

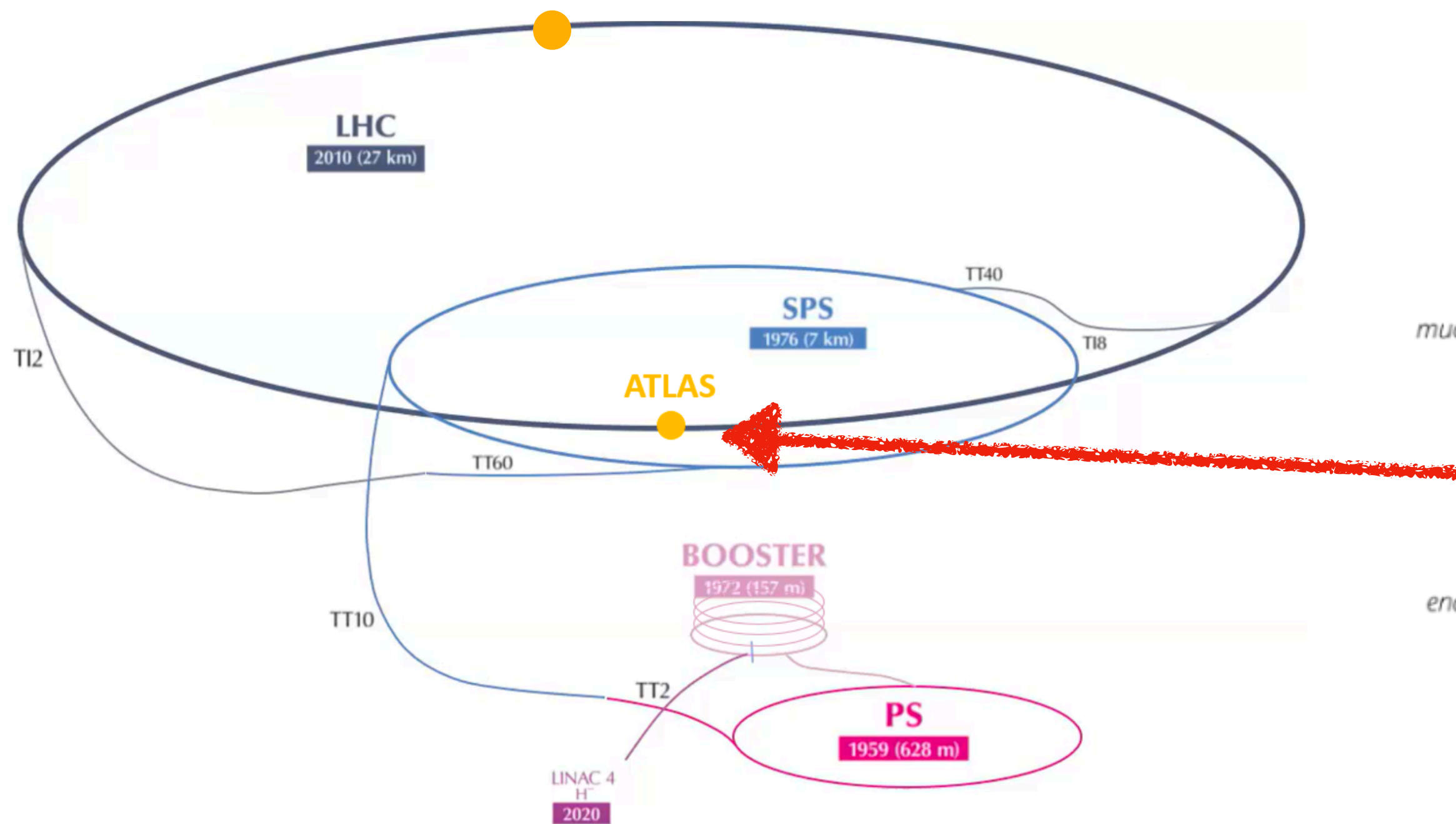
Searches for New Physics in Effective Field Theory Approaches from ATLAS

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on behalf of the ATLAS collaboration

26 June 26 / PASCOS @ Sheffield

Introduction 1

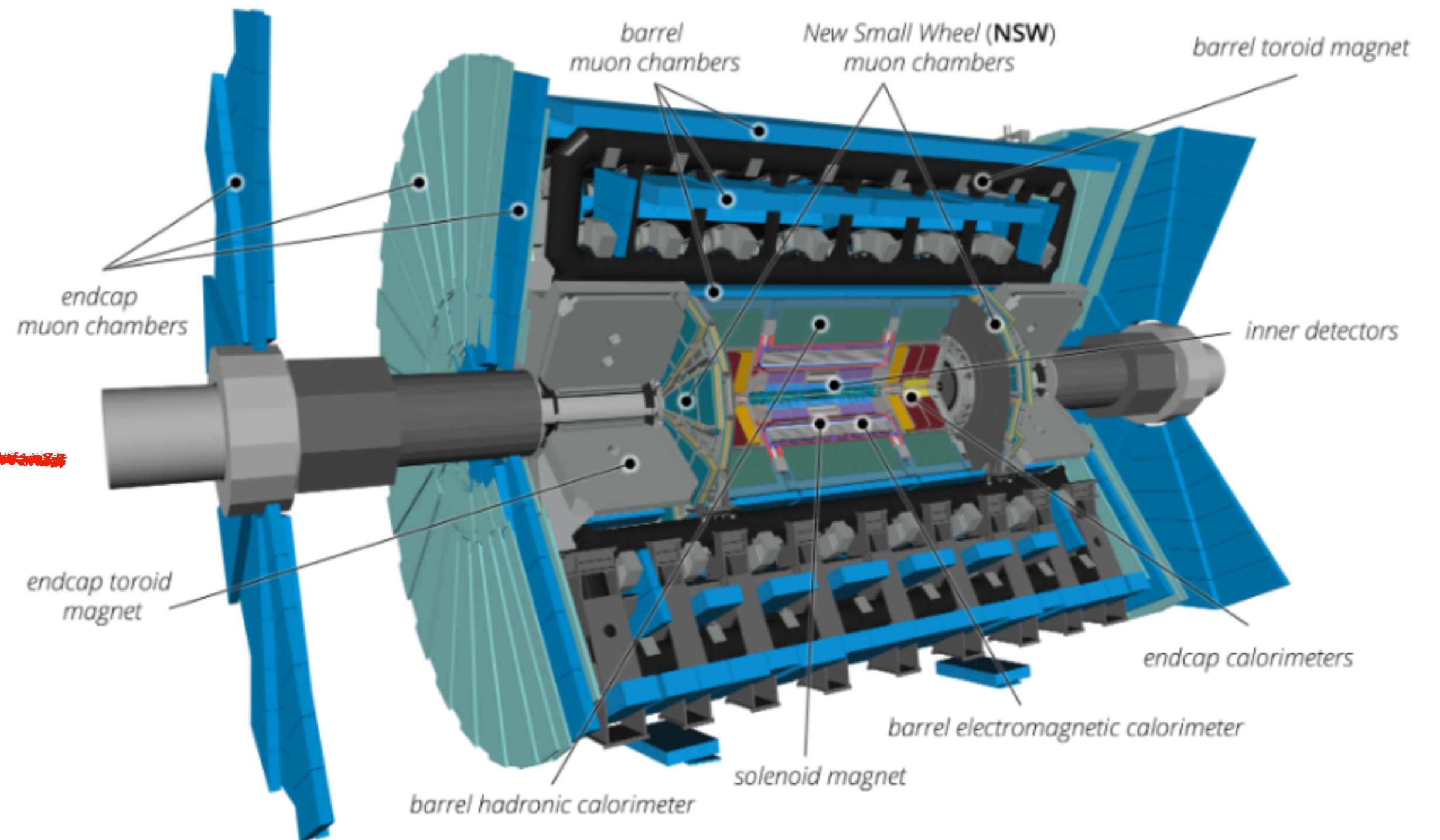
- Most of the data-taking done with proton-proton



- Beam energy 6.8 TeV (now)

- Cylindrical, ~hermetic

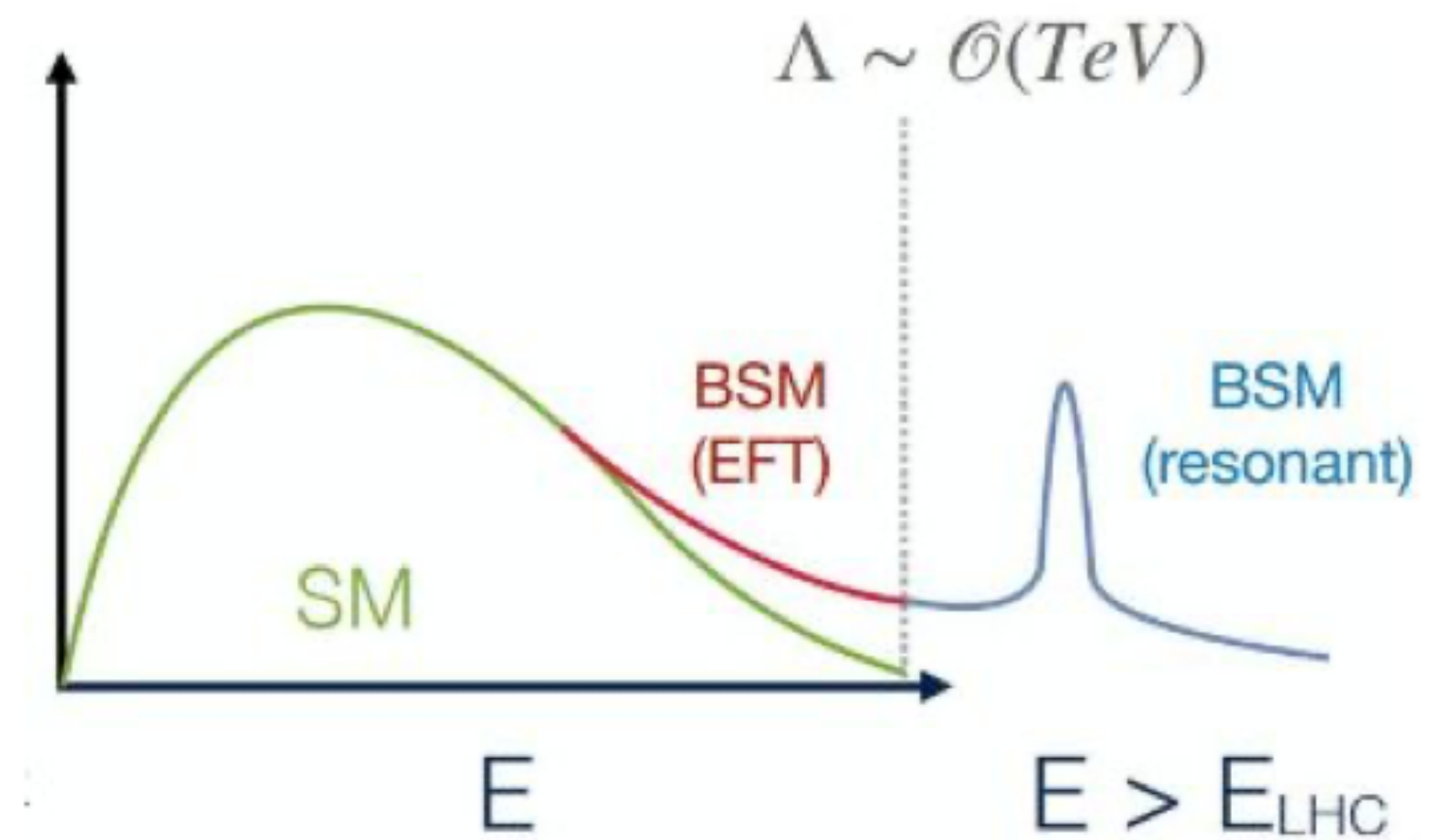
- Layers of sub-detectors



- Reconstruction of all types of objects useful for physics analyses like electrons, muon, jets

Introduction 2

- 🌐 Know that the Standard Model is incomplete, but did not observe BSM at the collider yet.
- 🌐 Are energies too high for the current experimental apparatus?
- 🌐 Extension of the SM Lagrangian with terms allowed by symmetries:
$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{c_i^{(6)}}{\Lambda^2} \mathcal{O}_i^{(6)} + \sum_i \frac{f_i^{(8)}}{\Lambda^4} \mathcal{O}_i^{(8)} + \dots$$
- 🌐 A consistent, near model-independent framework to study BSM effects across different measurements and potentially localize realizable models.



