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STUDY OF HIGGS EFFECTIVE COUPLINGS AT $e^{-}p$ COLLIDERS

HODA HESARI

SCHOOL OF PARTICLES AND ACCELERATORS, INSTITUTE FOR RESEARCH IN FUNDAMENTAL SCIENCES (IPM)

The LHeC is a proposed deep inelastic electron-nucleon scattering (DIS) machine which has been designed to collide electrons with an energy from 60 GeV to possibly 140 GeV, with protons with an energy of 7 TeV.

The future circular collider (FCC) has the option of colliding electron-proton with the electron energy E_e= 60 GeV that possibly goes up to E_e= 175 GeV and with the proton energy of E_p= 50 TeV.

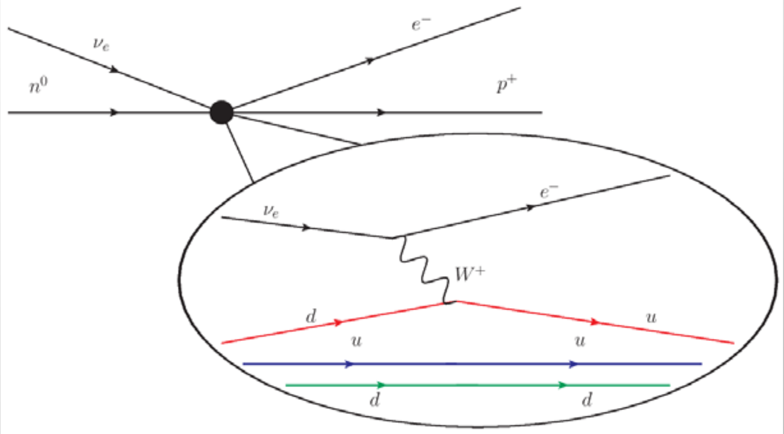
WHY EFFECETIVE FIELD THEORY?

- There are some reasons (Gravity, neutrino masses, baryon asymmetry, dark matter, …) to believe that the Standard Model is not the ultimate theory.
- the Standard Model of particle physics has been found to be a successful theory describing nature up to the scale of electroweak.

The standard model is an effective theory valid at TeV scale and there must be a bigger theory.

At energies below Λ, an EFT approach can be used theory.

e.g Fermi theory of weak interaction → standard model



EFFECTIVE FIELD THEORY(EFT)

In the EFT expansion all the operators are composed of all possible combinations of SM field . They have $SU(3)_c \times SU(2)_L \times U(1)_Y$ and Lorentz invariance.

In the EFT approach, lagrangian is:

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{c_i}{\Lambda}\mathcal{O}_i + \sum_i \frac{c_i}{\Lambda^2}\mathcal{O}_i + \text{h.c.}$$

Wilson coefficient

i th dimension-six operator

scale of new physics

just a single operator for dimension-five term. It is violates the lepton number

.

JHEP 1010 (2010) 085, Gradzadkowski,et al. → Assuming baryon number conservation, 59 independent operators.

The EFT is valid upto as scale Λ lying around TeV scale.

This approach is renormalizable order by order in the E/Λ expansion.

THE MOST GENERAL EFFECTIVE HIGGS LAGRANGIAN IN THE GAUGE BASIS

with the assumption of baryon and lepton number conservation and keeping only ***dimension-six*** operators, the most general $SU(3)_C \times SU(2)_L \times U(1)_Y$ gauge invariant Lagrangian can be constructed from the SM fields.

We concentrate on the dimension-six interactions of the Higgs boson, fermions, and the electroweak gauge bosons in the strongly interacting light Higgs (SILH) basis conventions :

$$\mathcal{L} = \mathcal{L}_{\mathrm{SM}} + \sum_i \overline{c}_i O_i = \mathcal{L}_{\mathrm{SM}} + \mathcal{L}_{\mathrm{SILH}} + \mathcal{L}_{CP} + \mathcal{L}_{F_1} + \mathcal{L}_{F_2} + \mathcal{L}_{G}$$

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strongly interacting light Higgs sector

$$
\begin{aligned}
\mathcal{L}_{\mathrm{SILH}} = {} & \frac{\bar{c}_H}{2v^2}\,\partial^\mu\left(H^\dagger H\right)\partial_\mu\left(H^\dagger H\right) + \frac{\bar{c}_T}{2v^2}\left(H^\dagger \overleftrightarrow{D^\mu} H\right)\left(H^\dagger \overleftrightarrow{D}_\mu H\right) - \frac{\bar{c}_6\,\lambda}{v^2}\left(H^\dagger H\right)^3 \\
& + \left[\left[\frac{\bar{c}_u}{v^2}\,y_u\,H^\dagger H\,\bar{q}_L H^c u_R + \frac{\bar{c}_d}{v^2}\,y_d\,H^\dagger H\,\bar{q}_L H d_R + \frac{\bar{c}_l}{v^2}\,y_l\,H^\dagger H\,\bar{L}_L H l_R\right] + \mathrm{h.c.}\right] \\
& + \frac{i\bar{c}_W\,g}{2m_W^2}\left(H^\dagger \sigma^i \overleftrightarrow{D^\mu} H\right)\left(D^\nu W_{\mu\nu}\right)^i \\
& + \frac{i\bar{c}_B\,g'}{2m_W^2}\left(H^\dagger \overleftrightarrow{D^\mu} H\right)\left(\partial^\nu B_{\mu\nu}\right) + \frac{i\bar{c}_{HW}\,g}{m_W^2}\left(D^\mu H\right)^\dagger \sigma^i \left(D^\nu H\right) W^i_{\mu\nu} \\
& + \frac{i\bar{c}_{HB}\,g'}{m_W^2}\left(D^\mu H\right)^\dagger\left(D^\nu H\right)B_{\mu\nu} + \frac{\bar{c}_\gamma\,g'^2}{m_W^2}\,H^\dagger H B_{\mu\nu}B^{\mu\nu} + \frac{\bar{c}_g\,g_S^2}{m_W^2}\,H^\dagger H G^a_{\mu\nu}G^{a\mu\nu} \\
& + \frac{i\tilde{c}_{HW}\,g}{m_W^2}\left(D^\mu H\right)^\dagger \sigma^i \left(D^\nu H\right)\tilde{W}^i_{\mu\nu} + \frac{i\tilde{c}_{HB}\,g'}{m_W^2}\left(D^\mu H\right)^\dagger\left(D^\nu H\right)\tilde{B}_{\mu\nu} \\
& + \frac{\tilde{c}_\gamma\,g'^2}{m_W^2}\,H^\dagger H B_{\mu\nu}\tilde{B}^{\mu\nu} + \frac{\tilde{c}_g\,g_S^2}{m_W^2}\,H^\dagger H G^a_{\mu\nu}\tilde{G}^{a\mu\nu} \\
& + \frac{\tilde{c}_{3W}\,g^3}{m_W^2}\,\epsilon^{ijk}W^{i\,\nu}_{\mu}W^{j\,\rho}_{\nu}\tilde{W}^{k\,\mu}_{\rho} + \frac{\tilde{c}_{3G}\,g_S^3}{m_W^2}\,f^{abc}G^{a\,\nu}_{\mu}G^{b\,\rho}_{\nu}\tilde{G}^{c\,\mu}_{\rho}\,.
\end{aligned}
$$

Weak doublet of higgs

Higgs boson quartic coupling

Vacumum expectation value = 246 GeV

Hermitian covariant derivative

Electroweak field strength tensor

Strong field strength tensor

Hermitian covariant derivative:

$$\Phi^\dagger \overleftrightarrow{D}_\mu \Phi = \Phi^\dagger D^\mu \Phi - D_\mu \Phi^\dagger \Phi$$

