Deep Neural Networks for Data Analysis with the CMS Detector at the LHC

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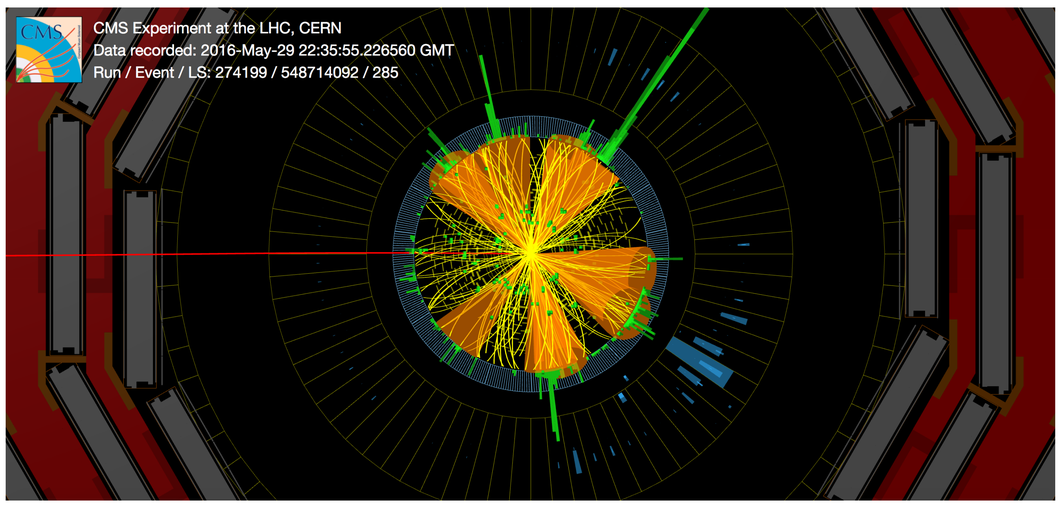
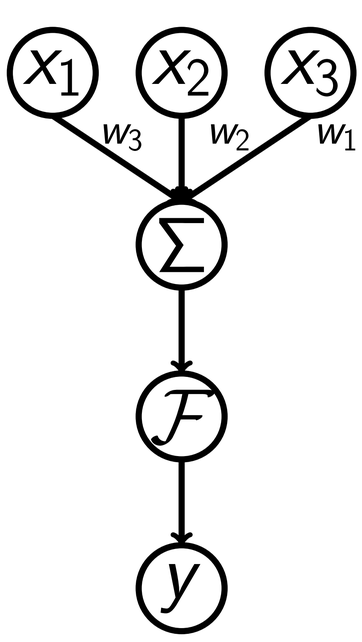
Deep neural network and CMS

CMS event display.

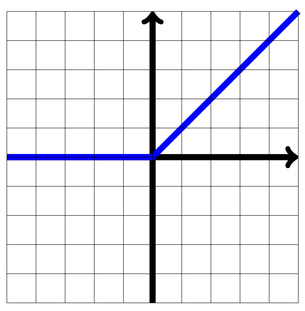


Neuron of a network.



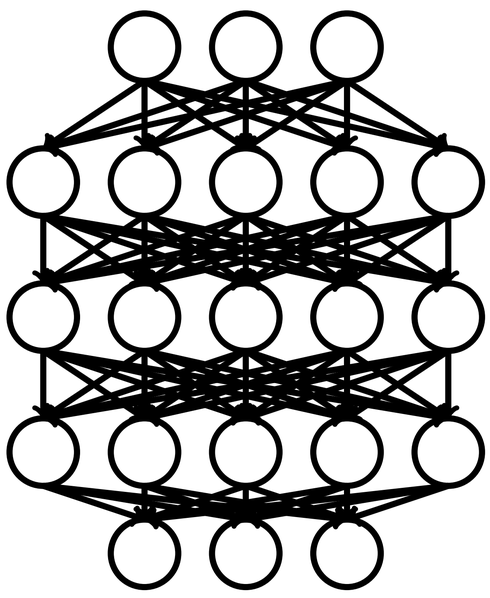
Σ: Matrix multiplication $\Sigma_{i=1}^{N} w_i x_i + b_i$

$\mathcal{F}$: Non-linear activation, e.g. ReLU



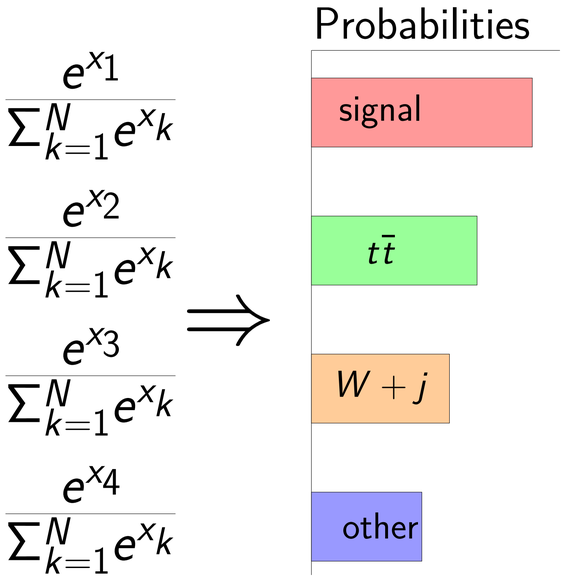
y: Output node

Fully connected network.



