Calibration QA for STS Silicon Modules

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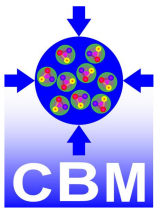
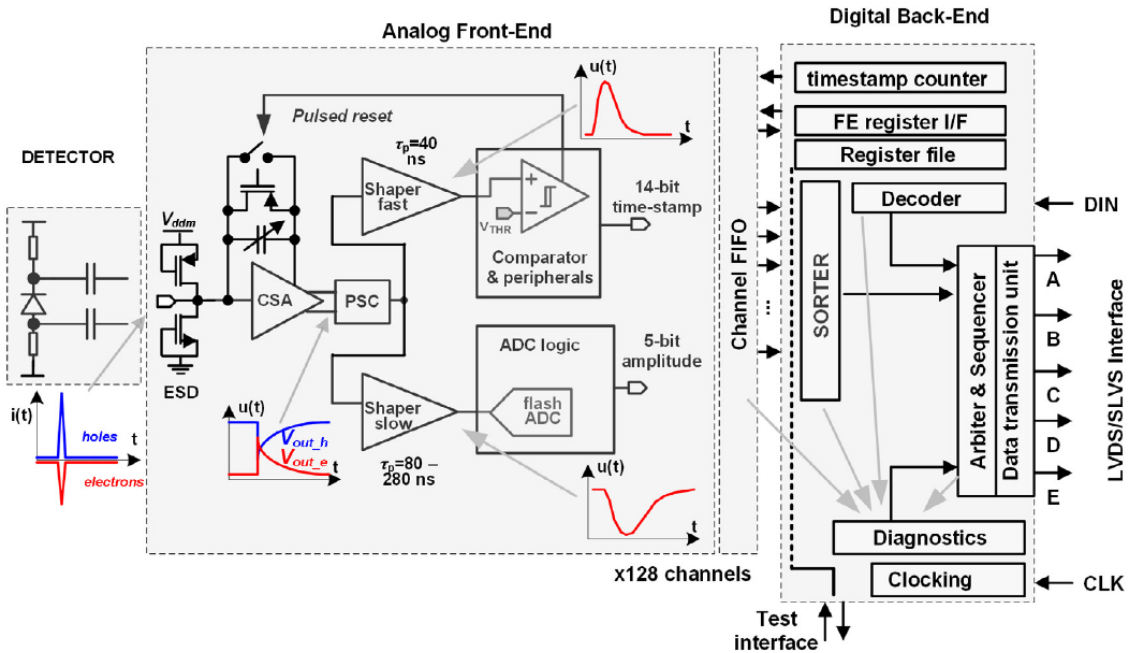
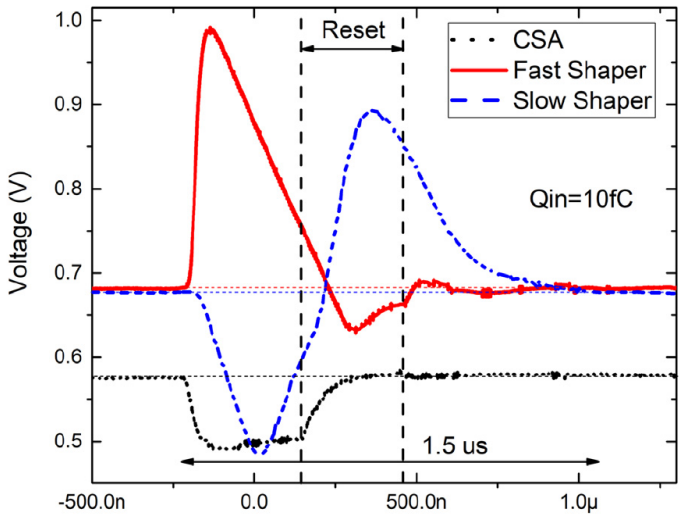


Overview

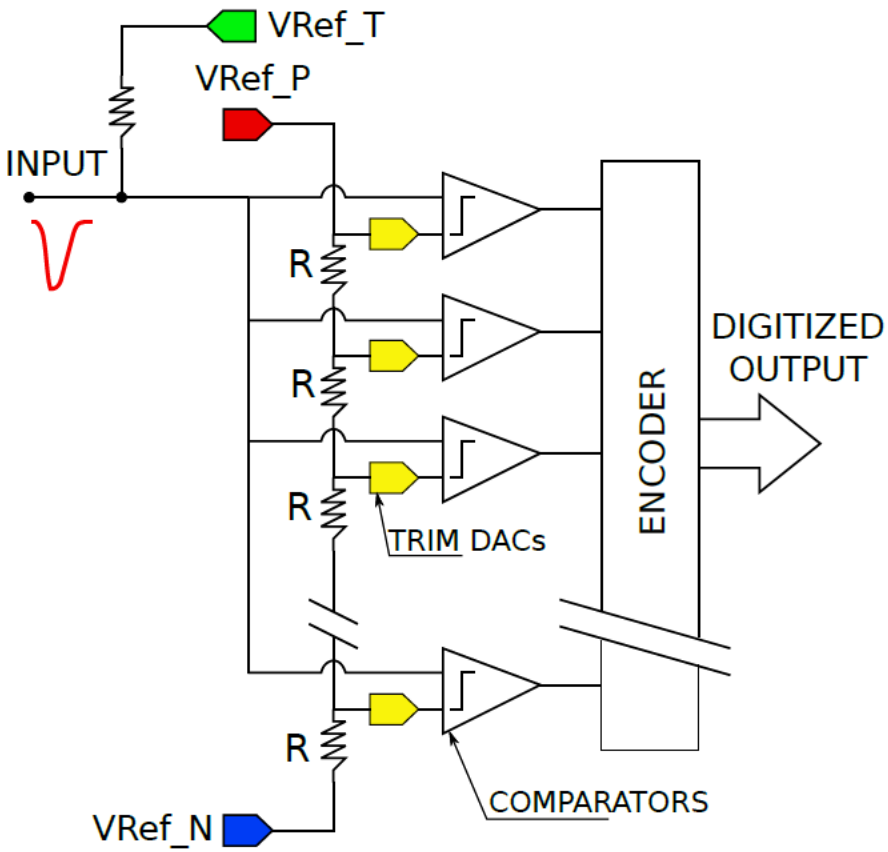
SMX v2.2 ASIC





- The polarity selection circuit (PSC) is to have only one pulse polarity.
- Two parallel signals paths are used for pulse processing
- A “fast shaper” with a comparator for the determination of the input charge arrival time
- A “slow shaper” followed by a 5-bit flash ADC for low-noise energy discrimination and measurement.

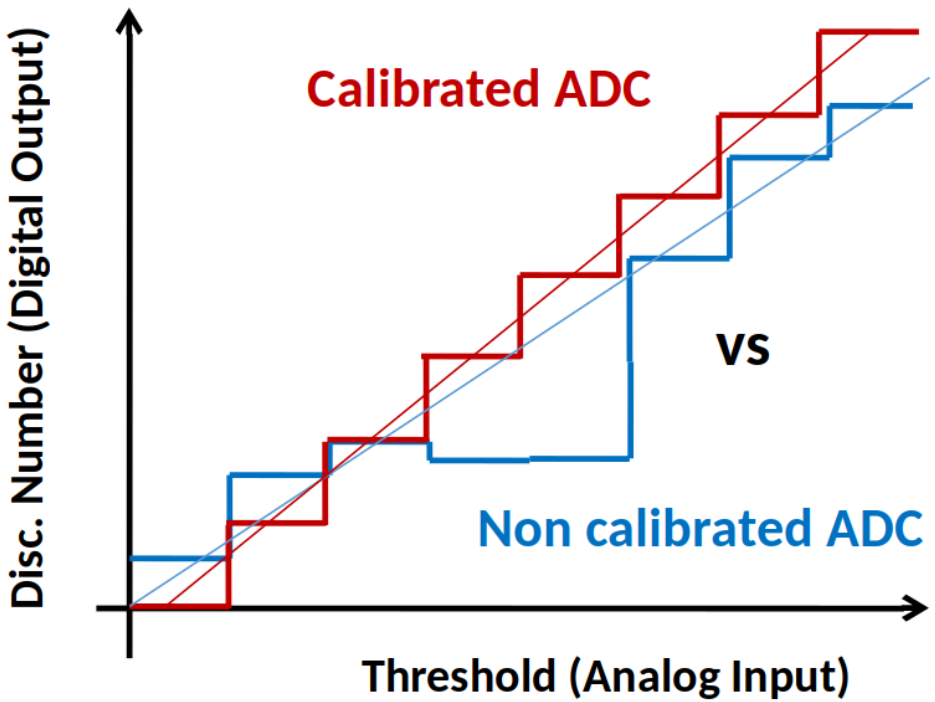
Amplitude measurement with Flash ADC



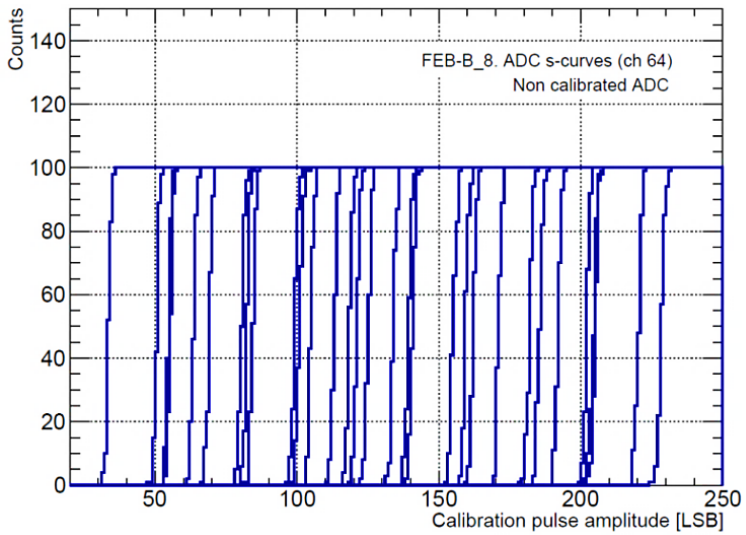
- 5-bit flash ADC (Analog-to-Digital Converter)
- 1 ADC/channel
- 5-bit resolution
- 2N-1 comparators
- Up to 15 fC (100 fc) in STS (MUCH) mode
- Trimming circuit with 8-bit resolution
- Diagnostic counter for each discriminator

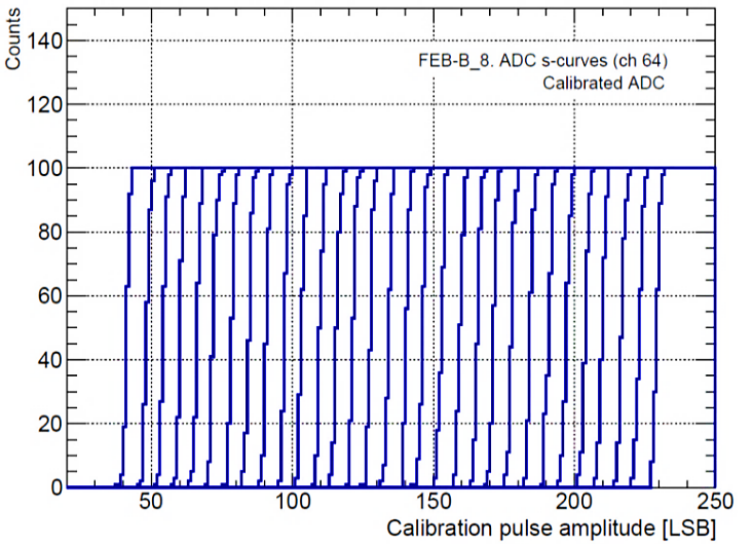
Why Calibration is Needed I

- The Double-Sided Silicon Microstrip (DSDM) module has 2048 readout channels, each with unique electrical characteristics.
- SMX v2.2 ASIC introduces channel-to-channel variations due to:
  - Threshold dispersion of discriminators.
  - Offset differences in front-end amplifiers.
  - Gain non-uniformity across the chip.



Why Calibration is Needed II

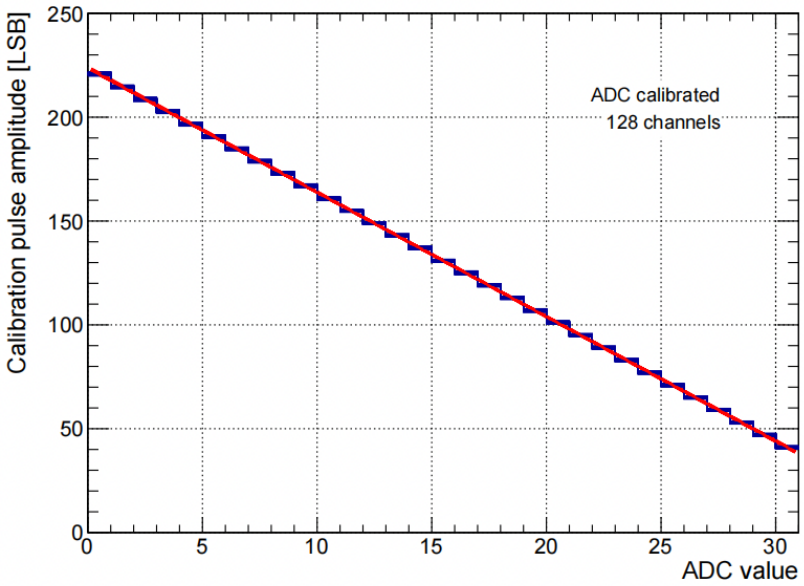




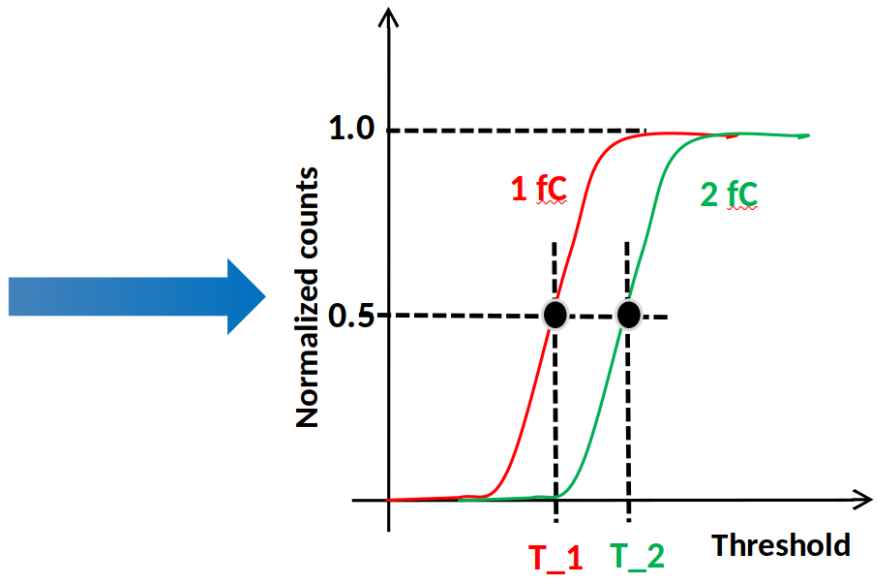
- Without calibration:
  - Different strips respond at different thresholds (non-uniform hit detection).
  - Increased noise hits and false triggers.
  - Loss of spatial and timing resolution.
- Calibration (trimming) aligns discriminator thresholds, ensuring:
  - behaviour of thresholds across discriminator steps.
  - Uniform detector efficiency across all strips.
  - Stable operation under high-rate CBM conditions.

Calibration Procedure

- Variation and mismatches can create significant chn-chn variations.
- The process describes an automated calibration algorythm designed to tune individual trim DACs for every discriminator of every channel across the whole detector.
- For a given injected test pulse amplitude, all 128 chns, have to produce an identical digital counter value from their ADC's.
- Calibration is split in two steps: Coarse and Fine scan.



(a) *Calibrated ADCs in 128 channels*



Coarse Scan

- Goal: quickly bring each chn's ADC count to near 50 % point, identify broken and unresponsive chns.
- Pulse Injection & Measurement
  - For a fixed number of iterations, the ASIC injects a number of test pulses. This process is done disc-by-disc, across all channels (divided in groups of 4).
  - The ADC counter of every disc of all chn groups is read back
- For disc (d) and for every chn, the algorythm calculates the aboslute difference between the measured count and target half-value. Trim DAC is adjusted according to the following logic.
  - If count number is too high, trim value is decreased, making the discriminator easier to fire.
  - If count number is too low, trim value is increased, making the discriminator harder to fire.
  - If count number is exaclty at 50% trim value is kept as is, but continues to iterate over next steps.
- Adjustment step is large initially $int(\frac{width}{n})$ and shrinks after each iteration, in order to prevent overshooting.

