

2024 TB - CAEN Readout

June 16, 2026

Friederike Bock



- 1 CAEN Set A - 45V
 - Overview
 - Pedestals
 - Gain Correlations
 - Muon Calibrations
 - LG-HG correlation - physics runs
 - QA data - e^- runs
- 2 Next steps

2024 TB - CAEN Readout Full Set A - analysis status

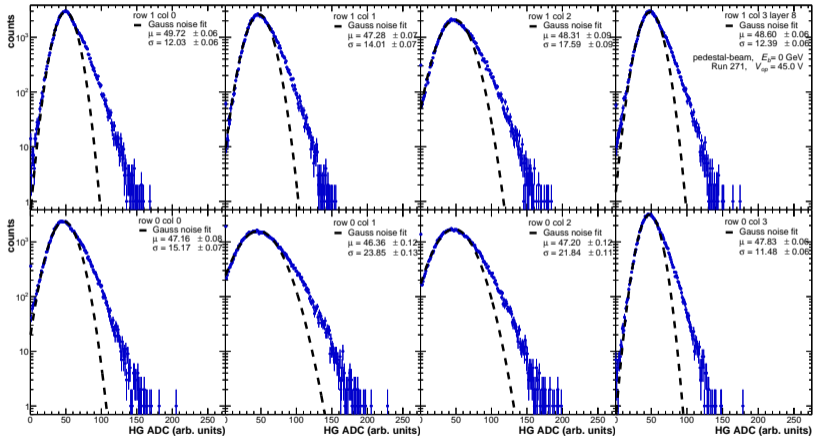
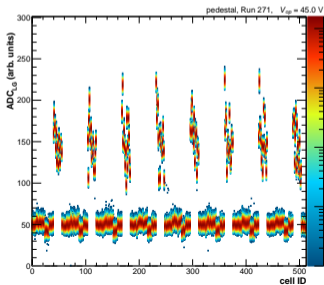
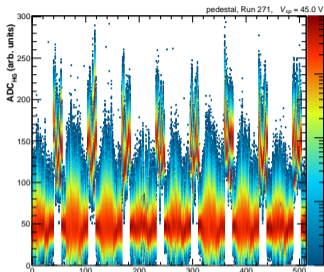
- time:
7.9.2024 1:48 -
7.9.2024 21:54
- $V_{op} = 45$ V,
 $V_{br} = 38.3$ V
- $t_{shape} = 87.5$ ns
- CAEN gain settings:
 $a_{HG} = 50, a_{LG} = 50$
- μ with large
scintillator triggers
- e^- and h^\pm with small
scintillators

CAEN Full set A: $V_{op} = 45$ V

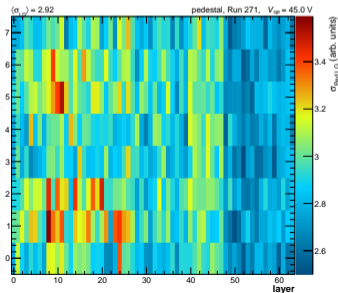
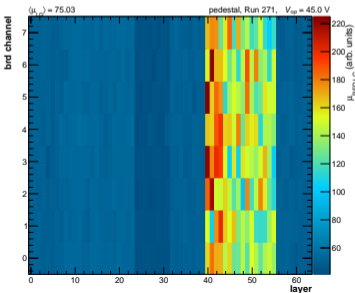
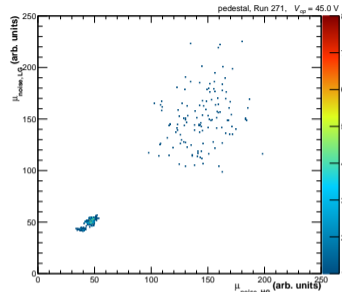
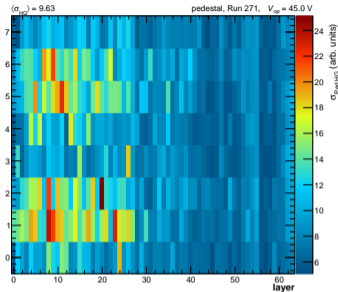
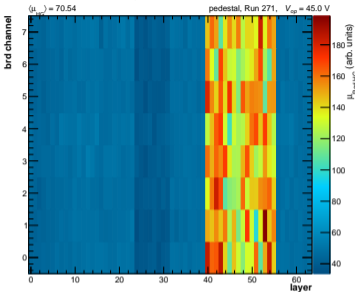
$t_{shape} = 87.5$ ns, hold-delay = 0, $a_{HG} = 50, a_{LG} = 50$, Sept 7, 1:48 - 21:54

Calibration sets:						
μ table position	(-5,0)	(5,0)	ped			
1 st	runs	244	250	271		
	tot events	96K	96K	101K		
2 nd	runs	282	283	277		
	tot events	100K	101K	103K		
Electron set (0,0):						
E	1 GeV	2 GeV	3 GeV	4 GeV	5 GeV	
e ⁻	runs	251	252	254	257	258
	tot events	25.1K	25.1K	34.5K	36K	34.6K
Hadron set (0,0):						
E	3 GeV	5 GeV	8 GeV	10 GeV		
h ⁻	runs	261	264	265	269	
	tot events	100.5K	96.7K	96.7K	100.3K	
E	5 GeV	8 GeV	10 GeV	15 GeV		
h ⁺	runs	270	272	274	275	
	tot events	101.2K	101.4K	100.2K	100.4K	

Muon calibration - Set 1: Pedestals

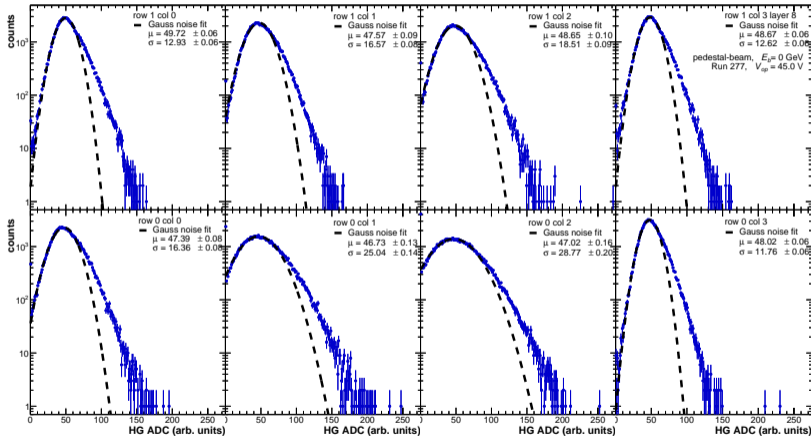
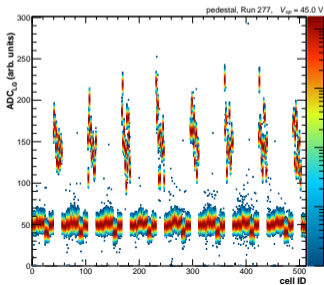
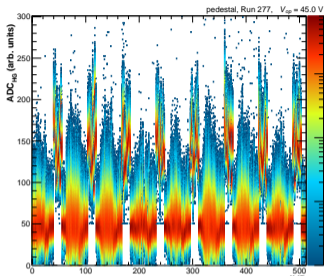


Muon calibration - Set 1: Pedestals

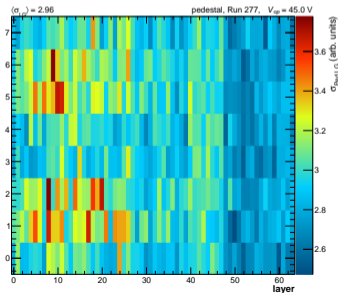
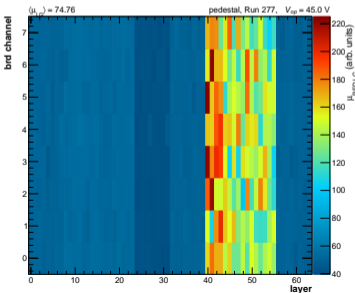
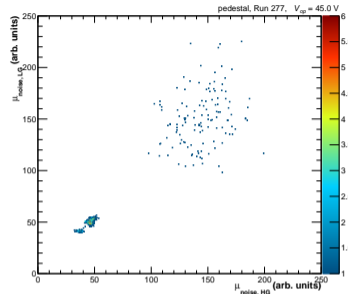
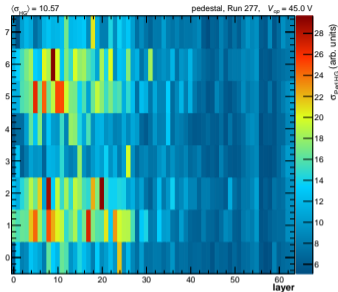
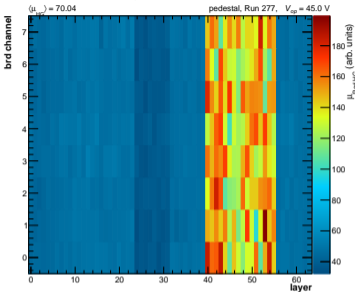


- Pedestal for all readout units set to 50 ADC
- Readout units 6 & 7 behaving significantly differently for all runs, pedestal around 150 ADC
- No loose cables found or and cables were even swapped
- Fitting converges for most cells
- HG & LG pedestal strongly correlated for RO 1-5 & 8

Muon calibration - Set 2: Pedestals

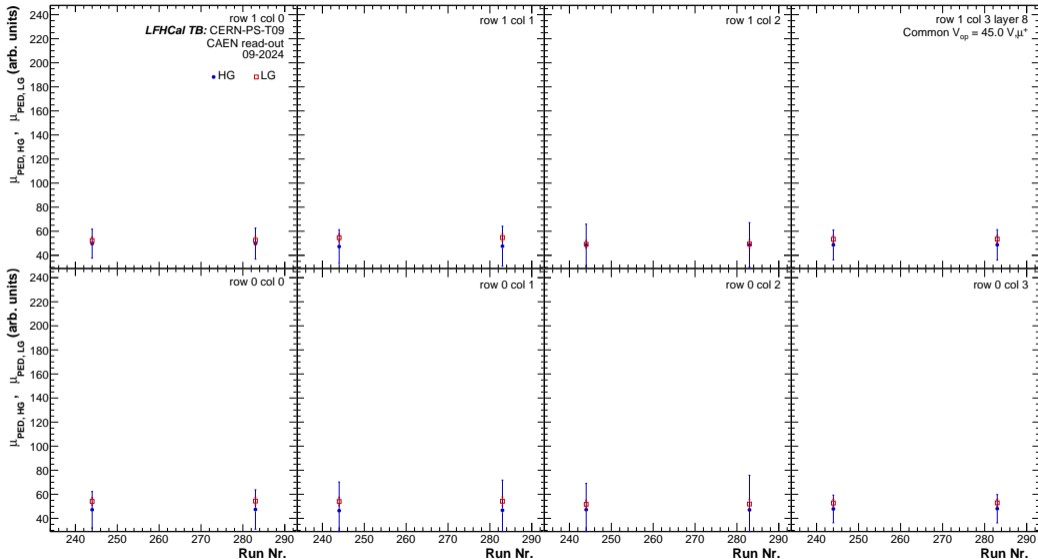


Muon calibration - Set 2: Pedestals

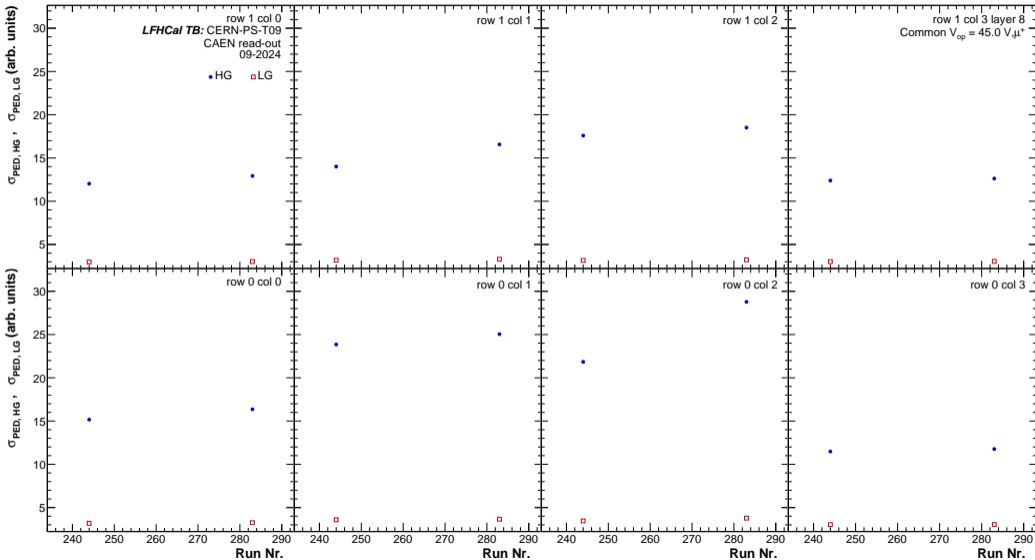


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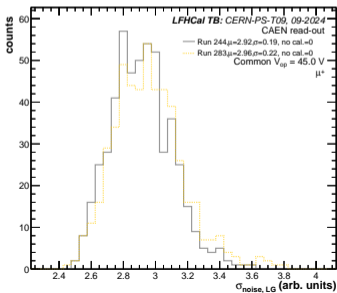
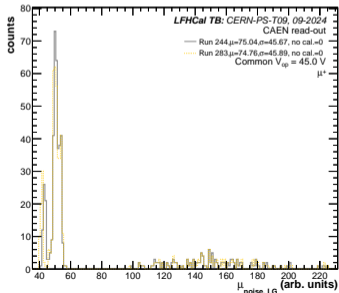
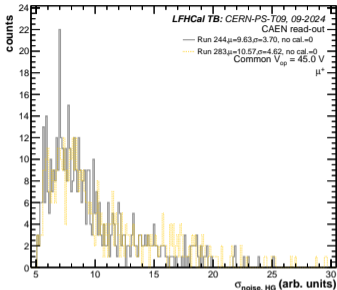
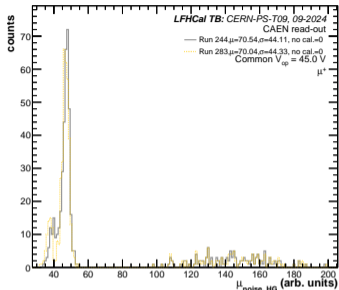
Muon calibration - Pedestal Comparison



