ATLAS Semiconductor Tracker Upgrade

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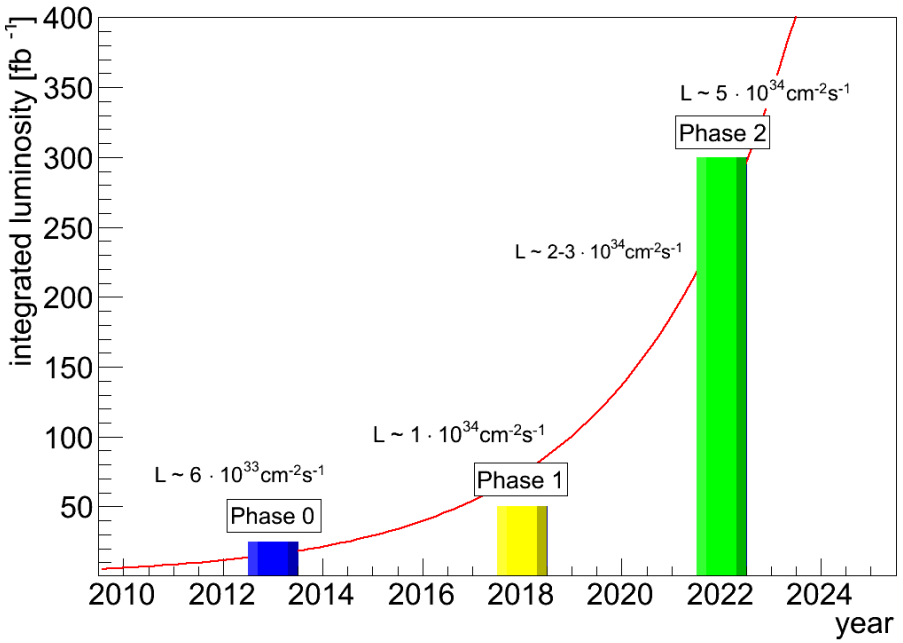
IOP 2013 Liverpool

LHC Upgrade Luminosity



Phase 2 (2022)

- High-Luminosity LHC (HL-LHC)
- Expected to reach $5 \times 10^{34}\ cm^{-2}s^{-1}$
- Centre-of-mass energy $\sqrt{s} = 14\ TeV$
- Average 140 proton-proton interactions

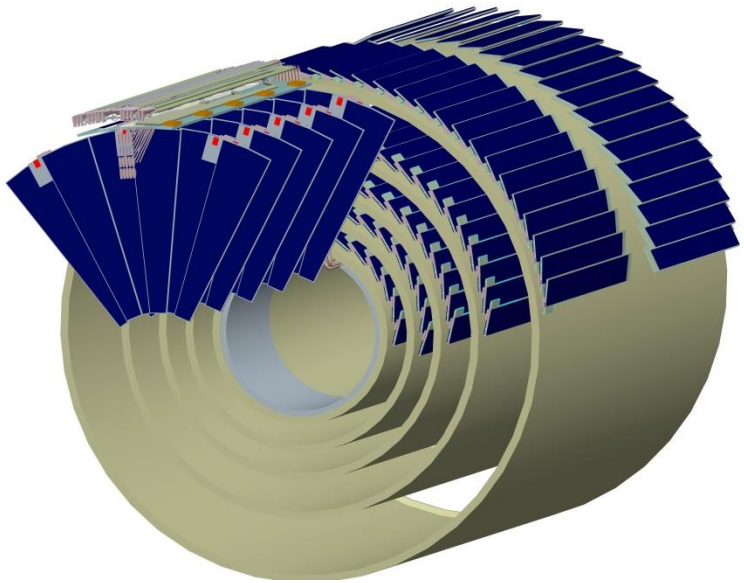
The ITk Upgrade

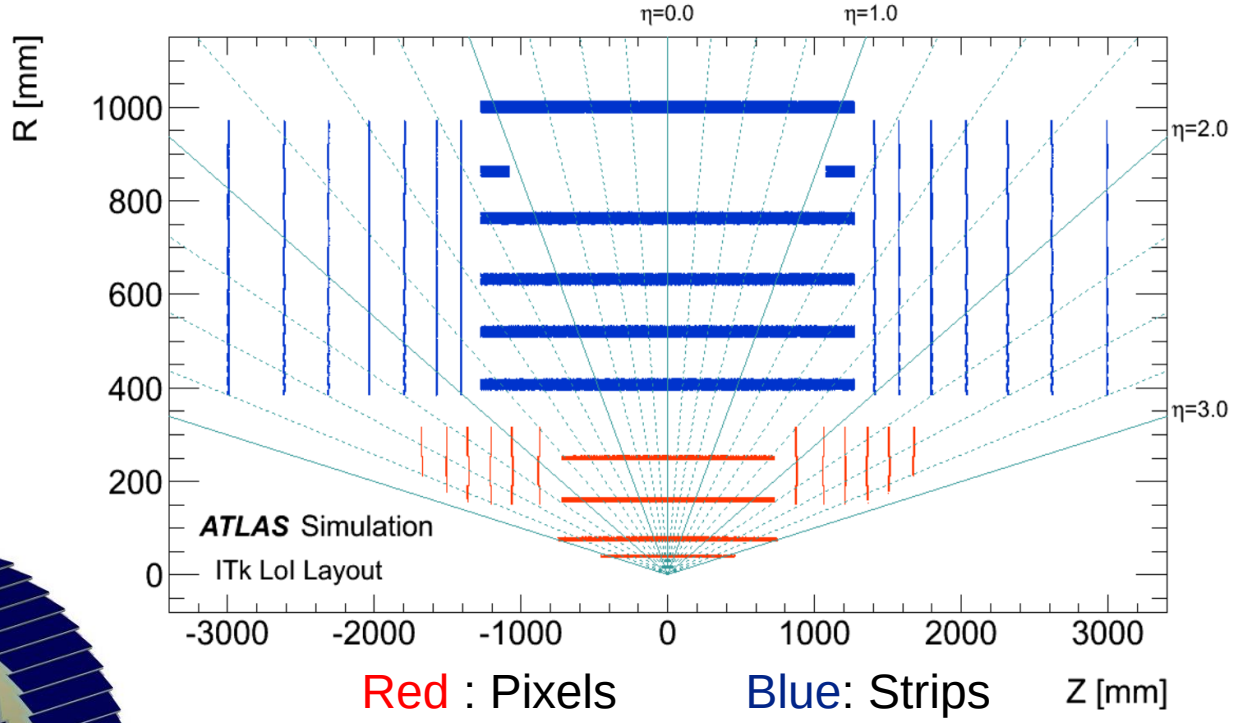
- End of the life time for the Inner Detector
- Redesign to withstand harsher conditions
  - Higher particle count
  - Higher radiation dosage
- All Silicon tracker
  - A balance between measurement precision and material profile
- Two Subsystems
  - Pixel layer
  - Silicon Microstrip layer

