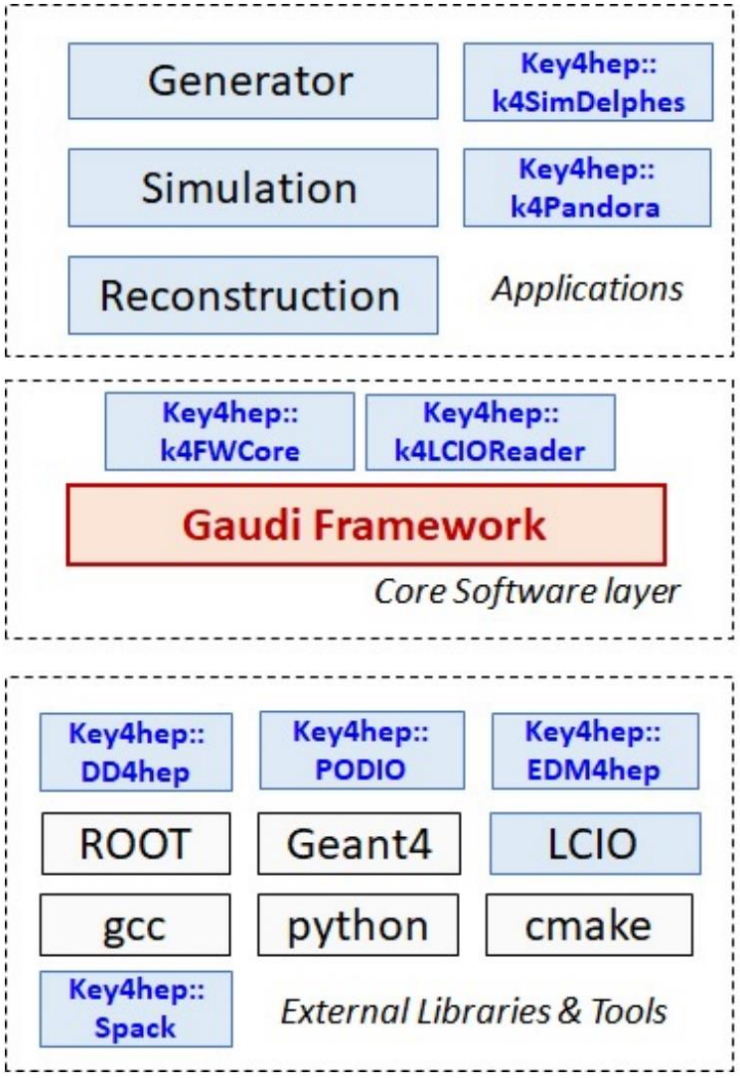
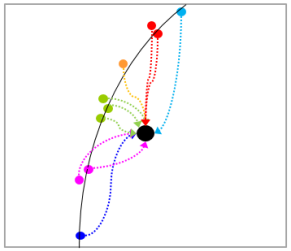
CEPCSW Software

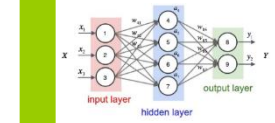
- CEPCSW software structure
  - External libraries:
    - DD4hep: complete detector description (geometry, B field, Material, …). Consistent description (simulation, reconstruction, analysis)
    - EDM4hep: the generic event data model for HEP experiments (see next slide)
    - …
  - Core software:
    - Gaudi framework: defines interfaces to all software components and controls their execution
    - K4FWCore: data service for EDM4hep
  - Applications:
    - CEPC-specific software: generator, Gean4 simulation, reconstruction, and analysis

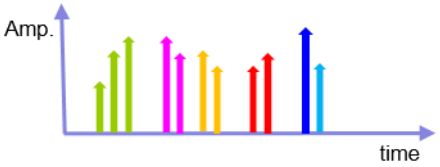


Ionization simulation

- The ionization simulation is done by combining Geant4 and TrackerHeed
  - TrackerHeed (from Garfield++) used for ionization process simulation
  - Geant4 for particle propagation (decay) in the detector, interaction with detector material, …
- Pulse simulation for each ionized electron
  - The Garfield++ simulation takes a long time
  - NN is used for fast simulation, simulating the time and amplitude of each pulse (ONNX runtime for inference)
- More details in this talk



