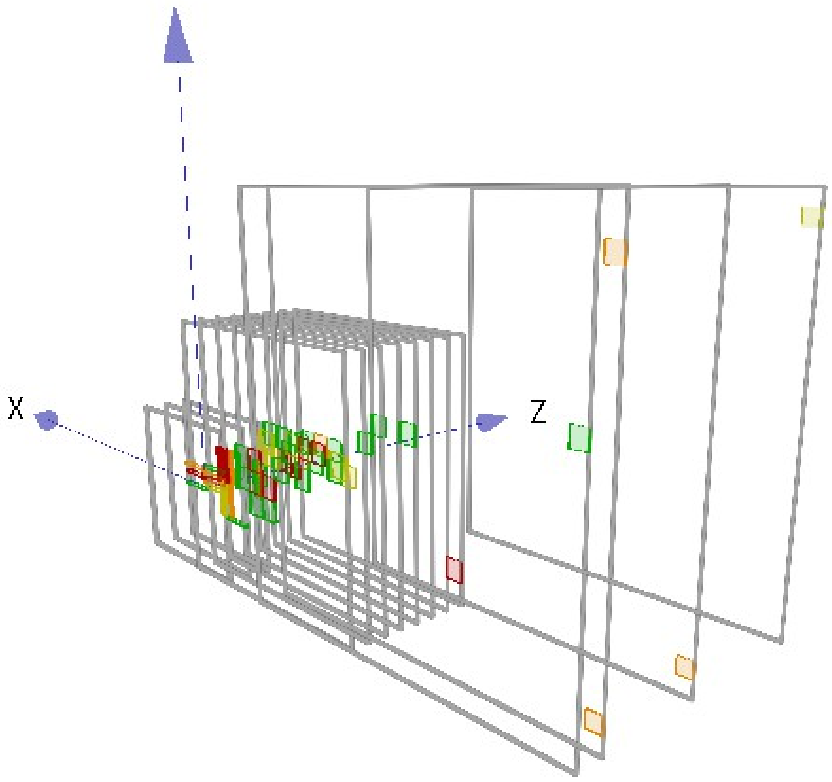
Analysis of CERN 2015 Test Beam Data of the AHCAL engineering prototype



Ambra Provenza
DPG Frühjahrstagung, Hamburg
1.03.2016

Outline

- The Analog Hadronic Calorimeter (AHCAL)
  - The Particle Flow Concept
  - Description of AHCAL
- The AHCAL Engineering Prototype
  - Test Beam Configuration
  - Motivation of an electron data analysis
  - Calibration
  - First look into electron data
  - Conclusion

Analog Hadronic Calorimeter (AHCAL)

> **A**nalog **H**adron **Cal**orimeter (**AHCAL**): hadronic calorimeter for a future $e^+ e^-$ linear collider

> **Goal of the calorimeter system**: calorimetric distinction between Z^0 and $W^{\pm}$ in their hadronic decay modes.

⇒ For this a total jet energy resolution of 3 - 4% in the range 50 – 250 GeV is needed.
Not achievable with a classic calorimeter.

> **Idea:** Apply Particle Flow concept

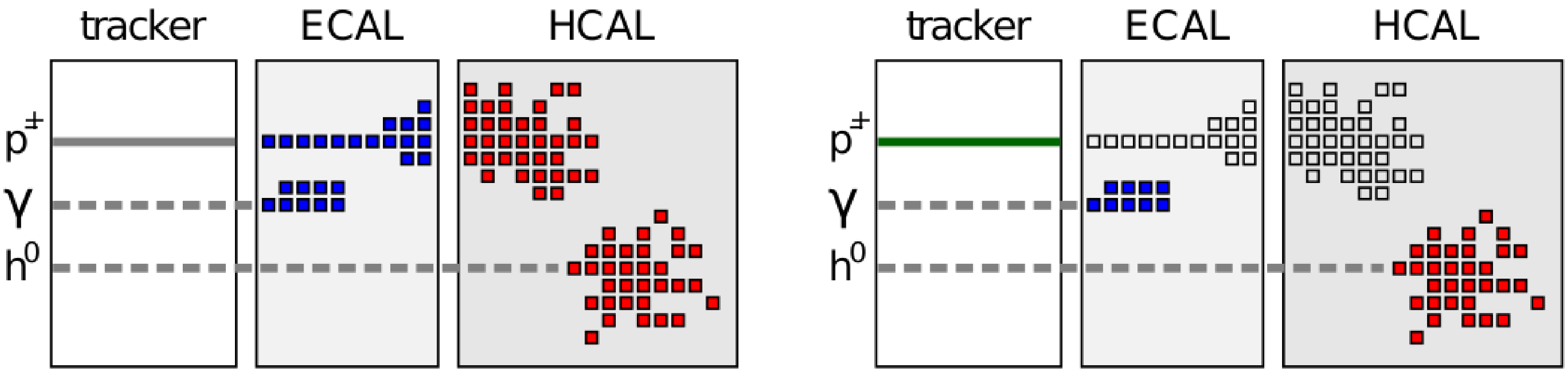
⇒ High granularity calorimeter is required

