Diboson production and impact on global fits

FCC UK Meeting
Queen Mary University of London, London, UK
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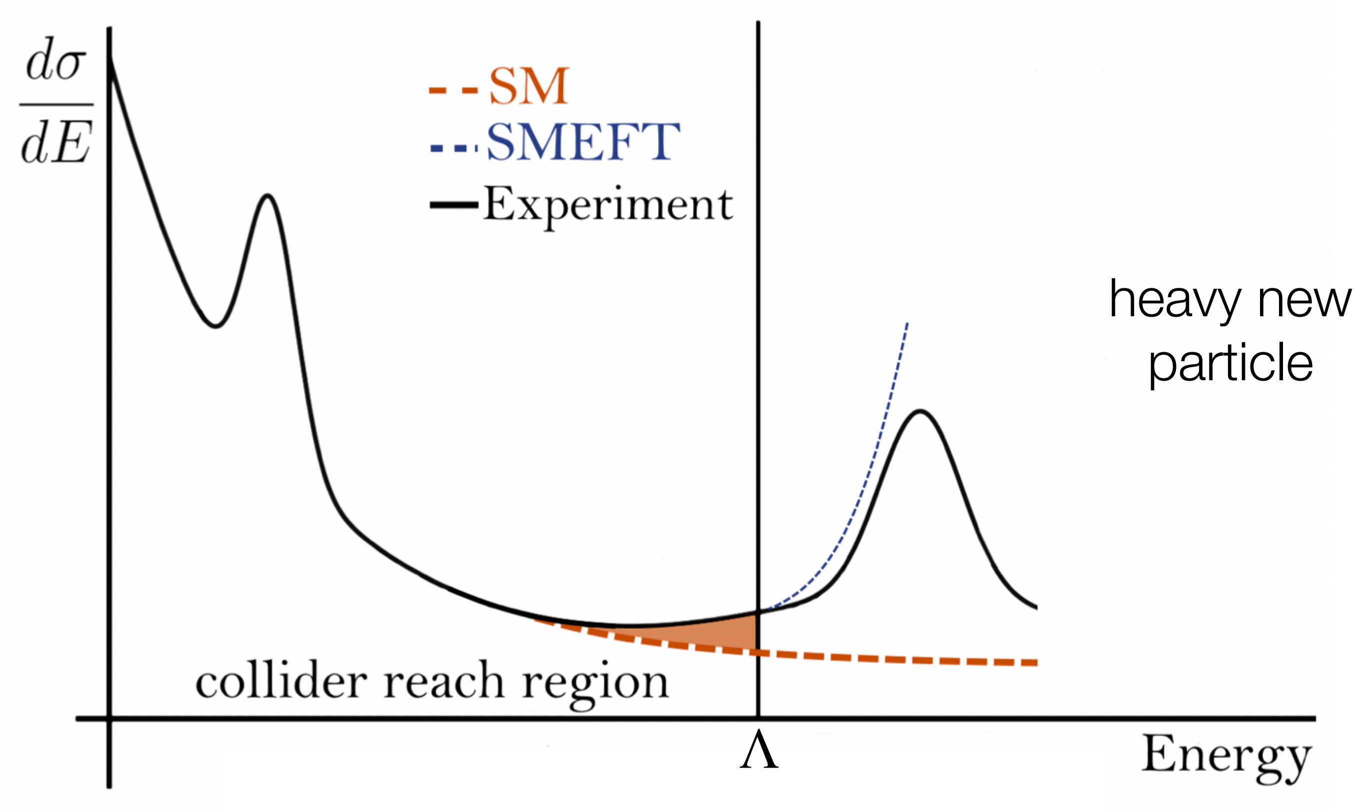
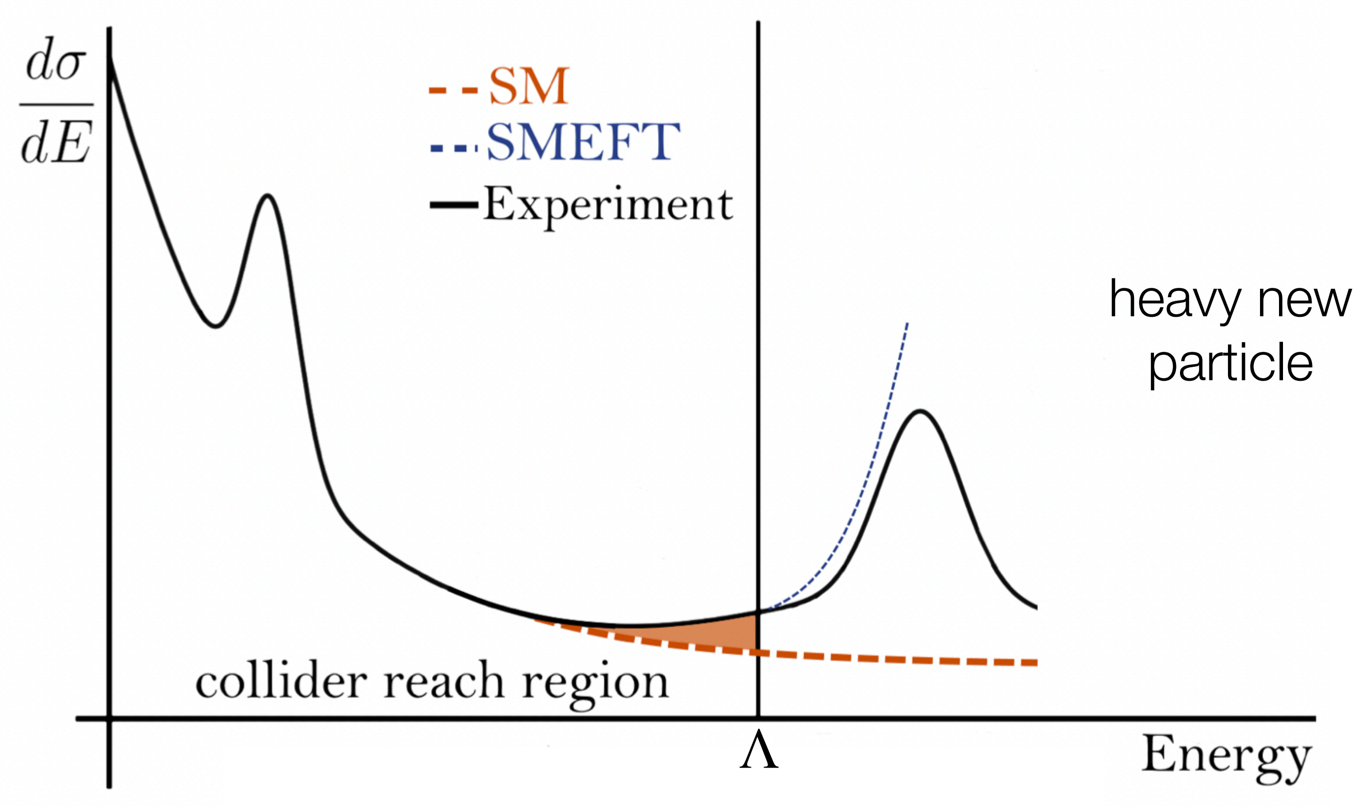
The SMEFT



