On-the-fly scale variations in SHERPA

Marek Schönherr

Universität Zürich

SHERPA Meeting, 07/01/2016

Universität Zürich[UZH]

FNSNF

FONDS NATIONAL SUISSE
SCHWEIZERISCHER NATIONALFONDS
FONDO NAZIONALE SVIZZERO
SWISS NATIONAL SCIENCE FOUNDATION

Scale variations in SHERPA

Which scales are there?

- renormalisation and factorisation scales (μ_R, μ_F) of matrix elements
  $\rightarrow$ can be reweighted, leads to same event kinematics
  `SCALES METS{FSF*MU_F2}{RSF*MU_R2}{QSF*MU_Q2};`
- resummation scale or parton shower starting scale (μ_Q)
  $\rightarrow$ cannot be reweighted, leads to different event kinematics
  `SCALES METS{FSF*MU_F2}{RSF*MU_R2}{QSF*MU_Q2};`
- multijet merging scale (Q_{cut})
  $\rightarrow$ cannot be reweighted, leads to different event kinematics
  `CKKW sqr(20./E_CMS);`

$\vdots$

- PDFs
  $\rightarrow$ PDFs in matrix elements can be reweighted, but not in shower
  `PDF_LIBRARY LHAPDFSherpa; PDF_SET NNPDF30_nnlo_as_0118;`

Scale variations in SHERPA

Explicit variations:

- can be done for any scale or PDF dependence
- functional form can be changed
- separate runs with changed input

On-the-fly variations:

- can be done for $\mu_{R|F}$ and PDF dependence of matrix elements
- functional form can currently not be changed
- full syntax cf. Manual, simplified syntax:

```
SCALE_VARIATIONS 0.25,0.25 0.25,1. 1.,0.25 1.,1. 1.,4. 4.,1. 4.,4.;
PDF_VARIATIONS NNPDF30_nnlo_as_0118[all];
```

- stored in `HepMC::WeightContainer` in LH naming convention
  `MUR<fac>_MUF<fac>_PDF<id>` LH'13 arXiv:1405.1067

