Calibration of the relative response of the ALICE electromagnetic calorimeter EMCAL

Outline

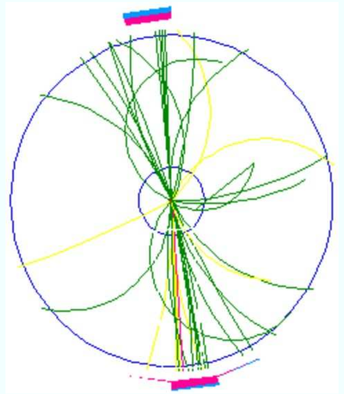
- **Physics motivations :**
  - → Quark-Gluon Plasma study
- **The experiment :**
  - → The ALICE experiment and its calorimeters
  - → EMCAL characteristics
- **Calibration with cosmic muons :**
  - → Experimental setup
  - → Analysis procedure
  - → Results
  - → Tracking time variations

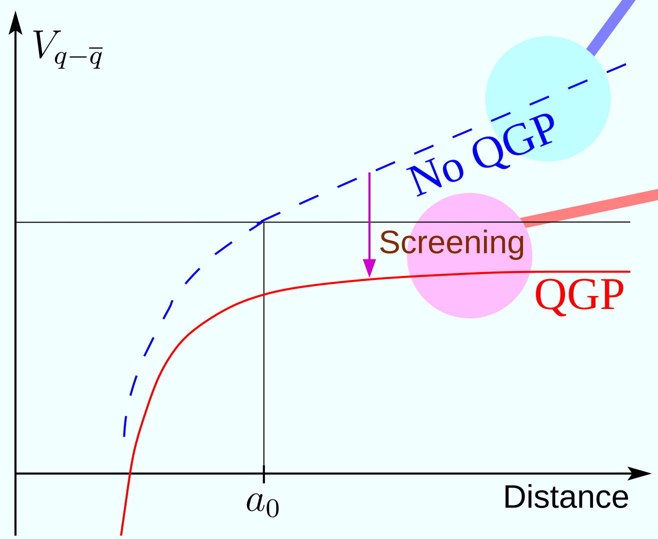
Julien FAIVRE
for the ALICE
collaboration

The Quark-Gluon Plasma (QGP) :

	Interaction :	
	Electromagnet.	Strong
Object	Charged particles	Quarks, gluons (partons)
Vector	Photon	Gluon

Observable objects are always color-neutral
⇒ partons hadronize :
they appear as jets



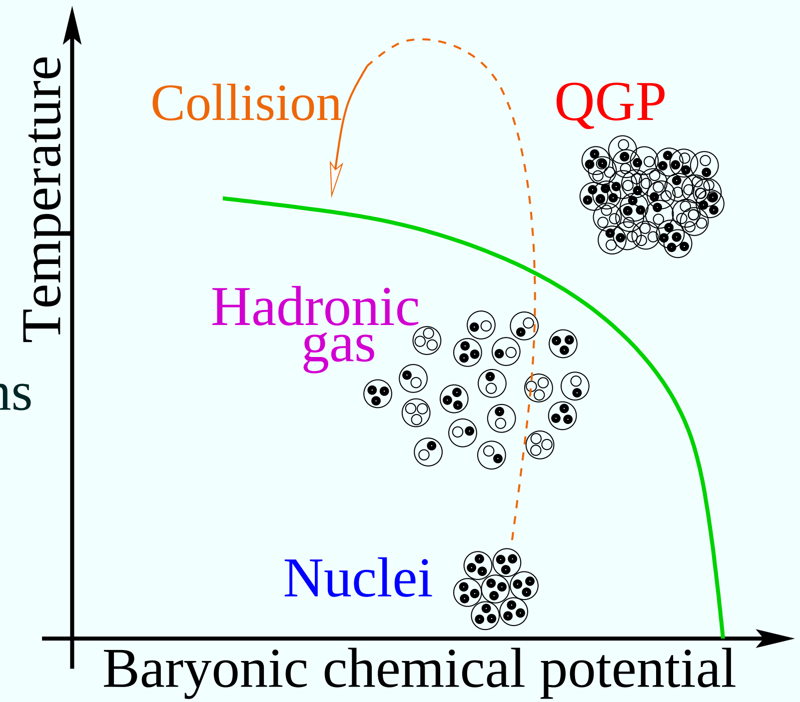


Large color charge density
⇒ screening
Color deconfinement
⇒ Quark-Gluon Plasma (QGP)

QGP : dense medium,
partonic (deconfined),
in thermal equilibrium

Why/how study the QGP :

- Phase transition predicted by Quantum Chromodynamics calculations (QCD = theory of the strong interaction)
- Large color charge density ?
  Ultra-relativistic heavy ion (e.g. Pb) collisions
  Reference experiments : p-p, p-A
- Study :
  → Phase diagram of nuclear matter
  → Behavior of the hot and dense matter
  → Test QCD calculations
  → Probe partonic composition of proton and nuclei



- ALICE : large experiment dedicated to the heavy ion collisions at LHC@CERN

Some probes which involve calorimetry :

- **Photons :**
  $\longrightarrow$ Reference (unaffected by strong interaction)
- **Thermal photons :**
  $\longrightarrow$ Get QGP temperature
- **Jets, azimuthal correlations between jets and hadrons or γ :**
  $\longrightarrow$ Get QGP density
  $\longrightarrow$ Learn how partons interact in QGP
  $\longrightarrow$ Investigate QGP equation of state
  $\longrightarrow$ Measure the in-medium modification of the parton fragmentation function
- **Heavy flavor (c and b quarks) :**
  $\longrightarrow$ Test QCD predictions of smaller in-medium energy loss
- All probes
  $\longrightarrow$ involve a test of QCD calculations
  $\longrightarrow$ provide data to constrain nucleon and nuclei parton content