Original fig. by C. Severi, M. Thomas, E. Vryonidou

The SMEFT



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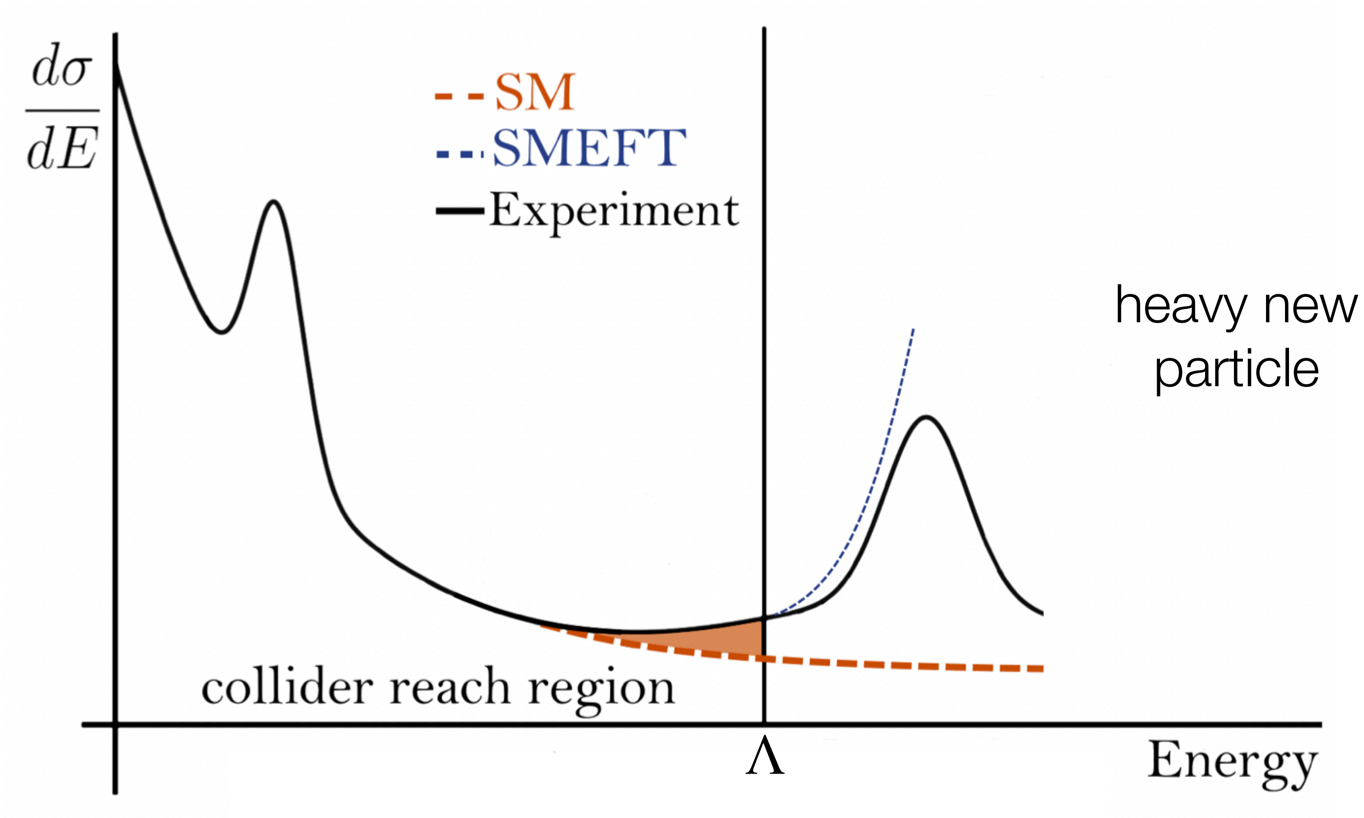
$$\mathcal{L}_{\rm EFT} = \sum_i \frac{c_i}{\Lambda^{d-4}} \mathcal{O}_i^{(d)} = \mathcal{L}_{\rm SM}^{(4)} + \sum_i \frac{c_i^{(5)}}{\Lambda} \mathcal{O}_i^{(5)} + \sum_i \frac{c_i^{(6)}}{\Lambda^2} \mathcal{O}_i^{(6)} + \ldots$$

