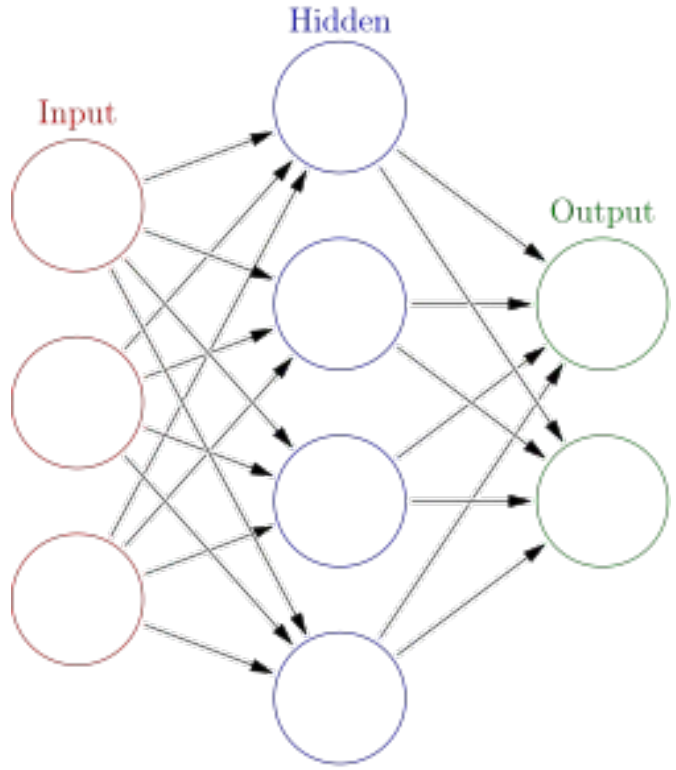
GRAPH NEURAL NETWORKS IN PARTICLE PHYSICS

