Task 12.5: Particle Flow Reconstruction

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on behalf of the Task 12.5 institutes

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Research Groups (main contacts)

- Dual Readout Calorimeters simulation & digitisation:
  - I. Vivarelli (Sussex), B. Di Micco (INFN Roma-3), S. Vallecorsa (CERN)
- ILC Calorimeter simulation & reconstruction:
  - G. Grenier (CNRS-IP2I), V. Boudry (CNRS-LLR)
- DUNE Near Detector simulation & reconstruction:
  - J. Marshall & J. Back (Warwick), M. Uchida (Cambridge)

Particle Flow for Dual Read-Out Calorimeter Status Report

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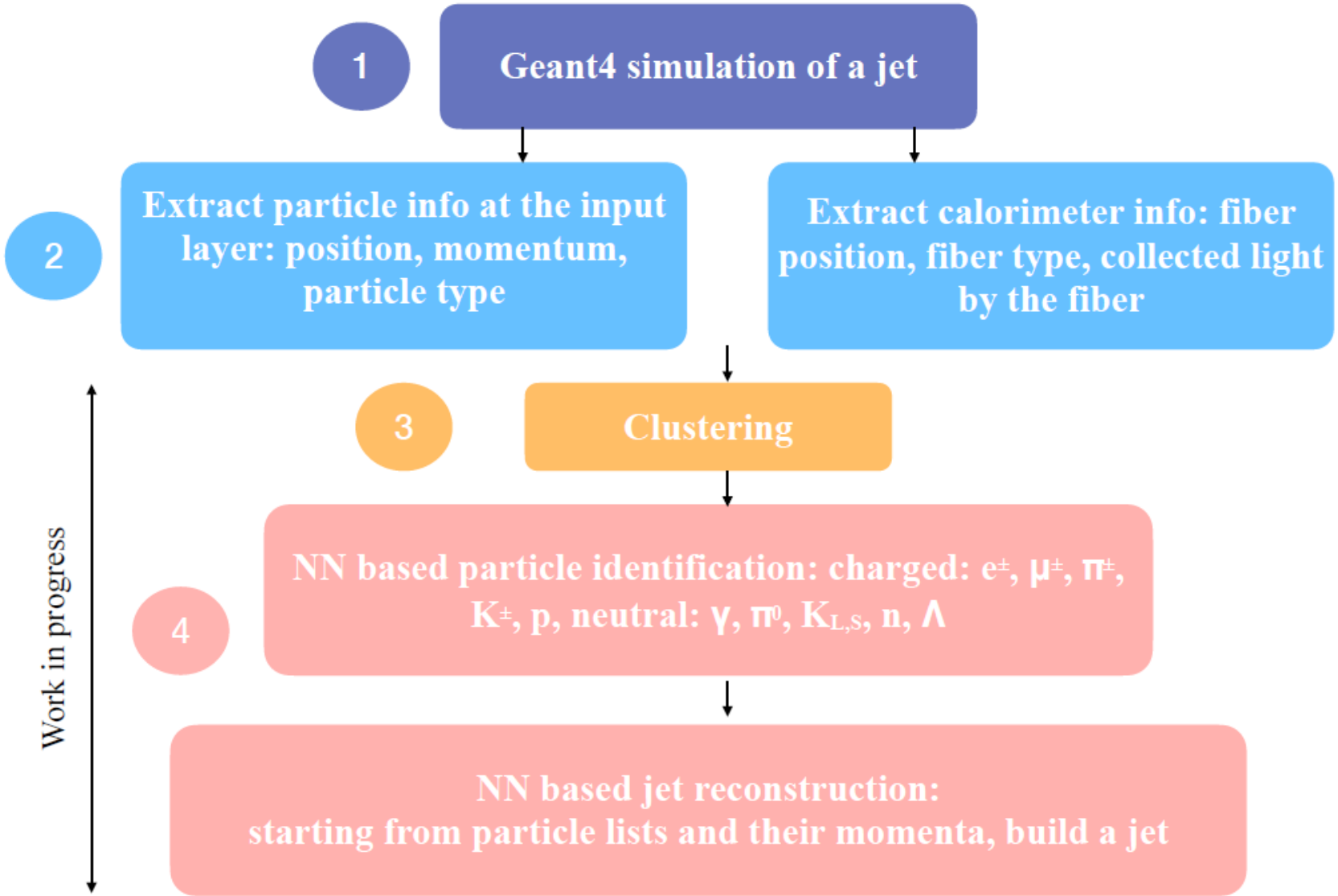
26th September 2022

