# Table of Contents

**Organization**

- Conveners: 1
- Communication and meetings: 1
- Meetings: 1

**Fiducial and differential cross sections**

- **Simplified template cross sections (STXS)**: 3
  - Recommended binning: Stage 1.2: 3
  - Bin definitions: 4
  - Theory uncertainties: 5
  - Other binning: 5
  - Stage 0: 5
  - Stage 1 (Obsolete, use Stage 1.2 instead): 5
  - Stage 1.1 (Obsolete, use Stage 1.2 instead): 5
- Code: 6
- References: 6
- Run 2 results: 6
- Run 1 results: 6
- Theory: precision calculations, BSM effects, etc.: 7
Organization

Conveners

- ATLAS: Hongtao Yang (LBNL)
- CMS: Lorenzo Viliani (Firenze)
- Theory: Frank Tackmann (DESY)

Communication and meetings

- Group discussions: lhc-higgs-prop-fidSTXS[@]cern.ch
- Contact with conveners: lhc-higgs-fidSTXS-convener[@]cern.ch

Meetings

- Next meeting: TBD

Links to previous meetings on fiducial cross sections:

- Kick-off meeting 24 June 2015
- 2nd meeting: focus on experimental aspects 27 Nov 2015
- 3rd meeting: towards YR4 2 Dec 2015

Links to previous meetings on STXS:

- Les Houches 2015
- TODO: add more
Fiducial and differential cross sections

In theories beyond the SM, the properties of the 125 GeV Higgs boson may not be determined only by a simple scaling of couplings. Instead, the kinematic distributions in the various Higgs production and decay channels may be sensitively modified by BSM (incl. EFT) effects. Fiducial cross sections (FXS), i.e. cross sections, whether total or differential, for specific states within the phase space defined by experimental selection and acceptance cuts, provide a largely model-independent way to test for such deviations in kinematic distributions. In particular, differential FXS are a powerful for scrutinizing the SM Lagrangian structure of the Higgs boson interactions, including tests for new tensorial couplings, non-standard production modes, determination of effective form factors, etc.
Simplified template cross sections (STXS)

The Higgs boson coupling measurements during the LHC Run1 had as their main results measured signal strength and multiplicative coupling modifiers. Simplified template cross sections (STXS) were developed to provide a natural way to evolve these coupling measurements in the future. Compared to the Run1 measurements, the STXS framework aims to separate more cleanly measurement and interpretation steps in order to reduce in a systematic fashion the theory dependencies that are folded into the measurements (including both the dependence on theoretical uncertainties and on the underlying physics model). In addition, they provide more finely-grained measurements (and hence more information for theoretical interpretations) while at the same time allowing and benefiting from the global combination of the measurements in all decay channels.

Here is a pictorial overview of the framework. The development was initiated at Les Houches 2015. Details on the guiding principles, common object definitions, and specific bin definitions are documented in chapter III.2 of YR4 as well as the Les Houches 2015 proceedings.

The primary goals of the STXS framework are to maximize the sensitivity of the measurements while at the same time to minimize their theory dependence. Consequently, some of their defining features are:

- Inclusive over the Higgs decays
  - This allows one to perform a global combination of all decay channels
- Measure cross sections (instead of signal strengths), in mutually exclusive regions of phase space
- Measure cross sections separated into production modes (or more generally kinematic templates)
  - Allows different efficiencies/acceptances for different production modes without incurring a dependence on the SM production mode mix
  - Currently, the main SM production processes act as kinematic templates, in the future more kinematic templates can be added (e.g. for a CP-odd Higgs)
- Non-Higgs backgrounds are subtracted
  - In the future, one could add templates for BSM sensitive backgrounds (e.g. for pp->WW)
- Simplified (idealized) bin definitions abstracted from the actual measurement categories
  - Allows for some acceptance corrections
  - Analyzes can use optimized selection at reconstruction level

The measured exclusive regions of phase space, called bins for simplicity, are specific to the different production modes. Their definitions are motivated by

