MDI and background studies with IDEA tracker

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Experiments: Simulation and reconstruction

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Introduction

- The current status of the simulation of the IDEA detector with FCCSW
- Validation of the detector
- Study of the impact of beam-background on the IDEA drift chamber
- Few investigations for the tracking

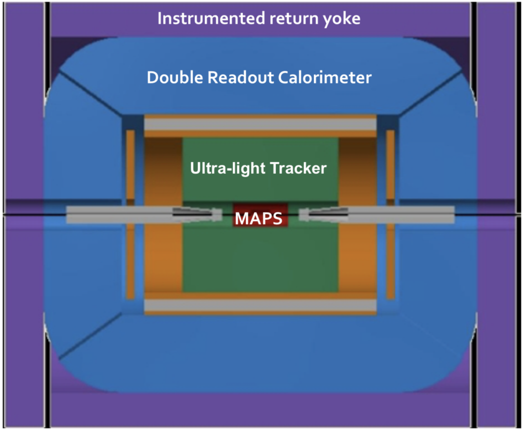
FCCSW: FCC Software

- 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

The IDEA detector concept for FCC-ee

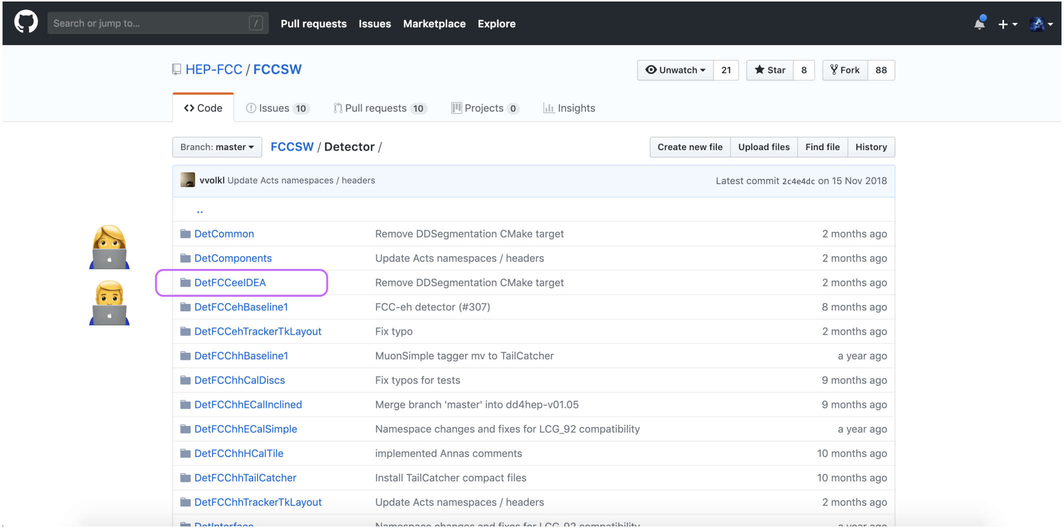
- The IDEA detector is one of the two detector concepts for the FCC-ee

- Main features of the IDEA concept
  - Vertex detector: MAPS
  - Ultra-light drift chamber with particle identification
  - Dual-readout calorimetry
  - Aditional silicon disk layers placed in the space between the drift chamber and the dual readout calorimeter to serve as a precise tracking layer and a pre showering device
  - 2 T axial magnetic field
  - Instrumented return yoke

