Pattern Recognition Techniques for LAr TPC Particle ID--- Voronoi Tessellation and Trees

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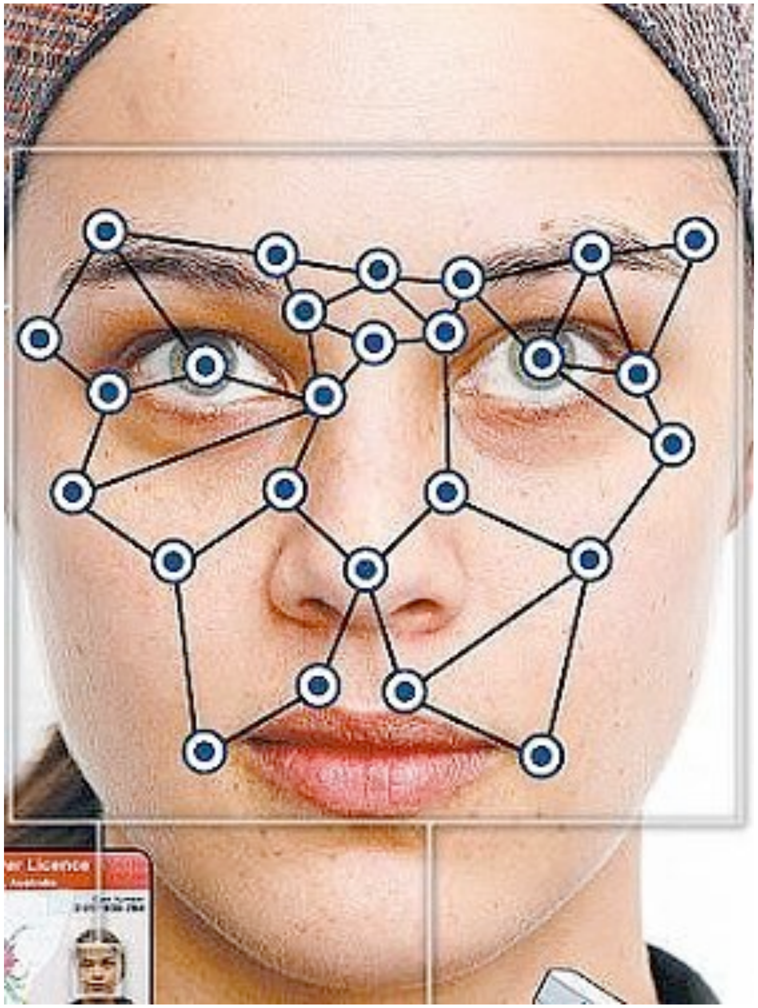
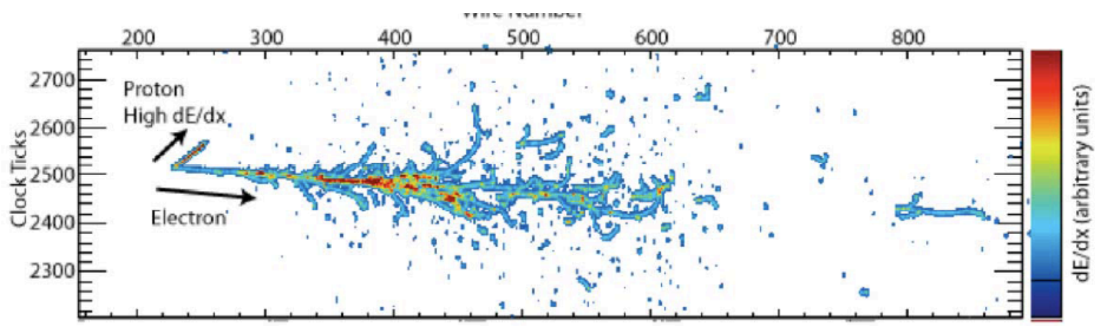
Last Meeting

Are These Problems Really Different?





Approach was to completely forget about physics---just make (say) π_0/e separation a technical problem.

Machine-readable Data

Make 1D distributions by calculating moments in time slices:

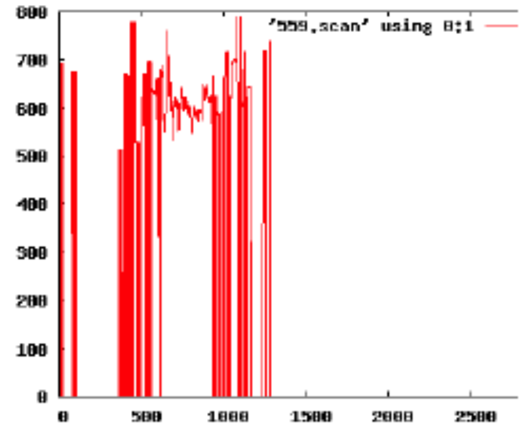
$$\bar{x}(t) = M_1(t) = \frac{\sum_x p(x,t)x}{\sum_x p(x,t)}$$

