Development of Ultra Fast Silicon Detectors (UFSD) using LGADs for space application

Astro Particle Physics - Laboratory

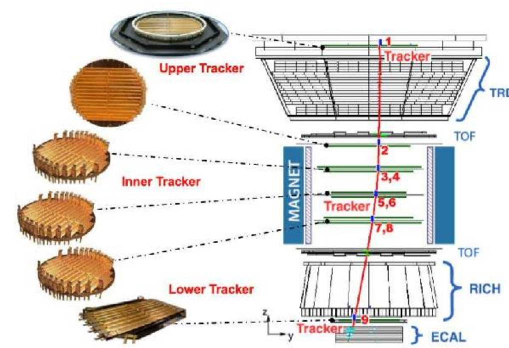
Introduction

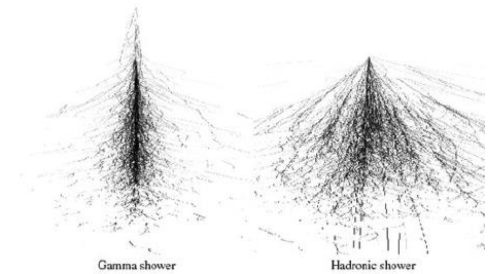
WHAT?

- Design and Fabricate strip sensors for space application.
- Optimization.

WHY?

- To include the timing into the tracker system
- Sensor which can do 4D tracking.
- Identify the hits coming from back-scattering from calorimeter.
- e/p identification (EM shower/ Hadron shower)
- Power consumption.

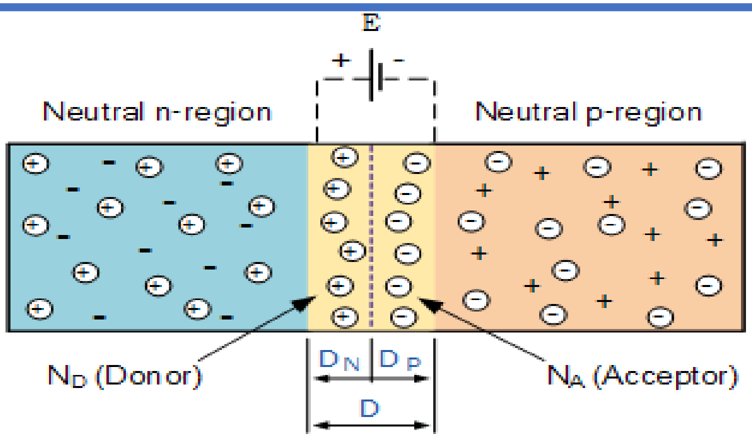




HOW?

- Identify a LGAD technology that fulfil the “space application” requirement.
- Characterize different sensors from different batches of production.
- Understand the Gain layer implementation.
- Perform IV/CV and TCT characterizations.