Strip System

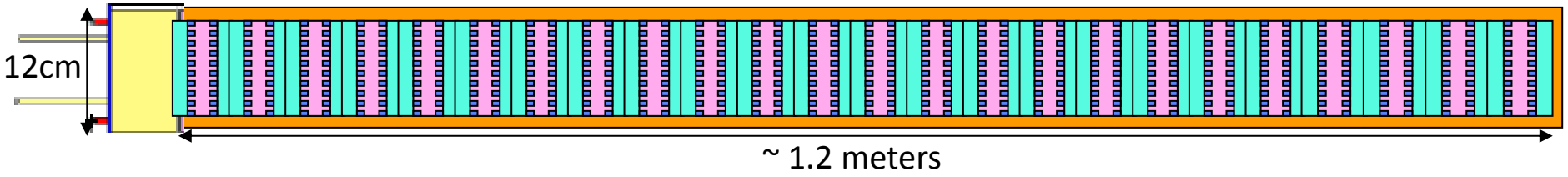
- 5 Barrel layers surrounding the pixel layer.
  - Radii 405mm → 1000mm
- 7 Endcap disks
  - at z-positions ±1415mm → ±3000mm.
- 2 Stub cylinders
  - between 4th and 5th barrel layer
- Every layer provides 2 hits (Slide 6)
- 10 possible hits per track in the region $|\eta| < 2.5$ (+4 from pixels)
  - Track reconstruction requires 11

ITk Layout

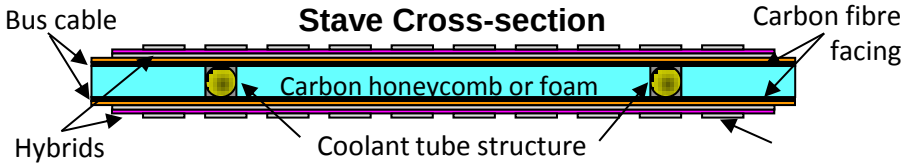


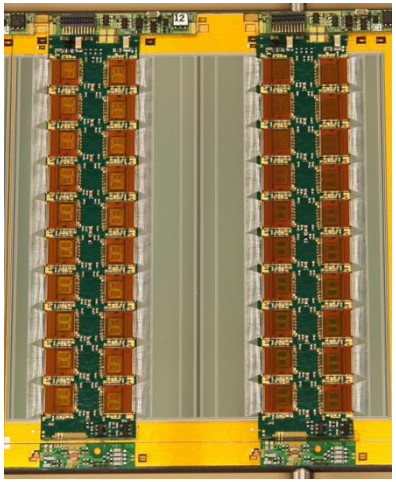

η=0.0
η=1.0
η=2.0
η=3.0
R [mm]
1000
800
600
400
200
0
-3000
-2000
-1000
0
1000
2000
3000
Z [mm]
ATLAS Simulation
ITk LoI Layout
Red : Pixels
Blue: Strips

Stave Concept



- Reduction in material
- Designed for mass production



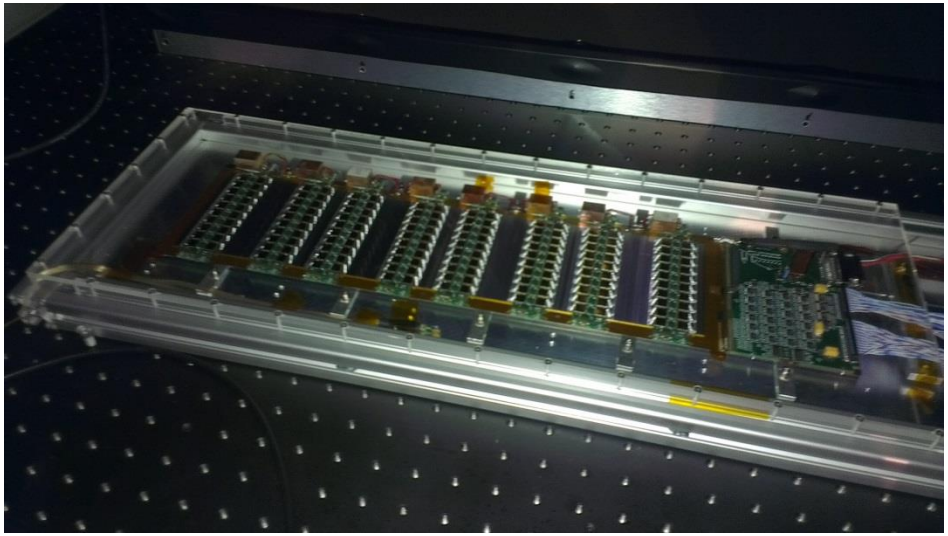


Module

- ~10cmx10cm n-in-p sensor
- 4 columns ~2.5cm each
- Two glued hybrids
- 20 ABCN-250 chips per hybrid
- 128 channels per chip

Stavelet

- Shortened stave
  - Proof of concept
- 4 modules in a stavelet
- 2 types of system powering
  - Serial powered
  - DCDC powered (*reporting on this*)
- Readout through HSIO board



