Wire-Cell 3D Imaging for DUNE-FD VD

Haiwang Yu

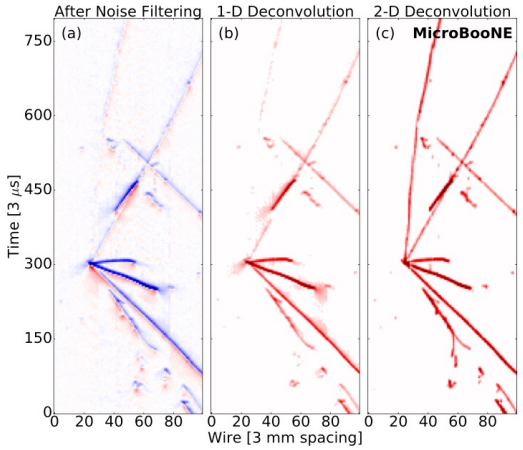
Wire-Cell Event Reconstruction

available in WCT

TPC simulation

noise filtering

signal processing



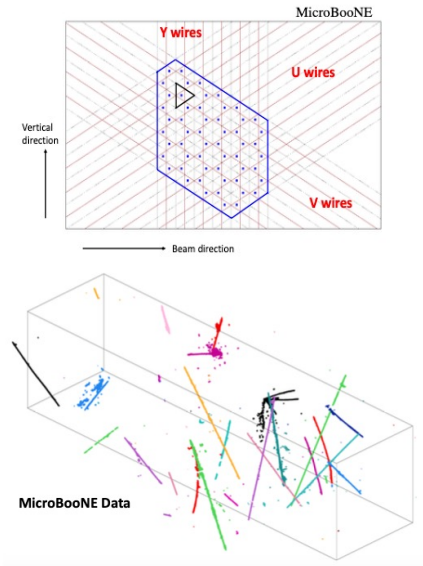
JINST 12 P08003 (2017)
JINST 13 P07006 (2018)
JINST 13 P07007 (2018)
JINST 16 P01036 (2020)

Porting in progress

3D imaging

clustering

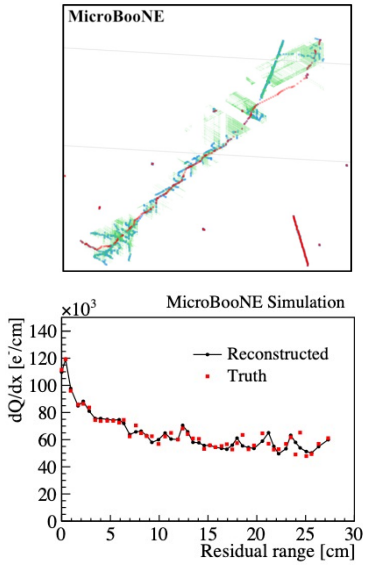
charge-light matching



JINST 13 P05032 (2018)
JINST 16 P06043 (2021)

3D trajectory & dQ/dx fitting

cosmic muon tagger

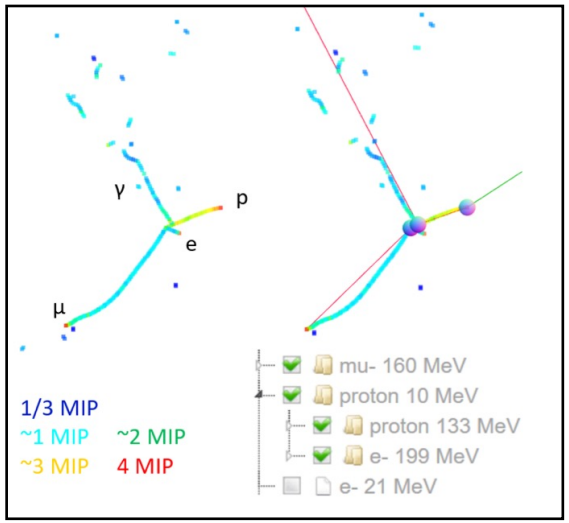


Phys. Rev. Applied 15, 064071 (2021)

multi-track fitting

DL-3D vertexing

particle identification



JINST 17 P01037 (2022)

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Wire-Cell 3D Imaging Principle