The Particle Flow Concept

> Particle Flow: measure the energy/momentum of the particle with the detector providing the best energy resolution

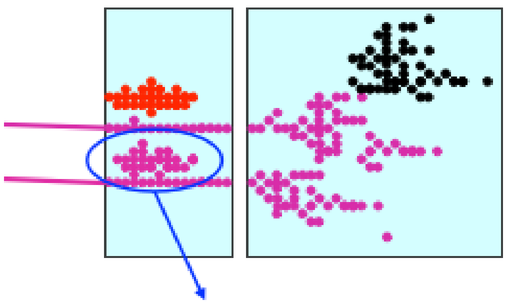
- Charged hadrons in the tracker ~ 60% E_{jet}
- Photons in the electromagnetic calorimeter (ECAL) ~ 30% E_{jet}
- Neutral hadrons in the HCAL ~ 10% E_{jet}

Than cluster single particles in jets

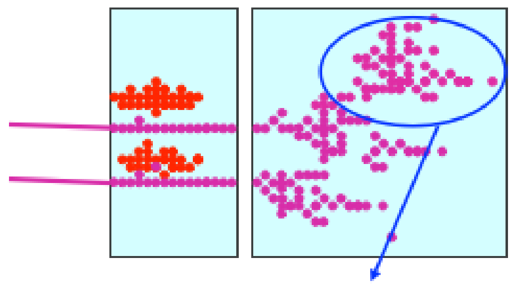


The Particle Flow Concept

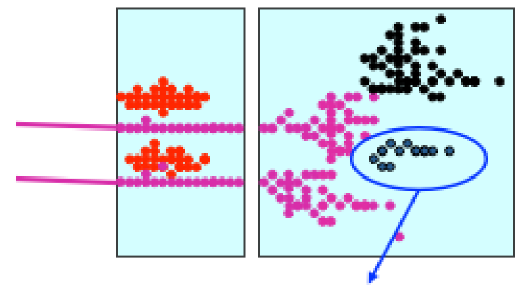
- Particle Flow: measure the energy/momentum of the particle with the detector providing the best energy resolution
- Limitation: Confusion



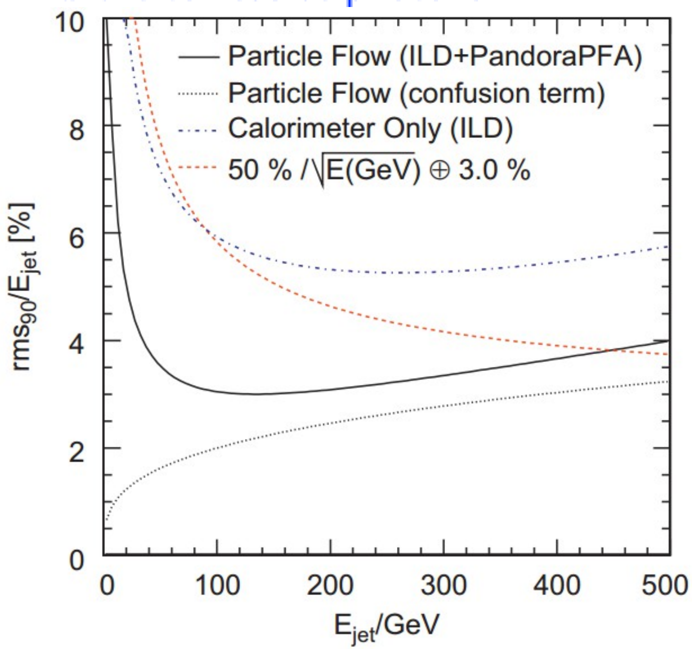
Failure to resolve photons



Failure to resolve neutral hadrons



Reconstruct fragments as separate neutral hadrons



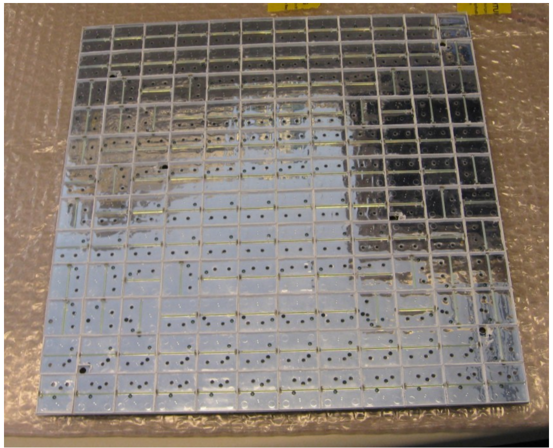
$$\sigma^2_{jet} = \sigma^2_{h^\pm} + \sigma^2_{h^0} + \sigma^2_{\gamma} + \sigma^2_{confusion} + \ldots$$

