IR-Improved DGLAP-CS Parton Shower Effects in W+n Jets

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We use recently introduced MC realizations of IR-improved DGLAP-CS parton showers to study the attendant improvement effects in W+n jets at the LHC in the MG5_aMC@NLO framework for the exact $O(\alpha_s)$ corrections.

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1. Theoretical Background

One can show that it is possible to improve the infrared aspects of the standard treatment of the DGLAP-CS evolution theory to take into account a large class of higher-order corrections that significantly improve the precision of the theory for any given level of fixed-order calculation of its respective kernels.

1.1 QCD

Using equation (1) restricted to QCD allows us to improve in the IR regime the kernels in DGLAP-CS theory.

1.2 QCED=QED⊗QCD

QED and electroweak (EW) are handled by the simultaneous resummation of QED and QCD infrared effects, QED⊗QCD resummation in the presence of parton showers.

2. HERWIRI1.031

Implementation of the new IR-improved kernels, equations (2-5) in the poster, in the framework of HERWIG6.5 results the new IR-improved parton shower MC HERWIRI1.031.

3. Methods

We use a computer program, MadGraph5_aMC@NLO, capable of computations of tree-level and next-to-leading order cross sections, of their matching parton shower simulations, and of the merging of matched samples that differ by light-parton multiplicity.

4. Results

The events generated in the previous section are showered by HERWIG6 and HERWIRI1.031 and histograms for E_T^{miss}, P_T^{Lepton} distribution and $P_T^{W^{\pm}}$ distribution are presented for $\sqrt{s} = 7, 8$ TeV. It is to be noted that there are, in general, differences between HERWIG6 and the exact IR-improved DGLAP-CS theory, HERWIRI1.031, in our distributions.

5. Conclusion and Future Work

Missing Transverse energy, E_T^{miss}, is used to study the non-detectable particles such as standard model neutrino or particles do not interact with the detector such as light supersymmetric particles, Where

$$MET = \not{\vec{E}}_T = |\vec{\not{E}}_T| \quad \text{and} \quad \vec{\not{E}}_T = -\sum_{i \,\in\, tracks} \vec{p}_T(i) \tag{5.1}$$

for massless particles. The transverse momentum distribution of heavy particles has different applications. Firstly, it is an important test of perturbative QCD. Secondly, it is central to the precise measurement of the W boson mass. In future work, we will compare our results with the available LHC data and discuss the corresponding phenomenological implications.

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Theoretical Background

One can prove that exact, amplitude-based resummation allows IR-improvement of the usual DGLAP-CS theory. This results in a new set of kernels, parton distributions and attendant reduced cross sections, so that the QCD perturbative result for the respective hadron-hadron or lepton-hadron cross section is unchanged order-by-order in α_s at large squared-momentum transfer. Refs .[3,4]

We can repeat the analogous arguments of Refs. [1,2], following the corresponding steps for S_{QCD} to get the "YFS-like" result as follows

QCD:

$$d\hat{\sigma}_{exp} = \sum_n d\hat{\sigma}^n = e^{SUM_{IR}(QCD)} \sum_{n=0}^{\infty} \left(\frac{1}{n!}\right) \int \prod_{j=1}^{n} \frac{d^3k_j}{k_j^0} \int \frac{d^4y}{(2\pi)^4} e^{(iy.(p_1+q_1-p_2-q_2-\Sigma k_j)+D_{QCD}} * \bar{\beta}_n(k_1,\dots,k_n)\frac{d^3p_2}{p_2^0}\frac{d^3q_2}{q_2^0}$$

(1)

With

$$SUM_{IR}(QCD) = 2\alpha_s \, Re \, B_{QCD} + 2\alpha_s \, \tilde{B}_{QCD}(K_{max}),$$

$$2\alpha_s \tilde{B}_{QCD}(K_{max}) = \int \frac{d^3k}{k^0} \tilde{S}_{QCD}(k)\theta(K_{max}-k),$$

$$D_{QCD} = \int \frac{d^3k}{k} \tilde{S}_{QCD}(k)[e^{-iy.k} - \theta(K_{max}-k)],$$

$$\frac{1}{2}\bar{\beta}_0 = d\sigma^{(1-loop)} - 2\alpha_s \, Re \, B_{QCD} \, d\sigma_B,$$

$$\frac{1}{2}\bar{\beta}_1 = d\sigma^{B1} - \tilde{S}_{QCD}(k) \, d\sigma_B, \dots,$$

Where the $\bar{\beta}_n$ are the QCD hard gluon residuals defined above; they are the non-Abelian analogs of the hard photon residuals defined by YFS.

DGLAP-CS IR-improved Kernels:

- $P_{qq}^{exp}(z) = C_F \, F_{YFS}(\gamma_q) \, e^{\frac{1}{2}\delta_q} \left[\frac{1+z^2}{1-z}(1-z)^{\gamma_q} - f_q(\gamma_q)\delta(1-z)\right]$ (2)

- $P_{Gq}^{exp}(z) = C_F \, F_{YFS}(\gamma_q) \, e^{\frac{1}{2}\delta_q} \frac{1+(1-z)^2}{z} z^{\gamma_q}$ (3)

- $P_{qG}^{exp}(z) = F_{YFS}(\gamma_G) e^{\frac{1}{2}\delta_G} \frac{1}{2}(z^2(1-z)^{\gamma_G}+(1-z)^2 z^{\gamma_G})$ (4)

