Noise correlations in the module electronic tests

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Motivation

- LBL has made 8 modules in the last year 1 was shipped to BNL
  - The measurement was done on 7 modules
- Input noise is the benchmark performance of modules
- Some differences remained among modules to be understood
  - We studied the relationship between glue height and noises in Kaili's talk, but didn't find the direct answer, this study will focus on the noise correlation among channels

	LS11	LS12	LS14	LS15	LS16	LS17	LS18
Name	Homer	Marge	Lisa	Maggie	Mihouse	Flanders	Nelson
Sensors	1938-21A	1938-21A	1938-21A	1938-18C	1938-18C	1938-18C	1938-18C
Hybrids	VPX30399	VPX30399	VPX30399	VPX30399	New	New	New
PowerBoard	V3.0	V3.0	V3.0	V3.0	V3.0	V3.1	V3.1
Stream0	772	755	812	776	797	811	818
Stream1	732	710	750	728	738	766	759
Total	752	733	781	752	768	788	789

tested in this talk

tested in this talk

Noise correlation

- Noise charge is an equation of
  - Noise voltage source Un
  - input and feedback capacitance Cf, Ci
  - strip-to-ground capacitance Cg
  - **interstrip capacitance Cs**
  -
- interstrip capacitance Cs contributes to the noise, which is the correlation among different channels, usually it only exists among neighbouring channels, but it can also probe potential problems of the module

Nucl.Instrum.Meth.A 309 (1991) 545-551

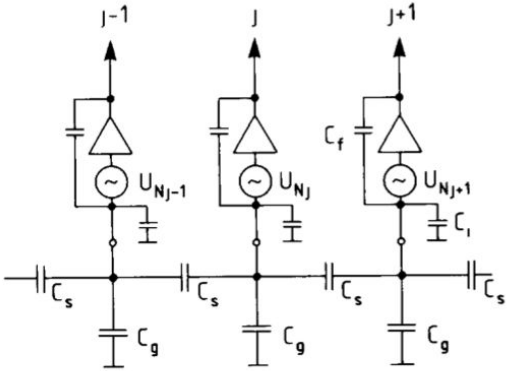
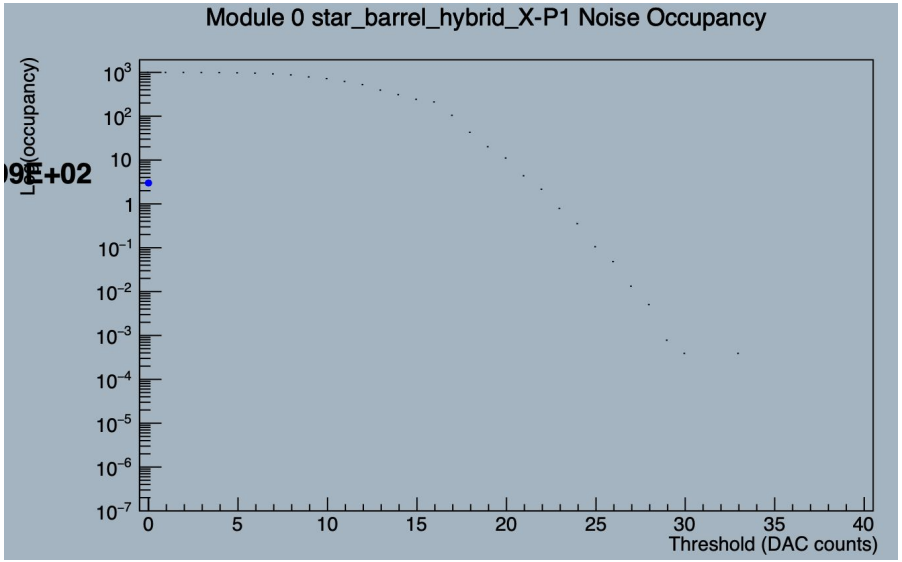


Fig. 3. Schematics of a strip detector with connected readout electronics.

Setup with Noise-Occupancy test

- We can check the correlation among channels by noise-occupancy (threshold scan with no injected charge)
- We'll check 1 baseline module (Noise ~750) and 2 newest modules (Noise ~800)



- In NO test, there are always 41 bursts/thresholds for one scan of thresholds
- We choose the threshold corresponding to 50% occupancy (log(C)~500 on this plot), which is the 13th point on the left

Raw event data mode

- Raw event data can record the hitmap of noise occupancy test
  - There are always 41 raw data files matching to the 41 thresholds
  - Each raw data file has 1000 hitmaps / triggers for the scan of 1 threshold

```
EventData_162_17_782.dat
EventData_162_17_783.dat
EventData_162_17_784.dat
EventData_162_17_785.dat
EventData_162_17_786.dat
EventData_162_17_787.dat
EventData_162_17_788.dat
EventData_162_17_789.dat
EventData_162_17_790.dat
EventData_162_17_791.dat
EventData_162_17_792.dat
EventData_162_17_793.dat
EventData_162_17_794.dat
EventData_162_17_795.dat
EventData_162_17_796.dat
EventData_162_17_797.dat
EventData_162_17_798.dat
EventData_162_17_799.dat
EventData_162_17_800.dat
EventData_162_17_801.dat
EventData_162_17_802.dat
EventData_162_17_803.dat
EventData_162_17_804.dat
EventData_162_17_805.dat
EventData_162_17_806.dat
EventData_162_17_807.dat
EventData_162_17_808.dat
EventData_162_17_809.dat
EventData_162_17_810.dat
EventData_162_17_811.dat
EventData_162_17_812.dat
EventData_162_17_813.dat
EventData_162_17_814.dat
EventData_162_17_815.dat
EventData_162_17_816.dat
EventData_162_17_817.dat
EventData_162_17_818.dat
EventData_162_17_819.dat
EventData_162_17_820.dat
EventData_162_17_821.dat
EventData_162_17_822.dat
EventData_162_17_823.dat
star_barrel_hybrid_X-P1_ABCStarNOPlot_20210219_153548.pdf
```

Raw event data

- The first hitmap of first Threshold, occupancy is ~100%
- This is the 1st hitmap / trigger, each threshold have 1000 triggers

```
Event data packet 1
  0: L0ID 0000 BCID 5 + 0 parity
0   0 Lo 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   1 Lo 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   2 Lo 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   3 Lo 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   4 Lo 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   5 Lo 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   6 Lo 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   7 Lo 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   8 Lo 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   9 Lo 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   0 Hi 11111111111111111111111111111110111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   1 Hi 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   2 Hi 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   3 Hi 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   4 Hi 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   5 Hi 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   6 Hi 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   7 Hi 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   8 Hi 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
0   9 Hi 11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
```

Raw event data

- The 1st trigger of 13th Threshold, occupancy is ~50%

```
Event data packet 1
  0: L0ID 0000 BCID 5 + 1 parity
 0  0 Lo 11101101001101101111111111011011100101110110100101111000010101011010010101011110101011100110110111011101100100111011011101101001
 0  1 Lo 10110111110110100101110110001101011110001010111111011011100101111001011001001111001100101011111111110101111011100101011011110111
 0  2 Lo 01110111001001001101110101011001111011001011111101010111010110110110101010010111010101010011011111101101010001101011000001101011
 0  3 Lo 10111111110101011010101101101100111111011110101110111110011001101110110110011101100010111101100111001111011011100101101100101111
 0  4 Lo 00100100010010111100010101110011011001000011001011001101111101110000101001001010011010100111100101101111101101110110110111101011
 0  5 Lo 11001011111010111111111111100111111010111011111011101111011111010111101101111010110011101101111111001011111011010110110101111
 0  6 Lo 10110101111111011111110001100100111111011110101110110111110010010011101011010111111101111010011111001101101111010110111011011001
 0  7 Lo 01001011101101110101010101100111111010101101111011111101111000110111101010111110111001011010011111001101001111011111101010101011
 0  8 Lo 11101011111011111011111111111111101101111111111110011110111111101101010111111011001111001010111111011110010011010110110110111
 0  9 Lo 11000110011011011011111111111101101001101111111011010111111000110101111101001101111011110101101110110111011011010011100110101011
 0  0 Hi 10101101100011111011111110001011001111100111011100111110011111100110100111010010111101001100011001101110010110100100111100001
 0  1 Hi 10100100101001101011001110110101010110010111101011101011110101111010111110100111010101010110110011011010101110000001101011101000101
 0  2 Hi 10010111101000001010111101111101101001111010111111010111100110011101000101101101101101111111011101010100111011011110101101110
 0  3 Hi 11111110011111110111010111101100101010110111011100111011100101110101101111011111011101011011110110101010110100101011011101011
 0  4 Hi 00011110100110101011010100101010110011111101111011111010001110111010111001101101001001110110110111010111111111011010110111011O
 0  5 Hi 11001101111101111101100011101111001111111101111110010101100110110110110110111101101111101100011011101010011011101111101101110
 0  6 Hi 10101110101111010011101001110011001111010111011011111011100111111010111011101101010111011010111001110001011010101111111111
 0  7 Hi 11111111101101111111111011001011111111011111110110010111011111011001100001111011111011101111111010110011011010110111111110111
 0  8 Hi 11111110110111111001110111011010111011010101110110111010100111011011100111001011111101011011101111111011110101101011001101111
 0  9 Hi 01001011011110110111011011101101110001011110111011111111101110111100111101011111101110011011111101011111111111110001110101011O
```

