Calibration of MPD Electromagnetic Calorimeter with Muons

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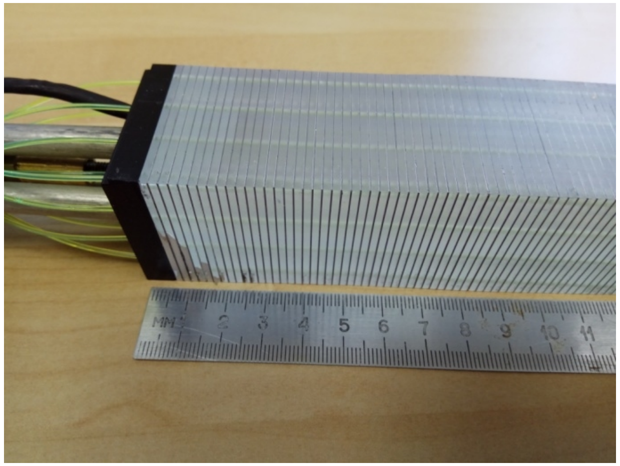
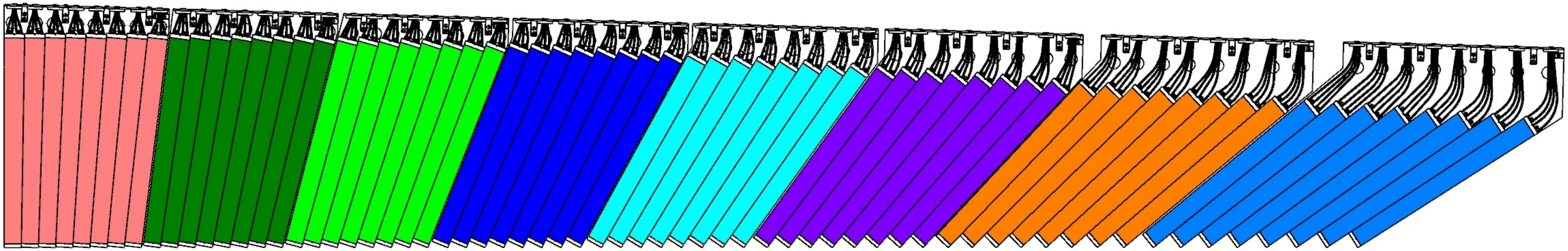
ECal Cell (Tower) Structure



- 210 layers of 1.5-mm-thick scintillator
- 210 layers of 0.3-mm-thick lead
- Rad. thickness of 11.2 X_0
- Max cell cross-section of 40×40 mm^2
- Diffuse reflector (white glue-paint) on the cell sides and the fibers ends
- Light collection and transport with 16 WLS fibers (*Kuraray Y11 (200)*)
- Light read-out with 6×6 mm^2 *Hamamatsu S13360-6025 MAPD*

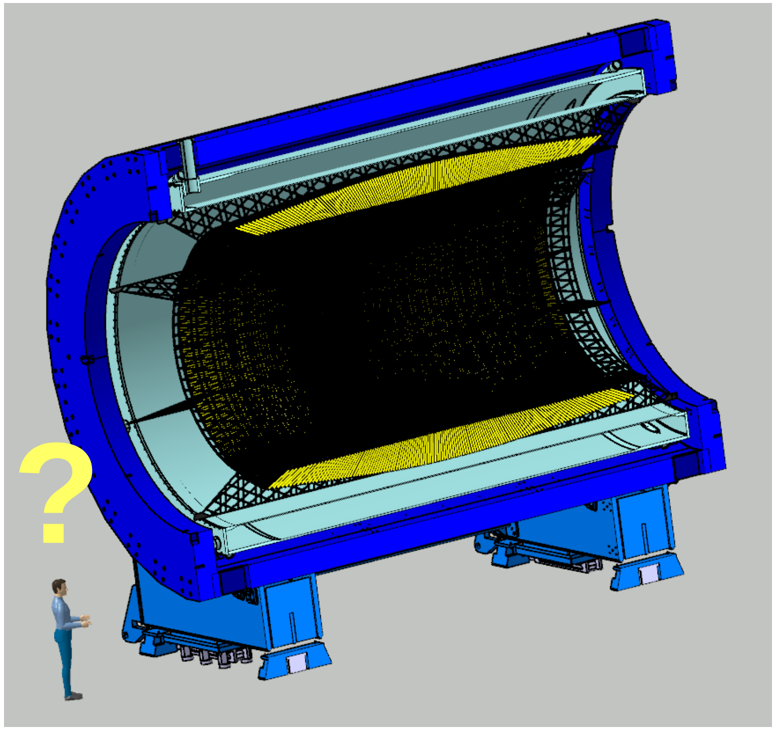
Projective Geometry of the Calorimeter:



Modules of 2×8 cells (8 types)

Each module type has an original geometry

Problems...



- Calorimeter cells have 64 types of shape.
- Calorimeter cells have original (and Z-asymmetric!) “surrounding”.
- Shashlyk-type cell (tower) has visibly not-uniform light collection.
- Relatively low energies of interest.
- High multiplicity of the secondary particles in central Au+Au collisions.
- 38,400 cells (towers).
- Not enough manpower and access time to electron beams to scan all towers.
- It’s highly desired to make modules and electronics QA and ECal modules calibration in the same time.
- QA and the calibration should be very reliable because modules will be <u>glued</u> into the half-sector container (viz., no “second chance”).

