IFAE
Institut de Física
d'Altes Energies

Neural Networks for discrimination between 1 and 2 particle events

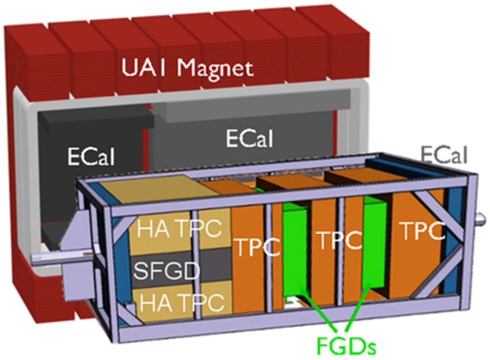
Marc Rodríguez Salazar

2023

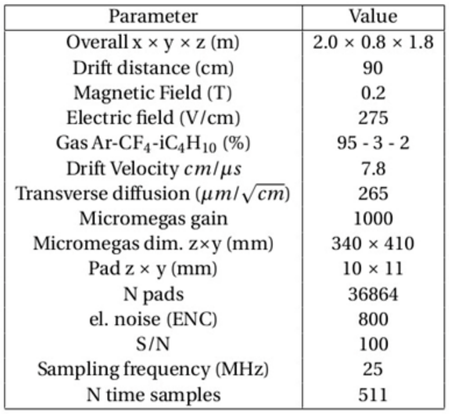
1 Introduction and Motivation

The main goal is to obtain a Machine Learning program for discriminating between 1 and 2 particle events in the ND280 near detector. This text presents all the code generated to achieve this goal.

First of all we are going to introduce a basic background of the experiment. In Figure 1a we can see the detector scheme, and in Figure 1b a table with the principal parameters.



(a) Detector sheme



Parameter	Value
Overall x × y × z (m)	2.0 × 0.8 × 1.8
Drift distance (cm)	90
Magnetic Field (T)	0.2
Electric field (V/cm)	275
Gas Ar-CF$_4$-iC$_4$H$_{10}$ (%)	95 - 3 - 2
Drift Velocity $cm/\mu s$	7.8
Transverse diffusion ($\mu m/\sqrt{cm}$)	265
Micromegas gain	1000
Micromegas dim. z×y (mm)	340 × 410
Pad z × y (mm)	10 × 11
N pads	36864
el. noise (ENC)	800
S/N	100
Sampling frequency (MHz)	25
N time samples	511

(b) Table with principal detector's parameters

Figure 1

The generated files are grouped in the next categories:

- Hattracks (Monte-Carlo True)
- Hatdigits
- ANN to discriminate 1 and 2 particles events
- CNN to discriminate 1 and 2 particles events
- CNN to discriminate proton and muons events

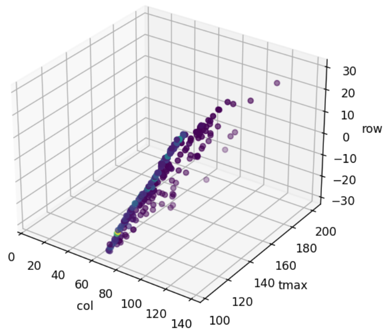
Below is a detailed explanation of what each code file does.

2 Hattracks (Monte-Carlo True)

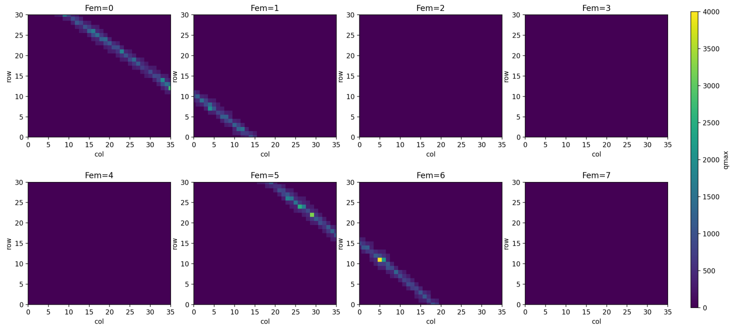
Hattracks.ipynb corresponds to the Monte Carlo-True of the simulated tracks. It generates histograms for different parameters (like energy, position, momentum...), and it also generates 3D graphs of the start and end coordinates to see the trajectory. The input is a dataframe.

