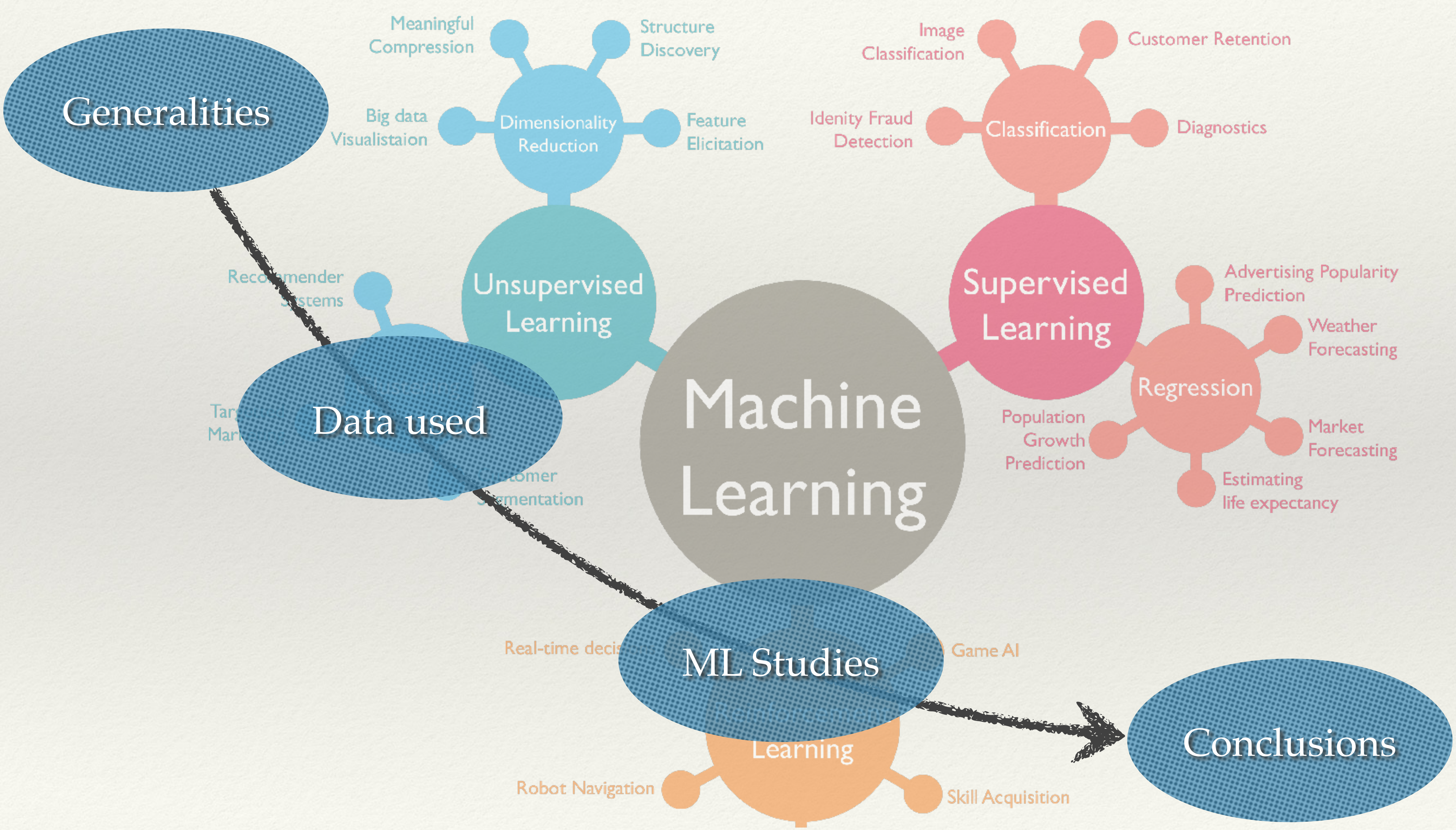
Related Collaborations

IN2P3/IRFU Machine Learning workshop, 22-23 January 2020

Waveform Processing using Artificial Neural Networks

G. Baulieu, L.Ducroux, J.Dudouet, X.Fabian, O. Stézowski, K. Zougagh (stage M1)

Outline

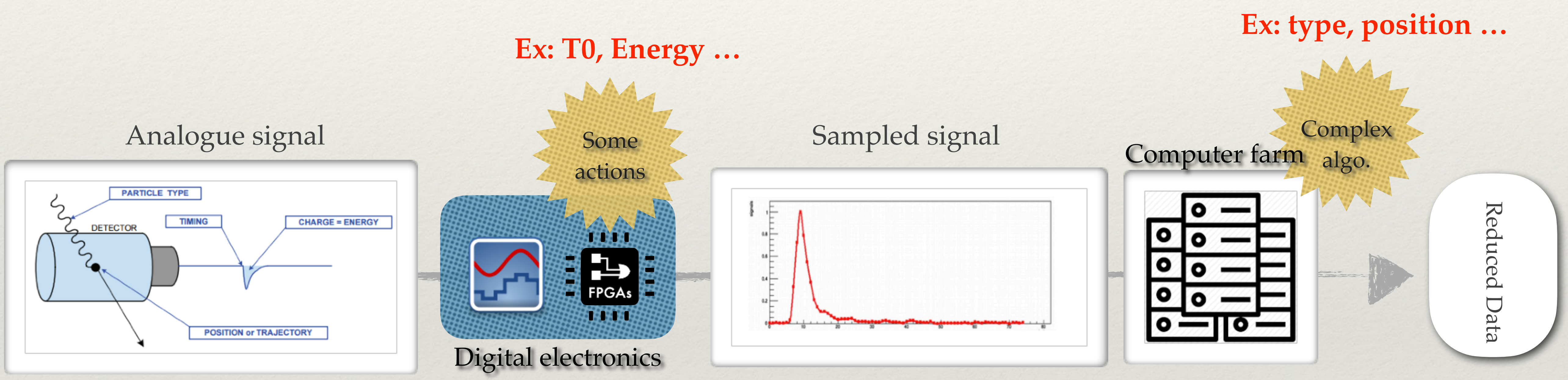


Generalities
Data used
ML Studies
Conclusions
Machine Learning
Unsupervised Learning
Dimensionality Reduction
Meaningful Compression
Structure Discovery
Big data Visualistaion
Feature Elicitation
Supervised Learning
Classification
Image Classification
Customer Retention
Idenity Fraud Detection
Diagnostics
Regression
Advertising Popularity Prediction
Weather Forecasting
Population Growth Prediction
Market Forecasting
Estimating life expectancy
Game AI
Learning
Robot Navigation
Skill Acquisition

One R&D trend in Nuclear Physics

Developments in :

Digital electronics + high data transfer (optical fiber, ethernet) + disk array + computers + … ?



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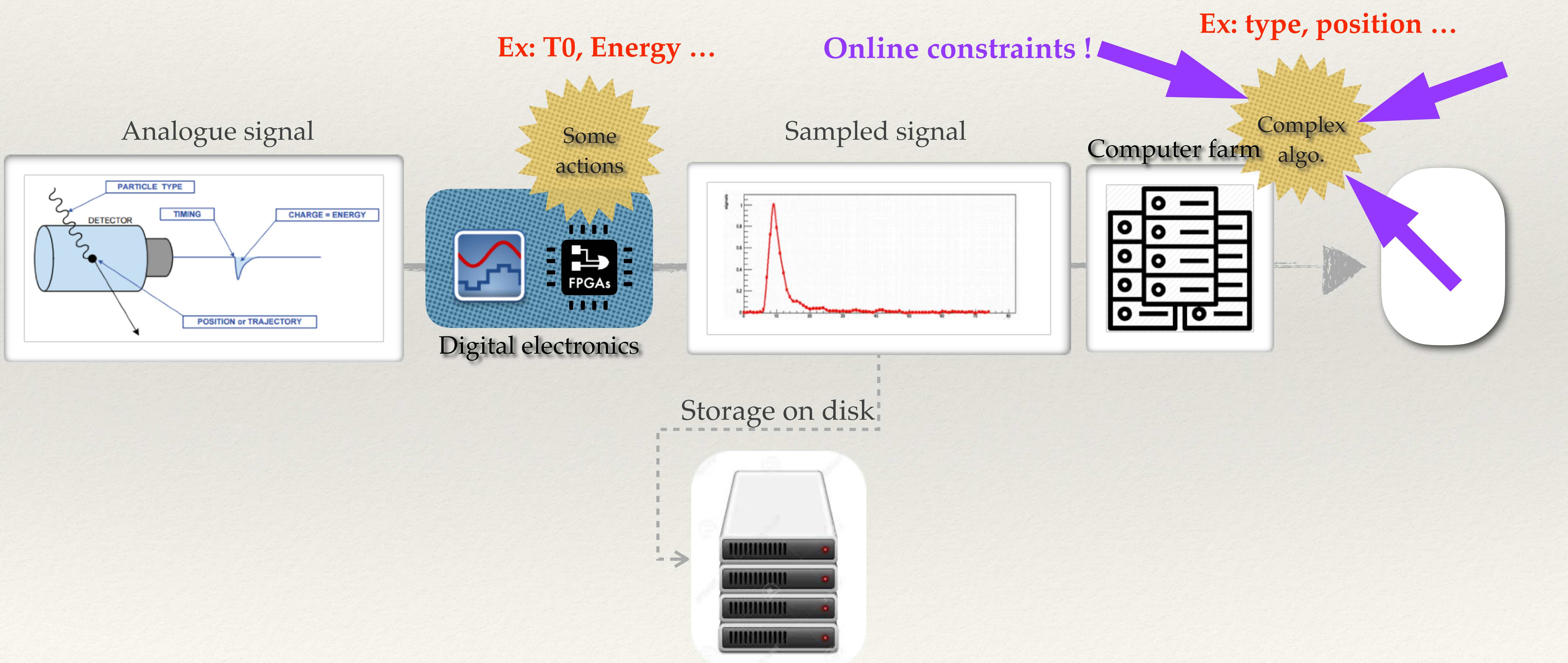

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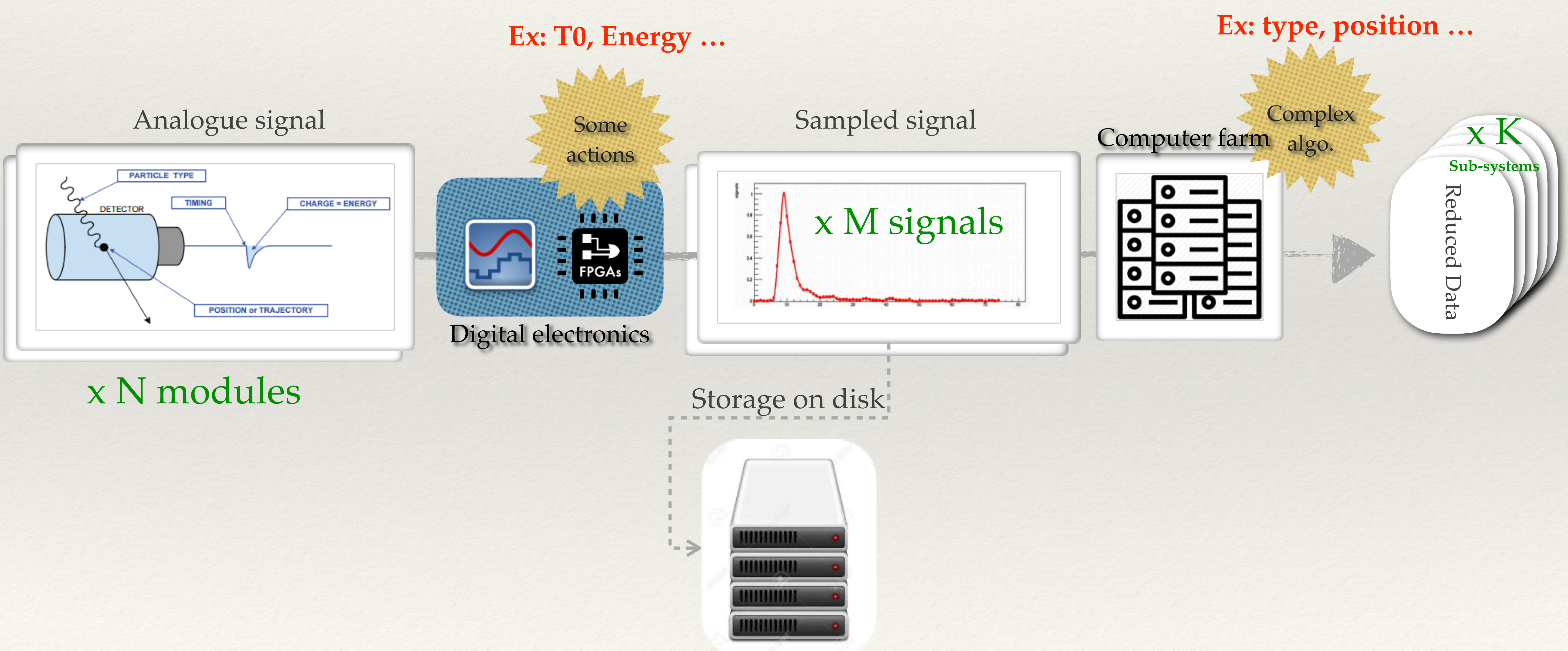

