Implementing the POWHEG Method in Herwig++

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The POWHEG Method

MC+NLO schemes combine best features of SMC and NLO calculations.

POWHEG scheme of Nason [hep-ph/0409146].

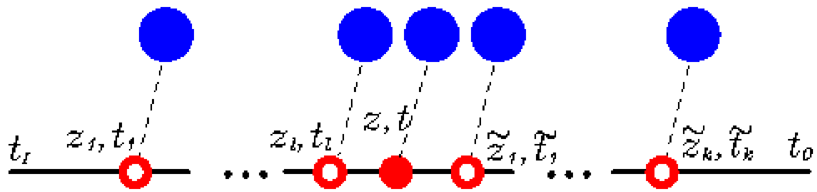
- No negative weights produced
- Hardest Emission generation MC independent
- Requires some changes to shower

Method implemented for e+e→hadrons and Drell-Yan vector boson production processes.

POWHEG Scheme

Hardest emission separated in shower.

$$\mathbb{S}(t_I) = \Delta(t_I, t_0)\langle\mathbb{I}| + \sum_{l,k=0}^{\infty} \int$$



Hardest emission generated from exact Matrix Elements.

- Hardest emission NLO configuration generated.
- Shower with a *pT* veto down to hard scale (truncated shower).
- Shower from with a *pT* veto.

Hardest Emission

NLO cross section can be written as,

$$d\sigma = \bar{B}(v) d\Phi_v [\Delta_R^{(NLO)}(0) + \Delta_R^{(NLO)}(p_T) \frac{R(v,r)}{B(v)} d\Phi_r]$$

$$\Delta_R = \exp\left(-\int d\Phi_r \frac{R(v,r)}{B(v)} \Theta(k_T(v,r) - p_T)\right)$$

$$\bar{B}(v) = B(v) + V(v) + \int (R(v,r) - C(v,r))\, d\Phi_r$$

NLO agreement with cross section retaining LL accuracy of shower

Born variables generated according to $\bar{B}(v) d\Phi_v$

Radiative variables generated according to $\Delta_R^{(\mathrm{NLO})}(p_T) \frac{R(v,r)}{B(v)} d\Phi_r$

e+e- Hardest Emission

To generate the radiative variables, need NLO radiative cross-section.

$$\sigma_r = \frac{\sigma_b C_F \alpha_S}{2\pi} \int dx_1 dx_2 \frac{x_1^2 + x_2^2}{(1-x_1)(1-x_2)}$$

Choose radiative variables *(p_T,y)* – simplifies integration region.

$$y = \frac{1}{2} \log \frac{1-x_2}{1-x_1} \qquad p_T^2 = s(1-x_1)(1-x_2)$$

Exponent of Sudakov Form Factor is:

$$\int d\Phi_r \frac{R(v,r)}{B(v)} \Theta(k_T(v,r) - p_T) = \int^{p_T} dp'_T dy' \frac{C_F \alpha_S p_T}{\pi s} \frac{x_1^2 + x_2^2}{(1-x_1)(1-x_2)},$$

(p_T,y) generated using the veto algorithm.

Born generation trivial in this case. $\bar{B} = \sigma_{LO} \left(1 + \frac{\alpha_S}{\pi}\right)$

Drell-Yan Hardest Emission

Three partonic processes contribute to radiative cross section

$q\bar{q} \to Vg$
$qg \to Vq$
$\bar{q}g \to V\bar{q}$

p_T chosen as a radiative variable to simplify integration region.

$$p_J = (p_T \cosh y_J, p_T \sin\phi, p_T \cos\phi, p_T \sinh y_J),$$
$$p_B = (m_T \cosh y_B, p_T \sin\phi, p_T \cos\phi, m_T \sinh y_B).$$

