Electroweak Corrections at the LHC

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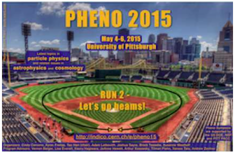


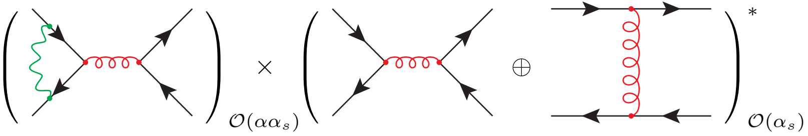
Outline

- Introduction
- Electroweak corrections in MCFM for
    - Neutral current Drell-Yan process
    - Top pair production
    - Di-jets production
- Conclusion and outlook

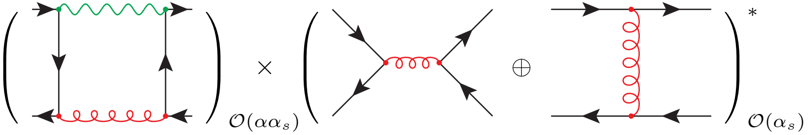
Outline

Example of electroweak corrections

- Electroweak corrections to di-jet production ($\mathcal{O}(\alpha\alpha_s^2)$)
  - EW vertex correction



  - EW box correction



Electroweak corrections enhanced via Sudakov logarithms

- Electroweak corrections at the LHC can be enhanced at high energies due to soft/collinear radiation of W and Z bosons.
- When all kinematic invariants $r_{ij} = (p_j + p_k)^2$ are much larger than the heavy particles in the loop, i.e.,
$|r_{ij}| \sim Q^2 \gg M_W^2 \sim M_Z^2 \sim M_H^2 \sim m_t^2$, electroweak corrections are dominated by Sudakov-like corrections:

$$\boxed{\alpha_W^l \log^n(Q^2/M_W^2)} \quad (n \leq 2l,\ \alpha_W = \frac{\alpha}{4\pi s_W^2})$$

  - $Q = 1\text{TeV}$,
  $\alpha_W \log^2(Q^2/M_W^2) \sim \boxed{6.6\%}$, $\alpha_W \log(Q^2/M_W^2) \sim \boxed{1.3\%}$
  - $Q = 14\text{TeV}$,
  DL $\sim \boxed{27\%}$, SL $\sim \boxed{2.6\%}$

Why electroweak corrections?

- The inclusion of EW corrections in LHC predictions is important for the search of new physics in tails of distributions, e.g., search for W', Z', non-standard couplings.
- It is also important for contraints on PDFs measurement.
- EW NLO $\boxed{\mathcal{O}(\alpha)}$ is expected comparable with QCD NNLO $\boxed{\mathcal{O}(\alpha_s^2)}$.

Why electroweak corrections?

- Calculations of electroweak corrections are often not readily available in public codes and can quickly become complicated (and CPU intensive) for high multiplicities.
- As a first step to improve predictions for the LHC at high energies, one could implement the Sudakov approximation of electroweak corrections.
  Example: Weak Sudakov corrections to Z $+ \leq 3$ jets in Alpgen
  M. Chiesa *et al*, PRL111 (2013).
  See also a recent proposal to add EW corrections to HERWIG:
  [http://arxiv.org/pdf/1401.3964.pdf] Link Here
- Our goal is to implement EW corrections in MCFM so that they become readily available to the experimental community and can be studied together with the already implemented QCD corrections.

Outline

Processes implemented in MCFM

- We will provide both the Sudakov approximation for EW corrections valid at high energies and the complete 1-loop weak corrections to be able to quantify the goodness of the approximation.
  - NC Drell Yan process
    - I Weak Sudakov correction ✓
    - II Exact NLO weak correction ✓
  - Top-pair production
    - I Weak Sudakov correction ✓
    - II Exact NLO weak correction ✓
  - Dijet production
    - I Weak Sudakov correction ✓
    - II Exact NLO weak correction ✓ *preliminary*
- For a recent review of status of EW corrections see: ▸ Link Here
  [https://phystev.in2p3.fr/wiki/_media/2013:groups:lh13_ew.pdf]