$$M_k(t) = \sqrt[k]{\frac{\sum_x p(x,t)(x - \bar{x}(t))^k}{\sum_x p(x,t)}}$$

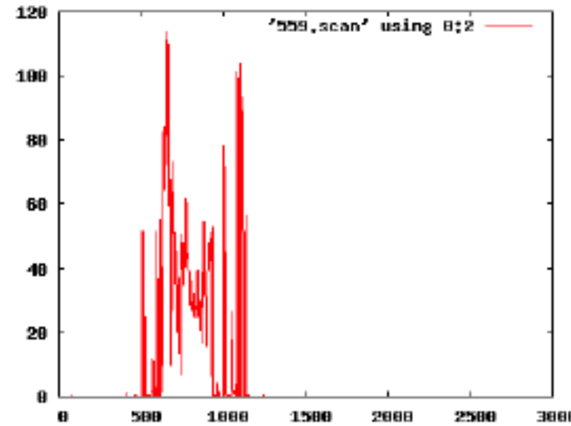
Where p(x,t) is the charge on wire *x* at time *t*.

Moments Plots

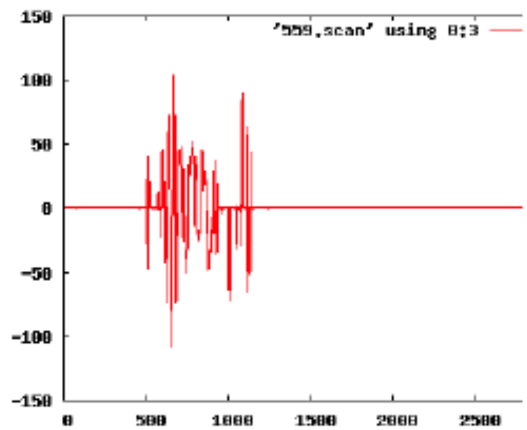
Figure 2: Plots of the first four moment signals



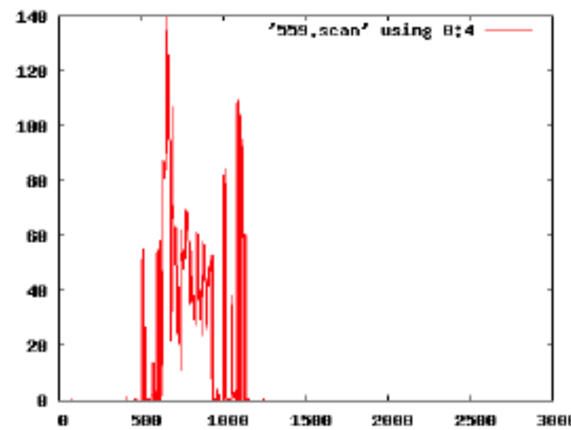
(a) M_1 vs time



(b) M_2 vs time



(c) M_3 vs time



(d) M_4 vs time

Then what??

