Automated global bounds on UV models via SMEFT observables

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MANCHESTER 1824

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An automated vision across scales

E

UV model

See Javier's, Tommaso and Jaco's, Guilherme's talks.

Apologies for not including all tools/codes due to space-time restrictions.

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MATCHETE [2212. 04510]

CoDEx [1808. 04403]

SM Effective Field Theory

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Observables and Data

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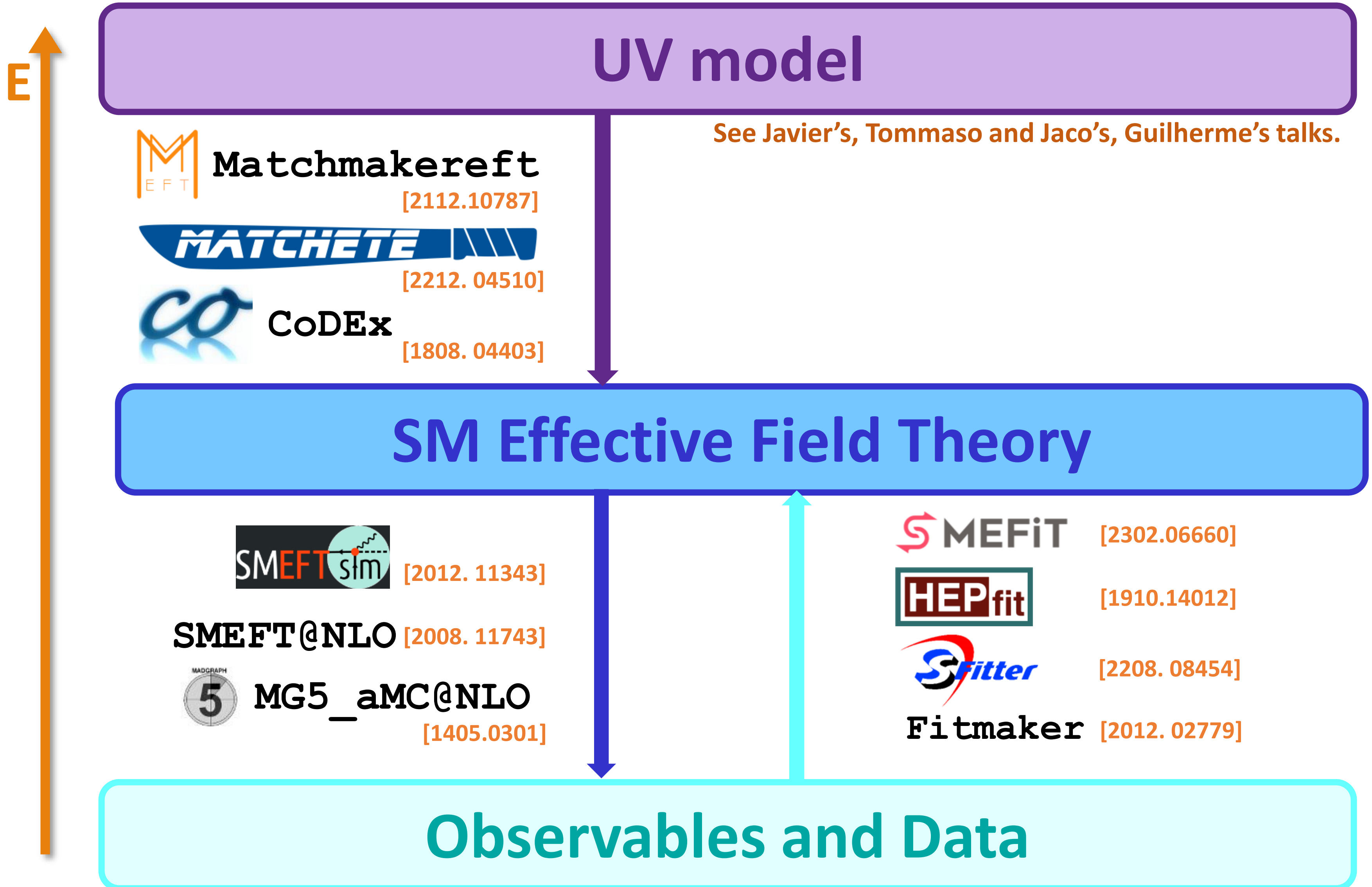

