Silicon Drift Detectors in the LHC experiment ALICE

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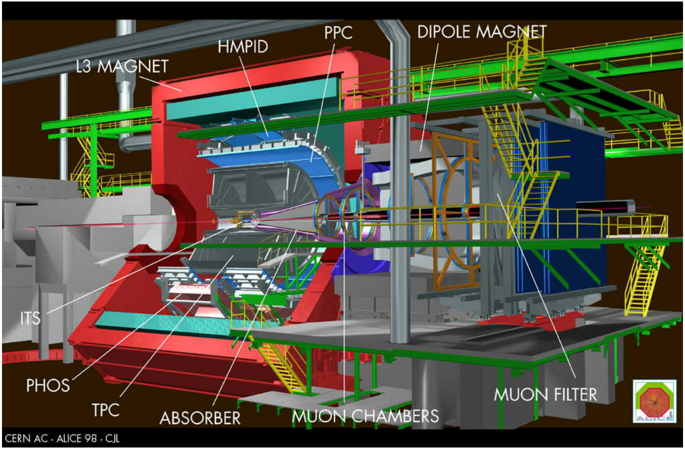
ALICE experiment



Design of Inner Tracking System

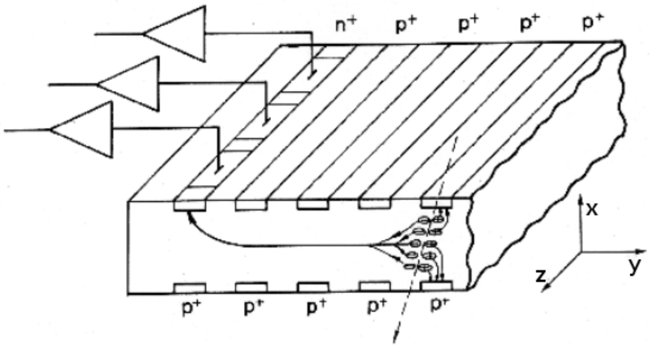
- Rapidity coverage $|\eta| < 0.9$
- Particle identification through specific energy loss
- Reduction of material in active volume (relative momentum resolution)
- 8000 tracks per unit of rapitity (maximum)
- 15000 simultaneously detected tracks
- Total dose during the lifetime 150 krad for the inner part
- Triggering - central trigger (whole ALICE), trigger of muon arm (pixel detectors in ITS)

Structure of Inner Tracking System

- Silicon Pixel Detector (SPD)
  - Primary vertex position
  - Consists of matrices of 256 $\times$ 256 pixels, thickness 250 μm
  - Inner radius 4 cm, outer radius 7 cm
  - Precision 12 μm $(r\phi)$, 70 μm (z)
- Silicon Drift Detector (SDD)
  - Two middle layers of ITS, dE/dx information
  - Inner radius is 14.9 cm, outer radius 23.8 cm
  - Precision 38 μm $(r\phi)$, 28 μm (z)
- Silicon Strip Detector (SSD)
  - Track connection between ITS a Time Projection Chamber
  - Active area of one module 73 $\times$ 40 mm^2, strips of length of 40 mm
  - Inner radius is 39.1 cm, outer radius 43.6 cm
  - Precision 20 μm $(r\phi)$, 830 μm (z)

Design of drift detector

- Crossing ionizing particle creates electron-hole pairs
- Holes are collected by the nearest cathodes
- Electrons are transported toward the anodes

