Investigation on EMC calibration method and Proposal for PANDA EMC calibration

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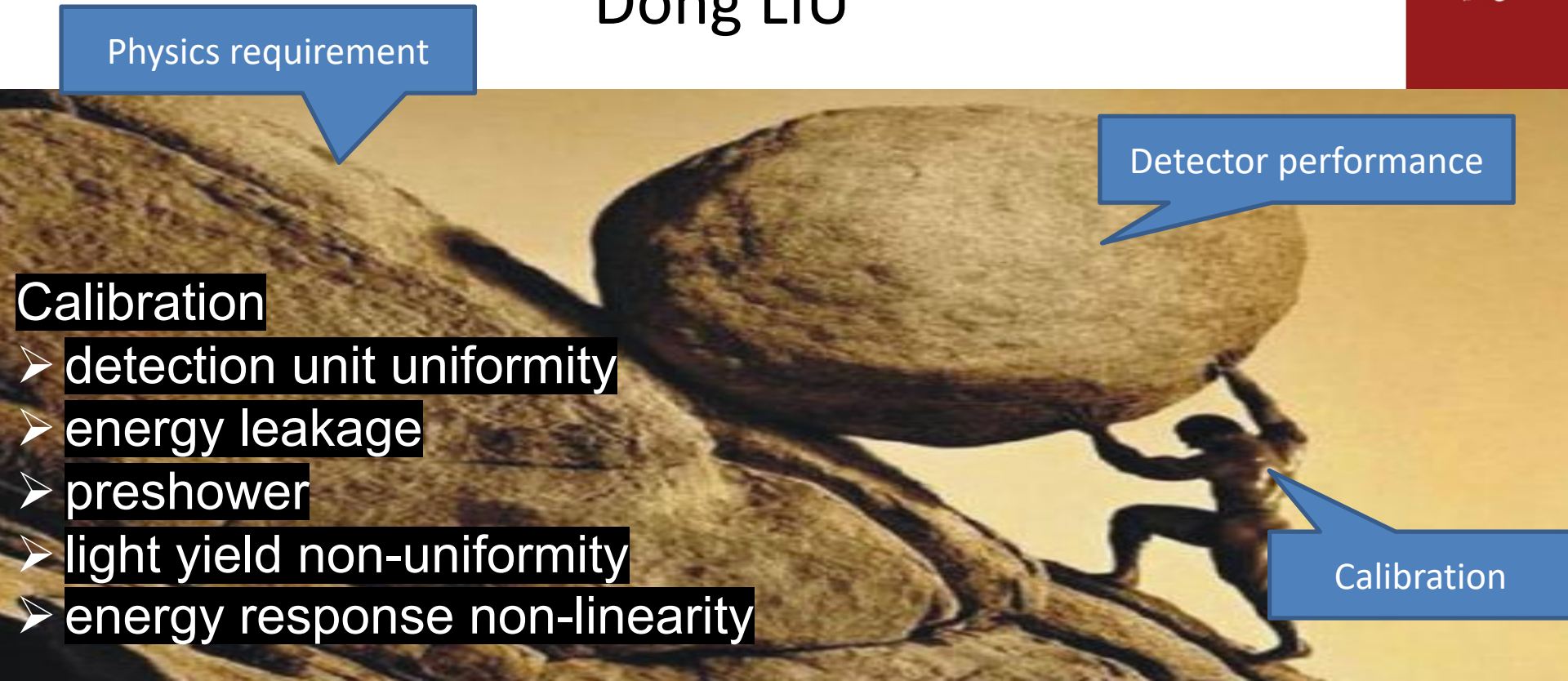


Contents

- Review
  - e^+e^- collision: BESIII, BelleII, BaBar, …
  - pp collision: CMS
  - $p\bar{p}$: PANDA
  - …
- Proposal
  - Calibration procedure

Calibration technique in ee collision

- Environment and detector
  - e^+e^- collision: rich e, μ and γ
  - Crystals: such as CsI(Tl), BGO …
- Samples
  - Cosmic ray
  - Bhabha
  - Di-μ
  - Di-γ
  - Test beam and radiative sources

