Silicon Detectors

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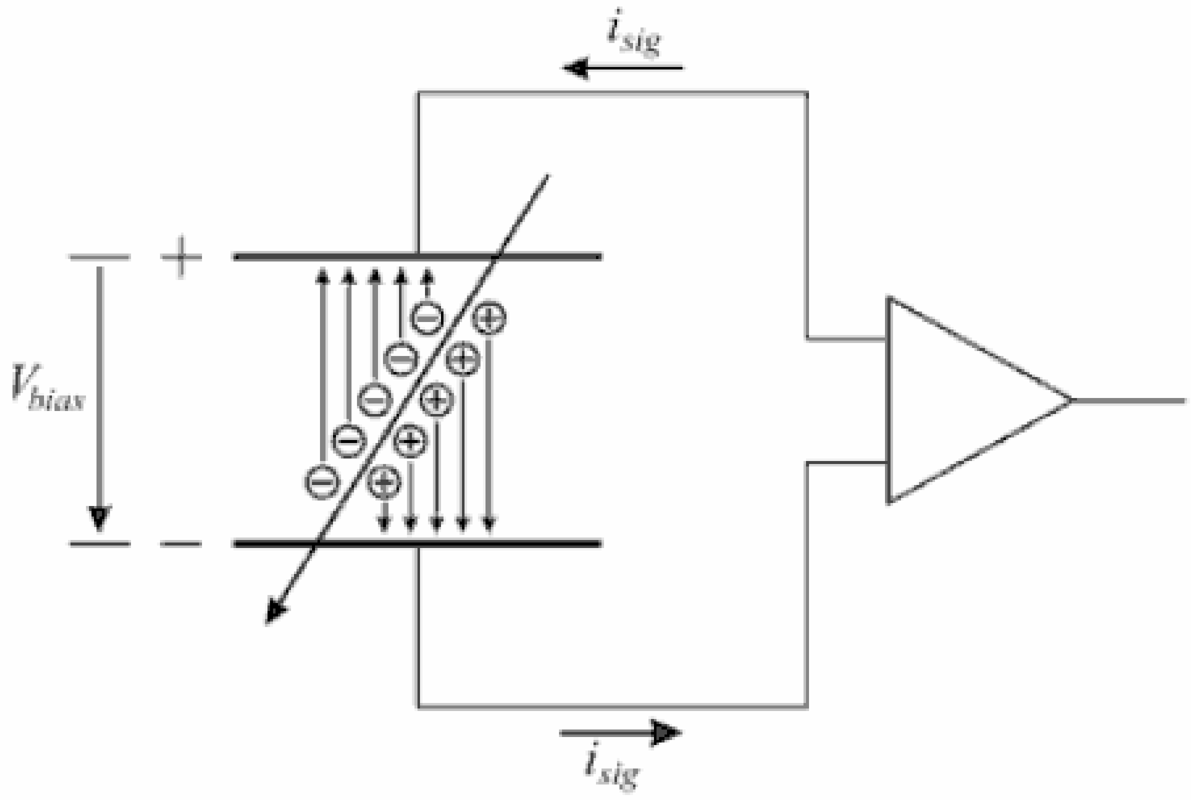
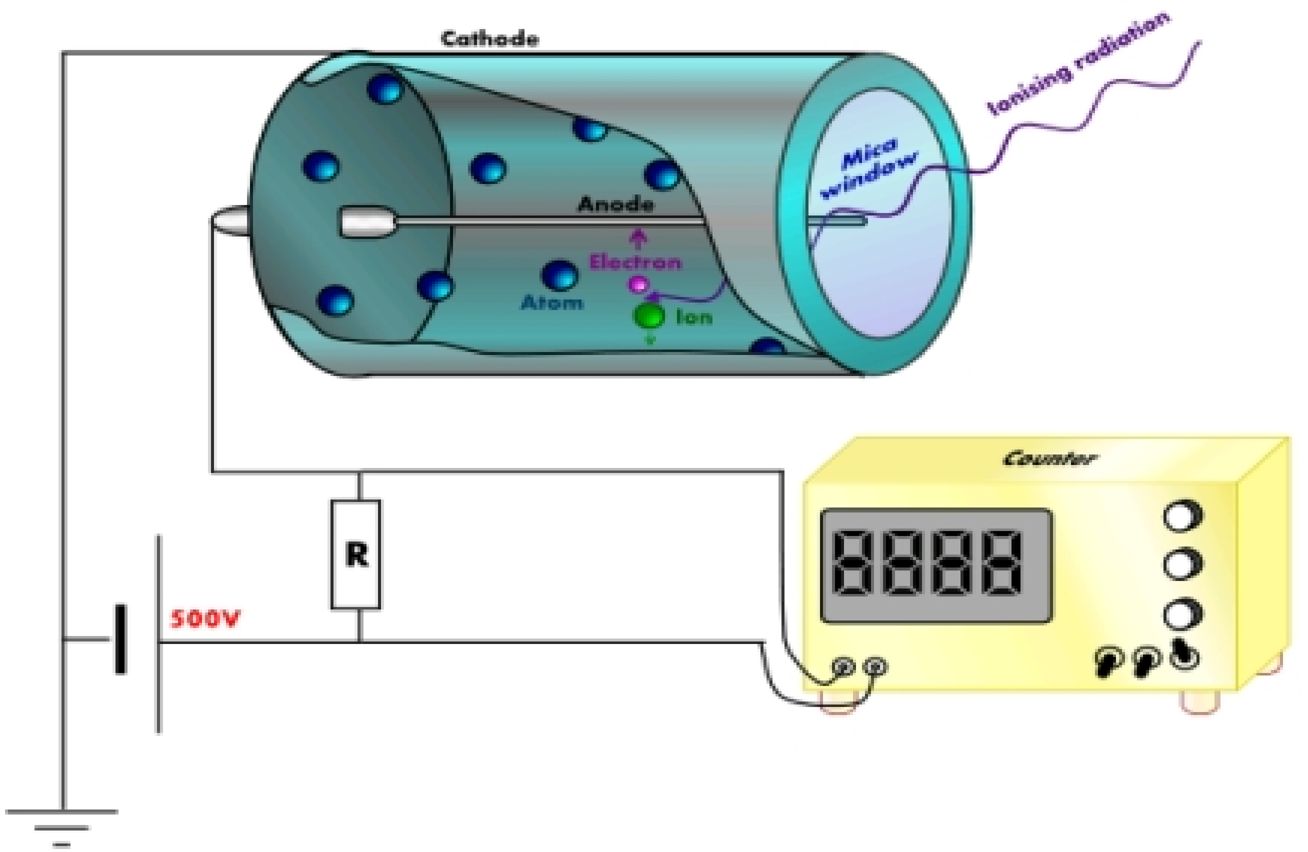
Basic principle of detectors

- Radiation produces free charges when passing through matter
- Free charges are collected, generating a signal



