Music, **Neighbors** and **tracking**

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ATLAS EXPERIMENT

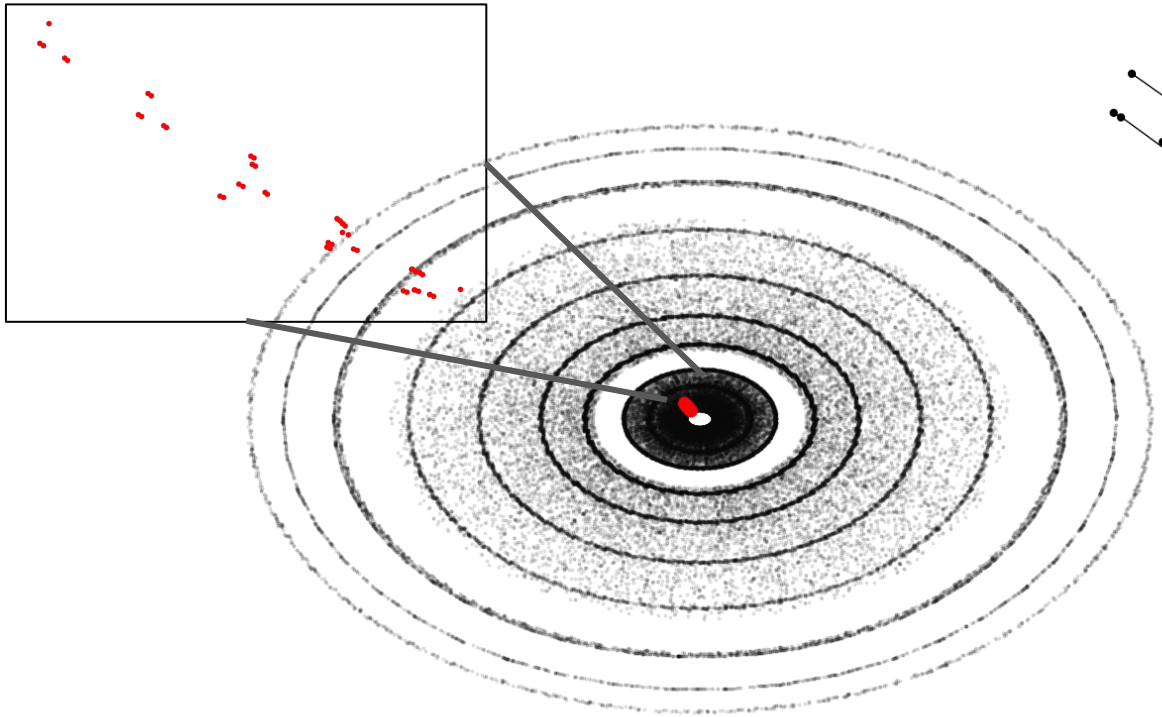
Motivation

- High-luminosity LHC (and future FCC) will bring very high pile-up scenarios
- Average 200 proton-proton collisions for HL-LHC (up to 1000 proton-proton collisions for FFC)
- Combinatorics becomes very challenging

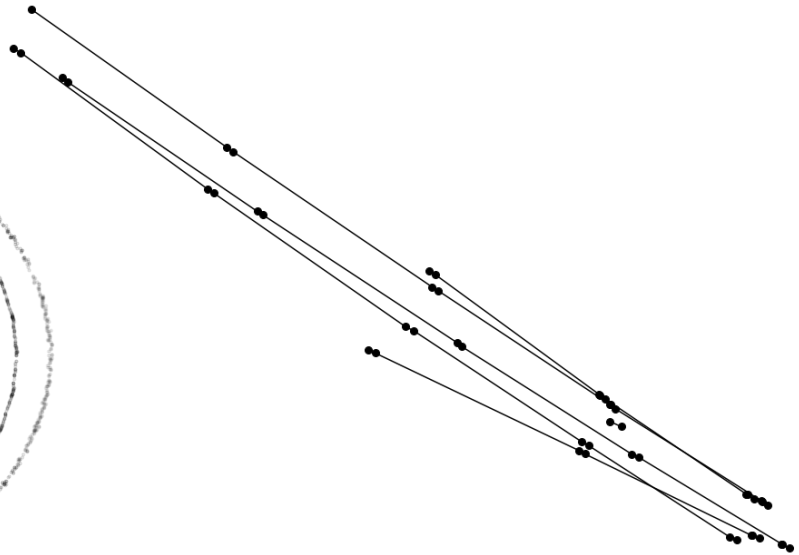
The approach

- Reduce combinatorial complexity : define regions
- Cluster inside regions

(1) Translate dataset to small sets



(2) Tracking in small set



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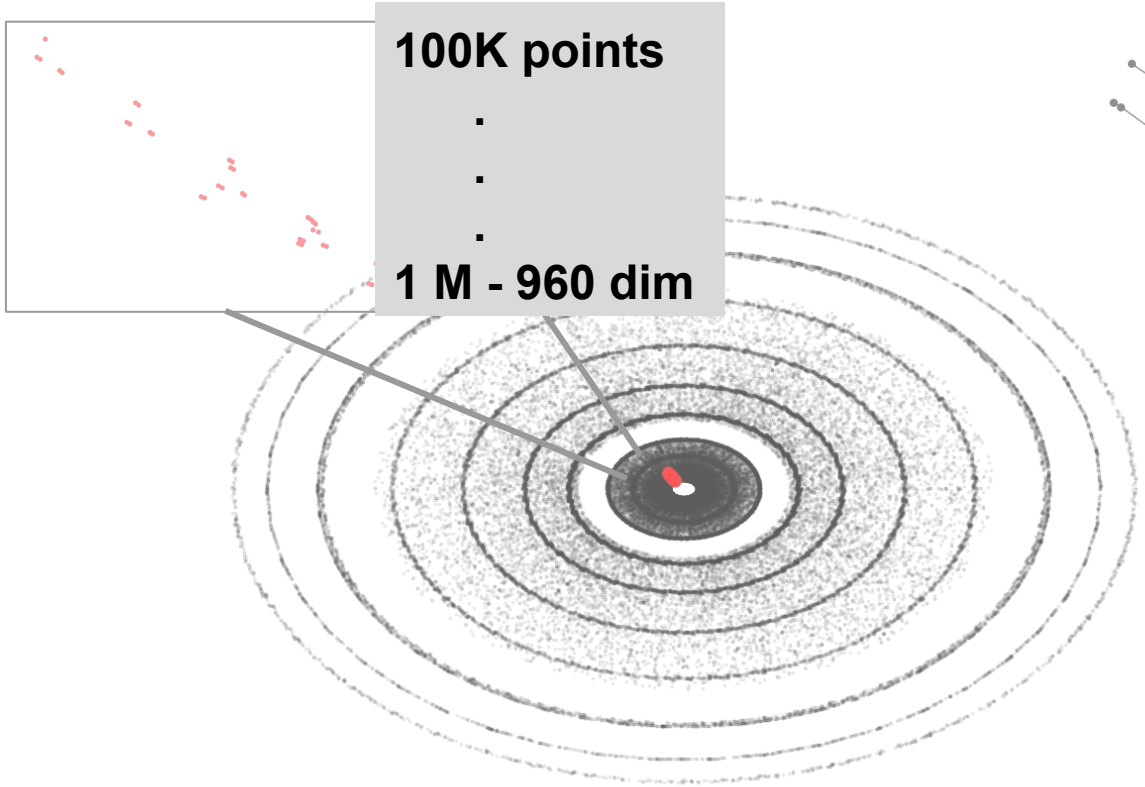

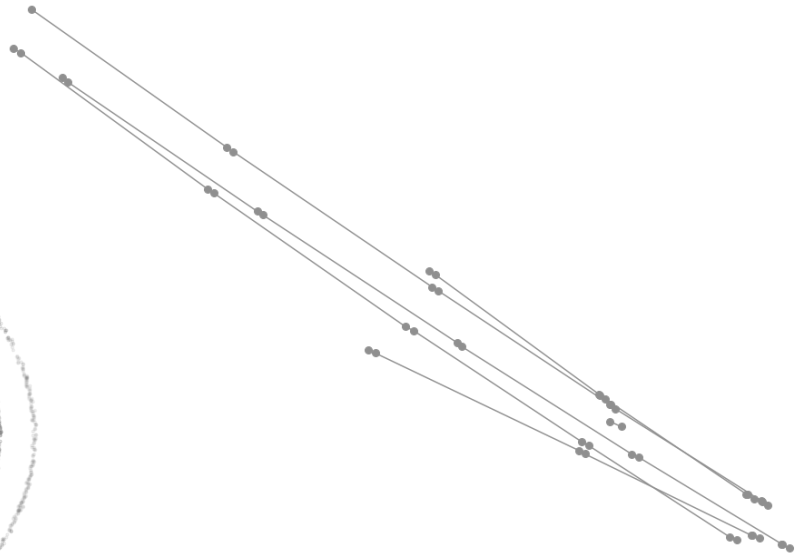

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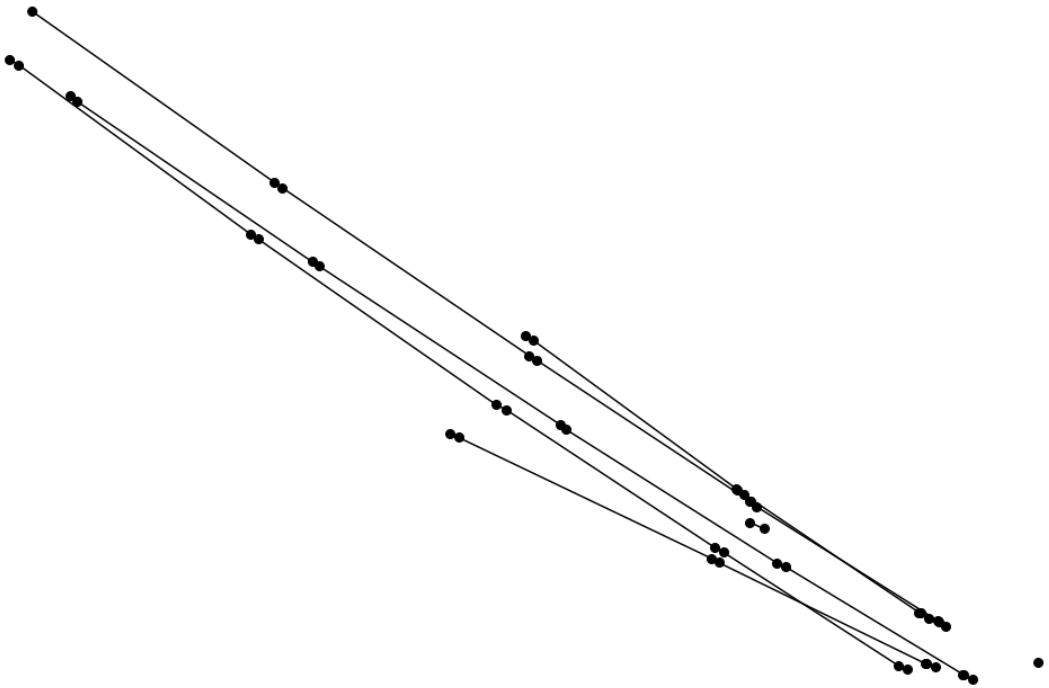

Spotify

- Accueil
- Rechercher
- Bibliothèque

ÉCOUTÉ RÉCEMMENT

Valencià.
PLAYLIST

Valencia
ALBUM

Calm Vibes
PLAYLIST

Deep House Relax
PLAYLIST

Pop Klassiker
PLAYLIST

Installer l'appli

greysab

Valencià.

irnemercury

LECTURE

588 TITRES

El Meu Poble	Txarango • Som Riu	4:24
Governant	Txarango • Som Riu	4:02
Corazón Viajero	Txarango • Som Riu	3:50
Camp de Batalla	Txarango • Som Riu	3:42
Com Dues Gotes d'Aigua	Txarango • Som Riu	3:59
Tant de Bo	Txarango • Som Riu	3:13
No t'Adormis	Txarango • Som Riu	4:01
La Dansa del Vestit	Txarango • Benvinguts al Llarg Viatge	3:37
Batega	Txarango • Som Riu	4:34
Compta amb Mi		3:08

El Meu Poble
Txarango

1:56 4:24

8

Spotify

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Valencià.
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Calm Vibes

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Tant de Be	3:13

Autoplay

Autoplay similar songs when your music ends.

