Characterization of LGAD sensors from CNM Run 7859

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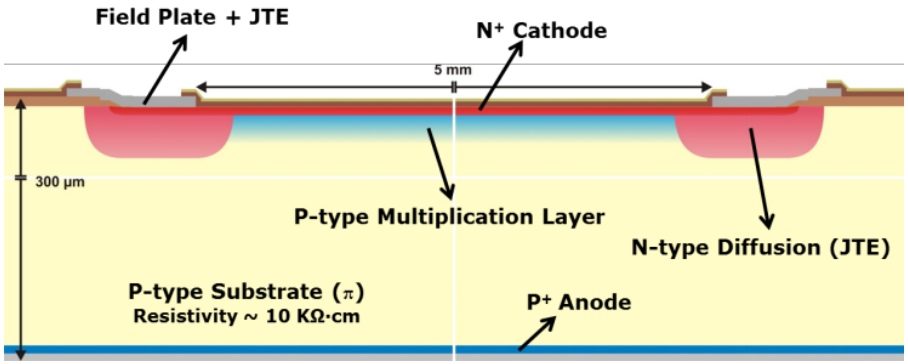
Wafer characteristics

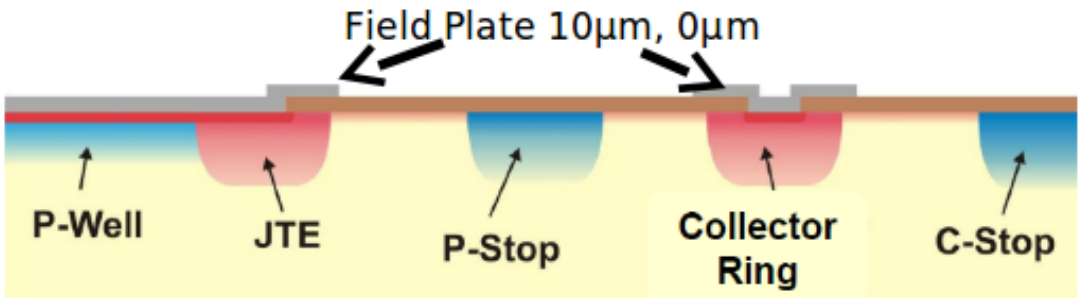
Multiplication layer dose: 1.8×10^{13} cm^{-2}

- Wafers 1 and 2.
- Only one LGAD without JTE.
- PIN diodes also available.



Multiplication layer dose: 2.0×10^{13} cm^{-2}

- Wafers 3 and 4.
- PIN diodes also available.



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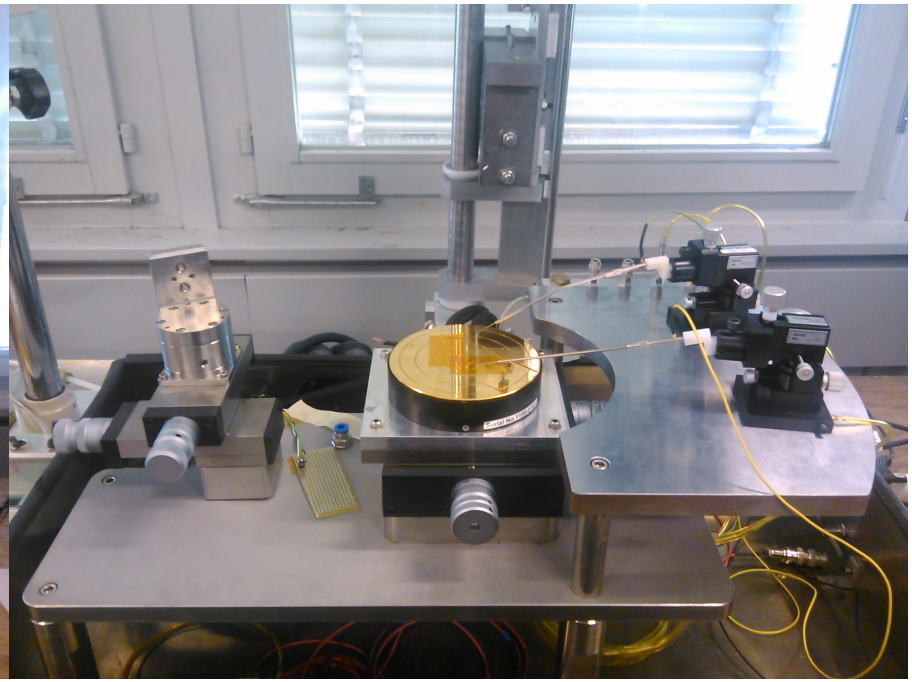
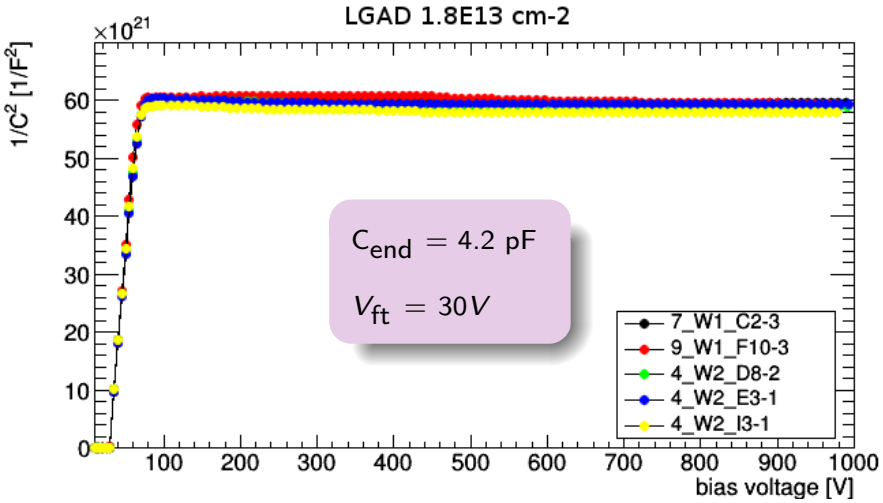
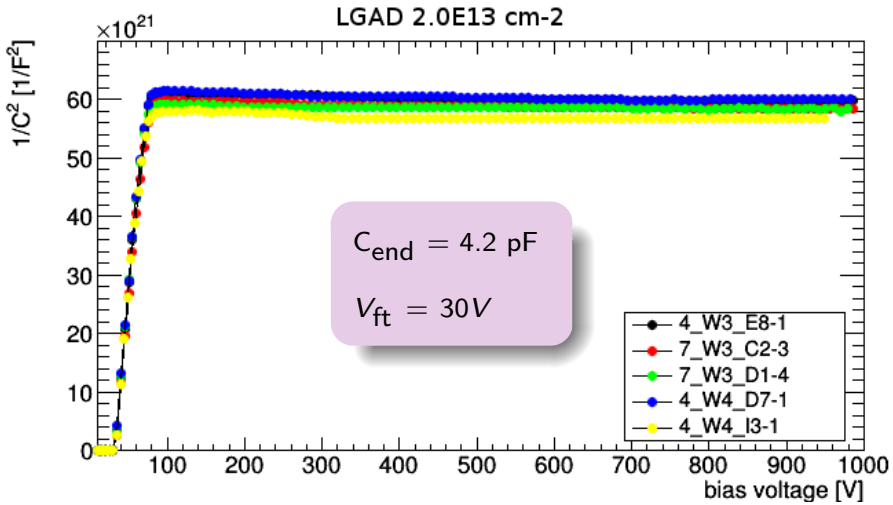
CV/IV measurements

