Negative Weight Suppression in Monte Carlo Samples

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Negative-weight suppression

Negative weights arise in calculations for many reasons. A problem not just for the numerical stability and the sample size needed for the calculation (which translates into limiting the precision and complexity of the calculations that can be performed). But negative weights and the breakdown of a probabilistic interpretation is a problem also for the application of many AI and machine learning techniques.

CERN TH organized and supported a workshop on **Negative-Weight suppression in Monte Carlo Samples** May 5-9.[1]

Three main topics discussed :-

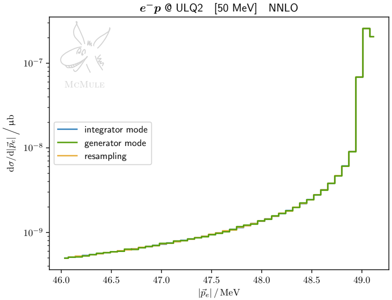
- Elimination of events with negative weights for production of colour singlet particles
- The application of methods of negative weight suppression in NNLO calculations
- Novel methods for the suppression of negative weights

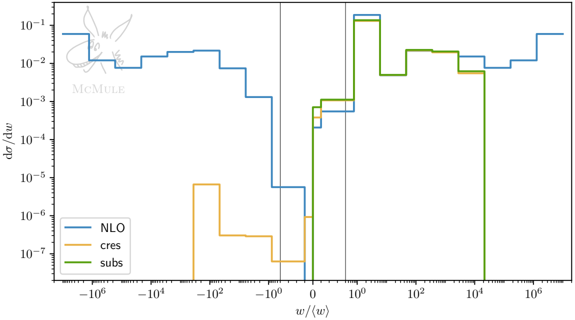
[1] Organized and supported in the context of the Next Generation Triggers project (https://nextgentriggers.web.cern.ch), task 1.5

Negative-weight suppression

All approaches introduce changes to long established approaches. Challenge:

- verify the methods do not change the description of the physics
- methods for comparing the improvement in the weight distribution





Statistical tests for similarity of (in this case three) distributions...

...with very different **variance and weight distribution**

Negative-weight suppression

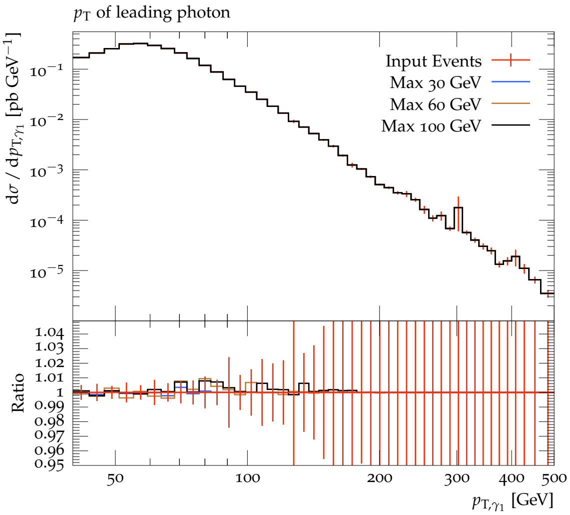
Work at Les Houches: Continue investigations started at CERN

- Statistical tests, e.g. two-sample Kolmogorov-Smirnov. Standard χ^2 insufficient, since one needs to test for systematic deviations, rather than purely statistical deviations.
- Ideas for how to illustrate and measure the variance reduction. Not necessarily only for overall distribution, but perhaps also differentially for distributions (i.e. improvement vs. p_t etc).

Several ideas exist. Welcome new suggestions, and event samples to use for verifying whether the tests can identify both correct and wrong results.