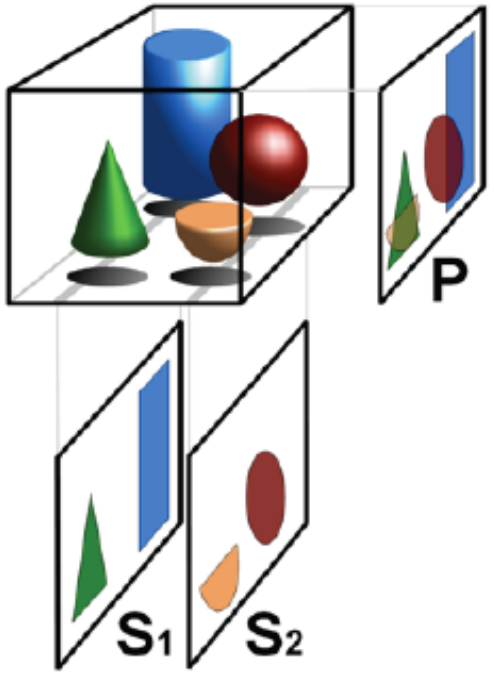
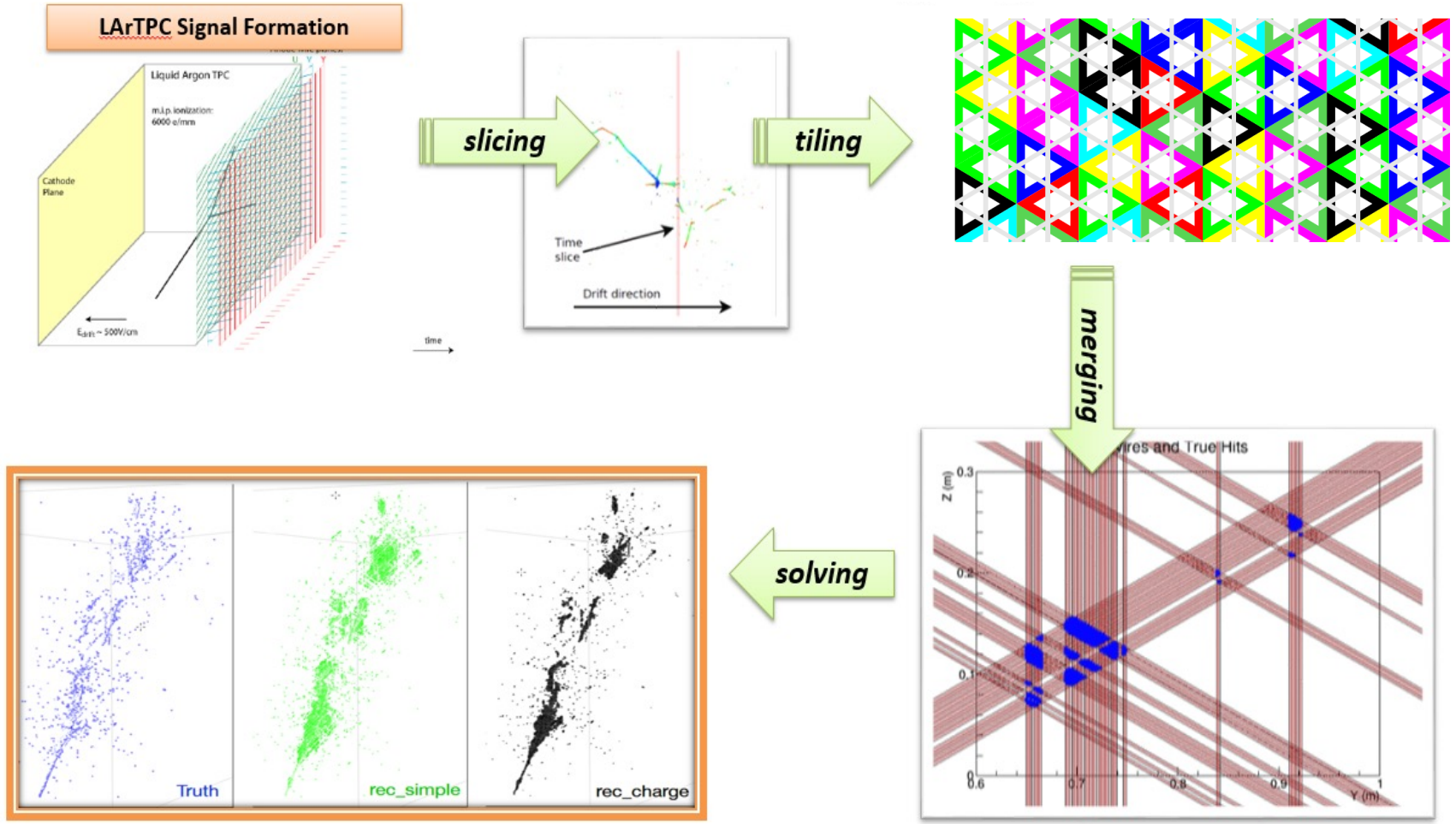


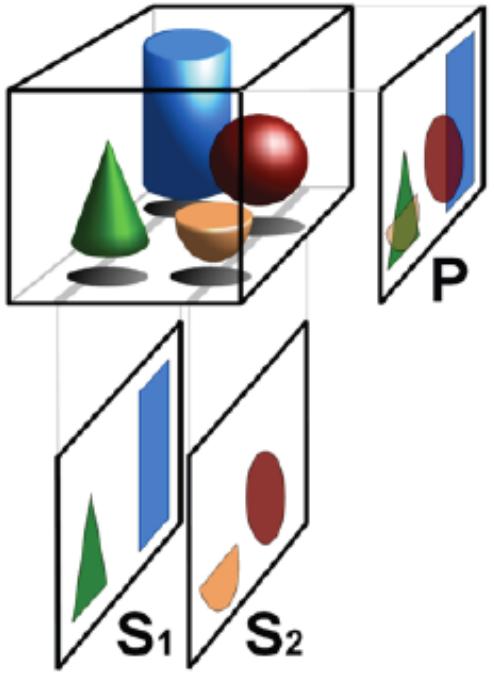
Fig.1:Basic principle of tomography: superposition free tomographic cross sections S1 and S2 compared with the projected image P

https://en.wikipedia.org/wiki/Tomography



"Three-dimensional Imaging for Large LArTPCs", JINST 13, P05032 (2018)