Standard Tests

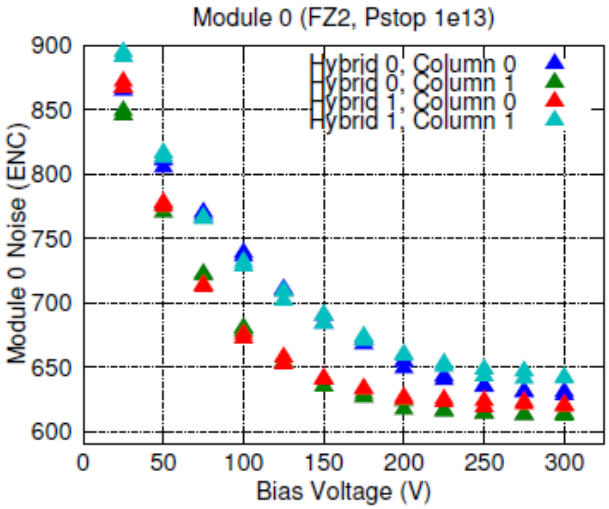
- Strobe delay
  - determines the correct Strobe Delay setting, corresponding to the timing of the charge injection pulse. To ensure the clock frequency will be synchronous with the pulse.
- 3pointGain
  - Threshold scans are performed for three different injected charges. The resulting response curve is fitted linearly to obtain values for its estimated discriminator offset, the channels gain and noise.
- Noise occupancy
  - Measures the noise occupancy as a function of threshold.

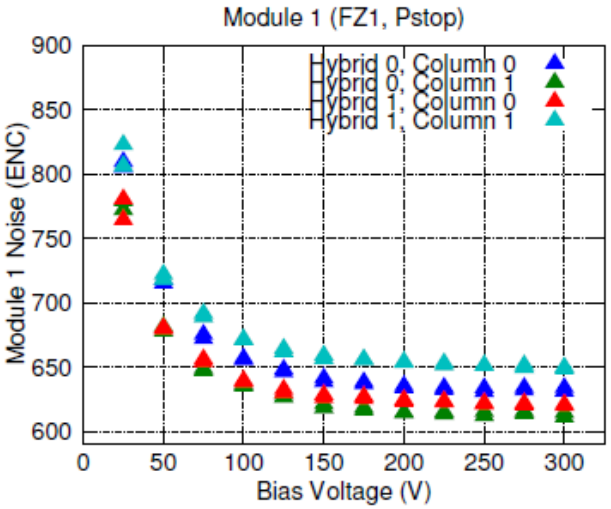
Following slides reporting on the tests done on the DCDC stavelet in B180 @ CERN.

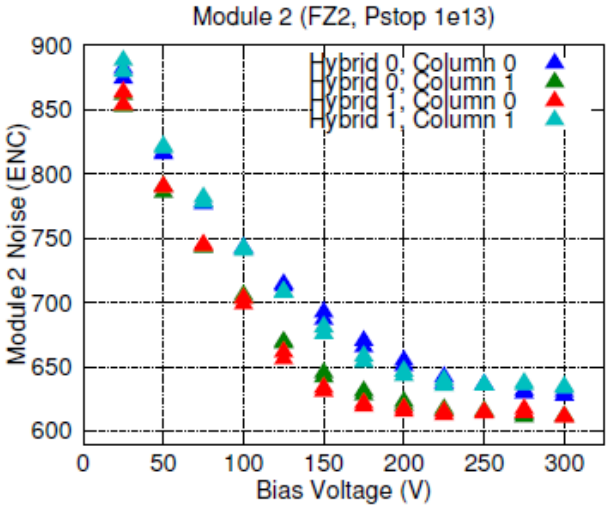
Noise vs. Variables

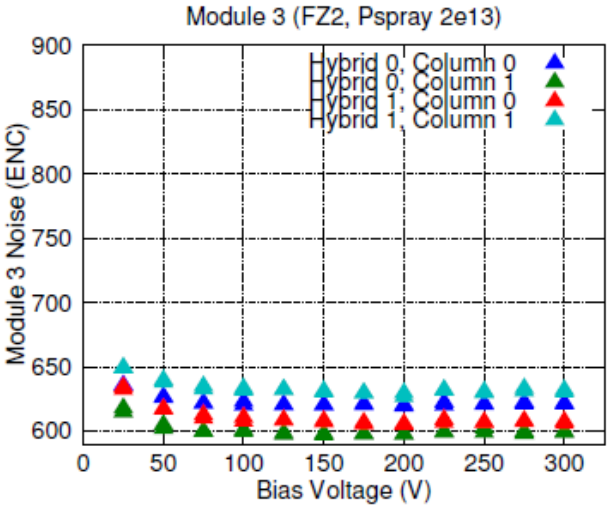
- Noise measured with 3pointGain scans at 1fC
- Noise reported as Electron Noise Count (ENC)
- Variables
  - Bias Voltage, Temperature, Low Voltage.

Noise vs. Bias Voltage[1]