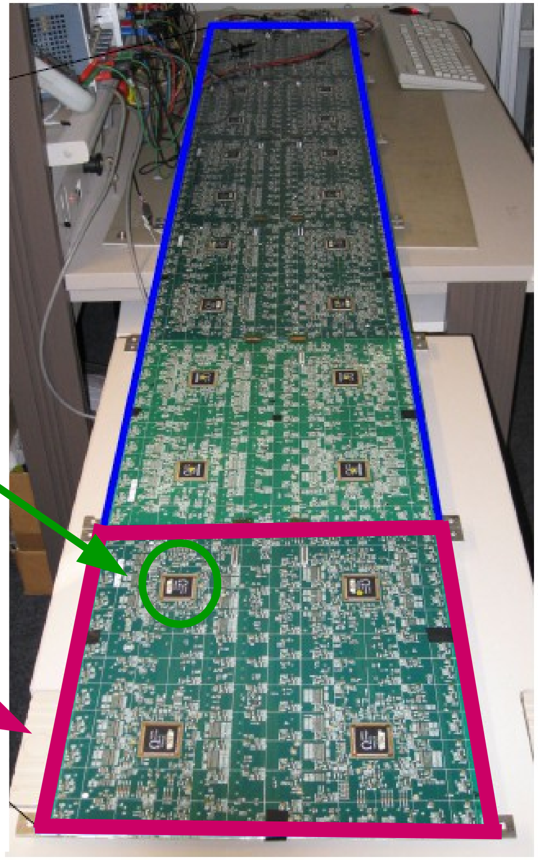
Dominates, in particular at high energy, but Particle Flow always a gain
Better confusion → high granularity!

Analog Hadronic Calorimeter (AHCAL)

> The **A**nalog **H**adron **Cal**orimeter **AHCAL**:

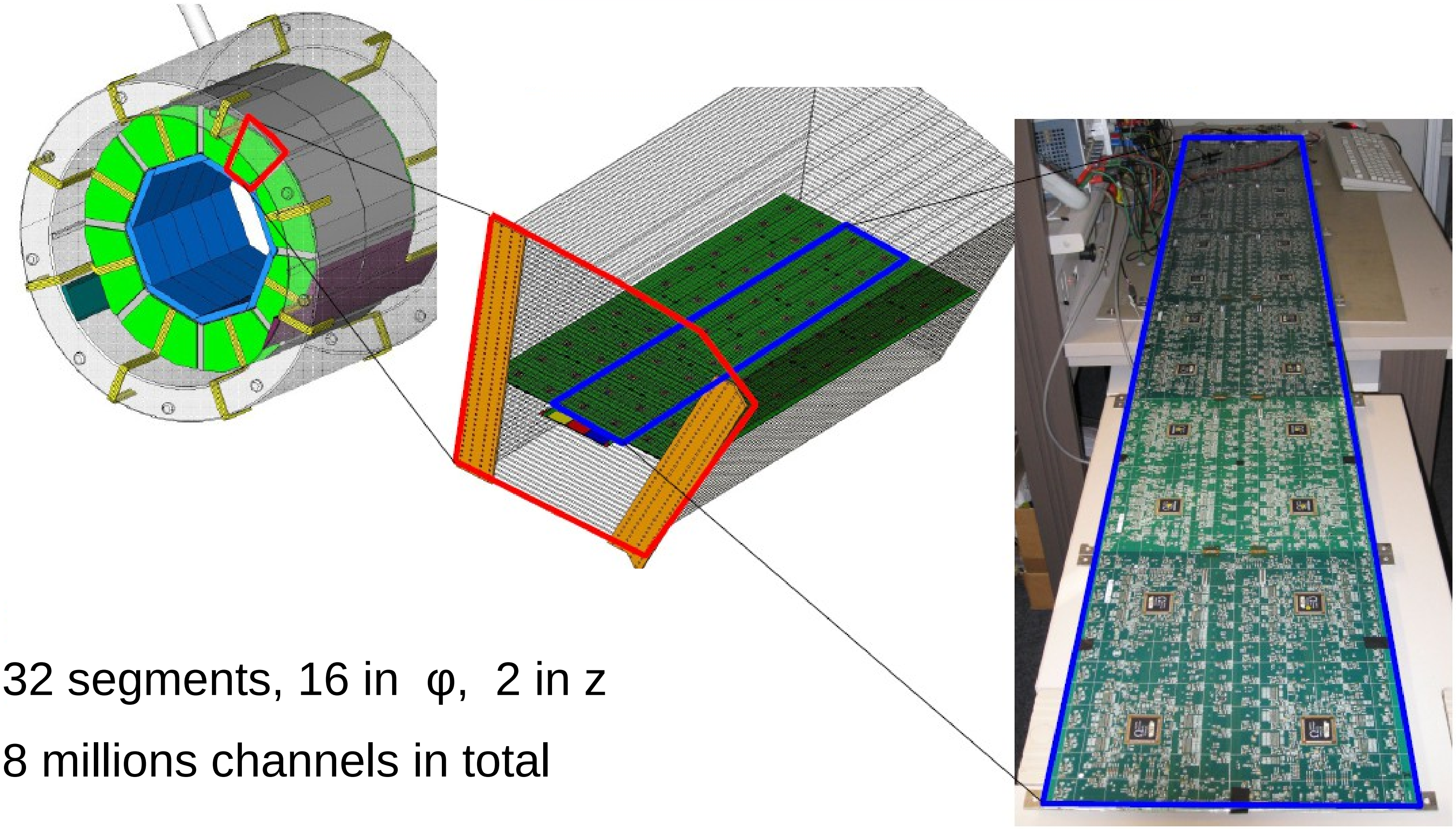
- Sandwich calorimeter:
- Absorber material: Steel
- Based on scintillator tiles of 3x3 cm²
- Read out using **Si**licon **P**hoto**M**ultiplier (one for each tile) **Read out with chips**
- **H**cal **B**ase **U**nit (**HBU**)
  36 x 36 cm²
  144 scintillating tiles





