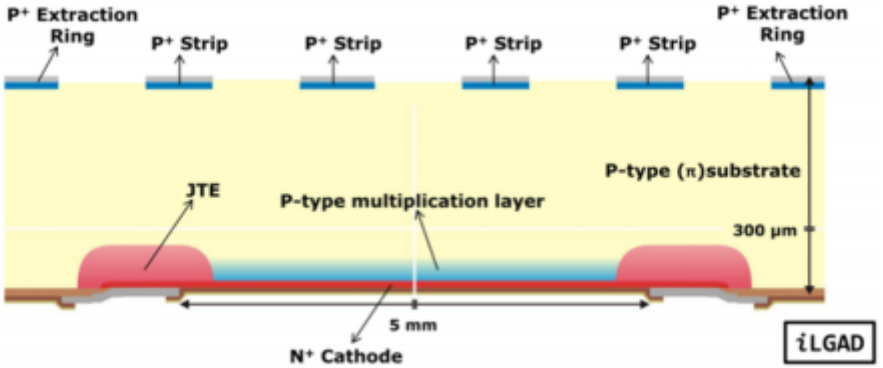


inverse LGAD:

Solving the LGAD fill factor problem

RD50

31st RD50 Workshop

CERN, 20th-22nd Nov. 2017

Jordi Duarte-Campderrós

IFCA Instituto de Física de Cantabria

CSIC Consejo Superior de Investigaciones Científicas

UC Universidad de Cantabria

CERN

The team

M. Carulla[1], J. Duarte-Campderrós[2,3], M. Fernández[2], D. Flores[1], A. García[2], G. Gómez[2], J. González[2], S. Hidalgo[1], R. Jaramillo[2], A. Merlos[1], M. Moll[3], D. Moya[2], R. Palomo[4], G. Pellegrini[1], D. Quirion[1], A. Ruiz[2], I. Vila[2]

[1] IMB-CNM (CSIC)

[2] IFCA (CSIC-UC)

[3] CERN

[4] Universidad de Sevilla

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.

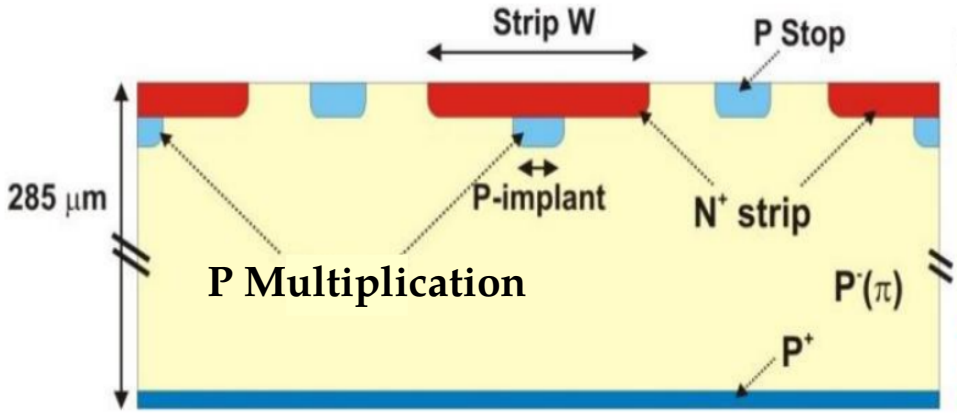
The n-in-p and p-in-p LGAD strip-like

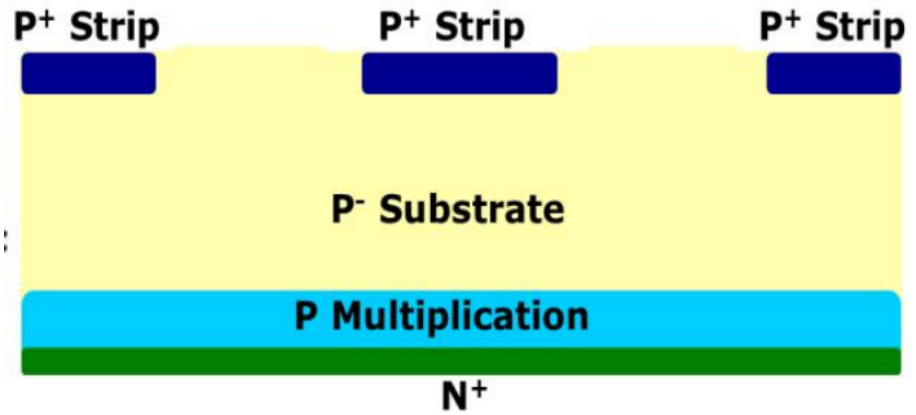
LGAD: a n-in-p micro-strips

- multiplication layer segmented
- collects negative carriers
- simple side process

iLGAD: a p-in-p micro-strips

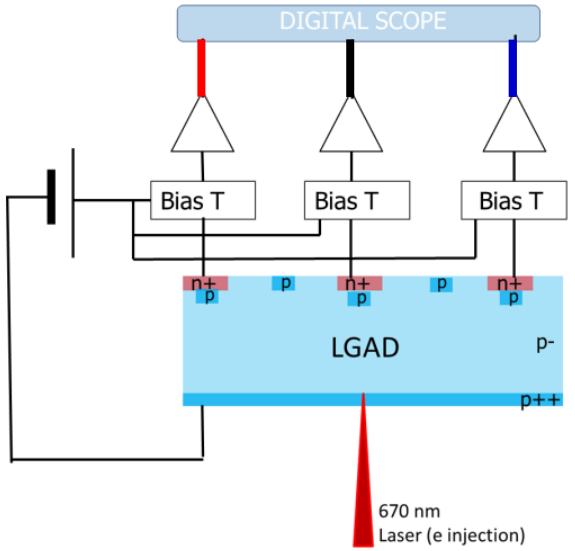
- no segmentation in the multiplication layer
- collects positive carriers (h)
- complex double side process

