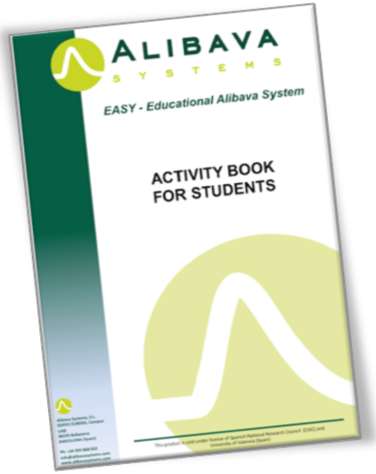
EXERCISES WITH EASY

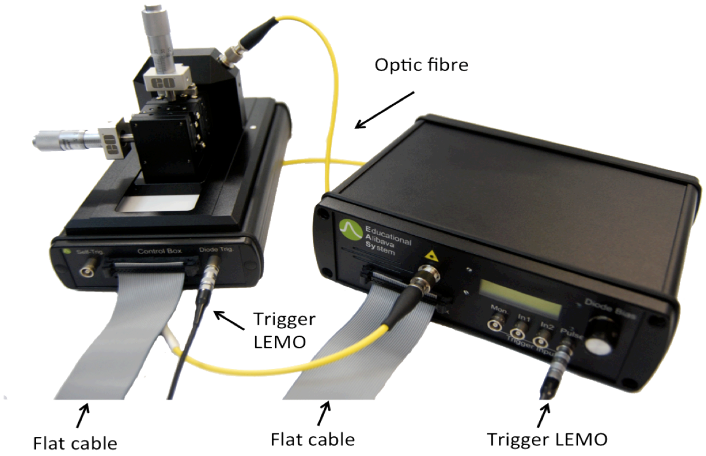
An introduction to silicon detectors



ALIBAVA SYSTEMS

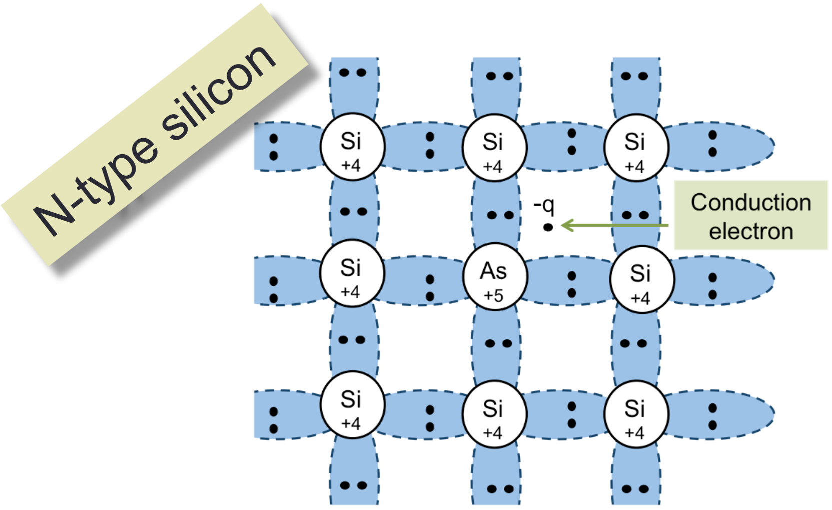
EASY - Educational Alibava System

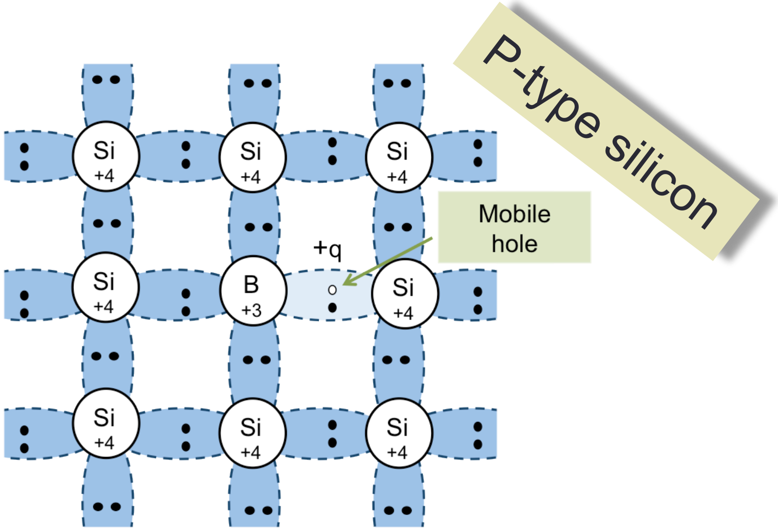
