Analysis of electron data and comparison with the simulation of the AHCAL Detector

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CALICE

Outline

- **AHCAL technological prototype.**
- **Test beam on June 2018 at SPS**
- **Motivation of the test beam**
- **Comparison of electron data with simulation**
- **Simulation of the beam line elements**
- **Electron selection**
- **Longitudinal shower profile**
- **Summary and outlook**

AHCAL technological prototype

Steel absorber stack with 39 layers:

- 38 active layers of 72*72 cm²

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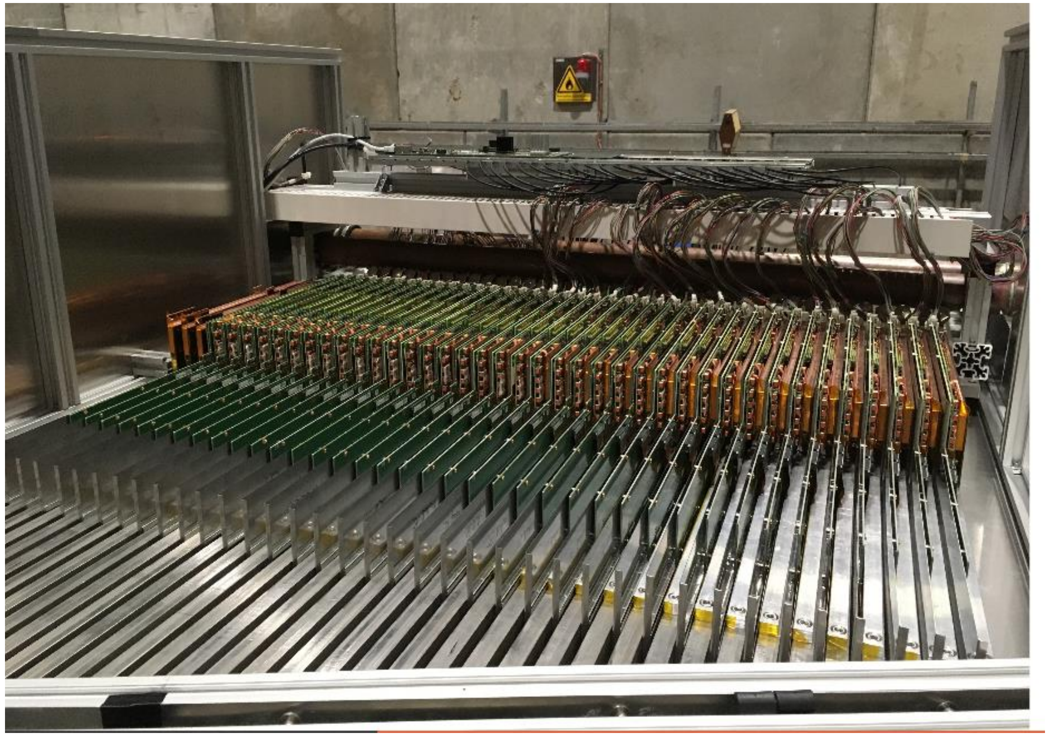
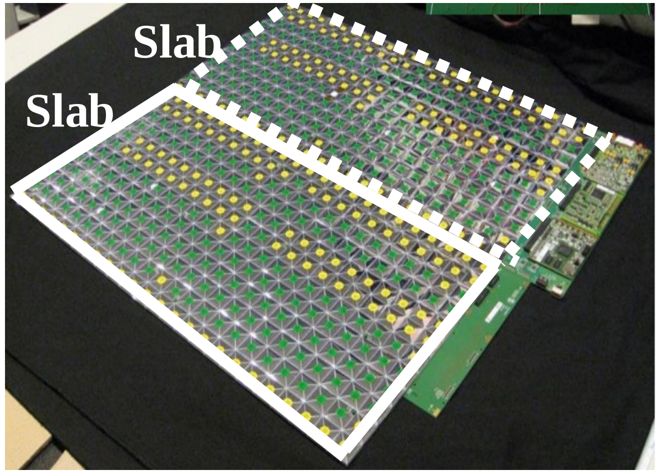
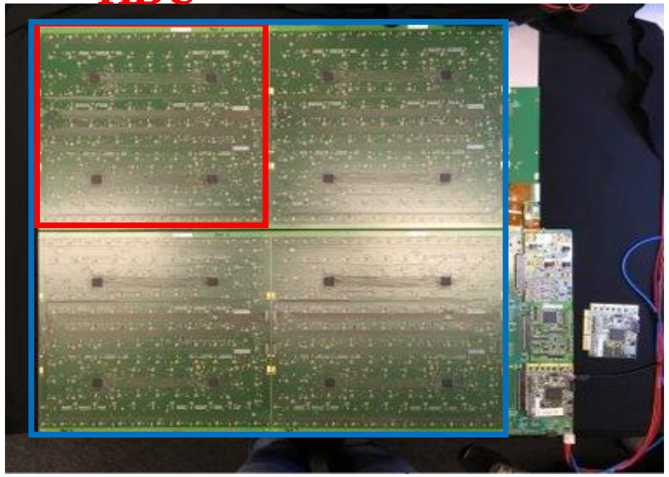
- 4 HBUs per module
  - 16 ASCIs (each with 36 channels)
  - 576 channels (tile size :3*3 cm²)

- 1 active Tokyo layer (Naoki talk)
  - Tile size: 6*6 cm²





HBU



Module

AHCAL technological prototype

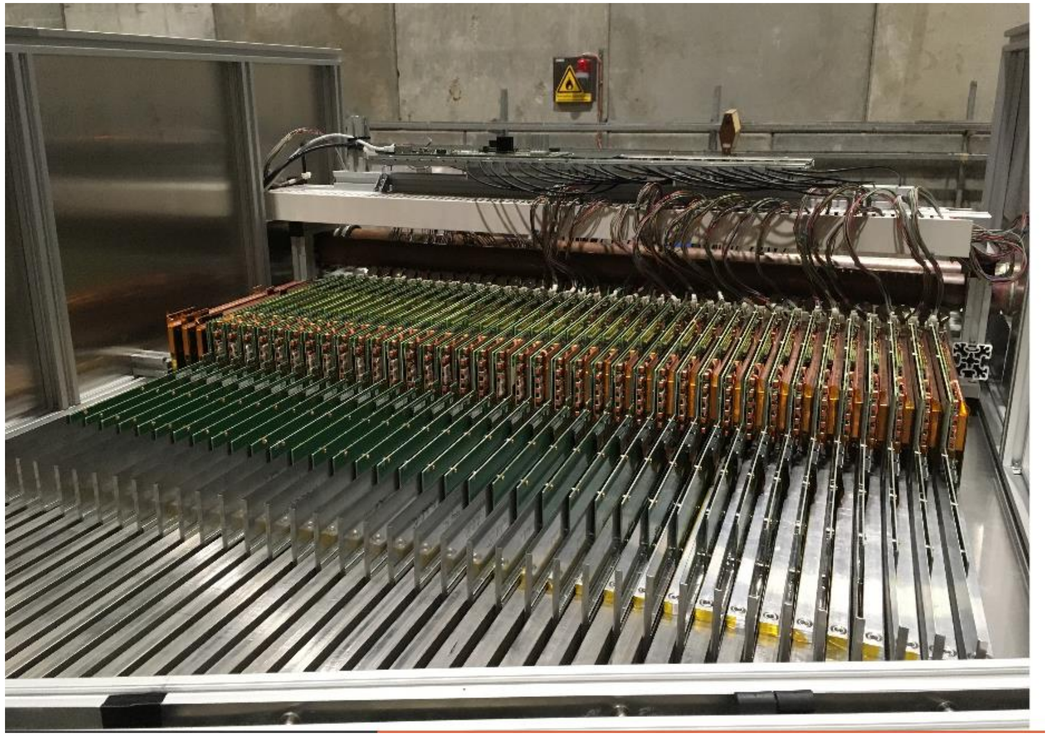
Steel absorber stack with 39 active layers:

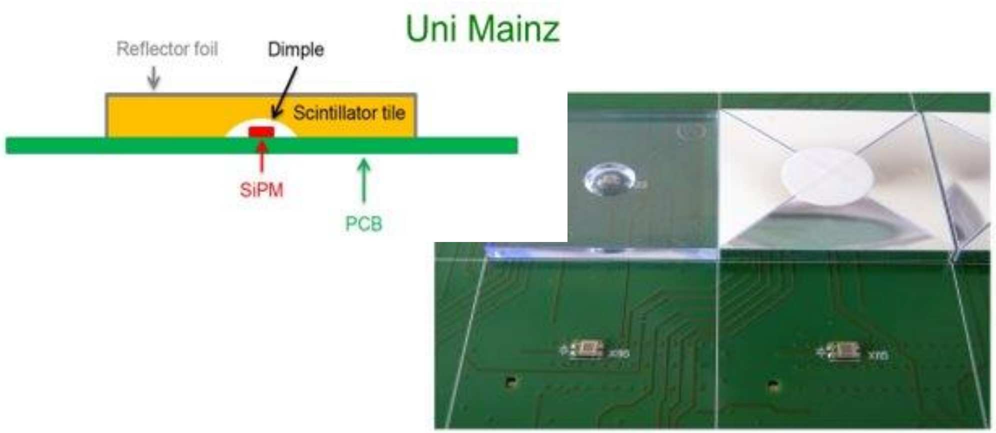
- 38 active layers of 72*72 cm²

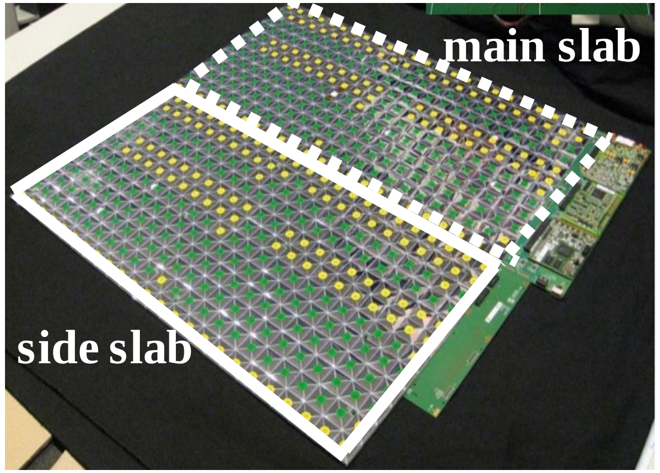
- 4 HCAL Base Units (HBUs) per module
  - 16 ASCIs (each with 36 channels)
  - 576 channels (tile size :3*3 cm²)

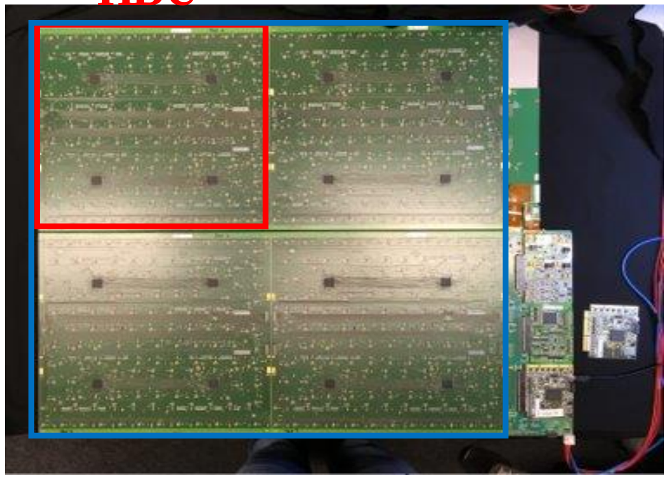
- 1 active Tokyo layer (Naoki talk)
  - Tile size: 6*6 cm²

- SiPMs mounted directly in the PCB







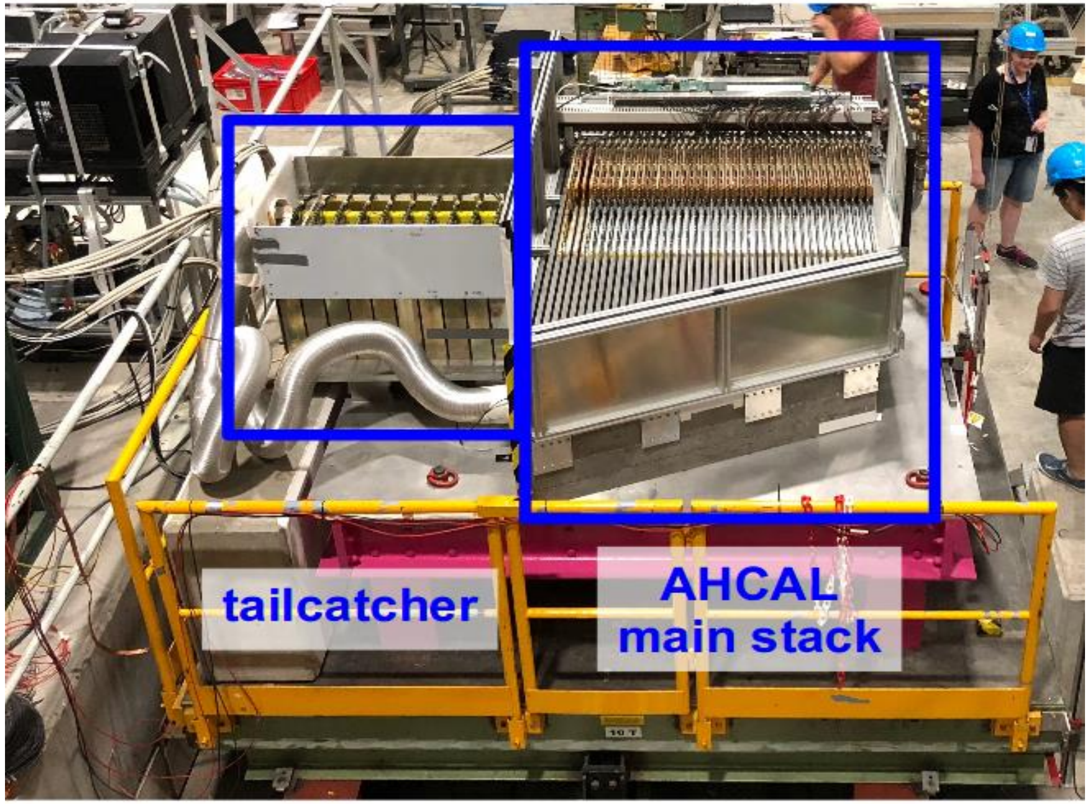


HBU

Module

AHCAL test beam at SPS

- Test beam has been done in June 2018 in the SPS in the H2 beam line.
- Tail catcher is sitting right behind the AHCAL.
- 1 pre-shower layer (1HBU) is front of the AHCAL.



