Simulation of $e^+ e^- \to H \to \gamma\,\gamma$ collisions for the FCC-ee project with the FCCAnalyses program.

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Abstract

The FCC-ee project aims to deepen the understanding of the Z, W, Higgs bosons, and the τ particle.

Being this a project that is planned to start its construction in 2030, it is necessary to know by means of simulations the characteristics and necessary adjustments in the detectors. In the present work, the FCCAnalyses package will be used, which takes data generated with EDM4hep for the simulation of $e^+ e^- \to H \to \gamma\,\gamma$ events with $\sqrt{s}$ = 240 GeV with a luminosity of 5 ab^{-1}. The results obtained will be used to help establish (along with the information gathered by the rest of the collaboration) the performance, design, stability, etc. of the detectors to maximize the sensitivity in this channel.

Objective

- Obtain the transverse momentum of photons that decays from the Higgs boson, when the production mechanism is the Higgsstrahlung process.

Introduction

The FCC project will have three stages with their respective characteristics (FCC-ee, FCC-hh, FCC-eh), the electron-positron collisions phase is the focal point for this work.

The FCC-ee aims to study with unparalleled precision the Higgs boson and its self-coupling, the Z and W bosons, the top quark, other Standard Model particles and to investigate the dynamics of electroweak symmetry breaking.

For this purpose, Higgs boson research will be done with a center of mass between 240 and 365 GeV at a luminosity between 5 and 1.5 ab^{-1} respectively. [1]

The two main mechanisms of Higgs boson production are the Higgsstrahlung process ($e^+ e^- \to ZH$) and the WW fusion process ($e^+ e^- \to H\,\nu_e\,\bar{\nu_e}$). Where it is expected to have 10^6 events for ZH and 10^5 events for WW.

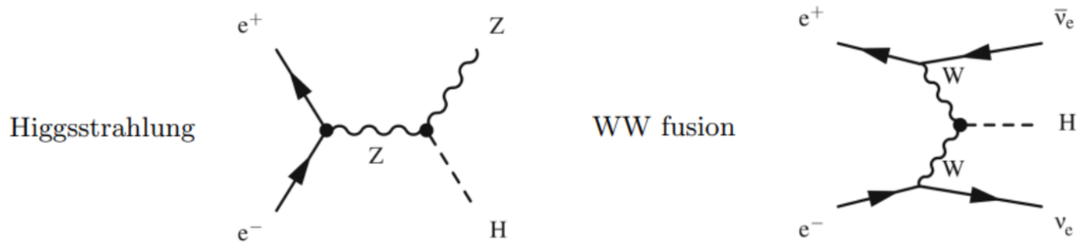

Figura 1: Feynmann diagrams for WW fusion (right) and the Higgsstrahlung (left) processes) Azzurri, 2022 [2]

The cross-section for the two main Higgs boson production forms is proportional to $g^4 HZZ/\Gamma_H$ and proportional to $g^4\ \nu_e\ \bar{\nu_e}\ H/\Gamma_H$ respectively, where Γ_H is the total decays of the Higgs boson.

For the channel of interest ($H \to \gamma\,\gamma$) of the HZ production, the relative uncertainty for a center of mass $\sqrt{s}$ = 240 GeV at 5ab^{-1} $\pm$ 9 %, for a center of mass $\sqrt{s}$ = 365 GeV at 1.5ab^{-1} $\pm$ 18 % , for the $\nu_e\ \bar{\nu_e}$ H production the relative uncertainty for a center of mass $\sqrt{s}$ = 365 GeV at 1.5ab^{-1} $\pm$ 22 %. [2]

Based on the analysis of the data collected by the DELPHI at the LEP 2 detector with a center of mass $\sqrt{s}$ from 161 to 208 GeV, by means of its event selection helps us to determine the background processes for $e^+ e^- \to \gamma\,\gamma$, where the dominant processes are those of Bhabha and Compton scattering events, being approximately 81 % of the events. however the other processes to consider are $e^+ e^- \to e^+ e^-\,\gamma\gamma$, $e^+ e^- \to \tau^+\tau^-(\gamma)$ and $e^+ e^- \to \nu\,\bar{\nu}\,\gamma\gamma$ [3]

Methodology

The EDM4HEP program, which is an event data model for future HEP collider experiments that uses Podio tools for the generation of events for future lepton and hadron colliders and also Delphes, which performs the function of the detector, was used to generate the graphs.

