HARD SCATTERING AND ELECTROWEAK CORRECTIONS AT THE LHC

J.H. Kühn

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   2. $V + \text{jet}$
   3. $W^+W^-$

III. QED Corrections; QED & PDFs

IV. $W,Z$ Radiation; Compensations?

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I. Introduction

"Typical" size of electroweak corrections: \( \frac{\alpha_{\text{weak}}}{\pi} \approx 10^{-2} \)

**new aspects at LHC:** \( \sqrt{s} \approx 1-2\text{TeV} \gg M_{W,Z} \)

strong enhancement of negative corrections

one-loop example: massive U(1)

\[
\Rightarrow \text{Born} \ast \left[ 1 + \frac{\alpha}{4\pi} \left( -\ln^2 \frac{s}{M^2} + 3 \ln \frac{s}{M^2} - \frac{7}{2} + \frac{\pi^2}{3} \right) \right]
\]

<table>
<thead>
<tr>
<th>( \frac{s}{M^2} )</th>
<th>( -\ln^2 \frac{s}{M^2} )</th>
<th>( +3 \ln \frac{s}{M^2} )</th>
<th>( -\frac{7}{2} + \frac{\pi^2}{3} )</th>
<th>( \Sigma )</th>
<th>( \ast 4 \frac{\alpha_{\text{weak}}}{4\pi} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \left( \frac{1000}{80} \right)^2 )</td>
<td>(-25.52)</td>
<td>(+15.15)</td>
<td>(-0.21)</td>
<td>(-10.6)</td>
<td>(-13%)</td>
</tr>
<tr>
<td>( \left( \frac{2000}{80} \right)^2 )</td>
<td>(-41.44)</td>
<td>(+19.31)</td>
<td>(-0.21)</td>
<td>(-22.3)</td>
<td>(-27%)</td>
</tr>
</tbody>
</table>

(four-fermion cross section \( \Rightarrow \text{factor 4} \))
• leading log$^2$ multiplied by $\text{(charge)}^2 = I(I + 1) = \begin{cases} 
\frac{3}{4} & I = \frac{1}{2} \\
\frac{2}{I} & I = 1 
\end{cases}$

$\Rightarrow$ further enhancement for W-pairs by nearly factor 2.

• important subleading logarithms (NLL+...)

• One-loop up to $\mathcal{O}(30\%) \rightarrow$ two-loop terms may be relevant

• interplay between electroweak and QCD corrections

• important differences between fermions and electroweak gauge bosons

• important differences between long. and transverse gauge bosons ($I = 1/2$ vs. $I = 1$)
II. One-Loop Results

1. Top and Bottom Pair Production


(Related Results:
Bernreuther, Fücker, Si
Moretti, Holten, Ross)
$q \bar{q} \rightarrow t \bar{t}$:

\[
\sim \mathcal{O}(\alpha_s)
\]

no interference with

\[
\sim \mathcal{O}(\alpha_{\text{weak}})
\]

(more problematic for $qq \rightarrow qq$!)

$gg \rightarrow t \bar{t}$:

\[
\sim \mathcal{O}(\alpha_s)
\]
$\mathcal{O}(\alpha_s^2 \alpha_{\text{weak}})$ weak corrections ($q \bar{q} \rightarrow t \bar{t}$)

cuts of second group individually IR-divergent
\( \mathcal{O}(\alpha_s^2 \alpha_{\text{weak}}) \) weak corrections \((gg \to t\bar{t})\)
large corrections for large $\sqrt{s}$

sizable $M_h$-dependence

(relative weak corrections [%])
Transverse momentum dependence

\[ \frac{\sigma_{\text{LO}}(p_T > p_{T_{\text{cut}}})}{\sigma_T} \]

**Relative Composition**

- Red: \( gg \rightarrow t\bar{t} \)
- Blue: \( q\bar{q} \rightarrow t\bar{t} \)
- Gray: sum

**Relative Weak Corrections** \( \sigma(p_T > p_{T_{\text{cut}}}) [%] \)

- \( M_h = 120 \text{ GeV} \)
- \( M_h = 1000 \text{ GeV} \)
- Blue: stat. error
**Total cross sections**

