LHCP2021

Precision from Diboson Processes at FCC-hh

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Based on arxiv:2004.06122 and arxiv:2011.13941

Motivation:

- Usually: Precision physics @hadron colliders difficult
- Exceptions: e.g. diboson production channels
- Exploit cleanliness of leptonic decay channels of the *V*-bosons and the diphoton channel of the *h*-boson
- Exploit energy growth of New Physics effects by studying high energy tail of distributions

The framework:

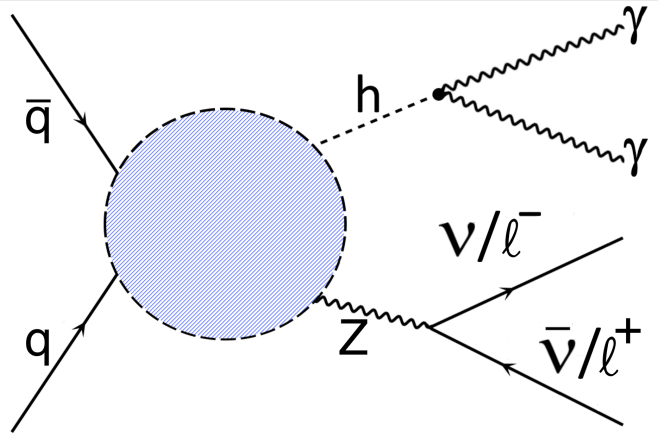
SMEFT: $\mathcal{L} = \mathcal{L}_{\text{SM}} + \sum_{d>4} \mathcal{L}^{(d)}$ with $\mathcal{L}^{(d)} \equiv \sum_i \frac{c_i^{(d)}}{\Lambda^{d-4}} \mathcal{O}_i^{(d)}$

We study small deviations from the SM

➔Optimize sensitivity to interference terms:

$$\mathcal{M}^2 = |\mathcal{M}_{\text{SM}}|^2 + \underbrace{2\text{Re}\mathcal{M}_{\text{SM}}\mathcal{M}^*_{\text{BSM}}}_{\propto \frac{c}{\Lambda^2}} + \underbrace{|\mathcal{M}_{\text{BSM}}|^2}_{\propto \frac{c^2}{\Lambda^4}}$$

The *Zh* process:



Leading contributions to energy growth:

$$\mathcal{O}^{(1)}_{\varphi q} = (\bar{Q}_L \gamma^\mu Q_L)\left(iH^\dagger \overleftrightarrow{D}_\mu H\right)$$

$$\mathcal{O}^{(3)}_{\varphi q} = (\bar{Q}_L \sigma^a \gamma^\mu Q_L)\left(iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H\right)$$

$$\mathcal{O}_{\varphi u} = (\bar{u}_R \gamma^\mu u_R)\left(iH^\dagger \overleftrightarrow{D}_\mu H\right)$$

$$\mathcal{O}_{\varphi d} = (\bar{d}_R \gamma^\mu d_R)\left(iH^\dagger \overleftrightarrow{D}_\mu H\right)$$

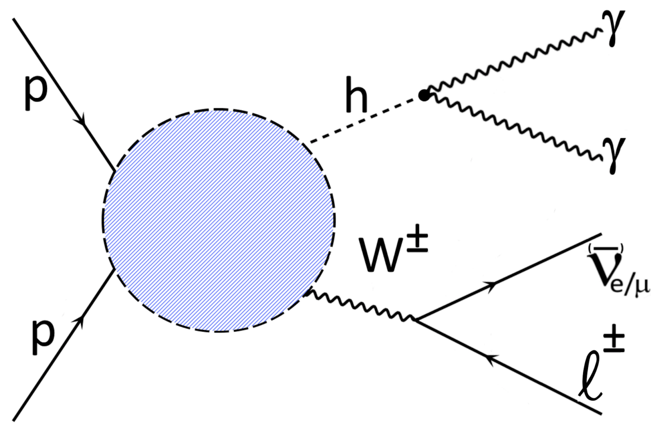
Leading interference terms:

$$|\mathcal{M}_{\text{SM}}|^2 \sim \sin^2\theta$$

$$\text{Re}\,\mathcal{M}_{SM}\,\mathcal{M}^*_{\text{BSM}} \sim \frac{\hat{s}}{\Lambda^2}\sin^2\theta$$

