

Status of W-DHCAL Calibration

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on behalf of the CERN PH-LCD group

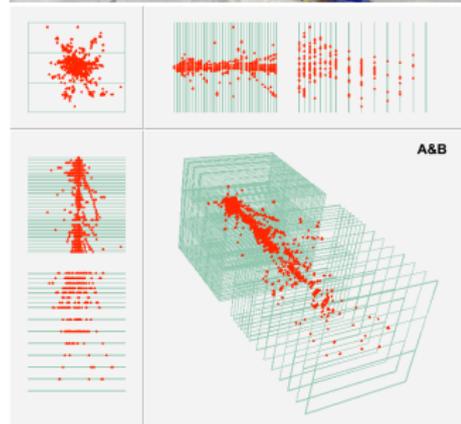
21. March 2014

Outline

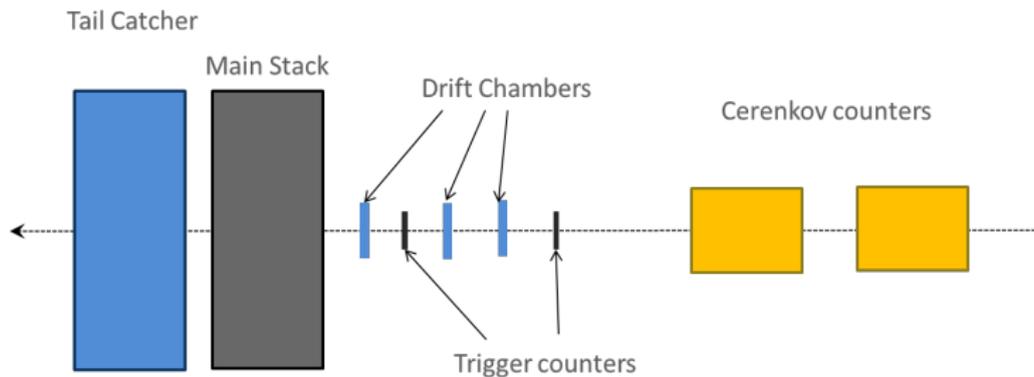
- 1 Introduction
- 2 Efficiency and Multiplicity
- 3 Calibration
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Data Taking at CERN (2012)

- 54 RPC layers:
 - 39 with tungsten absorber (main stack),
 - 15 with steel absorber (tail catcher)
- Each layer instrumented with 96×96 $1 \times 1 \text{ cm}^2$ pads $\Rightarrow \sim 500000$ channels
- PS (1–10 GeV): 1 run period of 2 weeks
- SPS (10–300 GeV): 2 + 1 + 1 weeks
- Dedicated μ and high rate runs
- In total ~ 30 million events recorded



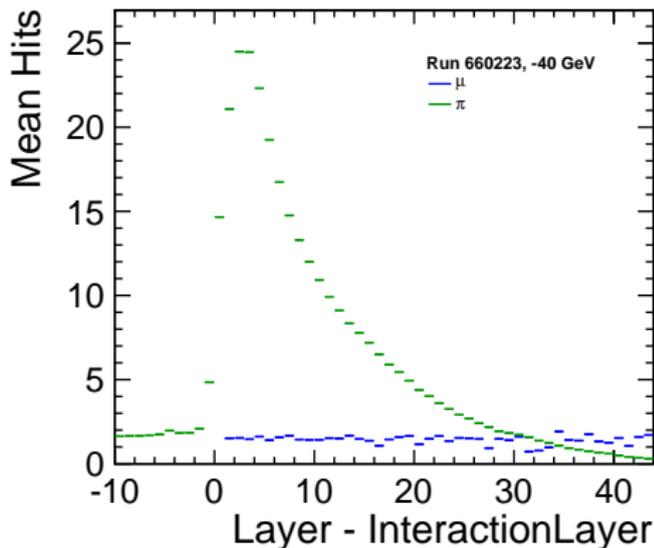
Data Taking at CERN (2012)



- 39 layers W-DHCAL + 15 layers Fe-DHCAL
- $10 \times 10 \text{ cm}^2$ scintillator triggers ($30 \times 30 \text{ cm}^2$ for dedicated muon runs)
- Three wire chambers \Rightarrow beam profile
- Two Cerenkov counters \Rightarrow particle identification

