Gas Detectors

The Particle Detector Brief Book

http://rkb.home.cern.ch/rkb/titleD.html

Widely used in many applications for radiation detection.

Cheap.

High resolution spatial information

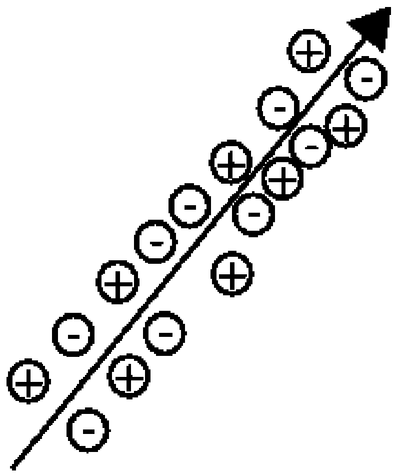
Low multiple scattering

Particle Identification via energy loss

Basic Principles

Charged particles traversing a gas leave a trail of ionization.

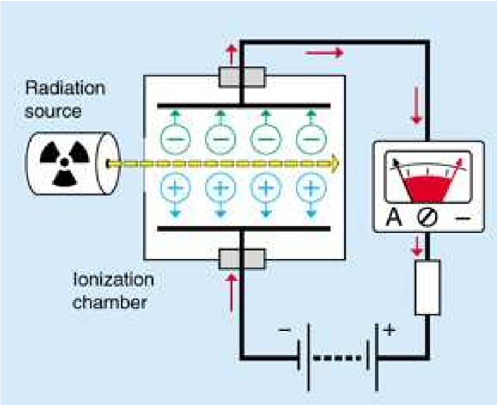
Amount of ionization proportional to energy loss (dE/dx)



The ionization is localized to the particle trajectory.

Apply an electric field and separate the electrons from ions before they can recombine

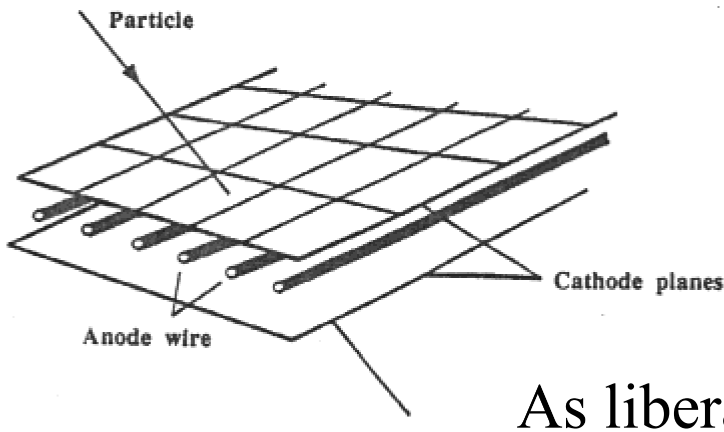
Ionization chamber measures the total charge deposited via induced current.



Gas Amplification.

A minimum ionizing particle traversing a gaseous medium typically releases 100 electrons per cm.

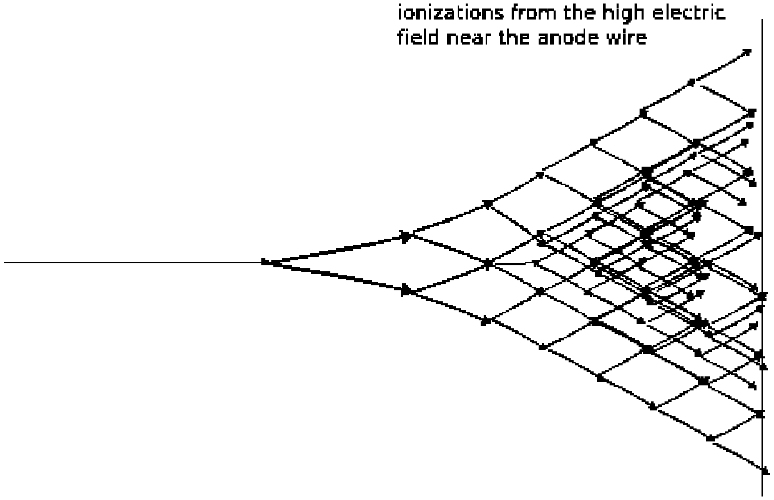
By placing the +ve high voltage on a thin anode wire, it possible to amplify this signal by a factor up to 10^6



The electric field around a wire increases as 1/r

As liberated electrons drift to towards the anode they cause secondary ioninizations.