We need some method to determine the calibration characteristics of the detector without the use of a beam of known energy.

Calibration on Real Data: Bootstrap Method ?

- Developed by R. Jones et al., NIM A566 (2006) 366:
  Uses π^0 width minimization technique via adjusting the gain of each individual channel (ϵ_i) to minimize the global fit function

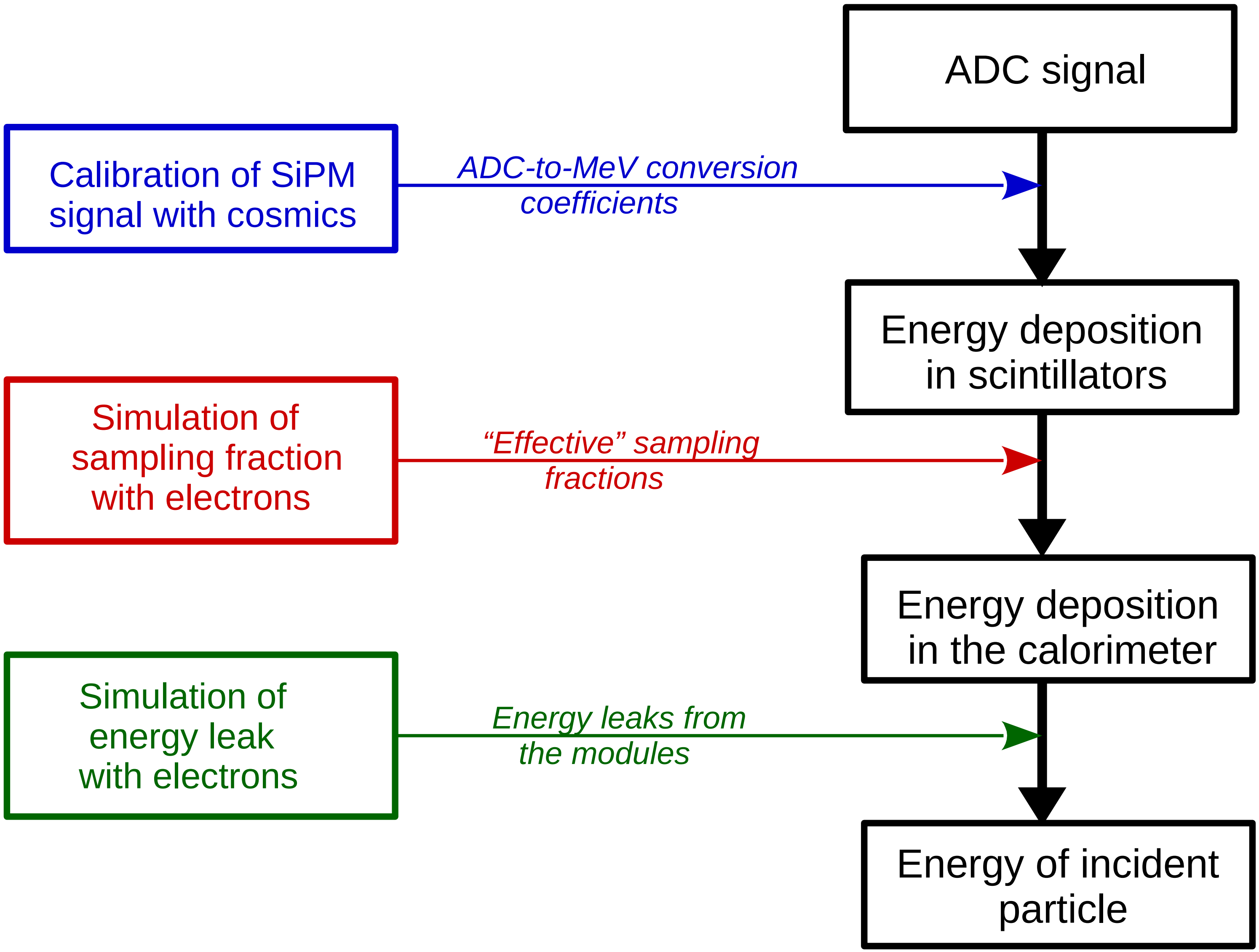
$$F = \sum_{i=1}^{N}(m_i^2 - m_0^2)^2 + 2\lambda \sum_{i=1}^{N}(m_i^2 - m_0^2)$$

$$\frac{\partial F'}{\partial \epsilon_k} = 2\sum_{i=1}^{N}\left(m_i^2 - m_0^2 + \lambda + \sum_{k'} \epsilon_{k'} \frac{\partial m_i'^2}{\partial \epsilon_k'}\right)\frac{\partial m_i'^2}{\partial \epsilon_k} = 0$$

- For RADPHI detector calorimeter (620 cells), the method works pretty well.
- For GlueX calorimeter (768 doulbe-sided cells), the method works also but requires pretty “close-to-the-truth” initial parameters to converge.
- What about MPD calorimeter (38,400 cells)? (Very good “initial” parameters will be needed for sure.)

