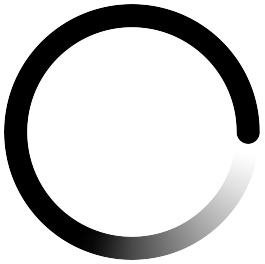
IDEA Drift Chamber in DD4hep

Discussion on Background Studies

Brieuc Francois (CERN)

FCC Detector Full Sim Working Meeting

Oct. 2nd, 2023



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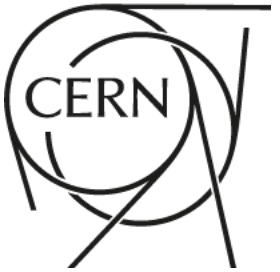
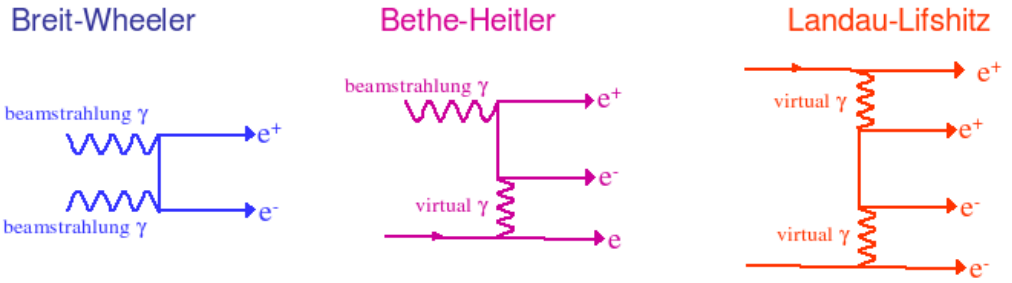


Introduction

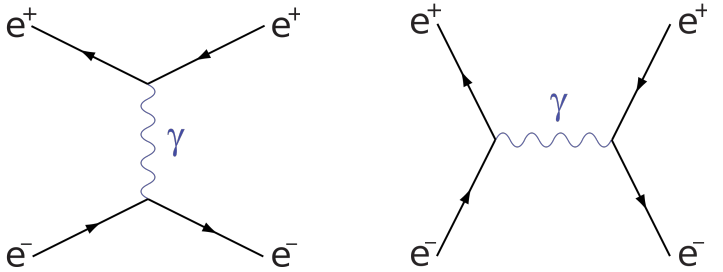
- All accelerators create “spurious” particles that can hit our detectors
  - E.g. circular e+ e- accelerator generates synchrotron radiation
- We must make sure that all our sub-detectors can sustain these background hits and we must evaluate potential performance loss
- Especially important for sub-detectors with long/delayed signals and large sensitive 'cells' volumes (e.g. drift chambers)
- Realistic estimation of the background impact requires detailed description of components before the detector (e.g. beampipe, masks, shields, vertex detector, …) + detailed description of the sub-detector and its response
  - Occupancy study done for CLD by Andrea Ciarma
- This talk: trigger discussion on how to study background effects in drift chambers

Background Sources

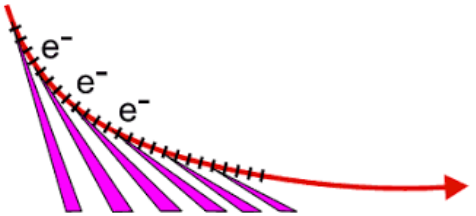
- Incoherent Pair Creation: e+ e- pairs from beamstrahlung or virtual photons during the bunch crossing



- Radiative Bhabha annihilation or scattering



- Synchrotron radiation, beam losses, beam gas (Compton with thermal photons)
- Processes handled by dedicated generators
  - GuineaPig++, BDSim, Xtrack, …