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strongly interacting light Higgs sector

two Higgs fields and a pair of quarks or leptons

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$$
\begin{aligned}
\mathcal{L}_{F_1} = {} & \frac{i\bar{c}_{HQ}}{v^2}\left(\bar{q}_L\gamma^\mu q_L\right)\left(H^\dagger \overleftrightarrow{D}_\mu H\right) + \frac{i\bar{c}'_{HQ}}{v^2}\left(\bar{q}_L\gamma^\mu\sigma^i q_L\right)\left(H^\dagger\sigma^i \overleftrightarrow{D}_\mu H\right) \\
& + \frac{i\bar{c}_{Hu}}{v^2}\left(\bar{u}_R\gamma^\mu u_R\right)\left(H^\dagger \overleftrightarrow{D}_\mu H\right) \\
& + \frac{i\bar{c}_{Hd}}{v^2}\left(\bar{d}_R\gamma^\mu d_R\right)\left(H^\dagger \overleftrightarrow{D}_\mu H\right) + \left[\frac{i\bar{c}_{Hud}}{v^2}\left(\bar{u}_R\gamma^\mu d_R\right)\left(H^{c\,\dagger} \overleftrightarrow{D}_\mu H\right) + h.c.\right] \\
& + \frac{i\bar{c}_{HL}}{v^2}\left(\bar{L}_L\gamma^\mu L_L\right)\left(H^\dagger \overleftrightarrow{D}_\mu H\right) \\
& + \frac{i\bar{c}'_{HL}}{v^2}\left(\bar{L}_L\gamma^\mu\sigma^i L_L\right)\left(H^\dagger\sigma^i \overleftrightarrow{D}_\mu H\right) + \frac{i\bar{c}_{Hl}}{v^2}\left(\bar{l}_R\gamma^\mu l_R\right)\left(H^\dagger \overleftrightarrow{D}_\mu H\right).
\end{aligned}
$$

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$\mathcal{L}_{SILH}$: strongly interacting light Higgs sector

$\mathcal{L}_{F_1}$: two Higgs fields and a pair of quarks or leptons

$\mathcal{L}_{F_2}$: a pair of quark or lepton, a Higgs field, and a gauge boson

$$
\begin{aligned}
\mathcal{L}_{F_2} = & \frac{\bar{c}_{uB}\, g'}{m_W^2}\, y_u\, \bar{q}_L H^c \sigma^{\mu\nu} u_R\, B_{\mu\nu} + \frac{\bar{c}_{uW}\, g}{m_W^2}\, y_u\, \bar{q}_L \sigma^i H^c \sigma^{\mu\nu} u_R\, W^i_{\mu\nu} \\
& + \frac{\bar{c}_{uG}\, g_S}{m_W^2}\, y_u\, \bar{q}_L H^c \sigma^{\mu\nu} \lambda^a u_R\, G^a_{\mu\nu} + \frac{\bar{c}_{dB}\, g'}{m_W^2}\, y_d\, \bar{q}_L H \sigma^{\mu\nu} d_R\, B_{\mu\nu} \\
& + \frac{\bar{c}_{dW}\, g}{m_W^2}\, y_d\, \bar{q}_L \sigma^i H \sigma^{\mu\nu} d_R\, W^i_{\mu\nu} \\
& + \frac{\bar{c}_{dG}\, g_S}{m_W^2}\, y_d\, \bar{q}_L H \sigma^{\mu\nu} \lambda^a d_R\, G^a_{\mu\nu} + \frac{\bar{c}_{lB}\, g'}{m_W^2}\, y_l\, \bar{L}_L H \sigma^{\mu\nu} l_R\, B_{\mu\nu} \\
& + \frac{\bar{c}_{lW}\, g}{m_W^2}\, y_l\, \bar{L}_L \sigma^i H \sigma^{\mu\nu} l_R\, W^i_{\mu\nu} + \text{h.}c.
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$\mathcal{L}_{\rm SILH}$: strongly interacting light Higgs sector

$\mathcal{L}_{F_1}$: two Higgs fields and a pair of quarks or leptons

$\mathcal{L}_{F_2}$: a pair of quark or lepton, a Higgs field, and a gauge boson

$\mathcal{L}_G$: gauge boson self-interactions

$$\mathcal{L}_G = \frac{g^3 \ \bar{c}_{3W}}{m_W^2} \epsilon_{ijk} W^i_{\mu\nu} W^{\nu j}{}_{\rho} W^{\rho\mu k} + \frac{g_s^3 \ \bar{c}_{3G}}{m_W^2} f_{abc} G^a_{\mu\nu} G^{\nu b}{}_{\rho} G^{\rho\mu c} + \frac{\bar{c}_{2W}}{m_W^2} D^\mu W^k_{\mu\nu} D_\rho W_k^{\rho\nu}$$
$$+ \frac{\bar{c}_{2B}}{m_W^2} \partial^\mu B_{\mu\nu} \partial_\rho B^{\rho\nu} + \frac{\bar{c}_{2G}}{m_W^2} D^\mu G^a_{\mu\nu} D_\rho G_a^{\rho\nu} \ ,$$

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$\mathcal{L}_{\mathrm{SILH}}$: strongly interacting light Higgs sector

$\mathcal{L}_{F_1}$: two Higgs fields and a pair of quarks or leptons

$\mathcal{L}_{F_2}$: a pair of quark or lepton, a Higgs field, and a gauge boson

$\mathcal{L}_G$: gauge boson self-energies and self-interactions

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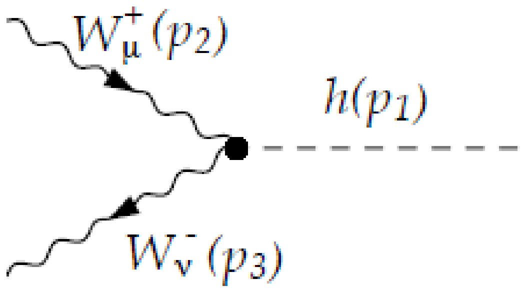
THE MOST GENERAL EFFECTIVE HIGGS LAGRANGIAN IN THE MASS BASIS

After electroweak symmetry breaking → ***lagrangian in the Mass basis***

arxiv:1310.5150v2[hep-ph].

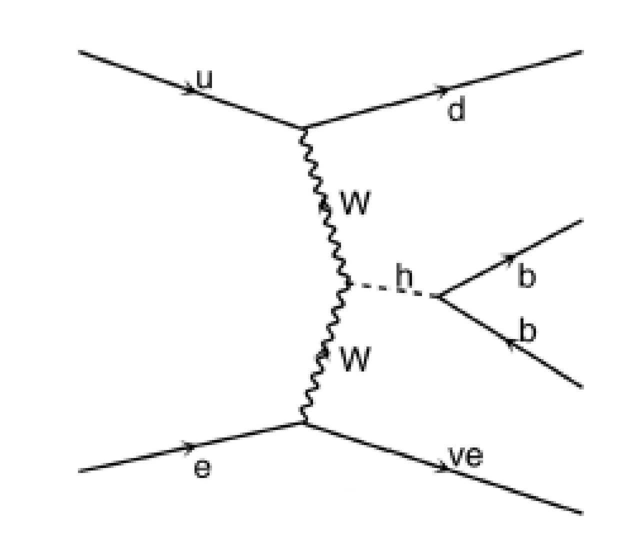
$W^{\nu}\partial^{\mu}W^{\dagger}_{\mu\nu}h$ $\quad$ $W^{\mu\nu}W^{\dagger}_{\mu\nu}h$



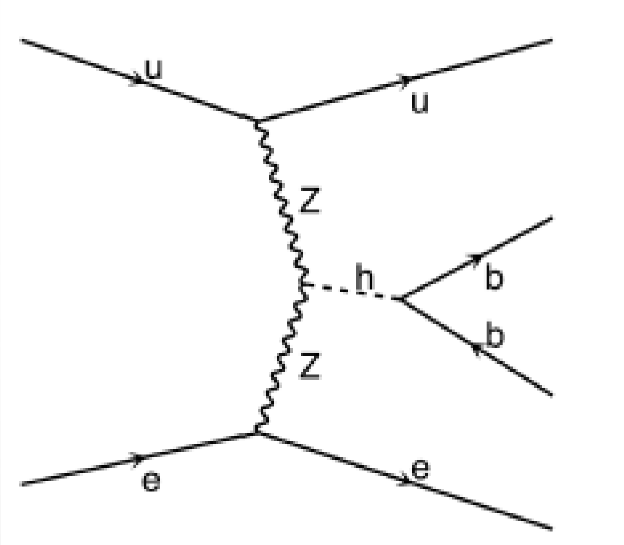
$$i\Big[\eta^{\mu\nu}\big(g m_W + g^{(1)}_{hww}\, p_2\cdot p_3 + g^{(2)}_{hww}(p_2^2+p_3^2)\big) - g^{(1)}_{hww}\, p_2^{\nu}p_3^{\mu} - g^{(2)}_{hww}\big(p_2^{\nu}p_2^{\mu} + p_3^{\nu}p_3^{\mu}\big) - \epsilon^{\mu\nu\rho\sigma}\tilde{g}_{hww}\, p_{2\rho}p_{3\sigma}\Big]$$

