Impact of the Recent Measurements of the Top-Quark and W-Boson Masses on Electroweak Precision Fits

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We assess the impact of the very recent measurement of the top-quark mass by the CMS Collaboration on the fit of electroweak data in the standard model and beyond, with particular emphasis on the prediction for the mass of the W boson. We then compare this prediction with the average of the corresponding experimental measurements including the new measurement by the CDF Collaboration, and discuss its compatibility in the standard model, in new physics models with oblique corrections, and in the dimension-six standard model effective field theory. Finally, we present the updated global fit to electroweak precision data in these models.

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The mass of the top quark (m_t) plays a crucial role in the study of standard model (SM) predictions for precision observables in the electroweak (EW) and flavor sectors, since several amplitudes are quadratically sensitive to m_t. Indeed, indirect bounds on the top-quark mass were obtained using EW and flavor observables well before its direct measurement [1,2]. Nowadays, m_t gives the dominant parametric uncertainty on several EW precision observables (EWPO) [3], among which is the W-boson mass (M_W). The posterior from a global fit omitting or including the experimental information on m_t and M_W is reported in Fig. 1. (We also show in the same figure analogous information in the $\sin^2\theta_{\rm eff}^{\rm lept}$ vs M_W plane.) All posteriors reported in this Letter are obtained from a Bayesian analysis performed with the `HEPfit` code [4], using state-of-the-art calculations for all EWPO [5–45]. All inputs used are reported in Table II, while the theory uncertainties we use are [42]

$$\delta_{\rm th}M_W = 4\,{\rm MeV},\quad \delta_{\rm th}\sin^2\theta_W = 5\times10^{-5},$$
$$\delta_{\rm th}\Gamma_Z = 0.4\,{\rm MeV},\quad \delta_{\rm th}\sigma^0_{\rm had} = 6\,{\rm pb},$$
$$\delta_{\rm th}R^0_\ell = 0.006,\quad \delta_{\rm th}R^0_c = 0.00005,\quad \delta_{\rm th}R^0_b = 0.0001. \quad (1)$$

From Fig. 1 it is evident that m_t and M_W are tightly correlated in the SM, so that experimental improvements in either one might challenge the validity of the SM and provide us with precious hints on what kind of new physics (NP) might be present at yet unprobed energy scales. Indeed, this is precisely the situation once the very recent measurement of m_t from the CMS Collaboration [47],

$$m_t = 171.77 \pm 0.38\ {\rm GeV}, \quad (2)$$

and of M_W from the CDF Collaboration [48],

$$M_W = 80.4335 \pm 0.0094\ {\rm GeV}, \quad (3)$$

are included in the analysis. This Letter is dedicated to assessing the impact of these measurements in the SM and in several parametrizations of physics beyond the SM.

Let us first consider the impact of the new measurement of m_t in Eq. (2). Following Ref. [3], we combine the 2016 Tevatron combination [49]; the 2015 CMS Run 1 combination [50]; the combination of ATLAS Run 1 results in Ref. [51]; the CMS Run 2 measurements in the dilepton, lepton + jets, all-jet and single-top channels [47,52–54]; and the ATLAS Run 2 result from the lepton + jet channel [55], assuming the linear correlation coefficient between two systematic uncertainties to be written as $\rho^{\rm sys}_{ij} = \min\{\sigma^{\rm sys}_i, \sigma^{\rm sys}_j\}/\max\{\sigma^{\rm sys}_i, \sigma^{\rm sys}_j\}$. In this way we obtain a new average (compared with Ref. [3]) given by

$$m_t = 171.79 \pm 0.38\ {\rm GeV}, \quad (4)$$

where the uncertainty is dominated, as expected, by the very recent CMS measurement [56]. However, since this average does not take into account the tensions between individual measurements, we also consider a *conservative average* in which the error is inflated to 1 GeV. While by

