Advanced Particle Flow

- **Development of advanced particle flow and pattern recognition algorithms in PandoraPFA**
- **Application to LHC, LC and neutrino experiments**

J. S. Marshall, *introducing work on behalf of many people,* 30 September 2016

Pandora for MicroBooNE

AIDA 2020

Pandora has been used for the official MicroBooNE summer analyses presented at Neutrino 2016

MicroBooNE Software Stack

- Neutrino event generator: GENIE 2.8.6 (and GENIE 2.10.6 for systematics studies)
- Cosmic event generator: CORSIKA v7.4003
- Particle tracking + detector response: GEANT v4.9.6.p04d + LArSoft v04_36
- Reconstruction: LArSoft v05_08 + Pandora v2.3.0a

M. Toups First Results From MicroBooNE 48

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- 7/4/16 MICROBOONE-NOTE-1019-PUB
  Convolutional Neural Networks Applied to Neutrino Events in a Liquid Argon Time Projection Chamber
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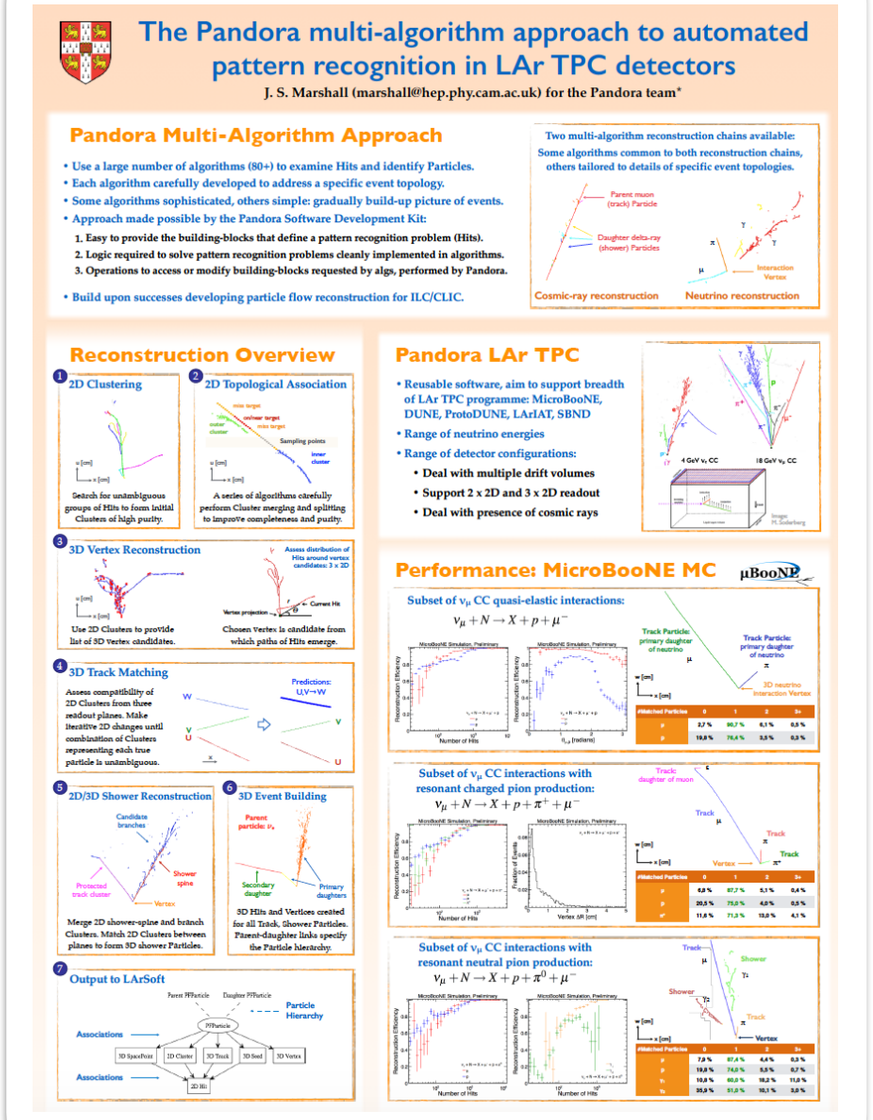
  A Method to Extract the Charge Distribution Arriving at the TPC Wire Planes in MicroBooNE
- 7/4/16 MICROBOONE-NOTE-1016-PUB
  Noise Characterization and Filtering in the MicroBooNE TPC
- 7/4/16 MICROBOONE-NOTE-1015-PUB
  The Pandora multi-algorithm approach to automated pattern recognition in LAr TPC detectors