Calibration technique in ee collision

- Samples
  - Cosmic ray: used by many experiments
    - Mainly minimum-ionization particle (MIP) μ.
    - dE/dx ~ constant
    - Uniformity calibration
    - $E_i^{dep} = ADC_i \times C_i = ADC_i \times c_i^{Elec} \times g_i = E_i^{elec} \times g_i$
      - ADC_i is the amplitude of electronic signal
      - C_i is the energy calibration coefficient
      - C_i^{Elec} is the coefficient obtained from cosmic ray or radiative sources
      - g_i is the calibration constant
    - Result is rough

Calibration technique in ee collision

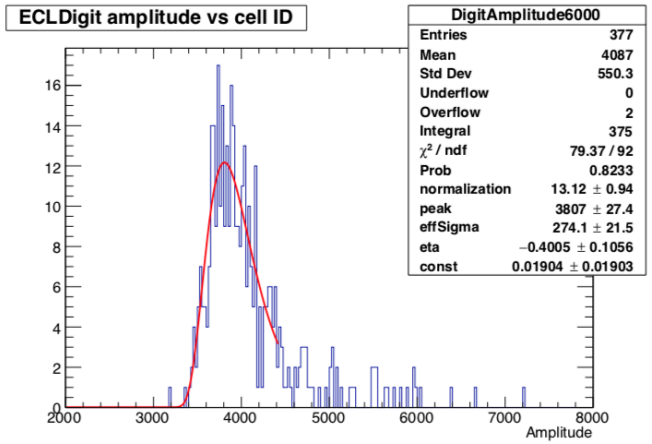
- Samples
  - Bhabha: used by BESIII, BelleII, BaBar, CLEO, …
    - High statistics
    - Well described in theory, and well simulated in MC
    - Method: $\chi^2 = \sum_{k=1}^{N} \frac{E_{exp}^{k} - \sum_{i}^{5\times5} g_i \cdot E_i^{elec}}{\sigma(\theta,\phi)}$
      - Minimize χ^2, then we have equations

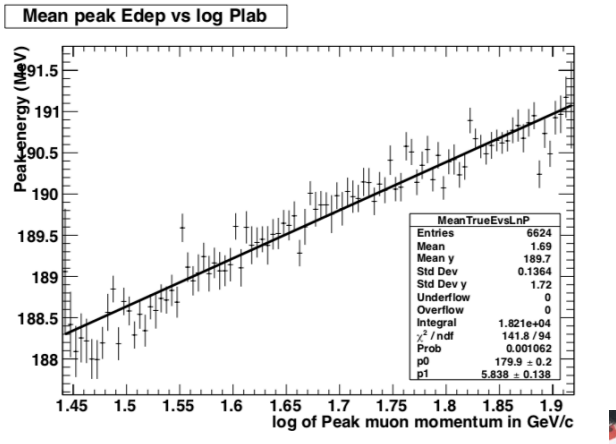
$$\sum_j g_j Q_{ij} = R_i, \text{ with } Q_{ij} = \sum_{k=1}^{N} \frac{E_{ik}E_{jk}}{\sigma_k^2}, \; R_i = \sum_{k=1}^{N} \frac{E_{ik}E_{\exp}^{k}}{\sigma_k^2}$$

      - Solve the equations to extract g_i
    - Good accuracy.

Calibration technique in ee collision

- Samples
  - Di-μ: used by BelleII, …
    - High statistics
    - No dependence on material between and before the crystal.
    - Relay only minimally on the response of other crystals

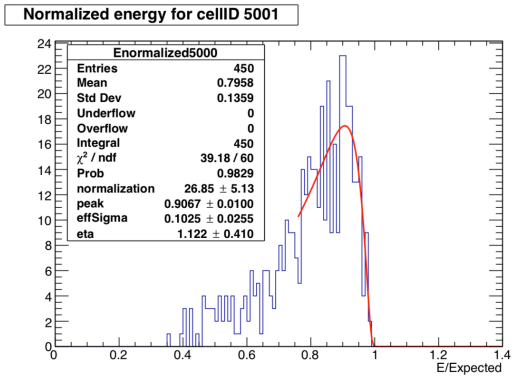




Calibration technique in ee collision

- Samples
  - Di-γ: used by BelleII, …
    - Method: compare the observed maximum energy in a crystal to that expected from simulation
    - The method minimizes systematic uncertainties from inactive material before the ECL

» $E_n = Ac_e c_s / E_x$,



- A : the digit amplitude; c_e: the electronics calibration constant; c_s: the current value of the single crystal energy calibration constant from γγ events; Ex: the expected maximum energy in this crystal from γγ events.