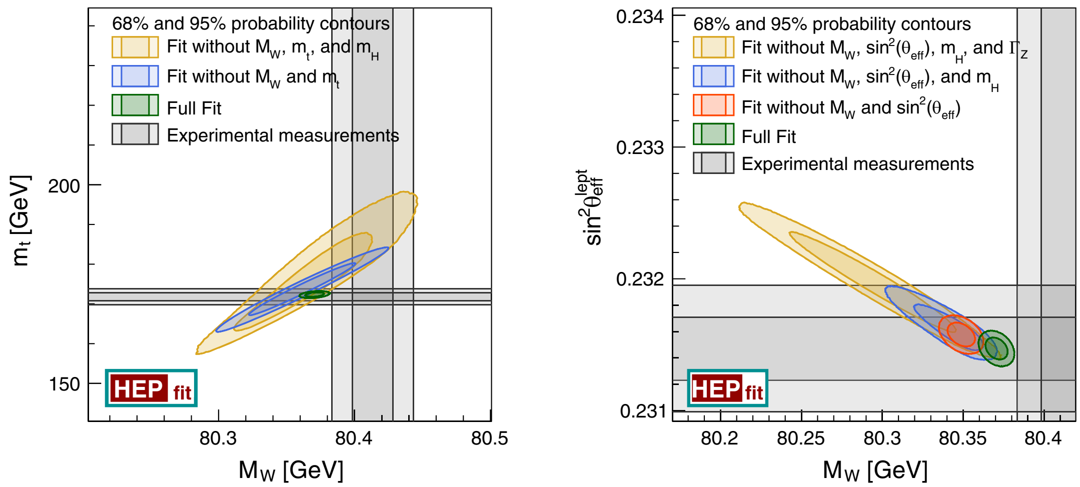

FIG. 1. Posterior from a global fit of all EWPO in the SM in the m_t vs M_W (top) and $\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$ vs M_W (bottom) planes, superimposed to the posteriors obtained omitting different observables from the fit in the *standard average* scenario. Dark (light) regions correspond to 68% (95%) probability ranges. Direct measurements are shown in gray. The corresponding results in the *conservative average* scenario are presented in the Supplemental Material [46] associated with this Letter.

following the particle data group (PDG) average method [57] the error might be rescaled up to 1.7 GeV, we consider 1 GeV to be conservative enough, also in view of the measurements of m_t from cross sections which recently achieved an accuracy better than 1 GeV [58]. For completeness, however, in the following we also comment on the impact of considering a 1.7 GeV uncertainty.

For the W-boson mass, we compute the average of all the existing measurements from LEP 2, the Tevatron, and the LHC. The new measurement from CDF gives, when combined with the D0 one, a Tevatron combination of (80.427 ± 0.0089) GeV [48]. This was combined with the LHC ATLAS [59] and LHCb [60] measurements assuming a common systematic uncertainty of 4.7 MeV, corresponding to the CDF uncertainty from parton distribution functions and QED radiation. The resulting number is combined in an uncorrelated manner with the LEP2 determination, obtaining a new average [61]:

$$M_W = 80.4133 \pm 0.0080 \text{ GeV}. \tag{5}$$

As in the top-quark mass case, there is however a significant tension between the new CDF measurement and the other measurements that enter in the calculation of Eq. (5), with $\chi^2/n_{\mathrm{dof}} = 3.59$. Therefore in a *conservative average*, we rescale the error on M_W to 0.015 GeV using the same method discussed for the case of m_t.

We then perform a series of fits to the different EWPO using both the *standard* [see Eqs. (4) and (5)] and *conservative* assumptions for the uncertainties of the top-quark and W-boson masses [62]. (Although we will discuss both scenarios throughout the text, the tables and figures in the main text will only report the results pertaining to the *standard average*. The results for the *conservative average* scenario can be found in the Supplemental Material [46] associated with this Letter.) In particular, we are interested in comparing the new averages with the corresponding predictions obtained in the SM. For that purpose we first perform a pure SM fit of all EWPO, excluding the experimental input for M_W, and from the posterior of such fit, we compute the SM prediction for M_W. The results are shown in Table I, where we also compare with the combined M_W values in each scenario via the 1D pull, computed as explained in Ref. [3]. As it is apparent, there exists a significant 6.5σ discrepancy with the SM in the *standard average*, which persists at the level of 3.7σ even in the *conservative* scenario [63], due to the large difference between the new CDF measurement and the SM prediction.

In Table II we consider the *standard average* scenario and present, in addition to the experimental values for all EWPO used, the posterior from the global fit, the prediction of individual parameters and observables obtained omitting the corresponding experimental information, the indirect determination of SM parameters obtained solely from EWPO, and the full prediction

TABLE I. Predictions (Pred.) and pulls for M_W in the SM, in the *oblique* NP models and in the SMEFT, using the *standard* and *conservative* averaging scenarios. The predictions are obtained without using the experimental information on M_W. See text for more details on the models listed in the table.