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SMEFiT [2302.06660]

HEPfit [1910.14012]

SFitter [2208. 08454]

Fitmaker [2012. 02779]

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This work
match2fit
SMEFiT
Matchmakereft

UV matching imposes constrains on WCs

Tree-level matching

See Javier's talk on Tuesday and Guilherme's just before.

$$\frac{\left(c_{qd}^{(1)}\right)_{3333}}{\Lambda^2} = -\frac{\left(y_\phi^d\right)_{33}^2}{6\,m_\phi^2}, \quad \frac{\left(c_{qd}^{(8)}\right)_{3333}}{\Lambda^2} = -\frac{\left(y_\phi^d\right)_{33}^2}{m_\phi^2}, \qquad \frac{(c_{d\varphi})_{33}}{\Lambda^2} = \frac{\lambda_\phi\,\left(y_\phi^d\right)_{33}}{m_\phi^2}, \quad \frac{c_\varphi}{\Lambda^2} = \frac{\lambda_\phi^2}{m_\phi^2}$$

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One loop-level matching

$$\frac{c_{\varphi\Box}}{\Lambda^2} = -\frac{g_1^4}{7680\pi^2}\frac{1}{m_\phi^2} - \frac{g_2^4}{2560\pi^2}\frac{1}{m_\phi^2} - \frac{3}{32\pi^2}\frac{\lambda_\phi^2}{m_\phi^2},$$

$$\frac{c_{t\varphi}}{\Lambda^2} = -\frac{\lambda_\phi \left(y_\phi^u\right)_{33}}{m_\phi^2} - \frac{g_2^4 y_t^{\rm SM}}{3840\pi^2}\frac{1}{m_\phi^2} + \frac{y_t^{\rm SM}}{16\pi^2}\frac{\lambda_\phi^2}{m_\phi^2} + \frac{\left(4\left(y_b^{\rm SM}\right)^2 - 13\left(y_t^{\rm SM}\right)^2\right)}{64\pi^2}\frac{\lambda_\phi \left(y_\phi^u\right)_{33}}{m_\phi^2}$$
$$- \left(12\lambda_\varphi^{\rm SM} + \left(y_b^{\rm SM}\right)^2 - 11\left(y_t^{\rm SM}\right)^2\right)\frac{y_t^{\rm SM}}{64\pi^2}\frac{\left(y_\phi^u\right)_{33}^2}{m_\phi^2} + \frac{3}{128\pi^2}\frac{\lambda_\phi \left(y_\phi^u\right)_{33}^3}{m_\phi^2},$$

Modifications on SMEFiT

See Tommaso and Jaco's talk on Wednesday.

SMEFiT supports relations among fit parameters like:

$$\sum_i a_i \left(c_1\right)^{n_{1,i}} \ldots \left(c_N\right)^{n_{N,i}} = 0$$

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Directly change the fit variables to the parameters of the UV model.

$$\sigma(\mathbf{c}) \xrightarrow[\mathbf{c} = f(\mathbf{g}_{\mathrm{UV}})]{\text{Automated in SMEFiT}} \sigma(\mathbf{g}_{\mathrm{UV}})$$

We assume flat priors on the couplings of the UV model.

Caveat: support only for polynomial matching expressions (and a bit more).

UV invariants

- Sensitive only to combinations of UV couplings that enter the WCs.

