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U.S. DEPARTMENT OF ENERGY

ITSDAQ Tutorial

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Outline

- Hardware Environment
  - ABCStar Module, Test box
- Software Environment
  - ITSDAQ
- How to run the module test

ITk Strips Data AcQuisition

ABC module paper:

https://drive.google.com/file/d/17gO3LLPXOHtYzvcszJuyqWYmmrwEdjvt/view?usp=sharing

General introduction for strips module

ITSDAQ Documentation:

https://atlas-strips-itsdaq.web.cern.ch/index.html

https://twiki.cern.ch/twiki/bin/viewauth/Atlas/StripsUpgradeDAQ

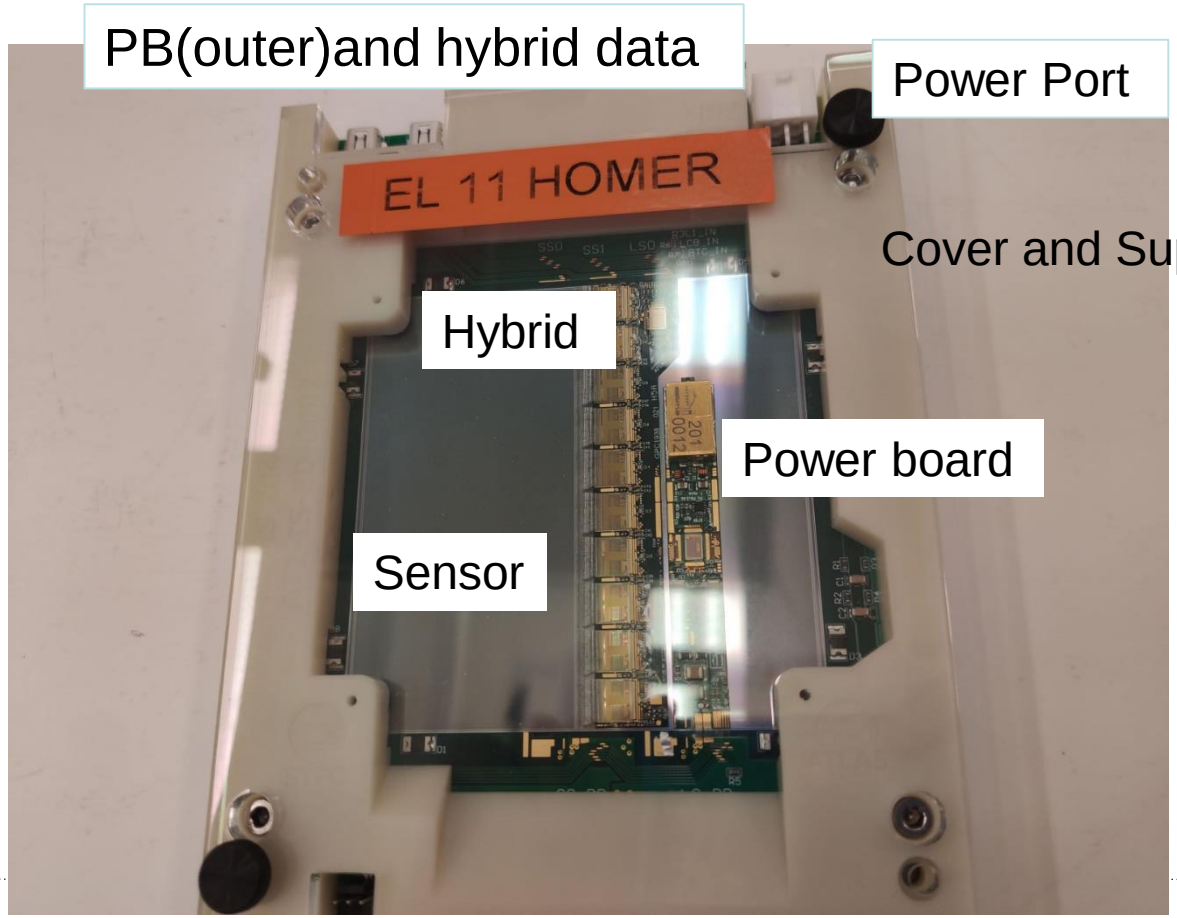
Gitlab:

https://gitlab.cern.ch/atlas-itk-strips-daq/itsdaq-sw

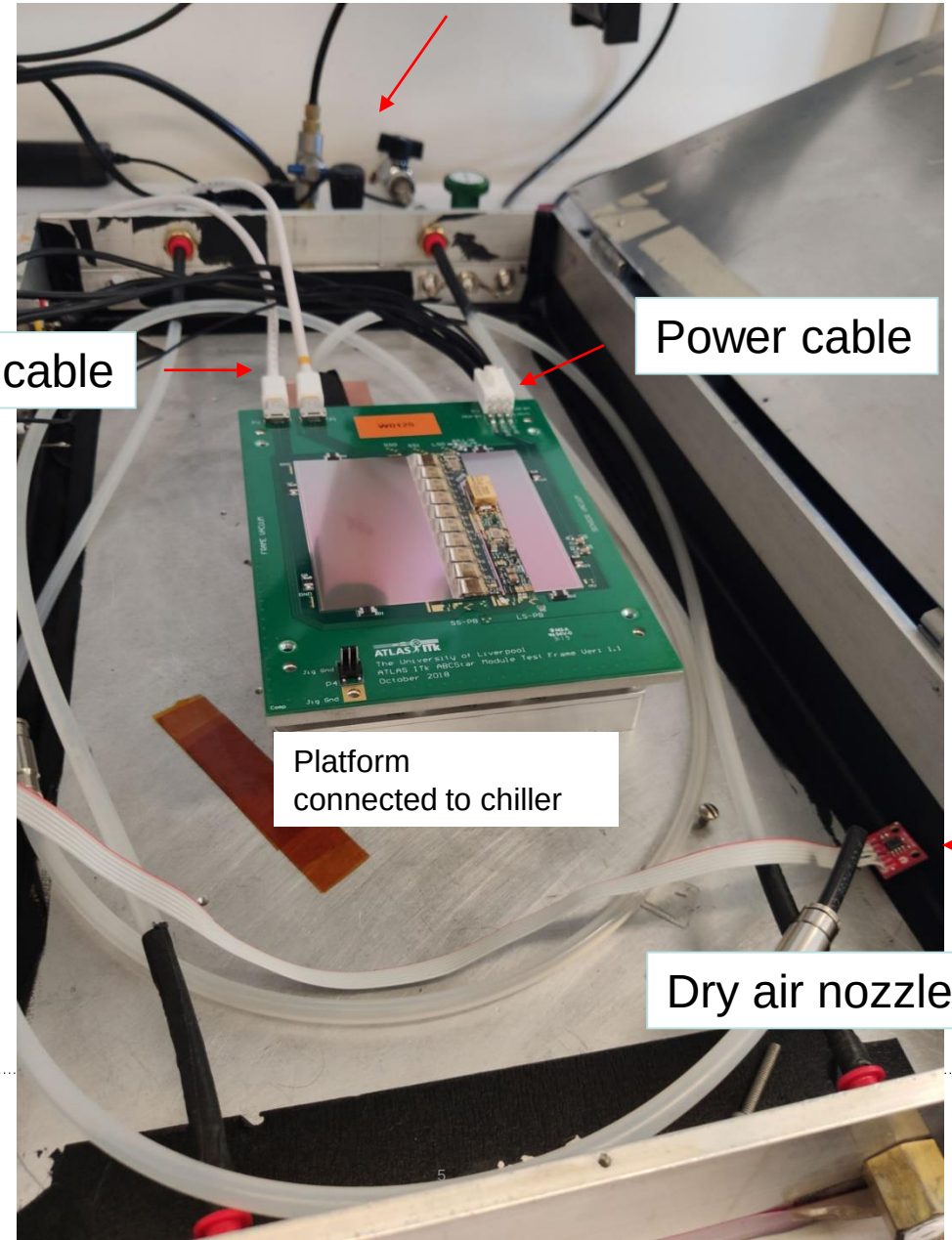
(Need to sign in usatlas-itk-strips-technical e-group first)

