Design of a drift chamber for an experiment at FCC-ee for IEEE Conferences

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***Abstract*—The physics aims at the electron positron option for the Future Circular Collider (FCC-ee) impose high precision requirements on the vertex and tracking detectors. The detector has also to match the experimental conditions such as the collisions rate and the presence of beam-induced backgrounds. A light weight tracking detector is under investigation for the IDEA (International Detector for Electron-Positron Accelerator) detector concept and consists of a drift chamber. Simulation studies of the drift chamber using the FCCSW (FCC software) are presented. Full simulations are used to study the effect of beam-induced backgrounds on such detector.**

I. Introduction

The FCC-ee high-luminosity circular electron-positron collider, with center-of-mass energies $\sqrt{s}$ from 91.2 GeV to 365 GeV, allows for high-precision measurements of the properties of the Z, the W, the top quark and the Higgs boson. As a predecessor of a new 100 TeV proton-proton collider, the FCC-ee collider is foreseen to be placed in a 100 km tunnel. The IDEA detector, one of the two detector concepts under development for FCC-ee, has demanding requirements to match the experimental conditions. Its main components consist of: an ultra-light silicon-based vertex detector, an ultra-light drift chamber for track reconstruction and particle identification, a double-readout calorimeter, a 2 T solenoid magnetic field and an instrumented return yoke. The drift chamber is being investigated using Geant4-based simulations. Its performance and the effect of beam-induced backgrounds are presented here-below.

II. Drift chamber

The parameters of the drift chamber for the IDEA detector is summarized in table I. The Isobutane gas is foreseen to be used. The time-difference method is combined with the stereo angle of the sensitive wires are used to improve the resolutions of the detector.

TABLE I: Parameters of the drift chamber for the IDEA detector

Length	4500 mm
Inner radius	345 mm
Outer radius	2000 mm
Number of sensitive wires	56448
Single cell resolution	0.1 mm

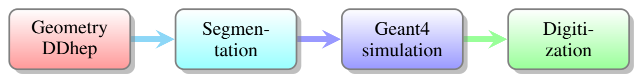


Fig. 1: The FCCSW simulation chain.

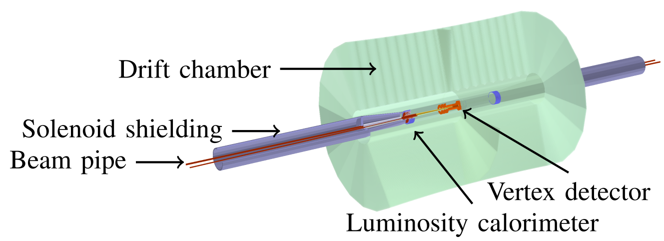


Fig. 2: The detectors at the interaction region for the FCC-ee IDEA concept.

III. Simulation with the FCC Software

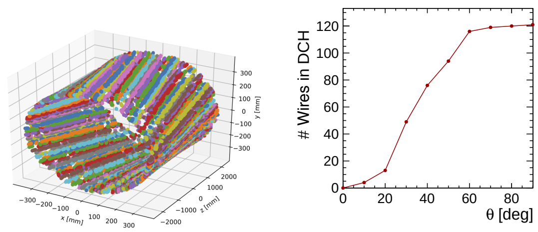
The FCC Software (FCCSW) [1] is a common software for all FCC experiments. It is based on the Gaudi software framework [2] for parallel data processing, Geant4 simulation toolkit [3] and the DD4hep detector description toolkit for high energy physics [4]. The FCCSW simulation pipeline is summarized in fig. 1 and described here-below.

A. Geometry description with DD4hep

First, the geometry of the detector is described using the DD4hep simulation framework. The implementation of the detectors in the interaction region for the IDEA detector is shown in fig. 2 and includes the beam pipe, the luminosity calorimeter, the vertex detector and the drift chamber. The geometry of the drift chamber is defined as layers of gas. In order to increase the simulation speed, the individual wires are not physically placed in the simulation software and the segmentation takes into account for their positions.

B. Segmentation

The segmentation of the sensitive gas detector contains the information on the positions of the wires in the detector. The segmentation for the first layer of the drift chamber is shown in fig. 3a. The total number of wires as a function of the polar angle θ is illustrated in fig. 3b.



(a) (b)

Fig. 3: (a) shows the segmentation of the first layer of the drift chamber. (b) shows the total number of wires as a function of the polar angle θ.

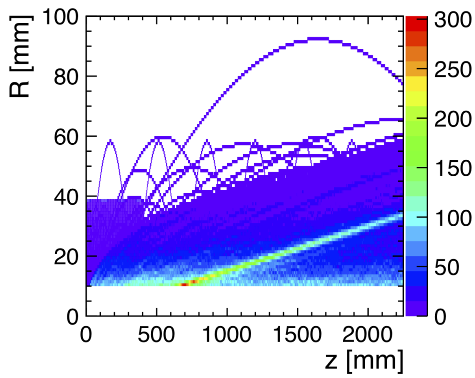


Fig. 4: The trajectory of the e^+e^- pairs in a 2 T magnetic field.

C. GEANT4 *simulation and digitization*

GEANT4 simulates the passage of particles through matter. For the drift chamber simulation, a step size of 2 mm is chosen in order to step trough the gas volume and calculate the energy deposited. The ionization charge is then drifted to the nearest wire. This allows for calculating the drift time and therefore the signal in the wires. Once the contribution from each GEANT4 step is calculated, the digitization step regroups the energy deposited with a drift time smaller than the maximum drift time in the cell.

IV. Impact of beam-induced backgrounds

One of the main sources of background at the FCC-ee experiments is generated from the strong electromagnetic force from the electron and positron bunches in the field of the opposite beam. This leads to the production of Beamstrahlung photons. The interactions of Beamstrahlung photons generate incoherent lepton pairs at low polar angles and mostly contained in the forward direction as shown in fig. 4. The GUINEA-PIG [5] event generator has been used to generate the incoherent e^+e^- background particles at a $\sqrt{s}$ of 365 GeV [6] and their impact on the drift chamber is studied below.

The occupancy due to e^+e^- incoherent pairs in the drift chamber is estimated to $\sim 2.85\%$ (averaged over 20 bunch crossings). In fact, the produced incoherent pairs have a low polar angle and only few of them reach the drift chamber. Most of the hits observed are due to the scattering of the pairs by interacting with the elements in the interaction region.

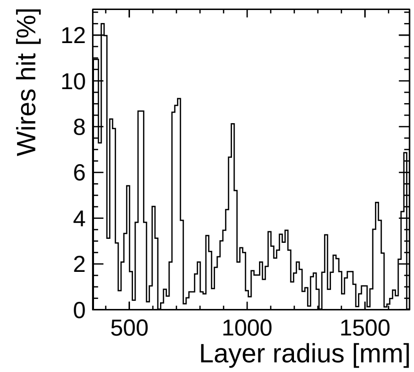


Fig. 5: The percentage of wires hit due to e^+e^- background as a function of the layer radius.

The occupancy of the drift chamber as a function of its radius is shown in fig. 5. The overall occupancy due to this background remains low and does not pose problems for the reconstruction of the tracks using the drift chamber.

V. Conclusion

The drift chamber for the IDEA detector concept has been investigated in full simulations using the FCCSW. The full simulation chain has been implemented and validated using this common software and the impact of one of the most important beam-induced backgrounds due to the incoherent e^+e^- pairs has been investigated in simulations. The overall impact remains low and does not pose problems for the track reconstruction with this detector.

Acknowledgment

The authors would like to thank...

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