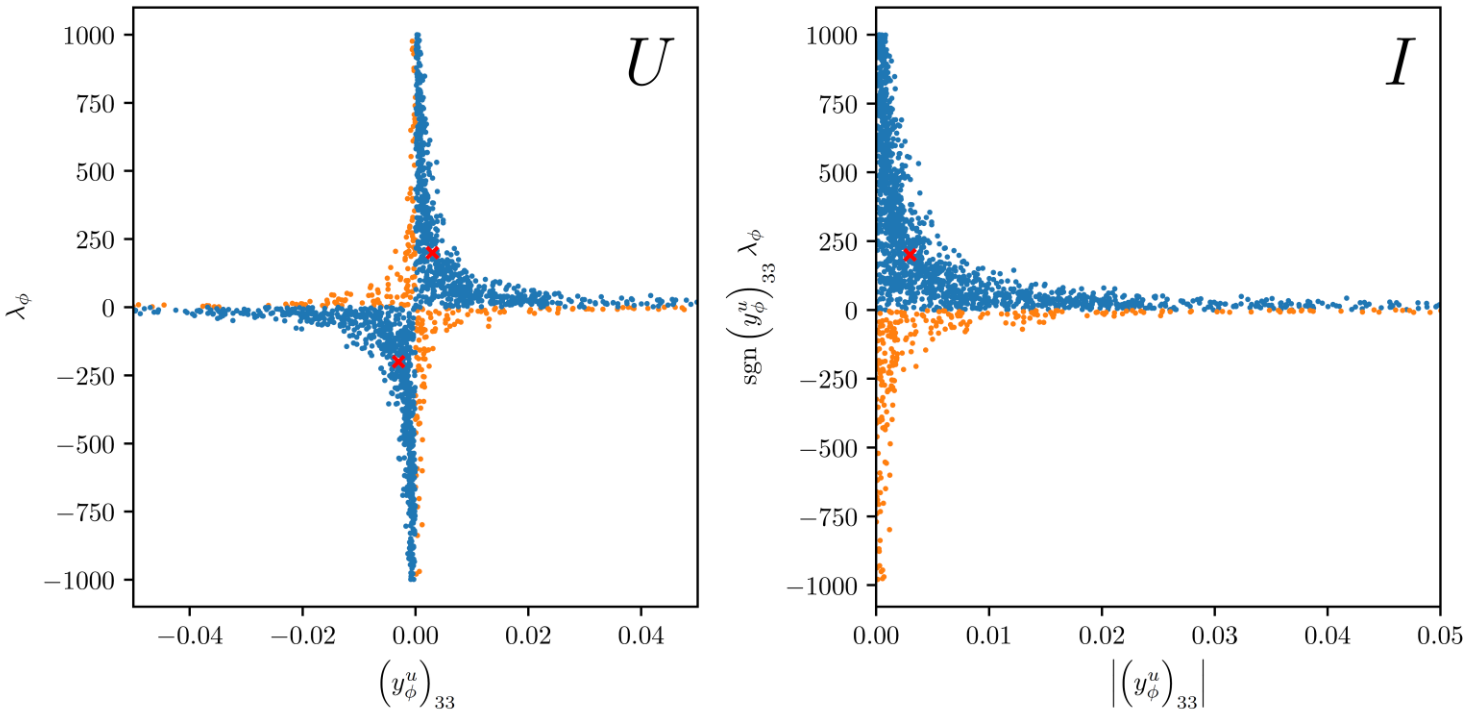
$h : U \to I$

"UV invariants"

$\mathbf{c} = f(\mathbf{g}_{\mathrm{UV}})$

$$f\,(h(g)) = f(h(g')) \iff h(g) = h(g')$$

$\mathbf{c} = f(h(\mathbf{g}_{\mathrm{UV}}))$



Disclaimer: not necessary to do the fit, but useful to understand the results.