Fine Scan

After all chns are near target, a fine scan is executed

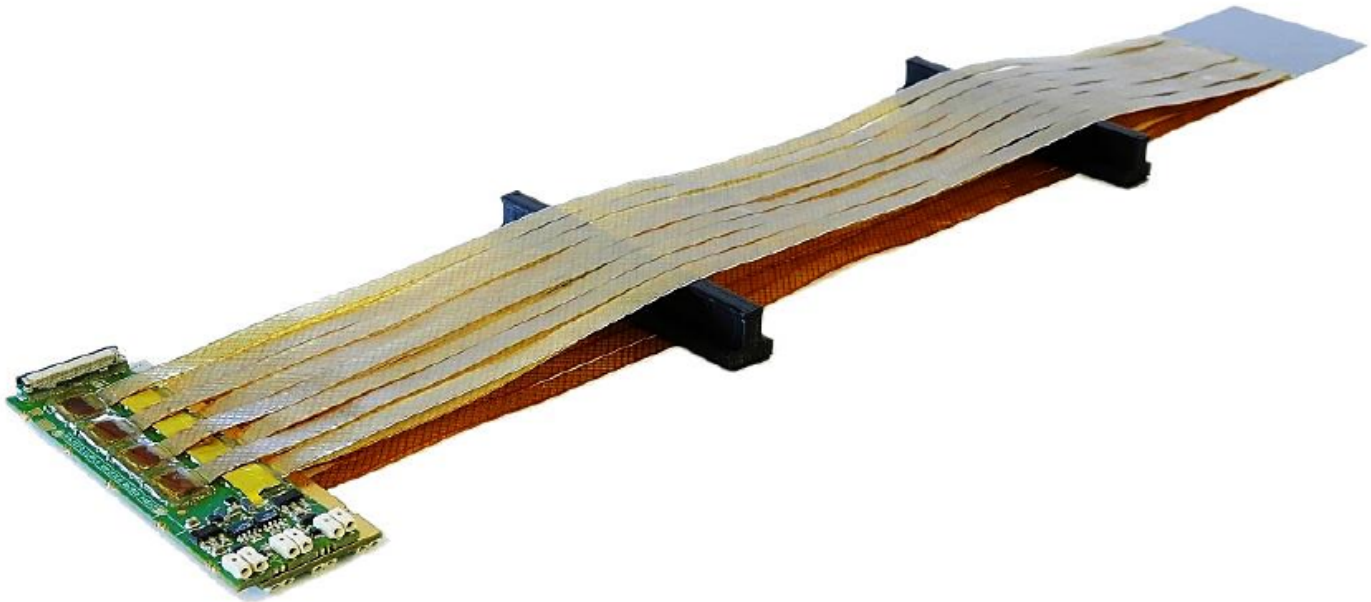
- Goal: Find the exact trim value, where the ADC response crosses 50% point.
- Trim DAC is swept through a small, fine resolution range, around coarse's scan value, according to:
  - ((coarse trim) - 5) up to ((coarse trim) - 5 + (*tr i fine max*) x (*tr fine step*) in steps of *tr fine step*.
  - For every trim step, a fixed number of pulses are injected
  - A response S-curve for every chn is produced, builded by the recorded ADC count.
- Half-Height Calculation
  - The target half-value for the fine scan is the half-height of the ADC response plateue, calculated by the last few trim steps to mitigate noise.
- The point, where the rising ADC count curve, crosses hald-height value is calculated by linear interpolation, between the step below and above the crossing point as:

$$trim_{final} = trim_{before} + (itr + \frac{y_{min}}{ymin+ymax}) * trim_{finescan}$$

Trim Data Handling

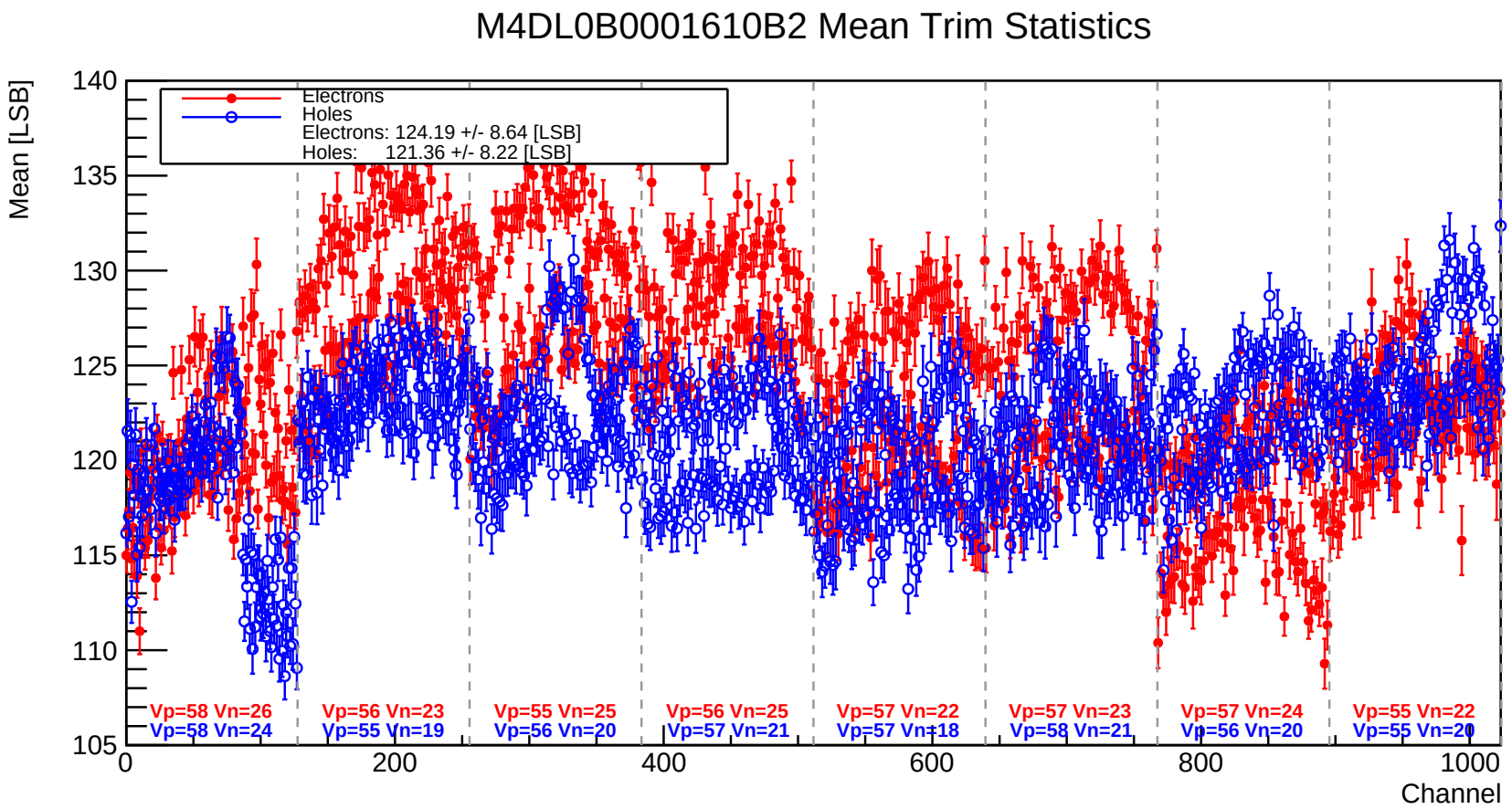
- Double-sided silicon microstrip sensor; separate electron and hole readout sides.
- Structure: channel index + 31 discriminator values.
- Each side: 8 ASICs; each ASIC: 128 channels; per channel: 31 discriminator trim values (index 0-30).
- Total per side: 1024 channels; full module: 2048 channels.
- Input data files per side: `elect_HW_i.txt`, `holes_HW_i.txt`, with structured rows: `ch:  chn val0 ...  val30`.
- Includes headers such as reference voltages $V_{Ref,T}$, $V_{Ref,N}$, $V_{Ref,P}$ and ADC range.
- Decided to set a cut in the range of analyzed data between 60 to 180 trim values (out of range data are excluded as -1 values).
- Fast disc values were not processed.

Module Trim Analysis



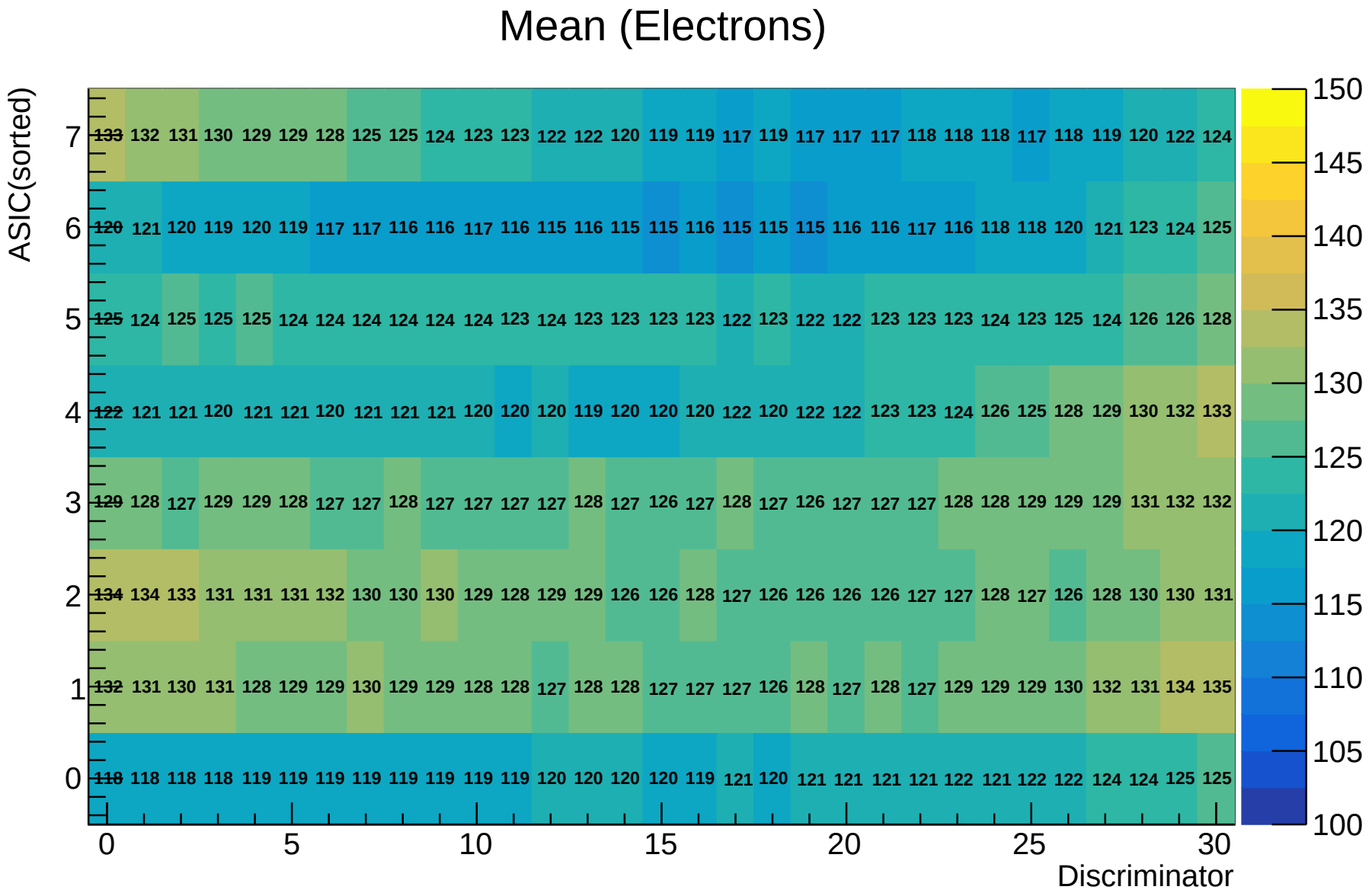
- Range of calibration amplitude [30-247]

Module Mean Trim per Disc vs Chn

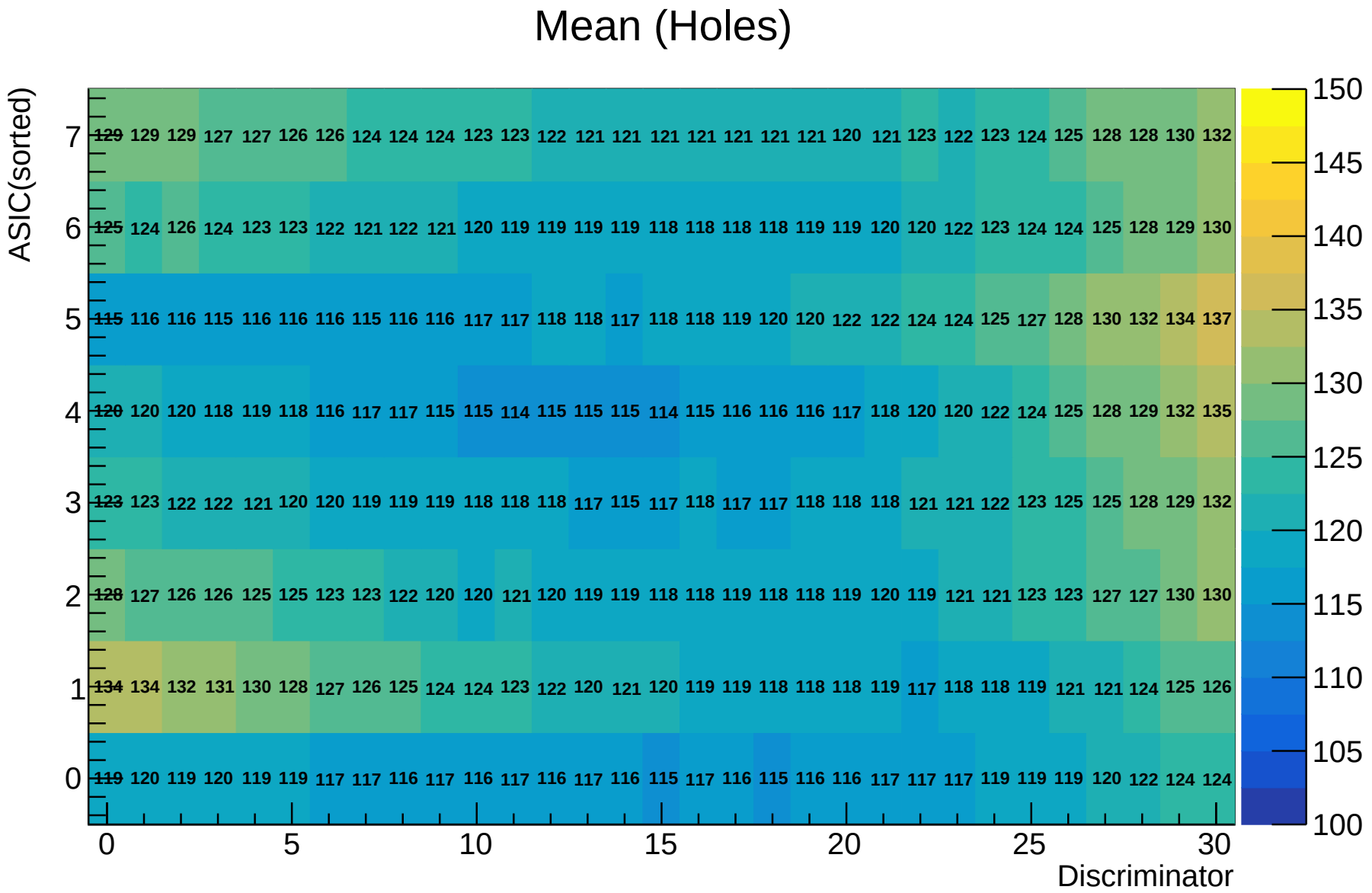


- ASIC to ASIC differences are compensated by different reference voltages, but a pattern is observed across each ASIC.

