# CIDeR-ML Workshop

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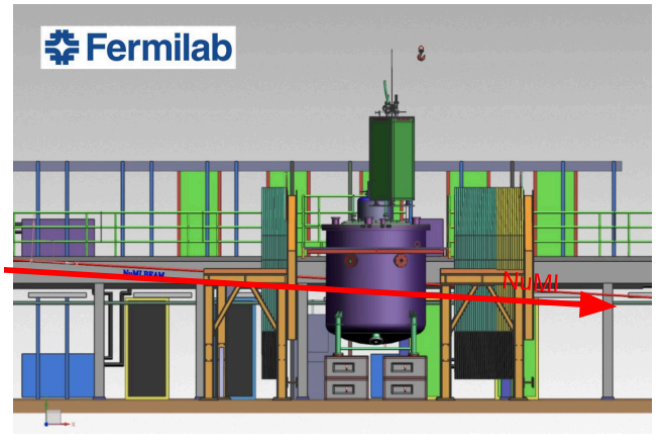
U.S. DEPARTMENT OF ENERGY | Stanford University

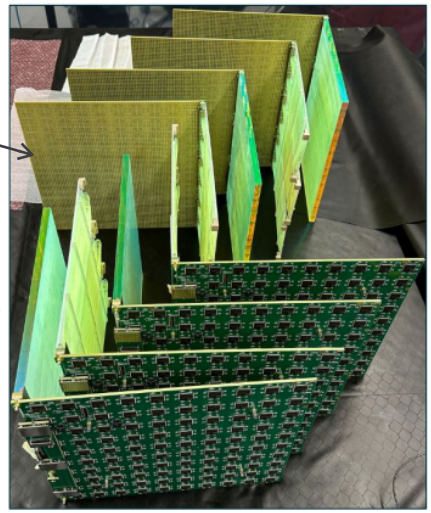
SLAC NATIONAL ACCELERATOR LABORATORY

# Introduction: ND-LAr 2x2

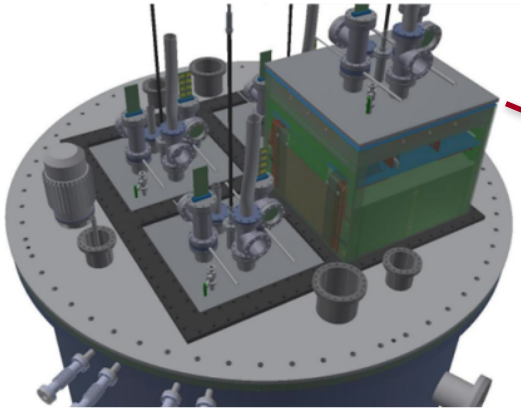
ND-LAr 2x2 at FNAL/NuMI



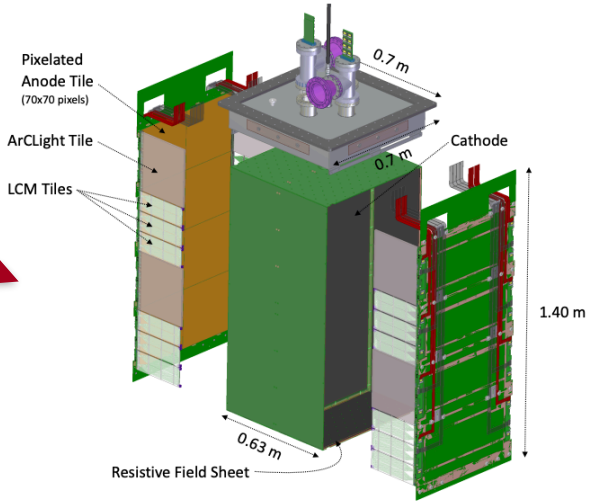

Tiles for Charge & Light Detection



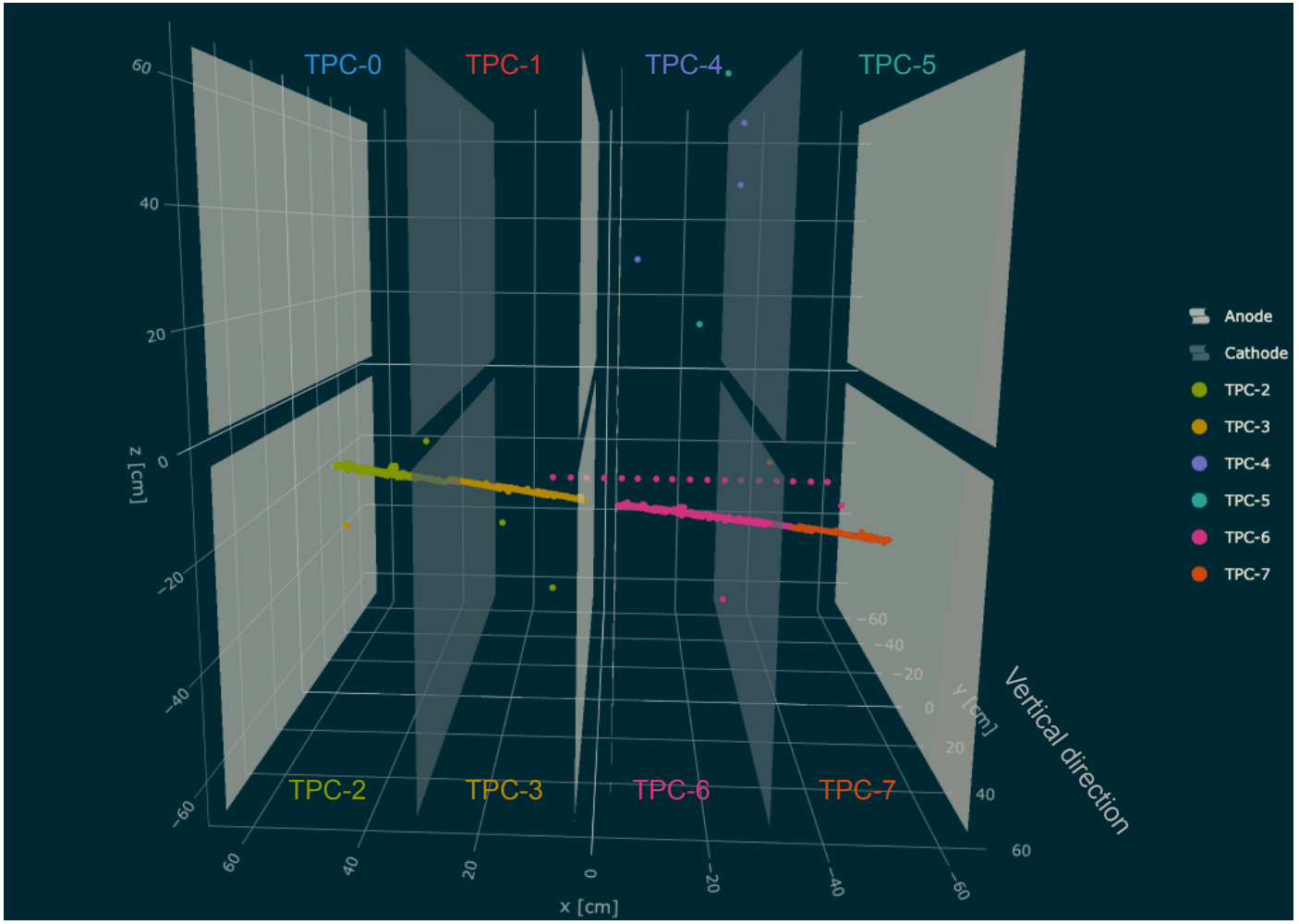

4 Modules



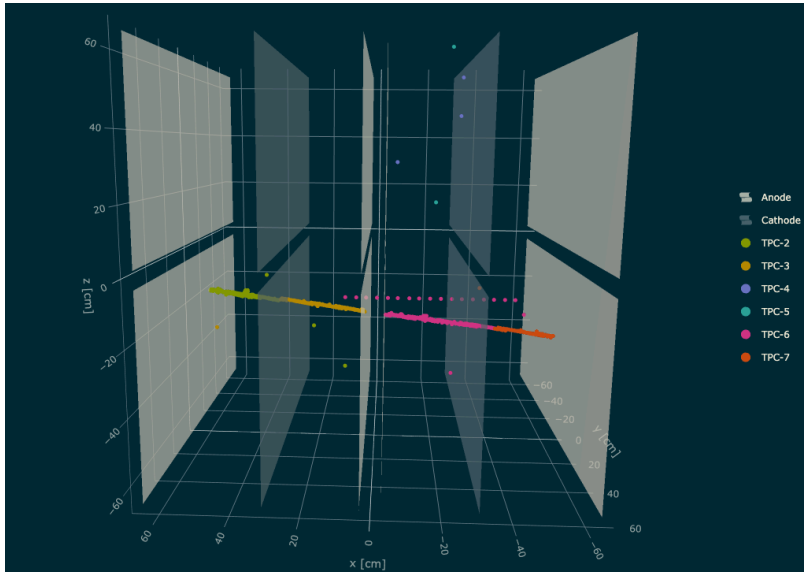
Breakdown of one module (2 TPCs)



