Basic Properties of Silicon Sensor

Group 20

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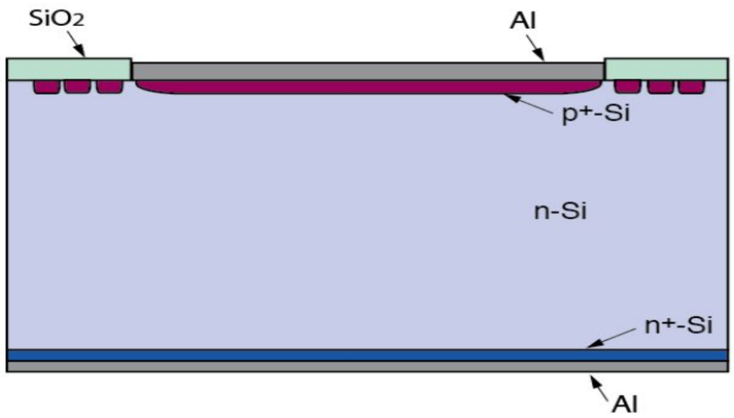
Overview

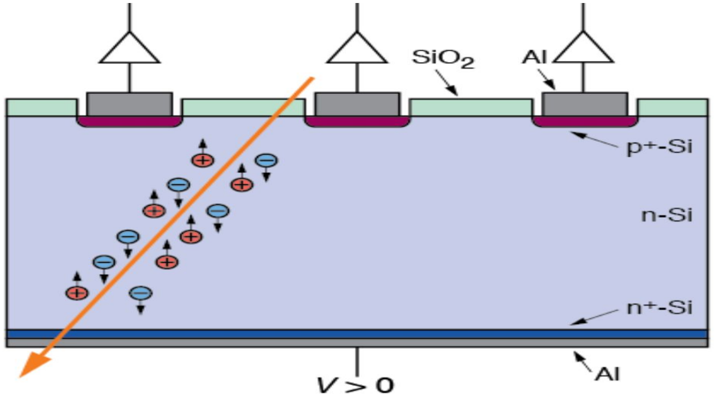
- Basic introduction to silicon sensors
- Study of silicon pad detector
- Low Gain Avalanche diode
- Study of silicon strip detector
- Summary

What are Silicon Sensors?

- p^+-i-n^+ type diode : **$p^+/n^+ \sim 10^{15}$ atoms/ cm^3 , i ~ 10^{12} atoms/cm^3**
- The diode is reversed biased to act as a detector.
- **Operating voltage higher than full depletion voltage.**



Pad detector



Strip detector

- High energy particle hits ➔ creation of e-h pair ➔ secondary ionization.

Transient Current Technique (TCT)

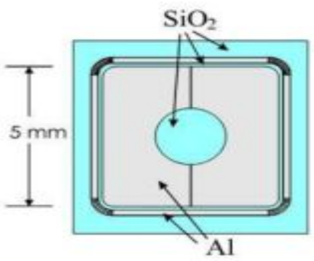
- The transient Current Technique has been one of the principal tools for studying solid state particle detectors over the last two decades.
- The basic properties of silicon sensor is studied using the motion of non-equilibrium free carriers.
- Since silicon has narrow band gap (1.12 eV), free charge can be created using light.
- Signal is due to induced current by moving charges

Shockley-Ramo Theorem : $I = q\vec{v}_q.\vec{E}_w$

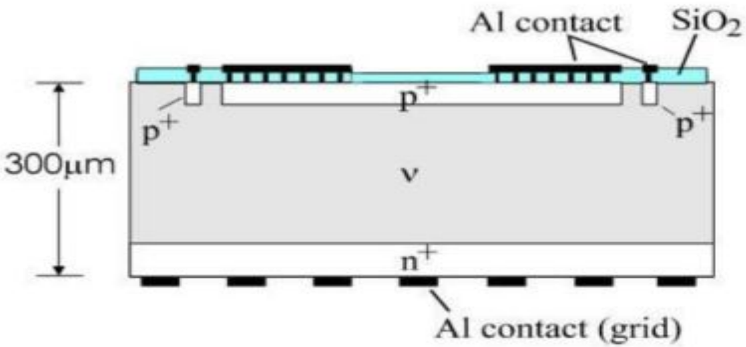
- E_w is weighting field, under the following conditions: collecting electrode raised to unit potential, and all other conductors grounded.
- E_w= V/D = 1/D and v =μE

