

# SMEFT status

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(CERN)

few references given as entry points to the literature

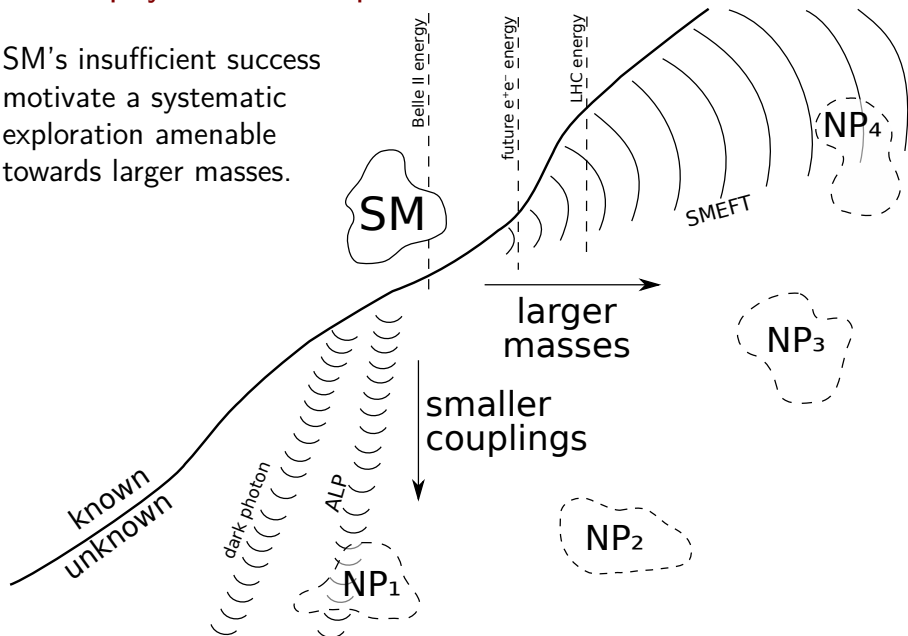
see also [HEFT 2023](#) talks (19-21 June)

[LHC EFT WG meetings](#), [Twiki](#)

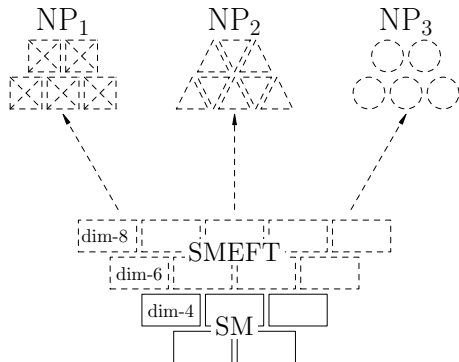


# Particle physics' landscape

SM's insufficient success motivate a systematic exploration amenable towards larger masses.

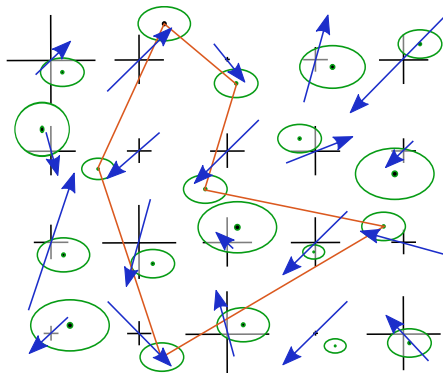


# Taking the SM to higher dimensions



- using established bricks (fields and symmetries)
- extension organised by relevance (dimension)
- including all deformations (theory space coverage)

# Isolating patterns of new physics



array of sensitive observables

- precise SM-EFT predictions
- precise measurements
- correlate deviations

# SMEFT status

1. Improved sensitivity (powerful observables, multidimensionally)
2. Global picture (parameterisation, sector combinations, fits)
3. Precise interpretation (higher-order SM/EFT corrections)
4. Models' connection (charting, matching, positing, bootstrapping)
5. New techniques & understanding (amplitudes, geometry)

# 1. Improved sensitivity

- matrix element method defines the theoretical optimal
- ML for invisible PS integration, shower, hadronisation, detector
- multidimensionality curse [Atwood, Soni '92] [Diehl, Nachtmann '94]  
[Gomez Ambrosio, ter Hoeve, Madigan, Rojo, Sanz '22]
- importance of reweighting [EFT WG studies: 28 June, 24 May, 6 April]  
negative NLO weights [Kraus, Martini, Uwer '19]
- ease, understanding, and control
- first non-trivial experimental use of ML for SMEFT [CMS '21]

## 2. Global picture

**Fitmaker** EWPO+diboson+Higgs+top, linear

[Ellis, Madigan, Mimasu, Sanz, You '20]

**SMEFiT** diboson+Higgs+top, some NLO QCD,

[Ethier, Magni, Maltoni, Mantani, Nocera, Rojo, Slade, Vryonidou, Zhang '21]

**HEPfit** EWPO, flavour, future

[de Blas, Pierini, Reina, Silvestrini '22]

**EFTfitter** top+B+EWPO, 14 op

[Grunwald, Hiller, Kröninger, Nollen '23]

**SFitter** EWPO+diboson diff.+Higgs, top+B

[Brivio, Bruggisser, Elmer, Geoffray, Luchmann, Plehn '22]

**OptEx** EWPO+diboson diff.+Higgs+diHiggs, 23 op, no 4f, linear

[Anisha, Das, Banerjee, Biekötter, Chakraborty, Patra, Spannowsky '21]

**Flavio** B+Drell-Yan+EWPO

[Greljo, Salko, Smolkovi, Stangl '22]

**HighPT** B+Drell-Yan

[Allwicher, Faroughy, Jaffredo, Sumensari, Wilsch '22]

[see the more comprehensive table by Anke Biekötter]

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**HEFit** EWPO, flavour, future

more observables

less restrictive flavour assumptions

better predictions

facilitated interpretations

→ build LHC legacy

[de Blas, Pierini, Reina, Silvestrini '22]

**FTfitter** top+B+EWPO, 14 op

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- shared predictions: validated, consistent, state-of-the-art

[H+EFT WG studies]

- cross-validation of fitting machineries

- uncertainties on EFT parameterisation

[Altmannshofer, Stangl '21]

- EFT in backgrounds (signal  $\rightarrow$  signature)

[CMS b+leptons '20, '23]

[ATLAS four-lepton '21]

- joint EFT+PDF fits

[Gao, Gao, Hobbs, Liu, Shen '22]

[Kassabov, Madigan, Mantani, Moore, Morales Alvarado, Rojo, Ubiali '23]

### 3. Precise interpretation

- $pp \rightarrow jj$  ( $q\bar{q}q\bar{q}$ ) [Gao, Li, Wang, Zhu, Yuan '11]
- $pp \rightarrow t\bar{t}$  ( $q\bar{q}t\bar{t}$ ) [Shao, Li, Wang, Gao, Zhang, Zhu '11]
- $pp \rightarrow VV$  [Dixon, Kunszt, Signer '99] [Melia, Nason, Röntsch, Zanderighi '11]
- EWPO (top) [Baglio, Dawson, Homiller, Lane, Lewis '17, '18, '19, '20] [Chiesa, Denner, Lang '18]
- top decays [Zhang, Greiner, Willenbrock '12]
- top FCNCs  $\text{UFO}$  [Zhang '14] [Boughezal, Chen, Petriello, Wiegand '19]
- $pp \rightarrow t\bar{t}$  (chromo-dipole) [Degrande, Maltoni, Wang, Zhang '14] [GD, Maltoni, Zhang '14]
- $h \rightarrow \gamma\gamma, VV, \gamma Z$  [Franzosi, Zhang '15]
- $h \rightarrow f\bar{f}$  [Hartmann, Trott '15] [Ghezzi, Gomez-Ambrosio, Passarino, Uccirati '15] [Dawson, Giardino '18]
- $pp \rightarrow tj$  [Dedes, Paraskevas, Rosiek, Suxho, Trifyllis '18] [Dawson, Giardino '18] [Dedes, Suxho, Trifyllis '19]
- $pp \rightarrow t\bar{t}Z, gg \rightarrow ZH$  [Biekötter, Cullen, Gauld, Pecjak, Scott, Smith '15, '16 '19, '20, '23]
- $pp \rightarrow t\bar{t}H, gg \rightarrow H_j, HH$  [Zhang '16] [de Beurs, Laenen, Vreeswijk, Vryonidou '18]
- $pp \rightarrow HV$  [Röntsch, Markus Schulze '14] [Bylund, Maltoni, Vryonidou, Zhang '16]
- $Z, W$  poles [Maltoni, Vryonidou, Zhang '16]
- $pp \rightarrow h$  [Degrande, Fuks, Mawatari, Mimasu, Sanz '16] [Alioli, Dekens, Girard, Mereghetti '18]
- $pp \rightarrow tjZ, tjh$  [Hartmann, Shepherd, Trott '16] [Bellafronte, Dawson, Ismail, Giardino '18, '18, '19, '22, '23]
- $pp \rightarrow \text{jets (triple gluon)}$   $\text{UFO}$  [Biekötter, Pecjak, Scott, Smith '23]
- Higgs self-coupling [Grazzini, Ilnicka, Spira, Wiesemann '16] [Deutschmann, Duhr, Maltoni, Vryonidou '17]
- EW Higgs &  $WW$  (top) [Degrande, Maltoni, Mimasu, Vryonidou, Zhang '18]
- EW  $pp \rightarrow t\bar{t}$  ( $ttZ, tth$ ) [Hirshi, Maltoni, Tsirikos, Vryonidou '18]
- all QCD and four-quarks  $\text{UFO}$  [McCullough '13] [Gorbahn, Haisch '16] [Degrassi et al. '16, '17] [Bizon et al. '16] [Kribs et al. '16]
- EW  $pp \rightarrow \ell^+\ell^-$  [Maltoni, Pagani, Shivaji, Zhao '17] [Di Vita, GD, Grojean, Gu, Liu, Panico, Riemann, Vantalón '17]
- EW  $QQQQ$  in  $gg \rightarrow h, h \rightarrow bb, pp \rightarrow tth$  [Vryonidou, Zhang '18] [GD, Gu, Vryonidou, Zhang '18] [Boselli, Hunter, Mitov '18]
- NNLO  $pp \rightarrow Zh \rightarrow \ell^+\ell^-b\bar{b}$  [Martini, Schulze '19] [Martini, Pan, Schulze, Xiao '21]
- NNLO VBF [Degrande, GD, Maltoni, Mimasu, Vryonidou, Zhang '20]
- NNLO  $pp \rightarrow \ell^+\ell^-$  [Dawson, Giardino '21, '22]
- NNLO  $pp \rightarrow Zh \rightarrow \ell^+\ell^-b\bar{b}$  [Alasfar, de Blas, Gröber '22]
- NNLO VBF [Haisch, Scott, Wiesemann, Zanderighi, Zanoli '22]
- NNLO  $pp \rightarrow Zh \rightarrow \ell^+\ell^-b\bar{b}$  [Asteriadis, Caola, Melnikov, Röntsch '22]

