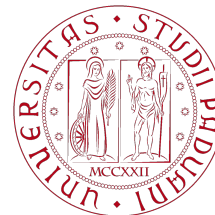


WG1 summary

1st COMETA General Meeting, İzmir (Türkiye)

01.03.2024

Giovanni Pelliccioli (MPP Garching), Ramona Gröber (Uni. & INFN Padova)



UNIVERSITÀ
DEGLI STUDI
DI PADOVA



Report on WG1 activities



116 registered members of WG1

16.4% are female/other gender, 19.0% from ITC countries, 59.5% are young researchers

Two on-line events with plenty of discussion

First WG1 online meeting - <https://indico.cern.ch/event/1338162/> - 10.Nov.2023

Topical meeting - 2 hours for 2 bosons - <https://indico.cern.ch/event/1360356/> - 17.Jan.2024

Two upcoming in-person events (topical workshops)

Effective Fiel Theory in Multiboson Production - <https://indico.cern.ch/event/1358085/> - 10-11.Jun.2024

Workshop on Vector-Boson Polarization - <https://indico.cern.ch/event/1371888/> - 23-14.Sep.2024

More information

COST action [webpage](#), COMETA [webpage](#), FosWiki page at [this link](#), Mattermost channel [here](#)

First WG1 meeting (introductory)



Effective Field Theory point of view (Ilaria Brivio)

Polarisation for multiboson production (Giovanni Pelliccioli)

Precision Physics for multiboson production (Ramona Gröber)

BSM Models for Multiboson (Jose Miguel No)

Emphasising **interplay** among various **areas of WG1** (and with **other WGs**)

2 hours for 2 bosons (topical meeting on VV/VH/HH)

VV production (Marius Wiesemann)

VLVL: polarised production (Rene Poncelet)

VH production (Stephen Jones)

HH production (Michael Spira)

Common issues

higher-order corrections **vital**

similar **issues** in computation of **massive processes** at higher order (for instance top mass renormalisation scheme uncertainty)

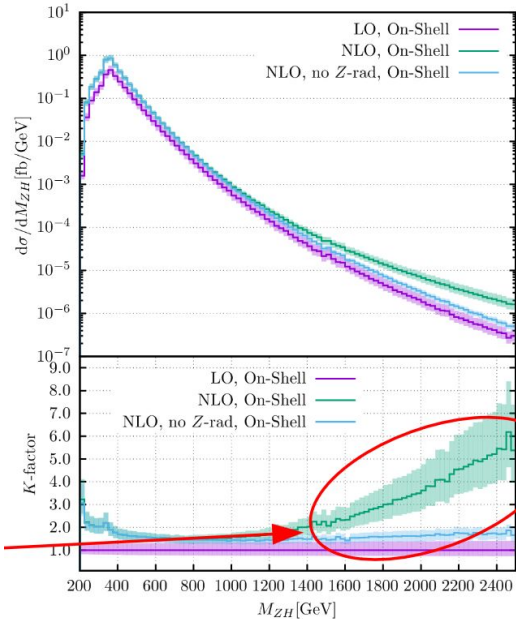
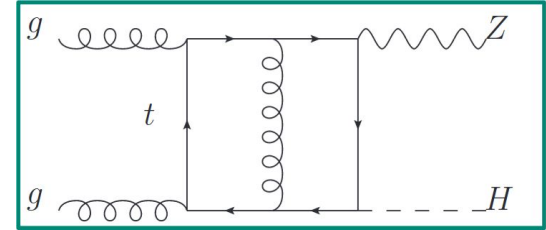
combined interpretation **within SMEFT**: one should include RGE running effects, NLO EW corrections, ...

Precision physics in ZH/ZZ/HH (talk by Marco)

Impressive improvement in precision predictions in ZH/ZZ/HH

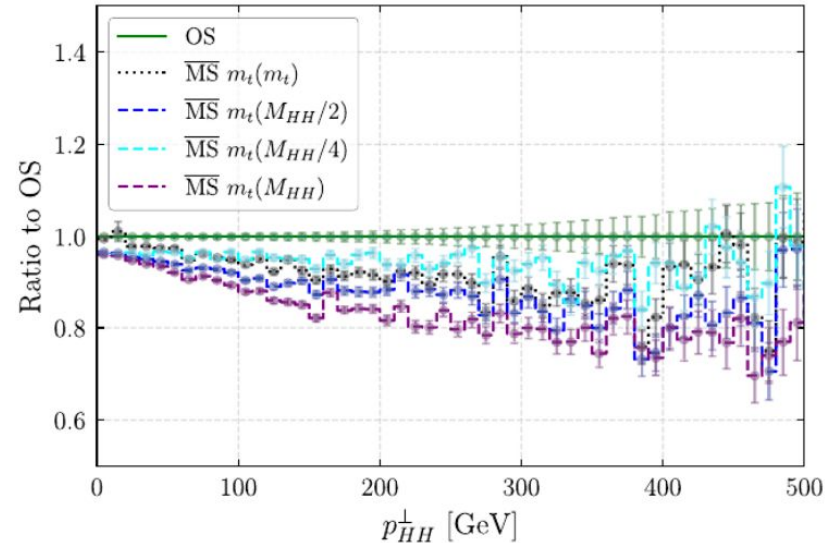
Gluon fusion components important also in ZH and ZZ