Outline

Sudakov logarithms calculations

- Vertex Part at Very High Energies in QED
  V. V. Sudakov, Soviet Phys. JETP3 (1956) 65
- Some Refs. for the general Sudakov logarithmic corrections
  P. Ciafaloni, D. Comelli, PLB446 (1999), arXiV:hep-ph/9809321; M. Beccaria *et al*, PRD61 (2000), arXiv:hep-ph/9906319; J. H. Kühn, A. A. Penin, arXiv:hep-ph/9906545; M. Melles, Phys. Rept.375(2003), arXiv:hep-ph/0104232; A. Denner, S. Pozzorini, EPJC18 (2001), arXiv:hep-ph/0010201; A. Denner, S. Pozzorini, EPJC21(2001), arXiv:hep-ph/0104127; S. Pozzorini, arXiv:hep-ph/0201077; W. Beenakker, A. Werthenbach, NPB630 (2002), arXiv:hep-ph/0112030; A. Denner *et al*, JHEP0811 (2008), arXiv:0809.0800.

▶ The general algorithm of Denner and Pozzorini is adopted in the implementation in MCFM

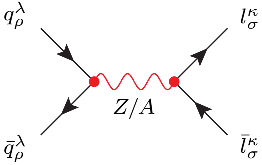
Relevant studies in existing references

- Electroweak Radiative Corrections to Neutral-Current Drell-Yan Processes at Hadron Colliders,
  U. Baur, O. Brein, W. Hollik, C Schappacher, and D. Wackeoroth, PRD65 033007 (2002), arXiv:hep-ph/010827
- Electroweak corrections to top-quark pair production in quark-antiquark annihilation,
  J. H. Kühn, A. Scharf and P. Uwer, Eur.Phys.J. C45 (2006) 139-150, arXiv:hep-ph/0508092
- Electroweak effects in top-quark pair production at hadron colliders,
  J. H. Kühn, A. Scharf and P. Uwer, Eur.Phys.J. C51 (2007) 37-53, arXiv:hep-ph/0610335
- Weak radiative corrections to dijet production at hadron colliders,
  S. Dittmaier, A. Huss and C. Speckner, JHEP1211 (2012) 095, arXiv:1210.0438

Outline

Sudakov approximation to Drell-Yan process

Process under consideration: $\bar{q}^{\lambda}_{\rho} q^{\lambda}_{\rho} l^{\kappa}_{\sigma} \bar{l}^{\kappa}_{\sigma} \to 0$



Born amplitude

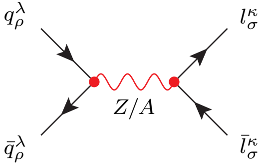
$$\mathcal{M}^{\bar{q}^{\lambda}_{\rho} q^{\lambda}_{\rho} l^{\kappa}_{\sigma} \bar{l}^{\kappa}_{\sigma}} = e^2 R_{q^{\lambda}_{\rho} l^{\kappa}_{\sigma}} \frac{\mathcal{A}}{\hat{s}} + \mathcal{O}(\frac{M_Z^2}{\hat{s}}),$$

$$R_{\phi_i \phi_k} := \sum_{N=Z,A} I^N_{\phi_i} I^N_{\phi_k} = \frac{1}{4c_W^2} Y_{\phi_i} Y_{\phi_k} + \frac{1}{s_W^2} T^3_{\phi_i} T^3_{\phi_k},$$

$Y_{\phi_{i,k}}$ — weak hypercharge; $T^3_{\phi_{i,k}}$ — 3rd component of weak isospin.

Sudakov approximation to Drell-Yan process

Process under consideration: $\bar{q}^{\lambda}_{\rho} q^{\lambda}_{\rho} l^{\kappa}_{\sigma} \bar{l}^{\kappa}_{\sigma} \to 0$



Born amplitude

$$\begin{aligned} \mathcal{M}^{\bar{q}^{\lambda}_{\rho} q^{\lambda}_{\rho} l^{\kappa}_{\sigma} \bar{l}^{\kappa}_{\sigma}} &= e^2 R_{q^{\lambda}_{\rho} l^{\kappa}_{\sigma}} \frac{\mathcal{A}}{\hat{s}} + \mathcal{O}\left(\frac{M_Z^2}{\hat{s}}\right), \\ R_{\phi_i \phi_k} &:= \sum_{N=Z,A} I^N_{\phi_i} I^N_{\phi_k} = \frac{1}{4c_W^2} Y_{\phi_i} Y_{\phi_k} + \frac{1}{s_W^2} T^3_{\phi_i} T^3_{\phi_k}, \end{aligned}$$

$Y_{\phi_{i,k}}$ — weak hypercharge; $T^3_{\phi_{i,k}}$ — 3rd component of weak isospin.