$$I = e_0 v/D = e_0 \mu E/D,$$

Detector specification



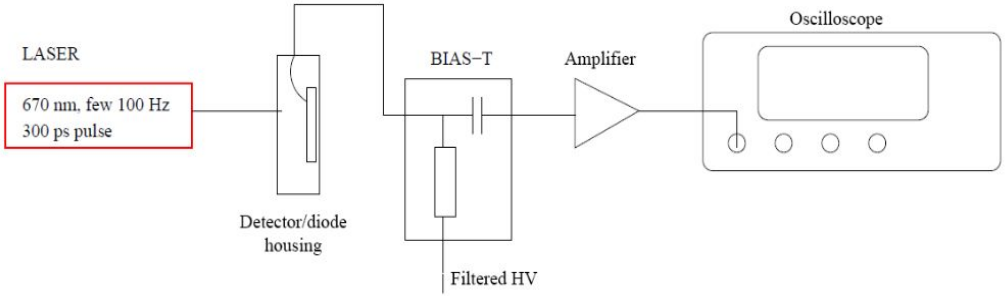
Top view of sensor



Side view of sensor

Sensor Specification:

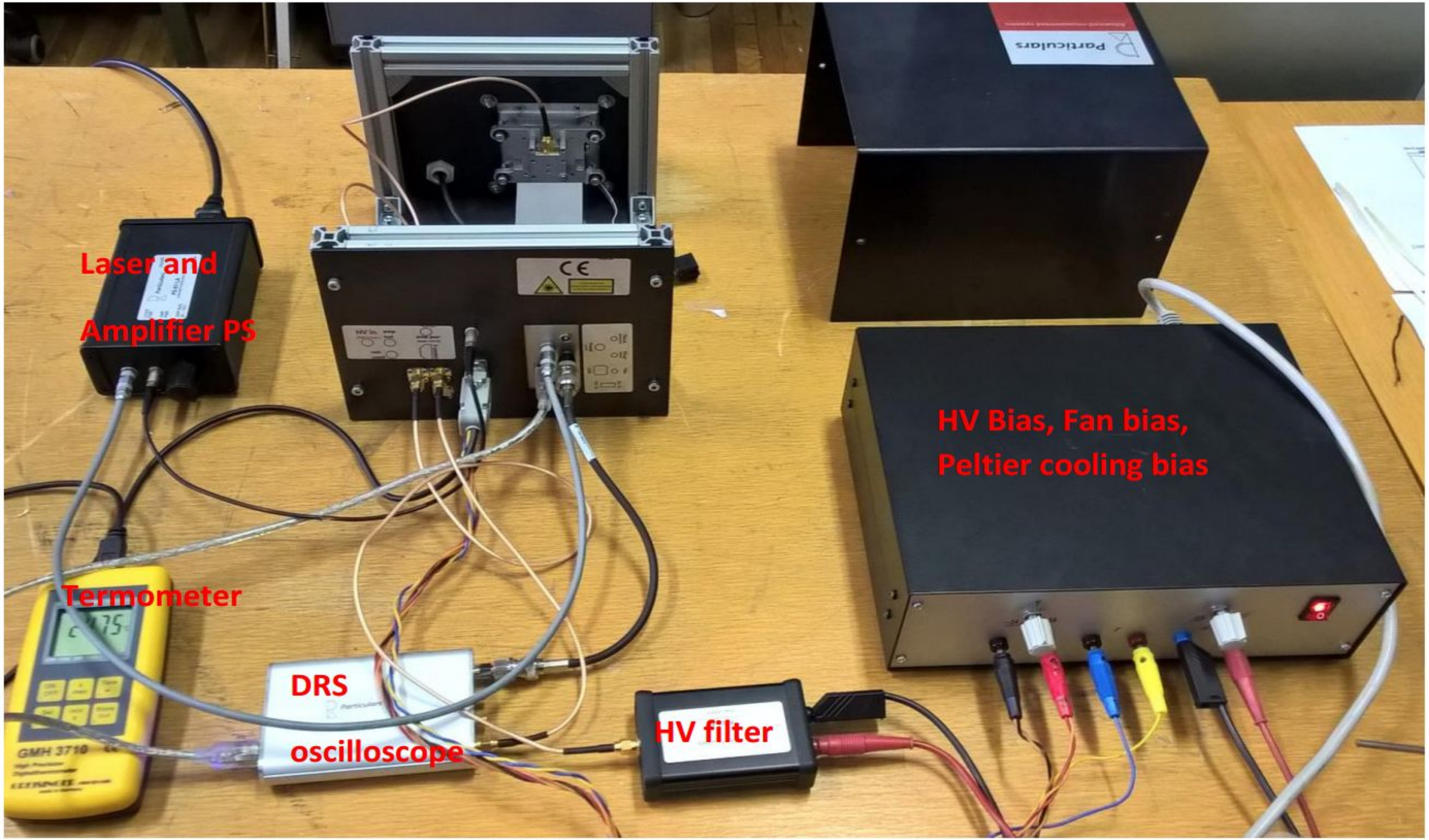
a) Thickness = 300 μm
b) Area = 5 mm × 5 mm
c) Resistivity =16 KΩ-cm



