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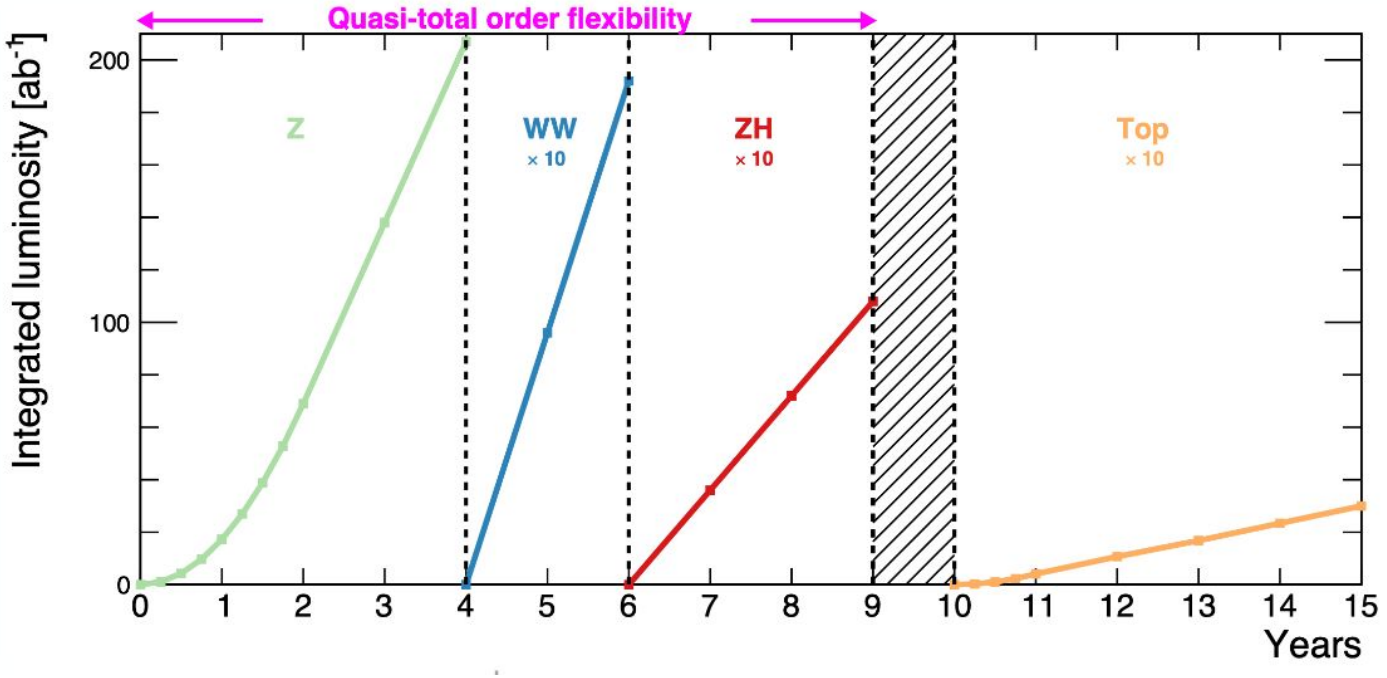
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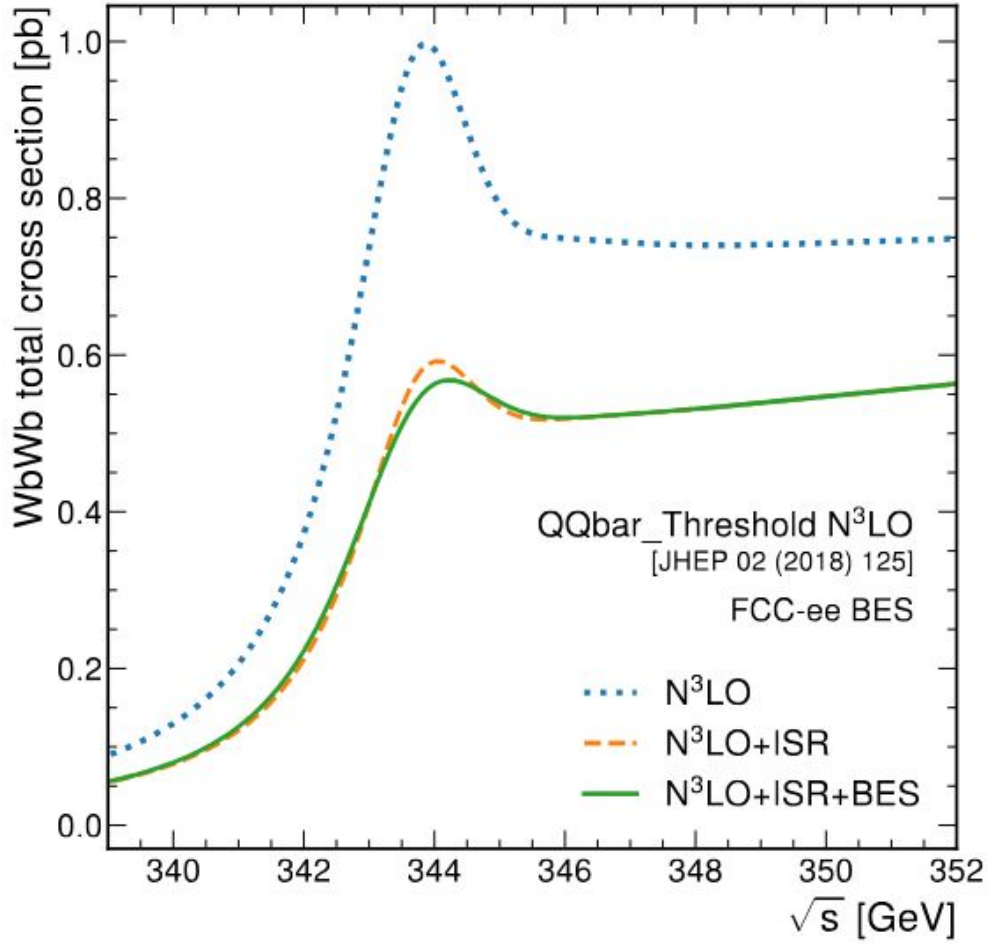
ICTEA
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Top-quark pair production sensitivity to heavy new physics at the FCC-ee

