Table 1: 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 (transverse plane)	0.1 mm

IDEA drift chamber

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1   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.

2   Drift chamber

The parameters of the drift chamber for the IDEA detector is summarized in table 1. A gas, composed of 90 % of Helium and 10 % of isobutane (C_4H_{10}), is foreseen to be used. Thanks to the average stereo angle of 0.1 radians, a longitudinal resolution of 1 mm can be achieved.
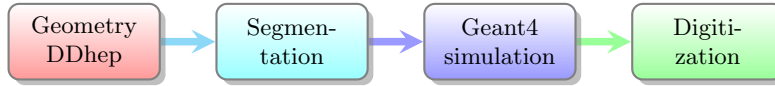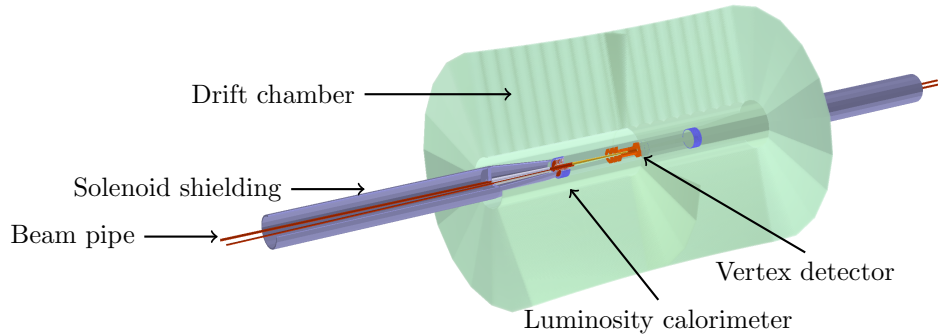
Figure 1: The FCCSW simulation chain.

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

3 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.

3.1 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. The interaction region consists of a beam pipe, a shielding solenoid, a luminosity calorimeter, a vertex detector and a 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 them into account.

3.2 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.
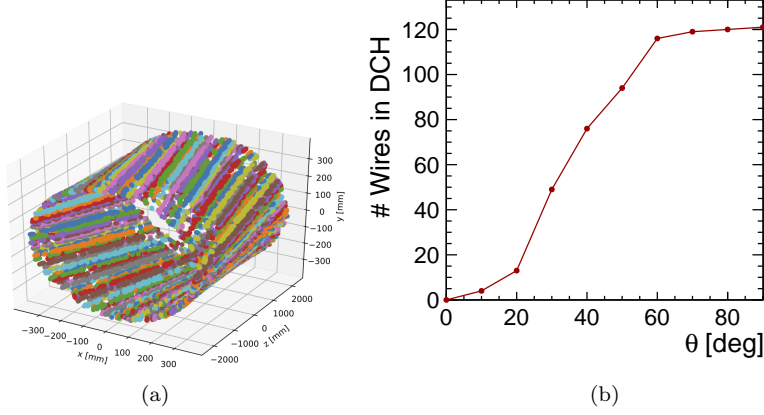
Figure 3: (a) shows the segmentation of the first layer of the drift chamber. (b) shows the total number of wires as a function of the polar angle θ (calculated using infinite momentum tracks from the origin).

3.3 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.

4 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 [6] and their impact on the drift chamber is studied below for $\sqrt{s}$ of 92.5 GeV and 365 GeV.

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 e^+e^- pairs by interacting with the elements in the interaction region.

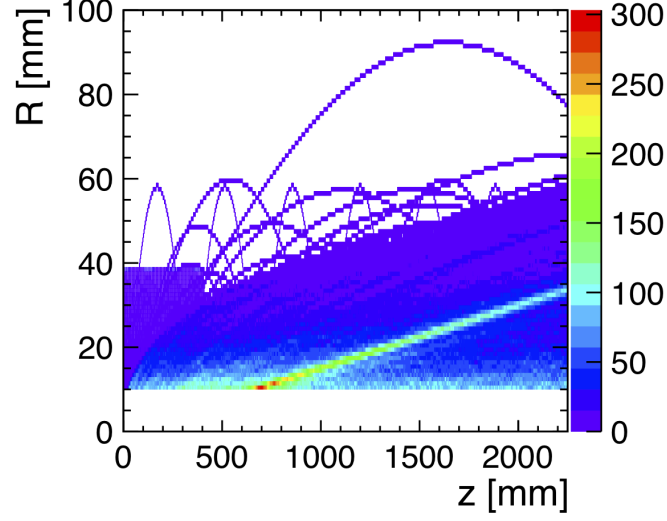The occupancy of the drift chamber as a function of its radius is shown