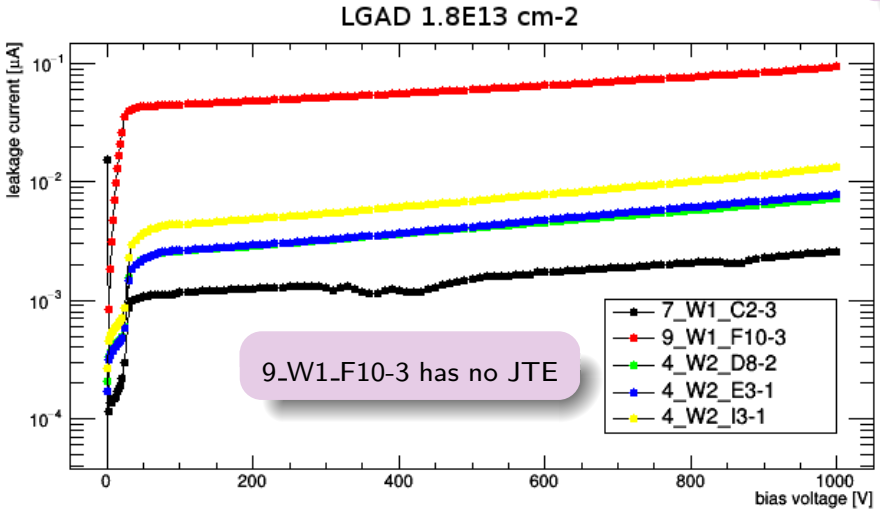


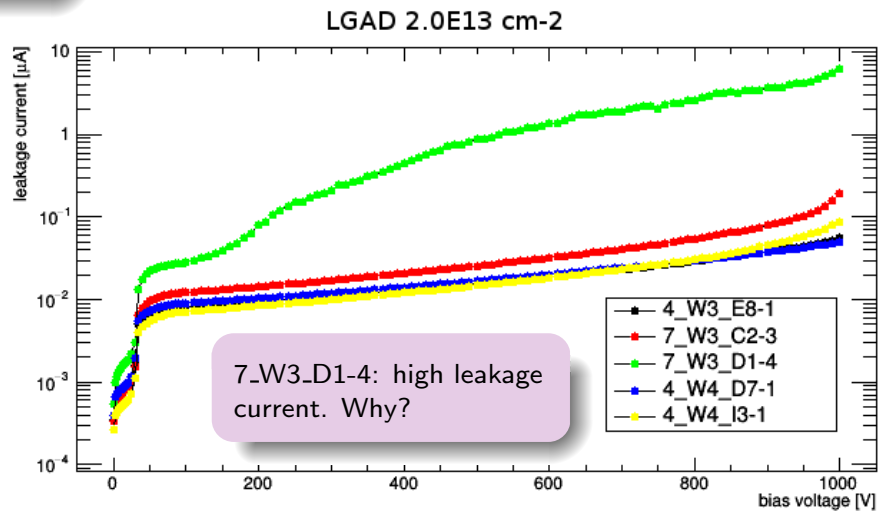
CV/IV curves (before irradiation)