Analog Hadronic Calorimeter (AHCAL)

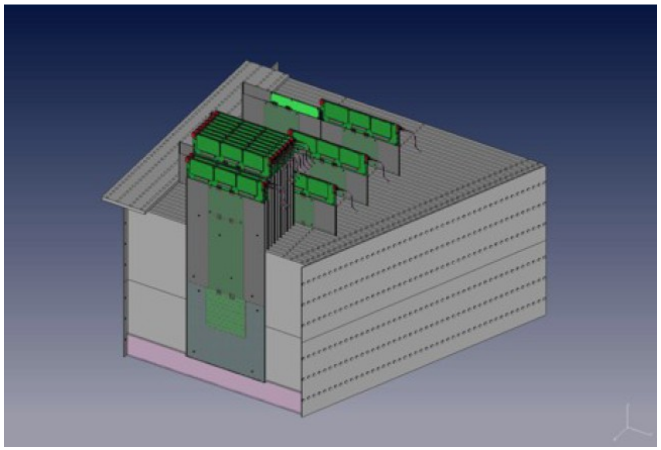
- The **A**nalog **H**adron **Cal**orimeter (**AHCAL**):

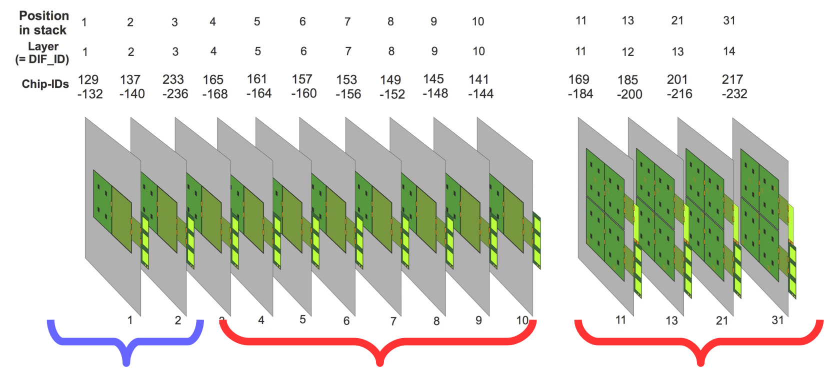


- 32 segments, 16 in φ, 2 in z
- 8 millions channels in total

The AHCAL Engineering Prototype: Cern Test Beam configuration

- 2 weeks of Test Beam at Cern in July 2015
- Steel absorber structure with 14 modules





2 EBU (Ecal Base Unit) 144 scintillating strips

8 HBUs

4 2x2 HBUs

- 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

Motivation for an electron data analysis

- The Physics capability of this detector already demonstrated with Physics Prototype **BUT . . .**

- **Physics Prototype**

active modules read out with **SiPm**

Signal read out with chips that worked in **external trigger mode**

- **Engineering Prototype**

active modules redout with **SiPm**

Signal read out with chips that work in **auto trigger mode**

!