Drift velocity ~ $10^6 - 10^7$ cm/s
Bandwidth~10 KHz to 3GHz

Circuit diagram for TCT

Experimental Setup



Generation of signal

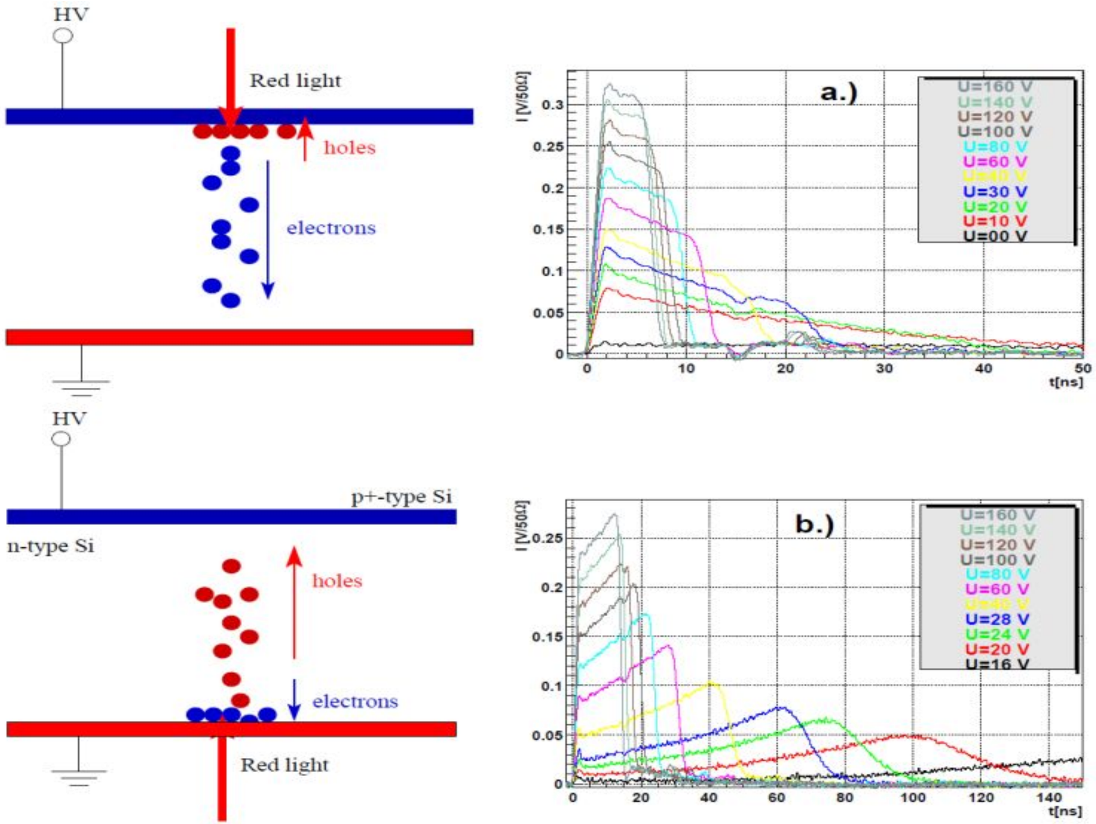
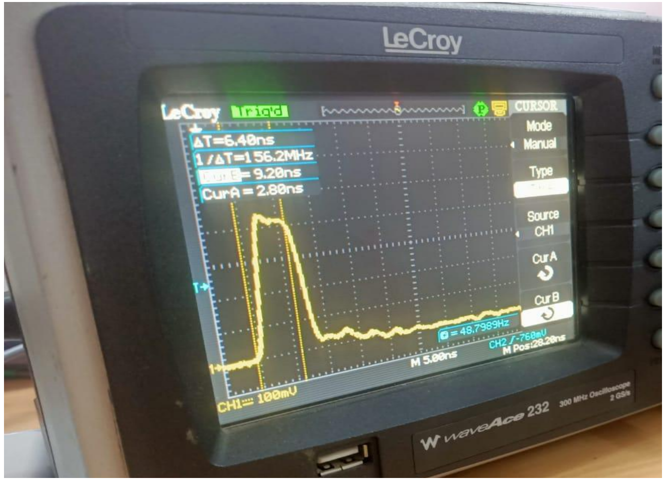


