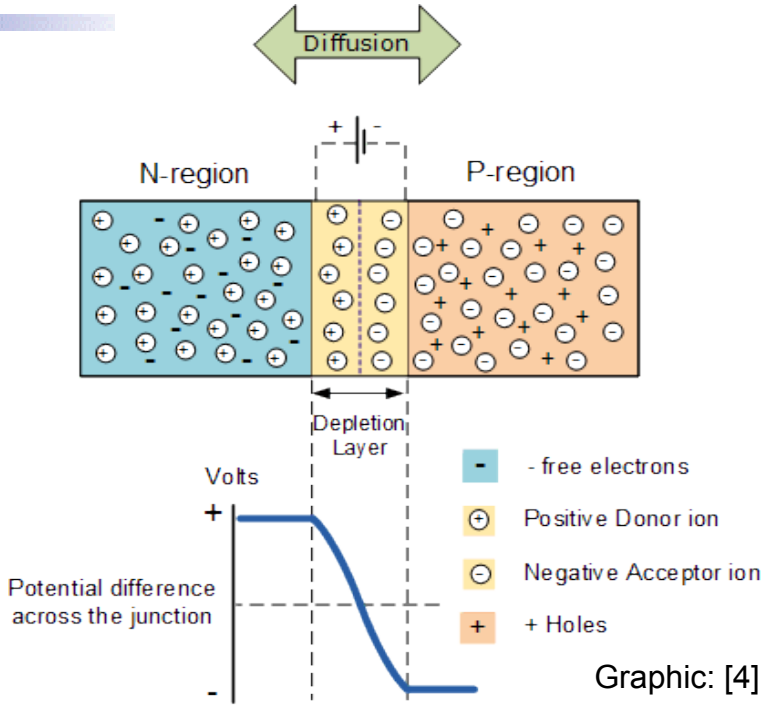
ALiBaVa

Characterization of Silicon Strip Sensors using LASER and Radioactive Sources

Ruth Jacobs
PH-DT Detector Development

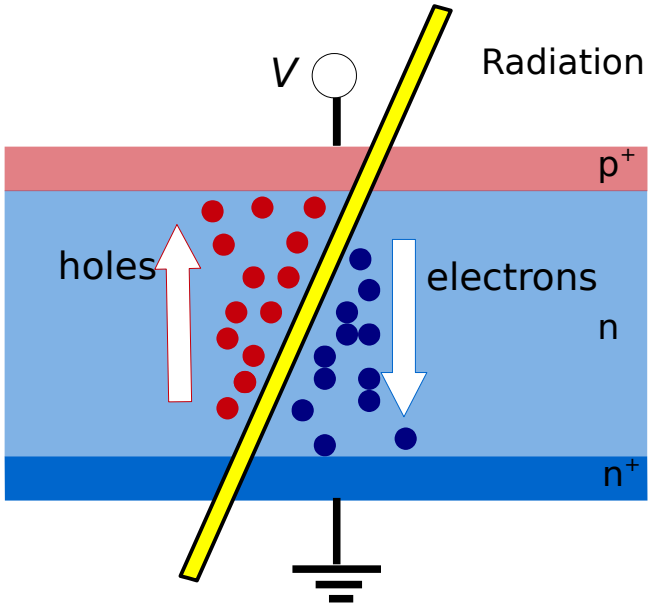
Silicon Sensors

- detect radiation with silicon sensor
- diode: pn – junction → see summer student lecture on silicon detectors by D. Bortoletto
- operation of diode: reverse bias voltage → extended space charge region (depletion zone)
- detector operation point: full depletion



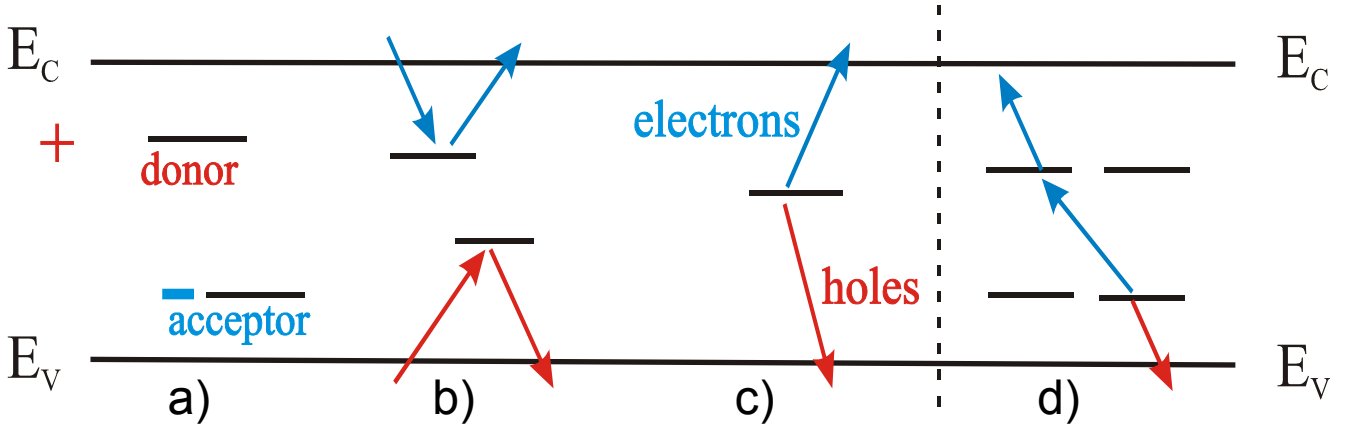
Graphic: [4]

