



中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

EDM for dN/dX study within the CEPCSW

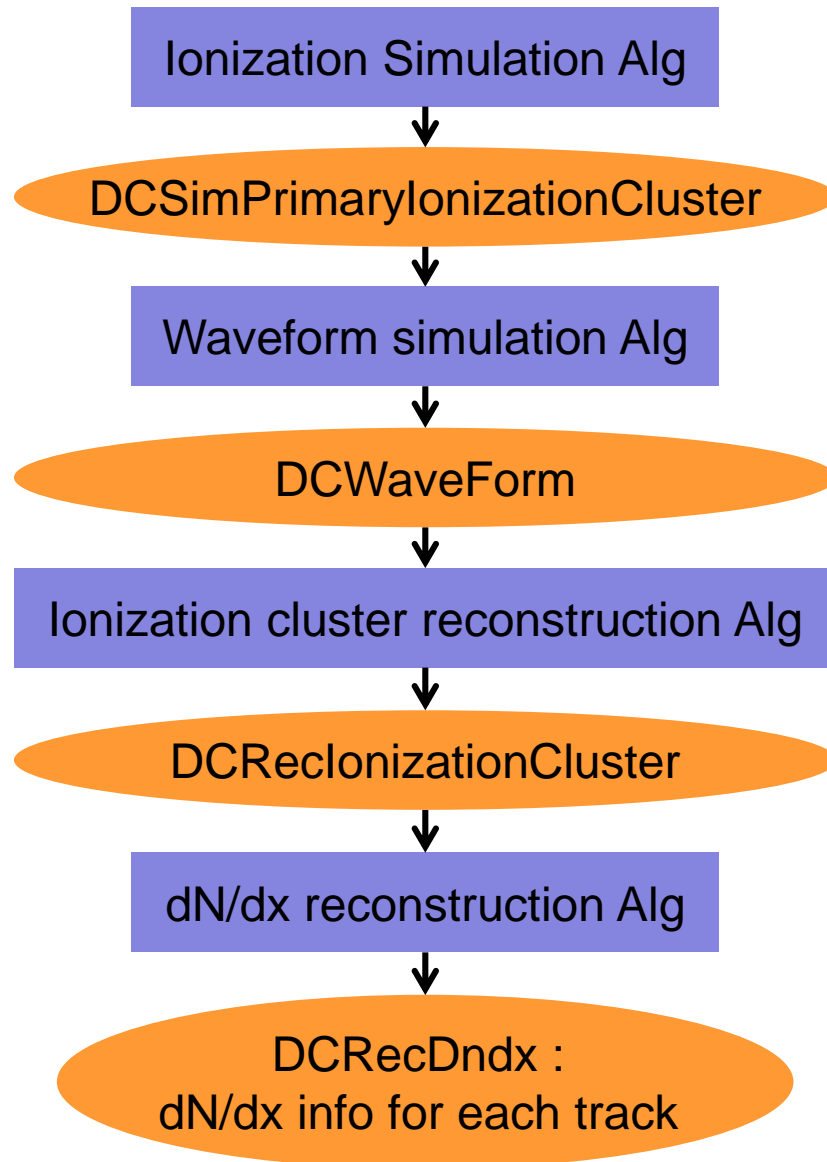
Wenxing Fang (IHEP)

Cluster counting meeting (2022.09.15)

Introduction

- ❖ As the dN/dx method has great potential for PID, studying dN/dx using full simulation of CEPC detector should be supported
- ❖ Try to develop the chain of dN/dx study based on CEPCSW
- ❖ CEPCSW is fully integrated with the key4hep, and the edm4hep is used for the event data model
- ❖ Currently, edm4hep does not include EDM for drift chamber study
- ❖ Try to develop a common EDM for the drift chamber based on PODIO