Figure 1: Schematic representation of e-h pair generation when observing induced signals from electrons (a) and holes (b). Electrons are travelling from the high field region towards the small field region, while for holes it is the other way around.

Data taking using oscilloscope : Laser falls on p-type



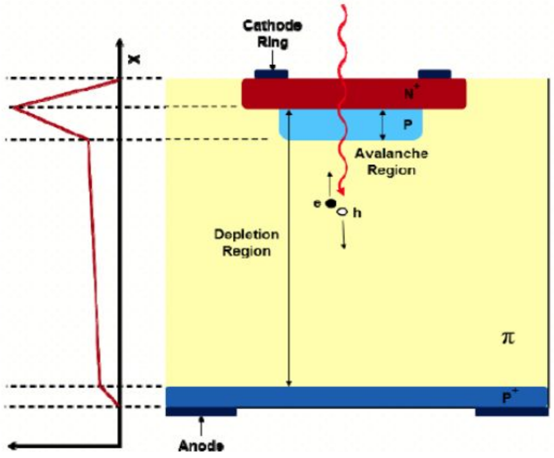
Thickness [cm]	Voltage [V]	E[V/cm]	Drift time [ns]	Drift velocity [cm/s]	Mobility [cm^2/Vs]
0.03	30	1000	25.2	1190476.19	1190.4
0.03	60	2000	11.8	2542372.88	1271.1
0.03	90	3000	9	3333333.33	1111.1
0.03	120	4000	7.6	3947368.42	986.84
0.03	150	5000	6.4	4687500	937.5
0.03	180	6000	6	5000000	833.3

Data taking using oscilloscope: Laser falls on n-type

Thickness[cm]	Voltage[V]	E[V/cm]	Drift time [ns]	Drift velocity [cm/s]	Mobility[cm^2/Vs]
0.03	90	3000	22	1363636.36	454.54

Low Gain Avalanche Detector

- **n^{++}-p^{+}-p** type silicon diode.
- In the very highly doped (~**10^{19}**) region avalanche multiplication takes place.



Low Gain Avalanche Detector

Signal observed on oscilloscope

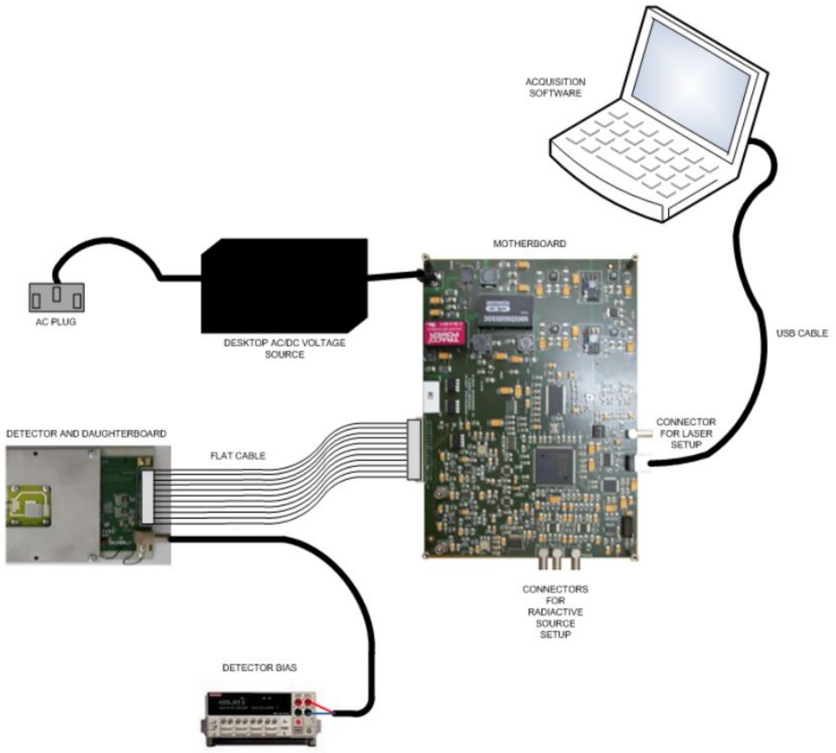
$$\boxed{Gain = \frac{V_a \mu_e}{V_b \mu_h}}$$