➔ Study p_T distribution (closely related to $\hat{s}$)

The *Wh* process:



Leading contributions to energy growth:

$$\mathcal{O}^{(3)}_{\varphi q} = (\bar{Q}_L \sigma^a \gamma^\mu Q_L)\left(iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H\right)$$

$$\mathcal{O}_{\varphi W} = H^\dagger H W^{a,\mu\nu} W^a_{\mu\nu}$$

$$\mathcal{O}_{\varphi \widetilde{W}} = H^\dagger H W^{a,\mu\nu} \widetilde{W}^a_{\mu\nu}$$

Leading interference terms:

$$|\mathcal{M}_{SM}|^2 \sim \frac{1}{4}\sin^2\theta\sin^2\theta_W + \frac{M_W}{\sqrt{\hat{s}}}\mathcal{F}(\theta,\theta_W)\cos\phi_W$$

$$\text{Re}\,\mathcal{M}_{SM}\,\mathcal{M}^{(3)*}_{\varphi q} \sim \frac{\hat{s}}{\Lambda^2}\left[\frac{1}{4}\sin^2\theta\sin^2\theta_W + \frac{M_W}{\sqrt{\hat{s}}}\mathcal{F}(\theta,\theta_W)\cos\phi_W\right]$$

$$\text{Re}\,\mathcal{M}_{SM}\,\mathcal{M}^*_{\varphi W} \sim \frac{\sqrt{\hat{s}}\,M_W}{\Lambda^2}\mathcal{F}(\theta,\theta_W)\cos\phi_W$$

$$\text{Re}\,\mathcal{M}_{SM}\,\mathcal{M}^*_{\varphi \widetilde{W}} \sim \frac{\sqrt{\hat{s}}\,M_W}{\Lambda^2}\mathcal{F}(\theta,\theta_W)\sin\phi_W$$

➔ Study p_T and ϕ_W distributions

Backgrounds for *Zh*:

Charged lepton channel

$$gg \to Zh \to \ell^+\ell^-\gamma\gamma$$

$$pp \to Z(\to \ell^+\ell^-)\gamma\gamma$$

Neutrino channel:

$$gg \to Zh \to \nu\bar{\nu}\gamma\gamma$$

$$pp \to Z(\to \nu\bar{\nu})\gamma\gamma$$

$$pp \to W\gamma\gamma$$

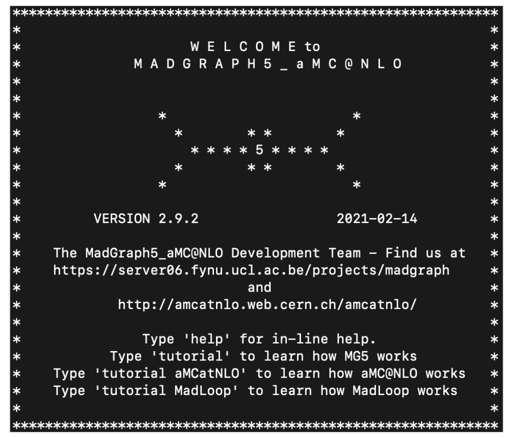
Backgrounds for *Wh*:

$$pp \to W\gamma\gamma$$

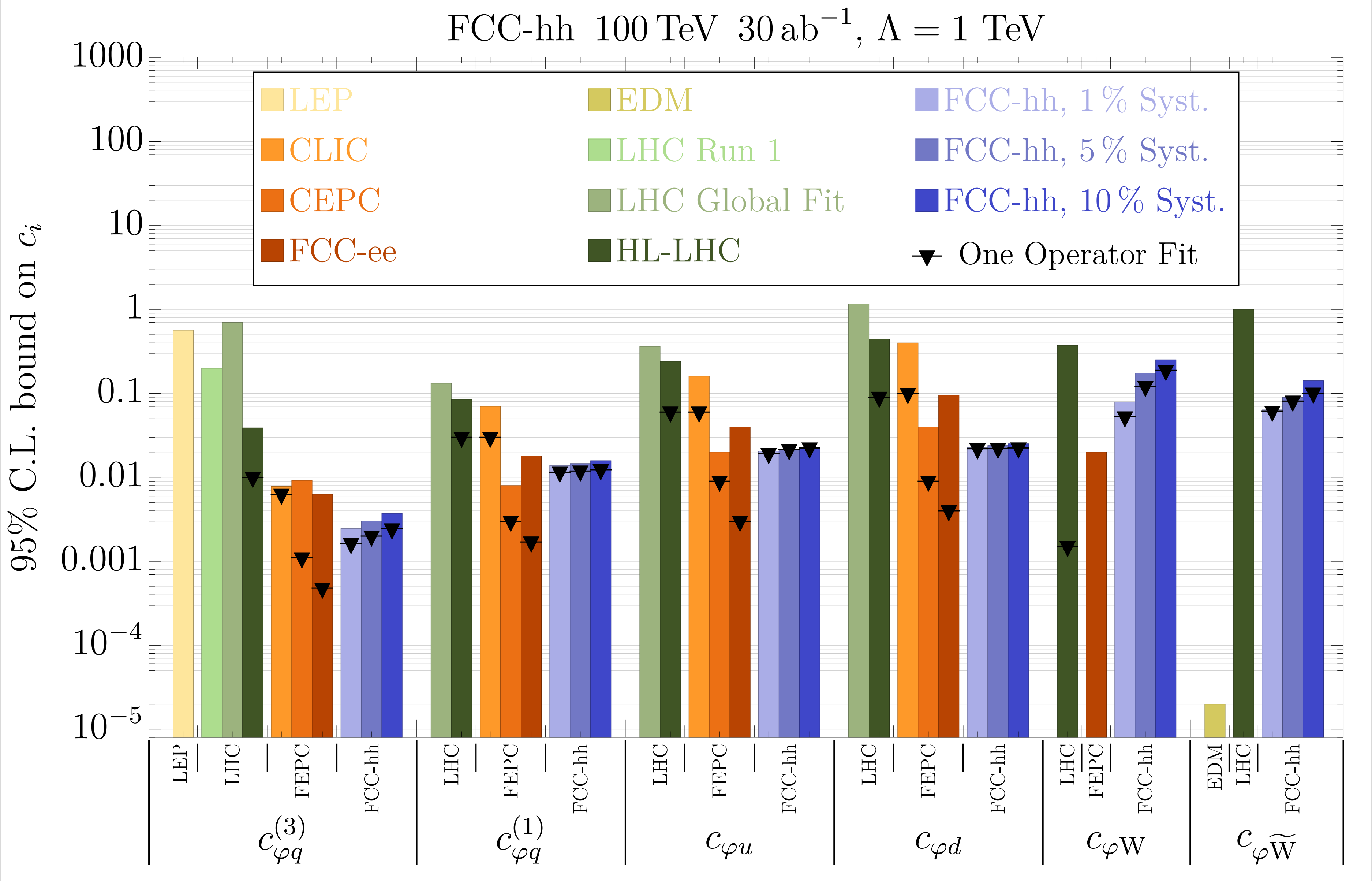
$$pp \to Wj\gamma$$

$$pp \to Wjj$$

The gory details:



Comparison to bounds from different experiments:



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Auxiliary Material

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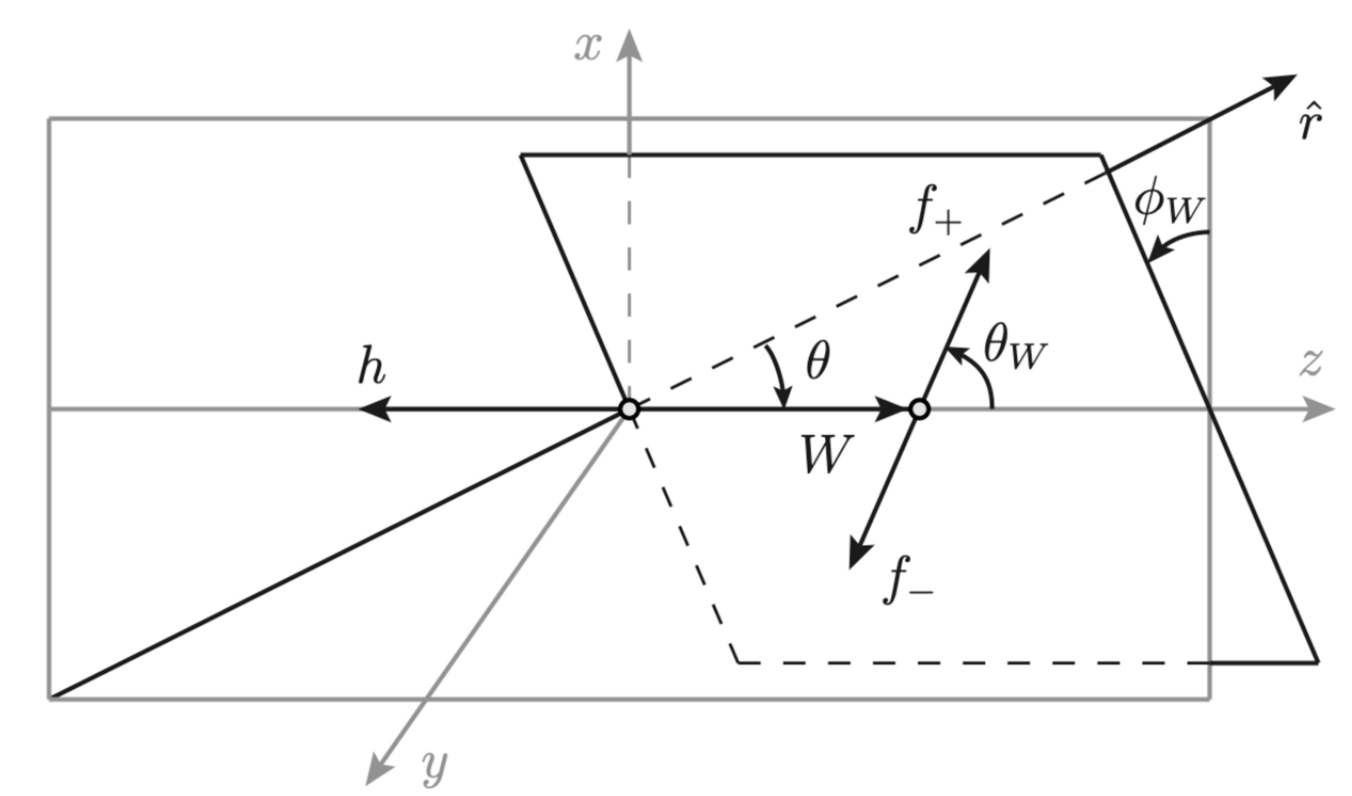
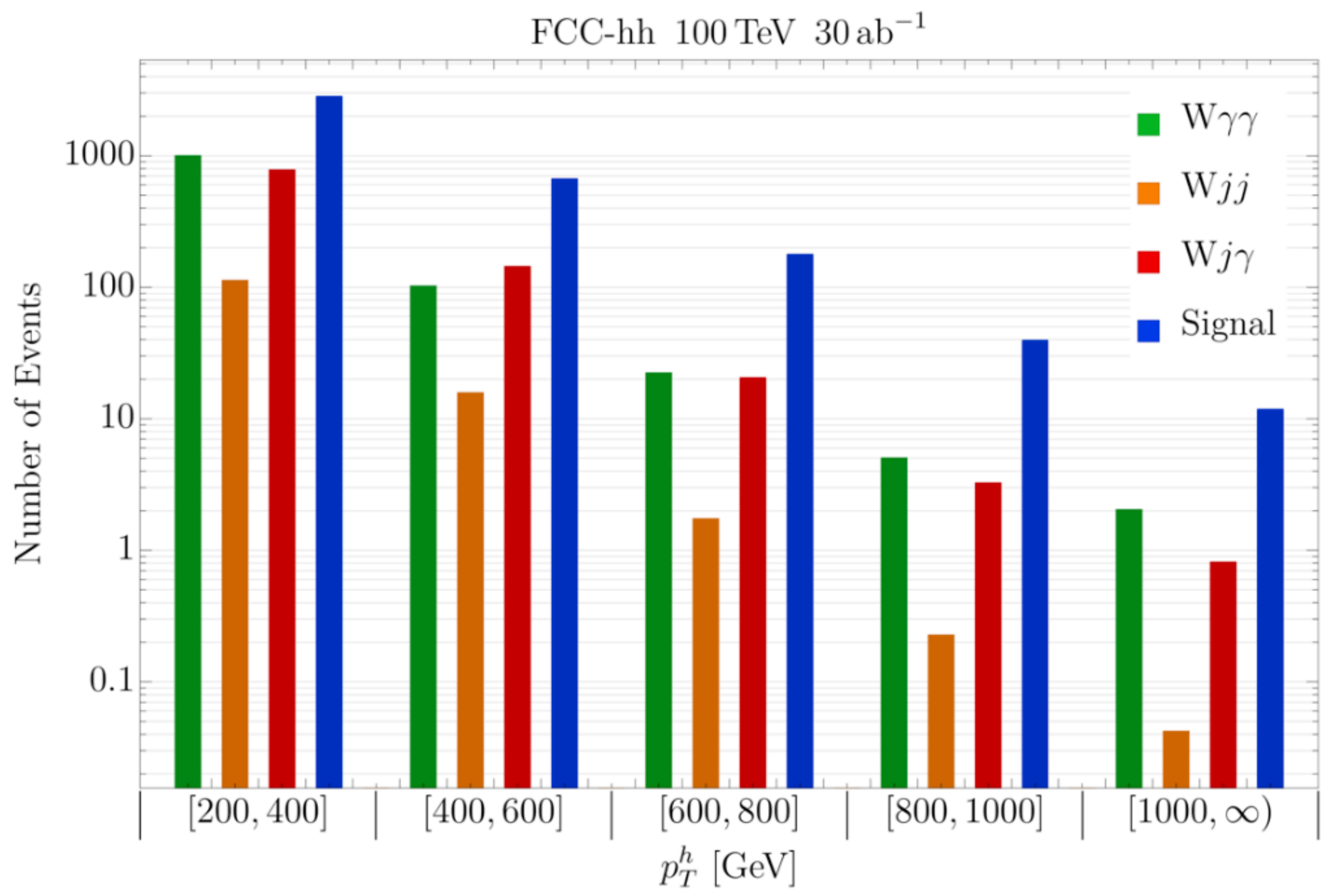
High energy tail of the h-decay channels at different colliders for Wh:

Higgs decay	Higgs BR	$n_{\text{HL-LHC}}$	$n_{\text{HE-LHC}}$	$n_{\text{FCC-hh}}$
$\bar{b}b$	0.6	600	$1 \cdot 10^4$	$2 \cdot 10^5$
$\tau\tau$	$6 \cdot 10^{-2}$	60	$1 \cdot 10^3$	$2 \cdot 10^4$
$\gamma\gamma$	$2 \cdot 10^{-3}$	2	40	700
$\mu\mu$	$2 \cdot 10^{-4}$	0.2	4	70
4ℓ	$1 \cdot 10^{-4}$	0.1	2	40

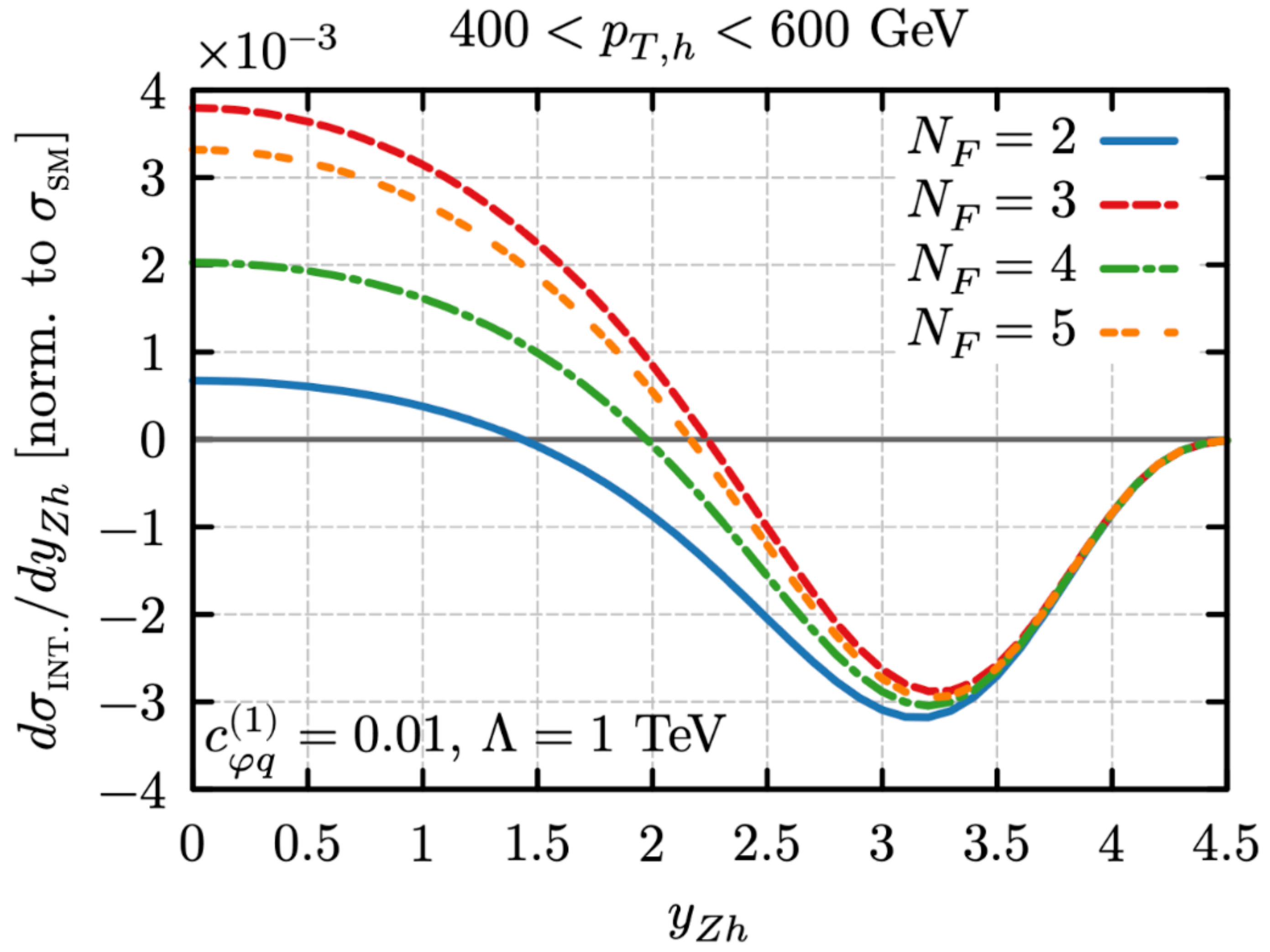
Definition of the angles:



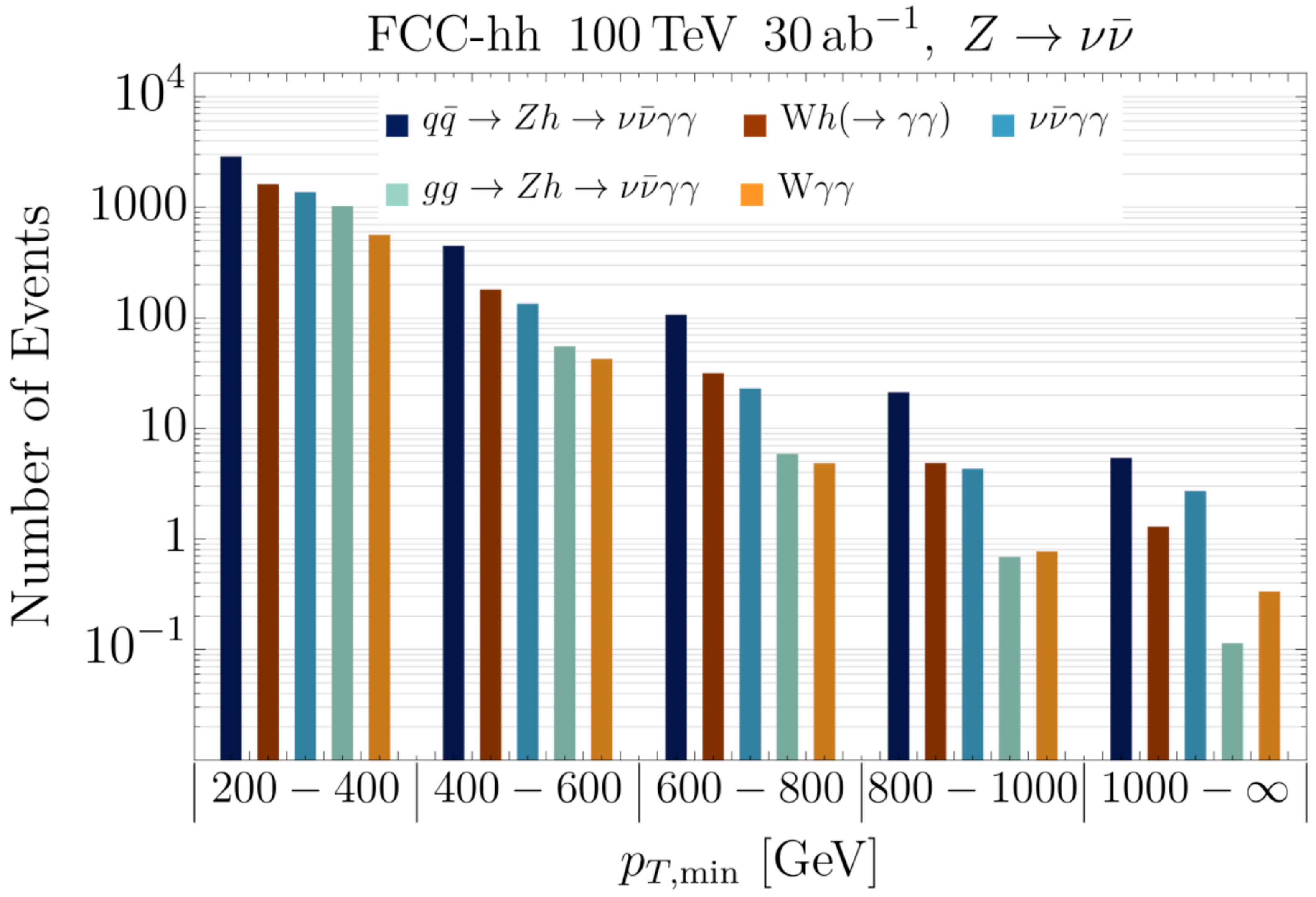
Backgrounds for Wh:



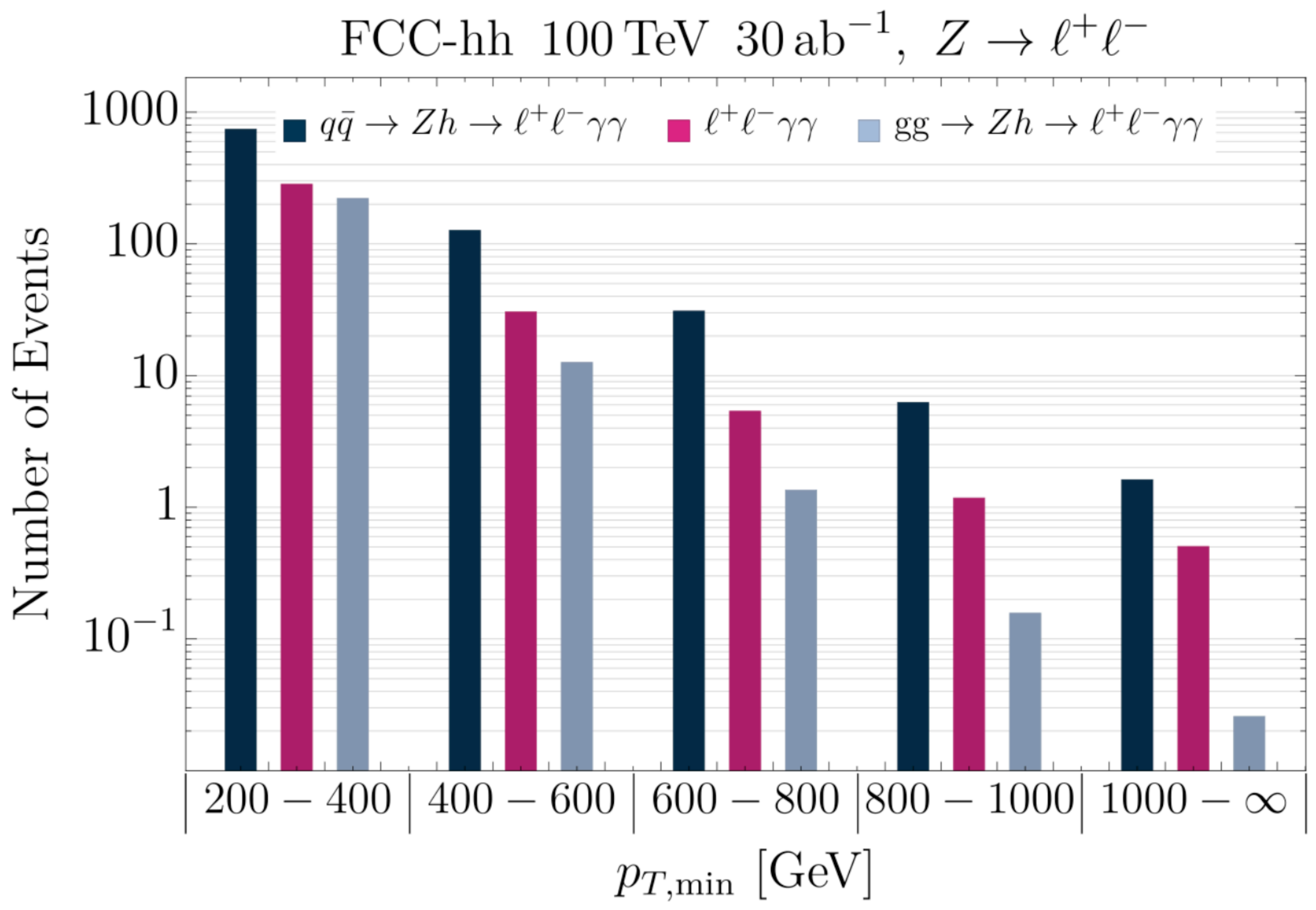
Rapidity dependence of the cross-section for different flavour-assumptions:



Backgrounds for $Z(\to \nu\bar{\nu})h$:



Backgrounds for $Z(\to \ell^+\ell^-)h$:



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95% C.L. bounds on $c_{\varphi q}^{(3)}$ depending on the EFT cut-off: