Determination of the energy resolution of the ALLEGRO electromagnetic calorimeter

using a correlation free procedure

Basile Dhont

Supervisor : Farès Djama

Special thanks to Jiashun Luo

CPPM – CNRS/IN2P3 / Aix-Marseille Université

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Energy resolution

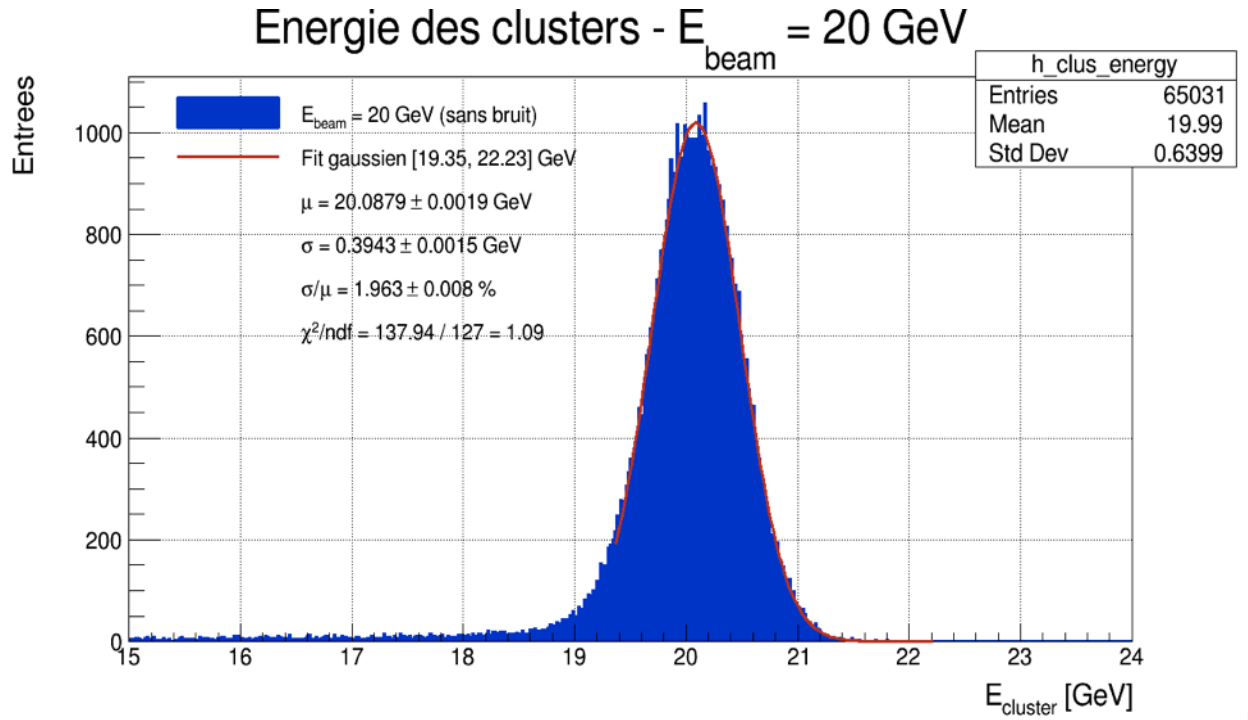
$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

a = stochastic term: sampling fluctuations

b = electronic noise term: readout electronics noise

c = constant term: geometric non-uniformities, leakage

Computing resolution in practice → Gaussian fit on the cluster energy distribution



Simulated data

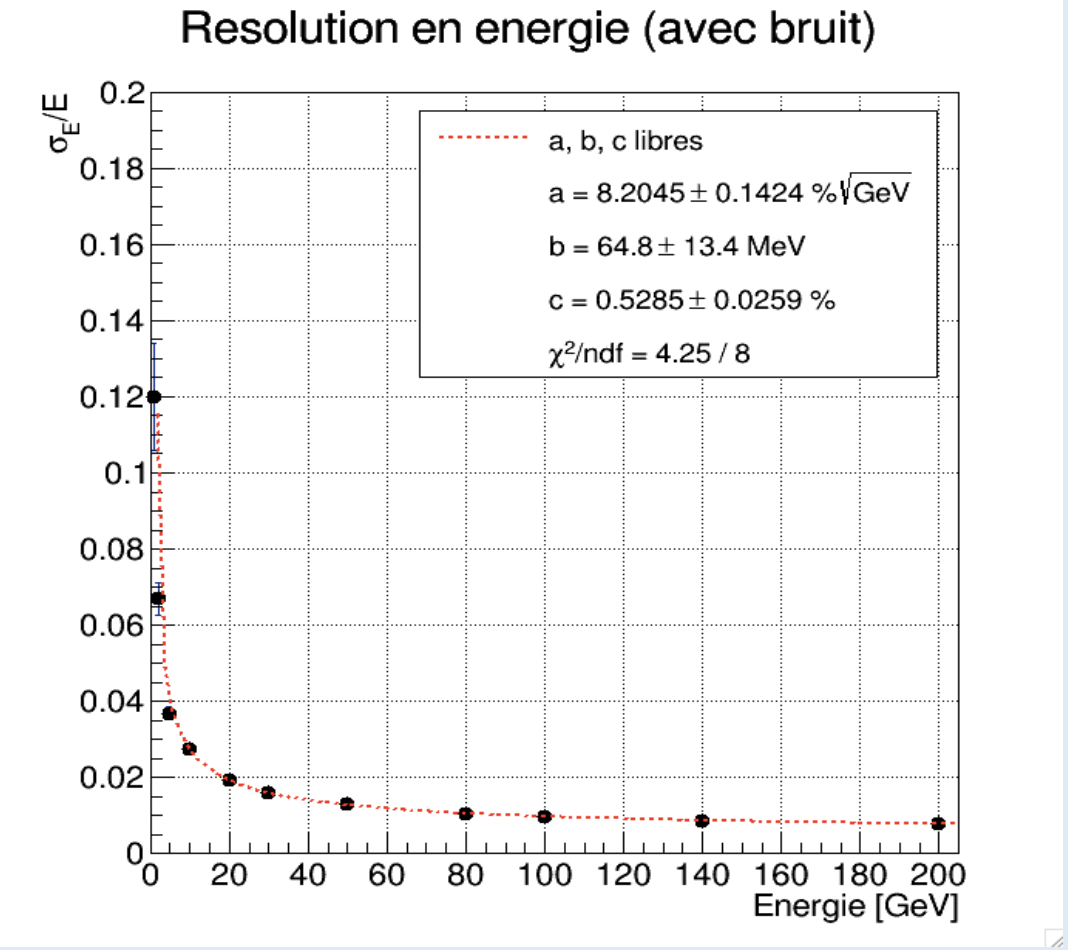
Analyses performed on simulated data in several stages:

- Generator: particle-gun type, produces electrons with defined energy and direction
- Simulation: particle propagation through the detector using Geant4
- Digitization: conversion of energy deposits into electrical signals, accounting for detector properties
- Reconstruction: grouping of neighboring cells receiving an energy deposit
  Reconstruction window: $\Delta\theta \times \Delta\phi = 9 \times 17$ cells^2 = 90×156 mrad^2

The following simulation was carried out on one module of the calorimeter ($\Delta\phi = \pi/8$), at energies: E = 1, 2, 5, 10, 20, 30, 50, 80, 100, 140, and 200 GeV

Problem: the 3 parameters are strongly correlated

Simultaneous fit (a, b, and c free):



Correlation matrix:

	a	b	c
a	1	- 0,97	- 0,98
b	- 0,97	1	+ 0,91
c	- 0,98	+ 0,91	1

Correlations close to ±1 ⇒ parameters not independent!

Solution: decoupled 3-step measurement

1. Stochastic term a: simulations without electronic noise, at a fixed point of the detector

2. Constant term c: simulations without electronic noise, full module, a fixed to the value found in the previous step

3. Electronic noise term b: simulations with electronic noise, full module, a and c fixed to previously found values

1. Stochastic term *a* :

Protocol:

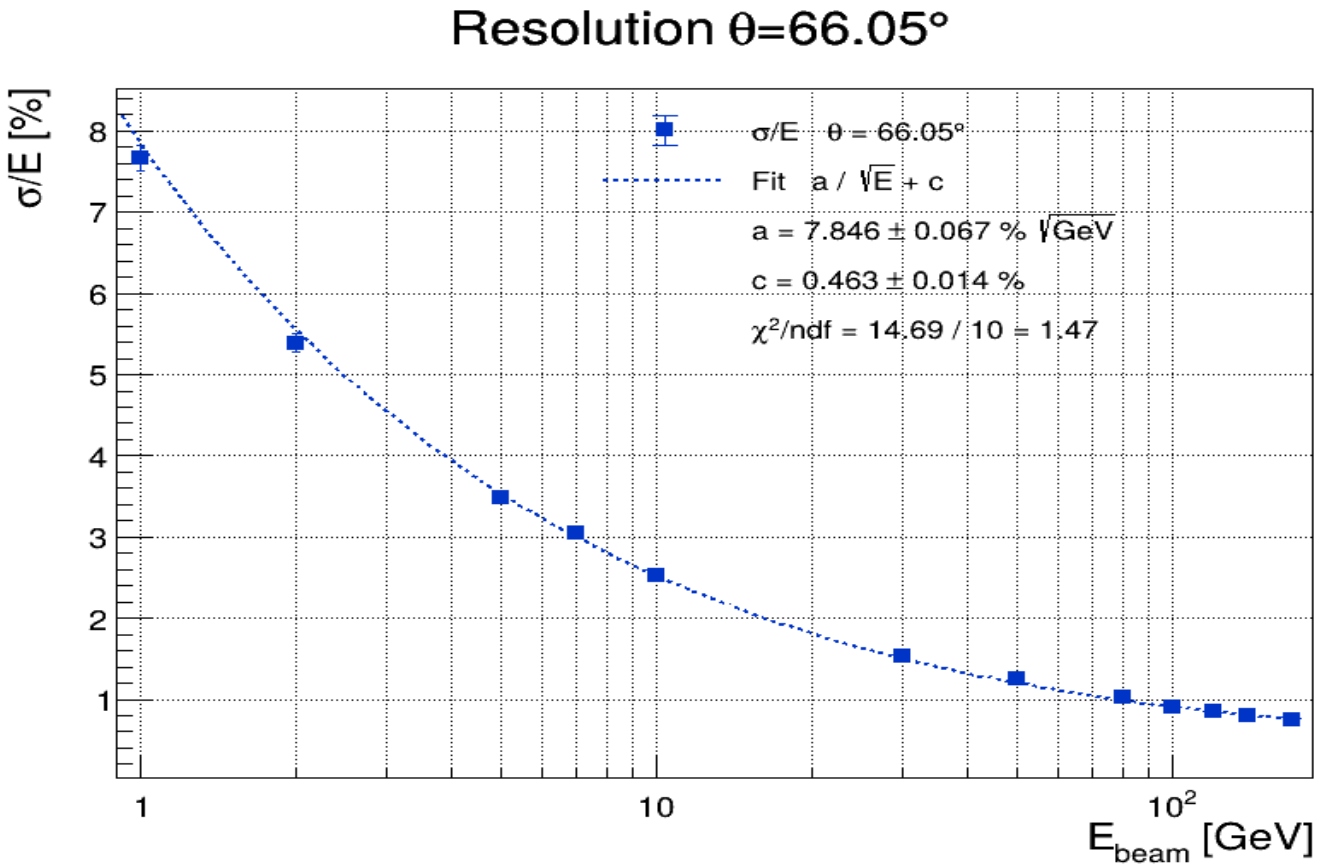
Without electronic noise → b/E term suppressed