Silicon Detector



- pn-junction
- Reverse Bias

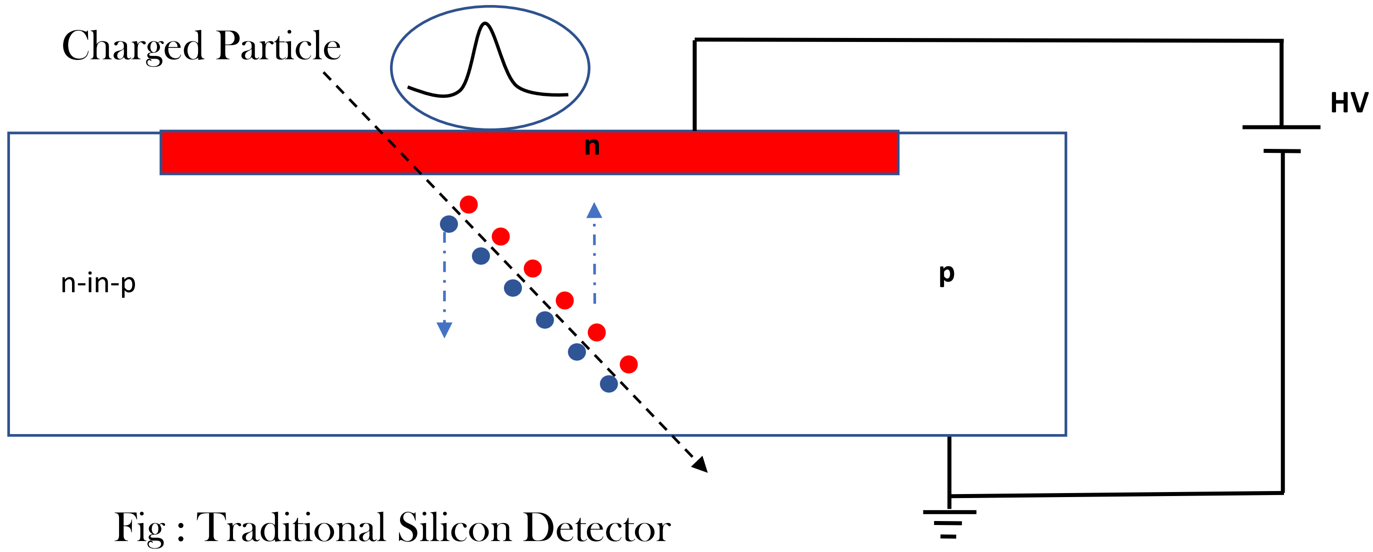


Fig : Traditional Silicon Detector

Good Timing:

- Large Signal
- Short rise Time

Low Gain Avalanche Detectors

- Low-gain avalanche process initiated by charge moving in large electrical fields.
- An additional doping layer of p+ material.
- Gain ≈ O(10) (Gain layer provides high field region)