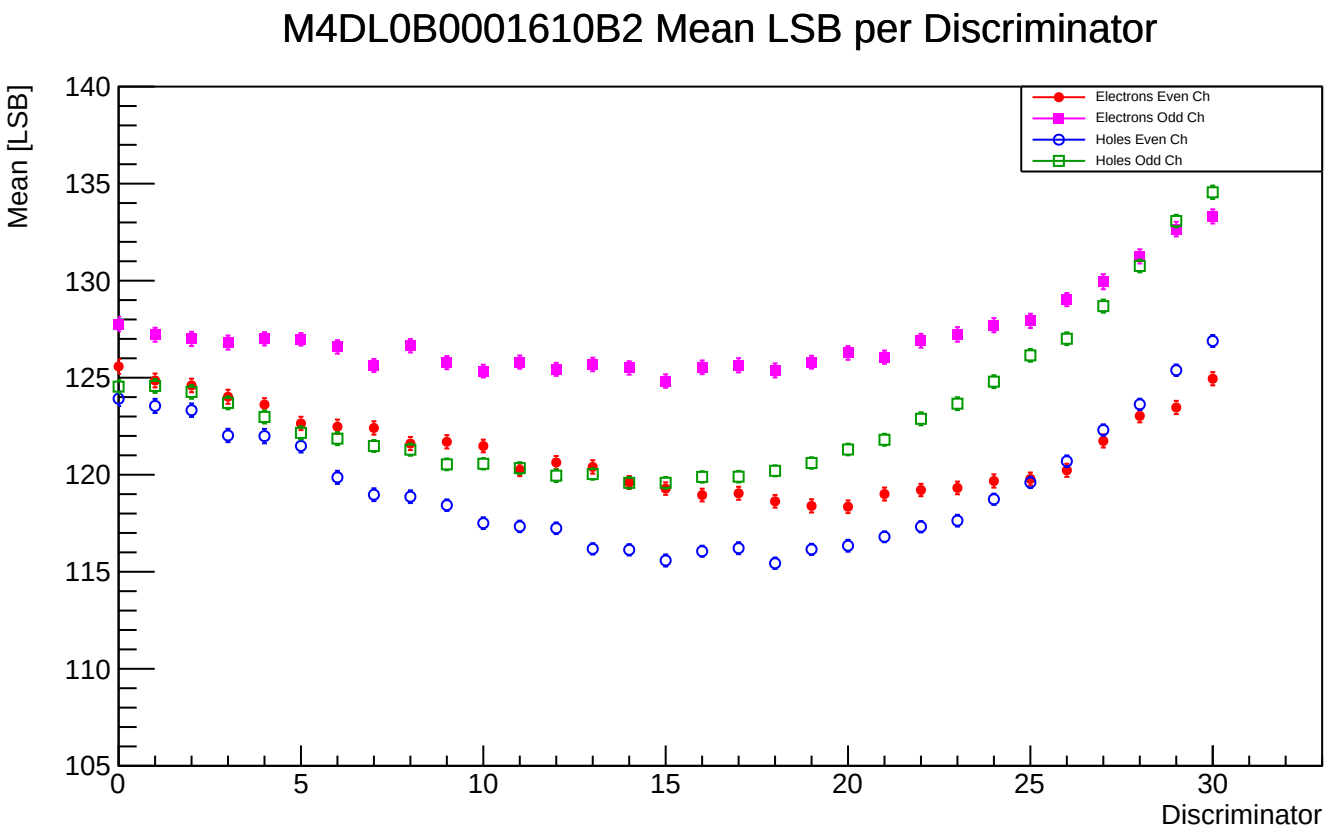
Module N-side Mean Trim Heatmap



Module P-side Mean Trim Heatmap



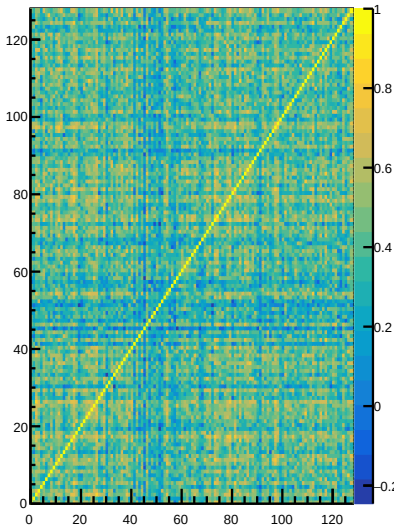
Module Mean Trim per Chn vs Disc



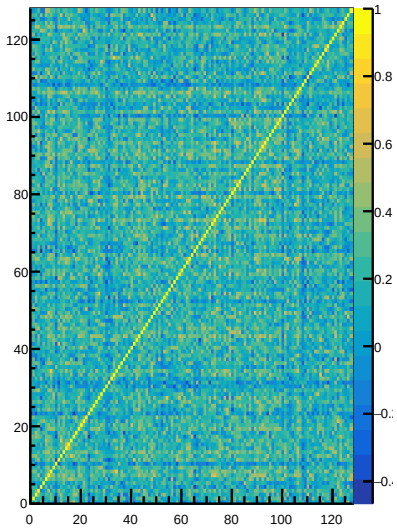
- Clear odd-even chn difference
- N-side has larger trim values across many analyzed modules
- U-pattern is observed, and trim values seem to converge for the last discriminators

Module N-side Channel Correlation

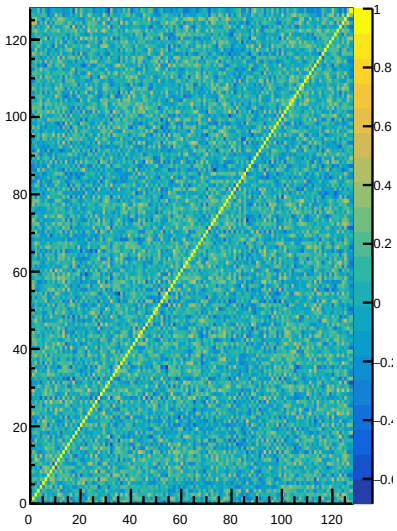
Electrons ASIC 7



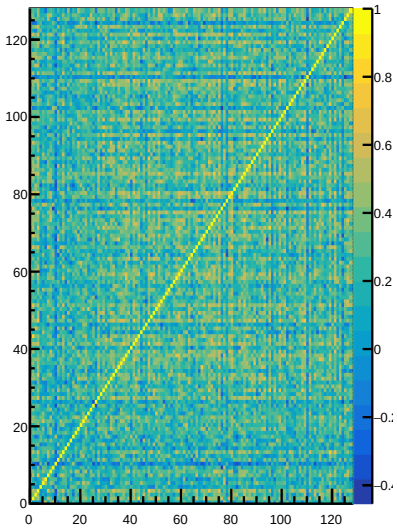
Electrons ASIC 6



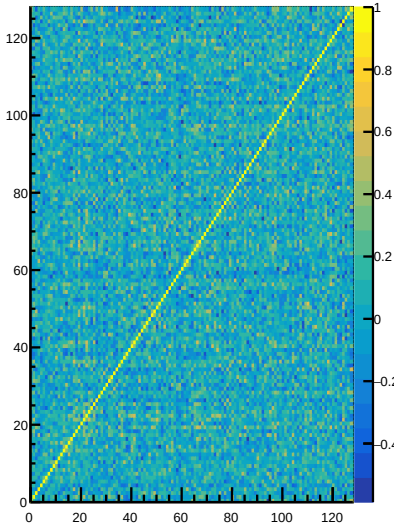
Electrons ASIC 5



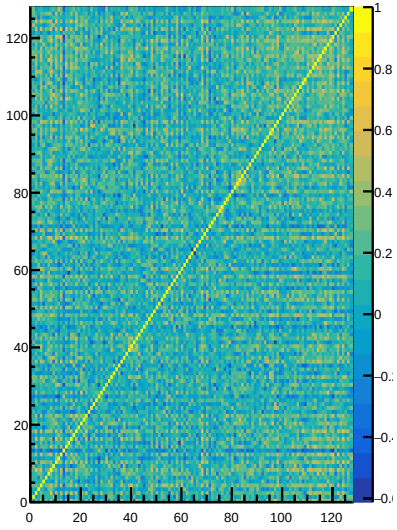
Electrons ASIC 4



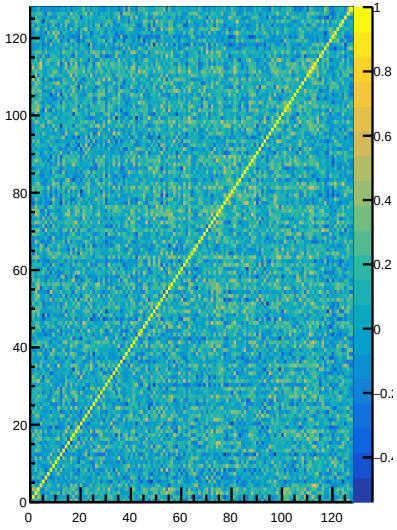
Electrons ASIC 3



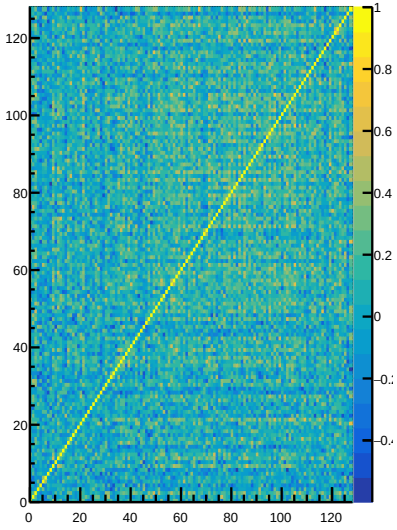
Electrons ASIC 2



Electrons ASIC 1

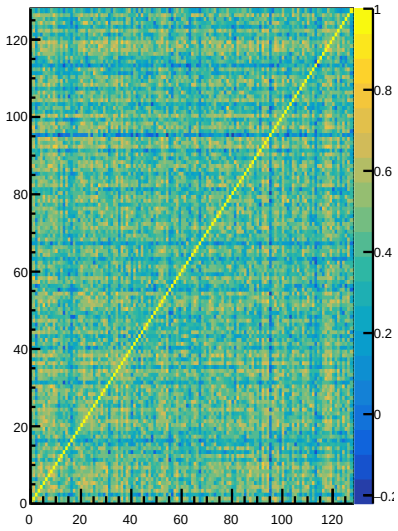


Electrons ASIC 0

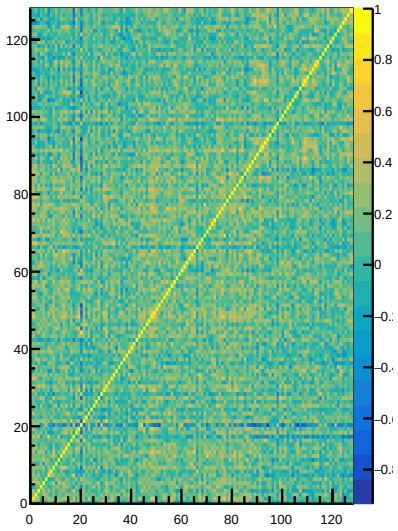


Module P-side Channel Correlation

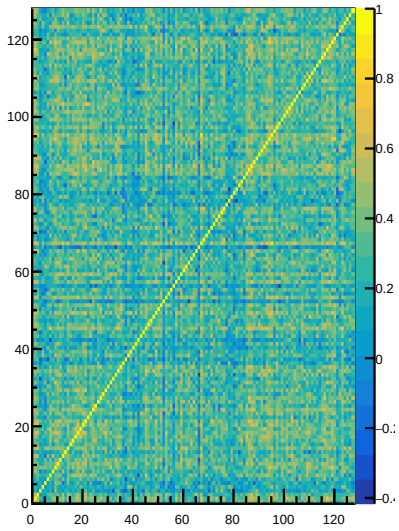
Holes ASIC 1



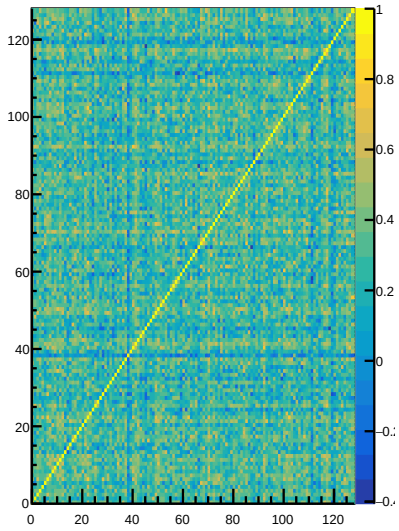
Holes ASIC 0



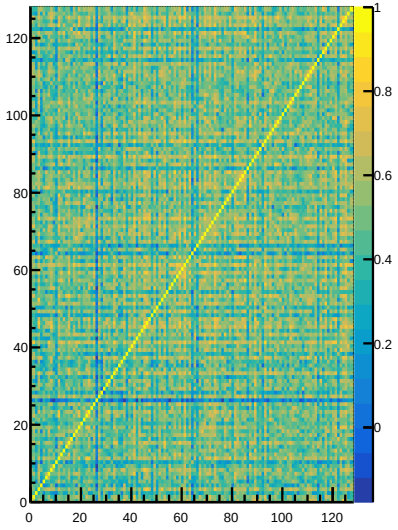
Holes ASIC 3



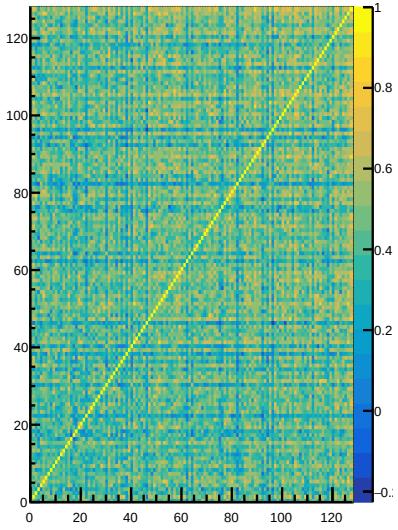
Holes ASIC 2



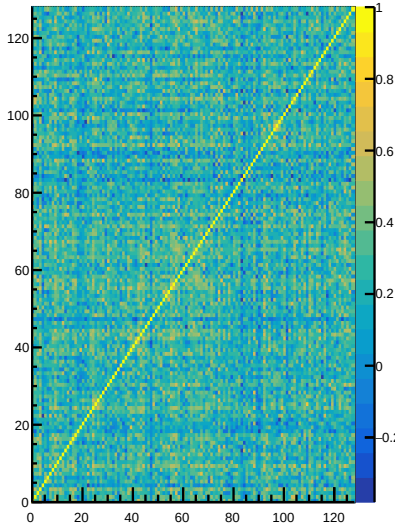
Holes ASIC 5



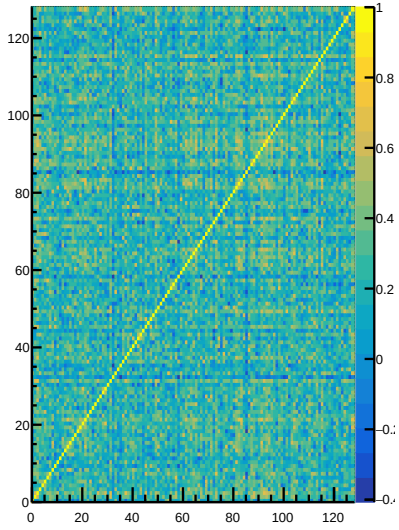
Holes ASIC 4



Holes ASIC 7



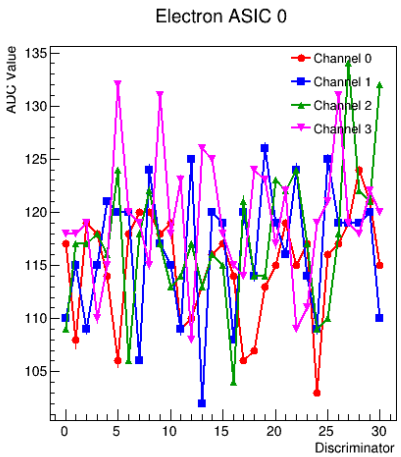
Holes ASIC 6

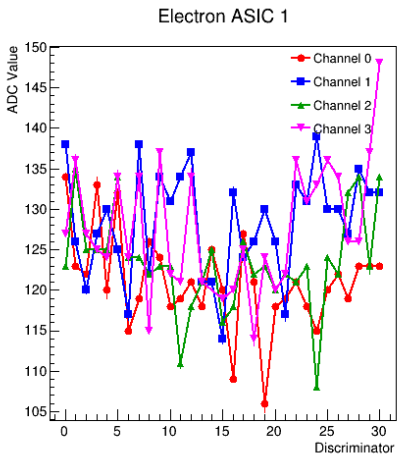


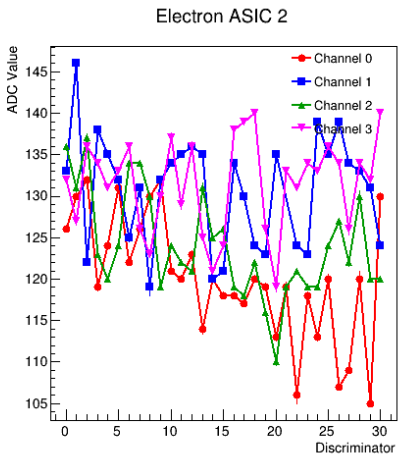
A more specific way of plotting data is needed in order to properly explore the meaning behind the patterns.

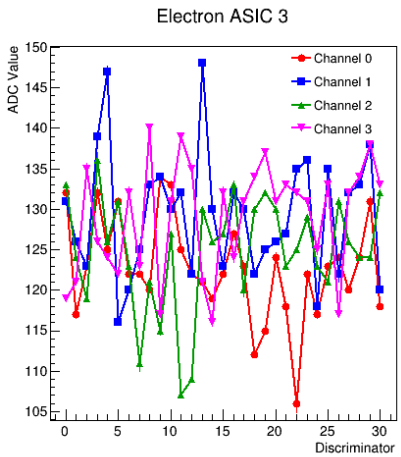
- First 4 ascending channels are selected and plotted, which correspond to different calibration groups.
- Channels are also sorted and plotted with their corresponding group in mind.

