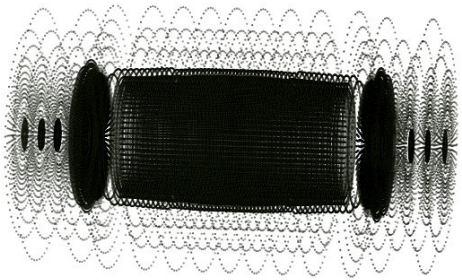
Investigations of Calorimeter Clustering at ATLAS Using Machine Learning



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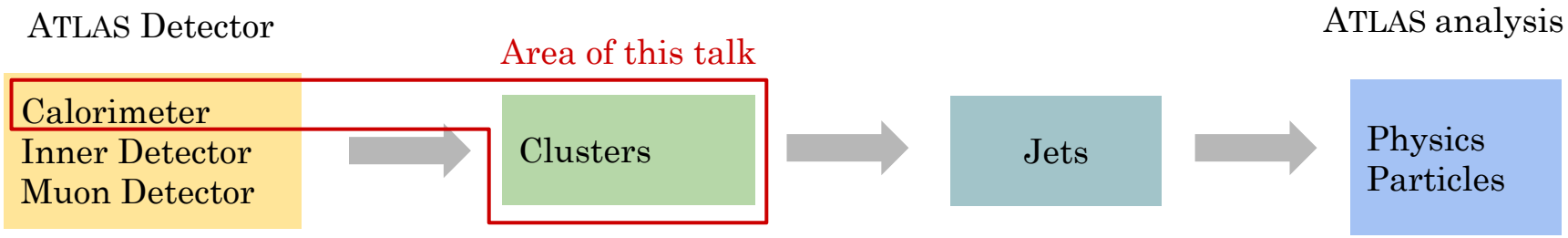
Outline

- A quick overview of calorimeter clustering
  - Quick discussion of the topological clustering algorithm at ATLAS
  - Effects of high luminosity and pile-up
- Quick introduction to neural nets
- Problem/Solution to neural nets on calorimeters
  - Discuss Objective function (or loss function)
  - Discuss Geometry
- Current Implementations

Context

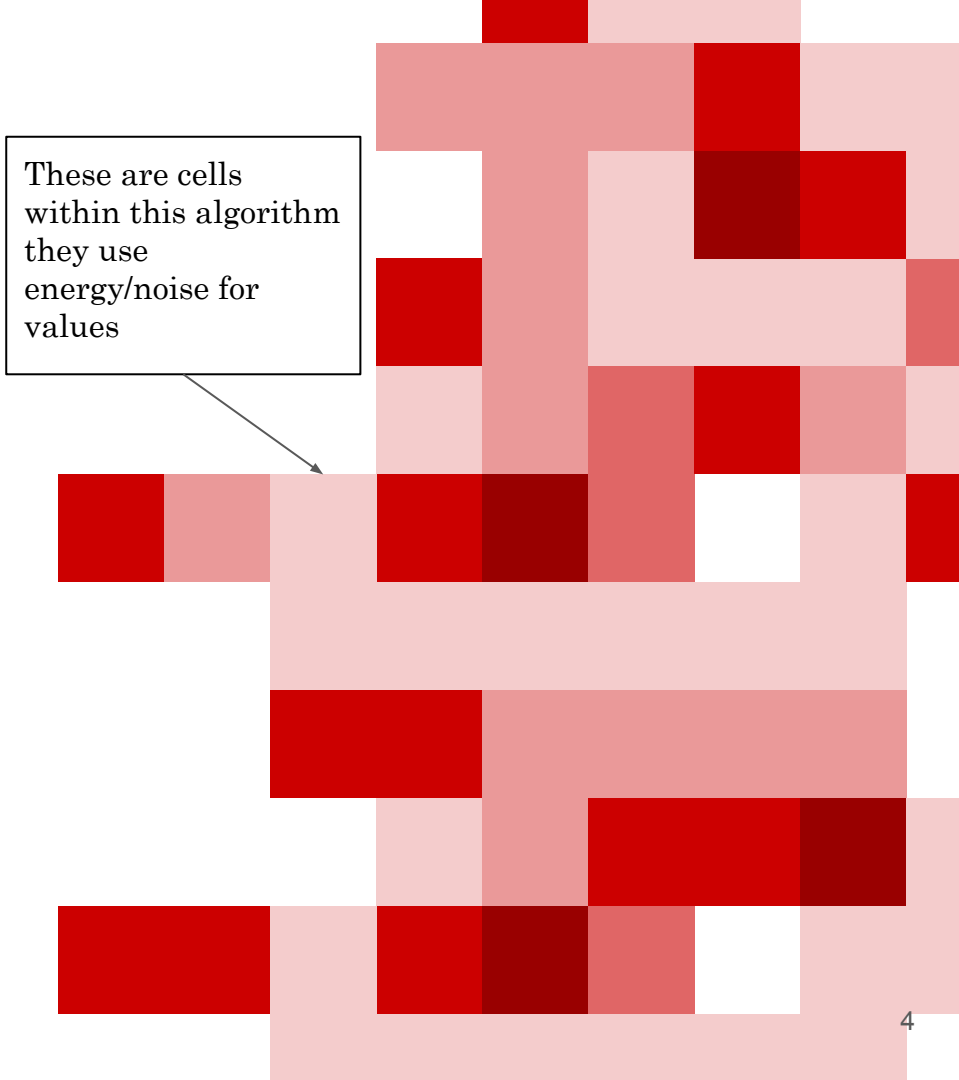


- We are looking at the formation of clusters which will further be refined into jets and particles.
- Currently this is done with the topological clustering algorithm (topocluster algorithm)
  - There are some concerns about it's abilities in higher pile-up situations

Topological clustering Algorithm

The goal of this algorithm is to turn a group of cells into a list of clusters. This algorithm is usually split into four steps.

1. Seed clusters
2. Grow protoclusters
3. Merge protoclusters
4. Split into final clusters



Topocluster paper can be found at:
https://arxiv.org/pdf/1603.02934.pdf

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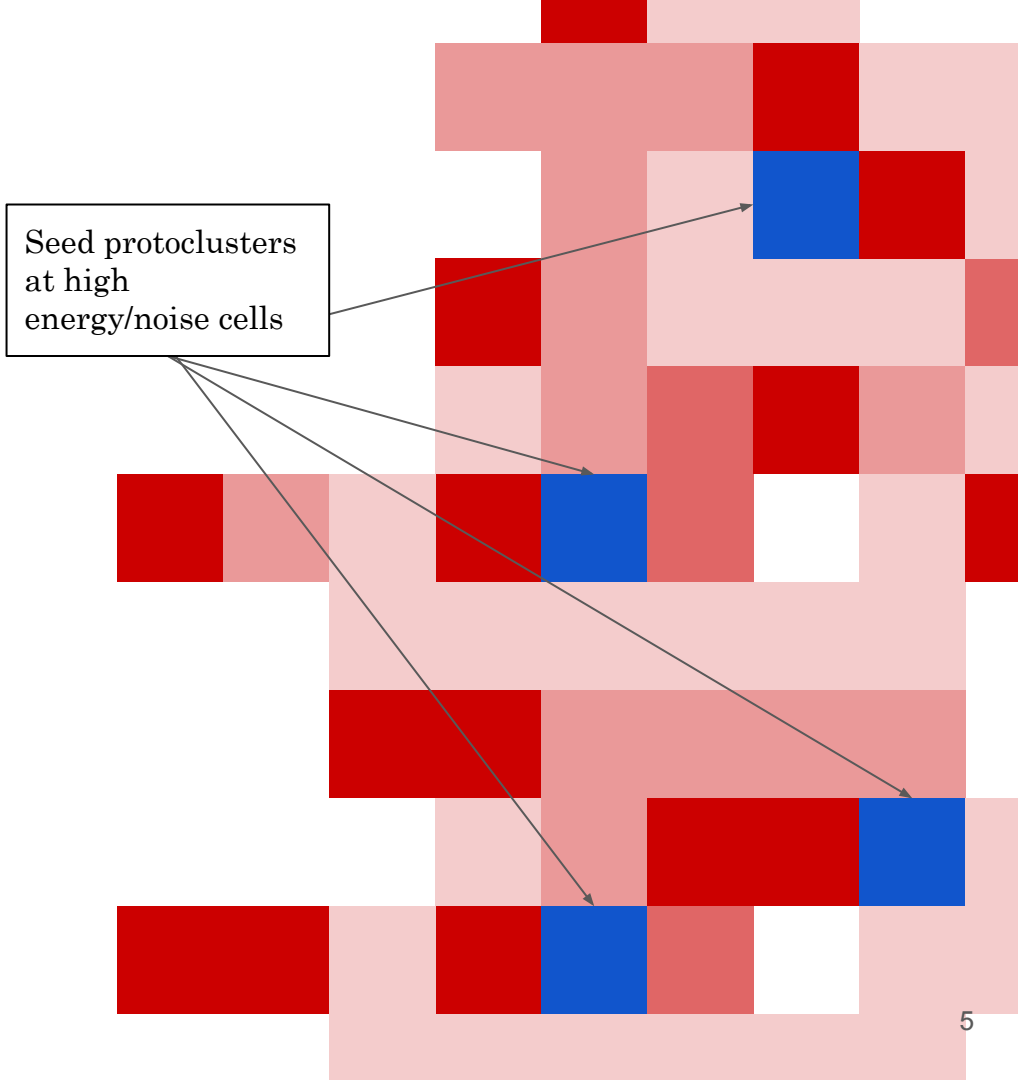