Basic principle of detectors

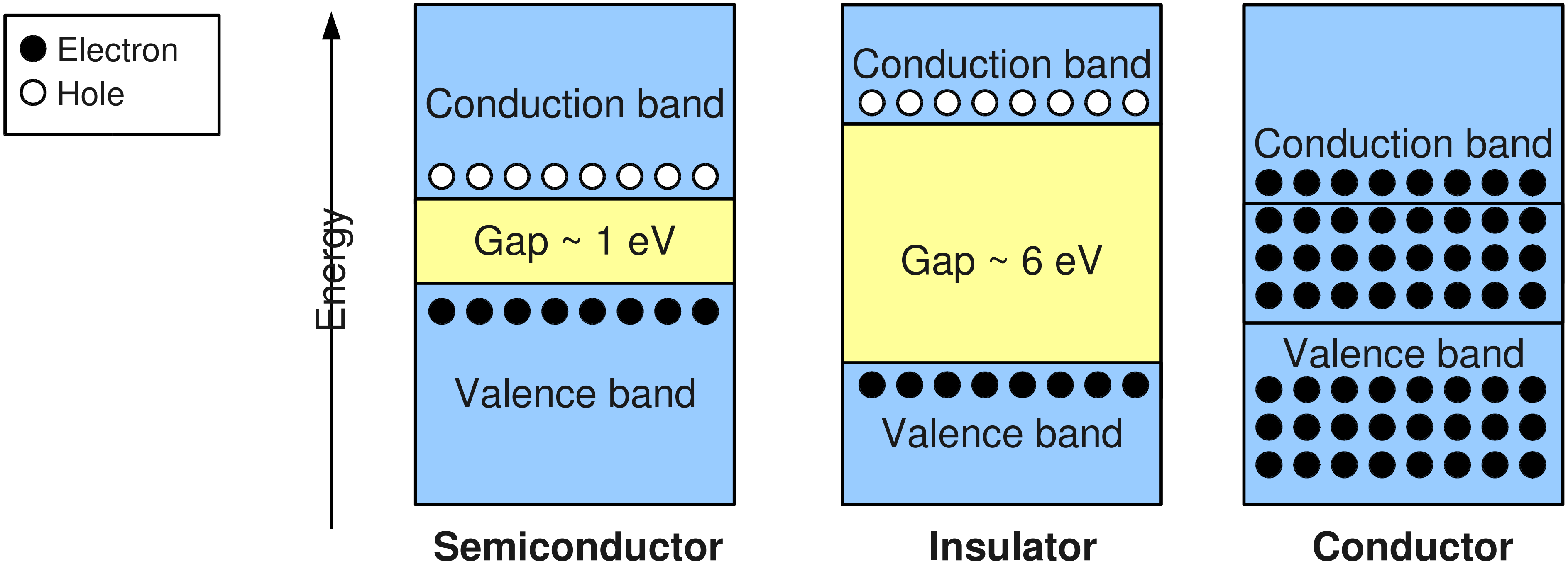
- e.g. Geiger Counter



- In silicon detectors, the 'ionizating chamber' is a p-n junction

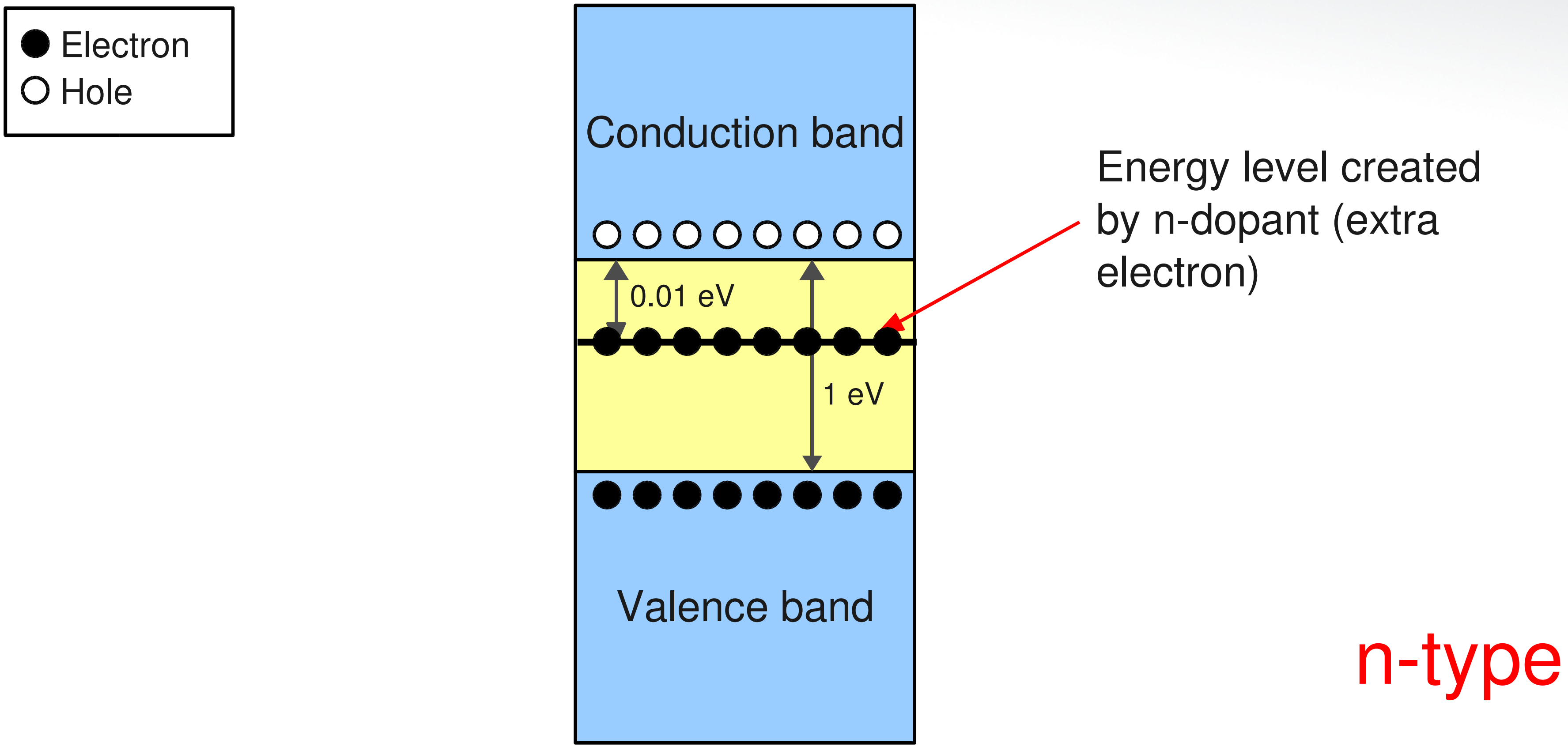
Band structure

- Periodical boundary conditions in Schroedinger equation gives rise to the band structure
- The width of the gap is determined by the lattice spacing between the atoms



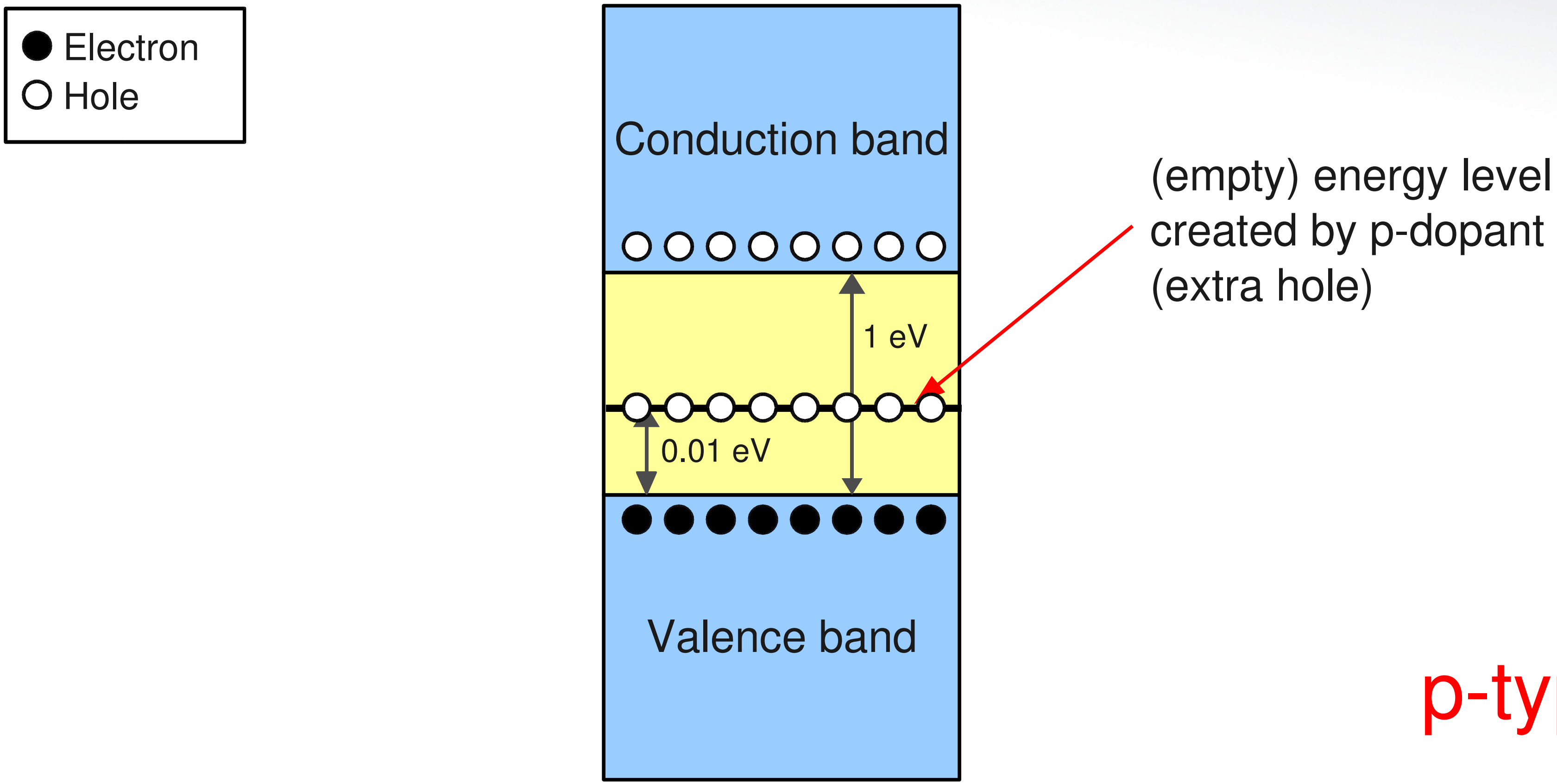
Doped semiconductors

- Dopping the silicon (Z=14) with phosphorous (Z=15) creates a new energy level close to the conduction band



Doped semiconductors

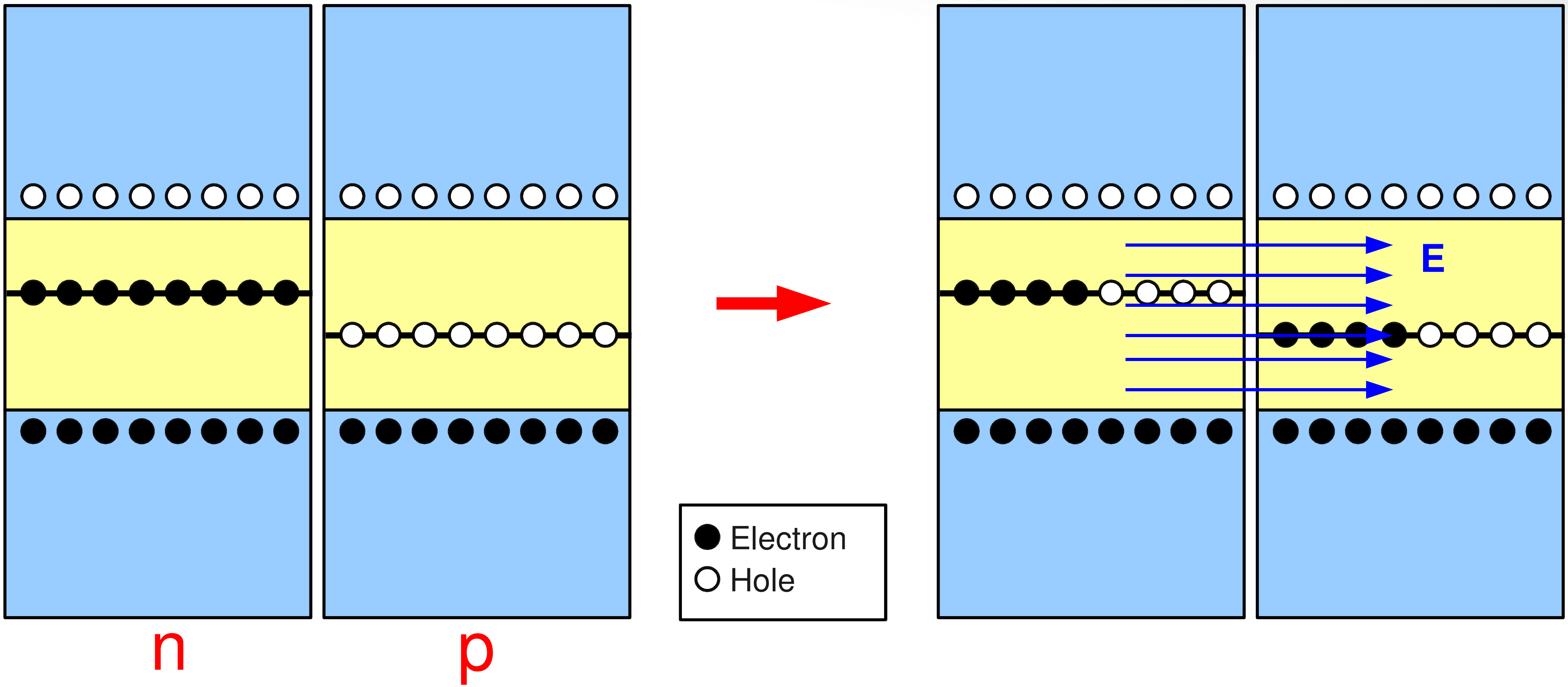
- Dopping the silicon (Z=14) with gallium (Z=31) creates a new, empty energy level close to the valence band



