ProtoDUNE neutron source hits

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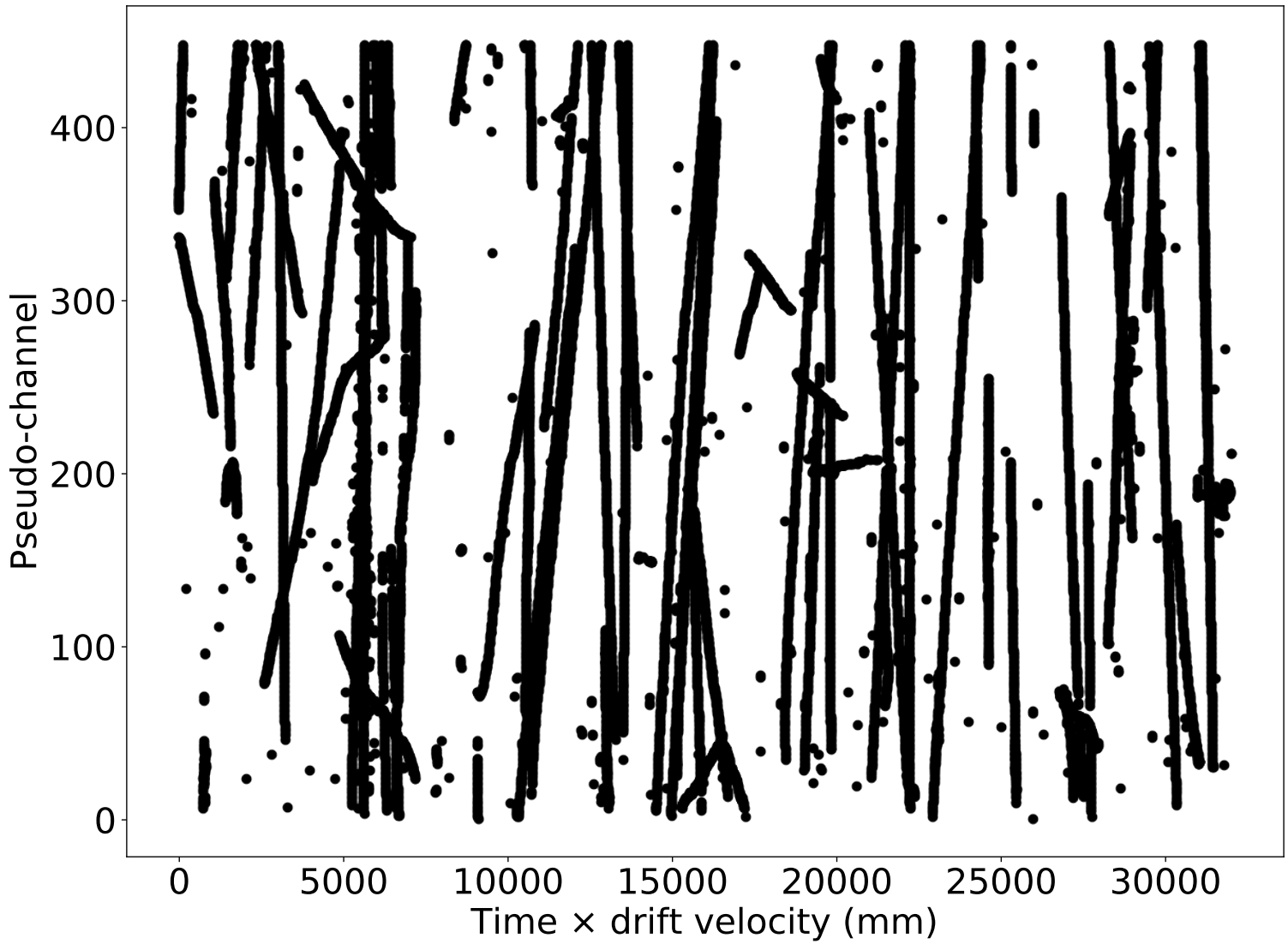
Introduction

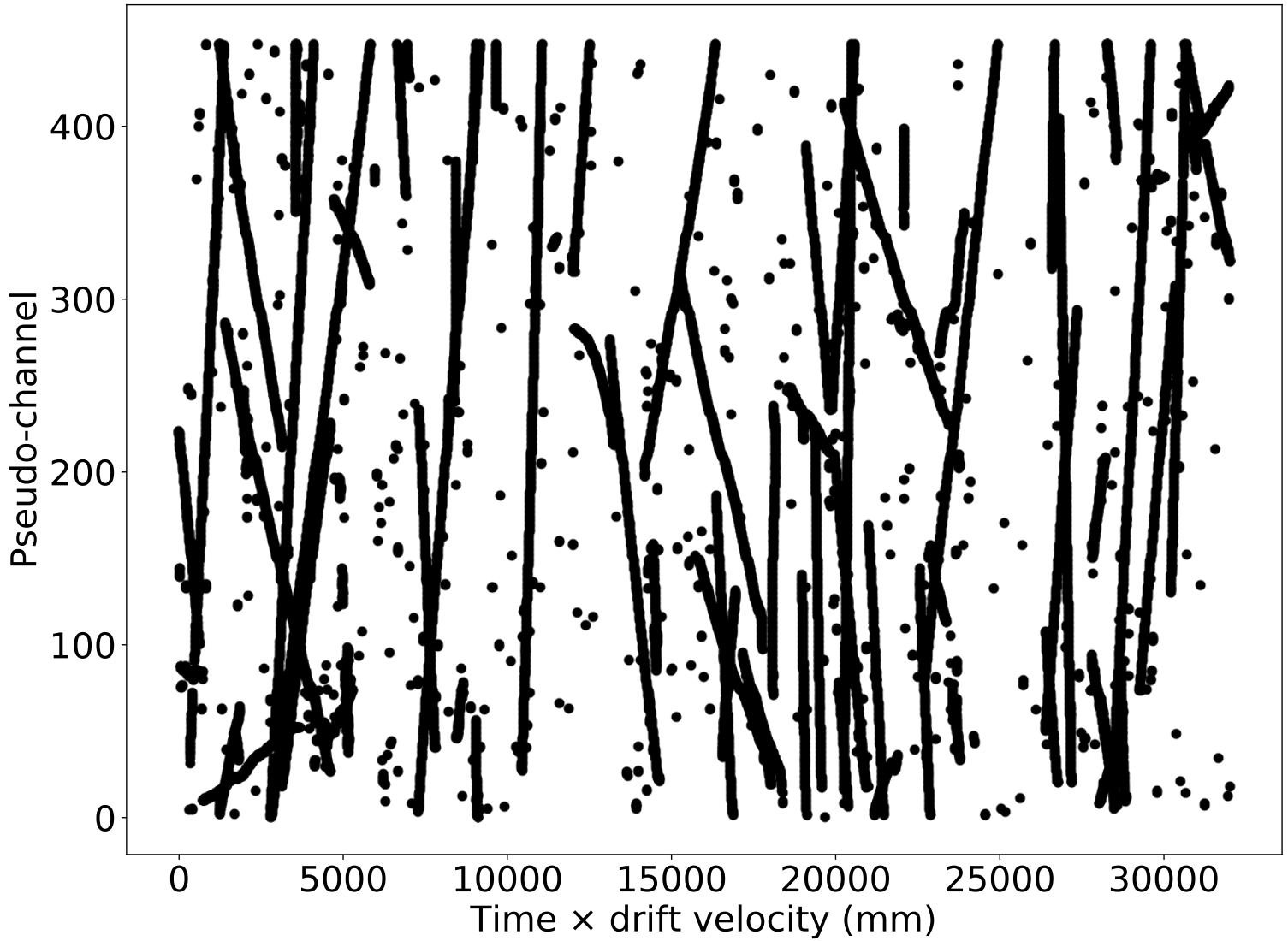
- Want to know if there's evidence of neutron-induced hits when the neutron source is on
- CPU-based hit finding finds hits *continuously* on collection channels. Giovanna saved hits from neutron source on/off periods on July 9/10 in APA 5; from APA 1 on July 14
- Overall hit rate APA 5 increases by $\sim 7\%$ when neutron source on
- Neutrons should leave small clusters compared to tracks, so we might be able to get a clearer signal with some simple reconstruction
- (I uploaded an earlier version of these slides to the elog. Since then I've added the APA 1 run and updated the drift velocity from $1\,\mathrm{mm}/\mu\mathrm{s}$ to $1.6\,\mathrm{mm}/\mu\mathrm{s}$. This slightly changes the plots but doesn't change conclusions)

Event display APA 5. Neutron source off



- Hits for 20ms. Neutron source off

Event display APA 5. Neutron source on

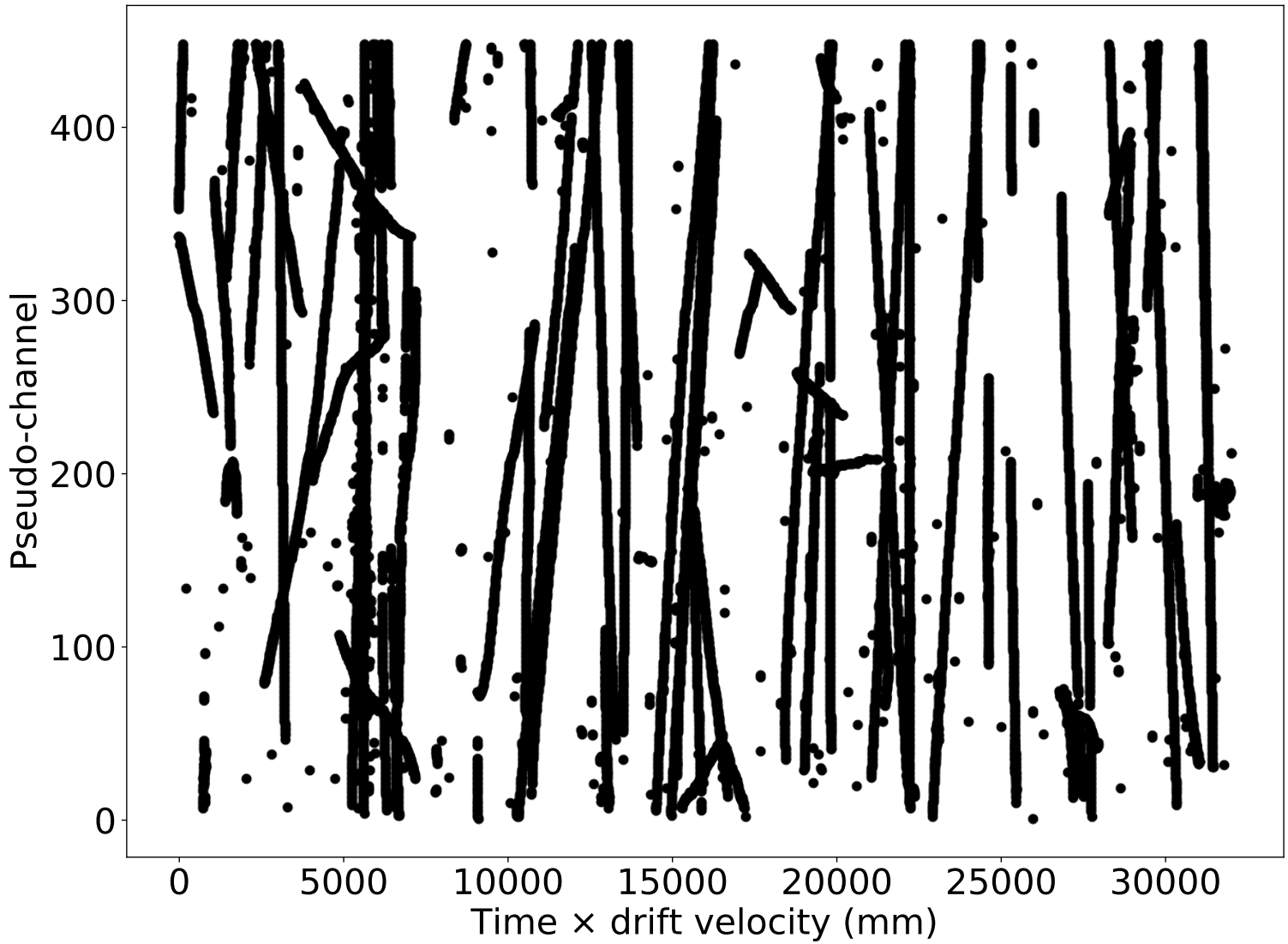


- Hits for 20ms. Neutron source on. Rate of small clusters looks higher, by eye

Simple track reconstruction

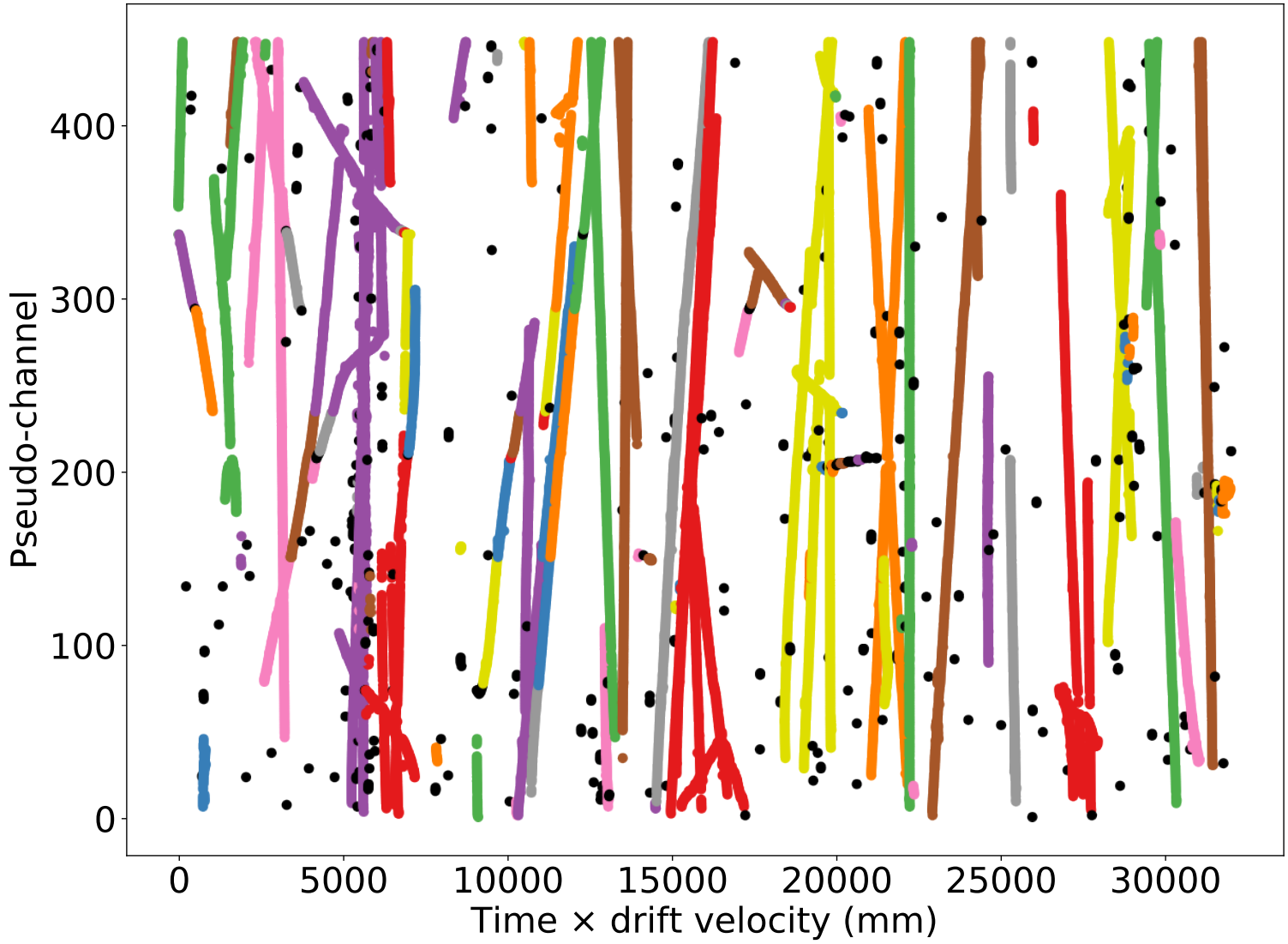
- We want to identify the small clusters that could be neutrons (or EM spray from muon tracks). Easier to identify the hits on tracks, and "neutrons" are everything else
- Use the clustering algorithm DBSCAN to find clusters of hits (corresponding to tracks). DBSCAN will leave some hits unclustered: these are the ones we care about
- DBSCAN is a terrible tracking algorithm (as you'll see), but all we care about here is identifying hits on tracks, not any track properties. And there's a python DBSCAN implementation available in `scikit-learn`, so it was easy to use it

DBSCAN example. APA 5. Neutron source off



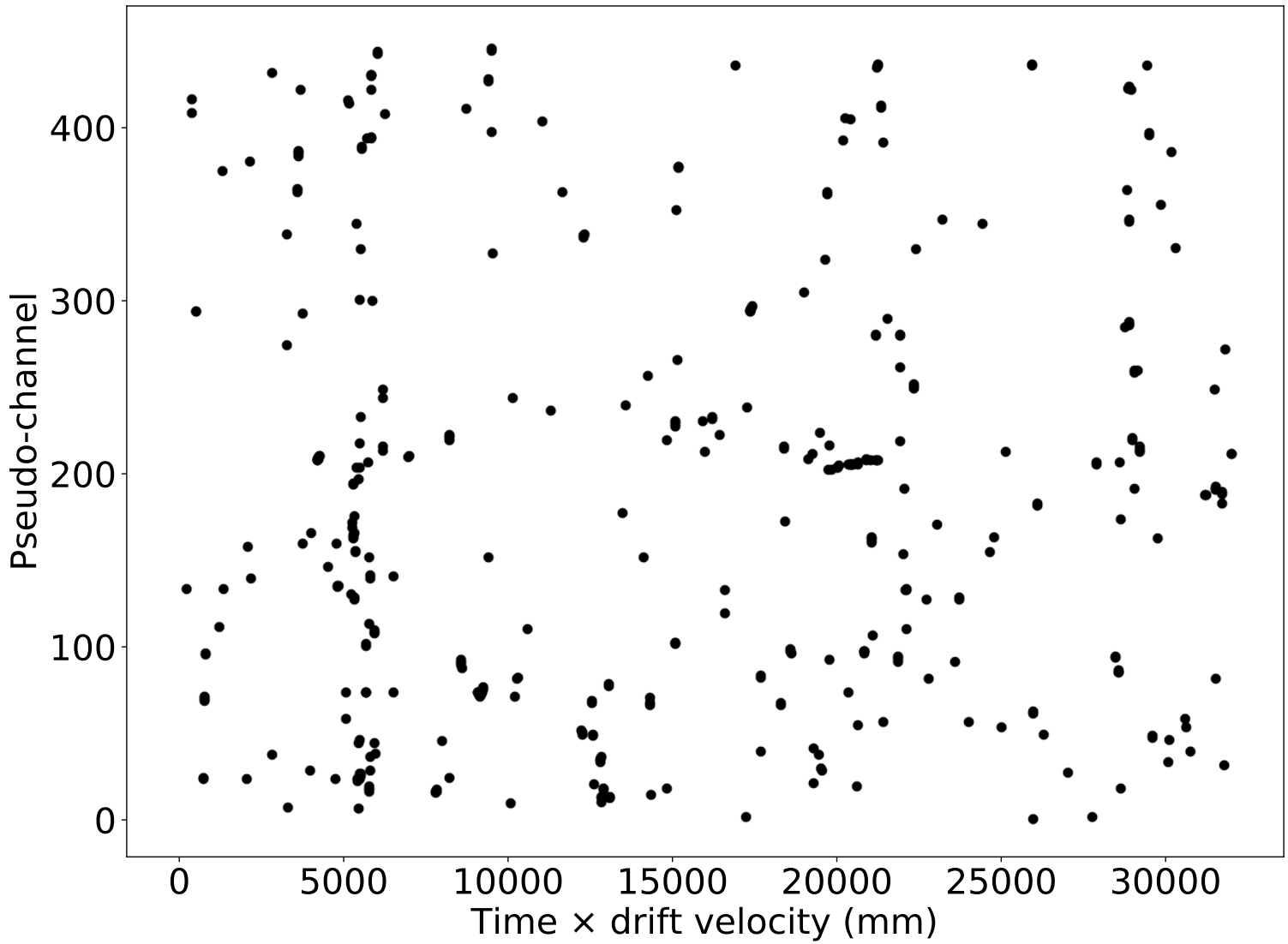
- Same event as above, before DBSCAN

DBSCAN example. APA 5. Neutron source off



- Hits are coloured according to their cluster. Unclustered hits are in black

DBSCAN example. APA 5. Neutron source off



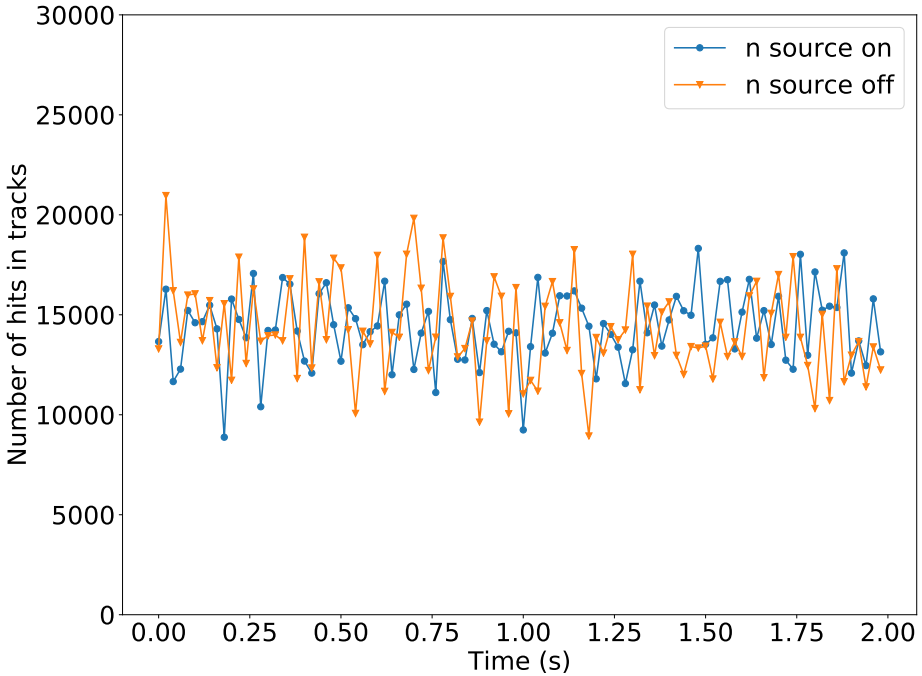
- Just the unclustered hits (ie, neutron candidates). A few more examples are in the backups

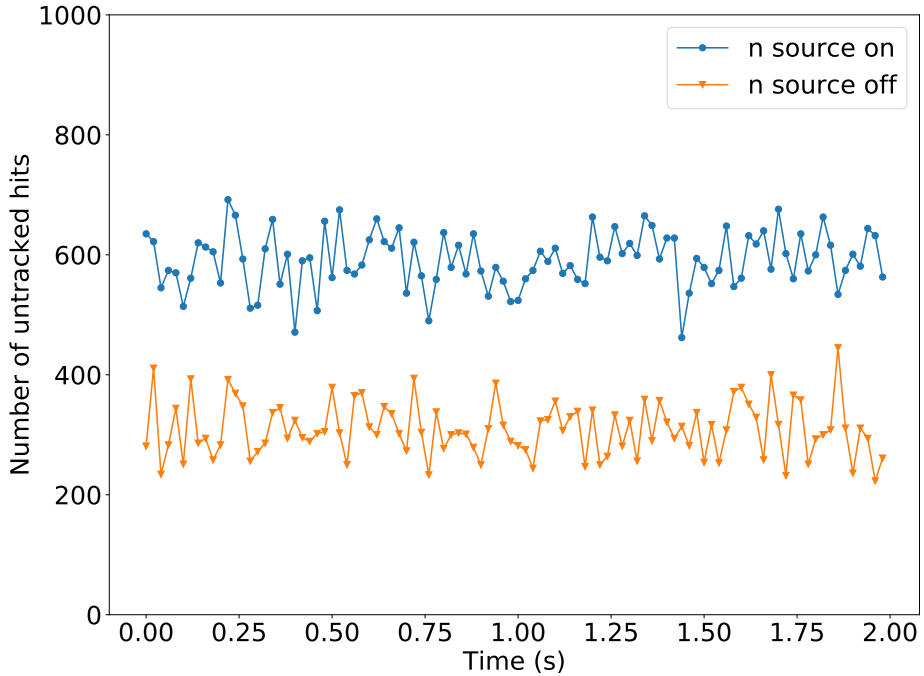
Analysis

1. Do the DBSCAN clustering on individual 20ms windows
2. Count unclustered hits per window
3. Compare neutron source on/off data

- Some details:
  - The hits come out of the hit finding with start time in 50 MHz ProtoDUNE clock ticks, and channel number in the offline channel numbering scheme. I rescale both of those to mm using the approximate drift velocity and the channel pitch, respectively.
  - DBSCAN only knows about "points", not extended hits, so for hits extended in time, I make a new point every 10 TPC ticks that the hit is over threshold. This improves the efficiency for reconstructing high-angle tracks.
  - There are noisy channels in the detector, which are suppressed in the hit finding. This causes gaps in the tracks, and causes the clusters to get split. Within each 20ms window, I take any channel which has no hits to be suppressed, and renumber the rest of the channels so their numbers are contiguous

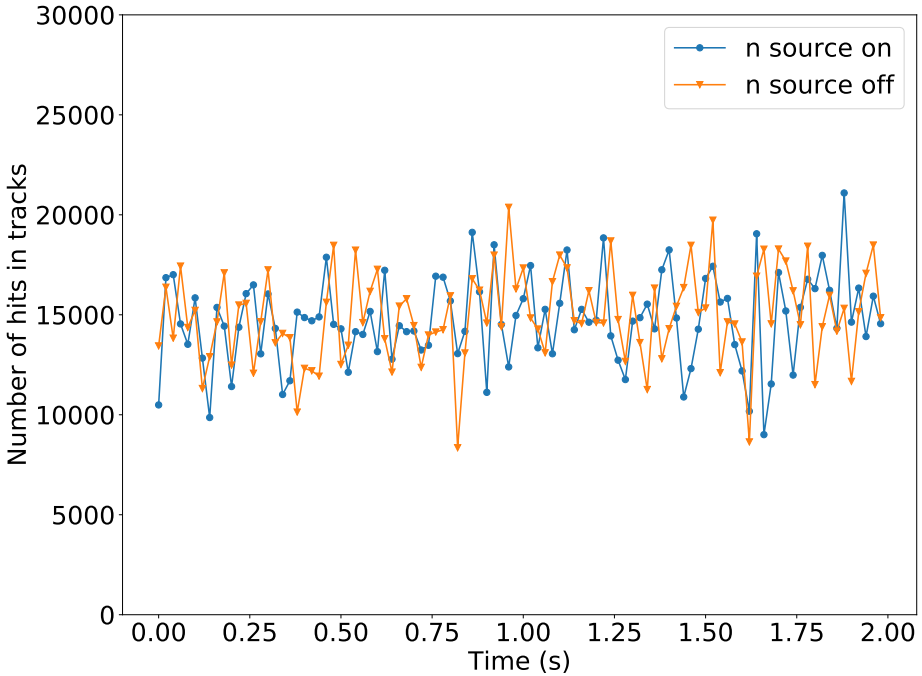
Clustered and unclustered hit rates, APA 5

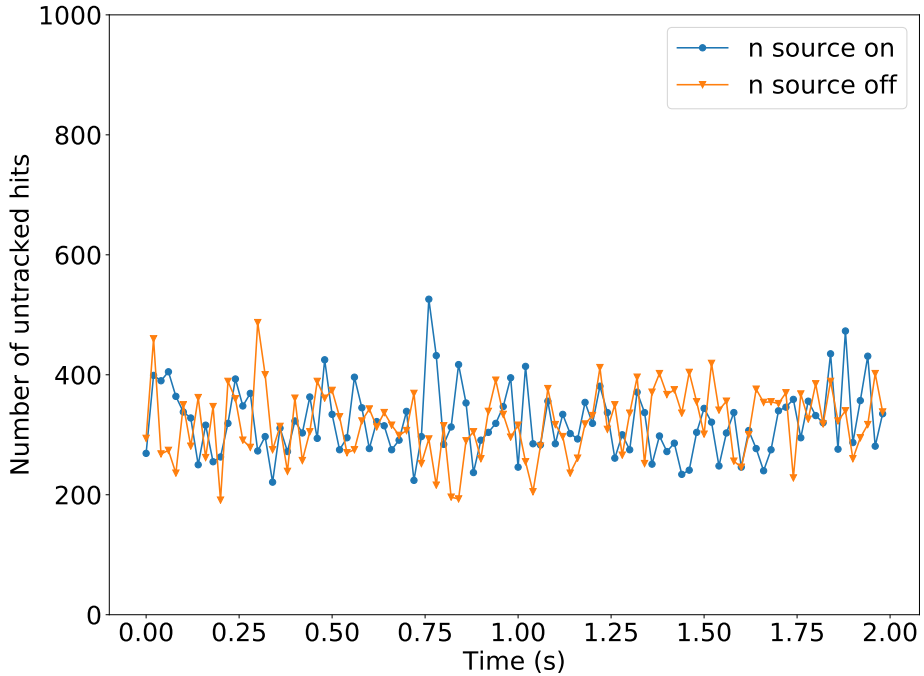




- Left: Number of hits clustered by DBSCAN (ie, tracked) in each 20ms window *vs* time
- Right: Number of unclustered hits (ie, neutron/EM candidates) in each 20ms window *vs* time
- (Just ran on 100 20ms windows to save time/memory)
- Tracked hits don't change with neutron source on. Untracked hits increase by about a factor of 2
- Clear evidence of neutron-like hits when source is on