Sergio Sánchez Cruz, based on arXiv:2609.16342 (J. De Piccoli, G. Durieux, SSC, M. Selvaggi)

FCC: a Higgs factory, but also a *top* factory



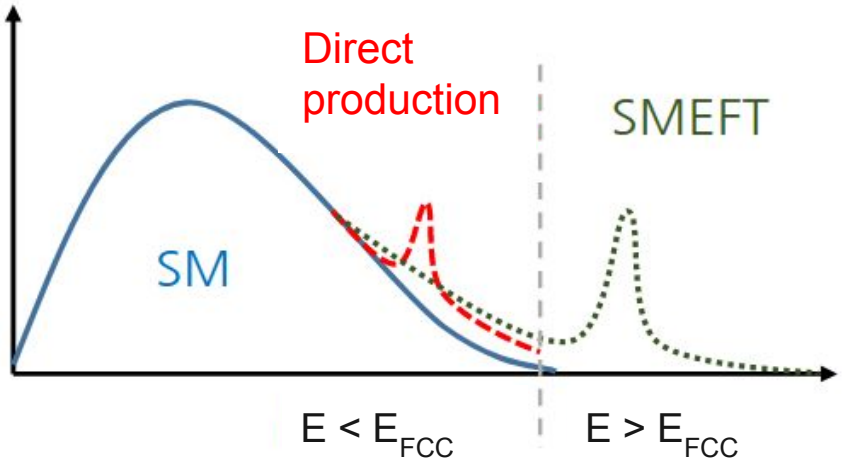


- Top threshold run ⟶ ~2.7 ab^{-1}, 2·10^6 ttbar pairs
- Precise measurements of $\mathbf{m_t}$ (± 6 MeV, 50 times more precise than present), and $\mathbf{\Gamma_t}$ (± 12 MeV, 15 times more precise)

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FCC as a discovery machine

- FCC sqrt(s) may not allow for the direct production of new particles
- Indirect searches may provide hints of new physics

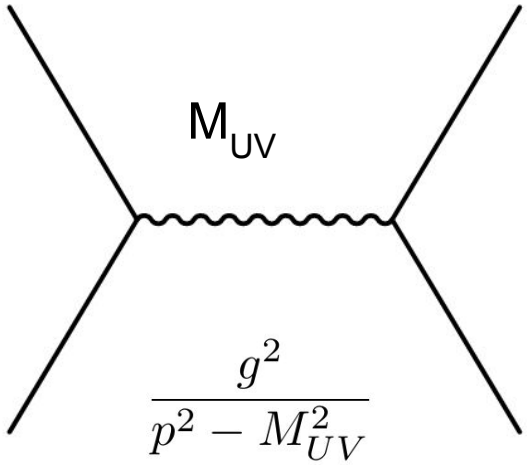


Wilson coefficient

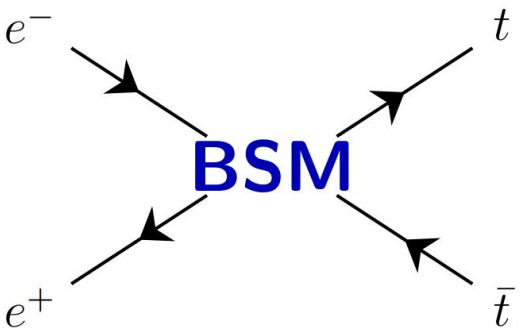
$$\mathcal{L} = \mathcal{L}_{SM} + \sum_i \frac{C_i}{\Lambda^2} O_i^{(6)}$$