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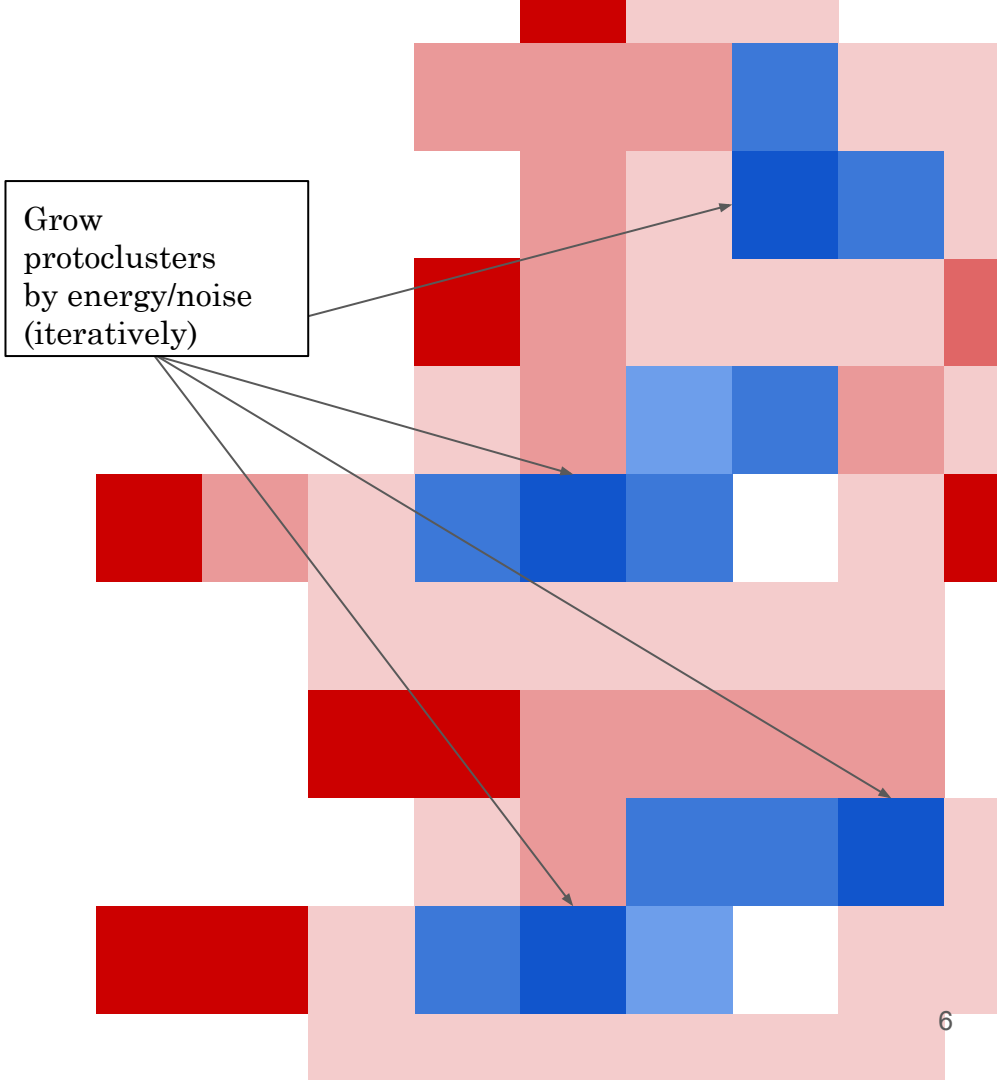

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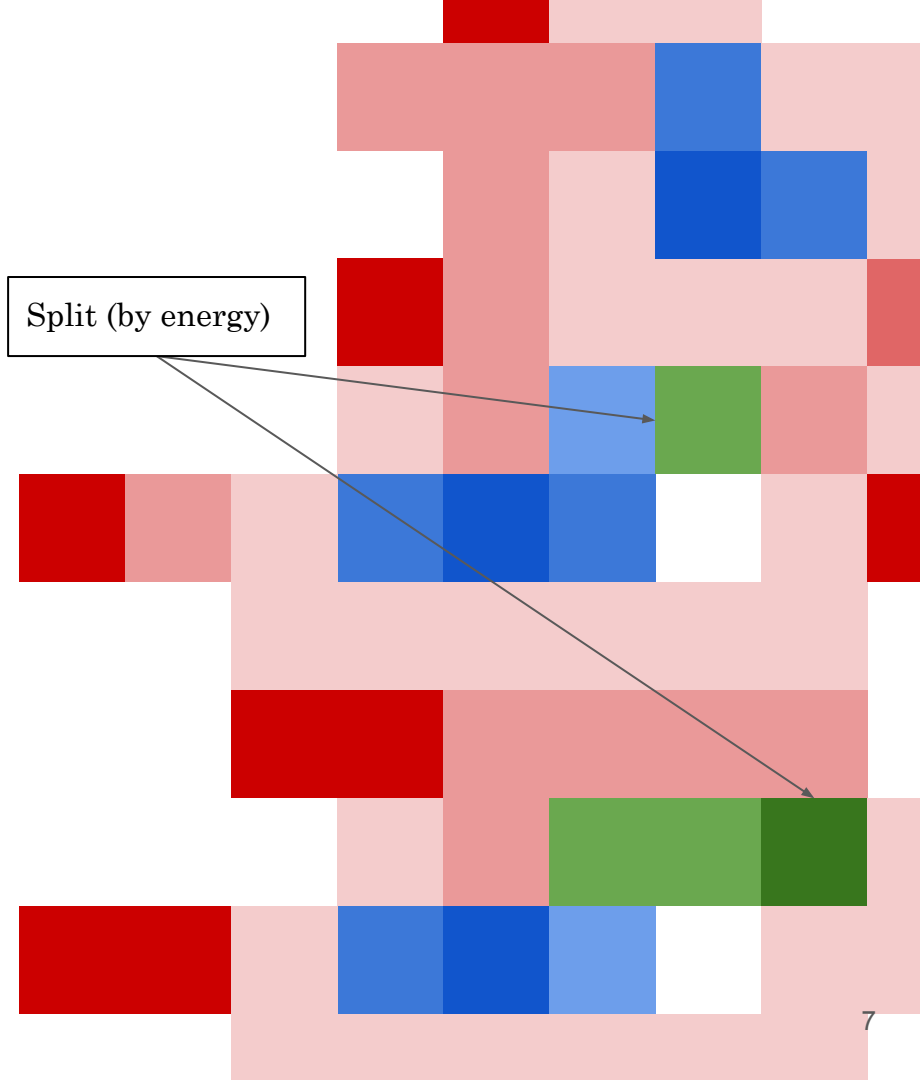
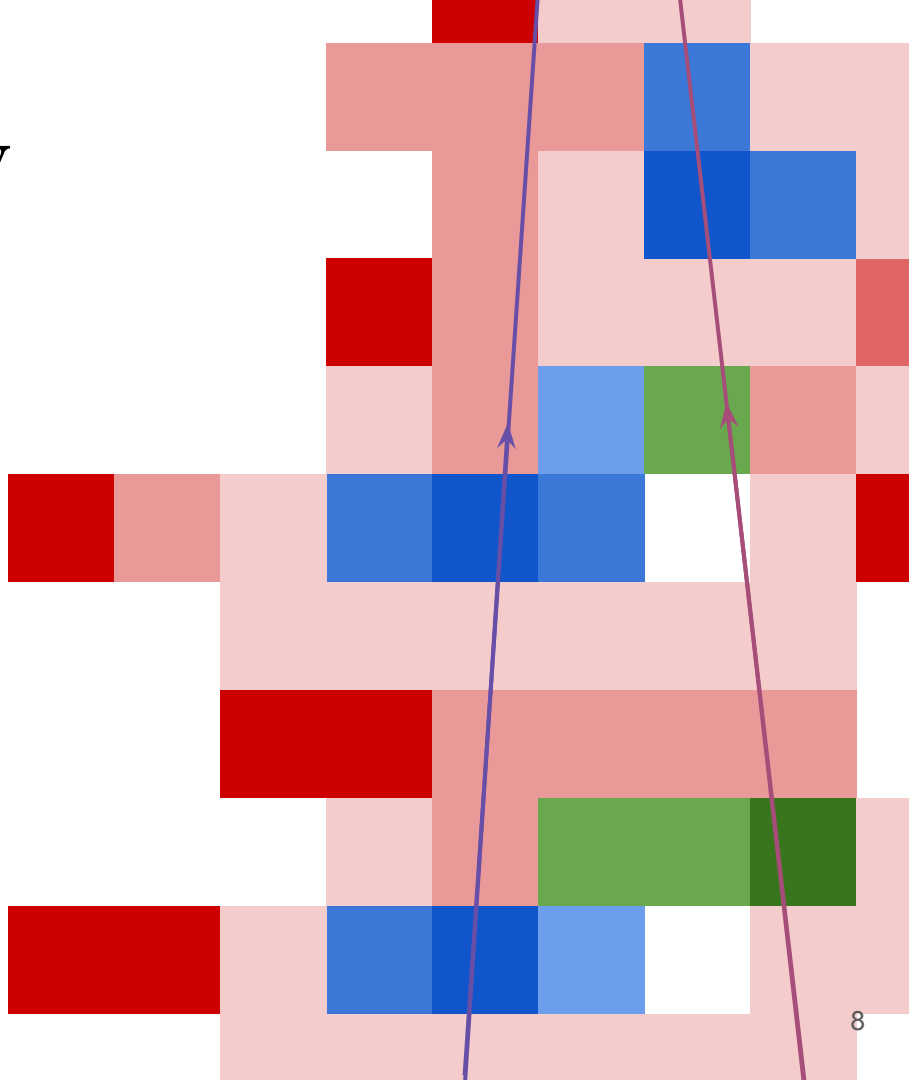