SM fields and symmetries

The SMEFT



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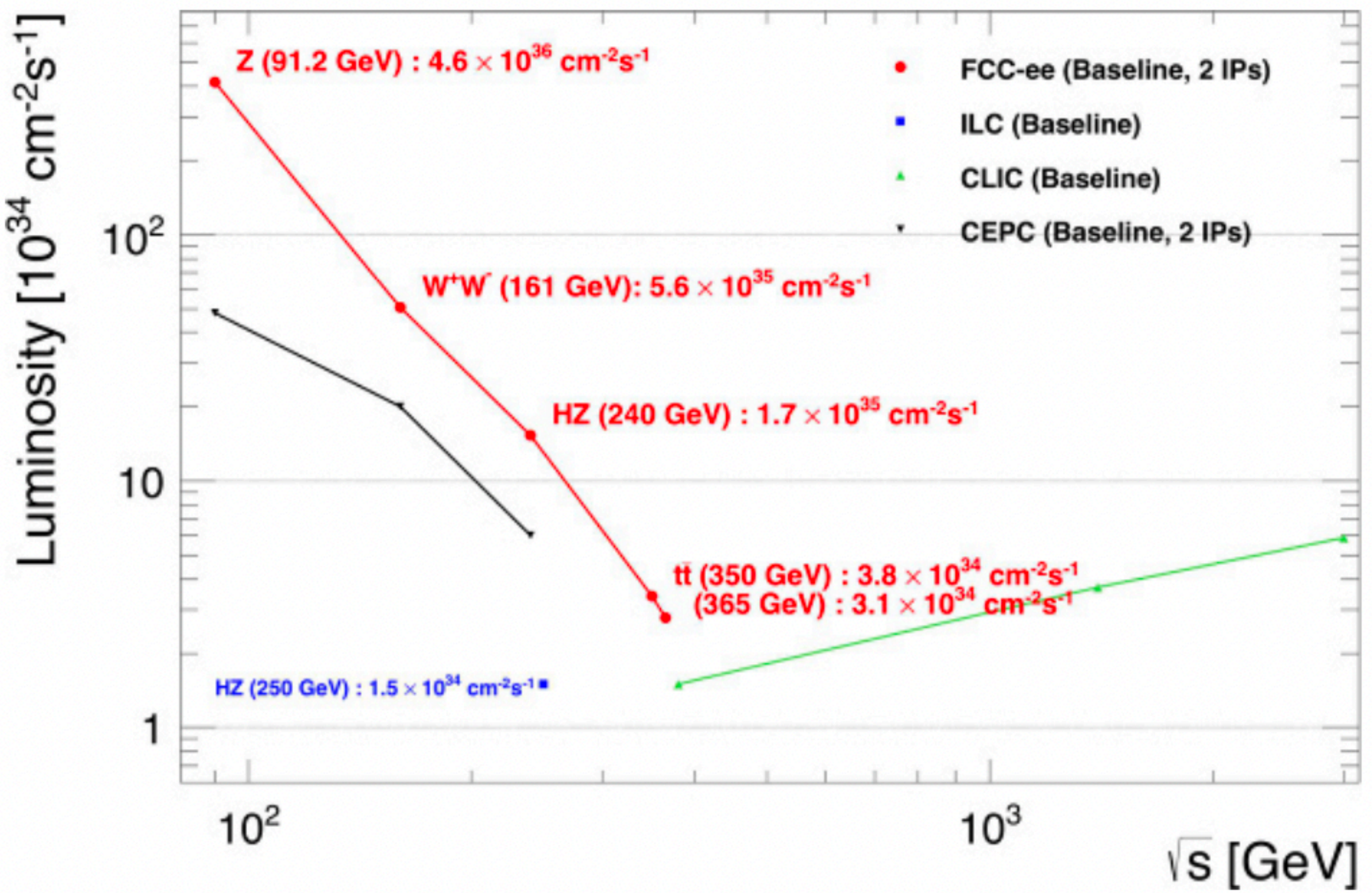
SM fields and symmetries

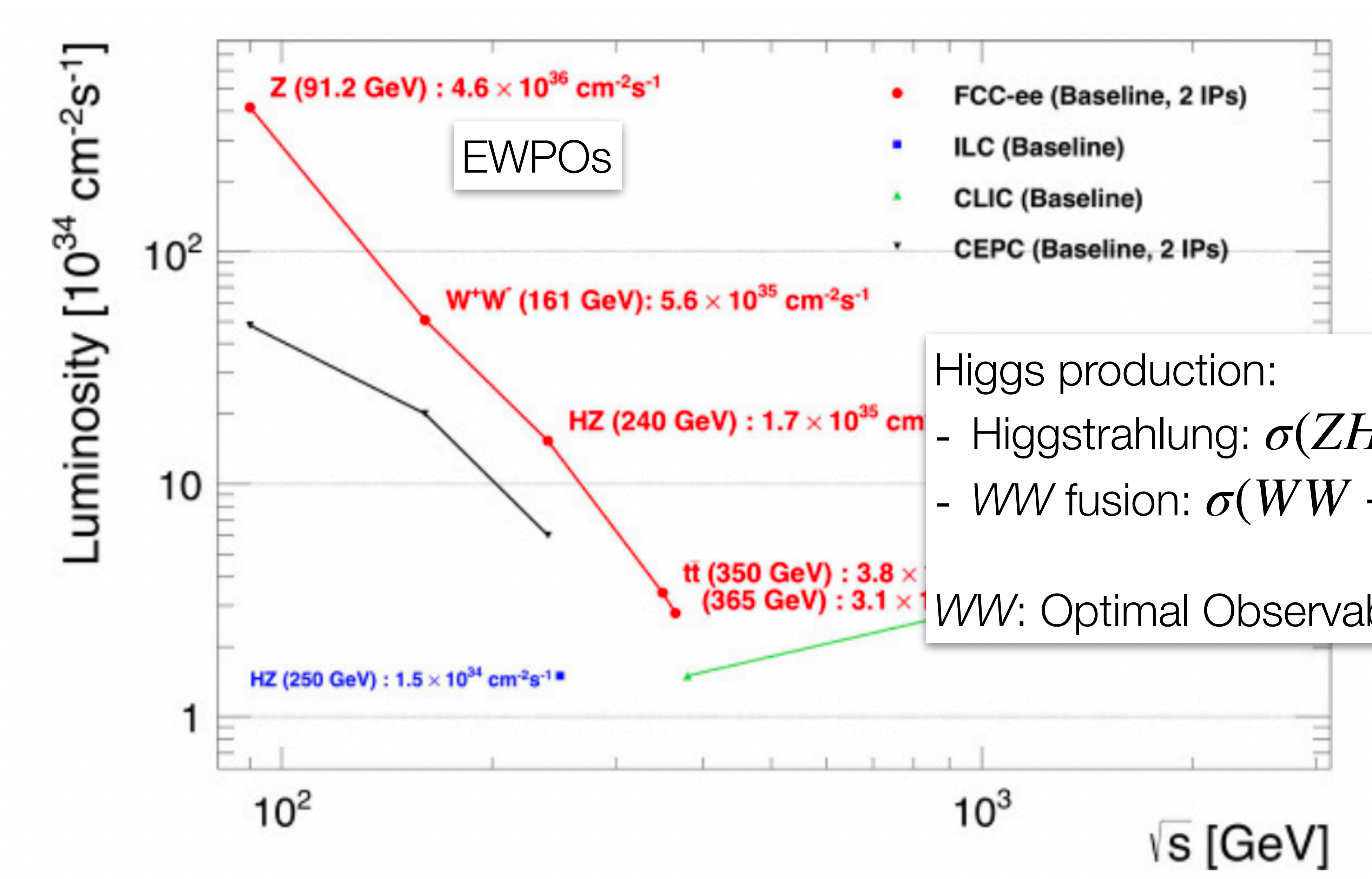
Ultimate goal: bounds on Wilson coefficients ➡ constraints on UV models