Raw event data

- The 1st-4th triggers of 41th Threshold, occupancy is 0%
- The file is compressed when hitmap is empty

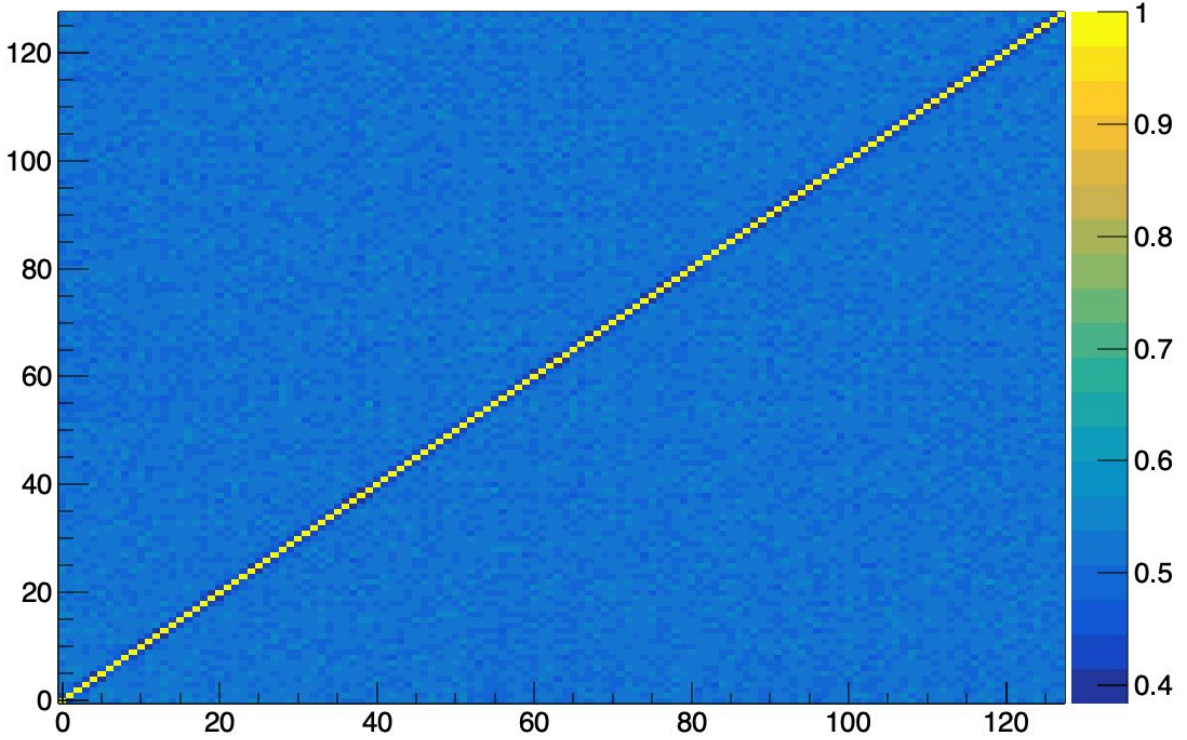
```
Event data packet 1
  0: L0ID 0000 BCID 5 + 1 parity
Event data packet 2
  0: L0ID 0001 BCID 1 + 0 parity
Event data packet 3
  0: L0ID 0002 BCID 1 + 0 parity
Event data packet 4
  0: L0ID 0003 BCID 1 + 1 parity
```

The correlation matrix

- Correlation is defined as the possibility that the occupancy of any channel is the same as a chosen channel (X=Y)
- We'll make a correlation matrix of N * N, where N is multiplicity of
  - 2 streams
  - 10 chips for 1 stream
  - 128 channels for 1 chip
- N = 2560
  - a 2560 * 2560 matrix is too hard for observation, I'll make the correlation matrix in 2 ways
    - 128 * 128 matrix of only one chip but all channels
    - 20 * 20 matrix of only one channel but all chips

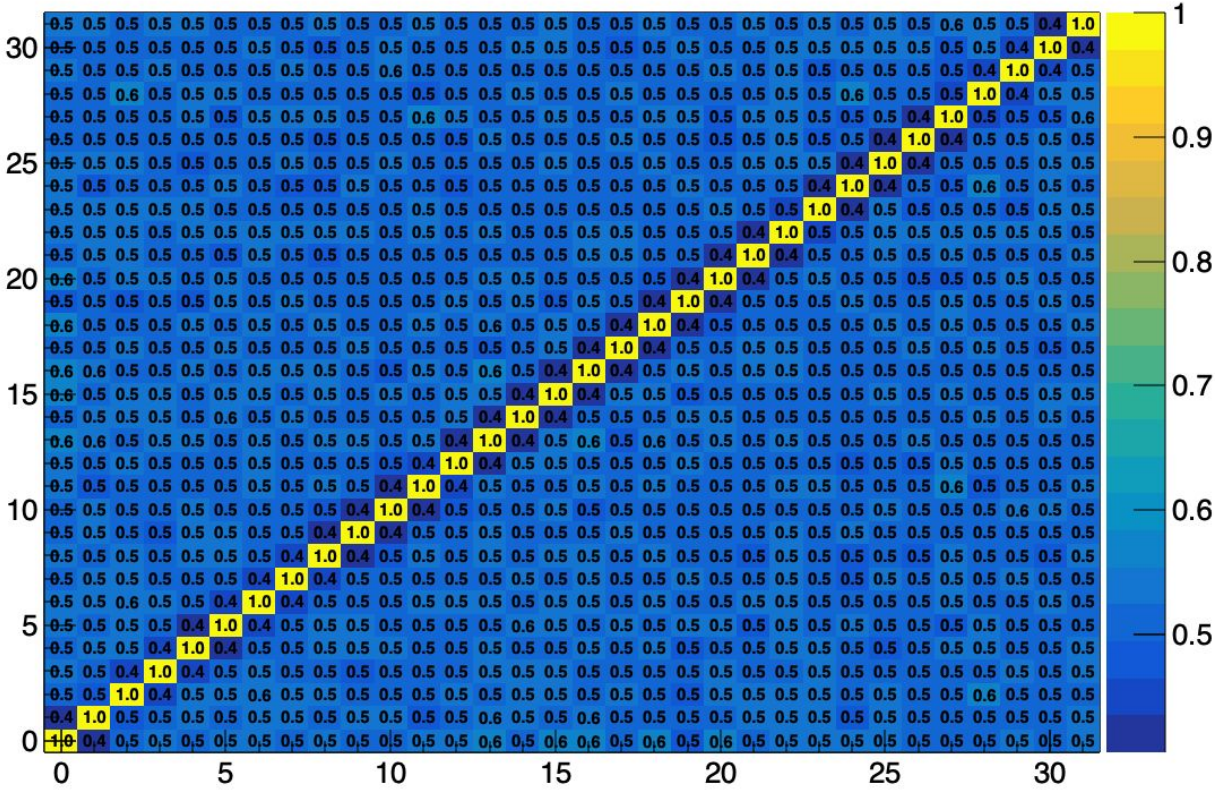
128*128 matrix of only one chip but all channel

- All channels are on the same chip and next to each other
- Plot for the 1st chip
- It's still too hard to show 128 channels
- divide it to four 32*32 matrix



