Development of Large-Area LGADs

For Space Application

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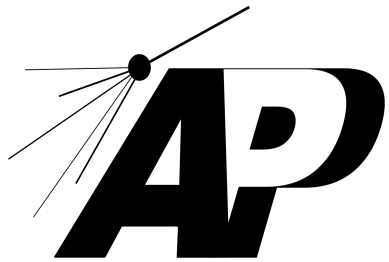

Trento Institute for
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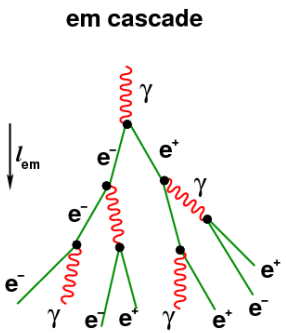
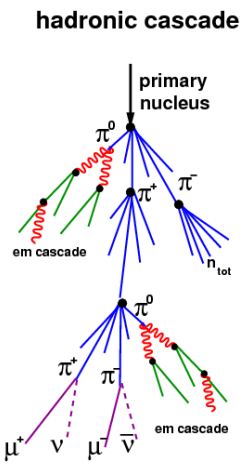
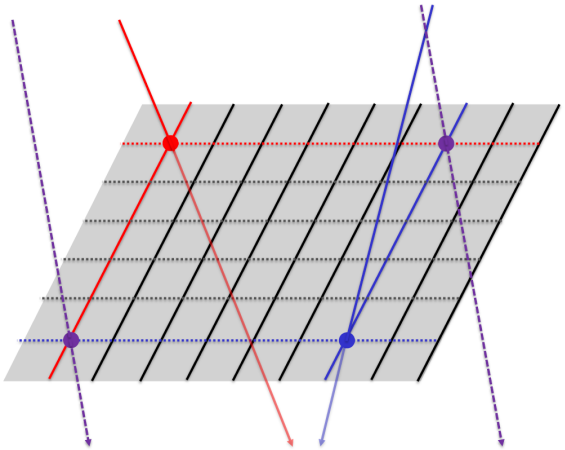
Introduction: Requirements of Time Resolving Tracking in space Experiments







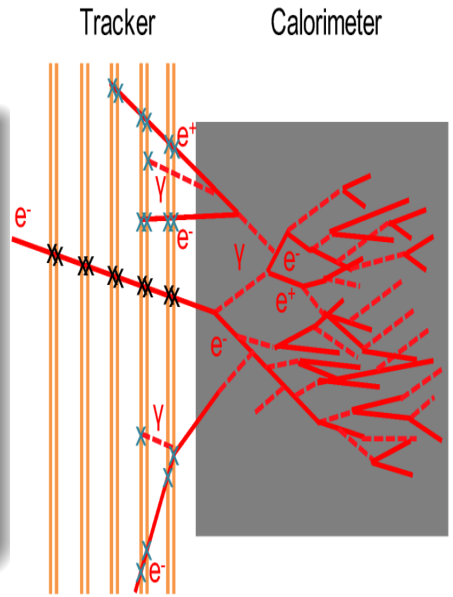
Velocity resolution crucial for isotopic measurements:

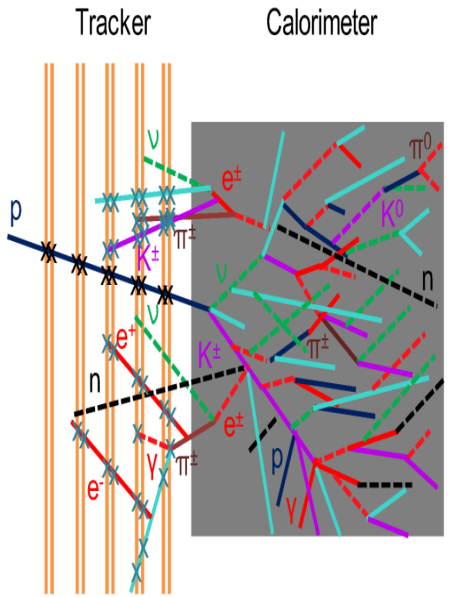
$$\frac{\delta M}{M} = \frac{\delta p}{p} + \gamma^2 \left(\frac{\delta \beta}{\beta}\right)$$

- d and anti-d
- ^{3}He/^{4}He
- ^{6}Li/^{7}Li

Advantages of 4D tracking

- **Identification of back-scattered hits from calorimeters.**
- **Ghost hits in "Si-MicroStrip" detectors.**
- **Time-of-flight (ToF) measurement**
- **Improved e/p identification**





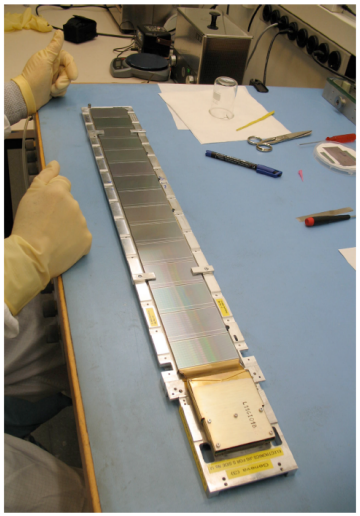
Space LGADs: Need for large channel?

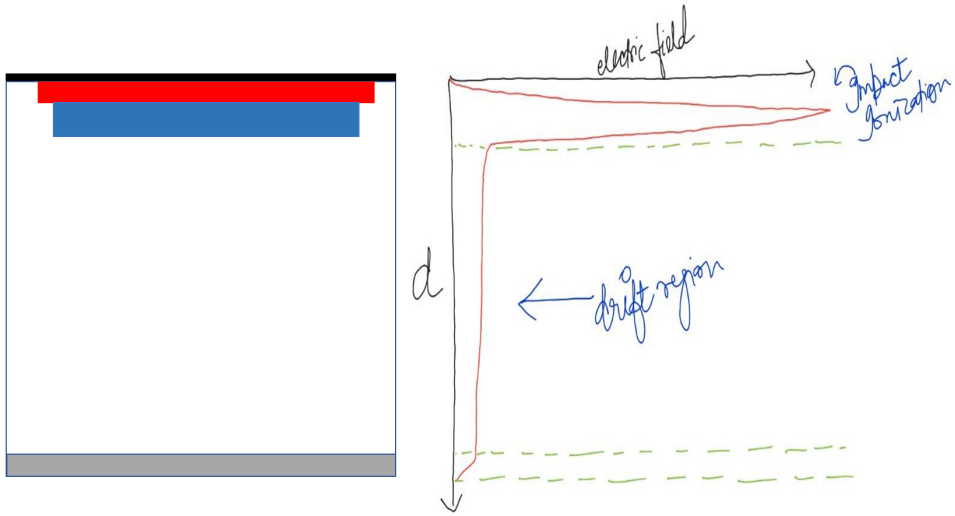
- Rate is not as high as in HEP
- Power Issue
  → *Reduce the number of channels*
- "Typical" Silicon sensor: strip, $\sim$ 100 μm pitch, 50-60 cm long ($\sim$ 1 cm^2)
- Timing ($\sim$ 50-60 ps) is desired.
- Low Earth Orbit Experiments
  →*Radiation is not an Issue*

