Task 12.5: Particle Flow Reconstruction

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WARWICK

on behalf of the Task 12.5 institutes

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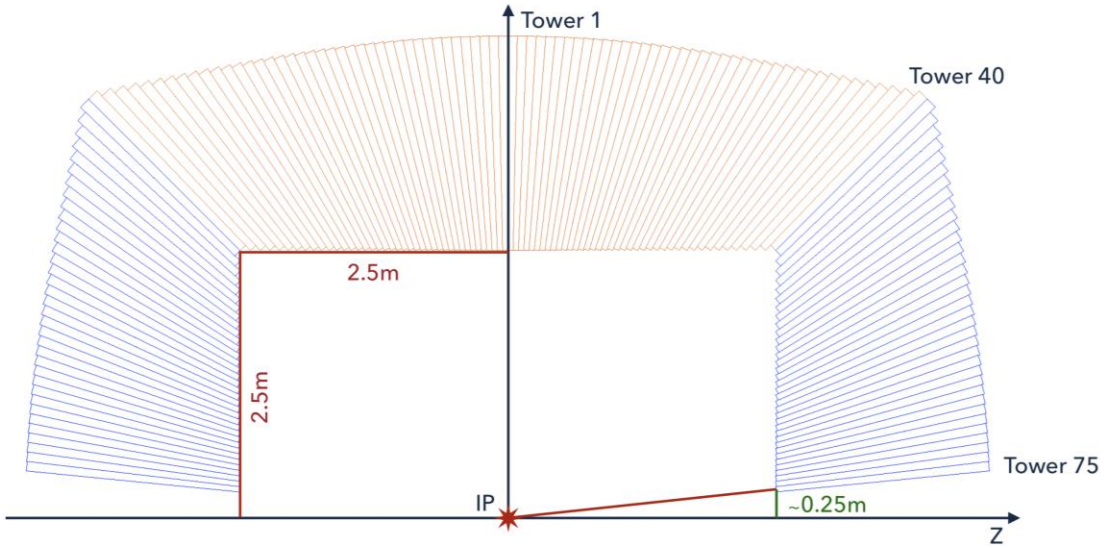
Updates

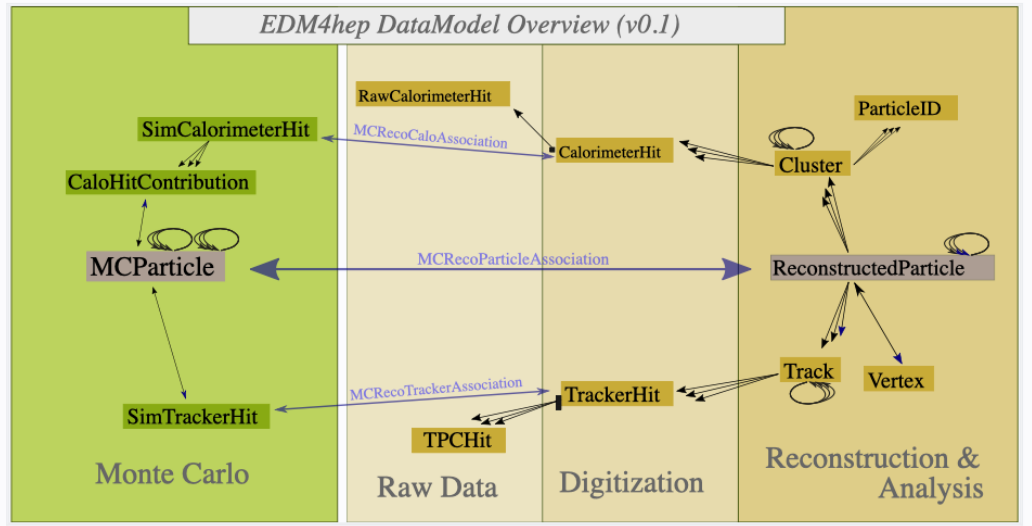
- Dual Readout Calorimeters: simulation & digitisation
  - I. Vivarelli (Sussex), B. Di Micco (INFN Roma-3), S. Vallecorsa (CERN)
- ILC Calorimeters: timing & digitisation
  - G. Grenier (CNRS-IP2I), V. Boudry (CNRS-LLR)
- DUNE Near Detector simulation & reconstruction
  - J. Marshall & J. Back (Warwick),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

