Wire-Cell ProtoDUNE Local Meeting

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Mar 25, 2026 (Wed)

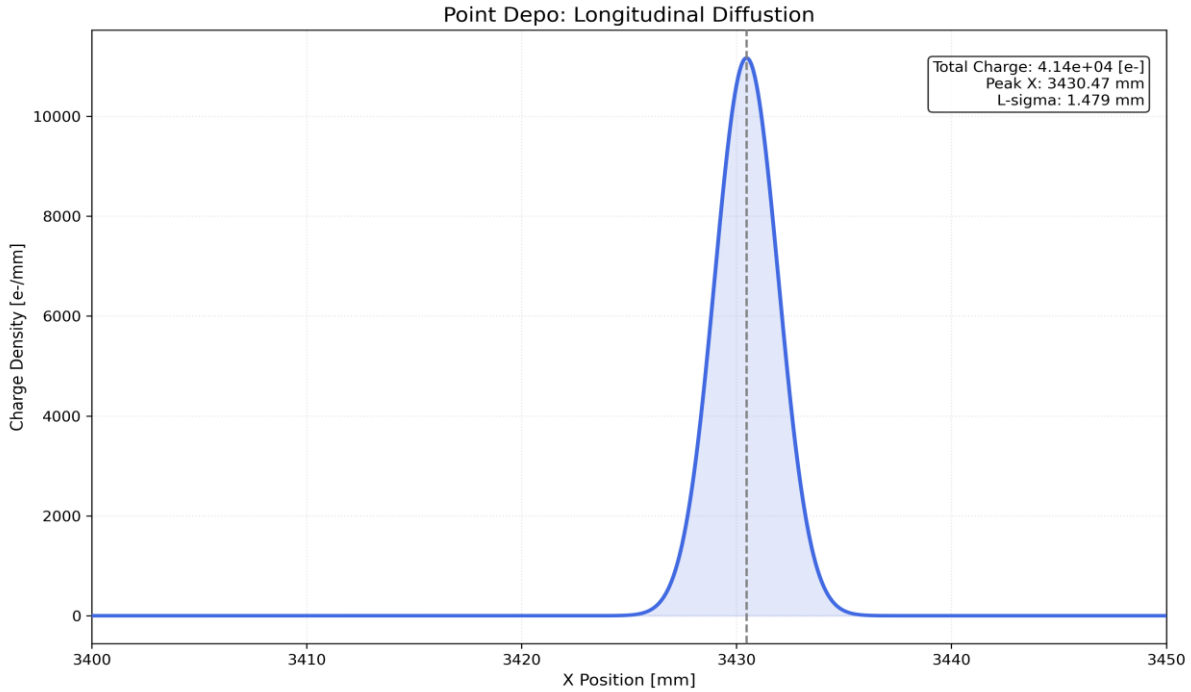
Wire-Cell 3D Imaging & Clustering
Blob Depo Fill: Time_offset Tuning

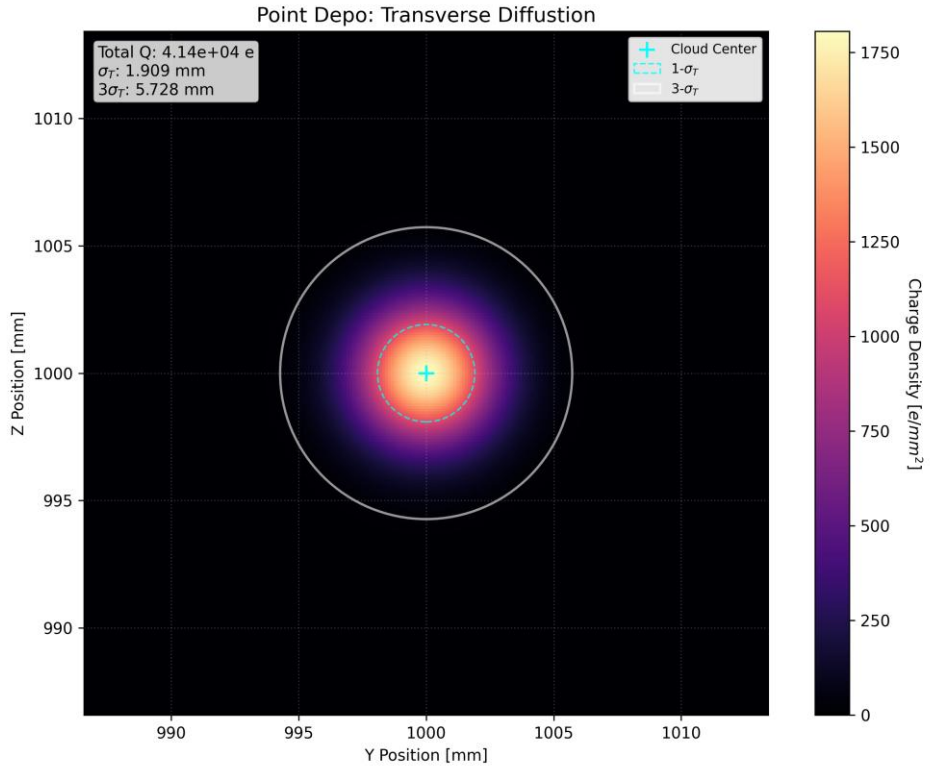
Point Depo Analysis

- (x,y,z) = (1000, 1000, 1000) [mm]
- charge = 50000 e-
- Gen time = 0 us

Drift →

- x = 3430.47, (y,z) = (1000,1000) [mm]
- charge = 41400 e-
- Arrival time = 1519.04062 us



