Deep learning based pulse shape discrimination for GERDA

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https://commons.wikimedia.org/wiki/File:Sound_wave.jpg
https://www.flickr.com/photos/downloadsourcefr/16361602656
https://commons.wikimedia.org/wiki/File:CMS_Higgs-event.jpg

Deep learning: Recognizing patterns

Speech recognition

Text recognition

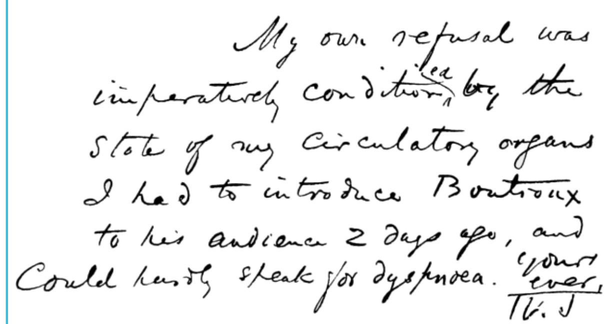
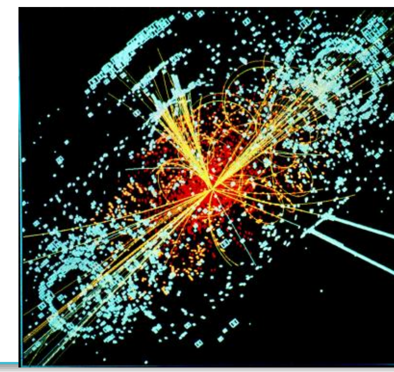

My own refusal was
imperatively conditioned by the
state of my circulatory organs
I had to introduce Boutroux
to his audience 2 days ago, and
Could hardly speak for dyspnoea. Yours ever,
Wm. J

