Scintillating Bubble Chamber

Silicon Photomultiplier Analysis

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

Queen's University

SNOLAB

Arthur B. McDonald
Canadian Astroparticle Physics Research Institute

SBC

Scintillating Bubble Chamber:

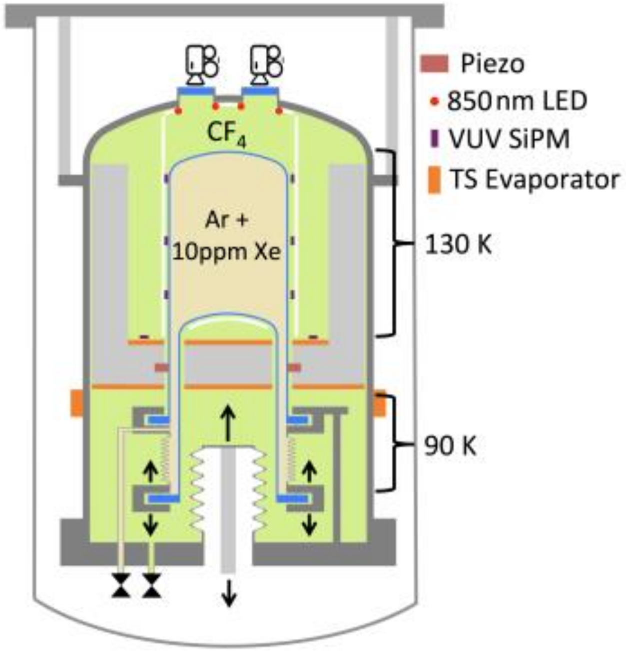
SBC-LAr10

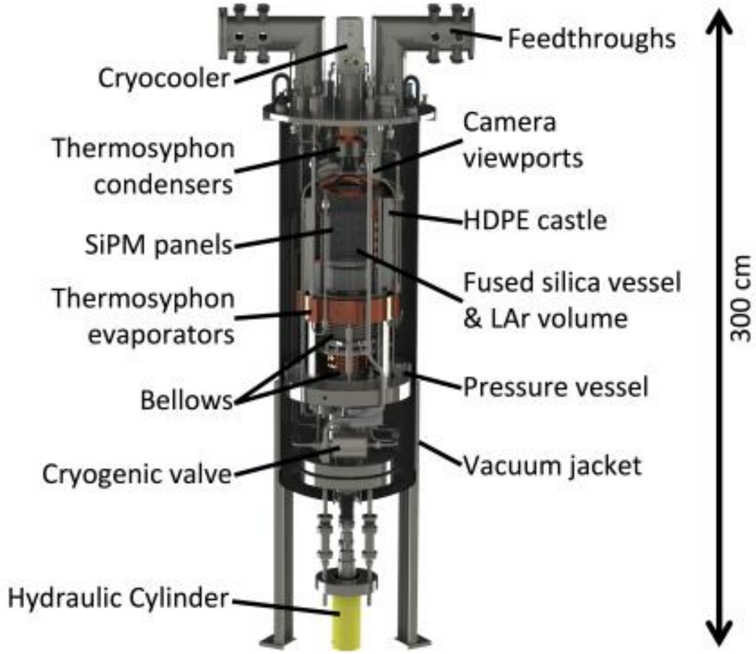
- Quasi-background-free Bubble Chamber
- 10 kg of liquid argon
- Aims to hit lower thresholds (100 eV)

Snowmass 2021 Scintillating Bubble Chambers: Liquid-noble Bubble Chambers for Dark Matter and CEvNS Detection [https://doi.org/10.48550/arXiv.2207.12400]

