HyCal Gain Stability Using the LMS

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Introduction

- Design Goal: To monitor and track the gain changes of each HyCal channel with an accuracy of $\pm 0.1 - 0.2$ %.
- Method: Flash each channel with known relative amount of light and acquire ADC responses, ADC_i^{LMS}. Monitor variations in light source with a set of reference counters (ADC_{Ref}^{LMS}); monitor gain of reference counters with radioactive alpha source (ADC_{Ref}^{YAP}).

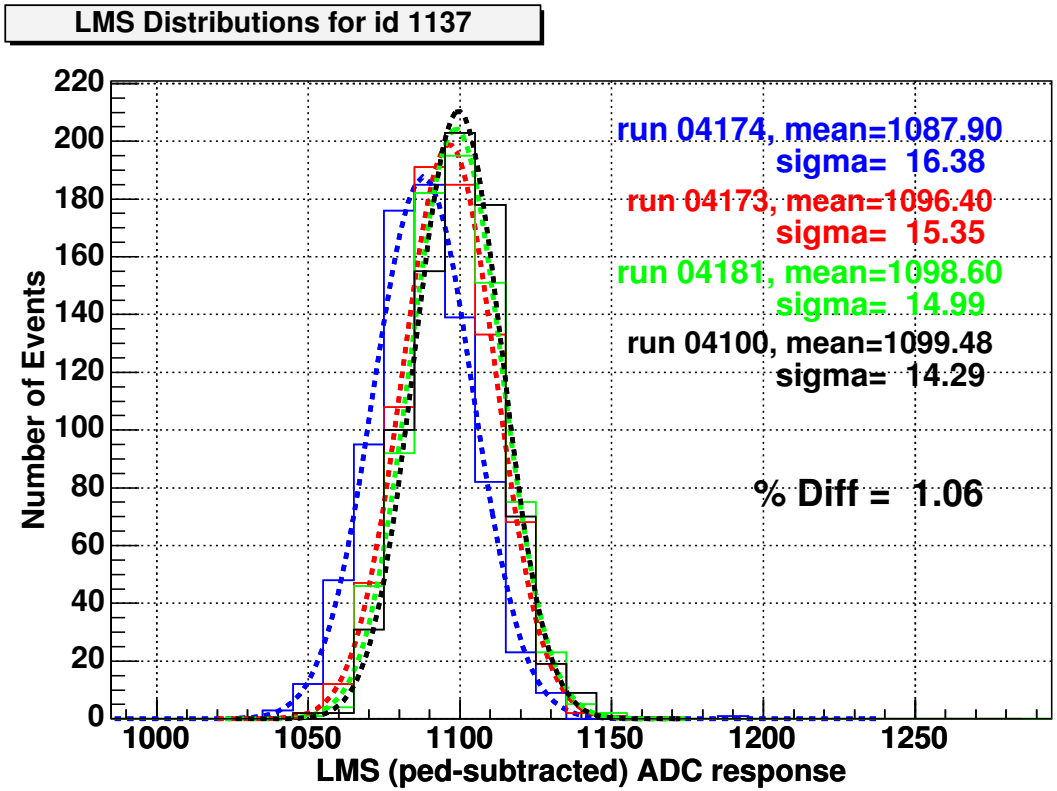
$$\text{Normalized ADC response} : N_i(t) = \overline{ADC}_i^{LMS}(t) \cdot \frac{\overline{ADC}_{Ref}^{YAP}(t)}{\overline{ADC}_{Ref}^{LMS}(t)} \quad (1)$$

$$\text{Cluster energy} : E(t) = \sum E_i(t) \cdot g_i(t), \text{ where } E_i(t) = \alpha_i \cdot ADC_i^{REAL}(t), \quad (2)$$

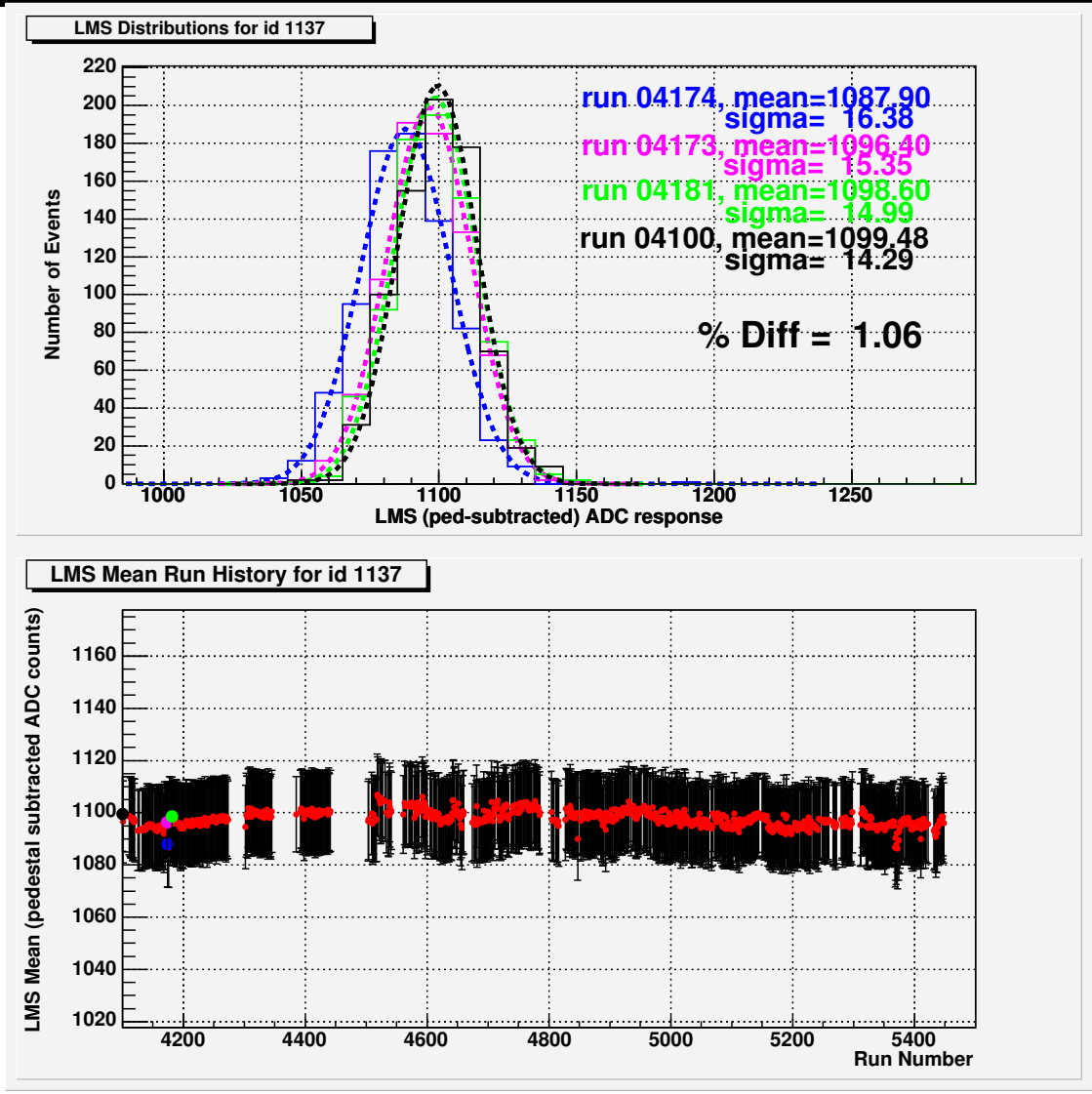
$$\text{and LMS gain factor} : g_i(t) = \frac{N_i(t_0)}{N_i(t)} \quad (3)$$

Short Term LMS Gain Stability: Beam Rate Dependence

- A $1-5$ % shift in the LMS ADC mean reponse has been observed for HyCal channel id's which were near the beam during the second phase of snake calibration runs.



Short Term LMS Gain Stability: Beam Rate Dependence



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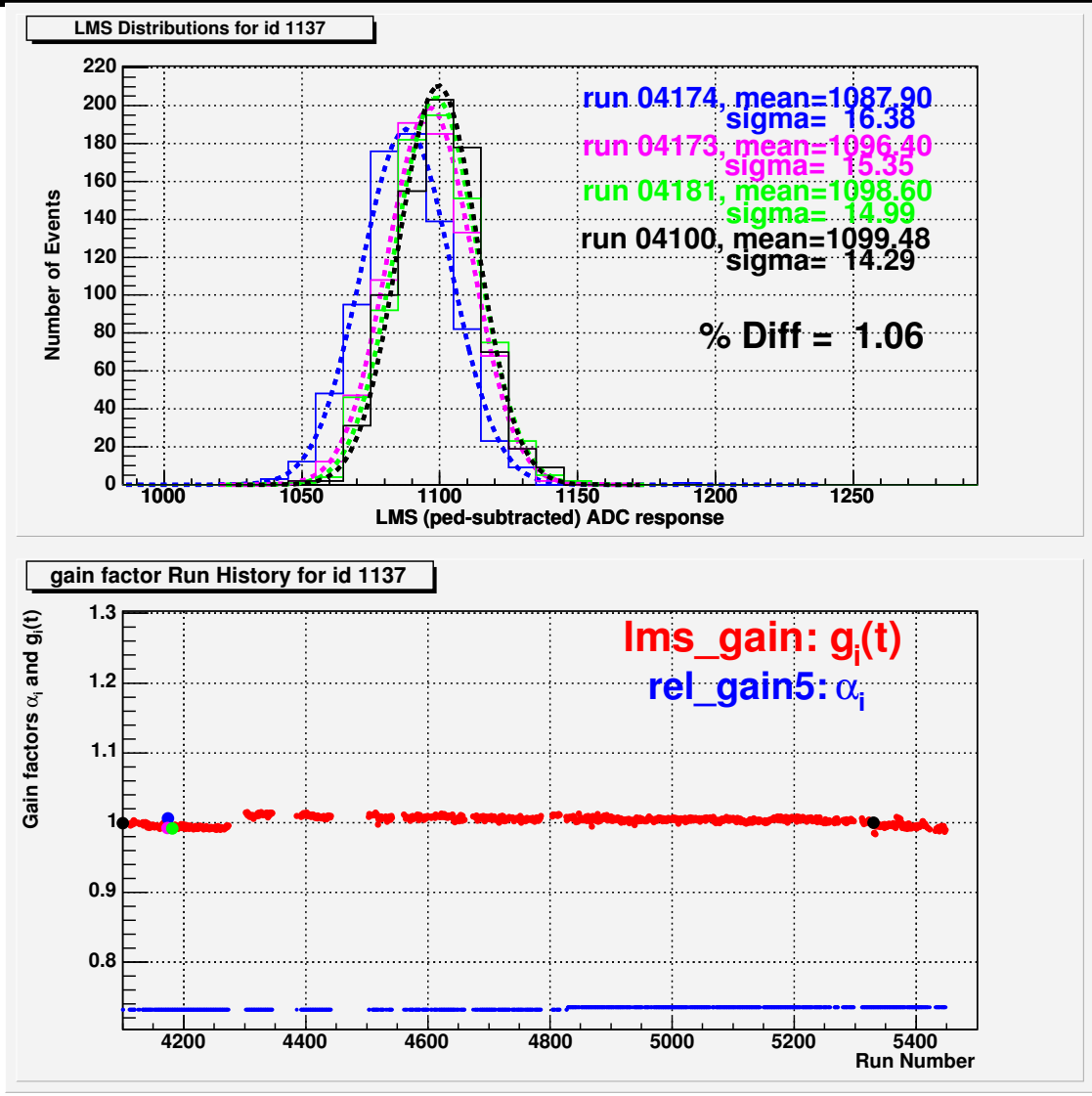

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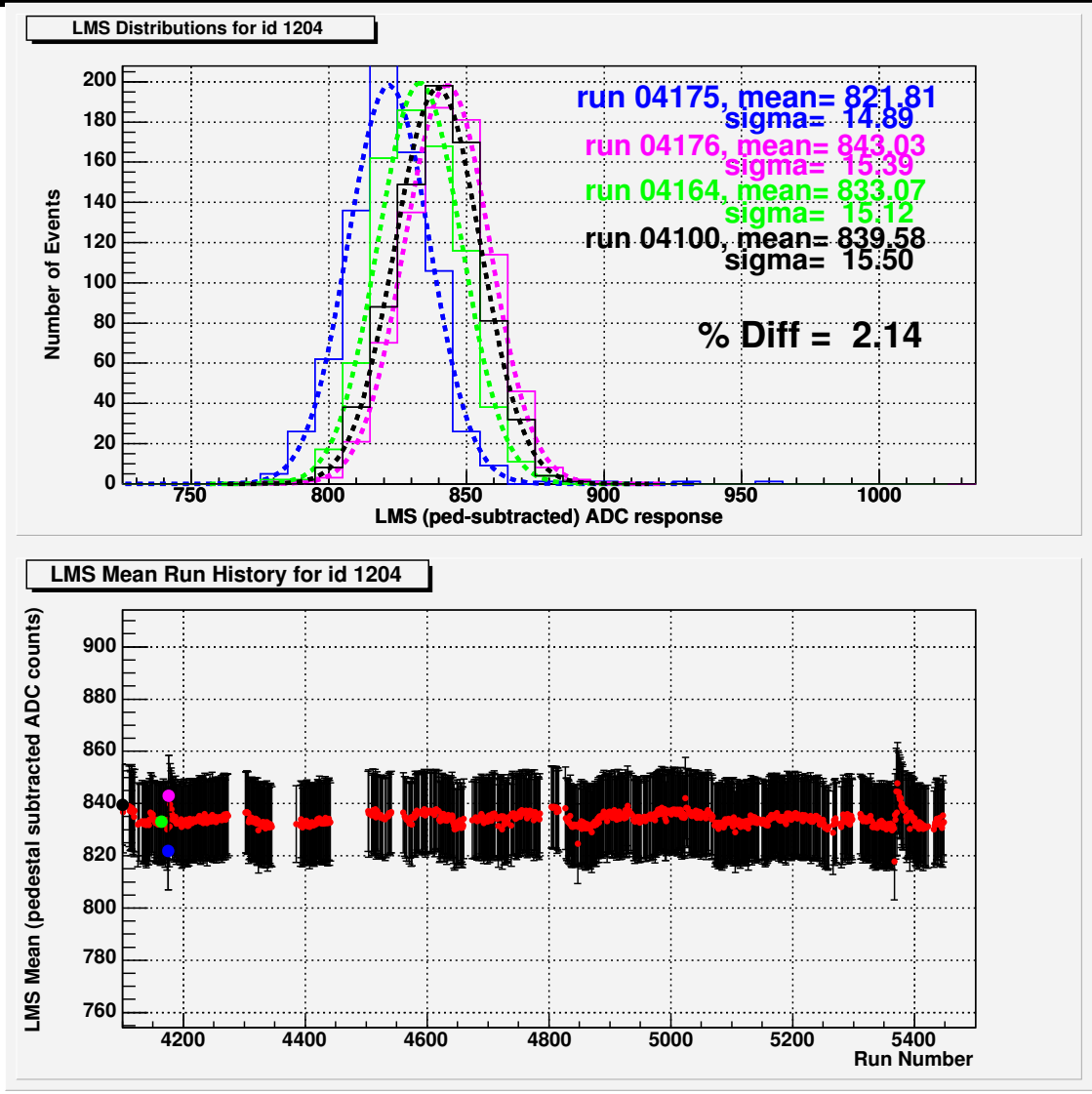