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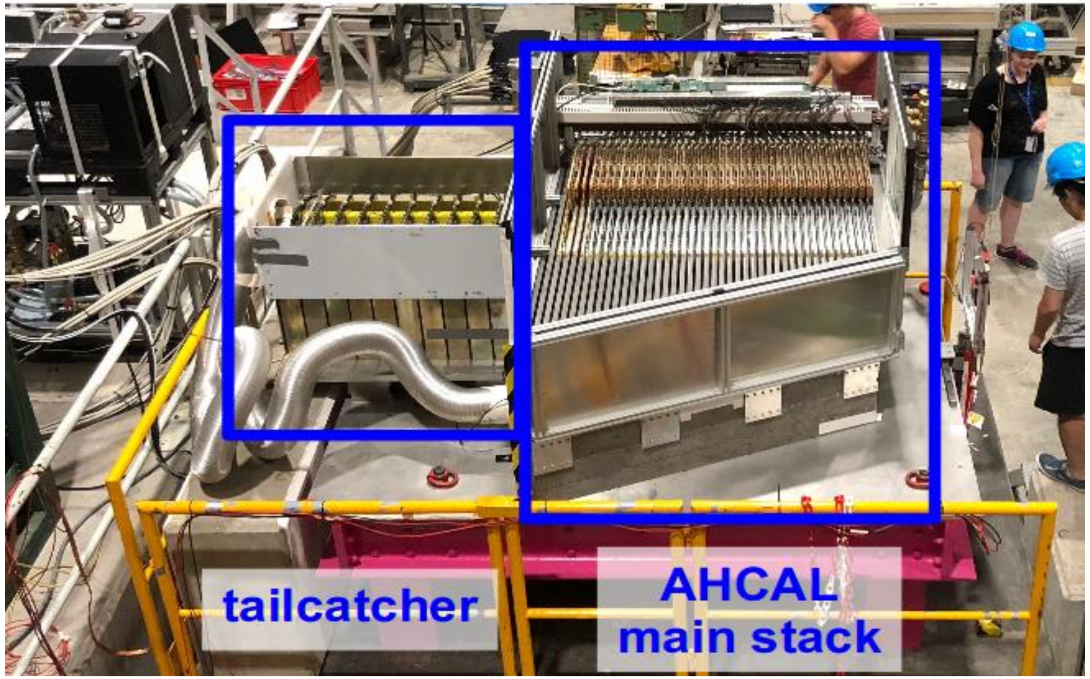
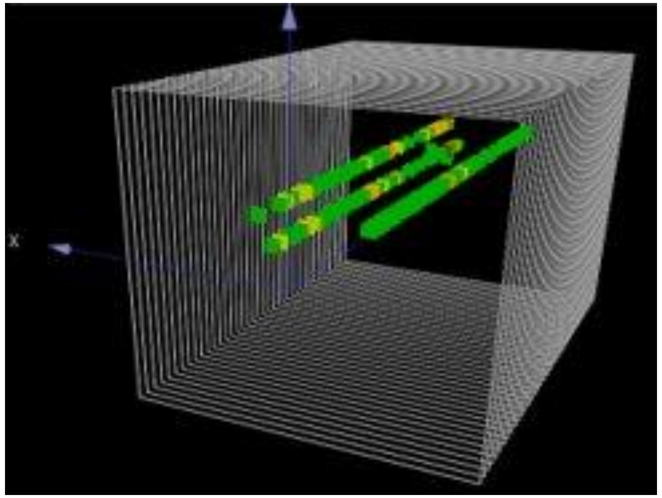
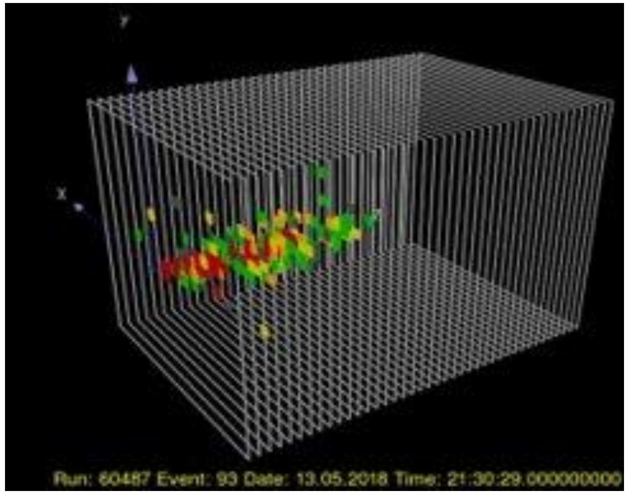


Data taking :

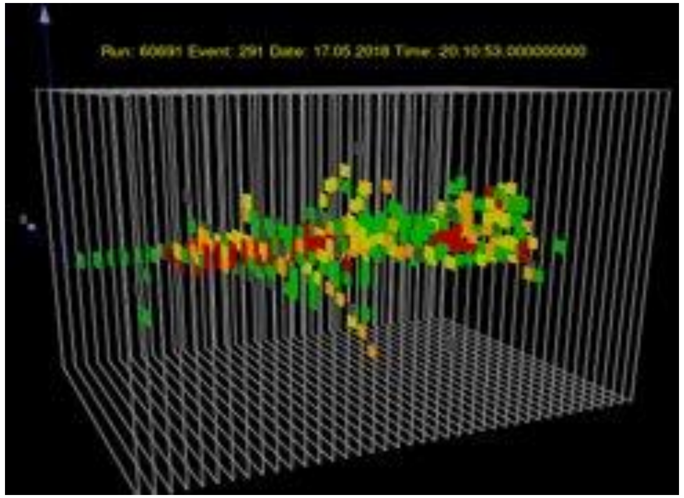
muons 40&120 GeV



electrons 10-100 GeV



negative pions 10-200 GeV



Motivation of the test beam

- Test the performance of the new SiPMs, tiles and readout system.
- AHCAL large prototype leads to demonstrate feasibility of mass production.
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- MIP Calibration
- High/Low Gain Intercalibration

LED run

- Gain Calibration
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- Cross check the calibration constants
- Shower profile
- EM performance of the detector
- Tune the simulation parameters

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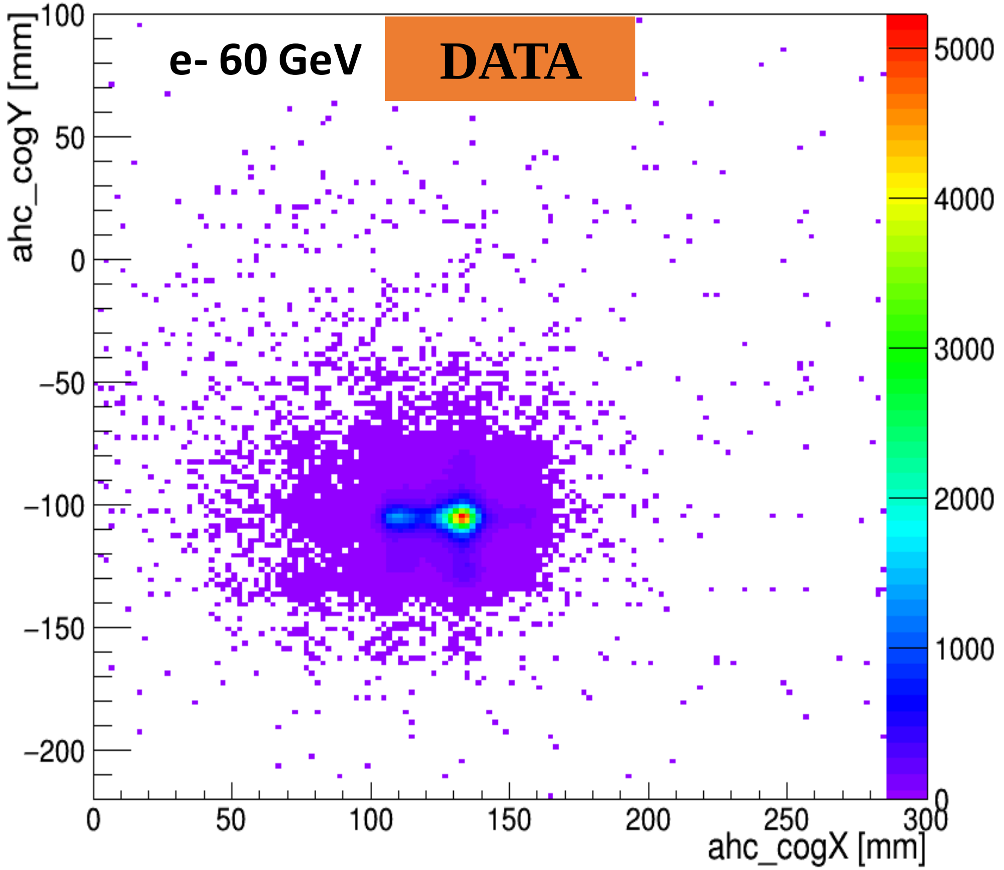
Pions analysis

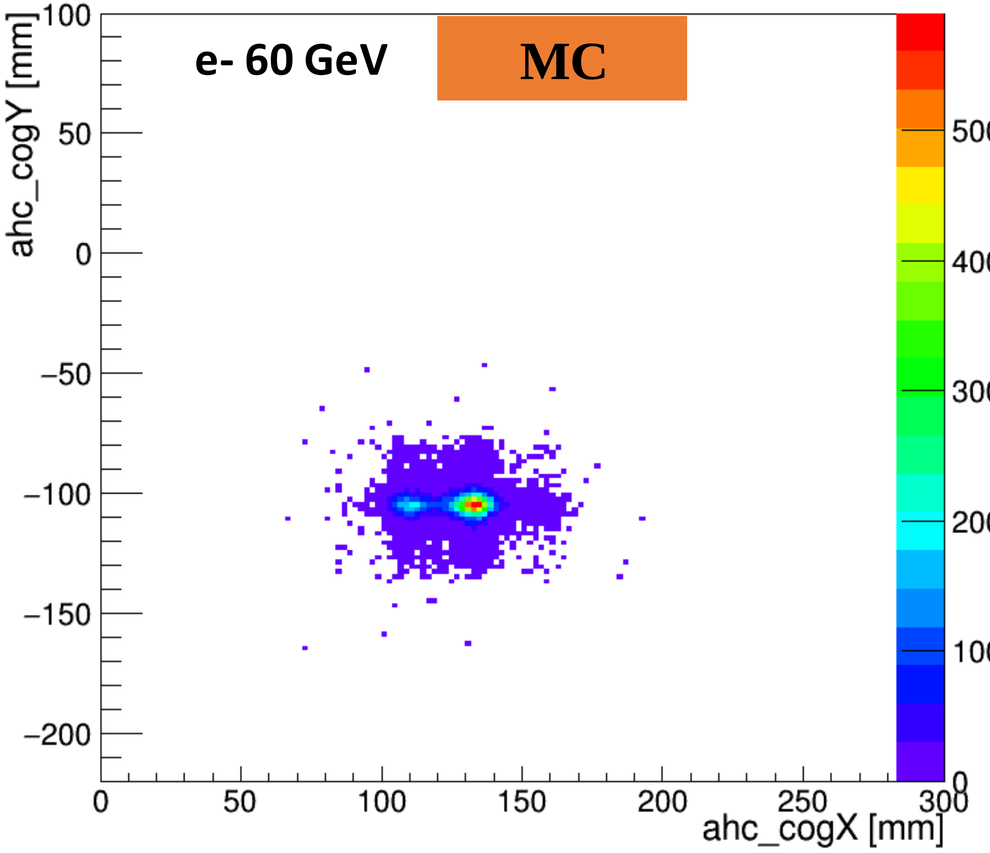
- Hadronic shower
- Shower separation

…

Data and Simulation comparison of electron

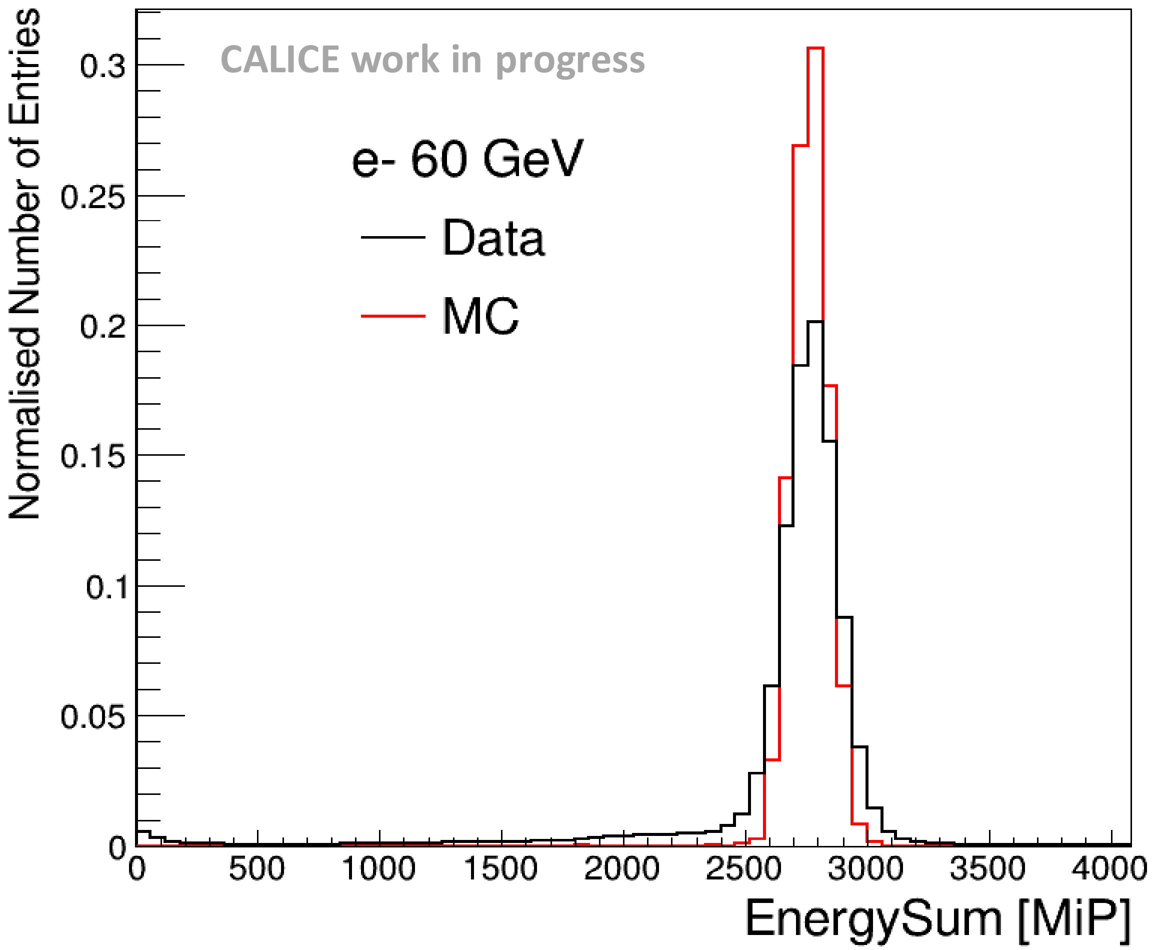
- cog_X vs cog_Y for data and simulation