Introduction 3

🌐 The two most comprehensive ATLAS interpretations per dimension will be shown:

🌐 Dim-6 (CERN-EP-2026-113): global ATLAS Run-2 EFT + Electroweak Precision Observables combination.

🌐 Dim-8 (CERN-EP-2026-076): Run-2 Vector Boson Scattering anomalous Quartic Gauge Coupling combination.

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)



Submitted to: Journal of High Energy Physics



CERN-EP-2026-113
24th April 2026

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)



Submitted to: Phys. Lett. B



CERN-EP-2026-076
20th March 2026

Effective field theory interpretation of ATLAS measurements involving the Higgs boson, electroweak bosons and the top quark

The ATLAS Collaboration

Combined effective field theory interpretation of measurements sensitive to quartic gauge boson couplings in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

The ATLAS Collaboration

Global dim-6 combination

Inputs

- Inputs from all sectors of physics analysis in ATLAS.
- Complemented by LEP+SLD for better EWPO sensitivity.
- Mix of full experimental likelihood format and Gaussian model.

Process	Dataset [fb ⁻¹]	SMEFT sensitivity
Higgs boson measurements [10–19]		
$pp \rightarrow H \rightarrow \gamma\gamma, ZZ^* \rightarrow 4\ell, WW^* \rightarrow \ell\nu\ell\nu$	140	Higgs boson operators
$pp \rightarrow H \rightarrow Z\gamma, \mu^+\mu^-$	140	Higgs boson operators
$pp \rightarrow H \rightarrow b\bar{b}, \tau^+\tau^-$	126–140	Higgs boson operators
Electroweak measurements [22–24]		
$pp \rightarrow W^+W^- \rightarrow e^\pm\nu\mu^\mp\nu$	36	four-fermion operators and triple gauge couplings
$pp \rightarrow W^\pm Z \rightarrow \ell^\pm\nu\ell^+\ell^-$	36	four-fermion operators and triple gauge couplings
$pp \rightarrow Zjj \rightarrow \ell^+\ell^-jj$	140	four-fermion operators and triple gauge couplings
HMDY measurements [25, 26]		
$pp \rightarrow Z/\gamma^* \rightarrow \tau^+\tau^-$	140	four-fermion operators involving leptons
$pp \rightarrow W^\pm \rightarrow \ell^\pm\nu$	140	four-fermion operators involving leptons
Top-quark measurements [27, 28]		
$pp \rightarrow t\bar{t} \rightarrow WbWb \rightarrow e^\pm\mu^\mp\nu\nu b\bar{b}$	140	four-fermion (heavy-flavour) operators
$pp \rightarrow t\bar{t} \rightarrow WbWb \rightarrow qq'b\ell\nu b$	140	four-fermion (heavy-flavour) operators
Di-Higgs measurements [20, 21]		
$pp \rightarrow HH \rightarrow b\bar{b}\gamma\gamma, b\bar{b}\tau^+\tau^-$	140	trilinear Higgs boson self-coupling
Electroweak precision observables [29–33]		
LEP, SLD, ATLAS EWPO	–	Weak boson–fermion couplings

SMEFT parametrization

86 operators are considered.

Warsaw basis.

Amplitude entering the cross-section where i and j run over possible operators:

$$|\mathcal{M}_{\text{SMEFT}}|^2 = |\mathcal{M}_{\text{SM}}|^2 + 2 \sum_i \frac{c_i}{\Lambda^2} \text{Re}(\mathcal{M}_{\text{SM}}^* \mathcal{M}_i) + \sum_{i,j} \frac{c_i c_j}{\Lambda^4} (\mathcal{M}_i^* \mathcal{M}_j).$$

The 1st term is the SM contribution, while the 2nd is the SM-BSM interference, and the 3rd is the pure BSM contribution.

Simulation done with MadGraph5_aMC@NLO using SMEFTsim 3.0 or SMEFTatNLO models.

Top flavour scheme.

1D results



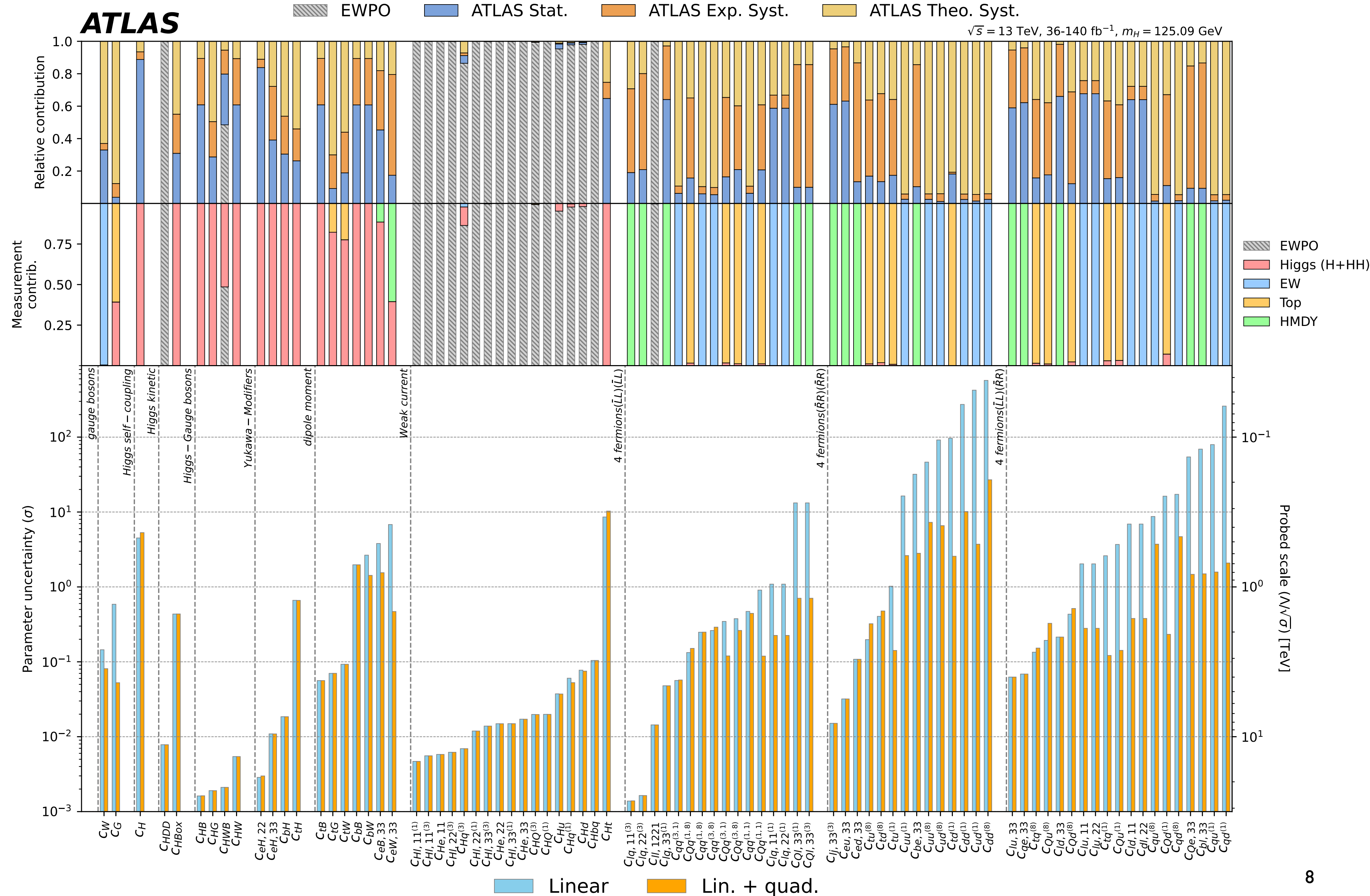
As a benchmark, results are provided when only one Wilson coefficient is floating.



Linear and quadratic results.

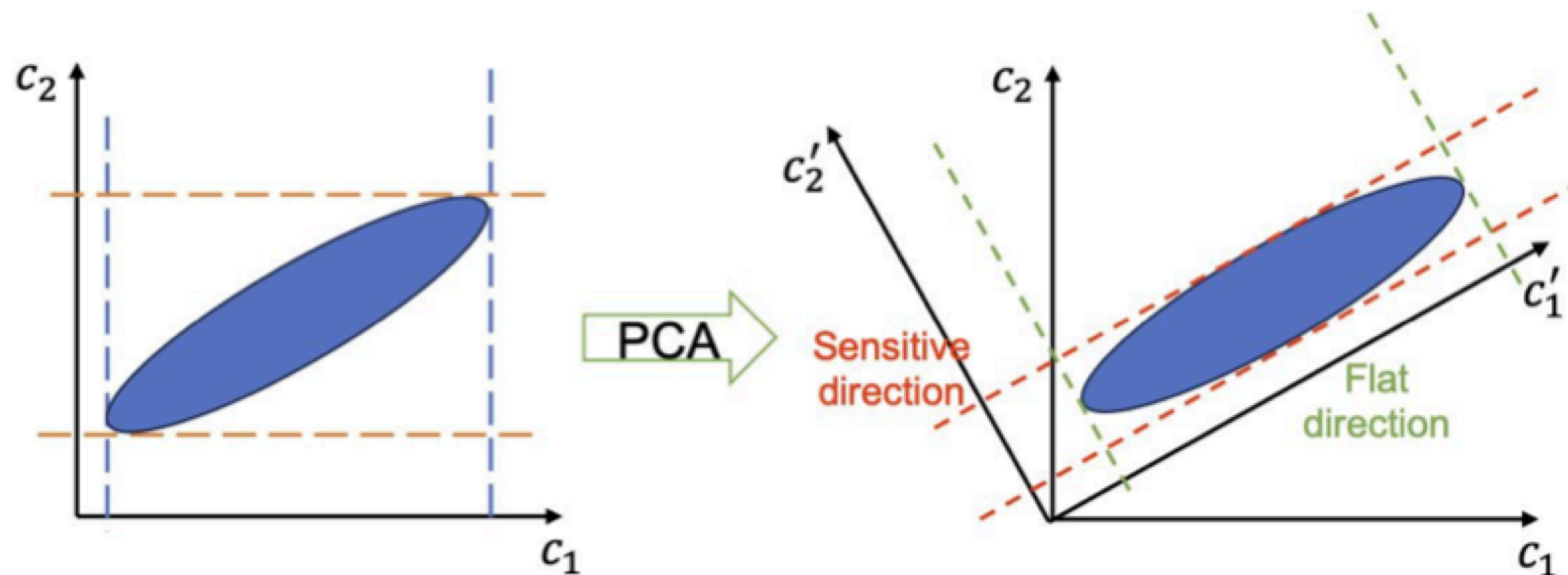


Contributions decomposition per type of input and uncertainty.