p-type

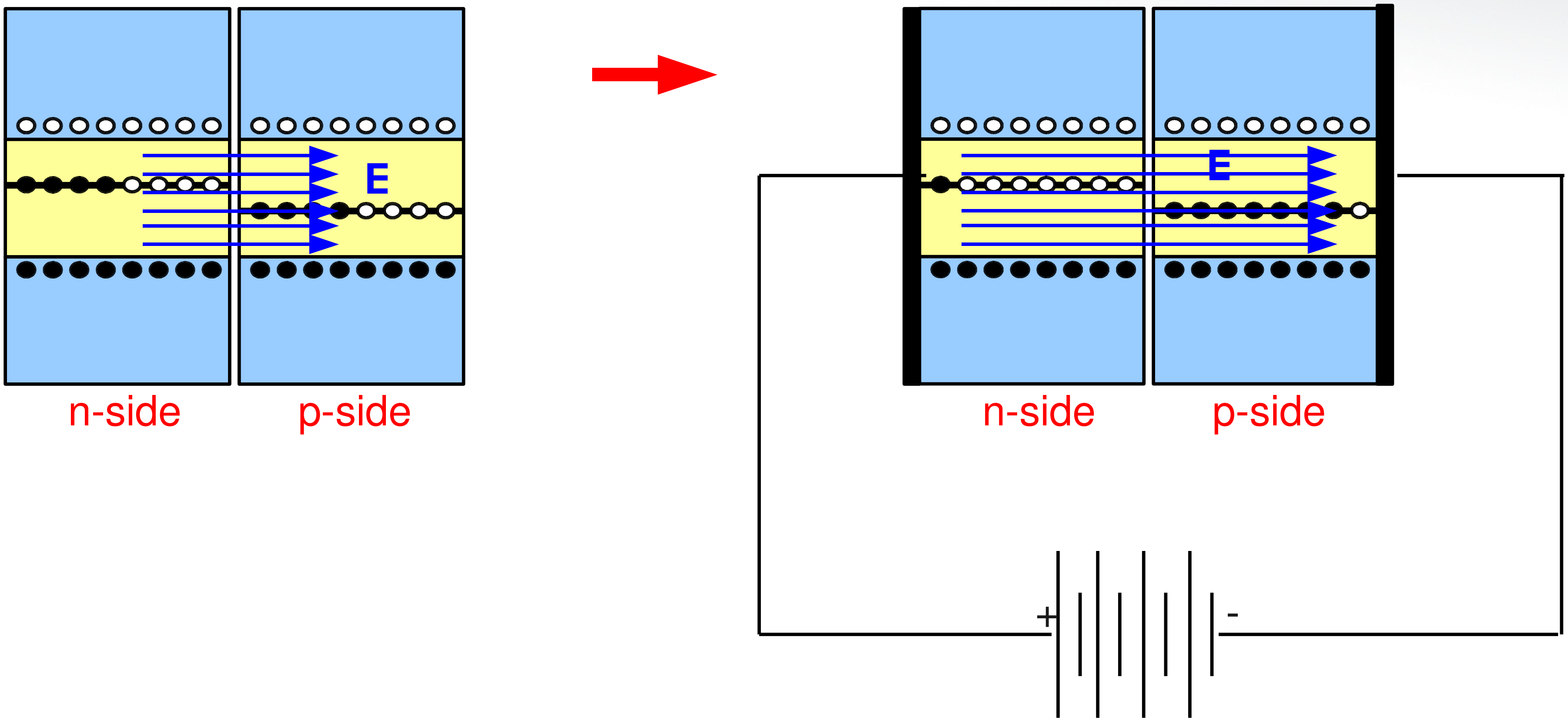
The p-n junction

- Putting them together, the diffusion of electrons turns the (initially neutral) n-material positive, and the p-material negative, creating an electric field between them



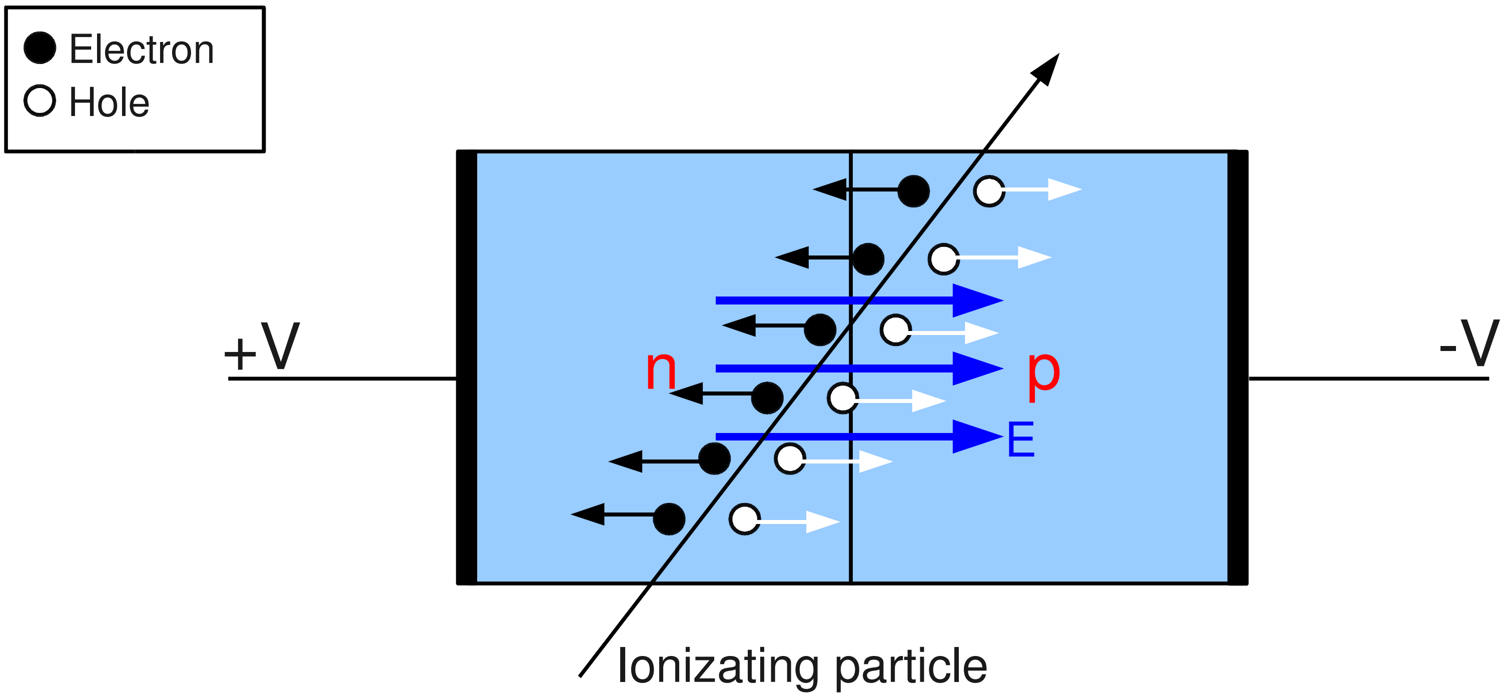
The p-n junction

- Under reverse bias (+V on n-side, -V on p-side) the electric field region increases



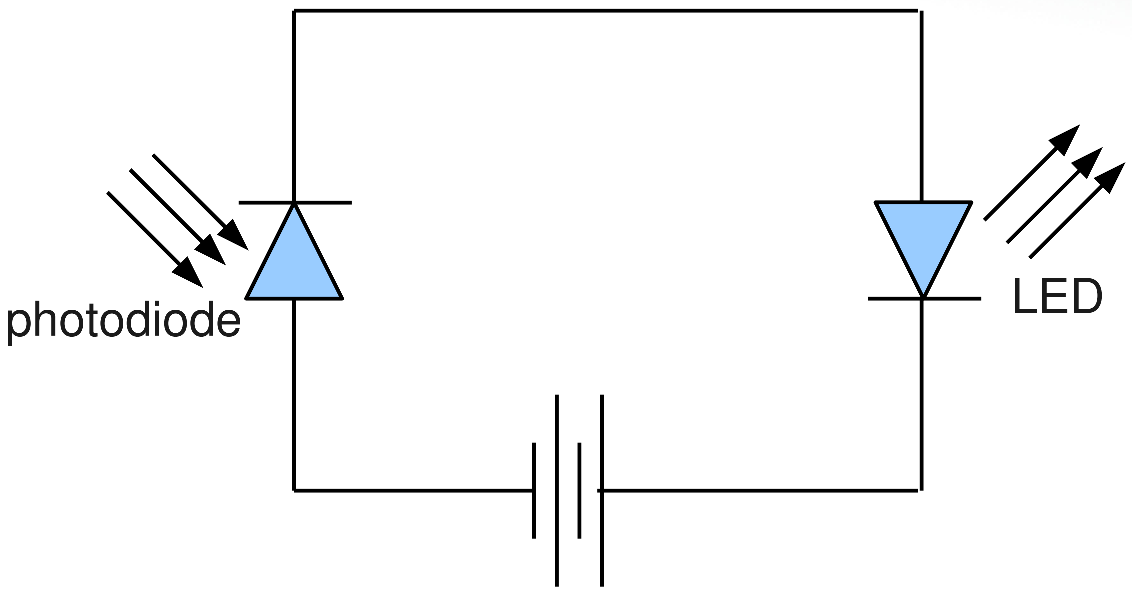
p-n junctions

- When a particle passes through the sensitive region, it ionizes the medium, liberating charges which are collected by the electric field
- In silicon, the minimum energy for electron-hole creation is 3.62 eV



