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Sezione di Padova

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Particle Identification in Silicon Detectors
A Deep Learning Approach

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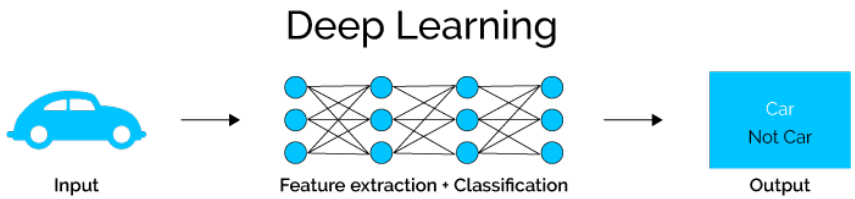
Outline



- Deep Learning approach and Neural Network models
- Dataset used
- Processing of the data and results

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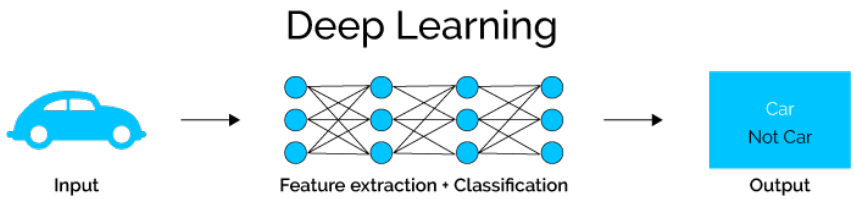

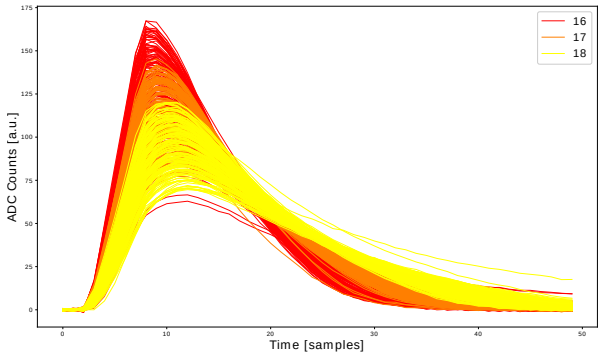

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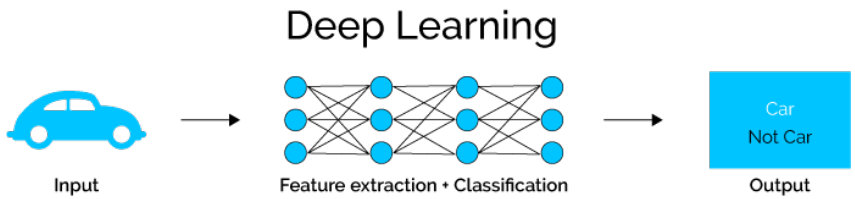
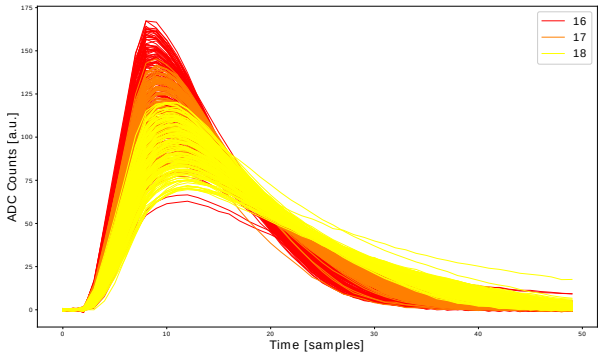
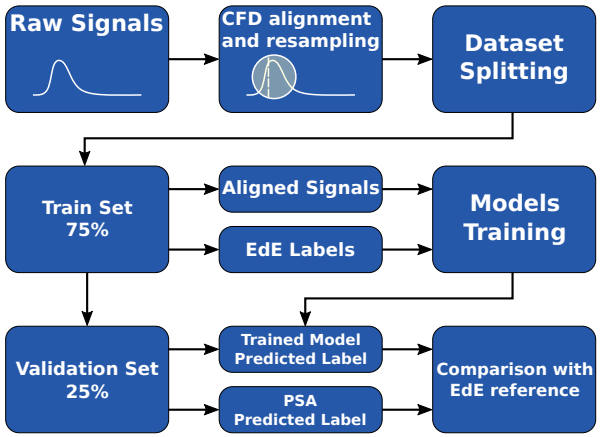
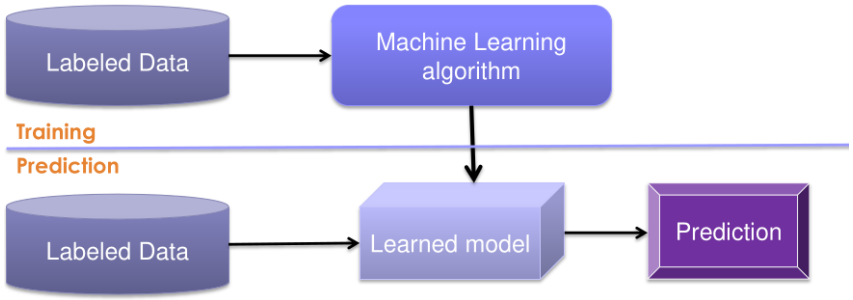




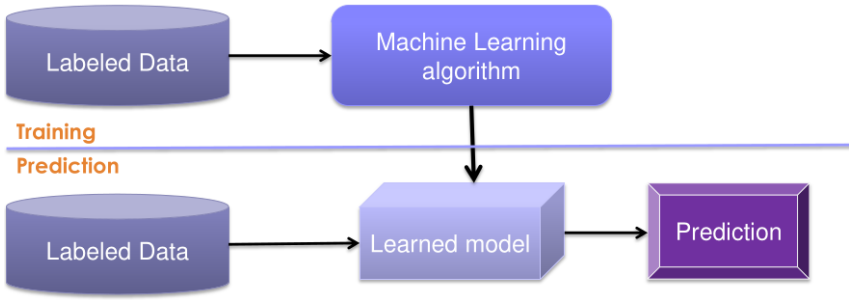


What is Deep Learning?