ACTIVITY BOOK FOR STUDENTS



Carlos Lacasta

Silicon Sensors: the material





Silicon atoms “connect” to each other via covalent bonds.

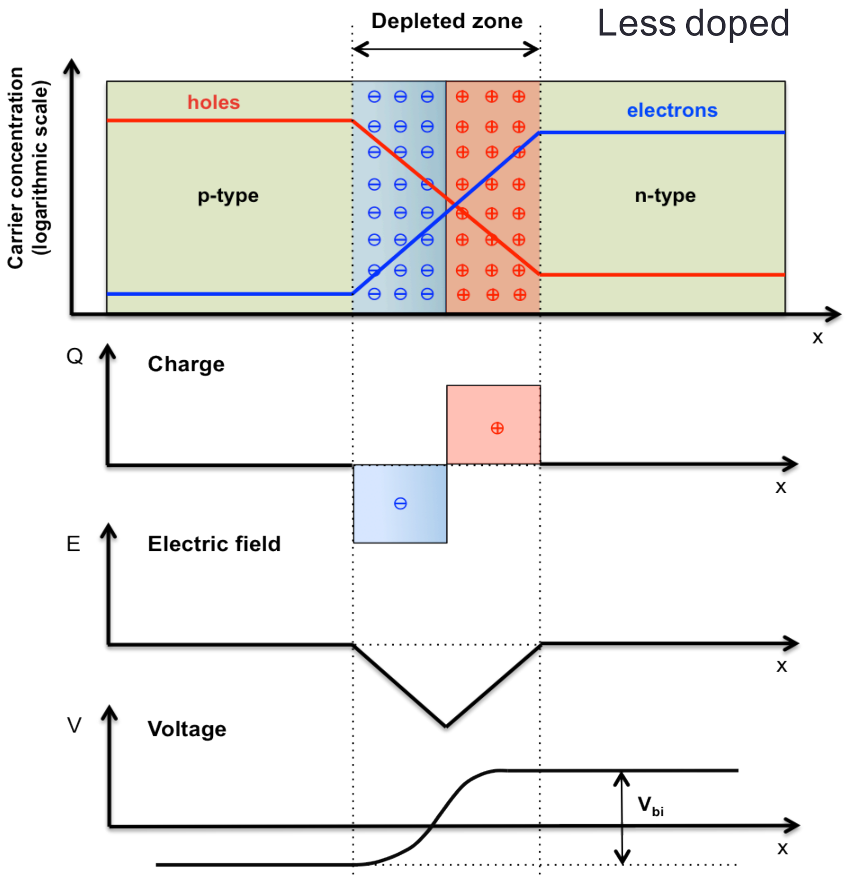
We can replace some Si atoms with As or B to have an excess (or defect) of electrons.