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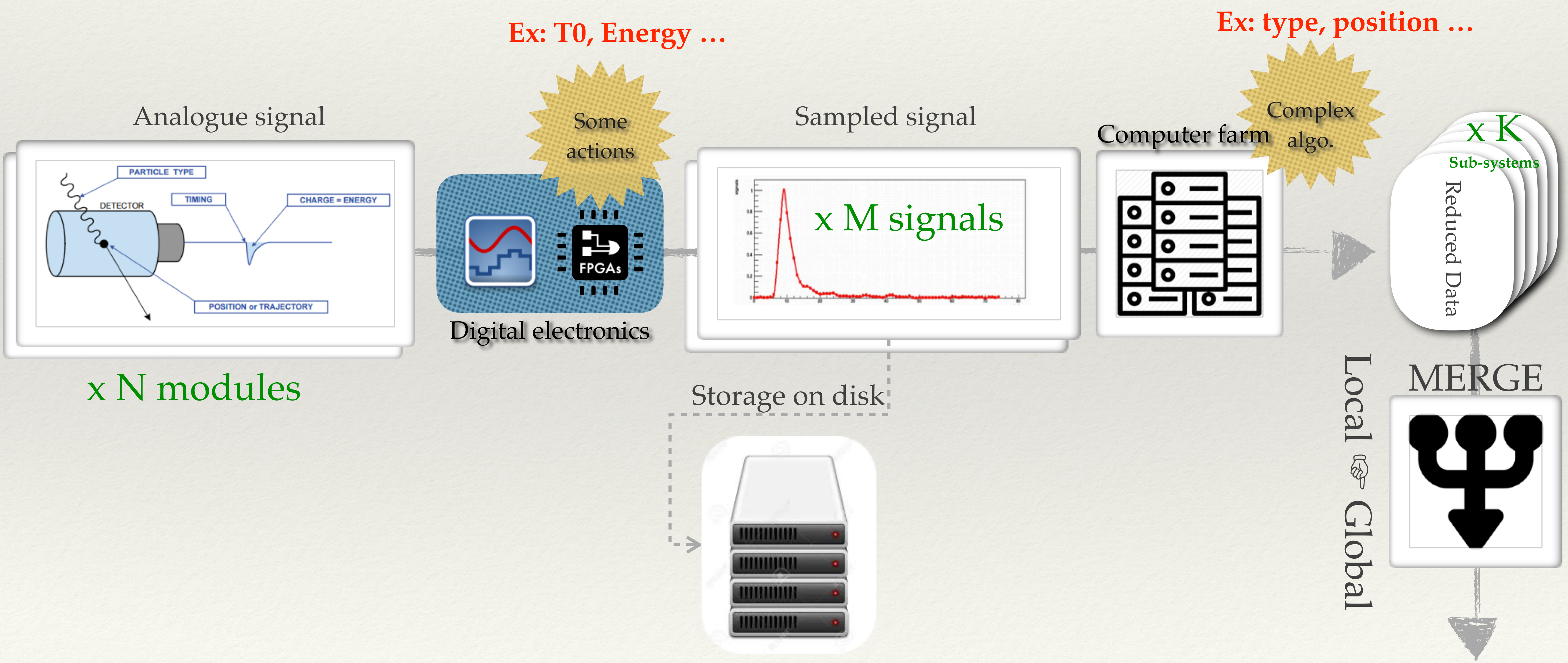

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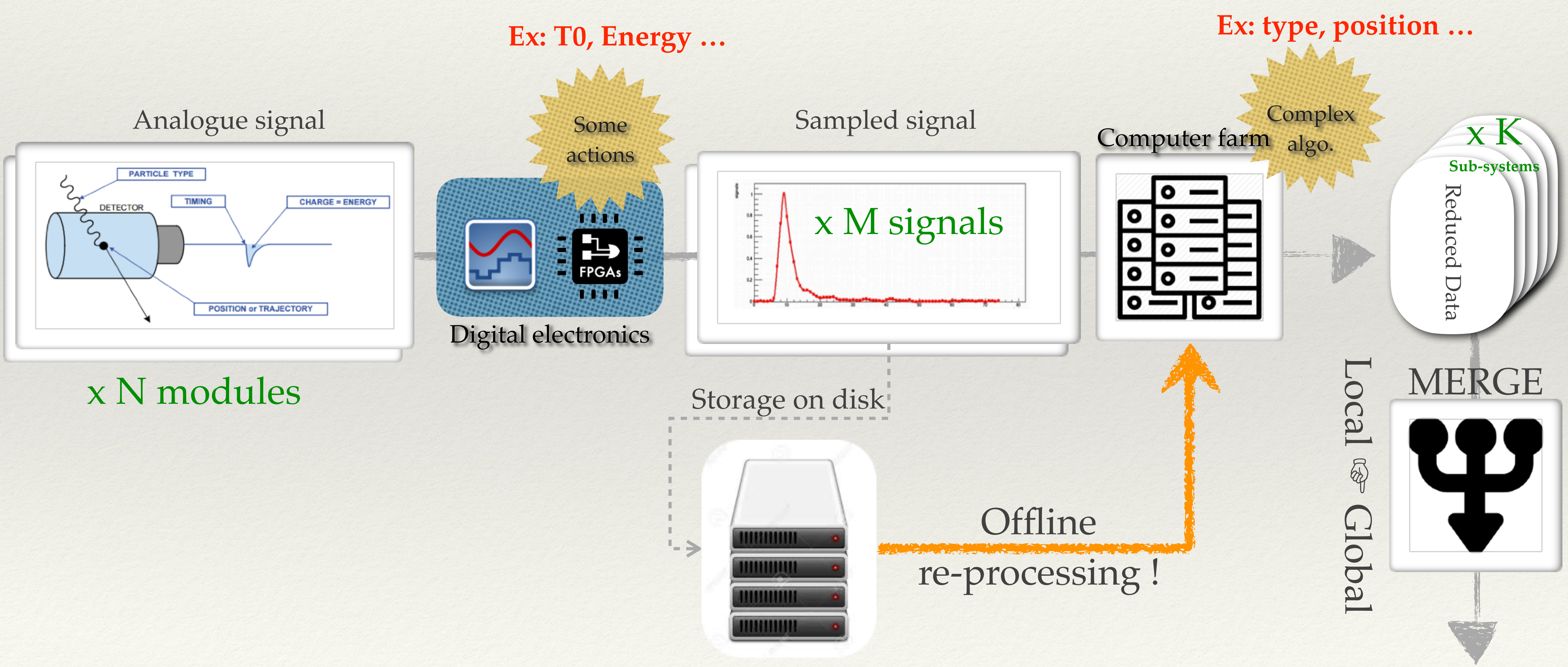

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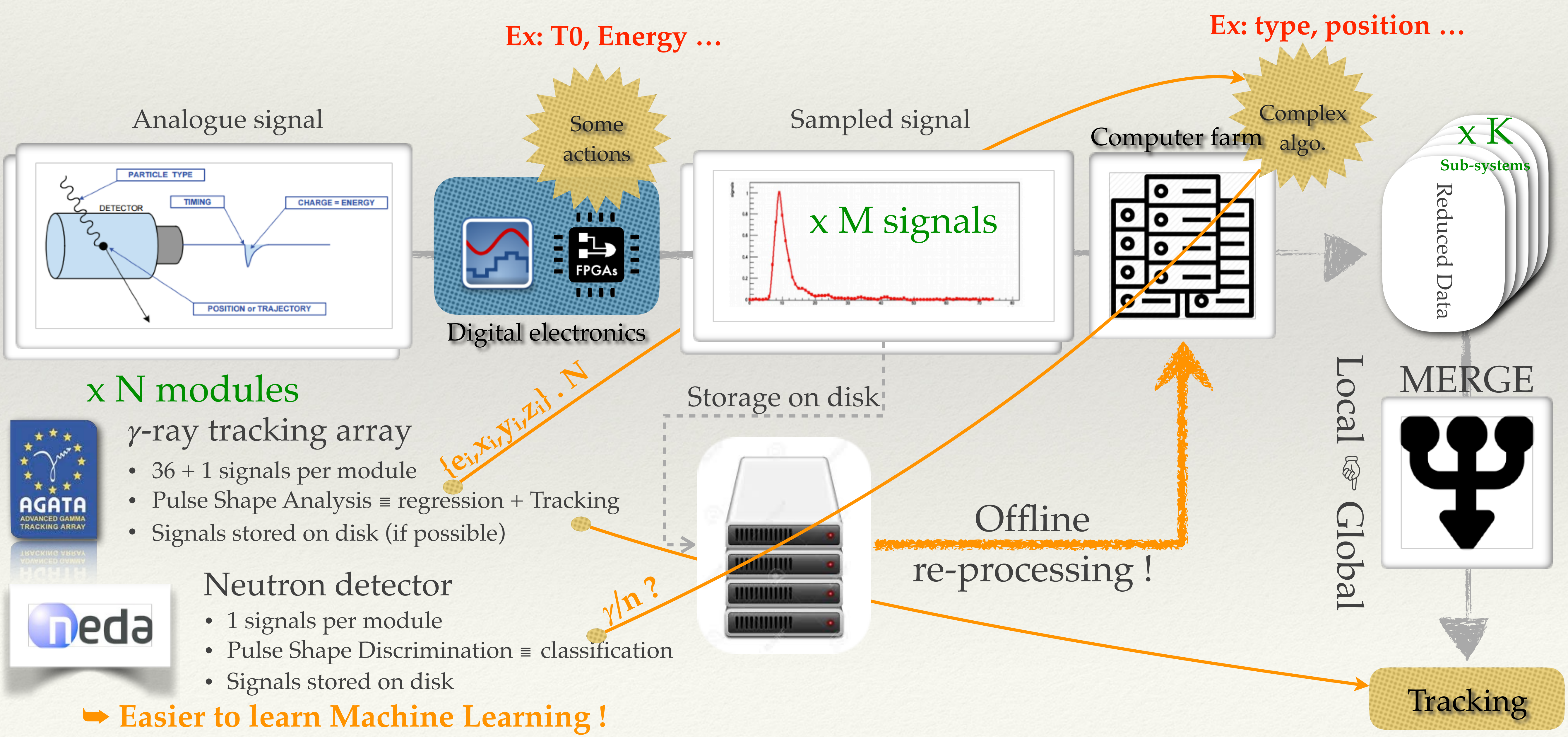
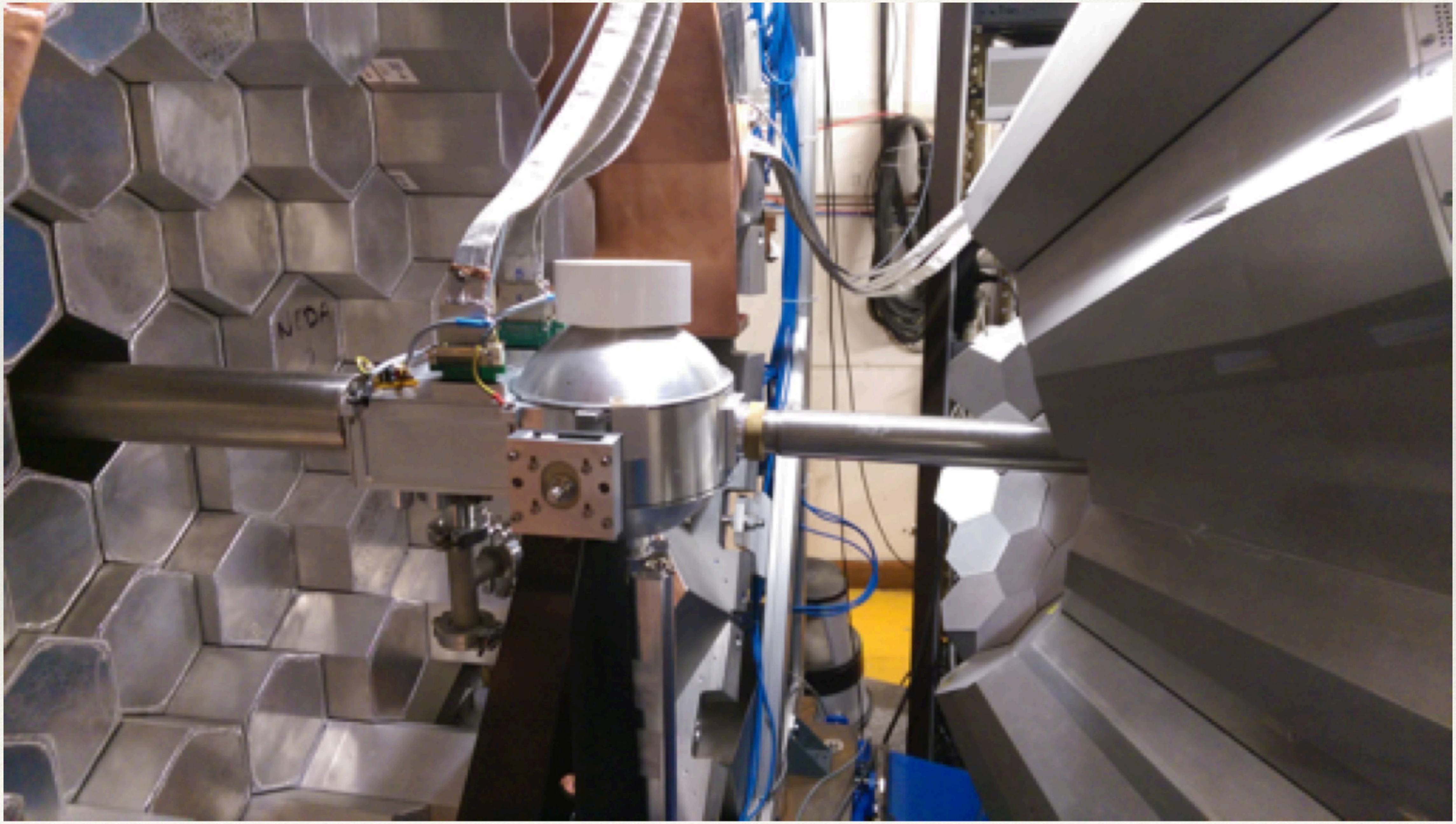


