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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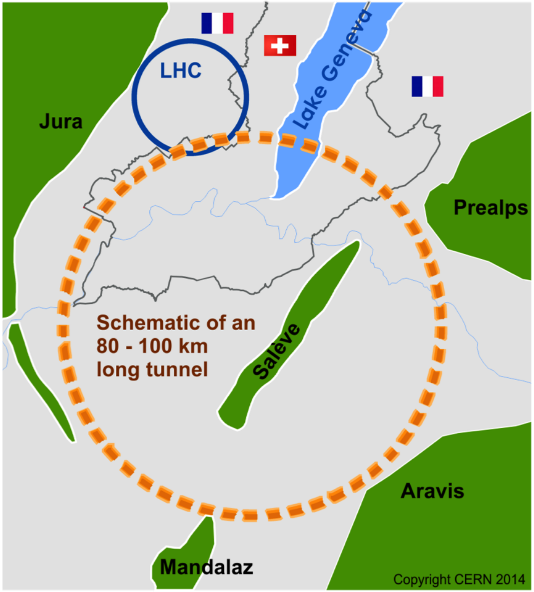
FCC Software: FCCSW

- 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 ⇒ where needed

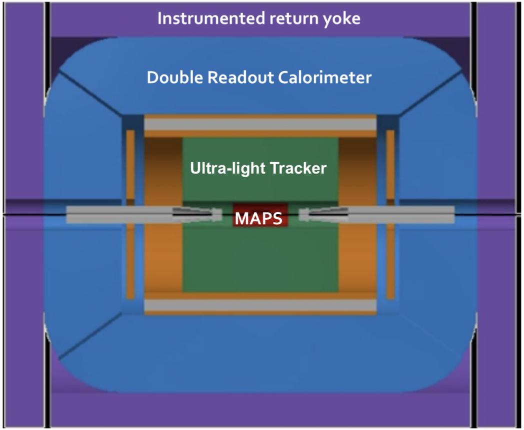


2 FCCee detector concepts

- 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



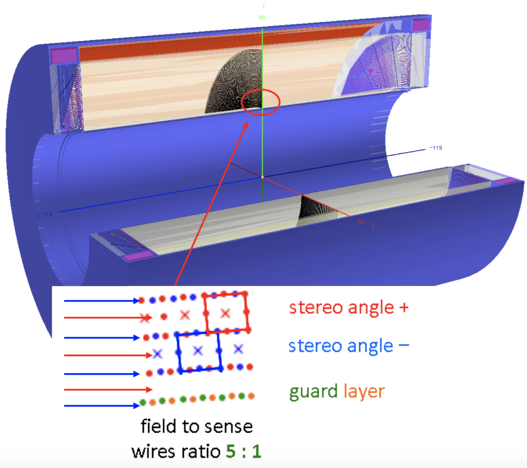
IDEA Drift Chamber (DCH)

- Track reconstruction & particle ID
- Layers divided into cells rotated with a certain stereo angle

Parameters

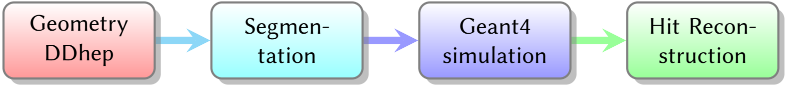
Length	4500 mm
Inner radius	345 mm
Outer radius	2000 mm
Nb. layers	112
Cell size	12 mm to 14.7 mm
Total nb. of sensitive wires	56448
Total nb. of field wires	282240
Total nb. of wires	338688
Gas	GasHe_90Isob_10
Wire material	Aluminum
Single cell resolution	0.1 mm

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



FCCSW simulation chain

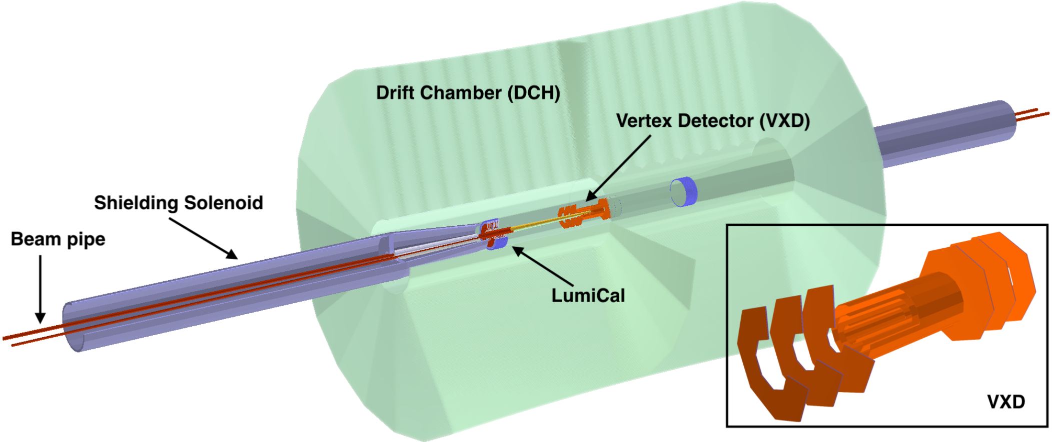
1. Detector geometry description with DD4hep
   - Collaborative effort with CLIC, ILC and LHCb
   - The IR region and the VXD from CLD are as well implemented in DD4hep
   - Definition of the gas layers in the DCH
2. Segmentation of the sensitive areas:
   - Information on the position of the sense wires instead of placing physical volumes
   - Speed up the simulation
3. Geant4 simulation:
   - Calculate the E_{dep} for each ionisation action
   - Charge drift to the wires
4. Hit reconstruction:
   - Combination of individual hit calculations from (3)
   - Calculation of the signal in the wire



