

# Theoretical Uncertainties

There have been considerable discussions in the LHC Higgs combination group on how to treat theoretical uncertainties.

Discussions are continuing with theorists at the BNL Higgs cross section workshop this week.

The LHC Higgs cross section group has tabulated inclusive cross sections with their uncertainties. However, experiments are sensitive to cross sections with detector acceptance:

$$\sigma_{\text{vis}} = \sigma_{\text{tot}} \times f_{\text{jet}} \times A$$

A= acceptance,  $f_{\text{jet}}$ =jet veto/bin

Issues:

How to factorize uncertainties and deal with correlations?

How to estimate uncertainties on  $f_{\text{jet}}$  and A

# A Proposal for Discussion

- Take the total cross sections and their uncertainties from the CERN Yellow Report: <http://arxiv.org/abs/1101.0593>
- Take central values for  $A$  and  $f_{jet}$  from whatever MC each collaboration is using, for example, MCatNLO after pT reweighting
- Estimate acceptance (except that on jet veto/bin) uncertainties from scale, PDF+as, MC models using appropriate programs
  - independent of those on the total cross sections;
  - completely correlated between ATLAS and CMS;Remaining arguments: **linear vs quadratic combination?**

- Estimate jet veto/bin (scale) uncertainties separately because of their relative large values and potential correlations with  $\sigma_{tot}$

Unresolved issues:

- **procedure for their estimations, fixed-order MC programs?**
- **whether and how to deal with correlations?**

# Seattle Workshop

Extensive discussions with theorists (Sally Dawson, Frank Tackmann and Dieter Zeppenfeld) at last week's Higgs workshop in Seattle (hosted by University of Washington).

Theorists' preferred procedure for binned cross section

- calculate cross sections for inclusive,  $\geq 1$  and  $\geq 2$  jets
- calculate cross section in each bin as

$$\sigma_0 = \sigma_{tot} - \sigma_{\geq 1}; \quad \sigma_1 = \sigma_{\geq 1} - \sigma_{\geq 2}; \quad \sigma_2 = \sigma_{\geq 2}$$

- uncertainties are calculated

$$\Delta\sigma_0 = \sqrt{(\Delta\sigma_{tot})^2 + (\Delta\sigma_{\geq 1})^2}; \quad \Delta\sigma_1 = \sqrt{(\Delta\sigma_{\geq 1})^2 + (\Delta\sigma_{\geq 2})^2}; \quad \Delta\sigma_2 = \Delta\sigma_{\geq 2}$$

- o The argument is that there are large log terms when cut on jets that are not accounted for in the fixed order calculations;
- o h.o. effects for each inclusive jet bins should be considered independent

# Is it Practical?

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Ongoing Higgs cross section workshop at BNL this week with many more participating theorists. Hopefully a consensus can be reached...

For the time being, let's consider how to implement the recipe

- inclusive cross sections from CERN Yellow Report;
- we don't have inclusive 1 and 2-jet cross sections, it is in fact difficult to match experimental conditions because parton and detector jet  $p_T$  match without full simulation.

My view is that the recipe may be a good long-term goal, but is probably not practical short-term for EPS combination

# A Short-Term Solution?

- Determine central values of jet bin fractions  $f_i$  from MC by each experiment for its selection;

- Calculate binned cross sections as

$$\sigma_i = f_i \times \sigma_{tot}$$

- Calculate uncertainties as

$$\Delta\sigma_i = \sqrt{(\Delta f_i)^2 \sigma_{tot}^2 + f_i^2 (\Delta\sigma_{tot})^2}$$

i.e. ignore the correlations between jet fraction and total cross section, it's simpler !

- take the uncertainty on the total cross section from CERN Yellow Report;
- estimate the uncertainty on the fraction using fixed order program such as HNNLO

# “Current” Issues

- Interference with other SM process:  
Examples:  $gg \rightarrow H \rightarrow gg$ / $gg \rightarrow gg$ ,  $gg \rightarrow H \rightarrow ZZ$ / $gg \rightarrow ZZ$ , ...  
Are they important? Do we have tools?
- Jet veto/multiplicity for ggH and VBF  
Are current MC generators up to the task?  
How to estimate uncertainties?  
(see Frank’s and Dieter’s presentations)
- Theory uncertainty breakdowns and correlations  
Sources: scale, PDF,  $\alpha_s$ , others (see Sally’s talk yesterday)  
Affected: total inclusive cross sections, acceptances, shapes, ...  
Issues: how to estimate these uncertainties?  
how to combine them together?  
what are their correlations?
- Others ?

# Total Cross Sections

## LHC Higgs combination group proposal

- For every process (both signal and background), determine its scale and PDF+as uncertainties  $\Rightarrow$  CERN Yellow Report
- Scale uncertainties for different processes are assumed to be independent;
- For PDF+as uncertainties, processes are categorized based on the LO initial state
  - gluon-gluon;
  - gluon-quark, gluon-antiquark;
  - quark-quark, quark-antiquarkUncertainties for processes with the same initial states are assumed 100% correlated.

# Visible Cross Sections

Experiments are sensitive to cross sections within detector acceptance. Proposal under discussion for the combination:

$$\sigma_{\text{vis}} = \sigma_{\text{tot}} \times A \times f$$

- Take the total cross sections and their uncertainties from the CERN Yellow Report;
- Estimate acceptance (except that on jet veto/bin) uncertainties from scale, PDF+as, ... using appropriate MC programs, and assume they are independent;
- Estimate jet veto/bin (scale) uncertainties separately and take into account potential correlations with those on the total cross sections
  - For  $gg \rightarrow H$ ,  $f_0$  is largely anti-correlated,  $f_1$  and  $f_2$  are largely correlated with the total cross section
- Take differences between NLO MC generators as a systematic