Image classification

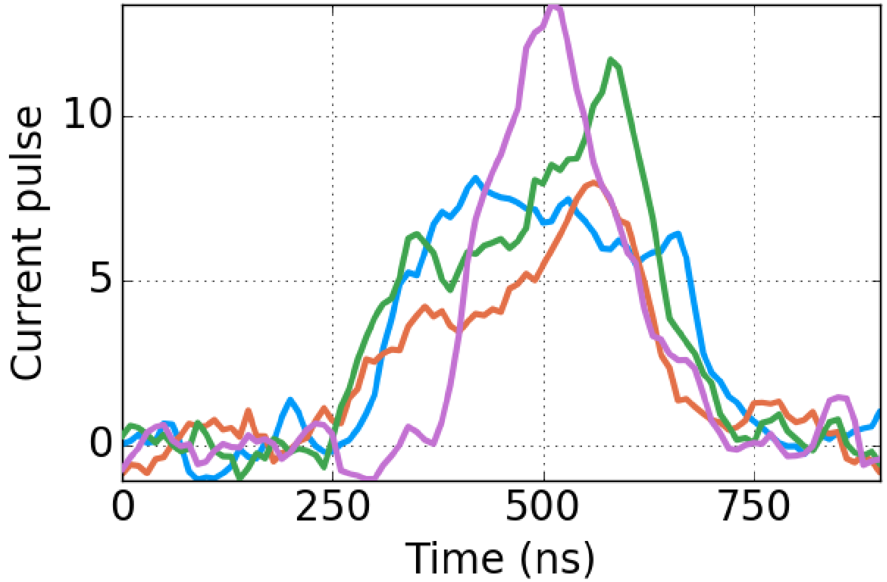
Particle reconstruction



- Deep learning is about recognizing patterns

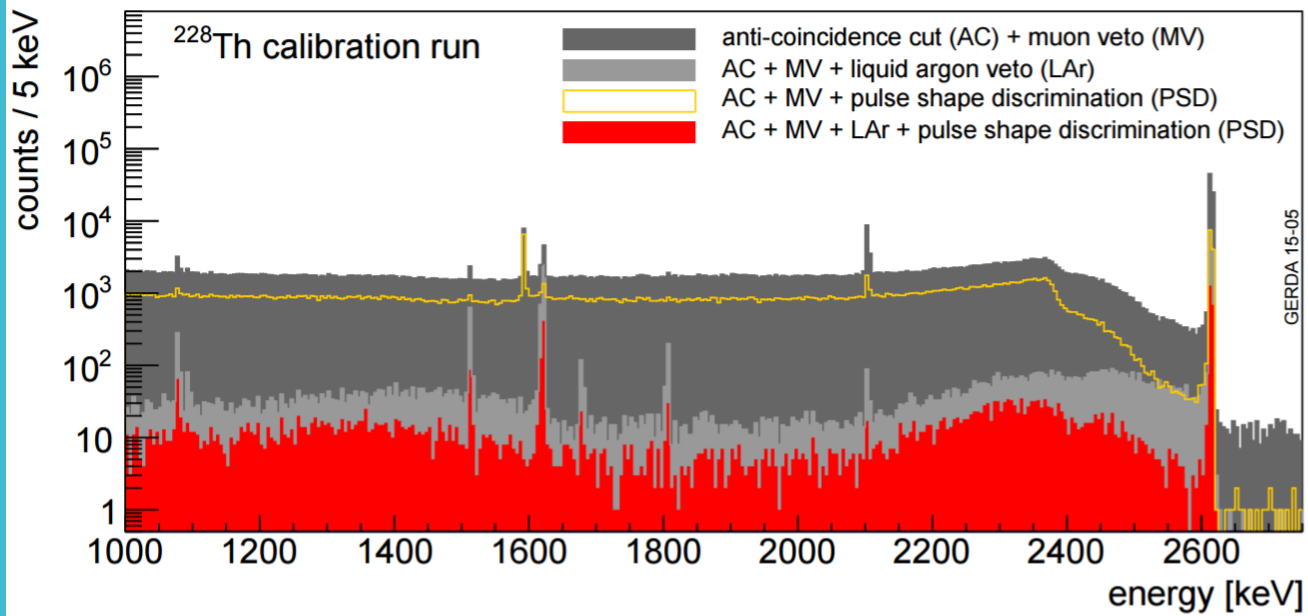
Pulse shapes and deep learning

Example waveforms from run 63 RG1 from 1.5 to 2.5 MeV



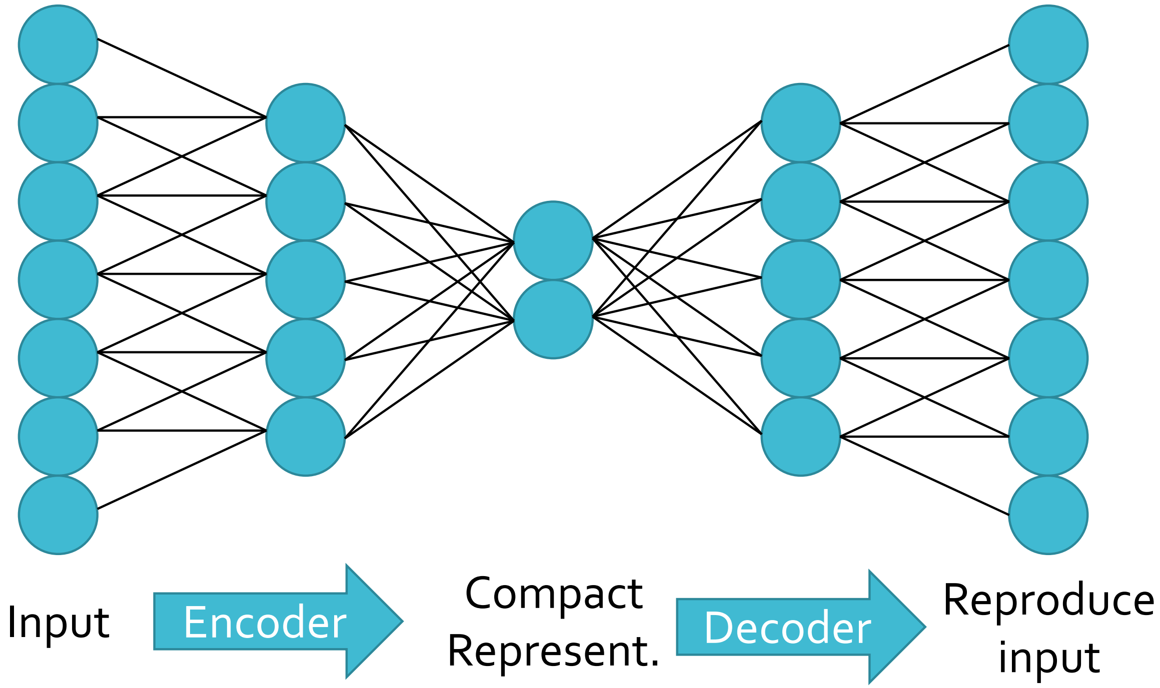
- Signal encodes type of pulse in ~1000 samples
  - Background rejection
- Patterns highly complex → deep learning for recognition