- Train network with reconstructed event features (lepton 4-momentum, jet 4-momenta, missing transverse momentum, ...)
- Optimize the network architecture (number of nodes, activation, ..)
- Go deep! Number of weights can be up to 10^6

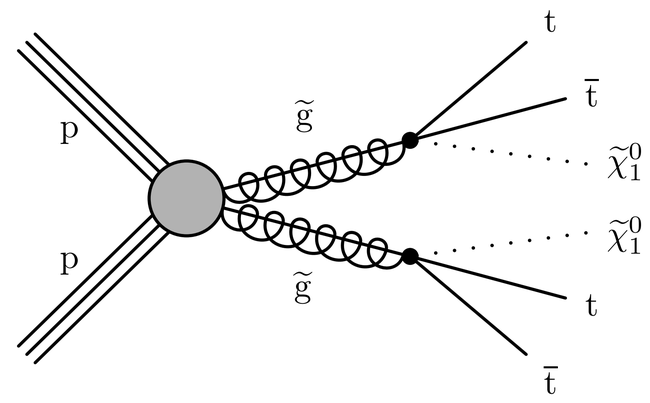
Classification.



- Classification of event typical problem in high energy physics
- Several physical processes can lead to the same event
- Use softmax activation ($\frac{e^{x_i}}{\sum_{k=1}^{N} e^{x_k}}$) for output layer
- Output as probability an event origins from specific process

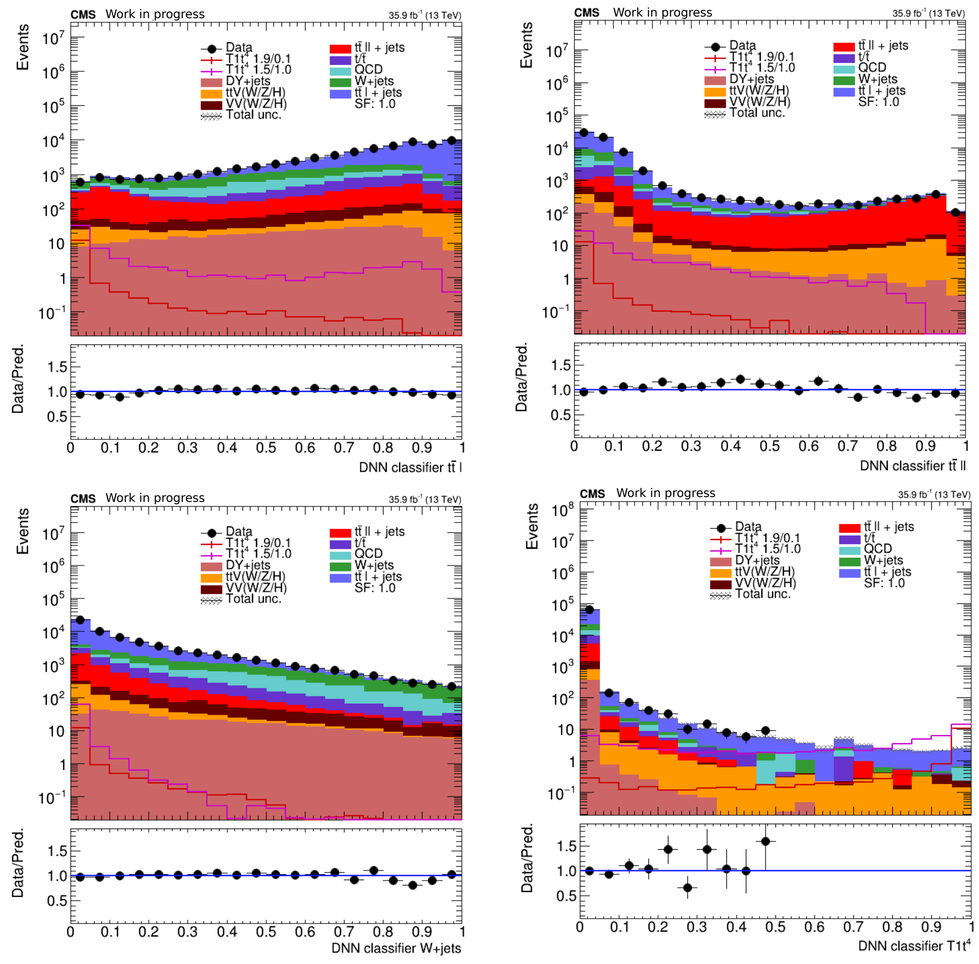
Deep neural network in SUSY

Supersymmetry.



- Supersymmetry (SUSY) as popular extension of the standard model
- Rich phase space and highly predictive
- Our model: Simplified decay of supersymmetric gluon to top quarks

Multiclassification.



- Dominant background processes: Top quark pair production and W boson production with associated jets
- The deep neural network is trained to identify each background and the signal
- For each process a probability (DNN classifier) is given as output and can be used to classify events as process with highest probability

Background estimation.

- Main challenge of physics analysis is the proper estimation of backgrounds
- Classifiers are used to extract normalization of background process simultaneously:

$$\begin{bmatrix}\alpha\\ \beta\\ \gamma\end{bmatrix} = \begin{bmatrix}B_{11} & B_{12} & B_{13}\\ B_{21} & B_{22} & B_{23}\\ B_{31} & B_{32} & B_{33}\end{bmatrix} = \begin{bmatrix}\text{data}_1\\ \text{data}_2\\ \text{data}_3\end{bmatrix}$$