



Jet Pairing Methods for Hadronic ZH Production at the FCC-ee

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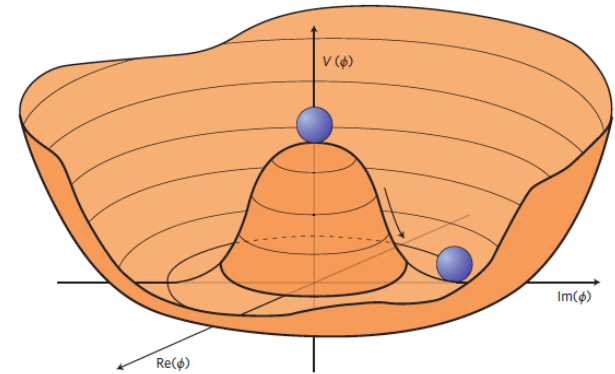
Under the direction of Elizabeth Brost and Abraham Tishelman-Charny

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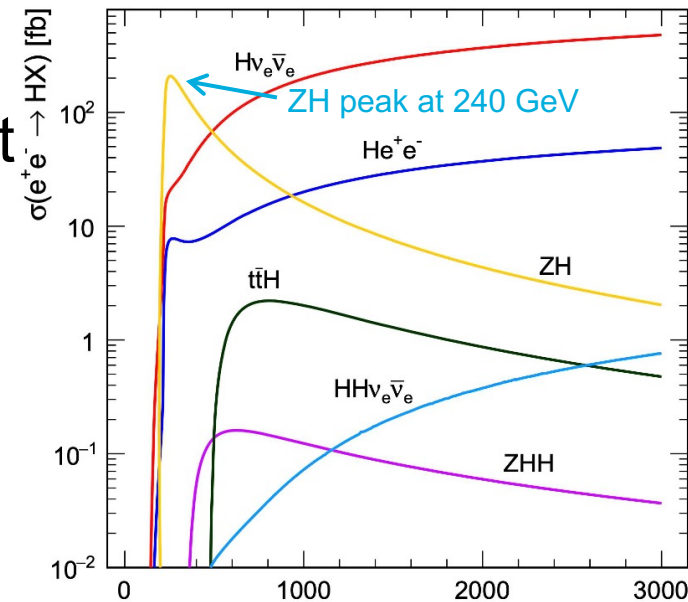
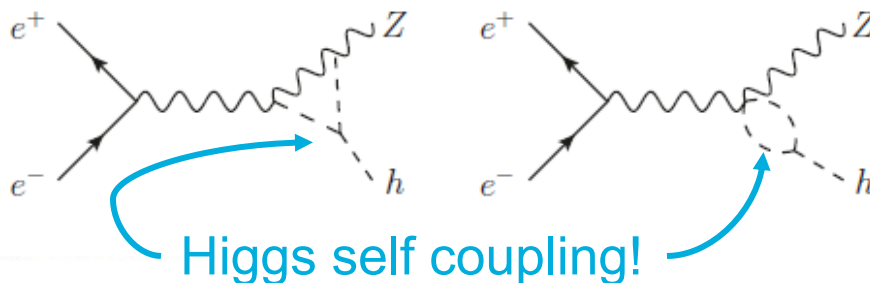


Motivation

- We want more precise measurements of the Higgs potential
 - Has implications on the stability of the universe
- Higgs self-coupling is directly related to the Higgs potential.
- Need to utilize a Higgs production channel with highest cross-section at FCC-ee
- ZH process is best candidate in a e^+e^- collider at 240 GeV



source: CERN



Cross sections for Higgs production \sqrt{s} [GeV] processes at an e^+e^- collider

