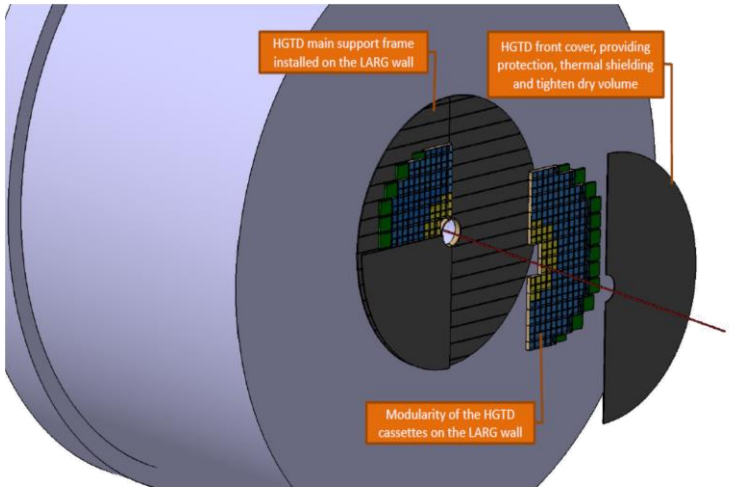

Timing performance and gain analysis of heavily irradiated LGAD diodes

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Test beam In collaboration with RD50: Matteo Centis
Sofia Otero Ugobono

Institut de Física d'Altes Energies

30th RD50 Workshop – 6 / 6 / 2017

•Overview

The Sensors

IVs

The Setup

Reference Calibration

Noise calibration

Cividec Results

UCSC Board Results

Breakdown and stability

Conclusions

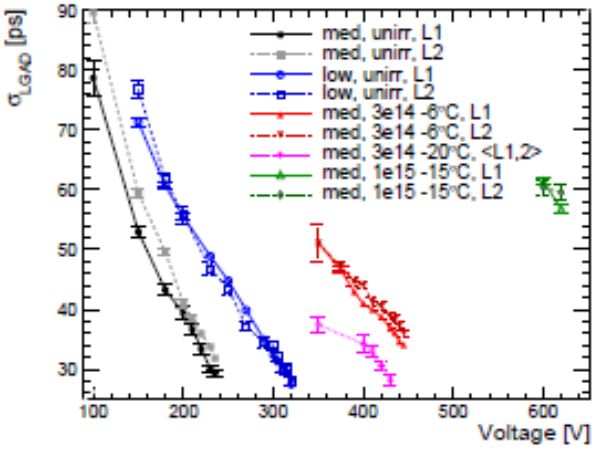
- Sensor list, current status and dta operations
- Pre and during test beam IVs
- Test beam setup @ H6A CERN
- SiPM Study and time reference calibration
- Oscilloscope noise calibration
- 3e15 and 6e15 results with CIVIDEC readout amplifier
- Gain voltage and timing resolution for 1e15 with UCSC single channel board
- Head-room, and double peak issues
- Plans and conclusiosn

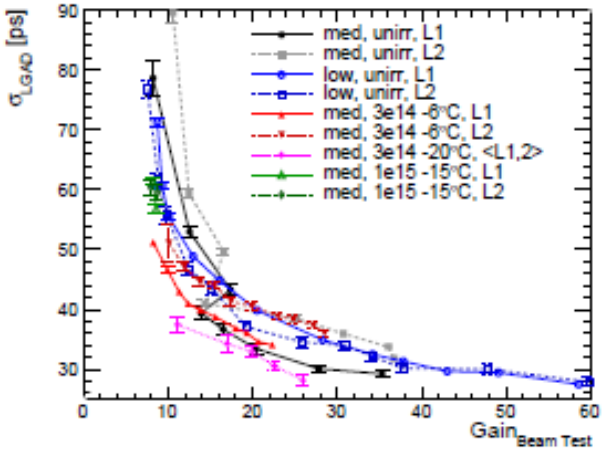
•Overview

- Continuation of previous results from January

Gain and time resolution of 45 µm thin Low Gain Avalanche Detectors before and after irradiation up to a fluence of 10^{15} n_{eq}/cm^2

