IMPACT OF FERMIONIC OPERATORS ON THE HIGGS WIDTH MEASUREMENT

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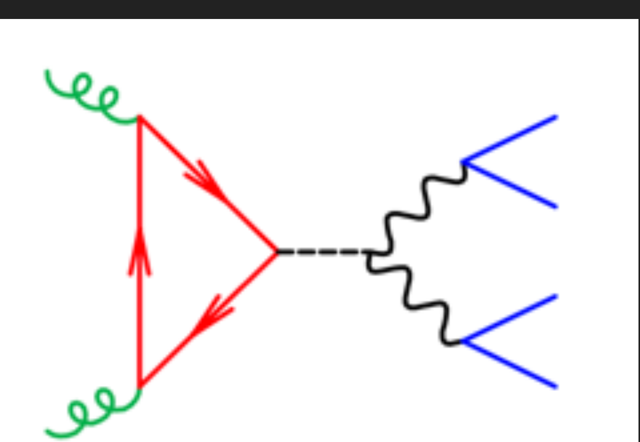
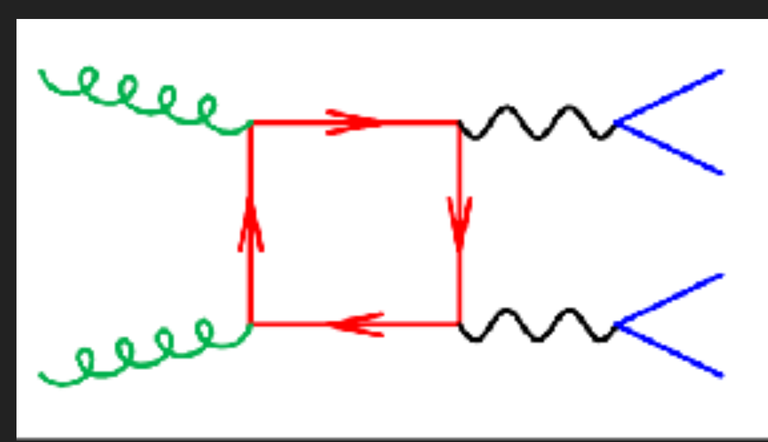
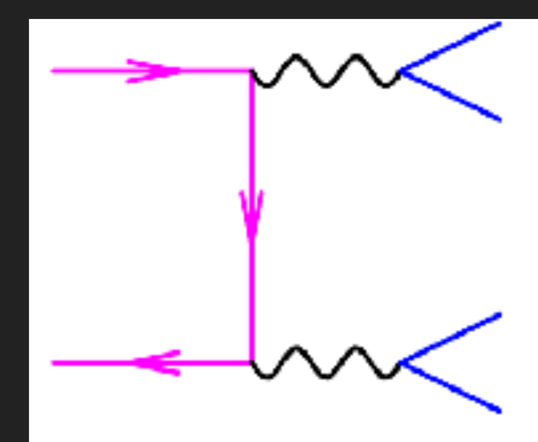
BASIC FACTS

- The off-shell Higgs cross section is large [Kauer-Passarino arXiv:1206.4803]
- Tail is independent of the H width.
- Within the SM, comparing on-shell and off-shell Higgs productions allows to measure the H width [Caola-Melnikov 1307.4935; Campbell-Ellis-Williams 1311.3589]

$$\sigma_{gg\to H\to ZZ} \propto \frac{g_{Hgg}^2 g_{HZZ}^2}{\Gamma_H} \qquad \frac{d\sigma_{gg\to H\to ZZ}}{dM_{4\ell}} \propto \frac{g_{Hgg}^2 g_{HZZ}^2}{(M_{4\ell}-M_H)^2}$$

