Yellow report precision EWK, status and plans

The LHC-EWWG Multiboson subgroup conveners

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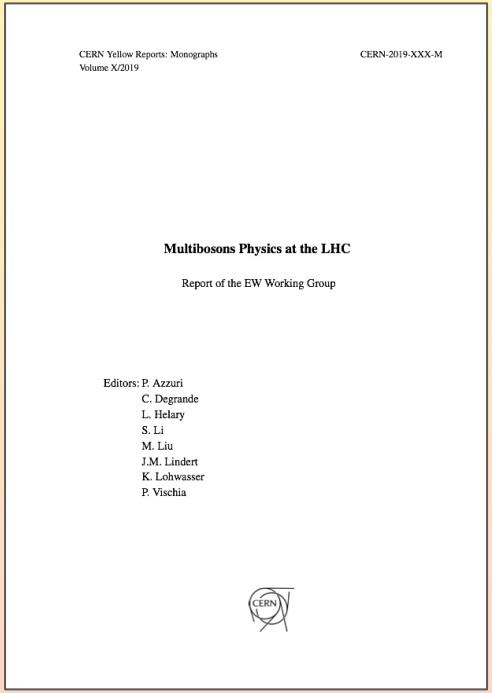
LHC EWWG summer 2020

YR status

gitlab: https://gitlab.cern.ch/lhcewkwg/lhcewkwg-multiboson/Report2018



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Multibosons Physics at the LHC

Report of the EW Working Group

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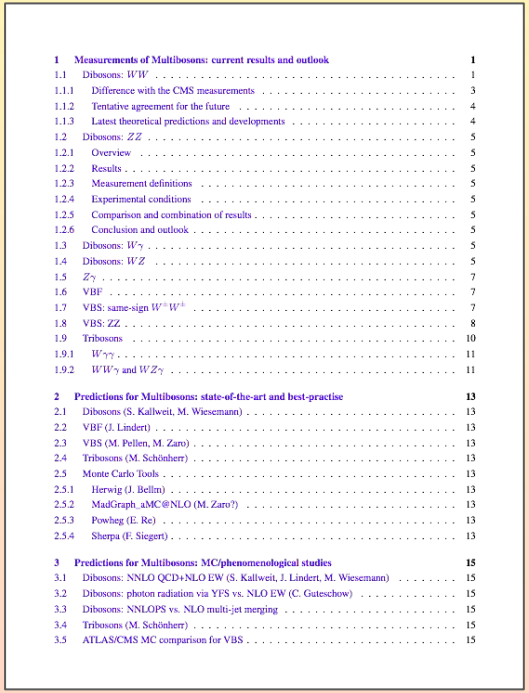
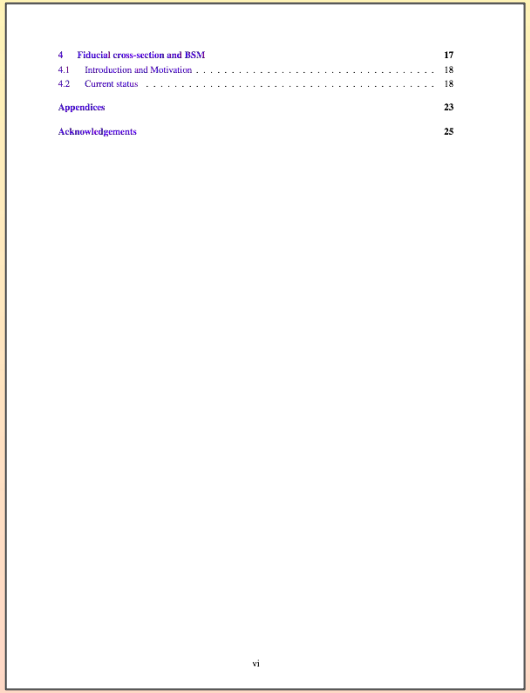




1. Measurements of Multibosons: current status → best practice for inter-experiment consistency
2. Predictions for Multibosons: state-of-the-art and best-practise
3. Predictions for Multibosons: MC/phenomenological studies
4. Fiducial cross-section and BSM

1. Measurements of Multibosons: current results and outlook

What's there

- WW (ATLAS, CMS, comparisons)
- WZ (CMS)
- VBS ssWW (ATLAS, CMS)
- ZZ (ATLAS CMS) and ZZ VBS
- Tribosons (Wγγ WWγ, WZγ)

How can I contribute?