SHOW ADVANCED SETTINGS

LOG OUT

About Spotify

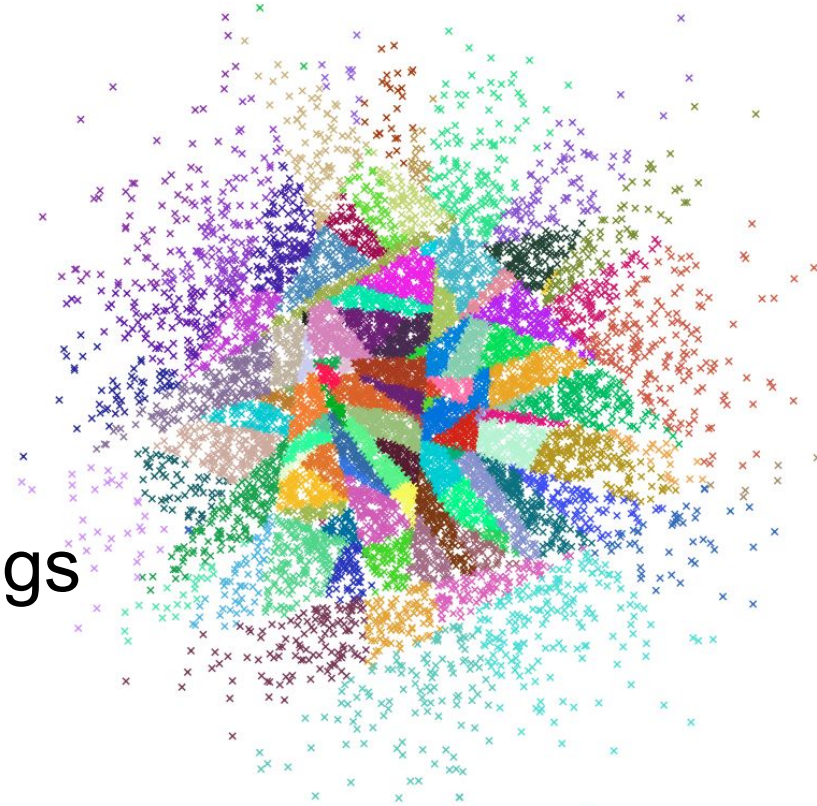
greysab

El Meu Poble
Txarango

1:56 4:24

9

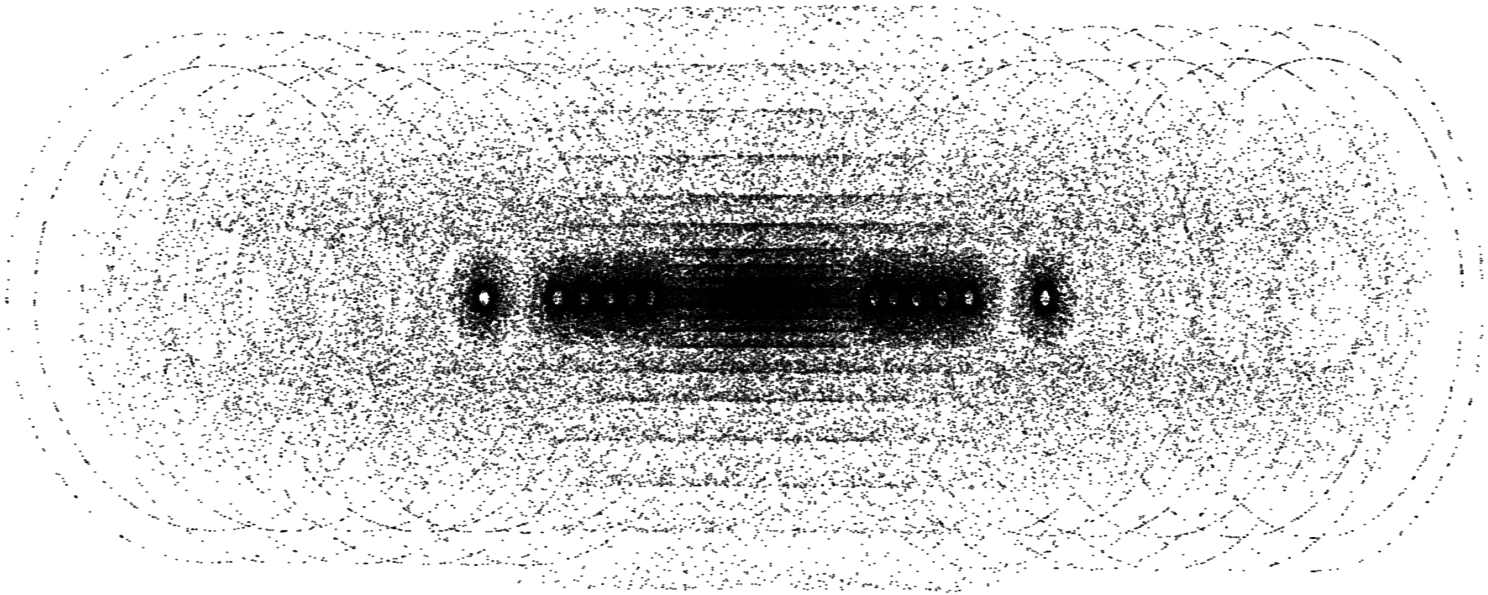
Spotify / **annoy**



- “Many millions of songs”
- **< 0.1ms** to get **n** similar songs

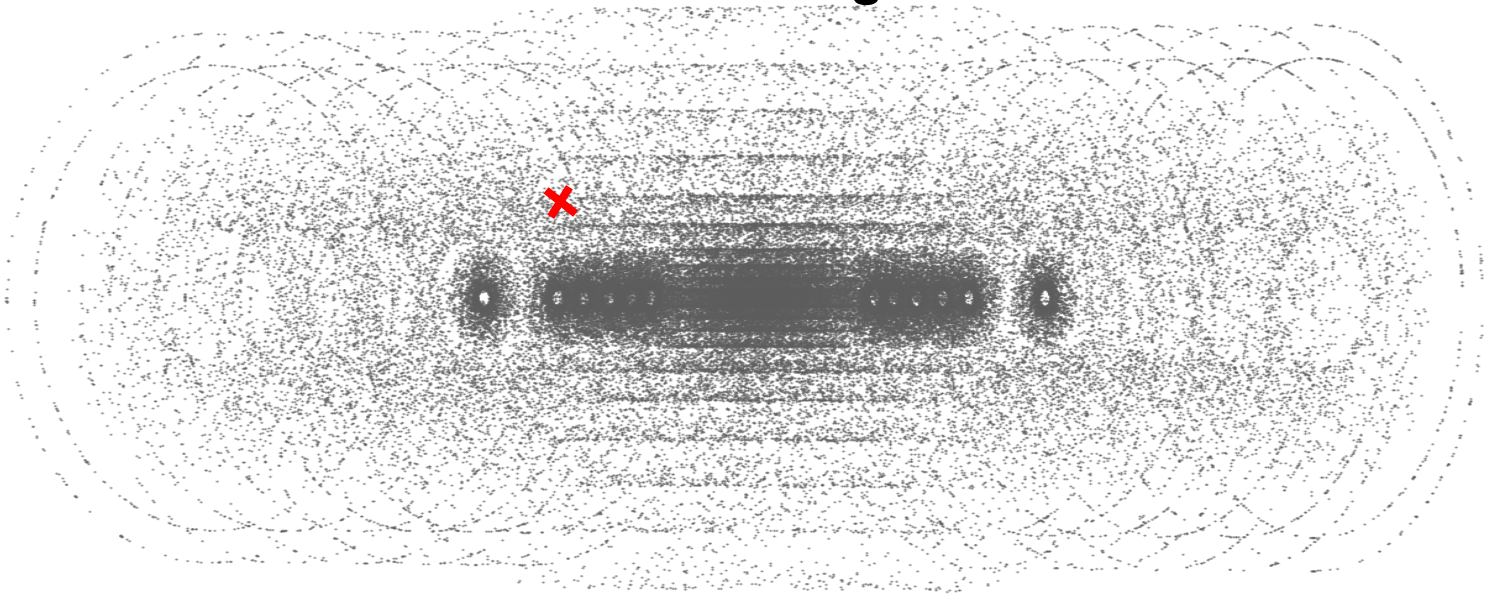
  [high-dimensional space]
- Unsupervised

Approximate Nearest Neighbors (ANN)



A **bucket** of neighbors

5 nearest neighbors in N dimensions



Traditionally, we do an exhaustive search - brute force

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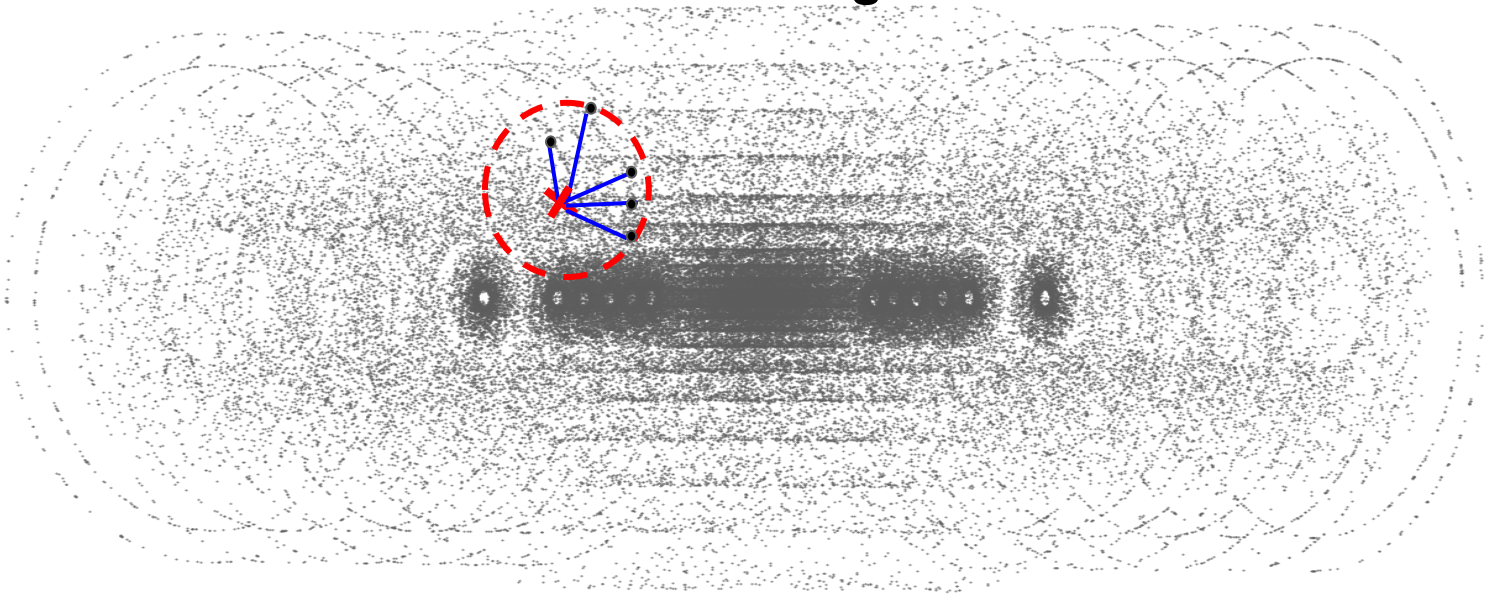

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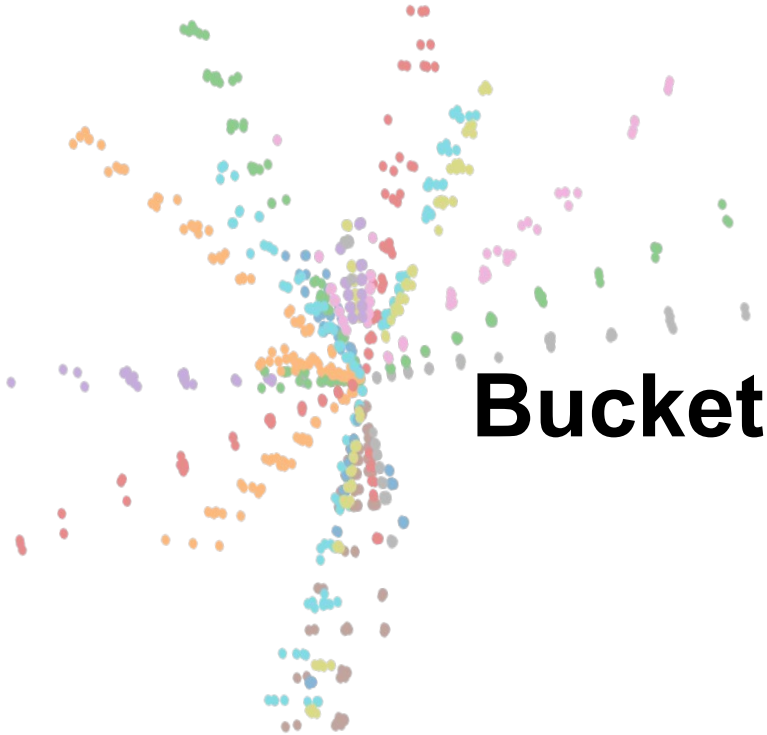
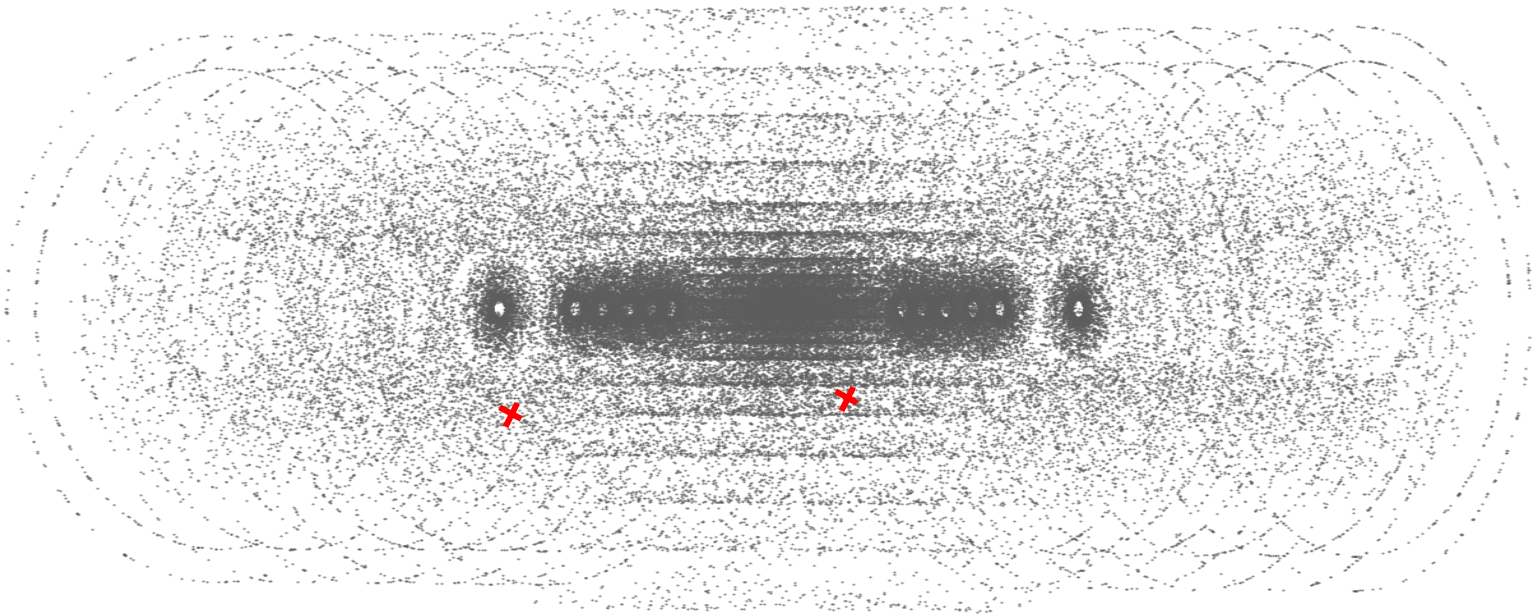


