Charge Collection of Silicon Sensors

Yebo Chen

On behalf of IHEP ATLAS ITk Group

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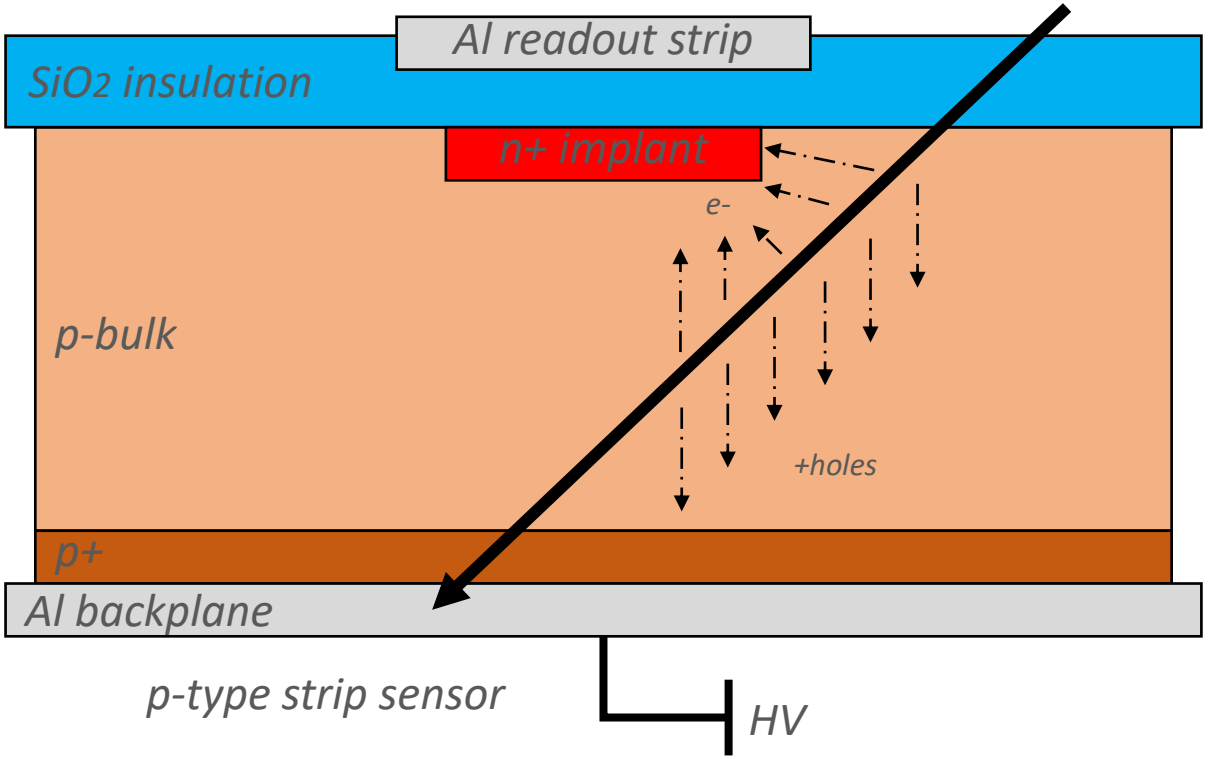
Outline

- Charge collection in silicon strip sensor
- Charge collection system
- ALiBaVa system
- Voltage sweep
- Conclusion

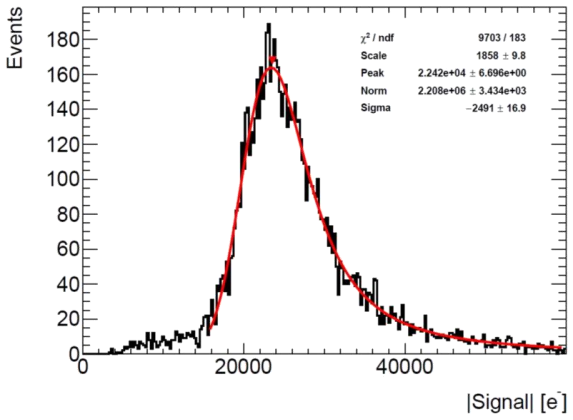
Charge collection in silicon strip sensor

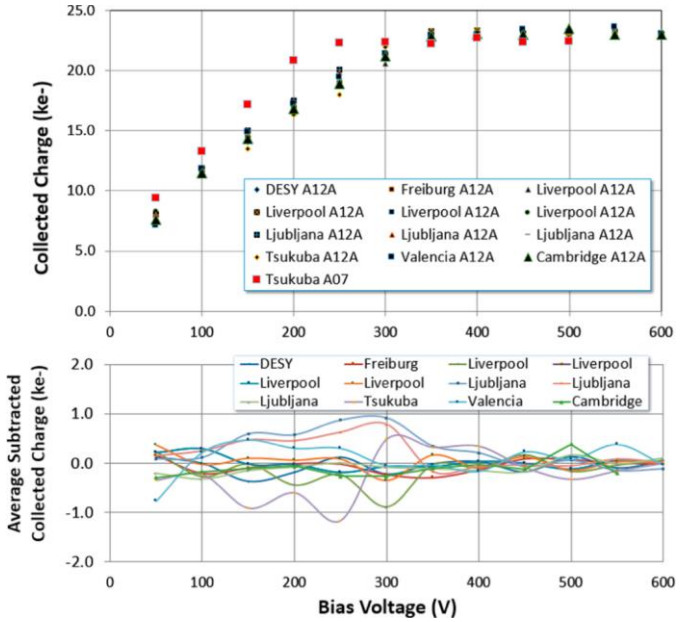
- Ionization
  - Electron-hole pairs generated along the particle trajectory and collected by the electrode via drift
- Capacitive coupling
  - Signal read out through AC coupling (p-type: negative current pulse)



Charge collection in silicon strip sensor

- Charge collection spectrum
  - A Landau function convoluted with a Gaussian





  - MPV: defined as a measure of the collected charge
  - Full charge collection above the full depletion voltage: 23100 e- for a sensor with a 300μm active depth