- Common RIVET routine for your favourite process which lacks it

What's in the making

- A few final states (Zγ, Wγ, VBS WZ)
- Phase space agreements
- Brief review of procedures and possible agreements
  - Use similar generators where possible? (but differences reported even with the same ones, see later slides)
  - Systematics: particularly the ones connected with generators (some are treated differently across experiments)
  - Unfolding: publish useful material (response+correlation matrices, etc), describe well the procedures

Review on measurements

Idea behind: Review and **agree on procedures and phase spaces** to allow at least for

→ a comparison of partial results

→ facilitate a combination of results for Full-Run 2 (without having to re-derive information)

This is common practice in LHC Higgs XS and LHC Top WGs

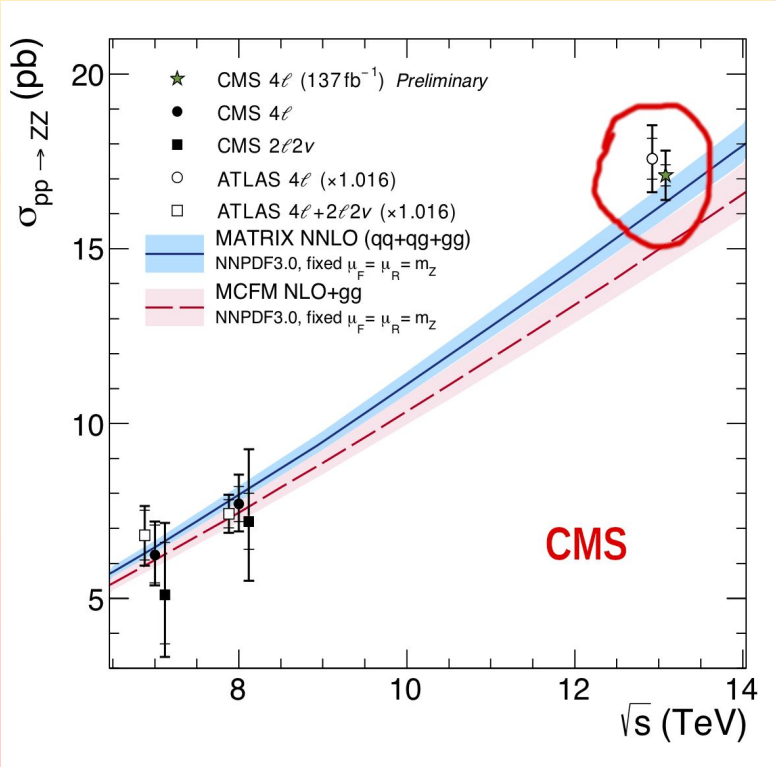
Could allow to have “ATLAS+CMS” rivet routines that can also be used by theorists to provide latest and greatest theory for comparisons (see also later slides on first ATLAS/CMS MC comparisons)

Examples are : **Z-mass window in ZZ production**

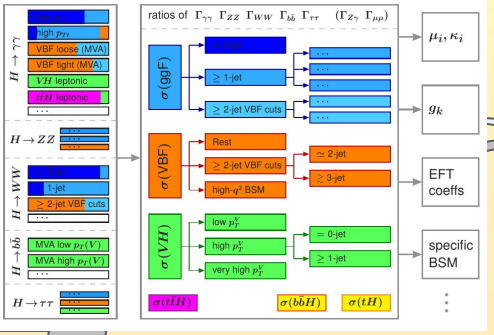
Current status: each experiment quotes extrapolation factor into the other experiements fiducial phase space

Thinking about combinations

- Anomalous Couplings
  - The latest ATLAS+CMS combination seems to be the 7 TeV one (**CMS-PAS-SMP-15-001**, PAS only!)
  - In the meantime, many results constrain much more the trilinear and quartic couplings
  - When do we want to produce the next combination?
  - Go for a 13 TeV one, skipping 8-TeV-only one
    - Would including 8 TeV results in 13 TeV combination be worth (sensitivity-wise) the pain of implementing it?
- Cross sections
  - Is it time to combine our measurements (extrapolated to the full phase space) in each production mode?
  - Agreements on phase space would make things easier
  - Plots of evolution with c.m.e. are supercool, but they all contain split ATLAS and CMS points: they could include a third point
- Concert with SMP-Combination (CMS) strategies and details!
  - These combinations already discussed within SMP-Comb?



