QCD predictions for Higgs physics

Laura Reina

Higgs Physics at the Tevatron and LHC, the QCD Issues
FNAL, November 09

- Introduction: Why/Where precision is needed.
- Overview of existing results.
- Answering questions (by examples).
- Conclusions and Outlook.
• The Tevatron is breaking new ground and meeting new challenges: exploring the Higgs low mass region, possible $2\sigma - 3\sigma$ evidence.  
  (→ see E. James’s and M. Verzocchi’s talks at this meeting)

• The LHC will cover the whole Higgs mass range and with high luminosity will have access to Higgs-boson precision physics.  
  (→ see J. Qian’s and A. Korytov’s talks at this meeting)

• Using the SM as a “template”, we can test our ability to pinpoint the properties of to-be-discovered scalar and pseudoscalar particles:
  ▶ identify main sources of systematic uncertainty;
  ▶ work at reducing them, both theoretically and experimentally.

• Building on solid SM ground, start exploring beyond SM scenarios in as much generality as possible, looking for most distinctive patterns and signatures of various realizations of EWSB.
Why/Where precision is needed

- The incredible physics potential of the Tevatron and LHC for Higgs-boson physics relies on our ability of providing very accurate QCD predictions (including interplay with EW corrections):
  - **Discovery**: precise prediction of signals/backgrounds;
  - **Identification**: precise extraction of parameters ($\alpha_s, m_t, M_H, y_{t,b}, M_X, y_X, \ldots$);
  - **Precision**: $\sigma_{W/Z}$ as parton luminosity monitors (PDF’s), …

- Higgs-boson physics has been an incredible playground for QCD calculations of the last decade. Many important developments came to address processes with:
  - poorly convergent perturbative corrections (Ex.: $gg \rightarrow H$)
  - several massive particles (Ex.: $Htt/Hbb$, $W/Zbb$, $ttbb$, …)
  - high multiplicity (Ex.: $VVV$, $V + 3j$, $ttbb$, …)
$M_h < 130 - 140 \rightarrow$ most difficult

Need precise theoretical understanding of both signal and background
State of the art of QCD calculations for hadronic processes

<table>
<thead>
<tr>
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<th>$2 \rightarrow 2$</th>
<th>$2 \rightarrow 3$</th>
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<td>$\alpha_s$</td>
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<td>$\alpha_s^3$</td>
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<td>LO</td>
</tr>
</tbody>
</table>

(from N. Glover)

Green light $\longrightarrow$ Done
Red light $\longrightarrow$ Still work in progress

NLO: $V + b\bar{b}/t\bar{t}, \;VV + j, \;VVV, \;H + 2j, \;t\bar{t} + j, \;V + 3j, \;t\bar{t}b\bar{b}, \ldots$

NNLO: $q\bar{q}, gg \rightarrow Q\bar{Q}$ (Czakon, Mitov, Moch: analytical for $m_Q^2 \ll s$, exact numerical estimate (06-08)), $q\bar{q} \rightarrow W^+W^-$ (Chachamis, Czakon: at $O(m_W^2/s)$ (08))
(plus: NNLO splitting functions (Moch, Vermaseren, Vogt (04))).
Why pushing the Loop Order . . .

- **Stability and predictivity of theoretical results**, since less sensitivity to unphysical renormalization/factorization scales. First reliable normalization of total cross-sections and distributions.

- **Physics richness**: more channels and more partons in final state, i.e. more structure to better model (in perturbative region):
  - → differential cross-sections, exclusive observables;
  - → jet formation/merging and hadronization;
  - → initial state radiation.

- **First step towards matching with algorithms that resum particular sets of large corrections in the perturbative expansion**: resummed calculations, parton shower Monte Carlo programs.
Main challenges . . .

- **Multiplicity and Massiveness** of final state: complex events leads to complex calculations. For a $2 \to N$ process one needs:
  - calculation of the $2 \to N + 1$ (NLO) or $2 \to N + 2$ real corrections;
  - calculation of the 1-loop (NLO) or 2-loop (NNLO) $2 \to N$ virtual corrections.

- **Flexibility of NLO/NNLO calculations via Automation**:
  - algorithms suitable for automation are more efficient and force the adoption of standards;
  - faster response to experimental needs (think to the impact of projects like MCFM).