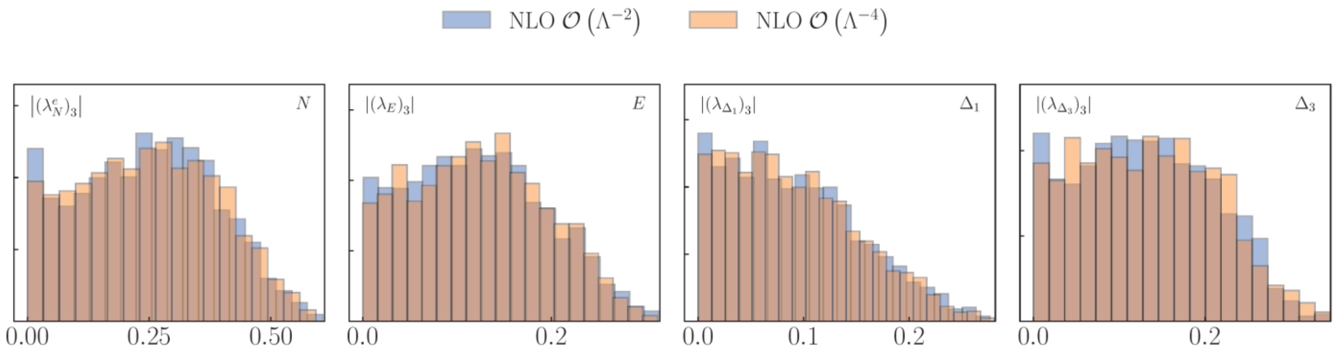
match2fit

https://github.com/arossia94/match2fit/

- A Wolfram Mathematica™ package
- Reads results from `Matchmakereft` and produces run cards that can be fed into `smefit` to perform a fit .
- Uses the same WC basis than SMEFiT.
- Automates the computation of the “UV invariants”.
- It runs `Matchmakereft` to perform matching and print the cards at once.
- Plus additional features (live demo in a few slides).

Caveat: v.1.0 supports only tree-level matching. 1-loop support is WIP.

Bounding vector-like fermions at tree level



Fermions	
Particle	Irrep
N	$(1,1)_0$
E	$(1,1)_{-1}$
Δ_1	$(1,2)_{-1/2}$
Δ_3	$(1,2)_{-3/2}$
Σ	$(1,3)_0$
Σ_1	$(1,3)_{-1}$
U	$(3,1)_{2/3}$
D	$(3,1)_{-1/3}$
Q_1	$(3,2)_{1/6}$
Q_7	$(3,2)_{7/6}$
T_1	$(3,3)_{-1/3}$
T_2	$(3,3)_{2/3}$
Q_5	$(3,2)_{-5/6}$

$m_{\text{UV}} = 1$ TeV

Coupling only to 3rd generation

Model	UV invariants	NLO $\mathcal{O}(\Lambda^{-2})$	NLO $\mathcal{O}(\Lambda^{-4})$
N	$\lvert(\lambda_N^e)_3\rvert$	[0, 0.47]	[0, 0.48]
E	$\lvert(\lambda_E)_3\rvert$	[0, 0.25]	[0, 0.25]
Δ_1	$\lvert(\lambda_{\Delta_1})_3\rvert$	[0, 0.21]	[0, 0.20]
Δ_3	$\lvert(\lambda_{\Delta_3})_3\rvert$	[0.0015, 0.26]	[0, 0.27]
Σ	$\lvert(\lambda_\Sigma)_3\rvert$	[0, 0.28]	[0, 0.29]
Σ_1	$\lvert(\lambda_{\Sigma_1})_3\rvert$	[0, 0.43]	[0, 0.42]
U	$\lvert(\lambda_U)_3\rvert$	[0, 0.82]	[0, 0.84]
D	$\lvert(\lambda_D)_3\rvert$	[0, 0.24]	[0, 0.23]
Q_1	$\lvert(\lambda_{Q_1}^u)_3\rvert$	[0, 0.93]	[0, 0.92]
Q_7	$\lvert(\lambda_{Q_7})_3\rvert$	[0, 0.91]	[0 0.91]
T_1	$\lvert(\lambda_{T_1})_3\rvert$	[0, 0.45]	[0, 0.47]
T_2	$\lvert(\lambda_{T_2})_3\rvert$	[0, 0.38]	[0, 0.38]