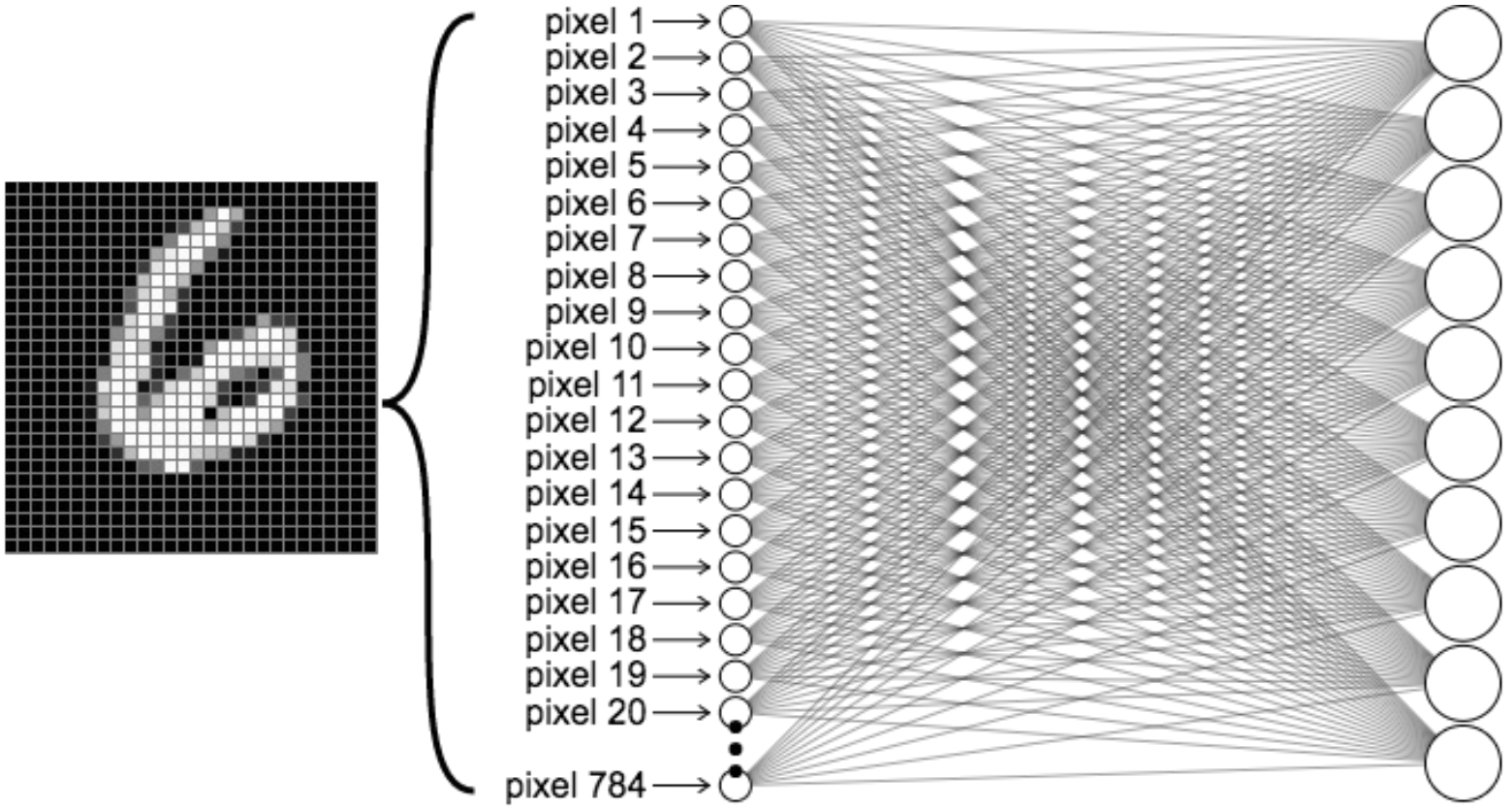
Magnus Guldbæk Hansen

(Artificial) Neural Network

- Emulates neurons, thus the name.
- Input layer takes defining features (pixel values, momentum, etc) as inputs for our Neural Network
- In the hidden layer is where the real computation takes place. This is where features are extracted.
- Finally, the output layer tells us the result, such as what number is drawn in our image (classification) or the energy of a system (regression).

