SEARCH FOR ELOECTRON NEUTRINOS AT THE SND@LHC

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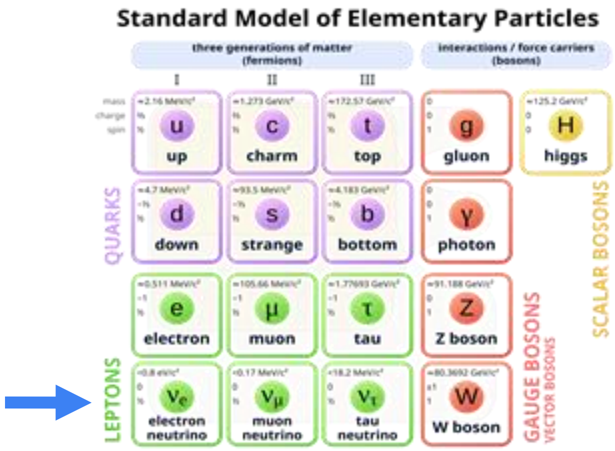
LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

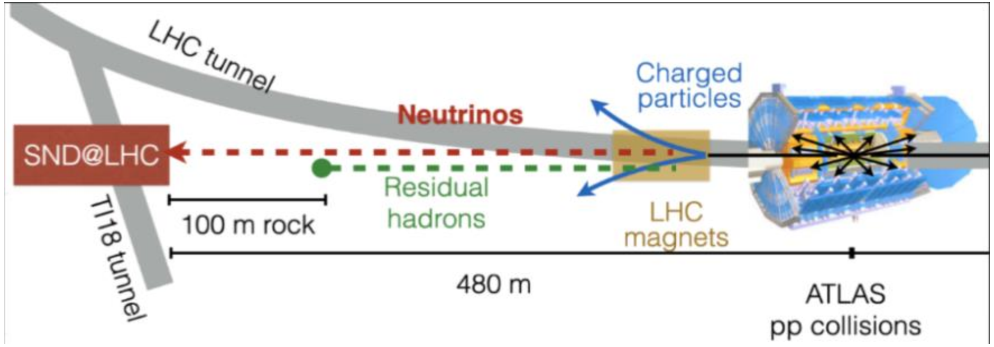
Motivation

- 2nd most abundant particle in the universe

  - Traditionally studied in processes such as nuclear beta decay or nuclear reactors

  - First observation of electron neutrinos in proton-proton collisions, produced at ATLAS, LHC- unique neutrino measurements!

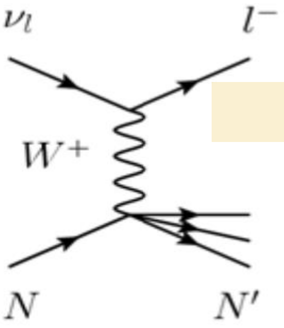




What are neutrinos and how can we identify them?

- Identification using the outgoing lepton – Electron (EM shower)
- Separate signal (charged current) the background (neutral current) using **topological signal selection**