Pulse Shape Discrimination in NEDA

Experiment NEDA + AGATA in coincidence [GANIL 2018]



Pulse Shape Discrimination in NEDA

Data from an experiment AGATA + NEDA + DIAMANT in coincidence [GANIL 2018]

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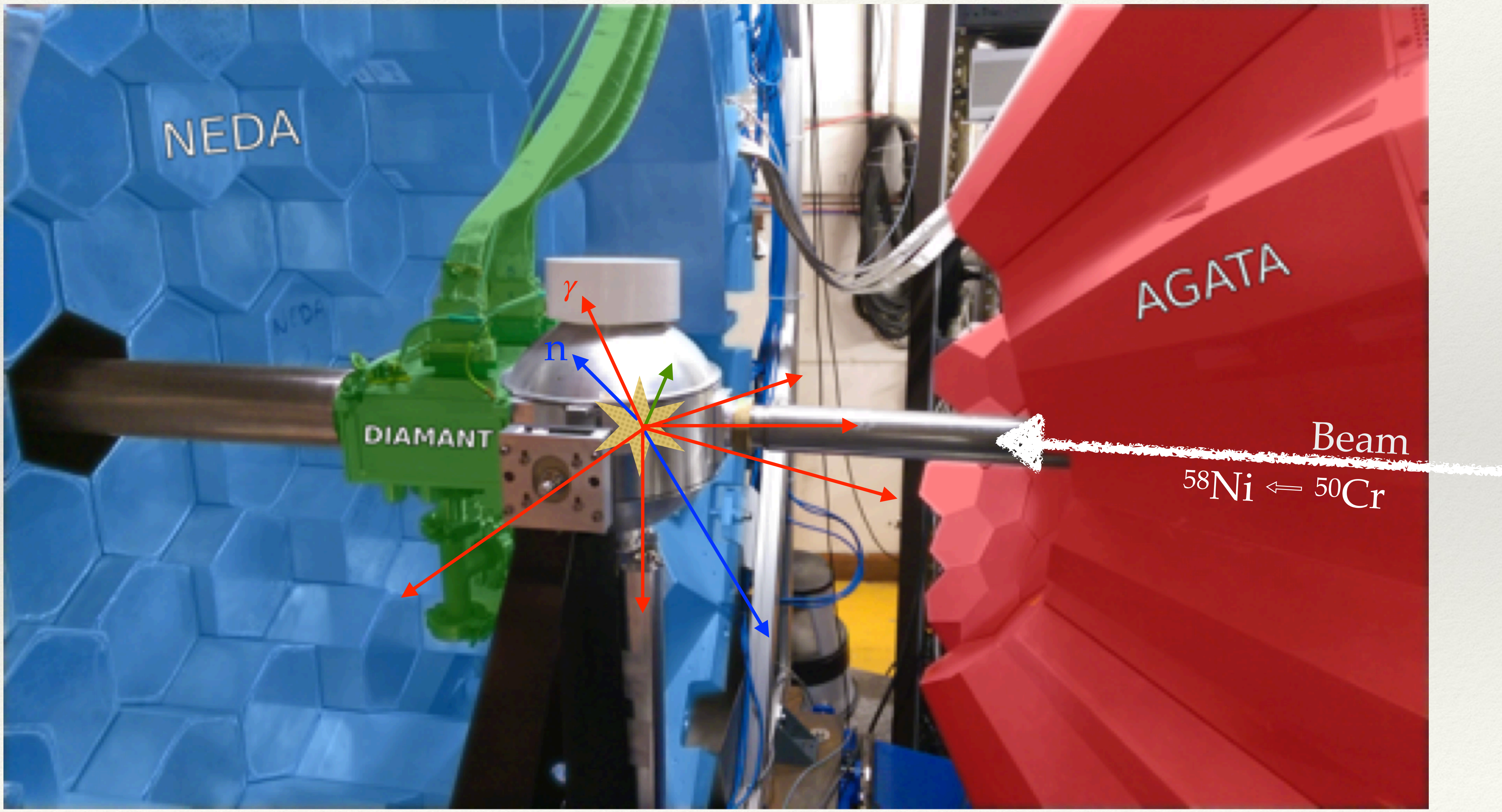

Pulse Shape Discrimination in NEDA

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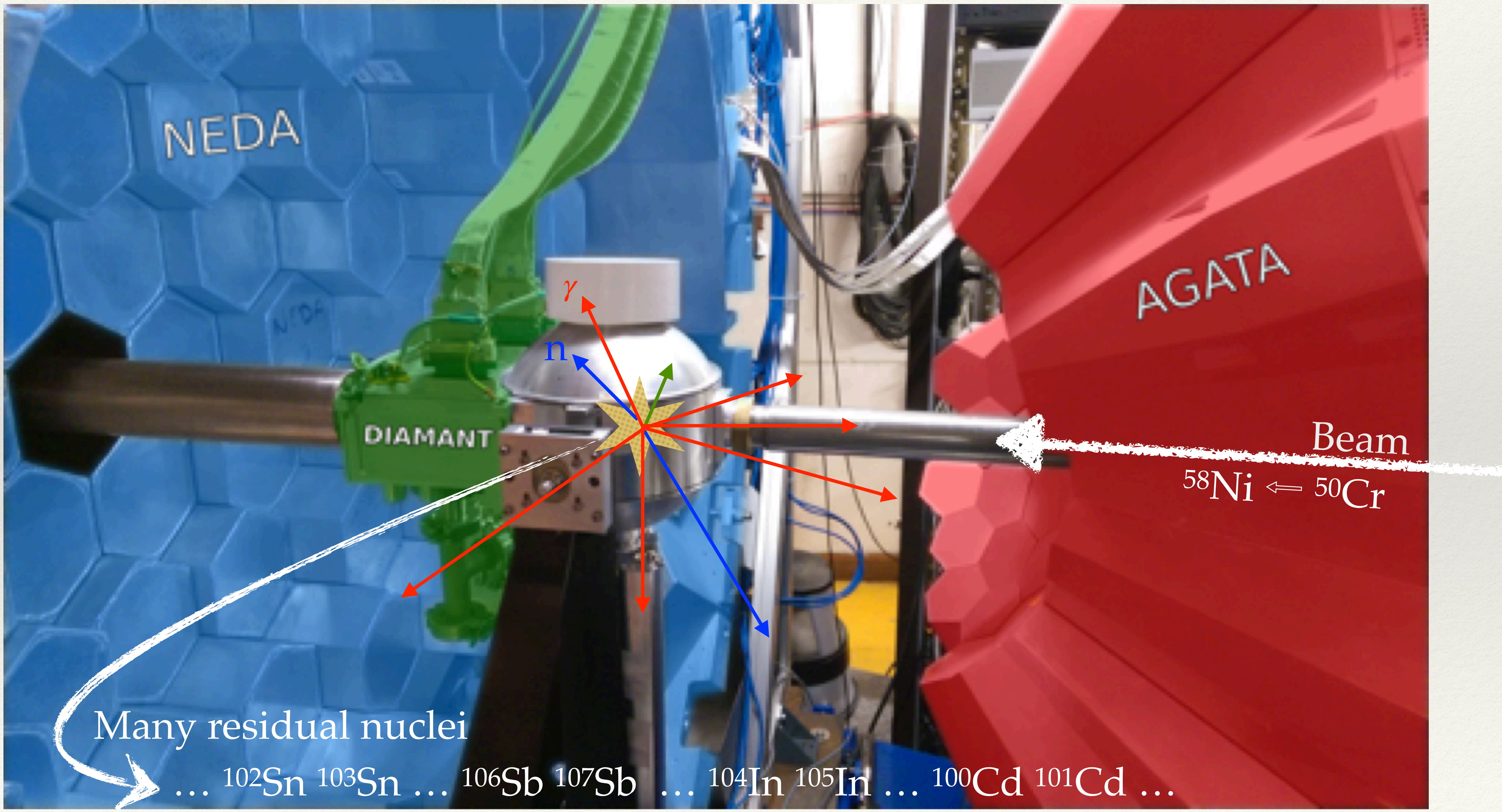