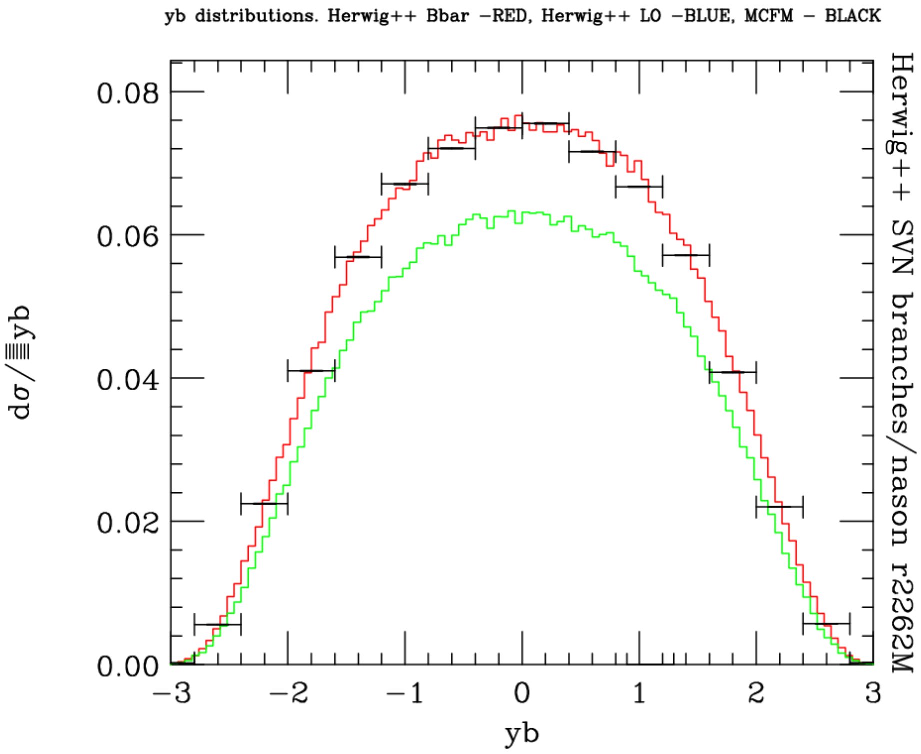
The $q\bar{q}$ contribution gives:

$$\int d\Phi_r \frac{R(v,r)}{B(v)} = C_F \frac{\alpha_s}{\pi} \int \frac{f_q(x_1) f_{\bar{q}}(x_2)}{f_q(x_1') f_{\bar{q}}(x_2')} \frac{\left[(\hat{t}-M^2)^2 + (\hat{u}-M^2)^2\right]}{\hat{s}\hat{t}\hat{u}} p_T dp_T dy_J.$$

$\bar{B}(v) d\Phi_v$ is now a non-trivial function of y_B .

Bbar in Drell-Yan

Requires NLO cross section as non-singular function of born variable.



Use born factorised result.

$$\bar{B}(y_B) = B(y_B)\int W(y_B,\tilde{x},v)d\tilde{x}dv$$

Reweighting of born ME.

Points generated using acdc.

$(\tilde{x},v)$ thrown away.

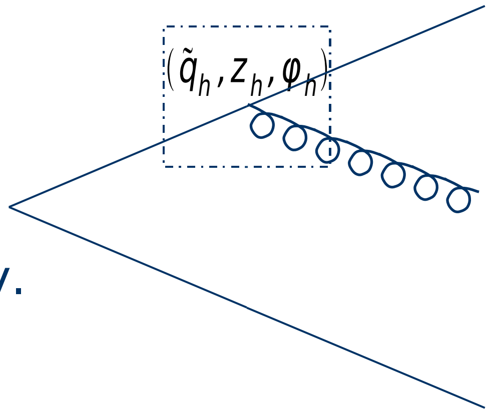
Inverse Momentum Reconstruction

Hardest emission generator for each process
-generates radiative variables
-constructs n+1 momenta

N+1 particles momenta and branching history.

Inverse momentum reconstruction.

Set of 1->2 shower emissions.