Inspired by Higgs STXS: Useful benchmarks!



[LHC EWWG Working group proposal]

Step towards making

global fits easier ?

→ and basis to start EFT investigations

- ***Keep just (differential) cross sections and measure (but in BSM phase space)***
- Profit from advantages of being **useful tool, interface, benchmark**

Multiboson Production

Final state	Object	Selection requirements
WW	**leptons**	p_T >25 GeV, $\|\eta\| < 2.5$
	neutrinos	$(\sum \vec{p}_\nu) > 30$ GeV
	jets	no jets with p_T >30 GeV and within $\|\eta\| < 5.0$
	final BSM region	$m_{\ell\ell}$: 380-600 GeV, >600 GeV
WZ	**leptons**	$p_{T,\text{lead}}$ >25 GeV, p_T >15 GeV, $\|\eta\| < 2.5$
	neutrinos	$(\sum \vec{p}_\nu) > 30$ GeV
	jets	no b-jets with p_T >30 GeV and within $\|\eta\| < 5.0$
	bosons	$m_{T,W}$ >30 GeV (see Eq. **??**), $\Delta(m_Z, m_{\ell\ell})$ <15 GeV
	final BSM region	$m_{T,WZ}$: 380-600 GeV, >600 GeV (see Eq. **??**)
ZZ	**leptons**	p_T >25 / 15 / 10 GeV (leading leptons), $\|\eta\| < 2.5$
	bosons	$\Delta(m_Z, m_{\ell\ell})$ <25 GeV
	final BSM region	m_{WZ}: 0.8-1.0 TeV, >1.0 TeV
$W\gamma$	**leptons**	p_T >35, $\|\eta\| < 2.5$
	photons	E_T >25, $\|\eta\| < 2.5$, $\Delta R(\ell, \gamma) > 0.7$
	neutrinos	$(\sum \vec{p}_\nu) > 30$ GeV
	bosons	$m_{T,W}$ >50 GeV
	final BSM region	$p_{T,\gamma}$: 25-60 GeV, 60-90 GeV, 90-150 GeV, >150 GeV
$Z(\to \ell\ell)\gamma$	**leptons**	p_T >35, $\|\eta\| < 2.5$
	photons	E_T >25, $\|\eta\| < 2.5$, $\Delta R(\ell, \gamma) > 0.4$
	bosons	$\Delta(m_Z, m_{\ell\ell})$ <10 GeV
	final BSM region	$p_{T,\gamma}$: 100-250 GeV, >250 GeV
$Z(\to \nu\nu)\gamma$	**photons**	E_T >25, $\|\eta\| < 2.5$, $\Delta R(\ell, \gamma) > 0.4$
	neutrinos	$(\sum \vec{p}_\nu) > 30$ GeV
	final BSM region	$p_{T,\gamma}$: 100-250 GeV, >250 GeV

Vectorboson Fusion

Final state	Object	Selection requirements
Z VBF / Zjj	**leptons**	$p_{T,\text{lead}}$ >25 GeV, $\|\eta\| < 2.5$
	jets	$p_{T,j1}$ >55 GeV, $p_{T,j1}$ >40 GeV, $\|\eta\| < 4.5$
	bosons	$\Delta(m_Z, m_{\ell\ell})$ <10 GeV
	further jets	p_T >25 GeV, none in interval between leptons
	event	p_T^{balance} <0.15 (see Eq. **??**)
	final BSM region	m_{jj}: 0.8-1.2 TeV, >1.2 TeV