- **Matching to Parton Shower Monte Carlos at NLO**.
  - instead of correcting NLO parton level calculation to match the hadron level, shower with NLO precision!
NLO: challenges have largely been faced and enormous progress has been made

- several independent codes based on traditional FD’s approach
- several NLO processes collected and viable in MFCM (→ interfaced with FROOT) [Campbell, Ellis]
- Enormous progress towards automation:
  - Virtual corrections: new techniques based on unitarity methods and recursion relations
    ▶ BlackHat [Berger, Bern, Dixon, Febres Cordero, Forde, Ita, Kosower, Maitre]
    ▶ Rocket+MCFM [Ellis, Giele, Kunszt, Melnikov, Zanderighi]
    ▶ HELAC+CutTools [Bevilacqua, Czakon, van Harmeren, Papadopoulos, Pittau, Worek]
  - Real corrections: based on Catani-Seymour Dipole subtraction or FKS subtraction
    ▶ Sherpa [Gleisberg, Krauss]
    ▶ Madgraph (MadDipole) [Frederix, Gehrmann, Greiner]
    ▶ Madgraph (MadFKS) [Hasegawa, Moch, Uwer]
• interface to parton shower well advanced:
  ▶ MC@NLO [Frixione, Webber, Nason, Frederix, Maltoni, Stelzer]
  ▶ POWHEG [Nason, Oleari, Alioli, Re]

When is NLO not enough?

• When NLO corrections are large, to test the convergence of the perturbative expansion. This may happen when:
  → processes involve multiple scales, leading to large logarithms of the ratio(s) of scales;
  → new parton level subprocesses first appear at NLO;
  → new dynamics first appear at NLO;
  → …

• When truly high precision is needed (very often the case!).

• When a really reliable error estimate is needed.
<table>
<thead>
<tr>
<th>Higgs process</th>
<th>$\sigma_{NLO,NNLO}$ (QCD only)</th>
</tr>
</thead>
</table>
C.J.Glosser et al., JHEP (2002); V.Ravindran et al., NPB 634 (2002)  
D. de Florian et al., PRL 82 (1999)  
C.Anastasiou, K.Melnikov, NPB 646 (2002) (NNLO)  
V.Ravindran et al., NPB 665 (2003) (NNLO)  
S.Catani et al. JHEP 0307 (2003) (NNLL)  
G.Bozzi et al., PLB 564 (2003), NPB 737 (2006) (NNLL)  
| $q\bar{q} \to (W, Z)H$ | T.Han, S.Willenbrock, PLB 273 (1991)  
| $q\bar{q} \to q\bar{q}H$ | T.Han, G.Valencia, S.Willenbrock, PRL 69 (1992)  
| $q\bar{q}, gg \to t\bar{t}H$ | W.Beenakker et al., PRL 87 (2001), NPB 653 (2003)  
| $q\bar{q}, gg \to b\bar{b}H$ | S.Dittmaier, M.Krämer, M.Spira, PRD 70 (2004)  
S.Dawson et al., PRD 69 (2004), PRL 94 (2005) |
| $g\bar{b}(\bar{b}) \to b(\bar{b})H$ | J.Campbell et al., PRD 67 (2003) |
| $b\bar{b} \to (b\bar{b})H$ | D.A.Dicus et al. PRD 59 (1999); C.Balasz et al., PRD 60 (1999).  
SM Higgs-boson production: theoretical precision at a glance . . .

QCD predictions for total hadronic cross sections of Higgs-boson production processes ($\mu_R/\mu_F$ scale dependence only, PDF’s uncertainties not included)

Still, much more to do: study the effect of QCD corrections on distributions, exclusive channels, background processes, . . .
NLO: Recently completed calculations (since Les Houches 2005): all relevant to Higgs-boson physics!