J. Lange et al., JINST 12 (2017) P05003





•Tested sensors and status

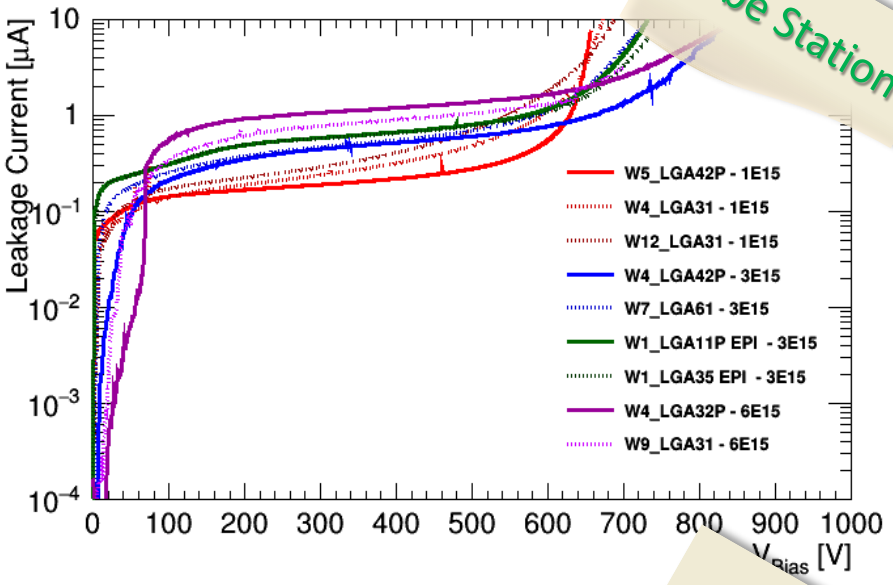
- Two un-irradiated sensors for reference
- One PIN per fluence for reference
- 1e15: High and Low implantation dose, nominal already tested
- 3e15: Nominal implantation dose
- 6e15: Nominal implantation dose

} **Neutron irradiated at JSI**

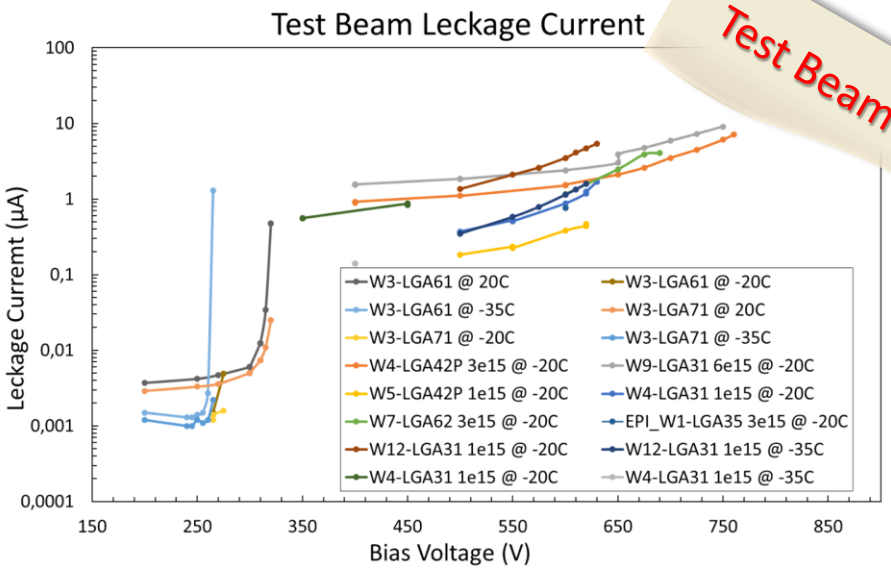
Status	Wafer	Irradiated Dose	Type	Implant
Standard Unirradiated	W3-LGA61	Un-irradiated	LGAD	Low
	W3-LGA71	Un-irradiated	LGAD	Low
Data at -20C and also -35C for W12	W4_LGA31	1e15	LGAD	Low
	W12_LGA31	1e15	LGAD	High
	W5_LGA42P	1e15	PIN	-----
Data at -20C	W7-LGA61	3e15	LGAD	medium
	W4-LGA42P	3e15	PIN	-----
Dead – No data	EPI_W1-LGA35	3e15	LGAD EPI	low
Data at -20C	W9-LGA31	6e15	LGAD	medium
Dead – No data	W4-LGA32P	6e15	PIN	-----

