Gamma-Ray Spectrum Analysis and Classification

A Machine Learning Perspective

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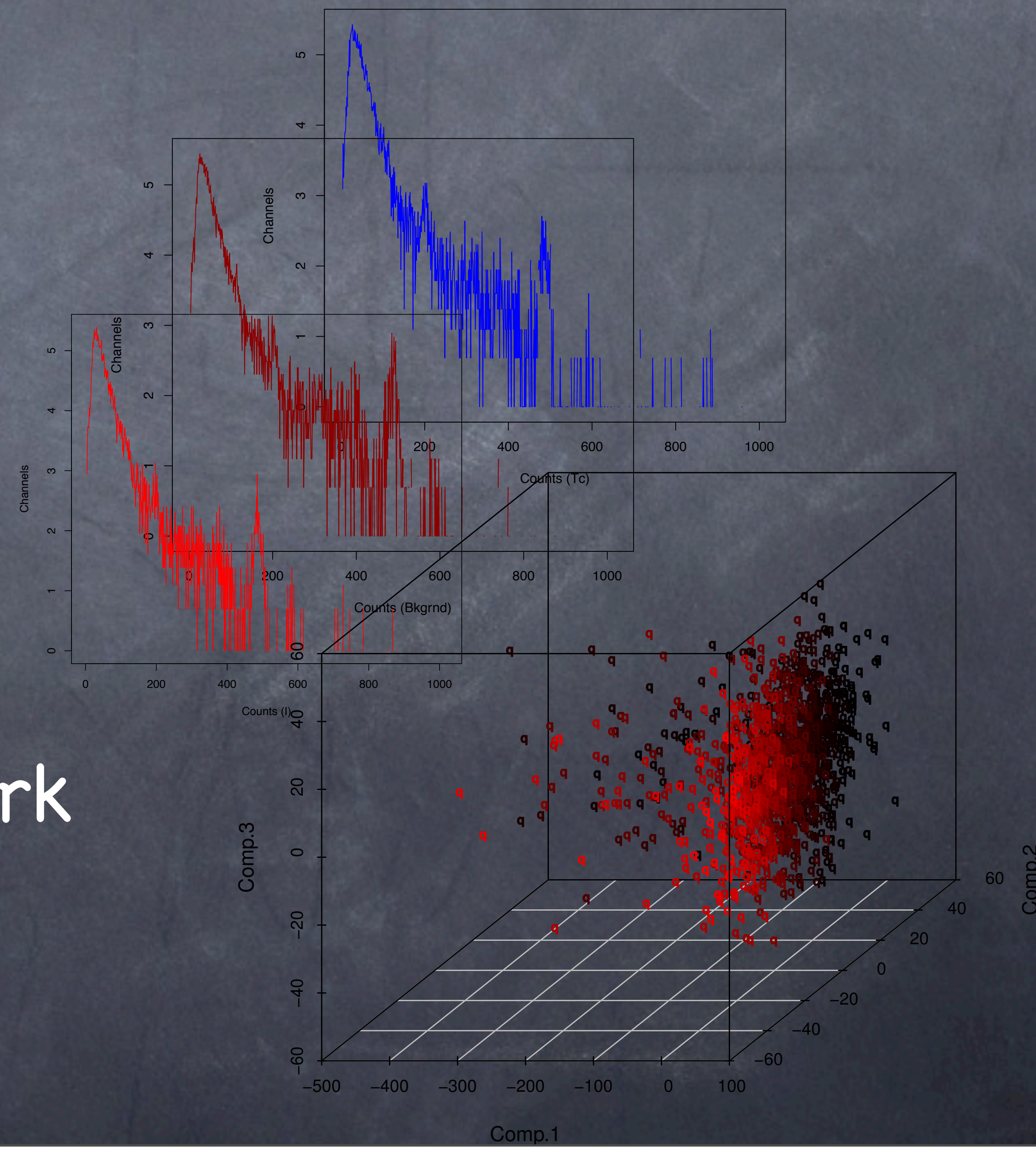
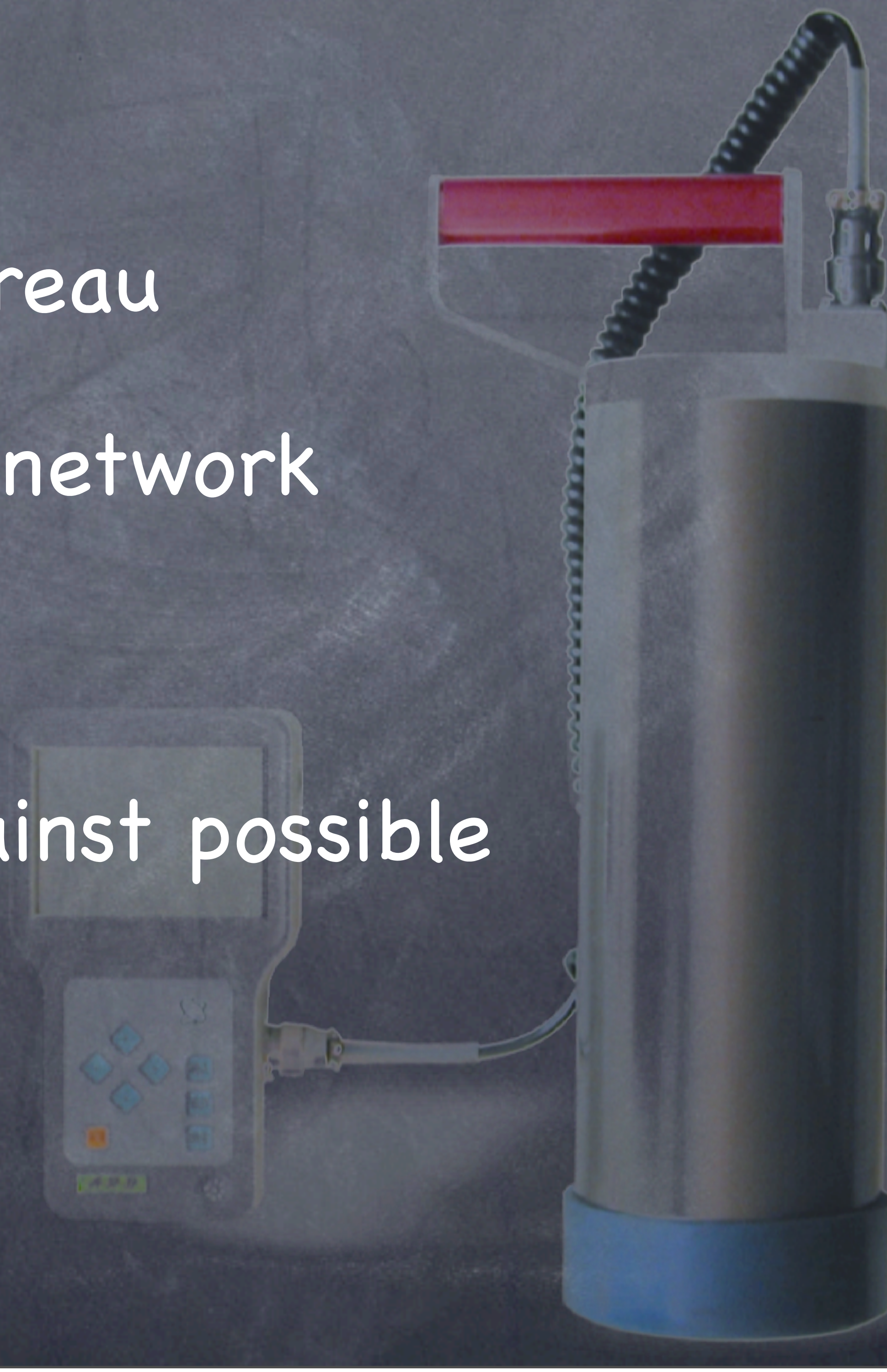
Outline

- Overview
- Data
- Experiments
- Results
- Conclusion / Future Work



Background

- HC Radiation Protection Bureau
  - Radioactivity monitoring network
  - Support CTBT
  - Secure public events against possible radioactive threats, etc.