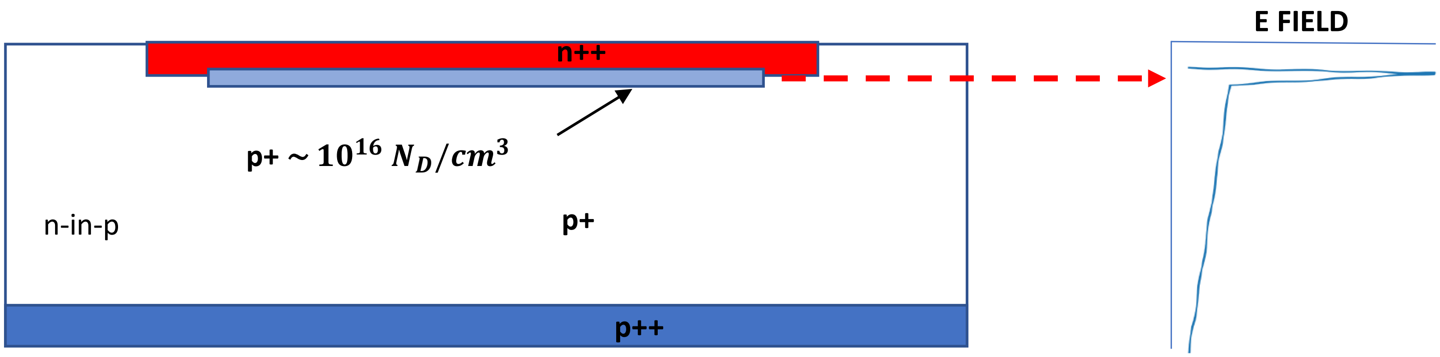


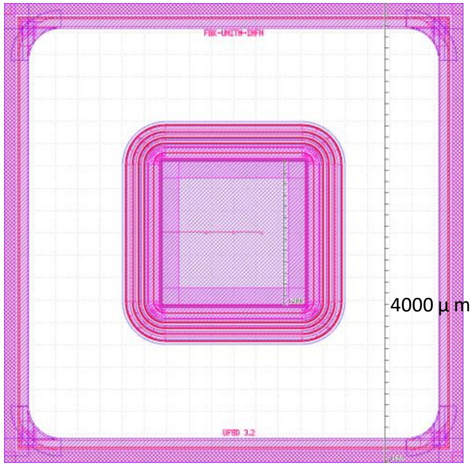
Fig : Low Gain Avalanche Detector

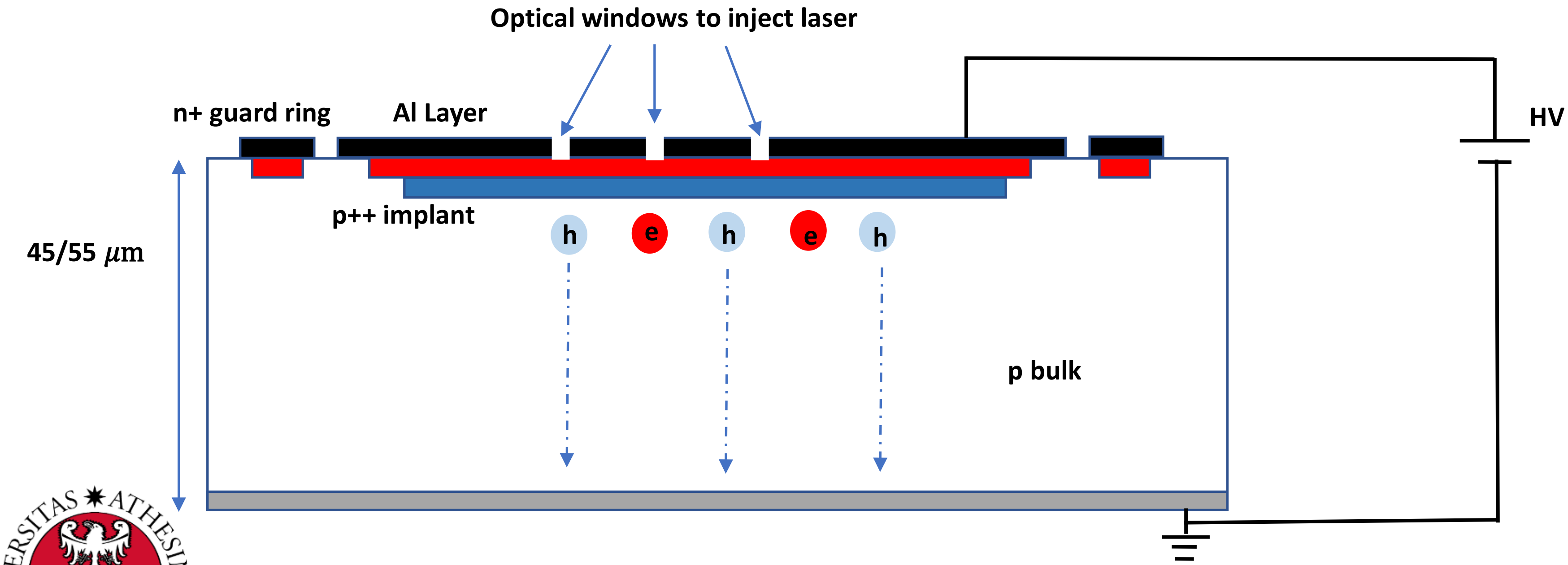
- UFSD (Ultra fast Silicon Detectors) are based on LGADs.
- Low gain → sufficient to perform accurate single particle time measurement.

Specification of the studied Sensors

- Active Thickness: 45 μm and 55 μm
- p-type (n-on-p configuration)
- Area = 4 mm^2
- Depletion Voltage = 45 V
- Guard Rings are connected to ground.

Top View (Dimensions are in micrometer)



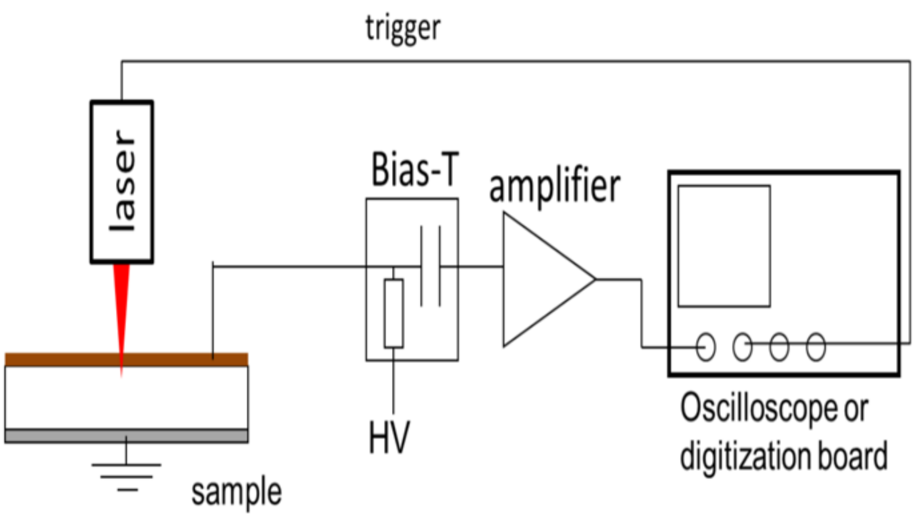


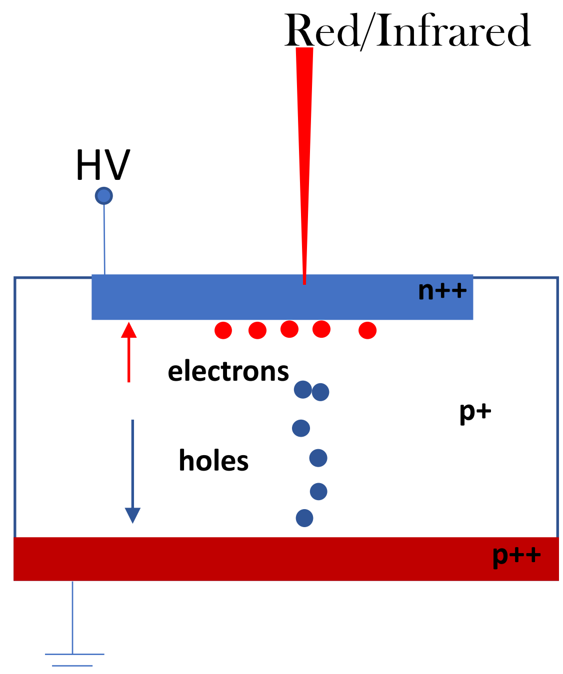
Transient Current Technique (TCT)

Transient Current Technique is used to study the characteristics of Silicon detectors by studying the signal generated by moving charge carriers inside detectors.