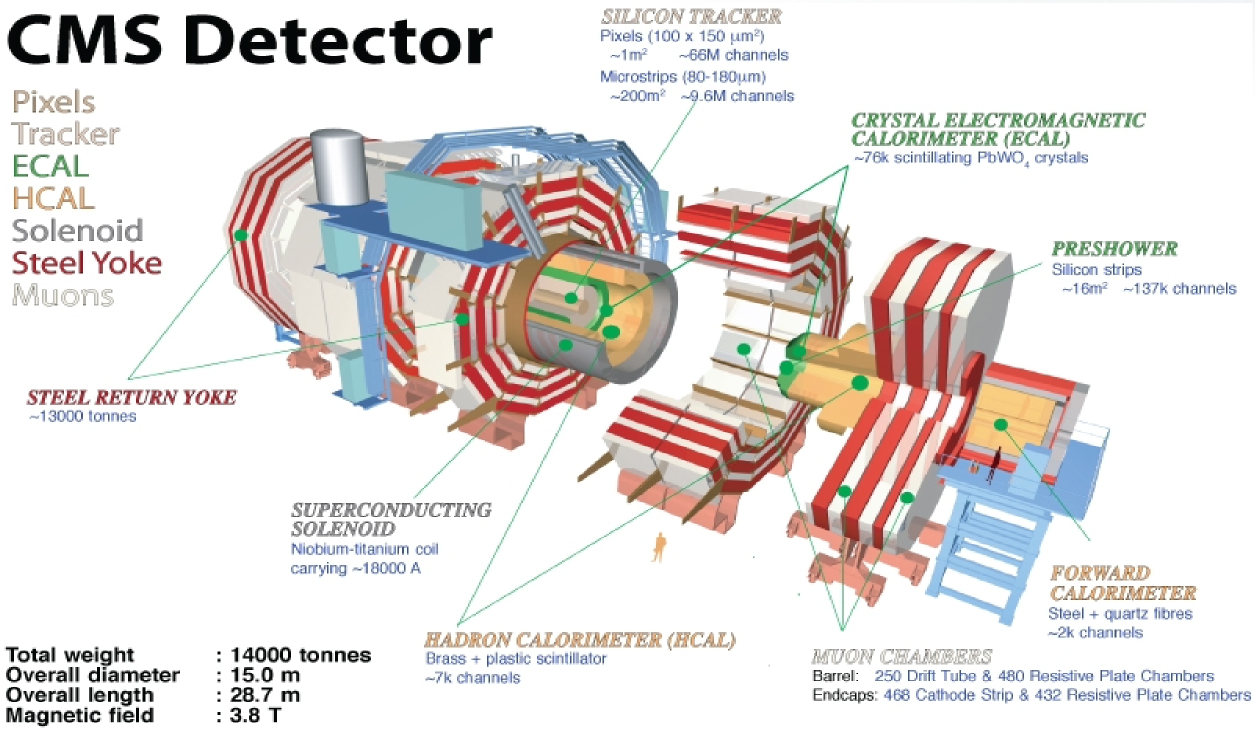
Practical example

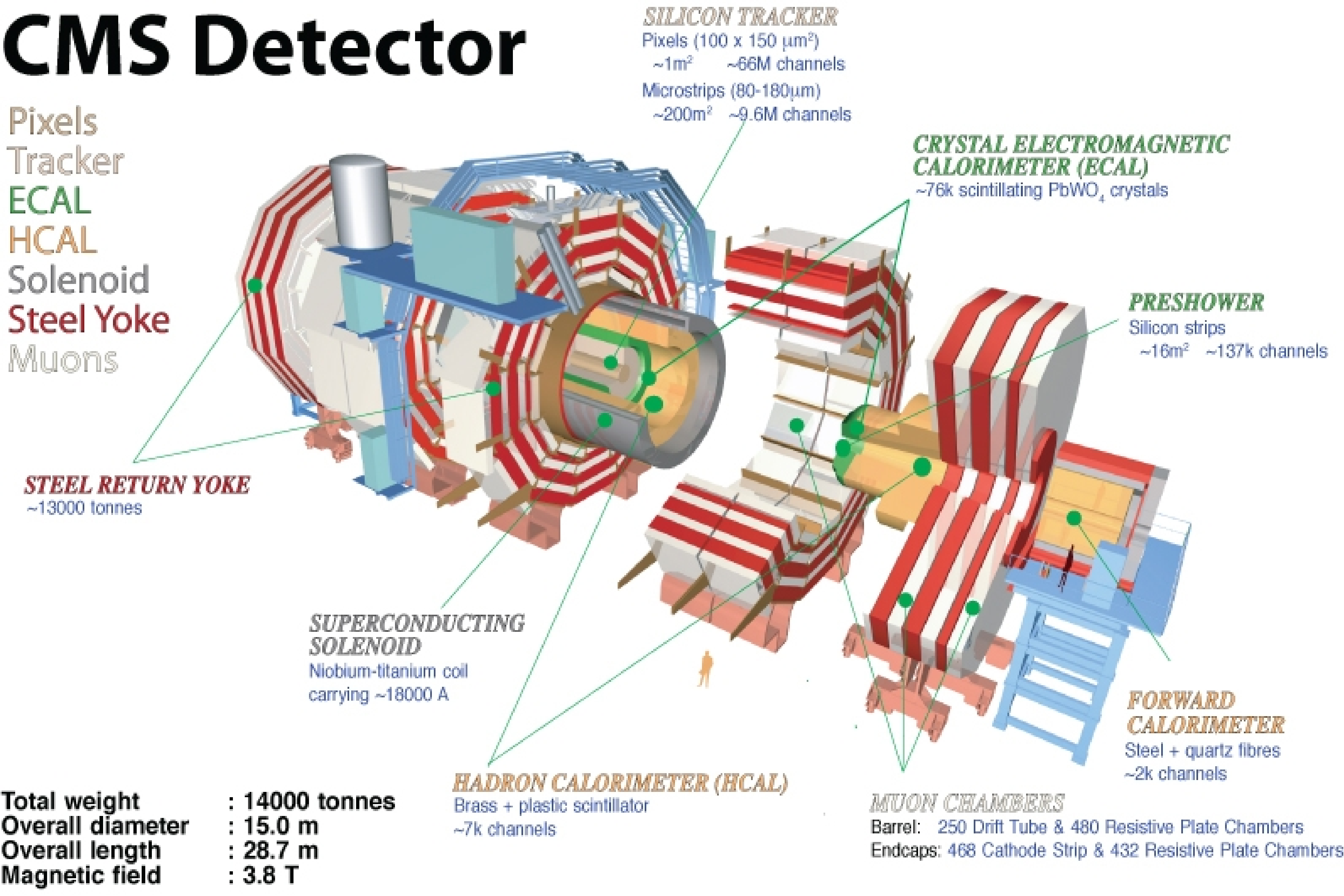
- Photodiode as an example of a p-n junction