Gas Amplification



Typical volatges on the anode wire are 1000 V – 2500 V.

Wires are typical 25 micron diameter gold-plated to reduce corrosion

Noble gasses provide the best amplification medium.

The secondary ionization process also releases UV photons.

Proportional Counters

The UV photons can initiate ionizations away anode and can lead to complete break-down of the gas.

If this happens the detector operates in “Geiger-Mode”.

Particle tracks can be observed visually as a “streamer-chamber” or a “spark chamber”

Most particle physics experiments prefer to operate in “proportional mode” where the charge deposited on an anode is proportional to the dE/dx of the incident particles

Proportional chamber include a “quenching” gas component like isobutane to absorb the UV photons

Detector Aging

Since gaseous detectors deliberately create many free radical ions, detector aging is an important issue.

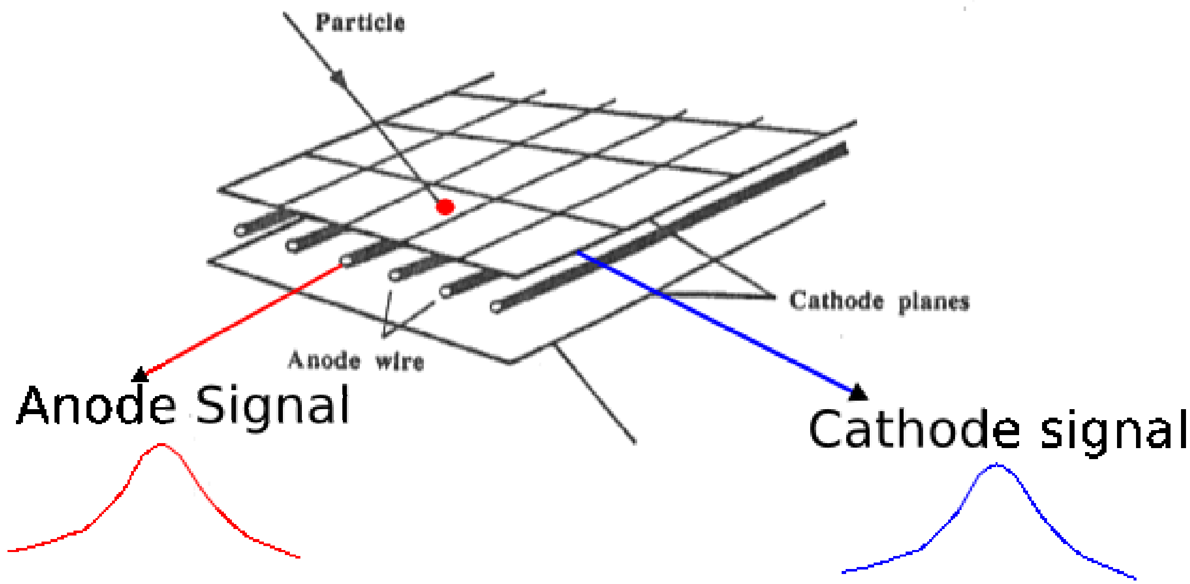
Chamber gases must be free of oxygen and water (since free Oxygen ions are highly corresive)

In addition the gas must be continuously circulated through the chamber to prevent the build up of polymerized molecules.

Detectors optimized for particle tracking use Helium, detectors used for X-ray detection employ Argon or Xeon.