Also at Neutrino2016 poster session



Status at time of Neutrino 2016 very well documented

Public note available here

Pandora for MicroBooNE

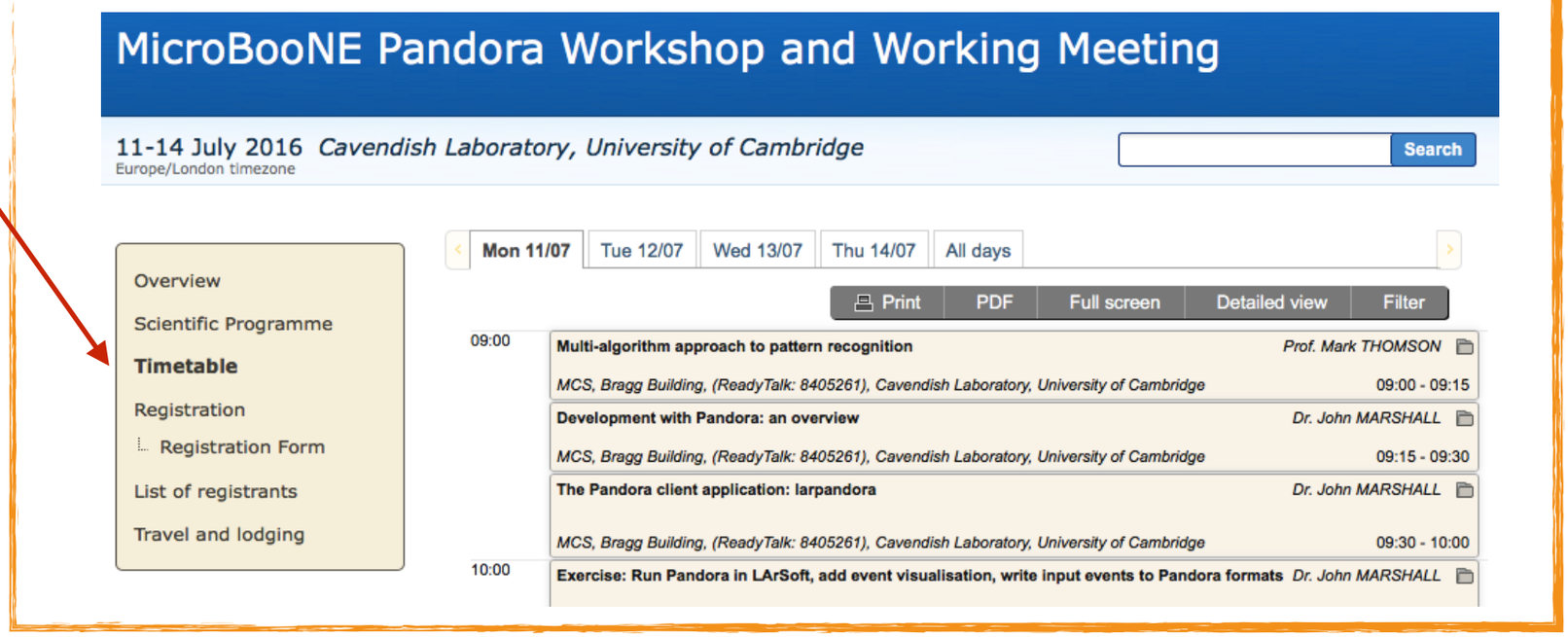
- **Hosted inaugural Pandora Workshop this summer in Cambridge, focused on MicroBooNE LAr TPC reco.**
- **4 days of talks and exercises after Neutrino 2016. Opportunity to understand all aspects of Pandora.**

Exercises:

1. Run Pandora in LArSoft
2. Create and configure a new algorithm
3. Add alg implementation for cluster creation
4. Add alg implementation for cluster merging
5. Add alg implementation for particle creation
6. Use output to LArSoft in an analyser
7. Particle merging
8. Track-Shower ID
9. More (Example content)

Exercises and Talks available from Indico or GitHub

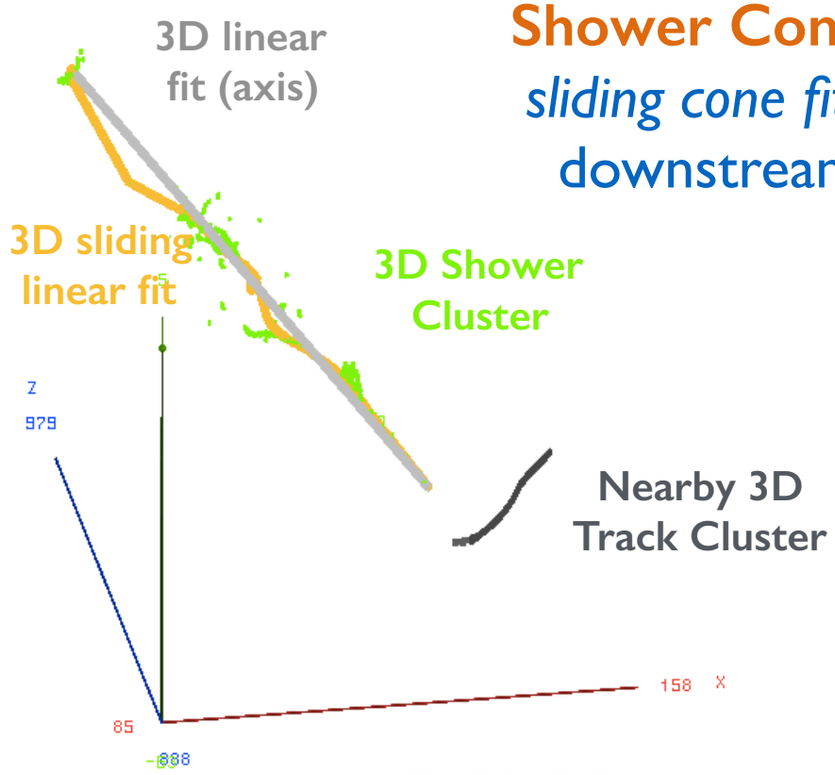
A great success, very good feedback. Will likely repeat (and inc. DUNE)