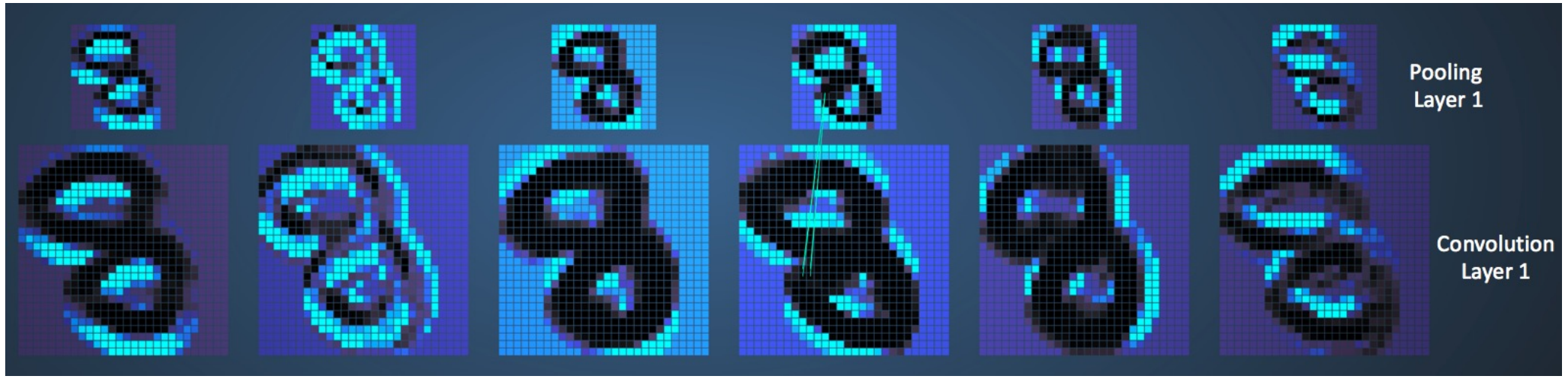


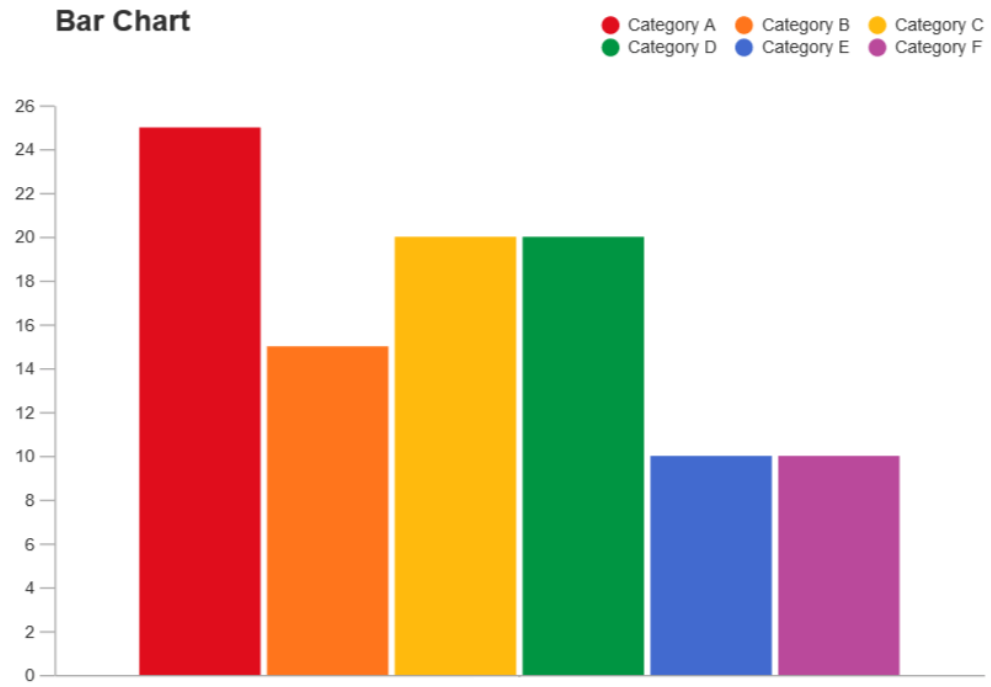
Example: MNIST



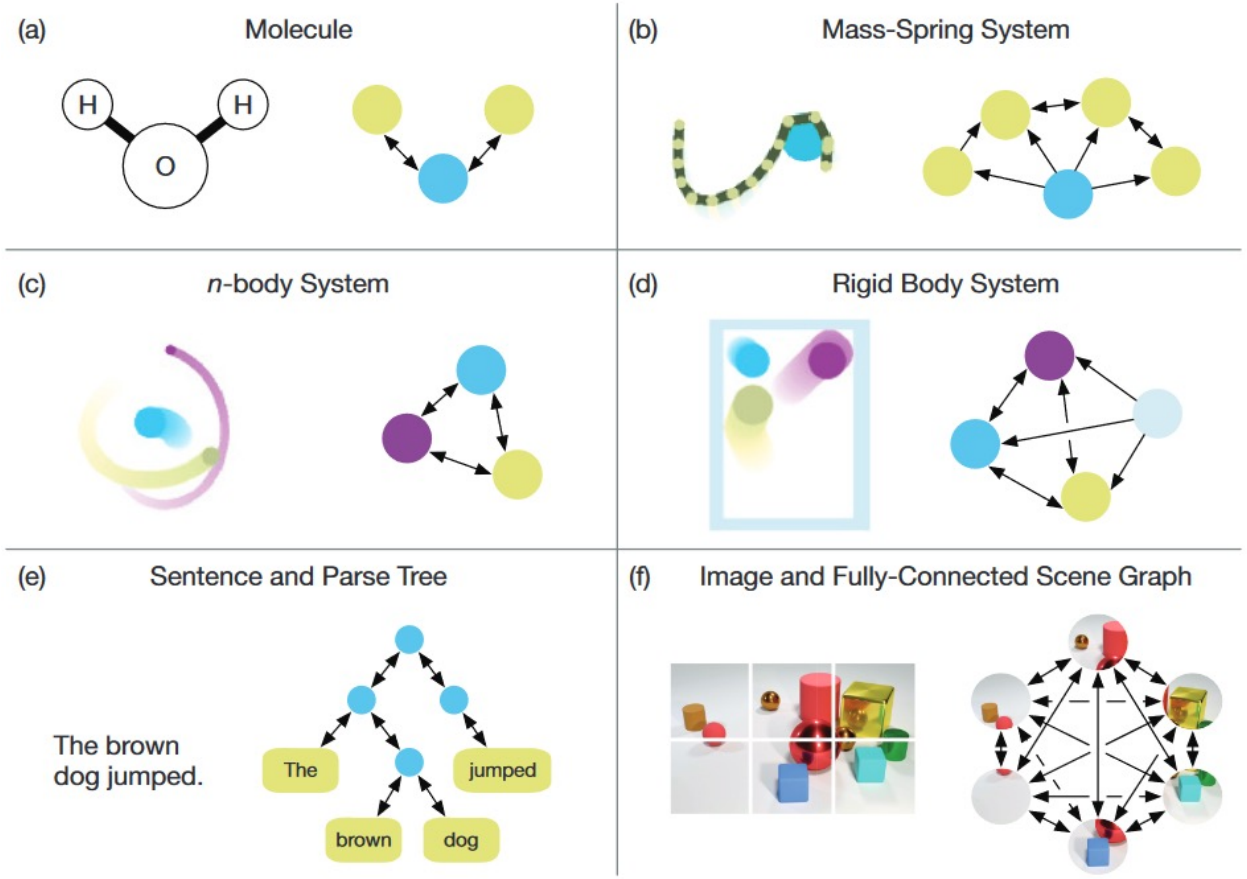
Types of networks

- Different types of Deep Learning , such as Fully Connected Network, Convolutional Neural Neetwork and Recurrent Neural Network.
- All of the above depend on having image/matrix like structure. That isn't always true.