2 Dimensional Readout

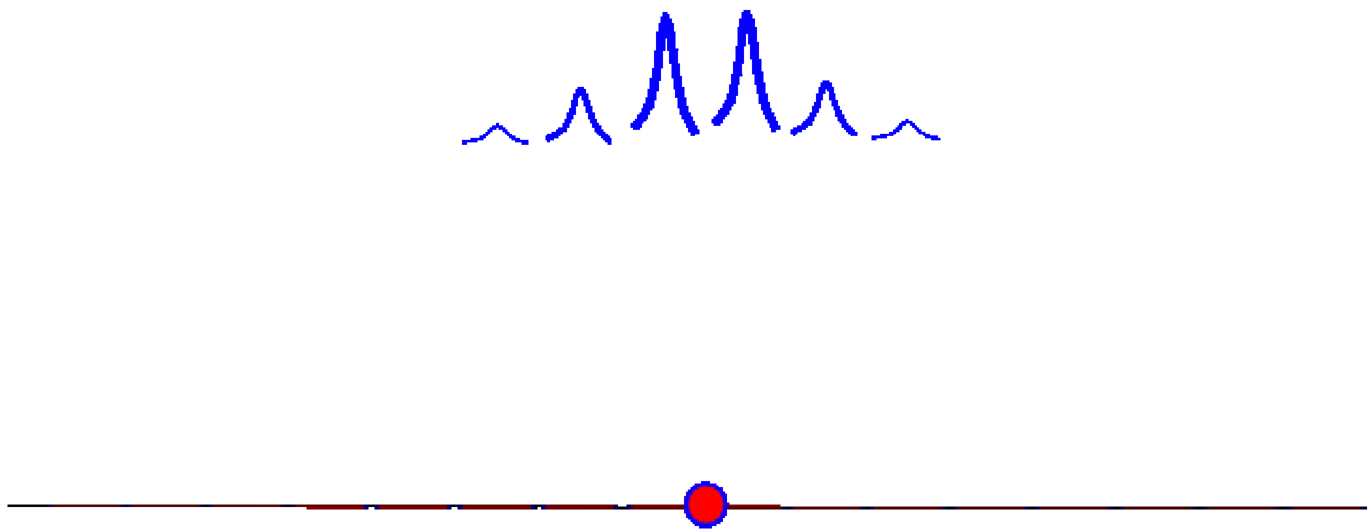
A the electron avalanche from the gas amplification induces pulses on both the anode +ve High voltage and on the cathodes



By placing the cathode perpendicular to the anode 2-D information is available.

Center of Gravity

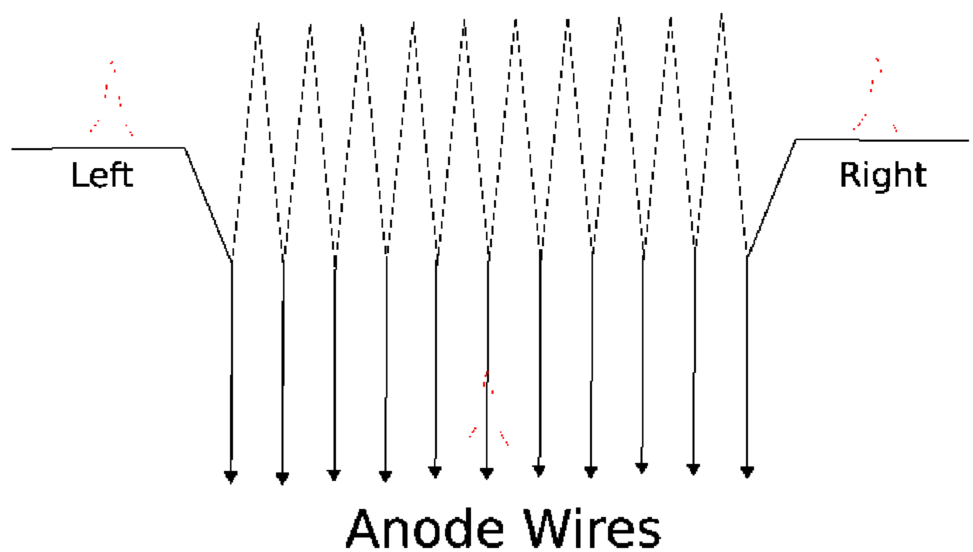
Can exploit center of gravity techniques to provide higher resolution from the cathode data.