UV scale

EFT operator

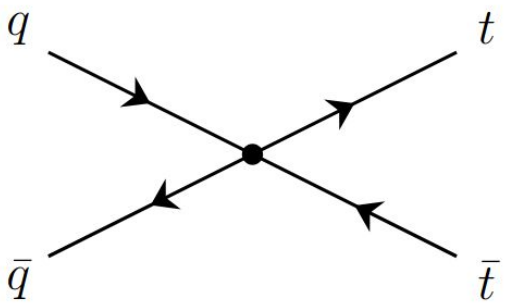


$p^2 \ll M_{UV}^2$

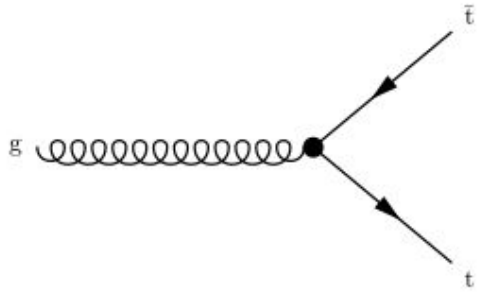


SMEFT in the top sector in a nutshell

4-quark interactions

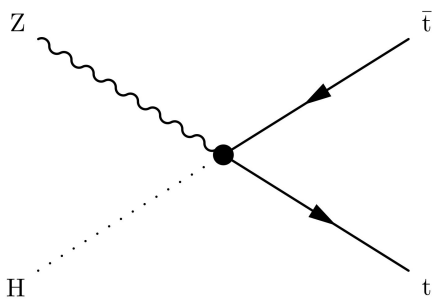


top+gluon interactions

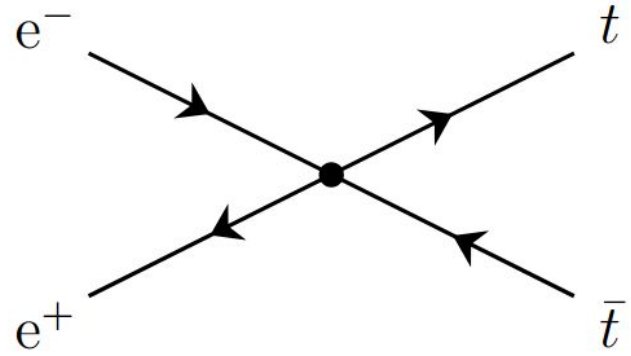


Large sensitivity from the LHC

top+Z/H/W/γ interactions



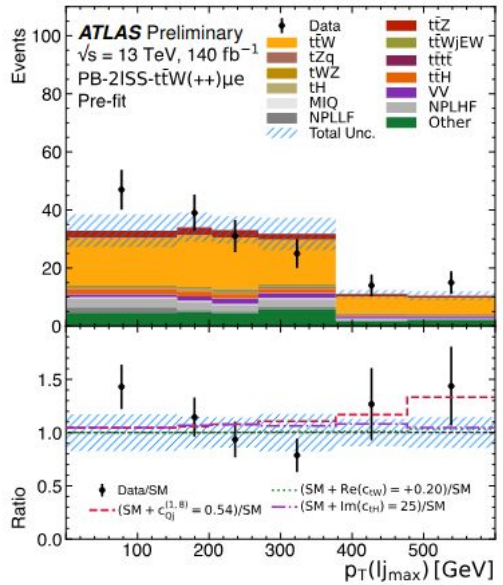
2-top-2-lepton interactions



Hard(er) at the LHC

Measurements at the LHC

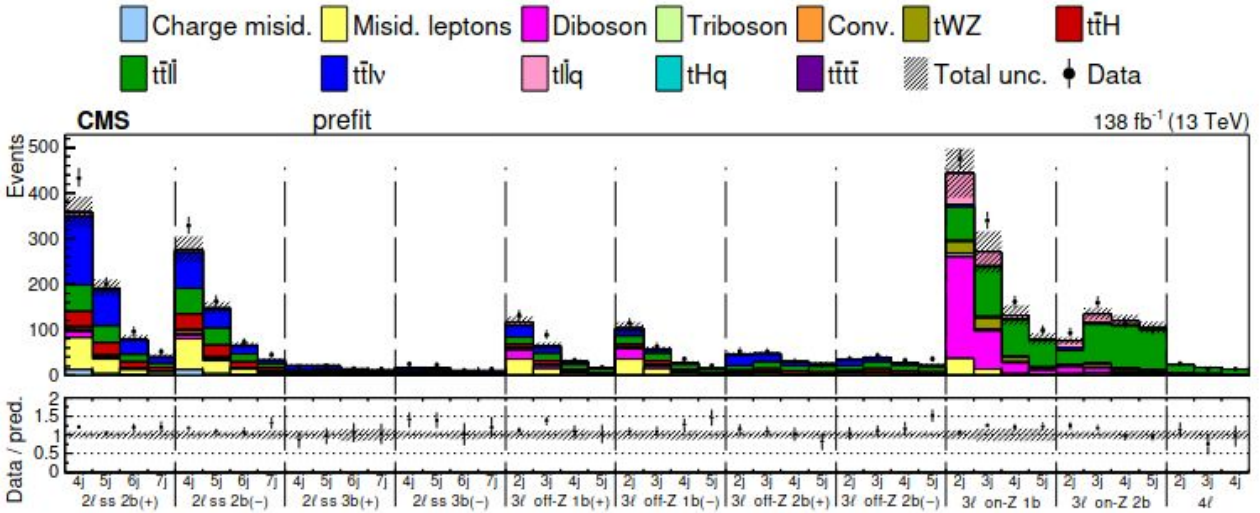
- **5 billion ttbar pairs at the end of HL-LHC** → excellent sensitivity to 4-quark and top+gluon through ttbar
- Operators involving top + ewk bosons and top + leptons can only be probed at the LHC *through associated top production*