Our module test environment

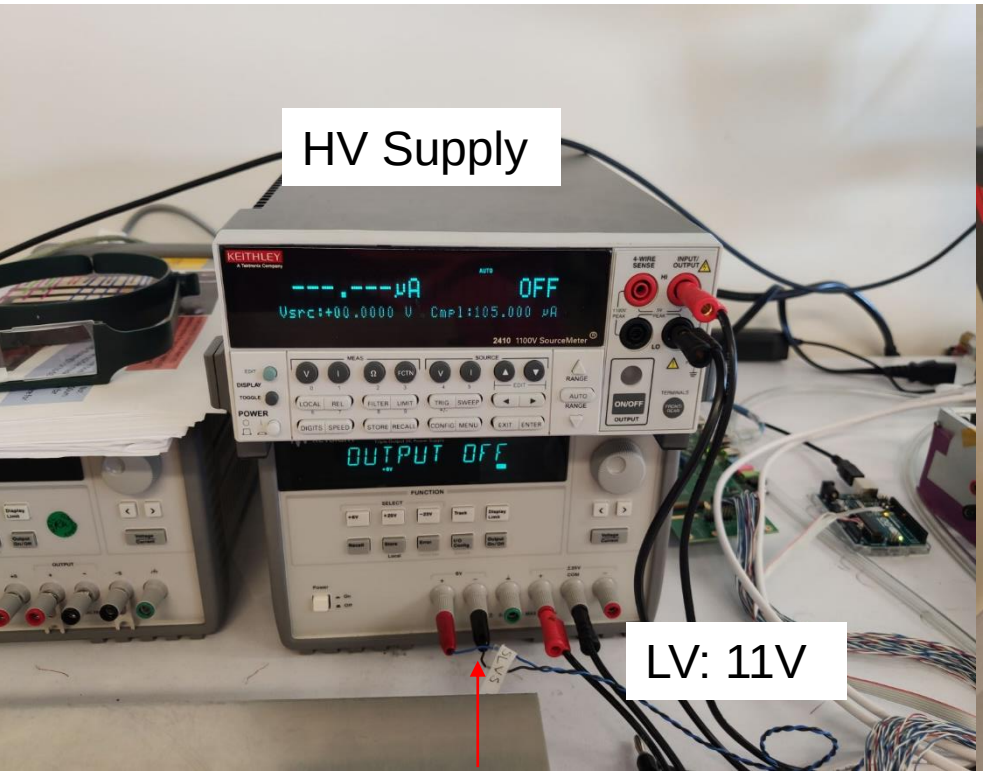
On one barrel Long Strip module, we have 10 ABCstar chips, 1 HCCstar chip, and 2560 readout channels.



Test box


Dry air valve
Data cable
Power cable
Platform
connected to chiller
Climate Sensor
Dry air nozzle

