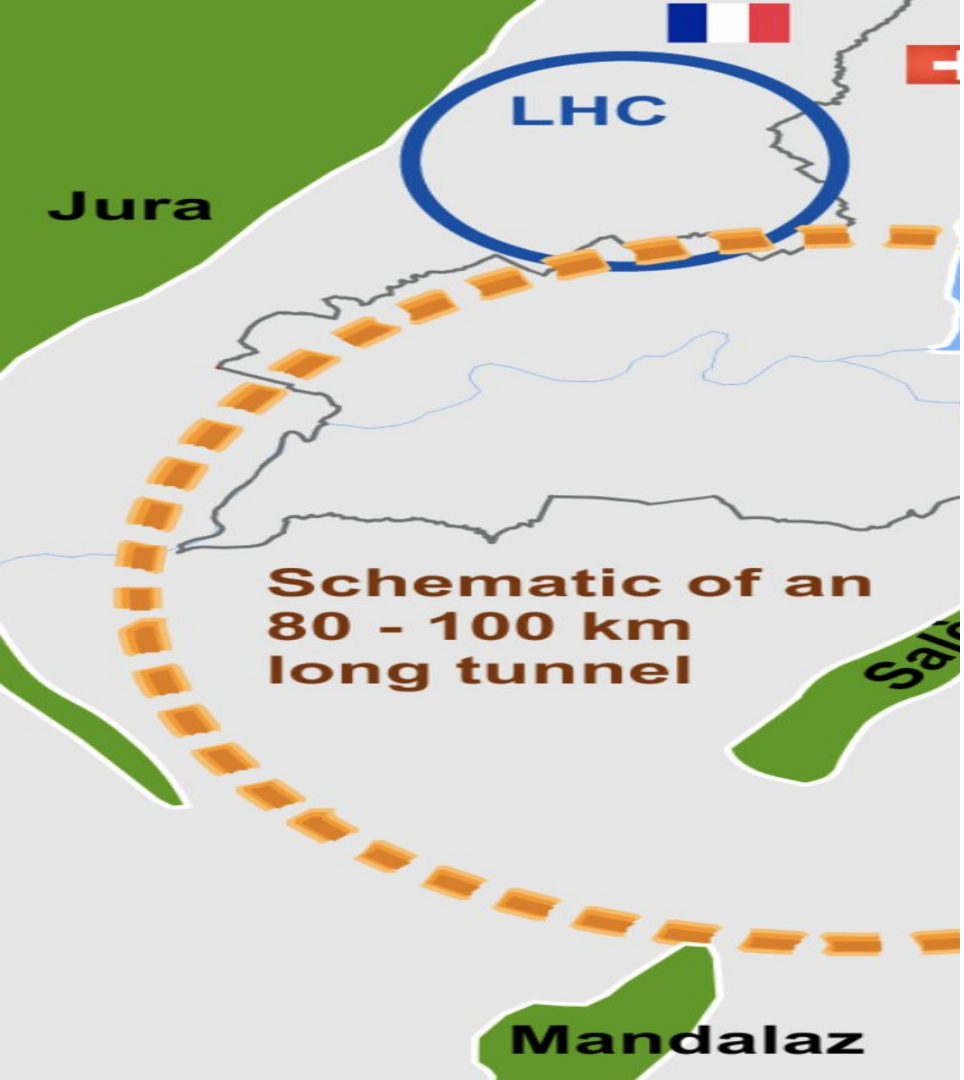

LOI Discussion

Recoil Mass and Higgs Coupling Measurements

EF02 Snowmass Meeting
November 12th, 2020

Markus Klute - MIT

Letter of Interest

Letter of Interest: Search for new scalars at FCC-ee

Aram Apyan,[a] **Markus Klute,**[b] **Tianyu Yang**[b]

[a] *Fermilab, USA*
[b] *Massachusetts Institute of Technology, USA*

Abstract: The FCC-ee provides a rich dataset at center-of-mass collision energies between 90 and 365 GeV. This data can be used to search for new scalars with couplings to the Z boson. We explore the Z boson recoil mass spectrum in search for beyond the standard model signature.

