Investigation of silicon strip sensors and alternative powering concepts for the ATLAS upgrade.

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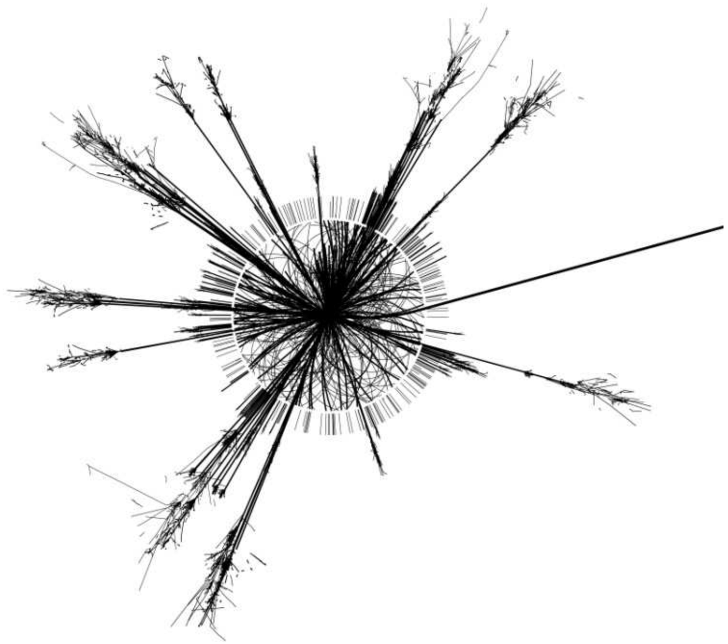


-DESY Zeuthen-
Summer Student Programme

Supervised by Conrad Friedrich, Hongbo Zhu and Ulrich Husemann

Introduction

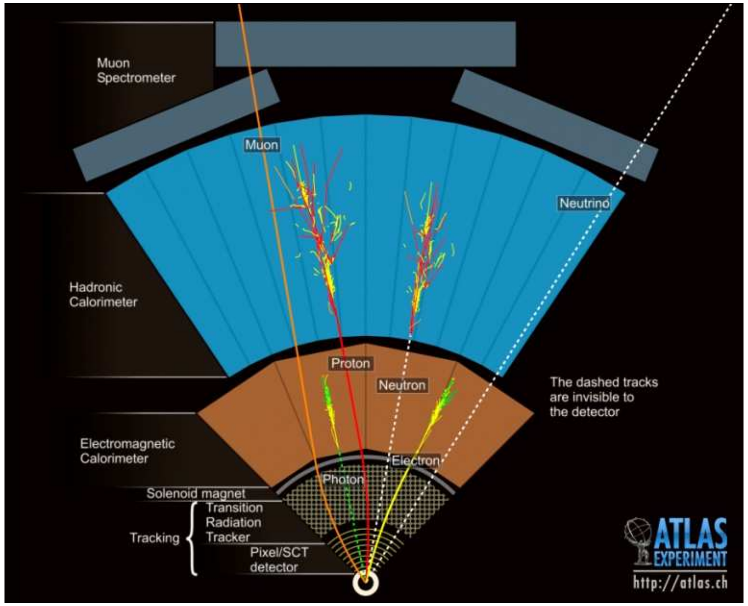
The topics I have worked on consisted of:

- Characterization of silicon sensors for the ATLAS SCT upgrade.
- Noise susceptibility tests of the ATLAS pixel front-end electronics.
- Investigation of piezoelectric transformers.

Remember:

My work was focused ATLAS inner detector.

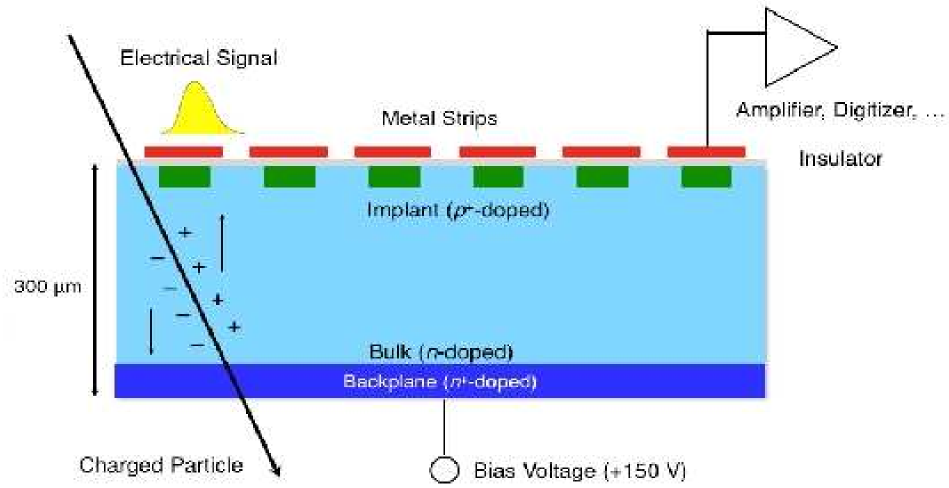
- This part is situated near the interaction point.
- The detectors receive high radiation dose and consequently will suffer damage.
- ATLAS group is involved in the research and development of detector components for their future replacement and upgrade.