Chain of dN/dx study

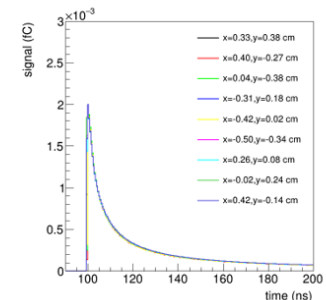
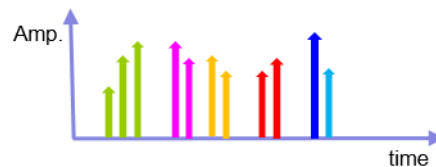
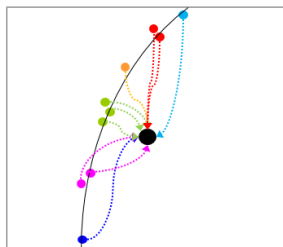


Ionization simulation

Geant4+TrackHeed+pulse_simulation(NN)

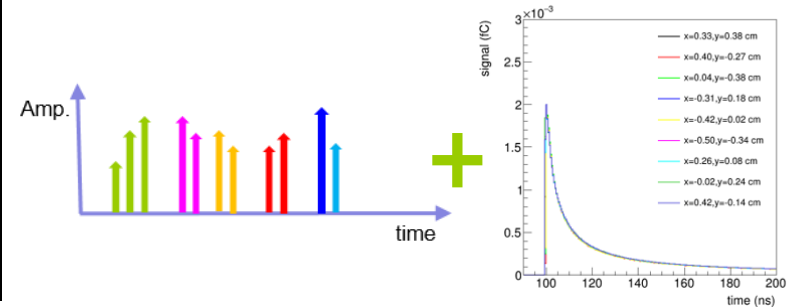


```
#----- DCSimPrimaryIonizationCluster
edm4dc::DCSimPrimaryIonizationCluster:
  Description: "Simulated Primary Ionization"
  Author : "Wenxing Fang, IHEP"
  Members:
    - unsigned long long cellID //ID of cell for this produced primary ionization.
    - float time //the primary ionization producing time in the lab frame in [ns].
    - int type //type.
    - edm4hep::Vector3d position //the produced primary ionization's position in [mm].
  VectorMembers:
    - unsigned long long ionCellID //ID of cell for this produced ionization.
    - float ionTime //the ionization producing time in the lab frame in [ns].
    - edm4hep::Vector3d ionPosition //the ionization's position in [mm].
    - float pulseTime //the pulse producing time in the lab frame in [ns].
    - float pulseAmplitude //the pulse's amplitude.
  OneToOneRelations:
    - edm4hep::MCParticle MCParticle //MCParticle that caused the hit.
```



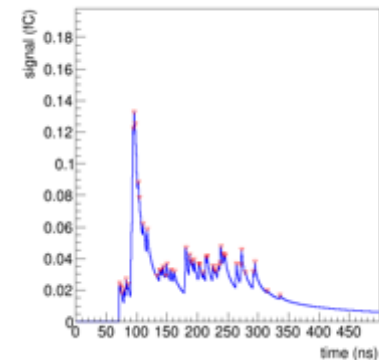
Waveform simulation

```
#----- DCSimPrimaryIonizationCluster
edm4dc::DCSimPrimaryIonizationCluster:
Description: "Simulated Primary Ionization"
Author : "Wenxing Fang, IHEP"
Members:
- unsigned long long cellID //ID of cell for this produced primary ionization.
- float time //the primary ionization producing time in the lab frame in [ns].
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- edm4hep::Vector3d position //the produced primary ionization's position in [mm].
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- unsigned long long ionCellID //ID of cell for this produced ionization.
- float ionTime //the ionization producing time in the lab frame in [ns].
- edm4hep::Vector3d ionPosition //the ionization's position in [mm].
- float pulseTime //the pulse producing time in the lab frame in [ns].
- float pulseAmplitude //the pulse's amplitude.
OneToOneRelations:
- edm4hep::MCParticle MCParticle //MCParticle that caused the hit.
```



Waveform simulation Alg

```
#----- DCWaveform
edm4dc::DCWaveform:
Description: "Waveform"
Author : "Wenxing Fang, IHEP"
Members:
- unsigned long long cellID //detector specific cell id.
- int type //type.
- float beginTime //begin time of the waveform.
- float interval //interval of each sampling in [ns].
VectorMembers:
- float rawData //charges.
```