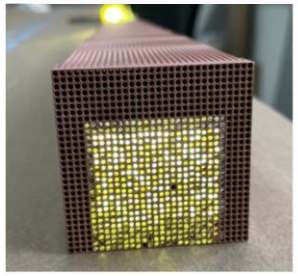
Integration of Dual Readout (IDEA) Calorimeter with EDM4hep

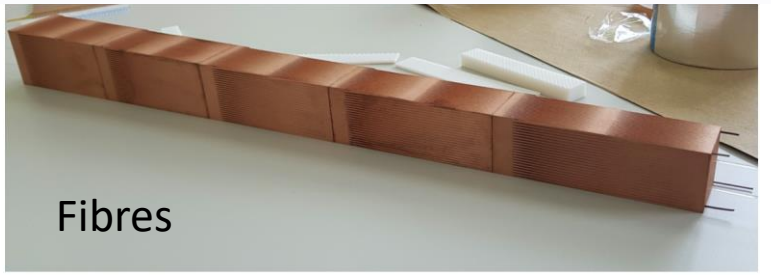
- EDM4hep : **event data model** for Future Circular Collider and Circular Electron Positron Collider frameworks
- **IDEA** (Innovative Detector for Elec-Pos Accelerator) dual readout simulation is routinely producing EDM4hep output
  - Git_IDEA_CALO_FIBER/tree/EDM4HEP simulation code branch includes relevant dependencies
- In parallel, a digitisation model to include SiPM response from incoming fibre light (**SimSiPM**) was developed by E. Proserpio
  - See talk in https://indico.cern.ch/event/979160
- Sensitive elements: **scintillation & Cherenkov** fibres read by SiPM



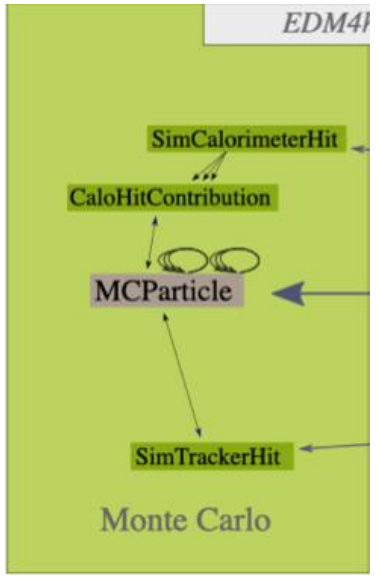
Sketch of single slice of IDEA calorimeter