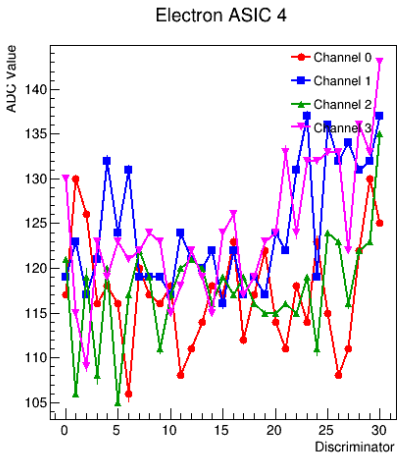
Module Ascending N-side Channel Mean Trim per Chn vs Disc

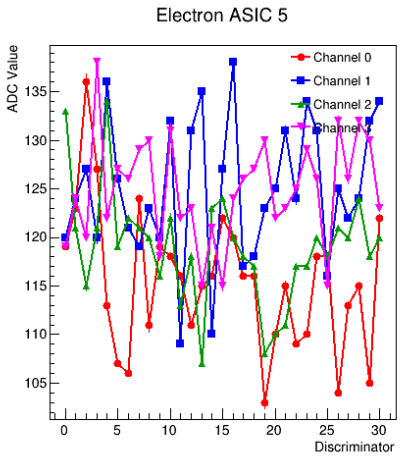


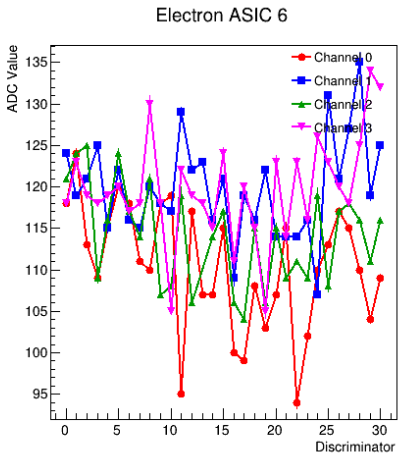


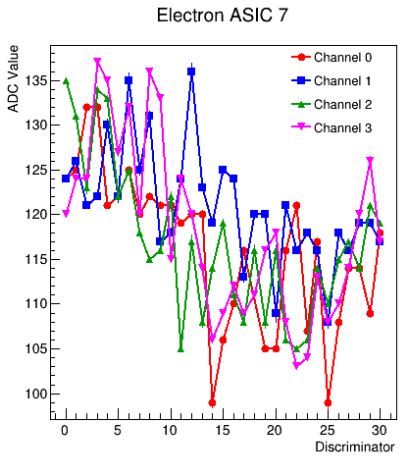




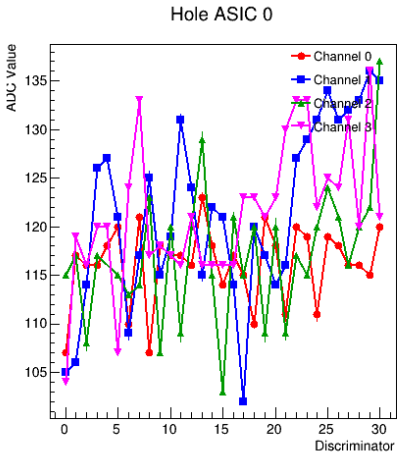


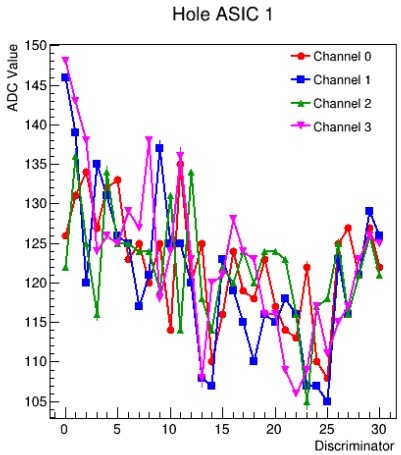


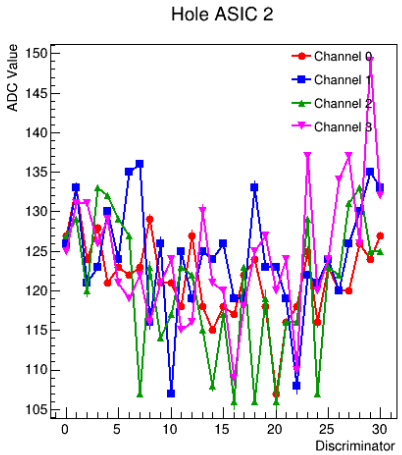


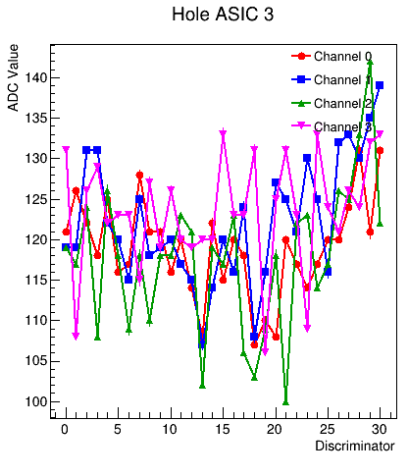


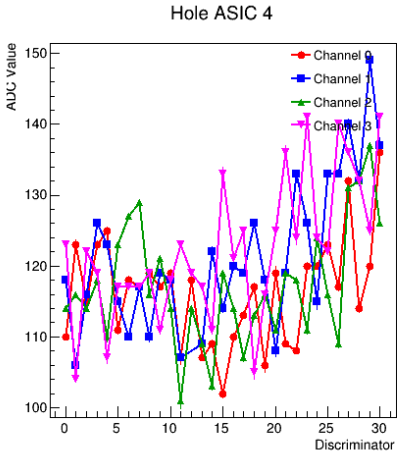
Module Ascending P-side Channel Mean Trim per Chn vs Disc