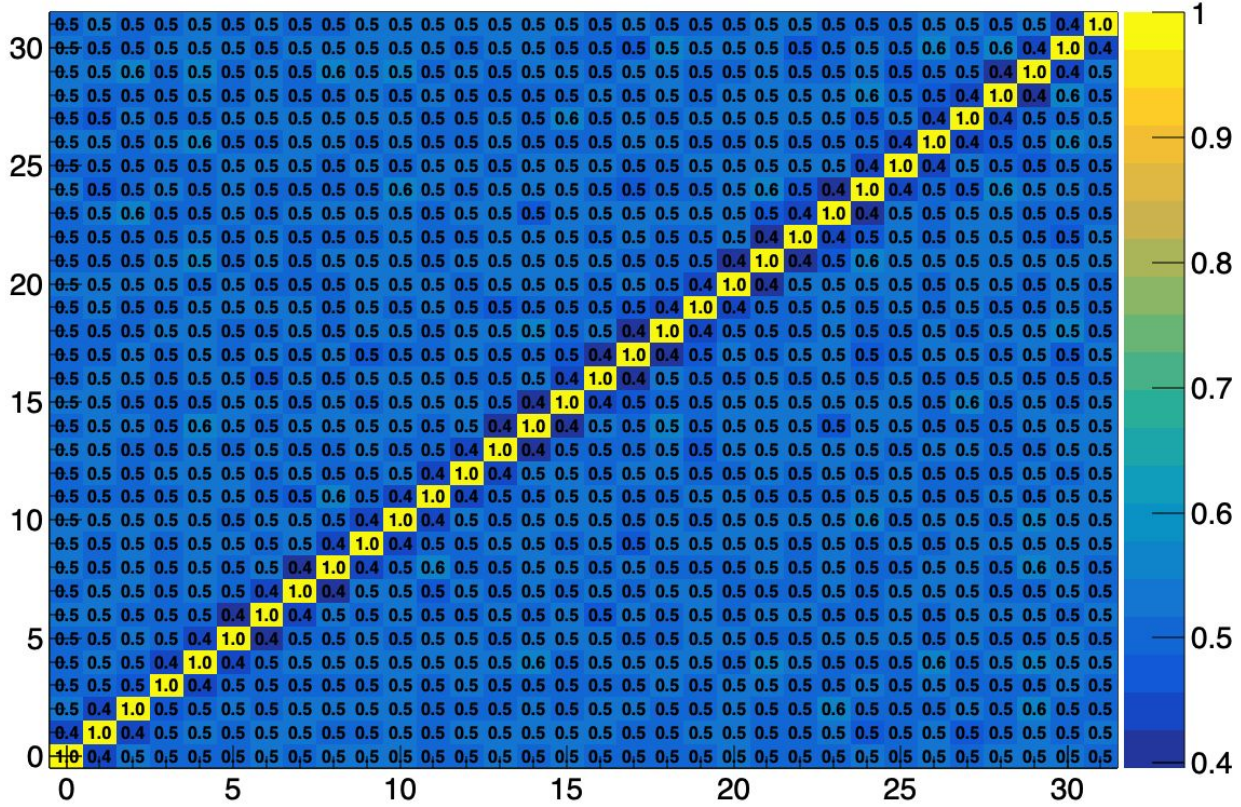
32*32 matrix of only one chip but all channel

- first 32 channels of stream0 chip0
- for the neighboring channels correlation is 0.4, others are 0.5



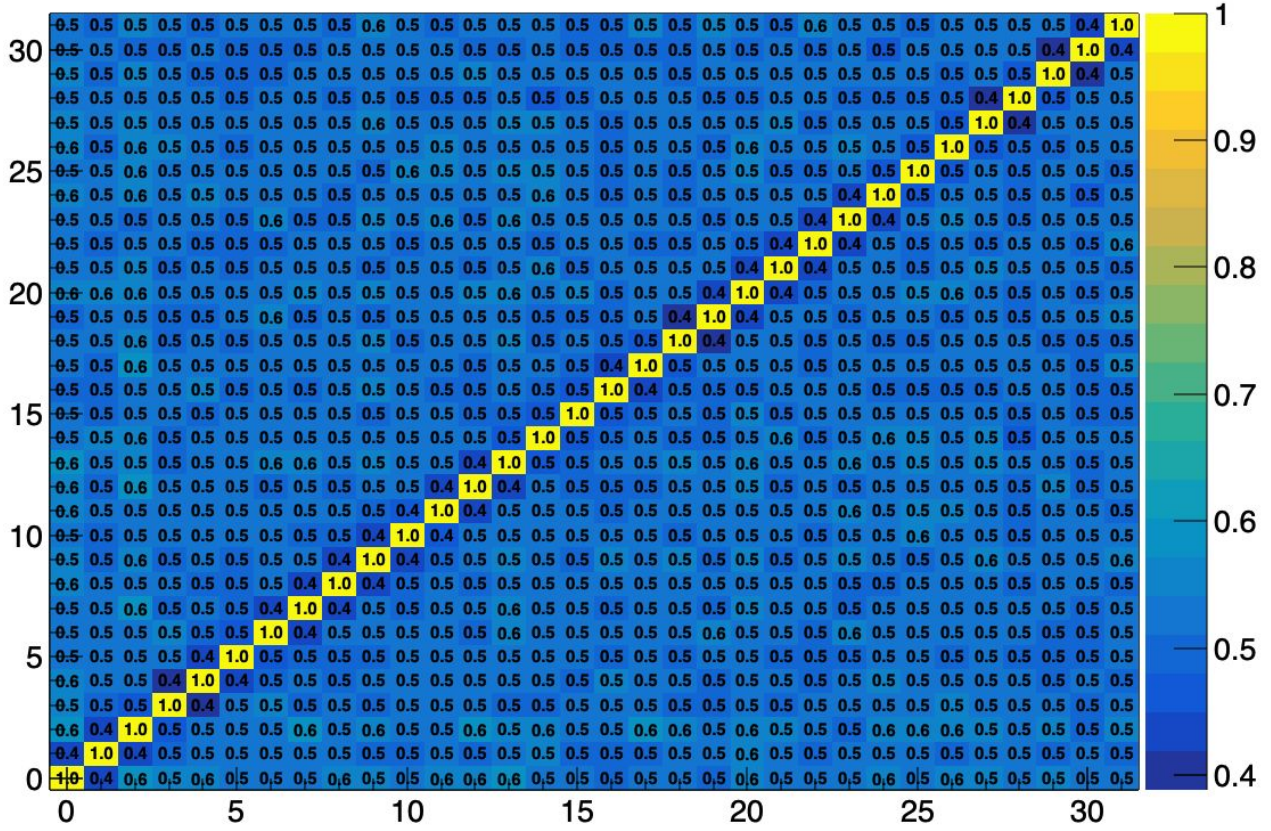
32*32 matrix of only one chip but all channel

- last 32 channels of stream0 chip0
- for the neighboring channels correlation is 0.4, others are 0.5



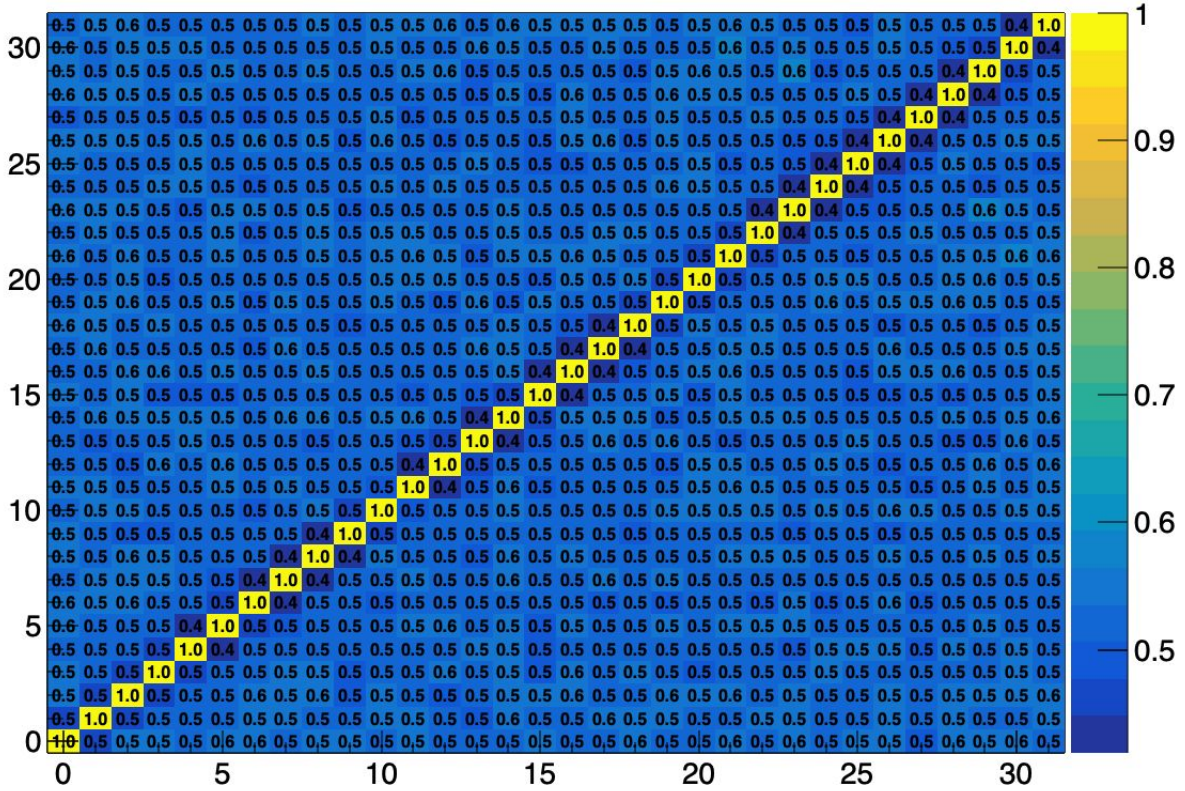
32*32 matrix of only one chip but all channel