Impact of higher luminosity

With higher luminosity comes a higher average number of simultaneous proton-proton collisions per bunch cross.

This excess of particles can lead to a ambiguity of energy depositions that originate from distinct particles

The topocluster algorithm's ability to operate in these environments has been called into question.



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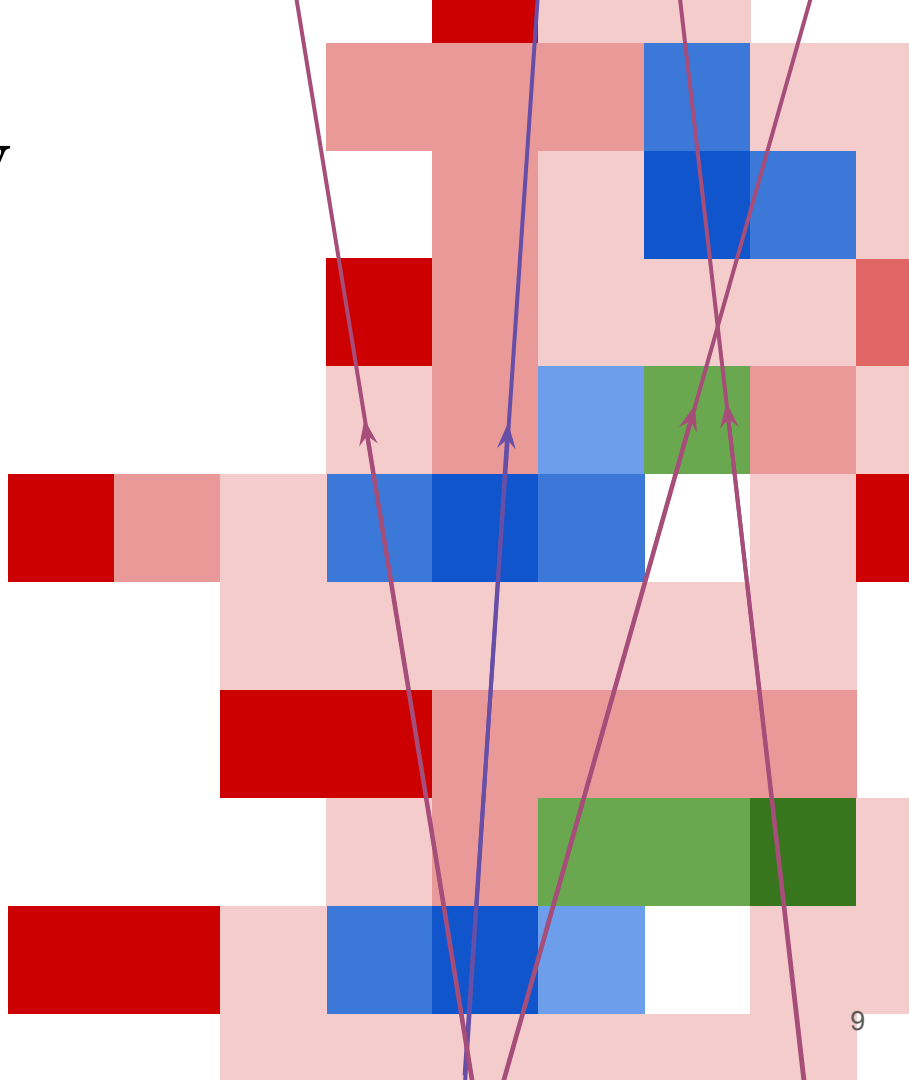
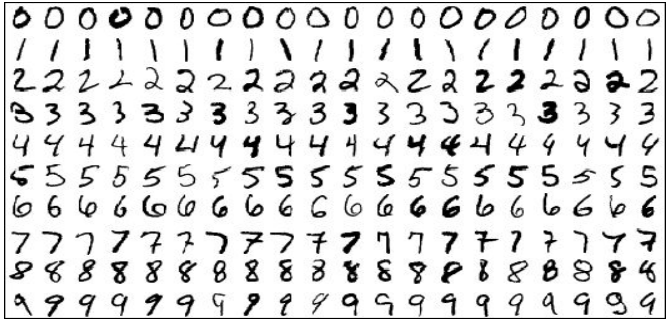