Muon calibration - Pedestal Comparison

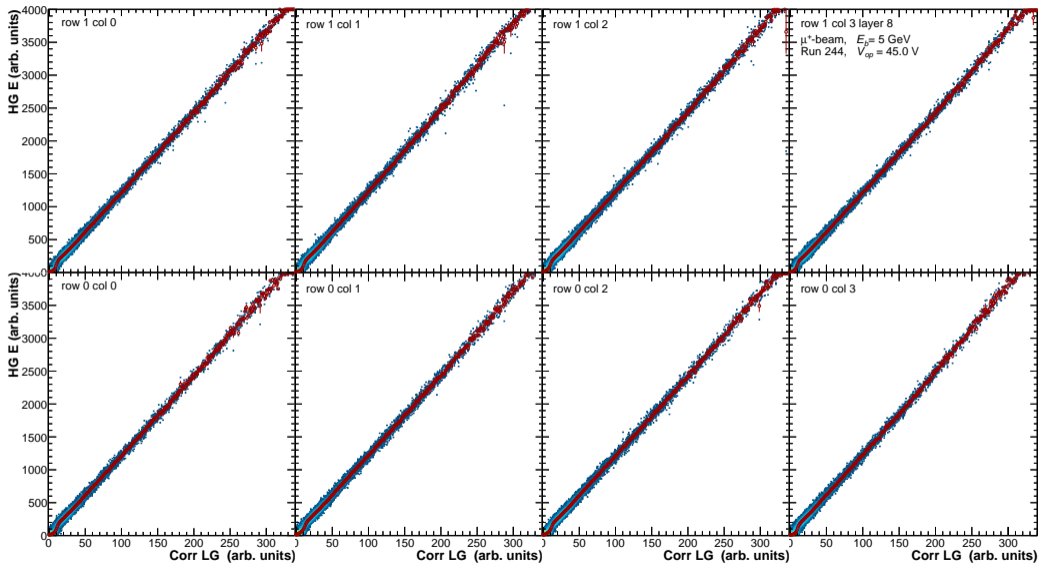


Muon calibration - Pedestal Comparison

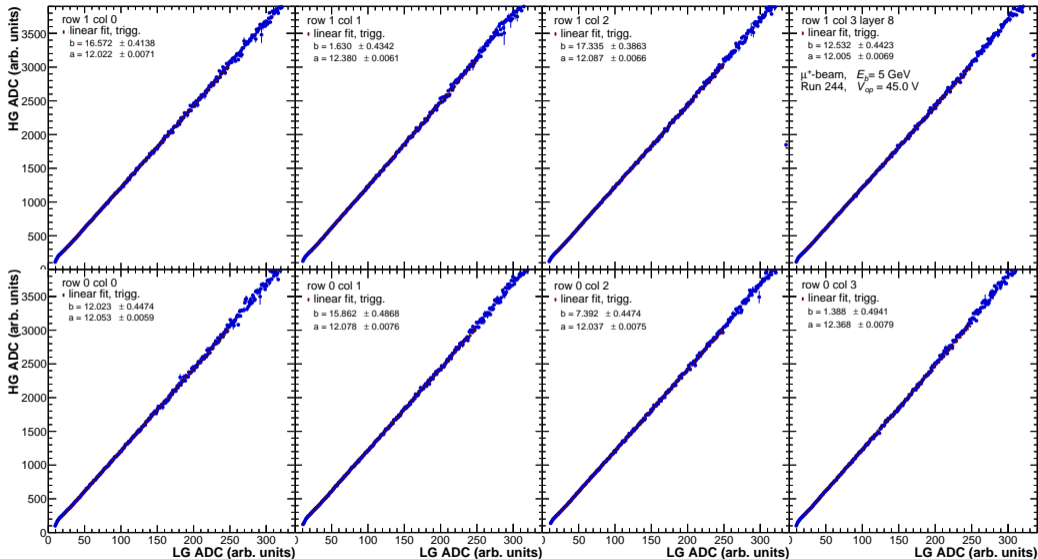


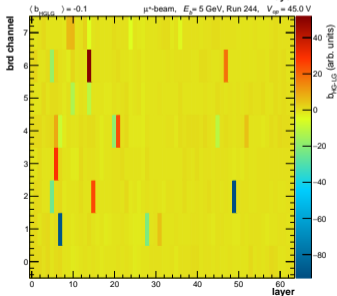
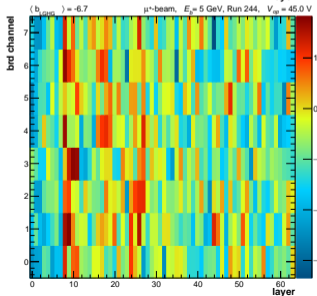
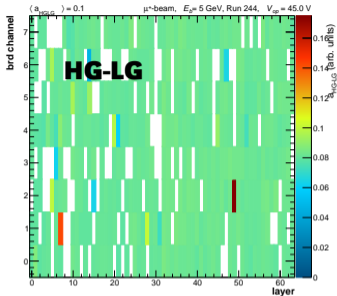
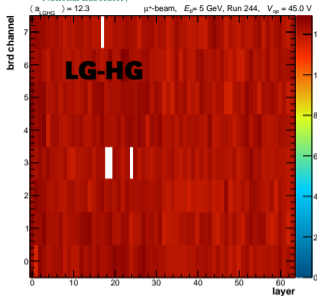
- Very similar pedestal position for both pedestal runs
- Width varies slightly between runs
- Later run with larger pedestal width
Outside temperature: 25.0C (Run 271) vs 23.9C (Run 277)

Muon calibration - LG-HG Correlation -Set 1



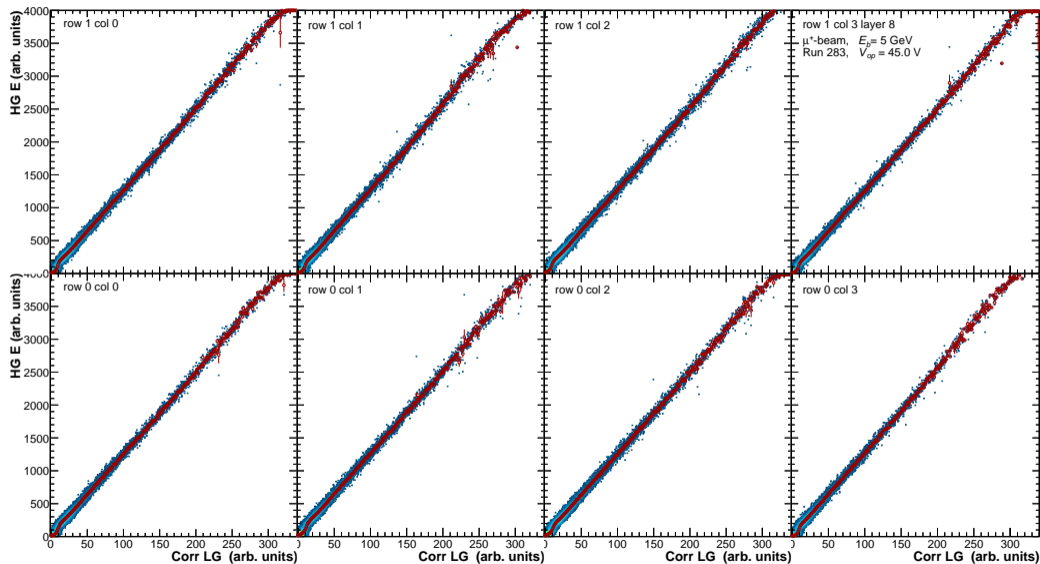
Muon calibration - LG-HG Correlation -Set 1



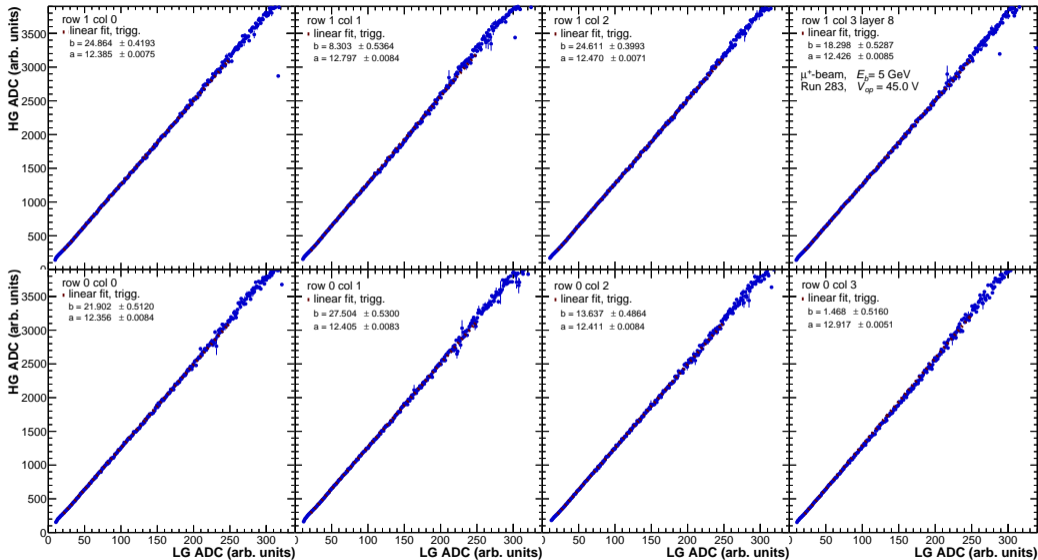


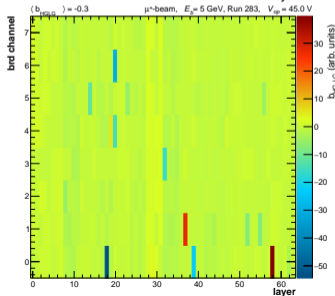
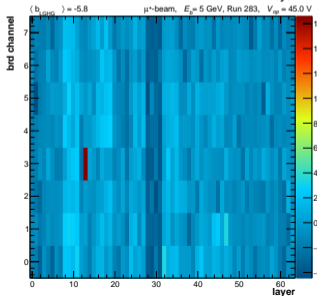
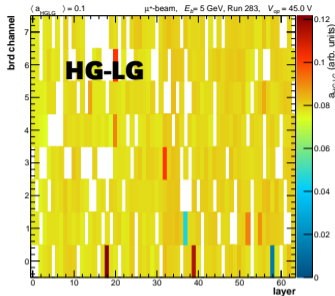
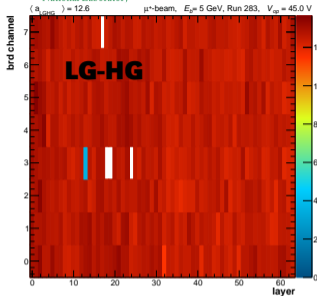
- LG-HG correlation much more stable to fit than HG-LG
- Average Slope for $\langle a_{LG-HG} \rangle = 12.5$ and $\langle a_{HG-LG} \rangle = 0.1$
- Intercept fluctuates a lot, $\langle b_{LG-HG} \rangle = -6.7$ and $\langle b_{HG-LG} \rangle = -0.1$

Muon calibration - LG-HG Correlation -Set 2



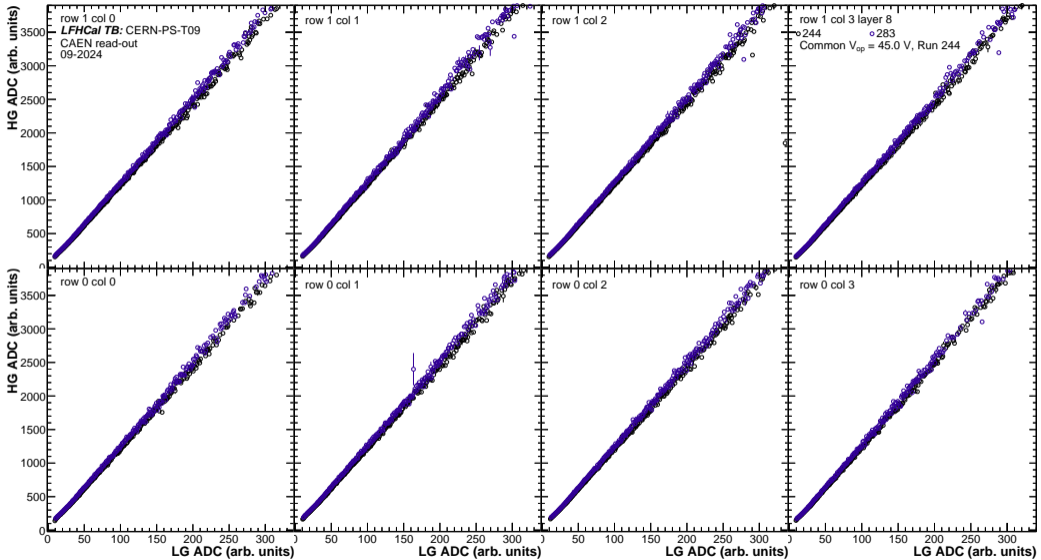
Muon calibration - LG-HG Correlation -Set 2