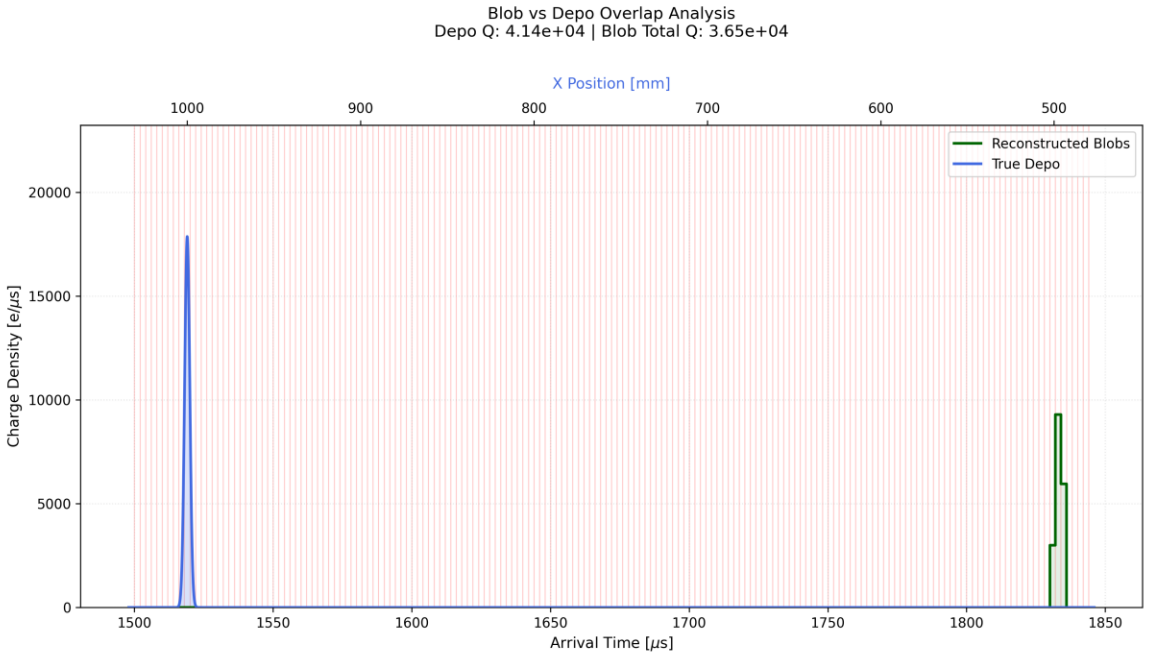


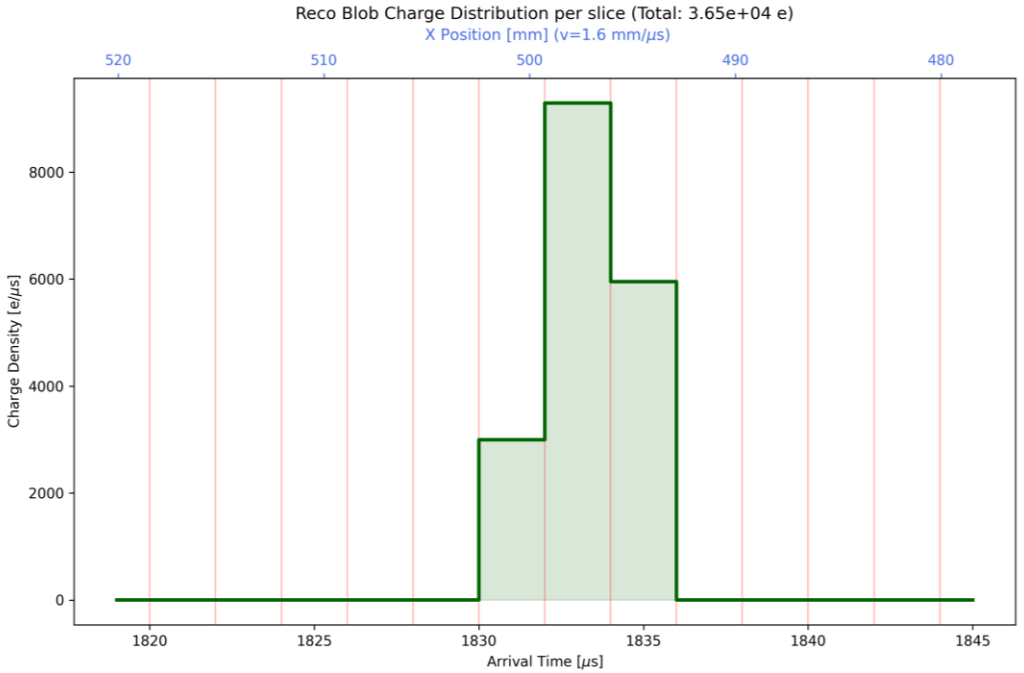
- From the drifted depo, blobs are reconstructed.
- Compare with blobs

Wire-Cell 3D Imaging & Clustering
Blob Depo Fill: Time_offset Tuning

Point Depo Analysis

- From the depo cloud, 3 blobs are reconstructed
- By setting time_offset, the depo is shifted in the BlobDepoFill





Idx	SliceID	Start [ns]	Span [ns]	Charge [e-]	Ratio [%]
0	915	1830000.00	2000.00	5.99e+03	16.43%
1	916	1832000.00	2000.00	1.86e+04	50.94%
2	917	1834000.00	2000.00	1.19e+04	32.63%

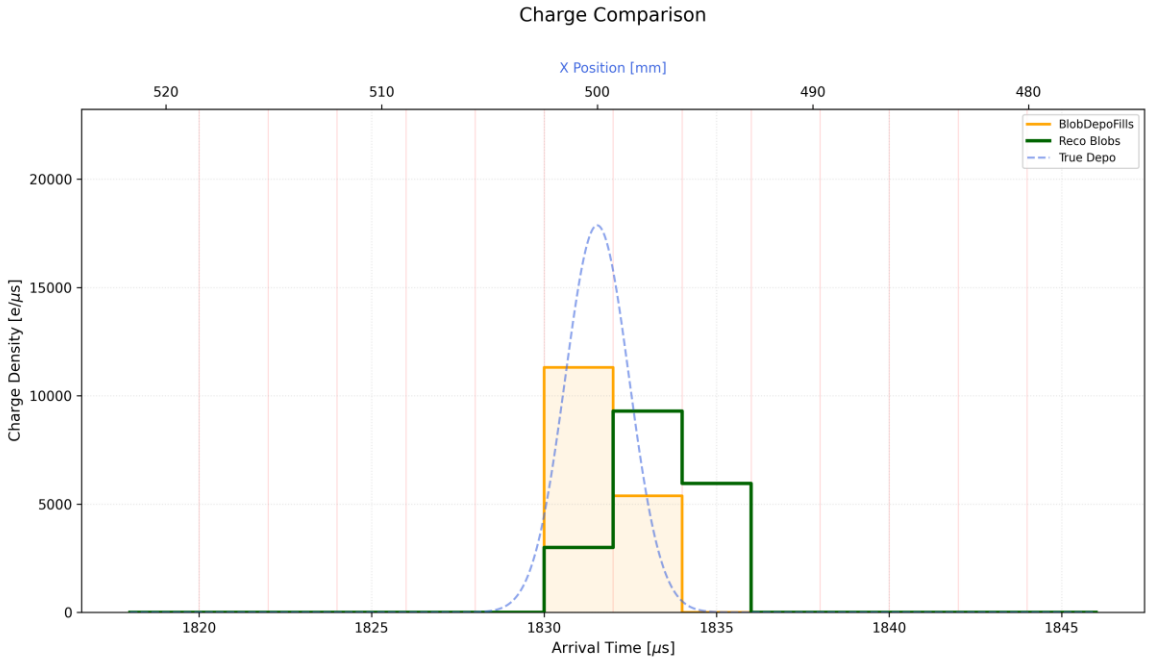
Total Number of Blobs: 3
Total Sum of Charges : 3.648e+04 [e-]