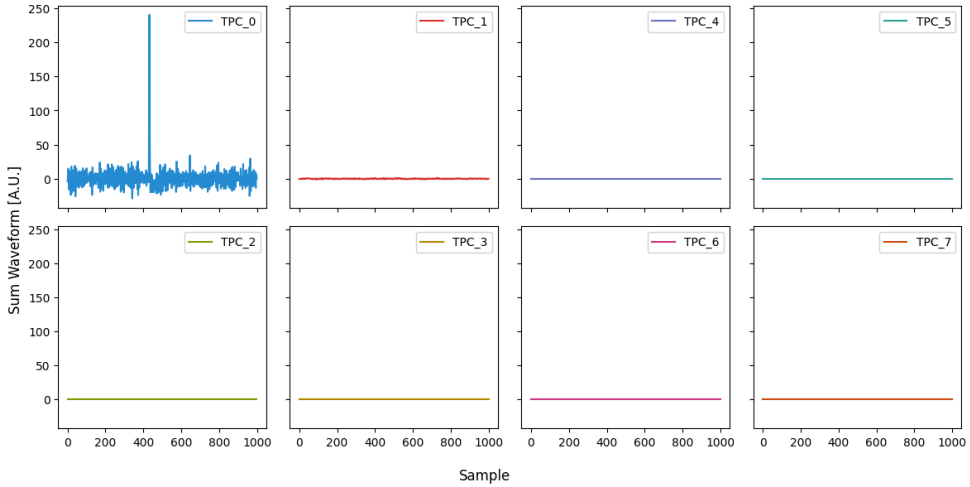
# Example: Non-Beam Event at 500 V/cm



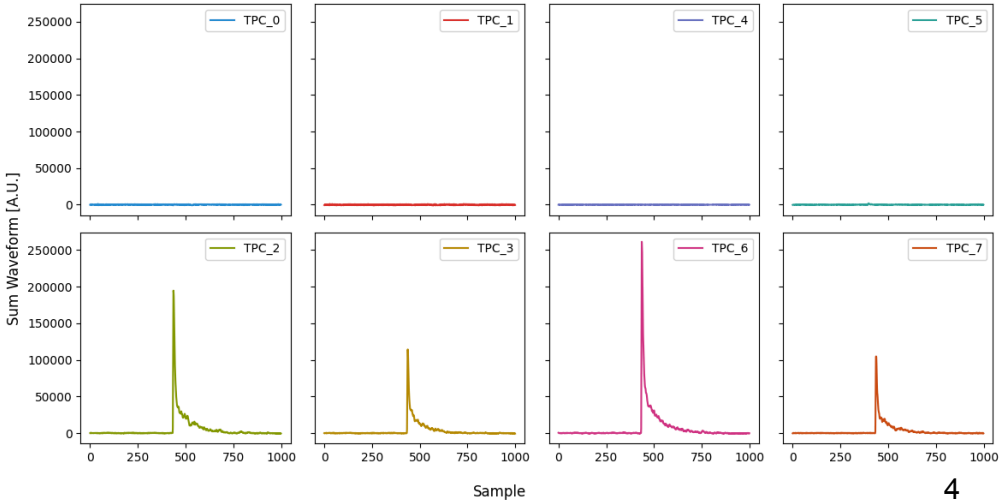
# Example: Charge-Light Trigger Matching



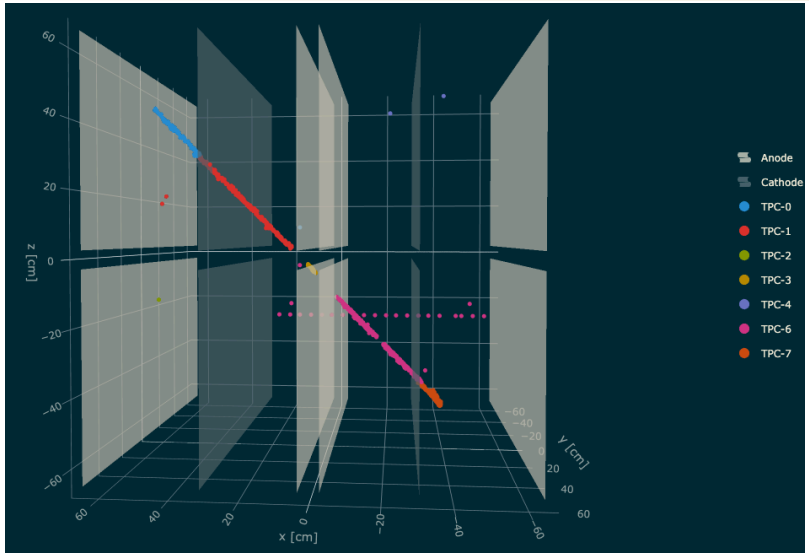

Default reco. w/ signal processing (NOT GOOD)

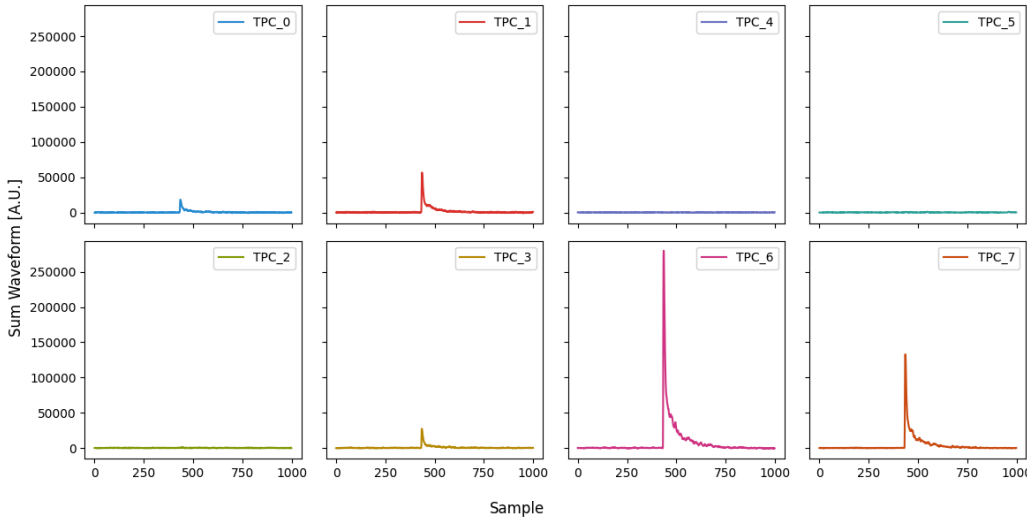


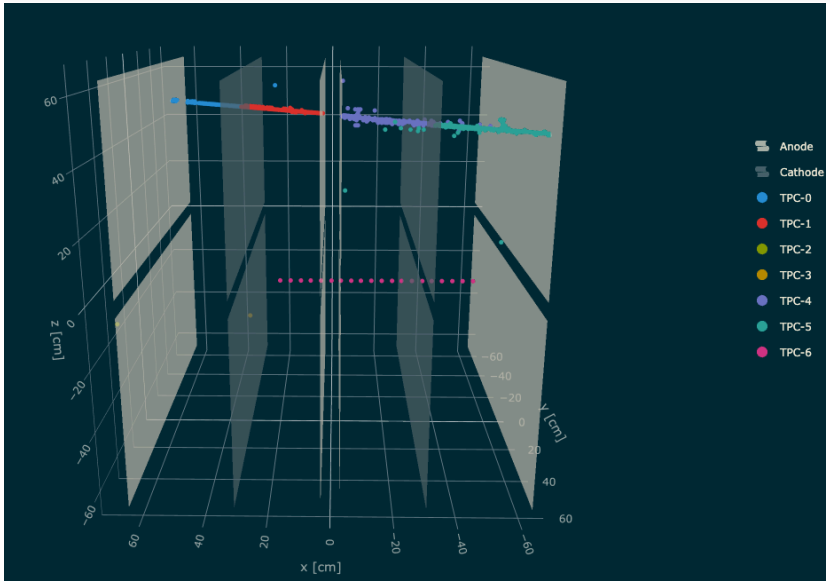

My educated guess using raw waveforms (OK?)