Frequency Domain

Ratio of transformed moments is related to event mean path vs. shower shape

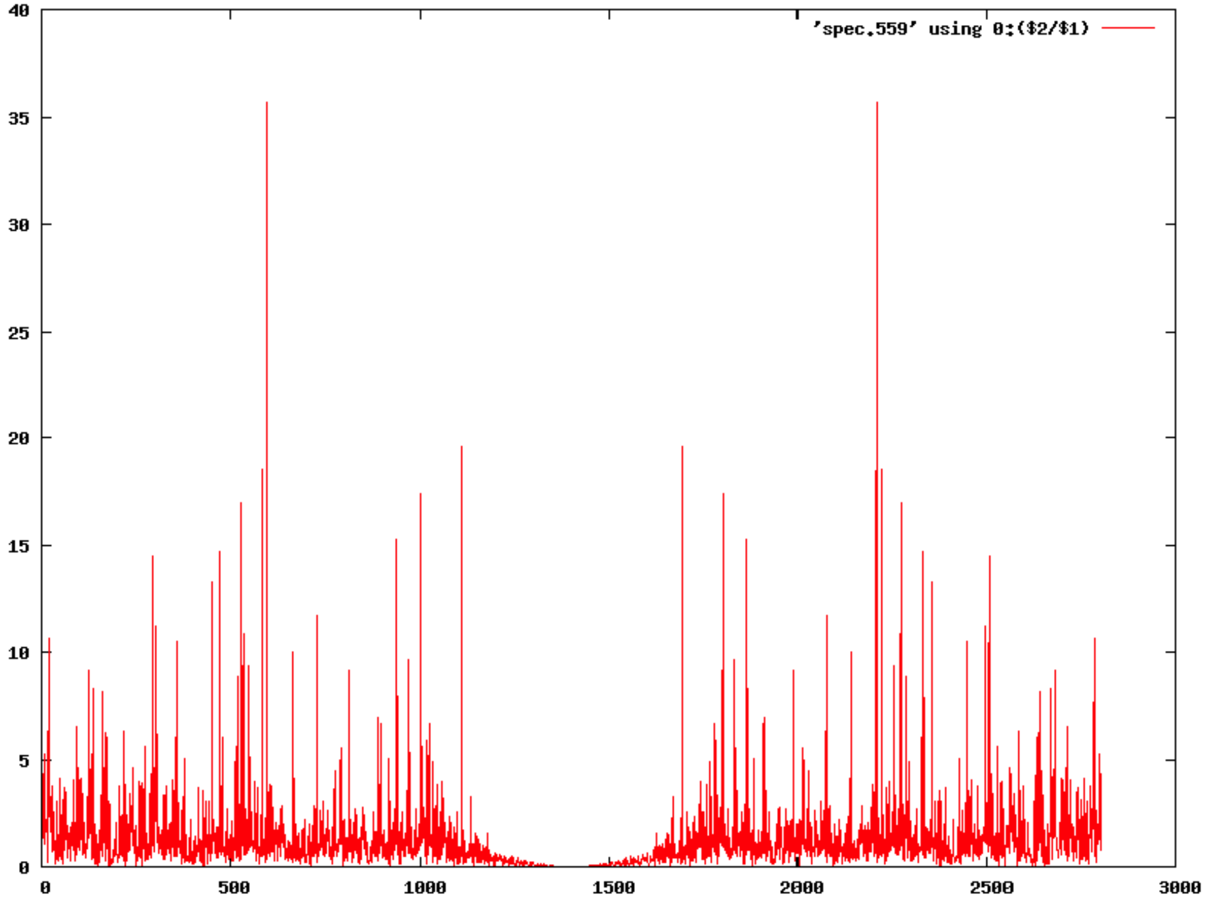
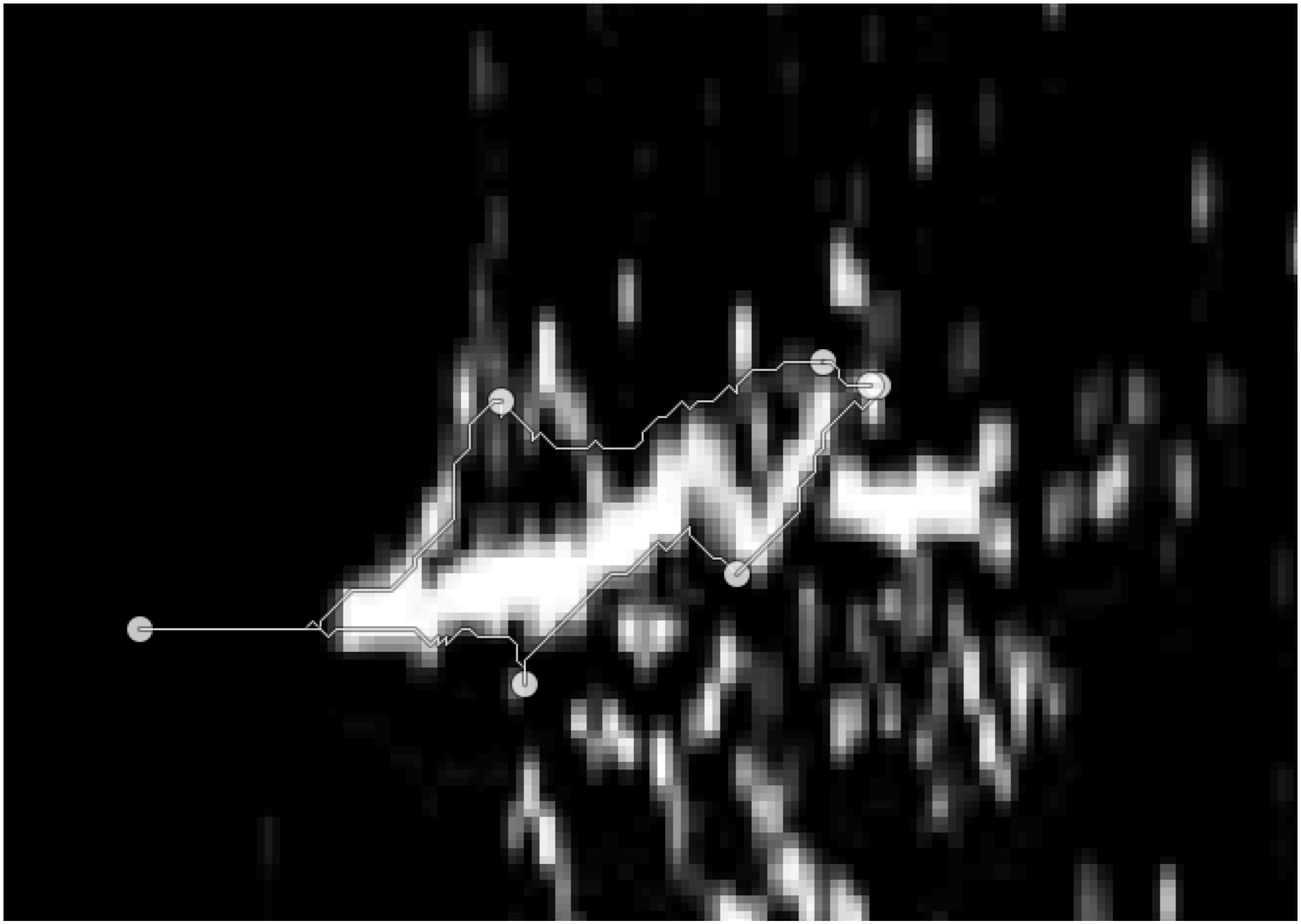