Wire-Cell 3D Imaging & Clustering
Blob Depo Fill: Time_offset Tuning

Point Depo Analysis

- With time_offset=312.5 us from PDHD 'param.jsonnet'

```
ductor : {
    nticks: $.daq.nticks + response_nticks,
    readout_time: self.nticks * $.daq.tick,
    start_time: tick0_time - response_time_offset,
},
```



Time [us]	True (e)	(%)	Fill (e)	(%)	Reco (e)	(%)
1826.0~1828.0	2.65e+00	0.0%	0.00e+00	0.0%	0.00e+00	0.0%
1828.0~1830.0	1.98e+03	4.8%	0.00e+00	0.0%	0.00e+00	0.0%
1830.0~1832.0	2.66e+04	64.3%	2.26e+04	67.8%	5.99e+03	16.4%
1832.0~1834.0	1.27e+04	30.6%	1.08e+04	32.2%	1.86e+04	50.9%
1834.0~1836.0	1.61e+02	0.4%	0.00e+00	0.0%	1.19e+04	32.6%
SUM [e-]	4.14e+04	100%	3.34e+04	100%	3.65e+04	100%
[% vs True]		100.0%		80.6%		88.1%

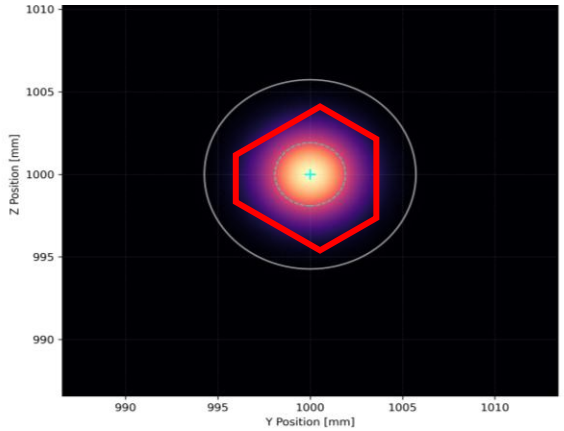
Wire-Cell 3D Imaging & Clustering
Blob Depo Fill: Time_offset Tuning

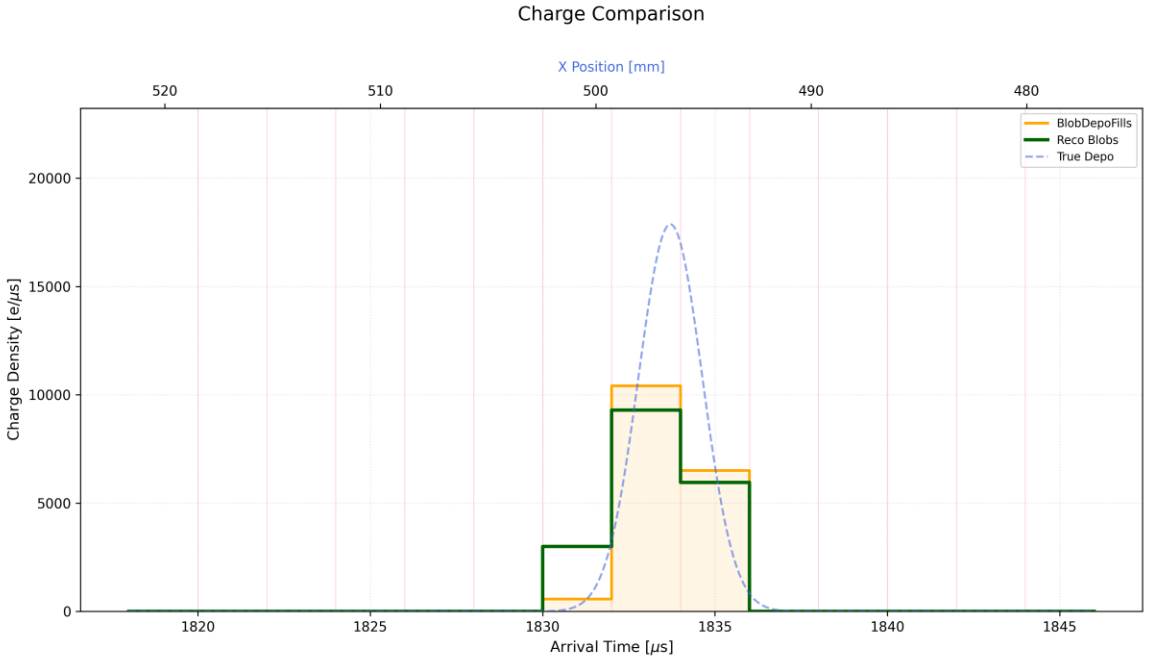
Point Depo Analysis

$$RSS = \sum (Ratio_{Depo,i} - Ratio_{Blob,i})^2$$

To find optimal time offset,
- Grid search
- minimizing RSS for charge ratio of each slice

-> time_offset=314.6674133 us





Time [us]	True (e)	(%)	Fill (e)	(%)	Reco (e)	(%)
1828.0~1830.0	1.25e+00	0.0%	0.00e+00	0.0%	0.00e+00	0.0%
1830.0~1832.0	1.34e+03	3.2%	1.14e+03	3.3%	5.99e+03	16.4%
1832.0~1834.0	2.45e+04	59.2%	2.08e+04	59.6%	1.86e+04	50.9%
1834.0~1836.0	1.53e+04	36.9%	1.30e+04	37.2%	1.19e+04	32.6%
1836.0~1838.0	2.72e+02	0.7%	0.00e+00	0.0%	0.00e+00	0.0%
SUM [e-]	4.14e+04	100%	3.50e+04	100%	3.65e+04	100%
[% vs True]		100.0%		84.4%		88.1%

Backup

Wire-Cell 3D Imaging & Clustering
Blob Depo Fill: Adding true info in the conventional pipeline

Metrics

- Two metrics for 3D Imaging performance evaluations in the **Blob level**

blob size -> charge smearing
ghost evaluation
de-ghosting algorithm performance

$$\text{Purity} = \frac{\text{Number of blobs with non-zero true charge}}{\text{Total number of reconstructed blobs}}$$

$$\text{Efficiency} = \frac{\text{Total true charge in blob}}{\text{Total true charge}}$$

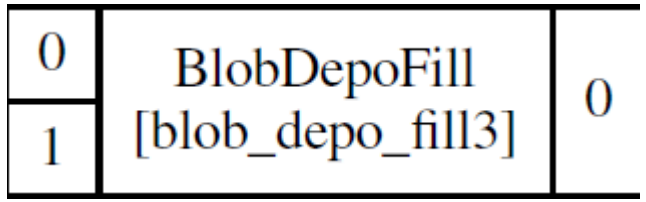
BlobDepoFill

(https://github.com/WireCell/wire-cell-toolkit/blob/18a8a5c06c8f8001e8dea5e3a577570ee473b79b/img/src/BlobDepoFill.cxx#L2)