Sudakov approximation to Drell-Yan process

Leading and subleading soft-collinear corrections

$$\delta^{LSC}_{\bar{q}^\lambda_\rho q^\lambda_\rho l^\kappa_\sigma \bar{l}^\kappa_\sigma} = -\sum_{f^\mu_\tau = q^\lambda_\rho, l^\kappa_\sigma} \left[C^{\mathrm{ew}}_{f^\mu_\tau} L(\hat{s}) - 2(I^Z_{f^\mu_\tau})^2 \log \frac{M_Z^2}{M_W^2} l_Z + Q^2_{f_\tau} \cancel{L^{em}(\hat{s}, \lambda^2, m^2_{f_\tau})} \right],$$

$$\delta^{SSC}_{\bar{q}^\lambda_\rho q^\lambda_\rho l^\kappa_\sigma \bar{l}^\kappa_\sigma} = -l(s) \left[4R_{q^\lambda_\rho l^\kappa_\sigma} \log \frac{\hat{t}}{\hat{u}} + \frac{\delta_{\lambda L}\delta_{\kappa L}}{s_w^4 R_{q^\lambda_\rho l^\kappa_\sigma}} \left(\delta_{\rho\sigma} \log \frac{|\hat{t}|}{s} - \delta_{-\rho\sigma} \log \frac{|\hat{u}|}{s} \right) \right]$$

$$-4Q_{q_\rho} Q_{l_\sigma} \cancel{l(M_W^2, \lambda^2)} \log \frac{\hat{t}}{\hat{u}}$$

$$L(\hat{s}) := \frac{\alpha}{4\pi} \log^2 \frac{\hat{s}}{M_W^2}, \quad l_Z = l(\hat{s}) := \frac{\alpha}{4\pi} \log \frac{\hat{s}}{M_W^2}.$$

$$C^{\mathrm{ew}} := \sum_{V^a = A, Z, W^\pm} I^{V^a} I^{\bar{V}^a},$$ Casimir operator.

Sudakov approximation to Drell-Yan process

Collinear or soft SL corrections

$$\delta^{C}_{\bar{q}^{\lambda}_{\rho} q^{\lambda}_{\rho} l^{\kappa}_{\sigma} \bar{l}^{\kappa}_{\sigma}} = \sum_{f^{\mu}_{\tau} = q^{\lambda}_{\rho}, l^{\kappa}_{\sigma}} \Bigg[3C^{\mathrm{ew}}_{f\mu} l_C - \frac{1}{4s^2_W} \left((1+\delta_{\mu R}) \frac{m^2_{f_\tau}}{M^2_W} + \delta_{\mu L} \frac{m^2_{f_{-\tau}}}{M^2_W} \right) l_{Yuk} + 2Q^2_{f_\tau} \cancel{l^{em}}(m^2_{f_\tau}) \Bigg]$$

Parameter renormalization corrections

$$\delta^{PR}_{\bar{q}^{\lambda}_{\rho} q^{\lambda}_{\rho} l^{\kappa}_{\sigma} \bar{l}^{\kappa}_{\sigma}} = \left[\frac{s_W}{c_W} b^{\mathrm{ew}}_{AZ} \Delta_{q^{\lambda}_{\rho} l^{\kappa}_{\sigma}} - b^{\mathrm{ew}}_{AA} \right] l_{PR} + \cancel{2\delta Z^{em}_e}$$

$$\Delta_{\phi_i \phi_k} := \frac{-\frac{1}{4c^2_W} Y_{\phi_i} Y_{\phi_k} + \frac{c^2_W}{s^4_W} T^3_{\phi_i} T^3_{\phi_k}}{R_{\phi_i \phi_k}}$$

$$l_C = l_{Yuk} = l_{PR} = l(\hat{s}) := \frac{\alpha}{4\pi} \log \frac{\hat{s}}{M^2_W}, \quad b^{\mathrm{ew}}_{AZ} = -\frac{19 + 22 s^2_{\mathrm{W}}}{6 s^2_{\mathrm{W}} c^2_{\mathrm{W}}}, \quad b^{\mathrm{ew}}_{AA} = -\frac{11}{3}.$$