- deploy NLO QCD, systematise NLO EW + their pheno
- gain accuracy+precision, new sensitivities+degeneracies
- account for RG running, go beyond one-loop
- explore  $\dim > 6$ , benchmark dim-6 truncation validity

[Aoude, Maltoni, Mattelaer, Severi, Vryonidou '22]

[Bern, Parra-Martinez, Sawyer '20]

[Ellis, Mimasu, Zampedri '23]

[Degrande, Li '23]

[Heinrich, Lang '22]

## 4. Models' connexion

- charting

EFT space populated by models

[GD, McCullough, Salvioni '22]

- matching

[LHC EFT WG note '22]

- CoDEx (func)
- Matchmakereft (diag)
- Matchete (func)

[Bakshi, Chakraborty, Patra '18]

[Carmona, Lazopoulos, Olgoso, Santiago '21]

evanescent op

[Fuentes-Martín, König, Pagès, Thomsen, Wilsch '22]

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- specific models

[Dawson, Fontes, Quezada-Calonge, Sanz-Cillero '23]

[Banta, Cohen, Craig, Lu, Sutherland '23]

- positivizing and bootstrapping

[Riembau '22] [Miro, Guerrieri, Gumus '22]

- BSM starts at dim-8
- pheno starts at dim-8
- sum rules apply at dim-6

[Bellazzini, Riva '18] [Gu, Wang, Zhang '20]

[Remmen, Rodd '22]

## 5. New techniques & understanding

- on-shell anomalous dimensions and selection rules

[Cheung, Shen '15], [Azatov et al. '16], [Bern et al. '19, '20][Jiang et al. '20], [Elias Miró et al. '20, '21],  
[Baratella et al. '20, '20, '21][Accettulli Huber, De Angelis '21], [Delle Rose et al. '22], [Baratella '22]  
[Machado, Renner, Sutherland '22], [Chala '23]

- on-shell operator enumeration

[Shadmi, Weiss '18], [Ma, Shu, Xiao '19], [Falkowski '19], [GD, Machado '19]  
[Li, Ren, et al. '20, '20], [Harlander, Kempkens, Schaaf '23]

- Hilbert series

[Kondo, Murayama, Okabe '22] [Sun, Wang, Yu '22]  
[Gráf, Henning, Lu, Melia, Murayama '22]

- on-shell EFT amplitude construction

[Aoude, Machado '19], [GD, Kitahara, Shadmi, Weiss '19], [GD et al. '20]  
[Balkin et al. '21], [Dong, Ma, Shu, Zheng '21, '22], [De Angelis '22]  
[Bradshaw, Chang, Chen, Liu, Luty '22, '23], [Liu, Ma, Shadmi, Waterbury '23]

- on-shell matching

[Delle Rose, von Harling, Pomarol '22]  
[De Angelis, GD 'xx]

- field geometry

[Corbett, Martin '23] [Martin, Trott '23]  
[Craig, Lee, Lu, Sutherland '23] [Helset, Jenkins, Manohar '22]  
[Brivio, Davighi, Alminawi 'xx]

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[Bonnetfoy, GD, Grojean, Machado, Roosmale Nepveu '21]

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