Charge collection in silicon strip sensor

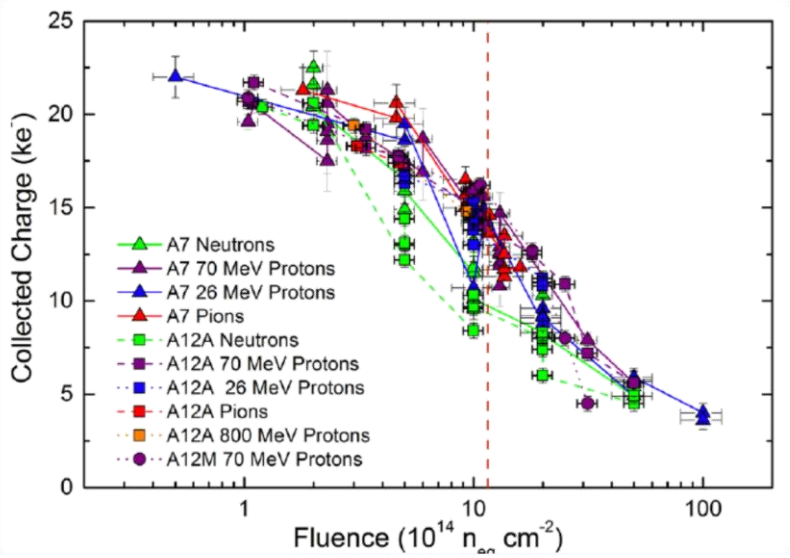
- Radiation environment expectations for the ITk detector

Table 3.6: Overview on maximal fluences and doses. The values including a safety factor of 1.5.

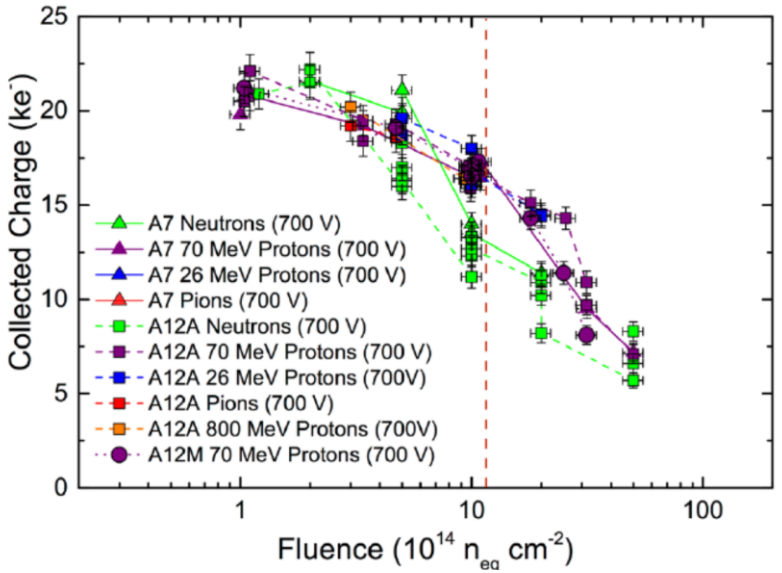
Layer	Radius [mm]	Maximal Fluence [n_{eq}/cm^2]	Maximal Dose [MRad]
Strips			
Long Strips	762	3.8×10^{14}	9.8
Short Strips	405	7.2×10^{14}	32.5
End-cap	385	1.2×10^{15}	50.4
Pixels			
Layer 0	39	1.87×10^{16}	1268
Layer 1	75	0.59×10^{16}	549
Layer 2	155	0.22×10^{16}	129
Layer 3	213	0.15×10^{16}	87
Layer 4	271	0.11×10^{16}	53
End-cap	80	0.62×10^{16}	477

Charge collection in silicon strip sensor

- Charge collection requirements (at the end of lifetime)
  - Bias voltage: -500 V
    Collected charge: 11,500 - 17,300 e^-
  - Bias voltage: -700 V
    Collected charge: 14,000 - 19,500 e^-



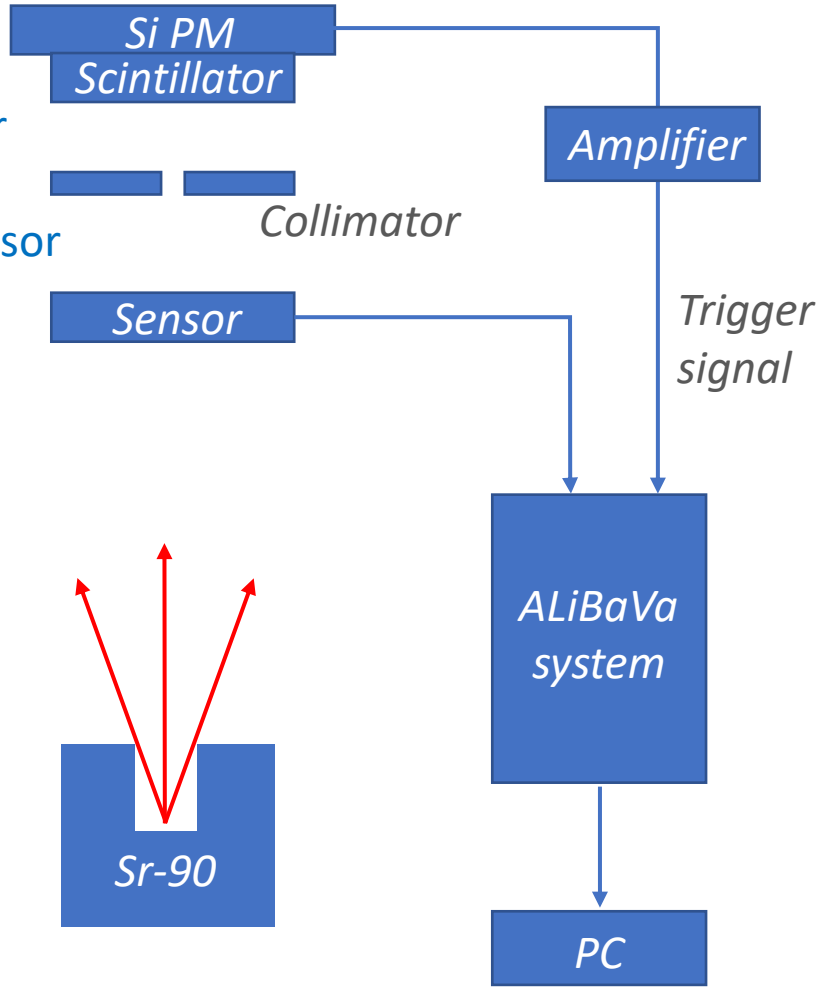
-500V



-700V

Charge collection system

- MIP source: Sr-90
- Trigger: scintillator and silicon photomultiplier
- Sensor to be tested: ATLAS17LS miniature sensor
- Read out system: ALiBaVa system