ν_e



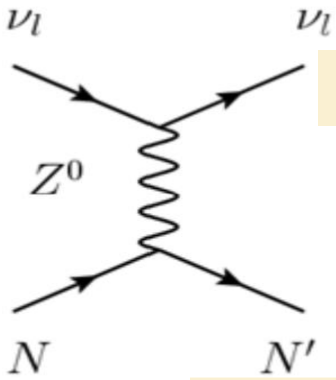
EM shower

Lepton - electron

Tungsten nucleon W^{47}

Hadronic shower

Charged Current (CC) interaction



neutrino

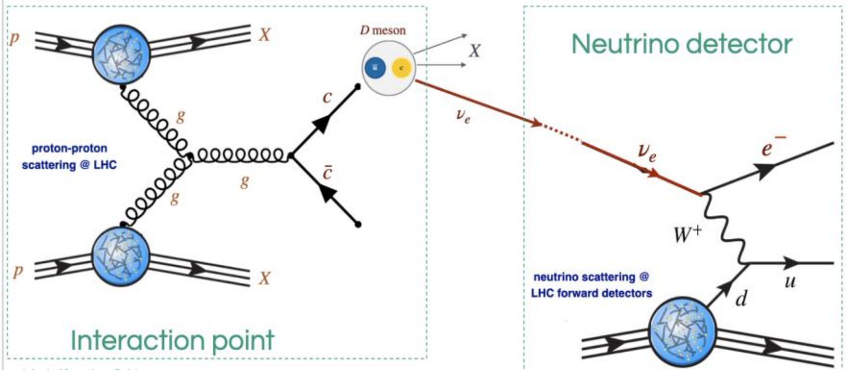
Tungsten nucleon W^{47}

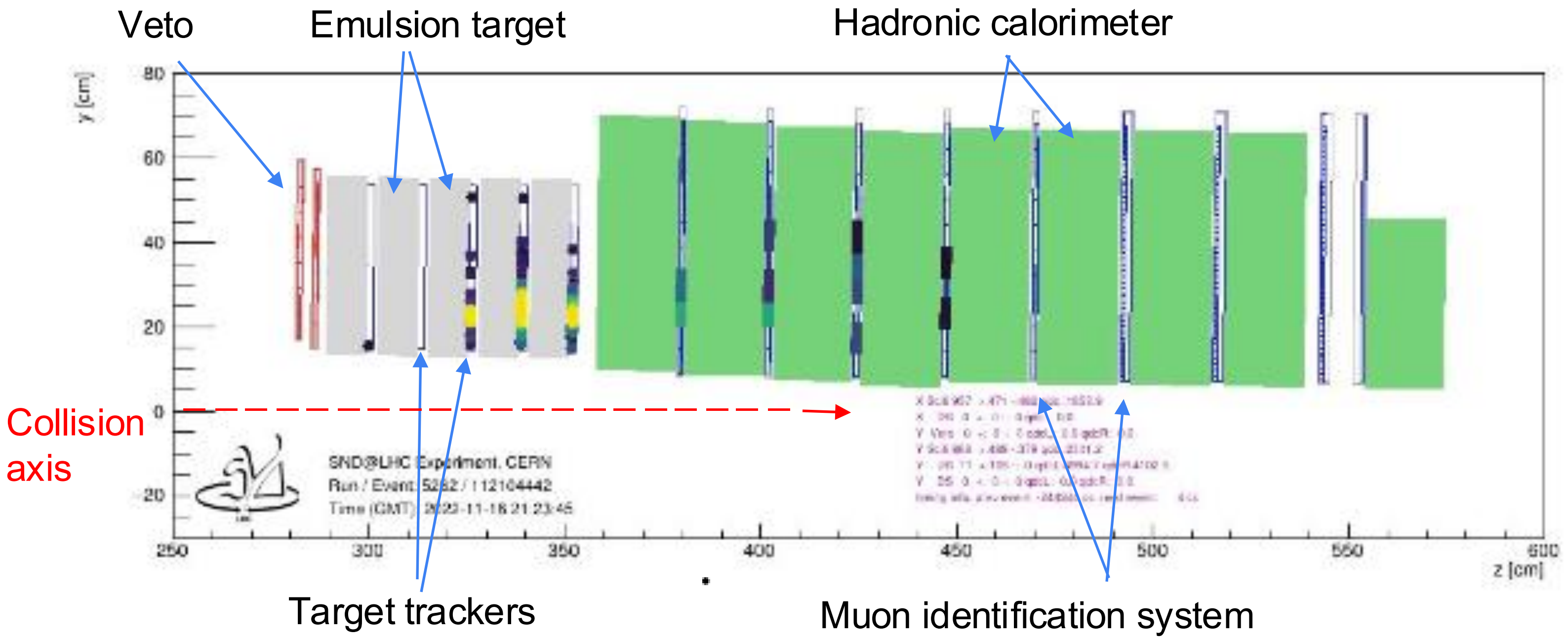
Hadronic shower

Neutral Current (NC) interaction

What SND@LHC consists of

- Incoming particles pass through the different layers of the detector.
- Trajectories of the particles can be reconstructed based on the signals they leave therein