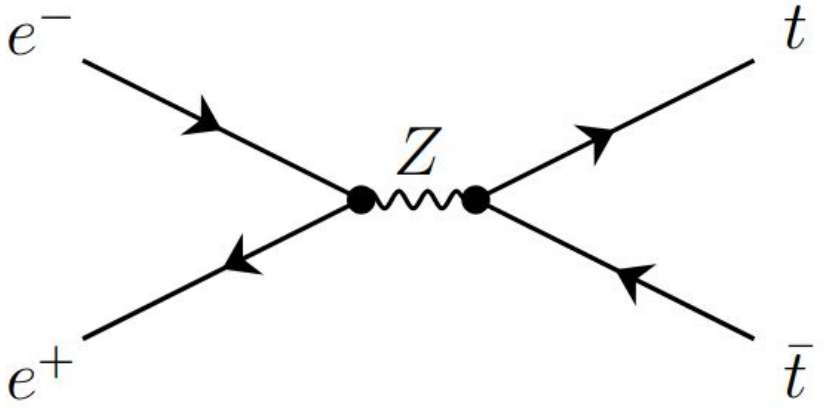
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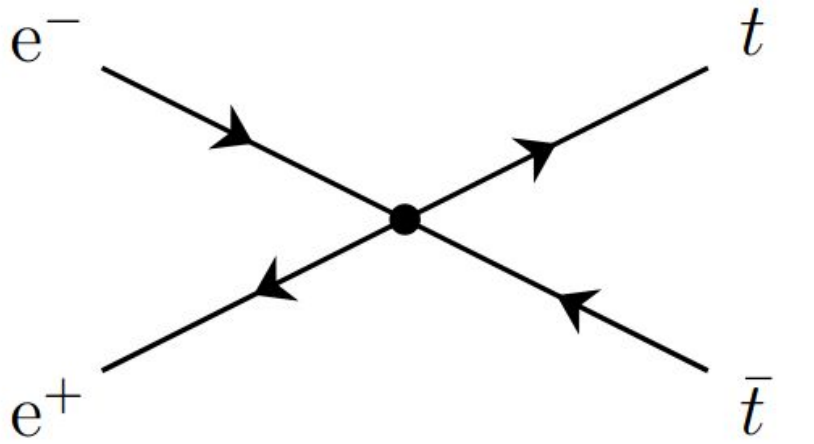
- Associated top production are much rarer processes → **parameter space will likely not be fully covered at the end of HL-LHC**



Top EFT at the FCC



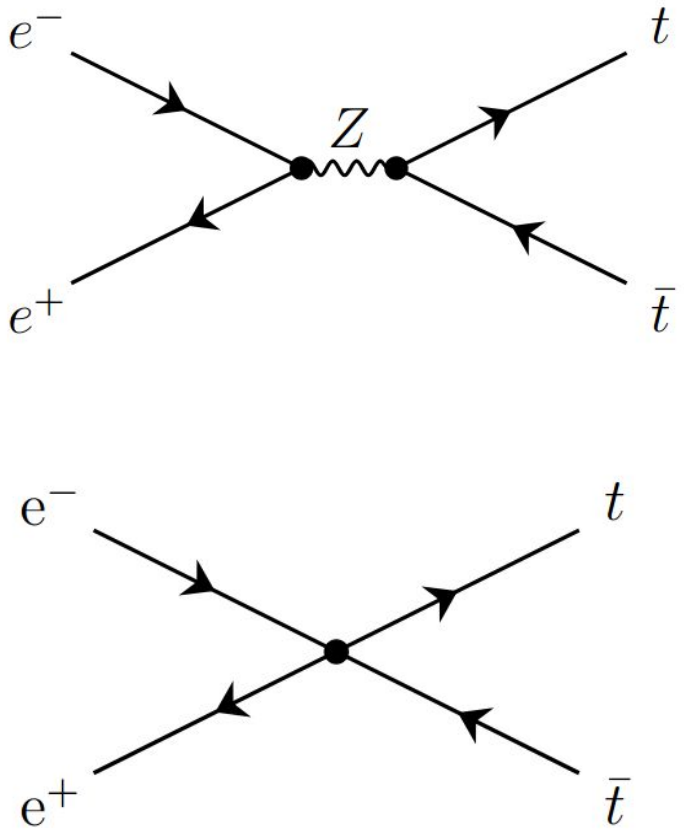
- FCC–ee will be a **unique scenario for top physics**
  - Clean initial state
  - Clean environment → full reconstruction of ttbar system, high-performance flavor tagging
  - **ttbar production occurs through ewk interaction**



- Several analyses already performed with optimal observables at FCC using the WbWb kinematics
- Goal is to perform a **global analysis** using the most state-of-the-art techniques and **improving the optimal** observables techniques