Resolution can be 10-20 times greater than strip width.

Delay line readout

Can determine which wire fired via a delay-line readout



Time of arrival between the left and right signals determines which wire fired. Can do the same trick for cathodes too.

Resistive Readout

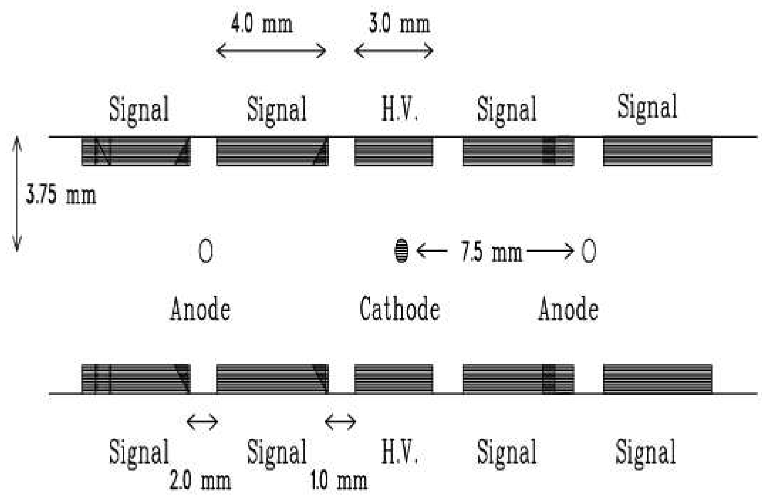
If we readout the signal from both ends of an anode with it is possible to infer the location of the avalnach from the pulse height at either end.

High Speed Chambers

MicroStrip Chambers

Drift Chambers

After the initial ionization, it is possible to arrange the electric field so that the electrons "drift" towards the anode at constant velocity.



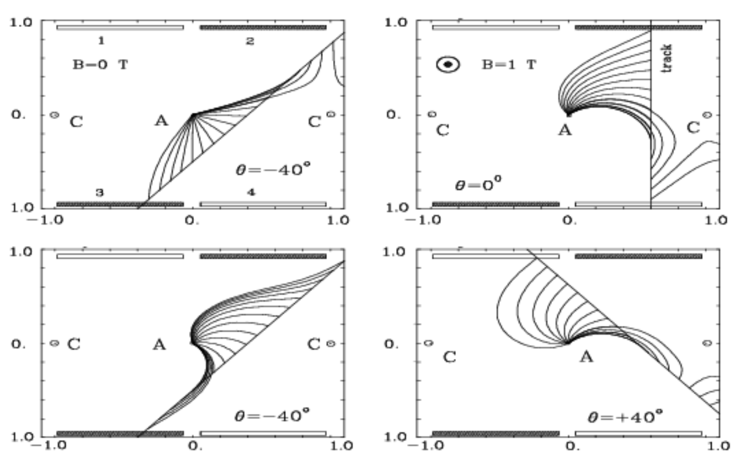
Then the location of the initial ionization can be interpolated from the time of the pulse on the wire.

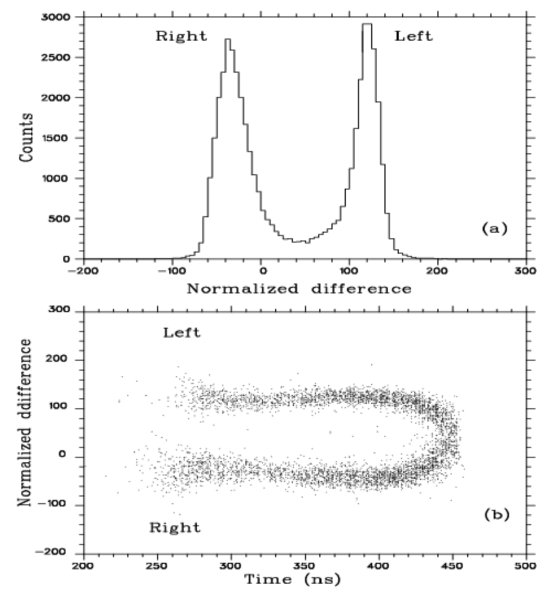
Position resolutions of 50 microns are typical with drift chambers.