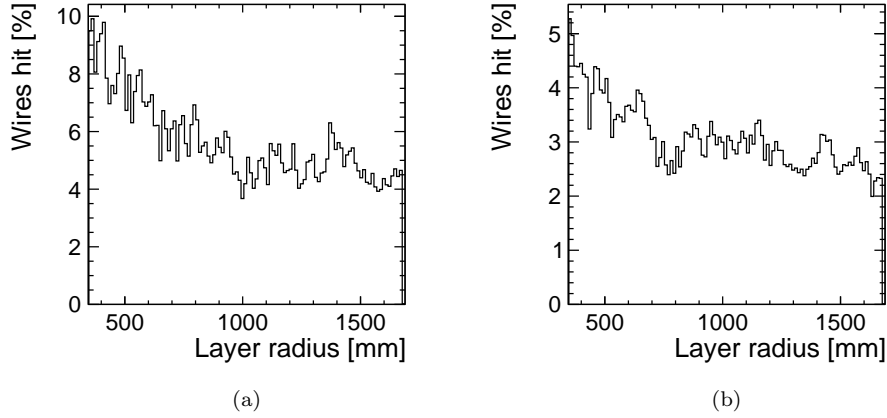Figure 4: The trajectory of the e^+e^- pairs in a 2 T magnetic field for a $\sqrt{s}$ of 365 GeV.

(a)

(b)

Figure 5: The percentage of wires hit due to e^+e^- background as a function of the layer radius for collisions at (a) $\sqrt{s}$=92.5 GeV and (b) $\sqrt{s}$=365 GeV.

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.

4

5 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 remains promising for the track reconstruction with this detector.

References

[1] "The Future Circular Collider Software Framework."

[2] G. Barrand *et al.*, "GAUDI - A software architecture and framework for building HEP data processing applications," *Comput. Phys. Commun.*, vol. 140, pp. 45–55, 2001.

[3] S. Agostinelli *et al.*, "GEANT4: A Simulation toolkit," *Nucl. Instrum. Meth.*, vol. A506, pp. 250–303, 2003.

[4] M. Frank, F. Gaede, and P. Mato, "DD4hep: A Detector Description Toolkit for High Energy Physics Experiments," *J. Phys.: Conf. Ser.*, vol. 513, p. 022010, Oct 2013.

[5] D. Schulte, "Beam-Beam Simulations with GUINEA-PIG," Mar 1999.

[6] G. Voutsinas, N. Bacchetta, M. Boscolo, P. Janot, A. Kolano, E. Perez, M. Sullivan, and N. Tehrani, "Luminosity- and Beam- Induced Backgrounds for the FCC-ee Interaction Region Design," in *Proceedings, 8th International Particle Accelerator Conference (IPAC 2017): Copenhagen, Denmark, May 14-19, 2017*, p. WEPIK004, 2017.

6 Additional checks on the number of wires hit

fig. 6 shows the number of wires hit for 100 GeV single muons at $\theta = 90°$ uniformly distributed over ϕ. The distribution contains some tail but the peak corresponds to 112 wires as expected.

The number of wires as a function of the polar angle θ is given in fig. 7.

7 The distance of closest approach (DCA)

For 100 GeV single muons, the DCA is being investigated as shown in fig. 8. The cell sizes, as they are implemented now, vary between $12 \times 12 \, \text{cm}^2$ and $14 \times 12 \, \text{cm}^2$. Therefore, the hits in the corners of the cell correspond to a DCA of $\sqrt{12^2 + 14^2}/2 = 9.22$ cm.
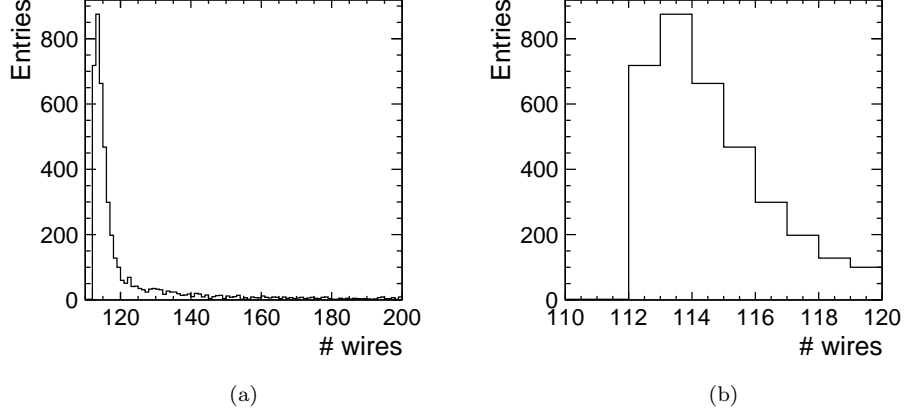
Figure 6: Number of wires hit in DCH for 100 GeV muons at $\theta = 90°$, averaged over ϕ.