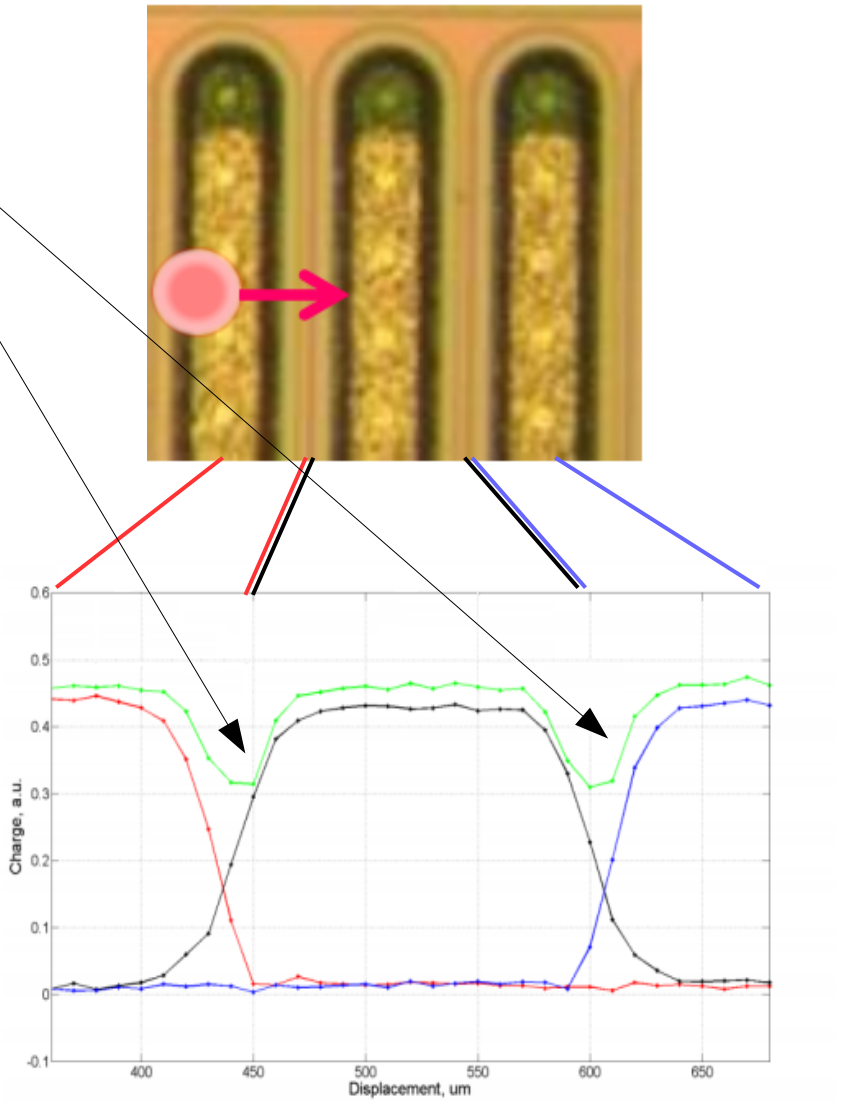




The fill factor problem in the LGAD

- LGAD shows signal deeps between the strips
  - signal collected not passing through multiplication layer

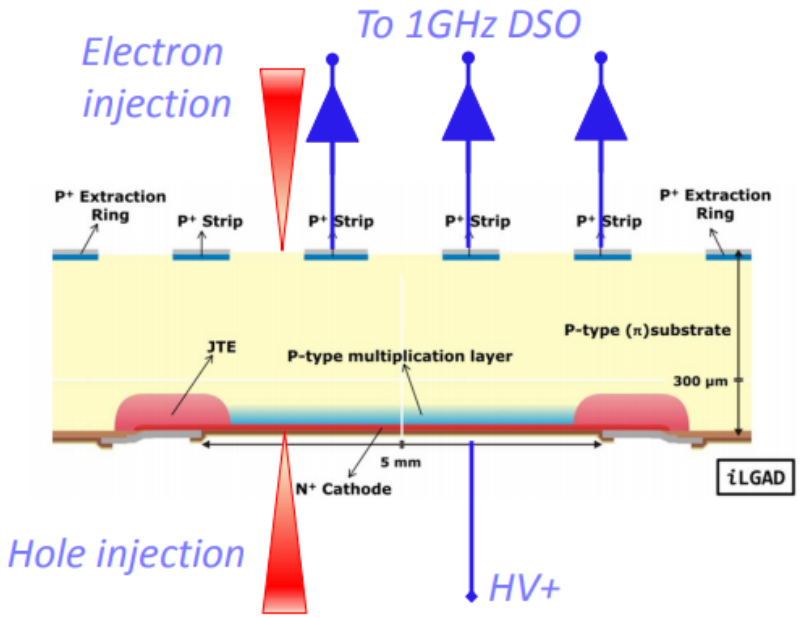




Back side red laser scanning transversal to the strip direction: electron injection

The fill factor in i-LGAD

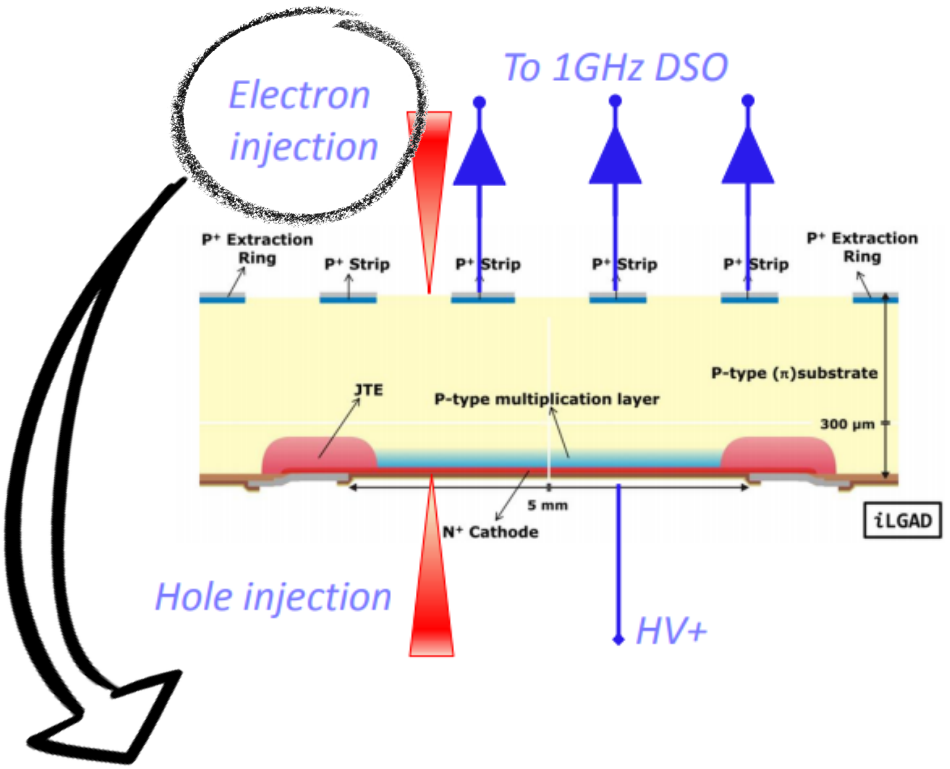
Multi-channel TCT on DC strips



- Simultaneous transient current acquisition (up to three strips)
- Electron/hole injection with 670 nm red laser back-side illumination

