KICKOFF: NEGATIVE WEIGHTS IN SHERPA

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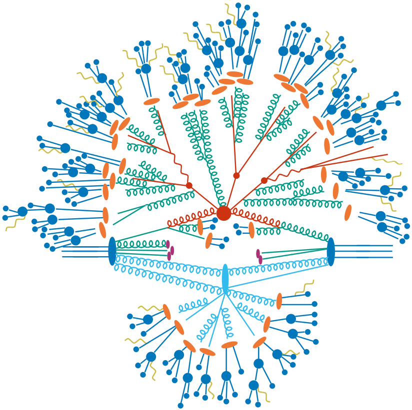


OVERVIEW

- Sherpa employs a variant of MC@NLO matching, called S-MC@NLO
- Discuss origin of negative weights in the S-MC@NLO method
- Discuss mechanisms to reduce negative weight fraction

  Not generic, but specific to Sherpa
- Focus on heavy hitters: V+jets and tt+jets
- Not my work: [K. Danziger, S. Höche, F. Siegert] arXiv:2110.15211
- Note that we did many performance improvements in (un)weighted event generation, but that does not address downstream processing and storage problems caused by negative events :(

Left table: Z + 0,1,2j@NLO + 3j@LO

Right table: tt + 0,1j@NLO + 2,3j@LO

	Positive Fraction	Negative Fraction
$\mathbb{S} + \mathbb{H}$	82%	18%
thereof $\mathbb{S}$	88%	58%
thereof $\mathbb{H}$	12%	42%

	Positive Fraction	Negative Fraction
$\mathbb{S} + \mathbb{H}$	75%	25%
thereof $\mathbb{S}$	91%	72%
thereof $\mathbb{H}$	9%	28%

ORIGIN OF NEGATIVE WEIGHTS IN S-MC@NLO

- **Hard events**: $\int \mathrm{d}\Phi_R \left[R(\Phi_R) - D^{(\mathcal{A})}(\Phi_R)\right]$
- $D^{(\mathcal{A})} = D^{(\mathcal{S})}\Theta\left(\mu_Q^2 - t\right)$.
- $D^{(\mathcal{S})}(\Phi_R) \to \sum_{ijk} \langle M_B(\Phi_B)| \frac{\mathbf{T}_{ij}\mathbf{T}_k}{\mathbf{T}_i^2} V_{ijk}(\Phi_R, \Phi_B) |M_B(\Phi_B)\rangle$,
- 1st reason for negative events:
  dipole approximation $D^{(\mathcal{S})}$ can be larger than $R \rightsquigarrow$ generic for MC@NLO
- **Standard events**:
  $\int \mathrm{d}\Phi_B \bar{B}^{(\mathcal{A})}(\Phi_B)\,[\bar{\Delta}^{(\mathcal{A})}\left(t_c, \mu_Q^2\right) + \int_{t_c}^{\mu_Q^2} \mathrm{d}\Phi_1 \frac{D^{(\mathcal{A})}(\Phi_B,\Phi_1)}{B(\Phi_B)} \bar{\Delta}^{(\mathcal{A})}\left(t, \mu_Q^2\right)]$
- 2nd reason for negative events: $D^{(\mathcal{A})}$ can be negative due to
  sub-leading colour configurations $\rightsquigarrow$ particular to S-MC@NLO
- 3rd reason: local K factor $\rightsquigarrow$ particular to MENLOPS

1ST REMEDY: LEADING COLOUR APPROXIMATION

- Use leading colour and leading spin approximation
- Numerical motivation: Corrections to large N_C limit in processes with two color charged particles at leading order typically suppressed by $1/N_C^2$, $\sim \mathcal{O}(10\,\%)$
- Theory motivation: these effects anyway not included in remaining shower emissions
- However actual phase space covered by parton shower extends far into non-logarithmic region; effects non-negligible?
- Should carefully validate process-by-process, observable-by-observable
- Done für V+jets and tt+jets [K. Danziger, S. Höche, F. Siegert] arXiv:2110.15211

2ND REMEDY: HARD EVENT SHOWER INTERPLAY

- Sudakov reweighting between hard n-jet event's 0th and nth jet required
- Can apply it also between nth jet and merging scale without spoiling accuracy
- Such additional Sudakov suppression reduces hard event contribution in soft region of phase space $\rightsquigarrow$ less negative weights
- implementation of the reweighting has also been discussed in the context of MC@NLO matching at fixed multiplicity