Clustered and unclustered hit rates, APA 1





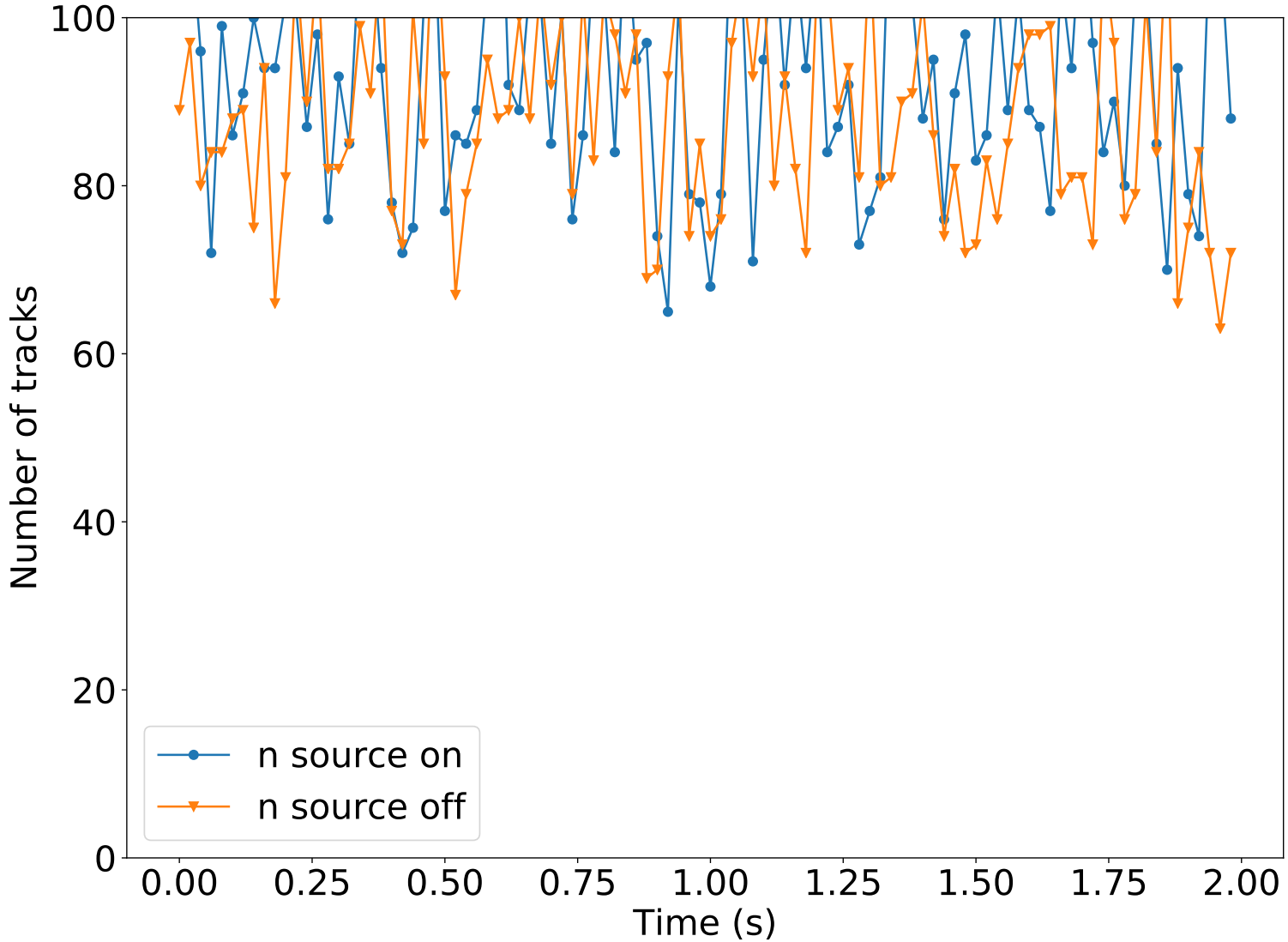
- The same for APA 1, which is further from the neutron source. No statistically significant increase in hits

Conclusions

- There's clear evidence of excess neutron-like hits in the detector when the neutron source is on, based on a very simple analysis
- A more sophisticated offline analysis with full reco should have no trouble picking up on this

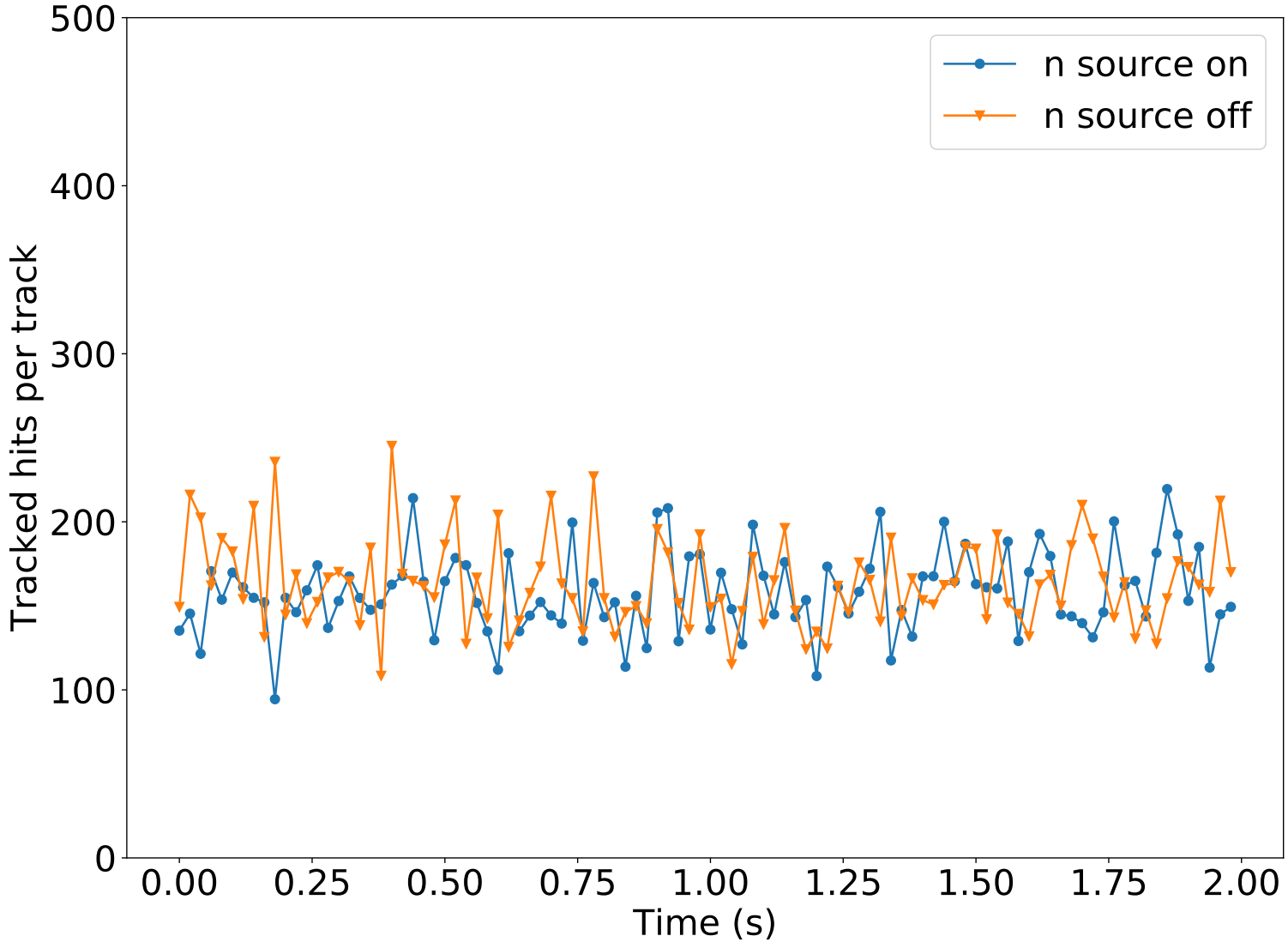
Backup slides

Number of clusters, APA 5



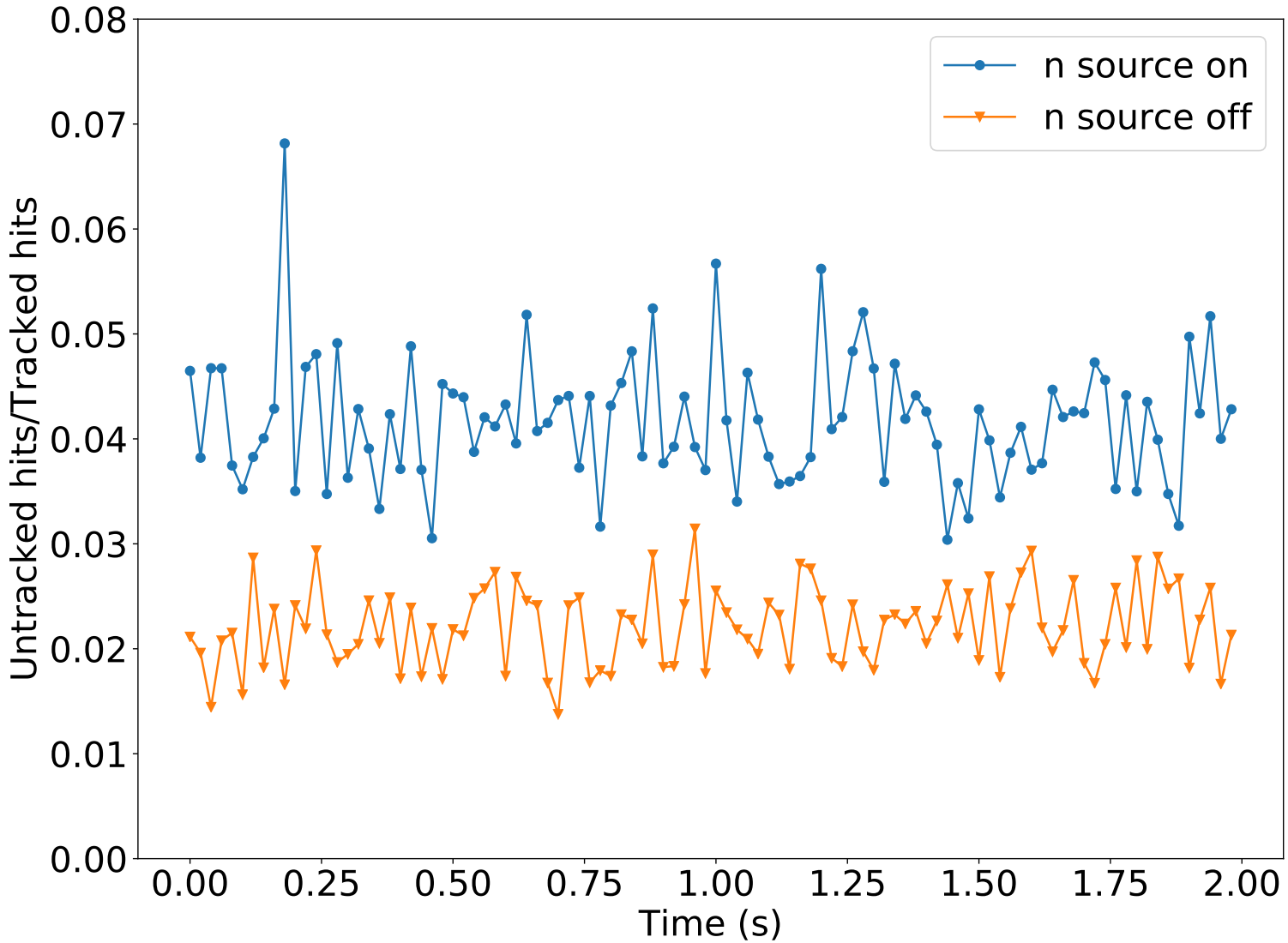
- Number of clusters (ie, tracks) identified per 20ms window. Shouldn't change with source on/off

Hits per track, APA 5

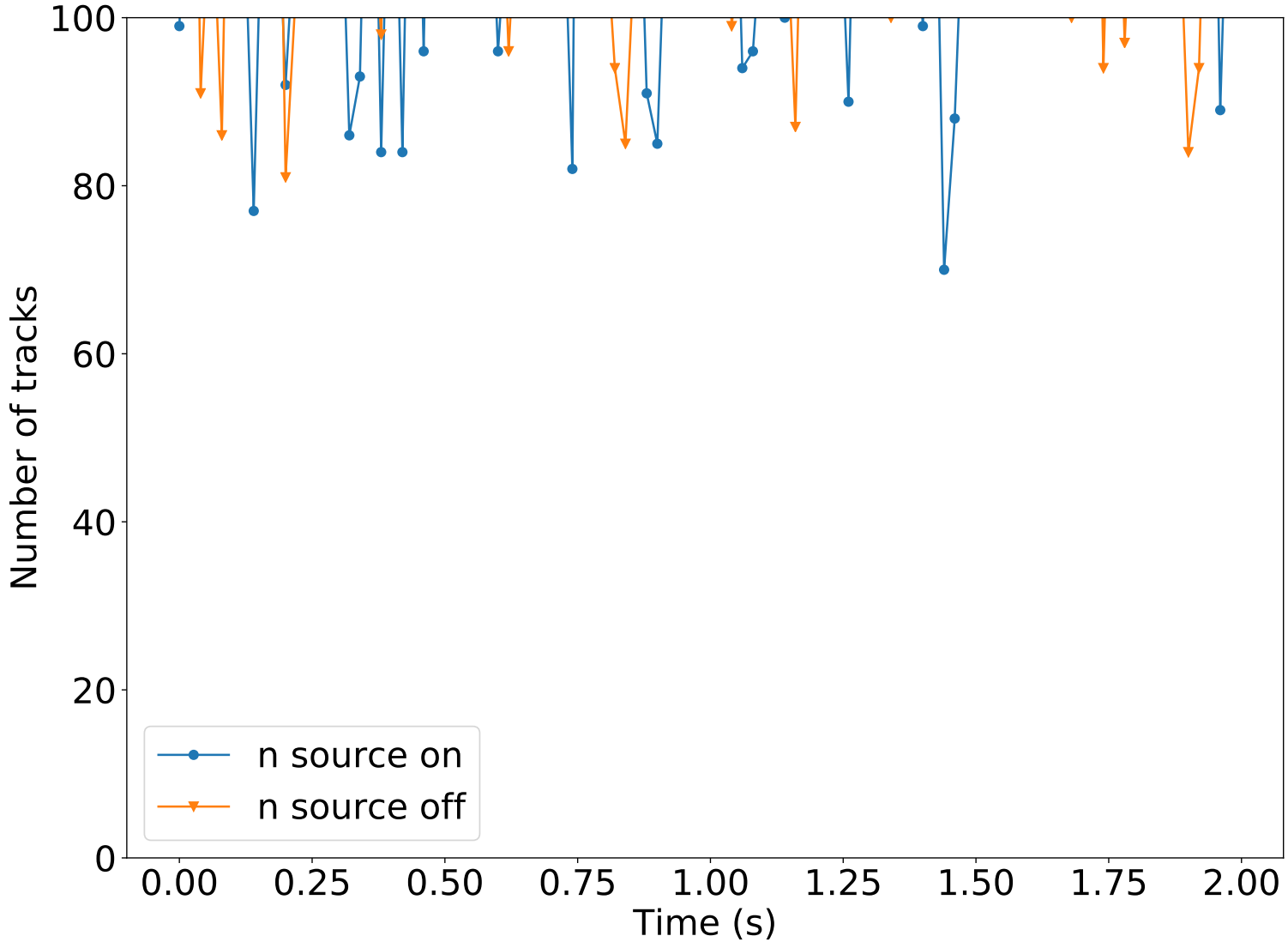


- Number of tracked hits per track. Shouldn't change with source on/off

Ratio of untracked hits to tracked hits, APA 5



Number of clusters, APA 1



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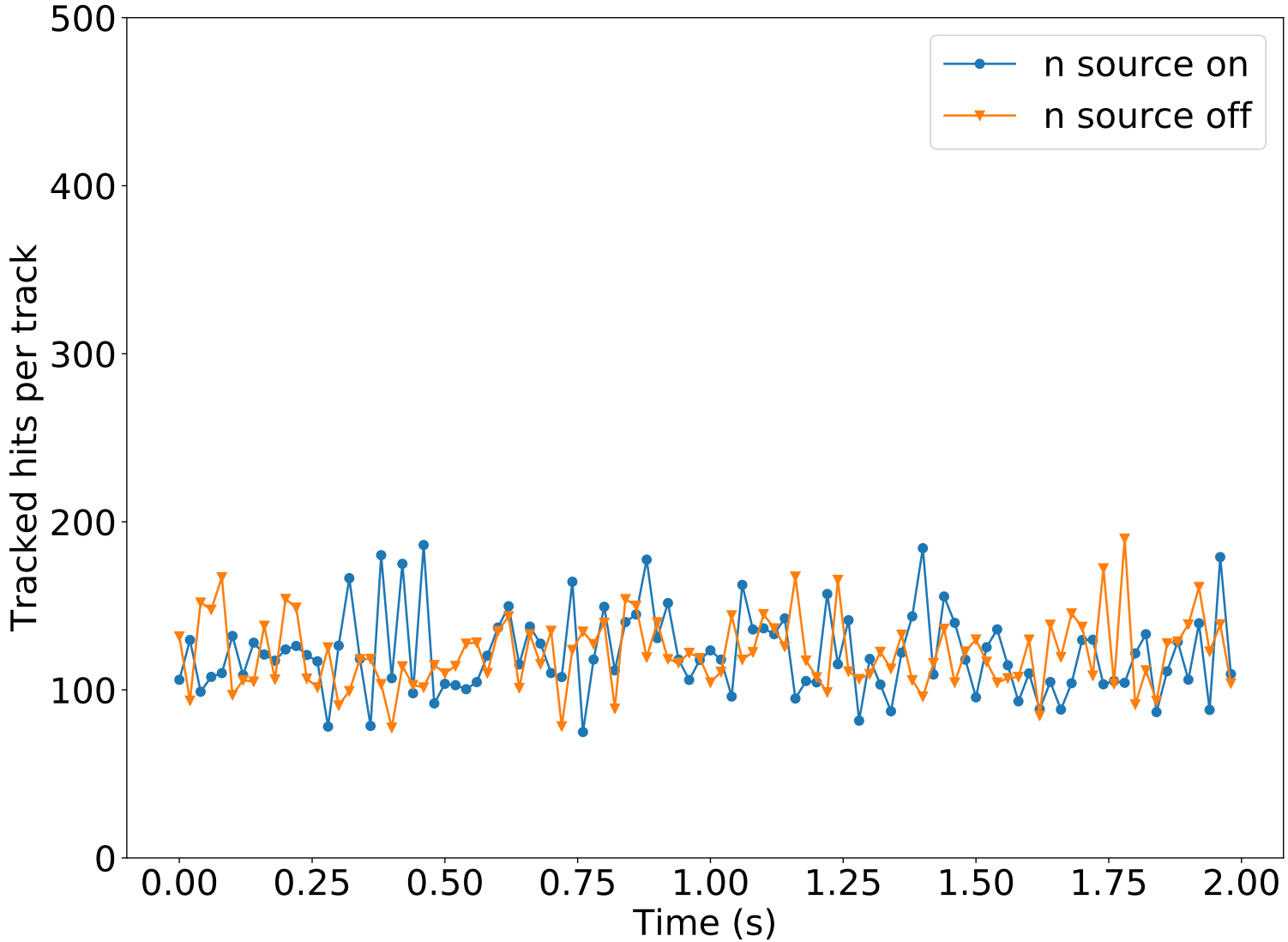

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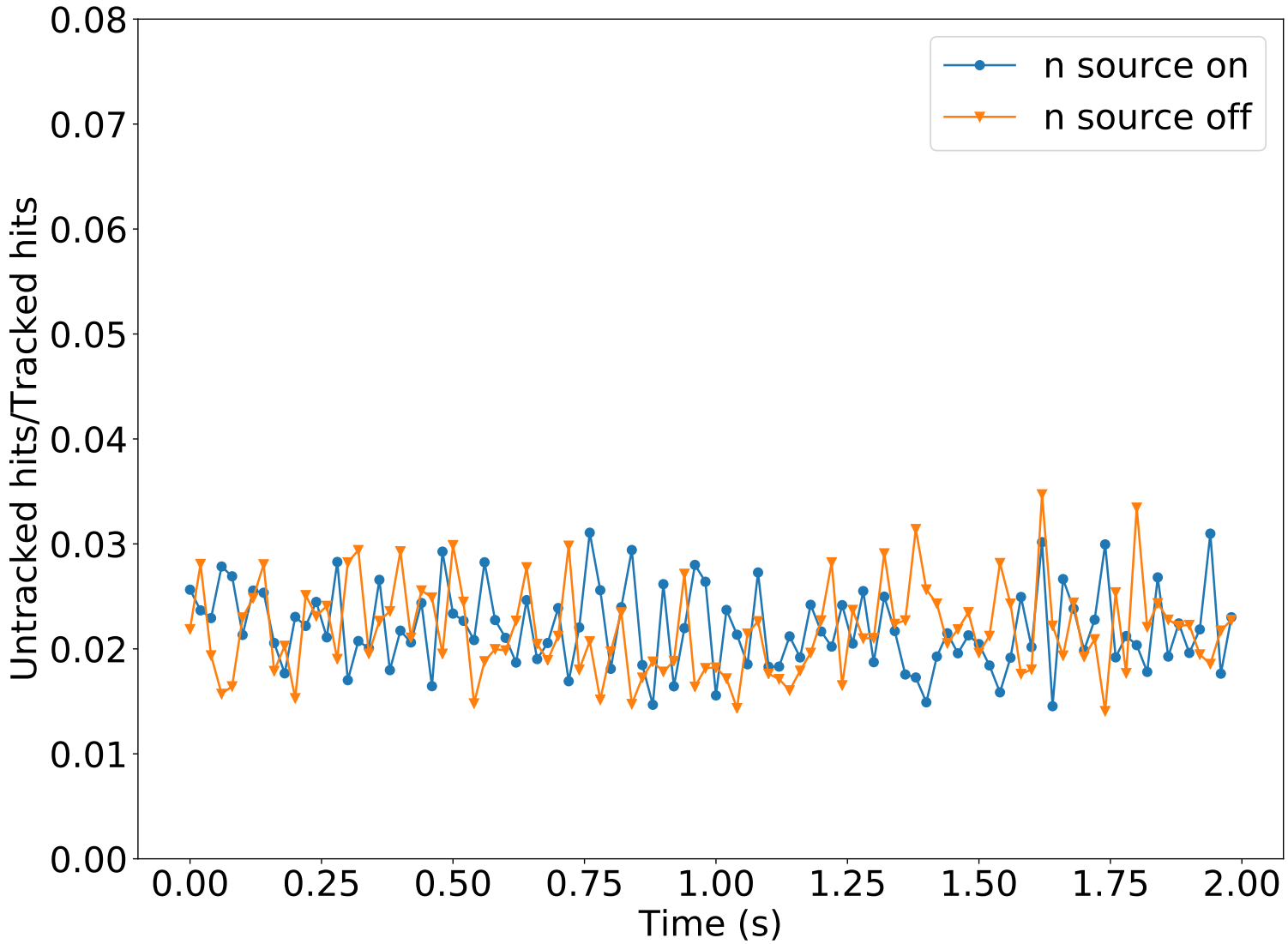
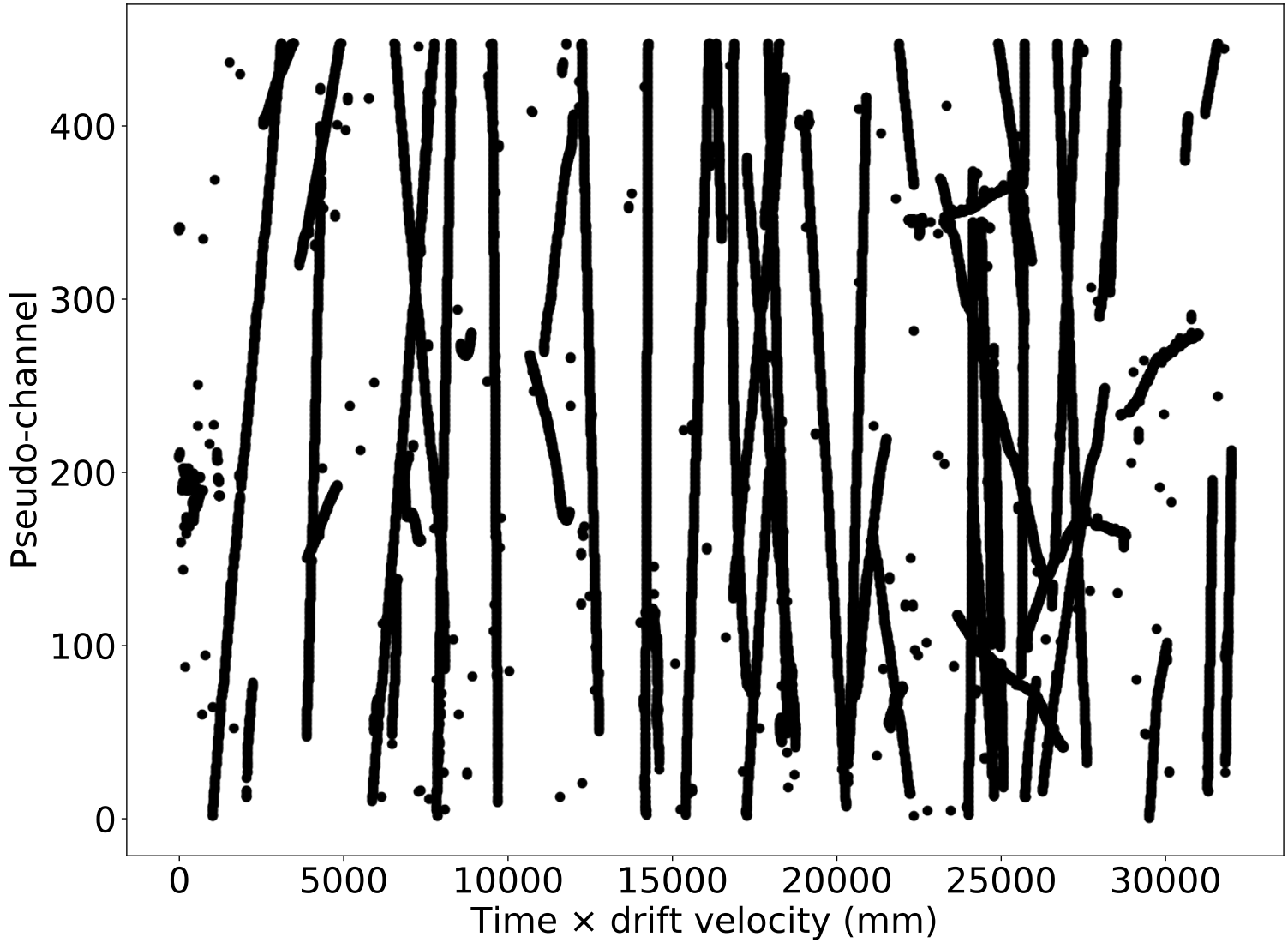


DBSCAN example 1. APA 5. Neutron source off



- Before DBSCAN

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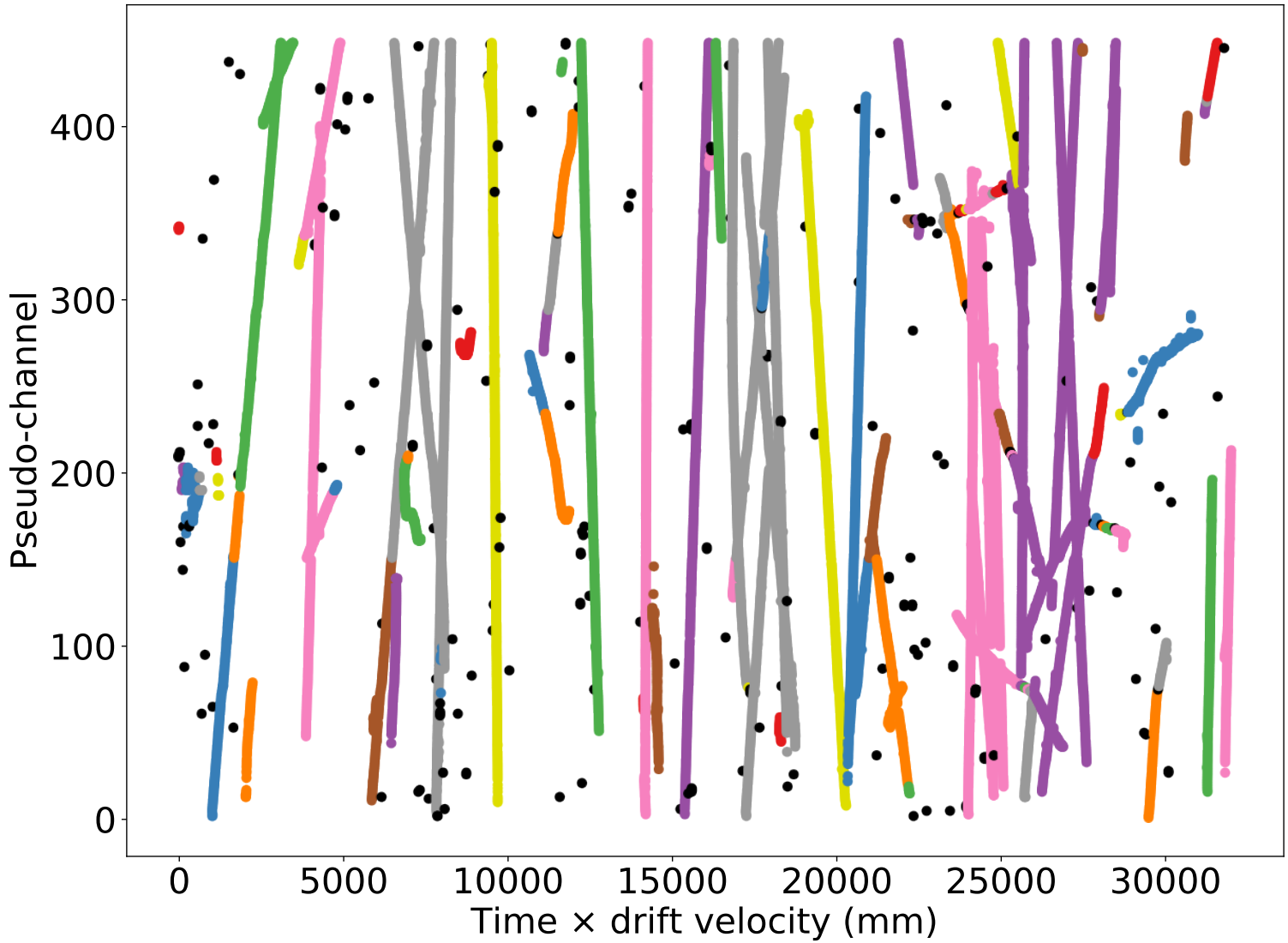