Silicon detectores in the CMS

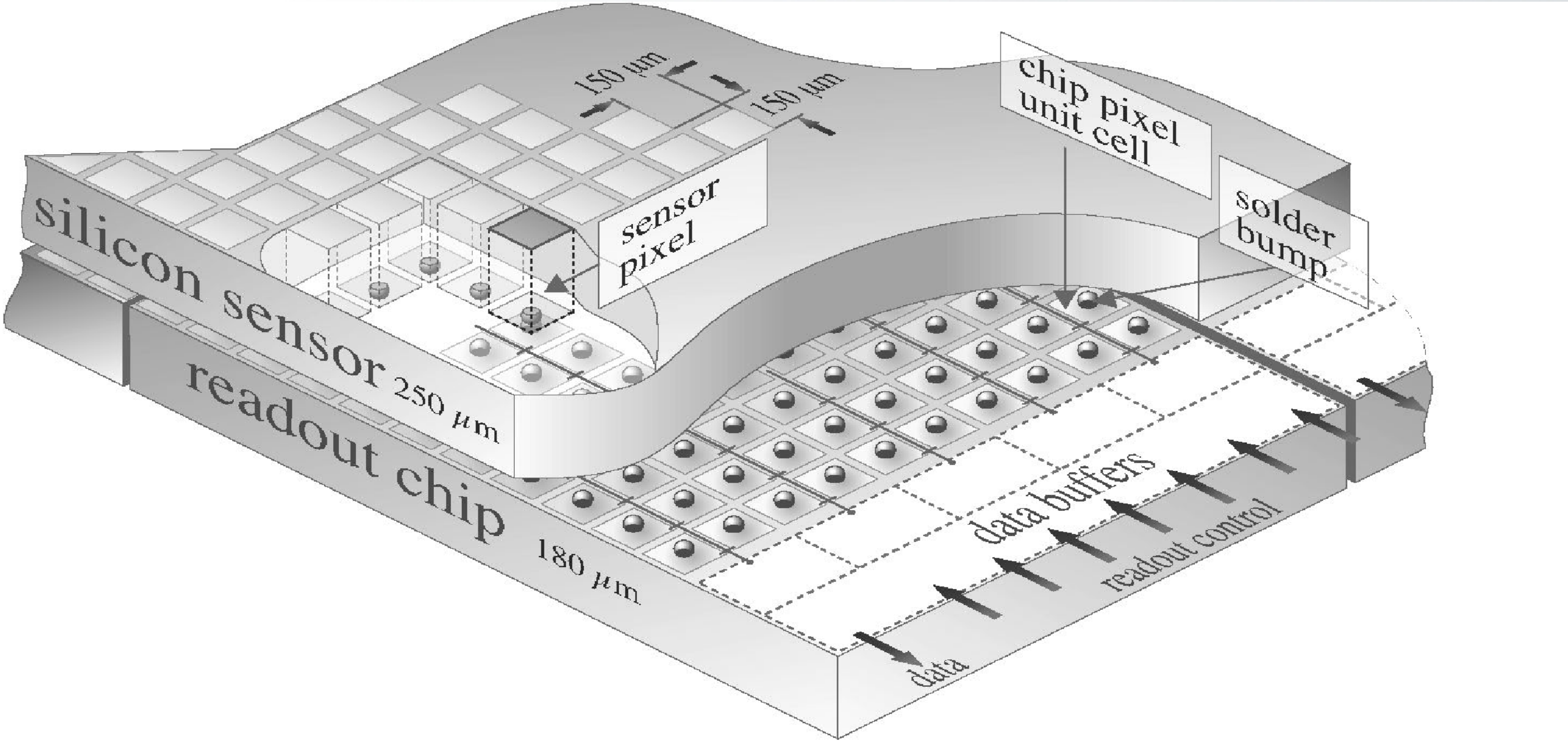
- p-n junctions can be arranged in several ways to make a detector
- The CMS has a *pixel* and *microstrips* system, which compose the *tracker*




CMS Detector
Pixels
Tracker
ECAL
HCAL
Solenoid
Steel Yoke
Muons
SILICON TRACKER
Pixels (100 x 150 μm²)
~1m² ~66M channels
Microstrips (80-180μm)
~200m² ~9.6M channels
CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76k scintillating PbWO4 crystals
PRESHOWER
Silicon strips
~16m² ~137k channels
STEEL RETURN YOKE
~13000 tonnes
SUPERCONDUCTING SOLENOID
Niobium-titanium coil carrying ~18000 A
FORWARD CALORIMETER
Steel + quartz fibres
~2k channels
HADRON CALORIMETER (HCAL)
Brass + plastic scintillator
~7k channels
MUON CHAMBERS
Barrel: 250 Drift Tube & 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip & 432 Resistive Plate Chambers
Total weight : 14000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T

The pixel system

- Each pixel is a p-n junction



Pixel

- The pixel system has a track accuracy of 2 micro, almost the 1 micro resolution of photographic emusion

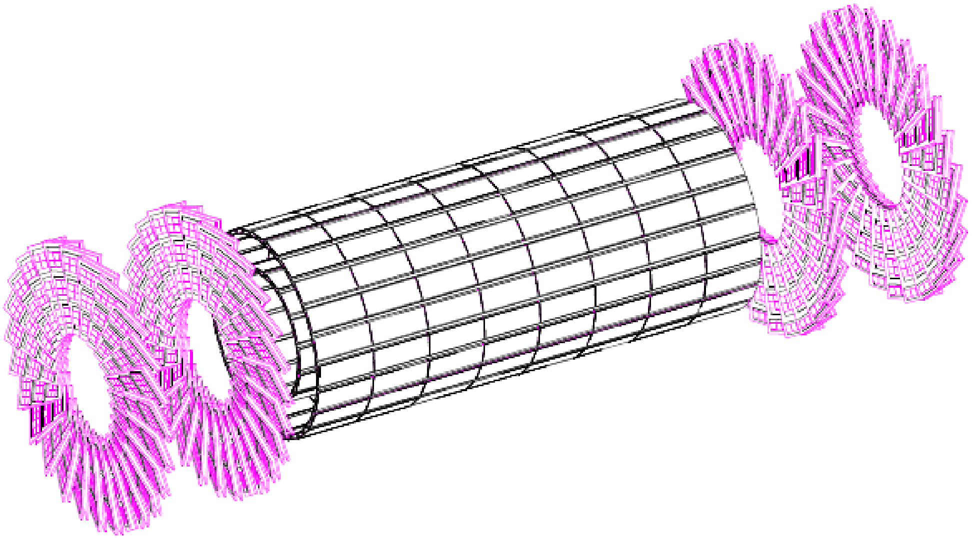
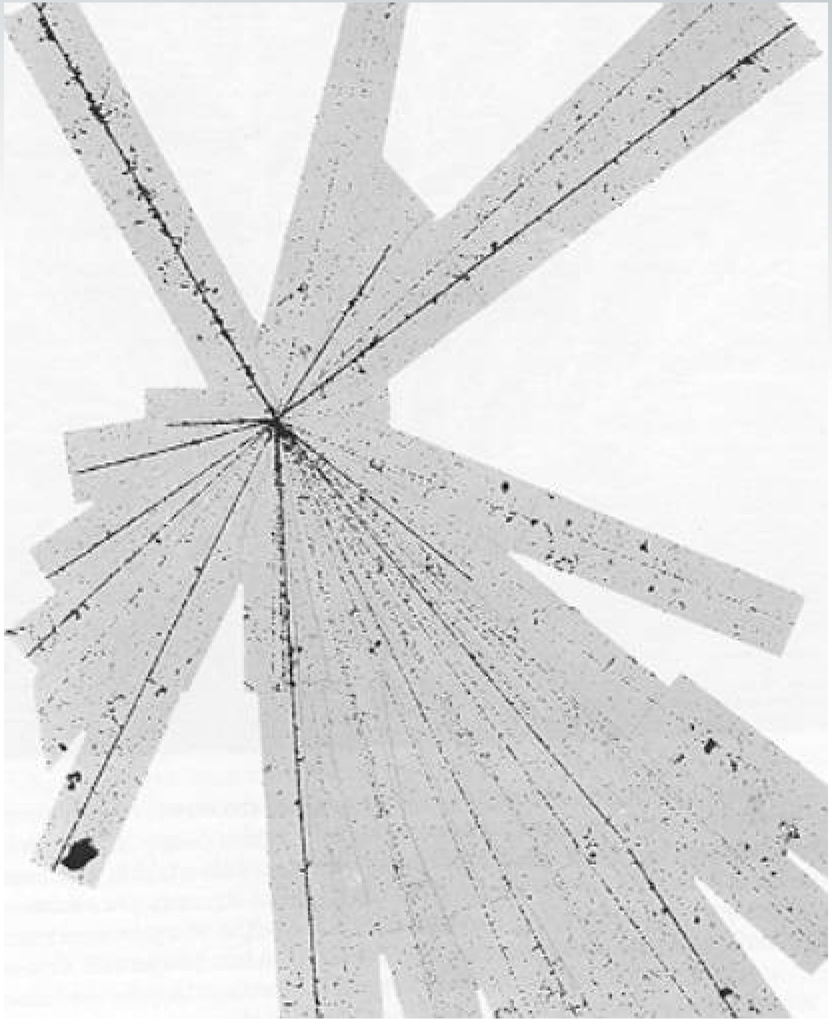
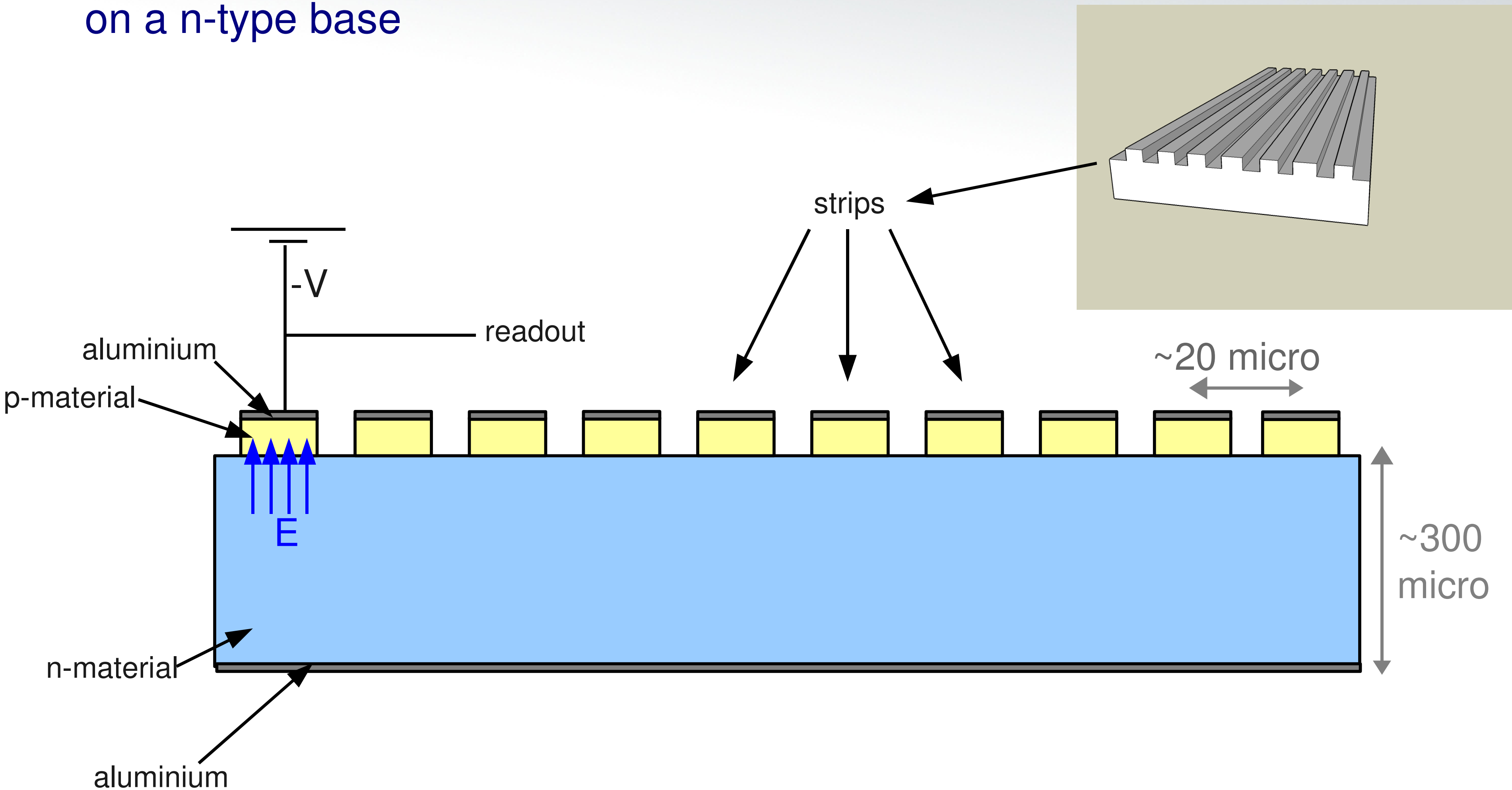


Fig. 2.3: Perspective view of the CMS pixel system in the high-luminosity configuration.