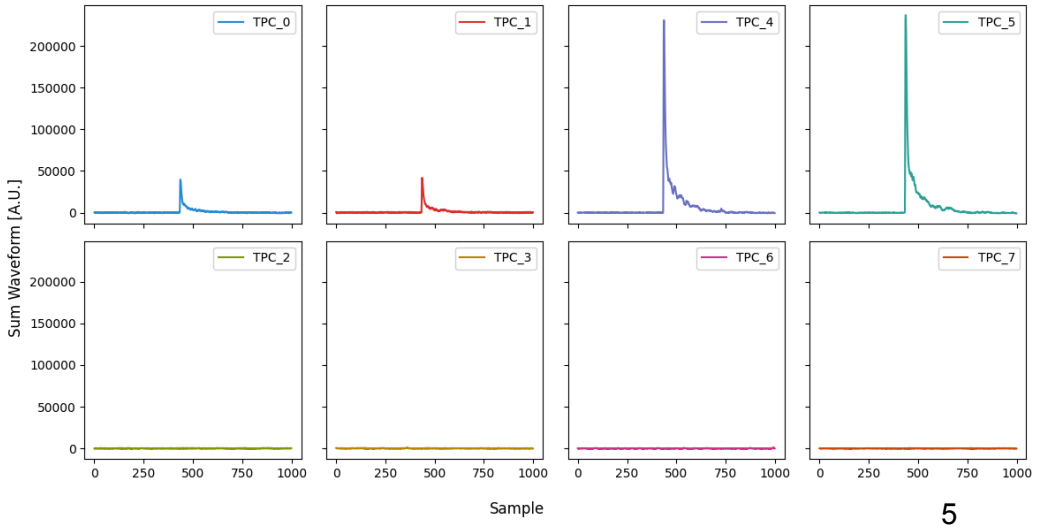


# More Example (My Guess Matching)

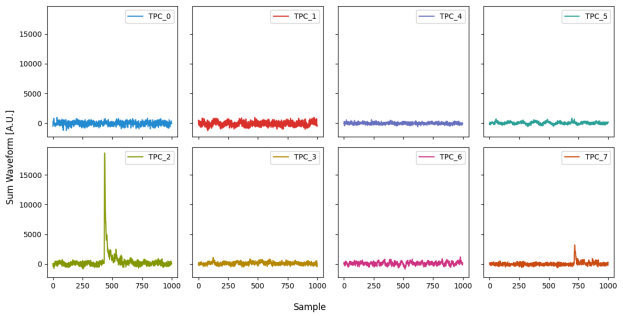


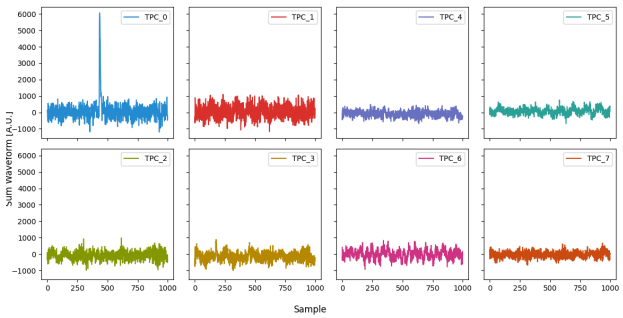



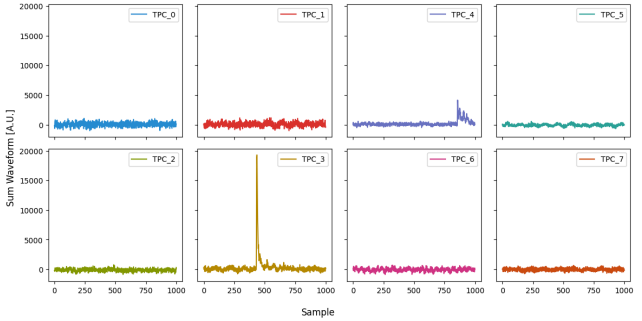



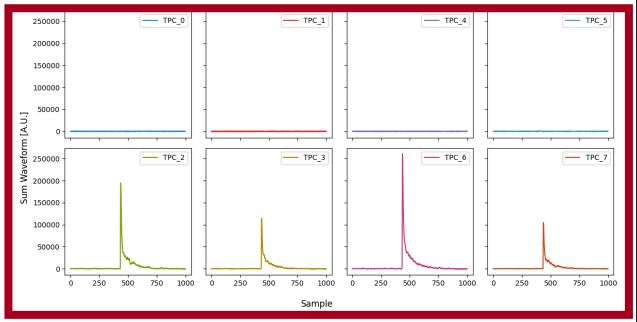



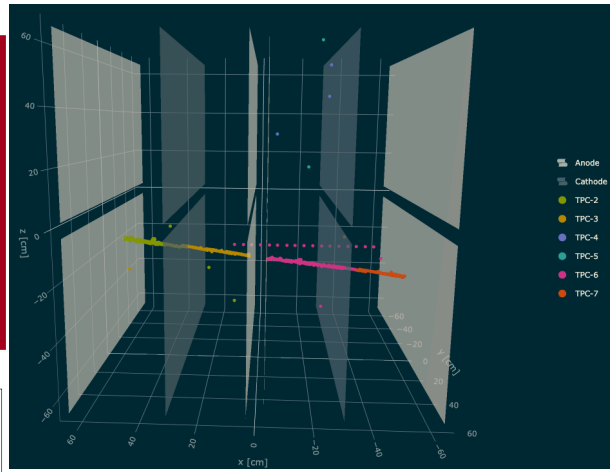
# Problem: Multiple Light Triggers

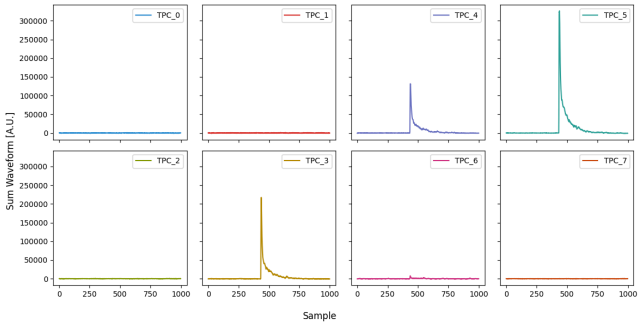


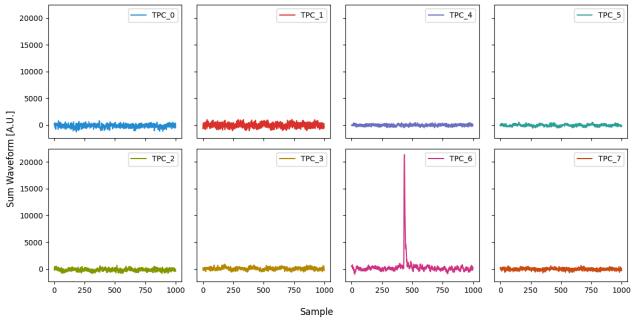



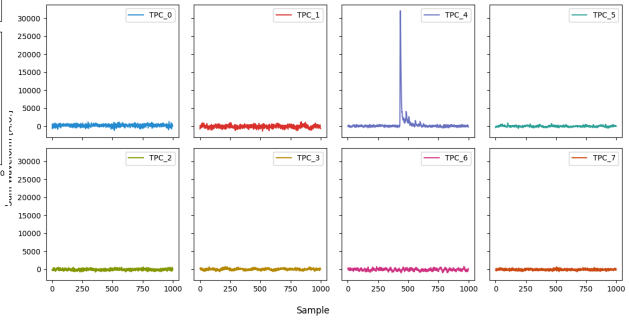



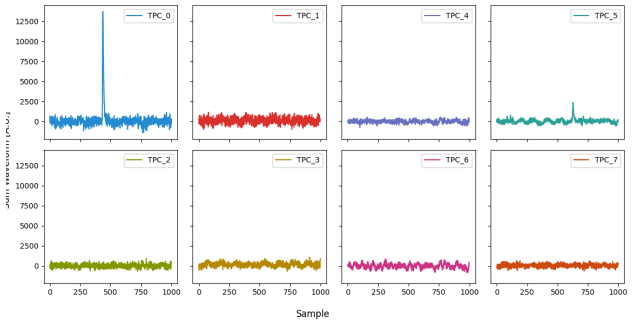



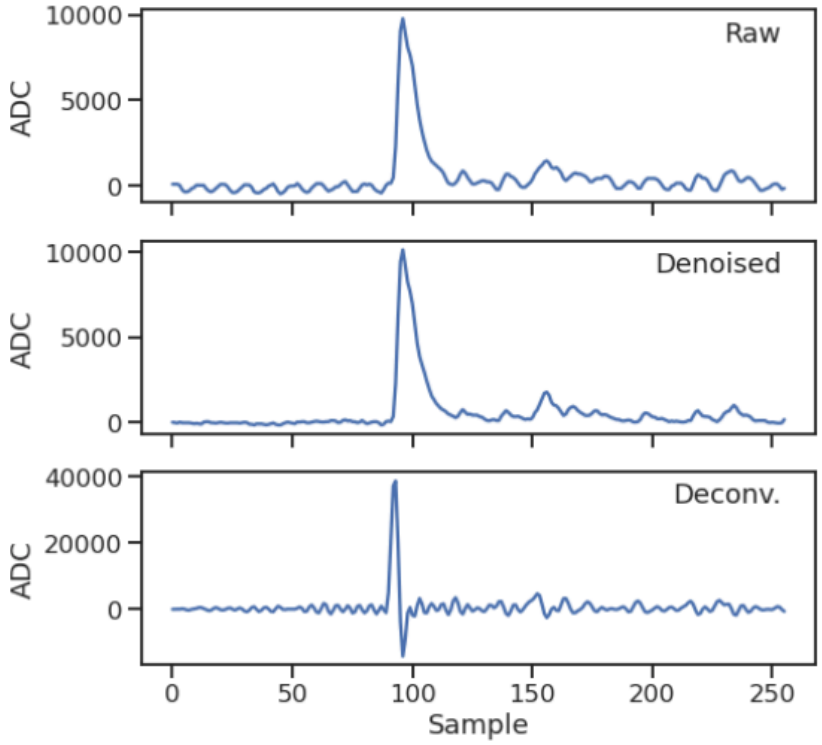



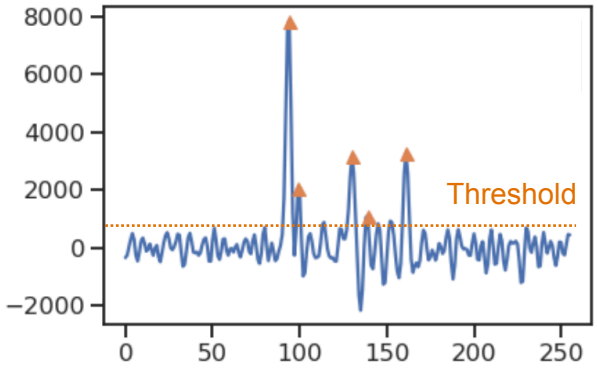



# Signal Processing

**Single Processing of SiPM Waveform**




**Peak Finding of SiPM Signal**



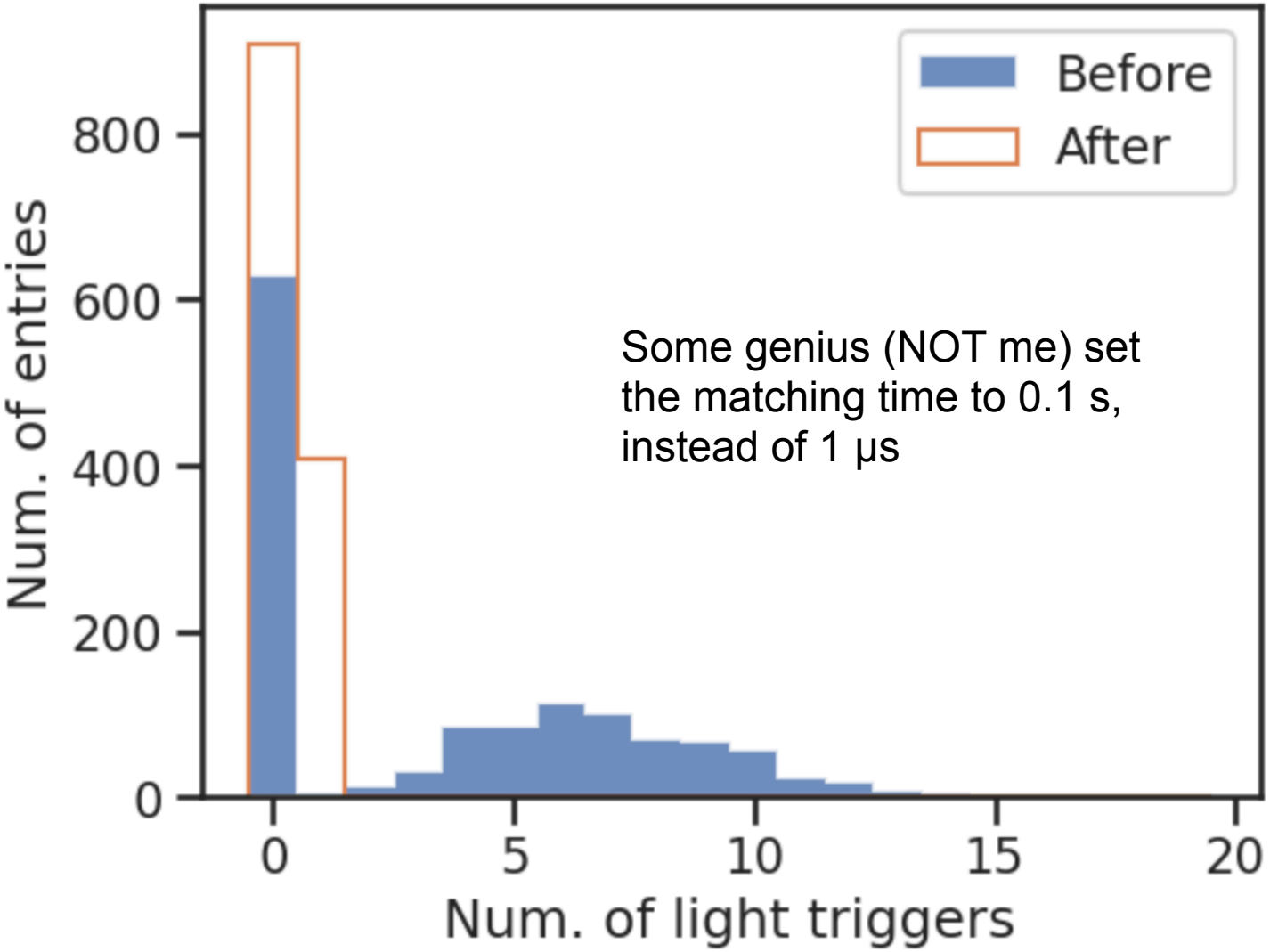