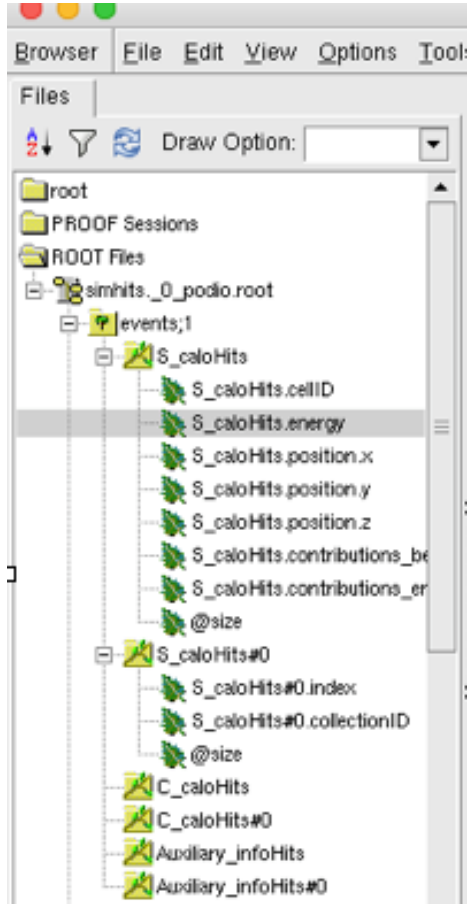




IDEA calorimeter event simulation

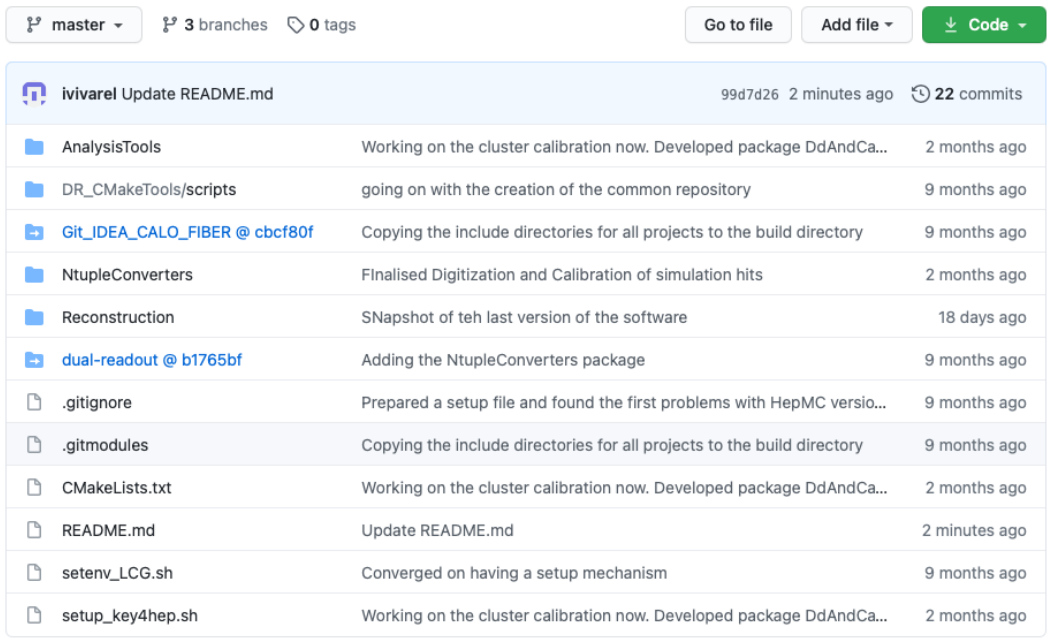


- **SimCalorimeterHit** = 1 fibre (with at least 1 photon)
  - Position, energy (number of photons), list of hit contributions
- **CaloHitContribution** = individual hit
  - Position, energy, photon time of arrival to SiPM
  - Arrival time estimated from global G4 hit time & distance to SiPM
    - 2.8 ns decay time for polystyrene added for scintillation fibre
- Write 2 **SimCalorimeterHit** containers: Scintillation & Cherenkov signals
- Auxiliary container contains information about leakage, total deposited energy etc.



IDEA calorimeter digitisation

- **SimSiPM digitisation code:**
  - https://github.com/EdoPro98/SimSiPM
- DRCalo: fully integrated software package, providing simulation, digitisation and preliminary reconstruction
  - Applies digitisation directly on **EDM4hep** output
  - Takes **SimCalorimeterHit** containers, applies SiPM simulation & writes out **CalorimeterHit** container
  - Works best directly on top of **key4hep** stack
  - **DRCalo Digitisation** directory: hook to digitisation code, along with run scripts and validation tests (C++ & python)



README.md

https://github.com/ivivarel/DRCalo

DRCalo

This package provides an integrated build for the IDEA dual readout standalone simulation, digitisation and reconstruction. The simulation and digitisation are introduced as submodules, and developed independently in their own repositories.

