SMEFT news

a random biased sample

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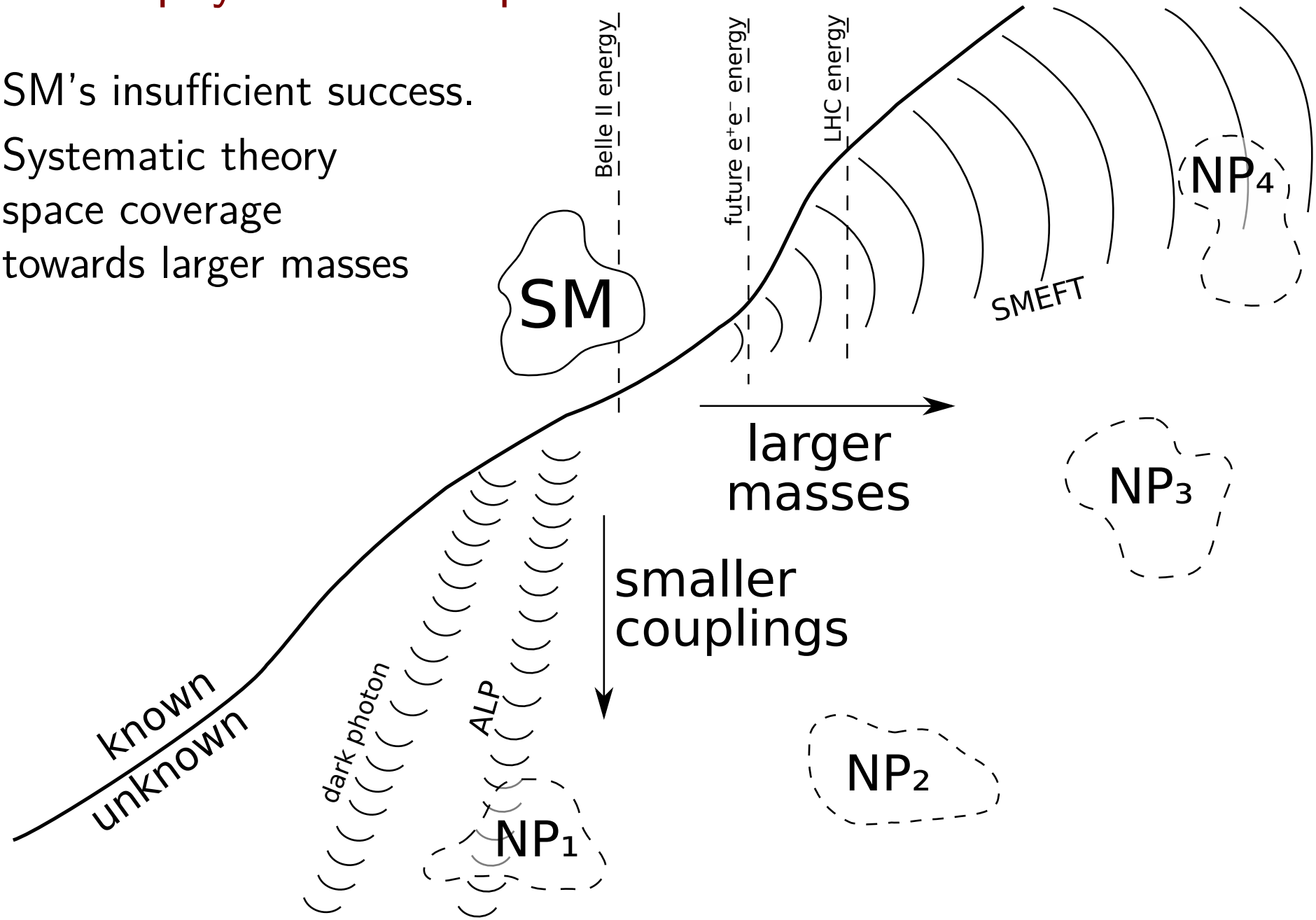
(CP3 – UCLouvain)