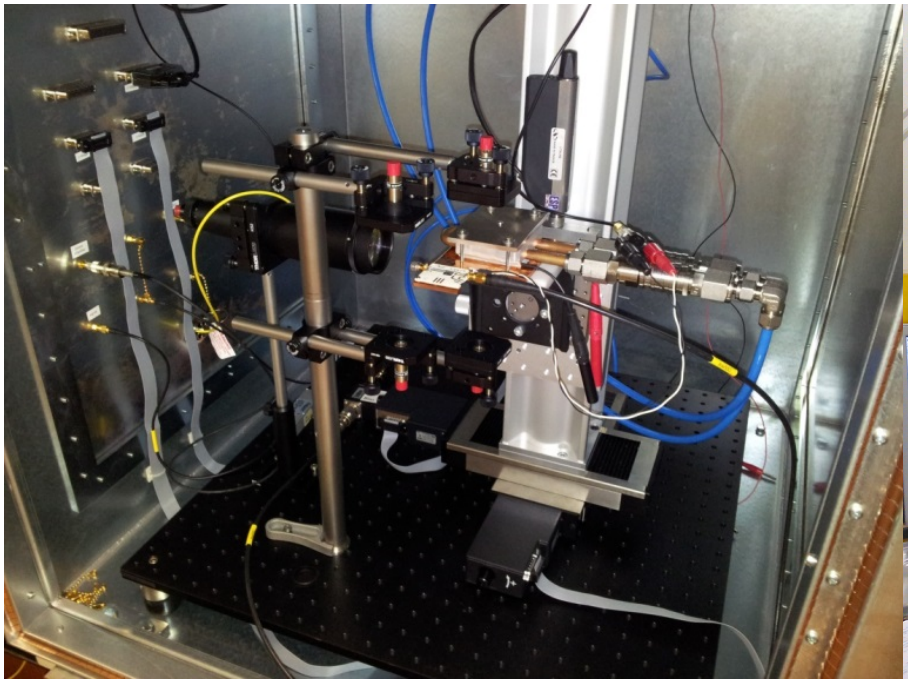


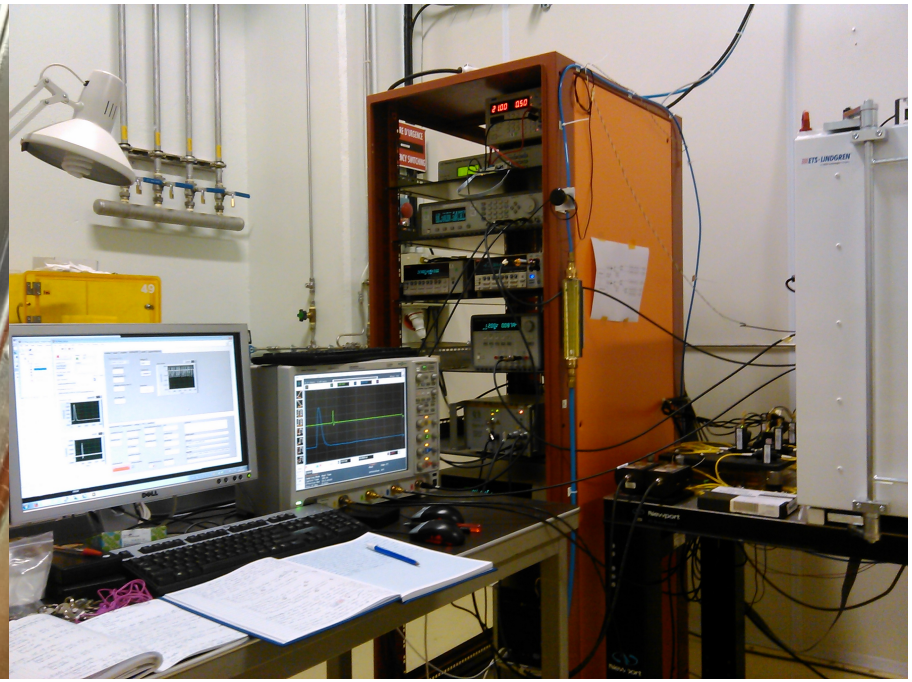
T = 20° C



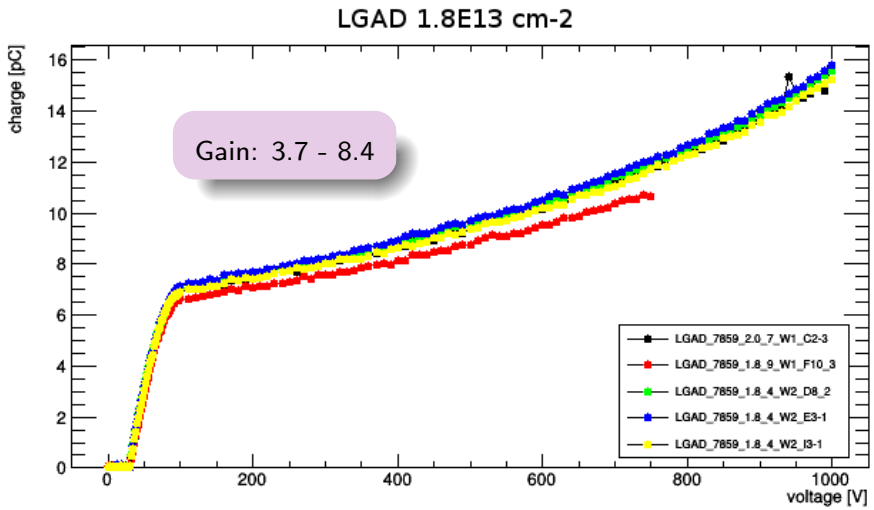


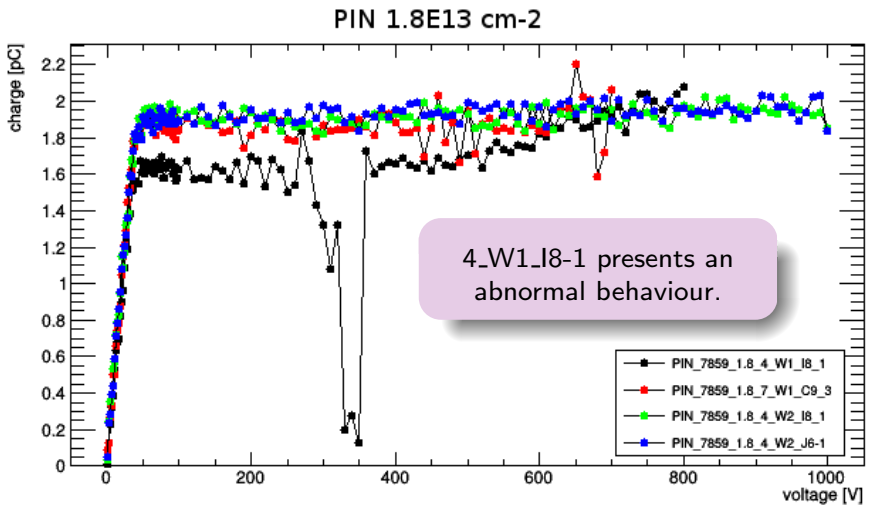
TCT+





TCT - IR back (before irradiation)





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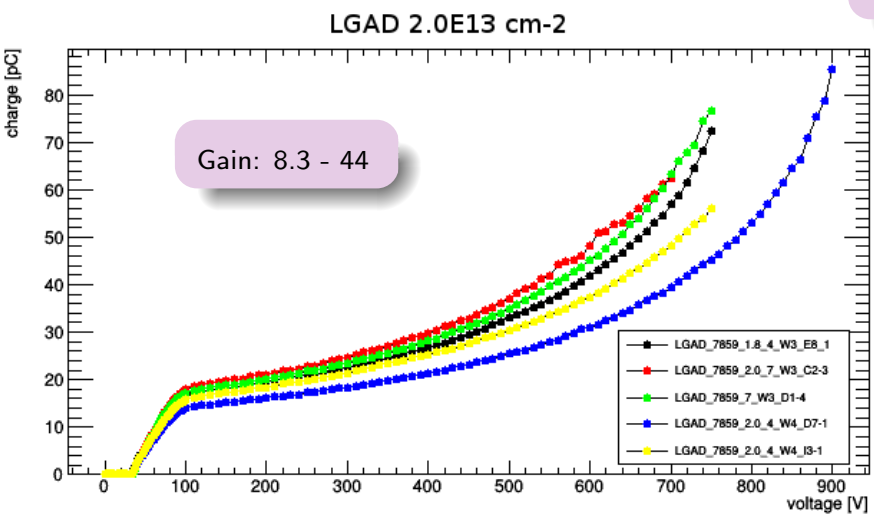
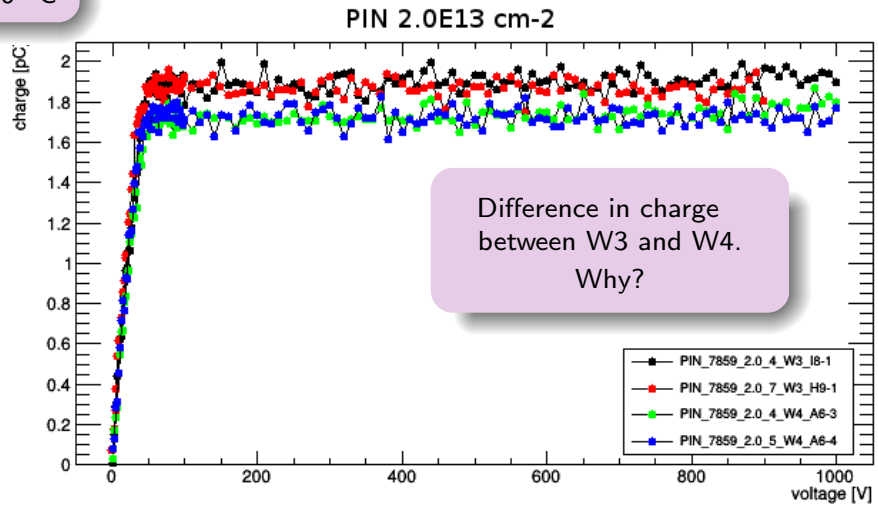
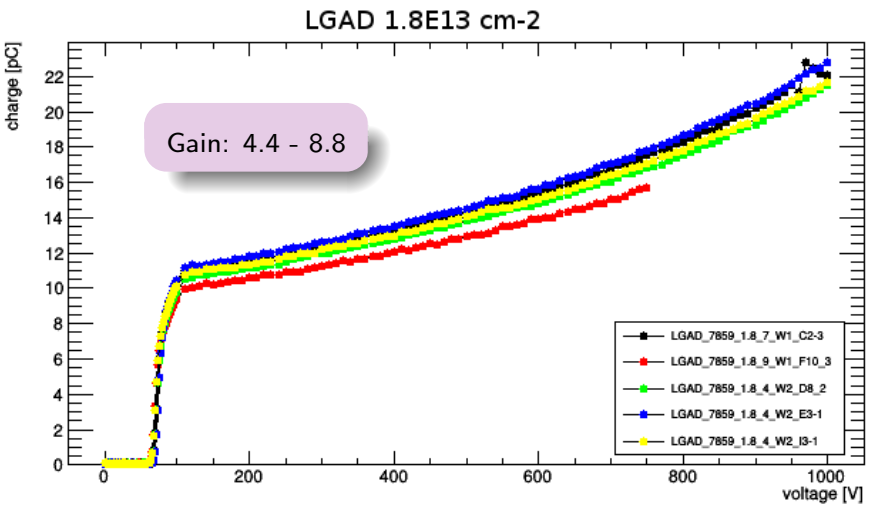
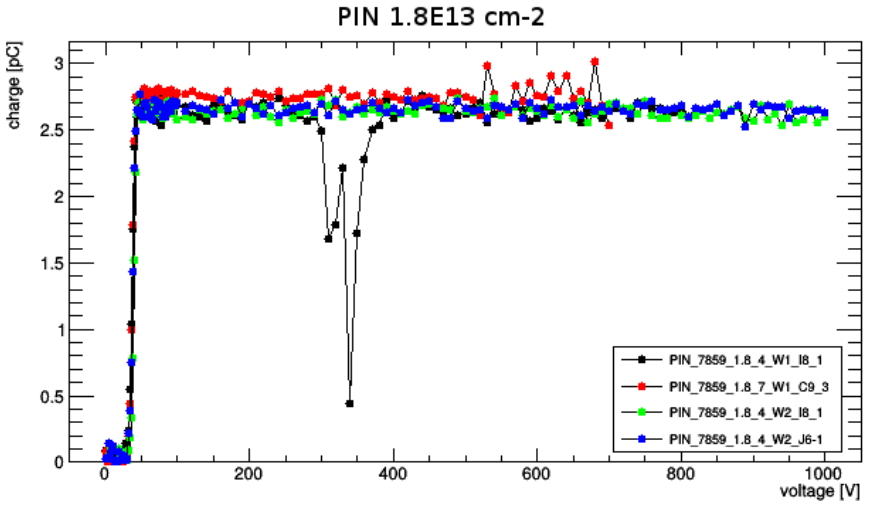




TCT - Red back (before irradiation)