**Calibration ADC=>p.e.**

# Goals: 2x2 Data Preparation

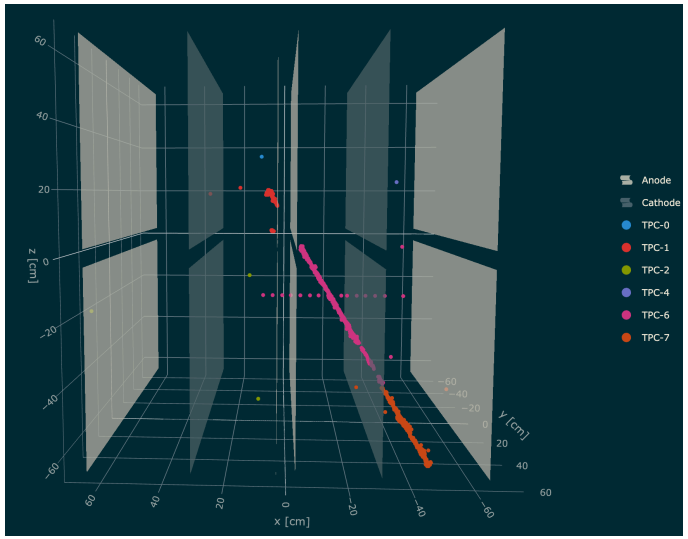
- ~~Check trigger matching [1 day]~~
  - ~~Reduce ambiguous triggers?~~
- ~~Validate channel mapping [0.5 - 1 day]~~
  - ~~Raw ADC (8x64) => TPC/SiPM (8x48)~~
  - ~~Cross-check w/ LUT (~close to data)~~
- Signal Processing [maybe? 1-2 days]
  - Noise filtering
  - Deconvolution
  - Hit finding (determine threshold)
  - Calibration ADC => p.e.
- ~~Event selection [1 day]~~
  - ~~Clean sample of isolated long track + light signal~~
- Gather above codes [1 day]
- Documentation [1 day]

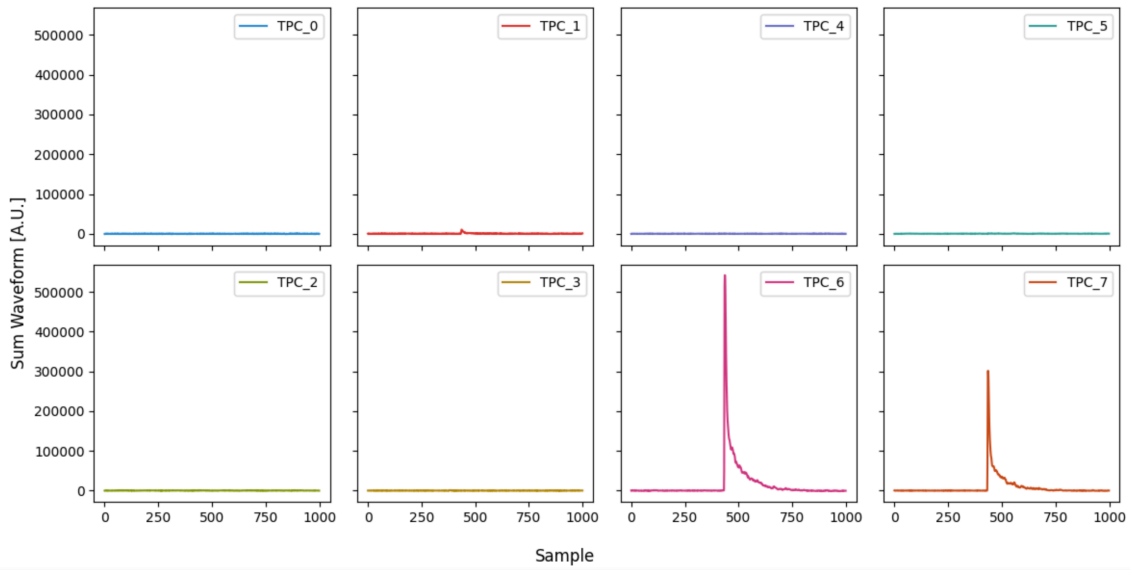
Prepare a workflow to process 2x2 data for SIREN track calibration.