- $P_{GG}^{exp}(z) =$
$C_G \, F_{YFS}(\gamma_G) \, e^{\frac{1}{2}\delta_G}\left\{\frac{1-z}{z}z^{\gamma_G}+\frac{z}{1-z}(1-z)^{\gamma_G}+\frac{1}{2}(z^{1+\gamma_G}(1-z)+z(1-z)^{1+\gamma_G}-f_G(\gamma_G)\delta(1-z)\right\}$ (5)

Where

$$\gamma_q = C_F \frac{\alpha_s}{\pi} = \frac{4C_F}{\beta_0}, \quad \delta_q = \frac{\gamma_q}{2}+\frac{C_F\alpha_s}{\pi}\left(\frac{\pi^2}{3}-\frac{1}{2}\right), \quad F_{YFS} = \frac{\exp(-C_E\gamma_q)}{\Gamma(1+\gamma_q)}, \quad \beta_0 = 11-\frac{2}{3}n_f, \gamma_G = C_G\frac{\alpha_s}{\pi}t = \frac{4C_G}{\beta_0},$$

$$\delta_G = \frac{\gamma_G}{2}+\frac{\alpha_s C_G}{\pi}\left(\frac{\pi^2}{2}-\frac{1}{2}\right), \qquad f_q(\gamma_q), f_G(\gamma_G) \text{ are normalization constans}$$

QCED: $QED \otimes QCD$

Following the discussion in Refs. [1,3,4,5], wherein we have derived the following expression for the hard cross sections in the SM $SU_{2L} \times U_1 \times SU_3^c$ EW-QCD theory:

$$d\hat{\sigma}_{exp} =$$
$$e^{SUM_{IR}(QCD)}\sum_{n,m=0}^{\infty}\frac{1}{n!m!}\int\prod_{j_1=1}^{n}\frac{d^3k_{j_1}}{k_{j_1}}\prod_{j_2=1}^{m}\frac{d^3k'_{j_2}}{k'_{j_2}}\int\frac{d^4y}{(2\pi)^4}e^{iy.\left(p_1+q_1-p_2-q_2-\Sigma k_{j_1}-\Sigma k'_{j_2}\right)+D_{QCED}}$$
$$\bar{\bar{\beta}}_{n,m}(k_1,\dots,k_n; k'_1,\dots,k'_m)\frac{d^3p_2}{p_2^0}\frac{d^3q_2}{q_2^0},$$ (6)

Where the new YFS-style [1] residuals $\bar{\bar{\beta}}_{n,m}(k_1,\dots,k_n; k'_1,\dots,k'_m)$ have n hard gluons and m hard photons.

With

$$SUM_{IR}(QCED) = 2\alpha_s Re \, B_{QCED}^{nls} + 2\alpha_s \tilde{B}_{QCED}^{nls}$$

$$D_{QCED} = \int\frac{d^3k}{k^0}\left(e^{-iky} - \theta(K_{max}-k^0)\right)\tilde{S}_{QCED}^{nls}$$

Where K_{max} is "dummy", "nls" $\equiv$ DGLAP-CS synthesization and

$$B_{QCED}^{nls} \equiv B_{QCD}^{nls} + \frac{\alpha}{\alpha_s}B_{QED}^{nls},$$

$$\tilde{B}_{QCED}^{nls} \equiv \tilde{B}_{QCD}^{nls} + \frac{\alpha}{\alpha_s}\tilde{B}_{QED}^{nls},$$

$$\tilde{S}_{QCED}^{nls} \equiv \tilde{S}_{QCD}^{nls} + \tilde{S}_{QED}^{nls}.$$

HERWIRI 1.031

By implementing the new IR-improved Dokshitzer-Gribov-Lipatov-Atarelli-Parisi-Callan-Symanzik (DGLAP-CS) kernels in the HERWIG6.5 environment one can generate a new Monte Carlo (MC), HERWIRI1.0(31), for hadron-hadron scattering at high energies. Refs. [2-7],[8]

Methods

1- Using mg5_aMC@NLO to generate the following processes:

- p p > l+ vl j j [QCD] for $\sqrt{s} = 7,8$ TeV
- p p > l- vl- j j [QCD] for $\sqrt{s} = 7,8$ TeV

For $n$events = 100000

2- Parton Shower (work in progress):
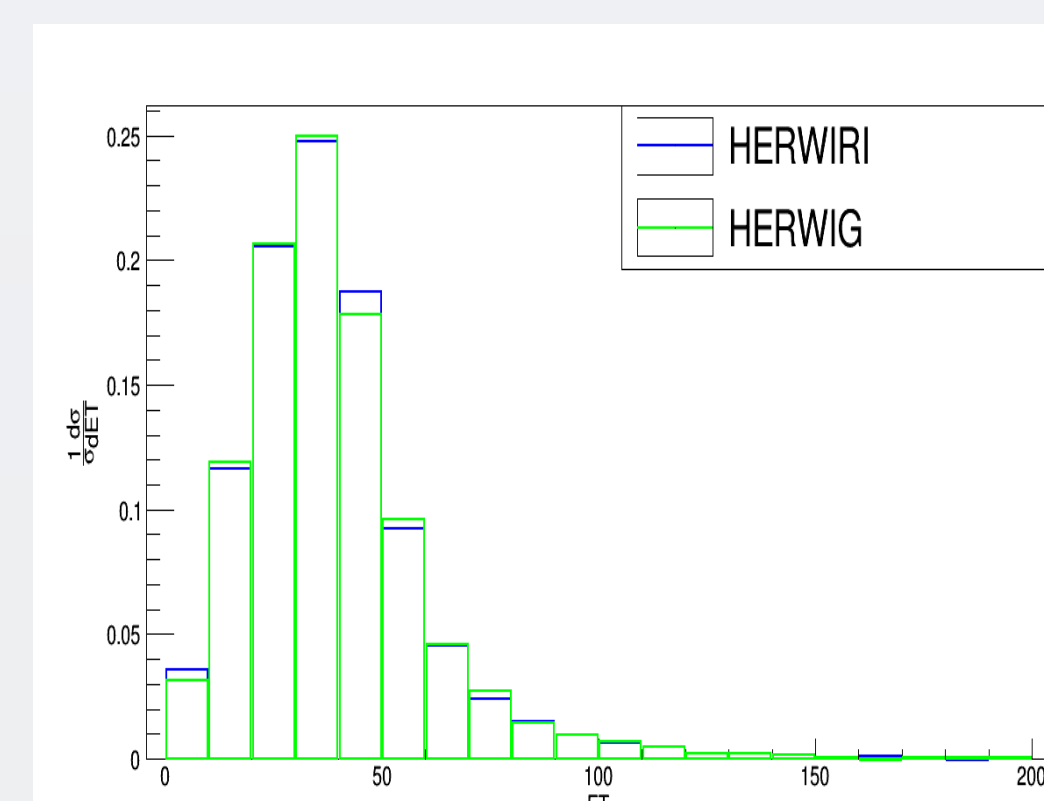
- HERWIGPP
- HERWIG 6521
- HERWIRI 1.031
- PYTHIA 8