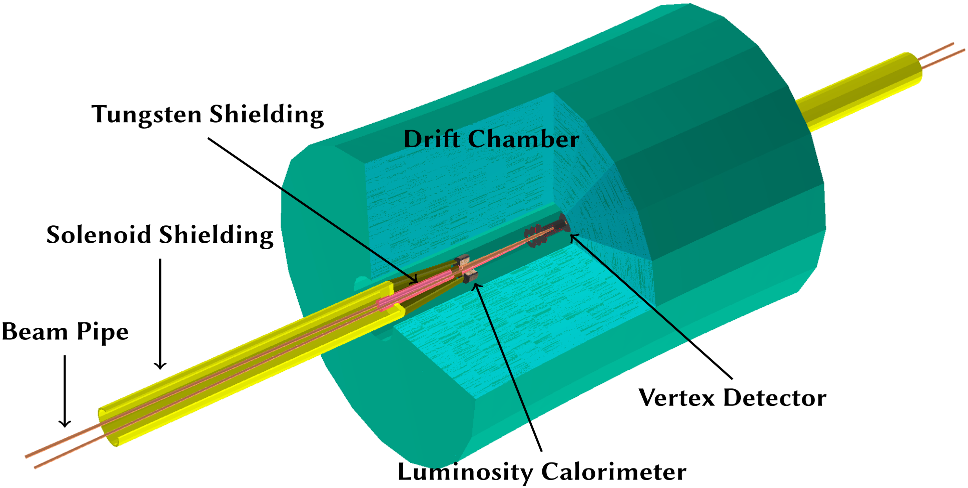


Give it a try!

https://github.com/HEP-FCC/FCCSW



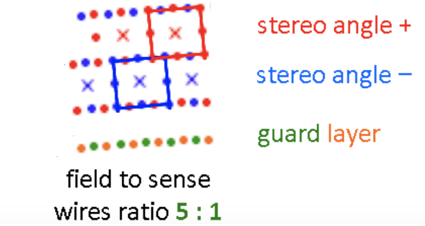
The IDEA detector as visualized with FCCSW



The IDEA drift chamber

- The parameters of the drift chamber

Gas	90 % Helium & 10 % isobutane (C_4H_{10})
Length	4 m
Inner radius	0.345 m
Outer radius	2 m
Nb. layer	112
Cell size	12 mm - 14.7 mm
Number of sensitive wires	56’448
Transverse resolution	0.1 mm
Longitudinal resolution	1 mm



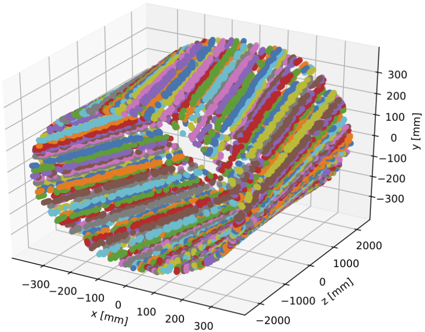
- Field wires surround the sense wires to provide homogeneous electric field for each cell.
- The wires are rotated with an average stereo angle of 0.1 radians to improve the longitudinal resolution along them.

The simulation chain in FCCSW

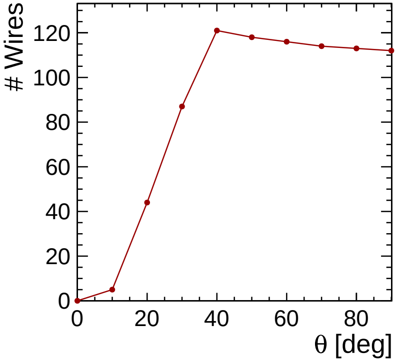
1. Detector geometry description with DD4hep
   - Collaborative effort with CLIC, ILC and LHCb
   - The IR region and the VXD from CLD are as well implemented in DD4hep
   - Definition of the gas layers in the DCH (with hyperboloid volumes)
2. Segmentation of the sensitive areas
   - Information on the position of the sense wires instead of placing physical volumes
   - Speeds 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
5. Track reconstruction with ACTS $\Rightarrow$ under investigation

The simulation of the drift chamber using FCCSW

- The sensitive wires as simulated in the first layer of the drift chamber with FCCSW.
- The DD4hep segmentation (DDSegmentation) is responsible to associate a hit to the wire it drifts to
  - Reduces the running time by avoiding to place each wire individually