	Pred. M_W (GeV)	Pull	Pred. M_W (GeV)	Pull
Model	*Standard average*		*Conservative average*	
SM	80.3499 ± 0.0056	6.5σ	80.3505 ± 0.0077	3.7σ
ST	80.366 ± 0.029	1.6σ	80.367 ± 0.029	1.4σ
STU	80.32 ± 0.54	0.2σ	80.32 ± 0.54	0.2σ
SMEFT	80.66 ± 1.68	-0.1σ	80.66 ± 1.68	-0.1σ

TABLE II. Experimental data, Posterior from the full fit, Indirect determination of individual SM paramers/Prediction of individual EWPO, Full Indirect determination of all SM parameters simultaneously, and Full Prediction of all EWPO simultaneously in the *standard average* scenario. The (Full) Indirect determination/(Full) Prediction is obtained omitting the experimental information on individual (all) SM parameters/individual (all) EWPO. The previous to the last observables, $\sin^2\theta_{\rm eff}^{\rm lept}({\rm HC})$ denotes $\sin^2\theta_{\rm eff}^{\rm lept}$ from hadron-collider (HC) measurements. The corresponding results in the *conservative average* scenario are presented in the Supplemental Material [46] associated with this Letter.

	Measurement	Posterior	Indirect/Prediction	Pull	Full Indirect	Pull	Full Prediction	Pull
$\alpha_s(M_Z)$	0.1177 ± 0.0010	0.11762 ± 0.00095	0.11685 ± 0.00278	0.3	0.12181 ± 0.00470	−0.8	0.1177 ± 0.0010	…
		[0.11576, 0.11946]	[0.11145, 0.12233]		[0.1126, 0.1310]		[0.1157, 0.1197]	
$\Delta\alpha_{\rm had}^{(5)}(M_Z)$	0.02766 ± 0.00010	0.027535 ± 0.000096	0.026174 ± 0.000334	4.3	0.028005 ± 0.000675	−0.5	0.02766 ± 0.00010	…
		[0.027349, 0.027726]	[0.025522, 0.026826]		[0.02667, 0.02932]		[0.02746, 0.02786]	
M_Z (GeV)	91.1875 ± 0.0021	91.1911 ± 0.0020	91.2314 ± 0.0069	−6.1	91.2108 ± 0.0390	−0.6	91.1875 ± 0.0021	…
		[91.1872, 91.1950]	[91.2178, 91.2447]		[91.136, 91.288]		[91.1834, 91.1916]	
m_t (GeV)	171.79 ± 0.38	172.36 ± 0.37	181.45 ± 1.49	−6.3	187.58 ± 9.52	−1.7	171.80 ± 0.38	…
		[171.64, 173.09]	[178.53, 184.42]		[169.1, 206.1]		[171.05, 172.54]	
m_H (GeV)	125.21 ± 0.12	125.20 ± 0.12	93.36 ± 4.99	4.3	247.98 ± 125.35	−0.9	125.21 ± 0.12	…
		[124.97, 125.44]	[82.92, 102.89]		[100.8, 640.4]		[124.97, 125.45]	
M_W (GeV)	80.4133 ± 0.0080	80.3706 ± 0.0045	80.3499 ± 0.0056	6.5	80.4129 ± 0.0080	0.1	80.3496 ± 0.0057	6.5
		[80.3617, 80.3794]	[80.3391, 80.3610]		[80.3973, 80.4284]		[80.3386, 80.3608]	
Γ_W (GeV)	2.085 ± 0.042	2.08903 ± 0.00053	2.08902 ± 0.00052	−0.1	2.09430 ± 0.00224	−0.2	2.08744 ± 0.00059	0.0
		[2.08800, 2.09006]	[2.08799, 2.09005]		[2.0900, 2.0988]		[2.08627, 2.08859]	
$\sin^2\theta_{\rm eff}^{\rm lept}(Q_{\rm FB}^{\rm had})$	0.2324 ± 0.0012	0.231471 ± 0.000055	0.231469 ± 0.000056	0.8	0.231460 ± 0.000138	0.8	0.231558 ± 0.000062	0.7
		[0.231362, 0.231580]	[0.231361, 0.231578]		[0.23119, 0.23173]		[0.231436, 0.231679]	
$P_\tau^{\rm pol} = \mathcal{A}_\ell$	0.1465 ± 0.0033	0.14742 ± 0.00044	0.14744 ± 0.00044	−0.3	0.14750 ± 0.00108	−0.3	0.14675 ± 0.00049	−0.1
		[0.14656, 0.14827]	[0.14657, 0.14830]		[0.1454, 0.1496]		[0.14580, 0.14770]	
Γ_Z (GeV)	2.4955 ± 0.0023	2.49455 ± 0.00065	2.49437 ± 0.00068	0.5	2.49530 ± 0.00204	0.0	2.49397 ± 0.00068	0.6