Pandora for MicroBooNE

Shower Completeness:

sliding cone fits to collect downstream fragments

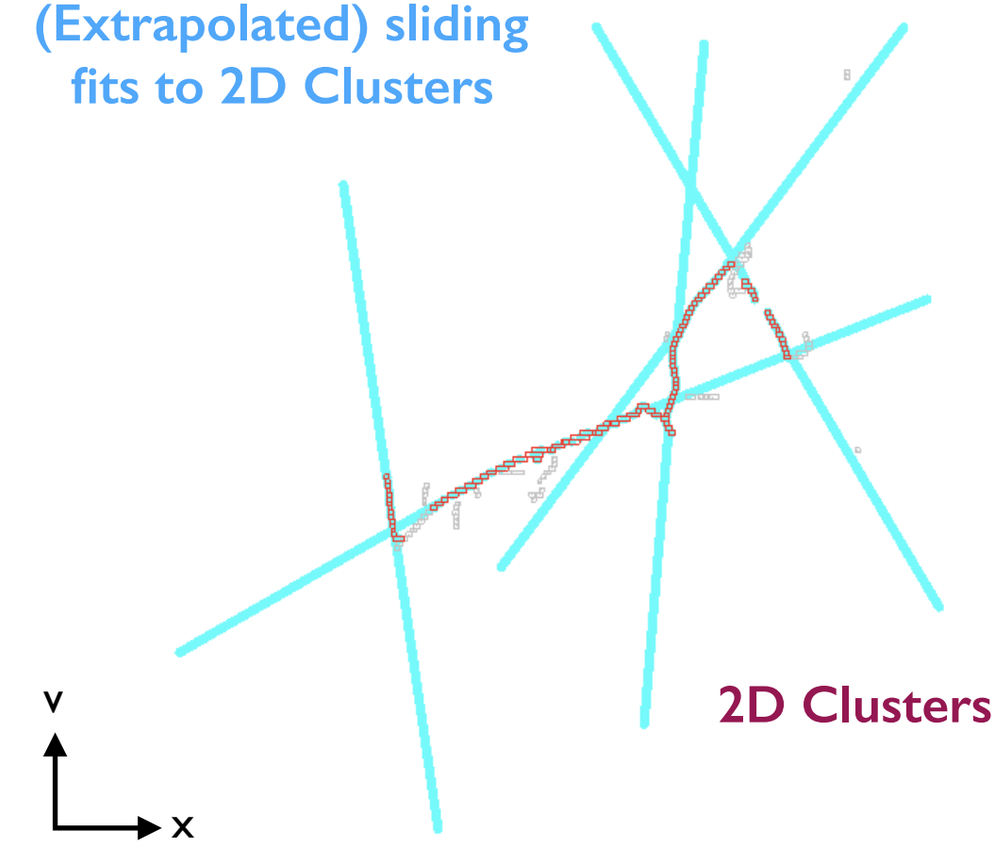


Currently working hard to identify and address remaining issues in the complex and diverse event topologies

Vertex Improvements:

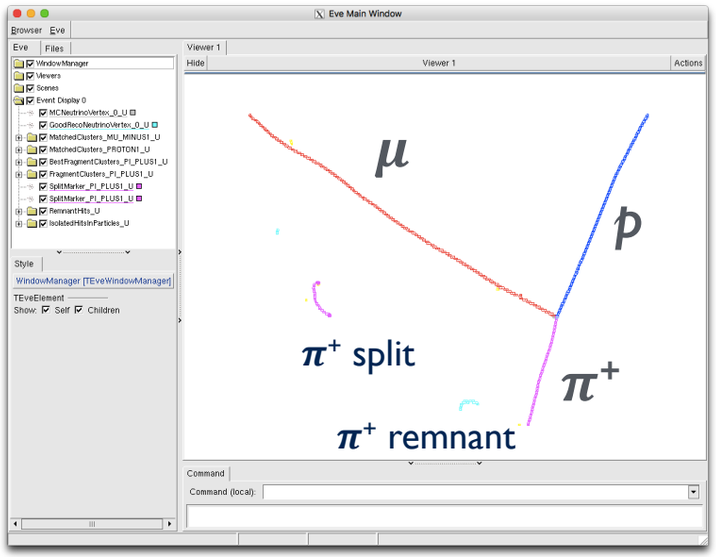
Additional vertex candidates and improved vertex selection approach