Figure 3: $\mathcal{F}[M_2]/\mathcal{F}[M_1]$ vs frequency

Peaks here can be used by your favorite learning algorithm

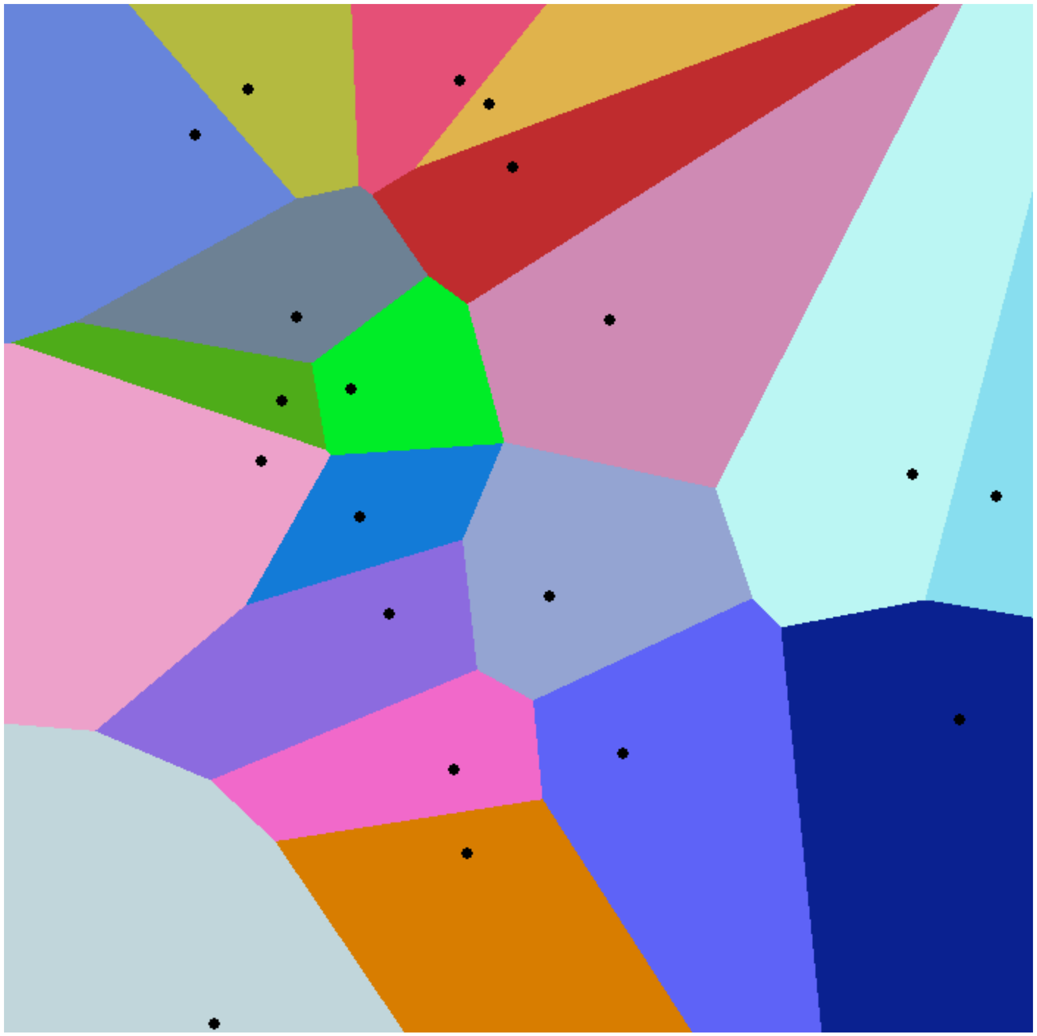
ID efficiency so far is ~60%?