3- Cuts (work in progress):

- Jets:
  - $R = 0.4$ [anti-k_T]
  - $|\eta^{jet}| < 2.8$
  - $p_T^{jet} > 30 \, GeV$

- Lepton:
  - $p_T > 25 \, GeV$
  - $1.37 < |\eta^e| < 1.51$
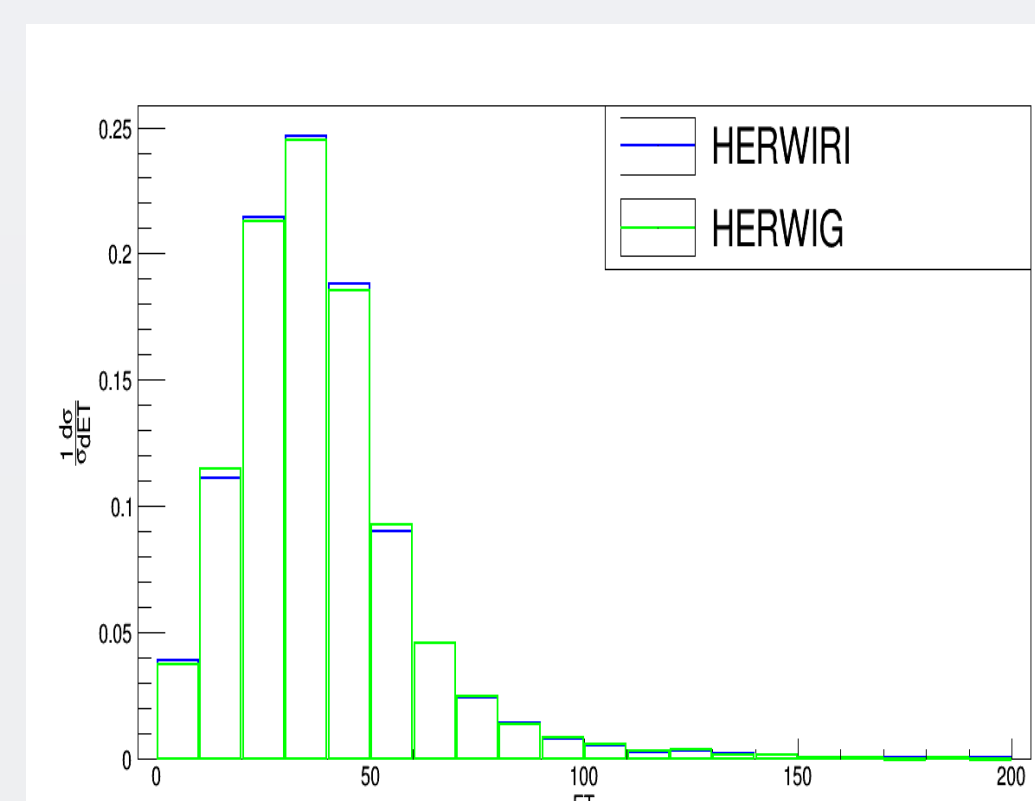 - $E_T > 15 \, GeV$
  - $E_T^{miss} > 25 \, GeV$
  - $M_T^W > 40 \, GeV$