“Isolated-cell” calibration with accuracy better than 2-3% will be very helpful as the “starting point”.

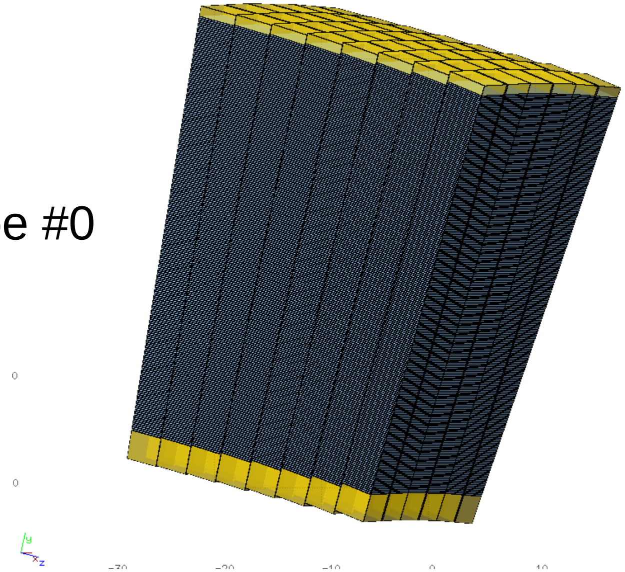
Very Simple Calibration Procedure

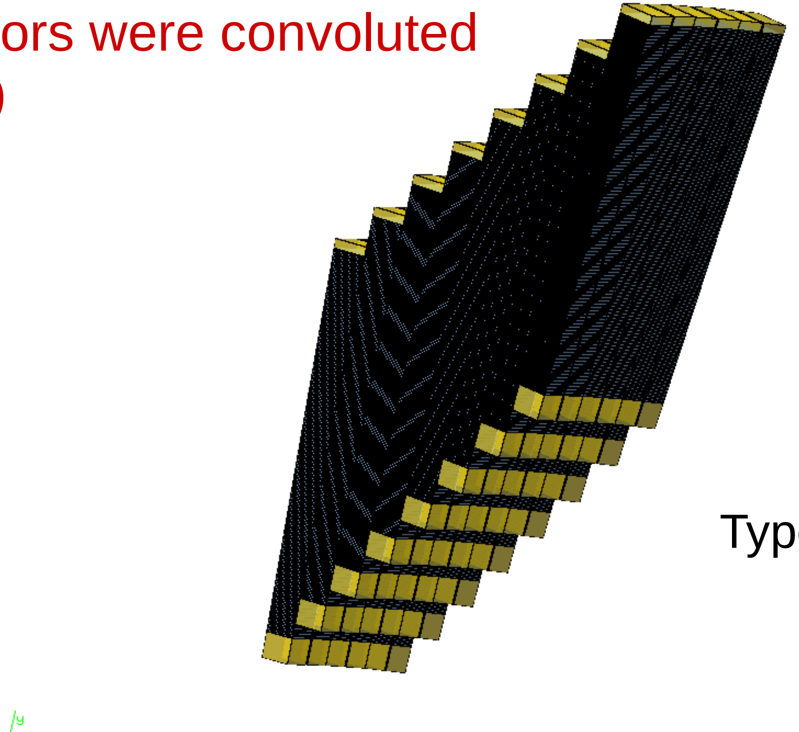


Simulations

- FLUKA version 2011.2x.7 Monte Carlo code
- Energy cuts and transport parameters were set according to one of the default FLUKA set CALORIMETRY (tuned)
- Detailed-structure model of assembly of 3 ECal modules
- Simulations for each type of ECal modules
- Electrons: a few energies from 0.1 to 2.0 GeV
- Cosmics: 2 GeV/c muons
- Energy depositions in scintillators were convoluted with attenuation function *A(x)*

Type #0





Type #7

Measured Attenuation in Towers (WLS fibres)

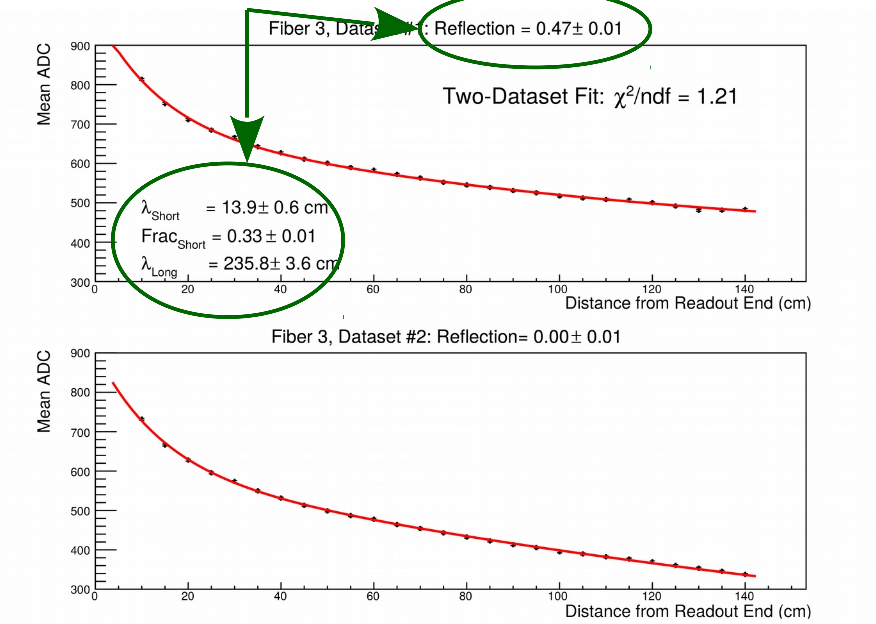
- Measurements with Kuraray Y-11 (200) WLS fibers (L=1.5 m)
- Light was injected from “Generic Ultra Bright Blue” LED from RS Components Company (high temperature stability)
- Light was detected with FEU-84 PMT
- Pin photodiode to monitor setup stability
- One measurement with white-paint reflector on the fiber end, and another one without reflection (oil bath)
- The parameters from the fit were used in the simulation

