DYRes performance on transverse-momentum distributions for Vector Boson production

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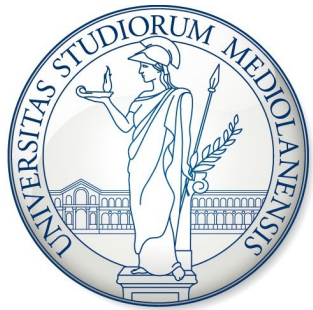

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- DYRes computes the transverse momentum (pT) distribution of Drell-Yan lepton pairs of high invariant mass M ($M \gg \Lambda_{QCD} \approx 1$ GeV) in pp or $p\bar{p}$ collisions (after higher terms resummation);
- We include leptonic decay of vector bosons with spin correlations, finite width effects and dependence on lepton variables, Ref. [1];

- At small pT $\longrightarrow$ resum to all-orders the logarithmical perturbative QCD contributions $\sim \alpha_S^n \ln^m(p_T^2/M^2)$ up to NNLL;
- Resummed results are combined with the known $\mathcal{O}(\alpha_S^2)$ fixed-order result at intermediate and large pT;
- Computation implemented by a partonic level Monte Carlo (VEGAS) $\longrightarrow$ kinematical cuts are applied only on final state.

- W and Z bosons $\longrightarrow$ consider finite width effects (default).
- Mass and width parameters :

Description	**Value (GeV)**
M_W	80.399
Γ_W	2.085
M_Z	91.1876
Γ_Z	2.4952

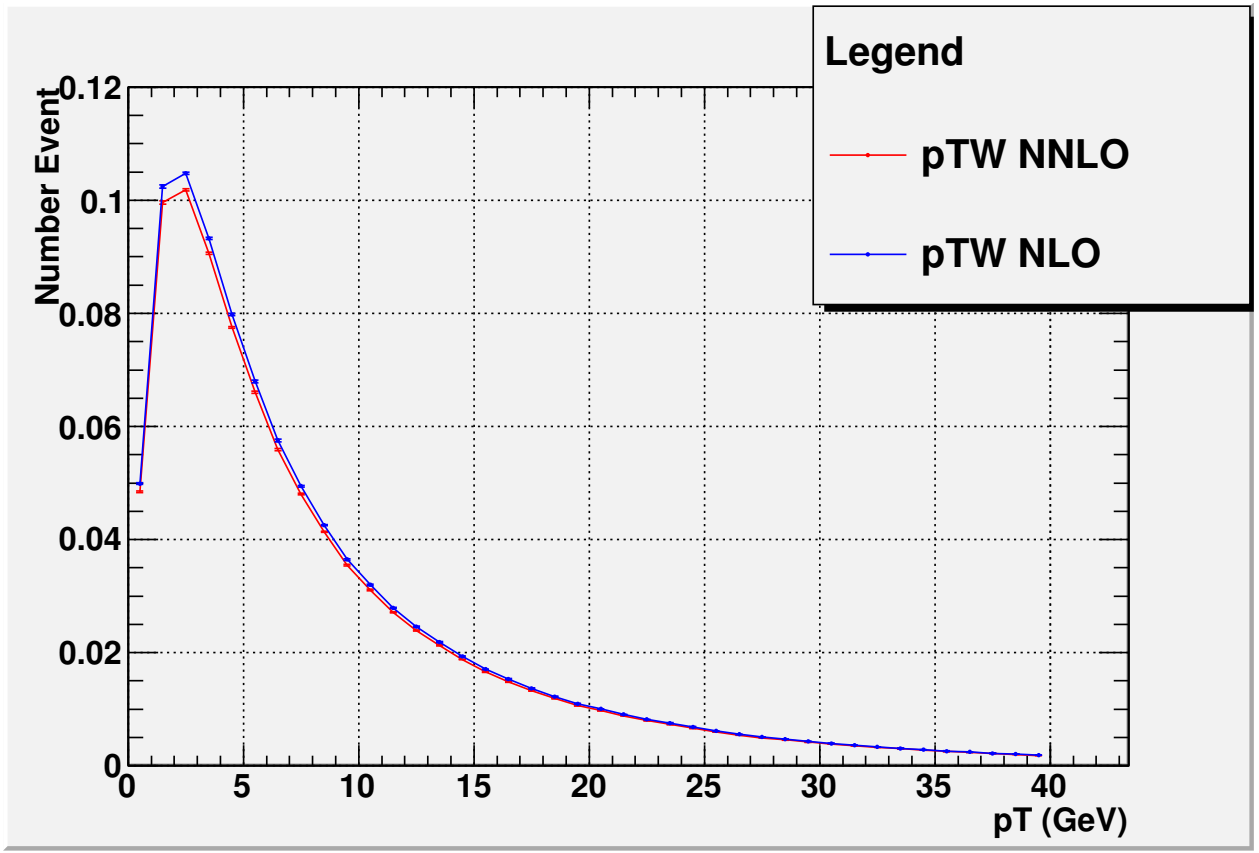
- EW parameters, CKM matrix elements $\longrightarrow$ PDG 2010, Ref. [2];
- EW couplings of W and Z are treated at the tree level.