Bucketing mechanism

A **bucket** of neighbors



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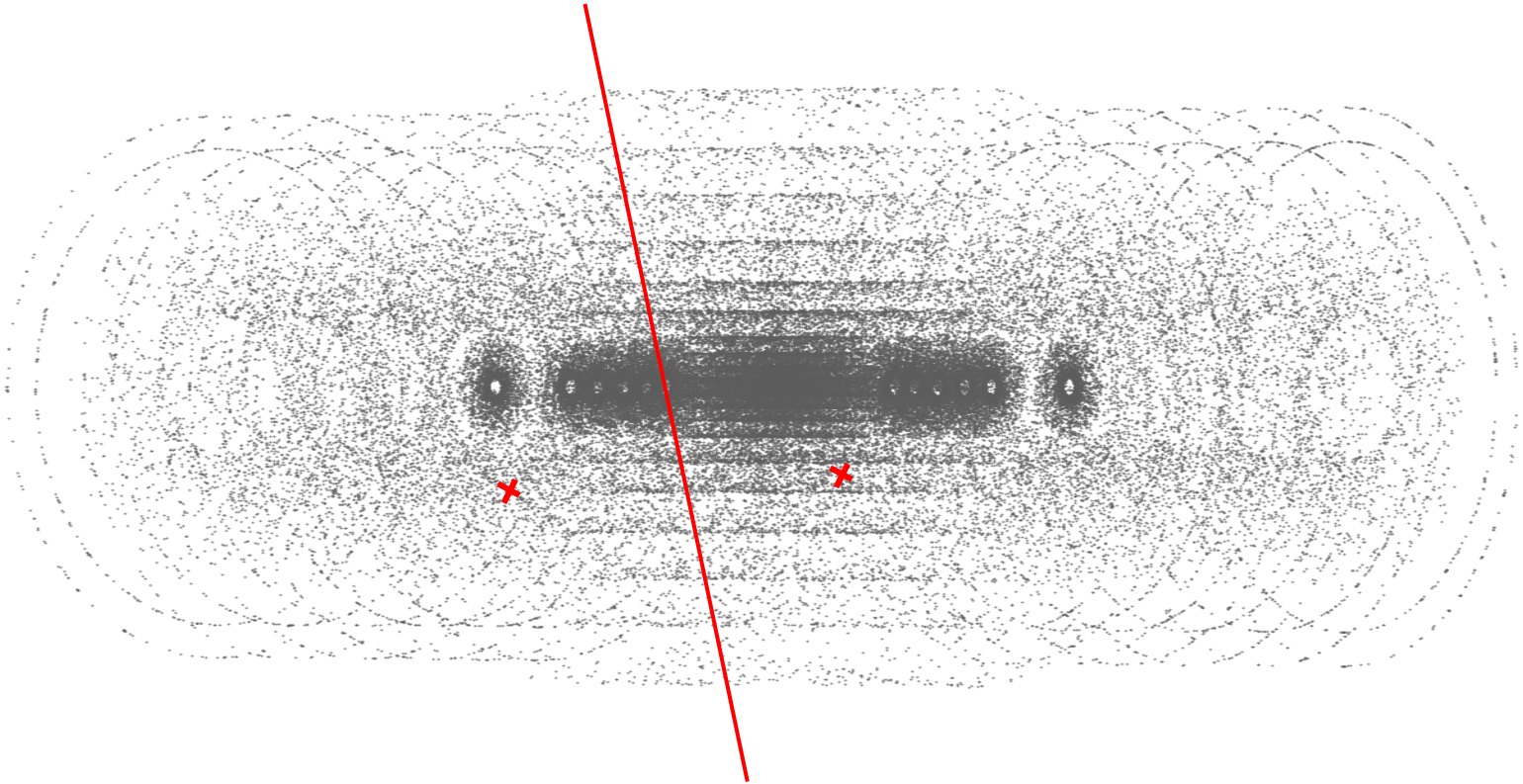

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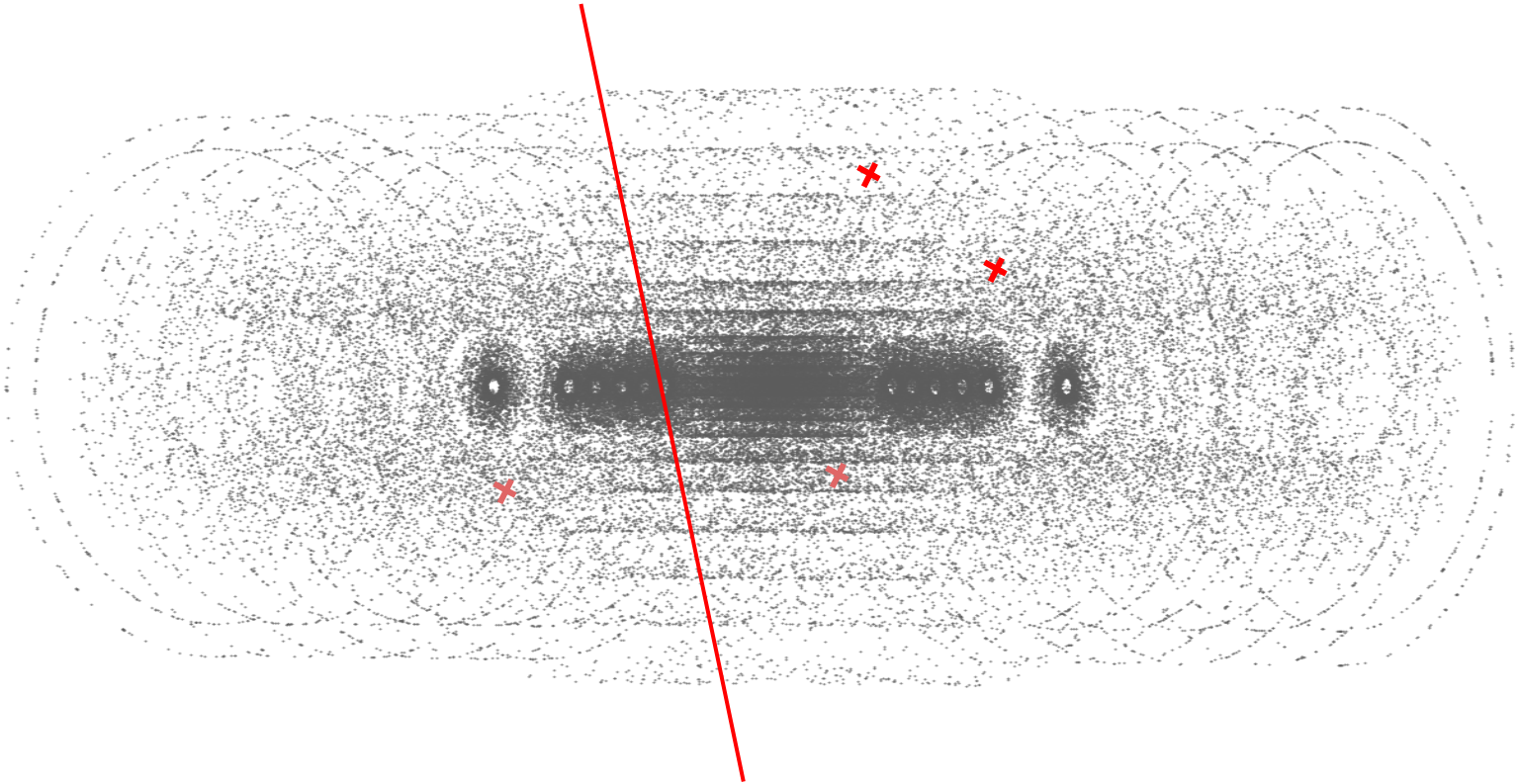

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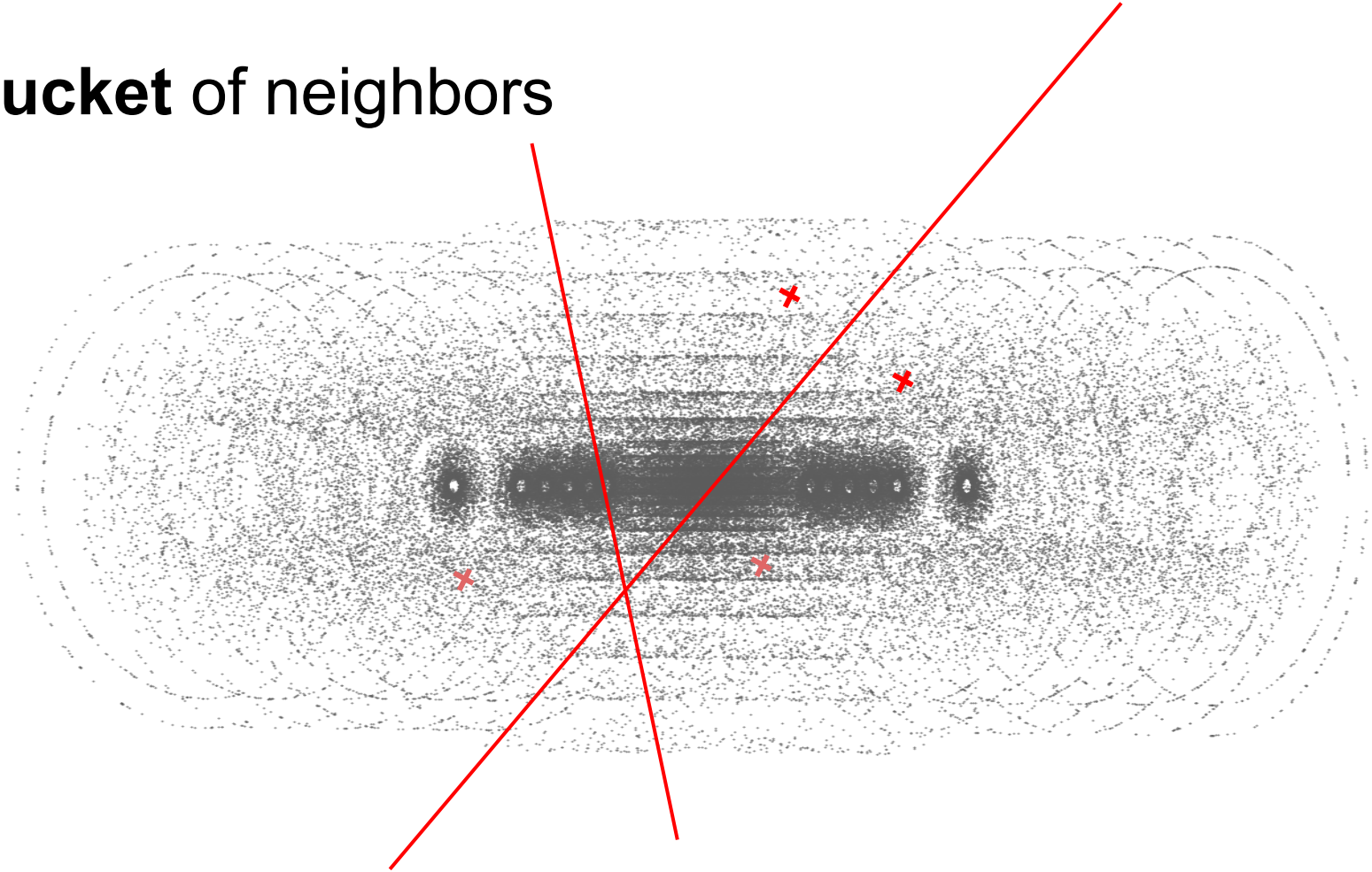