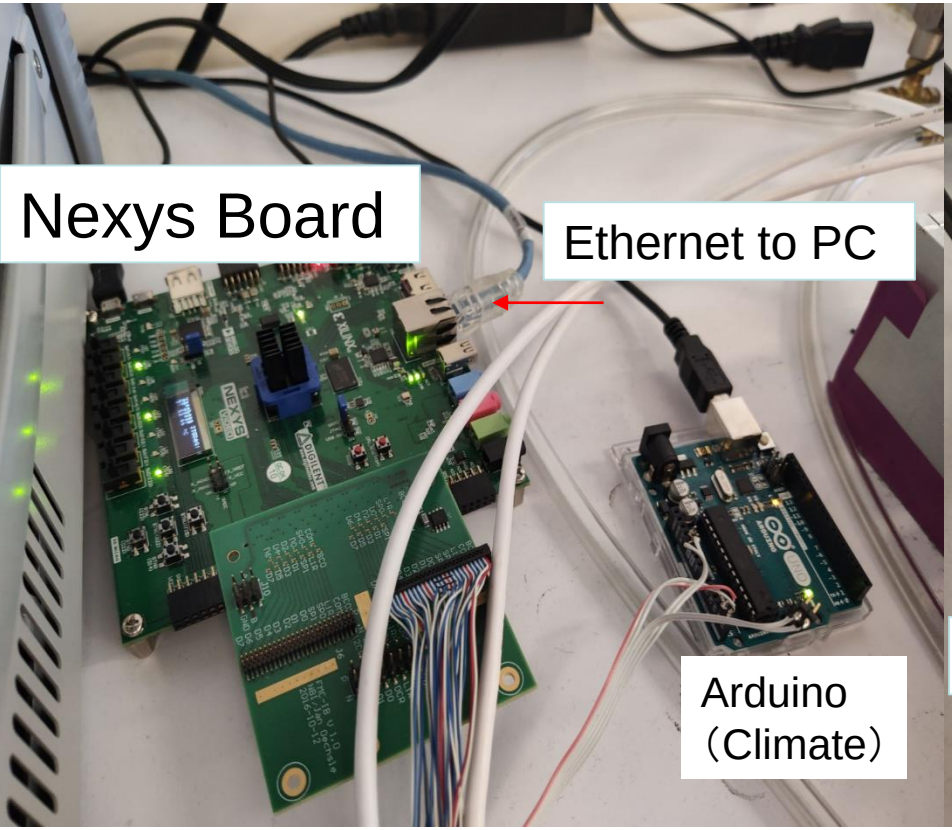
Power and temperature supply

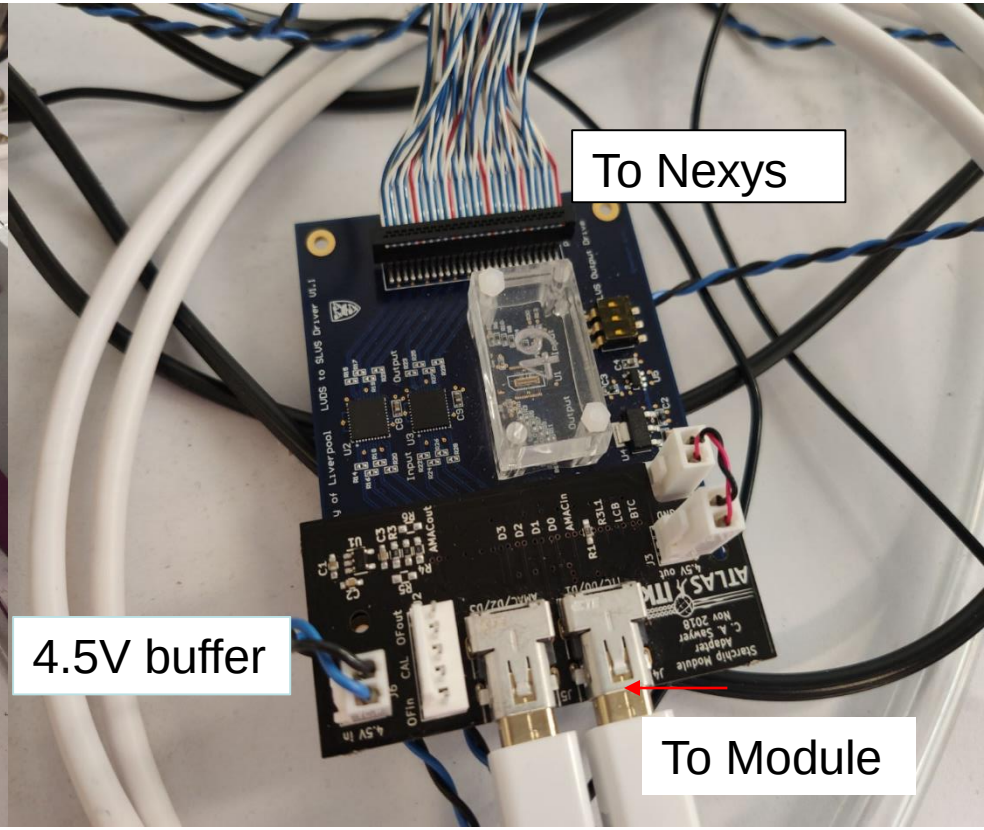


SLVS buffer: 4.5V

Data Cable Connection

$$\text{PC} \xrightarrow{\text{RJ45}} \text{Nexys} \rightarrow \text{SLVS Adpter} \xrightarrow{\text{MiniDP}} \text{Module}$$





SLVS Adpter

Hybrid panel and module test have different connection and different Nexys firmware.

Software preparation

- Install and compile ITSDAQ / Update to latest;
  - Instruction could be found in here
- Use latest firmware for Nexys.
  - Current one is nexysv_itsdaq_vb437_FIB_STAR.bit
  - For star module test, always with FIB_STAR
- Prepare module configuration files
  - Set vars like SCTDAQ_VAR and WorkDir;
  - Modify st_system_config.dat
- Open Arduino to monitor

```
Done in
setup_fpga.sh
```

```
Done in
continue_previous_test.sh
```

Upload script-> Serial Monitor

Commands on current Strips PC

```
Terminal 1:

cd ITk

./setup_fpga.sh

source continue_previous_test.sh

cd ./RUNITSDAQ.sh

//(Type your name, 2 letters)
```

setup_fpga.sh listed the Nexys firmware you want.

continue_previous_test.sh:

- SCTDAQ_VAR working dir
- SCTDAQ_ROOT ITSDAQ dir

Open ITSDAQ

```
Terminal 2: (Set HV)

cd ITk/IVScan

python Console.py


set_comp -v 50

iv_scan -v -350 -t 5
```

Open another terminal for HV control.

Set HV compliance current to 50μA.

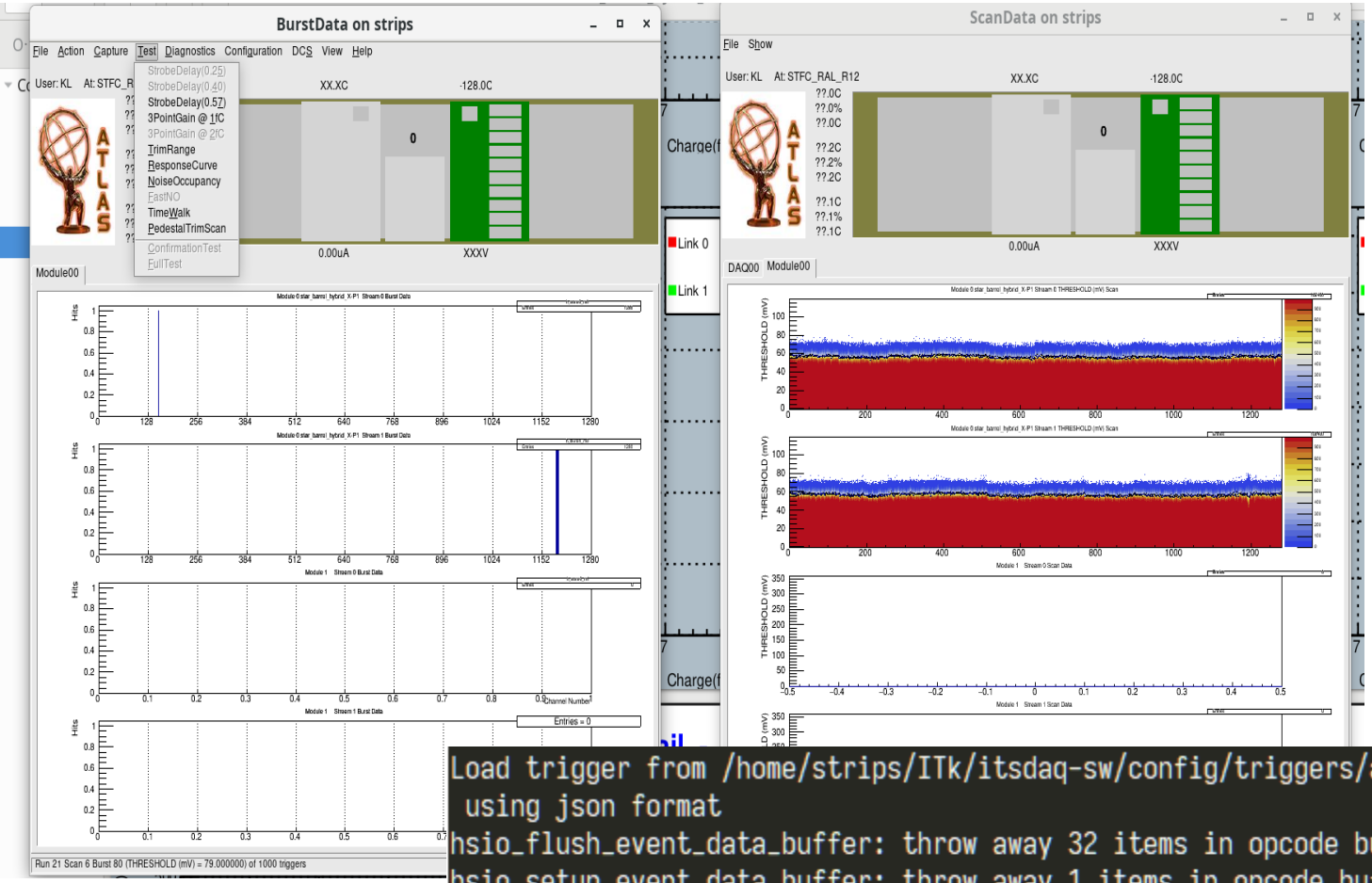
Ramp HV from 0V to -350V.

(Always negative!)

Every 5s, steps 10V.

For the IV-Scan test, record the scan from -350 to 0V

Software interface for ITSDAQ



In terminal:

```
Load trigger from /home/strips/ITk/itsdaq-sw/config/triggers/abc_star/load_fuse_id.json
 using json format
hsio_flush_event_data_buffer: throw away 32 items in opcode buffer
hsio_setup_event_data_buffer: throw away 1 items in opcode buffer
hsio_flush_event_data_buffer: throw away 23 items in opcode buffer
 1: (15) 9 8 7 6 5 4 3 2 1 0
ST() ...ready for action!
Run number is 26.
ST [1]
```

ITSDAQ Commands: AMAC

```
./RUNITSDAQ.sh
(Now in ITSDAQ Terminal)
(Type name for DB and type 1)
.L AMACv2.cpp
AMACv2_setID(0,0,0)
AMACv2_setID(0,0,0)
AMACv2_DCDC(0, 1, 0)
val = 0x00077700 //HV enabled, LDOs enabled
AMACv2_writeReg(0,40,val,0)
AMACv2_writeReg(0,41,val,0)
val = 0x00010100 //Release reset on HCC
AMACv2_writeReg(0, 46, val, 0)
AMACv2_writeReg(0, 47, val, 0)
e->Restart()
```

Load commands for AMAC control.