- The code needs input parameters such as initial state (colliding beams), perturbative orders, etc;
- We set input data by using integer numbers or logical variables (see Appendix for Input file example);
- Computation at NLL+NLO or NNLL+NNLO (world's best accuracy);
- NLO $\longrightarrow$ NNLO implies resummation NLL $\longrightarrow$ NNLL;

- **Cuts**
  - The `"cuts"` subroutine allows user to set kinematical cuts on the final state;
  - To take into account finite width effect the logical variable `zerowidth` must be set to `false`;
  - Not to spoil the validity of the all-order resummation procedure, kinematical cuts cannot be applied on the final-state jets ;

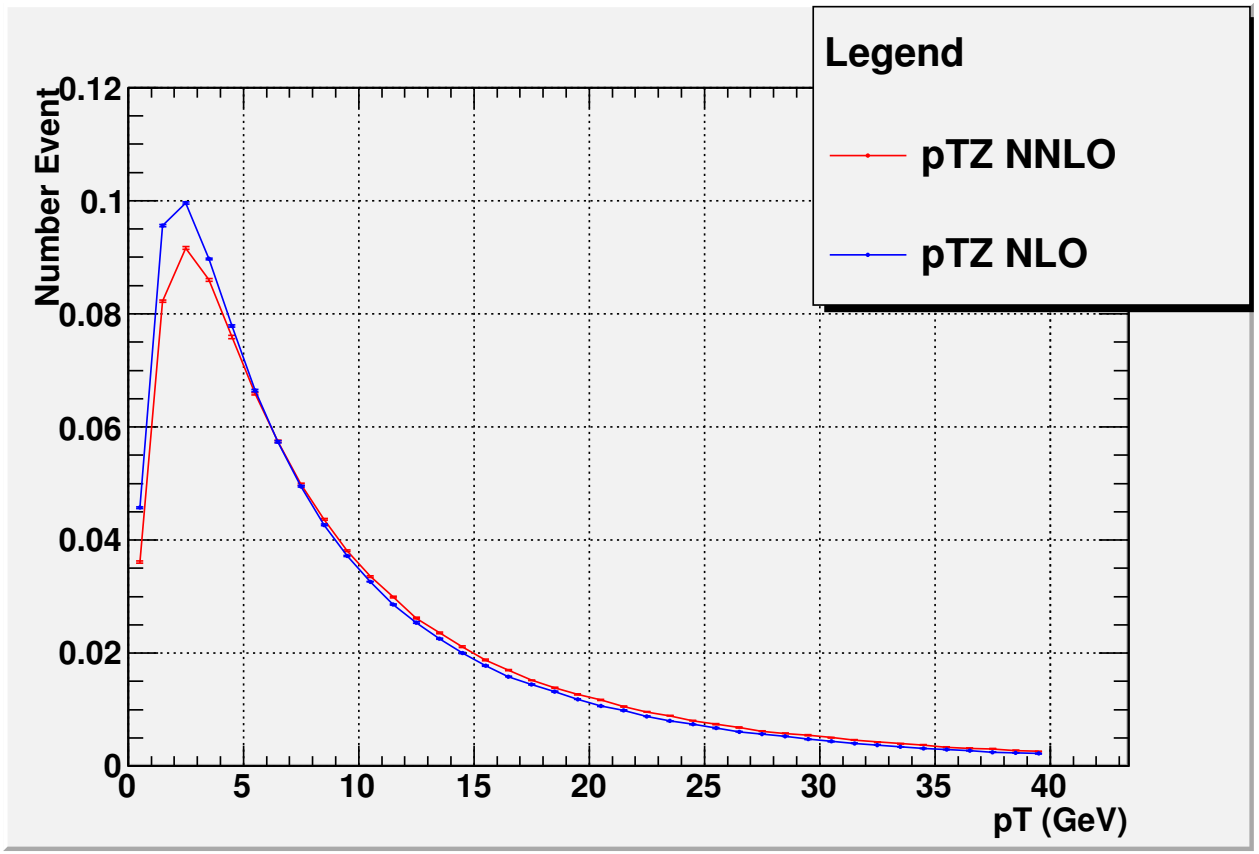
- **Output**
  - DYRes returns the total cross section and its error;
  - An **Outfile** with histograms and statistical errors;
  - Use a **Topfile** to check intermediate results.
- **Running time-scale with accuracy** $\approx 1\%$
  - NLL + NLO $\longrightarrow\sim$ 10 hours on standard PC;
  - NNLL + NNLO $\longrightarrow\sim$ 2 days on standard PC.