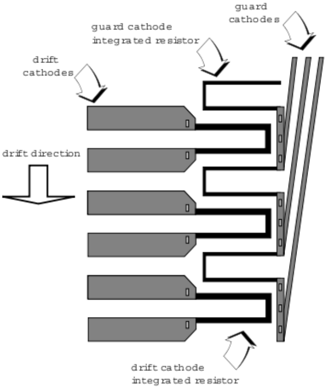


Generation of electrical field inside drift detector

- Poisson equation for potential of electric field

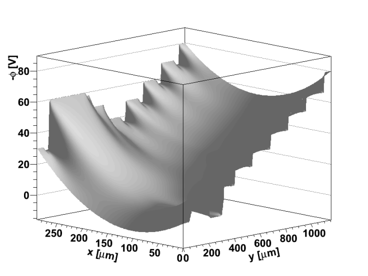
$$\frac{\partial^2(-\phi)}{\partial^2 x} + \frac{\partial^2(-\phi)}{\partial^2 y} = \frac{N_D q}{\epsilon_0 \epsilon_r}$$

- N_D is donor density
- Integrated voltage divider
- Electrodes in anode region are connected separately

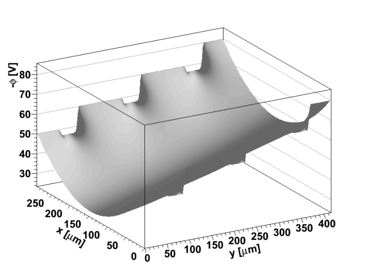


Potential of electrical field inside drift detector

Anode region



Linear region



Charge transport in drift detector

- Drift movement

$$v = \frac{\mu E}{1 + \frac{\mu E}{v_{sat}}}$$

- Mutual coulombic repulsion

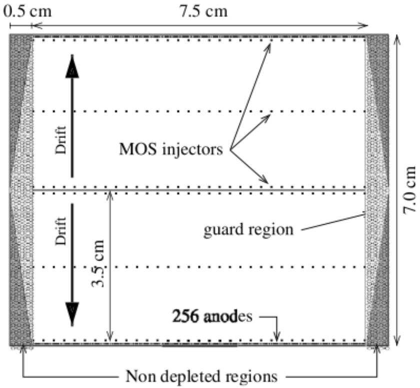
$$\phi_j = \sum_{i=1, i \neq j}^{N} \frac{1}{4\pi\epsilon_0\epsilon_r} \frac{e}{r_{ij}}.$$

- Thermal diffusion

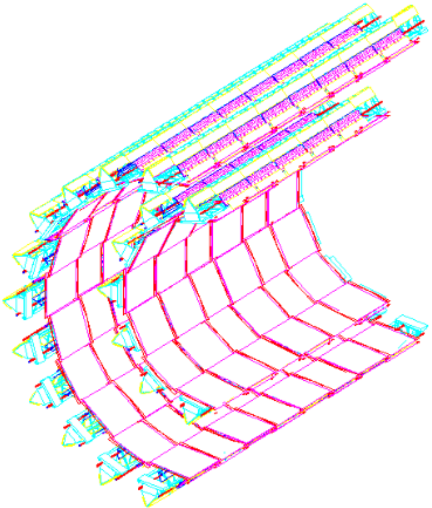
$$D = \mu V_t;\ V_t = \frac{kT}{q}$$

ALICE Drift detector module

- Neutron Transmutation Doped (NTD) silicon 300 μm wafer
- Division to two drift parts
- MOS charge injectors for calibration of the drift velocity (6.5 $\mu m/ns$)