•Test Beam IVs

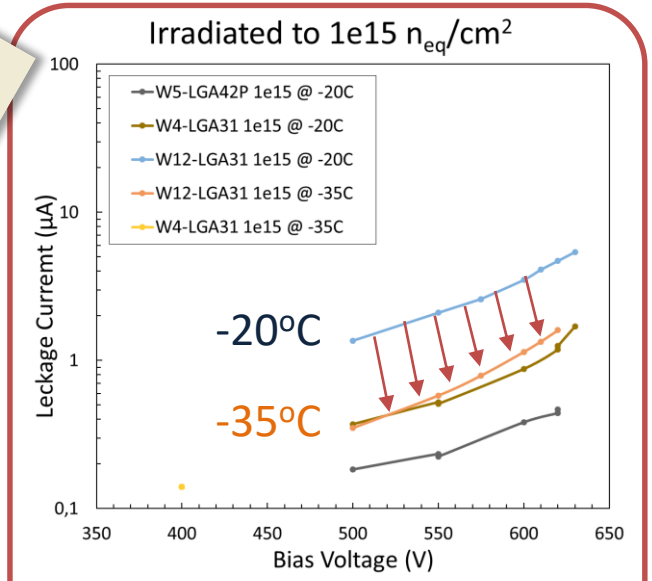
Probe Station

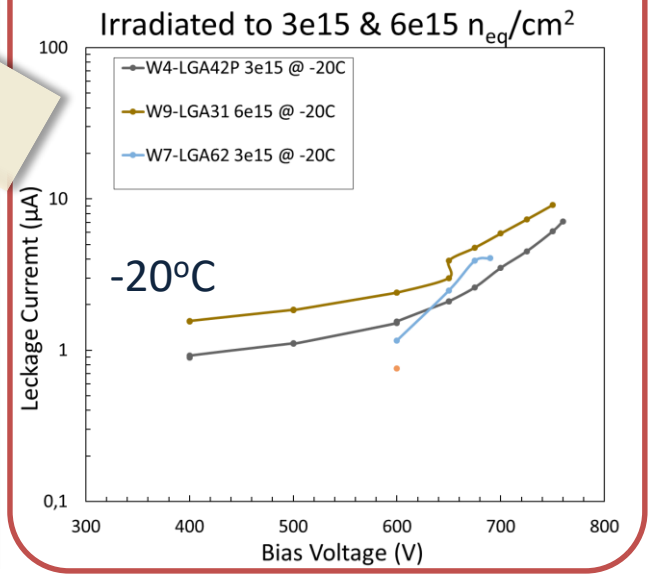


Test Beam



Irradiated





•Test beam Setup

- Test beam at CERN - H6A
- No tracking
- 120 GeV SPS protons
- Cold box and temperatures of -20C , -35C
- Annealed at 80C for 60 min

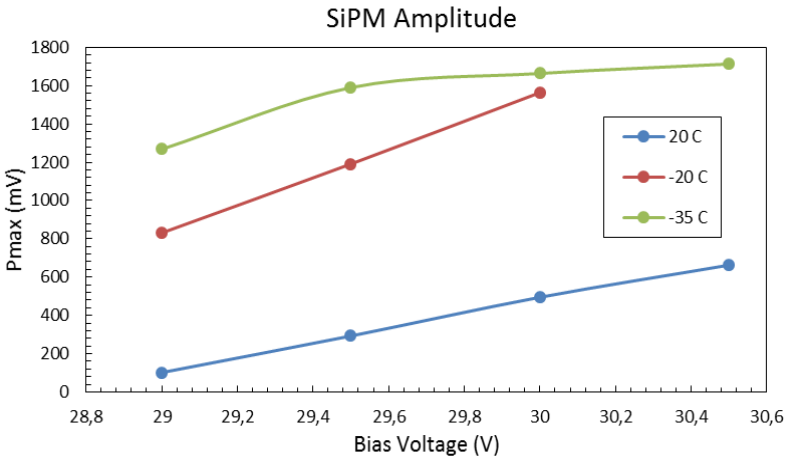
11 – 17 / 5

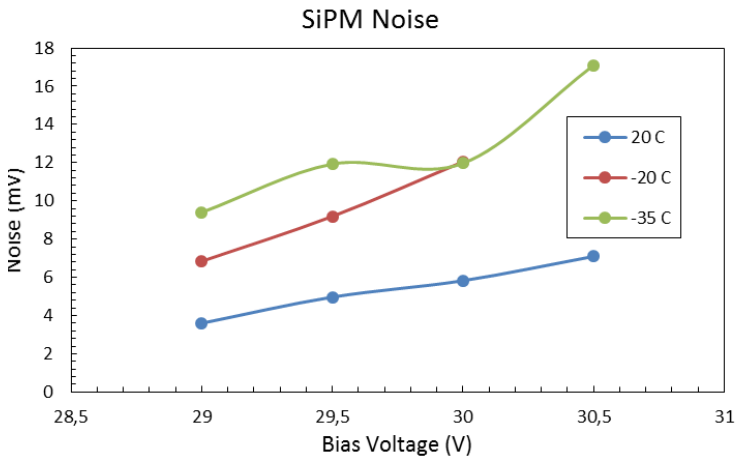
Four wire-bonds to decrease inductance

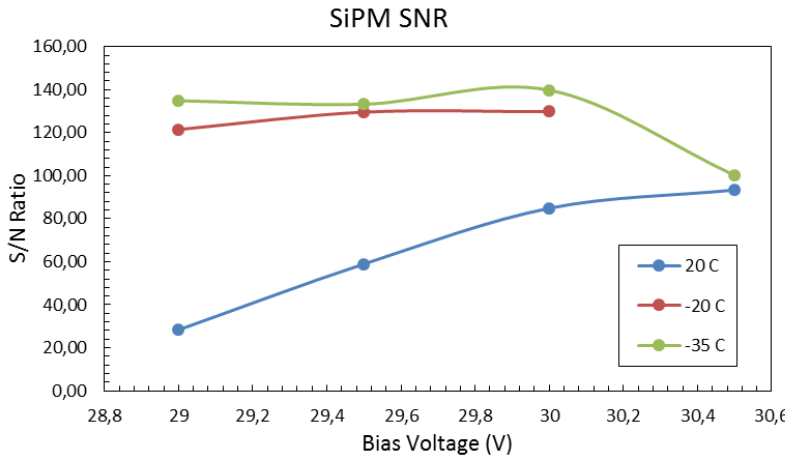
Two different readout boards:

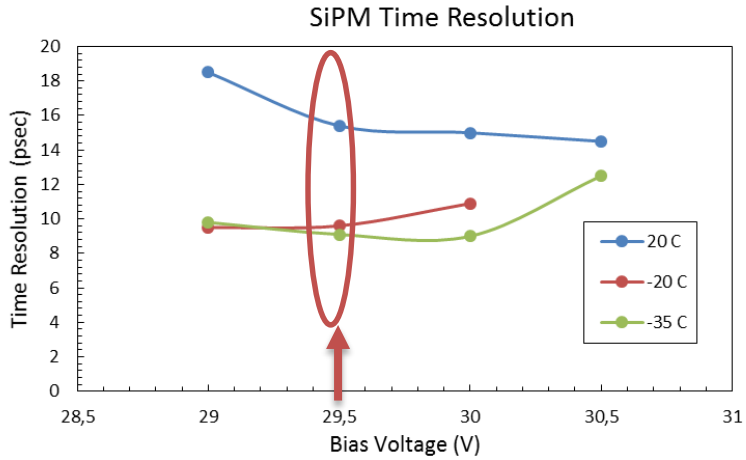
1. TCT board with HV RC filter + CIVIDEC TCT amplifier
    1. Passive board with simpler design
    2. No Shielding
    3. Problems with CIVIDEC termination
2. UCSC single channel board + mini-Circuits second stage amplifier
    1. Well shielded
    2. Less sensitive and optimised

•SiPM Studies and Reference



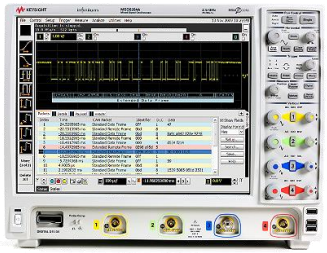


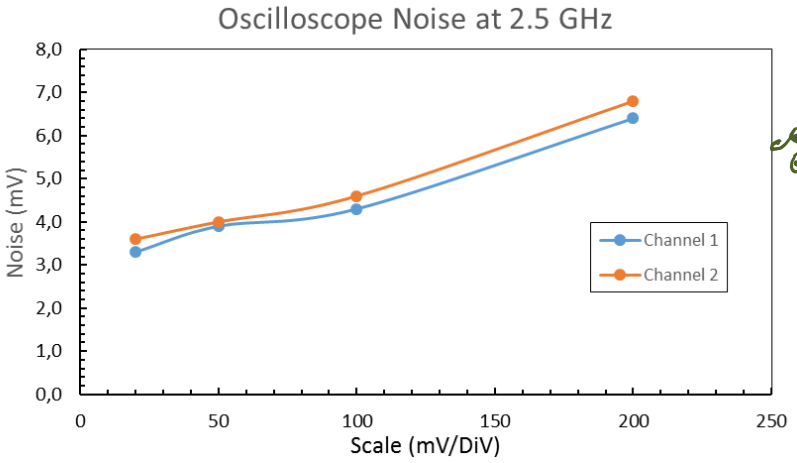




- SiPM study using two identical ST SiPMs (provided by AFP)
- Increasing bias increases signal amplitude but not always improves timing due to higher noise
- **Voltage of choice 29.5 with 15.4, 9.6 and 9.1 psec timing resolution**

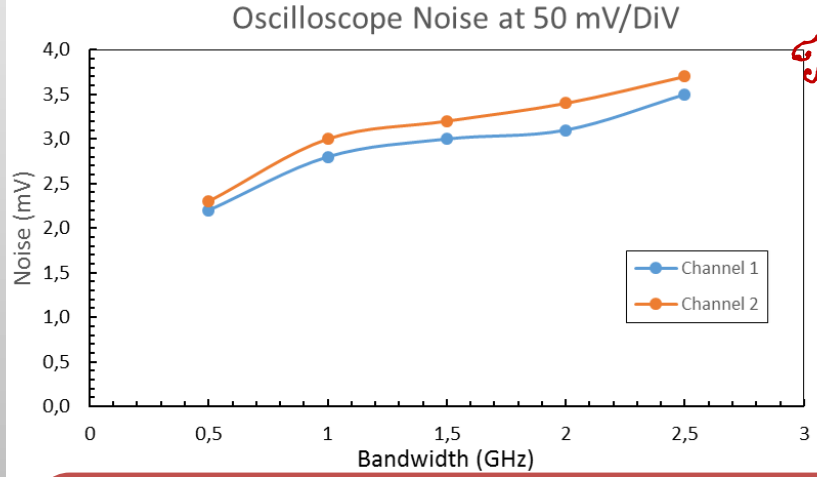
•Noise Calibration Studies





Specifications

- 2.5GHz four Channel Infiniium Agilent Scope
- 10 GSa/s in all channels
- 16 bit ADC output