Vectorboson Scattering

Final state	Object	Selection requirements
WW VBS / $WWjj$	**leptons**	p_T >20 GeV, $\|\eta\| < 2.5$, same-sign
	jets	$p_{T,j1}$ >30 GeV, $p_{T,j1}$ >30 GeV, $\|\eta\| < 4.5$, $\Delta\eta_{jj}$ >2.5
same-sign	**final BSM region**	m_{jj}: 0.25-0.5 TeV, >0.5 TeV
$Z\gamma$ VBS / $Z\gamma jj$	**leptons**	p_T >35, $\|\eta\| < 2.5$
	photons	E_T >75, $\|\eta\| < 2.5$, $\Delta R(\ell/j, \gamma) > 0.4$
	bosons	$\Delta(m_Z, m_{\ell\ell})$ <10 GeV
	jets	$p_{T,j1}$ >30 GeV, $p_{T,j1}$ >30 GeV, $\|\eta\| < 4.5$, $\Delta\eta_{jj}$ >3.0
	final BSM region	m_{jj}>0.5 TeV
WZ VBS /	**leptons**	$p_{T,\text{lead}}$ >25 GeV, p_T >15 GeV, $\|\eta\| < 2.5$
	neutrinos	$(\sum \vec{p}_\nu) > 30$ GeV
	jets	$p_{T,j1}$ >55 GeV, $p_{T,j1}$ >40 GeV, $\|\eta\| < 4.5$
	bosons	$\Delta(m_Z, m_{\ell\ell})$ <25 GeV
	further jets	p_T >25 GeV, none in interval between leptons
	event	p_T^{balance} <0.15 (see Eq. **??**)
	final BSM region	m_{WZ}: 0.8-1.0 TeV, >1.0 TeV
ZZ VBS / $ZZjj$	**leptons**	p_T >25 / 15 / 10 GeV (leading leptons), $\|\eta\| < 2.5$
	jets	$p_{T,j1}$ >55 GeV, $p_{T,j1}$ >40 GeV, $\|\eta\| < 4.5$
	bosons	$\Delta(m_Z, m_{\ell\ell})$ <25 GeV
	further jets	p_T >25 GeV, none in interval between leptons
	event	p_T^{balance} <0.15 (see Eq. **??**)
	final BSM region	m_{WZ}: 0.8-1.0 TeV, >1.0 TeV

Consistent comparisons/combinations

- For **any** consistent comparison/combination:
  Common definitions are useful if not strictly *needed*

- Discussed and not found to be too different, but not (yet) put into writing
  - Common pre-defined RIVET routines could be helpful here too
  - As definitions of formats on how to to put stuff into HEP data
    (and what systematic sources to quote)

- All of this would be work to be very difficult to do post-factum
  - (if we measured completely different things in Run-2 and then decided to combine/compare -> "*good luck!*")

Object (Truth) Definition in ATLAS and CMS
—
LHC EWWG Multiboson

Overview by LHC EWWG Multiboson

ATLAS public documents

- A public document from ATLAS side exist
  https://cds.cern.ch/record/2022743
- Motivation: More precise measurements and theory predictions -- use observables that allow:
  - Accurate comparison of theoretical and experimental results
  - Unambiguous comparison to future measurements possible
  - Minimal knowledge of experimental or model-dependent definitions of the final state objects.
- Based on the stable particles that enter in the detector and their physical parents
- Minimal extrapolation but simple and streamlined fiducial region (i.e. same η-range for electrons and muons)