Example from arxiv:2411.11651 (Andersen, Cueto, Jones, Maier)

- Investigation of the diphoton background for Higgs boson production
- Convergence as the maximum cell size is decreased
- Large tails of weights suppressed



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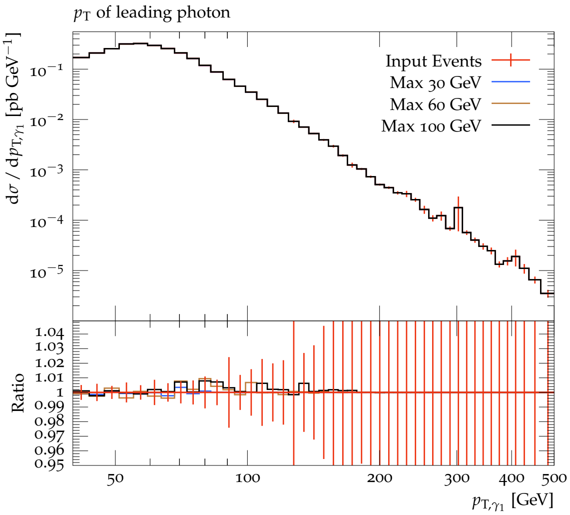

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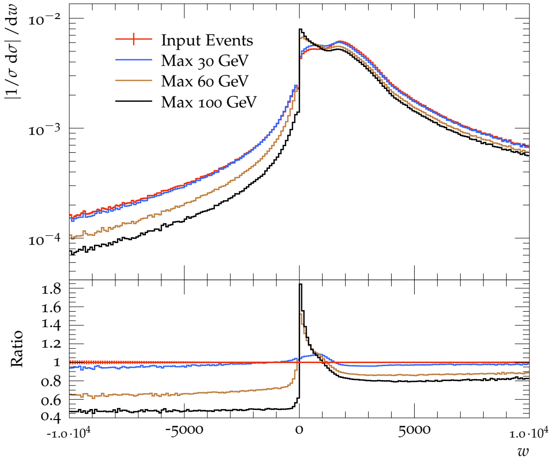

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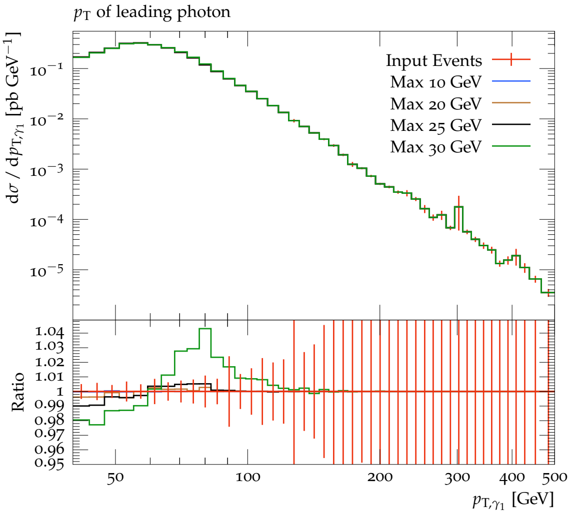
Investigate a worse metric to better illustrate what can go wrong
(note again the convergence)

Kolmogorov-Smirnov two-sample test

Max cell size	KS
10 GeV	1
20 GeV	0.999993
25 GeV	0.763904
30 GeV	0.000002 (2E-6)



Suppressing negative weights in generation

Slides from McFayden (MCNet Meeting 2018)

Negative weights a problem not just for the cost of generation, but also for the application of ML techniques etc.

Brief discussion of various techniques for suppressing negative weights directly int the generation

Aside | Negative event weights

- Any development here would be much appreciated…
- We cannot afford to run full simulation on samples with negative weight fraction >25%
  - Starting to become a deal-breaker
- Also has knock-on effects
  - For e.g. huge W/Z samples for high precision analyses we cannot currently use MC@NLO-like matching schemes.

Sample	DSID	Fraction of events with neg. weights [%]
Sherpa (lepton+jets)	364345	20.5
Sherpa (lepton+jets)	364346	20.4
Sherpa (dilepton)	364347	20.4
Sherpa ttbb (lepton+jets, CSSKIN, 4FS)	410329	24.4
Sherpa ttbb (lepton+jets, CMMPS, 4FS)	410335	25.7
aMC@NLO+Py8 (lepton+jets)	410441	23.7
aMC@NLO+Py8 (dilepton)	410442	23.7
aMC@NLO+Py8 (FxFx, 70 GeV)	410452	28.4
aMC@NLO+H++ (4FS, ttbb)	410245	37.2
Powheg+Herwig7 (lepton+jets)	410557	0.4
Powheg+Herwig7 (dilepton)	410558	0.4

9 Josh McFayden | MCnet | 11/4/2018