computation at higher orders is a challenging multi-scale problem



large higher order corrections at high invariant mass/ pT

gluon fusion component suffers from large top mass renormalisation scheme uncertainty that needs to be understood

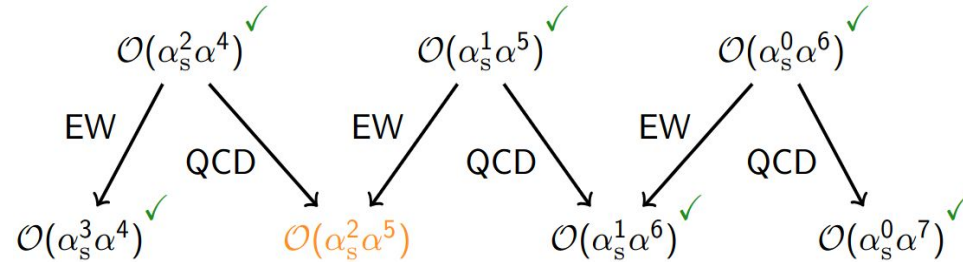


Precise VBS predictions (talk by Christopher)



VBS is one of the best probes of EWSB mechanism

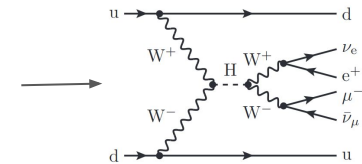
NLO off-shell program almost complete for fully leptonic



Process	W ⁺ W ⁺	W ⁺ Z	ZZ	W ⁺ W ⁻
$\sigma_{\text{NLO}}^{\alpha^7}$ [fb]	-0.2169(3)	-0.04091(2)	-0.015573(5)	-0.307(1)
$\sigma_{\text{LO}}^{\alpha^6}$ [fb]	1.4178(2)	0.25511(1)	0.097683(2)	2.6988(3)
δ^{α^7} [%]	-15.3	-16.0	-15.9	-11.4

NLO EW especially interesting (EW Sudakov-log enhancement in the tails)

Non-trivial **interplay** with **VBF-Higgs** in osWW



Next mid-term steps:

semi-leptonic decay channel (NLO challenging), **polarised VBS** (NLO involved, but within reach), **NLO matching to PS** (only available $\text{NLO}_{\text{EW}} \otimes \text{PS}_{\text{QED}}$, $\text{NLO}_{\text{QCD}} \otimes \text{PS}_{\text{QCD}}$), **EW-log resummation** (especially for high energy, automated in MG5, Sherpa, MoCaNLO), including **EFT** effects

Precise polarised predictions in SM (talk by Rene)

EWSB can be 'accessed' by extracting longitudinal-boson production rates

Several measurements by ATLAS/CMS in inc. WZ, ZZ and VBS-ssWW: **polarised-template fits**

Process	LO	NLO	NLO EW	NNLO	+ PS
pp → WW	X	X	X	X	X
pp → ZZ	X	X	X		X
pp → WZ	X	X	X		X
pp → W/Z	X	X	X	(X)	X
pp → W+j	X	X	(X)	X	
pp → Z+j	X	(X)			
pp → VH	(X)				
pol. VBS	X	X			

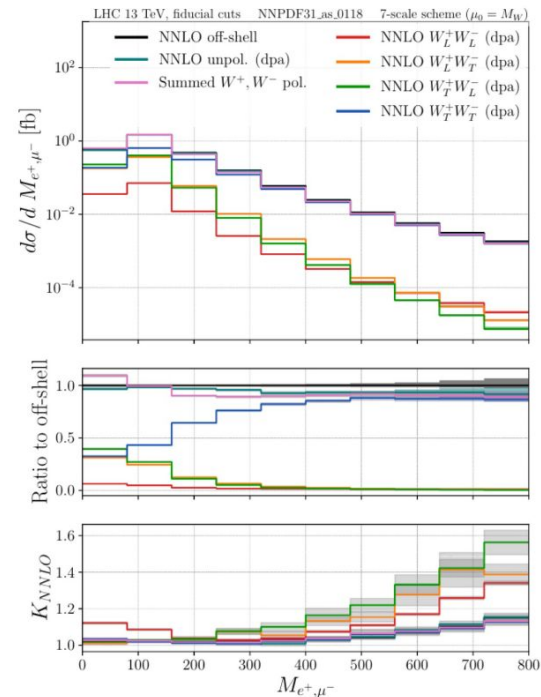
Urgent need for **higher-orders**
in **QCD & EW** coupling

different K-factors and
distribution shapes
for various pol. states!