Induced charge can be given by Ramo's theorem as:

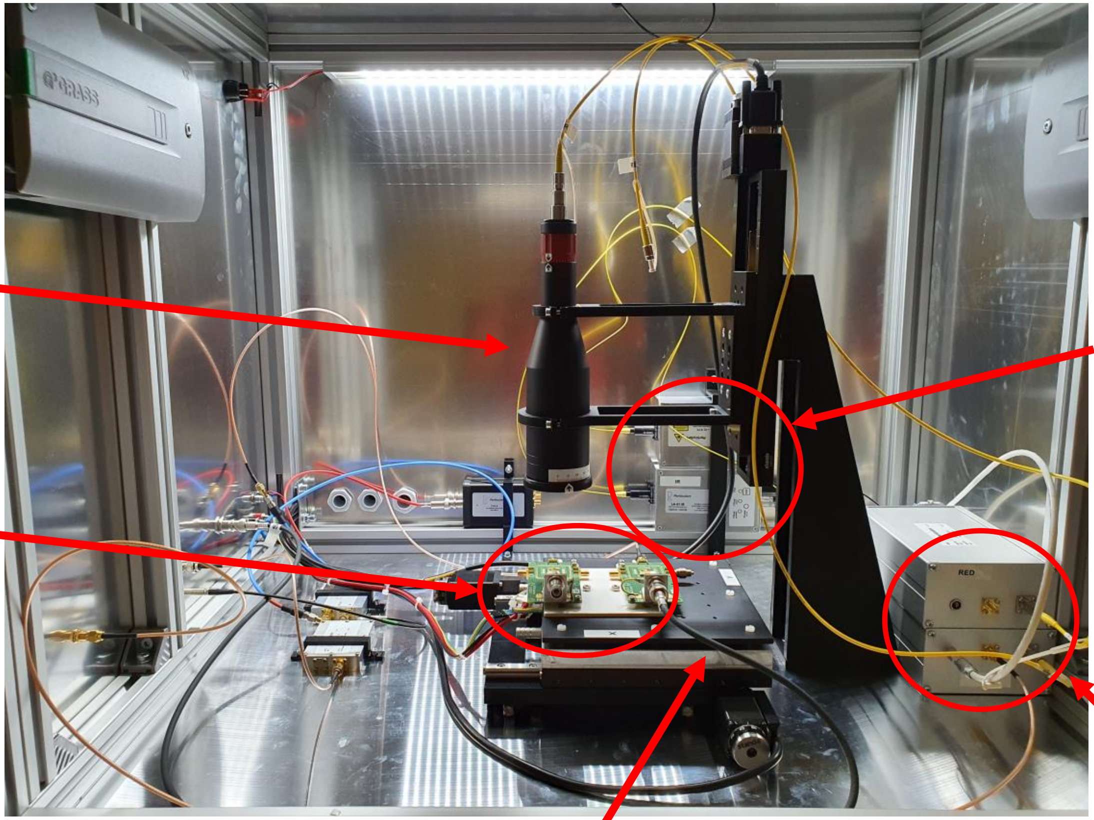
$$\mathrm{I(t)} = q_e v_{drift} E_w \propto v_{drift} = \mu(E)E \Rightarrow I(t) \propto E(z)$$





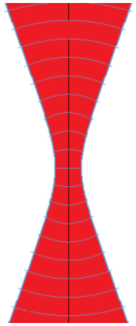
TCT setup in FBK

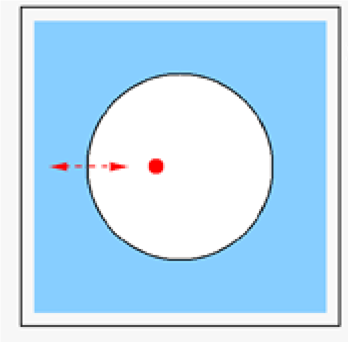
*We installed and calibrated the whole setup