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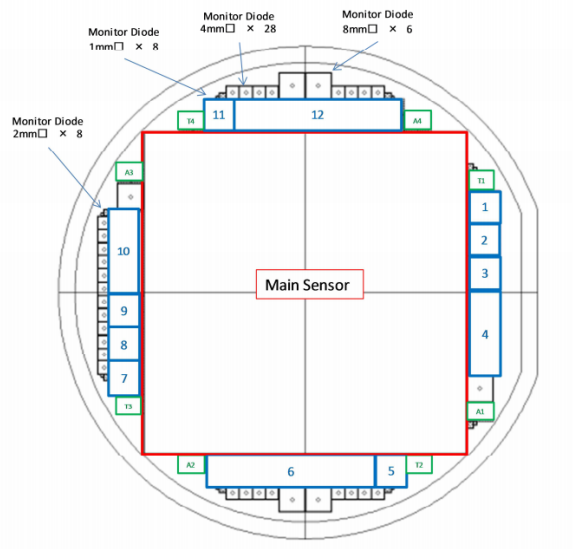
ATLAS17LS Wafer Layout



Miniature Sensors

	Structure (Label)	Type
1	Miniature strips (BBMS1)	MS-B
2	Miniature strips (BBMS2)	MS-A
3	Miniature strips (BBMS3)	MS-A
4	Short strips (BBSS1)	SS-B
5	Miniature strips (BBMS4)	MS-A
6	Long strips (BBLS1)	LS-B
7	Miniature strips (BBMS5)	MS-B
8	Miniature strips (BBMS6)	MS-A
9	Miniature strips (BBMS7)	MS-A
10	Short strips (BBSS2)	SS-A
11	Miniature strips (BBMS8)	MS-A
12	Long strips (BBLS2)	LS-A

Test Structure

A1-4	ATLAS Test Structure
T1-4	HPK Test Structure

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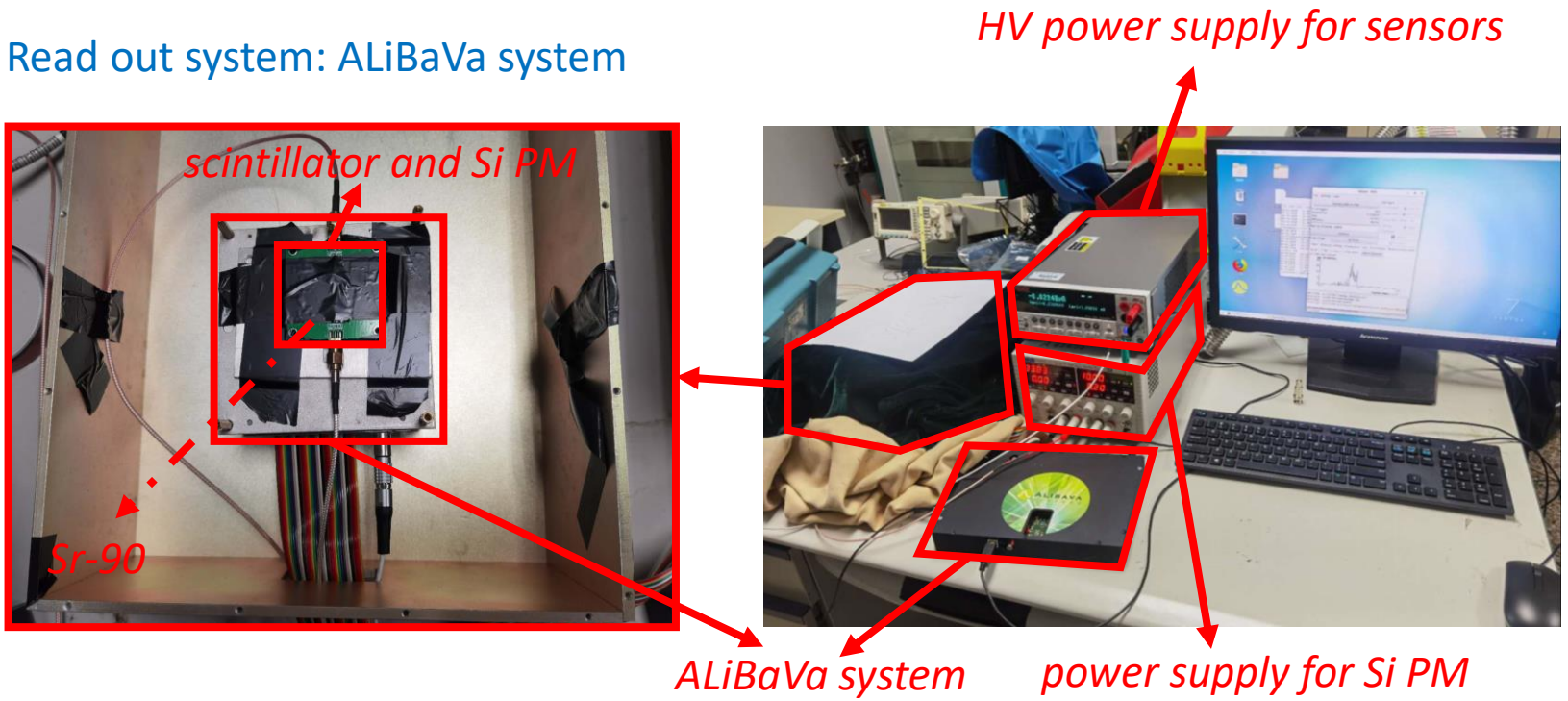