Solution?

LGADs

Excellent Timing resolution!!



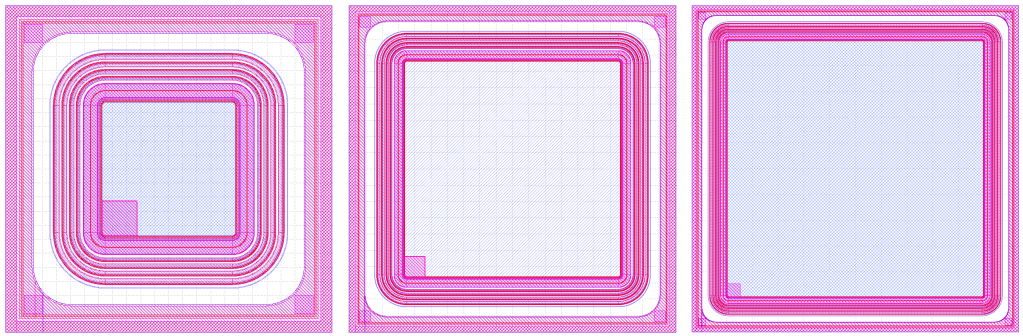


Specification of the DUT

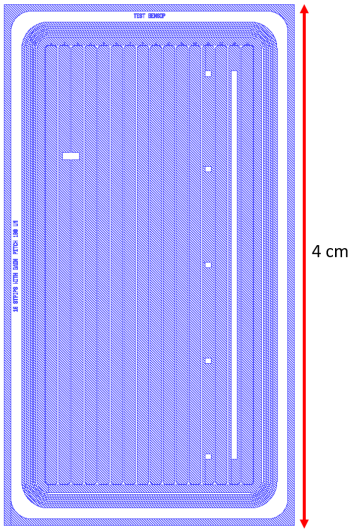
LGAD Pads

- Pads with different area: 1 × 1 mm^2, 2.5 × 2.5 mm^2, and 5 × 2.5 mm^2
- Metal frame

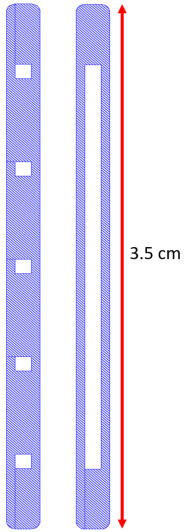
1 × 1 mm^2 **2.5 × 2.5 mm^2** **5 × 5 mm^2**