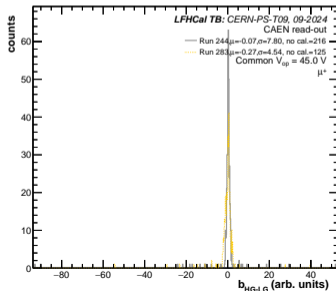
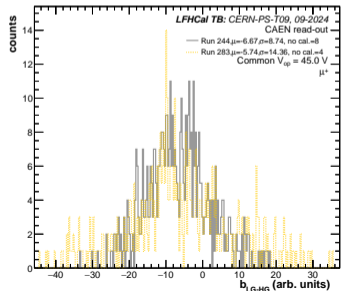
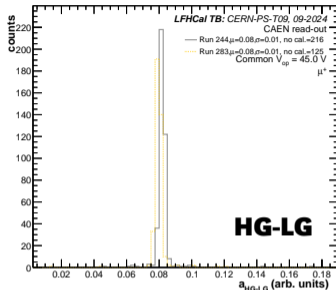
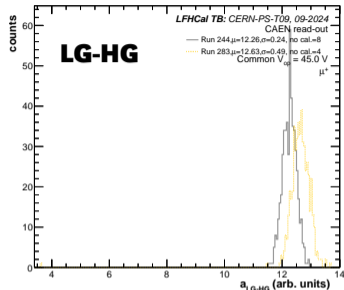


- LG-HG correlation much more stable to fit than HG-LG
- Average Slope for $\langle a_{LG-HG} \rangle = 12.6$ and $\langle a_{HG-LG} \rangle = 0.1$
- Intercept fluctuates a lot, $\langle b_{LG-HG} \rangle = -5.8$ and $\langle b_{HG-LG} \rangle = -0.3$

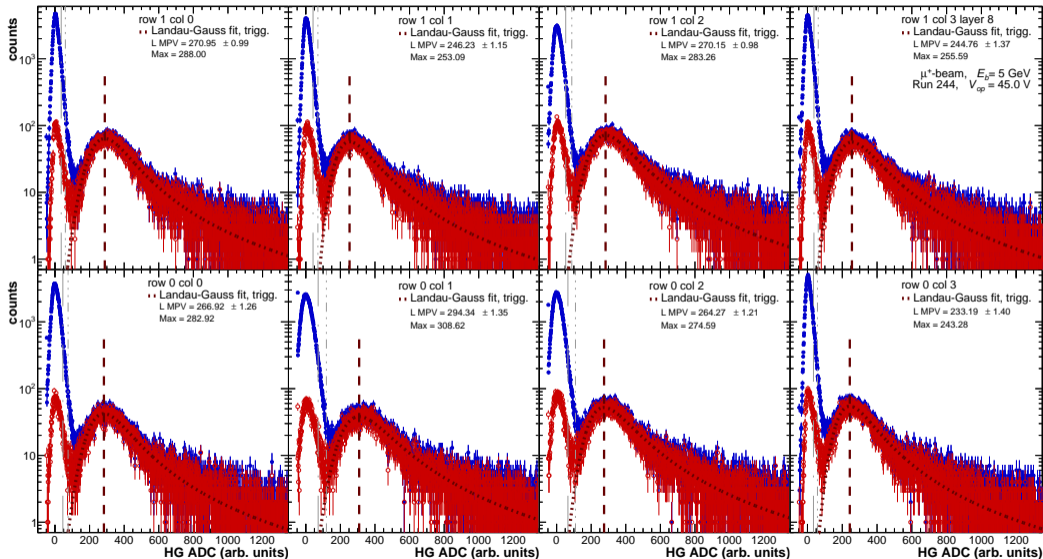
Muon calibration - LG-HG Correlation - Comparison

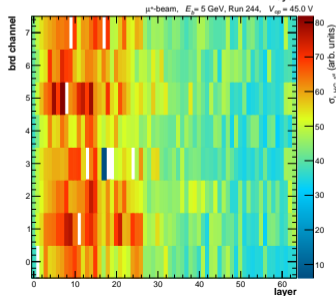
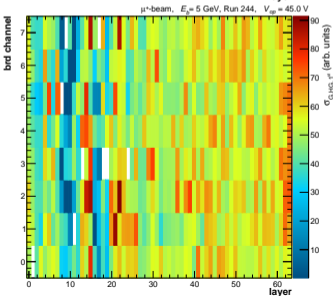
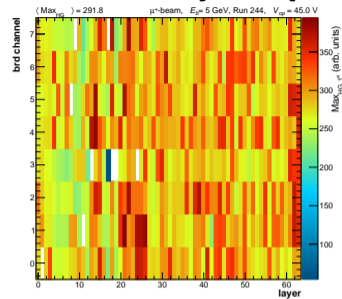
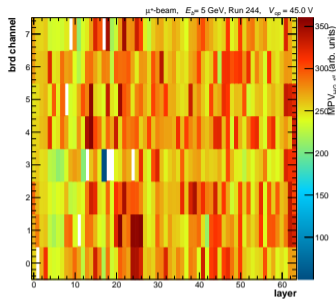
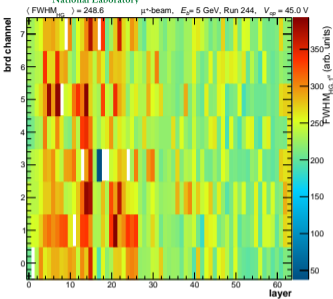


Muon calibration - LG-HG Correlation - Comparison



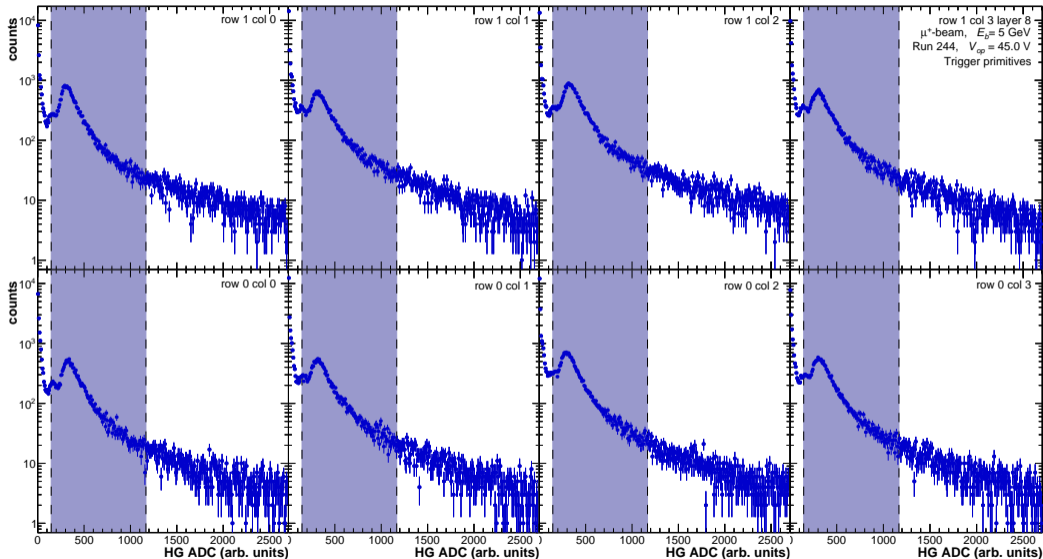
- LG-HG correlation slope average shifted in 2nd set ($\Delta\langle a \rangle = +0.4$), much larger spread in intercept parameter
- HG-LG follows inverse but much harder to fit \Rightarrow more fits fail



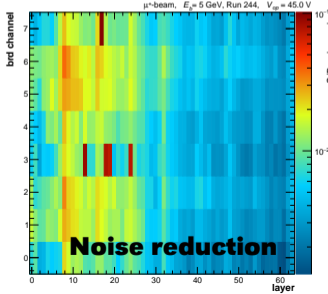
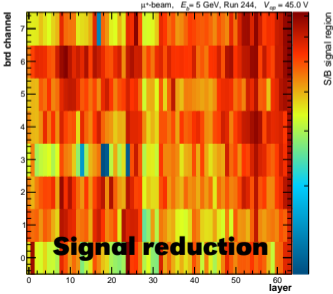
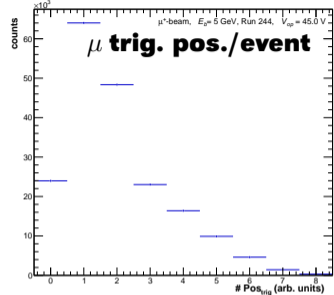
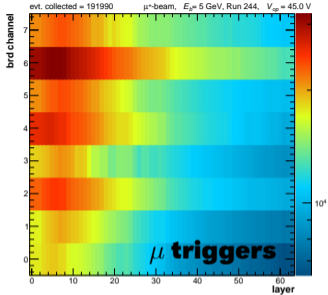
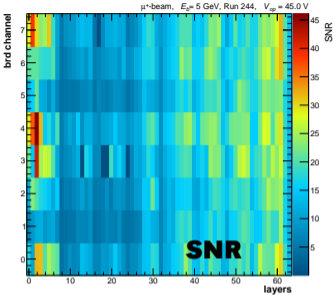


- Initial fit for 42 V still quite stable < 30 channels fail in initial fit (blue distribution previous slide)
- $\langle Max_{HG, mip} \rangle = 291.8$
- A bit biased towards lower values due to very pronounced pedestal peak
- No strong ch-by-ch variations in individual parameters

Muon calibration - Set 1: Muons HG - Trigger

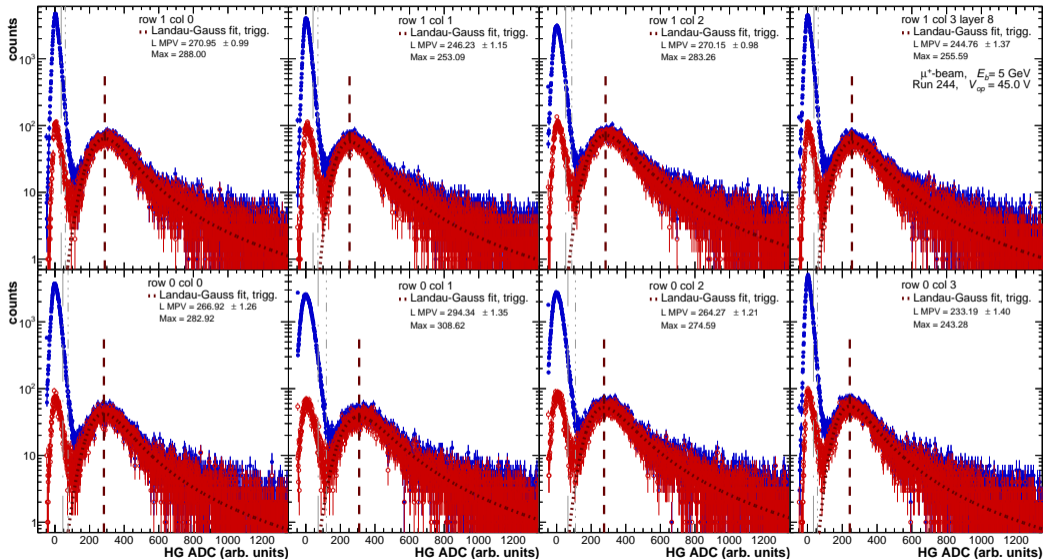


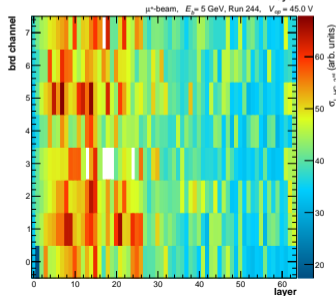
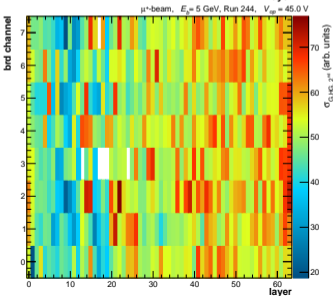
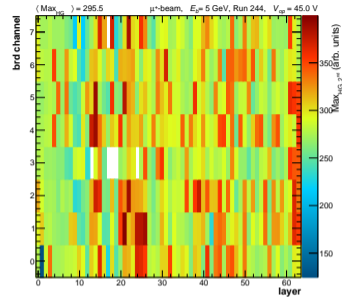
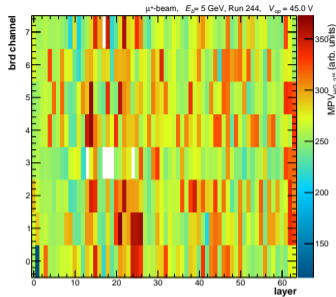
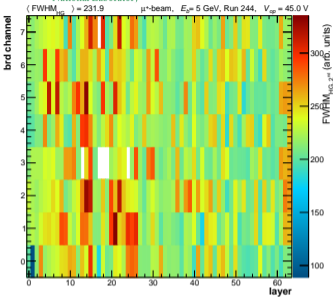
Muon calibration - Set 1: Muons HG - Trigger



- Trigger evaluation for fixed column and row (all z-segments) if average signal summed over all active cells in $z > 3\sigma_{ped,HG}$
- ⇒ Noise suppression could be improved by increasing $n\sigma_{ped,HG}$
- Clear enhancement in trigger primitives, 0th level muon selection within $0.5\langle Max_{HG,mip} \rangle < trig_{prim} < 4\langle Max_{HG,mip} \rangle$
- Same range used for skimming
- Significant reduction of noise peak (red vs. blue on next page)

