A New Event Analysis Framework for Future Higgs Factories

Di-Higgs Jet Reconstruction Using coffea

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coffea and EDM4hep: Novel Event Analysis

Columnar Object Framework for Effective Analysis (coffea):

- Fast, object-oriented pythonic analysis framework: makes use of awkward-array (numpy-like module with ragged arrays) and dask
- Vectorized and avoids use of loops
- Removes having to interface with files imports, 4-vector creation, and array managment from analysis process
- Object structure allows user to focus on physics

Event Data Model for High Energy Physics (EDM4hep):

- Data format intended for common use on future colliders projects as part of the Key4hep project

coffea and EDM4hep are still in development. Part of this project has been working on adding the EDM4hep data structure into coffea. All of the following analysis was done with coffea and EDM4hep.

What is a Higgs Factory and Why Do We Need One?

A Higgs Factory is

- a high energy lepton collider run at an ideal energy for the production of Higgs bosons
- designed to have very low backgrounds, which allows for high precision measurements of properties of the Higgs boson

These precise measurements could give insight into:

- CP violation
- matter/antimatter asymmetry
- the nature of dark matter

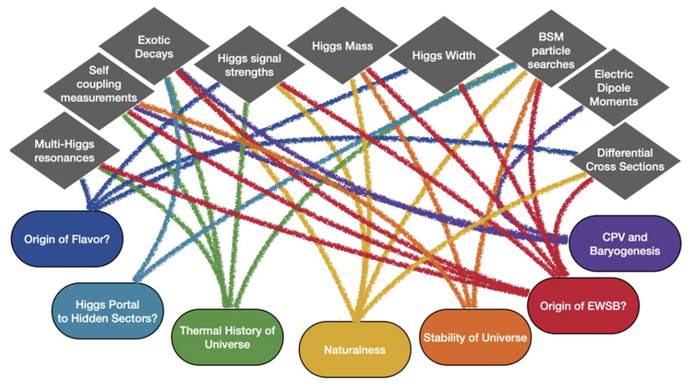


Fig. 1: Source: [1]

Higgs self-coupling could also be studied at a much higher cross section through more common decay channels. This would give insight into the shape of the Higgs potential.

The study below is looking at di-Higgs jet reconstruction for the Cool Copper Collider (C^3), a newly proposed future Higgs Factory [2].

Event Selection

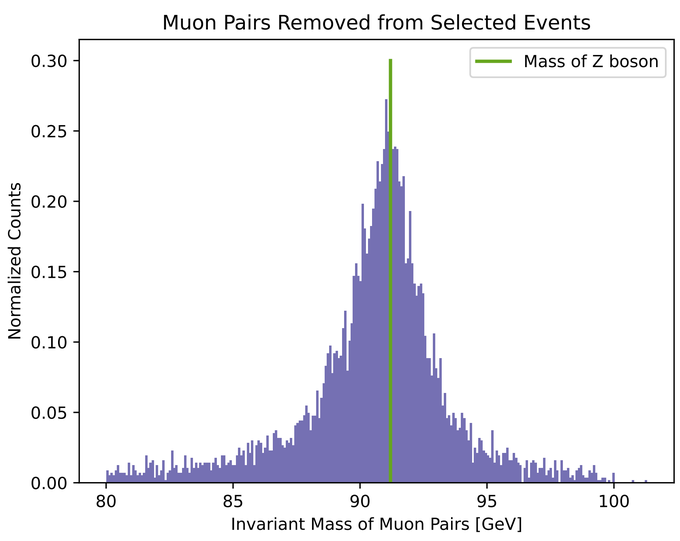
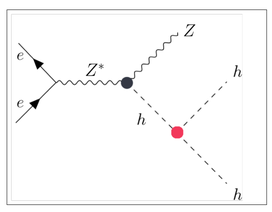


Fig. 2: We remove the muons coming from the Z boson before creating jets.

Events:

- Events simulated in Whizard 2.8.5 for ILC
- All events have two Higgs bosons and a Z boson



Event Level Selection:

- Select only events with a muon pair between 80 and 100 GeV

Inner Event Selection:

- Remove the muon pair closest to 91.2 GeV

Jet Reconstruction using fastjet

We are looking at the decay channel of Higgs boson to a b-quark pair. In a detector, quarks hadronize into a large spray of particles (know as a jet).