Subfield of machine learning where the algorithm attempt to learn representation of data by using hierarchy of multiple layers.

What is Deep Learning?



Subfield of machine learning where the algorithm attempt to learn representation of data by using hierarchy of multiple layers.

INPUT:

$$\tau = \{(x_i \in \mathbb{R}^n, y_i = \mathbf{g}(x_i) \in \mathbb{R}^m)\}_{i=1}^{N}$$

GOAL:

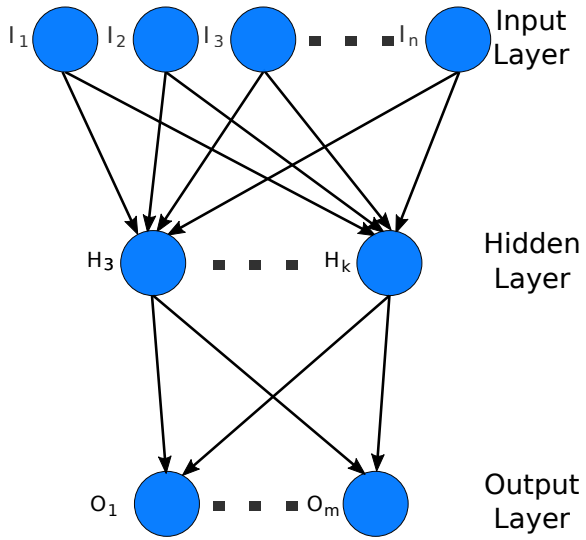
Find a parametric function $\mathbf{f}^*$ as close as possible to the unknow $\mathbf{g}$

OUR CASE:

Learn high level features embedded in silicon detector signals in a data driven manner and perform a classification based on particle type.

Architectures

Multi Layer Perceptron



The Perceptron

$$h_i = \sigma\left(\sum_{k=1}^{n} w_k^i x_k + b_k^i\right)$$

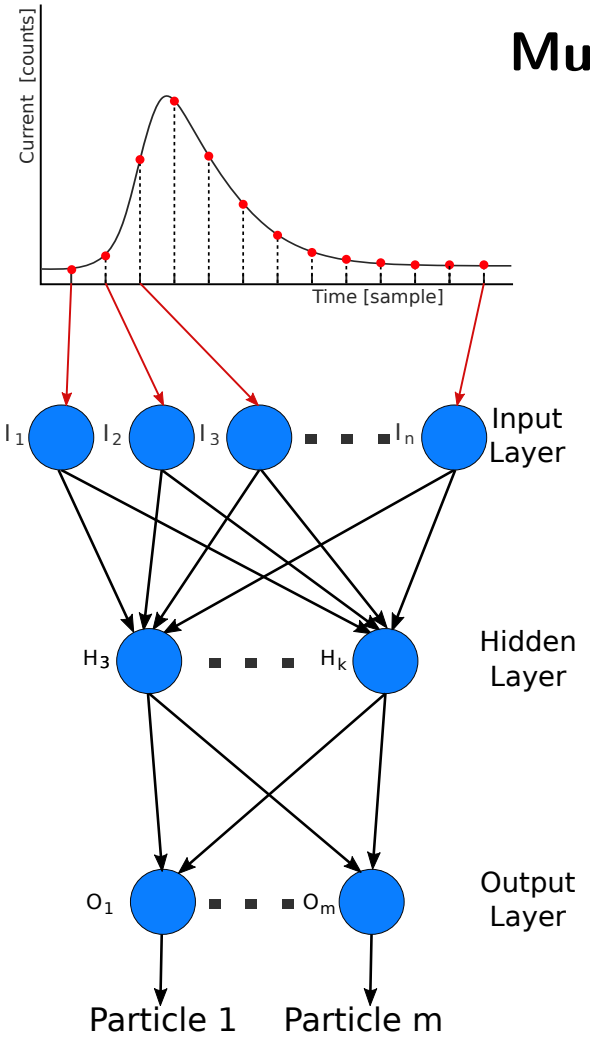
$\sigma \rightarrow$ activation function

$w^i \rightarrow i^{th}$ neuron set of weights

$b^i \rightarrow i^{th}$ neuron set of bias

Architectures

Multi Layer Perceptron



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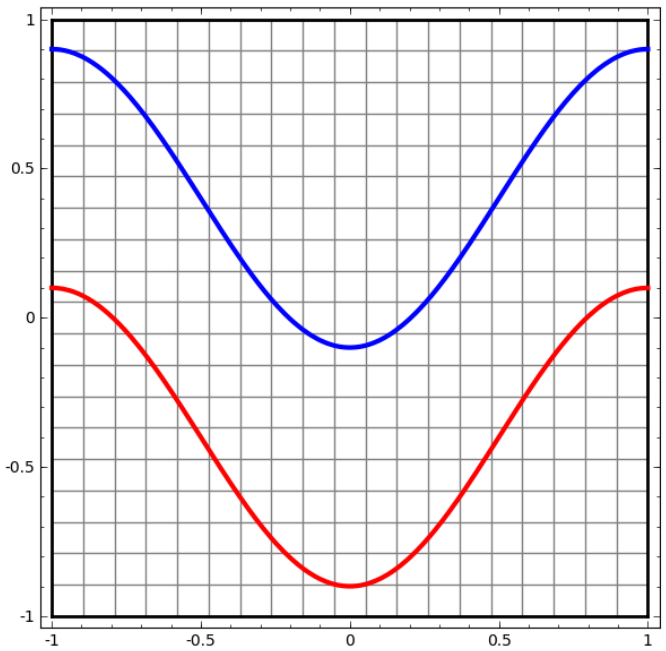
TRAINING

Find the optimal weights and bias values.