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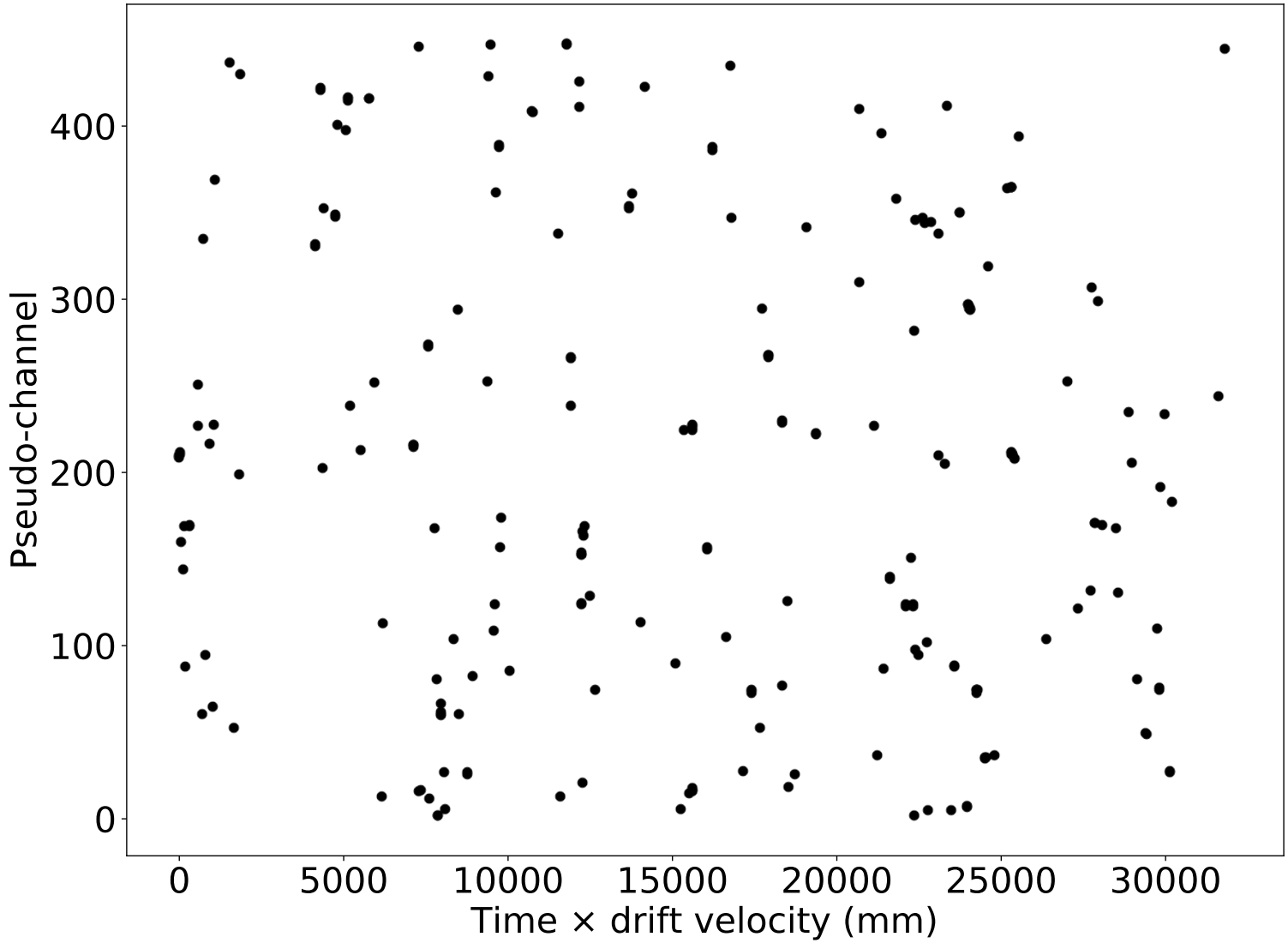

- Just the unclustered hits (ie, neutron candidates)

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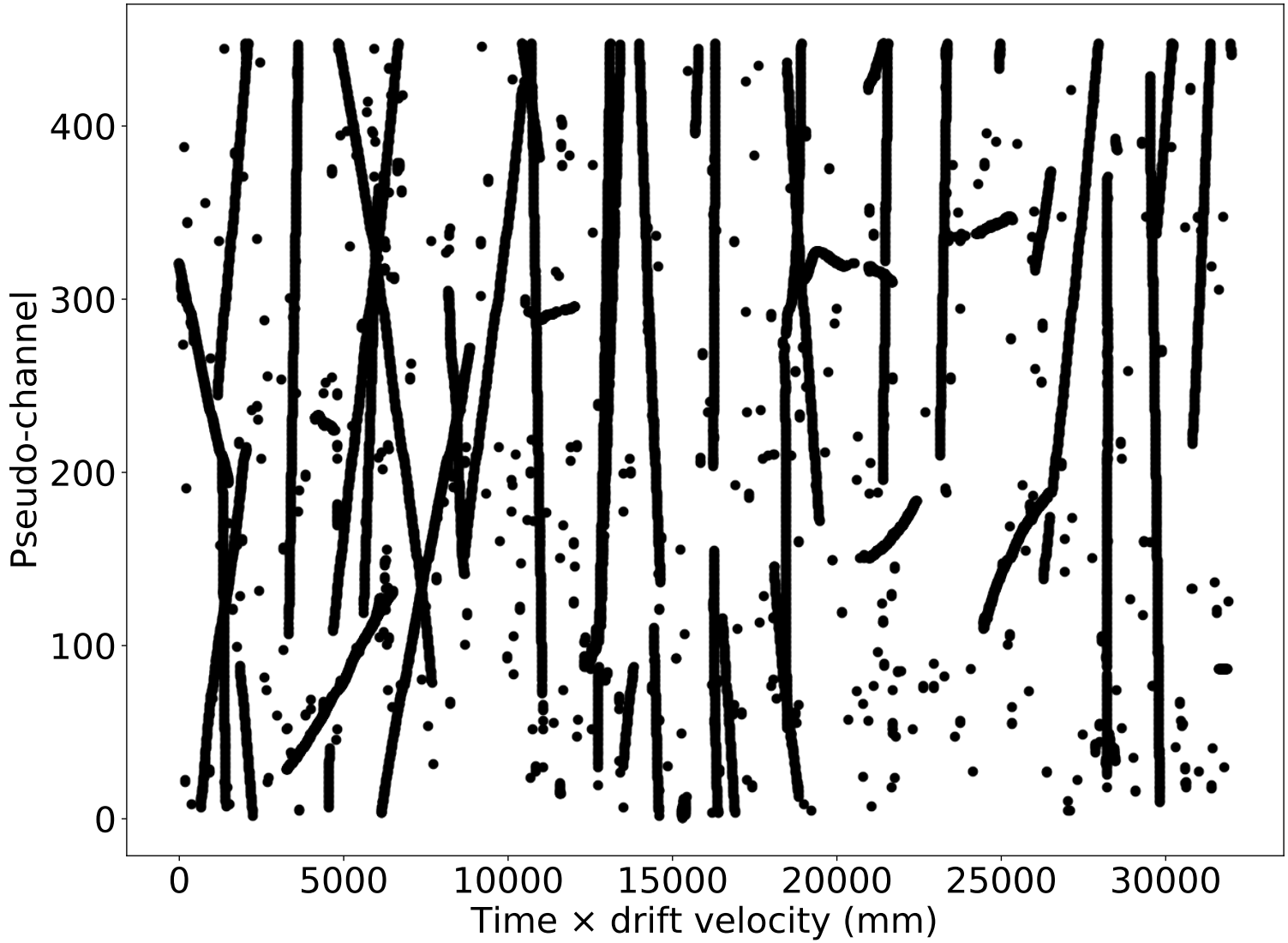

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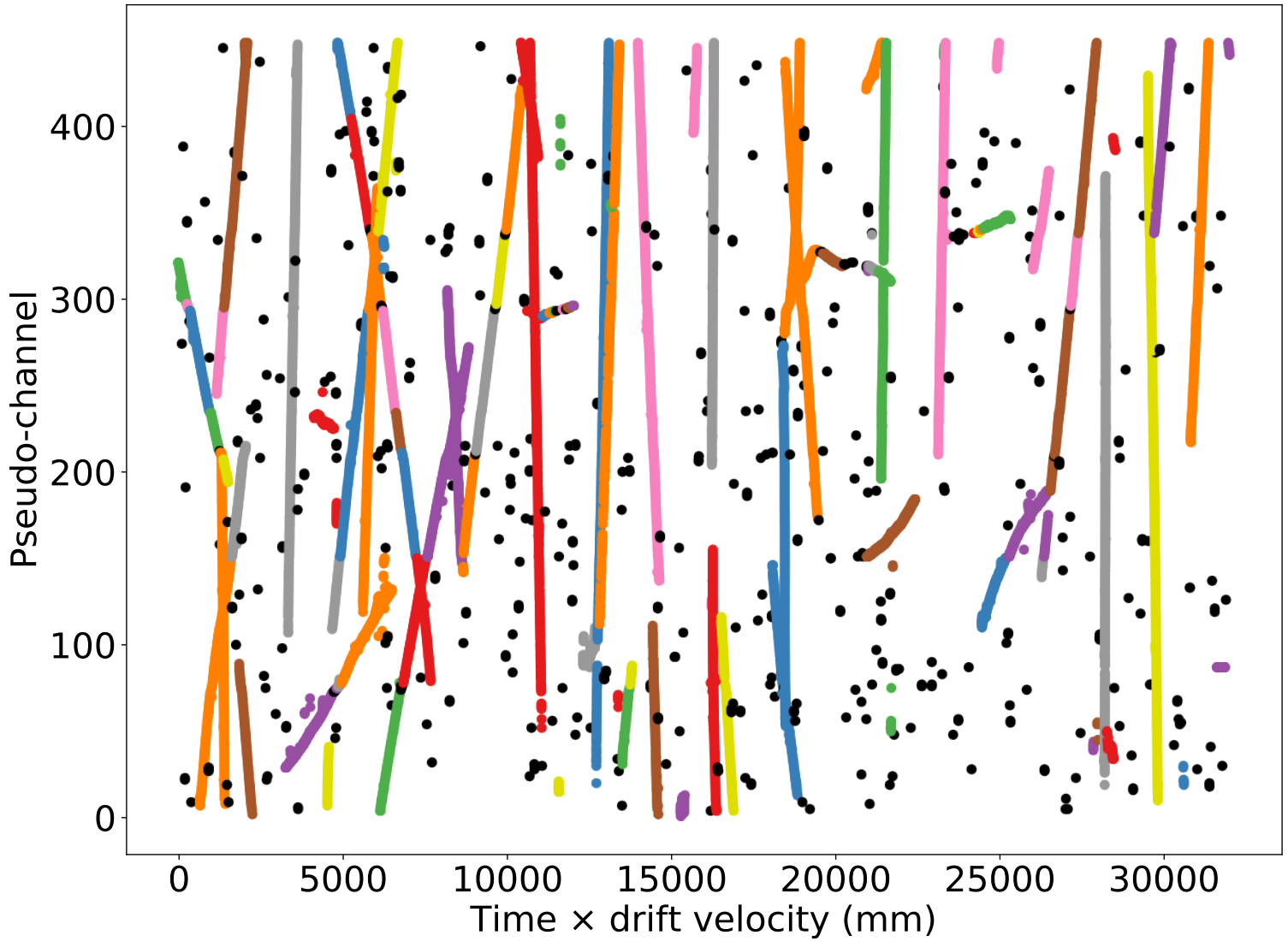

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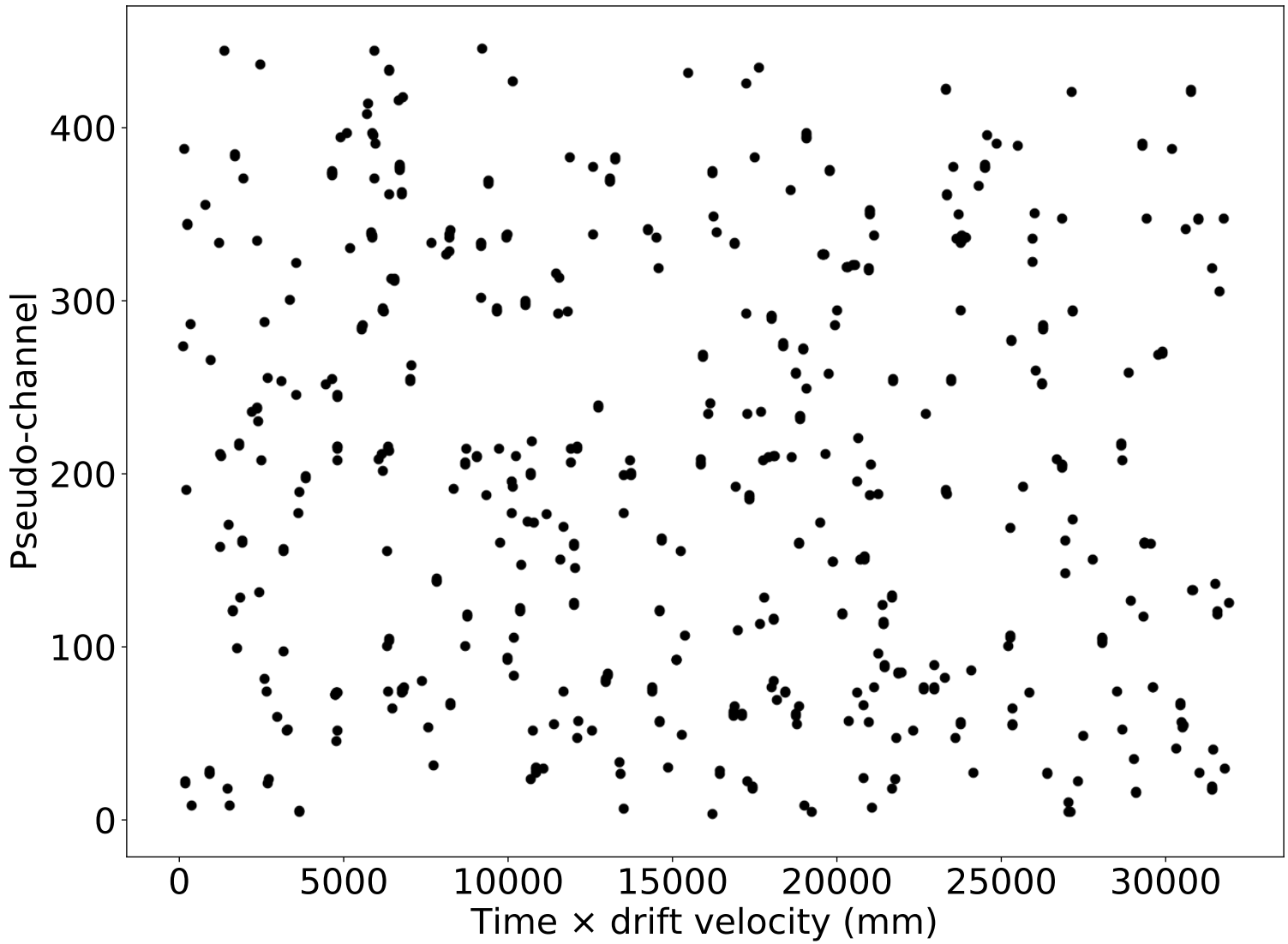

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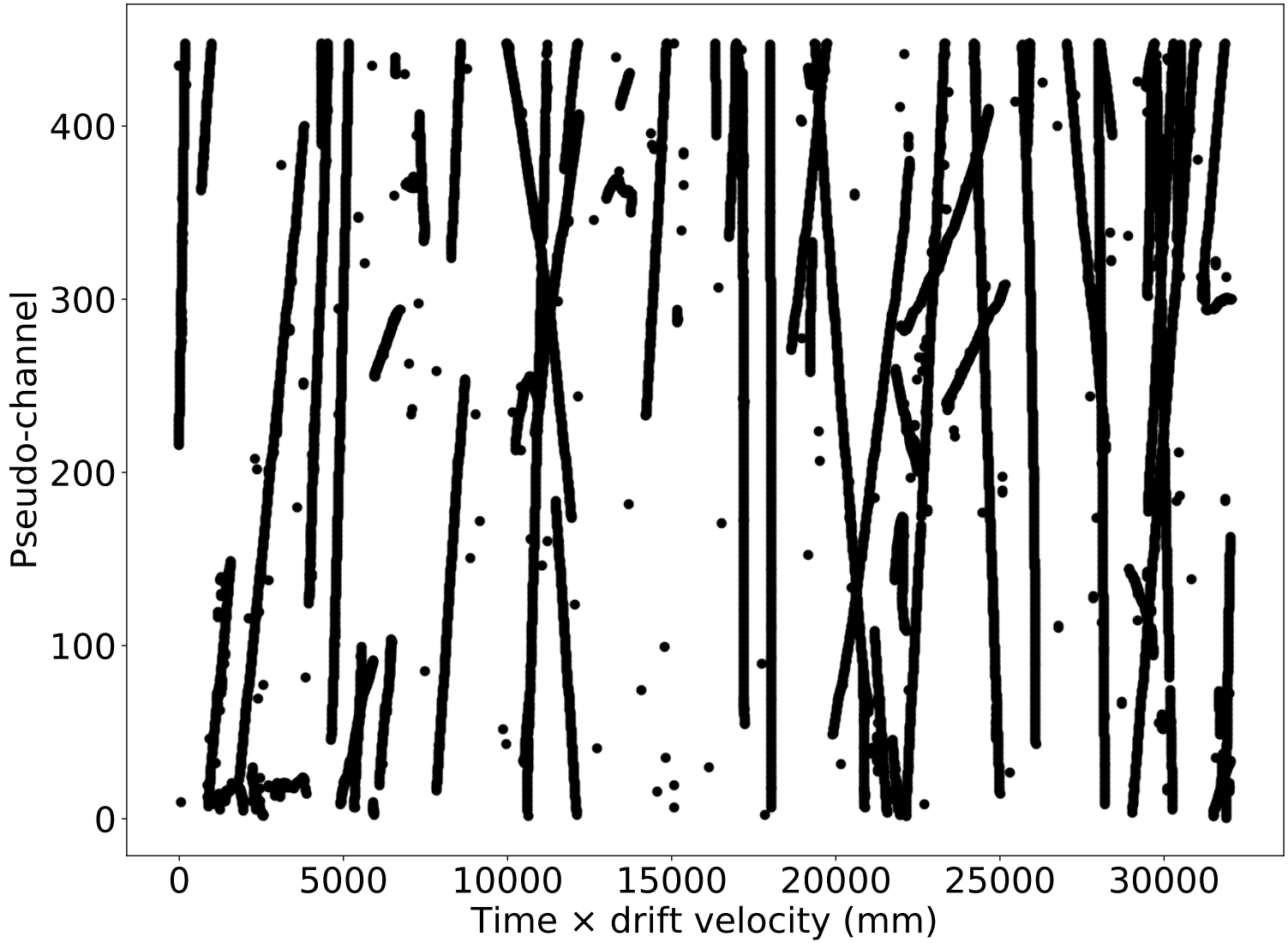
DBSCAN example 2. APA 5. Neutron source off



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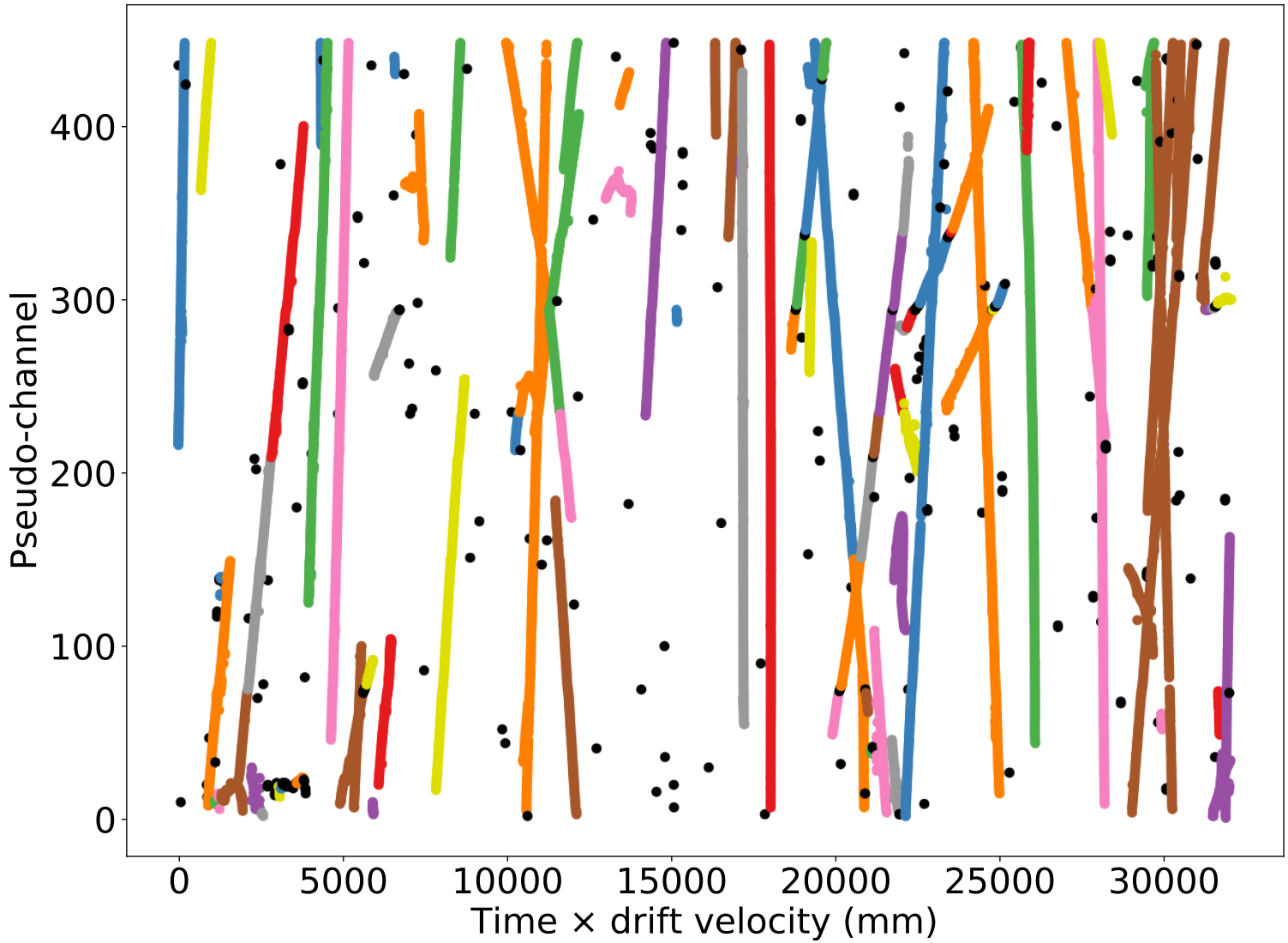

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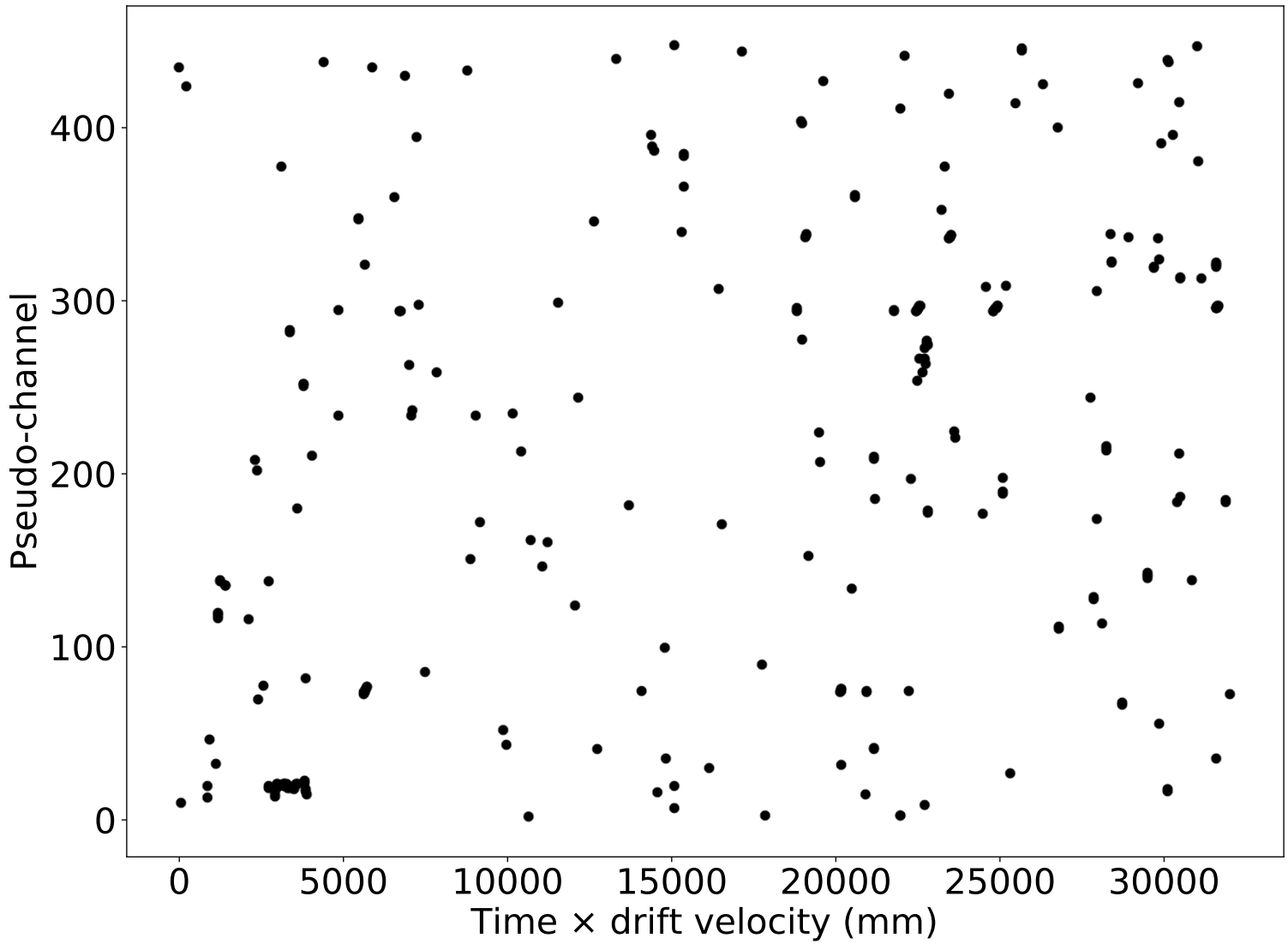