Cf. talk
Alessandra Fantoni

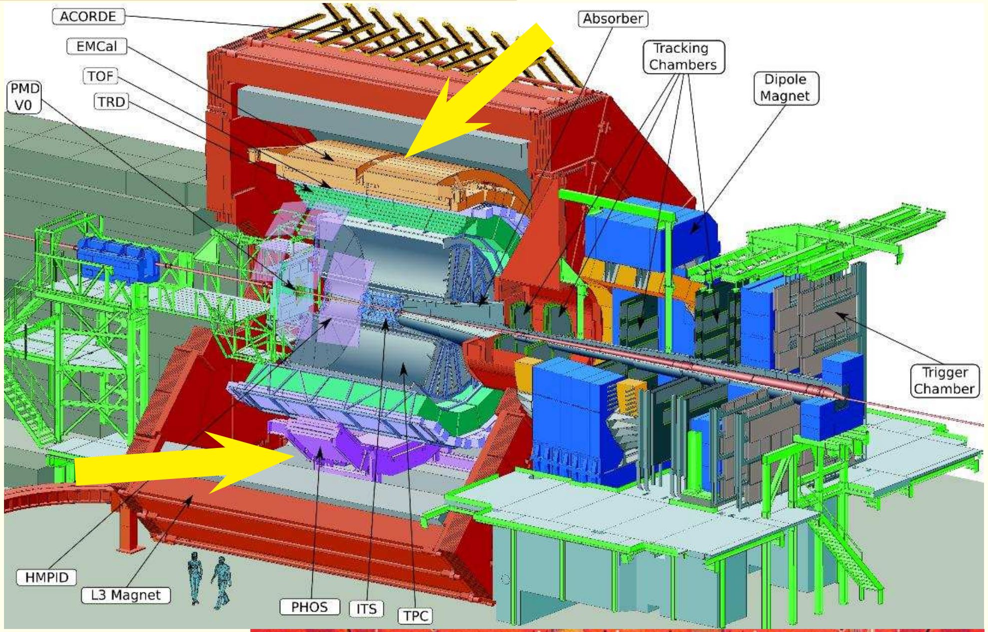
The calorimeter EMCAL :

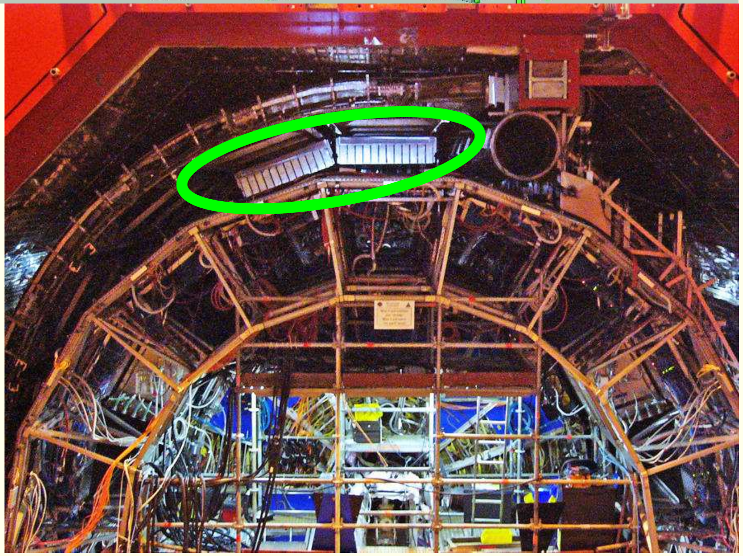
Total : 10×1152 channels

- 10 supermodules
- 1 supermodule = 3×8 strips
- 1 strip = 12 modules of 2×2 towers
- Segmentation : $6 \times 6\ cm$ ($4.5\ m$ from IP)
- Acceptance : $-0.7 < \eta < 0.7$, 100° in φ
- Located in front of PHOS

- Shashlik : Pb/scintillator stack
  with wavelength shifting optical fibers in
- Light collect. : avalanche photodiod (APD)
- LED gain monitoring system
- 8 temperature sensors per SM

- Provides a trigger for Physics



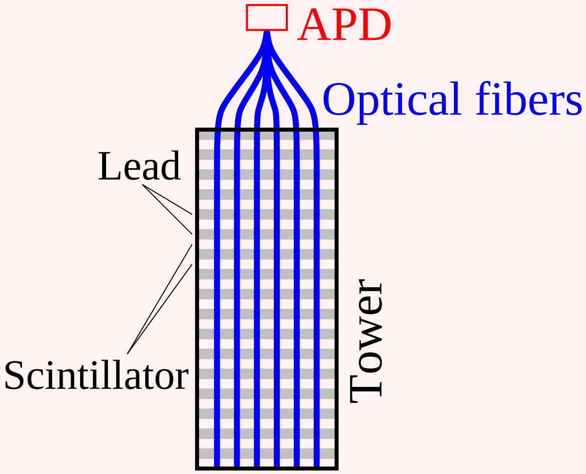


Currently : 4 supermodules installed

- Requirements : $\sigma_E/E < 2 \oplus 15/\sqrt{E}$
- Beam test : $\sigma_E/E = 1.7 \oplus 11.1/\sqrt{E} \oplus 5.1/E$
- Contribution miscalibration : adds in the constant term

Relative calibration with cosmic muons :

Pre-calibrate tower gains
before inserting in ALICE
Requirements : dispersion $< 10\ \%$



- APD gain = function of high voltage (measured)
- Towers have varying efficiencies (e.g. light collection)
- **Aim :** tune APD gains so they compensate for the varying efficiencies
  $\Rightarrow$ Each tower gives identical response to identical E deposit
- **How :** cosmic muons (permanent and free MIPs)

Take data → Calculate new HV
New HV = f(prev HV ; measured vs desired signal amplitude)