LHC BSM WG general meeting
CERN – 10 Nov. 2025

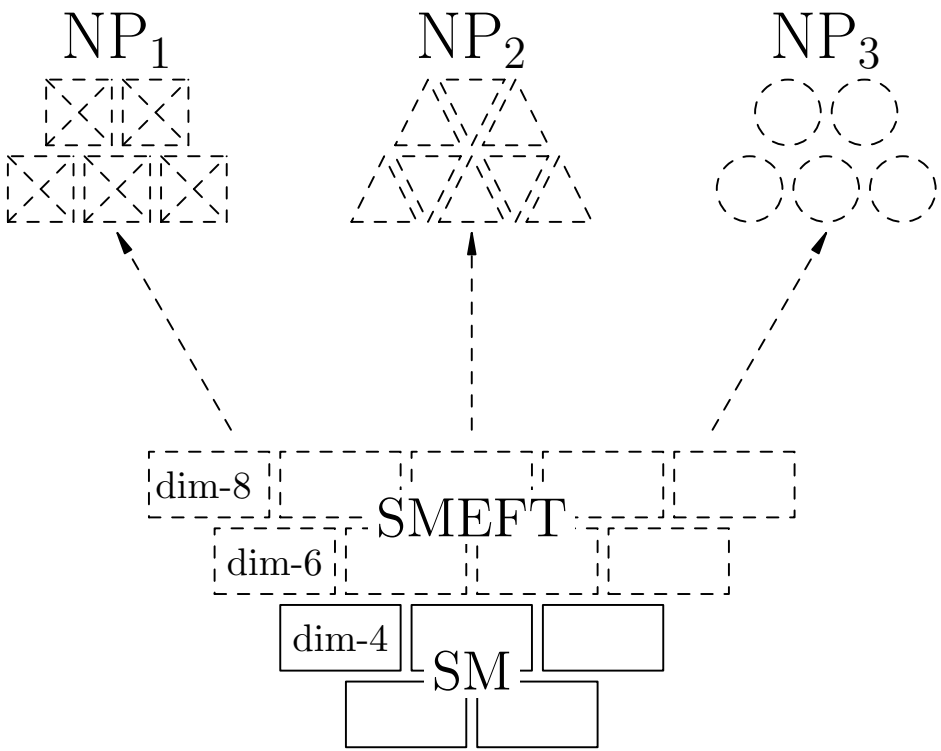
Particle physics landscape

SM's insufficient success.