Eigenvector basis 1

- 86 operators considered, but not possible to constrain them simultaneously due to flat directions.
- Instead, limits are provided on linear combinations of coefficients, obtained by PCA.



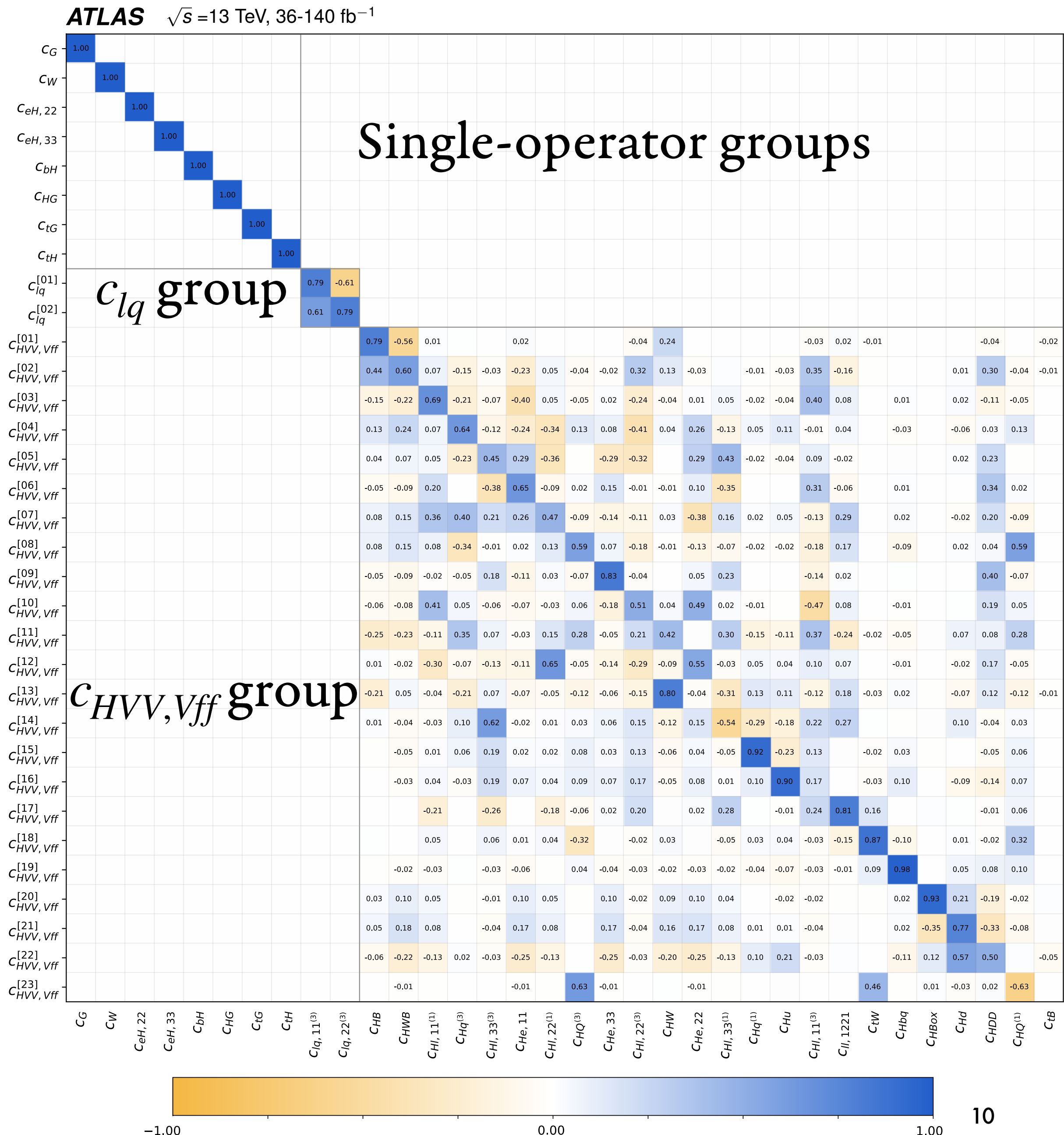
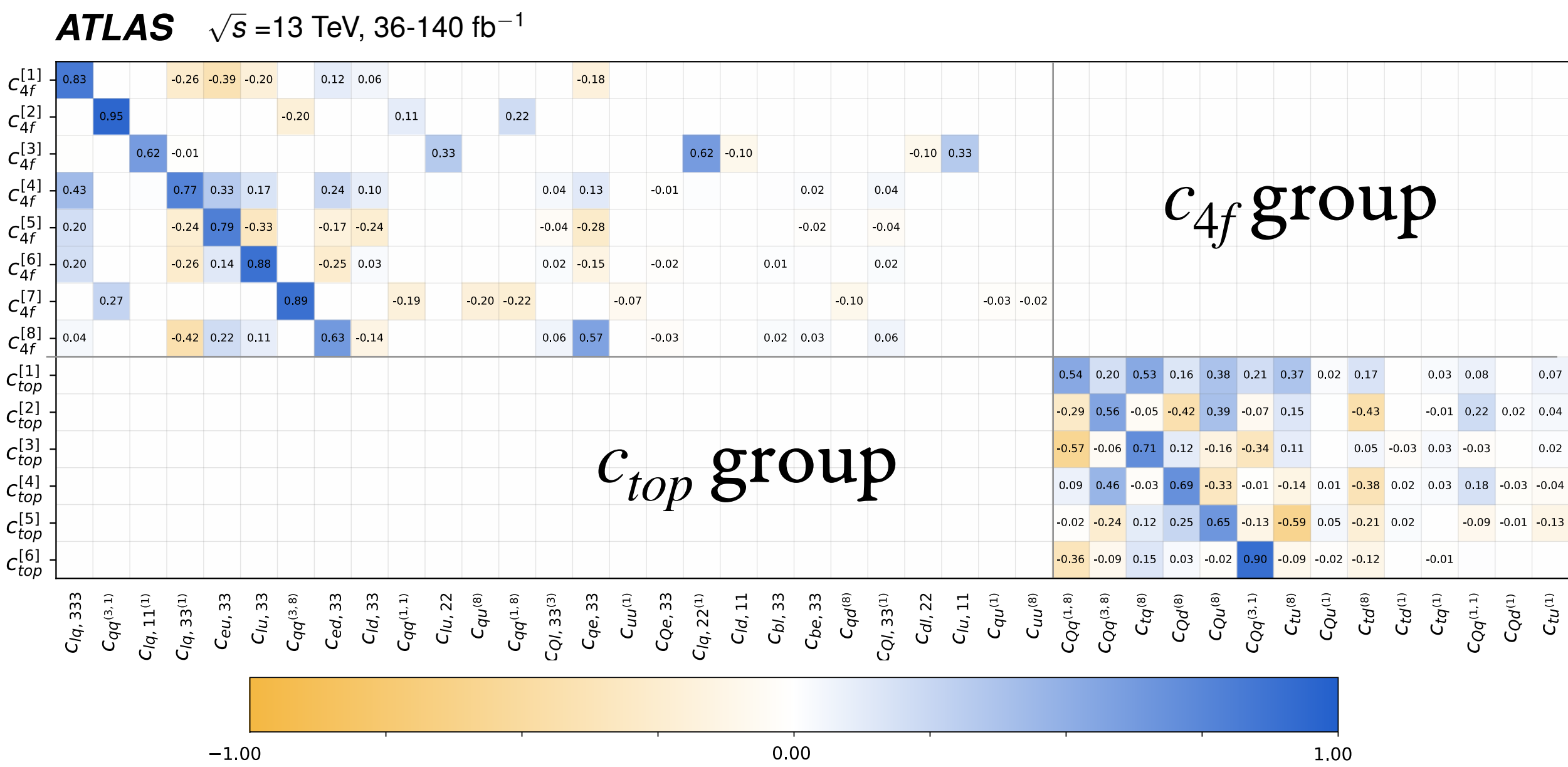
Eigenvector basis 2

🌐 PCA is performed in subgroups of coefficients for better interpretability.

🌐 Keeping the vectors with uncertainty below 10.

🌐 Obtained 48 (linear combinations of) operators: largest combination to date at the LHC.

🌐 HH included separately.