		[2.49329, 2.49581]	[2.49301, 2.49569]		[2.4912, 2.4993]		[2.49262, 2.49531]	
σ_h^0 (nb)	41.480 ± 0.033	41.4892 ± 0.0077	41.4914 ± 0.0080	−0.3	41.4613 ± 0.0303	0.4	41.4923 ± 0.0080	−0.4
		[41.4741, 41.5041]	[41.4757, 41.5070]		[41.402, 41.521]		[41.4766, 41.5081]	
R_ℓ^0	20.767 ± 0.025	20.7487 ± 0.0080	20.7451 ± 0.0087	0.8	20.7587 ± 0.0217	0.2	20.7468 ± 0.0087	0.7
		[20.7329, 20.7645]	[20.7281, 20.7621]		[20.716, 20.801]		[20.7298, 20.7637]	
$A_{\rm FB}^{0,\ell}$	0.0171 ± 0.0010	0.016300 ± 0.000095	0.016291 ± 0.000096	0.8	0.016316 ± 0.000240	0.8	0.01615 ± 0.00011	1.0
		[0.016111, 0.016487]	[0.016102, 0.016480]		[0.01585, 0.01679]		[0.01594, 0.01636]	
$\mathcal{A}_\ell$ (SLD)	0.1513 ± 0.0021	0.14742 ± 0.00044	0.14745 ± 0.00045	1.8	0.14750 ± 0.00108	1.6	0.14675 ± 0.00049	2.1
		[0.14656, 0.14827]	[0.14656, 0.14834]		[0.1454, 0.1496]		[0.14580, 0.14770]	
R_b^0	0.21629 ± 0.00066	0.215892 ± 0.000100	0.215886 ± 0.000102	0.6	0.215413 ± 0.000364	1.2	0.21591 ± 0.00010	0.6
		[0.215696, 0.216089]	[0.215688, 0.216086]		[0.21469, 0.21611]		[0.21571, 0.21611]	
R_c^0	0.1721 ± 0.0030	0.172198 ± 0.000054	0.172197 ± 0.000054	−0.1	0.172404 ± 0.000183	−0.1	0.172189 ± 0.000054	−0.1
		[0.172093, 0.172302]	[0.172094, 0.172303]		[0.17206, 0.17278]		[0.172084, 0.172295]	
$A_{\rm FB}^{0,b}$	0.0996 ± 0.0016	0.10335 ± 0.00030	0.10337 ± 0.00032	−2.3	0.10338 ± 0.00077	−2.1	0.10288 ± 0.00034	−2.0
		[0.10276, 0.10396]	[0.10275, 0.10400]		[0.10189, 0.10490]		[0.10220, 0.10354]	
$A_{\rm FB}^{0,c}$	0.0707 ± 0.0035	0.07385 ± 0.00023	0.07387 ± 0.00023	−0.9	0.07392 ± 0.00059	−0.9	0.07348 ± 0.00025	−0.8
		[0.07341, 0.07430]	[0.07341, 0.07434]		[0.07275, 0.07507]		[0.07298, 0.07398]	
$\mathcal{A}_b$	0.923 ± 0.020	0.934770 ± 0.000039	0.934772 ± 0.000040	−0.6	0.934593 ± 0.000166	−0.6	0.934721 ± 0.000041	−0.6
		[0.934693, 0.934847]	[0.934693, 0.934849]		[0.93426, 0.93491]		[0.934642, 0.934801]	
$\mathcal{A}_c$	0.670 ± 0.027	0.66796 ± 0.00021	0.66797 ± 0.00021	0.1	0.66817 ± 0.00054	0.1	0.66766 ± 0.00022	0.1
		[0.66754, 0.66838]	[0.66755, 0.66839]		[0.66712, 0.66922]		[0.66722, 0.66810]	
$\mathcal{A}_s$	0.895 ± 0.091	0.935678 ± 0.000039	0.935677 ± 0.000040	−0.4	0.935716 ± 0.000098	−0.5	0.935621 ± 0.000041	−0.5
		[0.935600, 0.935755]	[0.935599, 0.935754]		[0.935523, 0.935909]		[0.935541, 0.935702]	
${\rm BR}_{W\to\ell\bar\nu_\ell}$	0.10860 ± 0.00090	0.108388 ± 0.000022	0.108388 ± 0.000022	0.2	0.108291 ± 0.000109	0.3	0.108386 ± 0.000023	0.2
		[0.108345, 0.108431]	[0.108345, 0.108431]		[0.10808, 0.10851]		[0.108340, 0.108432]	
$\sin^2\theta_{\rm eff}^{\rm lept}$ (HC)	0.23143 ± 0.00025	0.231471 ± 0.000055	0.231474 ± 0.000056	−0.2	0.231460 ± 0.000138	−0.1	0.231558 ± 0.000062	−0.5
		[0.231362, 0.231580]	[0.231363, 0.231584]		[0.23119, 0.23173]		[0.231436, 0.231679]	
R_{uc}	0.1660 ± 0.0090	0.172220 ± 0.000031	0.172220 ± 0.000032	−0.7	0.172424 ± 0.000180	−0.7	0.172212 ± 0.000032	−0.7
		[0.172159, 0.172282]	[0.172159, 0.172282]		[0.17209, 0.17279]		[0.172149, 0.172275]	