Goal of Calibration

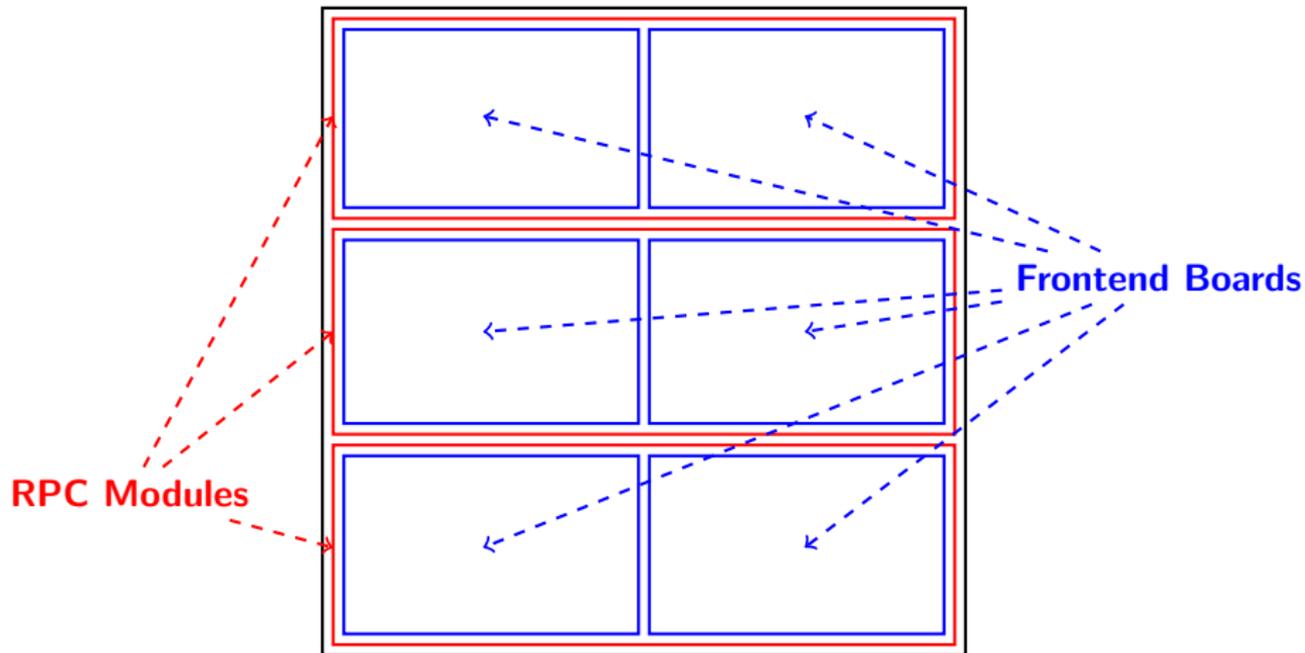
- DHCAL only measures number of hits
⇒ control efficiency (ϵ) and multiplicity (μ)
- Depends on temperature, pressure, voltage, ...
- Remove layer-to-layer and run-to-run fluctuations
- Determine nominal efficiency (ϵ_0) and multiplicity (μ_0) for digitization tuning

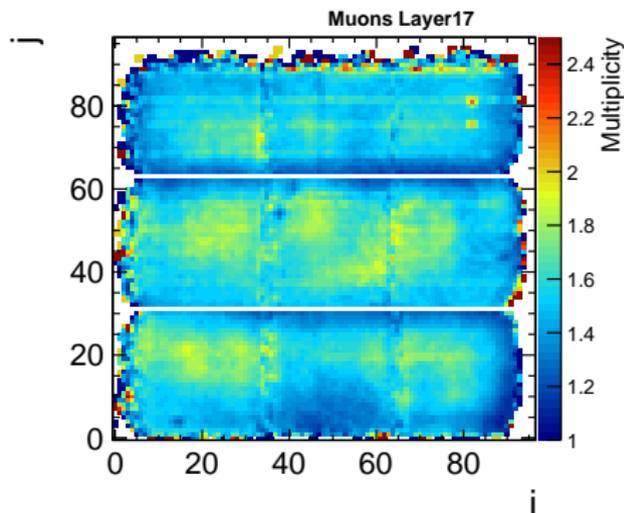
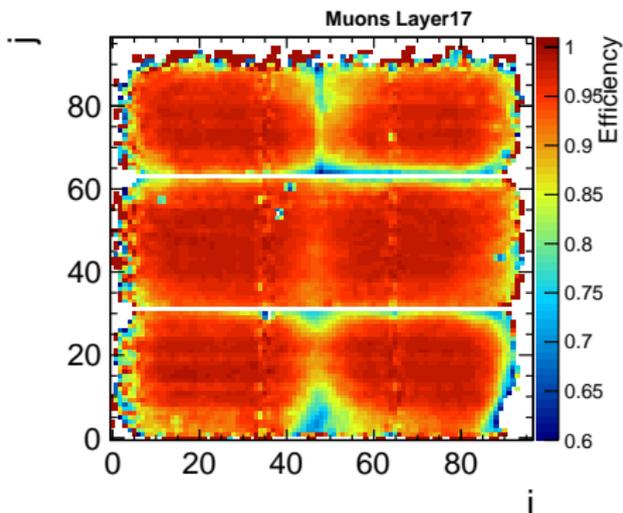


Determination of Efficiency and Multiplicity

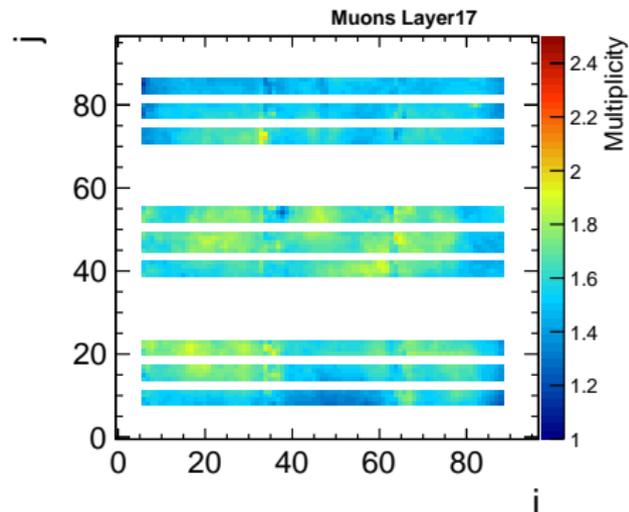
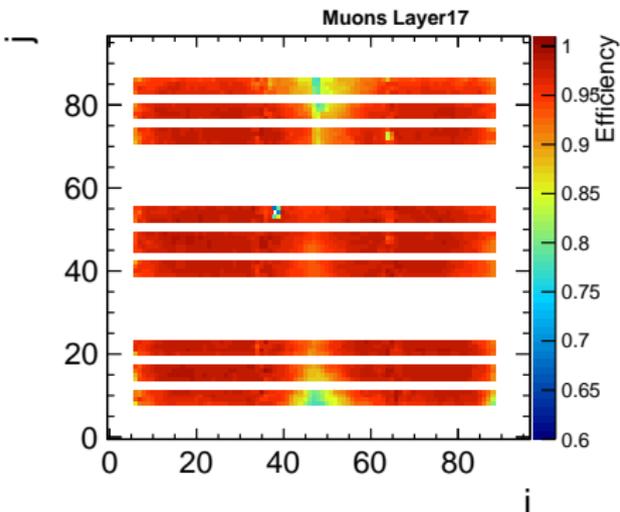
- Lose pre-selection for muon events based on number of active layers (> 30) and total number of hits (< 150)
- For each layer finds mip stub candidate in neighboring layers (± 3 layers, min 4 valid clusters)
- Only use clusters with 3 or less hits for mip stub candidates (no cut on layer of interest)
- Straight line fit to identify intersection with layer of interest, χ^2 cut to validate mip stub
- Determine if nearby cluster exists in layer of interest
- Efficiency: fraction of events with cluster found
- Multiplicity: mean cluster size for events with cluster found