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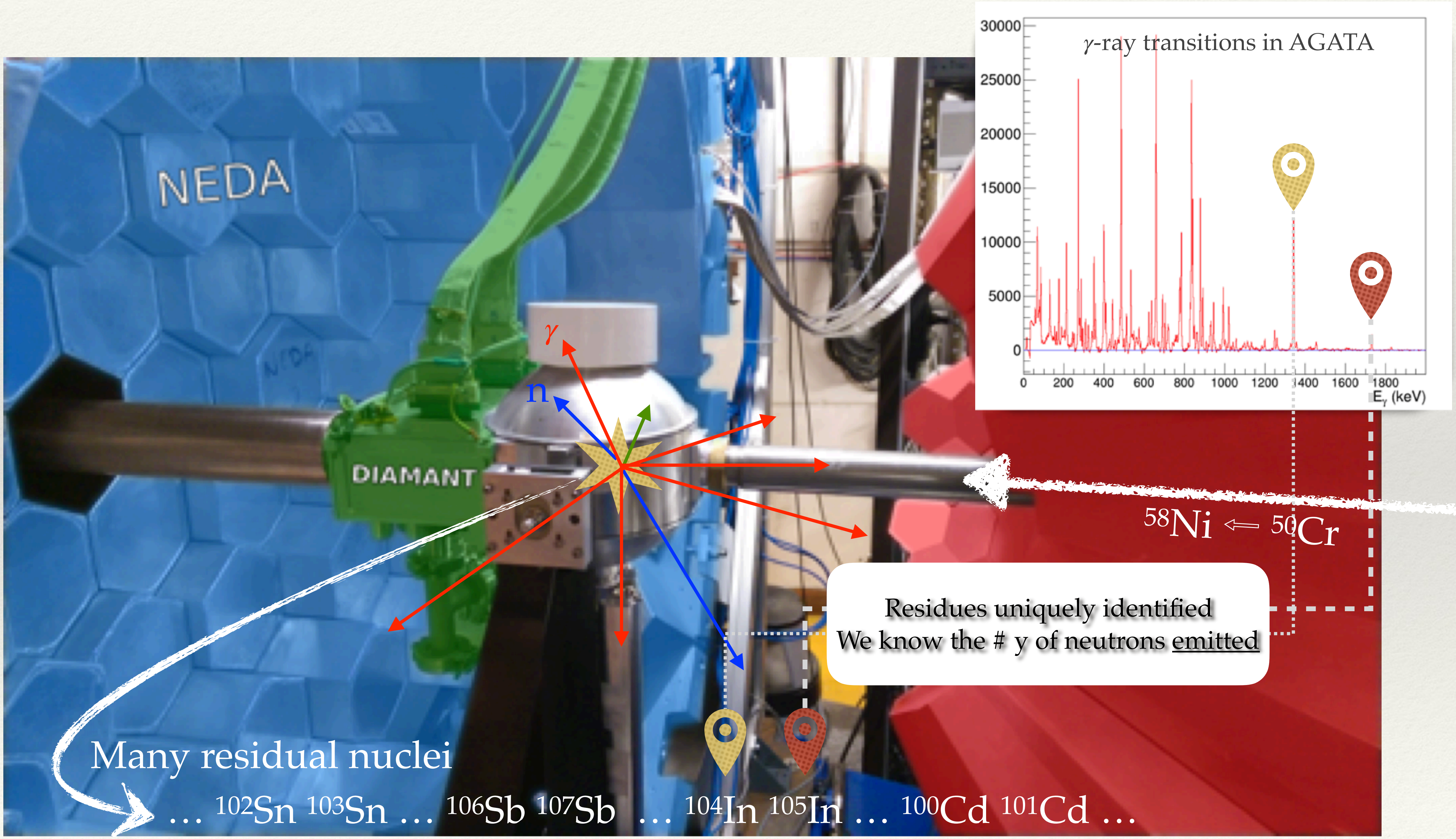

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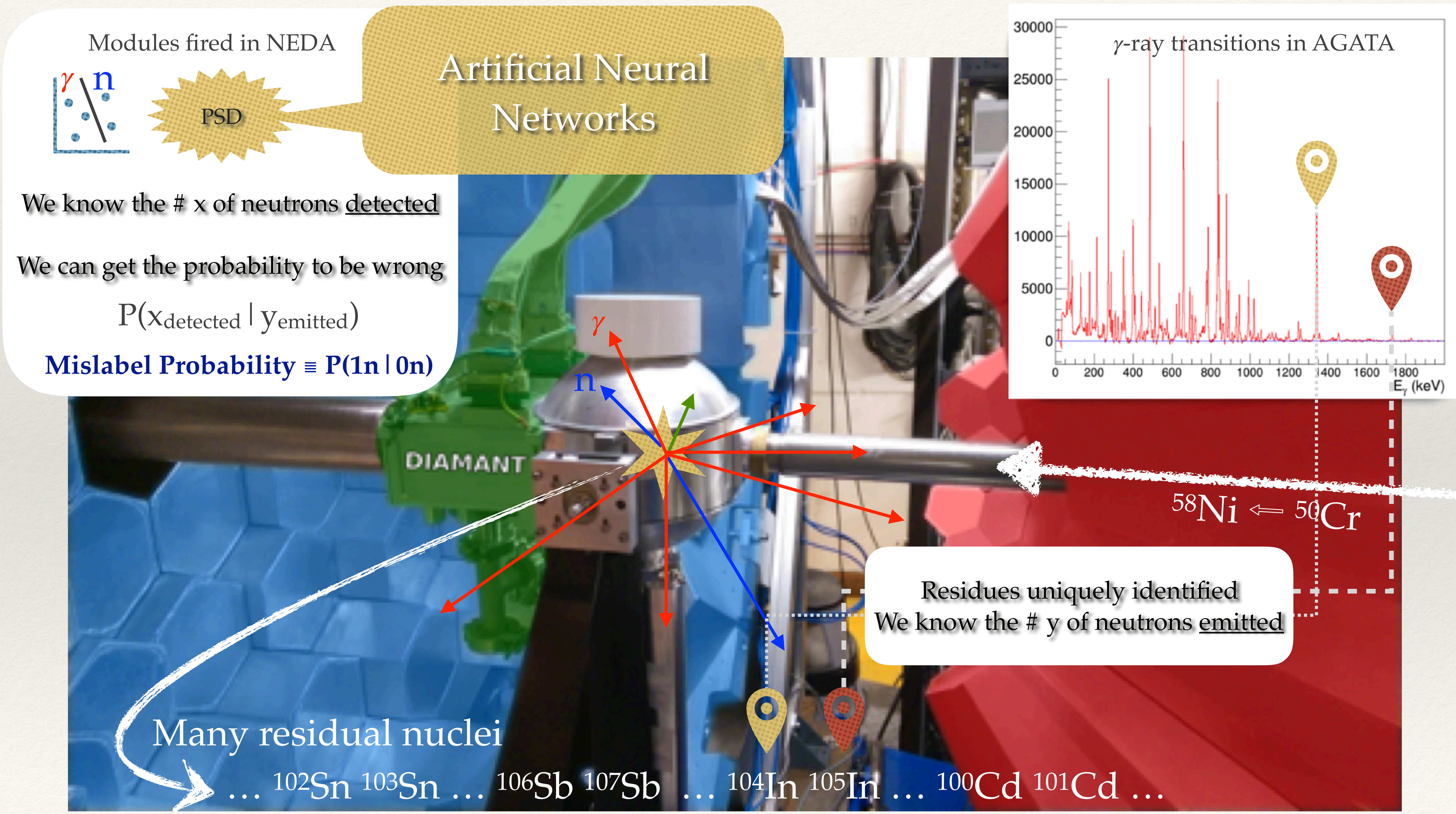
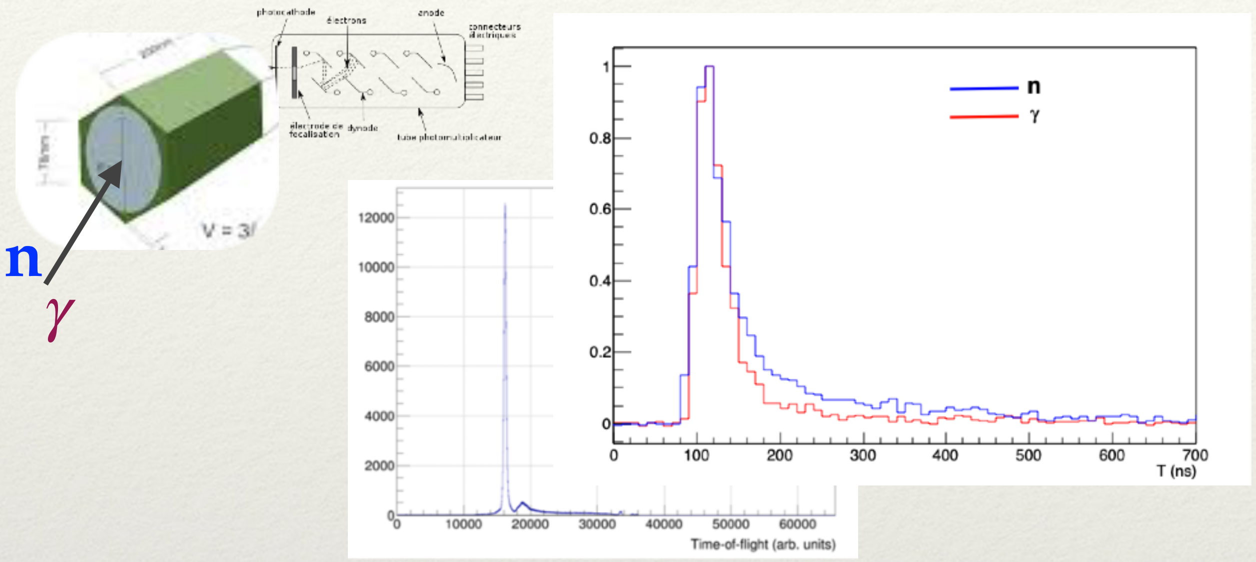


ML for Pulse Shape Discrimination



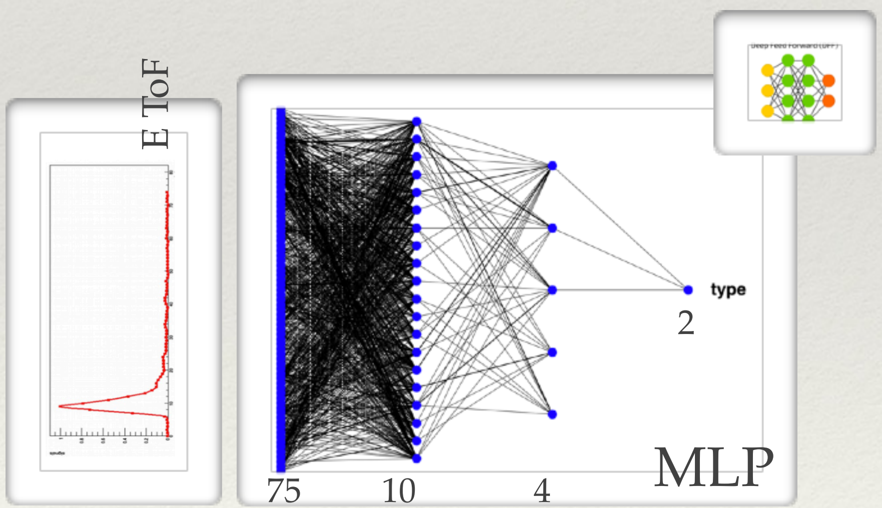
Inputs used for the **Discrimination :**
the waveform - the amplitude - the time of flight

