Exploring the Anomalous Top-Higgs FCNC Couplings at the electron proton colliders

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Outline

1. Top-Higgs FCNC coupings
2. Simulation and Analysis
3. Conclusion

The anomalous Top-Higgs FCNC couplings

Considering the FCNC Yukawa interactions in the effective field theory framework. The SM Lagrangian can be extended simply by allowing the following terms:

$$L = \kappa_{tuh}\,\bar{t}uh + \kappa_{tch}\,\bar{t}ch + h.c.$$

$$\Gamma_t = \Gamma^{SM}_{t\to w\text{-}b} + \Gamma_{t\to ch} + \Gamma_{t\to uh}$$

$$\Gamma_h = \Gamma^{SM}_h + \Gamma_{h\to u(\bar{t}^*\to \bar{b}w-)} + \Gamma_{h\to \bar{u}(t^*\to bw+)} + \Gamma_{h\to c(\bar{t}^*\to \bar{b}w-)} + \Gamma_{h\to \bar{c}(t^*\to bw+)}$$

After assuming the top quark decay width is dominated by the SM and neglecting the light quark mass, the branching ratio for t → qh is then given by

$$B(t\to u(c)h) = \frac{\kappa^2_{tu(c)h}}{\sqrt{2}G_F m_t^2}\,\frac{(1-\tau_h^2)^2}{(1-\tau_w^2)^2(1+2\tau_w^2)}K_{QCD} \simeq 0.58\kappa^2_{tu(c)h}$$

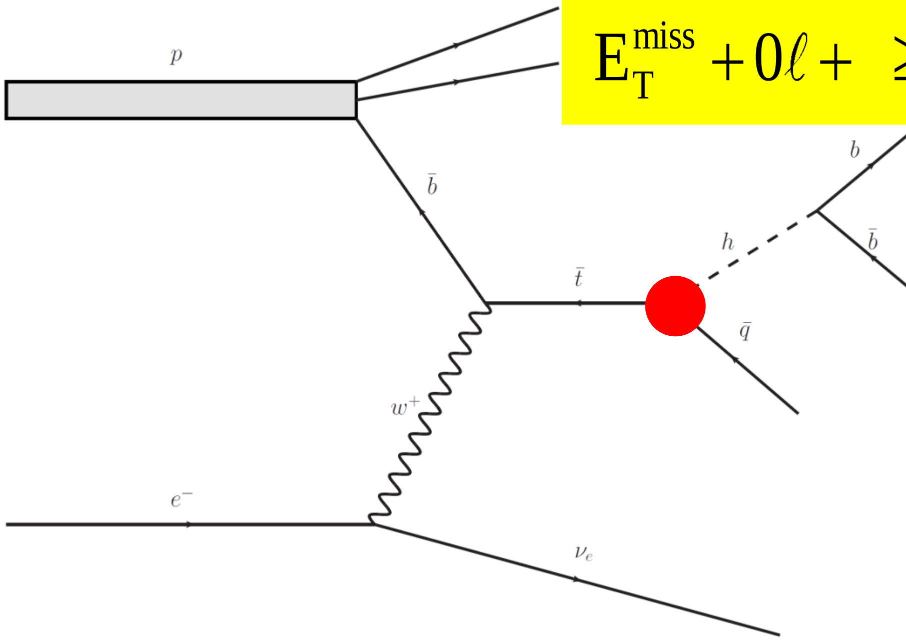
K_{QCD} ← 1.1

$$\tau_i = m_i/m_t$$

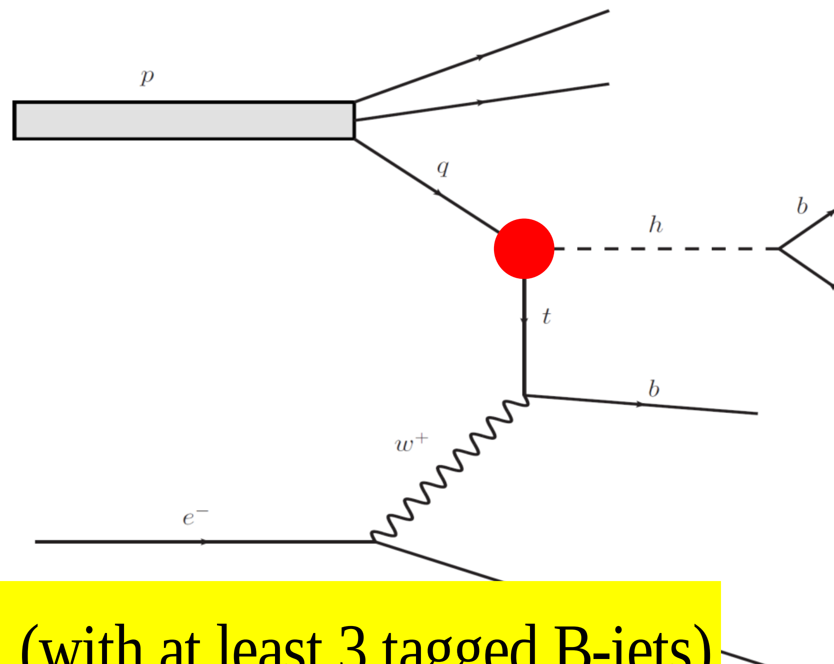
The signal

In our analysis, we only concentrate on t → uh mode

signal.I: $e^- p \to \nu_e \bar{t} \to \nu_e h\bar{q} \to \nu_e b\bar{b}\bar{q}$



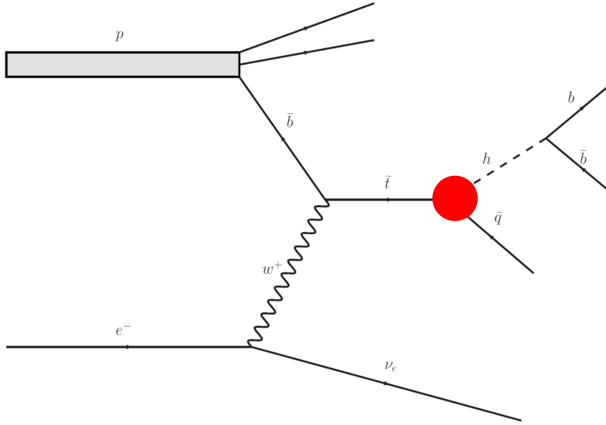
$E_T^{miss} + 0\ell + \geq 3$jets, (with at least 2 tagged B-jets)