This analysis

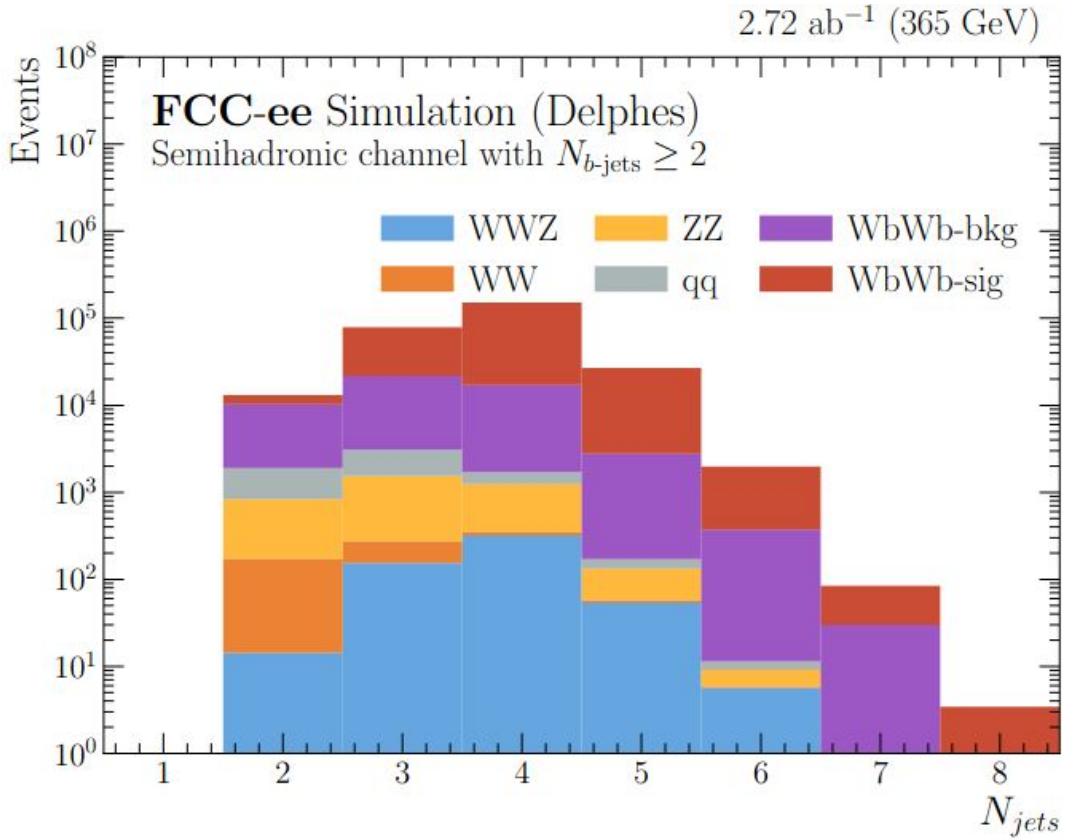
- Probing **12 independent operators** affecting ttbar production at the FCC
- Using **realistic simulations** of the WbWb process in the IDEA detector (Whizard + pythia 6 + delphes)
- **EFT predictions are obtained reweighting the samples**
  - Matrix elements obtained using Madgraph



Operator	Definition
$O_{\varphi q}^{1(ij)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar{q}_i \gamma^\mu q_j)$
$O_{\varphi q}^{3(ij)}$	$(\varphi^\dagger i\overleftrightarrow{D}^I_\mu \varphi)(\bar{q}_i \gamma^\mu \tau^I q_j)$
$O_{\varphi u}^{(ij)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar{u}_i \gamma^\mu u_j)$
$^\ddagger O_{uW}^{(ij)}$	$(\bar{q}_i \sigma^{\mu\nu} \tau^I u_j)\, \tilde{\varphi}\, W^I_{\mu\nu}$
$^\ddagger O_{uB}^{(ij)}$	$(\bar{q}_i \sigma^{\mu\nu} u_j)\, \tilde{\varphi}\, B_{\mu\nu}$
$O_{lq}^{1(ijkm)}$	$(\bar{l}_i \gamma^\mu l_j)(\bar{q}_k \gamma^\mu q_m)$
$O_{lq}^{3(ijkm)}$	$(\bar{l}_i \gamma^\mu \tau^I l_j)(\bar{q}_k \gamma^\mu \tau^I q_m)$
$O_{lu}^{(ijkm)}$	$(\bar{l}_i \gamma^\mu l_j)(\bar{u}_k \gamma^\mu u_m)$
$O_{e\bar{q}}^{(ijkm)}$	$(\bar{e}_i \gamma^\mu e_j)(\bar{q}_k \gamma^\mu q_m)$
$O_{eu}^{(ijkm)}$	$(\bar{e}_i \gamma^\mu e_j)(\bar{u}_k \gamma^\mu u_m)$
$^\ddagger O_{lequ}^{1(ijkm)}$	$(\bar{l}_i e_j)\, \varepsilon\, (\bar{q}_k u_m)$
$^\ddagger O_{lequ}^{3(ijkm)}$	$(\bar{l}_i \sigma^{\mu\nu} e_j)\, \varepsilon\, (\bar{q}_k \sigma_{\mu\nu} u_m)$

Analysis strategy

- Events with one reconstructed electron or muon and 4 jets are kept
- 2 b-jets are reconstructed using a transformer-based tagger [2202.03285]
  - 40% signal selection for the WbWb (1l) signal
  - Selected events are ~99% WbWb signal events, O(1%) background