Higgs and EW physics at FCC-ee



FCC-ee design report [e2019-900045-4]

Higgs and EW physics at FCC-ee



Higgs production:

- Higgstrahlung: $\sigma(ZH)$, $\sigma(ZH) \times BR(H)$
- *WW* fusion: $\sigma(WW \to H) \times BR(H)$

WW: Optimal Observables

FCC-ee design report [e2019-900045-4]

Diboson in SMEFT

Why diboson?

- probe of gauge bosons self-interaction
- interplay with the Higgs sector

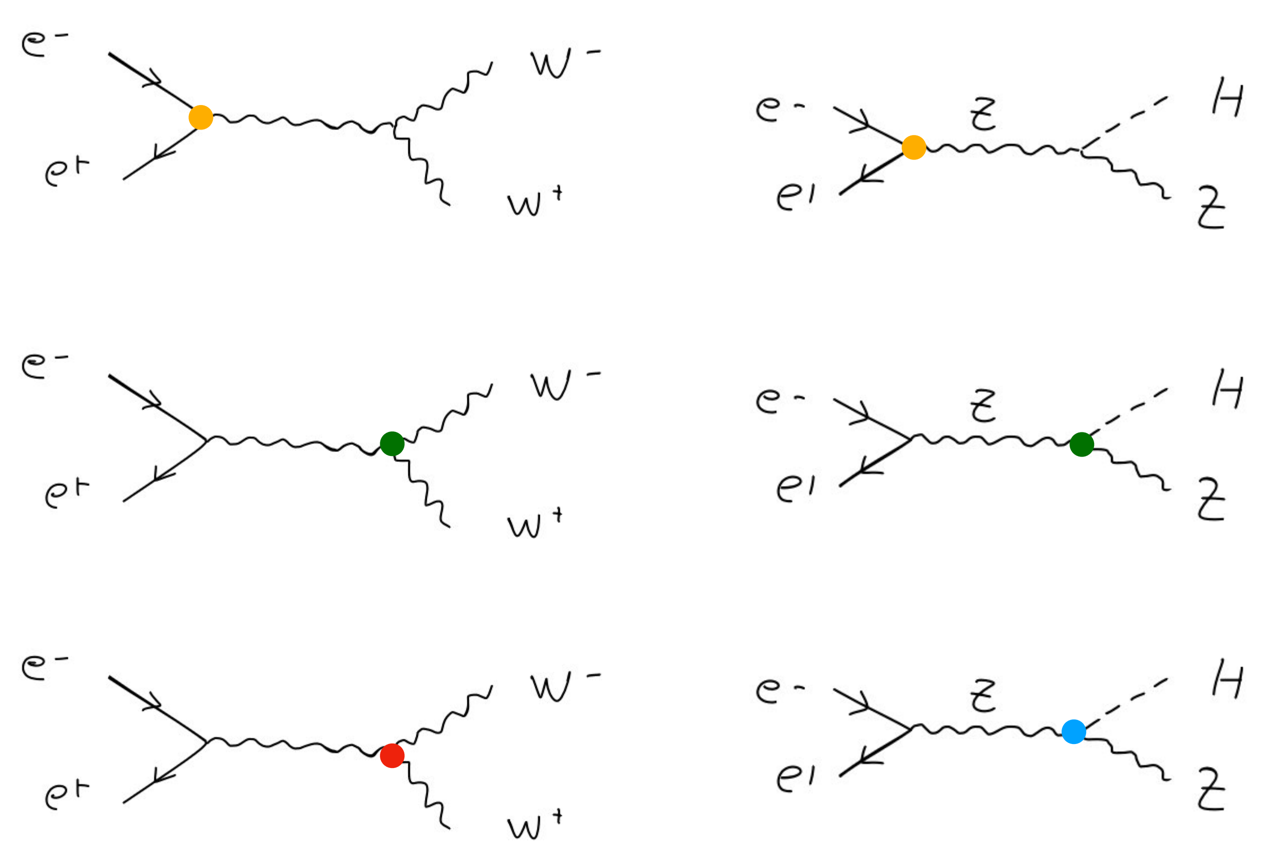
Warsaw basis

Operator	Definition
bosonic	
$\mathcal{O}_{\phi B}$	$(\phi^\dagger \phi) B^{\mu\nu} B_{\mu\nu}$
$\mathcal{O}_{\phi W}$	$(\phi^\dagger \phi) W_I^{\mu\nu} W_{\mu\nu}^I$
$\mathcal{O}_{\phi WB}$	$(\phi^\dagger \tau_I \phi) B^{\mu\nu} W_{\mu\nu}^I$
$\mathcal{O}_{\phi d}$	$\partial_\mu (\phi^\dagger \phi) \partial^\mu (\phi^\dagger \phi)$
$\mathcal{O}_{\phi D}$	$(\phi^\dagger D^\mu \phi)^\dagger (\phi^\dagger D_\mu \phi)$
$\mathcal{O}_{WWW}$	$\epsilon_{IJK} W_{\mu\nu}^I W^{J,\nu\rho} W_\rho^{K,\mu}$
two-fermion	
$\mathcal{O}_{\phi \ell_i}^{(1)}$	$i(\phi^\dagger \overleftrightarrow{D}_\mu \phi)(\bar{\ell}_i \gamma^\mu \ell_i)$
$\mathcal{O}_{\phi \ell_i}^{(3)}$	$i(\phi^\dagger \overleftrightarrow{D}_\mu \tau_I \phi)(\bar{\ell}_i \gamma^\mu \tau^I \ell_i)$