Silicon Strip and Pixel

Semiconductor Detector.

- General principle: When ionizing particle traverses semiconductor material, it generates free charge carriers.
- We use an external electric field to deplete the residual free charge and separates the pairs before they recombine, and collect them on electrodes producing a current pulse.

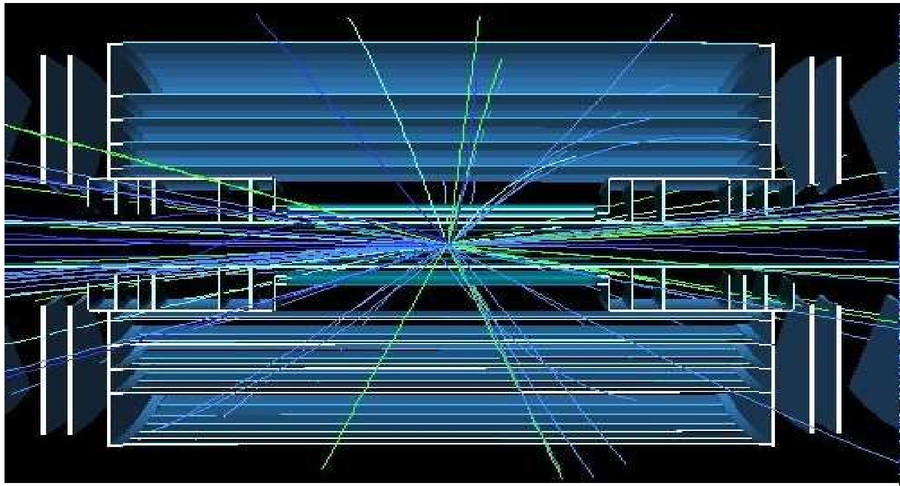


Strip Detectors.

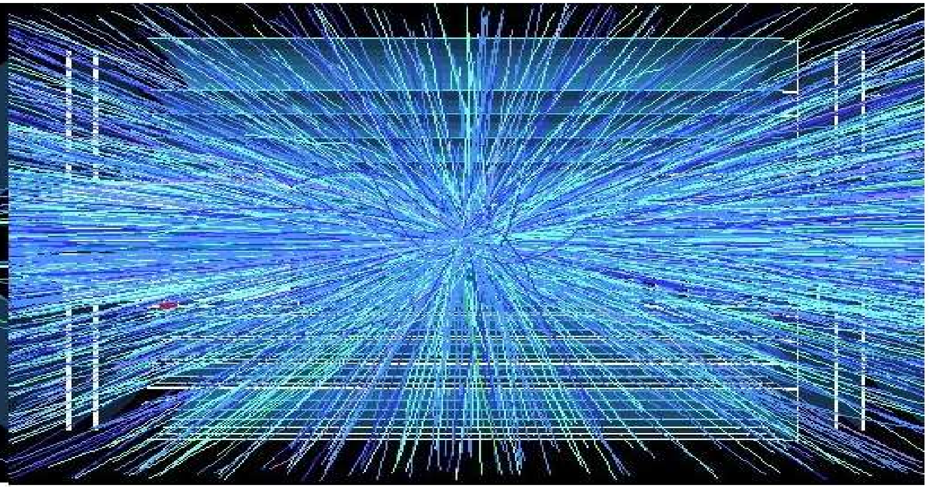
- One way to measure particle position is obtained by dividing the large-area of semiconductor diode into many small regions and read them out individually.
- The position of passage of the ionizing particle consequently is given by the location of the strips showing the signal.

Motivation

Tracks in LHC



Simulation tracks in sLHC



- The even higher luminosity at sLHC (LHC upgrade) will lead to an increase in the number of events from 20 to 300-400 per bunch crossing.
- If you want reconstruct all of this tracks individually, it will be necessary to increase the number of channels in the same space.
- I have studied prototypes of new sensors with better resolution.

- For taking measurements a probe station was used to connect the strip sensor pads via needles to the measurement devices.
- We used a PC and LabView program to automatically control and read them out.