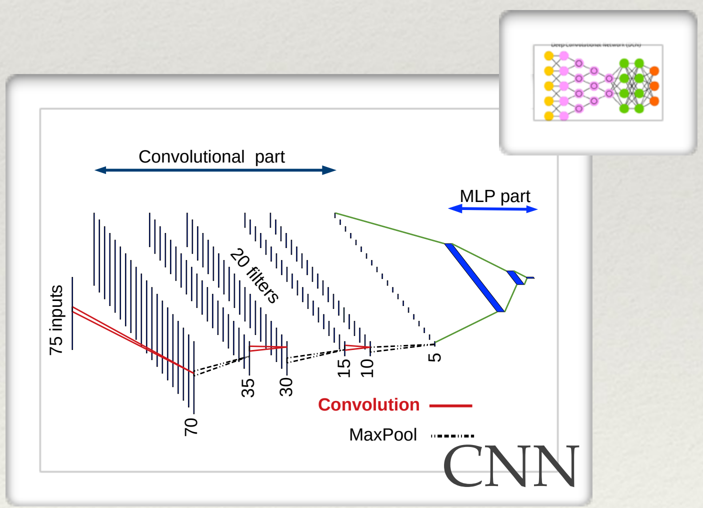
Common parametrisation of the signal

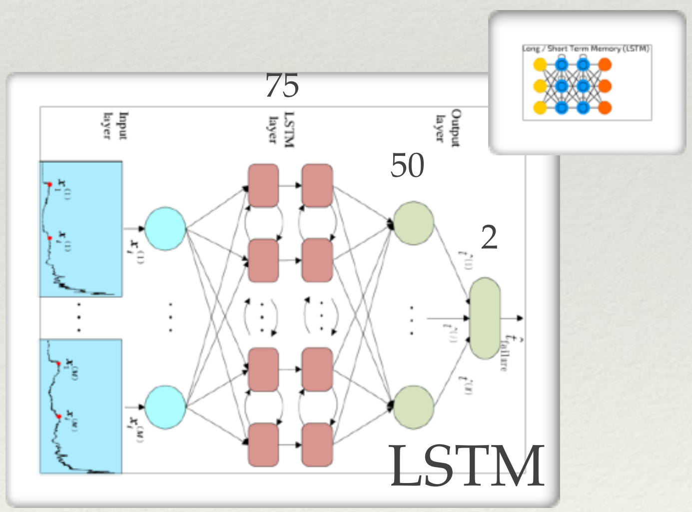
$s(t) = \mathbf{A}\,[\exp(-t/\mathbf{td1}) - \exp(-t/\mathbf{tr}) + \mathbf{R}^{*}(\exp(-t/\mathbf{td2}) - \exp(-t/\mathbf{tr})]$ if $t > \mathbf{T0}$

A amplitude = energy
td1, **td2**, **tr** independent of γ and **n**
T0 relies on how the signal is captured
R depends of the type of the particle

Three different Artificial Neural Network architectures tested : MLP / LSTM / CNN







👍 **pattern**

👍 **time series**

R&D NEDA

discrimination for low energy better that classical methods *
Implementation with ROOT - mono thread / CPU

➥ **Tensorflow / multi CPU / GPU**

Number of parameters
MLP: 814, LSTM: 10502, CNN: 7042

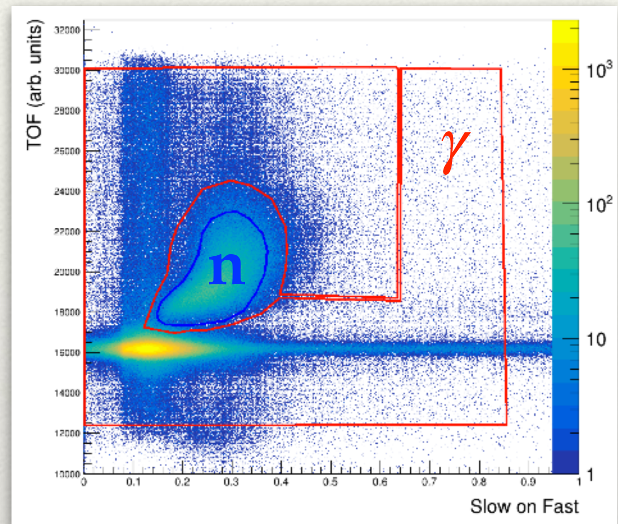
* Ronchi et al., NIMA 610 (2009) 534–539

ML for Pulse Shape Discrimination

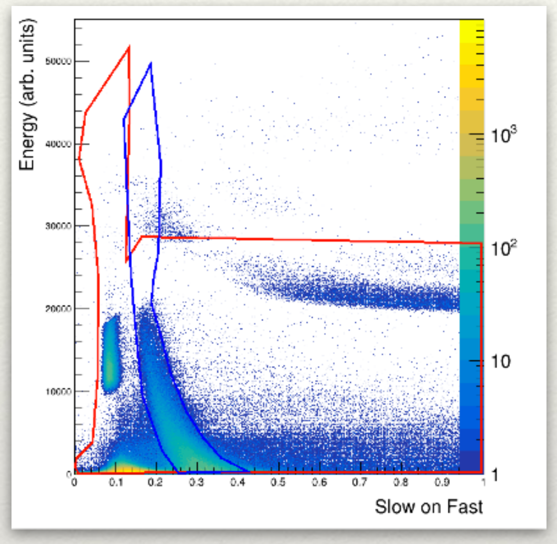
- Training of the networks, Keras, python interface (Tensorflow board), recent GPU card

Typical time : 0,5 to 1 hour

To build the training data set, combinaisons of 2D cuts (uniformly distributed)



&



+ selection of clean* waveforms

Relu + softmax + Cross entropy loss function

Optimizers:

MLP / CNN

- Stochastic Gradient Descent
- ADAM

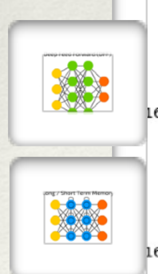
LSTM

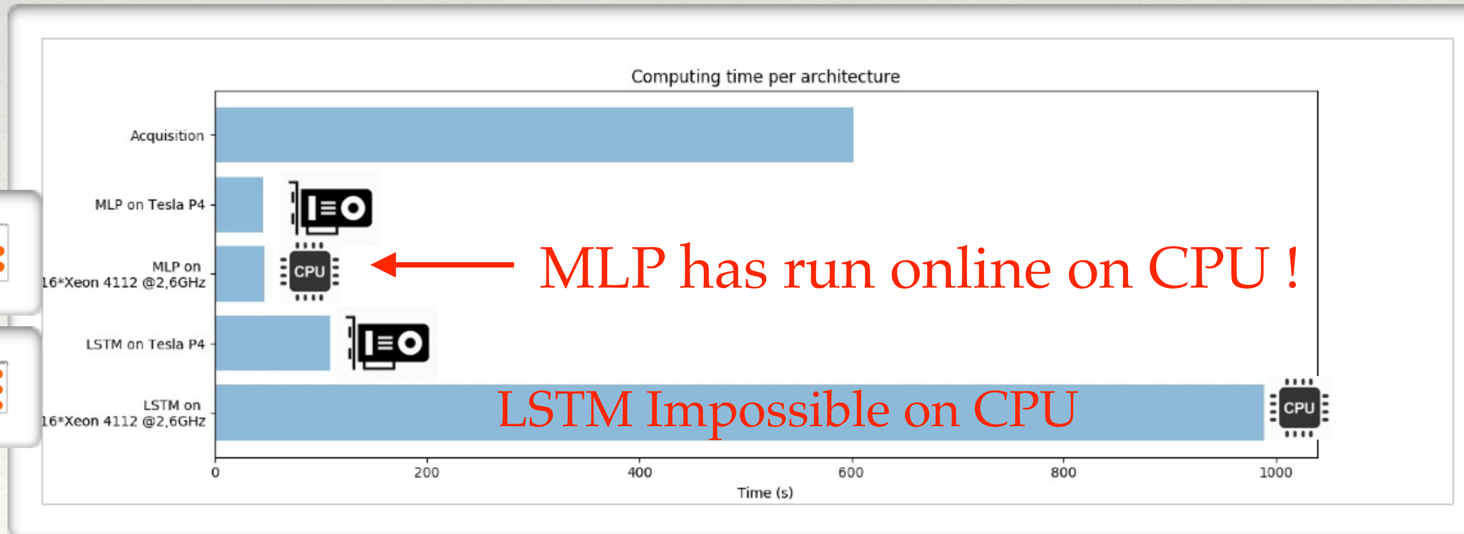
- Inference Tensorflow, C++ interface

➥ Batch of signals for efficiency

	MLP		CNN		LSTM	
Batch Size	CPU	GPU	CPU	GPU	CPU	GPU
5000	2μs	1μs	10μs	3μs	50μs	13μs
20000	1μs	1μs	12μs	2μs	60μs	10μs
80000	1μs	1μs	12μs	4μs	75μs	9μs