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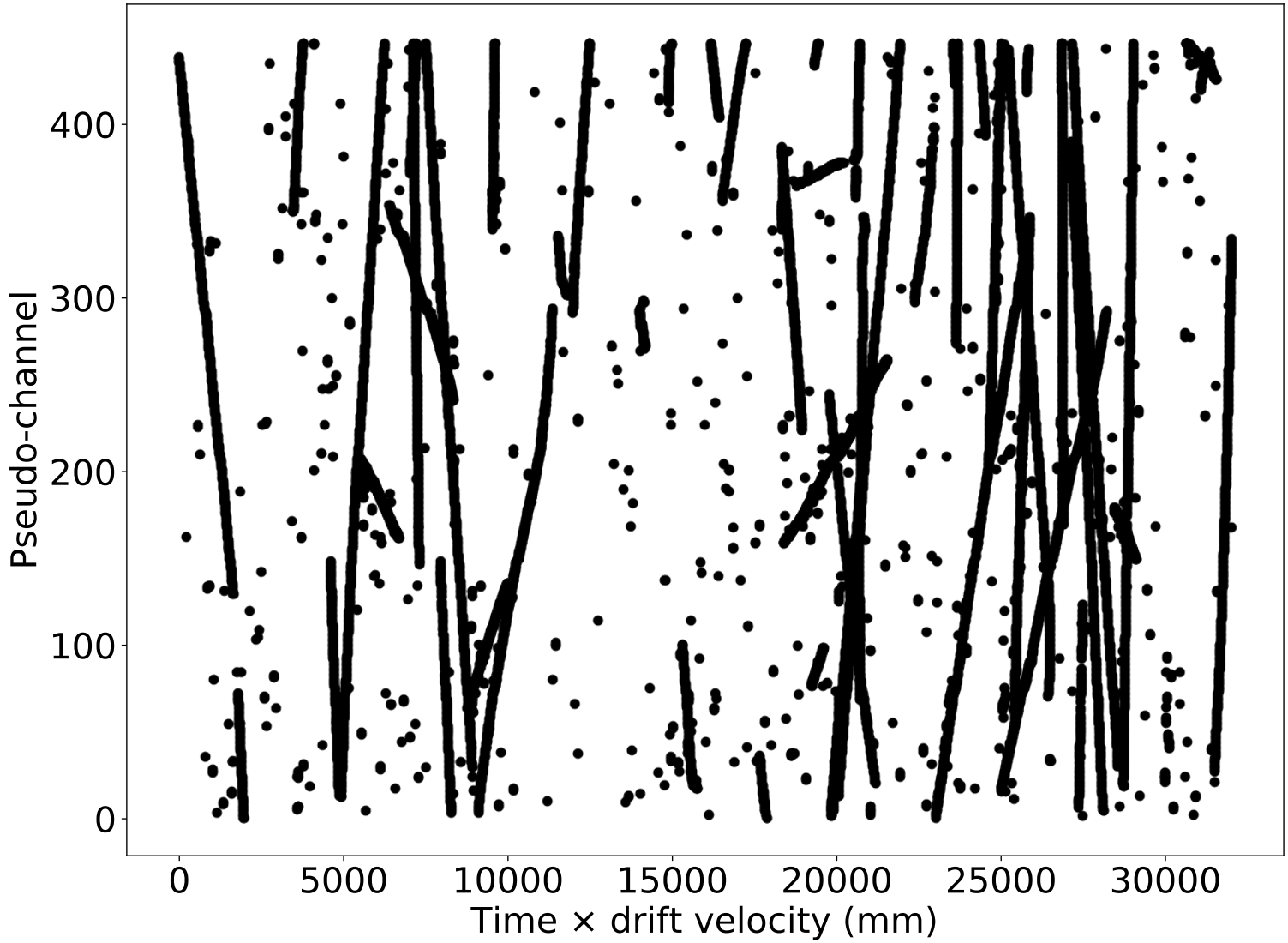

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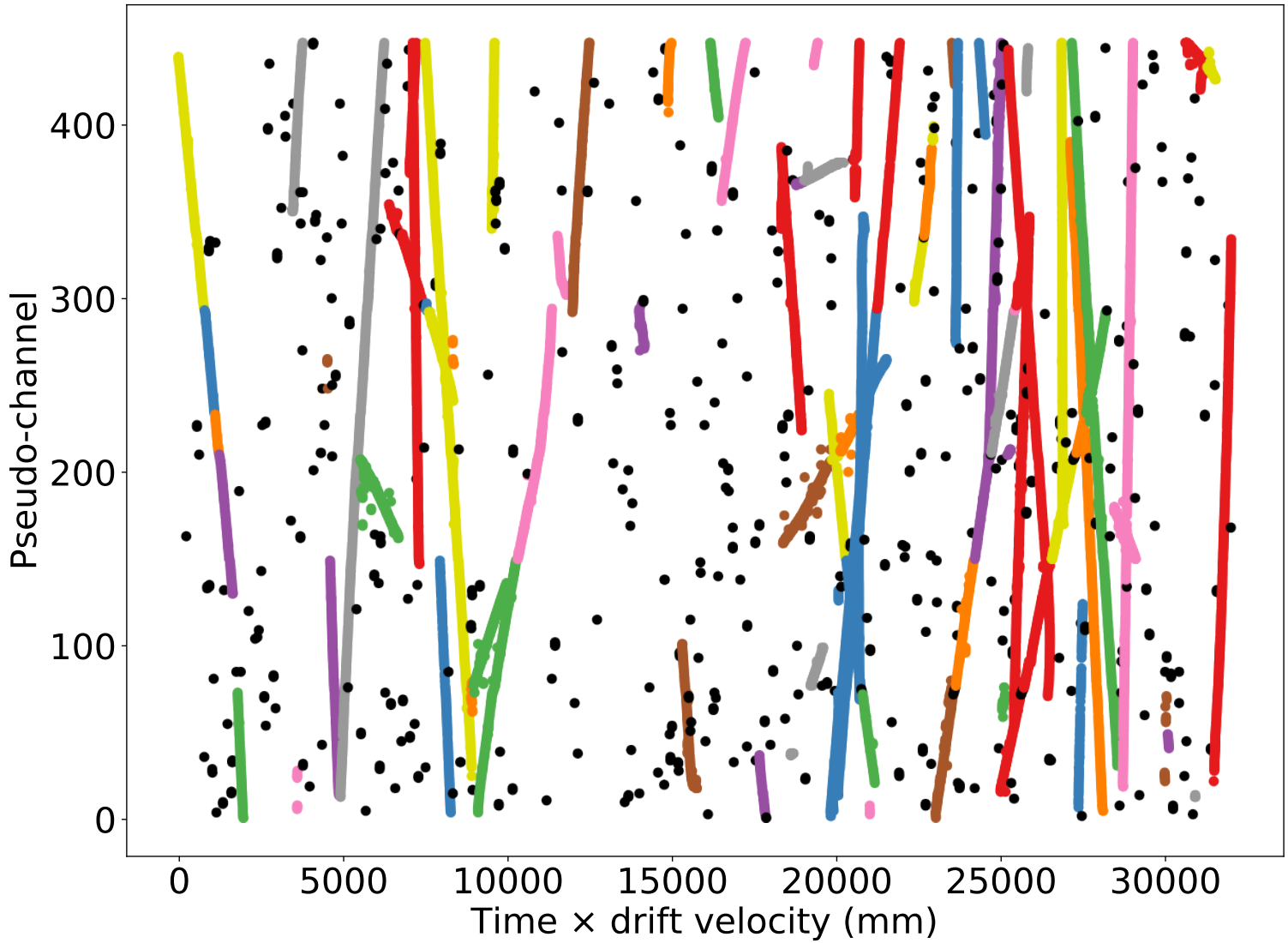

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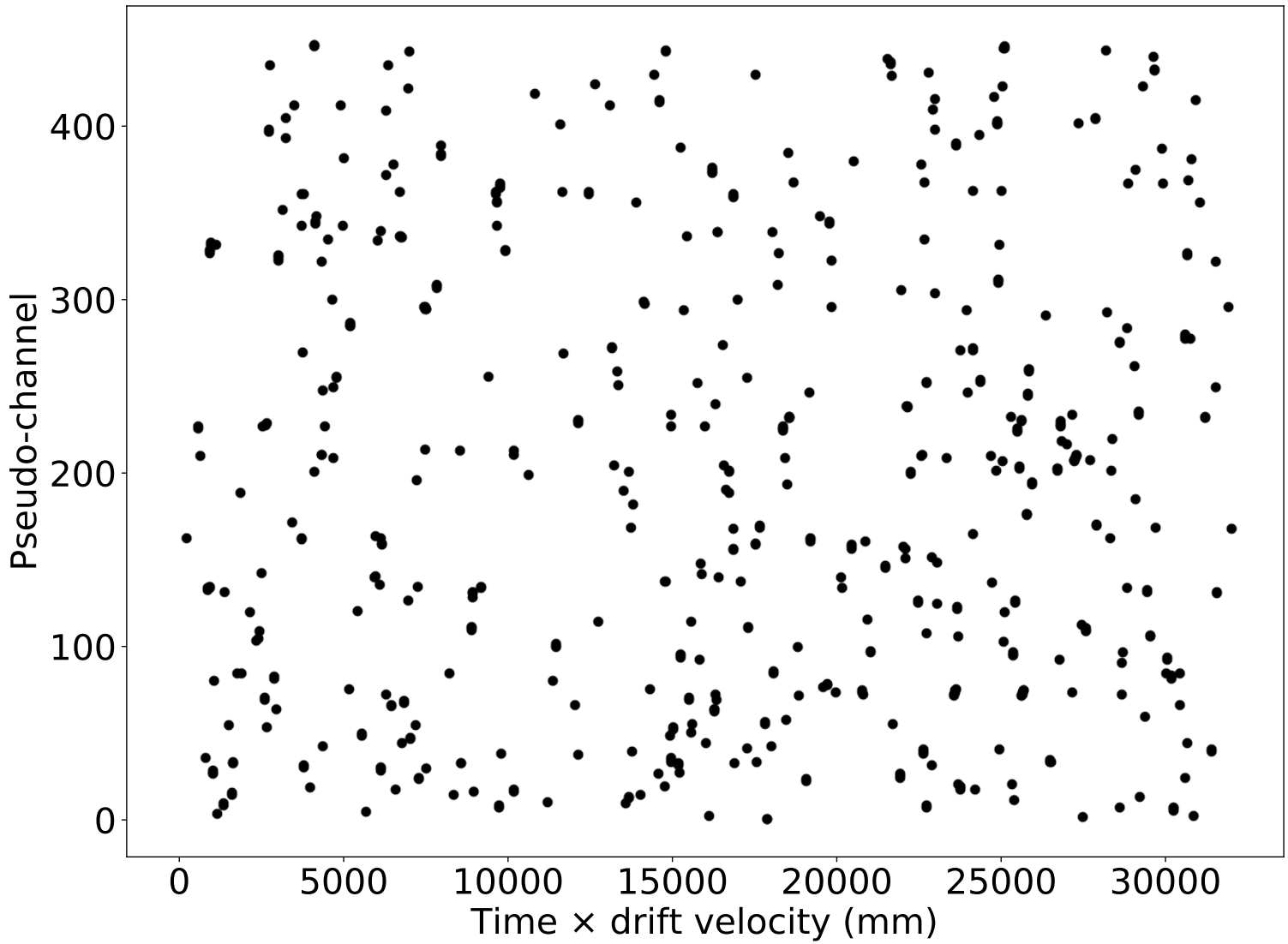

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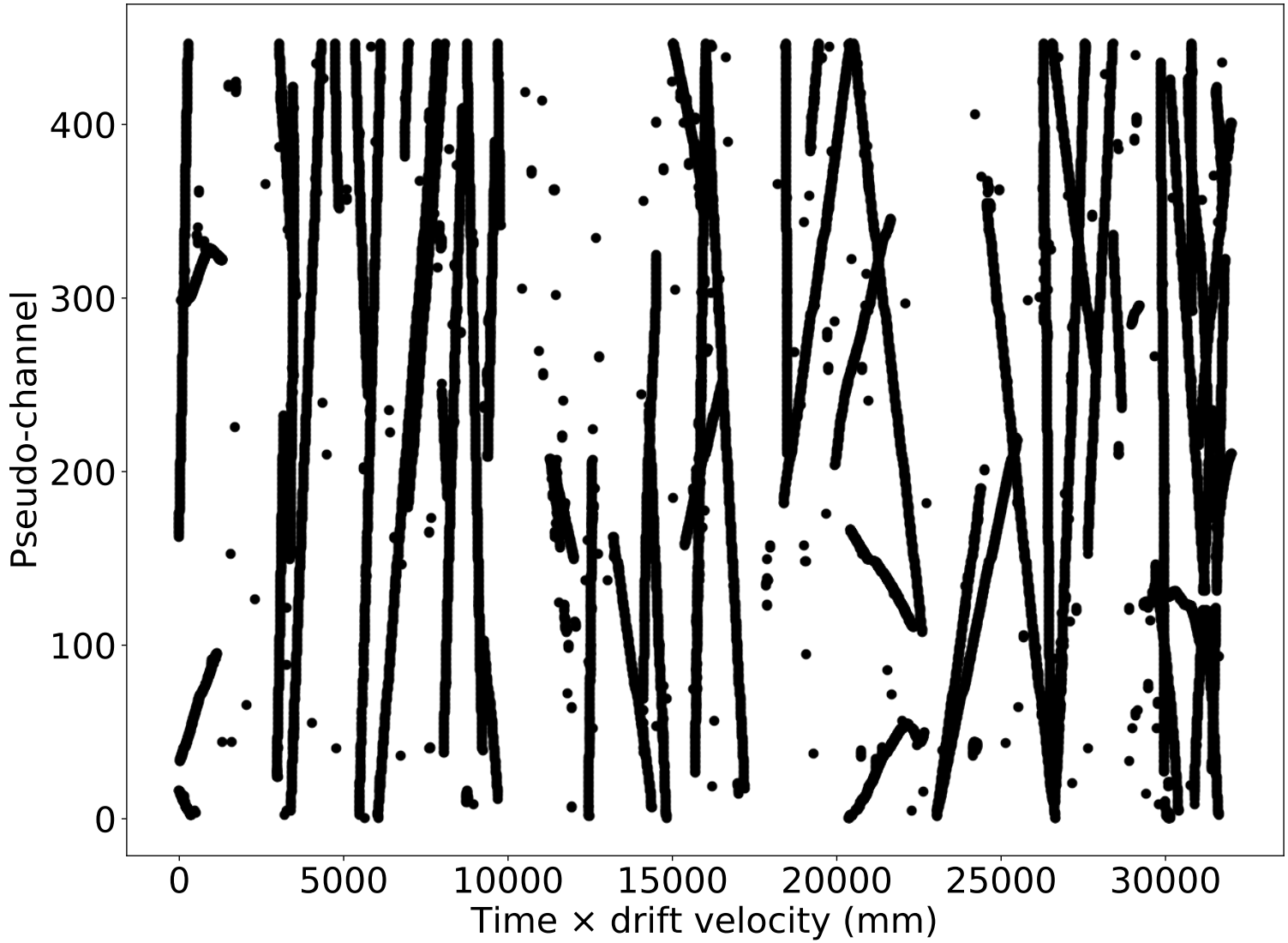

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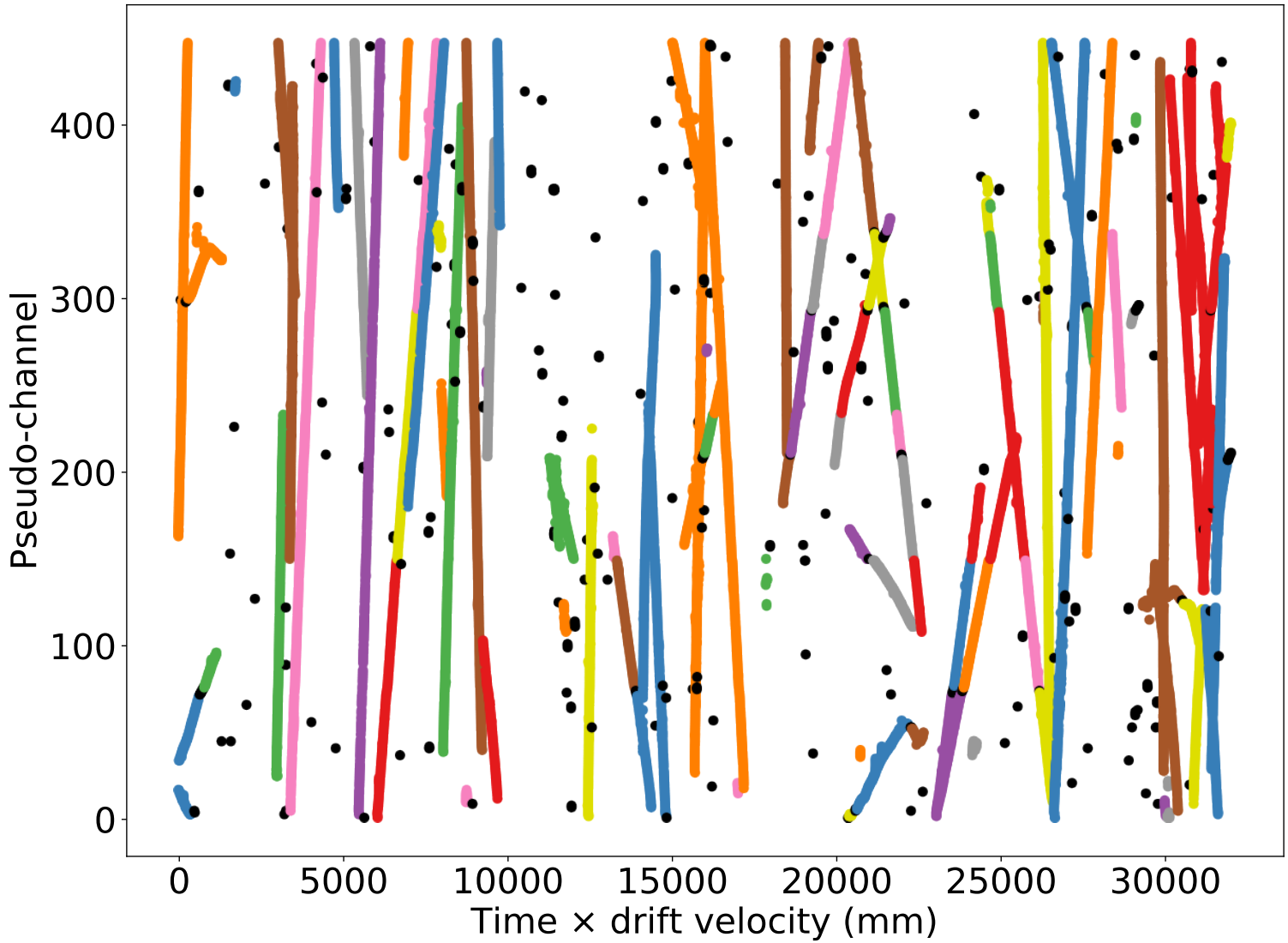

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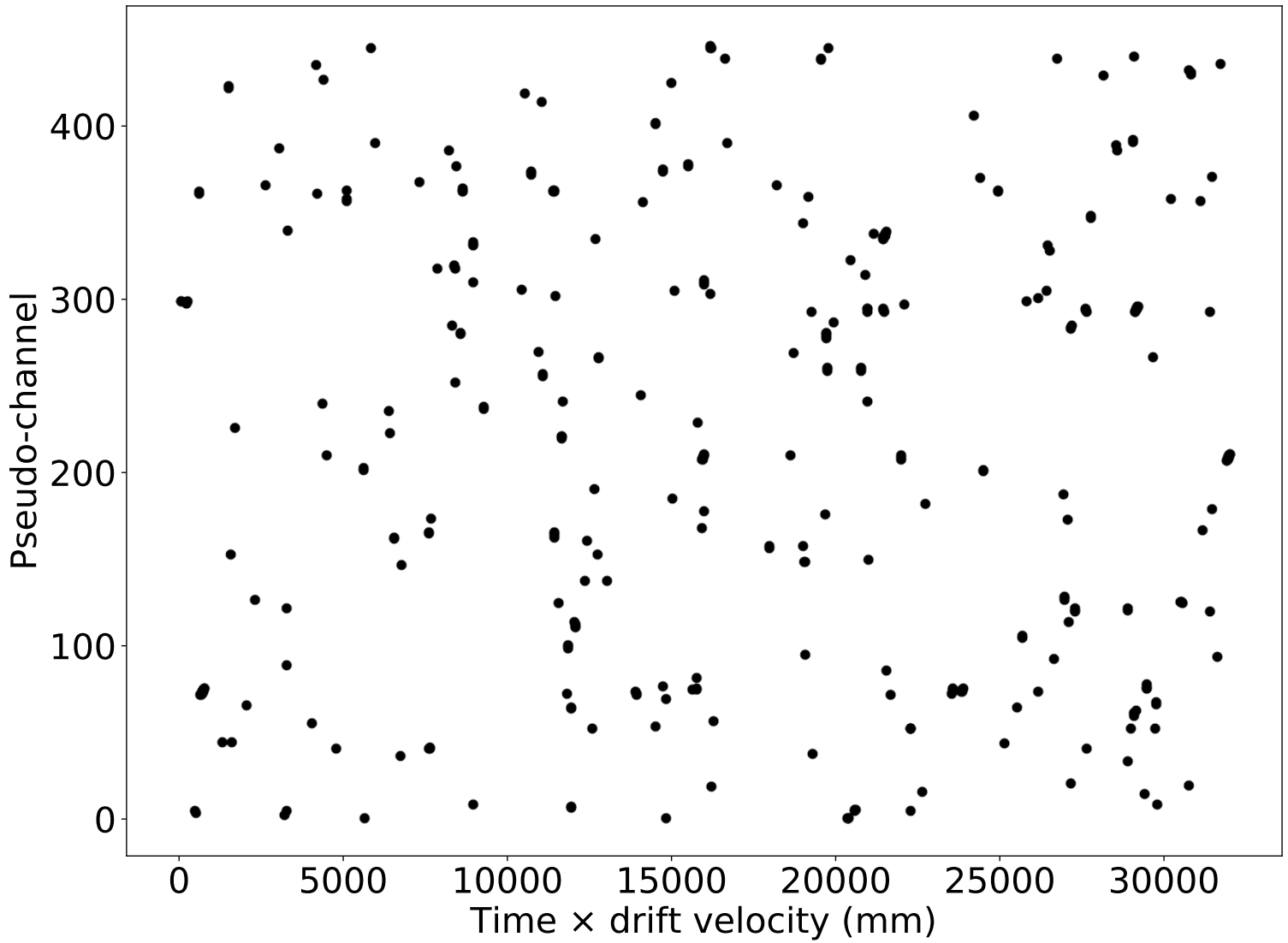

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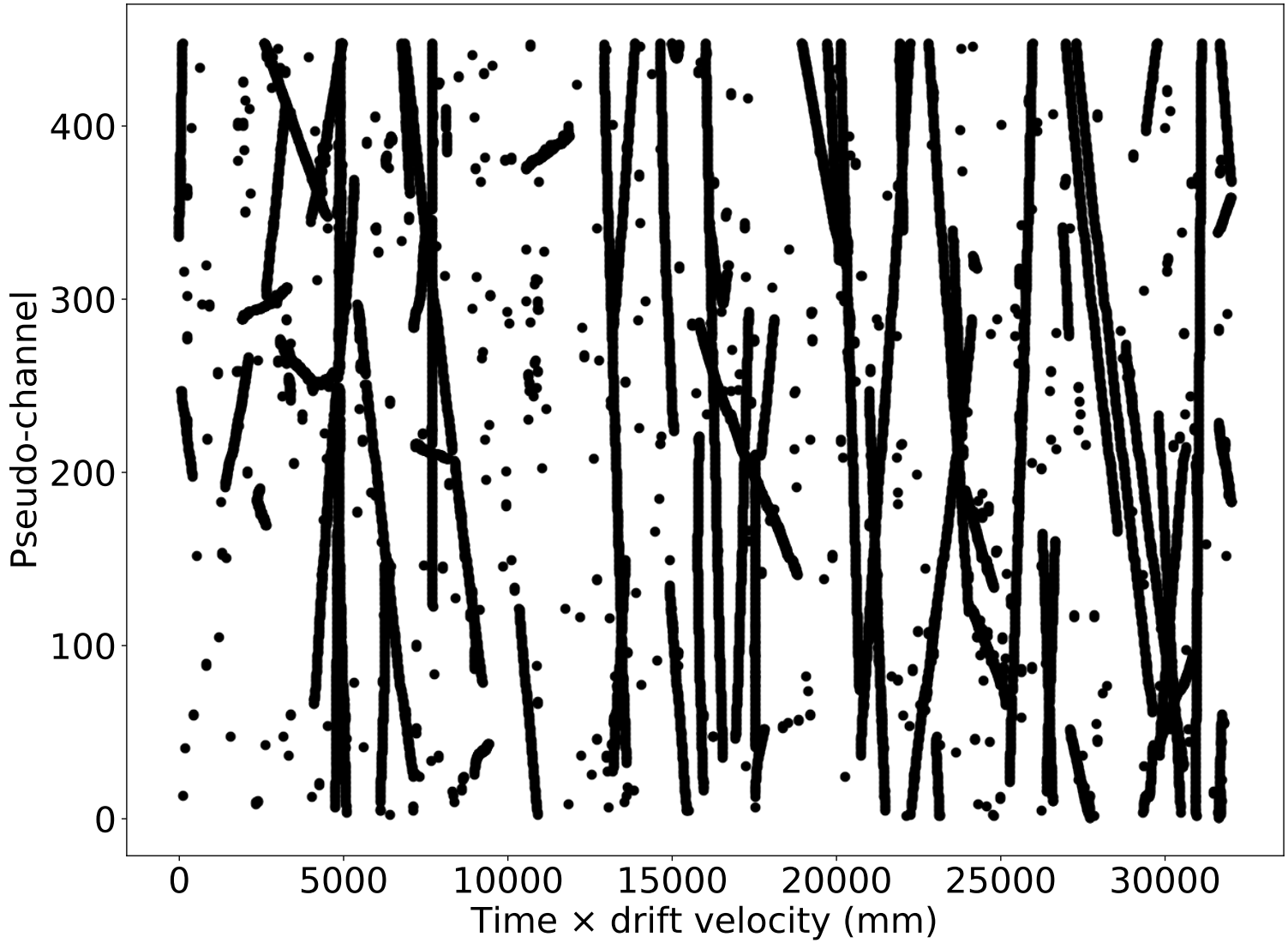

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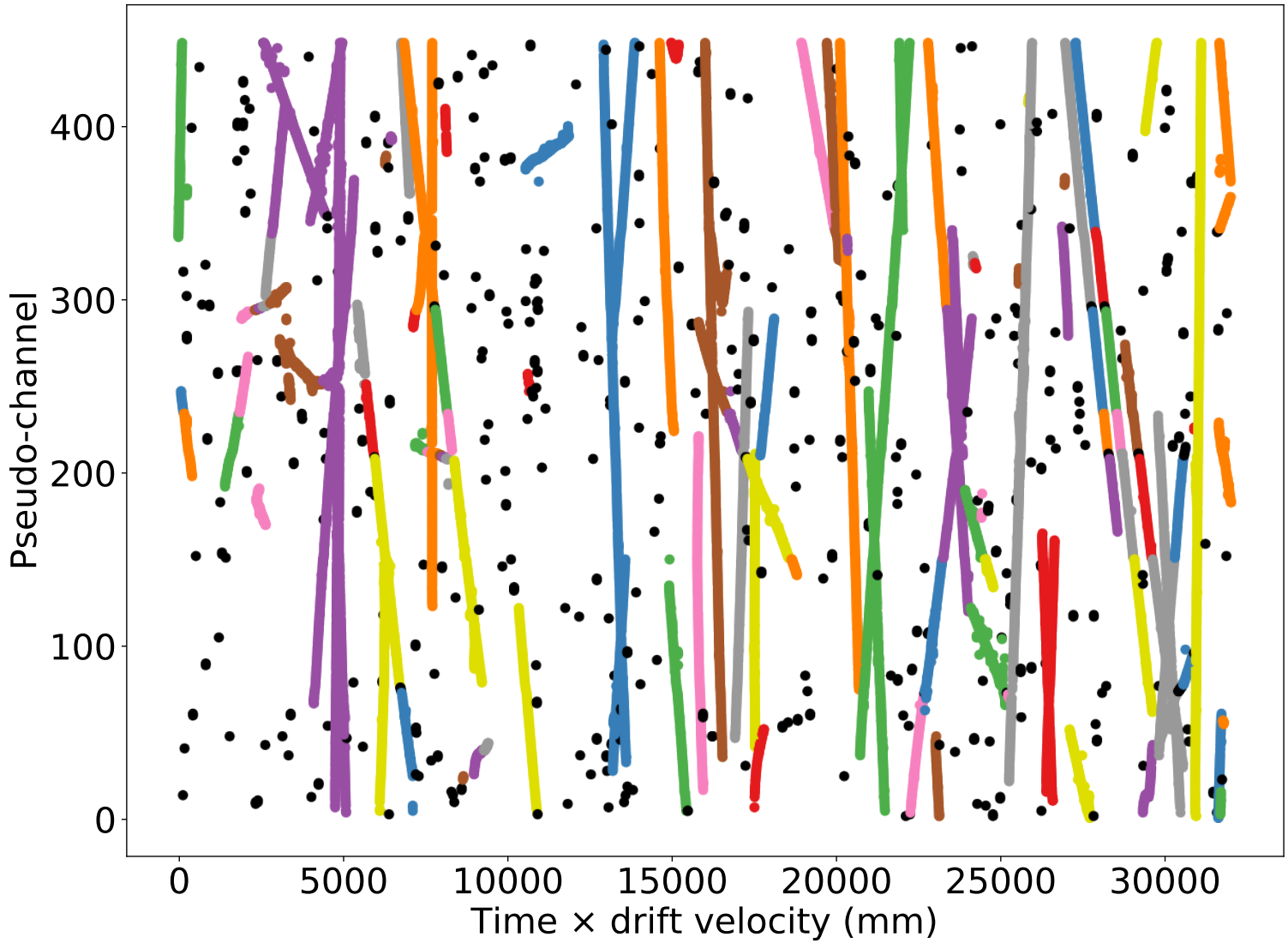