Overview of the Project



Software Implementation

- The aim of the project is to build a Neural Network based algorithm that, from a given collection of energy deposits in the calorimeter, is able to completely reconstruct a jet in the detector

(1) Geant4 jets simulation: outside the scope of this project, provided by Iacopo and his team in KEY4HEP format

(2) Extract particle/calorimeter info from simulations

- **New code** in *IDEADetectorSIM git repo*: *https://github.com/HEP-FCC/IDEADetectorSIM/tree/master/ParticleFlow_k4pandora*
- It is a code based on Pandora, that reads KEY4HEP format and produces an output to perform a Neural Network training
- **Preliminary plots** of electrons and photons kinematic variables in the *next slides*

(3) Clustering: several clustering algorithms already on the market, *i.e.* NN based reconstruction algorithm for LAr TPC for the DUNE experiment, with interfaces to run Pandora using Torch Data format —> Collaboration in progress with DUNE team

(4) NN based particle identification: use as basis a particle flow approach, which aims at identifying each single particle inside a jet

- Machine Learning with *TensorFlow*
- CPU & GPU installation performed on Roma Tre cluster
- First NN optimisation in the *next slides*

(4) NN based jet reconstruction: construct a regression algorithm for particle-jet assignment and jet energy reconstruction

Software Implementation - Block Scheme

Input from detector simulation (EDM4HEP) format

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Reading using KEY4HEP *code*

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Dumping algorithm, input variables for NN training

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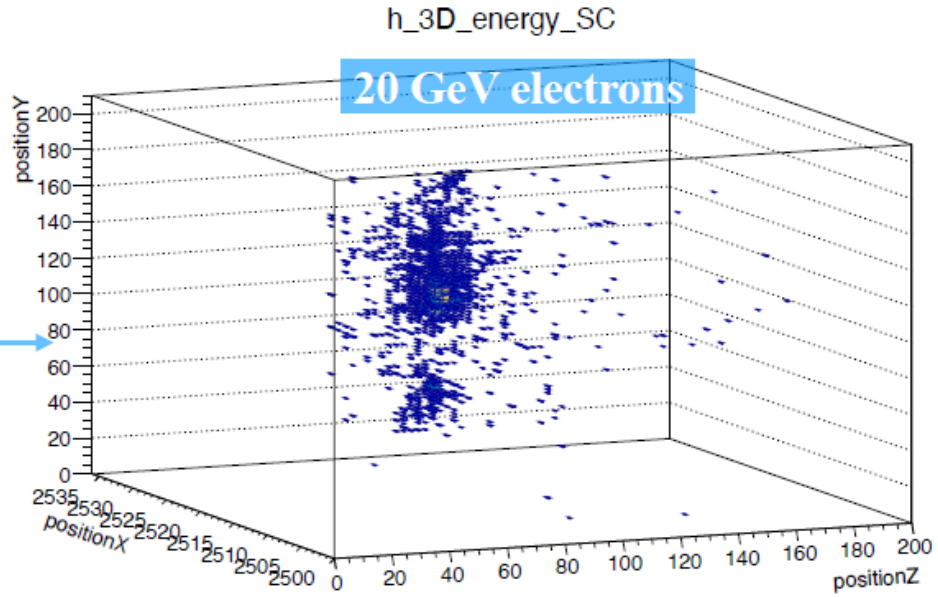
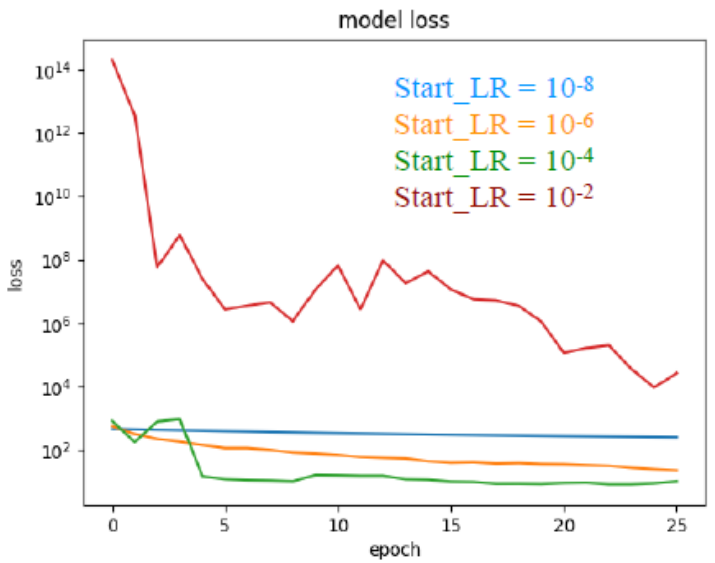
NN training using *Tensorflow* on CPU/GPU





