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Introduction

This twiki page summarises the results of a preliminary extrapolation of the combined Higgs measurements for HL-LHC studies, and the guidelines on how to extrapolate such HL-LHC results to the HE-LHC.

Guidelines for extrapolation of CMS&ATLAS LHC/HL-LHC couplings projections to HE-LHC

In ATLAS and CMS we encourage the theory groups to start using the numbers we have provide for HL-LHC couplings sensitivity in their HE studies to extrapolate them to 27 TeV. We will help as much as possible in this extrapolation work to understand the systematic uncertainties.

As an overall approach:

- In terms of how to extrapolate the systematics to High Energy LHC, we provide the HL-LHC uncertainties of the key measurements split into:
    1. **statistic component** - can be extrapolated with integrated luminosity just accounting by the different target luminosity
    2. **theoretical systematic component**, in which we rely on the theoretical community to decide how the theoretical uncertainties can be improved when going towards HE. They should not decrease steeply with luminosity, but whether the reduction should be a factor of 2 or larger, or whether they should be kept constant, is up to the theory community from our point of view
    3. **experimental systematic component** - we propose to assume the same experimental uncertainty in HL and in HE. With no real handle on how a HE detector would perform at the high PU level expected, this is the only assumption we can make at this point.

- Wherever possible, we also provide correlation matrices for the uncertainties

- Cross sections of processes to be adapted from 13/14TeV to 27TeV

- In the cases in which measurements are used in the theoretical studies / global fits that do not come from our new HL projections, but from Run2 results. In this case, the first thing to consider is the following summary SUMMARY TWIKI, which shows how to assign floors to experimental uncertainties for HL (which also serves be a baseline for HE as explained above). Since we imagine it might not be easy to interpret our Run2 results in terms of stat + theo + exp uncertainties and fold in the above recommendation, we can help to determine which uncertainties from Run2 to scale/reduce and which to keep constant on a case by case basis upon contact

Preliminary Higgs signal strength / coupling extrapolations for HL-LHC

The following summarises the results of a preliminary extrapolation of the combined Higgs measurements for HL-LHC studies, from the ongoing CMS-ATLAS coordination effort. The plots and overall extrapolation conditions were discussed in the following presentations:

- Preliminary update of CMS HL couplings (31/July/18)
- *ATLAS results will be added soon*
- *Combined ATLAS+CMS results will be added soon*

Further numerical details of the CMS numbers, to be used in extrapolations, can be found below

Details of the CMS projections

Preliminary update of CMS HL couplings (31/July/18)

Numbers have been updated to the final public CMS result (CMS-PAS-FTR-18-011)

Important notes:

- The numbers given here are **not officially approved by CMS**. They are have been made available now so they can be used as inputs for other studies targeting the Yellow Report. While we hope these are fairly representative of the final results the exact numbers are likely to change, on a timescale of 1-2 months, and should then be updated wherever they are used as input. Please use the numbers confidentially for now.
- These projections are currently CMS-only. Similar projections from ATLAS are expected soon, and following that an approximate CMS-ATLAS combination will be made
- The results are based on the HIG-17-031 analysis of 35.9 fb-1 of 13 TeV data given here: http://cms-results.web.cern.ch/cms-results/public-results/preliminary-resu - please consult this PAS for details on the signal parametrisations and what analyses are included.

In each of the following tables the total uncertainties are decomposed into four components:

1. **Stat**: statistical uncertainty
2. **SigTh**: theoretical uncertainty on the signal prediction (both inclusive cross section / partial width uncertainties and acceptance effects)
3. **BkgTh**: theoretical uncertainty on the background predictions
4. **Expt**: Experimental uncertainties

Furthermore, results are given for two scenarios, S1 and S2, for the scaling of the systematic uncertainties with integrated luminosity. In S1 the uncertainties are unchanged from their current values. In S2 experimental uncertainties are reduced with integrated luminosity, up to agreed limits agreed between CMS and ATLAS. Theoretical uncertainties are also reduced, typically by a factor of 0.5. Further details of this scenario are given in https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HLHELHCCommonSystematics.