Wire-Cell 3D Imaging Principle



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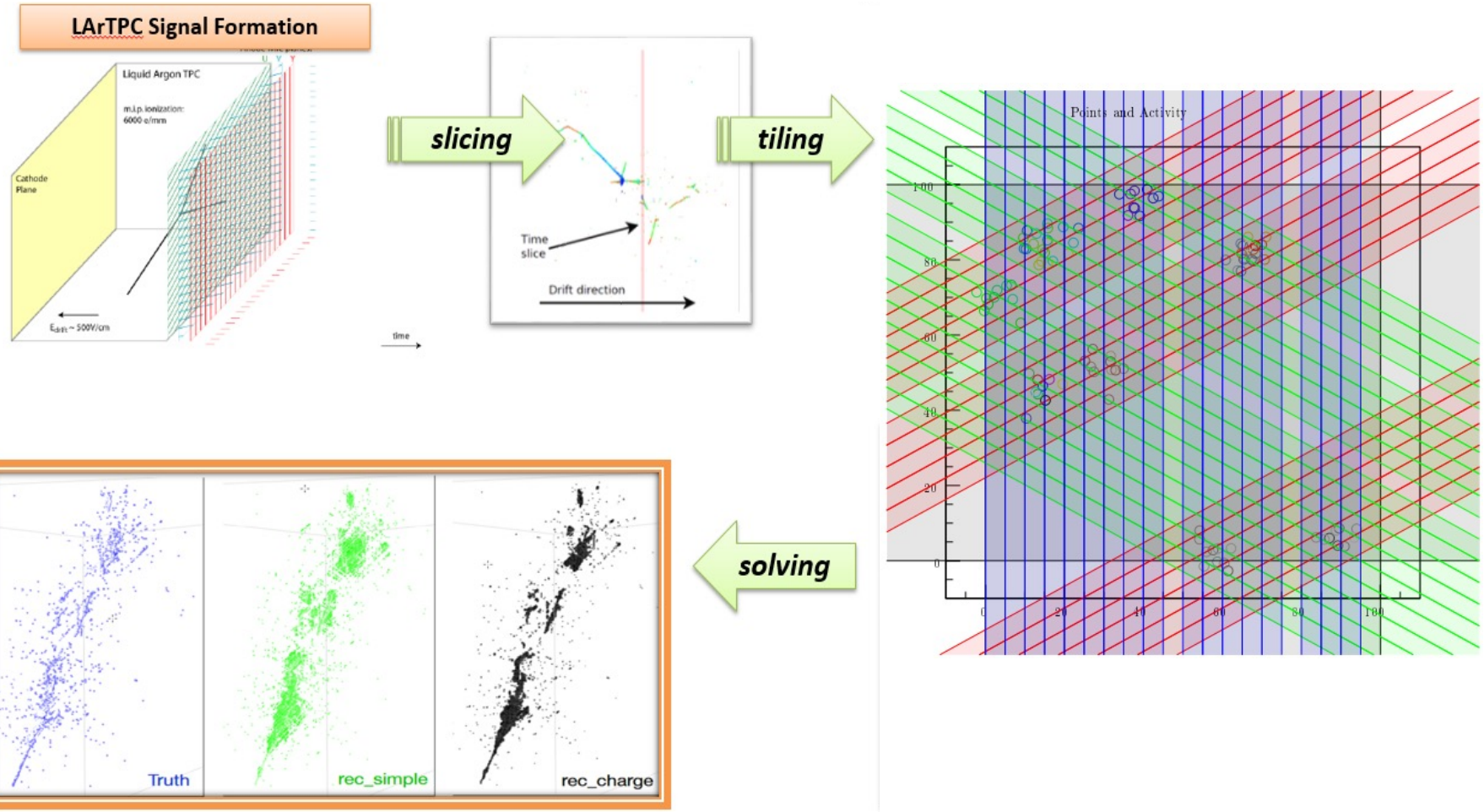
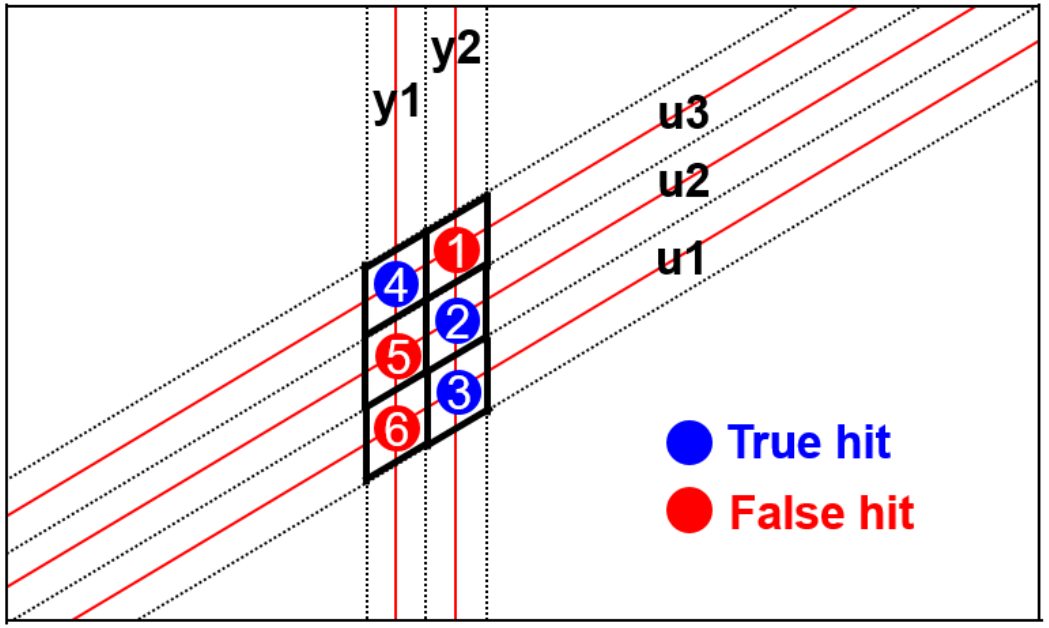


"Three-dimensional Imaging for Large LArTPCs", JINST 13, P05032 (2018)

Solving: usage of Charge, Sparsity, Positivity, Proximity



measured charges on Wires

$$y = A \cdot X$$

true charge to be resolved

$$\begin{pmatrix} y1 \\ y2 \\ u1 \\ u2 \\ u3 \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & a & a & a \\ a & a & a & 0 & 0 & 0 \\ 0 & 0 & a & 0 & 0 & a \\ 0 & a & 0 & 0 & a & 0 \\ a & 0 & 0 & a & 0 & 0 \end{pmatrix} \begin{pmatrix} H1 \\ H2 \\ H3 \\ H4 \\ H5 \\ H6 \end{pmatrix}$$

matrix determined by geometry, a=1

- The goal is to differentiate the true hits from fake ones by using the charge information
  - ~ large charge → true hits
  - ~ zero charge → fake hits
- Sparsity, positivity, and proximity information are added through compressed sensing (L1 regularization)