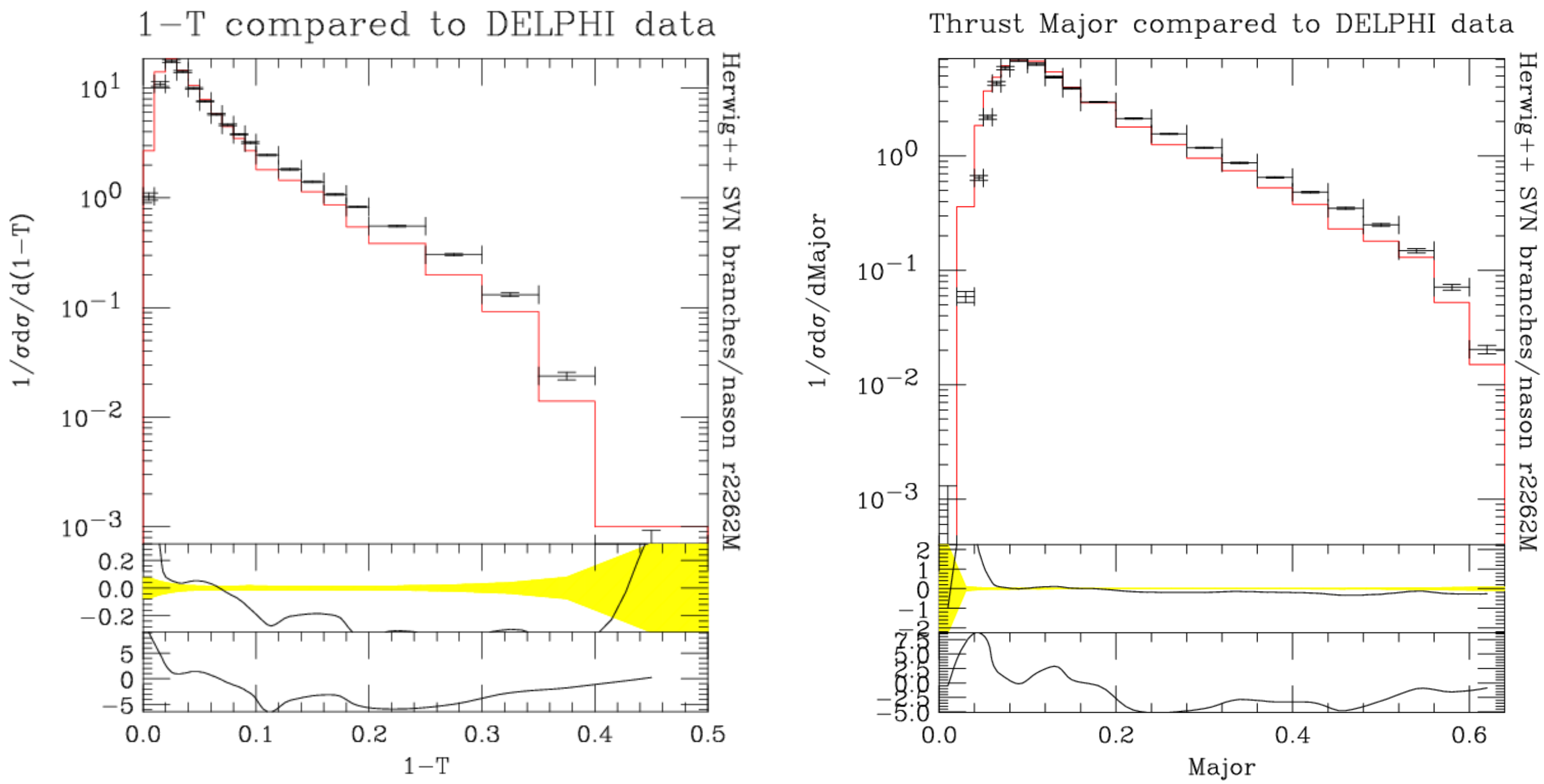
Nason shower procedes as a single shower with simple modifications.

POWHEG Shower Procedure

- Leading order configuration generated from reweighted ME.
- Hardest emission generator produces $(\tilde{q}_h, z_h, \varphi_h)$.
- Truncated shower evolves down to hardest emission scale.
  no flavour changing
  pT veto

  $z\tilde{q} > \tilde{q}_h$
- Splitting forced at $(\tilde{q}_h, z_h, \varphi_h)$.
- Vetoed shower evolves down to hadronization scale.
  pT veto

e+e- Plots


1−T compared to DELPHI data
1/σdσ/d(1−T)
Herwig++ SVN branches/nason r2262M
1−T
Thrust Major compared to DELPHI data
1/σdσ/dMajor
Herwig++ SVN branches/nason r2262M
Major

Drell-Yan Plots