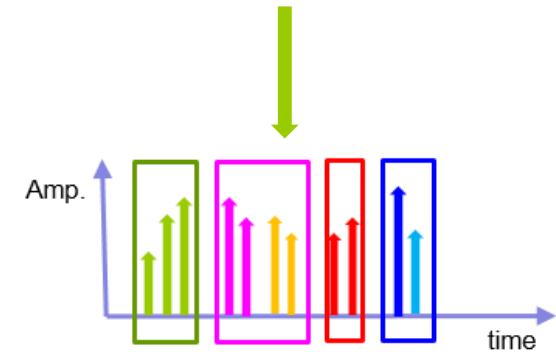
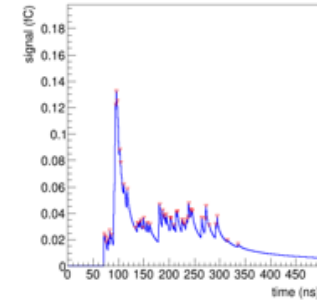


Ionization cluster reconstruction

```
#----- DCWaveform
edm4dc::DCWaveform:
  Description: "Waveform"
  Author : "Wenxing Fang, IHEP"
  Members:
    - unsigned long long cellID //detector specific cell id.
    - int type //type.
    - float beginTime //begin time of the waveform.
    - float interval //interval of each sampling in [ns].
  VectorMembers:
    - float rawData //charges.
```

Ionization cluster reconstruction Alg

```
#----- DCRecIonizationCluster
edm4dc::DCRecIonizationCluster:
  Description: "Reconstructed Ionization Cluster"
  Author : "Wenxing Fang, IHEP"
  Members:
    - unsigned long long cellID //ID of cell for this reconstructed primary ionization cluster.
    - int type //type.
    - float significance //significance of the reconstructed primary ionization cluster.
  VectorMembers:
    - float pulseTime //the pulse producing time in the lab frame in [ns].
    - float pulseAmplitude //the pulse's amplitude.
    - float pulseSignificance //significance of the pulse.
```

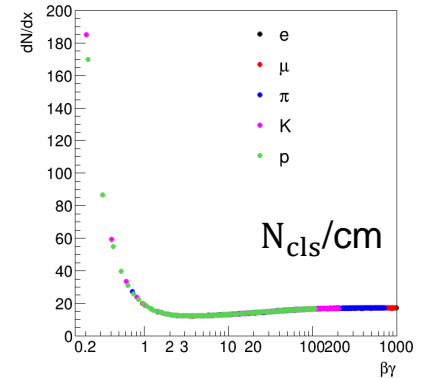


dN/dx reconstruction

rec ionization cluster collection

dN/dx reconstruction Alg

rec track collection



```
#----- Track
edm4hep::Track:
  Description: "Reconstructed track"
  Author : "F.Gaede, DESY"
  Members:
    - int32_t type //flagword that defines the type of t
    - float chi2 //Chi^2 of the track fit
    - int32_t ndf //number of degrees of freedom of the
    - float dEdx //dEdx of the track.
    - float dEdxError //error of dEdx.
    - float radiusOfInnermostHit //radius of the innermost hit that has be
  VectorMembers:
    - int32_t subDetectorHitNumbers //number of hits in particular subdet
    - edm4hep::TrackState trackStates //track states
    - edm4hep::Quantity dxQuantities // different measurements of dx quantities
  OneToManyRelations:
    - edm4hep::TrackerHit trackerHits //hits that have been used to create this
    - edm4hep::Track tracks //tracks (segments) that have been combin

# quantity with an identifier, a value and an error
edm4hep::Quantity:
  Members:
    - int16_t type // flag identifying how to interpret the quantity
    - float value // value of the quantity
    - float error // error on the value of the quantity
```