ALiBaVa system

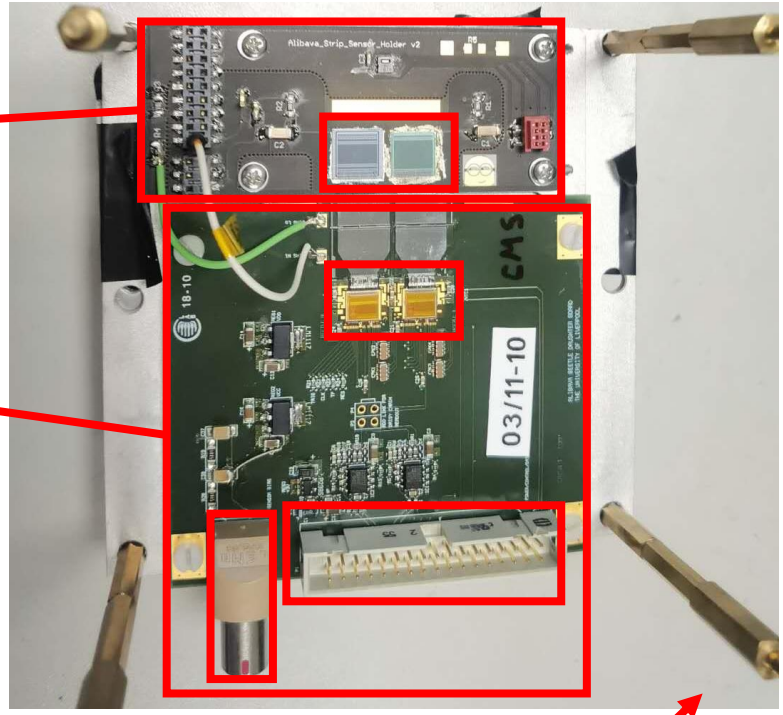
- ALiBaVa (A Liverpool Barcelona Valencia collaboration) system is an analogue readout system used to read out the signal from the sensors

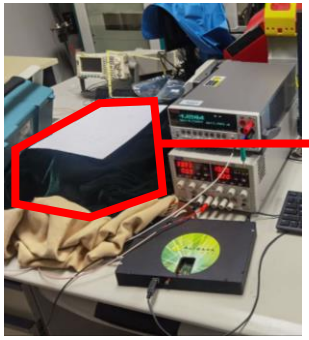
- Two different laboratory setups
  - Radioactive source setup
  - Laser setup

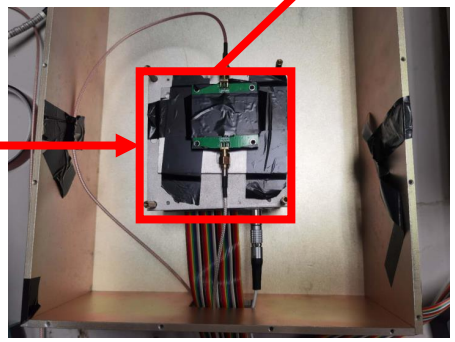
- Main components
  - Detector board
  - Daughter board
  - Mother board

ALiBaVa system

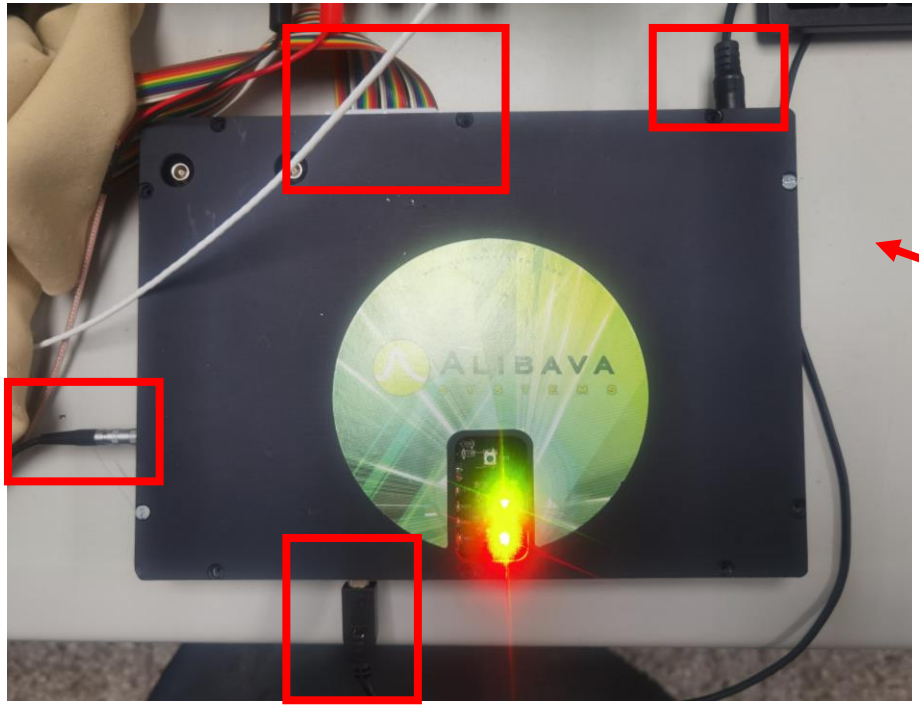
- Detector board
  - 1 or 2 sensors
- Daughter board
  - 2 Beetle chips
    - 128 channels each
    - Analogue or binary output mode
  - HV power supply for sensors
  - Sending analogue output signals to the motherboard