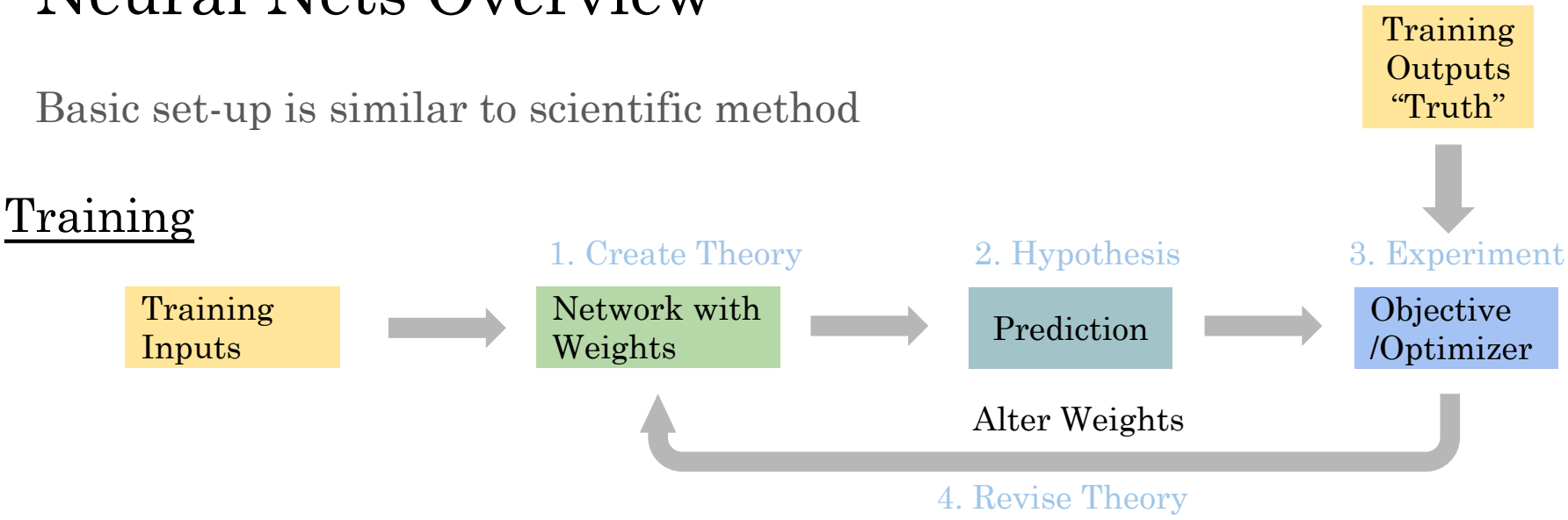
This is a clustering problem

- Clustering problems are a very common problem in many areas.
- Which machine learning techniques should we use?
- Looking at other classification / clustering problems such as the handwriting dataset, MNIST, give some idea of accuracy
- Goal is to classify handwritten digits into digital categories
- 60000 Training examples, 10000 Test examples
- Convolutional Neural Nets are among the top contenders

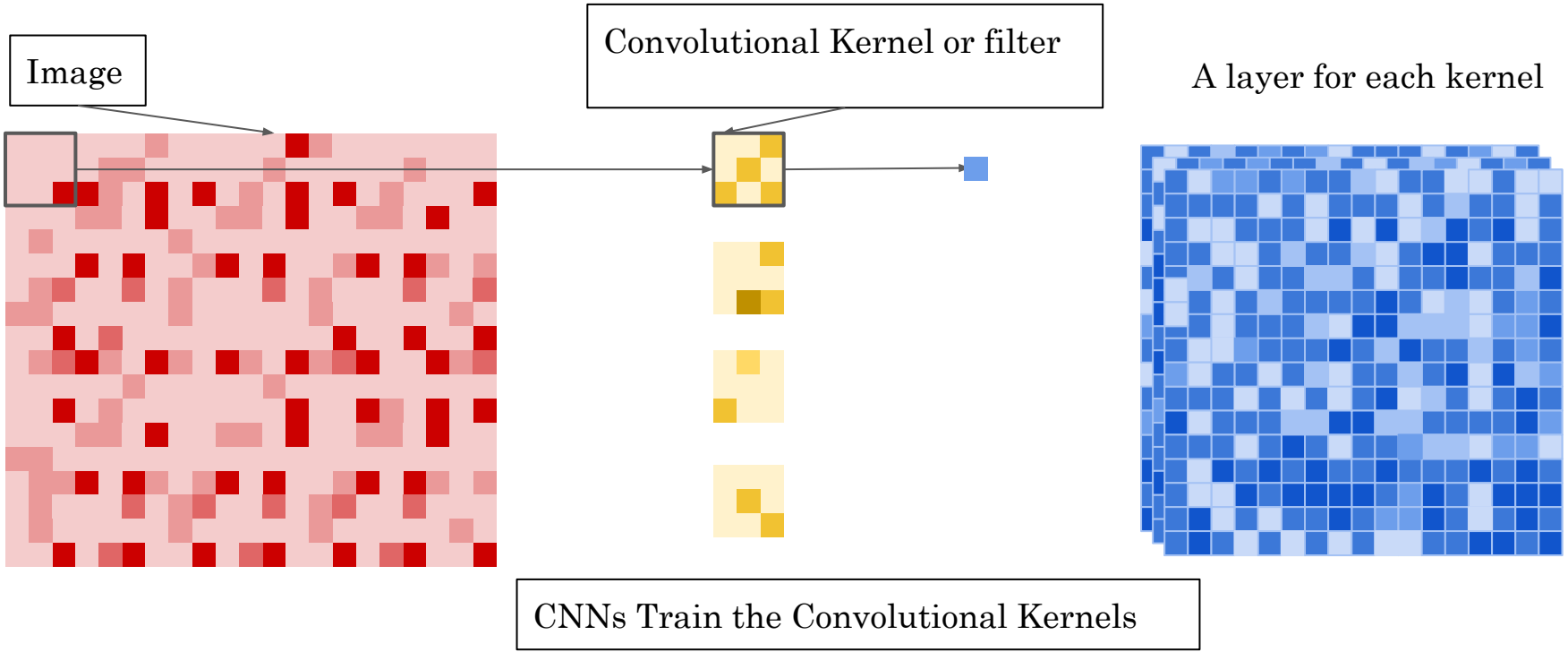


Neural Nets Overview

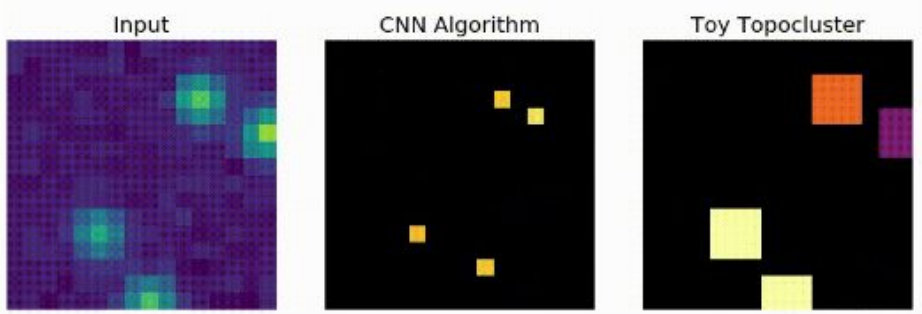
Basic set-up is similar to scientific method

