W-DHCAL Calibration

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CERN LCD

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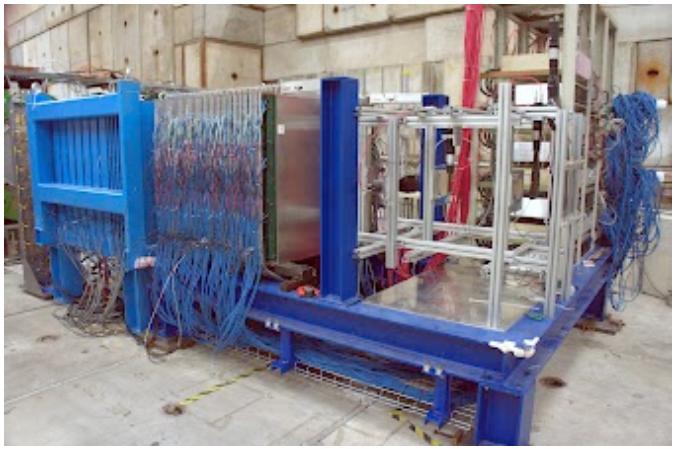
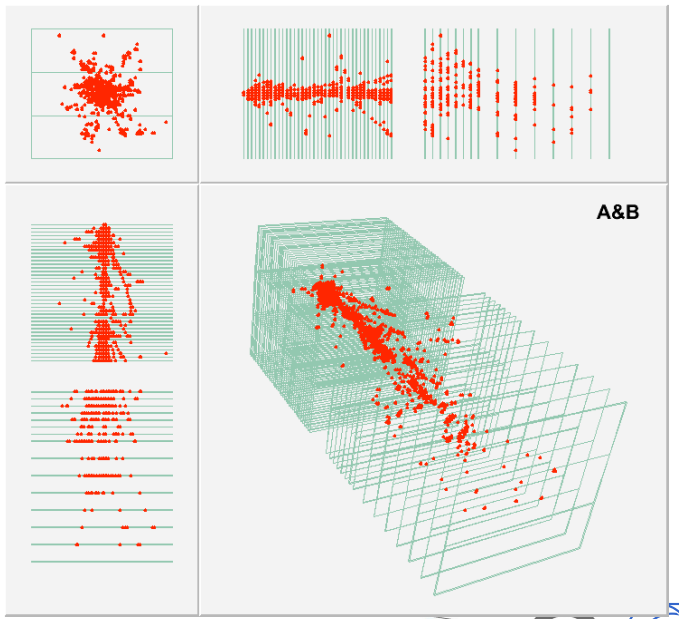
Outline

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
  $1 \times 1\,\mathrm{cm}^2$ 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





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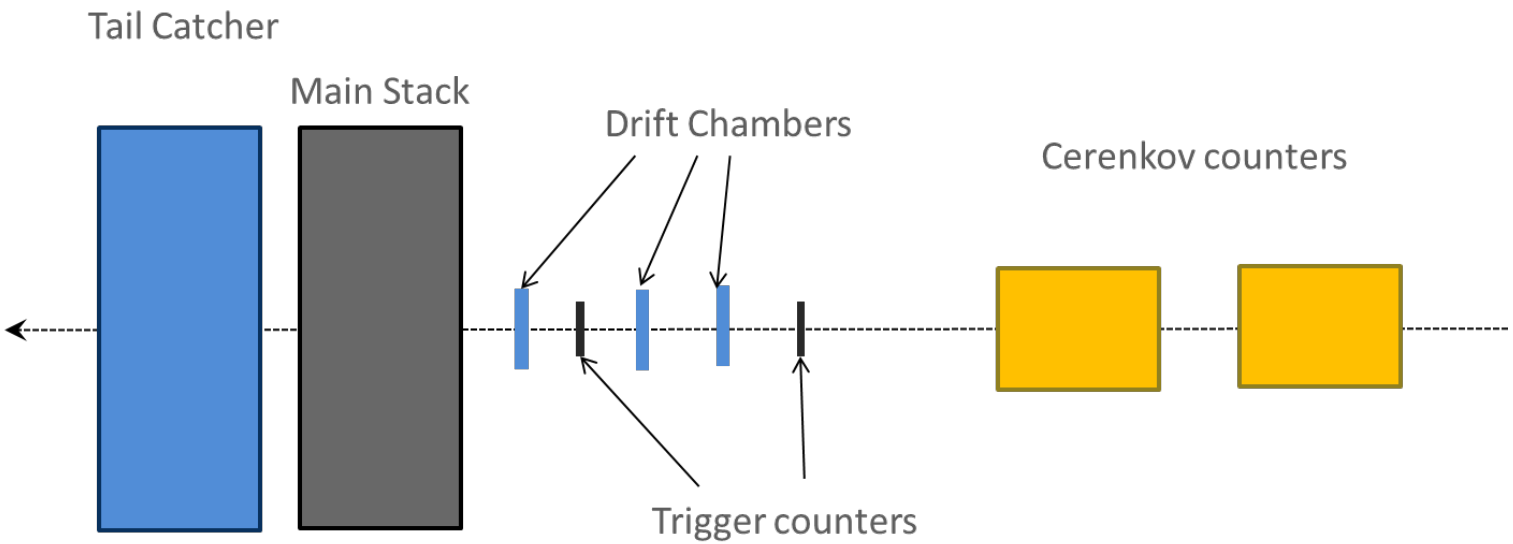
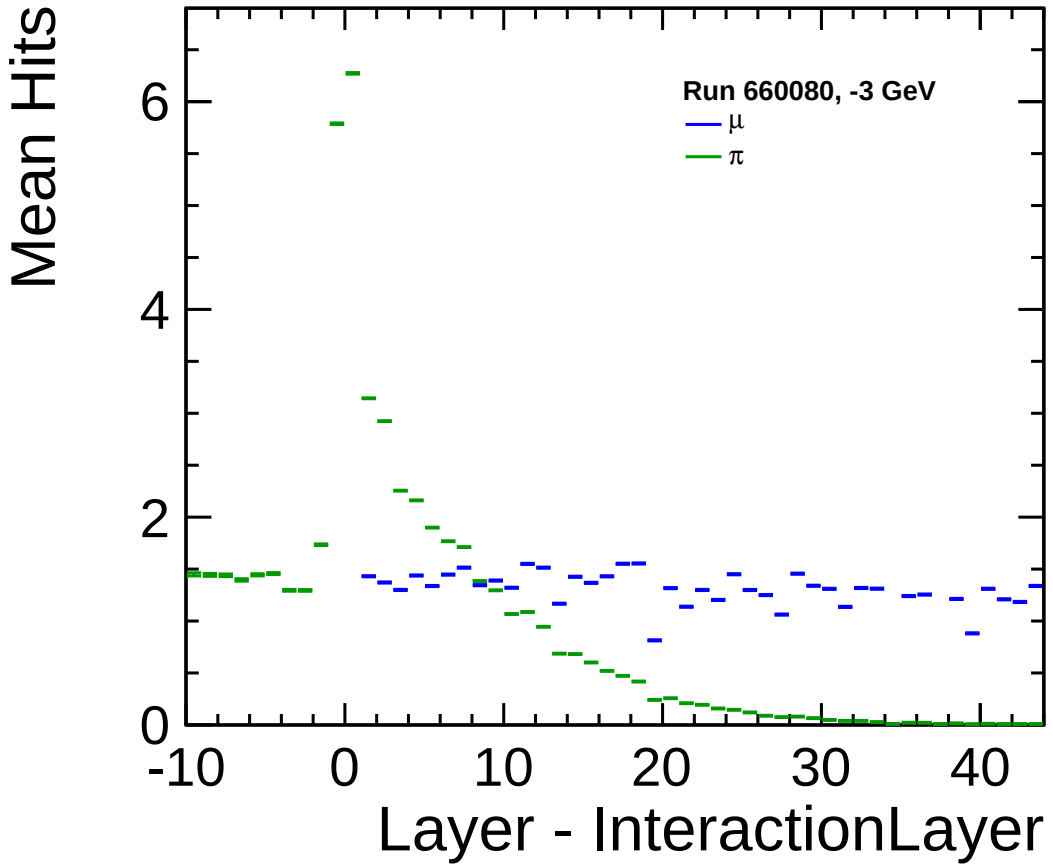


- 39 layers W-DHCAL + 15 layers Fe-DHCAL
- $10 \times 10\,\mathrm{cm}^2$ scintillator triggers ($30 \times 30\,\mathrm{cm}^2$ for dedicated muon runs)
- Three wire chambers $\Rightarrow$ beam profile
- Two Cerenkov counters $\Rightarrow$ particle identification

Why Calibrate?