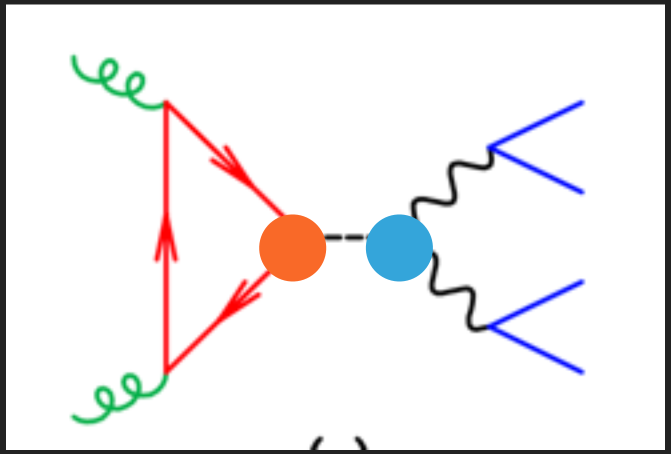


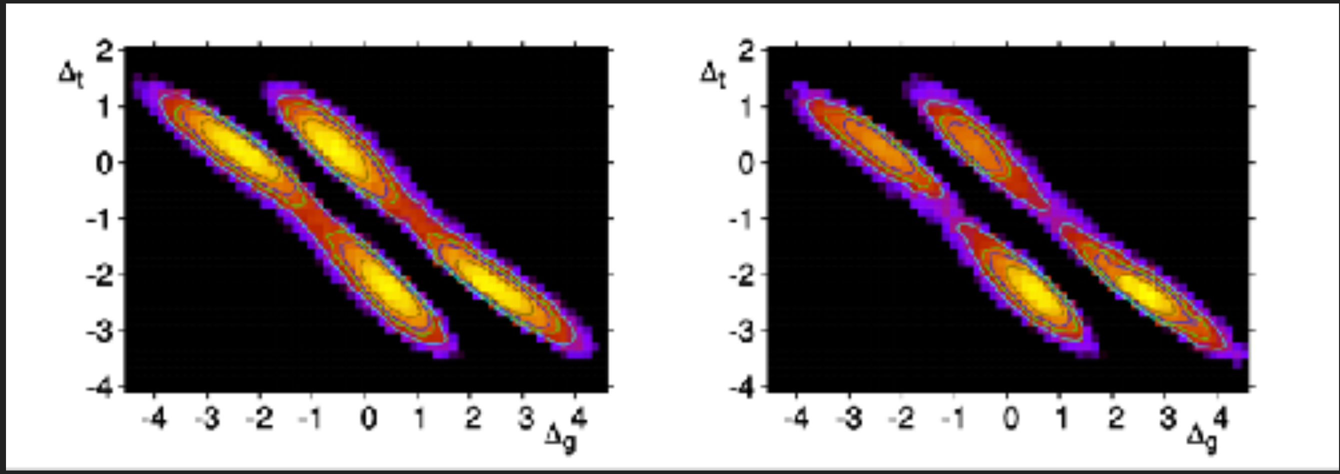




OUR GOAL

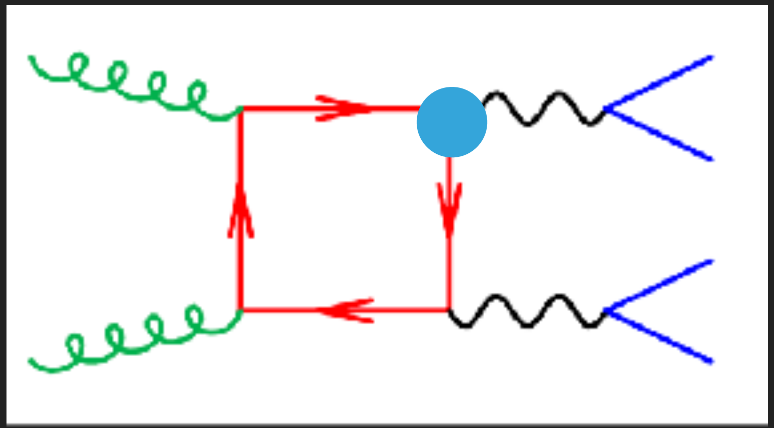
- We can also study the Higgs couplings [Gainer et al. 1403.4951; Englert-Spannowsky 1405.0285; Cacciapaglia et al. 1405.0285; Azatov et al. 1406.6338; ……]

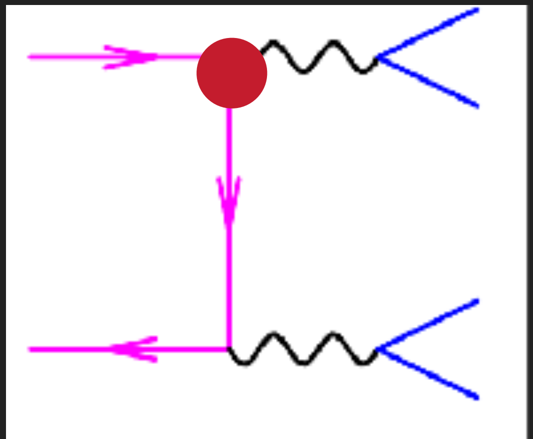




[Corbett et al. arXiv:1505.05516]