**Left:** Weak corrections to top-quark pair production at the Tevatron and **Right:** at the LHC for three different Higgs masses ($m_H = 120$ GeV (full line), $m_H = 200$ GeV (dashed), $m_H = 1000$ GeV (dash-dotted)).
The relative corrections to the $p_T$ and $M_{tt}$ distribution for the Tevatron for $m_H = 120$ GeV (bold histogram) and $m_H = 1000$ GeV (thin histogram).
LHC at 8 TeV, top-pair invariant mass

\[ \frac{d\sigma_{\text{NLO}} - d\sigma_{\text{LO}}}{d\sigma_{\text{LO}}} \times 100\% \]

\[ M_h = 125 \text{ GeV} \]

\[ M_{tt} \geq M_{tt}^{\text{cut}} \]

LHC: 8 TeV

\[ L = 20 \text{ fb}^{-1} \]

\[ \frac{\sigma_{\text{NLO}}(M_{tt} \geq M_{tt}^{\text{cut}})}{\sigma_{\text{LO}}(M_{tt} \geq M_{tt}^{\text{cut}})} \]
LHC at 8 TeV, transverse momentum

\[ \frac{d\sigma_{\text{NLO}} - d\sigma_{\text{LO}}}{d\sigma_{\text{LO}}} \text{ [%]} \]

\[ \frac{\sigma_{\text{NLO}}(p_T \geq p_T^{\text{cut}})}{\sigma_{\text{LO}}(p_T \geq p_T^{\text{cut}})} \]

LHC: 8 TeV

\[ M_h = 125 \text{ GeV} \]

\[ p_T \text{ [GeV]} \]

\[ p_T^{\text{cut}} \text{ [GeV]} \]

\[ L = 20 \text{ fb}^{-1} \]
Threshold behaviour: Tevatron and LHC

$\Rightarrow m_H$ and Yukawa coupling

dependence on Higgs mass
LHC: 8 TeV

dependence on Yukawa coupling: \( Y_{\text{top}} \Rightarrow 2 \times Y_{\text{top}} \)
Threshold behaviour

**Left:** Invariant mass distribution $d\sigma/dM$ from NRQCD and for a fixed NLO for LHC with $\sqrt{s} = 14$ TeV. The bands are due to scale variation for $\mathcal{L} \otimes F$ from $m_t$ to $4m_t$.

**Right:** Invariant mass distribution $d\sigma/dM$ from NLO calculation for LHC with $\sqrt{s} = 14$ TeV.
• analytical & numerical results available
  (earlier partial results by Beenakker et al., some disagreements)
  independent evaluation by Bernreuther, Fücker, Si ⇒ agreement
  Moretti, Holten, Ross ⇒ some disagreement ?

• \((\text{box contribution})_{\text{up–quark}} = - (\text{box contribution})_{\text{down–quark}}\)
  ⇒ suppression

• box contribution moderately \(\hat{s}\)-dependent

• corrections strongly increasing with \(\hat{s}\), angular dependent; \((M_{tt}/2 \text{ vs } p_T)\)

• sizable \(M_h\)-dependence, large effect close to threshold
  ⇒ determination of Yukawa coupling
$b\bar{b}$ production: similar to $t\bar{t}$

Additional contributions from:

- $gb \rightarrow gb$: (single $b$-tag) through crossing

- $bb \rightarrow bb$: $s$ and $t$ exchange;
  terms of $\mathcal{O}(\alpha_s\alpha_w)$ small
  corrections irrelevant

- $qq \rightarrow qq$ etc.: $s$ and $t$ exchange;
  terms of $\mathcal{O}(\alpha_s\alpha_w)$ contribute
  new terms of $\mathcal{O}(\alpha_s^2\alpha_w)$;
  interplay between QCD and EW corrections
  \(\Rightarrow\) Moretti et al.
II. 2. V + jet, V=W,Z,γ

JK, Kulesza, Pozzorini, Schulze
Denner, Dittmaier, Kasprzik, Mück
⇒ talk by Kasprzik
Complete one loop calculation
NLL approximation at two loops

- one-loop $\sim 30\%$ at $p_T \sim 1\, \text{TeV}$
- two-loop relevant above 1 TeV
- important angular-dependent logarithmic terms
- experiment: $p_T$ up to 2 TeV

Relative $\text{NLO}$ and $\text{NNLO}$ corrections w.r.t. the LO and statistical error for the unpolarized integrated cross section for $pp \rightarrow Zj$ at $\sqrt{s} = 14\, \text{TeV}$.