- DHCAL only measures number of hits
- Multiplicity μ and efficiency ϵ depend on many factors
  - Temperature
  - Pressure
  - Voltage
  - ...
- Temperature stabilized by tent and AC



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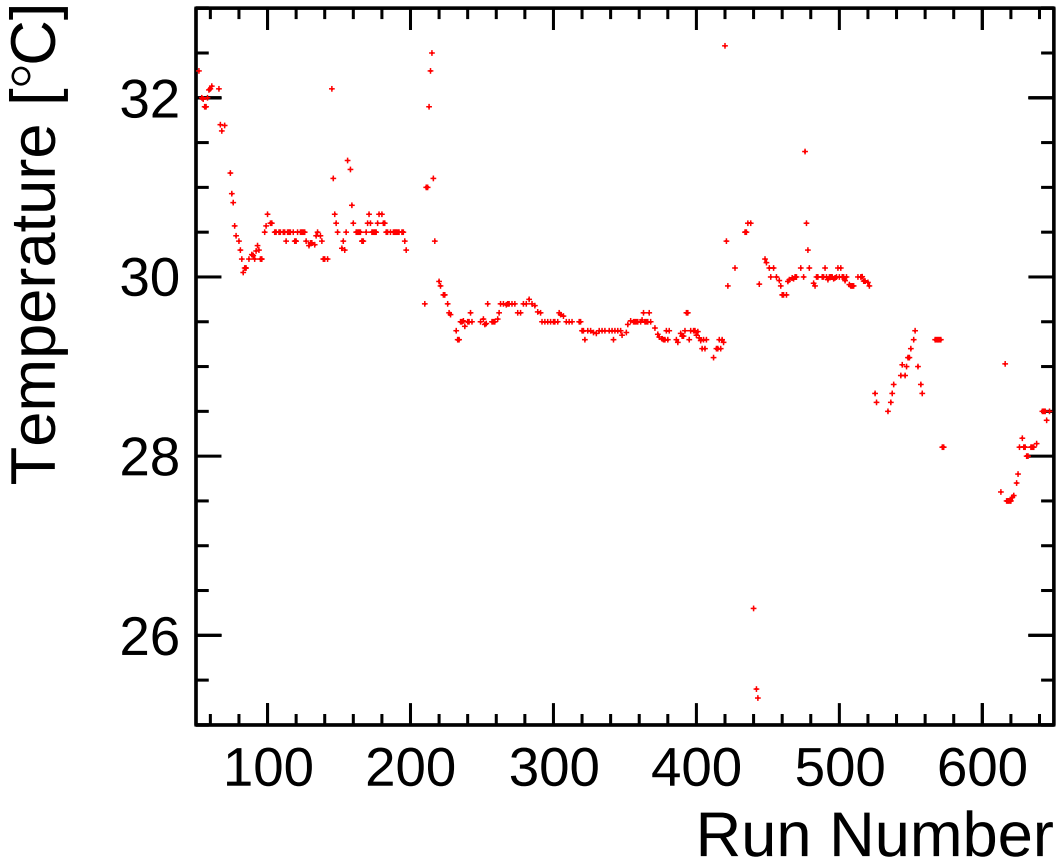

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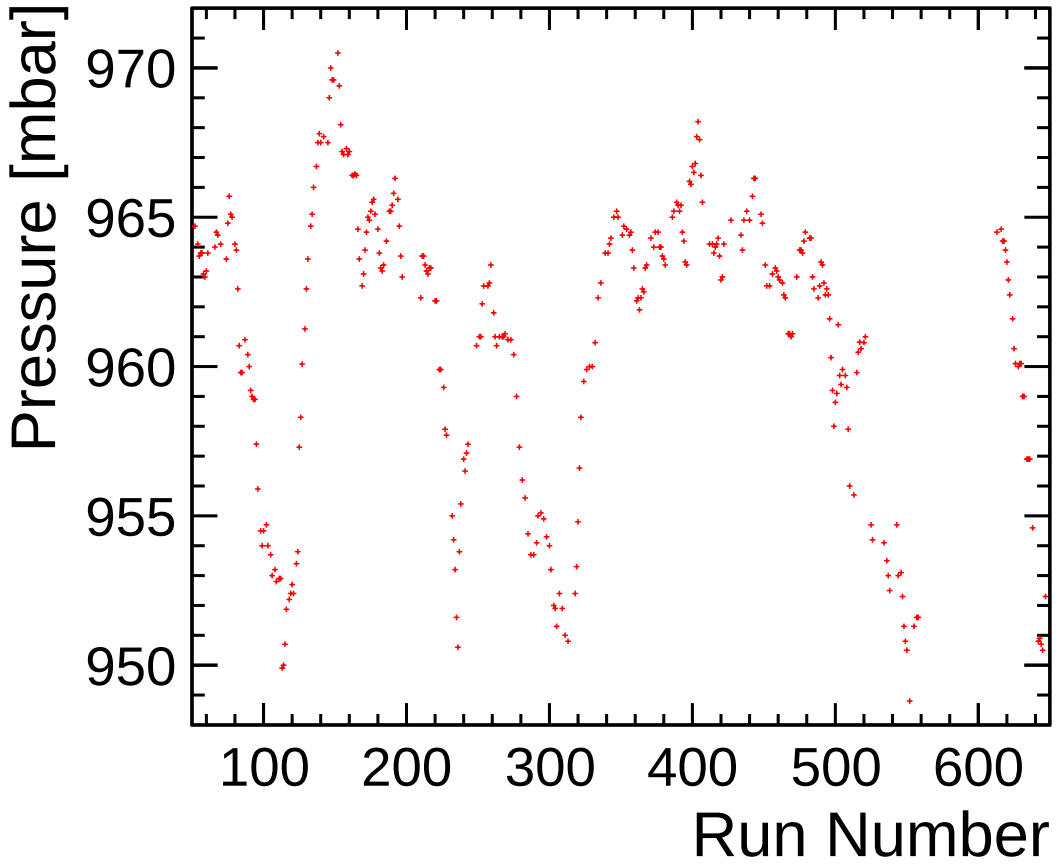

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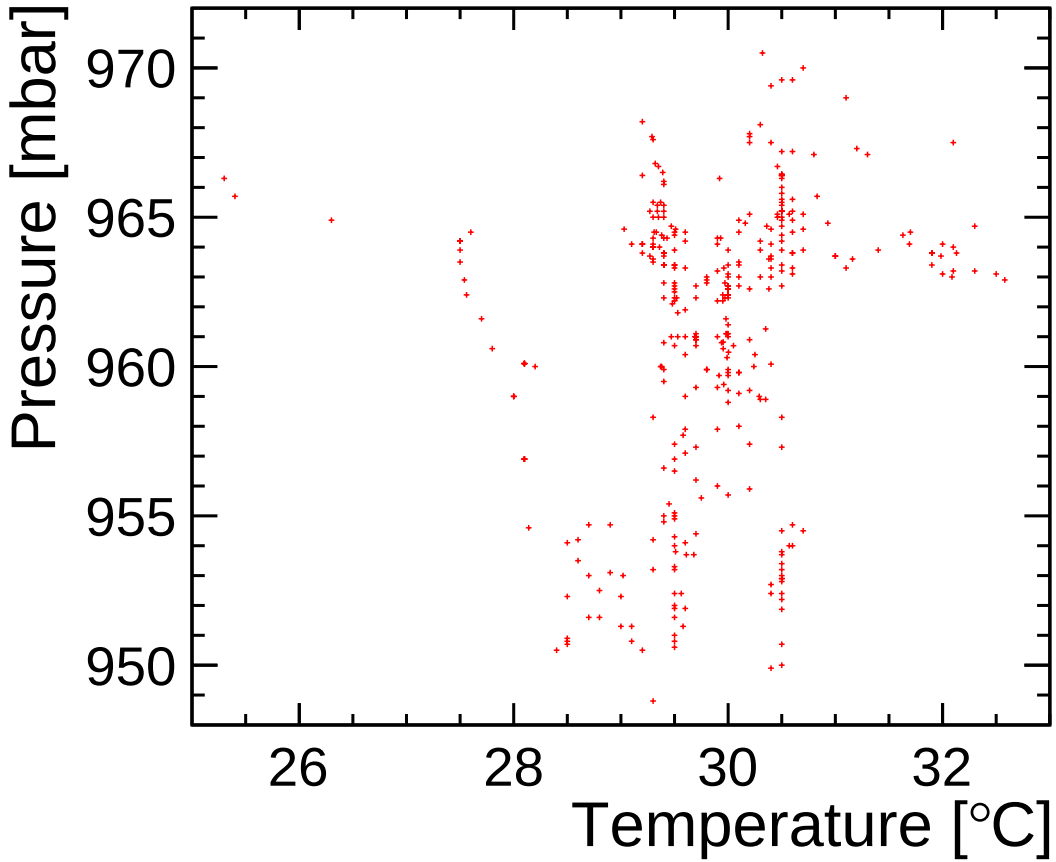