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





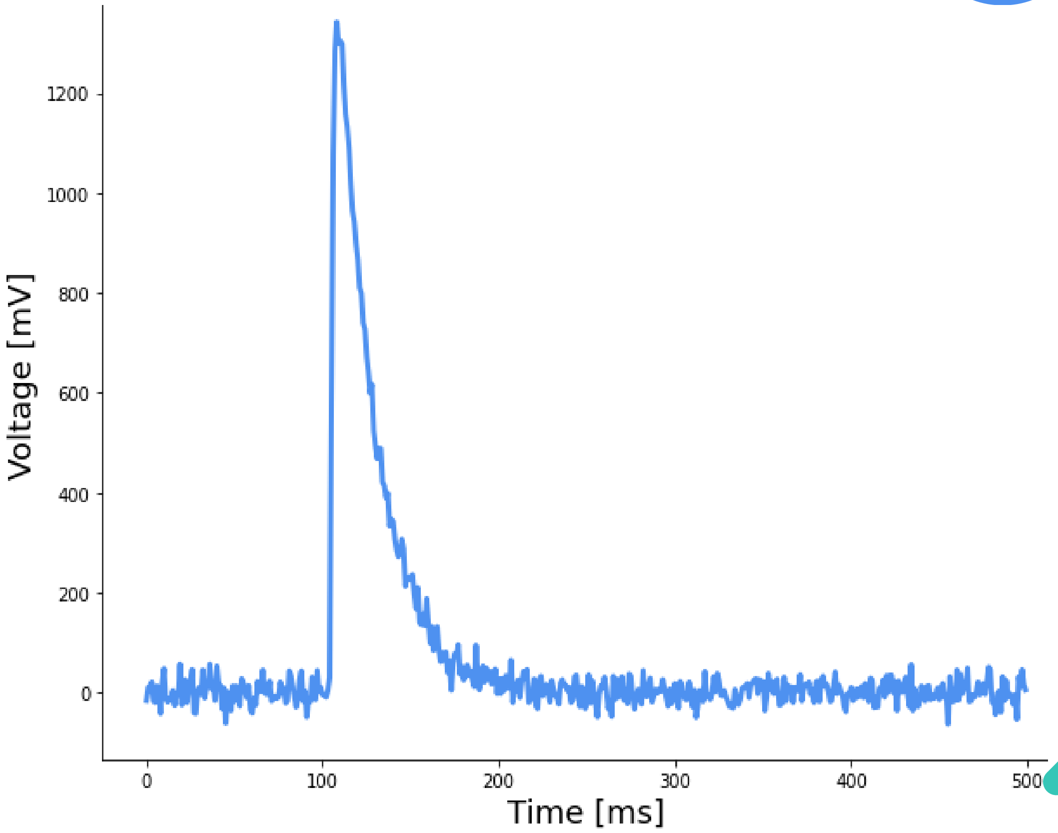
Snowmass 2021 Scintillating Bubble Chambers: Liquid-noble Bubble Chambers for Dark Matter and CEvNS Detection [https://doi.org/10.48550/arXiv.2207.12400]