- first 32 channels of stream1 chip0
- for the neighboring channels correlation is 0.4, others are 0.5



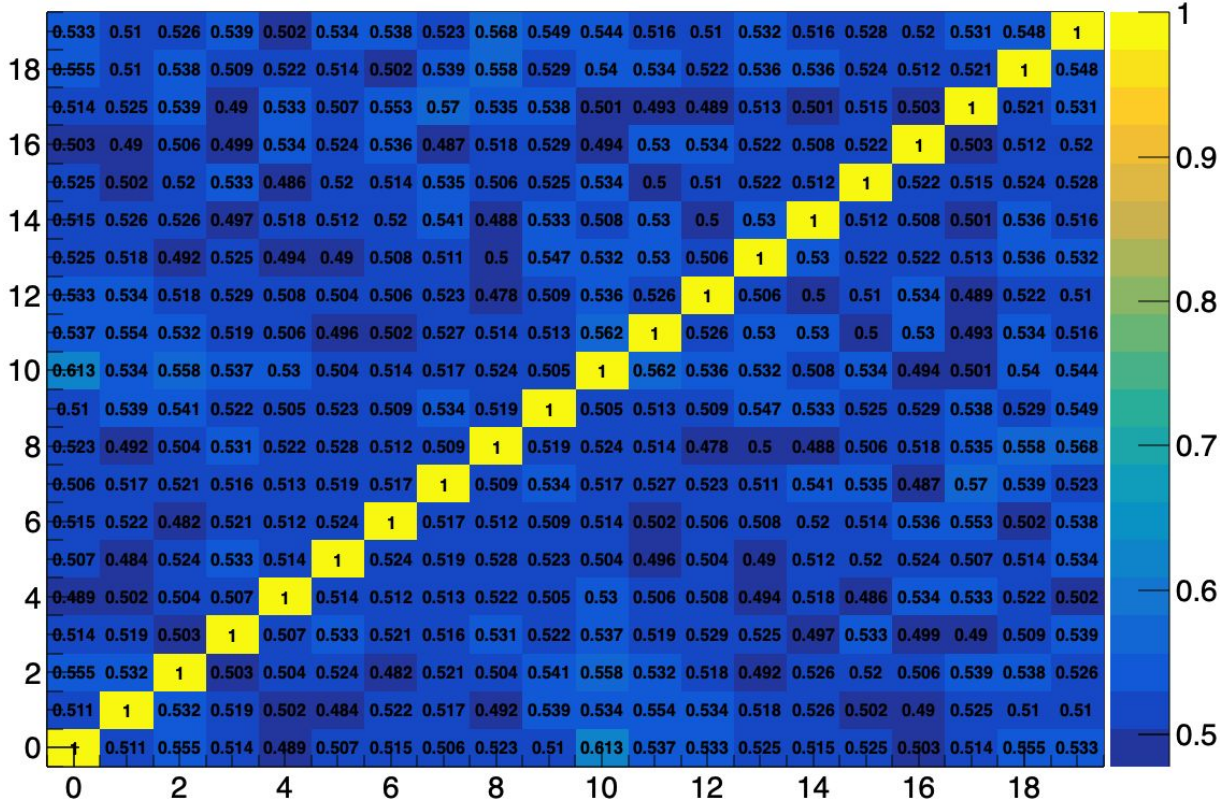
32*32 matrix of only one chip but all channel

- first 32 channels of stream0 chip9
- the conclusion is not changing
- The anti-correlation for neiboring channels are expected



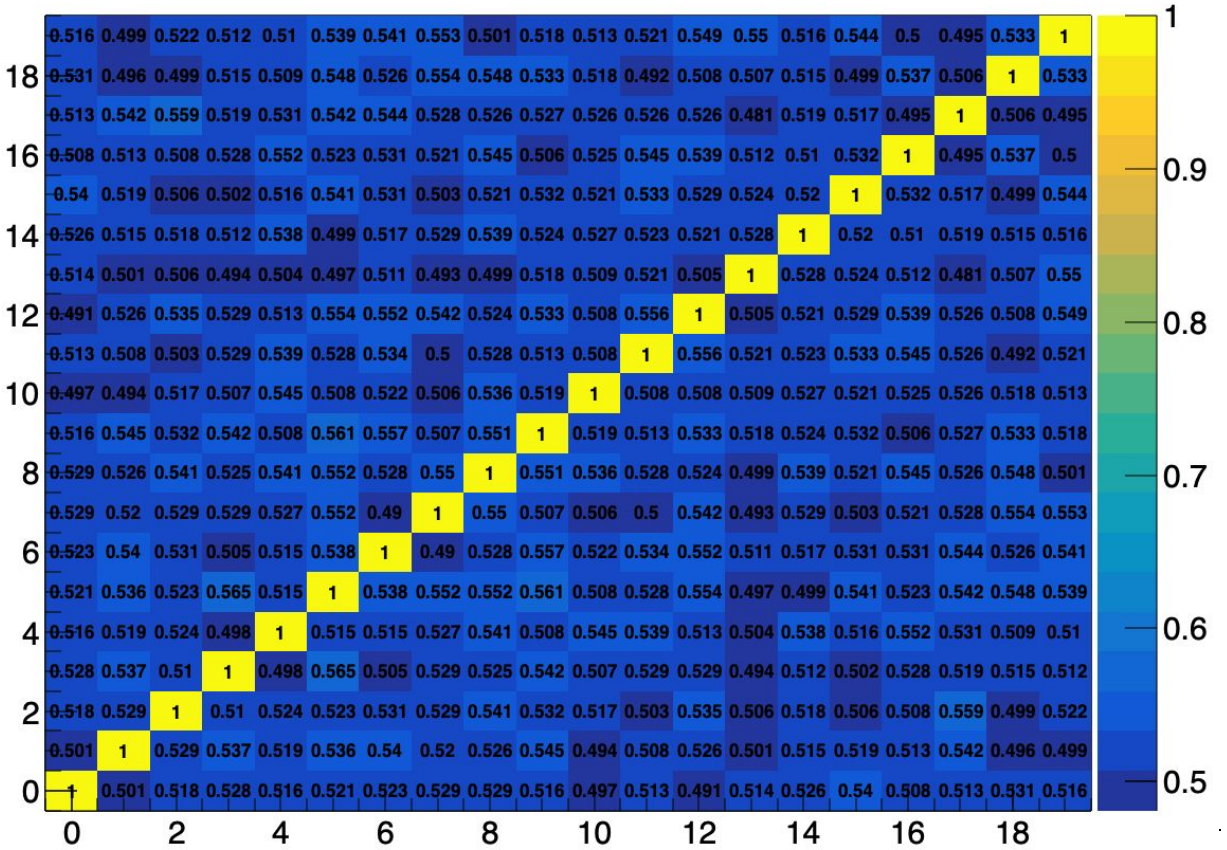
20 * 20 matrix of only one channel but all chips

- All channels are not next to each other
- Plot for the 1st channel
- 1000 triggers
- mostly chip-chip correlation varying in a range of 0.46-0.54, not constant, but they are ~0.5