L1 reg. $O(N!) \rightarrow O(m \times N)$

$$\chi^2 = (y - A \cdot x)^2 + \lambda \cdot \sum_i |x_i|$$

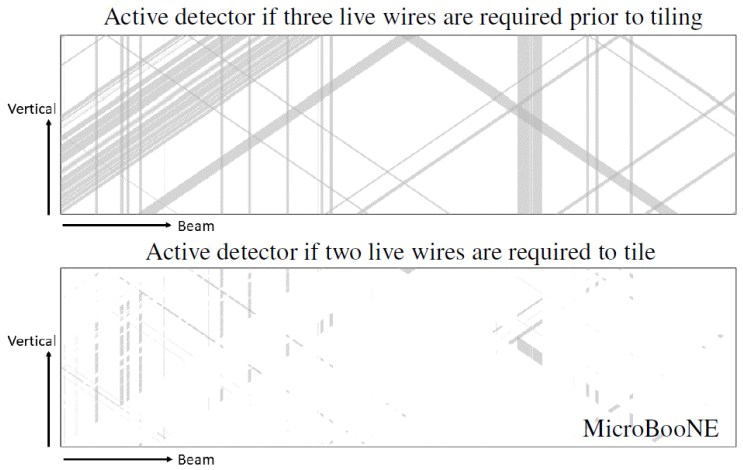
E. Candes, J. Romberg, T. Tao
arXiv-math/0503066

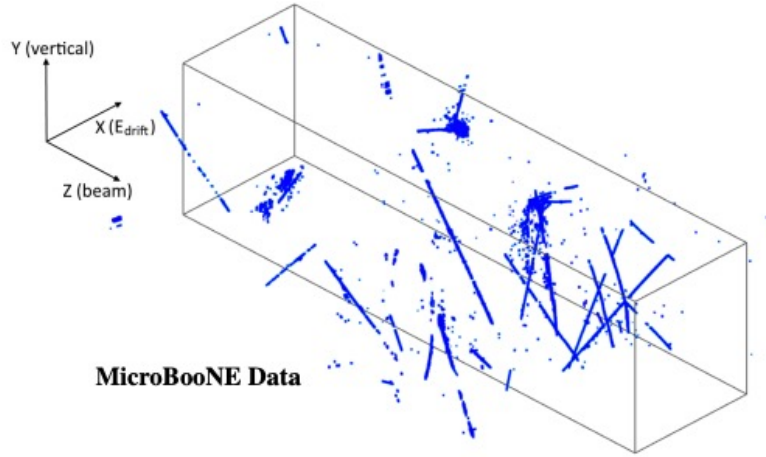
uboone Implementation

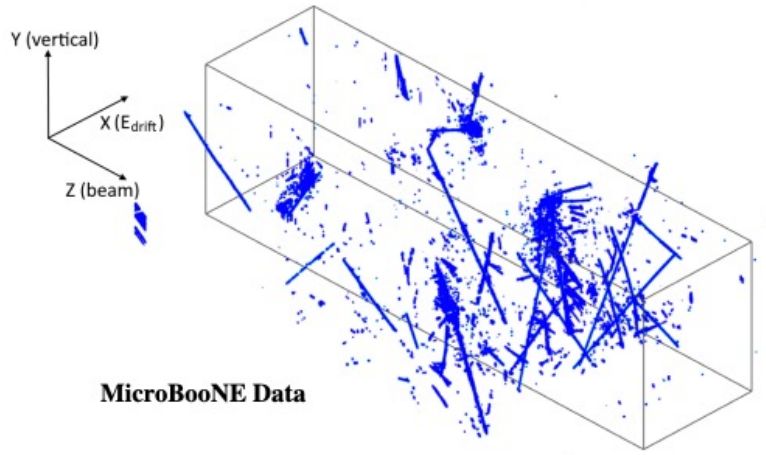
Implementation:

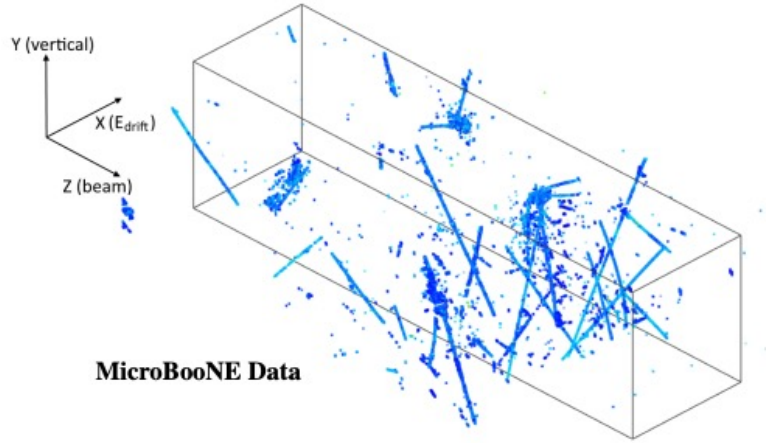
- https://arxiv.org/abs/2011.01375
- dead regions
- deghosting
- code: link

