# Towards NLO Event Generation in SHERPA

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[1] for SHERPA: J. Archibald, T. Gleisberg, S. Höche, F. Krauss, MS, S. Schumann, F. Siegert, J. Winter

# NLO cross section

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

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

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

# NLO event generation

- $2 \to N$ process kinematics and $2 \to N+1$ kinematics
- hard $2 \to N+1$ kinemtics should be according to $\mathrm{d}\sigma_R$ only, not $[\mathrm{d}\sigma_R - \mathrm{d}\sigma_A]$
- resolution criterion $J$ for extra emission has to be introduced
  $Q^2 > J$ extra emission constitutes extra jet
  $\to$ generate solely according to $\mathrm{d}\sigma_R$
  $Q^2 < J$ extra emission does not constitute extra jet
  $\to$ recombine extra emission, part of LO kinematics

$$\sigma_{NLO} = \int_N \mathrm{d}\sigma_B + \int_N \left[\mathrm{d}\sigma_V + \int_0^J \mathrm{d}\sigma_A\right] + \int_N \int_0^J \left[\mathrm{d}\sigma_R - \mathrm{d}\sigma_A\right] + \int_N \int_J^1 \mathrm{d}\sigma_R$$

# NLO event generation

- event generation in $2 \to N+1$ according to

$$\mathrm{d}\sigma_R\,\Theta(Q^2 - J)$$

- event generation in $2 \to N$ according to

$$\mathrm{d}\sigma_B + \mathrm{d}\sigma_V + \int_0^J \mathrm{d}\sigma_A + \int_0^J \left[\mathrm{d}\sigma_R - \mathrm{d}\sigma_A\right]$$

- depending on $J$, matrix element level events can be generated with positive weights only
  $\longrightarrow$ events can be unweighted

# Complications

- advisable to use Catani-Seymore dipole subtraction in SHERPA
  Nucl.Phys.B485(1997)291-419
- hardly integrable subtraction terms for realistic $J$
- massless subtraction terms are integrable for cut-off in $y$
  Phys.Rev.D68(2003)094002

$$\sigma_{NLO} = \int_N \mathrm{d}\sigma_B + \int_N \left[\mathrm{d}\sigma_V + \int_0^\alpha \mathrm{d}\sigma_A\right] + \int_N \int_0^J \left[\mathrm{d}\sigma_R - \mathrm{d}\sigma_A\right] + \int_N \int_\alpha^J \mathrm{d}\sigma_A$$

# What's already in?

- SHERPA can generate $\mathrm{d}\sigma_B$ and $\mathrm{d}\sigma_R$ automatically using AMEGIC++ or COMIX
  JHEP 0202(2002)044, JHEP 0812(2008)039
- SHERPA can generate $\mathrm{d}\sigma_A$ and $\int^{\alpha} \mathrm{d}\sigma_A$ in the Catani-Seymour dipole subtraction scheme using AMEGIC++
  Eur.Phys.J.C53(2008)501-523
- no public code available to automatically generate integrable $\mathrm{d}\sigma_V$
  $\rightarrow$ have to rely on hand-coded MEs at the moment
  $\rightarrow$ basic set of master integrals available
  $\rightarrow$ tensor calculus up to rank four available
  $\rightarrow$ see Frank's talk

# Immediate tasks

- restructure the ME handling to accomodate the multitude of squared MEs to be evaluated simultaneously
- restructure the code to handle the integration over the unresolved extra emission phase space
  $\rightarrow$ make sure the extra emission covers the whole phase space
  $\rightarrow$ use dipole kinematics from CSSHOWER++ JHEP 0803(2008)038
- integrate unresolved phase space per event
  $\rightarrow$ efficiency needed
  $\rightarrow$ luckily $\mathrm{d}\sigma_R - \mathrm{d}\sigma_A$ is flat
- attach parton shower in a meaningful way
- merge NLO $2 \rightarrow N$, NLO $2 \rightarrow N+1$, ...,
  LO $2 \rightarrow N+M$, LO $2 \rightarrow N+M+1$
- extend to massive partons