(Similarly, but smaller by a factor 2 for jet+\gamma)
additional complications:

- photon radiation as necessary part of virtual corrections (gauge invariance)
- IR singularities must be compensated by real radiation
- $p_T(W) = p_T(\text{jet}) + p_T(\gamma)$

(referenced results: Dittmaier, Kasprzik, ...)
ratios are less sensitive to QCD corrections
Two Approaches:

- dominant, logarithmically enhanced terms via evolution equation & separation of QED
  \[ \Rightarrow \text{one- and two-loop terms in NNLL} \]

  J.H.K., Metzler, Penin, Uccirati: JHEP 1106 (2011) 143
  related work based on SCET: Manohar,…

- one-loop calculation, including \( M_W^2 / \hat{s} \) terms and real radiation: full NLO
  Bierweiler, Kasprzik, J.H.K., Uccirati
  related work: logarithmically enhanced terms only, including W decays
  Accomando, Denner, Kaiser
Leading Order

\[ q \to W^+ W^- , \sqrt{s} = 1 \text{ TeV} \]

\[ \frac{d\sigma}{d\cos\theta} \]

- Strong enhancement for \( \Theta \to 180^\circ \)
- Dominance of transverse W
Also included: $\gamma\gamma \rightarrow WW$

also included: $gg \rightarrow WW$
Total cross sections LHC8, \( p_T > p_T,\text{cut} \)

\[ \sigma(\text{fb}) \]

\[ \text{pp} \rightarrow W^- W^+(\gamma/\text{jet}) + X \]

\text{at } \sqrt{s} = 8 \text{ TeV}

\[ \delta(\%) \]

- \( \delta_{\text{EW}} \)
- \( \delta_{\gamma\gamma} \)
- \( \delta_{gg} \)
- \( \delta_{\text{QCD}} \)
Total cross sections LHC14, $p_T > p_{T,\text{cut}}$

$\sigma(\text{fb})$

$\sigma(\text{fb})$

$\delta(\%)$

$pp \rightarrow W^-W^+(\gamma/jet) + X$

at $\sqrt{s} = 14 \text{ TeV}$
Differential LO cross sections for the W-boson rapidity gap with a minimal invariant mass of 1000 GeV at the LHC14. On the right-hand-side, the corresponding relative rates due to photon- and gluon-induced channels w.r.t. the $q\bar{q}$-contributions are shown, as well as the EW corrections.
### Drell-Yan process: \( pp \to l^+l^- + X \) at \( \sqrt{s} = 14\text{TeV} \)