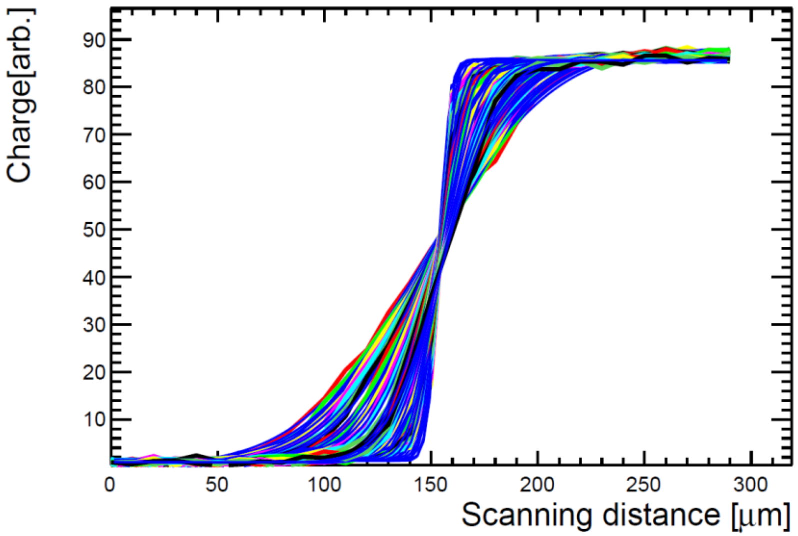


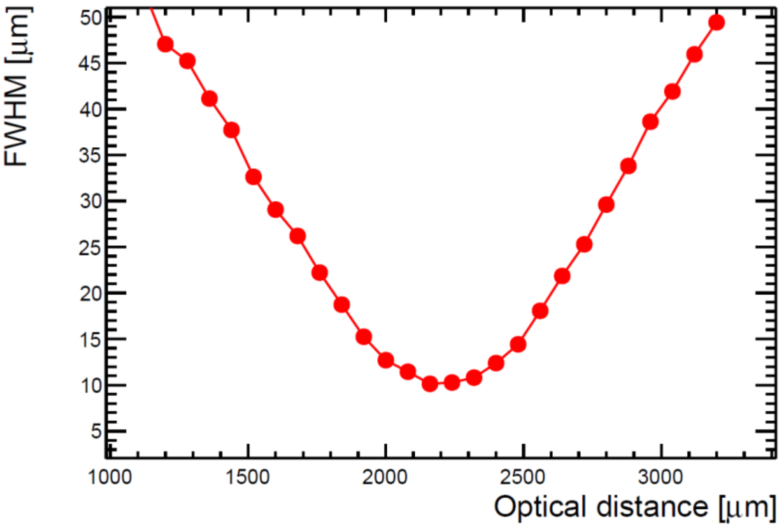
Laser Profile and parameters at 1060 nm

- Charge is measured for series of z points around focal point.
- FWHM is obtained by fitting for every Z.
- Focus is obtained by fitting the FWHM curve