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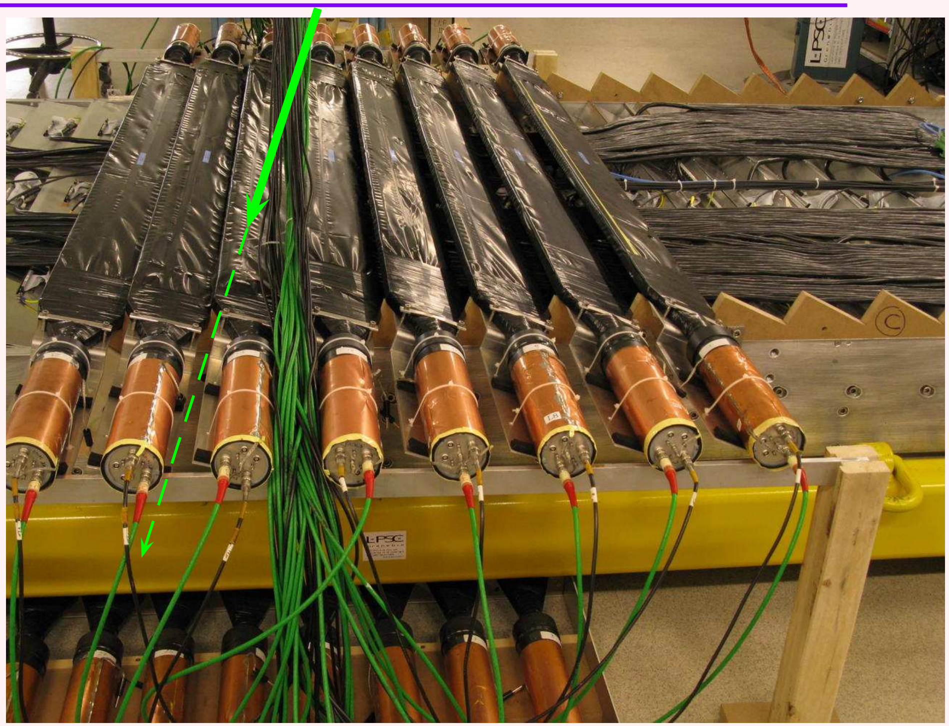
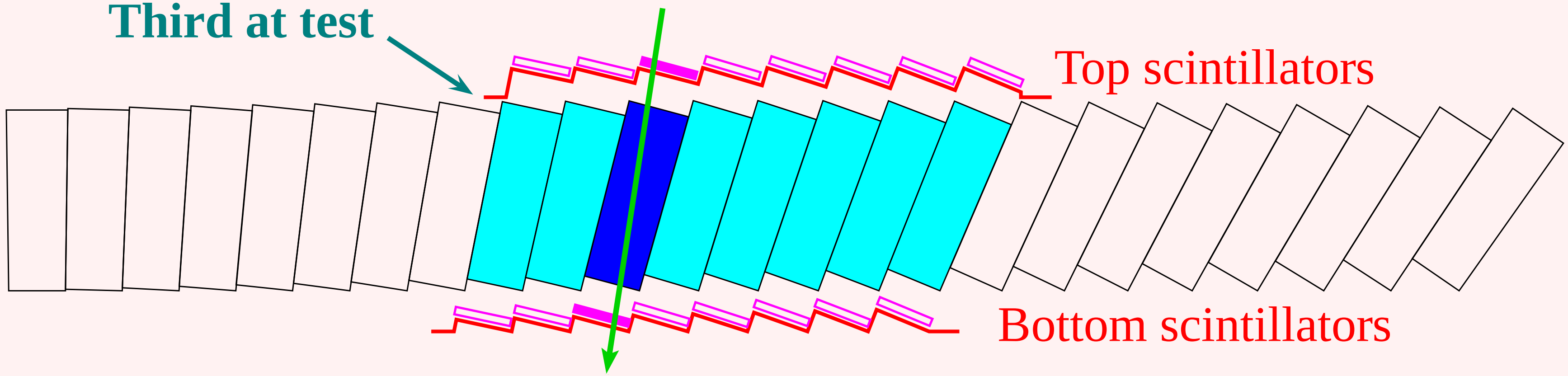
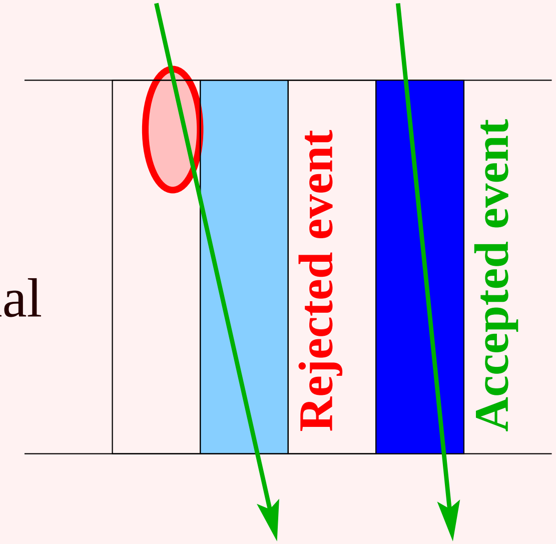


Mean deposited energy : $\simeq 28\ MeV$
(equivalent of $300\ MeV$ electrons)

- Experimental bench (side view) :