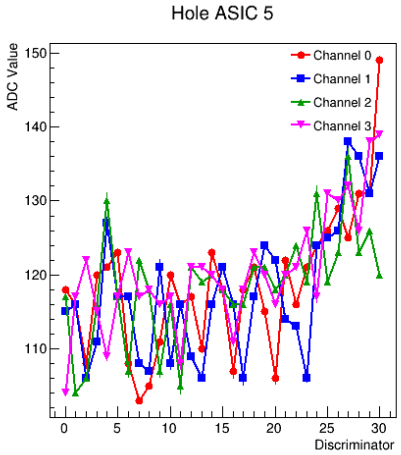


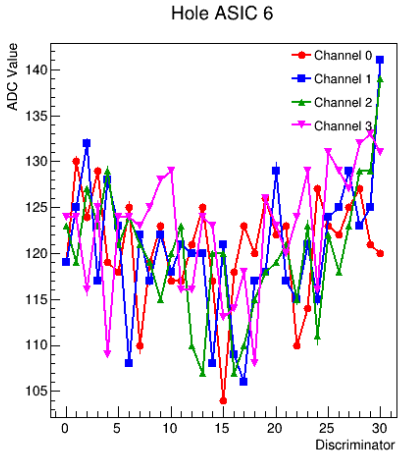


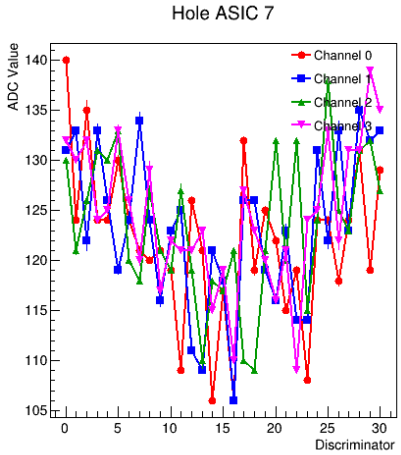




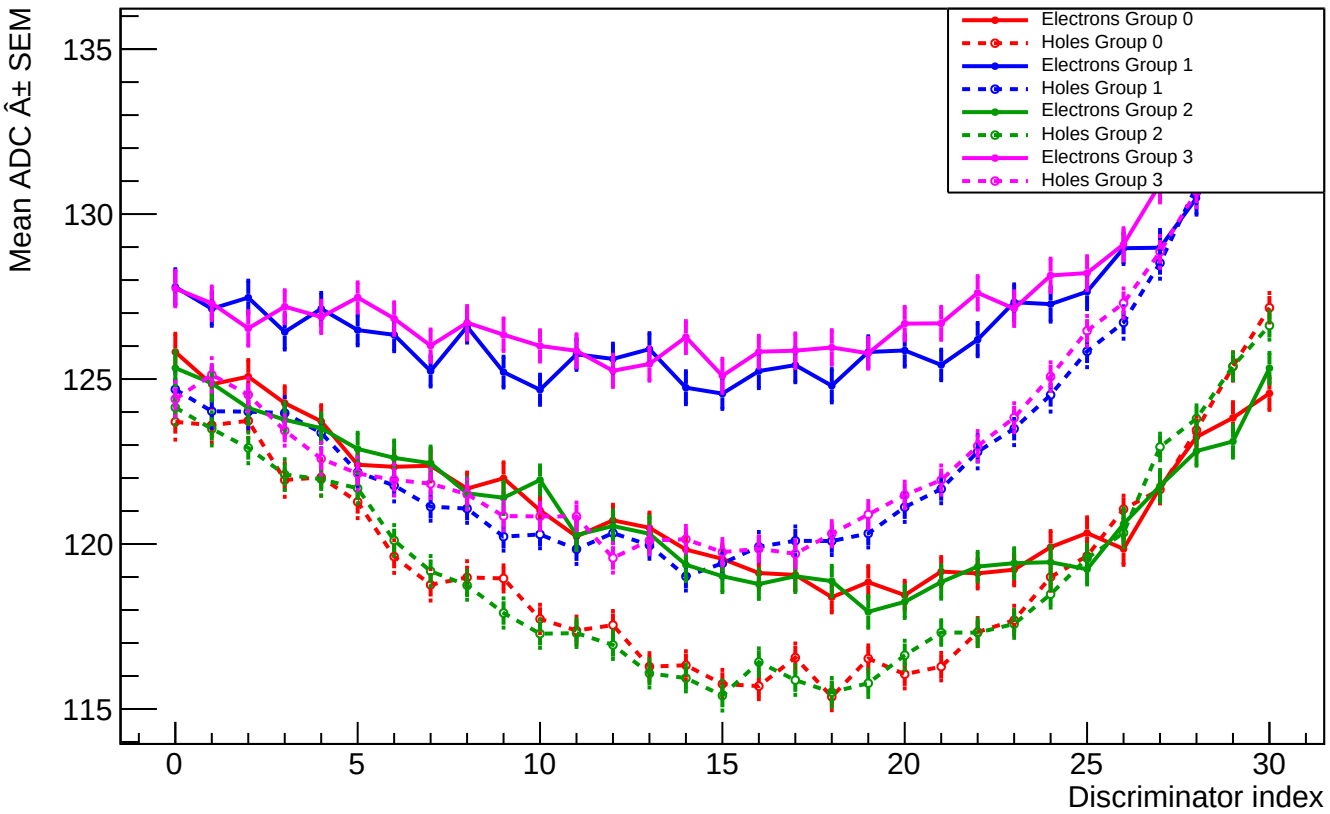






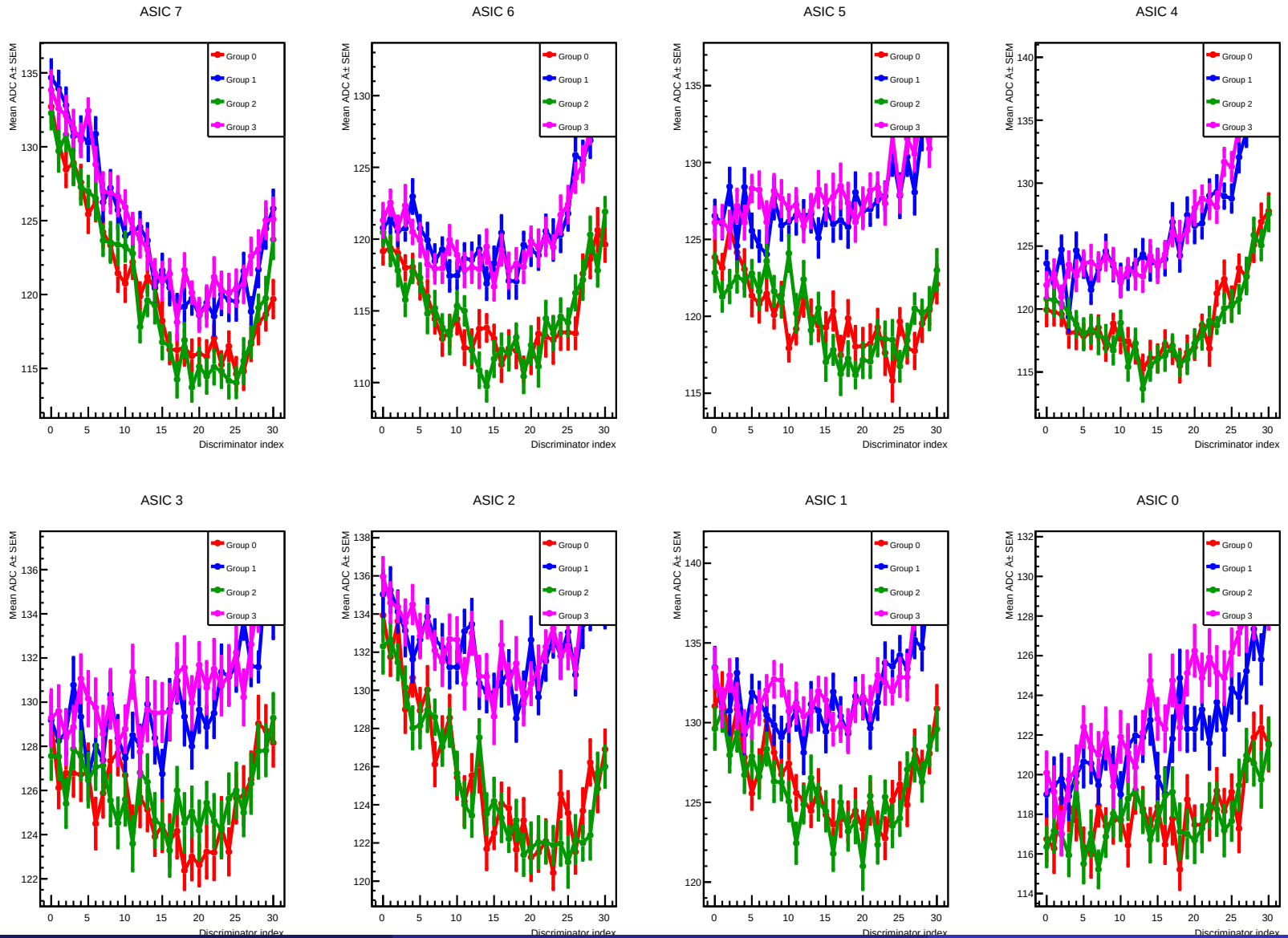


Module Group Mean Trim per Chn vs Disc

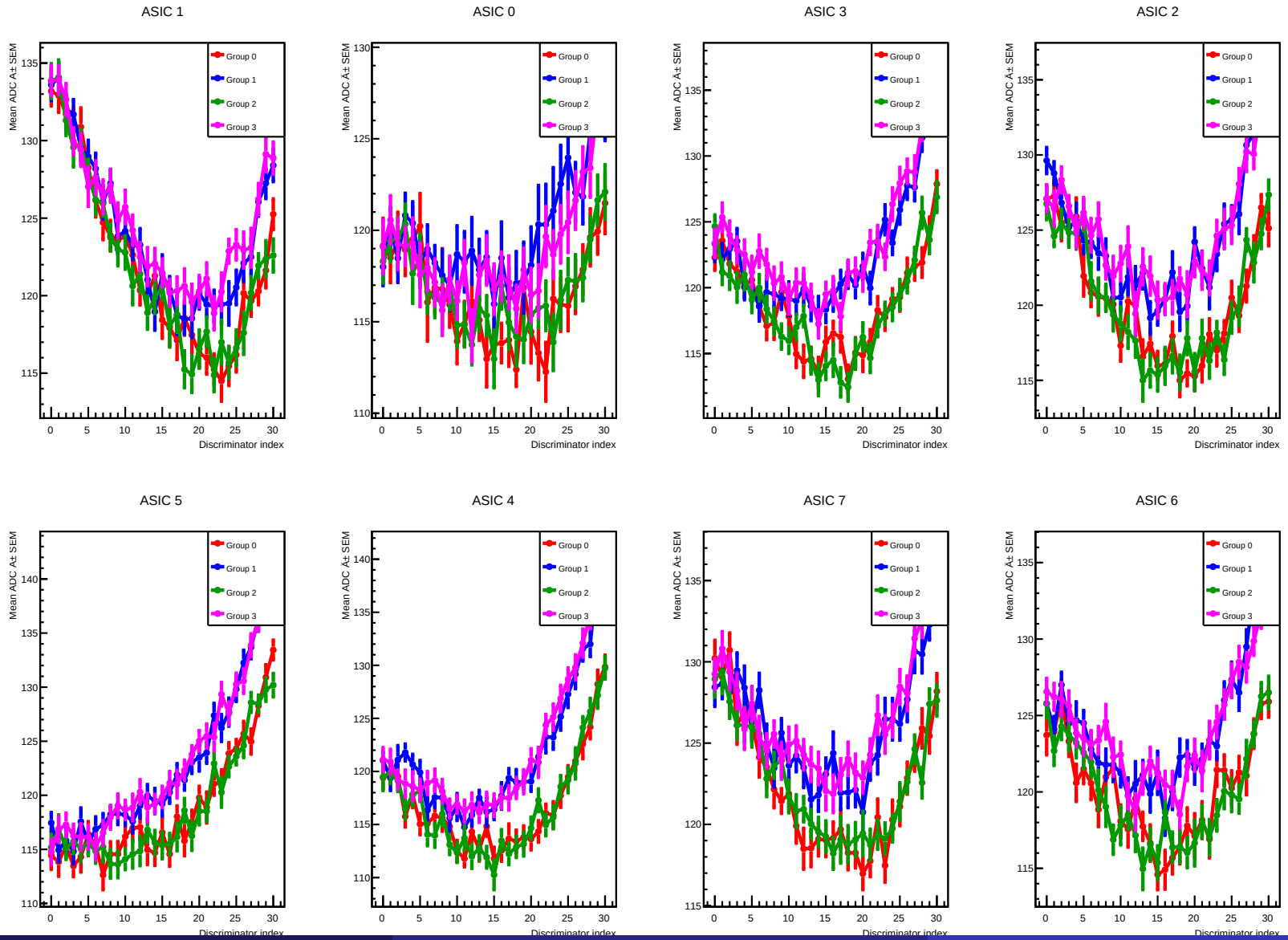


- Same U-pattern is observed
- Odd-even groups tend to follow a respective trend

Module Group N-side Mean Trim per Chn vs Disc each ASIC

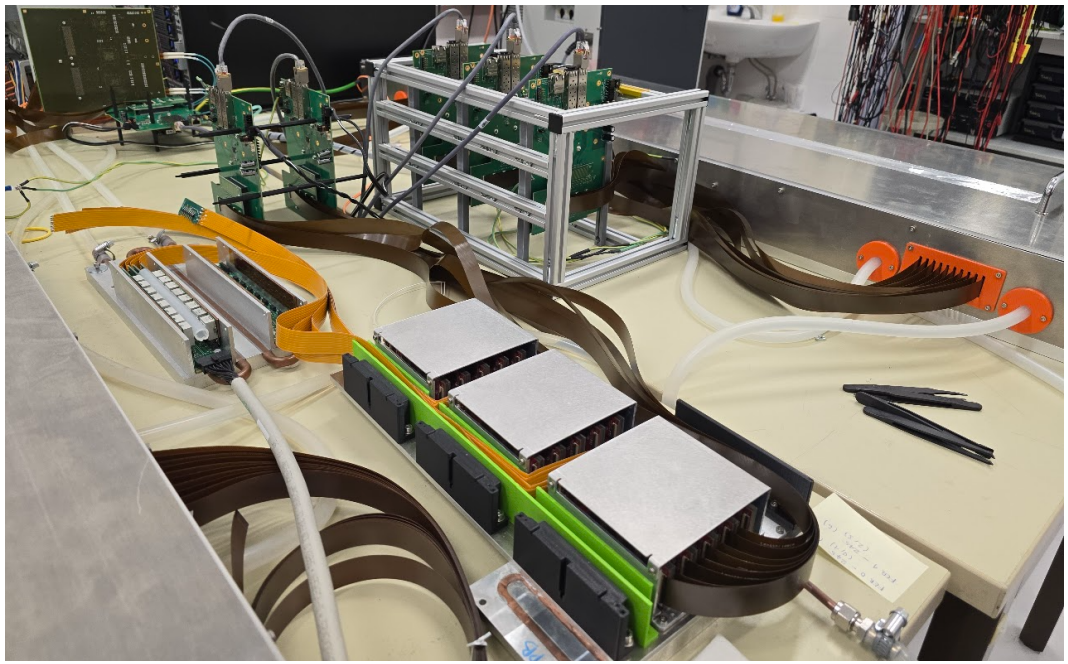


Module Group P-side Mean Trim per Chn vs Disc each ASIC

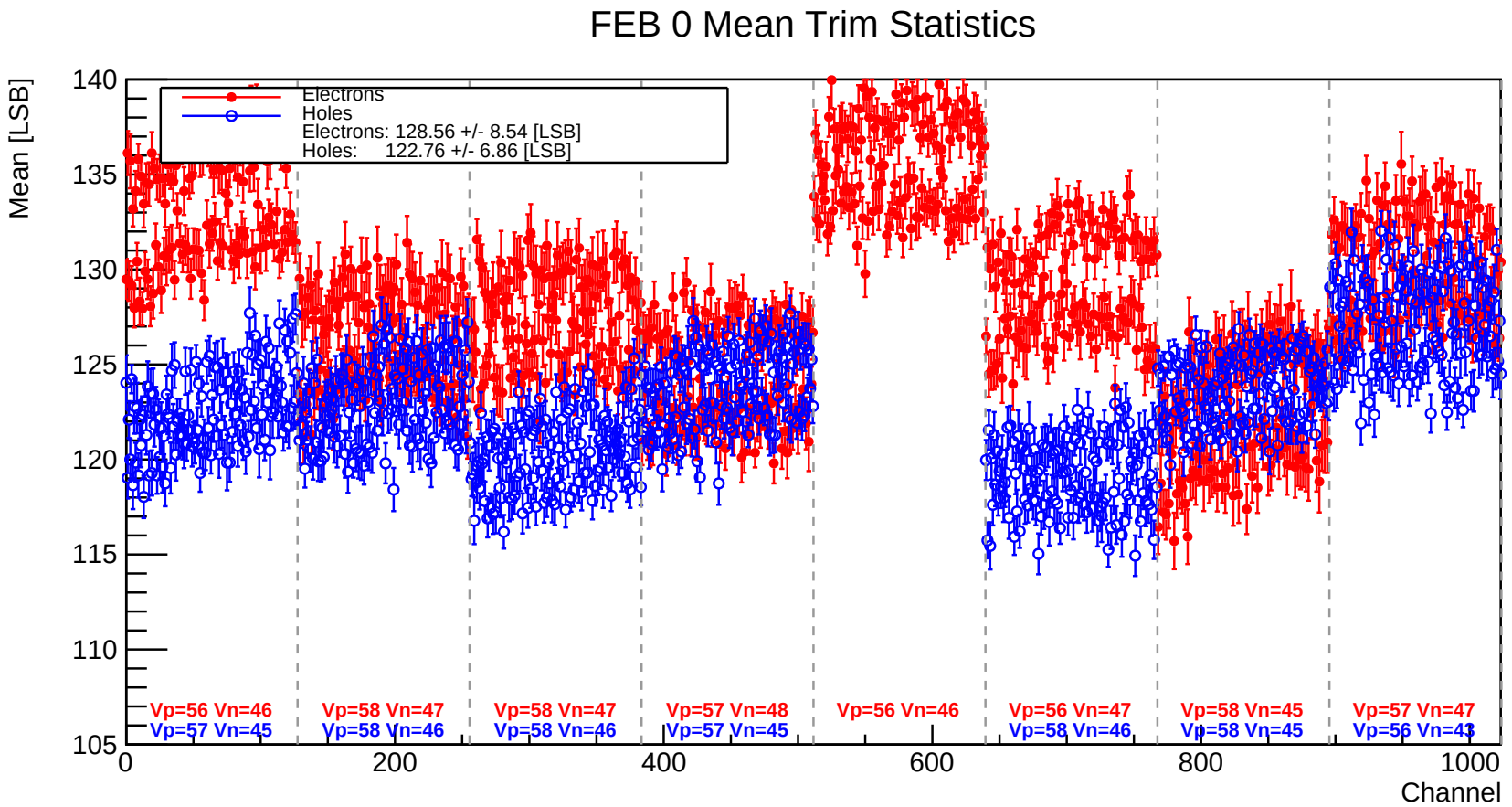


FEB Trim Analysis

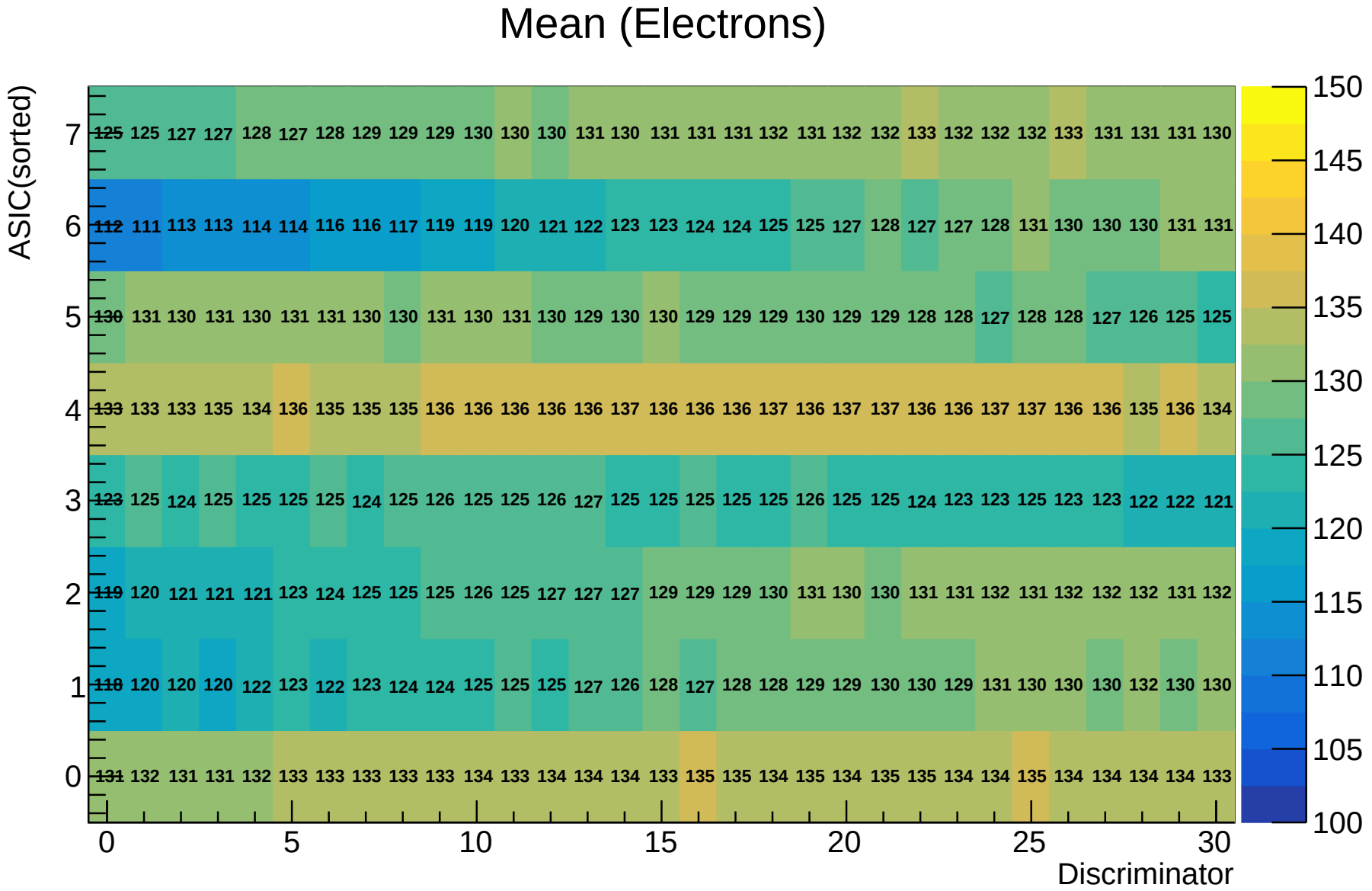
- Same idea as before, but standalone FEBs are tested, in a narrower and high-resolution amplitude range.
- Main observable differences can be accounted to the lack of attatched sensor and microcables.
- Tested FEBs tended to have communication issues with some ASICs
- Range of calibration amplitude [20-82]



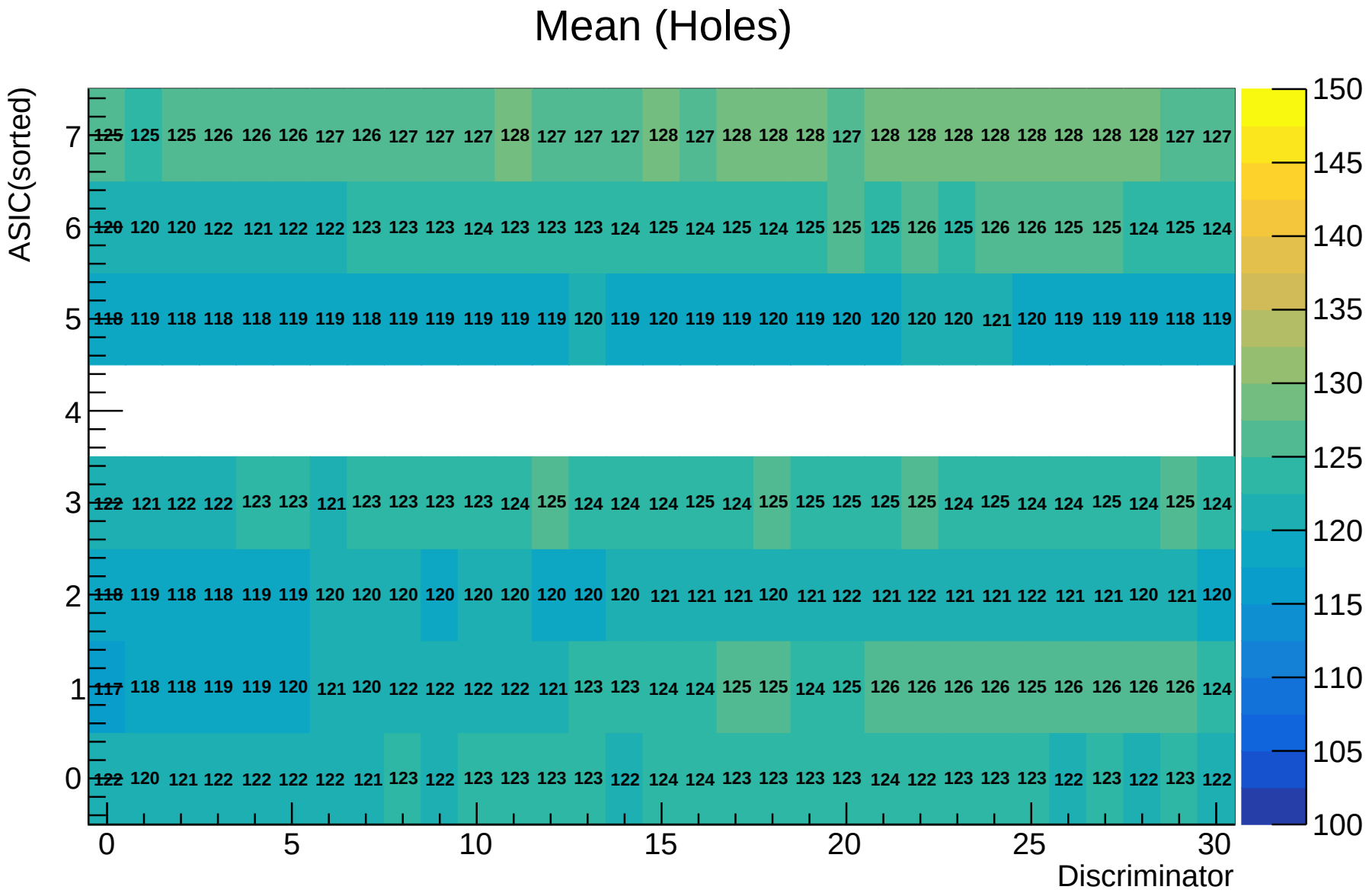
FEB Mean Trim per Disc vs Chn



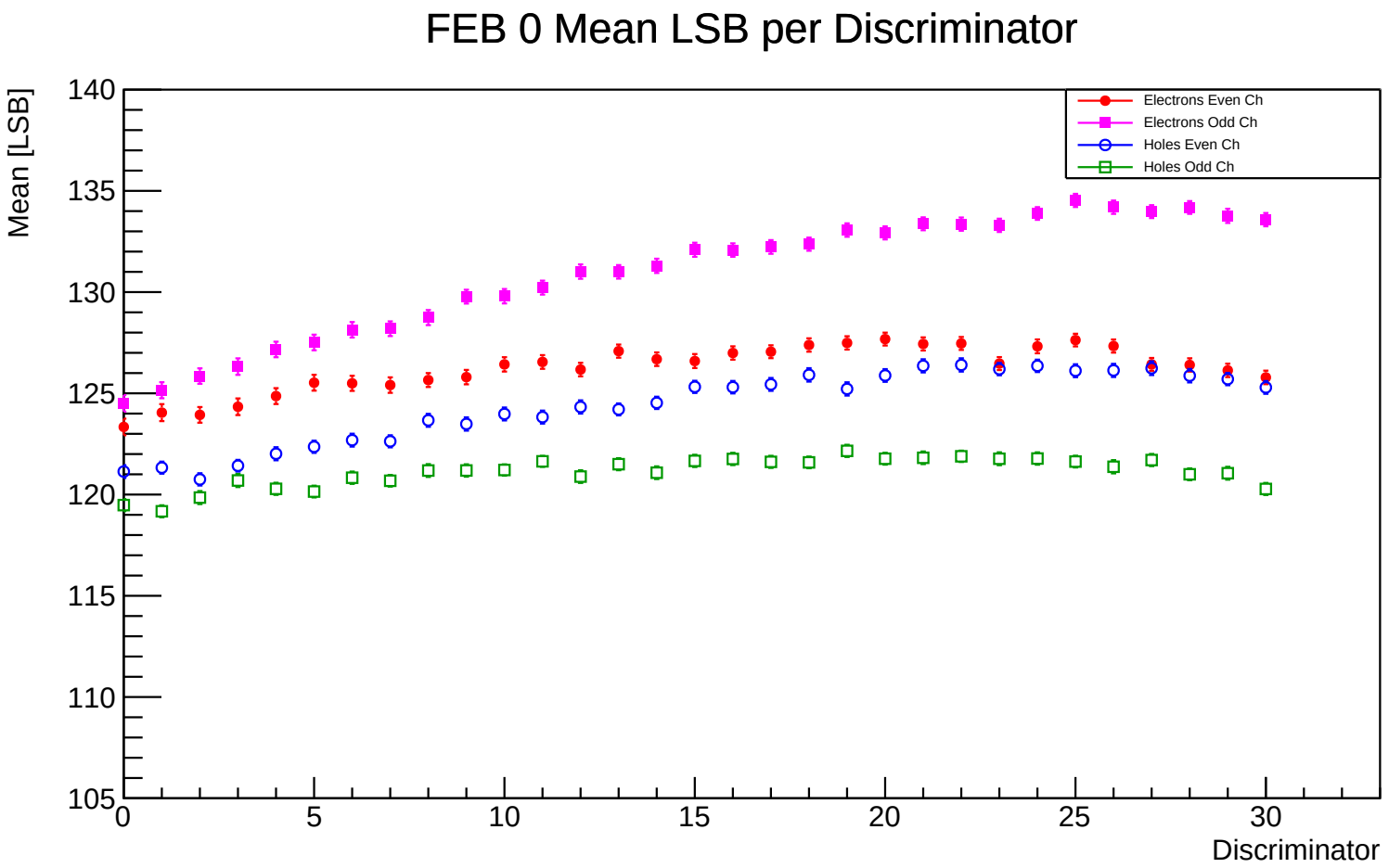
FEB N-side Mean Trim Heatmap



FEB P-side Mean Trim Heatmap



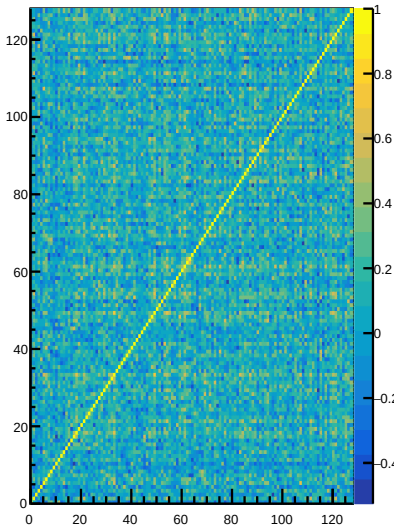
FEB Mean Trim per Chn vs Disc



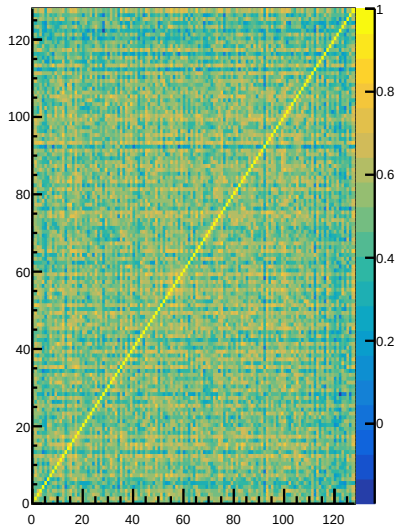
- Pattern seems to be reversed.