The input parameter setup

- Both calculations are included in MCFM
  - Exact
  - Sudakov

The input parameter setup in MCFM:

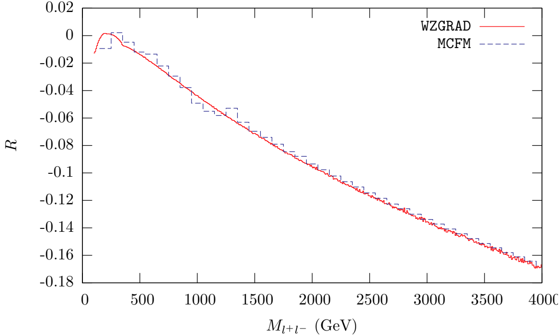
$$
\begin{aligned}
&G_\mu = 1.16639 \times 10^{-5}\,\mathrm{GeV}^{-2},\ \sin^2\theta_W = 1 - M_W^2/M_Z^2,\\
&\alpha_\mu = 1/132.5605045,\ \Gamma_Z = 2.4952\,\mathrm{GeV},\ \cos^2\theta_W = M_W^2/M_Z^2,\\
&M_Z = 91.1876\,\mathrm{GeV},\ M_W = 80.425\,\mathrm{GeV},\ M_H = 120\,\mathrm{GeV},\\
&m_e = 0.51099892\,\mathrm{MeV},\ m_\mu = 105.658369\,\mathrm{MeV},\ m_\tau = 1.777\,\mathrm{GeV},\\
&m_u = 66\,\mathrm{MeV},\ m_c = 1.2\,\mathrm{GeV},\ m_t = 173.2\,\mathrm{GeV},\\
&m_d = 66\,\mathrm{MeV},\ m_s = 150\,\mathrm{MeV},\ m_b = 4.6\,\mathrm{GeV},\\
&\mu_F = \mu_R = M_Z.
\end{aligned}
$$

One-loop weak correction: Numerical result

- Comparison with WZGRAD at 14 TeV

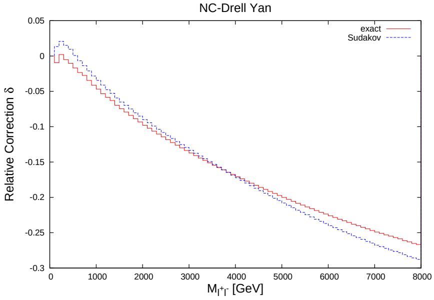
$$M_{l^+l^-} > 100\,\mathrm{GeV}, |p_{T,l^\pm}| > 20\,\mathrm{GeV}, |\eta_{l^\pm}| < 2.5$$

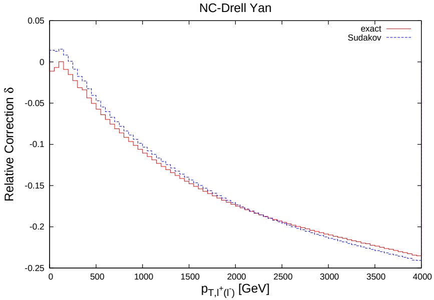
$$R = \frac{\sigma_{NLO} - \sigma_{LO}}{\sigma_{LO}}$$



Comparison: Sudakov approximation and exact calculation

- Invariant mass and transverse momentum distributions at LHC (14 TeV) with MCFM

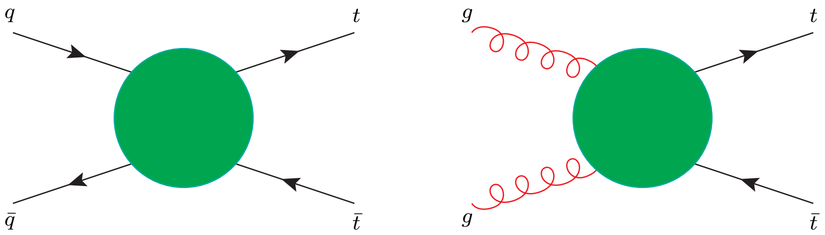




Outline

Sudakov approximation to $t\bar{t}$ production

Processes under consideration: $\bar{q}^{\lambda}_{\rho} q^{\lambda}_{\rho} t^{\kappa} \bar{t}^{\kappa} \to 0$ and $gg\, t^{\kappa}\bar{t}^{\kappa} \to 0$