$E_T^{miss} + 0\ell + \geq 3$jets, (with at least 3 tagged B-jets)

signal.II: $e^- p \to \nu_e hb \to \nu_e b\bar{b}b$

The background for signal.I



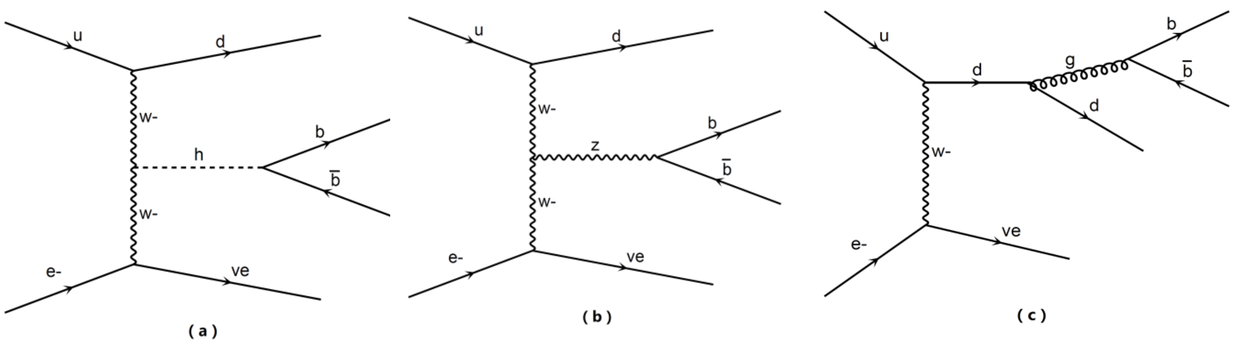
$E_T^{miss} + 0\ell + \geq 3$jets, (with at least 2 tagged B-jets)

irreducible backgrounds:

$e^-p \to \nu_e (H \to b\bar{b}) j$

$e^-p \to \nu_e (Z \to b\bar{b}) j$

$e^-p \to \nu_e (g \to b\bar{b}) j$



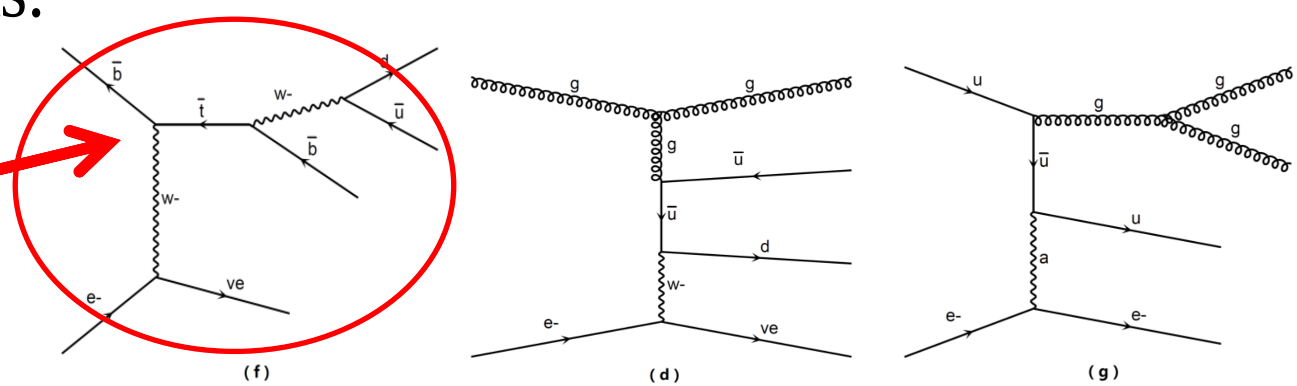
reducible backgrounds:

$e^-p \to \nu_e jjj$

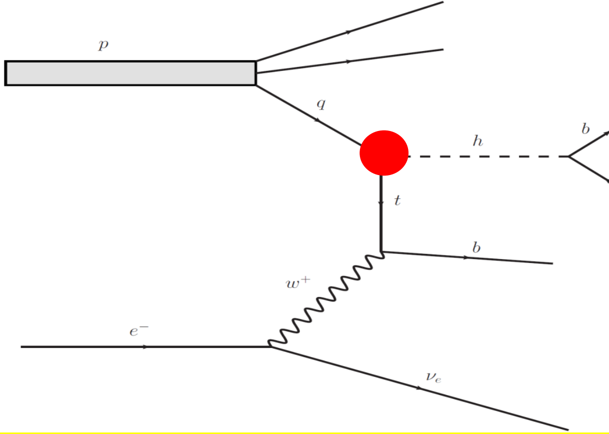
$e^-p \to \nu_e jjb/\bar{b}$

$e^-p \to \nu_e \bar{t}$

$e^-p \to e^-(g \to b\bar{b}) j$



The background for signal.II



$E_T^{miss} + 0\ell + \geq 3$jets, (with at least 3 tagged B-jets)