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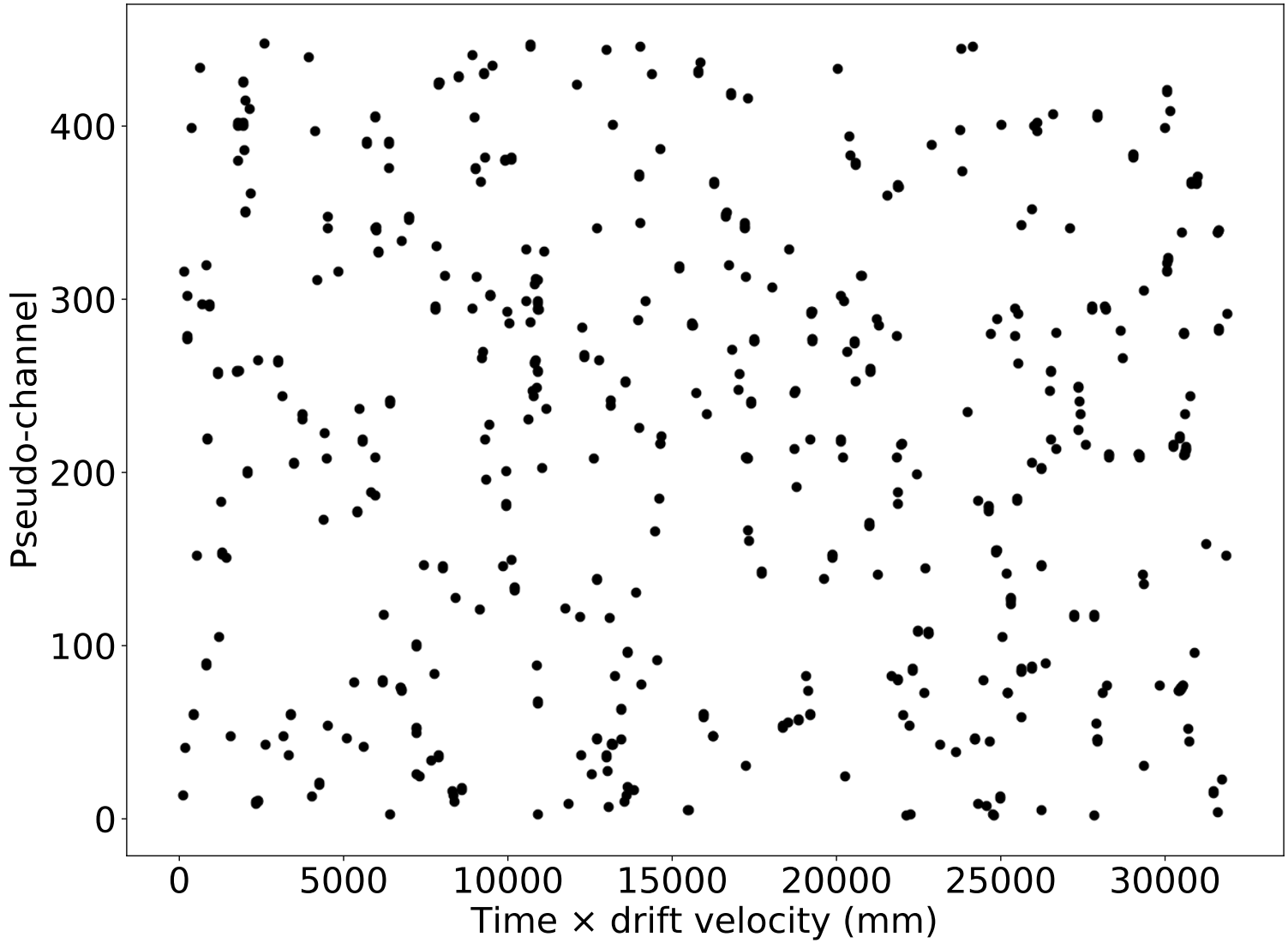

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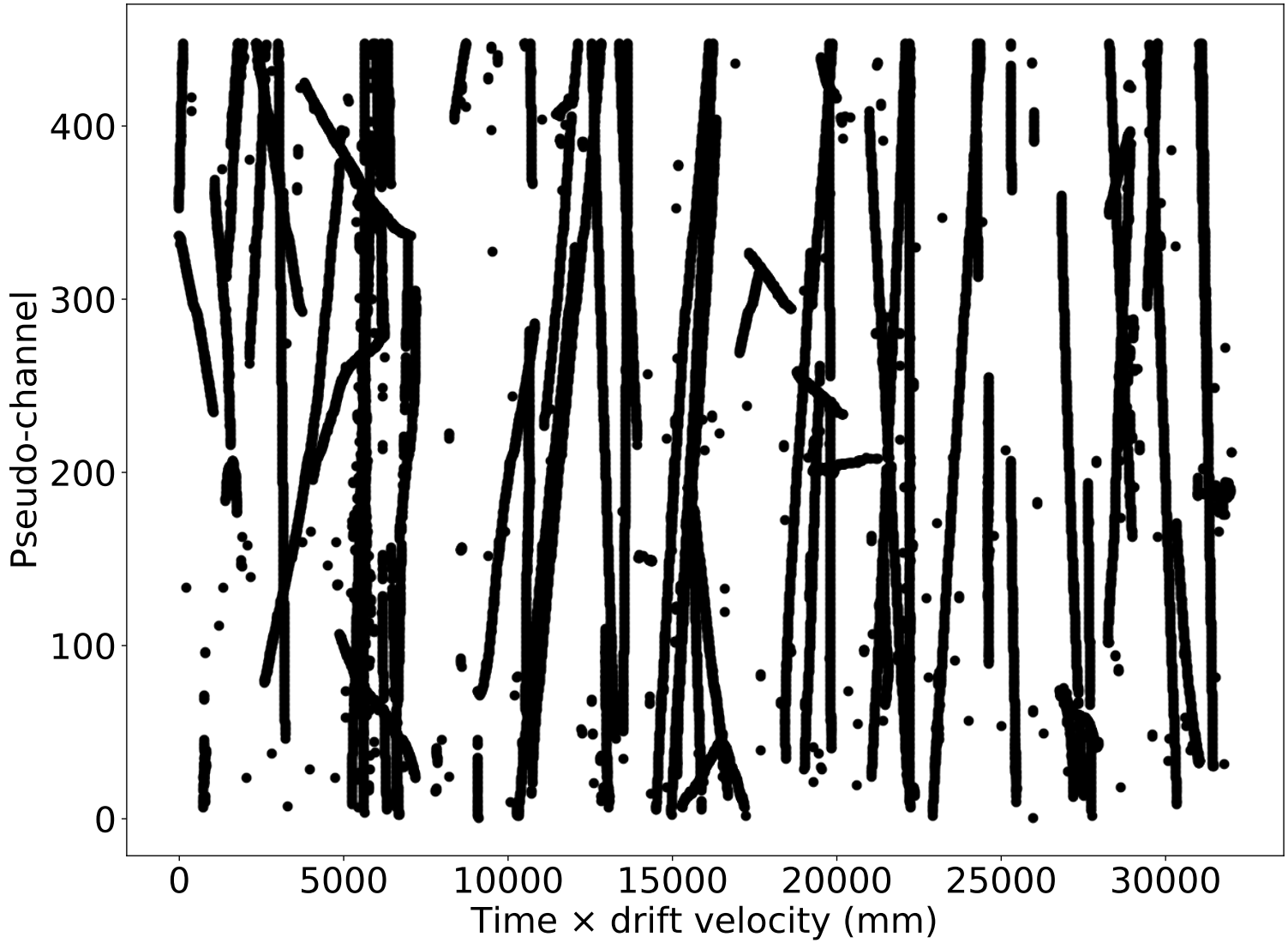
DBSCAN example 0. APA 5. Neutron source off



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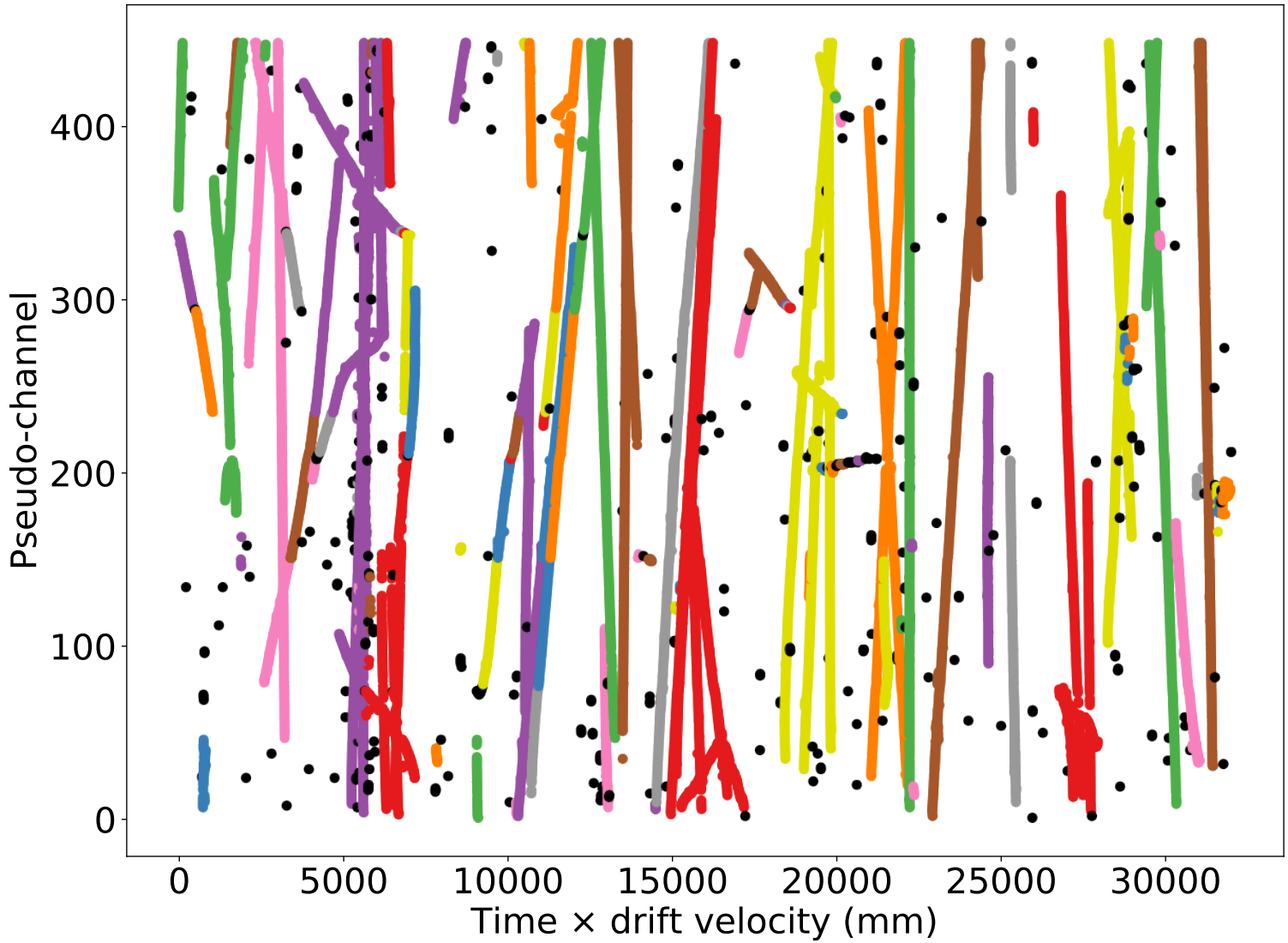

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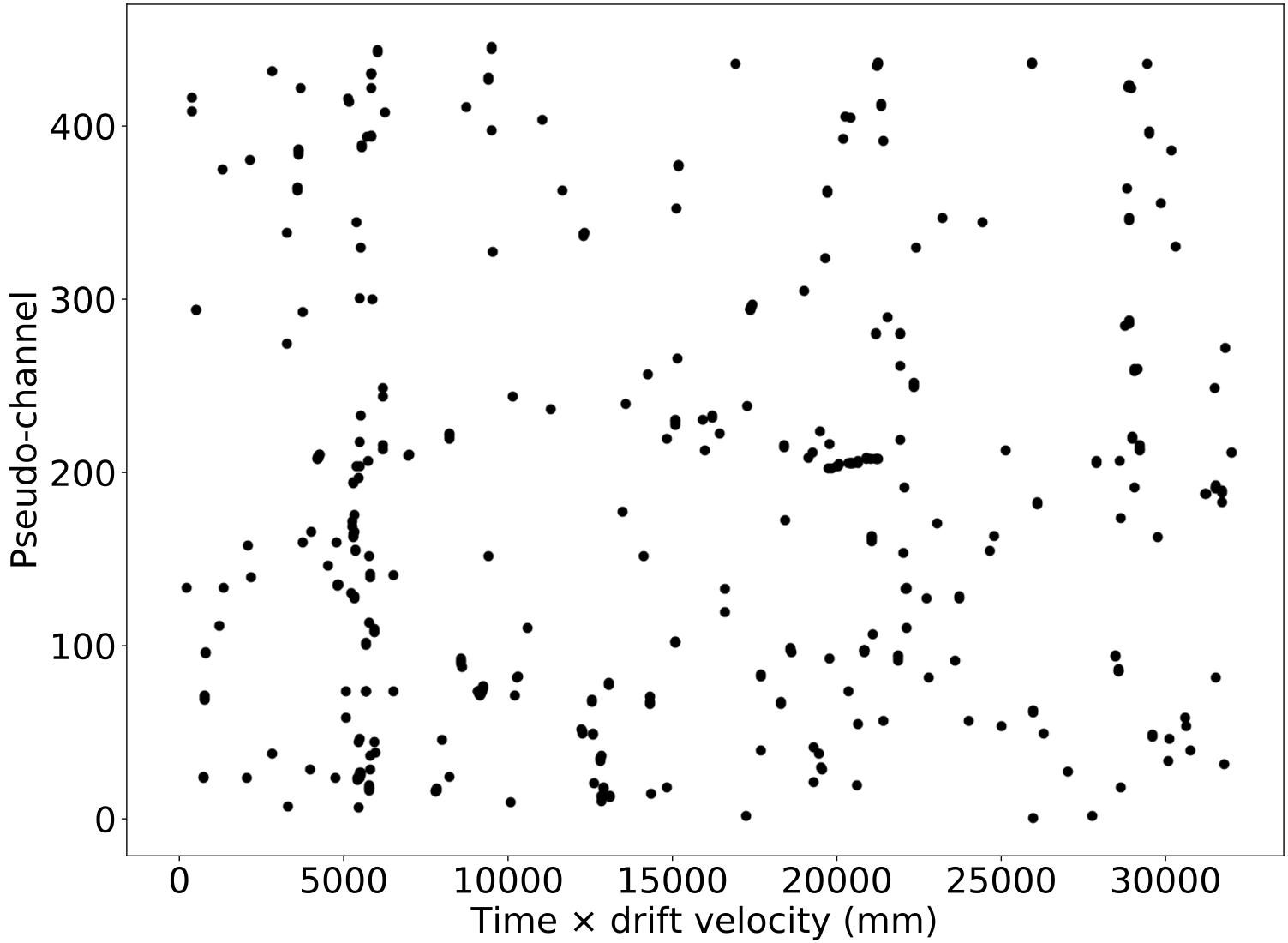

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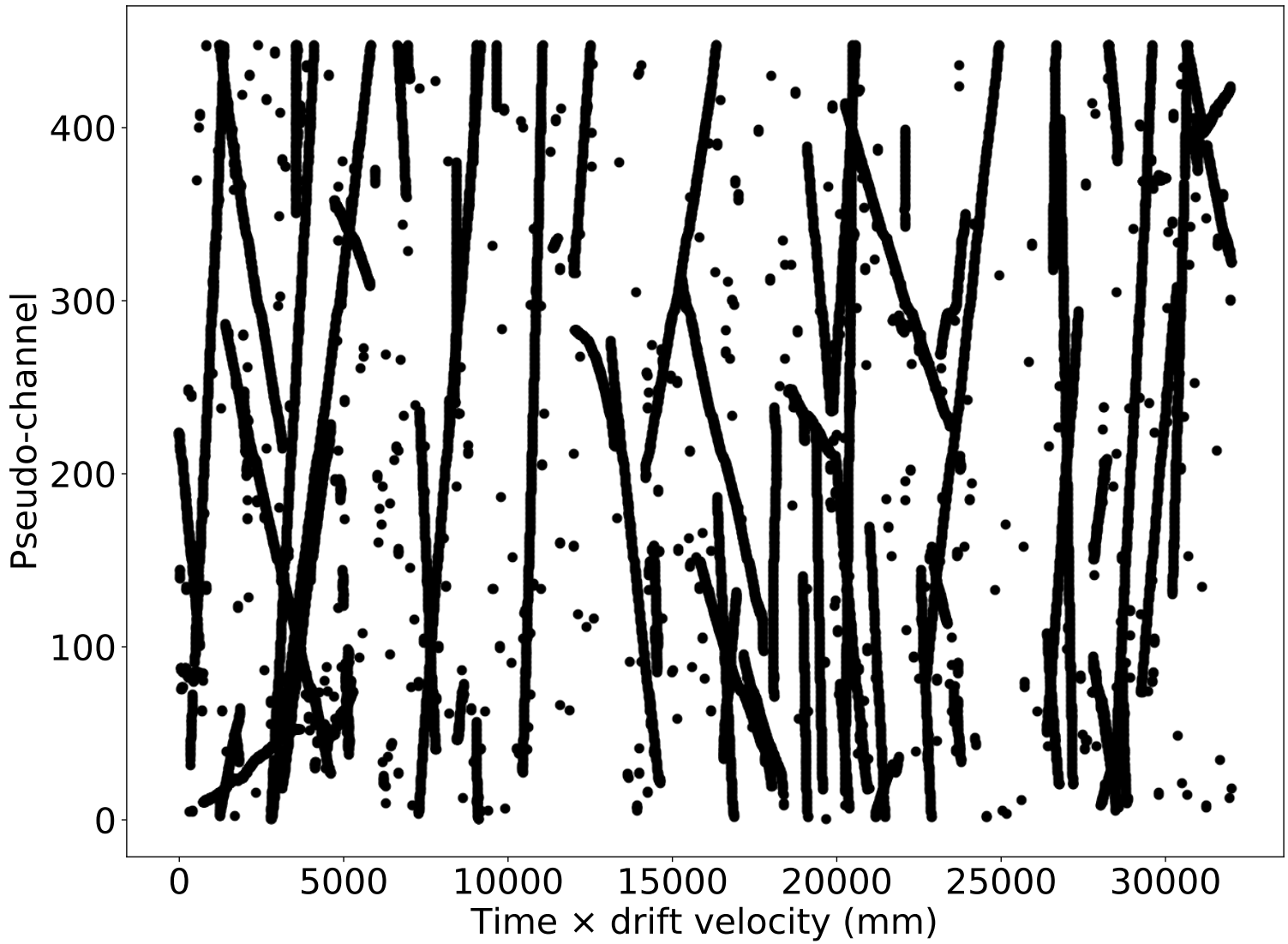

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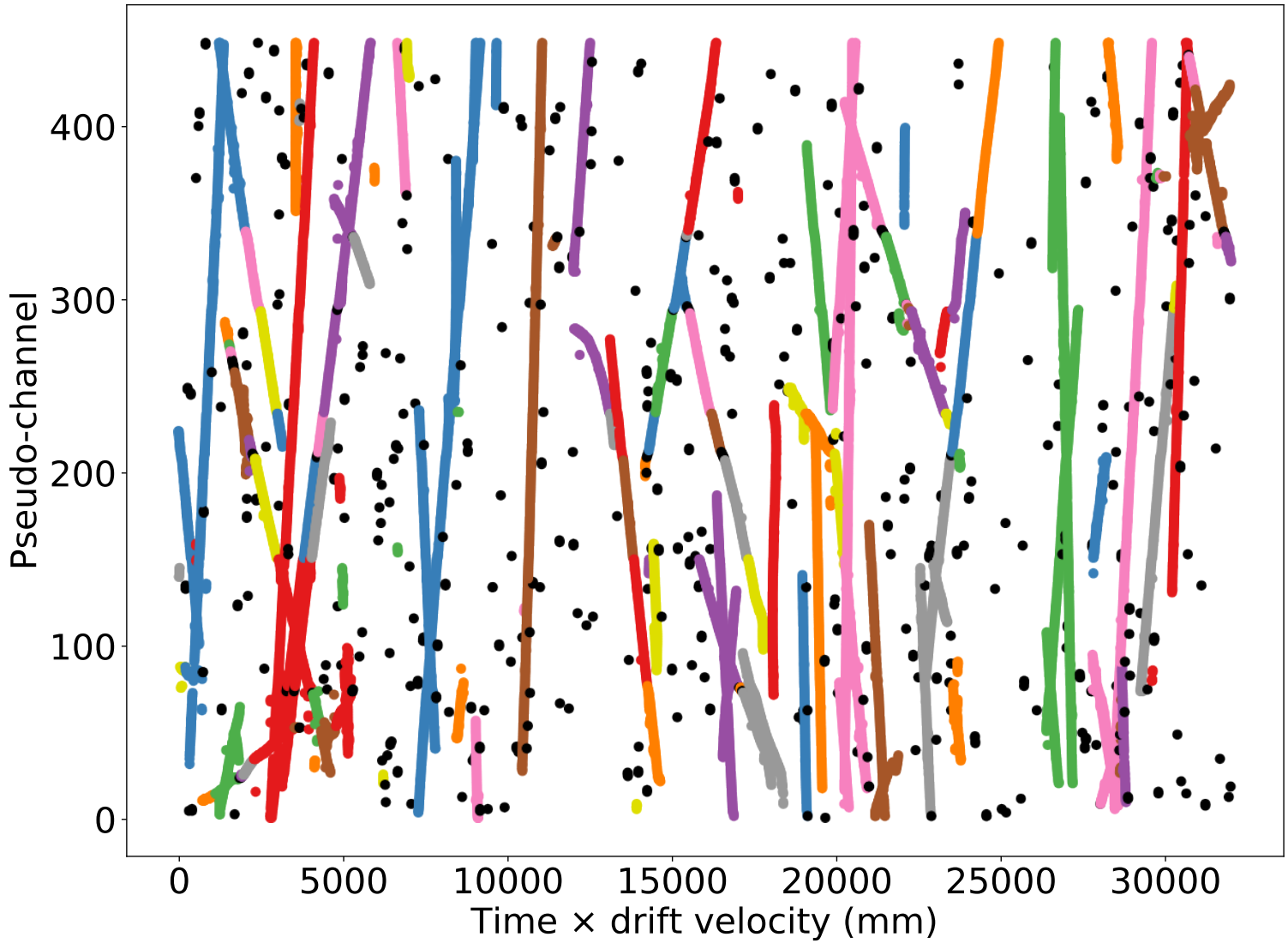

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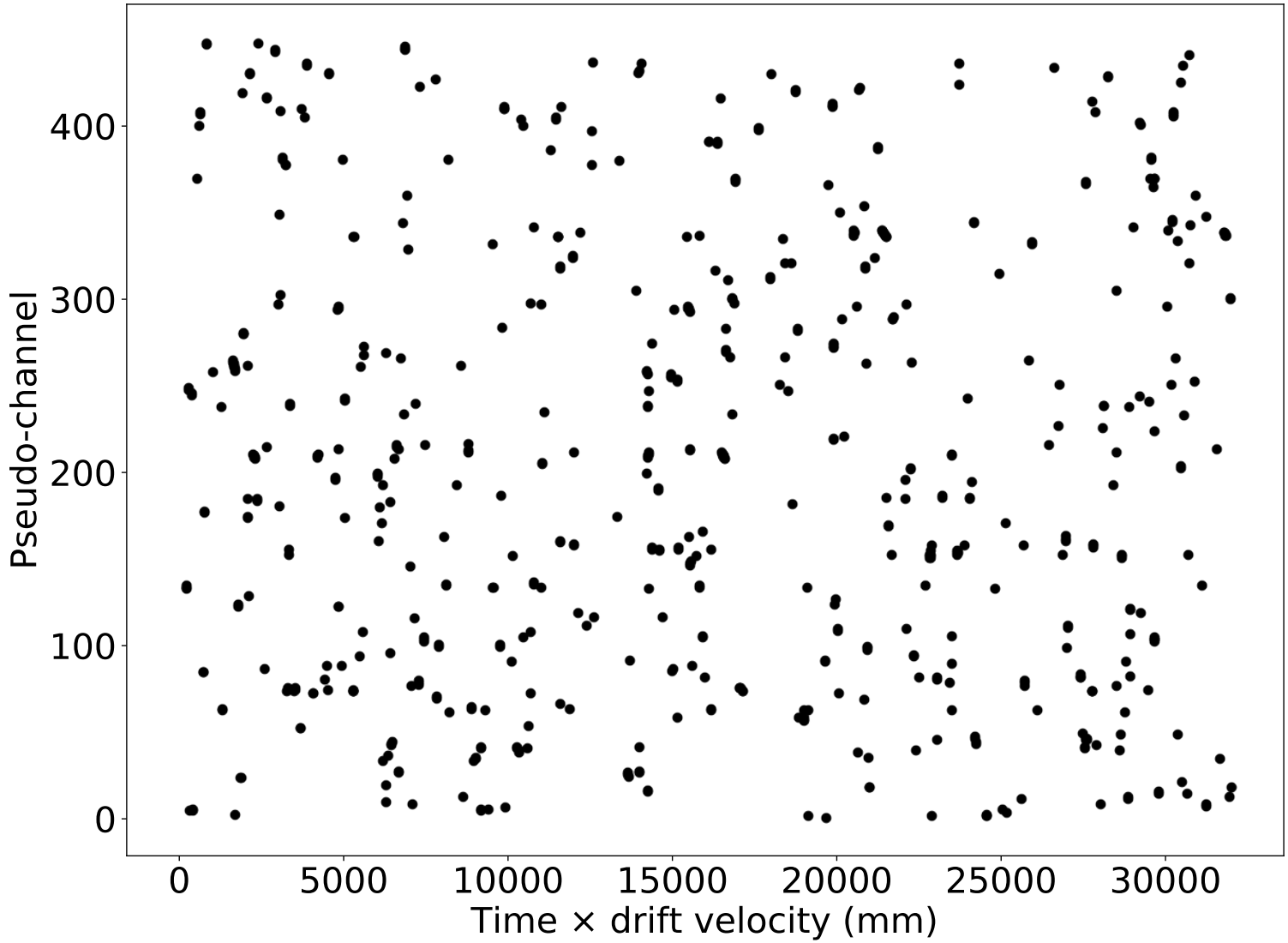

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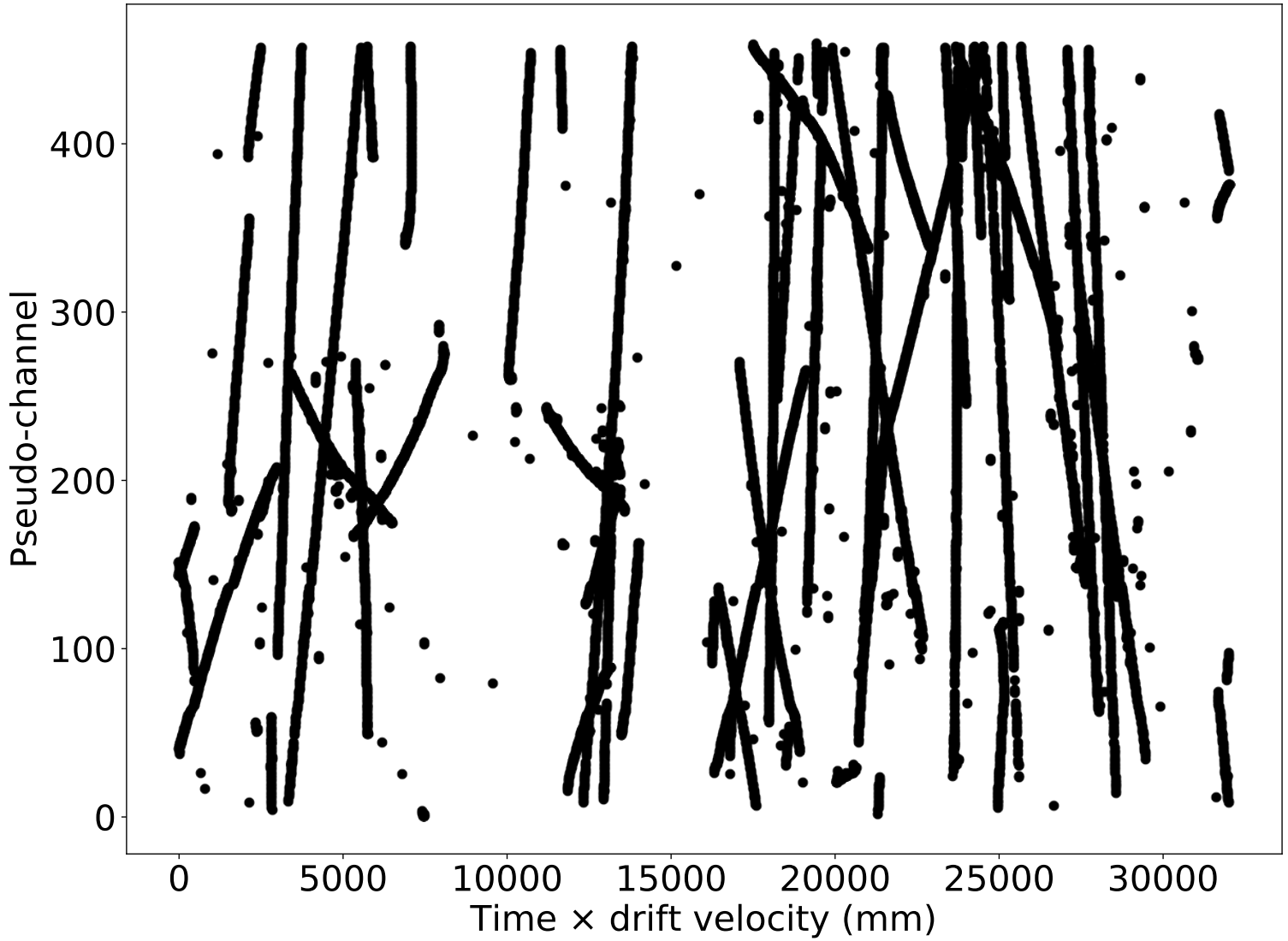
DBSCAN example 1. APA 1. Neutron source off