- Chiralities to initial and final states
  - massless initial quarks(gluons) $\to$ chirality $=$ helicity, conserved during transportation,
  - massive final top quarks $\to$ chirality $\neq$ helicity, oscillating along the moving direction.
- Use projector to restore the weak corrections in the chiral coupling

Sudakov approximation to $t\bar{t}$ production

- Two ways to proceed the calculation
  1. break down the amplitude with chiralities ✓
  2. calculate the matrix element square directly ✓

Chiral Born

$$|\mathcal{M}|^2_{\mathrm{Born}} = |\mathcal{M}_{\mathrm{LL}}|^2 + |\mathcal{M}_{\mathrm{RR}}|^2 + |\mathcal{M}_{\mathrm{LR}}|^2 + |\mathcal{M}_{\mathrm{RL}}|^2,$$
$$|\mathcal{M}_{\mathrm{LL}}|^2 = |\mathcal{M}_{\mathrm{RR}}|^2, \quad |\mathcal{M}_{\mathrm{LR}}|^2 = |\mathcal{M}_{\mathrm{RL}}|^2$$

- Universal correction independent of chirality

$$\sum_{f_\tau^\sigma} \left[-C^{\mathrm{ew}}_{f_\tau^\sigma} (\mathrm{L}(\hat{s}) - 3 \cdot l_c) \right] |\mathcal{M}|^2_{\mathrm{Born}}$$

- Angular dependence ($q\bar{q}$ channel) and Yukawa enhanced terms
- No parameter renormalization

One-loop correction to $\mathrm{t\bar{t}}$ production: Numerical result

- Input parameters

$$M_Z = 91.1876\,\mathrm{GeV},\ M_W = 84.425\,\mathrm{GeV},\ M_H = 120\,\mathrm{GeV},$$
$$m_b = 4.6\,\mathrm{GeV},\ m_t = 173.2\,\mathrm{GeV},\ \ s_W^2 = 0.2221236,$$
$$\alpha = \alpha_\mu = 1/132.5605045,\ \alpha_s(2m_t) = 0.09897922,$$
$$\mu_F = \mu_R = 2m_t.$$

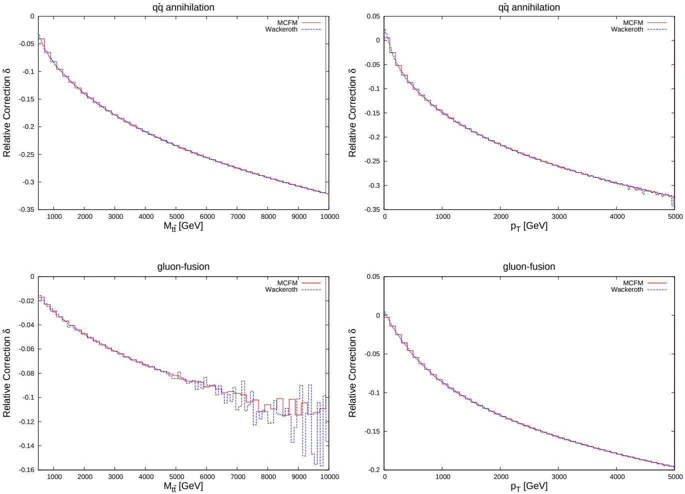
- The total cross sections

σ (fb)	$q\bar{q}$	gg	
$\mathcal{O}(\alpha_s^2)$	55408(9)	354251(66)	(MCFM)
LO	55386(18)	354254(47)	ref.[1]
$\mathcal{O}(\alpha\alpha_s^2)$	-1012.2(5)	-3887(1)	(MCFM)
NLO weak	-1011(1)	-3886(2)	ref.[1]