New (More Modest?) Goal: Feature Recognition



Gimp's "Intelligent Scissors"

Voronoi Tessellation



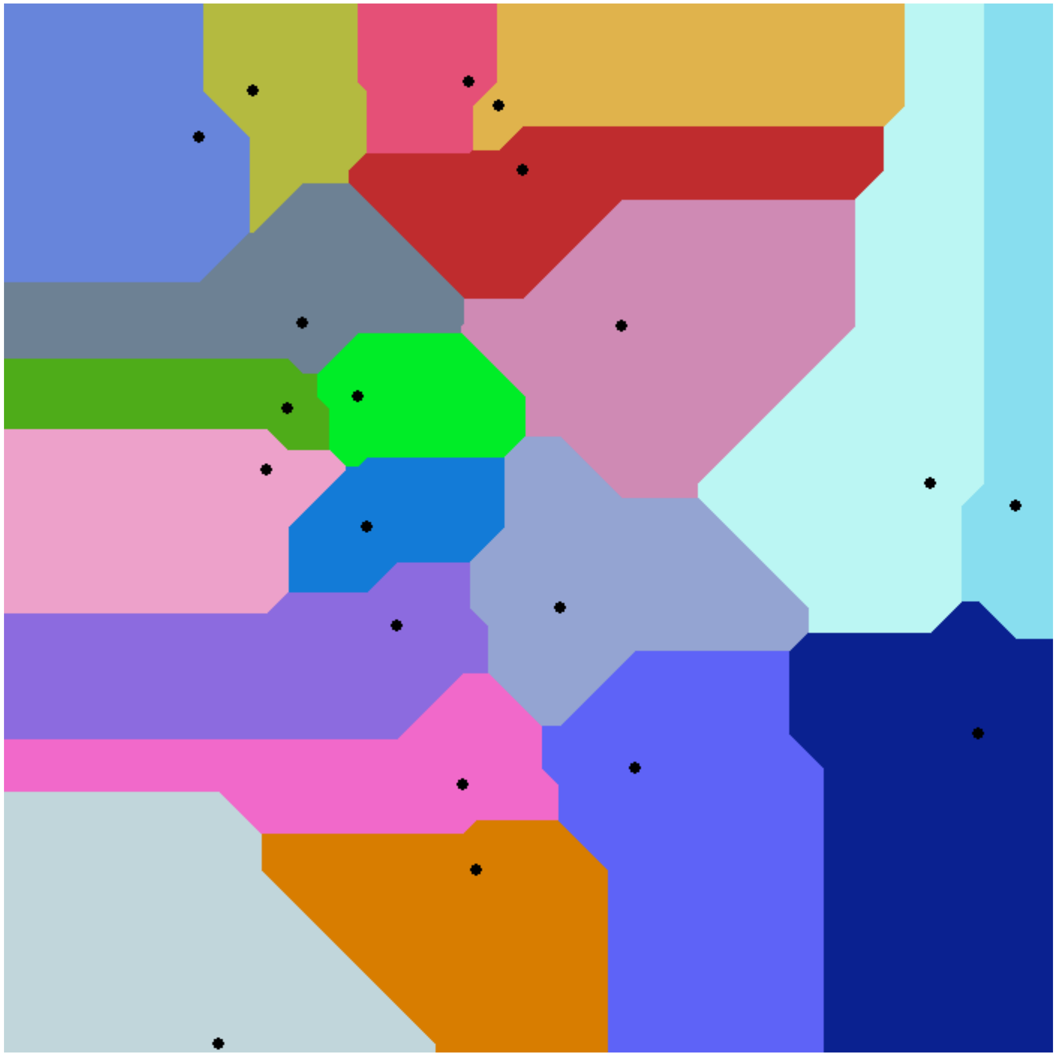
Divides space into zones such that all points within a zone are closer to that zone's "seed" than any other "seed."

Same as a Wigner-Seitz cell

Used in everything from robotic navigation to commerce to epidemiology.

