MENLOPS

Making the most out of POWHEG & MEPS events.

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Outline:

- NLOPS & MEPS features.
- Theoretical considerations for MEPS → MENLOPS.
- Making the most of available tools.
- A simple recipe for a MENLOPS sample.
- Case studies.

NLOPS

Features:

- Inclusive event sample ✔
- Exact description of hardest emission ✔
- Multi-jet radiation not even LO [shower approx] ✘
- LL resummation of multiple soft collinear emission ✔
- NLO normalisation and shape - virtuals ✔
- NLO sensitivity to μ_R and μ_F ✔
- Lots of well tested codes, automation in progress ✔ ✔

MEPS

Features:

- Inclusive event sample ✔
- Exact description of hardest emission ✔
- Multi-jet radiation LO ✔ ←- - -
- LL resummation of multiple soft collinear emission ✔
- LO normalisation and shape - virtuals ✘ ←- - -
- LO sensitivity to μ_R and μ_F ✘ ←- - -
- Lots of mature, trusted, highly automated codes ✔ ✔

POWHEG oversimplified

POWHEG hardest emission x-sec:

$$d\sigma = \overline{B}(\Phi_B)\, d\Phi_B \left[\overline{\Delta}(p_{T,min}) + \overline{\Delta}(p_T) \underbrace{\frac{R(\Phi_B, \Phi_R)}{B(\Phi_B)}} d\Phi_R \right]$$

Integrand in $\overline{\Delta}(p_T)$ is exactly

$$☞ \quad \int d\Phi_R\, [\, \dots\,] = \overline{\Delta}(p_{T,min}) + \int_{\overline{\Delta}(p_{T,min})}^{1} d\overline{\Delta}(p_T) = 1$$

MEPS in the POWHEG language

From general arguments the MEPS x-sec is:

[For Sudakovs red hats → blue hats]

Born x-sec [LO]

$$d\sigma = B(\Phi_B)\, d\Phi_B \left[\bar{\Delta}(p_{T,min}) + \bar{\Delta}(p_T)\, \frac{\bar{R}(\Phi_B, \Phi_R)}{B(\Phi_B)}\, d\Phi_R \right]$$

Effective Sudakov form factor; same LL accuracy as PS

Real emission x-sec ÷ Born x-sec

N.B. Integrand in $\bar{\Delta}(p_T)$ is not $\bar{R}(\Phi_B,\Phi_R)/B(\Phi_B)$!

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Effective Sudakov form factor; same LL accuracy as PS

Real emission x-sec ÷ Born x-sec

☞ $$\int d\Phi_R \, [\, \ldots \,] \equiv N(\Phi_B) \neq 1$$

MEPS in the POWHEG language

Unitarity breaking manifest as $\overline{B}_{ME}(\Phi_B)$ fn in MEPS:

$$d\sigma = \overline{B}_{ME}(\Phi_B)\, d\Phi_B \left[\frac{\overline{\Delta}(p_{T,min}) + \overline{\Delta}(p_T)\, \dfrac{\overline{R}(\Phi_B, \Phi_R)}{B(\Phi_B)}\, d\Phi_R}{N(\Phi_B)} \right]$$

Integrates to 1

$$\overline{B}_{ME}(\Phi_B) \equiv B(\Phi_B) \times N(\Phi_B)$$
$$= B(\Phi_B) \times [1 + O(\alpha_s)]$$

Turning MEPS into MENLOPS

Promoting MEPS → MENLOPS:

$$d\sigma = \overline{B}_{ME}(\Phi_B)\, d\Phi_B \left[\frac{\overline{\Delta}(p_{T,min}) + \overline{\Delta}(p_T)\, \dfrac{\overline{R}(\Phi_B, \Phi_R)}{B(\Phi_B)}\, d\Phi_R}{N(\Phi_B)} \right]$$

Integrates to 1

calculate $\overline{B}_{ME}(\Phi_B)$ and reweight MEPS by: $\dfrac{\overline{B}(\Phi_B)}{\overline{B}_{ME}(\Phi_B)}$

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Promoting MEPS → MENLOPS:

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MENLOPS

Features:

- Inclusive events sample ✔
- Exact description of hardest emission ✔
- Multi-jet radiation now LO ✔
- LL resummation of multiple soft collinear emission ✔
- NLO normalisation and shape - virtuals ✔
- NLO sensitivity to μ_R and μ_F ✔
- No codes, no testing, no automation, no time soon ✘

Practical question:

How close can you get to the exact

MENLOPS picture with today's tools?