- pT W transverse-momentum distributions: NLO vs NNLO



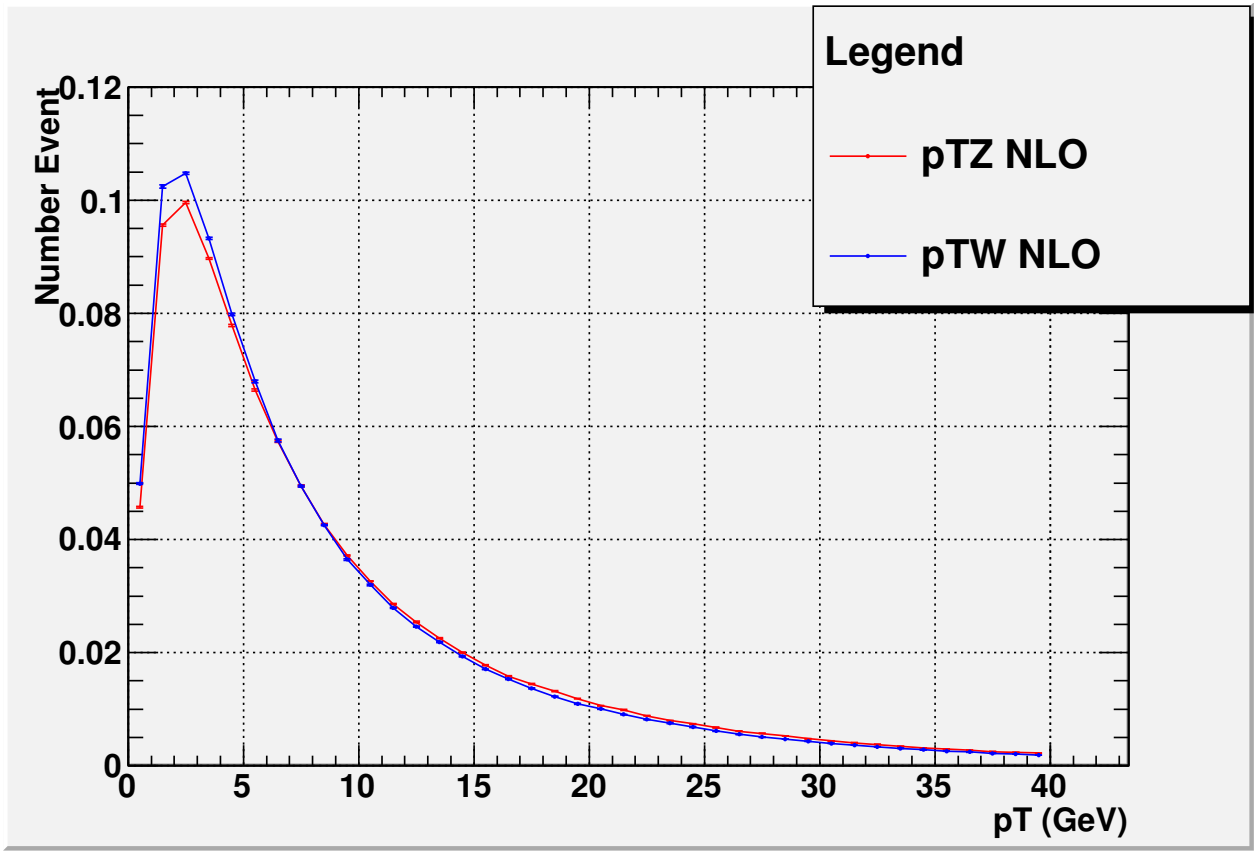
- *Process*: $p\bar{p} \rightarrow W^+ \rightarrow l^+\nu$,$\sqrt{s} = 1.96$ TeV, no cuts on final state.