FEB N-side Channel Correlation

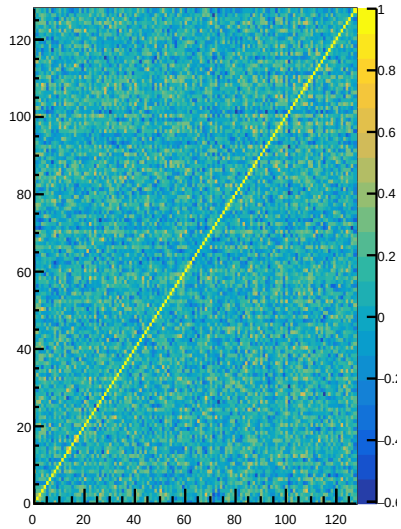
Electrons ASIC 7



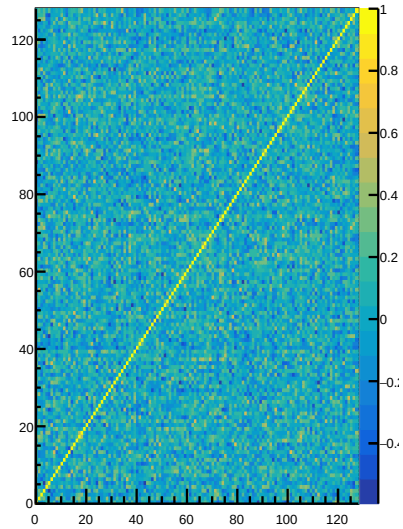
Electrons ASIC 6



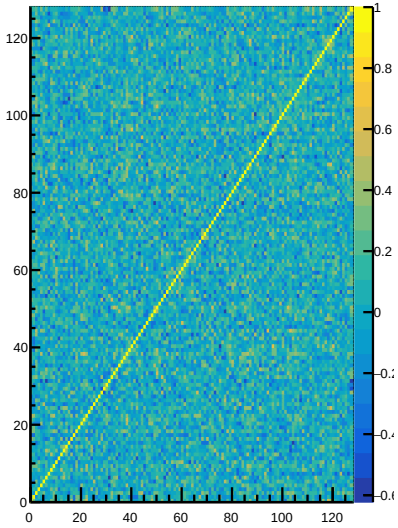
Electrons ASIC 5



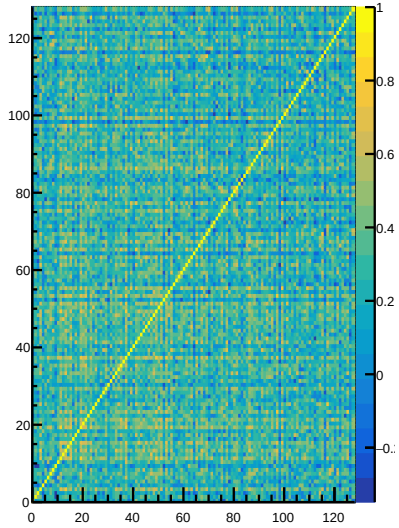
Electrons ASIC 4



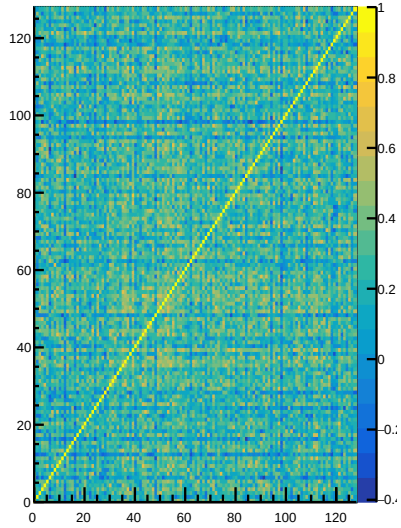
Electrons ASIC 3



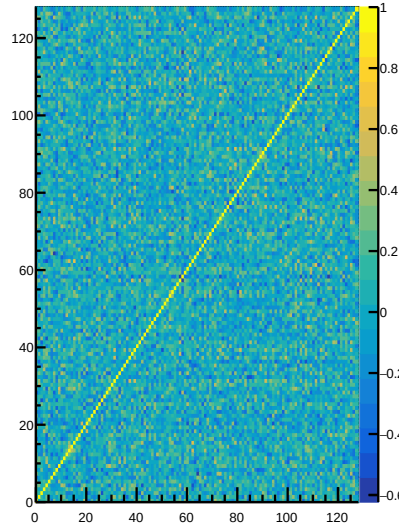
Electrons ASIC 2



Electrons ASIC 1

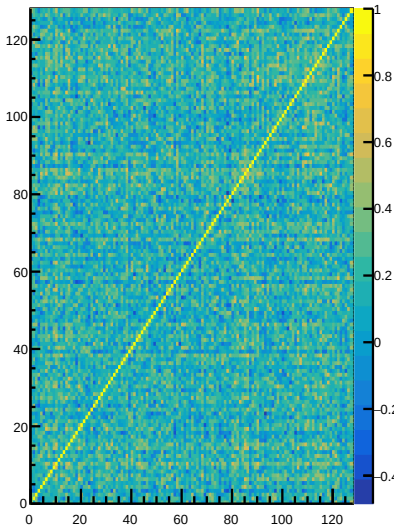


Electrons ASIC 0

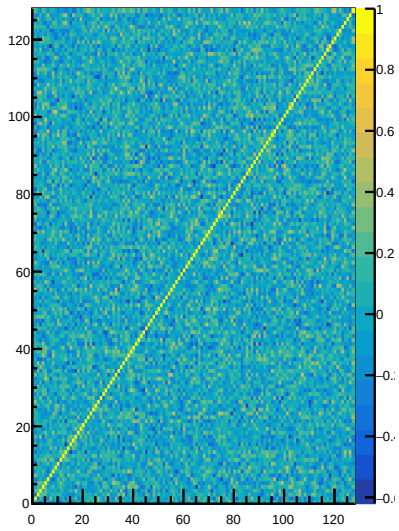


FEB P-side Channel Correlation

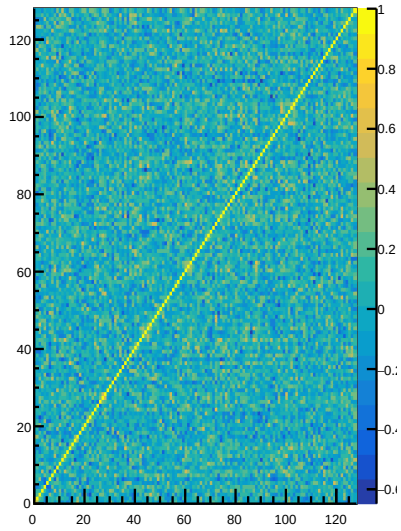
Holes ASIC 1



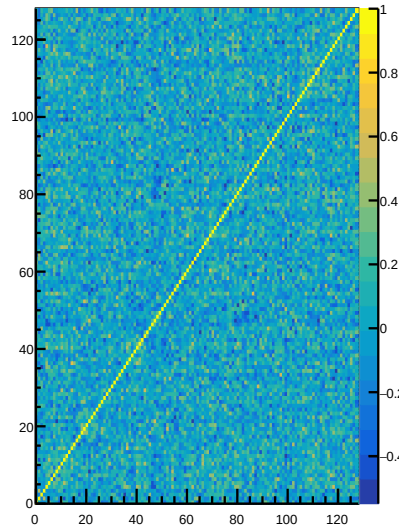
Holes ASIC 0



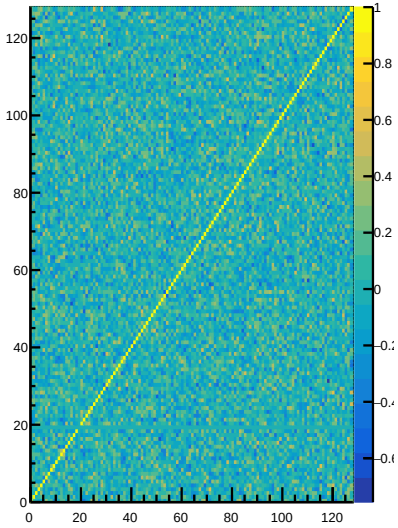
Holes ASIC 3



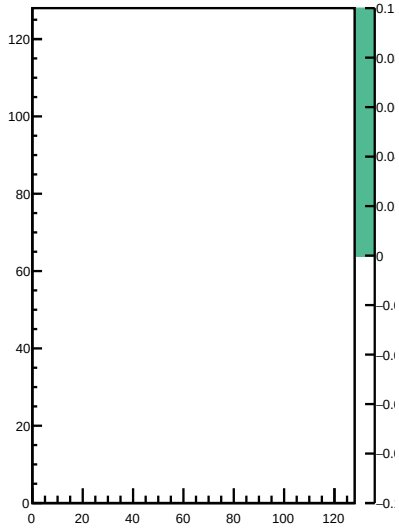
Holes ASIC 2



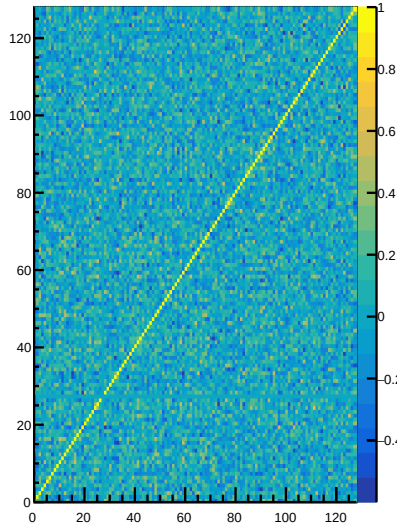
Holes ASIC 5



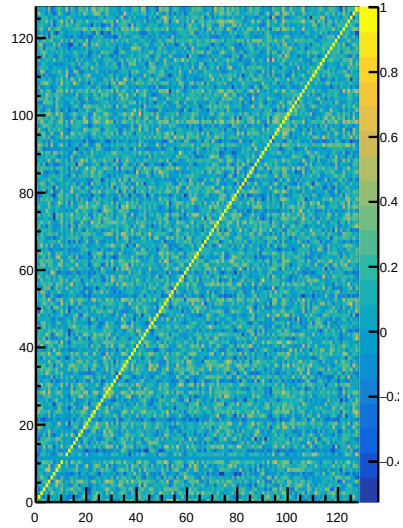
Holes ASIC 4



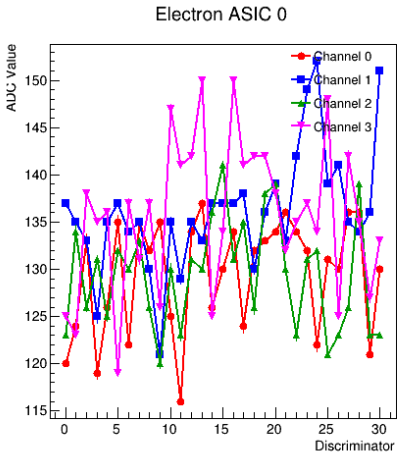
Holes ASIC 7

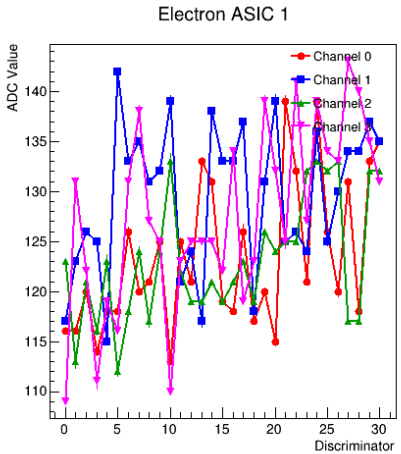


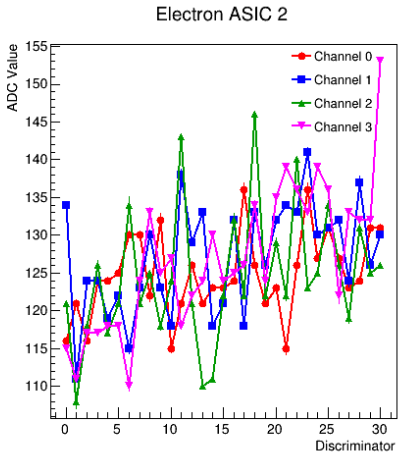
Holes ASIC 6

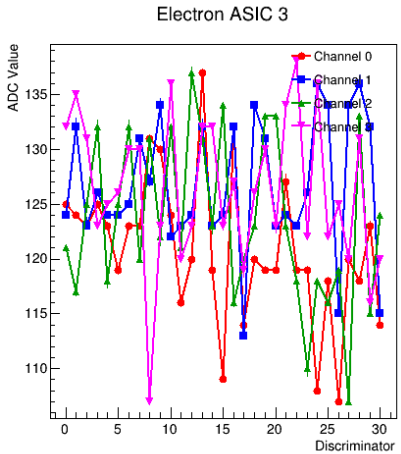


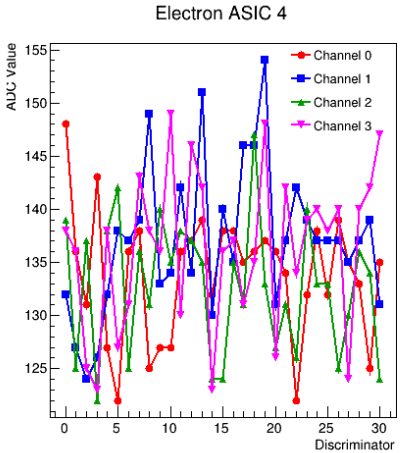
FEB Ascending N-side Channel Mean Trim per Chn vs Disc