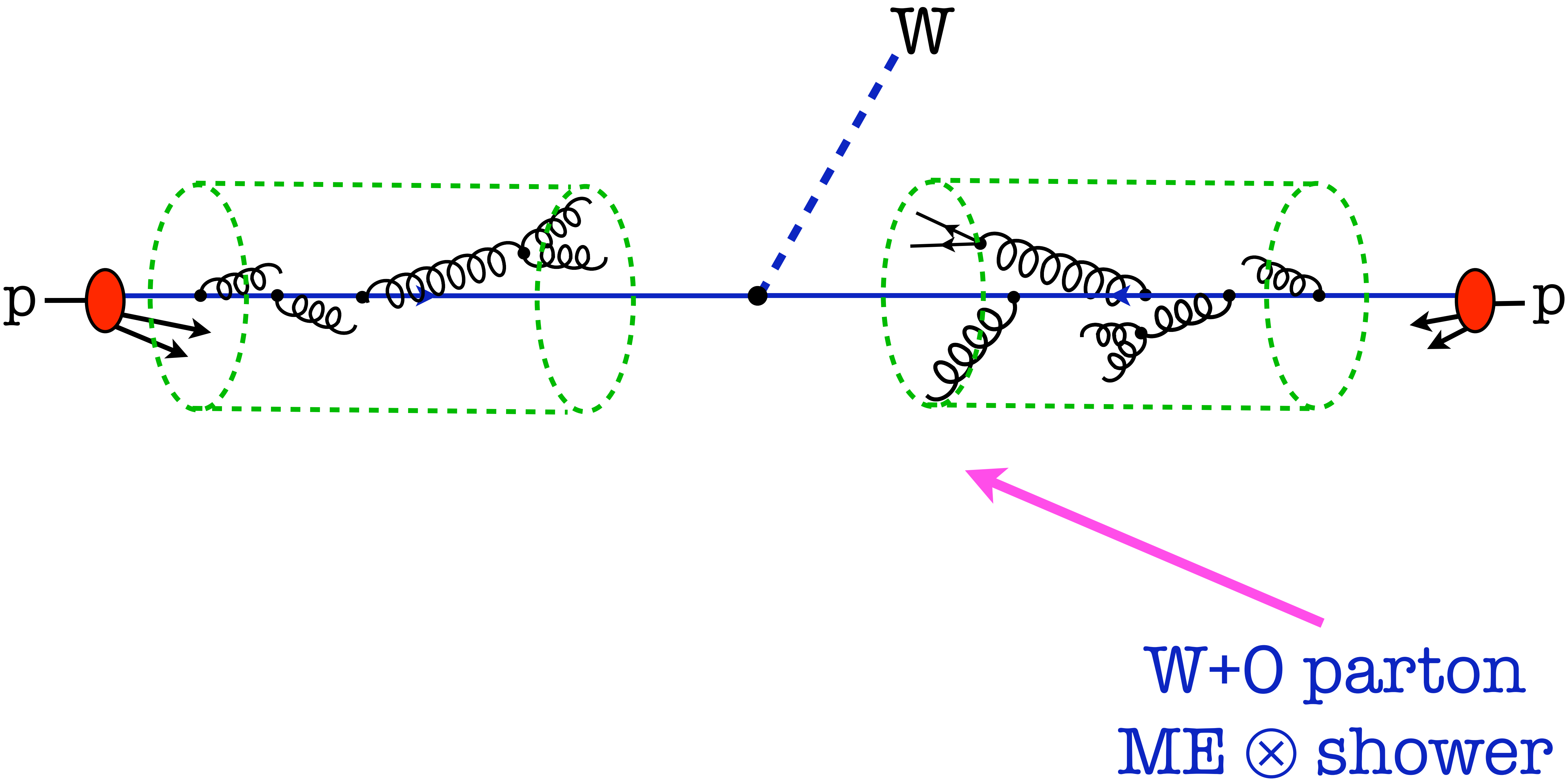
MENLOPS

0-jet events:

- 0-jet x-section: NLOPS NLO
  MEPS LO
- 0-jet events: NLOPS NLO
  MEPS LO
- NLOPS beats MEPS for 0-jet description; same description as MENLOPS for 0-jets.