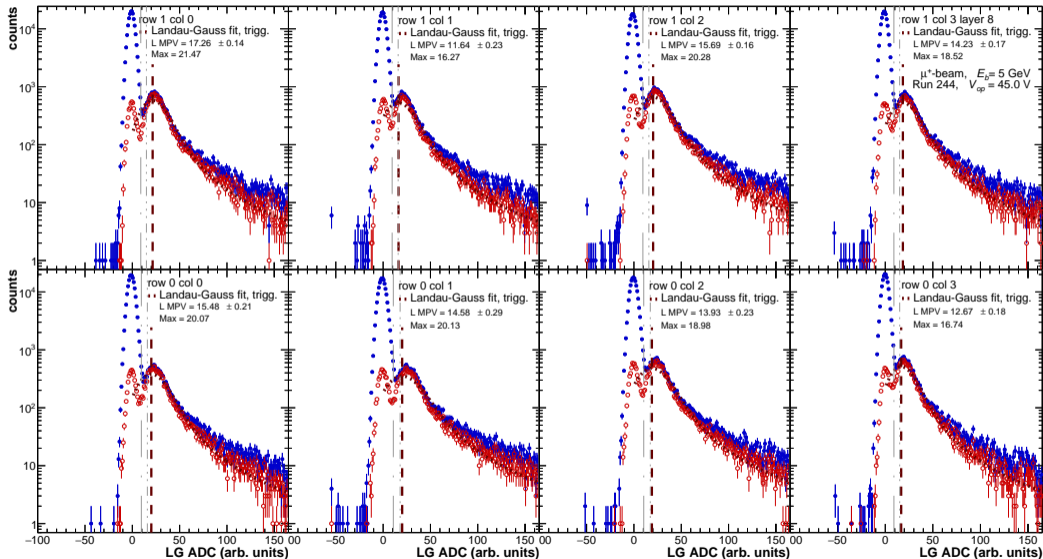
Muon calibration - Set 1: Muons HG - 0th ite



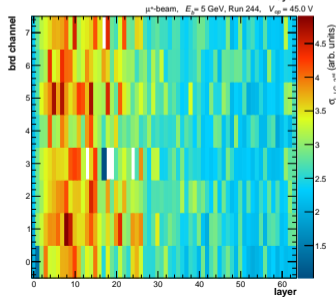
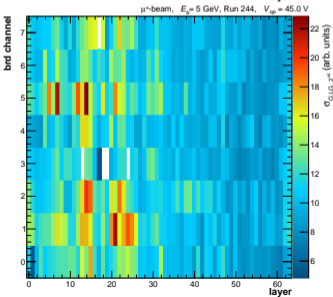
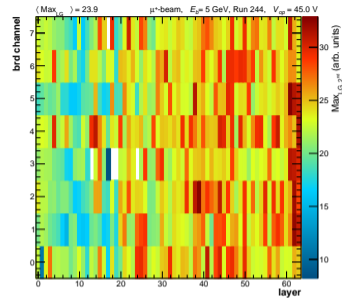
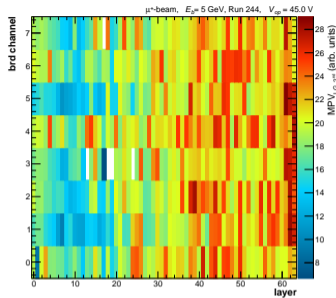
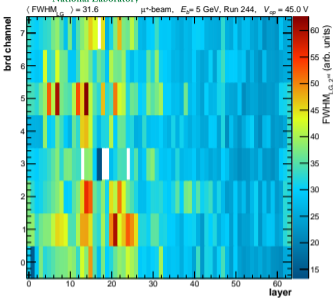


- Nearly all channels "fitable"
- 5 channels identified as bad
- Poor χ^2/ndf for some
- Constrained fit much more in width
- $\langle Max_{HG, mip} \rangle = 295.5$

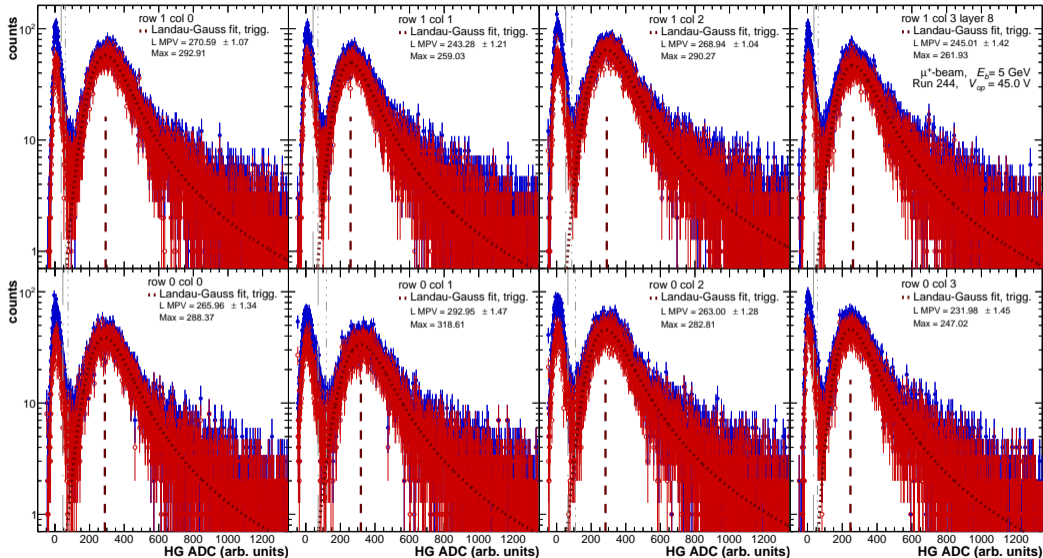
Muon calibration - Set 1: Muons LG - 0th ite



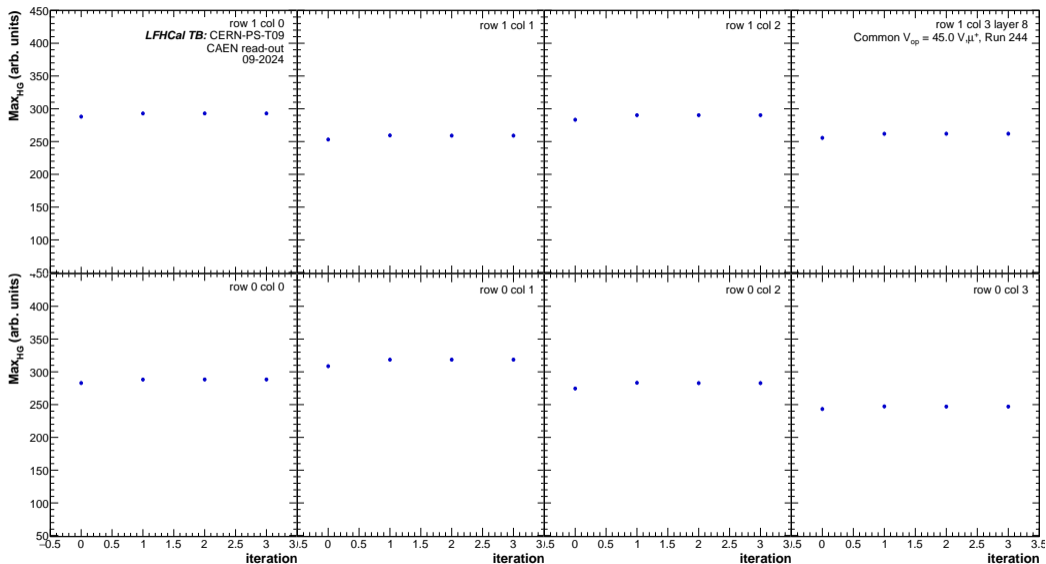
Muon calibration - Set 1: Muons LG - 0th ite



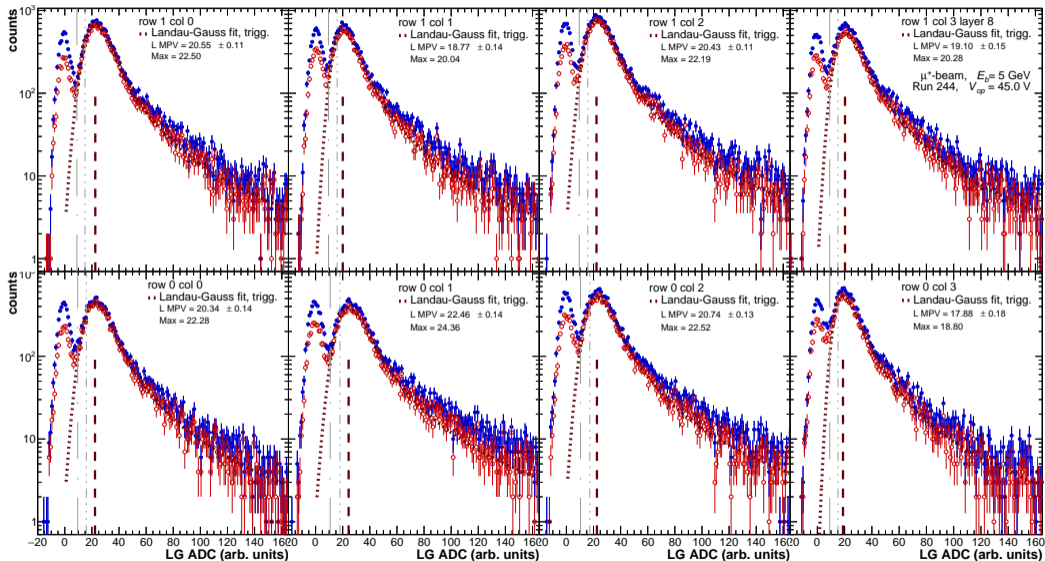
- First iteration fitting LG peaks, nearly all channels "fitable"
- 5 channels identified as bad
- Poor χ^2/ndf for some, signal and pedestal peak merge ($\sigma_{ped, LG} \approx 2.9$ ADC), reasonable separation
- $\langle \text{Max}_{LG, mip} \rangle = 23.9$



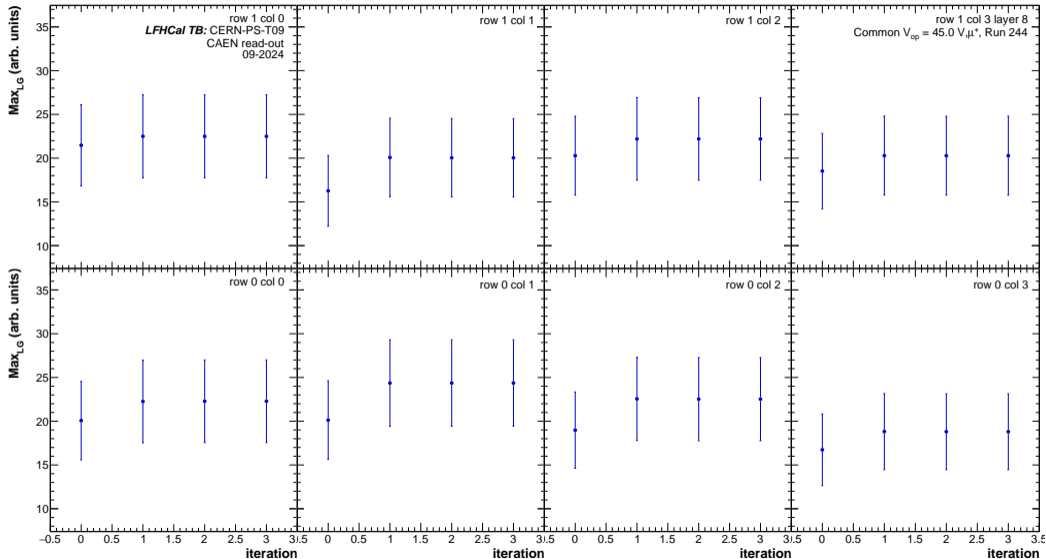
Muon calibration - Set 1: Muons - Iterations