$W^{\mu\nu}\tilde{W}^{\dagger}_{\mu\nu}h$

HIGGS PRODUCTION IN THE FUTURE ELECTRON-PROTON COLLIDER

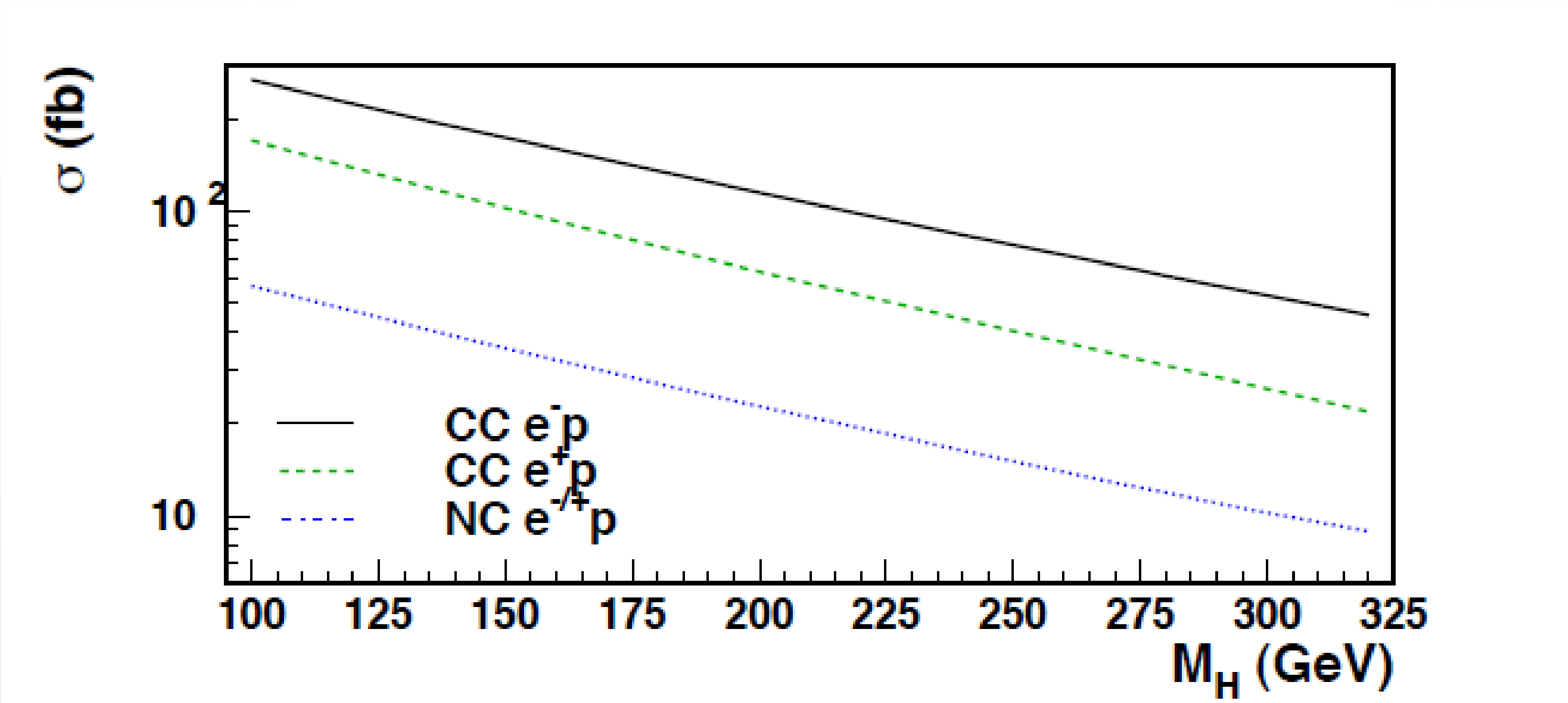


Feynman diagrams for charge current



Feynman diagrams for neutral current

HIGGS PRODUCTION IN ELECTRON-PROTON COLLIDER



Total produvtion cross section of SM Higgss boson in $e^{\pm}p$ collisions with $E_e = 140 GeV$ and $E_p = 7 TeV$, as a function of the Higgs Mass.

CERN-OPEN-2012-015 LHeC-Note-2012-002 GEN Geneva, June 13, 2012, LHeC Study Group.

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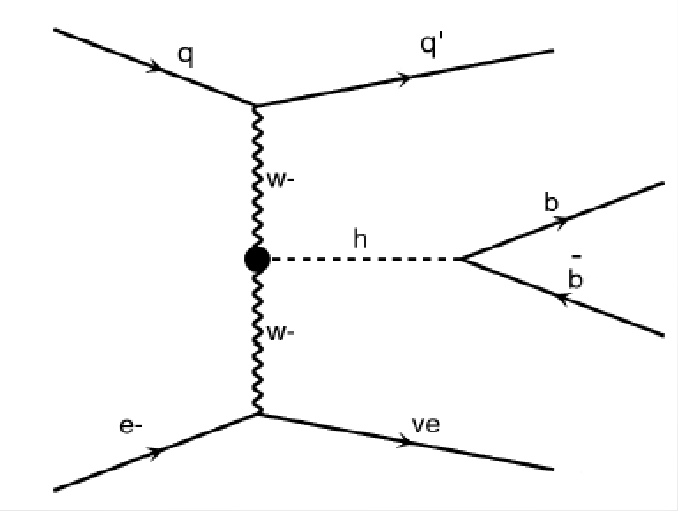
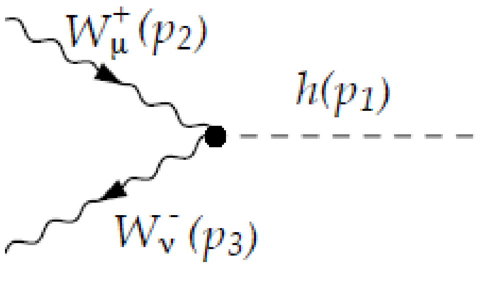
$e^- p \to hj\nu_e$ in the presence of dimension six operators

The full set of interactions generated by the dimension-six operators mentioned in the Higgs Effective Lagrangian $\mathcal{L}_{SILH}, \mathcal{L}_{F_1}, \mathcal{L}_{F_2}$ have been implemented in ***FeynRules*** (Alloul, Fuks,Comput. Phys. Com. **185**, 2250(2014))
and the model is imported to a Universal ***FeynRules*** Output (UFO) module (Alloul, Fuks and Sanz, ,JHEP **1404** (2014)),
Then, the UFO model files have been inserted in the ***MadGraph5-aMC@NLO*** (J.Alwall, *et al*. JHEP **1407**, 079 (2014).).
Monte-Carlo (MC) event generator to calculate the cross sections and generate the signal events.
The ***CTEQ6L1*** PDF set (Pumplin, et al, JHEP **0207**, 012 (2002)) is used as the proton structure functions.
The renormalization and factorization scales are set dynamically by ***MadGraph5-aMC@NLO*** default.
The next-to-leading order QCD correction to the signal process $e^- p \to hj\nu_e$ is found to be small
(Jager, *et al*. P.R.D **81**, 054018 2010)), Therefore, in this work the k -factor for the signal is assumed to be one.
The events of signal process are generated with ***MadGraph5-aMC@NLO*** then the Higgs boson decay into a $b\bar{b}$ pair is done with ***MadSpin*** module (Artoisenet, et al. JHEP **1303**, 015 (2013)).
Pythia 6 (Sjostrand, *et a*l. Comput. Phys. Commun **178**, 852 (2008)) package is utilized to perform fragmentation, hadronisation, initial- and final-state parton showers.
Jets are clustered using ***FastJet3.2.0*** (Cacciari, *et al*. Eur. Phys. J. C **72**, 1896 (2012)) with the k_T algorithm
(Soyez, arXiv:0807.0021 [hep-ph]).