- radiation detection: ionizing particles create electron hole pairs in depleted sensor
- e/h-pairs are separated by electric field and drift towards electrodes
- e/h-pair **movement** induces charge signal



Radiation Damage

- under influence of radiation, properties of silicon sensors change
- radiation introduces defects within silicon lattice
  → band structure changes



a) effective number of donors/acceptors changed (effective 'doping')
→ depletion voltage changes

b) & c) trapping of electrons and holes, de-trapping (thermal fluctuation)

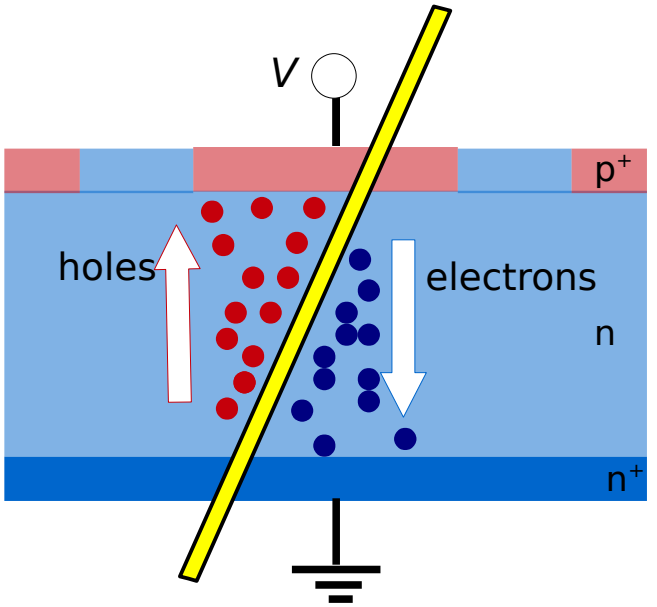
trapping time > 25ns → charge signal lost

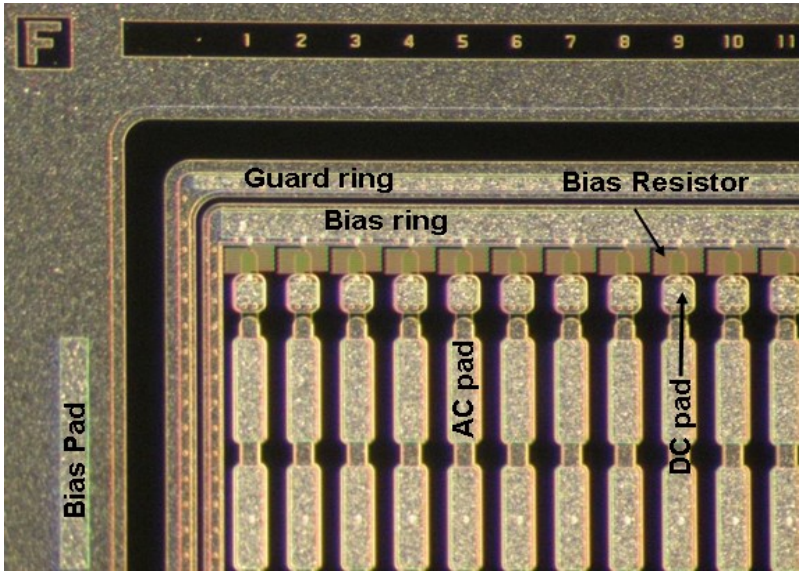
d) intermediate levels between valence band and conduction band
→ increased leakage current

- Radiation damage: reason for replacement of inner detectors during LHC upgrade!