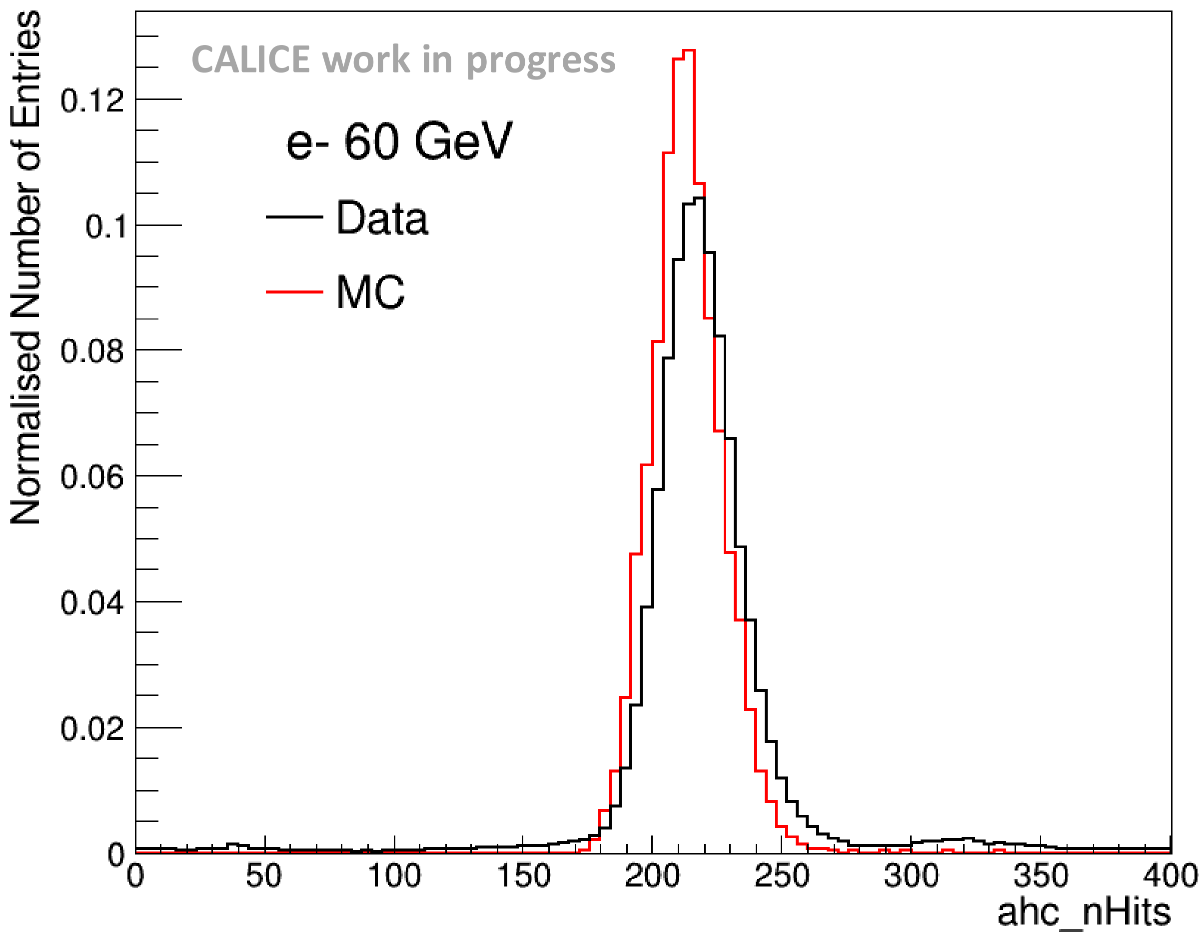




Data and Simulation comparison of electron

- No selection is applied to the data.
- The energy_sum distribution of MC looks more narrow than the data.
- Observation of more hits in the data than simulation.



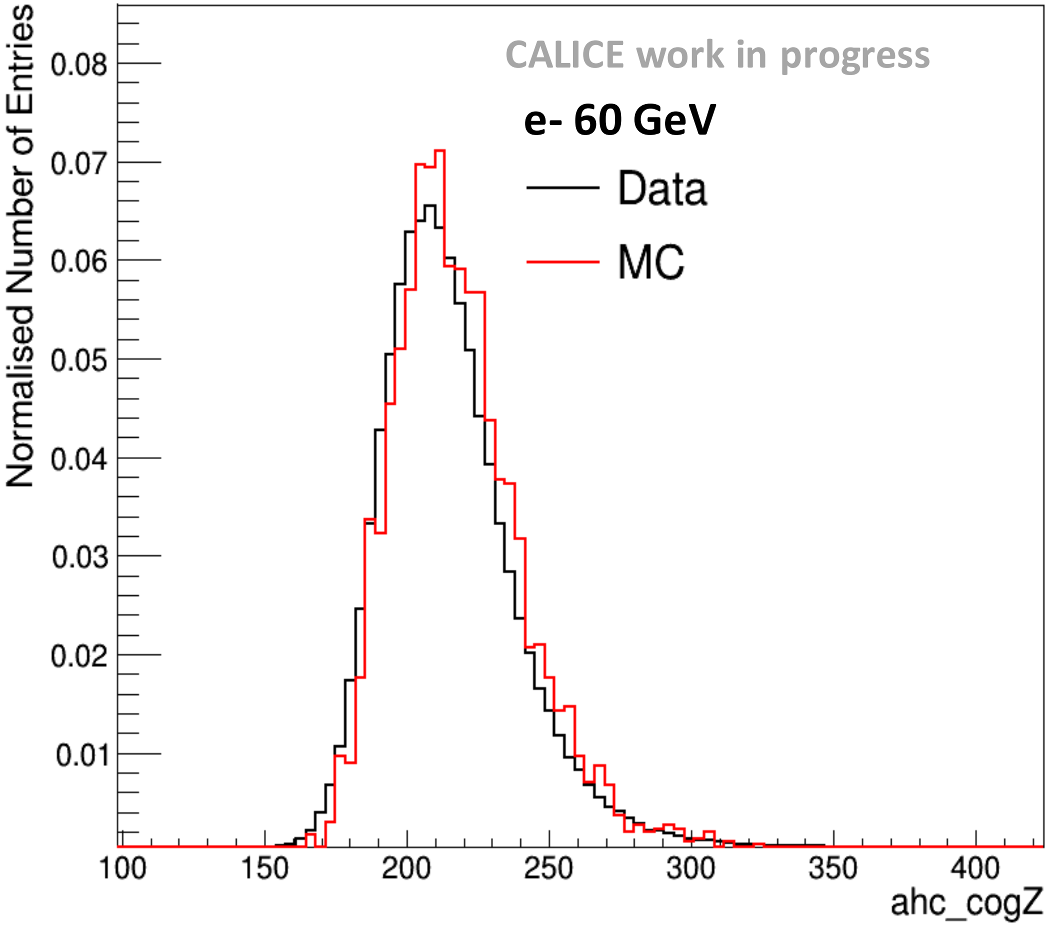


Data and Simulation comparison of electron

- Center of gravity in Z direction (cog_Z):

$$z_{\mathrm{cog}} = \frac{\sum_{i=1}^{N_{\mathrm{hits}}} E_i \cdot z_i}{\sum_{i=1}^{N_{\mathrm{hits}}} E_i}$$

E_i : energy deposit in the active cell
Z_i : position of the active cell
N_{hits} : number of active cells

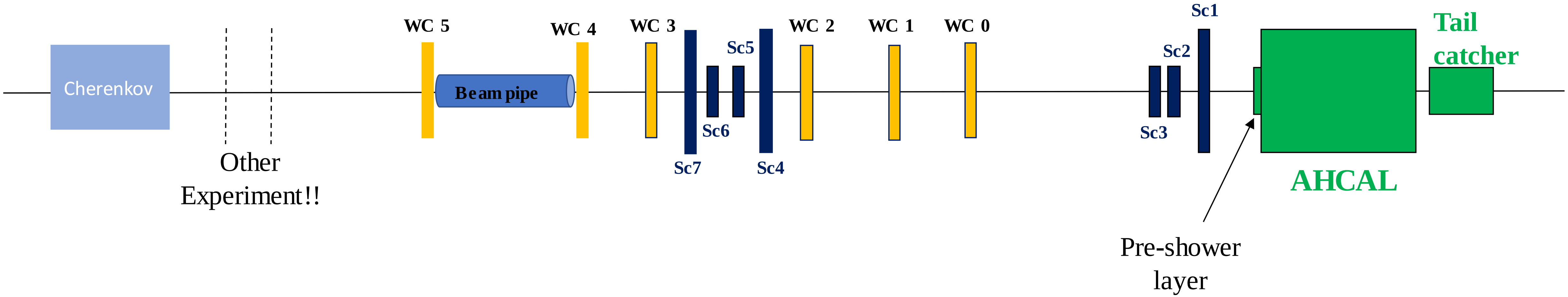


- Looking to the center of gravity of the shower in Z, the simulation start showering slightly later than data.

- It might be that the beam line of the simulation is still missing some elements.

Setup of the beam line of June test beam

- Scintillator Sc1, Sc2, Sc3, Sc5 and Sc6 are used for trigger validation.
- Wire chamber WC1, WC2, WC3 and WC4 are used for beam tracking.



- The setup of the beam line is quite complex.
- The implementation of all the beam instrument in the simulation is difficult.
- Additional material will be implemented to the simulation to take the missing material in the beam line in account.

Tuning the thickness of the additional material in the beam line

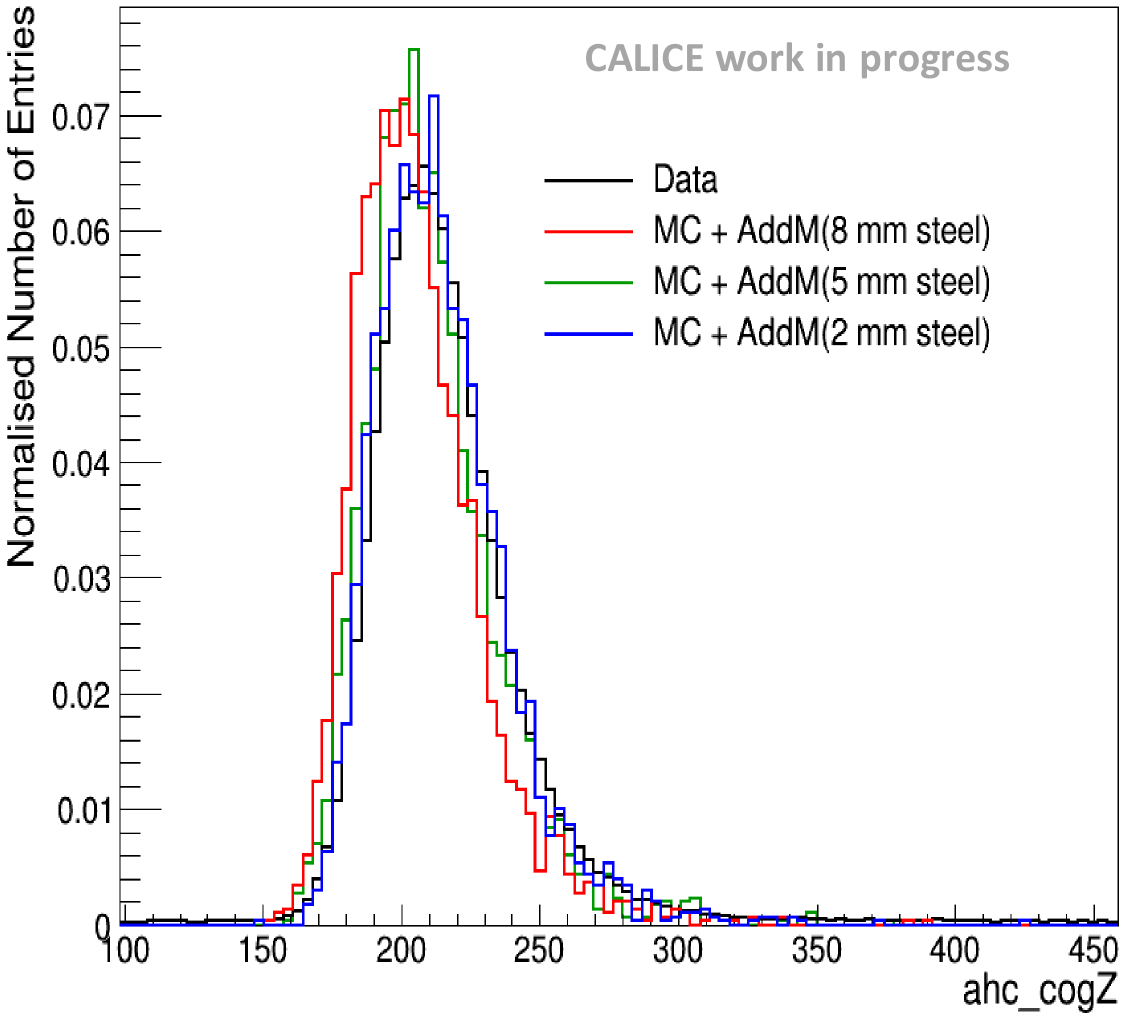
- Additional material(steel) is implemented in the beam line of simulation to take the elements missing in H2 beam line at the SPS in account.