<table>
<thead>
<tr>
<th>( M_{ll}/\text{GeV} )</th>
<th>( 50\rightarrow \infty )</th>
<th>( 100\rightarrow \infty )</th>
<th>( 200\rightarrow \infty )</th>
<th>( 500\rightarrow \infty )</th>
<th>( 1000\rightarrow \infty )</th>
<th>( 2000\rightarrow \infty )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma_0/\text{pb} )</td>
<td>738.733(6) 32.7236(3) 1.48479(1) 0.0809420(6) 0.00679953(3) 0.000303744(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \sigma_0</td>
<td>_{\text{FS/PS}}/\text{pb} )</td>
<td>738.773(6) 32.7268(3) 1.48492(1) 0.0809489(6) 0.00680008(3) 0.000303767(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \delta_{\gamma\gamma,0}/% )</td>
<td>0.17</td>
<td>1.15</td>
<td>4.30</td>
<td>4.92</td>
<td>5.21</td>
<td>6.17</td>
</tr>
<tr>
<td>( \delta_{\gamma\gamma,\text{phot}}/% )</td>
<td>-1.81</td>
<td>-4.71</td>
<td>-2.92</td>
<td>-3.36</td>
<td>-4.24</td>
<td>-5.66</td>
</tr>
<tr>
<td>( \delta_{q\bar{q},\text{phot}}/% )</td>
<td>-3.34</td>
<td>-8.85</td>
<td>-5.72</td>
<td>-7.05</td>
<td>-9.02</td>
<td>-12.08</td>
</tr>
<tr>
<td>( \delta_{\gamma\gamma,\text{phot}}/% )</td>
<td>0.073$^{+0.027}_{-0.024}$</td>
<td>0.49$^{+0.18}_{-0.15}$</td>
<td>0.17$^{+0.06}_{-0.05}$</td>
<td>0.23$^{+0.07}_{-0.06}$</td>
<td>0.33$^{+0.09}_{-0.08}$</td>
<td>0.54$^{+0.13}_{-0.12}$</td>
</tr>
<tr>
<td>( \delta_{q\bar{q},\text{weak}}/% )</td>
<td>-0.71</td>
<td>-1.02</td>
<td>-0.14</td>
<td>-2.38</td>
<td>-5.87</td>
<td>-11.12</td>
</tr>
<tr>
<td>( \delta_{\text{h.o.weak}}/% )</td>
<td>0.030</td>
<td>0.012</td>
<td>-0.23</td>
<td>-0.29</td>
<td>-0.31</td>
<td>-0.32</td>
</tr>
<tr>
<td>( \delta_{\text{Sudakov}}^{(2)}/% )</td>
<td>-0.00046</td>
<td>-0.0067</td>
<td>-0.035</td>
<td>0.23</td>
<td>1.14</td>
<td>3.38</td>
</tr>
<tr>
<td>( \delta_{q/\bar{q}\gamma,\text{phot}}/% )</td>
<td>-0.11</td>
<td>-0.21</td>
<td>0.38</td>
<td>1.53</td>
<td>1.91</td>
<td>2.34</td>
</tr>
<tr>
<td>( \delta_{\gamma\gamma,\text{phot}}/% )</td>
<td>-0.0060</td>
<td>-0.032</td>
<td>-0.11</td>
<td>-0.14</td>
<td>-0.16</td>
<td>-0.23</td>
</tr>
<tr>
<td>( \delta_{\gamma\gamma,\text{phot}}/% )</td>
<td>-0.011</td>
<td>-0.058</td>
<td>-0.22</td>
<td>-0.30</td>
<td>-0.39</td>
<td>-0.59</td>
</tr>
<tr>
<td>( \delta_{\gamma\gamma,\text{weak}}/% )</td>
<td>0.000045</td>
<td>0.00056</td>
<td>-0.025</td>
<td>-0.14</td>
<td>-0.31</td>
<td>-0.64</td>
</tr>
<tr>
<td>( \delta_{\text{QCD}}/% )</td>
<td>4.0(1)</td>
<td>13.90(6)</td>
<td>26.10(3)</td>
<td>21.29(2)</td>
<td>8.65(1)</td>
<td>-11.93(1)</td>
</tr>
</tbody>
</table>

Dittmaier, Huber (arXiv: 0911.2329v2 [hep-ph])
III. QED corrections: QED and PDFs

QED and EW one-loop corrections can be separated in some cases:

- Drell-Yan process: $q\bar{q} \rightarrow \mu^+ \mu^-$

- $\gamma\gamma$ or ZZ production: $q\bar{q} \rightarrow \gamma\gamma$ or ZZ

- Top pair production: $q\bar{q} \rightarrow t\bar{t}$ or $gg \rightarrow t\bar{t}$

not for $gg \rightarrow Wq'$, $q\bar{q} \rightarrow W^+W^-$, ...

naively estimated to be small: $\mathcal{O}(\frac{\alpha}{\pi}) \leq 1\%$
Results for $t\bar{t}$ (Hollik, Kollar)

Hollik, Kollar (arXiv:0708.1697[hep-ph])
## Results for $t\bar{t}$ (Hollik, Kollar)

<table>
<thead>
<tr>
<th>Process</th>
<th>$\sigma_{\text{tot}}$ without cuts [pb]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Born</td>
</tr>
<tr>
<td>$u\bar{u}$</td>
<td>34.25</td>
</tr>
<tr>
<td>$d\bar{d}$</td>
<td>21.61</td>
</tr>
<tr>
<td>$s\bar{s}$</td>
<td>4.682</td>
</tr>
<tr>
<td>$c\bar{c}$</td>
<td>2.075</td>
</tr>
<tr>
<td>$gg$</td>
<td>407.8</td>
</tr>
<tr>
<td>$g\gamma$</td>
<td></td>
</tr>
<tr>
<td>$pp$</td>
<td>470.4</td>
</tr>
</tbody>
</table>

Production cross section:

MRST2004qed

($O(\alpha_s)$ and $O(\alpha)$ improved)

### Comments:

- **large contribution** from $\gamma g \rightarrow t\bar{t}$ strongly dependent on $f_{\gamma/P}$

- **collinear singularities absorbed in PDF,** **but:** calculation without QCD corrections, PDF with $O(\alpha_s)$. 