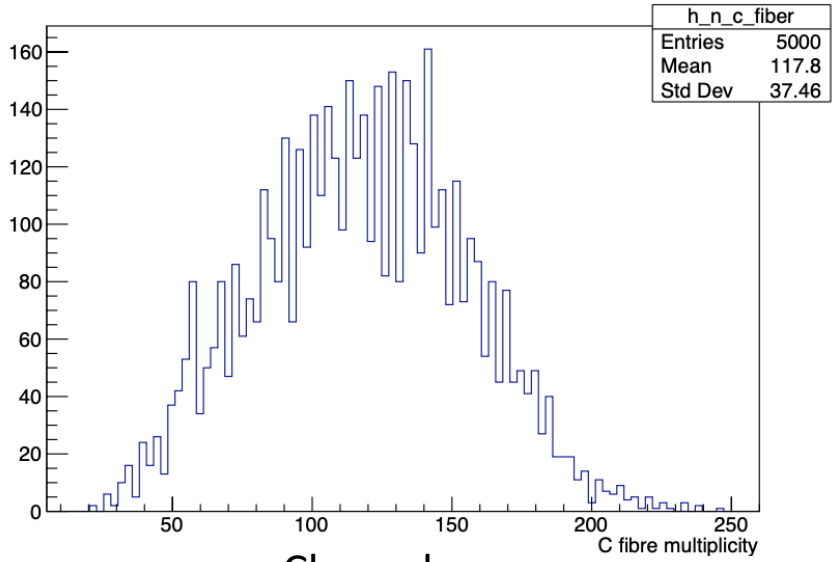
To use the package (from a machine mounting /cvmfs):

- checkout the package

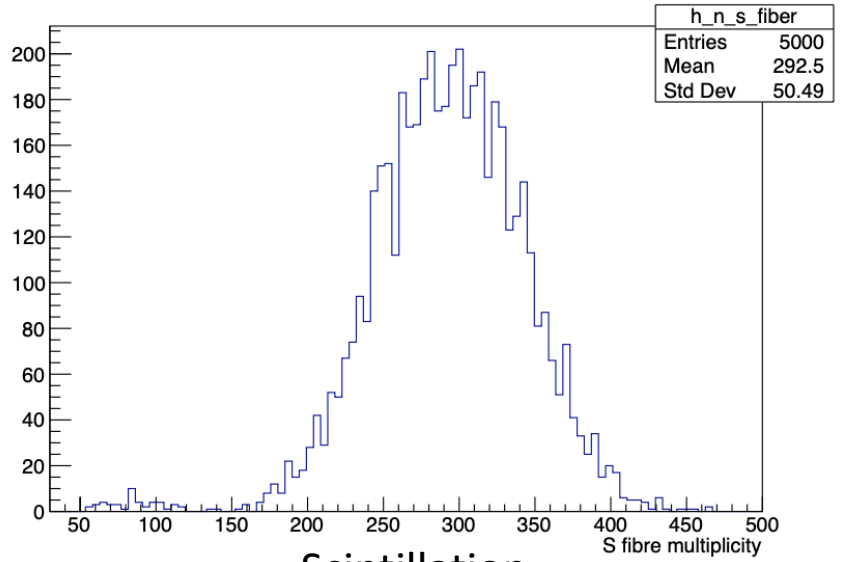
```
git clone --recursive git@github.com:ivivarel/DRCalo.git
```