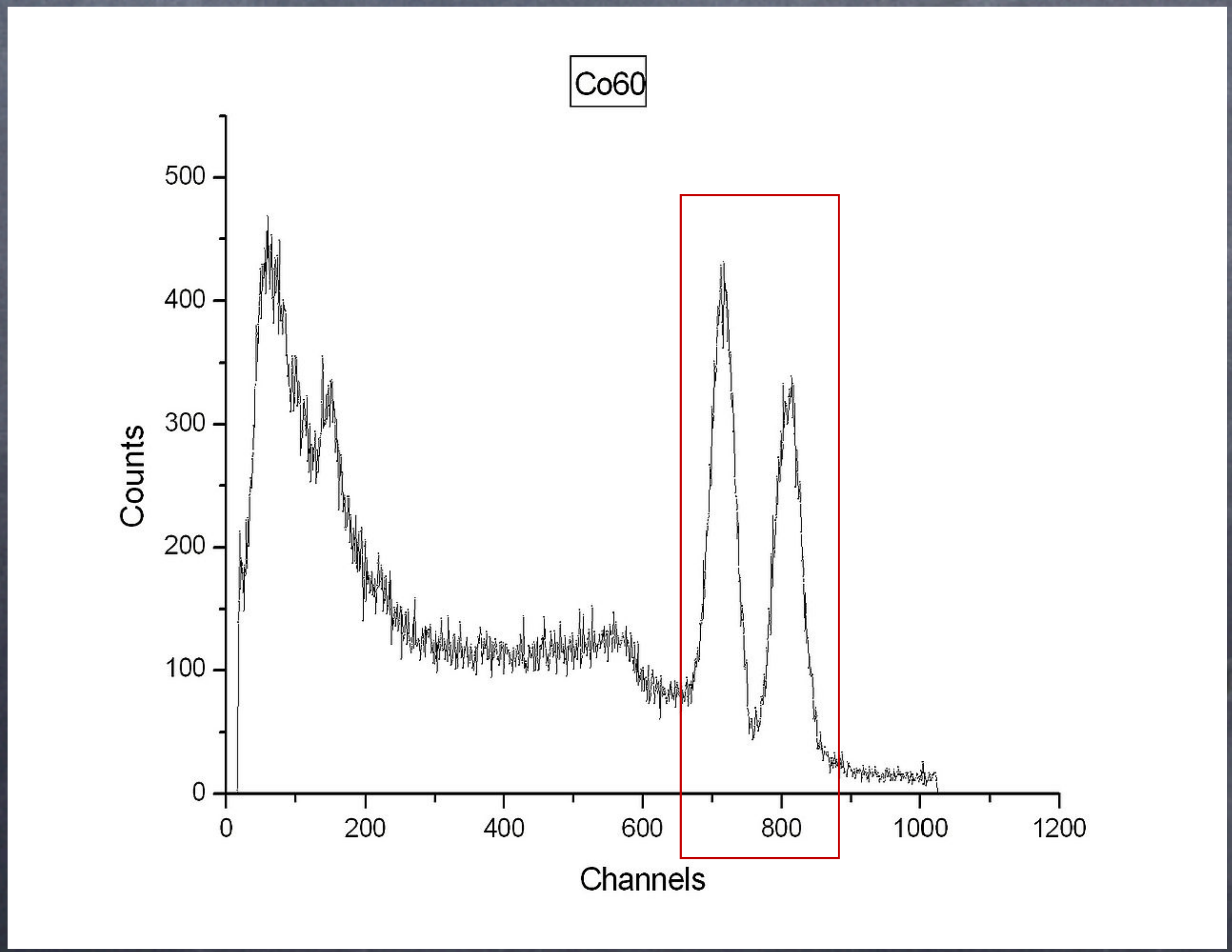


HC Problem Statement

- Goal: monitor and detect radioactive threats
    - Political gatherings, sporting events, etc.
- Strategy: Utilize human experts and ML algorithms
    - Minimize human involvement

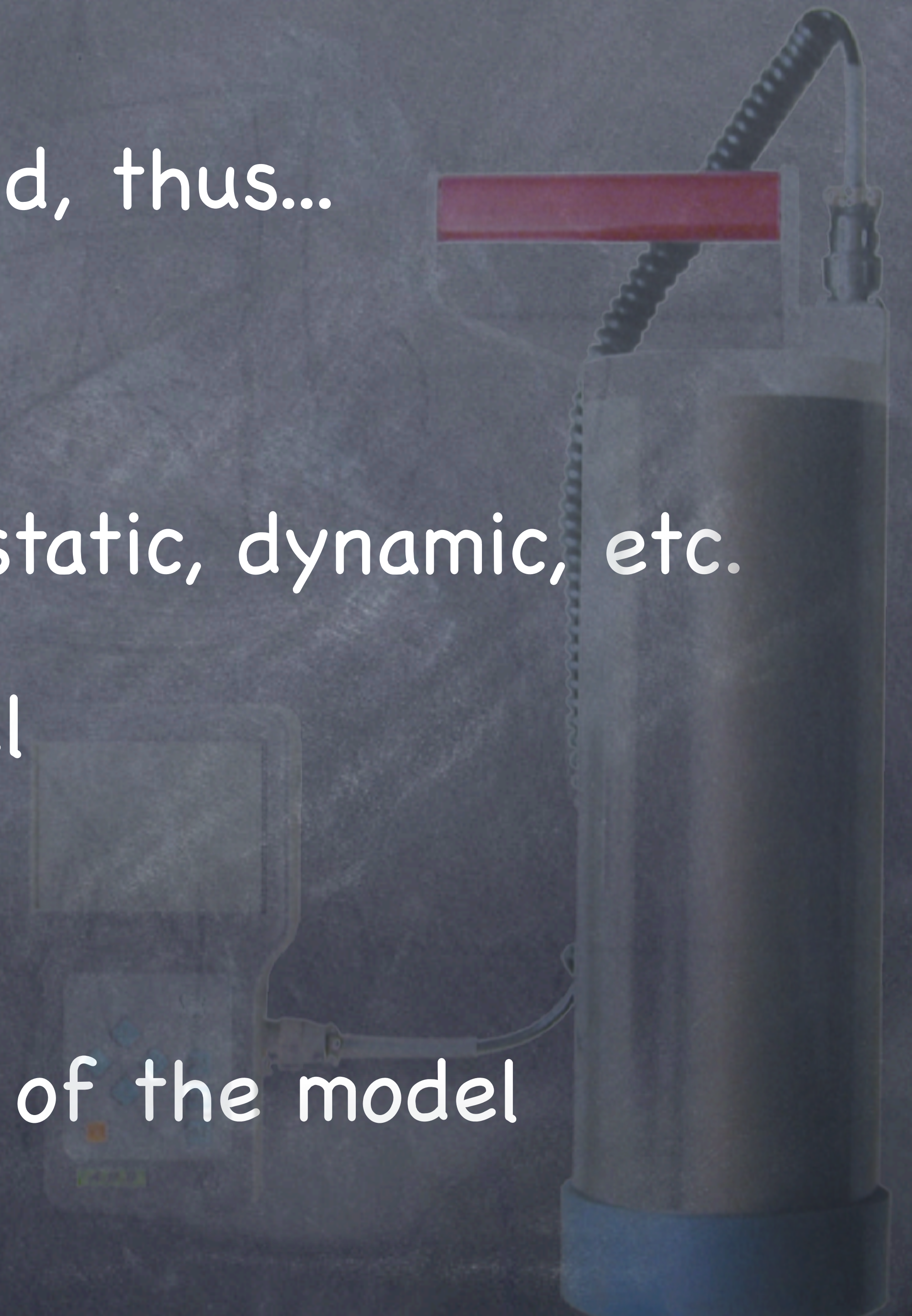
HC Objective

"Compile a multi-categorical dataset of gamma-ray spectra for use in the development and testing of ML algorithms"



An ML Perspective

- Few ``real" isotopes measured, thus...
  - How to build the model
    - Multi-class, one-class, static, dynamic, etc.
  - How to evaluate the model
    - What metrics to use
    - How certain can we be of the model