Representative Feynman diagrams at tree level for the $e^- p \to hj\nu_e$ in the presence of dimension six operators





$$i\Big[\eta^{\mu\nu}\big(g m_W + g^{(1)}_{hww} p_2 \cdot p_3 + g^{(2)}_{hww}(p_2^2 + p_3^2)\big) - g^{(1)}_{hww} p_2^\nu p_3^\mu - g^{(2)}_{hww}\big(p_2^\nu p_2^\mu + p_3^\nu p_3^\mu\big) - \epsilon^{\mu\nu\rho\sigma}\tilde{g}_{hww} p_{2\rho} p_{3\sigma}\Big]$$

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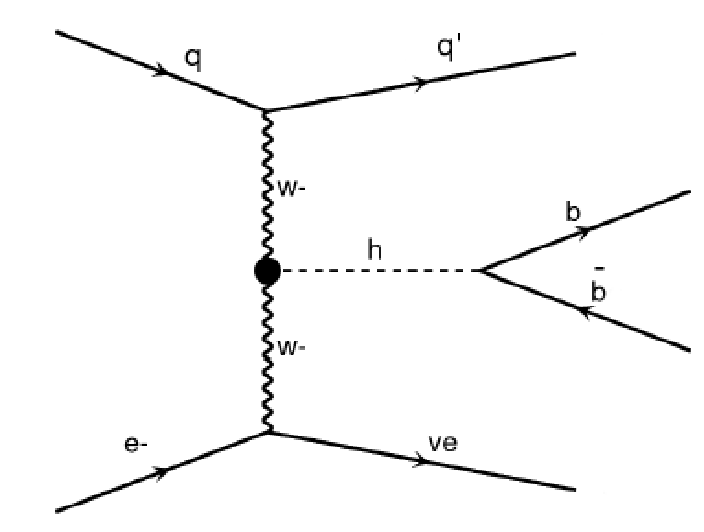
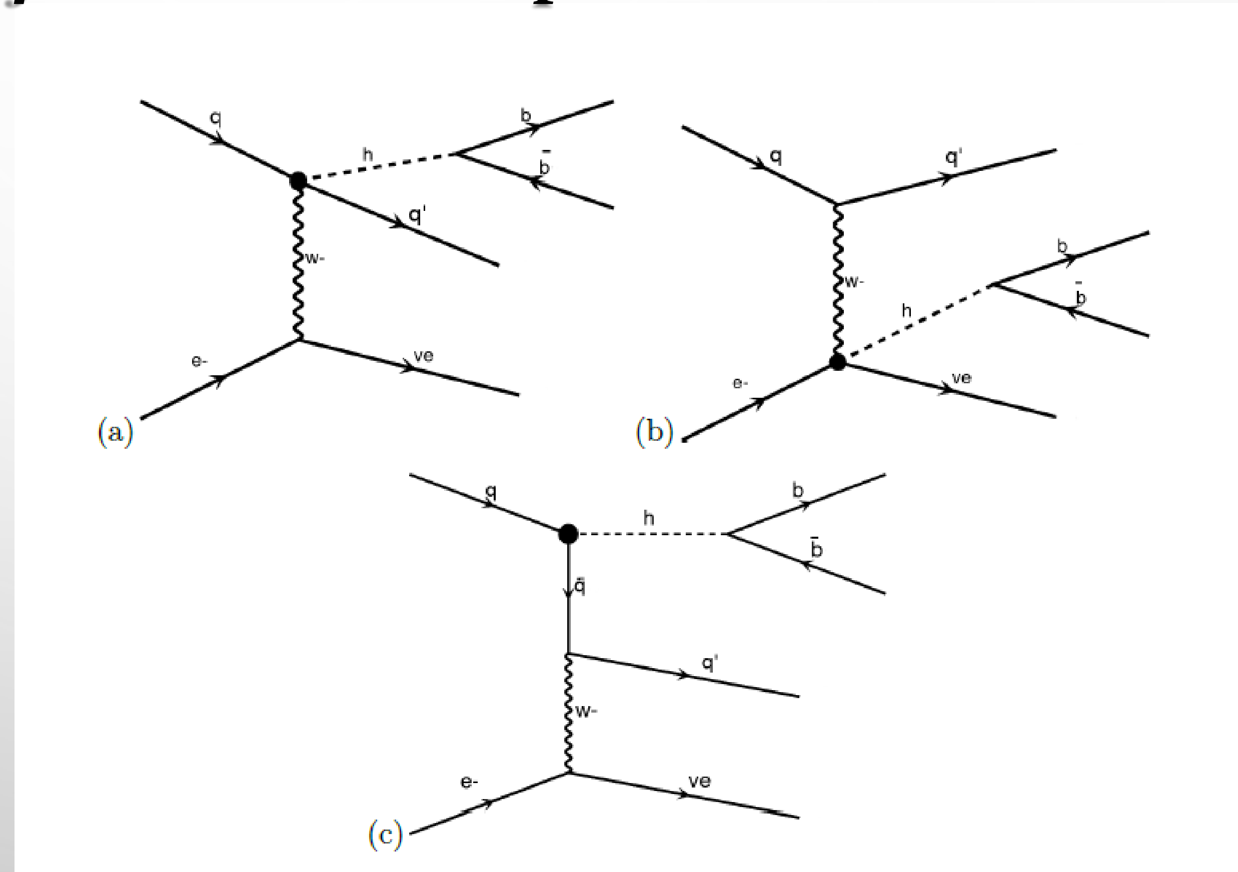




The vertices which receive contributions from the $\mathcal{L}_{\text{eff}}$ are shown by filled circules.

sensitive parameters:

Mass basis	Gauge basis
$g^{(1)}_{hww}$	$\frac{2g}{m_W}\bar{c}_{HW}$
$\tilde{g}_{hww}$	$\frac{2g}{m_W}\tilde{c}_{HW}$
$g^{(2)}_{hww}$	$\frac{g}{m_W}\{\bar{c}_W + \bar{c}_{HW}\}$
$g^{(L)}_{hwud}$	$\frac{\sqrt{2}g}{v}\bar{c}'_{HQ}V^{\mathrm{CKM}}$
$g^{(R)}_{hwud}$	$\frac{\sqrt{2}g}{v}\ \bar{c}_{Hud}$
$g_{hw\nu e}$	$\frac{\sqrt{2}g}{v}\bar{c}'_{HL}$

Backgrounds

Based on the signal final state that consists of missing transverse energy, a pair of $b\bar{b}$ from the Higgs boson decay and a forward jet, the backgrounds include processes with three jets and large missing energy in the final state. In particular, the following processes have been taken into account :

1) $bbb\nu_e$

2) $bbj'\nu_e$

3) $j'j'j'\nu_e$

4) $t\nu_e$.

5) $Wj\nu_e$.

6) $Zj\nu_e$.

$j' = u,d,c,s$

$j = u,d,c,s,b$

hadronic decay

Signal and Backgrounds Production and Simulation

- The electromagnetic and hadronic calorimeters resolutions are considered by the energy smearing of $\frac{5\%}{\sqrt{E(\text{GeV})}} \oplus 1\%$ And $\frac{60\%}{\sqrt{E(\text{GeV})}}$, respectively.

- The b-tagging efficiency is assumed to be 60% while mis-tag probabilities of 10% and 1% for c-quark jets and light-quark jets are considered, respectively.