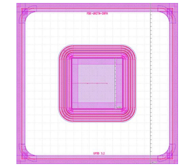






*Final Parameters: $w_0 = 11\ \mu m$ for both Red and Infrared Laser

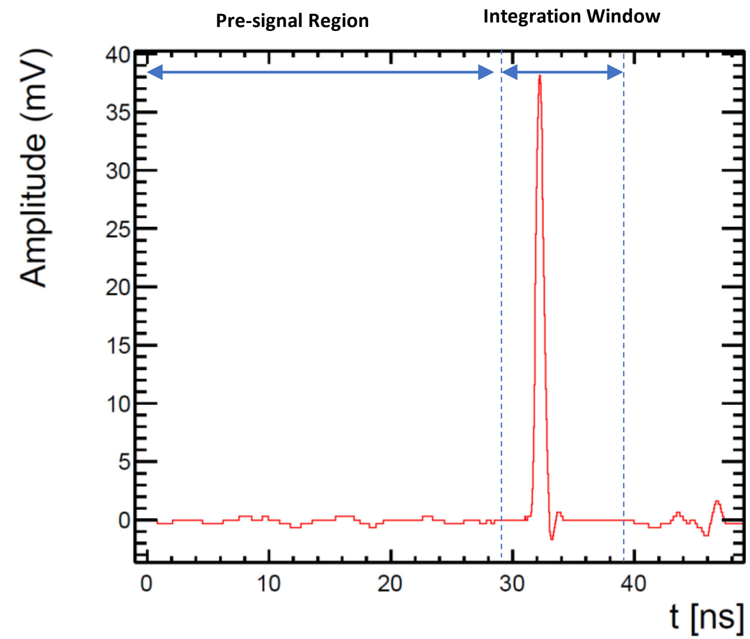
Collected Charge Measurement

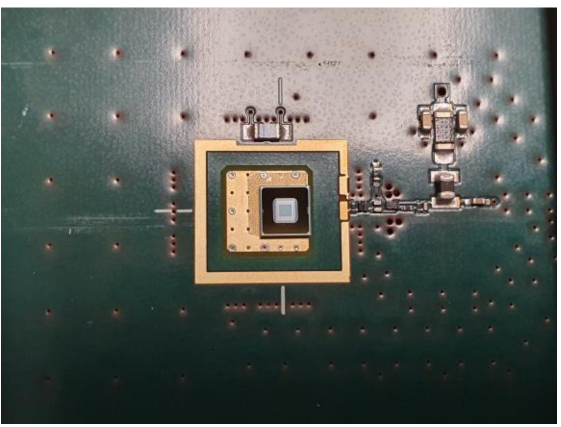


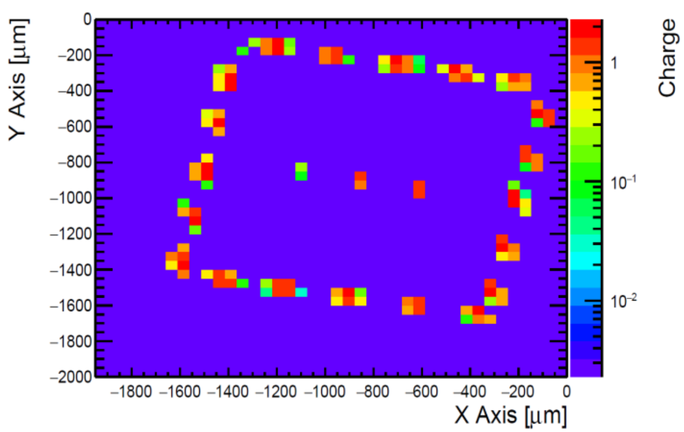
- Transients of the sensor V(t) are recorded.
- The average of the transients in the pre-signal region is subtracted from the whole (Baseline Correction)
- Collected charge is given as:

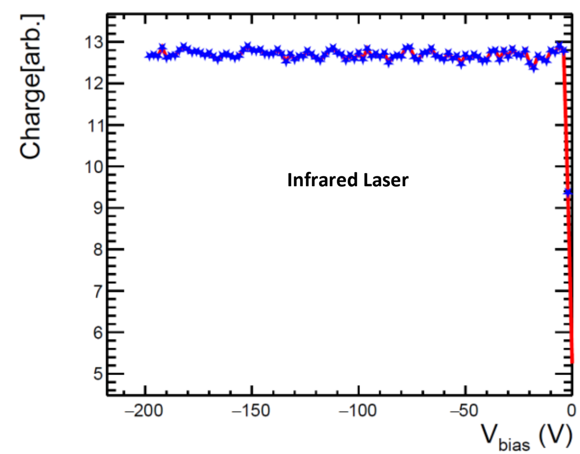
$$Q = \int_{t_s}^{t_e} \frac{V(t)}{G\,.\,R_L}\,dt\,,$$