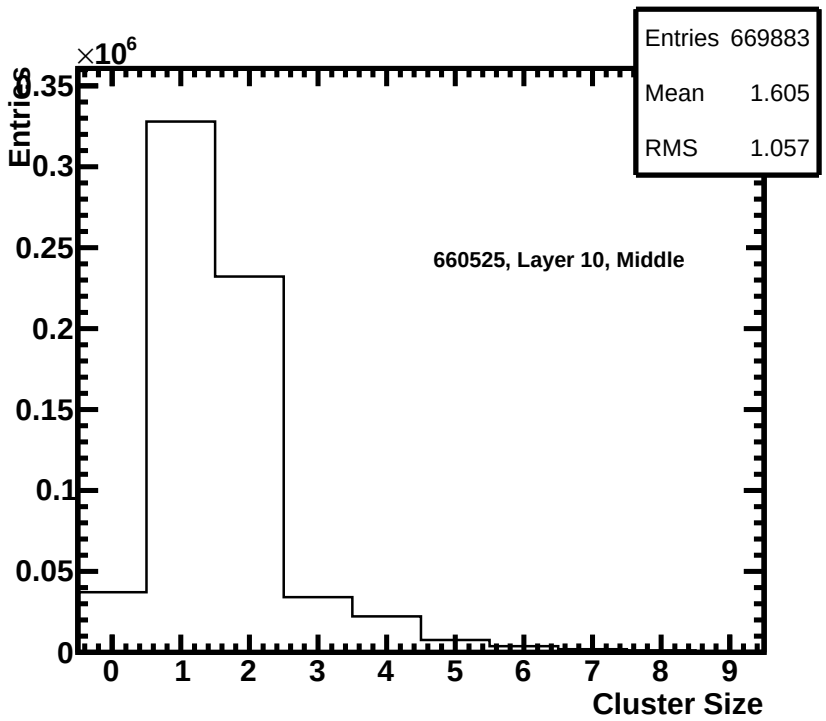
Data Preparation

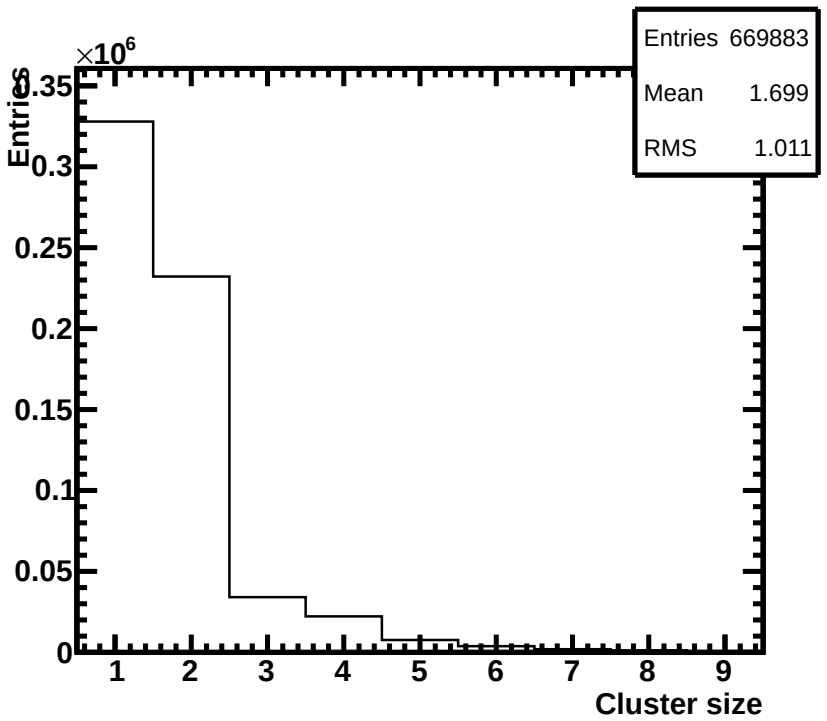
- Ignore duplicate hits
- Remove out of time hits: only accept bins -19 to -17
- Ignore dead and noisy cells (see Helga's talk)

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
- Straight line fit to verify mip stub and identify intersection with layer of interest
- Determine if nearby cluster exists in layer of interest
- Efficiency ϵ: fraction of events with cluster found
- Multiplicity μ: mean cluster size for events with cluster found
- Ignore if intersection is a module border or has been identified as dead or noisy