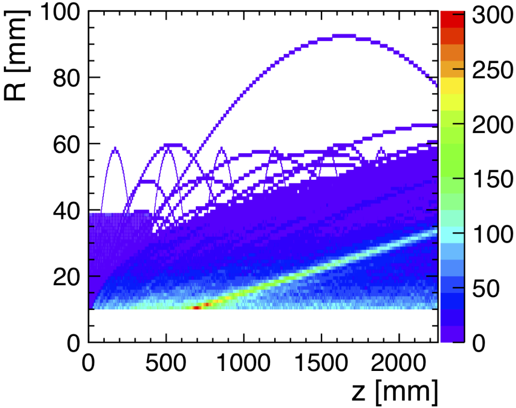
- The coverage of the drift chamber as a function of the polar angle θ is investigated.
- High coverage in the barrel region by $\sim$ 112 wires in average.
- In the forward region, silicon disks are foreseen to improve the track angle coverage.



Beam-induced backgrounds at FCC-ee

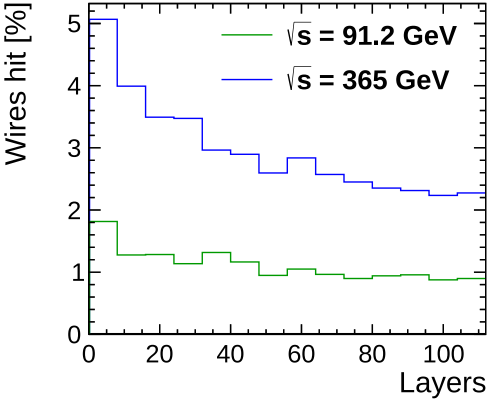
- Three main sources of beam-induced backgrounds at FCC-ee
  - **Incoherent e^+e^- pairs** due to bremstrahlung photons ⇒ highest source of background
  - $\gamma\gamma \rightarrow$ **hadrons** ⇒ Expected to have a very low impact
  - **Synchrotron radiation (SR)** ⇒ Dictates the design of the interaction region (IR)
    - Defines the beampipe radius, the design of the shielding (in Tungesten)
    - Mostly stopped by the shielding, few SR photons can hit the detector

- The trajectory of the e^+e^- pairs in a 2 T magnetic field (using helix extrapolation).
- No direct hits in the drift chamber (with inner radius of 345 mm)



The impact of the incoherent background pairs

- e^+e^- pairs is the background with the highest Impact
- The occupancy is defined as the percentage of wires hits per layer
- The average bunch spacing
  - At the Z stage ($\sqrt{s}$ =91.2 GeV): 19.6 ns
  - At the top stage ($\sqrt{s}$ =365 GeV): 3396 ns
- At the Z stage, the background is integrated over 4 BX to take into account the readout time for the signal.



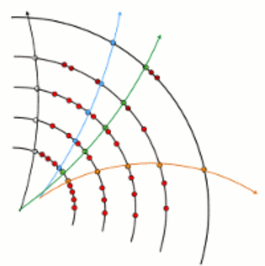
Conclusions on the beam-induced backgrounds

Background	Average occupancy	
	$\sqrt{s}$ = 91.2 GeV	$\sqrt{s}$ = 365 GeV
e^+e^- pair background	1.1%	2.9%
$\gamma\gamma \to$ hadrons	0.001%	0.035%
Synchrotron radiation	negl.	0.2%

- Based on experience from the MEG2 drift chamber, this is believed to be a manageable level.
- Exploiting the power of the drift chamber timing measurement, the background level can be greatly reduced.
- The track reconstruction in the presence of the beam-induced background needs to be investigated with the current simulation tools.