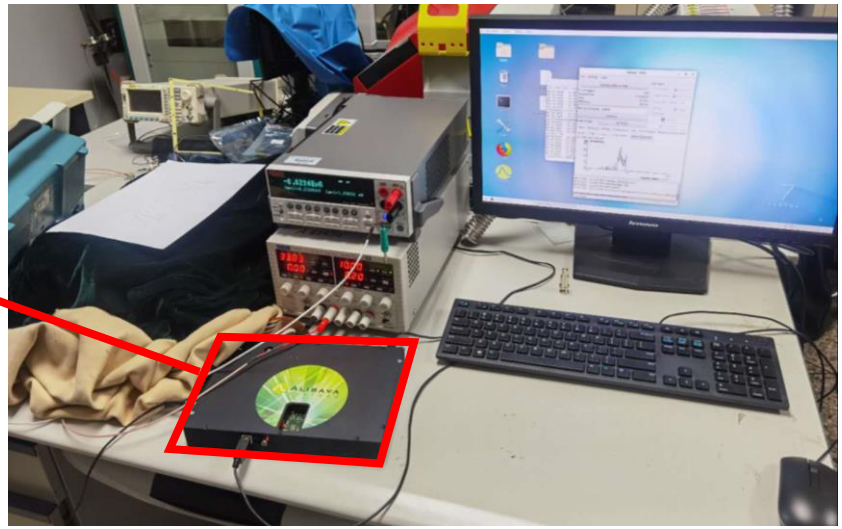






ALiBaVa system





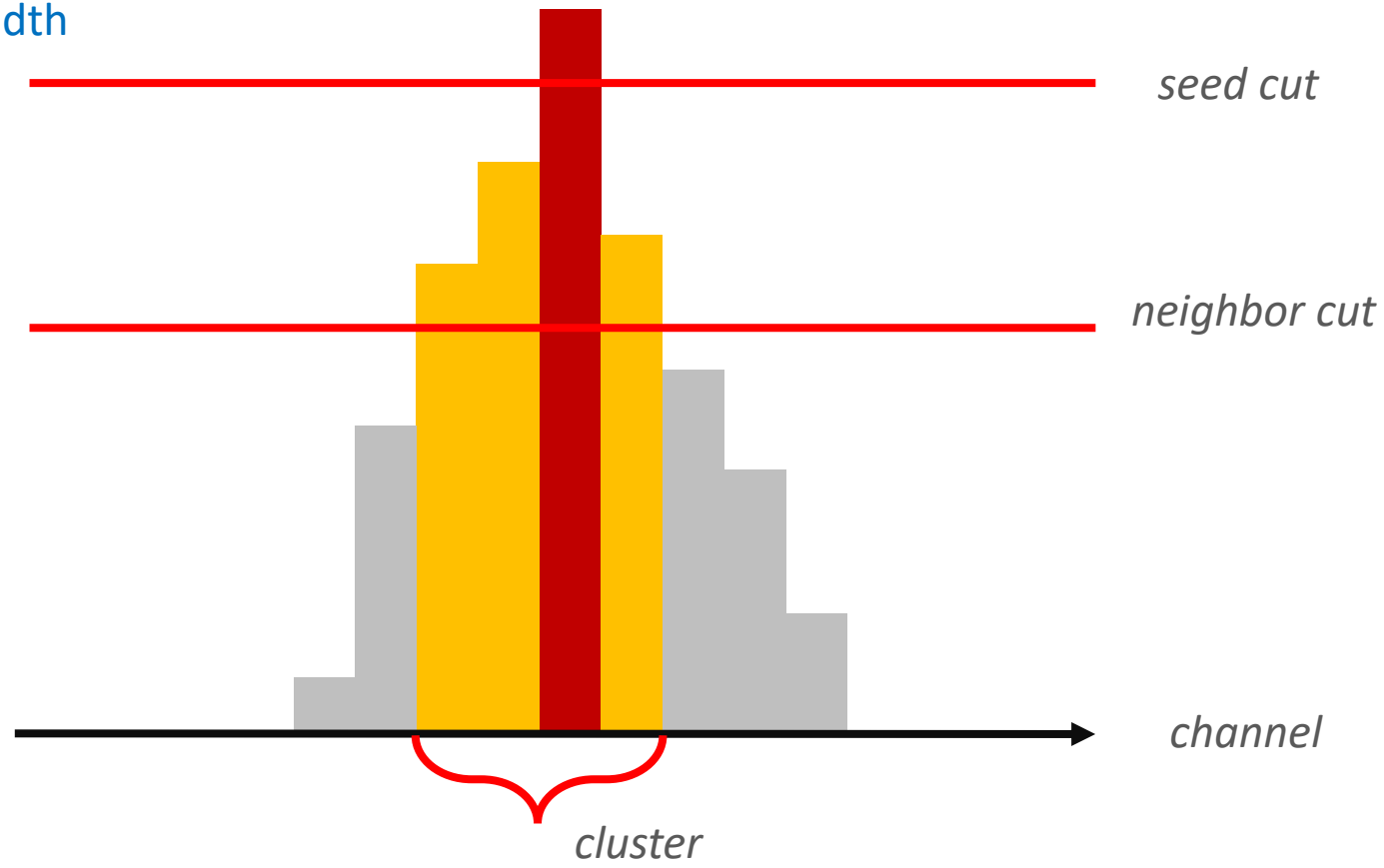
- Mother board
  - Amplification, filtering and digitalization of analogue signals
  - Trigger conditioning
  - Power supply for daughter board and mother board
  - Communication with a PC via USB

ALiBaVa system

- Working process of ALiBaVa system
  - Pedestal and noise scan
  - Calibration to obtain gains of each channel
  - Measurements
  - Analysis
    - Subtracting pedestals and common mode noises
    - Cluster finding
    - Pulse shape reconstruction to obtain the time window
    - Getting the collected charge spectrum

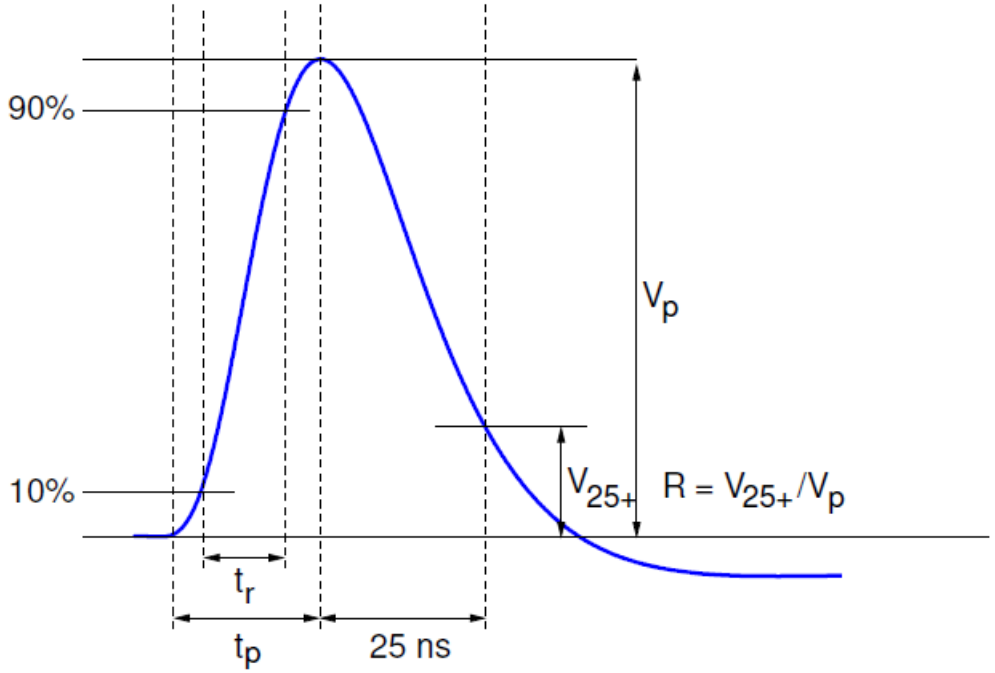
ALiBaVa system

- Cluster finding
  - Seed cut (5σ) only the peak
  - Neighbor cut (3σ)
  - Cluster width