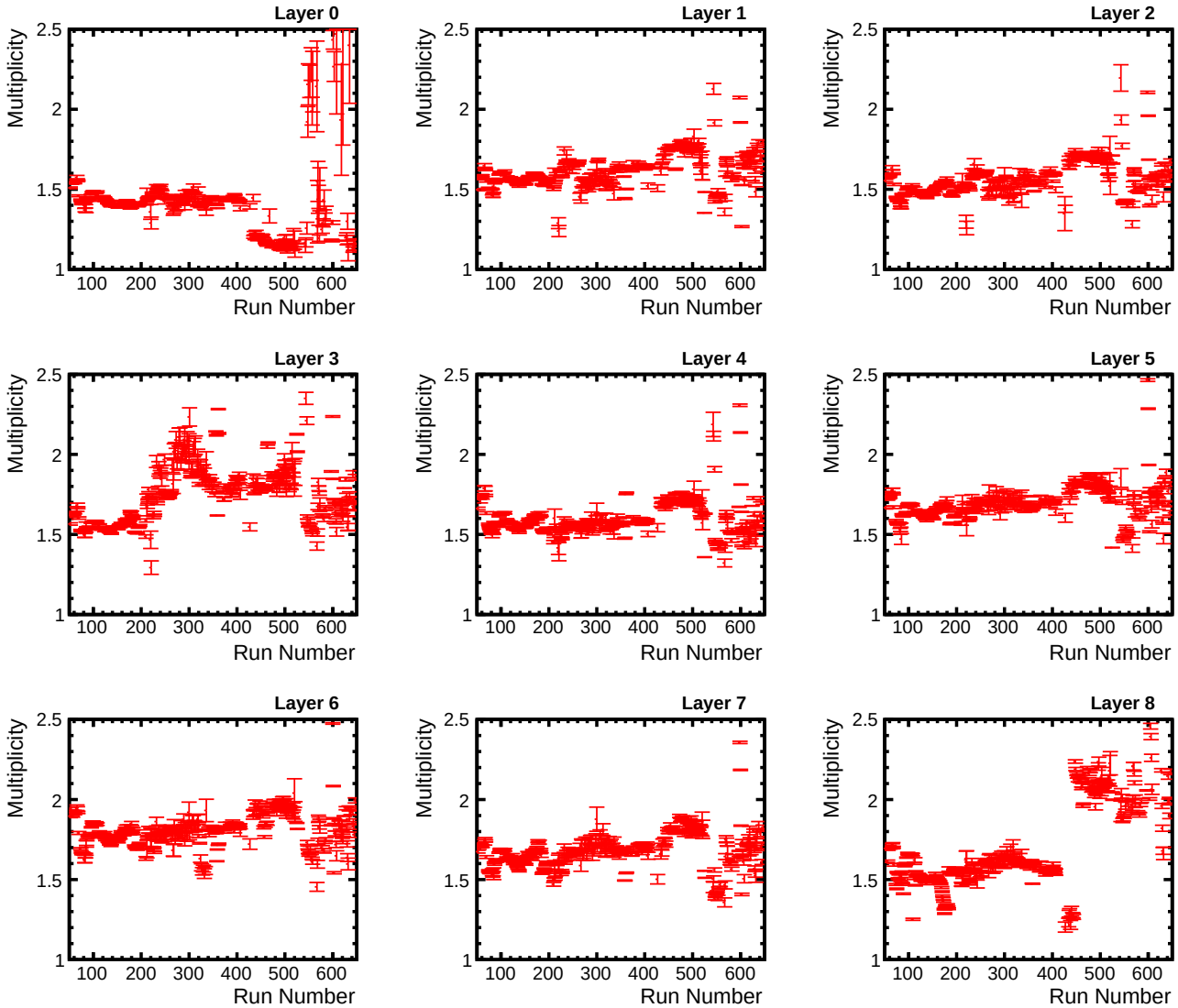
Example Histogram



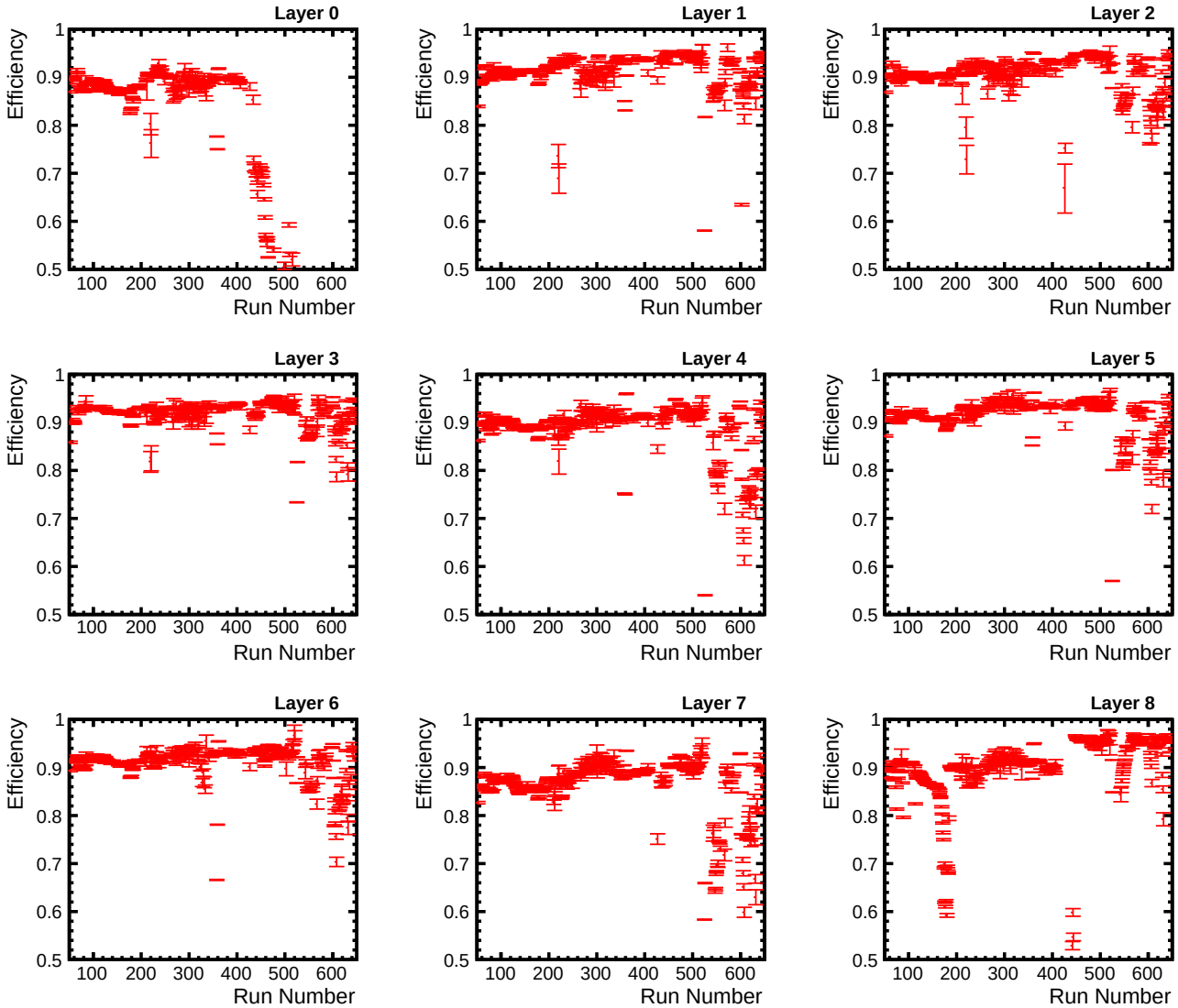


- Extract efficiency as $(N_{\text{total}} - N_0)/N_{\text{total}}$
- Extract multiplicity as mean excluding bin 0
- Determined for each module in each layer

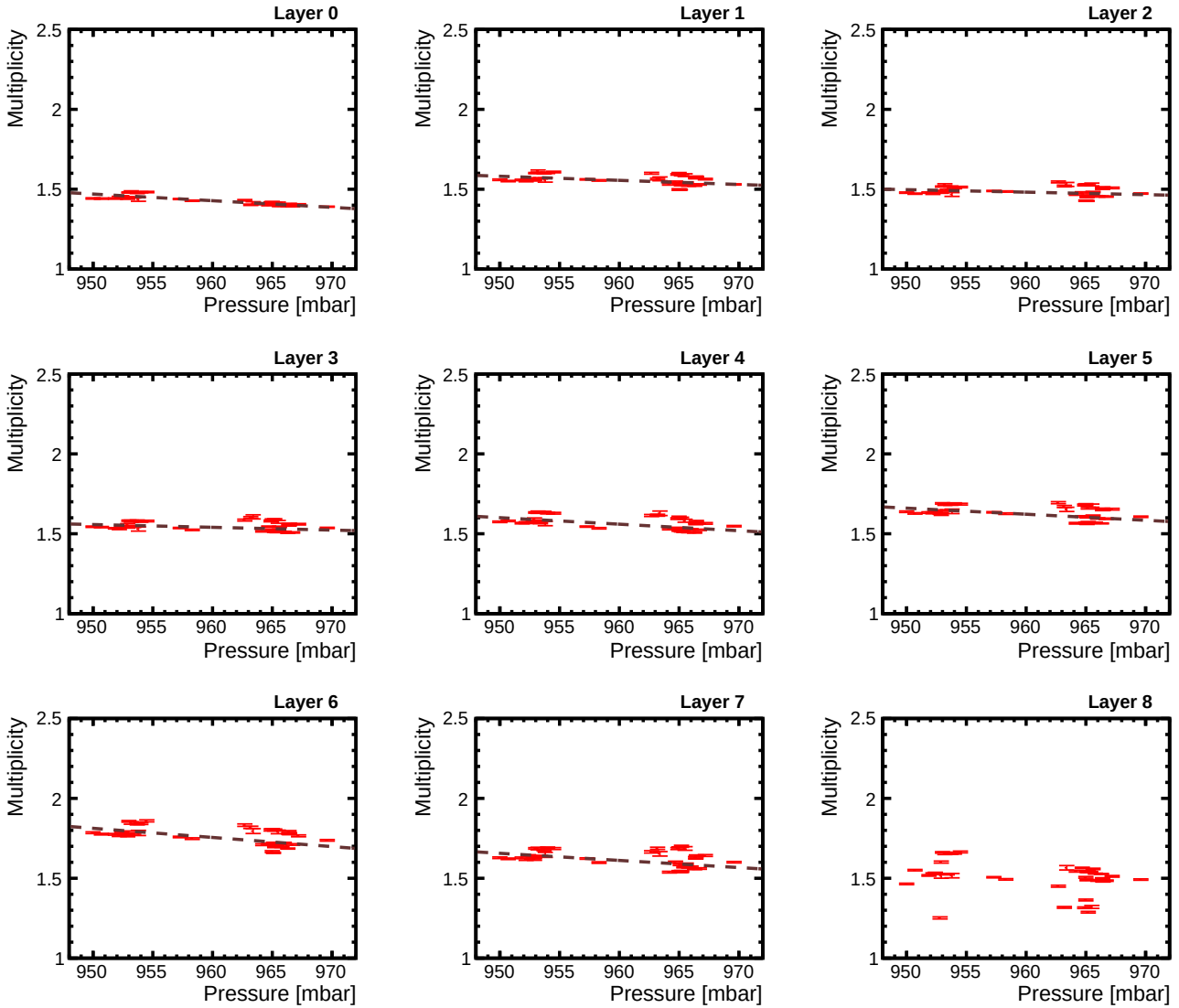
Development of the Multiplicity



Development of the Efficiency



Dependency on Pressure



PS only, $29\,\mathrm{C}^\circ < T < 30\,\mathrm{C}^\circ$

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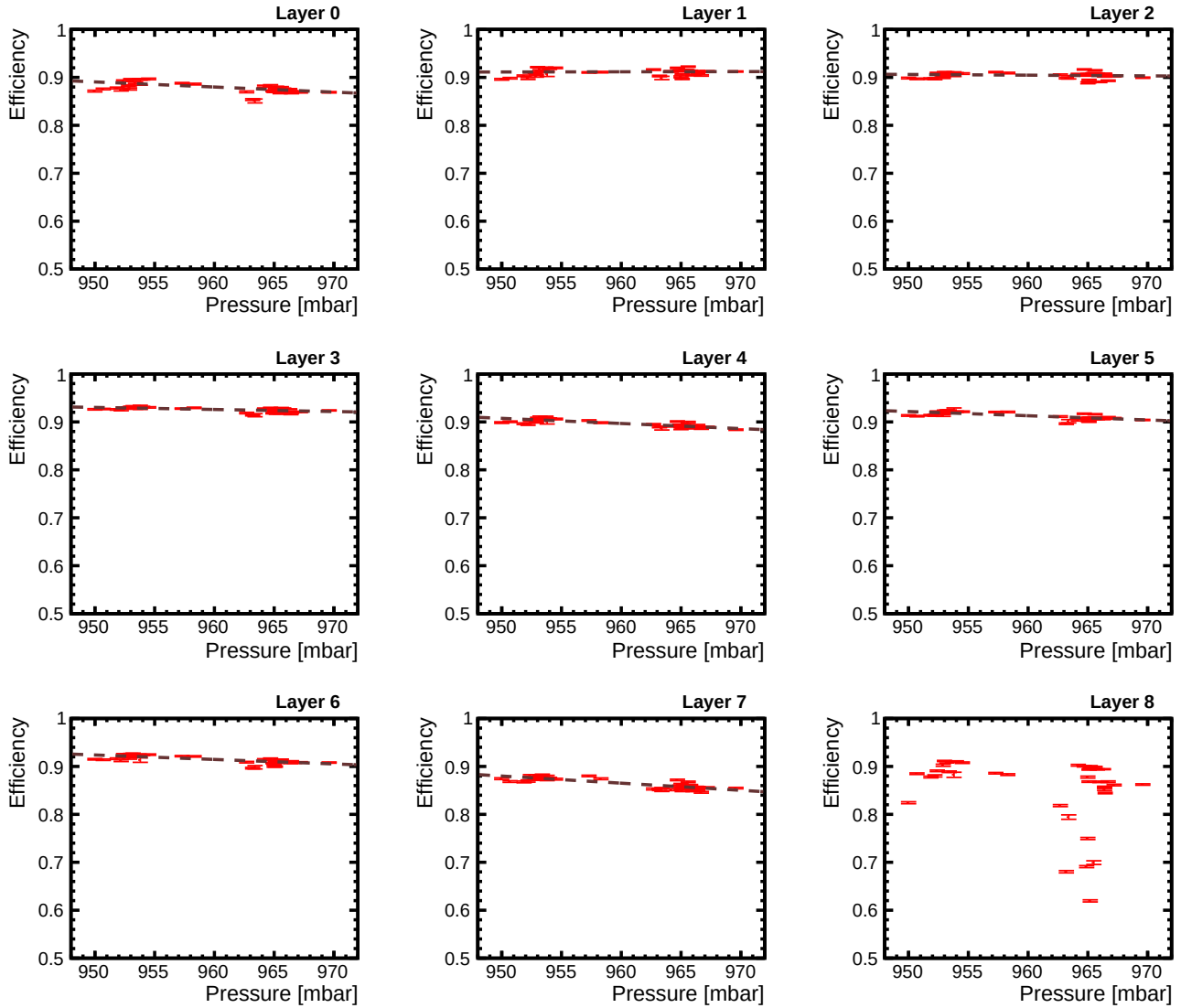