- Simulation is done for 3 different thicknesses of the steel: 8mm, 5mm and 2 mm.

- By looking to the center of gravity in Z of the shower we can check how much additional material we need in the beam line.

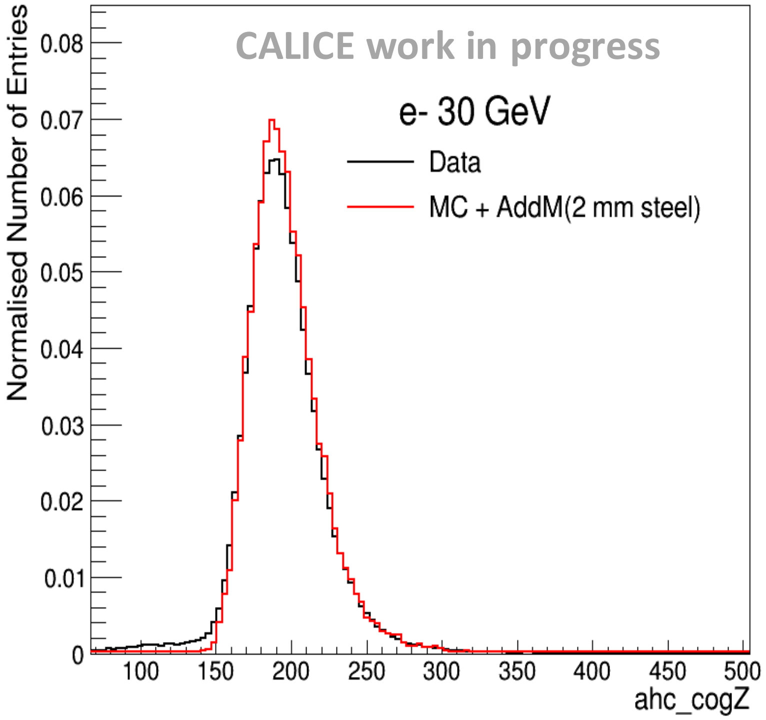
- The cog_Z distribution of the simulation with 2 mm of the steel as additional material looks superimposed on the data.

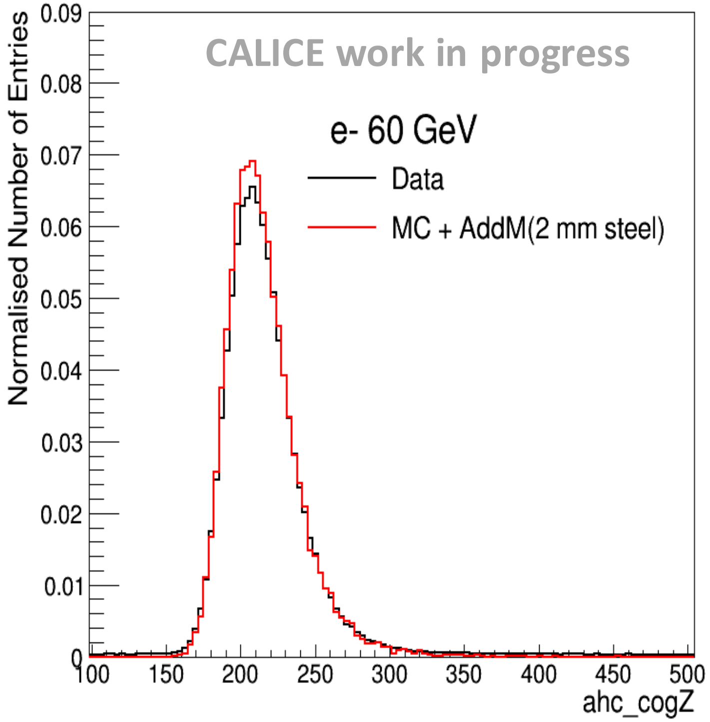
- 2 mm of steel (~ 0.14 Xo) will be the most relevant thickness for the simulation.

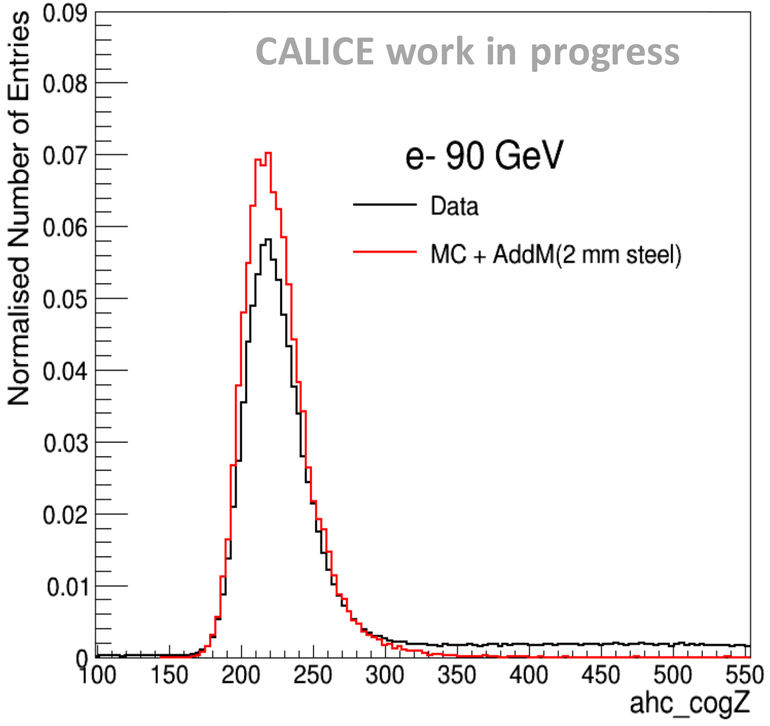


Tuning the thickness of the additional material in the beam line

- Check the center of gravity with 2 mm steel for different energies : 30 GeV, 60 GeV and 90 GeV
- We do not see any significant variation of the cog_Z for different energies.
- Which confirms that the relevant thickness of the additional material in the beam line is 2 mm of steel (~ 0.14Xo).



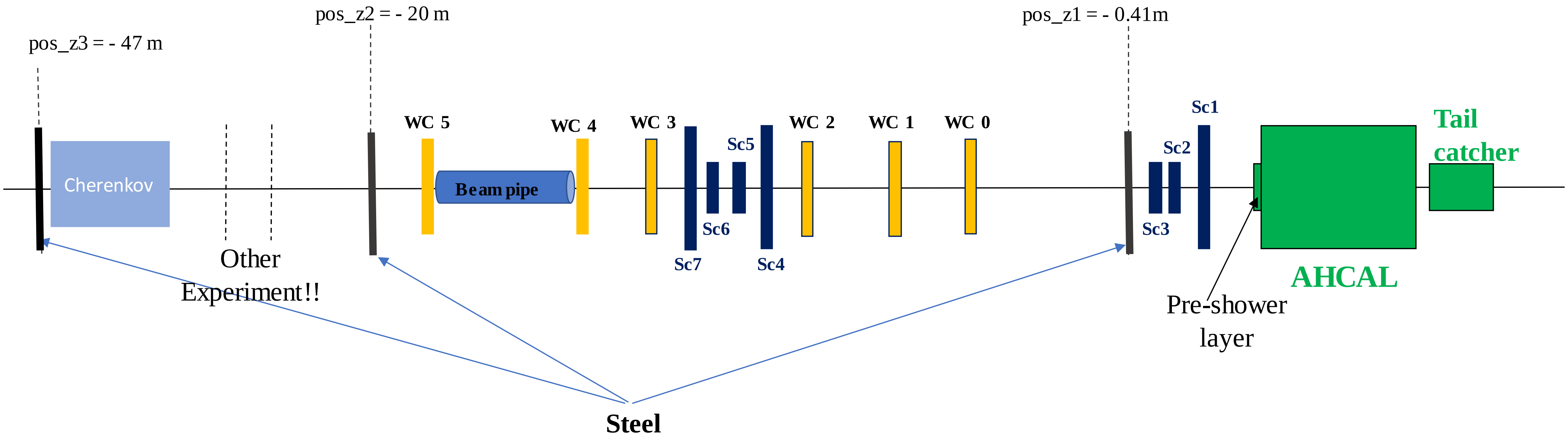




Tuning the position of the additional material

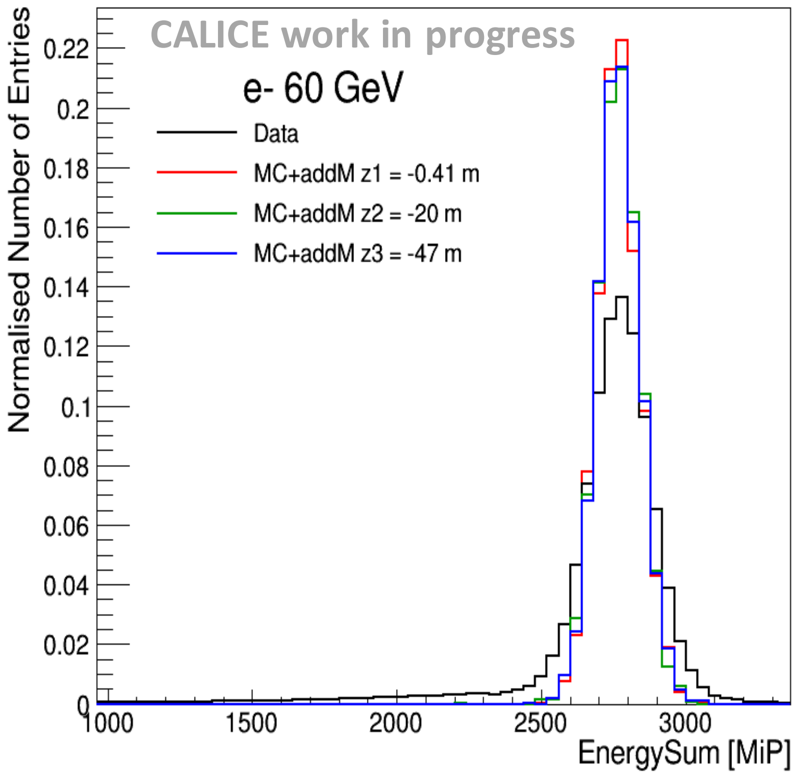
- Check if the position of the additional material has an influence on the simulation.

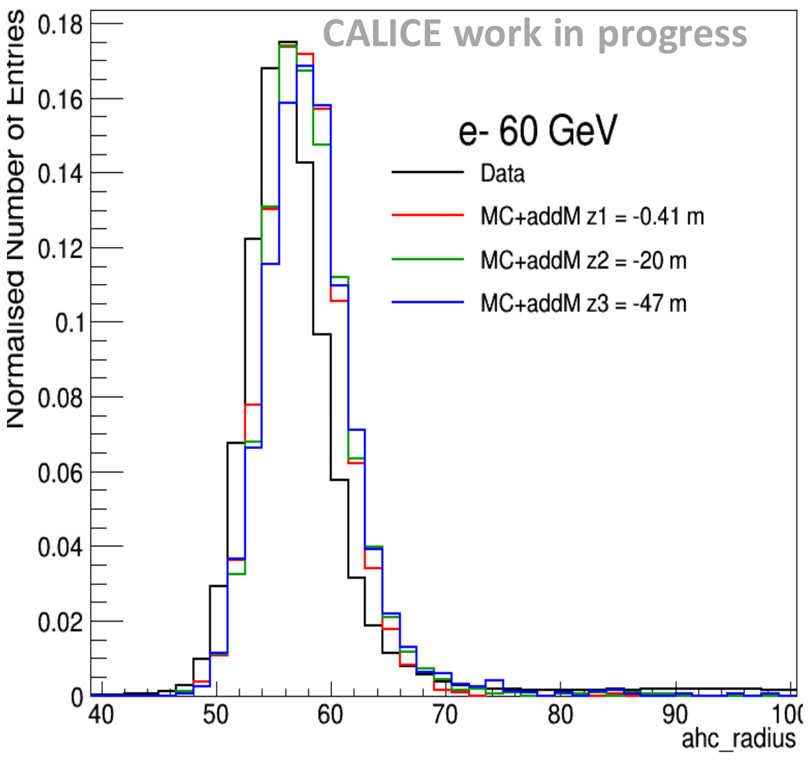
- Simulation with the additional material of steel (thickness : 2mm) in 3 different positions:
  pos_z1= - 0.41 m , pos_z2= - 20 m and pos_z3= - 47 m

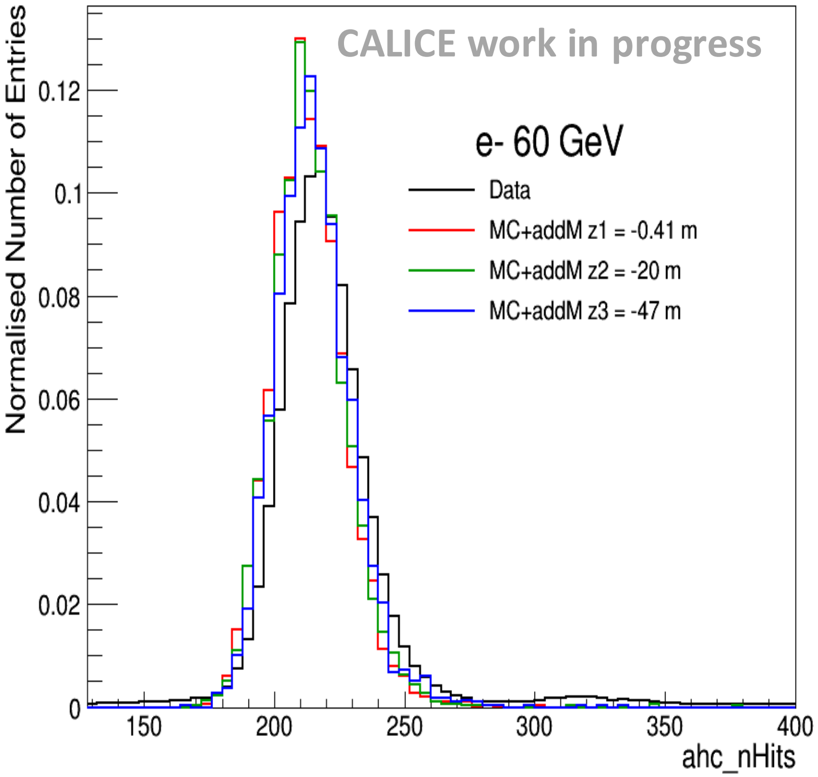


Tuning the position of the additional material

- Increase of the number of hits for the case where the additional material is at - 47 m.
- This increase is probably from the low energy radiation which happened while the interaction of the beam with the additional material.
- The energy_sum distribution is not affected by this radiation because of its low energy.
- Slight increase of the shower radius when the position is at -47 m.
- The relevant position of the additional material should be far from the detector at - 47m.