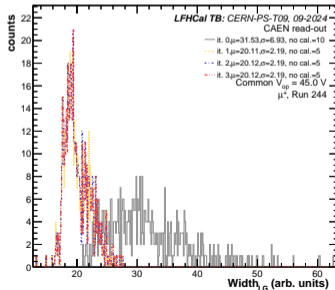
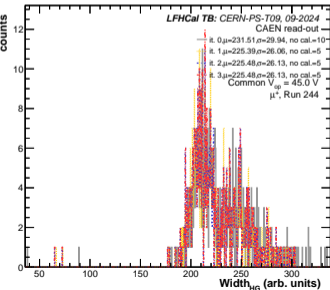
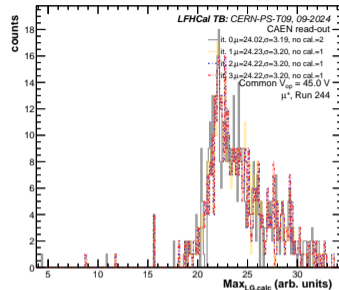
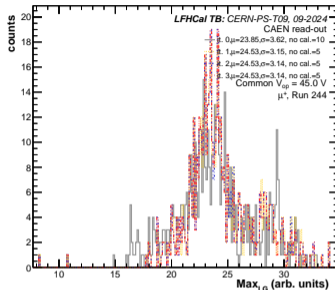
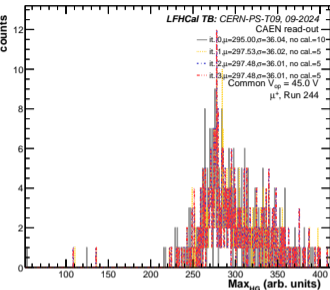
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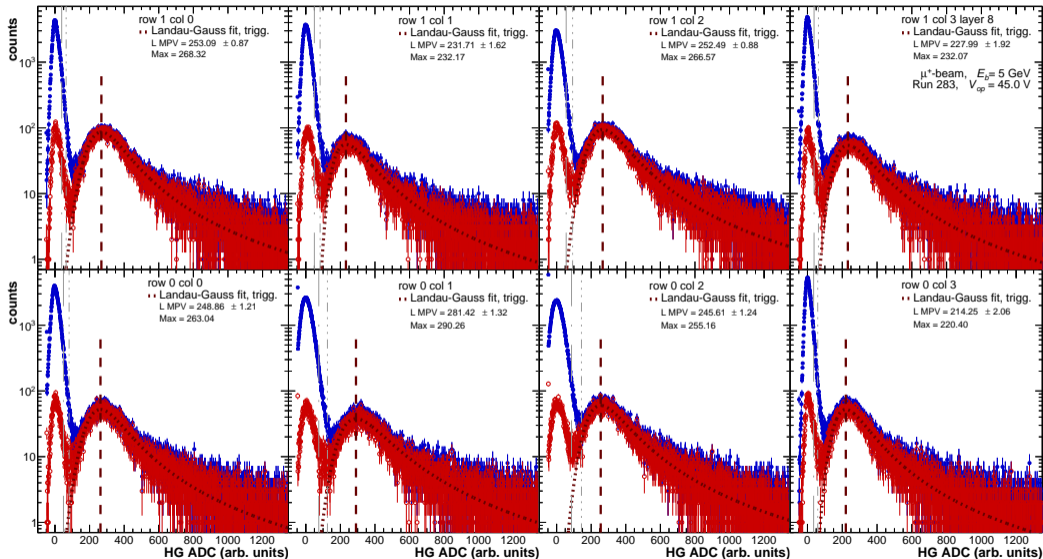
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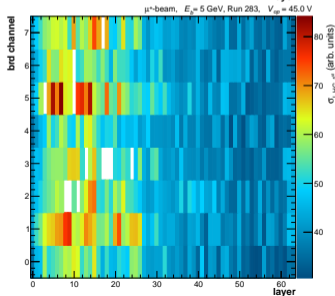
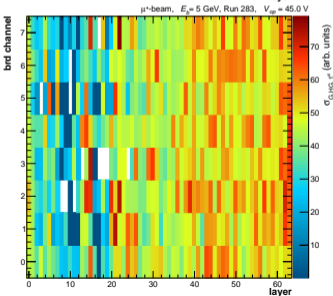
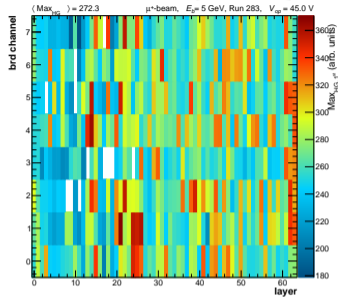
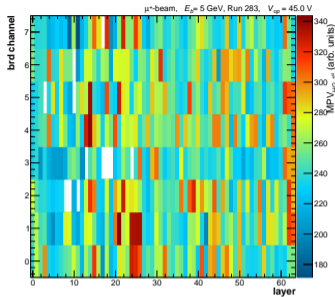
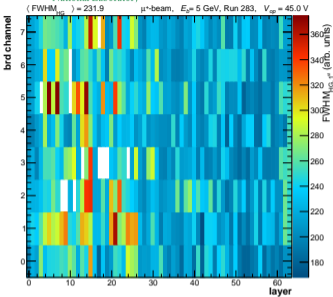


- Reduced mip selection range for trigger primitives
 $0.8 \langle Max_{HG, mip} \rangle < trigg_{prim} < 2 \langle Max_{HG, mip} \rangle$

⇒ Further reduction of noise peak

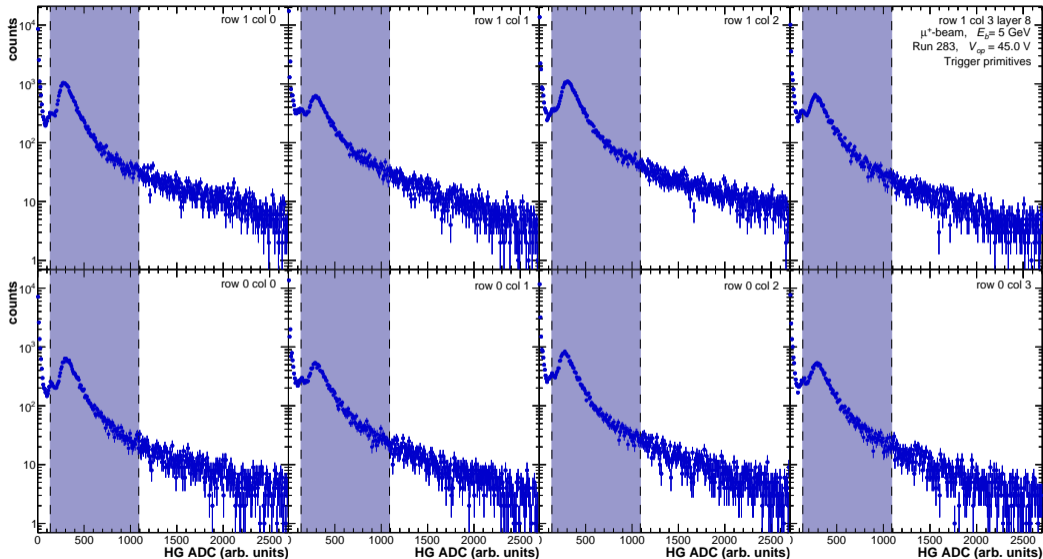
- Refined fitting during improved iterations using average mip from previous iteration as basis for constraints
- Convergence of most cells within 2-3 iterations



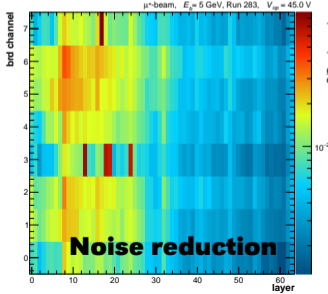
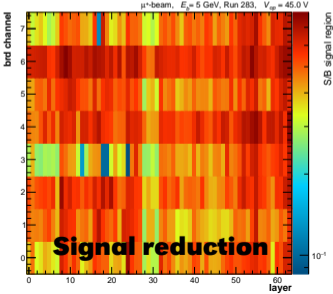
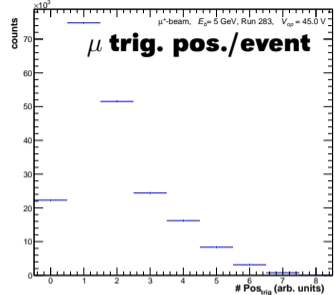
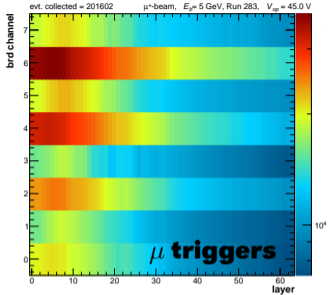
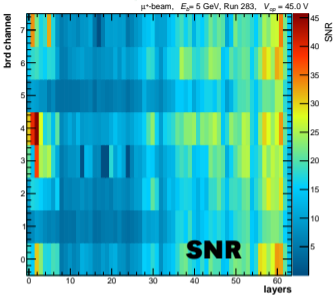


- Initial fit for 42 V still quite stable < 20 channels fail in initial fit (blue distribution previous slide)
- $\langle Max_{HG, mip} \rangle = 272.3$
- A bit biased towards lower values due to very pronounced pedestal peak
- No strong ch-by-ch variations in individual parameters, outliers in widths drive z-range of plots

Muon calibration - Set 2: Muons HG - Trigger

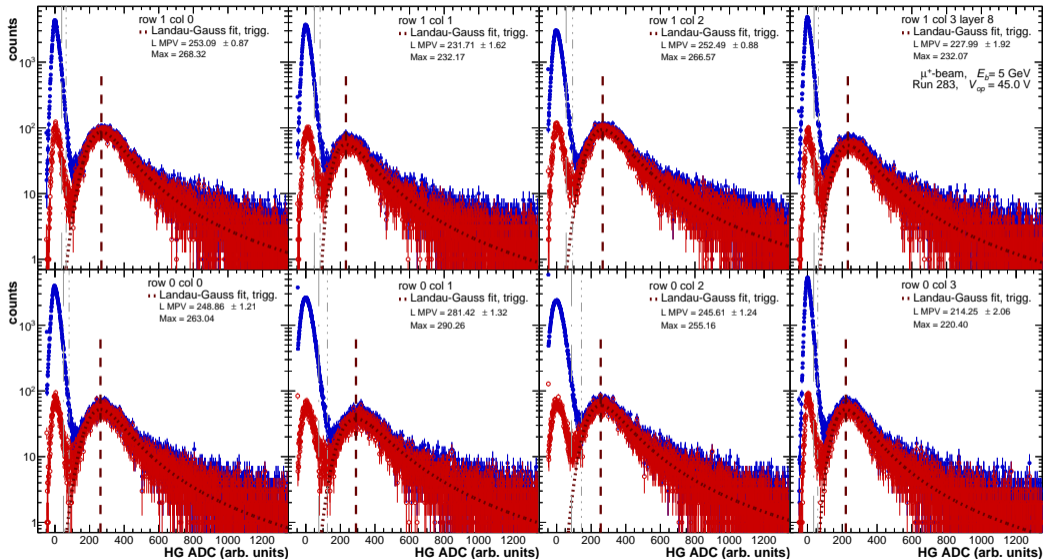


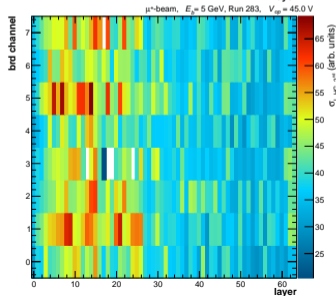
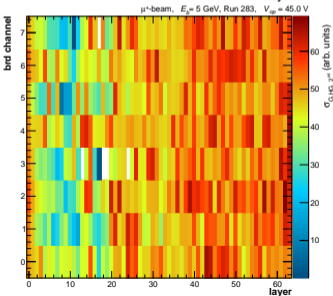
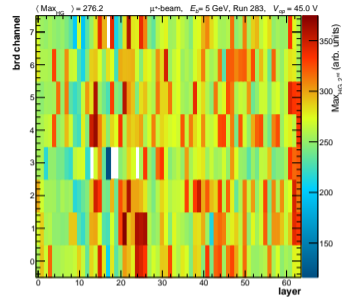
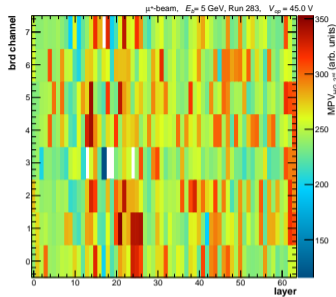
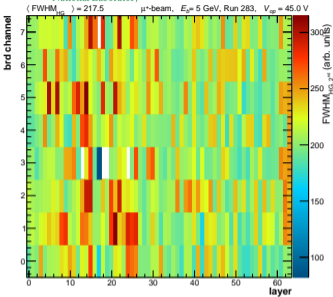
Muon calibration - Set 2: Muons HG - Trigger



- Trigger evaluation for fixed column and row (all z-segments) if average signal summed over all active cells in $z > 3\sigma_{ped,HG}$
- Clear enhancement in trigger primitives, 0th level muon selection within $0.5 \langle Max_{HG,mip} \rangle < trigg_{prim} < 4 \langle Max_{HG,mip} \rangle$
- Same range used for skimming
- Significant reduction of noise peak (red vs. blue on next page)

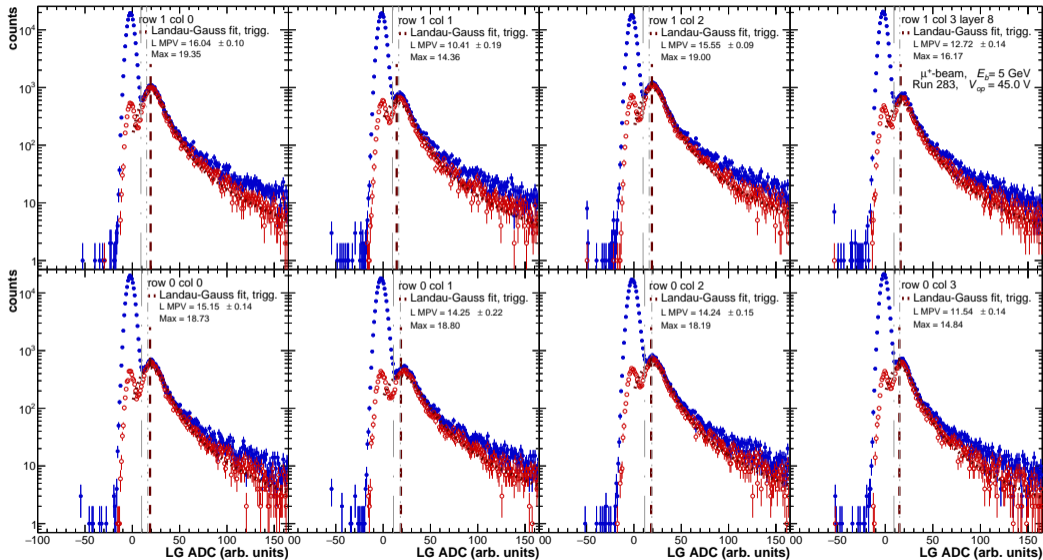
Muon calibration - Set 2: Muons HG - 0th ite