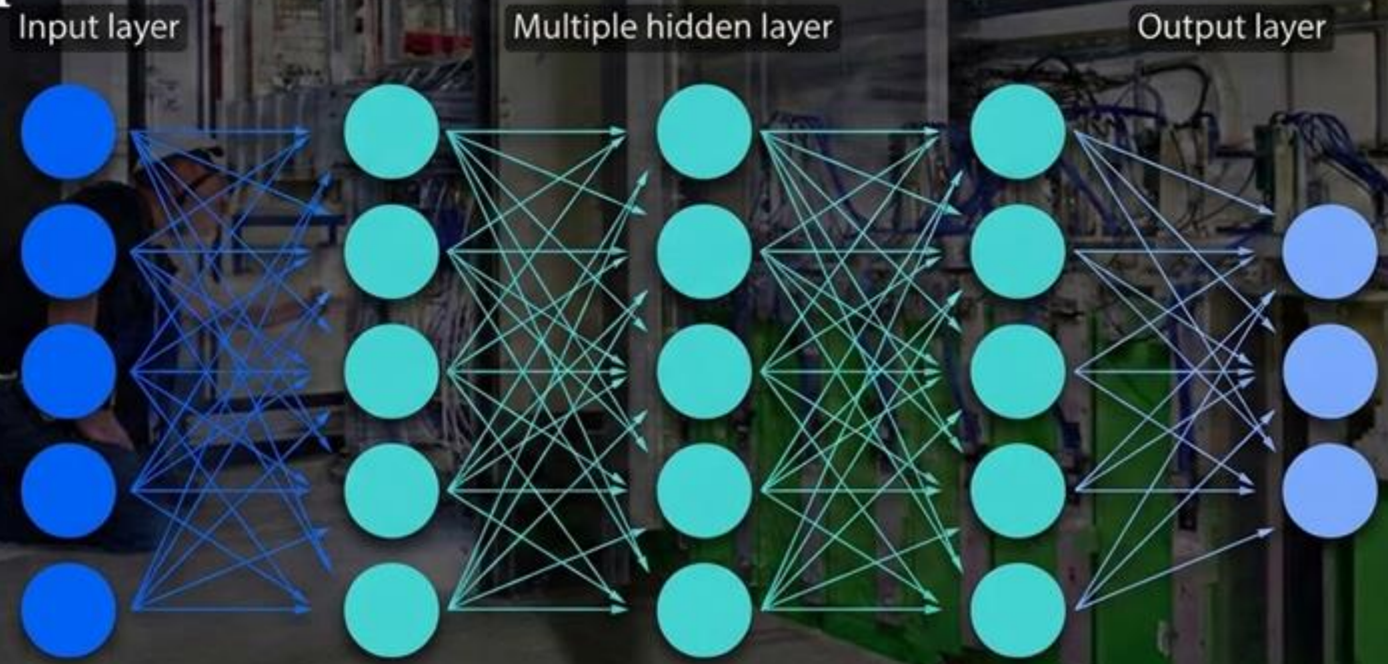
Variables studied

The characteristics of the detector let us measure the following magnitudes:

Magnitude	Hits in the SciFi	Density of hits in the SciFi	Hits in the upstream	Energy deposited in the upstream
Variable	f_n_hits_scifi_i	f_dens_scifi_i	f_n_hits_US_i	f_qdc_US_i

- Studying the variables we can reconstruct the interaction- identification of the incoming particle!

Idea: Implementation of neural network in an existing model



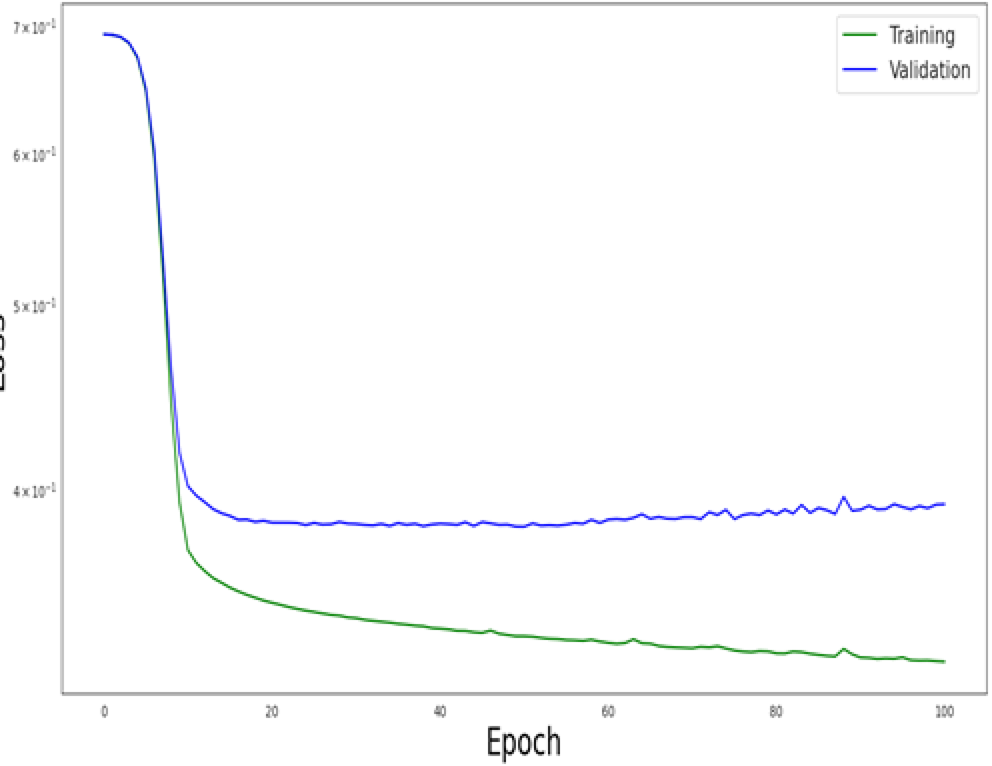
Training options and classifier : basic structure of the neural network