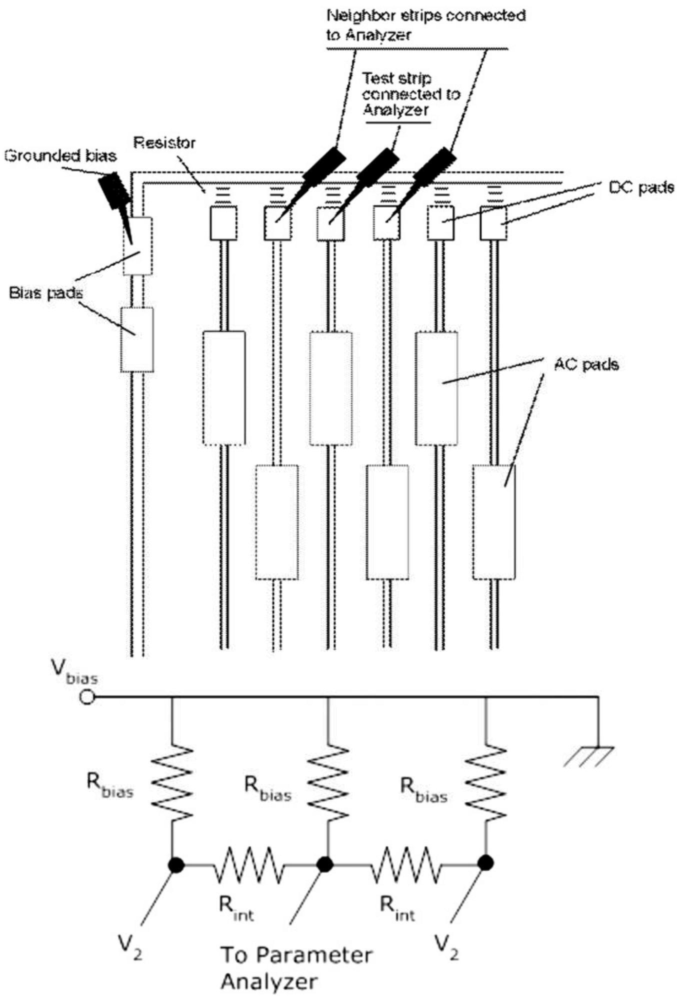
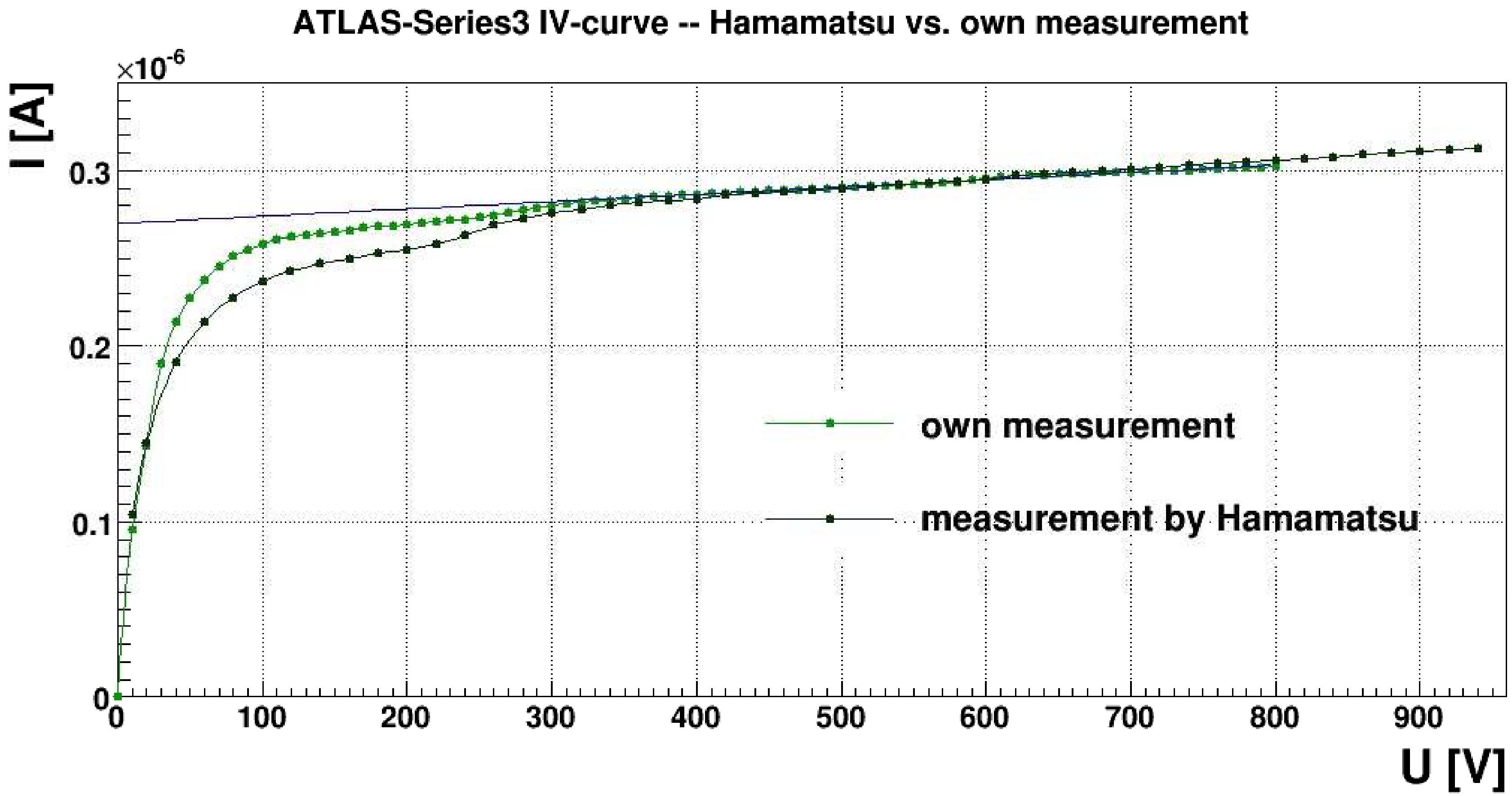