Bounds mostly from EWPOs

Vector bosons at tree level

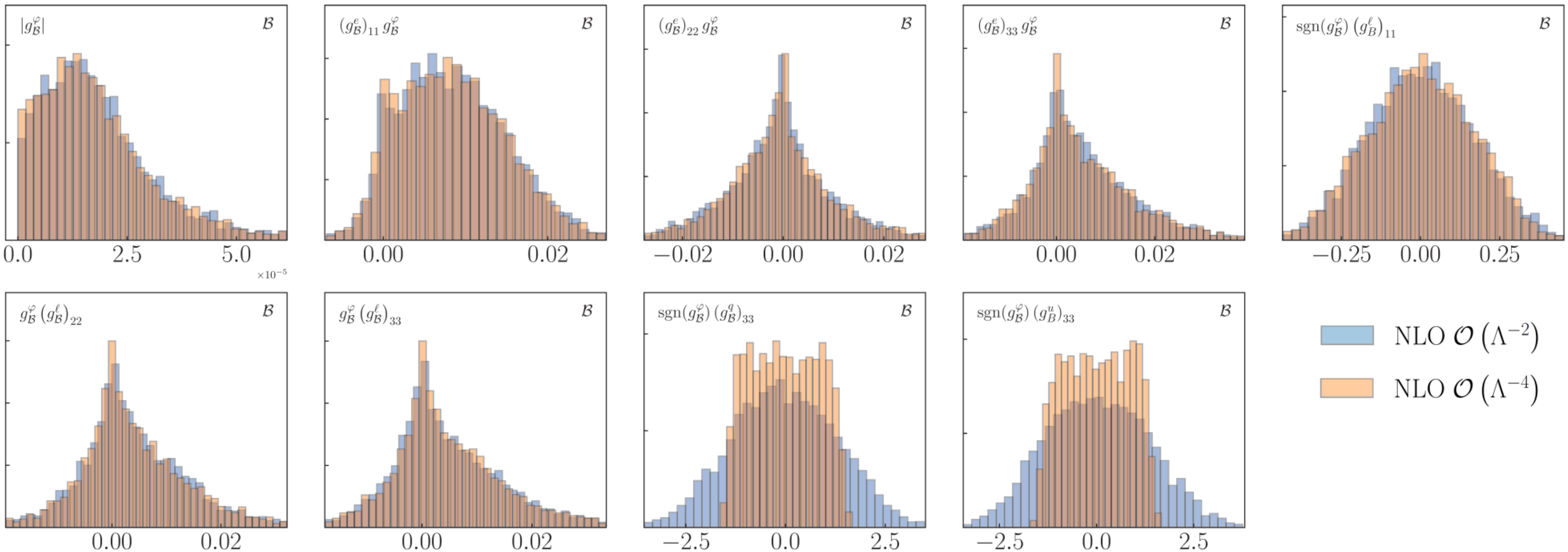
$\mathcal{B} \sim (1,1)_0$

$m_{\mathcal{B}} = 1$ TeV

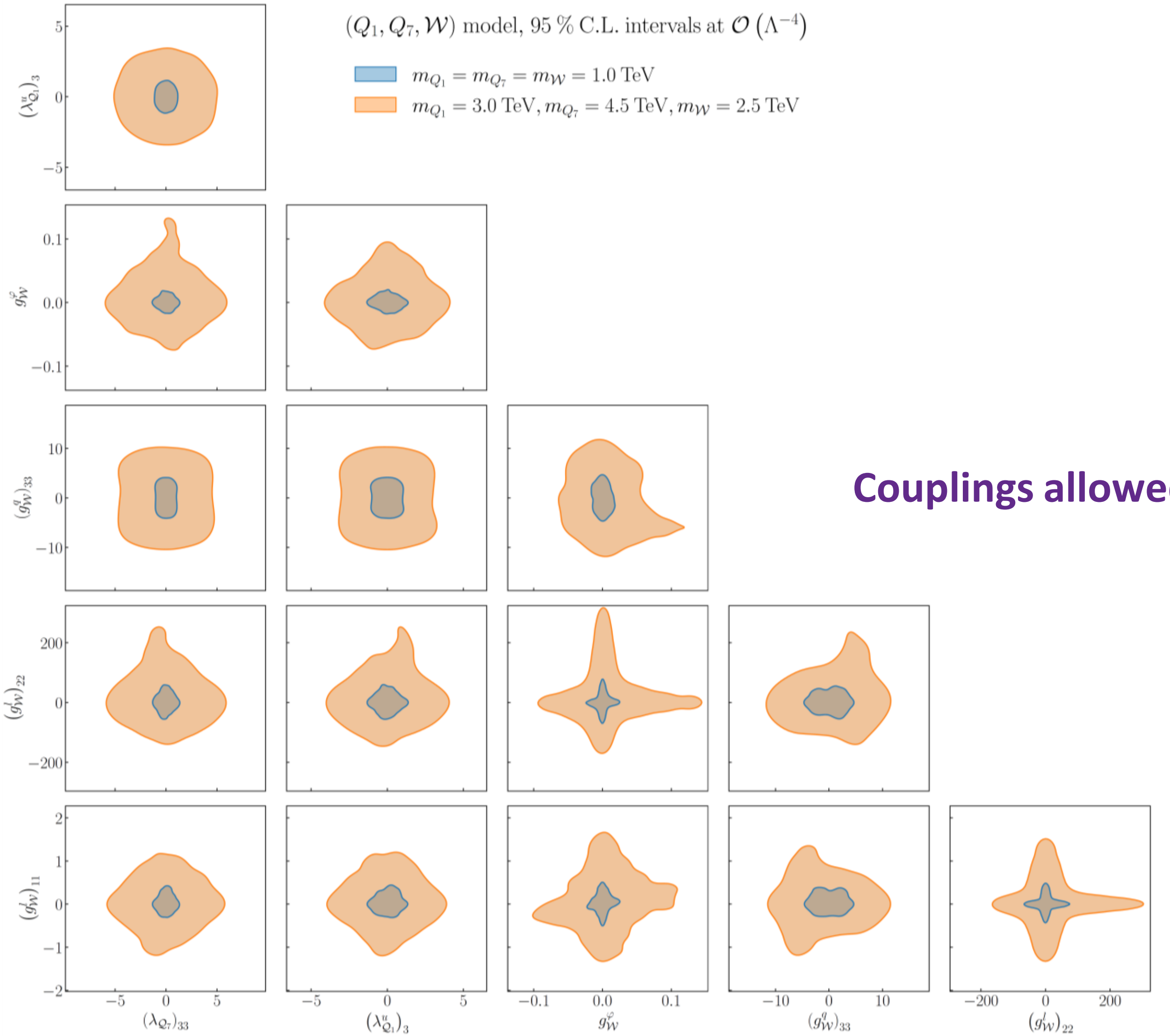
Couplings allowed by EFT flavor symmetry