<table>
<thead>
<tr>
<th>Process ((V \in {Z, W, \gamma}))</th>
<th>Calculated by</th>
</tr>
</thead>
<tbody>
<tr>
<td>(pp \rightarrow V+2) (\text{jets}(b))</td>
<td>Campbell, Ellis, Maltoni, Willenbrock (06)</td>
</tr>
<tr>
<td>(pp \rightarrow Vb\bar{b})</td>
<td>Febres Cordero, Reina, Wackeroth (07-08)</td>
</tr>
<tr>
<td>(pp \rightarrow VV+\text{jet})</td>
<td>Dittmaier, Kallweit, Uwer ((WW+\text{jet})) (07)</td>
</tr>
<tr>
<td>(pp \rightarrow VV+2) (\text{jets})</td>
<td>Campbell, Ellis, Zanderighi ((WW+\text{jet+decay})) (07)</td>
</tr>
<tr>
<td>(pp \rightarrow VV)</td>
<td>Binoth, Karg, Kauer, Sanguinetti (09)</td>
</tr>
<tr>
<td>(pp \rightarrow VVV)</td>
<td>Bozzi, Jäger, Oleari, Zeppenfeld ((\text{via WBF})) (06-07)</td>
</tr>
<tr>
<td>(pp \rightarrow H+2) (\text{jets})</td>
<td>Lazopoulos, Melnikov, Petriello (\text{ZZZ}) (07)</td>
</tr>
<tr>
<td>(pp \rightarrow H+2) (\text{jets})</td>
<td>Binoth, Ossola, Papadopoulos, Pittau ((WWZ, WZZ, WWW)) (08)</td>
</tr>
<tr>
<td>(pp \rightarrow H+3) (\text{jets})</td>
<td>Hankele, Zeppenfeld ((WWZ \rightarrow 6) leptons, full spin correlation) (07)</td>
</tr>
<tr>
<td>(pp \rightarrow t\bar{t}+\text{jet})</td>
<td>Campbell, Ellis, Zanderighi ((\text{NLO QCD to } gg\text{ channel})) (06)</td>
</tr>
<tr>
<td>(pp \rightarrow t\bar{t}Z)</td>
<td>Ciccolini, Denner, Dittmaier ((\text{NLO QCD+EW to WBF channel})) (07)</td>
</tr>
<tr>
<td>(gg \rightarrow WW)</td>
<td>Figy, Hankele, Zeppenfeld ((\text{large } N_c)) (07)</td>
</tr>
<tr>
<td>(gg \rightarrow HH, HHH)</td>
<td>Dittmaier, Uwer, Weinzierl (07), Ellis, Giele, Kunszt (08)</td>
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<tr>
<td>(gg \rightarrow t\bar{t}\ b\bar{b})</td>
<td>Lazopoulos, Melnikov, Petriello (08)</td>
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<tr>
<td>(gg \rightarrow t\bar{t} b\bar{b})</td>
<td>Binoth, Ciccolini, Kauer, Kramer (06)</td>
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<tr>
<td>(pp \rightarrow V+3) (\text{jets})</td>
<td>Binoth, Karg, Kauer, Rückl (06)</td>
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<td>(pp \rightarrow t\bar{t} b\bar{b})</td>
<td>Bredenstein et al., Bevilacqua et al. (09)</td>
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Still, many questions were raised at this workshop . . .

- What theory uncertainties should be included as acceptance uncertainties when setting limits on a cross section?
- Should the factorization/renormalization scales be varied separately or together?
- How are these higher order predictions related to the LO event generators that one most often uses?
- How to deal with higher order differential distributions?
- Using NLO (NNLO) calculations to provide best LO (NLO) estimates for multi-parton final states: best scale choice? impact of jet choice?
- What is the impact of jet vetoing on the theoretical uncertainty for a signal/background cross section?
- How to handle the uncertainty on processes that can be calculated using a Fixed or Variable Flavor Scheme (FFS/VFS)?
- Many more on Joey’s list!
No unique or simple answer . . .

Some guiding principles:

- reduce the dependence on unphysical scales (renorm./fact. scale);
- have the perturbative expansion of physical observables (inclusive $\sigma$, distributions, . . .) to show a well behaved convergence.

Several possible steps:

- add enough higher order corrections (NLO, NNLO) till: scale dependence improves, no large next order corrections expected;
- look for recurrent large contributions that may spoil convergence;
- find the best expansion parameter ($\alpha_s$, $\alpha_s$ times large logarithms, . . .);
- using scaling properties, resum large scale dependent corrections;
- find the best choice of unphysical scales to avoid generating large logarithmic corrections at all orders;
- study the effect of cuts and vetos.
Interesting to look at some examples, right from Higgs physics.
**Ex. 1**: $gg \rightarrow H$, main production mode (with $H \rightarrow \gamma\gamma, W^+W^-, ZZ$) … large K-factors, scale dependence, resummations, and more.