Layout of one DHCAL Layer

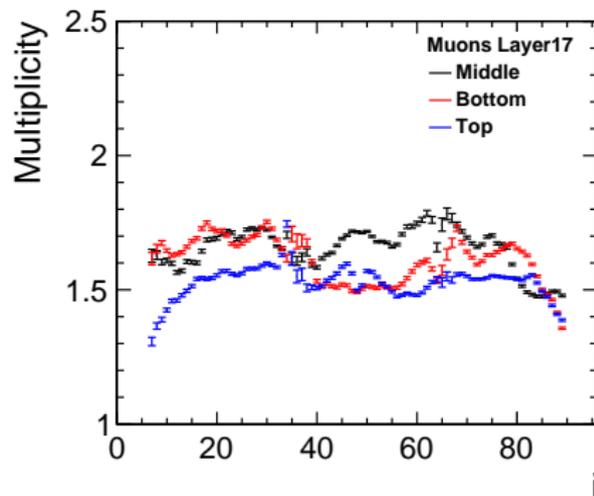
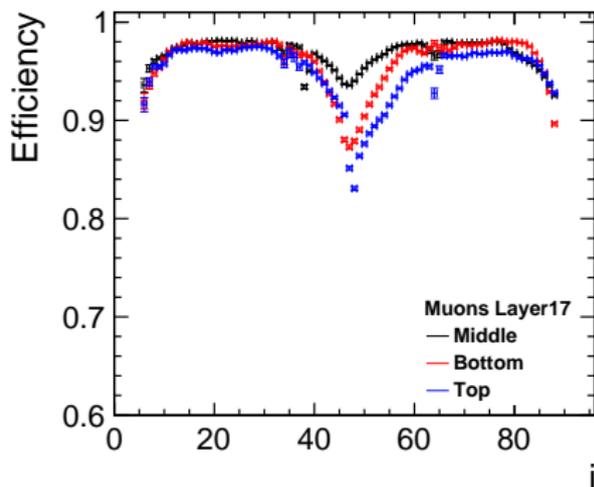




- Combine 18 muon runs taken with $30 \times 30 \text{ cm}^2$ triggers at 9 positions
- More than 500k events at each position allow to extract local efficiencies and multiplicities for each pad
- Beam runs only allow to extract efficiency and multiplicity for central region ($10 \times 10 \text{ cm}^2$ trigger with narrow beam spot)
- Average: $\epsilon_0 = 87.1\%$, $\mu_0 = 1.55$ (**Raw** calibration)

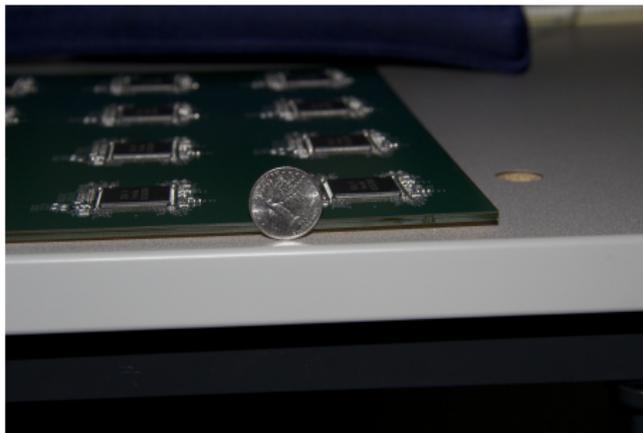


- Remove module boundaries and fishing lines to determine nominal values in clean regions
- Effect of fishing lines included in GEANT4 through material
- Module boundaries effect added in digitization by lowering effective charge depending on position
- Average: $\epsilon_0 = 94.6\%$, $\mu_0 = 1.61$ (**Cleaned** calibration)



