On the Presentation of the LHC Higgs Results

= towards Run 2 =

Les Houches Higgs working group
BSM session, 10-19 June 2014

clearly, we (we = both experimentalists and theorists)
want to make the most out of the Higgs results

PhD comics

so far: signal strengths

decay mode (γγ, WW, ZZ, bb, ττ, ...)

$$\mu(X,Y) \equiv \frac{\sigma(X)\,\mathrm{BR}(H \to Y)}{\sigma(X_{\mathrm{SM}})\,\mathrm{BR}(H_{\mathrm{SM}} \to Y)}$$

fundamental production mode such as gg fusion (ggF), VBF, etc.

(note that μ(Y) is not sufficient because BSM contributions may affect different production modes differently!)

- The likelihood in terms of μ(X,Y) allows for reinterpretation of the results in models where the efficiency and acceptance for each (X,Y) is approximately unchanged with respect to the SM → SM tensor structure

- In experimental practice, the data related to a single decay mode H→Y are divided into different categories (or "sub-channels") ❑, in order to improve sensitivity or discrimination among the production mechanisms X.

  Example: for γγ, these include "untagged", 2-jet tagged, and lepton tagged categories, designed to be most sensitive to ggF, VBF, and VH, respectively.

BSM perspective

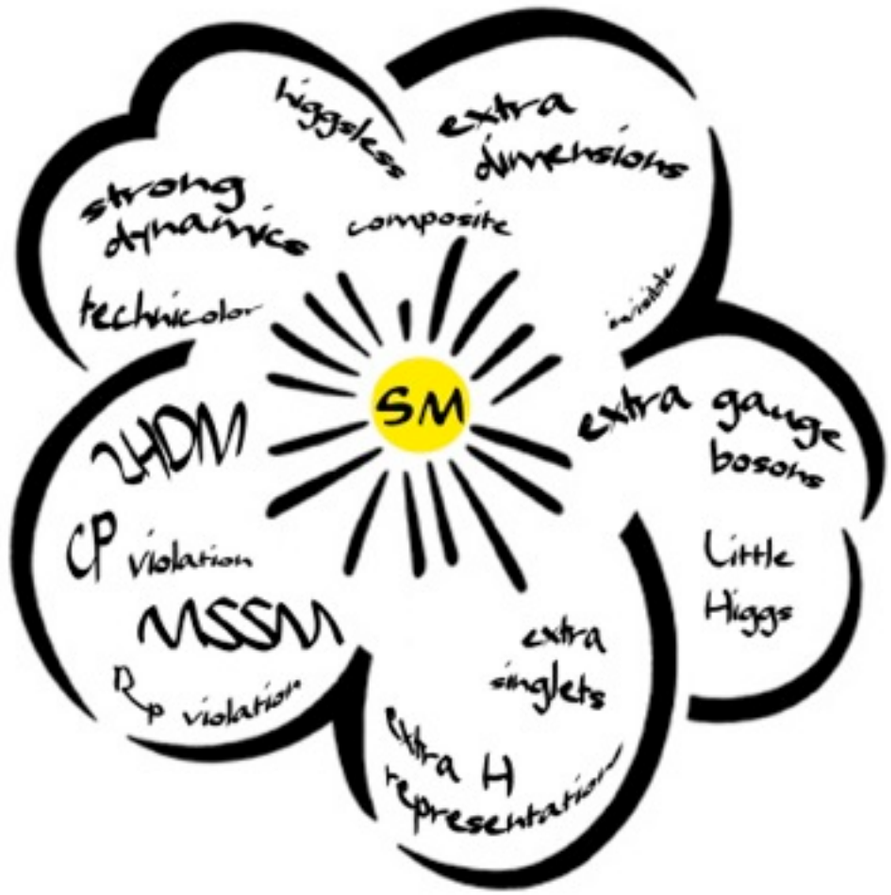
- In BSM theories, the Higgs production cross sections, decay branching ratios, kinematic distributions, and even the number of Higgs particles may differ from SM predictions.

- We have to distinguish between two classes of models by whether or not the selection efficiencies and detector acceptances for the various channels are independent of the model parameters.

- Same tensor structure as in the SM, no new production modes
  → signal strength modifiers

- New tensor structure, new prod. modes: MC simulation to compare with exp. data
  → differential distributions, form factors
  → fiducial cross sections

- See suggestions "On the presentation of the LHC Higgs results" in **1307.5865**.



arXiv:1307.5865

On the presentation of the LHC Higgs results

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(underlined: also present in session 2 of LH 2015)

Abstract:

We put forth conclusions and suggestions regarding the presentation of the LHC Higgs results that may help to maximize their impact and their utility to the whole High Energy Physics community.