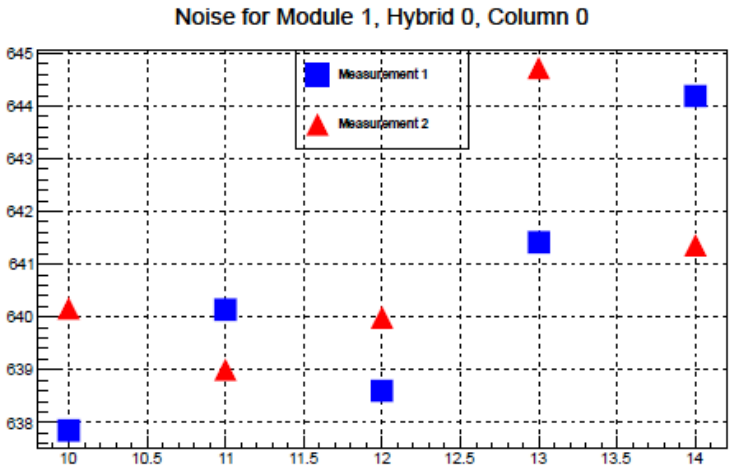


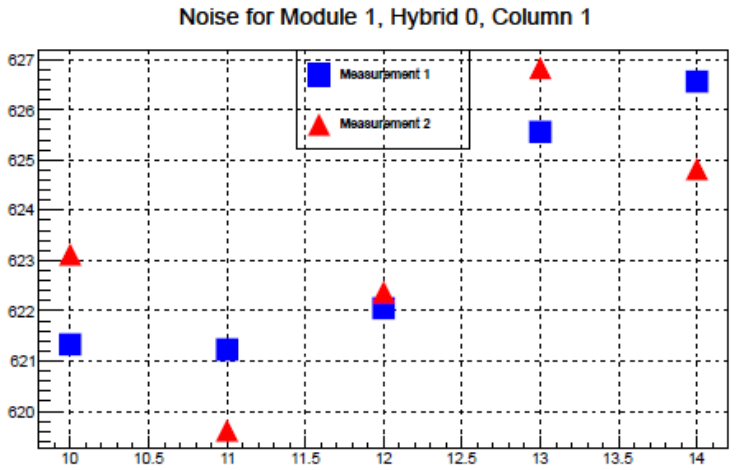


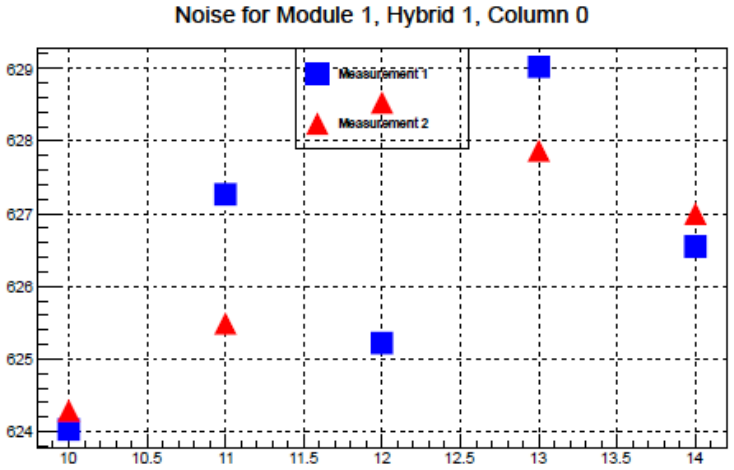


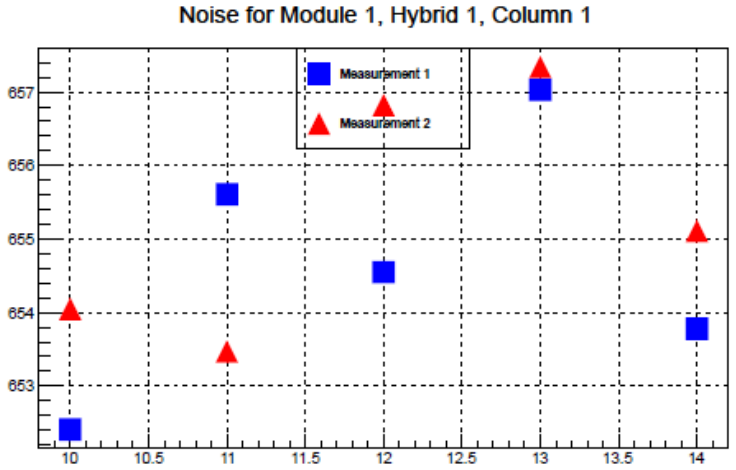


Noise vs. Low Voltage[1]