- source the key4hep stack

IDEA calorimeter example: 5 GeV pions

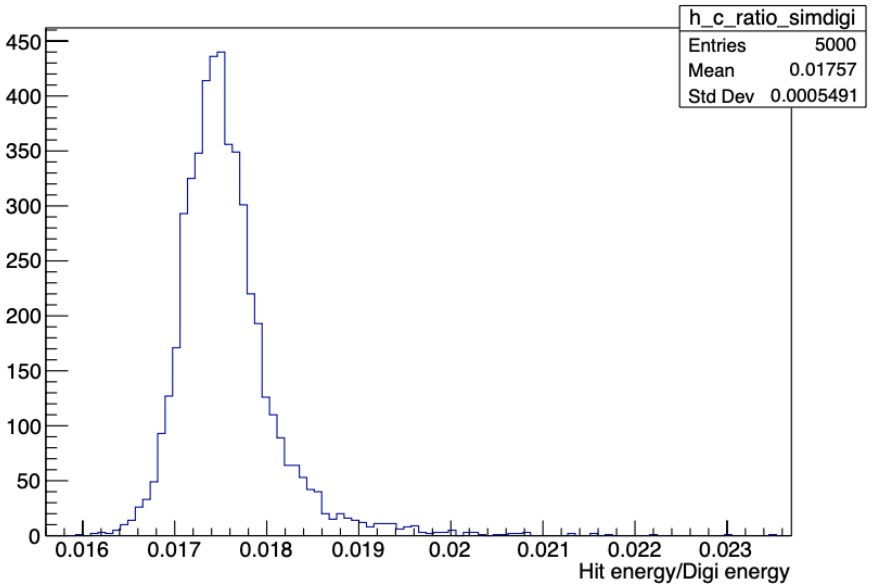


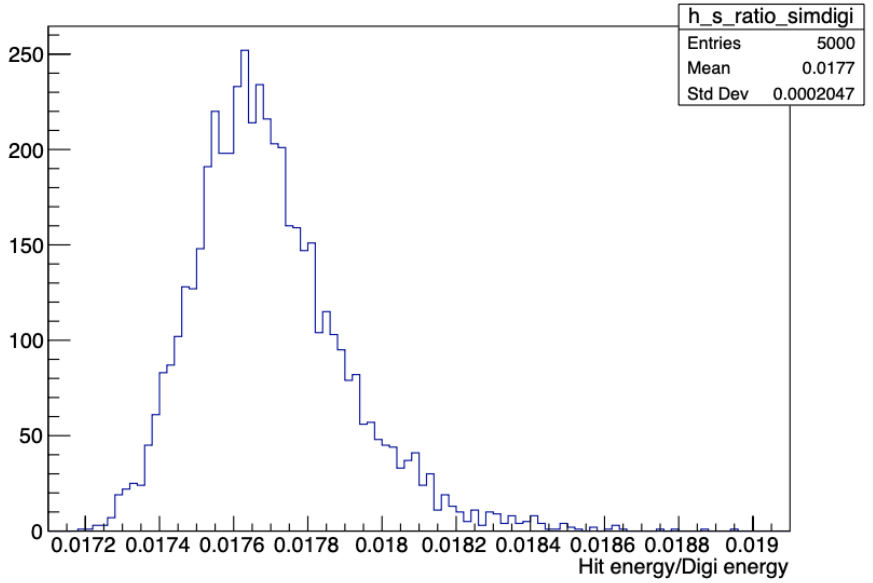
Cherenkov



Scintillation

Fibre multiplicity





Hit E/Digi E

APRIL (Algorithm for Particle Reconstruction @ ILC)