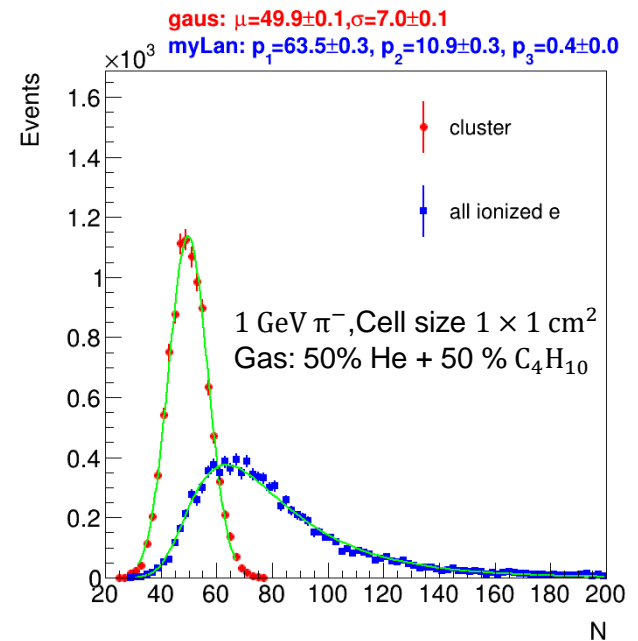
```
#----- DCREcDndx
edm4dc::DCRecDndx:
  Description : "DC dN/dx info of Track."
  Author : "Wenxing Fang, IHEP"
  Members :
    - int type //type.
    - float dNdx //reconstructed dNdx.
    - float dNdxError //error on reconstructed dNdx.
    - int particleType //particle type, e(0),mu(1),pi(2),K(3),p(4).
  VectorMembers:
    - unsigned long long cellID //DC cell id
    - float N //number of reconstructed primary ionization in DC cell
    - float edep //energy deposite in DC cell
    - float pathL //path length in DC cell in [mm]
    - float chi //chi for e(0), mu(1), pi(2), K(3), p(4)
    - float dNdxExpect //expected dNdx for e(0),mu(1), pi(2), K(3), p(4)
    - float dNdxSigma //expected sigma of dNdx for e(0),mu(1), pi(2), K(3), p(4)
  OneToOneRelations:
    - edm4hep::Track track //track that created the DC info.
```

<https://github.com/wenxingfang/CEPCSW/blob/master/Edm/edm4dc.yaml>

Back up

Motivation

- ❑ The particle identification is very important for CEPC flavor physics study. Good hadron separation up to 20 GeV is essential
- ❑ Traditionally: using dE/dx method
 - ❑ Due to the production of delta electron, the deposited energy follows Landau distribution
 - ❑ Resolution is $\sim 6\%$
- ❑ New technique: using dN/dx (cluster counting) method
 - ❑ The number of primary ionization follows Poisson distribution
 - ❑ Resolution could reaches $< 3\%$
- ❑ The dN/dx technique will be widely explored in CEPC drift chamber detector



User extension data in EDM4hep

- ❖ As there is no waveform data format in EDM4hep yet, user extension data is a way to add additional data.

- WIP: <https://github.com/key4hep/EDM4hep/pull/117>

Tao Lin

The proposed underlying data structure:

```
edm4hep::UserExt:  
  Description: "A simple struct with user defined int/float/double"  
  Author : "Tao Lin"  
  VectorMembers:  
    - int valI // data int  
    - float valF // data float  
    - double valD // data double
```

The proposed user APIs:

```
ud xyzi;  
xyzi.reg("x", 1, 0)  
  .reg("y", 1, 1)  
  .reg("z", 1, 2)  
  .reg("t", 2, 0)  
  .reg("i", 0, 0);
```

Runtime Type definition

```
xyzi.from(usrexts[i], 0)  
  .get("x", x)  
  .get("y", y)  
  .get("z", z)  
  .get("t", t)  
  .get("i", iii);
```