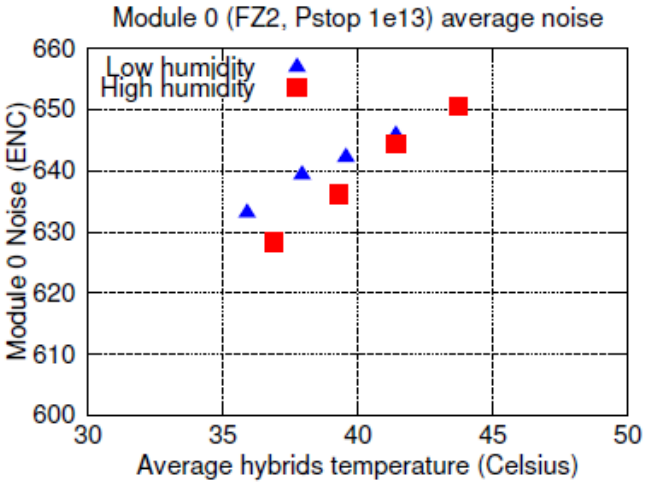


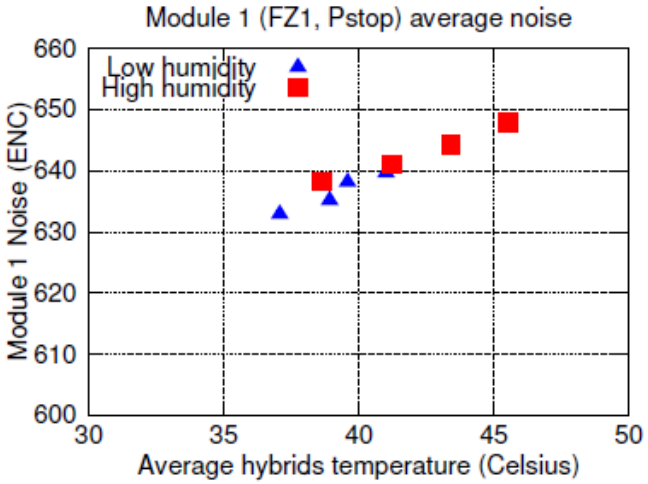


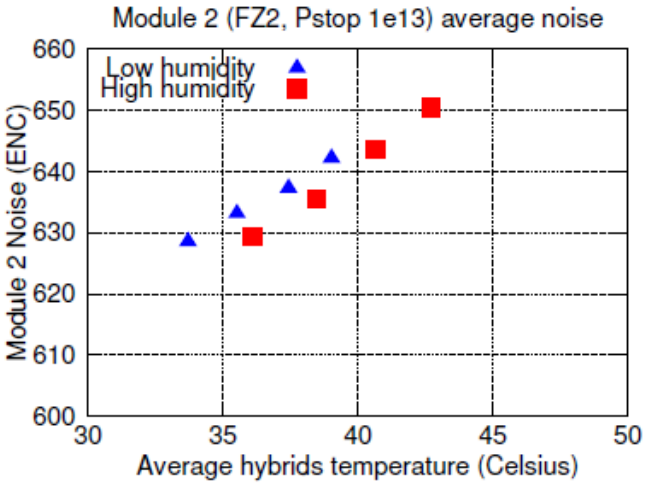


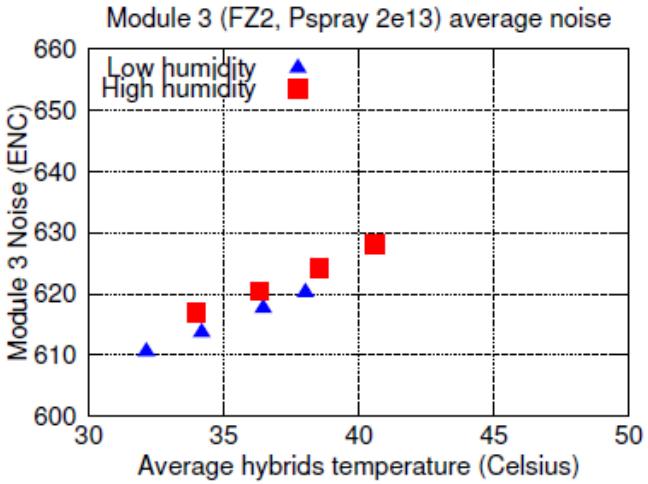


Noise vs. Temperature[1]

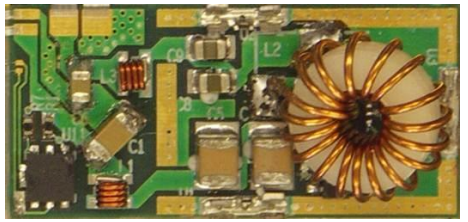








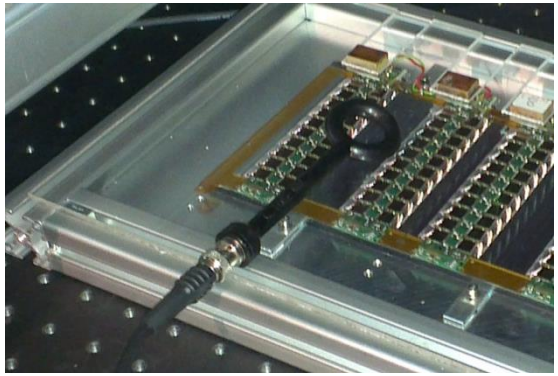
Stavelet's E-H field Susceptibility

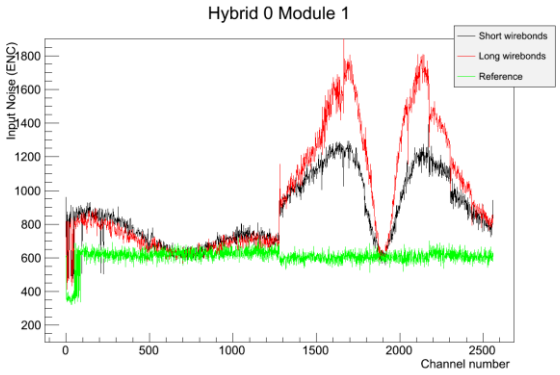


- DCDC converter is the main source of E-H fields.
- Shielding required
  - Thinnest possible. Minimize material budget
- H-field require thick shield
- E-field can be attenuated with a thin shield

H-field

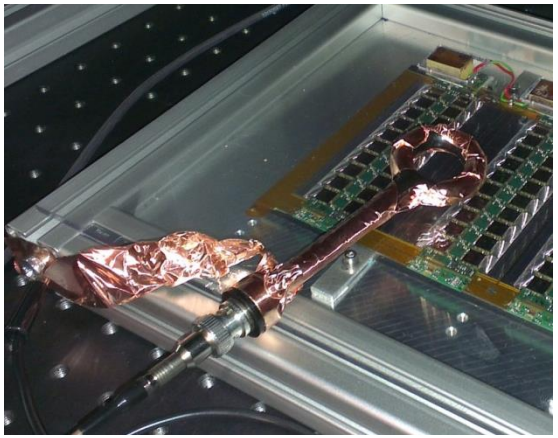
Non-grounded H-field loop probe
(-45dBm 4MHz Square wave)





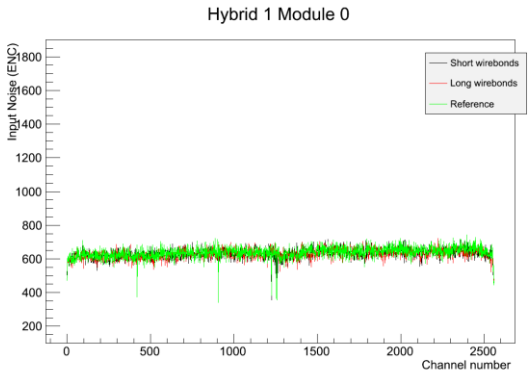
- Saddle shaped noise due to the geometry of the probe
- Noise shown for 1 hybrid (2 columns)

Shielded and Grounded loop probe
(-45dBm 4MHz Square wave)