Left-Right Ambiguity

Although we know which wire fired and the distance at which the ionization occurred, we don't know the "direction".

In the case of a planar drift chamber this is called the "left-right ambiguity".

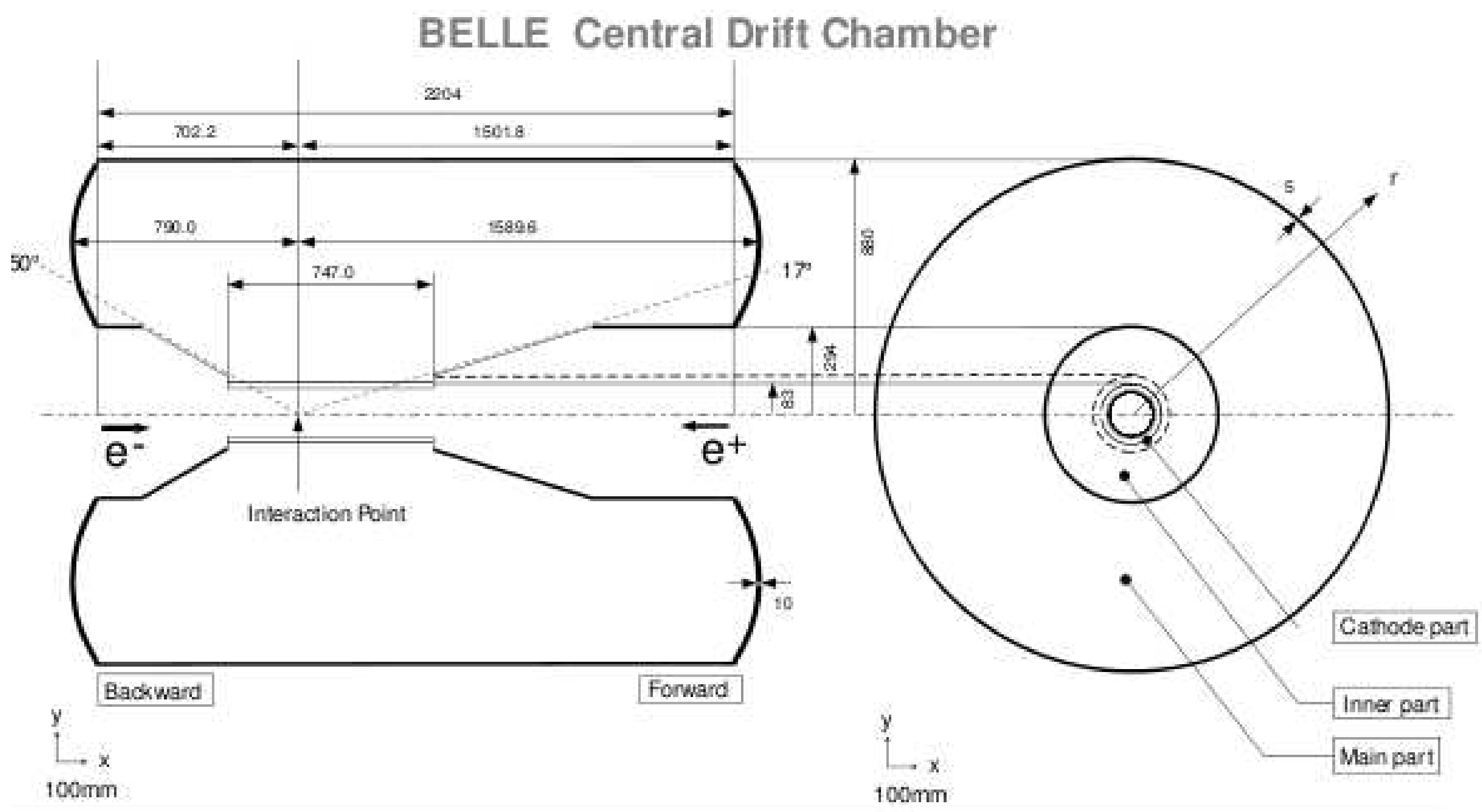