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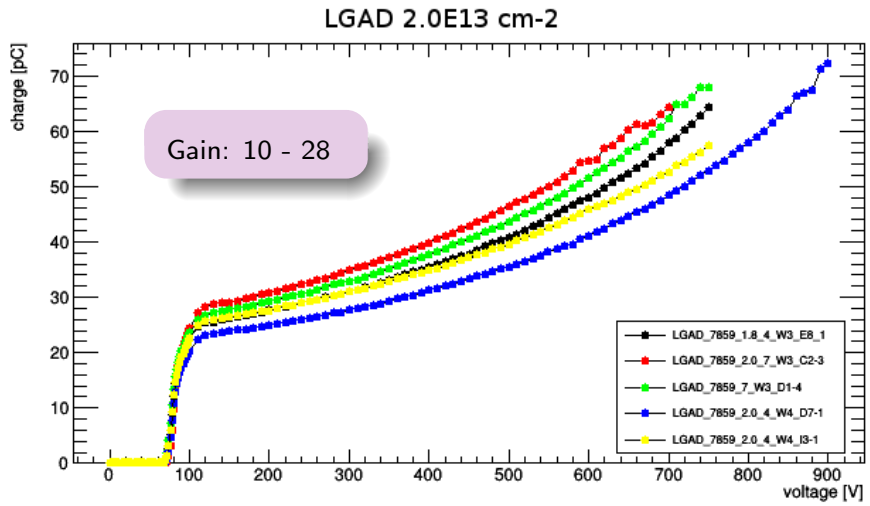
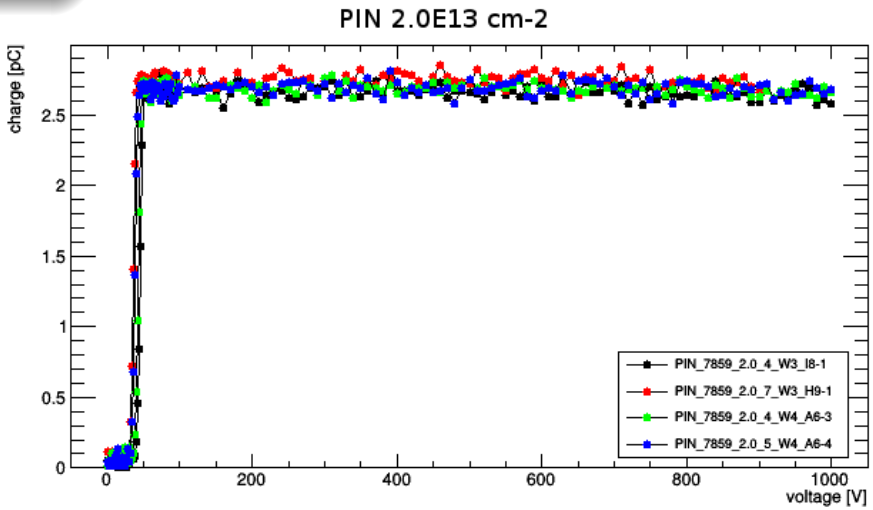
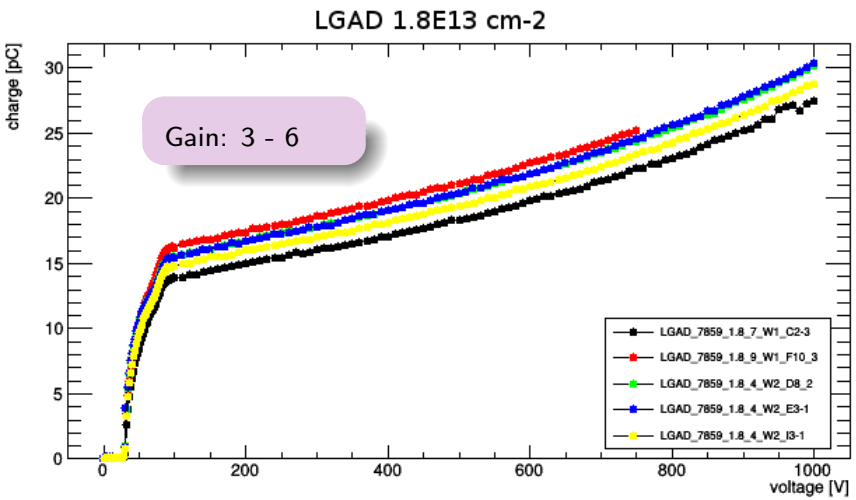
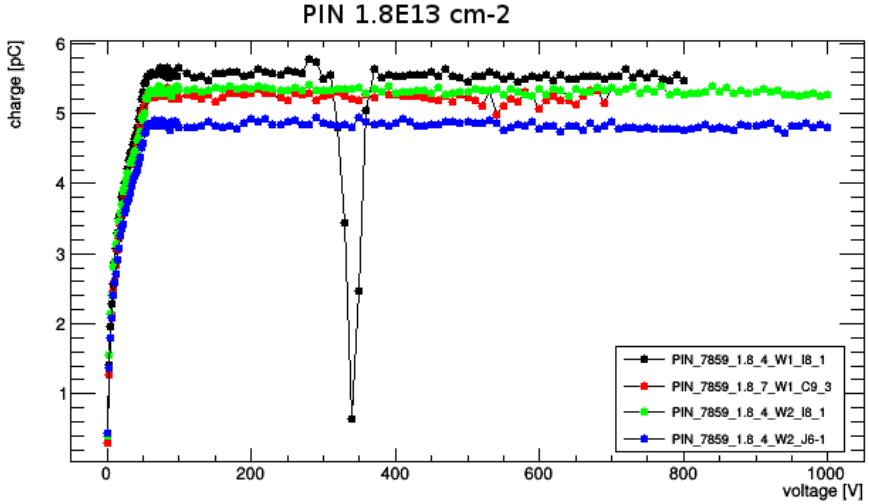


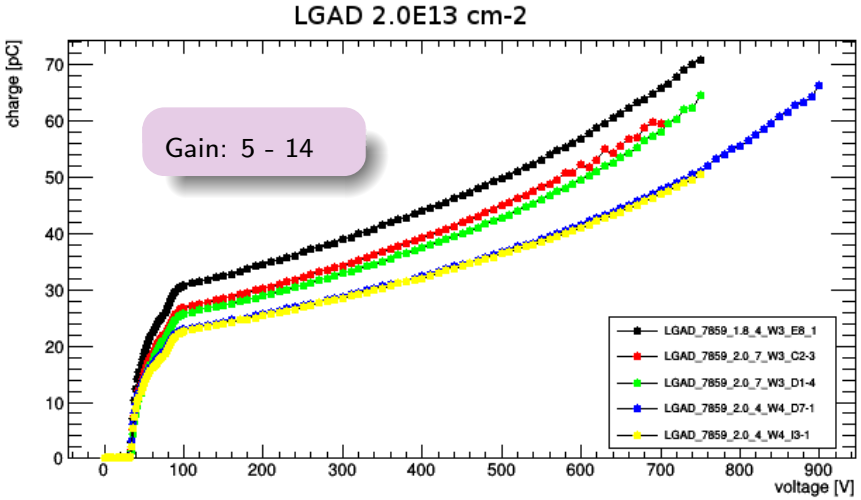


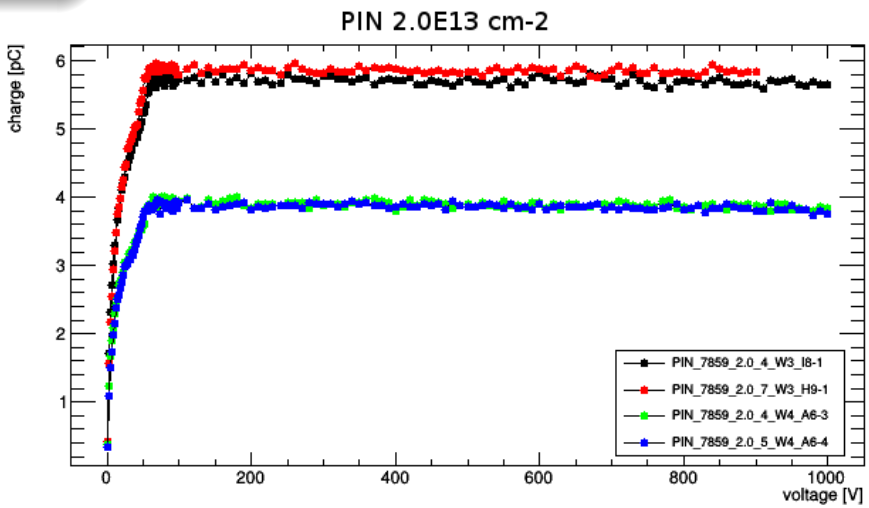
TCT - Red front (before irradiation)