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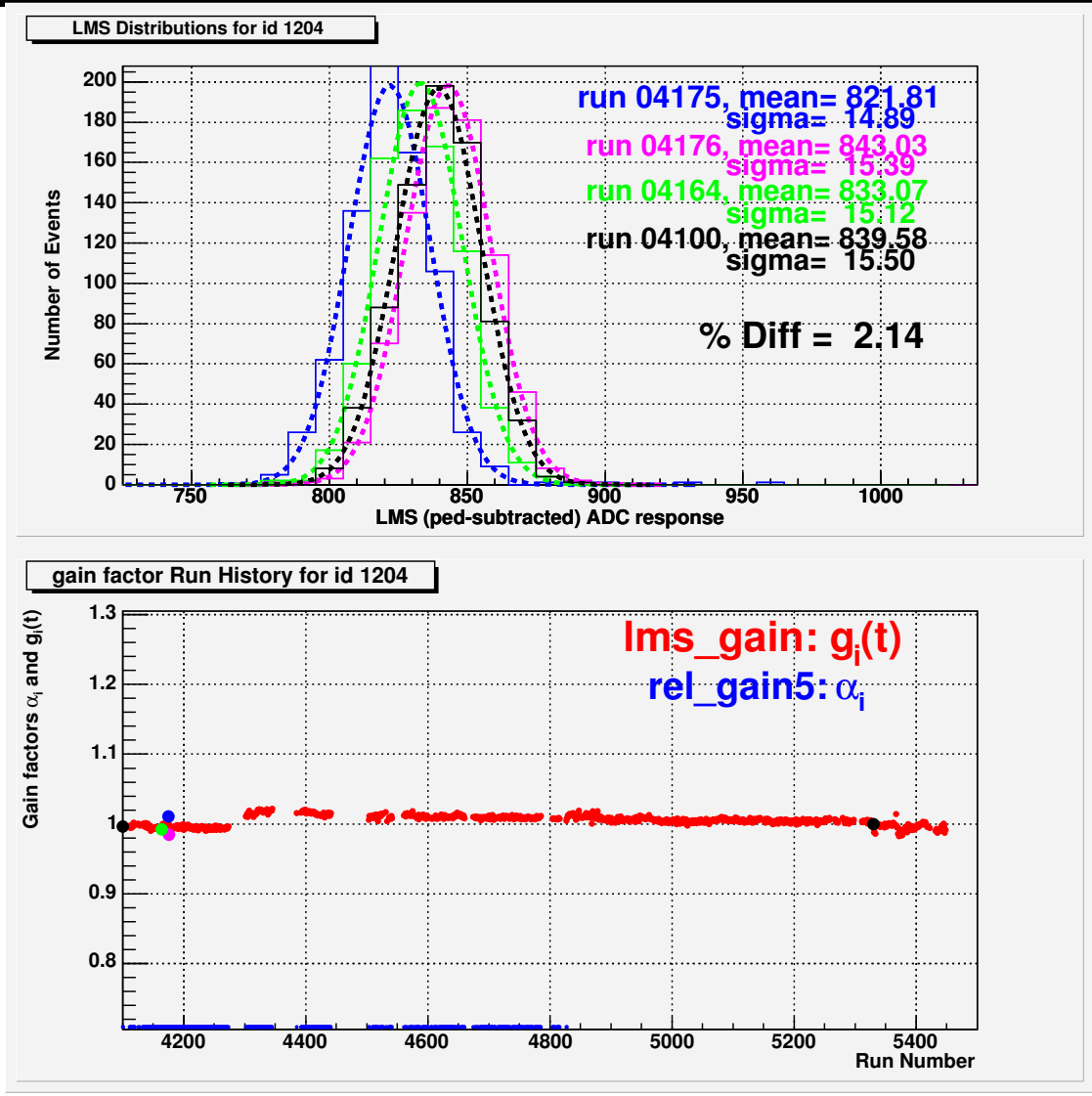

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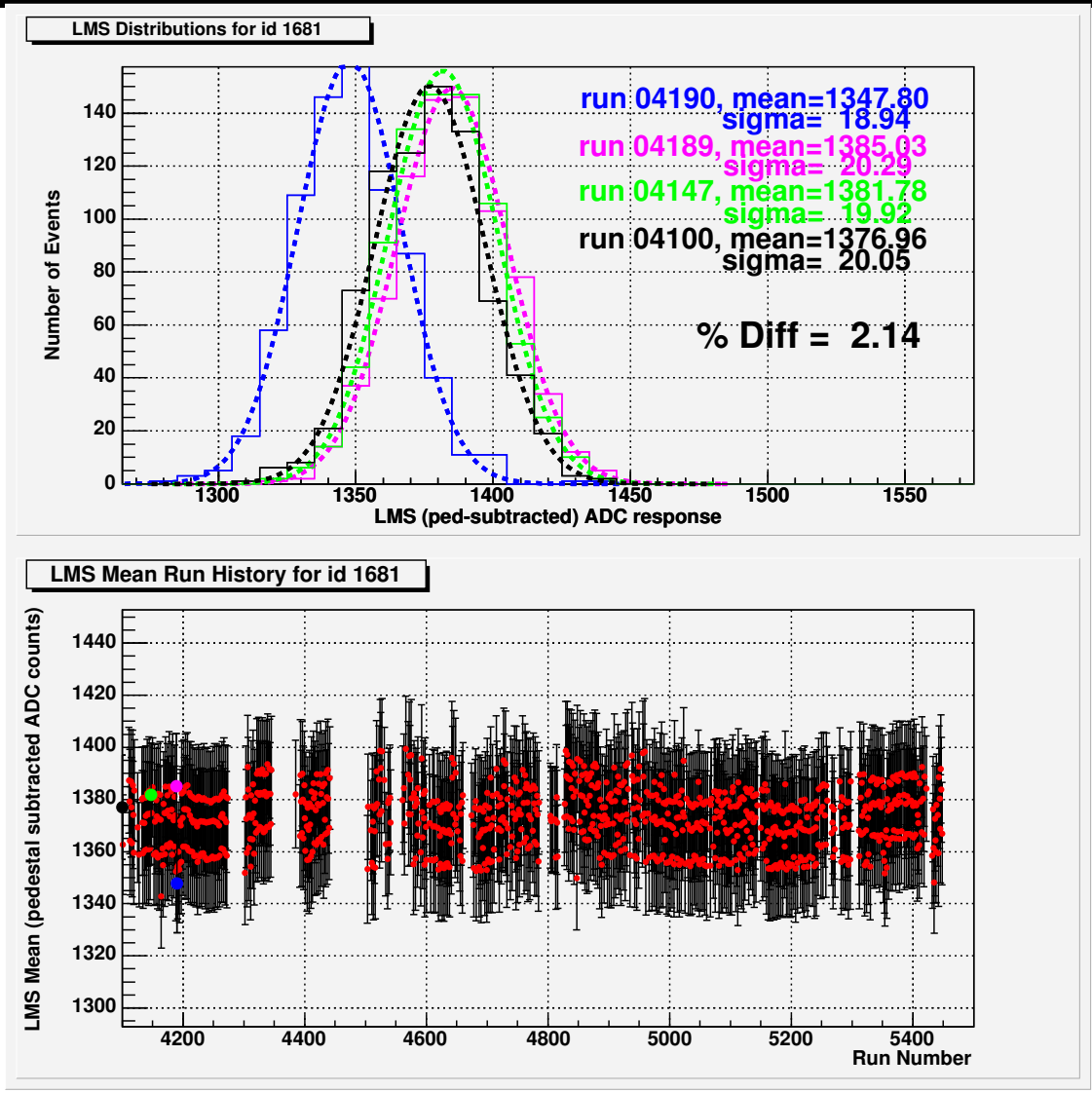

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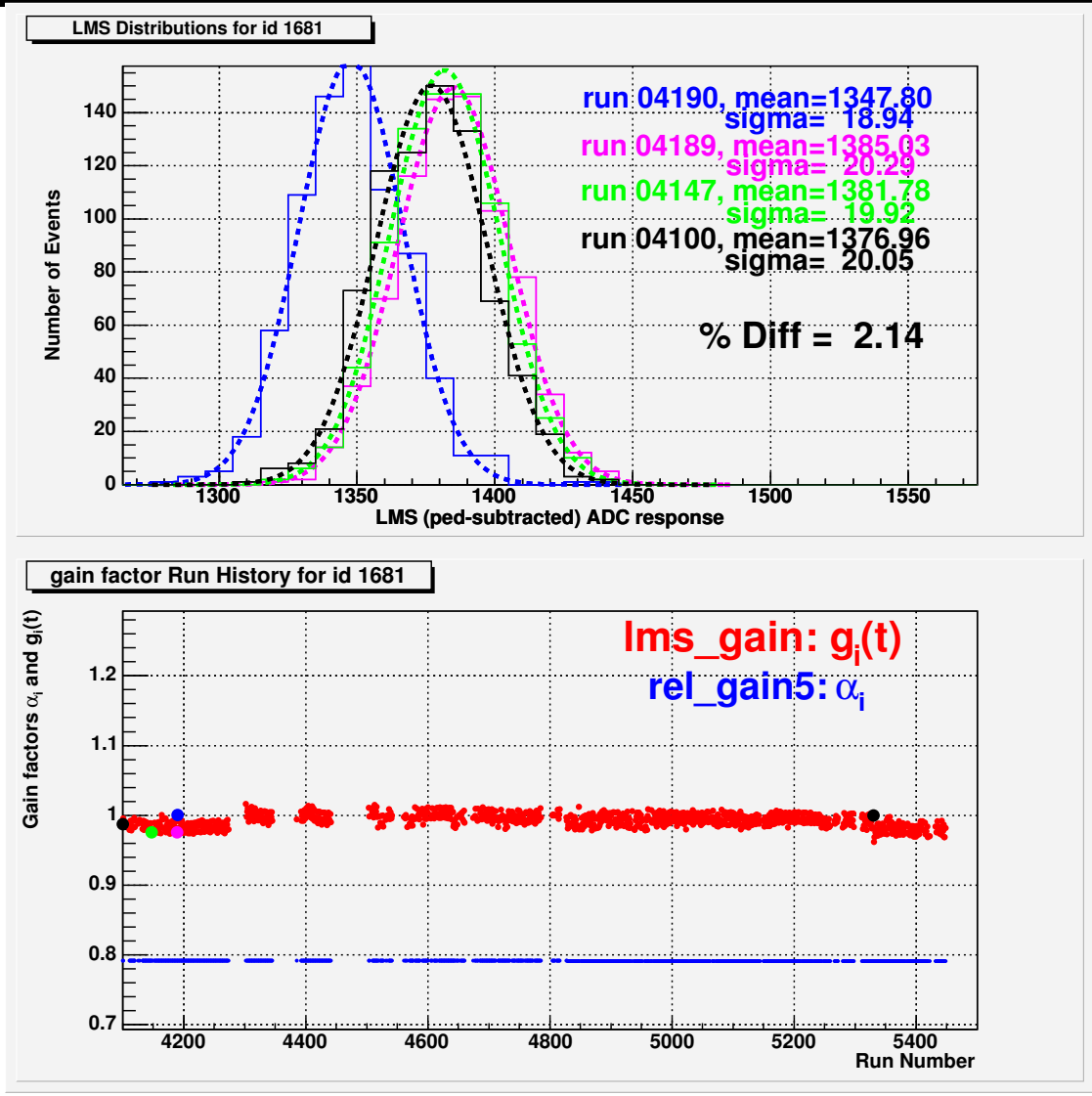

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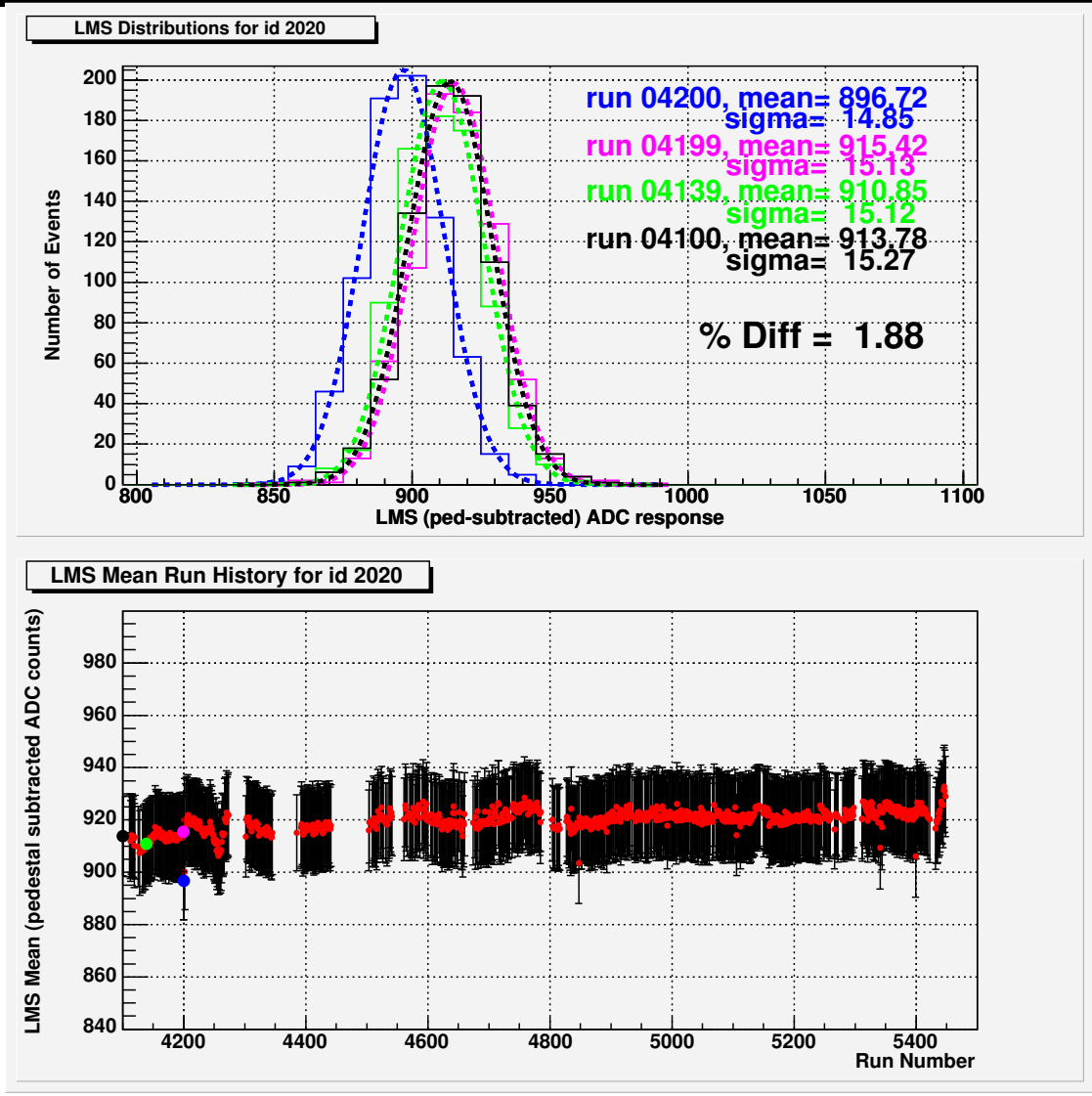