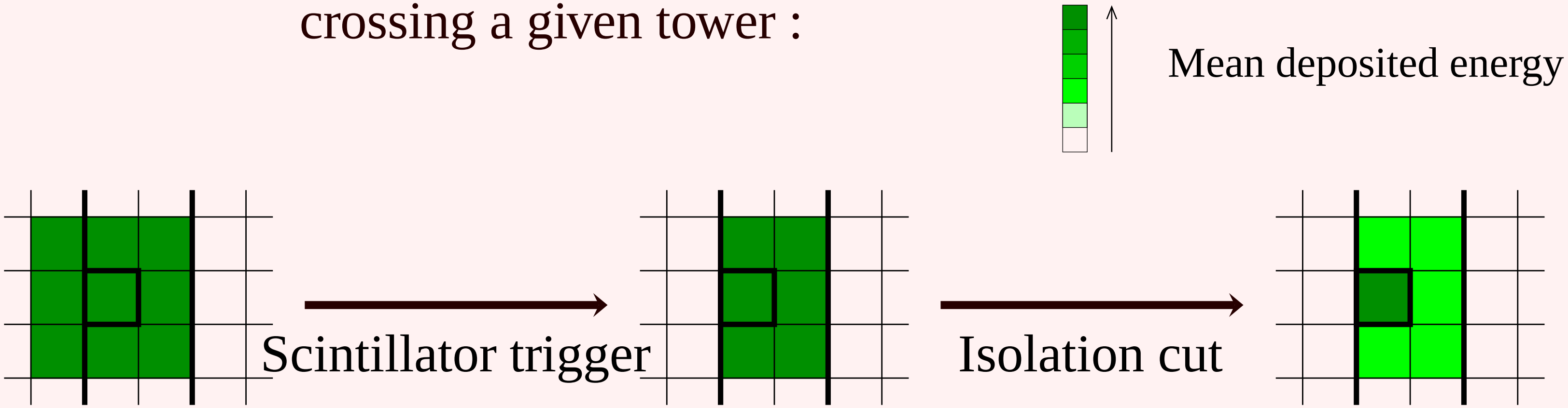


Isolation cut :



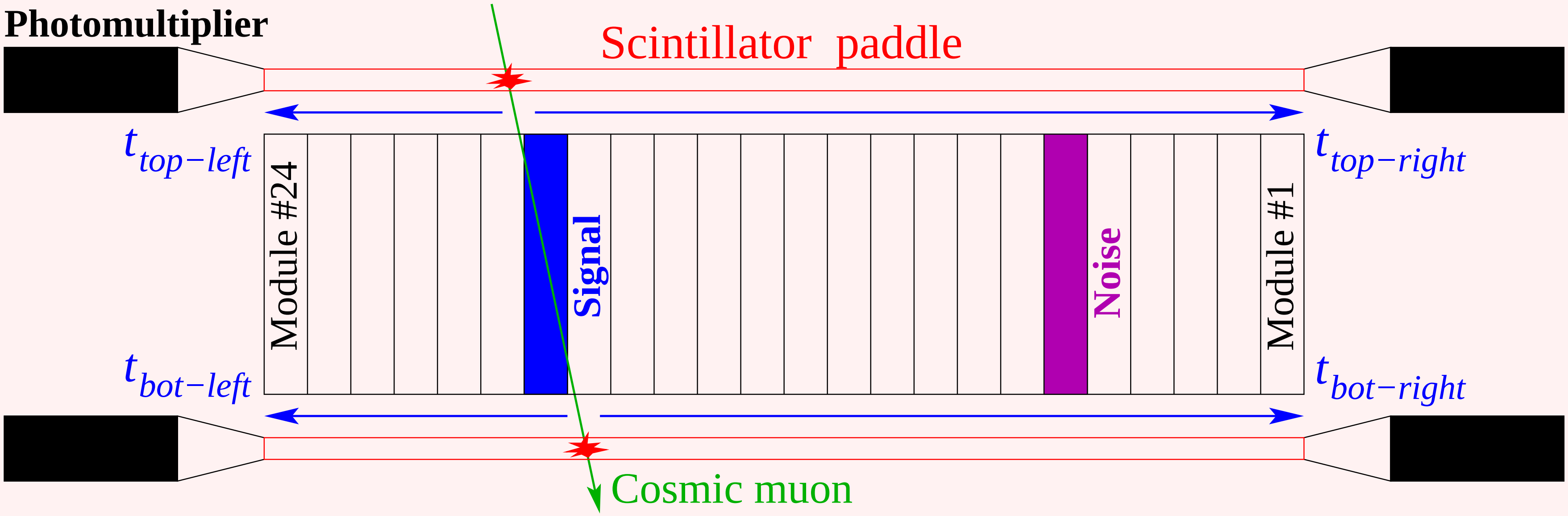
- Want narrow energy distribution
  ⇒ discard cosmics which hit more than 1 tower
  ⇒ discard event when a neighbor tower has some signal
  Isolation cut level limited by noise : 3 ADC

- "Map" of energy deposited by a muon crossing a given tower :

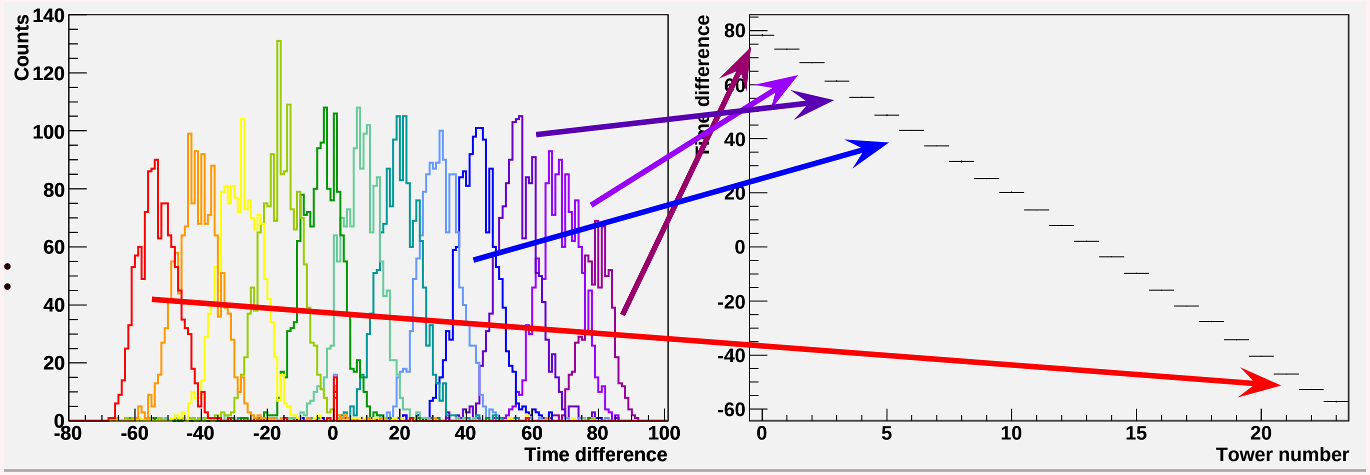


"Time of flight" (ToF) cut :