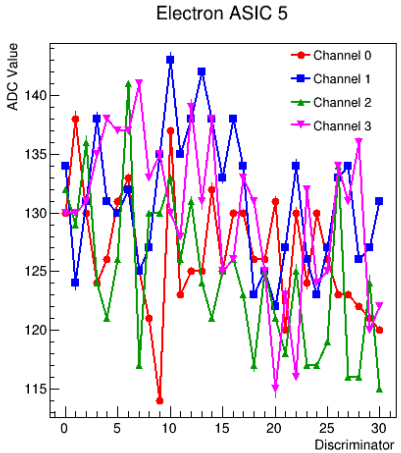


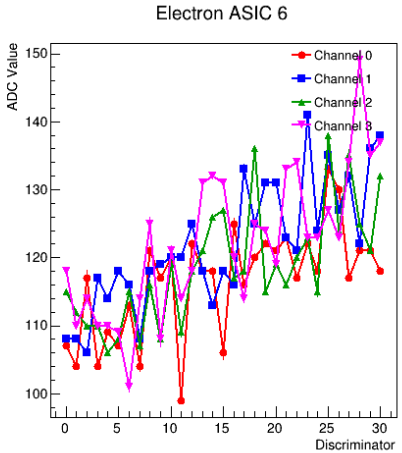


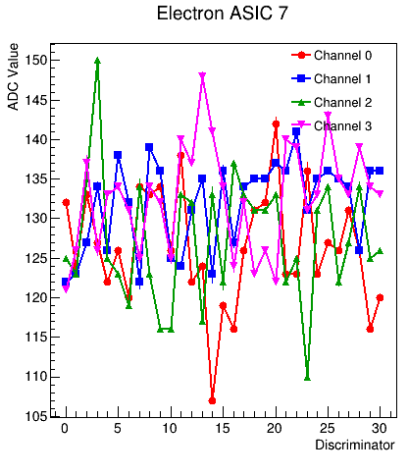




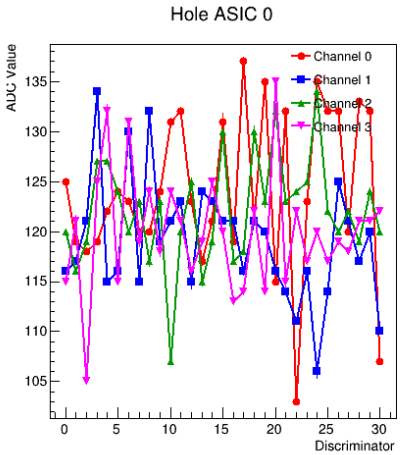


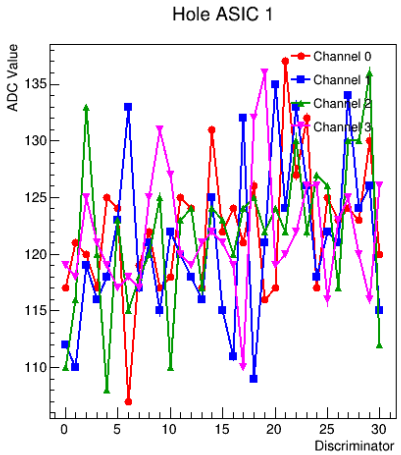


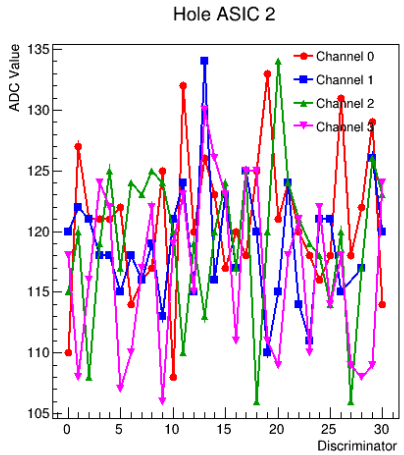


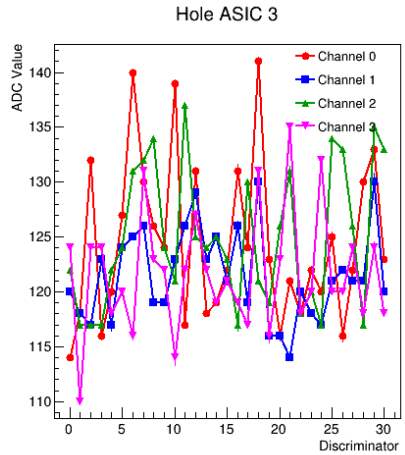


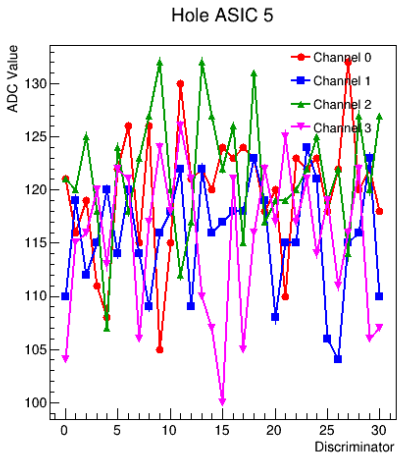
FEB Ascending P-side Channel Mean Trim per Chn vs Disc

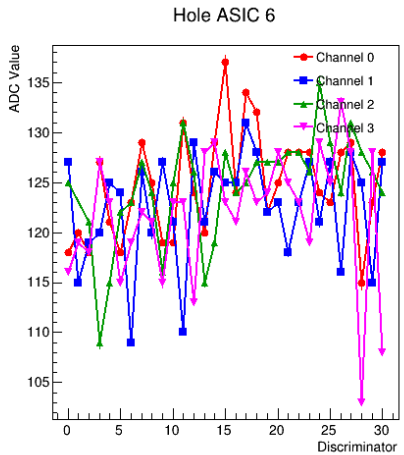


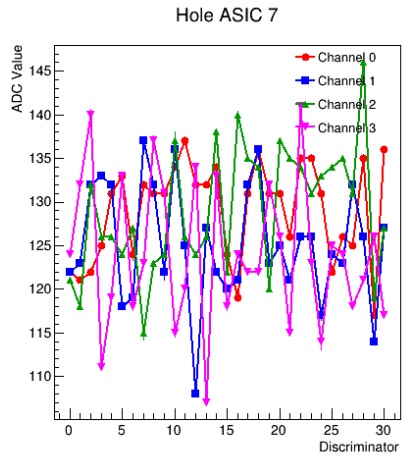




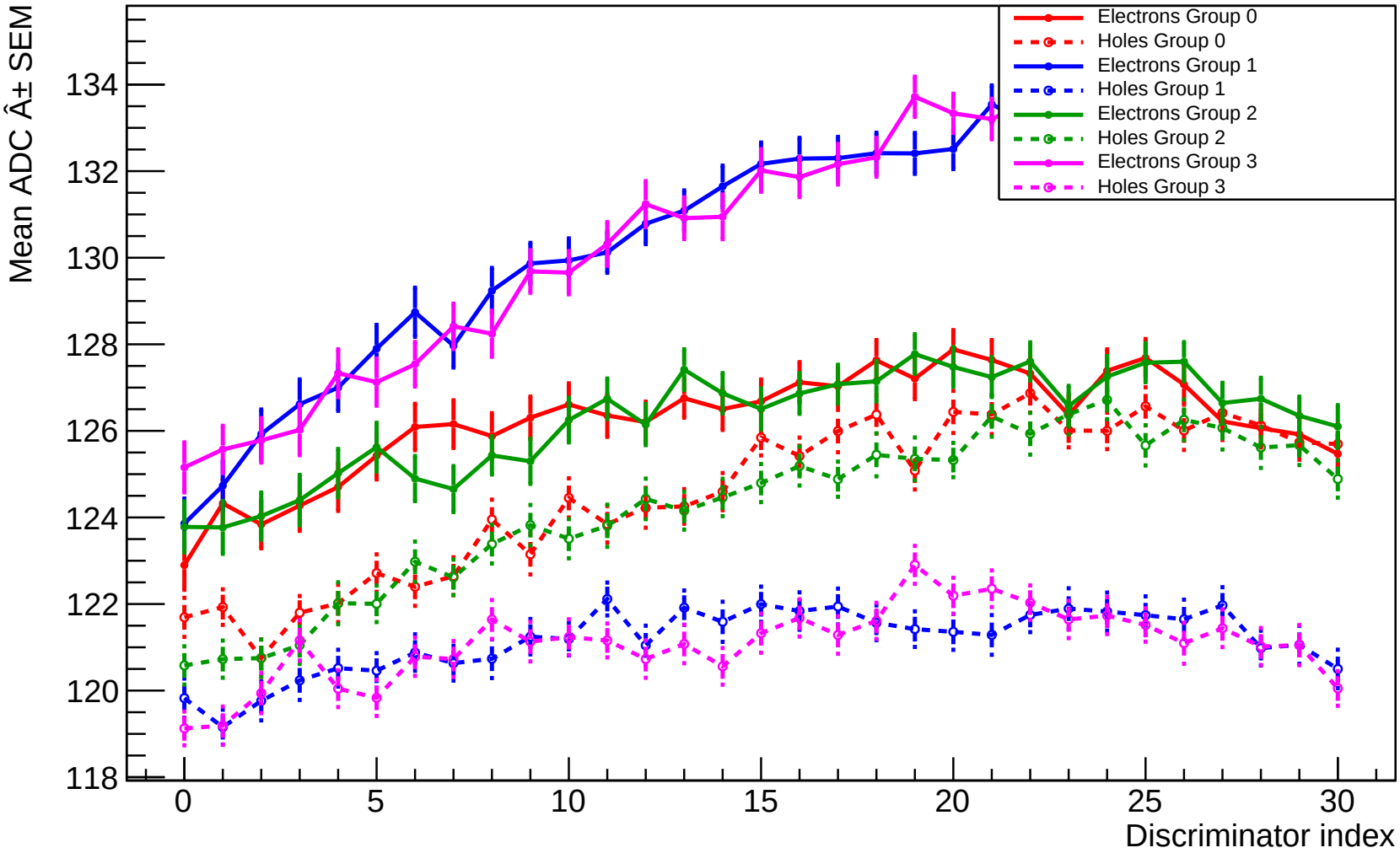




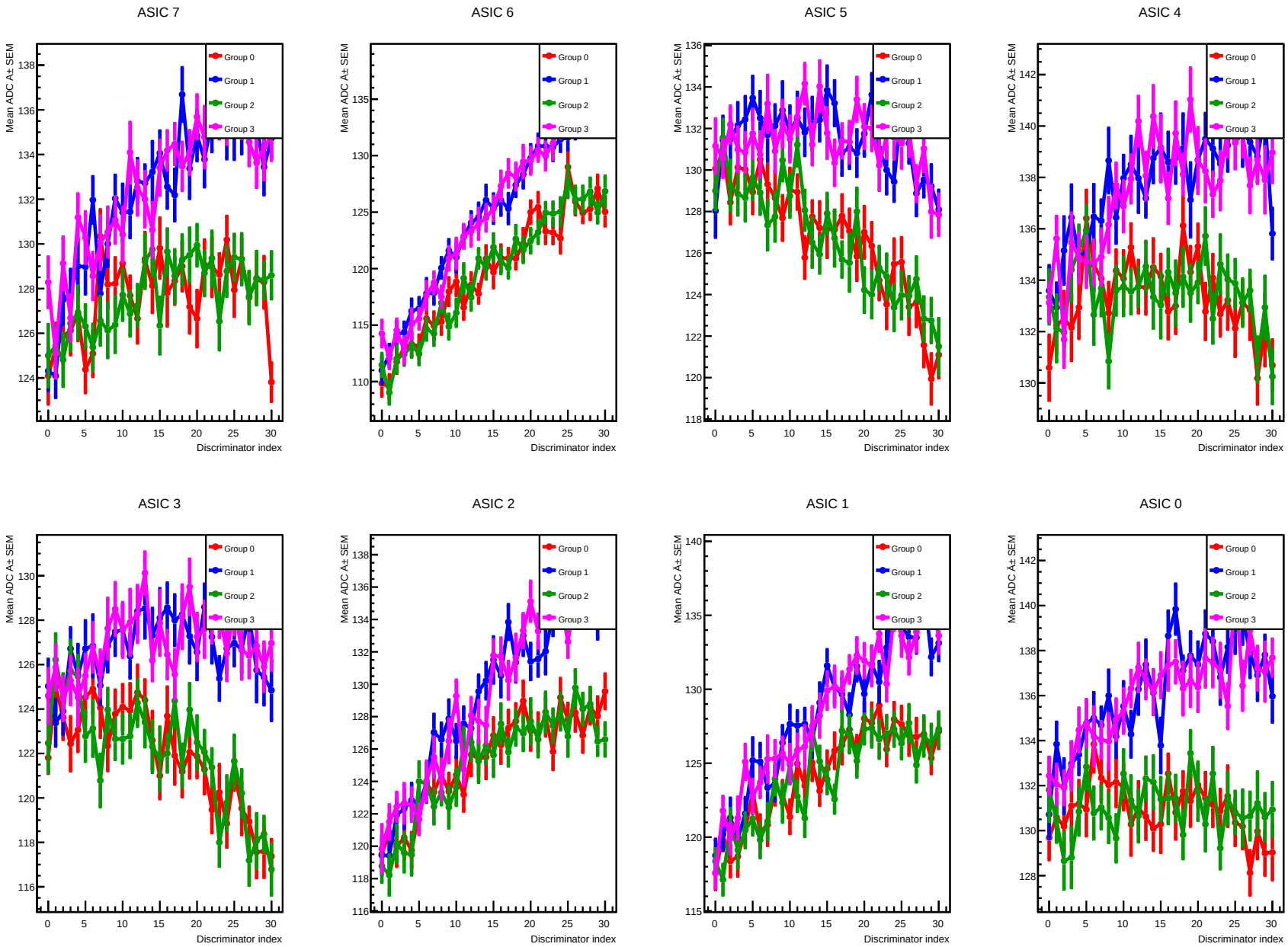




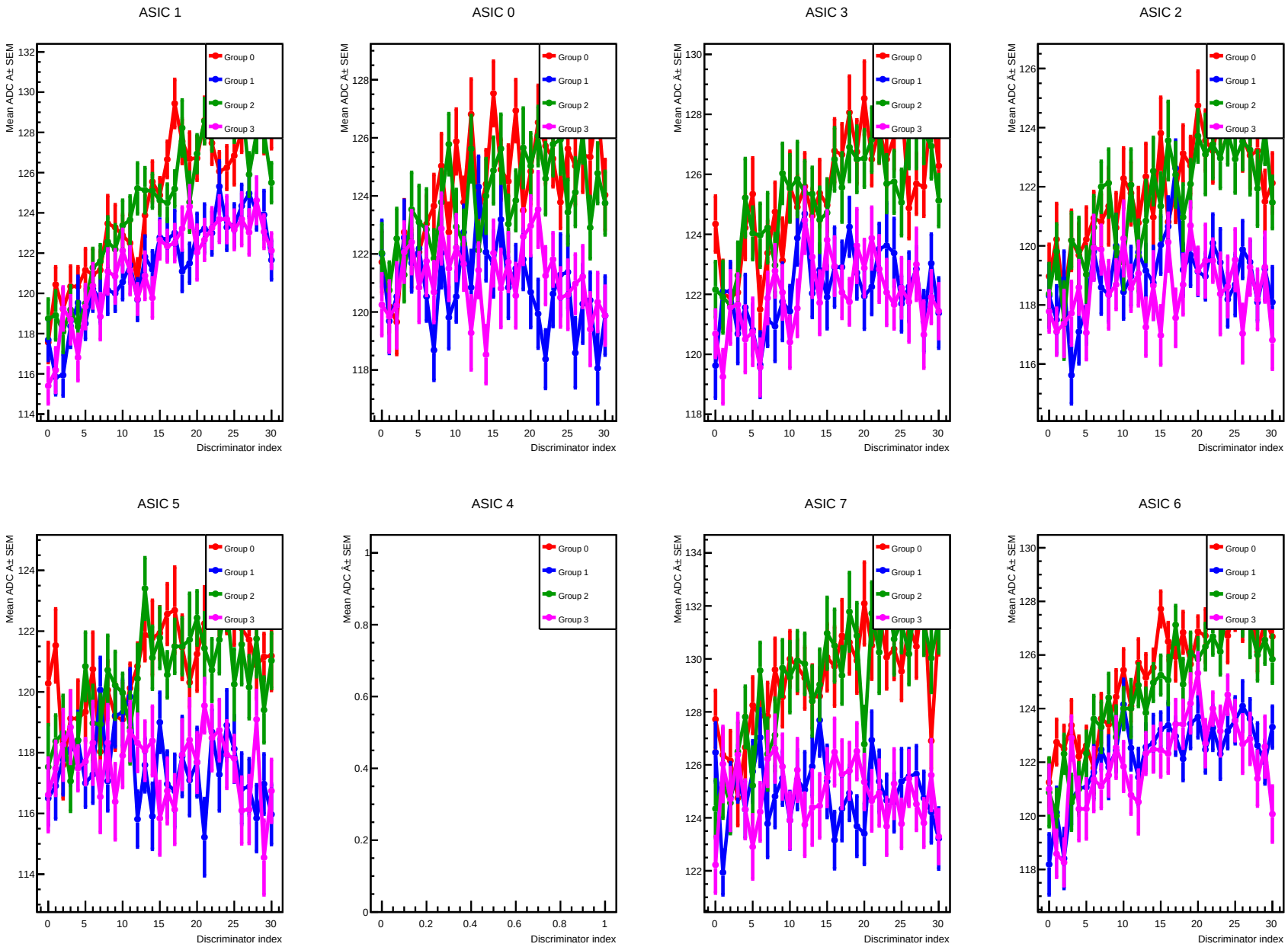
FEB Group Mean Trim per Chn vs Disc



FEB Group N-side Mean Trim per Chn vs Disc each ASIC



FEB Group P-side Mean Trim per Chn vs Disc each ASIC



Exploring Patterns

- Visualize distributions of trim values across channels, discriminators and ASICs.
- Identify systematic offsets, failed channels, outliers and unusual patterns.
- Compare electron vs. hole sides.
- Compare odd vs. even channel correlation.
- Compare distribution for completed module vs. standalone FEBs.

Novel Enhancements in Calibration Procedure

- Why start every disc from scratch?
  - Optimal trim value for disc d+1 is close to d
  - After finishing disc d calibration, calculate the average trim value across all chns (average by groups maybe be better?)
  - Use the average trim value as a starting guess for disc d+1
- Early termination
  - The algorythm monitors convergence per channel
  - If the error falls between a 5% tolerance the disc is marked as "converged"
  - Saves processing power, by skipping future coarse scan iterations
- Goal: reduce number of steps needed to converge, cutting calibration time.
- Coarse scan is already fast. How to speed up fine scan process ?