Results
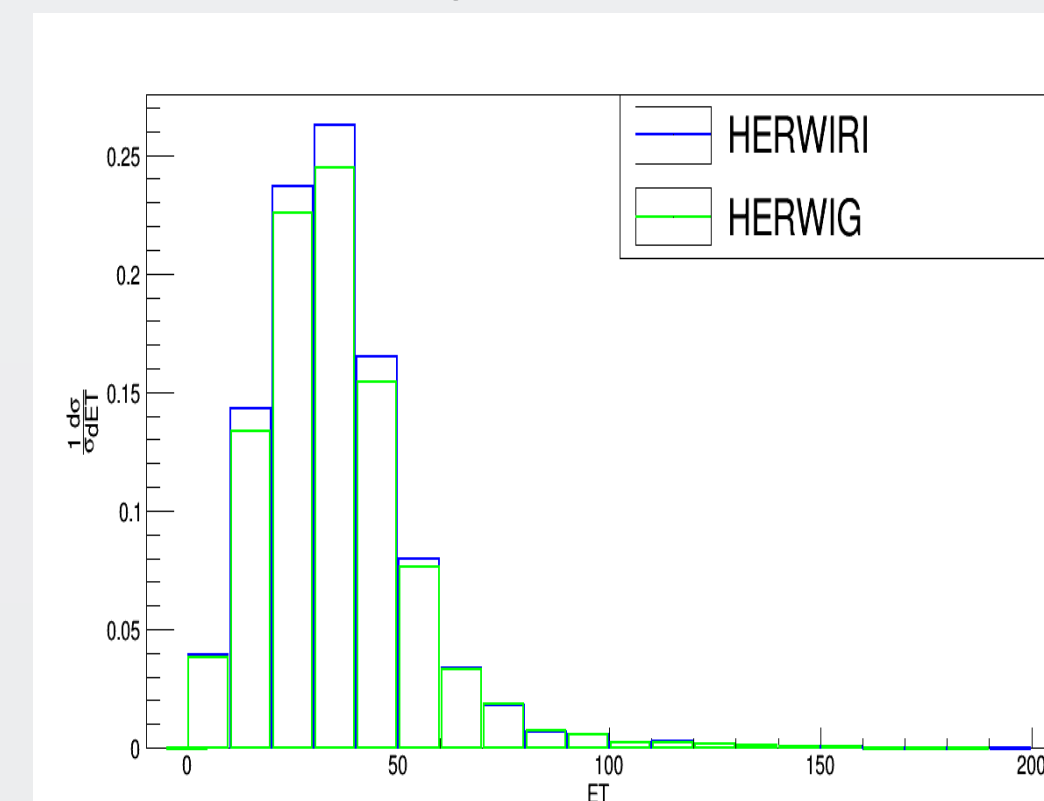
Missing E_T Distribution

$W^+ + 2 \, Jets \, @ \sqrt{s} = 7$ TeV $W^+ + 2 \, Jets \, @ \sqrt{s} = 8$ TeV