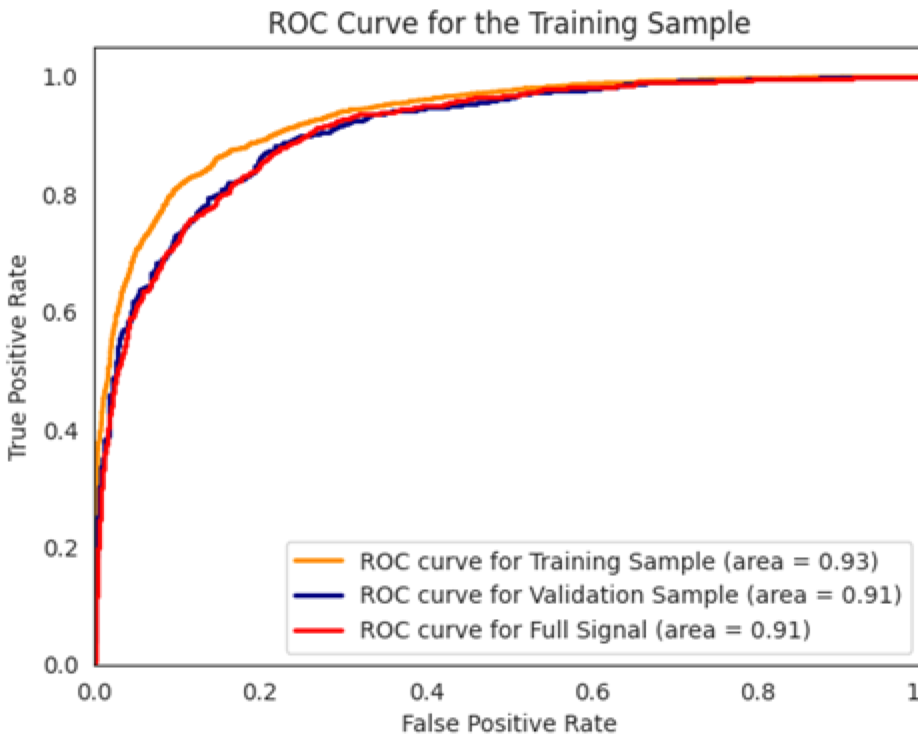
Binary classifier for signal and background events

- Input features: input data coming from MC simulations are standardized before training
- Activation function: ReLU $f(x)=\max[0,x]$ in hidden layers
- Classifier: sequential dense neural network: 3 hidden layers of depth and a width of 20 units each
- Output layer: a single sigmoid neuron returns the event signal probability

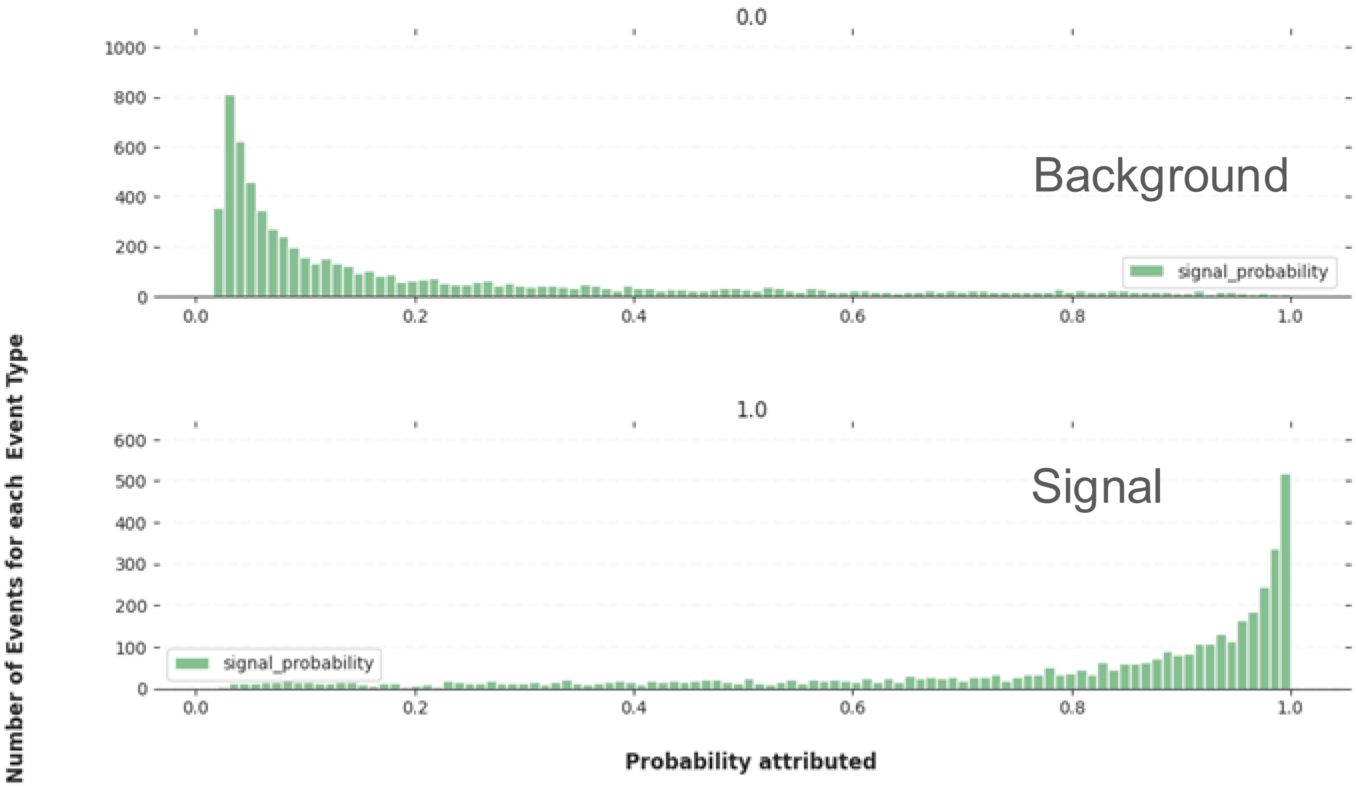
Training of the data:

Ensemble all the variables and events in a pandas dataframe, from 2022 and 2024.
Split data in 2 sections: training and validation, examine it in 1000 epochs.





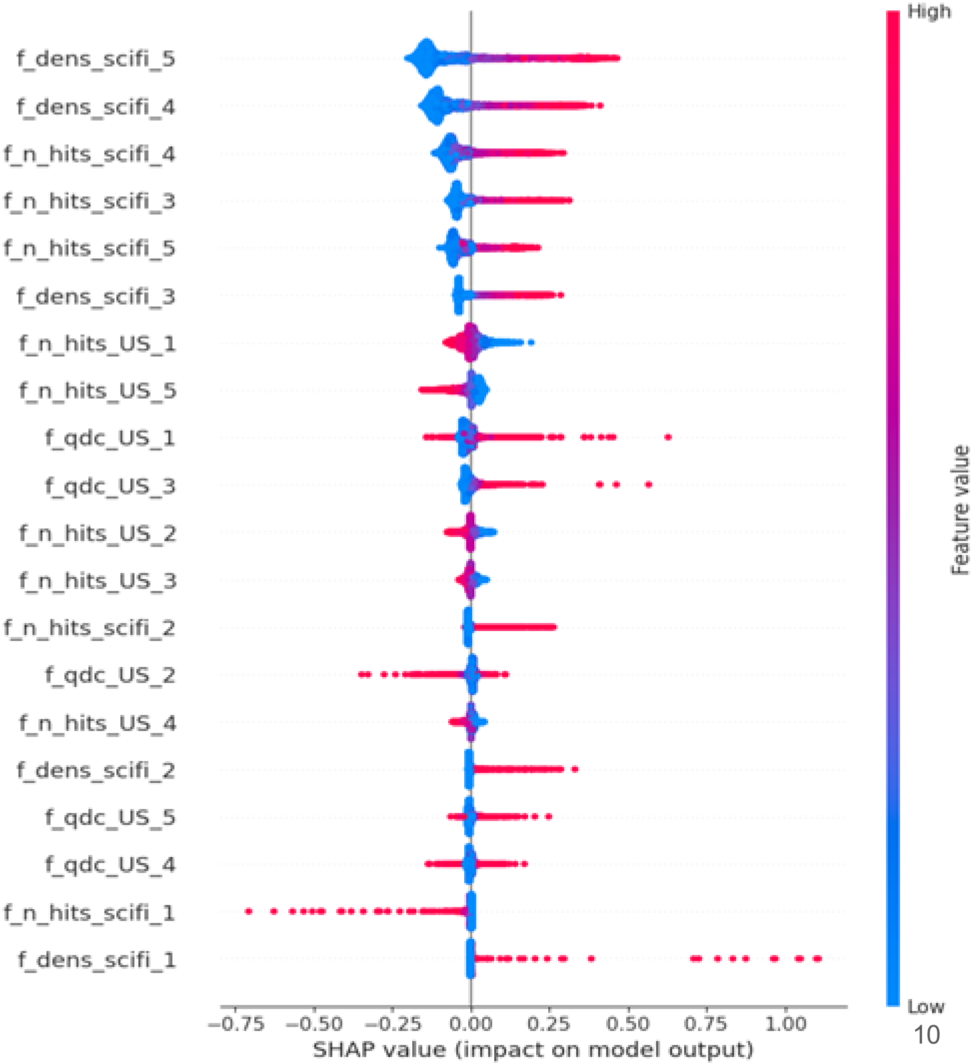
Output of the neural network: assign a probability of each event from 0 to 1, being 0 background and 1 signal