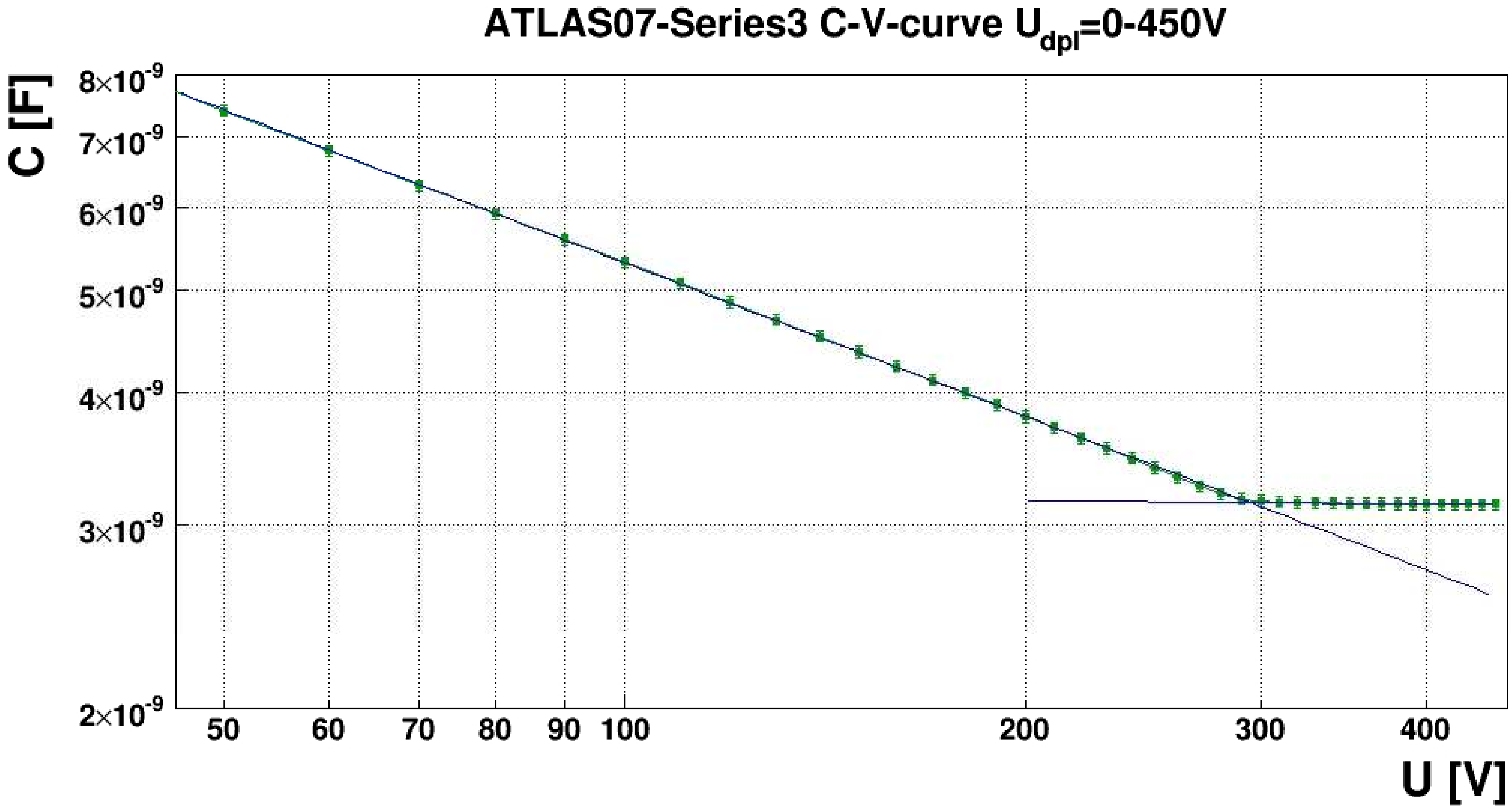