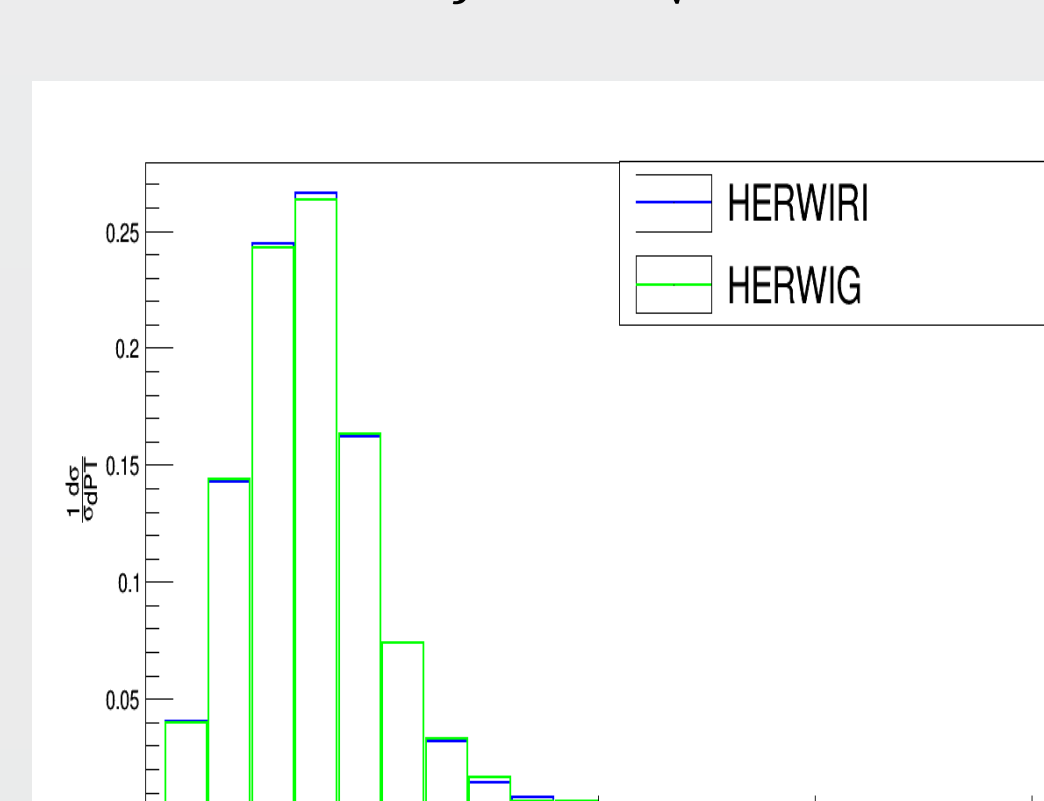$W^- + 2 \, Jets \, @ \sqrt{s} = 7$ TeV $W^- + 2 \, Jets \, @ \sqrt{s} = 8$ TeV
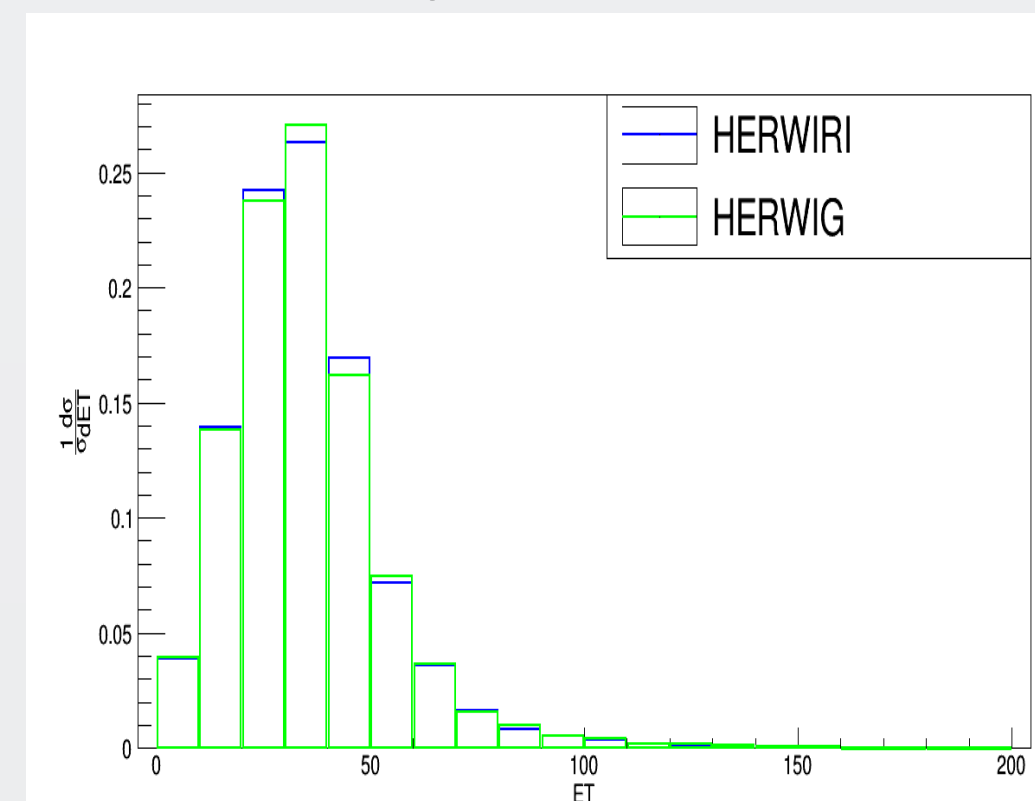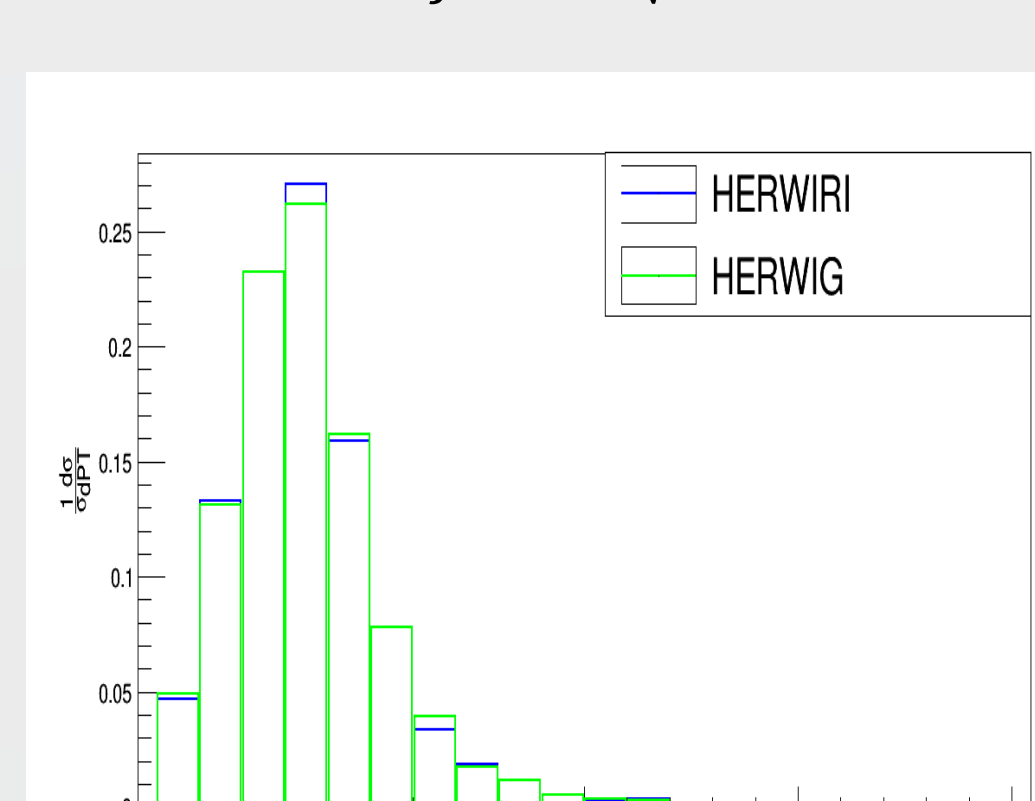