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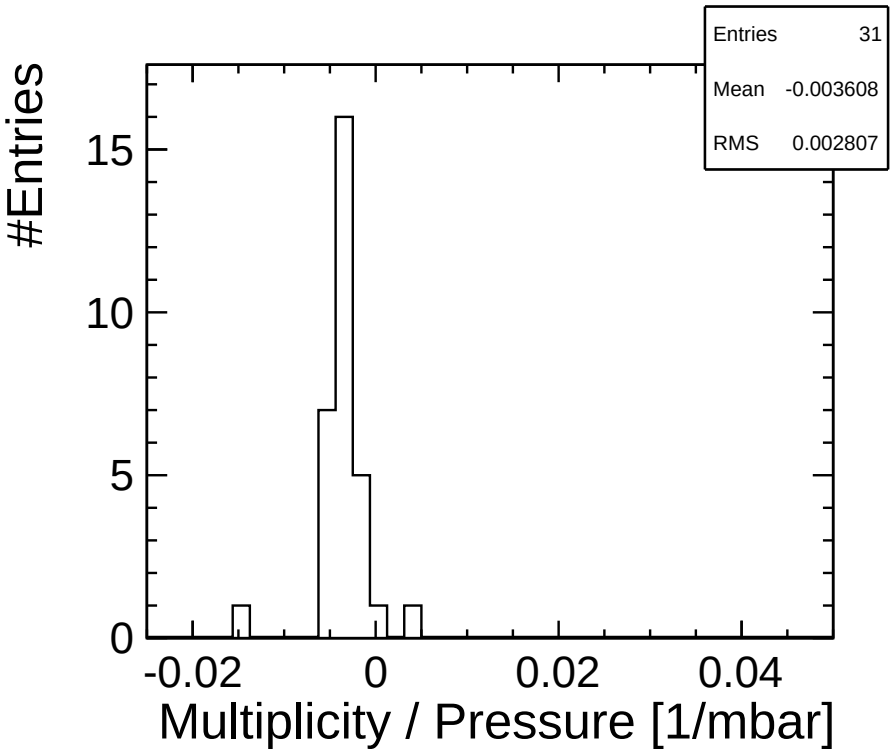
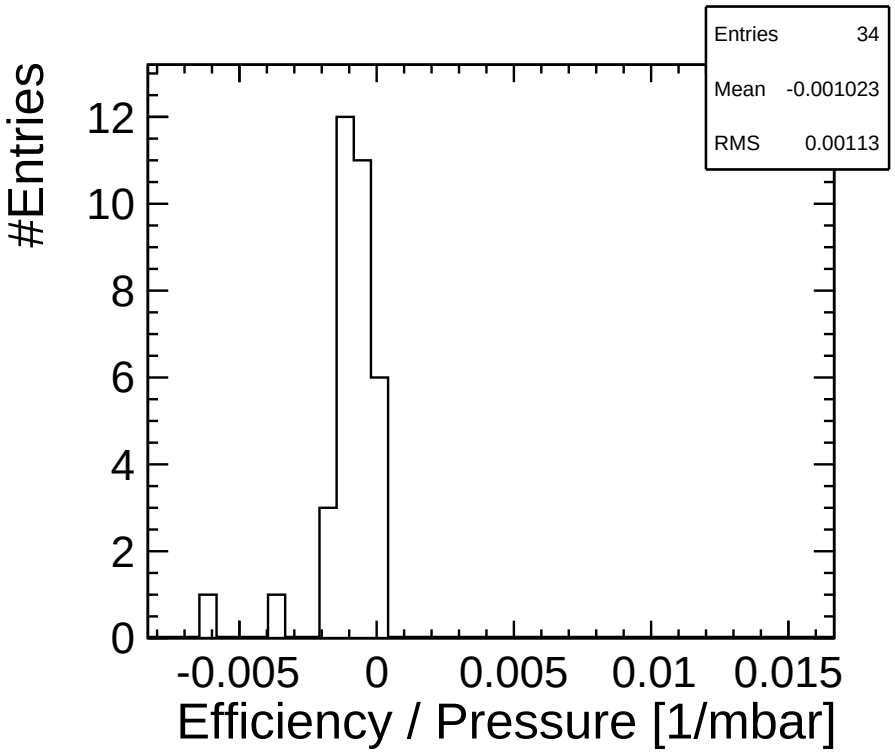
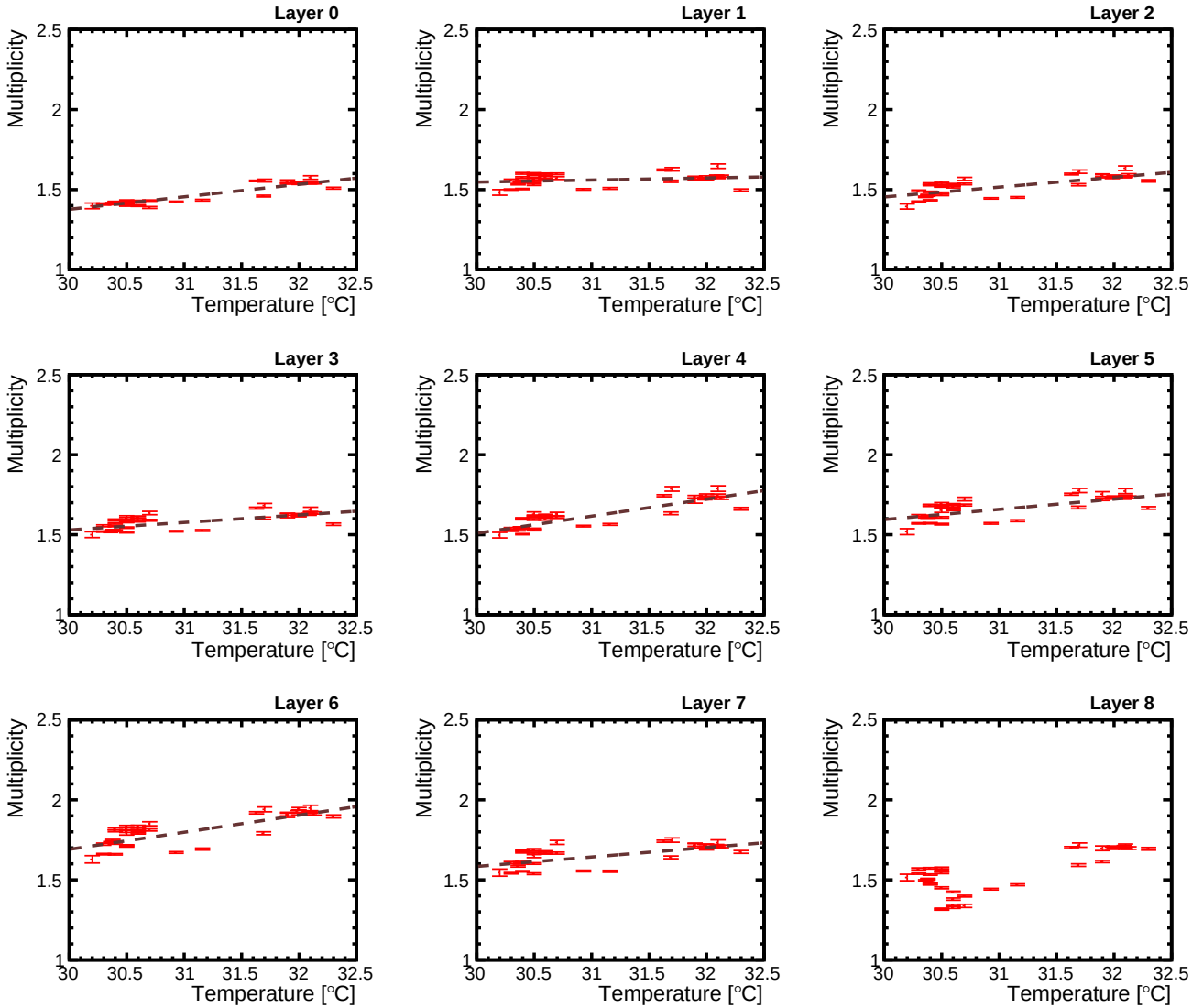




- $\Delta\mu \approx -0.0035\,/\mathrm{mbar}$
- $\Delta\epsilon \approx -0.1\%\,/\mathrm{mbar}$