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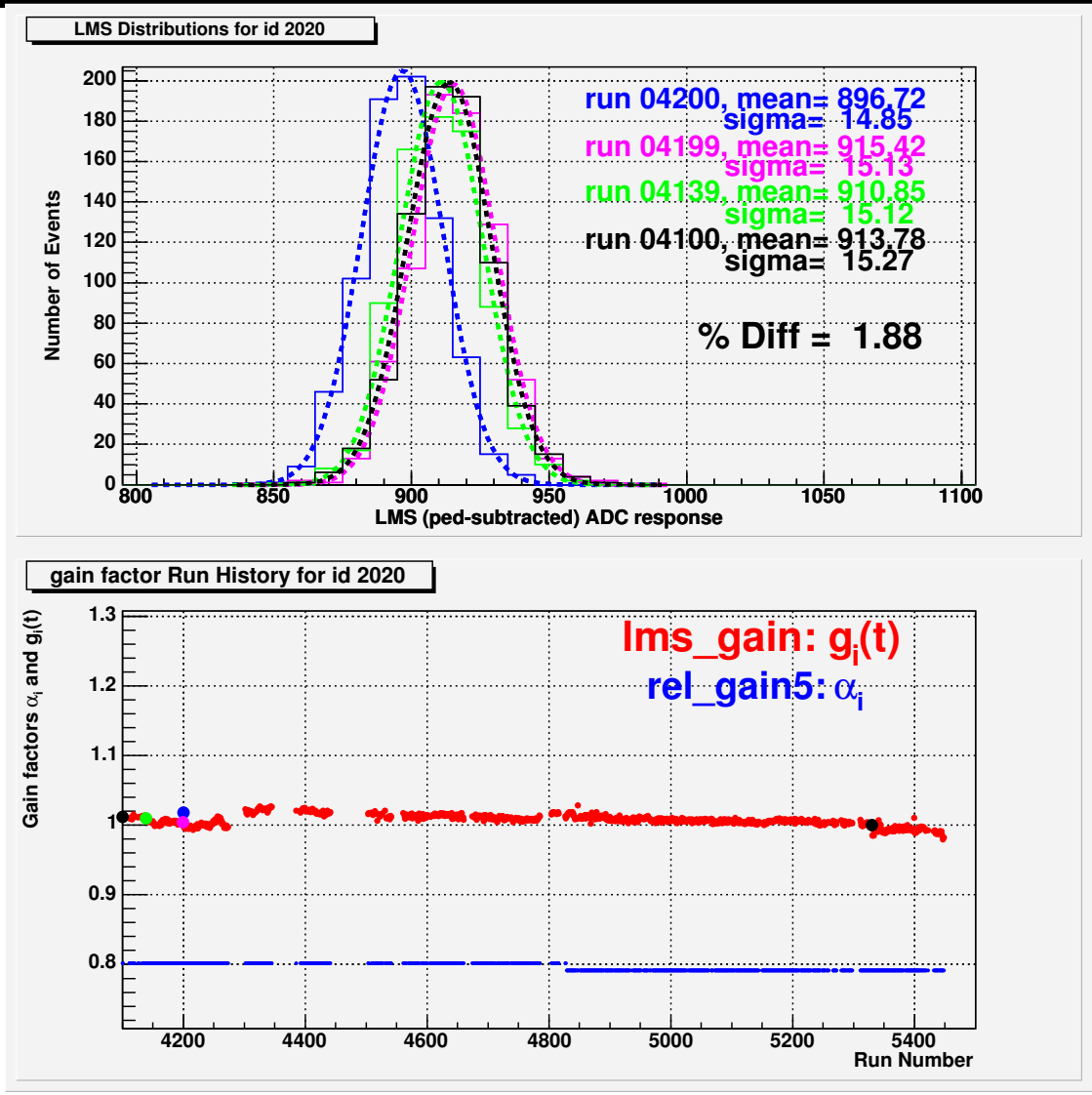

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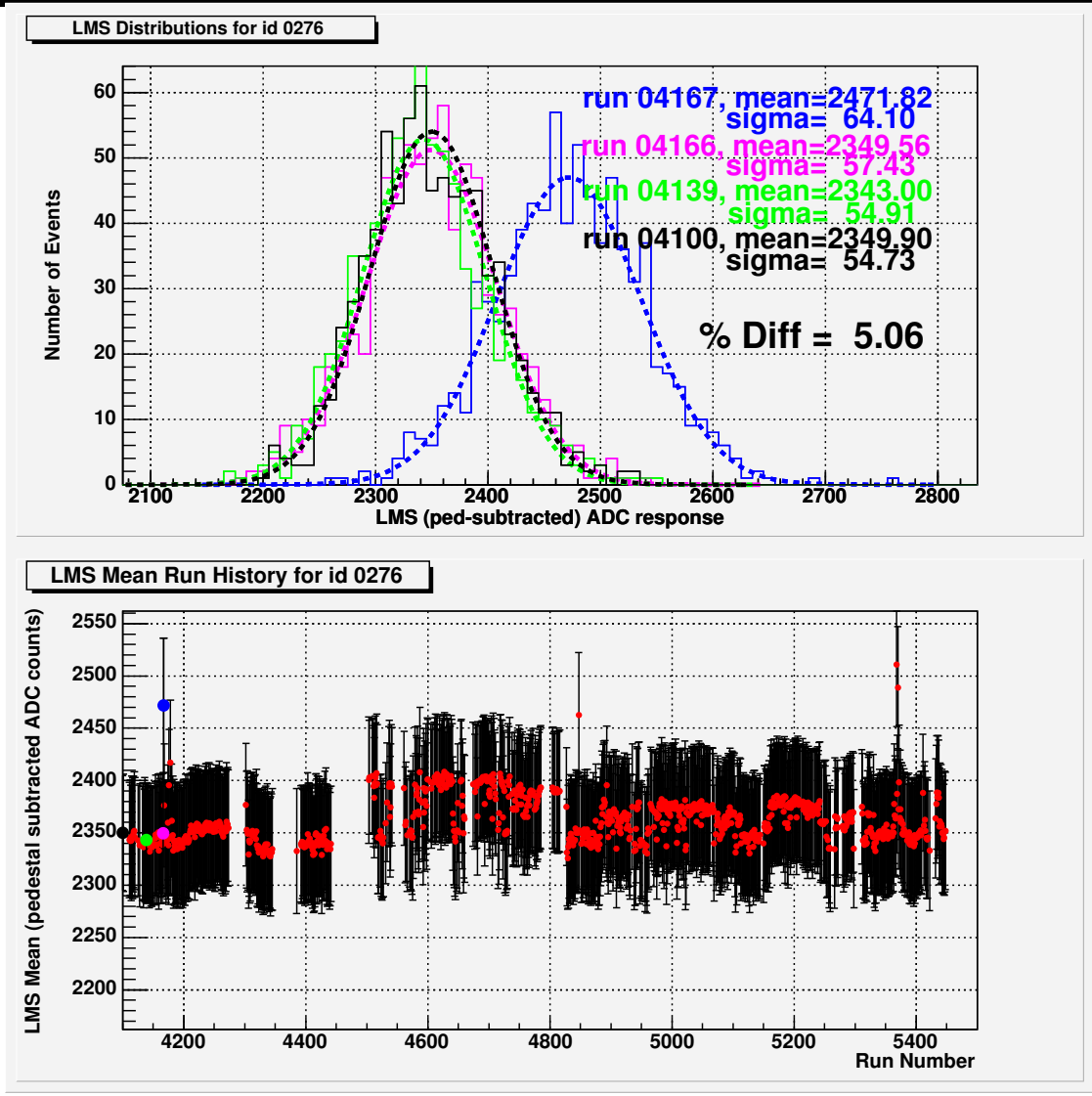

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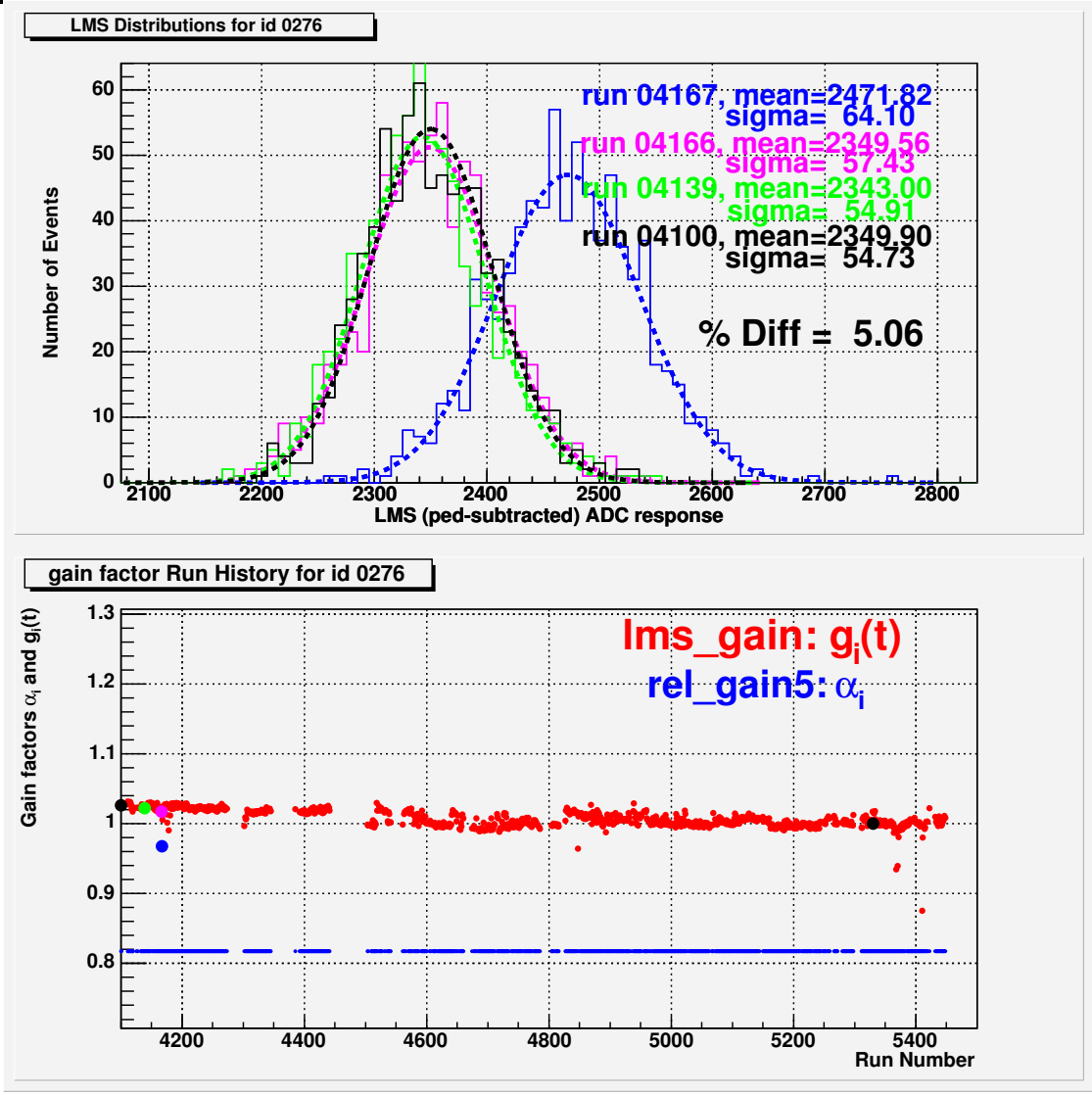