(Extrapolated) sliding fits to 2D Clusters



Event Validation Tools:

Colour-coded Particles and feature points

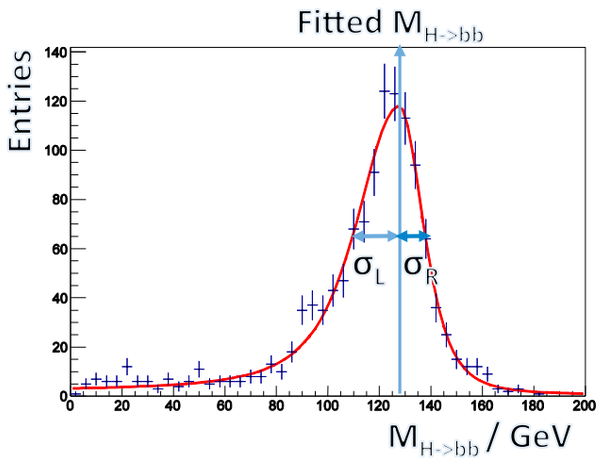


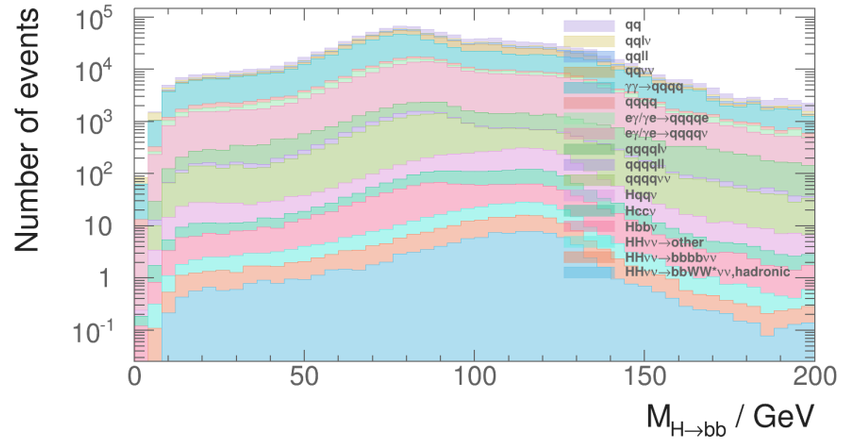
Pandora for ILC and CLIC

- **Double higgs analysis to measure the triple higgs coupling and the quartic coupling using HH->WWbb sub-channel.**

- Reconstructed invariant mass is important for jet pairing and for MVA.

- PFA crucial for providing an excellent jet energy and di-jet mass resolution.