1. Geometry

- Beam-pipe and interaction region (IR) taken from the CLD concept.
- Vertex detector also taken from the CLD concept.
- The drift chamber implemented from scratch in FCCSW.

Visualisation with FCCSW



2. Segmentation Strategy for DCH (1)

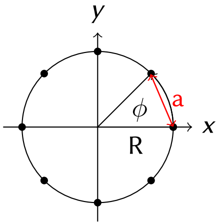
- Large number of wires $\Rightarrow$ requires a fast way to find the location of the closest wire hit
- Compute the azimuth angle of the hit ϕ for (x_{hit}, y_{hit})
  - (like if the wires were parallel to the z-axis).

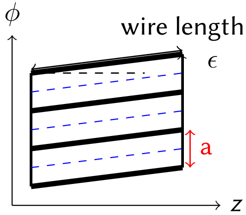
$$\phi = \arctan(y_{hit}/x_{hit}) \tag{1}$$

- 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: $\phi + \alpha$



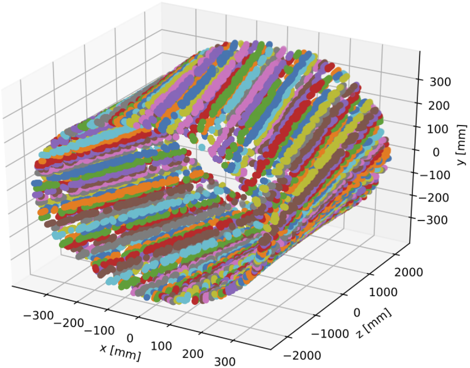


2. Segmentation: validation in simulation (2)

- 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



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

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

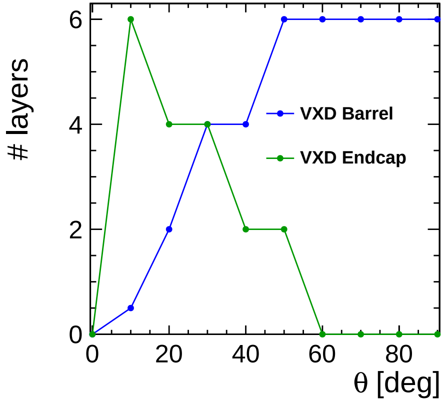
Reconstruction

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

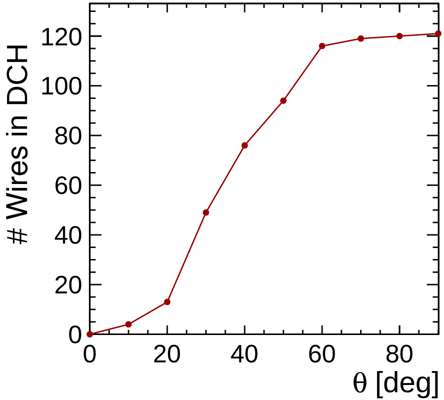
Number of sensitive layers vs. θ

- 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



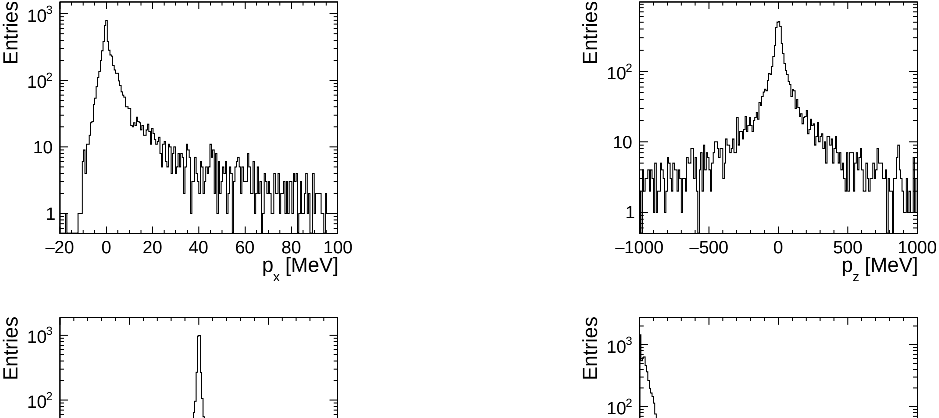
DCH



Background studies

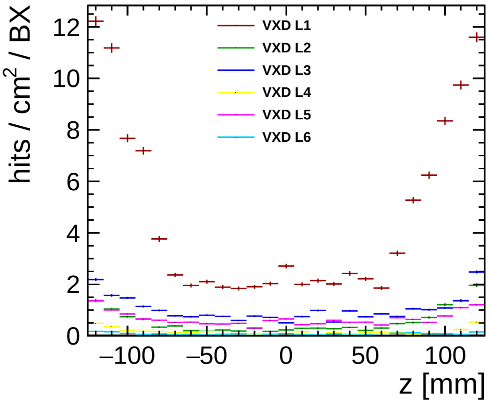
- The effect of incoherent $e+e-$ pairs on the interaction region (IR)
- Pairs generated using GuineaPig (c.f. Georgios Voutsinas)
- E_{cm} = 365 GeV
- Total nb. of particles: $\sim$ 6200