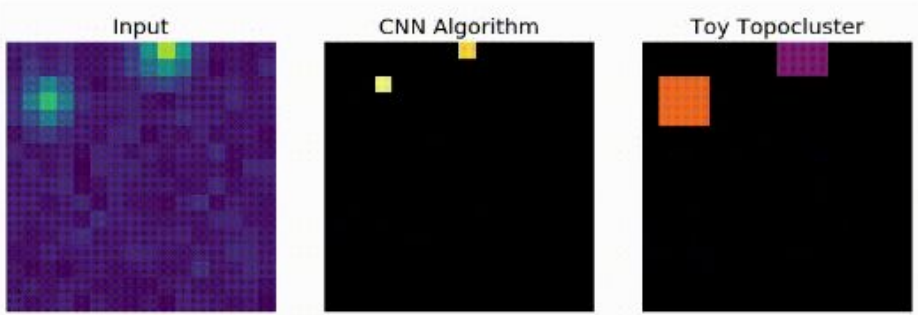


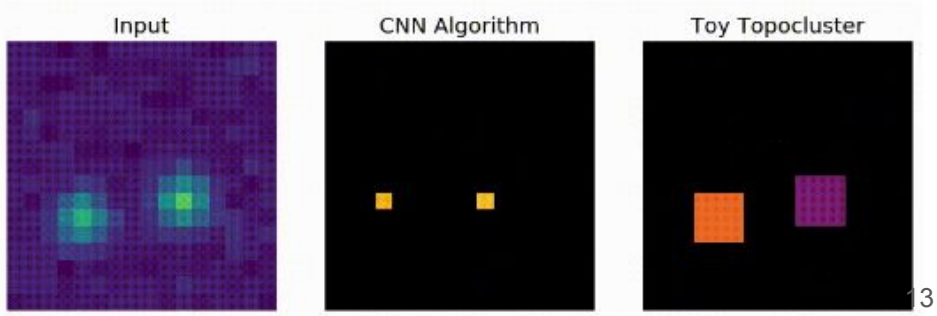
Convolutional Neural Networks Structure



Toy Model



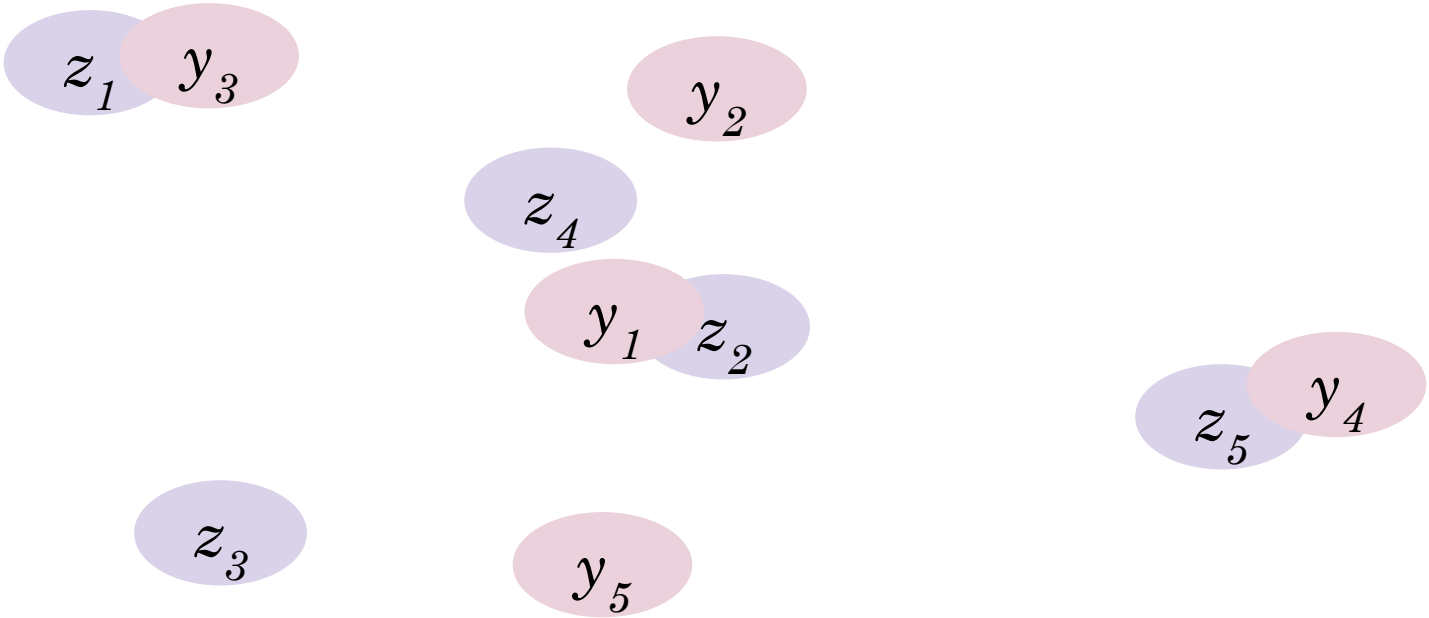




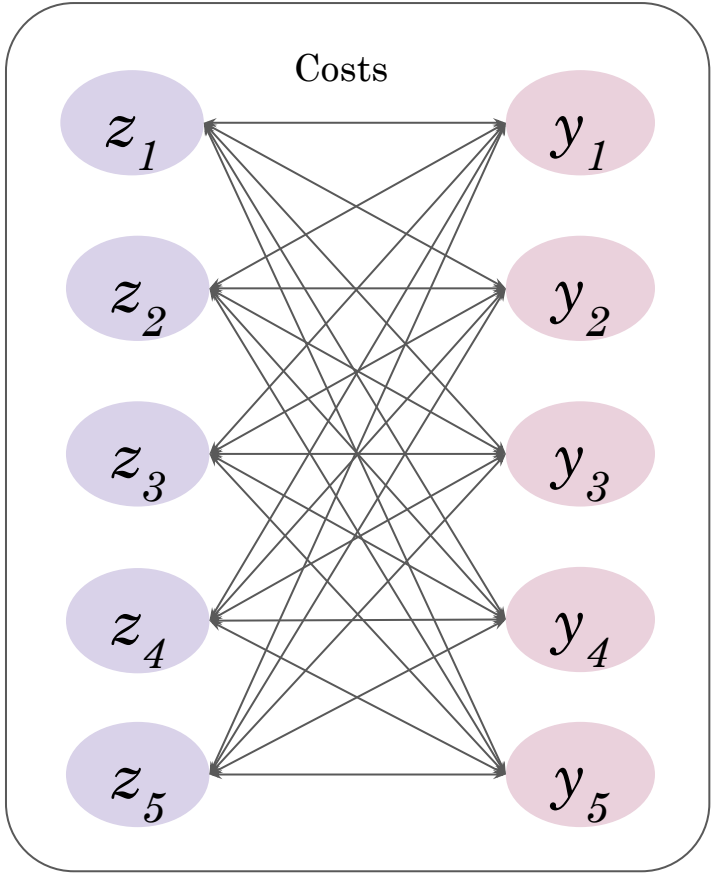
ATLAS work-in-progress

Problem 1. The Objective

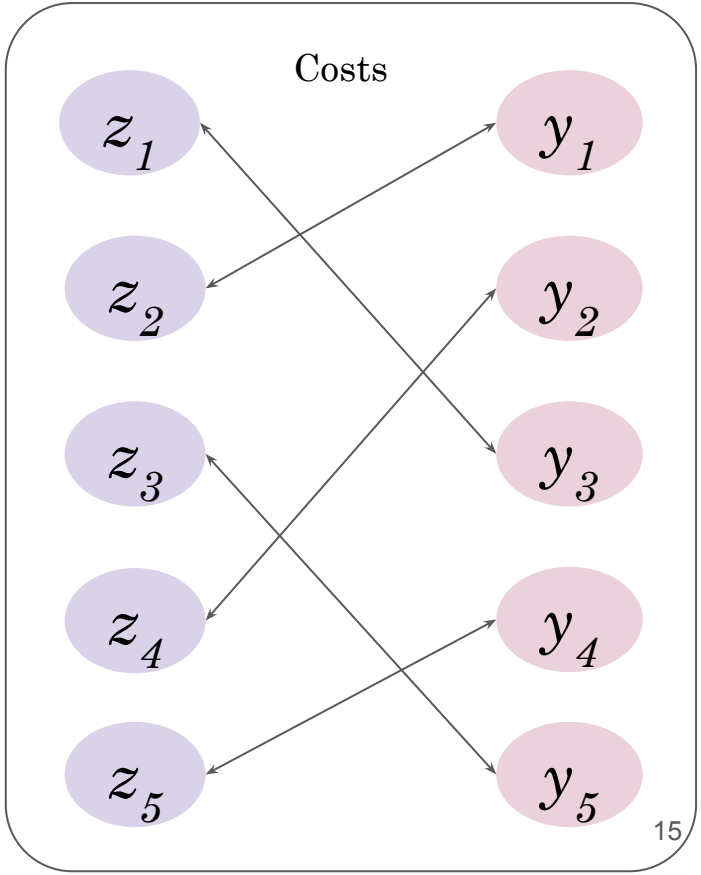
With y_i as solution and z_i as output. Because both lists are unordered the connection between output and “truth” is ambiguous.