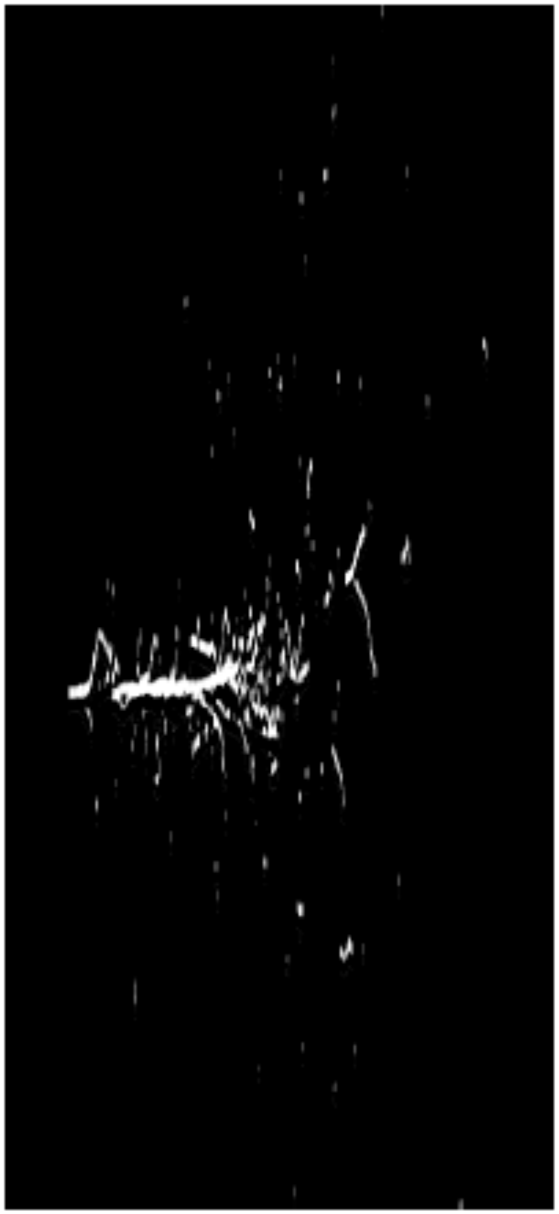
Voronoi Tessellation

Can use arbitrary metrics to define cells:



“Manhattan” metric

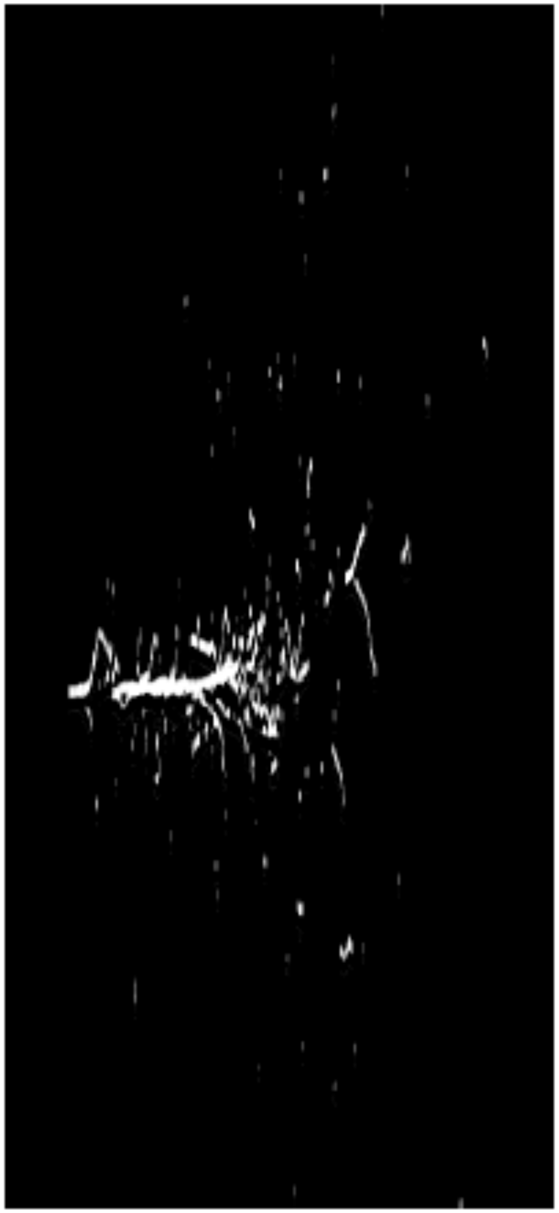
Voronoi Trees



To find features, Dan starts with a single seed and creates a Voronoi cell for it (which is just the whole event).

Then he scans outward until he finds a new "seed" which is determined by some threshold of charge above the surrounding empty space.