NLO QCD corrections calculated exactly and in the $m_t \to \infty$ limit: perfect agreement even for $M_H >> m_t$.

\[ \Downarrow \]

Dominant soft dynamics do not resolve the Higgs boson coupling to gluons

\[ L_{\text{eff}} = \frac{H}{4v} C(\alpha_s) G^{\alpha\mu\nu} G_{\mu\nu} \]

where, including NLO and NNLO QCD corrections:

\[ C(\alpha_s) = \frac{1}{3} \frac{\alpha_s}{\pi} \left[ 1 + c_1 \frac{\alpha_s}{\pi} + c_2 \left( \frac{\alpha_s}{\pi} \right)^2 + \cdots \right] \]
Fixed order NNLO:

- very large corrections in going LO → NLO (K=1.7-1.9) → NNLO (K=2-2.2);
- perturbative convergence LO → NLO (70%) → NNLO (30%): residual 15% theoretical uncertainty.
- Tevatron case: still some tension.

[Harlander, Kilgore (02)]
Resumming effects of soft radiation ...

Theoretical uncertainty reduced to:

\[ \rightarrow \approx 10\% \text{ perturbative uncertainty, including the } m_t \to \infty \text{ approximation.} \]

\[ \rightarrow \approx 10\% \text{ (estimated) from NNLO PDF’s (now existing!)}. \]

But ... recent update shows that: Going from MRST2002 to MSTW2008 greatly affects the Tevatron/LHC cross section: from \( 9\% / 30\% \text{ (} M_H = 115 \text{ GeV) to } -9\% / +9\% \text{ (} M_H = 200 / 300 \text{ GeV) !} \)
Resumming effects of soft radiation for $q_T^H$ spectrum ...

large $q_T \xrightarrow{q_T > M_H}$

perturbative expansion in $\alpha_s(\mu)$

small $q_T \xrightarrow{q_T \ll M_H}$

need to resum large $\ln(M_H^2/q_T^2)$

residual uncertainty:

LO-NLL: 15-20%

NLO-NNLL: 8-20%

[Bozzi, Catani, De Florian, Grazzini (04-08)]
Large $K$ factors interpreted in SCET . . .

. . . as mainly due to large $(\alpha_s C_A \pi)^n$ terms arising from double logarithmic terms in the gluon form factor. They can be resummed using effective theory techniques.

$\sqrt{s} = 14$ TeV

<table>
<thead>
<tr>
<th>$m_H$ (GeV)</th>
<th>100</th>
<th>120</th>
<th>140</th>
<th>160</th>
<th>180</th>
<th>200</th>
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<tbody>
<tr>
<td>$\sigma$ (pb)</td>
<td>90</td>
<td>70</td>
<td>50</td>
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<td>10</td>
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$G_{\mu\nu}G^{\mu\nu} \leftrightarrow$ SCET operators

\[ \rightarrow \text{improved convergence} \]
\[ \rightarrow \text{sizable effects: 13\% (Tevatron), 8\% (LHC)} \]

[Ahrens, Becher, Neubert, Yang (09)]
Exclusive NNLO results: $gg \rightarrow H, H \rightarrow \gamma\gamma, WW, ZZ$

Extension of (IR safe) subtraction method to NNLO

$\rightarrow$ HNNLO\textsuperscript{[Catani,Grazzini (05)]}

$\rightarrow$ FEHiP \textsuperscript{[Anastasiou,Melnikov,Petriello (05)]}

Essential tools to reliably implement experimental cuts/vetos.

jet veto (to enhance $H \rightarrow WW$ signal with respect to $t\bar{t}$ background) seems to improve perturbative stability of $y$-distribution $\rightarrow$ jet veto is removing non-NNLO contributions.
Full fledged ($gg \to H \to W^+W^- \to l^+\nu l^-\bar{\nu}$)

The magnitude of higher order corrections varies significantly with the signal selection cuts.

[Anastasiou, Dissertori, Stöckli (07)]
$gg \to H$ implemented in MC@NLO and POWHEG

$\rightarrow$ general good agreement with PYTHIA;
$\rightarrow$ comparison MC@NLO vs POWHEG understood;
$\rightarrow$ comparison with resummed NLL and NNLL results under control.