4 cm



3.5 cm

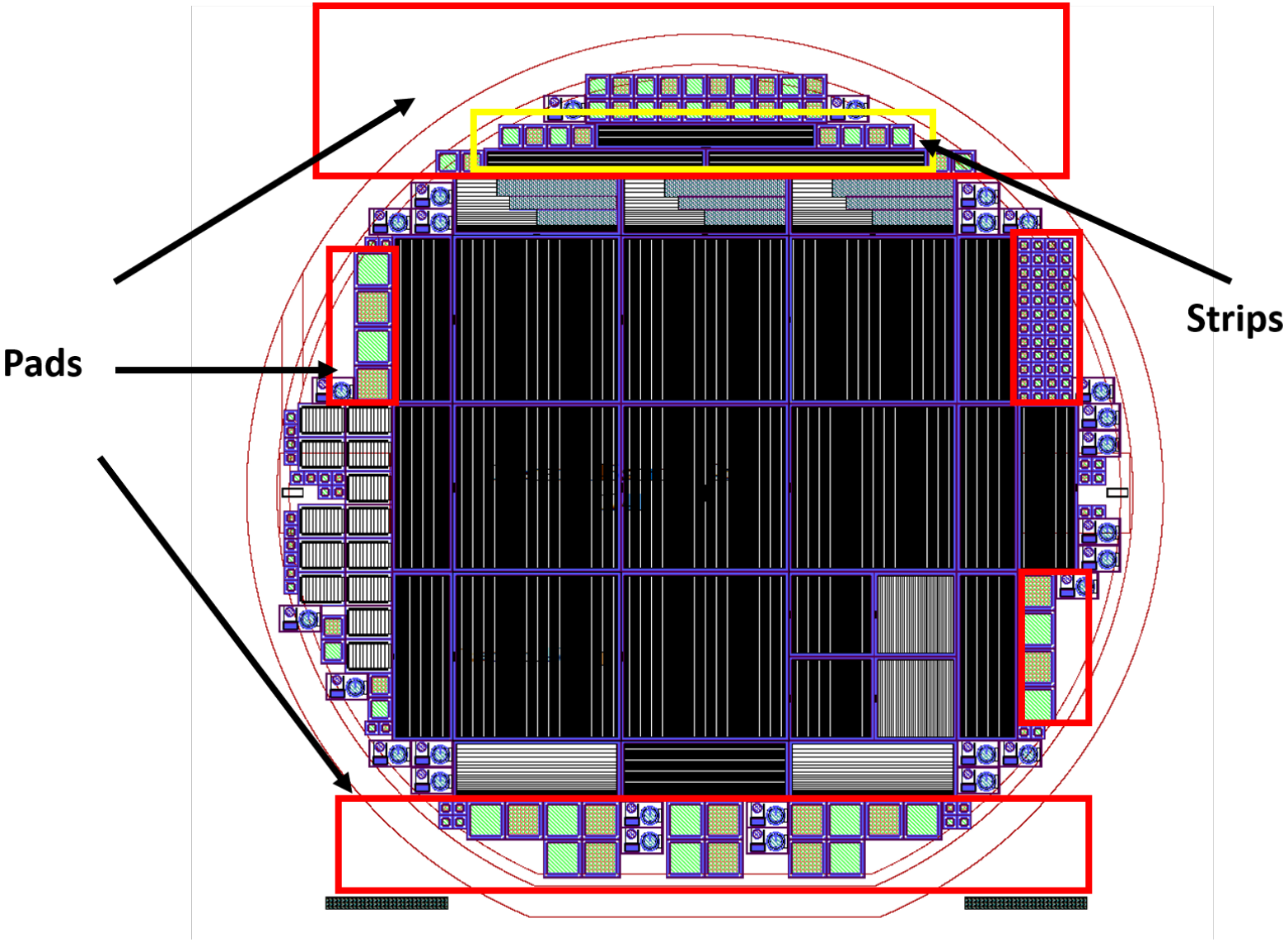


LGAD Strips

- 3.5 cm long, 192 μm pitch (Total 16 strips)
- Strip 15 is with single long opening
- Strip 13 is with multi openings
- The metal openings are 8.5 mm apart

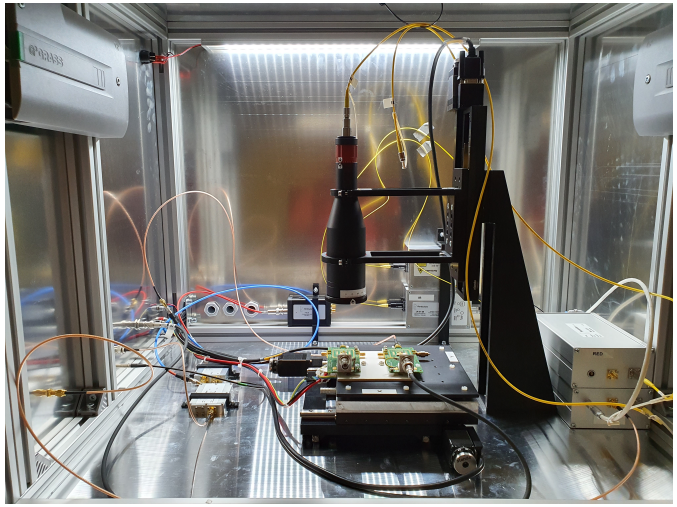
MoVeIT Production

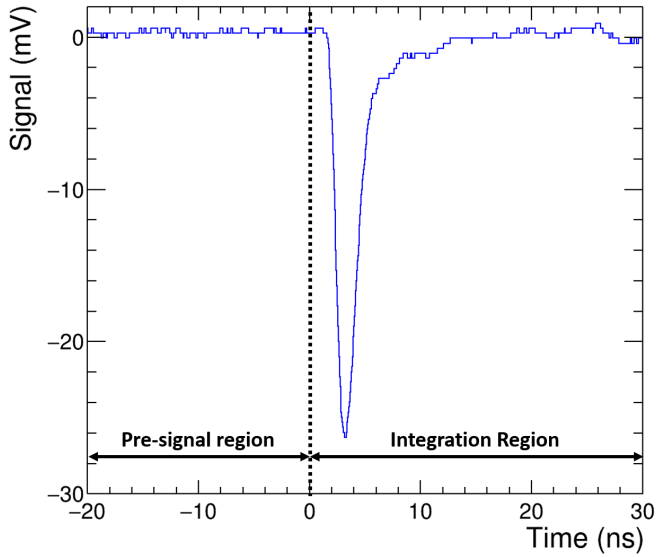
Standard LGAD Technology **Active Thickness: 45 μm**



Experimental Setup: TCT

- Particulars TCT setup
- Particulars broadband amplifier (53 dB)
- IR and Red Laser
- Beam Monitor
- 3 channel passive readout board





- V(t).
- Baseline Correction.
- Non measuring strips are terminated using 50Ω termination.
- Collected charge is given as:

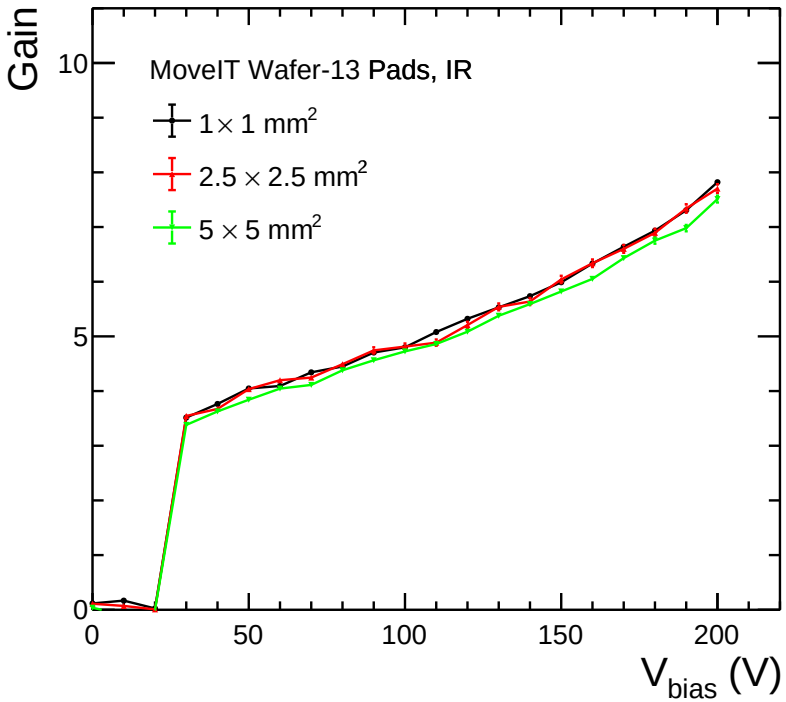
$$Q = \int_{t_0}^{t_f} I(t)dt,$$

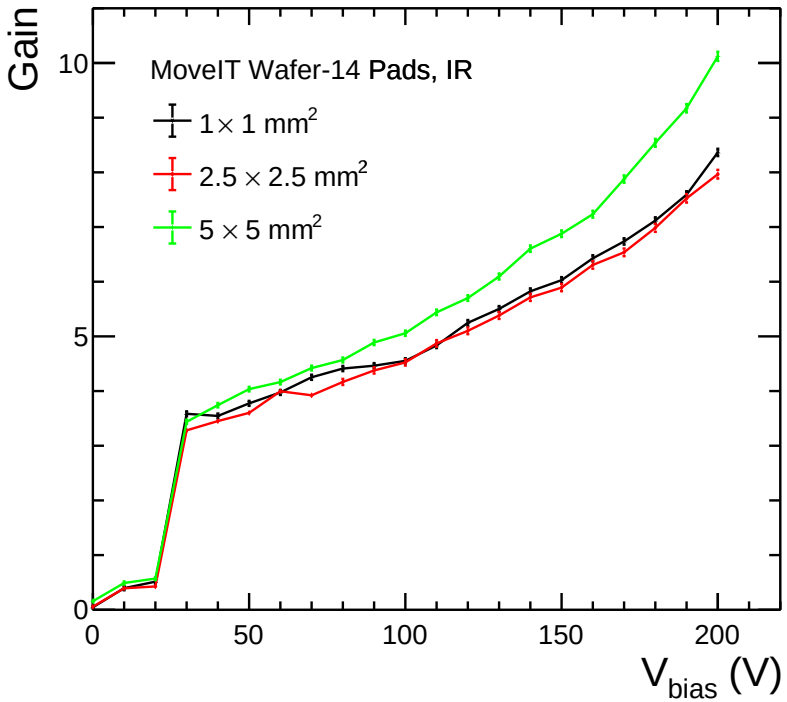
- Normalization of charge/amplitude.

Gain Comparison

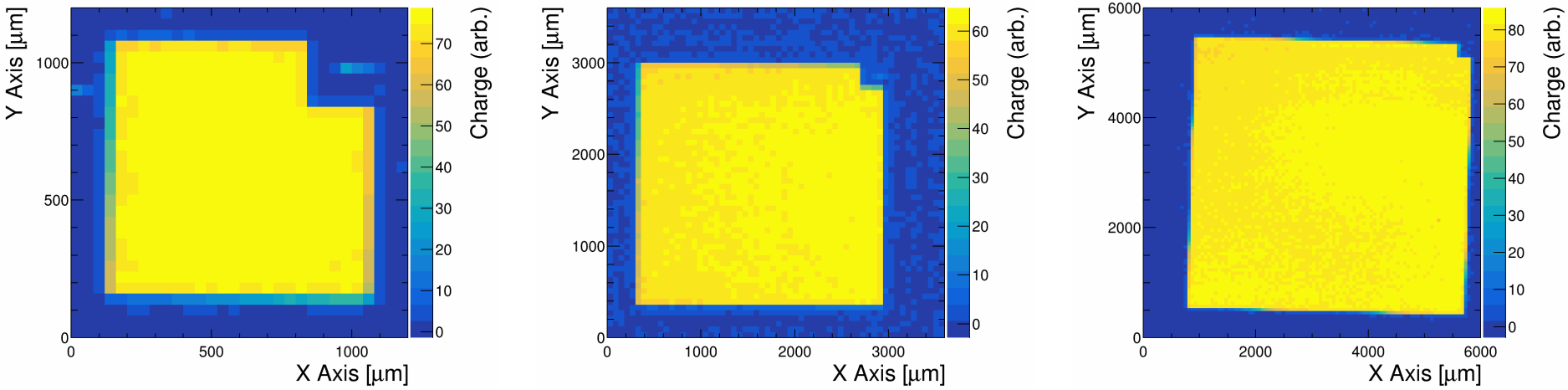
Gain Definition:

$$Gain = \frac{Q_{LGAD}}{Q_{PIN}}$$

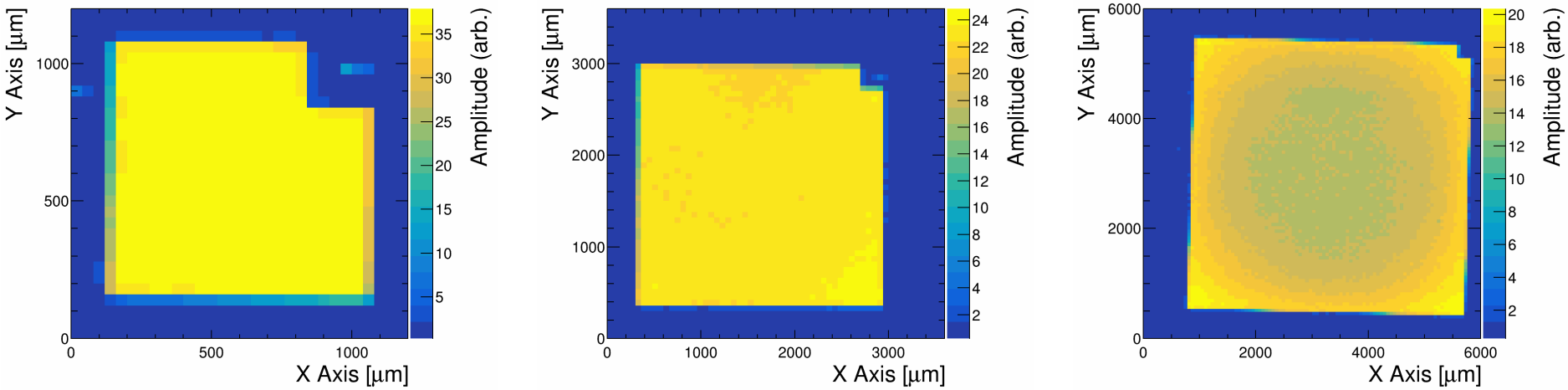




1×1 mm^2 2.5×2.5 mm^2 5×5 mm^2



Charge at V_{bias} = -200 V

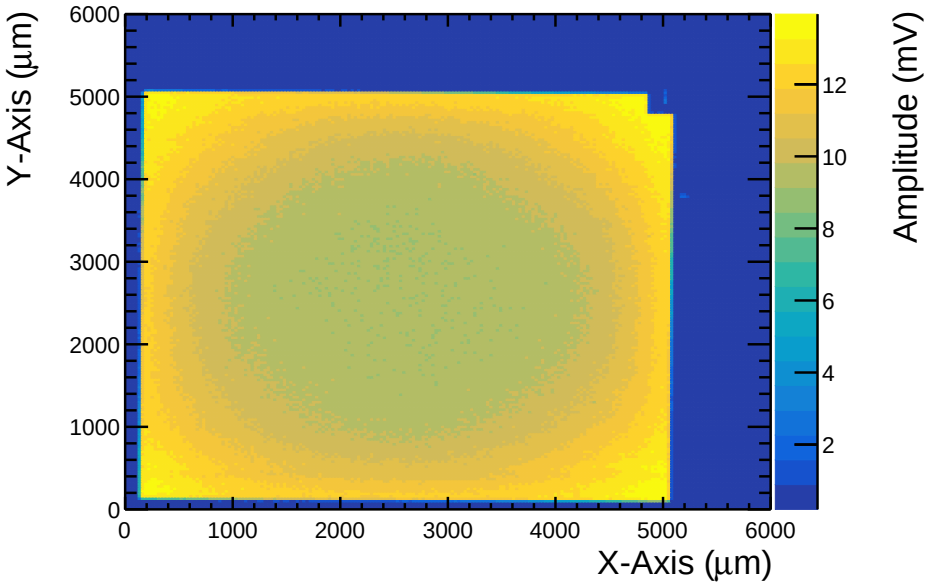


Amplitude at V_{bias} = -200 V

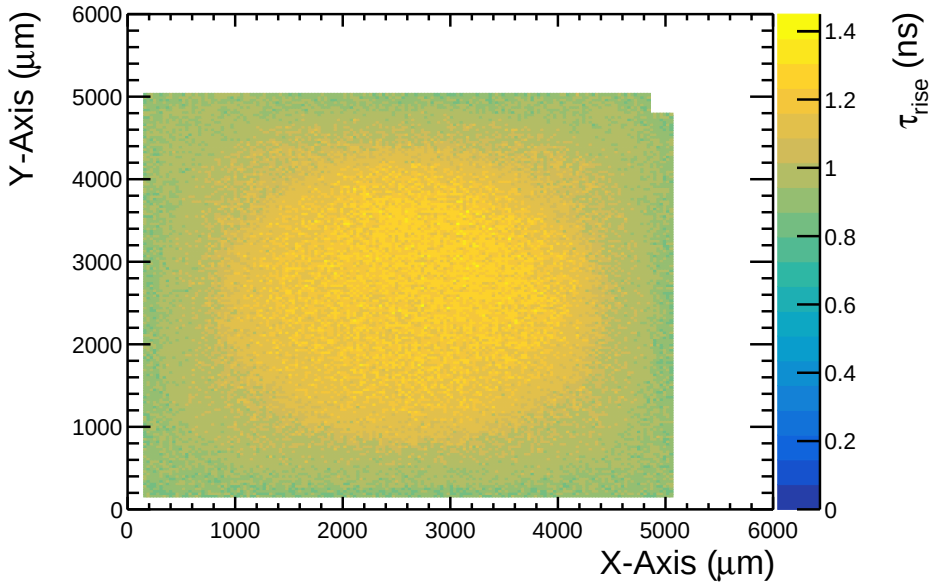
Significant non-uniformity of amplitude in pad with large area.

Big Pad Anomaly

Amplitude Map

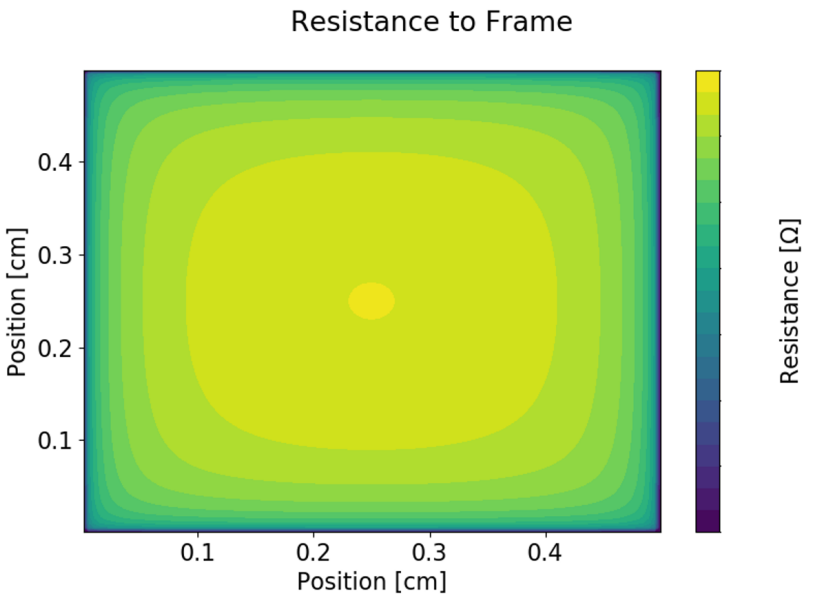


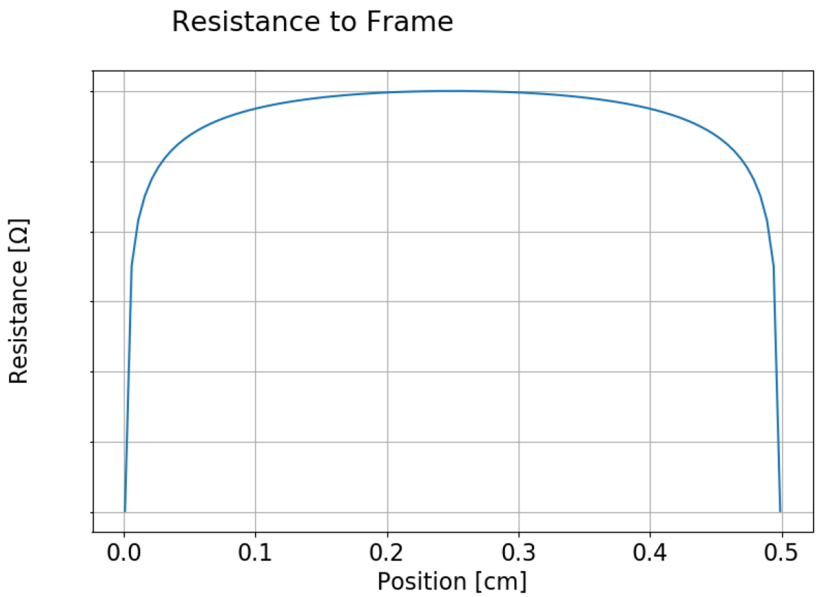
Rise-Time Map



- Significant decrease in amplitude towards center in non metallized big pads.
- Increase in rise-time towards center for the same data.
- This might be a resistive effect of the implant.
- It needs to be studied in a systematic way with some modelling and simulations.