- Minimizing the dependence on theoretical uncertainties that are directly folded into the measurements
- Maximizing experimental sensitivity
- Isolation of possible BSM effects
- Minimizing the number of bins without loss of experimental sensitivity

Since these are competing requirements a nontrivial compromise has to be achieved. In particular, to account for the evolving experimental sensitivity the STXS bins are thus defined in stages (corresponding to increasingly fine granularity)

Recommended binning : Stage 1.2

This section describes the second update of the Stage 1 binning (Stage 1.2). This definition supersedes the Stage 1 and Stage 1.1 binning described below, and should be used by new analyses performing STXS measurements. An overview of the binning can be found here.
Bin definitions

The Rivet tool\(^\text{a}\) that performs the STXS classification has also been updated to implement the Stage 1.2 scheme. The bins defined for each production process are as follows:

- **gg H** (gluon-fusion and gg \(\to (Z \to q\bar{q}) H\))

Stage 1.2

![Diagram of gg → H](image)

PDF version

NOTE: This process is defined as the usual gluon-fusion production including gg-induced EW corrections. This includes virtual EW corrections to the \(gg \to H\) form factor as well as real EW corrections, corresponding to \(gg \to ZH \to qq H\). (The latter are very small and are typically neglected at the present level of precision.) Furthermore, the same binning should also be applied to the bbH process in analyses in which it is not distinguishable from \(gg \to H\). In this case, measurements should report the sum of \(gg \to H + bbH\) for each bin.

- **EW qqH** (VBF and \(qq \to (V \to q\bar{q}) H\))

Stage 1.2

![Diagram of EW qqH](image)

PDF version

- **VH** (qq+gg \(\to (V \to \text{leptons}) H\))

Stage 1.2

![Diagram of VH](image)

PDF version
• **ttH**

Stage 1.2

<table>
<thead>
<tr>
<th>$p_T^f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>120</td>
</tr>
<tr>
<td>200</td>
</tr>
<tr>
<td>300</td>
</tr>
<tr>
<td>$\infty$</td>
</tr>
</tbody>
</table>

PDF version

### Theory uncertainties

- **ggF**: The uncertainties are based on the "2017" scheme described in this document and implemented in this code. The scheme was developed for the Stage 1 bin definition, and updates covering new Stage 1.2 features such as the new low-pT bin ($p_T^H<10$ GeV) are currently ongoing.
- **EW qqH**: A preliminary version of the uncertainty scheme is available in this tool. The numbers include VBF production only and should be updated to also include $(V \rightarrow qq)H$.
- **VH**: The uncertainties as described in this note.
- **ttH**: Uncertainties in bins of $p_T^H$ are in preparation.

### Other binning

#### Stage 0

Stage 0 bins

#### Stage 1 (Obsolete, use Stage 1.2 instead)

Stage 1 $gg \rightarrow H$ bins

Stage 1 EW qqH bins

Stage 1 VH bins

#### Stage 1.1 (Obsolete, use Stage 1.2 instead)

This section describes an updated definition of the Stage 1 binning (Stage 1.1). This definition supersedes the one provided above, and should be used by new analyses performing STXS measurements. The changes with respect to Stage 1 are not backwards-compatible (due to the VBF process which required some reorganization). A note describing these new binnings in more detail can be found here.

This update follows from discussions at the 2018 LHCHXSWG workshop and dedicated fid/dif/STXS subgroup meetings (here and here).

The Rivet tool that performs the STXS classification has also been updated to implement the Stage 1.1 scheme.

- **gg H** (gluon-fusion and $gg \rightarrow (Z \rightarrow qq)H$)

PDF version
NOTE: This process is defined as the usual gluon-fusion production including gg-induced EW corrections. This includes virtual EW corrections to the gg → H form factor as well as real EW corrections, corresponding to gg → ZH → qq H. (The latter are very small and are typically neglected at the present level of precision.) Furthermore, the same binning should also be applied to the bbH process in analyses in which it is not distinguishable from gg → H. In this case, measurements should report the sum of gg → H + bbH for each bin.

