NLO Event Generation with SHERPA

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Contents

NLO Cross Section

- LO cross section

$$\sigma_{LO} = \int_{N} \mathrm{d}\sigma_B$$

- NLO cross section

$$\sigma_{NLO} = \int_{N} \mathrm{d}\sigma_B + \int_{N} \mathrm{d}\sigma_V + \int_{N+1} \mathrm{d}\sigma_R$$

- $\mathrm{d}\sigma_V$ may be IR-divergent due to massless loop propagators
- $\int_{1} \mathrm{d}\sigma_R$ may be IR-divergent due to emission of massless line
  $\rightarrow$ sum is finite (KLN-theorem)

NLO Cross Section

Problem: $\mathrm{d}\sigma_V$ and $\mathrm{d}\sigma_R$ live in different phase spaces

- in $\mathrm{d}\sigma_V$ the loop integral is IR divergent
  $\longrightarrow$ every point in the N-dim. phase space carries the divergence structure as poles in $\frac{1}{\epsilon}$ and $\frac{1}{\epsilon^2}$ (in dim. renormalisation)
- for $\mathrm{d}\sigma_R$ the phase space integral over the extra emission is IR divergent
  $\longrightarrow$ a similar pole structure cannot be achieved by Monte Carlo integration (integration in integer number of dimensions only)

$\longrightarrow$ NLO cross section cannot be directly integrated using Monte Carlo methods
$\longrightarrow$ no obvious cancellation of divergences

Subtraction Schemes

$$\sigma_{NLO} = \int_N \mathrm{d}\sigma_B + \int_N \mathrm{d}\sigma_V + \int_{N+1} \mathrm{d}\sigma_R$$

individual terms rendered integrable by subtraction scheme
$\rightarrow$ needs to provide local counter terms $\mathrm{d}\sigma_A$ which are integrable over extra emission phase space

$$\sigma_{NLO} = \int_N \mathrm{d}\sigma_B + \int_N \overbrace{\left[\mathrm{d}\sigma_V + \int_1 \mathrm{d}\sigma_A\right]}^{\text{IR-finite loop integration}} + \int_{N+1} \underbrace{\left[\mathrm{d}\sigma_R - \mathrm{d}\sigma_A\right]}_{\text{IR-finite PS integration}}$$

The POWHEG Method

- generate N-jet event with

$$\mathrm{d}\sigma_B + \mathrm{d}\sigma_V + \mathrm{d}\sigma_I + \int\limits_1 \left[\mathrm{d}\sigma_R - \mathrm{d}\sigma_S\right]$$

- shower radiates real emission with Sudakov form factor

$$\Delta_t = \exp\left[-\int \theta(t_r - t)\,\frac{R}{B}\,\mathrm{d}\Phi_r\right]$$

$\longrightarrow$ shower needs to cover the whole phase space

Available in SHERPA

- automated Catani-Seymour subtraction term generation (in AMEGIC++) Gleisberg, Krauss: Eur.Phys.J.C53(2008)501-523
- LO ME generators (AMEGIC++, COMIX)
  Krauss, Kuhn, Soff: JHEP02(2002)044, Gleisberg, Hoeche: JHEP12(2008)039
- few built-in virtual MEs + extensive tensor integral library
- interfaces to NLO codes (BLACKHAT, GOLEM, etc.)
  Bern et al: arXiv:0902.2760, Binoth et al: arXiv:0810.0992
- parton shower (CSSHOWER++) Schumann, Krauss: JHEP03(2008)038

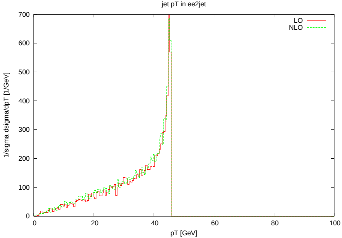
$\longrightarrow$ rearrange terms to give N-jet event with NLO weight
$\longrightarrow$ get correct real emission via POWHEG method

First Results on $ee \to 2jets$ at 91.25 GeV

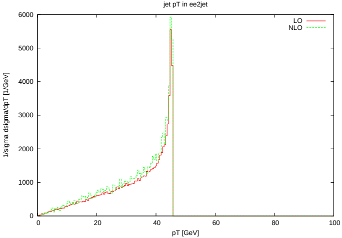
fixed order result:

$$\mathrm{d}\sigma_{NLO} \quad = \quad \left(1+\frac{\alpha_S}{\pi}\right)\mathrm{d}\sigma_{LO} \quad \text{with } (J=1)$$

unweighted event generation



weighted event generation




```
LO:     2_2__e-__e+__j__j :               40189.9 pb +- ( 18.29 pb = 0.045509 % )
NLO:    2_2__e-__e+__j__j__QCD(BVIRS) :   41712.5 pb +- ( 20.79 pb = 0.049842 % )
```

Further Ideas

Resumption Effects:

- determine $k_\perp^2$ of most probable splitting for real emission
  $\longrightarrow$ shower language
- consistently replace one power of α_S with $\alpha_S(k_T^2)$
  $\longrightarrow$ capture resummed large logarithms from higher orders
  $\longrightarrow$ enlarged possibility of softer emission

```
LO:        2_2__e-__e+__j__j :                 40189.9 pb +- ( 18.29 pb = 0.045509 % )
NLO:       2_2__e-__e+__j__j__QCD(BVIRS) :     41712.5 pb +- ( 20.79 pb = 0.049842 % )
NLO+NLL:   2_2__e-__e+__j__j__QCD(BVIRS) :     42757.4 pb +- ( 20.41 pb = 0.047748 % )
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Conclusion

Done:

- consistent use of already built-in components in new approach
- integration of $R + S$ converges
- numbers seem to be right
- inclusion of resummed corrections real extra emission via α_S rescaling

Todo:

- determine $\left(\frac{R}{B}\right)_{max}$ for POWHEG matching
- imposing upper cut-off J on real emission to make cross sections exclusive for multijet merging