- We want to access the impact of anomalous Zqq couplings that modify the backgrounds [Ztt studied by Azatov et al. arXiv:1608.00977]





- We extend the SM adding dimension-6 operators

$$\mathcal{L}_{eff} = \mathcal{L}_{SM} + \sum_n \frac{f_n}{\Lambda^2} + \cdots$$

- There are 59 independent dimension-six operators [Grzadkowski et al. arXiv: 1008.4884]
- The subset of fermionic operators relevant for our analysis is

$$\mathcal{O}^{(1)}_{\Phi Q,ij} = \Phi^\dagger (i\overleftrightarrow{D}_\mu \Phi)(\bar{Q}_i \gamma^\mu Q_j), \qquad \mathcal{O}^{(3)}_{\Phi Q,ij} = \Phi^\dagger (i\overleftrightarrow{D}^a_\mu \Phi)(\bar{Q}_i \gamma^\mu T_a Q_j),$$

$Z\bar{q}q$

$$\mathcal{O}^{(1)}_{\Phi u,ij} = \Phi^\dagger (i\overleftrightarrow{D}_\mu \Phi)(\bar{u}_{R_i} \gamma^\mu u_{R_j}), \qquad \mathcal{O}^{(1)}_{\Phi d,ij} = \Phi^\dagger (i\overleftrightarrow{D}_\mu \Phi)(\bar{d}_{R_i} \gamma^\mu d_{R_j}),$$

- Couplings: family diagonal and generation independent

- We also studied the dipole operators

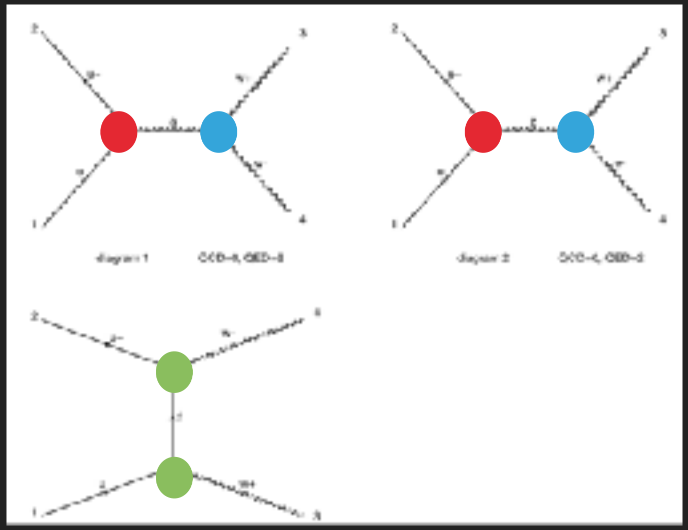
$$\mathcal{O}_{uW,ij} = i\overline{Q}_i \sigma^{\mu\nu} u_{R,j} \widehat{W}_{\mu\nu} \tilde{\phi} \quad , \qquad \mathcal{O}_{uB,ij} = i\overline{Q}_i \sigma^{\mu\nu} u_{R,j} \widehat{B}_{\mu\nu} \tilde{\phi} \quad ,$$

$$\mathcal{O}_{dW,ij} = i\overline{Q}_i \sigma^{\mu\nu} d_{R,j} \widehat{W}_{\mu\nu} \phi \quad , \qquad \mathcal{O}_{dB,ij} = i\overline{Q}_i \sigma^{\mu\nu} u_{R,j} \widehat{B}_{\mu\nu} \phi \quad ,$$