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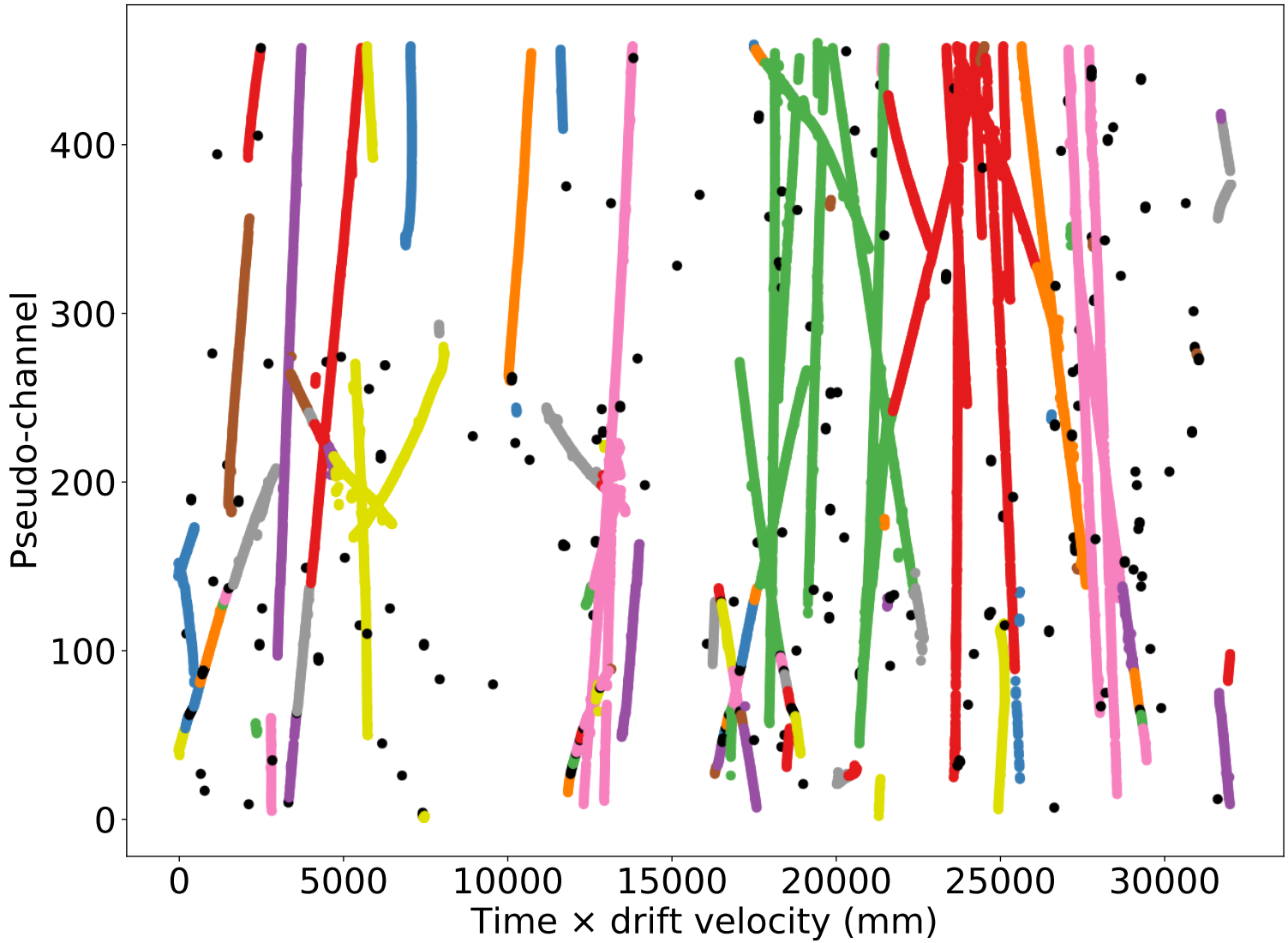

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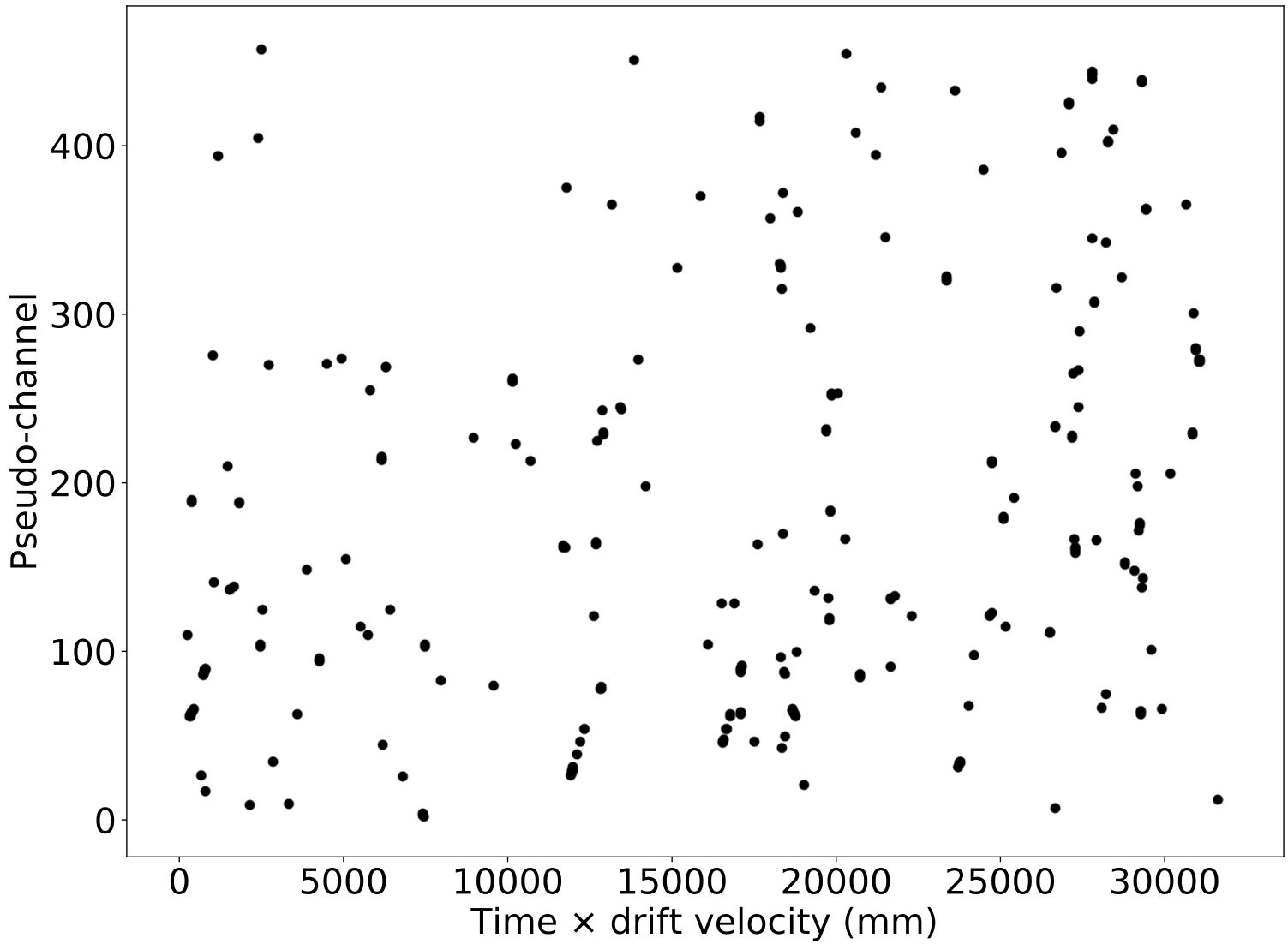

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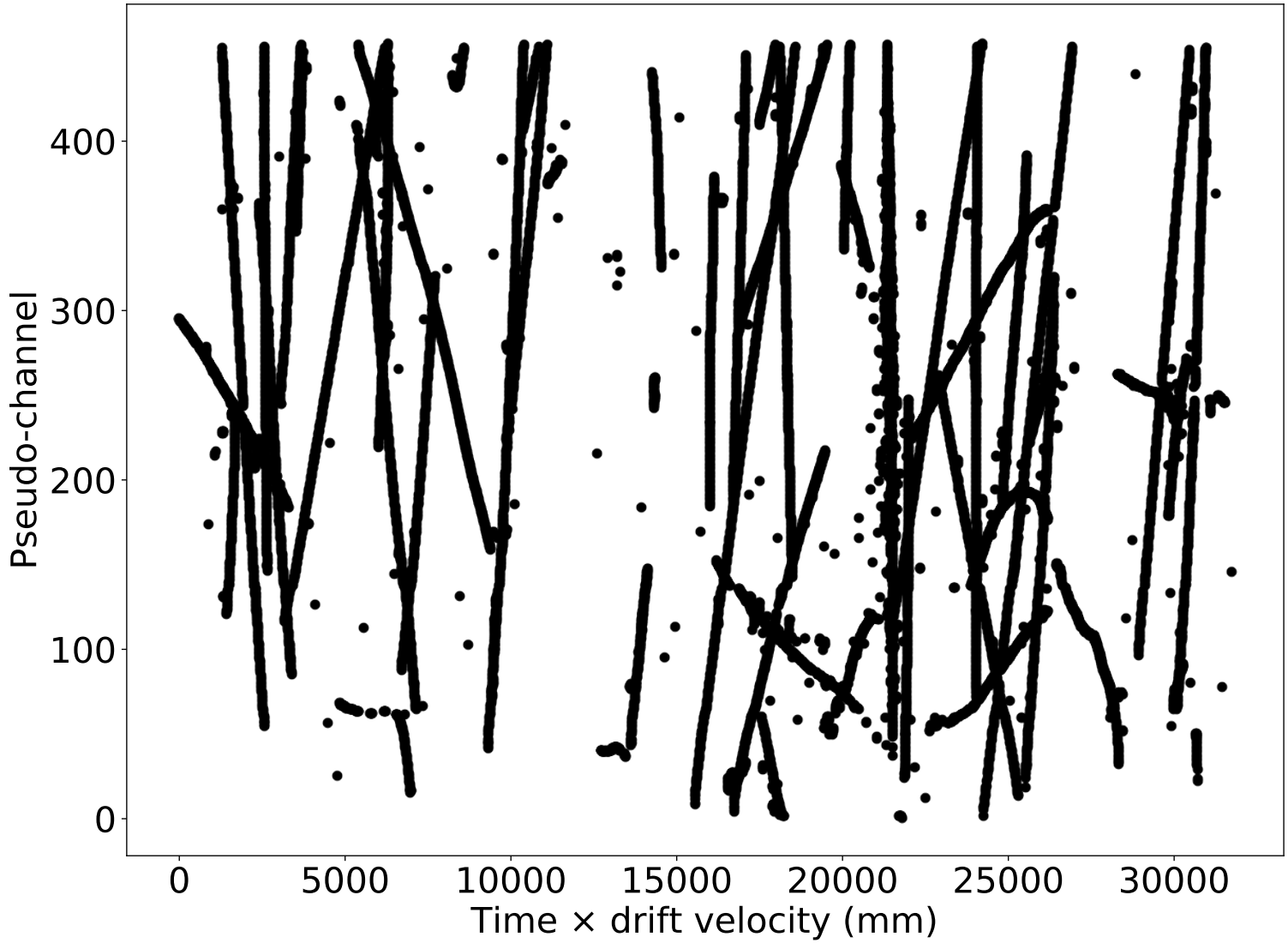

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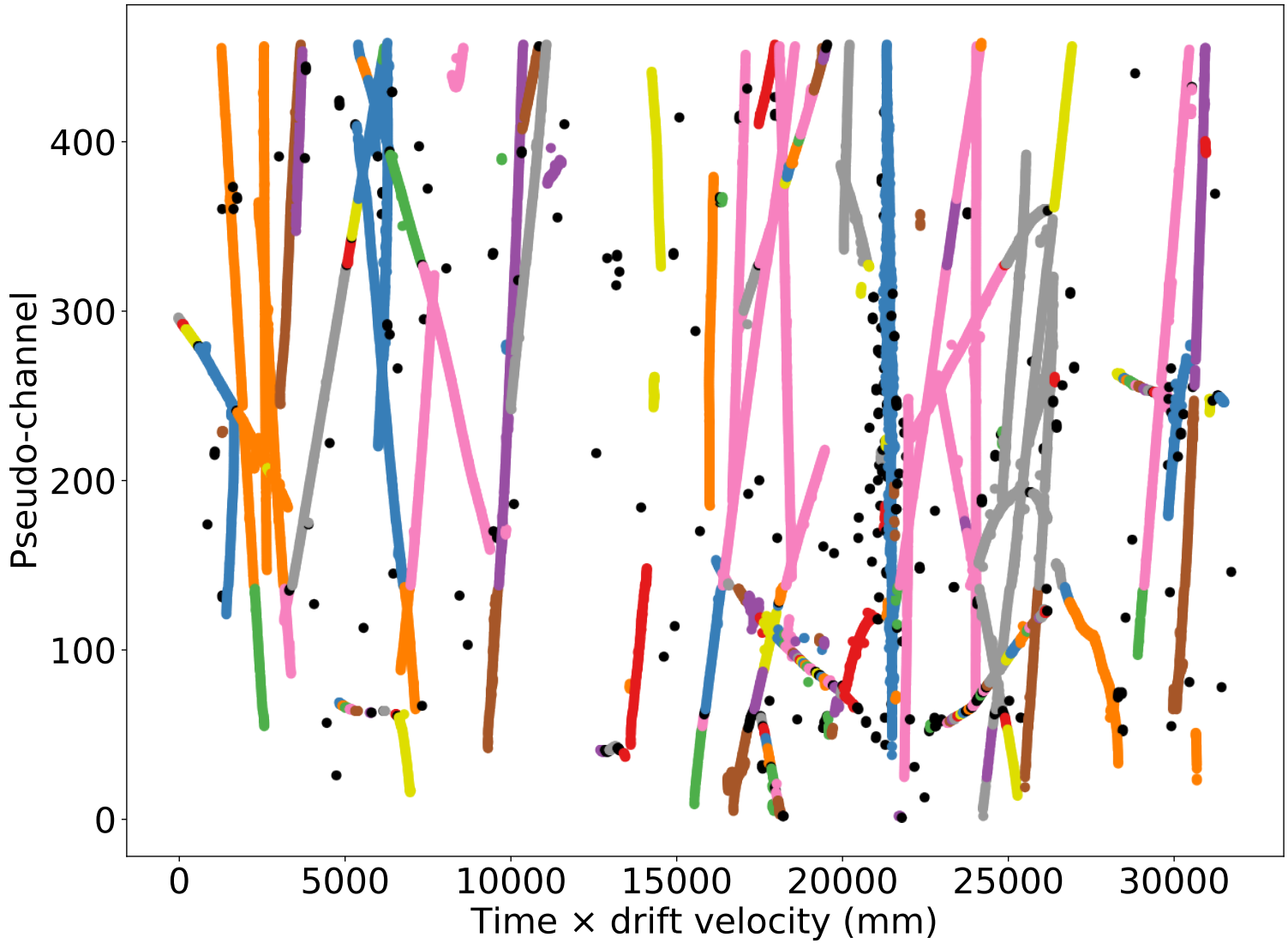

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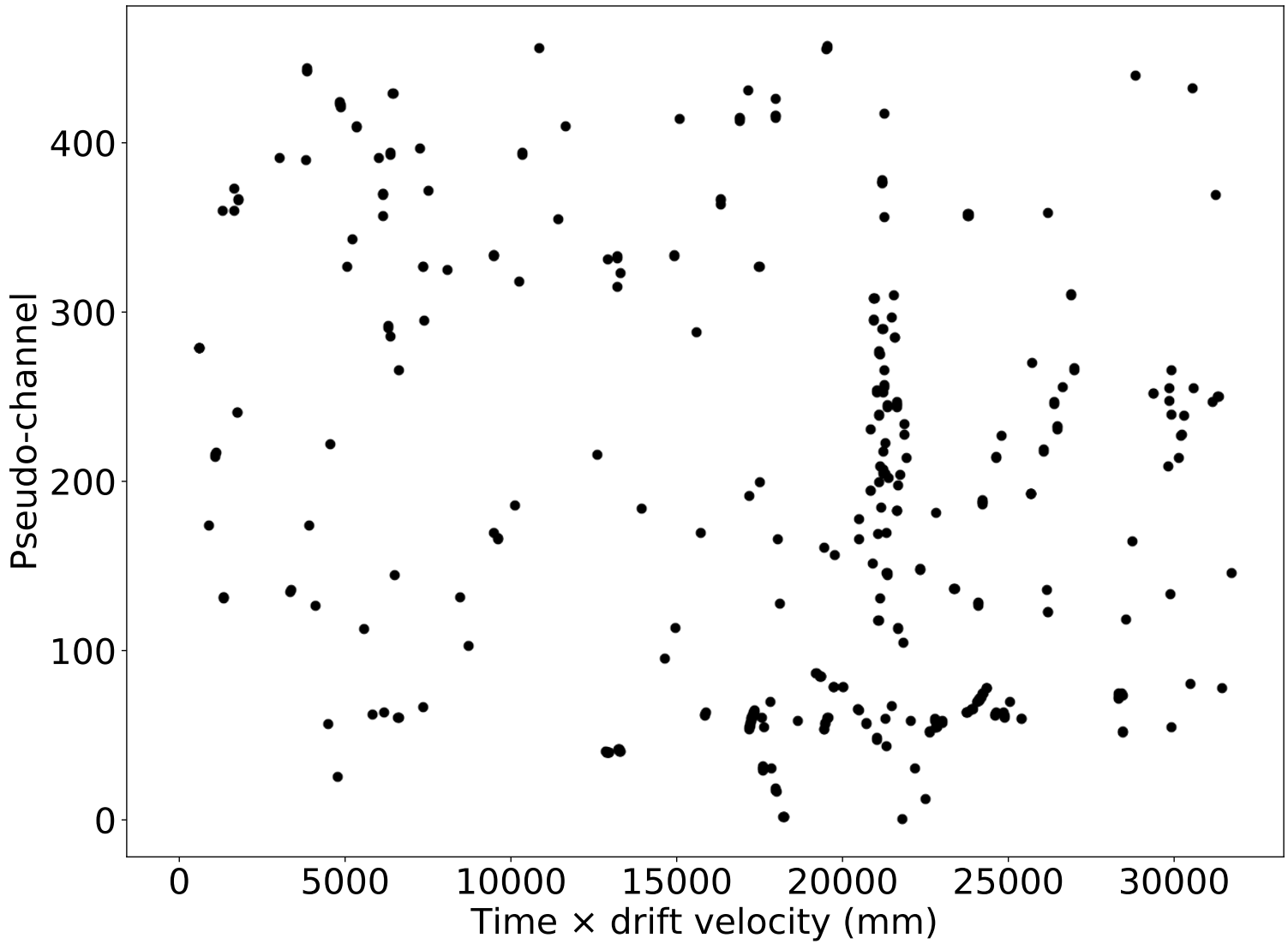
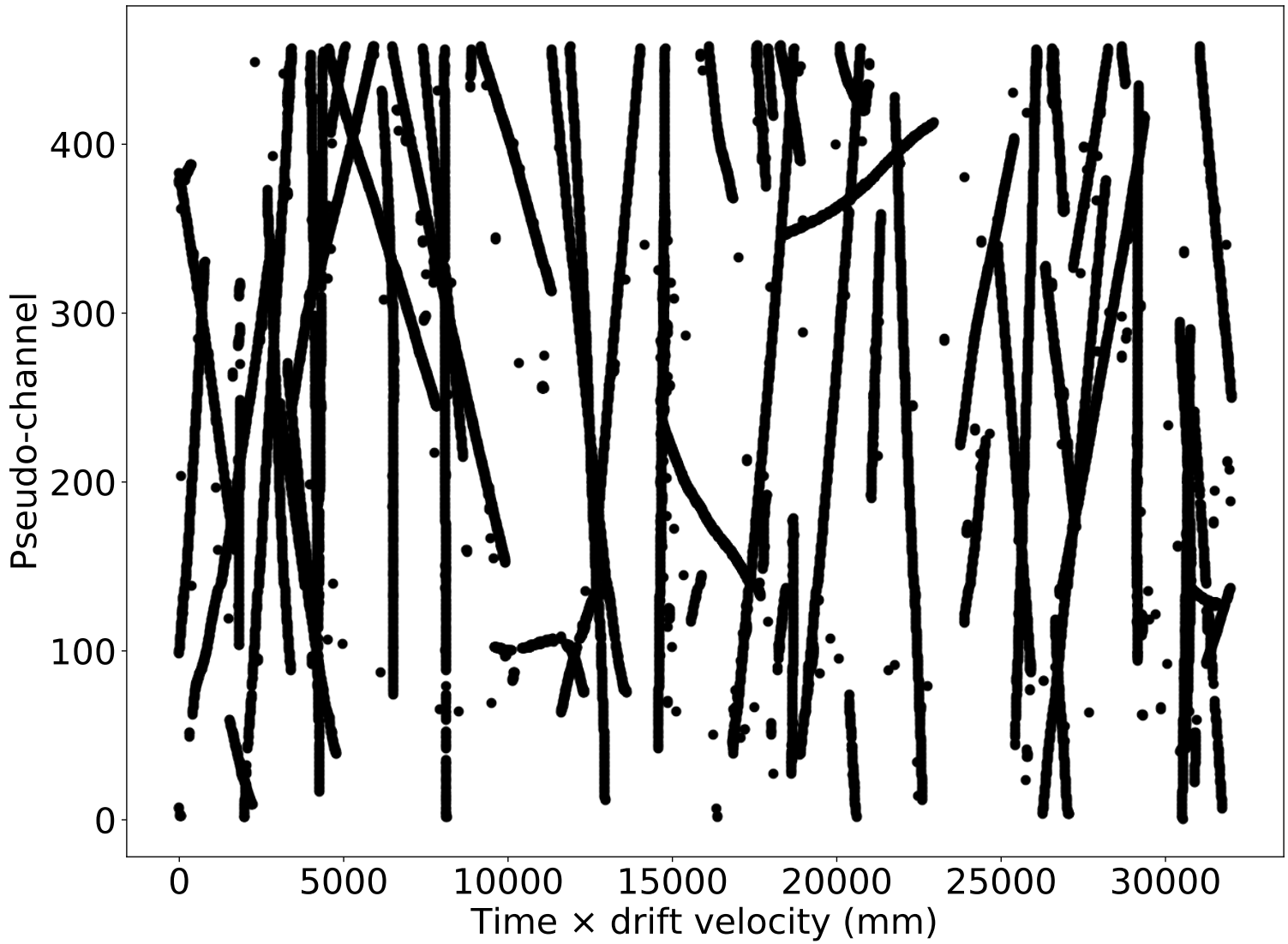
DBSCAN example 1. APA 1. Neutron source on



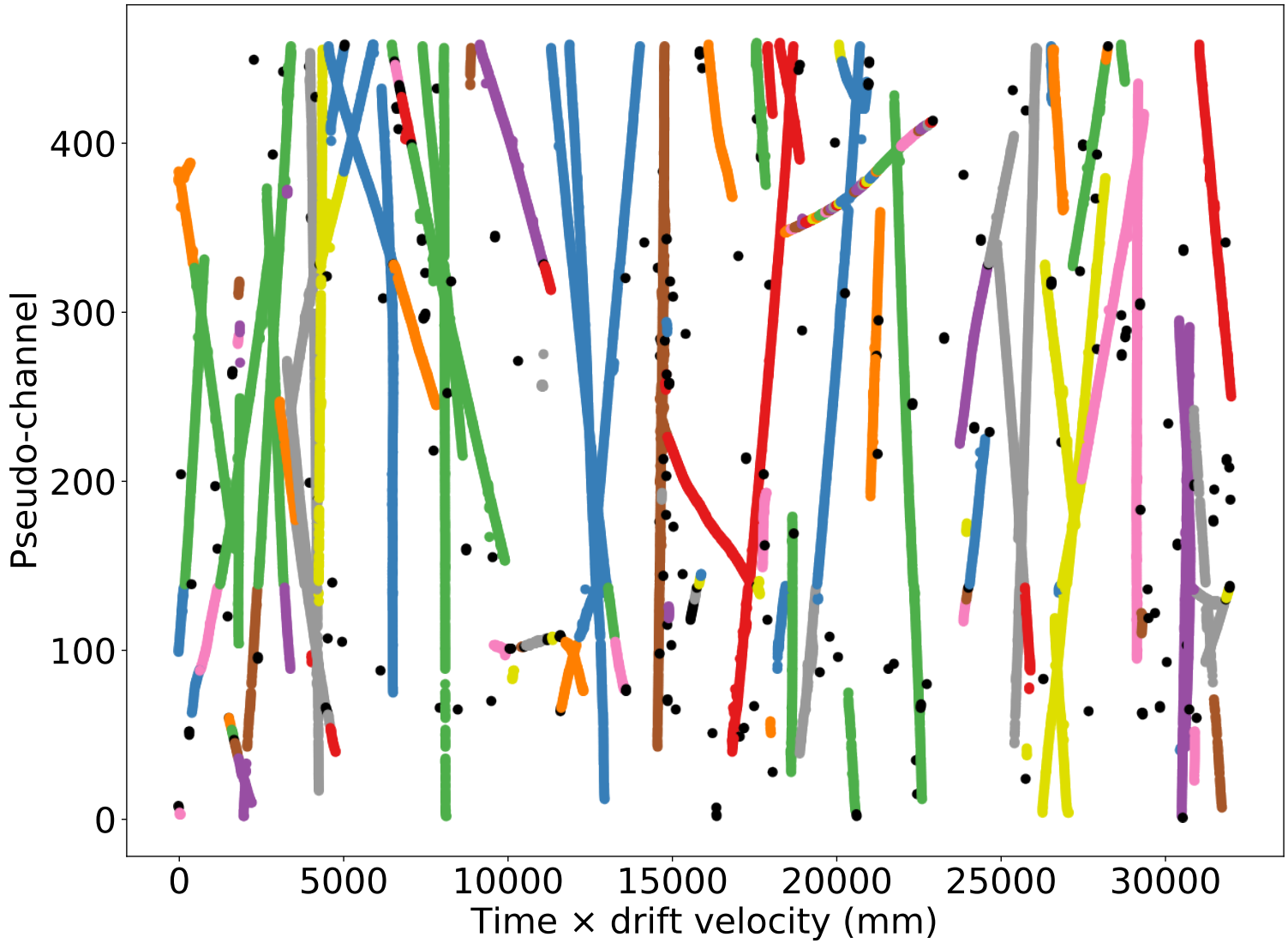
- Just the unclustered hits (ie, neutron candidates)

DBSCAN example 2. APA 1. Neutron source off



- Before DBSCAN

DBSCAN example 2. APA 1. Neutron source off



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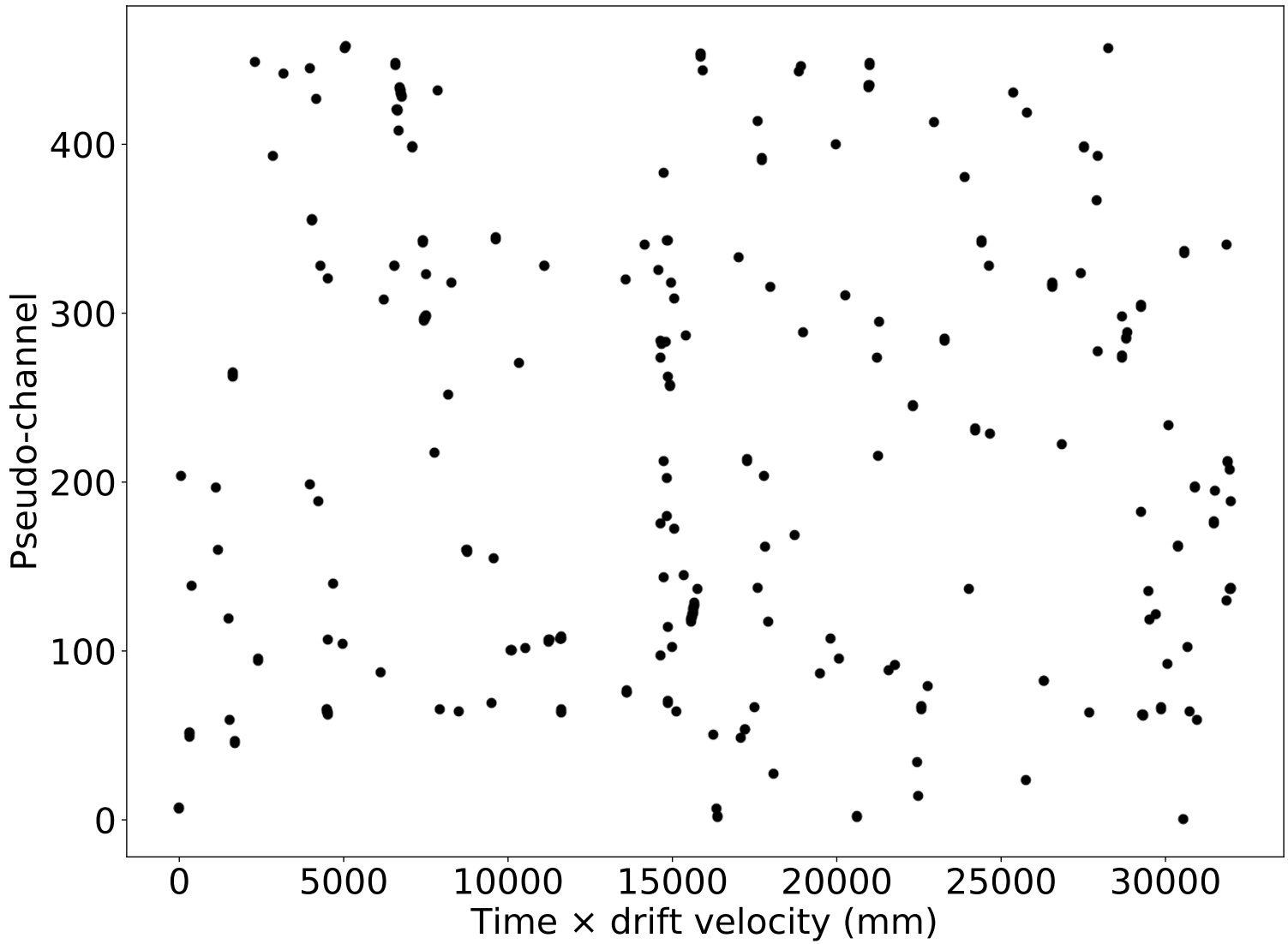

