Simulation of the drift chamber for the FCCee-IDEA detector concept within FCCSW

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Common detector technology:

Common software

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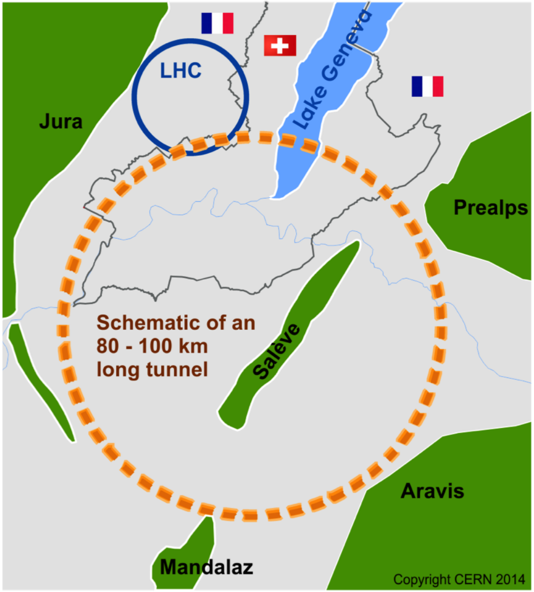
FCC Software: FCCSW

- Common software for all FCC experiments
  - ee, hh & eh
- Detector and physics studies
  - Fast & full simulations
  - One software stack from event generation to physics analysis
- Collaborative approach
  - LHC: Gaudi
  - CLIC: DD4hep
  - New solutions $\Rightarrow$ where needed

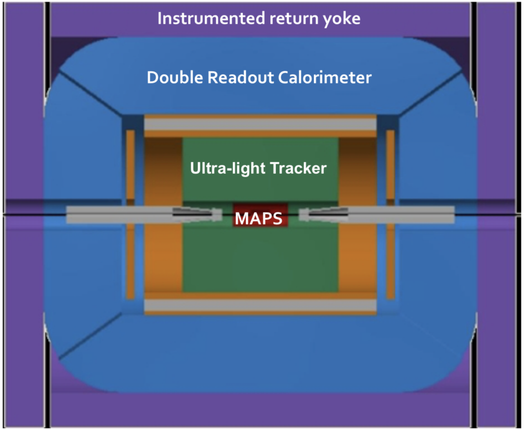


2 FCCee detector concepts

- The CLD detector concept (c.f. CLD detector model overview, Oleksandr Viazlo)
  - An adaptation of the CLIC detector model
    $\Rightarrow$ (Silicon-based vertex and tracking detectors)
  - Widely simulated with the ILCSoft
- The IDEA detector concept $\Rightarrow$ focus of this talk
  - Simulated using FCCSW

IDEA: Ultimate Goal

- Vertex detector: MAPS
- Ultra-light drift chamber with PID (DCH)
- Double read-out calorimetry (DR)
- Additional disk layers to be placed in the space between DCH and DR
- 2 T solenoidal magnetic field
- Instrumented return yoke
- Surrounded by large tracking volume (R$\sim$8 m) for very weakly coupled (long-lived) particles



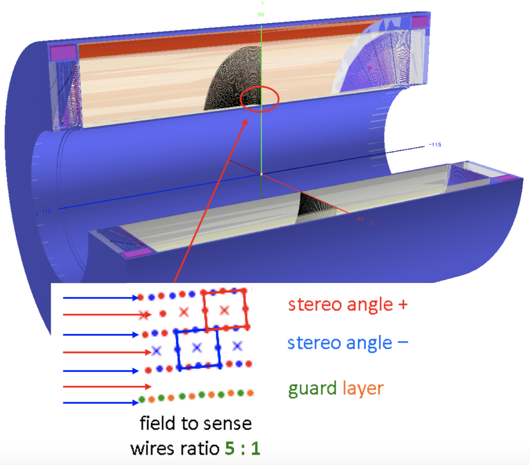
IDEA Drift Chamber (DCH)

- Talk by Giovanni Tassielli
- Track reconstruction & particle ID

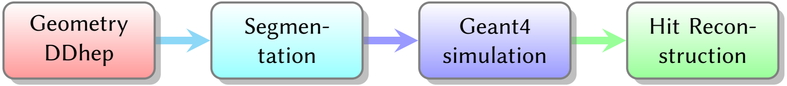
Parameters

Length	4500 mm
Inner radius	345 mm
Outer radius	2000 mm
Nb. layers	112
Cell size	12 mm to 14.7 mm
Total nb. of sensitive wires	56448
Total nb. of field wires	282240
Total nb. of wires	338688
Gas	GasHe_90Isob_10
Wire material	Aluminum
Single cell resolution	0.1 mm