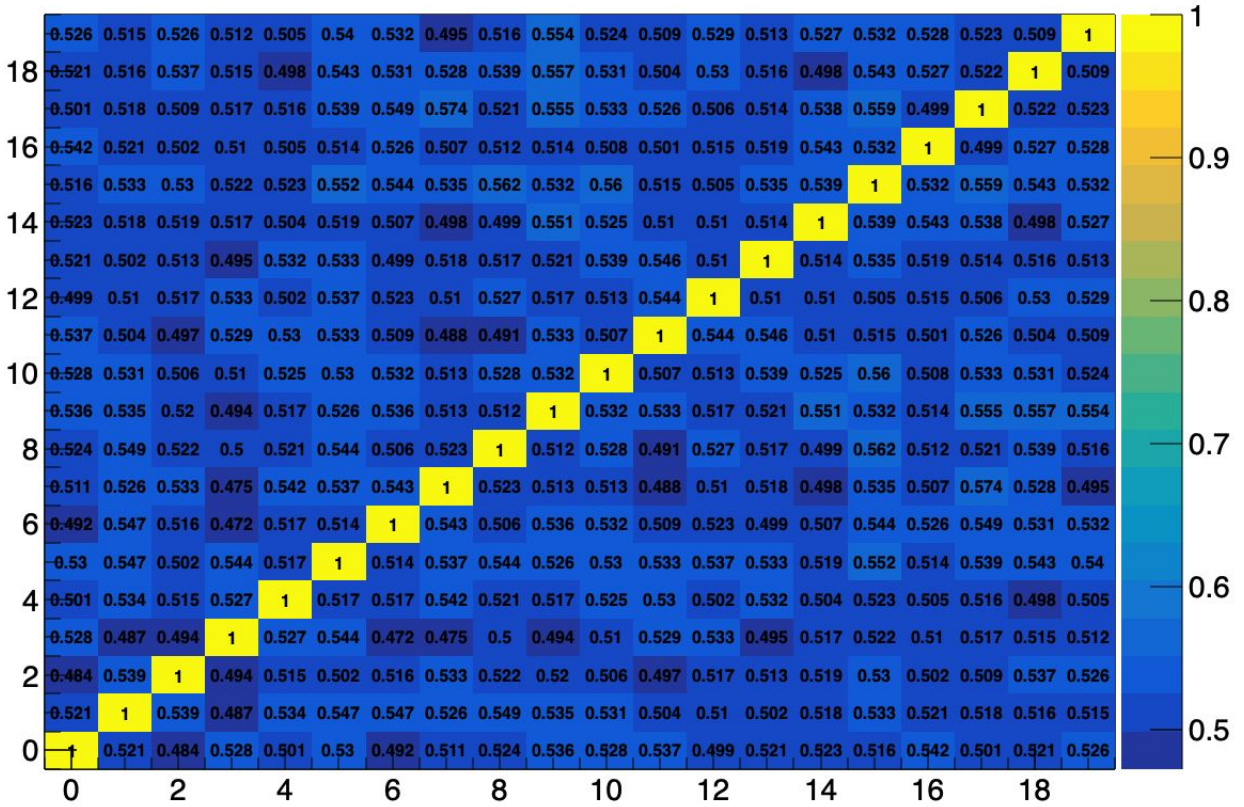
20 * 20 matrix of only one channel but all chips

- Plot for the 2nd channel



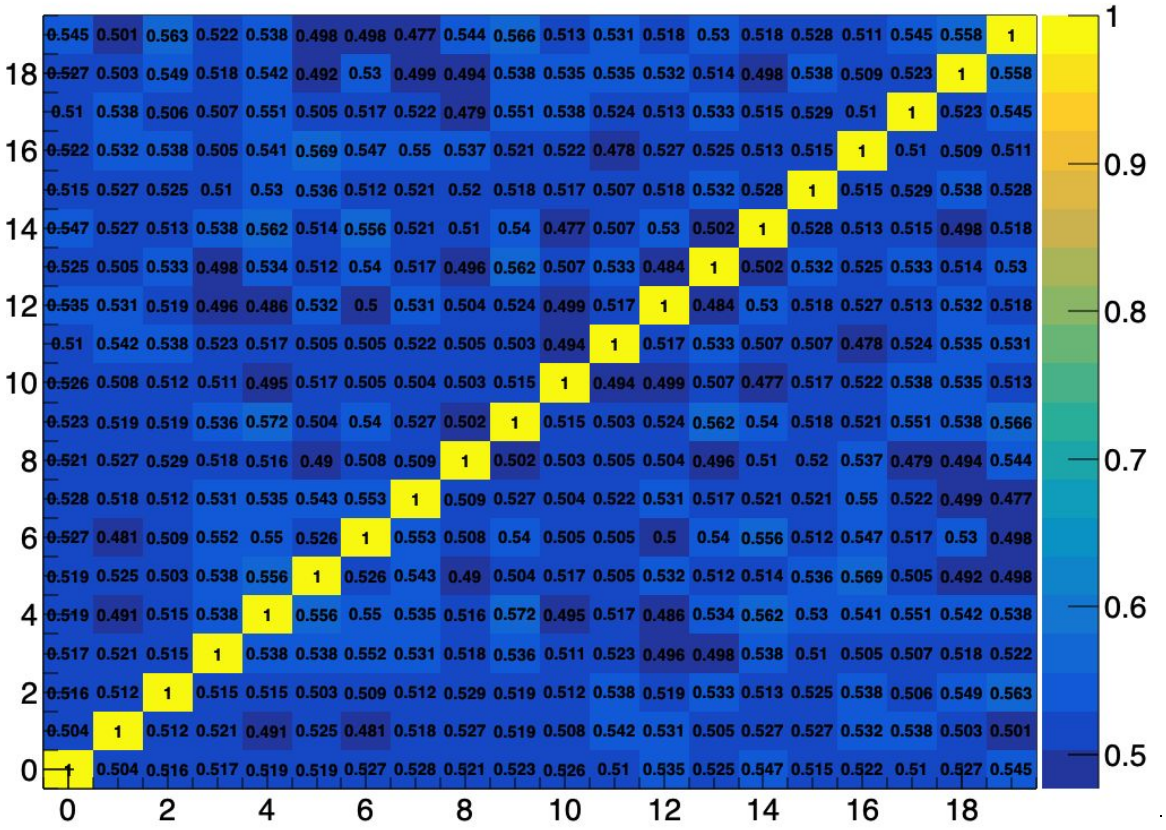
20 * 20 matrix of only one channel but all chips