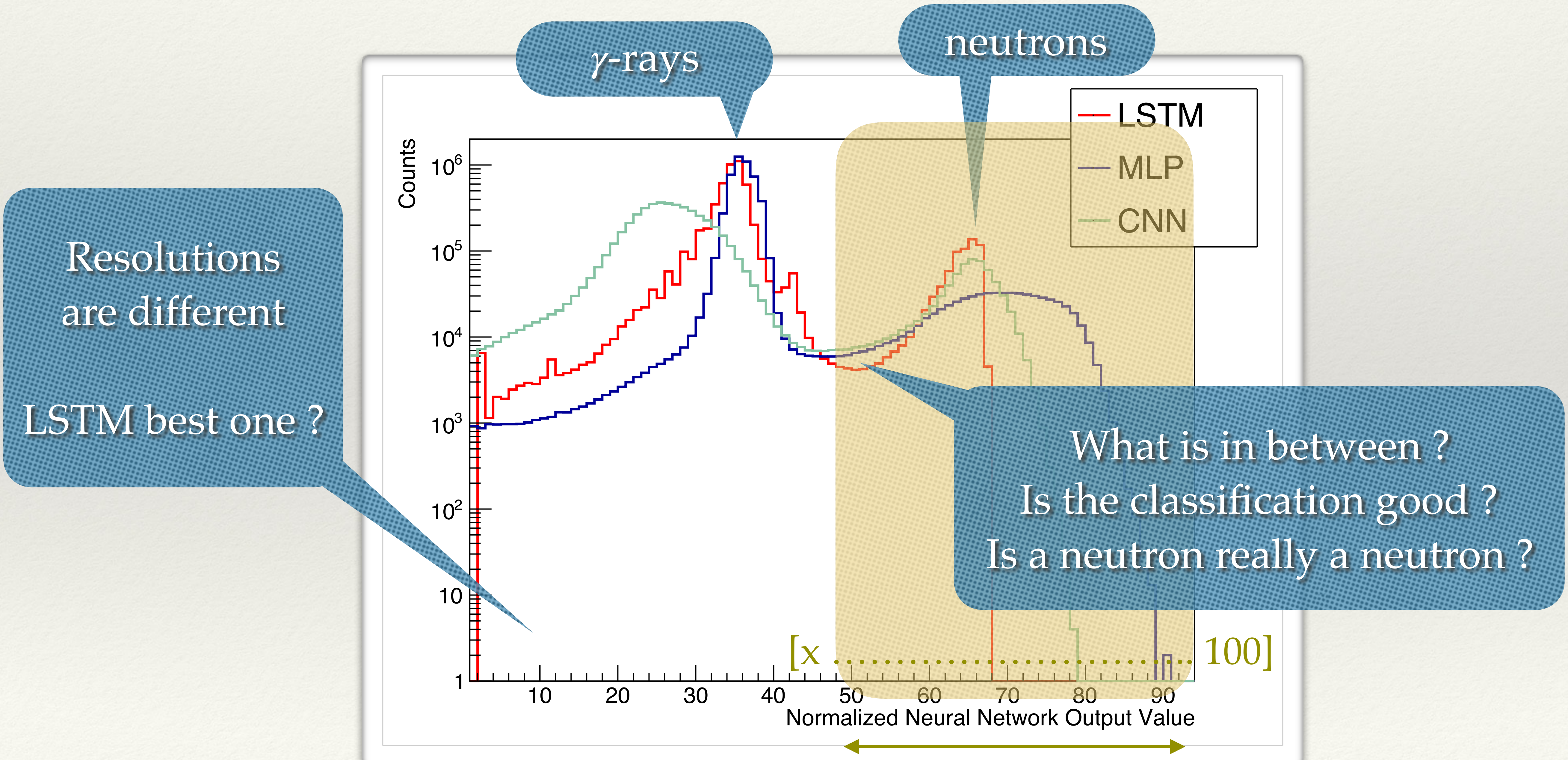
Typical time for one signal





ML for Pulse Shape Discrimination

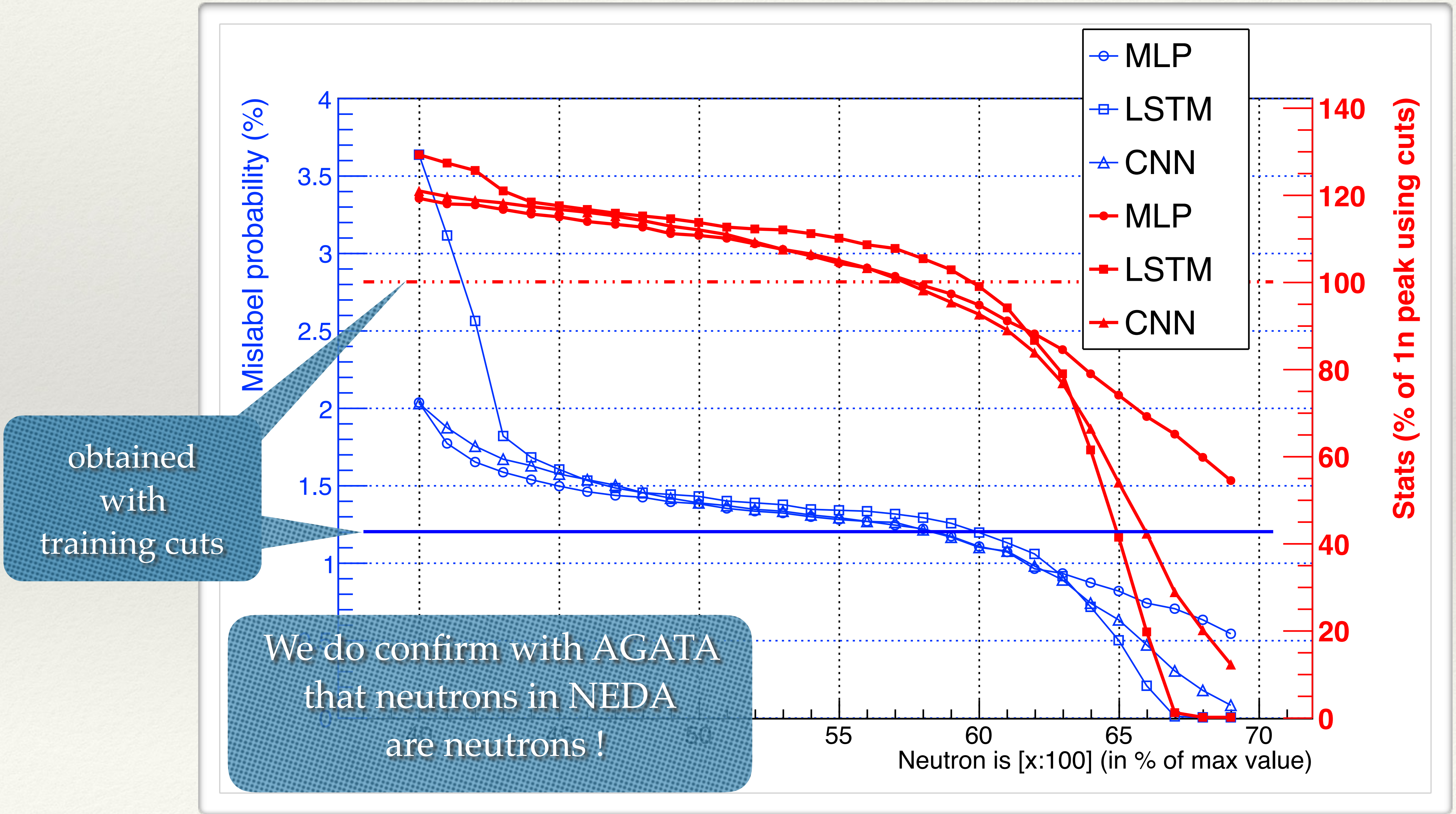
Distribution of the output value of the three different networks



Continuous parameter to play with growing cut in a multi-dimensional space !

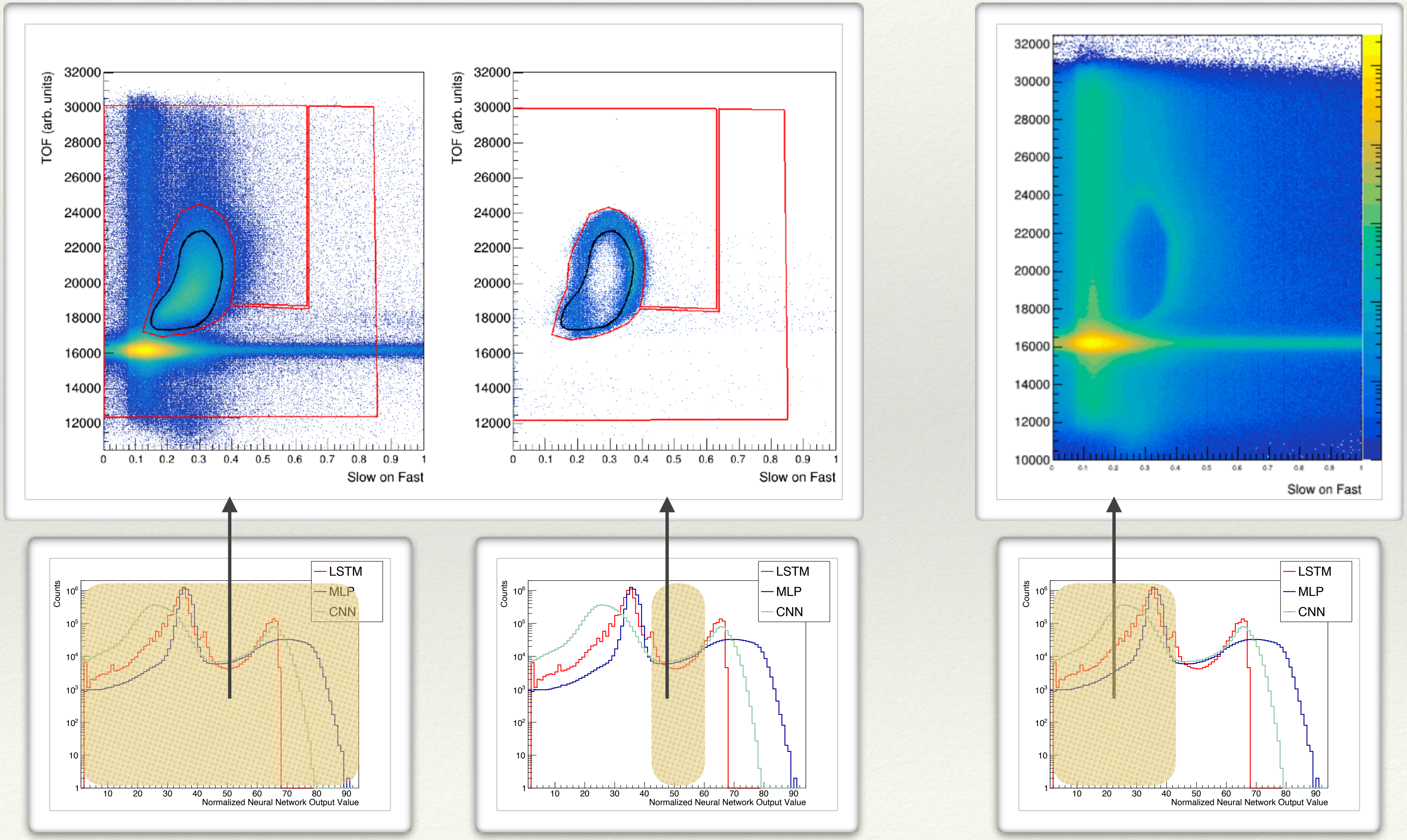
ML for Pulse Shape Discrimination

Mislabel probability and impact on statistics in good events



ML for Pulse Shape Discrimination

Interpolation capabilities



ML for Pulse Shape Discrimination

We had the feeling that LSTM seems a ‘better’ classifier. Why should it be ?

Other studies using synthetic signals generated from

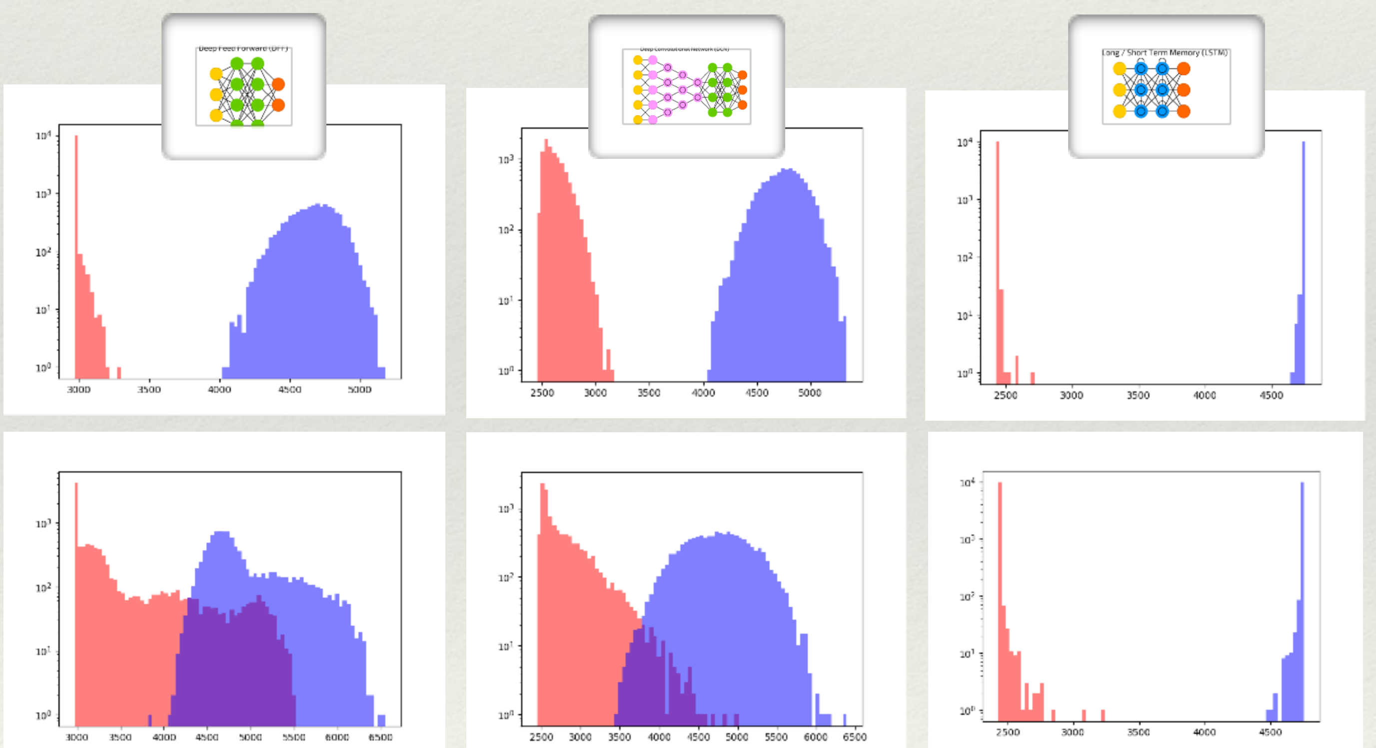
$$s(t) = \mathbf{A}\,[\exp(-t/\mathbf{td1}) - \exp(-t/\mathbf{tr}) + \mathbf{R}^{*}(\exp(-t/\mathbf{td2}) - \exp(-t/\mathbf{tr})] \text{ if } t > \mathbf{T0}$$

Training with Gaussian distribution $\boldsymbol{\sigma} = 2$ of **T0**, other parameters are constants