Architectures

Multi Layer Perceptron



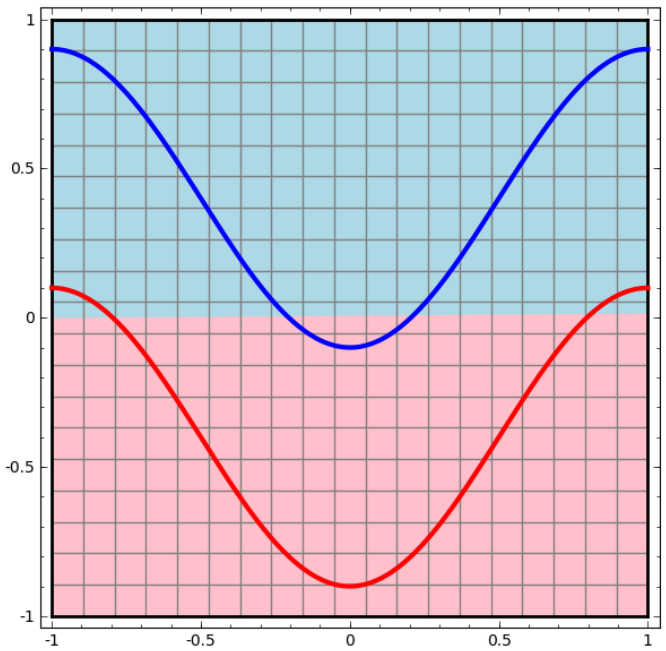
https://colah.github.io

An Example

Separation of two class of data.

Architectures

Multi Layer Perceptron



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An Example

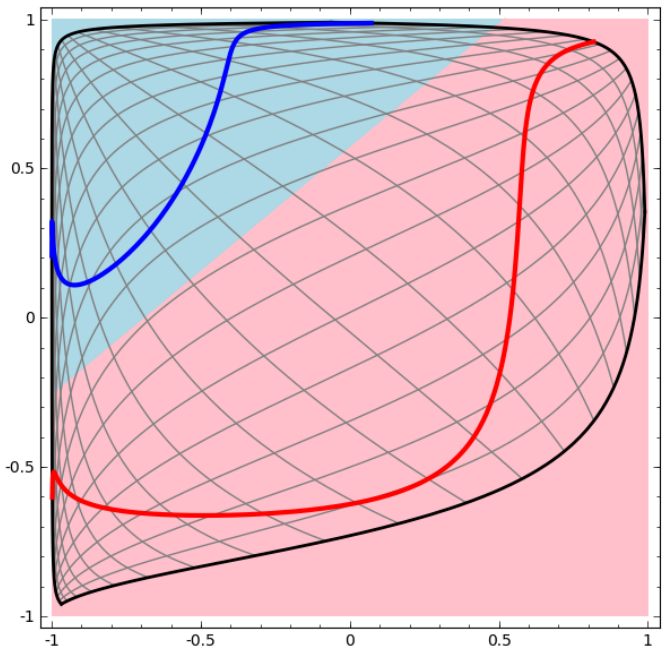
Separation of two class of data.

No Hidden layer

simple separation with a line

Architectures

Multi Layer Perceptron



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An Example

Separation of two class of data.

No Hidden layer

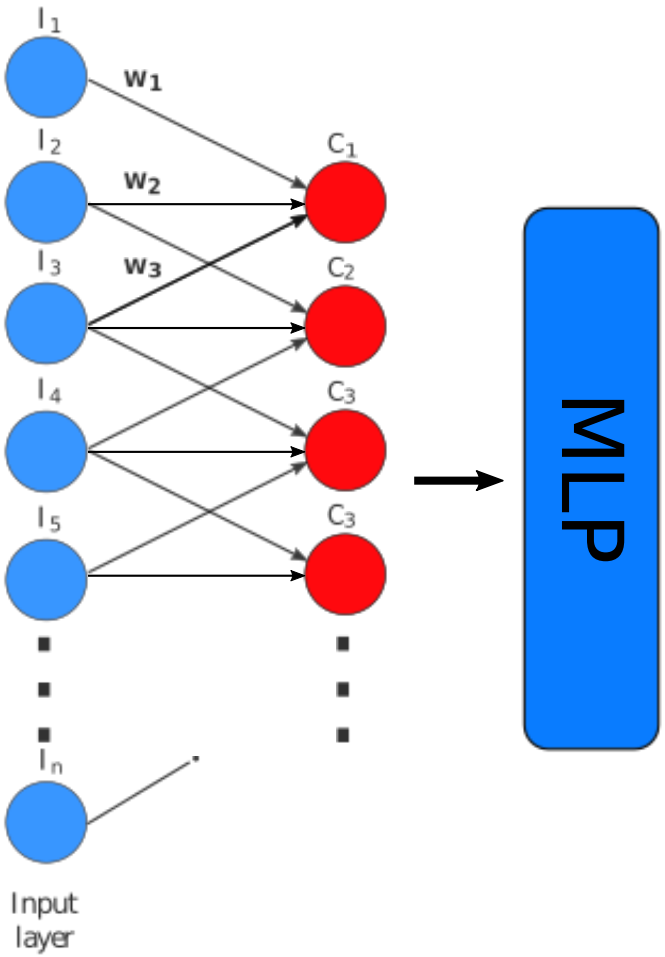
simple separation with a line

One Hidden layer

The Hidden layer learn a representation so that the data are linearly separable

Architectures

Convolutional Neural Network



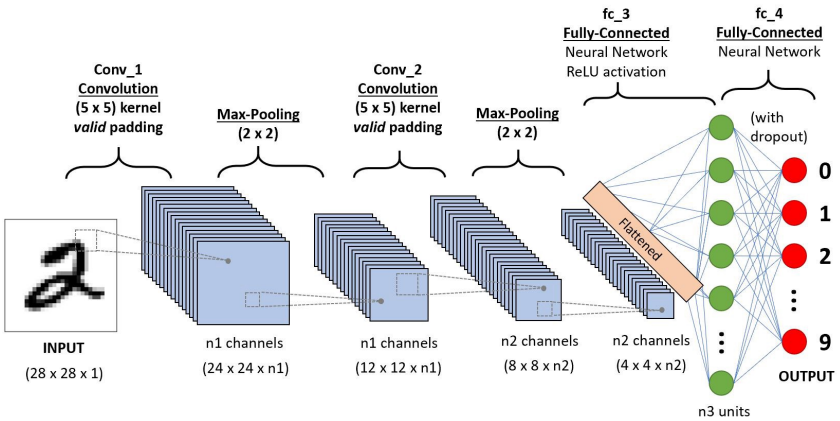
Set of convolution layers

Each hidden layer node is connected only to the neighbouring one.