dead regions









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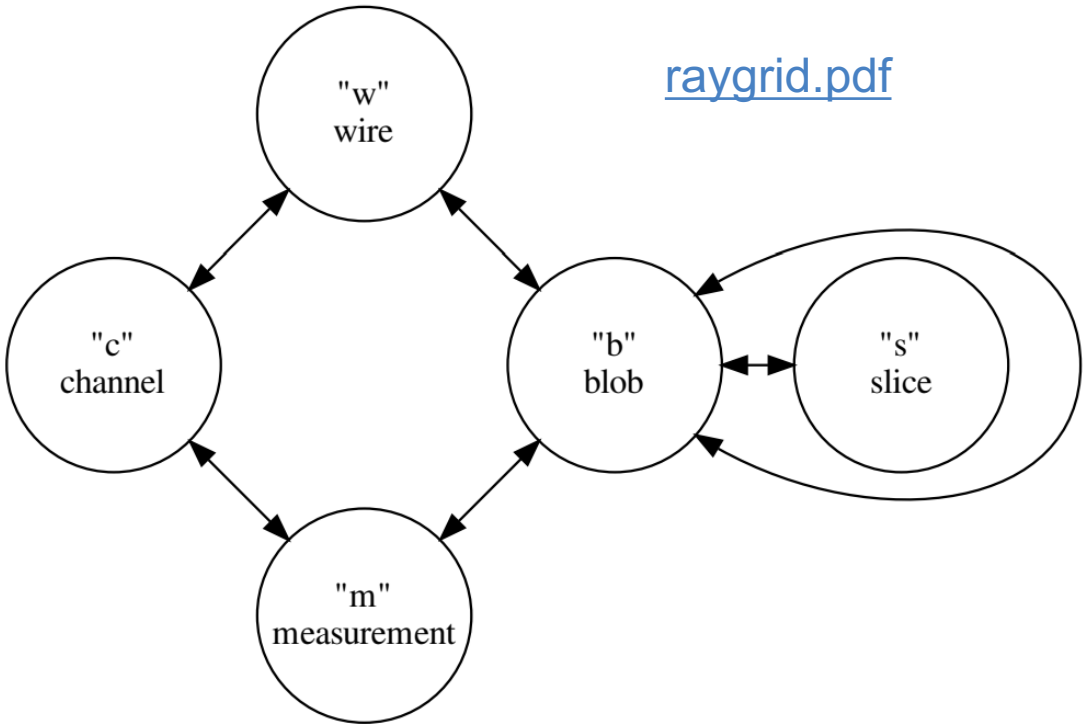
Prototype → Toolkit

- **Generalization → deploy to multiple experiments with only configuration change**
- Optimization → performance↑ and computing resources↓
- Working better with LArSoft → data flow through memory not disk
- Easier to maintain → modularized code, fewer interface objects, more functional

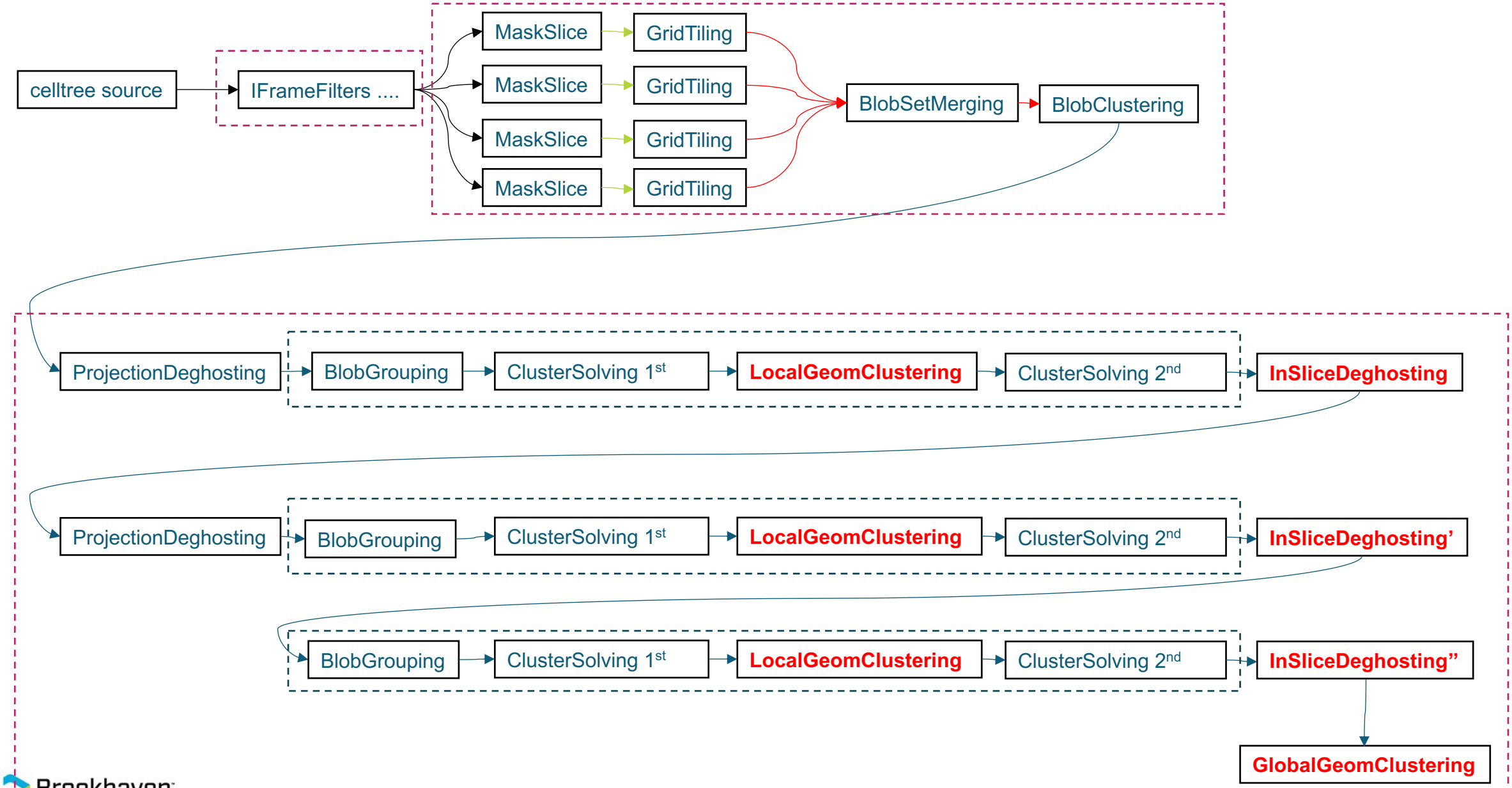
```
Blob {
        charge_map;
        time;
        ...
}

connectivity_map;
```