Getters

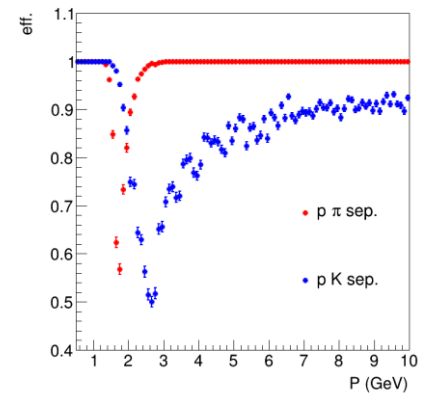
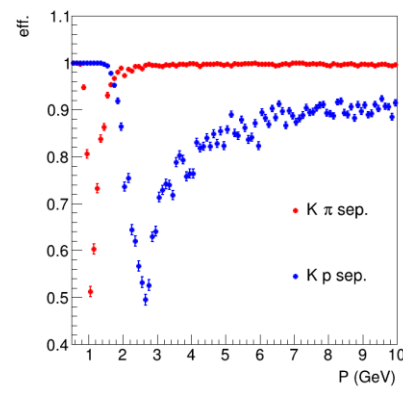
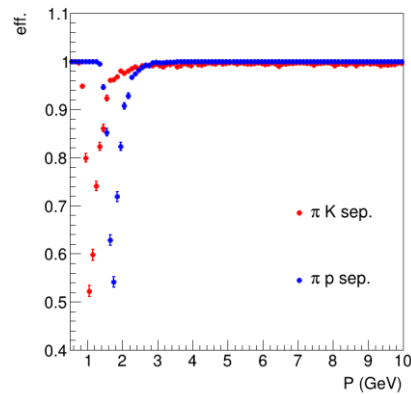
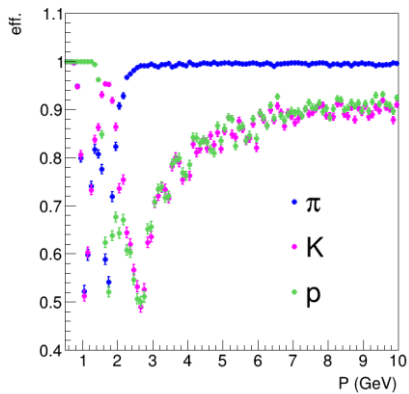
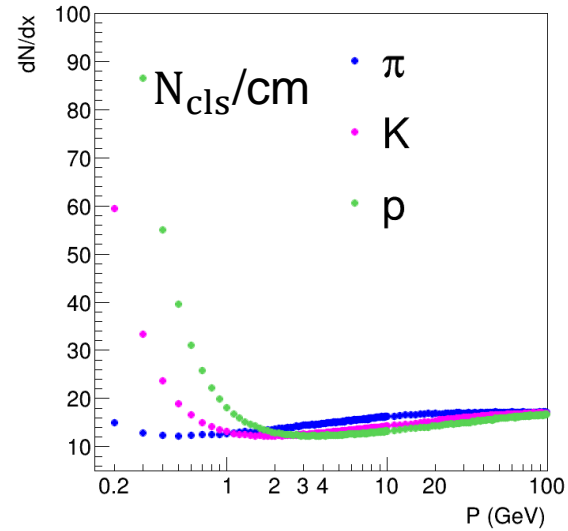
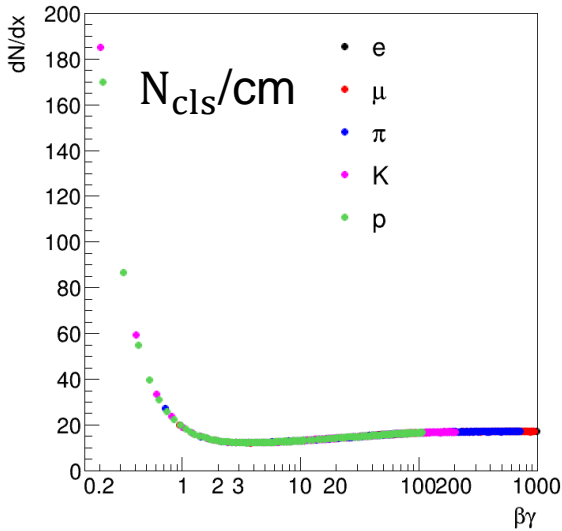
```
xyzi.put("x", x)  
  .put("y", y)  
  .put("z", z)  
  .put("t", t)  
  .put("i", i);
```

```
auto udv = usrexts.create();  
xyzi.to(udv);
```

Setters

Garfield++ simulation

90%He+10%C₄H₁₀



1 meter length