- Plot for the 64th channel



20 * 20 matrix of only one channel but all chips

- Plot for the 128th channel

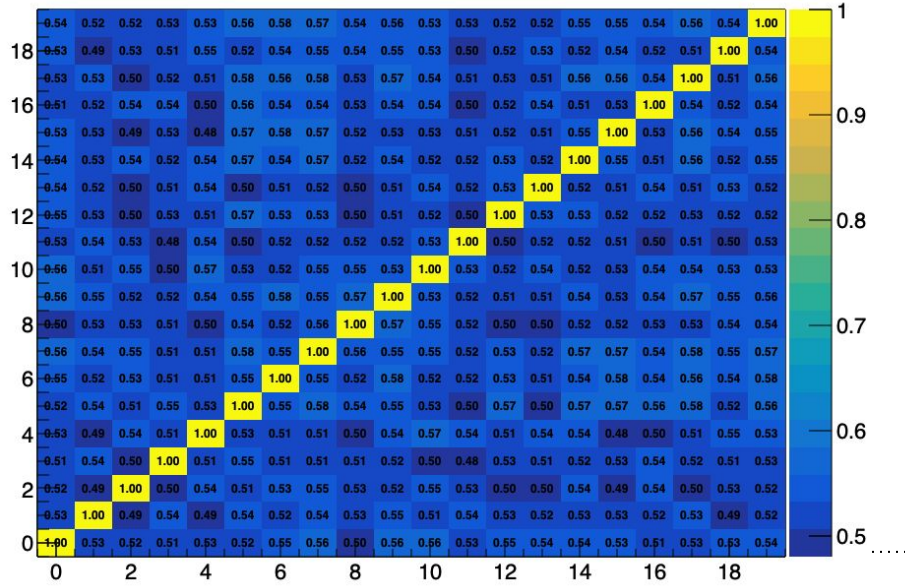


Newest 2 modules with higher noise

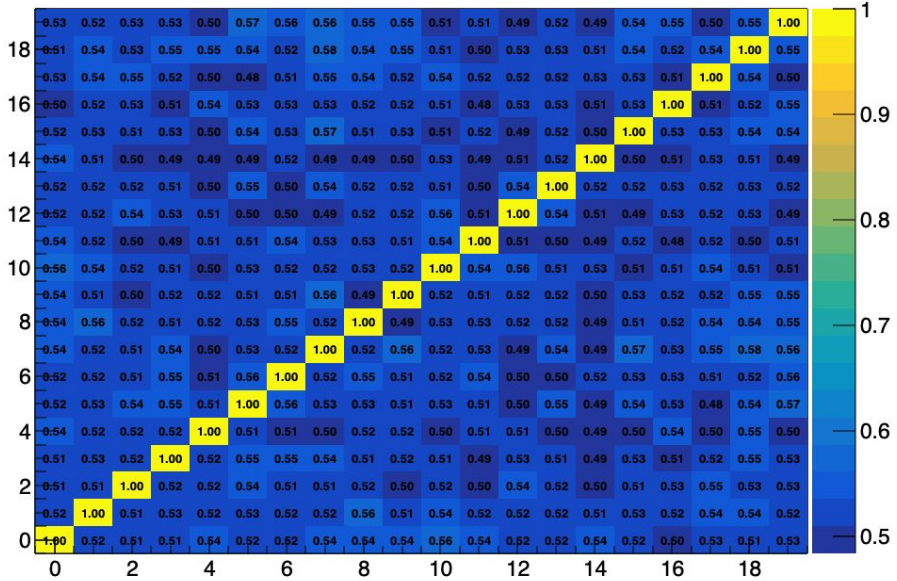
Correlation among chips (1st channel)

- Repeat the test for Nelson and Flanders
- Result with Nelson, Flanders are with stable noise (~800), correlations are very similar as Homer

Nelson



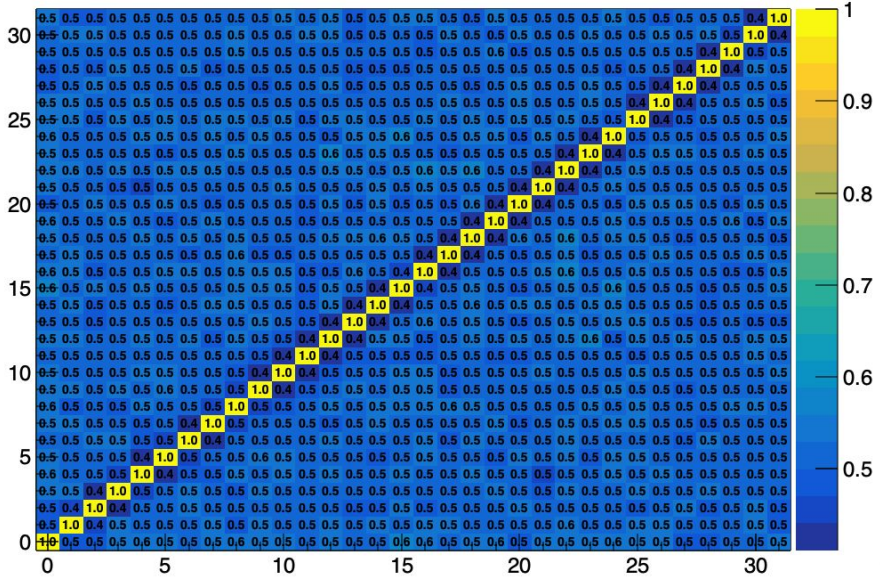
Flanders



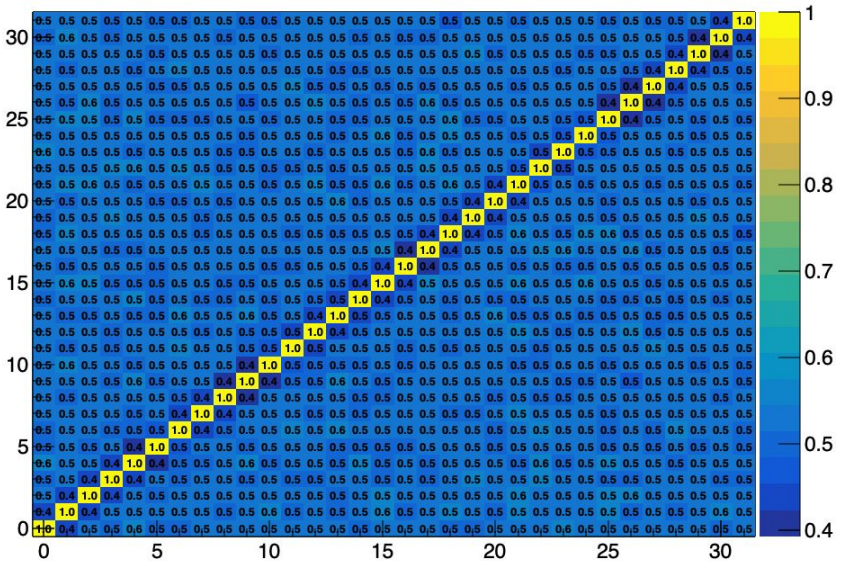
Correlation among channels (1st chip)

- The anti-correlation for near by channels remain the same
  - ~40% correlation for nearby channels, 50% correlation for separated channels

Flanders



Nelson



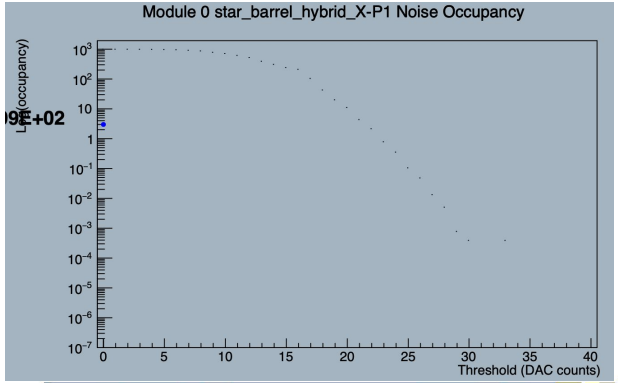
Summary

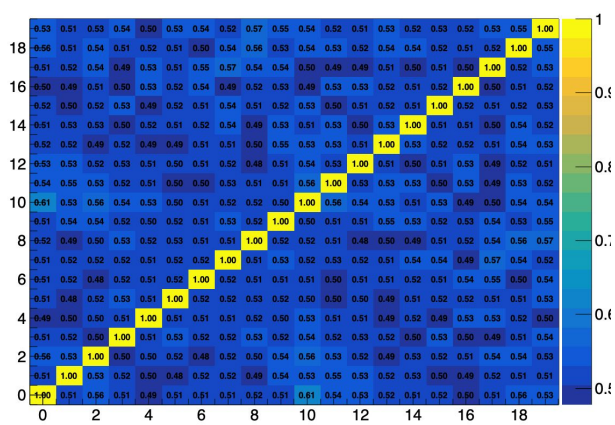
- The noise correlation was checked with noise occupancy test, for 3 modules
  - There's no strong chip-chip correlation for the same channel
    - the correlation is in a range of 0.45-0.54 but not exactly 0.5 or other constant value
  - The correlation between neay by channels is observed
    - The correlation is down to ~0.4 if 2 channels are neighbors, this anti-correlation is expected
  - No obvious difference between the modules with new/old powerboard.
- Next:
  - We'll need to think about other properties to identify the source of different noises

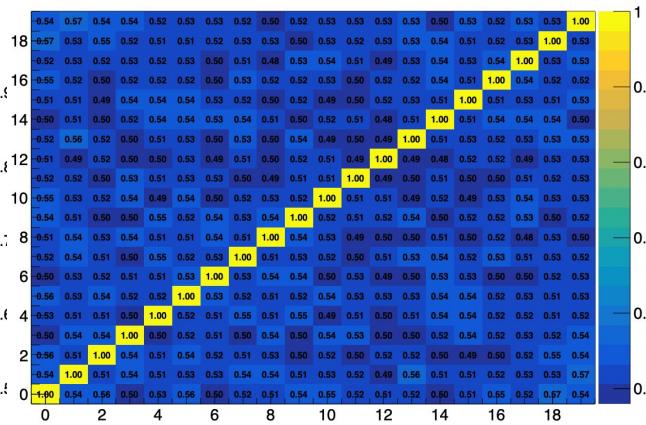
Backup

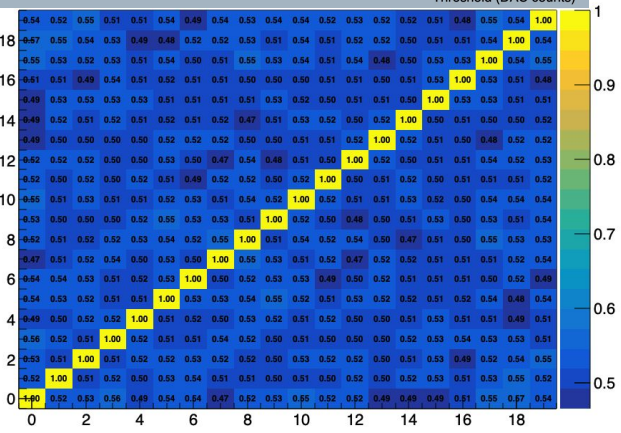
Is the threshold choice repeatable

- We choose the 13th threshold to be the one corresponding to 50% occupancy (log(C)=500 on this plot)
  - Confirming this threshold is repeatable in these 2 pages
  - Check the correlation several times with the 13th threshold, it always shows 50% correlation among chips, the correlation is repeatable is a range of 0.45-0.54