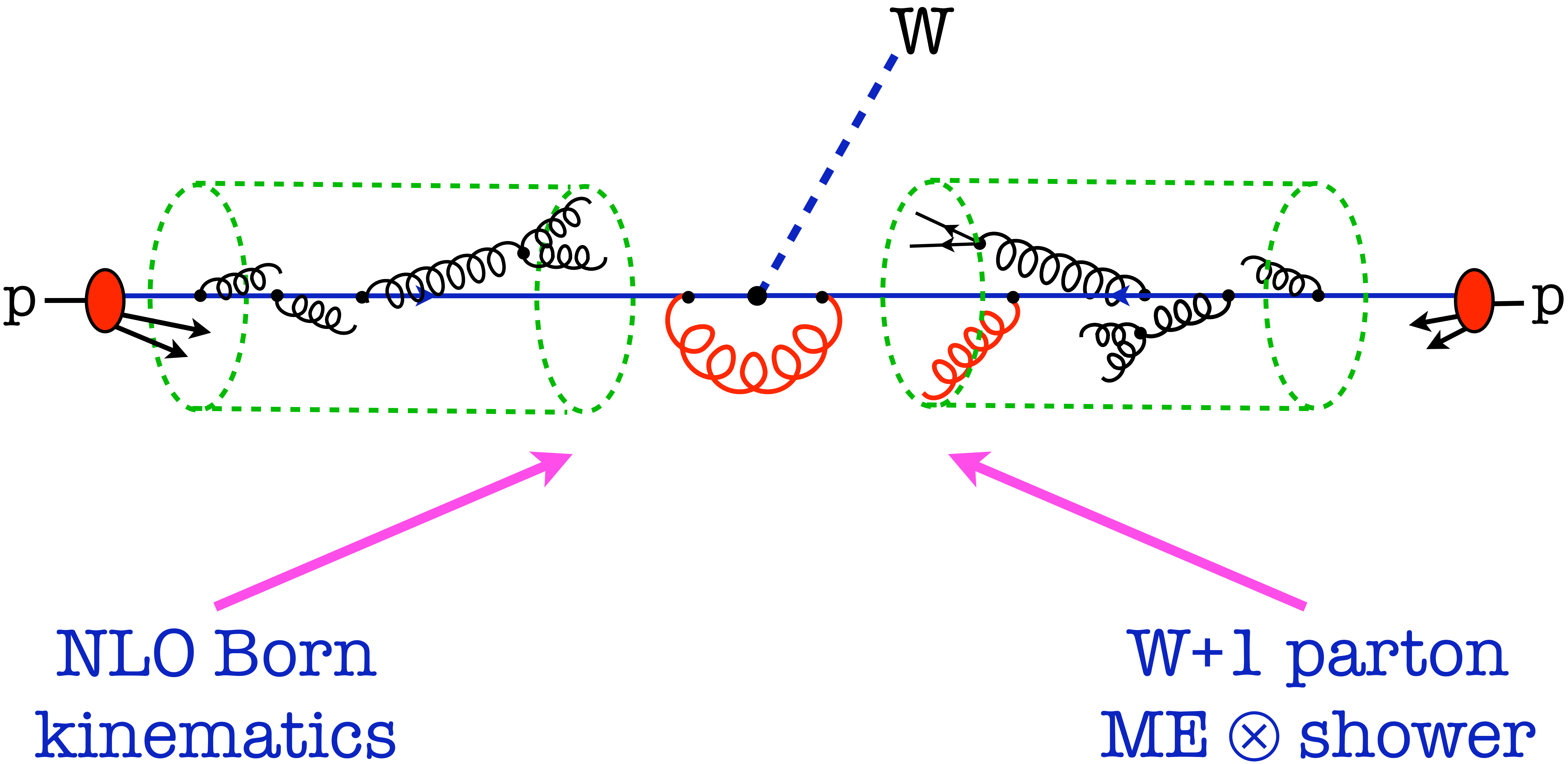
pp → W + 0 jets

MEPS



pp → W + 0 jets

NLOPS



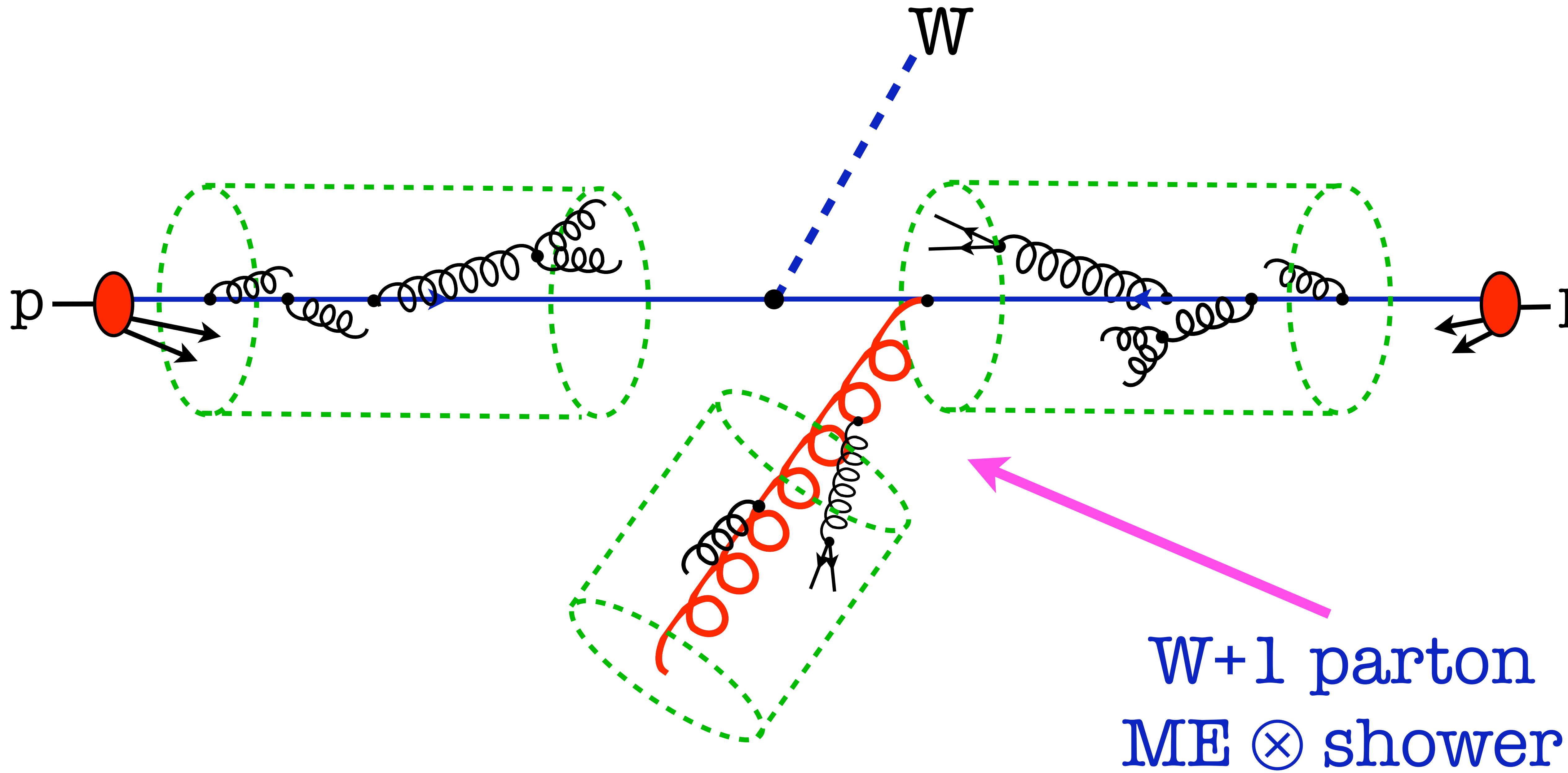
MENLOPS

1-jet events:

- 1-jet x-section: NLOPS nLO
  MEPS LO
- 1-jet events: NLOPS nLO
  MEPS LO
- NLOPS equal to MEPS for 1-jet description; same description as MENLOPS for 1-jets.