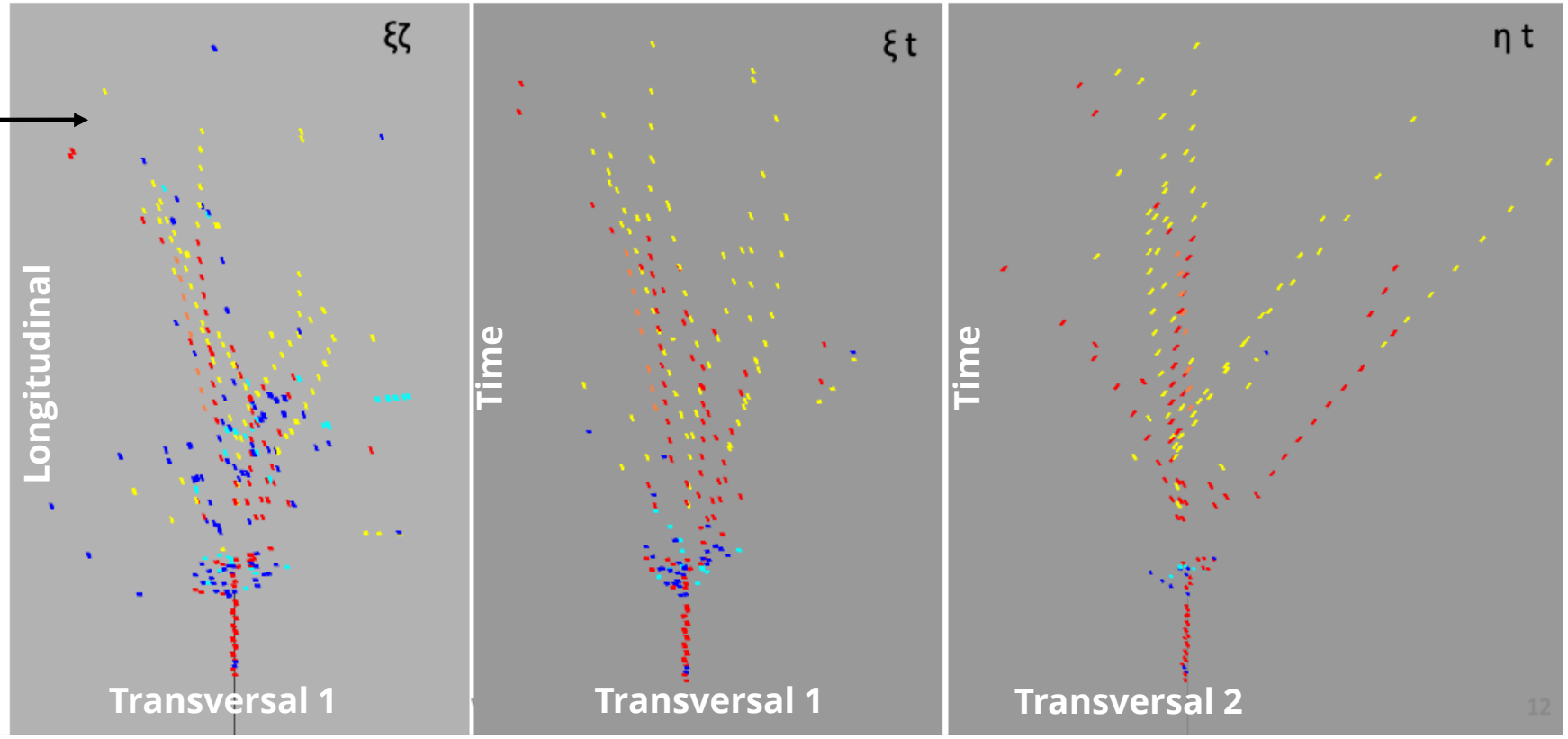
Include timing in PFA

- Preliminary ILD (detector) MC study to include timing in PFA
- Working on digitiser including timing (E and t resolution) for ILD SiW-Ecal and semi-digital Hcal (SDHCAL)
- Looking at CMS HGCAL (high granularity) reco for inspiration