The Assignment Problem

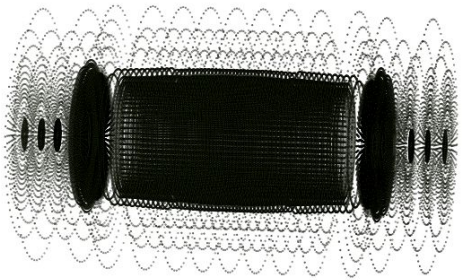


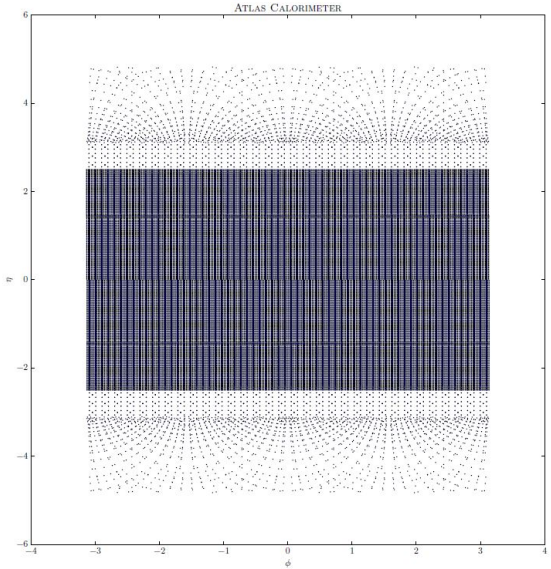
The Munkres/
Hungarian
Algorithm

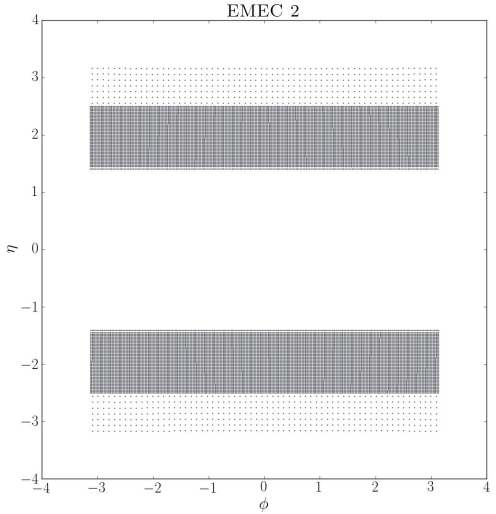


Problem 2. Geometry

Getting calorimeter cells into a form that convolutional neural nets can understand. The calorimeter has 33 calorimeter cell granularities.





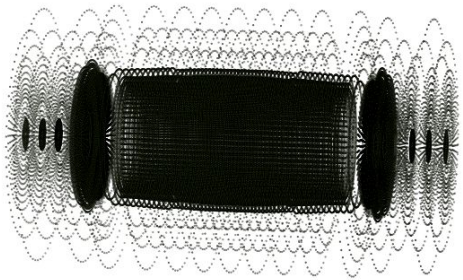


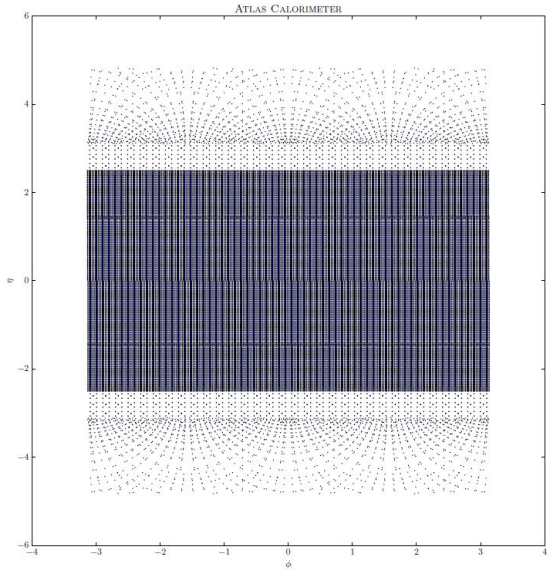
"Floor plans" of ATLAS
This is multiple layers

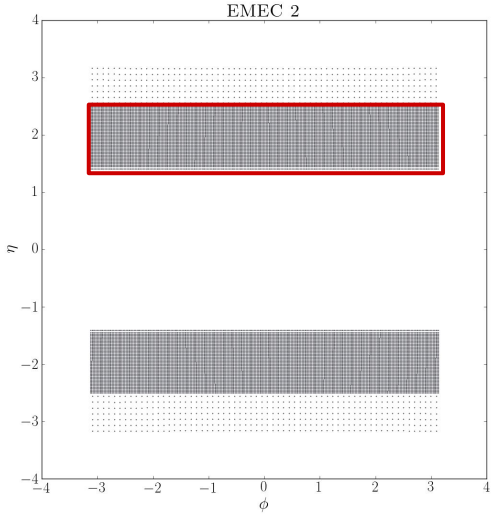
ATLAS work-in-progress

Problem 2. Geometry

Look at one specific granularity to start with.







“Floor plans” of ATLAS
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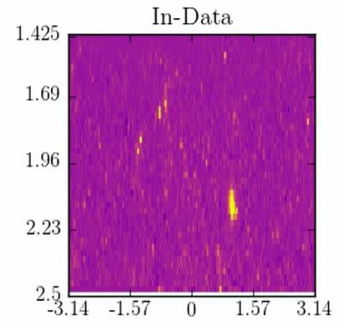
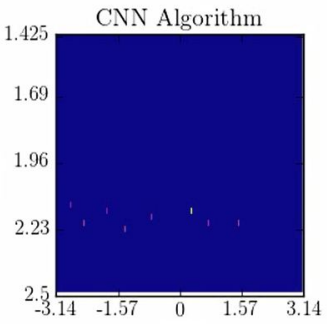
ATLAS work-in-progress

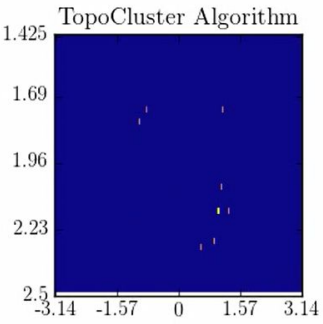
Truth Objects

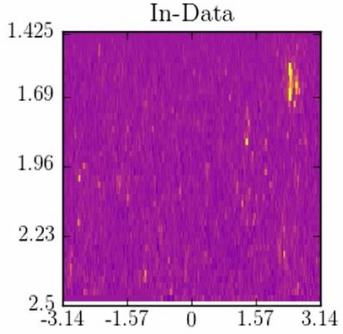
- For now use topological clusters as “truth” information to ensure that algorithm works
  - It should at least be able to replicate current results
- Eventual make use of simulations of ATLAS to create truth information