$c_s' = c_s / \langle E_n \rangle$, ⟨En⟩: the upper edge of the Novosibirsk fit

Calibration technique in ee collision

- Samples
  - Test beam: widely used
    - Specific particle type and energy as required
    - Used for precalibration
  - Radiative source: Babar, …
    - Known energy: about a few MeV
    - As a monitor
    - Low energy calibration

Calibration technique in pp collision

- Environment and detector
  - pp collision: rich hadrons
  - Crystals: such as PWO …
- Samples
  - Test beam
  - Laboratory measurement
  - Cosmic ray
  - Symmetry
  - π^0 -> γγ and η -> γγ
  - Isolated electron

Calibration technique in pp collision

- Samples
  - *Test beam*
  - Laboratory measurement
    - Measure the light yield (LY) in Laboratory
    - Calibration factor is inversely proportional to LY

$$\frac{1}{c_i} \sim LY \cdot \varepsilon_Q \cdot c_{ele} \cdot M,$$

  - *Cosmic ray*

Calibration technique in pp collision

- Samples
  - ϕ-symmetry: CMS
    - Takes advantage of the ϕ-symmetry of deposited energy.
      - The total energy deposited from a large number of events should be the same for all crystals in a ring at the same pseudorapidity (η).
      - Potential of providing rapid and repeated calibration
    - Method:
      - Intercalibrate crystals within rings at constant η
      - The intercalibration in ϕ is taken from the ratio of the total transverse energy deposited in one crystal to the mean of the total transverse energy collected by all crystals at the same value of η

Calibration technique in pp collision

- Samples
  - π^0 -> γγ: CMS
    - Rich π^0 in pp collision, and final state is γ's
    - For a given crystal, the invariant mass distribution is obtained from all π^0 candidates for which one of the photons is centered on this crystal. Iteratively, the calibration constants are updated according to the peak positions of such distributions. The energy and direction of each photon candidate are recalculated using the updated calibration constants. [*Inter-calibration of the CMS Barrel Electromagnetic Calorimeter Using pi0 to gg Decays*]

Calibration technique in pp collision

- Samples
  - Isolated electron: CMS
    - Z -> ee and J/ψ->ee

$$K_i = \frac{1}{\sum_{j=1}^{N_i} w_{j,i}} \sum_{j=1}^{N_i} \frac{P_j}{E_j^{5\times5}} w_{j,i}.$$