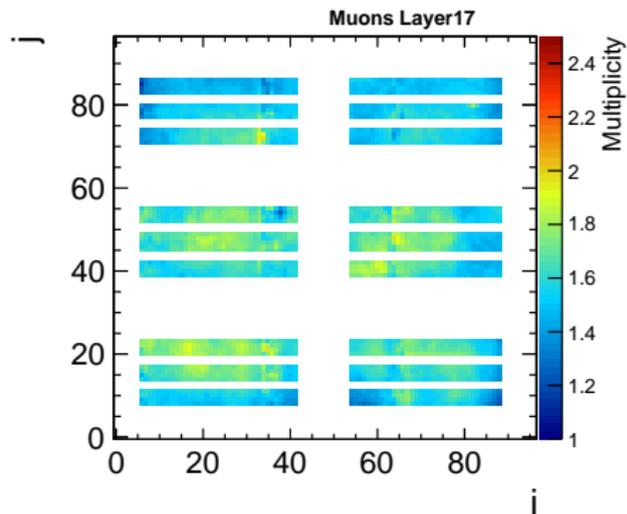
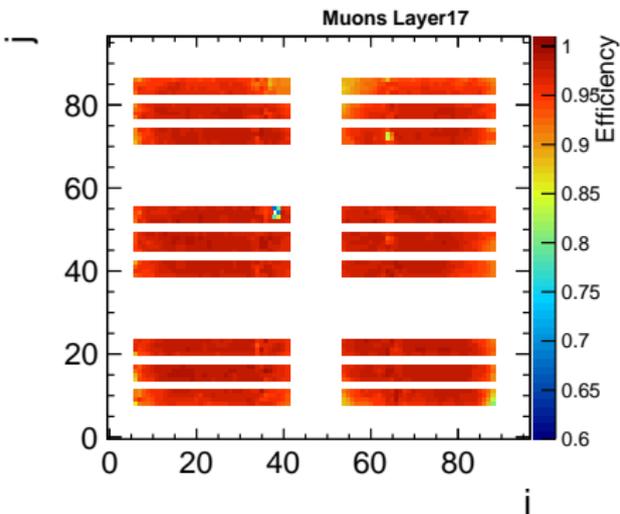
- Drop of efficiency in the centre of each module \Rightarrow not visible in Fe-DHCAL
- Multiplicity not affected in a similar fashion

Warping of Frontend Boards



Dime for size reference

- Front end boards warped over time leading to larger gaps at the edges



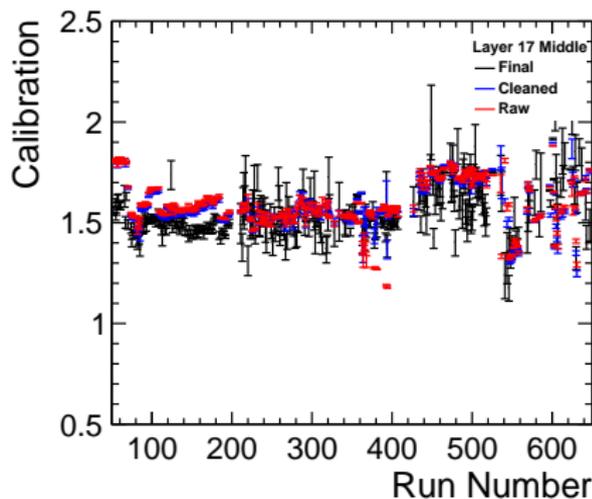
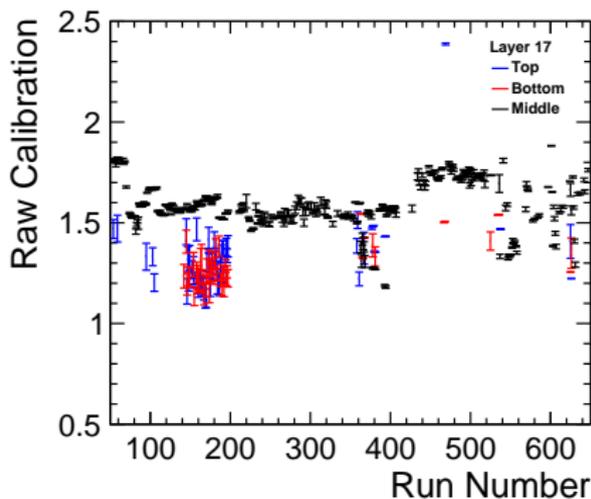
- Remove frontend board boundaries for final values
- Average: $\epsilon_0 = 95.3\%$, $\mu_0 = 1.61$ (**Final** calibration)

Calibration Procedure

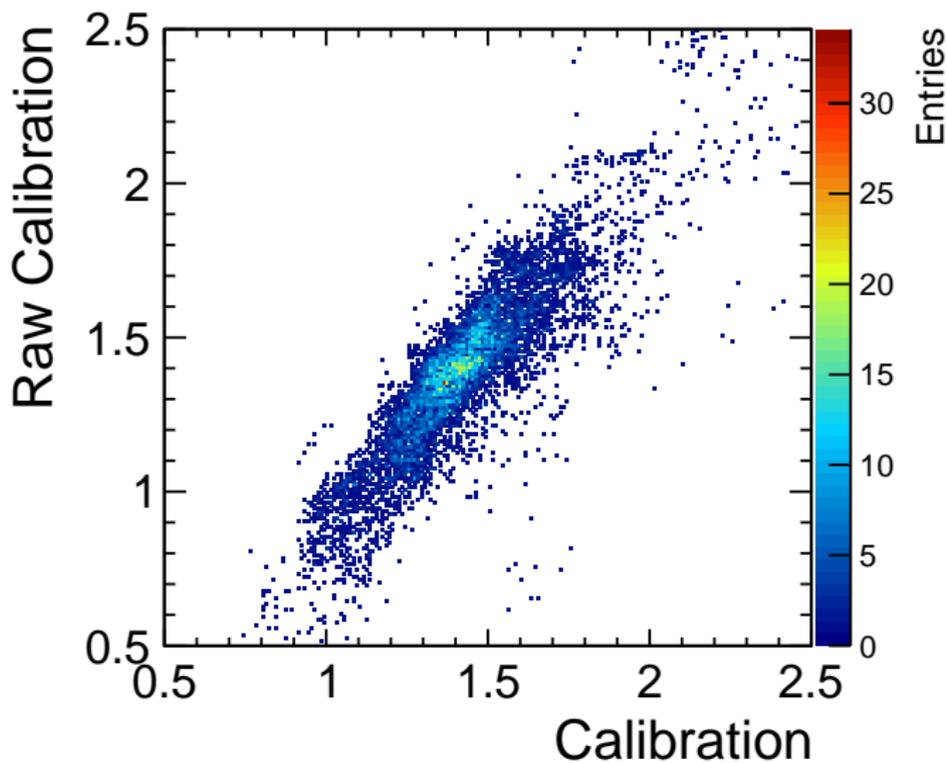
- Correct each hit for its local efficiency and multiplicity to nominal values:

$$N^{\text{calibrated}} = \sum_i^N \frac{\mu_0 \epsilon_0}{\mu_i \epsilon_i}$$

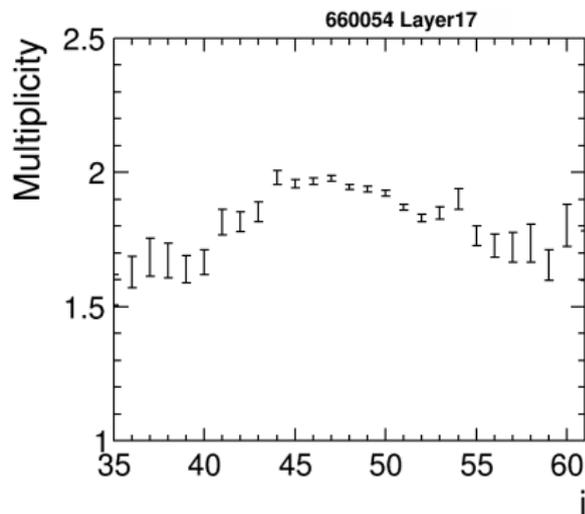
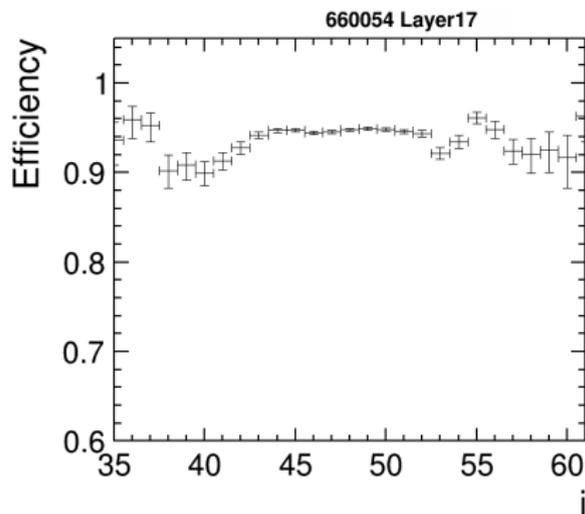
- μ_i and ϵ_i are determined for each module if possible (more than 100 entries)
 \Rightarrow works well only for central module