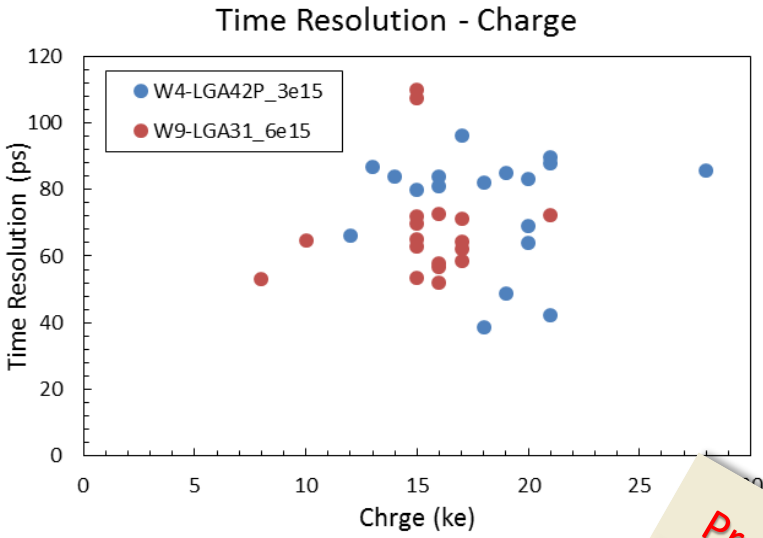


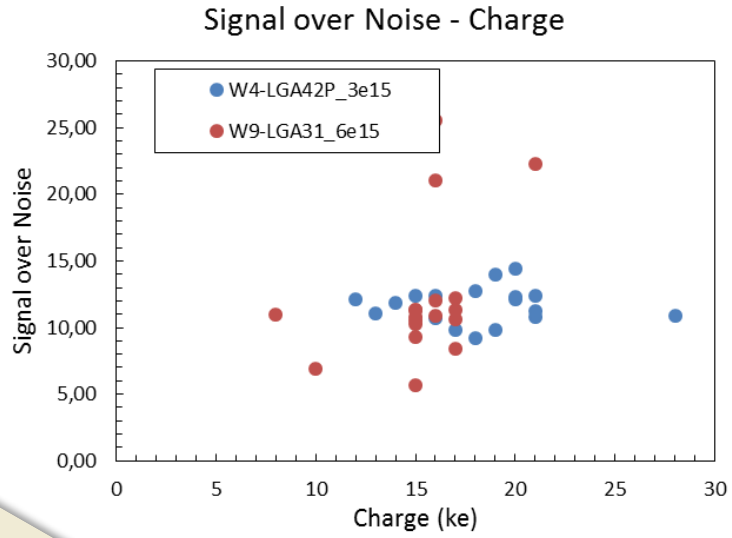
Noise Study

- **Vertical scale study:**
  - I. Unterminated inputs
  - II. Trigger on one channel and monitor other
- **Bandwidth Study:**
  - I. Amplifier on input
  - II. Trigger on baseline noise

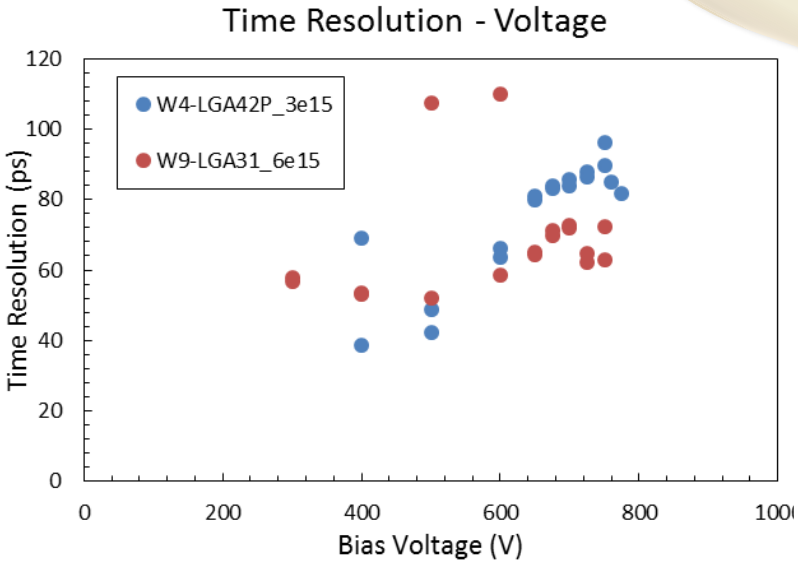
- ✓ **For CIVIDEC amplifiers, bandwidth set at 1GHz**
- ✓ **Signal usually for LGADs around 0.8GHz**
- ✓ **UCSC amplifier not affected by bandwidth variation**