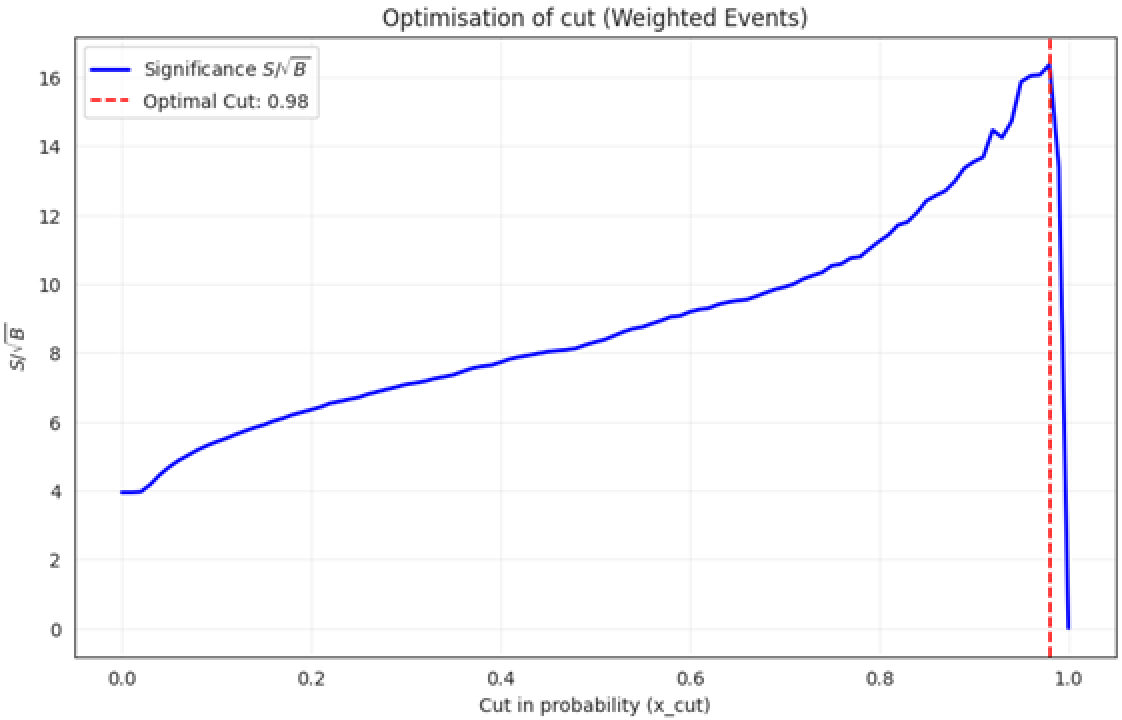
But how does the NN knows what probability assign?

SHAP values: impact on the model output

- Higher value of the feature: redder; else bluer
- Higher separation from the origin: better discrimination (right as signal and left as background)
- Ordered by importance from higher to lower



To improve the significance of the data: establish a cut



The best ratio S/sqrt(B) is 16.36 obtained with a cut of 0.98

Total retained yield: 5.63 events (8.64%)

Retained signal: 5.52 events (22.08%)

Retained background: 0.11 events (0.28%)