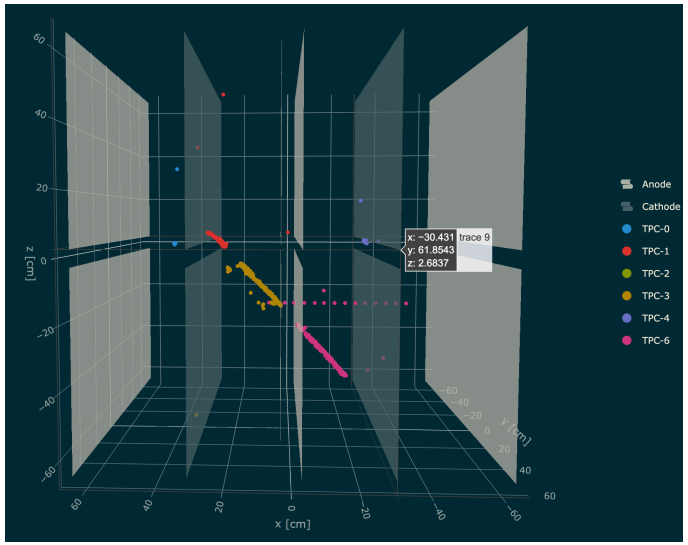
# FIXED: Trigger Matching

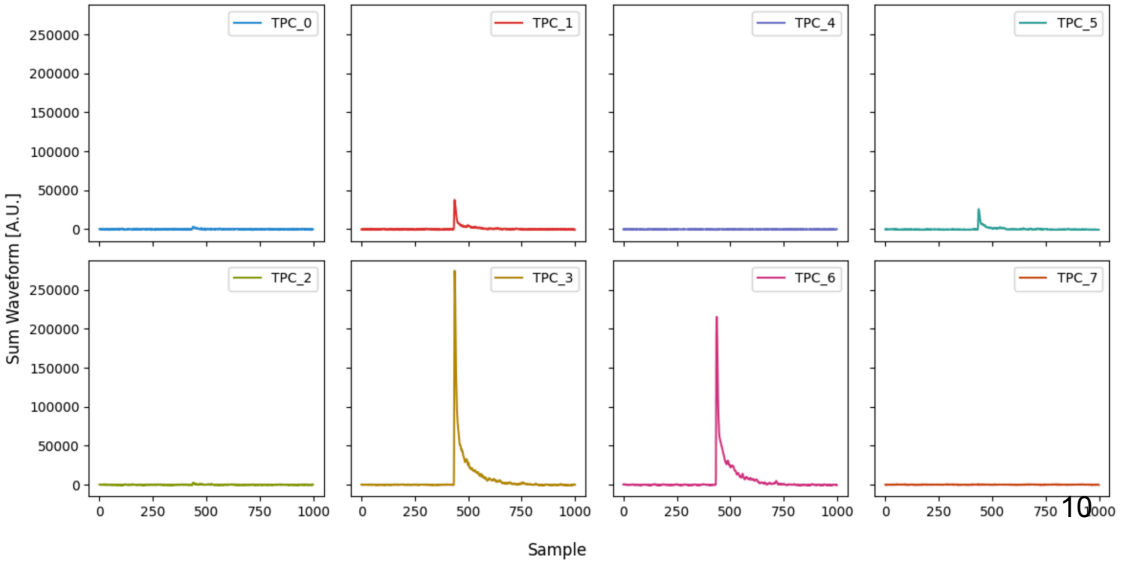


# FIXED: Examples

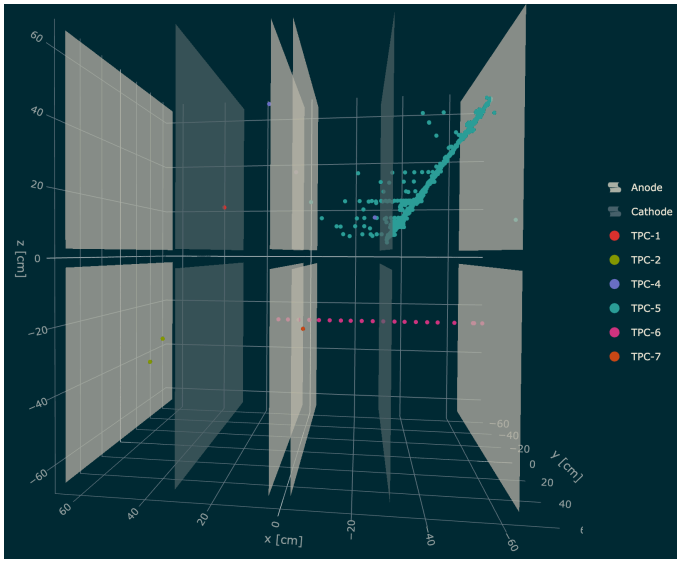


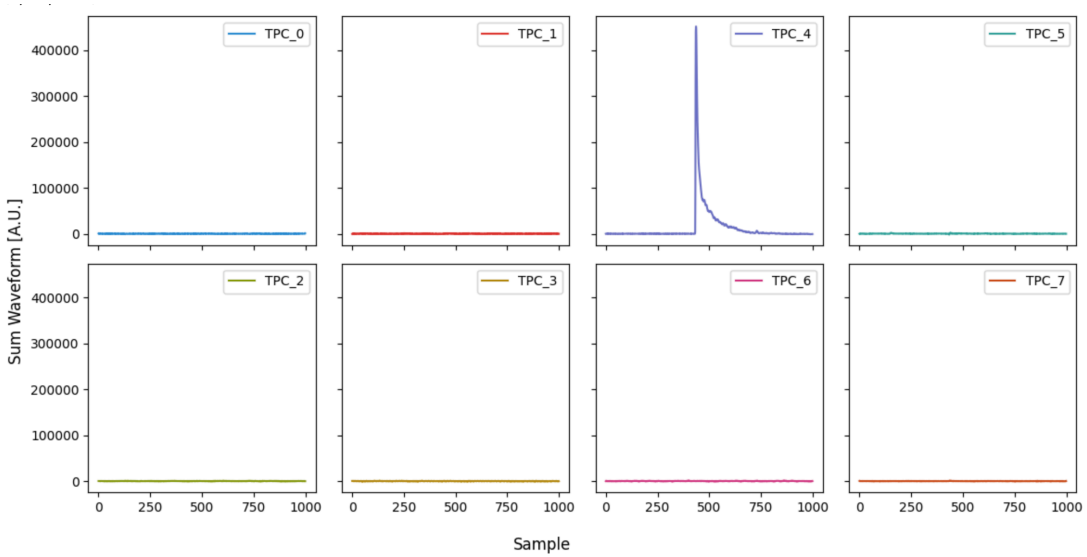



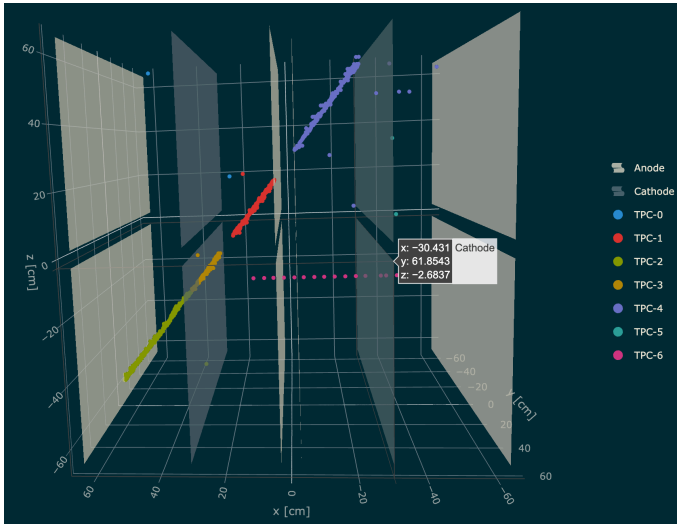



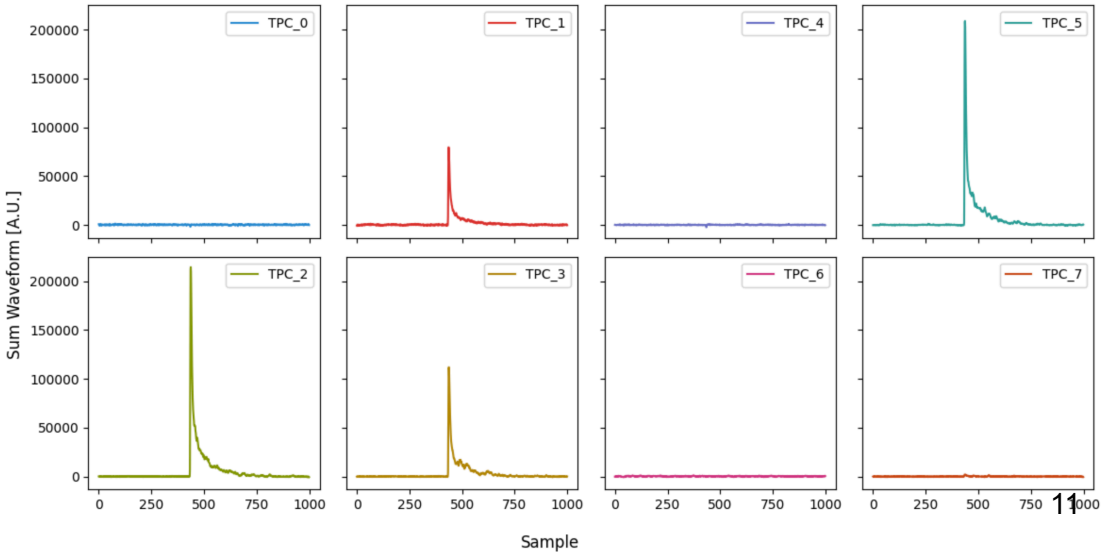



# Problem: Swapping of TPC 4 & 5 (for Light)

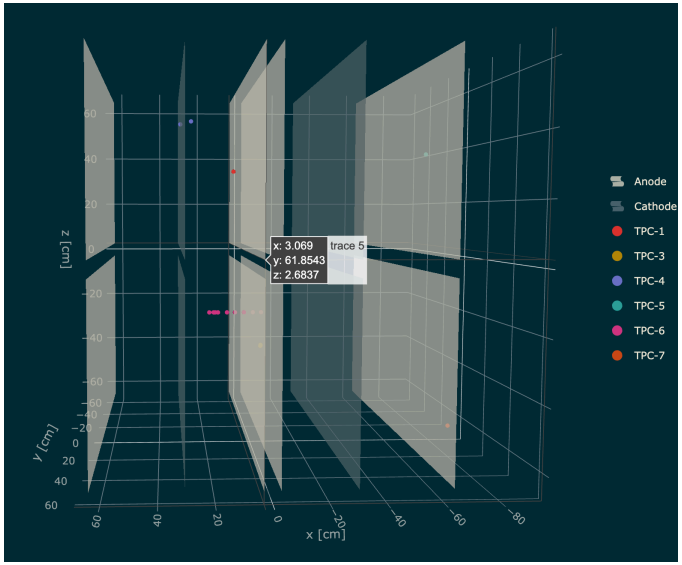


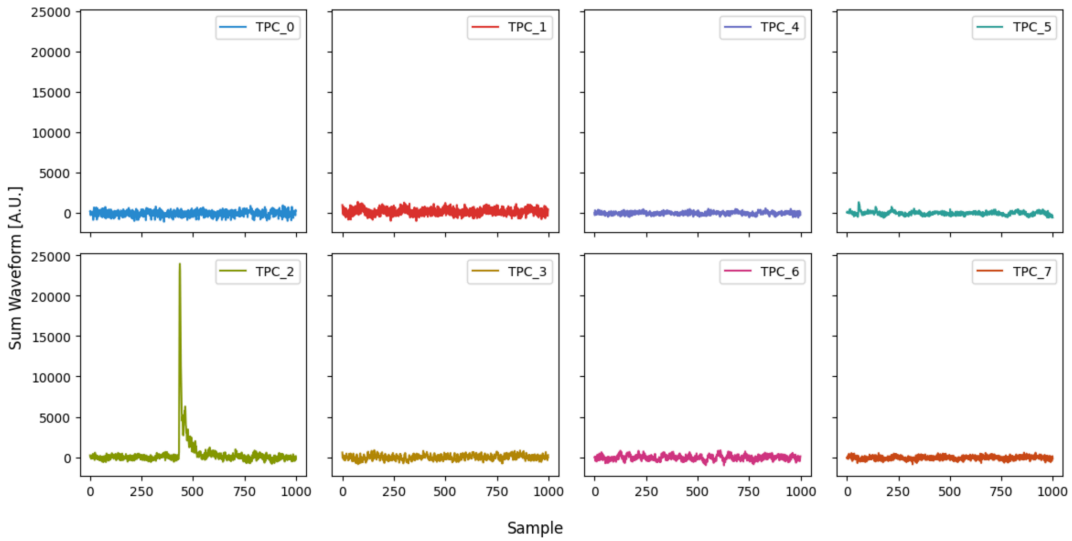