- Replace charges of reco blob with true charges in the blobs
- This node only replace the charge info, not position info, giving the position of reco blob

→ BlobDeopFill approach can be used for only evaluating about charge

Input: `ICluster` data ->
Input: `IDepoSet` data ->

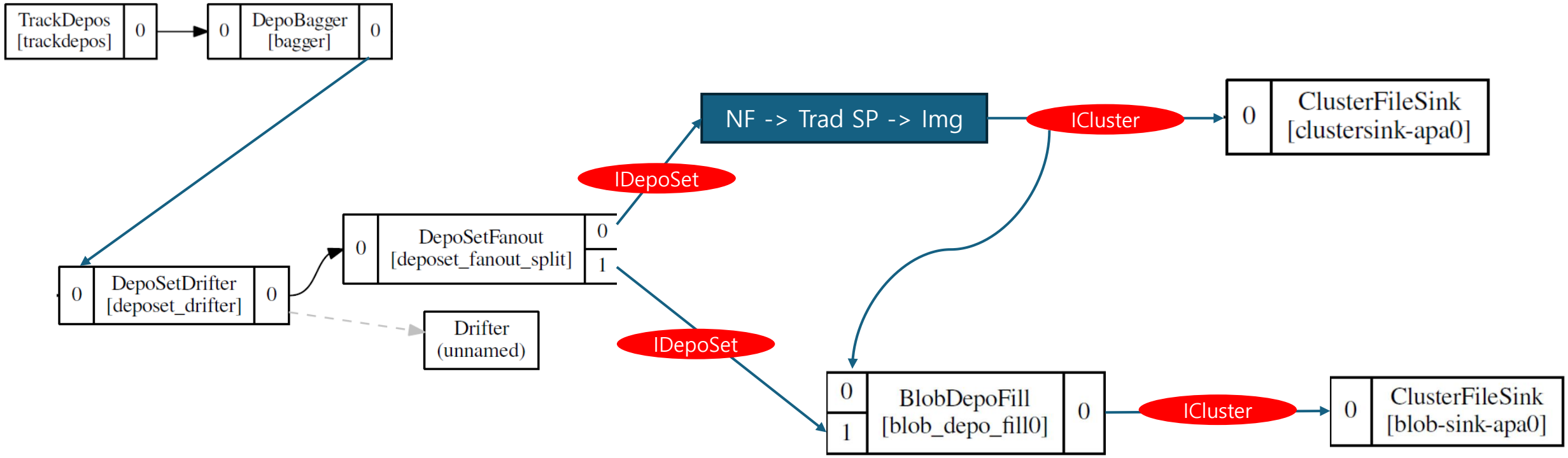


-> Output: `ICluster` data w/ true charge in the blob

Wire-Cell 3D Imaging & Clustering
Blob Depo Fill: Adding true info in the conventional pipeline

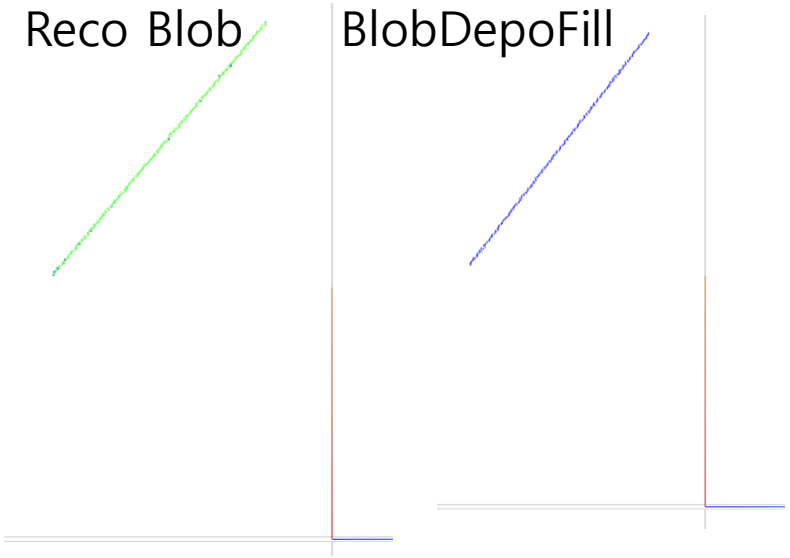
New PDHD configuration including BlobDepoFill nodes

- Wire-Cell standalone simulation: NF -> Trad SP -> Img
- Add BlobDepoFill nodes to the conventional img pipeline



Wire-Cell 3D Imaging & Clustering
Recall : Problems in BlobDepoFills

PDHD : Single track sim (apa2, thetaXZ=45 deg)

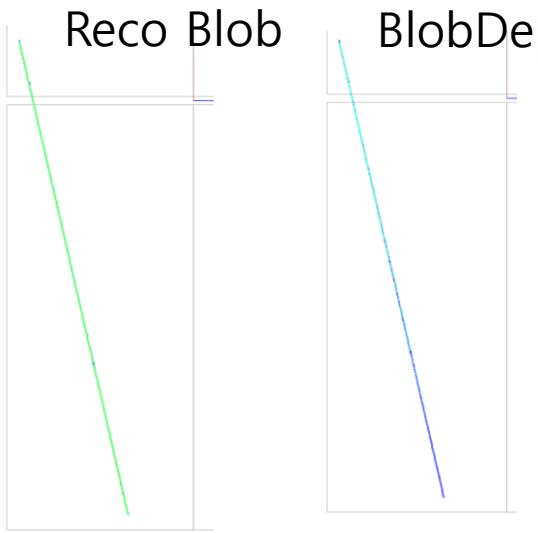


https://www.phy.bnl.gov/twister/bee/set/087c1325-4b0f-4db1-a5b7-53fa03b460a4/event/0/

- **No charge in BlobDepoFill**


```
285, 134.393, 114.77, 113.414, 164.641], "q": [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.
0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.
0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.
0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
```


PDVD : Single track sim (crp0 , thetaXZ=75 deg)



https://www.phy.bnl.gov/twister/bee/set/7eab4e64-8fa7-43d5-8b0f-3f58e40d7fef/event/0/

- **Charge was included, but not uniformly**


```
"q": [9090.95, 0.0, 6578.456, 0.0, 8776.368, 0.0, 0.0, 10281.951, 10557.898, 0.0, 9972.835, 3335.962, 136.821, 0.0, 198
9859.546, 7527.239, 0.0, 593.775, 7617.111, 0.0, 10021.493, 0.0, 0.0, 11637.681, 0.0, 11873.171, 11105.037, 0.0, 3595.36
0515.288, 0.0, 10398.631, 0.0, 7576.247, 0.0, 0.0, 4191.364, 0.0, 6616.562, 0.0, 8588.111, 0.0, 9874.841, 0.0, 10002.821
59, 0.0, 1463.194, 0.0, 11903.642, 11683.088, 0.0, 8343.749, 0.0, 0.0, 7091.705, 9229.479, 10314.313, 0.0, 0.0, 10585.78
4.525, 0.0, 213.194, 0.0, 257.054, 0.0, 9998.6, 0.0, 9733.907, 0.0, 0.0, 6817.027, 0.0, 8246.033, 0.0, 10599.194, 0.0, 1
196.524, 6159.936, 0.0, 0.0, 8497.627, 0.0, 9953.587, 0.0, 10615.896, 0.0, 10042.529, 0.0, 7034.571, 0.0, 0.0, 0.0, 0.0,
```