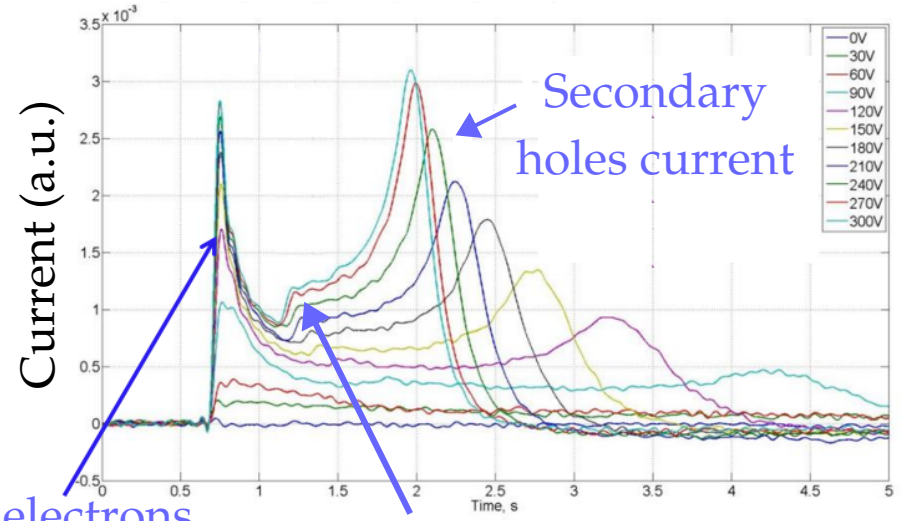
I-LGAD (r#8533) manufactured as DC mini sensors (biasing through decoupling capacitor)

The fill factor in i-LGAD (II)



- **First observation of signal amplication** (June 2016)

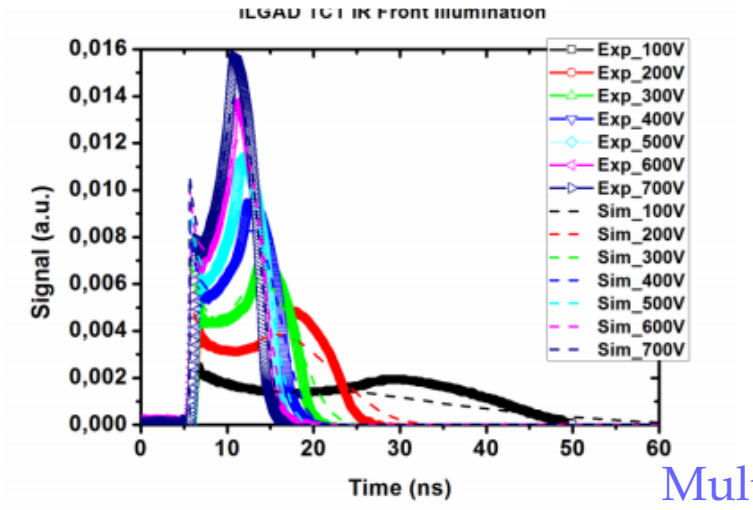
- Simultaneous transient current acquisition (up to three strips)
- Electron/hole injection with 670 nm red laser back-side illumination

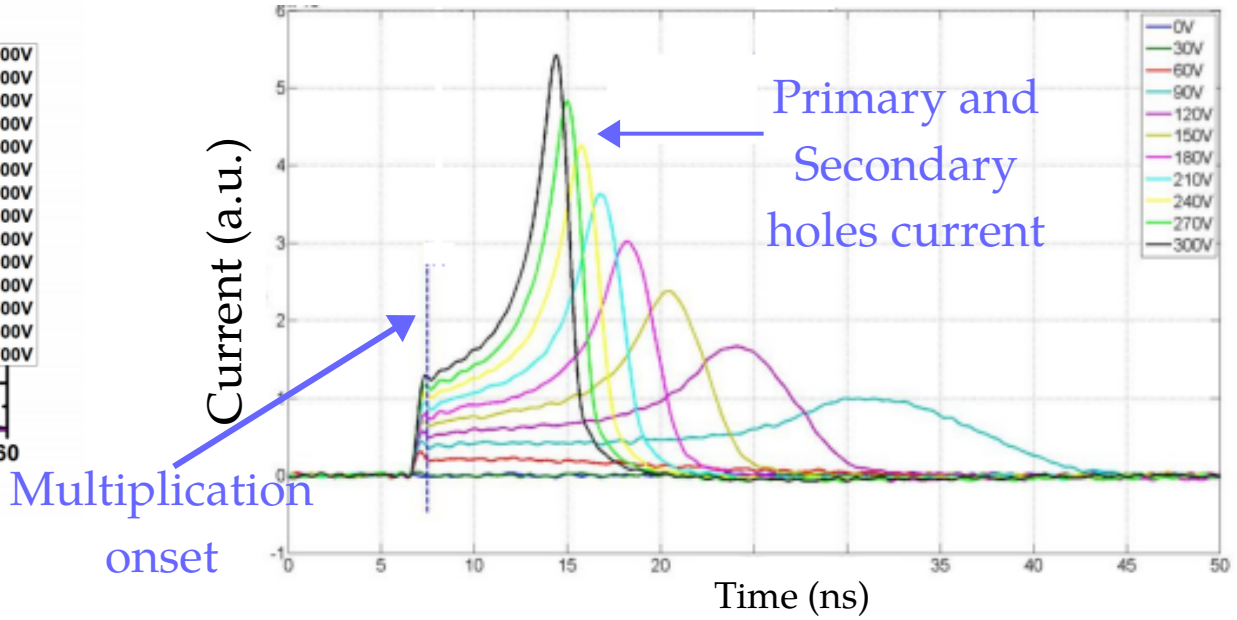


The fill factor in i-LGAD (III)

- IR Laser
  - Collected charge vs. Vbias: simulation qualitatively agrees with observed data