Correlation between Calibrations

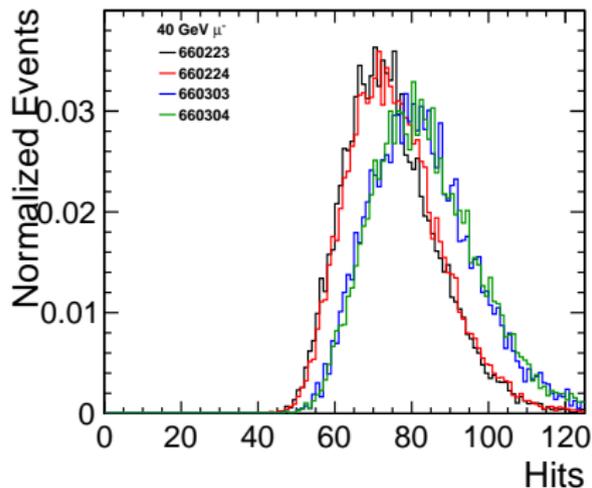


Time Dependence of Efficiency Drop

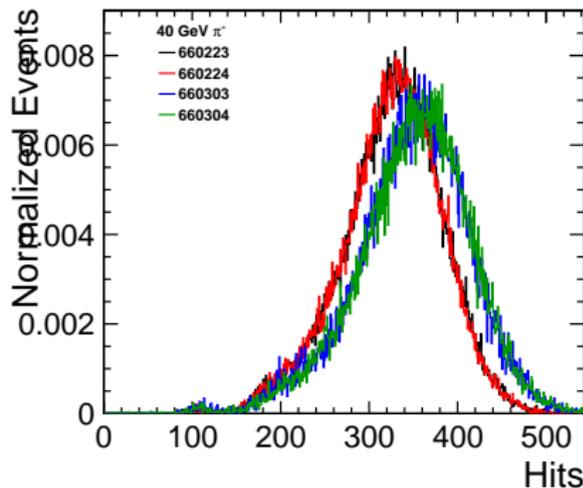


Response at 40 GeV

Muons



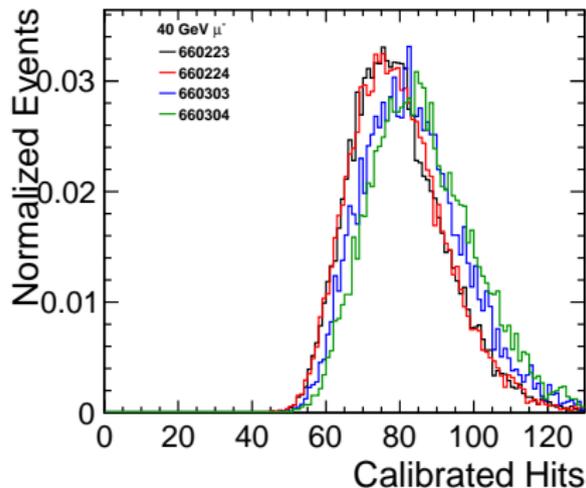
Pions



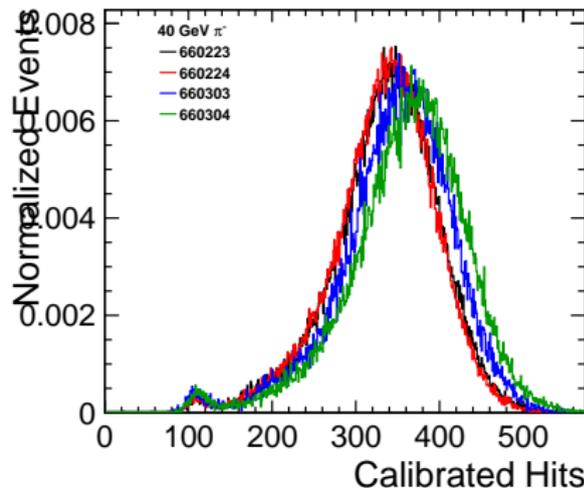
- Runs taken at same beam momentum and significantly different conditions allows to check calibration

Response at 40 GeV - Calibrated

Muons



Pions

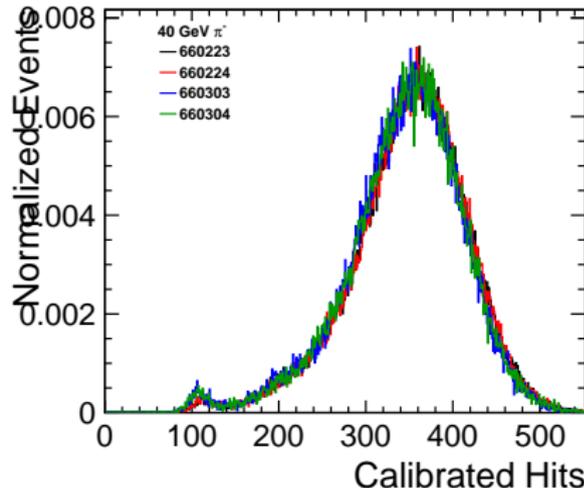
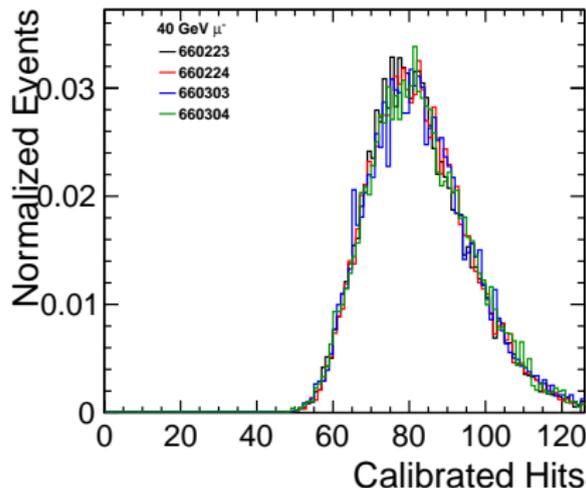


- Calibration improves the agreement but still slightly different response

Response at 40 GeV - Calibrated (with centre)

Muons

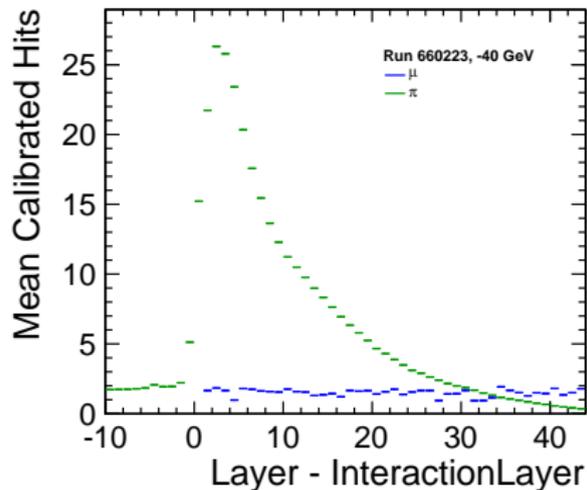
Pions



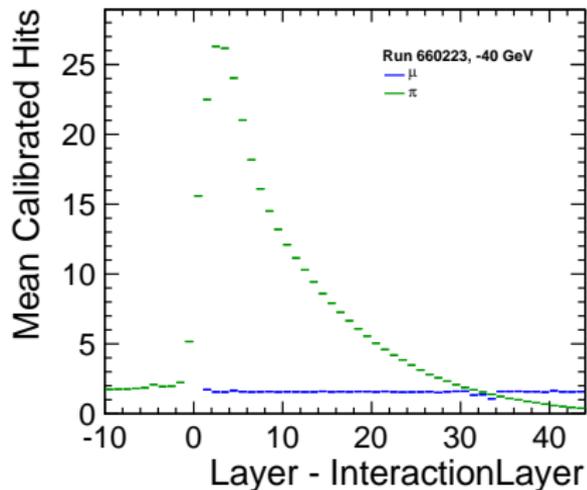
- Including the central region in the calibration gives best results
- Most hits end up in the region with reduced efficiency
 \Rightarrow important to describe this well

Longitudinal Shower Profiles (40 GeV)