Fixed direction → c term minimized

Fit :

$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}} \oplus c$$

Exemple at θ = 66.05° and φ = 0°



Averaged over several values of θ, we find *a = 7.75 ± 0.03 %/$\sqrt{GeV}$* and *c = 0.53 ± 0,01 %.*

2. Terme constant *c* :

Protocol:

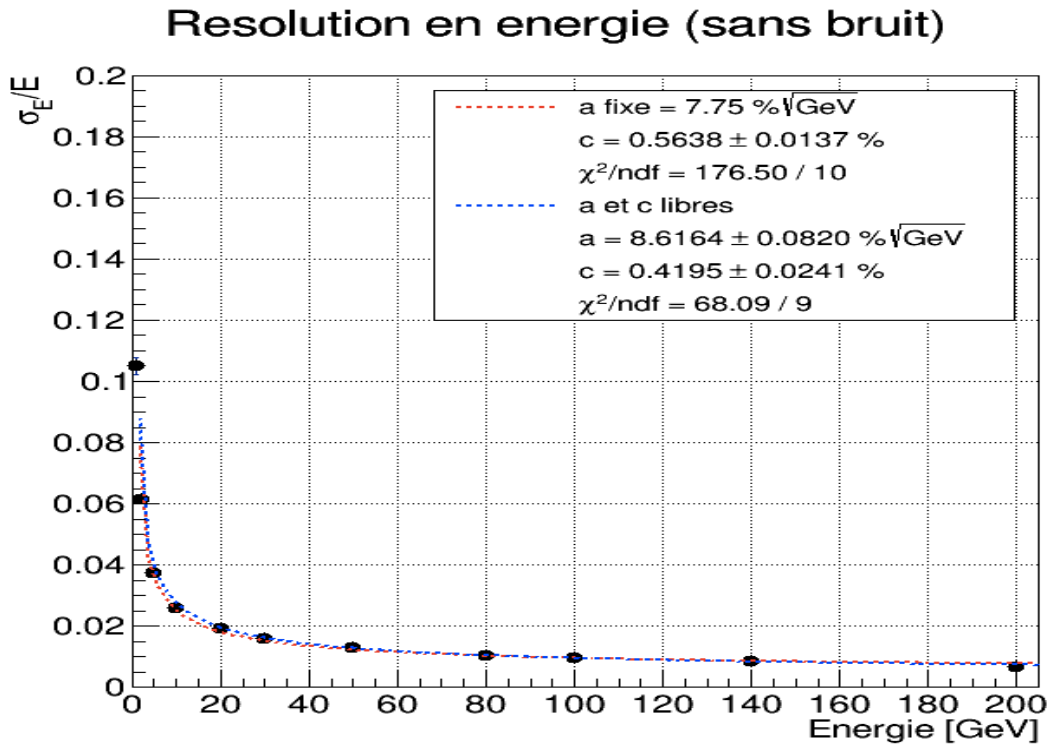
Without electronic noise → *b/E* term suppressed

Distribution over a full module → more realistic *c* term

Fit with a fixed:

$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}} \oplus c$$

Resolution curve:



a = 7.75 ± 0.03 %/$\sqrt{GeV}$ and *c = 0.56 ± 0.01 %.*

3. Electronic noise term *b*:

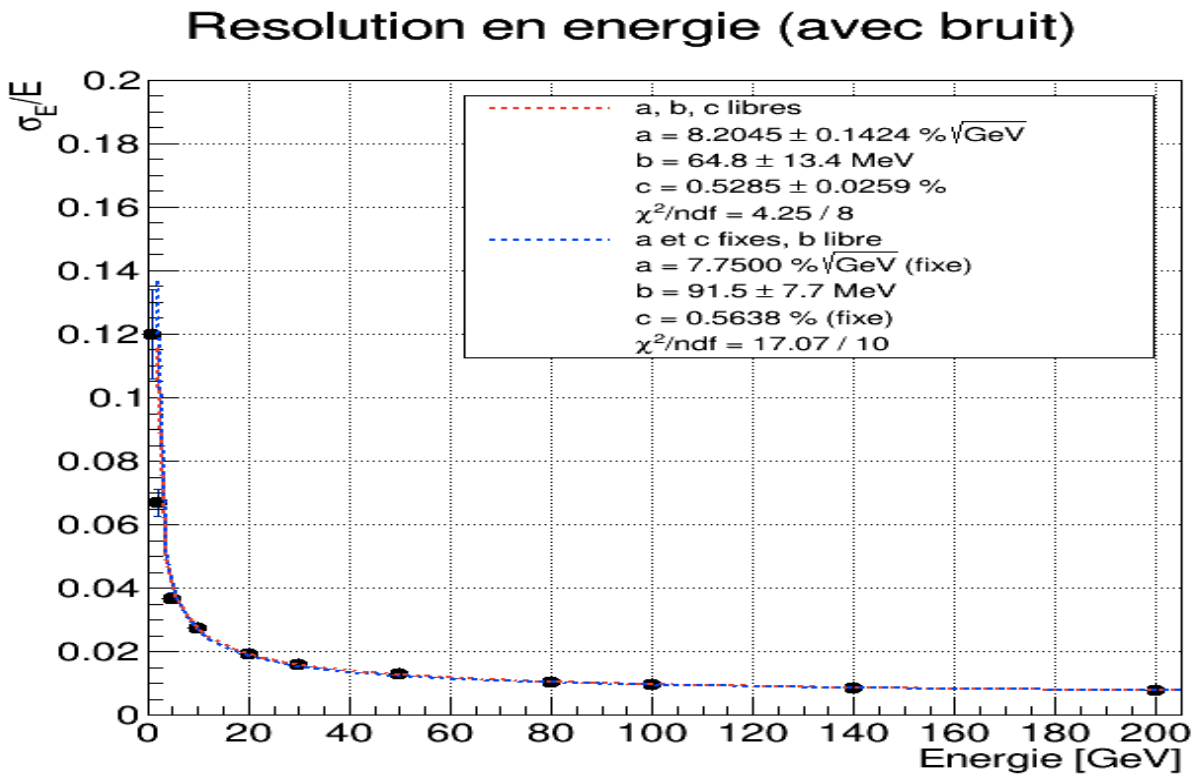
Protocol :

Same data as before, simulated with electronic noise

Fit with *a* and *c* fixed:

$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

Resolution curve:



a = 7.75 ± 0.03 %/√GeV, *b = 91.5 ± 7.7 MeV* et *c = 0.56 ± 0.01 %.*

Summury of results

Terme	Valeurs obtenue
Stochastic *a*	a = 7.75 ± 0.03 $\%/\sqrt{GeV}$
Constant *c*	c = 0.56 ± 0.01 %.
Electronic noise *b*	b = 91.5 ± 7.7 MeV

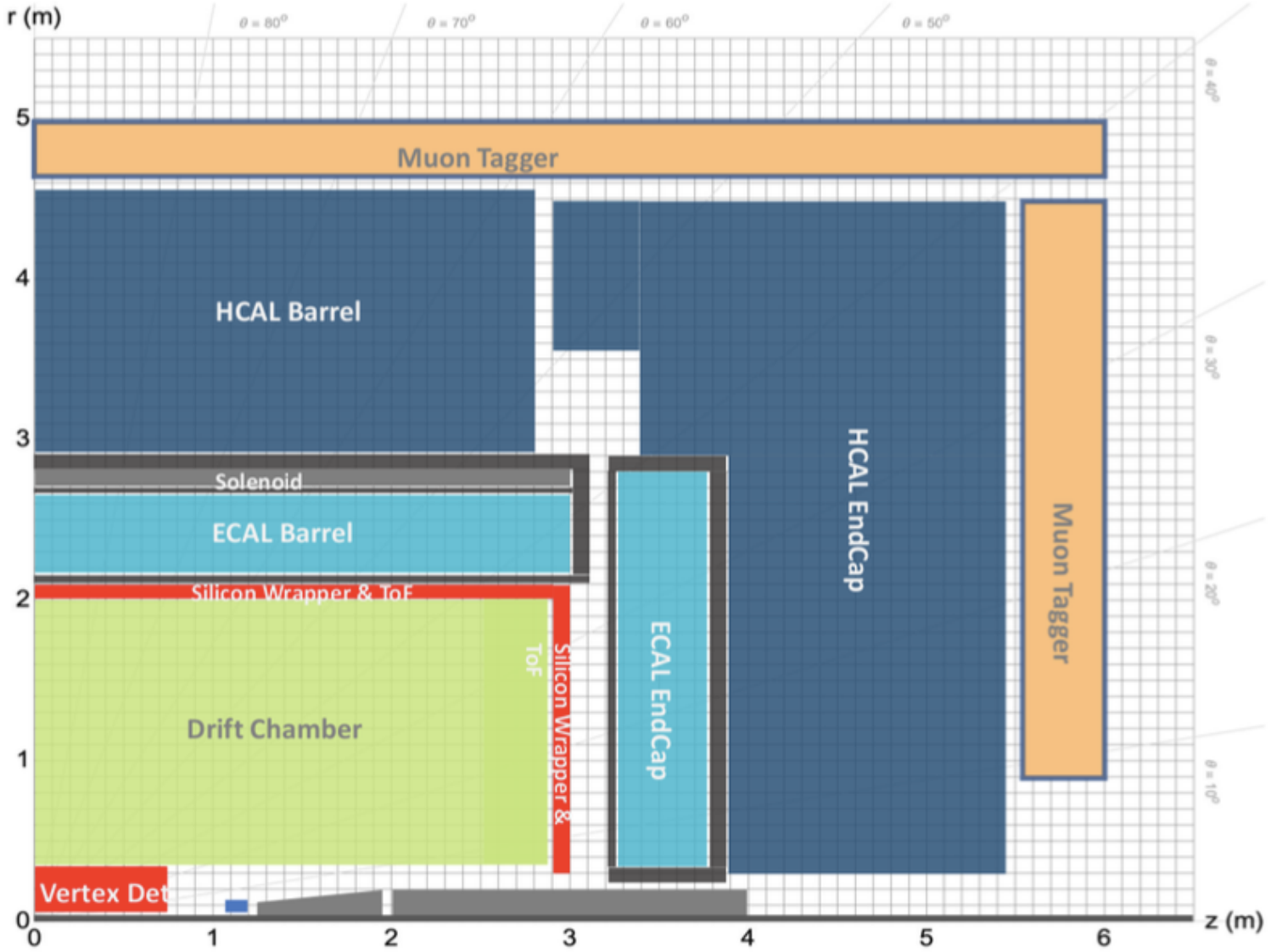
Decoupled methodology validated: results are consistent with expected performance.