Set the comm ID of the AMAC, **twice**.

Turn on DCDC.

(LV current changes)

Enable HV and LDOs. Now Hybrid is powered.

(LV current changes)

Release HCC reset

(LV current changes)

Restart

Register map for AMAC(Autonomous Monitor And Control)

Need the group atlas-itk-strips-asics permission

ITSDAQ Commands: HCC

```
(Followed by AMAC Commands)
hcc_star_reg_write(16,4)
hcc_star_reg_write(17,0xf0004223) //HCC ID varies.
abc_star_fast_command(2,2)
abc_star_fast_command(3,0)
e->ExecuteConfigs()
abc_star_fast_command(2,2)
abc_star_fast_command(3,0)
e->ExecuteConfigs()
```

Transfer Fuse ID to address register

Set new HCC comm ID.

Reset config **twice**

Here the HCC comm ID is dumped from the previous Hybrid test.

//Transfer Fuse ID to address register

```
hcc_star_reg_write(16,4)
```

//Dump register

```
st_dump_chip_registers()
```

Get the ID In address 17.

Start work

- Turn on
  - dry air and chiller. Monitored by Arduino.
  - HV and LV. Output off.
- Settle module down to the box, connect all the wires
  - Wait for humidity and temperature below 25% and 20°.
- Output on, LV and HV.
  - 6V output set to 4.5V
  - 25V output set to 11V
  - (After ITSDAQ enabled HV)
    - set HV compliance current to 50μA. Volts ramp to -350V.
- Open ITSDAQ

Chiller set to 15° but there would be difference between chiller and Arduino sensor.

Structure of Workdir

```
config
data
etc
hsio
ps
results
timers
```

config/st_system_config.dat: Overall configuration
(See sysconfig)
config/star_barrel_hybrid_X-P1.*: Hybrid co nfiguration.
Name set in st_system_config.dat
(See abcstar_config)

Test results storage:

results: plain text
data: root file
ps: pdf plots

Results stored by run number and scan number.
Each root file, strunX_X.root, corresponds to one inject charge scan.
One 3PG test would have 3 output files for 0.5fc, 1fc and 1.5fc.

Root file structure.
Histograms could be found directly.
Scan 0 and Scan 1 are the 2 sides of ABCchips.
Each 1280.

```
root [1] .ls
TFile**         strun20_7.root
 TFile*         strun20_7.root
  KEY: TObjString       Time;1  Collectable string class
  KEY: TObjString       Place;1 Collectable string class
  KEY: TObjString       Host;1  Collectable string class
  KEY: TObjString       User;1  Collectable string class
  KEY: TObjString       ModuleName;1    Collectable string class
  KEY: TObjString       DUT;1   Collectable string class
  KEY: TH2F     h_scan0;1       Module 0 star_barrel_hybrid_X-P1 Stream 0 THRESHOLD (mV) Scan
  KEY: TH2F     h_scan1;1       Module 0 star_barrel_hybrid_X-P1 Stream 1 THRESHOLD (mV) Scan
  KEY: TH1F     h_mean0;1       Module 0 star_barrel_hybrid_X-P1 Stream 0 Fitted Mean
  KEY: TH1F     h_mean1;1       Module 0 star_barrel_hybrid_X-P1 Stream 1 Fitted Mean
  KEY: TH1F     h_sigma0;1      Module 0 star_barrel_hybrid_X-P1 Stream 0 Fitted Sigma
  KEY: TH1F     h_sigma1;1      Module 0 star_barrel_hybrid_X-P1 Stream 1 Fitted Sigma
  KEY: TH1S     h_code0;1       Module 0 star_barrel_hybrid_X-P1 Stream 0 Fit Code
  KEY: TH1S     h_code1;1       Module 0 star_barrel_hybrid_X-P1 Stream 1 Fit Code
  KEY: TH1F     h_chisq0;1      Module 0 star_barrel_hybrid_X-P1 Stream 0 Chisq/NDF
  KEY: TH1F     h_chisq1;1      Module 0 star_barrel_hybrid_X-P1 Stream 1 Chisq/NDF
  KEY: TH1F     h_prob0;1       Module 0 star_barrel_hybrid_X-P1 Stream 0 Chisq Prob
  KEY: TH1F     h_prob1;1       Module 0 star_barrel_hybrid_X-P1 Stream 1 Chisq Prob
  KEY: TH1F     h_fom0;1        Module 0 star_barrel_hybrid_X-P1 Stream 0 Figure of Merit
  KEY: TH1F     h_fom1;1        Module 0 star_barrel_hybrid_X-P1 Stream 1 Figure of Merit
  KEY: TH2F     h_hitsPerLink0;1        Module 0 star_barrel_hybrid_X-P1 Stream 0 THRESHOLD (mV) Hits Per Link
  KEY: TH2F     h_hitsPerLink1;1        Module 0 star_barrel_hybrid_X-P1 Stream 1 THRESHOLD (mV) Hits Per Link
  KEY: TH1F     h_cluster0;1    Module 0 star_barrel_hybrid_X-P1  Stream 0 Cluster Size
  KEY: TH1F     h_cluster1;1    Module 0 star_barrel_hybrid_X-P1  Stream 1 Cluster Size
  KEY: TH2F     h_corr;1        Module 0 star_barrel_hybrid_X-P1  Correlated Hits
  KEY: TH1F     h_scan_tsent;1  Triggers Sent
  KEY: TH1F     h_scan_evcnt;1  DAQ card 0 Events Decoded
  KEY: TH1F     h_scan_ercnt;1  DAQ card 0 Decoding Errors
  KEY: TH1F     h_scan_tocnt;1  DAQ card 0 Timeouts
  KEY: TH1F     h_scan_xecnt;1  DAQ card 0 Cntrl Errors
  KEY: TObjString       schema_version;1        Collectable string class
  KEY: TDirectoryFile   system_info;1   system_info
  KEY: TDirectoryFile   scan_info;1     scan_info
  KEY: TDirectoryFile   scan_points;1   scan_points
  KEY: TDirectoryFile   configuration;1 configuration
```

Test step

Always run PedstralTrimScan first and StrobeDelay first.

Then:

- 3 Point Gain and Response VS Channel
  - Use manual script to get the S-Curves of RC test.
- Noise Occupancy
- TrimRange

https://atlas-strips-itsdaq.web.cern.ch/tests.html
Definitions for those tests.
More information could be found in Twiki and Module paper.