obtained using only the experimental information on SM parameters. For the individual prediction, indirect determination and for the full prediction we also report the pull for each experimental result. In this regard, from the individual indirect determination of the SM parameters in Table II, one can observe how the tensions introduced by the new measurements in the SM fit result in sizable pulls for the different SM inputs, at the level of 4σ (6σ) for $\Delta\alpha^{(5)}_{\rm had}(M_Z)$ and m_H (M_Z and m_t). Each pull can be converted in a *p value*, and the global consistency of the SM in the EWPO domain can be tested by looking at the distribution of *p values*. From Table II, in the indirect determination case, we find an average *p value* of 0.43 with a 0.36 standard deviation, while for the full prediction we obtain an average *p value* of 0.56 with a 0.30 standard deviation. Both values are compatible with the expectation of a flatly distributed *p value* between 0 and 1. Furthermore, we evaluate the global *p value* from the full prediction, taking into account all theoretical and experimental correlations. We obtain $p = 2.45 \times 10^{-5}$, corresponding to a global pull of 4.2σ, in the *standard* averaging scenario, and $p = 0.10$, corresponding to a global pull of 1.6σ, in the *conservative* averaging scenario [64].

In view of the significant discrepancy between the SM prediction and the experimental average for M_W, we discuss next the implications of the new Tevatron result on scenarios of NP beyond the SM. In particular we discuss the case of NP models which mainly introduce sizable EW *oblique* corrections (here denoted as *oblique* models) and the case in which NP is described at the EW scale by more general effective interactions, taking as a prototype example the dimension-six SM effective field theory (SMEFT). Let us first consider a class of NP models in which the dominant contributions to EWPO are expected to arise as oblique corrections, i.e., via modifications of the EW gauge-boson self-energies, and can thus be parametrized in terms of the S, T, and U parameters introduced in Refs. [65,66] (or equivalently by the $\epsilon_{1,2,3}$ parameters introduced in Refs. [67–69], although, for the sake of brevity, we consider here only the former set of parameters). The explicit dependence of the EWPO on S, T, and U can be found in Appendix A of Ref. [70]. If one assumes NP contributions to U to be negligible, then a prediction for M_W can be obtained from all other EWPO, as reported in Table I, and could reduce the SM discrepancy with the experimental value of M_W to a tension at the 1.5σ level. This scenario, $U \ll S, T$, (here defined as model ST) is expected in extensions with heavy new physics where the SM gauge symmetries are realized linearly in the light fields, in which case U is generated by interactions of mass dimension eight, and is then suppressed with respect to S and T, which are given by dimension-six interactions. Alternatively, to describe scenarios where sizable contributions to U are generated (here defined as models STU), we also consider the case where this parameter is left free [71]. In this case, since U is only very loosely constrained by Γ_W, M_W cannot be predicted with a reasonable accuracy. At the same time, this means that the apparent discrepancy with the new M_W measurement can be solved by a nonvanishing U parameter. In Table III we report the results of a global fit, including M_W, for the oblique parameters, while the corresponding probability density functions (p.d.f.) are presented in Fig. 2 We also report the value of the information criterion (IC) [73] of the fits, compared to the SM one. The posterior for the EWPO is reported in Table IV.