Before drift

```
============================================================
### [ DATA STRUCTURE & MEMORY ] ###
Container     : <class 'dict'>
Data Keys     : ['t', 'q', 'x', 'y', 'z', 'L', 'T']
Dict Size     : 7 (Number of keys)
Status        : Generation 1 (Pre-drift (Point-like))
Entry Summary : This generation contains total 1 depos.
Data Types    : t(float32), q(float32), x(float32), y(float32), z(float32), L(float32), T(float32)
Memory Usage  : 0.00 MB
------------------------------------------------------------
### [ PHYSICAL STATISTICS ] ###
q (Charge)     : Total -5.00e+04 | Mean -5.00e+04 [e-]
t (Time)       :     0.00 ~     0.00 [ns]
x (Position)   :  1000.00 ~  1000.00 [mm] (std: 0.00)
y (Position)   :  1000.00 ~  1000.00 [mm] (std: 0.00)
z (Position)   :  1000.00 ~  1000.00 [mm] (std: 0.00)
L (Long. sigma): 0.0000 [mm] (Point-like if 0)
T (Tran. sigma): 0.0000 [mm] (Point-like if 0)
>> Diagnosis: Pre-drift Point (L=T=0)
============================================================
```

After drift

```
============================================================
### [ DATA STRUCTURE & MEMORY ] ###
Container     : <class 'dict'>
Data Keys     : ['t', 'q', 'x', 'y', 'z', 'L', 'T']
Dict Size     : 7 (Number of keys)
Status        : Generation 0 (Post-drift (3D Gaussian))
Entry Summary : This generation contains total 1 depos.
Data Types    : t(float32), q(float32), x(float32), y(float32), z(float32), L(float32), T(float32)
Memory Usage  : 0.00 MB
------------------------------------------------------------
### [ PHYSICAL STATISTICS ] ###
q (Charge)     : Total -4.14e+04 | Mean -4.14e+04 [e-]
t (Time)       : 1519040.62 ~ 1519040.62 [ns]
x (Position)   :  3430.47 ~  3430.47 [mm] (std: 0.00)
y (Position)   :  1000.00 ~  1000.00 [mm] (std: 0.00)
z (Position)   :  1000.00 ~  1000.00 [mm] (std: 0.00)
L (Long. sigma): 1.4790 [mm] (Point-like if 0)
T (Tran. sigma): 1.9094 [mm] (Point-like if 0)
>> Diagnosis: Post-drift 3D Gaussian (L,T > 0)
============================================================
```

Blobs info

```
--- [ Dimension Transformation ] ---
Span/Thickness :    2000.00 [ns]  ->        3.20 [mm]
start of the blob : 1830000.00 [ns]
from_ductor_start_time : 2142500.00 [ns]

--- [ Coordinate Range Transformation ] ---
Axis            | Raw Range (ns/mm)          -> Undrifted Range (mm)
-------------------------------------------------------------------------
X (Drift)       | 1830000.0 ~ 1830000.0 [ns] ->    172.0 ~    172.0 [mm]
Y               |    986.5 ~   1010.5 [mm] ->    986.5 ~   1010.5 [mm]
Z               |    994.3 ~   1003.9 [mm] ->    994.3 ~   1003.9 [mm]

--- [ Top 3 Corners Sample ] ---
Corner [00] Raw : (1830000.0,   986.5,  1001.4) [ns, mm, mm]
         Und : (    172.0,   986.5,  1001.4) [mm, mm, mm]
                      (X: 1830000.0 ns -> 172.0 mm)
Corner [01] Raw : (1830000.0,  1010.5,  1001.4) [ns, mm, mm]
         Und : (    172.0,  1010.5,  1001.4) [mm, mm, mm]
                      (X: 1830000.0 ns -> 172.0 mm)
Corner [02] Raw : (1830000.0,   996.4,   994.3) [ns, mm, mm]
         Und : (    172.0,   996.4,   994.3) [mm, mm, mm]
                      (X: 1830000.0 ns -> 172.0 mm)
=================================================================
```

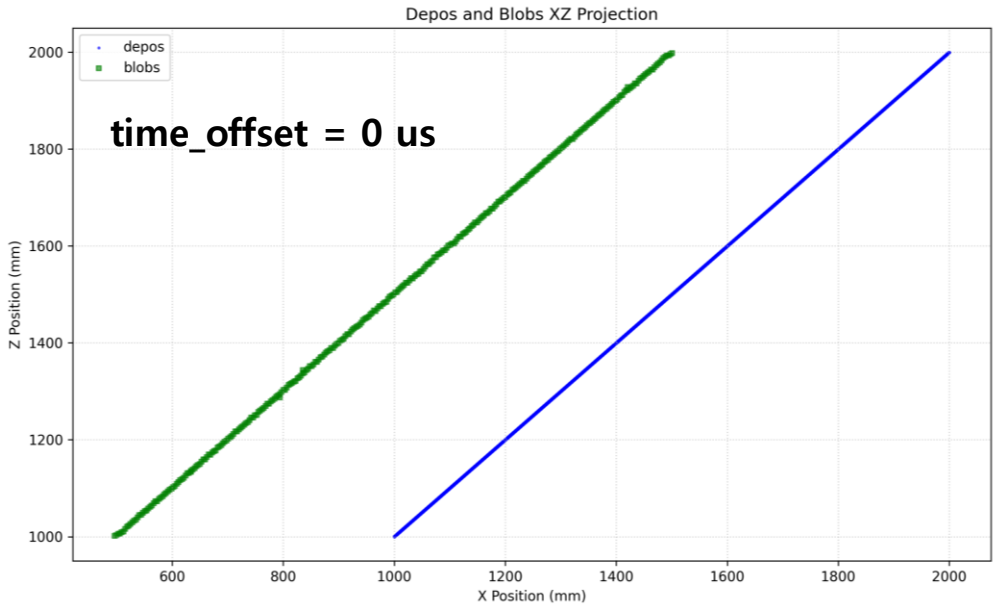
Wire-Cell 3D Imaging & Clustering
Blob Depo Fill: Adding true info in the conventional pipeline