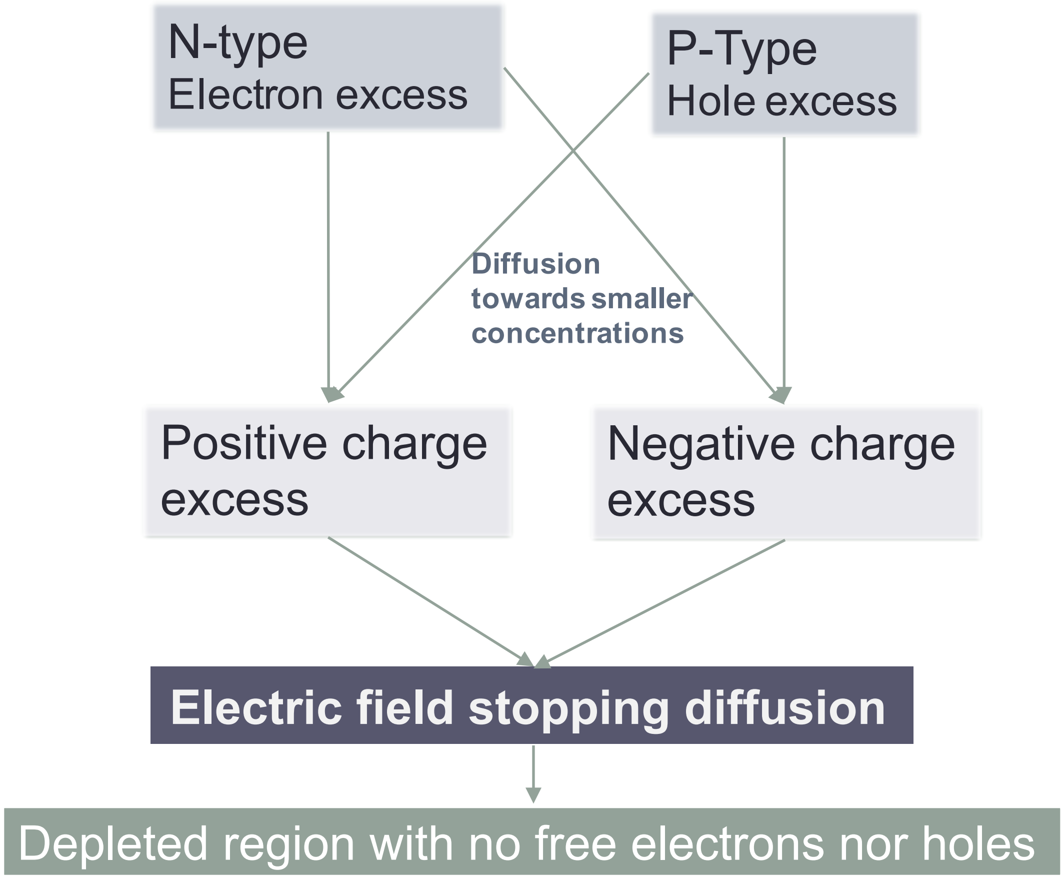
The electrons in excess can move around in the structure: **n-type** silicon

The “holes” (lack of electrons) can also move and behave as positive charges: **p-type**

The overall structure is neutral… There is no excess of charge.

The pn-juntion: equilibrium





N-type
Electron excess

P-Type
Hole excess

Diffusion towards smaller concentrations

Positive charge excess

Negative charge excess

Electric field stopping diffusion

Depleted region with no free electrons nor holes

The pn-junction: detector mode

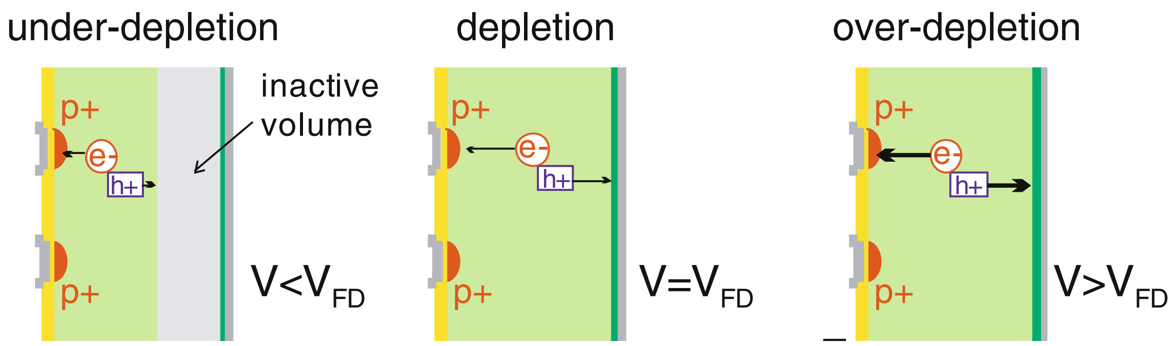
When a particle traverses

- the depleted region, the e/h pairs do not recombine with anything since the region is depleted and drift under the electric field inducing the signal in the electrode.
- Any other region, the e/h pairs will recombine with free majority carriers (e in n-side or h in the p-side) and is lost.