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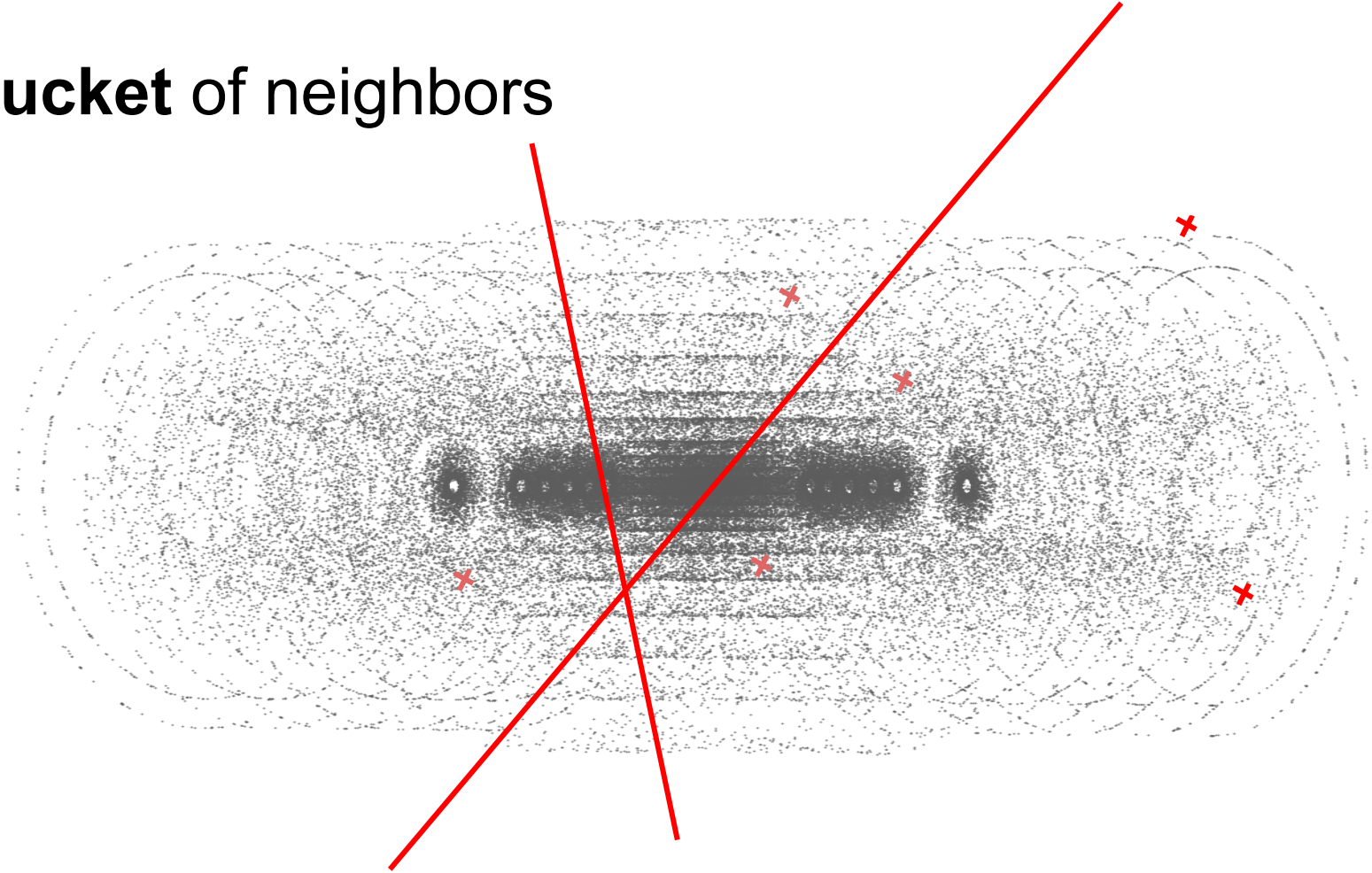

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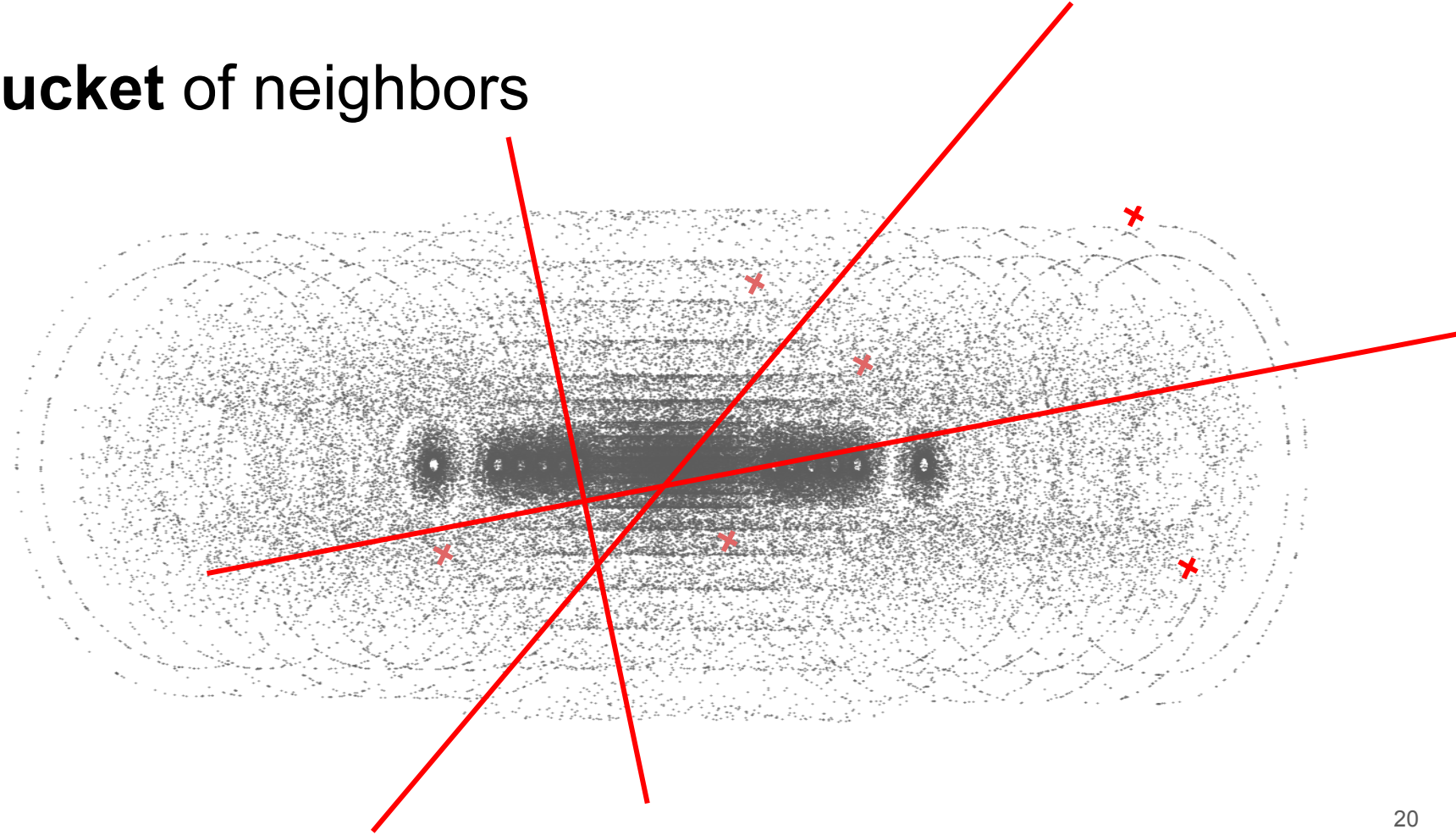
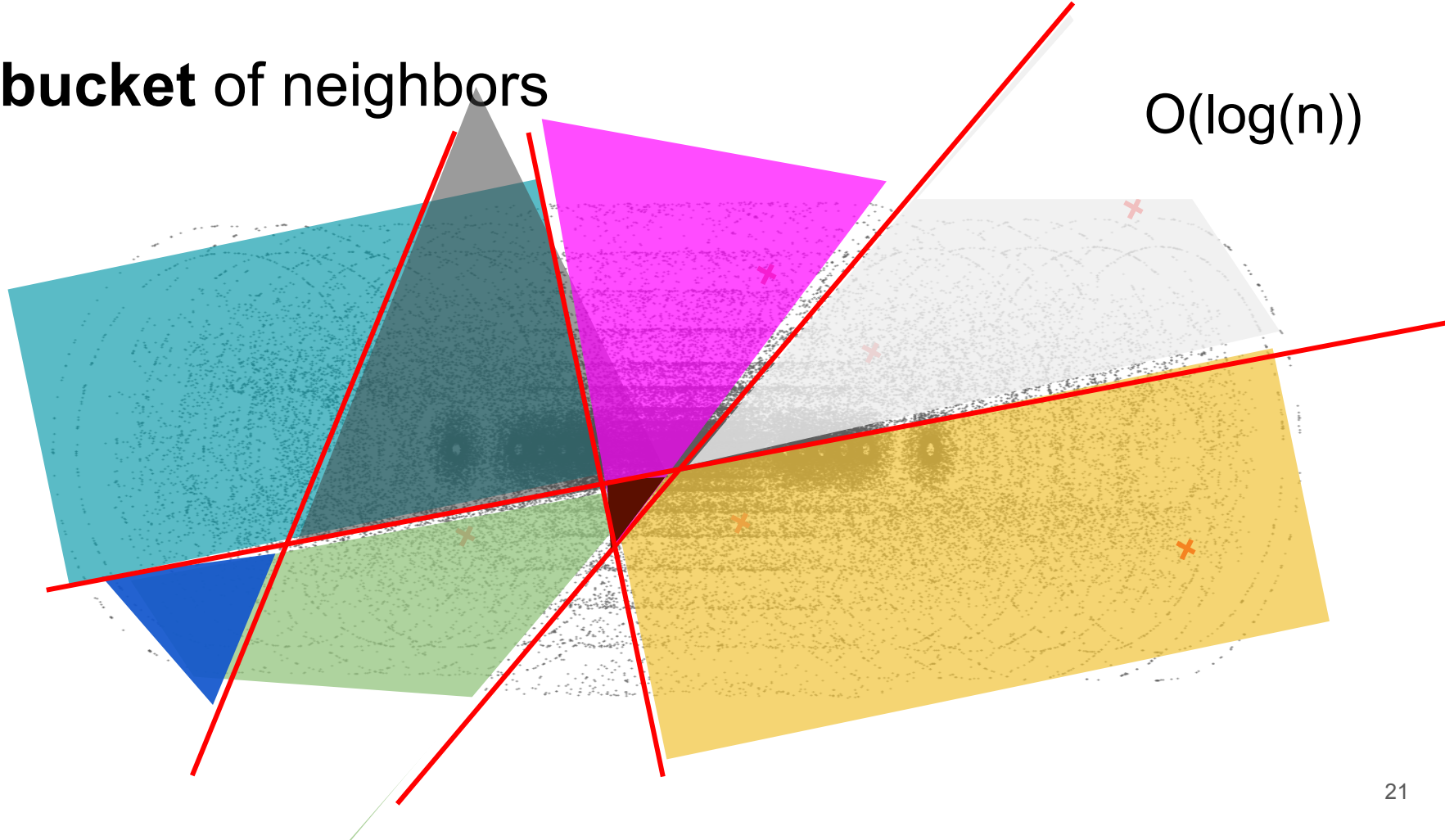
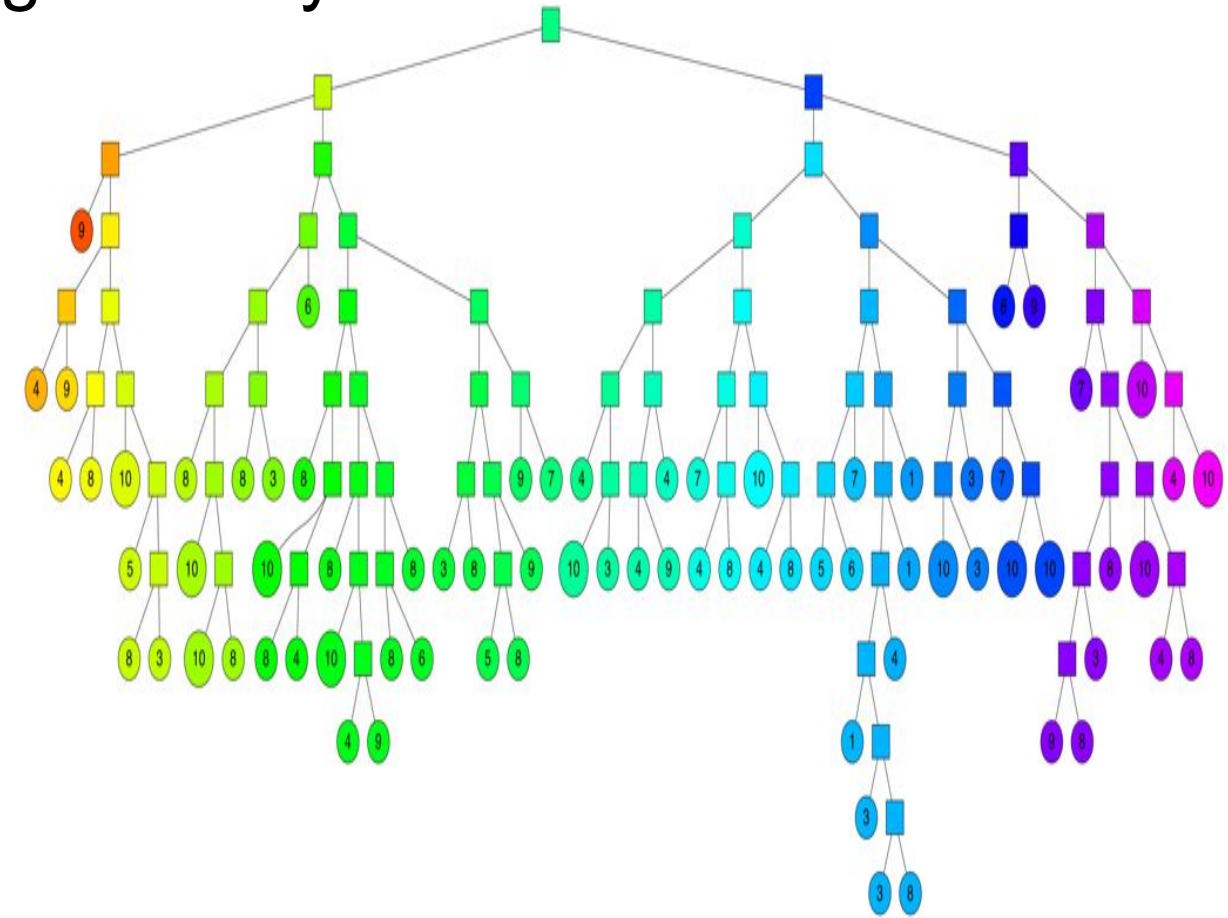