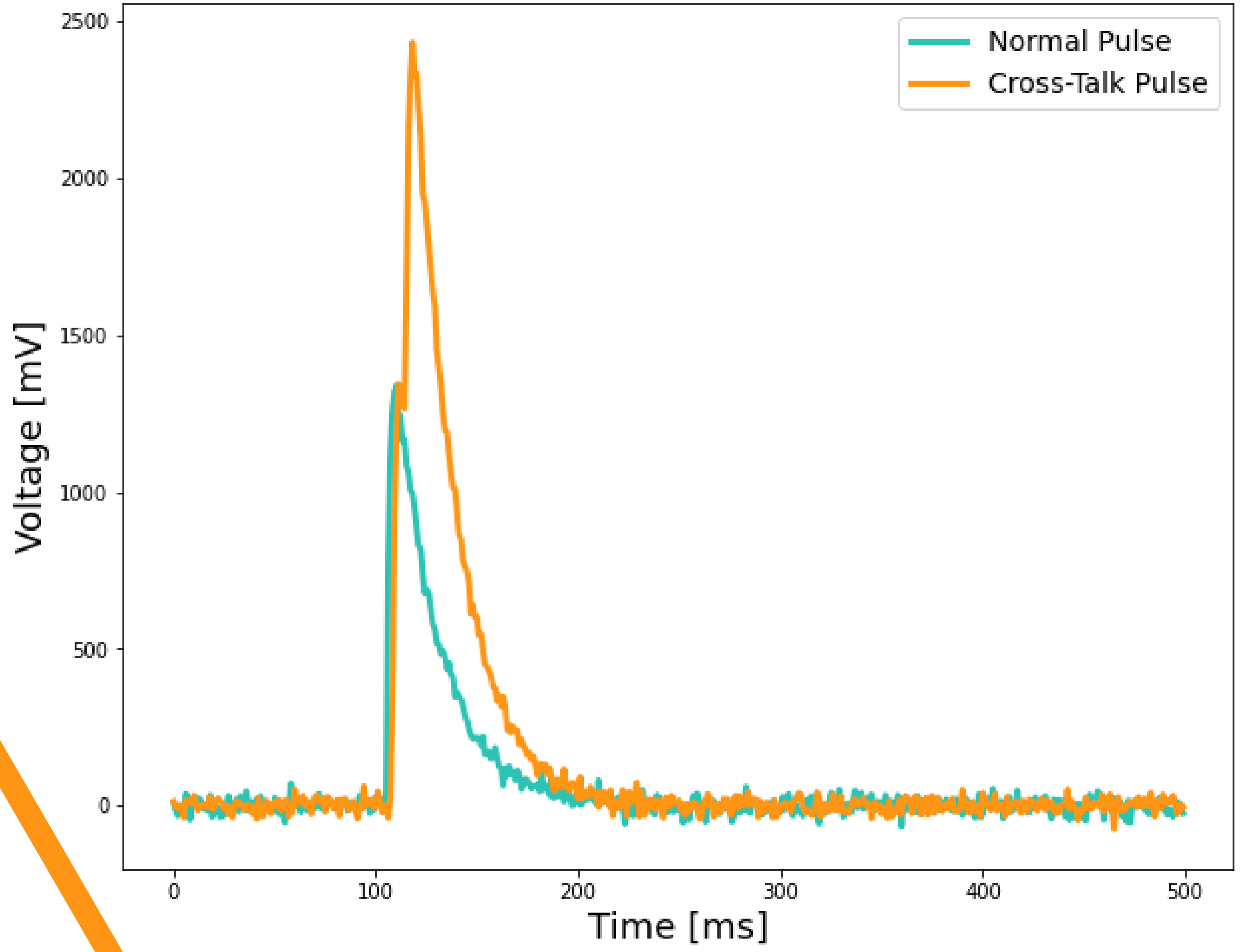
Silicon Photomultipliers (SiPMs)

