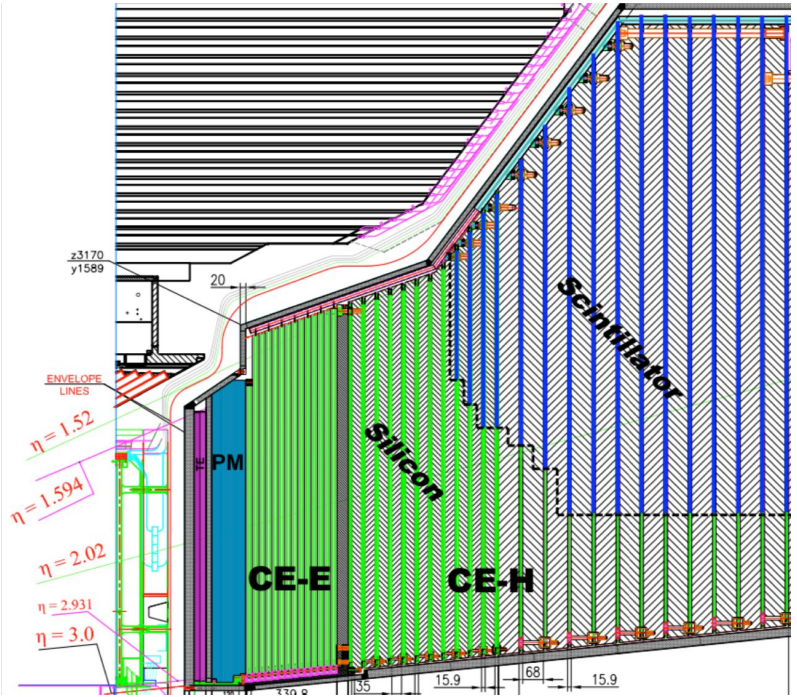
HIGH GRANULARITY CALORIMETER SIGNAL PROCESSING, WITH MACHINE LEARNING BASED RECONSTRUCTION IN THE CMS HGCAL

Shamik Ghosh | Alexandre Zabi, LLR - Ecole Polytechnique, CNRS, France

Introduction

- High Granularity Calorimeter HGCaL will replace existing CMS endcap calorimeters (preparing for HL-LHC)
- Highly granular calorimeter with ~6M detector channels from 50 layers
  - granular 5D (position(3), energy, time) signals
- Possibility of performing calorimetry with tracker like granular information.
- Challenge to fully utilize this information to extract physics objects out of the detector.



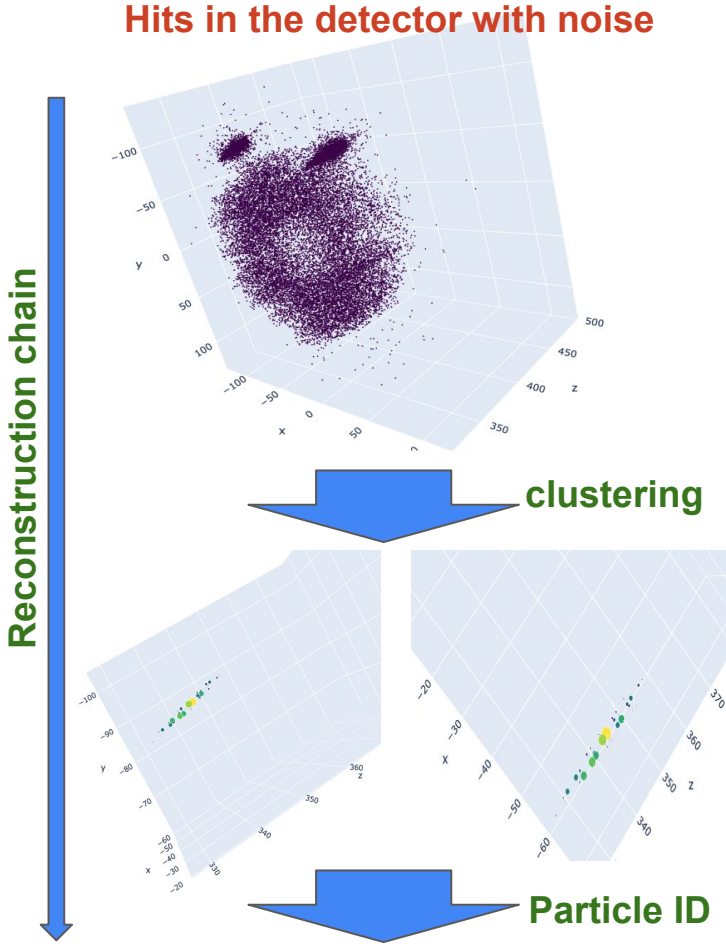
HGCal detector to be discussed in details during Alexandre Zabi's talk on Thursdsay