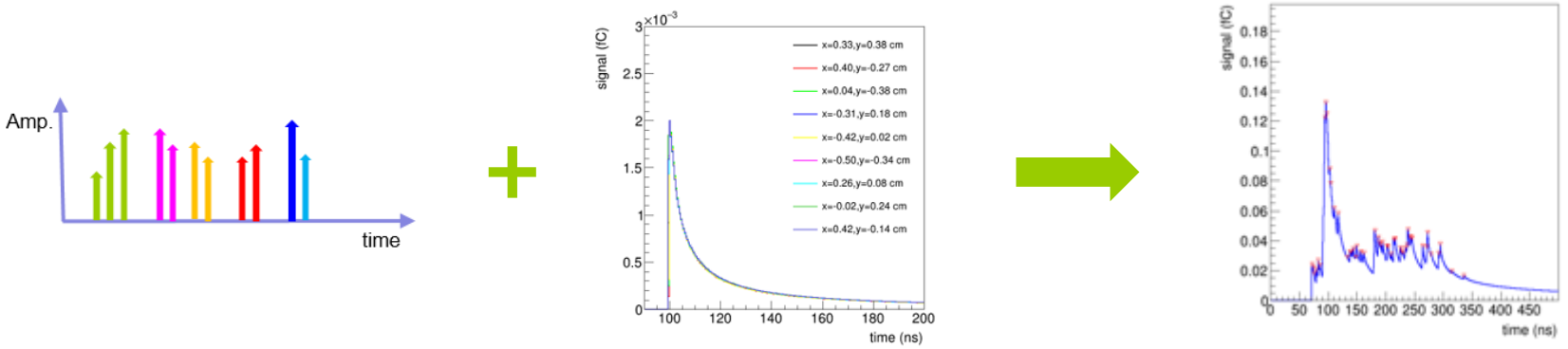





```
#---------- SimPrimaryIonizationCluster
edm4dc::SimPrimaryIonizationCluster:
  Description: "Simulated Primary Ionizati
  Author : "Wenxing Fang, IHEP"
  Members:
    - uint64_t cellID
    - float time
    - edm4hep::Vector3d position
    - int16_t type
  VectorMembers:
    - uint64_t electronCellID
    - float electronTime
    - edm4hep::Vector3d electronPosition
    - float pulseTime
    - float pulseAmplitude
  OneToOneRelations:
    - edm4hep::MCParticle MCParticle
```

Waveform simulation

- From Garfield++ simulation, it was found that the normalized pulse shapes are quite similar, the differences between pulses are the time and amplitude
- Using the simulated pulse time and amplitude together with the pulse shape template, the waveform can be easily simulated

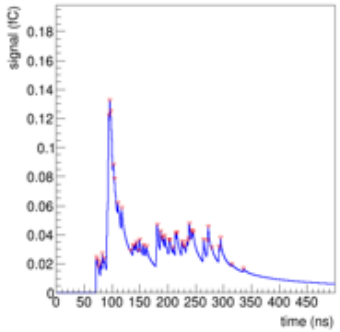


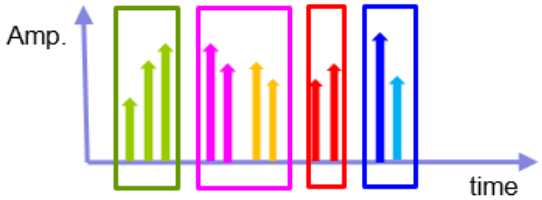
- To be more realistic, effects from the electronic noise and electronic response can be introduced to the waveform

```
#----------  TrackerData
 edm4dc::TrackerData:
   Description: "TrackerData"
   Author : "Wenxing Fang, IHEP"
   Members:
      - uint64_t cellID
      - float time
      - float interval
   VectorMembers:
      - float chargeValue
```

Ionization cluster reconstruction

- Using simulated waveform as input. Firstly, it reconstructs pulses (peak finding, derivative, deconvolution, NN, ...). Then it clustering the reconstructed pulses into several ionization clusters (time window, NN, ...)
- Outputs: reconstructed pulses and ionization clusters






```
#----------  TrackerPulse
 edm4dc::TrackerPulse:
   Description: "Reconstructed Tracker
   Author : "Wenxing Fang, IHEP"
   Members:
      - uint64_t cellID
      - float time
      - float charge
      - int16_t quality
      - std::array<float,3> covMatrix
   OneToOneRelations:
     - edm4dc::TrackerData trackerData
```