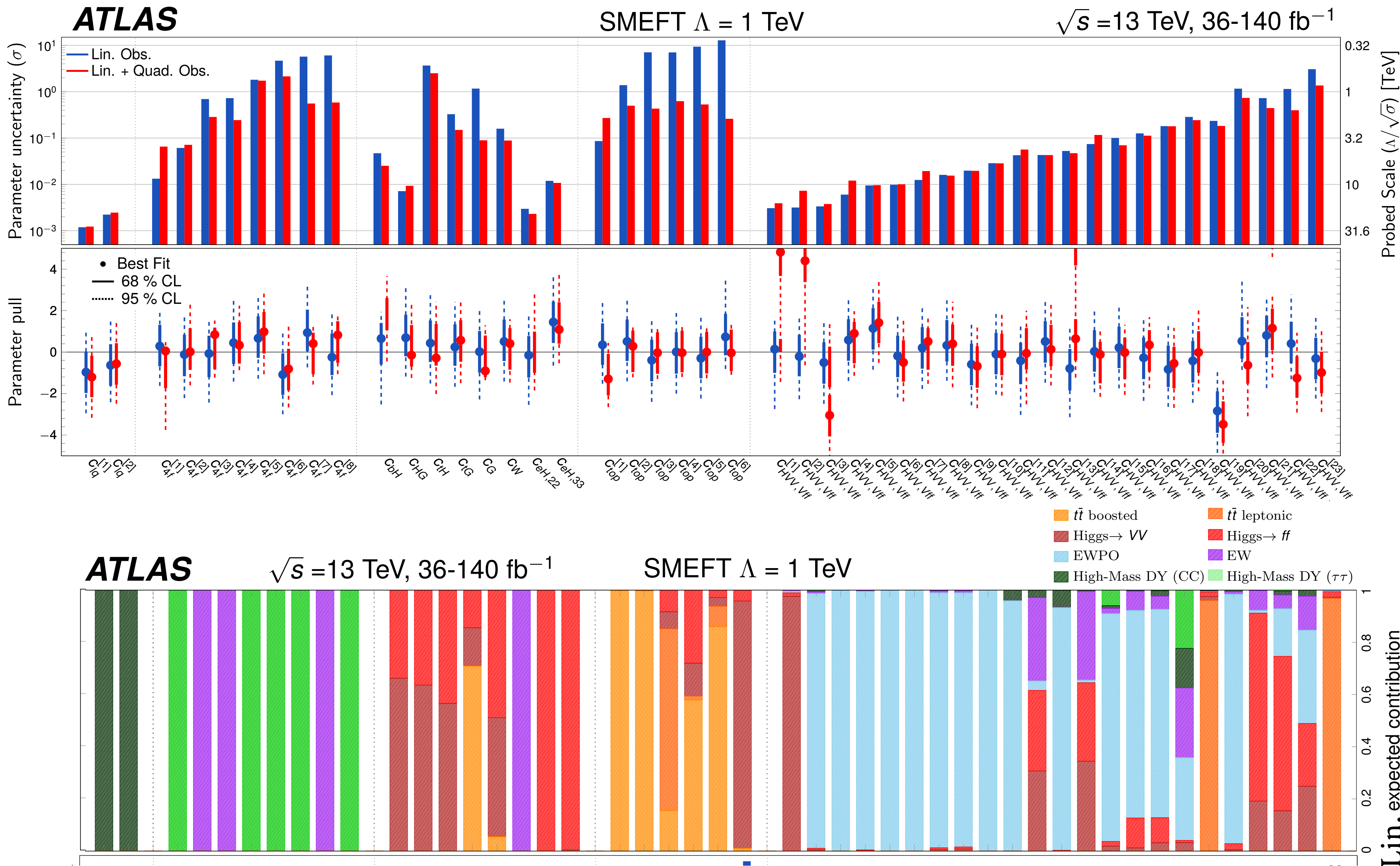


Eigenvector basis 3

68% and 95% confidence intervals.

Limits also reparameterized as limits of scale probed ($\Lambda = 1$ TeV convention elsewhere)

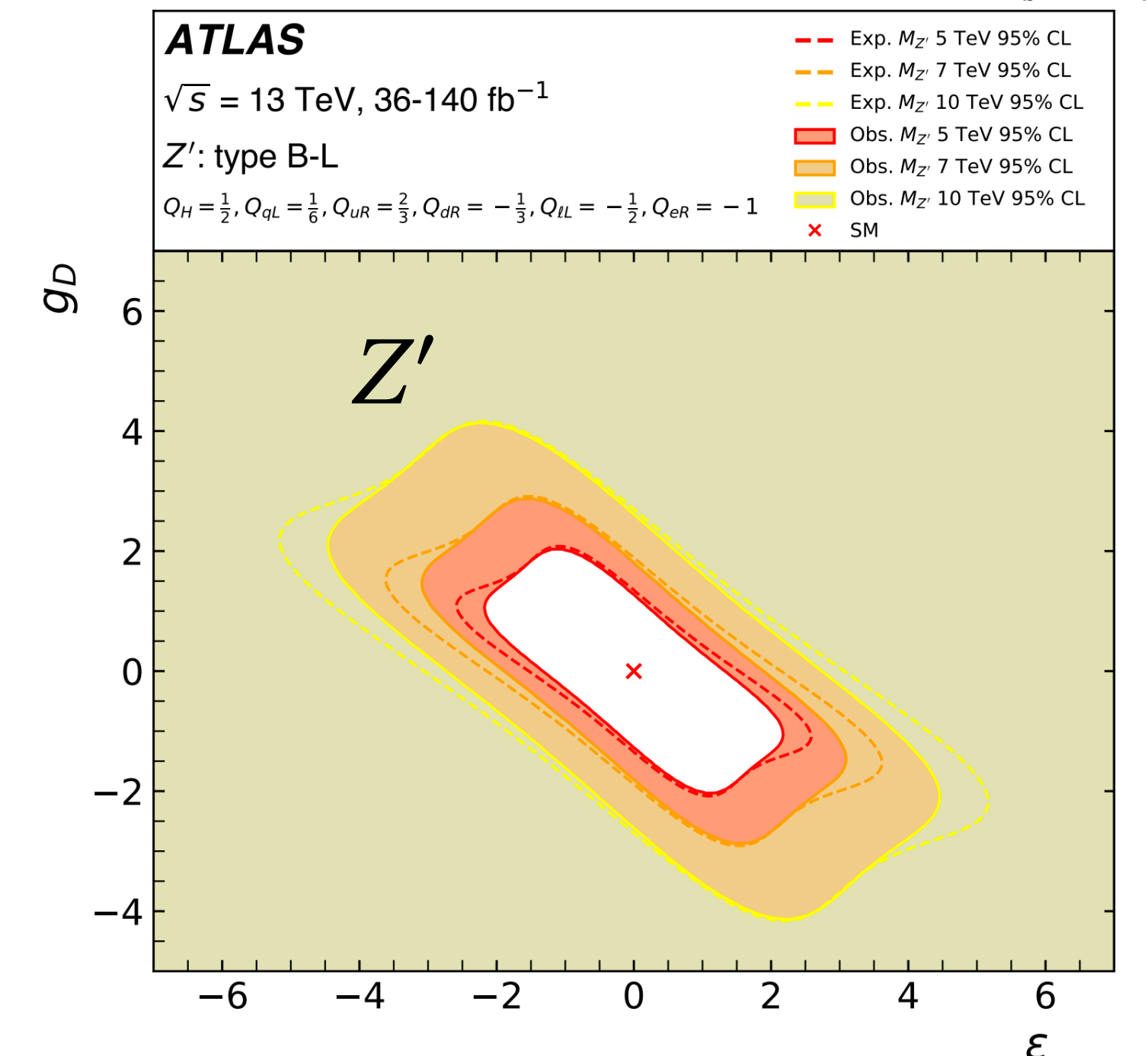
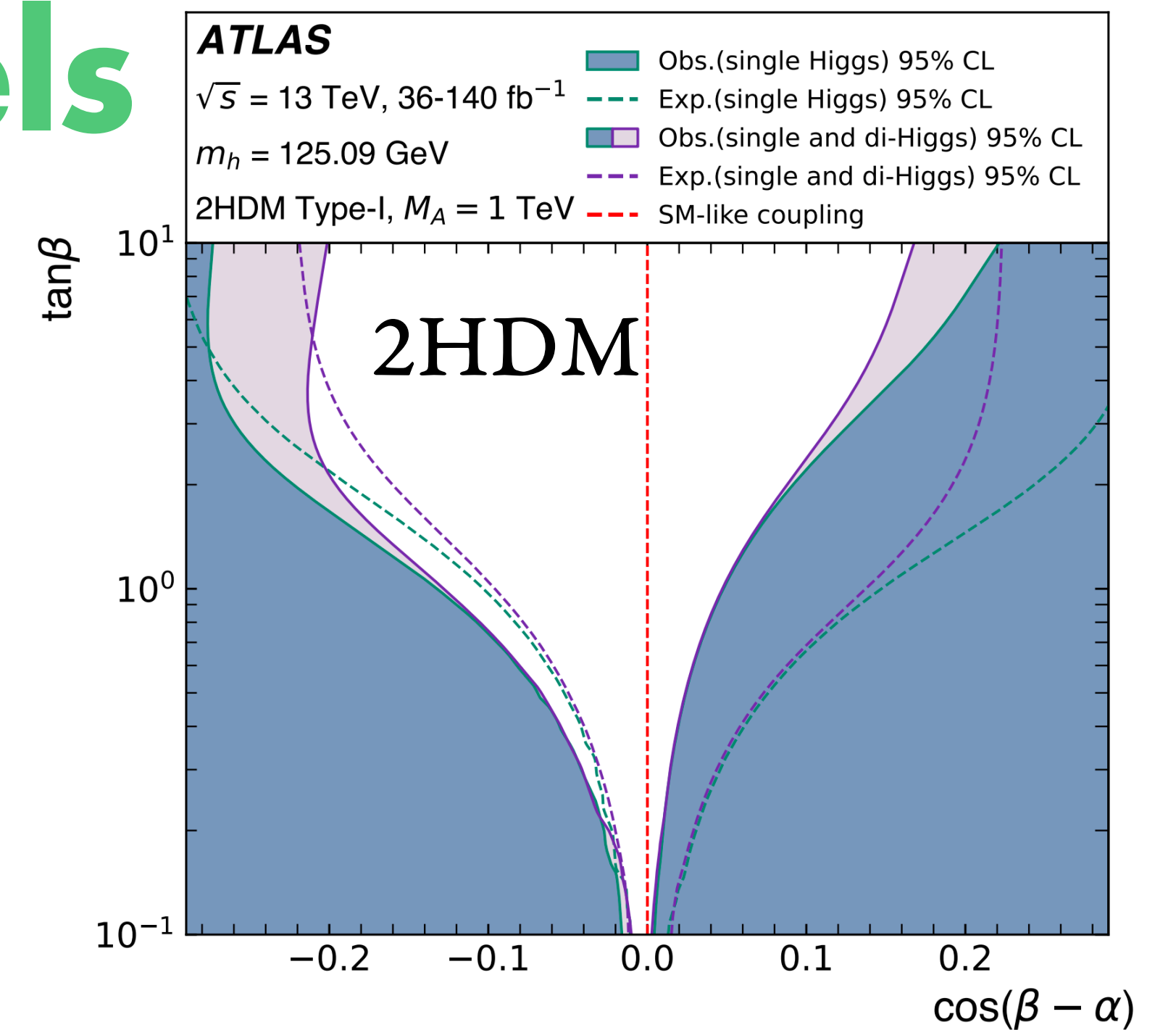
Expected contribution per group of inputs provided.