Areas for improvement:
a → increase sampling frequency
b → place electronics inside the cryostat to reduce thermally-induced electronic noise
c → lighter cryostat (carbon), better calibration

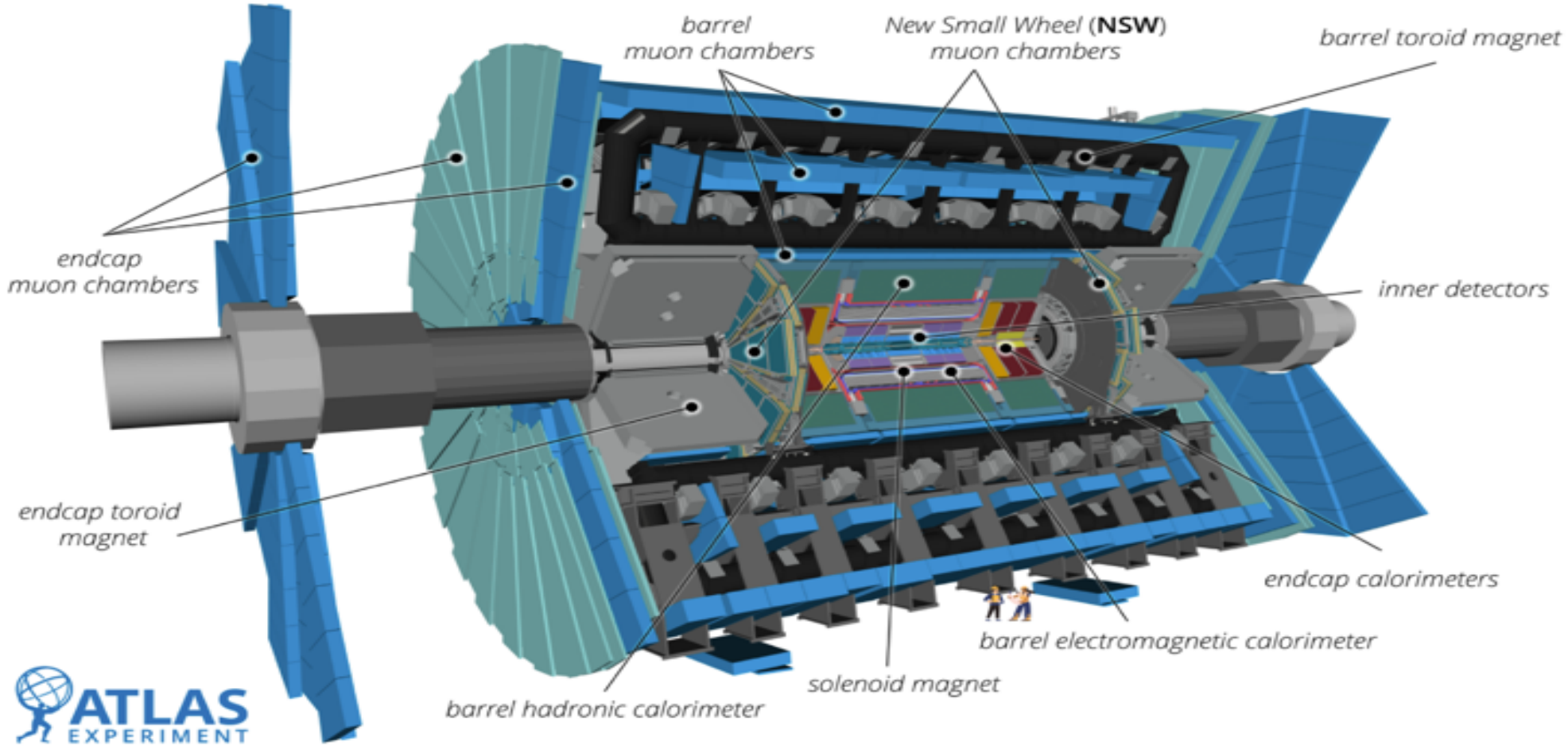
Ongoing optimization: replacing lead with tungsten, replacing liquid argon with krypton