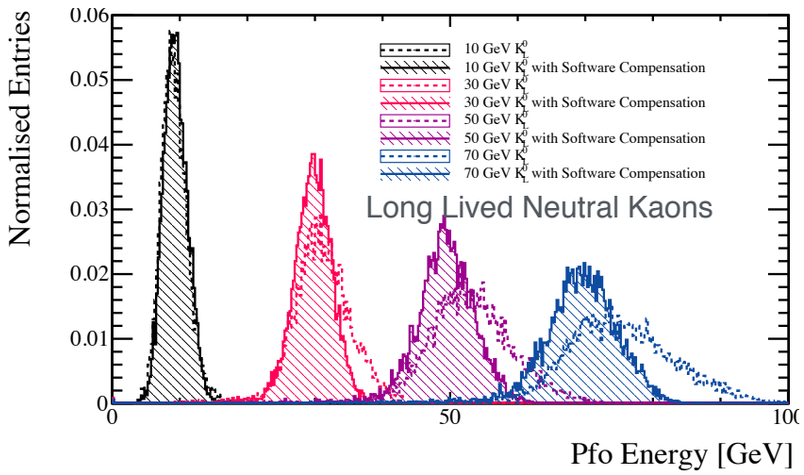


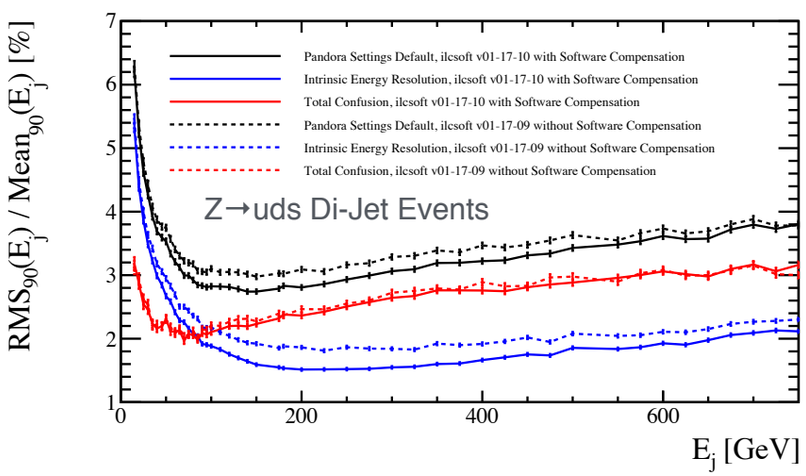


- **Software compensation has been applied to a non-default ILD detector that contains 60 layer HCal. The performance was then tested at CLIC like energies exceeding 1.4 TeV.**

- Calibration procedure refined to include training for software compensation.

- Once again a significant gain in performance was observed.





ILD with 60 Layer HCal

Update from CERN:

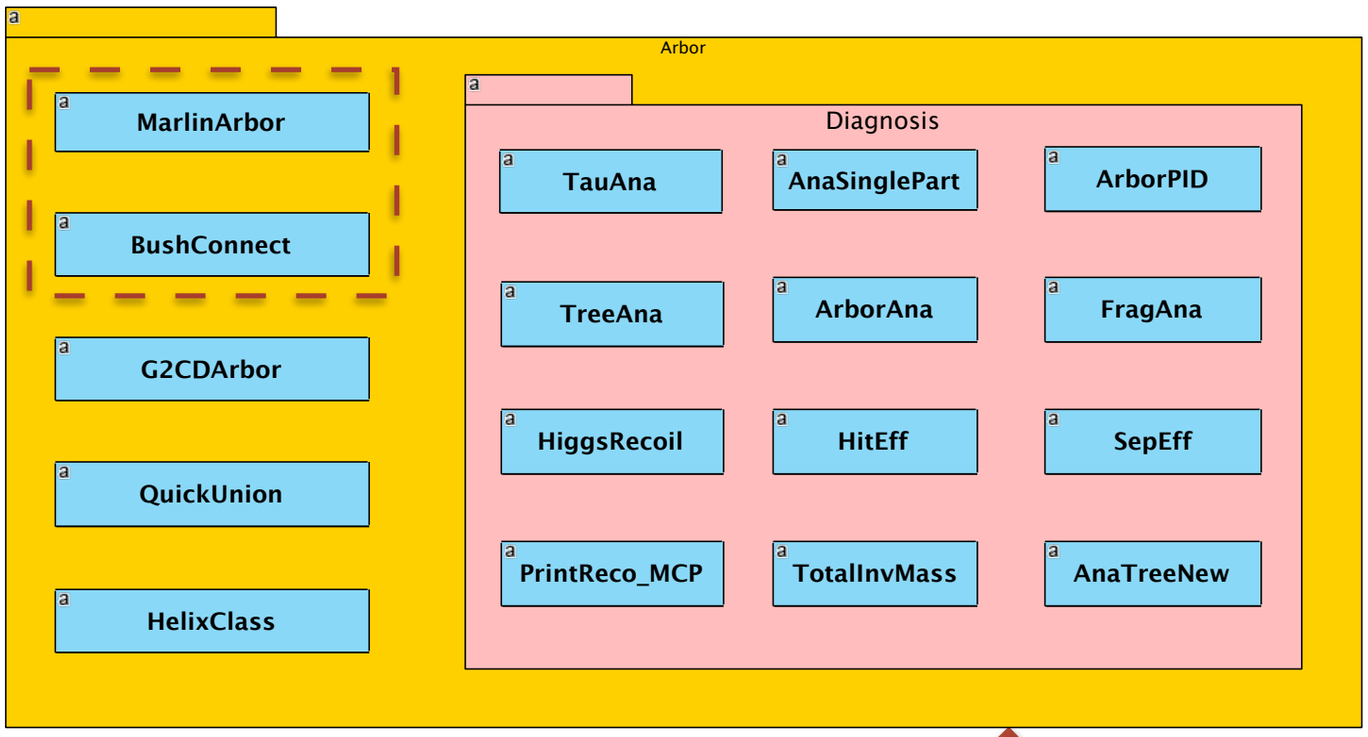
- Matthias Weber has been using the Pandora calibration toolkit with data simulated and reconstructed using DD4hep.

- Includes retraining of latest Pandora photon reconstruction algorithms, which uses a multivariate approach to separate photons from nearby charged hadrons.

Update from LLR / IHEP:

- Will now hand-over to Bo Li, who will describe recent progress with Arbor.