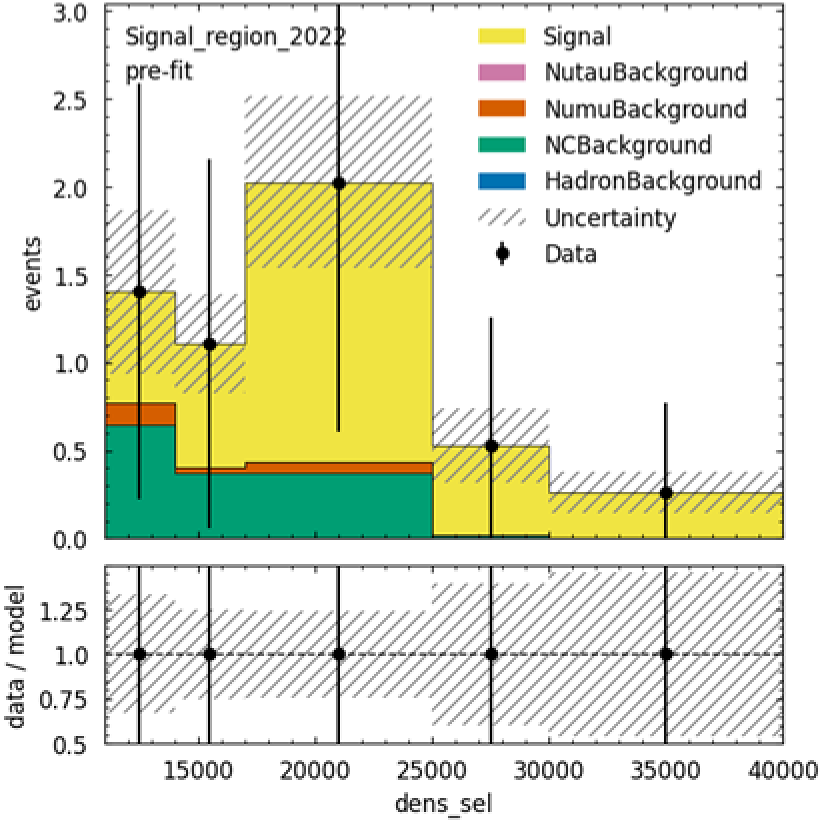
- We will try to find the cut that gives us the best significance without losing a lot of information on how precisely we can measure signal

After analysing several cuts in the probability…

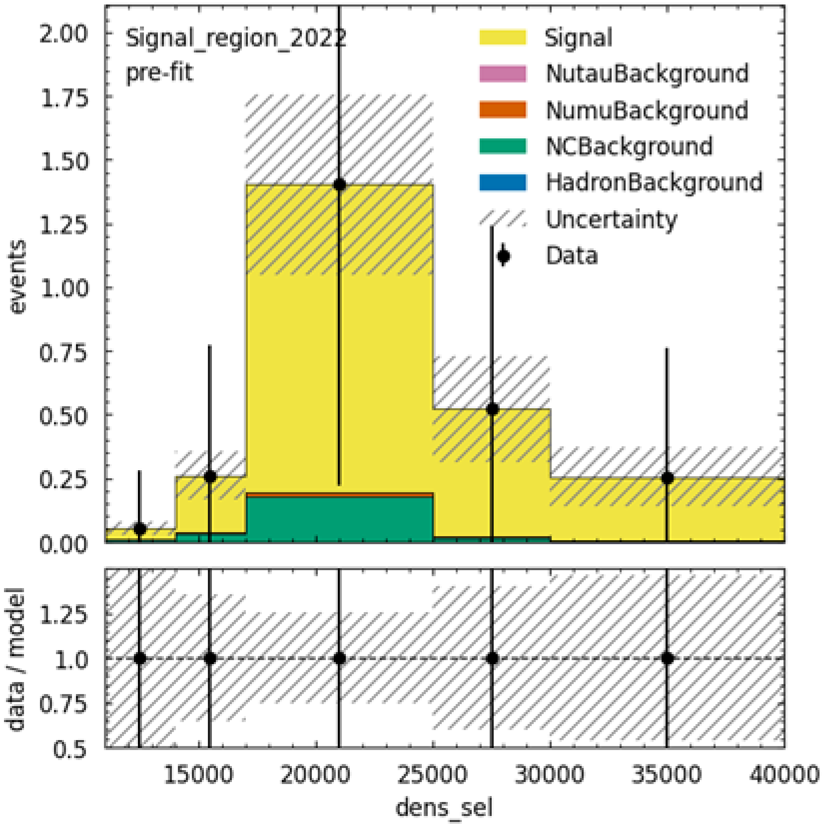
Cut	Exp significance (asimov data)	Signal_norm (asimov data)
0	4.762	1.0000+/-0.4370
0.60	4.709	1.000 +/- 0.435
0.70	4.770	1.000 +/- 0.435
0.75	4.819	1.000 +/- 0.435
0.80	4.862	1.0000 +/- 0.445
0.825	4.838	1.000 +/- 0.446
0.85	4.897	1.0000 +/- 0.453
0.875	4.887	1.0000 +/- 0.468
0.90	4.800	1.0000 +/- 0.484

2022 region: pre-fit (asimov data)

