Report on EFT activities from the LHC EW WG

Raquel Gomez Ambrosio, Kristin Lohwasser
(on behalf of the LHC EW contacts)

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Overview

- General overview over LHC EW WG
- Activities of sub-groups
- Focus on MB group
  - Achievements
  - Plans (survey)
- Summary

The LHC electroweak working group

- Started in 2012

LHC Electroweak WG https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCEW

WG 1: Drell-Yan physics and EW precision measurements

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/EWWG1

- pT W, Z, and W/Z resummation benchmarking
- QED/EW corrections for precision EW measurements (Z DY and s2weff observables)
- PDF benchmarking exercise
- Pseudodata for combination of sin2θeff measurements
- Pseudodata for combination of pTZ and DY measurements
- Work towards M_W combination
- Photon-induced process in DY measurements and s2weff observables

WG 2: Jets and EW bosons subgroup

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/EWWG2

- Z/W+jets Benchmark comparisons
- LHC tune / Intrinsic kT
- Jet substructure measurements
- Uncertainty treatment and analysis/data preservation (HEPdata et all)

Some general topics taken on mainly by one group (e.g. HEPdata) but relevant to all

WG 3: EW multi-boson production

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/EWWG2

- >10 final states
- Measurements of Multibosons: current results and outlook
- Combinations/Common phase spaces
- Predictions for multiboson production: Phenomenological studies EW corrections, NNLO
- Fiducial cross-section and BSM / EFT
- Effective field theory approaches

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LHC Electroweak WG https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCEW

WG 1: Drell-Yan physics and EW precision measurements

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/EWWG1

- pT W, Z, and W/Z resummation
- observables

Electroweak precision observables
→ precision could become ~comparable to LEP
→ natural input into EFT fits
→ not explored in that context

Possibility for some new projects?

WG 2: Jets and EW bosons subgroup

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/EWWG2

- Z/W+jets Benchmark comparisons
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- Jet substructure measurements
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WG 3: EW multi-boson production

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/EWWG2

- >10 final states
- Measurements of
- approaches

Multiboson production
→ Most related to EFT
→ with some ongoing / already finished projects

discussed in more detail in the following

WG1: Drell-Yan and EWPD

- pT W/Z and W/Z resummation
- QCD-EW corrections for EW precision measurements
- PDF benchmarking
- sin2eff measurements
- combination of pTZ and DY measurements
- …

➢ **No EFT applications explored so far**

WG2: Jets and EW bosons subgroup

- Z/W plus Jets benchmarking
- LHC tune/intrinsic kT
- Uncertainty treatment
- Analysis/Data preservation (HEPdata)
- …

  - **No EFT applications explored so far (mainly in Z/W+2jets(VBF))**
  - **HEP data and correlations information recommendations are mainly worked on in this group → very important base for combinations and consistent data treatment**

WG3: EW multi-boson production

- >10 final states
- Measurements of Multibosons: current results and outlook
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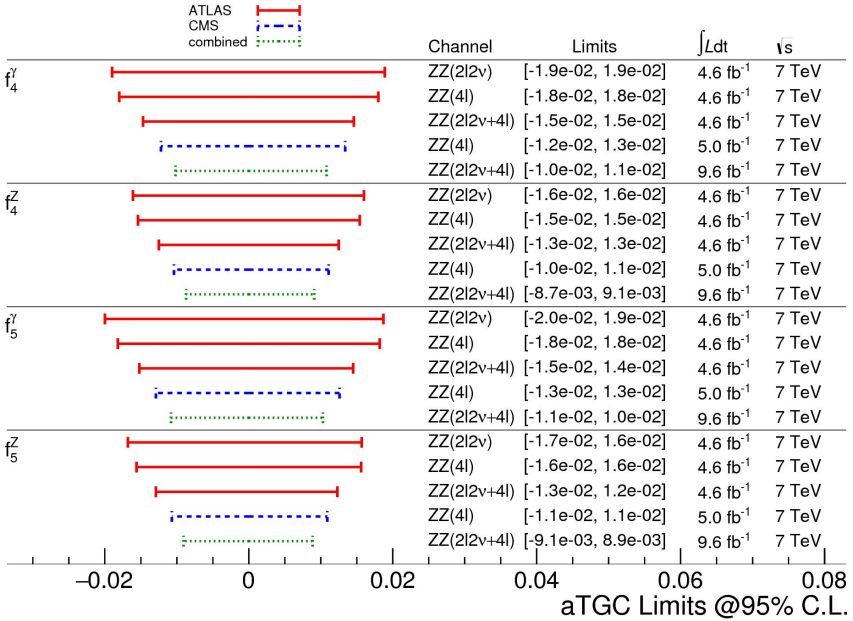
WG3: EW multi-boson production

