PROBING HZZ AT FCC-EE

I. Kahraman and O. Çakır*

Ankara University, Ankara, Türkiye

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The future circular e+e- collider (FCC-ee) would allow the Higgs scalar sector to be probed with high precision beyond that achievable at the LHC. Focus of the Higgs searches at the e+e- collider would be model independent determination of the Higgs couplings to gauge bosons and fermions. The measurement of single Higgs boson production cross section, using recoil mass or invariant mass methods, set the scale for Higgs coupling measurements. The studies have considered mostly the process e+e-→HZ (where Z decays into two opposite charge sign leptons) for the recoil mass method applied. However, in other studies it is shown the hadronic decays of the Z boson improves the sensitivity due to larger branching ratio. In this work, both the leptonic and hadronic final states considered to enhance the sensitivity. The results are compared at two center of mass energies 240 GeV and 365 GeV of the FCC-ee.

The Higgs boson is one of the most important particles sensitive to the new physics beyond the standard model (BSM) of particle physics, which was discovered at the LHC by the ATLAS and CMS collaborations [1]. It is also connected to numerous fundamental questions, then studies of its properties at future circular colliders (FCC) may provide some answers.

In the production and/or decay modes of the Higgs boson, the couplings to vector bosons and/or fermions can be probed precisely at the FCC-ee [2]. In this work, both the leptonic and hadronic decays of the Z boson (Fig. 1) considered to enhance the sensitivity. With the higher integrated luminosity of about 5/ab, corresponding to high statistics events, measurements can be performed with a binning and almost model independent way.

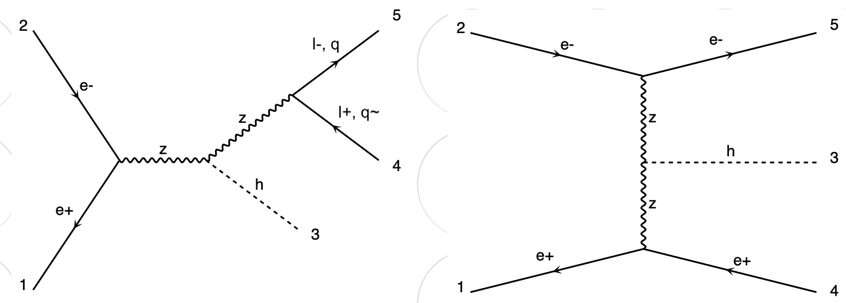

Fig.1: Single Higgs boson (h) production process (with 2l or 2j) including HZZ vertex.

The cross sections of the signal (Fig.2 weighted) and background processes (Fig.3 unweighted) have been produced with MadGraph5 [3]. Hadron level events are obtained from Pythia8 [4]. Detector simulation has been performed using Delphes [5] with IDEA detector card with small size samples for validation. Simulated events have been analyzed by using PyRoot [6]. Recoil mass measurement at different center of mass energies can be performed using relation

$M^2_{\text{recoil}} \simeq \left(\sqrt{s} - E_{f\bar{f}}\right)^2 - \vec{p}^{\,2}_{f\bar{f}} = s - 2\sqrt{s}E_{f\bar{f}} + m^2_{f\bar{f}}$

where $m_{f\bar{f}}$ peaks around m_Z, and M_{recoil} peaks around m_H.

Fig.3: Unweighted signal (HZ) and background (ZZ, WW, TT, OTHER) used in the analysis. Relevant event weights can be used in the analysis for the simulation at FCC-ee.