Systematic theory
space coverage
towards larger masses

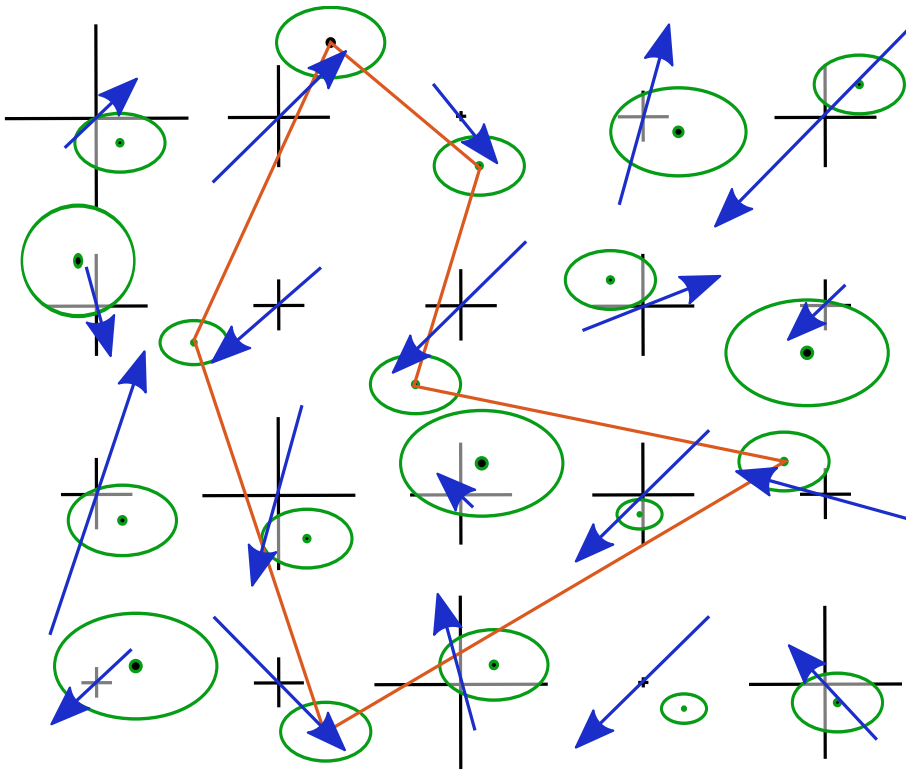


Taking the SM to higher dimensions



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

Isolating subtle patterns of new physics



array of sensitive observables

- precise SM&EFT predictions
- precise measurements

$\rightarrow$ correlate deviations

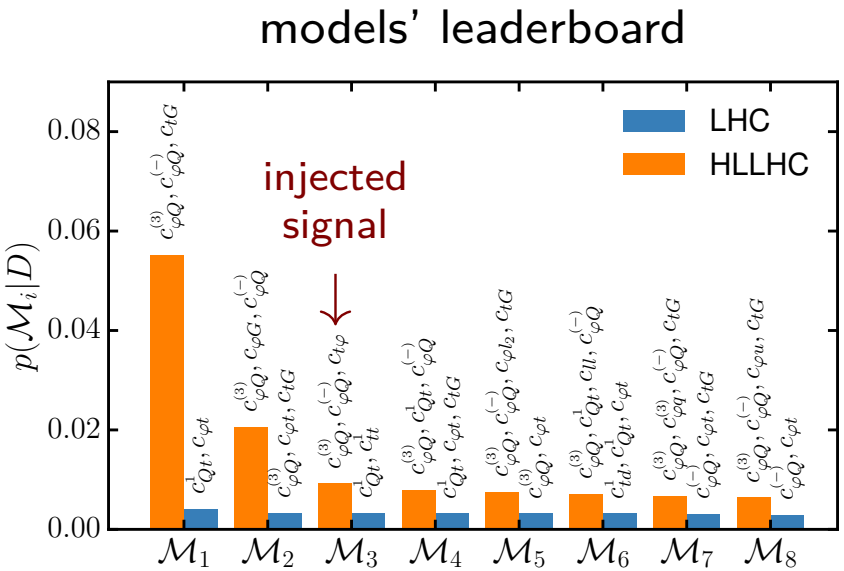
SMEFT space exploration with ML

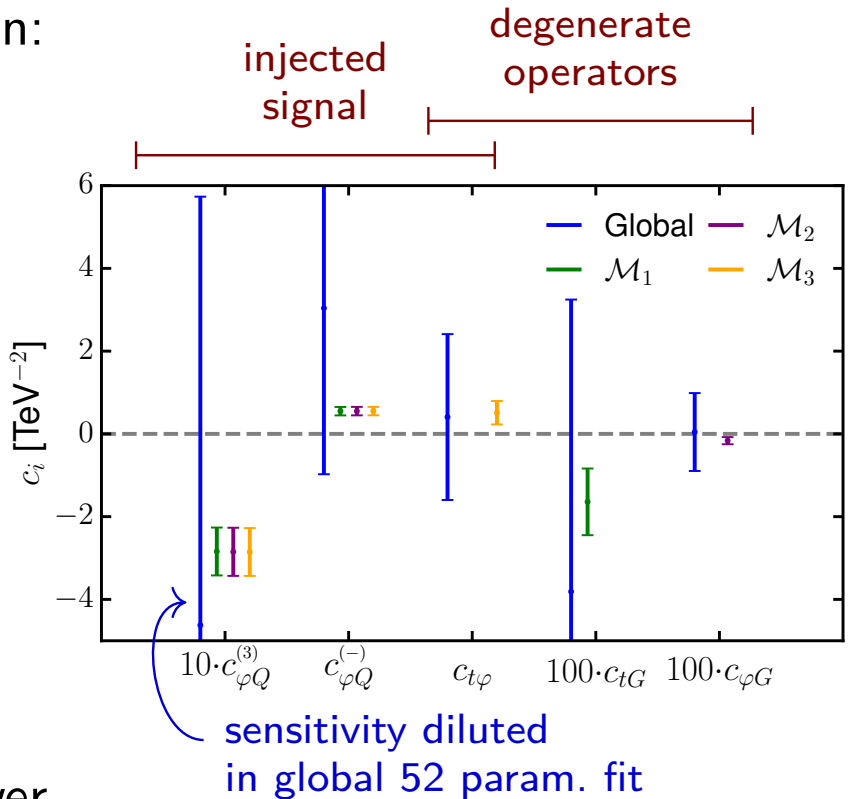
[Hirsch, Mantani, Sanz '25]

Genetic algorithm to find the simplest operator sets explaining data best.

Penalty for model complexity: $\chi^2 + n_{\text{operators}} \cdot \#$

Test with third-gen VLQ signal injection:





Simpler models concentrate data's power
on more specific questions leading to sharper answers.

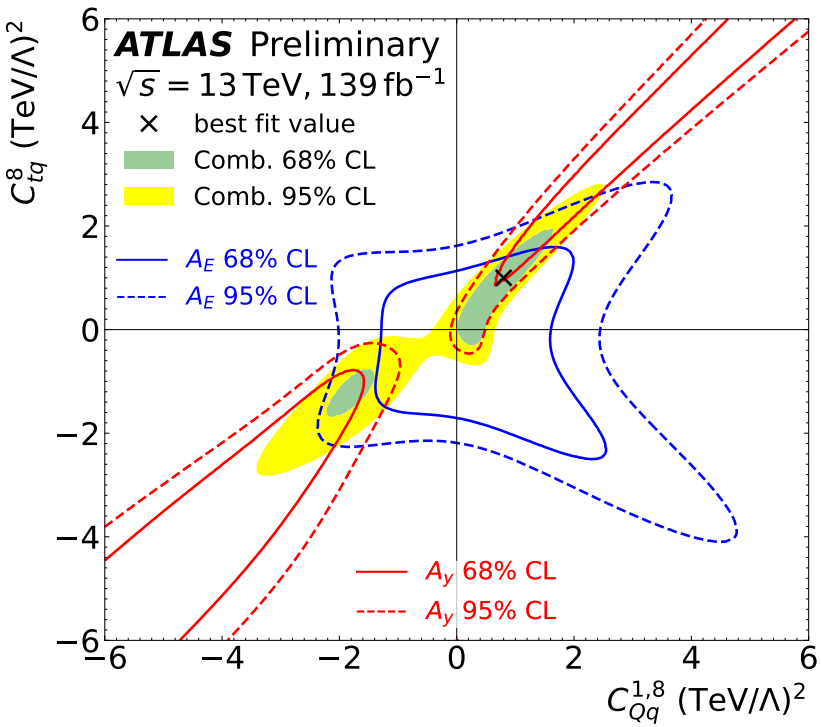
SMEFT parameterisation uncertainties

[ATL-PHYS-PUB-2025-037]

Combination of charge and energy asymmetries in $t\bar{t}j$ for $q\bar{q}Q\bar{Q}$ operators.