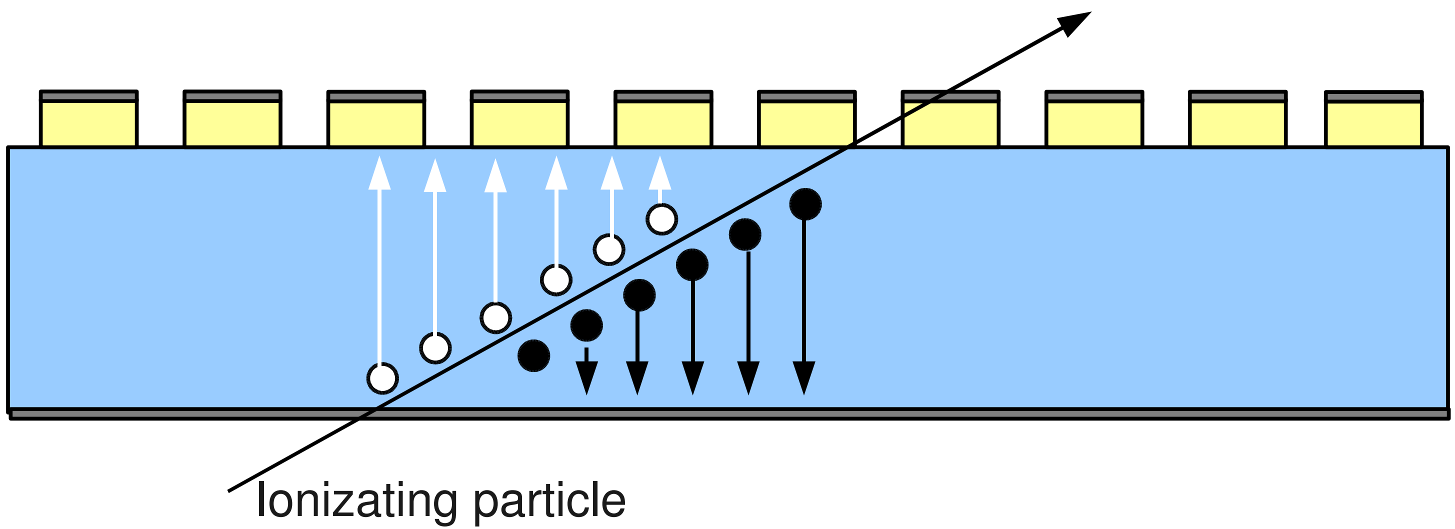
The Micro Strip System

- The micro strips system consist of p-type strips on a n-type base



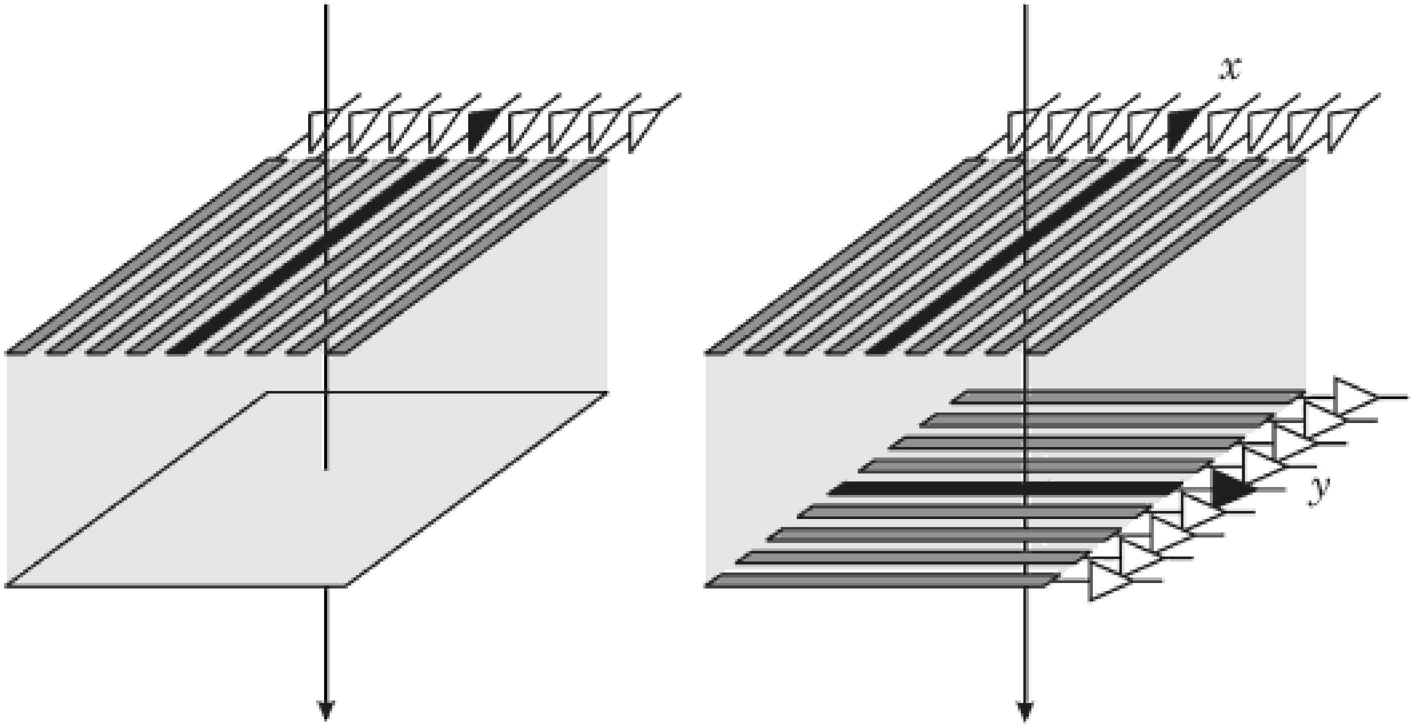
The Micro Strip System

- The micro strips system is less accurate than pixels and subjected to more noise, because each strip may receive several hits; that's because pixels are closer to the beam than strips