[Nason, Oleari, Alioli, Re]
Ex. 2: $p\bar{p}, pp \rightarrow b\bar{b}H$: hints of new physics?

4FNS vs 5FNS ...

b-quarks identification requires tagging ($p_T^b$ and $\eta^b$ cuts): **exclusive** (1 b-, 2 b-tags) vs **inclusive** (1 b-, 0 b-tags) cross section.

- **Exclusive modes** have smaller cross section, but also smaller background and they measure the bottom-quark Yukawa coupling unambiguously.

- **Inclusive modes** enhanced by large collinear $\ln(\mu^2_H/m_b^2)$ arising in the PS integration of untagged $b$-quarks in $gg \rightarrow b\bar{b}H$

They can be resummed by introducing a $b$-quark PDF:

$$b(x, \mu) = \frac{\alpha_s(\mu)}{2\pi} \log \left( \frac{\mu^2}{m_b^2} \right) \int_x^1 \frac{dy}{y} P_{qg} \left( \frac{x}{y} \right) g(y, \mu)$$
• Semi-inclusive and inclusive cross sections: 2 approaches
  → Use $q\bar{q}, gg \rightarrow b\bar{b}h$ (at NLO) → 4FNS
    imposing tagging cuts on only one or no final state $b$ quarks.
  → Use $b$-quark PDF, resumming the large collinear logs → 5FNS

$\begin{array}{c}
\begin{tikzpicture}[baseline=12,thick,scale=0.75]
\draw[->] (0,0) -- (1,0) node [midway,above] {$g$};
\draw[->] (1,0) -- (2,0) node [midway,above] {$b$};
\draw[->] (2,0) -- (3,0) node [midway,above] {$h$};
\draw[->] (3,0) -- (4,0) node [midway,above] {$b$};
\end{tikzpicture}
\end{array} \quad \begin{array}{c}
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\draw[->] (3,0) -- (4,0) node [midway,above] {$b$};
\end{tikzpicture}
\end{array}
\rightarrow 1 \text{ b-tag} \\
(bg \rightarrow bH)
\end{array}

$\begin{array}{c}
\begin{tikzpicture}[baseline=12,thick,scale=0.75]
\draw[->] (0,0) -- (1,0) node [midway,above] {$b$};
\draw[->] (1,0) -- (2,0) node [midway,above] {$h$};
\draw[->] (2,0) -- (3,0) node [midway,above] {$\bar{b}$};
\end{tikzpicture}
\end{array} \quad \begin{array}{c}
\begin{tikzpicture}[baseline=12,thick,scale=0.75]
\draw[->] (0,0) -- (1,0) node [midway,above] {$\bar{b}$};
\draw[->] (1,0) -- (2,0) node [midway,above] {$h$};
\draw[->] (2,0) -- (3,0) node [midway,above] {$b$};
\end{tikzpicture}
\end{array}
\rightarrow 0 \text{ b-tags} \\
(\bar{b}b \rightarrow H)
\end{array}$

Perturbative series ordered in Leading and SubLeading powers of $\alpha_s \ln(\mu_H^2/m_b^2)$.

→ Expect consistence at higher order when comparing $q\bar{q}, gg \rightarrow b\bar{b}H$ (NLO) to
  ▶ $b\bar{b} \rightarrow H$ (NNLO) (no $b$-tag)
    [R.Harlander, W.Kilgore; D.Dicus, T.Stelzer, Z.Sullivan, S.Willenbrock]
  ▶ $bg \rightarrow bH$ (NLO) (one $b$-tag)
    [J.Campbell, R.K.Ellis, F.Maltoni, S.Willenbrock]
Inclusive cross sections in the MSSM: 4FNS vs 5FNS

\[ \sigma_{\text{NLO}} \text{ [pb]} \] Tevatron, \( \sqrt{s} = 1.96 \) TeV

\[ \sigma_{\text{NLO}} \text{ [pb]} \] LHC, \( \sqrt{s} = 14 \) TeV

[\text{Dawson, Jackson, L.R., Wackeroth}]
Ex. 3: $W + 1 b$-jet: crucial background for $WH$ production

Combining 4FNS and 5FNS at NLO: best theoretical prediction

[Campbell, Ellis, Febres Cordero, Maltoni, L.R., Wackeroth, Willenbrock (09)]