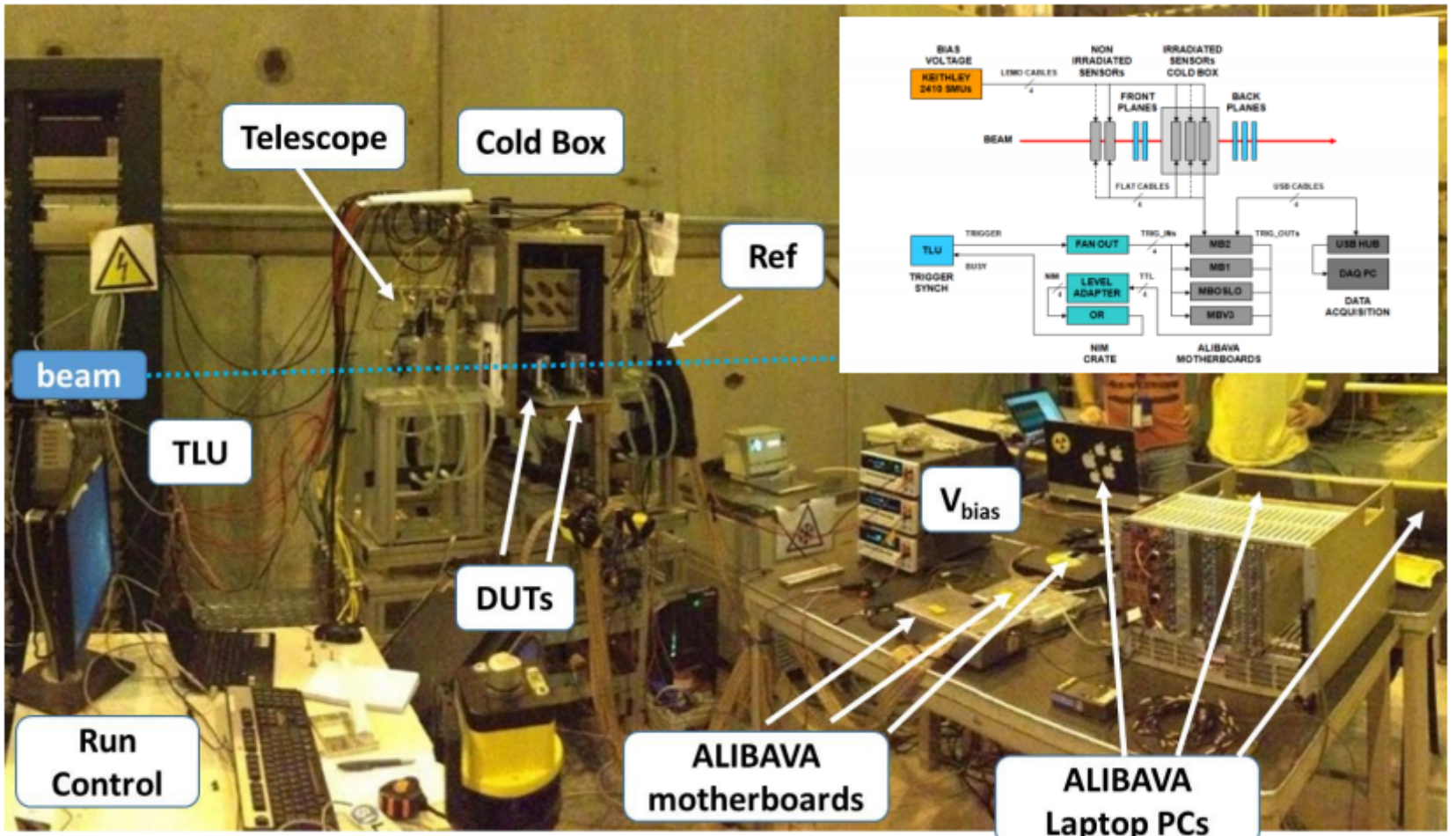
Simulation (arbitrary scales/simulation norm.)





MIP response: Test-Beam at SPS

Inverse-LGAD TB: **AIDA-2020 WP7 Setup**
aka as ATLAS ITK Setup (2016,2017)

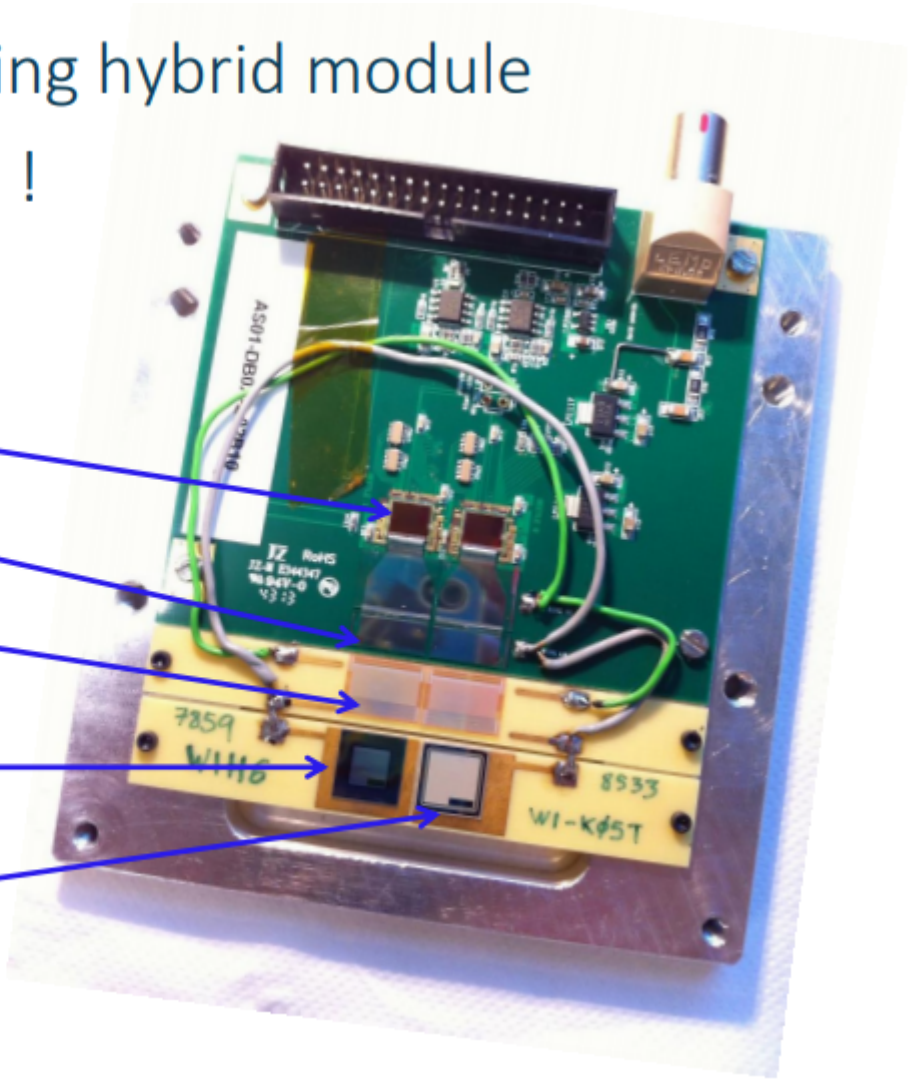


This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.

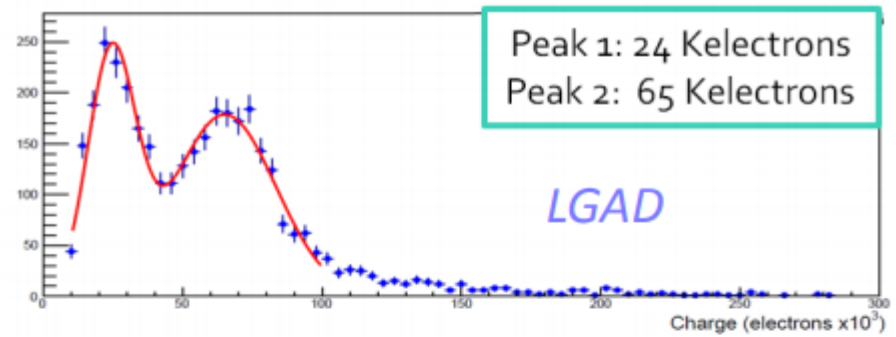
MIP response: Test-Beam at SPS

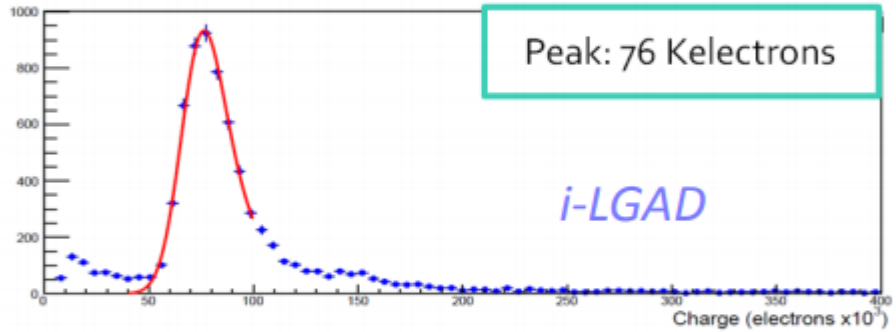
First ever multi-channel tracking hybrid module