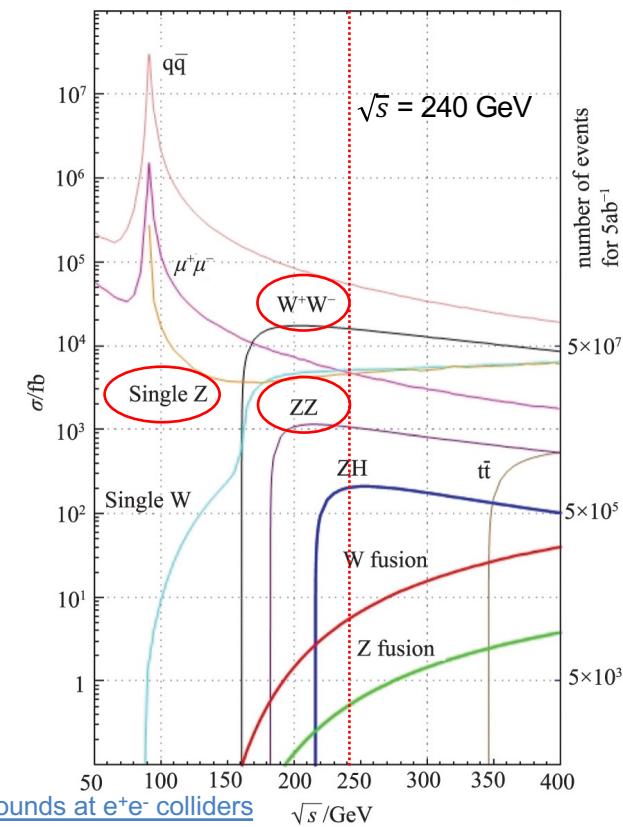
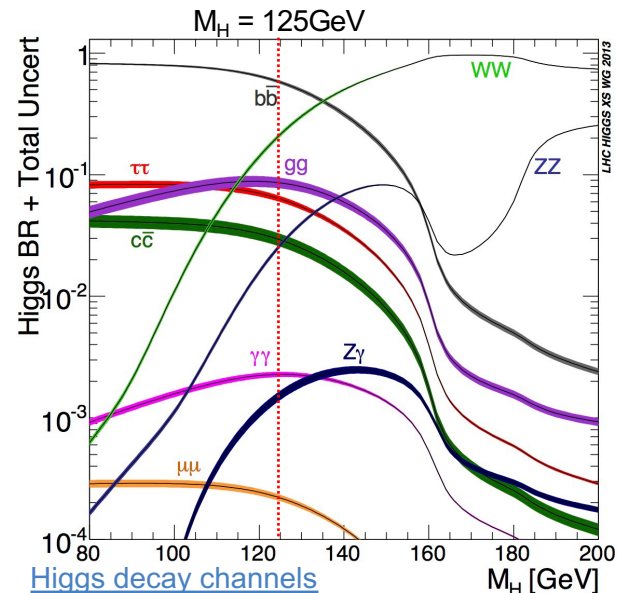
[arXiv:1307.5288](https://arxiv.org/abs/1307.5288)

Signal

- We're interested in studying the hadronic decay modes of ZH
- Focus on the $ZH \rightarrow c\bar{c}b\bar{b}$ process
 - $H \rightarrow b\bar{b}$ is the predominant decay mode at a Higgs mass of 125 GeV
 - $Z \rightarrow c\bar{c}$ gives a less interfering signal because $H \rightarrow c\bar{c}$ occurs infrequently
 - Ultimately study all decay modes

Background

- Used a few of the major backgrounds found at electron-positron colliders:
 - WW, ZZ, Zqq



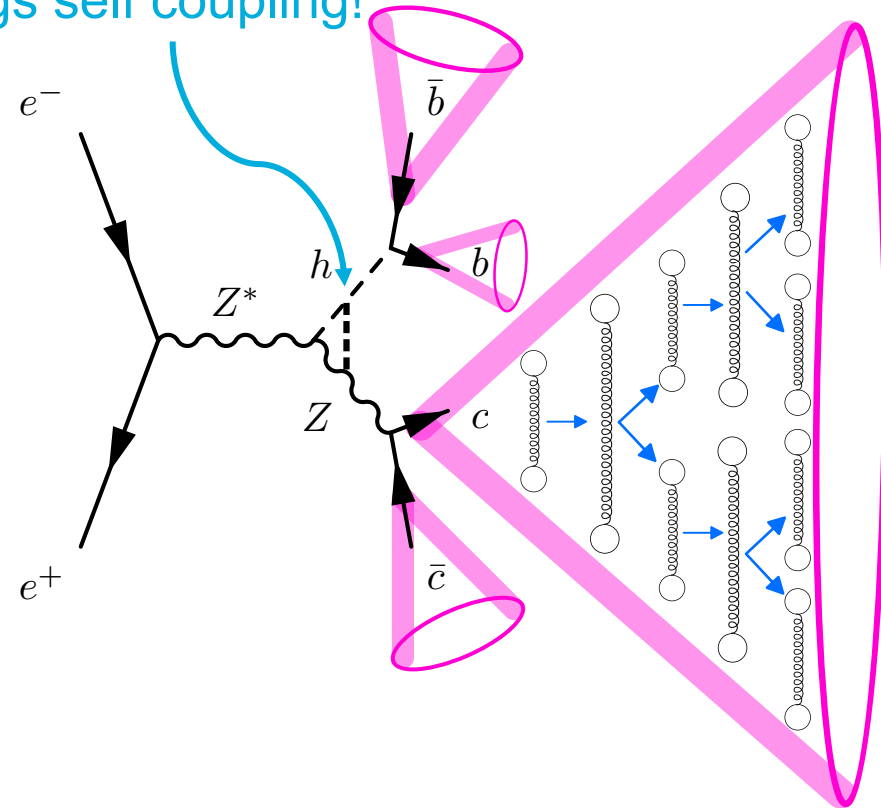
Jet identification process:

After ZH decays, it hadronizes into 4 jets

Use FCCAnalyses to analyze observations:

1. Reconstruct **exactly 4 jets** using Durham-kt algorithm
2. Compare methods of jet assignment of Z boson
3. Compare truth particle position to reconstructed jet location

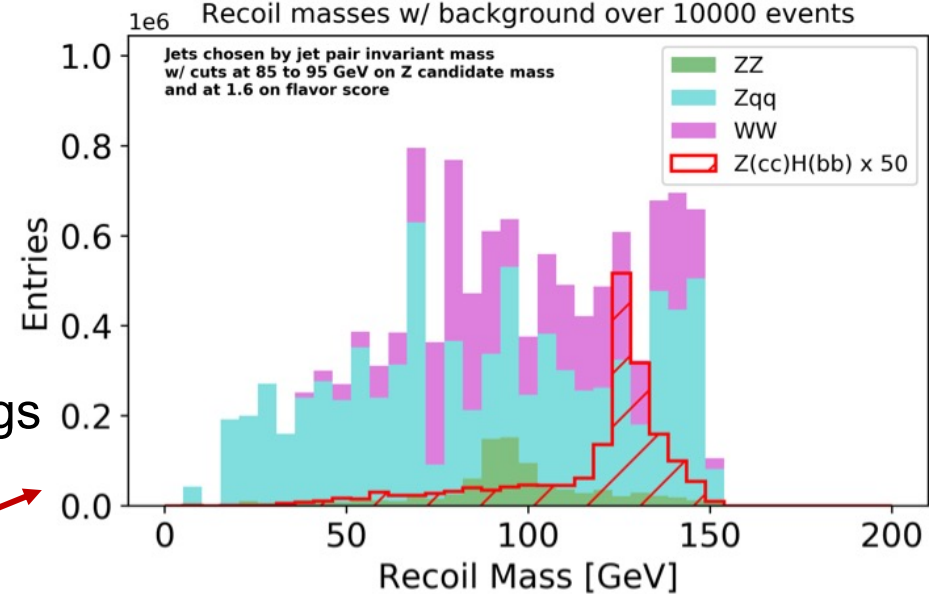
Higgs self coupling!



Identifying Z Candidate Jets

[Source code](#)

- $ZH \rightarrow c\bar{c}b\bar{b}$ simulations using IDEA detector (winter2023)
 - generated with Whizard and PYTHIA
- Compared **two methods** to choose “correct jets”
 - Identify Z boson jets
 - Calculate recoil mass as the Higgs signal

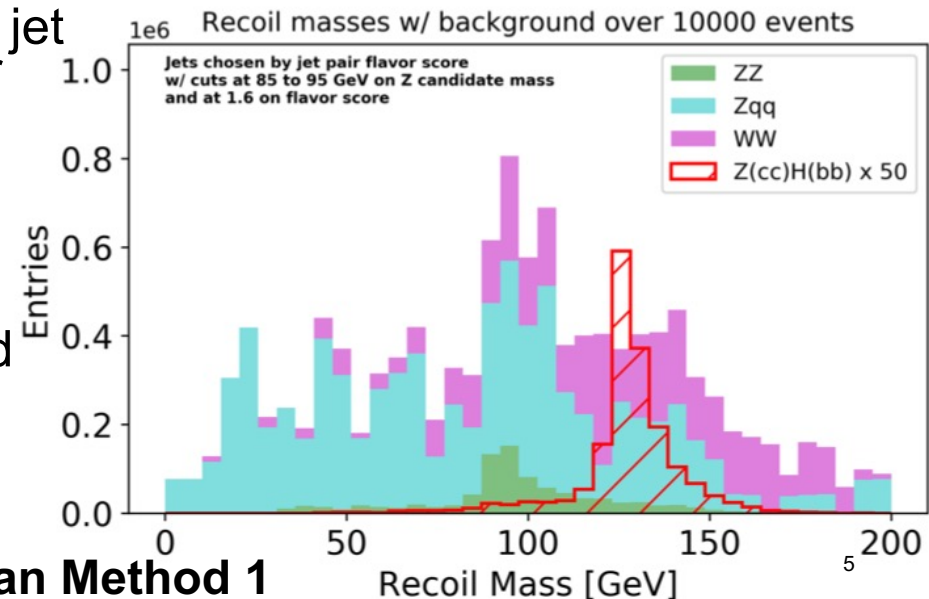


Method 1: Invariant Mass

- Calculate invariant mass of each jet pair permutation, then select pair closest to Z boson mass

Method 2: Flavor Score

- Neural network determines the likelihood that a jet was produced by a certain quark, in this case looking for charm quarks.