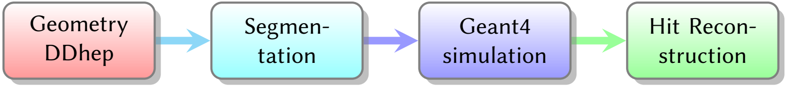
- Field wires: provide a uniform electric field
- Sensitive wires: record signal
- Field to sensitive wire ratio: 5:1



FCCSW simulation chain



FCCSW simulation chain



1. Geometry description

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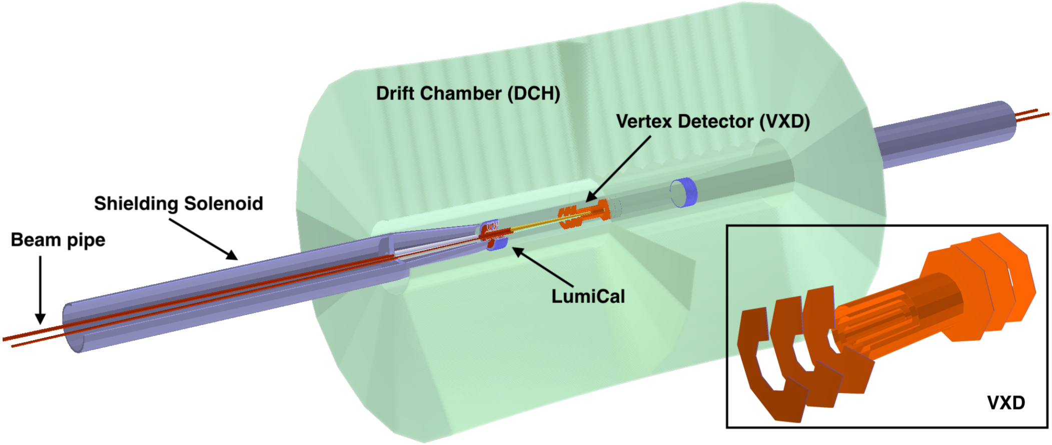
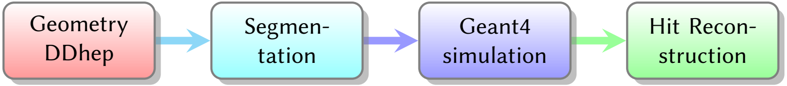
- Same interaction region (beampipe & instrumentation, VXD) as the CLD concept
- New implementation: drift chamber ⇒ only the gas volume is placed

Visualisation with FCCSW



FCCSW simulation chain



2. Segmentation

2. Segmentation Strategy for DCH (1)

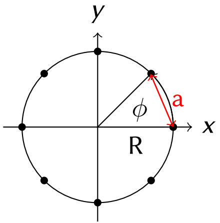
- Large number of wires $\Rightarrow$ requires a fast way to find the location of the closest wire hit
- Compute the azimuth angle of the hit ϕ for (x_{hit}, y_{hit})
  - (like if the wires were parallel to the z-axis).

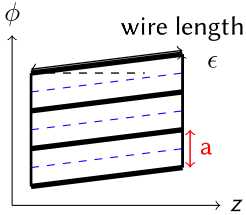
$$\phi = \arctan(y_{hit}/x_{hit}) \tag{1}$$

- The angle between the hit position and the wire detecting it is calculated:

$$\alpha = 2\arcsin\left(\frac{z_{hit}tan(\epsilon)}{2R}\right) \tag{2}$$

- Total hit azimuthal angle: $\phi + \alpha$



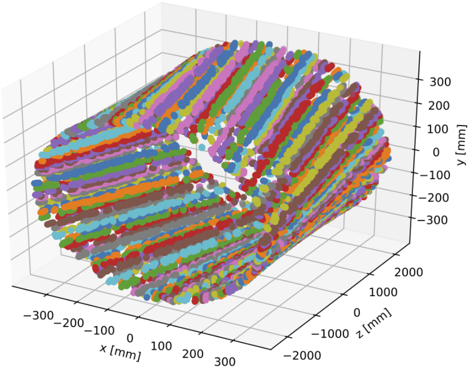


2. Segmentation: validation in simulation (2)

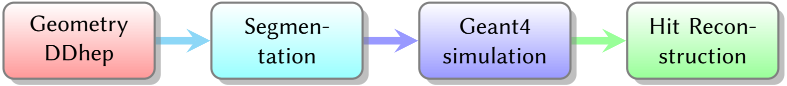
- Information on the location of the sensitive wires
- Associates a unique wire ID (cellID) to the wires
- Different granularity for different layers in the DCH
- The segmentation information is created while building geometry

  ⇒ Accessible in every step of the simulation

- First layer of the DCH
- Hits having the same wire ID are shown by the same color
- Validates the segmentation