Terminal output for one scan

```
Module 0 star_barrel_hybrid_X-P1 THRESHOLD (mV) scan from 5 to 255 in steps of 1
Number of active channels 2560
  Fit Results for chisq fit
                Mean    Sigma   Chisq   FOM     Prob    nGood   nBad
  Chip 0        50.239  3.68    0.7131  2.166   0.7996  128     0
  Chip 1        47.84   3.529   0.7071  0.2001  0.8175  128     0
  Chip 2        49.8    3.742   0.7134  0.4578  0.8304  128     0
  Chip 3        50.694  3.652   0.6714  0.3638  0.8479  128     0
  Chip 4        49.339  3.43    0.6442  1.776   0.872   128     0
  Chip 5        48.518  3.507   0.7353  0.2026  0.7864  128     0
  Chip 6        47.715  3.51    0.7569  0.2295  0.7696  128     0
  Chip 7        48.591  3.603   0.7665  0.3638  0.7712  128     0
  Chip 8        46.745  3.517   0.732   1.038   0.8074  128     0
  Chip 9        48.54   3.586   0.7034  12.14   0.8235  128     0
  Evens 48.802  3.576   0.7143  1.894   0.8126  1280    0
  Chip 0        49.828  3.504   0.7219  0.3069  0.8038  128     0
  Chip 1        48.197  3.341   0.6466  0.4462  0.8568  128     0
  Chip 2        49.917  3.527   0.6717  0.3339  0.8369  128     0
  Chip 3        50.08   3.438   0.6385  2.211   0.8799  128     0
  Chip 4        48.808  3.203   0.6593  0.6087  0.8336  128     0
  Chip 5        49.114  3.21    0.6755  0.3132  0.8413  128     0
  Chip 6        48.078  3.219   0.6469  0.1136  0.8608  128     0
  Chip 7        48.766  3.407   0.66    1.191   0.8531  128     0
  Chip 8        47.166  3.376   0.7092  0.6601  0.8114  128     0
  Chip 9        49.061  3.672   0.6646  0.6595  0.8428  128     0
  Odds  48.901  3.39    0.6694  0.6844  0.842   1280    0
  Overall       48.852  3.483   0.6919  1.289   0.8273  2560    0
Laurence Boccolini dit "Vous etes le maillon faible. Au revoir!!"
```

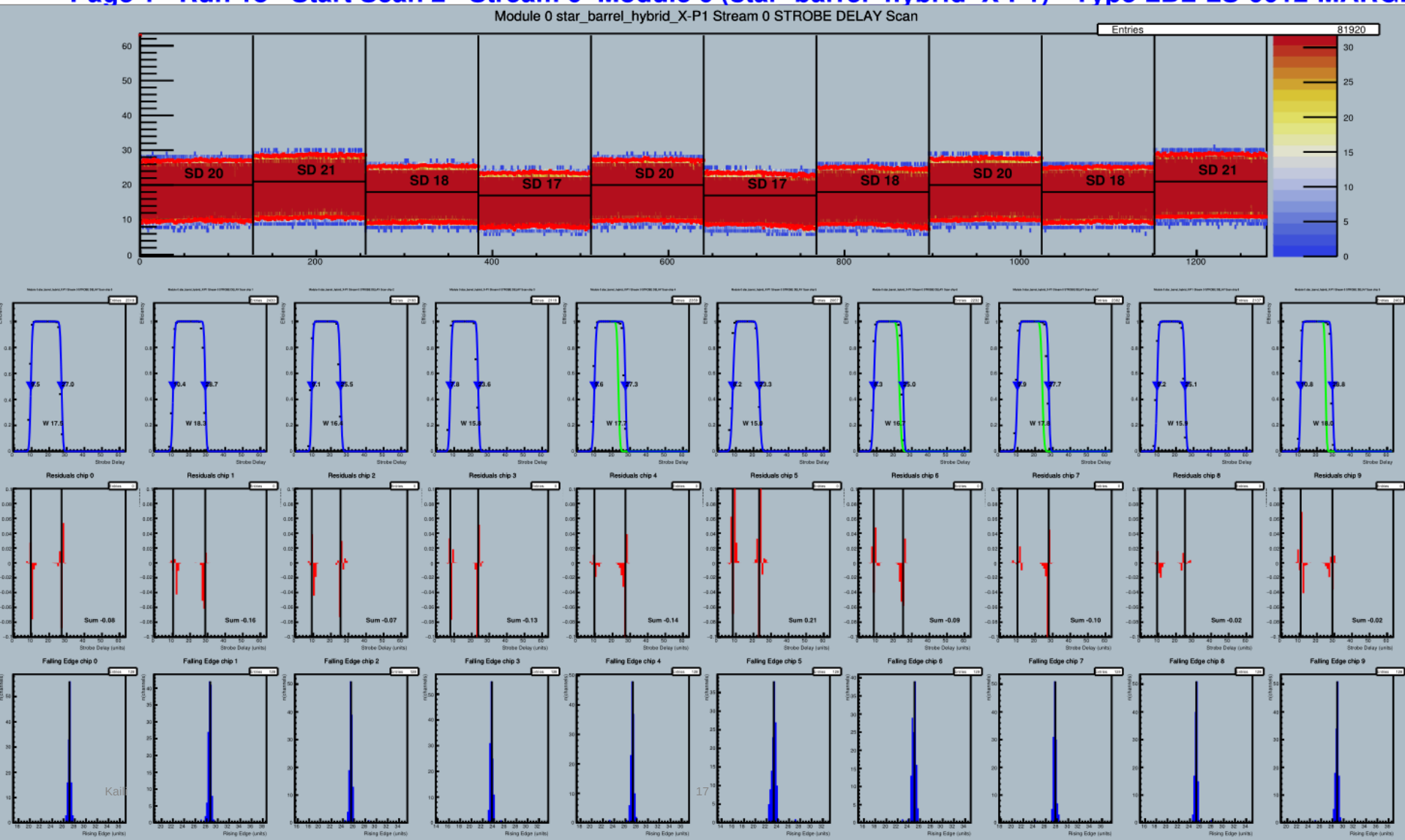
Dead Channels would show up here.

Strobe Delay Plot

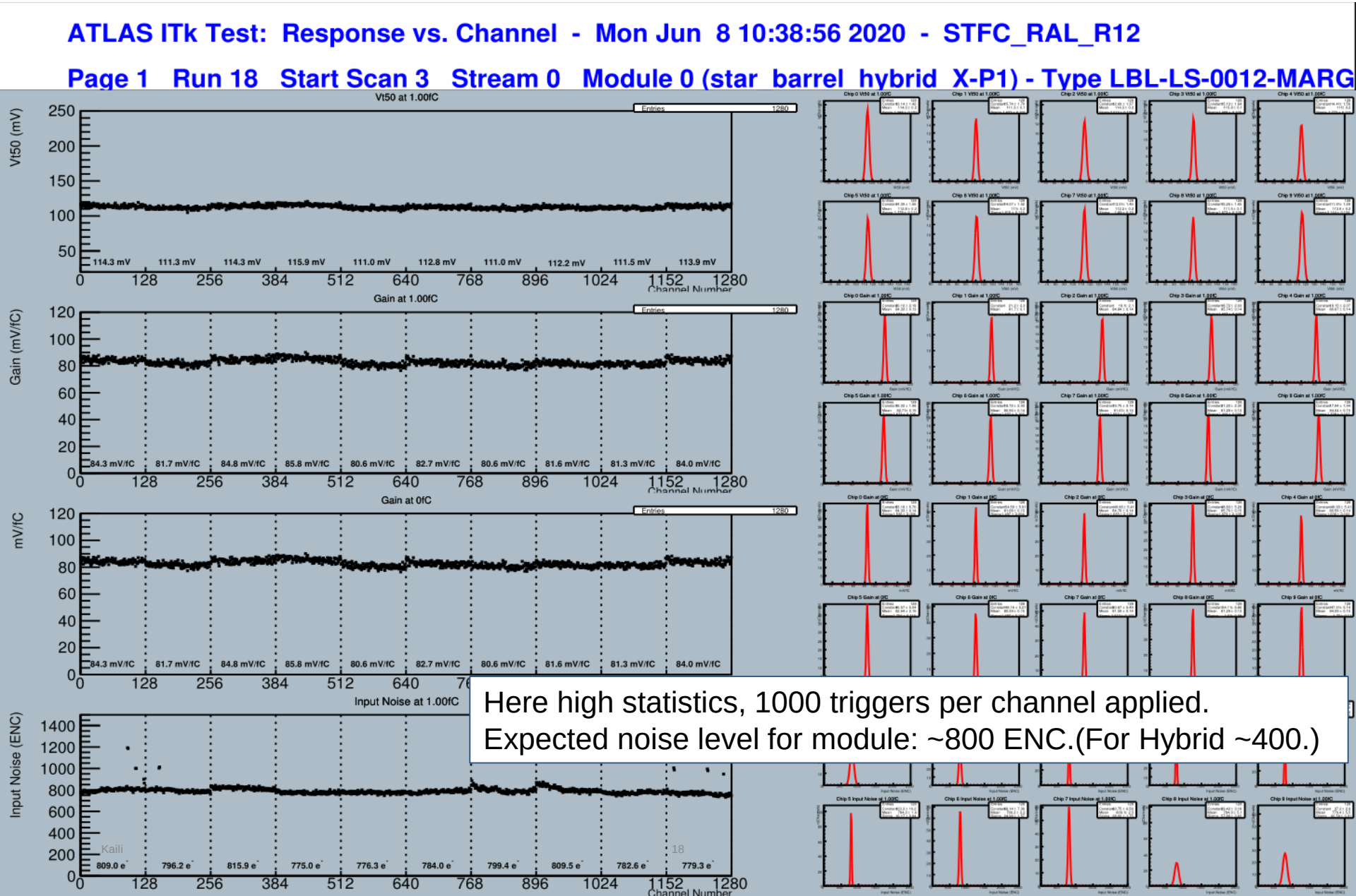
Default: set to 57%.
The expected result is a top hat like plot which can be analyzed to find the rising edge and falling edge.
The appropriate strobe delay is chosen as a fraction along the flat top.