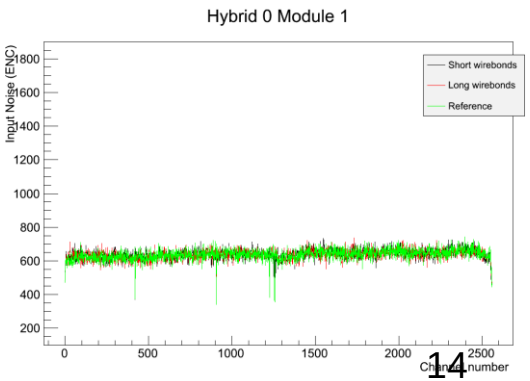


- Disappearance of the noise due to the absence of the E-field

Placed on top of the DCDC converter

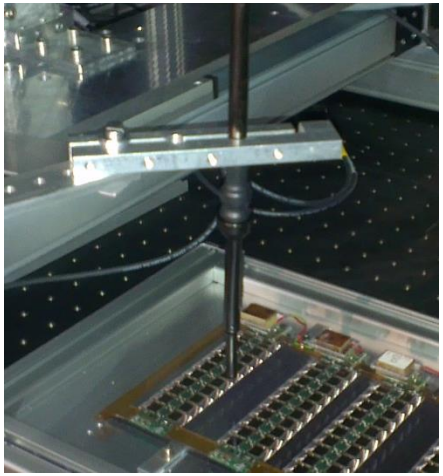


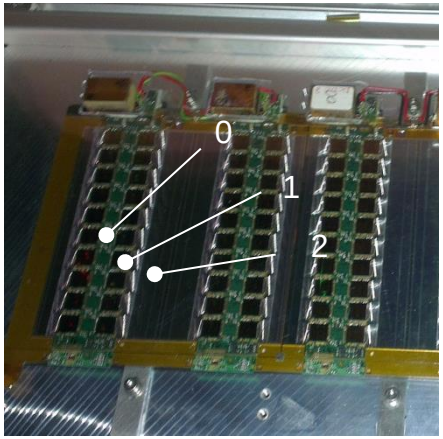
Placement as shown above

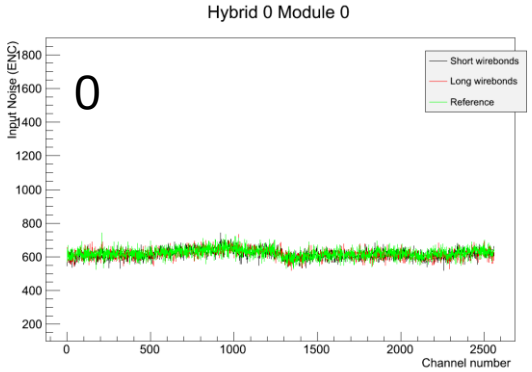


E-field

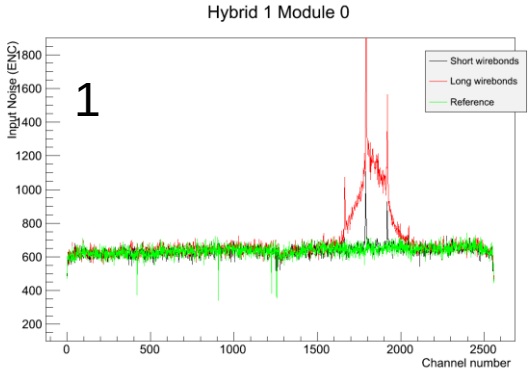
- Stub E-field probe pointing towards a module
- Driven with a 4MHz square wave
- Effective output -65dBm
- Stub probe produces a narrow E-field
- Stub probe was positioned at three different points



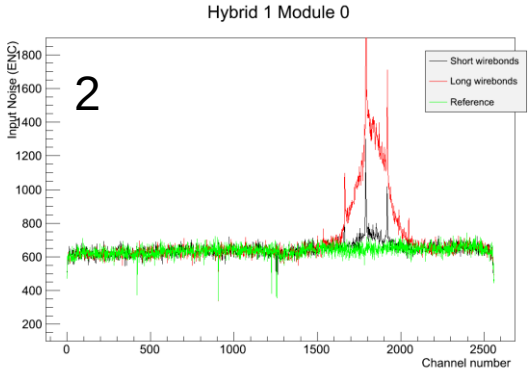




- Field too narrow to reach any of the wirebonds



- The field only covers the area around the chip. Only the long wirebonds are exposed to it while shielding the short bonds.

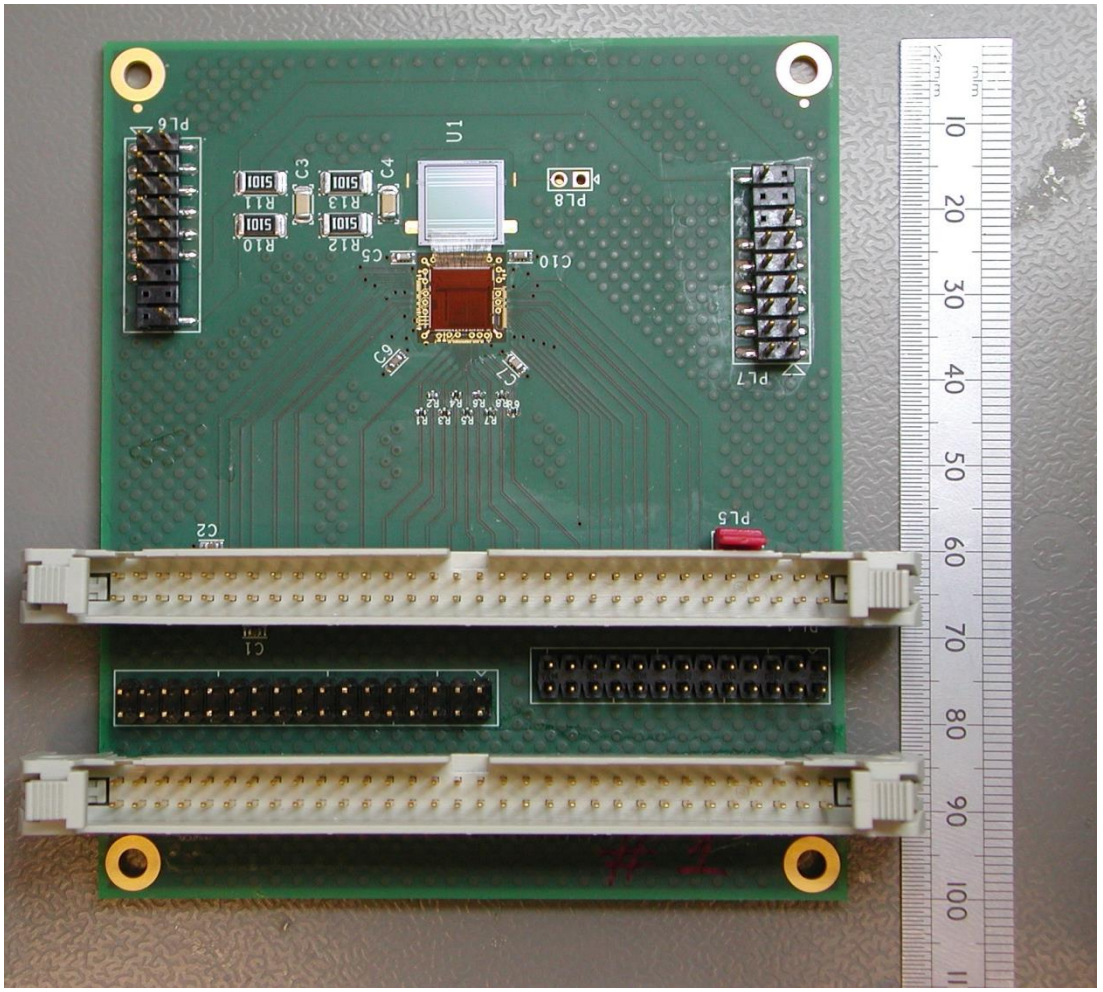


- The field is on top of the area where the wires are bonded to the strips. Both long and short wirebonds are exposed.