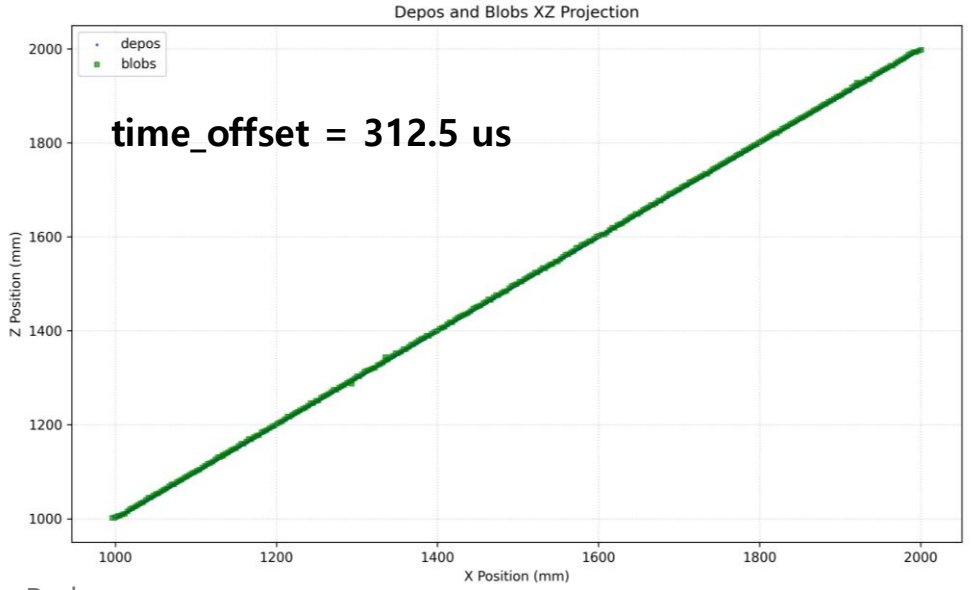
✓ Zero charge in BlobDepoFill is due to the time offset value

PDHD : Single track sim(apa2, thetaXZ=45 deg)

```
blob_depo_fill(anode, name, drift_speed=params.lar.drift_speed) :: g.pnode({
    type: "BlobDepoFill",
    name: "blobdepo-filler-%s"%name,
    data: {
        // fixme, breaks detector independence
        speed: drift_speed, //1.56*wc.mm/wc.us,
        time_offset: 312.5*wc.us, //314*wc.us,
```

- **drift_speed: 1.6 mm/us**
- **time_offset: 0 -> 312.5 us**





Wire-Cell 3D Imaging & Clustering
Blob Depo Fill: Adding true info in the conventional pipeline

✓ Zero charge in BlobDepoFill is due to the time offset value

PDHD : Single track sim(apa2, thetaXZ=45 deg)

```
blob_depo_fill(anode, name, drift_speed=params.lar.drift_speed) :: g.pnode({
    type: "BlobDepoFill",
    name: "blobdepo-filler-%s"%name,
    data: {
        // fixme, breaks detector independence
        speed: drift_speed, //1.56*wc.mm/wc.us,
        time_offset: 312.5*wc.us, //314*wc.us,
```

- **drift_speed: 1.6 mm/us**
- **time_offset: 0 -> 312.5 us**

The values came from *`sim.ductor.start_time`* in PDHD *`params.jsonnet`*

```
ductor : {
    nticks: $.daq.nticks + response_nticks,
    readout_time: self.nticks * $.daq.tick,
    start_time: tick0_time - response_time_offset,
},
```

```
local response_time_offset = $.det.response_plane / $.lar.drift_speed,
```

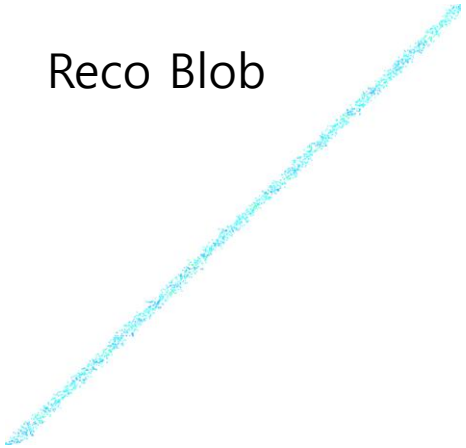
- tick0_time = -250 us (the absolute time of the first tick)
- response_plane = 10cm (where the field response functions start)
- response_time_offset = 62.5us
- **start_time = - 312.5 us**

Wire-Cell 3D Imaging & Clustering
Blob Depo Fill: Adding true info in the conventional pipeline

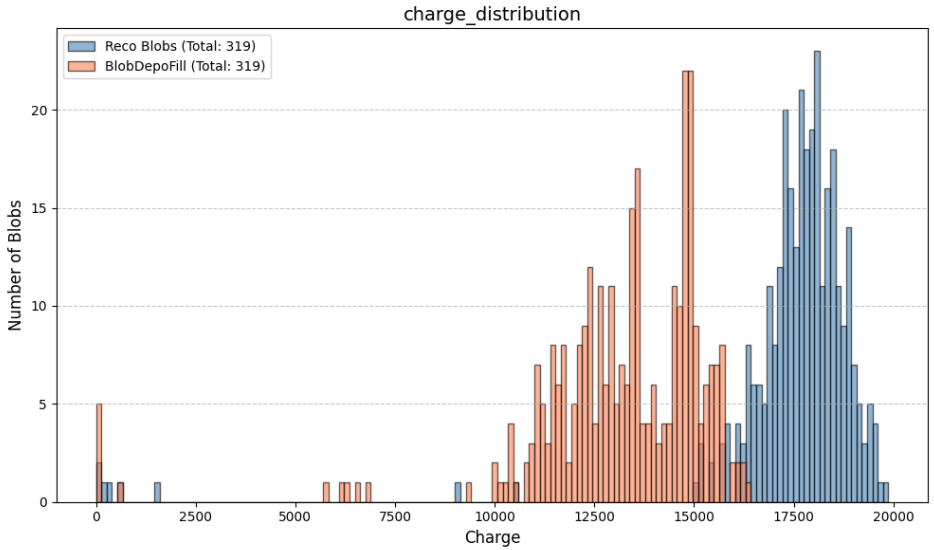
PDHD : Single track sim(apa2, thetaXZ=45 deg)

