Discussion:
Uncertainties for 
Signal cross sections

Massimiliano Grazzini
University of Zurich

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Goal of the workshop

Collect/address open questions raised in the process of the preparation of the EPPSU and related to precision physics at the LHC

- Reevaluate precision reach of HL-LHC
Expected uncertainties

“Optimistic scenario” S2:

- TH Uncertainties halved
- Linear combination replaced by combination in quadrature (ggF)

Very ambitious: is it realistic?
Current status: $ggF$

<table>
<thead>
<tr>
<th>$\sqrt{s}$</th>
<th>$\sigma$</th>
<th>$\delta$(theory)</th>
<th>$\delta$(PDF)</th>
<th>$\delta(\alpha_s)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 TeV</td>
<td>48.61 pb</td>
<td>$+2.08pb$ (+4.27%)</td>
<td>$\pm 0.89 pb$ ($\pm 1.85%$)</td>
<td>$+1.24pb$ (+2.59%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$-3.15pb$ (-6.49%)</td>
<td></td>
<td>$-1.26pb$ (-2.62%)</td>
</tr>
<tr>
<td>14 TeV</td>
<td>54.72 pb</td>
<td>$+2.35pb$ (+4.28%)</td>
<td>$\pm 1.00 pb$ ($\pm 1.85%$)</td>
<td>$+1.40pb$ (+2.60%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$-3.54pb$ (-6.46%)</td>
<td></td>
<td>$-1.41pb$ (-2.62%)</td>
</tr>
<tr>
<td>27 TeV</td>
<td>146.65 pb</td>
<td>$+6.65pb$ (+4.53%)</td>
<td>$\pm 2.81 pb$ ($\pm 1.95%$)</td>
<td>$+3.88pb$ (+2.69%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$-9.44pb$ (-6.43%)</td>
<td></td>
<td>$-3.82pb$ (-2.64%)</td>
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</tbody>
</table>

Linear combination of several sources of uncertainties
Current status: ggF
Current status: ggF

\[ \alpha_S(m_Z) = 0.118 \pm 0.0015 \]  \quad \text{(PDF4LHC15 and YR4)}

\[ \alpha_S(m_Z) = 0.1181 \pm 0.0011 \]  \quad \text{(PDG2018)}

Roughly speaking: relative impact of \( \alpha_S \) uncertainty doubled in the Higgs cross section

To achieve O(0.6%) precision in \( \sigma \) we need O(0.3%) precision on \( \alpha_S \)!
Other channels: possible improvements

- VBF: Current theory uncertainties at the per mille level but using structure function approach
  - computation of non factorised terms at NNLO

- VH: $gg \rightarrow ZH$ with full mass dependence

- $ttH$: signal cross section known with $O(10\%)$ uncertainties
  - NNLO needed at some point
To reach the control of theory systematics anticipated in Scenario S2 just computing one more perturbative order will not be enough!

A major step forward is required in

- PDFs
- QCD coupling $\alpha_s$
- Th/Exp cross talk
- Correlations
- Monte Carlo generators (Logarithmic accuracy, Merging matching...)

Comments
NLO: $gg \rightarrow ZH$

Despite highly accurate NNLO QCD+NLO-EW predictions still ZH not fully under control

$gg$ induced loop contribution (first appears at NNLO and leads to large uncertainties!)

Impact of $gg \rightarrow ZH$

<table>
<thead>
<tr>
<th>$\sigma$ (fb)</th>
<th>NLO</th>
<th>NNLO (DY-like)</th>
<th>NNLO</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHC8</td>
<td>$0.2820^{+2%}_{-2%}$</td>
<td>$0.2574^{+3%}_{-4%}$</td>
<td>$0.3112^{+3%}_{-2%}$</td>
</tr>
<tr>
<td>LHC14</td>
<td>$0.2130^{+10%}_{-12%}$</td>
<td>$0.1770^{+7%}_{-6%}$</td>
<td>$0.2496^{+5%}_{-2%}$</td>
</tr>
</tbody>
</table>

NLO corrections known only in large $m_t$ limit (~100%)

Altenkamp et al. (2012)