



Scintillating Bubble Chamber Silicon Photomultiplier Analysis

Queen's University • Ciaran Byles-Ho • Aug. 12, 2022



Scintillating Bubble Chamber:

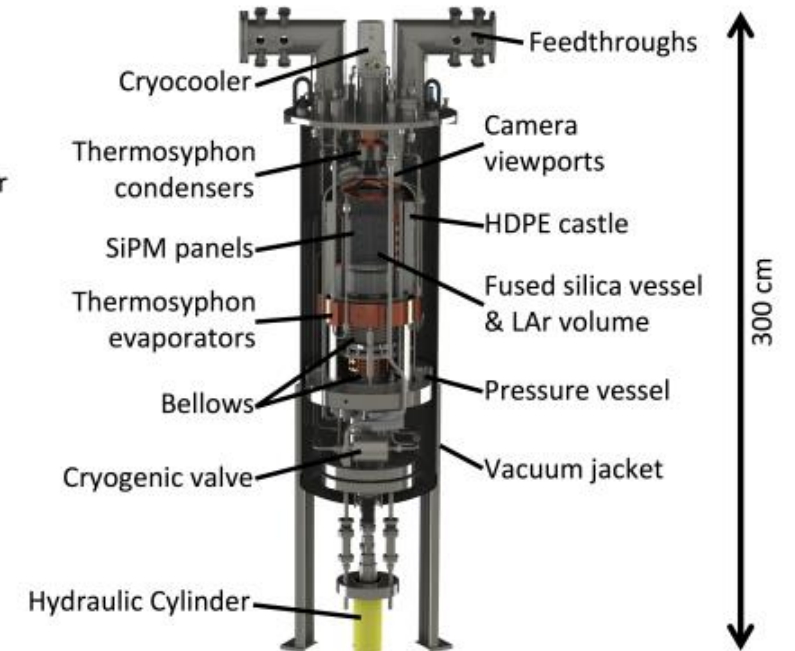
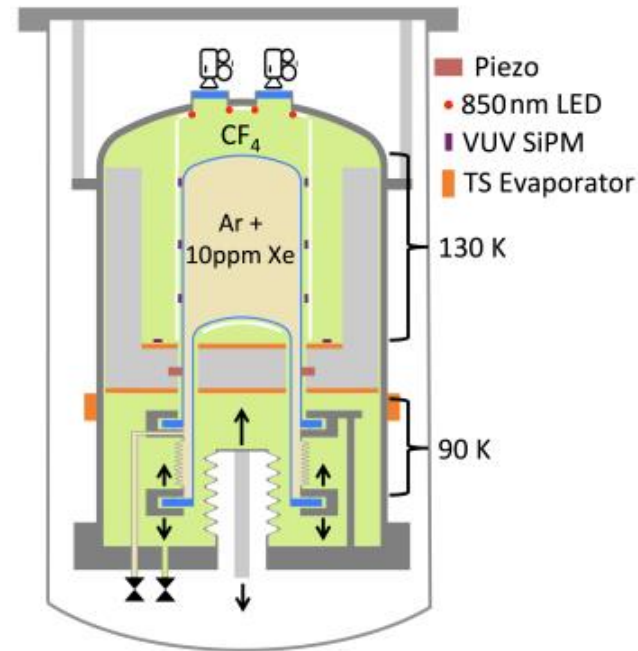
SBC-LAr10

- Quasi-background-free Bubble Chamber
- 10 kg of liquid argon
- Aims to hit lower thresholds (100 eV)



How does SBC work?

- Relies on electron recoils to lose energy through scintillation
- Bubbles nucleate after small energy depositions
- SiPMs detect scintillation light to veto high energy single-bubble events