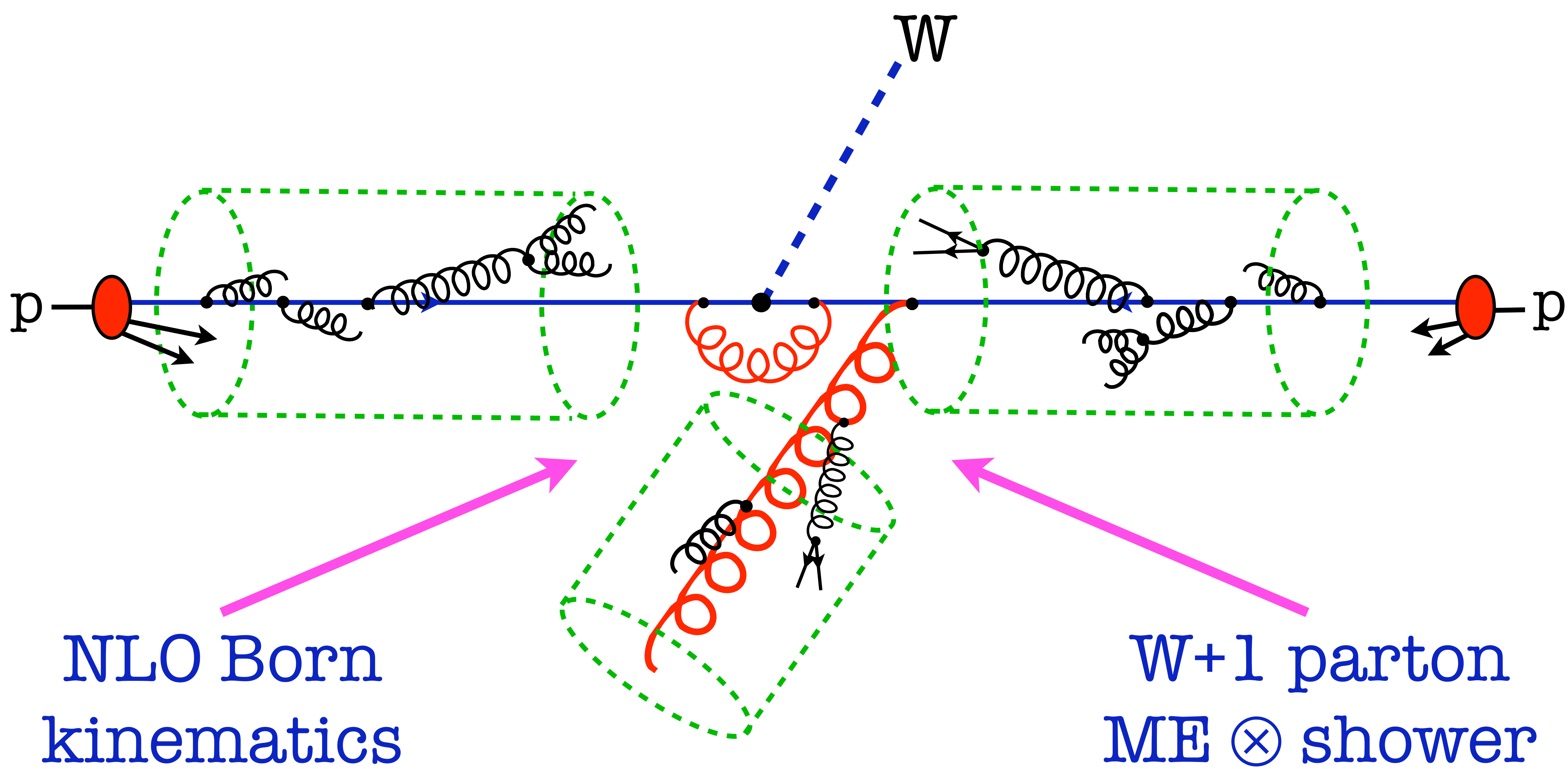
pp →W + 1 jets

MEPS



pp → W + 1 jets

NLOPS



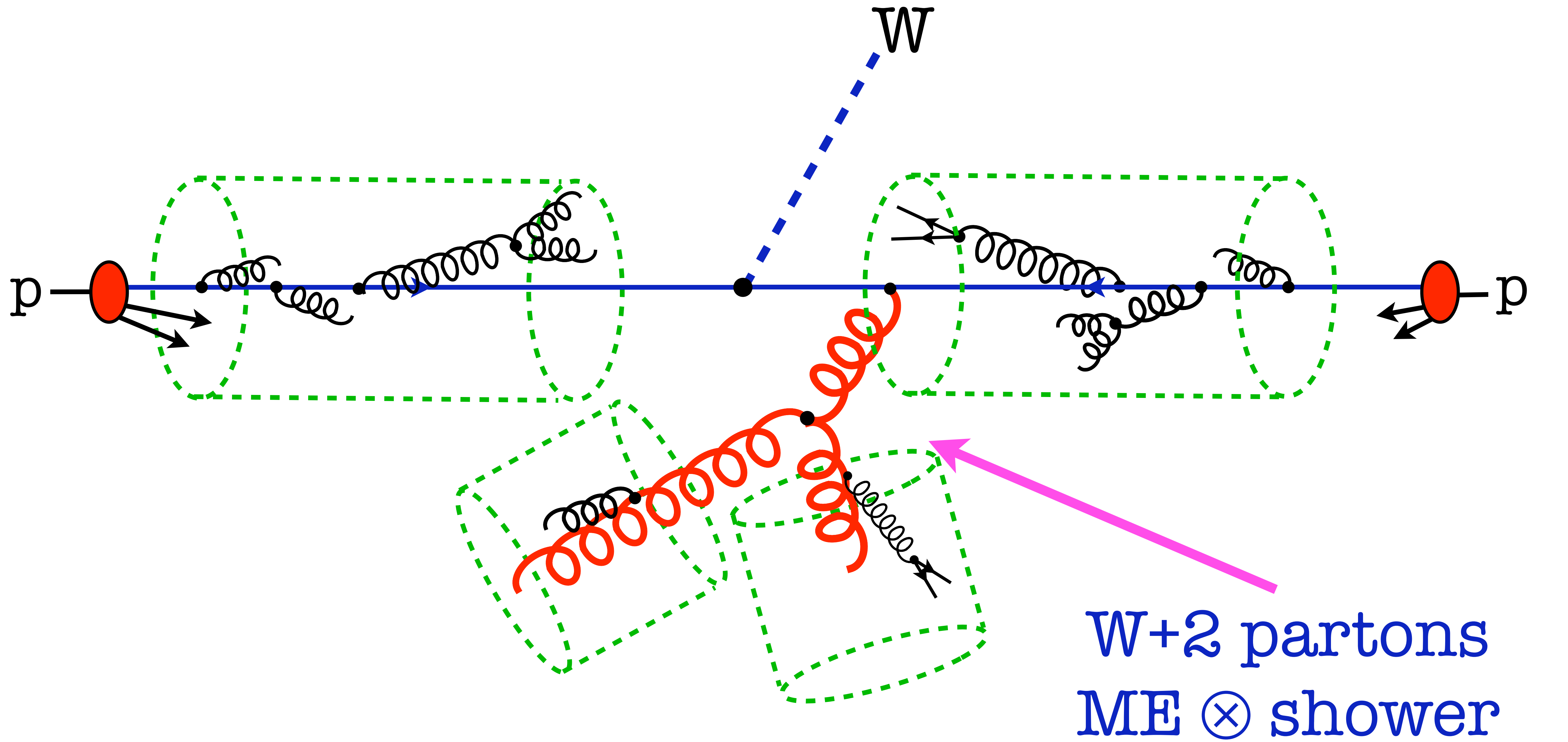
MENLOPS

2-jet events:

- 2-jet x-section: NLOPS not even LO
  MEPS LO
- 2-jet events: NLOPS not even LO
  MEPS LO
- MEPS beats NLOPS for 2-jet description; not as good as MENLOPS for 2-jets.