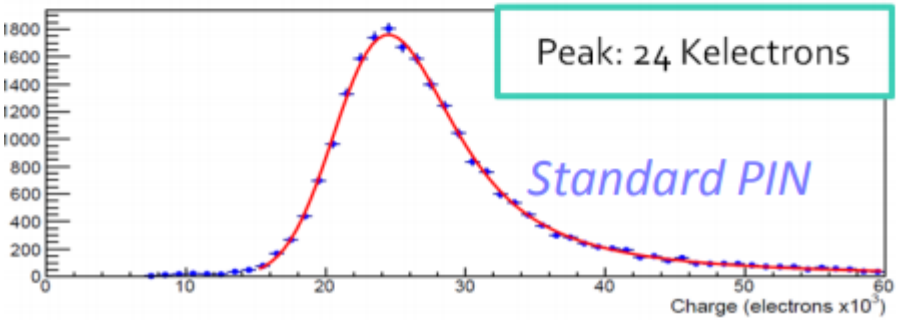
Based on I-LGAD & Strip LGAD !



MIP response: cluster charge distributions

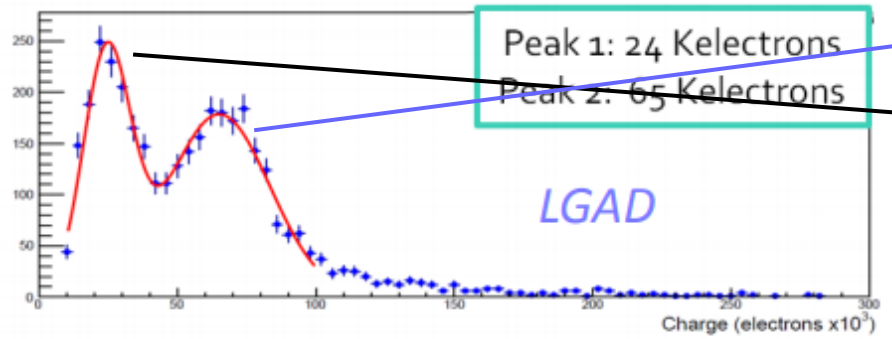


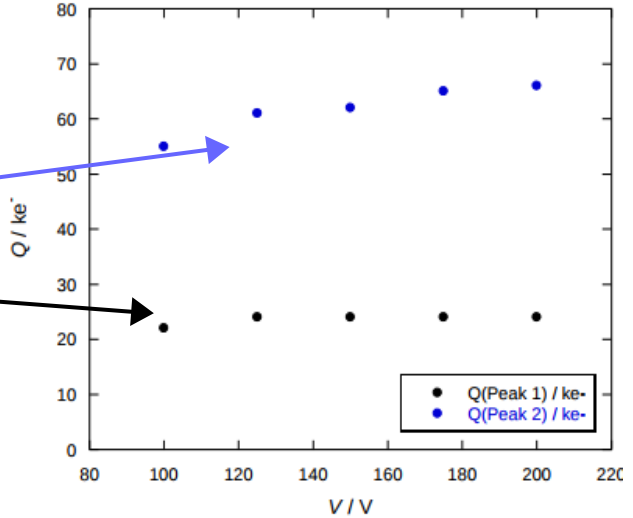


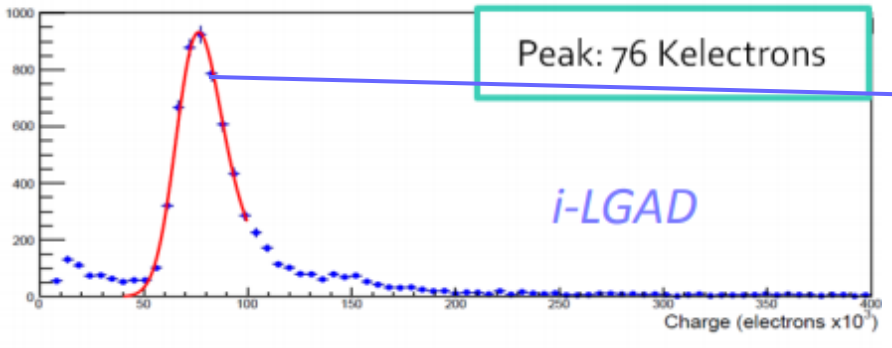


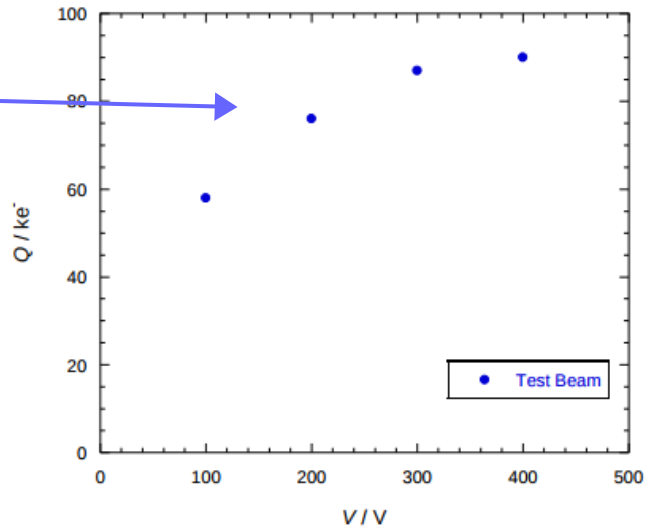
- LGAD
  - double peak structure: tracks with/without gain
- iLGAD
  - single peak → all tracks multiplied
- Reference sensor
  - standar strip detector with no gain