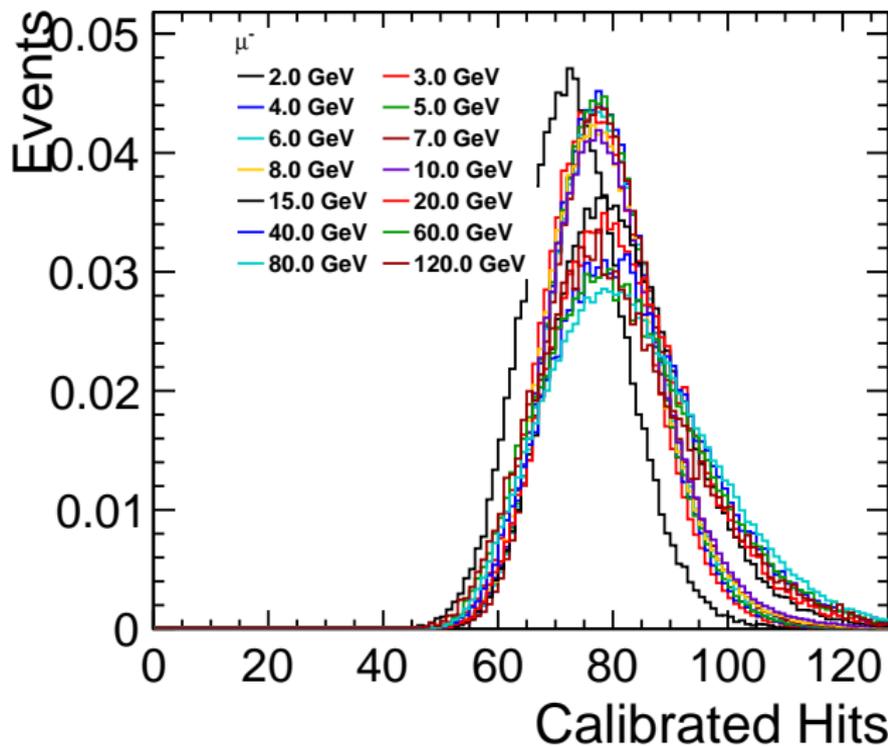
Calibration excluding centre



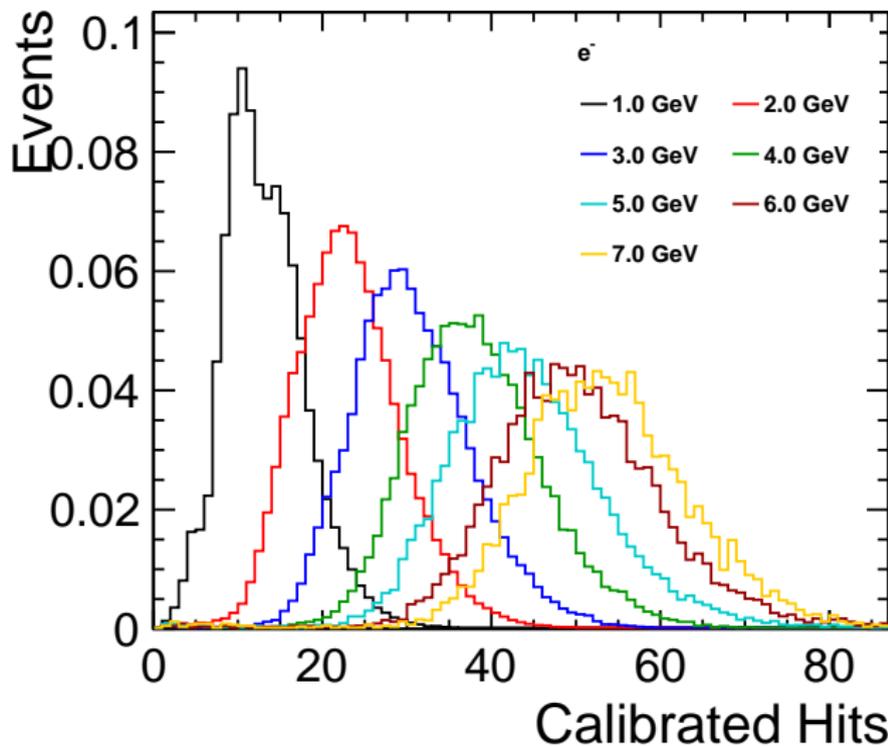
Calibration including centre



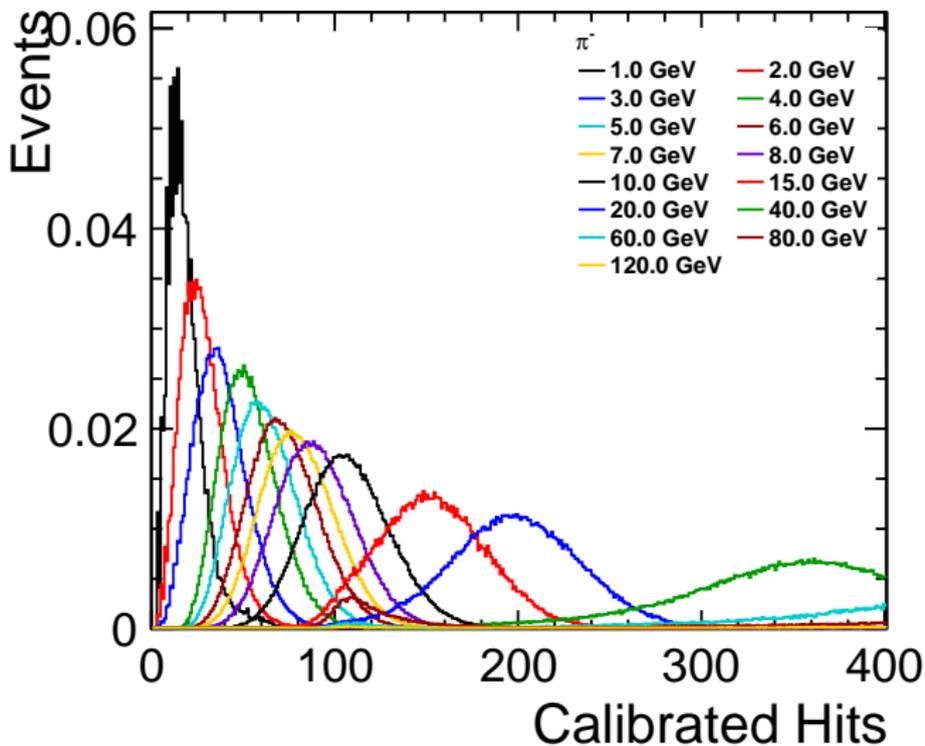
Calibrated Muon Response



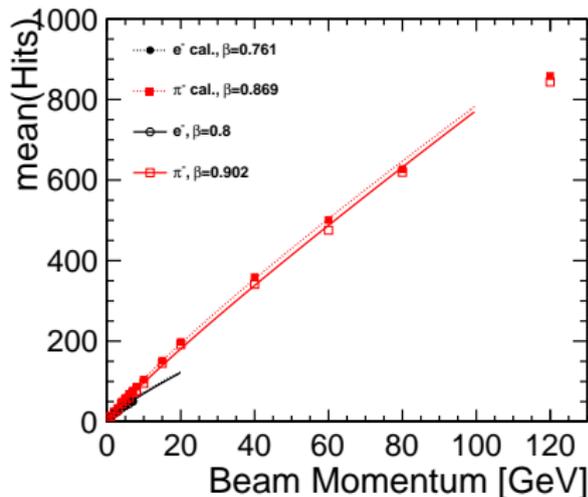
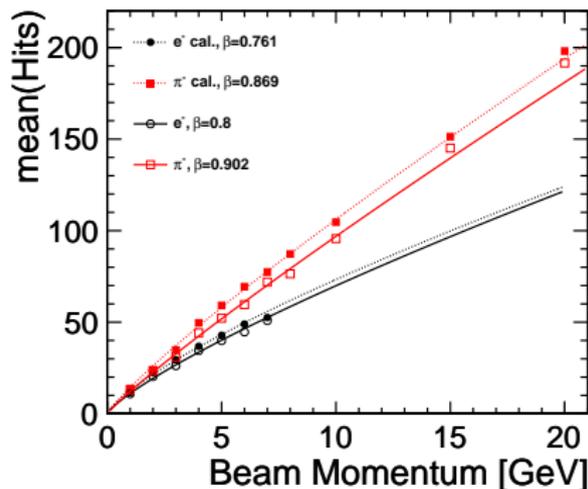
Calibrated Electron Response



Calibrated Pion Response

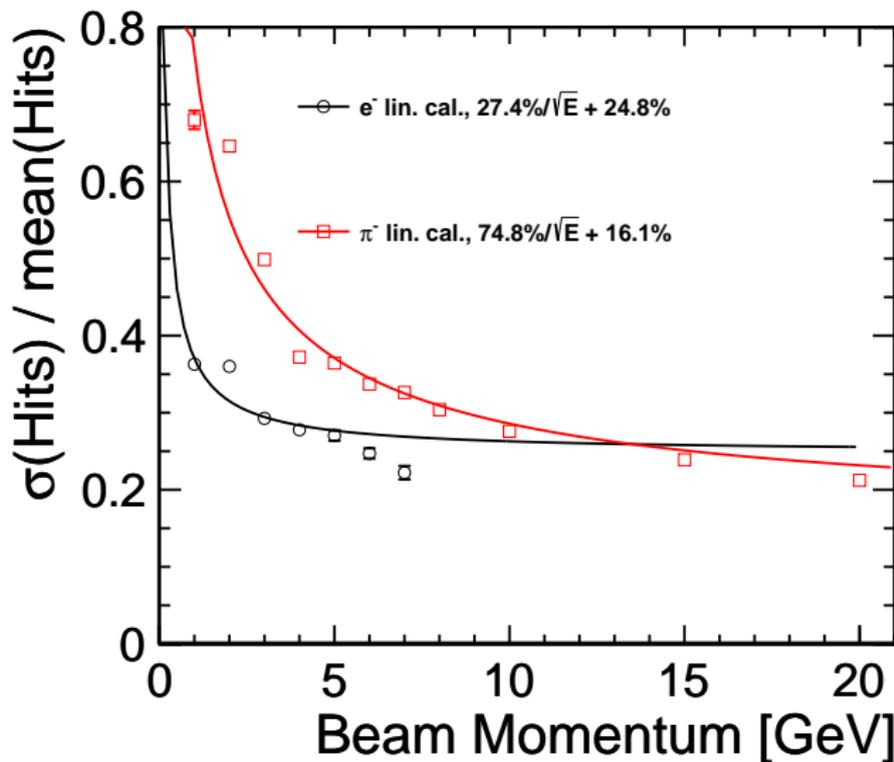


Linearity (Very Preliminary)



- Parametrize using $N = \alpha E^\beta$

Resolution (Very Preliminary)



Summary and Outlook

- It is crucial to have data and MC on the same level
- **Option 1:**
 - Include efficiency drop in digitization
 - Will likely only be an average description
 - Will require good description of beam profile
 - Data from different runs will not be normalized
- **Option 2:**
 - Apply local calibration (depending on z) where possible
 - Digitization can stay as it is (flat efficiency) using the nominal calibration constants in the clean region
 - Data from different runs will be normalized