The hits having the highest DCAs, have a very low energy deposit and are created due to only one step of GEANT4. Their energy deposition is shown in fig. 9.

By applying a cut of 100 eV, the DCA and the E_{dep} within the gas is shown in fig. 10. This cut reduces the amount of the hits due to signle-Geant4 steps. But on the other hand, the signal is lost.
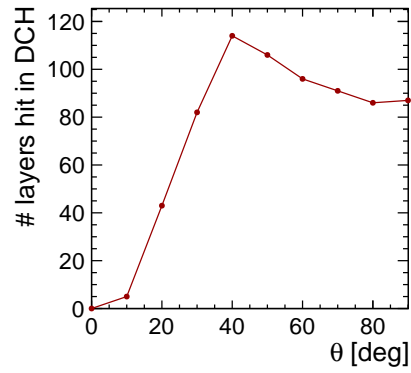
By applying a cut of 100 eV on the energy deposition, and a DCA cut of 0.8 cm and the E_{dep} within the gas is shown in fig. 11. This cut reduces the amount of the hits due to signle-Geant4 steps. But on the other hand, the signal is lost.
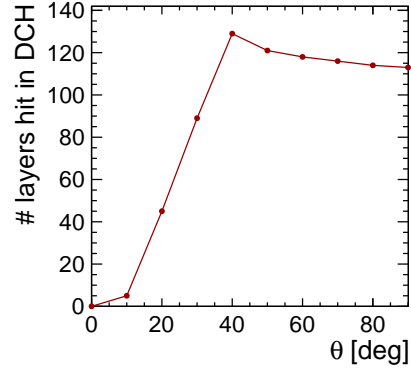
(a)
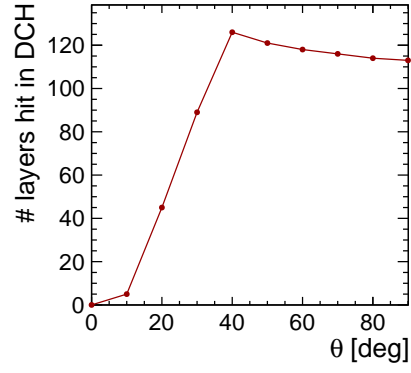
(b)

(c)

Figure 7: Number of wires as a function of θ for (a) no cut on E_{dep}, (b) $E_{dep} >$ 100 eV and (c) $E_{dep} > 500$ eV.
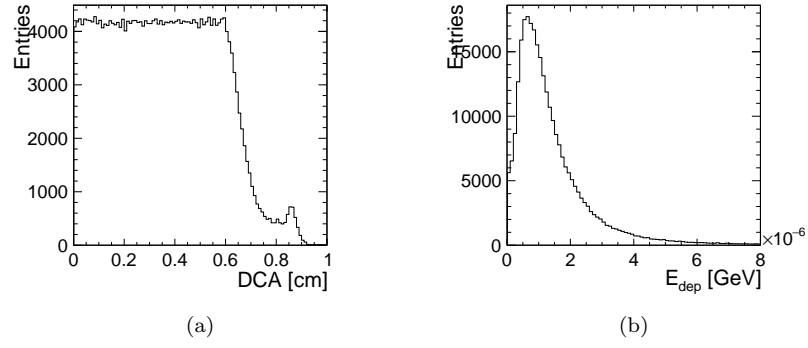
(a)

(b)

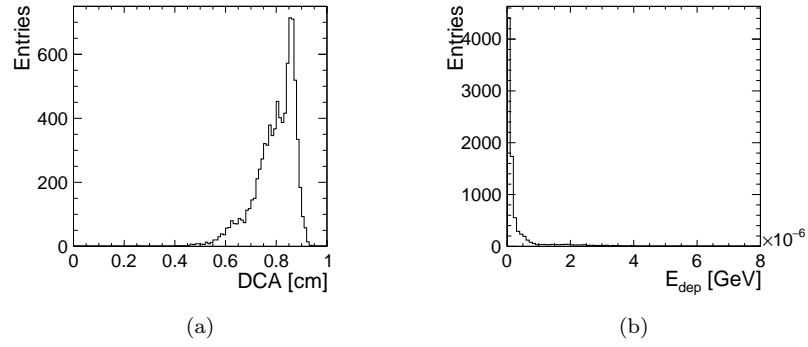Figure 8: DCA for 100 GeV muons with a uniform distribution in θ and ϕ.