GERDA data: Mostly unlabelled



- Terabytes of high-dimensional data, only tiny fraction labelled
- Not enough labelled training data → Hand-written parameter extraction (preprocessing)

Autoencoder: Unsupervised learning

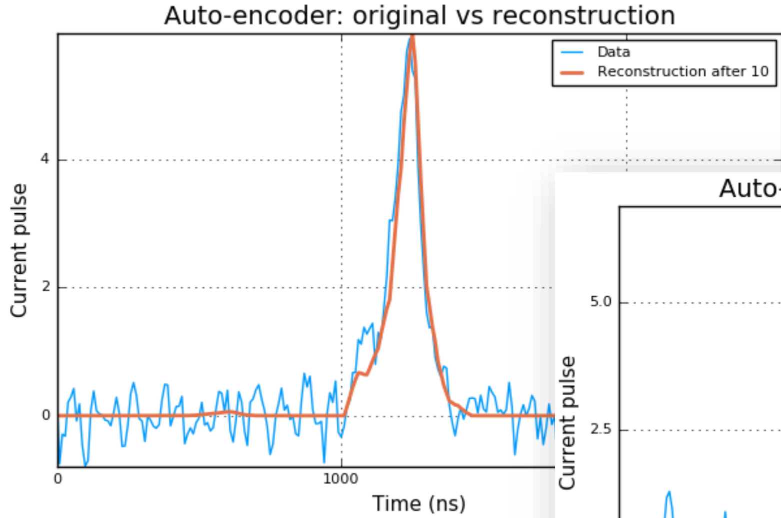


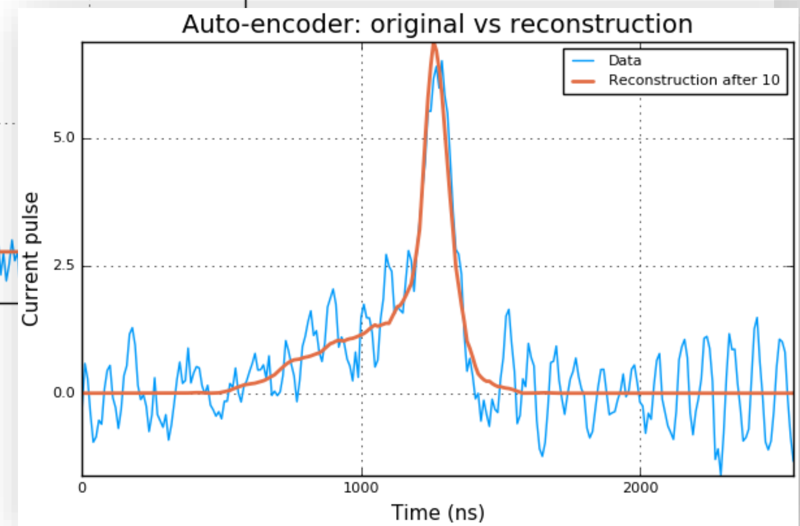
- Autoencoders learn the best compression of unlabelled data
- Encoder, decoder & compact representation are learned from data
- Compact representation ~2 orders of magnitude smaller than original pulse