[1] W. Beenakker *et al*, Nuclear Physics B411(1994) 343

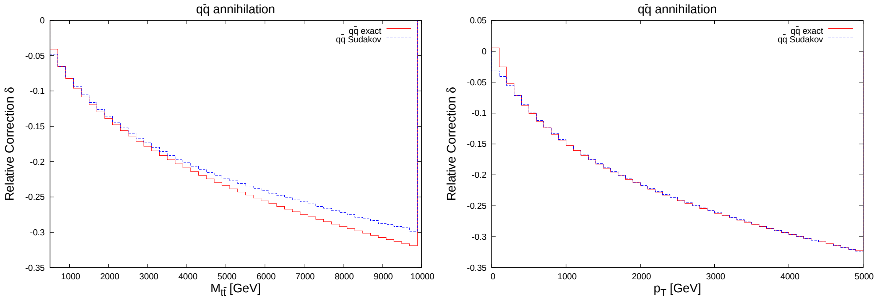
One-loop correction to $t\bar{t}$ production: Numerical result

- Cross-check of the exact result at LHC = 14 TeV



Comparison with Sudakov approximation

- Comparison between Sudakov approx and 1-loop exact calculation at LHC = 14 TeV with MCFM



Comparison with Sudakov approximation

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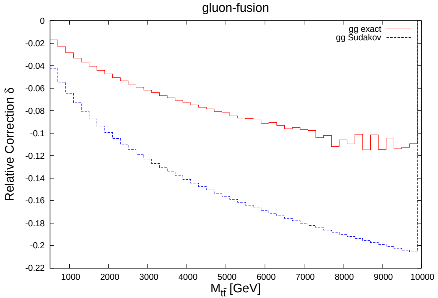
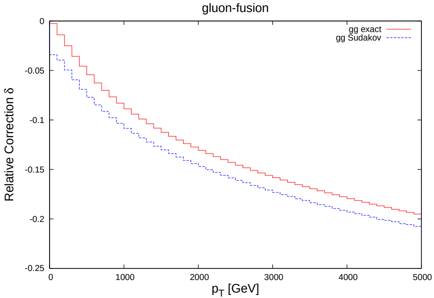
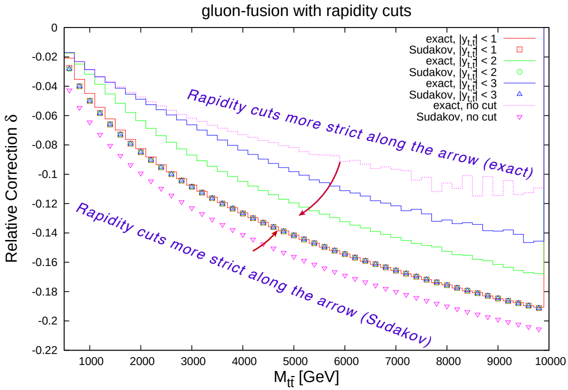




$$
\begin{aligned}
p_t &= (m_T \cosh y_t, p_T \sin\phi, p_T \cos\phi, m_T \sinh y_t), \\
p_{\bar{t}} &= (m_T \cosh y_{\bar{t}}, -p_T \sin\phi, -p_T \cos\phi, m_T \sinh y_{\bar{t}}), \\
M_{t\bar{t}}^2 &= 2m_t^2 + 2m_T^2 \cosh(y_t - y_{\bar{t}}) + 2p_T^2, \\
m_T &= \sqrt{p_T^2 + m_t^2}.
\end{aligned}
$$

Comparison with Sudakov approximation

- The invariant mass distributions with rapidity cuts; Sudakov approximation agrees well with the exact when $|y_{t,\bar{t}}| \lesssim 1$.



"..., it is clear that for the logarithmic approximation described be valid all Mandelstam variables $\hat{s}$, $\hat{t}$, $\hat{u}$ must be very large, condition which is obviously not fulfilled at small/large scattering angles." *[Weak corrections to gluon-induced top-antitop hadro-production]*

[S. Moretti *et al*, PLB639 (2006) 513]

"The gluon induced part, in contrast, is markedly angular dependent. For large $\hat{s}$ and small scattering angle the corrections are small, since the Sudakov-like behaviour cannot be expected in this case. At ninety degrees, in contrast, the Sudakov limit is applicable and the corrections become large." *[Weak Interactions in Top-Quark Pair Production at Hadron Colliders: An Update]*

J. H. Kühn *et al*, [arXiv:1305.5773]

Summary to $t\bar{t}$ production

- We implement EW corrections to the top-pair production in MCFM, making the calculation accessible to the public.
- Both EW Sudakov approximation and exact weak NLO are implemented in MCFM.
- Sudakov approximation works much better in quark-antiquark annihilation channel, in contrary to gluon-fusion channel which has a obvious discrepancy between Sudakov approximation and exact NLO in invariant mass distribution due to the information of angular dependence is missing in Sudakov approximation.
- With a scattering angle cut to gluon-fusion channel, we are able to get an agreement between both calculations.