Fit including MC and scale variation unc. on NLO SMEFT predictions

[see also Altmannshofer, Stangl '21]



Through nuisance parameters: one for μ_R, one uncorrelated for μ_F (?)

5-30% effect on EFT bounds

¿Scale choice?

¿Scale dependence of operator coefficients accounted for?

SMEFT expansion uncertainties

Loose constraints and high probed energies allow sizeable unknown dim>6

Various proposed recipes, no consensus [LHC EFT WG note '22]

One remedy applied experimentally already *clips* away high-energy tails

Recent proposal: [Chang, Luty, Ma, Montagno, Wulzer '25]

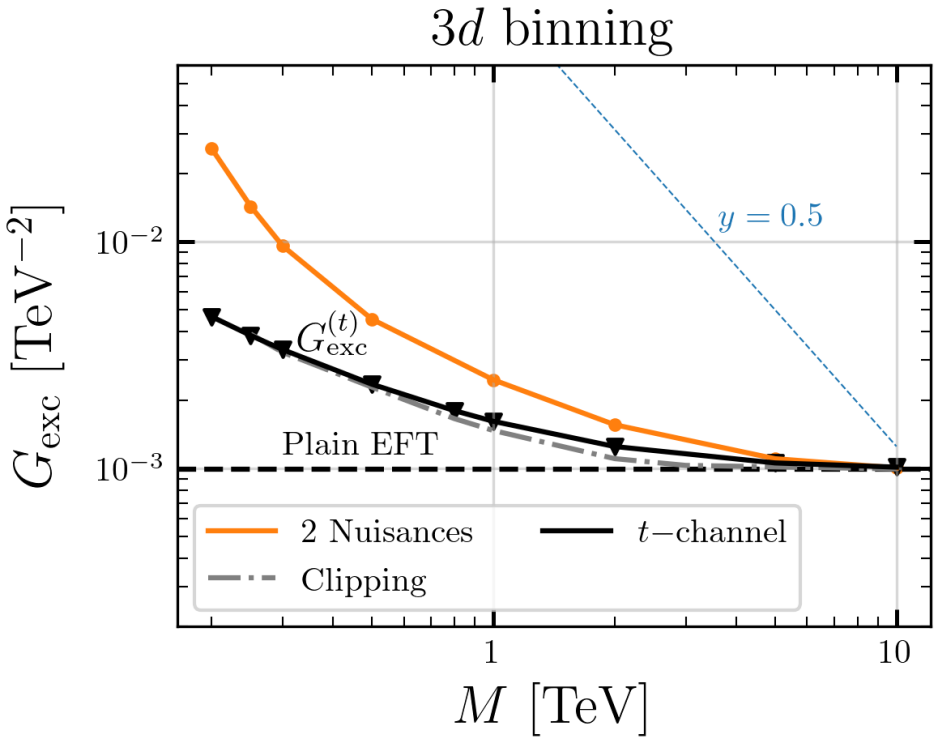
General (regulated) parameterisation of further energy growing effects

Scaled by c/M^n nuisance param's with set spread prior

→ has smooth realistic turn-on

→ avoids clipping variable selection and implementation

→ increases combination consistency



Two-loop running of α_s and m_t

[Duhr, Vasquez, Ventura, Vryonidou '25]
[Duhr, Ventura, Vryonidou '25]

For QCD,

- triple gluon operator,
- top chromo-magnetic operator,
- four-heavy quark operators (only gluon self-en.)

[see also: Naterop, Stoffer '24]
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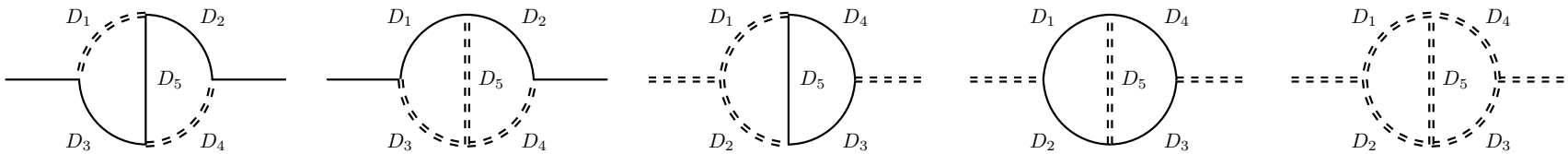
[Di Noi, Gröber '25]



From top and gluon self-energies in bkg-field gauge, in $\overline{\text{MS}}$ or on-shell