Measured gain = 4.5

Basic properties of silicon strip detectors

Experimental setup consists of

- Two Silicon strip detector
- ALIBAVA readout system :
  - Motherboard
  - Daughterboard
- Cs-137 beta electron source
- Scintillator coupled to PMT
- Temperature control system



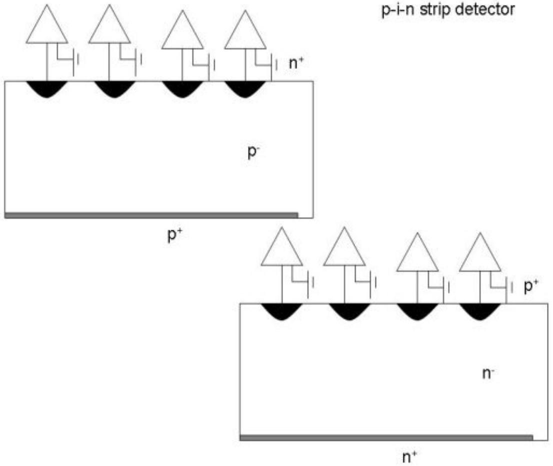
Experimental setup

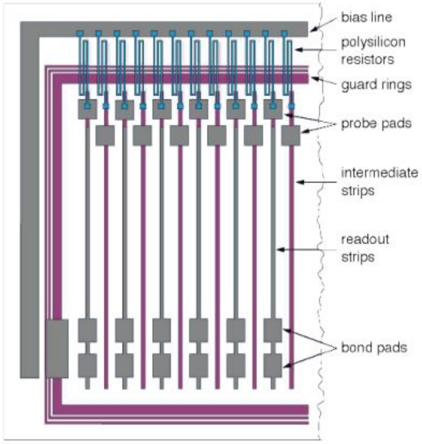
Components

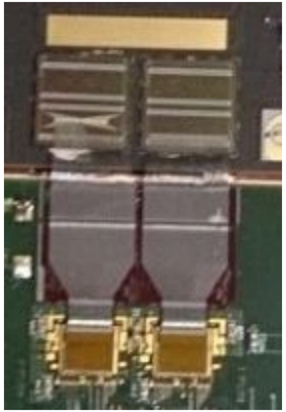
1. The strip detector(sensor) :ATLAS12 prototype

Dimension:- 1 cm x 1 cm and 300 μm thick

100 strips







Components

- **Readout chip**(Beetle Chip):- Two readout chips in our module with 128 channels each.
- **Trigger**:- Scintillator trigger +PMD is used. Help us to store interesting event.

- **Pipeline**:- Store the event->Beetle chip
  Waiting for trigger response-> to keep an event or not.

- **Readout System**:-
  - Daughterboard;- Beetle chip and sensor
  - Motherboard:- digitize the data and transfer it via USB to the PC

- **Cesium-137 source**(Minimum ionising particles,)
  Used End point energy of 137-Cs decay is 0.661MeV.