- The tracker of the LHeC detector is expected to cover pseudorapidity range up to 3. Therefore, for the b-tagging performance is valid up to $|\eta_{\text{b-jet}}| < 3$.For the light-jets, the calorimeter coverage is considered to be $|\eta_{\text{light-jet}}| < 5$.

Fernandez, et al. [LHeC Study Group], ”A Large Hadron Electron Collider at CERN: Report on the Physics and Design Concepts for Machine and Detector”, J. Phys. G **39**, 075001 (2012).

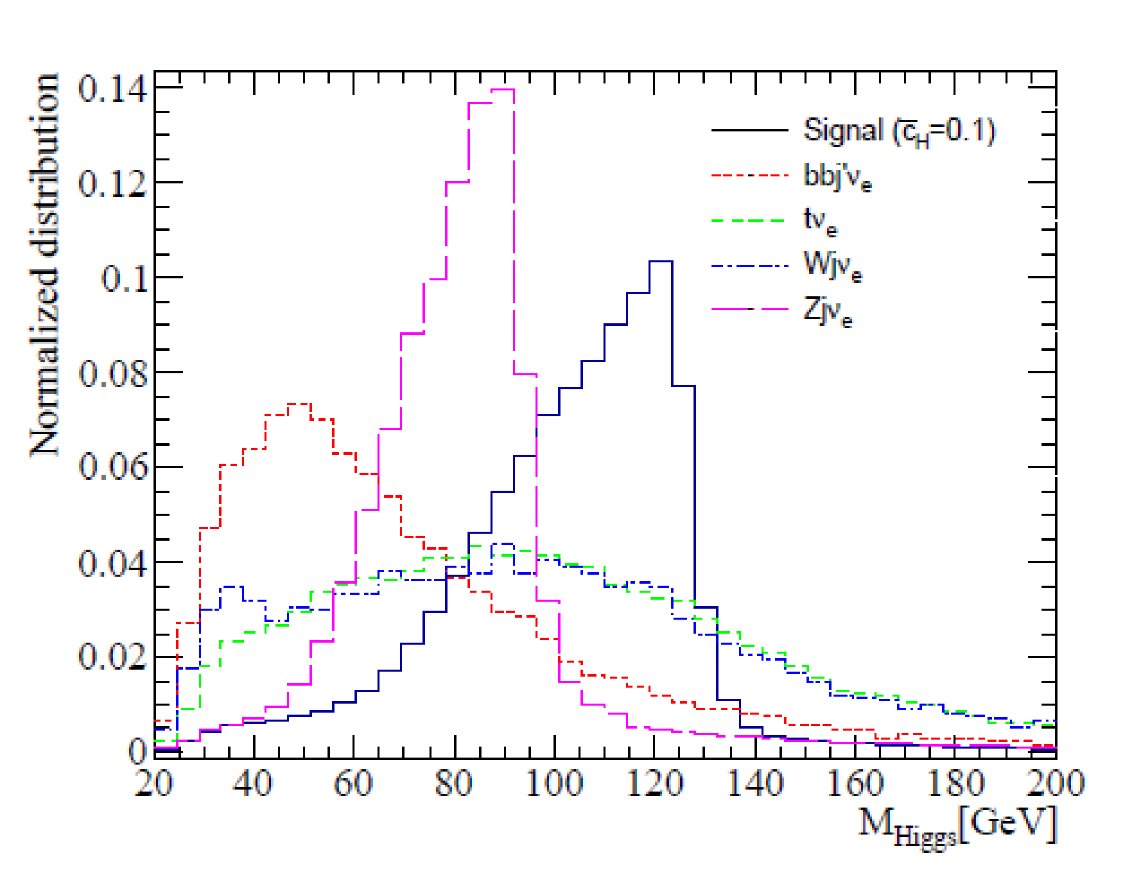
LHeC sensitivity

Jets are reconstructed with a distance parameter for the jet reconstruction algorithm $R = 0.7$.

- $p_{jet}^{T} > 20$ GeV.
- $E_{miss}^{T} > 20$ GeV.
- $E_{total}^{T} > 100$ GeV.

Fernandez, et al. [LHeC Study Group], ”A Large Hadron Electron Collider at CERN: Report on the Physics and Design Concepts for Machine and Detector”, J. Phys. G **39**, 075001 (2012).

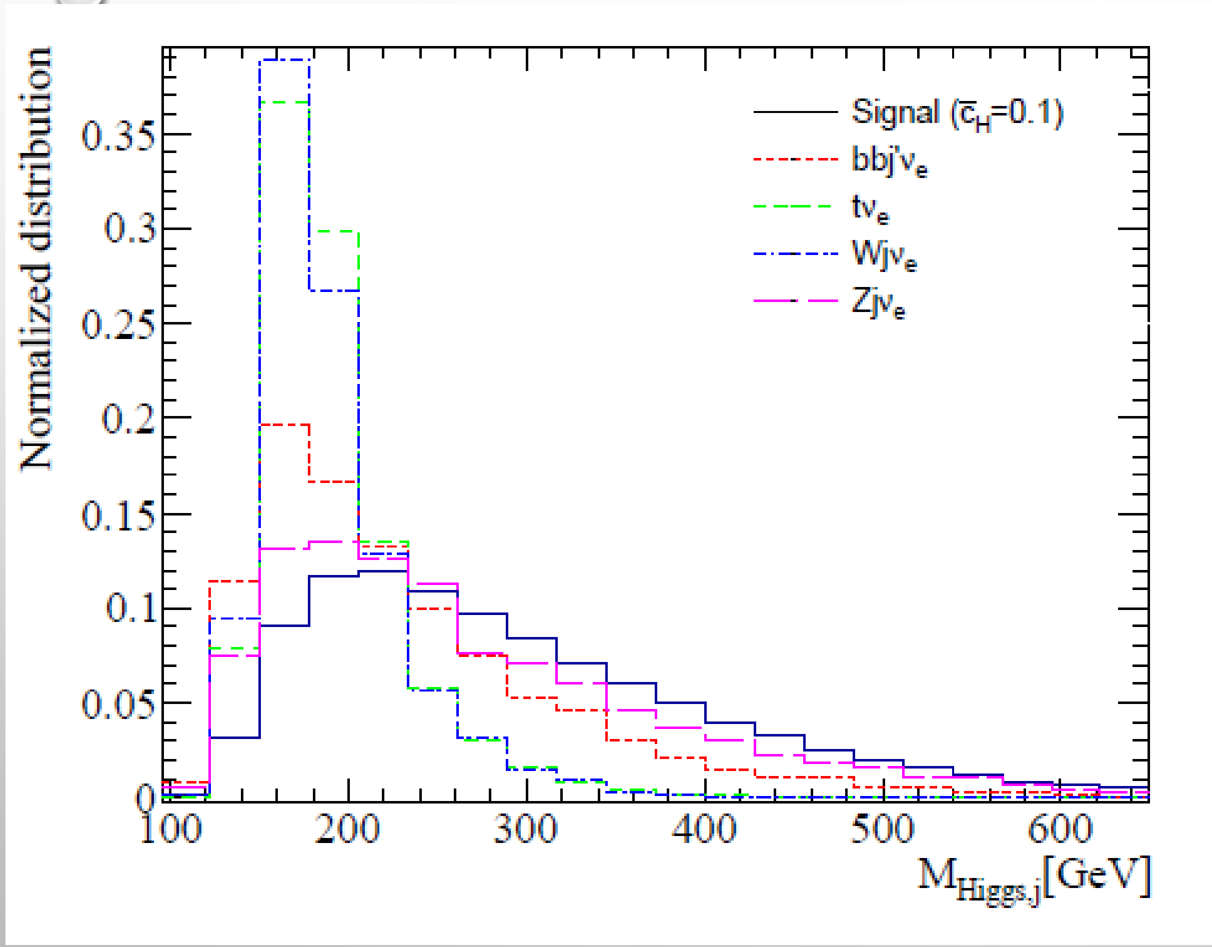
Higgs Mass:



For $E_p = 7TeV, E_e = 60\,\text{GeV}$.
The Higgs boson is reconstructed using the two b-tagged jets which give the closest mass to the nominal Higgs mass, 125 GeV. The figure show the reconstructed Higgs boson mass.

