A Discussion of Specific Ionisation in the Belle II Experiment

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Introduction

The Belle II experiment at the High Energy Accelerator Research Organization in Tsukuba, Japan collides electrons and positrons. A shower of particles are produced from these collisions, and most of them are detected by sub-detectc

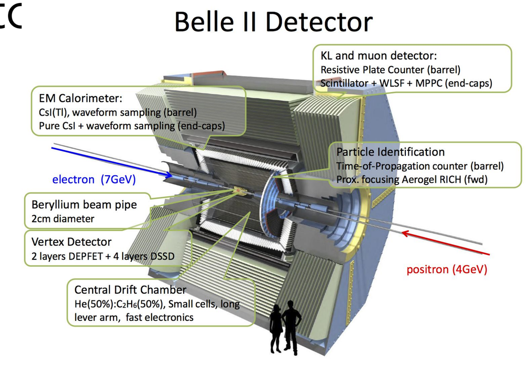


Figure 1: A diagram of the Belle II detector. We focus our attention on the Central Drift Chamber. [1]

The primary goal of the Belle II experiment is to gather data that point to something beyond the Standard Model. In particular, the parameters in the weak nuclear force are measured in experiments using decays involving the production of mesons with bottom or charm quarks.

A relevant sub-detector for particle identification is the Central Drift Chamber (CDC). This detector measures the specific ionization (dE/dx) of the charged particles passing through.

dE/dx In the CDC

- The CDC is composed of about 56,000 wires that surround the central collision area
- Two types of wires, sense and field wires
- Sense wires have a voltage of ~2200 V
- Field wires have 0V

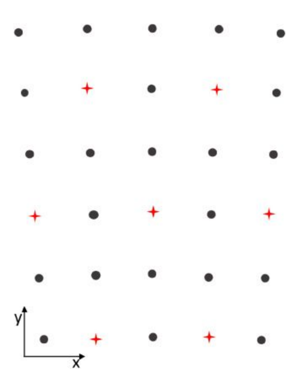


Figure 2: The wire configuration of the CDC. The red crosses represent the sense wires and the black dots are the field wires. We also notice that the wire separation increases as r increases. [2]

- 5 charged particles make it to CDC: electrons, muons, pions, kaons, and protons
- These particles ionise the gas, a mixure of He and C_2H_6
- Ionisation frees the electrons, which are detected by sense wires in the CDC
- As electrons gets closer to the wire, more and more electrons get ionised
- The intensity of the signal correlates with the amount of dE/dx that occurs

Band Plots

The dE/dx measurements help us create band plots, where we plot dE/dx against momentum or βγ.

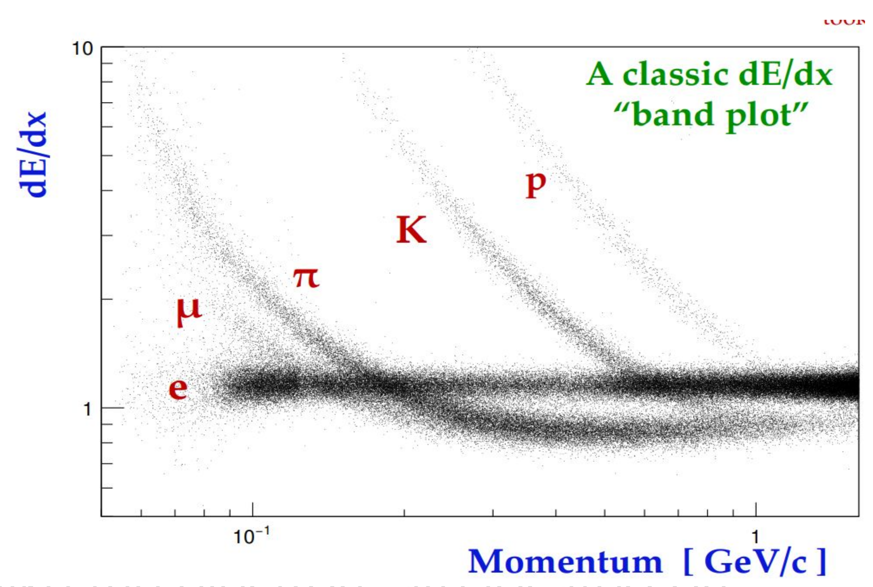


Figure 3: A band plot taken from the CLEO-c experiment with dE/dx against momentum. We see that each particle has a distinct curve. [3]