- pT Z transverse-momentum distributions: NLO vs NNLO

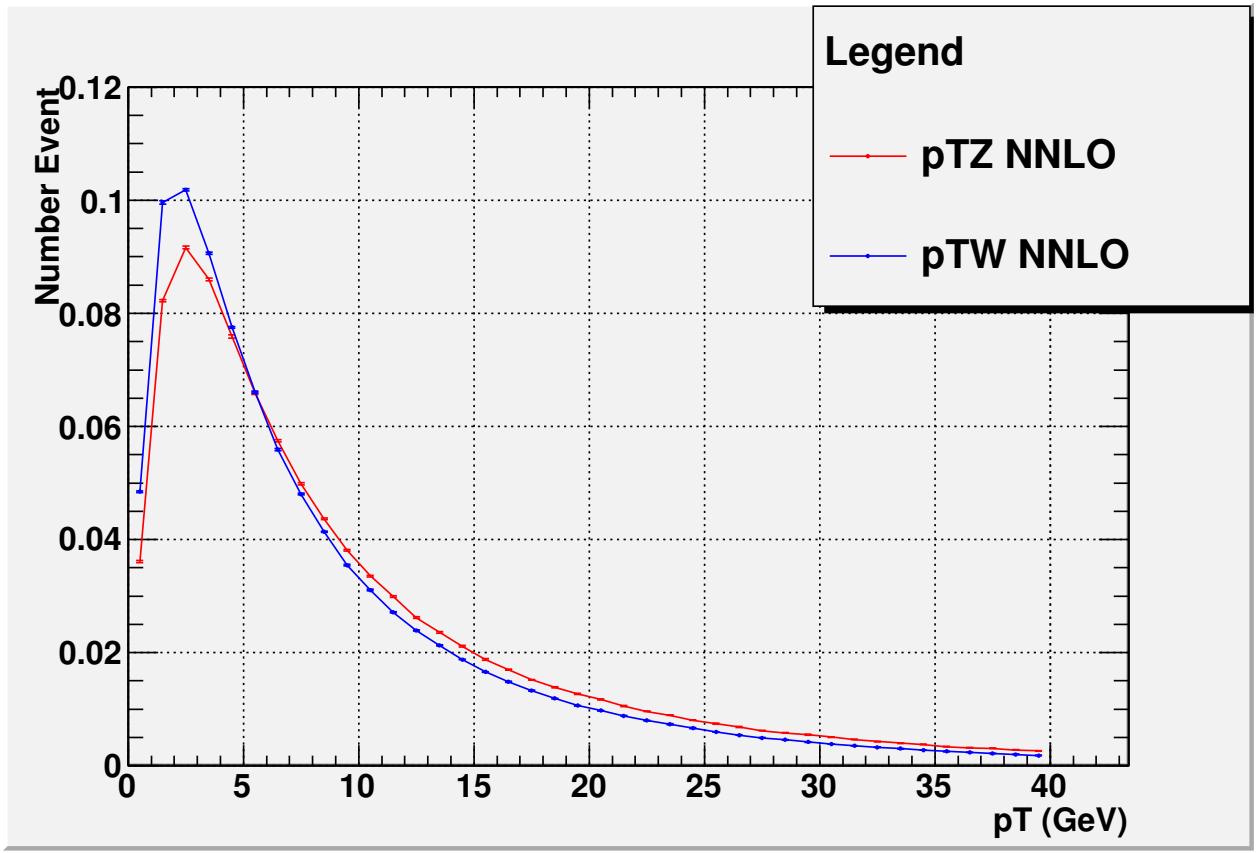


- *Process*: $Z/\gamma^* \to l^+ l^-$, $\sqrt{s} = 1.96$ TeV, di-leptonic invariant mass cuts $70 - 110$ GeV.