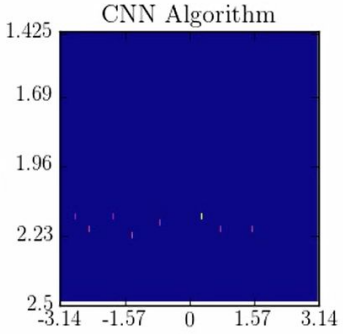
Preliminary results

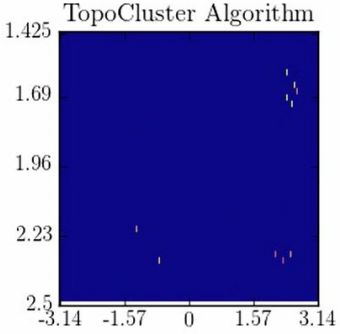


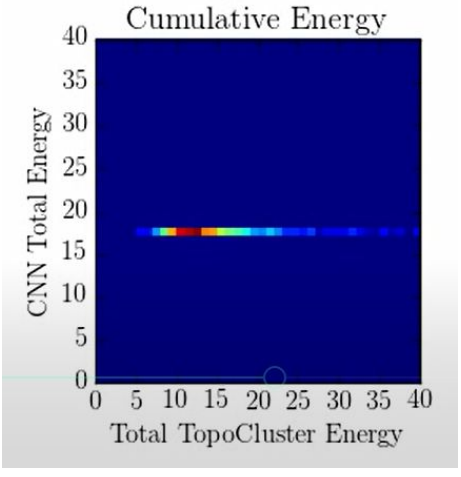












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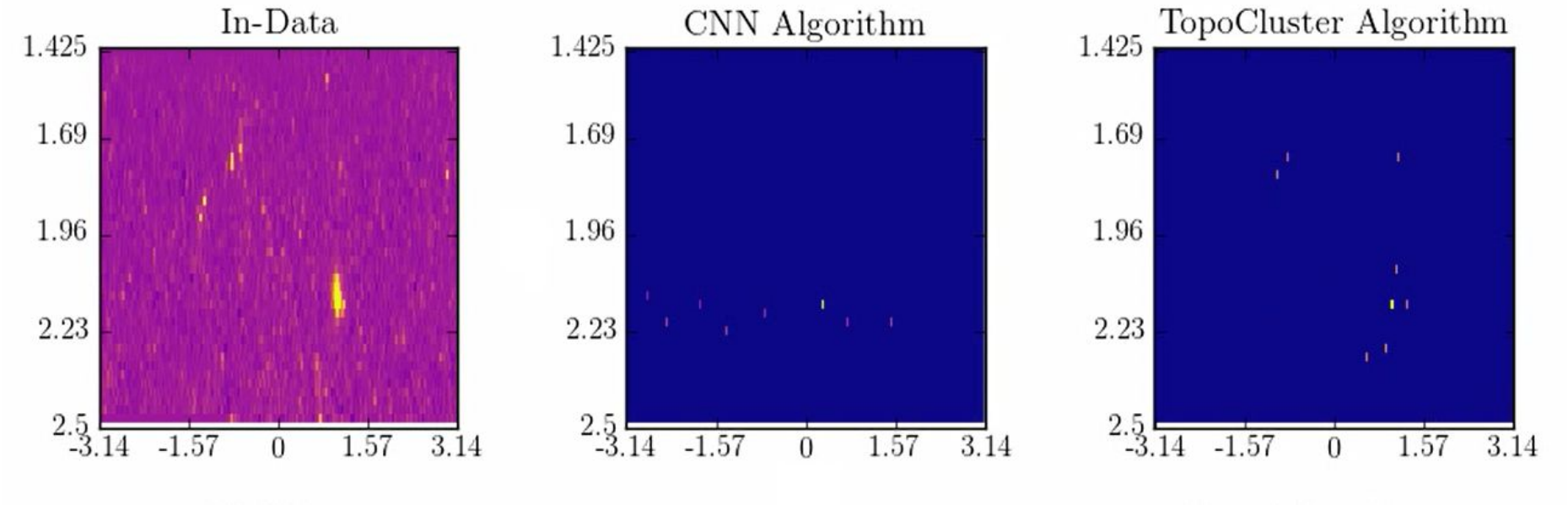


Software used

Python Libraries

- Keras with Theano as the backend
  - Only used CPU for this work
- Numpy and matplotlib
- numpyroot

ROOT

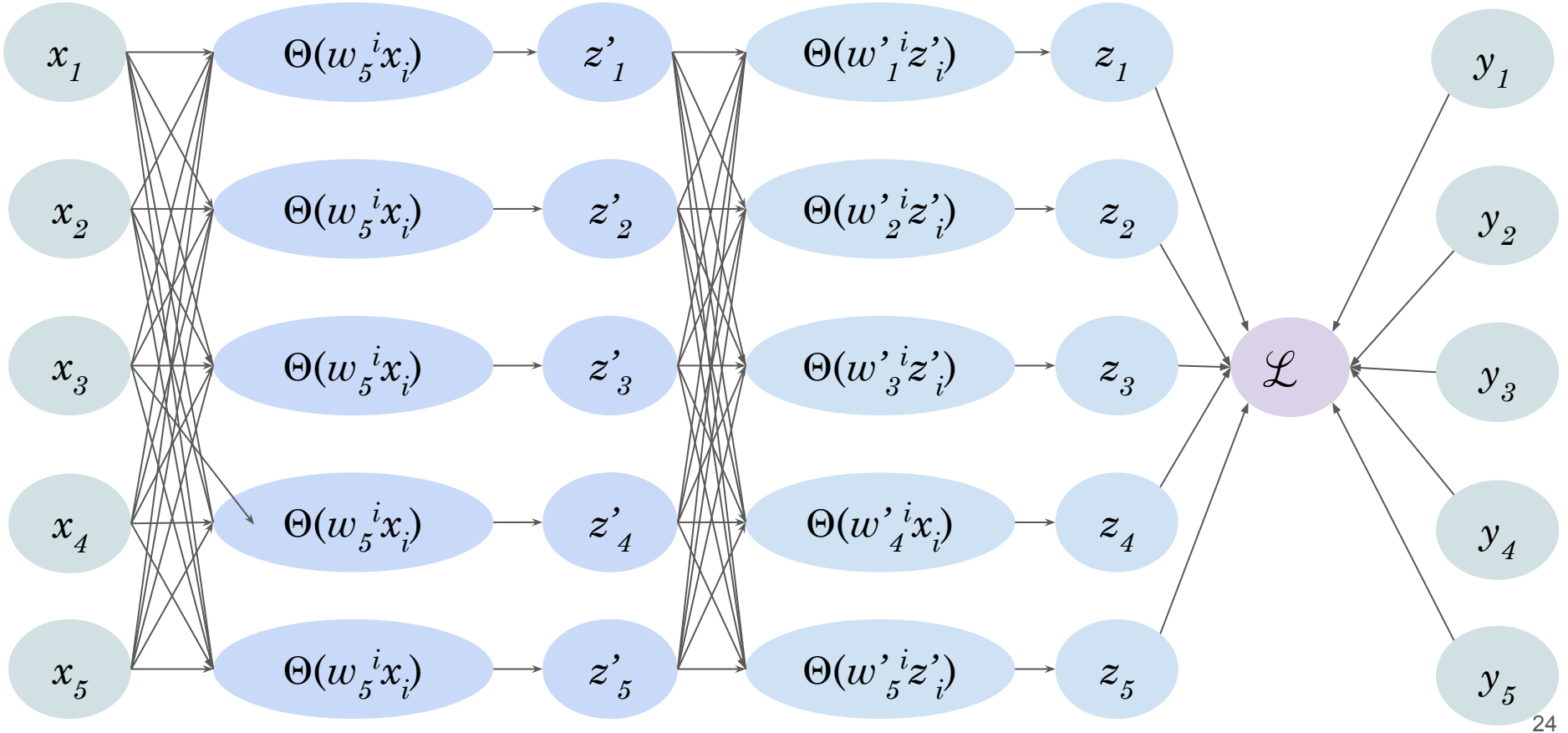
Thanks for your time!

Any question or comments?