Bar Chart
Category A
Category B
Category C
Category D
Category E
Category F
26
24
22
20
18
16
14
12
10
8
6
4
2
0

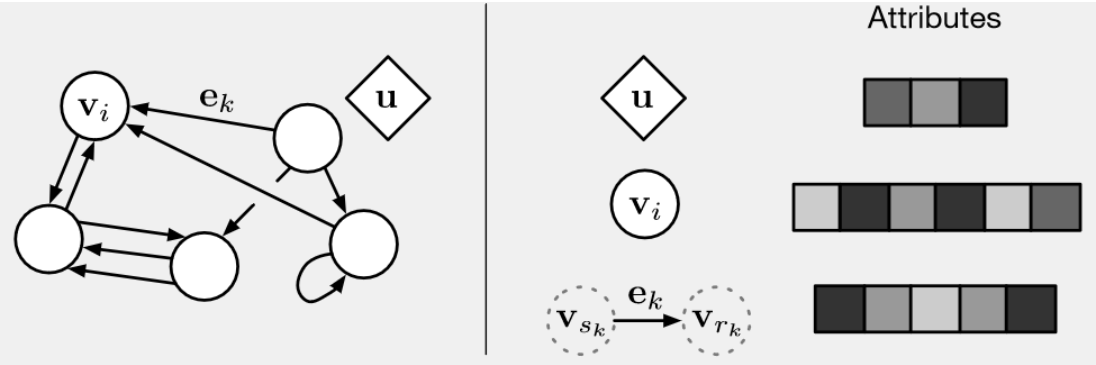
GRAPHS


(a) Molecule
H
H
O
(b) Mass-Spring System
(c) n-body System
(d) Rigid Body System
(e) Sentence and Parse Tree
The brown dog jumped.
The
jumped
brown
dog
(f) Image and Fully-Connected Scene Graph