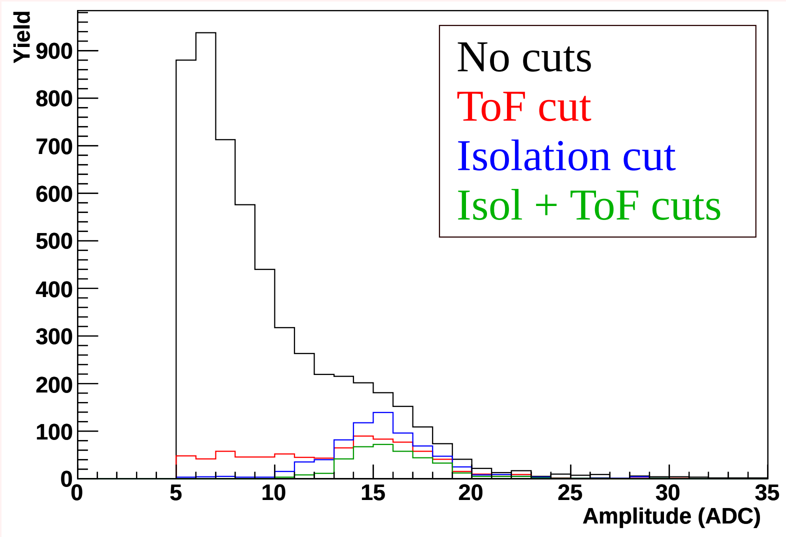
- Experimental bench (front view) :



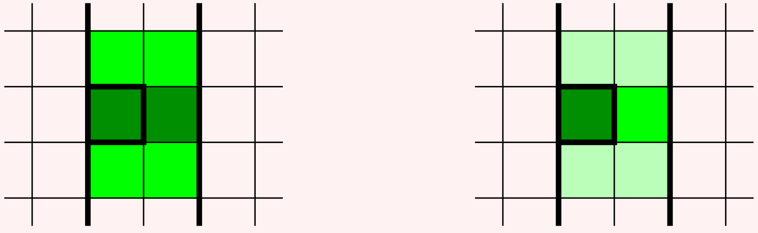
- Time difference between both photomultipliers :



Average signal amplitude :

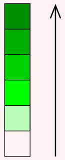


Where the muons deposit energy :



Only ToF

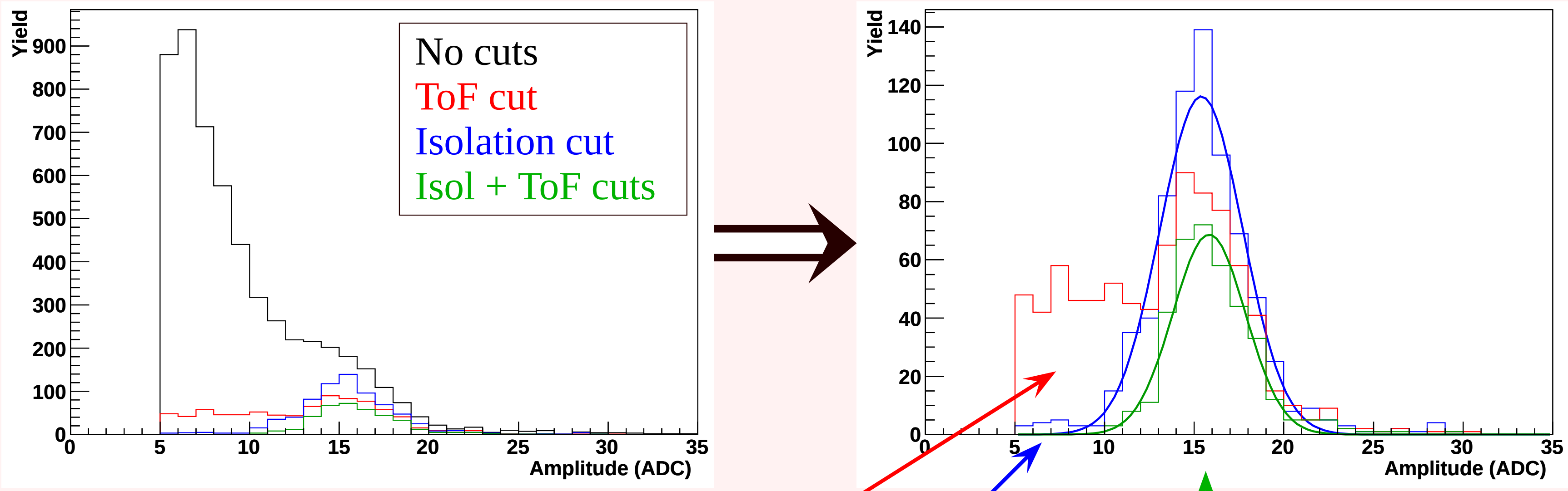
Isol + ToF cuts



Mean deposited energy

- Oblique muons are cut
  $\Rightarrow$ muons deposit energy in $\simeq$ a single tower
  $\Rightarrow$ narrow deposited energy distribution

Average signal amplitude :