Several recent developments for polarised SM (differential) cross sections

→ NNLO QCD for WW, NLO EW for WW (talk by Christoph), nLOPS in SHERPA (talk by Mareen), NLO EW+QCD for WZ/ZZ, NLOPS in POWHEG,

→ next 'frontier' polarised VBS @NLO



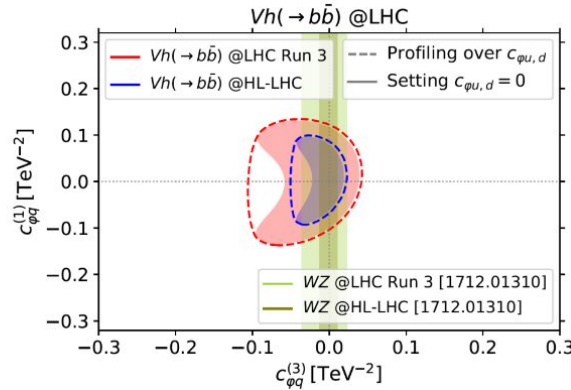
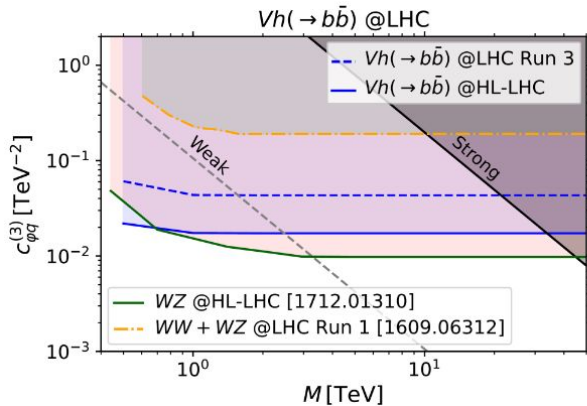
SMEFT in di/multi-boson (talk by Alejo)

VH has a rich SMEFT structure @ dim-6

Angular-observable 'resurrect' dim-6 interference in diboson

Several dim-8 operators give maximal energy growth in WV, milder effects in VH

Loop-induced diboson matters



Run-3 statistically limited

Essential to combine diboson processes to pin down flat directions (see also *Giorgio's talk*)

Next frontiers:

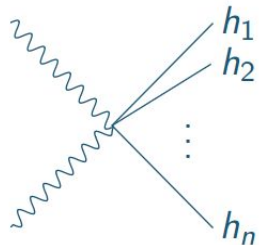
CP-odd @NLO QCD, triboson production (Eugenia's talk), NLO EW accuracy (...) for (HL)-LHC

Entanglement measurements for the FCC-ee

HEFT (vs SMEFT) in multi-Higgs (talk by Alexandre)

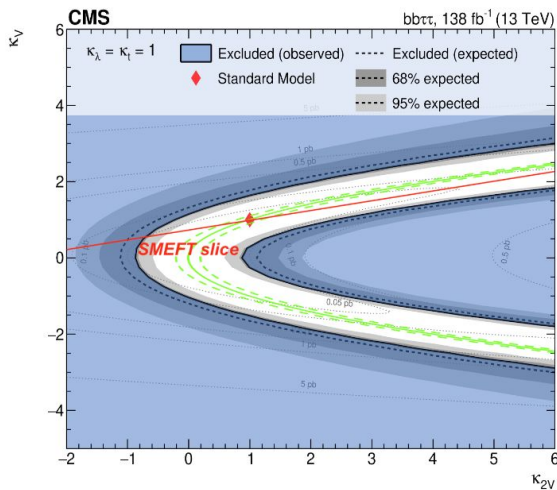
HEFT (EW Chiral Lagrangian) 'includes' SMEFT

$$\mathcal{L}_{\text{HEFT}} = \frac{1}{2} \partial_\mu h \partial^\mu h - V(h) + \frac{1}{2} \mathcal{F}(h) \partial_\mu \omega^i \partial^\mu \omega^j \left(\delta_{ij} + \frac{\omega^i \omega^j}{v^2 - \omega^2} \right)$$