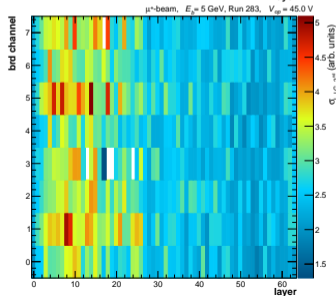
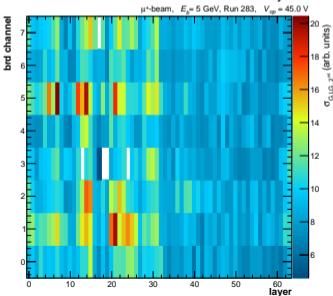
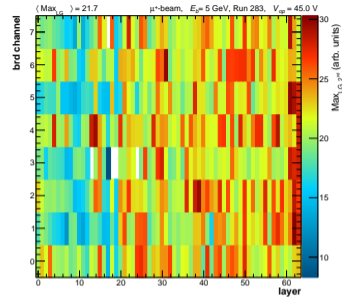
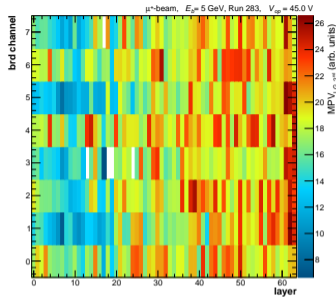
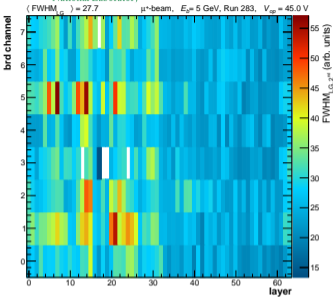




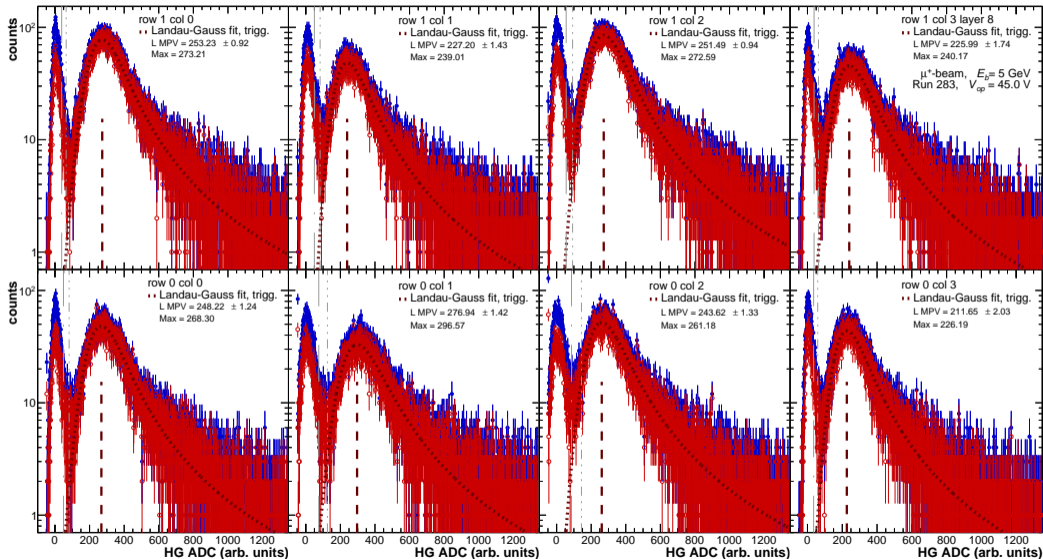
- Nearly all channels "fitable"
- 5 channels identified as bad
- Poor χ^2/ndf for some
- Constrained fit much more in width
- $\langle Max_{HG, mip} \rangle = 276.4$

Muon calibration - Set 2: Muons LG - 0th ite

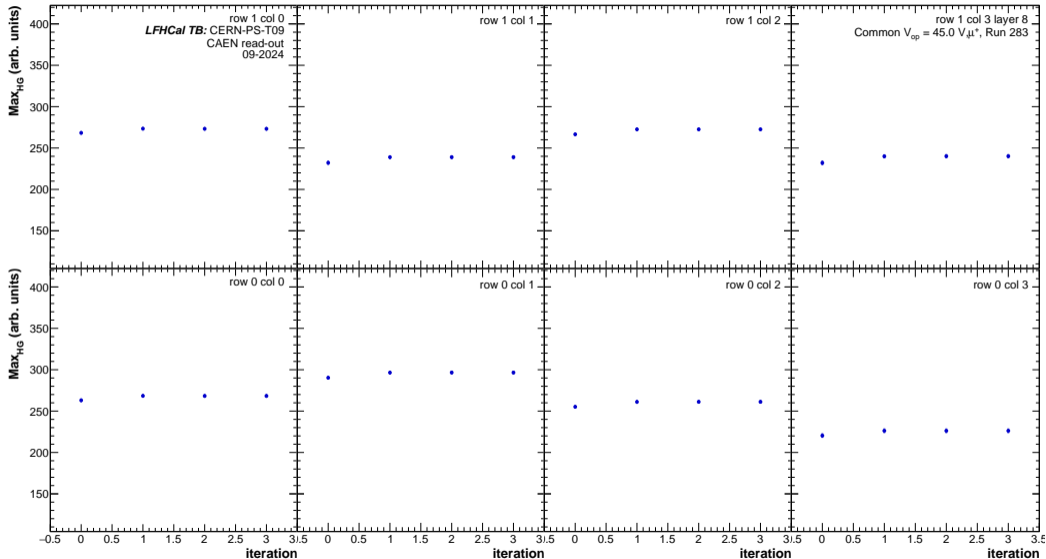




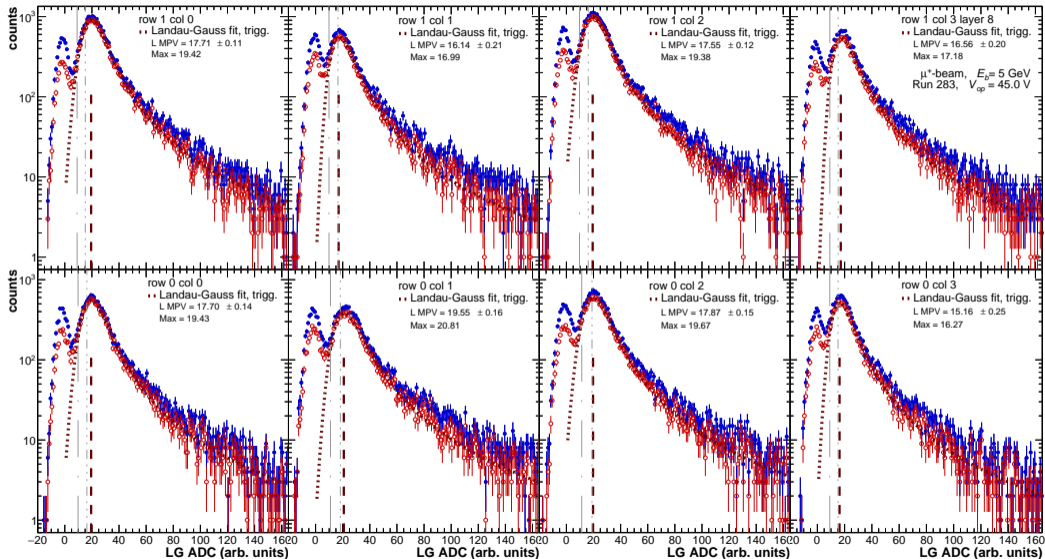
- First iteration fitting LG peaks, nearly all channels "fitable"
- 5 channels identified as bad
- Poor χ^2/ndf for some, signal and pedestal peak merge ($\sigma_{ped, LG} \approx 2.9$ ADC)
- $\langle Max_{LG, mip} \rangle = 21.7$



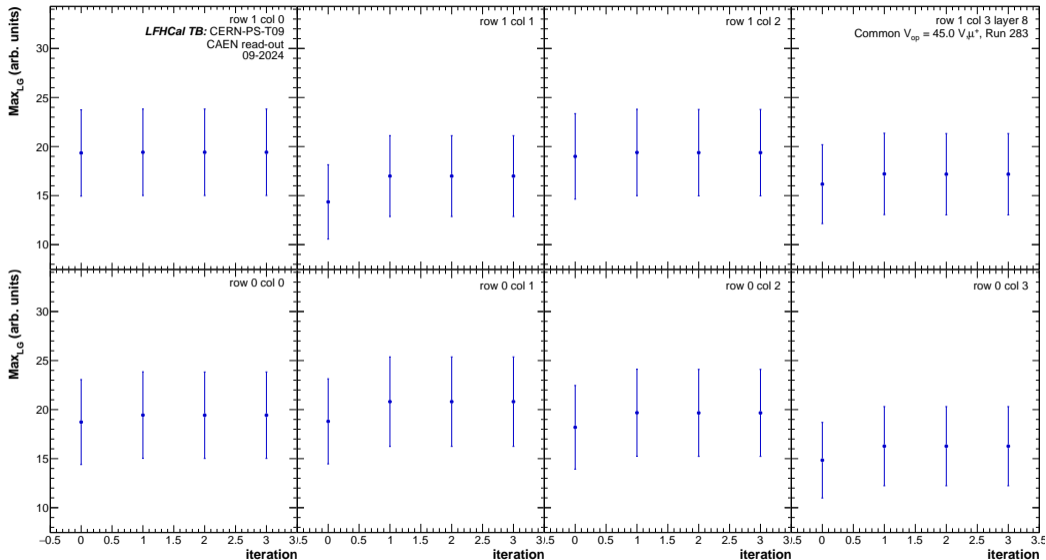
Muon calibration - Set 2: Muons - Iterations

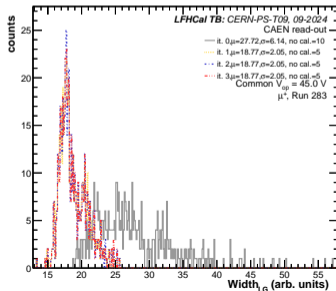
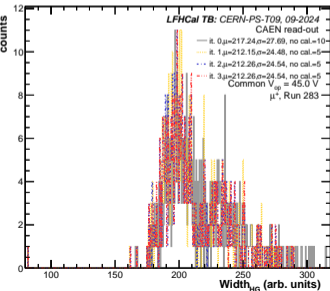
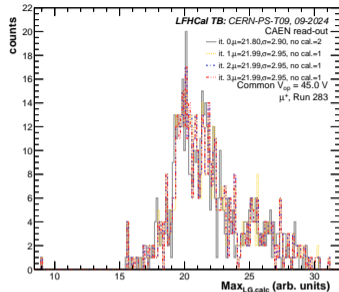
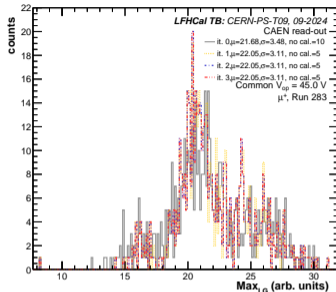
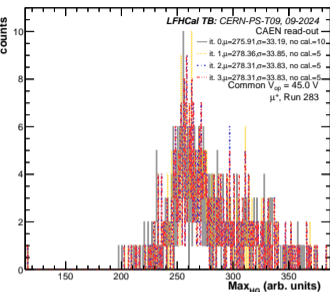


Muon calibration - Set 2: Muons - Iterations



Muon calibration - Set 2: Muons - Iterations



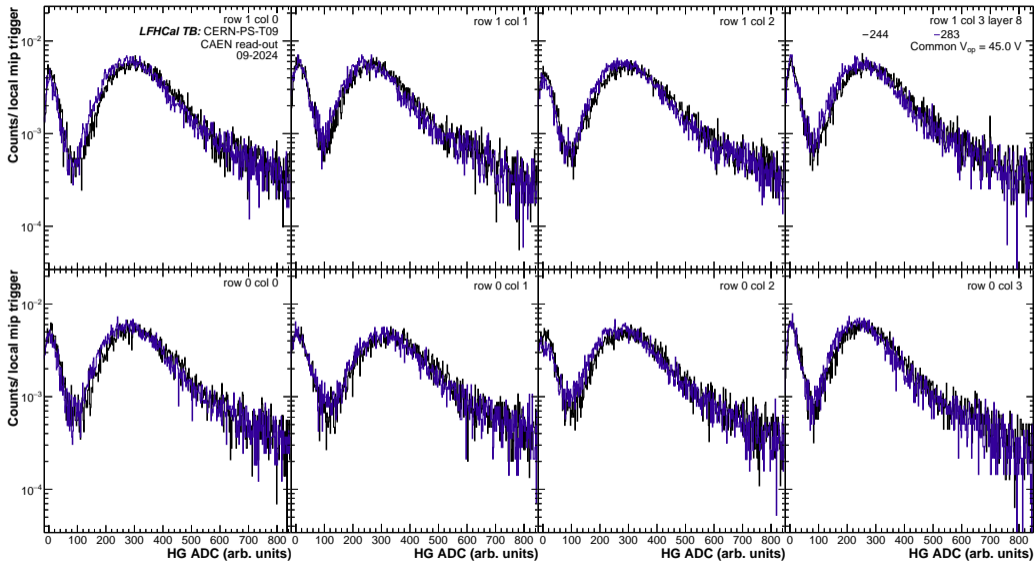


- Reduced mip selection range for trigger primitives
 $0.8 \langle Max_{HG,mip} \rangle < trigg_{prim} < 2 \langle Max_{HG,mip} \rangle$