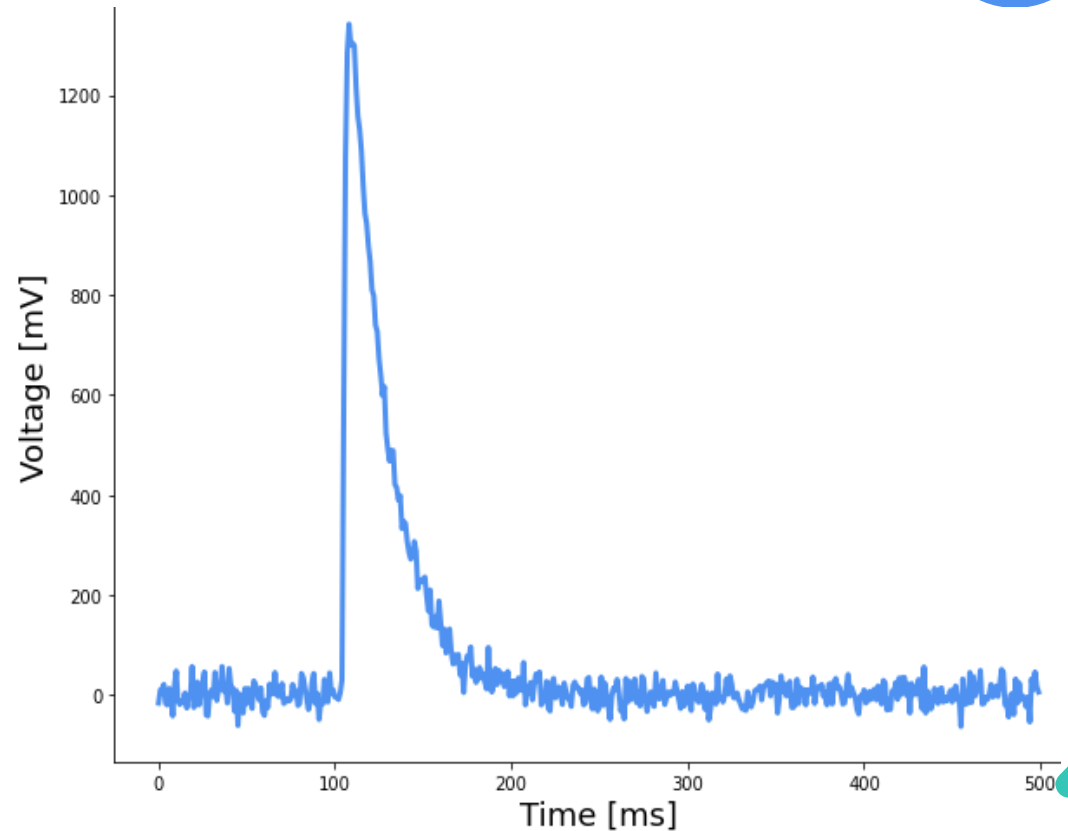


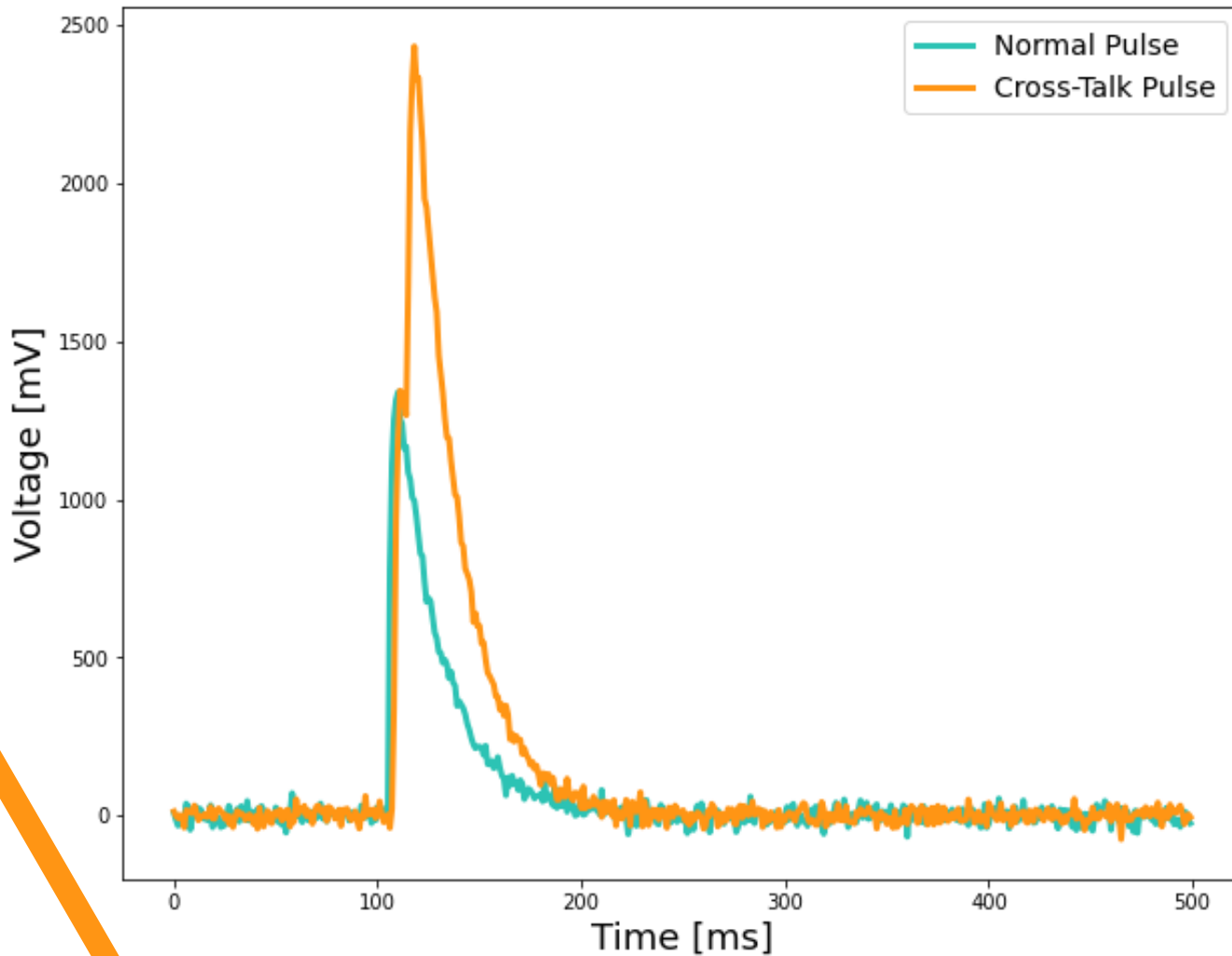
Silicon Photomultipliers (SiPMs)

- Detect single photons near UV to near IR
- SBC SiPMs detect LAr and LXe UV light
- Consists of many single-photon avalanche photodiodes (microcells)