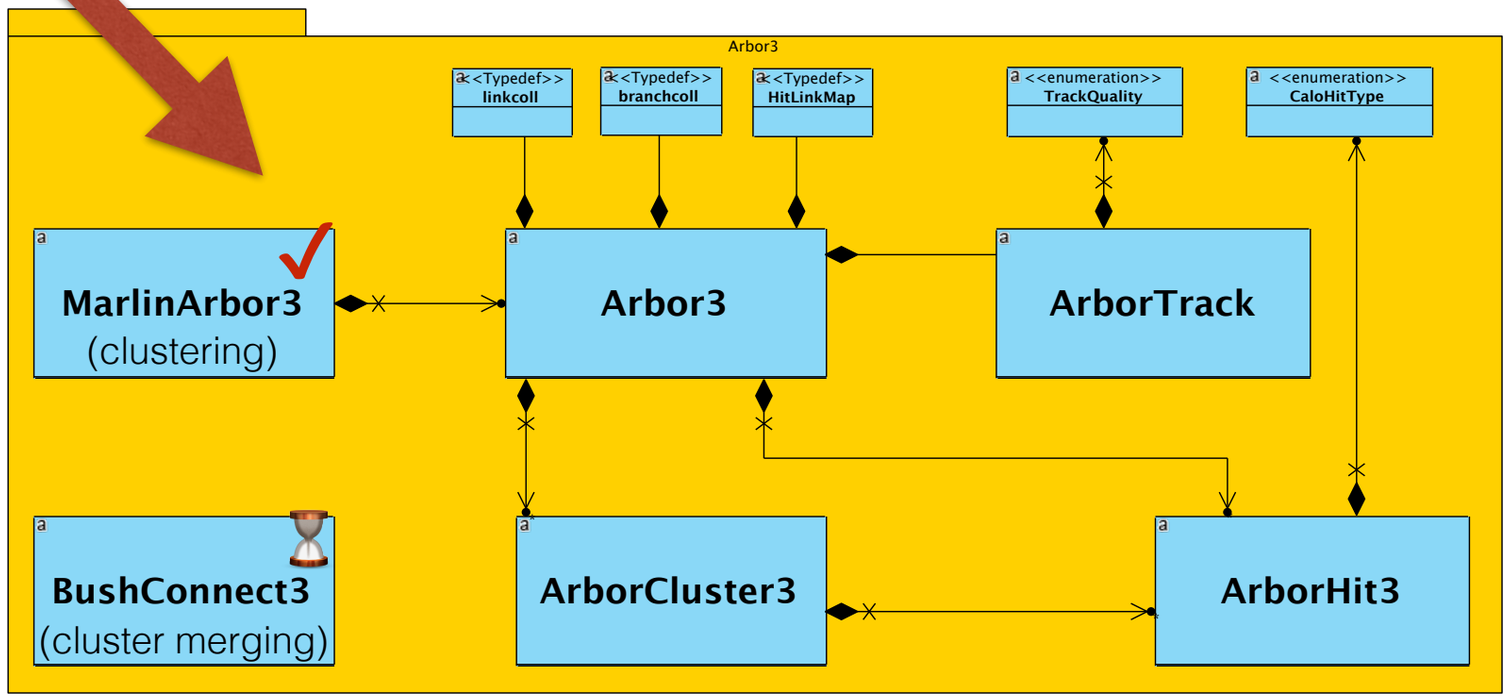
The updates of Arbor



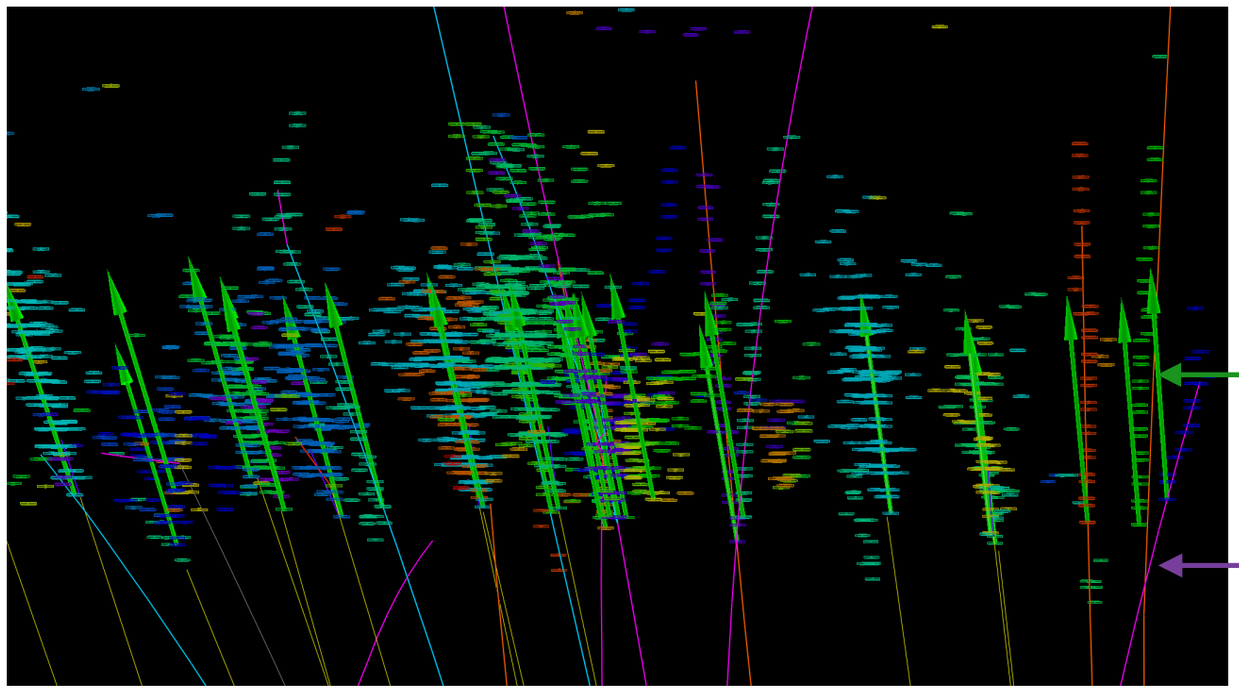
- **Refactoring**
- Reimplement the clustering code with considerations of clarifying the algorithm logic and reducing CPU time.
- Rewrite the codes in an OOP style.

