WG2 Higgs properties Summary & Plans

Daniele Barducci	Roma la Sapienza & INFN Roma1
Nicolas Berger	LAPP Annecy & ATLAS
Mauro Donega	ETH Zurich & CMS
Ken Mimasu	King's College London

WG2 Higgs properties Summary & Plans

See talk by
Christophe and Alessandro

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WG2 conveners

(Exp) N. Berger, S. Heim (ATLAS) & M. Donega, G. Ortona (CMS)

(Th)   D. Barducci & K. Mimasu

<u>Changes since last meeting</u>

G. Panico -> D. Barducci - Thanks Giuliano!

WG2 subgroup

Fiducial, differential and template XS subgroup

H. Yang (ATLAS), M. Bonanomi (CMS) & F. Tackmann (Th)

<u>Changes since last meeting</u>

A. de Wit -> M. Bonanomi - Thanks Adinda, welcome Matteo!

WG2 twiki

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHWG2

WG2 meetings

https://indico.cern.ch/category/5848/

WG2 2022 activities

- κ_λ **in single Higgs - STXS 1.2**

  - Finalisation and publication of the public note   LHCHWG-2022-02

- **Simplified template cross-sections**

  - STXS in SMEFT, for CPV & towards STXS 1.3

- **CPV in Higgs interactions**

  - Round table discussion https://indico.cern.ch/event/1163954/

  - Activities split in subgroups - *"divide and conquer"*

    - Common pars and CPV benchmarks https://indico.cern.ch/event/1203658/

    - Higgs and EDM interplay https://indico.cern.ch/event/1203719/

    - Combined ttH and CP properties https://indico.cern.ch/event/1207508/
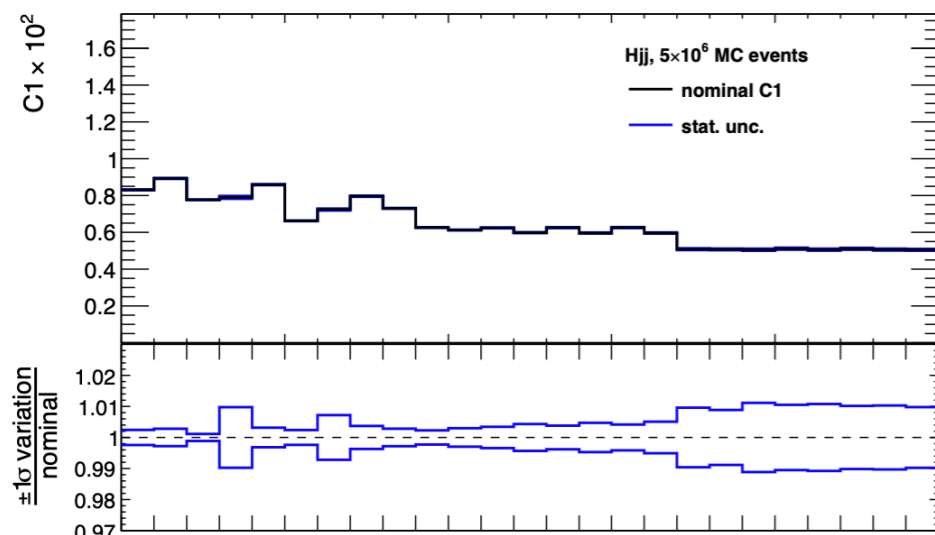
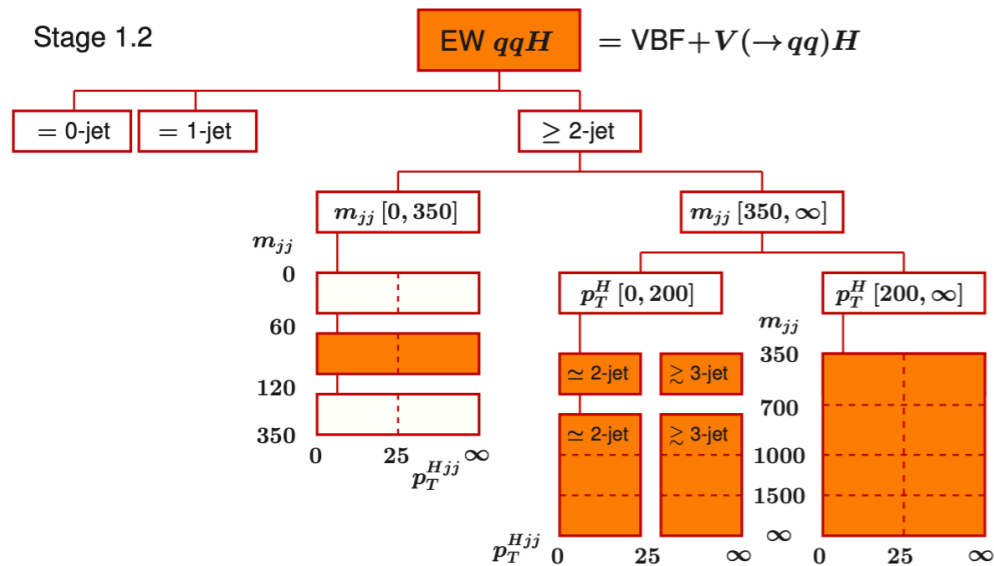   - Joint activity with WG3 - extended Higgs sectors