A global threshold has to be set

↓

If it is not well configurated the data is lost !

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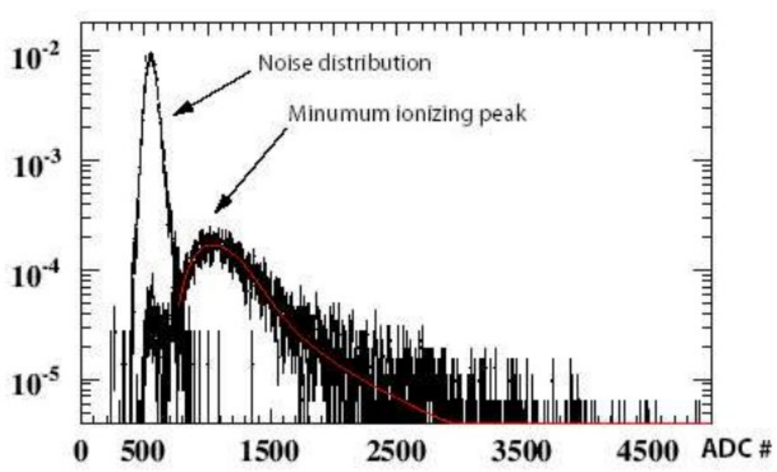

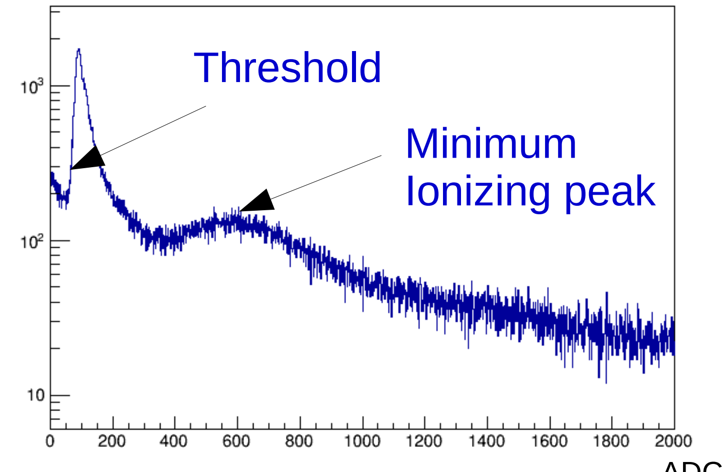

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- Different data acquisition:
  - > Be sure the detector is well calibrated.
  - > if not loose data it's possible → some energy is not measured

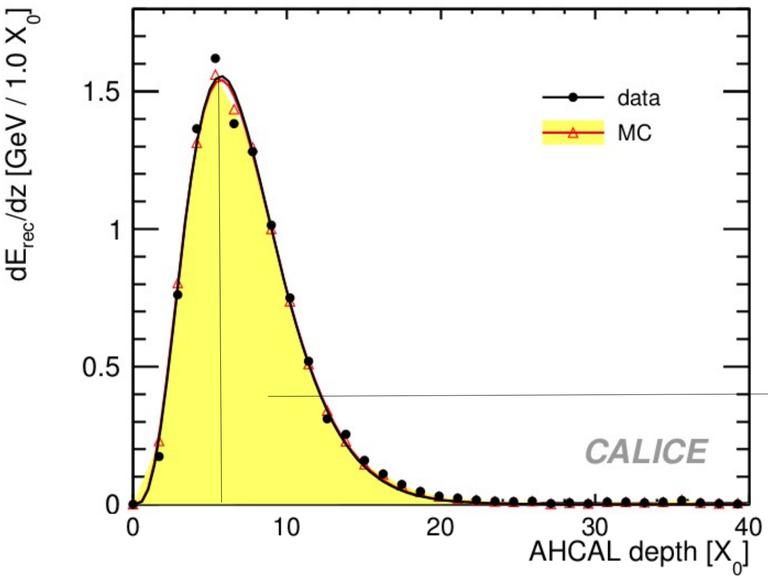
    → degradation of the energy resolution

Motivation for an electron data analysis

> Study electromagnetic (em) shower useful tool :

- High density of energy losses → study saturation effect and validate calibration
- Em shower contained in the prototype → check energy reconstruction and calorimeter response
- Well understood physics process → validate MC