In each event we reconstruct 4 jets using fastjet [3] with:

- exclusive clustering
- k_t algorithm
- $R = 1$

Benefits of using fastjet:

- modern pythonic version of FastJet
- integrates easily with coffea
- columnar approach makes it very fast

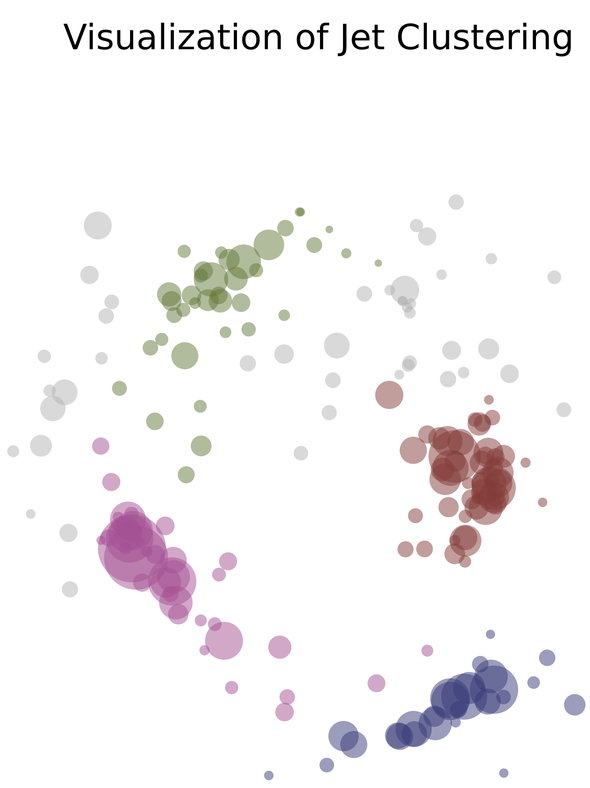


Fig 4: Illustration of jet clustering for one event. Each point is a particle in space. Each colour represents a jet, with the grey being particles not included in any jet. The size of a point corresponds to the energy of that particle.

Results

- four jets were created and combined into two dijets
- the particles in the dijets were compared to the true particles from the Higgs using linking

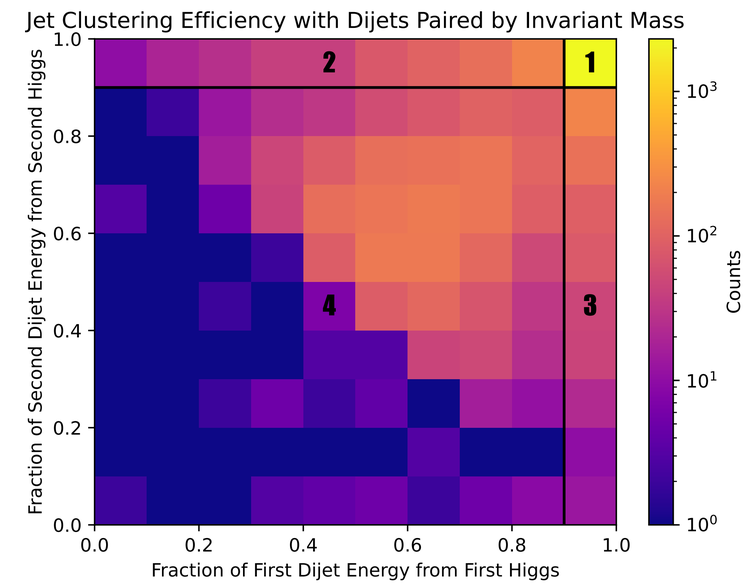


Fig. 5: This gives a benchmark of how well jets are being reconstructed, as ideally, they would all fall into Region 1.

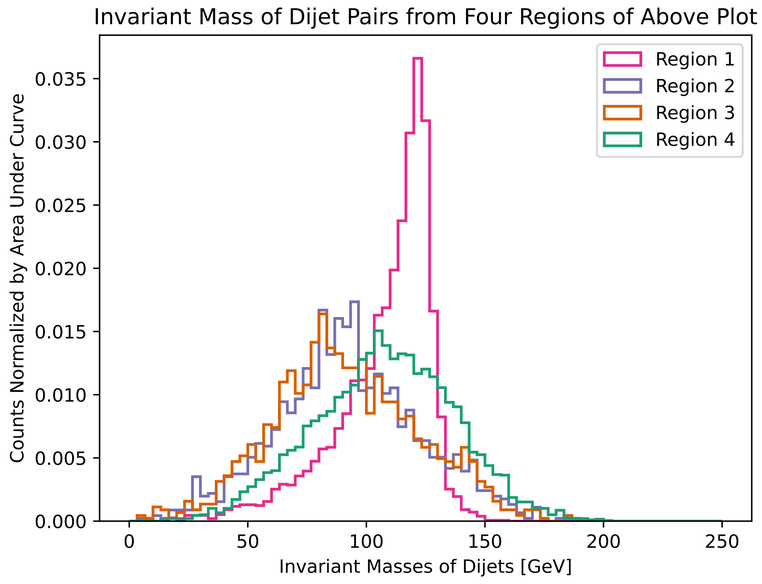


Fig. 6: This shows what might be causing problems in jet reconstruction and where we can improve.

References

[1] S. D. et al, "Report of the topical group on higgs physics for snowmass 2021: The case for precision higgs physics," 2022.

[2] M. B. et al, "C^3: A "cool" route to the higgs boson and beyond," 2021.

[3] A. Roy, J. Pivarski, and C. W. Freer, "An array-oriented python interface for FastJet," *Journal of Physics: Conference Series*, vol. 2438, p. 012011, feb 2023.