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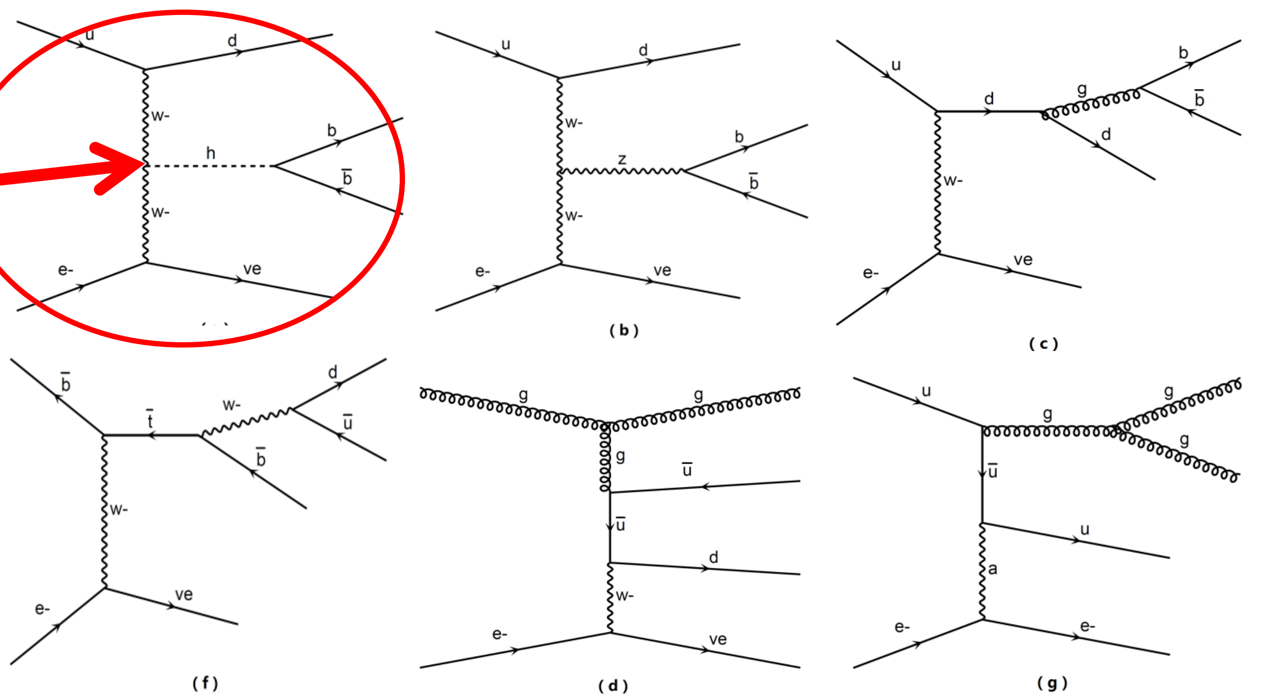
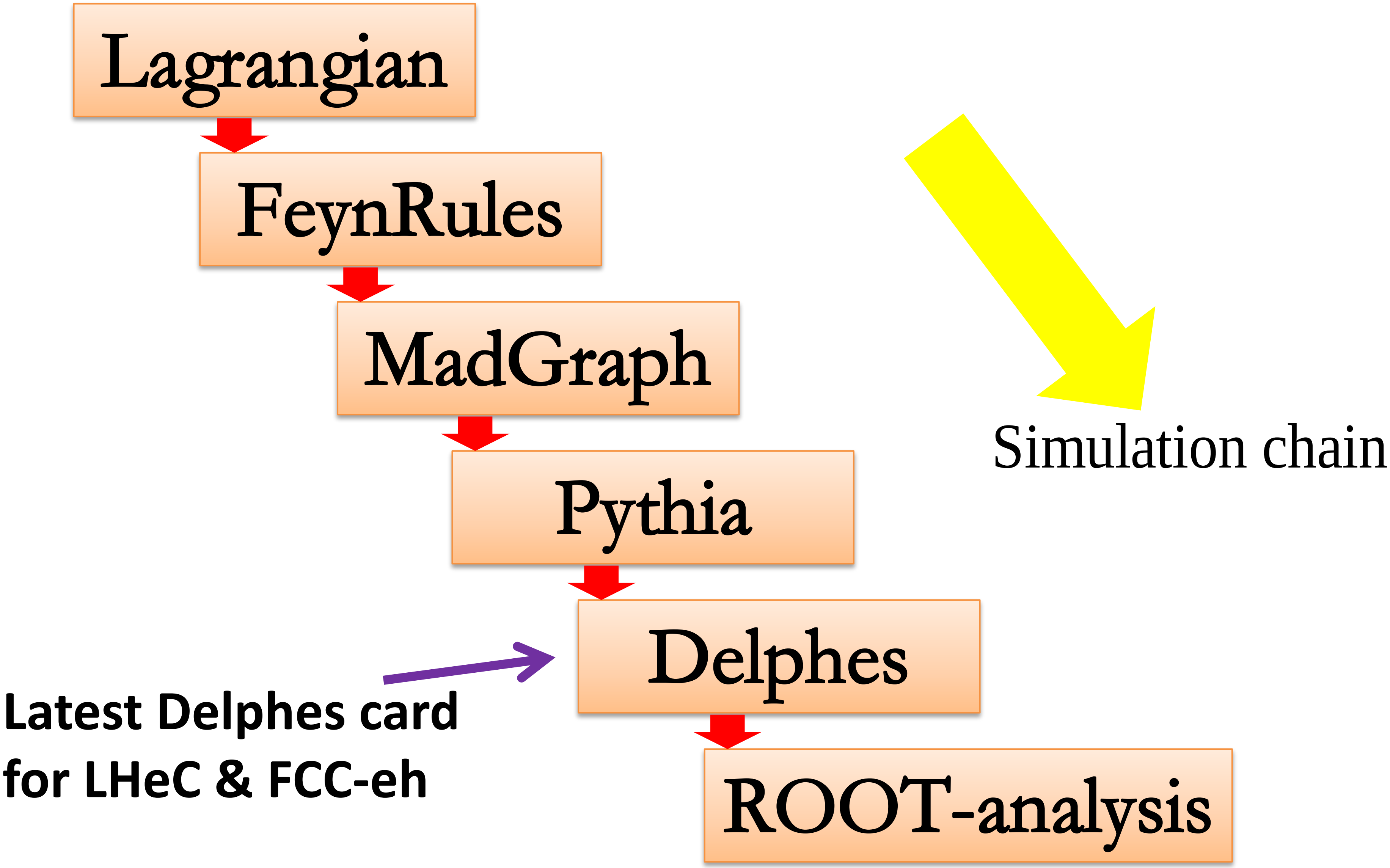
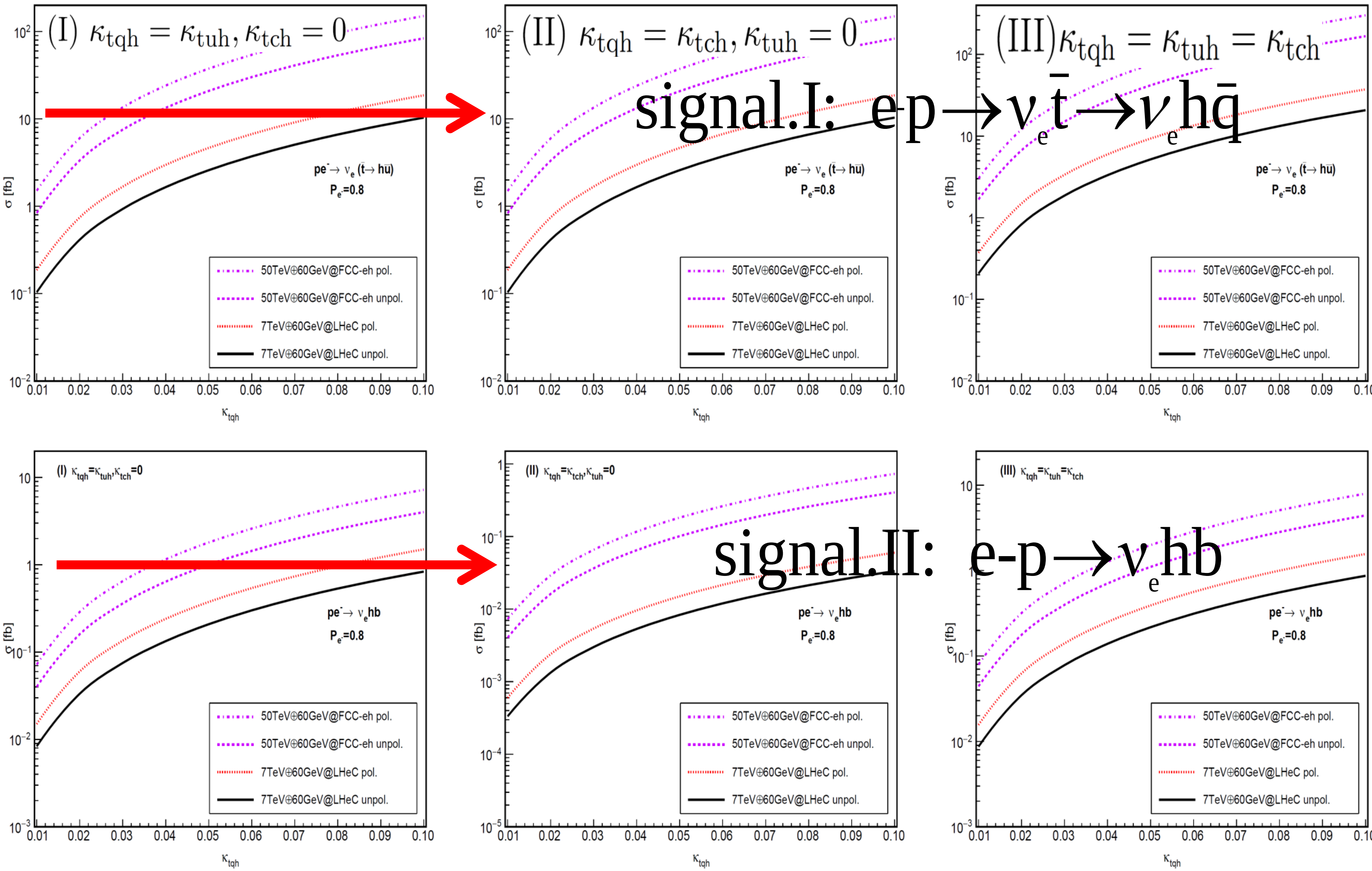