MIP response: cluster charge distributions

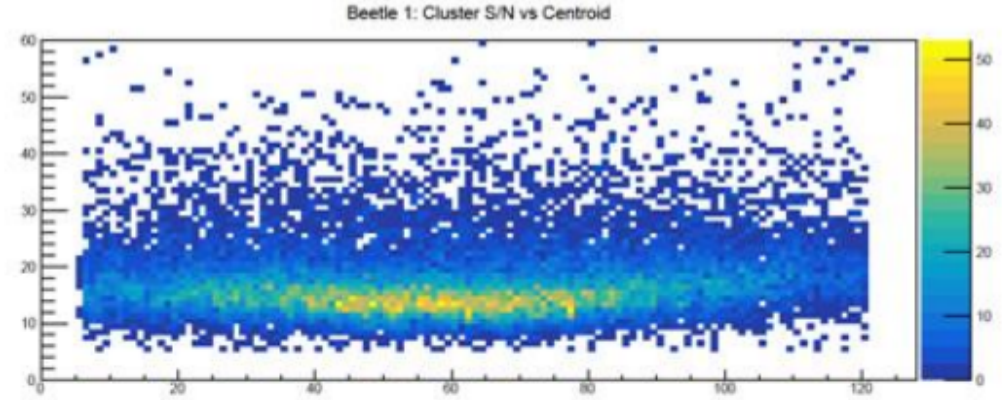


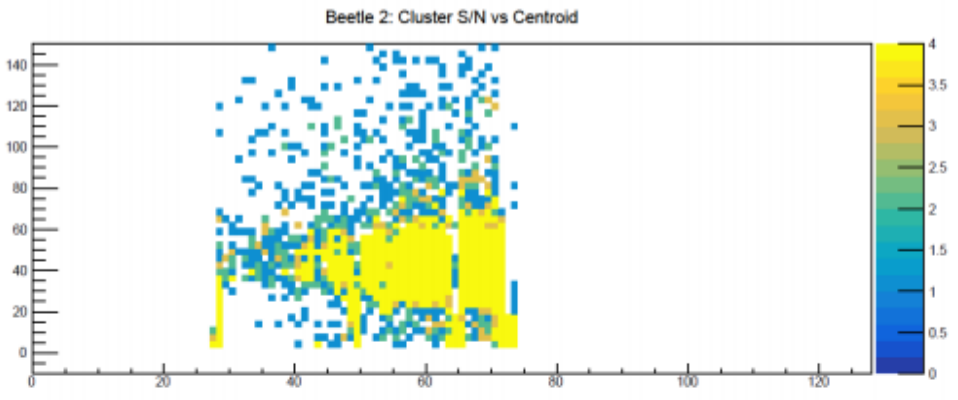


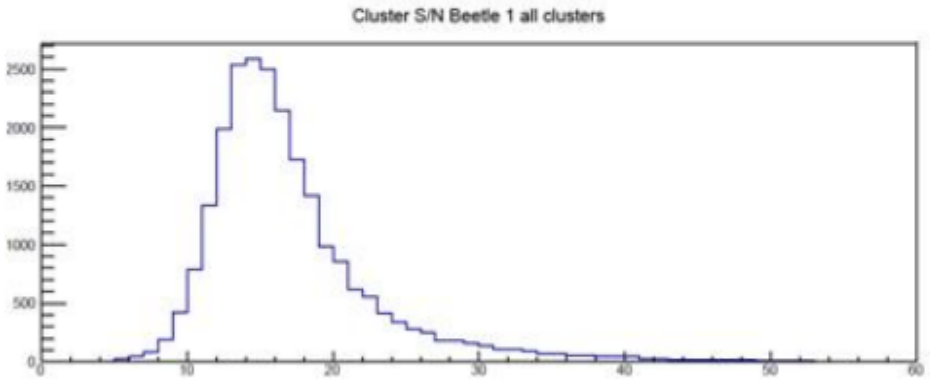


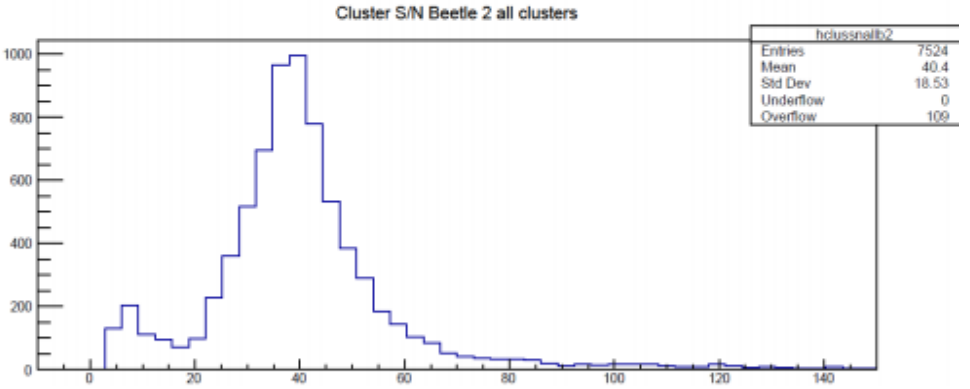


MIP response: Signal-to-Noise







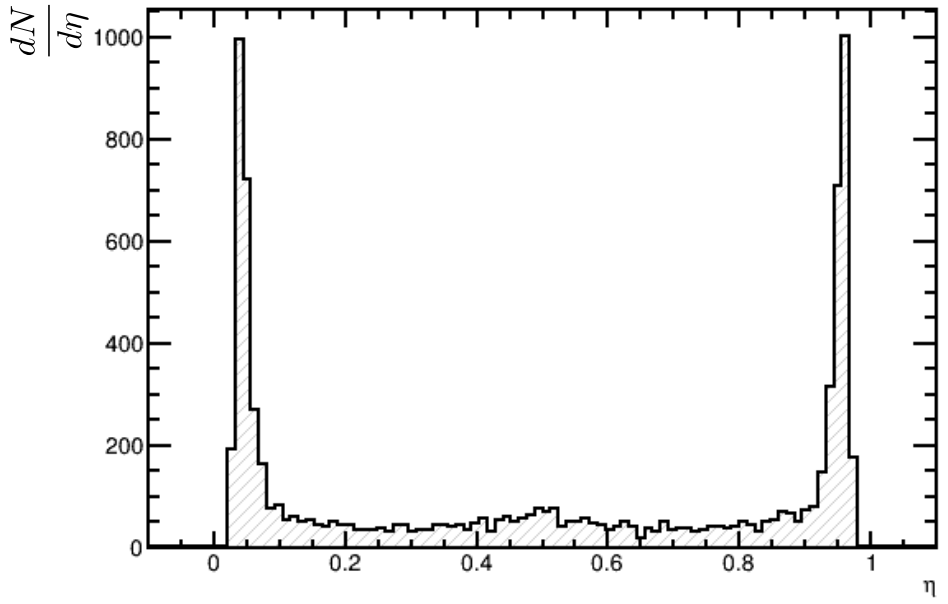


Reference sensor
S/N ≈ 17

iLGAD
S/N = 40

MIP response: Signal-to-Noise (II)