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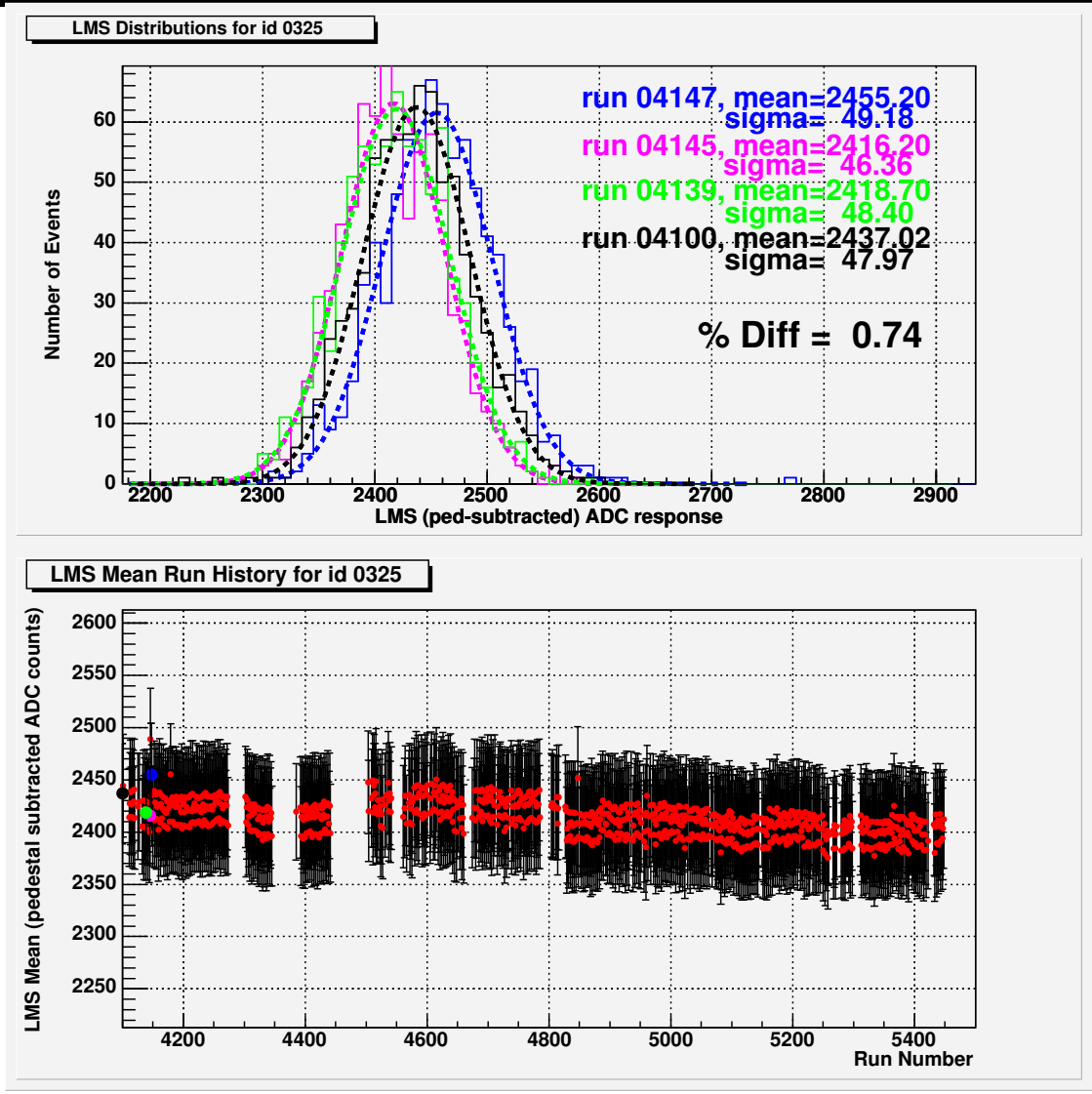

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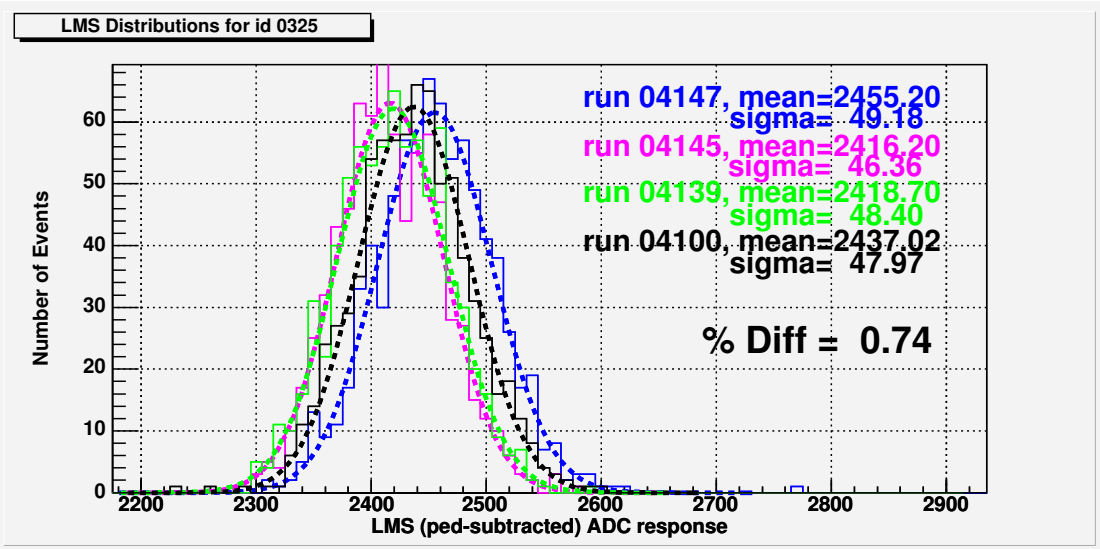

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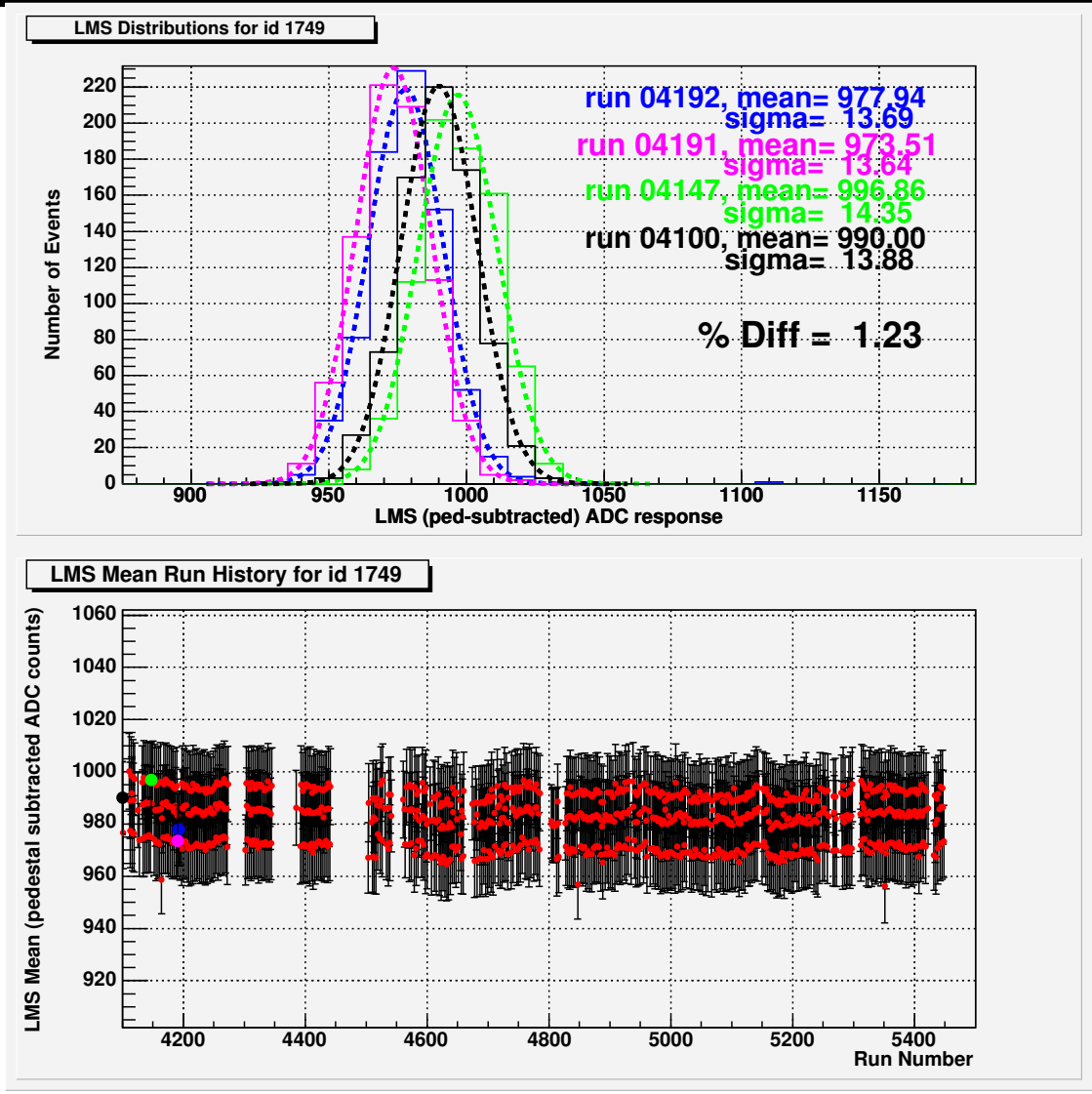

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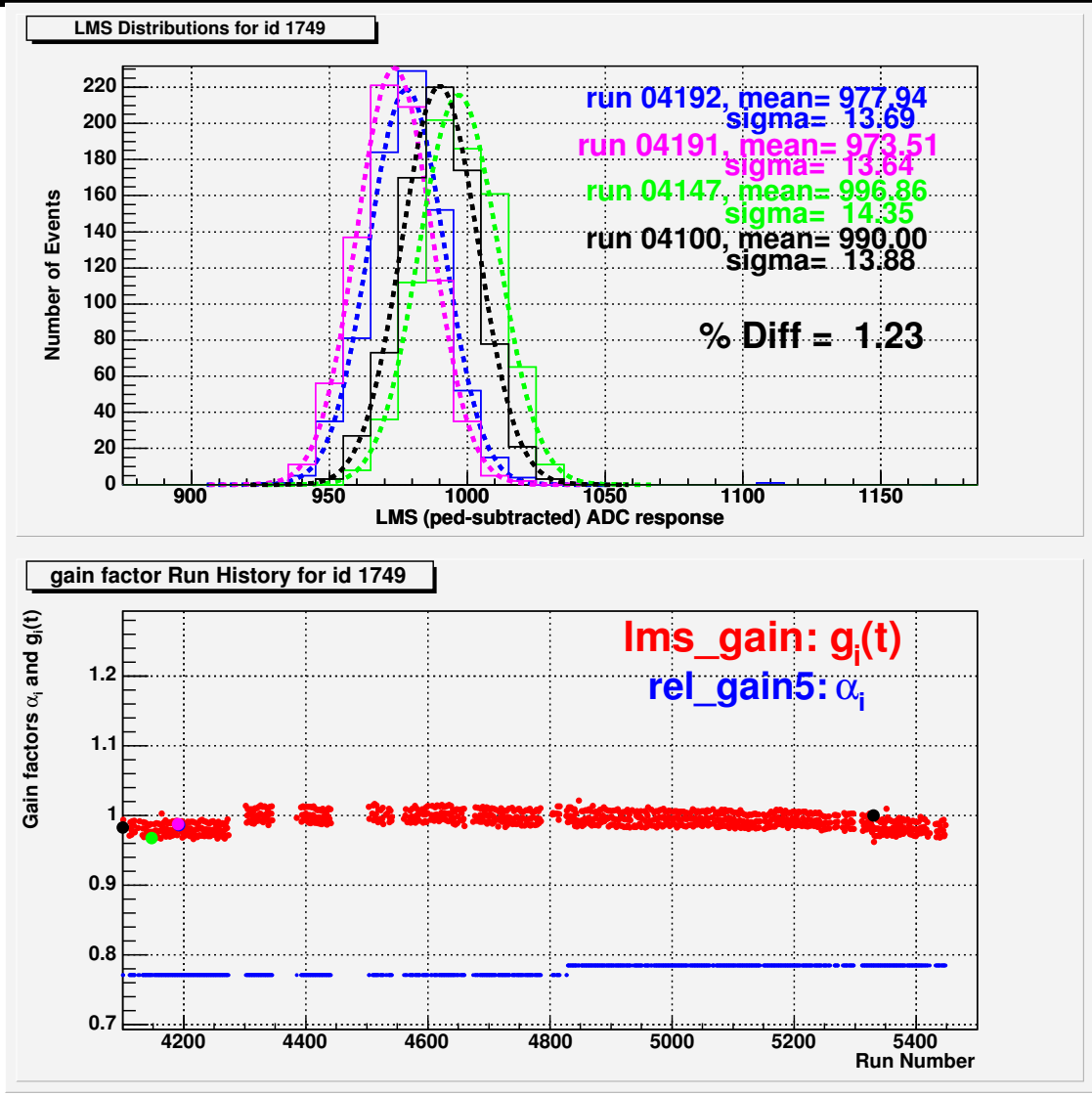
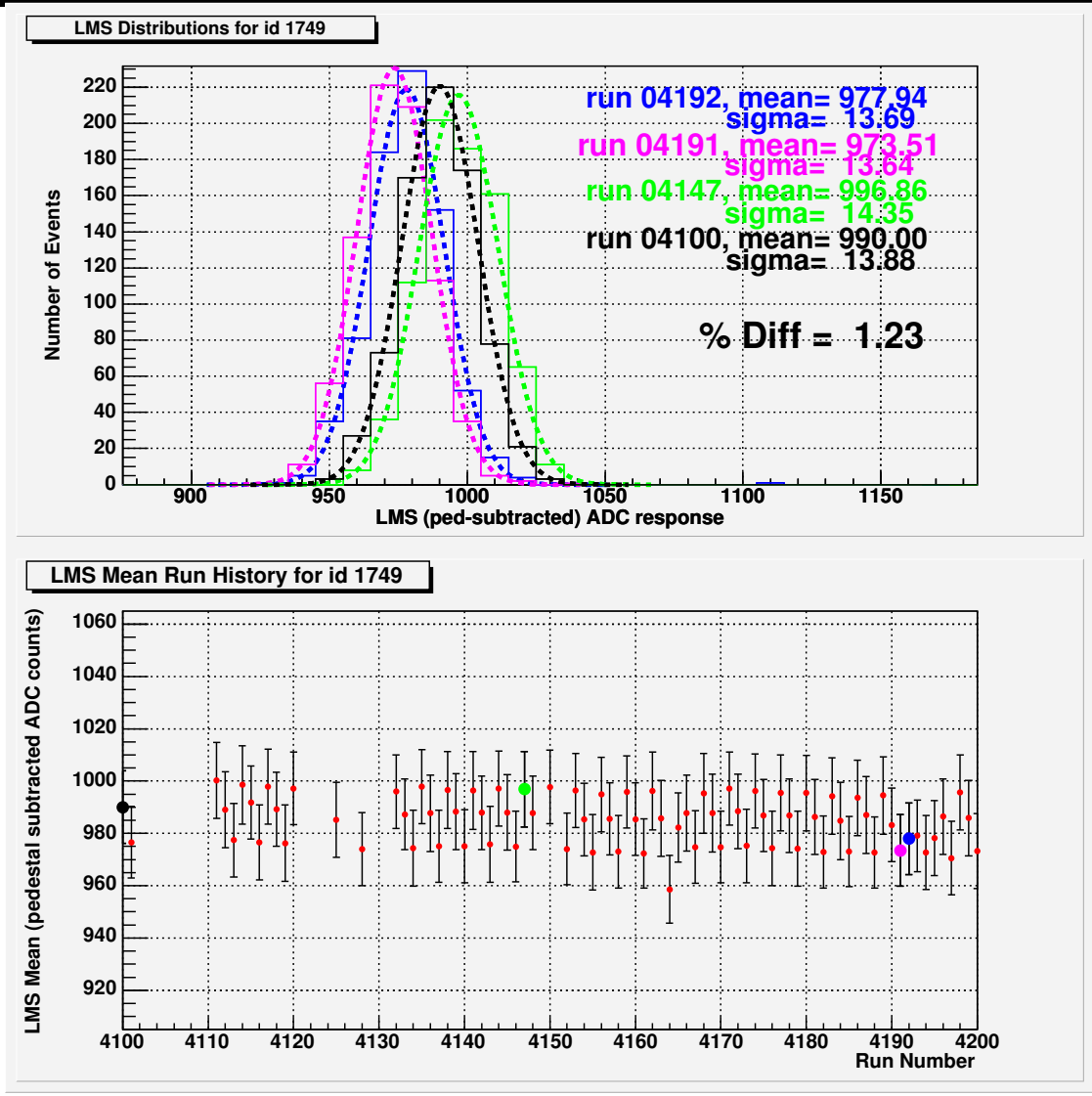