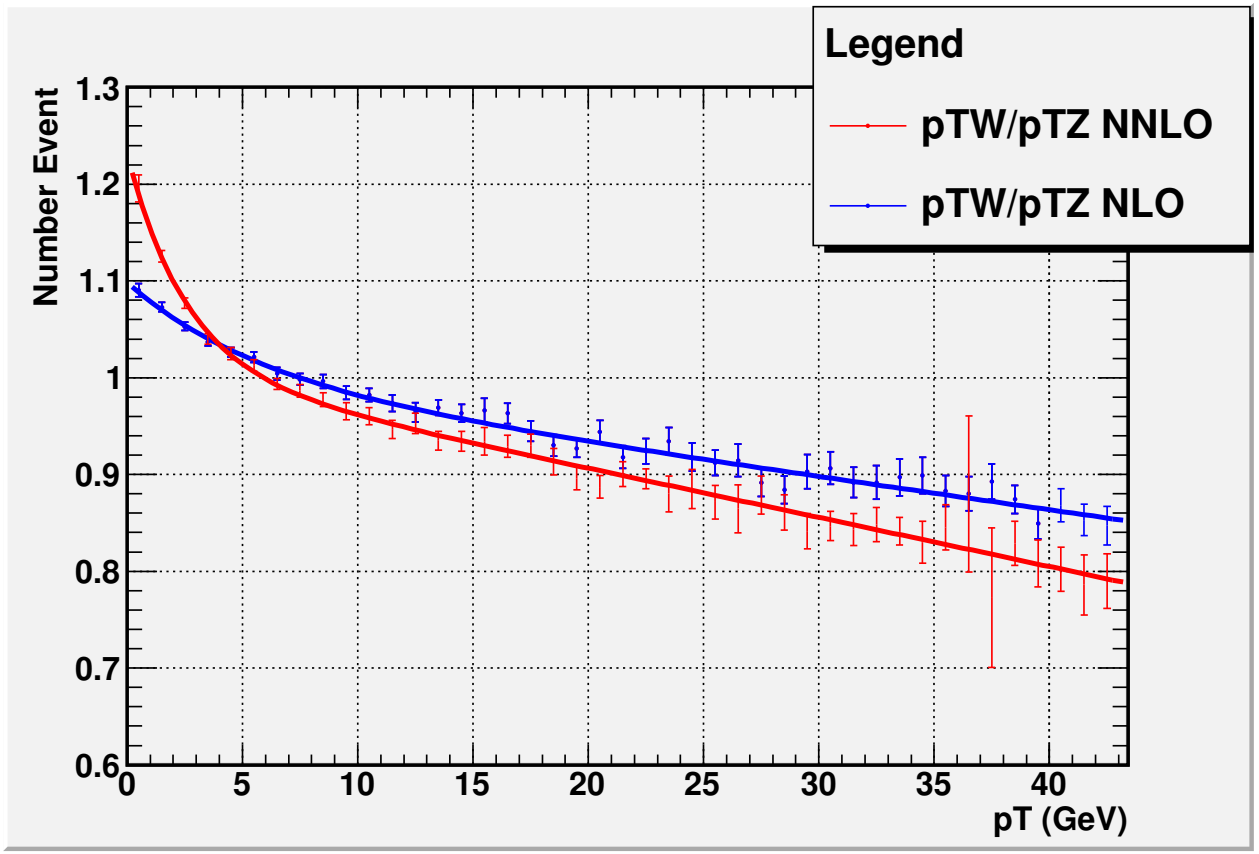
- pT W vs pT Z at NLO



- pT W vs pT Z at NNLO



- pT W ratio to pT Z: NLO vs NNLO



- *Fitting functions*: $f(x) = a + bx + c\exp(dx)$.

- **Next goals:**
  - Understanding better the difference between fixed order and resummed part;
  - Impact of the DYRes uncertainities on the W sistematic errors.

S. Catani, D. de Florian, G. Ferrera and M. Grazzini, arXiv:1507.06937 [hep-ph].

K. Nakamura *et al.* [Particle Data Group Collaboration], J. Phys. G **G37** (2010) 075021.

Appendix: Input file example

- The following is an Infile example for $W^+ \to l^+\nu$ at the Tevatron energies

```
 1.96d3              !  sroot
1 -1                 !  ih1, ih2
1                    !  nproc
80.399d0 80.399d0    !  mur, muf
2.0d0                !  a-param
0.0d0                !  g-param
1                    !  order
'tota'               !  part
.false.              !  zerowidth
70d0 110d0           !  mwmin, mwmax
20 25000000          !  itmx1, ncall1
20 25000000          !  itmx2, ncall2
600                  !  rseed
91 0                 !  set, member (native PDFs)
'MSTW2008nnlo68cl.LHgrid' 0 !  set, member (LHAPDFs)
'NameOutfile'              !  runstring
0                    !  number of itmx written on file
```

Appendix: Input file example

- `sroot`: Double precision variable for centre–of–mass energy (GeV).
- `ih1,ih2`: Integers identifying the beam (proton=1, antiproton=-1).