A **bucket** of neighbors

O(log(n))



Building a Binary Tree



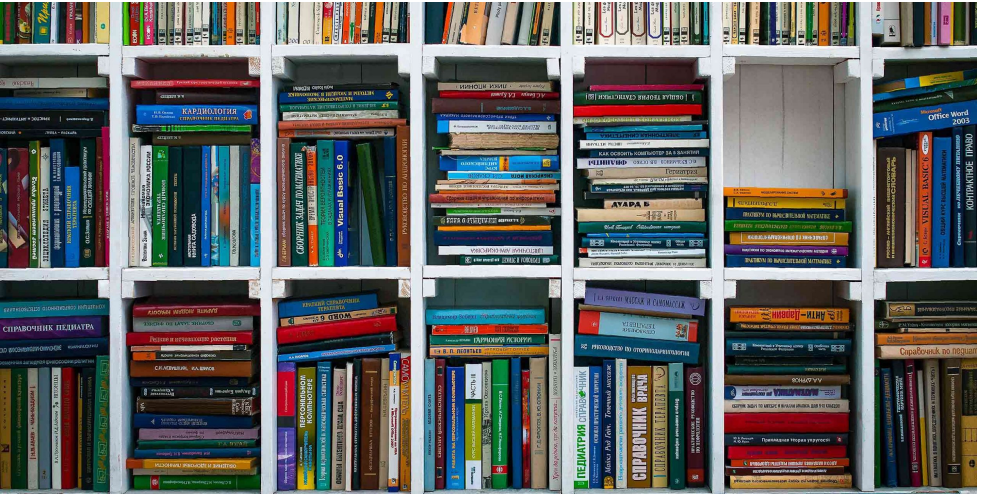
Data structures and algorithms

Data structure and Algorithm

- Some data structures associate with algorithm : trees, heaps, graphs...
- Some structures represent some concepts better than others
- The data structure can significantly reduce complexity

> "Algorithms are like **verbs** and data structures are like **nouns**. An algorithm is just a method for doing something on a computer; a data structure is a <u>layout for memory that represents some sort of data.</u>"
>
> Quora, **What's the difference between data structures and algorithms?**

Search complexity



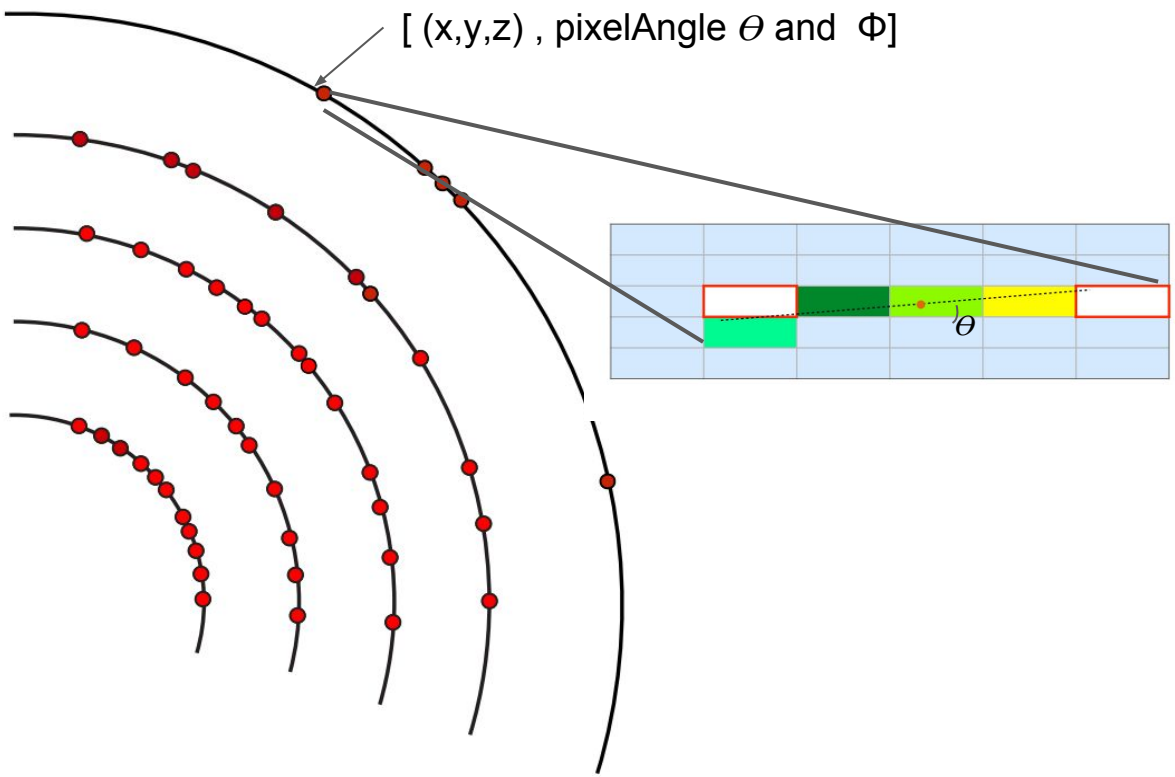
vs

Dataset

- 10K particles, 100K points
- 5 features : global x, y, z,

  local Θ, Φ
- Hashing library used :

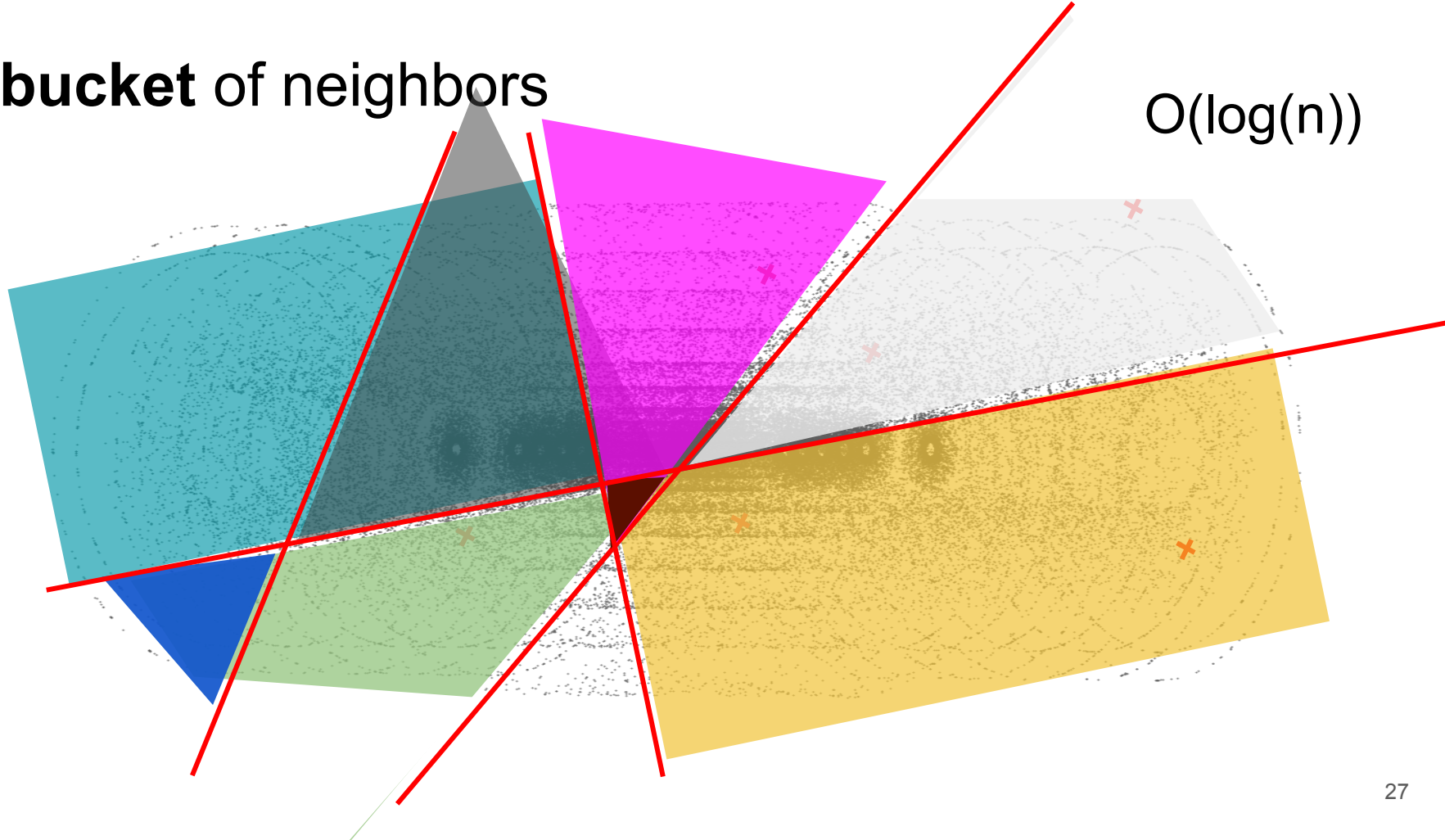
  HNSW, Annoy (spotify)
- Buckets parameters
  - bucket size
  - nb trees (graphs)



Simulated with ACTS, Ttbar event, mu 200

A **bucket** of neighbors

O(log(n))



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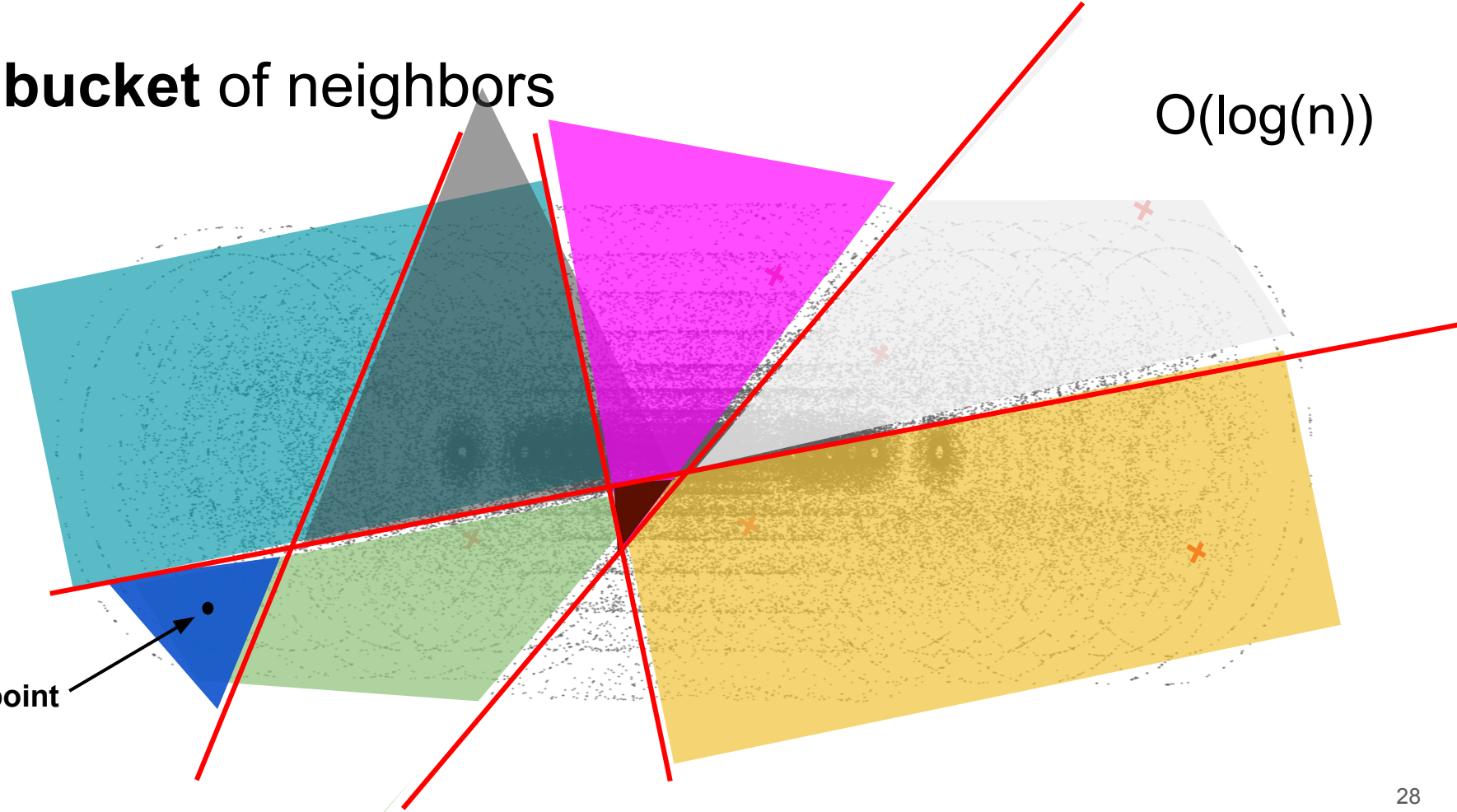