The weights are the same for all the nodes.

Architectures

Convolutional Neural Network



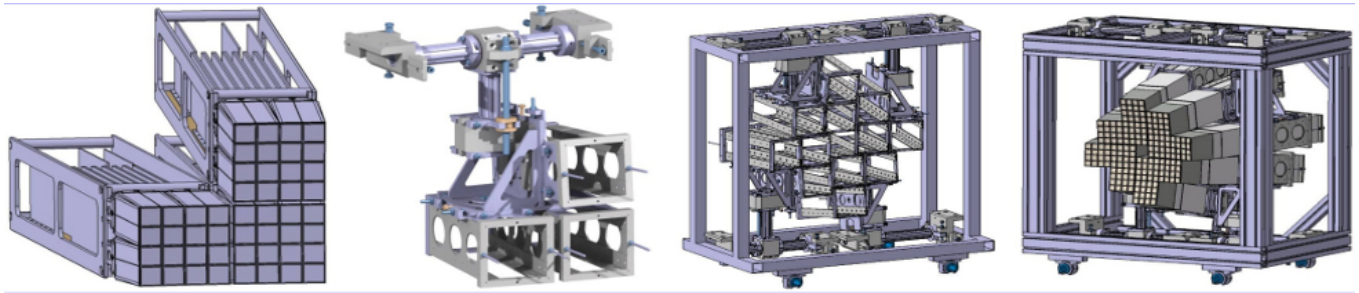
Set of convolution layers

Each hidden layer node is connected only to the neighbouring one. The weights are the same for all the nodes.

Classic Example

MNIST classification

FAZIA

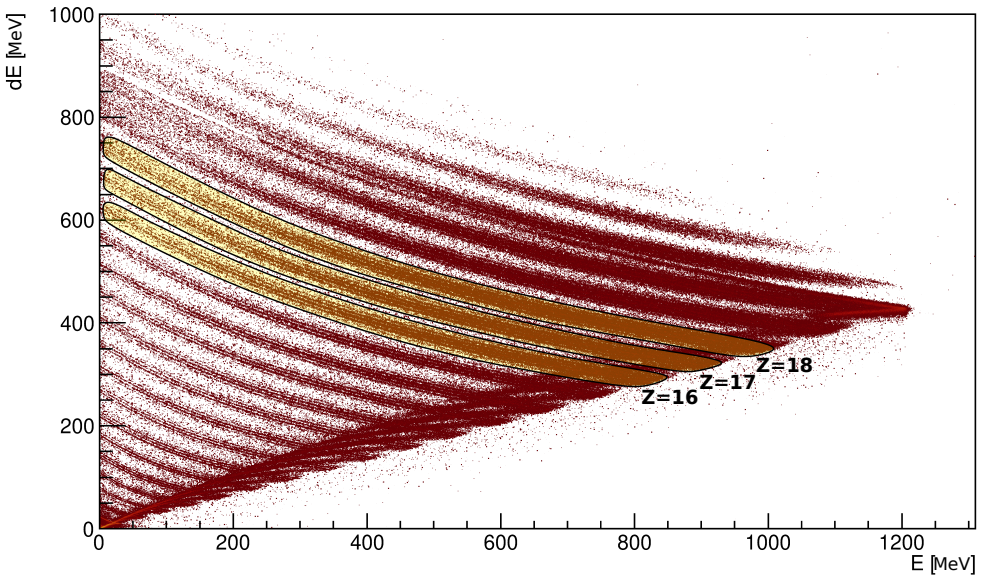


- From Coulomb barrier up to 100 A MeV.
- Three-stage telescopes:
  - → Si1: 300 μm
  - → Si2: 500 μm
  - → CsI(Tl) scintillator

  Datatset from a commissioning test from a single telescope.

(S. Valdré et al, NIM 930 (2019))

Dataset



Composition

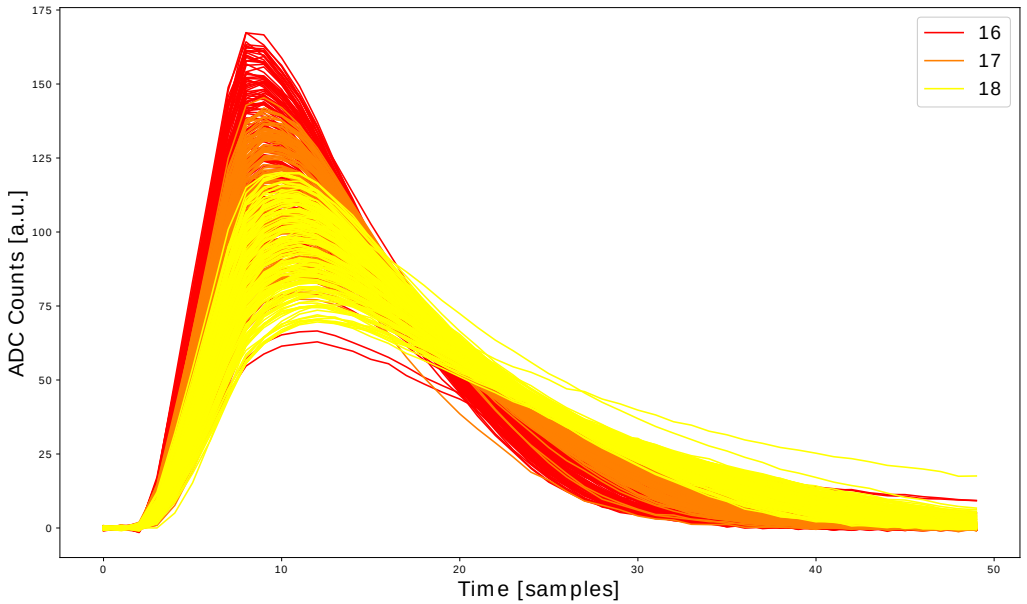
- $\sim 2 \cdot 10^6$ detected particles
- Z up to 23
- stopped in the second layer