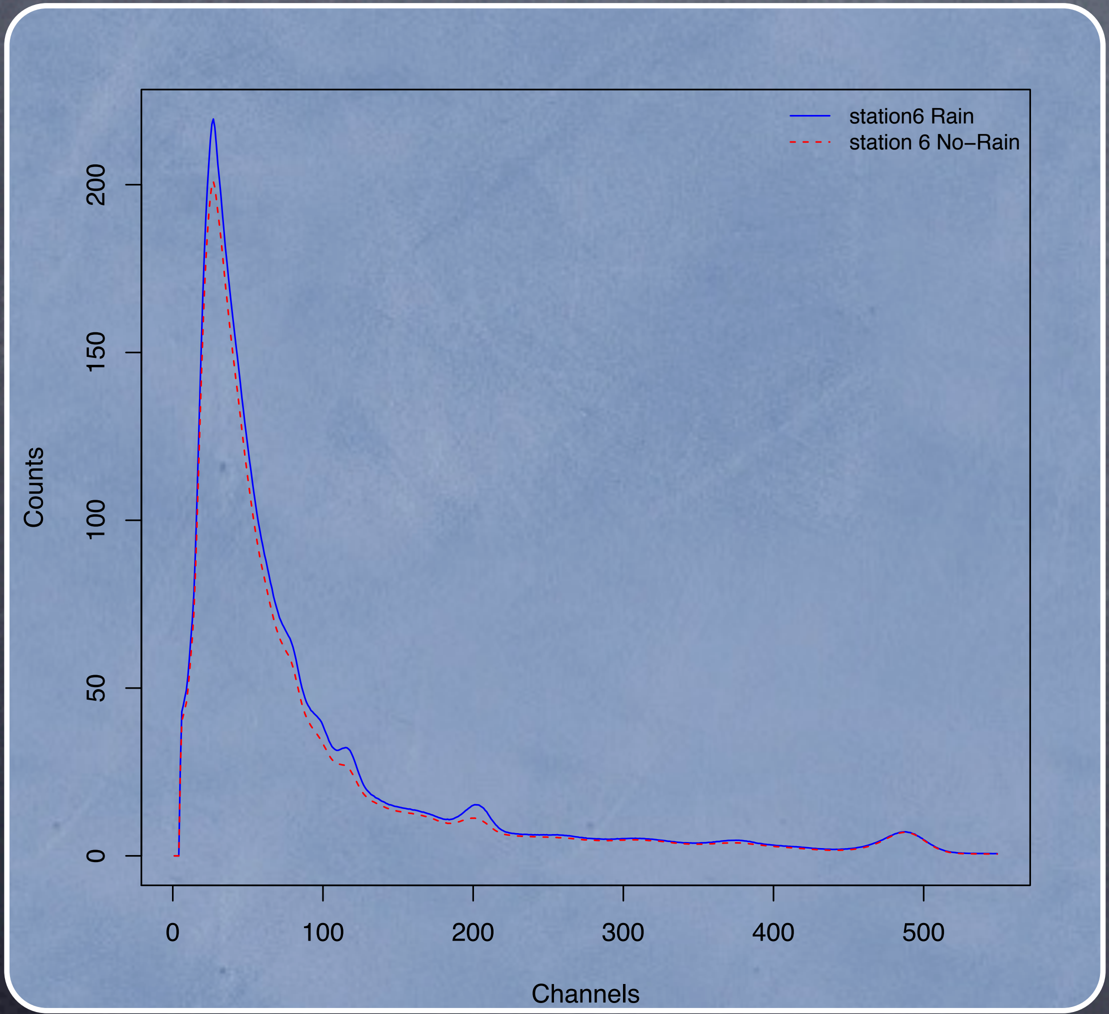


NARNIA Data

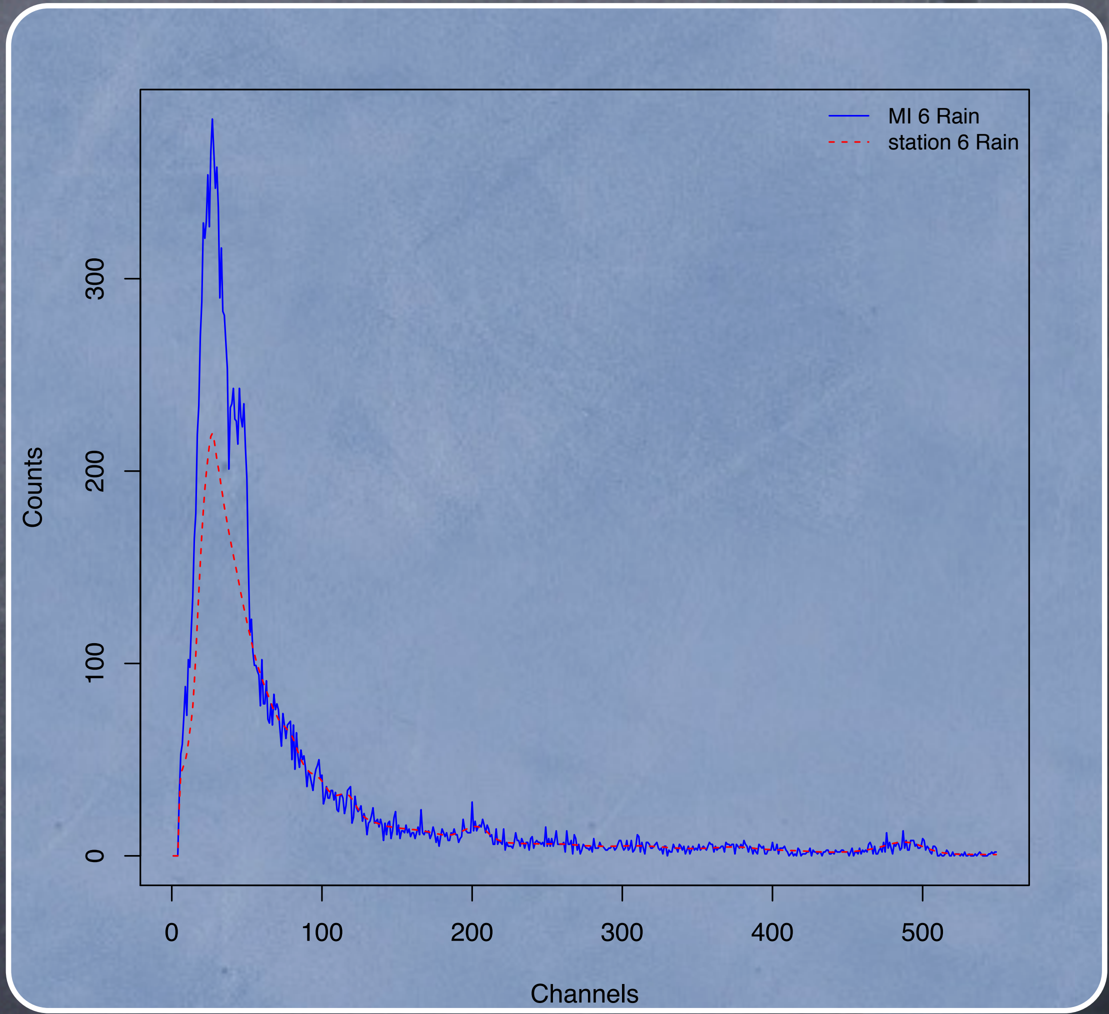
- Collection:
  - 18 GRS detectors at Vancouver 2010
  - 1,024 int-valued channels
  - One reading / station / minute
    - |DS| = 43,000 x 18
    - Bkgrnd + I, Tc, Th, Cs, Co