The simulation



The cross section without $H\to b\bar{b}$ decay



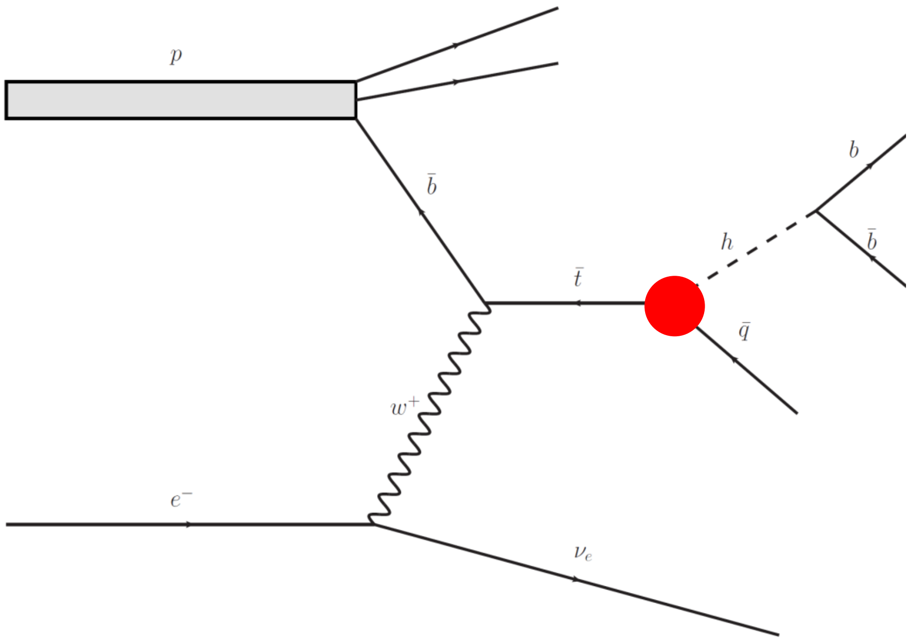
The signal after basic cuts

$p_T^{k_0} \geq 20\text{GeV}, \ |\eta^{k_0}|<10, \ k_0=j,b,\ell$

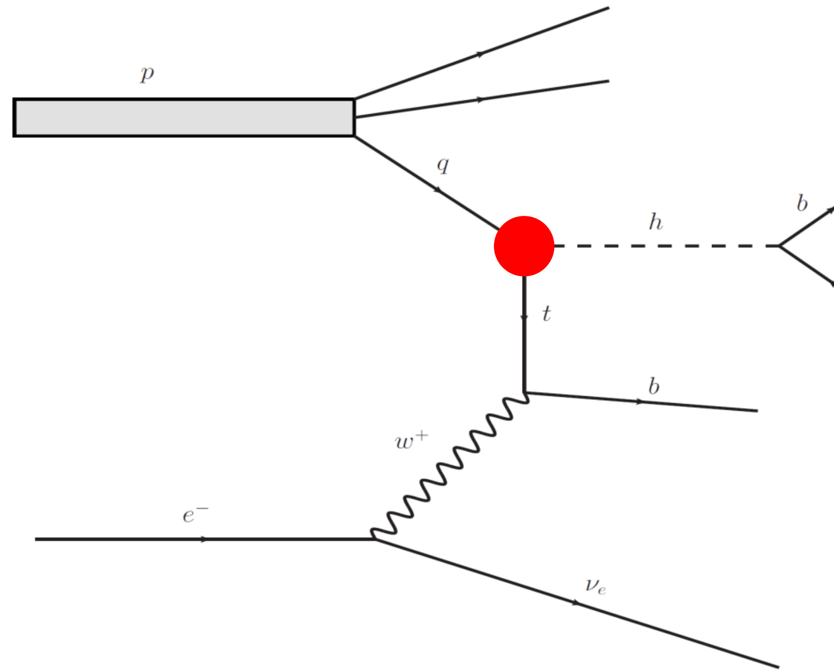
$\Delta R(k_1,k_2)>0.01, \ \ k_1k_2=jj,j\ell,jb,bb,b\ell$

$\kappa_{tuh}=0.1$

signal.I: $e\text{-}p \to \nu_e \bar{t} \to \nu_e h\bar{q} \to \nu_e b\bar{b}\bar{q}$