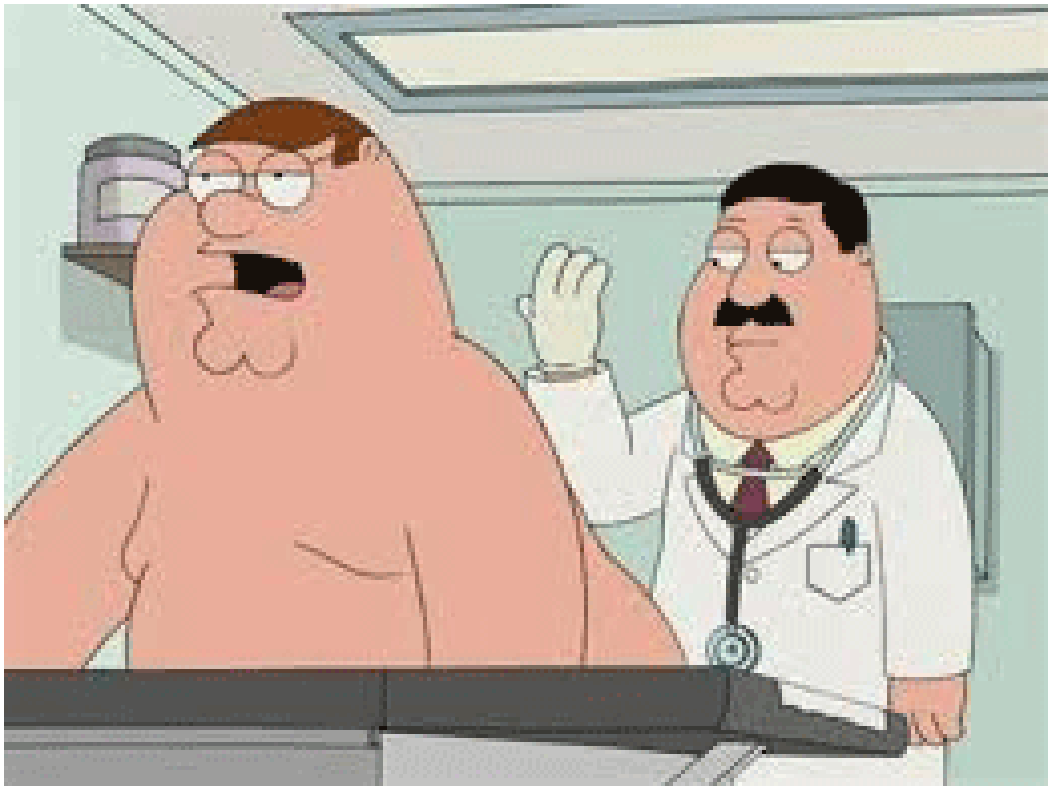
- Spikes are at the edges of each chip. Every 128 channels

Laser Tests @ RAL

- Mini sensor wirebonded to a ABCN-250 chip
- Laser 1064nm 50μJ
- Test to see how much charge the chip can handle
- Final tests with ABCN130



Questions?



References

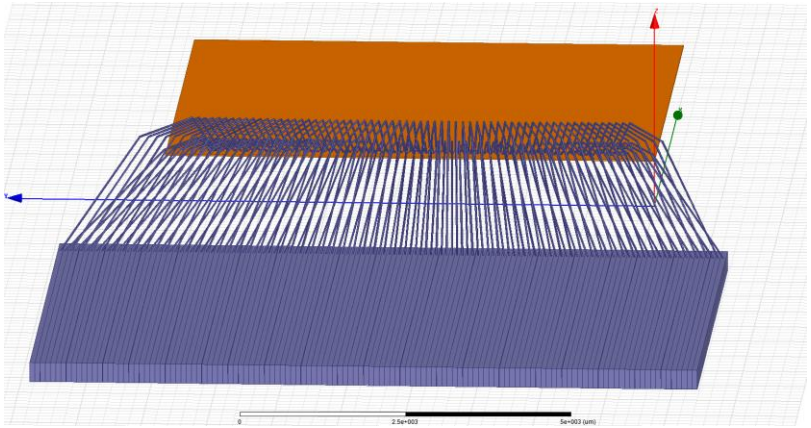
1. DC-DC Stavelet Studies in CERN B180, C. A. Garcia, ATLAS Upgrade Week, SLAC, 27/03/2012
2. ATLAS Strip Tracker Stavelets, P. W. Philips, TWEPP, Vienna, 26/09/2011
3. ATLAS Inner Tracker LoI, S. Burdina et al, CERN, 11/02/2013
4. Electrical Tests of SCT Hybrids and Modules, P. W. Phillips et al, CERN, 14/11/2000.