Lepton P_T Distribution

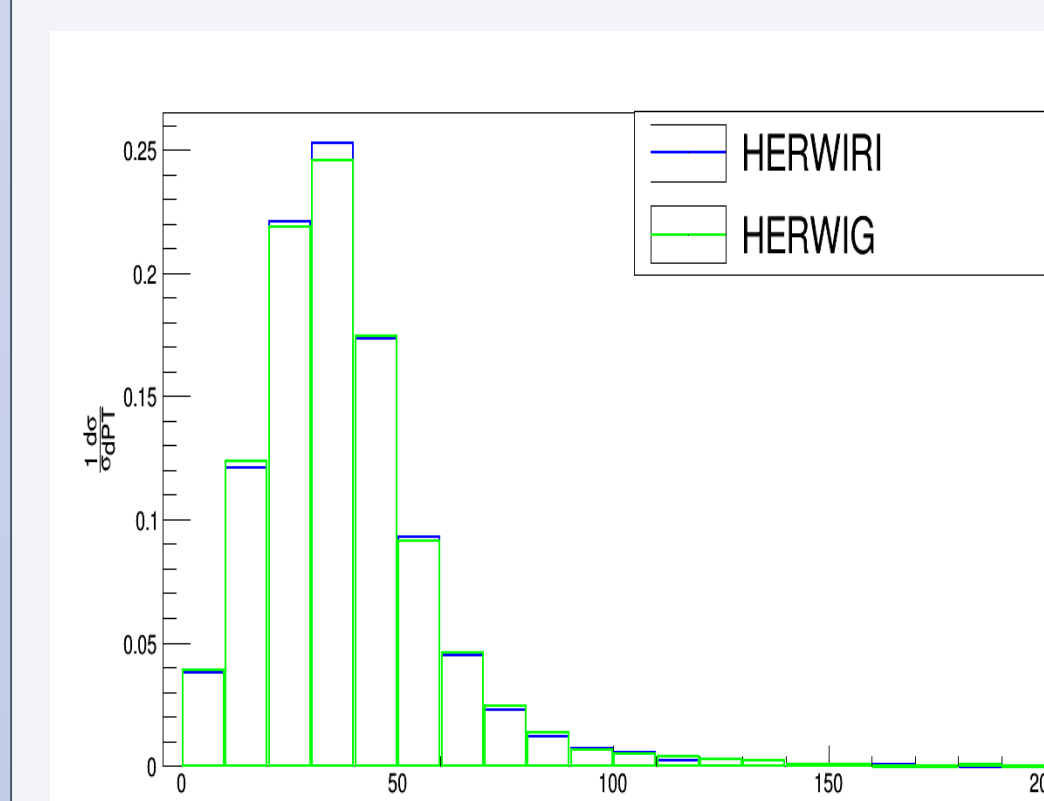$W^+ + 2 \, Jets \, @ \sqrt{s} = 7$ TeV $W^+ + 2 \, Jets \, @ \sqrt{s} = 8$ TeV
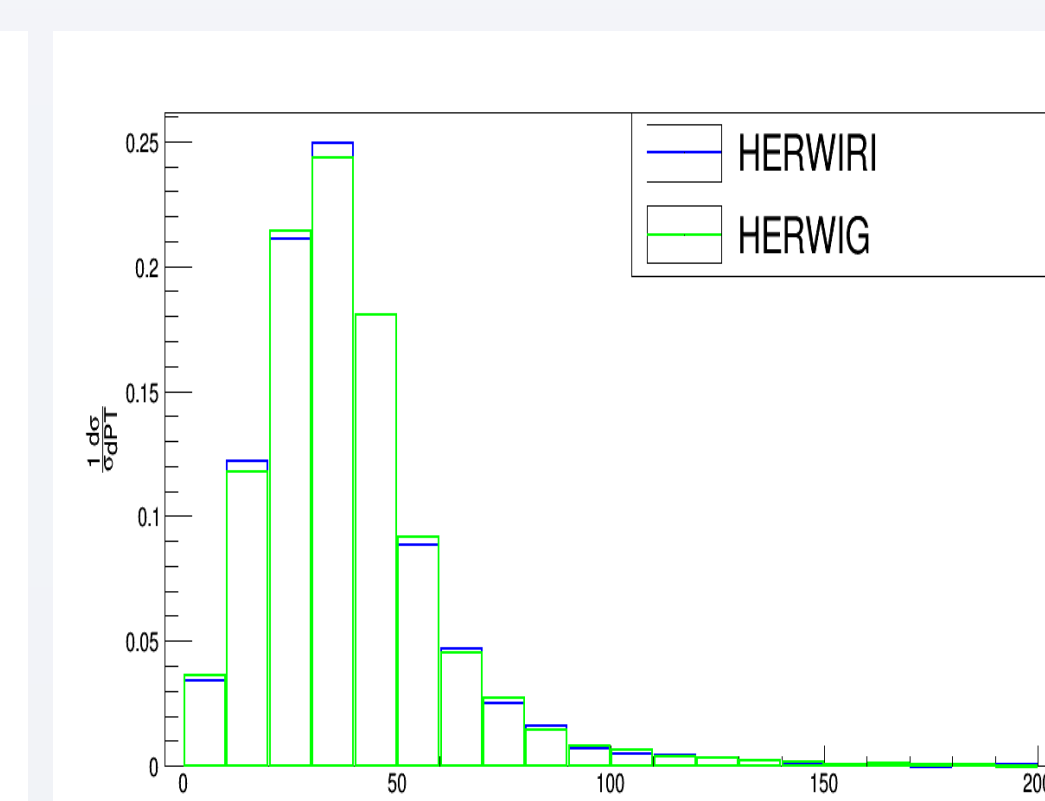

Lepton P_T Distribution (Cont.)