Illustration of strip detector connection pads.

Results

The most important measurement, I-V and C-V, are shown in the following figure:




ATLAS07-Series3 C-V-curve U_dpl=0-450V
C [F]
8×10^-9
7×10^-9
6×10^-9
5×10^-9
4×10^-9
3×10^-9
2×10^-9
50
60
70
80
90
100
200
300
400
U [V]

This table show the results our own measurements and a comparison to the design specification:

	ATLAS07 specifications	Measurement
Leakage Current	$< 200\mu$A at 600V	$\sim 0.3\mu$A at 600V
Full Depletion Voltage	< 500V	295V
Coupling Capacitance at 1kHz	$> 20p$F/cm	Tested*
Silicon Bias Resistans	1.5 ± 0.5MΩ	1.17MΩ
Current through dielectric	$I_{\text{diel}} < 10n$A	Not Tested (destructive)
Strip Current I_{strip}	No explicit limit	Tested*
Inter-Strip Capacitance	$< 1.1p$F/cm	Tested*
Inter-Strip Resistance	$> 10 \times R_{\text{bias}} \sim 15M\Omega$	Not Tested*

*automatic probe station is needed to reliably measure this characteristic.

Pixel Detectors

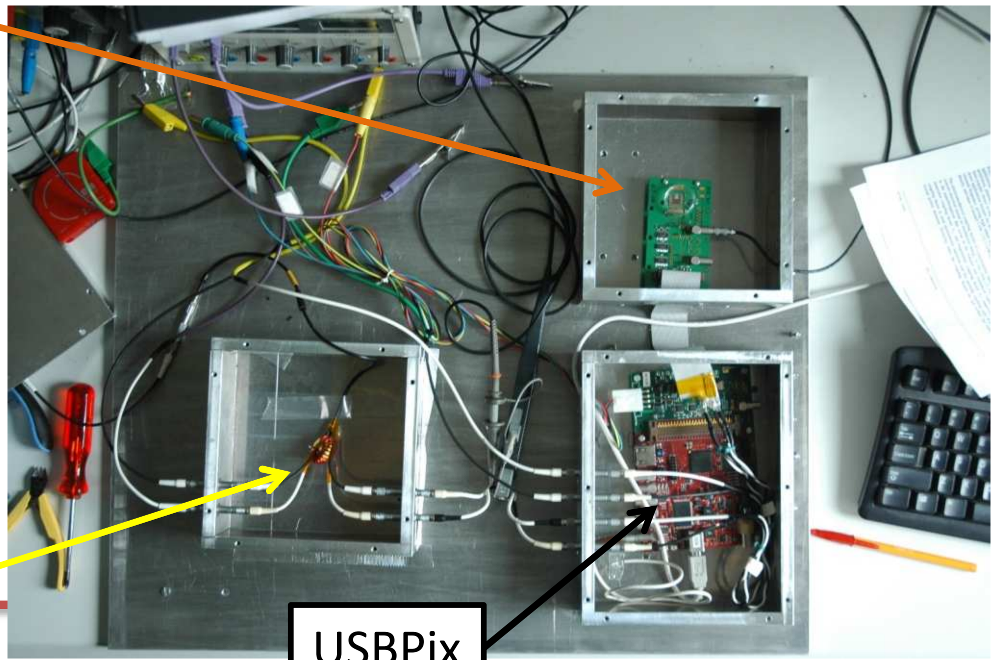
- Based on the same principle as strip detector.
- The semiconductor diode is divided into very small rectangular shapes.
- Ensures high spatial resolution in two coordinates.

Motivation

- It is crucial to identify and quantify possible sources of influence on their operation and know within which frequency range are important.
- For example: the power sources generate alternative currents in the powering cables.

Noise susceptibility measurement

- We used an oscilloscope to measure the current and voltage of the noise signal.
- To readout the pixel data, we used the Stcontrol software.