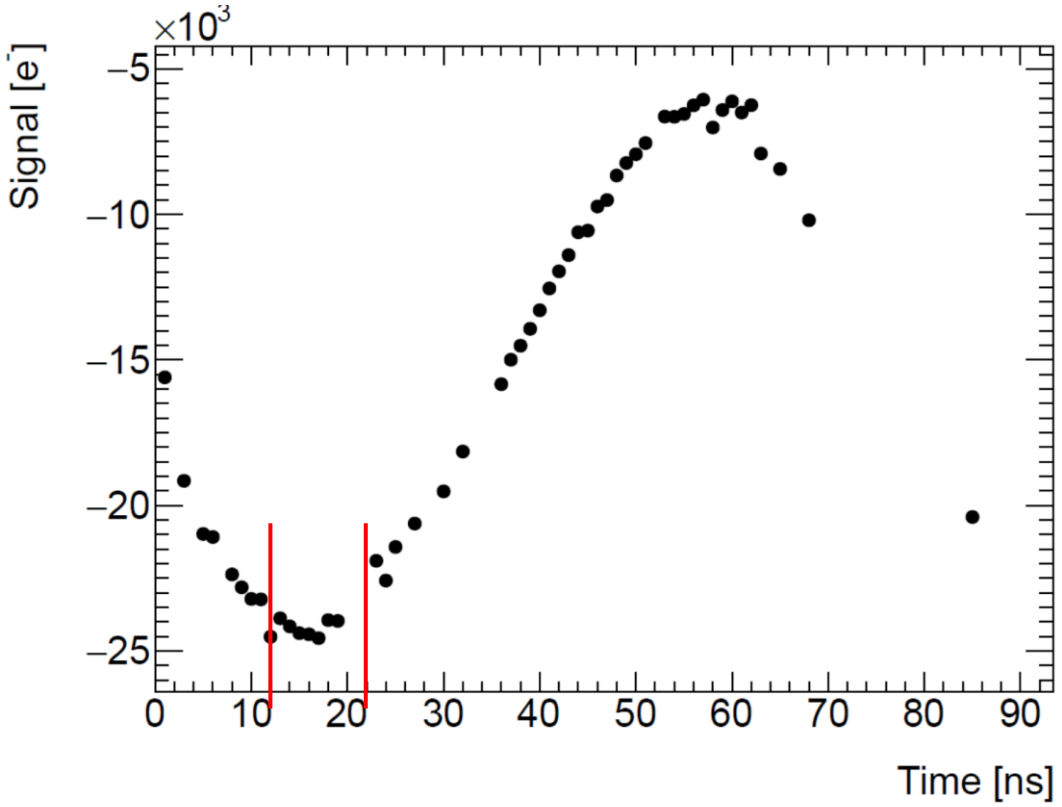
ALiBaVa system

- Pulse shape reconstruction
- Pulse shape
  - Peaking time or rise time
  - Peaking voltage
- Signal has a certain peaking time while peaking time of noise is random

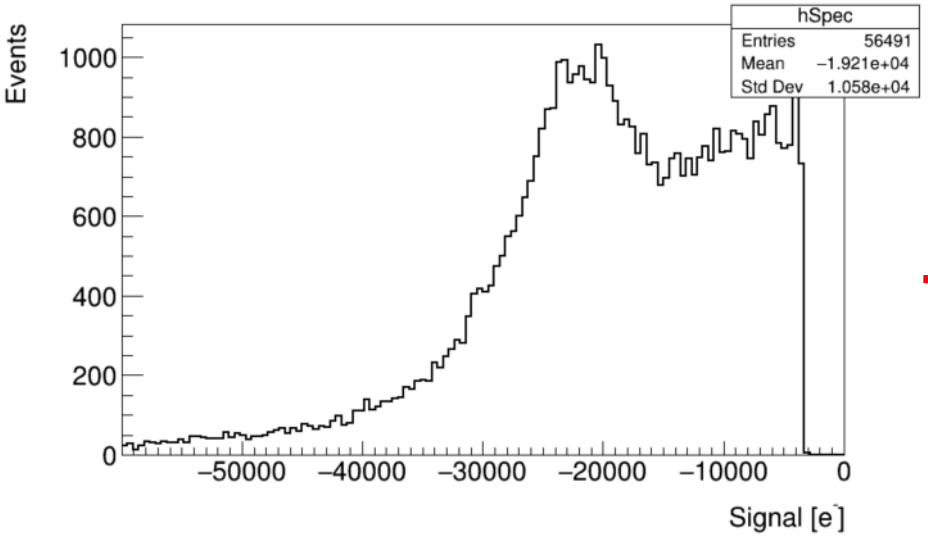


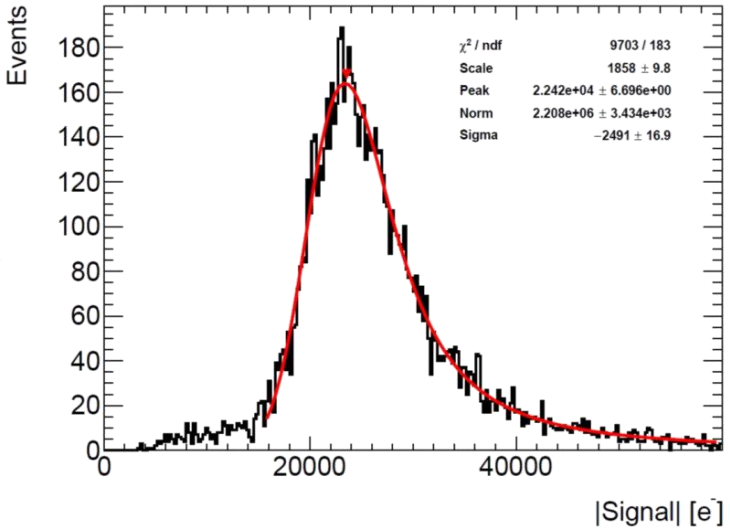
ALiBaVa system

- Pulse shape reconstruction
- Non-irradiated p-type
- Bias voltage: -210V
- Peak: 17ns
- Time Window: [12ns, 22ns]