EOM-redundant and gauge-variant operators, to absorb subdivergences:

$$\bar{t}\,(i\not{D} - m)^2\, t \qquad \bar{t}\,\not{G}\,(i\not{D} - m)\, t \qquad \ldots$$

Decoupling scheme for MC generators/PDFs/parton showers with

$$\alpha_s^{\text{SMEFT}} = \alpha_s^{\text{SM}} + \mathcal{O}(\Lambda^{-2}) \text{ and } \beta^{\text{SMEFT}} = \beta^{\text{SM}}$$

Two-loop SMEFT anomalous dimensions

Targetted results and methodological advances

[Bern, Parra-Martinez, Sawyer '20]
[Elias Miró, Ingoldby, Riembau '20]
[Elias Miró, Fernandez, Gumus, Pomarol '21]
[Jenkins, Manohar, Naterop, Pagès '23]
[Di Noi, Gröber, Heinrich, Lang, Vitti '23]
[Jenkins, Manohar, Naterop, Pagès '23]
[Fuentes-Martín, Palavríc, Thomsen '23]
[Di Noi, Gröber, Mandal '24]
[Born, Fuentes-Martín, Kvedaraitė, Eller Thomsen '24]
[Haisch '25]
[Fuentes-Martín, Moreno-Sánchez, Eller Thomsen '25]
[...]

with a diversity of scheme choices...

Full SMEFT coming soon!

Warsaw basis change

[LHC EFT WG meeting, 20 Oct 2025]

Proposal:

Tensor *lequ* into scalar *luqe*, to avoid NDR trace reading-point ambiguity

$|H|^2\Box|H|^2$ into $|H|^2|D_\mu H|^2$, to avoid EOM-redundant terms

Gauge coupling factors in front of field strength operators

Turn triplet and octet into non-irrep bilinears

If you ask me,

experts can swallow some amount of inconvenience (incl. a posteriori conversion) to avoid generating confusion for everyone else, at a point in time where one basis eventually emerged as standard.

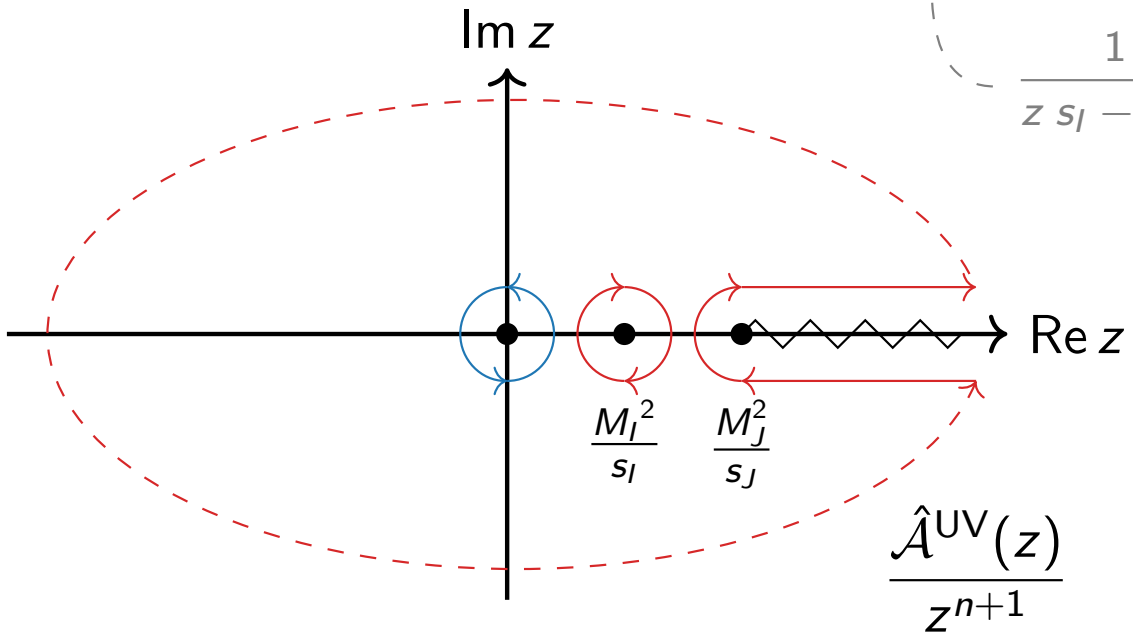
[De Angelis, GD '23]