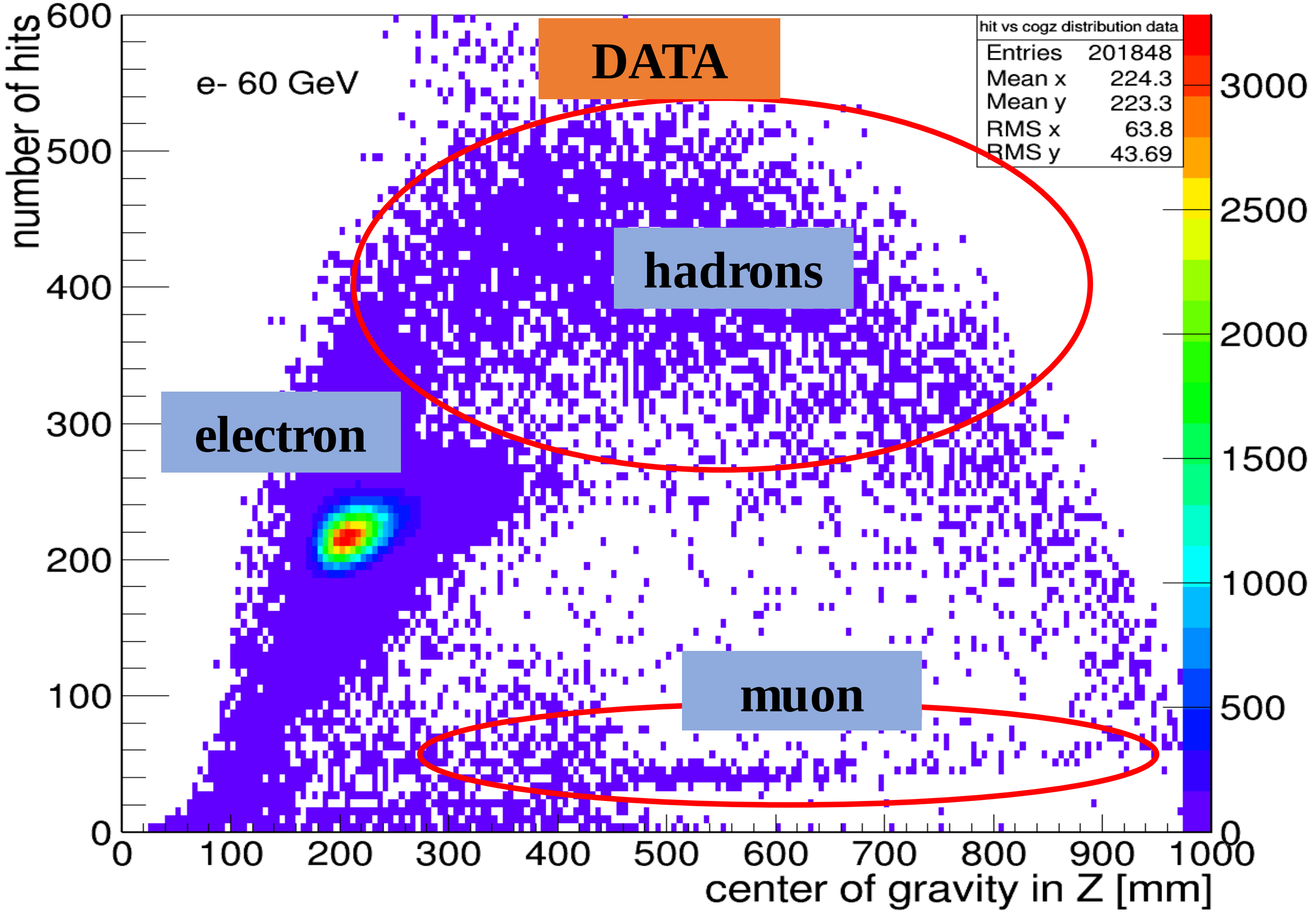


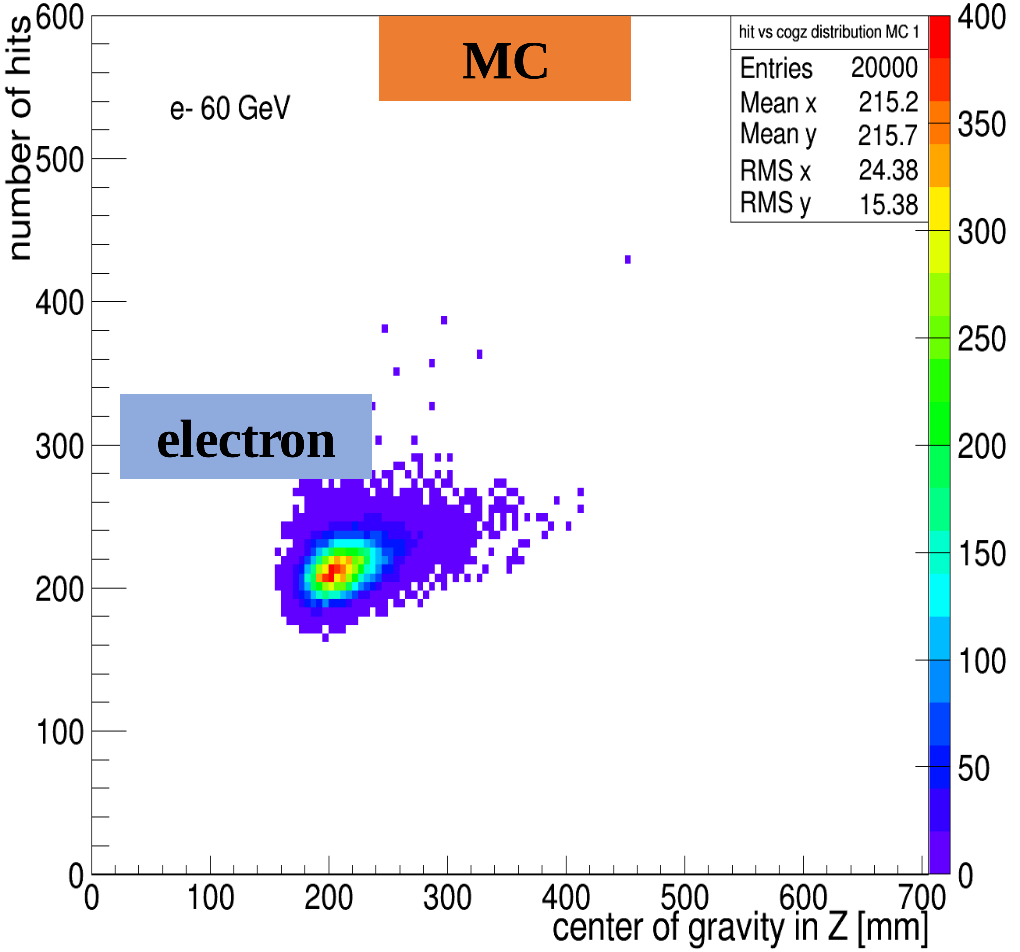




Electron selection

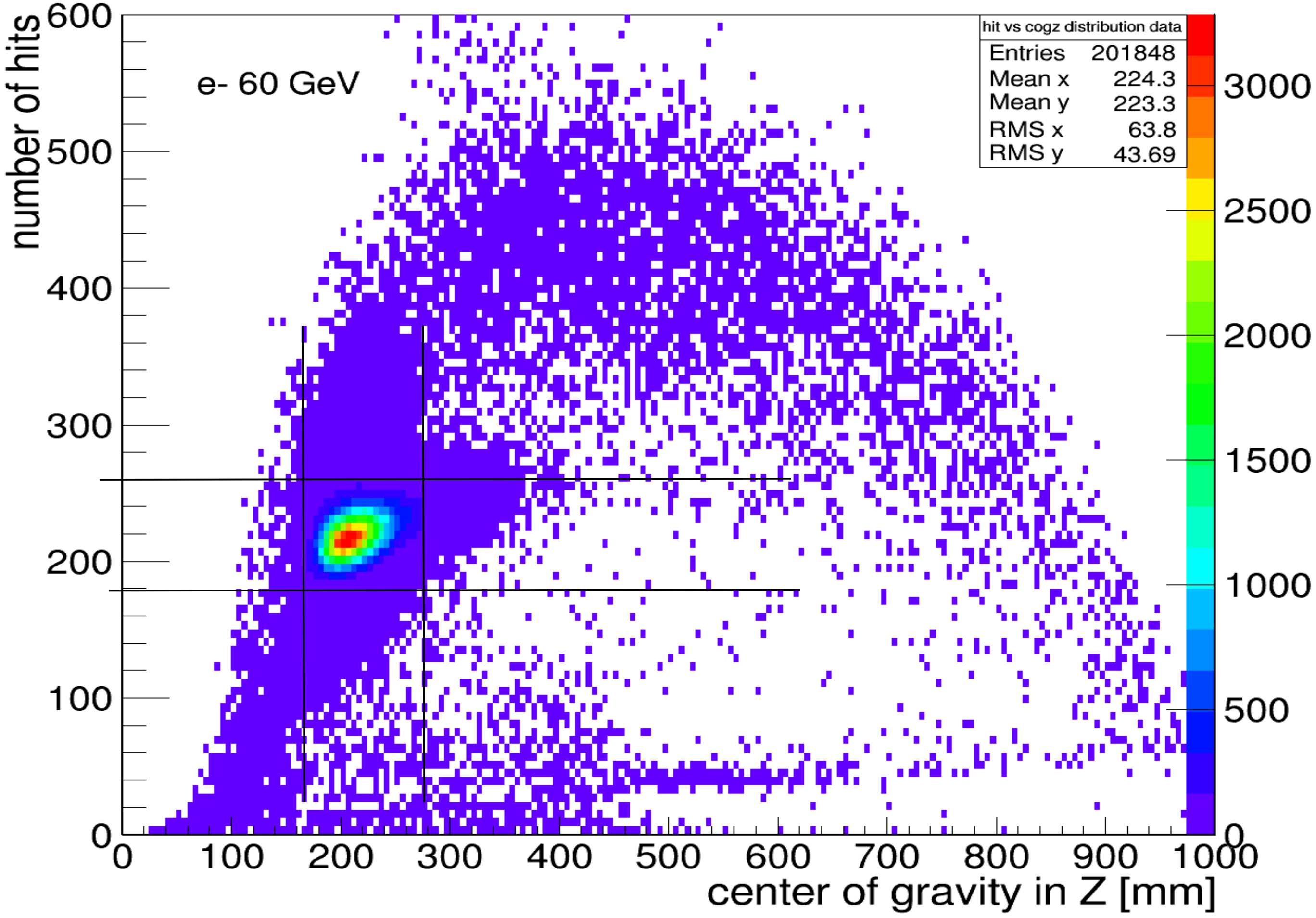
- Contamination of electron data by hadrons and muons
- From the center of gravity in Z direction we can distinguish the hadrons which shower later than the electron and muons with number of hits ~ number of layers.