TABLE III. Results of the global fit of the oblique parameters to all EWPO in the *standard average* scenario. The corresponding results in the *conservative average* scenario are presented in the Supplemental Material [46] associated with this Letter.

	Result	Correlation		Result	Correlation		
	$(\mathrm{IC_{ST}}/\mathrm{IC_{SM}} = 25.0/80.2)$			$(\mathrm{IC_{STU}}/\mathrm{IC_{SM}} = 25.3/80.2)$			
S	0.100 ± 0.073	1.00		0.005 ± 0.096	1.00		
T	0.202 ± 0.056	0.93	1.00	0.040 ± 0.120	0.91	1.00	
U	…	…	…	0.134 ± 0.087	−0.65	−0.88	1.00

We then relax the assumption of dominant oblique NP contributions and consider generic heavy NP within the formalism of the dimension-six SMEFT. Here we work in the so-called *Warsaw basis* [74] assuming fermion universality, and as in the fits presented above, we use the

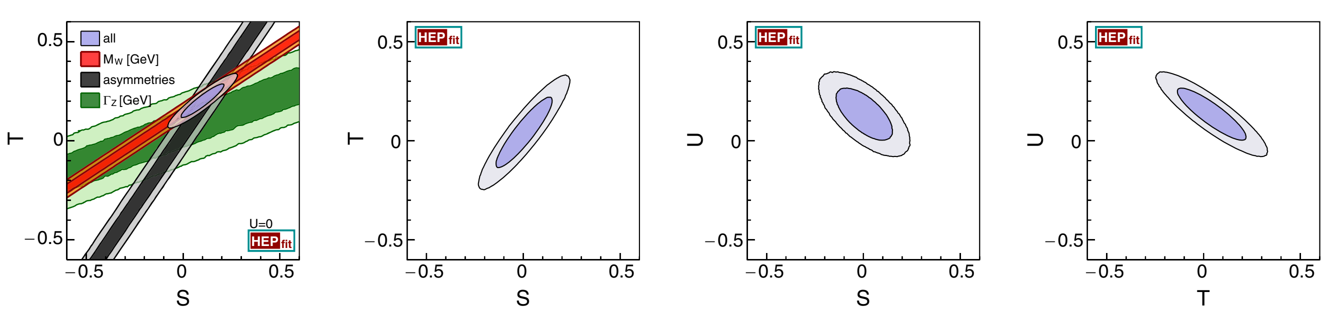

FIG. 2. P.d.f.s for oblique parameters from a global fit to all EWPO for the *standard average* scenario. Left: scenario with $U = 0$. Center and right: scenario with $U \neq 0$. Dark (light) regions correspond to 68% (95%) probability ranges. The corresponding results in the *conservative average* scenario are presented in the Supplemental Material [46] associated with this Letter.

TABLE IV. Posterior distributions for the global fit to all EWPO in the *standard average* scenario for the NP scenarios discussed in the text. For the reader's convenience we also report experimental data in the first column. The measurements interpreted as determinations of the effective leptonic weak mixing angle, namely $\sin^2\theta_{\rm eff}^{\rm lept}(Q_{\rm FB}^{\rm had})$ and $\sin^2\theta_{\rm eff}^{\rm lept}$ (HC), are not included in the SMEFT fits. The corresponding results in the *conservative average* scenario are presented in the Supplemental Material associated with this Letter.