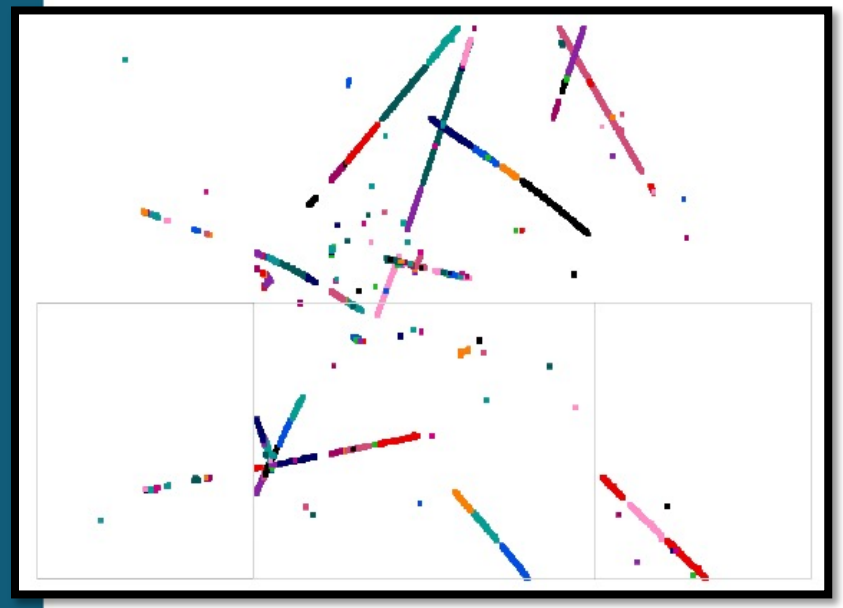
raygrid.pdf

Configuration: uboone imaging pipeline in WCT

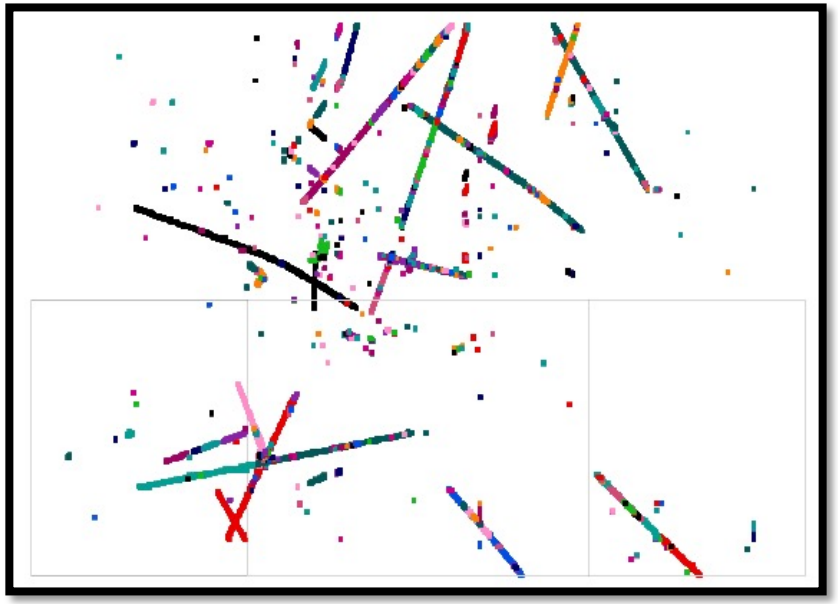


BEE Event display

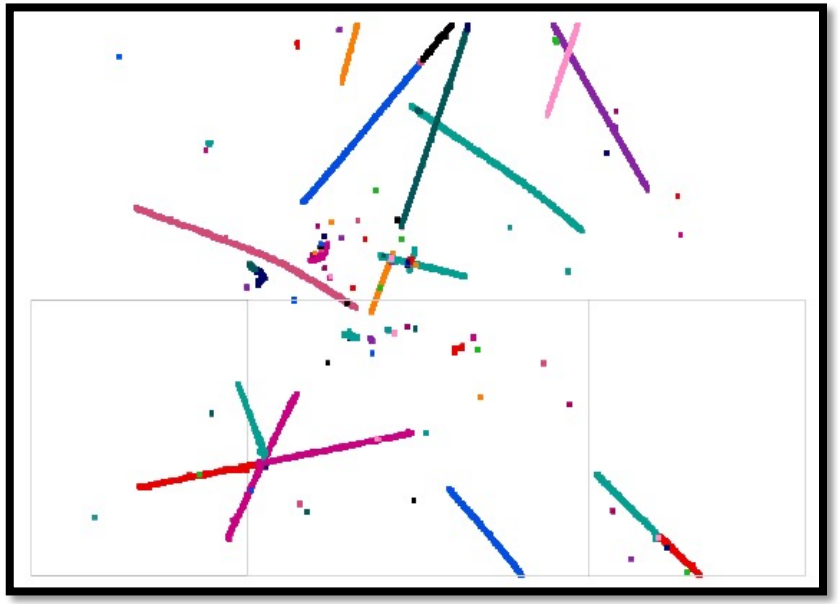
3-view only



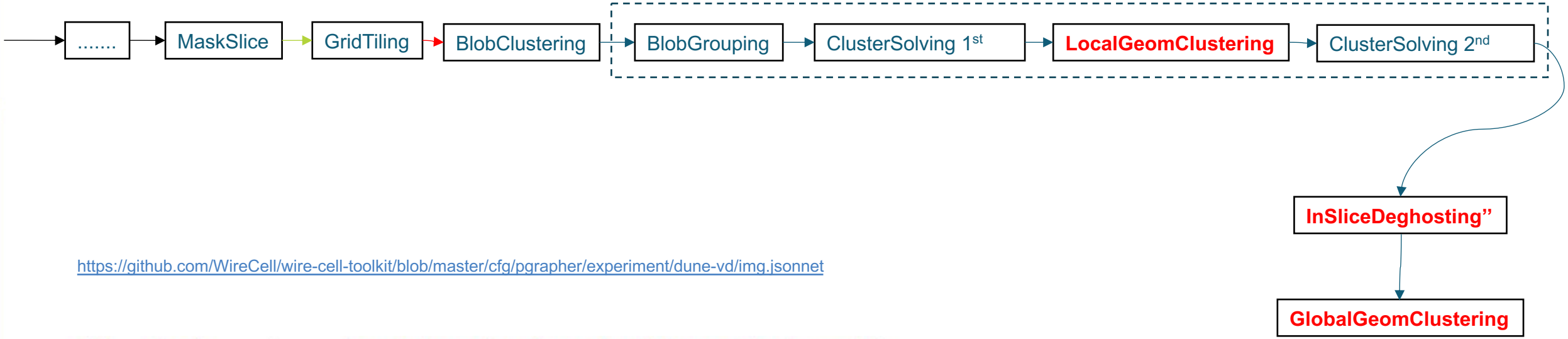
2-view w/o deghosting



2-view w deghosting



DUNE-FD-VD: Simplified version for now



https://github.com/WireCell/wire-cell-toolkit/blob/master/cfg/pgrapher/experiment/dune-vd/img.jsonnet