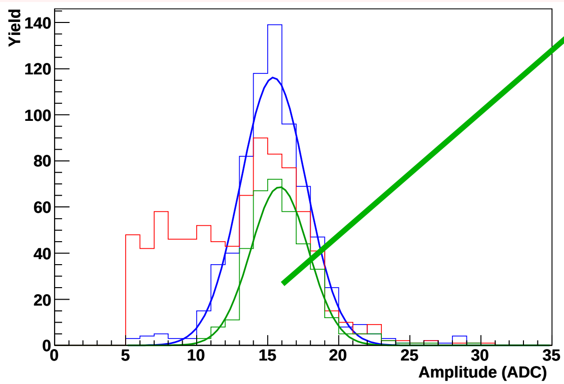
Cuts : ToF + scintillator selection

Cuts : isol + signal shape + this tower has the largest signal

- Mean of gaussian fit over distributions with isolation and ToF cuts
  $\longrightarrow$ **average signal amplitude**

- Measure average signal amplitude for all towers
- Then iteratively tune high voltages
  to move all average signal amplitudes to e.g. 16 ADC

Contributions to the width :



- $\sigma_{\text{tot}} = \sigma_{\text{deposited E}} \oplus \sigma_{\text{EMCAL resol}} \oplus \sigma_{\text{digit}} \oplus \sigma_{\text{temperature}} \oplus \sigma_{\text{other}}$

$\rightarrow$ $\sigma_{\text{tot}} \simeq 14 - 17\%$

$\rightarrow$ $\sigma_{\text{deposited E}} \simeq 12 - 16\%$

$\rightarrow$ $\sigma_{\text{EMCAL resol}} \simeq 3.8 - 4.1\%$

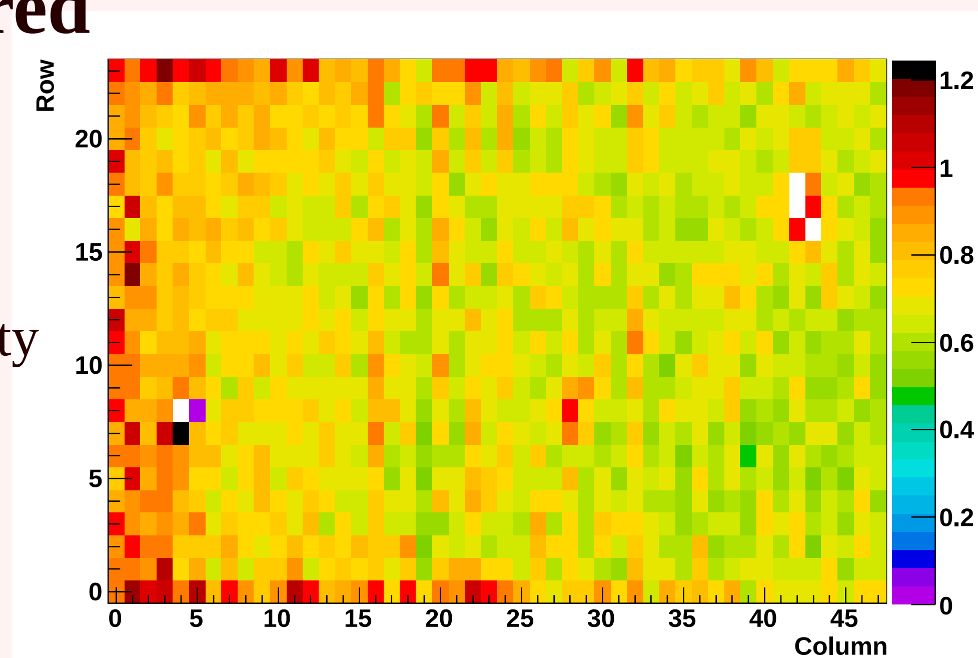
$\rightarrow$ $\sigma_{\text{digitization}} \simeq 1.8\%$

$\rightarrow$ $\sigma_{\text{temperature}} \simeq 1.5 - 3.0\%$

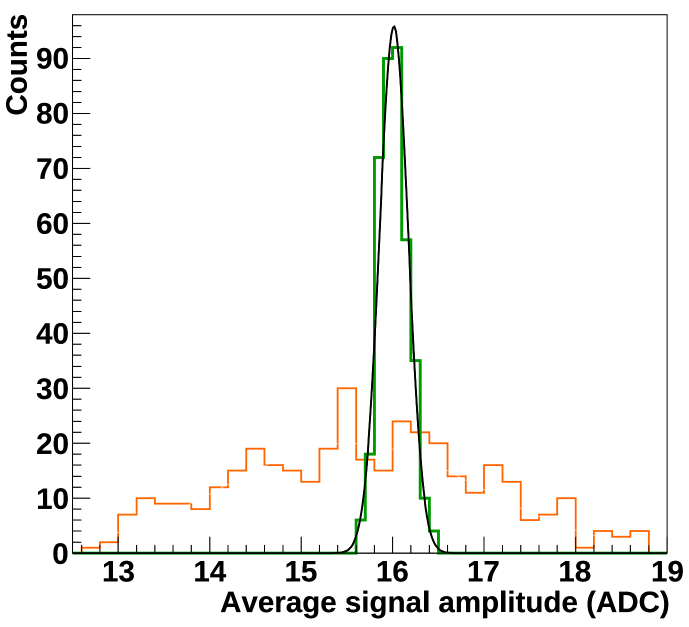
$\rightarrow$ σ_{other} = electronic noise, signal fit, pedestal subtraction, residual oblique muons, ...