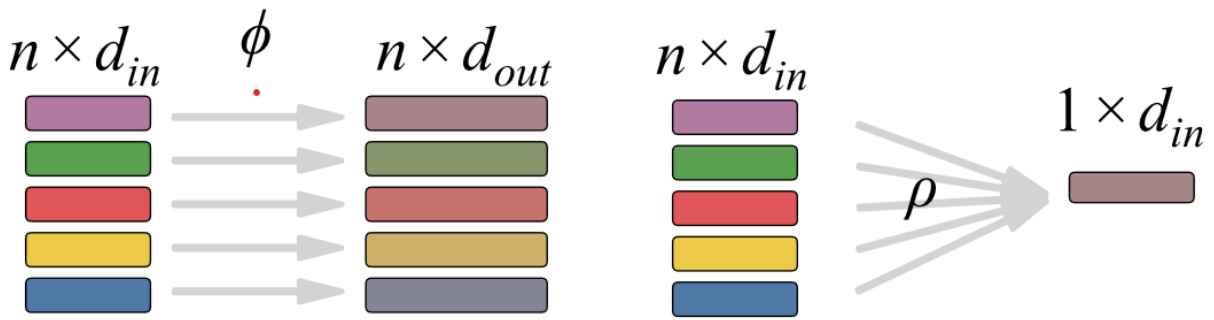
GRAPHS

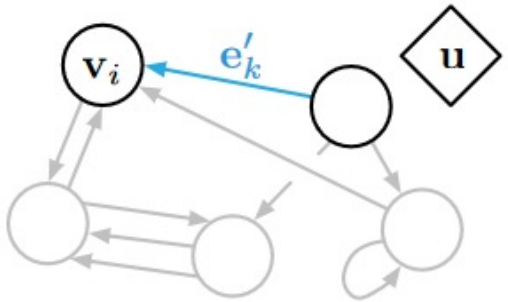
Graph network

We define our graph G to have a set of attributes, $\boldsymbol{u}$. Similarly, our nodes V have attributes $\boldsymbol{v}_i$ and our edges E have attributes $\boldsymbol{e}_k$.