Tracking & FCCSW

- ACTS: A Common Tracking Software
- High-level track reconstruction modules to be used for any tracking detector
- Ultimate goal for tracking in FCCSW



- Implementations needed for the DCH
  - The geometry (wires, rotations with the stereo angle)
  - In the extrapolation step, a new strategy to manage the high number of wires to limit the computation time (ex. navigation, ...)
- For FCCSW, the Tricktrack software provides the seeding algorithms (initially implemented for FCC-hh and based on the CMS tracking software)

Tracking: Hough transform

- Before tackling ACTS, a faster solution is to use the Hough transform
- Used for feature extraction in image analysis, computer vision, ...
  - Identification of lines, ellipses, circles
- Initially invented for the analysis of bubble chamber photographs
- A possible solution for the drift chamber
  - Use Tricktrack for seeding in the VXD and limit the search region in the drift chamber.
  - Hough Transform for pattern recognition $\Rightarrow$ track reconstruction efficiency
  - The track parameters are obtained by using the extrapolation algorithms provided by ACTS or Tricktrack

Example: detecting a simple line

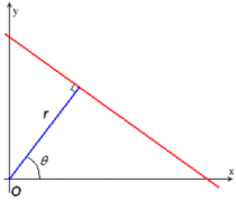
- Represented as a point (b, m) in the parameter space

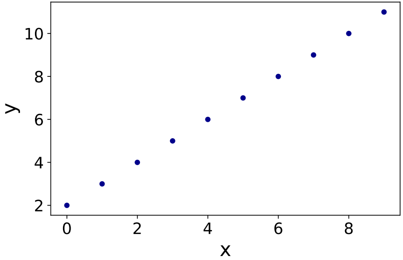
$$y = m \cdot x + b \tag{1}$$

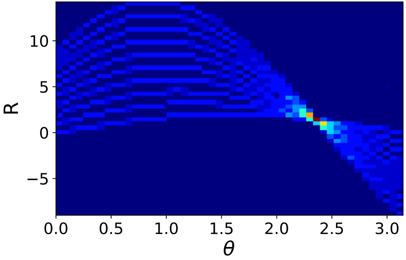
- Hough space: (r, θ)

$$r = x \cdot \cos(\theta) + y \cdot \sin(\theta) \tag{2}$$

  - A line corresponds to local maxima in the Hough space.

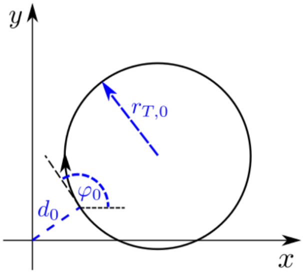


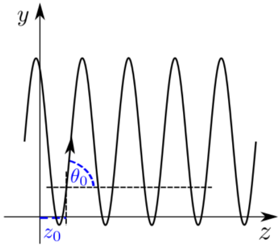




A track in a magnetic field

- Parametrization by a helix
  - ϕ_0: initial azimuthal angle
  - d_0: distance of closest approach
  - $r_{T,0}$: the radius of the track
  - θ_0: the initial polar angle
  - z_0: the initial z-coordinate at the point of closest approach
- Algorithm:
  - Map a helix trajectory into a straight line (conformal transform)
  - Find track parameters in the Hough space
  - Computation of the track parameters
- Reference → DOI: 10.1051/epjconf/201715000014





Summary & Outlook

- The IDEA detector well integrated within FCCSW
- The impact of the beam-induced backgrounds on the drift chamber is studied
  - Estimation of the occupancy
  - Reasonable based on past experience with the drift chamber for MEG2
- Investigation on the tracking $\Rightarrow$ methods to be implemented soon.

Thank you for your attention!

Backup slides

The dimensions of the vertex & tracking detectors

- FCCee_o1_v02

Parameters	FCCee (Si)	FCCee (IDEA)
VXD Barrel r_{in}	17 mm	17 mm
VXD Barrel r_{out}	59 mm	59 mm
VXD Barrel length	250 mm	250 mm
VXD Endcap r_{in}	24 - 45 mm	24 - 45 mm
VXD Endcap r_{out}	102 mm	102 mm
VXD Endcap $z_{position}$	159-301 mm	159-301 mm
Tracker Barrel r_{in}	127 mm	345 mm
Tracker Barrel r_{out}	2100 mm	2000 mm
Tracker Barrel length	2528 mm	4500 mm
Tracker Endcap r_{in}	78 mm	N.A.
Tracker Endcap r_{Out}	2080 mm	N.A.
Tracker Endcap z_{pos} range	524:2190 mm	N.A. mm