Back up

ALLEGRO Schematic

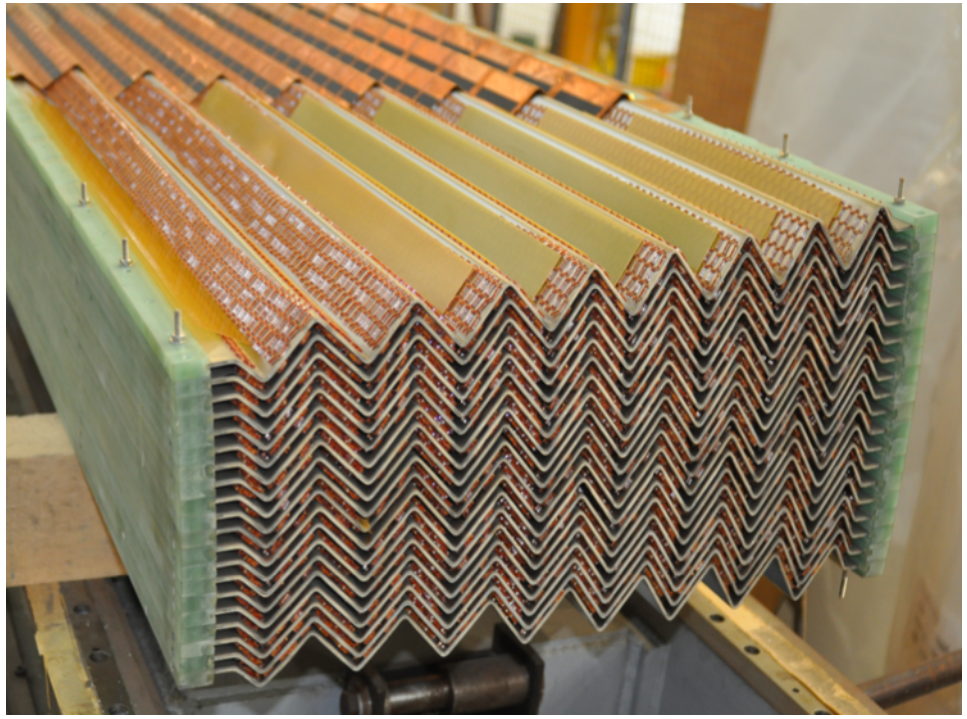


ATLAS Schematic

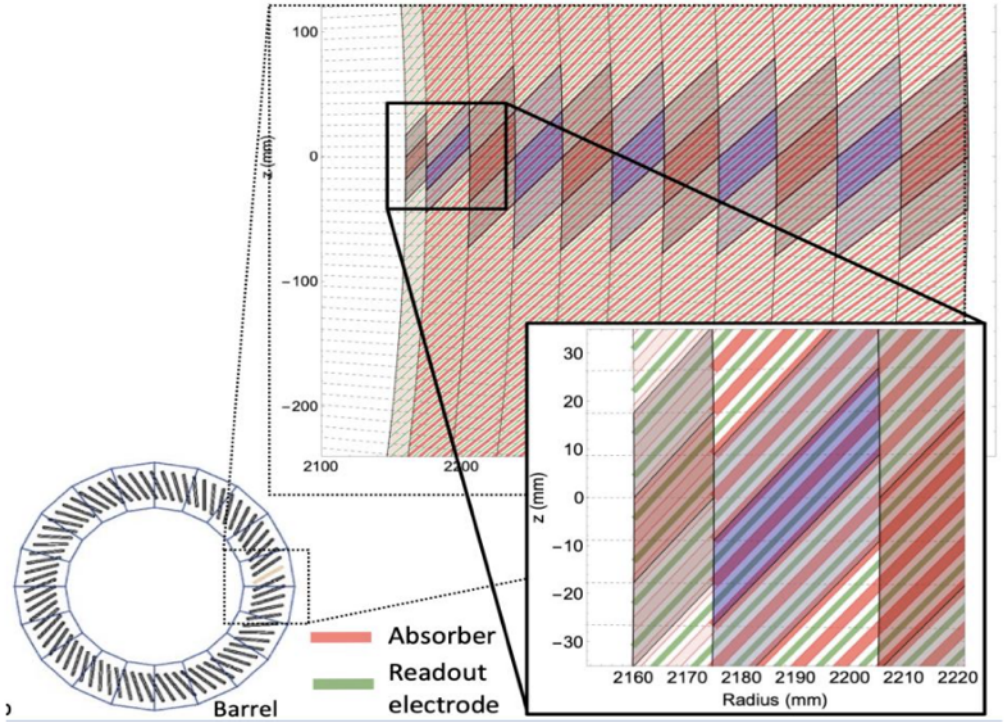