Outline

Di-jet production

- Processes under consideration:
  - $\boxed{\text{quark-induced:}}$ $q_i\bar{q}_i \to q_j\bar{q}_j$, and its crossing symmetries such as $q_iq_j \to q_iq_j$, etc.
  - $\boxed{\text{gluon-induced:}}$ $gg \to q\bar{q}$, and its crossing symmetries such as $gq \to qg$, etc.
- Processes calculated directly:
  - $q_i\bar{q}_i \to q_j\bar{q}_j$, for both $i \neq j$ and $i = j$, respectively.
  - $gg \to q\bar{q}$
- The rest of the production processes is obtained via crossing symmetries of the directly calculated production

Note: $q_{i,j}, q \in \{u, d, s, c\}$

Crossing symmetries

- $\boxed{\text{All quark-induced production via crossing symmetries}}$ $i \neq j$

  1 $q_i\bar{q}_i \to q_j\bar{q}_j$, $\boxed{\text{direct calculation}}$

  2 $q_iq_j \to q_iq_j$, $(2 \to 3,\ 3 \to 4,\ 4 \to 2;\ s \to t,\ t \to u,\ u \to s)$

  3 $\bar{q}_iq_i \to \bar{q}_jq_j$, $(1 \leftrightarrow 2, 3 \leftrightarrow 4;\ --)$

  4 $\bar{q}_i\bar{q}_j \to \bar{q}_i\bar{q}_j$, $(1 \to 3,\ 3 \to 2,\ 2 \to 1;\ s \to t,\ t \to u,\ u \to s)$

  5 $q_i\bar{q}_j \to q_i\bar{q}_j$, $(2 \leftrightarrow 3;\ s \leftrightarrow t)$

  6 $\bar{q}_iq_j \to \bar{q}_iq_j$, $(1 \to 3,\ 3 \to 4,\ 4 \to 2,\ 2 \to 1;\ s \leftrightarrow t)$

  7 $q_i\bar{q}_i \to q_i\bar{q}_i$, $\boxed{\text{direct calculation}}$

  8 $\bar{q}_iq_i \to q_i\bar{q}_i$, $(1 \leftrightarrow 2;\ t \leftrightarrow u)$

  9 $q_iq_i \to q_iq_i$, $(2 \to 3,\ 3 \to 4,\ 4 \to 2;\ s \to t,\ t \to u,\ u \to s)$

  10 $\bar{q}_i\bar{q}_i \to \bar{q}_i\bar{q}_i$, $(1 \to 3,\ 3 \to 2,\ 2 \to 1;\ s \to t,\ t \to u,\ u \to s)$

where $12 \to 34$ denotes $q_i\bar{q}_i \to q_j\bar{q}_j$

Crossing symmetries

- All gluon-induced production via crossing symmetries

1 $gg \to q\bar{q}$, $\boxed{\text{direct calculation}}$

2 $gq \to gq$, $(2 \leftrightarrow 3, 3 \leftrightarrow 4, 4 \leftrightarrow; \; s \leftrightarrow t, t \leftrightarrow u, u \leftrightarrow s)$

3 $g\bar{q} \to g\bar{q}$, $(2 \to 3; \; s \leftrightarrow t)$

4 $qg \to qg$, $(1 \leftrightarrow 4; \; s \leftrightarrow t)$

5 $\bar{q}g \to \bar{q}g$, $(1 \to 2, \; 2 \to 4, 4 \to 3, \; 3 \to 1; \; s \leftrightarrow t)$

6 $q\bar{q} \to gg$, $(1 \leftrightarrow 3, \; 2 \leftrightarrow 4; \; t \leftrightarrow u)$