7.97 fb at the LHeC
64.27 fb at the FCC-eh

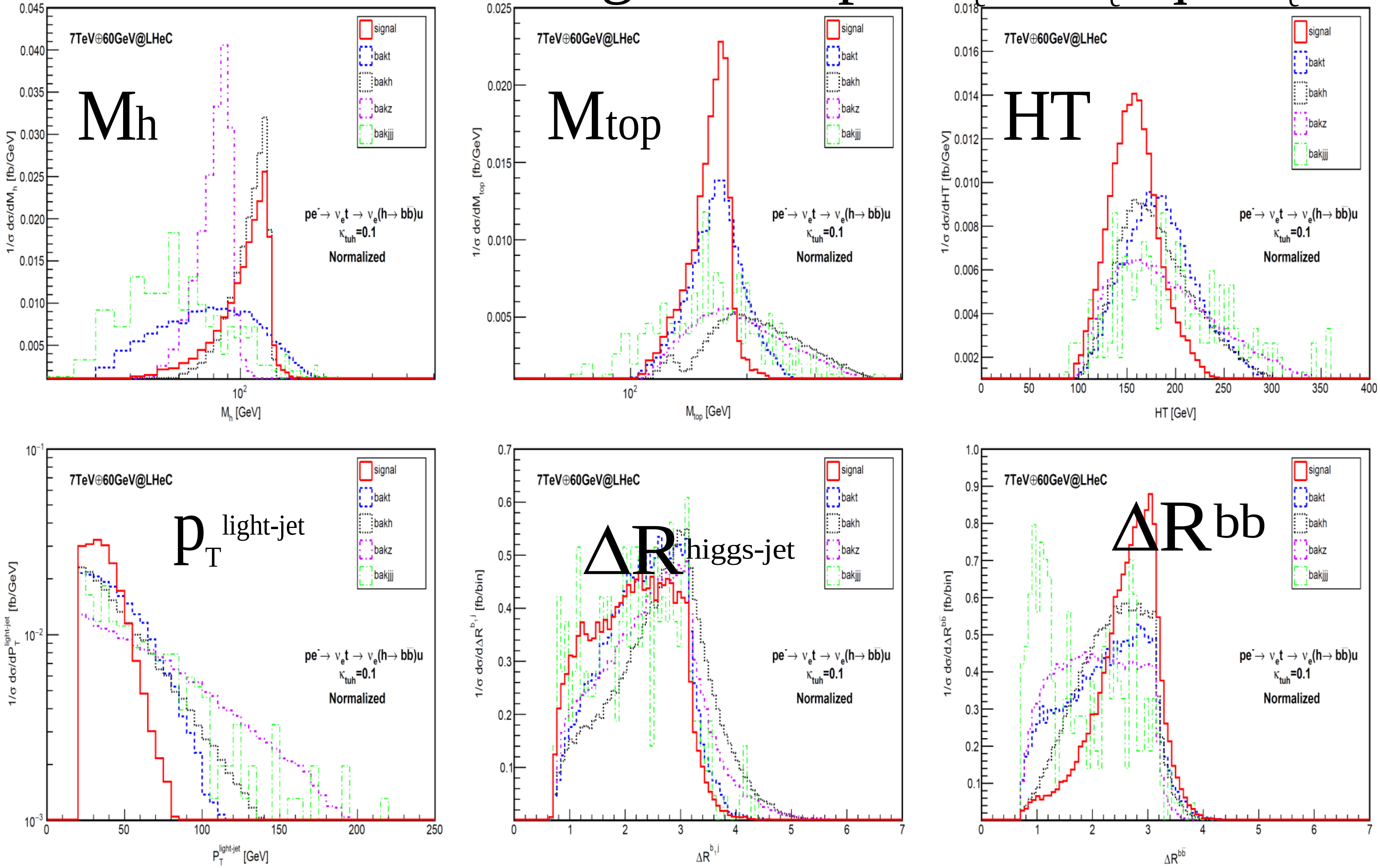


0.64 fb at the LHeC
3.084 fb at the FCC-eh

signal.II: $e\text{-}p \to \nu_e hb \to \nu_e b\bar{b}b$

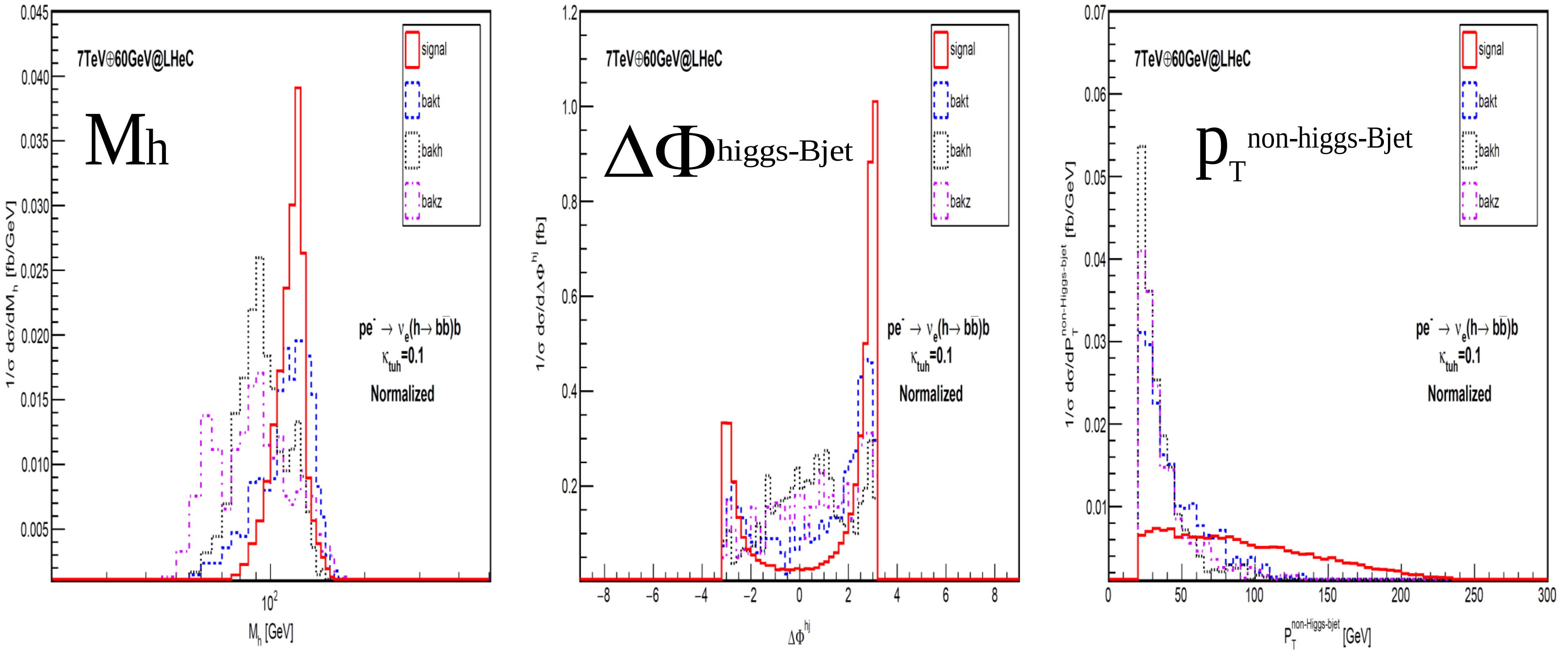
The distribution for signal.I

signal.I: $e^{-}p \to \nu_e \bar{t} \to \nu_e h \bar{q} \to \nu_e b \bar{b} \bar{q}$