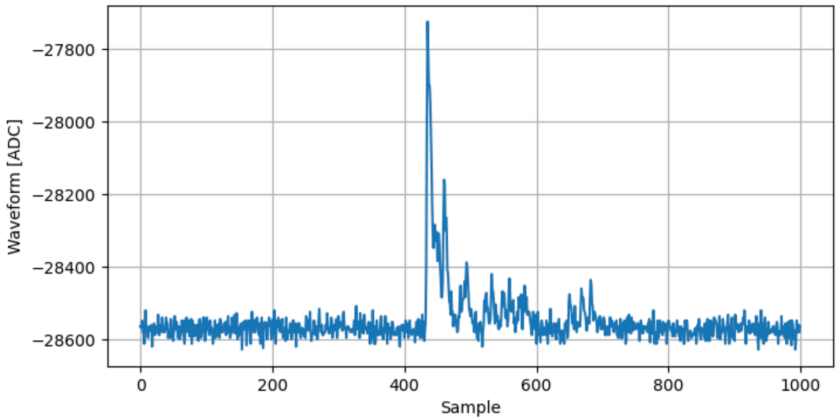



# Problem: Light Trigger but No Charge Activity

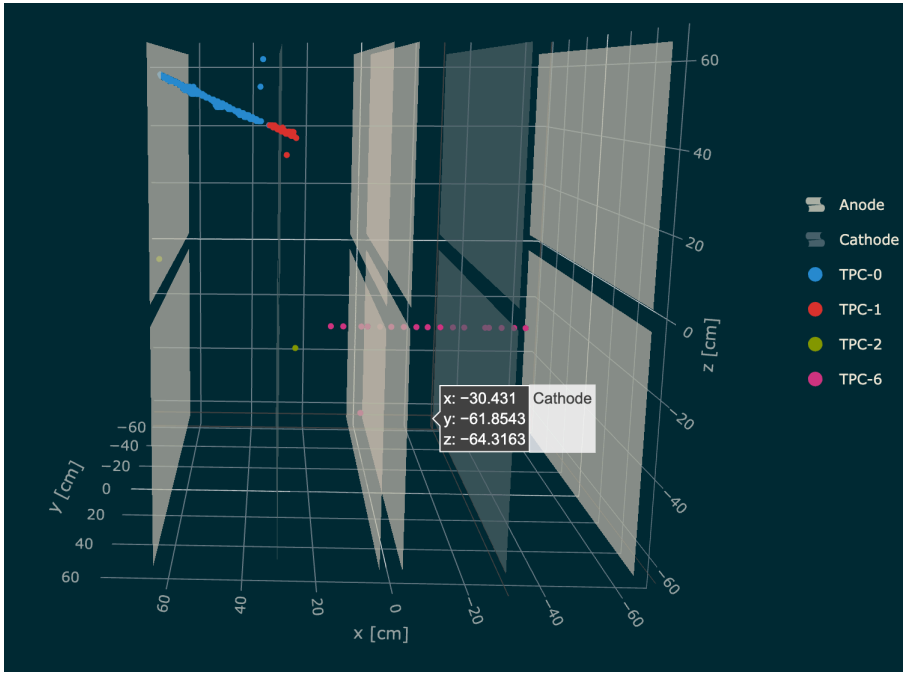


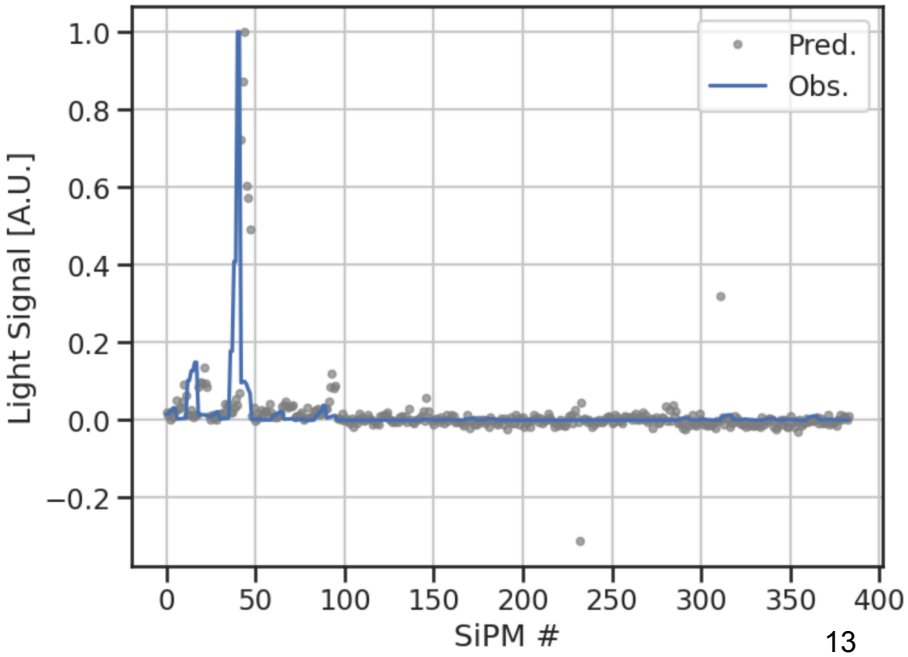



# Charge-to-Light Prediction

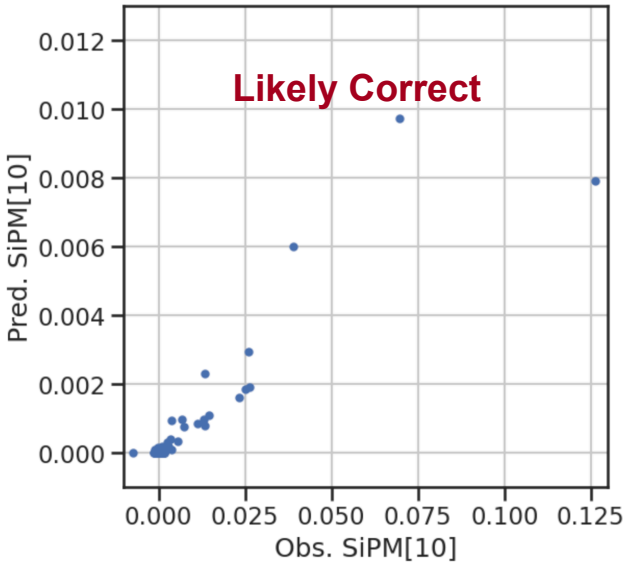


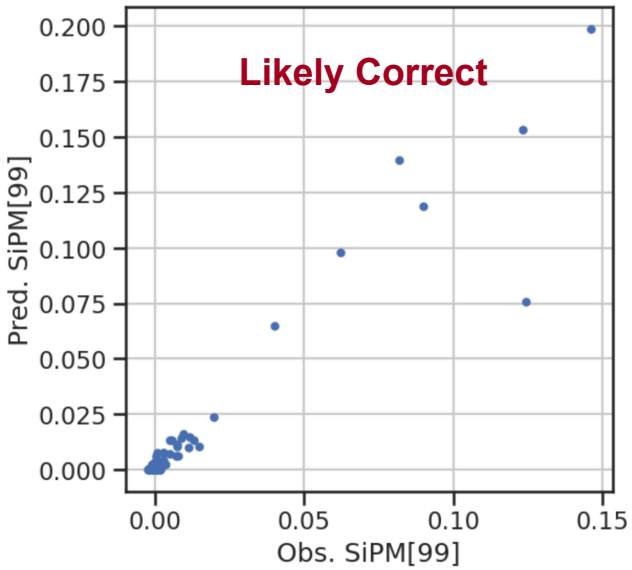

**Obs.:** Area of the waveform after pedestal subtraction
**Pred:** Prediction of light signal using charge image and visibility LUT