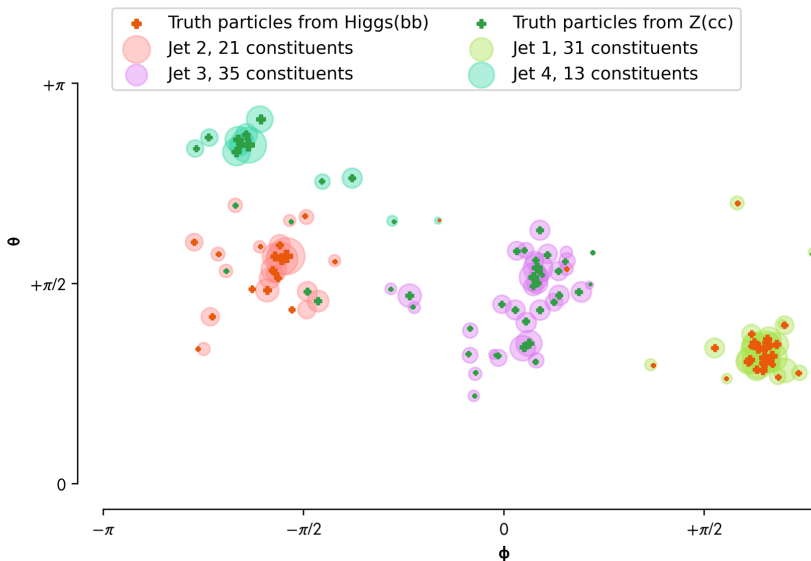


$\frac{S}{\sqrt{B}}$ for Method 2 is 1.36 times greater than Method 1

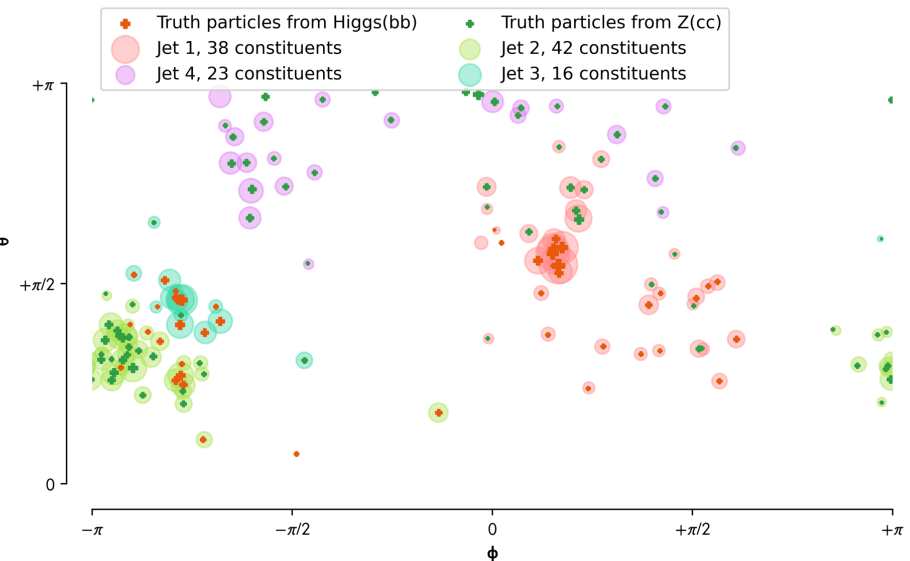
Truth Information

- Allows us to understand how often we're selecting jets correctly.
 - More useful than $\frac{S}{\sqrt{B}}$, which is calculated using reconstructed data
- Mapped truth particles and jet assignment to make visual observations about reconstruction choices
- Reconstruction not perfect (see right) --- motivates study of other reclustering methods

Z(cc)H(bb) events, after selections, Durham-kt N=4



Z(cc)H(bb) events, after selections, Durham-kt N=4



Observed particles sorted by jet, graphed by location on phi and theta

Conclusions and Next Steps

- Studying ZH process at FCC-ee with eventual goal of using it to constrain Higgs self-coupling
- Able to reconstruct jets and determine truth information, which will continue to be helpful in other analyses.
 - Implemented FCCAnalyses software
- Two methods identified for tagging Z boson jets: invariant mass and flavor score.
 - Flavor score method performed better using reconstruction information, now must check if truth information agrees.
- Must compare other reconstruction algorithms and modes (e.g. anti-kt)

Acknowledgments

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This project is not export controlled

Vacuum Stability

[source](#)