With this program were generated the data: wzp6_ee_mumuH_ecm240, p8_ee_ZH_ecm240, wzp6_ee_eeH_ecm240, etc. Which are contained in the IDEA spring 2021 database and were used in this work.

Subsequently, these data were treated with the FCCAnalyses framework in which are the analyzers and filters that contain the configuration of the necessary parameters to allow merging processes, normalize to the required luminosity, and plot the signal with different backgrounds.

For this work, the necessary addresses and libraries were created by making a local copy of the GitHub container in LXPLUS and the following steps were followed:

- source ./setup.sh
- mkdir build install
- cd build
- cmake ...
- DCMAKE_INSTALL_PREFIX=../install
- make install
- cd ..

Finally, the analyzer ZH_higgs_gaga.py was used and modified for this process, in which the reconstruction of the photons decaying from the Higgs boson of the Higgsstrahlung process is considered and then a selection is made.

Results

For the simulated processes, one million simulations were performed for the process $e^+ e^- \to HZ$, $H \to \gamma\,\gamma$ with $\sqrt{s}$ = 240 GeV with a luminosity of 5 ab^{-1}

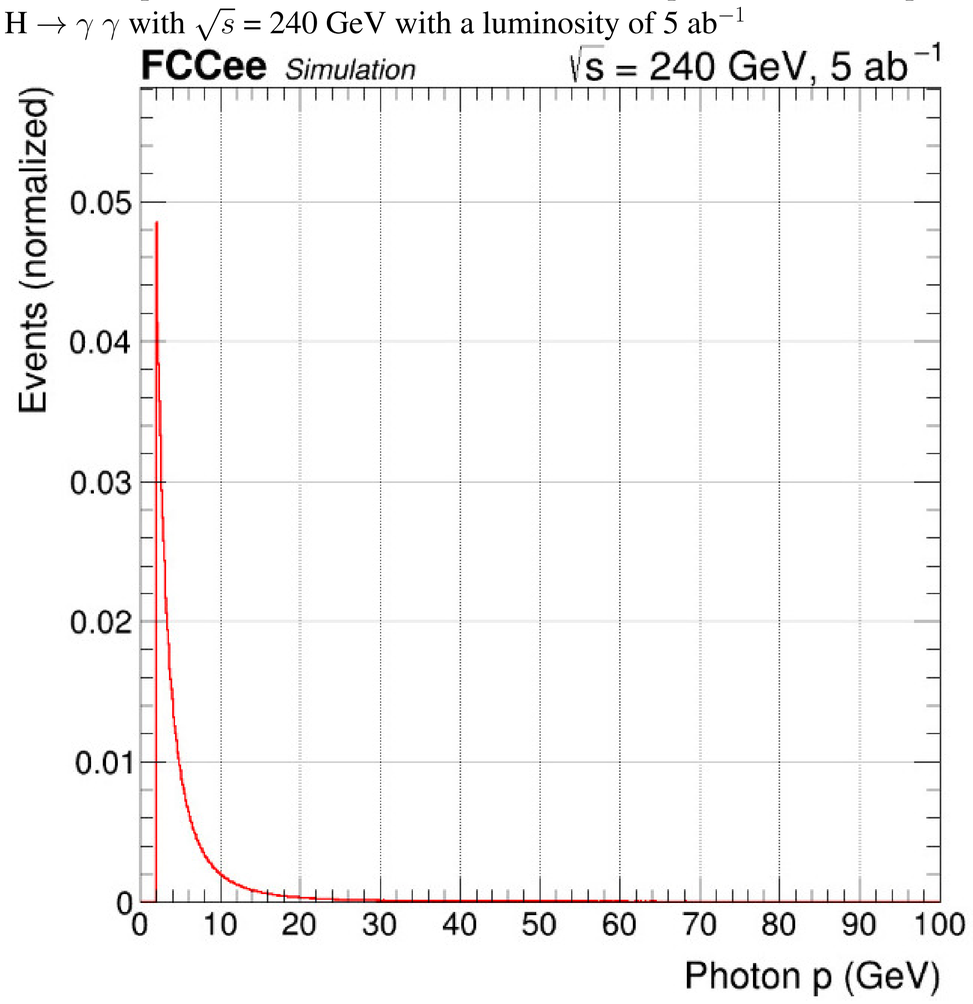

Figura 2: Transverse momentum of photons in $e^+ e^- \to HZ$, $H \to \gamma\,\gamma$

As can be seen from the graph, the peak in the number of events related to the transverse momentum of the photons is at the value of 2 GeV, and the largest number of events is in the interval from 2 to 30 GeV, but the Higgs boson has a mass of 125 GeV, it is expected that on average the photons have a mass of 62.5 GeV, so a cut is made at 30 GeV, to thus discard the photons that come from other processes, this results in figure 3.