Lepton definition

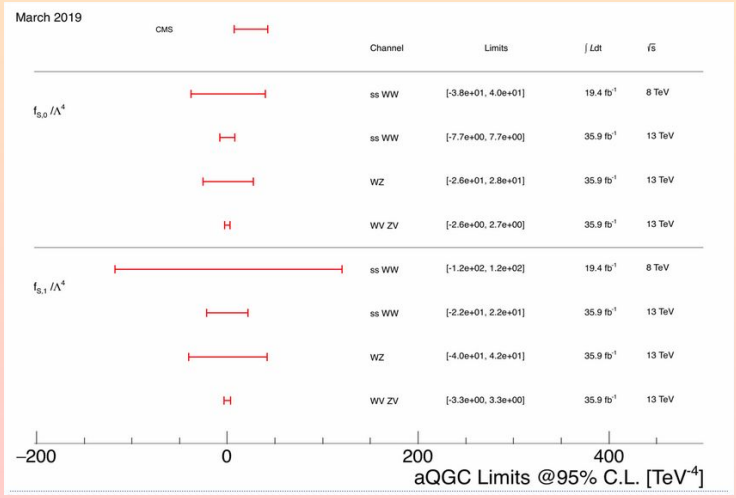
- Use promt leptons → no association to W, Z.. mother particles needed
- Definition using mother particles are equivalent (where information is availabl but *not model-independent → **use prompt leptons**
- What about QED Final state radiation (FSR)? → leads to different leptons
  - **Born leptons:** leptons prior to FSR - defined by LO diagram in α_{QED}
    Not strictly physical, neglect interference between initial and final state QED radiation in W/Z
  - **Bare leptons:** leptons "after QED FSR", depend on technical details of implementation of QED radiation on MC generators
  - **Dressed leptons:** using a cone of dR<0.1 around bare lepton and adding all prompt photons to lepton can remedy model-dependence of final state leptons, negligible impact of ISR photons
    Dressed lepton measurements can be directly combined! (difference electron-muon < 0.1%)

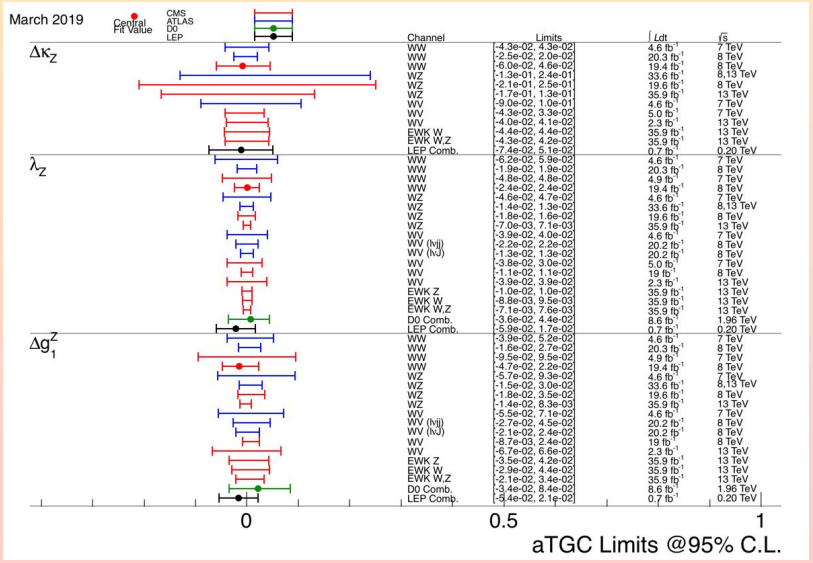
Jet flavour

- **Ghost association:**
  - HF hadrons do not fullfill lifetime criterium for stable particles → excluded from jet finding
  - Can be *included* nonetheless as infinitifely small momentum particles (i.e. do not change pT)
  - Can then be associated to a jet → ghost-association
  - HF jet is:
    - A b-jet if contains at least 1 ghost-associated b-hadron
    - A c-jet if contains at least 1 ghost-associated c-hadron but no b-hadron
- How is this implemented in e.g. Rivet?

Status of the anomalous couplings Summary Plots

- Matthew Herndon and Marc-Andre Pleier in charge of updating them
- Latest plots can be found in the [CMS public twiki]
- Plots are up-to-date to before SM@LHC
  - Analyses with a factor of 200 worse in sensitivity have been removed
- Criteria for inclusion/exclusion never really discussed
  - To keep the number of measurements in a given plot to a reasonable level
  - So far, some cutoff relative to the best measurement for a particular operator
- Help or comments on style always very welcome!