Understanding SiPMs

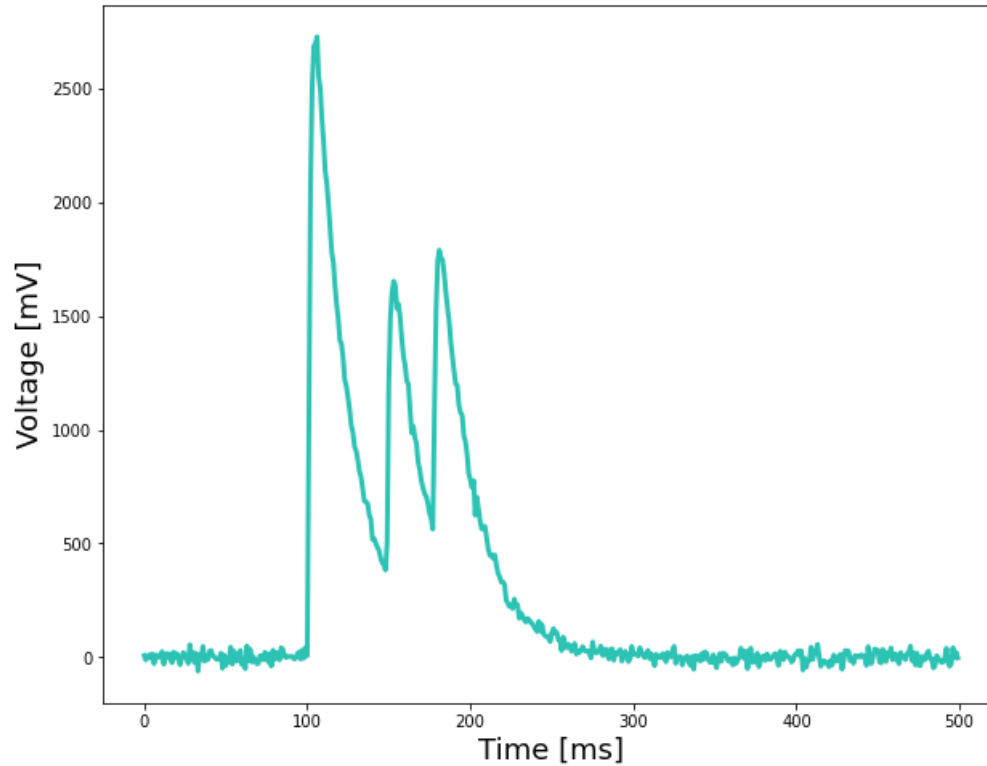
- A microcell drifts towards an avalanche region when a photon hits
- The microcell then activates a self-sustaining avalanche
- **Dark Event:** generation of pulse without light
 - Crosstalk
 - After Pulsing