Extra information is required to resolve this. This example from the CHAOS detector employs the induced cathode signals.

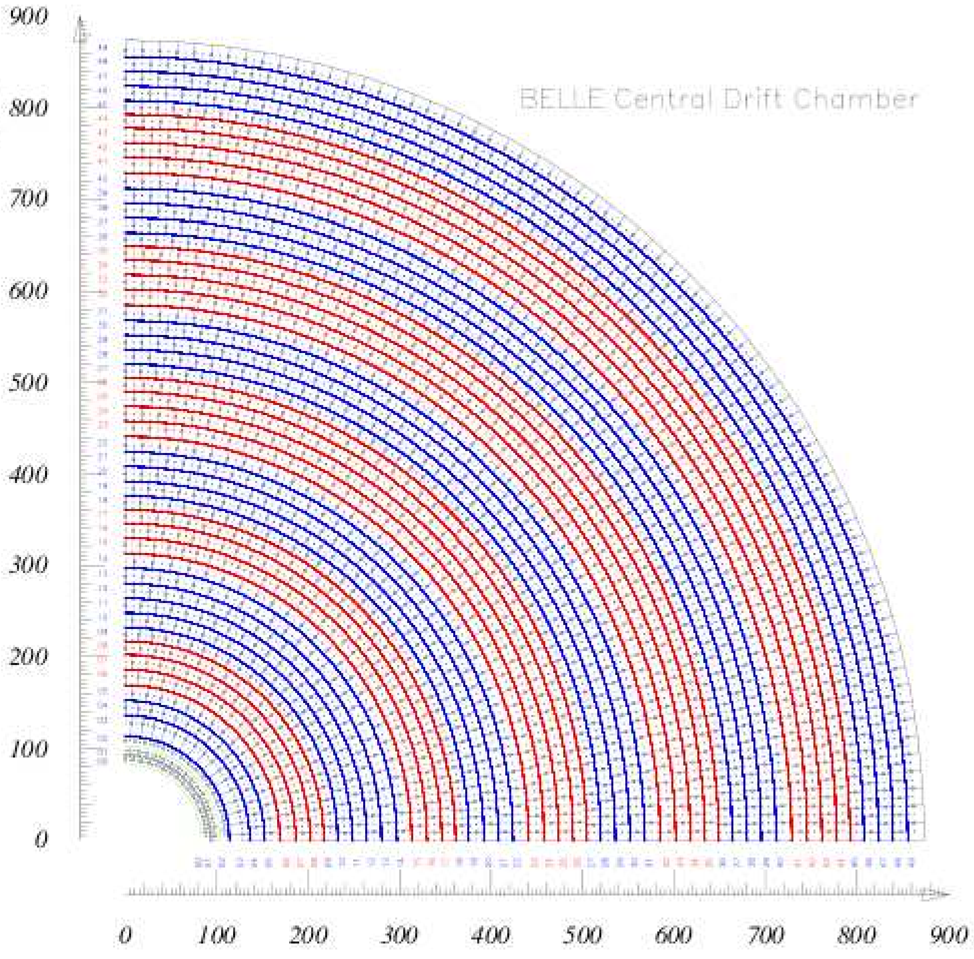
3 Dimensional Chambers

Possible to instrument a 3-dimensional volume with a light-weight scructure to provide a 3-Dmensional drift tracking chamber.