ATLAS SCT Module Test: Strobe Delay - Mon Jun 8 10:37:22 2020 - STFC_RAL_R12 - SD fraction 0.5

Page 1 Run 18 Start Scan 2 Stream 0 Module 0 (star_barrel_hybrid_X-P1) - Type LBL-LS-0012-MARGI

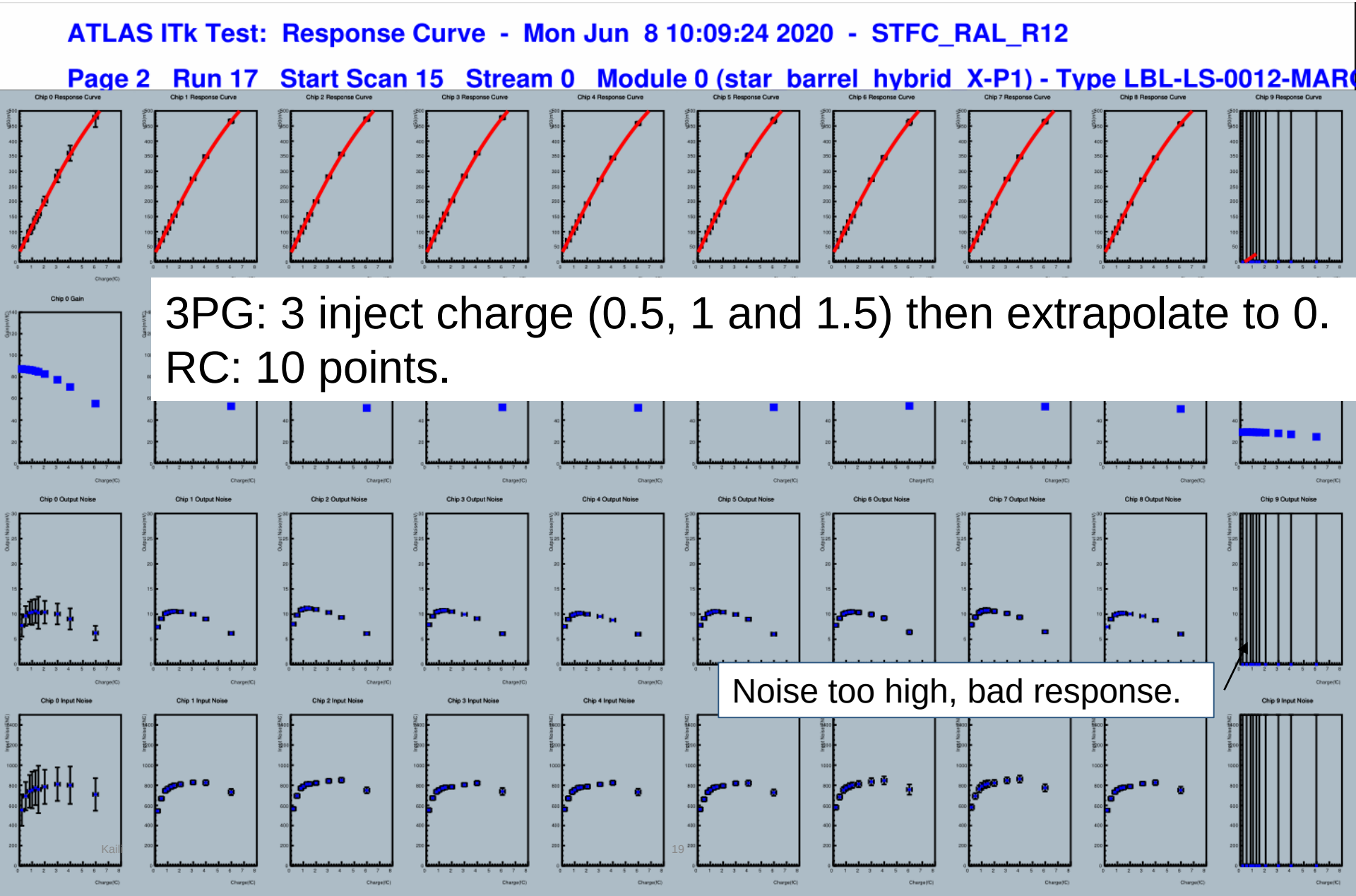


3PG / Response vs. Channel Result



Here high statistics, 1000 triggers per channel applied.
Expected noise level for module: ~800 ENC.(For Hybrid ~400.)

3PG / Response vs. Channel Result(2)