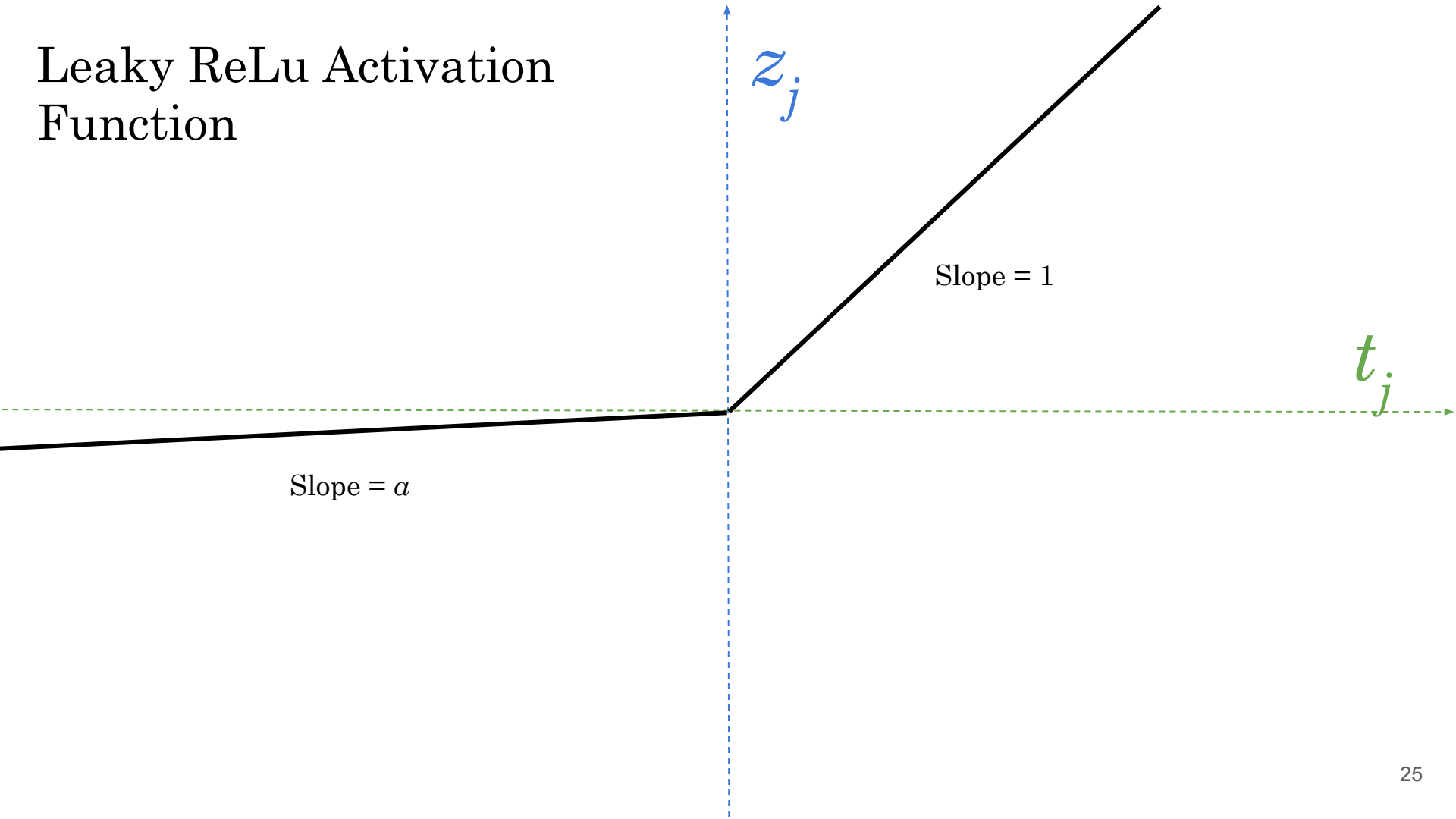
Also email: graemen@uvic.ca

Extra Material

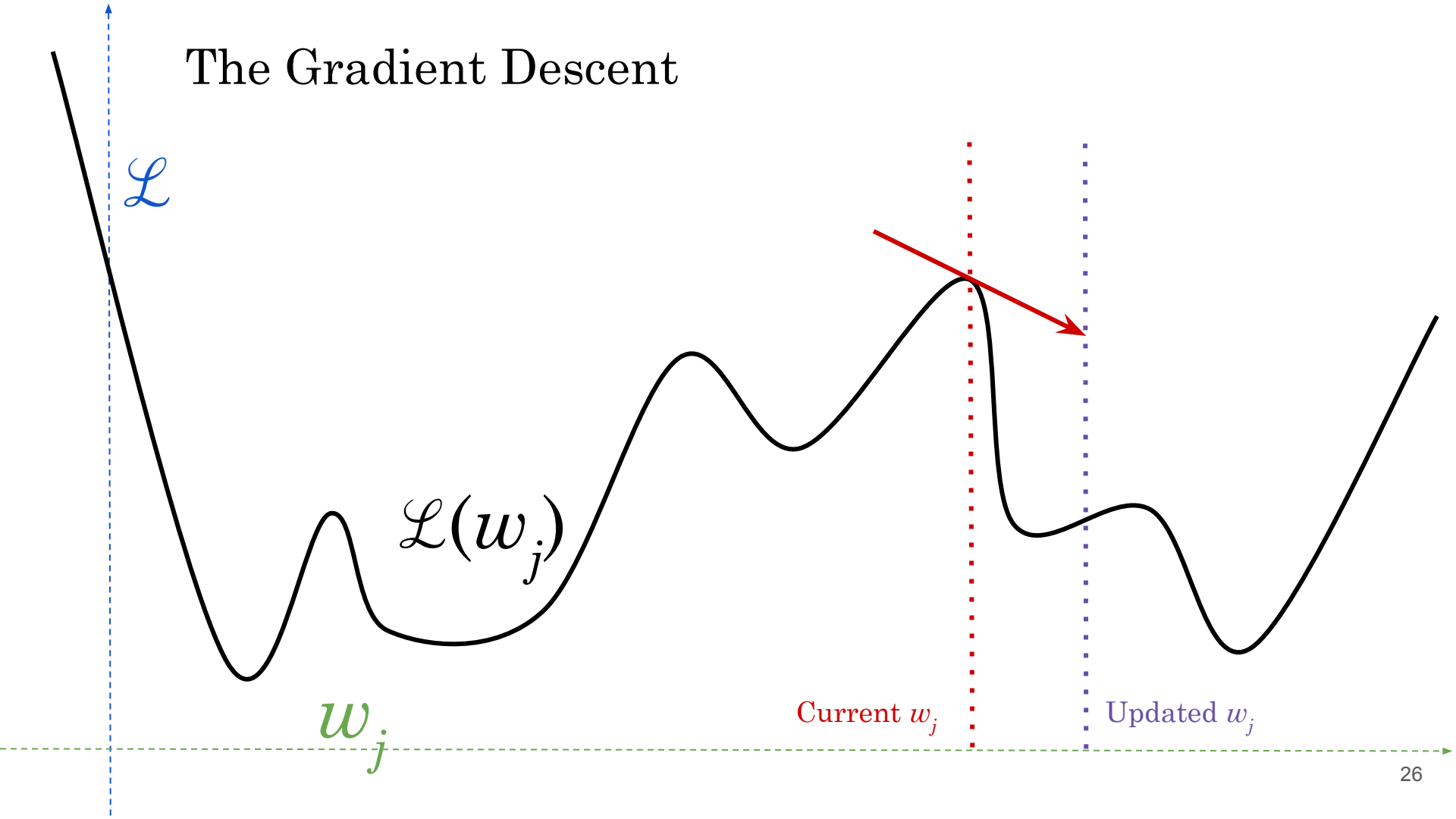
Neural Nets Structure



Leaky ReLu Activation Function

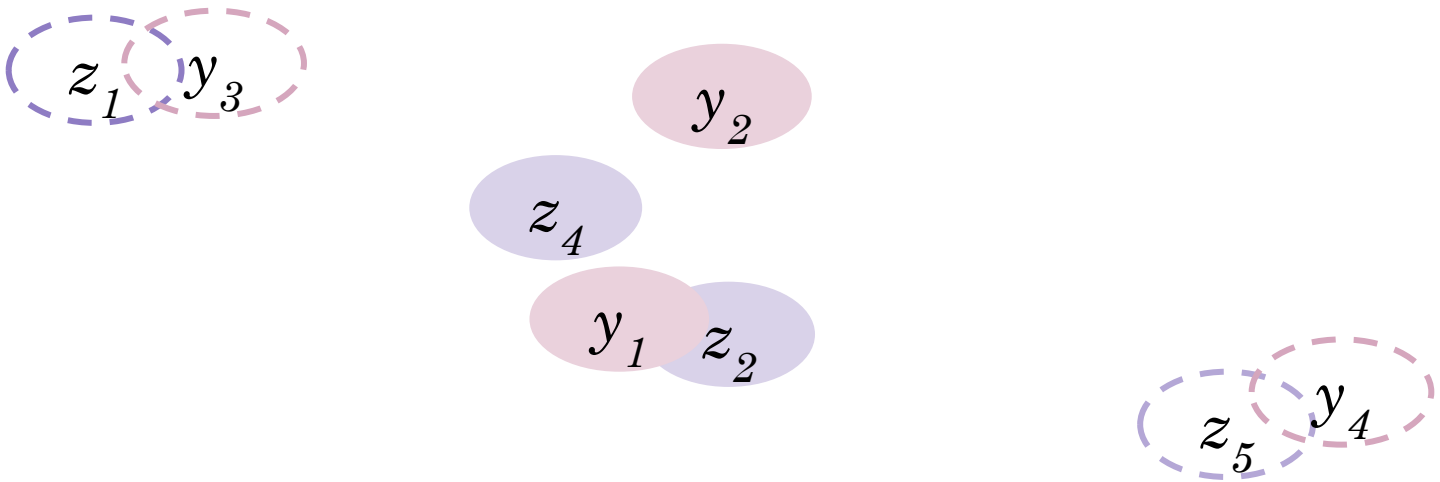


The Gradient Descent



Number of Clusters

- Neural Nets have fixed dimensional outputs
- Ghost Clusters
- Only assign error based on energy



The Training Phase