	Measurement	ST	STU	SMEFT
M_W (GeV)	80.4133 ± 0.0080	80.4100 ± 0.0077	80.4133 ± 0.0080	80.4133 ± 0.0080
Γ_W (GeV)	2.085 ± 0.042	2.09214 ± 0.00072	2.09251 ± 0.00075	2.0778 ± 0.0070
$\sin^2\theta_{\rm eff}^{\rm lept}(Q_{\rm FB}^{\rm had})$	0.2324 ± 0.0012	0.23142 ± 0.00013	0.23147 ± 0.00014	…
$P_\tau^{\rm pol} = \mathcal{A}_\ell$	0.1465 ± 0.0033	0.1478 ± 0.0011	0.1474 ± 0.0011	0.1488 ± 0.0014
Γ_Z (GeV)	2.4955 ± 0.0023	2.49812 ± 0.00099	2.4951 ± 0.0022	2.4955 ± 0.0023
σ_h^0 (nb)	41.480 ± 0.033	41.4910 ± 0.0077	41.4905 ± 0.0077	41.481 ± 0.032
R_ℓ^0	20.767 ± 0.025	20.7506 ± 0.0084	20.7510 ± 0.0084	20.769 ± 0.024
$A_{\rm FB}^{0,\ell}$	0.0171 ± 0.0010	0.01638 ± 0.00023	0.01630 ± 0.00024	0.01659 ± 0.00032
$\mathcal{A}_\ell$ (SLD)	0.1513 ± 0.0021	0.1478 ± 0.0011	0.1474 ± 0.0011	0.1488 ± 0.0014
R_b^0	0.21629 ± 0.00066	0.21591 ± 0.00010	0.21591 ± 0.00010	0.21632 ± 0.00065
R_c^0	0.1721 ± 0.0030	0.172198 ± 0.000054	0.172200 ± 0.000054	0.17159 ± 0.00099
$A_{\rm FB}^{0,b}$	0.0996 ± 0.0016	0.10362 ± 0.00075	0.10336 ± 0.00077	0.1008 ± 0.0014
$A_{\rm FB}^{0,c}$	0.0707 ± 0.0035	0.07407 ± 0.00058	0.07387 ± 0.00059	0.0734 ± 0.0022
$\mathcal{A}_b$	0.923 ± 0.020	0.934812 ± 0.000097	0.934779 ± 0.000099	0.903 ± 0.013
$\mathcal{A}_c$	0.670 ± 0.027	0.66815 ± 0.00052	0.66796 ± 0.00053	0.658 ± 0.020
$\mathcal{A}_s$	0.895 ± 0.091	0.935710 ± 0.000096	0.935676 ± 0.000097	0.905 ± 0.012
${\rm BR}_{W\to\ell\bar\nu_\ell}$	0.10860 ± 0.00090	0.108386 ± 0.000022	0.108380 ± 0.000022	0.10900 ± 0.00038
$\sin^2\theta_{\rm eff}^{\rm lept}$ (HC)	0.23143 ± 0.00025	0.23142 ± 0.00013	0.23147 ± 0.00014	…
R_{uc}	0.1660 ± 0.0090	0.172220 ± 0.000032	0.172222 ± 0.000032	0.17161 ± 0.00098

$\{\alpha, G_\mu, M_Z\}$ EW input scheme [75]. In the Warsaw basis, there are a total of ten operators that can modify the EWPO at leading order, but only eight combinations of the corresponding Wilson coefficients can be constrained by the data in Table II [76,77]. Using the notation of Ref. [74], these combinations can be written as, e.g. [76],

$$\hat{C}_{\varphi f}^{(1)} = C_{\varphi f}^{(1)} - \frac{Y_f}{2} C_{\varphi D}, \qquad f = l, q, e, u, d, \tag{6}$$

$$\hat{C}_{\varphi f}^{(3)} = C_{\varphi f}^{(3)} + \frac{c_w^2}{4 s_w^2} C_{\varphi D} + \frac{c_w}{s_w} C_{\varphi WB}, \qquad f = l, q, \tag{7}$$

$$\hat{C}_{ll} = \frac{1}{2}[(C_{ll})_{1221} + (C_{ll})_{2112}] = (C_{ll})_{1221}, \tag{8}$$