The distribution for signal.II

signal.II: $e\text{-}p \to \nu_e h b \to \nu_e b\bar{b}b$



The cut flow dependence for signal.I

σ (fb)

7TeV⊕60GeV@LHeC unpol.	$\sigma_{\rm ini}$ Basic cuts	≥3 jets with 2 tagged Bjets	$M_{\rm top} \in [100, 180]$	$M_{\rm h} \in [100, 130]$	$ht \in [80, 185]$
signal.I[$\kappa_{\rm tqh} = 0.1$]	7.95	1.05	0.88	0.56	0.48
bakt	1321	61.00	34.83	8.33	4.8
bakh	92.45	15.80	3.37	1.62	1.14
bakz	70.74	10.11	3.05	0.13	0.07
bakjjj	21730	13.26	5.87	0.78	0.35
Total BG	-	100.15	47.12	10.87	6.36
$\mathcal{SS}[1{\rm ab}^{-1}]$	-	3.31	4.05	5.31	5.89

50TeV⊕60GeV@FCC-eh unpol.	$\sigma_{\rm ini}$ Basic cuts	≥3 jets with 2 tagged Bjets	$ht \in [80, 165]$	$M_{\rm h} \in [90, 125]$	$M_{\rm top} \in [120, 170]$
signal.I[$\kappa_{\rm tqh} = 0.1$]	64.27	17.82	12.13	8.14	7.64
bakt	10660	1294.59	238.02	51.53	38.12
bakh	508.3	168.58	43.08	27.53	12.78
bakz	357.2	104.69	21.22	0.97	0.05
bakjjj	90050	197.93	34.58	1.26	1.08
Total BG	-	1765.79	336.90	81.29	52.53
$\mathcal{SS}[100\ {\rm fb}^{-1}]$	-	4.23	6.57	8.88	10.3

signal.I: $e^- p \to \nu_e \bar{t} \to \nu_e h \bar{q} \to \nu_e b \bar{b} \bar{q}$

The cut flow dependence for signal.II

σ (fb)

7TeV⊕60GeV@LHeC unpol.	σ_{ini} Basic cuts	3 tagged Bjets	$p_T^{non-Higgs-bjet} \in$ [200, 475]	$\Delta\Phi^{hB_j} \in$ [0, −2.6] or [2.8, 3.2]	$M_h \in$ [90, 270]
signal.II[$\kappa_{tqh} = 0.1$]	0.64	0.06	6.5×10^{-3}	5.6×10^{-3}	5.22×10^{-3}
bakt	1320	1.78	0	0	0
bakh	92.45	0.18	0.555×10^{-3}	0.555×10^{-3}	0.555×10^{-3}
bakz	70.74	0.09	1.7×10^{-3}	0.42×10^{-3}	0
bakjjj	21730	0.13	0	0	0
Total BG	-	2.18	2.25×10^{-3}	0.98×10^{-3}	0.555×10^{-3}
$\mathcal{SS}[1ab^{-1}]$	-	2.67	3.27	3.72	4.1

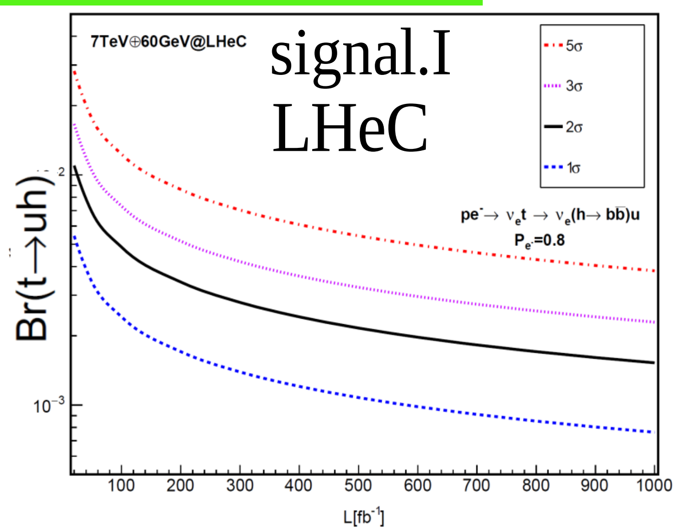
50TeV⊕60GeV@FCC-eh unpol.	σ_{ini} Basic cuts	3 tagged Bjets	$p_T^{non-Higgs-bjet} \in$ [255, 410]	$\Delta\Phi^{hB_j} \in$ [0, −2.6] or [3.0, 3.2]	$M_h \in$ [105, 390]
signal.II[$\kappa_{tqh} = 0.1$]	3.084	0.54	0.082	0.052	0.031
bakt	10660	99.99	0.043	0	0
bakh	508.3	8.94	0.007	0.002	0.001
bakz	357.2	4.0	0.054	0.013	0
bakjjj	90050	12.79	0	0	0
Total BG	-	125.72	0.104	0.016	0.001
$\mathcal{SS}[1\ ab^{-1}]$	-	1.51	7.23	9.78	12.70

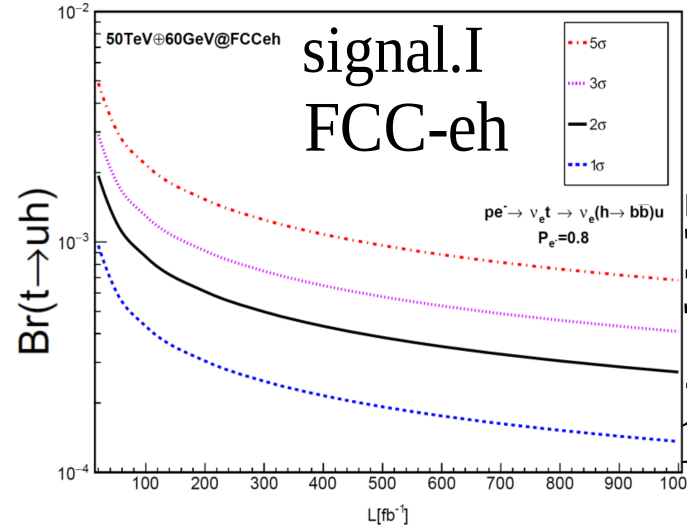
signal.II: $e\text{-}p \to \nu_e h b \to \nu_e b\bar{b}b$