With reflection (like in ECal cells):

$$A_1(x) = 0.5*[Frac*\exp(-x/\lambda_S) + (1-Frac)*\exp(-x/\lambda_L)] + 0.5*Refl*[Frac*\exp((x-2L)/\lambda_S) + (1-Frac)*\exp((x-2L)/\lambda_L)]$$

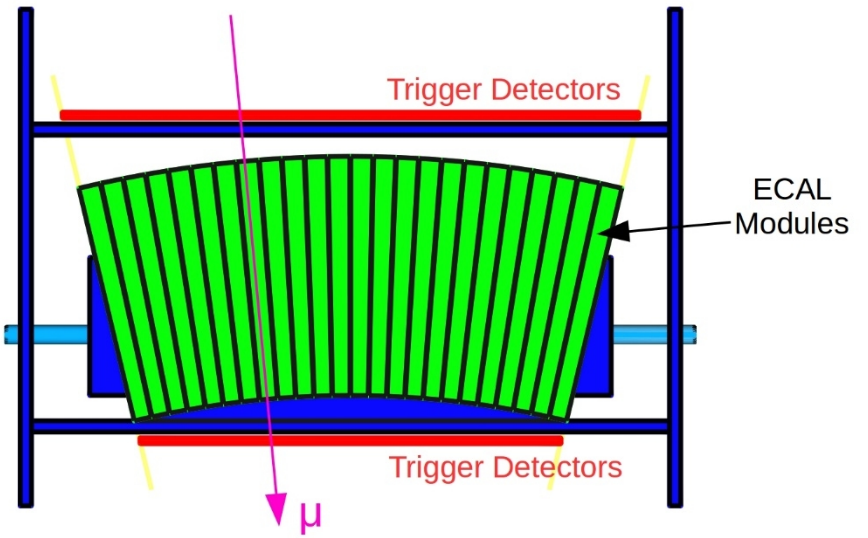
Without reflection (attenuation only):

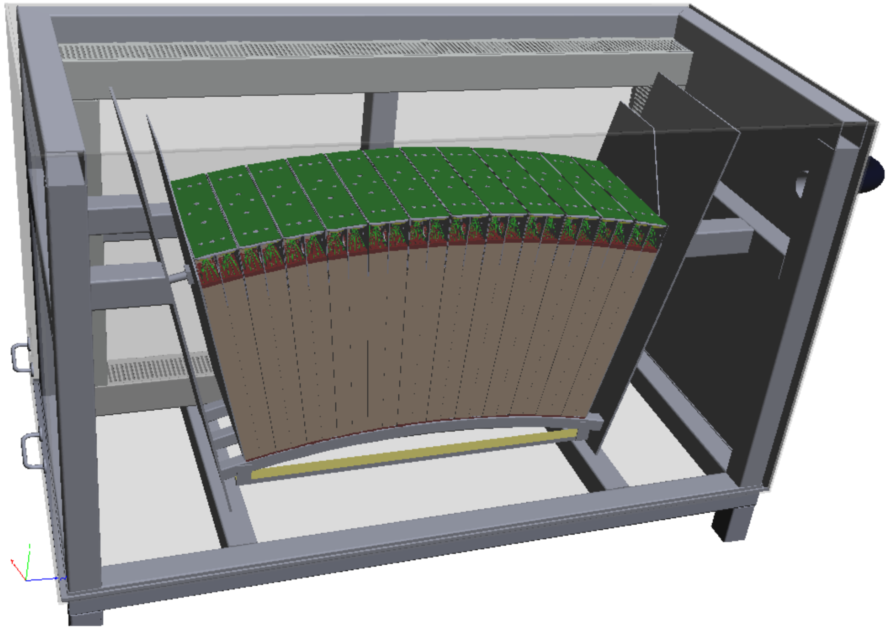
$$A_2(x) = 0.5*[Frac*\exp(-x/\lambda_S) + (1-Frac)*\exp(-x/\lambda_L)]$$