Voronoi Trees

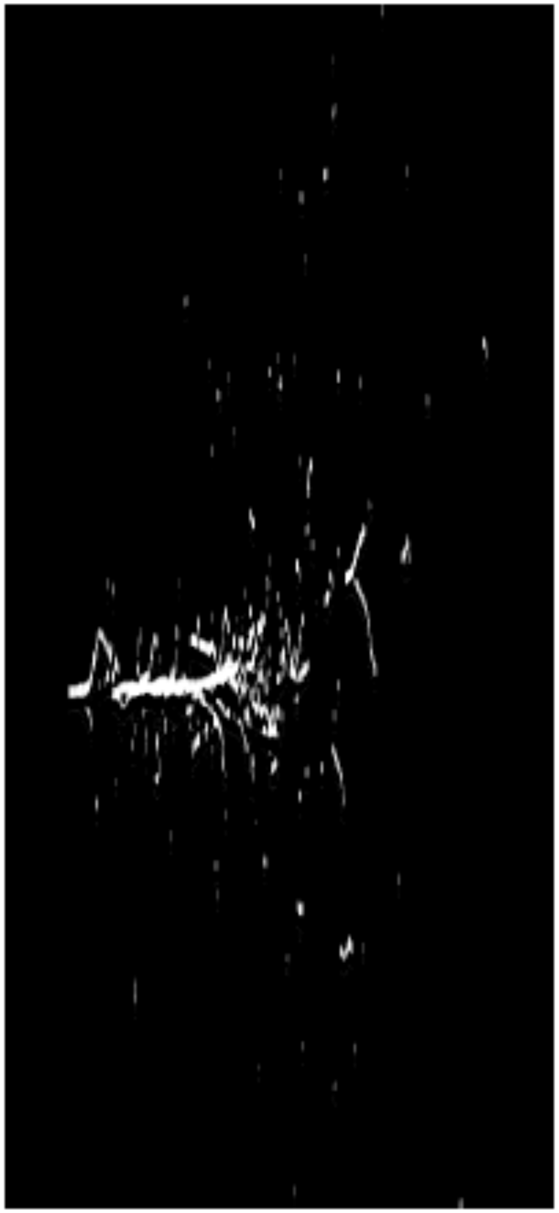


Each time a new seed is discovered, he re-tessellates the space.

Then he scans outward again from each seed.

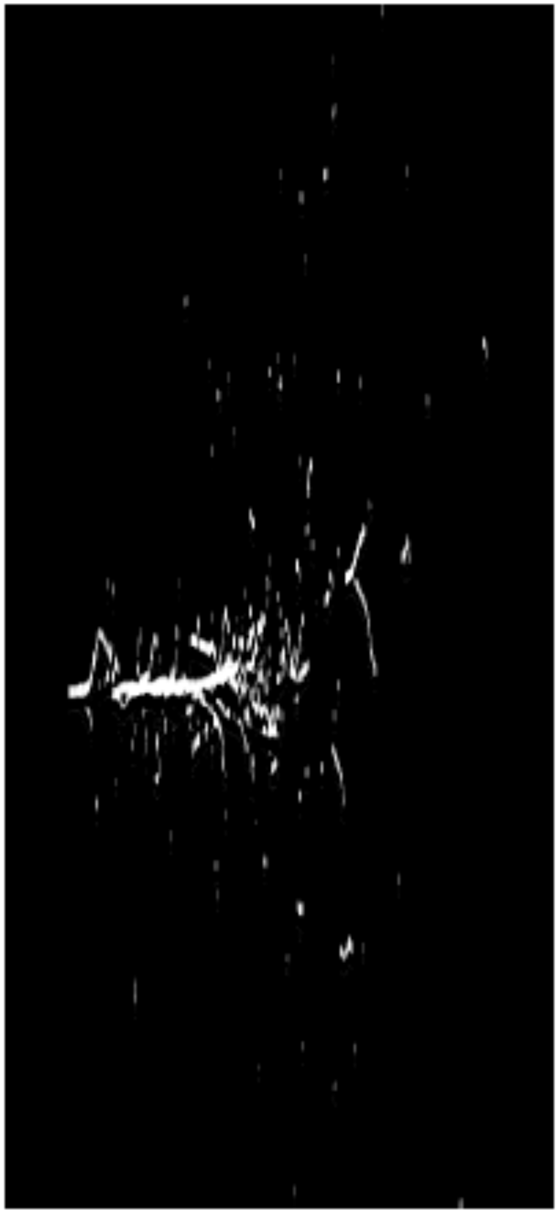
He keeps a set of known seeds, a Voronoi tessellation of the TPC vs wire plane corresponding to those seeds, and a set of edges of the tessellation.

Voronoi Trees



A "tree" is created by discovering new seeds within each Voronoi cell---the new seeds have their own (new) Voronoi cells but have been derived from the original seed (they are members of that tree).

Extracting Features



Trees are then broken into "sub-events"---individual tracks---based on the local charge density.

Results in paths that have similar charge density (presumably the same ionizing particle).