For each event

↓

(E_1,E_2, second layer signal)

Dataset



Composition

- $\sim 2 \cdot 10^6$ detected particles
- Z up to 23
- stopped in the second layer

For each event

↓

(E_1,E_2, second layer signal)

Events Selected

→ Z=16 S

→ Z=17 Cl

→ Z=18 Ar

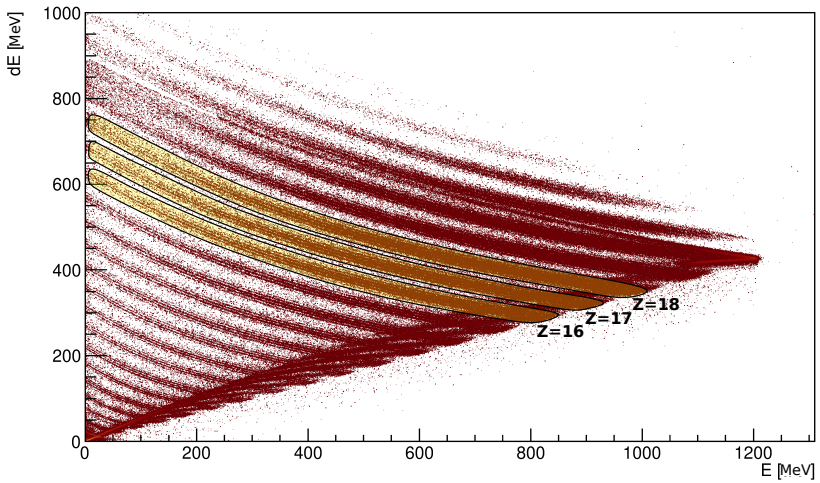
Dataset

The dataset provided is perfectly suited for this kind of test

REFERENCE LABEL

Double Layer identification

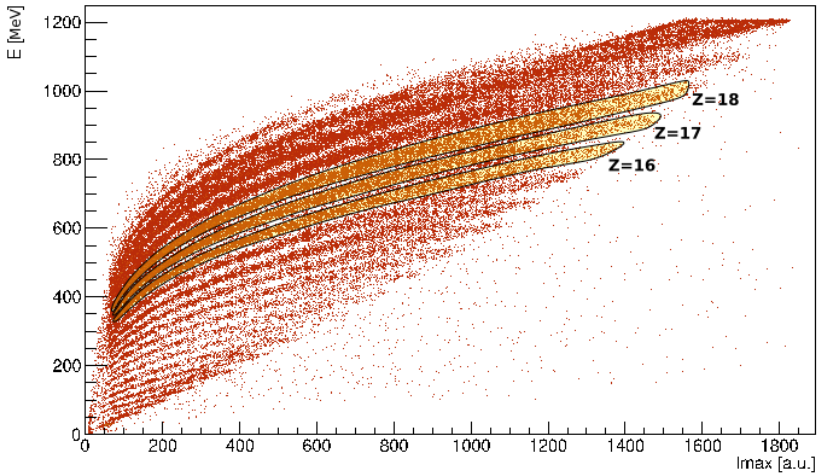
EΔE



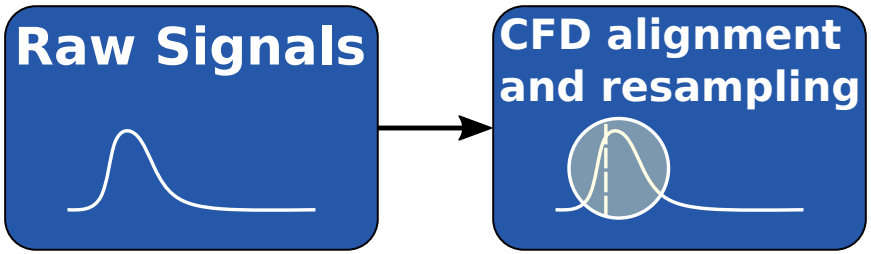
COMPARISON LABEL

Single Layer identification

PSA: Current maximum vs. Energy



Data Processing



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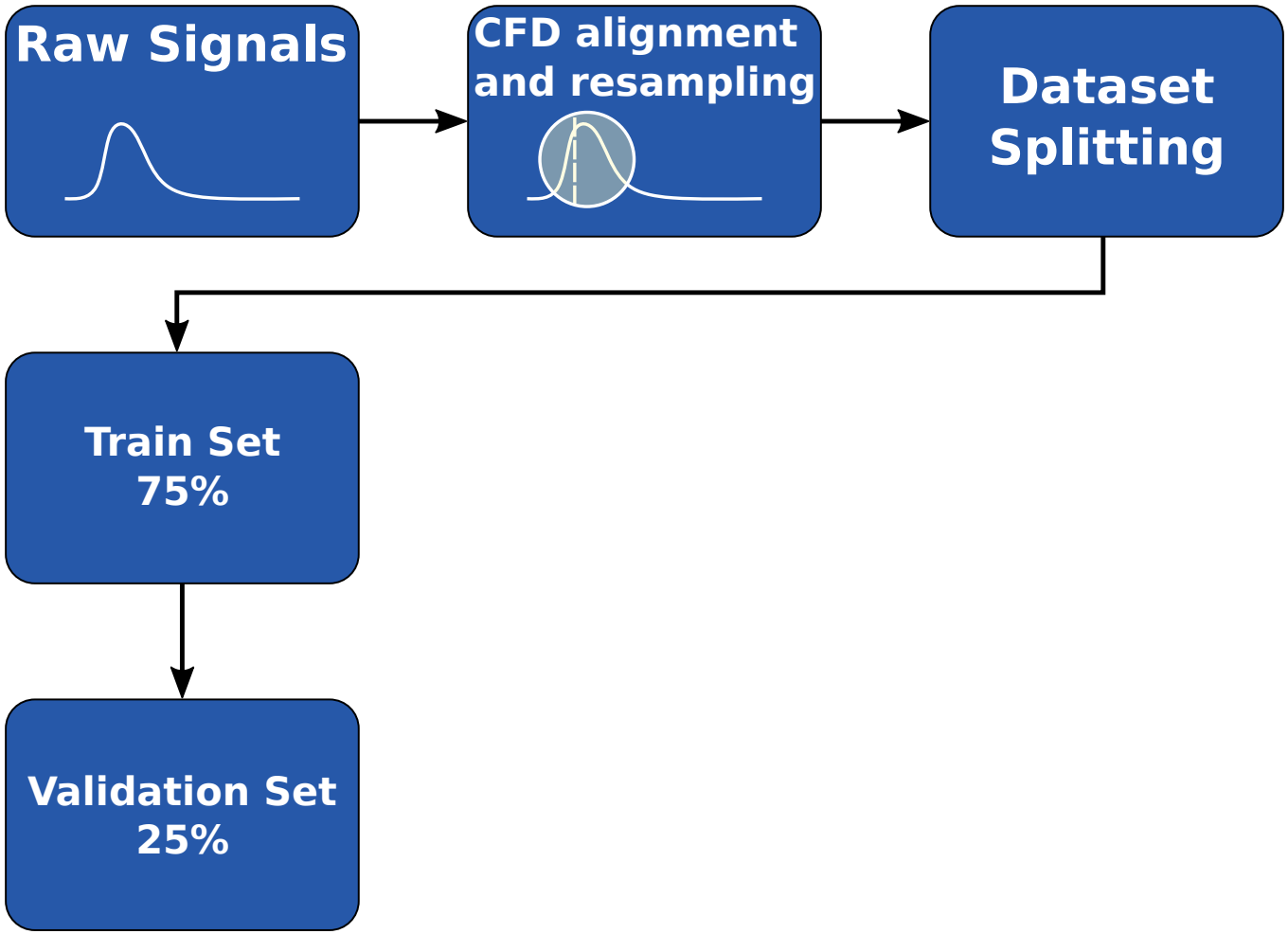