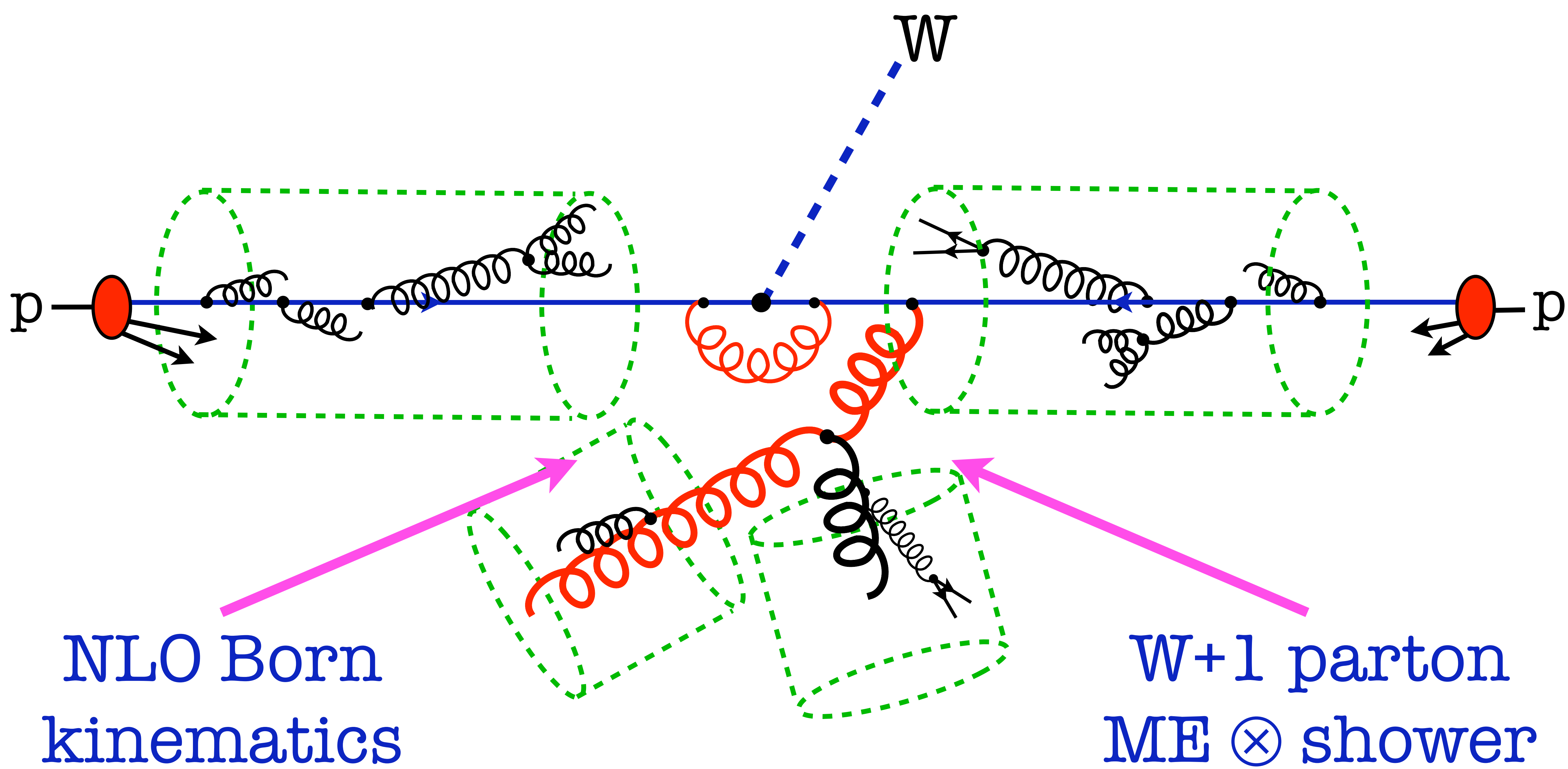
pp → W + 2 jets

MEPS



pp → W + 2 jets

NLOPS



Practical question:

How close can you get to the exact

MENLOPS picture with today's tools?

MENLOPS

Poor man's recipe for MENLOPS:

- 0-jet x-sec = NLOPS [as in exact case]
- n-jet x-sec = MEPS n-jet x-sec × K[≥ 1-jet]

  [as in exact case]

- total x-sec therefore as in NLOPS
- 0-jet events from NLOPS [as in exact case]
- 1-jet events from NLOPS [as in exact case]
- n-jet events from MEPS for n ≥ 2

Won't this destroy NLO accuracy?

It will if you aren't careful.

You put in a bunch of LO MEPS events containing 2 or more jets!

Basically, in the exact formula, for ≥2-jet events, you swapped:

$$\frac{\overline{B}(\Phi_B)}{\overline{B}_{ME}(\Phi_B)} \rightarrow K[\geq 1\text{-jet}]$$

Won't this destroy NLO accuracy?

It won't ...

if the number of 2-jet events is a fraction less than $O(\alpha_s)$ of the total sample ...

i.e. NLO accuracy is safe so long as the MENLOPS scale isn't too small.

Case studies: $t\bar{t}$ and W production

- MEPS: MadGraph with 'MLM-k_T' scheme
- NLOPS: POWHEG-hvq [$t\bar{t}$, tops set stable]
- NLOPS: POWHEG-w [$W^- \rightarrow e^- \bar{\nu}_e$]
- PYTHIA: Q^2 ordered shower in MEPS
- PYTHIA: p_T ordered shower for NLOPS
- PDF: MRST 2002 NLO used everywhere
- LHC nominal C.O.M. energy $\sqrt{S}$ = 14 TeV

Case studies: $t\bar{t}$ and W production

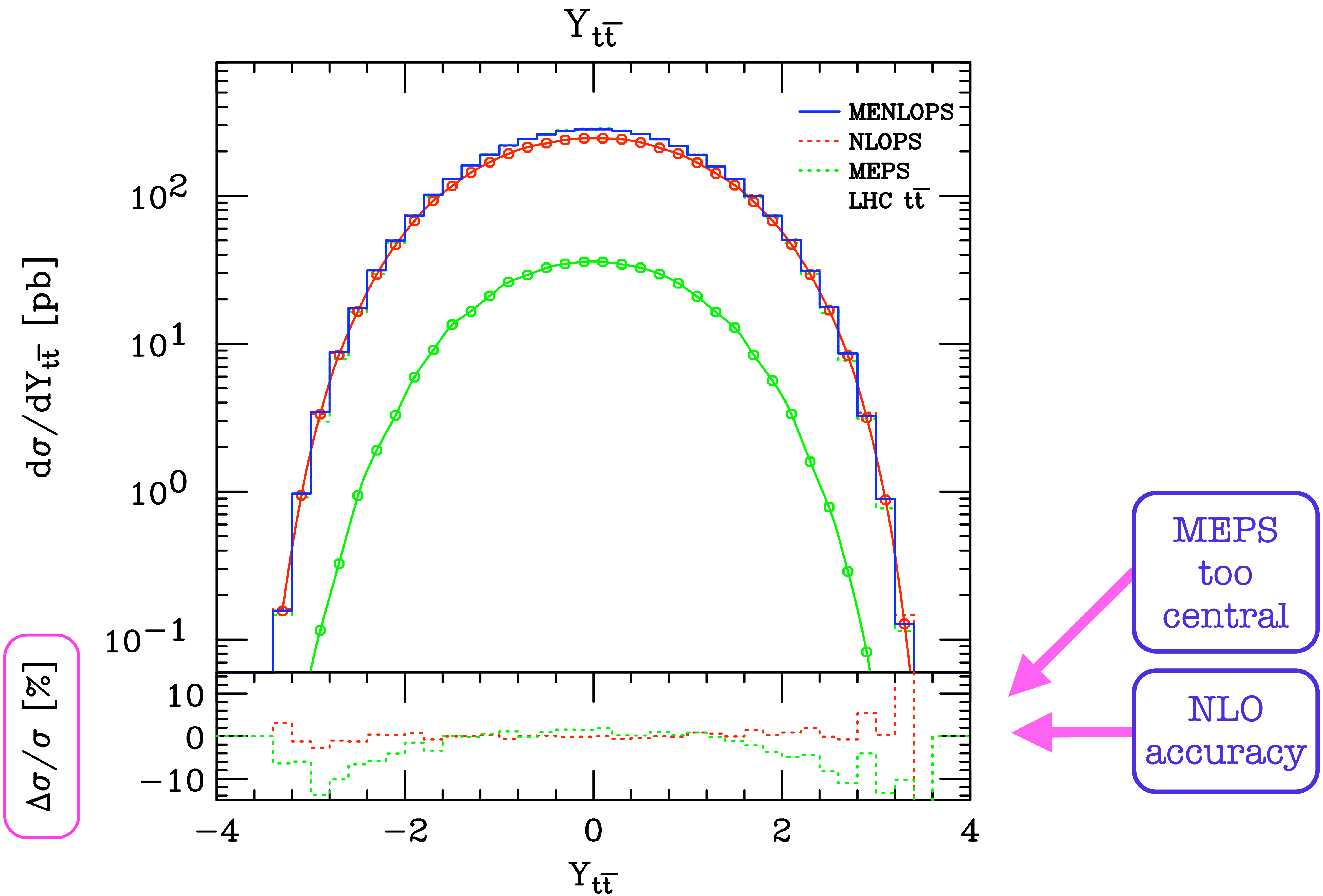
<u>$t\bar{t}$ production:</u>

- MEPS merging scale: 30 GeV
- MENLOPS clustering scale: 60 GeV
- MENLOPS MEPS content: 12.5 %