My Strip Sensor Samples

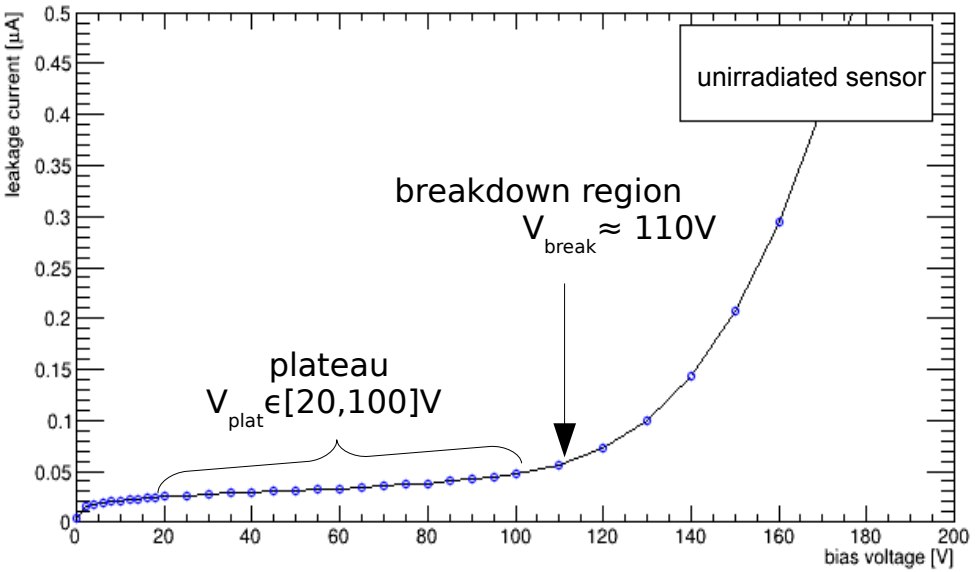
- detect radiation with information about its position
  (e.g tracking detector)
- improve spatial resolution: segmented surface
- 1D-segmentation: strips, 2D-segmentation: pixels
- sensor samples being studied:
  - silicon strip sensors (manufacturer: Micron)
  - 131 strips on each sensor
  - sensor dimensions: 12.5x12.5x0.3mm^3
  - three different doping types
    (n-in-p, n-in-n, p-in-n)
  - two different methods to grow
    single crystal silicon (magnetic Czochralski,
    Float Zone)
  - depletion voltages (unirradiated) ~10-90V
  - irradiated with 24GeV protons (PS CERN)
    fluences: ~(7E14 – 3E16)p/cm^2





Leakage Current and Capacitance

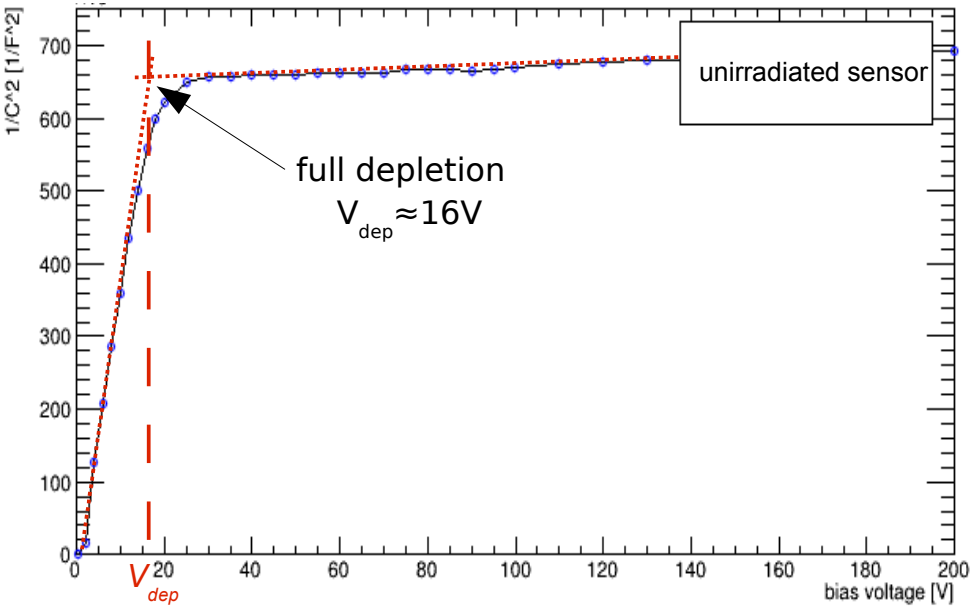
- measure leakage current and sensor capacitance for varying bias voltage
- leakage current reaches plateau above depletion voltage
- higher voltages: breakdown, high current



- capacitance of sensor with depletion zone of width *d*: plate capacitor with distance *d*