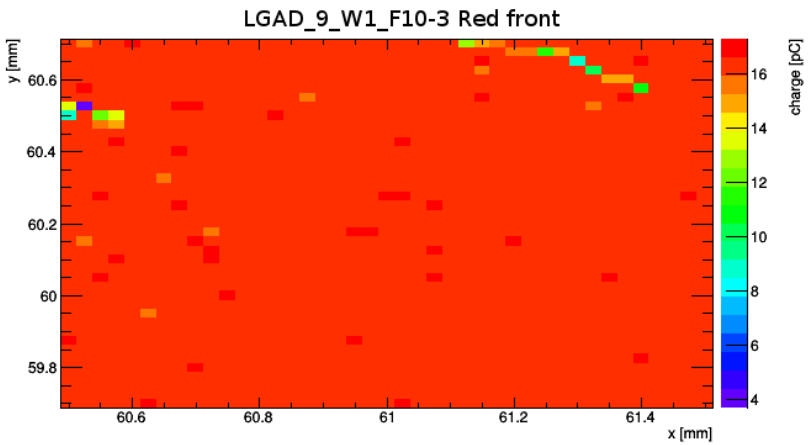
T = -20° C

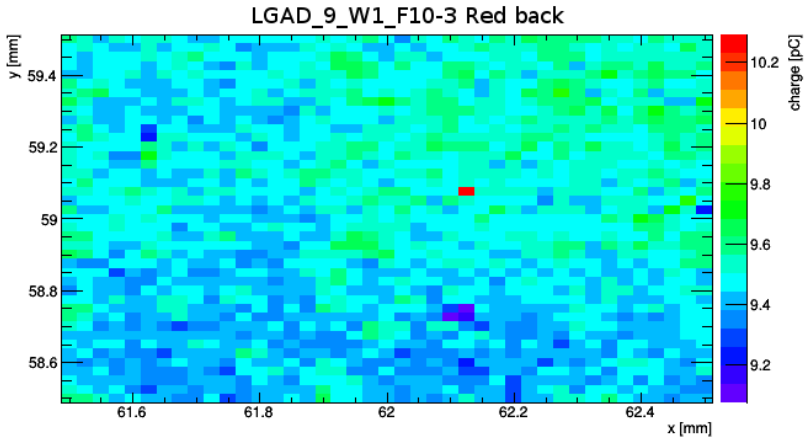




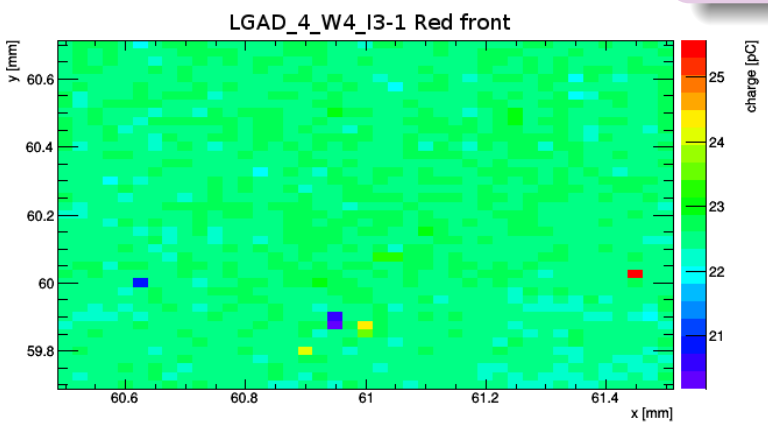
Homogeneity at 100 V (before irradiation)