- `nproc`: Type of process: $W^+ \to l^+\nu$ (`nproc=1`), $W^- \to l^-\bar{\nu}$ (`nproc=2`), $Z/\gamma^* \to l^+l^-$ (`nproc=3`).
- `mur, muf`: Renormalization (μ_R) and factorization (μ_F) scales (GeV): always of the order of m_W or m_Z (or $m_{l\nu}$ and m_{ll} if these invariant masses are very different from m_W and m_Z).
- `a-param`: Resummation scale ($\mu_Q = M/a_{param}$).
- `g-param`: Non-perturbative smearing parameter.
- `order`: Order of the calculation: NLL+NLO (1), NNLL+NNLO (2).
- `part`: Part of the calculation to be performed: `virt` for virtual contribution, `real` for real contribution, `tota` for the complete calculation.
- `itmx1, ncall1`: Number of iterations and calls to VEGAS for setting the grid.

Appendix: Input file example

- `zerowidth`: `true` → vector bosons produced on-shell. `false` → vector bosons produced off-shell.
- `mwmin, mwmax`: Lower and higher limit on the vector boson (lepton pair) invariant mass.
- `itmx2, ncall2`: Number of iterations and calls to VEGAS for the main run.
- `rseed`: Random number seed.
- `iset, nset`: PDF set chosen and the member for PDF errors (if the native PDF interface is used).
- `PDFname, PDFmember`: PDF set chosen and integer identifying the member for PDF errors (if the LHAPDF interface is used).
- `runstring`: String for grid and output files.
- `pr`: Number of last itmx to write on file (this option could use several GBytes of disk space).