Results

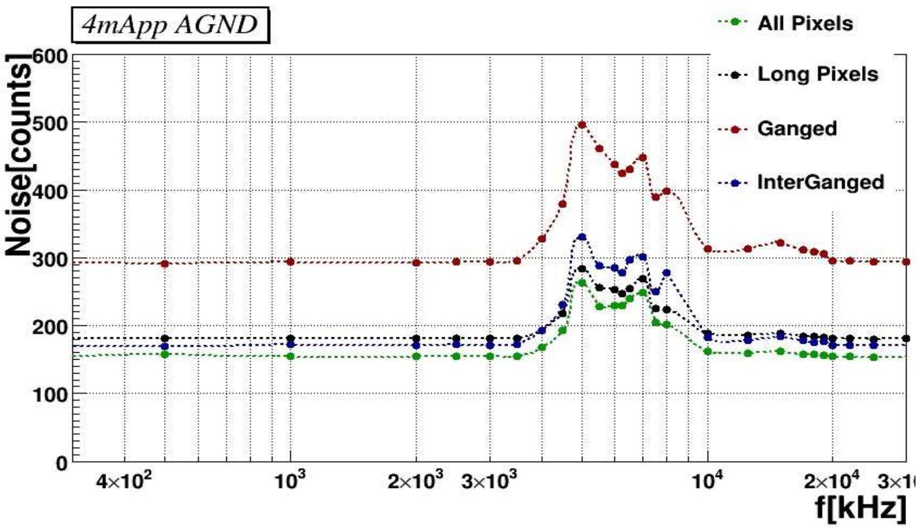
The pixel detector is powered through four different cables:

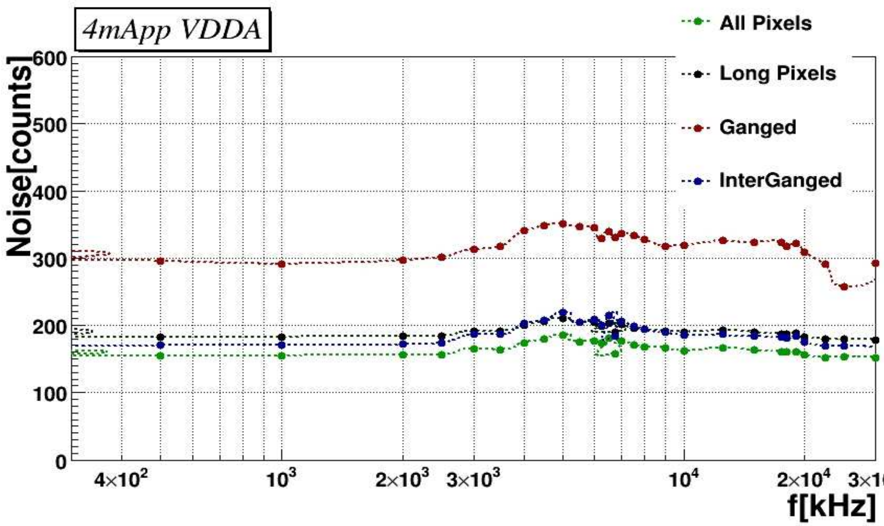
- Two for the digital part (VDDD, DGND).
- Two for the analog part (VDDA, AGND).

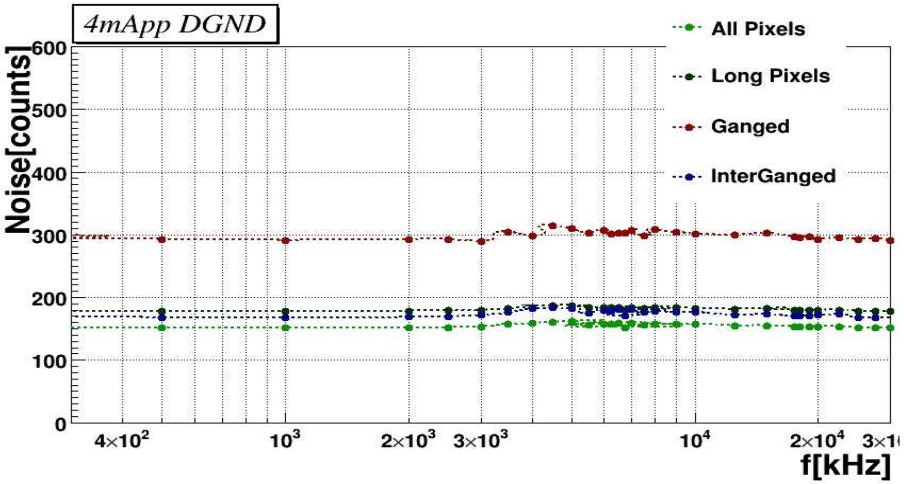
Measures:

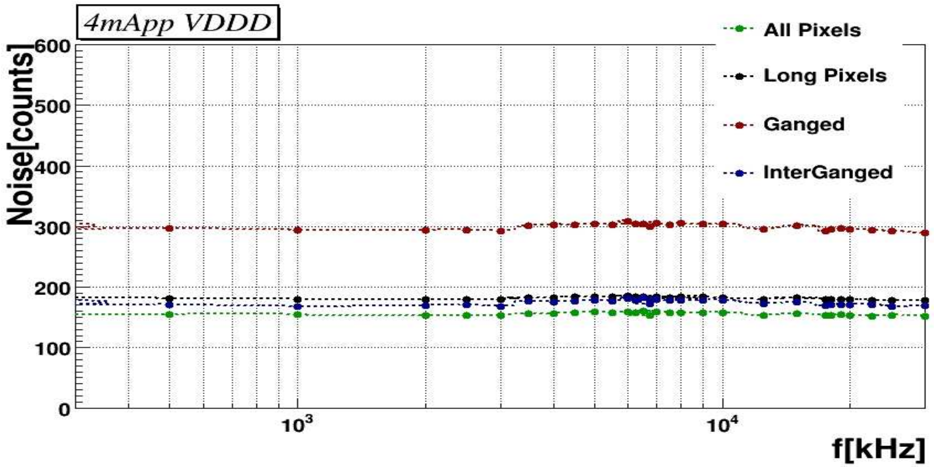
- Differential mode noise: Noise currents were induced into all four lines separately
- Common mode noise: Noise currents were induced into both lines of the analog/digital part at same time.

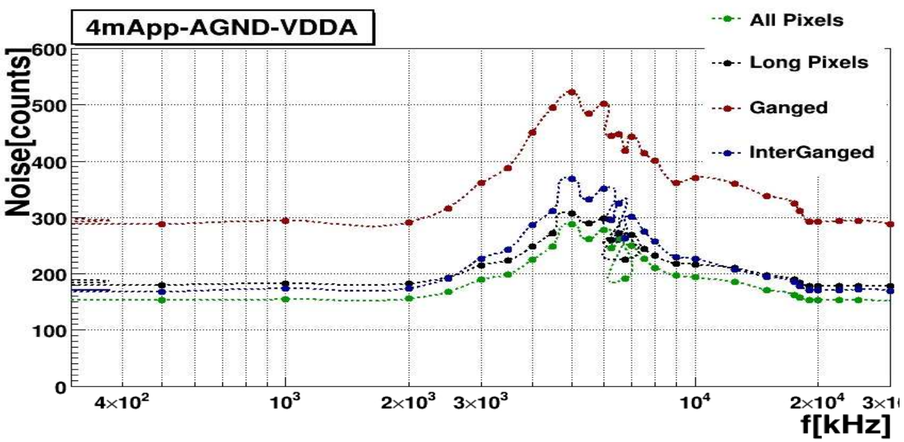
We plotted the readout noise over the frequency of the injected signal in the different type of pixels:

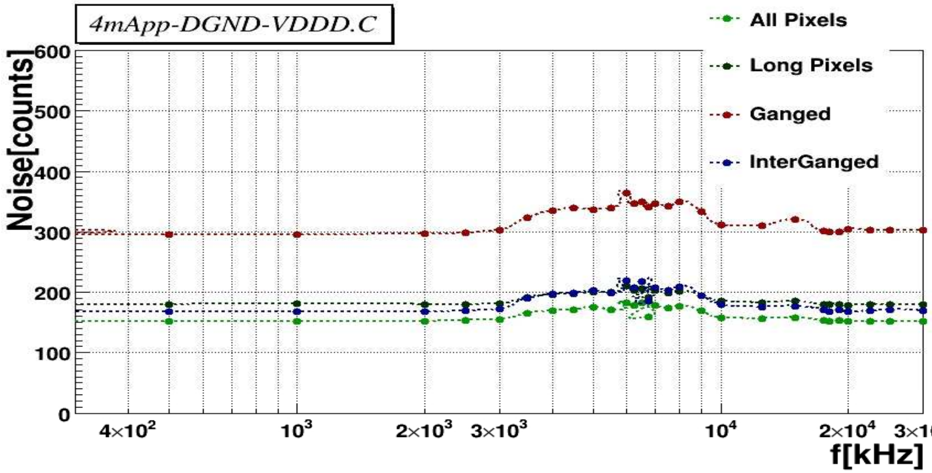












- As expected, the most sensitive part is the analog part, because the analog ground (AGND) is used as a reference voltage for the amplifier.
- The experience and knowledge gained from these test can be easily transferred to future similar measurements of strip detector.