> Longitudinal Profile of 10 GeV positron



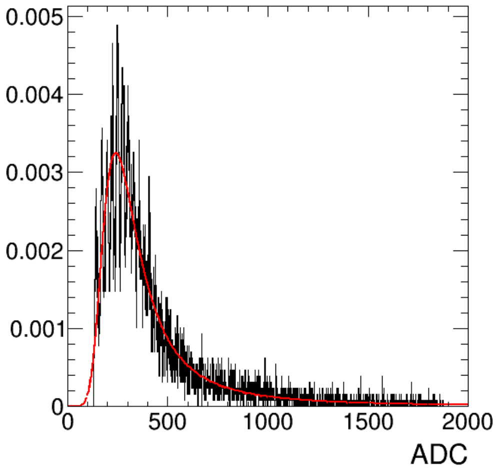
In Fe: $X_0 = 1.757$ cm ($\lambda = 16.77$ cm)

~ 5 X_0

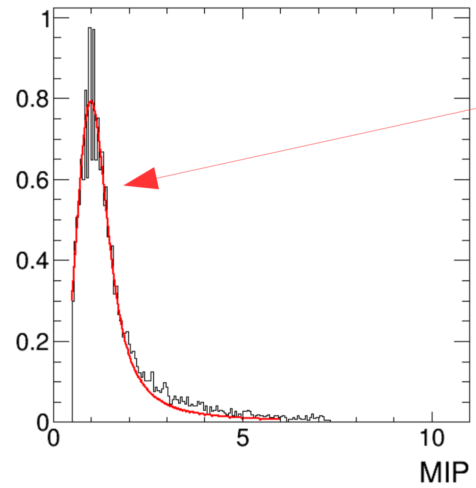
Detector Calibration

> First step: Check detector calibration with muons data

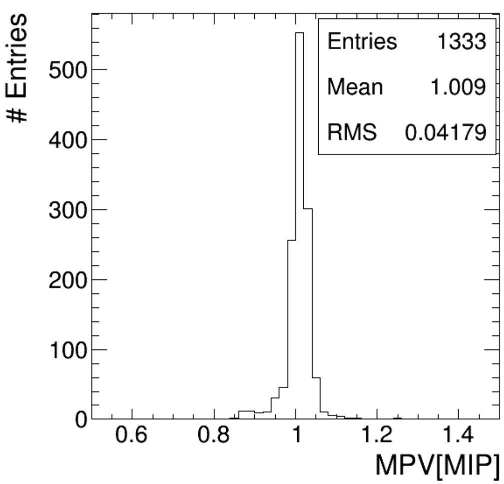
Response of calorimeter equalized to a common physics signal produced by a **M**inimum **I**onising **P**articles (**MIP**)



$$E_{MIP} = \frac{A_i[ADC]}{C_i^{MIP}}$$

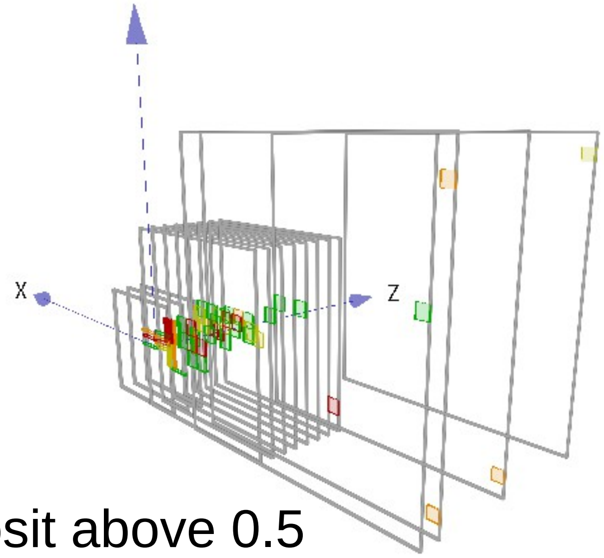


MPV of the fit function ~1 as expected



Distribution with mean value ~1 with an RMS of 4%!