<u>W^- production:</u>

- MEPS merging scale: 20 GeV
- MENLOPS merging scale: 25 GeV
- MENLOPS MEPS content: 5 %

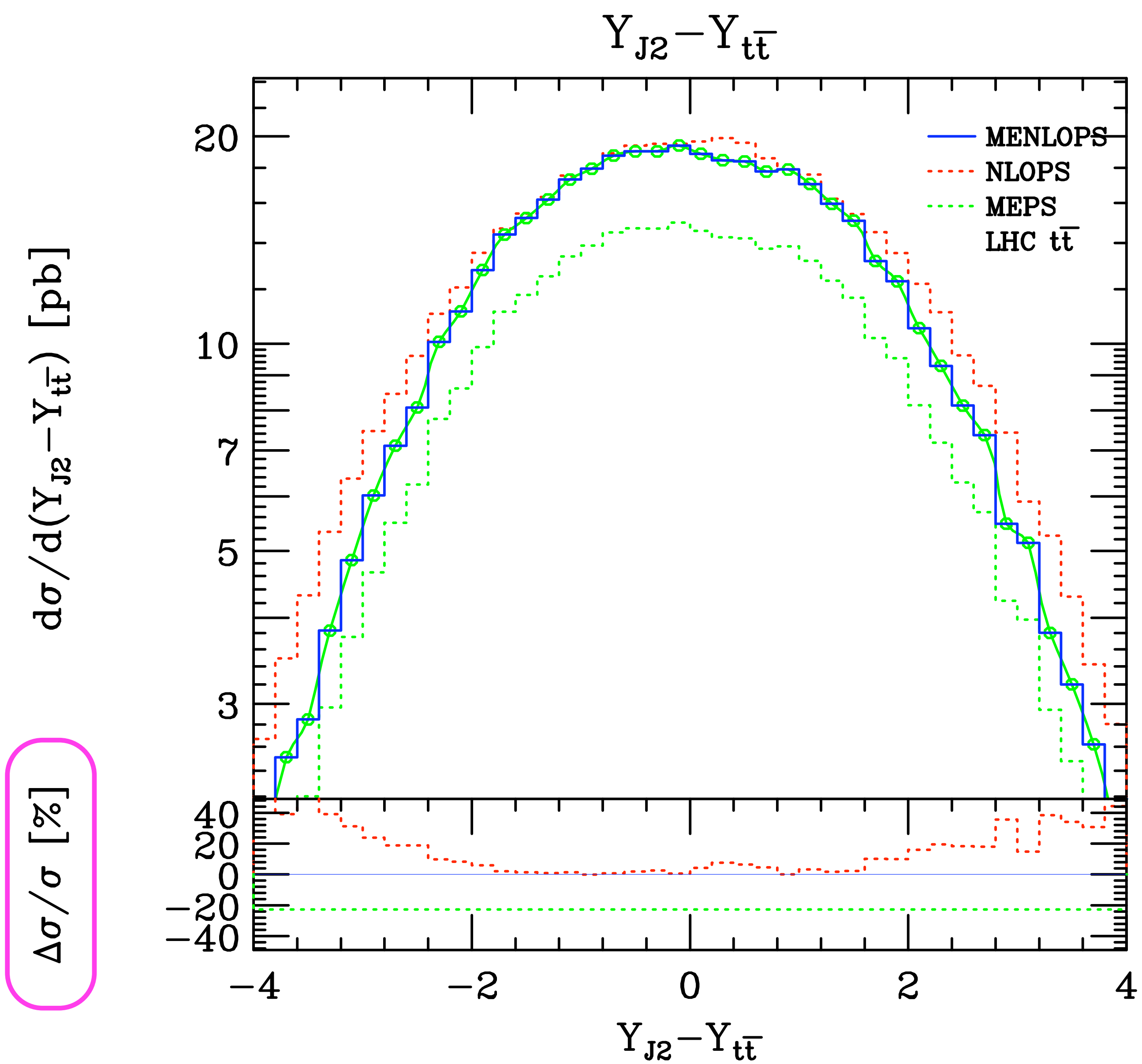
Inclusive quantities: $t\bar{t}$ rapidity