Dispersive EFT matching

- equate $\mathcal{A}^{\text{EFT}}$ and $\mathcal{A}^{\text{UV}}$ order by order in the zero-momentum expansion
- dilate (with $z^{D/2}$) and enforce $\underset{z=0}{\text{Res}} \dfrac{\hat{\mathcal{A}}^{\text{EFT}}(z)}{z^{n+1}} = \underset{z=0}{\text{Res}} \dfrac{\hat{\mathcal{A}}^{\text{UV}}(z)}{z^{n+1}}$
- EFT: $\underset{z=0}{\text{Res}} \dfrac{\hat{\mathcal{A}}^{\text{EFT}}(z)}{z^{n+1}} = c_n \, \text{poly}_n(s_I)$ with $\mathcal{A}^{\text{EFT}}_{\text{tree}} = \sum_k c_k \, \text{poly}_k(s_I)$
- UV: $\underset{z=0}{\text{Res}} \dfrac{\hat{\mathcal{A}}^{\text{UV}}(z)}{z^{n+1}} = \oint_{z=0} dz \, \dfrac{\hat{\mathcal{F}}^{\text{UV}}(z)}{z^{n+1}} = \left[\sum \text{Res} + \int \text{Disc} + \int_\infty \right] \dfrac{\hat{\mathcal{A}}^{\text{UV}}(z)}{z^{n+1}}$

$\log(M_J^2 - z\, s_J)$

$\dfrac{1}{z\, s_I - M_I^2}$



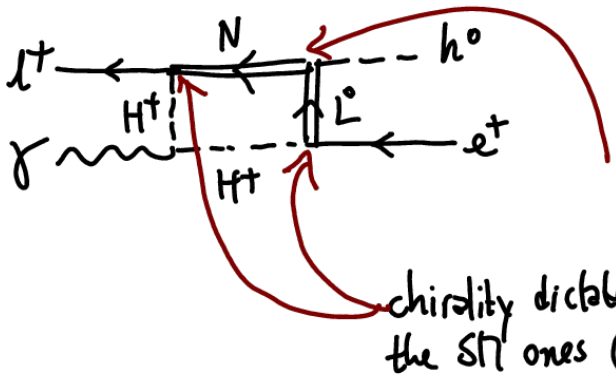
EFT matching from just cuts!

Magic matching zeros

[Arkani-Hamed, Harigaya '21]
[Craig, Garcia Garcia, Vainshtein, Zhang '21]
[Delle Rose, von Harling, Pomarol '22]
[Hook '22]

Zero matching coefficients without standard symmetry explanation

E.g. vector-like leptons $L \sim (\underline{1}, \underline{2}, -1/2)$ $N \sim (\underline{1}, \underline{1}, 0)$ to $\frac{[e\gamma][l\gamma]}{\Lambda^2}$



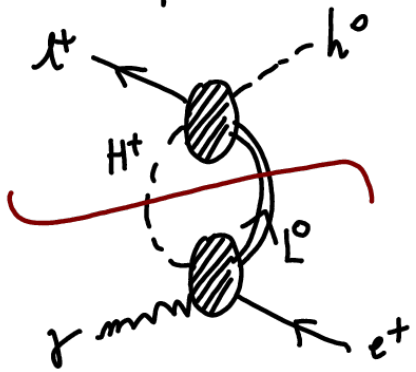
two possible choices of chiralities

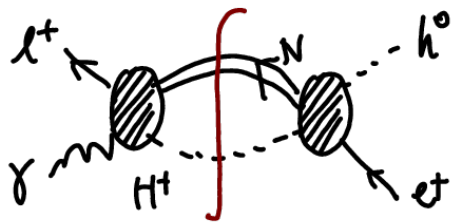
- Y_N : picks up masses from propagator
- Y'_N : picks up momenta "

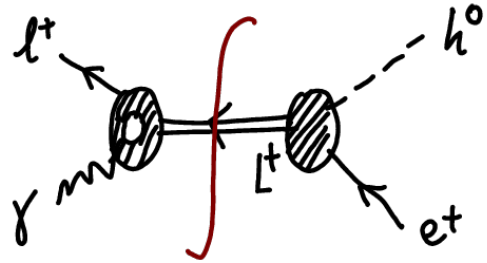
Y'_N focus on this

On-shell amplitude cuts :

(in the unbroken EW phase but separating $SU(2)_L$ components)







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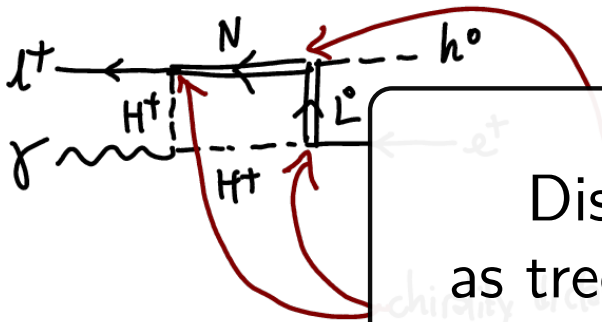
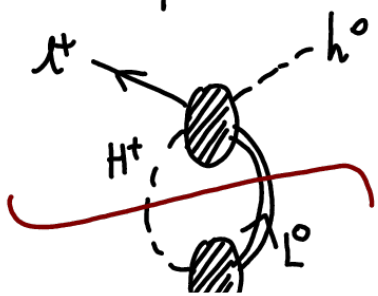
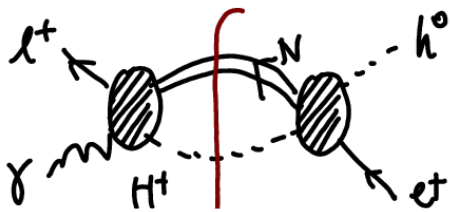


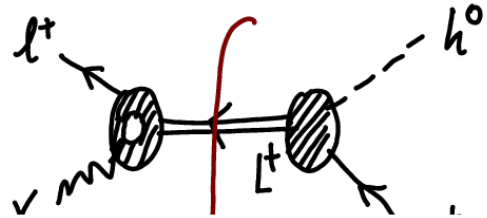
Dispersively understood
as tree-level non interference!