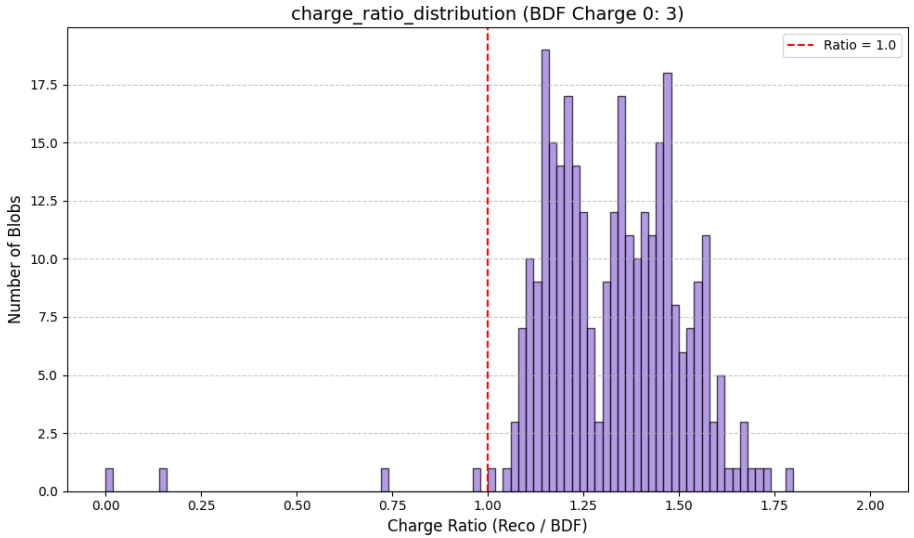
https://www.phy.bnl.gov/twister/bee/set/2a446d42-2231-4dc6-ad64-a4c74e9d0831/event/0/?theme=light

Reco Blob



BlobDepoFill





- Charge distributions are not well-match yet.
- Fine tunings for the time offset is required.

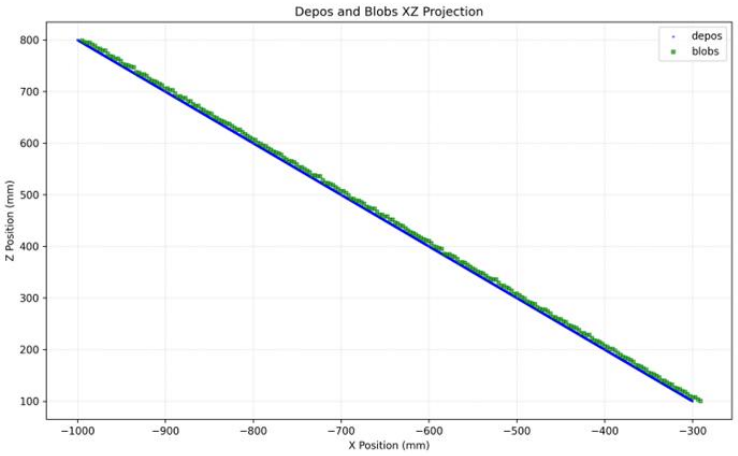
Wire-Cell 3D Imaging & Clustering

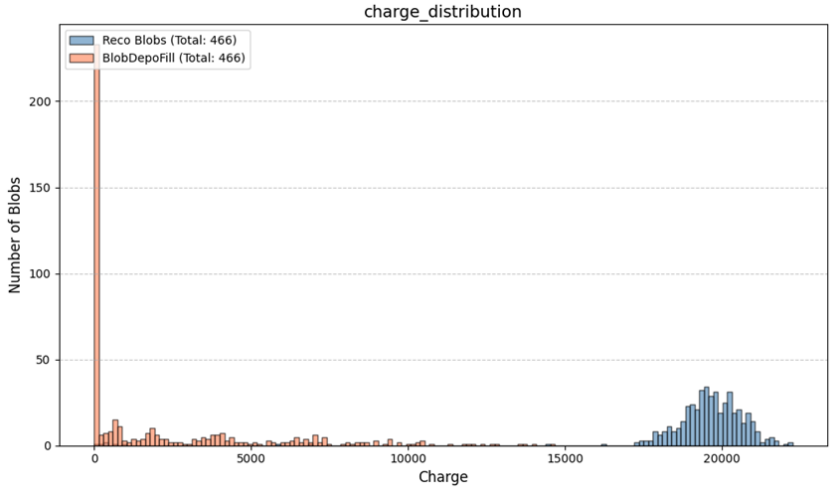
Blob Depo Fill: Adding true info in the conventional pipeline

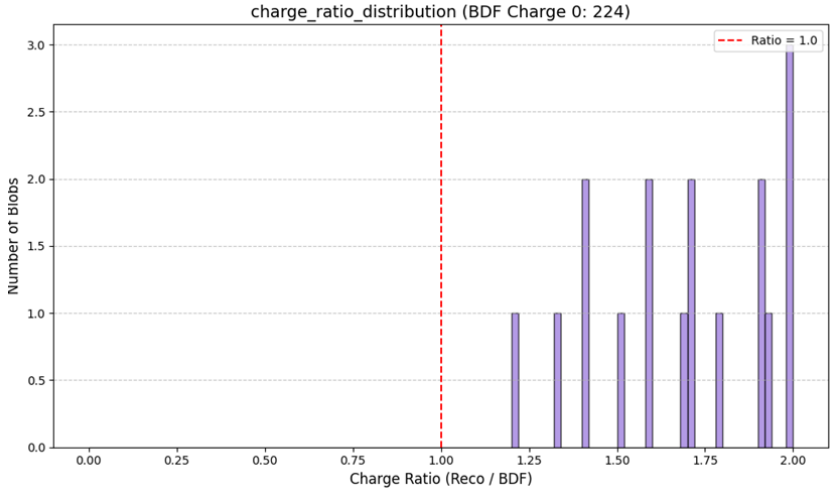
PDVD : Single track sim(crp0 , thetaXZ=45 deg)