Signal strength per production mode

L = 3000 fb-1		Expected uncertainty [%]				
POI	Scenario	Total	Stat	SigTh	BkgTh	Expt
μ_{ggH}	S1	5.7	0.8	5.4	0.9	1.2
	S2	3.1	0.8	2.8	0.6	0.9
μ_{VBF}	S1	4.7	2.6	3.0	1.3	2.1
	S2	3.7	2.6	2.1	0.3	1.6
μ_{WH}	S1	8.2	4.6	2.9	3.3	5.2
	S2	6.4	4.6	1.4	2.7	3.2
μ_{ZH}	S1	7.2	3.9	5.1	2.5	2.1
	S2	5.7	3.9	3.0	2.3	1.7
μ_{ttH}	S1	9.9	1.8	8.3	4.1	3.1
	S2	6.2	1.8	4.2	3.4	2.4

Show correlation matrix for S1: Hide

μ_{ggH}	1.00	-0.02	0.01	0.12
μ_{VBF}	-0.02	1.00	0.13	0.06
μ_{WH}	0.01	0.13	1.00	-0.0
μ_{ZH}	0.12	0.06	-0.07	1.00
μ_{ttH}	0.03	0.04	-0.01	0.00
	μ_{ggH}	μ_{VBF}	μ_{WH}	μ

Show correlation matrix for S2: Hide

μ_{ggH}	1.00	-0.05	0.00	0.06
μ_{VBF}	-0.05	1.00	0.07	0.03
μ_{WH}	0.00	0.07	1.00	-0.0
μ_{ZH}	0.06	0.03	-0.05	1.00
μ_{ttH}	0.03	0.03	-0.01	0.00
	μ_{ggH}	μ_{VBF}	μ_{WH}	μ

Signal strength per decay mode

L = 3000 fb-1		Expected uncertainty [%]				
POI	Scenario	Total	Stat	SigTh	BkgTh	Expt
$\mu^{\gamma \gamma }$	S1	4.6	1.3	3.5	0.3	2.6
	S2	3.1	1.3	2.1	0.3	1.7
μ^{WW}	S1	4.2	1.0	3.7	1.0	1.4
	S2	2.8	1.0	2.2	0.9	1.1
μ^{ZZ}	S1	5.0	1.6	3.5	1.9	2.5
	S2	3.3	1.6	2.1	0.7	1.7
μ^{bb}	S1	7.2	2.1	5.4	3.6	2.3
	S2	4.7	2.1	2.5	2.9	1.7
$\mu^{\tau \tau }$	S1	3.9	1.6	2.6	1.5	1.9
	S2	2.9	1.6	1.8	0.6	1.4
$\mu^{\mu\mu}$	S1	13.0	9.1	5.2	0.8	7.6
	S2	9.6	9.1	2.6	0.8	1.7

Show correlation matrix for S1: Hide

$\mu^{\gamma \gamma }$	1.00	0.51	0.46	0.02
μ^{WW}	0.51	1.00	0.45	0.02
μ^{ZZ}	0.46	0.45	1.00	0.03
μ^{bb}	0.02	0.02	0.03	1.00
$\mu^{\tau \tau }$	0.50	0.45	0.38	0.01
$\mu^{\mu\mu}$	0.18	0.17	0.15	0.01
	$\mu^{\gamma \gamma }$	μ^{WW}	μ^{ZZ}	$\mu^{\mathrm{m$

Show correlation matrix for S2: Hide

$\mu^{\gamma \gamma }$	1.00	0.42	0.39	0.02
μ^{WW}	0.42	1.00	0.39	0.03
μ^{ZZ}	0.39	0.39	1.00	0.02
μ^{bb}	0.02	0.03	0.02	1.00
$\mu^{\tau \tau }$	0.44	0.32	0.31	0.02
$\mu^{\mu\mu}$	0.13	0.13	0.12	0.01
	$\mu^{\gamma \gamma }$	μ^{WW}	μ^{ZZ}	$\mu^{\mathrm{m$

Signal strength per production x decay mode

L = 3000 fb-1		Expected uncertainty [%]				
POI	Scenario	Total	Stat	SigTh	BkgTh	Expt
	S1	7.1	1.9	5.8	1.0	3.3