Scale variations in SHERPA

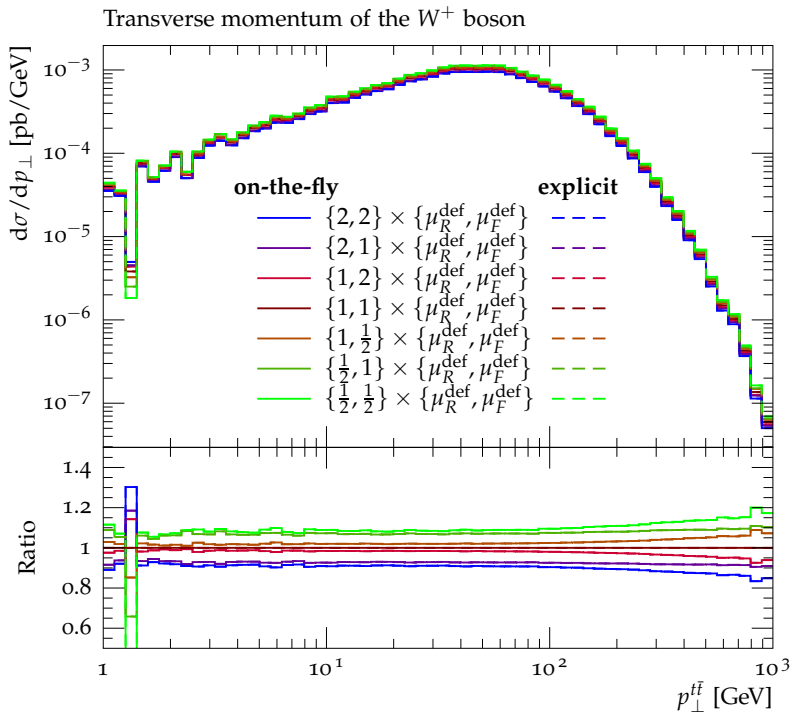
Disclaimer

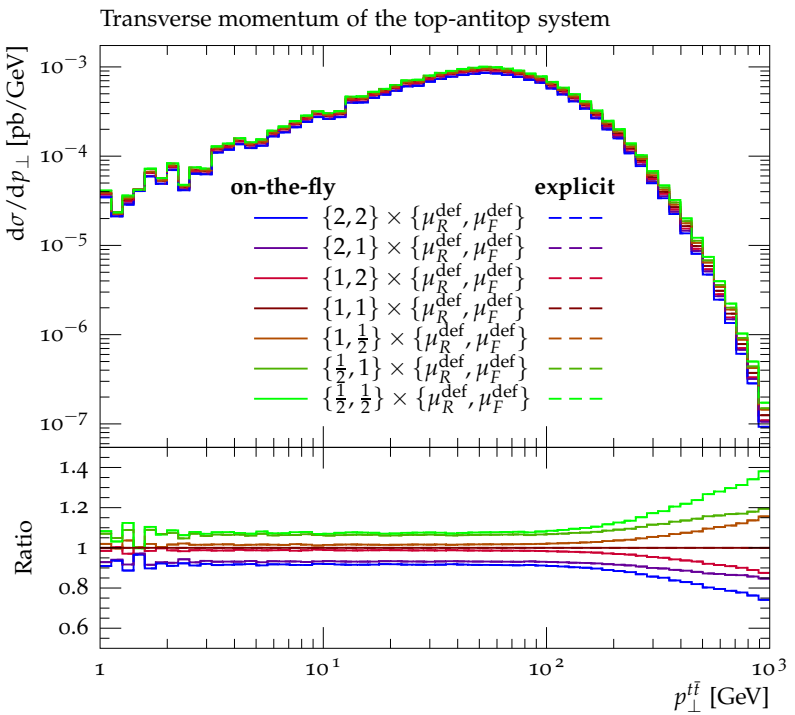
- On-the-fly scale variations in SHERPA-2.2.0 limited to
  - fixed-order calculations LO, NLO
  - matched calculations LOPS, NLOPS (S-MC@NLO)
  - multijet merged calculations MEPS
- on the way for MENLOPS, MEPS@NLO, NNLOPS (UN^{2}LOPS)

Examples

- $pp \to t\bar{t}W$ with S-MC@NLO
- $pp \to \ell^+\ell^- + \leq 4$ jets with MEPS

Scale variations in $pp \to t\bar{t}W^+$ (S-MC@NLO)