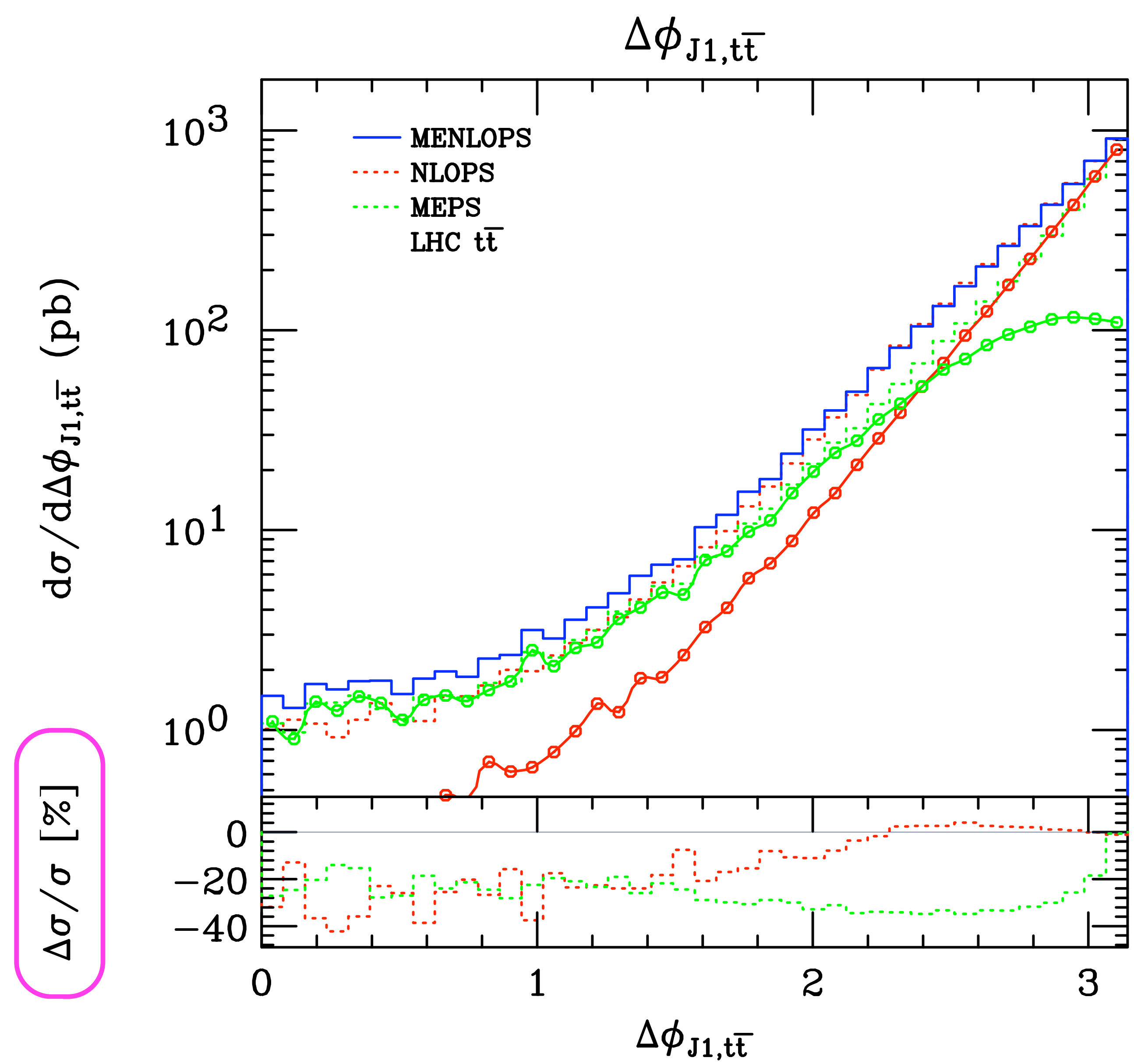


MENLOPS = NLOPS subsample + MEPS subsample

NLOPS default MEPS default × K

Y_{J2}-$Y_{t\bar{t}}$ and $\Delta\phi_{J1,t\bar{t}}$ in $t\bar{t}$ events





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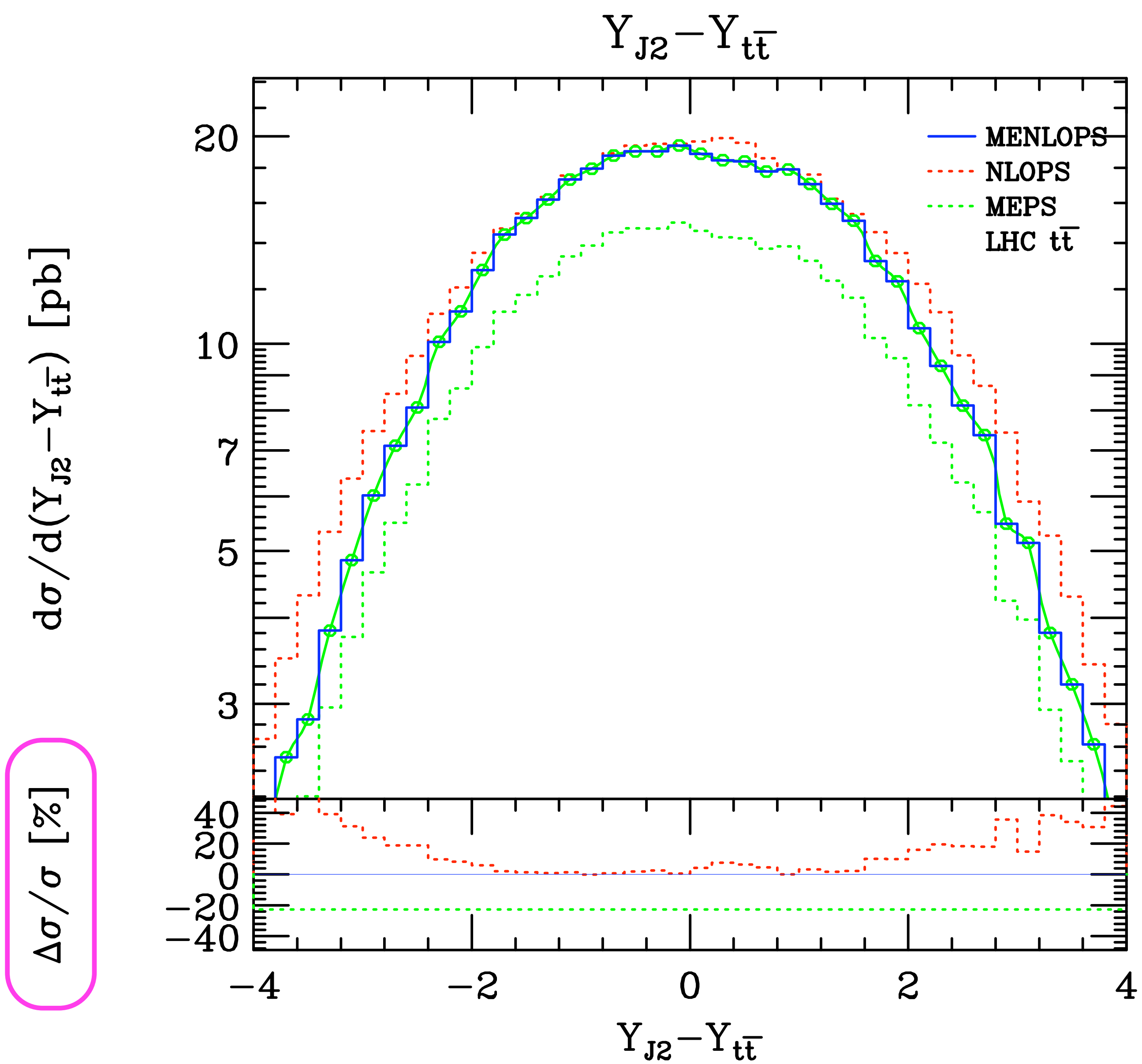
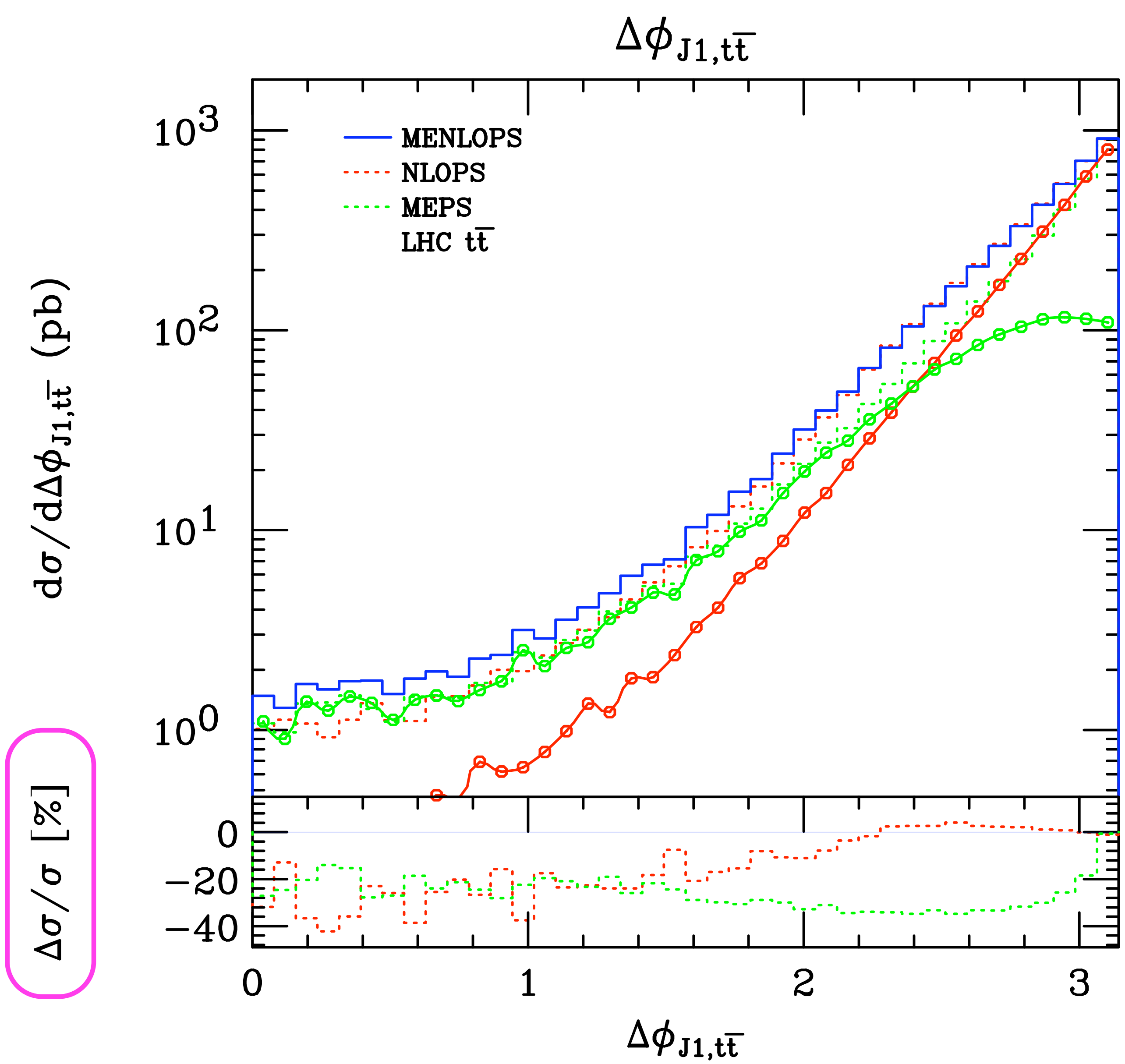
Y_{J2}-$Y_{t\bar{t}}$ and $\Delta\phi_{J1,t\bar{t}}$ in $t\bar{t}$ events