$$C_{PC} = \varepsilon \frac{A}{d}$$

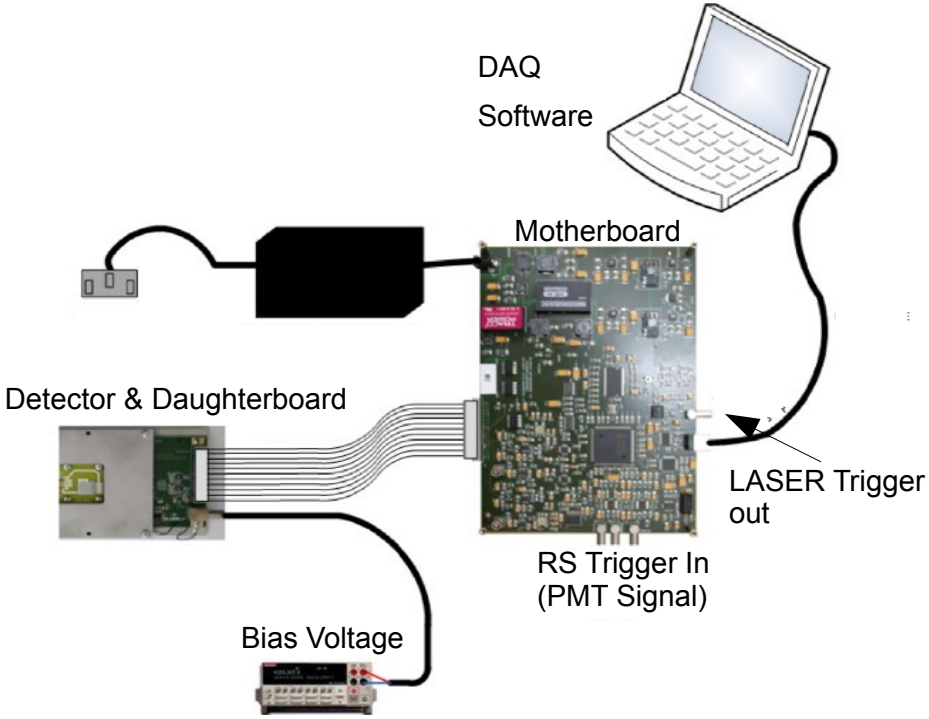
- plot inverse capacitance squared → proportional to d^2

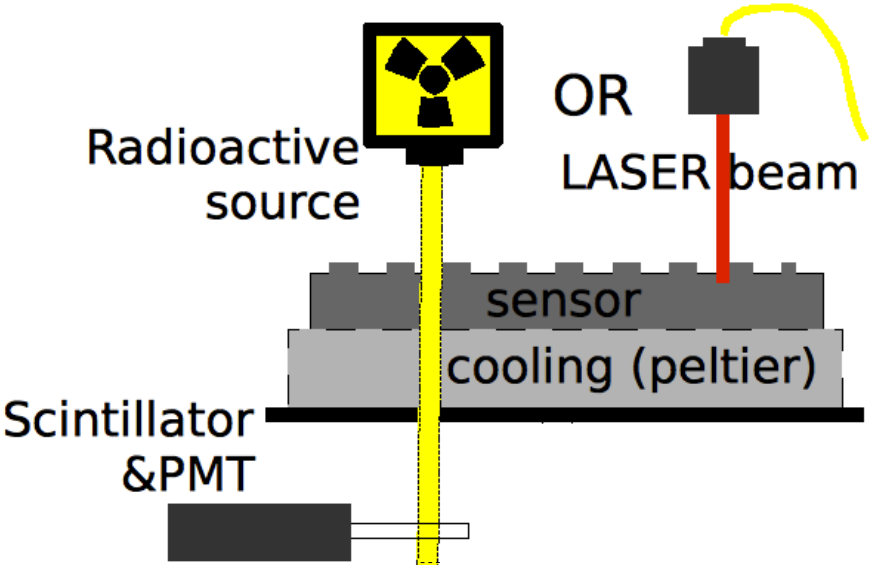


- Capacitance for varying voltage:

$$C = A\sqrt{\frac{\varepsilon}{2\rho\mu V}}$$

ALiBaVa Setup

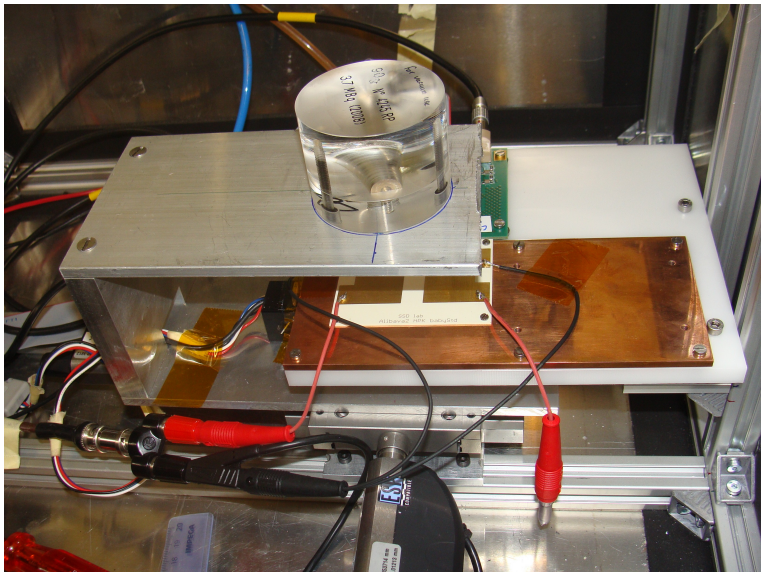


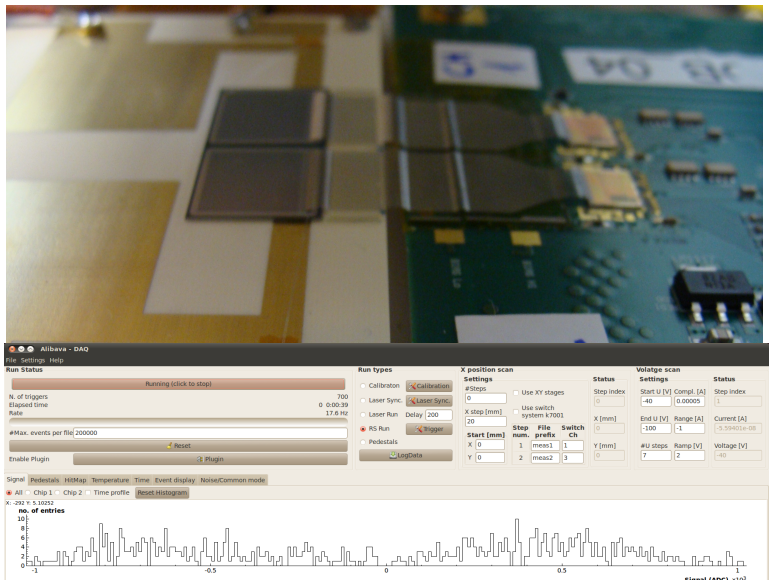


- AliBaVa: readout system designed for research on strip sensors
- signal induced by pulsed LASER or radioactive source
- LASER setup: optical (red) or infrared LASER pulse triggered internally by motherboard (trigger frequency 1kHz), readout triggered internally
- radioactive source setup: in our case ^{90}Sr (β^-), readout triggered by signal of photomultiplier connected to scintillator

Project Work (so far)

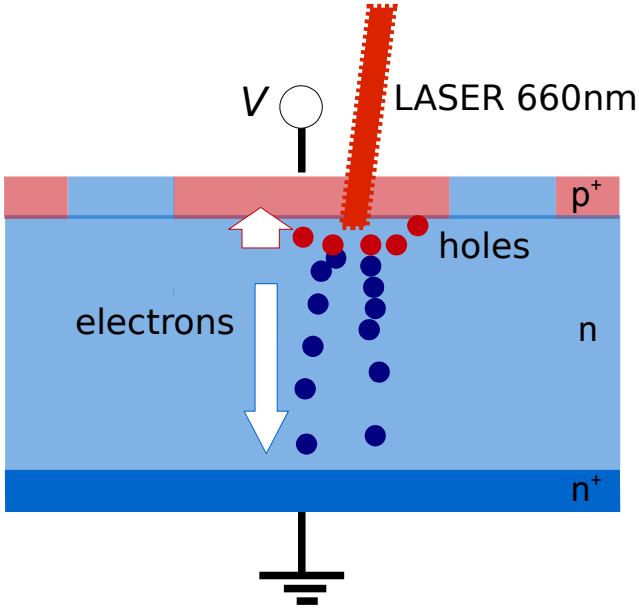
- Set up:
  - assembly and alignment of setup
  - compile and run newest software version, test hardware (motherboard, xy stages)
  - cooling system
- Understand:
  - readout chain, readout chip parameters, trigger
  - backgrounds
  - calibrate the setup
  - run analysis macros, own analysis scripts
- Perform measurements with unirradiated sensors:
  - CV/IV measurements
  - Laser test measurements
  - Test measurements with radioactive source