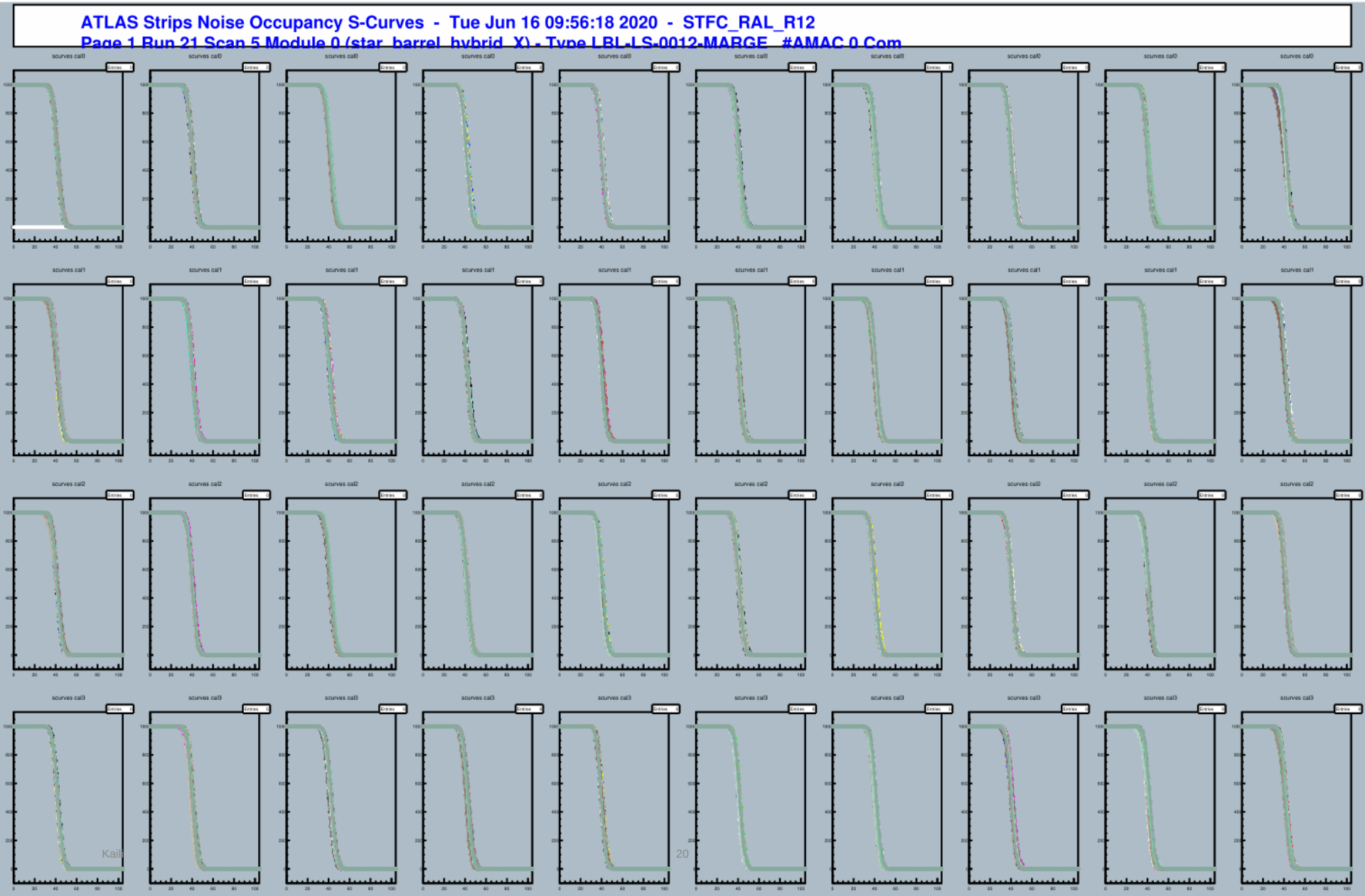


3PG: 3 inject charge (0.5, 1 and 1.5) then extrapolate to 0.
RC: 10 points.

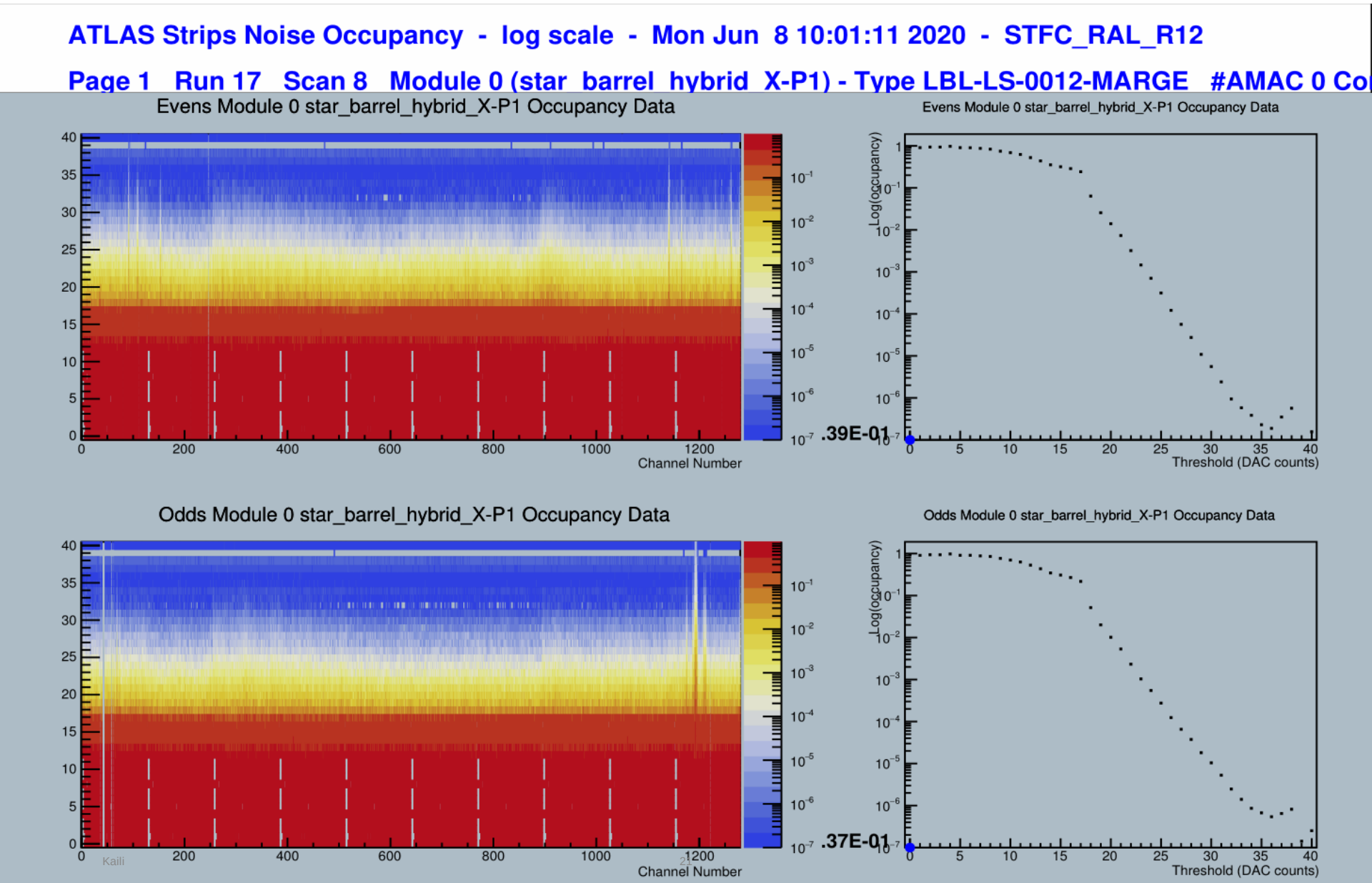
Noise too high, bad response.

RC test S-Curve

Here list 32*10*4=1280 channels



Noise Occupancy



Finish test……

- Ramp HV back to 0V. (Important!)
  - `iv_scan -v 0 -t 5`
- Turn off LV, HV.
- Disconnect the module.
- Exit HV Console and ITSDAQ.
- Switch off FPGA board.
- Turn off chiller, and dry air.

Useful links

ABC module paper:

https://drive.google.com/file/d/17gO3LLPXOHtYzvcszJuyqWYmmrwEdjvt/view?usp=sharing

ITSDAQ Documentation:

https://atlas-strips-itsdaq.web.cern.ch/index.html

https://twiki.cern.ch/twiki/bin/viewauth/Atlas/StripsUpgradeDAQ

Gitlab:

https://gitlab.cern.ch/atlas-itk-strips-daq/itsdaq-sw

(Need to sign in usatlas-itk-strips-technical e-group first)

Useful links

Twiki test page

https://twiki.cern.ch/twiki/bin/viewauth/Atlas/ABCStarHybridModuleTests

https://twiki.cern.ch/twiki/bin/view/Atlas/ITkStrips

One old/outdated version module test document:

https://docs.google.com/document/d/1Ep9Gbrr1lLEOma32GRhq-TWVMqyKIbcgtH4sQRugpY4/edit?usp=sharing

Firmware list

http://www.hep.ucl.ac.uk/~warren/upgrade/firmware/

AMAC Register map

https://gitlab.cern.ch/atlas-itkstrasic-group/AMAC/-/blob/master/doc/v2a/AMAC_v2a_Registers-20200313.pdf

Backup

Concepts and definitions you may need on tests

Strobe delay

This is an analogue test, looking at strip data.