On-shell amplitude cuts :

(in the unbroken EW phase
but separating $SU(2)_L$ components)







Easier way: decouple L first and find that the dim-5 operator $\bar{N} e \, \epsilon_{ij} H^i H^j$ vanishes.

Conclusions

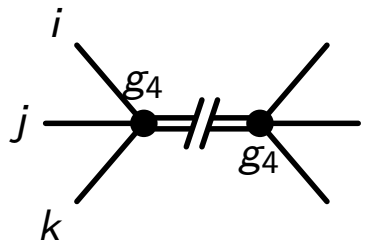
SMEFT has become a prime interpretation tool for HEP data,
complementary to resonant searches.

It enables the discovery of subtle new physics correlations,
and encodes the LHC legacy for heavy NP constraints.

A vibrant community (both TH & EXP)
pushes advances in various directions.

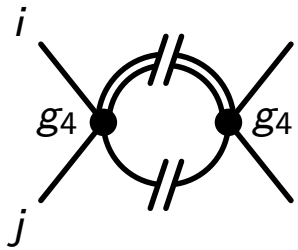
Extras

Simple toy $\Phi\phi^3$ example



$$: \operatorname*{Res}_{z=M^2/s_{ijk}} \frac{|\mathcal{A}(\phi\phi\phi \to \Phi)|^2}{z s_{ijk} - M^2} \frac{1}{z^{n+1}}$$

$$= \frac{g_4^2}{M^2} \left(\frac{s_{ijk}}{M^2}\right)^n$$

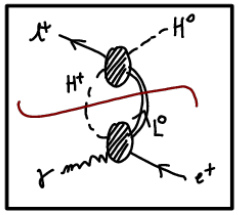


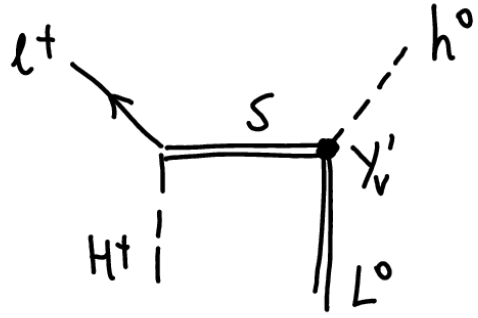
$$: \frac{1}{2\pi} \int_{M^2/s_{ij}}^{\infty} \frac{\mathrm{d}z}{z^{n+1}} \int \mathrm{dLIPS}\, |\mathcal{A}(\phi\phi \to \phi\Phi)|^2$$

$$= \frac{1}{2\pi} \int_{M^2/s_{ij}}^{\infty} \frac{\mathrm{d}z}{z^{n+1}} \frac{1}{8\pi} \left(1 - \frac{M^2}{z s_{ij}}\right) g_4^2$$

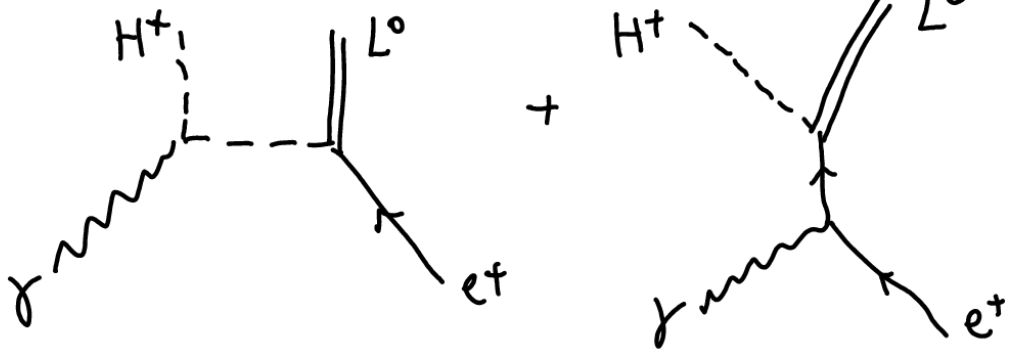
$$= \frac{g_4^2}{16\pi^2 n(n+1)} \left(\frac{s_{ij}}{M^2}\right)^n \qquad \text{for } n > 0$$