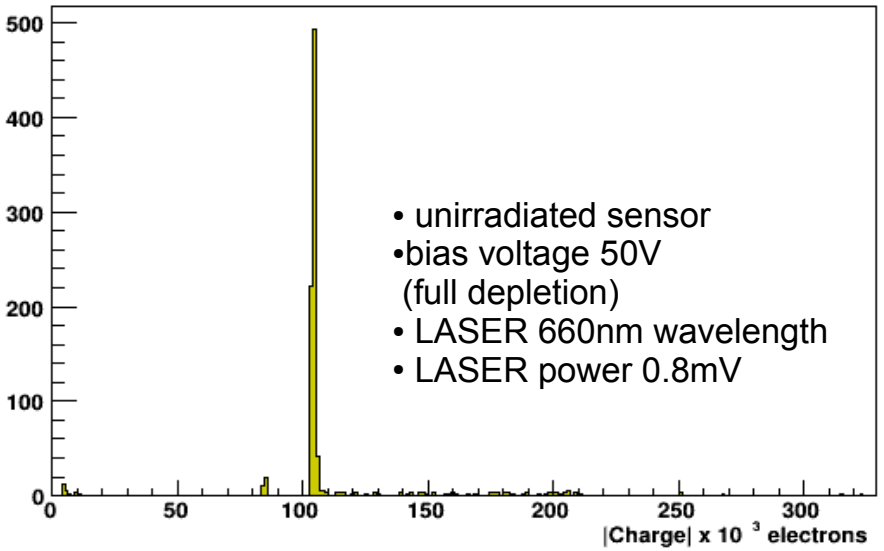


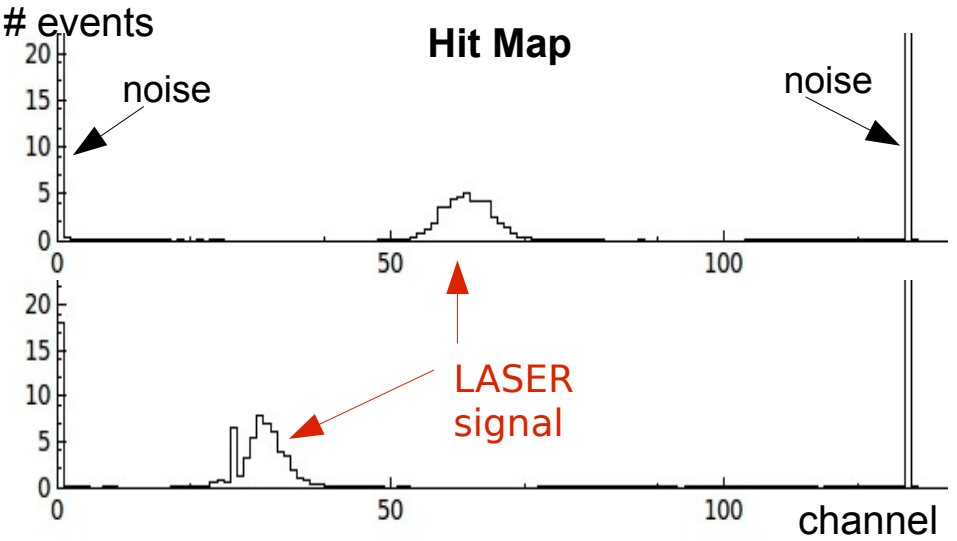


LASER Setup

- LASER penetrates ~3µm layer of silicon
- cloud of electron-hole pairs
- no secondary ionization, all energy of LASER pulse deposited in sensor
  → expect sharp gaussian peak
- peak charge value determined by LASER energy deposit within active region







- proof of principle: take data with LASER at two different positions on the sensor

RS Spectrum & CCE

- radioactive source ^{90}Sr (β)

- β particles penetrate entire sensor and lose part of their energy

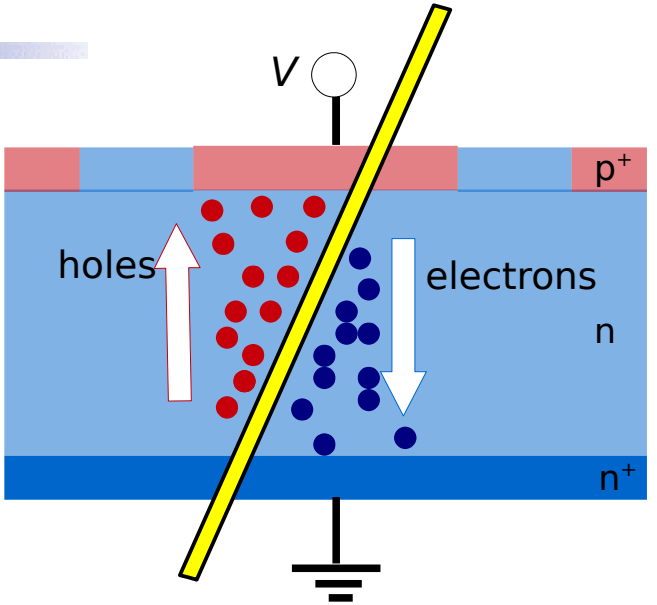
  → expect Landau distribution (convolution with gaussian)

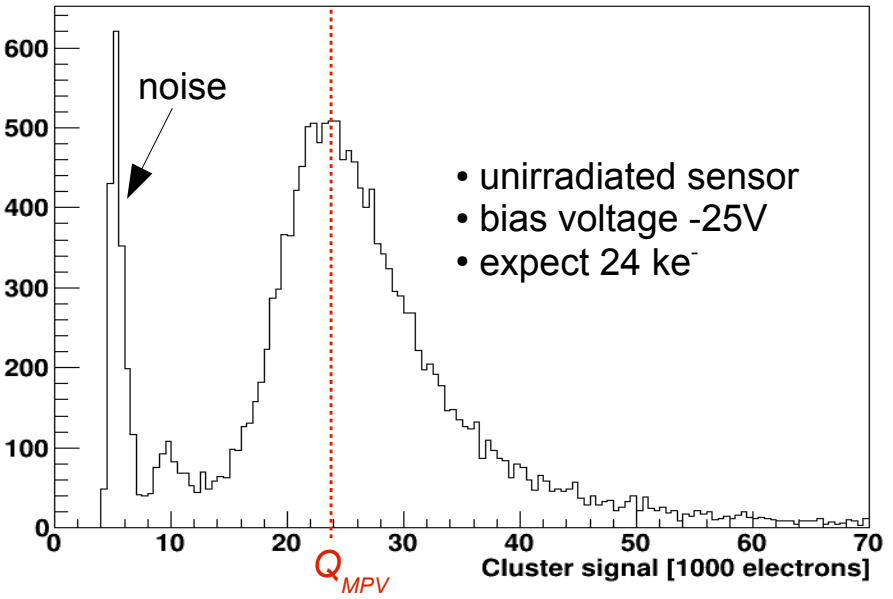
- compare most probable value of collected charge before Q_{MPV}^{unirr} and after irradiation Q_{MPV}^{irr}