Test with Gaussian distribution $\boldsymbol{\sigma} = 20$ of **T0**

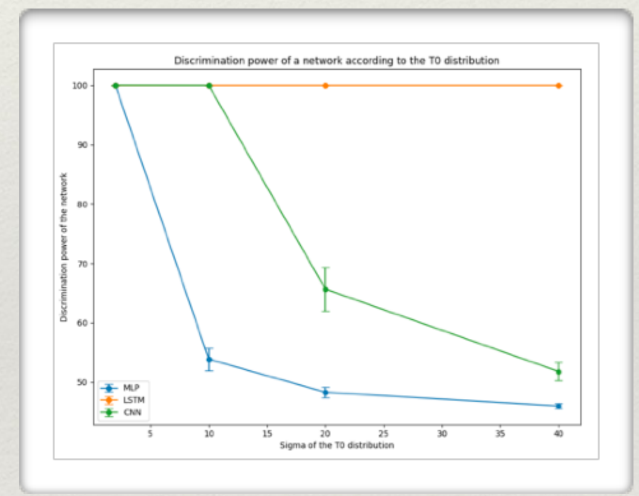
$\boldsymbol{\sigma} = 2$

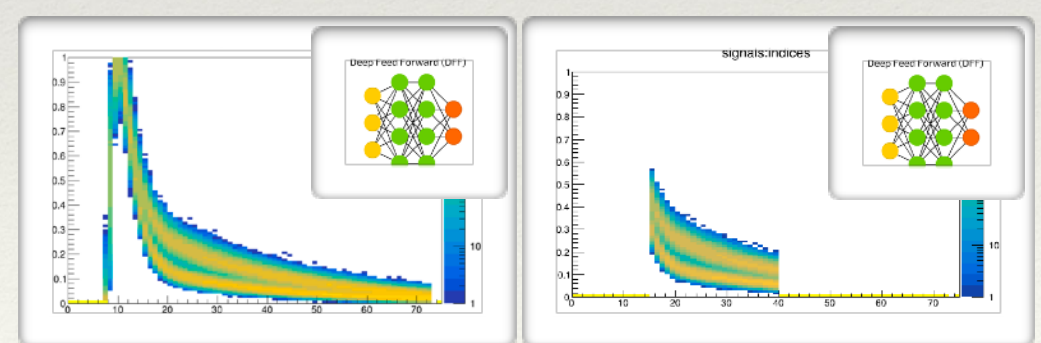
$\boldsymbol{\sigma} = 20$



Neural network output value

LSTM the most robuste !

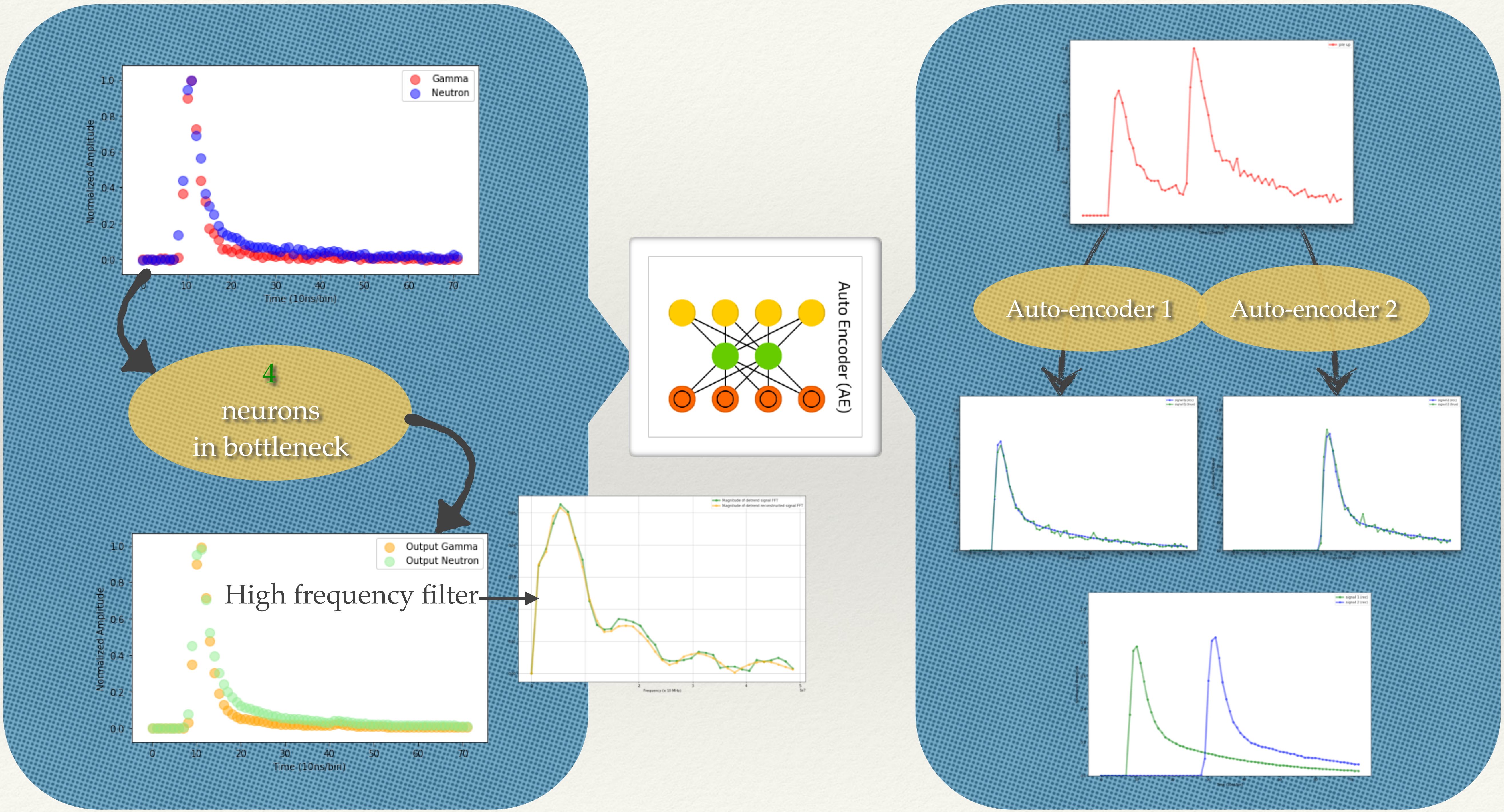




Truncated signals give the same output …

Feature extraction ≡ calibration really does matter !

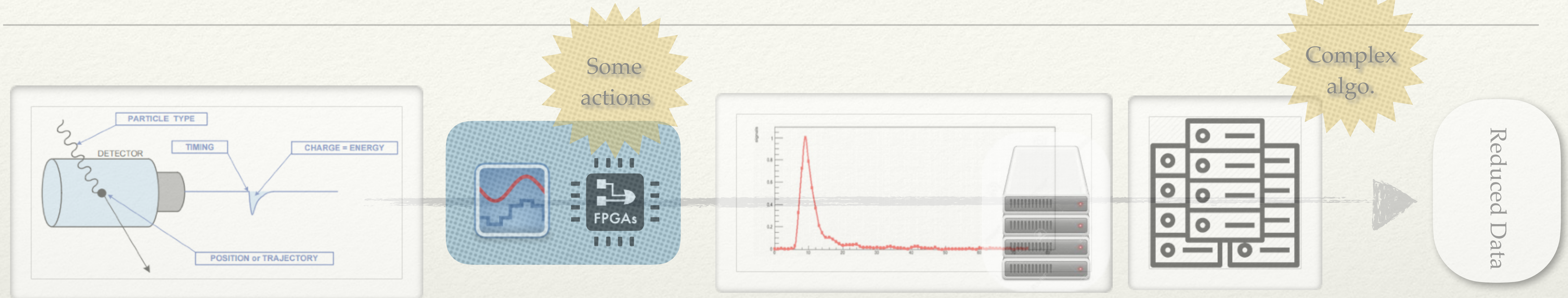
Signals and auto encoders



Data compression !

Denoising : Pile-up deconvolution

Conclusions / Perspectives



Our first steps in using Machine Learning for data processing, 3 ANN architectures studied

- ➤ MLP has run online in CPU farms !
- ➤ AGATA to qualify/quantify the γ/n discrimination in NEDA
- ➤ LSTM has some advantages, less sensitive to bad alignment of modules (time)
- ➤ Auto encoders into the game for compression / de-noising

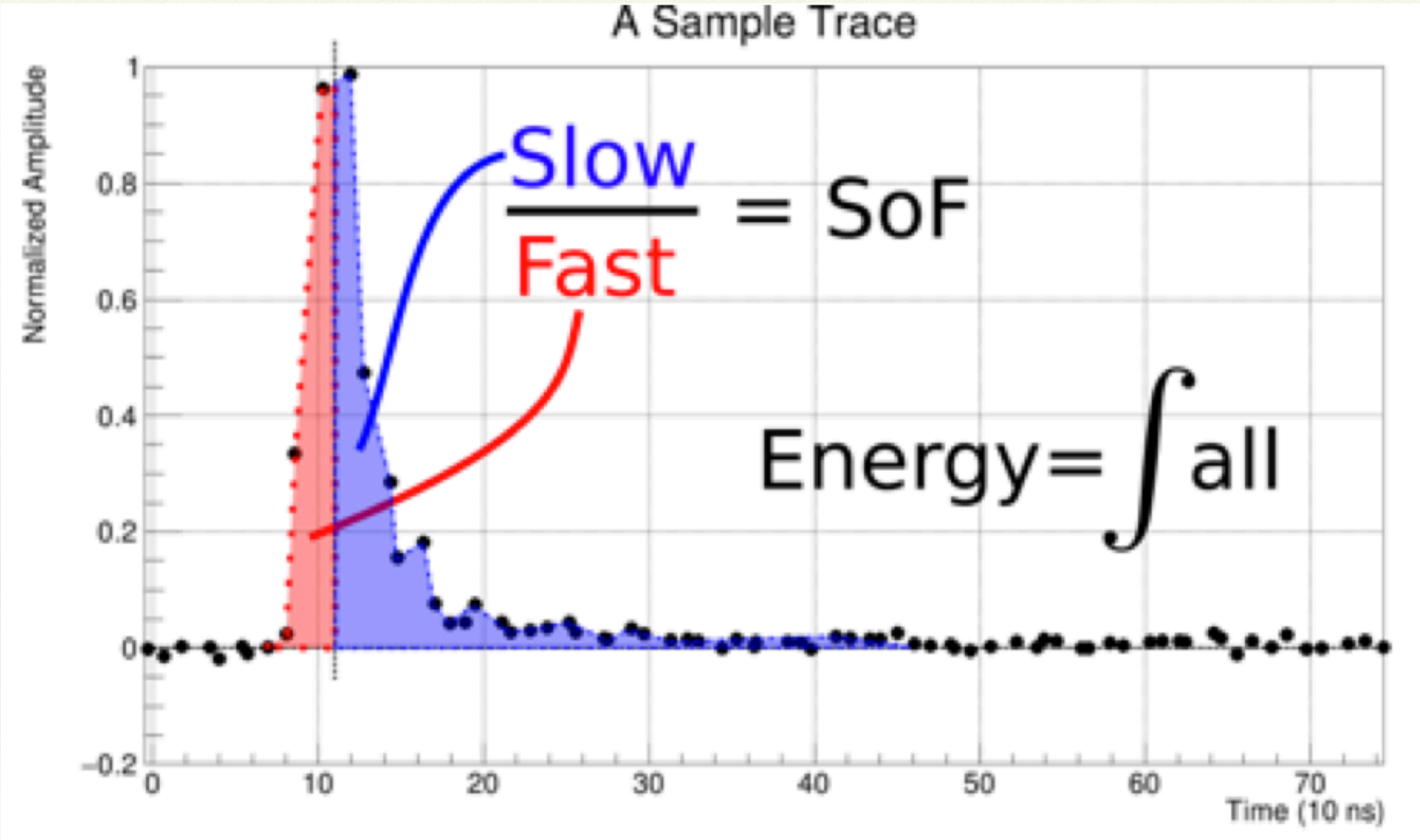
Many thanks to The GPU farm @ CC

Our future steps in using Machine Learning for data processing - NEDA

- ➤ Move to production -online- for data compression / de-noising / anomalies
- ➤ ANNs at lower stages ? FPGA ?