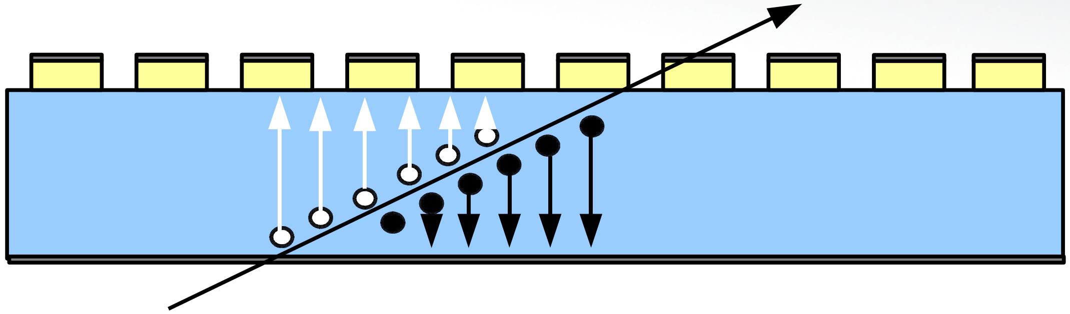
Micro Strips

- Micro strips can be arranged in a way to give (x,y) position

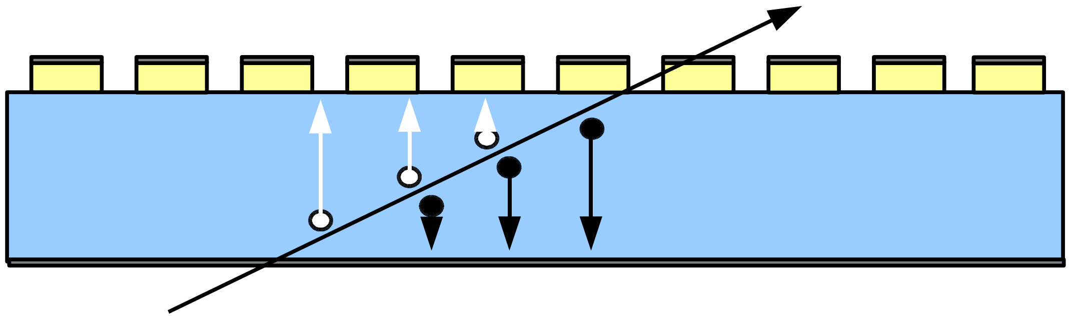


dE/dx measurement

- dE/dx information is proportional to the number of ionized atoms



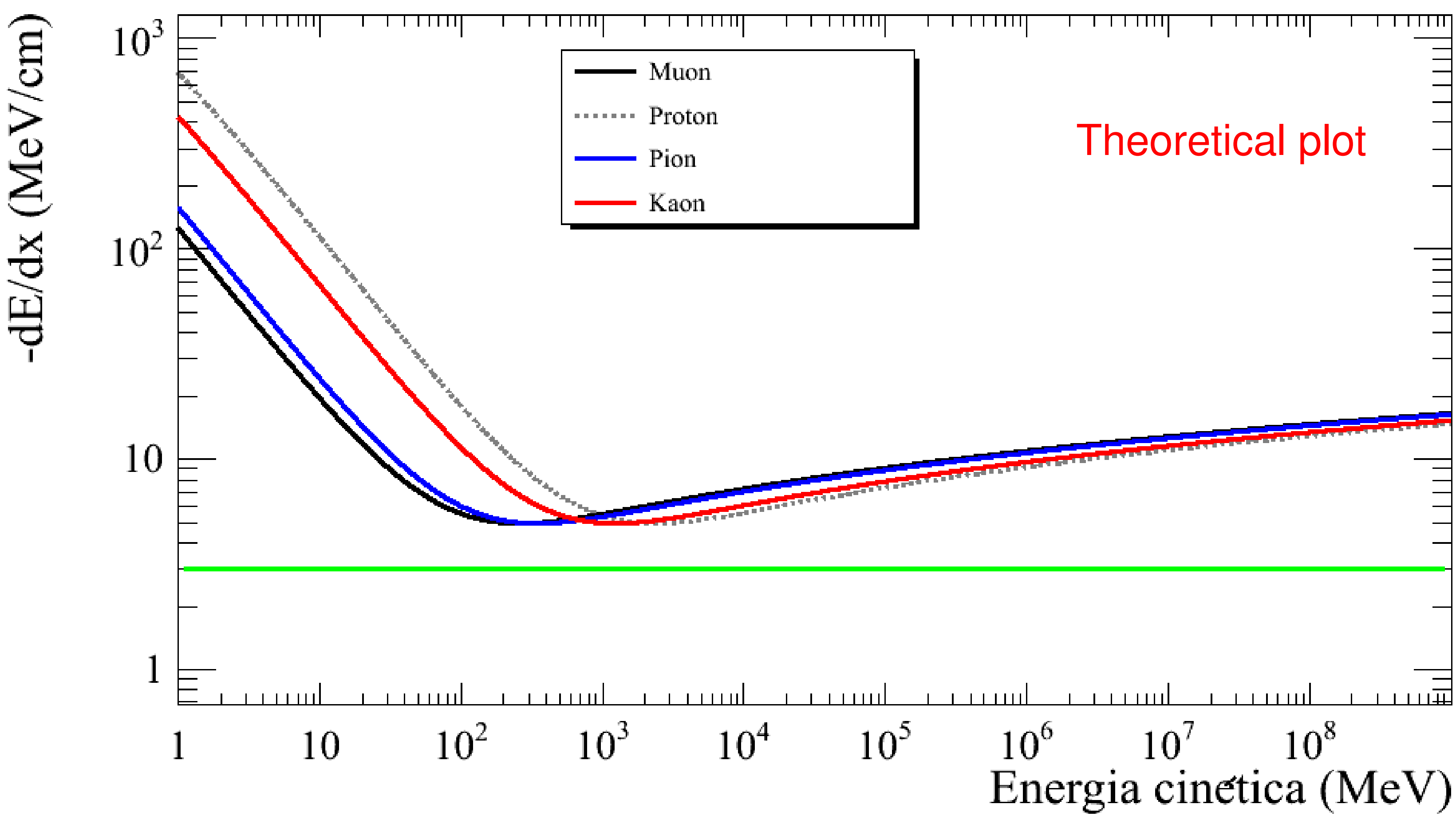
High dE/dx



Low dE/dx

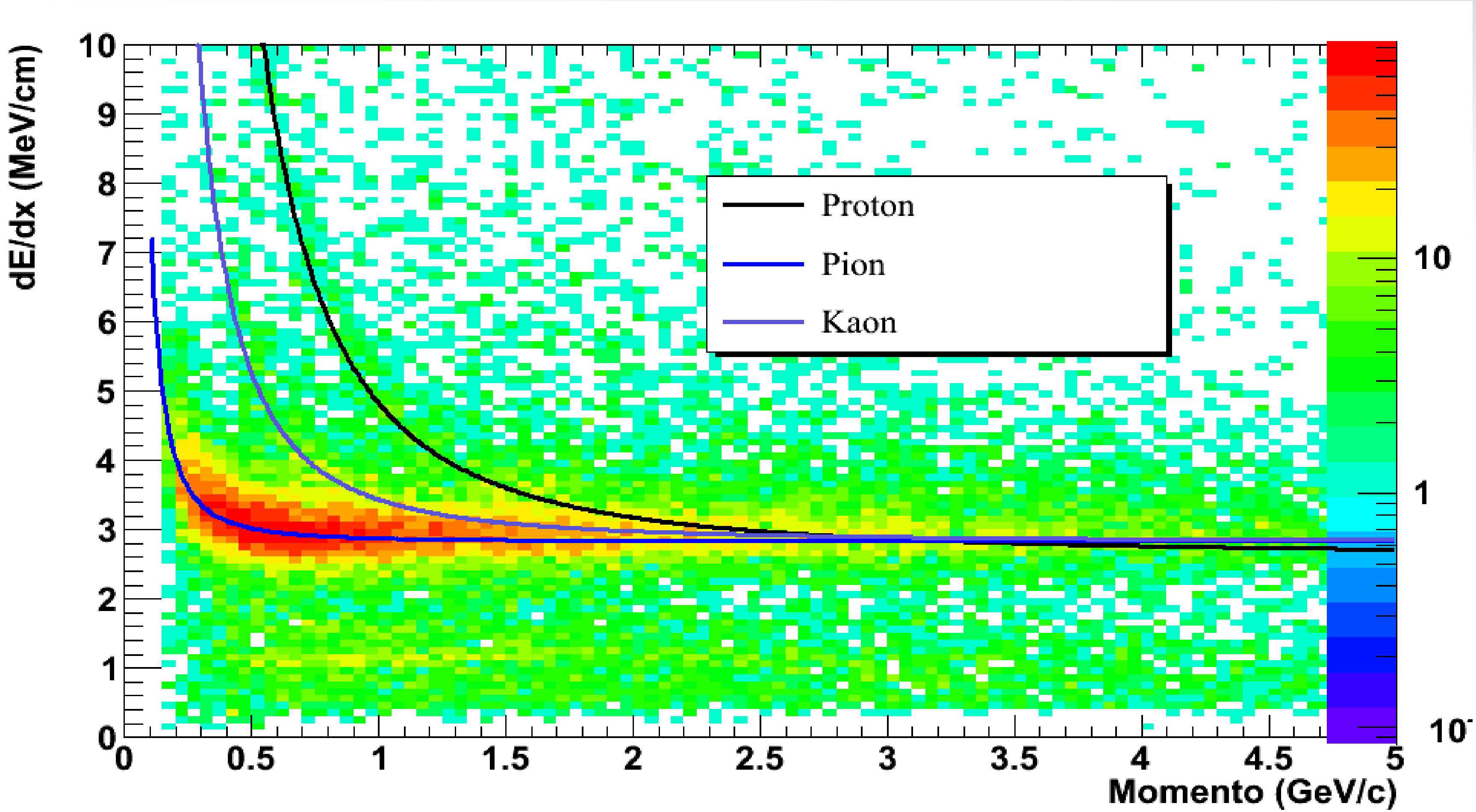
dE/dx analysis

- dE/dx depends on the mass of each particle



dE/dx analysis

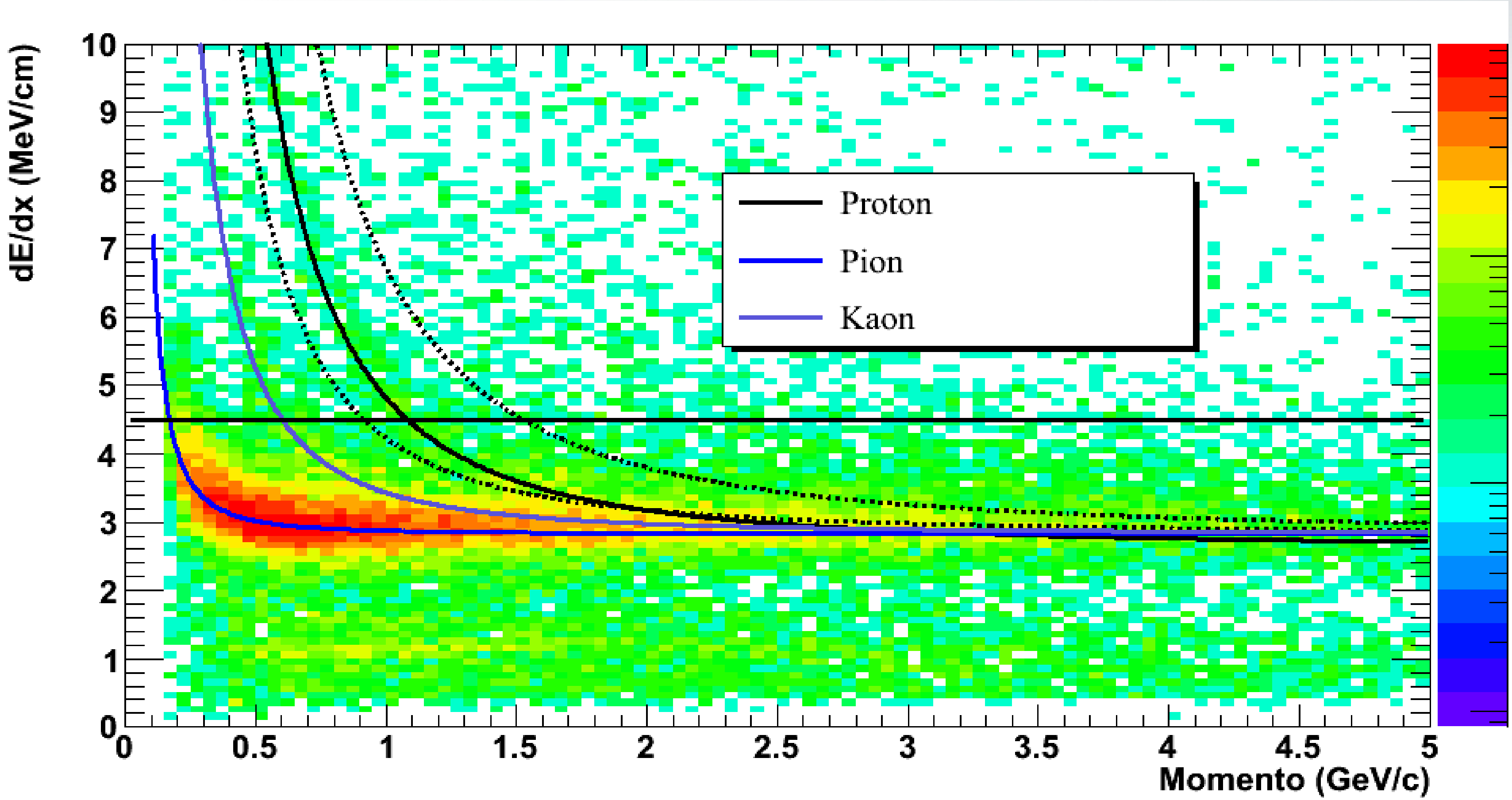
- Using dE/dx information it is possible to identify the particle