- calculate charge collection efficiency (CCE)

$$CCE = \frac{Q_{MPV}^{irr}}{Q_{MPV}^{unirr}}$$

→ expect: trapping reduces the CCE





Summary & Outlook

So far:

ALiBaVa system set up for measurements with LASER and radioactive source

Tests performed with one unirradiated Micron strip sensor sample

Now:

characterize several different types of unirradiated Micron sensors

measurements for varying bias voltage

LASER surface and edge strip scans

CCE measurements with radioactive source

compare sensor performance before and after irradiation with different fluence

→ Thankfully: Still 7 weeks to go! :)

Acknowledgements

SSD group members:

M. Fernandez Garcia[1]
C. Gallrapp[2]
M. Moll[2]
H. Neugebauer[2]
D. Sekihata[3]

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[2] CERN
[3] Hiroshima University

SSD lab:

Bld. 28/2-017

Visit the lab and see the setup?
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Bibliography

[1] Spieler, H.: Semiconductor Detector Systems, Oxford Univ. Press 2005

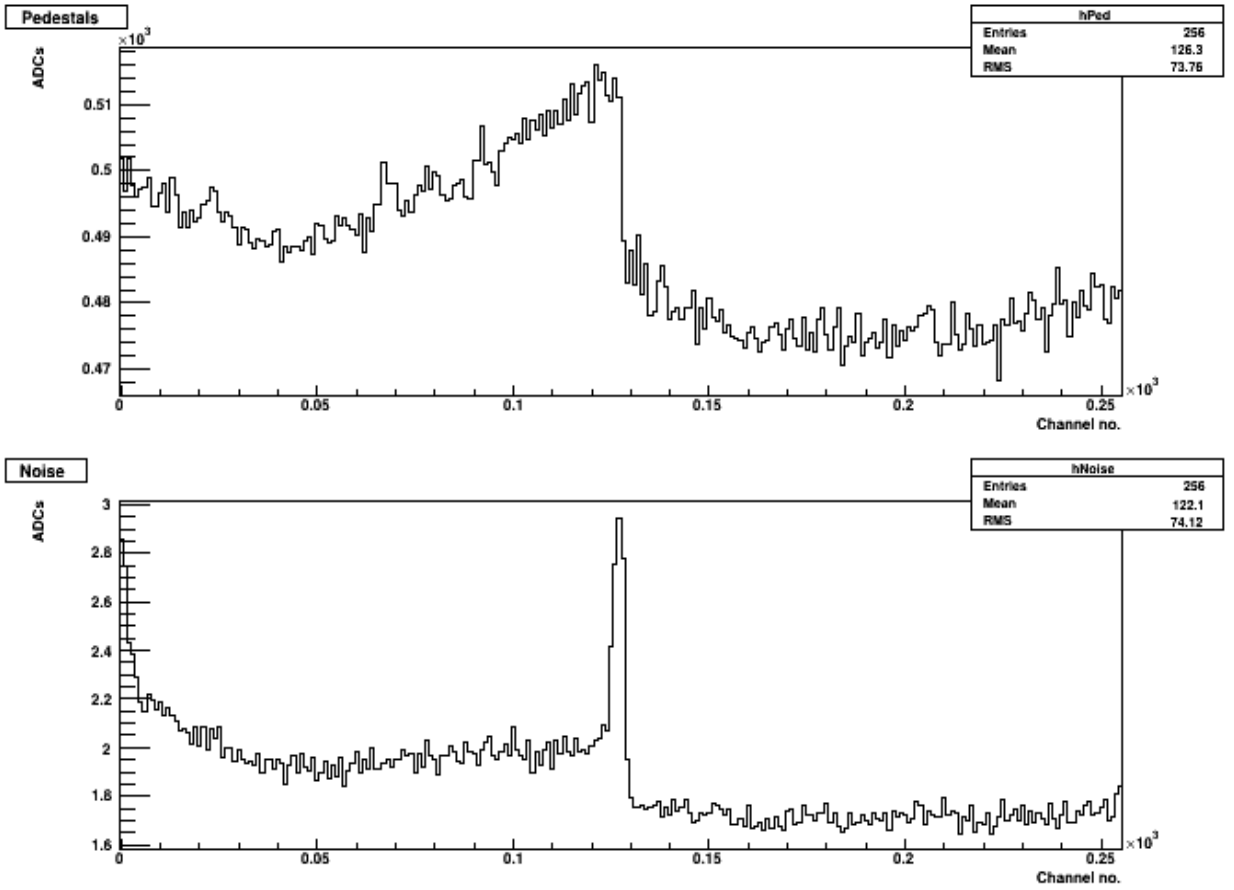
[2] Moll, M. et al., Slides for the Summer Student Workshop 2013

[3] Marco-Hernandez, R.: A portable readout system for silicon microstrip sensors, Nucl. Inst.,623,1,11/2010, p. 207-209 DOI: http://dx.doi.org/10.1016/j.nima.2010.02.197