Piezoelectric Transformers

Motivation

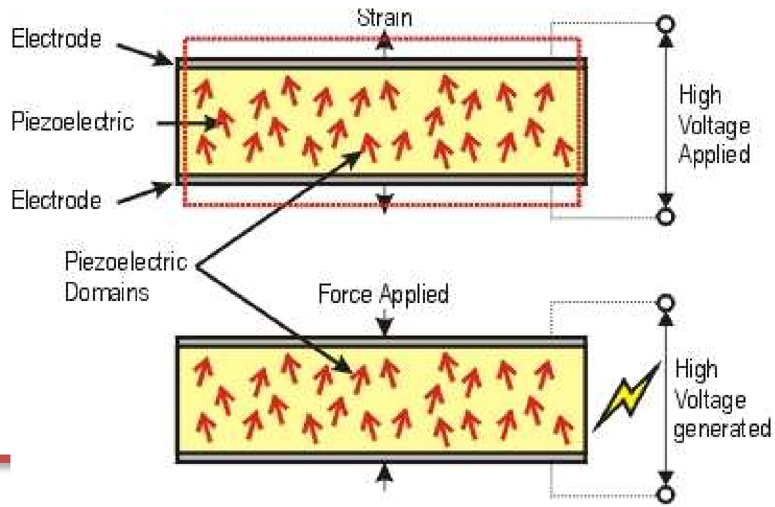
- The future ATLAS upgrade involves an increase in the number of detector modules.
- Nowadays power is transferred at 2V on two individual cable to each module.
- **It will be inevitable to switch to an alternative powering scheme, because it will be impossible to put more cables inside the designated spaces.**

One solution is to transfer power at high voltage (12V) to a group of modules and convert the voltage locally with small transformers.

For this, piezoelectric transformers are a good candidates.

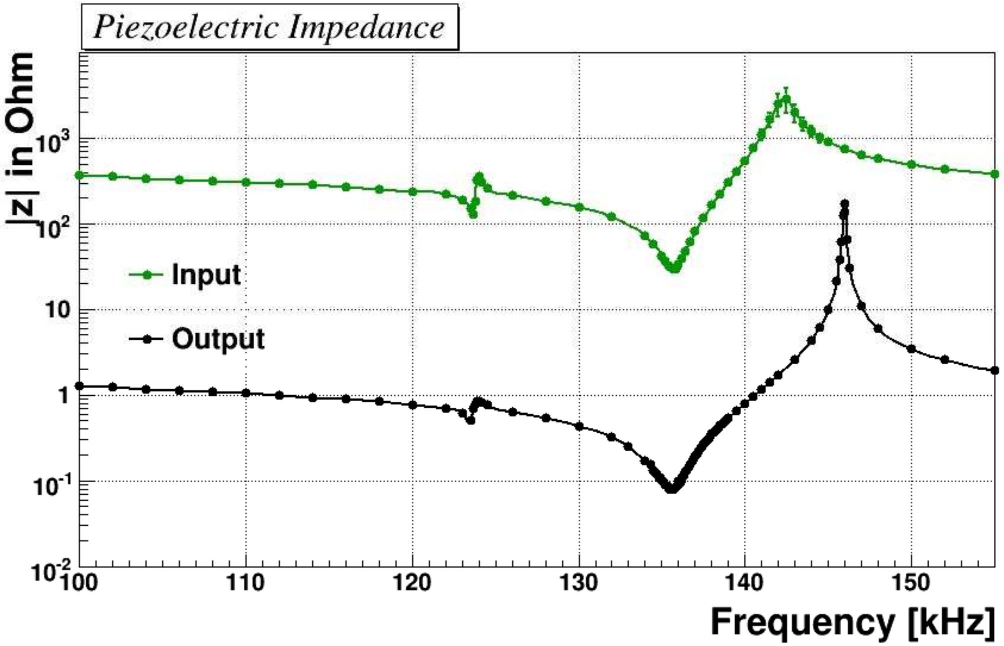
Piezoelectric ceramics

- Develop an electric field when mechanically stressed (piezoelectric effect).
- Develop a strain upon the application of an electric field (inverse piezoelectric effect).



Results

- The piezoelectric transformers consist of two coupled pieces of piezoelectric ceramics with pairs of connections for input and output.
- We connected a function generator to the input (output) and apply sinusoidal signals of different frequency and measure the current, voltage and phase with an oscilloscope in the output (input)
- We used **|z|=u/i** to calculate the impedance.



- High efficientcy is only reached when operating them close the resonance frequency.

Summary

Although the research topics I have been working on were presented independently, they are strongly linked:

The need to increase the resolution of ATLAS inner detector for the operation at sLHC involve the **development of new pixel and strip detectors** and create problems like insufficient space inside the detector.
One solution is to power the detector modules in groups, by converting the current locally using DC-DC converters or **piezoelectric transformers**.
It is important know the **influence of the converter switching noise** and the sensitive frequency ranges.

Even though the LHC and ATLAS have been running reliably and taking data efficiently for several month now, **research and develop for its upgrade in approximately 10 years have already started.**