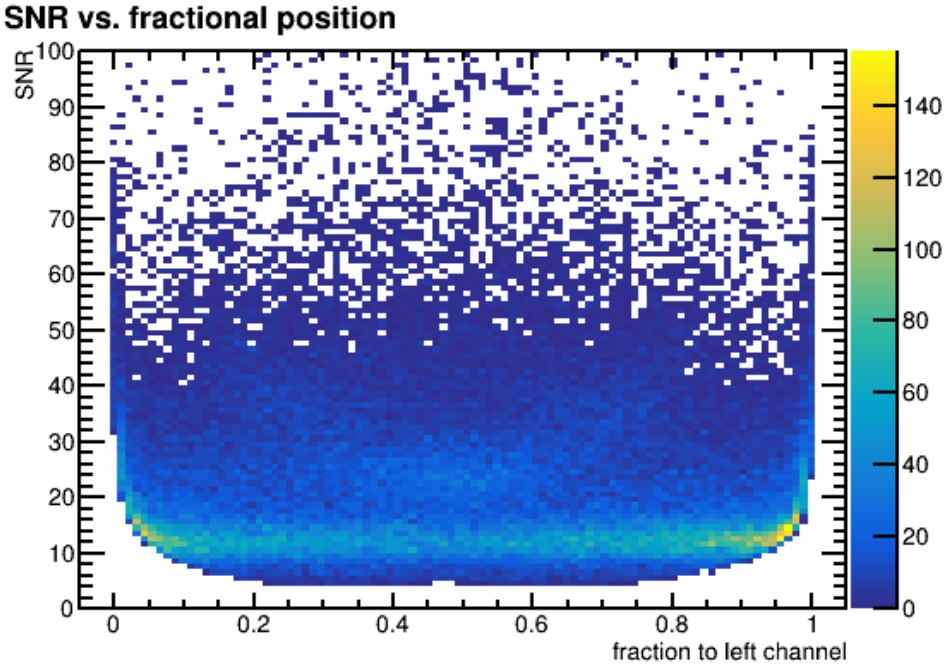
- Fractional position dependence of the SNR (clusters size 2)
  - collected cluster charge distribution: $\frac{dN}{d\eta}, \quad \eta \equiv \frac{Q_{Right}}{Q_{Left} + Q_{Right}}$
  - average impact point: $x(\eta) = \frac{1}{N_0} \int_0^{\eta} \frac{dN}{d\eta} d\eta$

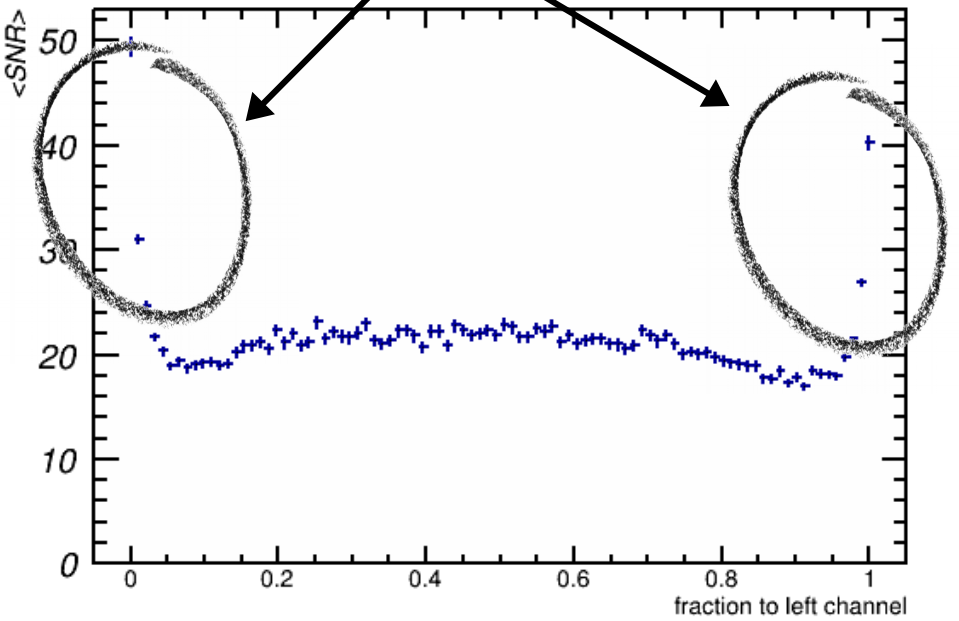


MIP response: Signal-to-Noise (II)

- Standard Strip sensor: **uniform** SNR over the pitch width.
  Average SNR ~ 21

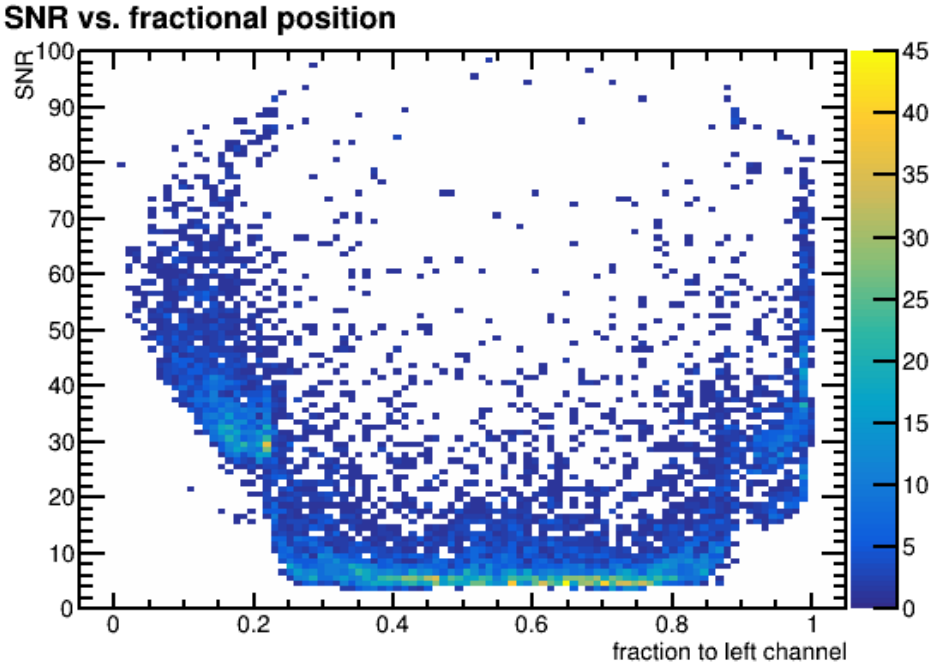
Artifact: selection algorithm, cluster size 2, close to the edges