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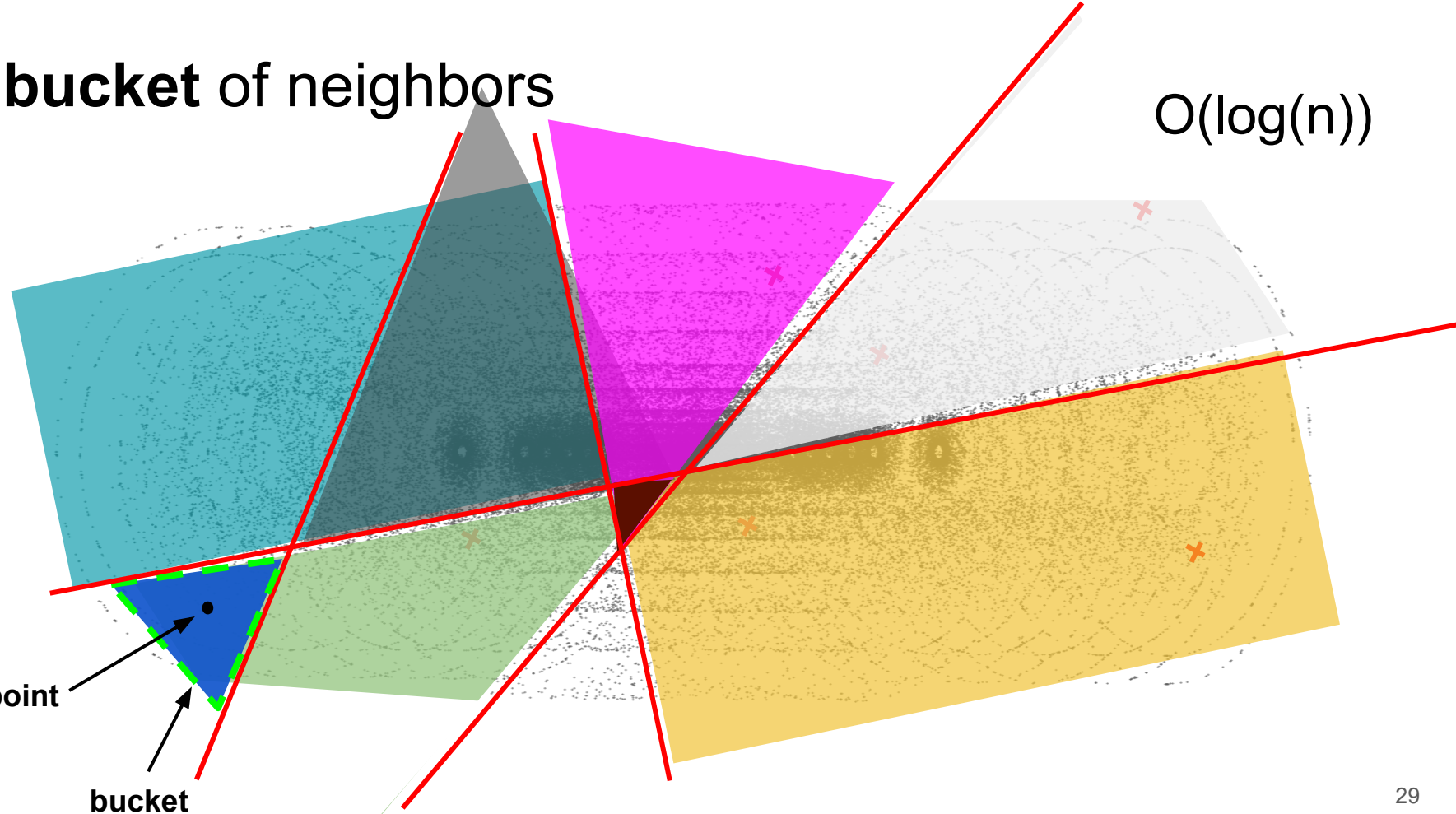
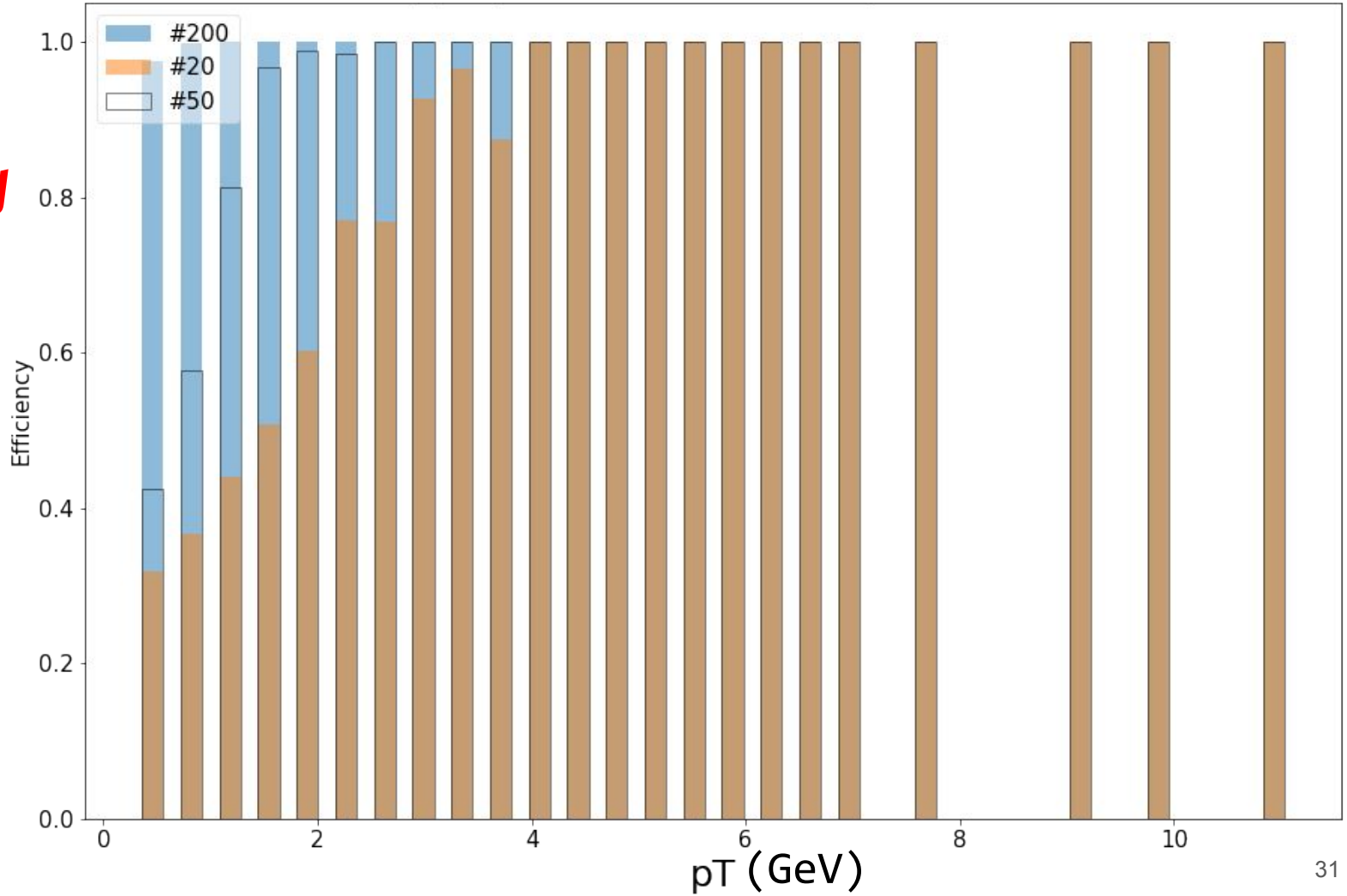


Efficiency

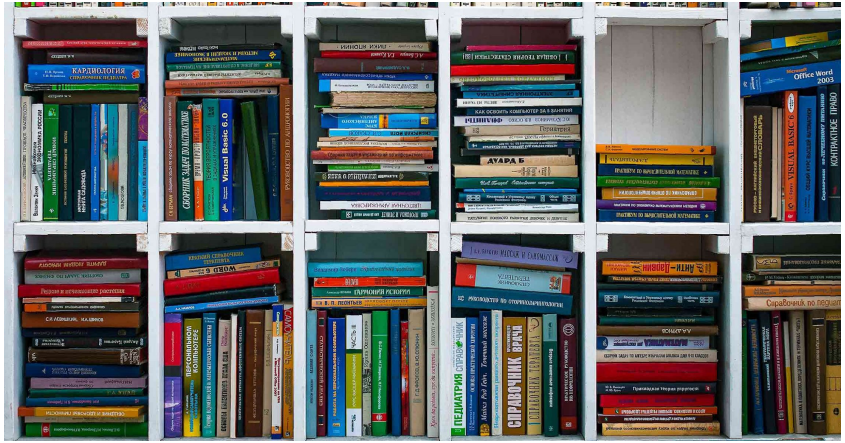
- Using truth information :
  - Count number of trackable particles found in a bucket
  - “Trackable particles” = 8 points (avg 11)
  - Efficiency as :

    nb_trackable_particles_found/ total_trackable_particles (~9K)