$$R_L = 50\,\Omega, G = 10, t_e - t_s = 10ns$$



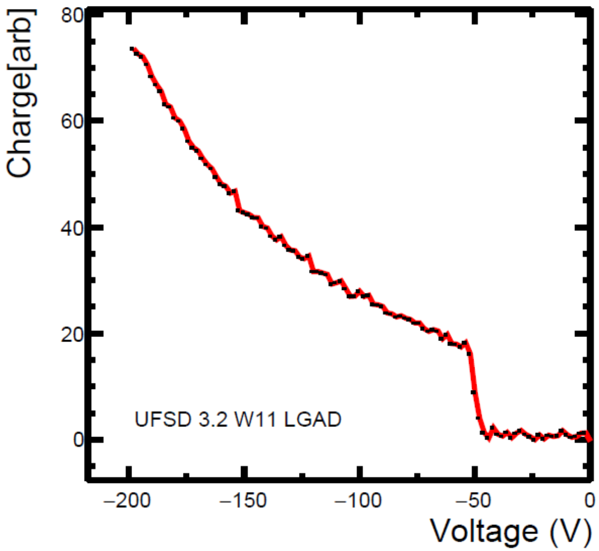


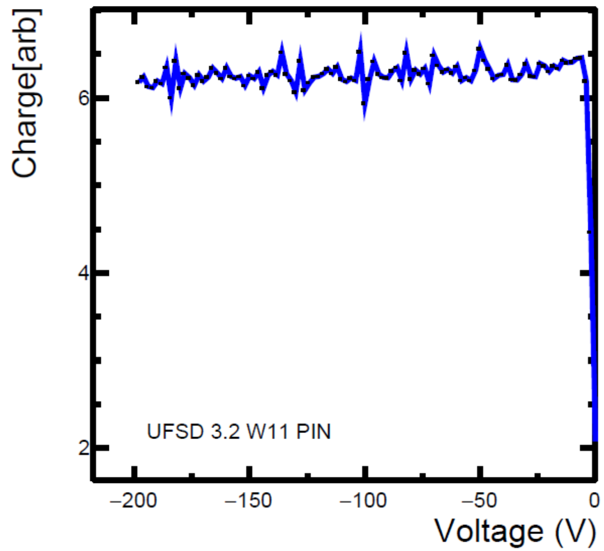


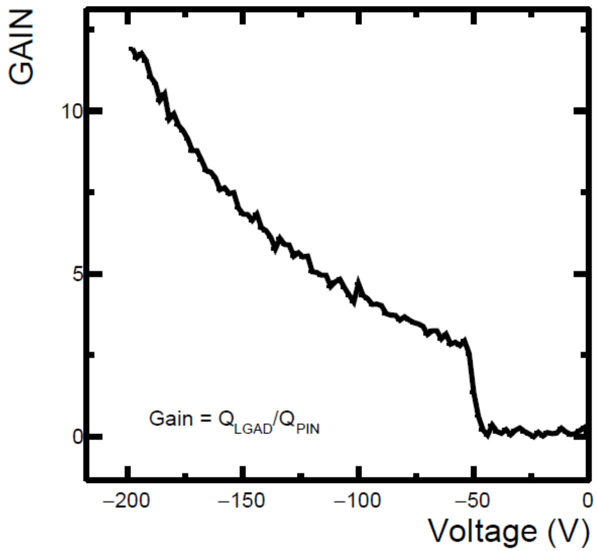


Gain Measurements

$$Gain = \frac{(Charge)_{LGAD}}{(Charge)_{PIN}},$$

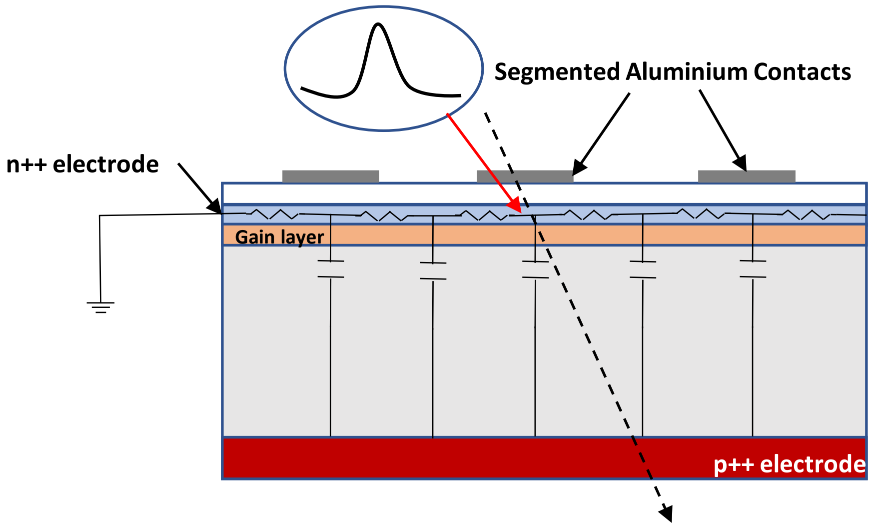




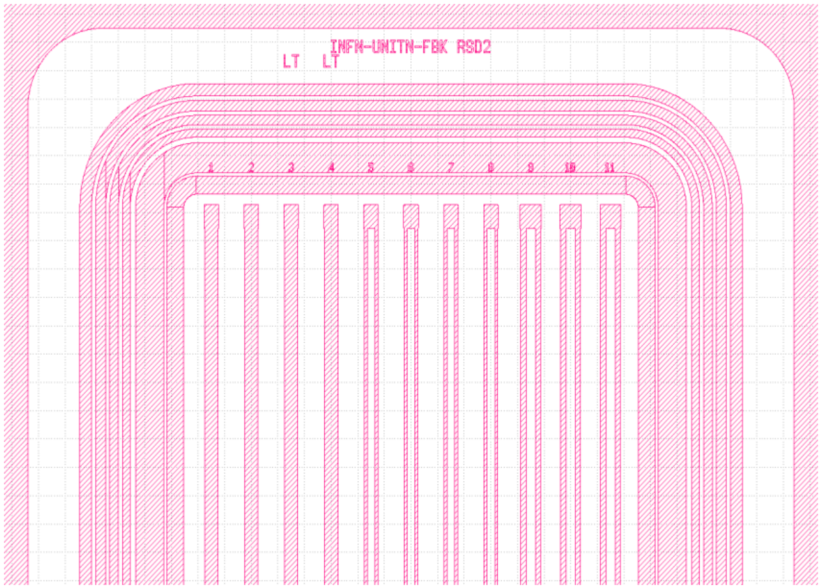


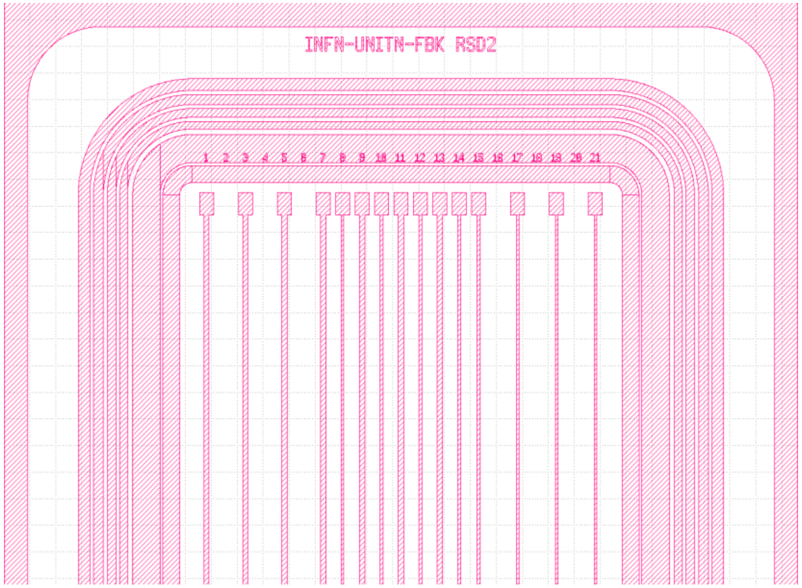
***Gain at 200 V is around 12**

RSD2 Strip Layout



- ✓ 2 Strip sensors with different geometries have been designed for RSD2.
- ✓ Different thickness and pitch.
- ✓ TCT measurement feasible design.



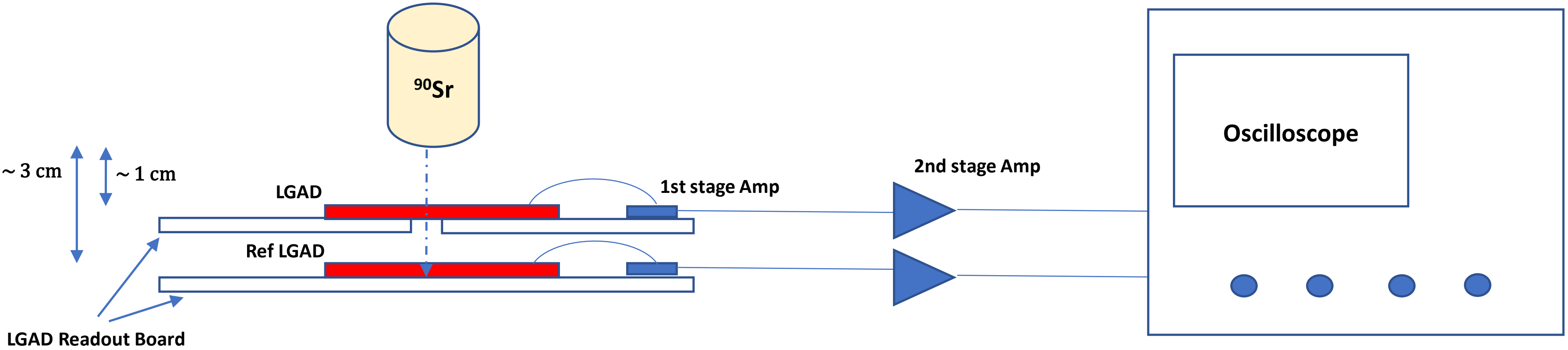


Conclusions

- ✓ IV/CV characteristics.
- ✓ Installation TCT
- ✓ Characterization using TCT
- ✓ Gain Uniformity with TCT
- ✓ Collaboration in design
  - ✓ Strip for MOVEIT “standard tech”
  - ✓ Strip in AC coupled technology
- ✓ Data analysis of RSD1 strip sensors.

Upcoming Activities

- Characterization of strip sensors from MoVeIT (Modeling and Verification for Ion Beam Treatment) production.
- Characterization of strip sensors from RSD2 production.
- Build a Timing setup using Strontium 90



- Design sensor layout of complete wafer for the space application.
- After production we need to characterize the sensors using both TCT setup and the β-setup.

THANK YOU