NARNIA Data

Bkgrnd
Rain Vs No-Rain

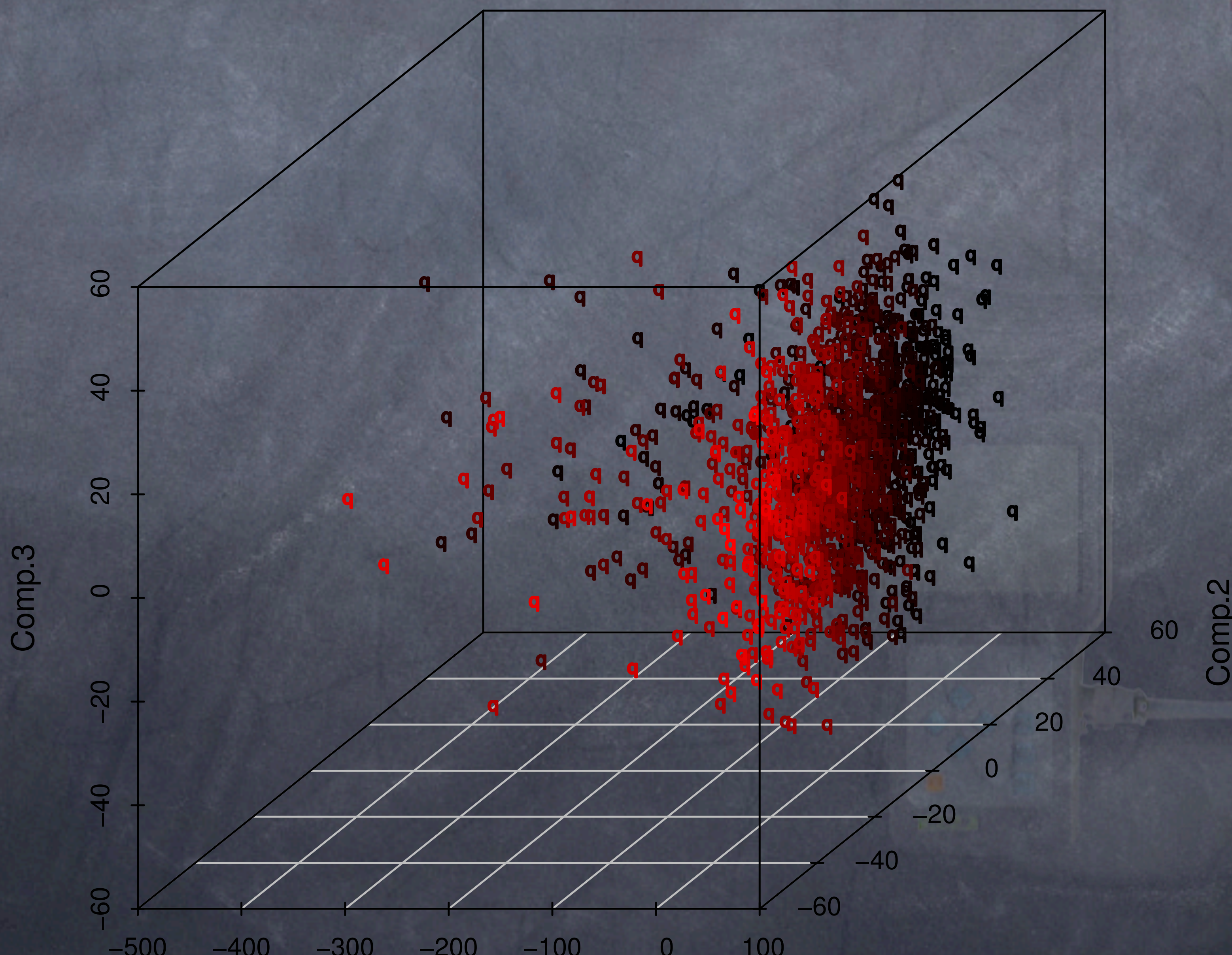


Tc
Rain Vs Bkgrnd

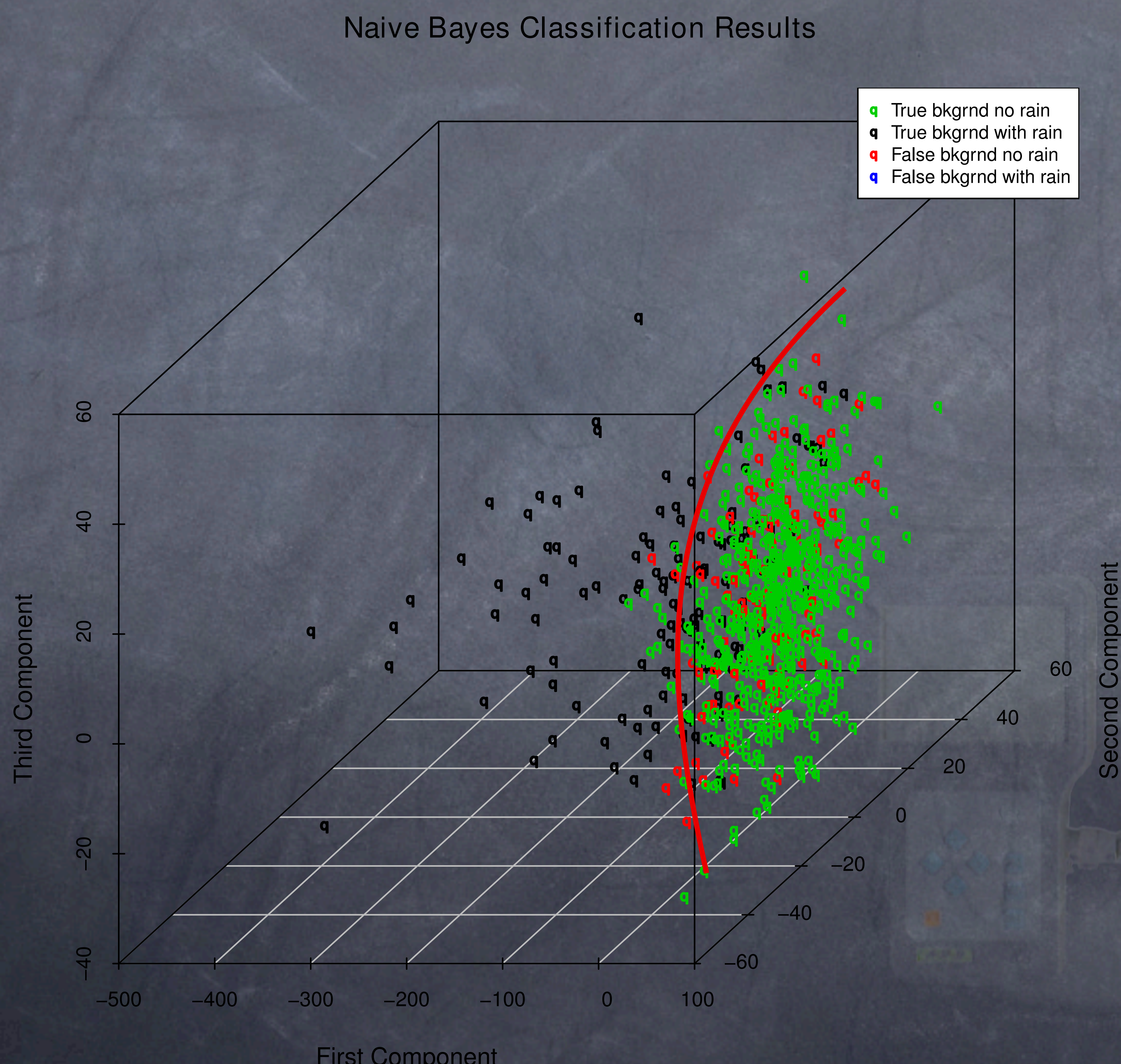


NARNIA Data

PCA Rain Vs No-Rain

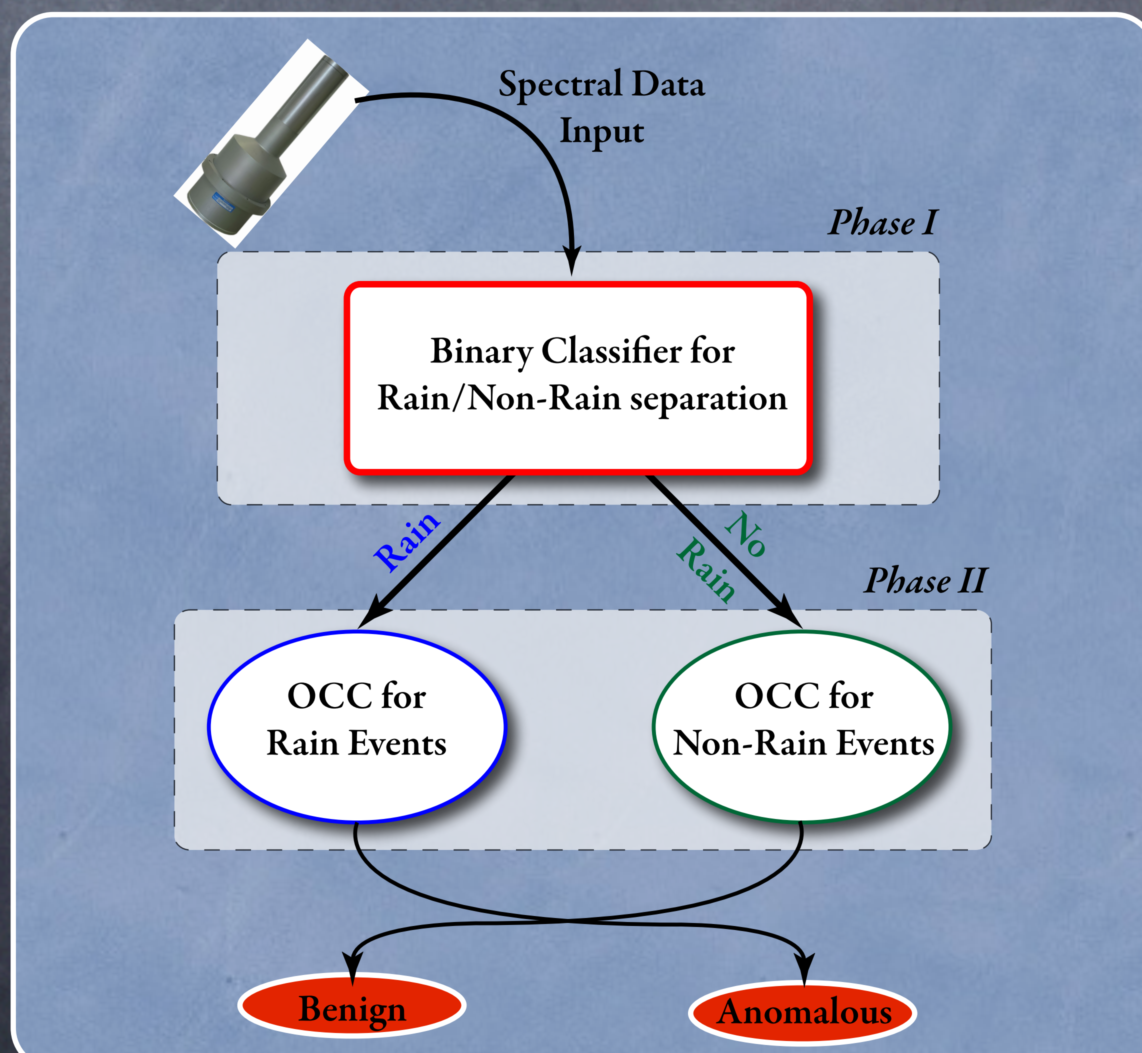


NARNIA Data

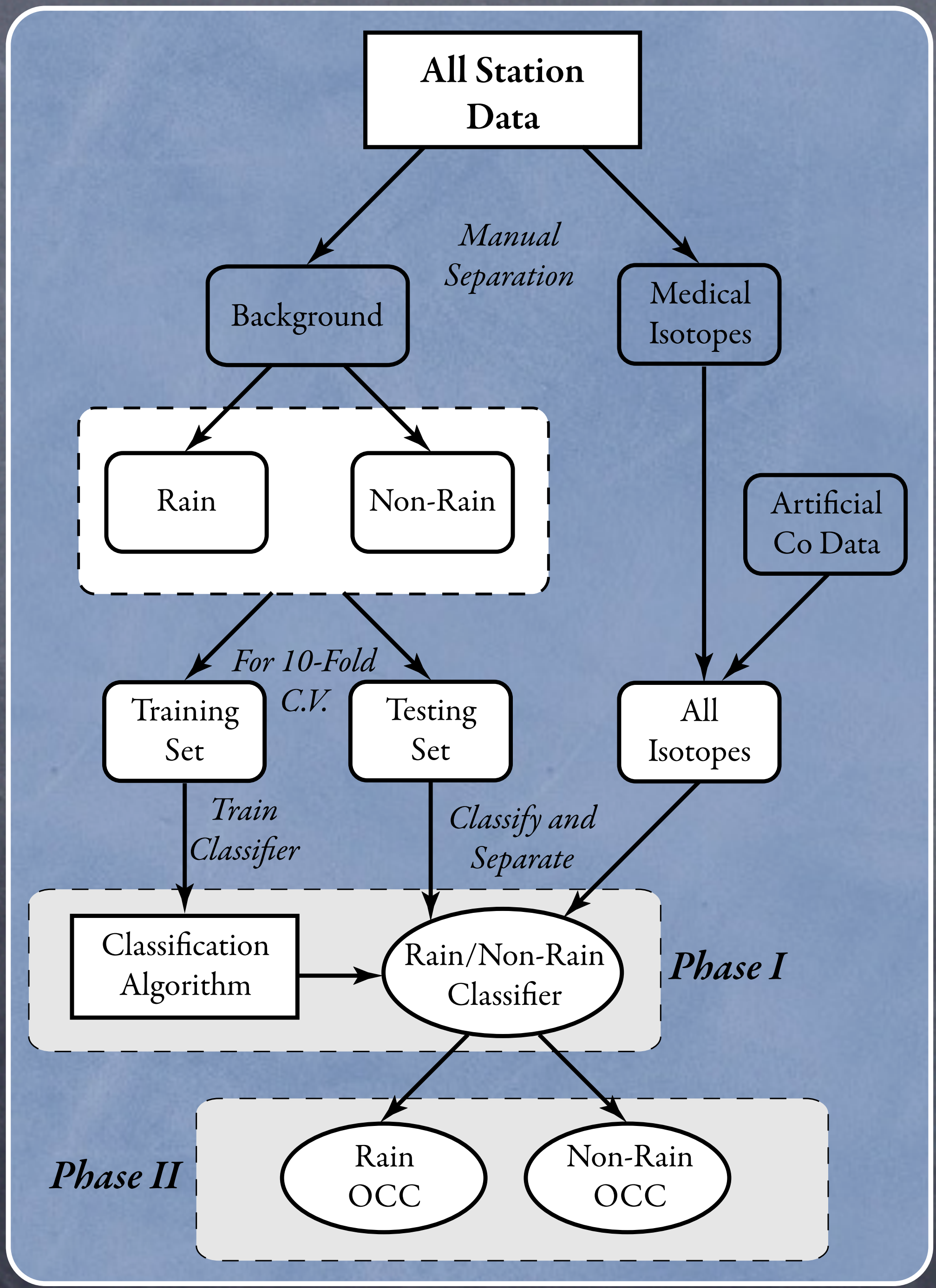

Naive Bayes Classification Results
True bkgrnd no rain
True bkgrnd with rain
False bkgrnd no rain
False bkgrnd with rain
Third Component
Second Component
First Component
60
40
20
0
−20
−40
−60
−500
−400
−300
−200
−100
100