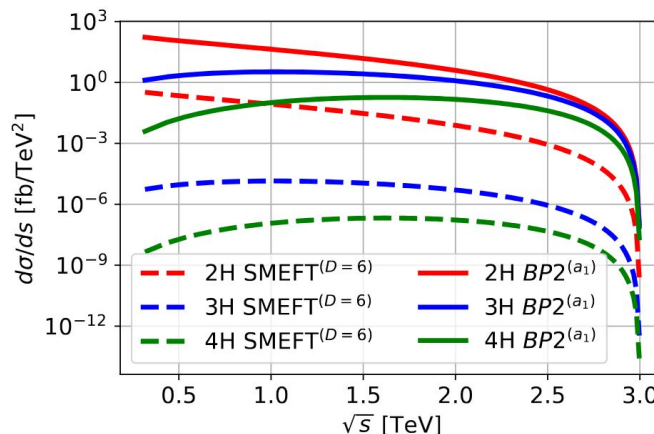


$$= -\frac{n! a_n}{2v^n} s \rightarrow \text{VBF production of multiple Higgses in HEFT can test SMEFT}$$

Approx cross sections for CLIC lepton collider in the EWBA



kV vs k2V plane in HH (bbττ decay channel)



@ 3TeV: 3/4 Higgs could signal SMEFT is not sufficient

BSM physics in di-Higgs production (talk by Francisco)



allowed values

	Type I	Type II
κ_λ	[-0.5, 1.3]	[0.6, 1.0]
λ_{hhH}	[-1.7, 1.6]	[-1.8, 1.5]

bin size and smearing can make reconstruction at HL-LHC difficult

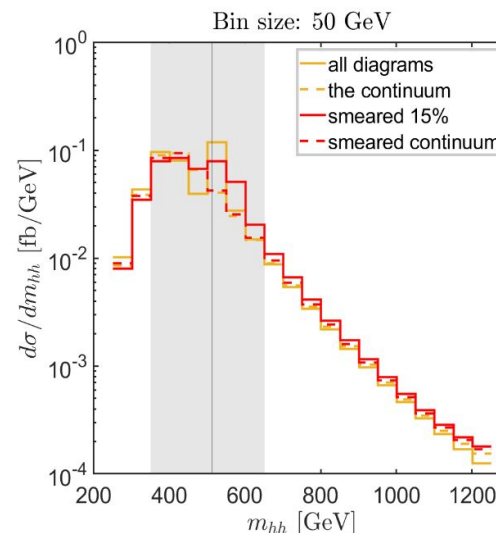
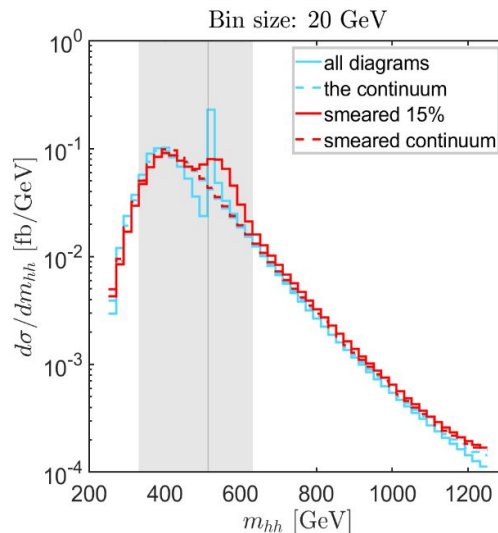
Next steps:

one-loop corrections to trilinear Higgs self-coupling even in alignment limit important to include

resonant double Higgs production possible in the 2HDM (see also Konstantin's talk for fermionic Higgs portal)

interference important with SM HH

resonant peak or peak/dip structure tells sign of λ_{hhH}



Raised points and concluding remarks

Higher orders in SM

- challenging calculation of massive loops in gluon-induced processes at two loops
- automation urgent for NLO QCD/EW corrections in complicated multi-boson processes **+WG3**
- push state-of-art accuracy for polarised predictions

SMEFT & HEFT

- combination of di(multi)boson processes within SMEFT mandatory **+WG2/3**
- needed guidance in NLO QCD event generation with SMEFT included **+WG3**
- further test SMEFT validity (vs HEFT)

Extended Higgs sectors

- focus on di-Higgs production for trilinear coupling and sensitivity to Higgs-to-BSM coupling

Keep an eye on

- machine-learning techniques (EFTs, tagging) **+WG2/3**
- entanglement observables (EFT, BSM, polarisation) **+WG3**

More discussion in the panel sessions!

Looking forward to seeing you at the next WG1 events!