Resistance Modelling

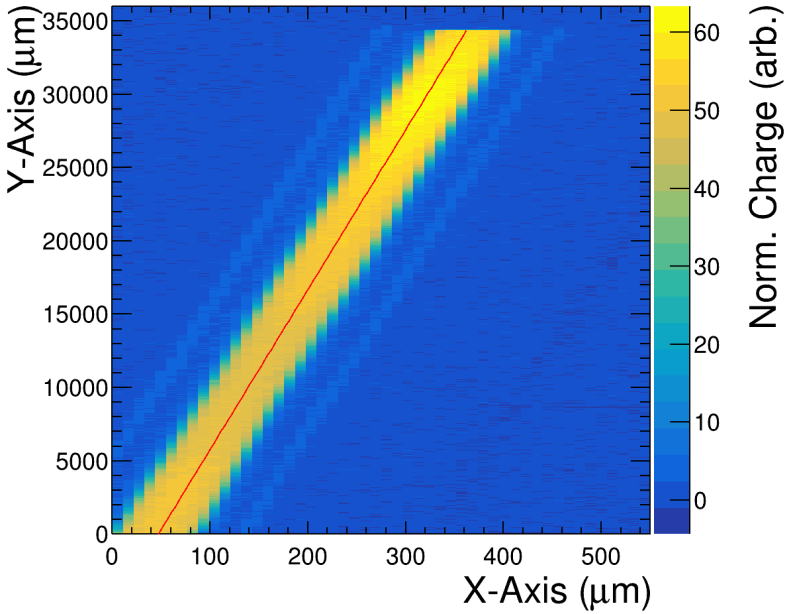


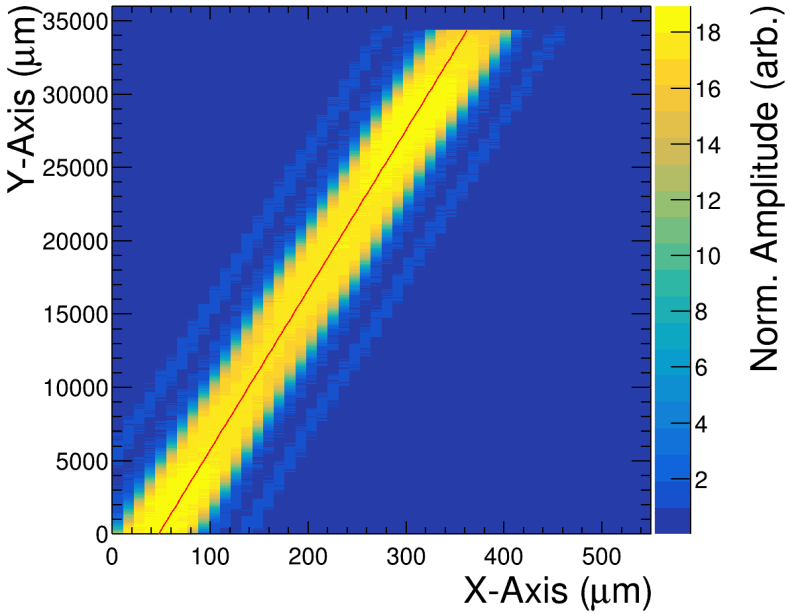


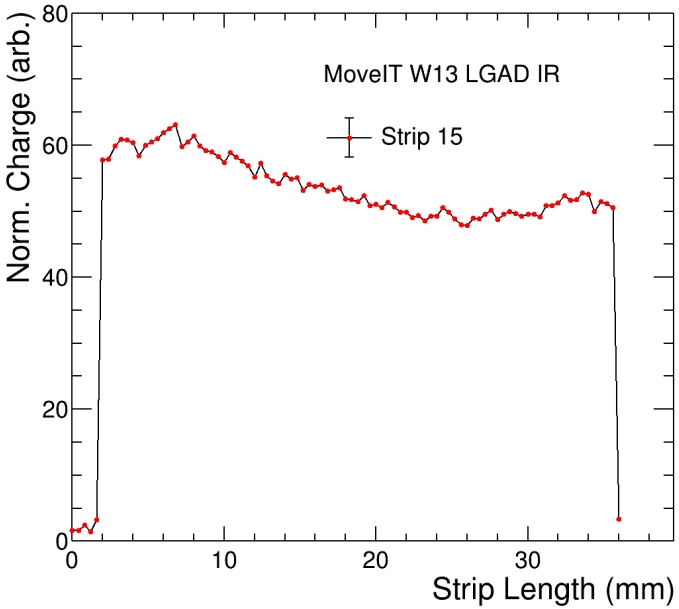
- Resistance of implant with metal frame.
- Maximum resistance at the center of the pad as seen by the signal.
- Similar shape observed in the experimental data.

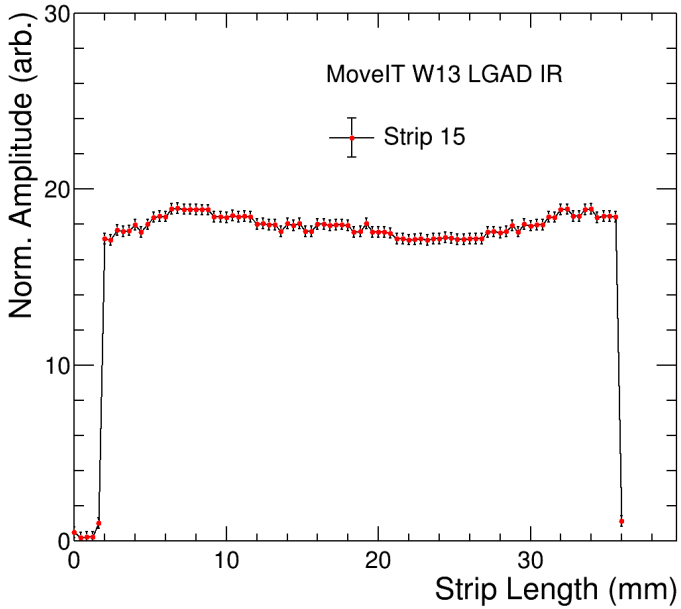
Need more in depth study to fit experimental data.