PS only, $962\,\mathrm{mbar} < p < 965\,\mathrm{mbar}$

Dependency on Temperature



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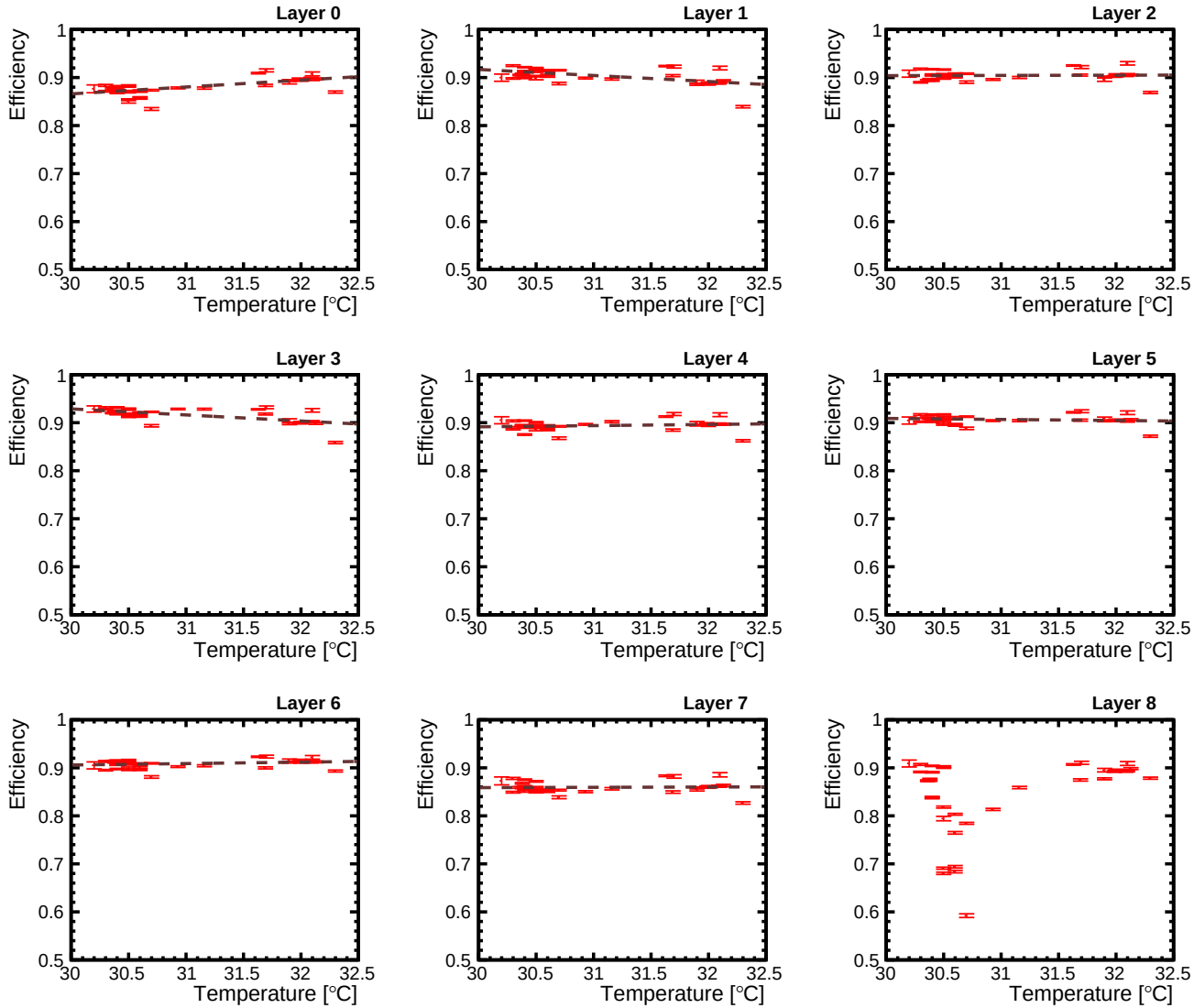

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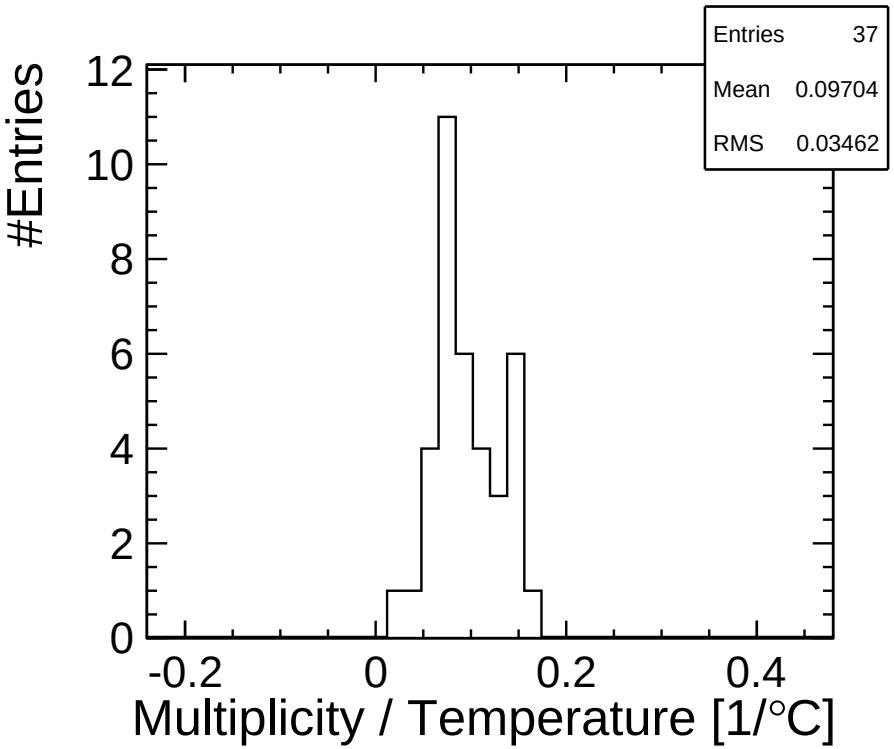
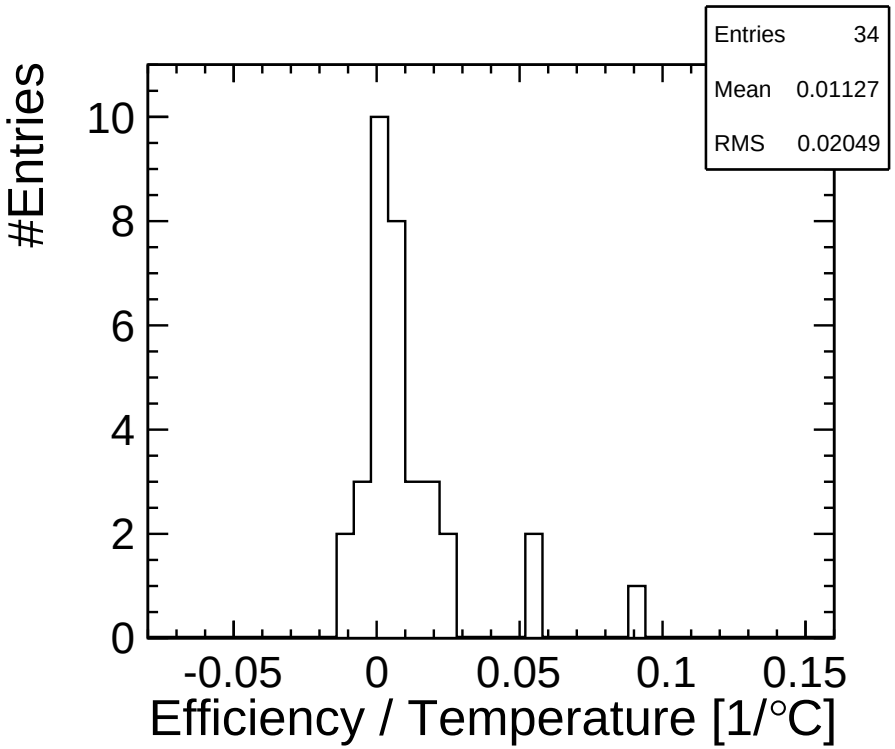




- $\Delta\mu \approx 0.01\,/\mathrm{C}^\circ$
- $\Delta\epsilon \approx 1\%\,/\mathrm{C}^\circ$

PS only, $962\,\mathrm{mbar} < p < 965\,\mathrm{mbar}$

Calibration Procedure

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

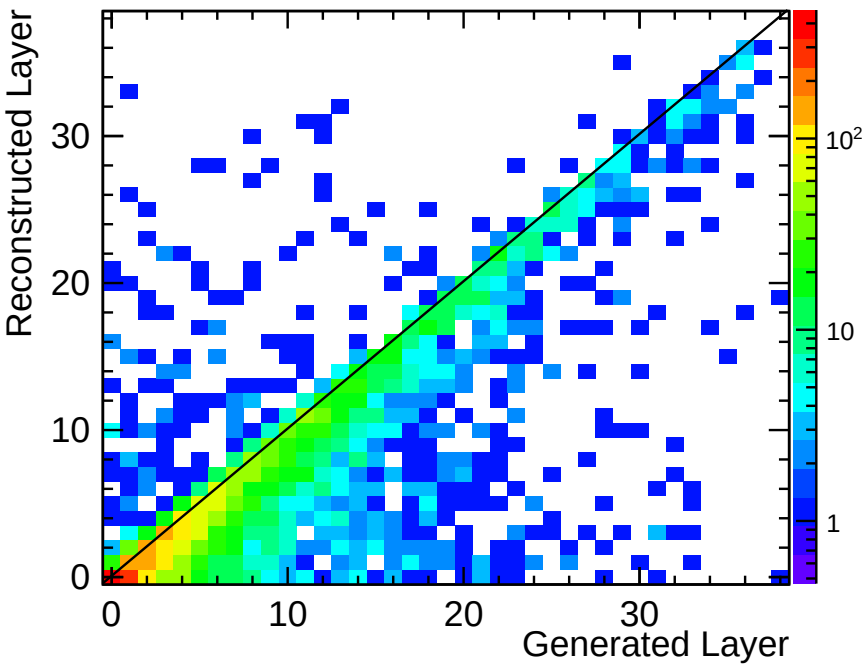
$$E = \alpha \sum_i^N \frac{\mu_0 \ \epsilon_0}{\mu_i \ \epsilon_i}$$