- Common ATLAS/CMS combination of ZZ (7 TeV)
  - https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2016-036/
- Timeline: >1 year (setup and cross-checks of codes)
- **aTGC interpretation in effective Vertex parametrization (published around the start of Run-2)**
- **Run-1 and start of Run-2: usage of custom TGC codes**

(with aposteriori conversion to SMEFT operators)



For Run-2: Comparisons of EFT results

- First channel to go “EFT” was WW

$$\frac{c_W}{\Lambda^2} = \frac{2}{M_Z^2}\Delta g_1^Z = \frac{2}{M_Z^2}(\tan^2\theta_W \Delta\kappa_\gamma + \Delta\kappa_Z)$$

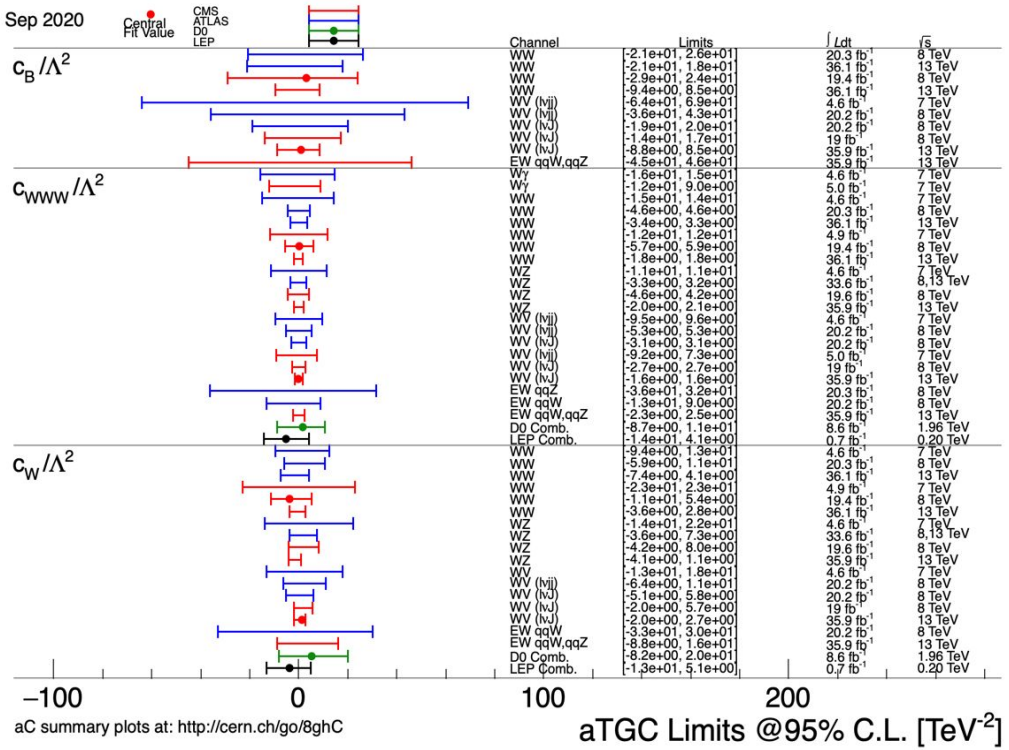
$$\frac{c_B}{\Lambda^2} = \frac{2}{M_W^2}\Delta\kappa_\gamma - \frac{2}{M_Z^2}\Delta g_1^Z$$

$$= \frac{2}{\tan^2\theta_W M_Z^2}\Delta g_1^Z - \frac{2}{\sin^2\theta_W M_Z^2}\Delta\kappa_Z = \frac{2}{M_Z^2}(\Delta\kappa_\gamma - \Delta\kappa_Z)$$

$$\frac{c_{WWW}}{\Lambda^2} = \frac{2}{3g^2 m_W^2}\lambda_\gamma = \frac{2}{3g^2 m_W^2}\lambda_Z$$

$$\frac{c_{\tilde{W}}}{\Lambda^2} = \frac{2}{m_W^2}\tilde{\kappa}_\gamma = -\frac{2}{\tan^2\theta_W m_W^2}\tilde{\kappa}_Z$$

$$\frac{c_{\tilde{W}WW}}{\Lambda^2} = \frac{2}{3g^2 m_W^2}\tilde{\lambda}_\gamma = \frac{2}{3g^2 m_W^2}\tilde{\lambda}_Z$$



arXiv:1205.4231

https://twiki.cern.ch/twiki/bin/view/CMS%20Public/Physics%20Results%20SMPaTGC

WG3: EW multi-boson production

- Following the combination, at lot of discussions went into:
  - Unitarity and validity
  - More consistent framework for Run-2 (EFT approach → *this as was bit before the development of SMEFT/MG5 frameworks)*
  - Establishing common approach between experiments *(resulted in internal recommendations within experiments)*
- https://indico.cern.ch/category/3290/
- Discussions around measurements: ***what*** EFT/aTGC parameters to measure / common phase spaces / MC treatment / …