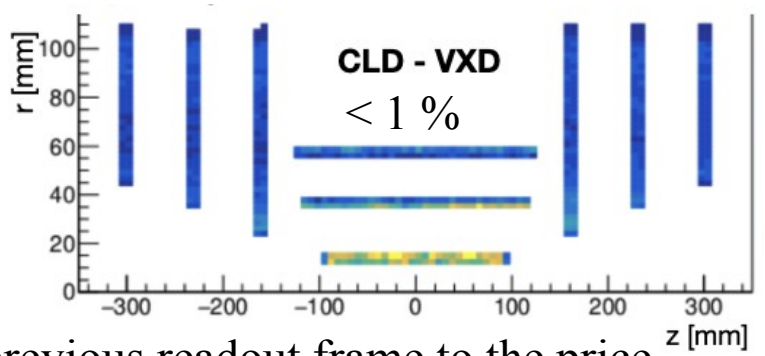


Workflows

- Background particles are provided by external tools
  - Imported in the Geant4 simulation
    - Through the Gaudi algorithm MDIReader from k4Gen
      - Only one event can be processed
    - Or, in ddsim, by directly feeding it with a 'pair' (dataformat) file
- For production, we may want to avoid generating the full Geant4 simulation for every background “events” (time consuming)
- Generate a bunch of background “events” and pass them to Geant4 to get the simHits, then overlay them on the physics events before digitization
  - If we generated enough background events, it is equivalent to giving background particles to the simulation but faster
  - A tool exists for that in ILCSoft (OverlayTimingGeneric)
    - Can already be used for any DD4hep detector geometry
    - Still bound to slcio but work is ongoing to port this to edm4hep native
      - k4Overlay

CLD Background Study

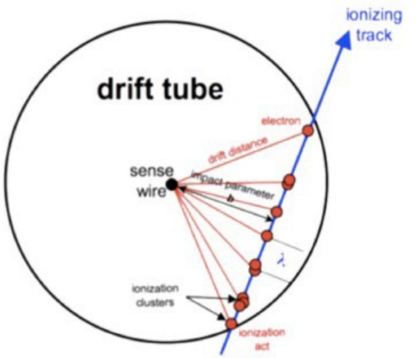
- How was the background study performed for the CLD tracker (Silicon sensors)?
  - Various external generators provide background particles for one BX
  - Get their induced **simHits** with k4Gen MDIReader
  - Derive occupancy map (percentage of fired sensor from background hit) based on hit density, sensor size and "cluster size" (number of neighbor sensors fired by a hit due to e.g. cross-talk), apply a safety factor
  - Since a Silicon sensor (CMOS like) is "ON" for ~ 5-10 μs after a hit fired it, multiply the occupancy by the corresponding number of BX

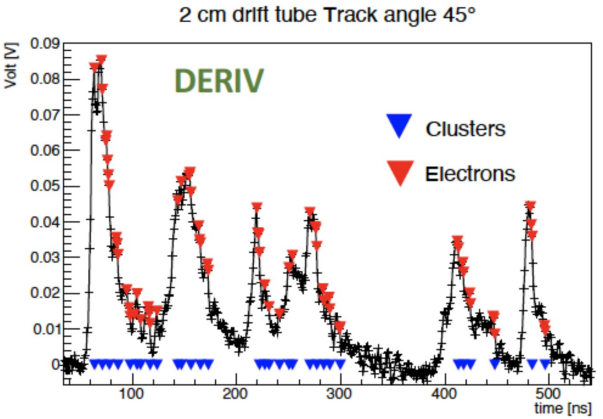


- Strongly depends on the readout strategy!
  - Digital: we can discard sensors that were fired in the previous readout frame to the price of efficiency or keep all fired sensors for a given readout frame to the price of fakes
  - Analog: we can see additional charge w.r.t. previous readout frame → lower effect
- Impact of background hit occupancy on tracking efficiency, fake rate and resolution would provide useful insights
  - Requires MDIReader modifications: overlay from many earlier BX's for a single event, be able to overlay different background "events" for a generation of multiples events
  - Or switch to the overlay from ILCSoft

Drift Chamber Background Study

- A simple estimation of the occupancy as for Silicon sensors seems not sufficient for drift chambers
  - The closest thing to a "sensor" is the gas-volume associated to a sense wire (12-14.5 mm x 12-14.5 mm x 4 m)
  - Drift Chambers intrinsically rely on analog readout → an occupancy map does not mean much
  - As opposed to the Silicon sensors, **simHits** seems not enough to have a robust estimation of the impact of background
    - A simple digitization algorithm is ongoing
      - Association between Geant4 simHit and the closest wire + smearing of the z-position and drift distance
      - Seems not enough either...
    - Is there a way to estimate the impact of background with reasonable assumptions or simplifications on the digitization, without passing by the **full waveform**?





- If not, we will have to wait for the detailed drift chamber digitizer to be in Full Sim

Open questions for background studies

- Do we expect multiple wires to be fired from a single hit?
  - Cross-talk, secondary particles
- What time window should be considered for background hit 'integration'?
- Is there any energy threshold for a hit to be reconstructed
- Handles we have to remove background should also be implemented
  - Timing (background hits have different time structure)
  - Cluster counting (background photons do Compton scattering → cluster size == 1)
  - …

Additional material