SiPMs Background **Crosstalk**

- Occurs when primary avalanche in one microcell triggers another in an adjacent cell
- Occurs in on top or near initial pulse
- Causes increased initial pulse magnitude
- May have inflection point



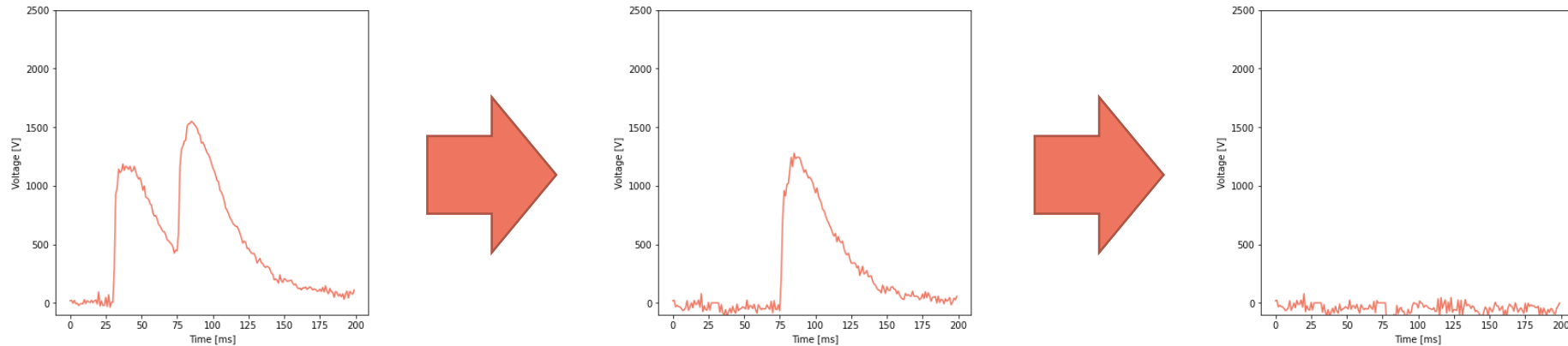
SiPMs Background After-Pulsing

- There is a probability that an adjacent cell may release a delayed pulse
- Occurs in recover phase
- Lesser magnitude than original if near original

Motivation

To explore new methods of determining the **dark noise rate** and **cross talk probability** using **machine learning** methodologies and compare to algorithmic approaches.

Pulse Counting with Computational Algorithms



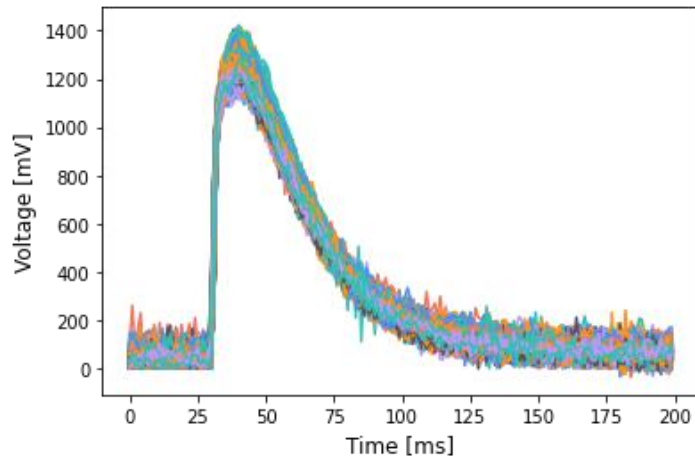
VUV-sensitive Silicon Photomultipliers for Xenon Scintillation
Light Detection in nEXO