Ultimate goal: EFT interpretation of the EW sector

- Follow the steps of the work done in the Higgs and top working groups
- The EW sector is historically interesting (unitarity, EWPD, TGCs, QGCs, Mz, Mw….)
- It is necessary to have good description of any possible BSM effects
  - In EWDP
  - In all EW processes (thinking towards a global fit)

EWPD

Traditionally: Use LEP data to constrain EFT operators affecting EWPD

- Would be good to have an LHC interpretation of EWPD
- LHC runs on a different energy regime, different initial state particles, different assumptions regarding ISR and FSR
- Seems sensible to make sure we have a good understanding of how EFT effects on EWPD might change from LEP to LHC

Single Boson, Diboson and VBS

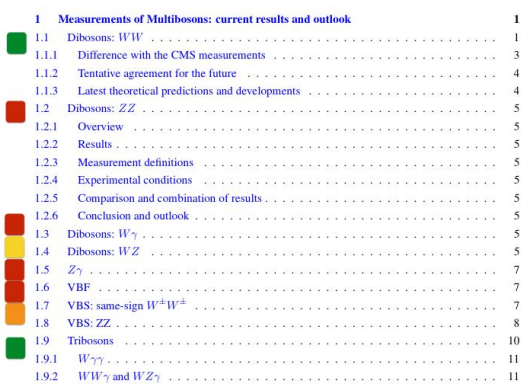
- Loads of works studying these processes in EFT, however very difficult to find agreement in conventions (choice of basis, etc)
- Generally:
  - Dimension 6 EFT studied in diboson production
  - Dimension 8 EFT studied in VBS (→ vbscanaction.web.cern.ch/)
  - Not many works use the Warsaw basis

Single Boson, Diboson and VBS: Difficulties

- Using different basis for TGC and QGC makes the comparison difficult
  - ➢ if dim-X affects TGC, it also affects QCC and vice versa.
- Using a basis other than the Warsaw/SILH/Higgs makes the comparison with Higgs physics and top physics results very difficult

WG3: EW multi-boson production: planned YR

1. Measurements of Multibosons: current results and outlook



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Green -> done/in good shape
Yellow -> is assigned and being worked on
Orange -> needs to be updated (and possibly reassigned?)
Red -> needs to be reassigned

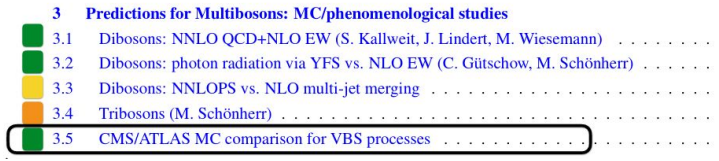
(Re)discussion needed on scope:

Reviews vs. Recommendations vs. joint (sub)-phase-space definitions

Chapter 2

Predictions for Multibosons: state-of-the-art and best-practise

3. Predictions for Multibosons: MC/phenomenological studies



3 Predictions for Multibosons: MC/phenomenological studies
3.1 Dibosons: NNLO QCD+NLO EW (S. Kallweit, J. Lindert, M. Wiesemann)
3.2 Dibosons: photon radiation via YFS vs. NLO EW (C. Gütschow, M. Schönherr)
3.3 Dibosons: NNLOPS vs. NLO multi-jet merging
3.4 Tribosons (M. Schönherr)
3.5 CMS/ATLAS MC comparison for VBS processes

- **Chap 4: EFT survey → more details to follow**
- aTGC/EFT summaries (comparing standalone exp. measurements):
  - https://twiki.cern.ch/twiki/bin/view/CMS%20Public/Physics%20Results%20SMPaTGC

EFT survey: Dibosons (YR)

- Systematic review of multiboson processes:
- → which (Warsaw basis) operators do they constrain?
- → how sensitive are they (relatively speaking, w/r to other processes)

Class A:	**Diboson production**		
	A1: $WW(\to \ell^+\ell^-\nu\bar{\nu})$	A2: $WZ(\to \ell^+\ell^-\ell\nu)$	A3: $ZZ(\to \ell^+\ell^-\ell^+\ell^-)$
	A4: $W\gamma(\to \ell\nu)$	A5: $Z\gamma(\to \ell\ell\gamma)\gamma$	A6: $Z\gamma(\to \nu\nu\gamma)\gamma$
Class B:	**vector-boson fusion (VBF)**		
	B1: $Zjj(\to \ell^+\ell^-$	B2: $Wjj(\to \ell\nu$	
Class C:	**vector-boson scattering (VBS)**		
	C1: $W^\pm W^\pm\, jj(\to \ell^\pm\ell^\pm\nu\bar{\nu})jj$	C2: $WZ\, jj$	C3: $WZ\, jj$ (QCD)
	C4: $ZZ\, jj$	C5: $ZZ\, jj$ (QCD)	C6: $Z\gamma\, jj$
	C7: $W^\pm W^\mp\, jj$	C8: $W^\pm W^\mp\, jj$ (QCD)	