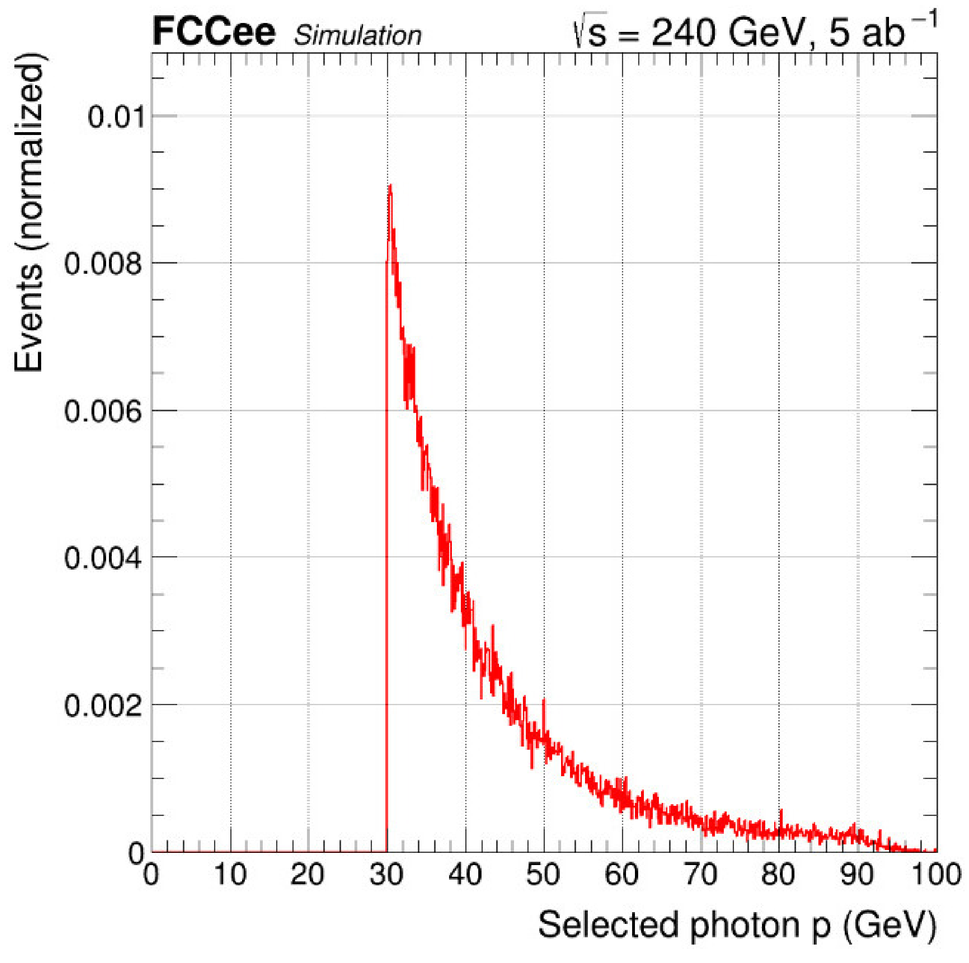

Figura 3: Transverse momentum of photons in $e^+ e^- \to HZ$, $H \to \gamma\,\gamma$ with cut-off at 30 GeV

Conclusions

Once the transverse momentum of the photons from the Higgs boson decay in the Higgsstrahlung process has been obtained, the next step of this project is to compare it with their predominant backgrounds in order to maximize the sensitivity in this channel and help establish the characteristics of the detectors.

Referencias

[1] Rebeca Gonzalez Suarez. The Future Circular Collider (FCC) at CERN. *PoS*, DISCRETE2020-2021:009, 2022.

[2] Paolo Azzurri, Gregorio Bernardi, Sylvie Braibant, David d'Enterria, Jan Eysermans, Patrick Janot, Ang Li, and Emmanuel Perez. A special Higgs challenge: measuring the mass and production cross section with ultimate precision at FCC-ee. *Eur. Phys. J. Plus*, 137(1):23, 2022.

[3] J. Abdallah et al. Determination of the e+ e- —> gamma gamma (gamma) cross-section at LEP 2. *Eur. Phys. J. C*, 37:405–419, 2004.