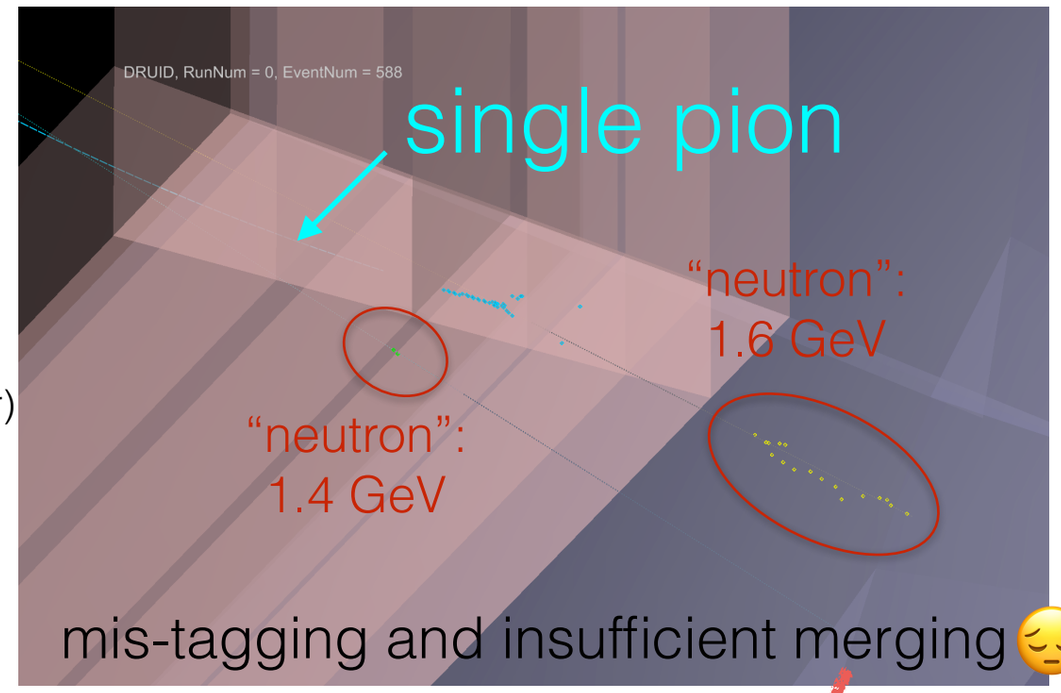
- **Updates**
- Add the options of using time and pre-clustering in the clustering procedure
- Take hits in TCMT into account
- Move hard-coded parameters to steering file