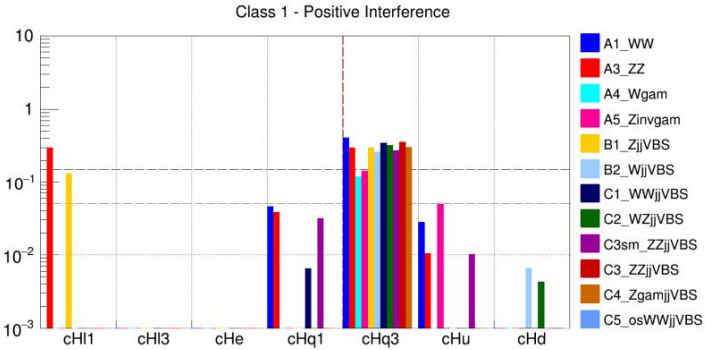
EFT survey: Dibosons (YR)

- "General" BSM regions with high sensitivity (based on experimental measurements)
  - Projections / general cuts

Diboson Production		
Final state	Object	Selection requirements
WW	**leptons**	$p_{\mathrm{T}} > 25$ GeV, $\lvert\eta\rvert < 2.5$
	neutrinos	$(\sum \vec{p}_{\nu}) > 30$ GeV
	jets	0 or 1 jet with $p_{\mathrm{T}} > 30$ GeV and within $\lvert\eta\rvert < 5.0$
	final BSM region	BSM1: 0 jet, $m_{\ell\ell} > 600$ GeV
		BSM2: 1 jet, $m_{\ell\ell} > 600$ GeV
		BSM3: 0 jet, $p_{T,\ell_{\mathrm{lead}}} > 400$ GeV
		BSM4: 1 jet, $p_{T,\ell_{\mathrm{lead}}} > 400$ GeV
WZ	**leptons**	$p_{\mathrm{T,lead}} > 25$ GeV, $p_{\mathrm{T}} > 15$ GeV, $\lvert\eta\rvert < 2.5$
	neutrinos	$(\sum \vec{p}_{\nu}) > 30$ GeV
	jets	no b-jets with $p_{\mathrm{T}} > 30$ GeV and within $\lvert\eta\rvert < 5.0$
	bosons	$m_{\mathrm{T},W} > 30$ GeV (see Eq. 21), $\Delta(m_Z, m_{\ell\ell}) < 15$ GeV
	final BSM region	BSM1: $m_{\mathrm{T},WZ}$: > 600 GeV (see Eq. 22)
		BSM2: $m_{3\ell} > 1250$ GeV
ZZ	**leptons**	$p_{\mathrm{T}} > 25$ / 15 / 10 GeV (leading leptons), $\lvert\eta\rvert < 2.5$
	bosons	$\Delta(m_Z, m_{\ell\ell}) < 25$ GeV
	final BSM region	BSM1: $m_{ZZ} > 1.0$ TeV

EFT survey: Dibosons (YR)

Coefficient	A: Diboson production						B: VBF		C: Vectorboson scattering							
Class 1	A1: WW	A2: WZ	A3: ZZ	A4: $W\gamma$	A5: $Z\gamma$ ($\ell\ell\gamma$)	A6: $Z\gamma$ ($\nu\bar{\nu}\gamma$)	B1: Zjj	B2: Wjj	C1: $W^{\pm}W^{\pm}$ jj	C2: WZ jj	C3: WZ jj (QCD)	C4: ZZ jj	C5: ZZ jj (QCD)	C6: $Z\gamma$ jj	C7: $W^{\pm}W^{\mp}$ jj	C8: $W^{\pm}W^{\mp}$ jj (QCD)
c_G											✓		✓			✓
$c_{\widetilde{G}}$											✓		✓			✓
c_W	✓	✓		✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
$c_{\overline{W}}$	✓	✓		✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Class 2																
c_H													✓			✓



General “affectedness” (above)

Specific % sensitivity w/r to the SM (still working on better presentation)

Comparison with current MB limits:
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMPaTGC

Thank you!

- EFT mainly features in LHC EW MB discussions
  - Common agreement on usage of SMEFT (though not - yet - documented)
  - Work on survey of diboson EFT sensitivity
- EWPO at the LHC unexplored
  - Concentration on ingredients to precision measurements
  - Question during EW meeting on planned used of pseudodata in LHC EFT group
- Person power interested to contribution could be crucial