ML System

Hyp: Readings that are most dissimilar are of significant interest



Data Processing

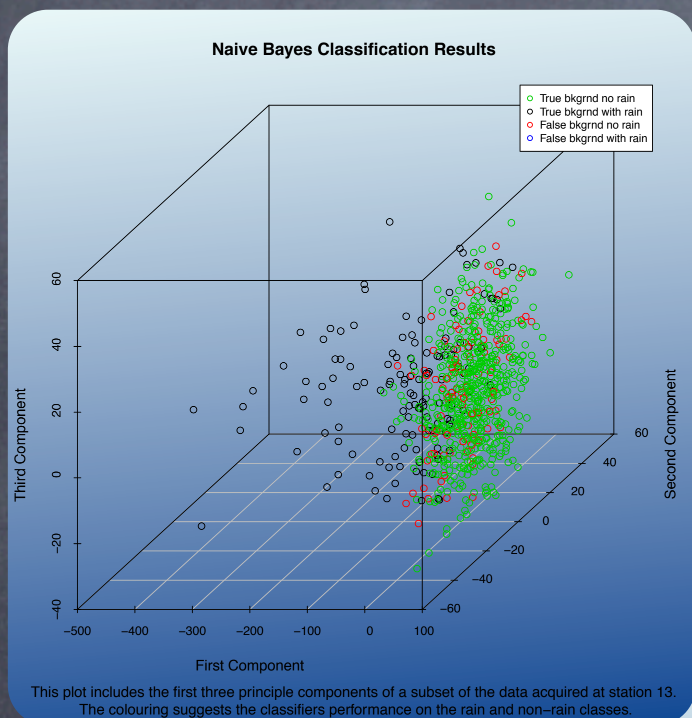


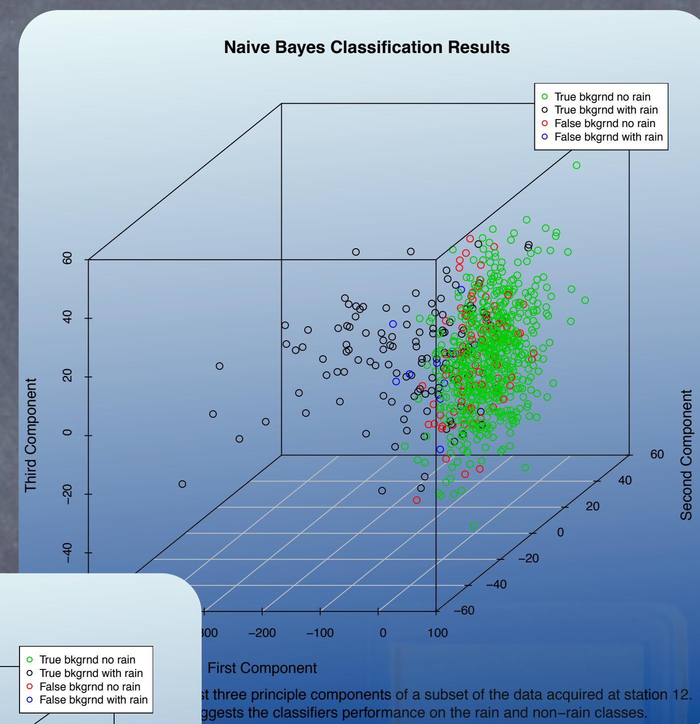
An ML Perspective

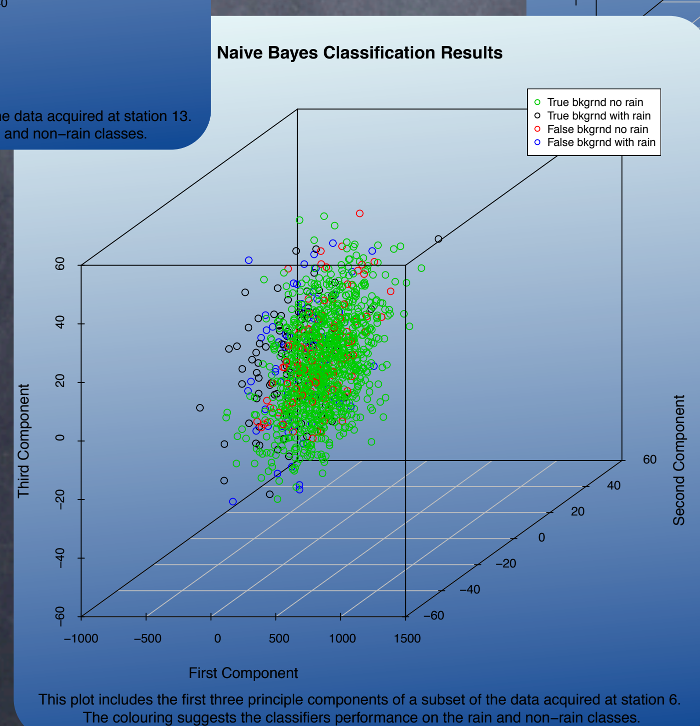
- Rain separation: ML to identify heavy rain events
  - Binary Vs OC learning
    - Extra info Vs labelling
  - Static Vs temporal classification
    - Simplicity Vs leveraged context
  - ocSVM, SVM, J48, NB, IBK