* EWPD and diboson production constrain these operators

[Corbett et al. arXiv:1306.0006; Almeida et al. arXiv:1812.01009 arXiv:1905.05187]

operator	EWPD (TeV^{-2})	EWPD+EWDBD (TeV^{-2})
$\mathcal{O}_{\phi Q}^{(1)}$	[-0.083,0.10]	[-0.034,0.11]
$\mathcal{O}_{\phi Q}^{(3)}$	[-0.60,0.12]	[-0.45,0.13]
$\mathcal{O}_{\phi d}^{(1)}$	[-1.2,-0.13]	[-0.64,-0.007]
$\mathcal{O}_{\phi u}^{(1)}$	[-0.25,0.37]	[-0.17,0.37]
$\mathcal{O}_{uW}$	[-10.,10.]	[-0.29,0.29]
$\mathcal{O}_{uB}$	[-41.,41.]	[-1.9,1.9]
$\mathcal{O}_{dW}$	[-10.,10.]	[-0.36,0.36]
$\mathcal{O}_{dB}$	[-38.,38.]	[-1.9,1.9]

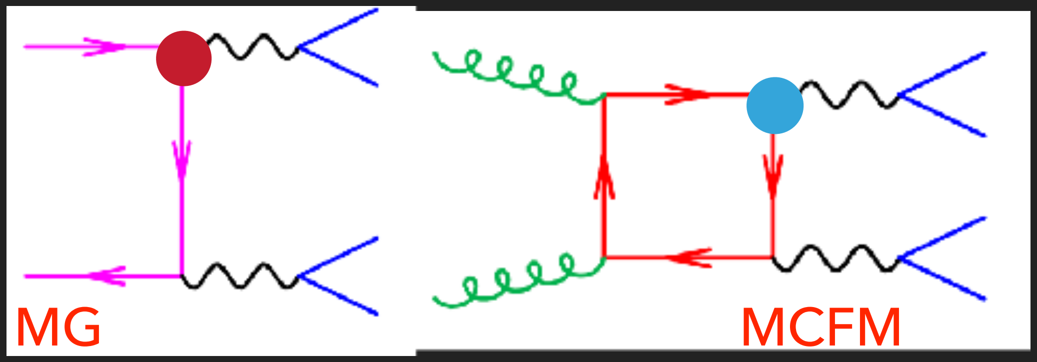


- To extract the Higgs width we write

$$\sigma(gg \to \ell^+\ell^-\ell^+\ell^-) = \sigma_{\rm cont} + \sqrt{X}\sigma_{\rm inter} + X\sigma_H \ ,$$

and fit for $X = \mu_{4\ell} \times \dfrac{\Gamma_H}{\Gamma_H^{SM}}$

- We evaluate the irreducible backgrounds in the presence of anomalous fermionic couplings



- We studied the impact of the anomalous couplings in the width determination using the lowest order in $1/\Lambda$ (dominant contribution)

- We introduced the following set of cuts (inspired by CMS)

$$p_T^\ell > 10 \text{ GeV} \quad , \quad |\eta_\ell| < 2.4 \quad , \quad p_{T,\text{hardest}}^\ell > 20 \text{ GeV}$$