Short Term LMS Gain Stability: Bi/Tri-modal Response



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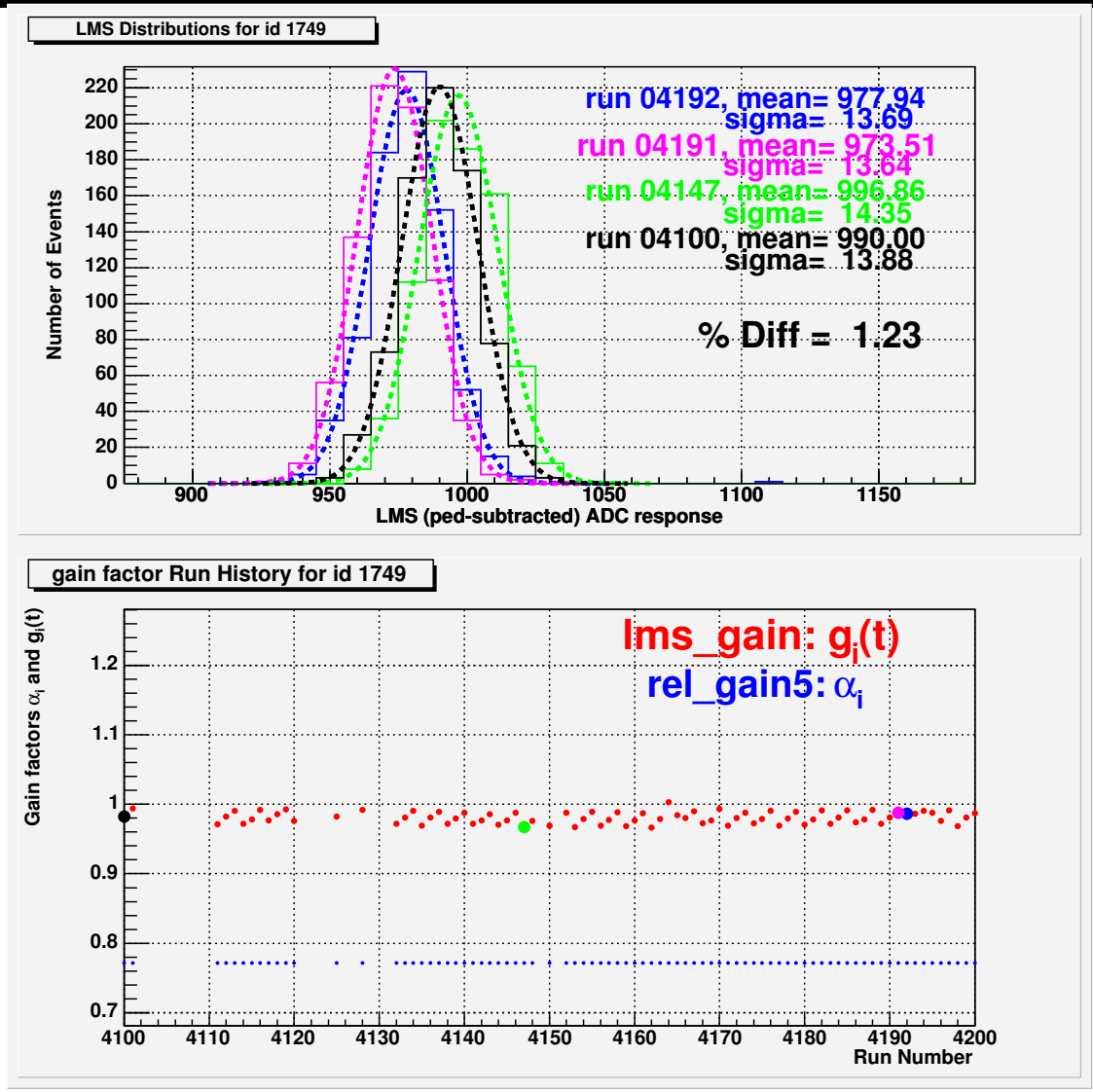

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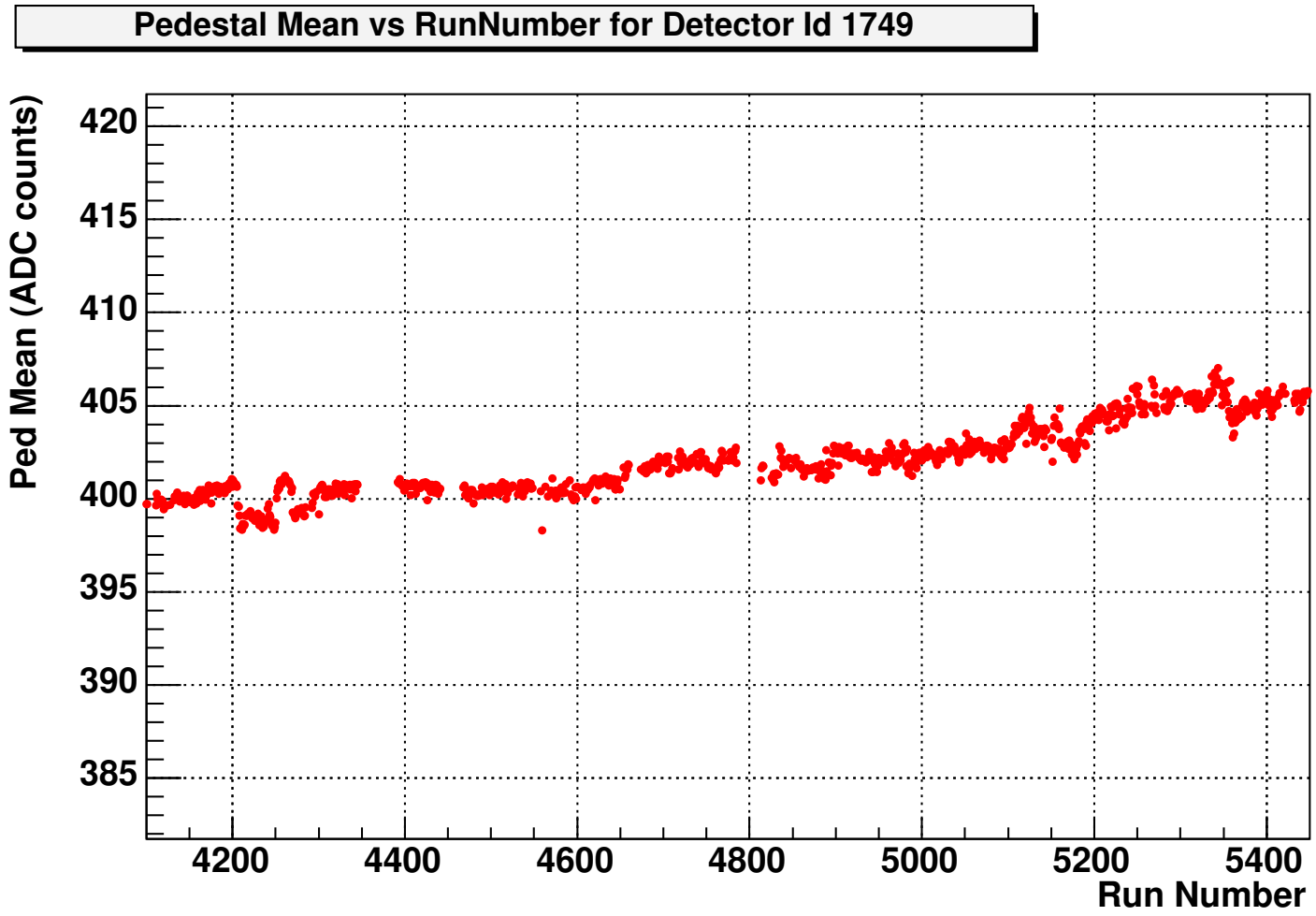
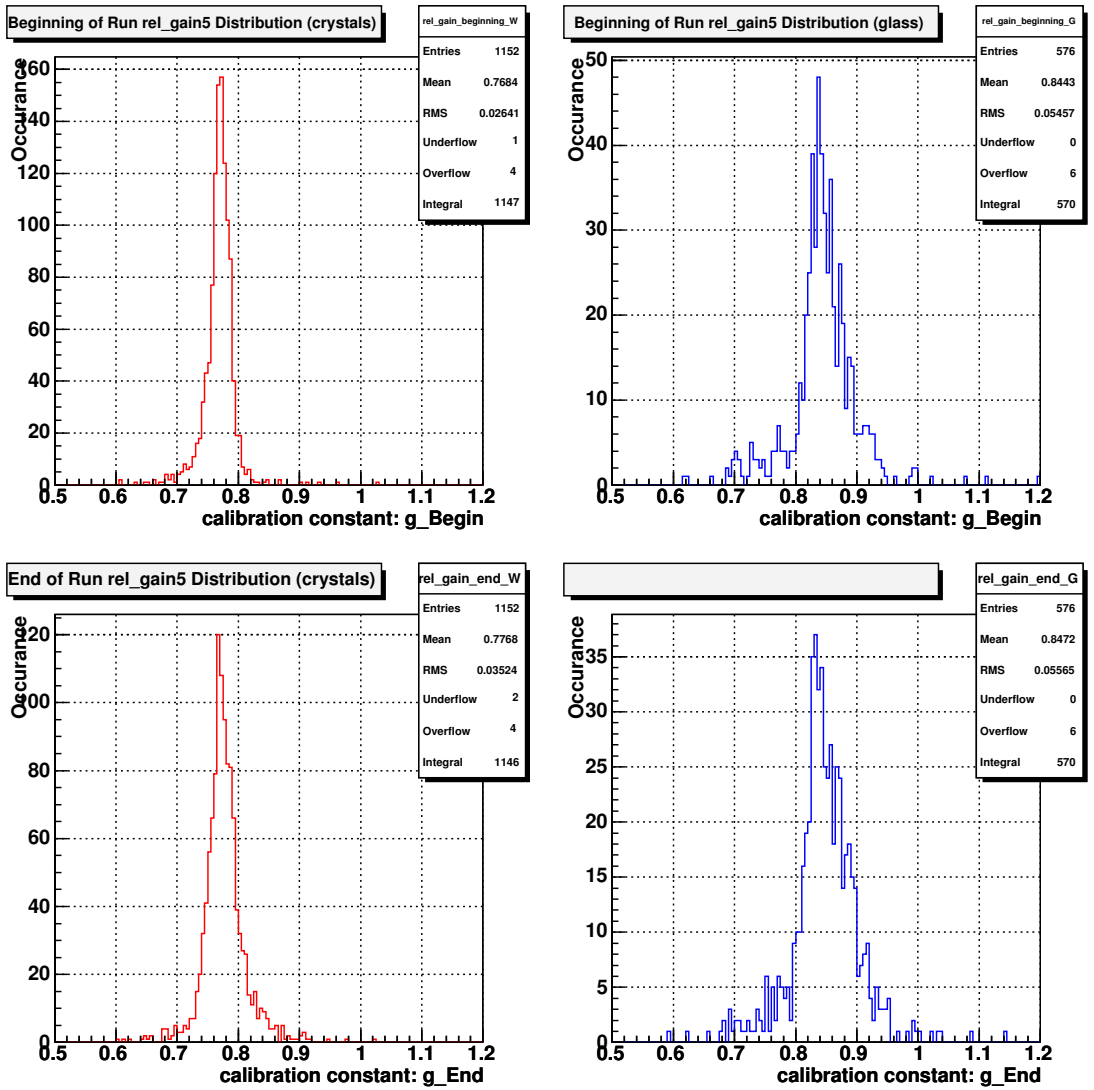