- Lighter particles, like the electron, are located on the curve that flattens out at a much lower momentum
- Muons and pions have a similar rest mass, so their curves overlap a considerable amount making it harder to differentiate them

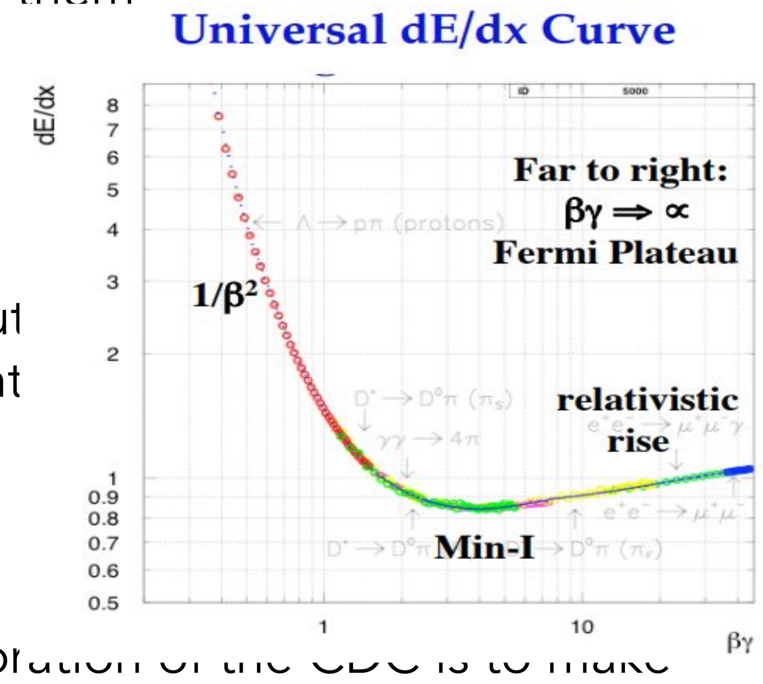


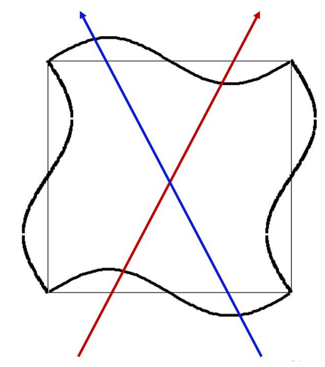
Figure 4: A band plot with dE/dx against **βγ**. We see that all of the particles lie on the same curve. [4]

- Universal curve exists because βγ divides out mass, the only relevant distinguishing feature for ionization, from momentum
- The main goal of calibration of the CDC is to make these band plots as narrow as possible
- The charged particles attain a minimum ionization (Min-I), where the particle ionises the gas at the lowest rate
- They also asymptotically approach a constant dE/dx at high momentum
- We call it a fermi plateau, and it occurs after a particle experiences a relativistic rise after the Min-I

Cell Geometry

- If we treat the sense wires as the central wire, then the 8 surrounding field wires make up a "cell"
- External magnetic field bends charged particles in the CDC
- Cell is no longer symmetric

Figure 5: Adjustment of the cell boundary. We see that diagonal paths traversing through the cell are no longer equal in length due to the symmetry breaking. [5]



- Distance of closest approach, DOCA, is the shortest distance between a point on the track and the sense wire of the cell
- Entrance angle is between the track and radial direction
- Together, the two metrics determine the track of the charged particle in the CDC
- This helps us calculate the dE/dx.

Future Plans

Our summer project seeks to improve the measurement of dE/dx & PID in the CDC. Based on existing experiments, we think significant improvements are possible. There are corrections of the path length that we want to verify. We will also test ways of averaging measurements. We will try to bridge the gap between our expectation and current dE/dx calibration's performance.

Conclusion

Particle accelerator detectors, like the one in the Belle II experiment, have complex processes to detect particles and identify them. The CDC has an arrangement of wires that allow us to detect charged particles produced by the collision. We measure the ionisation the particles induce in the gas. We also find the length of the particle's track, and together with the ionisation, we calculate the dE/dx of the particles. We typically plot the specific ionisation against the momentum of the particle, and it helps us identify the particle. We want our detectors to be as accurate as possible when it comes to identifying the particle, so we calibrate the CDC.

Literature cited

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