Uncertainty on the measured average signal amplitude :

- $\sigma_\mu = \frac{\sigma_{\text{tot}}}{\sqrt{N}}$
- Typical statistical relative uncertainty on the average signal amplitude for a 23-hour run (in %)
  $\rightarrow$ Below the 1 % level

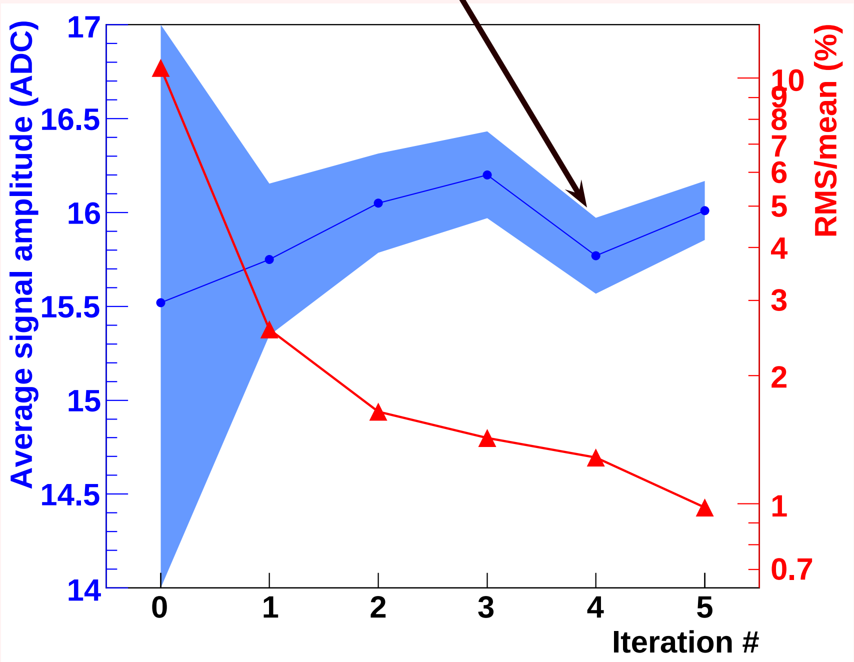


Relative calibration results :



- Dispersion (width ÷ mean) of average signal amplitudes from all towers :
  - → Start with worse than 10 %
  - → Reach < 2 % in 2-3 iterations

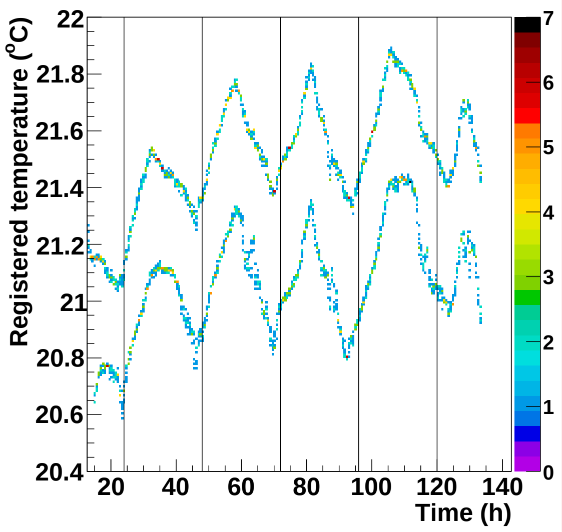
(Temperature rise in the hall)

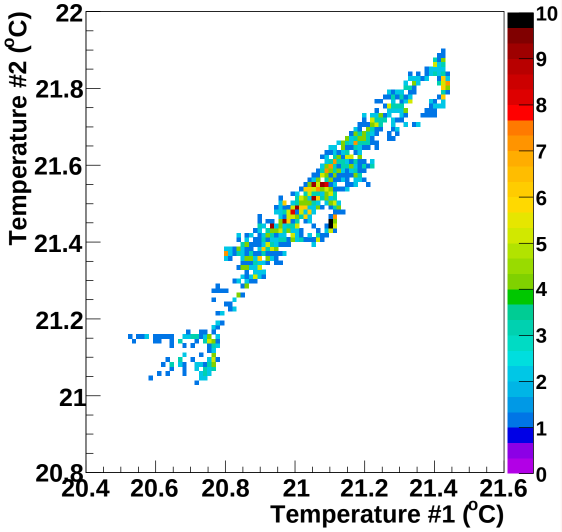


- 5 iterations : spread keeps going down ! ⇒ dominated only by statistics collected and number of iterations
- ⇒ relative calibration provided after 3 iterations is reliable → can reach the 1 % level

Tracking the tower gain changes :

- **Temperature sensors :** correlation between 2 sensors gives uncertainty $\simeq 0.2\,°$
- Temperature dependance of APD gain G : $\frac{1}{G}\frac{dG}{dT} \simeq -1.5 \rightarrow -4\%/K$ $\Rightarrow$ control of the relative calibration at the < 0.5 % level



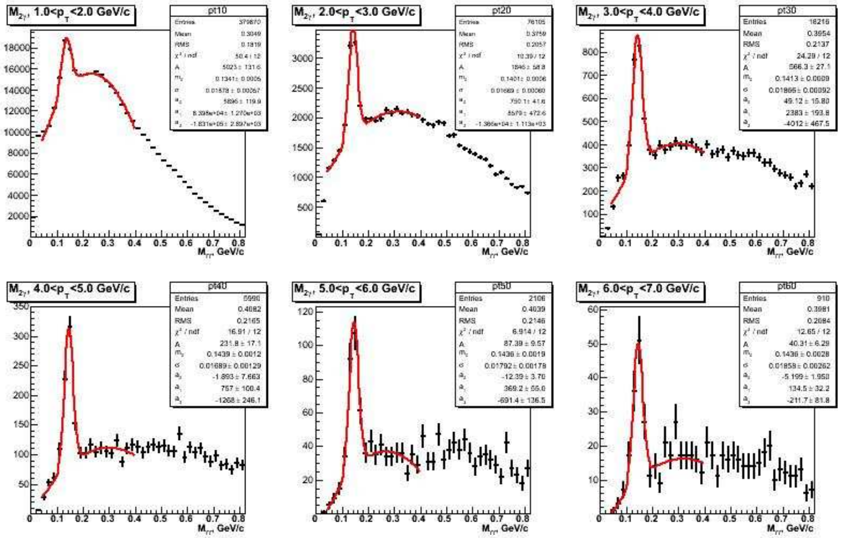


- **LED monitoring :** currenly under study
  LED pulse illuminates tower *and* goes to reference APD
  $\Rightarrow$ real-time monitoring of tower gain changes

Conclusion :

	How	Requirem.	Status	Limits
Pre-calibration	Cosmics	< 10 %	$\simeq 2$ %	Time
Online monitoring	LED	< 5 %	OK	LED statistics
Offline monitoring Offline calibration	Temperature Particles	$\simeq 1$ %	OK Simu OK	Sensors accuracy Stat, HV digitiz.