Spectra from Cosmic Muons

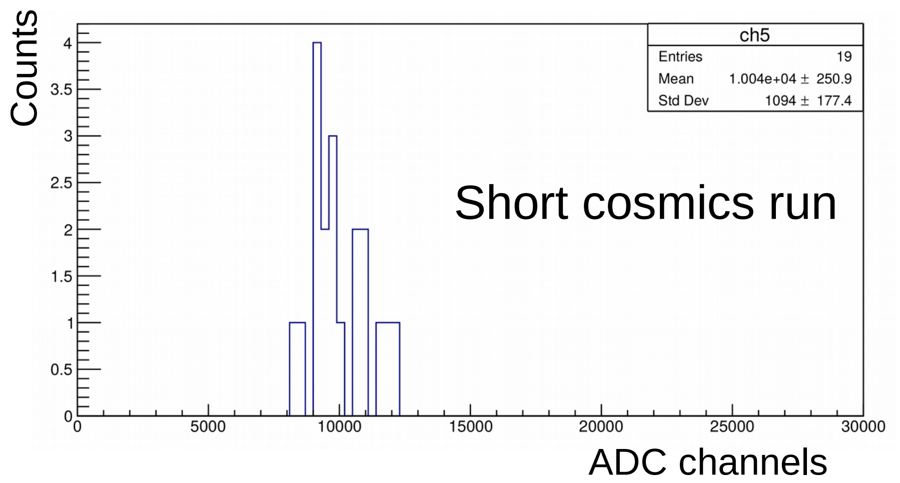
- All ECal modules with specific electronic boards & operation conditions.
- Trigger selects muons that travel along the module axis.
- 8 stands for 8 types of modules.
- Test 12 modules per stand in 2 weeks.
- All modules calibration in 1 year.

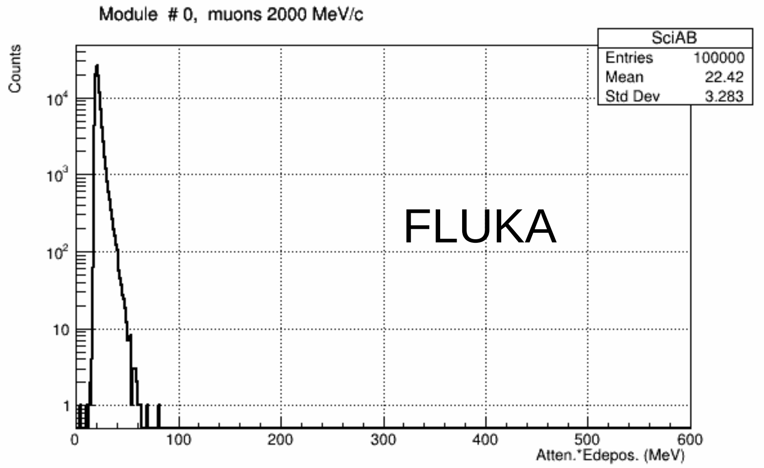




Calibration of SiPM Signals with Cosmics

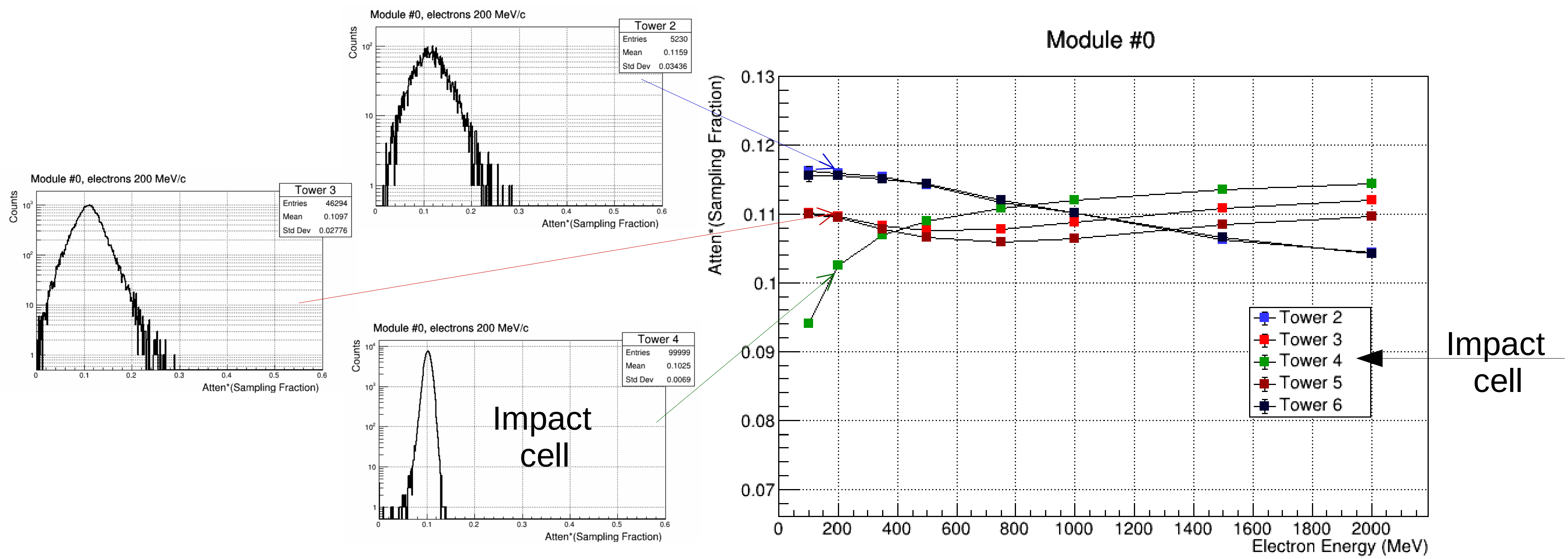
- ADC distributions from “longitudinal” cosmic muons are **very compact**.
- 2-weeks cosmic run provides enough statistics (800-1000 events) for accurate measurement of the distribution mean value.
- Conditions in the simulation exactly reproduce the cosmic run conditions.
- For each ECal cell, ADC-to-MeV coefficient (*SCC*) will be obtained by fitting the simulated distribution to the measured spectrum.