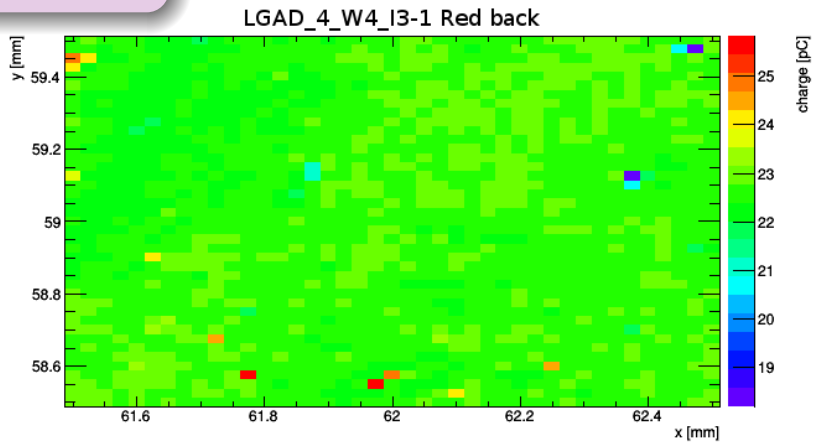
LGAD 1.8×10^{13} cm^{-2}





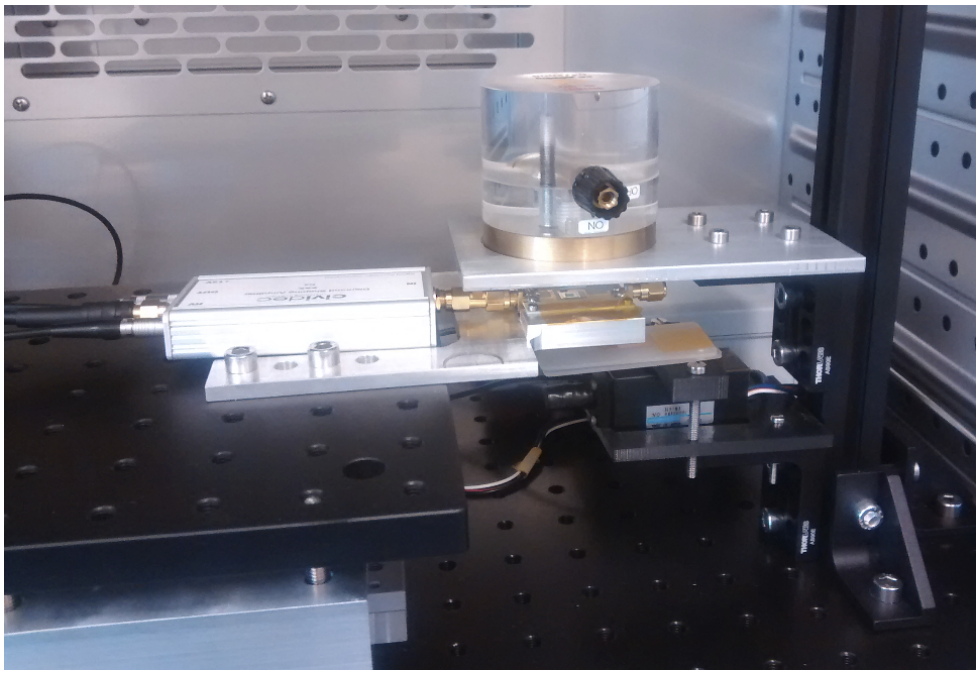
LGAD 2.0×10^{13} cm^{-2}



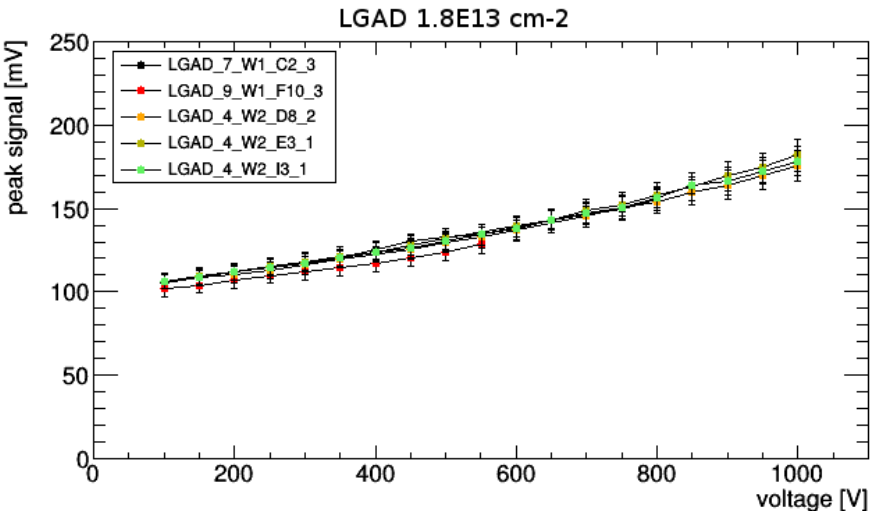


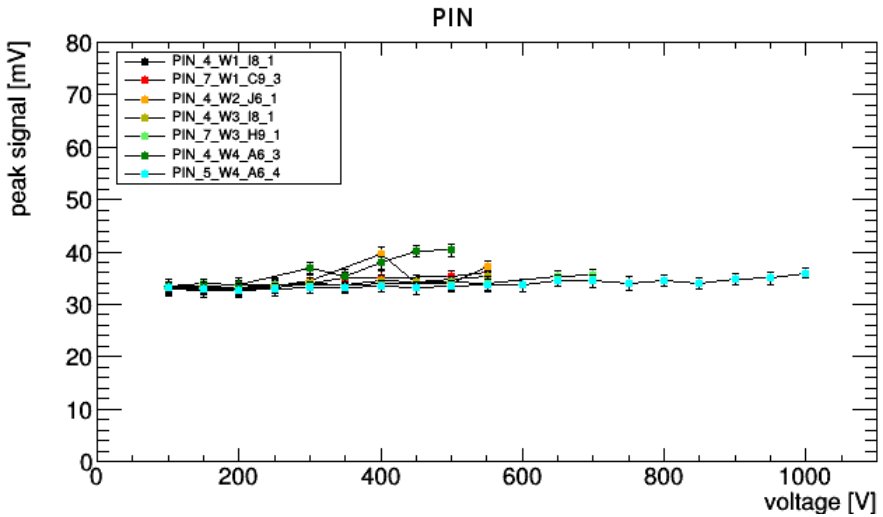
They are homogeneous now.

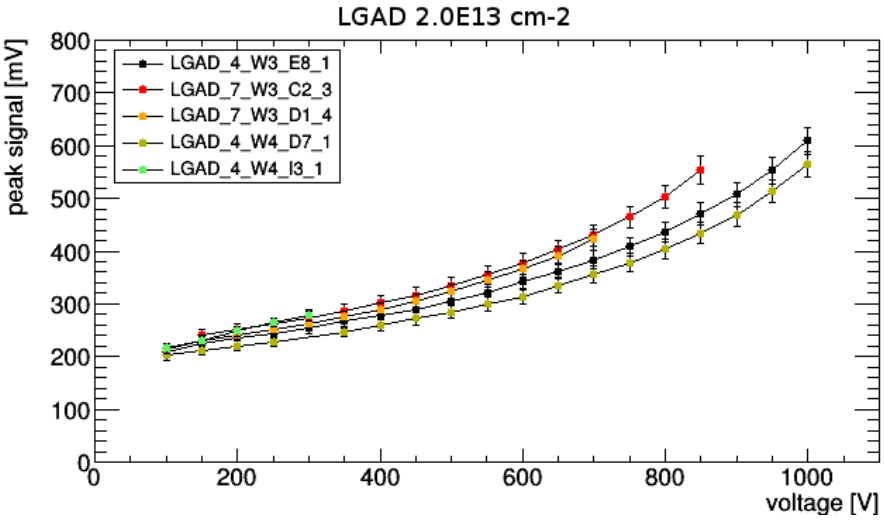
Sr-90 source measurements



Sr-90 source measurements (before irradiation)







Results at 20°C

- Peak signal in PIN diode:
  - $\sim$ 34 mV
- Gain LGAD 1.8:
  - at 200V $\rightarrow \sim$ 3.2
  - at 1000V $\rightarrow \sim$ 5.3
- Gain LGAD 2.0:
  - at 200V $\rightarrow \sim$ 7.3
  - at 1000V $\rightarrow \sim$ 17.6

Gain

Gain values obtained at 700 V for each type of measurement

	TCT – IR back	TCT – Red back	TCT – Red front	Sr-90
1.8×10^{13} cm^{-2}	5.7	6.2	4.3	4.4
2.0×10^{13} cm^{-2}	W3 = 31.9 W4 = 25.7	21.4	W3 = 10.6 W4 = 12.9	11.7

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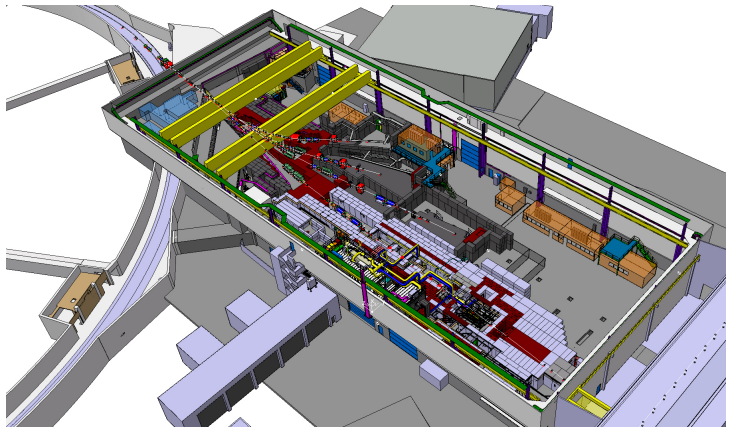
Irradiation campaign

- Irradiation performed at the PS facility.
  - 24-GeV protons.
- Sets of 4 sensors

$$\left.\begin{array}{l} \text{2 PINs} \\ \\ \text{2 LGADs} \end{array}\right\} \begin{array}{c} \text{1 from W1 or W2} \\ \& \\ \text{1 from W3 or W4} \end{array}$$

- Fluences:
  - 10^{12} 1 MeV n_{eq}/cm^2
  - 10^{13} 1 MeV n_{eq}/cm^2
  - 10^{14} 1 MeV n_{eq}/cm^2
  - 10^{15} 1 MeV n_{eq}/cm^2



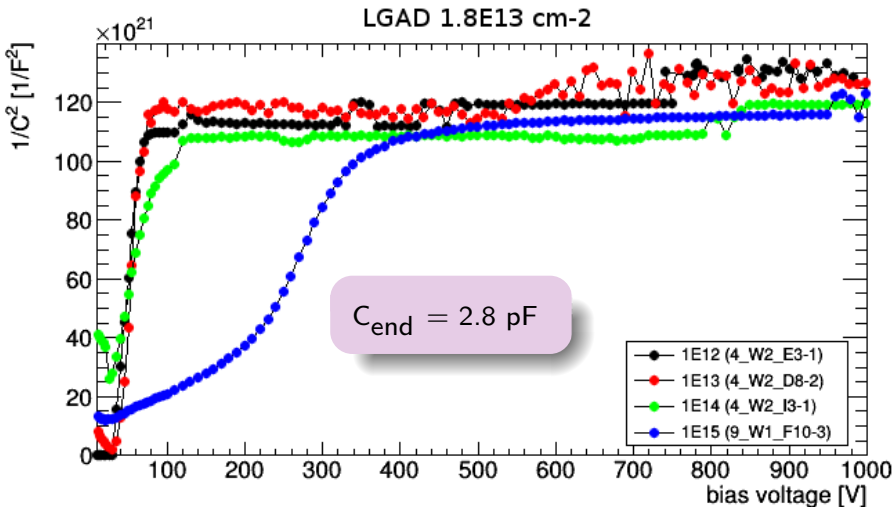
References

- 1 MeV $n_{eq}/cm^2 \equiv 1.6$ p/cm^2

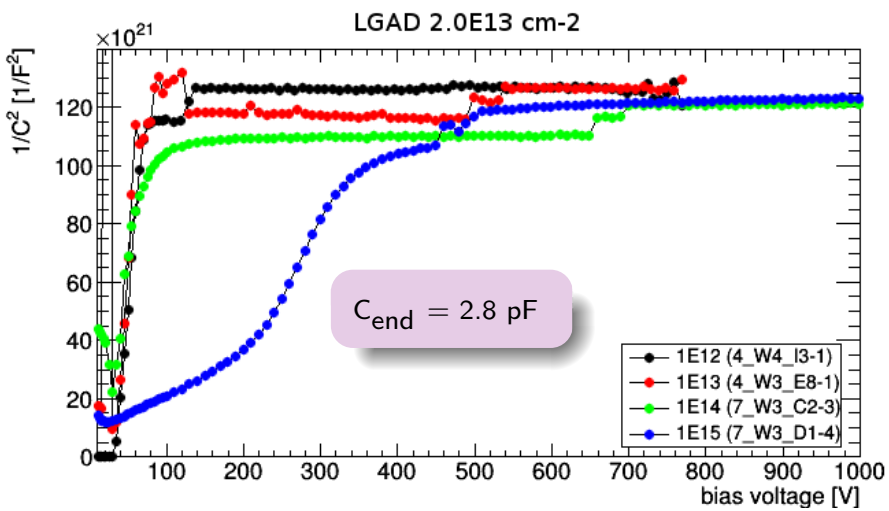
Multiplication layer dose:

- W1 and W2: 1.8×10^{13} cm^{-2}
- W3 and W4: 2.0×10^{13} cm^{-2}

CV/IV curves (after irradiation)

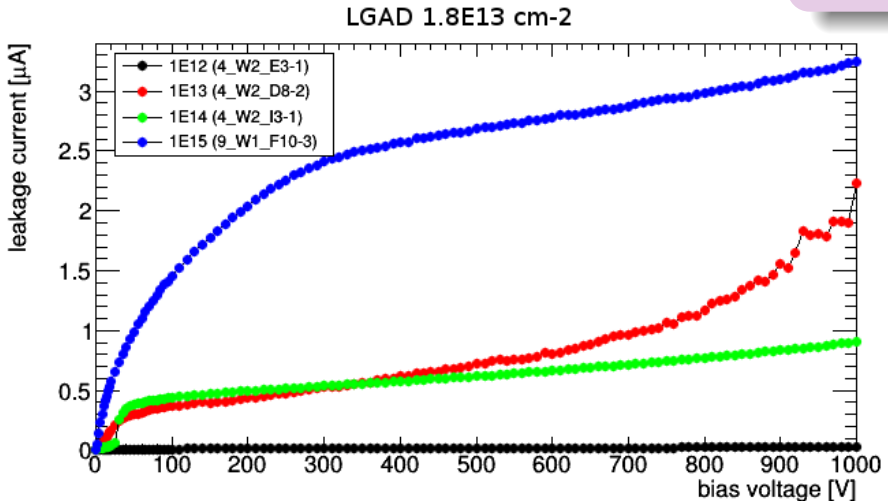


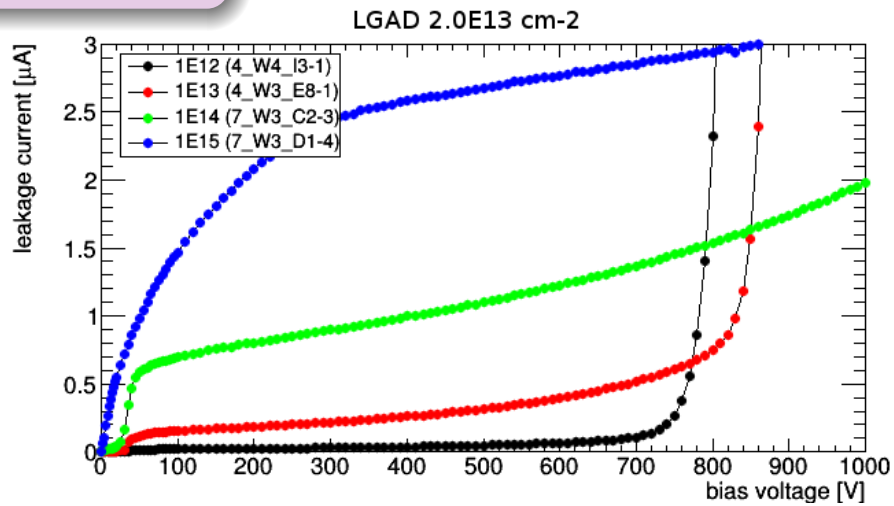
$C_{end} = 2.8$ pF



$C_{end} = 2.8$ pF

T = -20° C
Annealing: 80 min @ 60° C





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Microstrip LGADs (before irradiation)

Objective:

Compare microstrip LGADs and PINs.

Measurement

Red back TCT (e^- injection).

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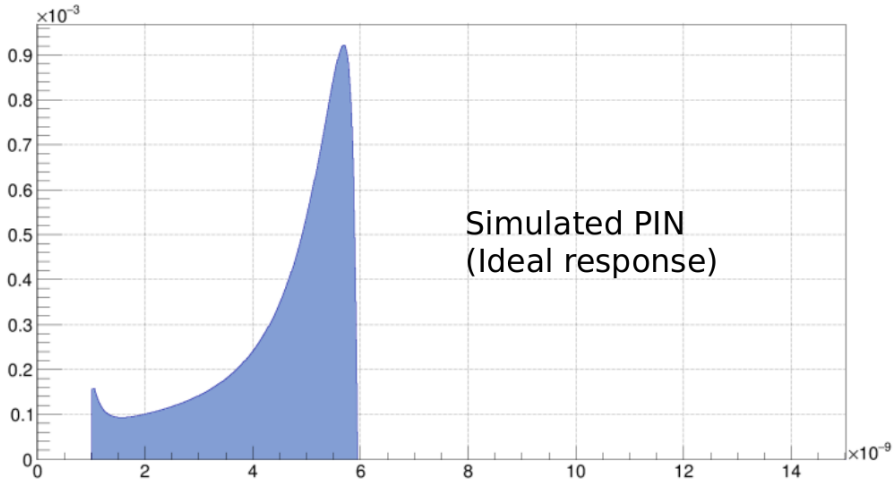
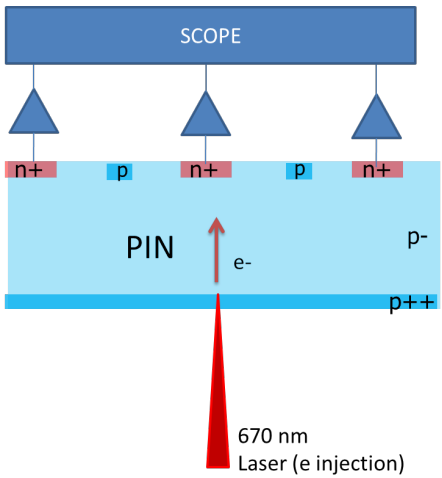
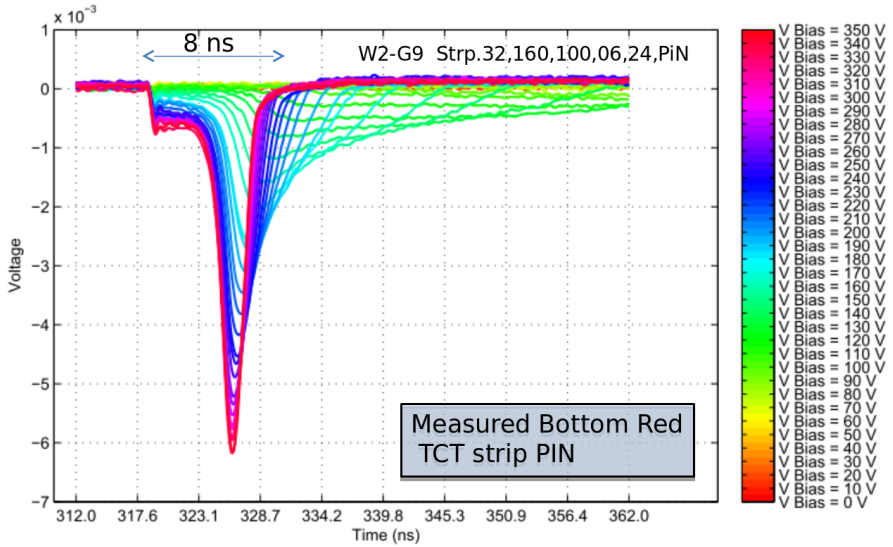