$\mathcal{O}_{\phi e}$	$i(\phi^\dagger \overleftrightarrow{D}_\mu \phi)(\bar{e} \gamma^\mu e)$
four-fermion	
$\mathcal{O}_{\ell\ell}$	$(\bar{\ell}_1 \gamma_\mu \ell_2)(\bar{\ell}_2 \gamma^\mu \ell_1)$

$$\text{EWPOs} : \mathcal{O}_{\phi D},\ \mathcal{O}_{\phi WB},\ \mathcal{O}_{\phi \ell_1}^{(1)},\ \mathcal{O}_{\phi \ell_1}^{(3)},\ \mathcal{O}_{\phi \ell_2}^{(3)},\ \mathcal{O}_{\phi e},\ \mathcal{O}_{\ell\ell}$$

$$W^- W^+ : \mathcal{O}_{\phi D},\ \mathcal{O}_{\phi WB},\ \mathcal{O}_{WWW},\ \mathcal{O}_{\phi \ell_1}^{(1)},\ \mathcal{O}_{\phi \ell_1}^{(3)},\ \mathcal{O}_{\phi \ell_2}^{(3)},\ \mathcal{O}_{\phi e},\ \mathcal{O}_{\ell\ell}$$

$$ZH : \mathcal{O}_{\phi D},\ \mathcal{O}_{\phi WB},\ \mathcal{O}_{\phi d},\ \mathcal{O}_{\phi W},\ \mathcal{O}_{\phi B},\ \mathcal{O}_{\phi \ell_1}^{(1)},\ \mathcal{O}_{\phi \ell_1}^{(3)},\ \mathcal{O}_{\phi \ell_2}^{(3)},\ \mathcal{O}_{\phi e},\ \mathcal{O}_{\ell\ell}$$



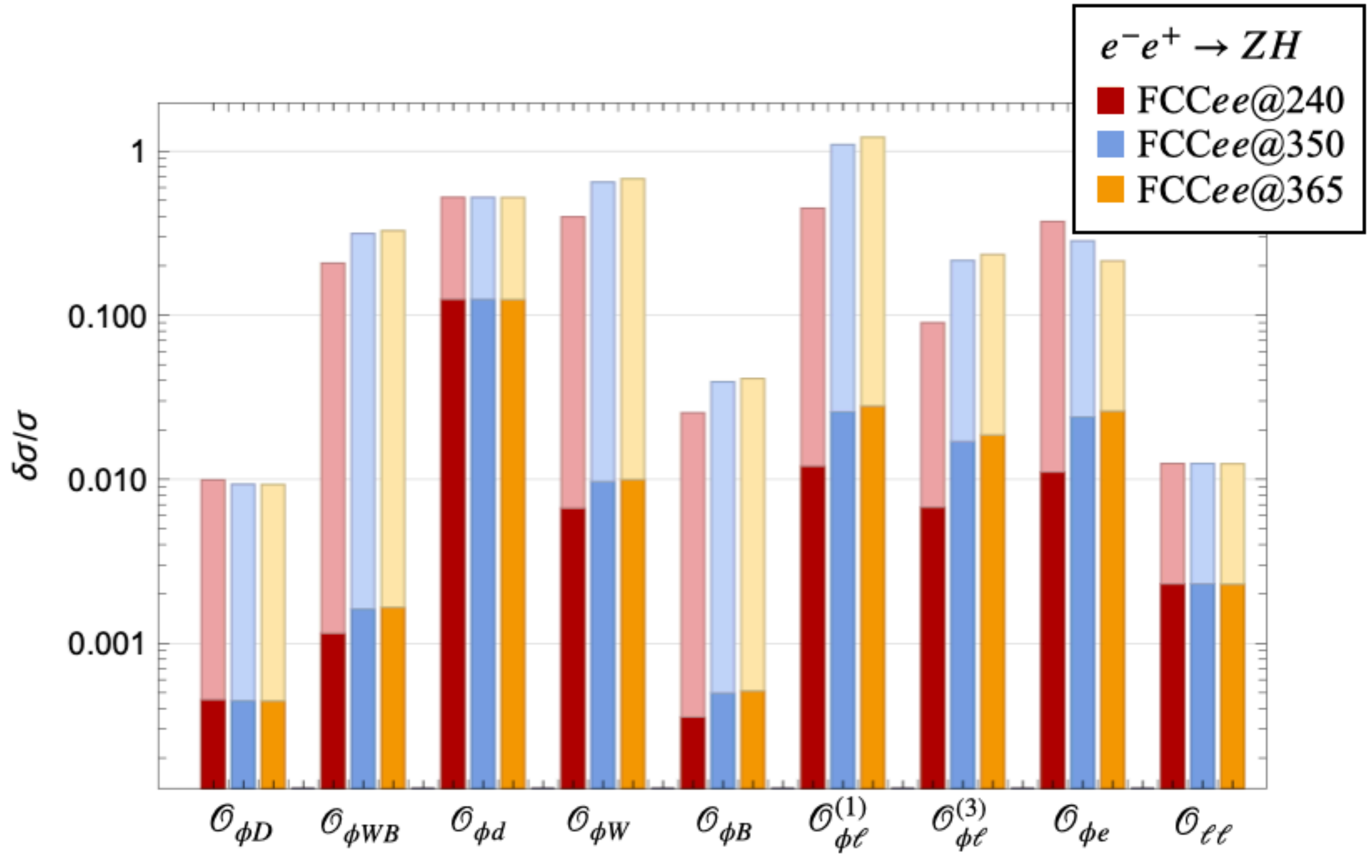
Higgstrahlung

- $e^-e^+ \to ZH$
- fully inclusive cross-section $\sigma(ZH)$ is possible thanks to recoil mass techniques