- Optimizer Adam
- Epochs = 26
- N. layers = 10
- Testing different START learning rate

Optimised APRIL PFA for hadronic jets

G. Grenier (CNRS-IP2I), V. Boudry (CNRS-LLR)

- Released software tools to generate samples for calibrating APRIL for the ILD: https://github.com/SDHCAL/SDHCAL_ILD_prod

- Masters students' summer internships on calibration preparation work:
  - ➢ Dijet MC generator level jet energy resolution
    - ○ Finding energy ranges for photons & neutral hadrons to achieve accurate calibration
  - ➢ Optimisation of SiW-ECAL energy resolution
    - ○ Comparing hit counting and energy sums, especially for low energy photons (< 10 GeV)

- CALICE test beam participation over last 3 months
  - SDHCAL beam test completed 28th Sept

Reconstruction for the DUNE Near Detector (ND)

John Back & John Marshall (Warwick),
Steve Dennis, Jingyuan Shi, Melissa Uchida, Leigh Whitehead (& Alex Moor) (Cambridge),
Tingjun Yang (Fermilab), Munera Alrashed (Kansas State), Richie Diurba & Anja Gauch et al. (Bern)

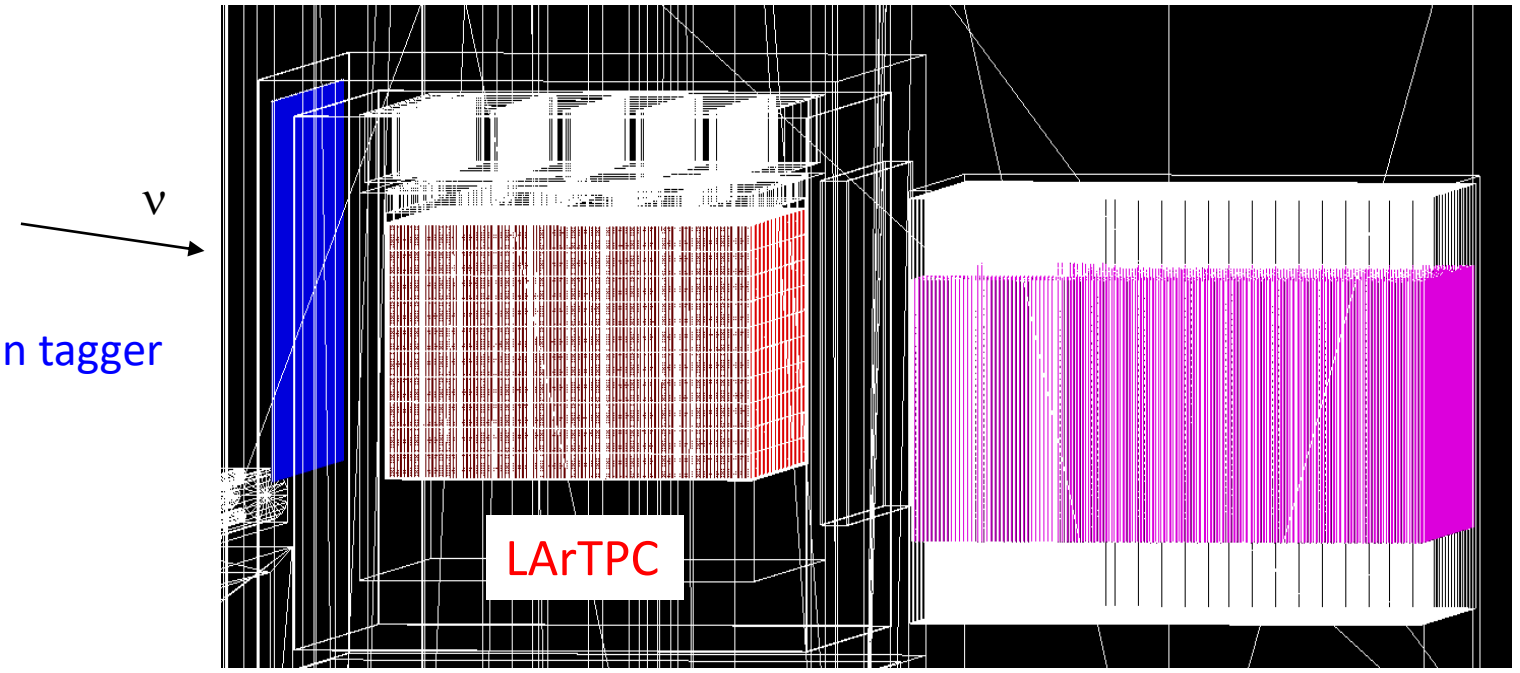
- Using Pandora for LArTPC ND reconstruction
- Previous work: Geant4 single particles (e,μ,π) & single ν (GENIE) interactions

- Now studying Geant4 simulations of high multiplicity ν (GENIE) events:
  - LBNF 120 GeV, 1.2 MW proton beam on graphite target (secondary $\pi \rightarrow \mu\nu$): 7.5×10^{13} p per spill
  - ND will have ~60 ν interactions per proton beam spill (occurring every 1.2 sec) due to protons-on-target (POT) rate, ND size & location w.r.t LBNF target complex