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

What's in the making

- Review of Theory status of
  - **VV** (Kallweit/Wiesemann)
  - **VBF** (Lindert)
  - **VBS** (Pellen/Zaro)
  - **Tribosons** (Schönherr)

- Review of MC tools for multibosons
  - Herwig (Bellm)
  - MG5_aMC@NLO (Zaro?)
  - Powheg (Re)
  - Sherpa (Siegert)

3. Predictions for Multibosons: MC/phenomenological studies

Talk by J. Lindert

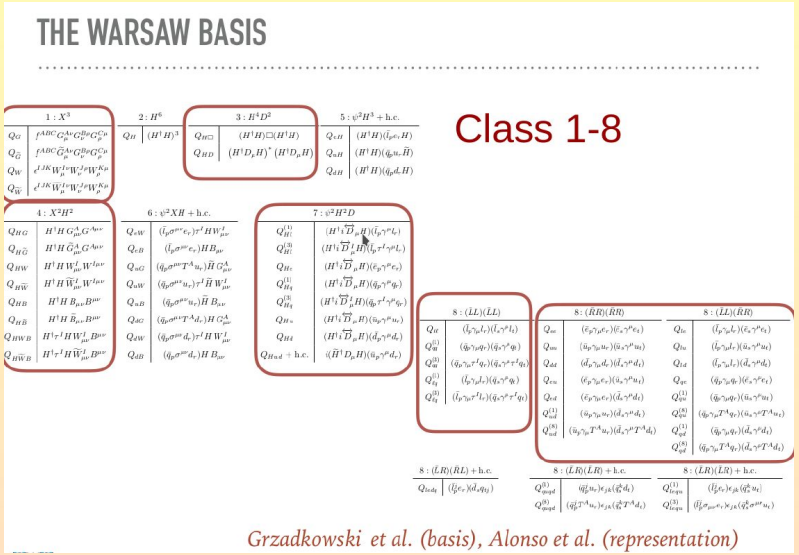
Talk by M. Schönherr

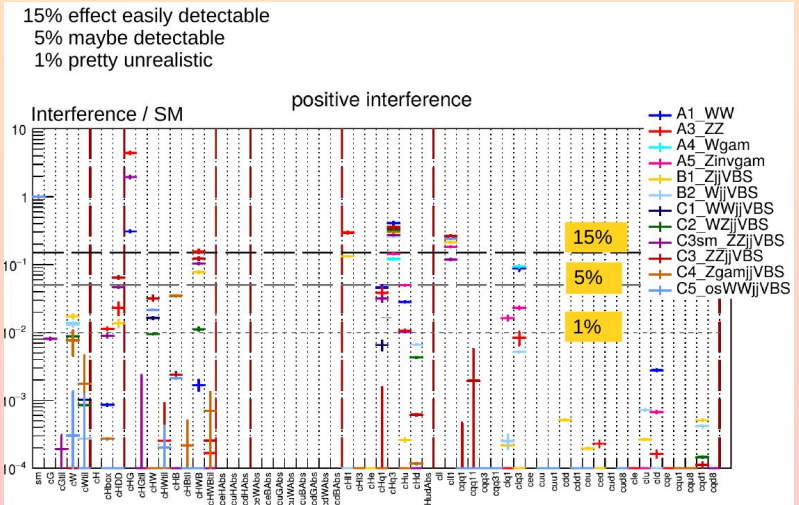
Talk by K. Lohwasser

4. Fiducial cross-section and BSM

- Recommendation for how to treat DimO6 SMEFT theory (Warsaw basis)
- Which operators interesting for which process?
  (survey using rough phase spaces)
- Use benchmark phase spaces?

R. Gomez Ambrosio,
K. Lohwasser
- C. Degrande





Summary

- Yellow Report: things are marching, expect draft **end of summer**
  - Some items need contribution (RIVET routines, MC comparisons)

- Combinations: discussions should start/continue
- Simulators show differences, sometimes even when the setup should be equivalent
  - 4 leptons: YSF and Photos yield some differences…
  - VBS comparisons using RIVET show striking differences in ssWW
  - Call for volunteers to check other processes in CMS/ATLAS/Theory comparison
    - VBF processes could be equally interesting (mjj modelling) -> esp. b/c of BDT usage -> V+jets group ?
    - ZZ -> 4l lineshape (difficult to get the contributions right, and similar issues as WW)
  - The more people can provide comparison studies, the better we can understand what is going on!