Expected uncertainty ~0.5%

Current bounds from fitmaker:
J. Ellis et al. [2012.02779]

individual
marginalised



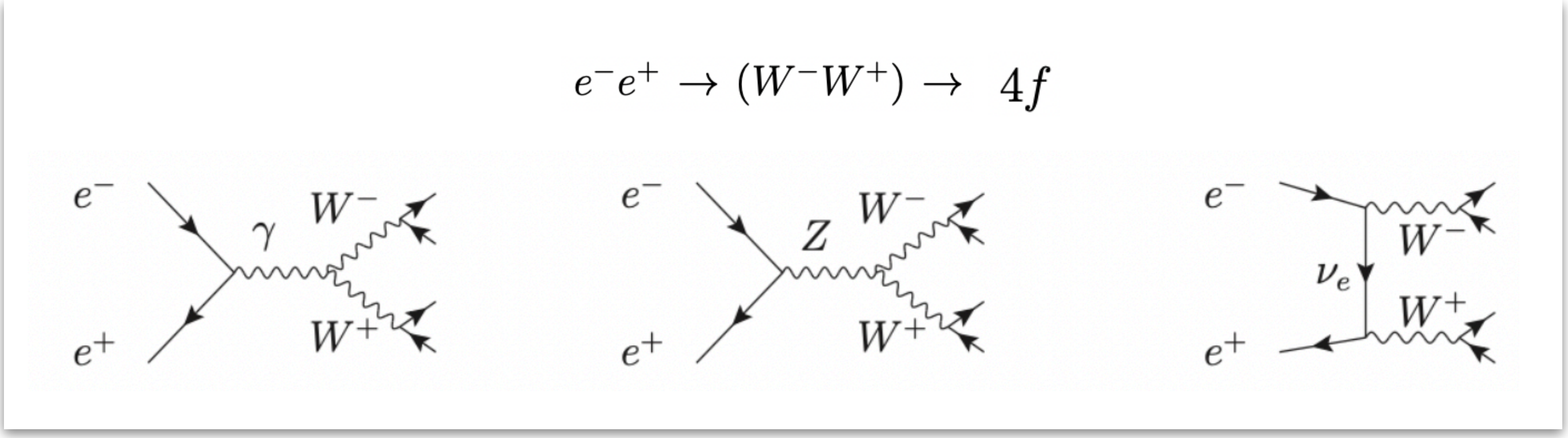
EC et al, in preparation

Expected significant improvement on current bounds

WW with Optimal Observables

Doubly resonant 4 fermion production

- fully leptonic
- semileptonic
- hadronic



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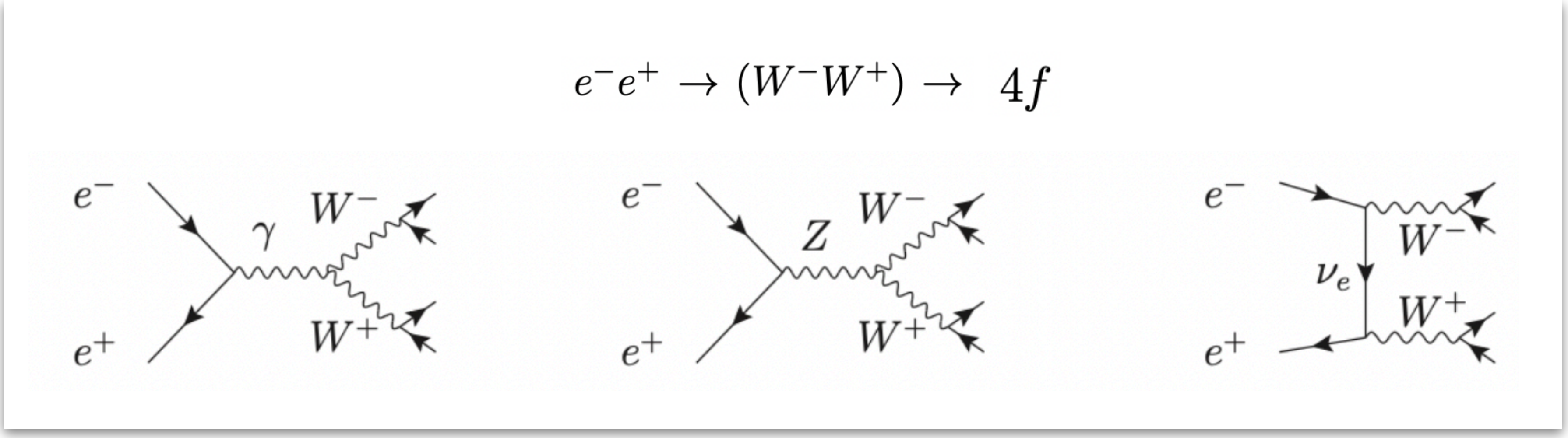