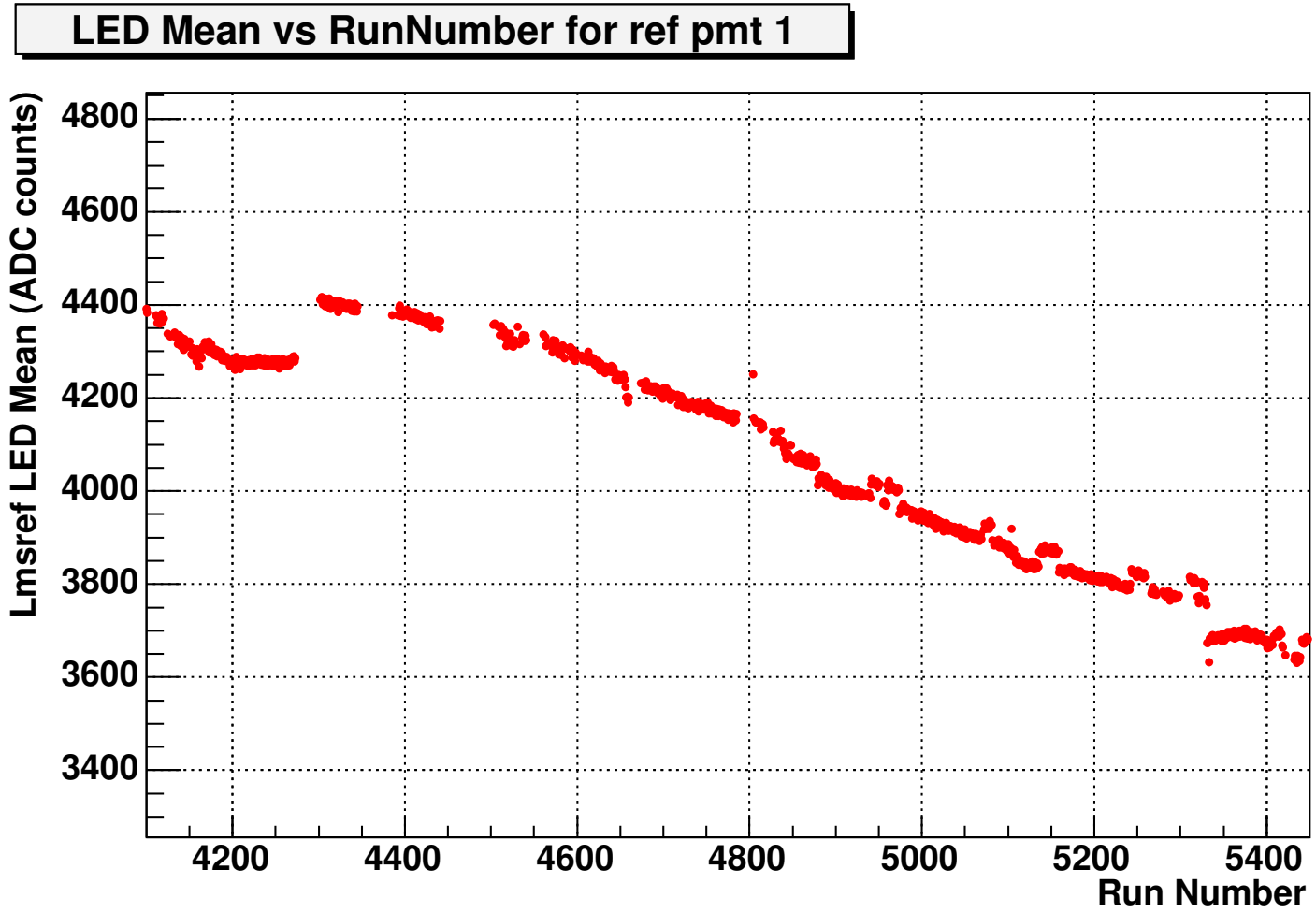
Short Term LMS Gain Stability: Conclusions

- This analysis and presentation only scrapes the surface of the sea of short-term LMS response anomalies.
- In light of the $1-5$ % difference in LMS response depending on beam rate, both the lms analysis' methodology and the usefulness of its results become precarious.
- It was fould that 286 or 25 % of $PbWO_4$ channels exhibited strong bi/tri-modal LMS response behavior, and ~ 45 or 8 % of PbGlass exhibited this behavior.
- Other patterns of short term gain instability were observed, but not explored in this study.

Long Term LMS Gain Stability: Snake Scan gain (α_i)



Long Term LMS Gain Stability: LMS Reference PMTs



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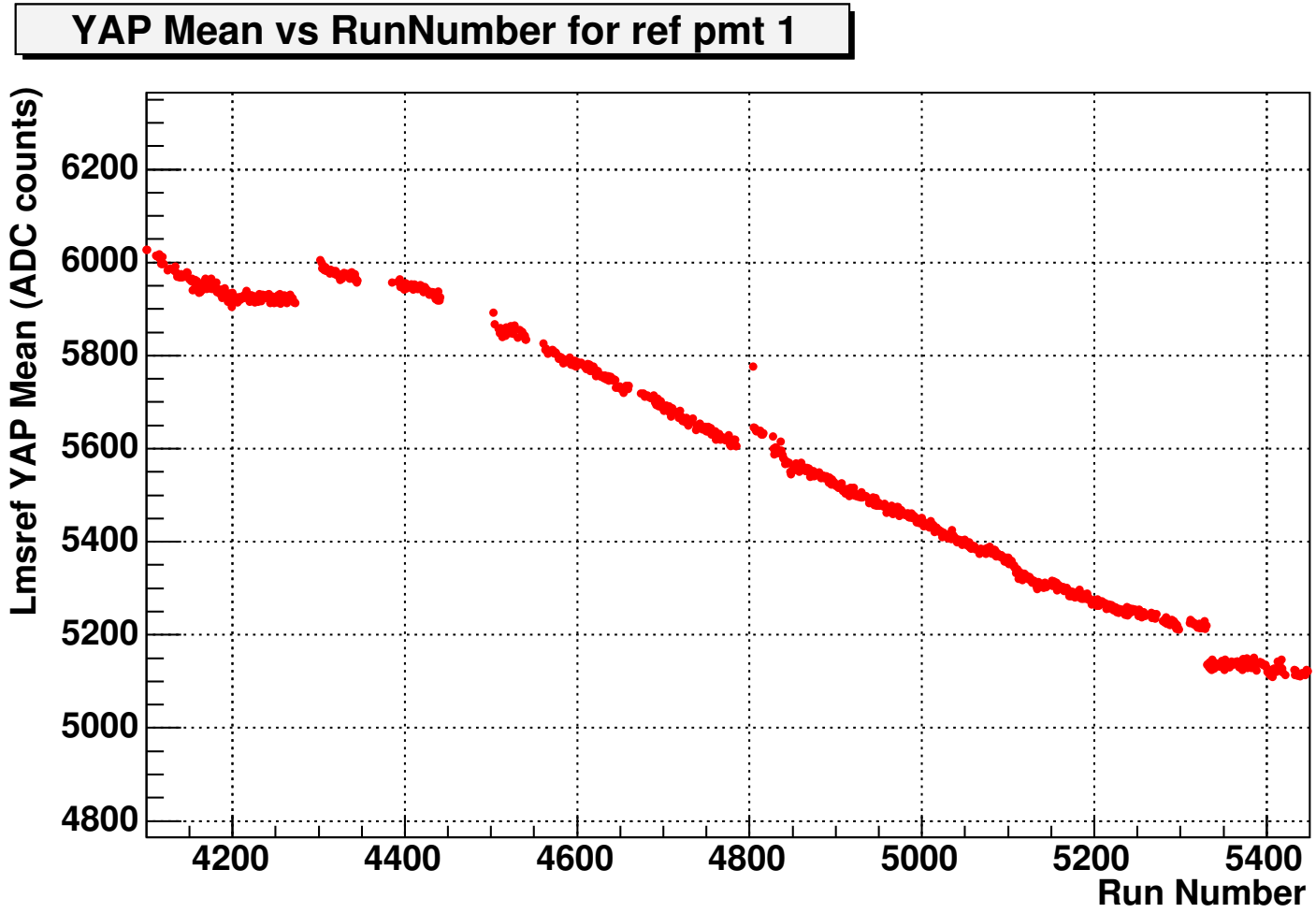

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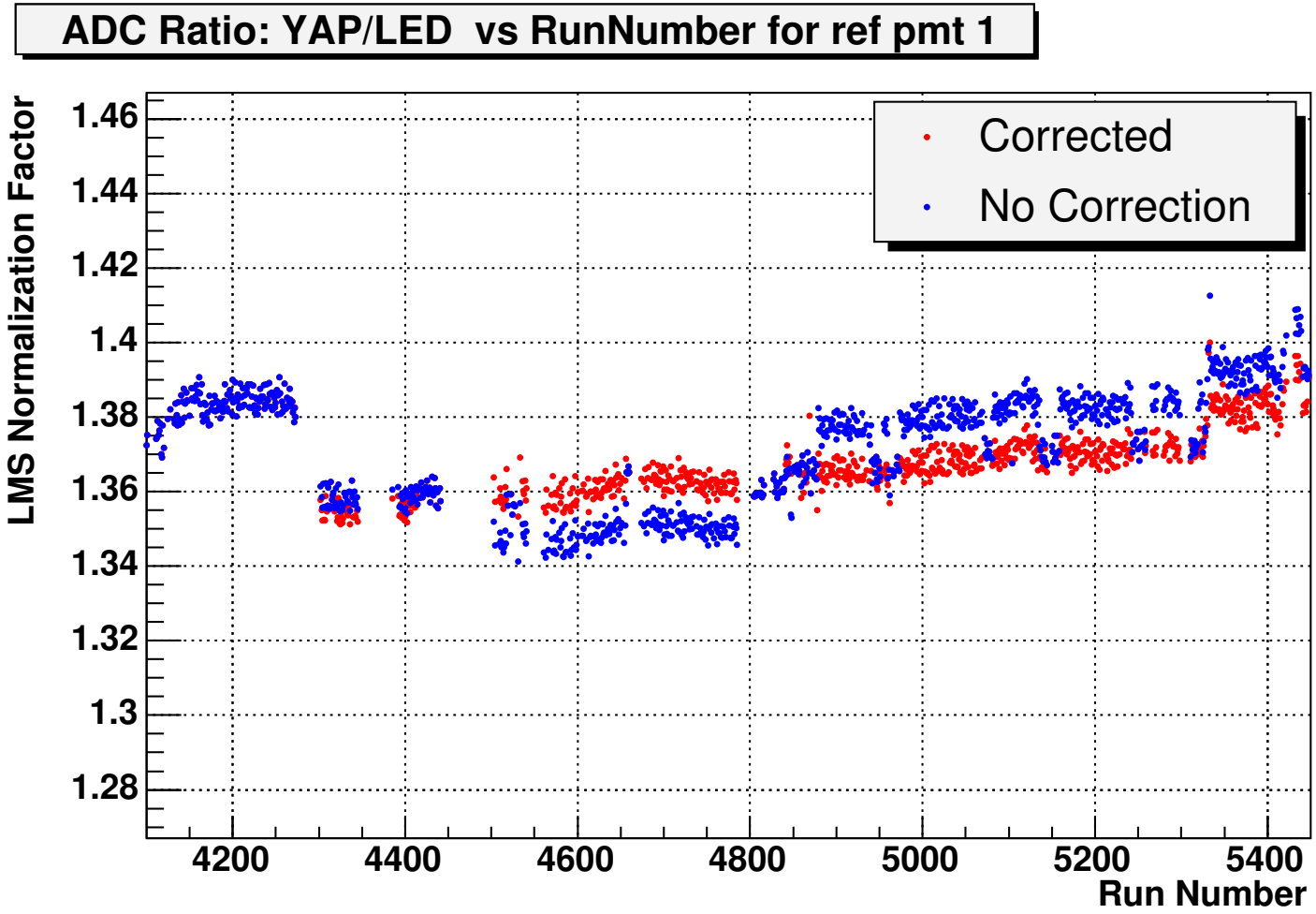


Long Term LMS Gain Stability: Analysis Procedure

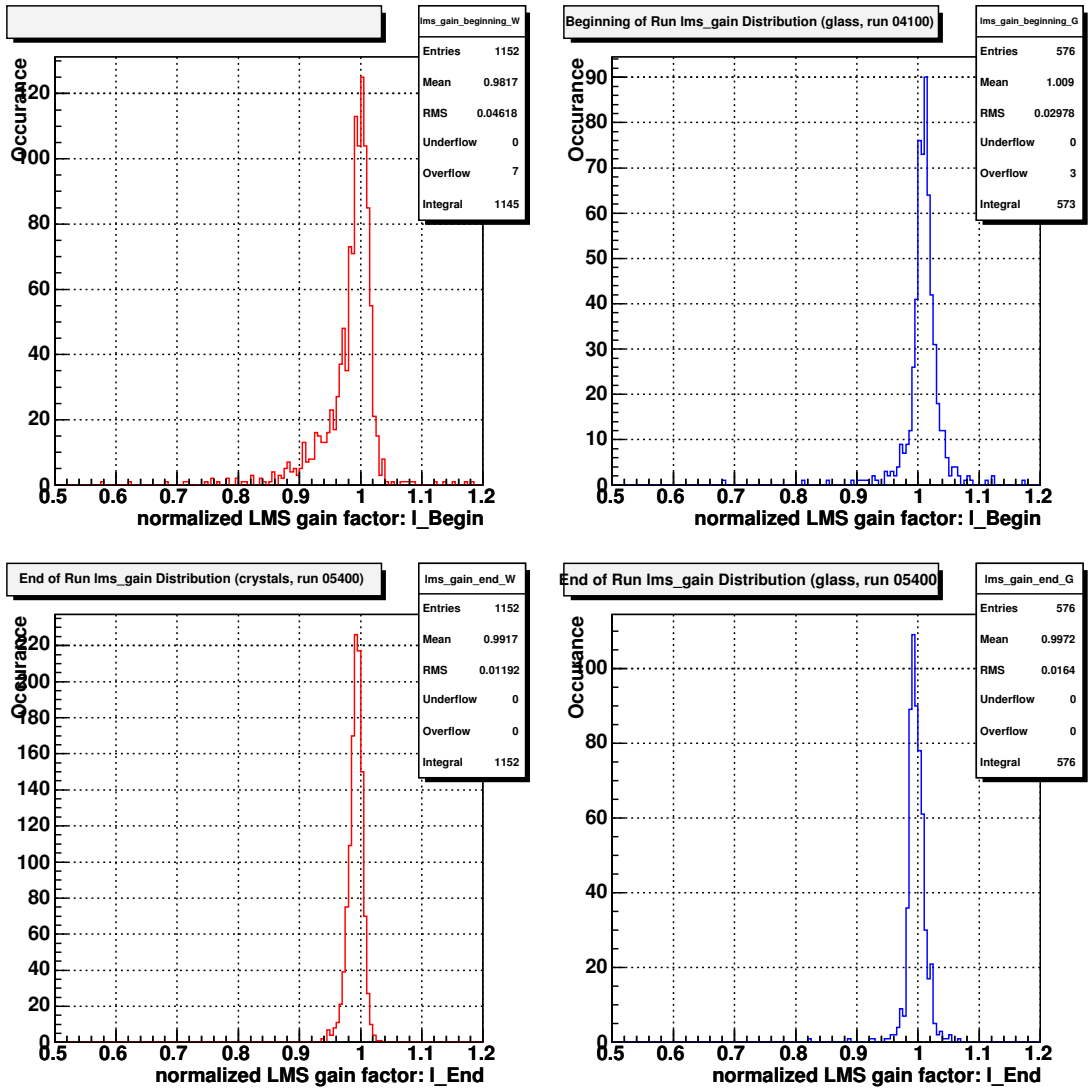
- For the run in question, each channel's LMS ADC mean response is multiplied by the corrected normalization constant from ref pmt1.

$$\text{Normalized ADC response} : N_i(t) = \overline{ADC}_i^{LMS}(t) \cdot \frac{\overline{ADC}_{Ref}^{YAP}(t)}{\overline{ADC}_{Ref}^{LMS}(t)} \tag{4}$$