$\mu_{\mathrm{ggH}}^{\gamma \gamma}$						
	S2	4.2	1.9	3.1	0.9	2.1
$\mu_{\mathrm{ggH}}^{\mathrm{ZZ}}$	S1	6.6	2.1	5.4	1.7	2.7
	S2	4.0	2.1	2.8	0.7	1.8
$\mu_{\mathrm{ggH}}^{\mathrm{WW}}$	S1	6.6	1.2	6.2	1.0	1.5
	S2	3.7	1.2	3.1	0.9	1.2
$\mu_{\mathrm{ggH}}^{\tau \tau}$	S1	8.1	2.6	6.6	1.7	3.5
	S2	5.5	2.6	3.9	0.7	2.9
$\mu_{\mathrm{ggH}}^{\mathrm{bb}}$	S1	34.0	20.6	23.5	3.2	10.0
	S2	24.7	20.6	12.2	1.5	2.6
$\mu_{\mathrm{ggH}}^{\mu \mu}$	S1	16.6	13.4	5.5	1.9	8.0
	S2	13.8	13.4	3.2	0.6	2.0
$\mu_{\mathrm{VBF}}^{\gamma \gamma}$	S1	22.3	5.2	8.3	1.3	19.9
	S2	12.8	5.2	4.2	0.3	10.9
$\mu_{\mathrm{VBF}}^{\mathrm{ZZ}}$	S1	15.2	11.7	9.1	2.4	1.8
	S2	13.4	11.7	6.0	0.8	1.3
$\mu_{\mathrm{VBF}}^{\mathrm{WW}}$	S1	8.6	6.3	5.2	1.8	2.0
	S2	7.3	6.3	3.1	1.1	1.6
$\mu_{\mathrm{VBF}}^{\tau \tau}$	S1	5.5	3.8	2.9	1.5	2.0
	S2	4.4	3.8	1.7	0.4	1.3
$\mu_{\mathrm{VBF}}^{\mu \mu}$	S1	57.5	53.2	18.7	4.5	11.3
	S2	54.0	53.2	9.8	1.0	2.6
$\mu_{\mathrm{WH}}^{\gamma \gamma}$	S1	14.5	13.6	3.2	1.4	3.7
	S2	13.9	13.6	2.0	0.2	1.7
$\mu_{\mathrm{WH}}^{\mathrm{ZZ}}$	S1	48.0	46.5	6.2	2.8	7.8
	S2	47.8	46.5	4.1	0.8	3.8
$\mu_{\mathrm{WH}}^{\mathrm{WW}}$	S1	15.8	12.9	5.9	2.2	6.5
	S2	13.8	12.9	3.1	1.5	3.1
$\mu_{\mathrm{WH}}^{\mathrm{bb}}$	S1	16.3	5.6	4.7	10.8	9.8
	S2	9.4	5.6	2.3	5.1	5.1
$\mu_{\mathrm{ZH}}^{\gamma \gamma}$	S1	23.9	23.1	5.2	1.5	2.9
	S2	23.3	23.1	3.2	0.4	1.2
$\mu_{\mathrm{ZH}}^{\mathrm{ZZ}}$	S1	82.5	75.7	27.0	7.6	16.4
	S2	78.6	75.7	15.9	1.3	9.9
$\mu_{\mathrm{ZH}}^{\mathrm{WW}}$	S1	20.7	17.2	10.3	2.4	3.5
	S2	18.4	17.2	5.6	1.7	3.0
$\mu_{\mathrm{ZH}}^{\mathrm{bb}}$	S1	9.7	4.2	7.9	3.1	2.3
	S2	6.5	4.2	3.9	2.6	1.9
$\mu_{\mathrm{ttH}}^{\gamma \gamma}$	S1	12.5	7.7	8.8	1.0	3.9
	S2	9.4	7.7	4.4	0.2	2.7
	S1	26.9	23.6	10.9	2.5	4.2