Early Modification Results

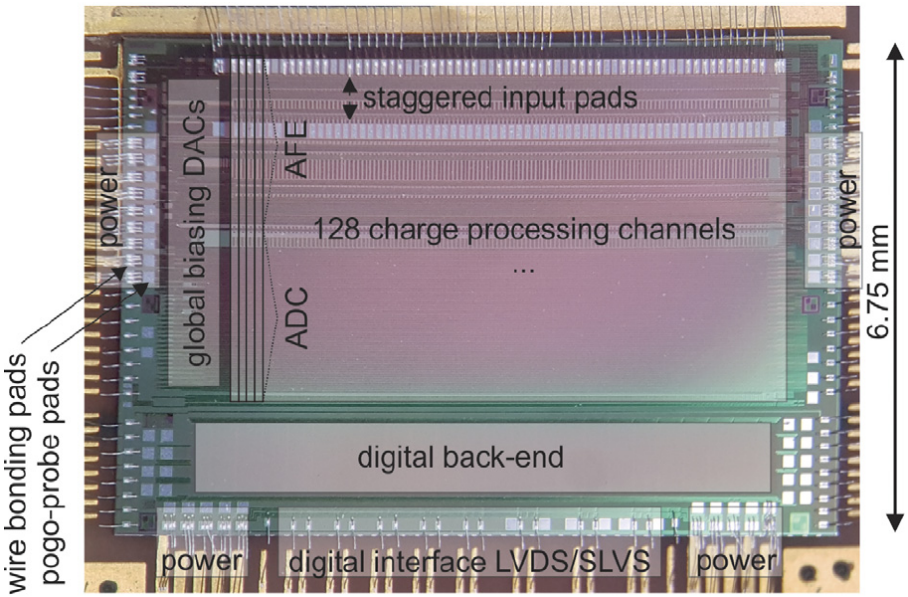
- Most of the channels (≈ 80) per discriminator, failed to converge within the 5% tolerance level.
- Average iteration steps were cut around 7-8 steps, in contrast to the max 11 steps
- Average coarse scan for each discriminator was around 4 seconds.
- Use of pair of groups mean trim value (2 seeds instead of 1) might help speed up the process even further.
- The use of sample deviation of trim values per pair of groups, may reduce drastically the fine scan iteration steps, without affecting the quality of data.
- Gained calibration time efficiency can not be specified, further investigation in modifying the procedure is required.

Thank You !

Backup Slides

SMX v2.2 ASIC

- STS-MUCH-XYTER (SMX) v2.2 is the readout ASIC used in STS, designed for silicon microstrip tracking.
- Offers low power consumption and self triggering characteristics, with Flash ADC and buffer integration.
- Responsible for digitizing analog charge signals into time (fast path)/energy (slow path) values.
- Digitized hits include 5-bit charge, 14-bit time stamp, 8-bit counter.
- Linearity range up to 15 fC



Sample module trim data file

```
# ID XA-000-08-002-000-006-136-01
# Tag _trim_
# Date 240826_17:38:56
# Vref_p 55
# Vref_n 19
# Thr2_glb 35
# Vref_t 118
# Vref_t_range 1
# Pol 1
# ADC range 30-247
# FAST disc 30
ch:   0  126  131  134  127  132  133  123  125  120  125  114  135  120  125  110  116  124  119  118  123  117  114  113  122  110  108  125  127  121  127  122   33
ch:   1  146  139  120  135  131  126  125  117  121  137  125  125  120  108  107  123  119  115  110  116  115  118  116  107  107  105  123  116  121  129  126   32
ch:   2  122  136  125  116  134  125  125  124  124  119  131  114  134  118  114  122  120  124  120  124  124  123  116  105  117  118  125  116  121  126  121   39
ch:   3  148  143  138  124  126  125  129  127  138  118  124  136  123  108  120  121  128  124  123  116  116  109  106  109  117  111  115  117  123  126  125   18
ch:   4  138  131  121  129  131  124  122  124  118  122  130  123  114  111  121  122  107  120  110  119  117  110  114  120  103  110  119  104  119  121  124   32
ch:   5  135  133  128  125  131  133  121  123  122  121  122  120  124  124   -1  116  123  103  117  111  122  116  119  101  122  122  117  117  131  122  123   27
ch:   6  130  134  129  124  126  134  119  132  122  120  117  117  119  117  117  120  108  122  117  102  107  109  116  121  119  125  104  116  126  107  120   30
ch:   7  146  132  131  131  130  127  134  126  120  127  126  121  125  120  120  117  119  123  117  124  120  120  109  108  122  126  116  126  132  135  126   20
ch:   8  146  127  125  121  135  125  125  133  124  121  130  124  122  122  118  118  100  121  107  124  106  123  107  108  118  115  125  121  115  126  119   41
ch:   9  135  137  133  129  127  131  138  132  130  121  128  119  127  117  126  122  116  122  115  119  116  115  110  121  102  120  110  120  124  126  133   18
ch:  10  127  140  123  134  125  127  121  122  119  130  116  116  118  114  106  120  108  116  101  121  120  113  109  120  114  107  110  116  117  122  111   32
ch:  11  135  130  138  129  123  123  127  137  128  114  120  122  117  121  117  126  131  125  119  113  123  119  118  127  117  124  124  120  114  119  123   29
ch:  12  139  138  131  125  135  119  131  125  130  117  122  117  114  115  121  111  122  117  122  120  116  117  109  123  107  120  126  125  109  122  123   29
ch:  13  129  127  125  134  125  133  117  136  122  124  123  127  125  122  131  118  124  124  120  123  120  116  121  118  110  124  125  118  124  130  120   25
ch:  14  134  136  133  124  135  125  125  123  120  123  107  106  109  119  119  120  125  106  106  114  118  123  105  116  113  110  107  118  124  117  107   30
ch:  15  139  128  125  135  122  136  114  146  125  119  122  125  120  110  109  125  123  119  121  109  120  119  118  121  130  119  107  121  116  120  124   21
ch:  16  131  129  124  136  117  108  122  125  118  125  105  117  129  123  117  118  114  115  121  124  116  124  113  117  117  110  122  126  129  122  123   24
ch:  17  134  140  133  136  126  127  124  125  134  117  109  131  121  122  108  124  116  131  122  119  125  117  114  119  121  115  106  125  120  135  124   24
ch:  18  133  121  130  121  135  124  123  129  117  104  121  108  123  118  122  122  121  114  107  118  122  119  104  108  114  115  107  130  122  110  117   37
ch:  19  133  134  133  130  136  133  122  122  123  122  120  119  121  122  123  126  126  111  118  125  119  118  114  108  122  127  125  108  121  131  121   13
ch:  20  138  134  135  135  129  130  122  135  121  123  125  126  124  104  131  109  114  105  118  117  108  119  121  121  109  118  118  121  117  119  125   27
ch:  21  134  133  135  125  130  131  132  126  124  121  127  123  124  132  123  119  114  118  113  101  117  116  116  119  113  126  124  121  130  118  130   27
ch:  22  131  131  125  123  131  125  120  129  123  122  132  132  120  121  117  122  116  117  117  115  127  120  122  110  114  126  115  118  126  121  127   37
ch:  23  132  127  128  133  124  124  122  130  127  123  131  123  116  122  119  125  119  119  119  119  106  106  122  108  121  120  121  121  135  126  124   25
ch:  24  132  135  138  123  144  131  125  124  124  125  118  131  122  117  121  106   -1  119  109  115  117  107  120  107  119  114  114  121  117  118  120   21
ch:  25  131  133  126  126  122  134  124  121  119  118  121  116  125  122  117  111  116  105  122  124  108  118  119  109  119  120  125  124  133  118  131   22
ch:  26  132  136  126  136  124  122  120  125  125  120  117  121  119  105  115  115  104  122  107  122  124  114  117   99  119  119  121  123  125  126  133   44
ch:  27  130  136  130  127  134  129  129  124  129  124  115  122  111  136  124  123  112  121  115  113  116  121  118  125  119  115  122  120  124  131  124   15
ch:  28  126  129  136  137  131  134  132  130  119  129  124  119  116  120  122  123  122  105  118  132  105  107  105  108  115  109  115  120  123  124  118   34
ch:  29  134  129  123  139  121  130  133  126  130  121  117  122  119  117  126  118  122  119  117  118  117  118  110  123  118  117  109  109  121  121  120   24
ch:  30  136  125  126  119  133  131  123  123  123  119  127  124  121  116  118  120  107  131  115  107  108  120  108  107  109  104  118  116  118  126  126   41
ch:  31  130  133  135  125  124  107  129  124  134  123  123  115  122  133  119  118  121  120  111  107  119  130  114  122  127  115  130  125  122  124  137   17
ch:  32  132  131  144  130  125  121  119  123  122  134  124  130  113  129  115  113  121  117  123  114  115  116  116  117  108  122  121  110  129  117  125   41
ch:  33  138  140  134  130  134  120  127  131  127  130  125  120  121  120  131  125  122  125  101  108  122  115  125  118  119  114  120  130  131  141  134   21
ch:  34  146  134  135  136  136  127  130  125  121  119  117  125  116  119  124  115  106  117  118  103  123  109  103  124  118  120  121  106  120  123  116   37
ch:  35  130  138  137  123  123  117  123  130  123  120  132  121  124  124  133  119  120  125  119  116  119  116  121  124  122  126  113  107  121  132  123   24
ch:  36  136  139  132  132  132  121  125  120  125  124  132  123  125  123  121  104  122  115  109  116  122  108  117  106  106  107  119  118  120  118  126   24
ch:  37  122  140  140  135  132  120  120  126  124  114  123  124  120  135  119  116  121  125  117  110  117  121  121  117  129  118  118  116  121  121  122   29
ch:  38  134  125  132  132  135  136  123  126  126  121  129  128  130  123  110  119  115  118  106  105  108  118  110  108  118  118  123  113  118  124  121   32
ch:  39  134  131  151  124  129  126  129  122  135  123  122  126  126  119  116  121  117  121  115  126  115  122  116  124  115  129  123  116  125  136  133   20
ch:  40  124  135  146  135  130  124  137  106  124  122  123  116  120  125  118  115  129  122  125  104  116  132  108  121  120  123  121  115  109  106  122   36
```

Sample of FEB trim data file

```
# ID XA-000-09-004-011-017-008-11
# Tag _trim_
# Date 250815_15:12:17
# Vref_p 58
# Vref_n 46
# Thr2_glb 16
# Vref_t 114
# Vref_t_range 1
# Pol 1
# ADC range 20-82
# FAST disc 20
ch:   0  117  121  120  117  125  124  107  119  122  117  118  125  124  117  131  122  124  121  126  116  117  137  127  132  117  125  123  124  123  130  120   17
ch:   1  112  110  119  116  118  123  133  117  121  115  122  120  118  116  125  115  111  132  109  121  135  124  133  126  118  122  121  134  124  126  115    9
ch:   2  110  116  133  120  108  123  115  118  120  125  110  123  124  117  124  123  120  124  125  122  124  122  130  122  127  126  117  130  130  136  112   21
ch:   3  119  118  125  121  119  117  118  117  125  131  127  120  119  121  122  121  119  110  132  136  119  120  122  126  126  116  123  125  120  116  126   16
ch:   4  114  121  107  121  108  121  120  136  119  123  131  114  124  115  131  126  139  123  131  132  120  131  121  121  130  125  126  122  122  133  137   30
ch:   5  121  118  109  118  120  115  117  115  115  125  117  115  122  121  124  121  122  107  121  114  120  119  136  121  130  117  119  124  122  124  116   15
ch:   6  118  123  115  110  103  118  114  118  122  118  122  135  116  122  120  125  125  125  124  107  134  123  131  127  135  122  130  124  137  119  135   23
ch:   7  116  116  120  116  116  126  120  115  116  115  121  120  116  119  121  116  120  124  132  130  117  114  120  122  124  125  134  126  124  126  125   18
ch:   8  121  122  122  120  126  116  121  121  121  125  117  119  107  132  134  119  125  127  120  125  119  124  122  124  124  117  132  139  122  133  134   28
ch:   9  119  116  120  110  118  116  116  111  133  118  117  117  117  116  120  120  127  120  124  116  131  131  119  138  134  122  123  118  118  116  116   25
ch:  10  122  110  109  118  124  122  117  117  123  116  123  127  118  118  121  121  122  127  139  120  131  139  132  140  132  130  132  131  132  126  130   23
ch:  11  107  116  119  122  118  105  121  115  121  125  123  125  121  117  113  126  124  121  119  134  118  119  130  118  116  120  121  132  118  120  117   16
ch:  12  109  125  117  119  122  118  110  133  123  122  132  115  117  121  125  117  122  121  136  130  121  123  122  131  136  136  130  133  122  131  126   26
ch:  13  121  119  116  122  125  121  116  120  108  115  115  115  117  114  123  132  135  118  131  122  118  119  124  110  120  121  131  123  125  133  119   17
ch:  14  118  120  124  108  118  123  124  123  132  121  119  121  132  126  125  123  124  123  126  121  119  133  132  132  138  126  134  130  133  132  123   20
ch:  15  116  112  110  109  113  115  121  116  117  122  118  132  119  119  117  121  125  130  125  115  122  131  116  123  123  126  115  123  122  120  124   21
ch:  16  108  120  106  119  124  124  121  118  135  131  116  108  107  123  132  131  126  125  133  117  120  125  118  124  124  118  127  123  133  120  119   38
ch:  17  108  115  123  115  115  123  122  121  118  120  119  112  117  115  125  123  133  115  122  129  121  121  121  119  122  119  123  135  120  106  121   12
ch:  18  118  122  121  118  116  117  120  121  120  132  122  105  132  123  125  123  121  122  127  119  122  126  120  125  130  122  107  130  124  120  122   27
ch:  19  120  121  123  108  105  121  111  106  126  119  116  116  113  126  120  123  124  124  126  116  119  123  122  123  125  120  130  119  132  120  127   20
ch:  20  124  120  123  117  111  122  122  119  124  126  118  123  118  125  119  117  122  133  134  119  132  116  135  134  127  119  123  126  131  122  110   25
ch:  21  122  115  114  125  119  114  122  126  117  118  116  119  125  123  123  125   -1  135  134  125  120  126  116  127  122  117  124  133  125  119  123   16
ch:  22  117  120  119  121  123  120  122  124  121  116  134  122  133  122  123  123  124  125  125  124  120  125  140  126  121  113  123  122  120  127  126   25
ch:  23  109  127  118  122  116  119  122  126  123  118  126  123  122  118  115  119  124  125  127  127  126  130  119  120  123  122  126  115  116  120  121   16
ch:  24  120  119  126  118  119  119  110  116  127  123  131  122  121  120  126  123  119  134  122  121  120  126  123  133  122  122  124  136  137  123  133   32
ch:  25  121  116  105  121  125  116  134  131  120  121  118  124  120  125  131  121  121  132  122  122  131  117   -1  125  118  139  124  126  120  117  116   19
ch:  26  118  116  112  137  122  121  120  117  126  115  110  116  124  126  121  119  126  122  127  122  123  120  131  126  120  139  135  121  120  135  133   29
ch:  27  107  110  120  106  120  118  113  124  121  125  123  122  118  120  132  122  132  121  117  125  103  124  132  121  130  123  135  123  124  127  119   22
ch:  28  121  125  105  119  123  115  123  122  119  133  114  120  126  121  123  120  131  133  118  136  121  117  126  131  133  139  122  133  125  132  122   26
ch:  29  120  119  116  124  113  120  119  107  114  133  125  121  116  125  123  122  125  118  130  116  118  112  122  132  118  125  132  126  121  119  111   25
ch:  30  126  114  122  110  109  125  123  115  125  133  120  118  116  122  122  121  122  125  133  117  133  133  120  125  130  134  126  124  120  132  133   23
ch:  31  111  114  125  118  119  125  111  115  119  111  122  131  118  123  123  121  120  117  122  124  116  125  125  135  135  119  121  122  122  129  120   28
ch:  32  118  116  117  116  123  119  115  117  123  125  115  132  121  134  136  132  138  135  125  116  125  133  117  118  124  125  116  132  132  134  121   37
ch:  33  113  115  124  125  118  126  120  118  123  127  125  120  132  137  121  122  118  121  126  136  126  132  125  137  119  120  124  137  121  127  123   23
ch:  34  120  138  117  115  104  120  125  123  122  110  117  127  136  125  126  123  134  117  123  120  133  127  122  135  131  119  137  131  123  124  120   35
ch:  35  108  121  118  122  119  121  125  106  117  121  127  115  124  119  111  134  131  119  125  120  109  106  124  121  121  122  129  119  130  120  125   28
ch:  36  115  119  122  121  125  126  116  116  117  117  127  135  116  134  123  131  127  122  125  126  135  132  133  125  119  127  139  136  121  121  135   34
ch:  37  123  106  108  122  104  120  124  116  121  122  127  123  119  116  119  123  116  117  111  120  121  127  125  121  117  121  135  120  117  118  121   32
ch:  38  117  110  118  118  116  108  114  121  133  116  133  121  114  115  118  122  132  121  120  132  126  122  117  131  131  131  131  124  131  132  122   32
ch:  39  115  125  120  125  119  115  123  121  123  119  124  117  125  124  116  122  123  121  133  123  126  123  123  125  120  107  116  117  126  126  116   19
ch:  40  113  118  122  123  125  117  121  117  122  111  122  114  122  114  116  125  131  133  134  136  131  122  132  121  126  125  124  131  124  125  121   34
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Sample of novel coarse scan modification output