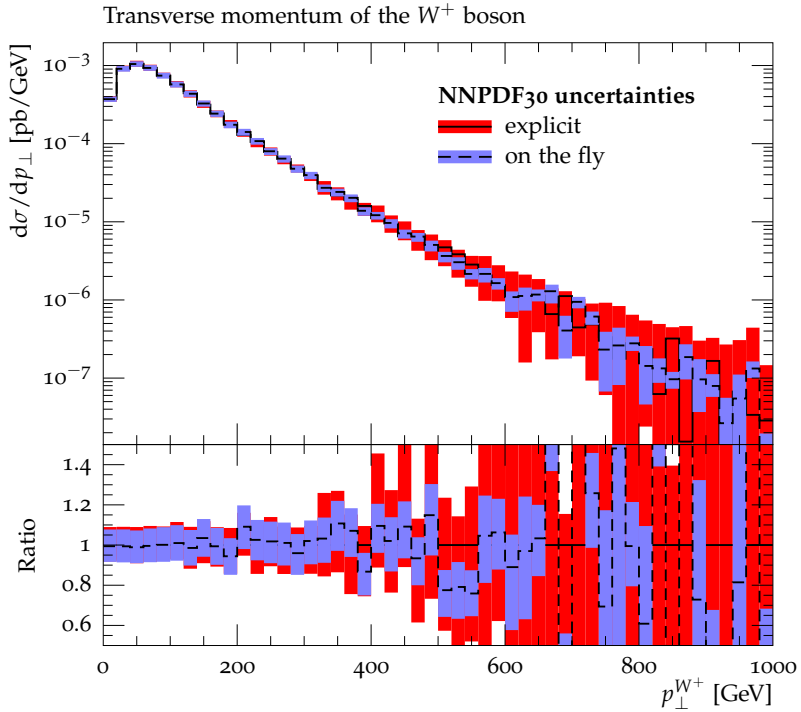


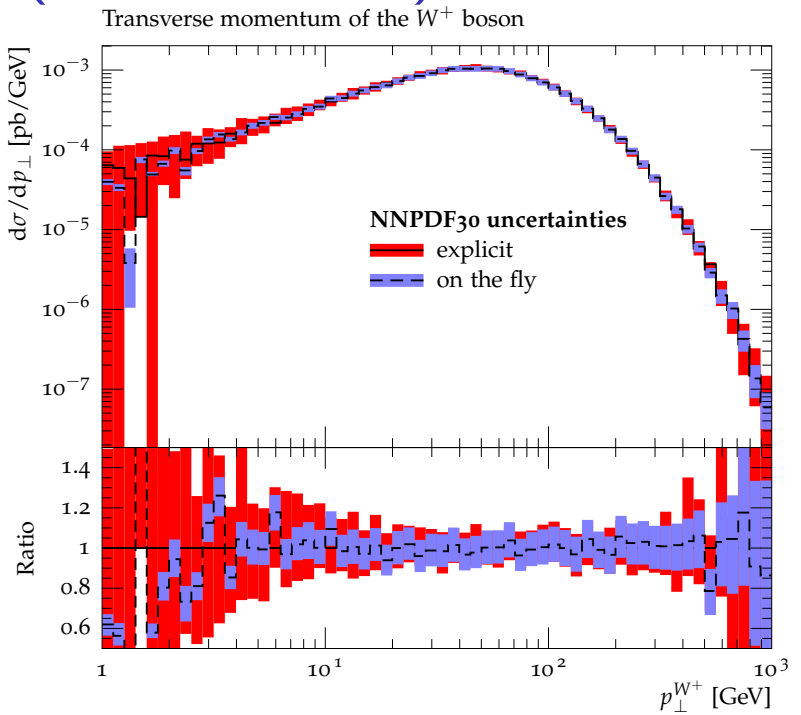



```
SCALE_VARIATIONS 0.25,0.25 0.25,1. 1.,0.25 1.,1. 1.,4. 4.,1. 4.,4.;
```

$\Rightarrow$ explicit $\mu_{R|F}$-variations exactly reproduced by on-the-fly variations ($\mu_{R|F}$ in parton shower not included, as usual)

PDF variations in $pp \to t\bar{t}W^+$ (S-MC@NLO)



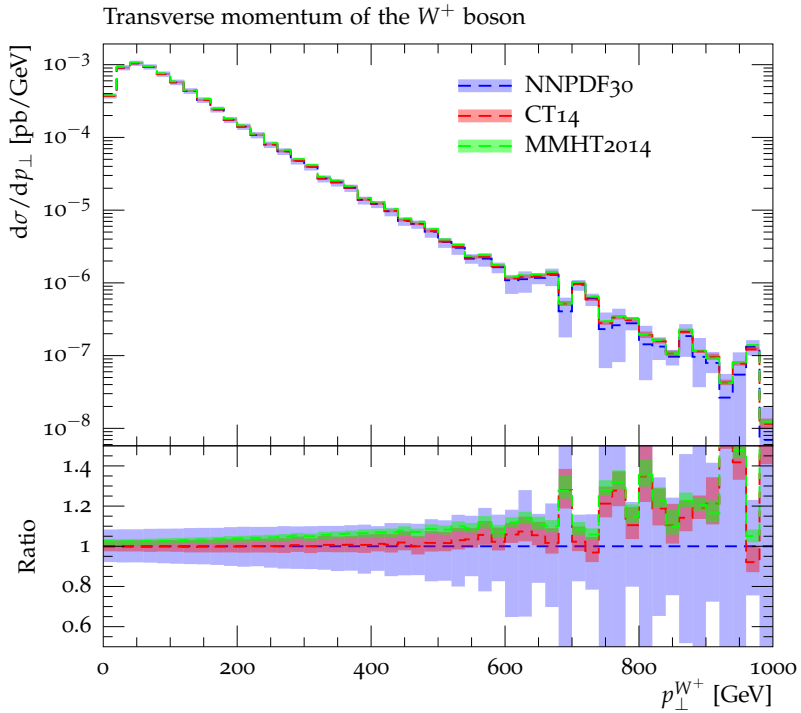


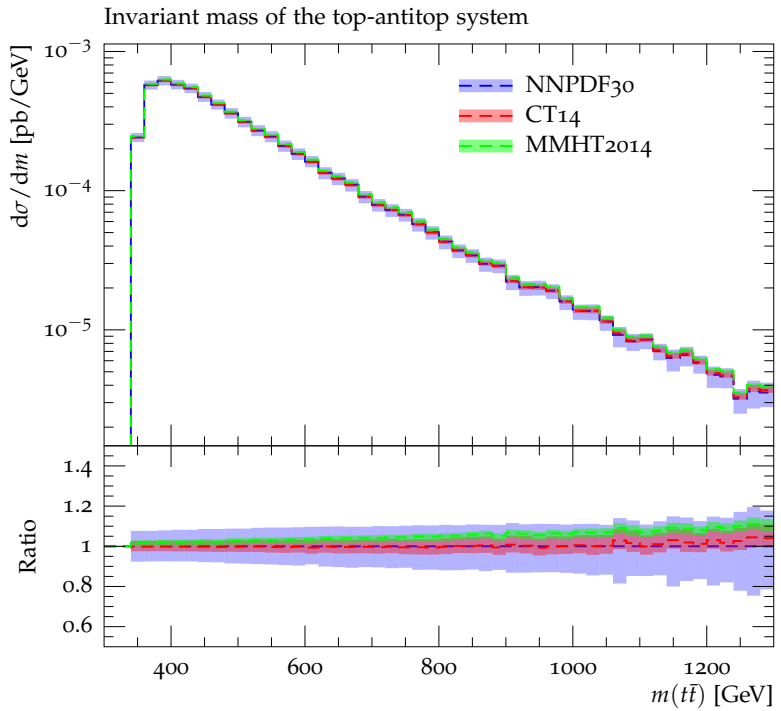
$\Rightarrow$ on-the-fly only varies PDF in ME varied, not in parton shower
  $\to$ only part of the uncertainty