We want this depleted region as large as possible.
We do it by applying an external voltage that forces the diffusion of the majority carriers into the “other side”. The width will be:

$$w = \sqrt{2\epsilon\rho\mu V_{bias}}$$

Pn-junction: detector mode



$$C = \varepsilon \frac{A}{w}$$

Noise in the readout electronics grows with capacitance at the input

The sensitive volume depends on the bias voltage.

We cannot extend it beyond the actual size of the detector

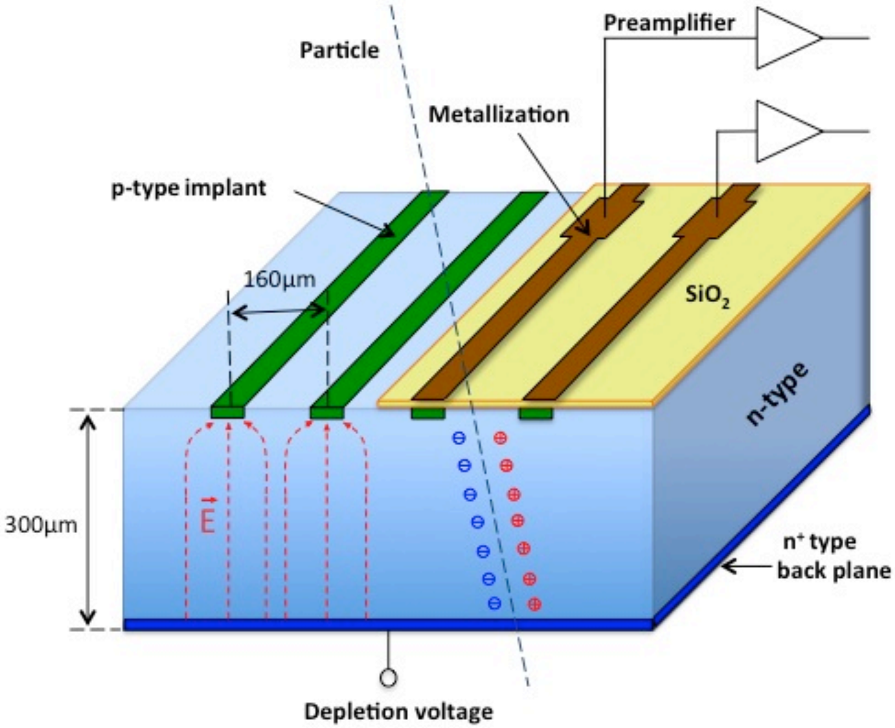
1. What happens when we use a $V_{dep} > V_{FD}$?
2. Do we gain anything ?

The amount of energy measured will scale with the depth of the depletion region. To find the depletion voltage we can:

1. Charge collection .vs. V_{dep} will saturate when $V_{dep} = V_{FD}$
2. How to determine V_{FD} without particles ?

Prove it using the ^{90}Sr source in the EASY

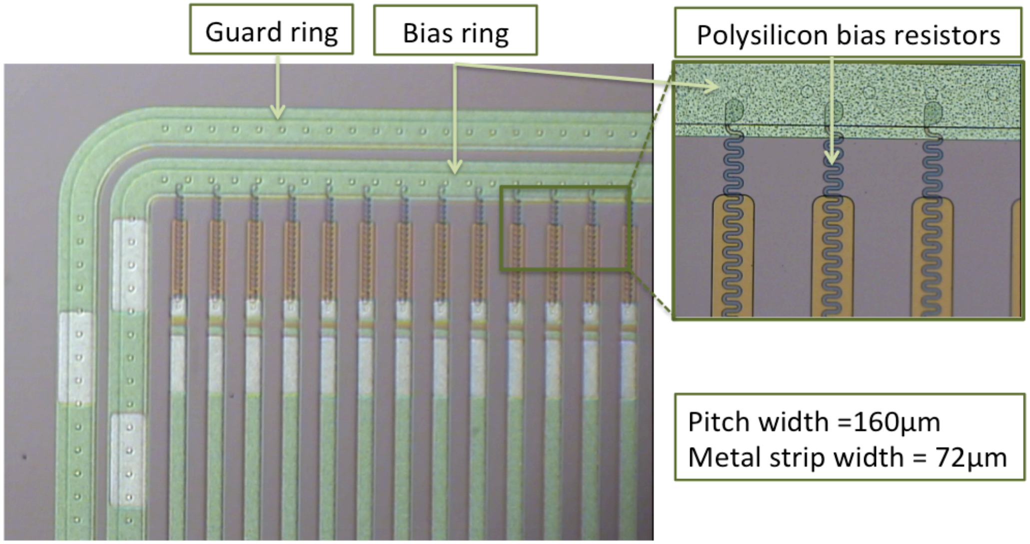
The silicon strip sensor



We can "create" many of those junctions all along a silicon slab.

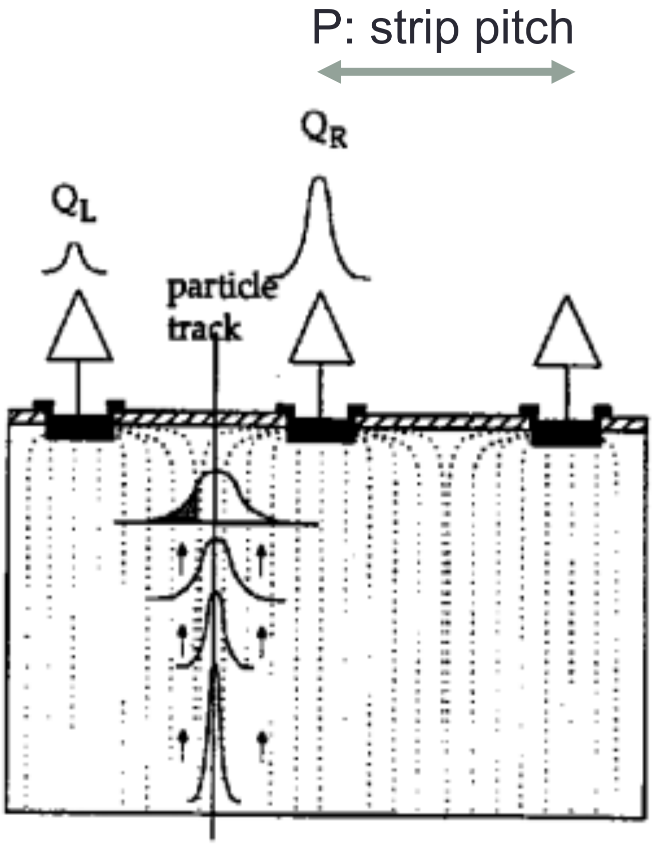
We call them strips. They are separated by a constant distance or angle that we call pitch.

We put an Al layer on top of the strip for the electric connection



Pitch width =160μm
Metal strip width = 72μm

The silicon Strip signal


P: strip pitch

Distance between neibourg strips, pitch, P.

Signal can be shared between strips depending on how the electric field makes them drift along the field lines. We have multi-strip clusters.

If we have analogue readout we use the centre of gravity to compute the position.

$$X = \frac{Q_L x_L + Q_R x_R}{Q_L + Q_R} \xrightarrow{X_L=0,\, X_R=P} \mathrm{X} = \mathrm{P}\,\frac{Q_R}{Q_L+Q_R}$$

What is the error on the position determination if the noise on the charge measurement is N and the total signal is $S=Q_L+Q_R$?

What would be the error with a binary readout, that is we only have a 0 or 1 telling whether the particle has hit that strip ?

Use the laser system to see how charge is shared between strips. Can

Analysing the signal

- Compare the spectrum from the ^{90}Sr source and the laser
  - What is the shape of the source spectrum ? And that of the laser ?
  - Explain why they are different.
- Can the ^{90}Sr spectrum be considered a MIP (end point ~ 2.5MeV) ?
- What is the expected energy deposited by a MIP on a 300µm thick silicon detector ?
  - Silicon density: 2.6 g/cm^3.
  - If the excitation energy of silicon is 3.6 eV, how many e/h pairs will be produced ?