Lab Objectives

- Visualise and explore signals corresponding to the shower of particles inside the detector
  - Simplest particles like photons and pions

- Assign properly the signals associated with individual particles with minimal contamination(**clustering**)
  - Single particles
  - Multiple close by particles with noise

- Properly utilise the signals attributed to a particle to identify the type of the particle (**particle ID**)
  - Photon vs pion

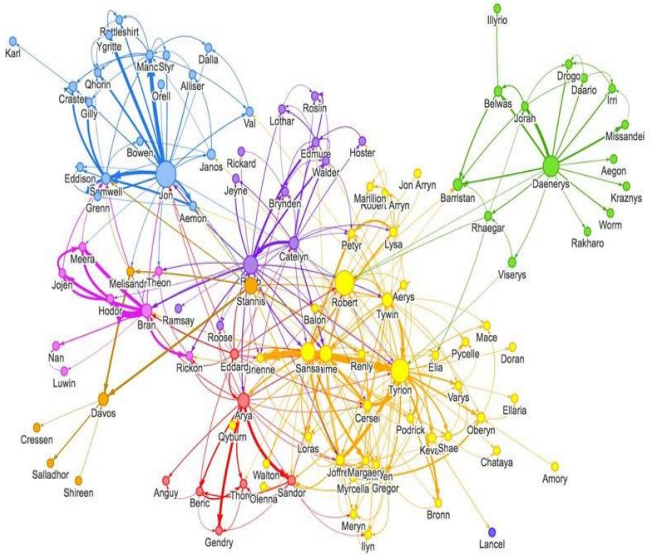


Ideas can be ported to your favourite experiment as well!

Algorithms explored

- Clustering : State of the art tools to be discussed for clustering
  - **K-means** clustering
  - **DBSCAN**
  - **Custom energy-density based clustering**(similar to that used in CMS)

- Particle ID : State of the art **Graph Neural Networks(GNNs)** to be considered
  - Hand crafted variables representing shower information has limitations
  - Use machine learning to extract maximal information
    - Use GNNs which excel at handling the 5D information the detector provides and building powerful representations of the showers
    - GNNs handle irregular geometries (hexagonal pixel size:a difficult task for out-of-the box Convolutional Neural networks) naturally.



Social media network classification using GNNs: CNNs/ RNNs do not work on this kind of data

We will use powerful and popular graph network library: pytorch geometric

Fun and powerful packages: Hope to see you there!

Installation guide:

- Create a fresh conda environment
  - conda create --name py3613 python=3.6.13 (this python version is preferred)
- Activate the new environment and install all the other packages inside this environment
  - conda activate py3613
- Install pytorch according to your system from:
  - https://pytorch.org/
- Install scipy
  - `conda install -c anaconda scipy`
- Install scikit-learn according to your system from:
  - https://scikit-learn.org/stable/install.html
- Install matplotlib
  - `conda install -c conda-forge matplotlib`
- Install tqdm
  - `conda install -c conda-forge tqdm`
- Install pytorch geometric according to your system from:
  - https://pytorch-geometric.readthedocs.io/en/latest/notes/installation.html
- Install jupyter
  - `conda install -c anaconda jupyter`
- wget https://shghosh.web.cern.ch/shghosh/INFIERI2021/allschoolfinalmaterial.tar.gz OR just download by clicking
  - All the notebooks and data are inside this tarball
- tar -xzvf allschoolfinalmaterial.tar.gz
  - Cd inside the untarred directory
- jupyter notebook --port=8088 --no-browser

Installation contd...

Or in linux systems with conda installed

- Get the list of all packages needed
  - wget https://shghosh.web.cern.ch/shghosh/INFIERI2021/torchtest.yml
- conda env create --file torchtest.yml
- conda activate torchtest
- conda install jupyter
- Download and untar to get the data and the notebooks
  - jupyter notebook --port=8088 --no-browser

Also the notebooks can be found in github at:
https://github.com/sameasy/Infieri2021
The data has to be downloaded from the link mentioned above

Some references:

- Calorimetry
  - Calorimetry: Energy Measurement in Particle Physics Book by R. Wigmans
  - https://indico.cern.ch/event/855973/contributions/3602188/attachments/1979913/3296643/calorimetry_sauvan_esipap2020.pdf : Awesome lecture 1
  - https://indico.cern.ch/event/124299/contributions/93835/attachments/74344/106642/EDIT_Calo_lecture_lr.pdf : Awesome lecture 2
- Clustering
  - https://cs.wmich.edu/alfuqaha/summer14/cs6530/lectures/ClusteringAnalysis.pdf
- Graph Neural Networks:
  - Pytorch_geometric examples and tutorials : refer website
  - https://arxiv.org/abs/1812.08434 : Review article(a bit old)
  - https://arxiv.org/abs/1801.07829 : DGCNN paper
  - https://arxiv.org/abs/2003.08013 : DRN paper