Lastly ALIBAVA_DAQ software

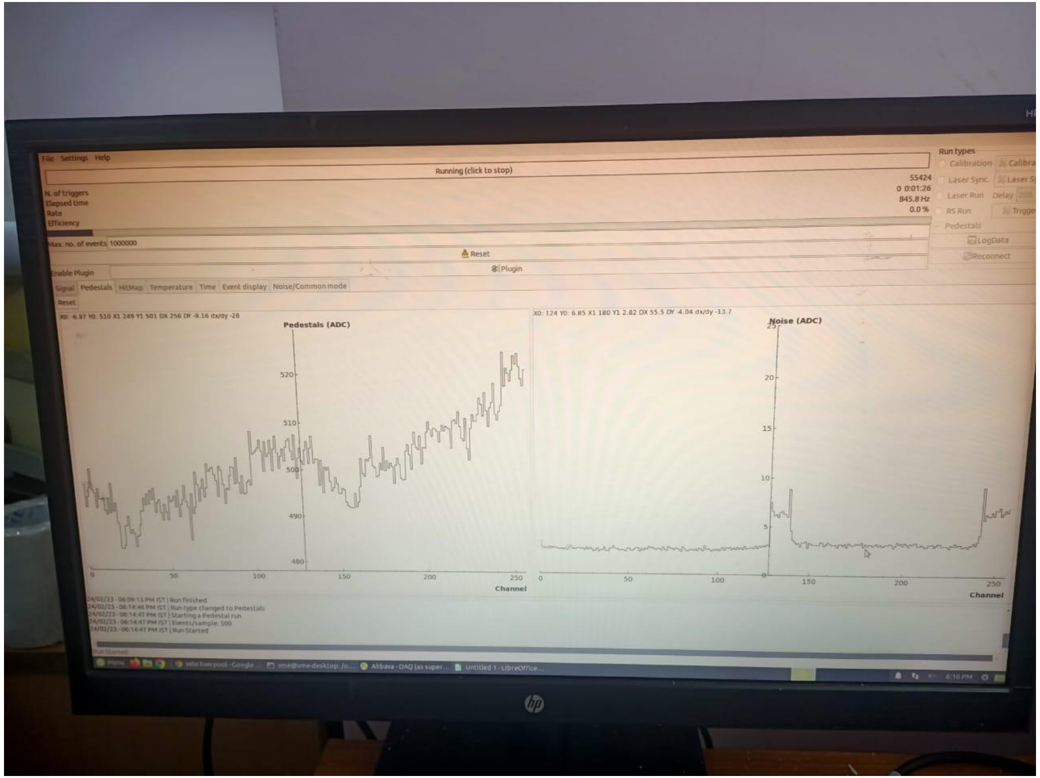
Use of ALIBAVA experimental setup

1.**Measurement of the noise in the detector**

Main source of Noise:-

Leakage current:- Due to minority carrier

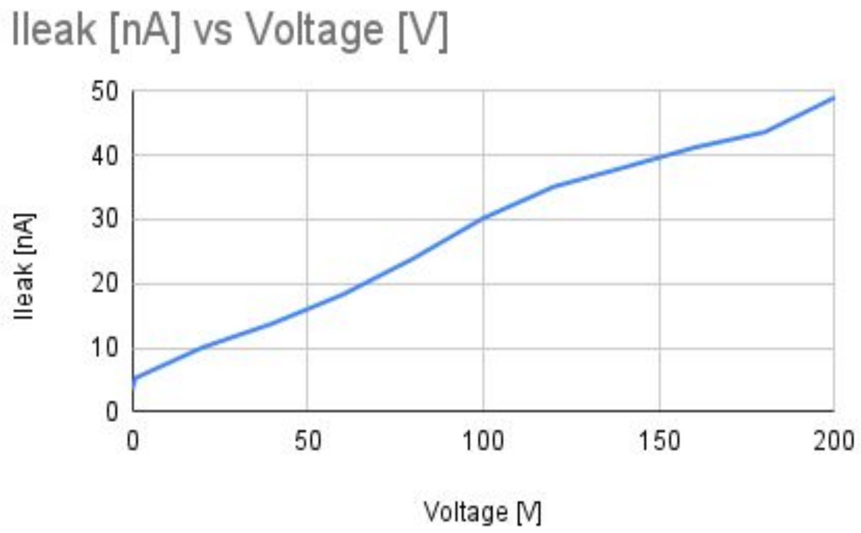
Detector capacitance:- capacitance of the diode