Some of the bounds →

Model	UV invariants	NLO $\mathcal{O}(\Lambda^{-2})$	NLO $\mathcal{O}(\Lambda^{-4})$
	$\lvert g_{\mathcal{B}}^{\varphi}\rvert$	$[0,\ 4.6\cdot 10^{-5}]$	$[0,\ 4.6\cdot 10^{-5}]$
	$(g_{\mathcal{B}}^{e})_{11}\, g_{\mathcal{B}}^{\varphi}$	[-0.0022, 0.022]	[-0.0032, 0.021]
	$(g_{\mathcal{B}}^{e})_{22}\, g_{\mathcal{B}}^{\varphi}$	[-0.025, 0.025]	[-0.025, 0.025]
	$(g_{\mathcal{B}}^{e})_{33}\, g_{\mathcal{B}}^{\varphi}$	[-0.016, 0.029]	[-0.014, 0.030]
$\mathcal{B}$	$\mathrm{sgn}(g_{\mathcal{B}}^{\varphi})\,(g_{B}^{\ell})_{11}$	[-0.32, 0.33]	[-0.32, 0.30]



Multi-particle models at tree level



$$Q_1 \sim (3,2)_{1/6}$$

$$Q_7 \sim (3,2)_{7/6}$$

$$\mathcal{W} \sim (1,3)_0$$

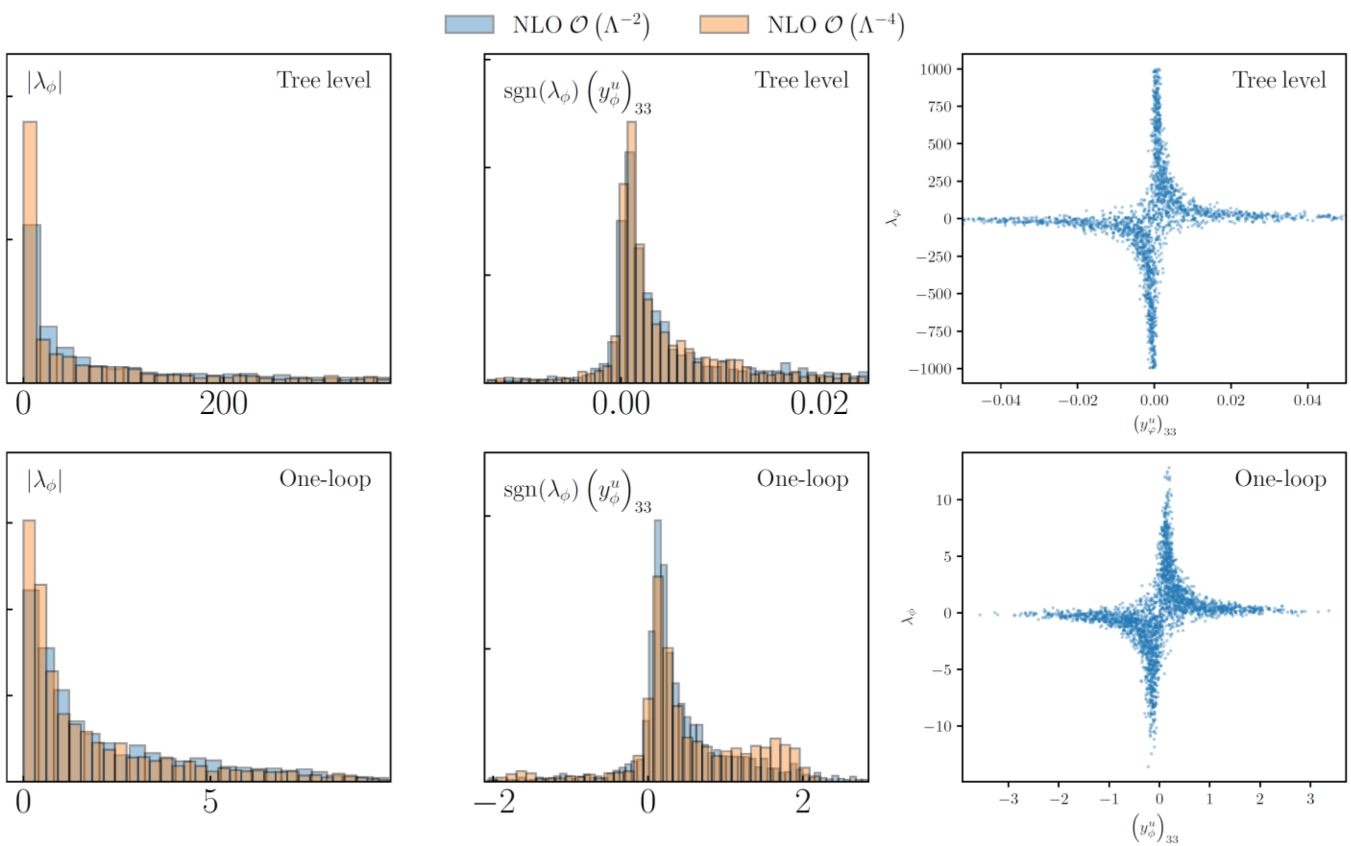
Couplings allowed by EFT flavor symmetry

One-loop matching makes a difference

$$\phi \sim (1,2)_{1/2} \qquad m_\phi = 1\ \text{TeV}$$

$$\mathcal{L}_{\rm UV} \supset -\left(y_\phi^u\right)_{ij} \phi^\dagger i\sigma_2 \bar{q}_L^{T,i} u_R^j - \lambda_\phi \phi^\dagger H |H|^2 + h.c.$$