900 GeV data plot

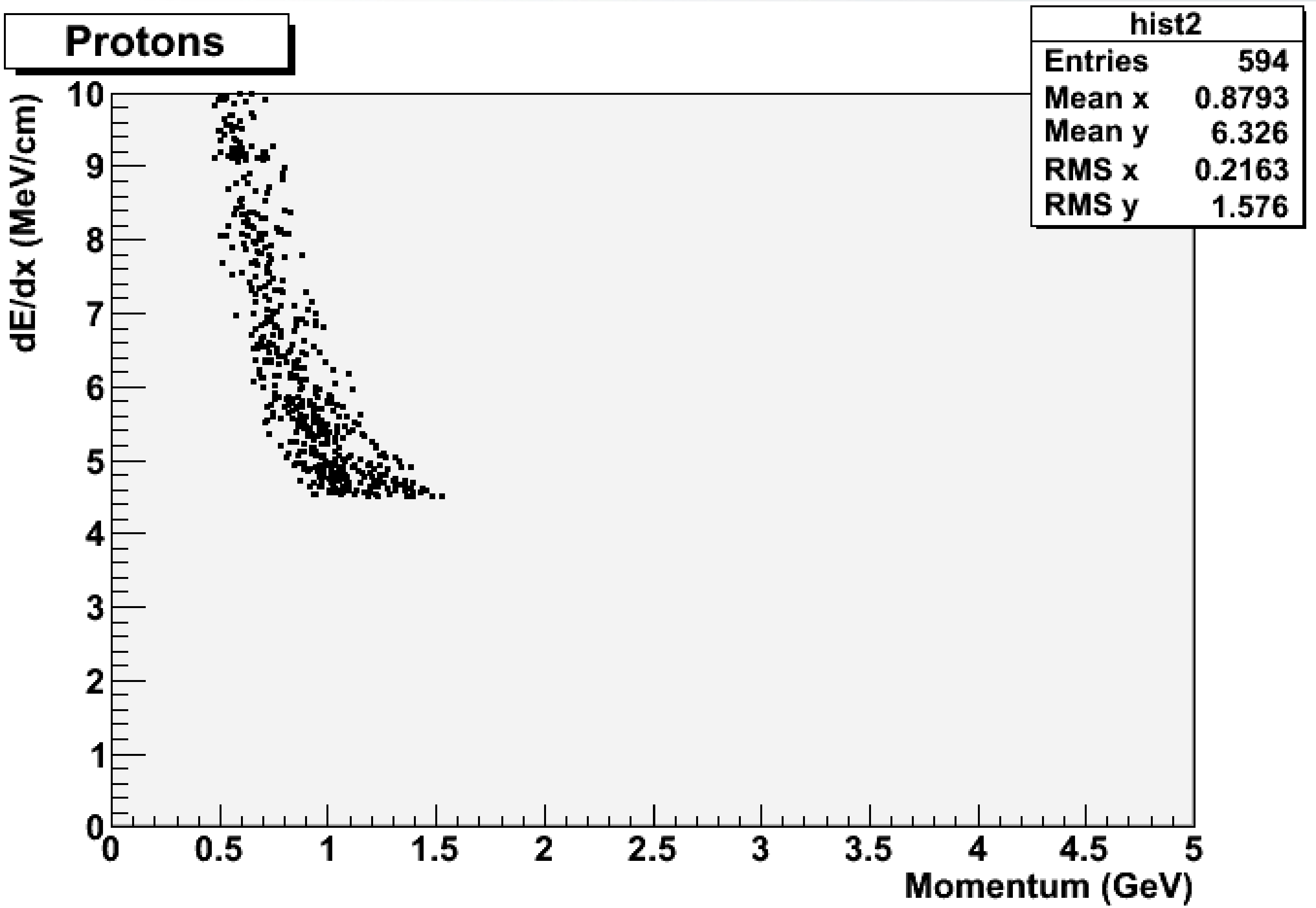
dE/dx analisys

- One can select particles defining a region in the (dEdx, P) plane



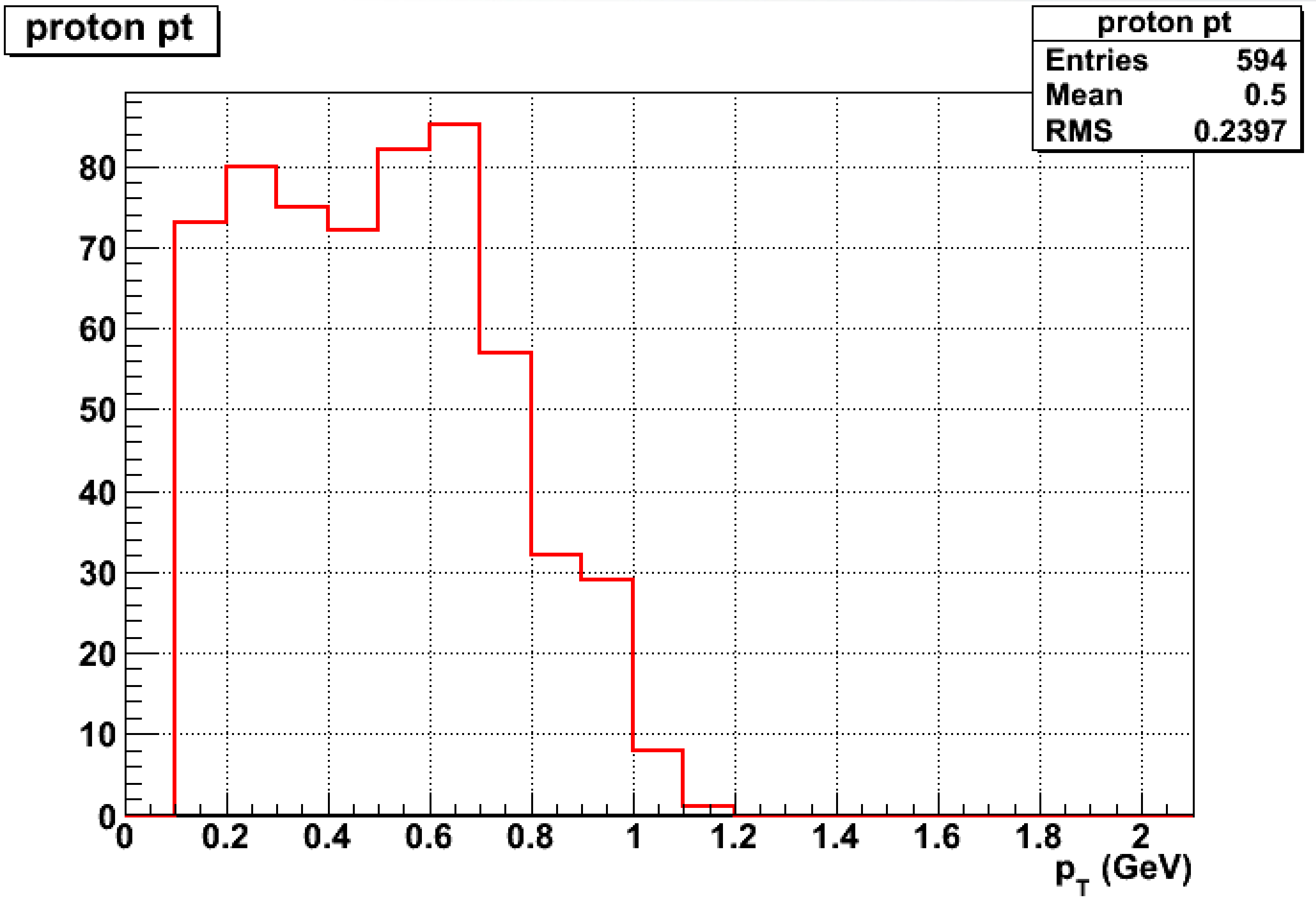
dE/dx analisys

- Example of protons selection



dE/dx analisys

- Once selected, one are able to extract informations from the particle, e.g. the pT distribution of the protons



References

- [1] H. Spieler, Semiconductor detector systems
- [2] W. R. Leo, Techniques for Nuclear and Particle Physics Experiments
- [3] PDG
- [4] http://cmsdoc.cern.ch/cms/TDR/TRACKER/tracker_tdr_files.html