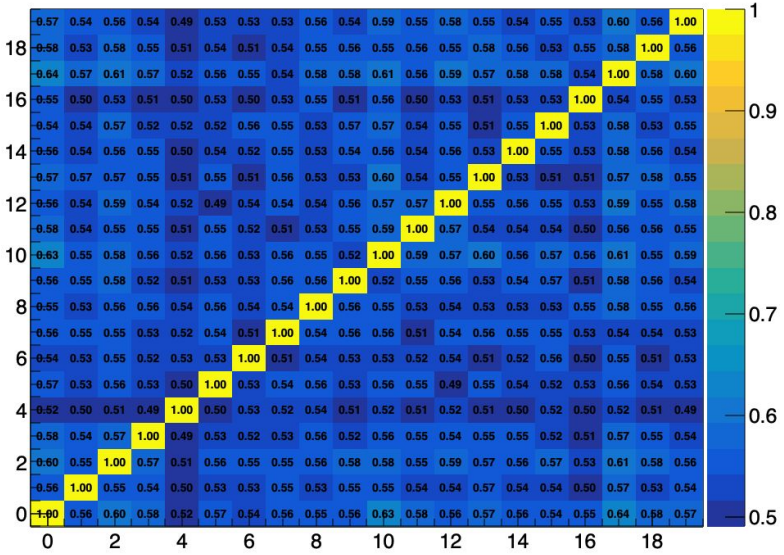




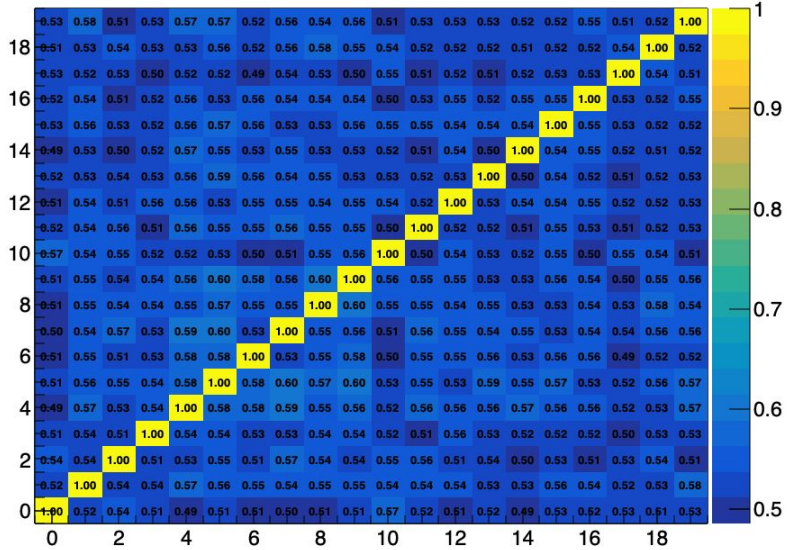
Is the threshold choice repeatable

- The points not correspoinding to 50% possibility is also checked
- Correlaitons are slightly >50% because the possiblities of passing threshold != 50%

Homer 12th threshold



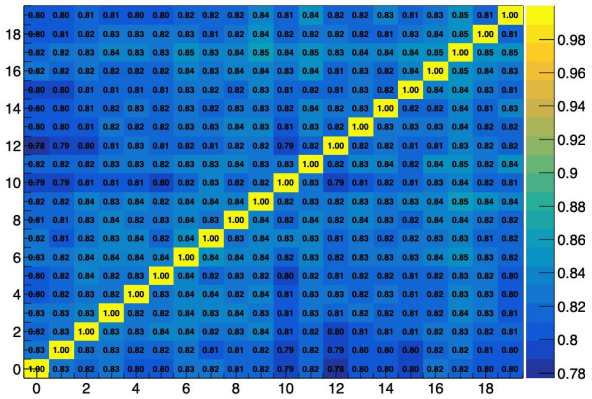
Homer 14th threshold



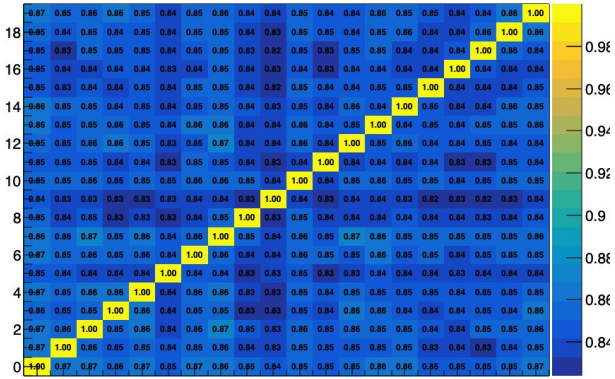
Other thresholds in NO

- Correlation when occupancy is around 10% (the 18th threshold)
  - When occupancy is 10%, there are more possibility X==Y, the expected value is 90%*90% + 10% * 10% = 82%, the tables below are expected
- Very similar result among the 3 modules