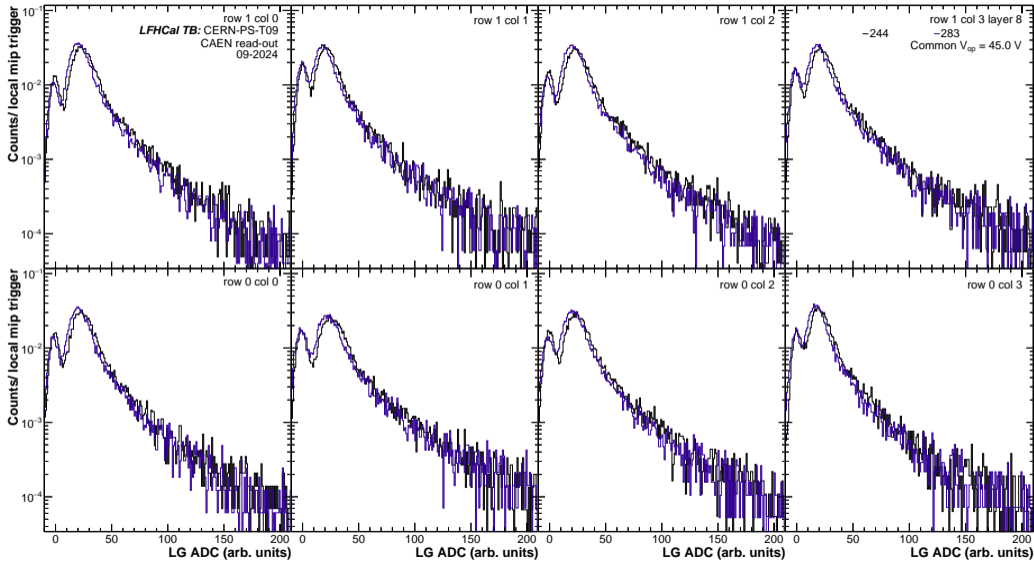
⇒ Further reduction of noise peak

- Refined fitting during improved iterations using average mip from previous iteration as basis for constraints
- Convergence of most cells within 2-3 iterations

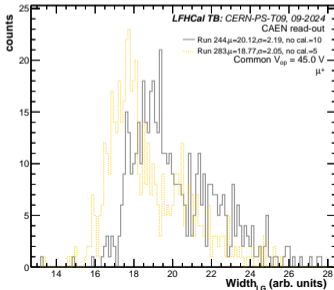
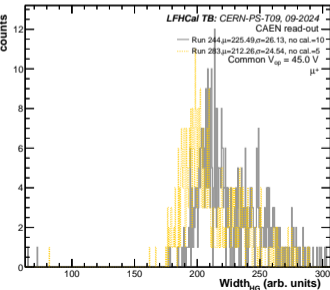
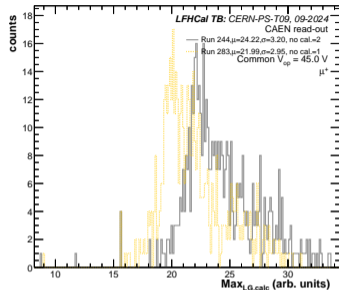
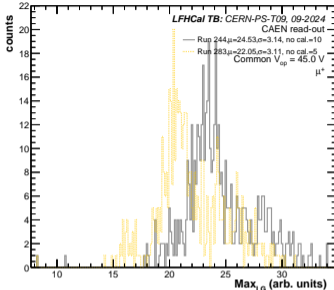
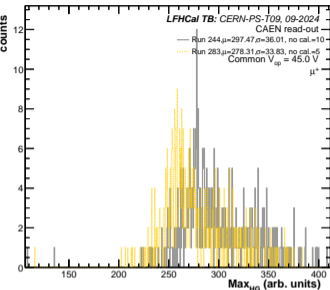
Muon calibration - Comparison Sets



Muon calibration - Comparison Sets

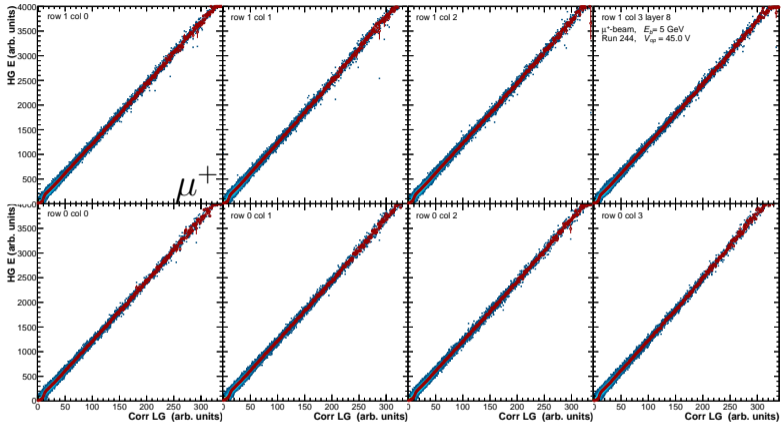


Muon calibration - Comparison Sets



- 2nd set significantly lower average mip max
- 2nd set smaller spread in nearly all quantities

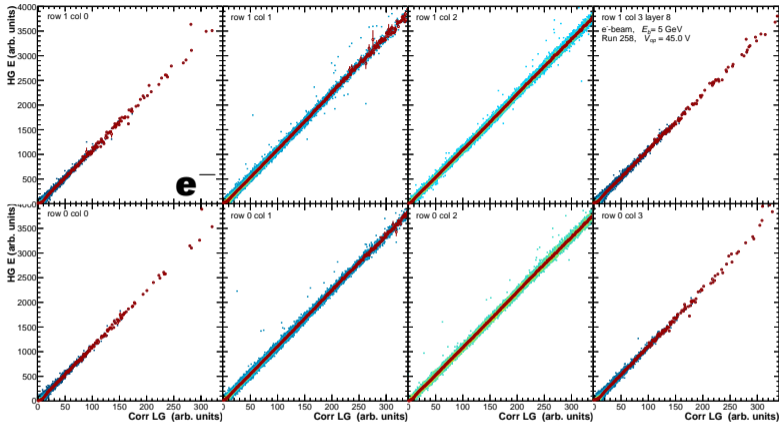
LG-HG correlation - Comparison Sets



μ^+ - Runs 244 & 283

- Slope ≈ 12.5
- Little spread, no additional bands

LG-HG correlation - Comparison Sets



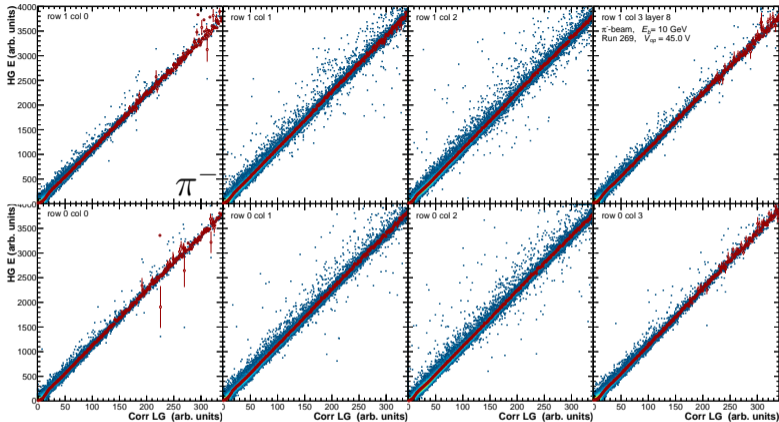
μ^+ - Runs 244 & 283

- Slope ≈ 12.5
- Little spread, no additional bands

e^- - Runs 251-258

- Significantly lower slope than μ^+
- Little spread, no additional bands
- Not enough ADC reach to calibrate all ch.
→ outer in each layer & later layers

LG-HG correlation - Comparison Sets



π^- - Runs 261-269

- Significantly lower slope than μ^+
- Common slope with e^-
- Little spread, no additional bands

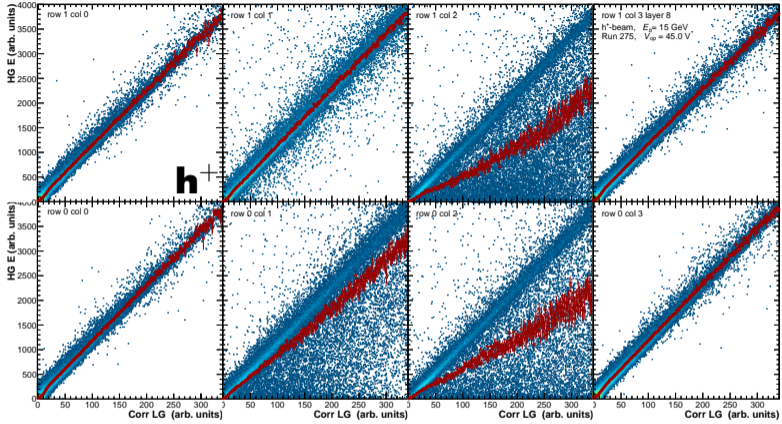
μ^+ - Runs 244 & 283

- Slope ≈ 12.5
- Little spread, no additional bands

e^- - Runs 251-258

- Significantly lower slope than μ^+
- Little spread, no additional bands
- Not enough ADC reach to calibrate all ch.
→ outer in each layer & later layers

LG-HG correlation - Comparison Sets



π^- - Runs 261-269

- Significantly lower slope than μ^+
- Common slope with e^-
- Little spread, no additional bands

h^+ - Runs 270-275

- Significantly lower slope than μ^+
- Mostly common slope with e^-
- Higher energy runs with add. band at HG=0, significantly larger number of off-diagonal elements
- Incident particle rate related?
- Can we get rid of these events? - reject whole event if for a cell $HG \approx 0 \& LG \gg 0$

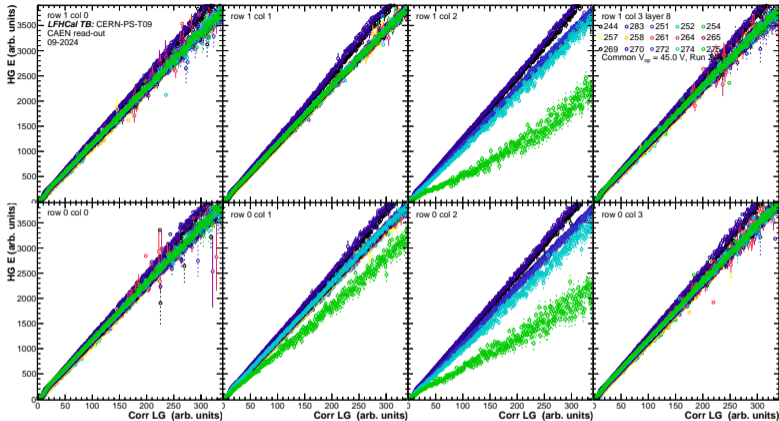
μ^+ - Runs 244 & 283

- Slope ≈ 12.5
- Little spread, no additional bands

e^- - Runs 251-258

- Significantly lower slope than μ^+
- Little spread, no additional bands
- Not enough ADC reach to calibrate all ch.
 → outer in each layer & later layers

LG-HG correlation - Comparison Sets



π^- - Runs 261-269

- Significantly lower slope than μ^+
- Common slope with e^-
- Little spread, no additional bands

h^+ - Runs 270-275

- Significantly lower slope than μ^+
- Mostly common slope with e^-
- Higher energy runs with add. band at $HG=0$, significantly larger number of off-diagonal elements
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μ^+ - Runs 244 & 283

- Slope ≈ 12.5
- Little spread, no additional bands

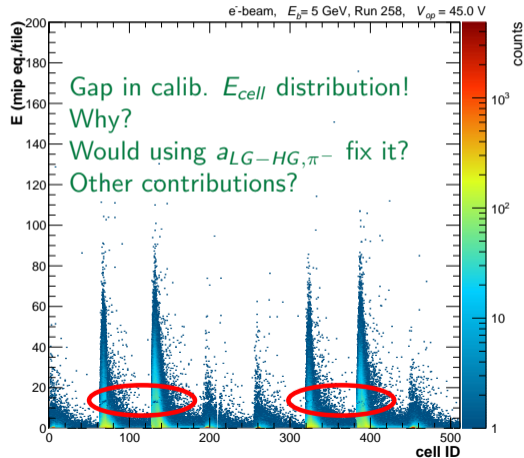
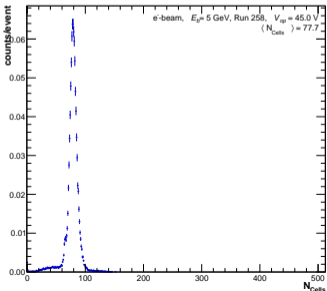
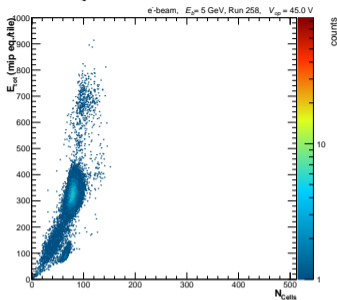
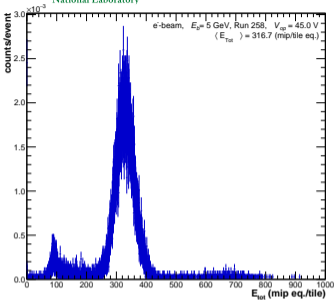
e^- - Runs 251-258

- Significantly lower slope than μ^+
- Little spread, no additional bands
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→ outer in each layer & later layers

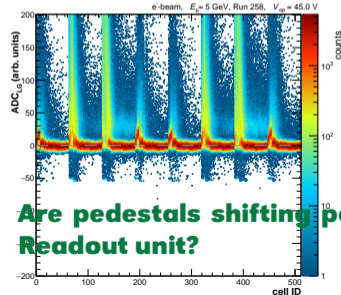
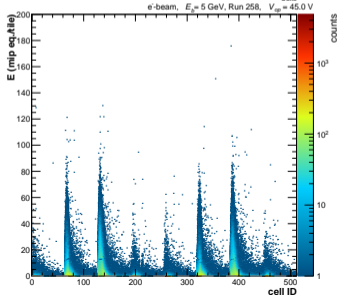
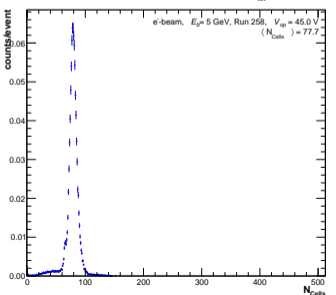
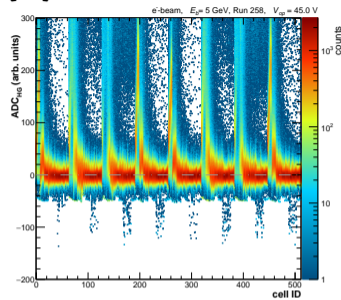
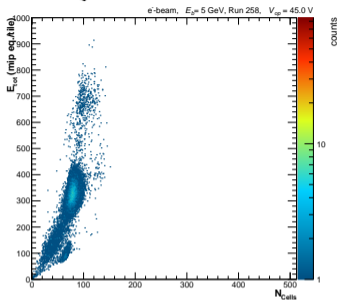
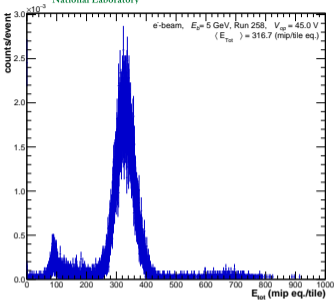
Direct comparison

- Cells with high energy deposits significantly distorted for h^+ , $E \geq 10\text{GeV}$
- Use a_{LG-HG} from π^- runs for calib of h^\pm & e^- ?