and two lepton pairs compatible with Z

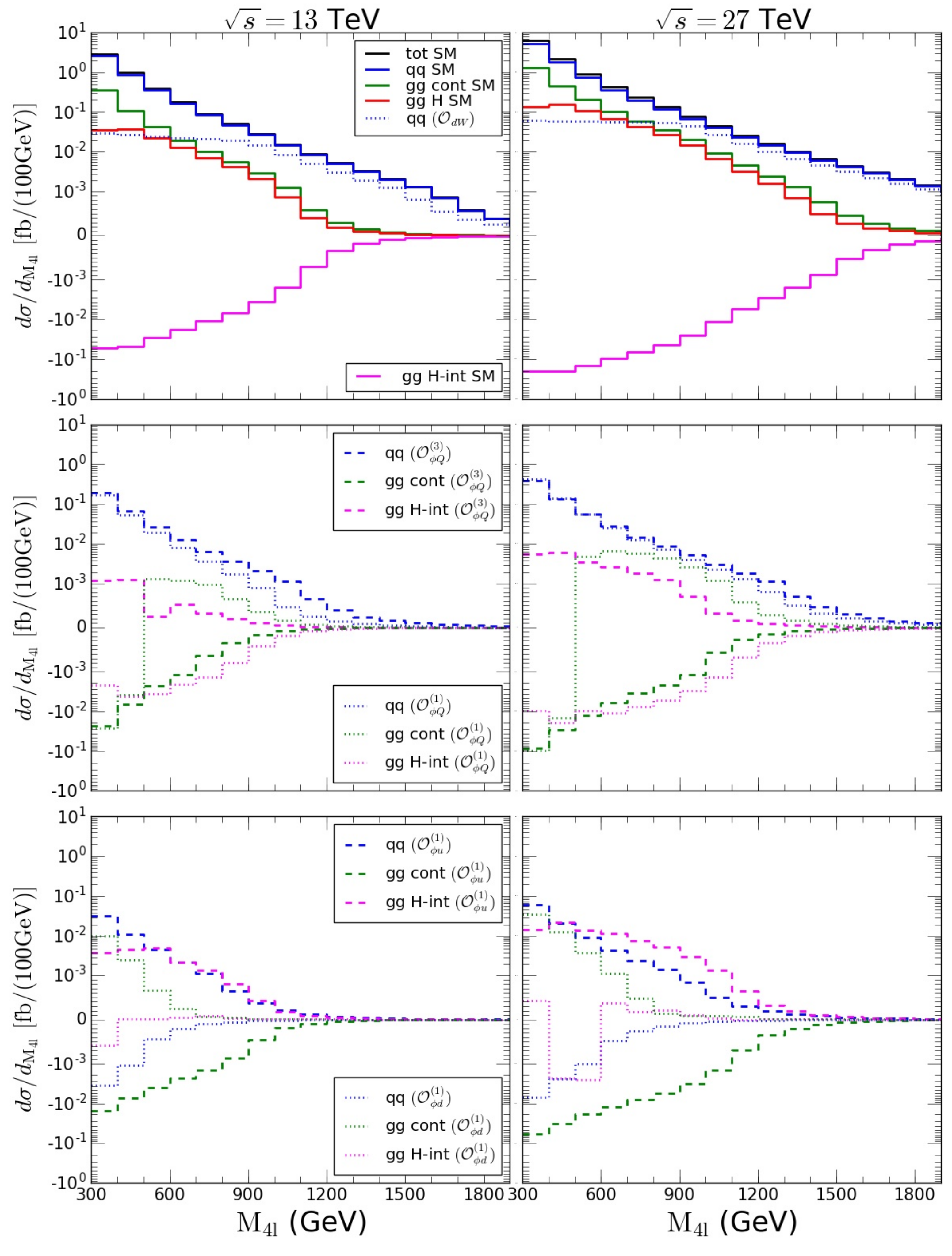
$$40 < m_{\ell\ell} < 120 \text{ GeV}$$

we considered LHC Runs 2 and 3, as well as High-Luminosity and High-Energy LHC

RESULTS

- Effect of the fermionic operators

$$\frac{f}{\Lambda^2} = 1\ \text{TeV}^{-1}$$



- To understand the anomalous coupling effects

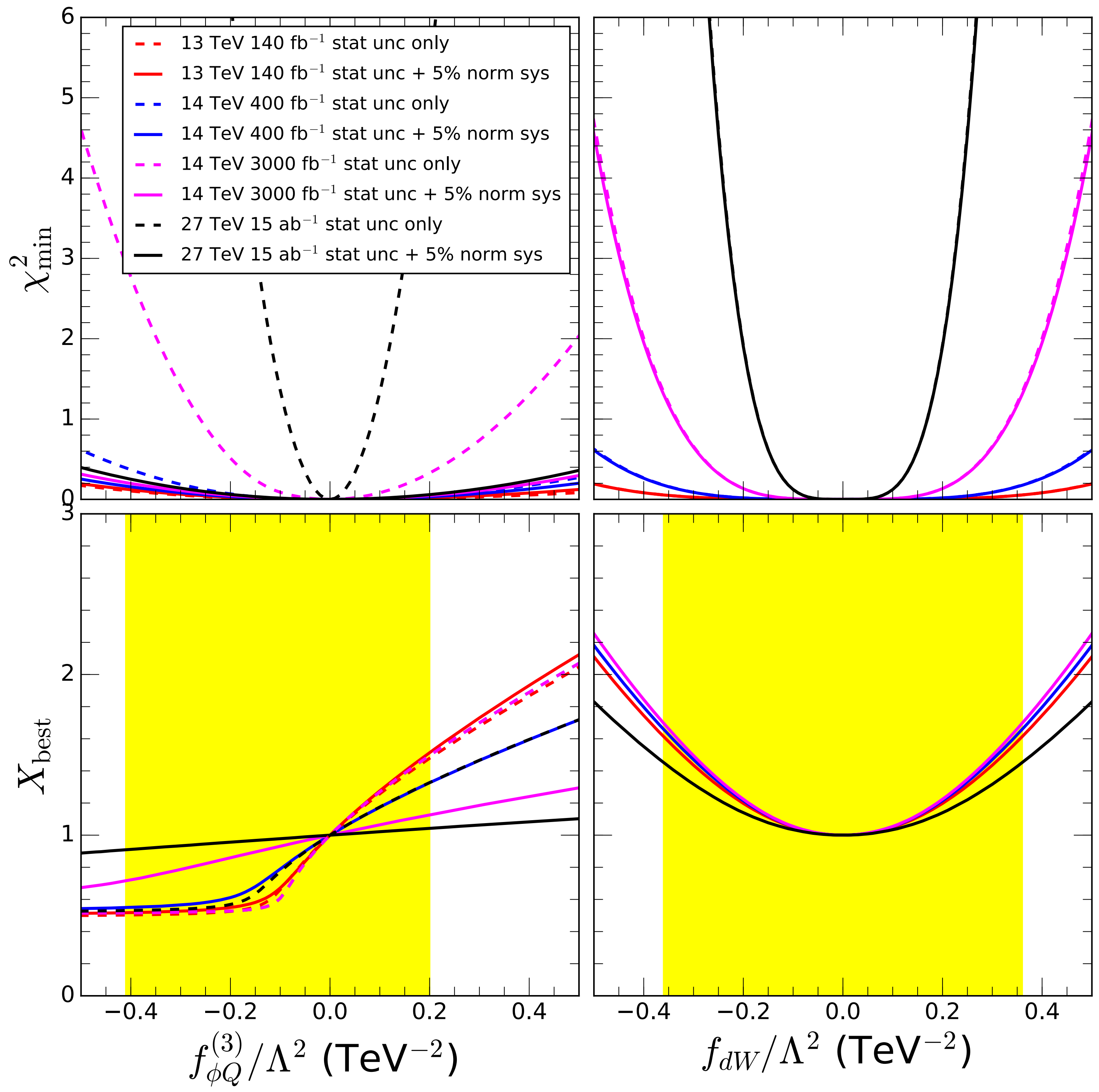
$$N_X = \mathcal{L} \times \left[\sigma_{q\bar{q}}^{SM} + \sigma_{gg}(X, f=0)\right] = N_{model}$$

$$N_D = \mathcal{L} \times \left[\sigma_{q\bar{q}}^{SM} + \sigma_{q\bar{q}}^{ano}(f) + \sigma_{gg}(X=1, f)\right] = N_{data}$$

we then fitted for X

$$\chi^2(X) = 2 \min_{\xi} \left\{ \sum_{j=bins} \left[(1+\xi)\, N_{model}^{j}(X) - N_{data}^{j} + N_{data}^{j} \ln \frac{N_{data}^{j}}{(1+\xi)\, N_{model}^{j}(X)} \right] + \frac{\xi^2}{\delta_{\xi}^2} \right\}$$