where s_w, c_w are the sine and cosine of the weak mixing angle, Y_f denotes the fermion hypercharge, and we have absorbed the dependence on the cut-off scale of the SMEFT, Λ, in the Wilson coefficients, i.e., the above coefficients carry dimension of $[\text{mass}]^{-2}$. Furthermore, the effective EW fermion couplings always depend on $\hat{C}_{ll}$ via the following combinations, fixed by the corresponding fermionic quantum numbers (see, e.g., Ref. [78]),

$$\hat{C}_{\varphi f}^{(3)} - \frac{c_w^2}{2 s_w^2} \hat{C}_{ll} \quad \text{and} \quad \hat{C}_{\varphi f}^{(1)} + Y_f \hat{C}_{ll}, \tag{9}$$

such that the effects of $\hat{C}_{ll}$ cannot be separated from other operators using only Z-pole observables. The flat direction can be broken by the W-boson mass, which depends on $\hat{C}_{\varphi l}^{(3)} - \hat{C}_{ll}/2$, or any observable sensitive to its value, e.g., the W-boson width Γ_W. The comparatively low precision of the experimental measurement of Γ_W (∼2%) thus results in a weak prediction for M_W from the SMEFT fit, with an uncertainty somewhat below 2 GeV [79] (see Table I), which can easily fit the experimental measurement, via a nonzero value of the combination $\hat{C}_{\varphi l}^{(3)} - \hat{C}_{ll}/2$. Indeed, as can be seen in Table V, the two operators involved in the combination are strongly correlated between them, but also

TABLE V. Results from the dimension-six SMEFT fit in the *standard average* scenario. The values of the Wilson coefficients $\hat{C}_i$ are given in units of TeV^{-2}. The corresponding results in the *conservative average* scenario are presented in the Supplemental Material [46] associated with this Letter.

	Result	Correlation Matrix ($\text{IC}_{\text{SMEFT}}/\text{IC}_{\text{SM}} = 31.8/80.2$)							
$\hat{C}_{\varphi l}^{(1)}$	-0.007 ± 0.011	1.00							
$\hat{C}_{\varphi l}^{(3)}$	-0.042 ± 0.015	−0.68	1.00						
$\hat{C}_{\varphi e}$	-0.017 ± 0.009	0.48	0.04	1.00					
$\hat{C}_{\varphi q}^{(1)}$	-0.018 ± 0.044	−0.02	−0.06	−0.13	1.00				
$\hat{C}_{\varphi q}^{(3)}$	-0.113 ± 0.043	−0.03	0.04	−0.16	−0.37	1.00			
$\hat{C}_{\varphi u}$	0.090 ± 0.150	0.06	−0.04	0.04	0.61	−0.77	1.00		
$\hat{C}_{\varphi d}$	-0.630 ± 0.250	−0.13	−0.05	−0.30	0.40	0.58	−0.04	1.00	
$\hat{C}_{ll}$	-0.022 ± 0.028	−0.80	0.95	−0.10	−0.06	−0.01	−0.04	−0.05	1.00

with $\hat{C}_{\varphi l}^{(1)}$. The latter correlation can be understood from the fact that the combination $\hat{C}_{\varphi l}^{(1)} + \hat{C}_{\varphi l}^{(3)}$ is the one that directly corrects the left-handed electron couplings, which is measured to the per-mil level. The extraction of this coupling from the data, however, is typically correlated with the one on the right-handed coupling, sensitive to $\hat{C}_{\varphi e}$, slightly complicating the correlation pattern more in the output of the global fit. It is, in fact, in the information of the leptonic operators where one observes the main difference between the fits using the standard and conservative averages of the experimental values. This is reflected in changes in their correlations as well as mild changes, of order ten percent, in their uncertainties, whereas the central values of the Wilson coefficients stay approximately the same. The posterior for the EWPO in this case is also reported in Table IV.

In conclusion, recent measurements of m_t [47] and M_W [48] are introducing some tensions in global fits of EW precision observables. In this Letter we have studied their impact on electroweak precision fits both in the SM and in some prototype scenarios of NP beyond the SM. Future EW precision measurements at both the LHC and the HL-LHC will add to this picture and contribute to confirm or resolve potential tensions in the SM.

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[62] Unlike in Ref. [3], we do not consider an inflated uncertainty for the Higgs-boson mass in the *conservative* scenario since, as noted in that reference, this has little impact on the output of the EW fit. We thus use $m_H = (125.21 \pm 0.12)$ GeV [3] in all the fits presented here.
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