APRIL PFA

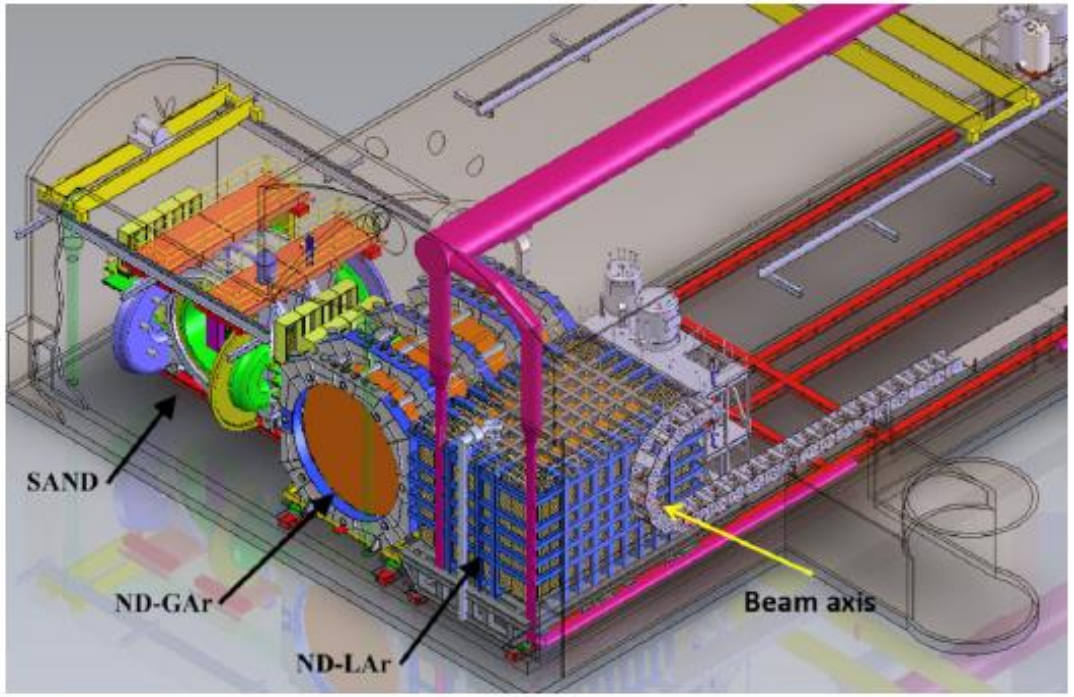
- Developing an algorithm to split big clusters as an alternative to Pandora reclustering method
- Testing the concept on SDHCAL prototype MC simulation will begin soon.

Same shower, different 2D projections (Ecal & Hcal)



Blue electrons, Cyan positrons, Red pions, Orange kaons, Yellow protons

Reconstruction for DUNE Near Detector (ND)



FERMILAB-PUB-21-067-E-LBNF-PPD-SCD-T

Three components: ND-LAr, ND-GAr, SAND.
ND-LAr and ND-GAr can move off axis.

- **ND-LAr:** ν-Ar interactions for comparison to FD. Pixelated readout accommodates high rate.
- **ND-GAr:** high pressure GArTPC surrounded by ECAL, 0.5T magnetic field, muon system.
- **SAND:** magnetised beam monitor - an inner tracker (2 tech options) surrounded by ECAL.