0.07 ms per query



Data structure … again

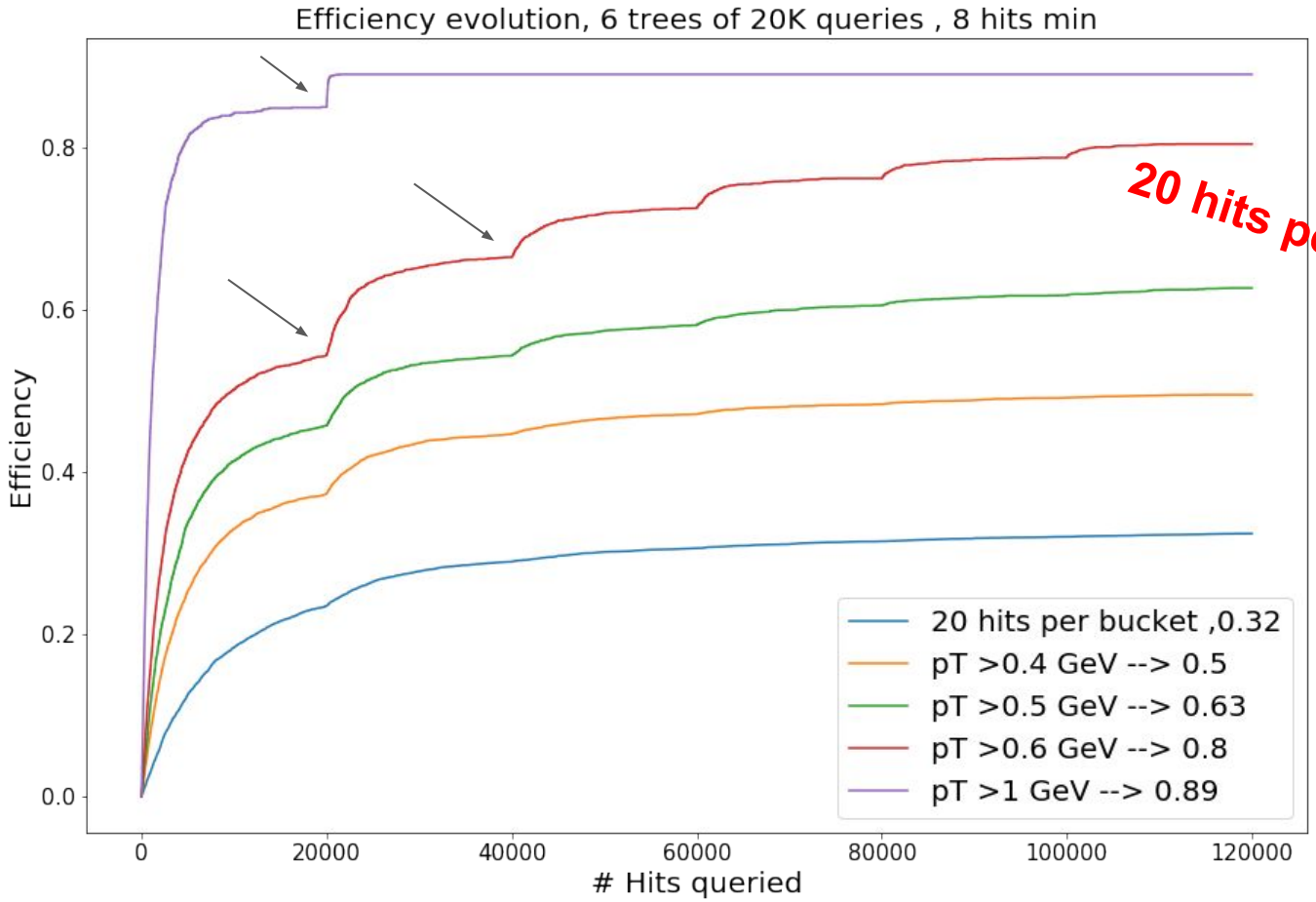


Finding & **removing** particles

Rebuilding data structure

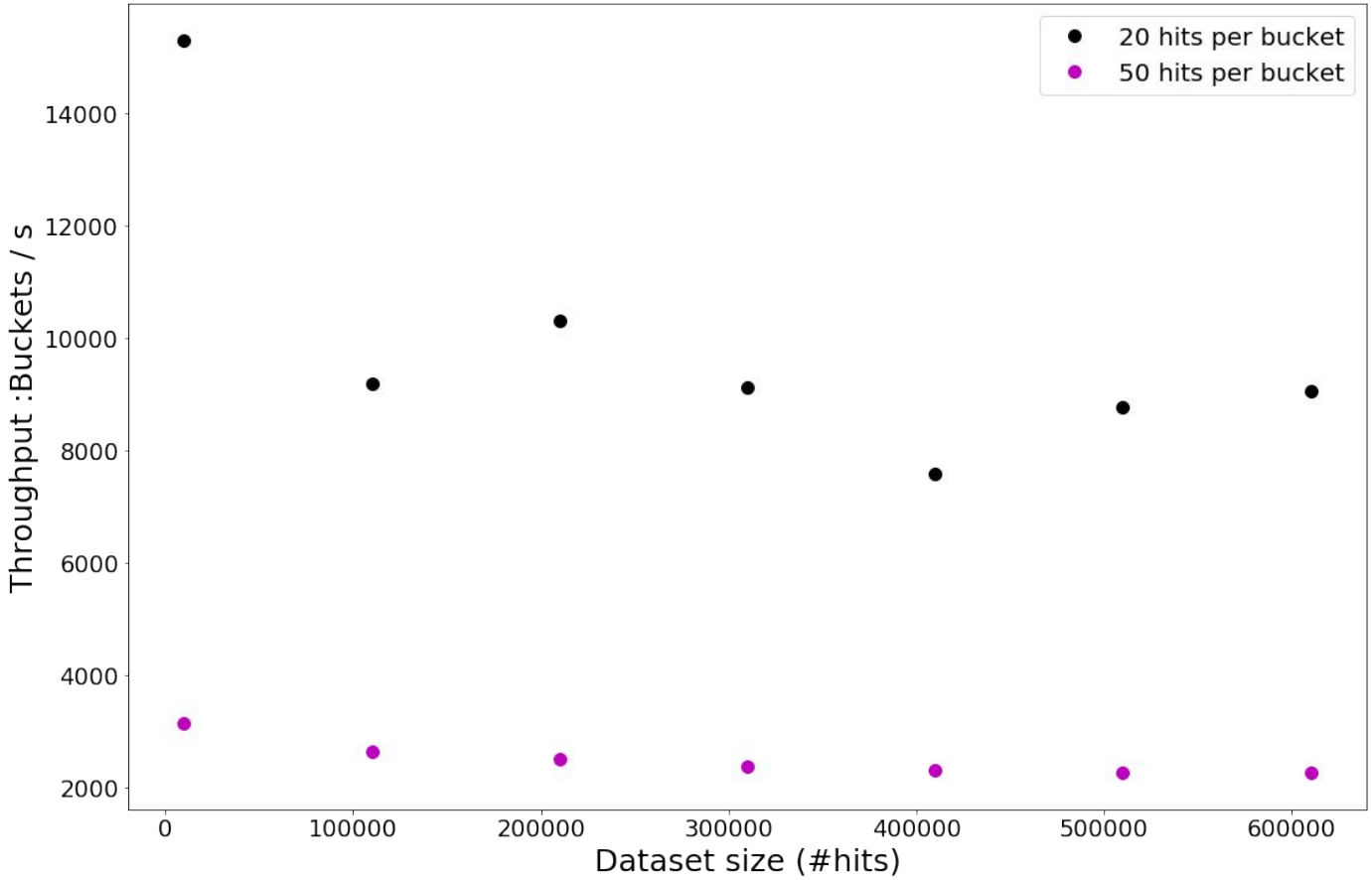
Rebuilding the data structure

0.07 ms per query



20 hits per bucket

Scaling of bucketing



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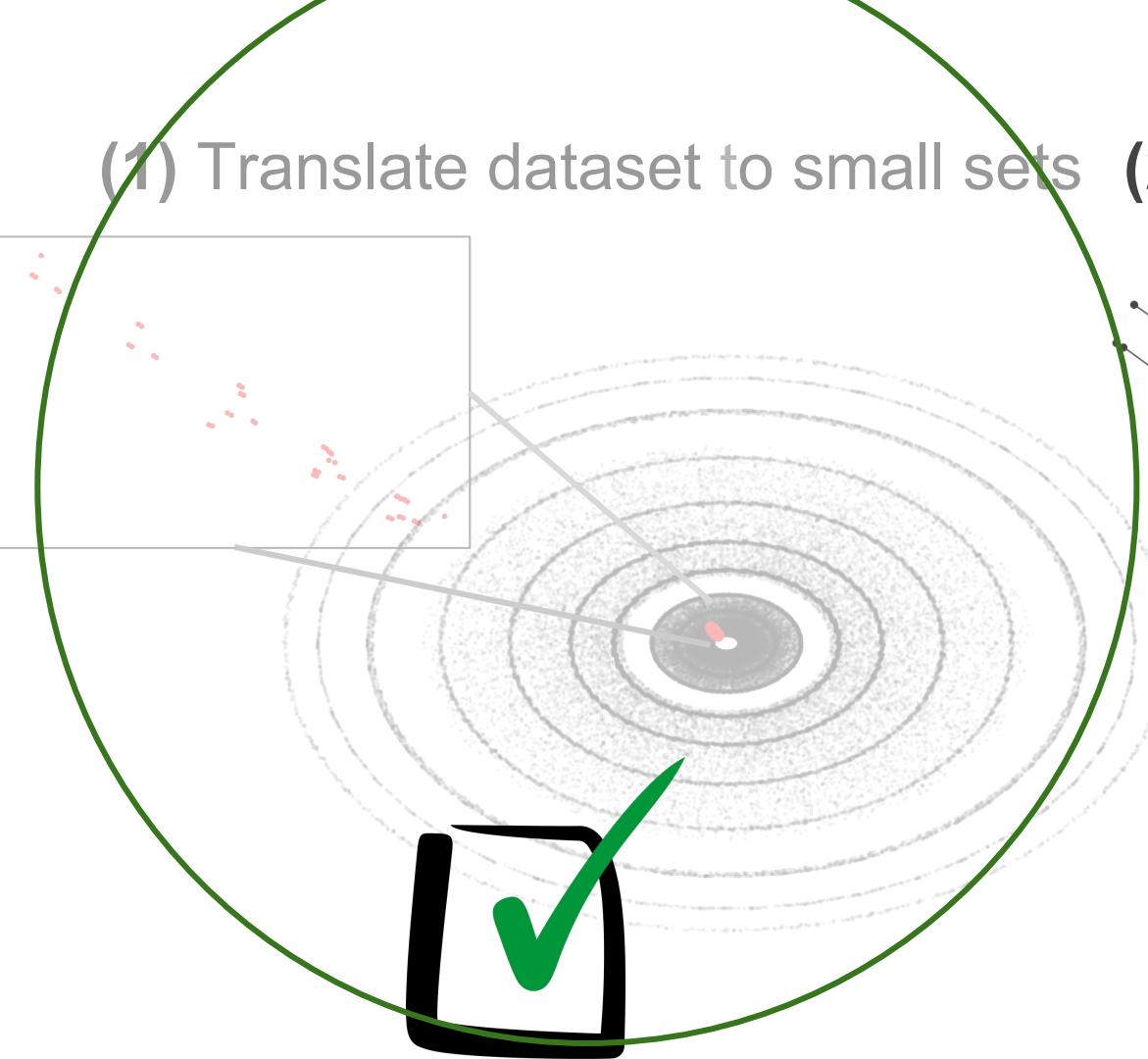
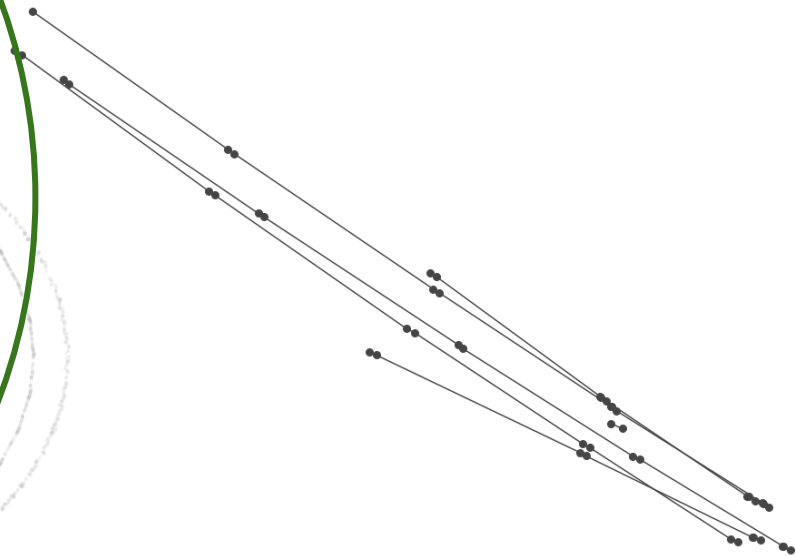
(2) Tracking in small set





Clustering inside buckets

Clustering inside buckets

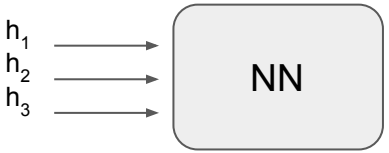
- Complexity low enough for (any) technique to work **fast**...**but**
- Data driven approach has **- many -** advantages
  - A single technique to work hand in hand <u>with data structure</u>
  - Independance towards physics
    - expected to work as well for displaced tracks
    - Low pT, impact parameter…etc
  - Towards non-parametric approaches