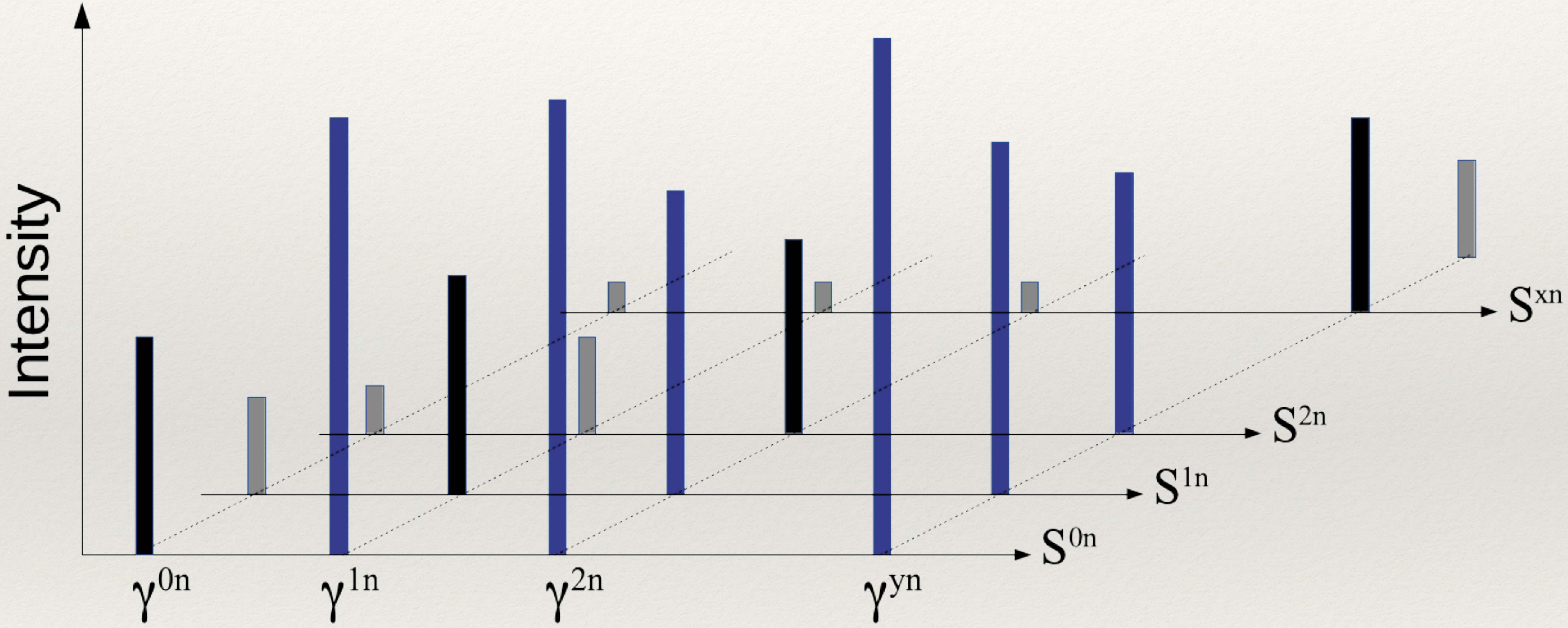
Our future steps in using Machine Learning for data processing - AGATA

- ➤ Much more complex : Pulse Shape Analysis ≡ regression + Tracking (cluster stage)
- ➤ No model for the shapes of the pulses. It relies on complex simulations / scanning



A Sample Trace
Normalized Amplitude
Time (10 ns)
Slow
Fast
= SoF
Energy= ∫all

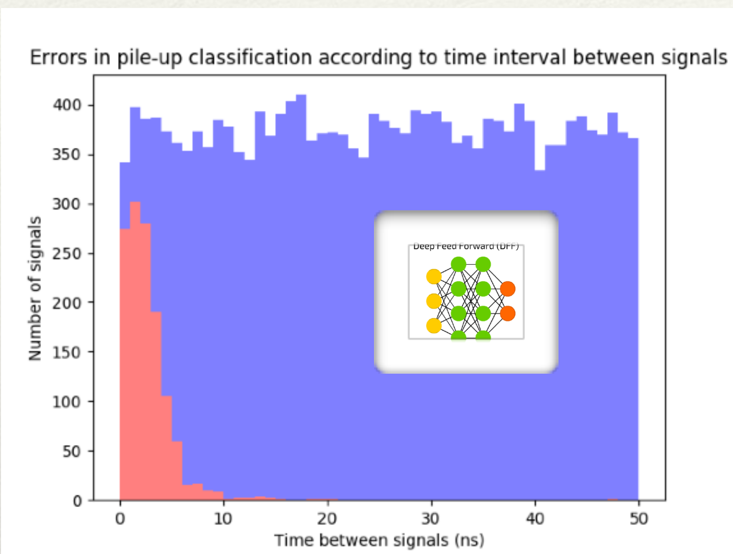
Classification & Mislabel

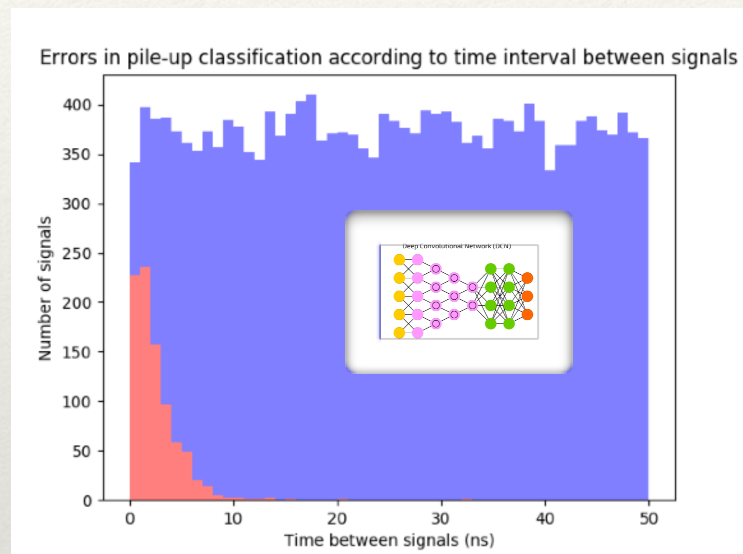


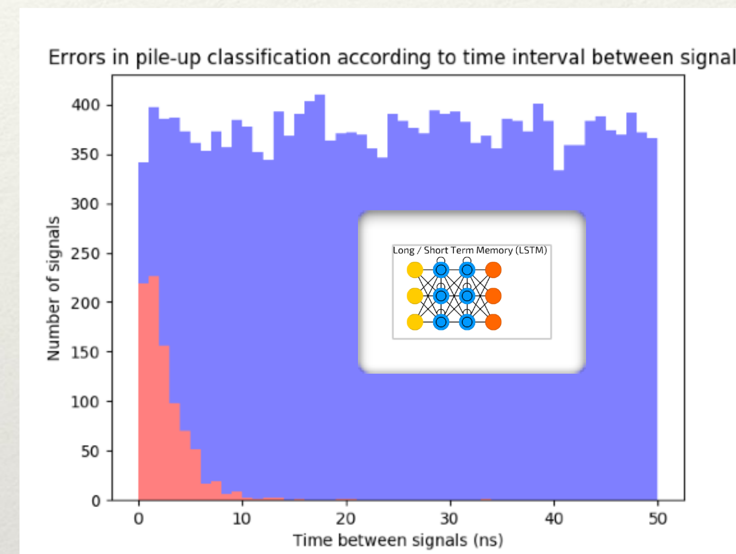
Machine Learning on signals

Study 2: Pileup identification

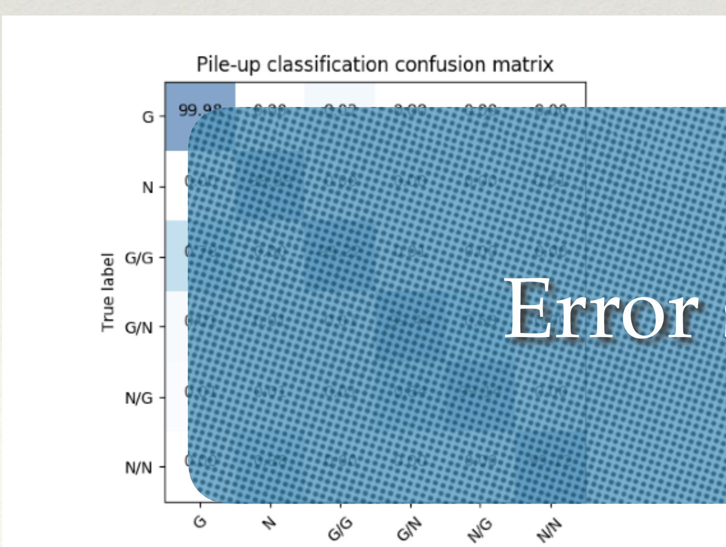
Error as fonction of the time between signals

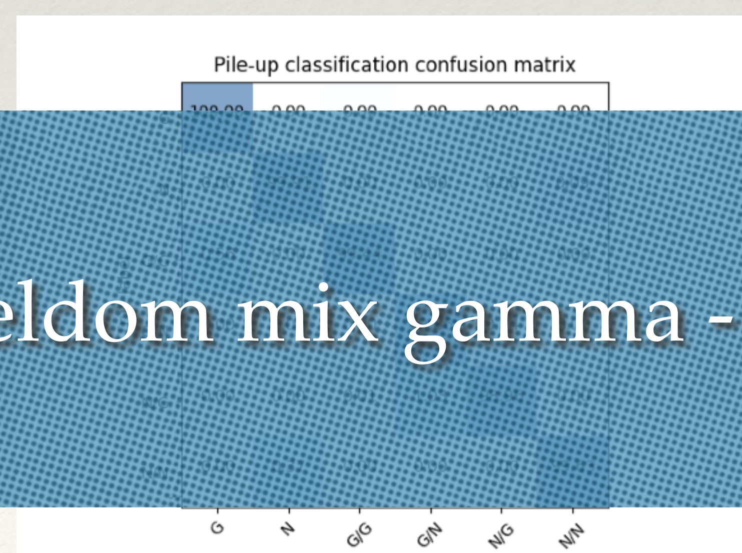


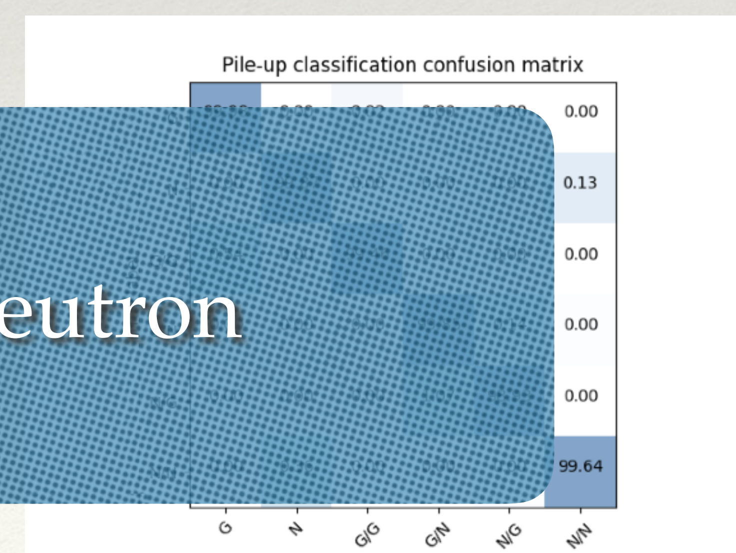




Confusion matrix







Error seldom mix gamma - neutron


epoch_categorical_accuracy
0.990
0.985
0.980
0.975
0.970
0.965
0.960
0.955
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Name Smoothed Value Step Time Relative
CNN 2020-01-08 17:41:37.482816 0.9828 0.9828 350.0 Wed Jan 8, 18:44:34 1h 2m 44s
LSTM 2020-01-08 18:44:50.793384 0.9861 0.9861 130.0 Wed Jan 8, 19:14:56 29m 10s
MLP 2020-01-08 17:07:32.840584 0.9802 0.9802 270.0 Wed Jan 8, 17:41:27 33m 46s