10% systematic uncertainty

The discovery potential

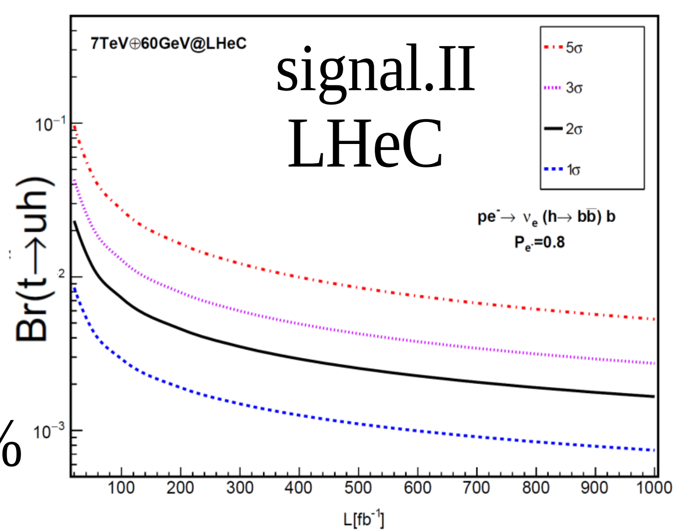
5σ: 0.38%
3σ: 0.23%
2σ: 0.15%
1σ: 0.07%

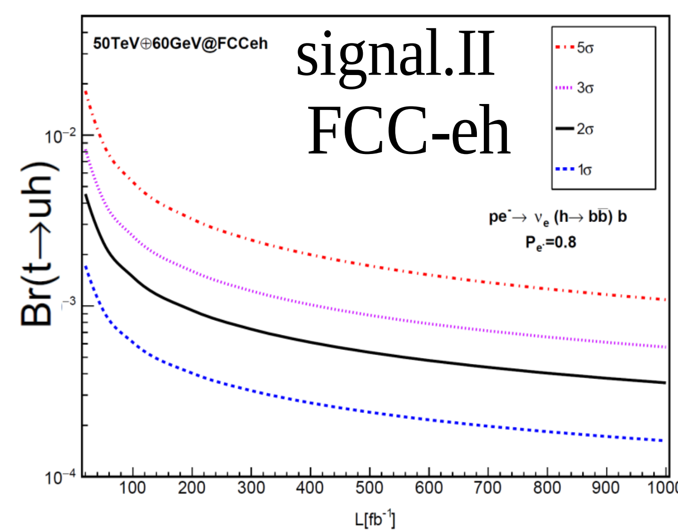




5σ: 0.068%
3σ: 0.041%
2σ: 0.027%
1σ: 0.014%

5σ: 0.53%
3σ: 0.27%
2σ: 0.17%
1σ: 0.074%

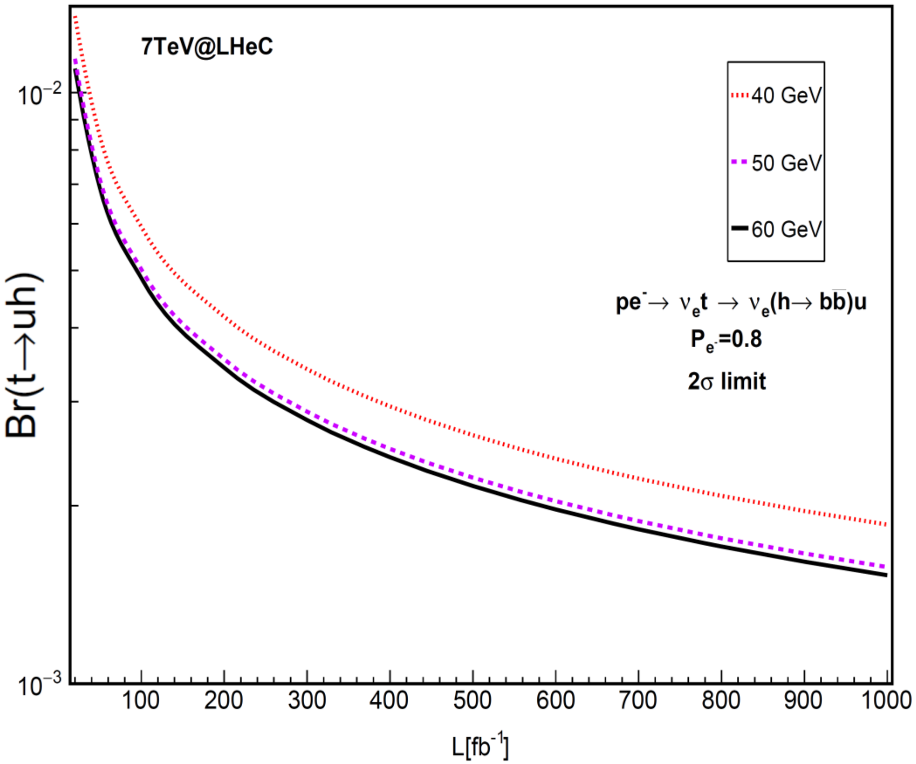


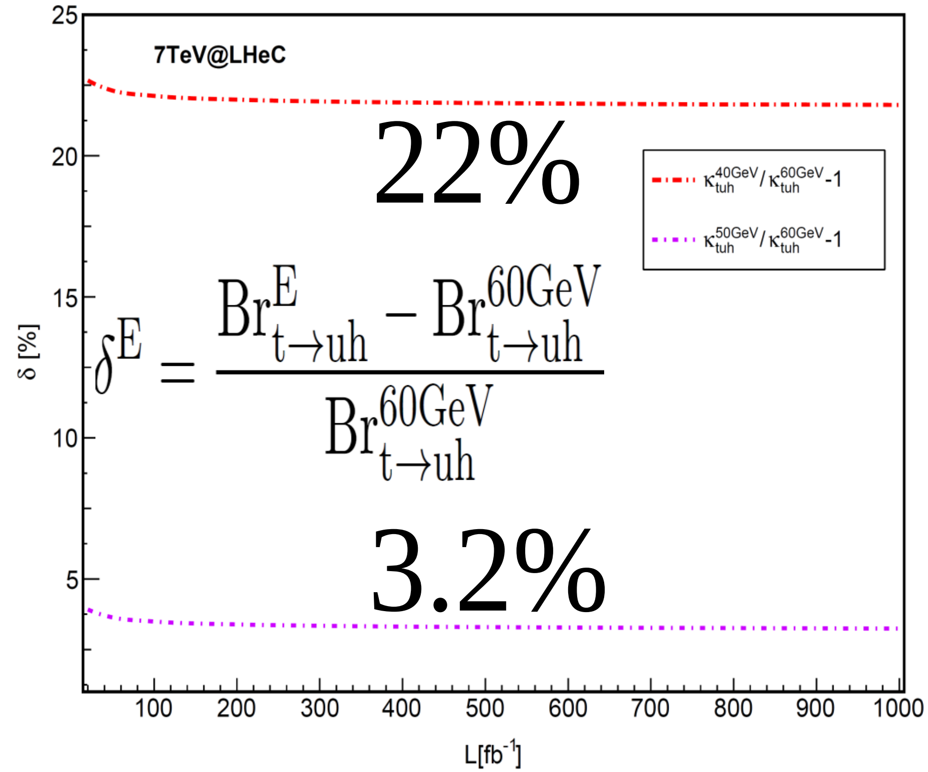


5σ: 0.109%
3σ: 0.057%
2σ: 0.035%
1σ: 0.016%

- LHC $t\bar{t}\to wb+qh\to \ell\nu b+\gamma\gamma/bbq$
  8TeV ATLAS(CMS) 20.3(19.7) fb-1
  $Br(t\to uh)\leq 0.45(0.55)\%$
- LHC $t\bar{t}\to Wb+qh\to \ell\nu b+\gamma\gamma q$
  14TeV 3000 fb-1 3σ $Br(t\to uh)\leq 0.23\%$

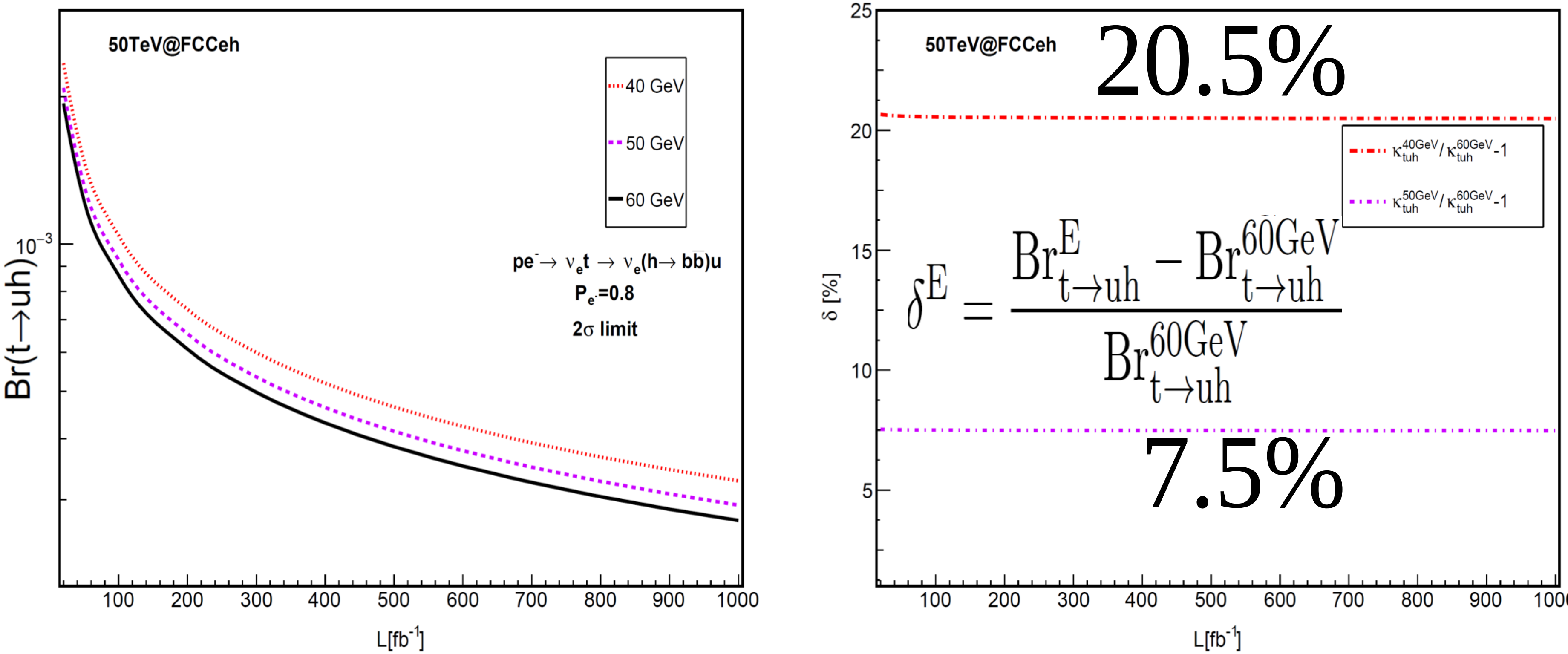
The dependence on electron beam at 7TeV LHeC





- We check that the ratio does not change no metter you are considering 1σ, 2σ, 3σ or 5σ.
- We conclude that the discovery potential reduce 3.2%(22%) if the electron beam change from 60 GeV to 50(40) GeV for 7 TeV LHeC.

The dependence on electron beam at 50TeV FCC-eh



- We check that the ratio does not change no metter you are considering 1σ, 2σ, 3σ or 5σ.
- We conclude that the discovery potential reduce 7.5%(20.5%) if the electron beam change from 60 GeV to 50(40) GeV for 50 TeV FCC-eh.

Conclusion

1. We investigate an updated analysis on searches for top-Higgs FCNC Yukawa interactions through

   signal.I : $e^{-}p \to \nu_e \bar{t} \to \nu_e h\bar{q} \to \nu_e b\bar{b}\bar{q}$

   signal.II: $e^{-}p \to \nu_e hb \to \nu_e b\bar{b}b$

2. With 80% electron polarisation, 1 ab-1, 10% δsys. uncertainty, the 3σ discovery significance limit on $Br(t \to uh)$ are

0.23×10^{-2}	0.041×10^{-2}
$7TeV\oplus60GeV$@LHeC	$50TeV\oplus60GeV$@FCC-eh.

3. We give an estimate on how the sensitivity would change when we reduce the elctron beam energy due to the cost reasons. Our conclusion is that the discovery potential reduce

3.2%(22.0%)	60 GeV to 50(40) GeV	7 TeV LHeC
7.5%(20.5%)	60 GeV to 50(40) GeV	50 TeV FCC-eh


Thanks!