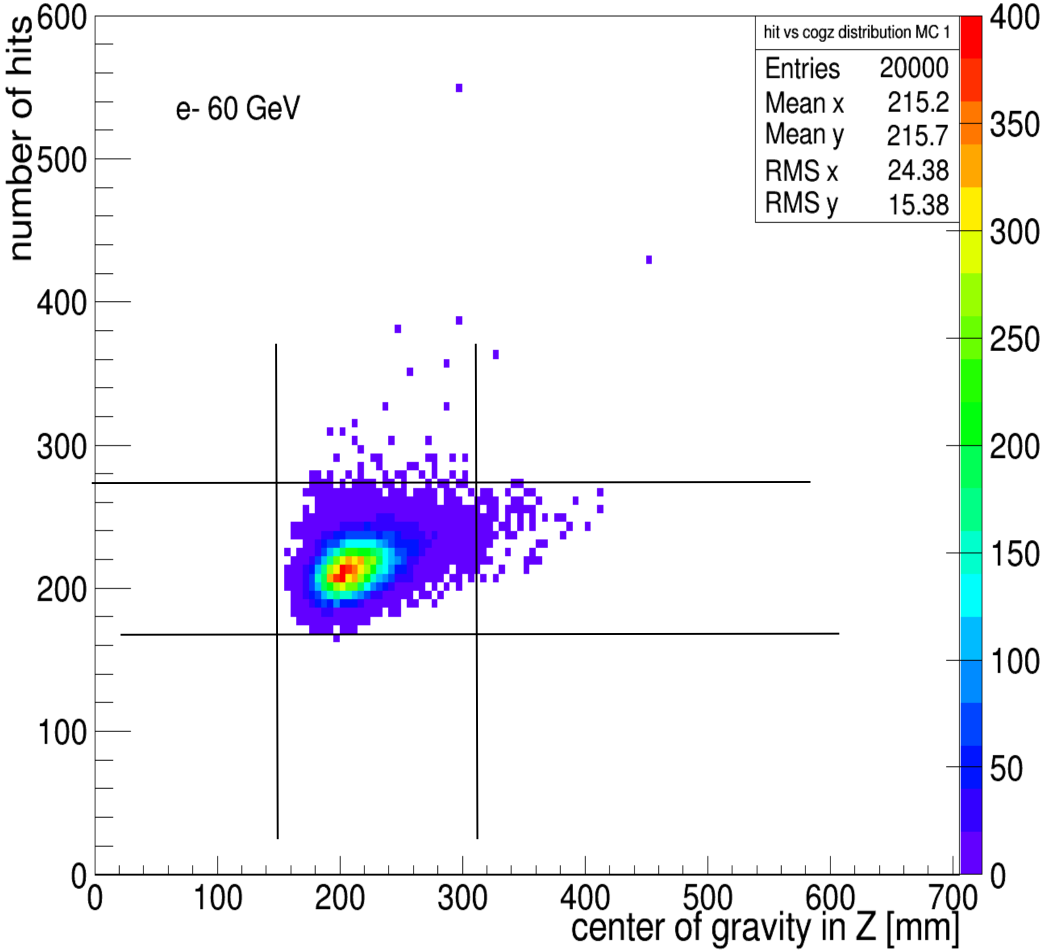




Electron selection

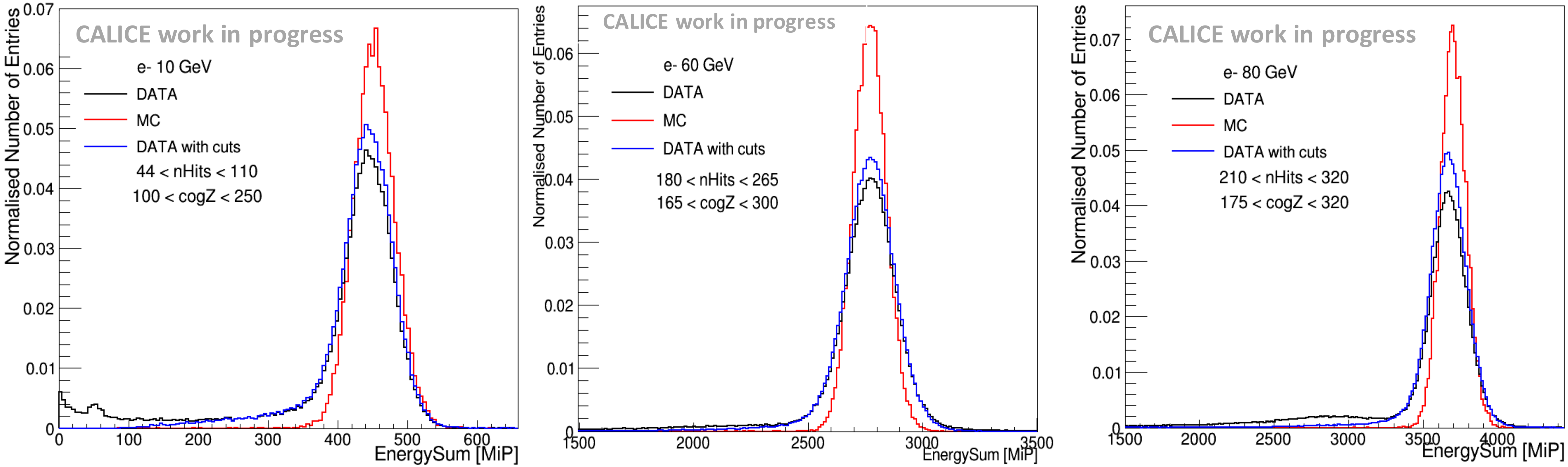
- Rejection of the contamination by cutting in the number of hits and cog_Z direction
- Defining the cuts from simulation and then applying the cuts to the data





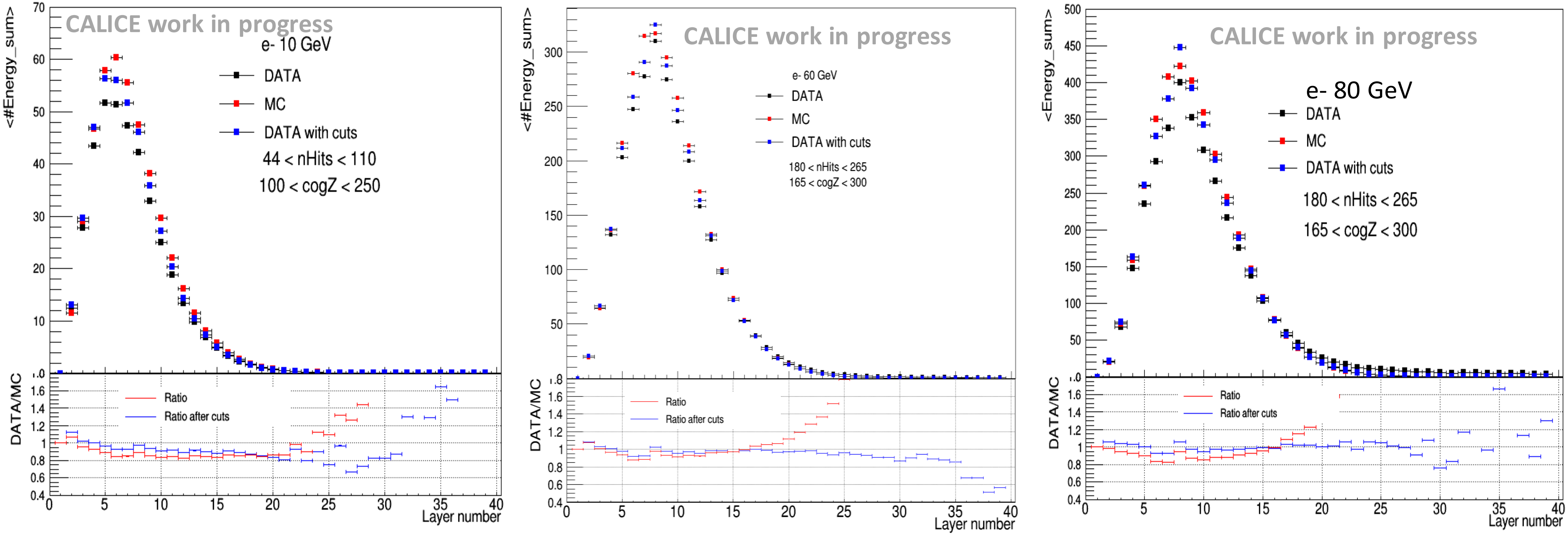
Energy sum distribution for different energies

- The cuts on nhits and cog_Z didn't remove the whole tail on the left.
- The tail on the left can be from electron with low energy or also from hadrons.
- The resolution of MC distribution is too good comparing the data distribution.
- Dead cells, dead space between tile and the air gap between the slabs are not yet implemented in the simulation => **excess in the energy sum !**



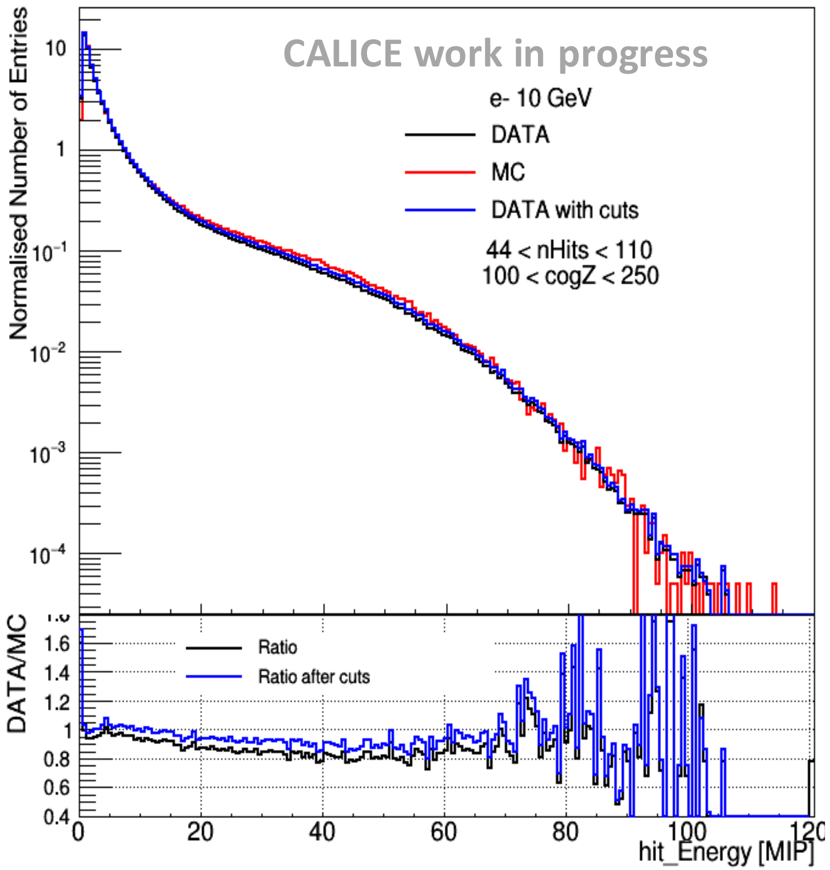
Longitudinal shower profile for different energies

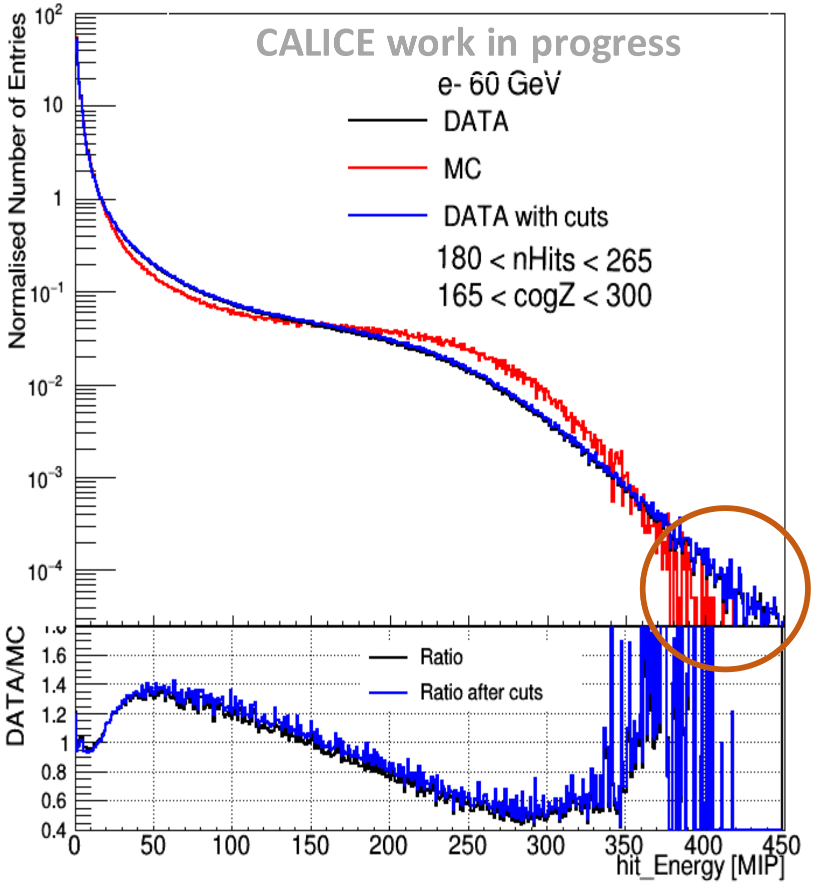
- After the cuts we observe a good agreement in the first 5 layers.
- From the ratio of 60 and 80 GeV we see a good agreement also in the latest layers, and difference of 3% to 6% in the 5 layers where the electron deposit most of their energy.