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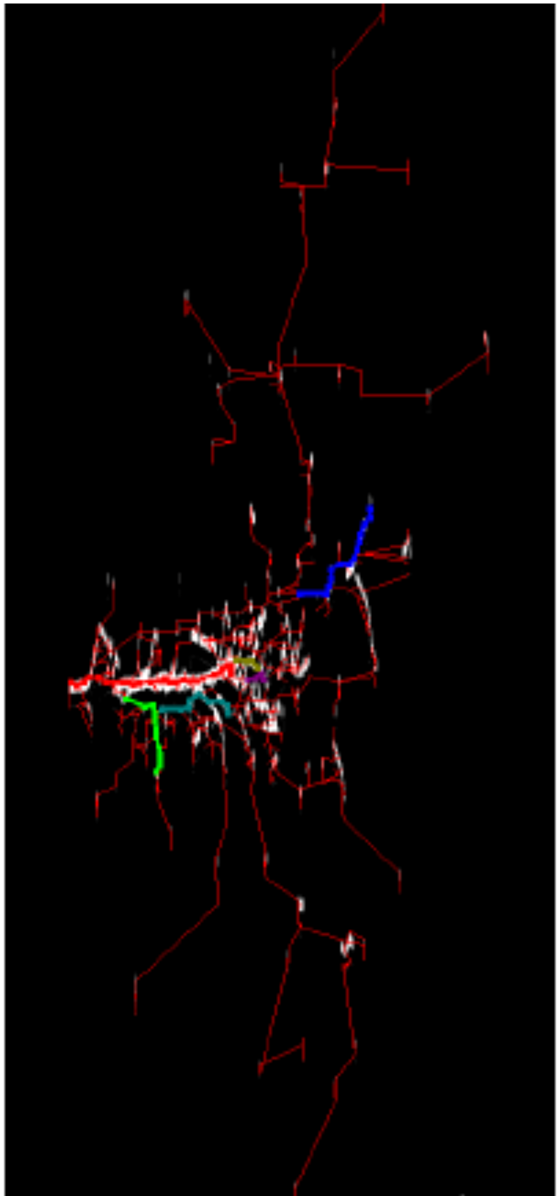

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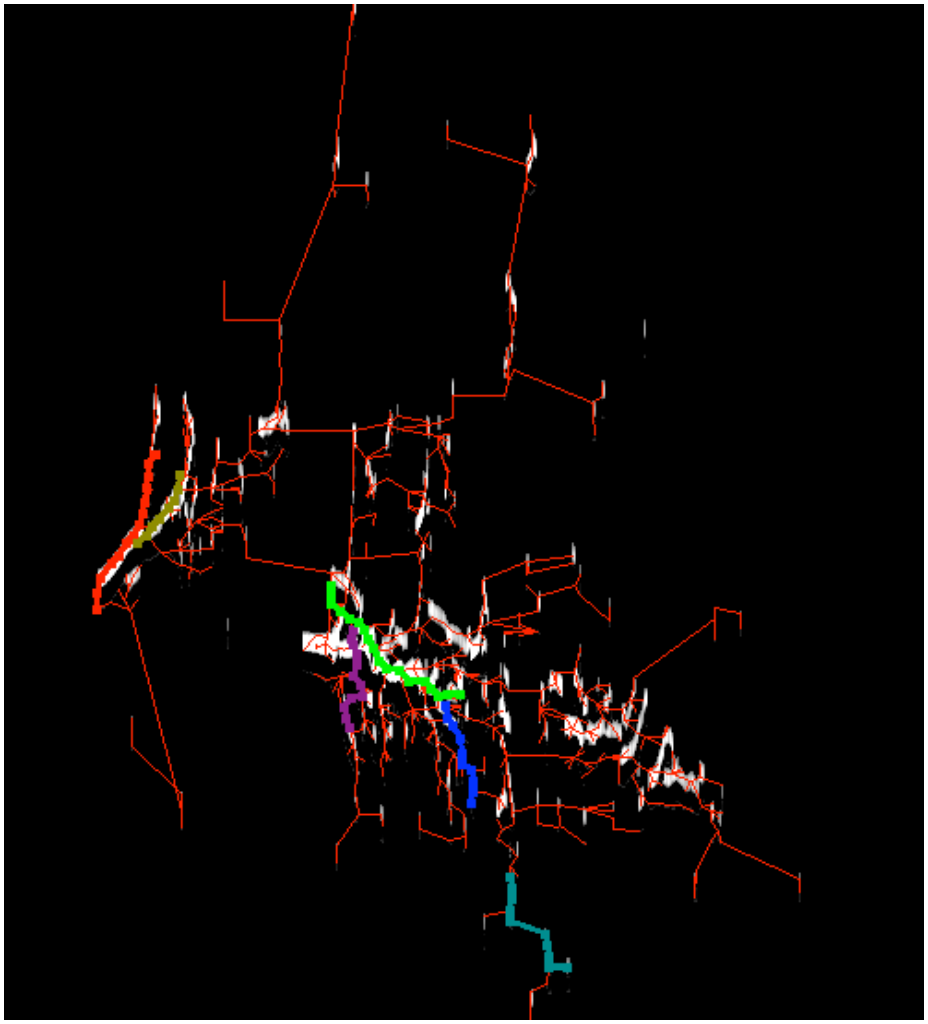
Fragment	Weight
Red	489
Green	114.7
Blue	113.9
Brown	107
Purple	96.8
Cyan	89.9

Figure 2: A clear e^-

Extracting Features



Further Work

- Would like to associate features between views
- Can we associate physical momentum vectors to tracks?
- Maybe use a “physical” metric to define Voronoi cells?
- Need to see how often found tracks are corresponding to real tracks