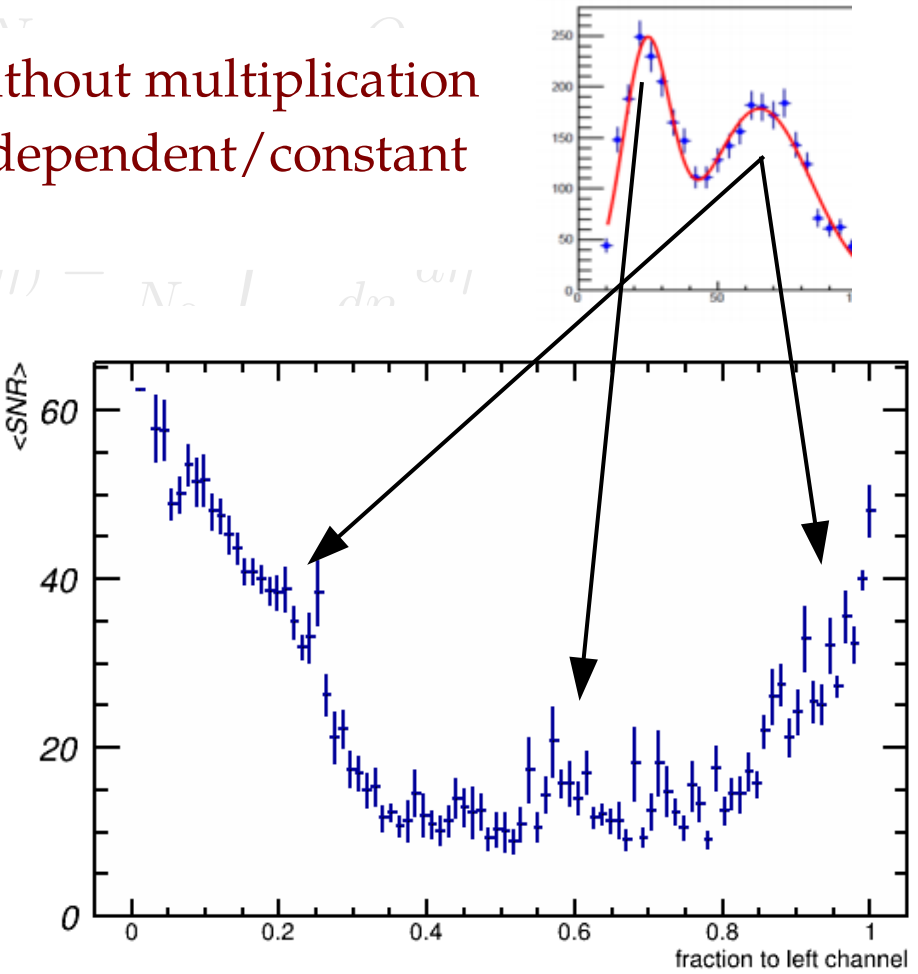




MIP response: Signal-to-Noise (II)

- LGAD: two different regions with/without multiplication
  - each corresponding to the Vbias-dependent/constant Landau's peak





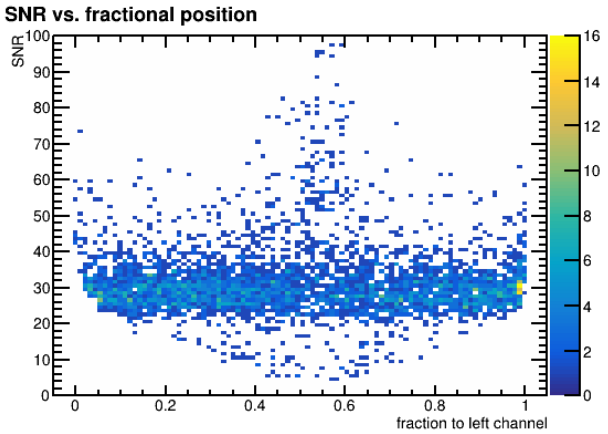
MIP response: Signal-to-Noise (II)

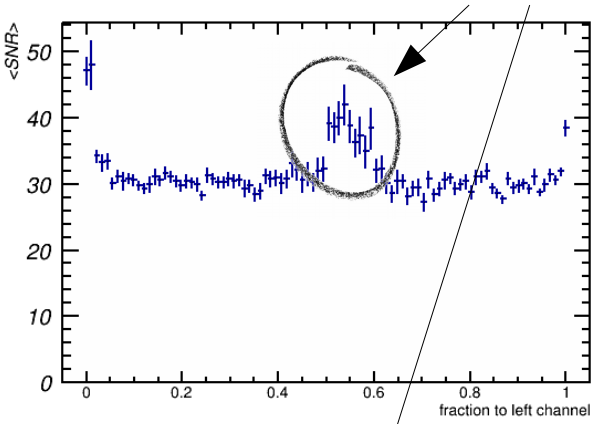
- iLGAD: uniform SNR over the pitch width:
  Average SNR ~ 45 (400V)

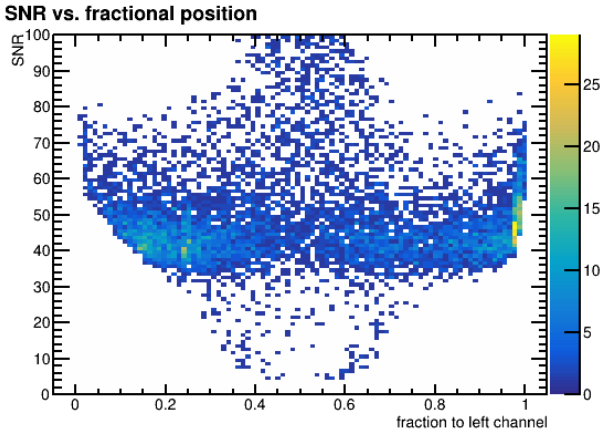
Artifact due to electronics

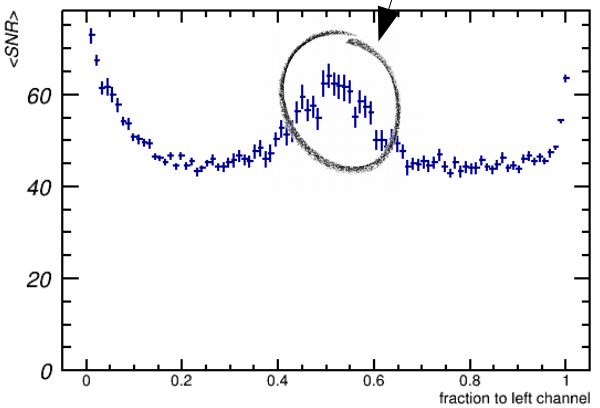
100 V bias

400 V bias









i-LGAD, the ultimate timing detectors?

- Radiation hardness: if the segmentation characteristic size is large (order of few mm^2) against thickness of the diode (less than 50 um) → constant weighting field → Only difference w.r.t. LGAD is the signal polarity
- Complicated fabrication process: complex double side process, must be studied yield efficiencies, … So far, just 3 sensors available

Summary

- Detailed characterization of strip-LGADs and inverse-LGAD
- Performing as expected
- Studying the feasibility of thin detectors
- I-LGAD technology of choice for implementing a strip detector with intrinsic gain and timing capabilities

BACKUP

Signal amplification footprint

- Distinct signature of signal amplification
- Injections of electon into the anode: resulting transient current is a sequential contribution of primary electrons reaching the amplification layer and secondary holes drifting towards the anode