3 Hatdigits

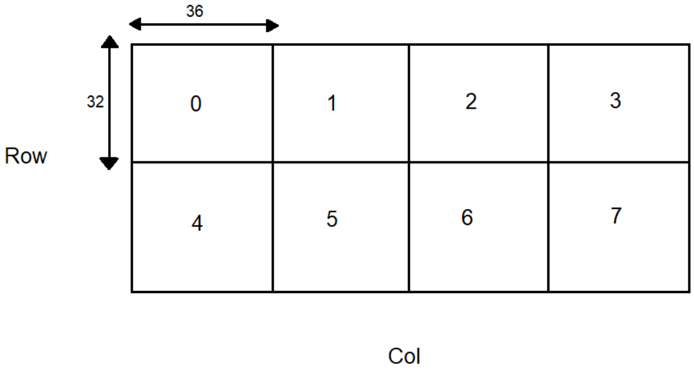
- 3D-Hatdigits-Images-Input.ipynb: it generates a 3D graph of the FEMS in the detector.

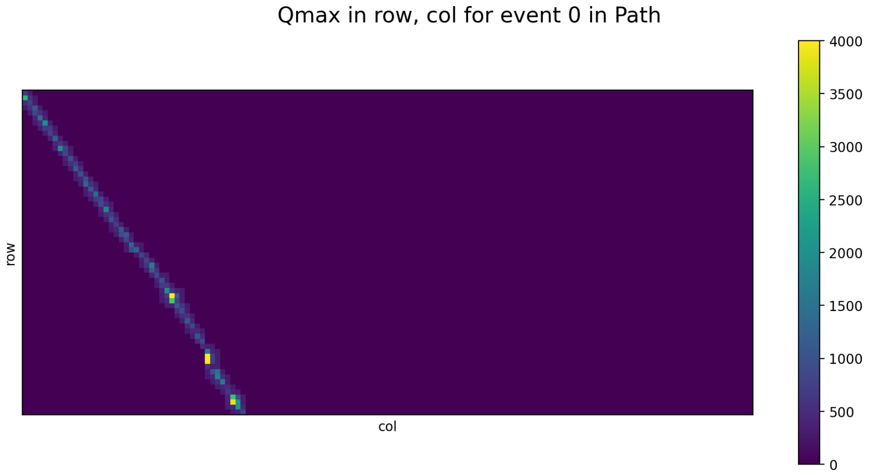


- Obtaining-Image-Input.ipynb: it generates a 2D graph of the FEMS in the detector but differentiating between FEMS.



- Image-Input.ipynb: it generates a single image with all the FEMS together (a continue image).

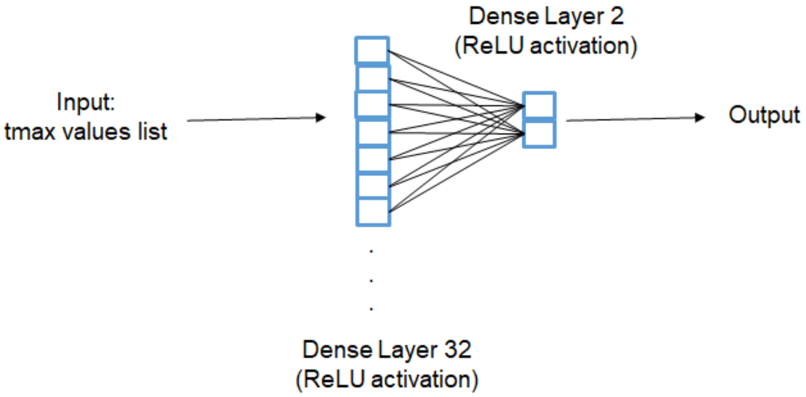




The input of all these codes is a dataframe.