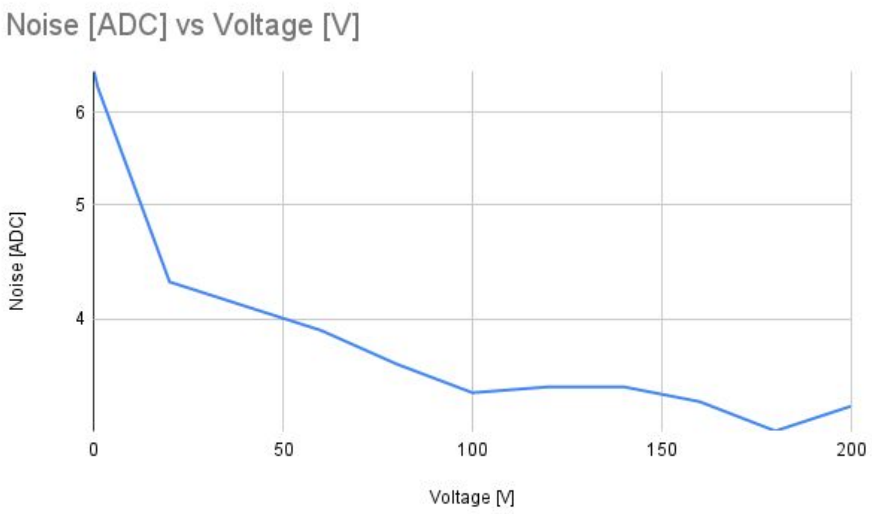


Pedestal Value:- ADC count when no signal

Observations

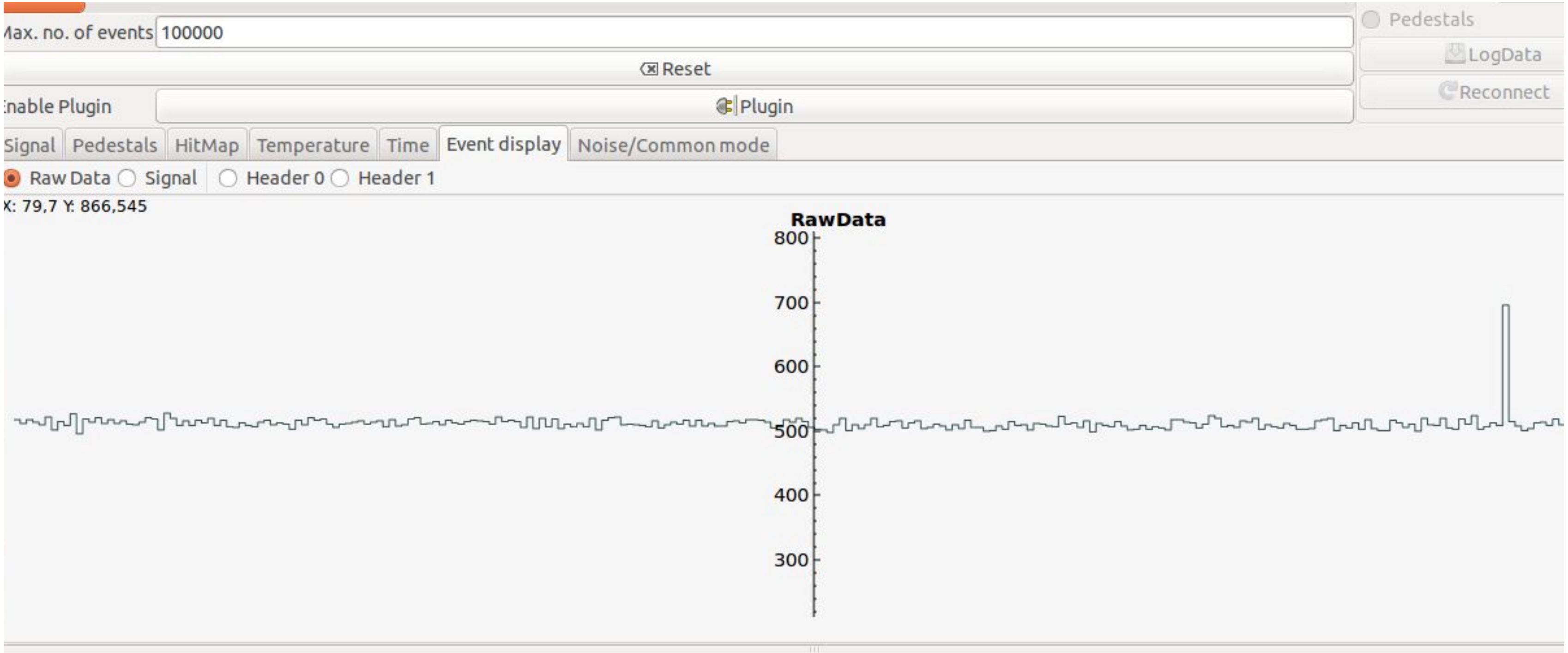
- Noise decrease with the depletion voltage due to reduction of the detector capacitance (depletion region increases)