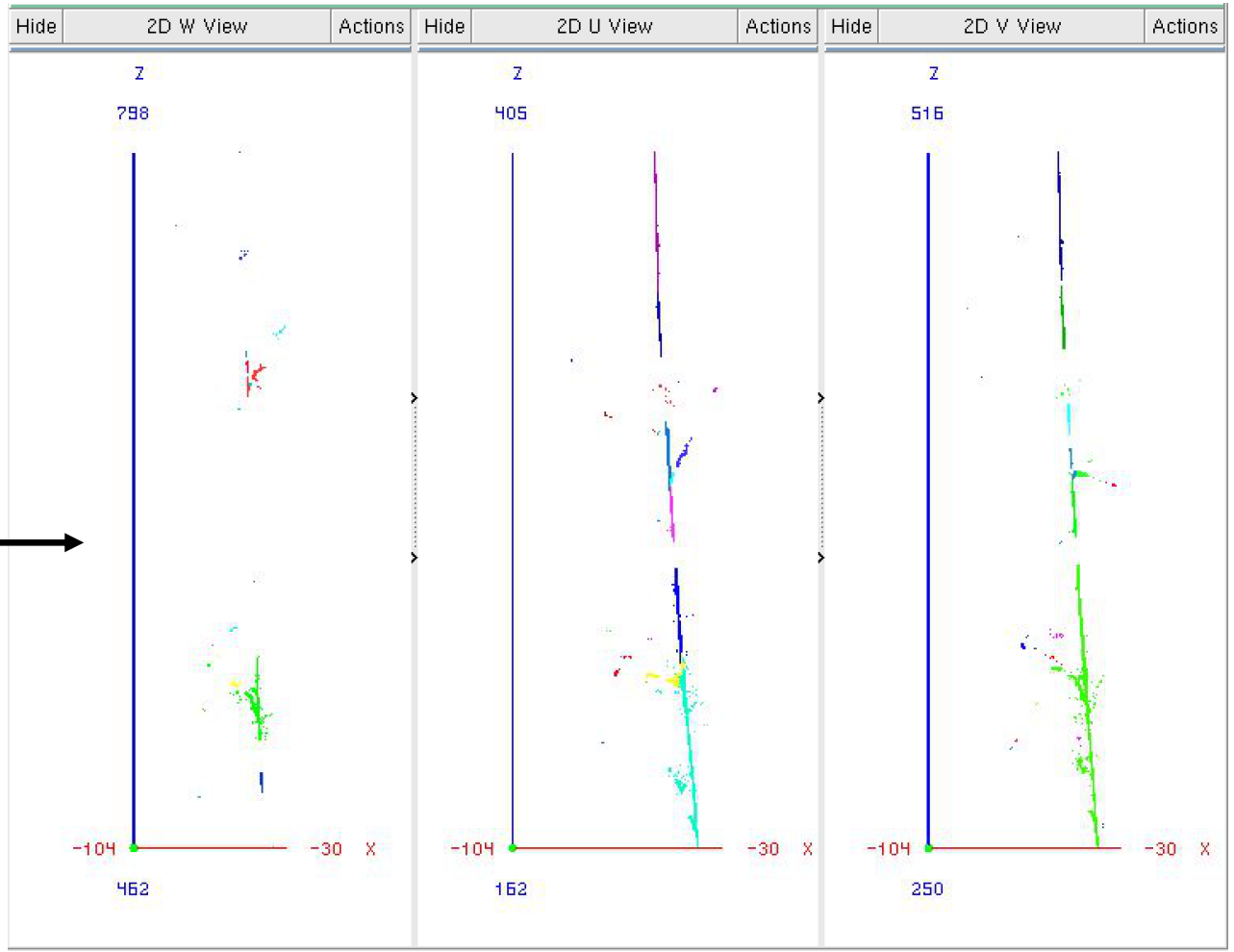
System for on-Axis Neutrino Detection

Day 1: Temporary Muon Spectrometer will be added (MINOS-style steel-scintillator sandwich calorimeter).
Will eventually be replaced by ND-GAr (plans not finalised)

- **Pandora** reconstruction: will initially use LArTPC & ILC algorithms for DUNE ND
- Adapting **2D-view** algorithms (u,v or w with common drift-time coordinate) to work with **native 3D** hits
- Planning to have 0.5 PostDoc working at Cambridge soon (combining with other funds)

LAr calorimeter simulation & reconstruction

- Simulation uses **edep-sim** (https://github.com/ClarkMcGrew/edep-sim)
  - G4 hit "segments": start & stop points
  - Ionization & scintillation processes
  - No hit digitisation
- Can pass these hit lists to Pandora **LArReco**:
  - 3D and/or 2D TPC views ux, vx, wx
    where x = drift time coordinate
  - Hit position = 0.5*(start + stop)
- Preliminary **2D LArTPC clustering** →
- Working on **hit voxelisation**
  - Allow basic cleanup (e.g. MIP cuts)
  - Apply energy calibration
  - More points along (start,stop) path to enhance features for reconstruction



10 GeV muon: W, U and V 2D views