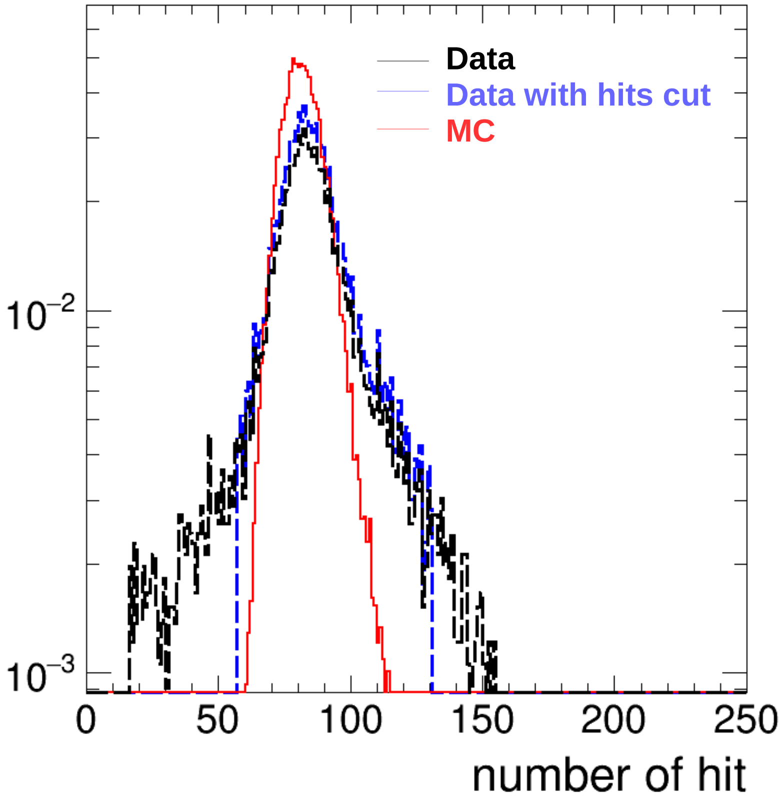


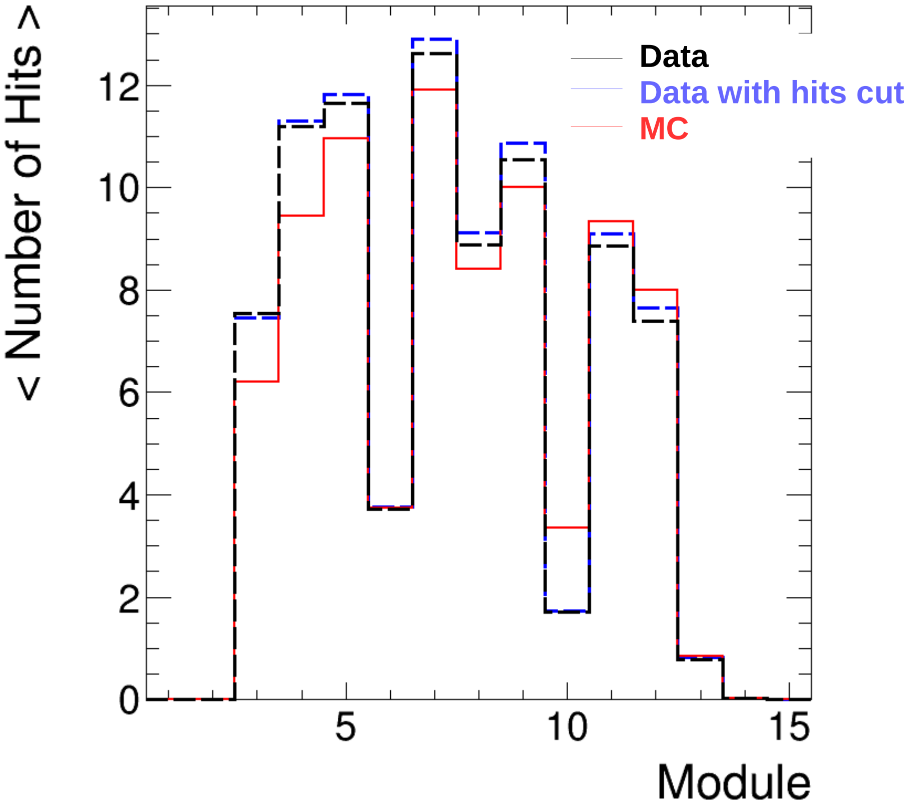


Comparison selection

> Number of hits distribution with & without cut on the number of hits

Electron 30 GeV





Comparison selection

> Energy sum distribution with & without cut on the number of hits

Electron 30 GeV