Matching to concrete models

Assuming that BSM will appear at a mass scale well above the electroweak scale, the parameters of a given complete model can be mapped onto SMEFT Wilson coefficients. Two models considered:

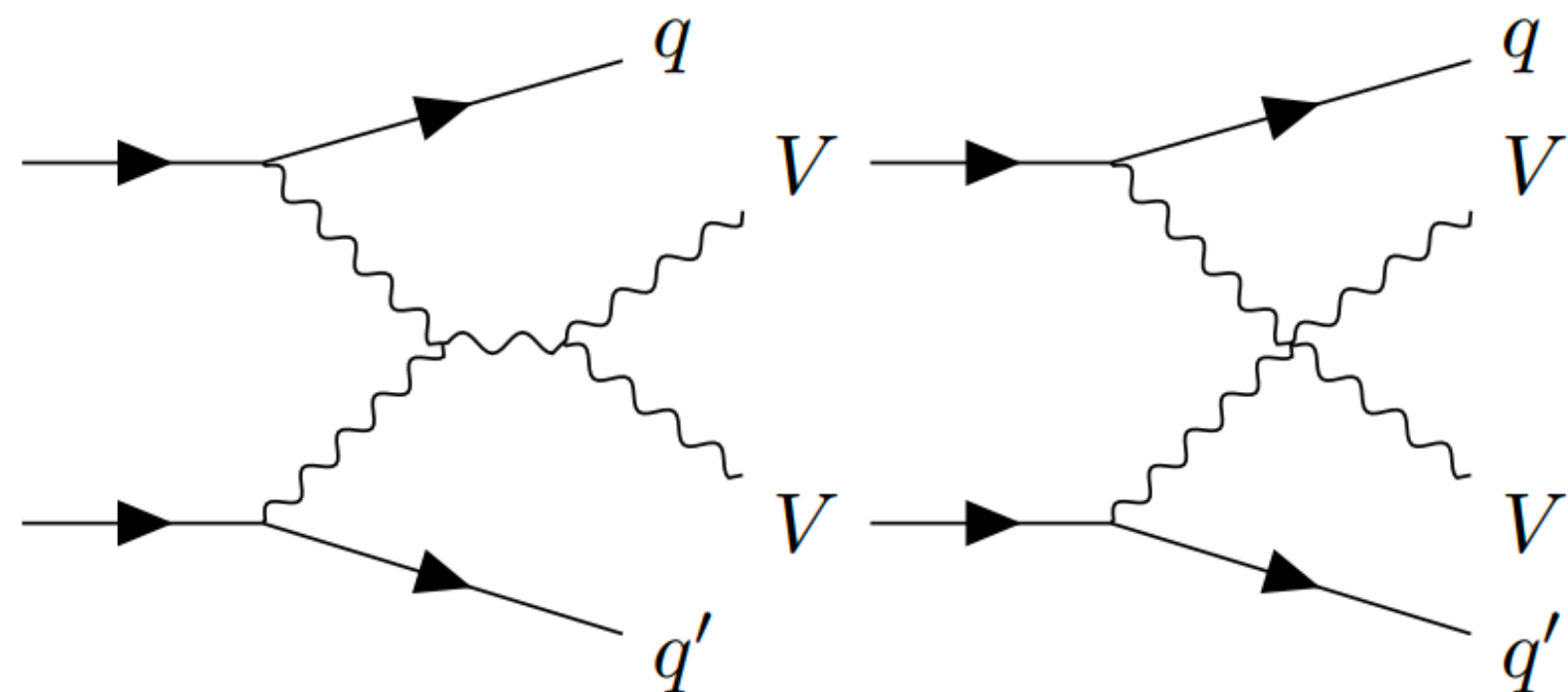
- Two-Higgs-Doublet Models (2HDM) - particularly sensitive to Higgs boson data but profits from the inclusion of HH and other sectors.
- Models with an additional neutral gauge boson (Z') can be matched to both four-fermion and Higgs-sector operators.



VBS dim-8 combination

Inputs

🌐 Vector boson scattering processes are particularly sensitive to dim-8 operators.



🌐 Different input analyses, production, and decay modes allow to profit from their complementarity and to obtain coherent all-around bounds.

Analysis	Input type	Éboli operator results	Luminosity [fb ⁻¹]	Reference
$VVjj \rightarrow (\ell\ell jj/\ell\nu jj/\nu\nu jj)jj$	Reco-level Differential	Full	140	[27]
$WZjj \rightarrow l^+l^-l^\pm\nu jj$	Reco-level Differential	Partial	140	[18]
$W^\pm W^\pm jj \rightarrow l^\pm\nu l^\pm\nu jj$	Reco-level Differential	Full	139	[14]
$ZZjj \rightarrow l^+l^-l^+l^-jj$	Unfolded Differential	None	140	[20]
$W\gamma jj \rightarrow l^\pm\nu\gamma jj$	Unfolded Differential	Full	140	[22]
$Z\gamma jj \rightarrow \nu\bar{\nu}\gamma jj$	Reco-level Inclusive	Partial	139	[24]
$Z\gamma jj \rightarrow l^+l^-\gamma jj$	Unfolded Differential	None	140	[25]
$W\gamma\gamma \rightarrow l^\pm\nu\gamma\gamma$	Reco-level Differential	None	140	[29]

Operators considered

🌐 Éboli model (MadGraph5_aMC@NLO is used for simulation), CP-even.

🌐 Subset of the total dimension-8 operators specifically producing aQGCs.

🌐 Operators are grouped into three families depending on field content: scalar, tensor, and mixed.

$$\begin{aligned}
 O_{S0} &= \left[(D_\mu \Phi)^\dagger D_\nu \Phi \right] \times \left[(D^\mu \Phi)^\dagger D^\nu \Phi \right], & O_{T0} &= \text{Tr} \left[\hat{W}_{\mu\nu} \hat{W}^{\mu\nu} \right] \times \text{Tr} \left[\hat{W}_{\alpha\beta} \hat{W}^{\alpha\beta} \right], & O_{M0} &= \text{Tr} \left[\hat{W}_{\mu\nu} \hat{W}^{\mu\nu} \right] \left[(D_\beta \Phi)^\dagger D^\beta \Phi \right] \\
 O_{S1} &= \left[(D_\mu \Phi)^\dagger D^\mu \Phi \right] \times \left[(D_\nu \Phi)^\dagger D^\nu \Phi \right], & O_{T1} &= \text{Tr} \left[\hat{W}_{\alpha\nu} \hat{W}^{\mu\beta} \right] \times \text{Tr} \left[\hat{W}_{\mu\beta} \hat{W}^{\alpha\nu} \right], & O_{M1} &= \text{Tr} \left[\hat{W}_{\mu\nu} \hat{W}^{\nu\beta} \right] \left[(D_\beta \Phi)^\dagger D^\mu \Phi \right] \\
 & & O_{T2} &= \text{Tr} \left[\hat{W}_{\alpha\mu} \hat{W}^{\mu\beta} \right] \times \text{Tr} \left[\hat{W}_{\beta\nu} \hat{W}^{\nu\alpha} \right], & O_{M2} &= \left[B_{\mu\nu} B^{\mu\nu} \right] \left[(D_\beta \Phi)^\dagger D^\beta \Phi \right] \\
 & & O_{T5} &= \text{Tr} \left[\hat{W}_{\mu\nu} \hat{W}^{\mu\nu} \right] \times B_{\alpha\beta} B^{\alpha\beta}, & O_{M3} &= \left[B_{\mu\nu} B^{\nu\beta} \right] \left[(D_\beta \Phi)^\dagger D^\mu \Phi \right] \\
 & & O_{T6} &= \text{Tr} \left[\hat{W}_{\alpha\nu} \hat{W}^{\mu\beta} \right] \times B_{\mu\beta} B^{\alpha\nu}, & O_{M4} &= \left[(D_\mu \Phi)^\dagger \hat{W}_{\beta\nu} D^\mu \Phi \right] B^{\beta\nu} \\
 & & O_{T7} &= \text{Tr} \left[\hat{W}_{\alpha\mu} \hat{W}^{\mu\beta} \right] \times B_{\beta\nu} B^{\nu\alpha}, & O_{M5} &= \left[(D_\mu \Phi)^\dagger \hat{W}_{\beta\nu} D^\nu \Phi \right] B^{\beta\mu} + \text{h.c.} \\
 & & O_{T8} &= B_{\mu\nu} B^{\mu\nu} B_{\alpha\beta} B^{\alpha\beta}, & O_{M7} &= \left[(D_\mu \Phi)^\dagger \hat{W}_{\beta\nu} \hat{W}^{\beta\mu} D^\nu \Phi \right] \\
 & & O_{T9} &= B_{\alpha\mu} B^{\mu\beta} B_{\beta\nu} B^{\nu\alpha}.
 \end{aligned}$$

🌐 Some operators modify SM couplings, some add new ones.

🌐 S0 and S2 are merged for ATLAS historical reasons.

Theoretical bounds

Unitarity:

-  To avoid violation, forced to remove aQGC after some energy. The scheme agreed by LHC analyses is the clipping technique.
-  EFT contributions are set to 0 depending on the clipping value chosen $m_{VV} \leq C$ and limit compared to PhysRevD.101.113003.

Positivity:

-  Assume BSM obeys unitarity, locality, and causality.
-  Cross-sections on the helicity-amplitude must be positive-definite at all scales.

-  Bounds taken from JHEP12(2019)032.

$$c_{S,0} + c_{S,1} + c_{S,2} > 0, \quad 2c_{T,0} + 2c_{T,1} + c_{T,2} > 0,$$

$$c_{S,0} + c_{S,2} > 0, \quad 4c_{T,6} + c_{T,7} > 0,$$

$$c_{S,0} > 0, \quad c_{T,7} > 0,$$

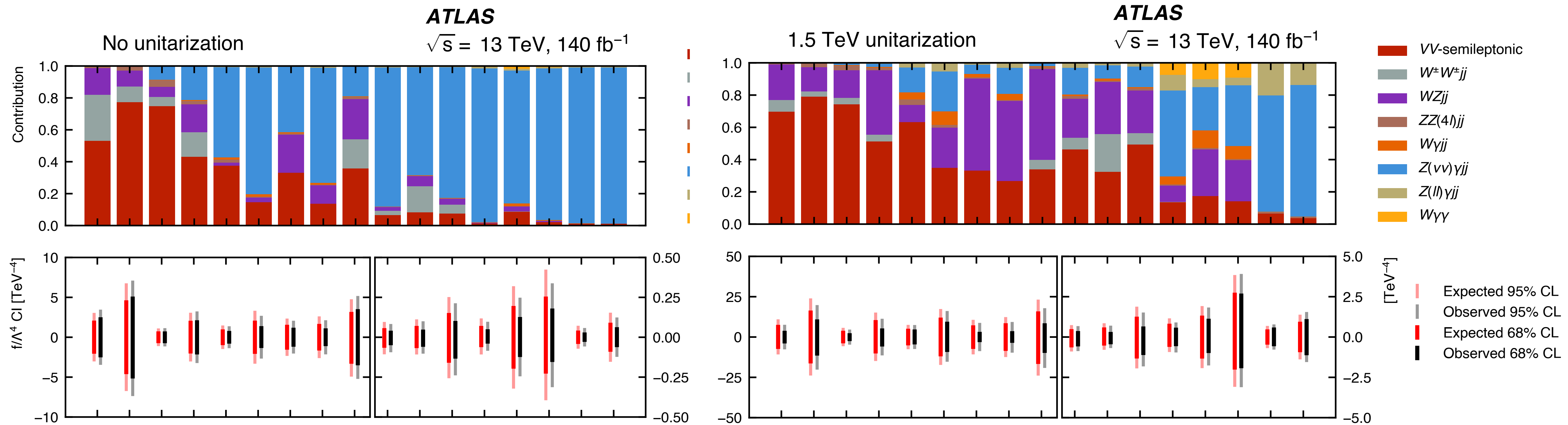
$$2c_{M,1} - c_{M,7} > 0, \quad 2c_{T,8} + c_{T,9} > 0,$$

$$c_{M,3} > 0, \quad c_{T,9} > 0.$$

1D results 1

🌐 68% and 95% limits are provided at different clipping points.