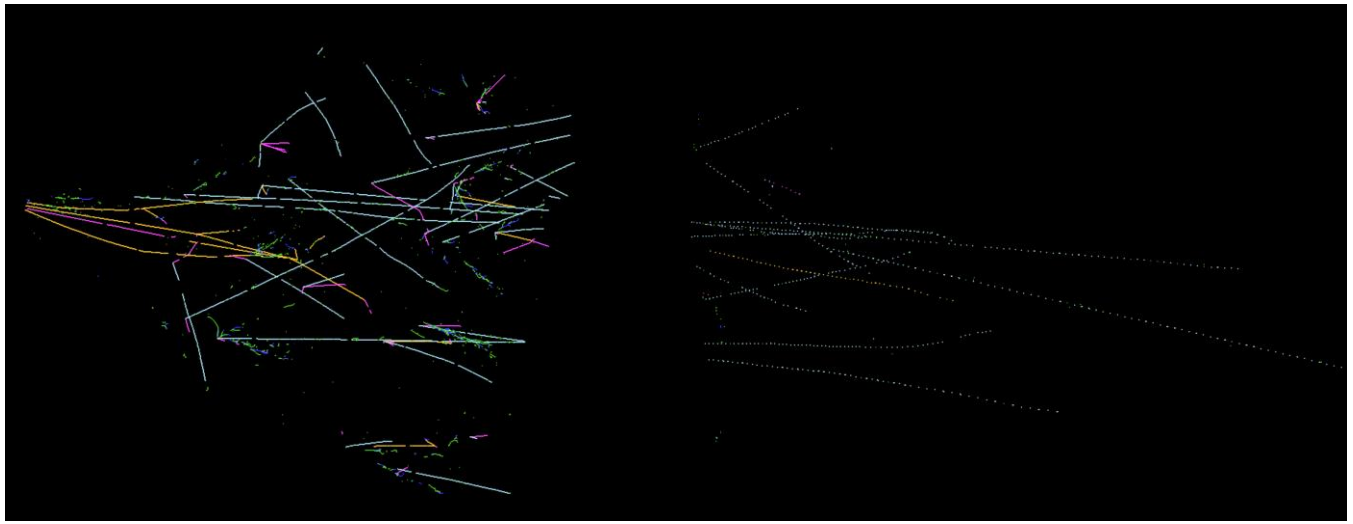
- Working on using Pandora to reconstruct Proto-DUNE data
  - Convert HDF5 (Hierarchical Data Format) files, then test reco algorithms

- Created LArRecoND package for Pandora ND code development

Geant4 ND geometry



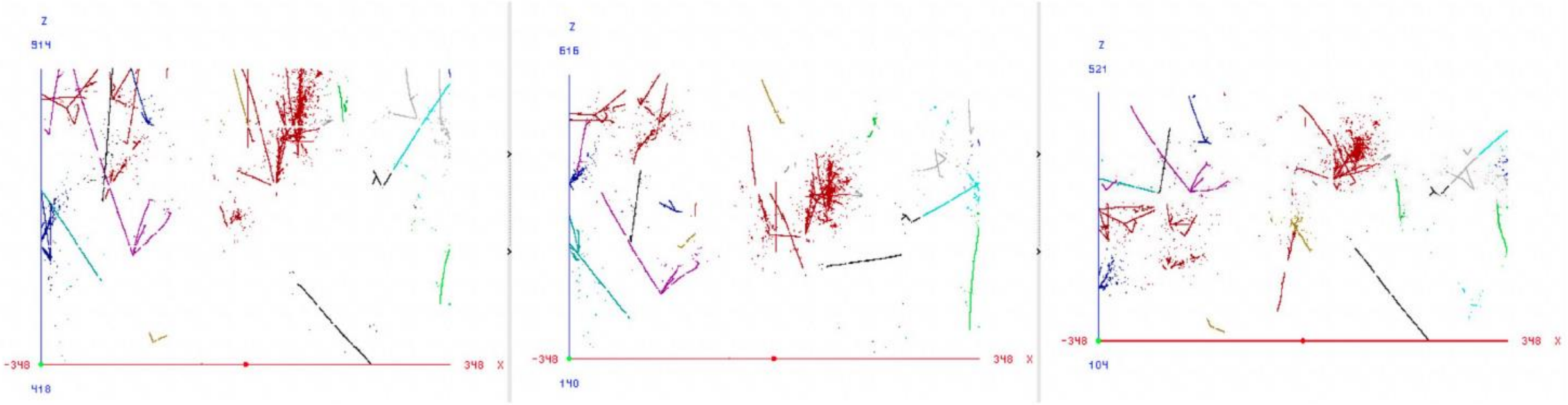
Full spill example



Slicing

Break up complex spills into independent ν interactions: **1 slice ≅ 1 ν**

1. Group together hits into Particle Flow Objects (PFOs) without using vertices
2. Find main ν vertex for each slice to improve PFOs



2D projections of reconstructed PFOs, **1 colour = 1 slice**

Looks reasonable, but needs improvement

Need to quantify **performance** using Pandora **Hierarchy** tools (developed by Andy Chappell, Warwick)