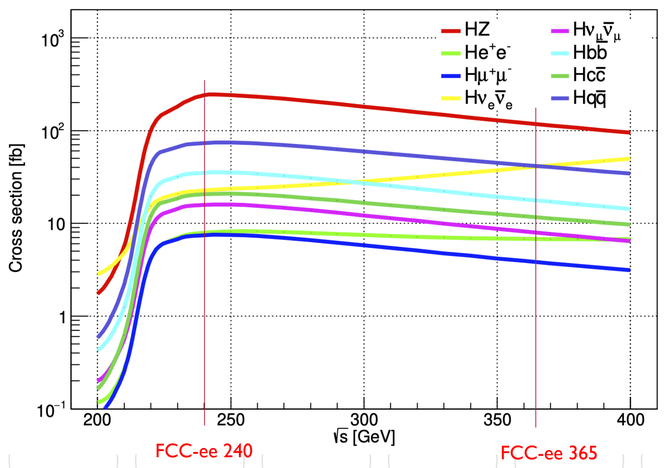

Fig.2: Cross sections for single Higgs boson (H) production processes at a range of center of mass energies 200-400 GeV.

One of the key determinants of the measurement precision of HZZ is the narrowness of the recoil mass peak (Fig.4). Leptonic recoil mass analysis gives a fine precision on HZZ at $\sqrt{s}$ = 240 GeV (where the cross section is the largest for HZ production) compared at $\sqrt{s}$ = 365 GeV. Hadronic recoil gives less precision due to jet energy resolution σ_E which also scales linearly with energy [7]. The detail of the uncertainty study on ZH production cross section at two different energies (240 GeV and 365 GeV) can be found in a recent study Ref. [8].

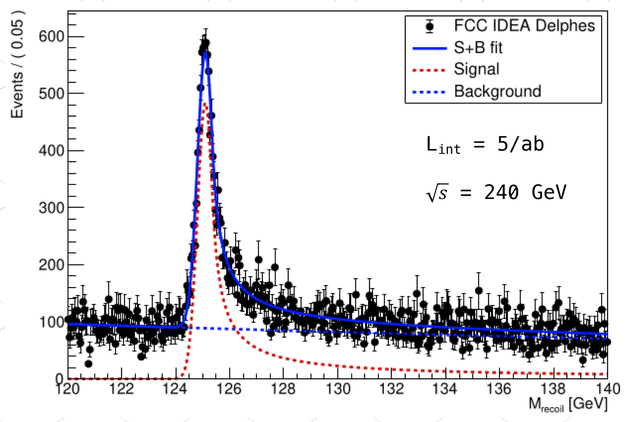

Fig.4: Recoil mass spectrum from signal (S) and background (B) with a DSCB fit implementation in the analysis.

Further analysis have been performed with scripts within FCCSW [9] using larger statistics samples from central production. Within the events, Z boson is reconstructed from the high-mass dilepton or dijets. Dominant backgrounds resulting in two leptons and/or two jets are determined from various backgrounds, and fits to dilepton or dijet invariant mass distributions of Z boson candidates as well as fits to two jet invariant mass distribution of Higgs boson candidates are used to extract the number of signal events. S/B optimization with cuts on H to dijets and Z decay pairs (applying cuts on Pt, Eta, Mll, Mjj, Pll, etc.), the ZH production cross section can be measured with a better precision in different ranges of leading particle momentum at different center of mass energies. The recoil mass method are used to measure Higgs mass with an uncertainty of about 10 MeV at $\sqrt{s}$=240 GeV and 40 MeV at $\sqrt{s}$=365 GeV.

The total cross section of HZ production $\sigma(e^+e^- \to HZ) \propto g^2_{HZZ}$ and final state ($H \to f\bar{f}$) is proportional to $g^2_{HZZ} \times g^2_{Hf\bar{f}} / \Gamma_H$. At FCC-ee the cross section for HZ production is expected to about 0.5% accuracy.Different production modes or decay modes can be determined by the ratio of $\sigma \times BR$ values. Therefore, probing HZZ from the recoil mass distributions is essential.

Considering all possible opportunities makes FCC-ee stand out among other Higgs factory proposals. Especially at 240 GeV, for ZH study, significant efforts are awaiting experimentalists and theorists to reduce systematic uncertainties and achieve advanced statistical precision.

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* ikahraman@ankara.edu.tr