- amplitudes used instead of form factors
- all EFT orders obtained at once
- nothing to know about —or compute in— the EFT (in dimreg)
- fewer legs and loops





$$\sim Y'_V \frac{[lHL\rangle}{s_{lH} - M_S^2}$$

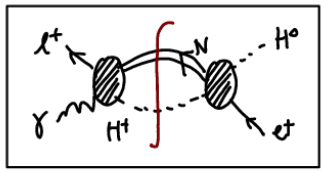


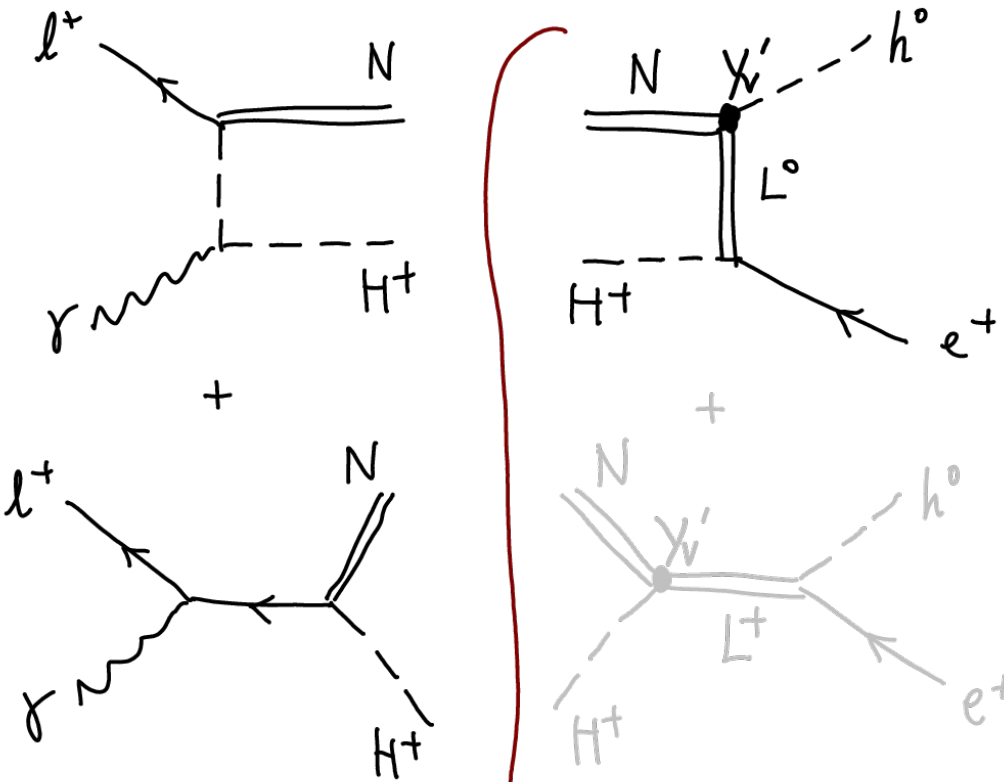
$$\sim \frac{M_L \langle LH\rangle}{\langle H\gamma\rangle \langle e\gamma\rangle}$$

Contracting the $\underline{L}$ spinors gives

$$[lH(M_L)H\rangle = 0$$ (since H is massless and on-shell)

So the cut vanishes identically (before any phase-space and cut integral) and gives zero contribution at all EFT order!

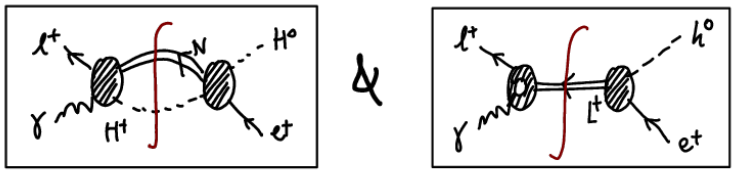




$$\sim \frac{\langle \underline{N} H \rangle}{\langle l\gamma \rangle \langle H\gamma \rangle} \qquad \sim \nu' \frac{[eH\underline{N}\rangle}{s_{He} - M_L^2}$$

The $\underline{N}$ spinor contraction also vanishes identically.

Magic zero understood from non-interference!
At all EFT orders!



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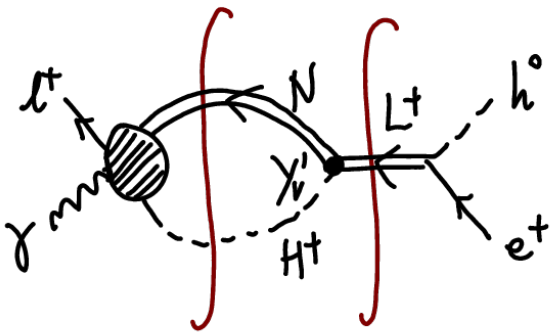

Last family of contributions, not discussed in the litterature for Y_V'.

Contributing both to 1- & 2-particle cuts but only at order $\frac{1}{M_N^2}\frac{1}{M_L^2}$ i.e. dim-8.