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Drell-Yan (Dittmaier, Huber)

admixture from $\gamma\gamma \rightarrow \mu^+\mu^-$

<table>
<thead>
<tr>
<th>$M_{\mu\mu}$</th>
<th>$\langle 50, \infty \rangle$</th>
<th>$\langle 100, \infty \rangle$</th>
<th>$\langle 200, \infty \rangle$</th>
<th>$\langle 500, \infty \rangle$</th>
<th>$\langle 1000, \infty \rangle$</th>
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<tr>
<td>$\delta_{\gamma\gamma}/%$</td>
<td>0.17</td>
<td>1.15</td>
<td>4.30</td>
<td>4.92</td>
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</tr>
</tbody>
</table>

(MRST2004qed, $O(\alpha_s)$ and $O(\alpha)$ corrections, include photon PDFs.)

$\gamma\gamma \rightarrow W^+W^-$: (⇒ talk by Bierweiler)

- prediction strongly dependent on PDF
  (MRST2004qed ≡ educated guess)

- $\sigma(\gamma\gamma \rightarrow W^+W^-) \xrightarrow{s \rightarrow \infty} \frac{8\pi\alpha^2}{M_W^2}$
  (strongly enhancement in forward-backward direction)
IV. Real W, Z Radiation: Compensation?

- soft and/or collinear radiation may (partly) compensate or overcompensate virtual corrections:

- model study (Bell, J.K., Rittinger arXiv:1004.4117; EPJC) strong dependence on cuts! asymptotic energies (multi-TeV)

- MC simulation with decays for $t\bar{t}$ (Baur) partial compensation

- semi-realistic evaluation (on-shell W, Z) (Bierweiler, Kasprzik, J.K.)
  $q\bar{q} \rightarrow W^+W^- (\gamma)$ (Born + one-loop)
  vs. $q\bar{q} \rightarrow W^+W^-Z$
  $q\bar{q} \rightarrow W^+W^-W^+ + c.c.$
Aim: real radiation taken care of by MC ⇒ different final states:

$\bar{t}t$: $q\bar{q} \rightarrow \bar{t}tZ$; $q\bar{q} \rightarrow t\bar{b}W$; ...

$W^+W^-$: $q\bar{q} \rightarrow W^+W^-Z$, ...
V. Two Loop Results (Sudakov Logarithms)

one-loop: $\sim 30\%$

$\Rightarrow$ two-loop: $\sim ?$

(Vast amount of literature since $\sim 2000$)

Karlsruhe (Jantzen, J.K., Metzler, Penin, Smirnov, Uccirati)

Fadin, Lipatov, Martin, Melles

PSI (Denner, Melles, Pozzorini, ...)

Ciafaloni, ...

Manohar, ...
A) Form Factor and Evolution Equations

Born:
\[ \mathcal{F}_{\text{Born}} = \bar{\psi}(p_2)\gamma_\mu \psi(p_1) \]

\[ \frac{\partial}{\partial \ln Q^2} \mathcal{F} = \left[ \int_{M^2}^{Q^2} \frac{dx}{x} \gamma(\alpha(x)) + \zeta(\alpha(Q^2)) + \xi(\alpha(M^2)) \right] \mathcal{F} \]