$$95 \leq M_{\text{Higgs}} \leq 135 \quad \boldsymbol{GeV}$$

Higgs + jet Mass:



For $E_p = 7TeV, E_e = 60\,\text{GeV}$
Among the light jets, the highest p_T one is taken as the light flavor jet. The figure the invariant mass distribution of the Higgs+jet.

$$260 < M_{\text{Higgs,j}} < 1000 \;\; \boldsymbol{GeV}$$

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impacts of all cuts

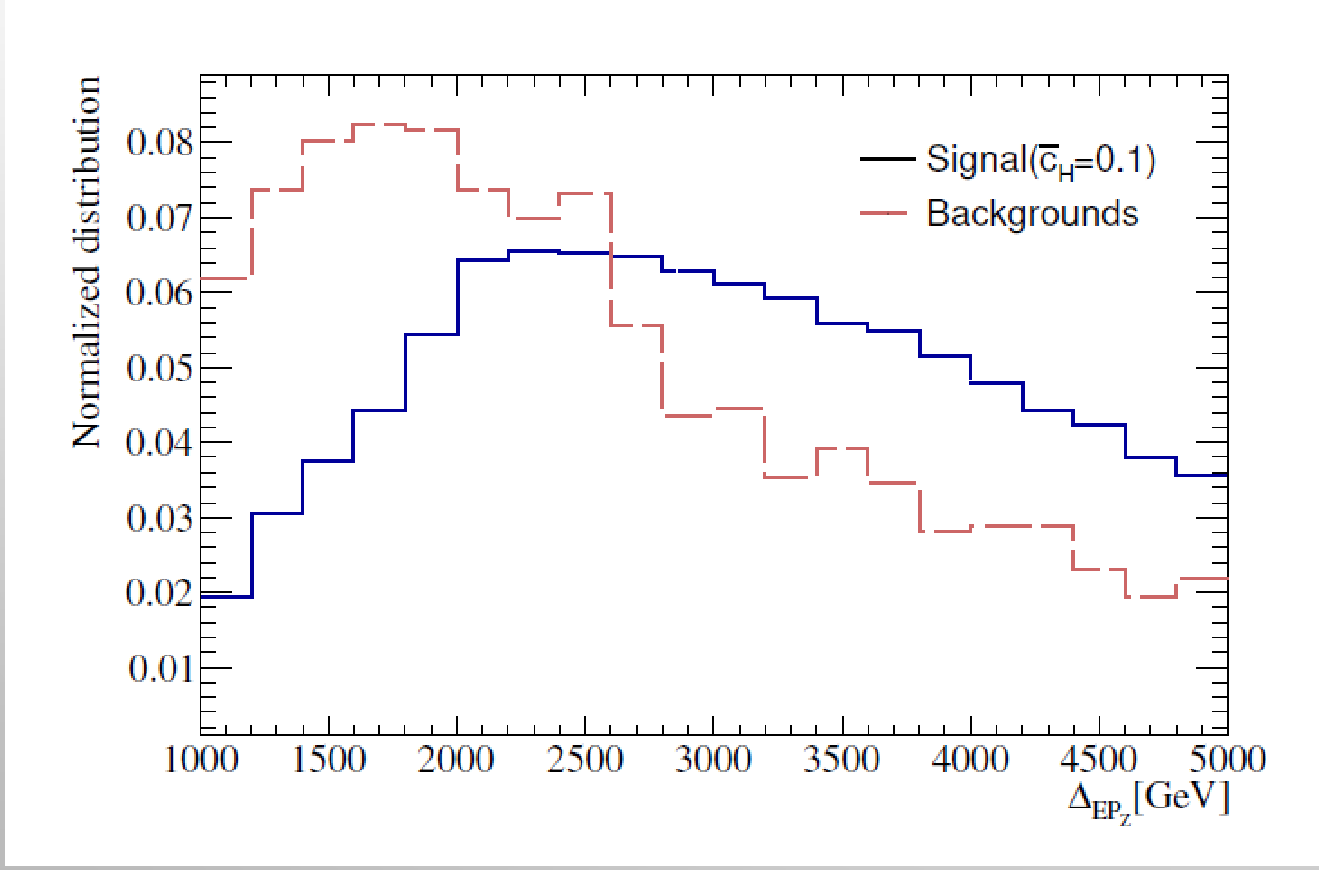
LHeC collider	Signal	Standard Model (SM)	Backgrounds			
Cuts	$\bar{c}_H = 0.1$	$hj\nu_e$	$bbj'\nu_e$	$t\nu_e$	$Wj\nu_e$	$Zj\nu_e$
Cross sections (in fb)	84.8	94.3	639.5	1287	1885	379.6
Acceptance cuts	18.10	20.12	12.15	96.76	37.81	16.33
$95 \leq M_{\rm Higgs} \leq 135$ (GeV)	9.69	13.07	1.28	23.60	10.08	1.52
$260 < M_{\rm Higgs,j} < 1000$ (GeV)	6.37	7.05	0.45	1.77	0.76	0.72

Cross section (in fb) for signal and background events after applied kinematic cuts used for this analysis at the LHeC with $E_p = 7TeV, E_e = 60\,\mathrm{GeV}$.

Sensitivity estimate

The sensitivity are obtained using a χ^2 analysis over all bins of Δ_{Ep_Z} distribution. It is defined as:

$$\Delta_{Ep_Z} = (E_{b-jet_1} - p_{z,b-jet_1}) + (E_{b-jet_2} - p_{z,b-jet_2}) + (E_{light-jet_1} - p_{z,light-jet_1}).$$



Normalized distribution for the Δ_{Ep_Z} for signal and all background processes after applying all cuts.

$$\chi^2(\{c_n\}) = \sum_{i=bins}^{N} \frac{(f_i(\{c_n\}) - s_i^{SM})^2}{\Delta_i^2}.$$

$$\{c_n = \bar{c}_H, \bar{c}_{Hud}, \bar{c}_{HW}, \overline{c'}_{HL}, \overline{c'}_{HQ}, \bar{c}_W, \tilde{c}_{HW}\}$$

Sensitivity estimate

number of signal events in the i-th bin

$$\chi^2(\{c_n\}) = \sum_{i=bins}^{N} \frac{(f_i(\{c_n\}) - s_i^{SM})^2}{\Delta_i^2}.$$

statistical uncertainty

SM expectationin the i-th bin

$$\{c_n = \bar{c}_H, \bar{c}_{Hud}, \bar{c}_{HW}, \bar{c}'_{HL}, \bar{c}'_{HQ}, \bar{c}_W, \tilde{c}_{HW}\}$$