Letter of Interest: Higgs boson coupling measurements to charm quarks at FCC-ee

Aram Apyan,[a] **Matthew Baldwin,**[b] **Franco Bedeschi,**[c] **Gregorio Bernardi,**[d] **Alain Blondel,**[d] **Loukas Gouskos,**[e] **Patrick Janot,**[e] **Markus Klute,**[b] **Giovanni Marchiori**[d] **and Michele Selvaggi**[e]

[a] *Fermilab, USA*
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Abstract: The Higgs boson is expected to decay with a branching fraction of about 3% to $c\bar{c}$. The decay signature will be extremely difficult to isolate and measure at the LHC, but is directly accessible at FCC-ee if an efficient c-tagging algorithm, able to disentangle $c\bar{c}$ decays from other copious hadronic Higgs boson decays ($b\bar{b}$ and gg, and to a lesser extent, ZZ* and WW*) with high purity, can be designed. An ideal (100% efficient and 100% pure) tagging algorithm would yield a measurement of $\sigma_{ZH} \times BR(H \to c\bar{c})$ with a precision better than 1%. Starting from the related experience developed at LHC and other e^+e^- collider projects, and with the help of the latest machine-learning technologies, such an algorithm will be developed, first with fast simulation, and then in the full context of the constraints from the interaction region and detector layout. The impact of the interaction-region and detector design (beam pipe radius, vertexing, vertex mass determination, tracker material, ...) on the precision $\sigma_{ZH} \times BR(H \to c\bar{c})$ measurement will be studied. As a by-product, similar studies for the $H \to b\bar{b}$ and $H \to gg$ decays will be conducted as well. The need for calibration data at the Z pole will be estimated (frequency, number of events).

Overview

Higgs cross section (HZ)

studied leptonic channel

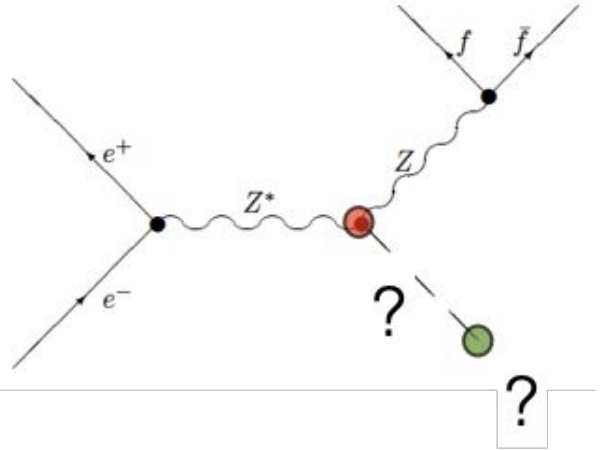
Higgs to invisible searches

studied leptonic and hadronic channels

Searches for new scalars

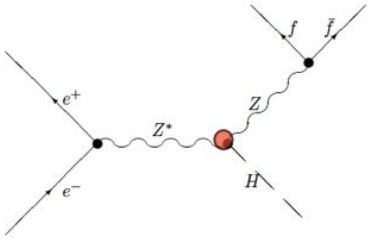
started with leptonic channel

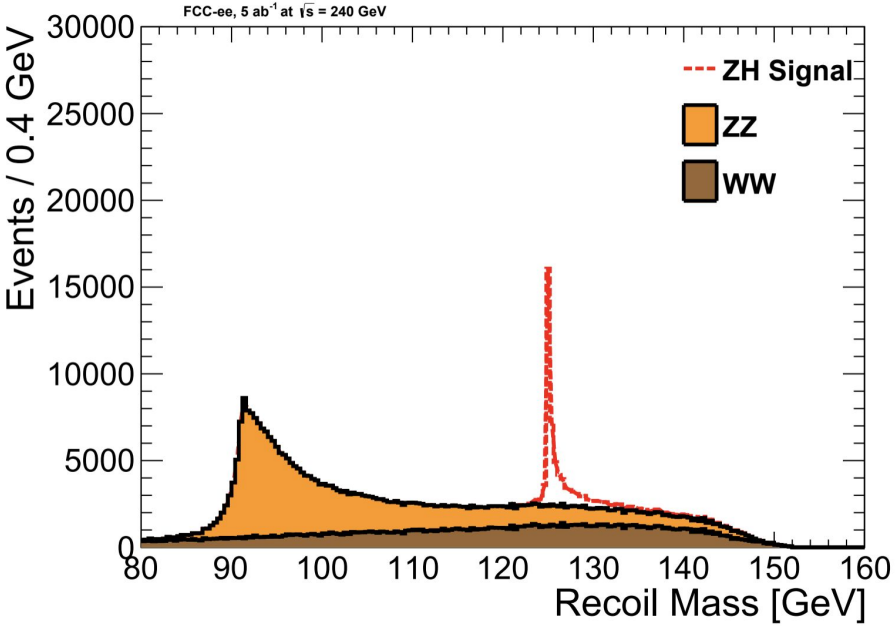
Higgs to bb,cc,gg couplings



$$m^2_{\text{recoil}} = (\sqrt{s} - E_{\ell\ell})^2 - |\vec{p}_{\ell\ell}|^2$$

ZH Cross Section





Dominante background WW and ZZ

Main selection: Z mass, Z trans. and long. momentum, accolinearity, ...