Jamil et al. 2019

Unsupervised Machine Learning

K-means Clustering

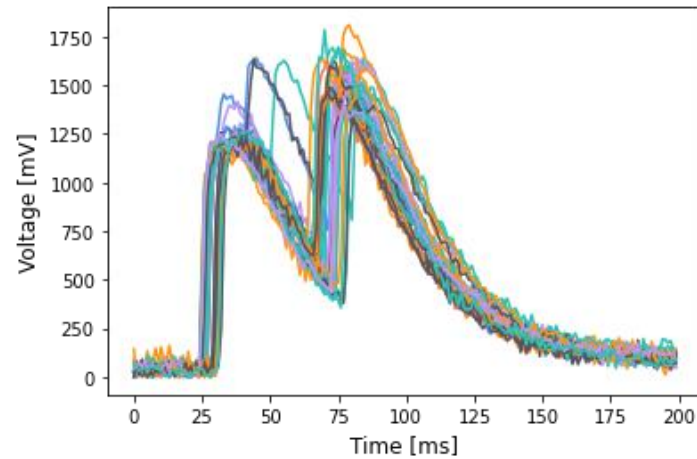
50 Clusters • 10 000 Initial Pulses



Cluster 0

Normal

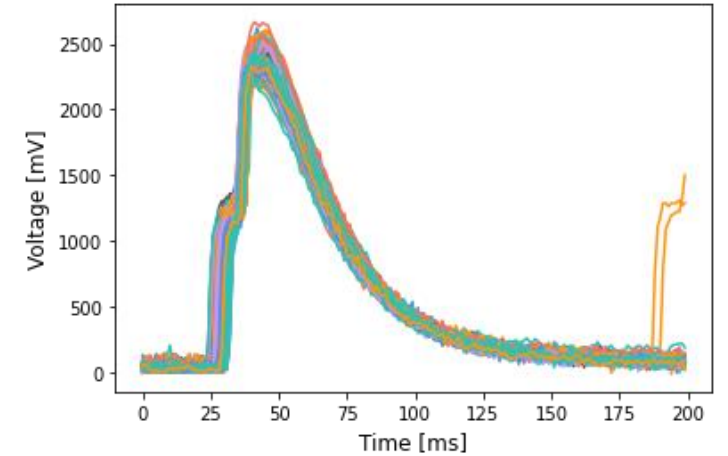
925 Pulses



Cluster 12

After Pulsing

31 Pulses



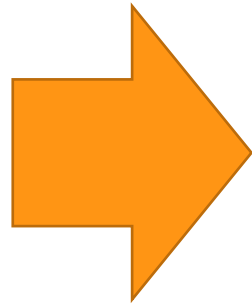
Cluster 1

Delayed Crosstalk

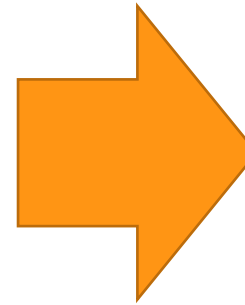
160 Pulses

Resulting Algorithm