Autoencoder in action

10 compact parameters

Detector GDooD, run 62
Input: high-frequency pulse center-aligned, cut to length 2.76 µs



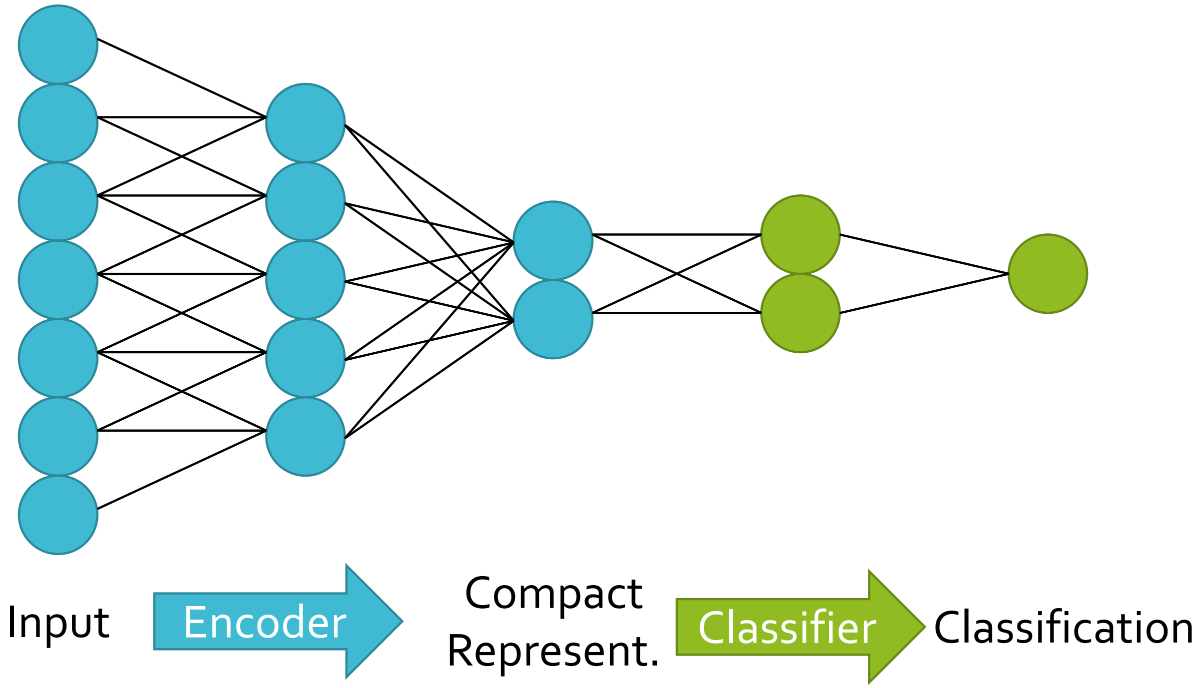


- Reconstruction from compact representation
  - Less information than original pulse
- Noise is not learned as it follows no pattern

Advantages of the autoencoder

- Unsupervised
  - Can be trained on unfiltered data sets
- Compact representation
  - Low-dimensional
  - No noise information