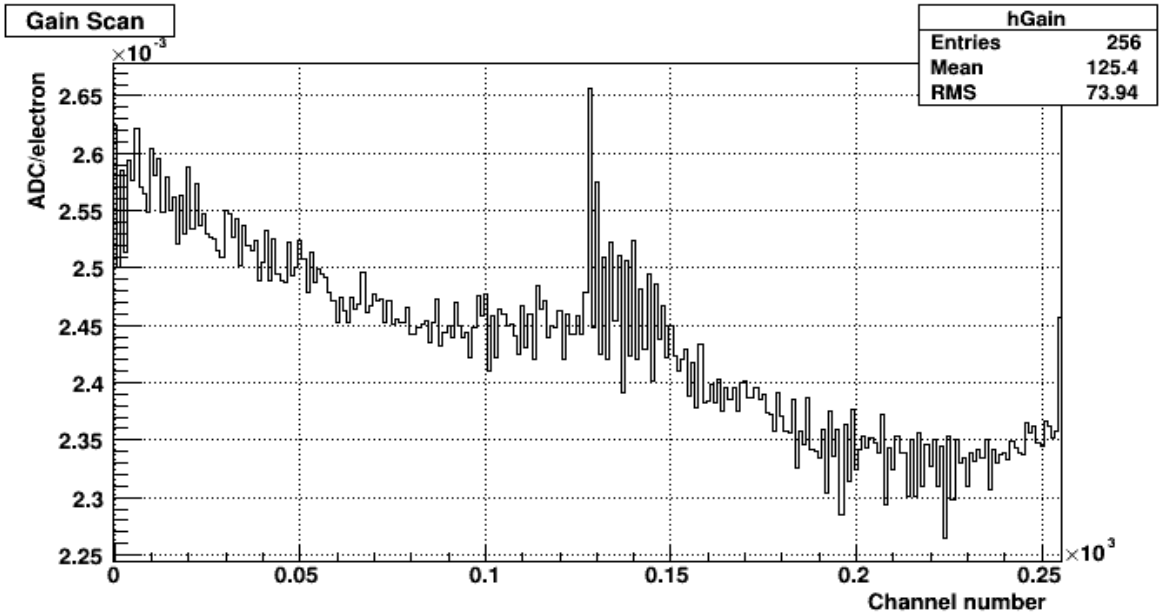
Pictures:

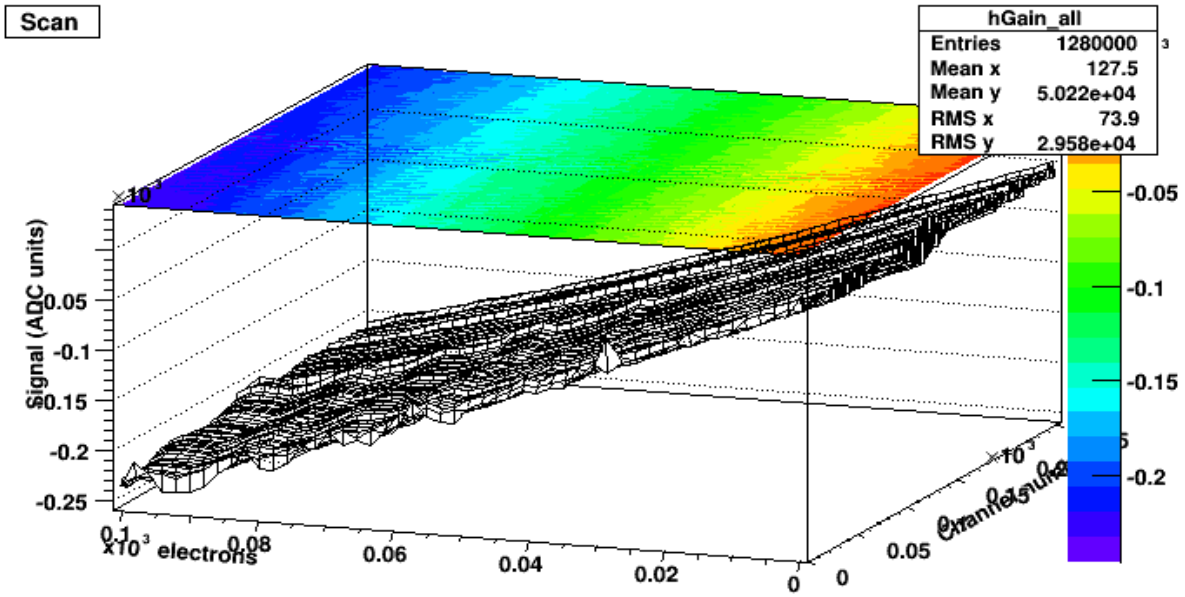
[4] http://www.electronics-tutorials.ws/diode/diode4.gif

Backup 1: Pedestals & Noise



Backup 2: Calibration





Backup 3: Beetle Chip Parameters