ALiBaVa system





- Pulse shape reconstruction
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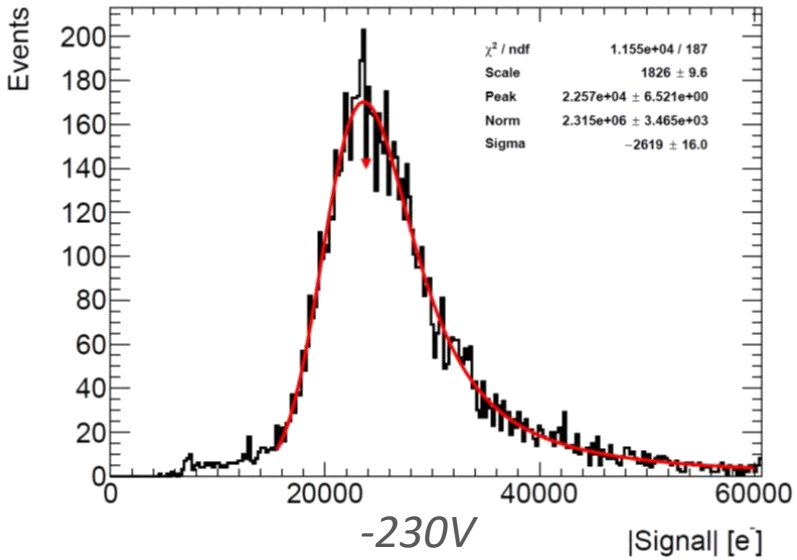
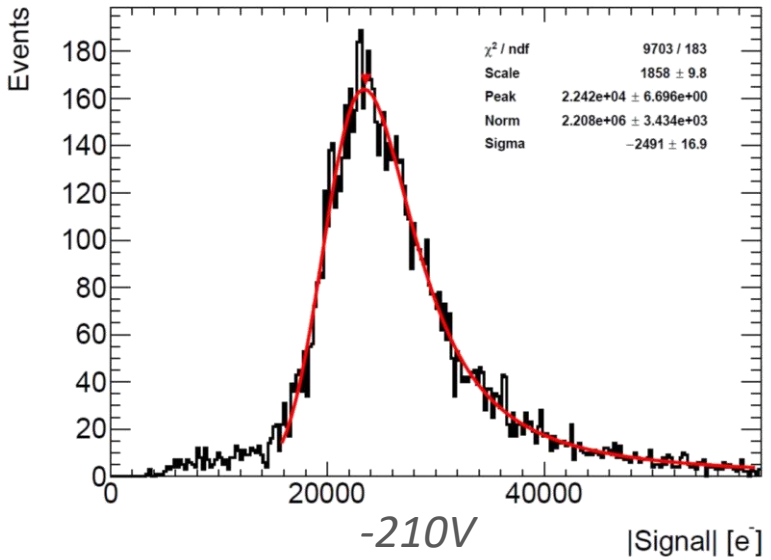
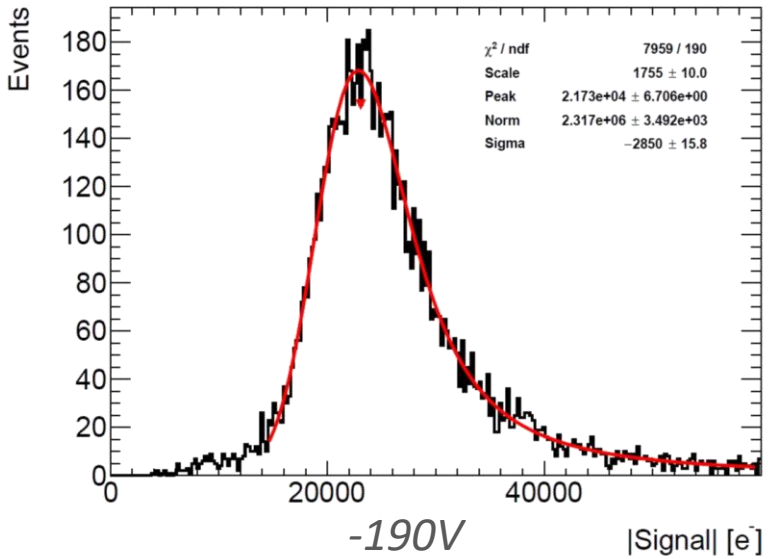
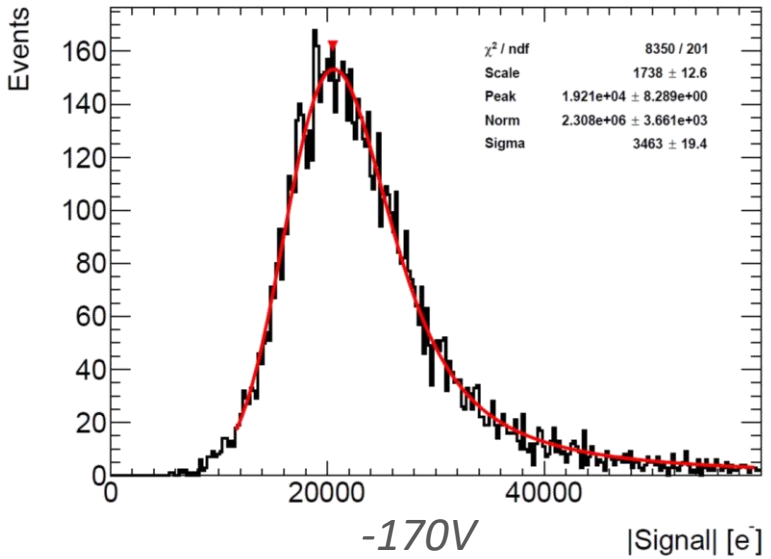
Voltage sweep

- Time Window: [12ns, 22ns]