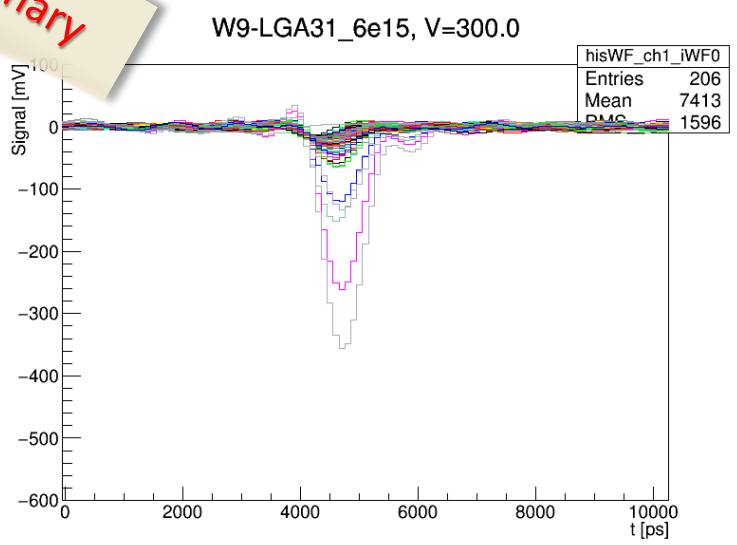
•CiVIDEC results



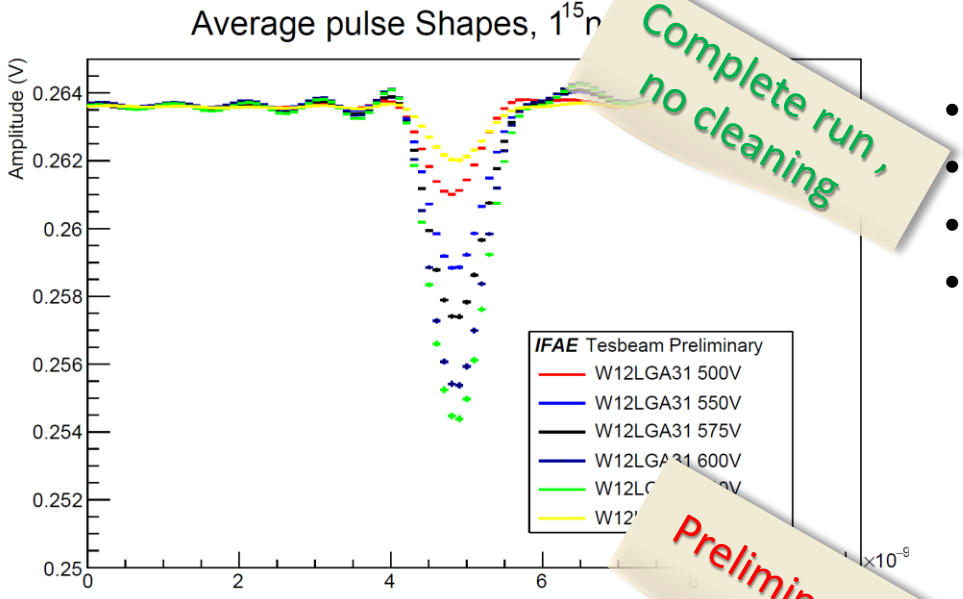


Preliminary



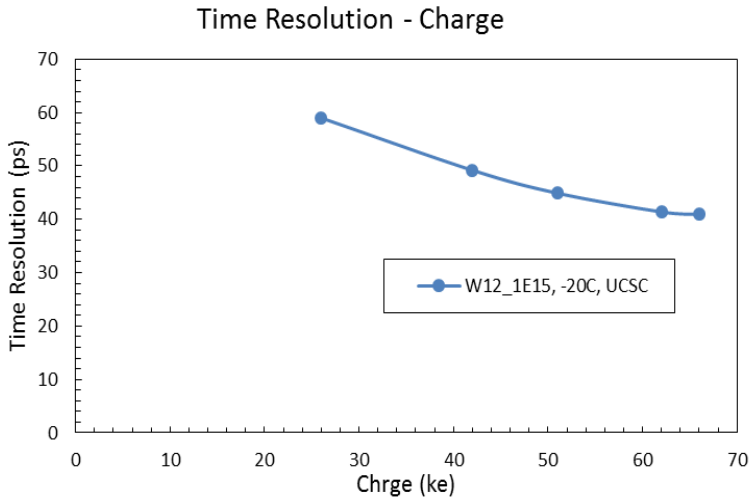


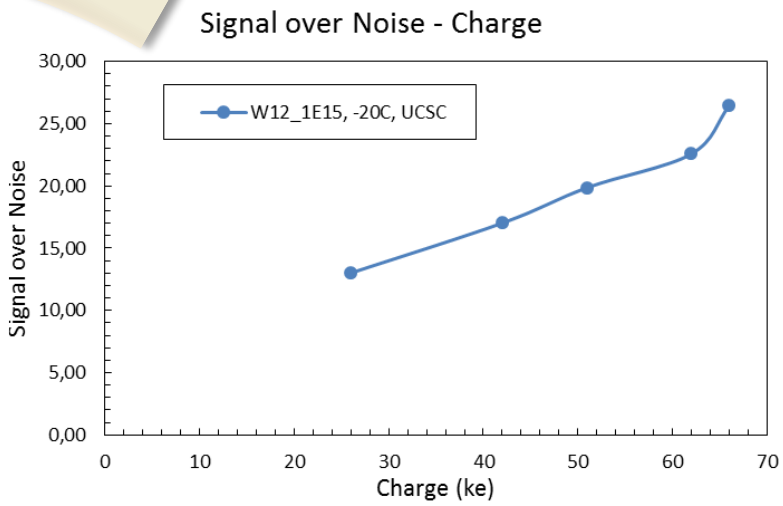
•Results with UCSC board



- Cleaner pulse shapes
- Much higher S/N ratio
- Mo secondary reflections
- Unfortunately only 1e15 survived until the end