- Relative calibration :
  Three 1-night data-taking enough to calibrate 1/3 supermodule to < 2 %
- π^0 peak in Alice with real data
  (no further relative calibration)



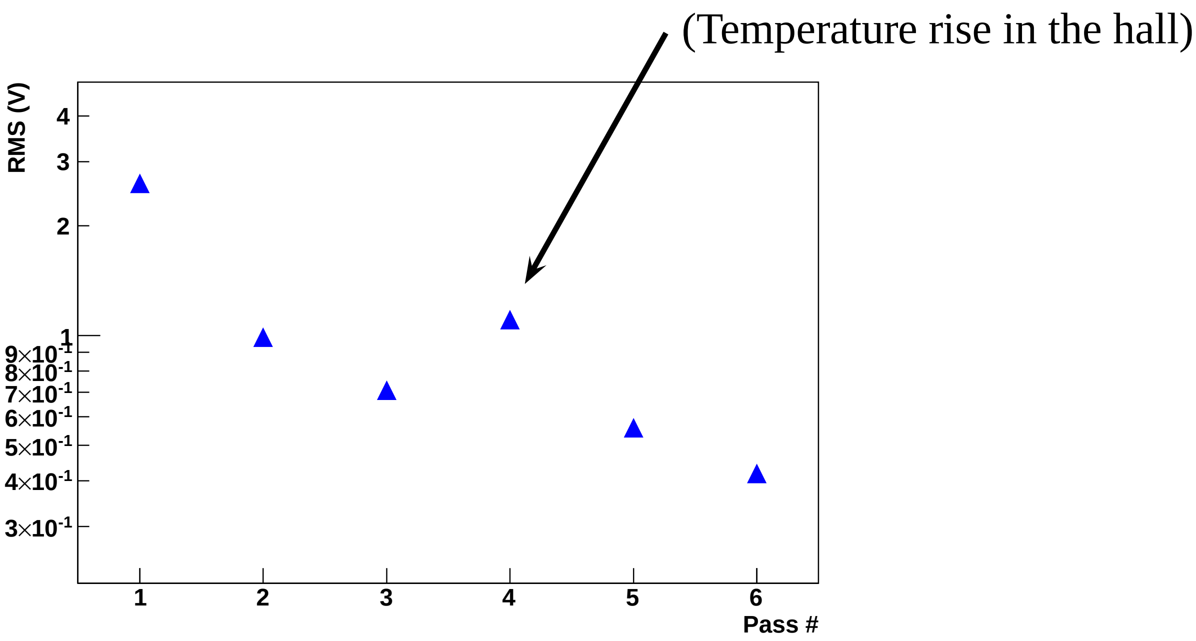
To be done next :

- Relative & absolute calib. with real data
  (MIPs, electrons matched with TPC tracks, π^0)
- Check how well LED and temperature monitoring perform in real situation
- DCAL extension ($\simeq$ doubles EMCAL acceptance) : same procedure

BACKUP’s

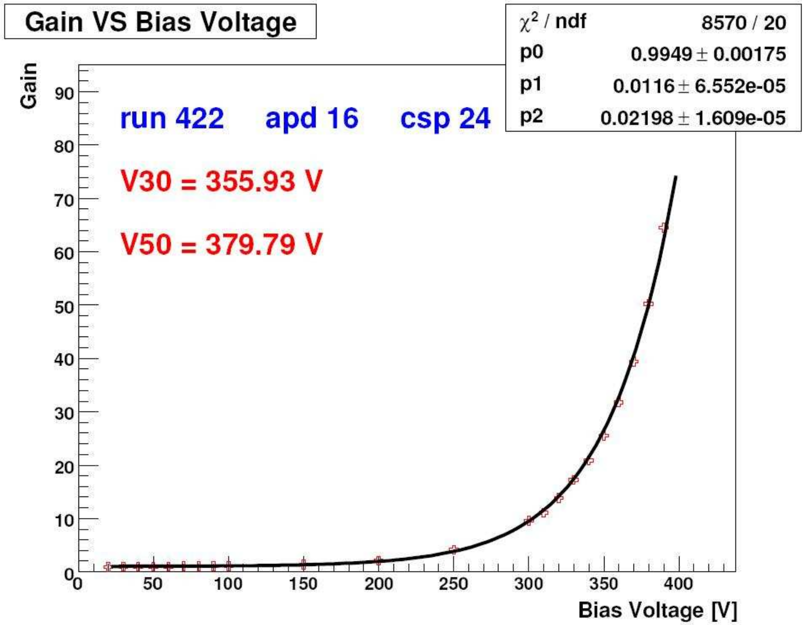
Convergence of the APD high voltages :

- High voltage digitization : 0.2 V/bit
- Limit on gain calibration : $\simeq 0.5$ %



APD gain as a function of high voltage :

- $G(V) = A + Be^{kV}$



EMCAL data :

- Tower size (active volume) : $\simeq 6.0\times \simeq 6.0 \times 24.6\ cm^3$
- Tower size : $\Delta\varphi \times \Delta\eta = 0.0143 \times 0.0143$
- Layers : $76 \times 1.44\ mm$ Pb
  $77 \times 1.76\ mm$ scintillator
- Number of radiation lengths : $20.1\ X_0$

Expected Physics performance with EMCAL :