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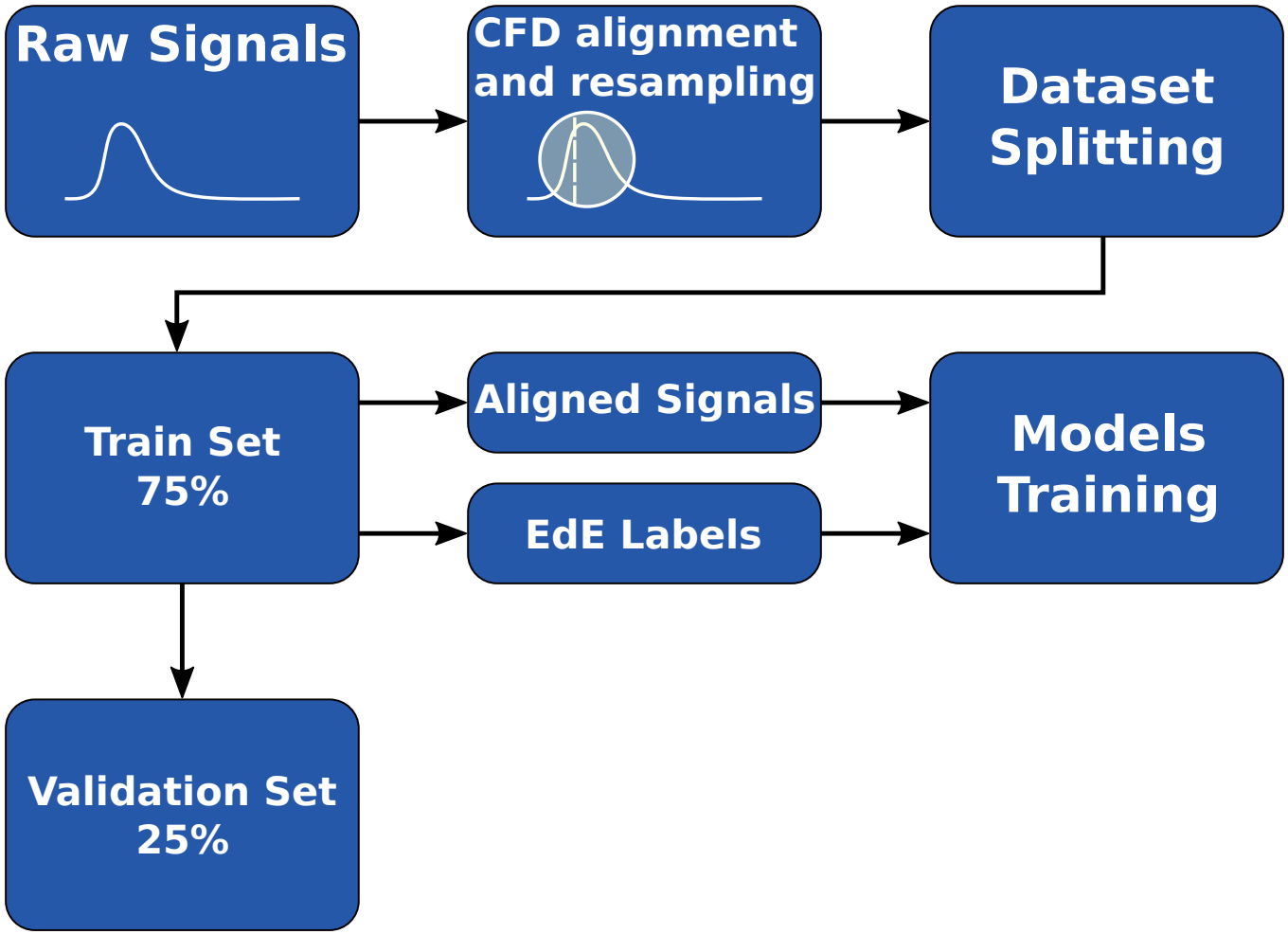