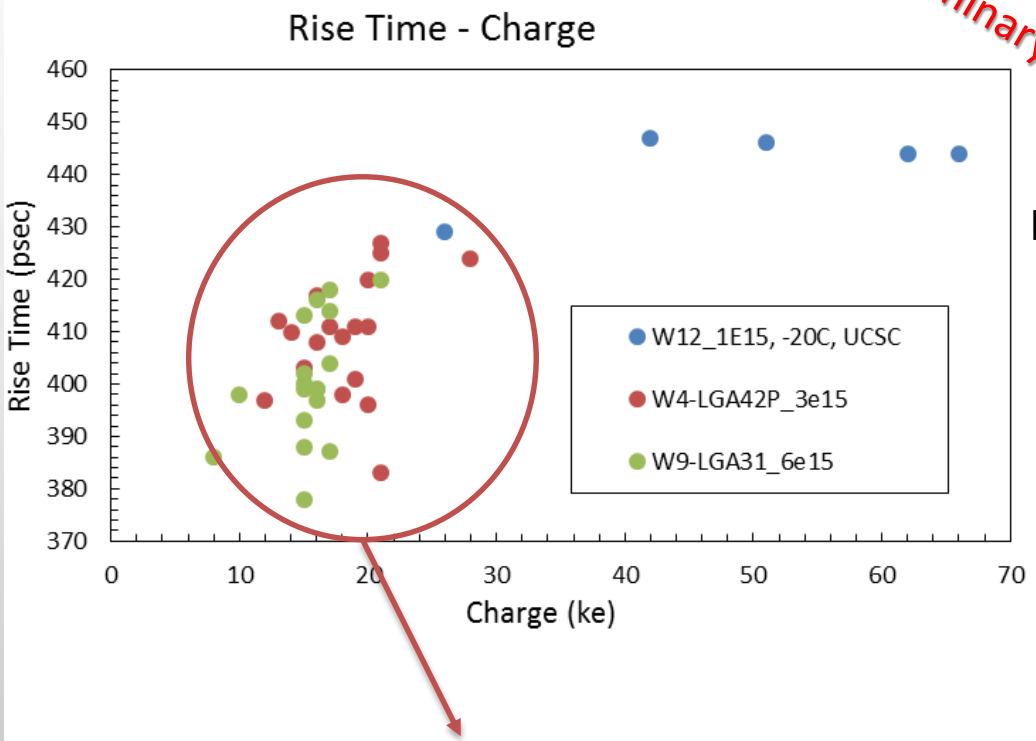
Timing resolution up to 40 psec





•Rise Time analysis

Preliminary

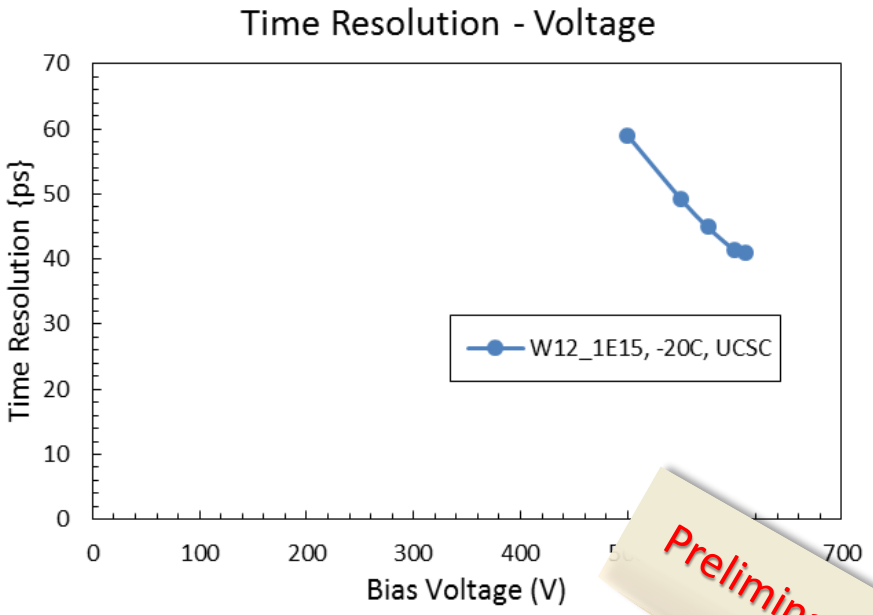


1e15 Irradiated sits at the upper high corner with Higher rise time and more collected charge

Defined as 10 – 90 %

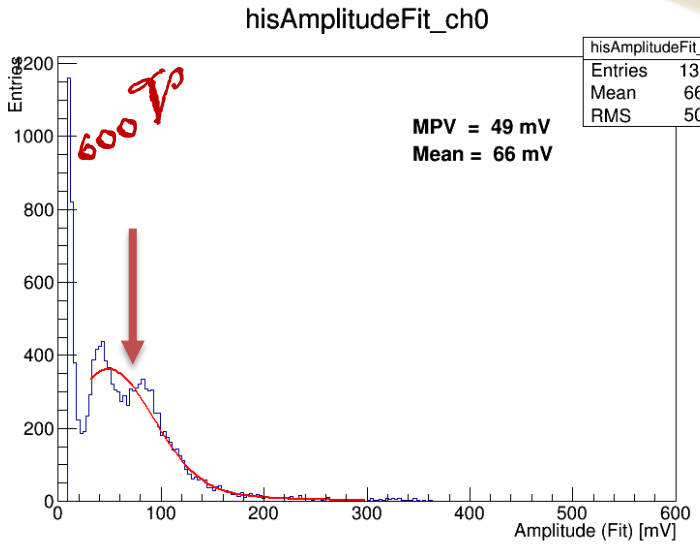
PIN DIODE and 6e15 sit at the no – gain region of the rise time plot
Also first point of the 1e15 (lowest bias voltage)

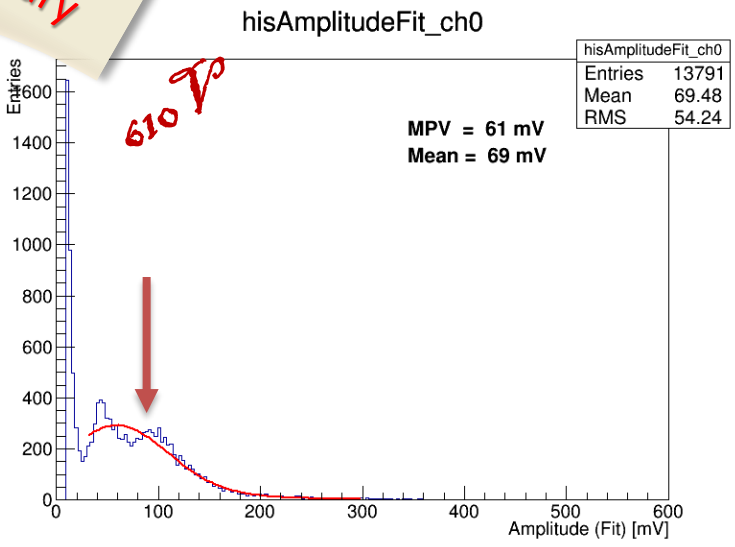
•Break-down and stable operation



- Sensor has gain, has to be calibrated
- Stable operation up to 610V
- Best resolution at last point, very marginal operation
- **Secondary peak in amplitude distribution – more pronounced with voltage**

Preliminary





•Conclusions

Perspectives and further developments

- ✓ There seems to be no apparent gain for 3e15 and 6e15 irradiated devices
- ✓ Very high noise and problems with pulse shape
- ✓ With 1e15 high dose sensor timing resolution up to 40 psec
- ✓ Non recoverable sensor breakdown, need headroom
- ✓ Double peak in amplitude distribution, effect more pronounced with voltage increase

Nest Steps

- ➢ Recoverable data with CiVIDEC?
  - ➢ More elaborate technics for noise rejection
  - ➢ Reconstruct pulse shapes from internal reflections
- ➢ Study and understand double peak effect