- 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

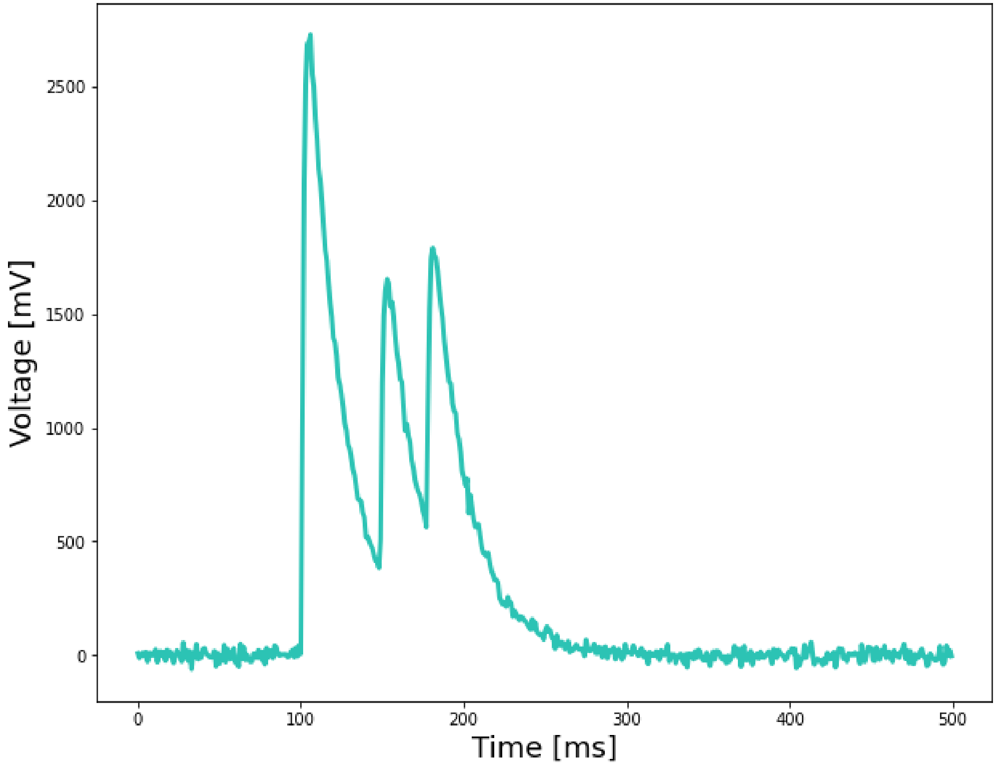




SiPMs Background

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



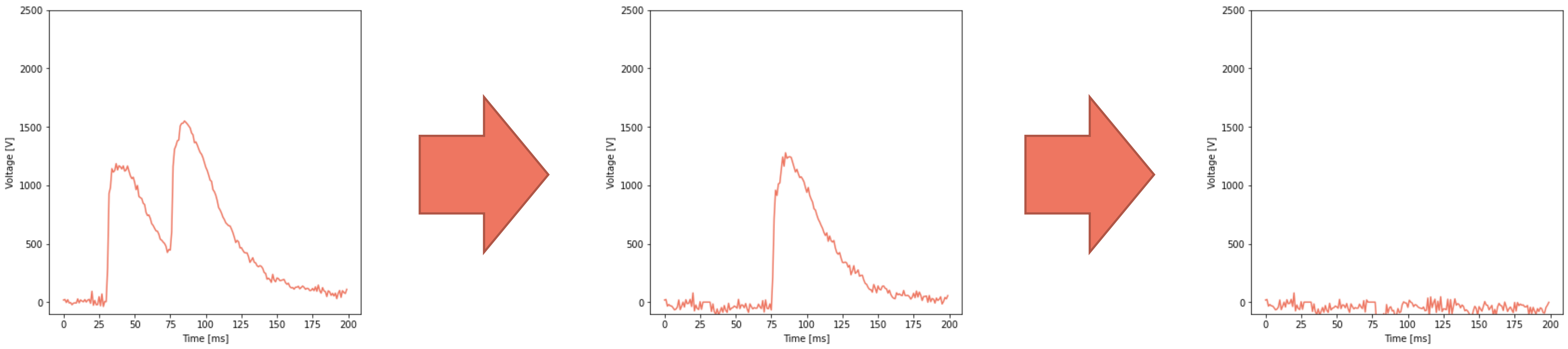
SiPMs Background **After-Pulsing**

- 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



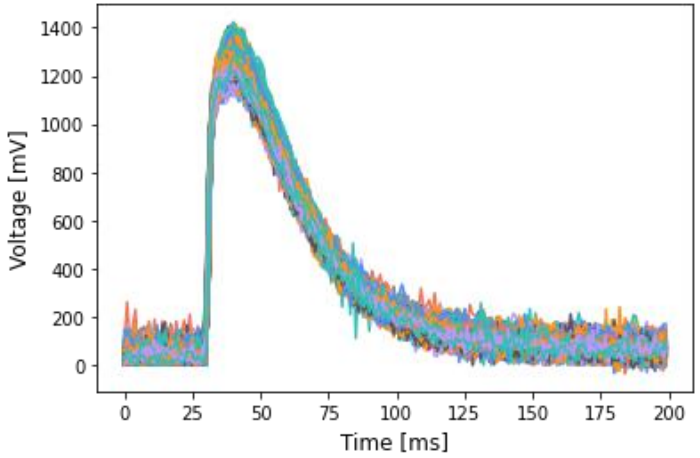
VUV-sensitive Silicon Photomultipliers for Xenon Scintillation Light Detection in nEXO