Model	UV invariants	LO $\mathcal{O}(\Lambda^{-2})$	LO $\mathcal{O}(\Lambda^{-4})$	NLO $\mathcal{O}(\Lambda^{-2})$	NLO $\mathcal{O}(\Lambda^{-4})$
ϕ (tree-level)	$\lvert\lambda_\phi\rvert$	[0, $8.2 \cdot 10^2$]	[0, $7.4 \cdot 10^2$]	[0, $8.0 \cdot 10^2$]	[0, $7.9 \cdot 10^2$]
	$\text{sgn}(\lambda_\phi)\left(y_\phi^u\right)_{33}$	[-0.11, 1.0]	[-0.20, 2.1]	[-0.19, 0.62]	[-0.18, 1.7]
ϕ (one-loop)	$\lvert\lambda_\phi\rvert$	[0, 7.6]	[0, 7.6]	[0, 7.6]	[0, 7.1]
	$\text{sgn}(\lambda_\phi)\left(y_\phi^u\right)_{33}$	[-0.81, 2.8]	[-1.2, 2.3]	[-0.80, 2.2]	[-0.87, 2.1]



match2fit

Live in Benasque

Conclusions

- Flexible code to do fits on UV models.
- Capable to handle great variety of models.
- Designed for improvement and expansion
- Several ways of improving it:
  - Full 1-loop support
  - Interface to other matching and fitting codes.
  - Inclusion of RGEs
  - More general flavor symmetries
  - …

Thanks for your attention!

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