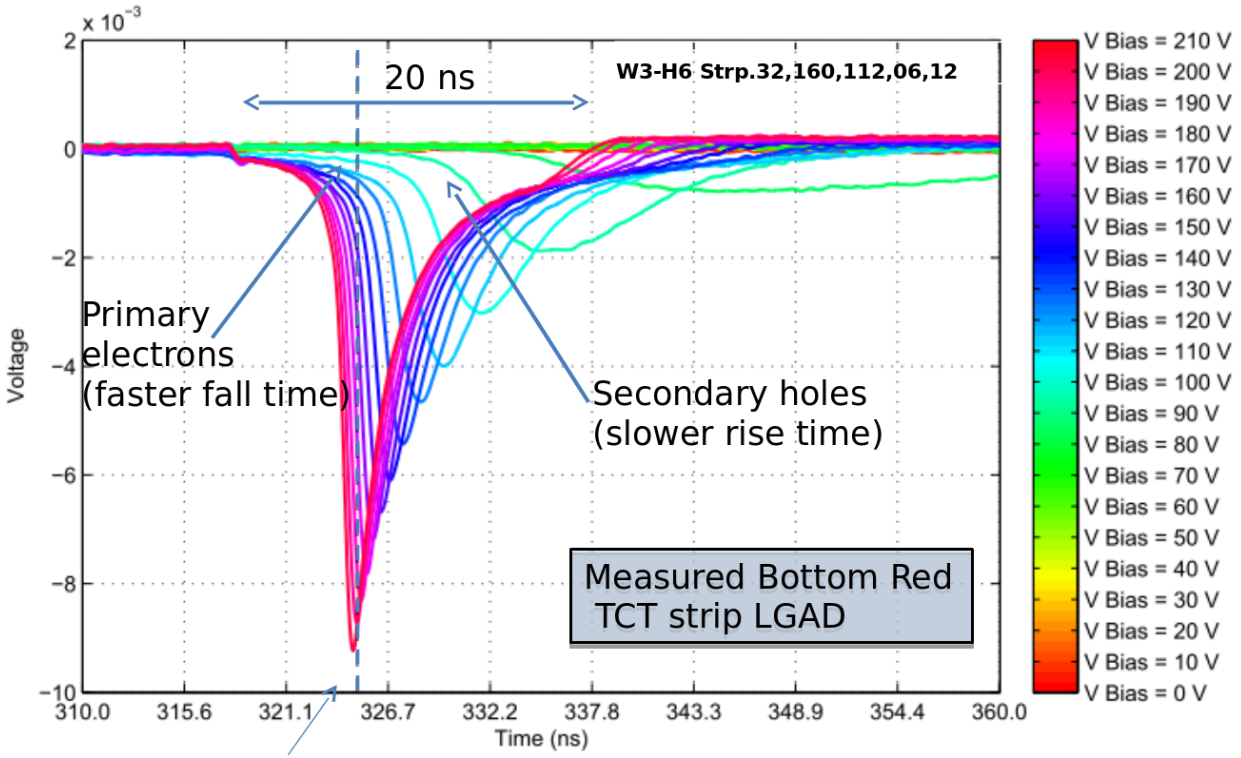




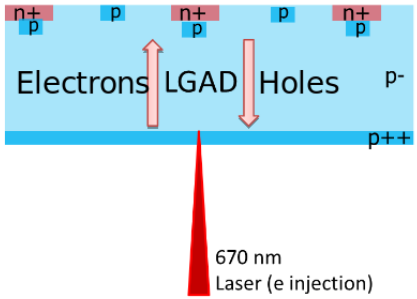
Microstrip LGADs (before irradiation)

Observations

- Wider TCT pulses with respect to the PINs.
- Charge increases with voltage.
- Waveform clearly shows the drift sequence for electrons and holes.



Multiplication on-set



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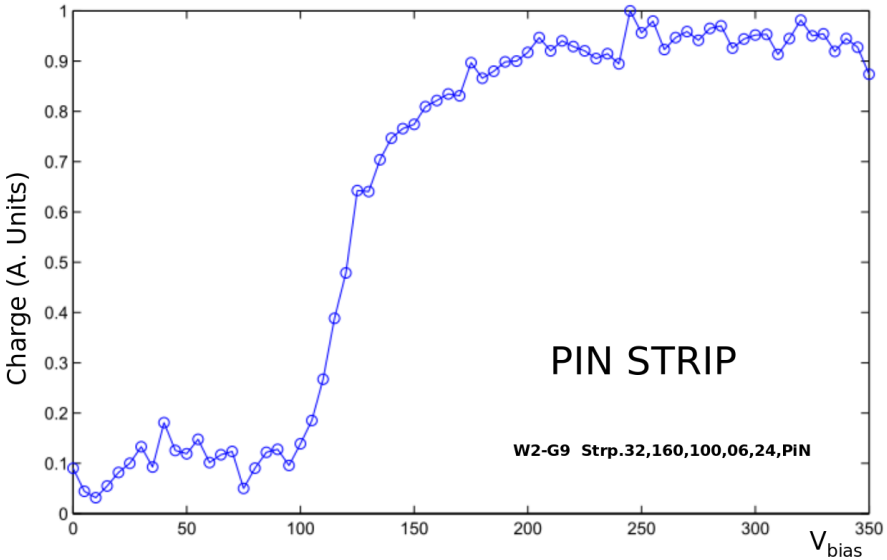
Microstrip LGADs (before irradiation)

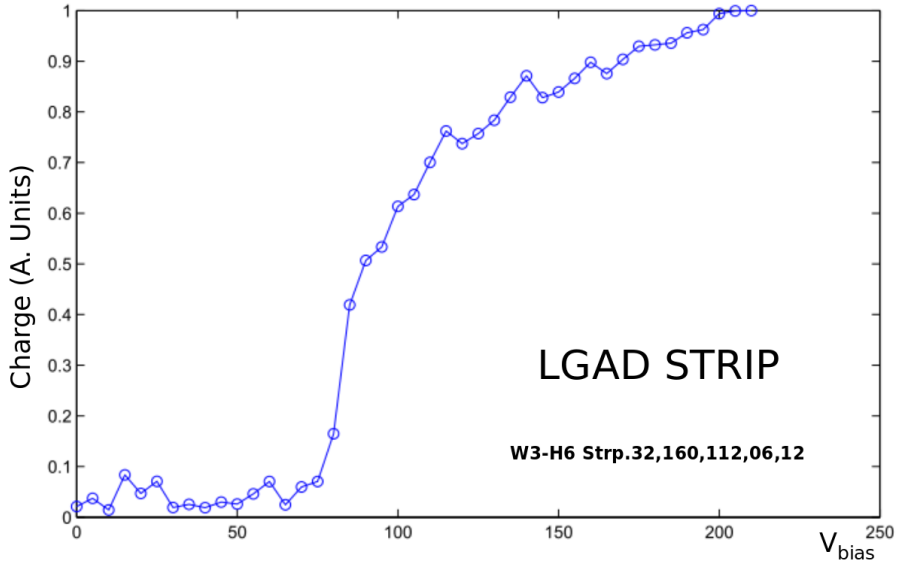
Observations

Charge collection

- for the PINs it stabilises after depletion,
- for the LGADs it continues increasing.

  ↪ The higher the voltage the higher the multiplication.





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Conclusions

- LGADs from CNM run 7859 were analysed.
- There were samples with two different multiplication-layer implant doses:
  - 1.8×10^{13} cm^{-2}
  - 2.0×10^{13} cm^{-2}
- CV/IV curves before and after irradiation are as expected (in most cases).
- TCT+ results before irradiation:
  - Charge collection curves for 1.8×10^{13}cm^{-2} LGADs are as expected.
  - Abnormal charge collection behaviour in on of the PINs from W1. ⚠
  - For IR back and red front
    $\hookrightarrow$ Both 2.0×10^{13}cm^{-2} LGADs and PINs show a difference in charge collection between wafers (W3 and W4). ⚠
  - Homogeneous charge collection before irradiation.
- Sr-90 source measurements are as expected.
- Gain values for TCT IR back and Sr-90 differ greatly. ⚠
- Wafers 3 and 4 (same multiplication layer dose) present different gains for TCT IR back and red front. ⚠
- Microstrip LGADs behave as expected before irradiation.

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What comes next?

- TCT+
  - Verify homogeneity after irradiation.
  - Study charge profile.
    - Compare to the charge profile of irradiated PIN diodes.
    - Calculate gain after irradiation.
- Sr-90
  - Analyse charge collection after irradiation.
- Microstrip LGADs
  - Continue with their study before and after irradiation.

Thank you

Backup Slides

Foot voltage vs fluence

After irradiation defining the foot voltage is not trivial.

Multiplication layer dose	1.8×10^{13} cm^{-2}	2.0×10^{13} cm^{-2}
Fluence (1 MeV n_{eq}/cm^{-2})	Foot voltage (V)	
10^{12}	30	30
10^{13}	30	30
10^{14}	25	30
10^{15}	20	25