Jamil et al. 2019

Unsupervised Machine Learning

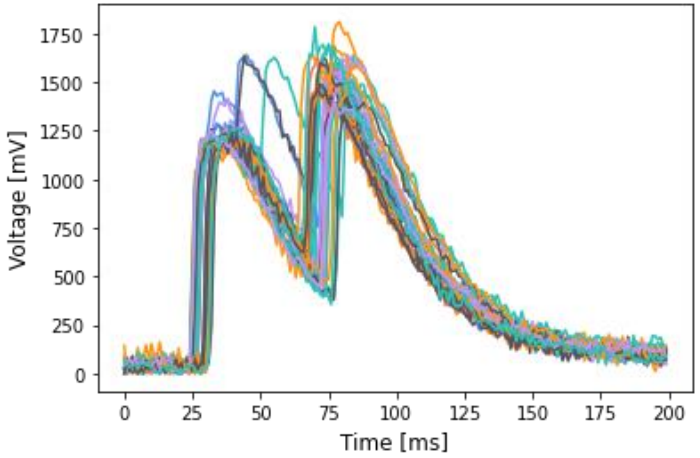
K-means Clustering

50 Clusters • 10 000 Initial Pulses



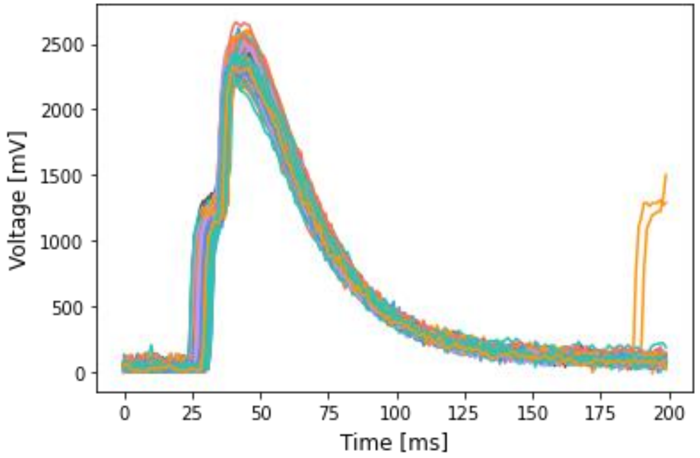
Cluster 0

Normal
925 Pulses



Cluster 12

After Pulsing
31 Pulses

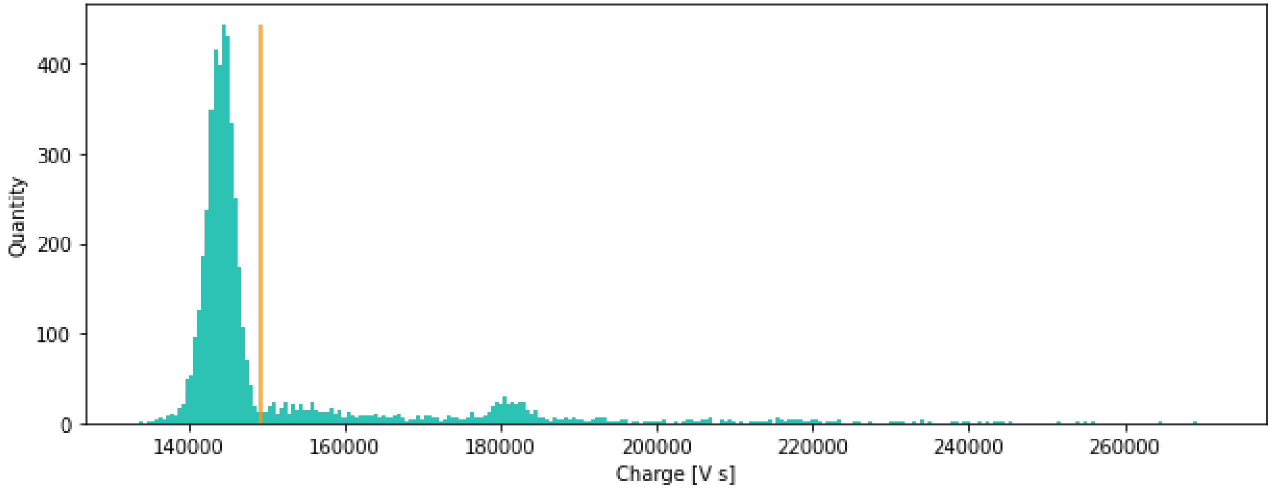


Cluster 1

Delayed Crosstalk
160 Pulses

Resulting Algorithm

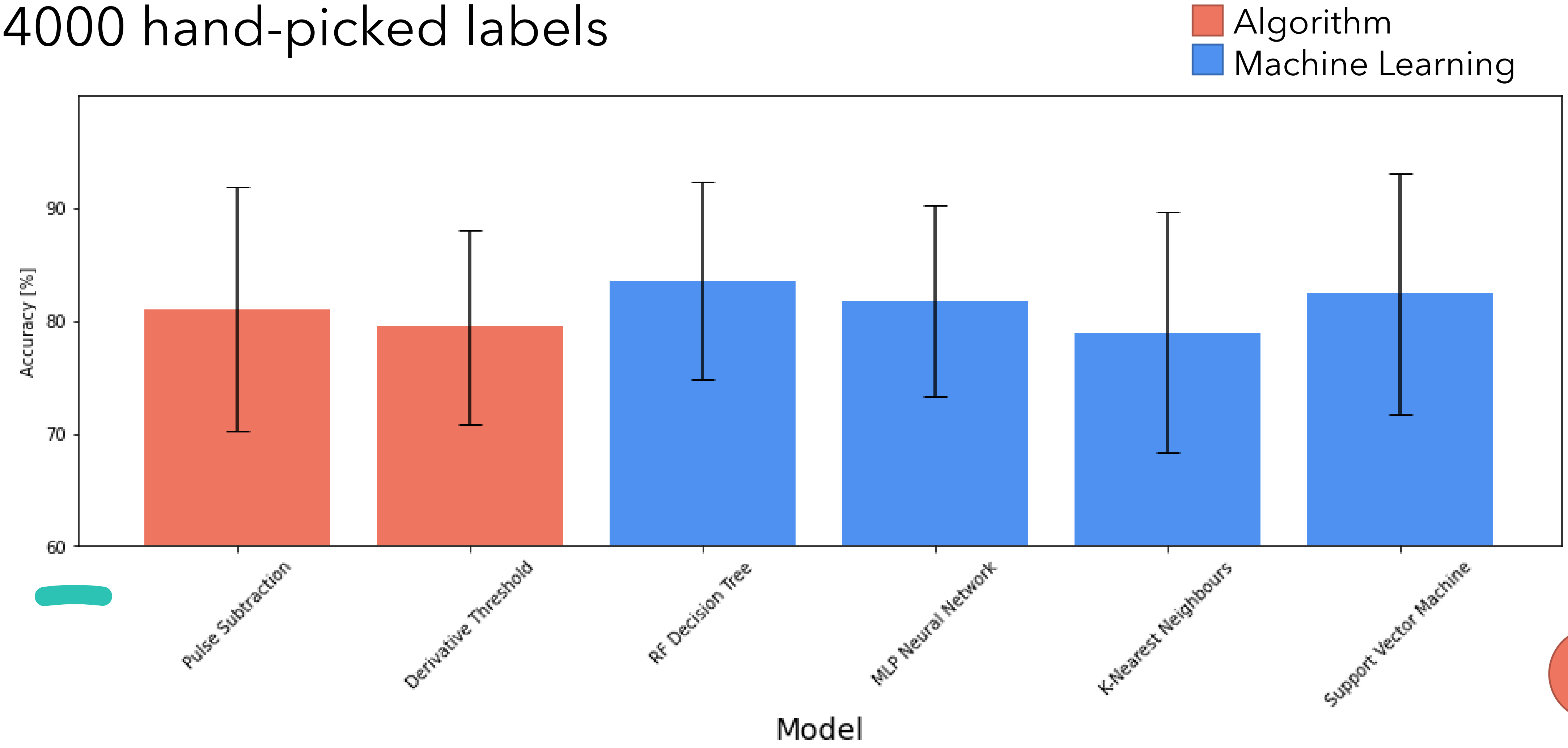
Data Input → K-means Threshold Determinant → Algorithm



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

Supervised Machine Learning

~4000 hand-picked labels



Current Results

Traditional Algorithms

- Accurately calculates t0
- 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

Ciaran Byles-Ho
ciaran.bylesho@queensu.ca
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