$$\kappa_\lambda = \frac{\lambda_3}{\lambda_3^{SM}} \simeq \frac{\lambda_3}{0.13}$$
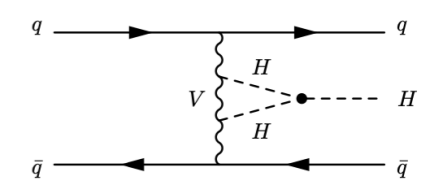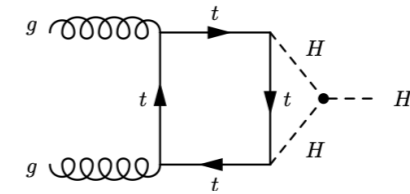
κ_λ **in single H**

κ_λ in single Higgs STXS 1.2 - complementarity with HH

Parametrization of single H xs in STXS 1.2 bins

$$\frac{\sigma^i_{NLO_{EW}}}{\sigma^i_{NLO_{EW},SM}} = \frac{Z_H^{BSM}\left\{\sigma^i_{LO,SM}\left[(\kappa_\lambda - 1)C_1^i + \kappa_i^2 K_{EW}^i\right]\right\}}{\sigma^i_{LO,SM}K_{EW}^i}$$
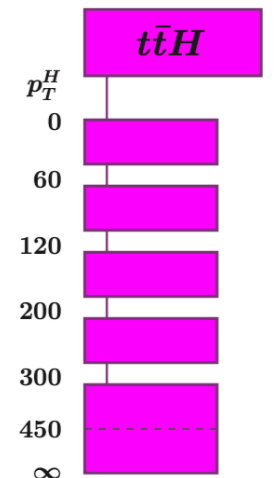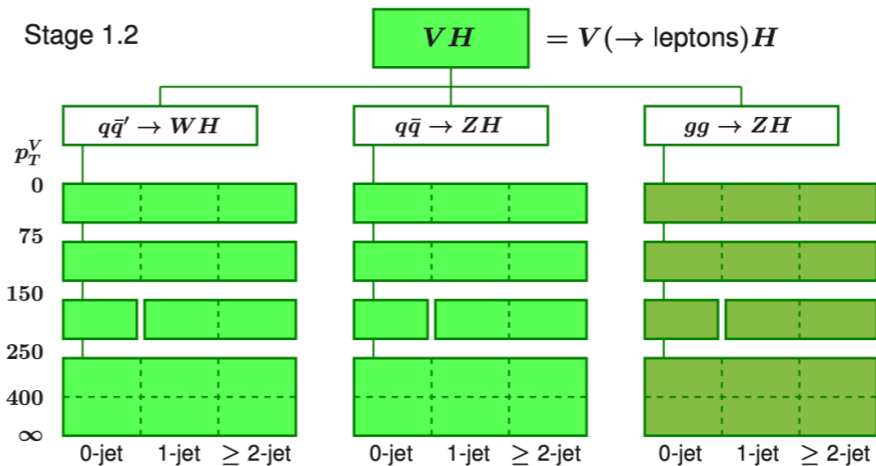
Modeling of the single-Higgs simplified template cross-sections (STXS 1.2) for the determination of the Higgs boson trilinear self-coupling
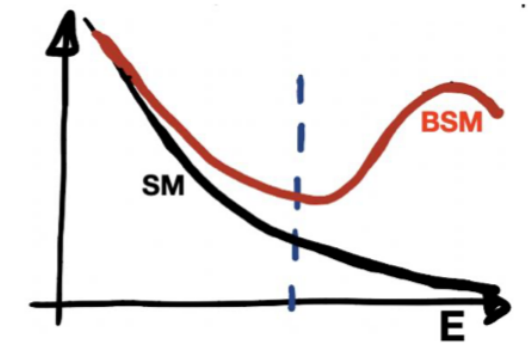
Note out on March 11th