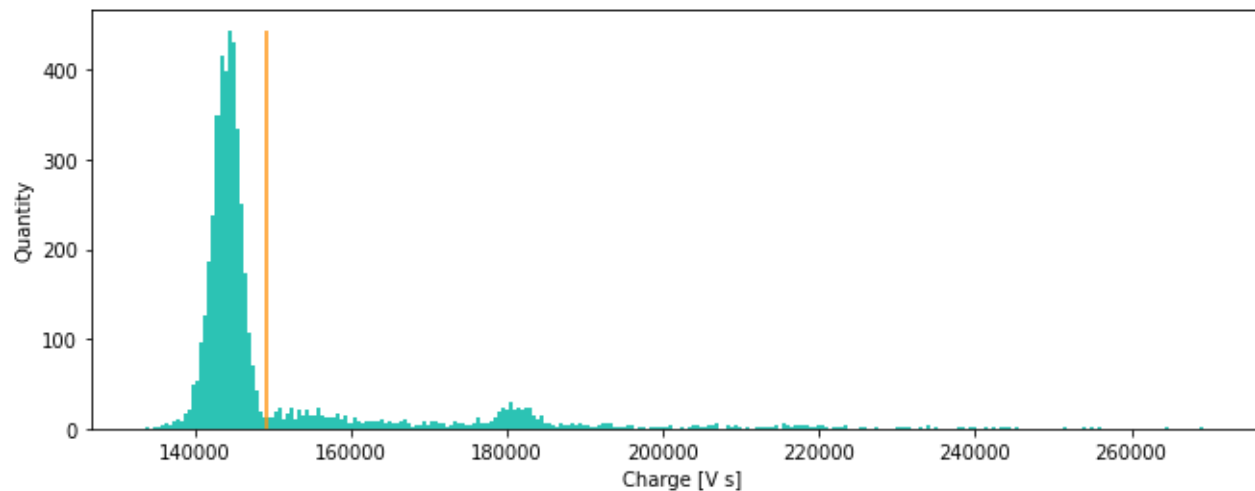
Data Input



**K-means
Threshold
Determinant**



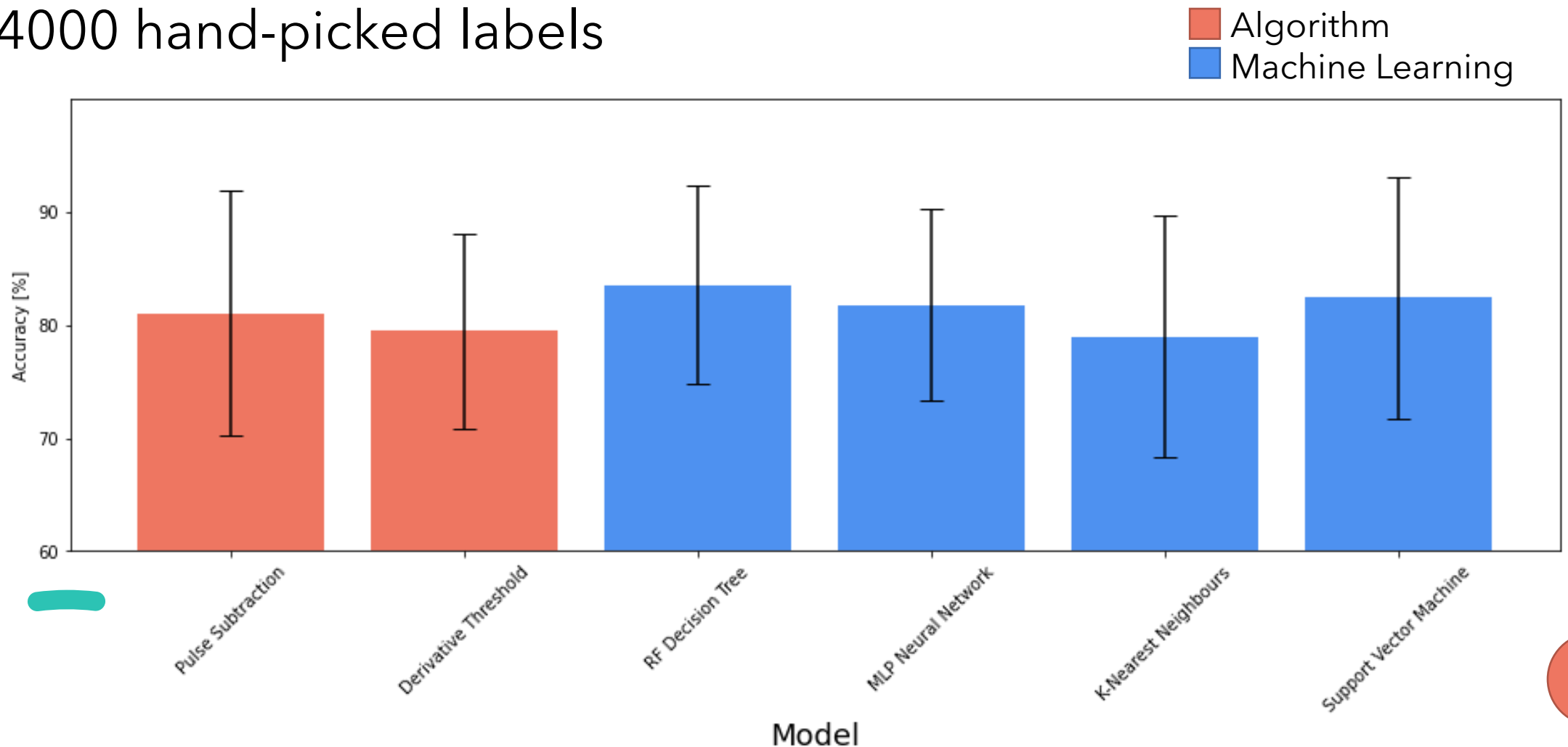
Algorithm



Improved pulse
parameter error
from 20% to 1%
on simulated
data

Supervised Machine Learning

~4000 hand-picked labels



Current Results

Traditional Algorithms

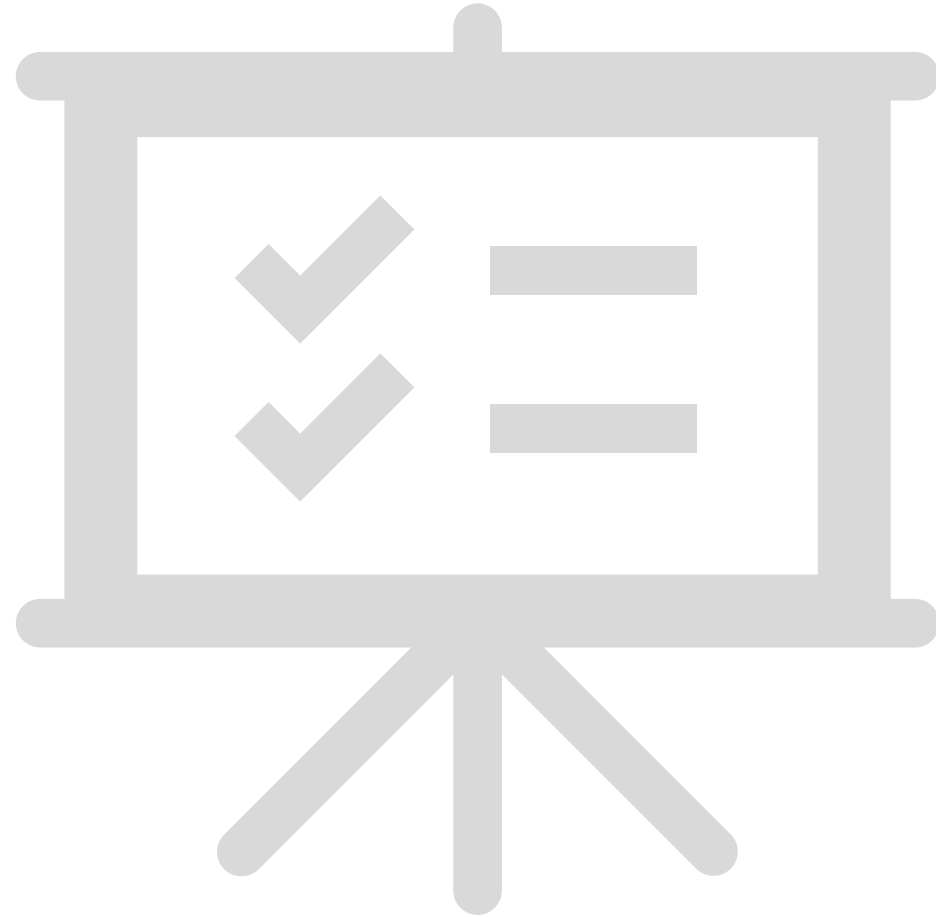
- Accurately calculates t_0
- Calculates charge
- Near 100% accuracy on simulated data

Machine Learning

- Real Dataset
 - Near-even distribution of labels
 - ~80% accuracy
- Trial run
 - 1000 unseen datapoints
 - Uneven distribution of labels
 - ~90% Accuracy

Conclusion

- Unsupervised ML effectively classifies background groups
- Supervised ML can be used for pulse analysis
- ML can effectively improve current algorithmic approaches





Thank you

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