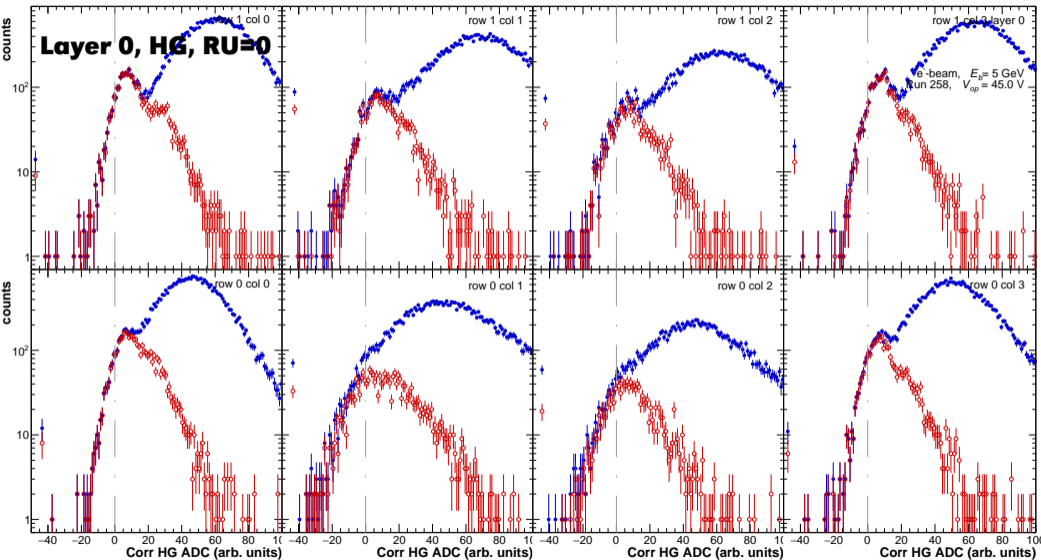
QA: e^- , $E = 5 \text{ GeV}$ (1)



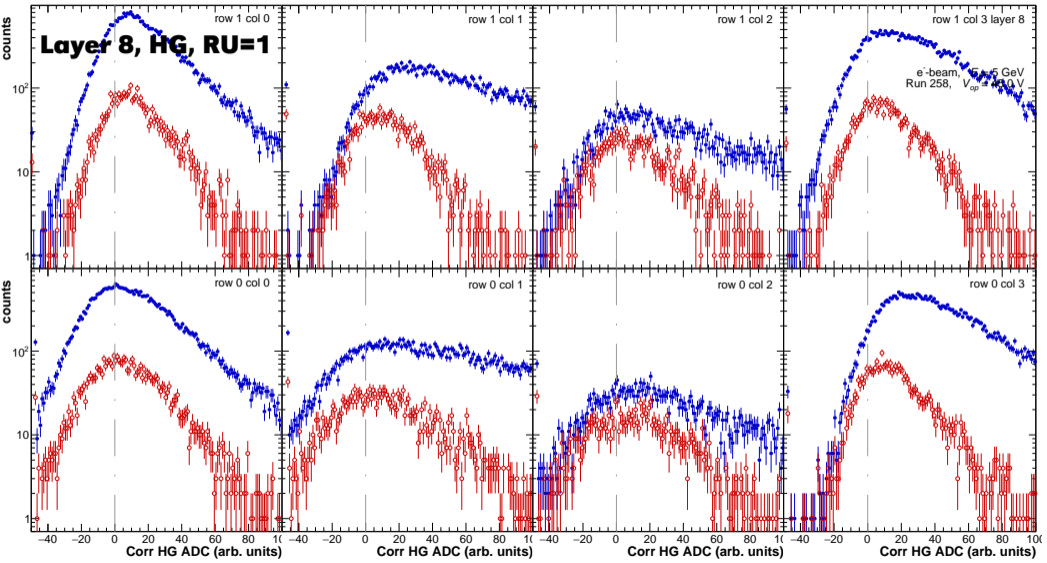
QA: e^- , $E = 5$ GeV (1)



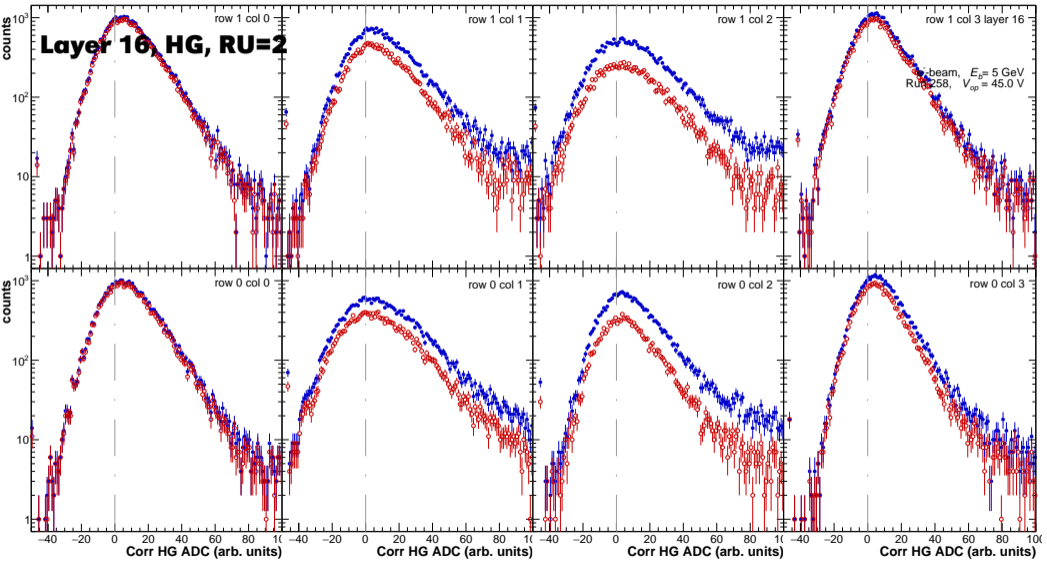
Are pedestals shifting per Readout unit?



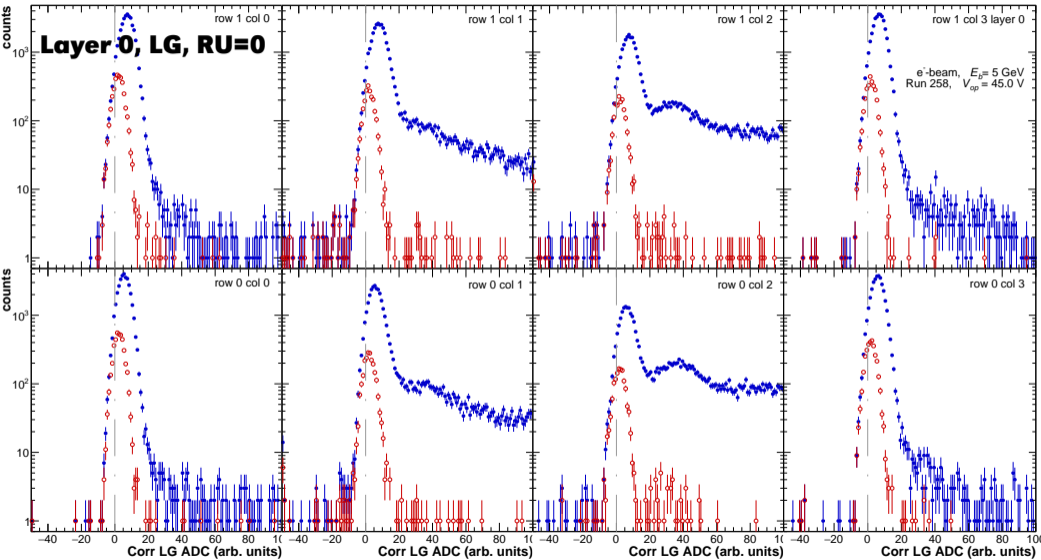
- Attempt to isolate noise triggers
- Pedestal shifts seem to correlate with total charge in RU
- LG shifted less than HG
- Offset consistent per layer



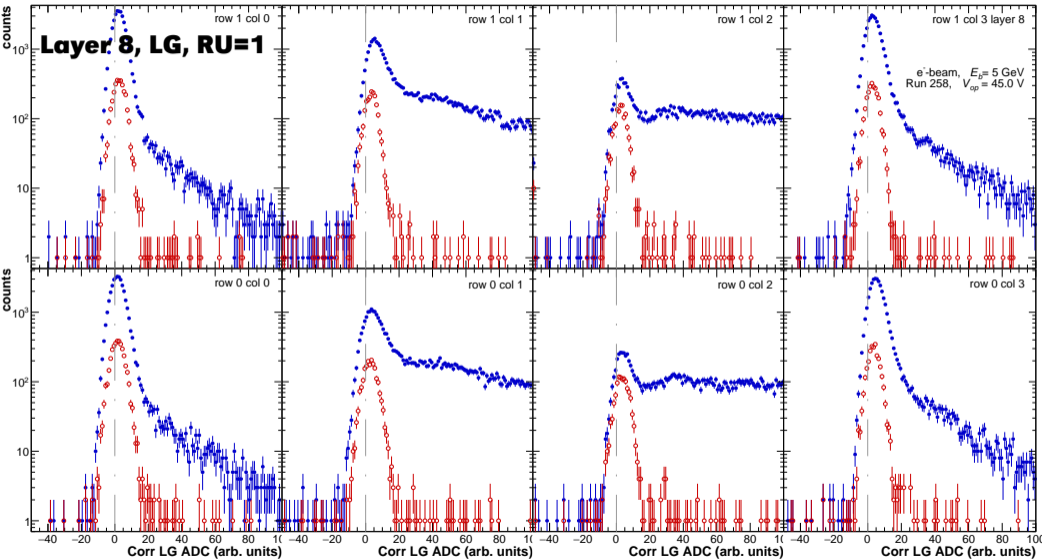
- Attempt to isolate noise triggers
- Pedestal shifts seem to correlate with total charge in RU
- LG shifted less than HG
- Offset consistent per layer



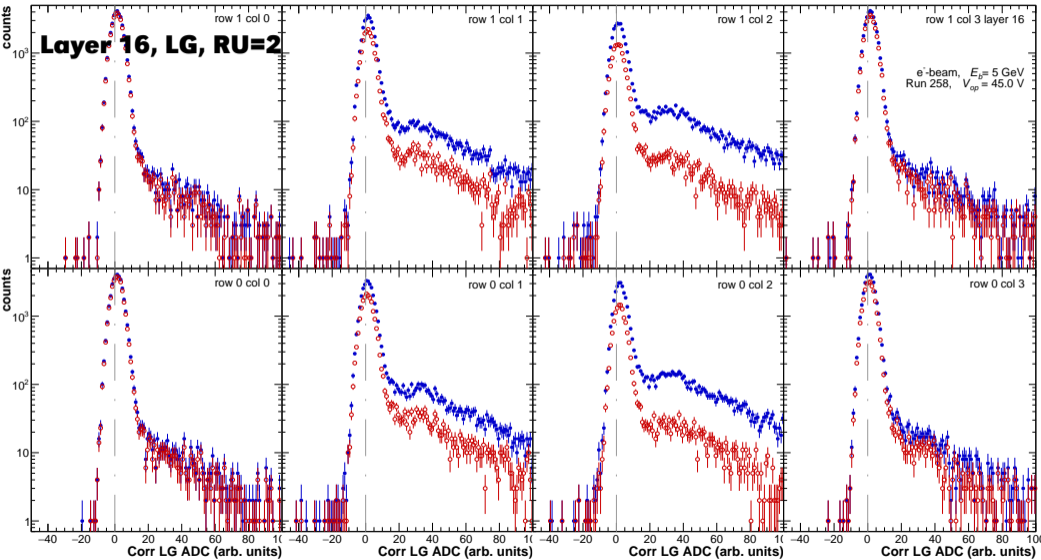
- Attempt to isolate noise triggers
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- LG shifted less than HG
- Offset consistent per layer



- Attempt to isolate noise triggers
- Pedestal shifts seem to correlate with total charge in RU
- LG shifted less than HG
- Offset consistent per layer

2024 TB - CAEN Readout Next steps

Next steps

- Redo event time difference evaluation
 - Can we find a time difference cut restoring same conditions for LG-HG corr as for muons
 - Can we get rid of these weird $HG = 0$ events like that?
- Attempt to remove events where a channel had $HG = 0$ but $LG > XX$ after pedestal subtraction
- Evaluate LG-HG corr values based off π^- runs & patch calib objects
- Reevaluate pedestal per layer for physics runs?