  [R. Frederix, S. Frixione, S. Prestel and P. Torrielli] arXiv:2002.12716

CORE LOCAL K FACTOR

- Negative weight fraction at NLO increasing when going to higher multiplicities
- Exploit by reducing cases where high-multi NLO matrix elements evaluated without necessity
- This is the case for the local k factor used in MENLOPS to provide smooth merging between multis at NLO and LO:

$$k_m\left(\Phi_m, \Phi_{m+1}\right) = \frac{\overline{\mathrm{B}}_m\left(\Phi_m\right)}{\mathrm{B}_m\left(\Phi_m\right)}\left(1 - \frac{\mathrm{H}_m\left(\Phi_{m+1}\right)}{\mathrm{B}_{m+1}\left(\Phi_{m+1}\right)}\right) + \frac{\mathrm{H}_m\left(\Phi_{m+1}\right)}{\mathrm{B}_{m+1}\left(\Phi_{m+1}\right)}$$

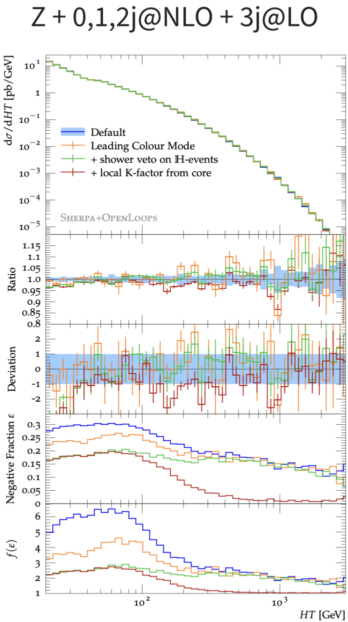
- Usually use highest multi NLO matrix element available
- Instead cluster back completely and use core NLO matrix element
- Expected to reduce negative weight fraction in high p_T regions, where high-multiplicity LO matrix elements contribute most

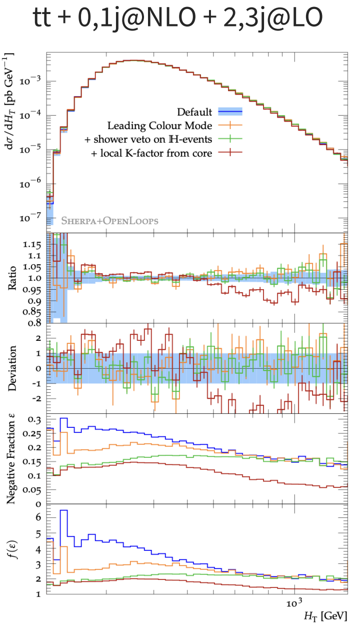
Z + 0,1,2j@NLO + 3j@LO

	Negative Weight Fraction
Default	18.1%
Leading Colour Mode	14.0%
+ shower veto on $\mathbb{H}$-events	9.6%
+ local K-factor from core	9.1%

tt + 0,1j@NLO + 2,3j@LO

	Negative Weight Fraction
Default	24.8%
Leading Colour Mode	18.7%
+ shower veto on $\mathbb{H}$-events	14.5%
+ local K-factor from core	12.6%


Z + 0,1,2j@NLO + 3j@LO
dσ/dHT [pb/GeV]
Default
Leading Colour Mode
+ shower veto on H-events
+ local K-factor from core
Sherpa+OpenLoops
Ratio
Deviation
Negative Fraction ε
f(ε)
HT [GeV]


tt + 0,1j@NLO + 2,3j@LO
dσ/dH_T [pb GeV^-1]
Default
Leading Colour Mode
+ shower veto on H-events
+ local K-factor from core
Sherpa+OpenLoops
Ratio
Deviation
Negative Fraction ε
f(ε)
H_T [GeV]

CONCLUSIONS

- Some methods correspond to approximations which are valid within the claimed precision of the sample but can change the physics predictions of the simulation.
- For Z+jets and tt+jets setups, no critical differences found
- Resulting negative weight fractions halved, to $\epsilon \approx 10\,\%$