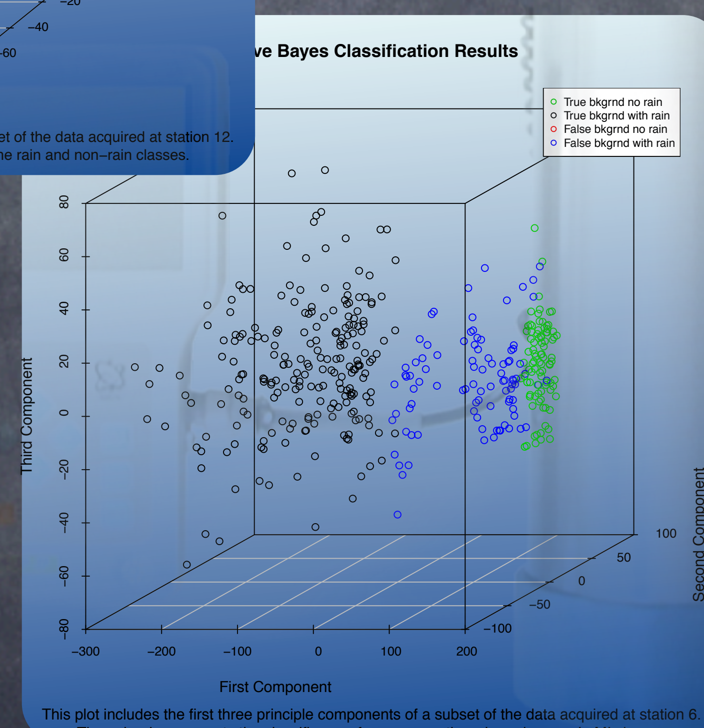
Experiments

Binary rain separation



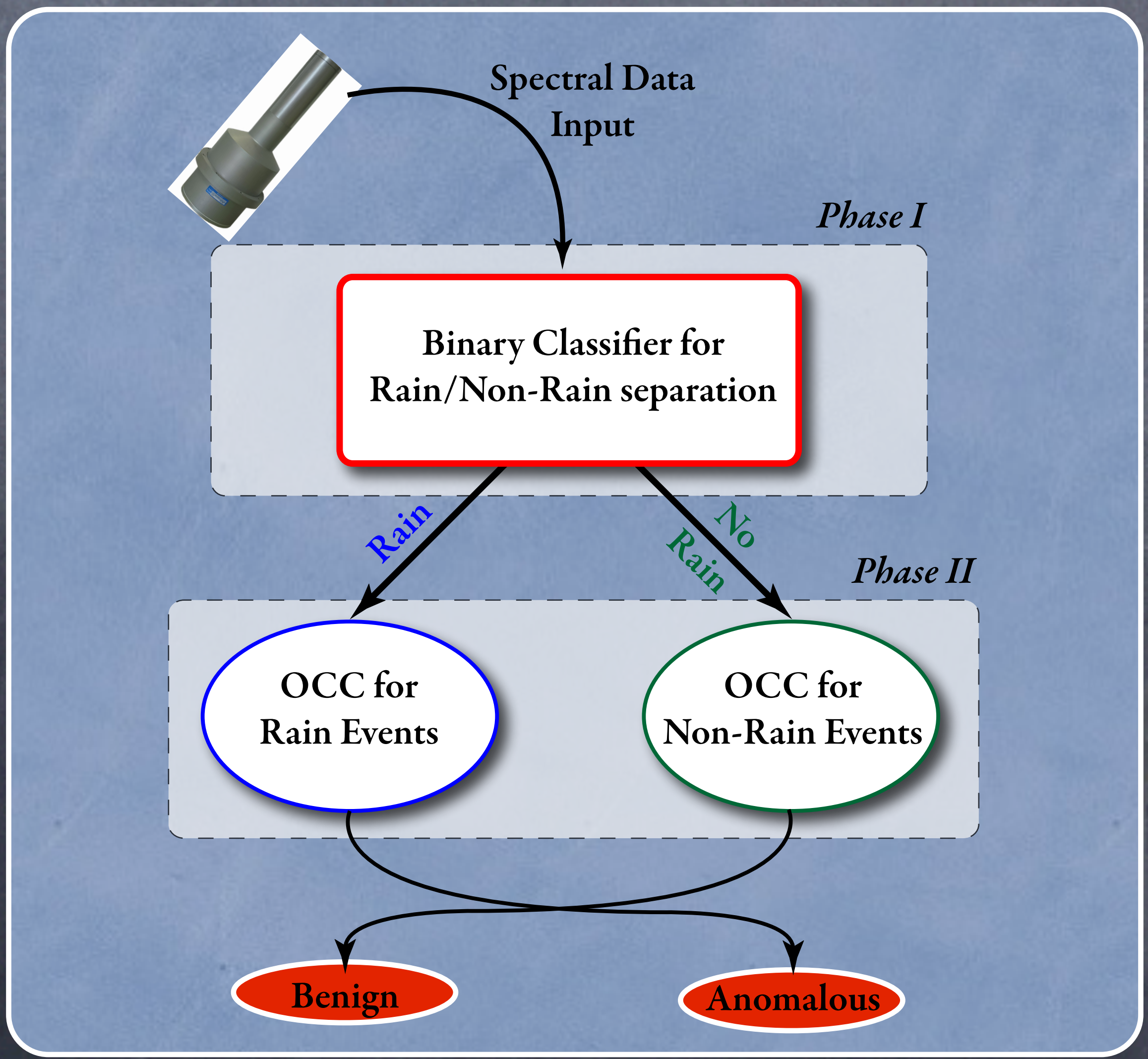






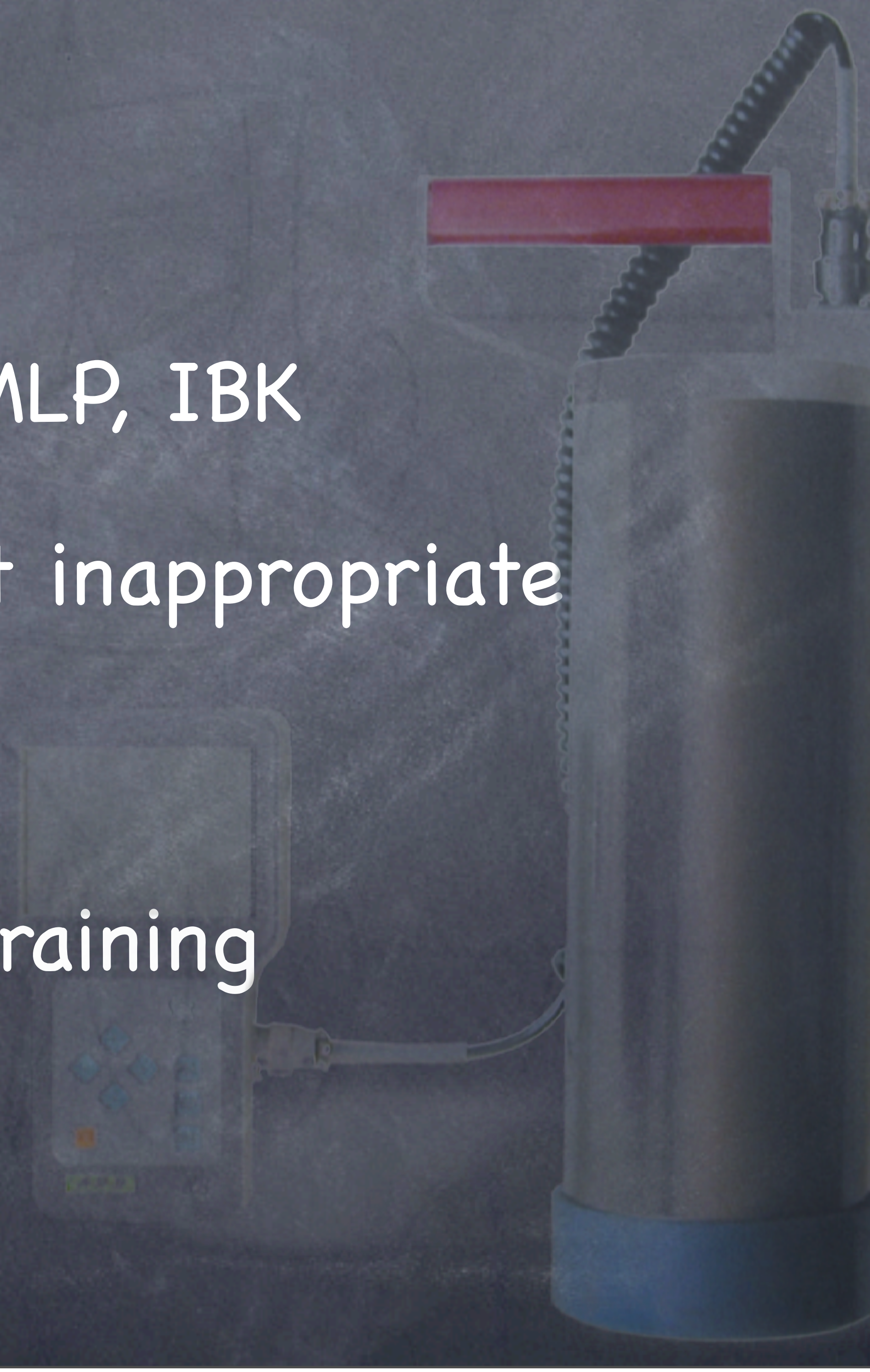
ML System

Hyp: Readings that are most dissimilar are of significant interest



Experiments

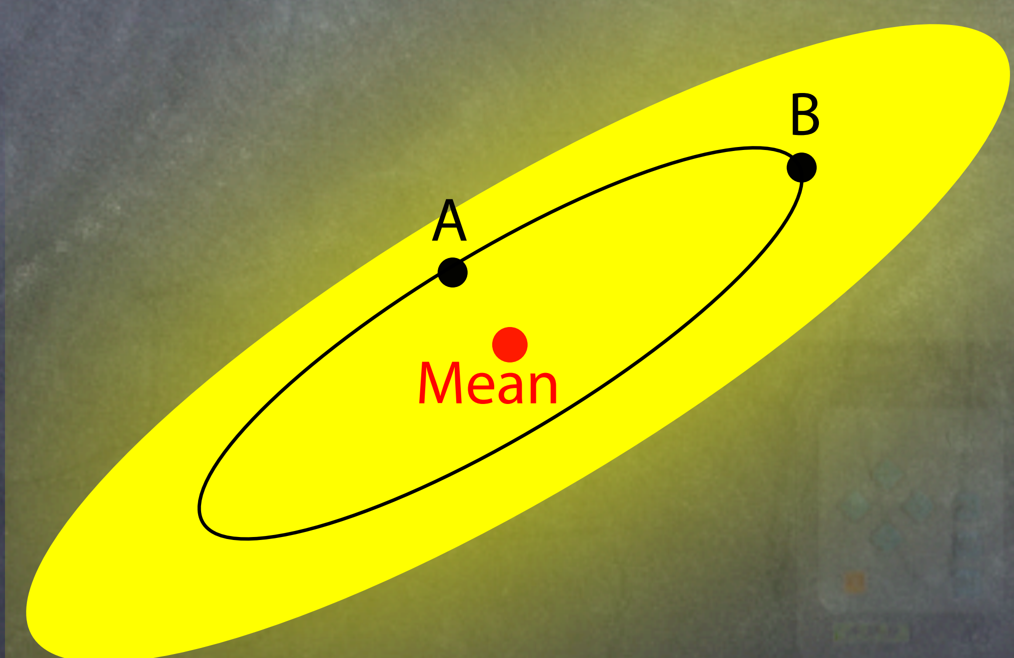
- Algorithms applied
  - Binary: SVM, J48, NB, MLP, IBK
    - Performed well, but inappropriate
  - One class: ocSVM, AA
    - Pour results, slow training