Consistently combine 4FNS ($m_b \neq 0$) and 5FNS ($m_b = 0$) at NLO in QCD:

1. $qq' \rightarrow Wb\bar{b}$ at tree level and one loop ($m_b \neq 0$)
2. $qq' \rightarrow Wb\bar{b}g$ at tree level ($m_b \neq 0$)
3. $bq \rightarrow Wbq'$ at tree level and one loop ($m_b = 0$)
4. $bq \rightarrow Wbq'g$ and $bg \rightarrow Wbq'\bar{q}$ at tree level ($m_b = 0$)
5. $gq \rightarrow Wb\bar{b}q'$ at tree level ($m_b \neq 0$) → avoiding double counting:

$\rightarrow$ indeed: a fully consistent NLO 5FNS calculation (S-ACOT scheme).
- improved scale dependence: NLO corrections to $gq \rightarrow Wb\bar{b}q'$ partially included;
- need to keep $m_b \neq 0$ for final state $b$ quarks (one $b$ quark has low $p_T$)

- four signatures studied: exclusive/inclusive, with single and double-$b$ jets, using $p_T^j > 15$ GeV, $|\eta^j| < 2 - 2.5$, cone algorithm with $\Delta R = 0.7$:
  - $Wb$, $W(b\bar{b})$ (exclusive)
  - $Wb$ and $Wb + j$, $W(b\bar{b})$ and $W(b\bar{b}) + j$ (inclusive)

  which can be combined to obtain different backgrounds, ...
- both contributions play important complementary roles (Tevatron/LHC, inclusive/exclusive);
- NLO results at a glance:

<table>
<thead>
<tr>
<th>Collider</th>
<th>Exclusive cross sections (pb)</th>
<th>Inclusive cross sections (pb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$Wb$</td>
<td>$W(b\bar{b})$</td>
</tr>
<tr>
<td>TeV $W^+(=W^-)$</td>
<td>8.02+0.62[-0.05]=8.64</td>
<td>3.73-0.02[-0.02]=3.71</td>
</tr>
<tr>
<td>LHC $W^+$</td>
<td>40.0+48.4[22.6]=88.4</td>
<td>22.7+11.7[11.7]=34.4</td>
</tr>
<tr>
<td>LHC $W^-$</td>
<td>29.8+29.4[12.6]=59.2</td>
<td>17.2+6.5[6.5]=23.7</td>
</tr>
</tbody>
</table>

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<tr>
<td></td>
<td>$Wb + X$</td>
</tr>
<tr>
<td>TeV $W^+(=W^-)$</td>
<td>11.77+2.40[0.77]=14.17</td>
</tr>
<tr>
<td>LHC $W^+$</td>
<td>53.6+136.1[68.9]=189.7</td>
</tr>
<tr>
<td>LHC $W^-$</td>
<td>39.3+88.2[44.6]=127.5</td>
</tr>
</tbody>
</table>

→ first number: Processes 1 + 2 (pure 4FNS)
→ second number: Processes 3 + ⋯ + 5 (pure 5FNS plus $qg \rightarrow Wb\bar{b} + q'$)
→ number in square brackets: Process 5 alone ($qg \rightarrow Wb\bar{b} + q'$)
Comparison with CDF measurement: a puzzle?

CDF Note 9321 (arXiv:0909.1505):

\[ \sigma_{b-\text{jet}}(W + b\text{jets}) \cdot Br(W \to l\nu) = 2.74 \pm 0.27(\text{stat}) \pm 0.42(\text{syst}) \text{ pb} \]

[Neu, Thomson, Heinrich]

From our \(W + 1b\) calculation:

[Campbell, Febres Cordero, L.R.]

\[ \sigma_{b-\text{jet}}(W + b\text{jets}) \cdot Br(W \to l\nu) = 1.22 \pm 0.14 \text{ pb} \]

For comparison:

ALPGEN prediction: 0.78 pb
PYTHIA prediction: 1.10 pb
Conclusions and Outlook

• Enormous QCD activity for Higgs physics in the past decade: brought incredible progress, raised new questions.

• Now possible to answer questions like:
  
  • How to reliably estimate the theoretical error?
  • How to use existing NLO/NNLO QCD calculations?

• We have just scratched the surface: More discussion will come through this workshop!