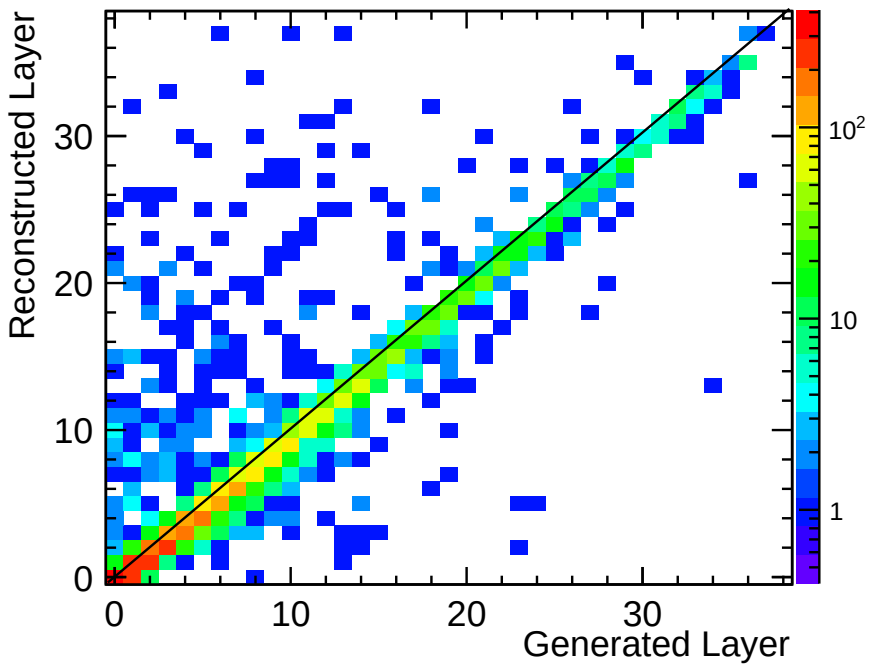
- μ_i and ϵ_i are determined for each module in each layer from muons within the run: works well only for central module
- Could use temperature and pressure dependence to correct for run conditions and use single calibration set $\Rightarrow$ need to remove voltage dependence
- μ_0 and ϵ_0 are the nominal values, determined as average from all modules and layers in all dedicated muon runs:

$$\mu_0 \approx 1.63, \ \epsilon_0 \approx 81\%$$

Interaction Layer Definition

- Old definition: minimum of 3 hits in two consecutive layers
- New definition of interaction layer based on a three layer hit average
- Require increase of factor 2 and minimum average of 4
- Assume 3 hits in each "layer before stack" to allow identification in first layer

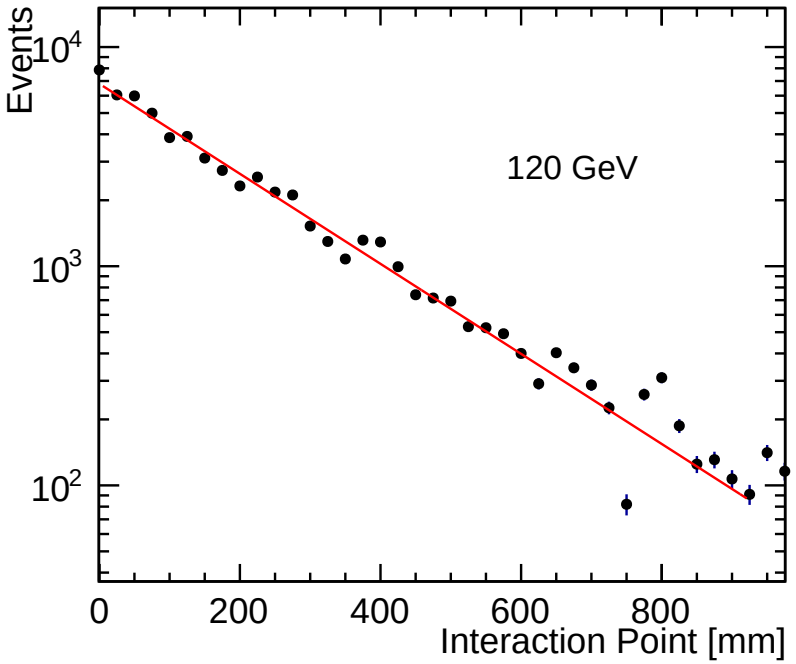


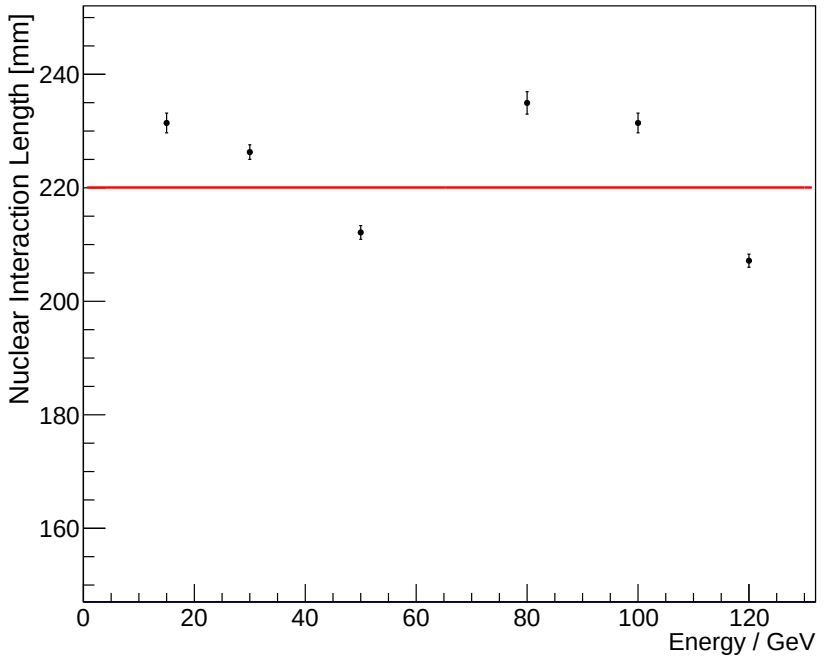


Christian Reichelt (Technical University of Denmark)

Interaction Layer Definition

- Verified in data and MC that the interaction layer follows exponential drop
- Interaction length extracted from exponential fit as expected