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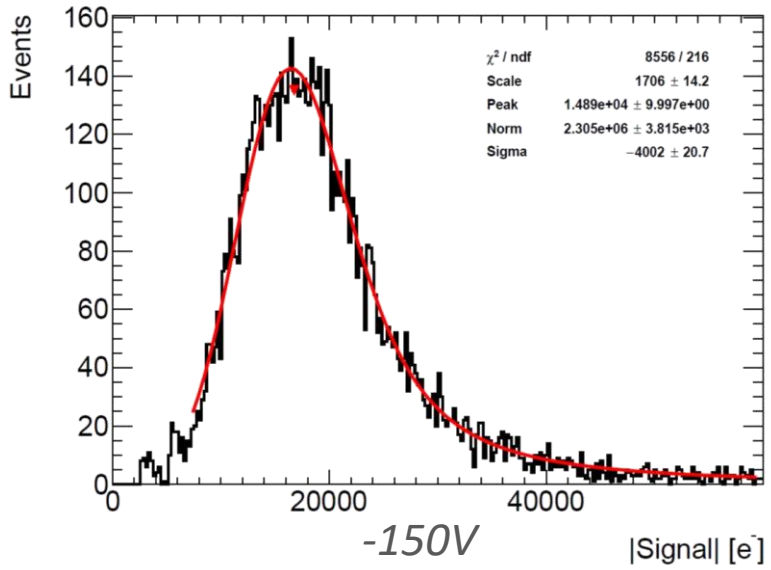

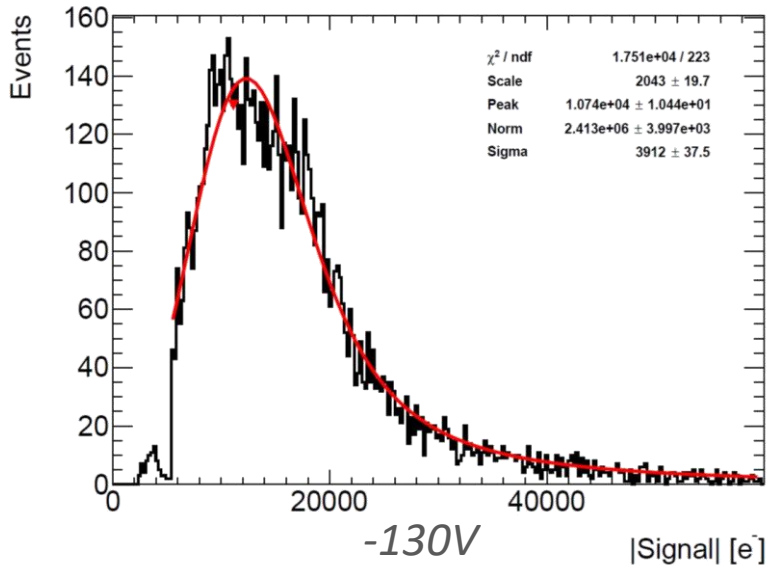

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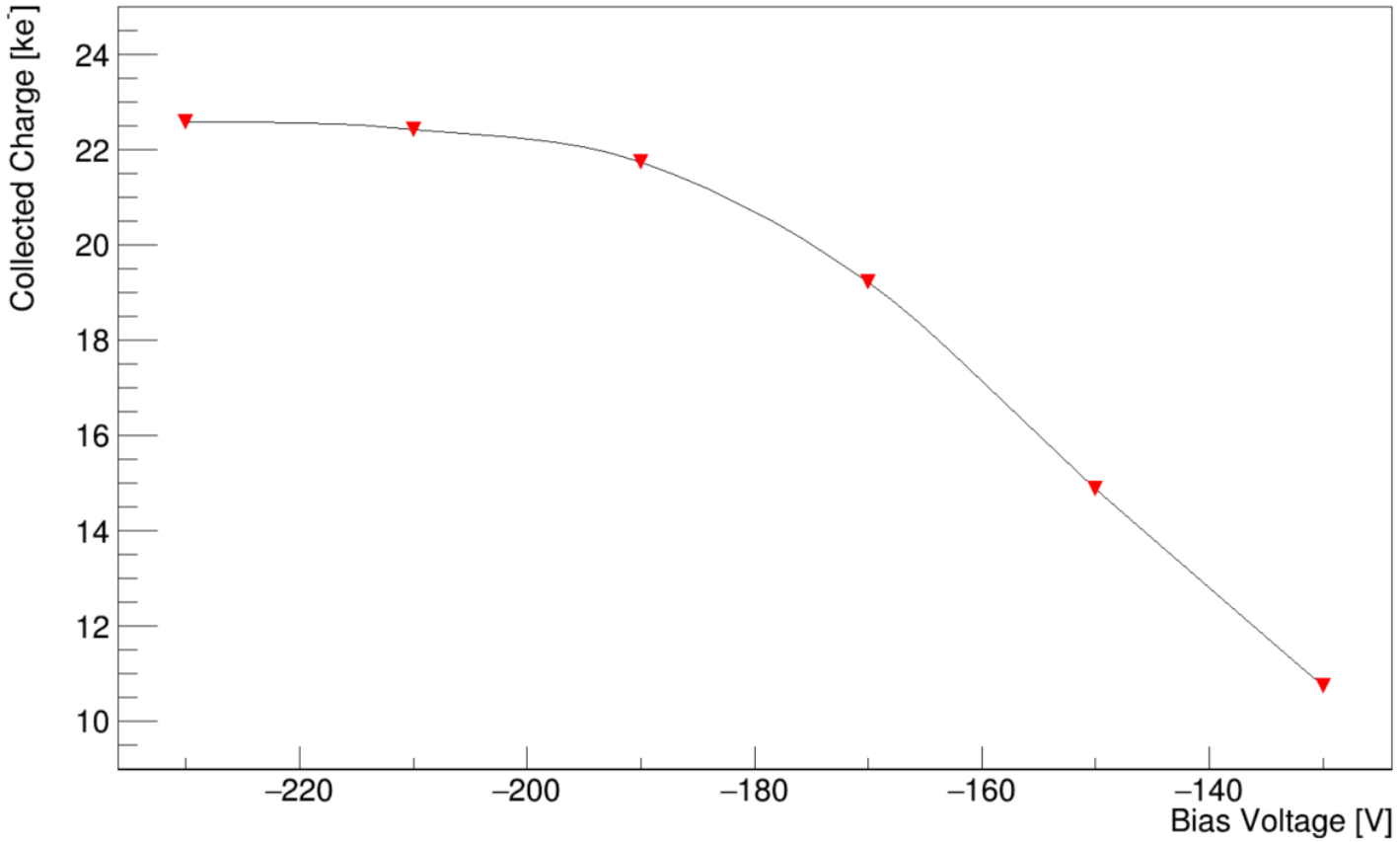

Conclusion

- Experimental setup established for silicon sensor charge collection measurement
- Gained experience with the ALiBaVa data acquisition system
- Next
  - Higher bias voltage
  - Improved setup with better collimation
  - Measurements with sensors before and after irradiation

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Thanks!