FCCSW simulation chain



3. Geant4 hit simulation & reconstruction

3. Hit simulation and reconstruction of the DCH

Hit Simulation

- Geant4: Stepping in the gas with a G4Step length of 2 mm
- Reject ionisation acts with:
  - $E_{dep} < 10$ eV
  - `G4Step` length $< 5\mu$m
- Drift the charge deposition to the nearest wire
  - Compute the distance of the closest approach
  - Calculate the drift time assuming a constant drift velocity of 2 cm/μs
  - Calculate the total time of the hit

$$t_{hit} = t_{drift} + t_{\text{signal}} + t_{\text{particle flight}} \tag{3}$$

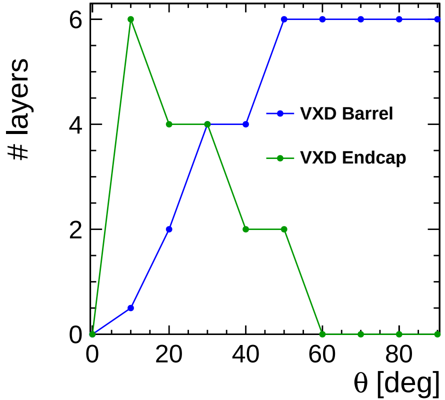
Reconstruction

- Hit: regroup the E_{dep} with a drift time smaller than the maximum drift time in the cell

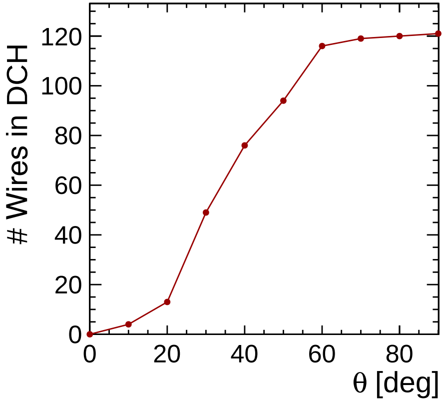
Number of sensitive layers vs. θ

- Number of layers hit by 100 GeV $\mu-$
  - $\theta = 0^\circ$: in the forward direction
  - $\theta = 90^\circ$: in the barrel
  - Averaged over ϕ

VXD

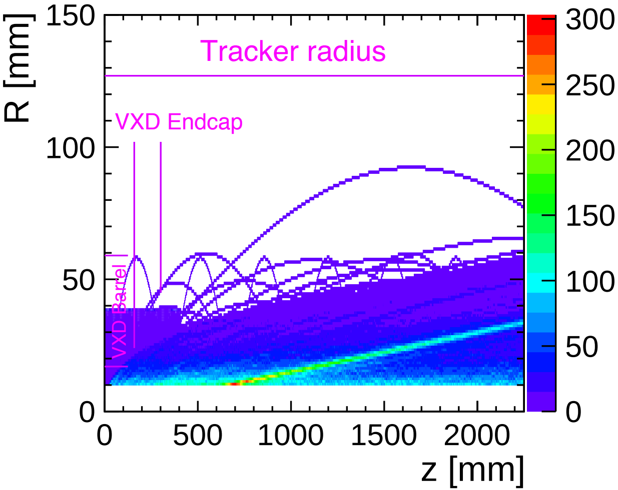


DCH



Impact of the beam background on the interaction region (IR)

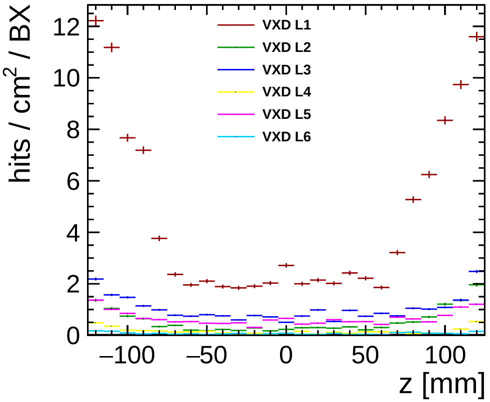
- The effect of e^+e^- pairs from $\gamma\gamma$ collisions (dominated by beamstrahlung photons)
- Pairs generated using the GuineaPig software (c.f. Georgios Voutsinas)
- E_{cm} = 365 GeV
- Total nb. of particles: $\sim$ 6200 / BX
- A fortiori, no tracks reach the DCH wires