$\mu_{\mathrm{ttH}}^{\mathrm{ZZ}}$						
	S2	24.6	23.6	5.1	1.8	3.1
$\mu_{\mathrm{ttH}}^{\mathrm{WW}}$	S1	13.8	4.2	8.2	4.5	9.1
	S2	9.7	4.2	4.2	3.0	6.9
$\mu_{\mathrm{ttH}}^{\mathrm{bb}}$	S1	18.2	2.8	8.7	15.2	3.9
	S2	11.6	2.8	4.3	10.0	2.7
$\mu_{\mathrm{ttH}}^{\tau \tau }$	S1	18.6	8.7	9.1	3.5	13.1
	S2	14.9	8.7	4.8	2.1	10.9

Show correlation matrix for S1: Hide

$\mu_{\mathrm{ggH}}^{\gamma \gamma }$	1.00	0.65
$\mu_{\mathrm{ggH}}^{\mathrm{ZZ}}$	0.65	1.00
$\mu_{\mathrm{ggH}}^{\mathrm{WW}}$	0.70	0.68
$\mu_{\mathrm{ggH}}^{\tau \tau }$	0.62	0.56
$\mu_{\mathrm{ggH}}^{\mathrm{bb}}$	-0.01	-0.01
$\mu_{\mathrm{ggH}}^{\mu \mu }$	0.26	0.25
$\mu_{\mathrm{VBF}}^{\gamma \gamma }$	-0.16	0.01
$\mu_{\mathrm{VBF}}^{\mathrm{ZZ}}$	0.01	0.00
$\mu_{\mathrm{VBF}}^{\mathrm{WW}}$	-0.01	-0.03
$\mu_{\mathrm{VBF}}^{\tau \tau }$	0.04	0.01
$\mu_{\mathrm{VBF}}^{\mu \mu }$	0.00	-0.02
$\mu_{\mathrm{WH}}^{\gamma \gamma }$	0.06	0.02
$\mu_{\mathrm{WH}}^{\mathrm{ZZ}}$	0.01	0.05
$\mu_{\mathrm{WH}}^{\mathrm{WW}}$	0.02	0.01
$\mu_{\mathrm{WH}}^{\mathrm{bb}}$	-0.01	-0.01
$\mu_{\mathrm{ZH}}^{\gamma \gamma }$	0.02	0.02
$\mu_{\mathrm{ZH}}^{\mathrm{ZZ}}$	0.03	-0.06
$\mu_{\mathrm{ZH}}^{\mathrm{WW}}$	0.13	0.13
$\mu_{\mathrm{ZH}}^{\mathrm{bb}}$	0.02	0.03
$\mu_{\mathrm{ttH}}^{\gamma \gamma }$	0.08	0.02
$\mu_{\mathrm{ttH}}^{\mathrm{ZZ}}$	0.00	0.05

$\mu_{\mathrm{ttH}}^{\mathrm{WW}}$	0.02	0.01
$\mu_{\mathrm{ttH}}^{\mathrm{bb}}$	0.00	0.00
$\mu_{\mathrm{ttH}}^{\tau \tau }$	0.02	0.01
	$\mu_{\mathrm{ggH}}^{\gamma \gamma }$	μ_{ggH}