$w_{j,i} = E_{j,i} / E_j^{5\times5}$ is the weight of i-th crystal in j-th event

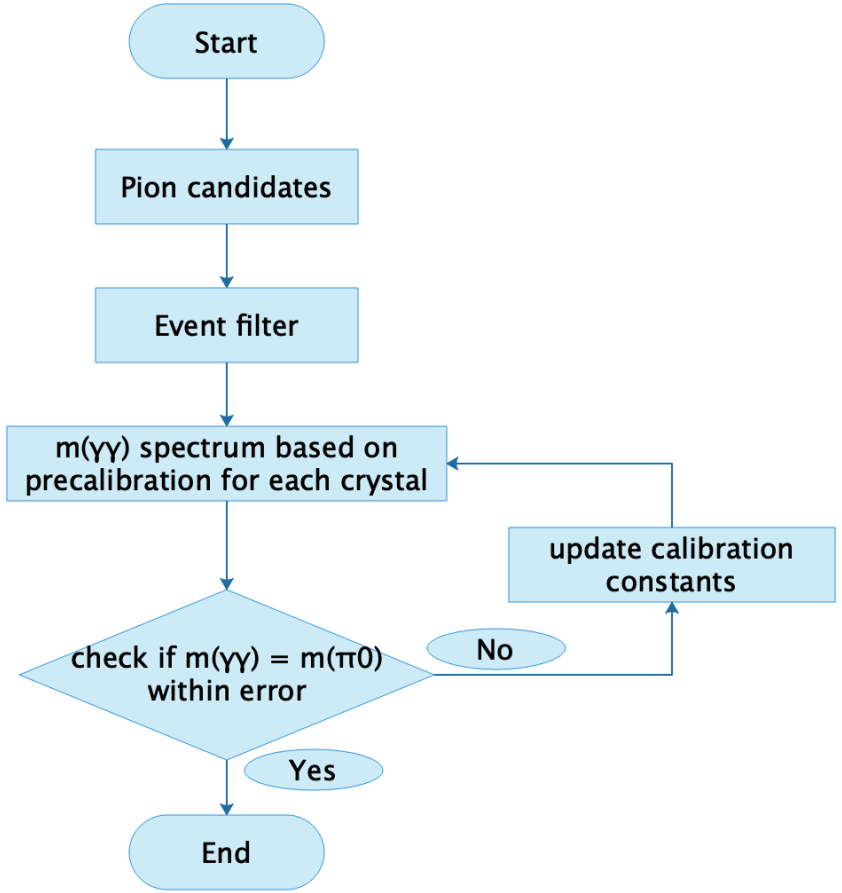
- Better accuracy

Calibration technique in PANDA

- Samples
  - Cosmic muon will provide initial seed
  - $p\bar{p} \rightarrow \pi^0\pi^0\pi^0/\eta \rightarrow \gamma's$
  - Not detailly described in TDR

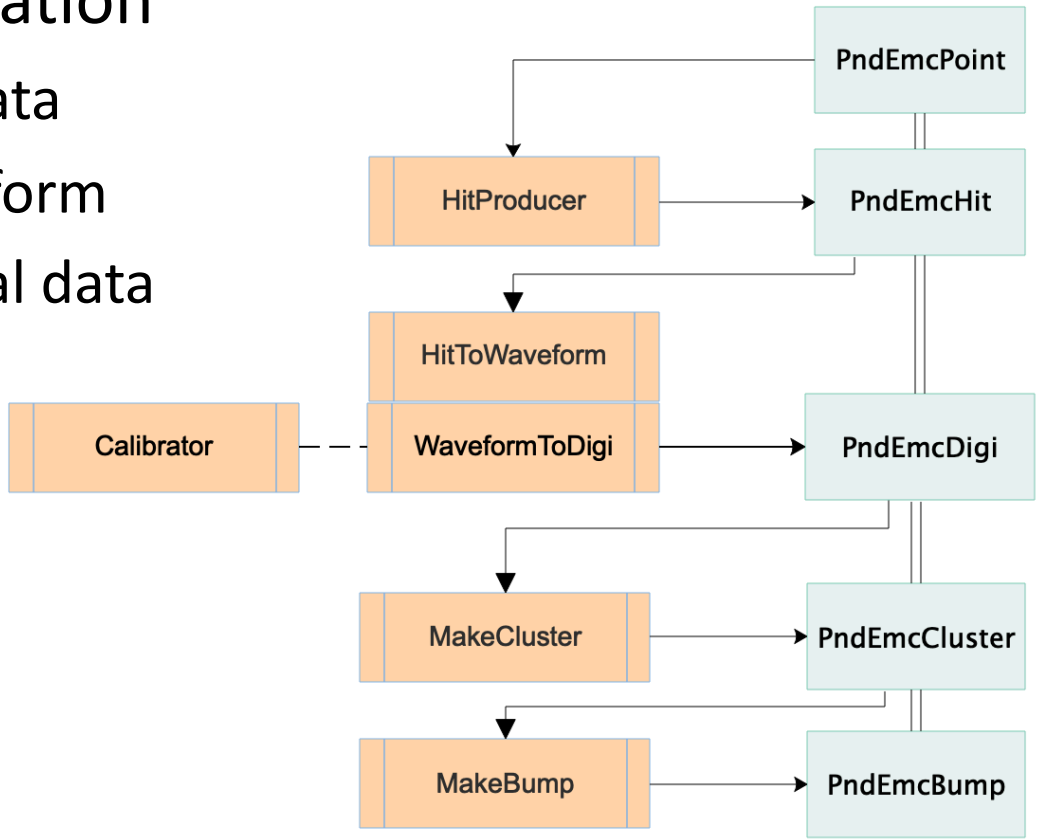
Calibration technique

- Procedure
  - Refer to CMS
  - Effects are tangled
    - Non-uniformity
    - Crystal to crystal difference
    - Electronics
    - …
  - Consider isolated electron as sample If statistic is enough.
- Calibration constants should be imported in the data processing