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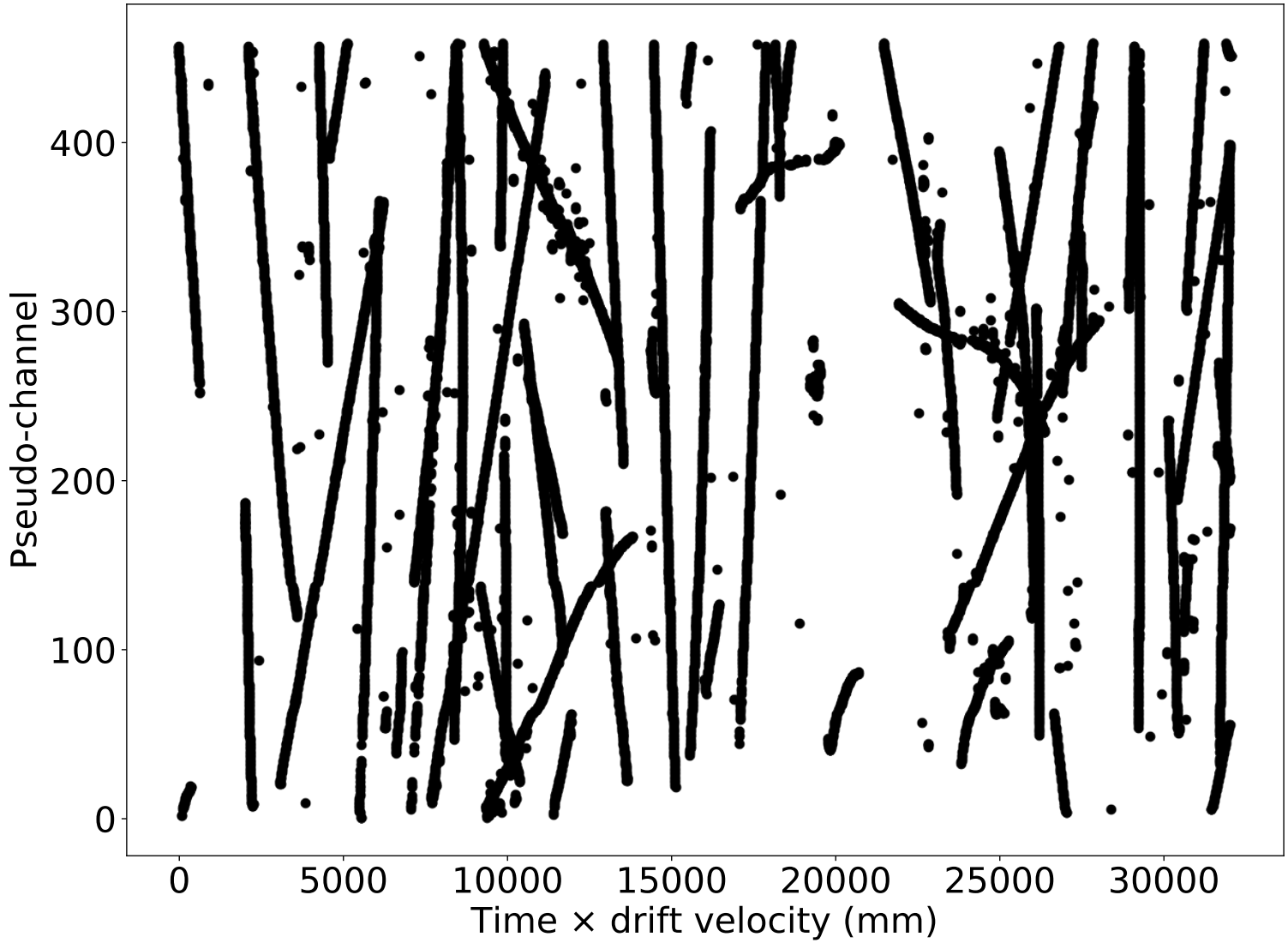
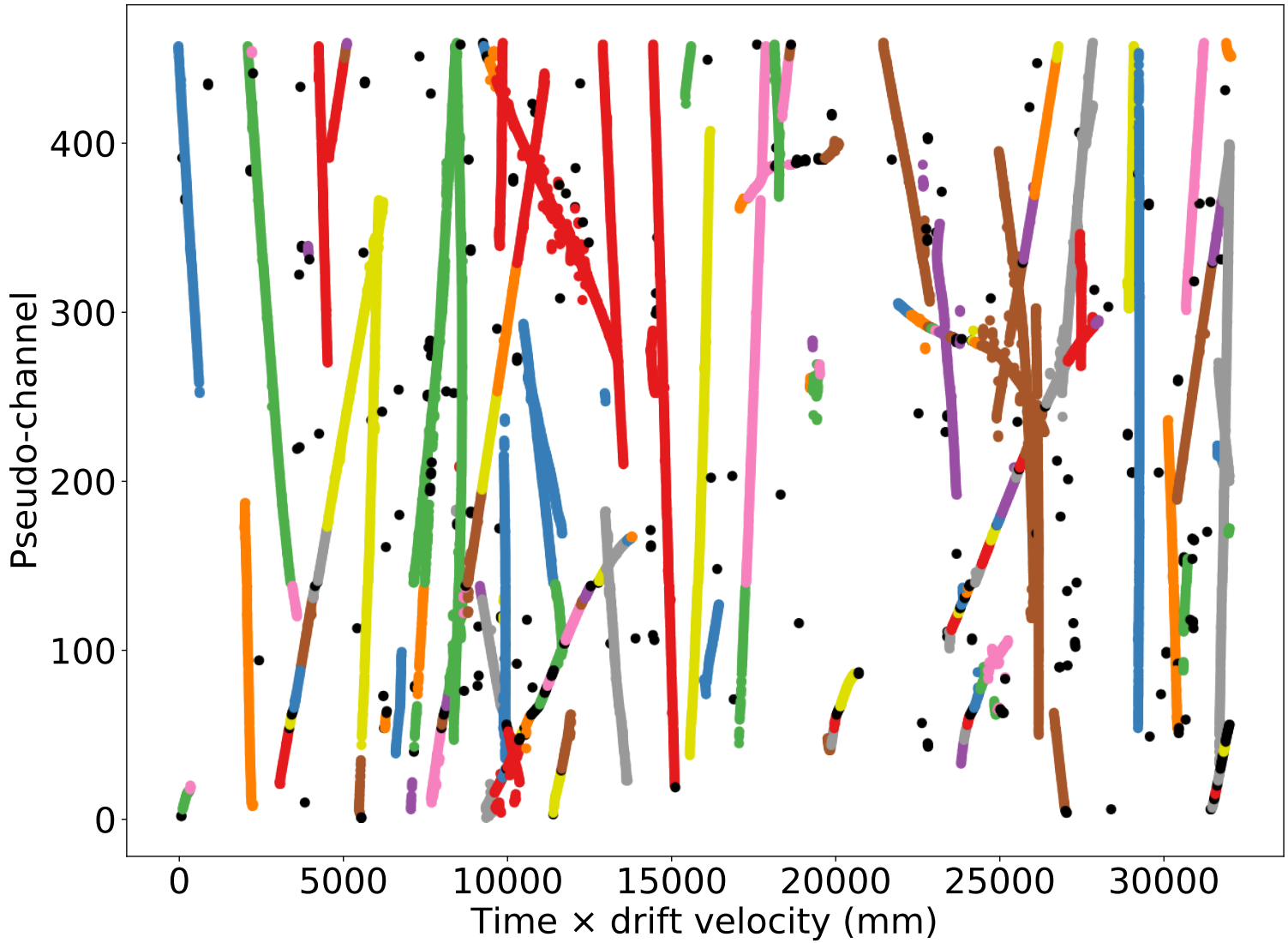


- Before DBSCAN

DBSCAN example 2. APA 1. Neutron source on



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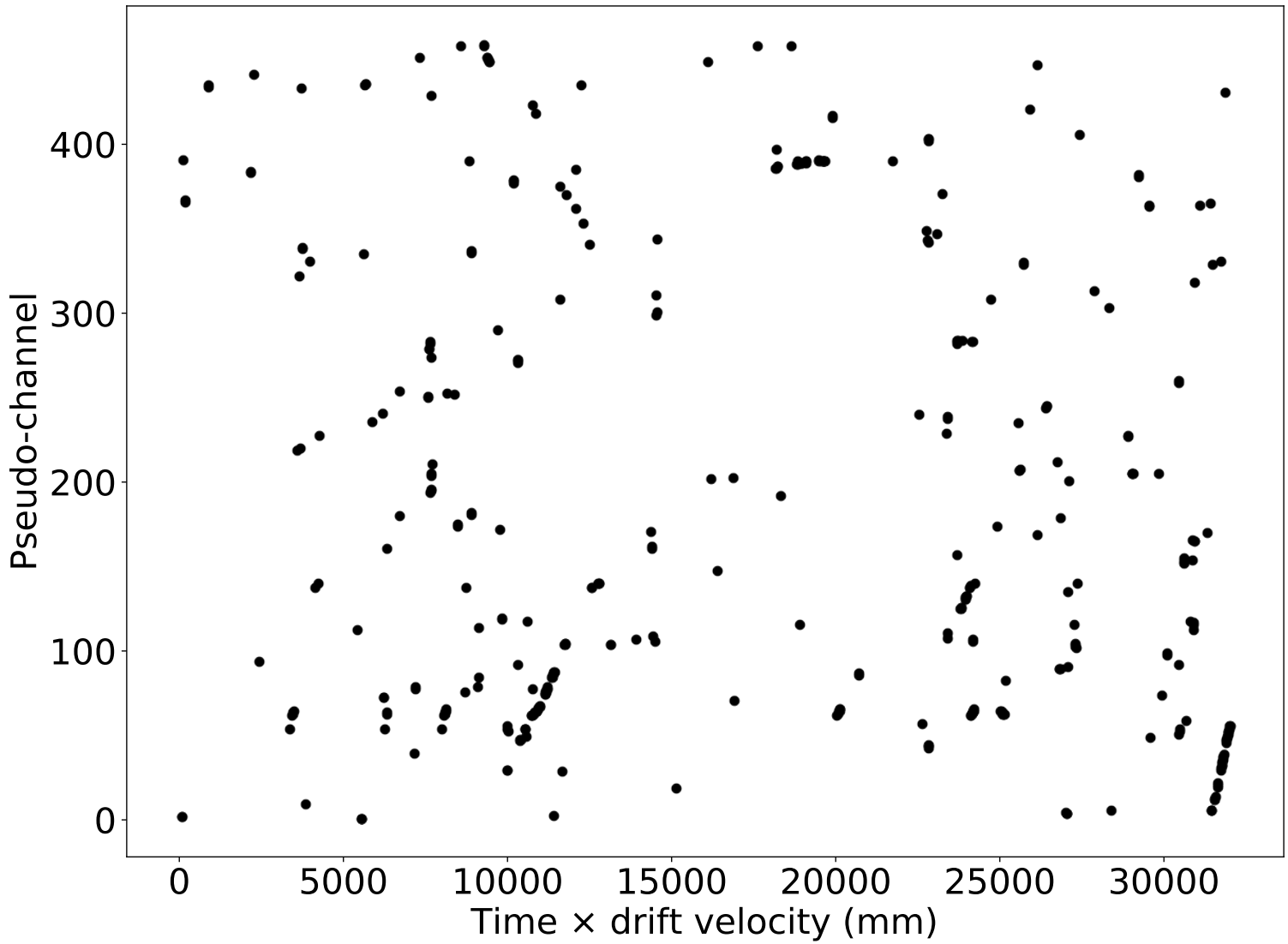

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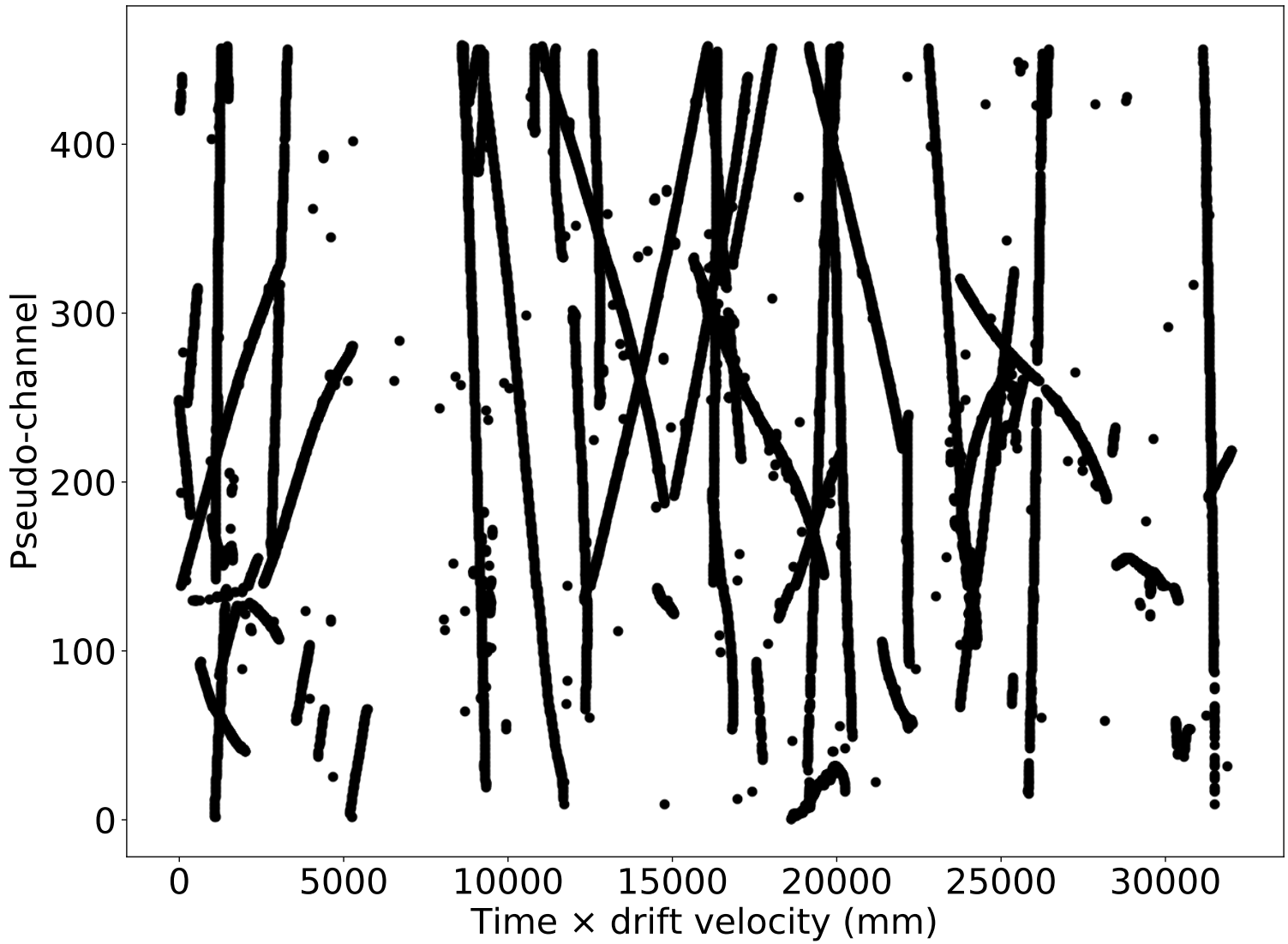
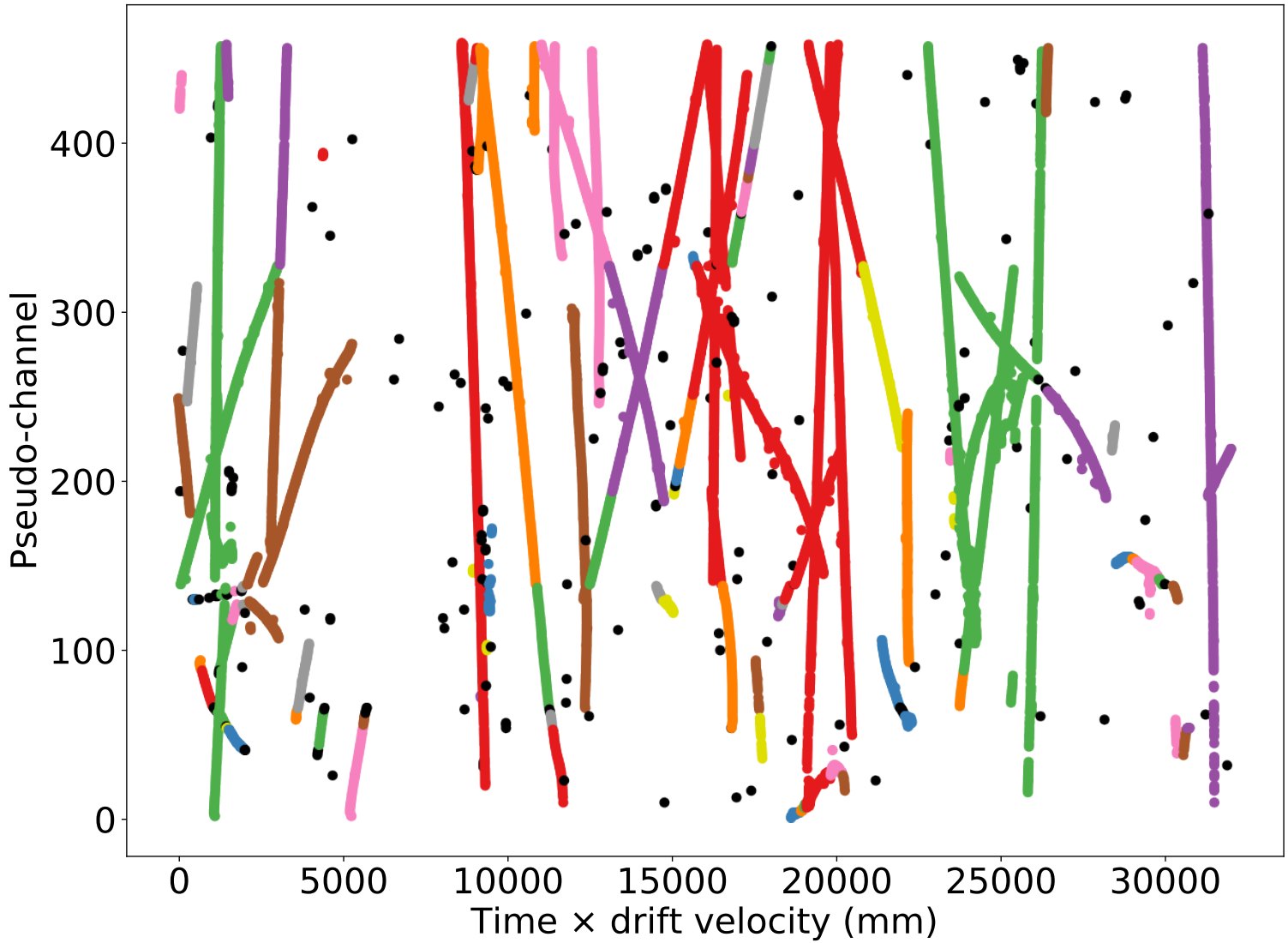
DBSCAN example 3. APA 1. Neutron source off



- Before DBSCAN

DBSCAN example 3. APA 1. Neutron source off



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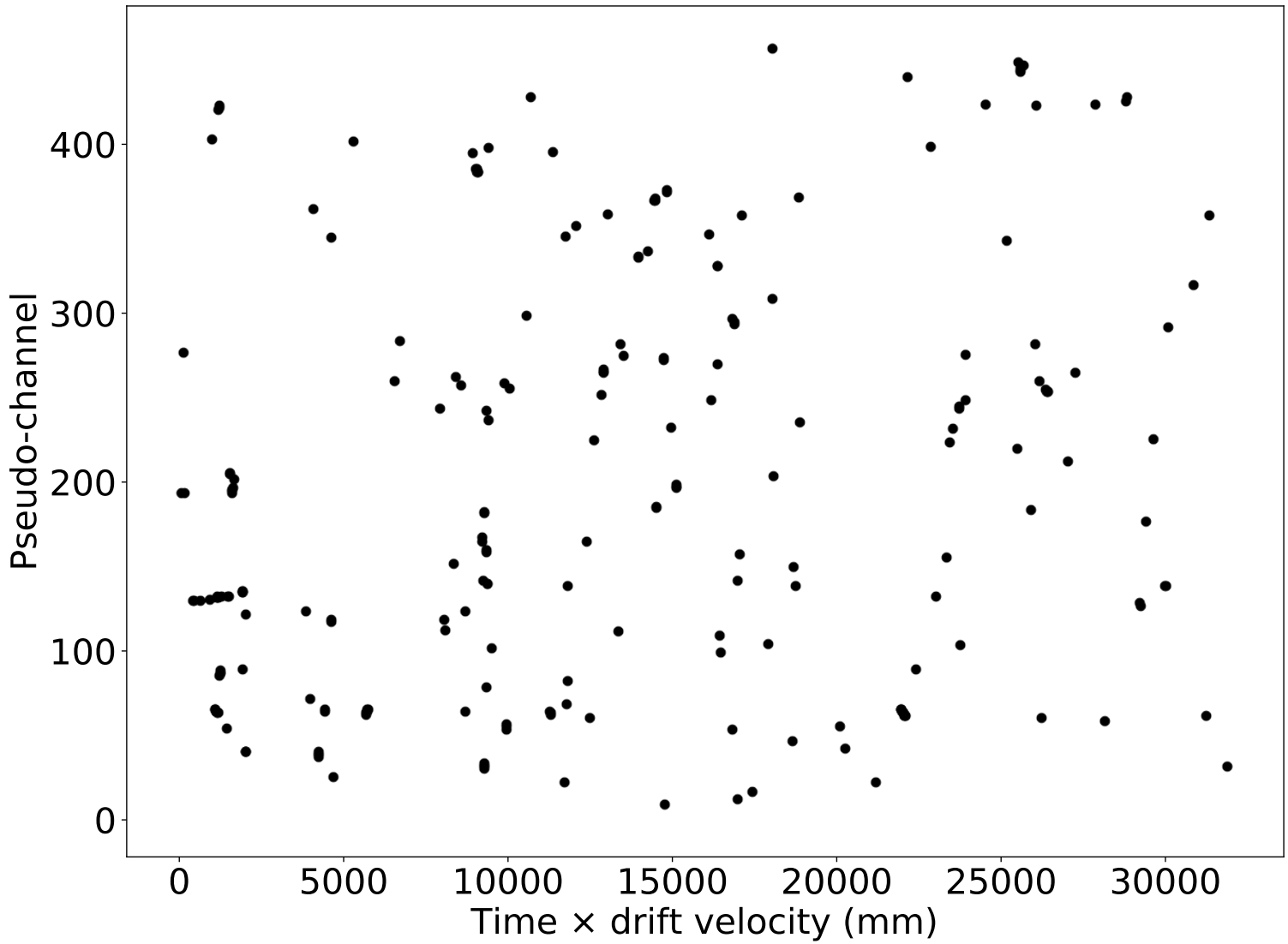

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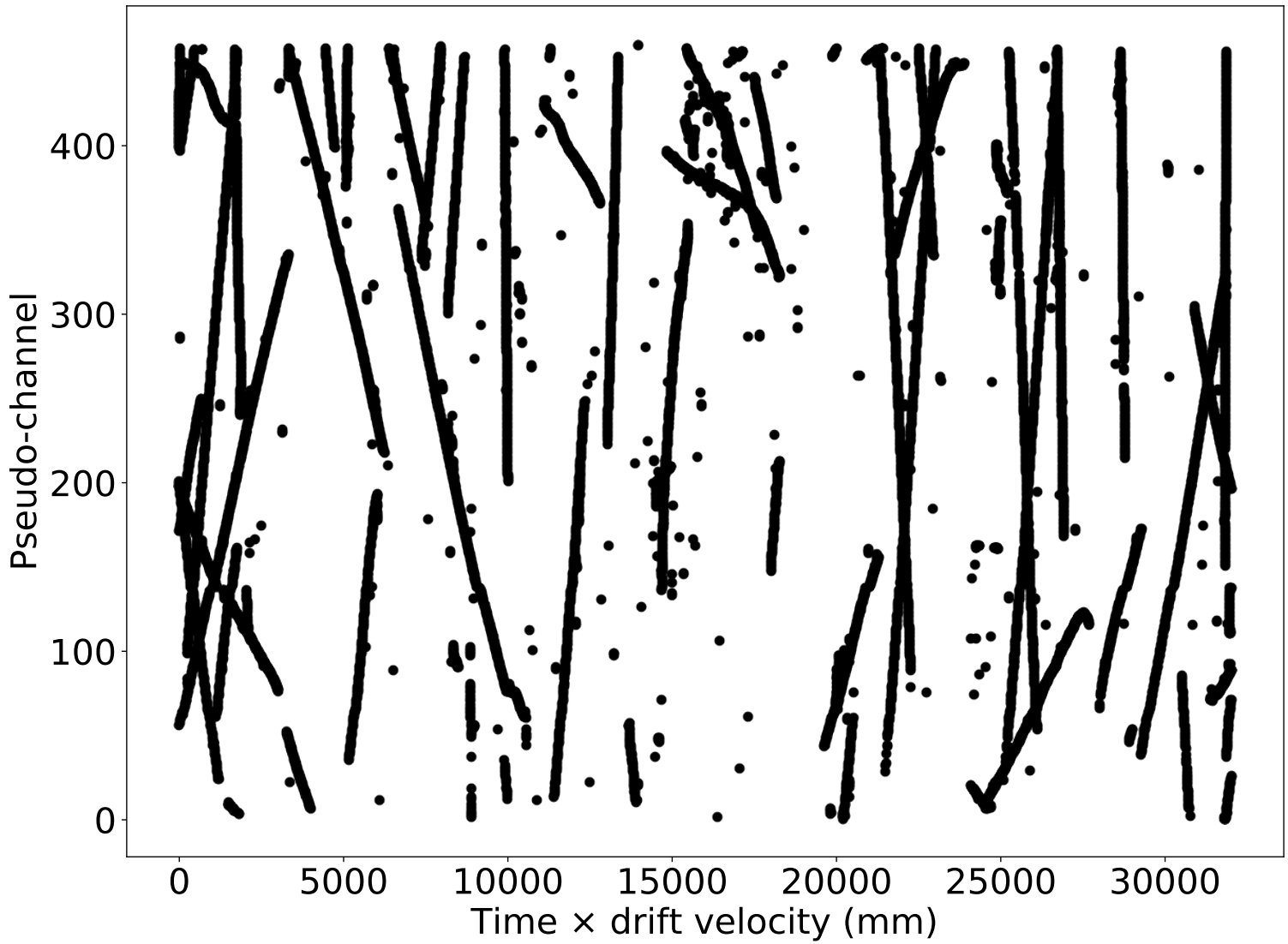