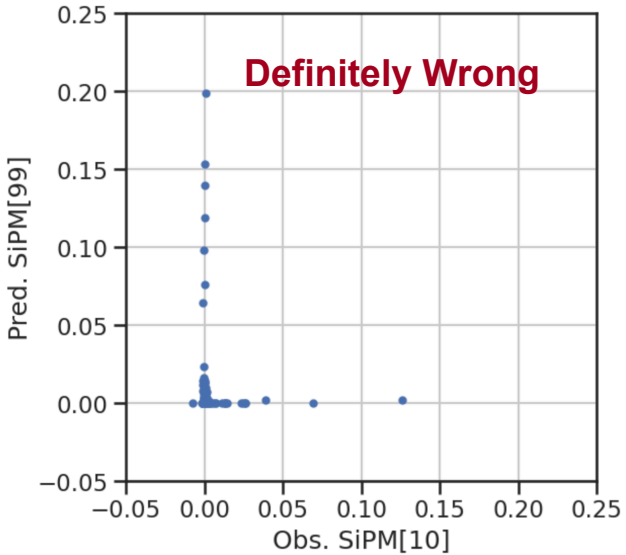


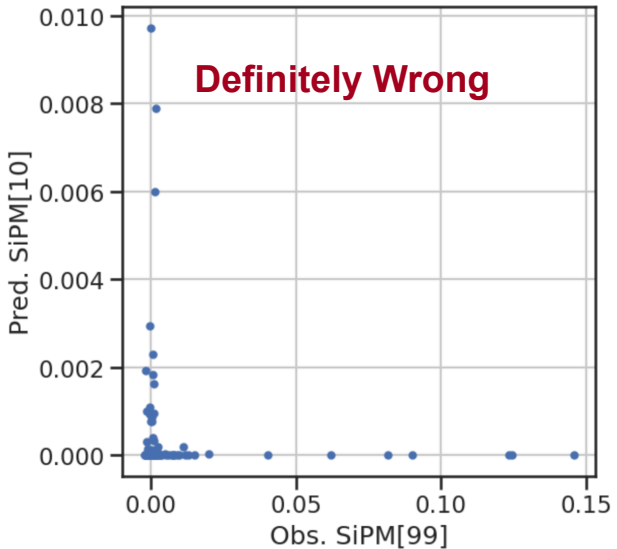



# Validation Channel Map w/ Correlation Plots

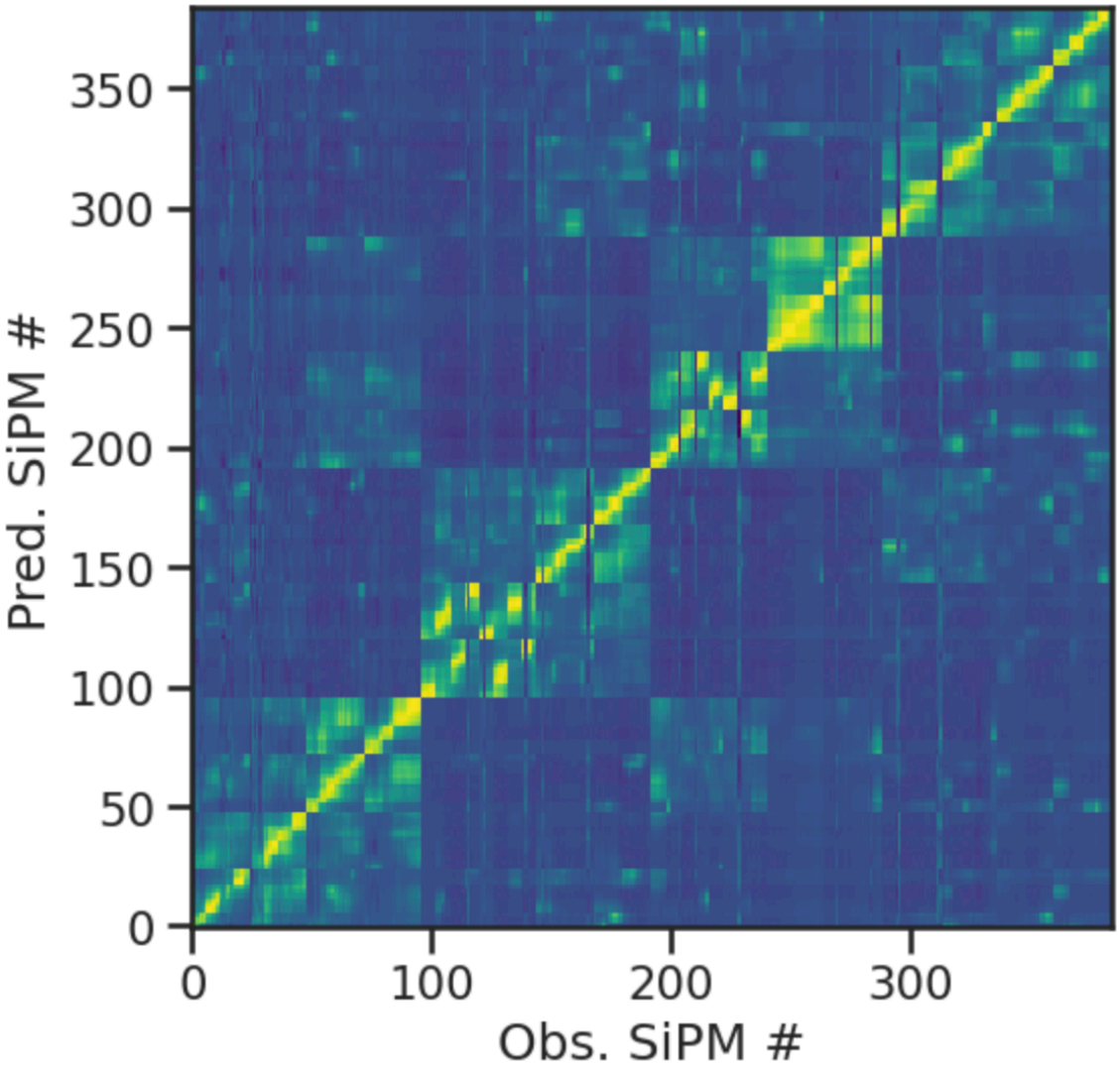


# Cross Correlation

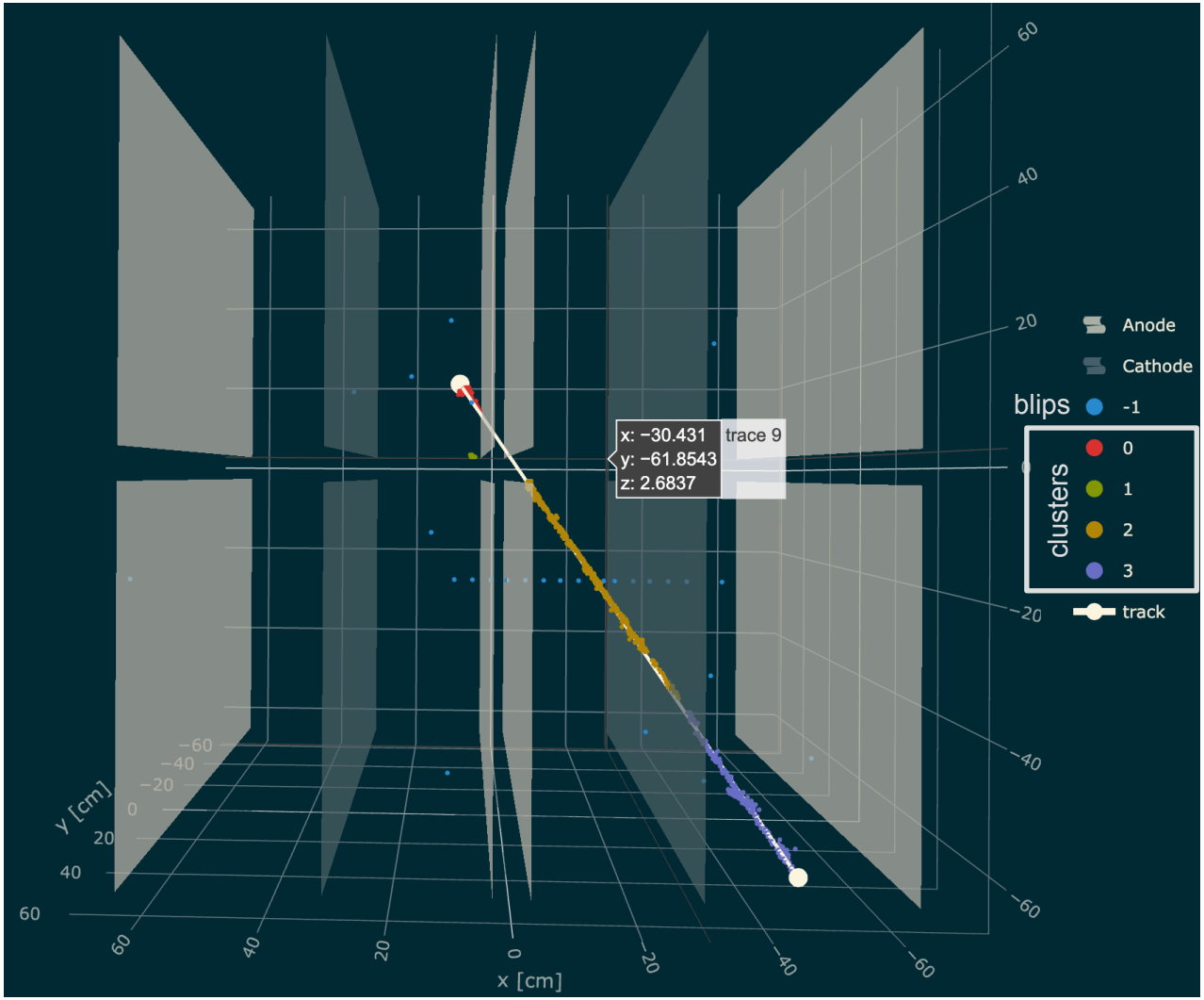



Ideally we expect high correlation on the diagonal if the channel map matched to the LUT.