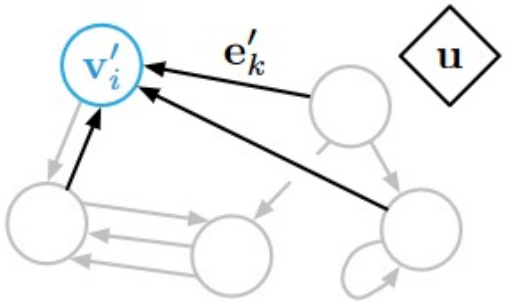


Update and aggregate functions

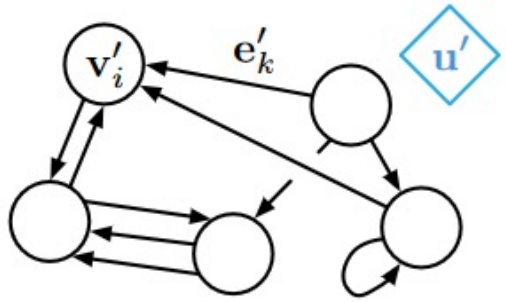




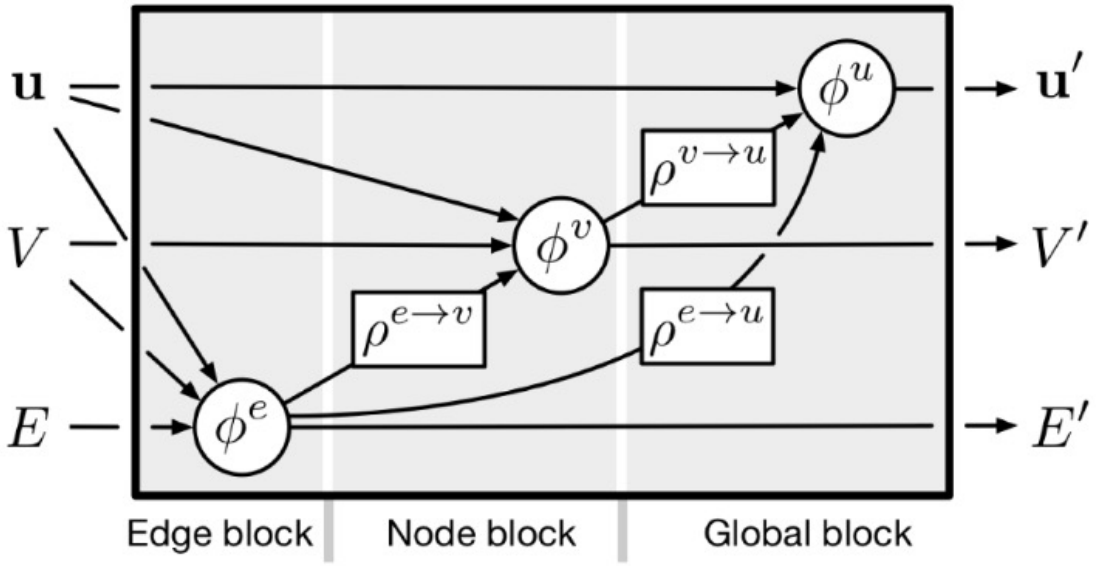
(a) Edge update



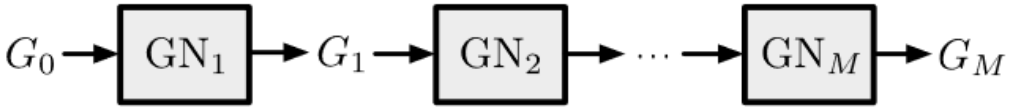
(b) Node update



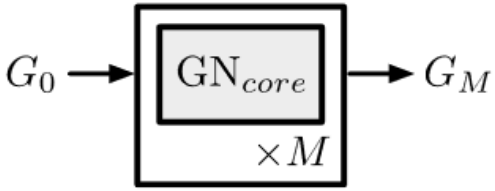
(c) Global update



Unshared, deep GN stack



Shared, recurrent GN stack



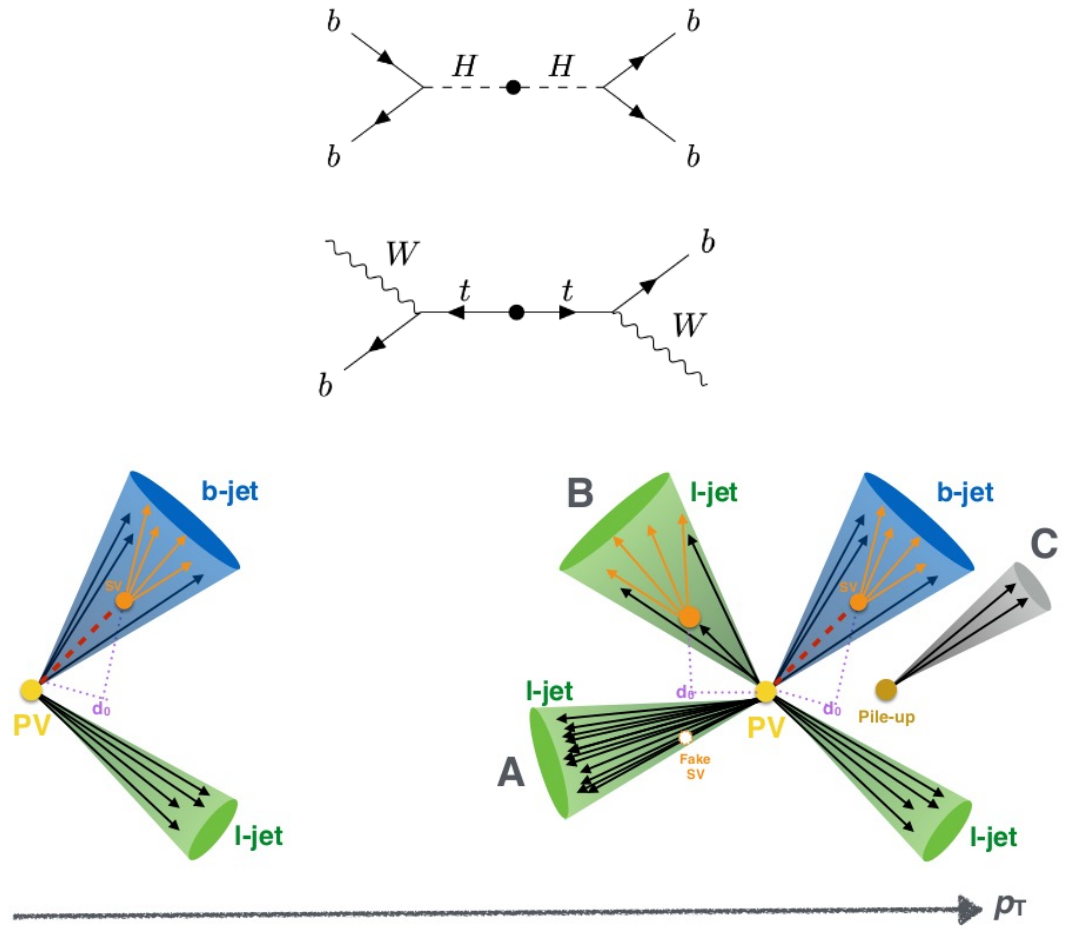
GRAPH NETWORK BLOCK

Flavour Tagging/ Jet Classification

We can observe jets, sprays of particles from a decay, but those for heavier hadrons (B and C) are rarer.