- **drift_speed: 1.473 mm/us**
- **time_offset: 360.6833 -> 372.878479294 us**

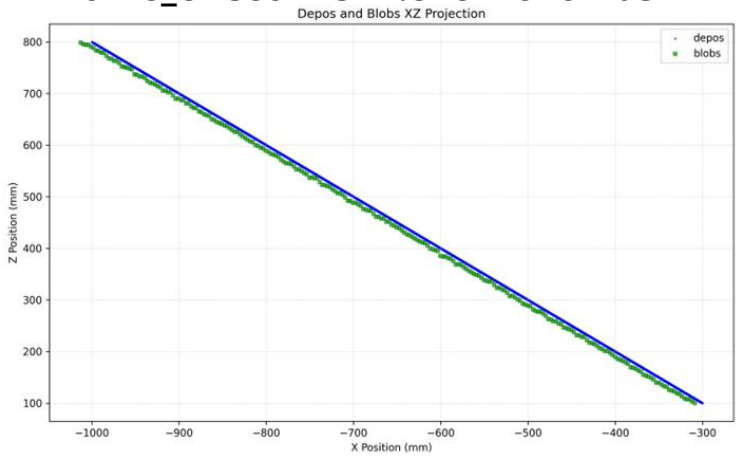
- **time_offset = 360.6833 us**

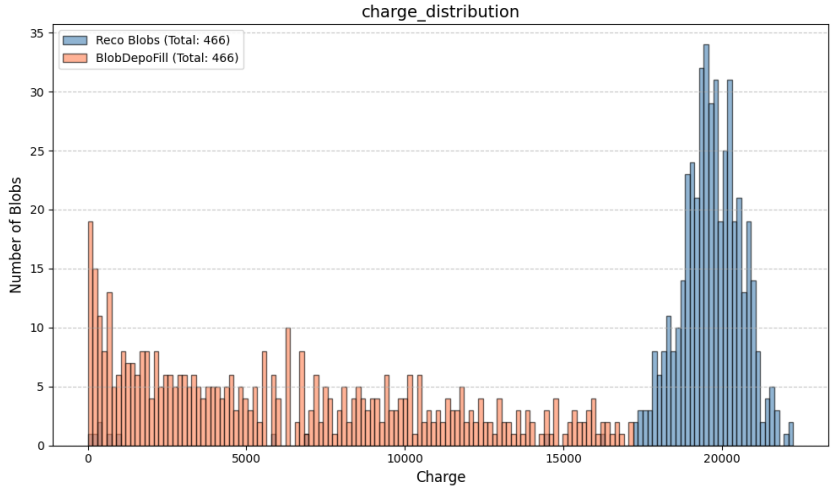


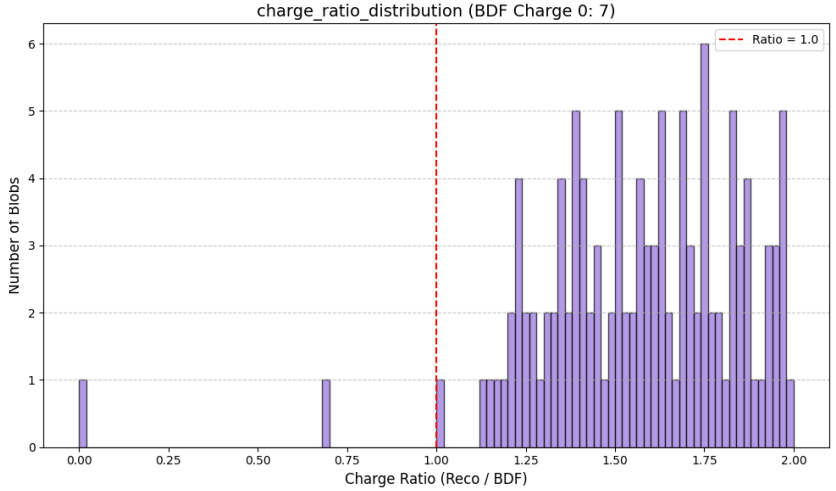




- **time_offset = 372.878479294 us**



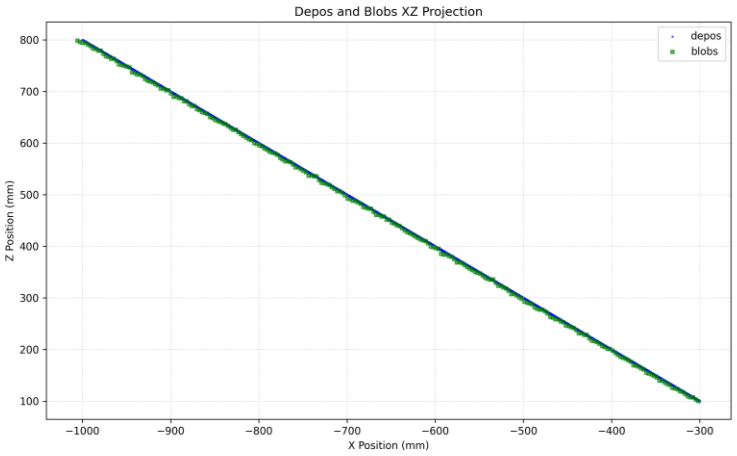


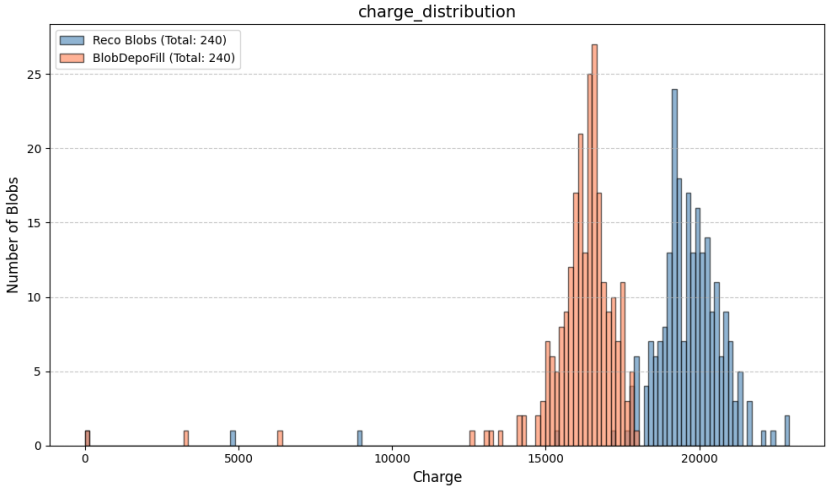


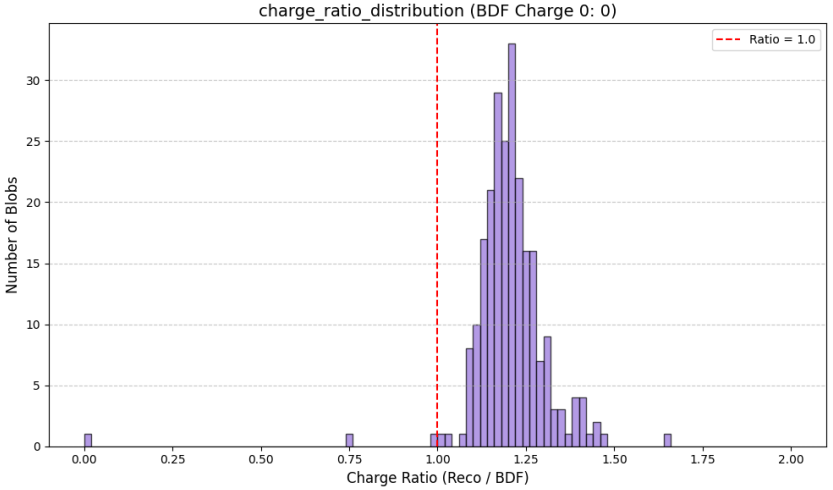
Wire-Cell 3D Imaging & Clustering
Blob Depo Fill: Adding true info in the conventional pipeline

PDVD : Single track sim(crp0 , thetaXZ=45 deg)

- **time_offset = 368 us**







- Also, fine tunings are required for both PDHD&PDVD.
- The metrics for charge can be calculated.
- The metrics can be refined to better represent the charge ratio distribution.

Wire-Cell 3D Imaging & Clustering
Blob Depo Fill: Time_offset Tuning

Track (APA2, ThetaXZ=45)