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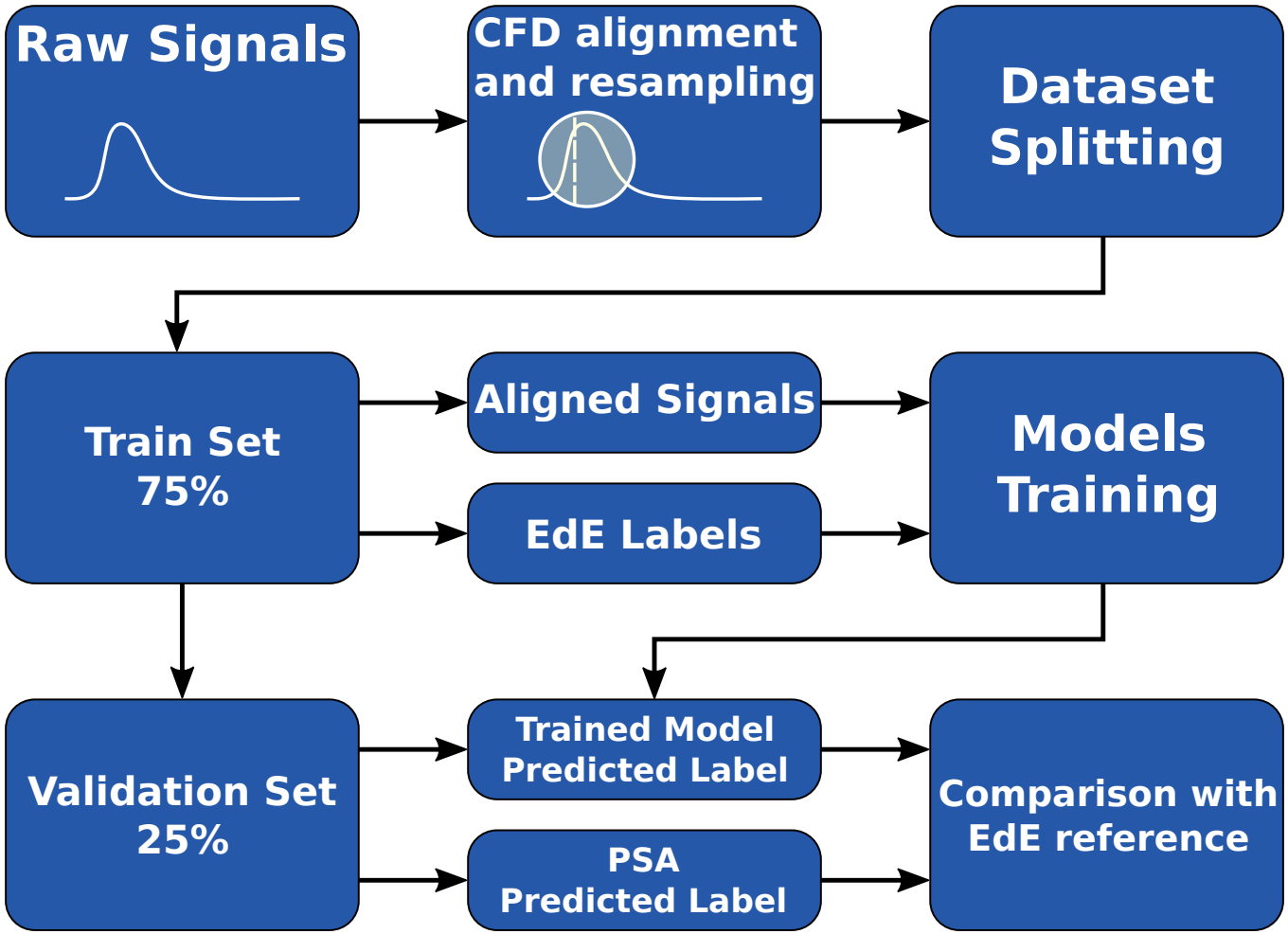
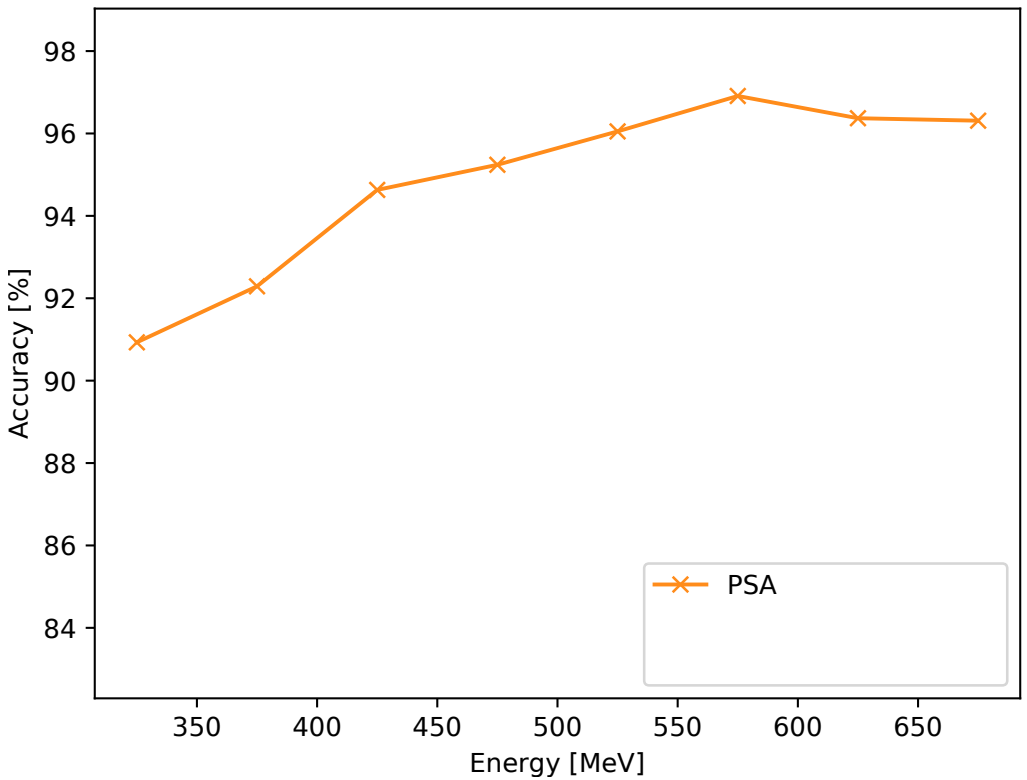