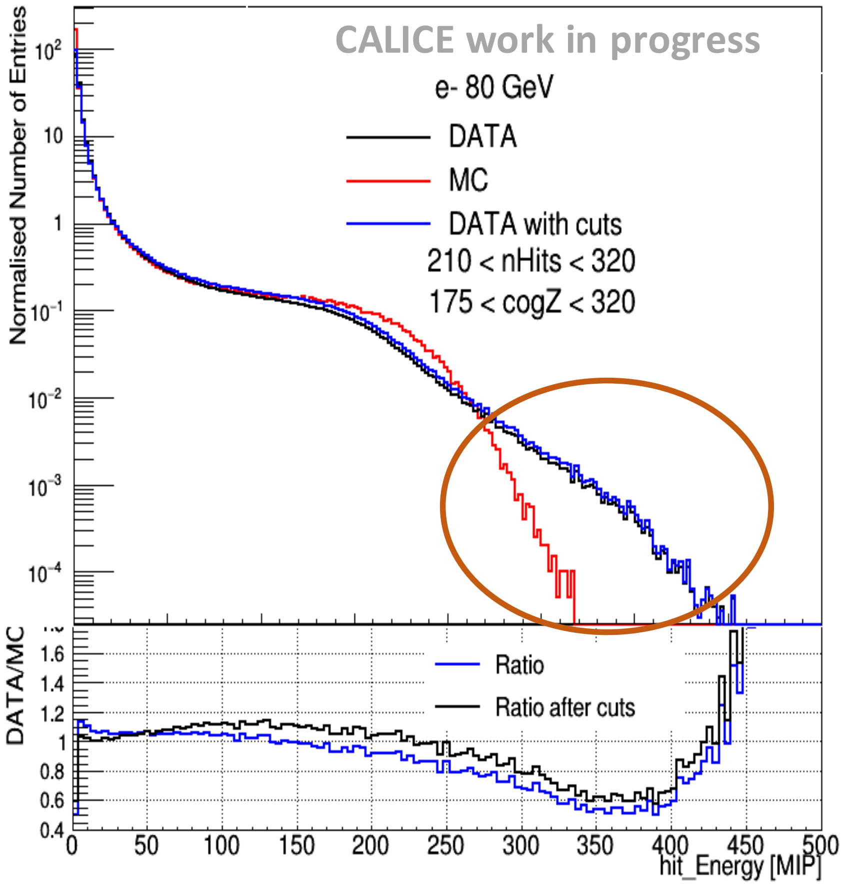


Hit Energy distribution for different energies

- Number of effective pixels used in the de-saturation is 2533 pixels (Olin talk)
- Hit energy distribution for data at low energy (10 GeV) looks similar to MC, but it's not the case for high energy
- This difference might be from the N-effective pixels
- Hit energy distribution need to be checked for each layer







Summary

- Electrons are an important data sample to cross check the calibrations and simulation parameters
- Tuning the additional material in the beam line lead to good agreement of cogZ for all beam energies
- Simple cut on nhits and cogZ improves situation, but does not remove the complete tail in the energy sums
- More detailed comparison needs selection of electron events

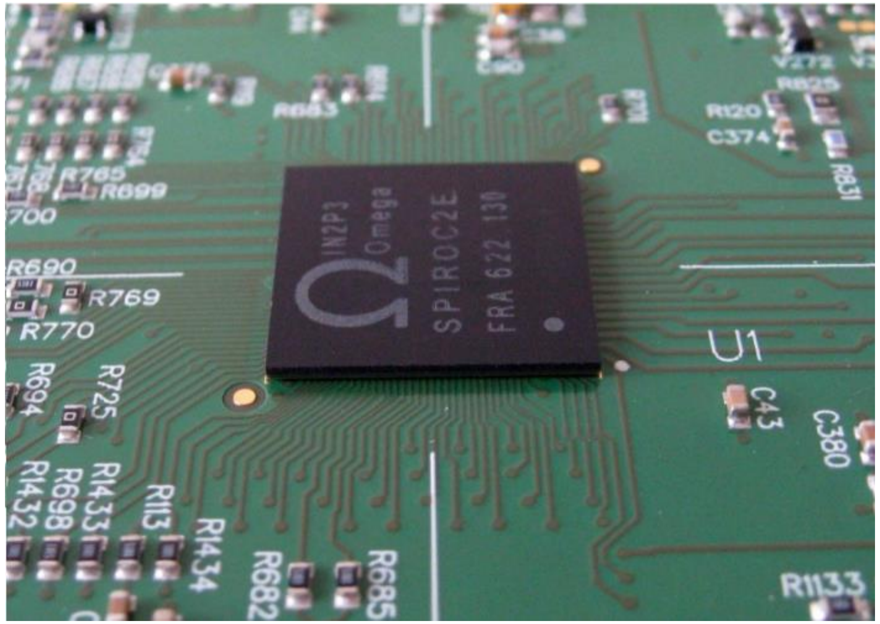
Outlook

- ParticleID (Vladimir) will be used to improve the event selection
- More investigation to understand the tail in the energy sums
- Further tuning of the simulation parameters if needed

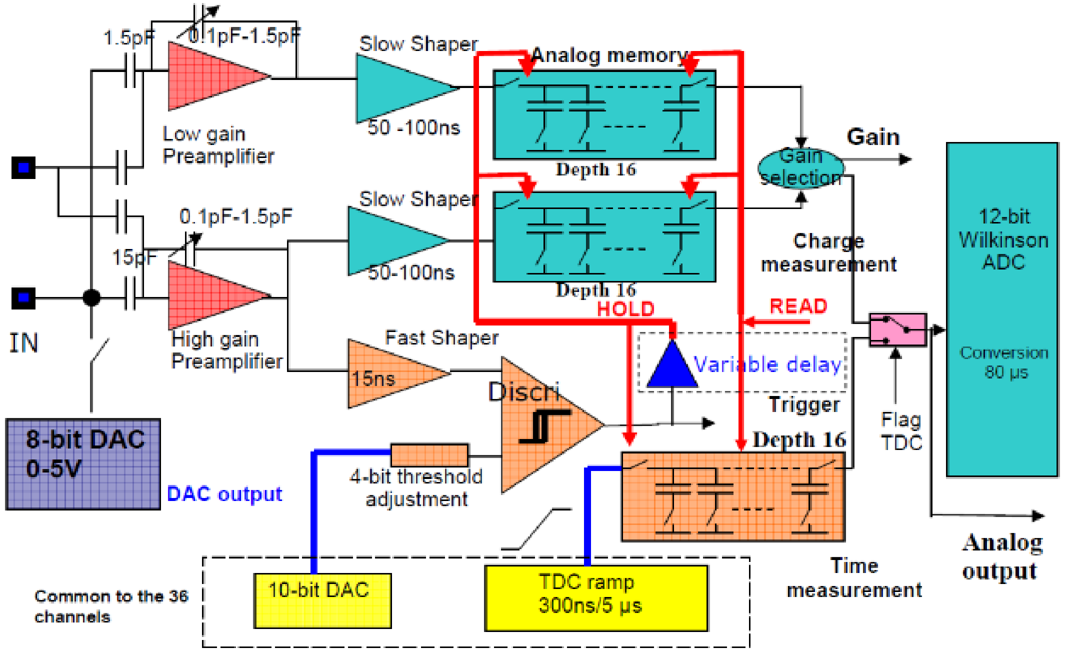
Back up

SPIROC2E

Details of the SPIROC 2E chip

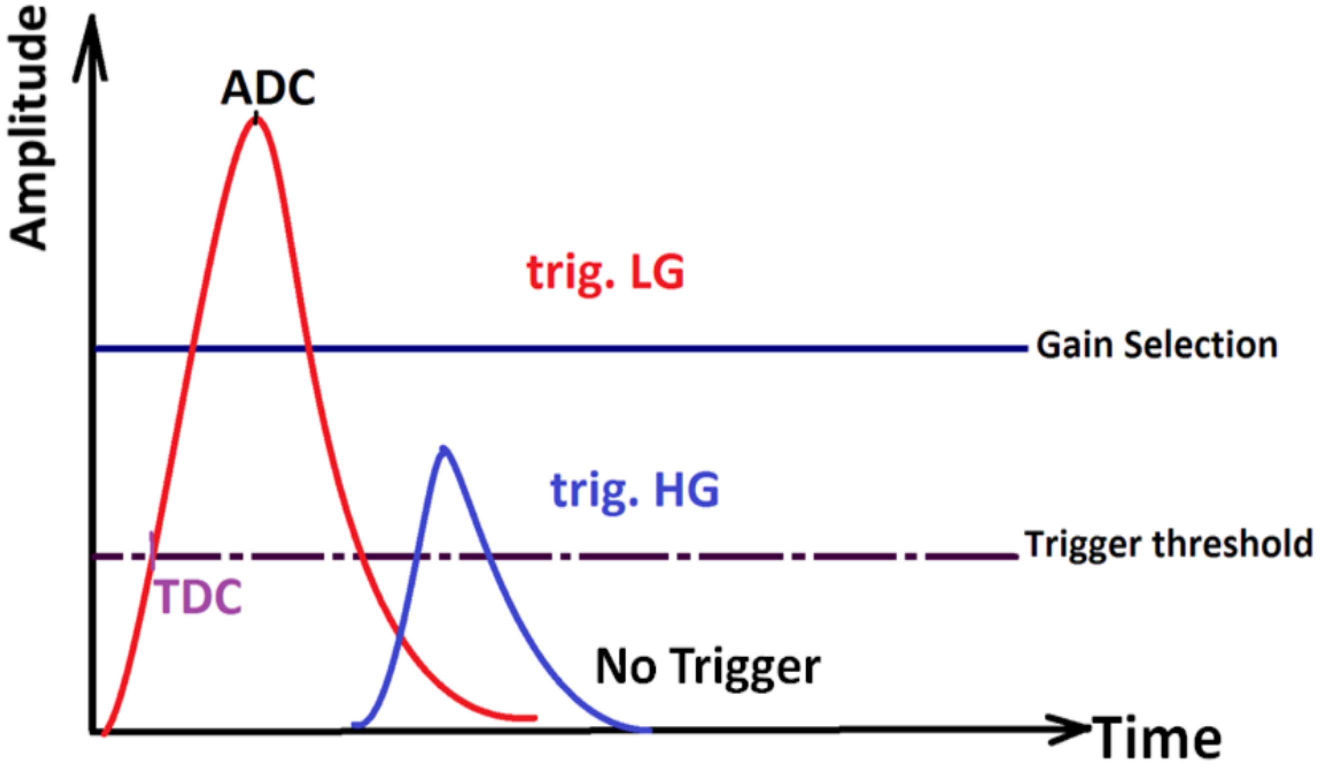


- Block scheme of one channel



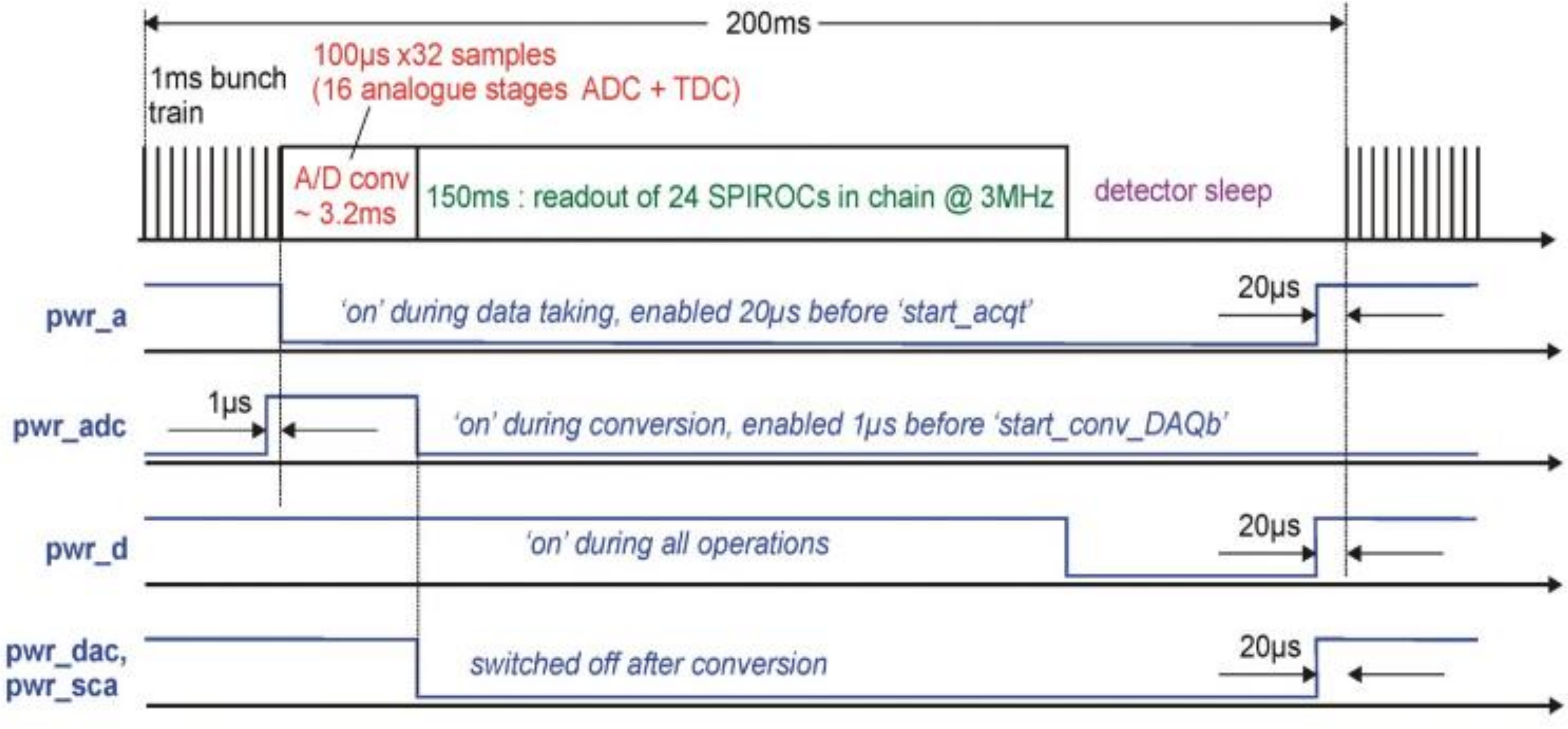
- Spiroc2ESPIROC2E developed by Omega.
- 36 channels.
- Individual readout of 36 tiles.