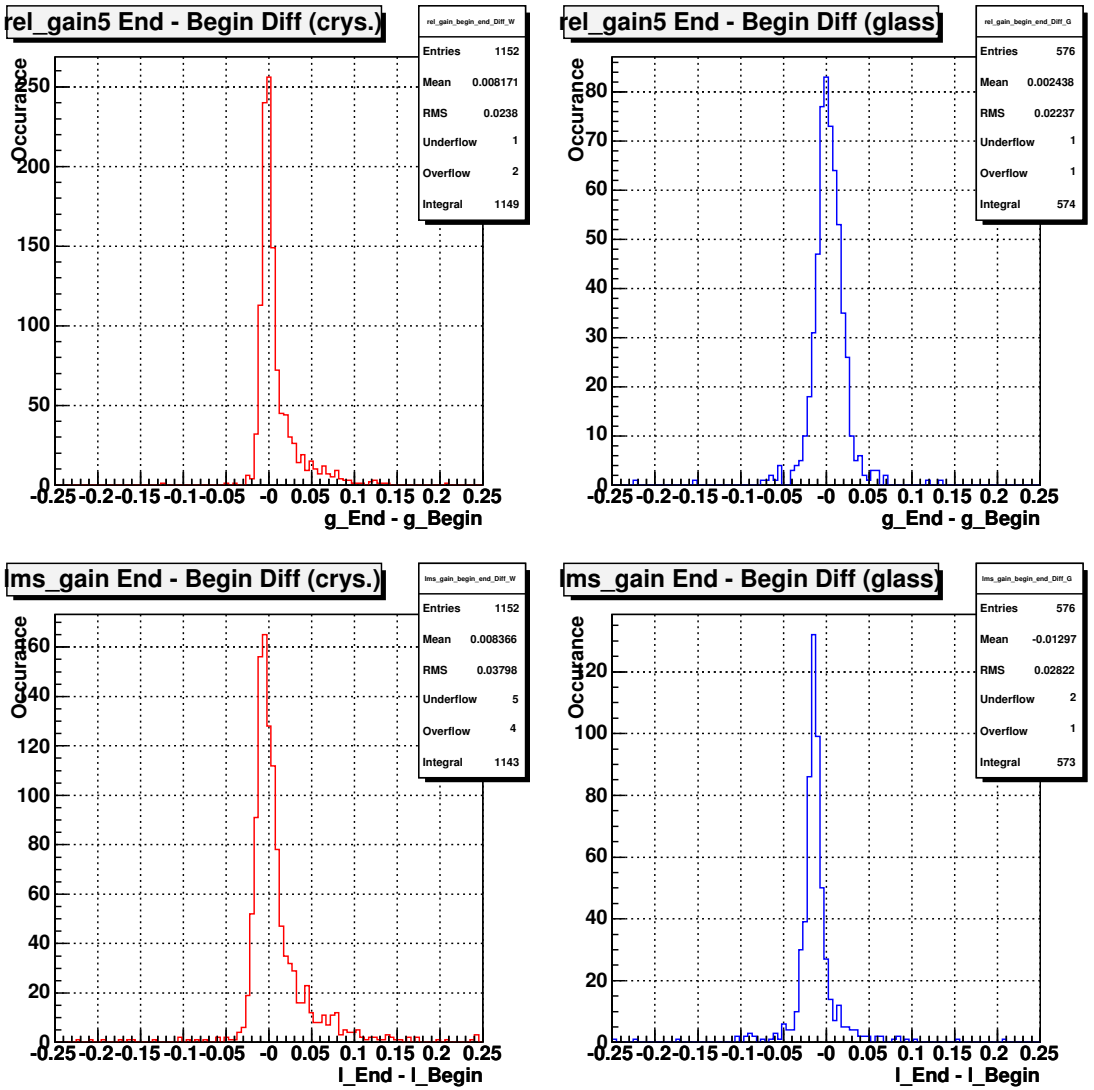
- The lms gain factor is calulated relative to run 5330–which was the last run before moving HyCal to the transporter for final snake scan.

$$\text{LMS gain factor} : g_i(t) = \frac{N_i(5330)}{N_i(t)} \tag{5}$$

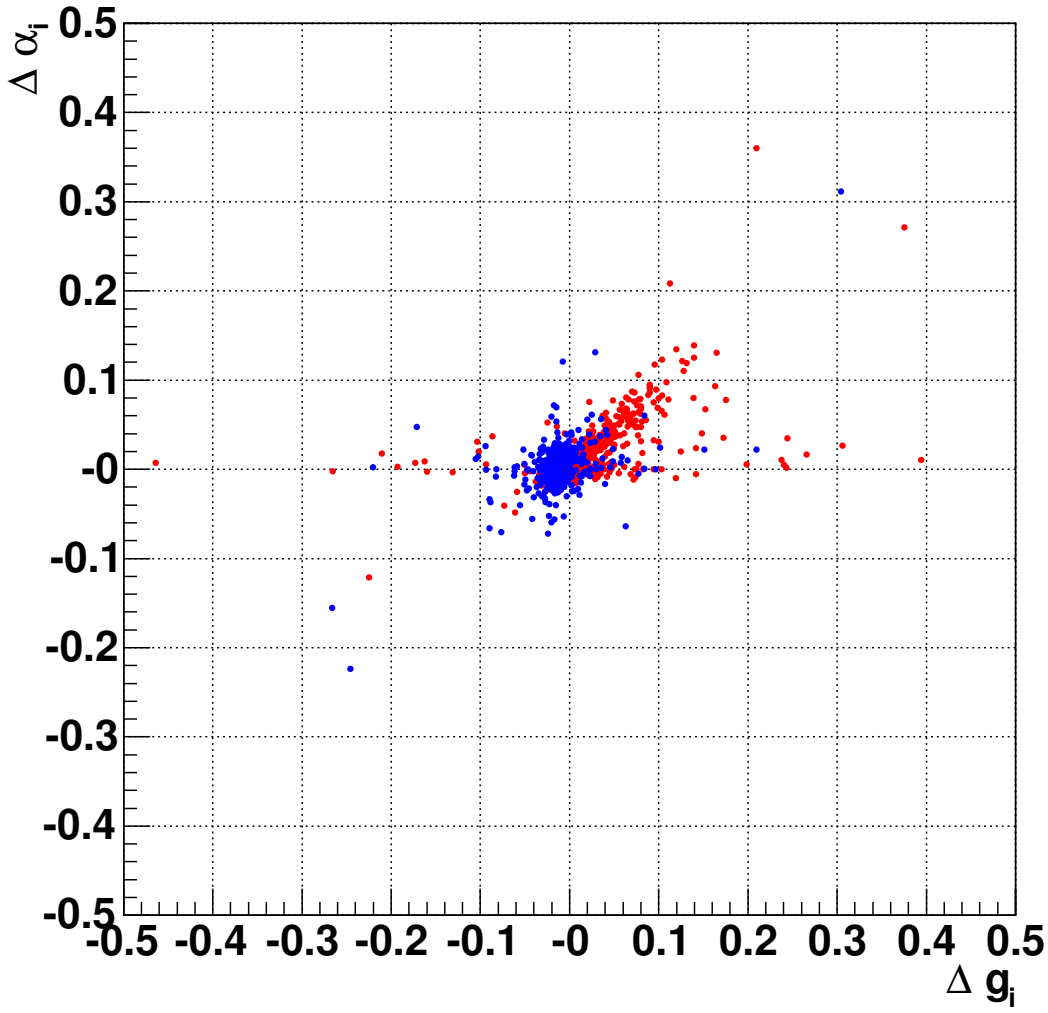
Long Term LMS Gain Stability: LMS gain (g_i) Results



Long Term LMS Gain Stability: Begin-End Gain Diffs



Long Term LMS Gain Stability: Begin-End Diff Correlation



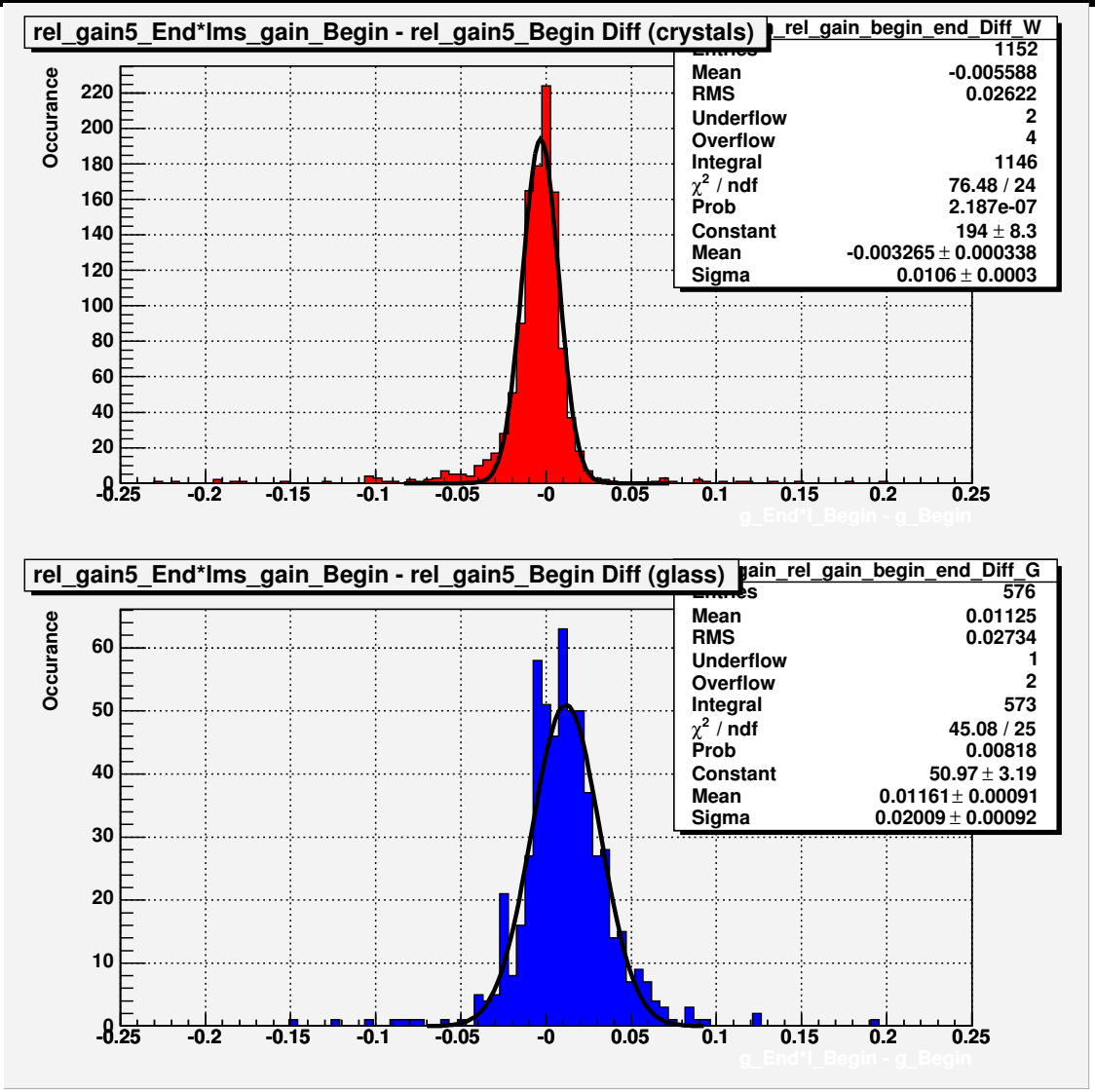
Long Term LMS Gain Stability: Begin-End Consistency

- The absolute gain of each channel was measured just before and after production data collection.
- This provides for an ideal consistency check of the LMS performance...see how well the LMS gain connects the beginning and end point calibrations.
- To do this, check the validity of the following equality by histogramming its result for each id:

$$\alpha_i(\text{End}) * g_i(\text{Begin}) - \alpha_i(/mathrmBegin) = 0 \quad (6)$$

- For the following results, End = run 5400 and Begin = run 4100.