Sometimes it's difficult to differential SiPMs in the same optical module (group of every 6 SiPMs), in particular adjacent pair, 2n v.s. 2n+1

Definitely some parts are INCORRECT.

# Event Selection



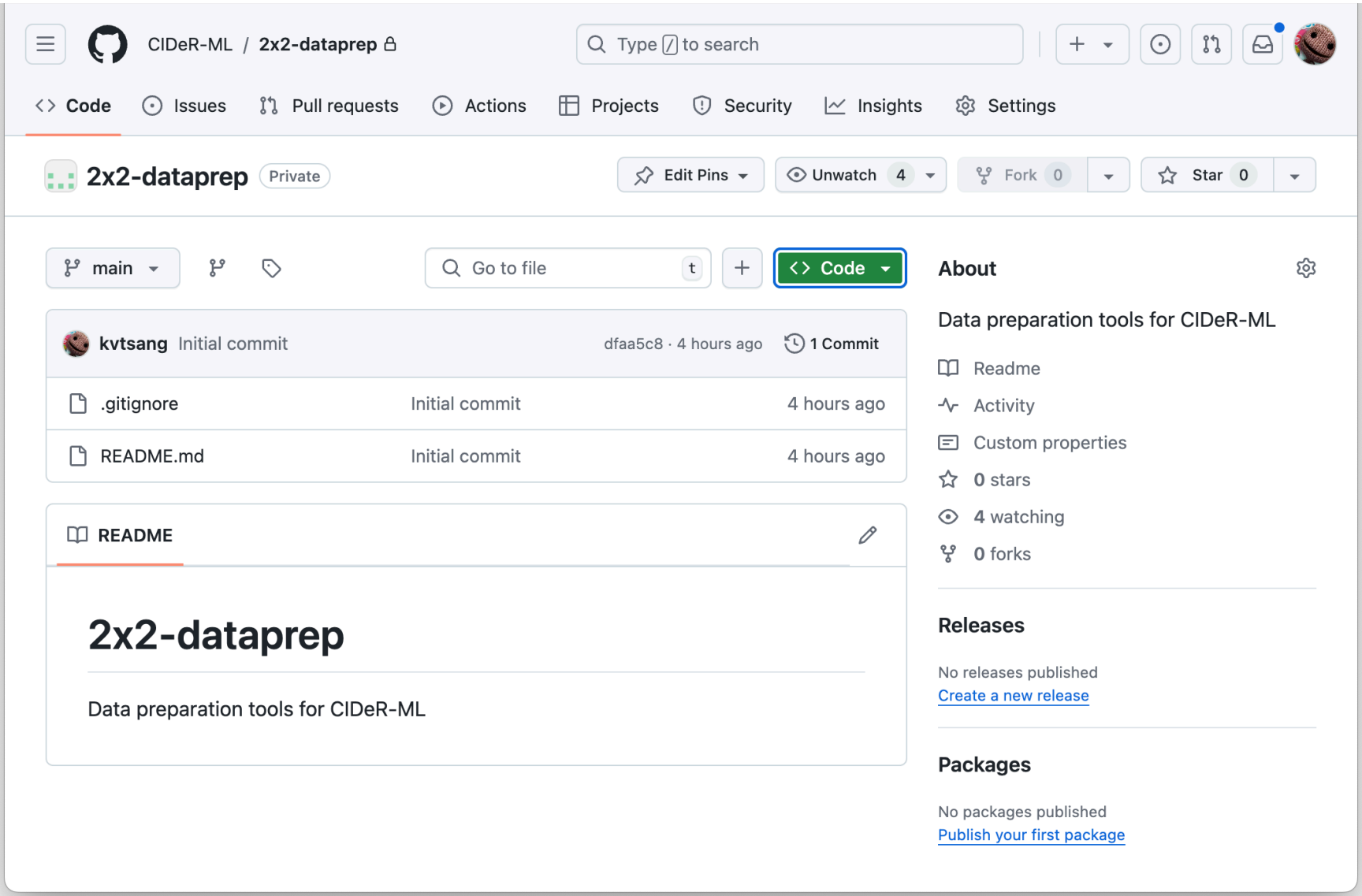

- Align each TPC w/ trigger time (T0)
- Run dbscan on charge image (min_samples=5, eps 2.5=cm)
- Remove small blips
- Fit the big clusters with a straight line and locate end points
- Possible to cut on goodness-of-fit to remove non-track like events (shower, multiple objects …)

# Current Status (Aug 7)

- One-to-one matching for charge and light event
- T0 correction based on trigger time
- Raw waveform processing
- SiPM channel maps
    - No show stopper as long as we pick all active channels
- [Nice to have] Light signal process
    - Noise filtering on baseline
    - Gain calibration table, ADC => p.e.
    - Workable in ADC unit
- Crossing track selection

Next Task: Gather all above code pieces and form a data processing workflow

# Work in Progress …



# Un-Flow 2x2 Data File

**Matched Charge-Light events in plain HDF5 format**

```
(nersc-flow) login27:2x2_beam$ h5ls -r test.h5
/                        Group
/qpts                    Dataset {90052/Inf, 4}
/qpts__idx               Dataset {148/Inf}
/sum_adc                 Dataset {147/Inf, 384}
/sum_adc__idx            Dataset {148/Inf}
/tpcs                    Dataset {90052/Inf}
/tpcs__idx               Dataset {148/Inf}
/wvfm                    Dataset {147/Inf, 8, 64, 1000}
/wvfm__idx               Dataset {148/Inf}
```

**Charge dataset: qpts**

```
qpts__idx[:8]
```

ev 1

```
array([   0,  232,  483, 1012, 1909, 3042, 3333, 4047], dtype=uint64)
```

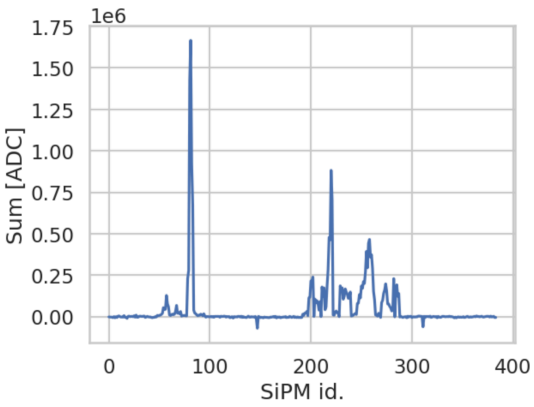
ev 0 ev 2

```
qpts
```

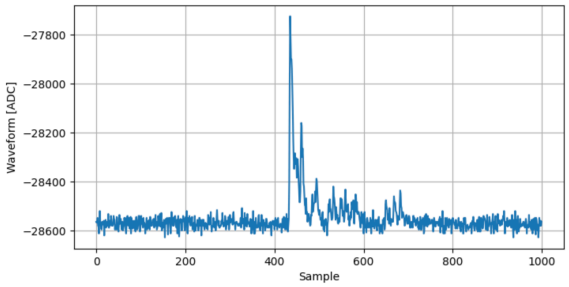
X Y Z Q

```
array([[ 10.149627 , -39.2409   , -25.2971   ,   7.5200195],
       [ 44.757607 , -46.7787   ,  23.0801   ,  12.841797 ],
       [ 35.609932 , -49.8825   ,  19.0895   ,   5.391309 ],
       ...,
       [-39.569134 ,  51.40669  ,  20.890812 ,  20.292286 ],
       [-29.873438 ,  39.767437 ,   8.475613 ,   9.64873  ],
       [-33.433525 ,  40.931362 ,   9.639538 ,  10.713086 ]],
      dtype=float32)
```

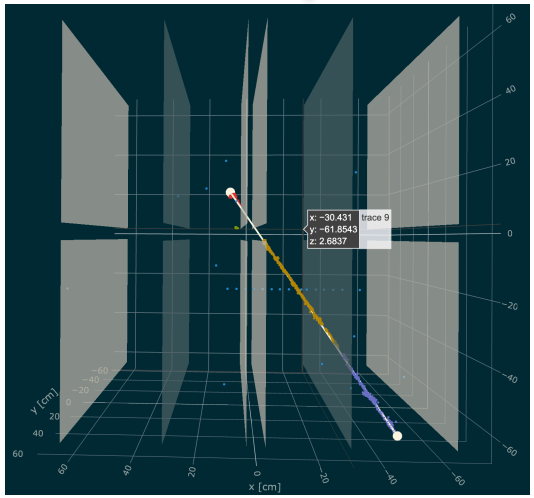
**Light Signal** (w/ channel map)
Baseline subtracted, sum area




**Raw waveform** (no channel map)




1-to-1 matching



# Goals: 2x2 Data Preparation
# At the end of the workshop

SLAC

- ~~Check trigger matching [1 day]~~
  - ~~Reduce ambiguous triggers?~~
- ~~Validate channel mapping [0.5 - 1 day]~~
  - ~~Raw ADC (8x64) => TPC/SiPM (8x48)~~
  - ~~Cross-check w/ LUT (~close to data)~~
- Signal Processing [maybe? 1-2 days]
  - Noise filtering
  - Deconvolution
  - Hit finding (determine threshold)
  - Calibration ADC => p.e.
- ~~Event selection [1 day]~~
  - ~~Clean sample of isolated long track + light signal~~
- ~~Gather above codes [1 day]~~
- Documentation [1 day]

Prepare a workflow to process 2x2 data for SIREN track calibration.