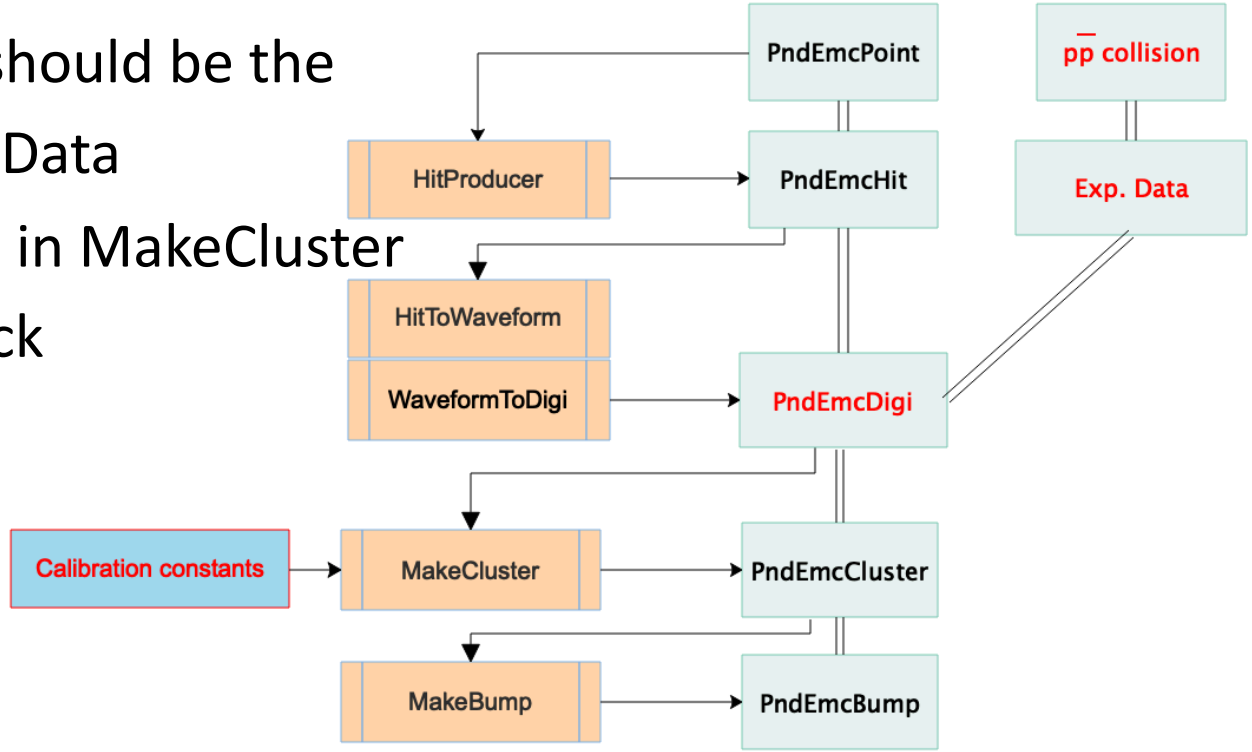
Calibrator

- Implementation in PandaRoot
  - Current implementation
    - No place for raw data
    - I suppose no waveform saved in experimental data
    - Not easy to check calibration constant



Calibrator

- Implementation in PandaRoot
  - PndEmcDigi should be the same as Exp. Data
  - Calibrate Digi in MakeCluster
  - Easier to check



The calibration constants should be imported at a proper place

Summary

- Investigate calibration techniques used by previous experiments, BESIII, BelleII, BaBar, CMS, …
  - Cosmic ray, laboratory measurement, test beam (common)
  - di-μ, di-γ, bhabha (in ee collision)
  - π^0, η decays (in pp and $p\bar{p}$)
  - ϕ symmetry
  - isolated electron
- Propose the data processing in PandaRoot
  - Calibration procedure similar to CMS
  - Make the Digi to be consistent with exp. data
  - Add calibrator to MakeCluster

Thank you!