- Before DBSCAN

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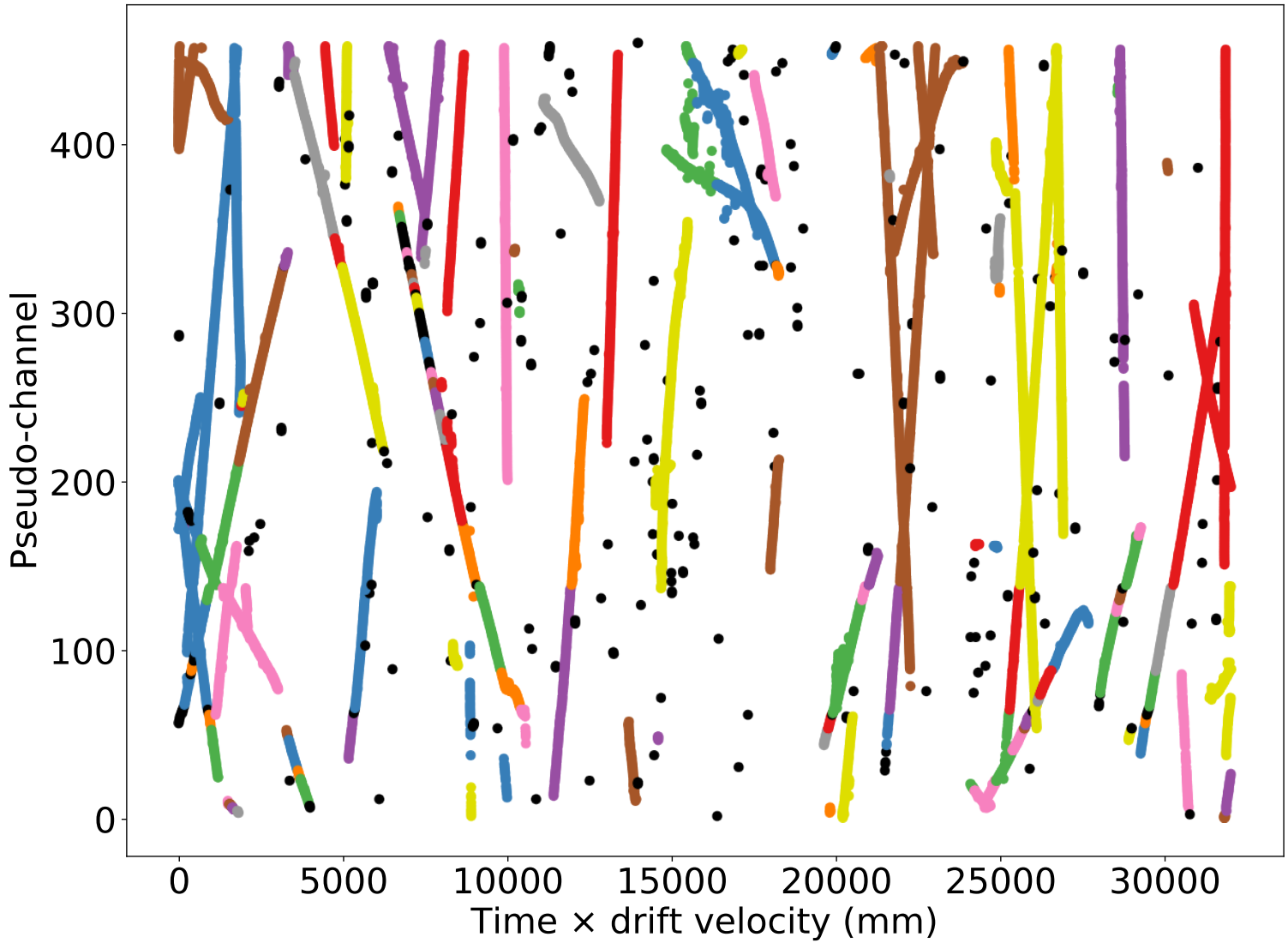

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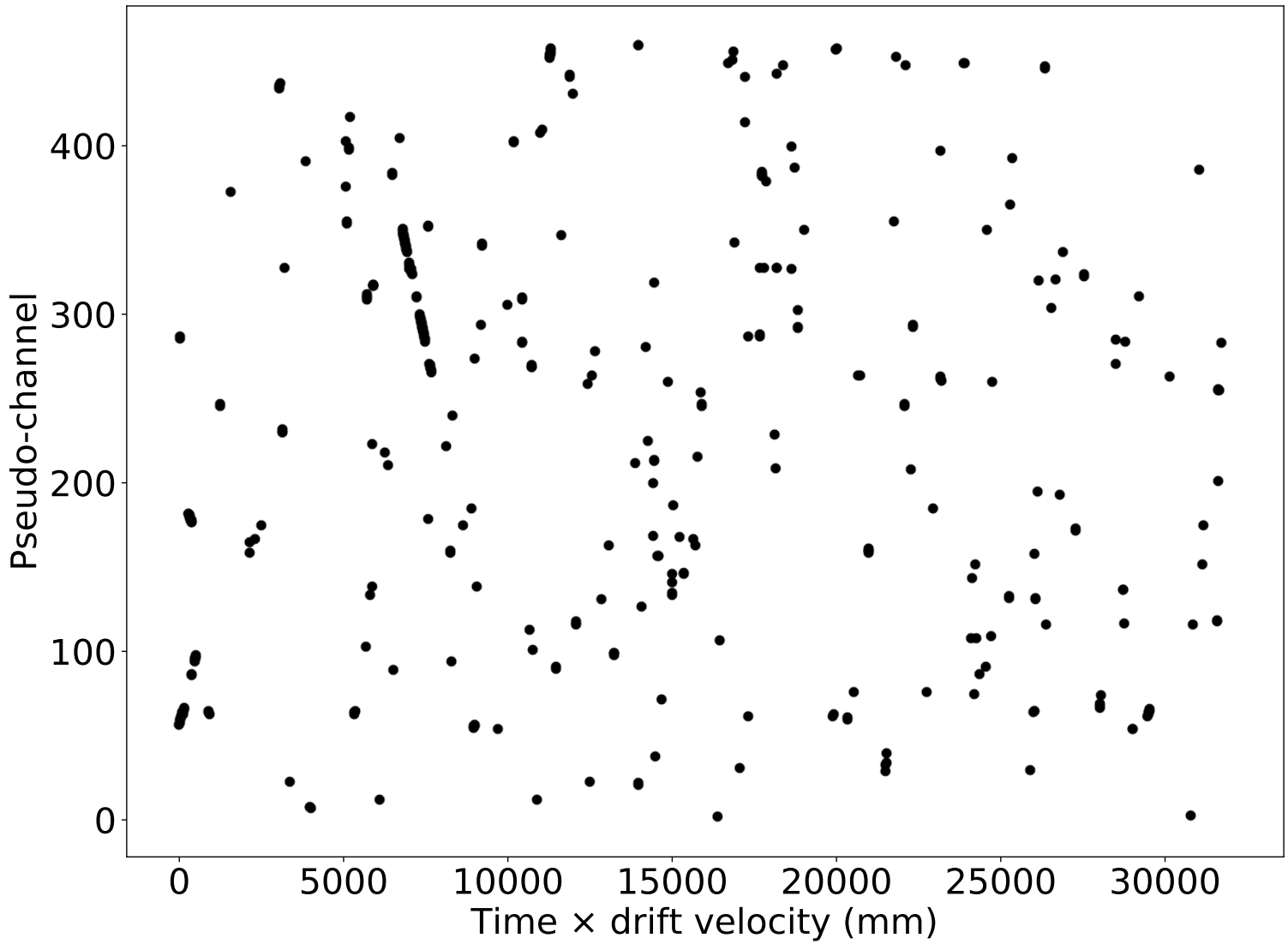

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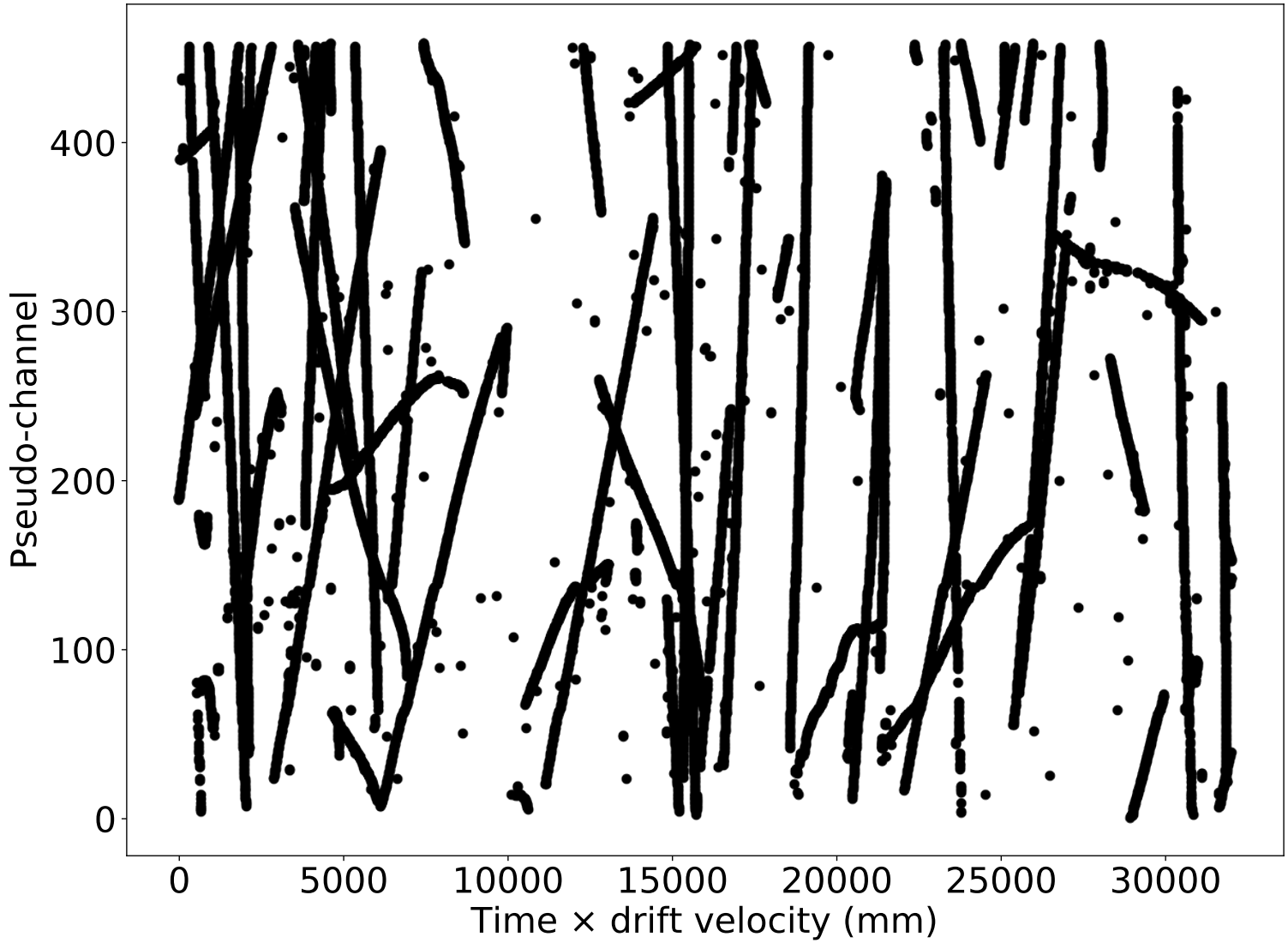
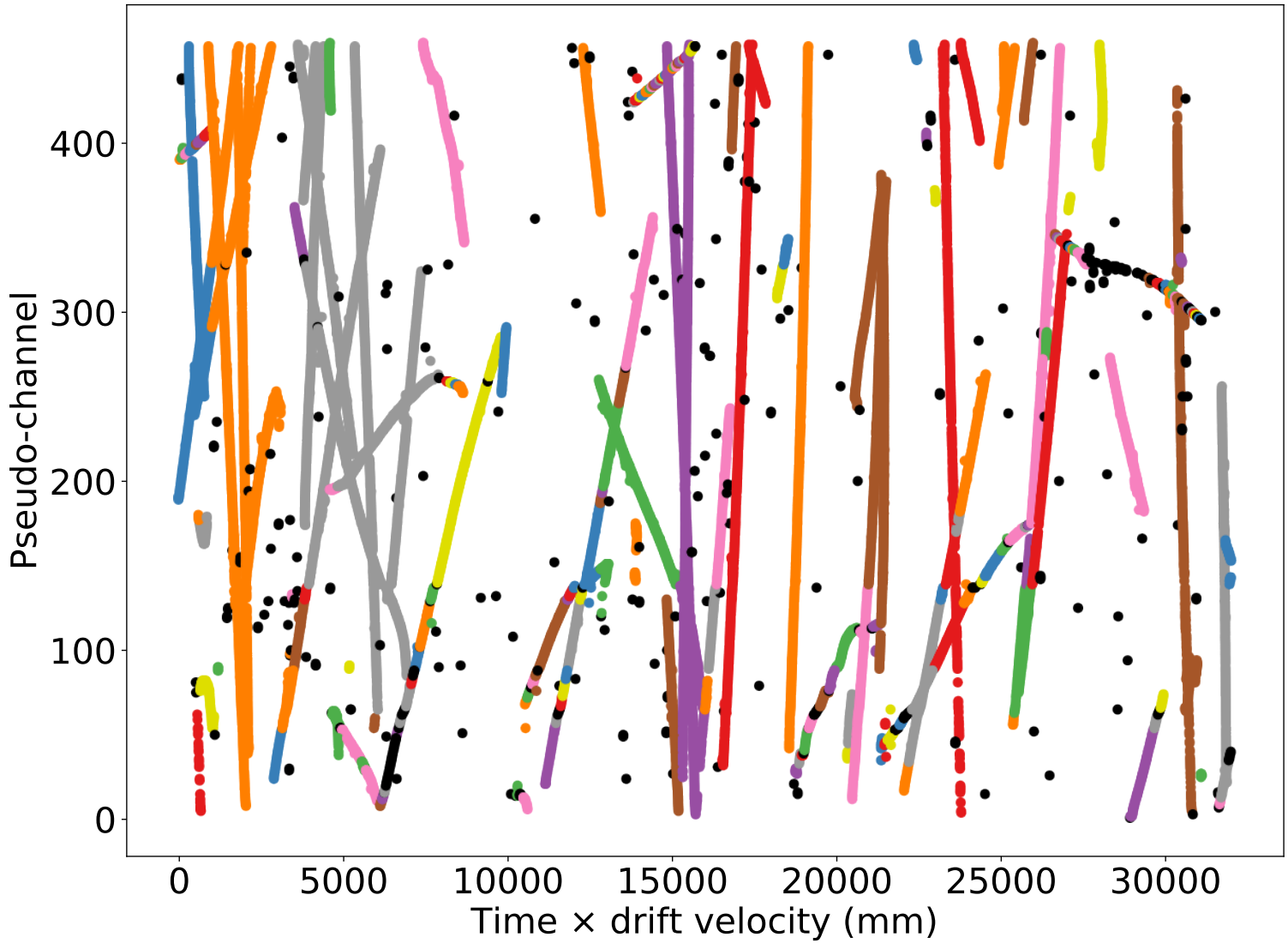
DBSCAN example 0. APA 1. Neutron source off



- Before DBSCAN

DBSCAN example 0. APA 1. Neutron source off



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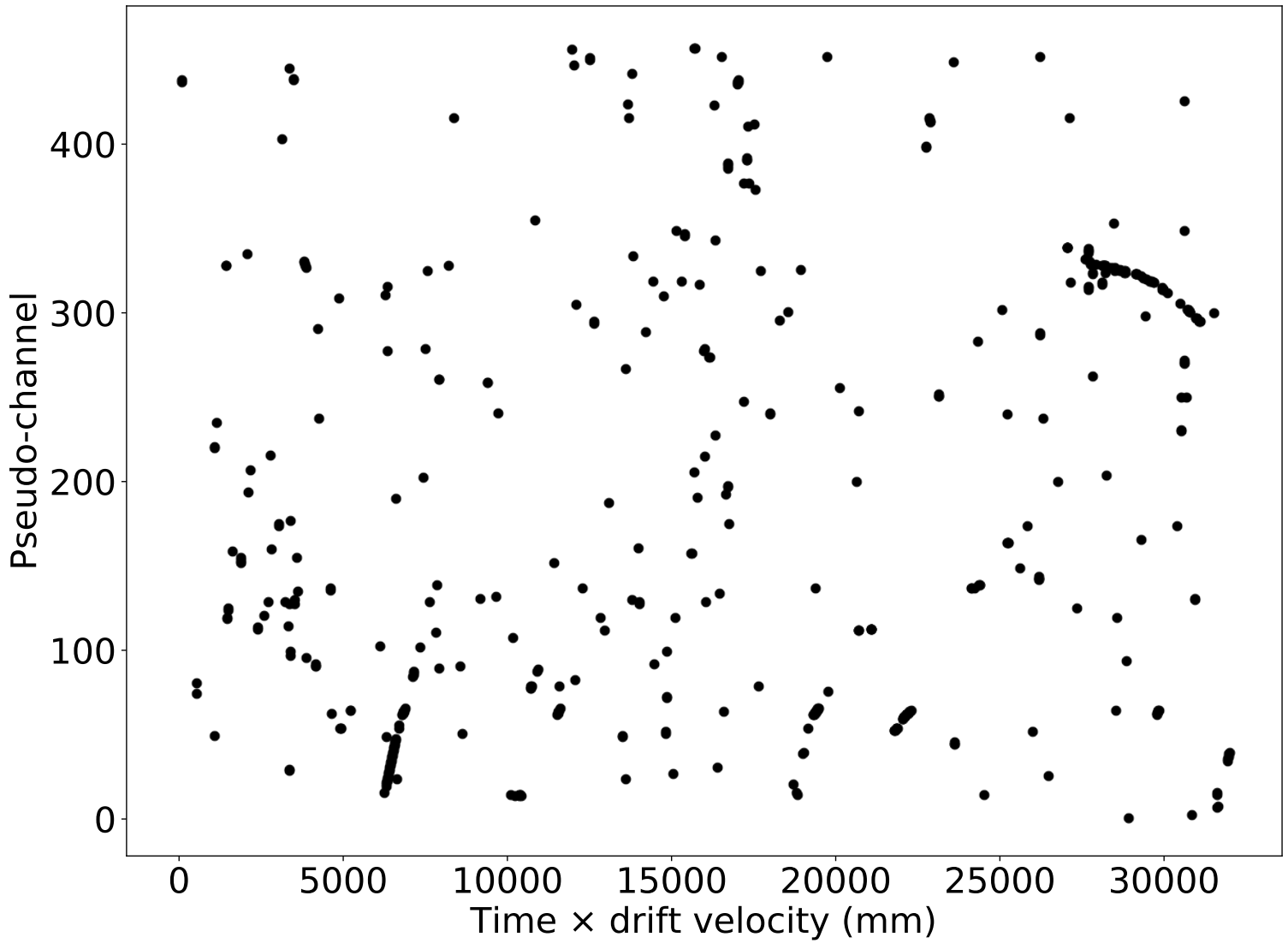

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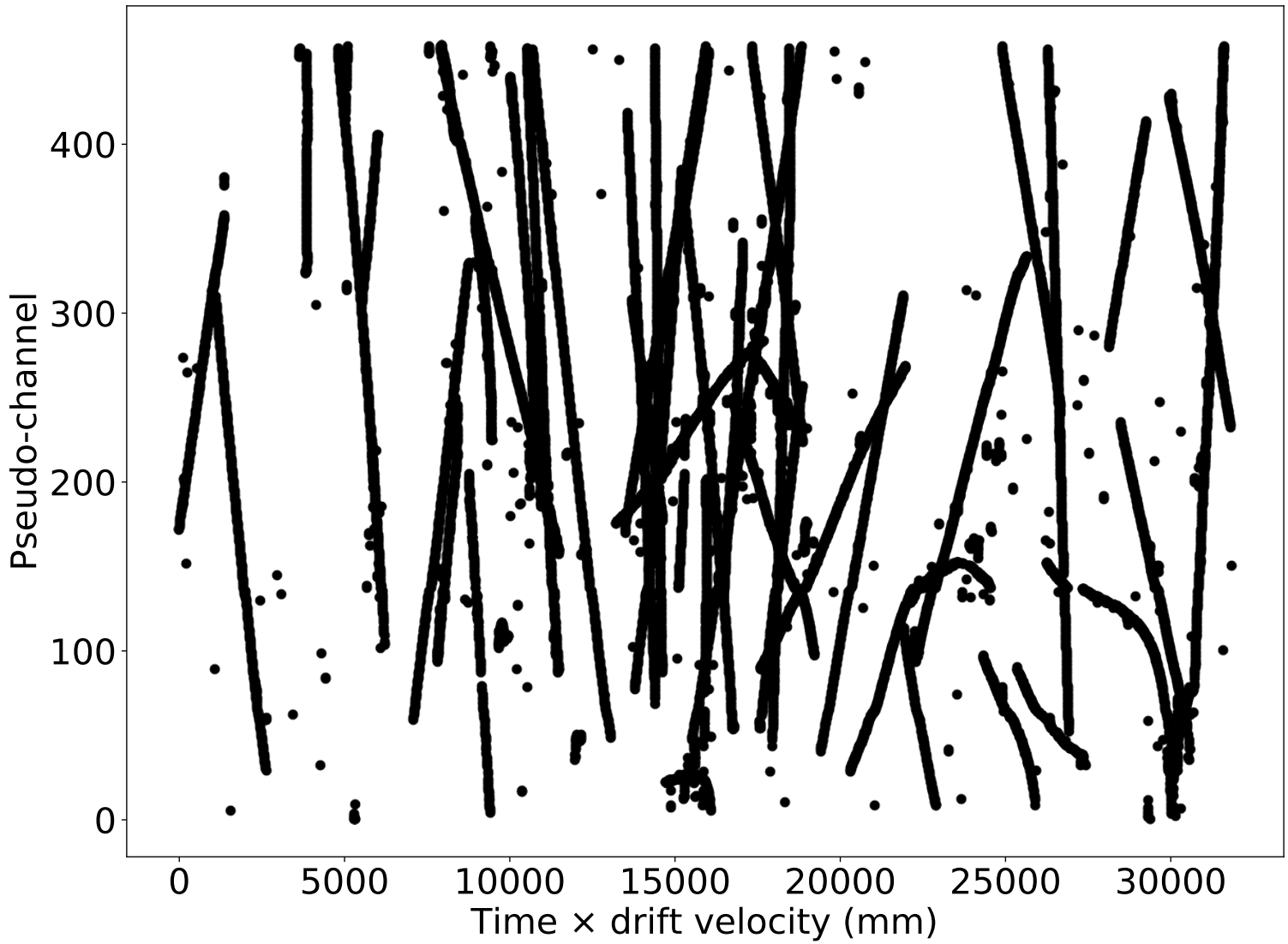

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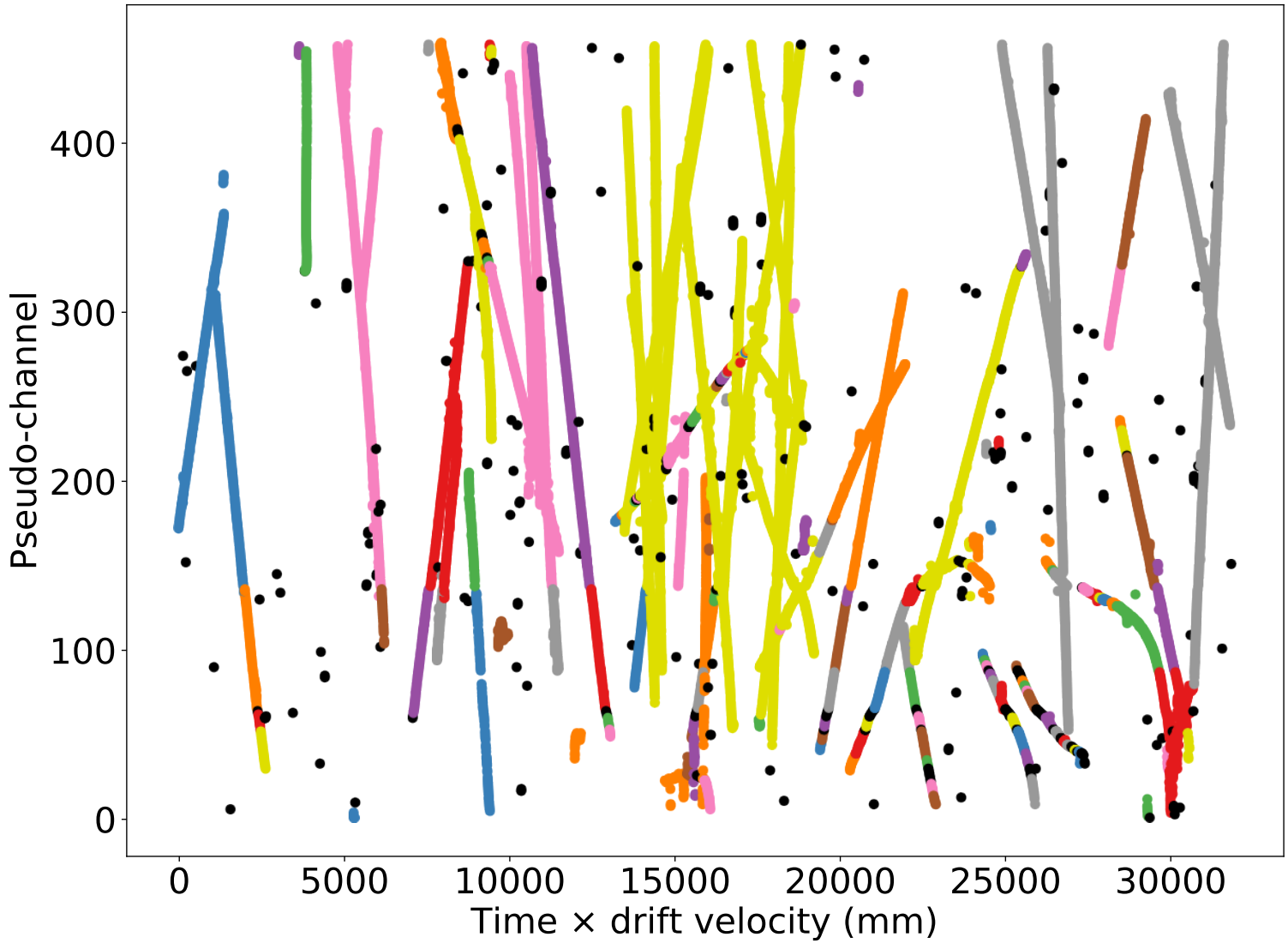

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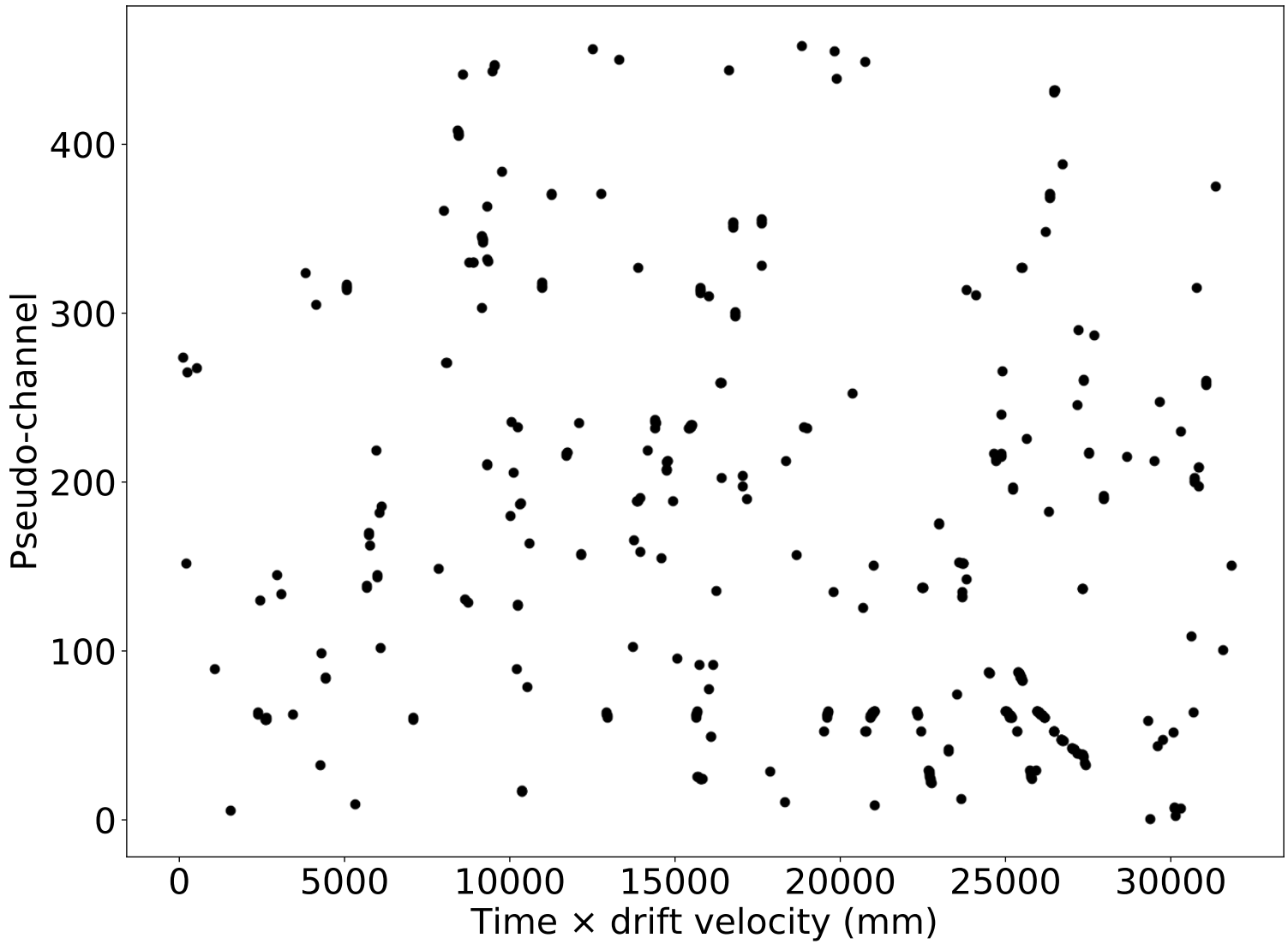

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