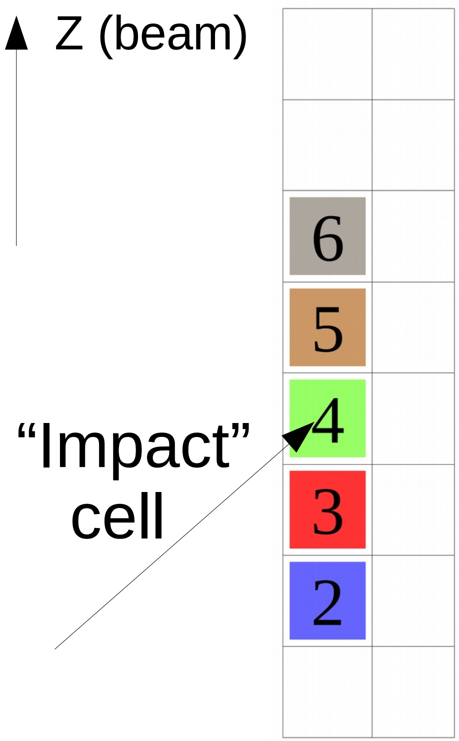
Simulation of "Effective" Sampling Fraction (*ESF*)

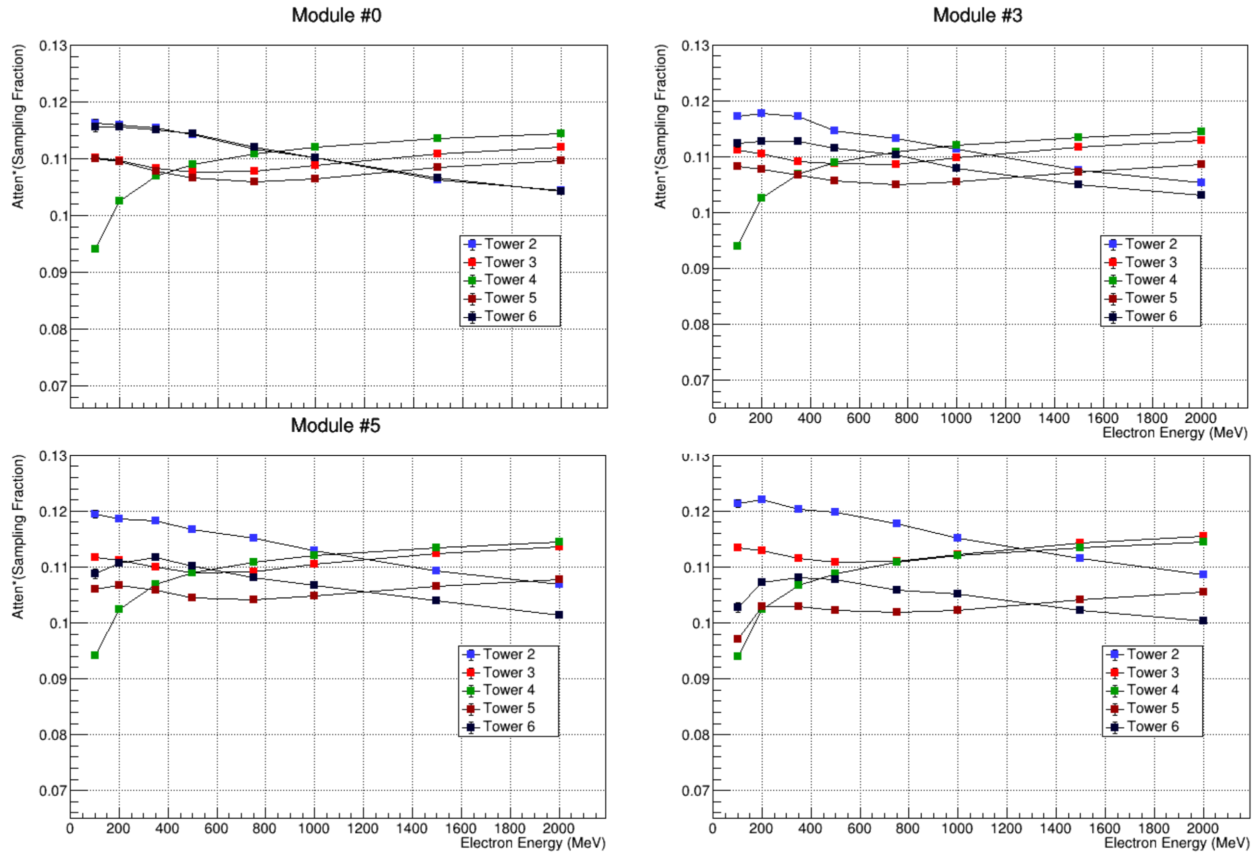
- "Pencil" electron beam impacts the cell in the center of assembly.
- Ratio of the "effective" (viz., convoluted with atten. function) energy that is deposited in scintillators to the energy deposited in whole cell materials.
- Visible electron-energy dependence (that is quite different from the energy dependence for "real" sampling fraction!).
- ESF is different for the "impact" cell and the surrounding cells.