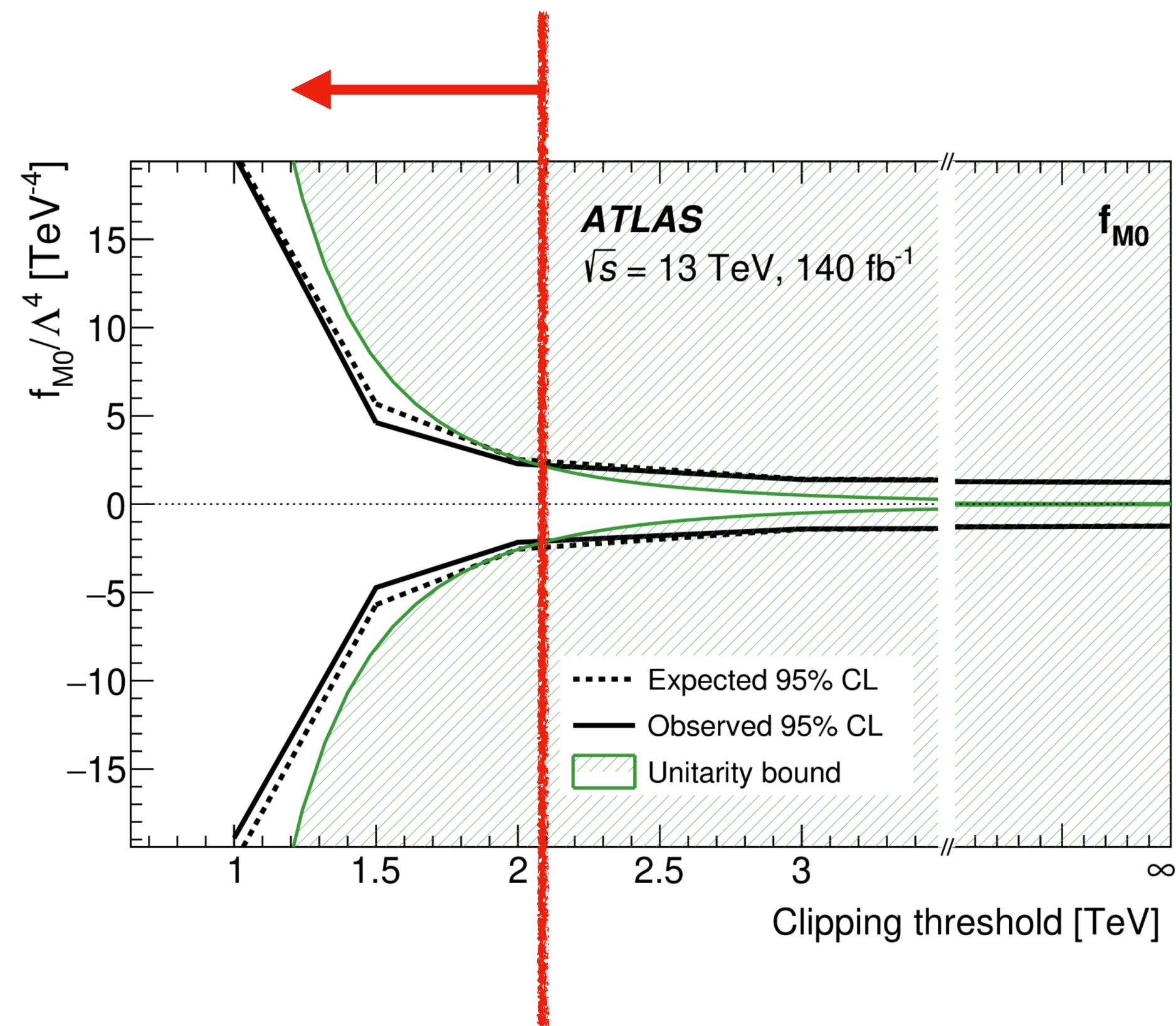
🌐 Relative contribution per input changes with clipping.



1D results 2

Unitarized limits are the ones where the unitarity bound and measured bound intersect.
Provided for all operators.

Measured bound is meaningful below the threshold.