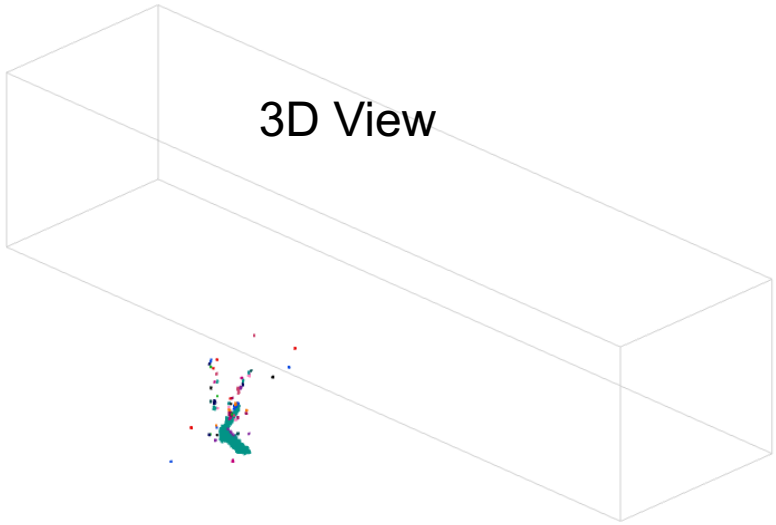
```
98  local sp_maker = import 'pgrapher/experiment/dune-vd/sp.jsonnet';
99  local sp = sp_maker(params, tools, { sparse: false, use_roi_debug_mode: false,} );
100 local sp_pipes = [sp.make_sigproc(a) for a in tools.anodes];
101
102 local img = import 'pgrapher/experiment/dune-vd/img.jsonnet';
103 local img_maker = img();
104 local img_pipes = [img_maker.per_anode(a) for a in tools.anodes];
```

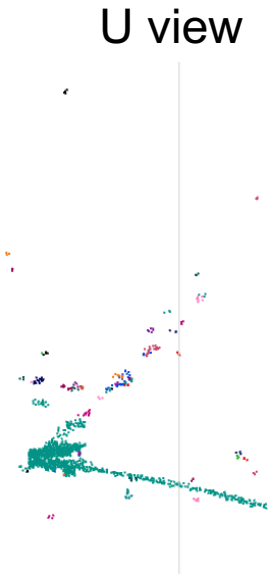
- The parameters of img() could be similar like sp.

BEE Event display (using uboone boundary for now)

https://www.phy.bnl.gov/twister/bee/set/6105426a-8b4c-40a5-97bb-c6cbdd43463a/event/0/

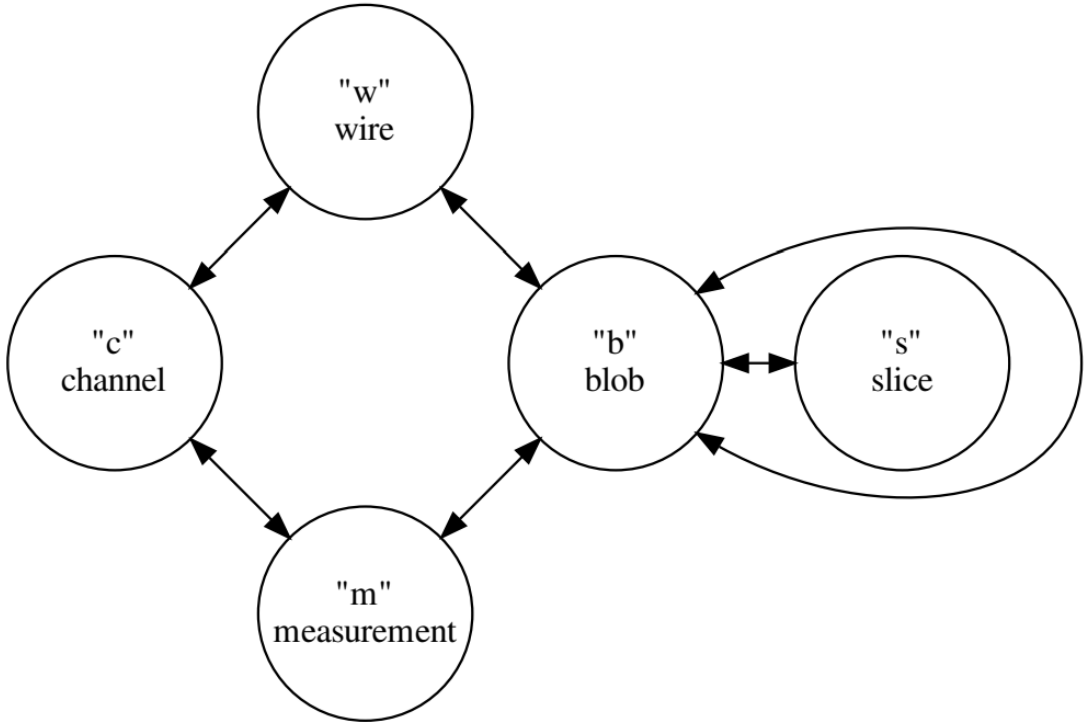
Points for BEE are randomly sampled from the reconstructed 3D ”blob”s