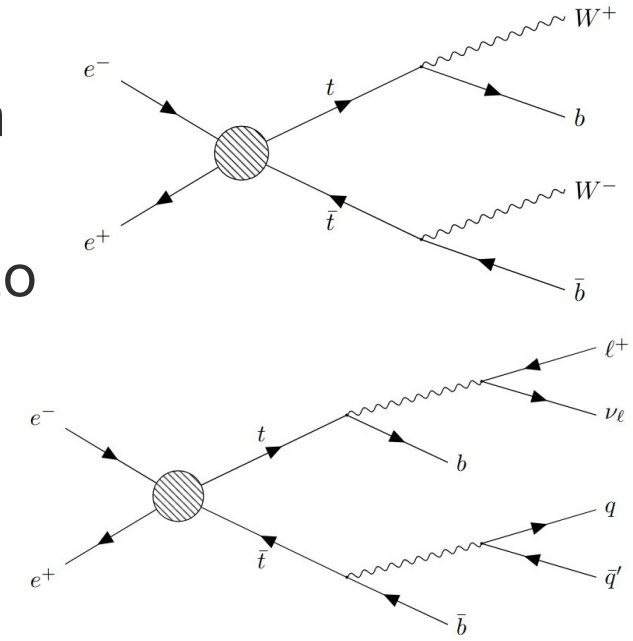
Optimal observables

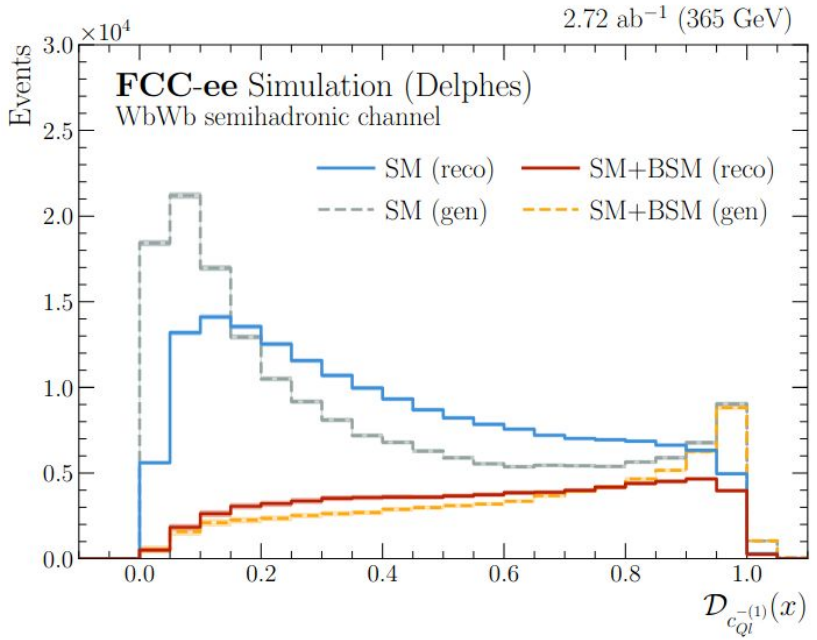
- **Optimal observables built based on matrix elements**
- For each operator, a matrix-element based discriminator is used

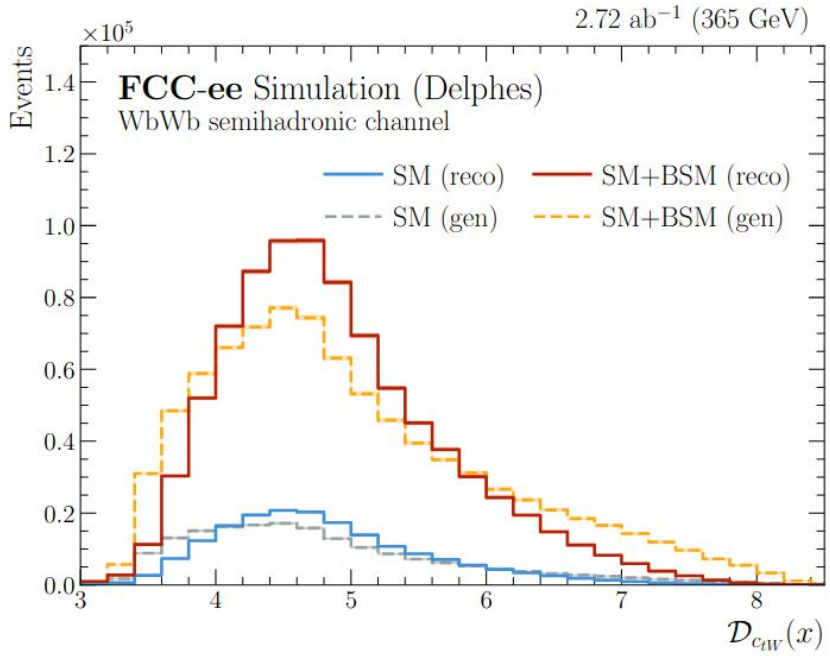
$$\mathcal{D}(x_{\text{reco}}, \{c_i\}) = \frac{|A_{\text{SM}}(x_{\text{reco}}) + \sum_i A_{\text{SMEFT},i}(x_{\text{reco}})\, c_i/\Lambda^2|^2}{|A_{\text{SM}}(x_{\text{reco}})|^2}$$

amplitudes obtained using Madgraph **for the 2→6 process**

- Final state objects are the inputs to the discriminator
- Observables are optimal, modulo background and detector effects

