POWHEG method in Herwig++

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Outline

Parton Showers

- Parton showers simulate QCD radiation from coloured particles

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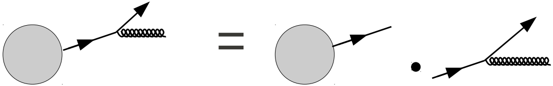


$$d\sigma_{n+1} = d\sigma_n \underbrace{\frac{\alpha_s}{2\pi}\frac{dt}{t}P_{q\to qg}(z)dz}_{\text{splitting probability}} \quad (1)$$

- t: evolution parameter, e.g. virtuality of the parent parton
- $z = E_{\text{gluon}}/E_{\text{parent}}$

Parton Showers

- Regularize splitting probability with a cutoff on gluon p_T
- Still leaves large logarithms
- Parton showers resum leading logarithms
  - Good approximation in soft/collinear limit
  - Doesn't describe harder emissions well
- POWHEG method uses NLO real emission matrix element to generate hardest emission

Parton Showers

- Inclusive cross section for the highest p_T emission:

$$d\sigma^{\rm PS} = B(\Phi_n)d\Phi_n \Big[\overbrace{\Delta(t_{\rm max}, t_{\rm min})}^{\rm No\,splitting} + \underbrace{\Delta(t_{\rm max}, t)\frac{dt}{t}dz\frac{\alpha_s}{2\pi}P_{ab}(z)}_{{\rm Splitting\,at\,scale}\,t} \Big] \qquad (2)$$

- Sudakov form factor:

$$\Delta(t_{\rm max}, t) = \exp\left(-\int_t^{t_{\rm max}} \frac{dt'}{t'}\int dz\frac{\alpha_s}{2\pi}P_{ab}(z)\right) \qquad (3)$$

Sudakov Form Factor

- Parton showers include virtual corrections through unitarity,

$$\mathcal{P}(\text{resolvable}) + \mathcal{P}(\text{unresolvable}) = 1 \tag{4}$$

- Probability of not branching in infinitesimal range of evolution parameter, t,

$$1 - d\mathcal{P}_{ab\to c}(t) \tag{5}$$

- Probability of not branching between two scales of finite separation,

$$\lim_{N\to\infty} \prod_{n=1}^{N} (1 - d\mathcal{P}_{ab\to c}(t_n)) \tag{6}$$

- Which gives the Sudakov form factor,

$$\Delta(t_{\max}, t) = \exp\left(-\int_t^{t_{\max}} d\mathcal{P}_{ab\to c}(t')dt'\right) \tag{7}$$

Powheg Method

- Inclusive cross section for the highest p_T emission:

$$d\sigma^{\mathrm{POWHEG}} = \bar{B}(\Phi_n)d\Phi_n\big[\Delta^{\mathrm{POWHEG}}(t_{\mathrm{max}}, t_{\mathrm{min}}) + \Delta^{\mathrm{POWHEG}}(t_{\mathrm{max}}, t)d\Phi_r\frac{R(\Phi_n,\Phi_r)}{B(\Phi_n)}\big] \quad (8)$$

- Φ_r - phase space variables of the emitted parton
- $\bar{B}(\Phi_n)$ - NLO-weighted Born level cross section

$$\bar{B}(\Phi_n) = B(\Phi_n) + \left[V(\Phi_n) + \int C(\Phi_n,\Phi_r)d\Phi_r\right] + \int [R(\Phi_n,\Phi_r)d\Phi_r - C(\Phi_n,\Phi_r)d\Phi_r] \quad (9)$$

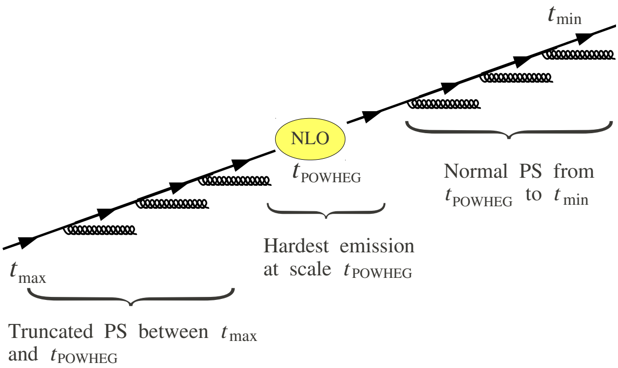
POWHEG Method

- Sudakov form factor:

$$\Delta^{\mathrm{POWHEG}}(t_{\mathrm{max}}, t) = \exp\left(- \int d\Phi_r \frac{R(\Phi_n, \Phi_r)}{B(\Phi_n)} \right) \tag{10}$$

- Modifies total cross section and radiation patterns

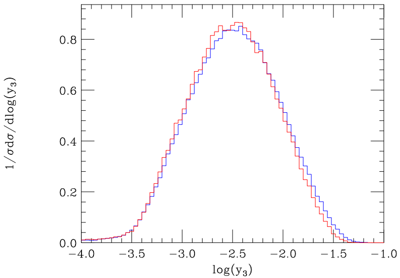
Truncated Shower



- Veto any emission in PS that is harder than POWHEG one

Top Decay

- POWHEG vs. parton shower in Herwig++ for $t \to W\, b\, g$



- Jet measure: $y_3 = \frac{2}{s} \min_{ij} \left(\min \left(E_i^2, E_j^2 \right) (1 - \cos\theta_{ij}) \right)$, where i and j label the jets.

Conclusion and Outlook

- Parton showers describe soft/collinear emissions well
- POWHEG formalism - hardest emission generated with NLO real emission matrix element

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- Parton showers describe soft/collinear emissions well
- POWHEG formalism - hardest emission generated with NLO real emission matrix element
- Implement for decays of supersymmetric particles in Herwig++