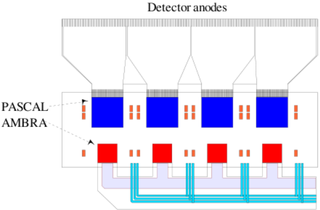


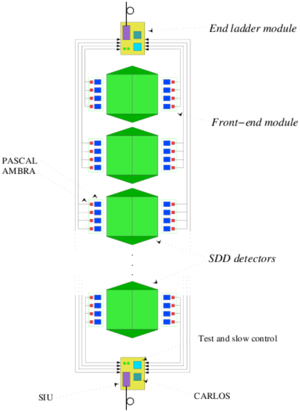
ALICE Drift detector assembly



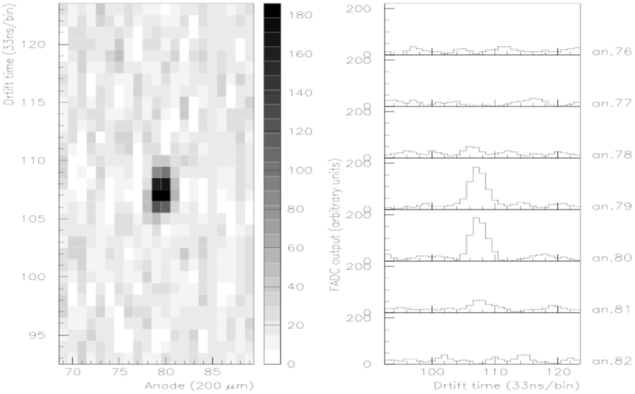
Readout electronics design

- Hybrid integrated circuit PASCAL, digital AMBRA
- Gain 27 mV/fC, peaking time 40 ns
- Sampling rate: 40 MHz, conversion with 10 bit precision
- Overall readout time 250 μs



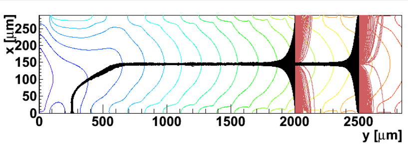


Hit reconstruction in drift detector

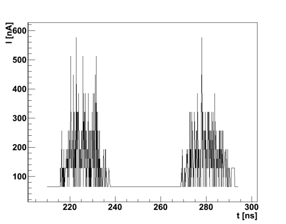


Double hit in drift direction

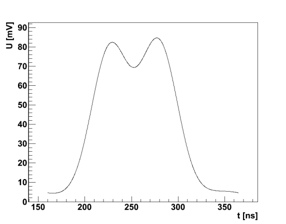
2x 20 000 electron-hole pairs, 2000 a 2500 μm above the edge of module



Anode current

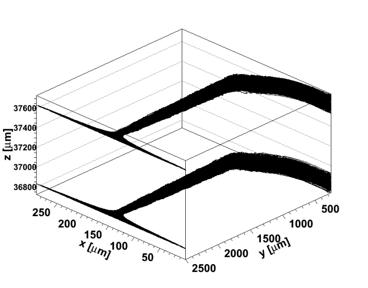


Output voltage

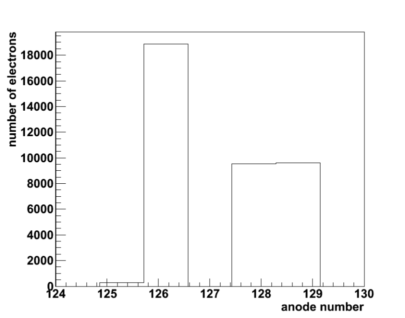


Double hit in anode direction

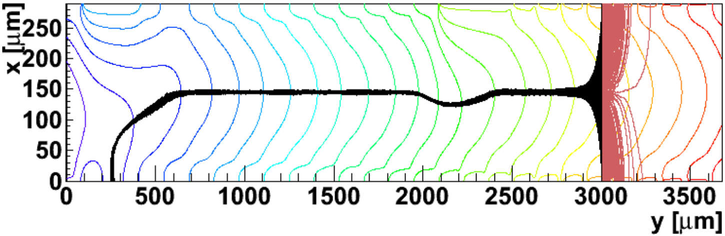
2x 20 000 electron-hole pairs, mutual distace 800 μm



Anode distribution of arrival electrons



Simulation of detector with defect of electrical field (short circuin on cathodes)



Premise physics functions of the ALICE Inner Tracking System

- Improvement of momentum resolution
- Mass resolution for heavy states (D mesons, J/Ψ)
- Detection of low momentum particles (< 100 MeV/c) - only ITS
- Separation of tracks with close momenta
- Primary vertex and secondary vertices
- Multi-strange hyperons Ξ^- and Ω^-
- Full decay topology reconstruction

Bibliography

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