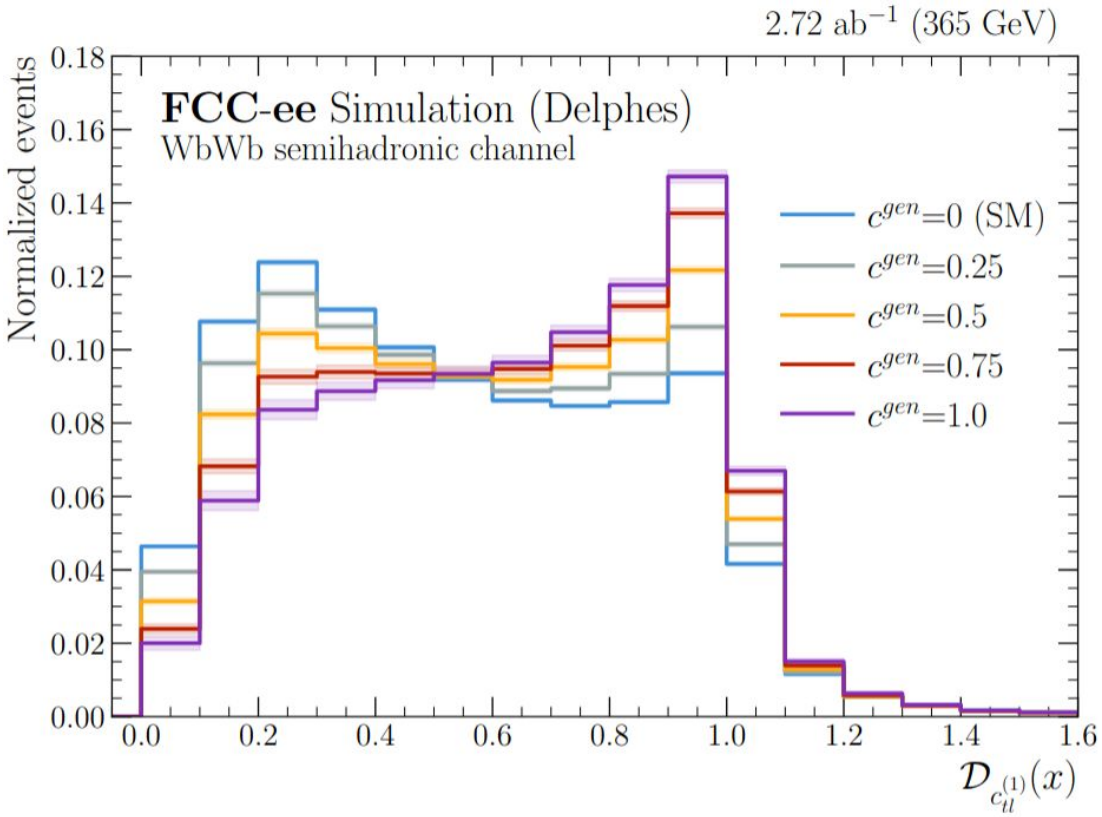






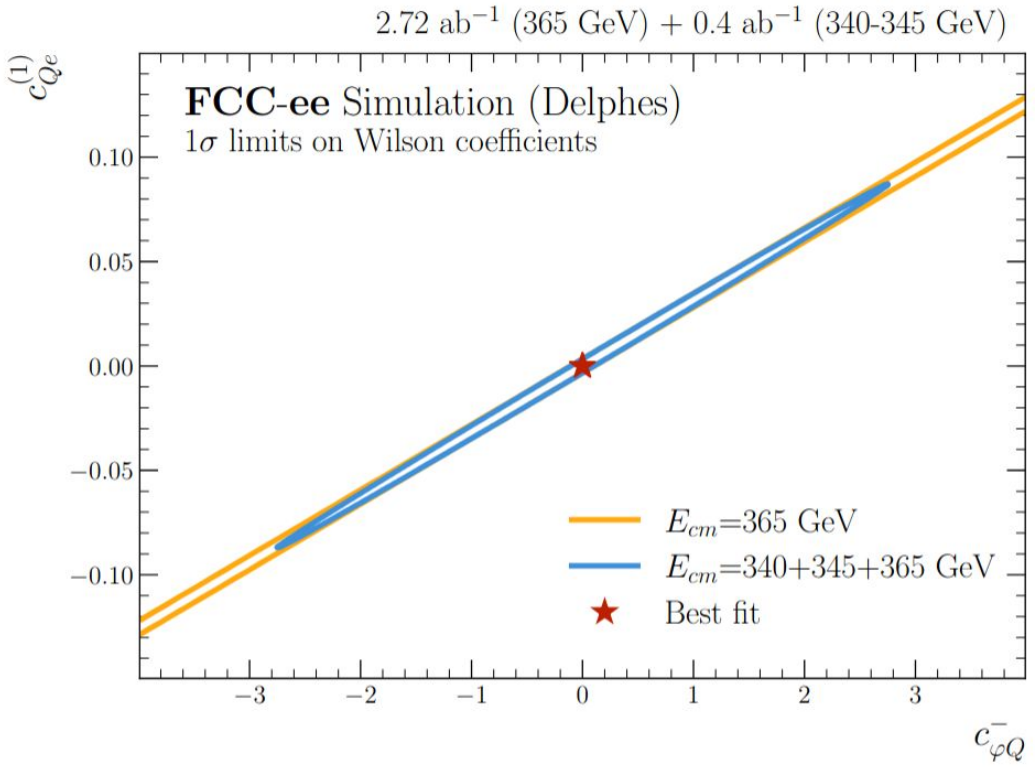
Optimal observables

- $\mathcal{D}(x_{\text{reco}}, \{c_i\})$ is optimal for a single operator, not for the 12 operators
- Goal is to constrain all operators simultaneously
- Strategy is to have 2 bins x 12 observables $\longrightarrow$ 4096 bins