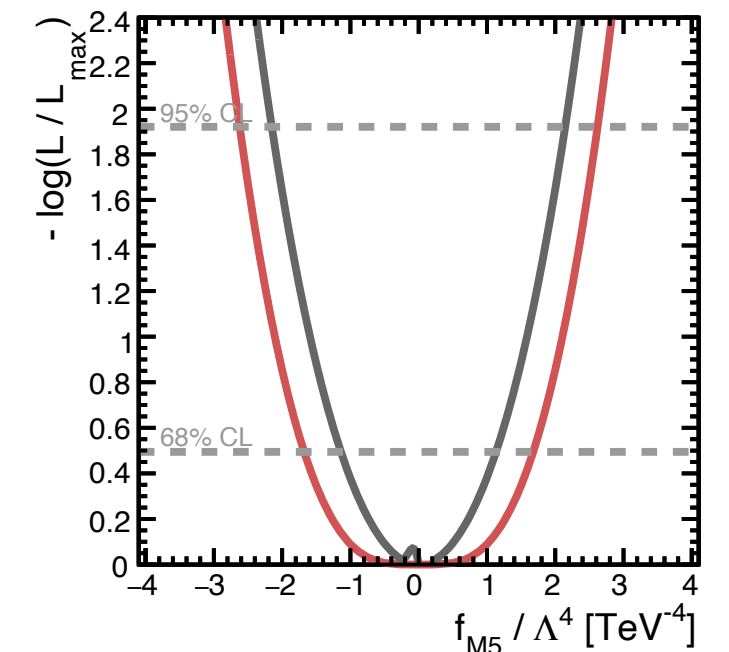
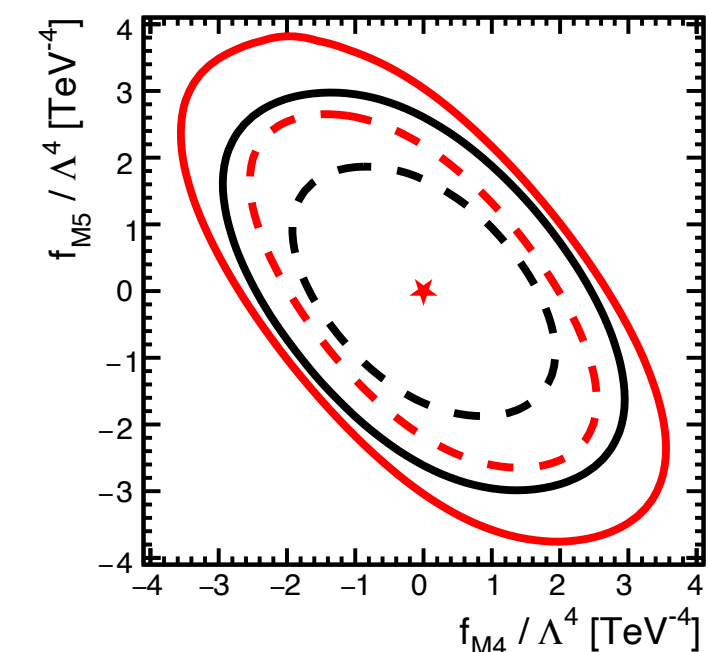
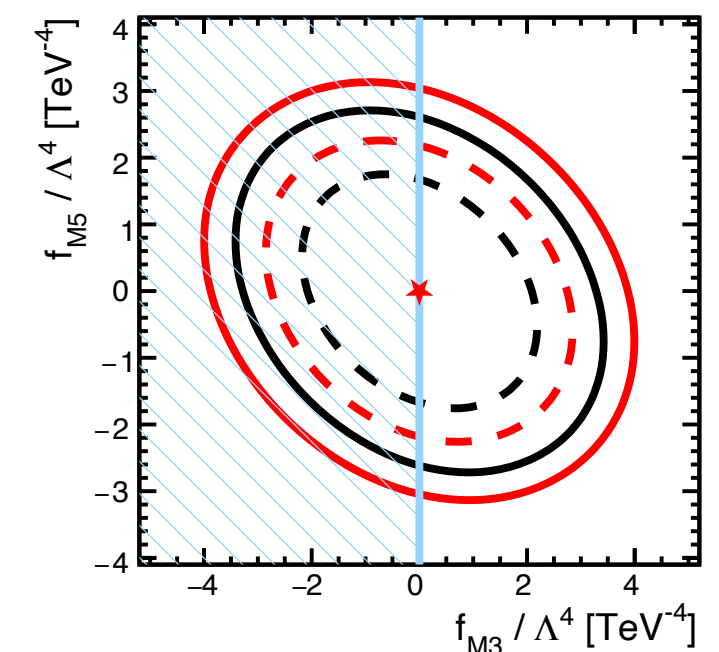
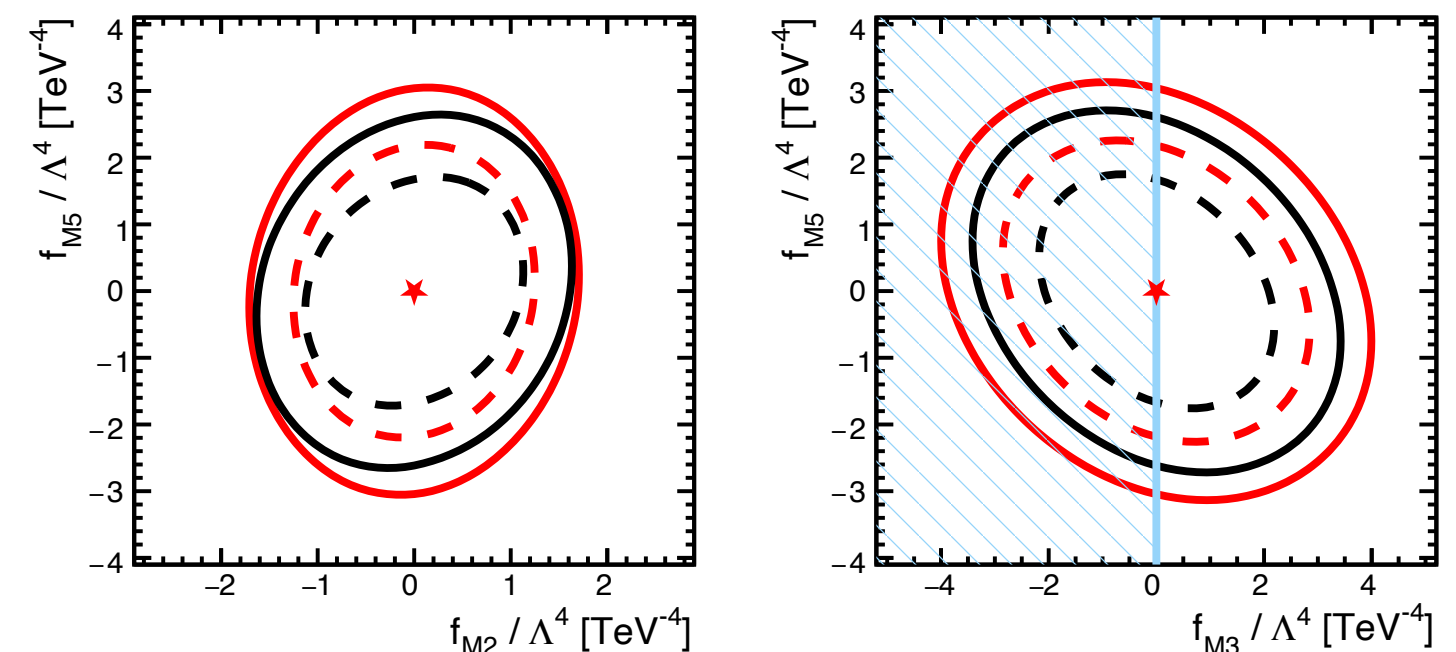
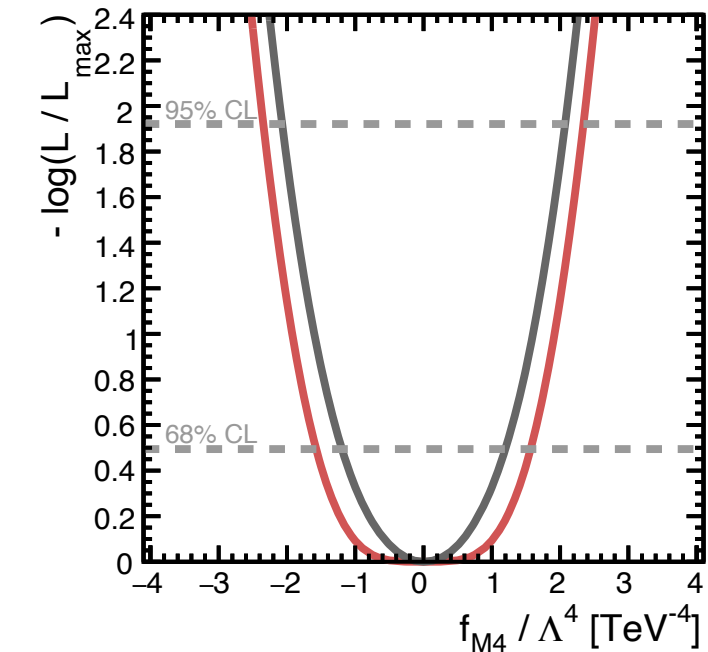
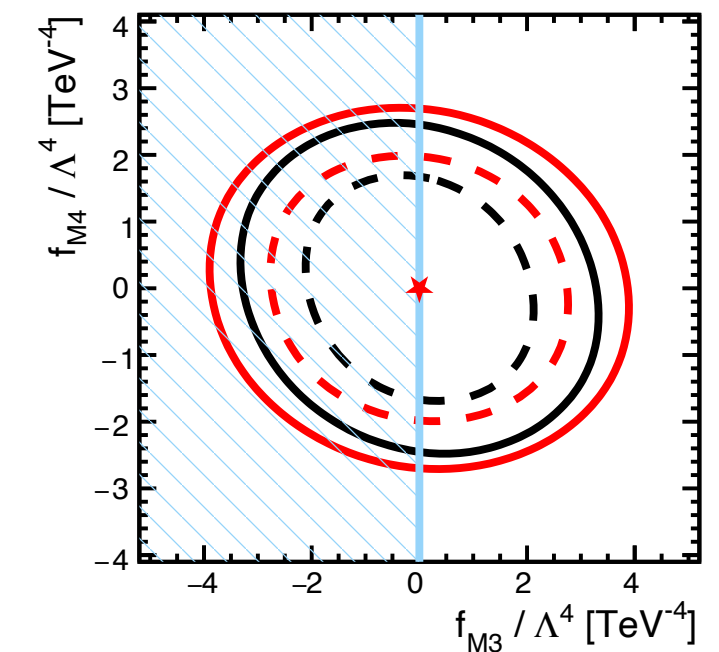
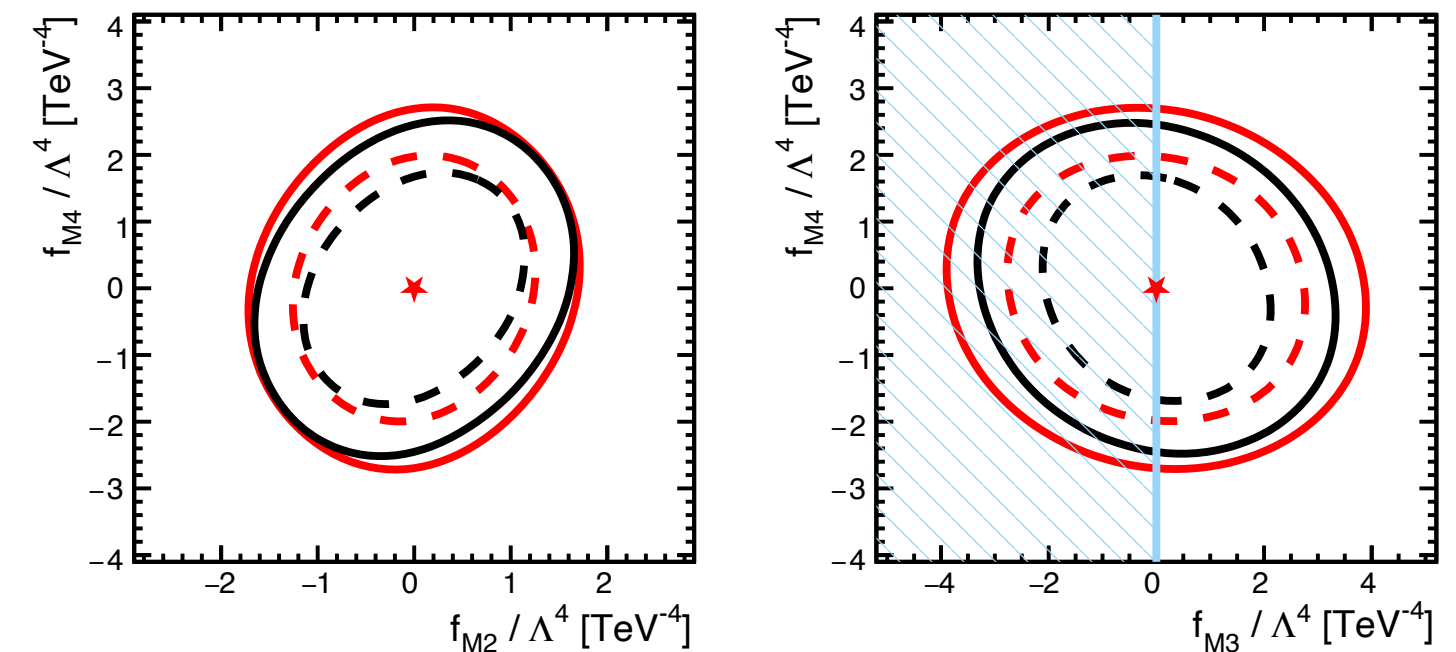
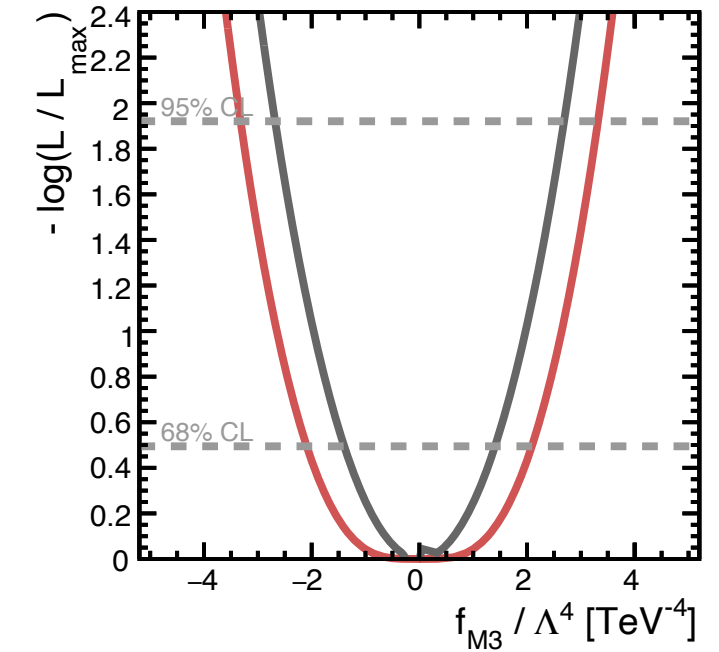
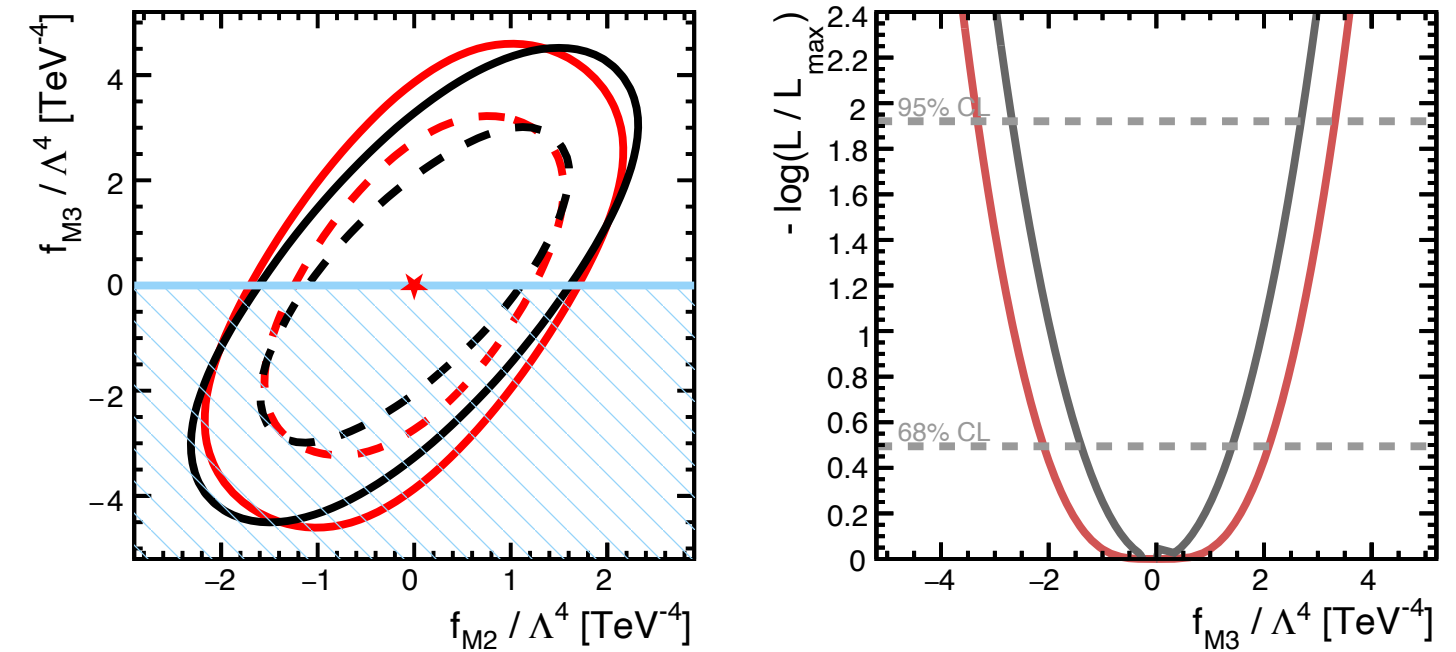
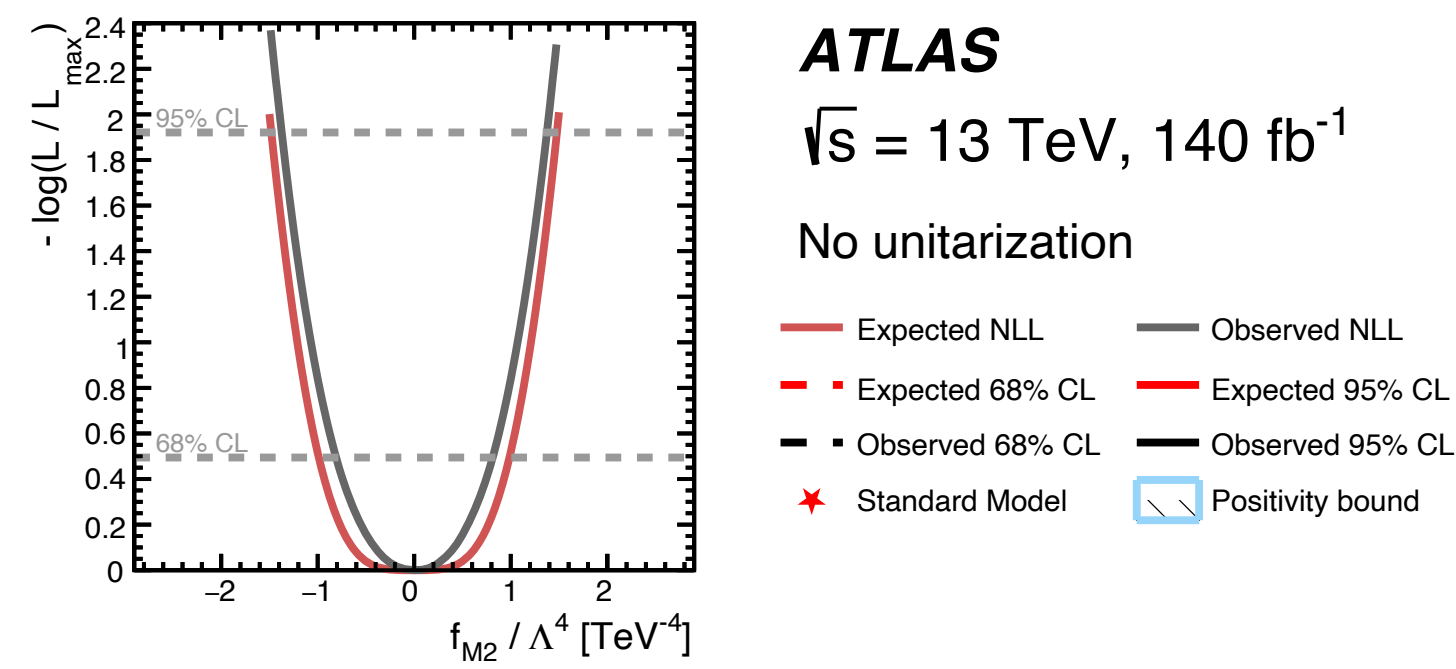
Coefficient	Observed	
	Confidence Intervals [TeV^{-4}]	Unitarization cut-off [TeV]
f_{S02}/Λ^4	[-4.96, 4.90]	2.1
f_{S1}/Λ^4	—	—
f_{M0}/Λ^4	[-2.08, 2.22]	2.1
f_{M1}/Λ^4	[-5.44, 5.18]	2.3, 2.4
f_{M2}/Λ^4	[-23.7, 22.8]	1.1
f_{M3}/Λ^4	[-6.56, 6.63]	2.2
f_{M4}/Λ^4	[-3.59, 3.63]	2.3
f_{M5}/Λ^4	[-3.04, 3.10]	2.9
f_{M7}/Λ^4	[-7.90, 7.65]	2.5, 2.6
f_{T0}/Λ^4	[-0.32, 0.22]	2.2, 2.4
f_{T1}/Λ^4	[-0.16, 0.16]	3.1
f_{T2}/Λ^4	[-0.61, 0.42]	2.5, 2.7
f_{T5}/Λ^4	[-0.15, 0.17]	3.0, 3.2
f_{T6}/Λ^4	[-0.55, 0.57]	2.5
f_{T7}/Λ^4	[-0.52, 0.56]	3.2, 3.3
f_{T8}/Λ^4	[-0.28, 0.28]	2.0
f_{T9}/Λ^4	[-0.53, 0.53]	2.1