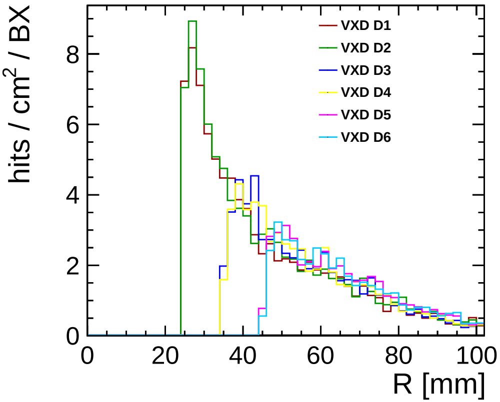
Impact of incoherent pairs in the VXD

- The number of hits is averaged over 30 BX

- Vertex Barrel



- Vertex Endcap

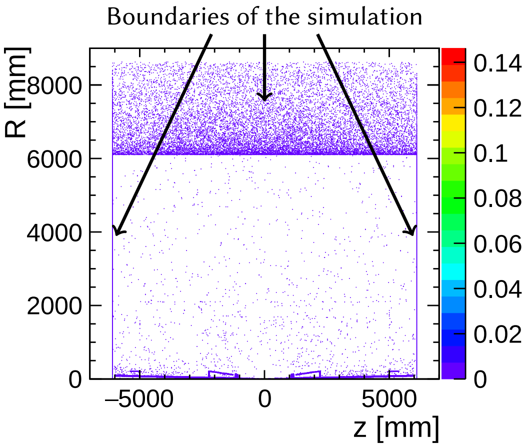


- Comparisons with the ILCSoft in progress & encouraging
- The level of this background does not pose problem for pattern recognition

Impact of incoherent pairs in the DCH: work in progress

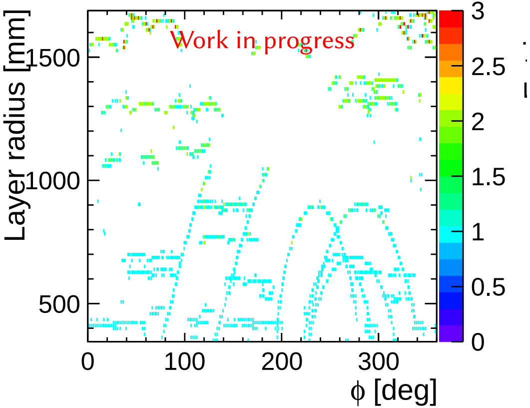
- Expected acceptable level of occupancy for a successful pattern recognition: $\sim 5\%$
- Most of the hits are due to the backscattering
- The estimation of the occupancy is pessimistic due to unclear behaviour of GEANT4 at the boundary conditions and the lack of calorimeter, magnet and yoke around the DCH in the simulation
  $\Rightarrow$ **Work in progress - stay tuned!**

- Vertices of backscattering particles



Background hits in the DCH

- Pattern recognition possible for occupancy levels of:
  - 20% for inner-most layers
  - 5% for outer-most layers
- Hits due to the background
  - Loopers
  - Tracks in the forward region



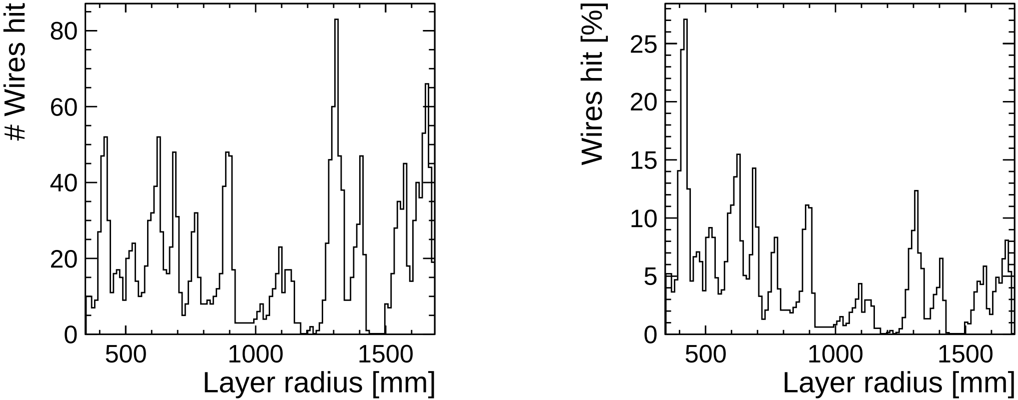
Summary & Outlook

- Full simulation of the FCCee-IDEA detector concept with FCCSW
- Implementation of the drift chamber $\Rightarrow$ geometry, segmentation, simulation & reconstuction
- Validations done and still ongoing
- First physics studies:
  - Impact of beam-induced backgrounds: e^+e^- pairs from $\gamma\gamma$ collisions
  - Estimation of the occupancy in the VXD and DCH with FCCSW and comparison with ILCSoft
  - More investigation on the occupancy is needed for the DCH to draw final conclusions
- Future work:
  - Implementation of a realistic material around DCH
  - Study the effect of other beam-induced backgrouds (the synchrotron radiation & $\gamma\gamma \rightarrow$ hadrons)
  - Track reconstruction in FCCSW

Thank you for your attention!

Backup slides

Impact of incoherent pairs in the DCH: work in progress



Secondary vertices produced