Show correlation matrix for S2: Hide

$\mu_{\mathrm{ggH}}^{\gamma \gamma }$	1.00	0.48
$\mu_{\mathrm{ggH}}^{\mathrm{ZZ}}$	0.48	1.00
$\mu_{\mathrm{ggH}}^{\mathrm{WW}}$	0.54	0.52
$\mu_{\mathrm{ggH}}^{\tau \tau }$	0.46	0.37
$\mu_{\mathrm{ggH}}^{\mathrm{bb}}$	-0.01	-0.01
$\mu_{\mathrm{ggH}}^{\mu \mu }$	0.14	0.13
$\mu_{\mathrm{VBF}}^{\gamma \gamma }$	-0.18	0.00
$\mu_{\mathrm{VBF}}^{\mathrm{ZZ}}$	0.02	-0.11
$\mu_{\mathrm{VBF}}^{\mathrm{WW}}$	-0.01	-0.03
$\mu_{\mathrm{VBF}}^{\tau \tau }$	0.02	0.00
$\mu_{\mathrm{VBF}}^{\mu \mu }$	0.01	-0.01
$\mu_{\mathrm{WH}}^{\gamma \gamma }$	0.00	0.01
$\mu_{\mathrm{WH}}^{\mathrm{ZZ}}$	0.01	0.01
$\mu_{\mathrm{WH}}^{\mathrm{WW}}$	0.02	0.01
$\mu_{\mathrm{WH}}^{\mathrm{bb}}$	0.00	-0.01
$\mu_{\mathrm{ZH}}^{\gamma \gamma }$	-0.03	0.01
$\mu_{\mathrm{ZH}}^{\mathrm{ZZ}}$	0.03	-0.09
$\mu_{\mathrm{ZH}}^{\mathrm{WW}}$	0.06	0.06
$\mu_{\mathrm{ZH}}^{\mathrm{bb}}$	0.02	0.02
$\mu_{\mathrm{ttH}}^{\gamma \gamma }$	0.08	0.01
$\mu_{\mathrm{ttH}}^{\mathrm{ZZ}}$	0.00	0.05
$\mu_{\mathrm{ttH}}^{\mathrm{WW}}$	0.02	0.01

$\mu_{\mathrm{ttH}}^{\mathrm{bb}}$	0.00	0.00
$\mu_{\mathrm{ttH}}^{\tau \tau }$	0.01	0.01
	$\mu_{\mathrm{ggH}}^{\gamma \gamma }$	$\mu_{\mathrm{ggH}

Coupling modifiers

This model includes the effective gluon and photon couplings modifiers κ_{g} and κ_{γ}. All BSM or invisible branching ratios are assumed be zero.

L = 3000 fb-1		Expected uncertainty [%]				
POI	Scenario	Total	Stat	SigTh	BkgTh	Expt
$\kappa_{\gamma }$	S1	2.9	1.1	1.8	1.0	1.7
	S2	2.0	1.1	0.9	0.8	1.2
κ_{W}	S1	2.6	1.0	1.7	1.1	1.1
	S2	1.8	1.0	0.9	0.8	0.8
κ_{Z}	S1	2.4	1.0	1.7	0.9	0.9
	S2	1.7	1.0	0.9	0.7	0.7
κ_{g}	S1	4.0	1.1	3.4	1.3	1.2
	S2	2.5	1.1	1.7	1.1	1.0
κ_{t}	S1	5.5	1.0	4.4	2.7	1.6
	S2	3.5	1.0	2.2	2.1	1.2
κ_{b}	S1	6.0	2.0	4.3	2.9	2.3
	S2	4.0	2.0	2.0	2.2	1.8
$\kappa_{\tau }$	S1	2.8	1.2	1.8	1.1	1.4
	S2	2.0	1.2	1.0	0.9	1.0
κ_{μ}	S1	6.7	4.7	2.5	1.0	3.9
	S2	5.0	4.7	1.3	0.8	1.1

Show correlation matrix for S1: Hide

$\kappa_{\gamma }$	1.00	0.69	0.59	0.37
κ_{W}	0.69	1.00	0.61	0.46
κ_{Z}	0.59	0.61	1.00	0.34
κ_{g}	0.37	0.46	0.34	1.00
κ_{t}	0.24	0.31	0.31	0.30
κ_{b}	0.69	0.79	0.62	0.61
$\kappa_{\tau }$	0.70	0.66	0.55	0.45
κ_{μ}	0.31	0.30	0.26	0.11
	$\kappa_{\gamma }$	κ_{W}	κ_{Z}	$\ka

Show correlation matrix for S2: Hide

$\kappa_{\gamma }$	1.00	0.66	0.57	0.29
κ_{W}	0.66	1.00	0.58	0.39

$				
κ_{Z}	0.57	0.58	1.00	0.24
κ_{g}	0.29	0.39	0.24	1.00
κ_{t}	0.18	0.25	0.24	0.34
κ_{b}	0.65	0.74	0.56	0.67
κ_{τ}	0.66	0.59	0.50	0.43
κ_{μ}	0.27	0.27	0.23	0.09
	κ_{γ}	κ_{W}	κ_{Z}	\ka

-- AndrewGilbert - 2018-08-30

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