2D results

2D fits are performed for 17 pairs of operators (only those that have non-zero cross terms considered).

Degradation of 2D limits compared to limits on individual operators when cross terms are important.

Positivity bounds can exclude more than half of the probed parameter space.



17D results

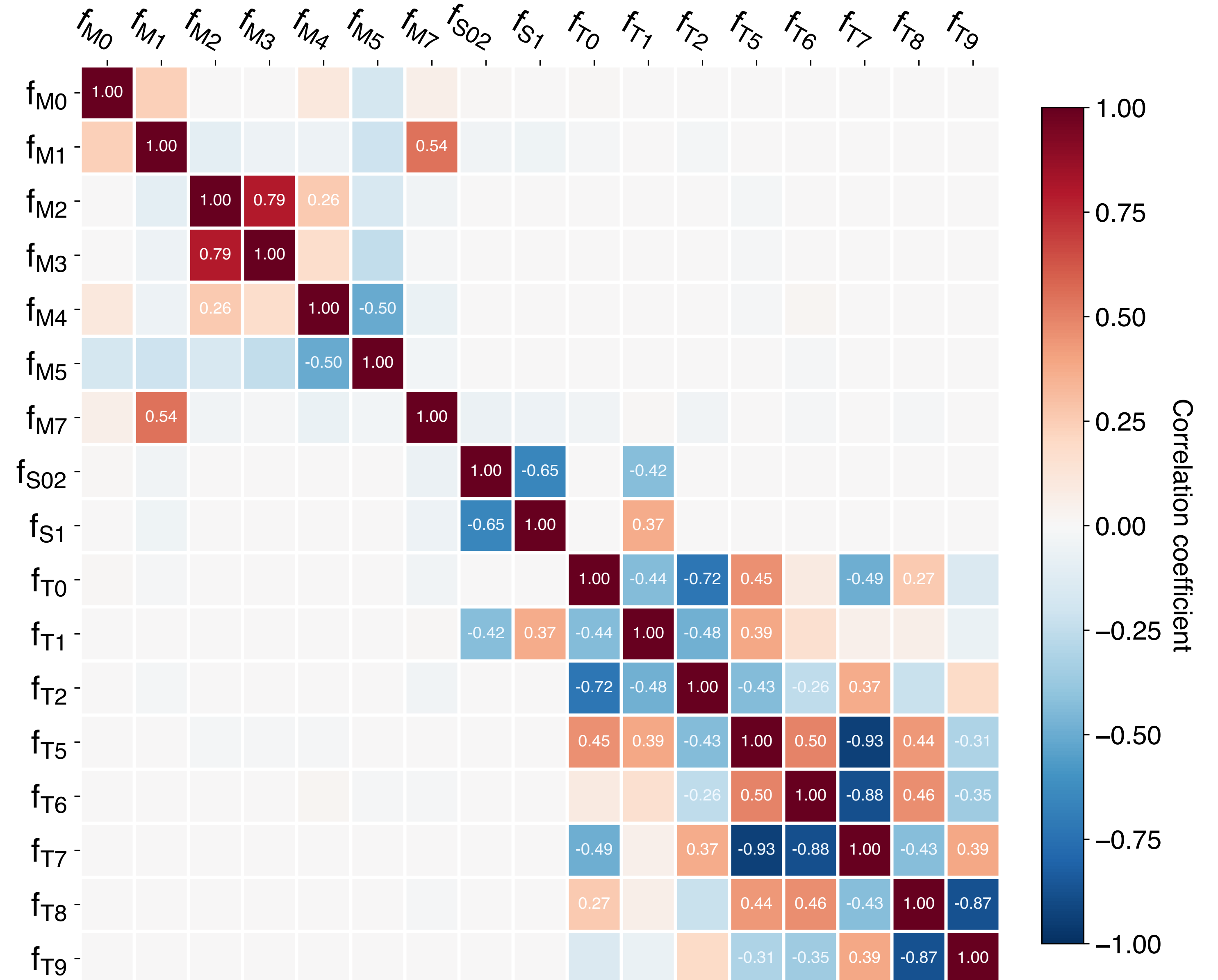
Unlike in dim-6 case, simultaneous constraint over all the operators is possible without PCA.

Weaker limits compared to 1D and 2D, but no oversimplification.

The correlation matrix structure resembles cross-term impacts.

ATLAS

$\sqrt{s} = 13 \text{ TeV}, 140 \text{ fb}^{-1}$



Conclusion

Two ATLAS comprehensive EFT interpretations are public! Dim-6 and dim-8.

Dim-6:

-  Wide range of different inputs: H, HH, EWPO, DY, Top, EW.
-  1D limits for 86 operators provided.
-  47 (linear combinations of) operators are simultaneously constrained.
-  Matching to 2HDM and Z' is performed.

Dim-8:

-  First ATLAS combination of the sort covering 8 complementary analyses.
-  Éboli basis.
-  Currently most stringent constraints (up to 96% tighter than the previously published): 1D, 2D, 17D.
-  Unitarity and positivity bounds incorporated.

The End