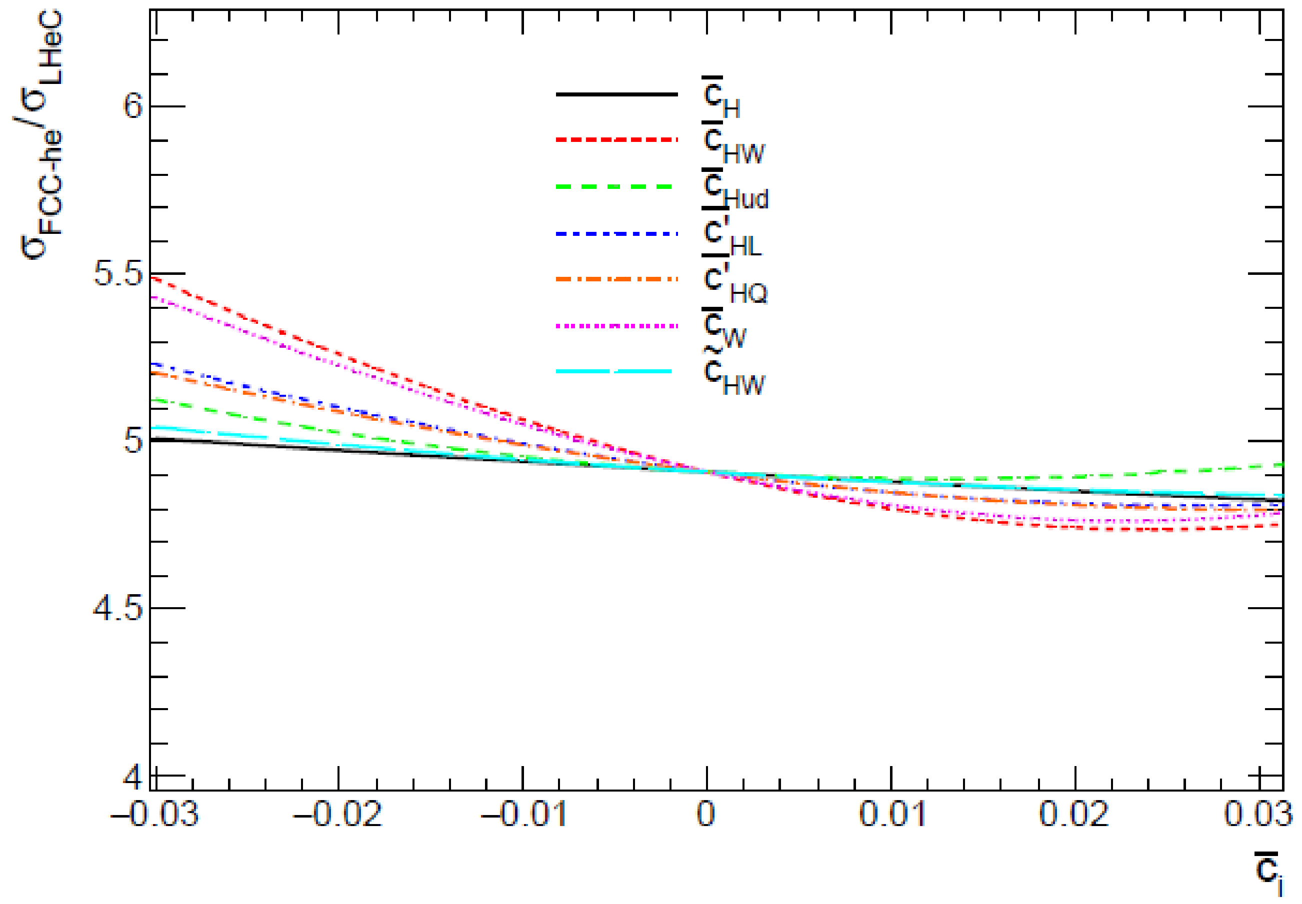
$$f_i(\{c_n\}) = s_i^{SM} + \sum_{n=1}^{7} (\alpha_n \bar{c}_n + \beta_n \bar{c}_n^{\,2}).$$

Results

Wilson coefficients	LHeC-300 (140 GeV)	LHeC-3000 (140 GeV)	LHeC-300 (60 GeV)	LHeC-3000 (60 GeV)	LHC-3000
$\bar{c}_H[\times 100]$	$[-0.90, 0.95]$	$[-0.29, 0.29]$	$[-7.8, 8.8]$	$[-2.5, 2.6]$	$[-4.40, 3.50]$
$\bar{c}_{Hud}[\times 100]$	$[-0.80, 0.80]$	$[-0.25, 0.25]$	$[-6.26, 8.33]$	$[-2.40, 2.86]$	—
$\bar{c}_{HW}[\times 100]$	$[-1.40, 1.70]$	$[-0.47, 0.50]$	$[-2.3, 2.8]$	$[-0.79, 0.83]$	$[-0.4, 0.4]$
$\bar{c}'_{HL}[\times 100]$	$[-1.30, 1.40]$	$[-0.40, 0.40]$	$[-8.1, 2.7]$	$[-2.6, 2.7]$	—
$\bar{c}'_{HQ}[\times 100]$	$[-1.50, 1.60]$	$[-0.50, 0.50]$	$[-2.20, 2.70]$	$[-0.79, 0.76]$	—
$\bar{c}_W[\times 100]$	$[-1.00, 1.00]$	$[-0.36, 0.37]$	$[-1.20, 1.40]$	$[-0.42, 0.44]$	$[-0.40, 0.40]$
$\tilde{c}_{HW}[\times 100]$	$[-0.70, 0.70]$	$[-0.20, 0.20]$	$[-11.4, 9.2]$	$[-4.2, 3.6]$	—

Predicted constraints at 95% C.L. on dimension-six Wilson coefficients for the LHeC with the electrons energy of $E_e = 60\,\text{GeV}$ and $E_e = 140\,\text{GeV}$, and for integrated luminosities of $300\,\text{fb}^{-1}$ and $3000\,\text{fb}^{-1}$.

FCC-he sensitivity



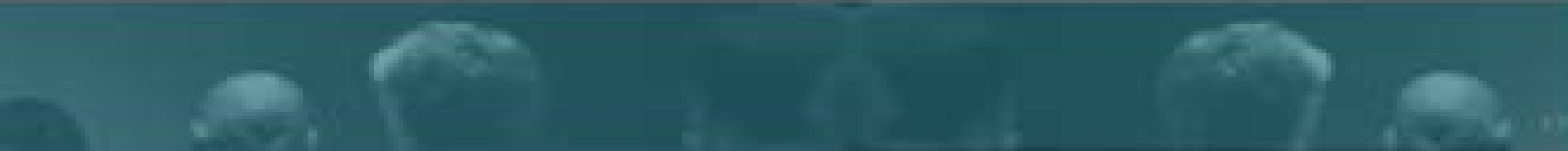
when the couplings are varying in the range of -0.03 to 0.03, the cross section at the FCC-he increases by a factor of around 5 with respect to the LHeC.

Results

Wilson coefficients	LHeC-300 (140 GeV)	LHeC-3000 (140 GeV)	FCC-he-300	FCC-he-3000	LHC-3000
$\bar{c}_H[\times 100]$	$[-0.90, 0.95]$	$[-0.29, 0.29]$	$[-1.00, 1.00]$	$[-0.30, 0.35]$	$[-4.40, 3.50]$
$\bar{c}_{Hud}[\times 100]$	$[-0.80, 0.80]$	$[-0.25, 0.25]$	$[-0.90, 0.90]$	$[-0.29, 0.29]$	——
$\bar{c}_{HW}[\times 100]$	$[-1.40, 1.70]$	$[-0.47, 0.50]$	$[-0.90, 1.00]$	$[-0.30, 0.30]$	$[-0.40, 0.40]$
$\bar{c}'_{HL}[\times 100]$	$[-1.30, 1.40]$	$[-0.40, 0.40]$	$[-1.80, 2.00]$	$[-0.60, 0.66]$	——
$\bar{c}'_{HQ}[\times 100]$	$[-1.50, 1.60]$	$[-0.50, 0.50]$	$[-1.90, 2.00]$	$[-0.60, 0.60]$	——
$\bar{c}_W[\times 100]$	$[-1.00, 1.00]$	$[-0.36, 0.37]$	$[-0.70, 0.80]$	$[-0.20, 0.20]$	$[-0.40, 0.40]$
$\tilde{c}_{HW}[\times 100]$	$[-0.70, 0.70]$	$[-0.20, 0.20]$	$[-0.90, 0.90]$	$[-0.28, 0.28]$	——

Predicted constraints at 95% C.L. on dimension-six Wilson coefficients for the LHeC and FCC-he colliders and integrated luminosity of $300\,\mathrm{fb}^{-1}$ and $3000\,\mathrm{fb}^{-1}$.

Thanks!



FCC-he sensitivity

- FCC-he employs the 50 TeV proton beam of a proposed circular proton-proton collider.
- Similar to the LHeC case, FCC-he is sensitive to $\bar{c}_H$, $\bar{c}_{Hud}$, $\bar{c}_{HW}$, c'_{HL}, c'_{HQ}, $\bar{c}_W$, and $\tilde{c}_{HW}$ Wilson coefficients.
- The same analysis strategy as presented for the LHeC is followed for the FCC-he.
- The Higgs boson decay into $b\bar{b}$ pair is considered and a χ^2-fit is utilized to estimate the sensitivities.