Experiments

Alternate Algorithms: based on the hypothesis of ranking and anomalies

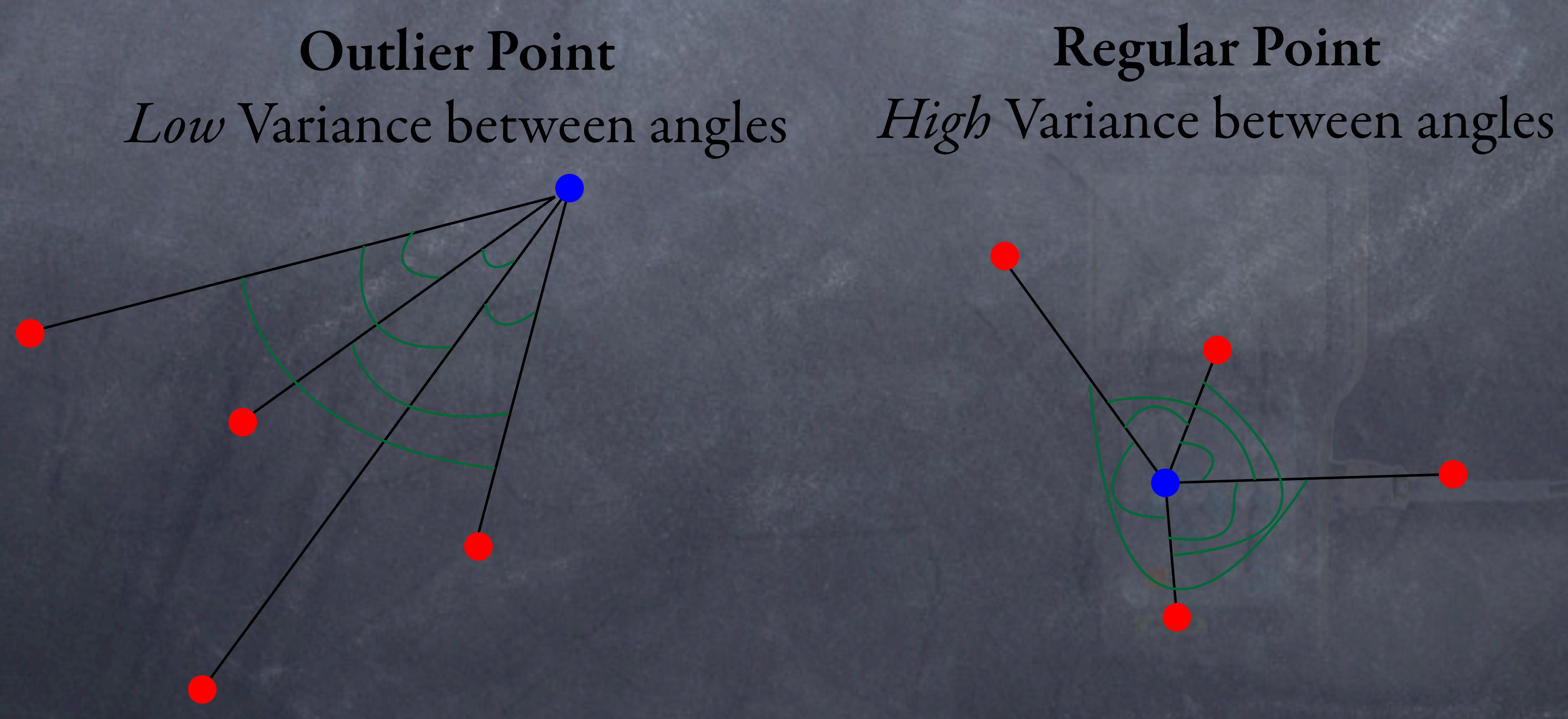
Mahalonibis Distance



Experiments

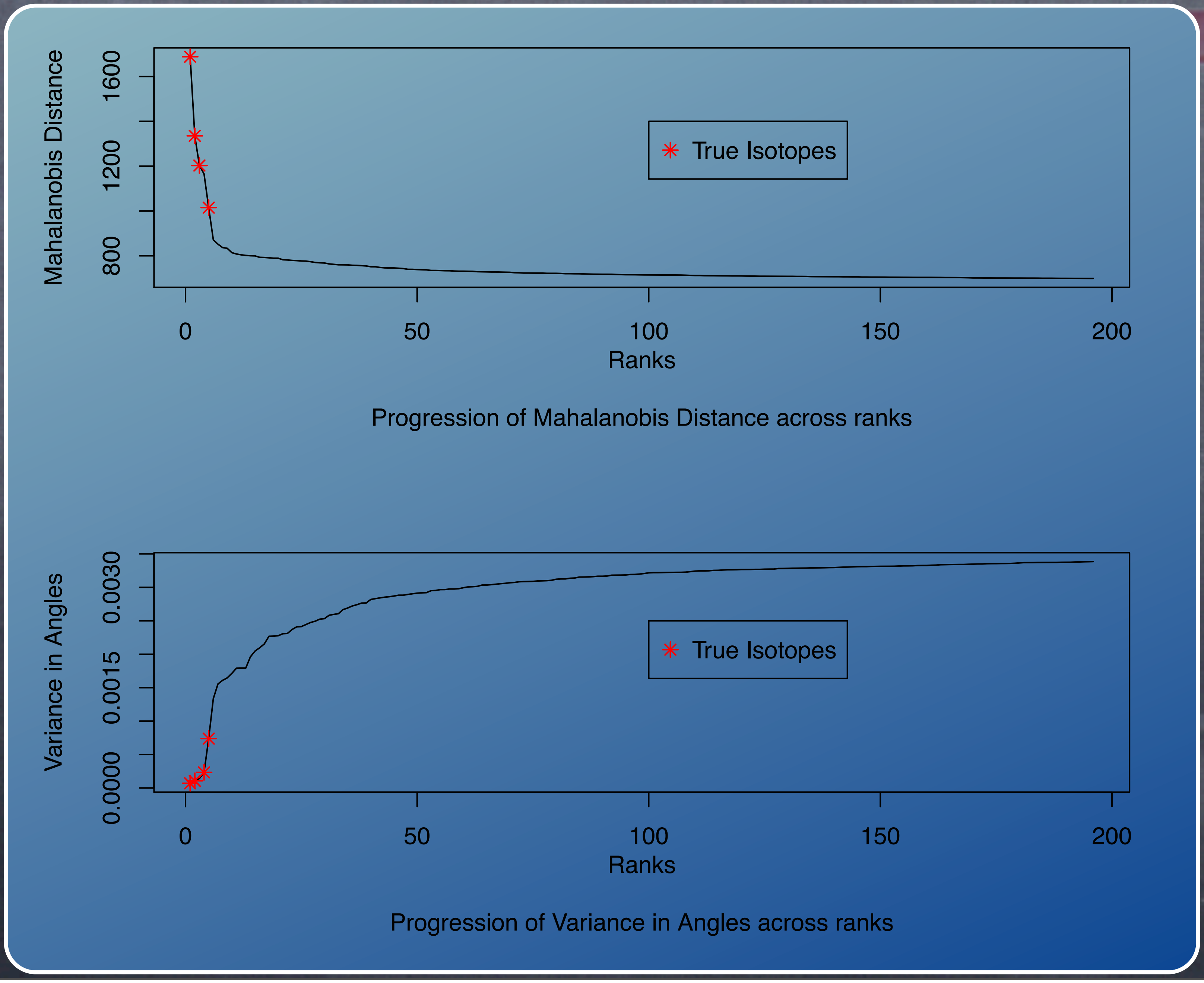
Alternate Algorithms... continued

Variance in Angle
Spectrum



Hypothesis

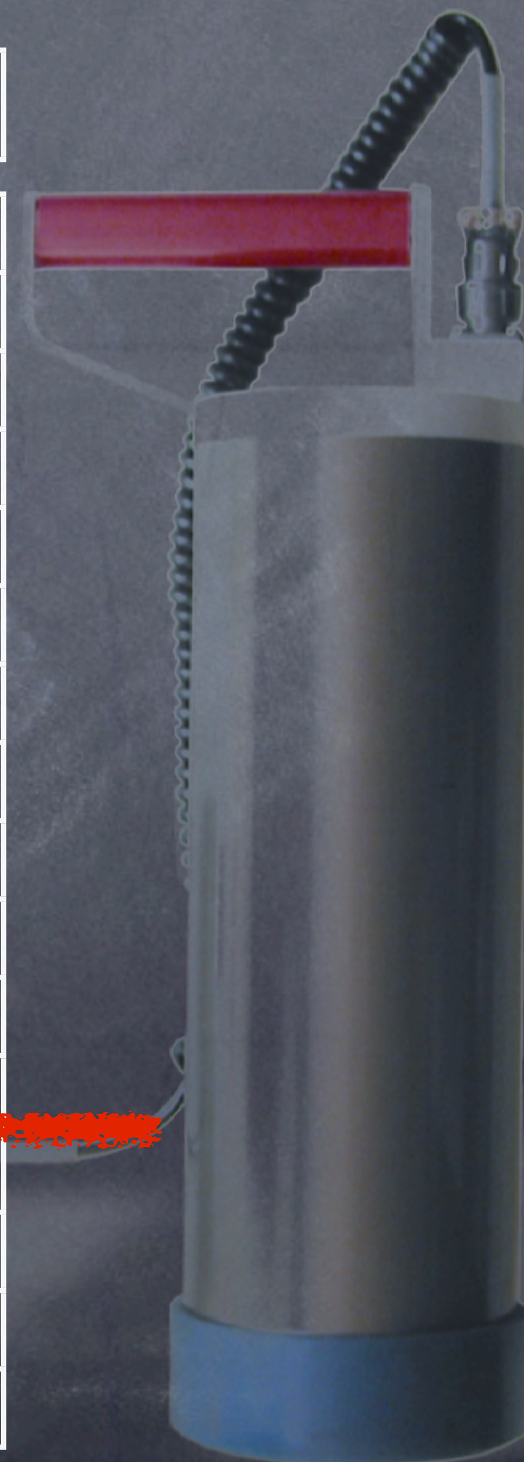
Anomalous instances near the top



Results

Isotope	Station 13	Station 12	Station 6
Thallium	NA	NA	0/2
Iodine	1/5	1/2	1/2
Technicium	1/3	0/2	1/7
Caesium	8/15	NA	NA
Cobalt 50.1	19/304	3/304	0/304
Cobalt 50.2	19/314	3/314	0/314
Cobalt 75.1	2/307	0/307	0/307
Cobalt 75.2	1/320	0/320	0/320
Cobalt 100.1	0/305	0/305	0/305
Cobalt 100.2	0	0	0
Cobalt 200.1	0	0	0
Cobalt 200.2	0	0	0
Cobalt 300.1	0	0	0
Cobalt 300.1	0	0	0
Cobalt 500.1	0	0	0
Cobalt 500.2	0	0	0