(a)

(b)

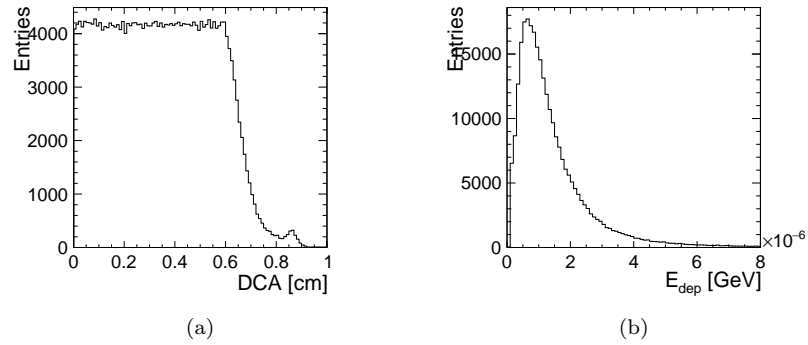Figure 9: DCA and E_{dep} of hits created due to only one step of GEANT4.

(a)

(b)

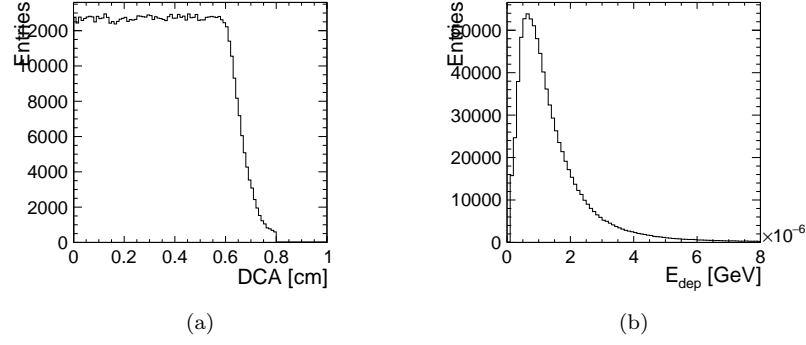Figure 10: DCA and E_{dep} by applying a cut of 100 eV on the E_{dep}.

(a) (b)

Figure 11: DCA and E_{dep} by applying a cut of 100 eV on the E_{dep} and a cut of 0.8 cm on the DCA.
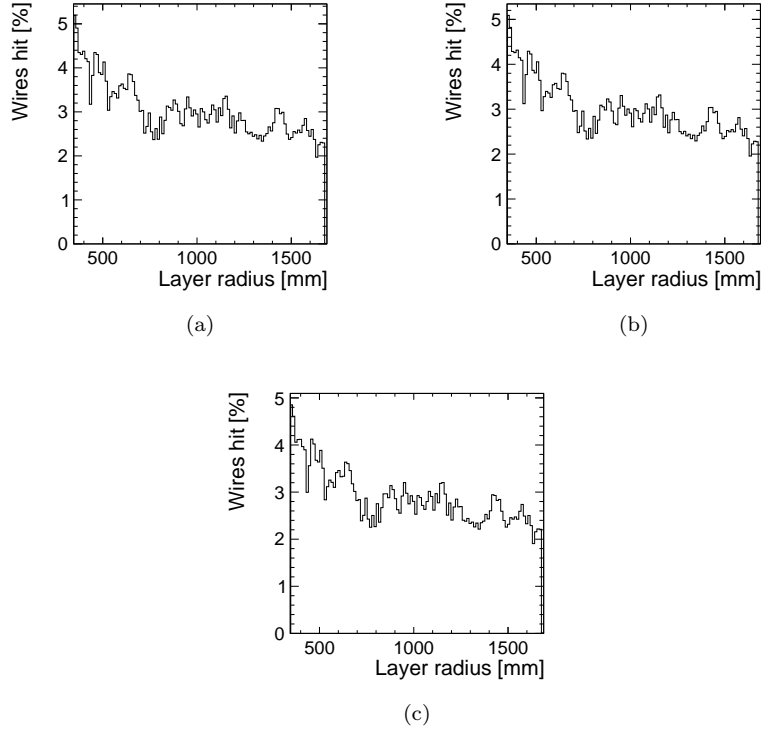

(a) (b)

(c)

Figure 12: The incoherent pairs at the top stage with different cuts on the deposited energy

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