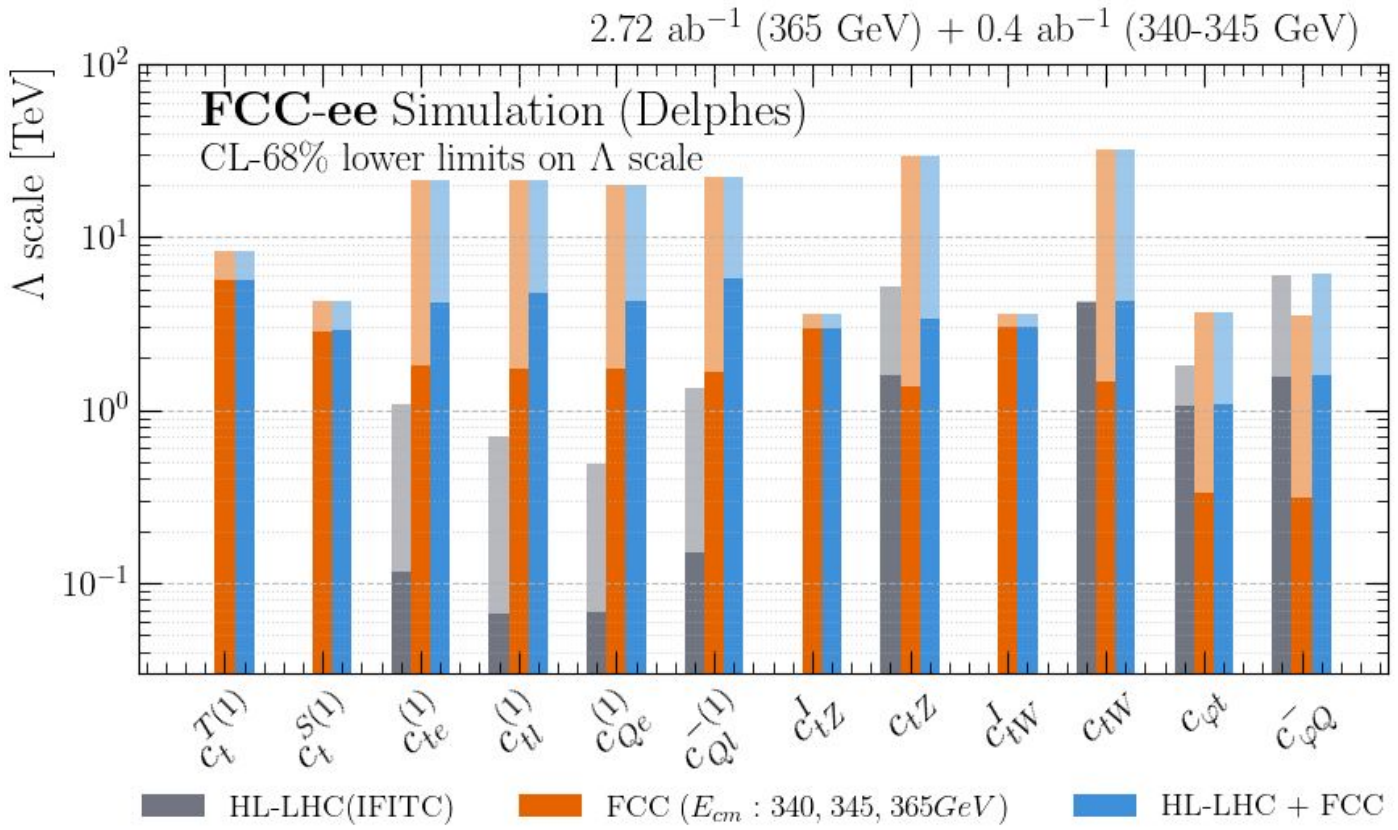
Center-of-mass energy dependence

- Most of the sensitivity coming from the sqrt(s)=365 GeV run
- Runs at sqrt(s)=340 and 345 GeV help lift degeneracies between top+boson and 4-fermion operators, which have a different energy dependency
- Baseline is 2.7 ab^{-1} @ 365 GeV and 0.4 ab^{-1} @ 340 and 345 GeV



Results

- **FCC-ee** will allow to set limits on new physics up to **30 TeV to 3 TeV**
  - **HL-LHC** will reach **5 TeV - 600 GeV**
- **FCC-ee** will set limits up to **7 TeV - 300 GeV** in *global analyses*
  - **HL-LHC** will reach **between 7 TeV and < 100 GeV**



- **Combination of FCC-ee and HL-LHC will exclude between 7 and 1 TeV**

Conclusions

- Presented an update of the sensitivity of the FCC-ee to electroweak EFT operators in the top sector
- Improvements with respect to previous studies are the usage of $2 \rightarrow 6$ kinematic information
- Using also realistic detector simulation, reconstruction and event selection
- Results show the power of the FCC-ee to discover new physics in the top sector and the complementarity with the HL-LHC program

Acknowledgements

This work was supported by the “Ramón y Cajal” program under Project No. RYC2024-048719-I, funded by ICIU/AEI/10.13039/501100011033 and by the FSE+.

Back-up

Comparison with previous FCC results

Different improvements / changes with respect to previous FCC projections:

- Additional sensitivity from kinematic of decayed particles
- More realistic detector simulation
- Realistic treatment of event selection and background
- Some sensitivity loss due to the unbinned approach