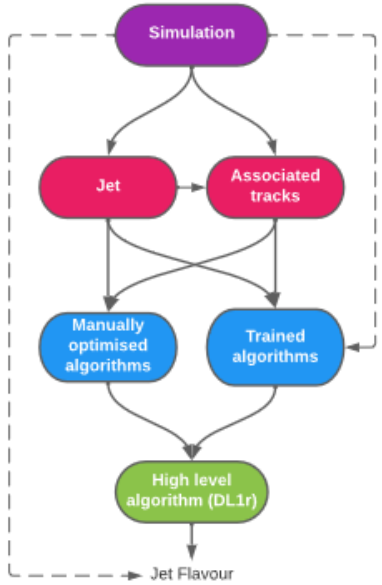
Thus, when in an experiment we actually do generate say a B or C-jet, we want to know.

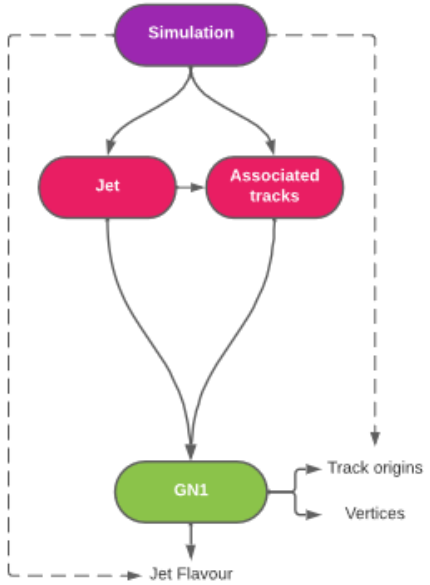
Flaovur tagging is the method by which we do so.

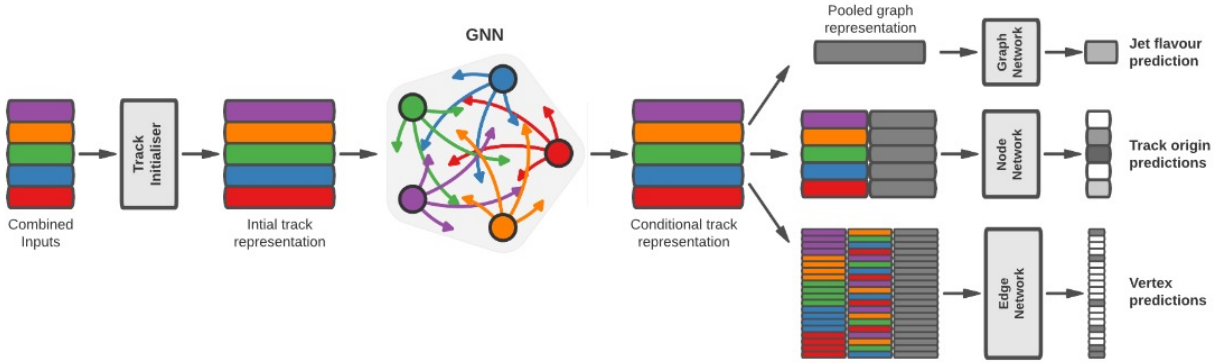


GNN at the ATLAS detector

- Old Algorithm relied on lower level algorithms and was hard to edit.
- New algorithm (GN1) allows for auxiliary training objectives, Track origins and if 2 tracks share a vertex.







GNN at the ATLAS detector