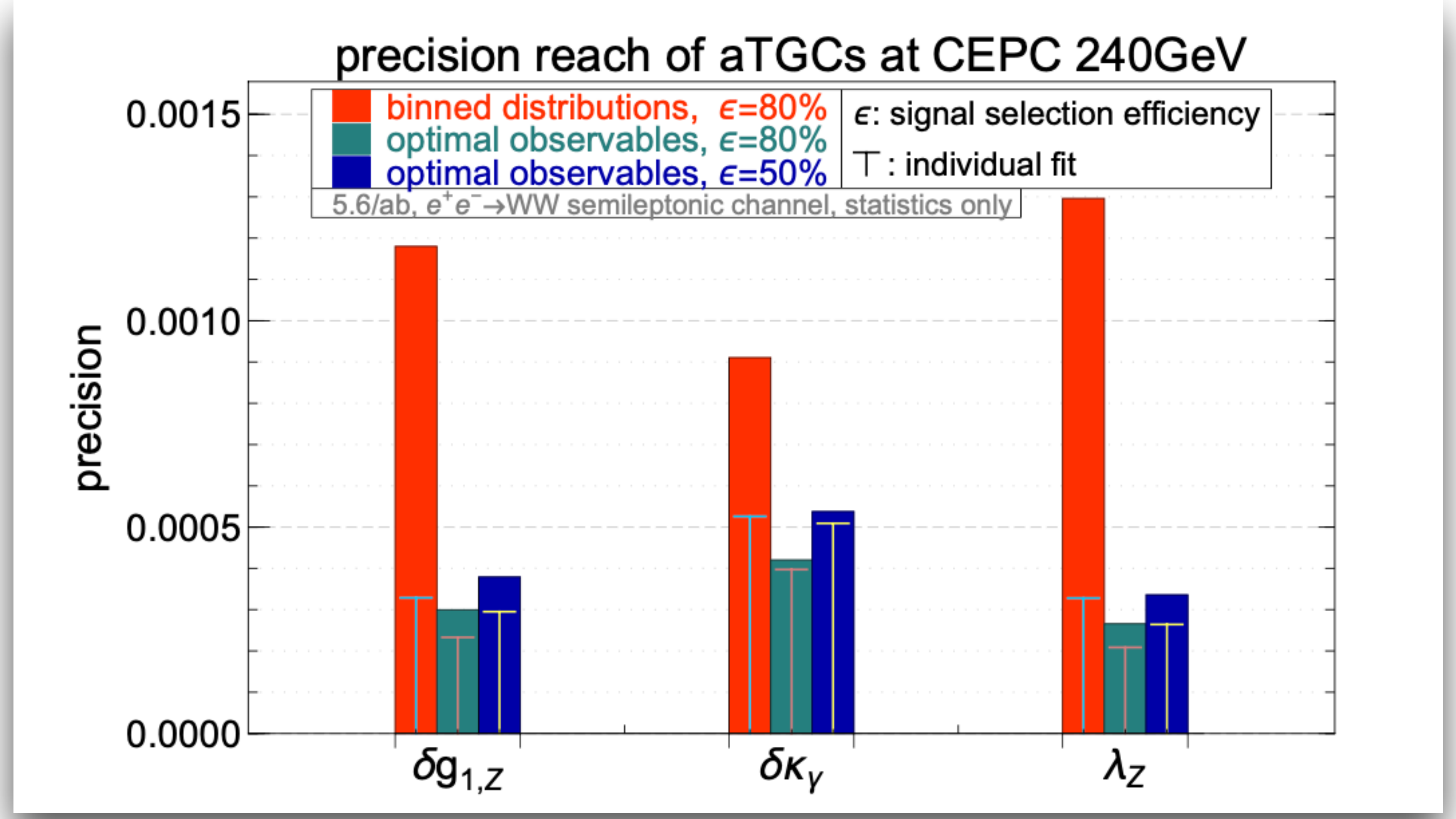
ASSUMPTIONS

- linear dependence over WCs
- systematics is negligible

→ we can define **Optimal Observables**

- retain all the differential information
- maximal sensitivity to the Wilson coefficients

WW with Optimal Observables



J. de Blas et al. [1907.04311]

Optimal Observables

- Consider a differential distribution

$$\frac{d\sigma}{d\Phi} = S_0(\Phi) + \sum_i c_i S_i(\Phi) \equiv S(\Phi)$$

SM *set of m WCs* *linear contribution*

- The Optimal Observables are defined as

n events $n = \mathcal{L}\sigma$

n sets of kinematic variables $\Phi_1, ..., \Phi_n$

$$O_i = \frac{1}{n}\sum_k^n \frac{S_i(\Phi_k)}{S_0(\Phi_k)}$$ *~ signal / background*