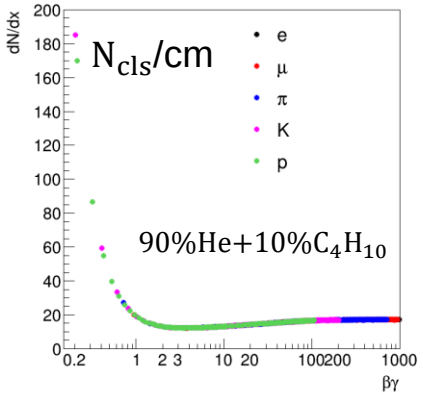
```
#----------  RecIonizationCluster
 edm4dc::RecIonizationCluster:
   Description: "Reconstructed Ionization
   Author : "Wenxing Fang, IHEP"
   Members:
      - uint64_t cellID            //cell
      - float significance         //signi
      - int16_t type               //type.
   OneToManyRelations:
      - edm4dc::TrackerPulse trackerPulse
```

dN/dx reconstruction

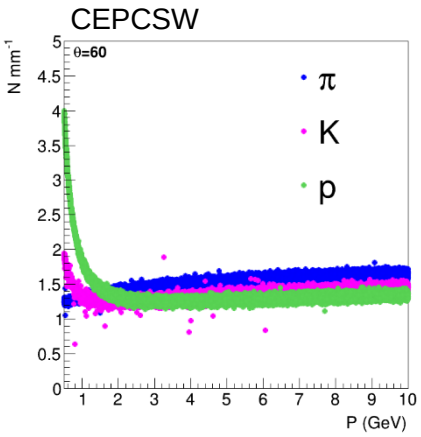
- Inputs: the reconstructed track and reconstructed ionization cluster
- From the reconstructed track, one can get the track length in each drift chamber cell (dX). And the reconstructed ionization cluster gives the number of clusters in each cell (dN)
- The dN/dx for each cell can be calculated. The truncated mean method could be used to calculate dN/dx for each track
- Output: RecDndx including the dN/dx, particle type, and chi for different particle hypotheses, …

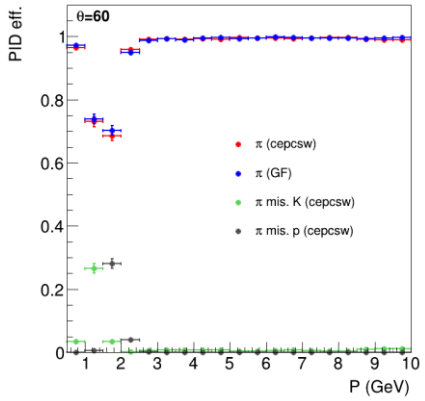
```
#-------------  RecDndx
edm4dc::RecDndx:
  Description : "dN/dx info of Track."
  Author : "Wenxing Fang, IHEP"
  Members :
    - float dNdx
    - float dNdxError
    - int16_t particleType
    - int16_t type
    - std::array<edm4dc::Hypothesis, 5> hypotheses
  VectorMembers:
    - edm4dc::HitLevelData hitData
  OneToOneRelations:
    - edm4hep::Track track
```

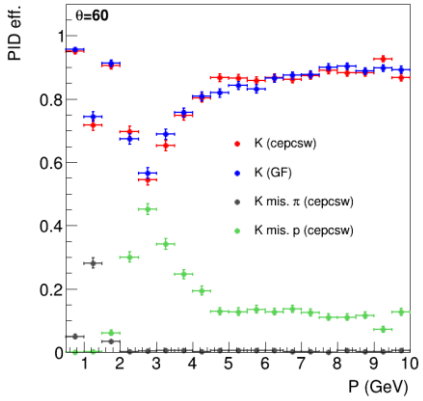
```
components:
    #---------- Hypothesis for 5 particle types
    edm4dc::Hypothesis:
      Members:
        - float chi2       // chi2
        - float expected   // expected value
        - float sigma      // sigma value

    #---------- hit level data
    edm4dc::HitLevelData:
      Members:
        - uint64_t cellID    // cell id
        - uint32_t N         // number of reconstructed ionization cluster.
        - float  eDep        // energy deposit.
        - float  pathLength  // track path length in [mm].
```

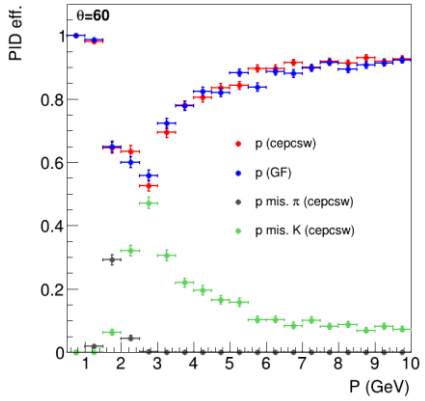


Preliminary dN/dx PID results









- Checked the dN/dx PID performance for gas ($90\%\mathrm{He}+10\%\mathrm{C_4H_{10}}$) using CEPCSW and Garfield++
- Using MC truth information (number of clusters, tracker length)
- The PID performance obtained in CEPCSW has good agreement with the standalone Garfield++ simulation