Cross section uncertainty of 0.7% with 5ab^{-1} at 240 GeV

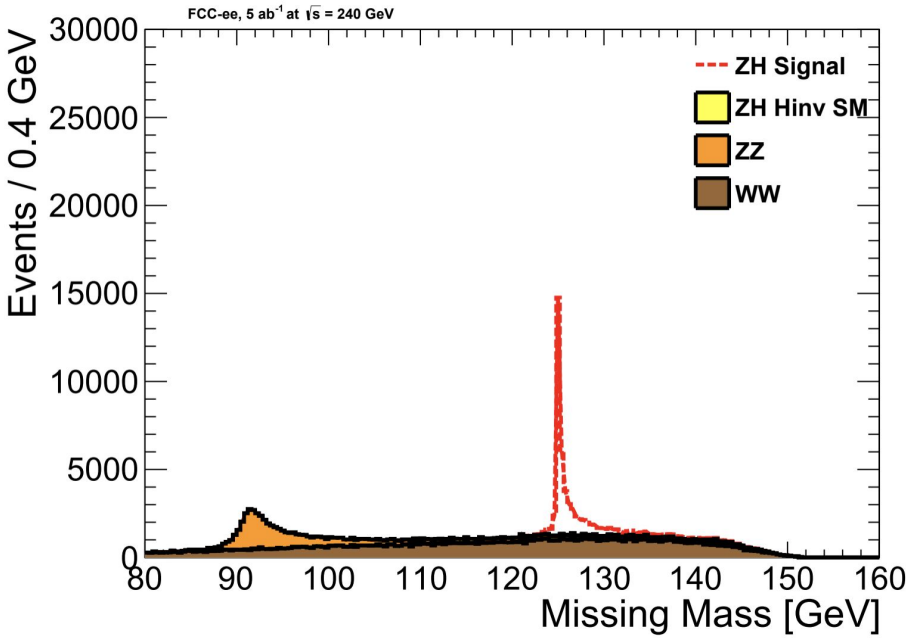
Looking at hadronic channel and adding mass measurement.

Higgs to invisible searches - leptonic channel

Dominante background WW and ZZ

Main selection: Z mass, Z trans. and long. momentum, accolinearity, veto other activity

Upper limit with $5ab^{-1}$ at 240 GeV of 0.5% on Higgs branching ratio to invisible



Also studied here
https://arxiv.org/abs/1605.00100

Higgs to invisible searches - hadronic channel

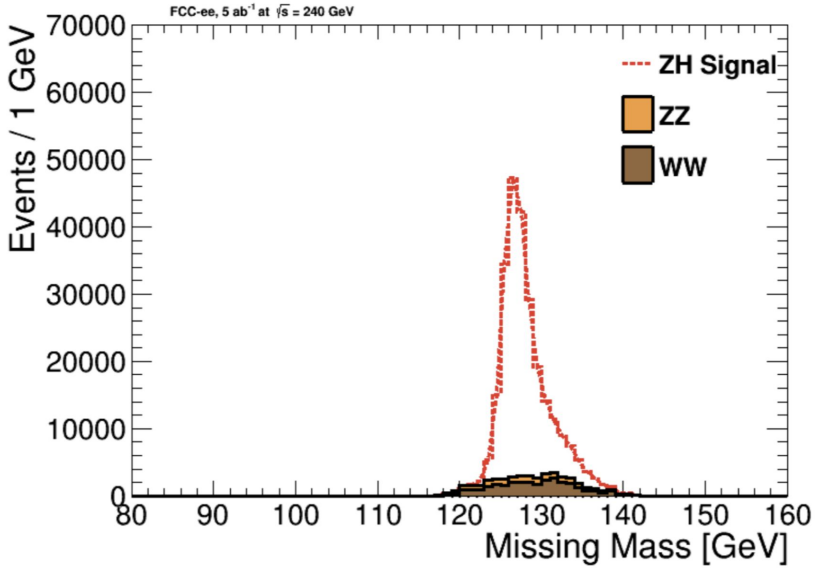
Dominante background WW and ZZ

Main selection: Z mass, lepton veto, limit add. hadronic activity

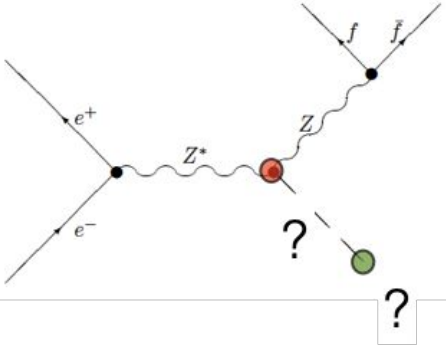
First pass demonstrates power of the hadronic channel

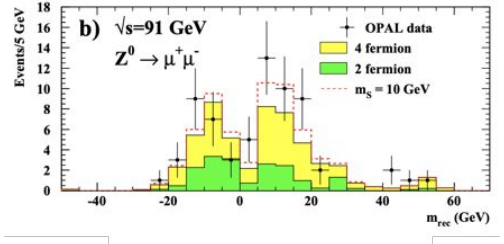
Z(vv)H(bb) sample not yet included. Can we rejected with visible mass cut.