Gain Selectron



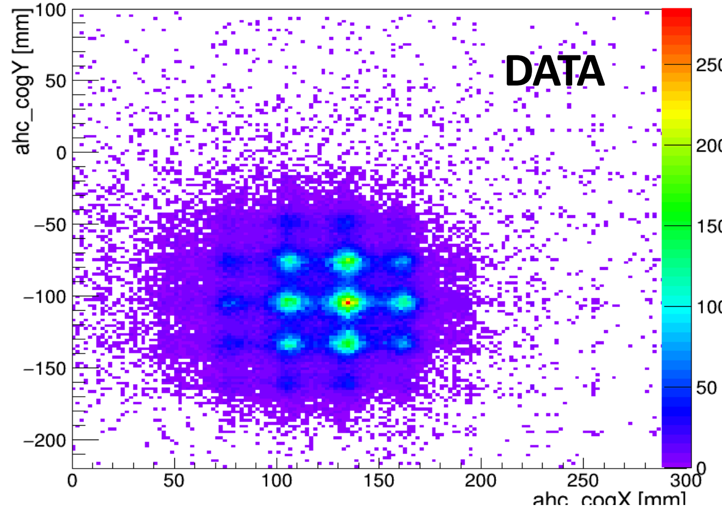
- Two thresholds can be set in the SPIROC independently
- Trigger threshold defines at which input signal charge the spiroc triggers (fast shaper)
- Gain threshold defines at which input signal charge the HG or LG is results digitized (slow shaper)

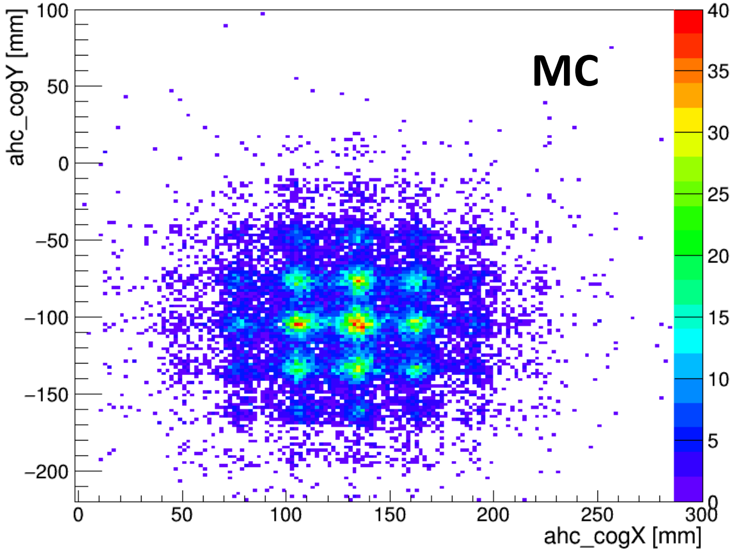
Power pulsing



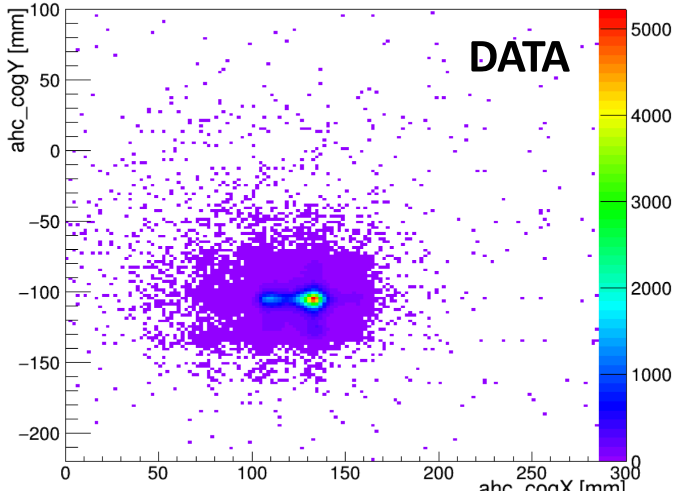
Center of gravity in X & Y for MC and DATA

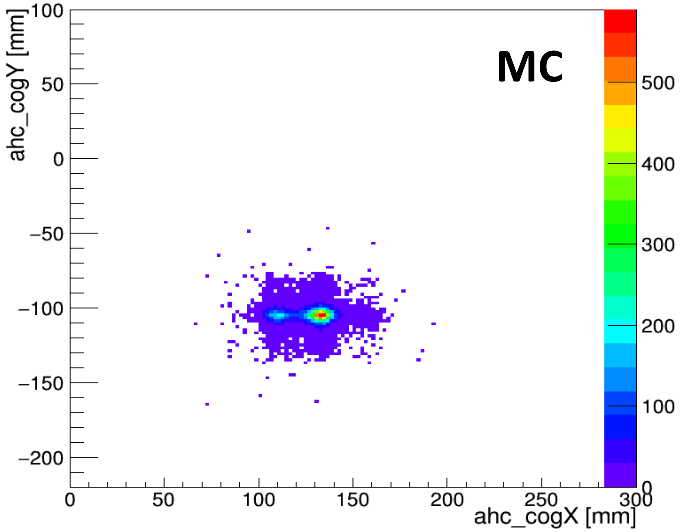
e- 10 GeV



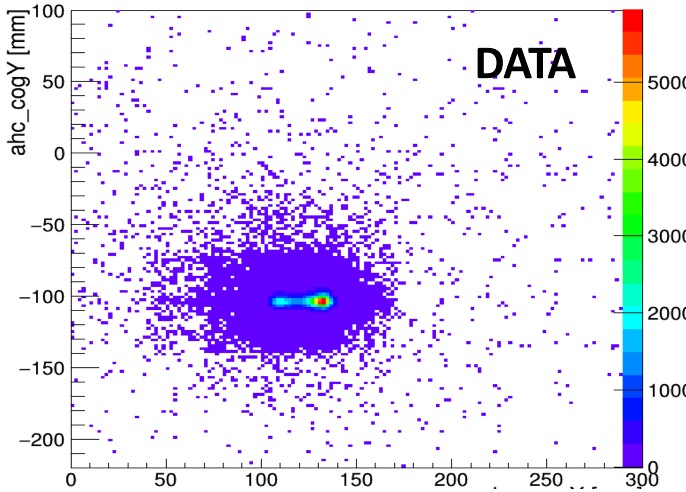


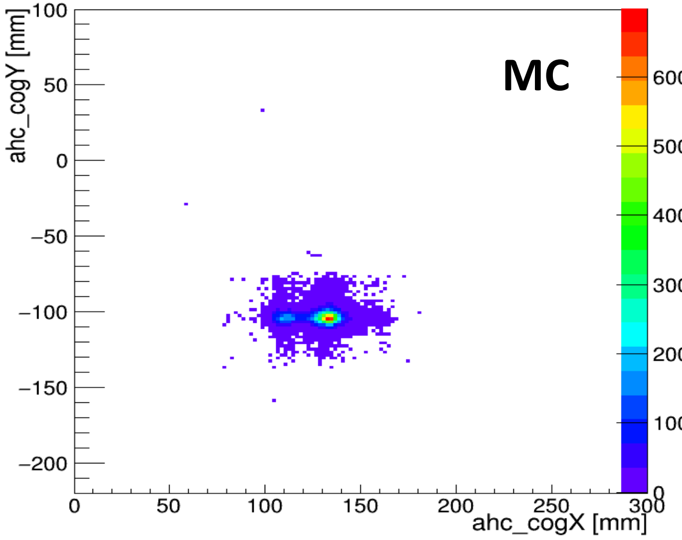
e- 60 GeV



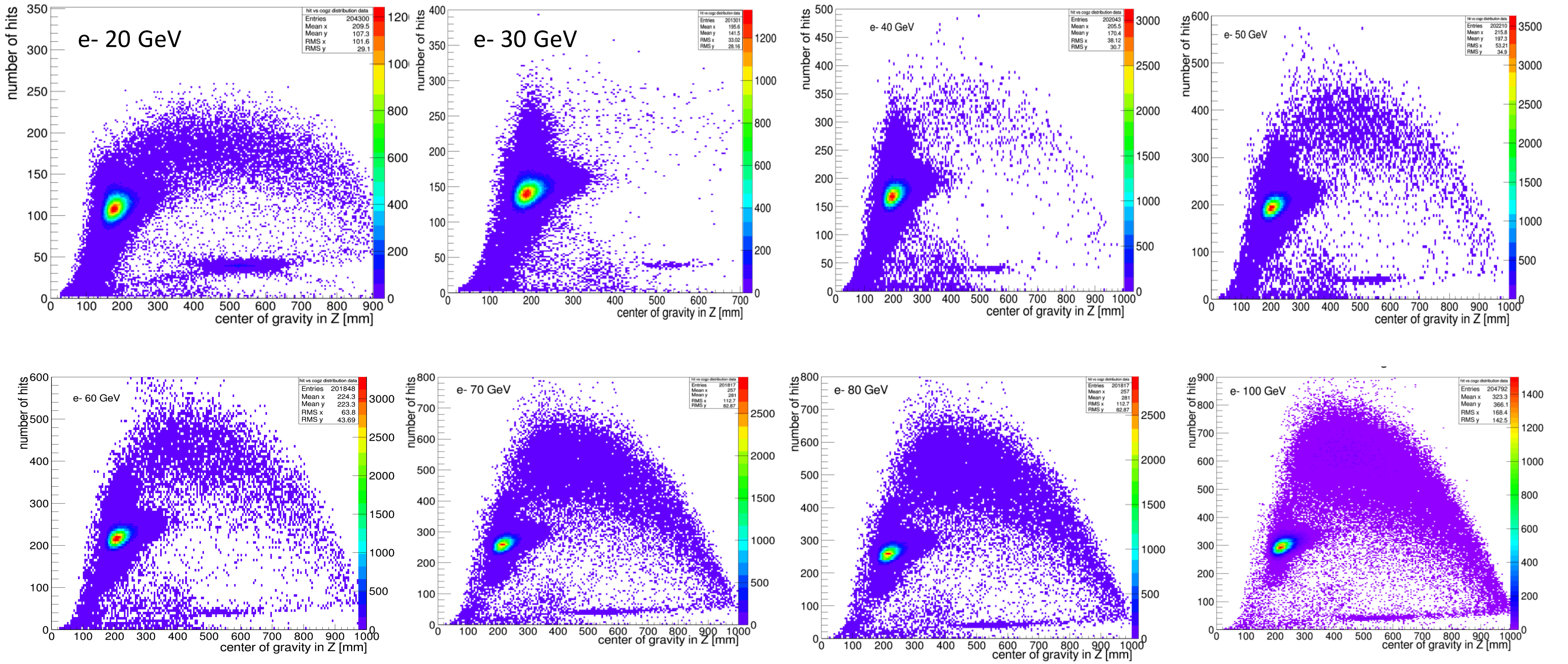


e- 80 GeV

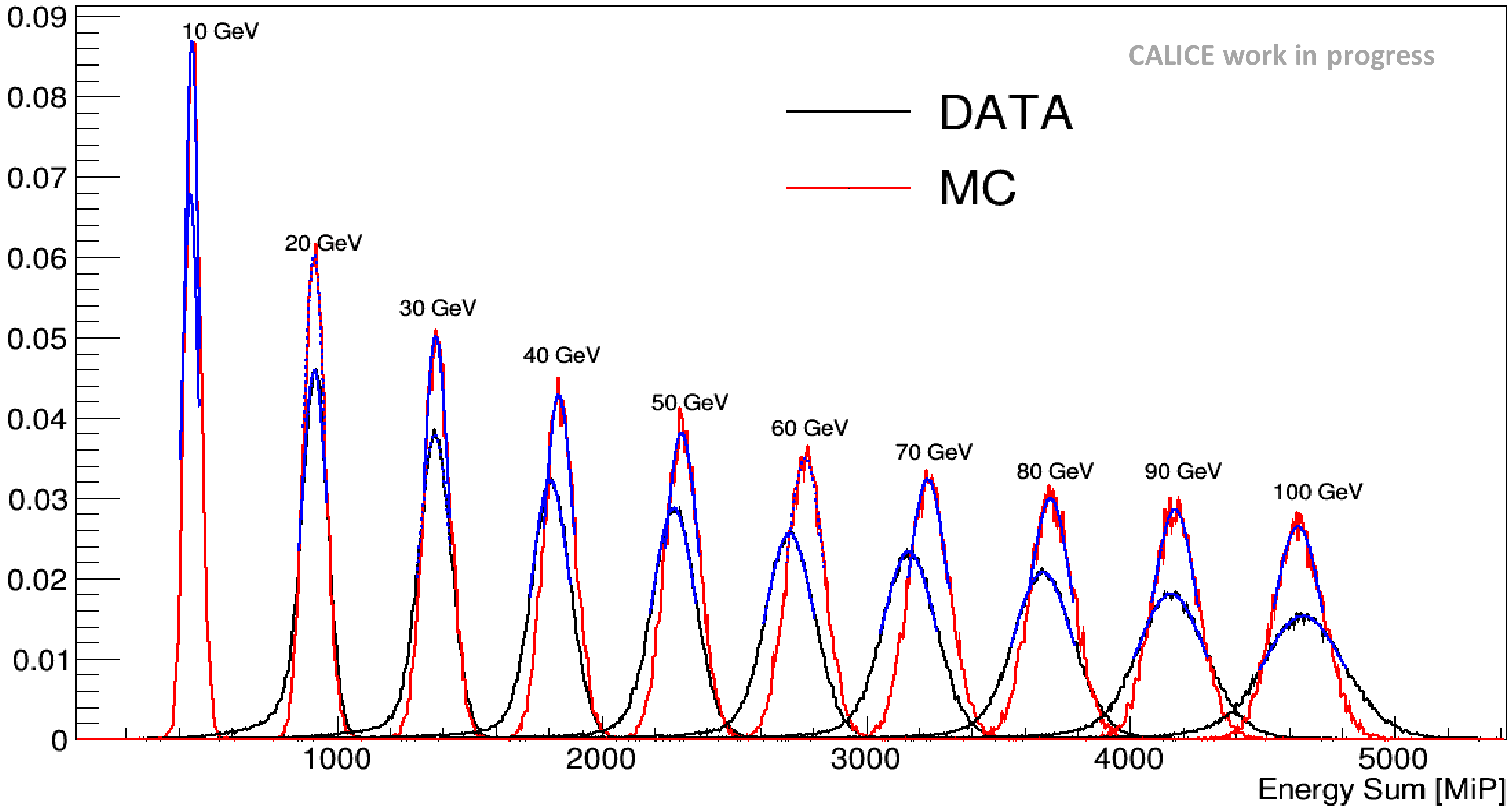




Nhits vs center of gravity in Z for different energies



Energy_sum (DATA &MC) for different energies



Hits distribution (DATA &MC) for different energies