7 $\bar{q}q \to gg$ $(1 \leftrightarrow 4, \; 2 \leftrightarrow 3; --)$

8 $gg \to gg$, $\boxed{\text{no weak correction}}$

where $12 \to 34$ denotes $gg \to q\bar{q}$

Sudakov approximation to di-jet production

- EW corrections to QCD leading order
- Processes calculated directly:
  - I $\bar{q}^{\lambda}_{\rho} q^{\lambda}_{\rho} q^{\kappa}_{\sigma} \bar{q}^{\kappa}_{\sigma} \to 0$ (subprocesses 1 & 7 in four-quark catergory)
  - II $gg\, q^{\kappa}_{\sigma} \bar{q}^{\kappa}_{\sigma} \to 0$ (subprocess 1 in two-gluon-two-quark catergory)
- Calculations are analogous to that in $t\bar{t}$ production (i.e., taking massless limit of the top-quark $m_t \to 0$)

terms contribute to logarithmic corrections

- Universal correction independent of chirality

$$\sum_{f^{\sigma}_{\tau}} \left[-C^{\mathrm{ew}}_{f^{\sigma}_{\tau}} (\mathrm{L}(\hat{s}) - 3 \cdot l_c) \right] |\mathcal{M}|^2_{\mathrm{Born}}$$

- Angular dependence ($q\bar{q}$ channel)
- $\boxed{\text{No Yukawa enhanced terms}}$
- $\boxed{\text{No parameter renormalization}}$

One-loop weak corrections to di-jet production

- Structure of the full NLO calculation
  - QCD & EW LO cross sections of $\mathcal{O}(\alpha_s^2, \alpha_s\alpha, \alpha^2)$
  - fixed $\mathcal{O}(\alpha_s^2\alpha)$:

$$d\hat{\sigma}(\alpha_s^2\alpha) \propto \begin{cases} 2\mathrm{Re}\left[\mathcal{M}(\alpha_s\alpha)\cdot\mathcal{M}^*(\alpha_s)\right] \\ 2\mathrm{Re}\left[\mathcal{M}(\alpha_s^2)\cdot\mathcal{M}^*(\alpha)\right] \end{cases}$$

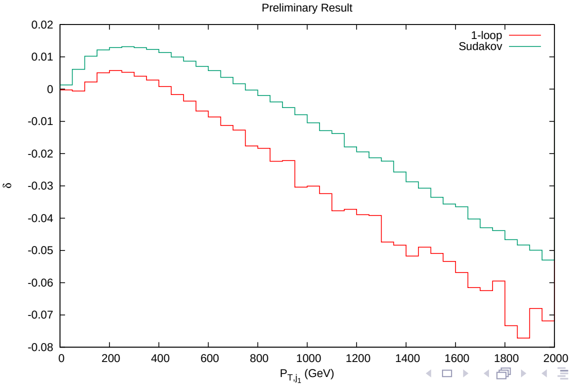
- Input settings

$$\begin{aligned} &G_\mu = 1.16637\times 10^{-5}\,\mathrm{GeV}^{-2}, \\ &M_W = 80.398\,\mathrm{GeV},\ M_Z = 91.1876\,\mathrm{GeV}, \\ &\Gamma_W = 2.141\,\mathrm{GeV},\ \Gamma_Z = 2.4952\,\mathrm{GeV}, \\ &\mu_R = \mu_F = p_{T,1}. \end{aligned}$$

Comparison with Sudakov approximation (preliminary)

- Comparison between Sudakov approximation and 1-loop exact calculations at LHC = 14 TeV

$$|p_{T,j}| > 25\,\mathrm{GeV},\ |y_j| < 2.5;\ \mathrm{anti-k_t},\ R = 0.6$$



Conclusion and outlook

- The EW radiative corrections are very important at the LHC due to the Sudakov logarithmic terms.
- We have completed the implementation of both the Sudakov and exact weak NLO corrections to NC-DY and top-pair production into MCFM.
- In top pair production, sudakov approximation works better in quark-antiquark annhilation channel; while it deviates off the exact NLO corrections in gluon-fusion channel due to the missing information on angular dependence.
- The implementation of EW corrections to dijet production in MCFM is ongoing.
- We would like to continue, for instance, with implementation for ZZ/WW production etc.