Long Term LMS Gain Stability: Consistency Results



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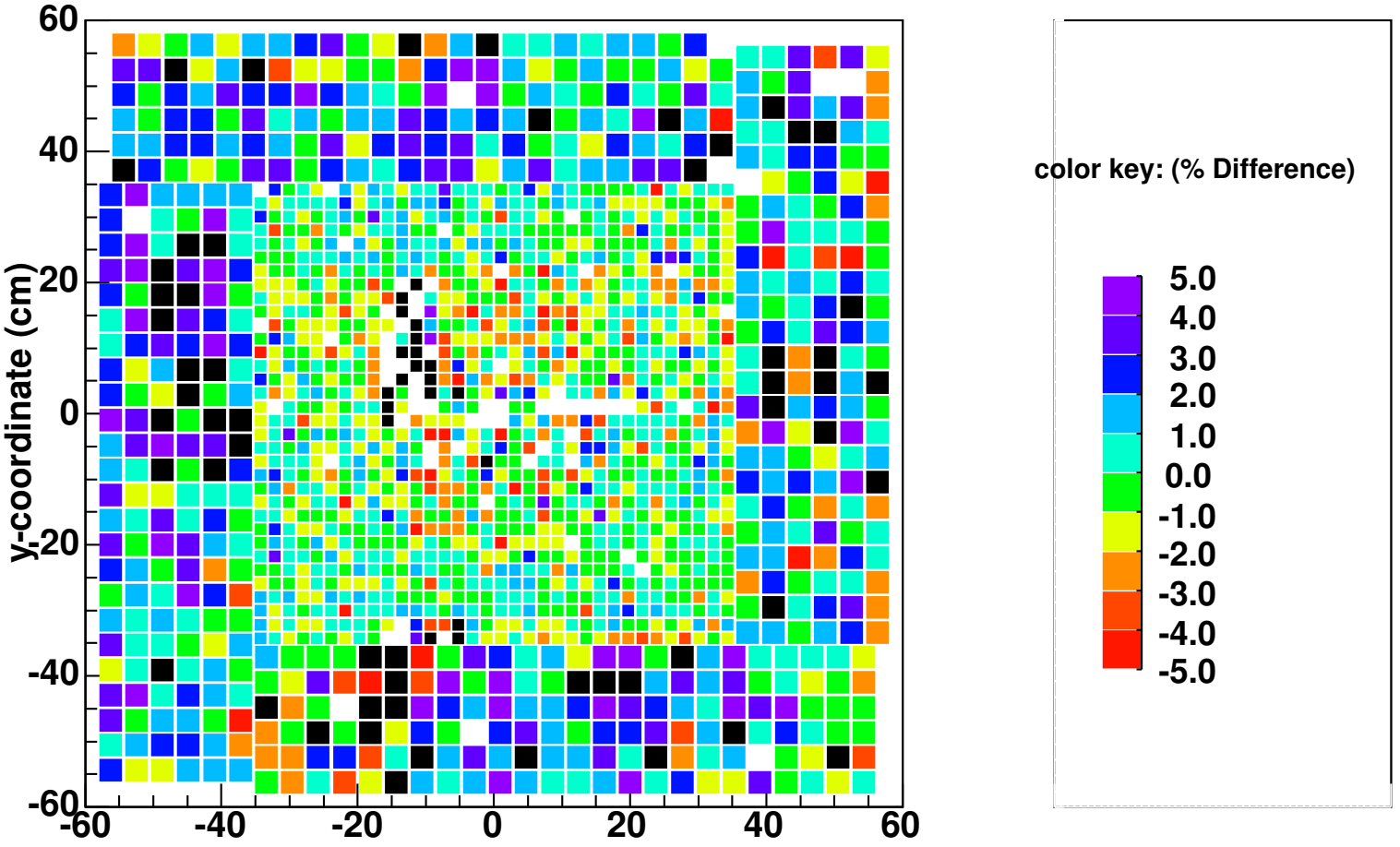
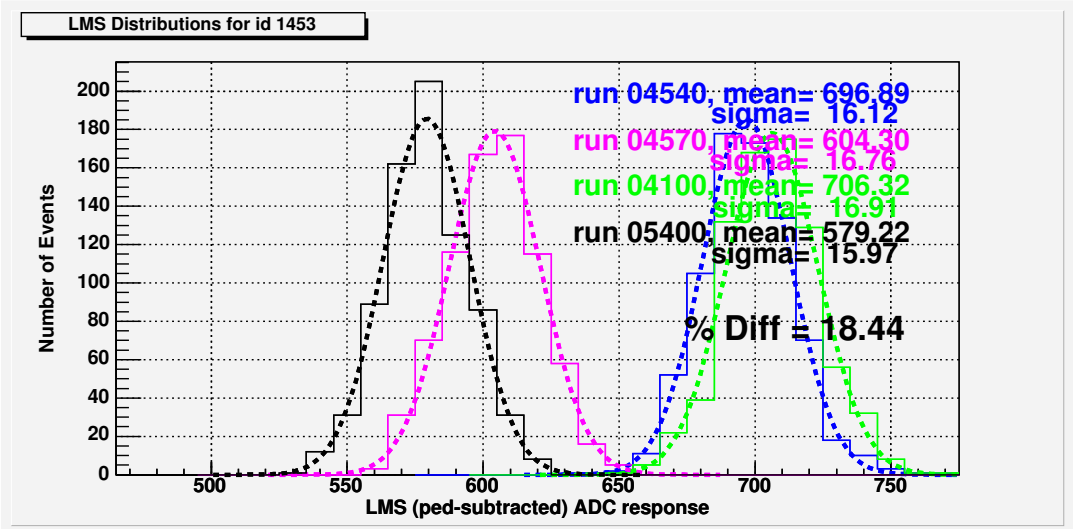


Long Term LMS Gain Stability: Anomalies



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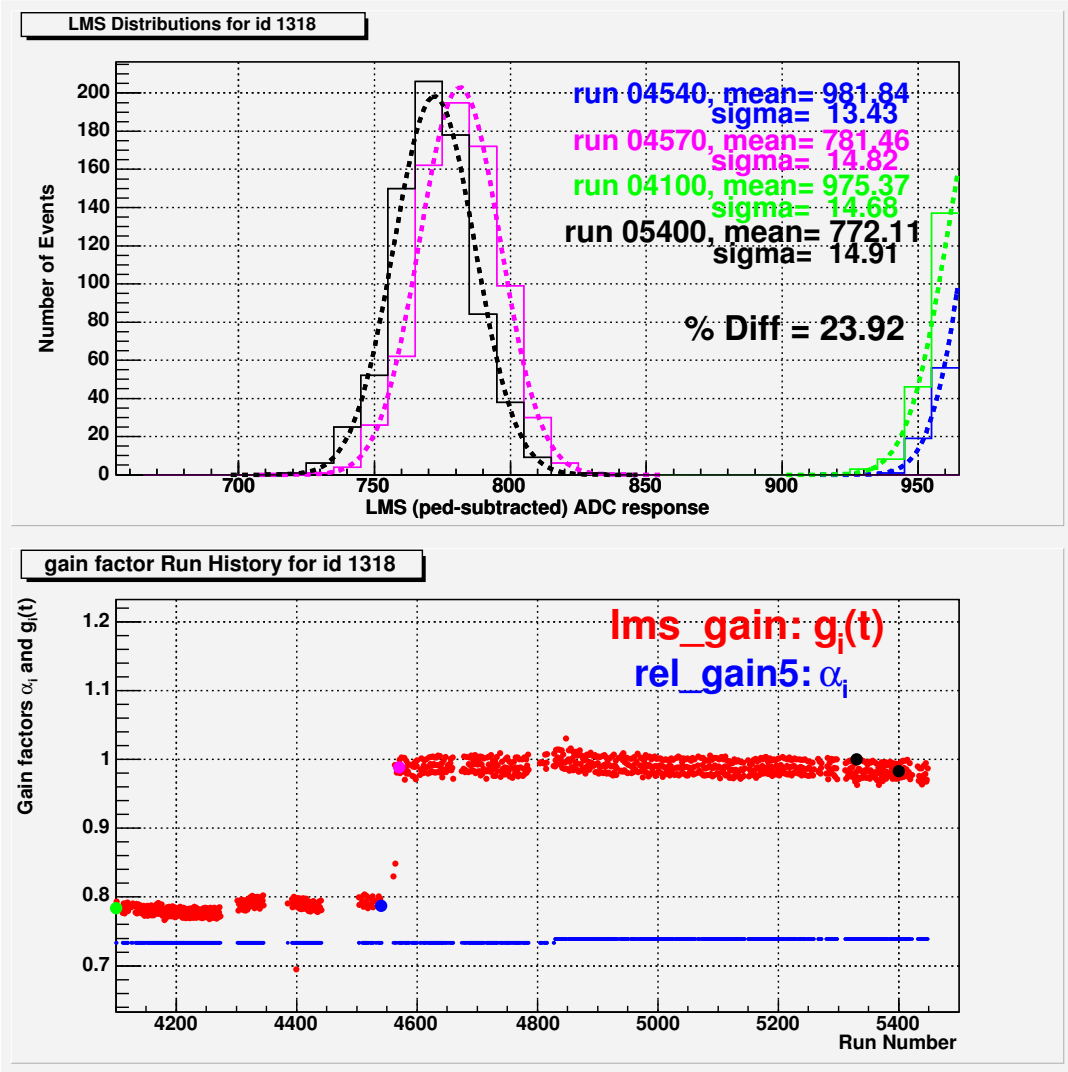

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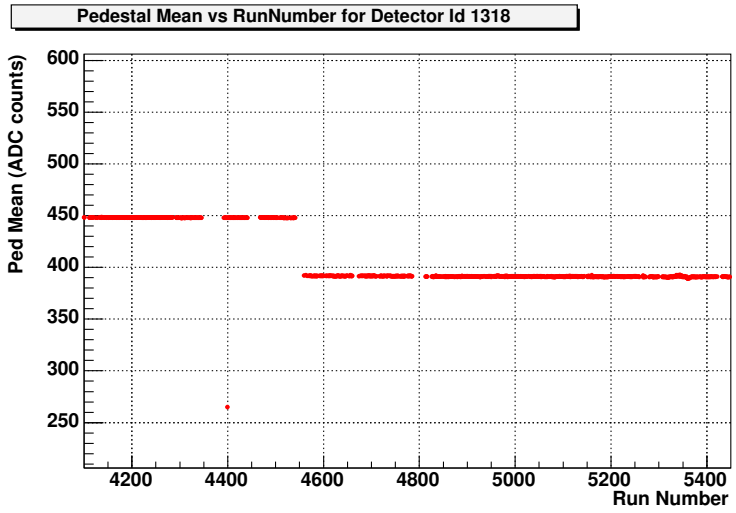

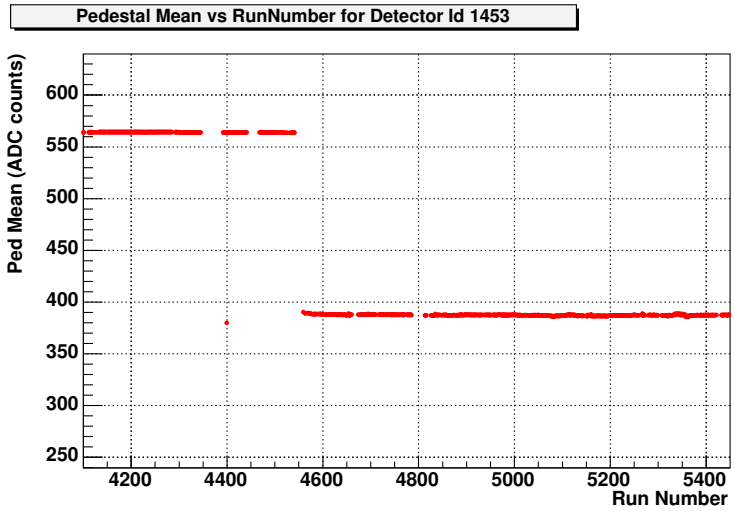

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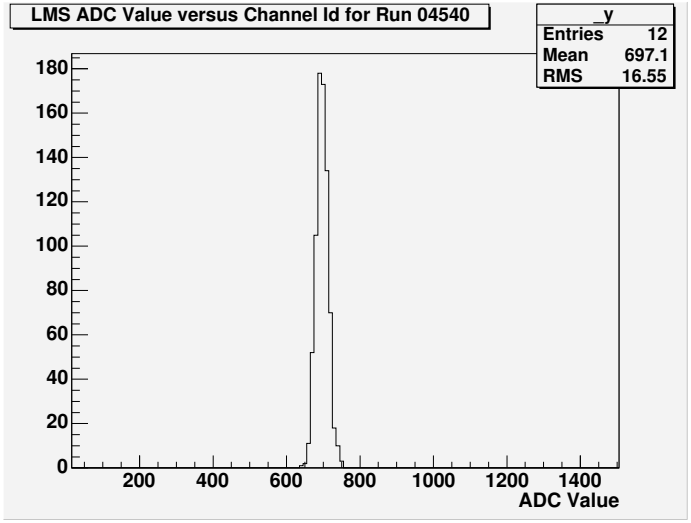

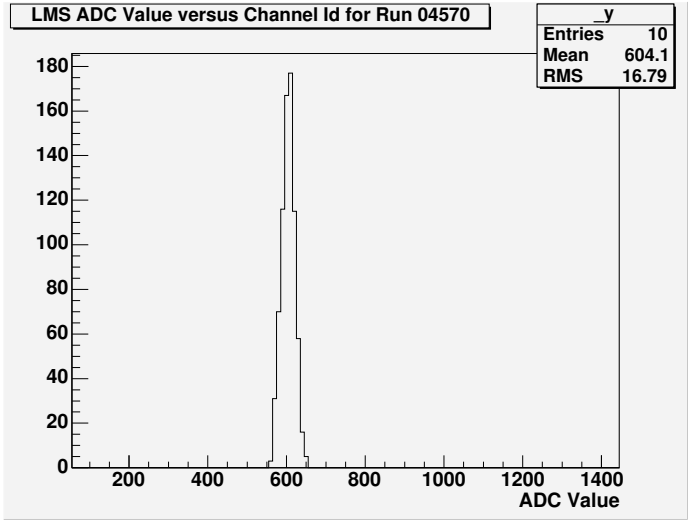

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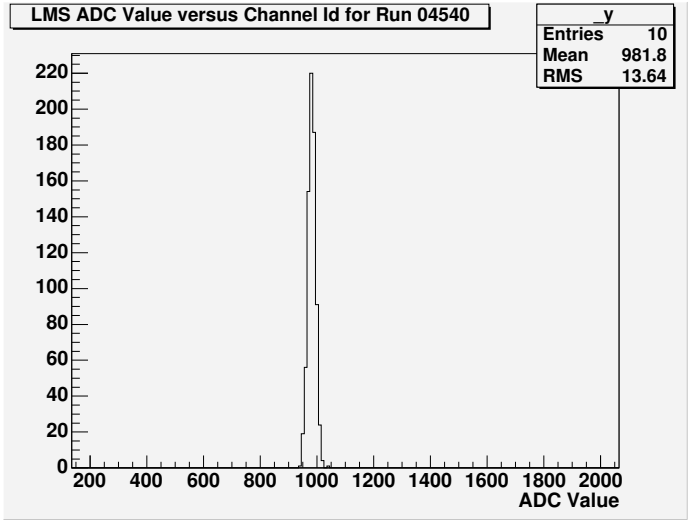

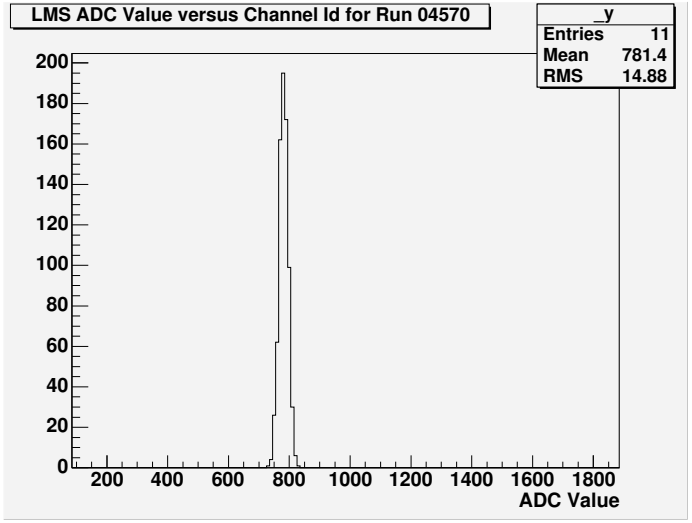

Summary

- Absolute HyCal gains did not change much from beginning to end.
- The spread in the begin-end gain differences are ~ 3 % and are consistent with each other.
- Crystal Δg_i ($\sim$highly) correlated with $\Delta\alpha_i$; glass displays less correlation.
- There are 2 obvious problem areas seen in HyCal visual of LMS gain consistency check: ROC4 slot22 ADC replacement anamoly ??? and lost calibration snake data file(s). These need more attention.
- Given the large $(1-5$ %) short term gain instabilities of the LMS, combined with the results of the long term LMS gain consistency check, the goal of $0.1-0.2$ % gain tracking precision will become at best 10 times worse.
- Comparison of LMS results with Compton's will provide important cross checks as well as help determine which counters may benefit from LMS gain correction and which may not.