First look into electron data

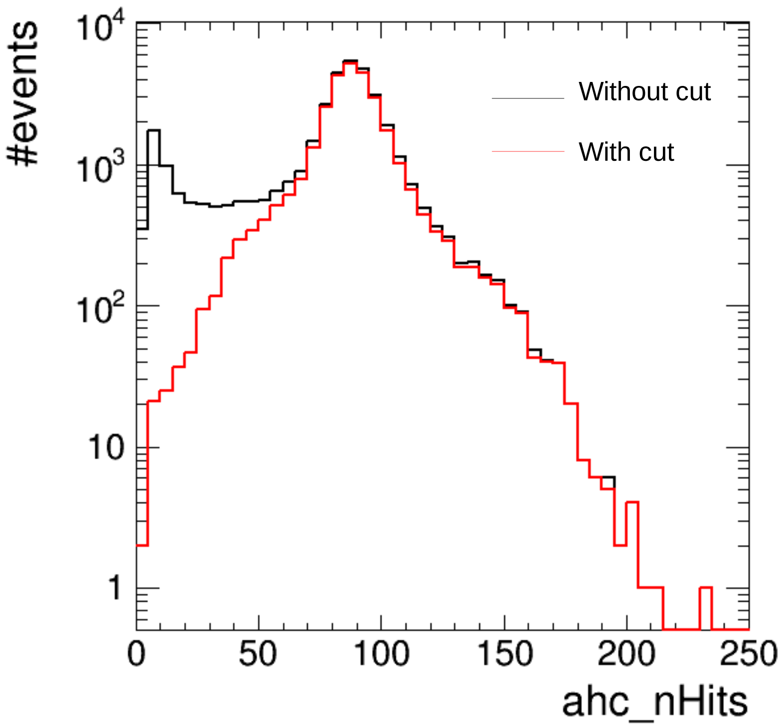


- Dedicated electrons run recorded
  - Small contamination from muon and pion
- Simple and reasonable selection applied:
  - Remove the noise:
    - Only energy deposit above 0.5 considered
    - Cut on the center of the gravity of the shower
  - Require almost all the energy contained in the first 12 modules (~13 X_0) to avoid high energy deposit due not to electron