Collins, Sen

\[ \Rightarrow \mathcal{F} = \mathcal{F}_{\text{Born}} F_0(\alpha(M^2)) \exp \left\{ \int_{M^2}^{Q^2} \frac{dx}{x} \left[ \int_{M^2}^{x} \frac{dx'}{x'} \gamma(\alpha(x')) + \zeta(\alpha(x)) + \xi(\alpha(M^2)) \right] \right\} \]
aim: \( N^4LL \) ⇒ corresponds to all terms of the form:

\[
\alpha^n \left[ \mathcal{L}^{2n} + \mathcal{L}^{2n-1} + \mathcal{L}^{2n-2} + \mathcal{L}^{2n-3} + \mathcal{L}^{2n-4} \right]_{\text{LL, NLL, NNLL, N}^3\text{LL, N}^4\text{LL}}
\]

\( \mathcal{L} \equiv \ln \left( Q^2/M^2 \right) \)

\( \text{NNLL requires running of } \alpha \) (i.e. \( \beta_0 \) and \( \beta_1 \)) and:

- \( \zeta(\alpha), \xi(\alpha), F_0(\alpha) \) up to \( \mathcal{O}(\alpha) \) (one-loop)
- \( \gamma(\alpha) \) up to \( \mathcal{O}(\alpha^2) \) (massless two loop)

\( \text{N}^3\text{LL requires two-loop calculation in high-energy limit including linear logarithms (available for non-abelian theory)} \)

\( \text{N}^4\text{LL requires complete two-loop calculation in high-energy limit (available for abelian theory)} \)
B) Two-Loop Results: Massive U(1) Model

\[ F_{\alpha}(M, Q) = F_{\text{Born}} \left[ 1 + \frac{\alpha}{4\pi} f^{(1)} + \left( \frac{\alpha}{4\pi} \right)^2 f^{(2)} + \ldots \right] \]

\[ f^{(2)} = \frac{1}{2} \mathcal{L}^4 - 3 \mathcal{L}^3 + \left( 8 + \frac{2}{3}\pi^2 \right) \mathcal{L}^2 - (9 + 4\pi^2 - 24\zeta_3) \mathcal{L} \]

\[ + \frac{25}{2} + \frac{52}{3}\pi^2 + 80\zeta_3 - \frac{52}{15}\pi^4 - \frac{32}{3}\pi^2 \ln^2 2 + \frac{32}{3} \ln^4 2 + 256 \text{Li}_4 \left( \frac{1}{2} \right) \]

\[ \mathcal{L} \equiv \ln(Q^2/M^2) \]
C) Massive SU(2) form factor in 2-loop approximation

2-loop vertex diagrams (massless fermions, massive bosons):

Abelian \((C_F^2)\): 

non-Abelian \((C_FC_A)\): last 2 +

Higgs:

fermion \((C_FT_Fn_f)\):

\[+ 1\text{-loop} \times 1\text{-loop corrections} + \text{renormalization}\]
\[ f_2 = \frac{9}{32} \mathcal{L}^4 - \frac{19}{48} \mathcal{L}^3 - \left( -\frac{7}{8} \pi^2 + \frac{463}{48} \right) \mathcal{L}^2 \\
+ \left( \frac{39 \text{Cl}_2(\frac{\pi}{3})}{2 \sqrt{3}} + \frac{45}{4} \frac{\pi}{\sqrt{3}} - \frac{61}{2} \zeta_3 - \frac{11}{24} \pi^2 + 29 \right) \mathcal{L} \]
Extensions to: 4-fermion scattering (detailed discussion: Penin et al.)

gauge boson pair production (J.K., Metzler, Penin, Uccirati)

Complication: massless photon! \(\Rightarrow\) QED subtracted
VI. Open Questions:

• QCD $\otimes$ EW: ambiguities

\[(1 + \delta_{QCD})(1 + \delta_{EW}) - (1 + \delta_{QCD} + \delta_{EW}) = \delta_{QCD}' \delta_{EW}\]

e.g.:

$\delta_{QCD} \sim 40\%$; $\delta_{EW} \sim 30\%$

first steps: virtual corrections for $q\bar{q} \rightarrow Z$ of $\mathcal{O}(\alpha_w\alpha_s)$ available: J.K., Veretin (no Sudakov logs!)

• definition of final state:

do we consider $W$ (hard) $\oplus$ $g$ (hard) $\oplus$ $W$ (soft) part of $W$-pair production?

• Can we discriminate $top \rightarrow Wb$ or $W \rightarrow q\bar{q}'$, $Z \rightarrow q\bar{q}$ from fat QCD jets?