$\Rightarrow$ explicit changes PDF in matrix elements and in parton shower
  $\to$ full PDF uncertainty, does not yield identical events
  $\to$ careful not to envelope statistical fluctuations (as above maybe)

$\Rightarrow$ on-the-fly variation has different PDFs in ME and parton shower
  $\to$ inconsistent MC@NLO and parton shower evolution

PDF4LHC (old) variations in $pp \to t\bar{t}W^+$ (S-MC@NLO)





$\Rightarrow$ combine with scale and α_s variation to arrive at full PDF4LHC unc.
central value + 217 variations (208 PDFs + 7 scales + 2 α_s)

Timings in $pp \to \ell^+\ell^- + \leq$ 4jets (particle level simulation)

weighted events

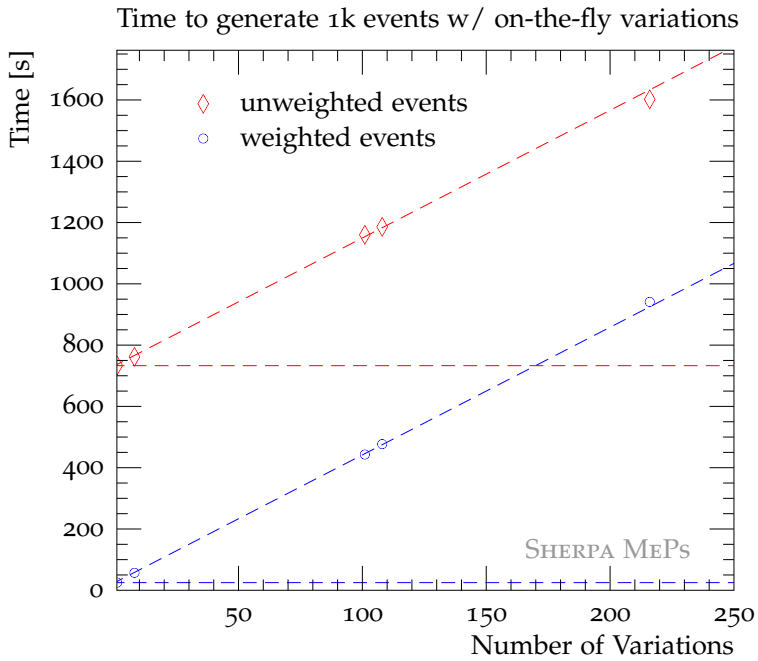
- low baseline per event timing (25s/1k)
- constant offset per computed variation

$\Rightarrow$ 217 vars. $\to$ factor 38

(partially) unweighted events

- high baseline per event timing (730s/1k)
- constant offset per computed variation

$\Rightarrow$ 217 vars. $\to$ factor 2.2



$\mu_{R\|F}$	$\to$	7
PDF (NNPDF30)	$\to$	100
$\mu_{R\|F}$+PDF	$\to$	107
PDF4LHC (old)	$\to$	217

$\to$ time to compute variations independent of event generation mode

$\Rightarrow$ **huge gain for standard (partially) unweighted events**

Conclusion

SHERPA-2.2.0

- on-the-fly weight variation calculation available
- currently limited to
  - fixed-order calculations LO, NLO
  - matched calculations LOPS, NLOPS (S-MC@NLO)
  - multijet merged calculations MEPS
- on the way for MENLOPS, MEPS@NLO, NNLOPS (UN^{2}LOPS)
- syntax:

```
SCALE_VARIATIONS 0.25,0.25 0.25,1. 1.,0.25 1.,1. 1.,4. 4.,1. 4.,4.;
PDF_VARIATIONS NNPDF30_nnlo_as_0118[all];
```

- scale variations currently supported for constant factors
  $\rightarrow$ HepMC output optionally contains all ingredients for arbitrary variations

Thank you for your attention!