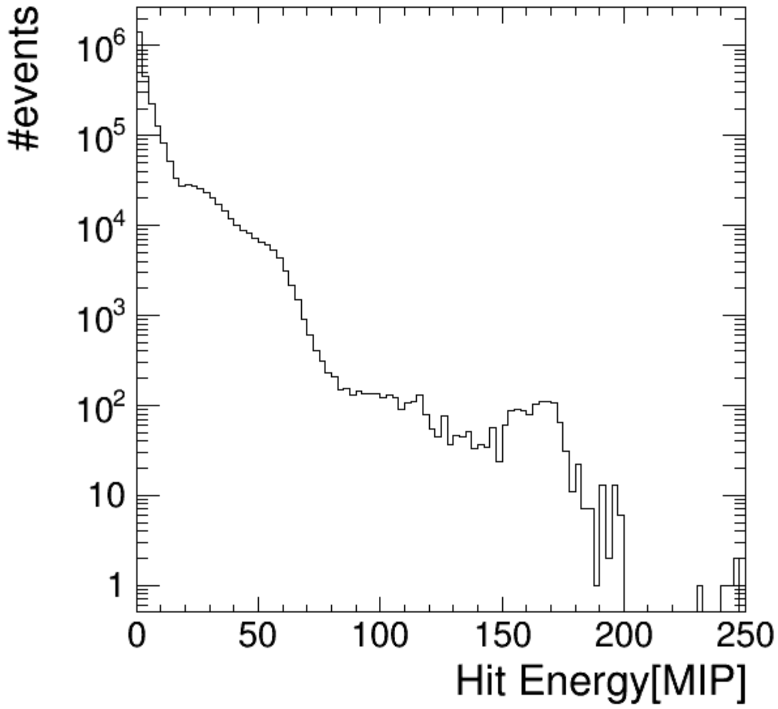
First look into electron data

> Here 30 GeV electrons are considered

Number of hit distribution **before** and **after** the selection



Hit distribution energy distribution



First look into electron data

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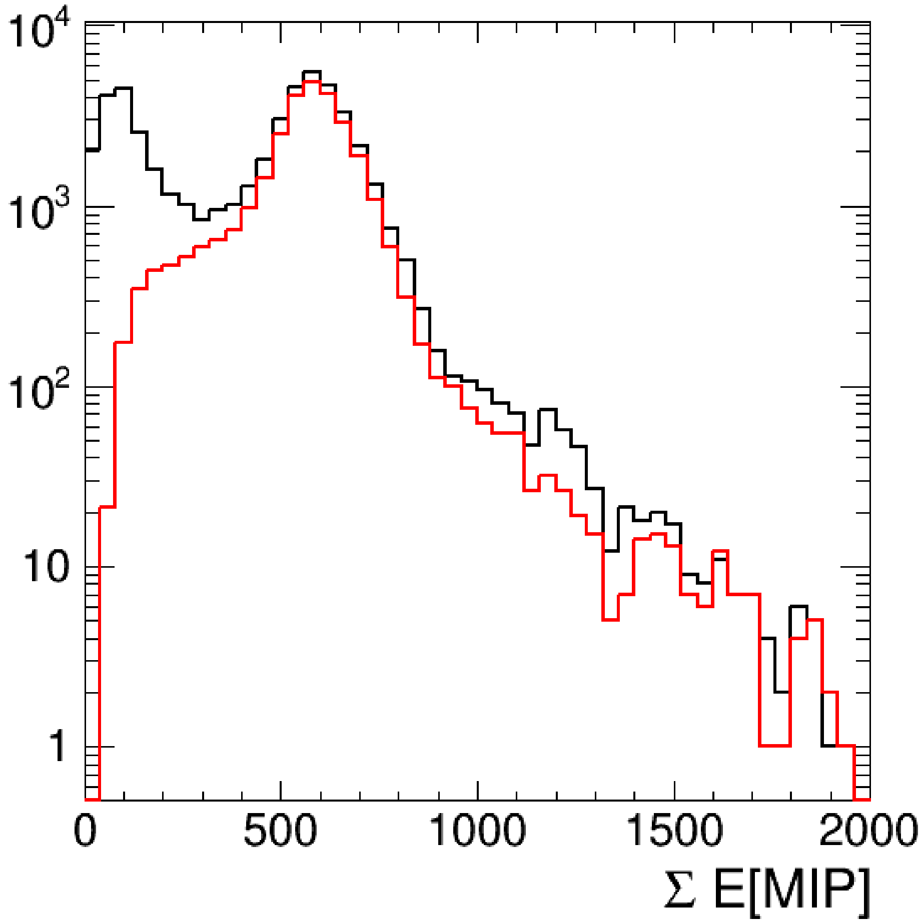
Comparison between the energy sum distribution **without cut** and **with cut**



Conclusion

- Validation of the detector calibration with a Monte Carlo simulation

- Tune the electron selection with the Monte Carlo simulation

- Study the electromagnetic response and compare it with previous result

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    - → some energy is not measured → degradation of the energy resolution

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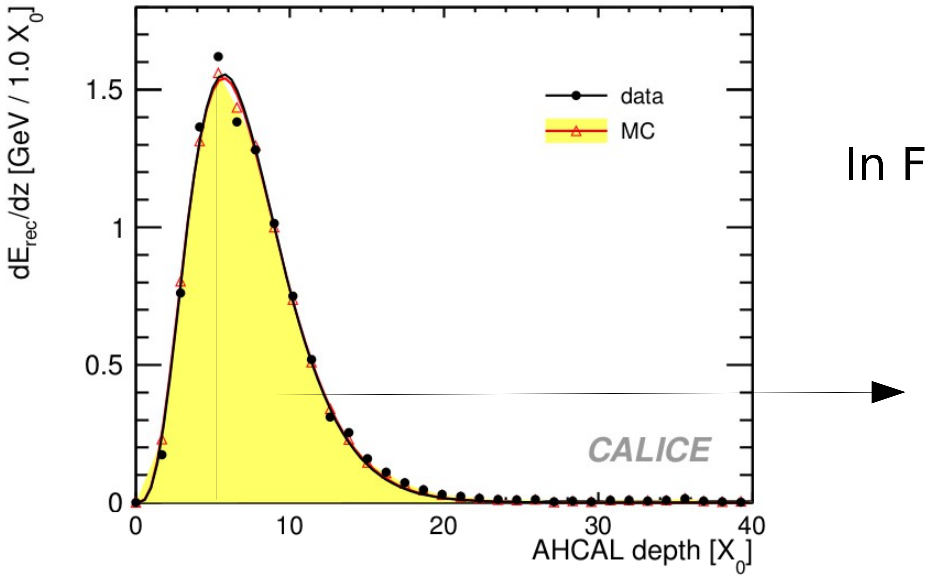

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First look into electron data

> Electron:

1) put an event display (from the elog)

2) Do you expect shower contained in your detector? (longitudinal development and transverse development)

3) Plots

- Beam profile (X vs Y)
- Hit energy spectra
- Nhits distribution
- Energy Sum (maybe also at different energies?)

First look into electron data

- Dedicated electron run recorded
  - Small contamination from muon and pion

- Simple and reasonable selection applied:
  - Remove the noise:
    - Only energy deposit above 0.5 considered
    - Cut on the beam position (-10 mm $< y < 80$; $-80 < x < 50$)
    - Cut on the number of hit per event (nHits > 20)
  - Cut on the energy sum in the last 2 layers to avoid high energy deposit due not to electron