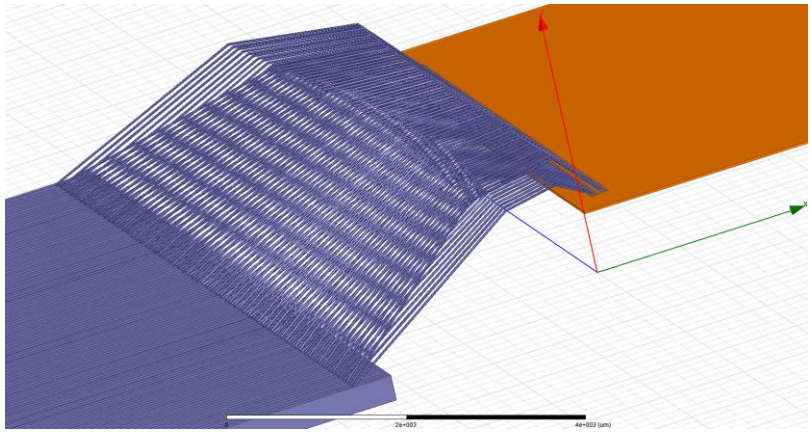
Backup slides

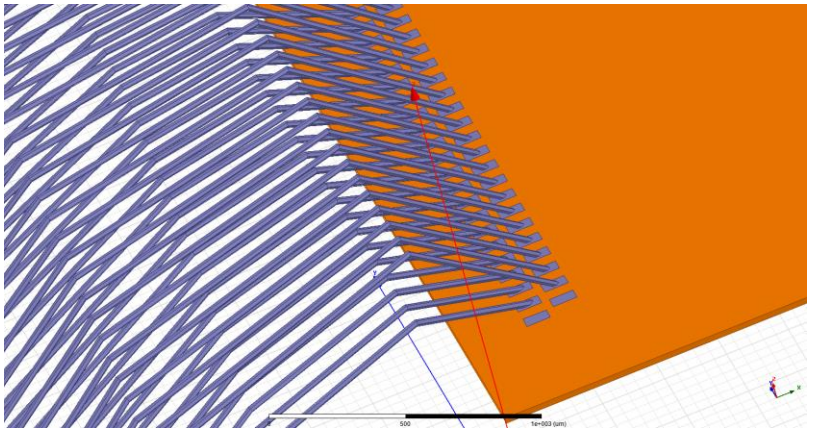
ABCN130

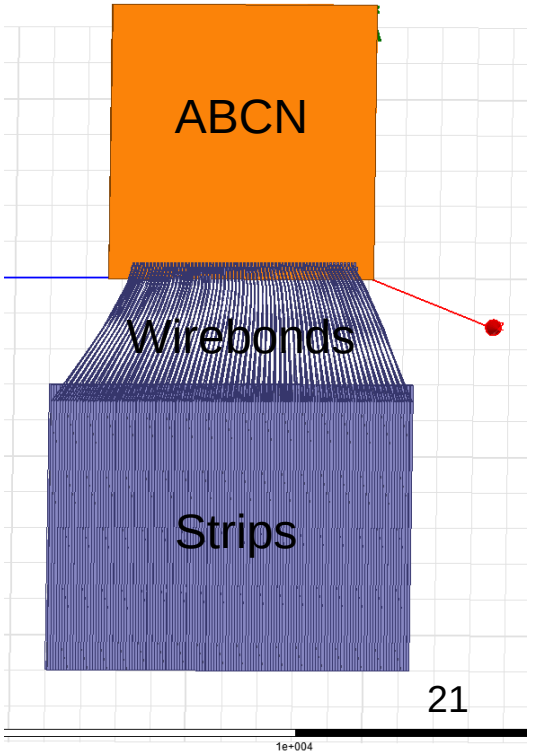
- 256 Input channels
  - ABCN-250 128 Input channels
- 130nm CMOS technology
- 1.3V external power supply
- Three Trigger types, L0, R3 and L1 control the data flow.
- Xon / Xoff flow control between chips.
- Readout clock up to 160Mbits/sec
- Readout mode compatible with an external Hybrid Controller Chip, HCC
- SEU errors handling
- Fast cluster finder logic

Simulation (Model)



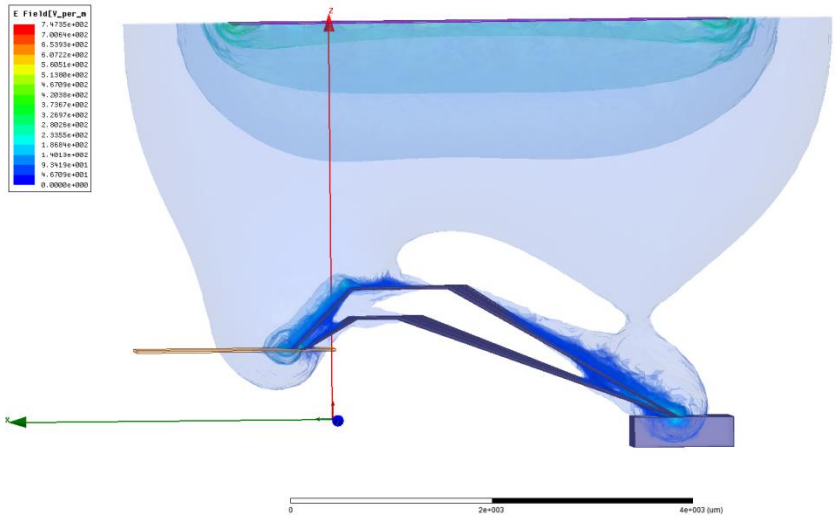


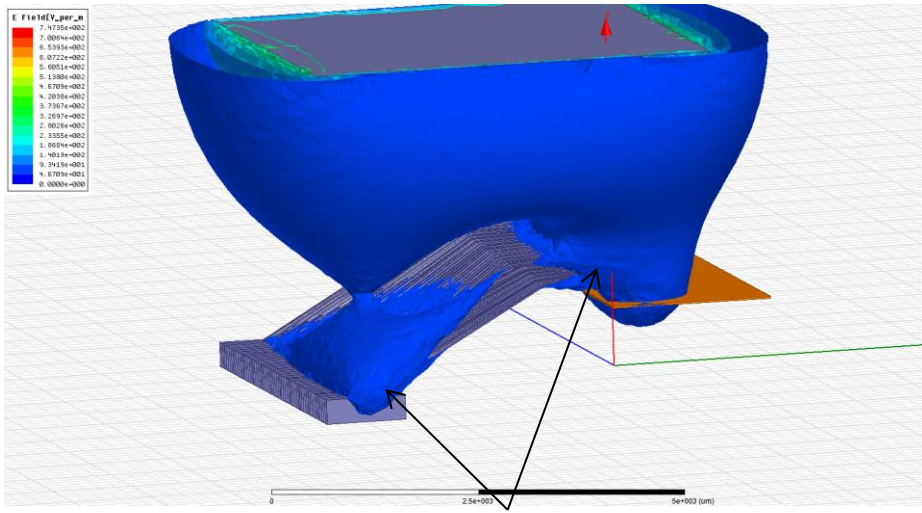




- Full model drawn in Ansoft HFSS
- Due to limited computing resources model was halved.

Simulation (Solution)





Reason for the spikes