- **EW qqH** (VBF and qq → (V → qq) H)

PDF version

- **VH** (qq+gg → V(→ leptons) H)

PDF version

**Code**

The relevant code is hosted in the STXS gitlab area:

- Classification: Rivet routines that assign STXS bin labels to a given MC event.
- VBF Uncertainties: Code computing theory uncertainty values for events in the VBF categories.

**References**

**Run 2 results**

- Measurement of fiducial, differential and production cross sections in the H → WW decay channel with 13.3 fb-1 of 13 TeV proton-proton collision data with the ATLAS detector, ATLAS-CONF-2016-067
- Study of the Higgs boson properties and search for high-mass scalar resonances in the $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$ decay channel at $\sqrt{s} = 13$ TeV with the ATLAS detector, ATLAS-CONF-2016-079
- Combined measurements of the Higgs boson production and decay rates in $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$ and $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$ final states using pp collision data at $\sqrt{s} = 13$ TeV in the ATLAS experiment, ATLAS-CONF-2016-081

**Run 1 results**

- Measurement of the transverse momentum spectrum of the Higgs boson produced in pp collisions at $\sqrt{s}=8$ TeV using the $H \rightarrow WW$ decays, CMS Collaboration, CMS-PAS-HIG-15-010
- Measurement of differential and integrated fiducial cross sections for Higgs boson production in the four-lepton decay channel in pp collisions at $\sqrt{s}=7$ and 8 TeV, CMS Collaboration, arXiv:1512.08377
- Measurement of differential cross sections for Higgs boson production in the diphoton decay channel in pp collisions at $\sqrt{s}=8$ TeV, CMS Collaboration, arXiv:1508.07819
- Constraints on non-Standard Model Higgs boson interactions in an effective field theory using differential cross sections measured in the $H \rightarrow WW$ decay channel at $\sqrt{s}=8$ TeV with the ATLAS detector, ATLAS Collaboration, arXiv:1508.02507
- Measurements of the Total and Differential Higgs Boson Production Cross Sections Combining the $H$ and $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$ Decay Channels at $\sqrt{s}=8$ TeV with the ATLAS detector, ATLAS Collaboration, Phys. Rev. Lett. 115, 091801 (2015)
Fiducial and differential cross sections of Higgs boson production measured in the four-lepton decay channel in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector, ATLAS Collaboration, Physics Letters B 738 (2014) 234-253

Measurements of fiducial and differential cross sections for Higgs boson production in the diphoton decay channel at $\sqrt{s}=8$ TeV with ATLAS, ATLAS Collaboration, JHEP09(2014)112

Theory: precision calculations, BSM effects, etc.

Selected references, certainly incomplete. Let us know to add your paper.

- High energy resummation of transverse momentum distributions: Higgs in gluon fusion, Stefano Forte, Claudio Muselli, arXiv:1511.05561
- Pushing Higgs Effective Theory to its Limits, Johann Brehmer, Ayres Freitas, David Lopez-Val, Tilman Plehn, arXiv:1510.03443
- Fiducial cross sections for Higgs boson production in association with a jet at next-to-next-to-leading order in QCD, Fabrizio Caola, Kirill Melnikov, Markus Schulze arXiv:1508.02684
- Benchmarks for Higgs Effective Theory: Extended Higgs Sectors, Martin Gorbahn, Jose Miguel No, Veronica Sanz, arXiv:1502.07352
- Resolving the Higgs-Gluon Coupling with Jets, Malte Buschman, Christoph Englert, Dorival Goncalves, Tilman Plehn, Michael Spannowsky, arXiv:1405.7651
- Complete Higgs Sector Constraints on Dimension-6 Operators, John Ellis, Veronica Sanz, Tevong You, arXiv:1404.3667
- Probing top-partners in Higgs+jets, Andrea Banfi, Adam Martin, Veronica Sanz, arXiv:1308.4771