HC



Results

1-Phase Vs 2-Phase System

Station 13

1- Tier		2 - Tier	
TP	FP	TP	FP
3900	24	3900	10

Station 12

1- Tier		2 - Tier	
TP	FP	TP	FP
3918	98	3918	36

Station 6

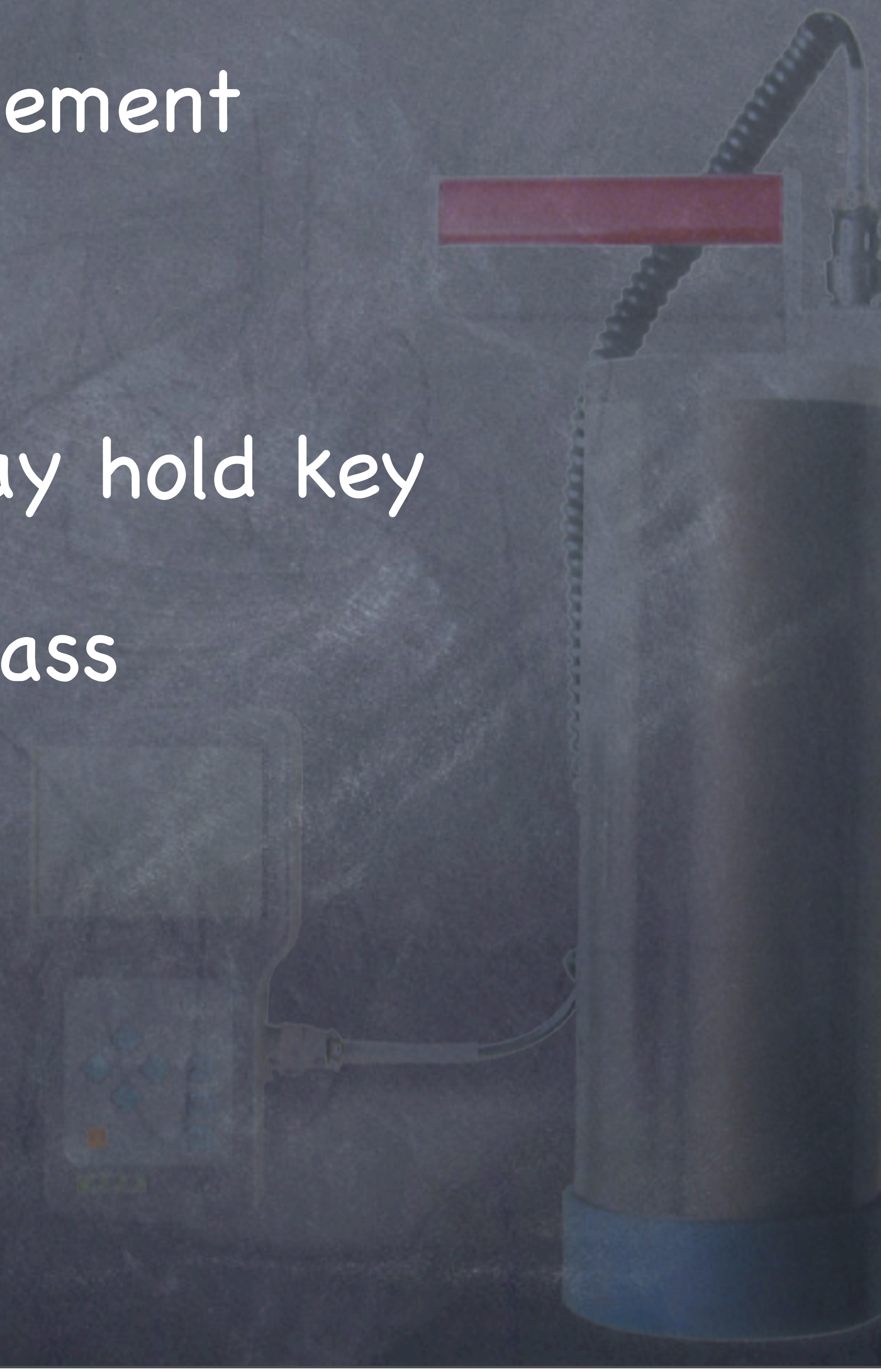
1- Tier		2 - Tier	
TP	FP	TP	FP
3950	336	3950	144

Conclusion

- Proposed a 2-phased ML system
  - I - separate rain from non-rain
  - II - rank instance according to rarity
- Significantly outperforms HC's system
  - HC - no Co less than 200 strength

Future Work

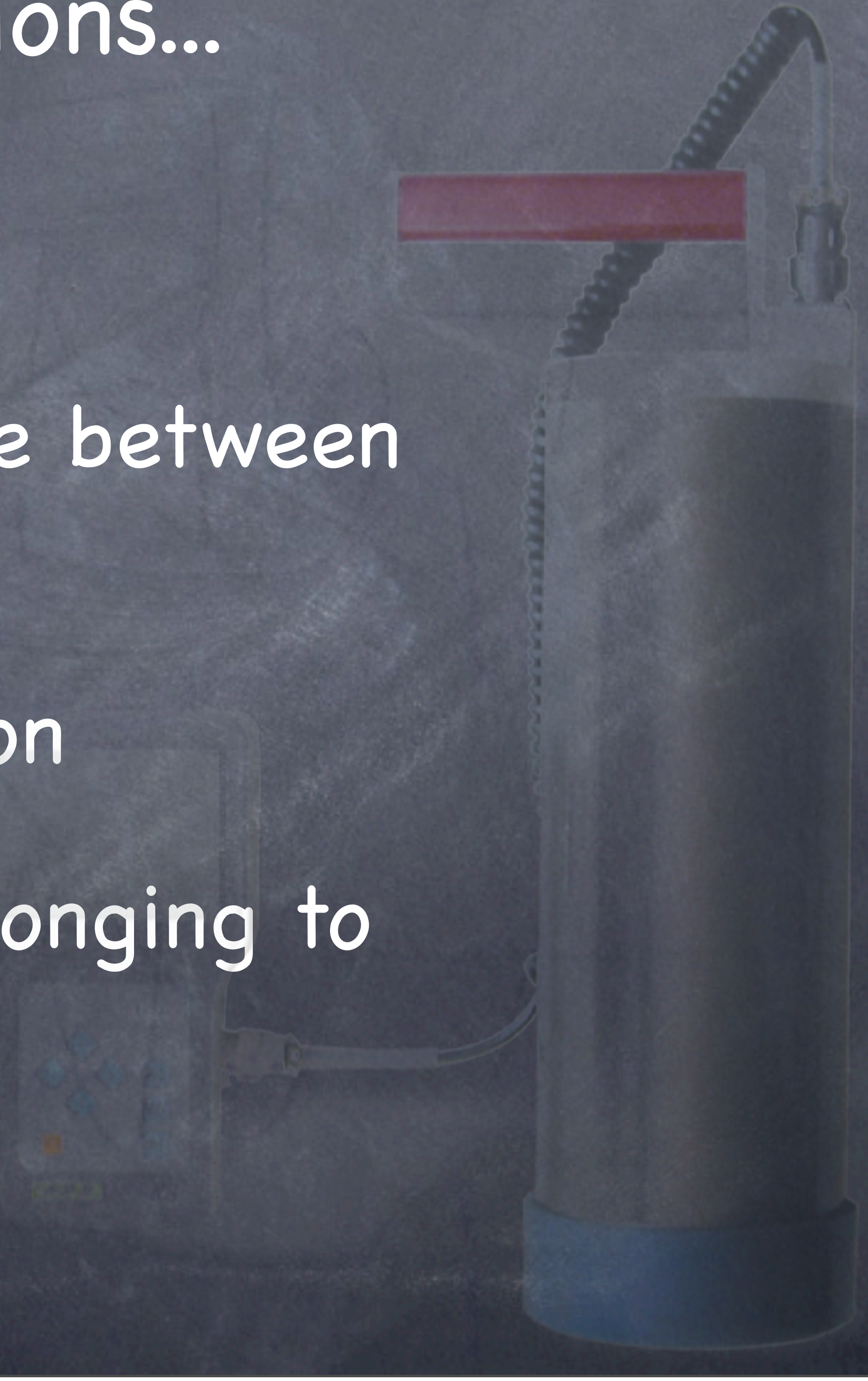
- Aim: minimize expert involvement
  - i.e., reduce FPs
- Improved rain separation may hold key
  - OC learning on positive class
  - Expectation Maximization
  - Semi-supervised
  - Temporal analysis



Future Work

Other open questions...

- Threshold selection
  - Where do we draw the line between normal and abnormal
- Individual isotope classification
- Classification of instances belonging to multiple classes
- Temporal analysis



Thank you!

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