$W^- + 2 \, Jets \, @ \sqrt{s} = 7$ TeV $W^- + 2 \, Jets \, @ \sqrt{s} = 8$ TeV
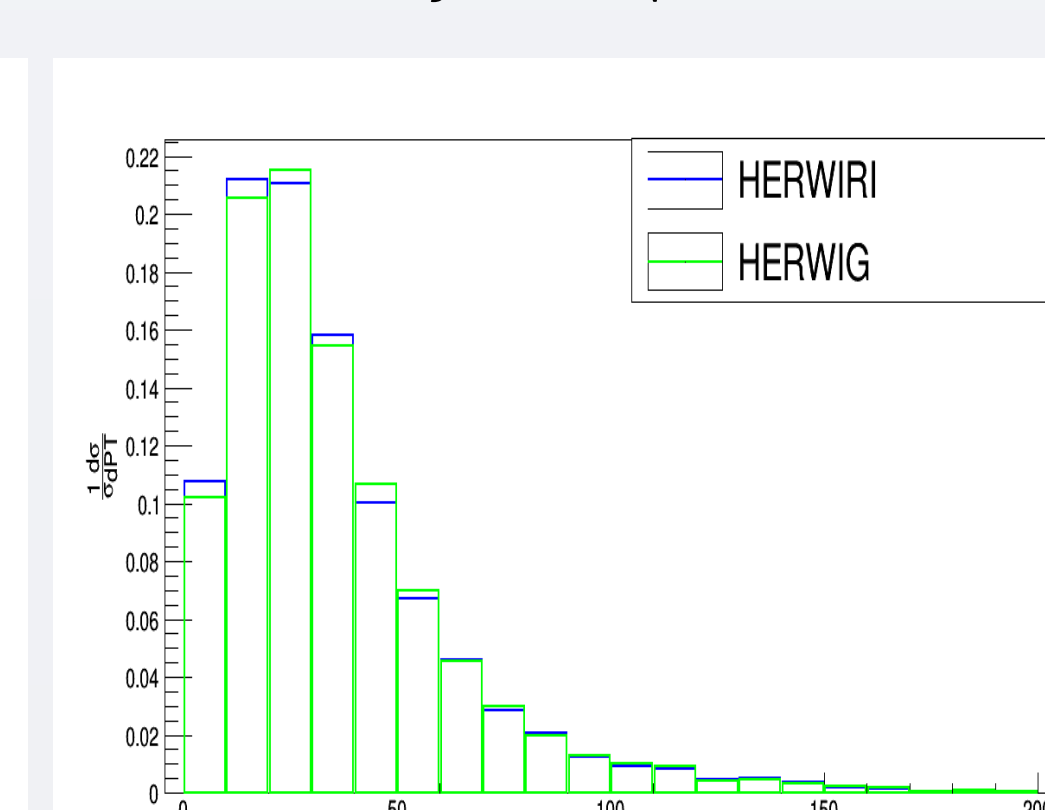