M. Diehl and O. Nachtmann [9402271]

- The χ^2 is defined as

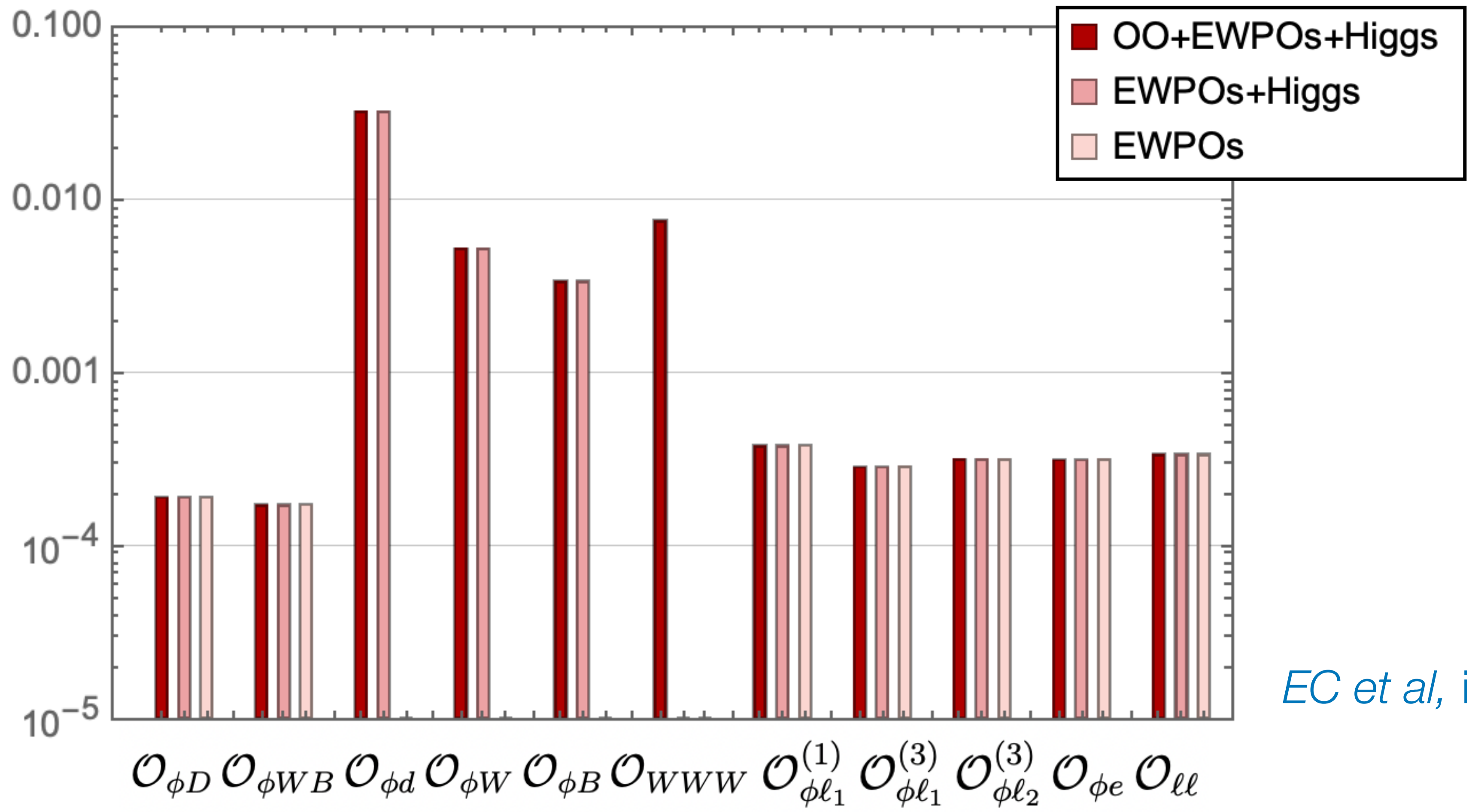
$$\chi^2 = \sum_i \sum_j (E[O_i] - O_i^{\text{meas}})\ \text{cov}(O_i, O_j)^{-1}\ (E[O_j] - O_j^{\text{meas}})$$

theoretical *experimental*

Results

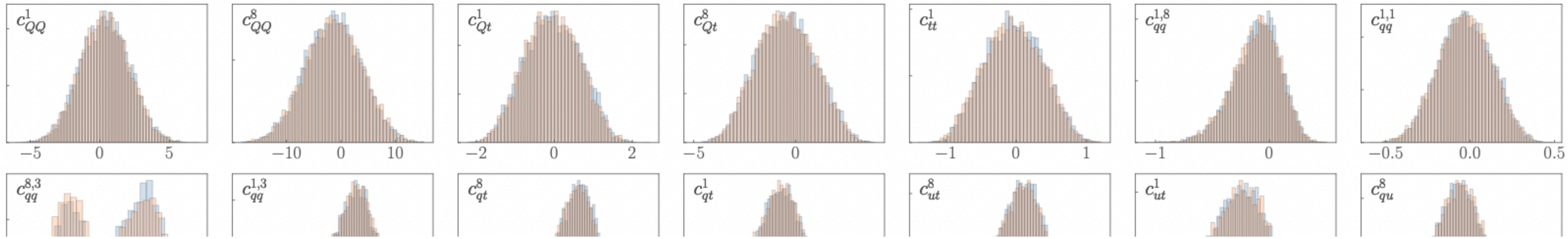
- EWPOs at Z-pole
- Higgs: $\sigma(ZH)$, $\sigma(ZH) \times BR(H)$, $\sigma(WW \to H) \times BR(H)$ at $\sqrt{s}$ =240, 365 GeV
- Optimal Observables: $e^-e^+ \to W^-W^+ \to \ell^-\bar{\nu}_\ell \ell^+ \nu_\ell$ at $\sqrt{s}$ =240, 365 GeV

- 95%CL individual bounds
- projected uncertainties from *Snowmass '21 [2206.08326]*
- linear LO SMEFT $\mathcal{O}(\Lambda^{-2})$



EC et al, in preparation

Global fits with SMEFiT



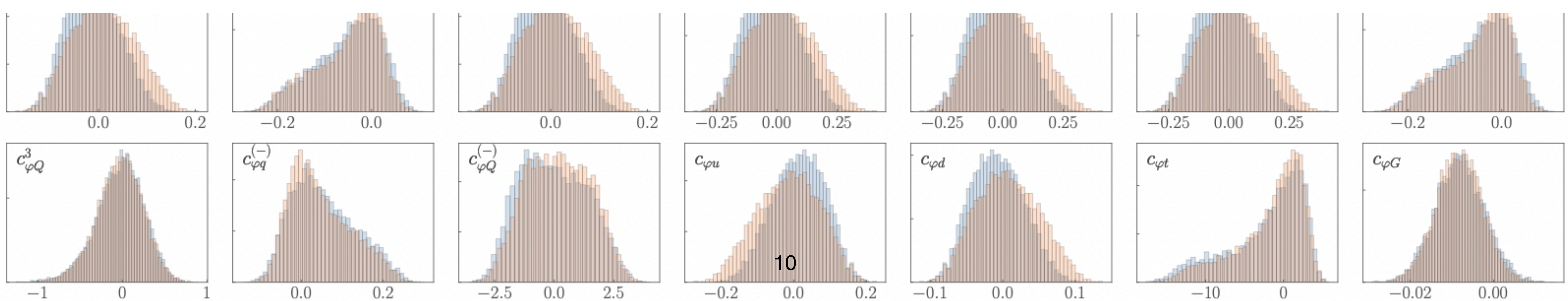
- open source python package for global SMEFT fits

  T. Giani, G. Magni, J. Rojo [2302.06660]

- large HEP dataset (LHC Run I and II, LEP EWPOs)

- **soon will support future collider projections (HL-LHC, FCC-ee)**

  SMEFiT collab., '24



Thank you!