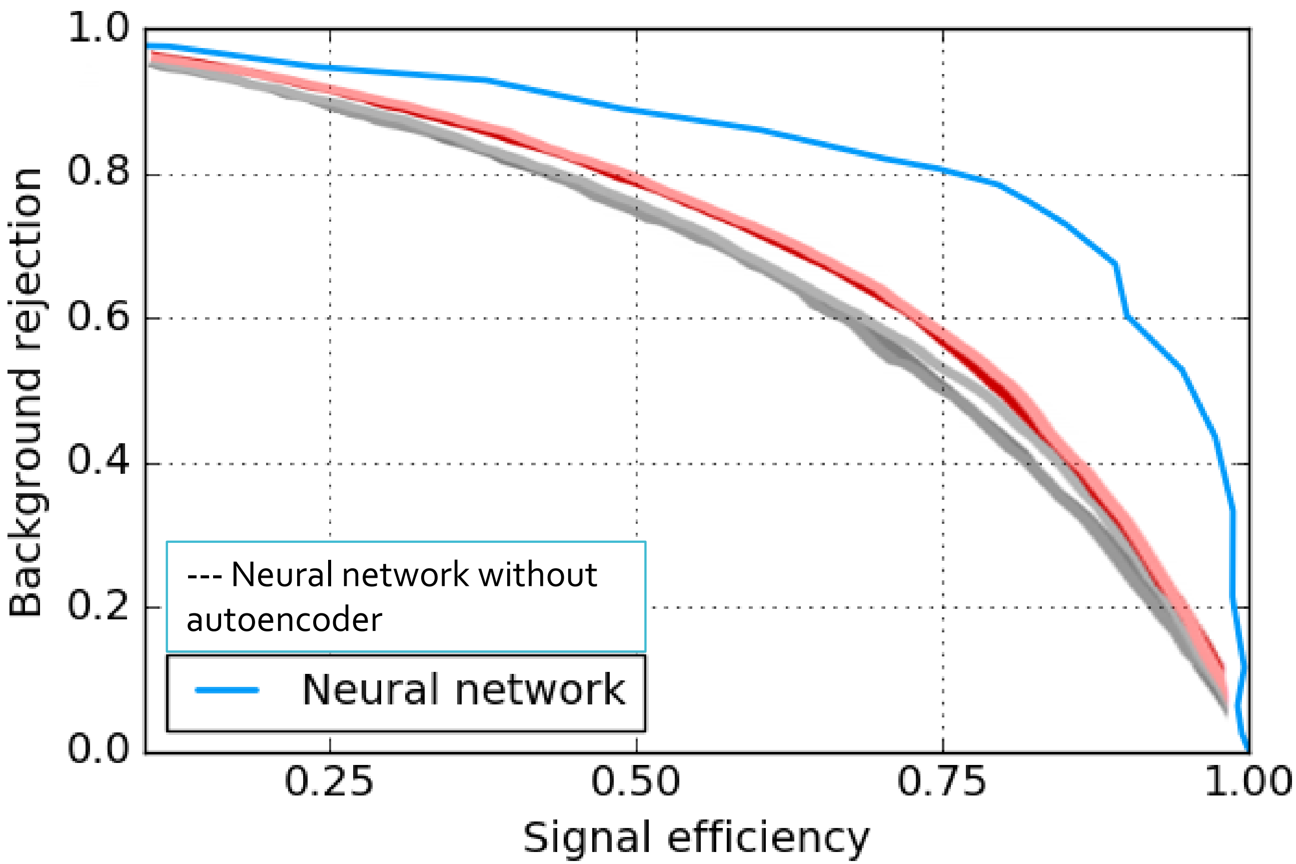
Classification with autoencoder and neural network



- Train autoencoder on ALL data
- Train neural network on compact representation of labelled data

Detector RG1, run 62, Autoencoder and PSD network with 2 hidden layers trained on run 63

Autoencoder + neural network for Coax



- Performance with autoencoder much better

Summary & Outlook

- New method for pulse analysis
  - Key technique: Unsupervised information reduction
  - Competitive compared to current methods
- Outlook
  - Use simulated pulses for training