Sampling calorimeter

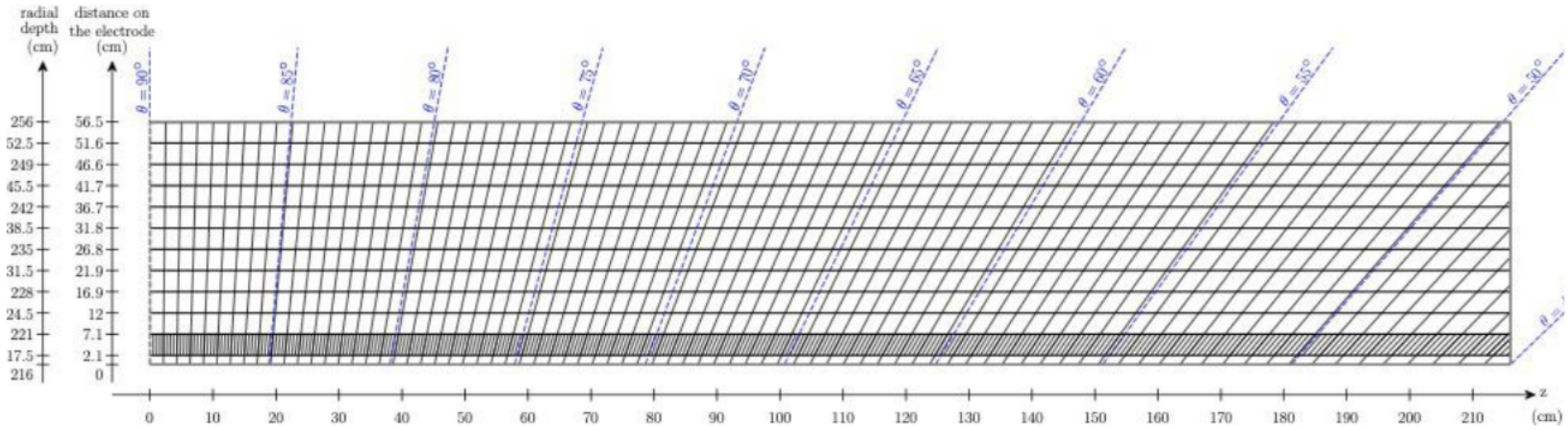
- ATLAS : accordion-shaped

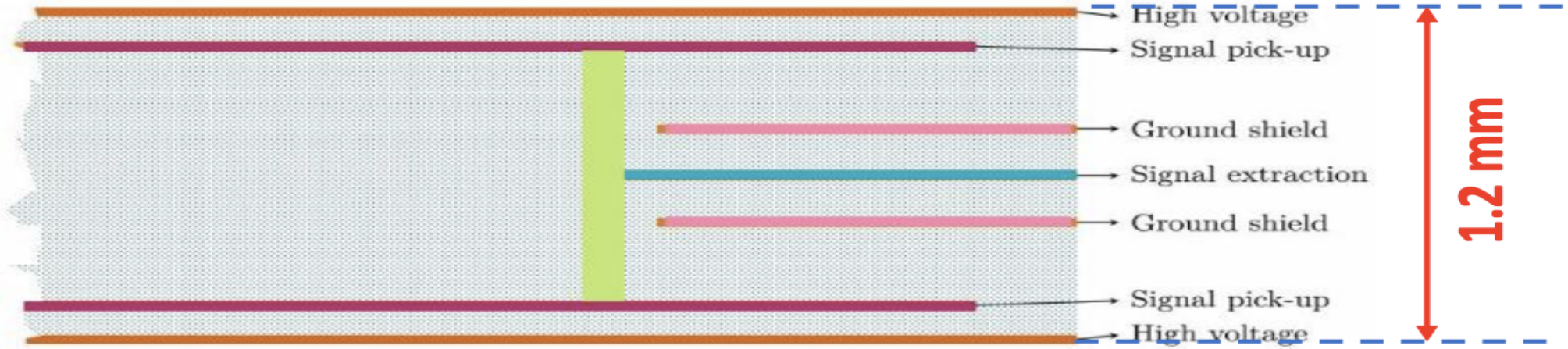


- ALLEGRO :