Accuracy of the methods

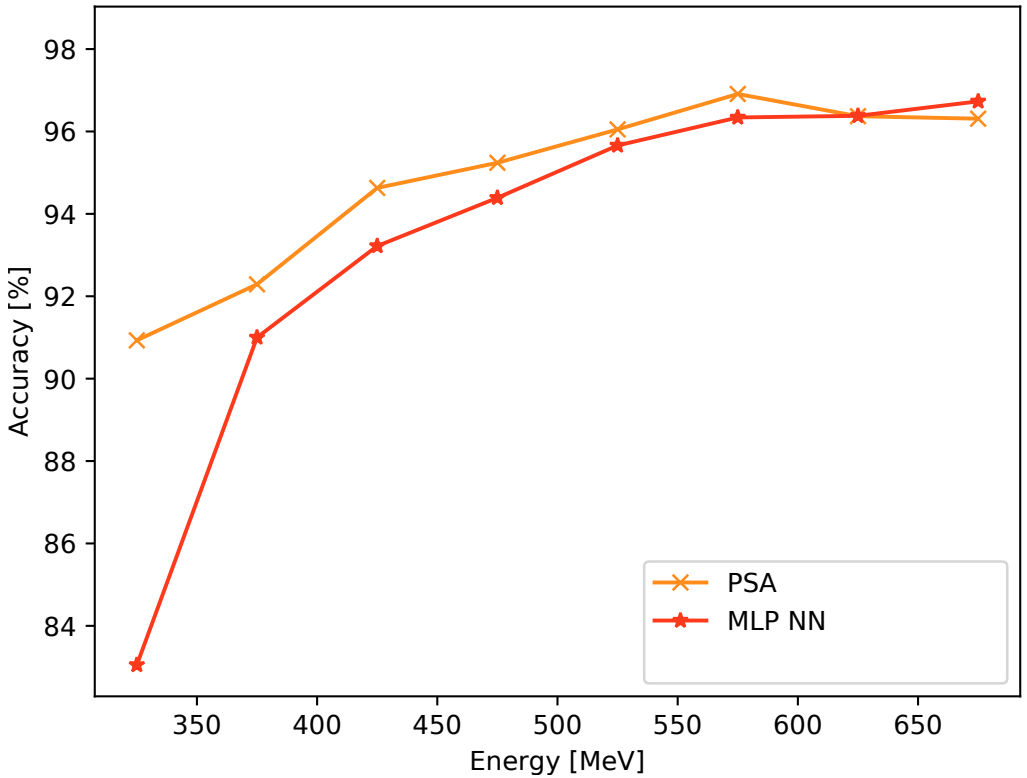


$$\text{Accuracy} = \frac{\text{Correct ID}}{\text{Total}}$$

PSA method

Current maximum vs. Energy

Accuracy of the methods



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PSA method

Current maximum vs. Energy

MLP

4 Hidden Layers

200,100,50,25 units

Tanh activation function

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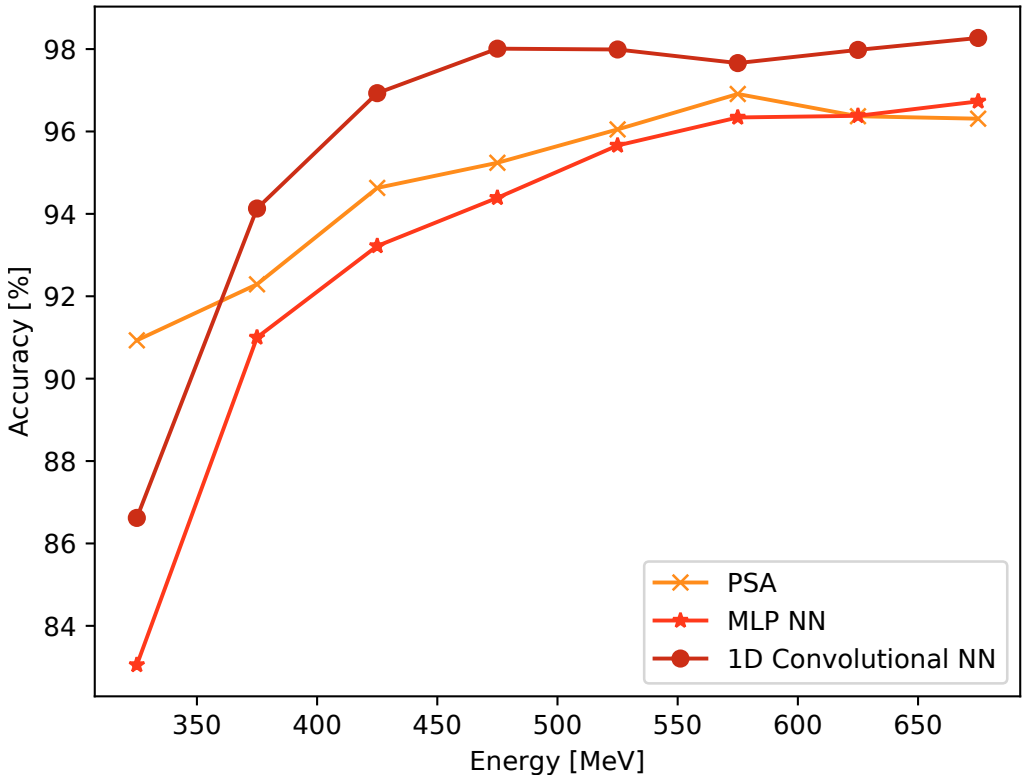

$$\text{Accuracy} = \frac{\text{Correct ID}}{\text{Total}}$$

PSA method

Current maximum vs. Energy

MLP

4 Hidden Layers

200,100,50,25 units

Tanh activation function

CNN

3 Conv. Layers

20,40,60 units

ReLu activation function

Summary

Perspective:

- Investigate the accuracy trends.
- Exploit the lower efficiency at lower energies (Test with simulated signal?).
- Test the algorithms on light particles(experiment at LNL CN accelerator).
- Test other architectures (RNN..)

Acknowledgments

Thanks to the FAZIA collaborations for providing the dataset and the simulation tool.

Thank you for attention!