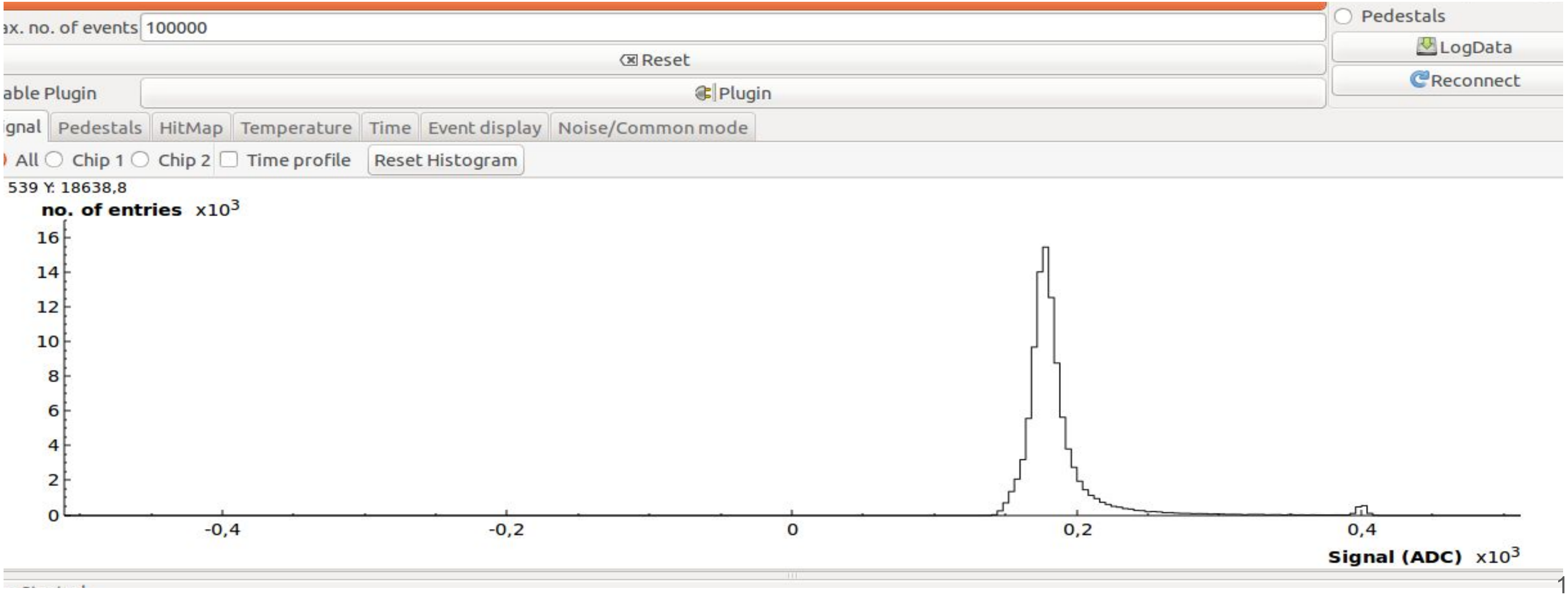
2. Obtaining the spectra of the signal

- Now load the source:
- To extract signal:- we cut off the pedestal.



Spectra of cesium-137

- Only considered :- if SNR(signal to noise ratio) = signal[ADC]/noise[ADC] > 10
- After pedestal and noise cutoff we obtain the signal.



For 200V(V-depletion) i.e full depletion

- Expected collected charge electron=23000 when Avg ADC= 57.5(Calibration)
- Gain=23000/57.5 = 398.613
- No. of electron contributing noise = Gain*Noise[ADC] =1343.32

Summary

- We have obtained the noise and we measure the mobility of electron and holes.
- We were able to see the saturation effects of drift velocity.
- We observed that drift velocity of electrons saturates faster than drift velocity of holes.
- We get to know how electric field generates in silicon detectors.
- We also calculated gain of LGAD.
- We have observed the noise of a silicon strip detector as a function of bias voltage.
- We have observed the signal spectra of Cs-137.

Thank you for your kind attention !!