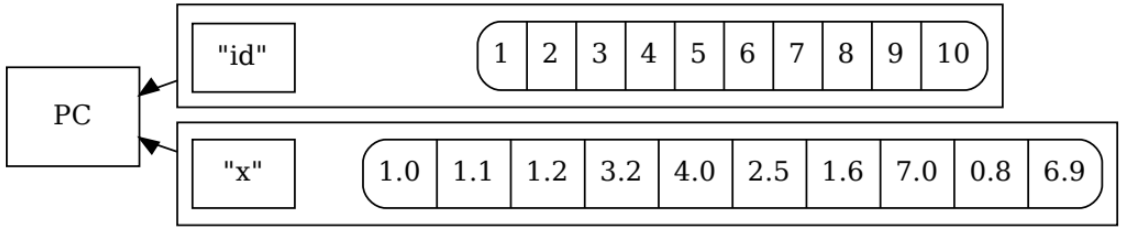
Current Wire-Cell interface objects

ICluster



- ICluster contains full SigProc waveforms and reconstructed 3D “blob”s and auxiliary information with minimum redundancy.
- PointCloud is based on WireCell::ITensor for persistency and can utilize KDTree for spacial information.

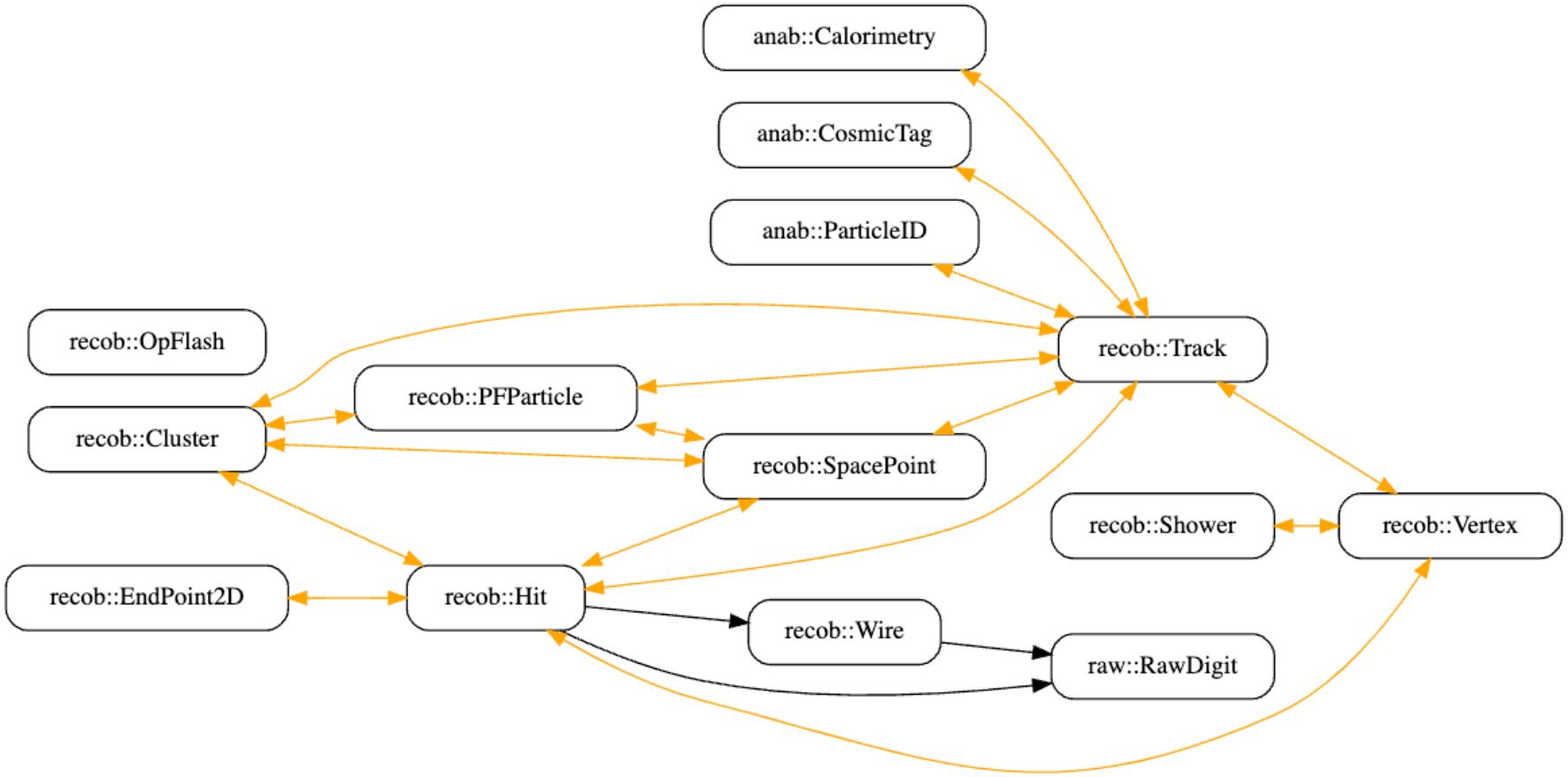
PointCloud



LArSoft data products

https://larsoft.github.io/LArSoftWiki/Data_products_architecture_and_design

https://nusoft.fnal.gov/larsoft/doxsvn/html/SpacePoint_8h_source.html



recob::SpacePoint	
int	fID
double[3]	fXYZ
double[6]	fErrXYZ
double	fChisq

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Summary and next

- All Wire-Cell 3D imaging functions from Prototype (used in uboone) are available in Wire-Cell Toolkit
  - can be configured for DUNE and other experiments
  - available in larsoft v09_80_00rc2, with larwirecell v09_80_00rc2 and wirecell v0_25_1.
- Can handle bridged geom
  - Current configuration is for bridged geom., which one should we use?
- Currently only standalone output for WireCell::ICluster. We are figuring out the proper data object in LArSoft.