LHCHWG-2022-02

Simplified template cross-sections and…

- STXS natural framework for **SMEFT** interpretations

  Moving towards global fits, multi-direction constraints
  Talk by Ana & Matthew review of exp. interpretation

  Future: common SMEFT parametrization for exp and th. Public note (?)

  - Efficiency: avoid double work
  - Balance between common param and cross-validation

  w/ LHC EFT WG
  this friday

- **STXS 1.2 uncertainties**

- ATLAS+CMS+TH effort for common scheme - Public doc in 2023

- Towards **STXS 1.3**

  Talk by Benedict

- Additional bins, where, for what (CPV, decays…) and how?
- Improvement on the theory side needed (predictions, MC…)
- different $\sqrt{s}$, 13 TeV vs 13.6 TeV, how to compare/combine?

  Talk by Matteo

CPV in Higgs interaction

- Large th interest, connection to EW baryogenesis
- Two kick-off meetings (so much interest!!!) to collect ideas and people

WG2 activity on CP violation in Higgs interactions: kick-off meeting (part 1)	**Dec 2021**
WG2 activity on CP violation in Higgs interactions: kick-off meeting (part 2)	**Jan 2022**

From 2021 general meeting

- Identify existing/new channels/observables sensitive to CPV
- Study how to best implement them in global analyses, e.g. STXS
- Harmonize approaches across exps in view of future combinations
- Recommendation for common pars to maximize CPV NP LHC reach

'admixture' model $\boxed{\kappa \cos\alpha + \tilde{\kappa}\sin\alpha}$ $\Leftrightarrow$ $\boxed{\begin{matrix} \tilde{C}_{HWB} & \tilde{C}_{HB} & \tilde{C}_W & \tilde{C}_{tW} & \tilde{C}_{tB} \\ \tilde{C}_{HW} & \tilde{C}_{HG} & \tilde{C}_G & \tilde{C}_{tG} & \tilde{C}_{tH} \end{matrix}}$ SMEFT

- Quantify LHC complementarity with other probes (EDMs…)

Deliverable: LHCWG recommendation note

Journal
Scipost
CERN monograph
Twiki

- Open google doc: link   [comments & input welcome]
- Les Houches style sign up system   [share & register]
- Minutes & relevant information are stored
- Contact people appointed for each sub activity

WG2 Activity: CP-violation in Higgs interactions

Proposed studies document

STXS bins for CPV	2
ttH phenomenological studies	3
Common parametrisations	4
CPV Benchmarks	5
Quantifying interplay with EDMs/low energy	6
Joint WG3 activity	7

Merged (Common parametrisations & CPV Benchmarks)

Common pars & CPV violating benchmarks
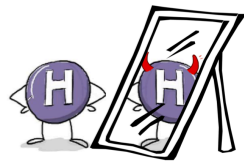
Activity with the most definite plans & goals

• Many LHC analyses testing Higgs CP properties since 2012

• Next step: **going global & enabling UV model interpretation**

• **Can WG2 help providing some guidelines?**

   - Avoid standardisation, create dictionary $\tilde{k}_f, f_{\mathrm{CP}}, \theta_{\mathrm{CPV}}$ SMEFT/HEFT

   - Menu' of "motivated" models for global interpreations

   <u>Bottom-up:</u> subset of parameters motivated by symmetries & UV patterns (Flavor symmetries, MFV, Froggart-Nielses…)
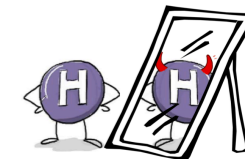
   <u>Top-down:</u> consider explicit model & identify correlations between low energy CPV couplings

• Goal: provide a note as a reference document inspired by the <u>BSM benchmark LHCWG note</u>

LHC-HXSWG-2019-006

& common parametrisations for CPV

BSM Benchmarks ~~for Effective Field Theories~~ in Higgs ~~and Electroweak~~ Physics

Activity with

- Many LHC
- Next step:
- **Can WG2**

  - Avoid s   SMEFT/HEFT

  - Menu'