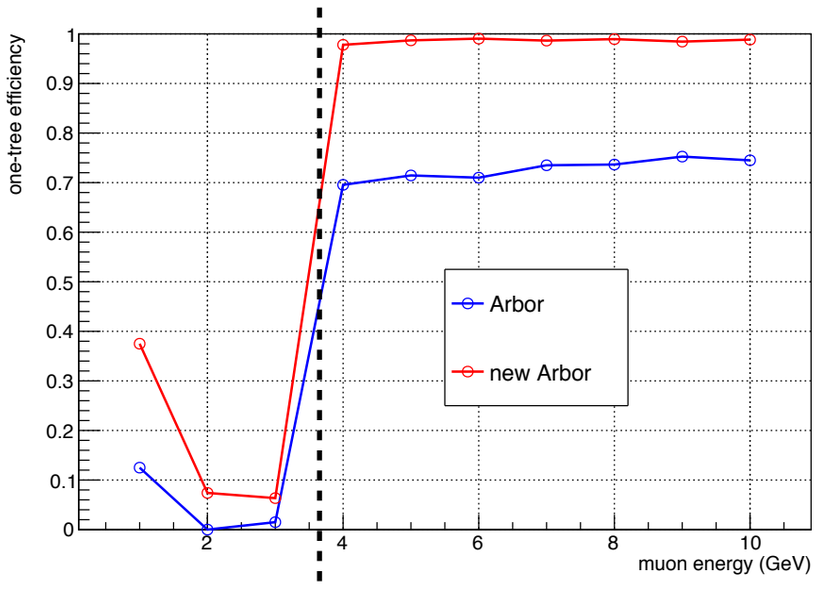
- **Ongoing**
- The algorithm of track-cluster matching and cluster merging(BushConnect) is still under optimization.
- The performance of the sub-algorithms used, such as photon tagging, is to be validated.

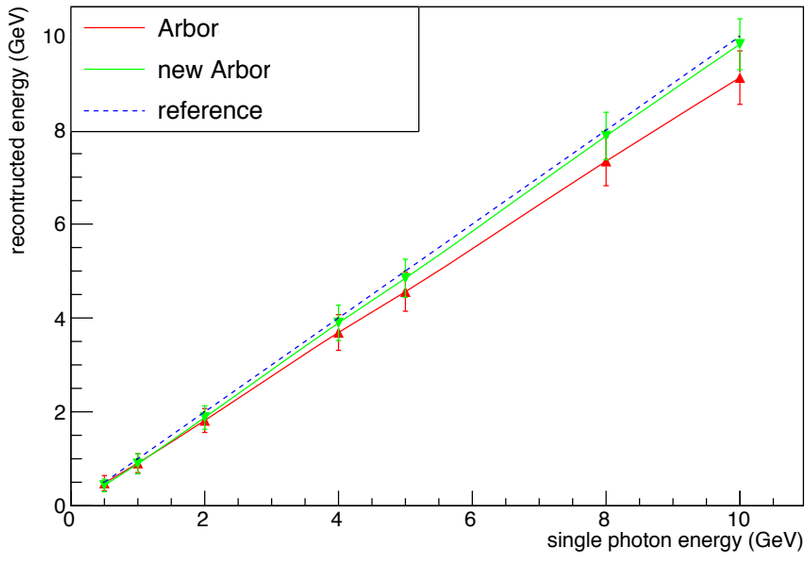


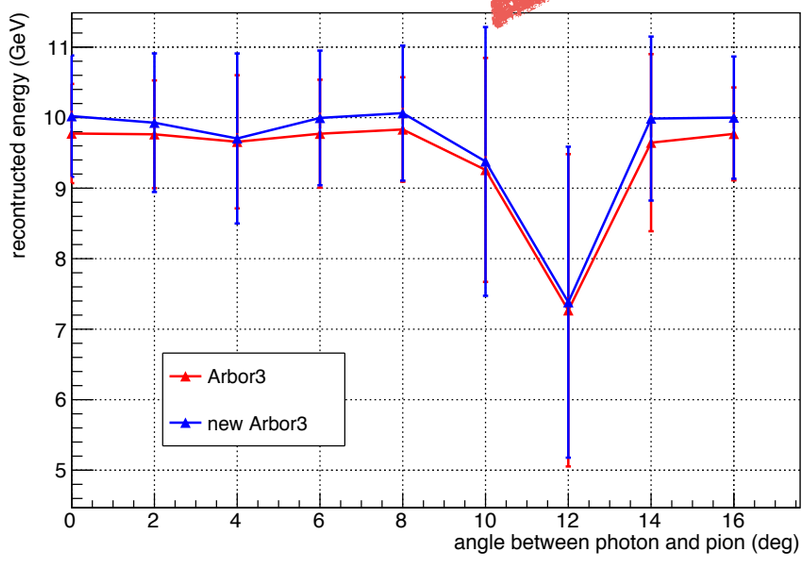
Preliminary performance











- The clustering performance of new Arbor3 is better than before
- Merging and tagging performance have to be improved

The git repository

master | Arbor | Find File

Name	Last Commit > 2b5810b4 – about 14 hours ago Merged code from branch. History	Last Update
examples	Build the k-d tree just before the hit linking.	about a month ago
source	Merged code from branch.	about 14 hours ago
.gitignore	Cosmetics	about 21 hours ago
Arbor Code v3.mm	Cosmetics	about 21 hours ago
CMakeLists.txt	update Vincent's email	about 23 hours ago
README	new commit	5 months ago

https://gitlab.com/bo.li/Arbor

- For studying the performance, the old Arbor code is still kept in the repository.
- Here is a tag (v3.4.0) of Arbor. We will keep going on for optimizing and test algorithm, and hopefully a formal release will be before December.