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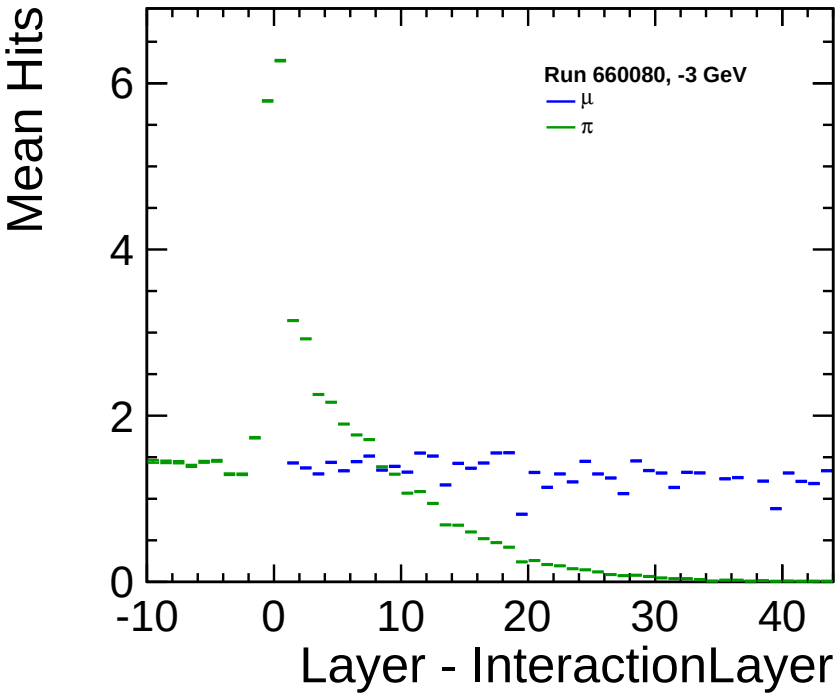
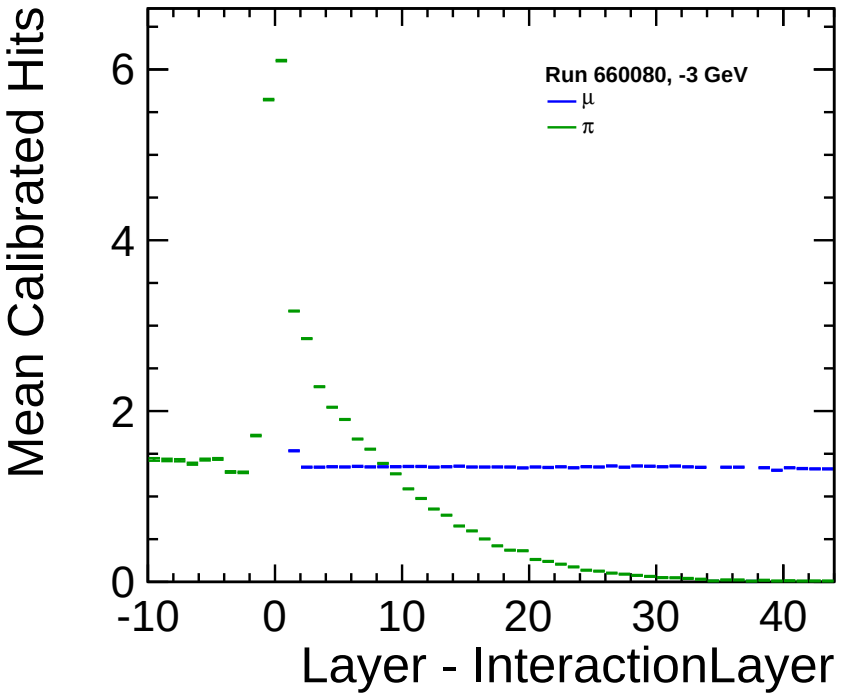
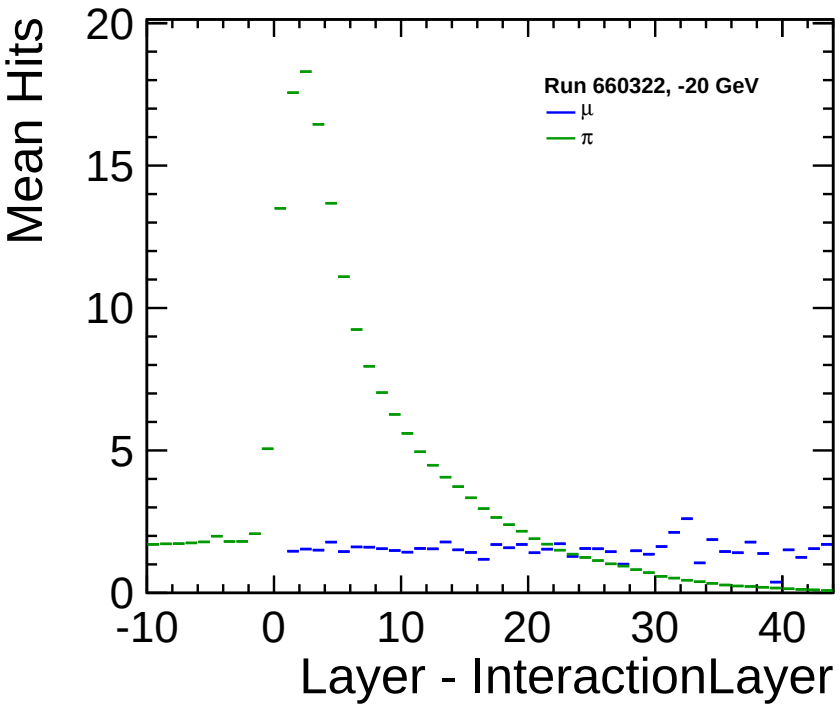
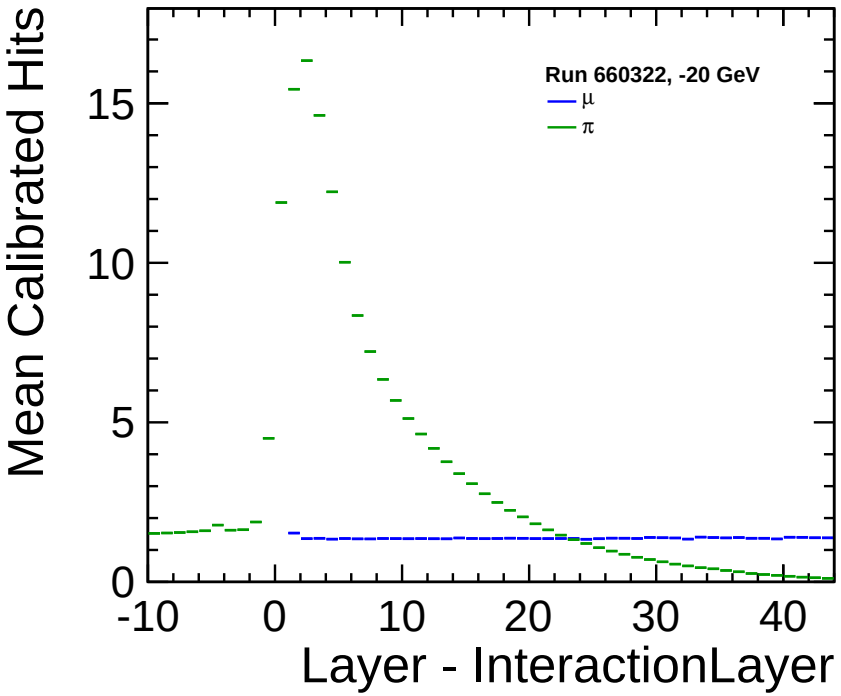
Longitudinal Shower Profiles (3 GeV)



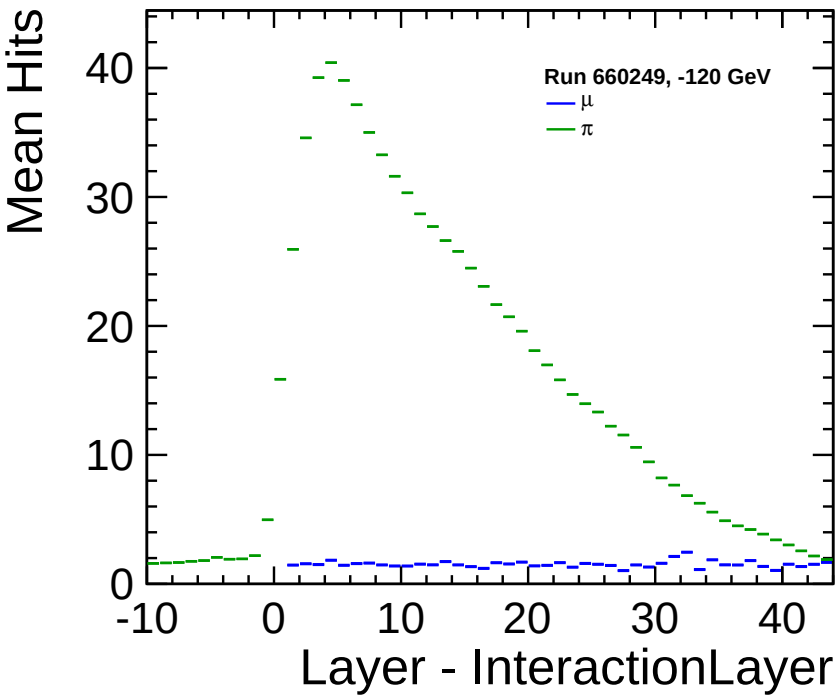


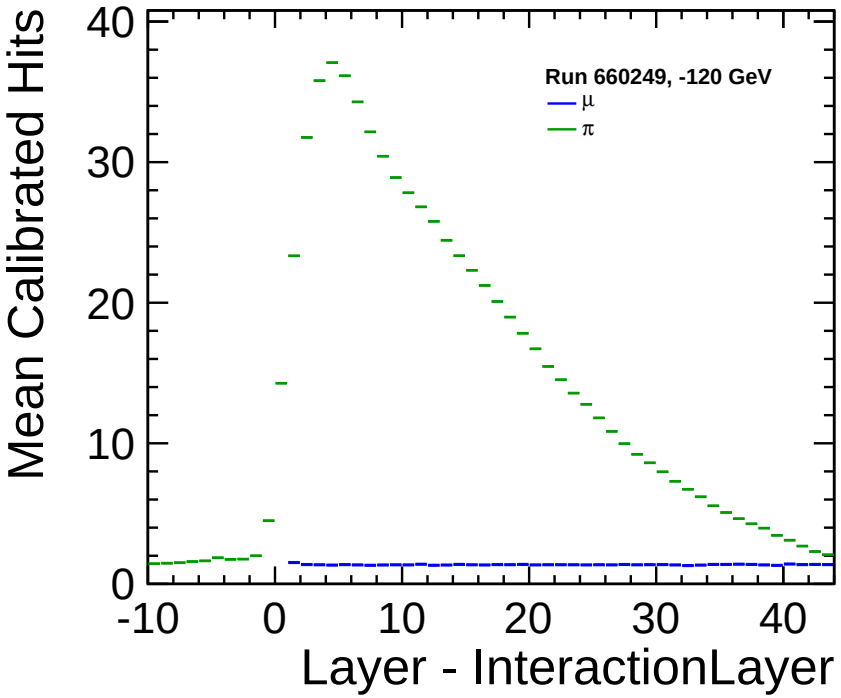
Longitudinal Shower Profiles (20 GeV)





Longitudinal Shower Profiles (120 GeV)





Summary and Outlook

- Hit multiplicity and efficiency depend on temperature, pressure and voltage
- Re-weight hits to eliminate these fluctuations
- Obtain calibration values for each run from muons within the run
- Next step: introduce density weighted calibration (see Lei's talk)
- Improve particle identification using Monte Carlo