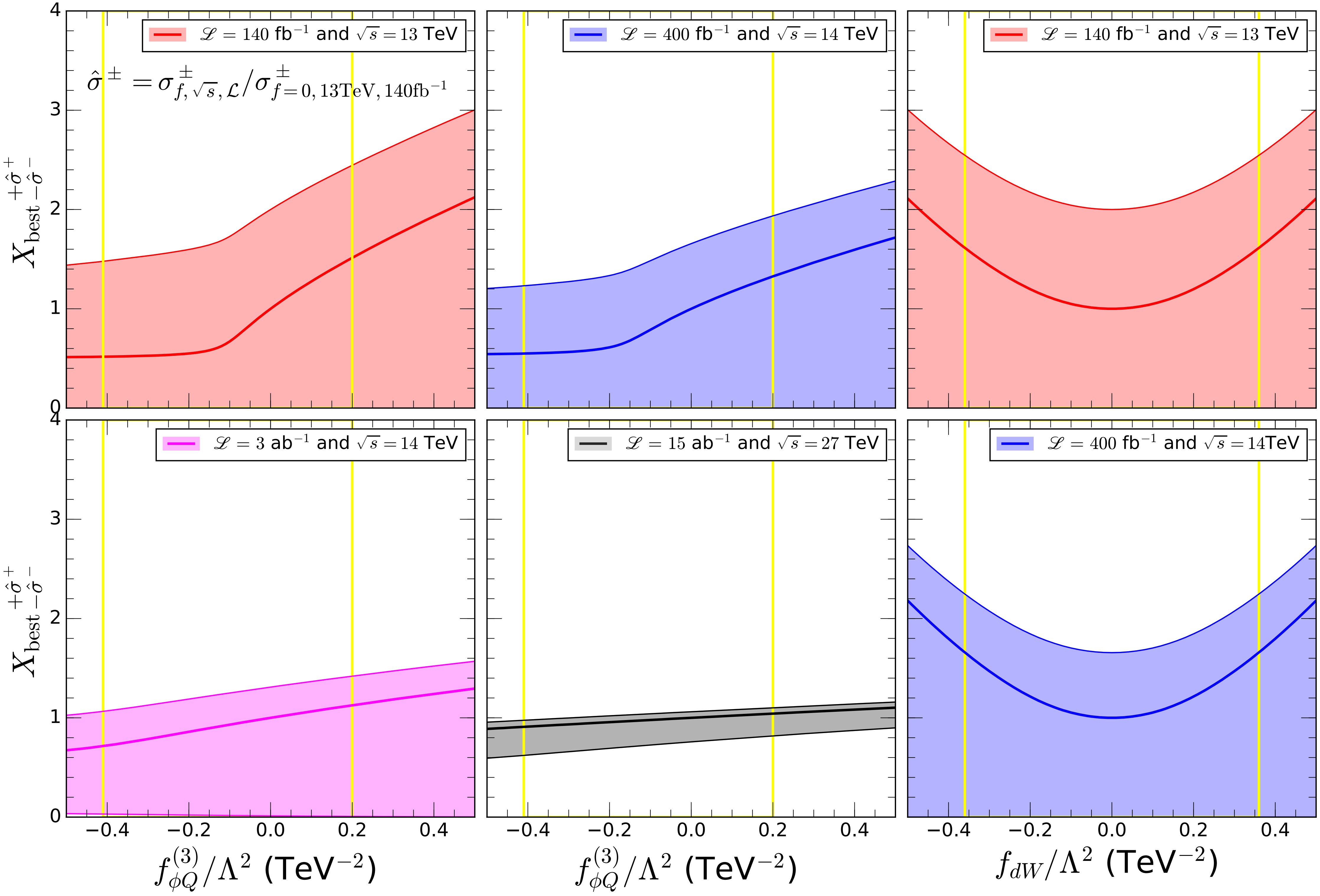
- Impact of the anomalous couplings on the fit (2 scenarios)



- We defined the 1 sigma upper and lower errors

$$\hat{\sigma}^{\pm} \equiv \frac{\sigma^{\pm}(f, \sqrt{s}, \mathcal{L})}{\sigma^{\pm}(0, 13\ \mathrm{TeV}, 140\ \mathrm{fb}^{-1})}$$