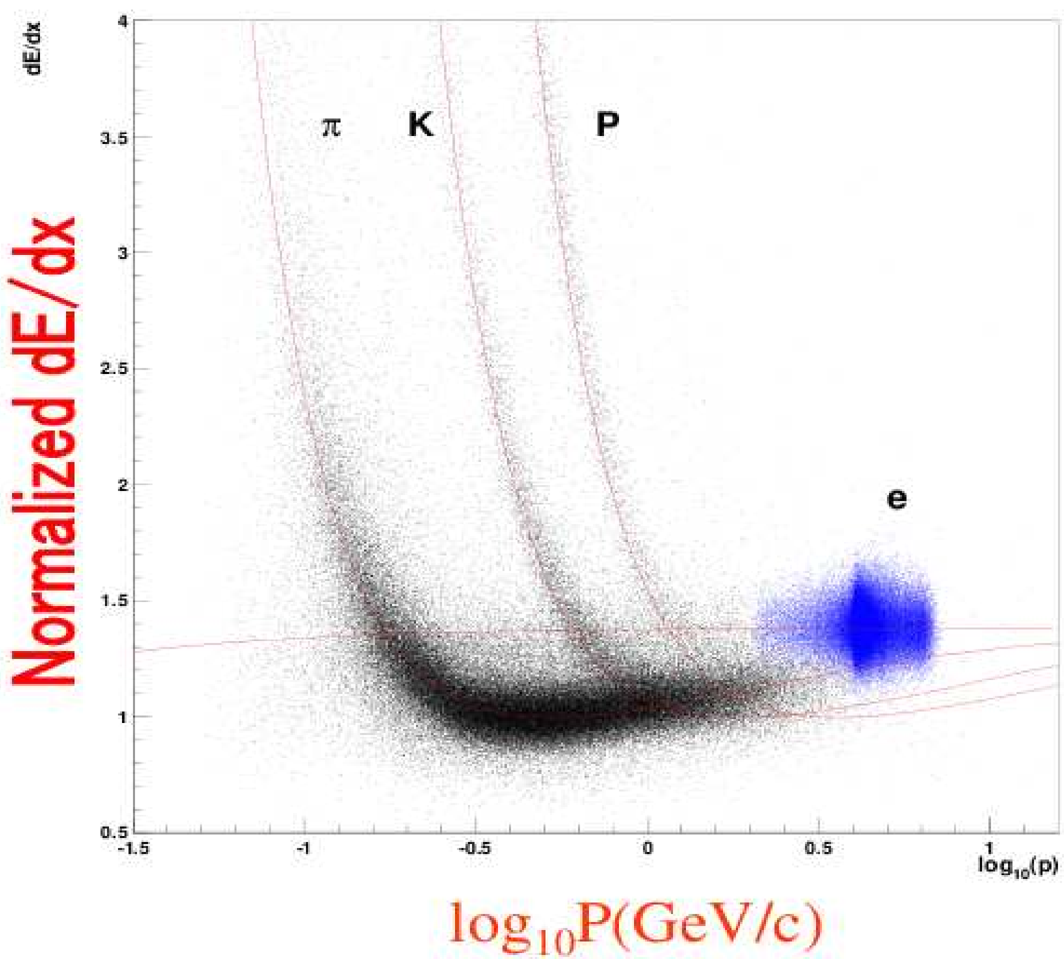
Belle CDC

- Active region
  - → R= 88mm : inner most sense wire
  - → R=863mm : outer most sense wire
- Wires
  - → 30µm$^{\phi}$ Au-W for sense wire
  - → 126µm$^{\phi}$ Al for field wire
- Square cells
  - → 16mm(r)X~18mm(rϕ)
- 6(axial)+5(stereo) super layers
  - → 50 layers in total
- Readout channels
  - → 8400 for sense wires
  - → 1792 for cathode strips



Belle CDC

Can employ the Bethe-Bloch equation to use the pulse height from the wires to measure particle velocity.



Time Projection Chambers

Transition Radiation Detectors