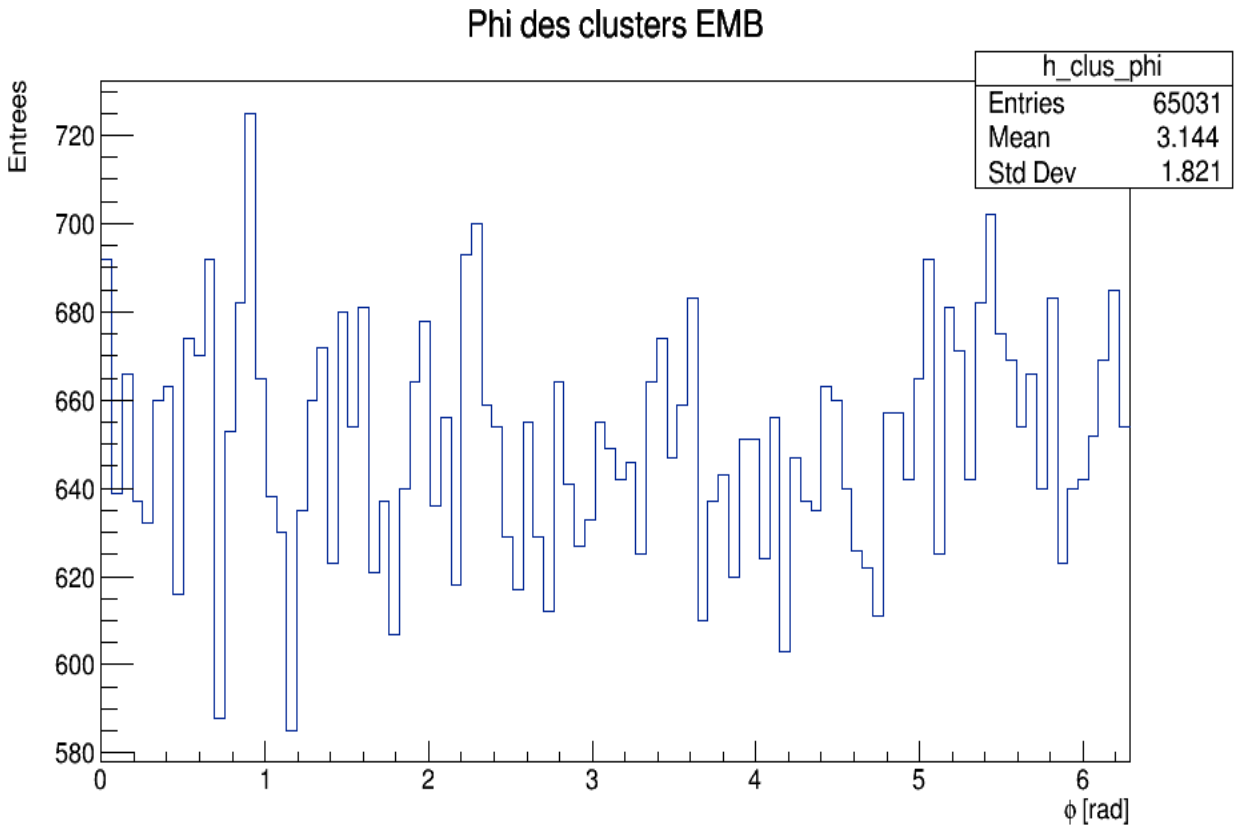


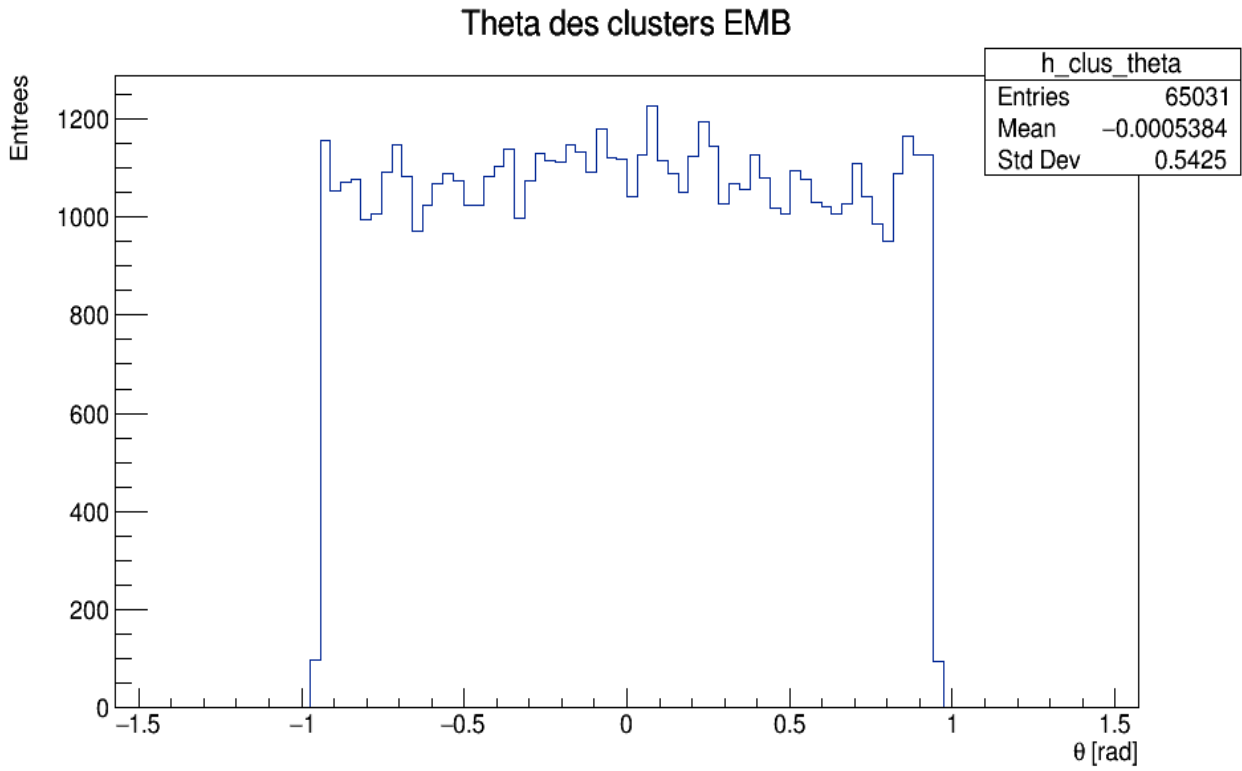
ALLEGRO electrodes design





phi and theta distribution of the clusters





Correlation matrices

For the fit without electronic noise:

	a	c
a	1	-0.63
c	-0.63	1

(average over the four fits)

For the fit with electronic noise:

	a	b	c
a	1	- 0.97	- 0.98
b	- 0.97	1	+ 0.91
c	- 0.98	+ 0.91	1

Noise map as a function of theta