Hit Map of Strip (single opening)

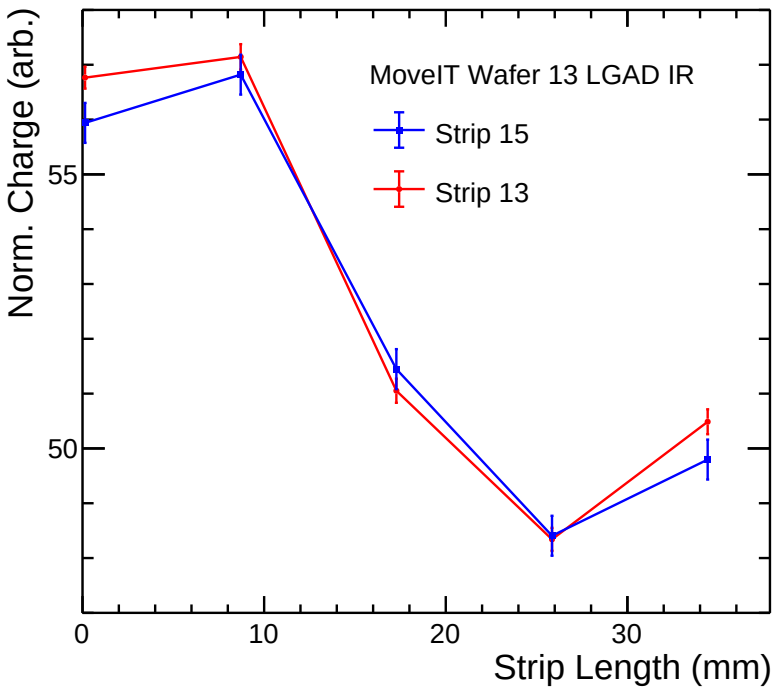


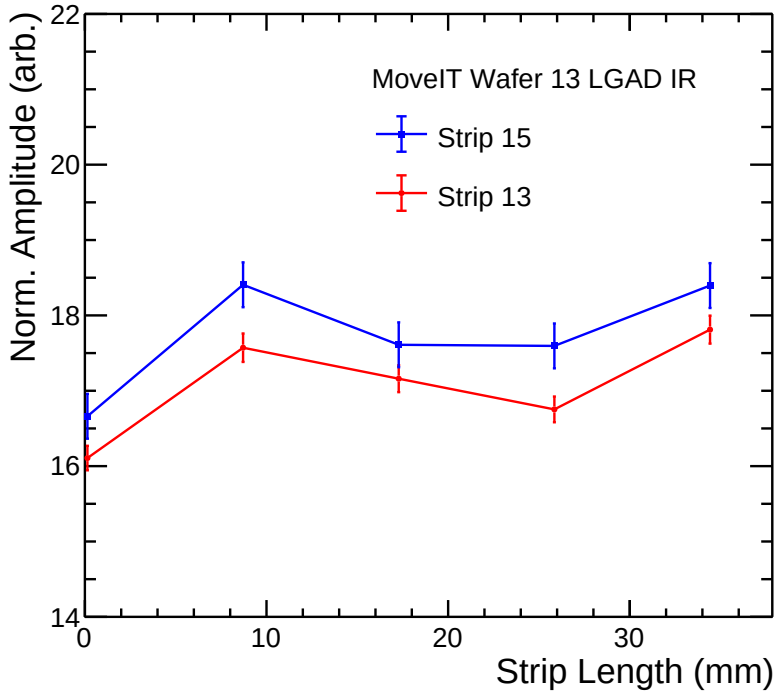






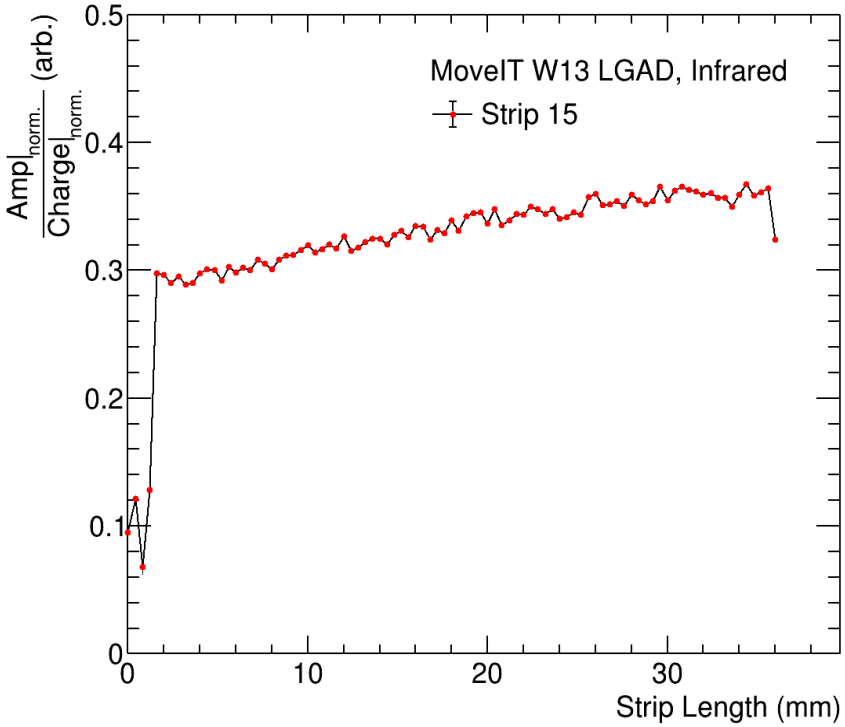
Charge and Amplitude v/s Strip Length

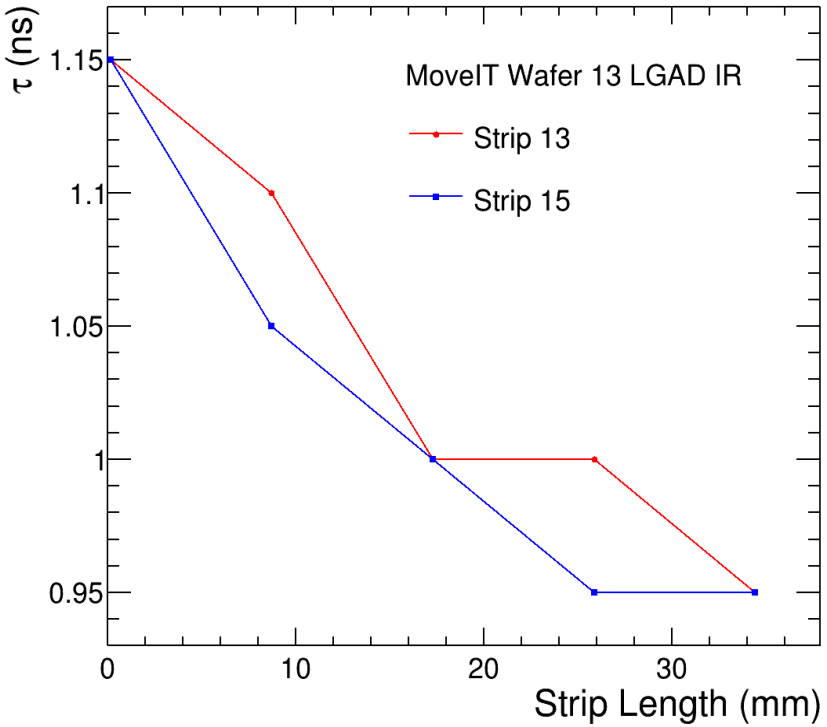




- Non uniformity in charge collection.
- Both strips shows similar trend
- Non-uniformity in the gain layer (sensors in the outer edge of wafer)
- Amplitude increases with increase in distance from readout

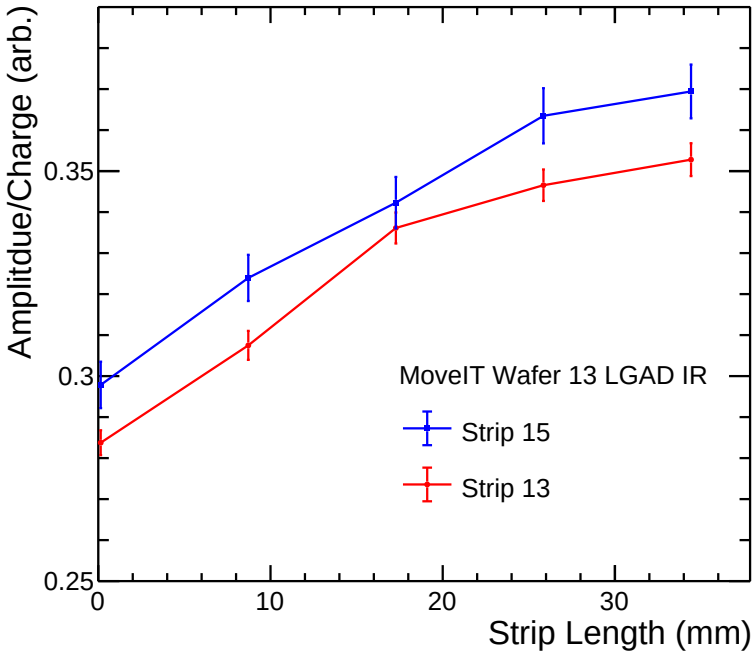
Strip 15: Ratio & Rise Time



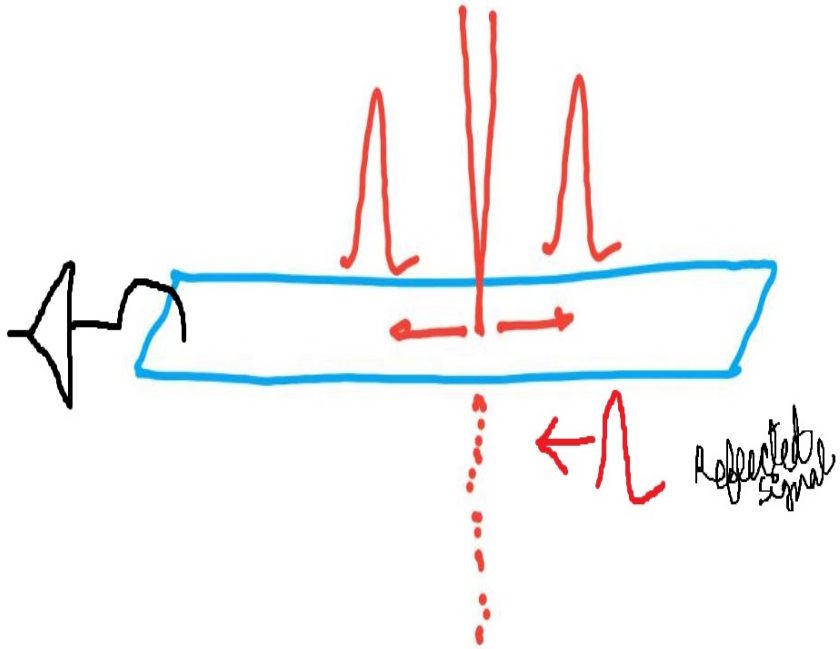


- Ratio of amplitude and charge shows a linear rise along the strip length.
- Read-out is from the left pad for both strips.
- Decrease in rise time along the strip length for both strips.

Ratio (Amplitude/Charge)



Reflection



- The ratio increases as we move away from the readout pad.
- The ratio of amplitude and charge shows consistent behaviour for both strips.
- Change in signal shape.

Summary and Outlook

The single channel big pads and long strips from the standard LGAD technology were studied using the IR-TCT.

- Change in signal shape has been observed in the big pads.
  → Resistive effect of implant
- Significant change in the amplitude along the strip.
- The rise time changes in both big pads and long strips.
  → Signal reflection might be a cause for different signal shape. We need to study the effect of reflection in more detail and find an optimal solution to corrected it (if necessary).
- New production batch devoted to space application.
  → Will be used to study these effects and other parameters.
- Upcoming Timing setup (^{90}Sr).

Acknowledgment: We would like to thank MoVeIT group.

Thank you for your attention