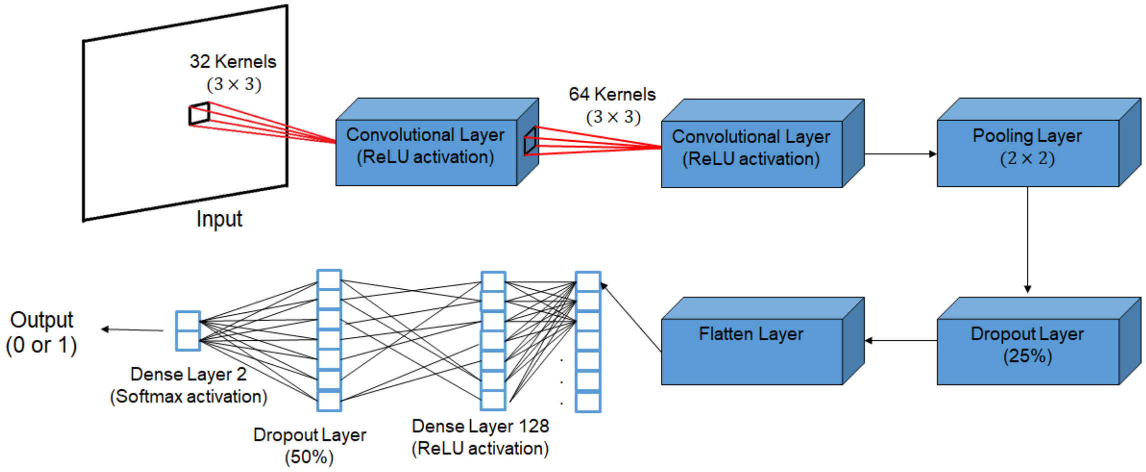
4 ANN to discriminate 1 and 2 particles events

- Preparing-the-ANN-input.ipynb: it generates a .csv file with the randomized input entries. It stores only pads with a signal other than 0 in the following format: [row, col, qmax, tmax], in order to save space.
- ANN-to-discriminate-1-and-2-particles-event.ipynb: a binary classifier ANN with 2 layers, that takes a list of tmax values (from the .csv file) and predicts the number of particles. It generates the corresponding confusion matrix, the loss vs epoch graph, the accuracy vs epoch graph and ROC curve.



5 CNN to discriminate 1 and 2 particles events

- Preparing-the-CNN-input.ipynb: it generates a .csv file with the randomized input entries. It stores only pads with a signal other than 0 in the following format: [row, col, qmax, tmax], in order to save space.
- Convert-df-to-a-matrix.ipynb: it converts the entries row, col, qmax or tmax of the dataframe to a matrix and an image.
- Histograms-tmax-and-qmax.ipynb: it generates a histogram graph of the qmax or tmax values.
- CNN-to-discriminate-1-and-2-particles-event.ipynb: a binary classifier CNN. It builds a tensor of images (matrix with the tmax values of the .csv file) as input, and predicts the number of particles. It generates the corresponding confusion matrix, the loss vs epoch graph, the accuracy vs epoch graph and ROC curve.



6 CNN to discriminate proton and muons events

- Preparing-the-CNN-input-(proton-muons).ipynb: it generates a .csv file with the randomized input entries. It stores only pads with a signal other than 0 in the following format: [row, col, qmax, tmax], in order to save space.
- CNN-to-discriminate-protons-and-muons-event.ipynb: the same CNN architecture than "CNN-to-discriminate-1-and-2-particles-event.ipynb", but used to discriminate between protons and muons events.

7 Next Steps

- Use qmax insted of tmax in the CNNs.
- Use both, qmax and tmax (2 channels) for better performance of the CNNs.
- Discriminate between other different particles.