Simulation of *ESF* (cont.)

- While ESF is about the same for the “impact” cells in the different module types, it is quite different for the “side” cells.



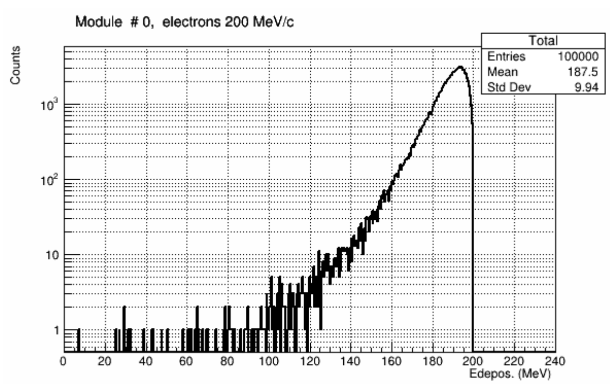


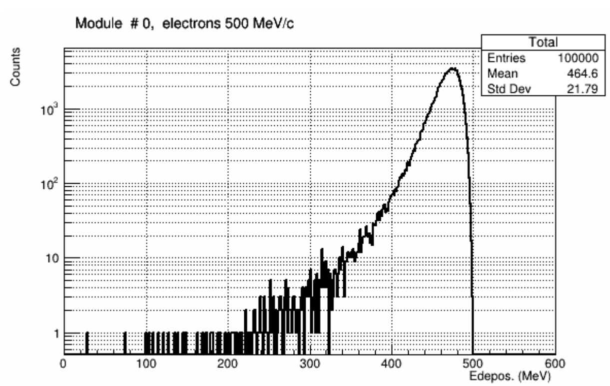
If not compensated, this “surrounding” asymmetry will cause (in addition to the energy distortion up to 5-8%) the θ-angle (viz., p_T) distortion.

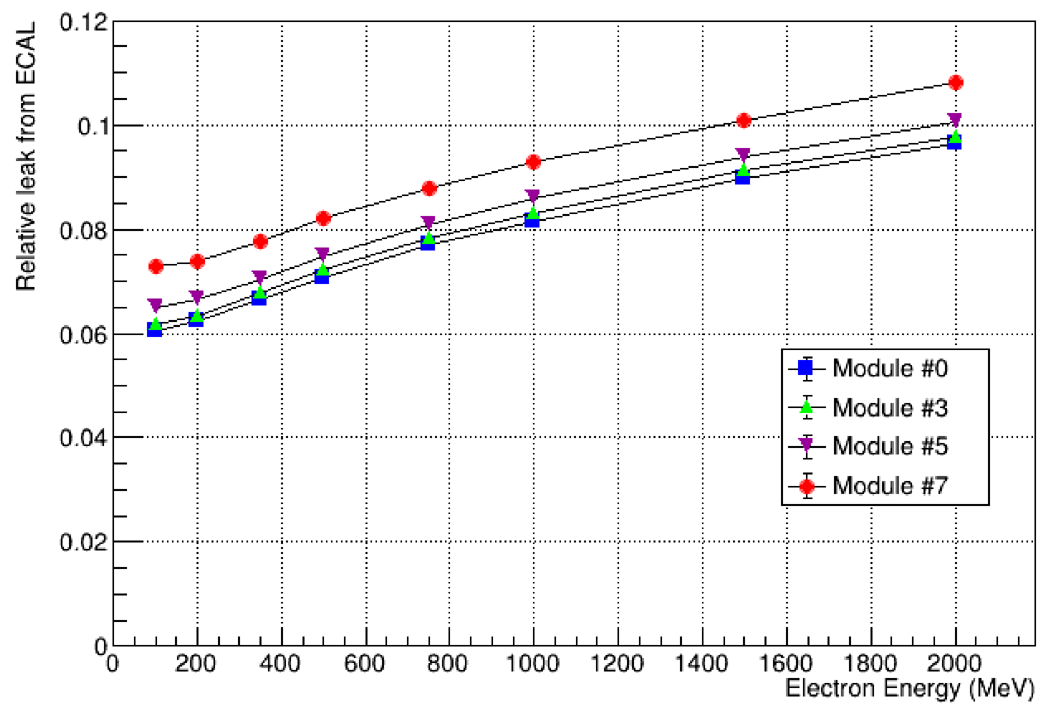
Simulation of Relative Energy Leak (*REL*)