Before NN cut

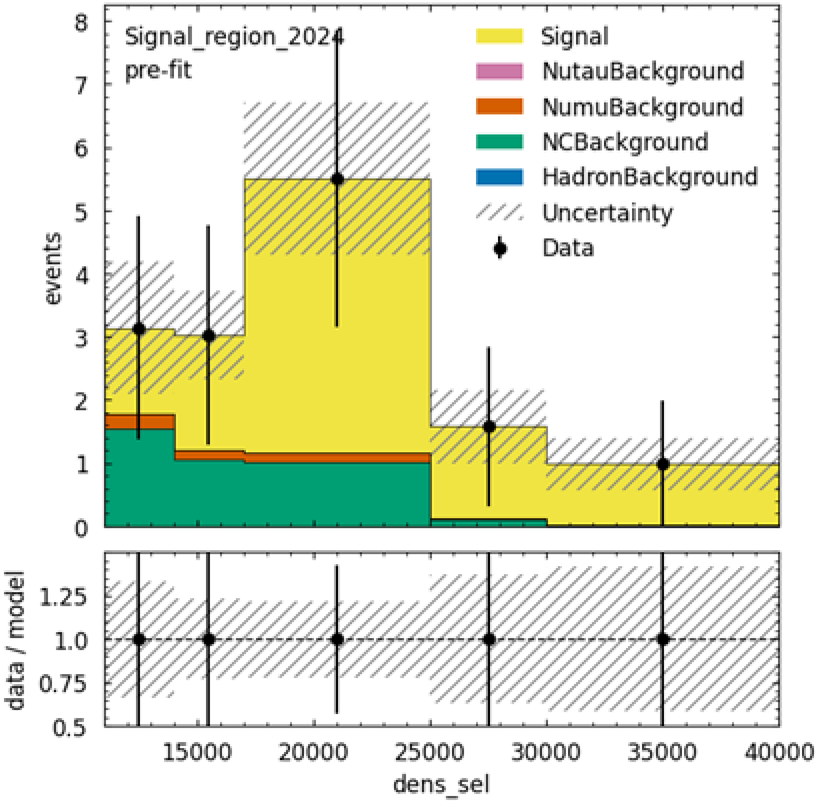


After NN cut (0.85)



2024 region: pre fit

Before NN cut



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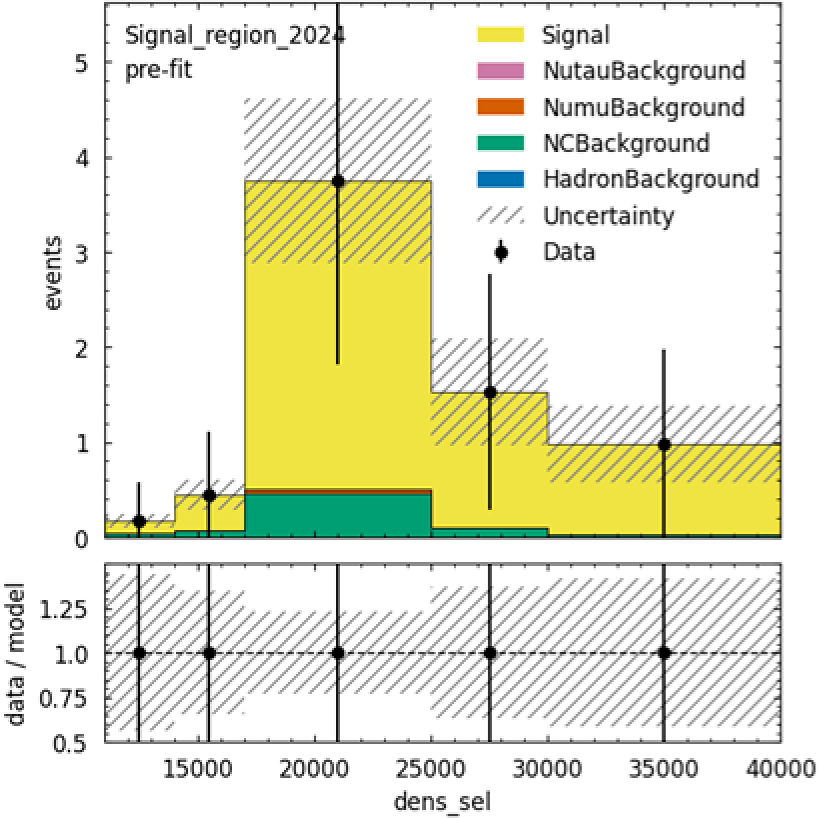

Conclusions and possible next steps...

- Studied variables for neutrino identification at SND@LHC
- Significance improvement when measuring simulations of electron neutrino
- Evaluate the NN on other samples/ real data
- Look for possible updates in the detector on the best SHAP values

Questions?