- When injecting charge into the front-end of the chip, the pulse can be delayed with respect to the system clock.
- This test scans over the possible delay values while injecting a large charge.
- The expected result is a top hat like plot which can be analysed to find the rising edge and falling edge.
- The appropriate strobe delay is chosen as a fraction along the flat top.

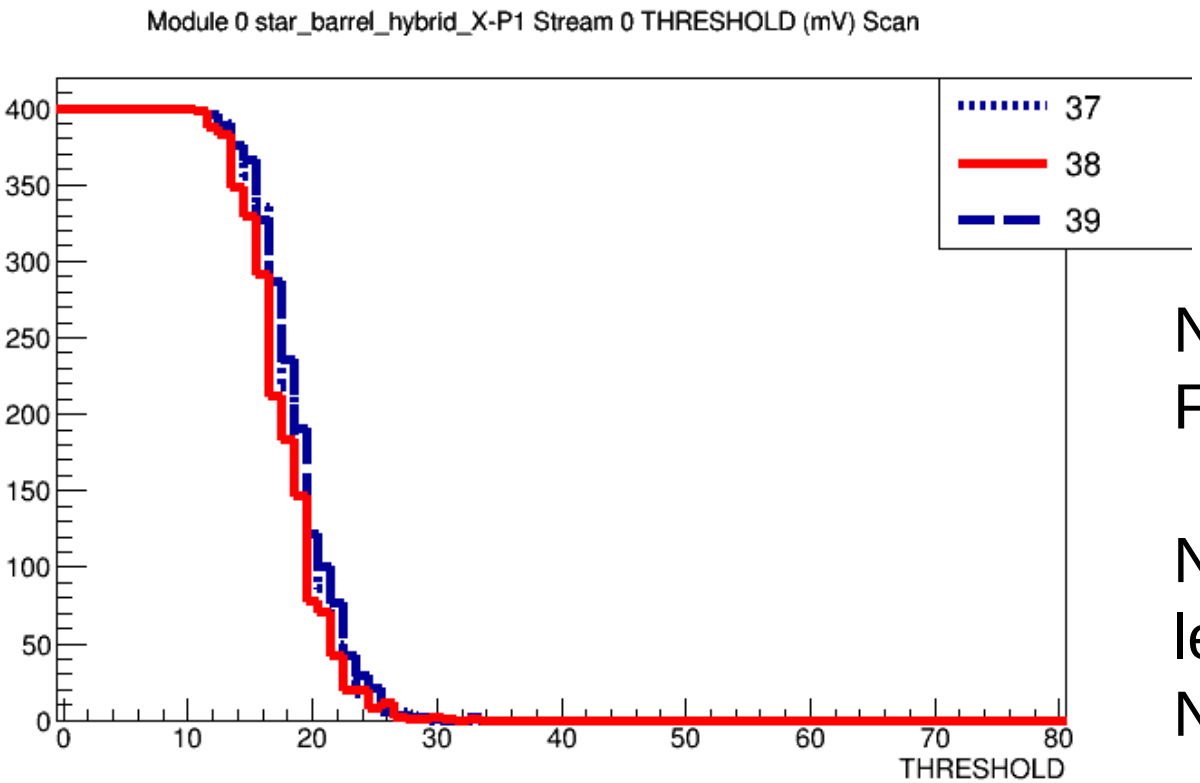
NB: the strobe delay test is typically run before any other charge injection tests.

Response Curve (including three point gain)

The response curve is used to measure the response of the front end (in mV or DAC counts) to the injection of a calibration charge.

- This is done by carrying out a series of scans over the threshold DAC.
- For each scan, a different charge is injected into the front-end (3 charges for the three point gain, more, typically 10, for the response curve).
- The output is an S-curve for each channel for each charge.
- The analysis proceeds by fitting the S-curve to find the median threshold (a.k.a. vt50, threshold voltage for 50%) and standard deviation (output noise) for each charge. (see next slide)
- A fit is made of these values to a straight line (for the 3-point gain) or an exponential (for the response curve).
- The chip gain is the gradient of this slope, and the input noise is derived from the output noise at a particular charge by dividing by the gain. The noise is often quoted in electrons, equivalent to the charge of the noise.

S-Curve: For one channel



Noisewidth:
FWHM of the slope.

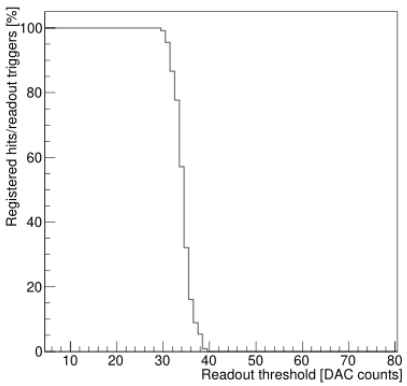
Normalized noise level, ENC= Noisewidth / Gain.

X Axis: Readout threshold [DAC counts]

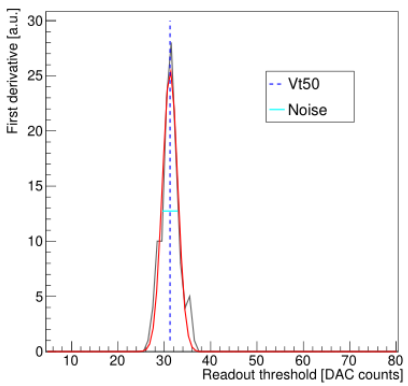
The 50% occupancy point indicates the threshold value, which corresponds to the injected charge after amplification, and the width characterizes the noise.

From the 50% points we generate the response curve which represent the shift in response as a function of increasing injected charge, which is fitted to a straight line.

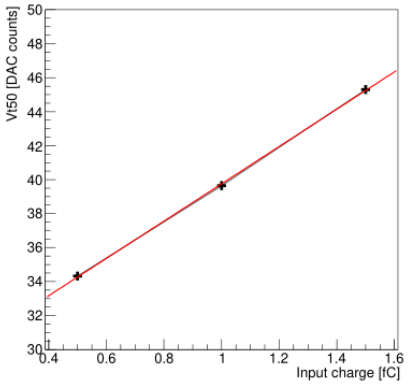
The gain is taken as the slope of the fit.
Gain = (response)/ (input charge).



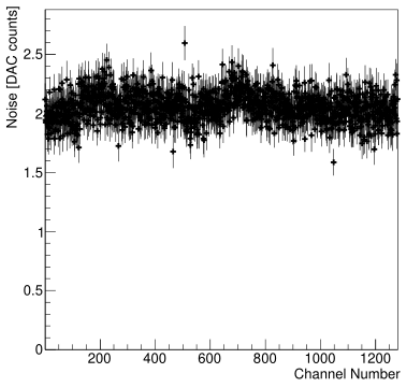
(a) S-curve obtained from a threshold scan of a readout channel.



(b) First derivative of an S-curve with Vt50 and noise.



(c) Gain of individual readout channel, from Vt50 measurements.



(d) Noise of channels from all ASICS on one hybrid (about 400 ENC).