W P_T Distribution
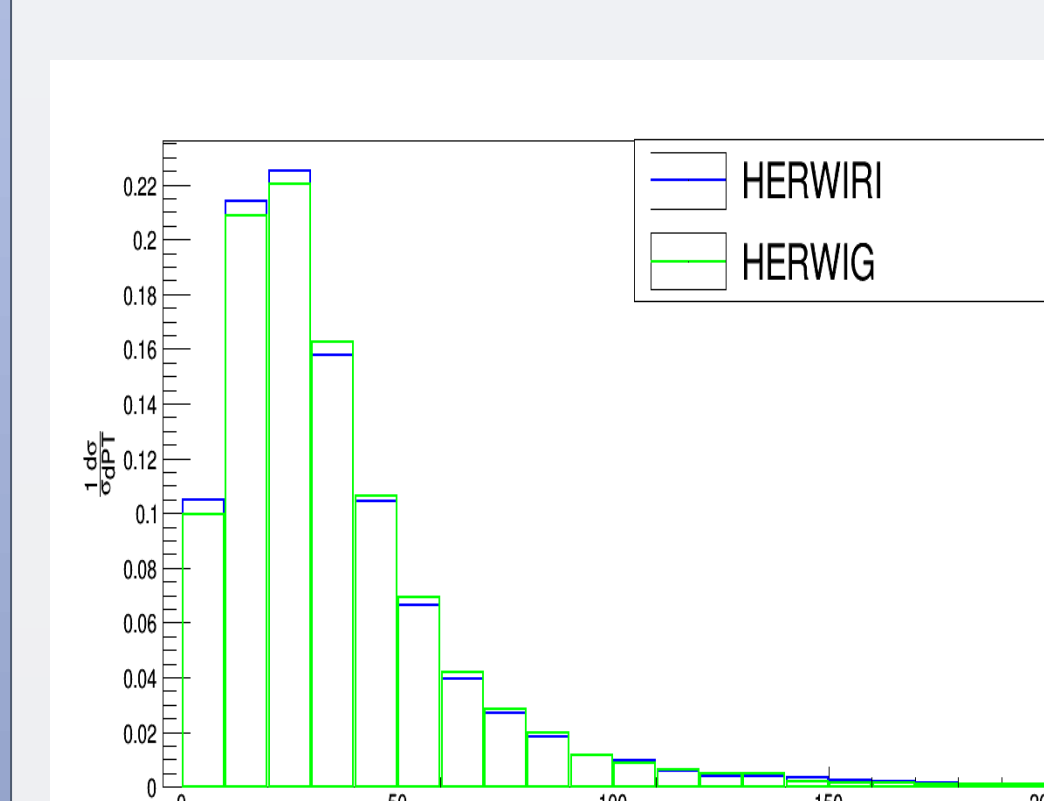
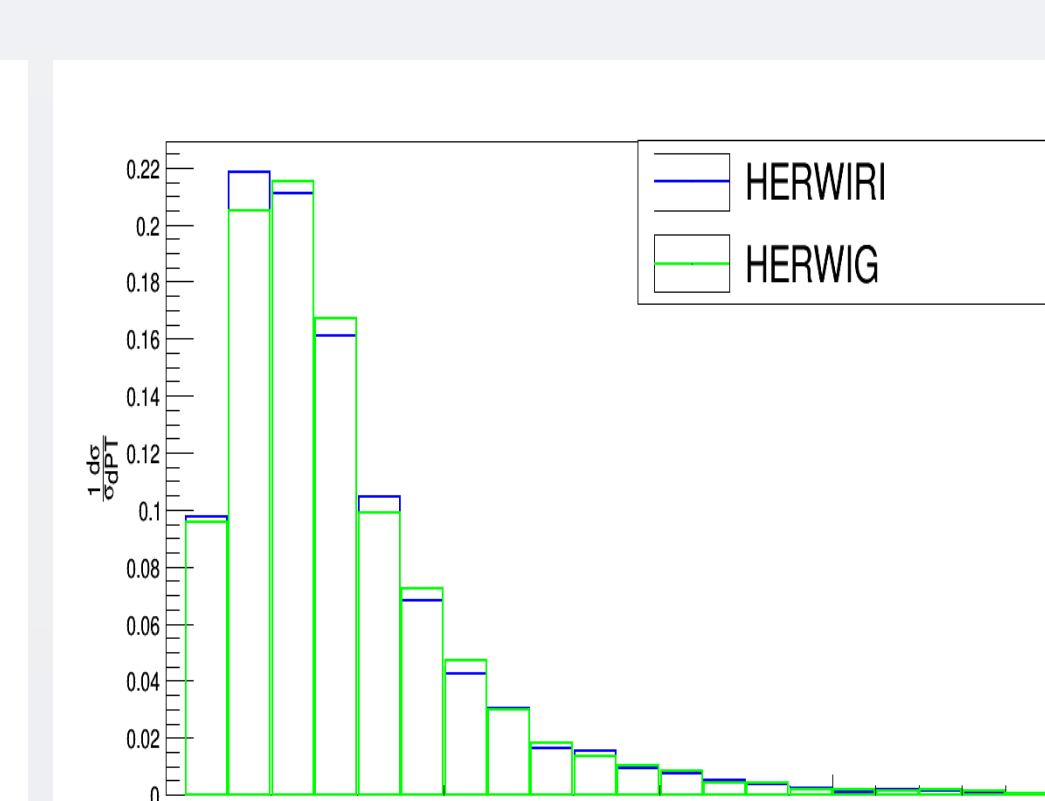$W^+ + 2 \, Jets \, @ \sqrt{s} = 7$ TeV $W^+ + 2 \, Jets \, @ \sqrt{s} = 8$ TeV
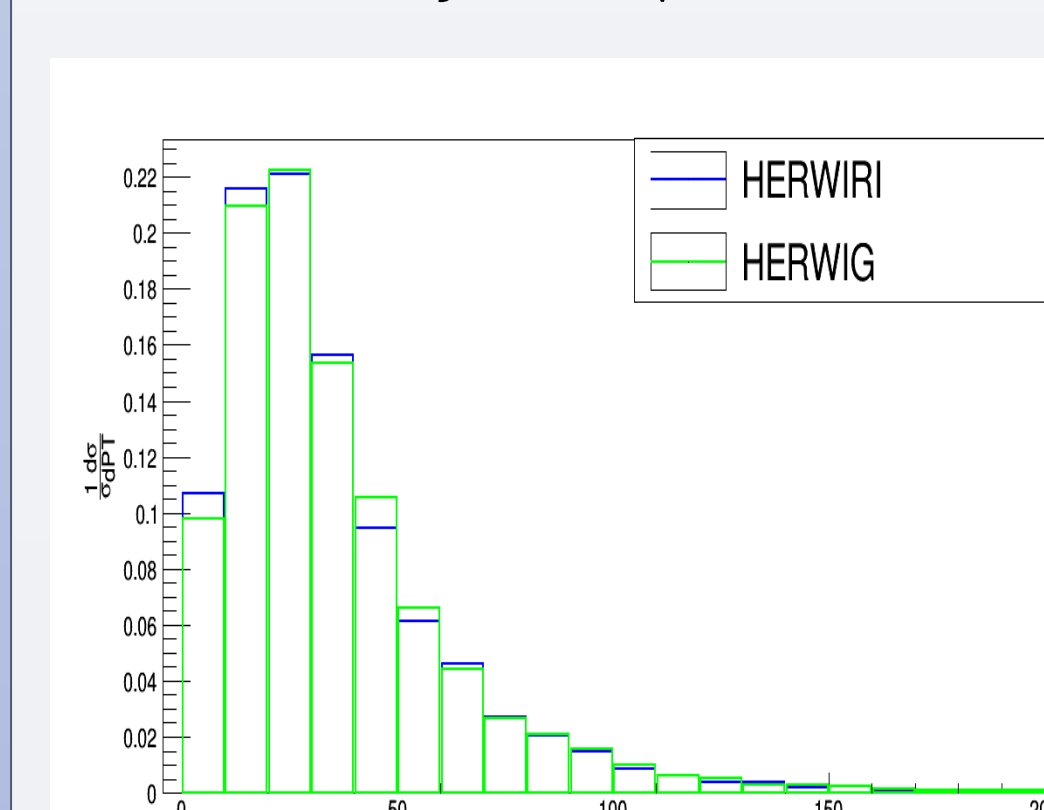
$W^- + 2 \, Jets \, @ \sqrt{s} = 7$ TeV $W^- + 2 \, Jets \, @ \sqrt{s} = 8$ TeV

Conclusion and Future Work

We have introduced a new approach to QCD parton shower MC's based on the new IR-improved DGLAP-CS kernels in Refs. [3,4] and we have realized the new approach with the MC HERWIRI1.031 in the HERWIG6.5.

We are going to repeat the same approach for n jets where $n = 0, 1, 3$ and compare our results with the most recent available data.

References

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