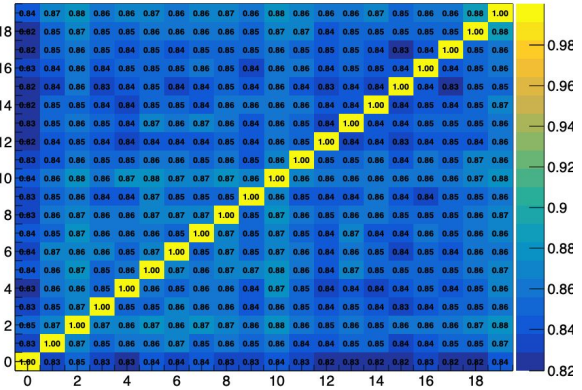
Flanders



Nelson



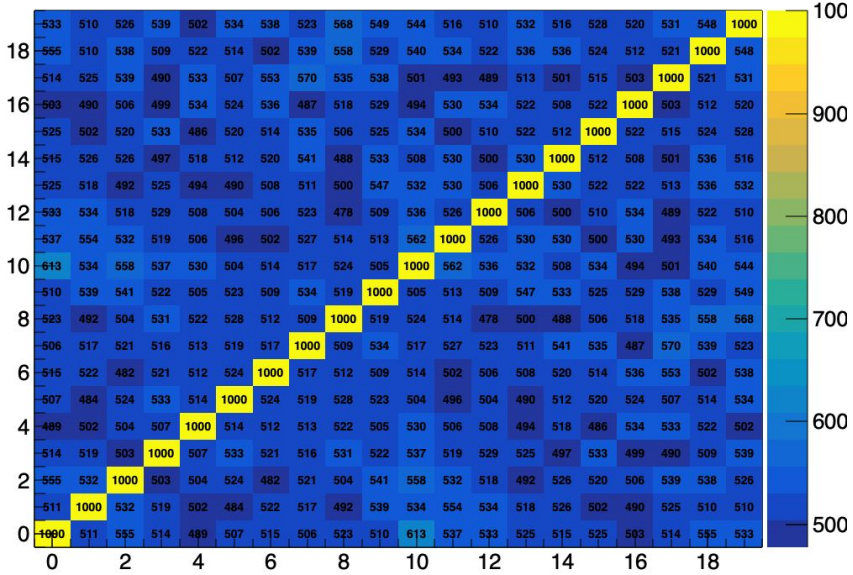
Homer



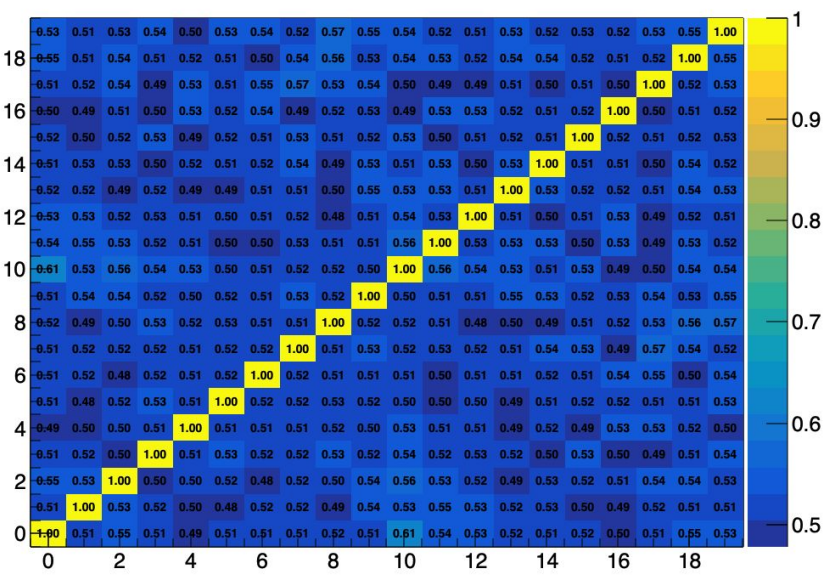
Counting numbers for 1000 triggers

- Correlation is “X==Y” in all the 2D plots

Homer 13th threshold, for channel 1
- counting of 1000 triggers



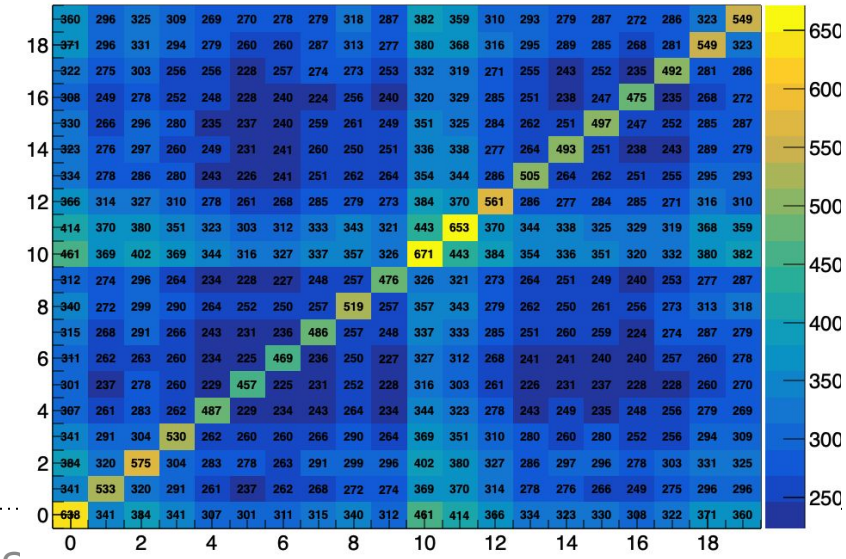
Homer 13th threshold - fraction of X=Y



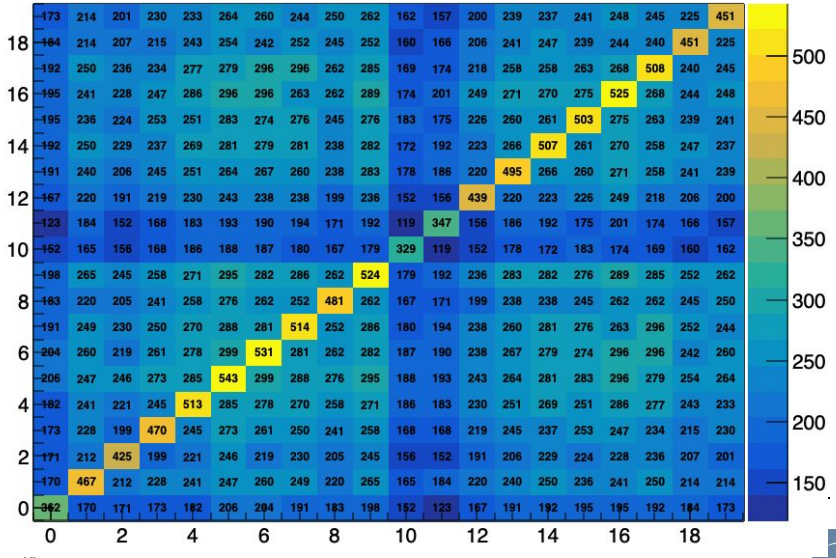
X==1 and X==0 cases

- The correlations are different when X is already 1 or 0, but it's still 50% when sum up the 2 tables: keep using the definition of X==Y
- The possibilities for of a particular channel to fire are different, but it's shown for all modules

Homer 13th threshold, for channel 1
X=1 and Y=1



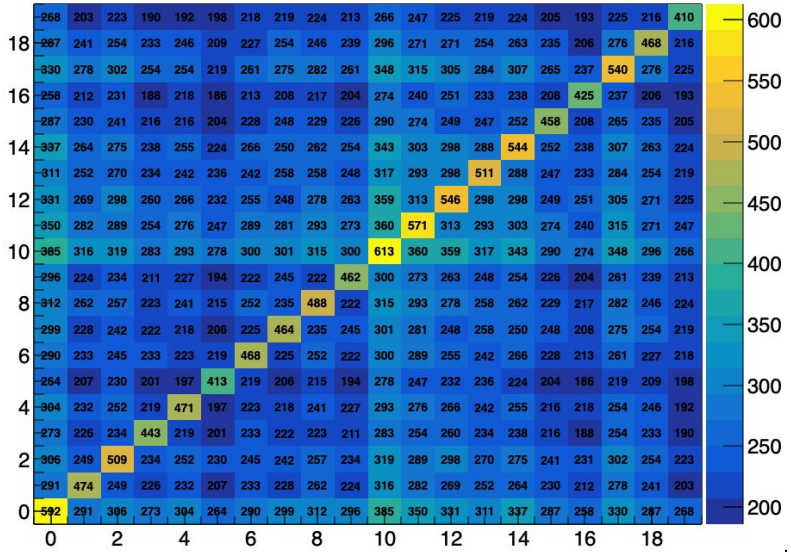
Homer 13th threshold, for channel 1
X = 0 and Y = 0



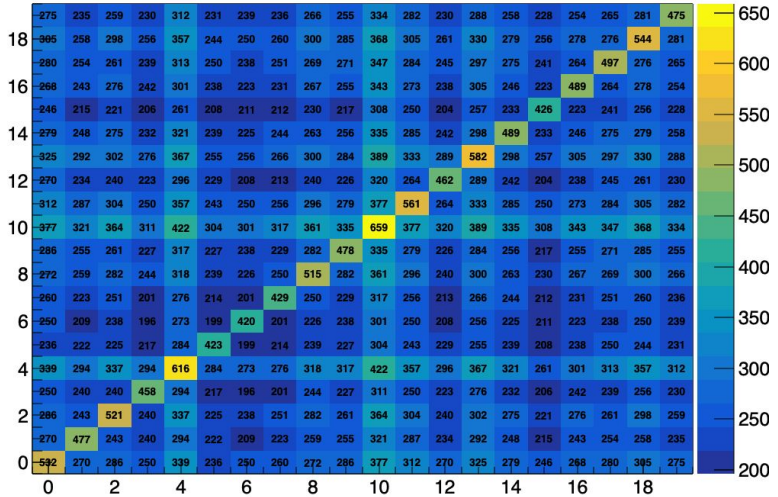
X==1 and X==0 cases

- The possibilities for of a particular channel to fire are different, but the similar feature is shown for all modules

Flanders 13th threshold, for channel 1
X=1 and Y=1



Nelson 13th threshold, for channel 1
X = 1 and Y = 1



Raw event data

- The 1st-4th triggers of 41th Threshold, occupancy is 0%

```
Event data packet 1
  0: L0ID 0000 BCID 5 + 1 parity
Event data packet 2
  0: L0ID 0001 BCID 1 + 0 parity
Event data packet 3
  0: L0ID 0002 BCID 1 + 0 parity
Event data packet 4
  0: L0ID 0003 BCID 1 + 1 parity
```

- The 42th output file, trigger format is different (and it's always empty), so I think it's not relevant and it's ignored

```
Event data packet 1001
Event data packet 1002
Event data packet 1003
Event data packet 1004
```