Proposed approach

Supervised model trained on **buckets**

evaluating if **N** hits belong together

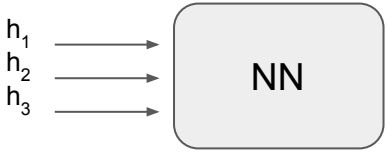
Supervised learning

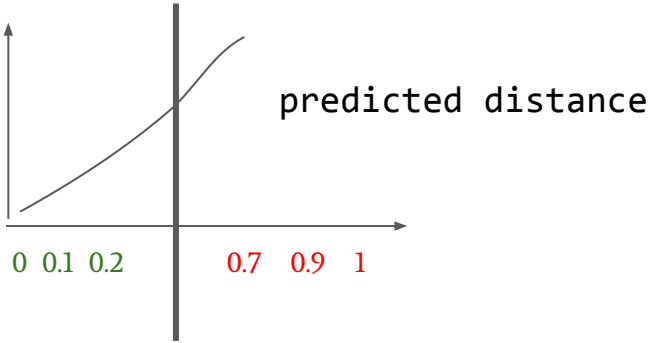


0 same particle

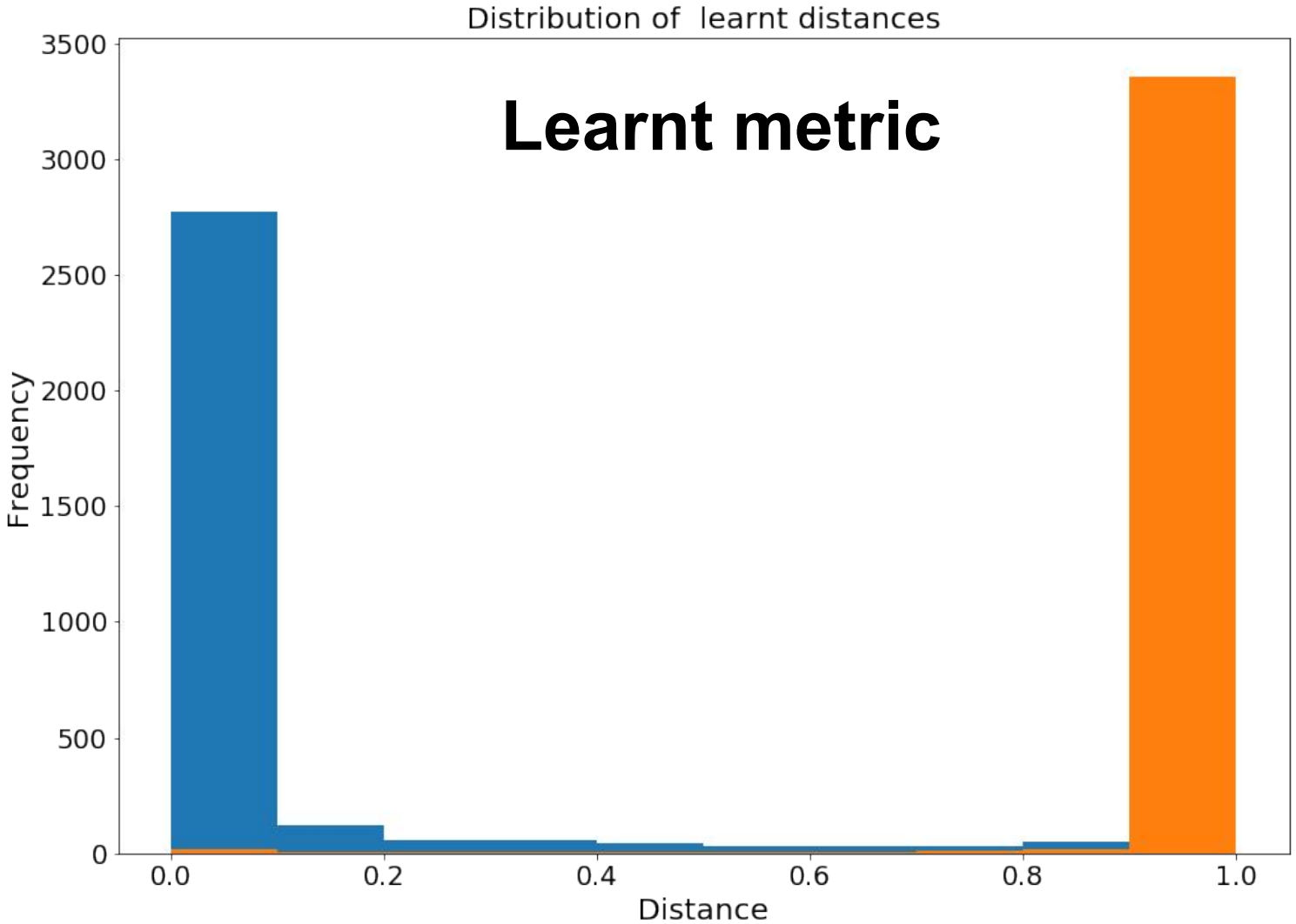
1 different particle

Training

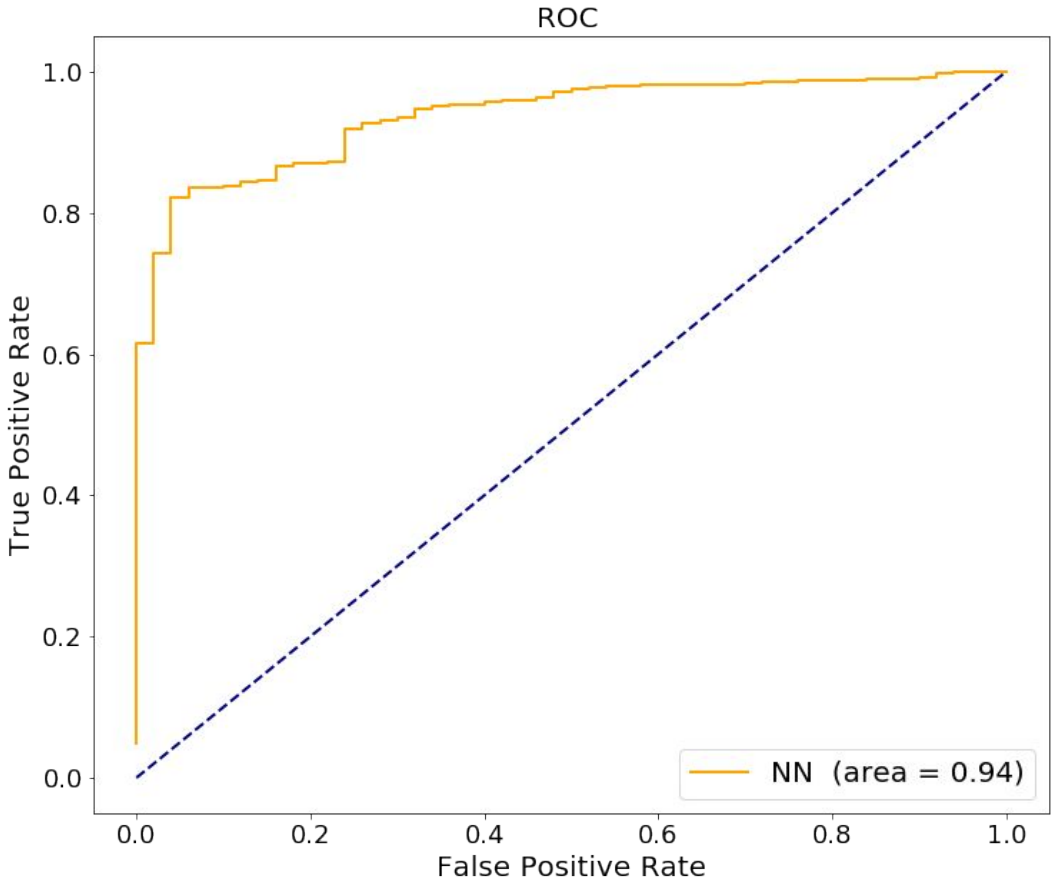




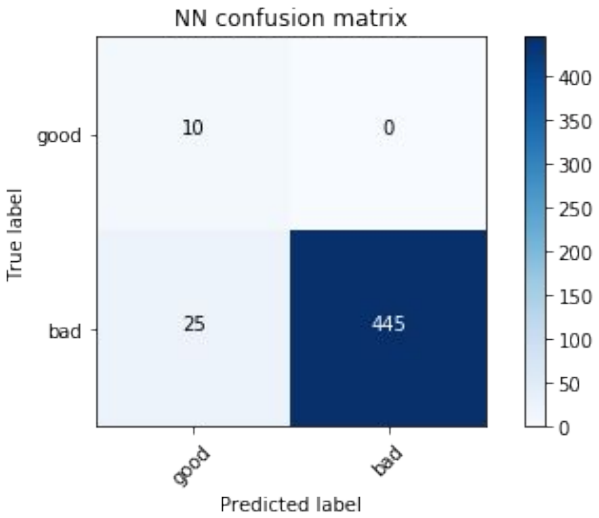
Test (new event)


Distribution of learnt distances
Learnt metric
Frequency
Distance
0
500
1000
1500
2000
2500
3000
3500
0.0
0.2
0.4
0.6
0.8
1.0

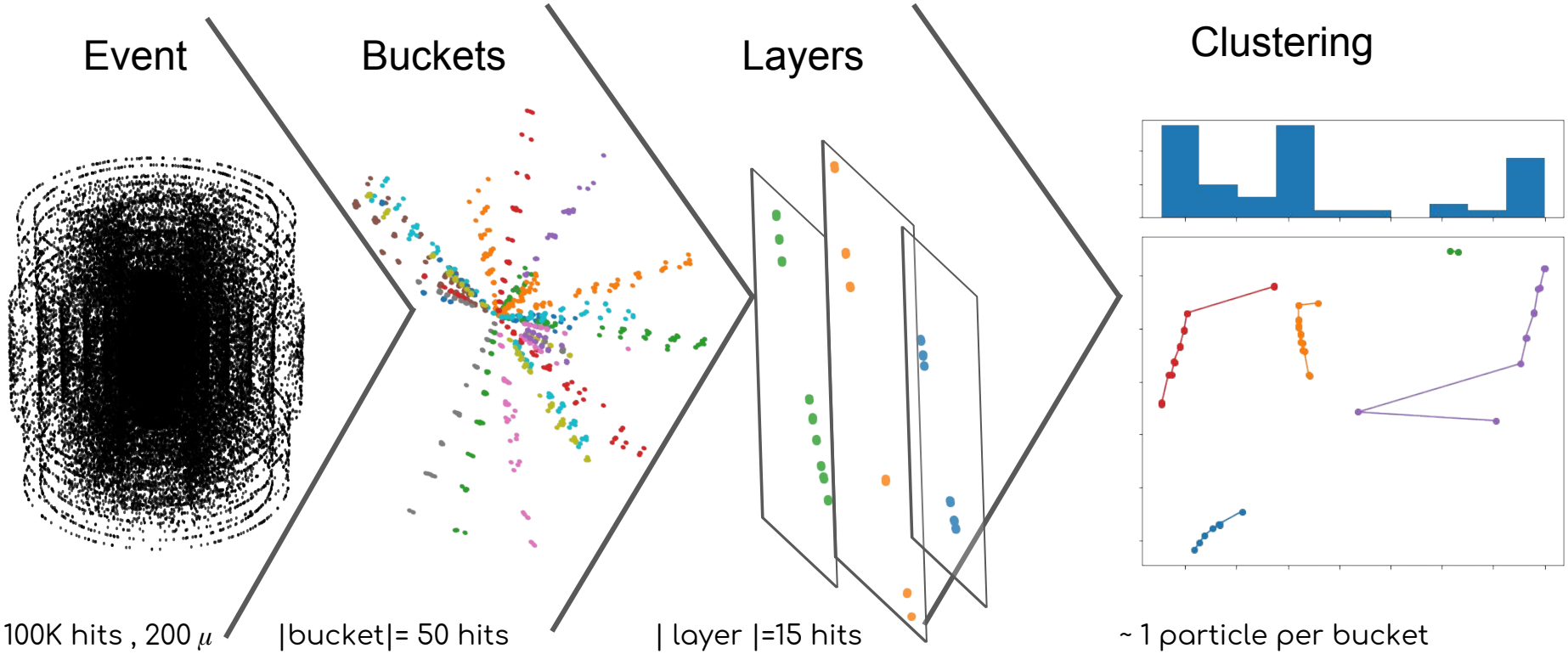
Preliminary results



5 Buckets - N=30 hits
3K segments/predictions



Buckets and data structure



Conclusion and next steps

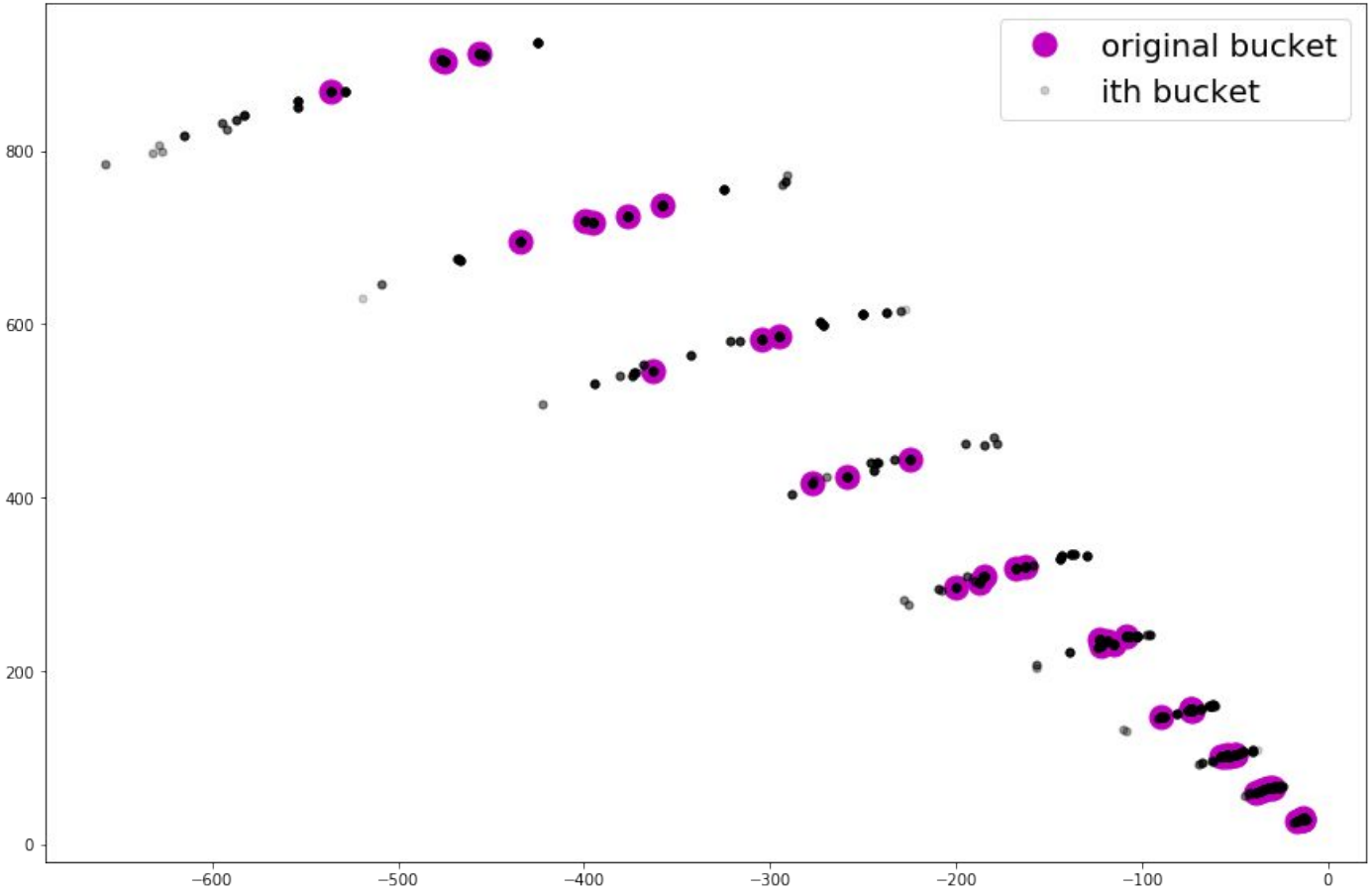
- Faster and efficient data structures for tracking : ~reading tracks
- Open source hashing /ANN libraries :

github.com/nmslib/hnswlib and github.com/spotify/annoy

Next

- Robust against physics parameters change : displaced tracks, Trigger.
- Implementation into Athena

Backup


original bucket
ith bucket
800
600
400
200
0
−600
−500
−400
−300
−200
−100
0