RESULTS

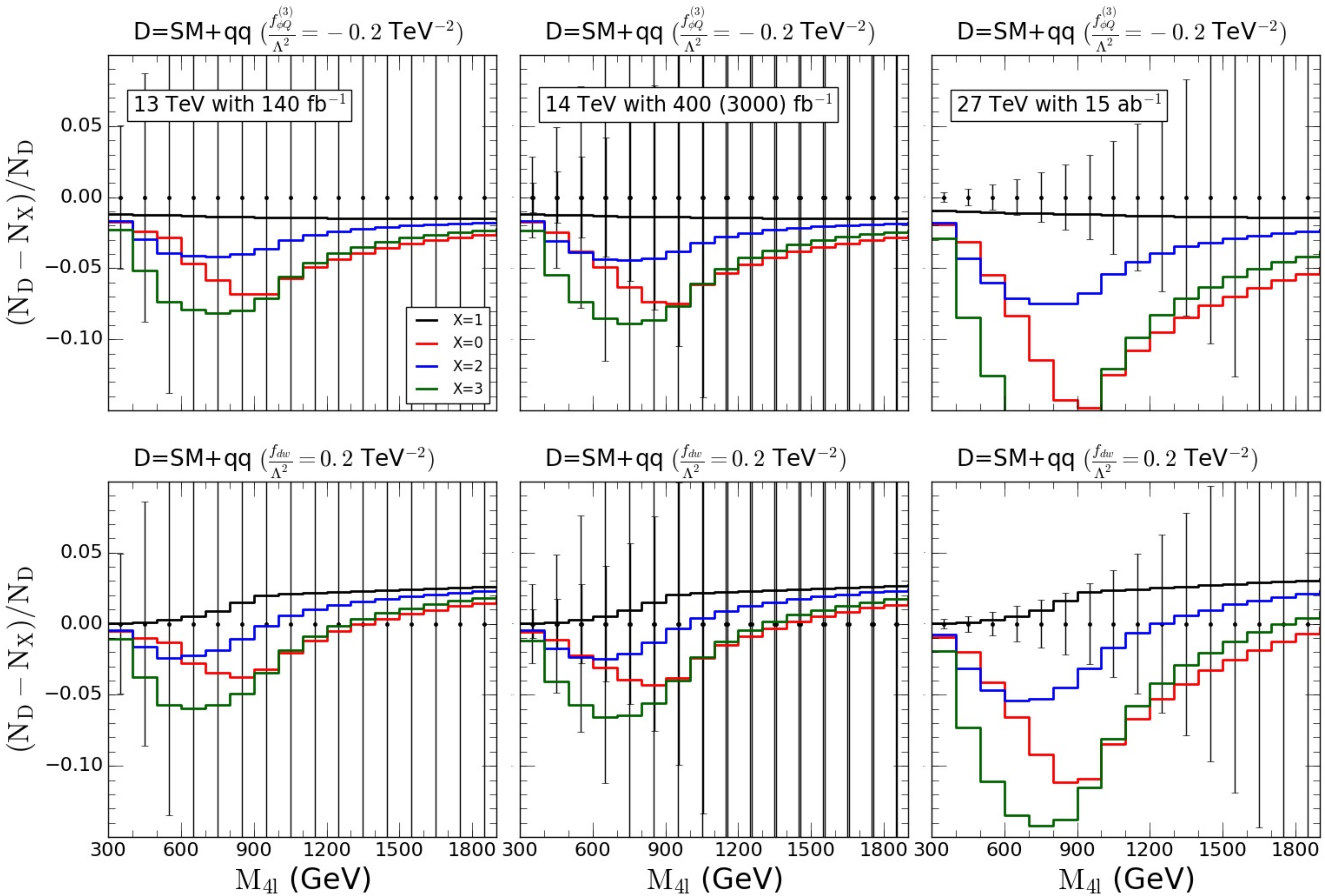


$\mathscr{L} = 140$ fb^{-1} and $\sqrt{s} = 13$ TeV
$\hat{\sigma}^{\pm} = \sigma^{\pm}_{f,\sqrt{s},\mathcal{L}} / \sigma^{\pm}_{f=0,\,13\mathrm{TeV},\,140\mathrm{fb}^{-1}}$
$\mathscr{L} = 400$ fb^{-1} and $\sqrt{s} = 14$ TeV
$\mathscr{L} = 140$ fb^{-1} and $\sqrt{s} = 13$ TeV
$\mathscr{L} = 3$ ab^{-1} and $\sqrt{s} = 14$ TeV
$\mathscr{L} = 15$ ab^{-1} and $\sqrt{s} = 27$ TeV
$\mathscr{L} = 400$ fb^{-1} and $\sqrt{s} = 14$TeV
$X_{\mathrm{best}}^{\hat{\sigma}^+ + \hat{\sigma}^-}$
$f^{(3)}_{\phi Q}/\Lambda^2$ (TeV^{-2})
$f^{(3)}_{\phi Q}/\Lambda^2$ (TeV^{-2})
f_{dW}/Λ^2 (TeV^{-2})

- Inclusion of anomalous couplings of gauge bosons to fermions have an impact at Higgs width analyses for Run 2 and Run3 .
- Higher statistics mitigate the effect of the anomalous couplings.
- To de done: full anomalous coupling study; matrix elements method

Thank you

RESULTS



largest statistical weights originates from the smaller 4-lepton invariant mass bins

- 95% C.L. regions