  Bottom-   s &
  UV patt

  Top-dow   between
  low ene

- Goal: provi   BSM
benchmark

Contents

2023 goal

in Higgs ~~and Electroweak~~ Physics

CPV in ttH

$$\mathcal{L}_{\text{top-Yuk}} = -\frac{y_t^{\text{SM}}}{\sqrt{2}} \bar{t}(c_t + i\gamma_5 \tilde{c}_t)tH$$

$$|\mathcal{M}_{t\bar{t}H}|^2 = c_t^2 |\mathcal{M}_{t\bar{t}H}^{\text{CP-even}}|^2 + 2c_t \tilde{c}_t Re[\mathcal{M}_{t\bar{t}H}^{\text{CP-even}} \mathcal{M}_{t\bar{t}H}^{\text{CP-odd}^*}] + \tilde{c}_t^2 |\mathcal{M}_{t\bar{t}H}^{\text{CP-odd}}|^2$$

- Probably the most active topic in the LHC CPV pheno community

- Large interest, many people signed the gdoc
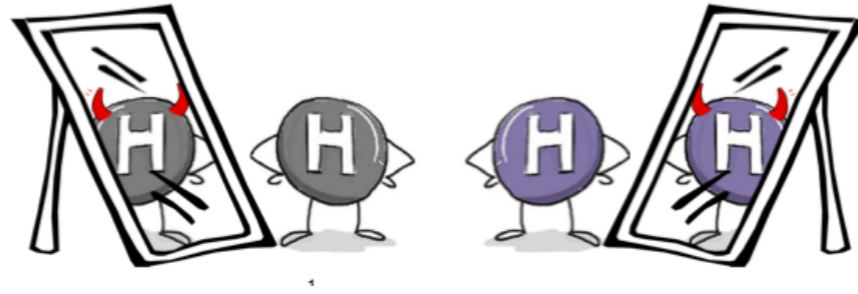
What can WG2 do? Concrete plans

- Improved MVA for CPV signal discrimination

    - Parametrized models depending on CP-angle, not only pure odd

    - CP-odd observable as input

    - Fully hadronic ttH, impact of tH…

- "Global" CPV fit exercise $\{\tilde{C}_{t\phi}, \tilde{C}_{tG}, \tilde{C}_{\phi G}\} + \{C_{t\phi}, C_{tG}, C_{\phi G}\}$

    - Combined analysis with H signal strengths

    - Other CPV modifications, e.g. dipole, CPV ggH couplings…

Joint WG2 + WG3 activity

- Higgs CPV (can be) related to extended Higgs sector -> WG3!
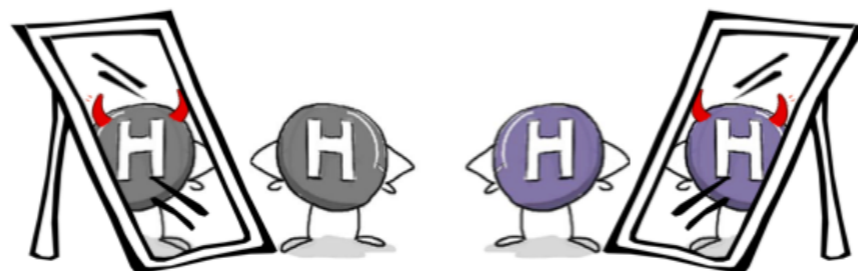

- Establish benchmark models and identify interesting parameter space regions for CPV studies

Joint WG2 + WG3 activity

- Higgs CPV (can be) related to extended Higgs sector -> WG3!

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EDM Complementarity

- Would LHC exps like to quantify the impact of data on global picture including EDM & other low energy probe?

- Sometimes LHC is more sensitive than EDMs, e.g. $h \to \mu\mu$

- Had an internal meeting with ATLAS & CMS conveners

- Conclusion: definitively interesting, but maybe a bit too early… on hold

... and 2023?

- Common pars & benchmarks for CPV

  - Note in preparation, contributors welcome

  - Call for contribution can be envisaged

- ttH CPV pheno

  - Established two concrete directions

  - Discussions and person power welcome!

  - Work on similar lines for CPV in gauge boson interactions ?

- WG2 + WG3 joint activity

  - Resume discussion in early 2023, to sharpen the goal

- EDMs and low energy probes complementarity

  - On hold for now…

Thanks you all for your work in 2022
More to be done in 2023!!!

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