$$REL = (E_0 - \Sigma E_i) / E_0$$

REL also has visible energy and module-type dependences







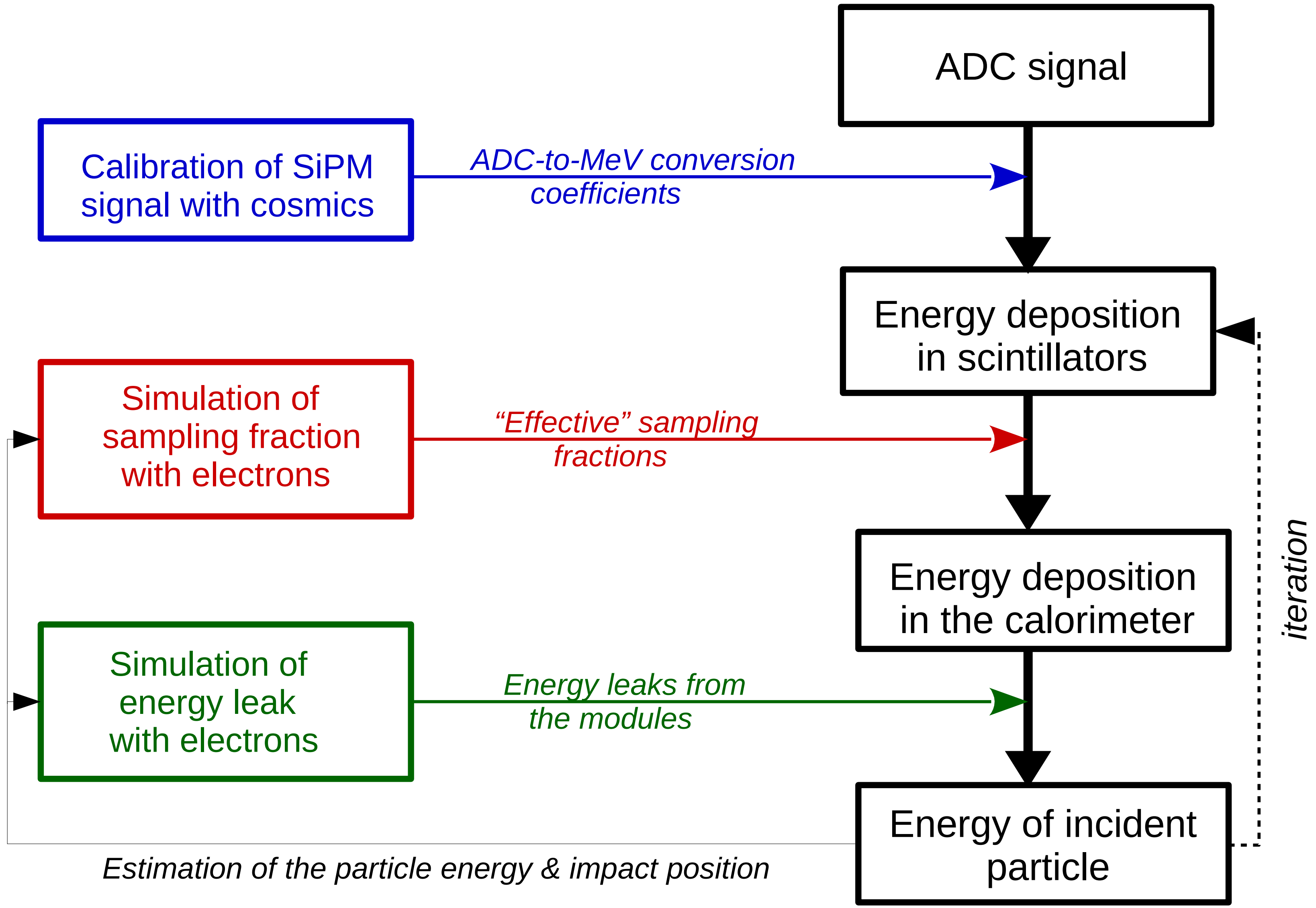
Simple Linear Formula

$$E = \Sigma\ [(ADC_i * SCC_i / ESF_i(E)) / (1 - REL_i(E))]$$

Pro: Calibration parameters are the functions of the incident particle energy & impact position
=> No non-linear corrections are required!

Con: Calibration parameters require a priori knowledge of the incident particle energy & impact position.

Solution: Iterative Procedure of Calibration



Conclusions

- We plan to perform ECal “initial” calibration procedure that relies on “energy scale” measurements with MIP (muons) and detailed simulation of the calorimeter parameters.
- Very preliminary test was done with electron beam @ LPI RAS (Troitsk, Moscow reg., Russia).
- More accurate and comprehensive tests @ LPI RAS are planned in January 2020 to evaluate the calibration procedures.
- Production of the calibration parameters requires massive simulations in 2020.
- We plan to perform the measurements with MIPs (cosmic muons) for all ECal modules during 2020 and 2021.
- Correction on signal saturation because of finite number of SiPM cells should be applied on the top of this calibration.

Acknowledgments:

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