Conclusions and suggestions from the workshops
"Likelihoods for the LHC Searches", 21-23 Jan 2013 at CERN,
"Implications of the 125 GeV Higgs Boson", 18-22 March 2013 at LPSC Grenoble,
and from the 2013 Les Houches "Physics at TeV Colliders" workshop.

differential distributions

- Differential distributions of decay products in Higgs n-body decays (n>2) carry valuable information about the tensor structure of the Higgs couplings.

- For example, for H → VV* → 4f decays, assuming massless fermions,

$$\mathcal{A}(H \to V_\mu^1 V_\nu^2) = \frac{1}{v}\left(F_1(p_1^2,p_2^2)2m_V^2\eta_{\mu\nu} + F_2(p_1^2,p_2^2)p_{1\nu}p_{2\mu} + F_3(p_1^2,p_2^2)\epsilon_{\mu\nu\rho\sigma}p_1^\rho p_2^\sigma\right)$$

At 0th order, $F_1 = a_1$ (constant) and $F_2 = F_3 = 0$, with $a_1 = 1$ in the SM.

At order(p^2), $F_{2,3} = a_{2,3}$ and $F_1 = a_1 + a_4(p_1^2 + p_2^2)$.

- Constraints on these and analogous form factors can help probe the structure of the HVV couplings.

- Differential distributions of the associated jets in VBF as well as polarization and kinematic distributions of the vector bosons in VH production, also carry important information.

1307.5865

fiducial cross sections

- In situations in which the kinematic distribution of the signal depends on model parameters, simple scaling of production cross sections and decay branching ratios (relative to the SM) is not sufficient → one must account for the change in the signal selection efficiency.

- In order to address this broader class of theories, we advocate the measurement of fiducial cross sections, i.e. cross sections (total or differential) for specific final states within the phase space defined by the experimental selection and acceptance cuts.

- Fiducial cross sections can be interpreted in the context of whatever model, if a) the model and b) the selection criteria defining defining the "fiducial volume" can be implemented in a MC generator.

$$\sigma_i^{\rm fid} = \sum_j A_{ij}^{\rm th} \times \sigma_j^{\rm tot}$$

↑ fiducial volume acceptance

- Also has advantage of largely separating experimental and theoretical errors.

— fiducial cross sections were heavily discussed at Les Houches 2013
— effort is required also from the theory community to develop the necessary tools

- NB this is meant in addition to, not instead of, signal strength modifiers μ.
Complementary to each other, both provide very valuable information in their own right.

LH session I

Discussion on Differential Higgs Cross Section Measurements

http://phystev.cnrs.fr/wiki/2015:groups:higgs:diff

LH session I

Discussion on Pseudo Observables/Cross Sections for Higgs Measurements

http://phystev.cnrs.fr/wiki/2015:groups:higgs:pseudoxsecs

http://phystev.cnrs.fr/wiki/2015:groups:higgs:pseudoxsecs

pseudo-FXS

- Proposal by Michael Dührssen and Frank Tackmann: as a first step, provide fiducial cross sections in specific kinematic bins
- Simple cut-based selection of ggF, VBF, VH - like production
  - jets are assumed as anti-kt 0.4, |eta|<4-5, pT>=25-30 GeV
  - bins are exclusive (in the selection, start from the lowest bin on the list)
- ggF-like:
  - 0 jet
  - ≥ 1 jet : pT(Higgs) < mH, pT(Higgs) > mH, pT(Higgs) < 200 GeV (250?)
  - ≥ 2 jets : (mjj, Δηjj cuts as for VBF), split into =2 and >=3 by a pTHjj cut
- VBF-like:
  - rest
  - ≥ 2 jets : mjj, Δηjj cuts, split into =2 and >=3 by a pTHjj cut
    "high-q^2" bin (high pTj1 ?)
- This should be in addition, not instead of, to the fully differential FXS for H→γγ and H→ZZ→4 leptons

the task at hand

- Help define sensible fiducial volumes for the first phase of Run 2 measurements
- Session I people want us to give an overview which BSM effects can be expected in which kinematic distribution
- Fiducial cross sections (FXS) should be complementary to fits of form factors and EFT operators directly done by the experimental collaborations: agree across sub-groups
- .....