Momentum distribution

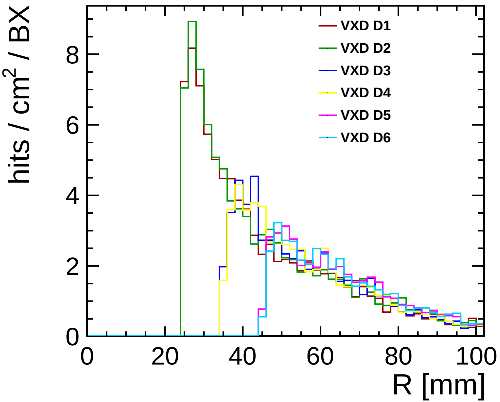


Background studies for the VXD: work in progress

- Vertex Barrel



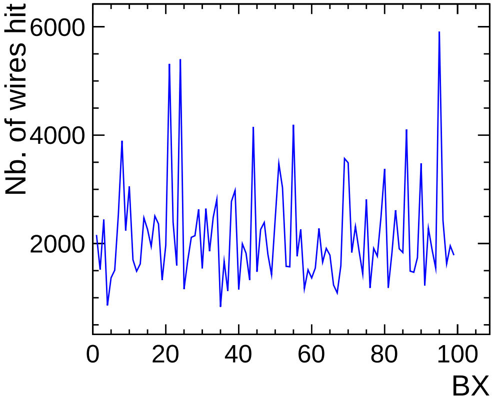
- Vertex Endcap



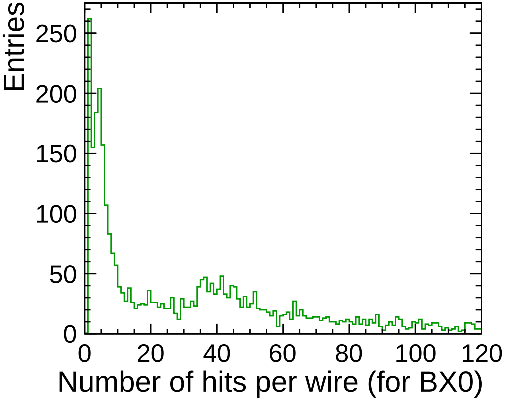
- Validations with ILCSoft in progress and promising

Background studies for the DCH: work in progress

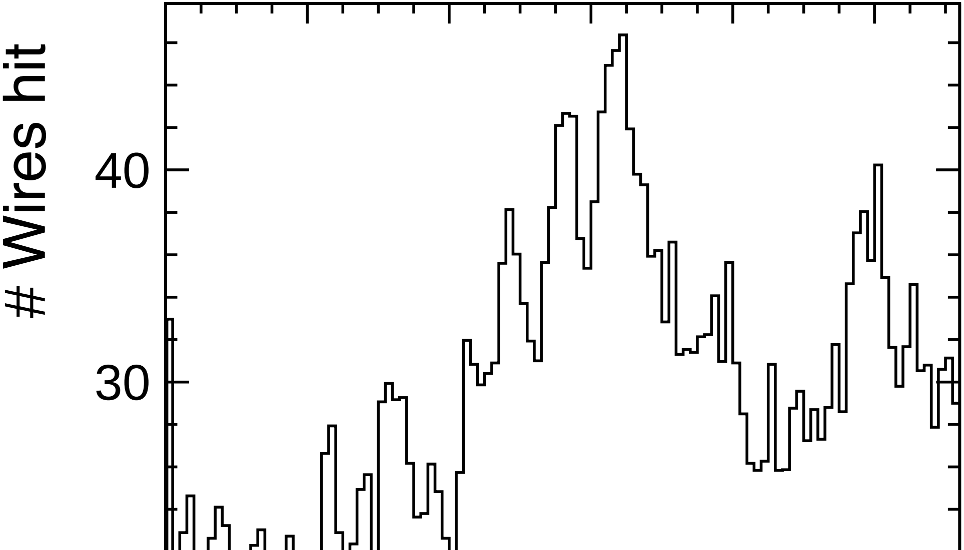
- Number of wires with different IDs recorded a signal
  - Average: 3345.7 wires



- Number of hits recorded per wire in the first BX
- Mostly 1-hit per wire
- Several hits per wire: pile-up or same



Background studies for the DCH: number of hits per layer



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- incoherent pairs
  - Estimation of the occupancy in the VXD and DCH with FCCSW and comparison with ILCSoft
- Future work:
  - Tracking