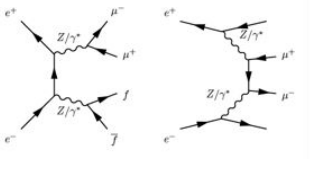
Further optimization with b-tag category, ML, ...



Searches for new scalar







Decay-mode independent searches for new scalar bosons with the OPAL detector at LEP

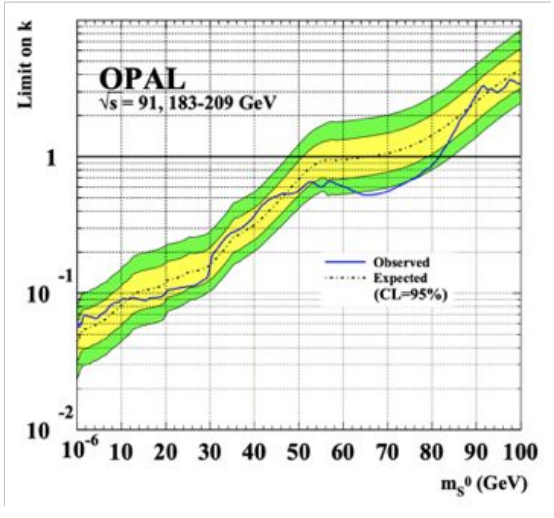
The OPAL Collaboration

Abstract

This paper describes topological searches for neutral scalar bosons S^0 produced in association with a Z^0 boson via the Bjorken process $e^+e^- \to S^0Z^0$ at centre-of-mass energies of 91 GeV and 183–209 GeV. These searches are based on studies of the recoil mass spectrum of $Z^0 \to e^+e^-$ and $\mu^+\mu^-$ events and on a search for S^0Z^0 with $Z^0 \to \nu\bar{\nu}$ and $S^0 \to e^+e^-$ or photons. They cover the decays of the S^0 into an arbitrary combination of hadrons, leptons, photons and invisible particles as well as the possibility that it might be stable.

No indication for a signal is found in the data and upper limits on the cross section of the Bjorken process are calculated. Cross-section limits are given in terms of a scale factor k with respect to the Standard Model cross section for the Higgs-strahlung process $e^+e^- \to H^0_{SM}Z^0$.

These results can be interpreted in general scenarios independently of the decay modes of the S^0. The examples considered here are the production of a single new scalar particle with a decay width smaller than the detector mass resolution, and for the first time, two scenarios with continuous mass distributions, due to a single very broad state or several states close in mass.

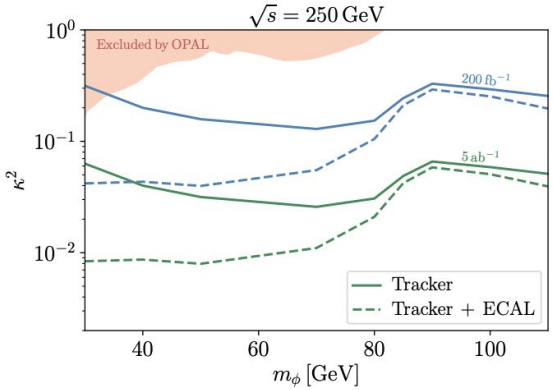


Searches for new scalar

Explore complete FCC-ee dataset

Phase	Run duration (years)	Center-of-mass Energies (GeV)	Integrated Luminosity (ab^{-1})	Event Statistics
FCC-ee-Z	4	88-95	150	3×10^{12} visible Z decays
FCC-ee-W	2	158-162	12	10^8 WW events
FCC-ee-H	3	240	5	10^6 ZH events
FCC-ee-tt	5	345-365	1.5	10^6 $t\bar{t}$ events

Also studied here
https://arxiv.org/abs/1801.08164
https://arxiv.org/abs/1812.08289



Model independent search to be complemented by search with explicit scalar boson signatures

Conclusion

Retraining team for FCC-ee studies. You are welcome to join!

Aiming to extend and document set of FCC-ee studies.

Focus on detector design questions

Studying

- ZH cross section and mass
- Higgs to invisible (leptonic and hadronic channels)
- Scalar boson search
- Higgs to bb,cc,gg couplings (not detailed here)