FCC-he sensitivity

One of the interesting characteristics of the signal events at the FCC-he, which requires to use a particular strategy for reconstruction of the Higgs boson.

At the FCC-he, Higgs bosons of the signal events are produced highly boosted.

From the topological point of view, They have a different decay compared to the Higgs bosons which are not boosted.

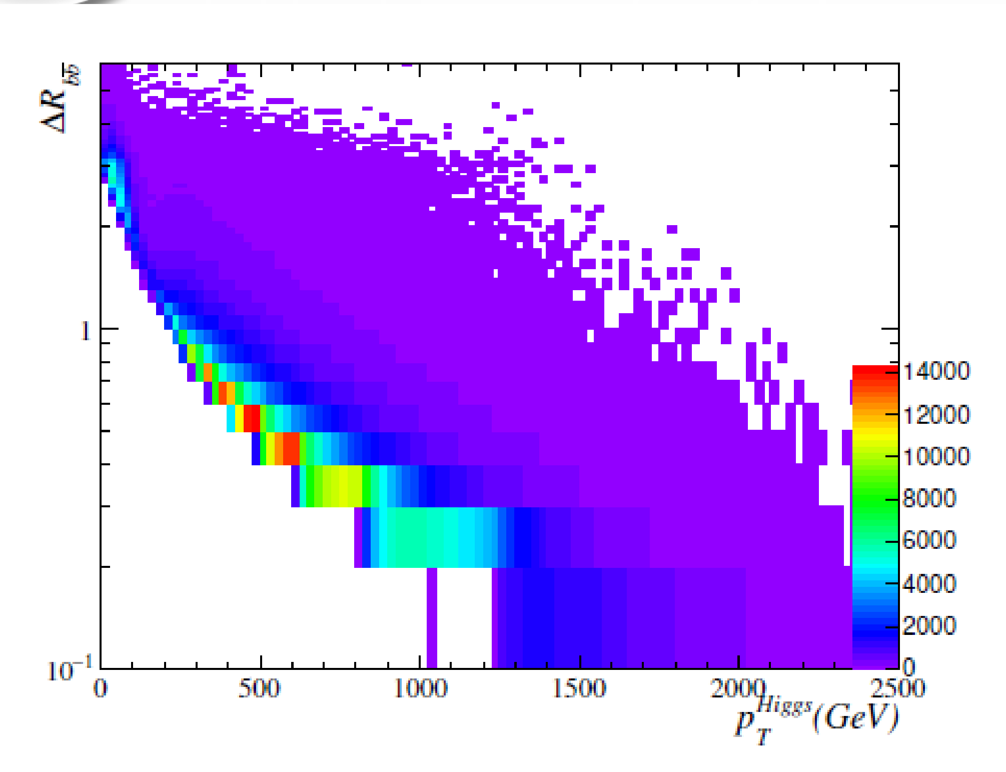
The angular separation of a $b\bar{b}$ pair produced in a Higgs boson decay can be written as:

$$\Delta R_{b\bar{b}} \simeq \frac{1}{\sqrt{x(1-x)}} \frac{m_H}{p_T}$$

momentum fractions of the b-jets.

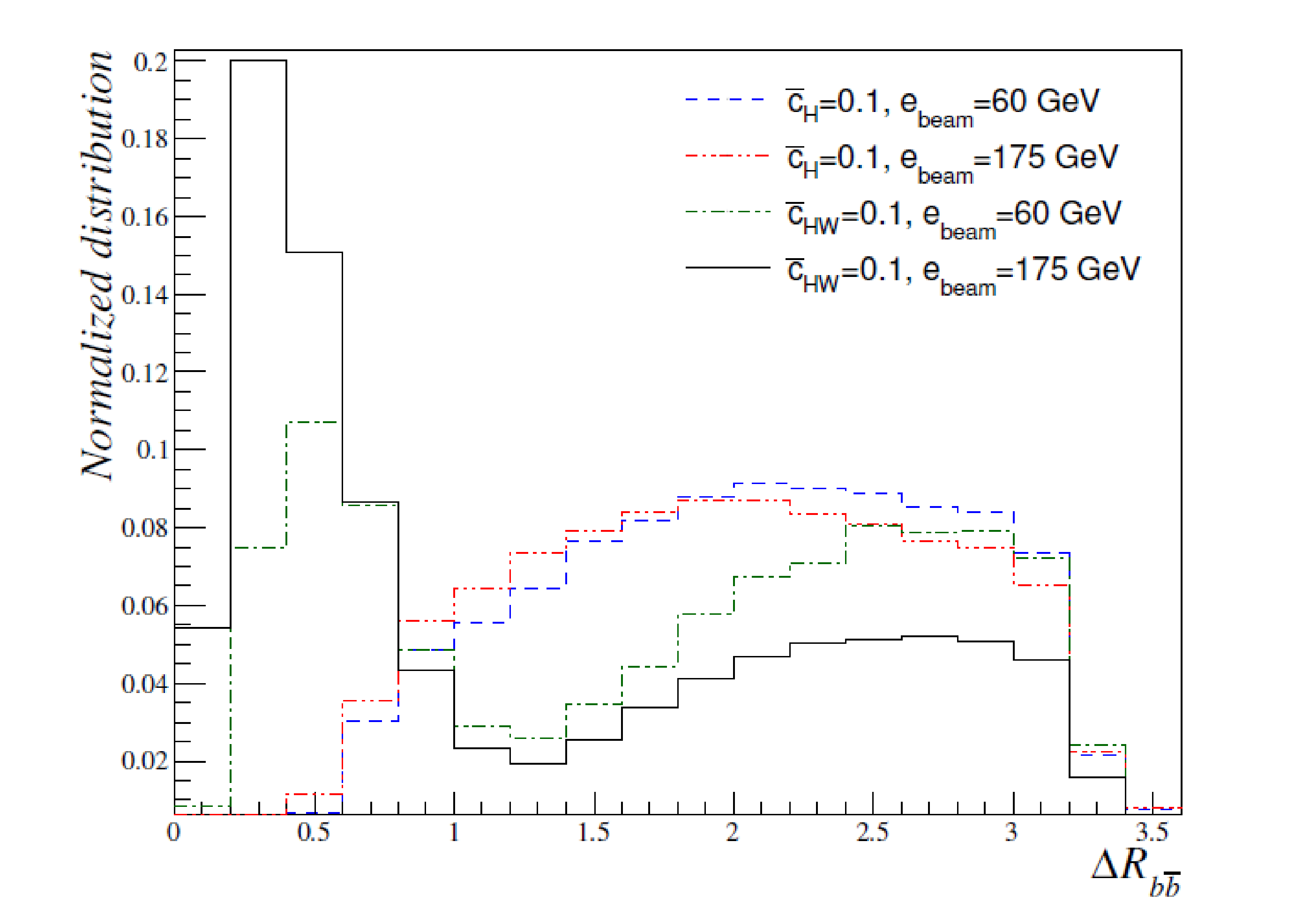
transverse momentum of the Higgs boson

FCC-he sensitivity



two dimensional plots of angular separation of $b\bar{b}$ pair $\Delta R_{b\bar{b}}$ in terms of the Higgs boson transverse momentum for signal process with $\bar{c}_{HW} = 0.1$. if the Higgs boson have a transverse momentum $p_T >$ 300 GeV, the angular separation between two b-jets from the Higgs decay is $\Delta R < 0.3$. Then , the common jet reconstruction would not be usable for **all** of signal events. An alternative method of fat jet algorithm is applied (Butterworth, et al. Phys. Rev. Lett. **100**, 242001 (2008).) for the boosted Events.

FCC-he sensitivity



The normalized distribution of ΔR between Two b-quarks from the Higgs boson decay for the FCC-he. The distributions for two electron energies $E_e = 60$ and 175 GeV, and $E_p = 50\,\mathrm{TeV}$ proton for two signal scenarios $\bar{c}_H = 0.1$ and $\bar{c}_{HW} = 0.1$.

The plot clearly shows that for the signal scenario of $\bar{c}_{HW}$,by incrasing the colliding electron beam energy from 60 GeV to 175 GeV the Higgs bosons are produced in boosted regime.