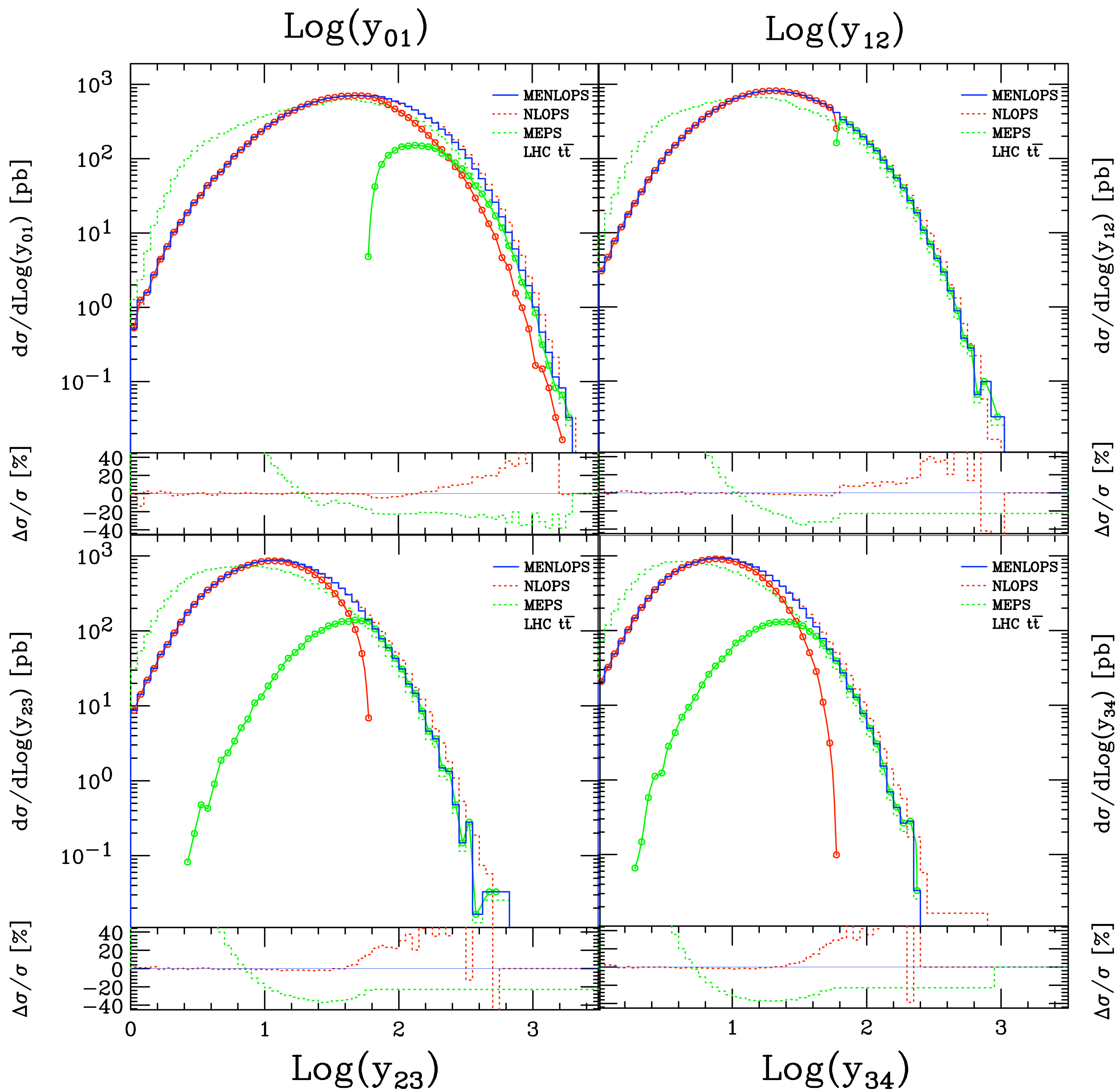


Jet 2 seems to have more correlation with Jet 1 in NLOPS w.r.t. MEPS

MENLOPS = NLOPS subsample + MEPS subsample

NLOPS default MEPS default × K

Log[y_{nm}] differential jet rates in $t\bar{t}$ events

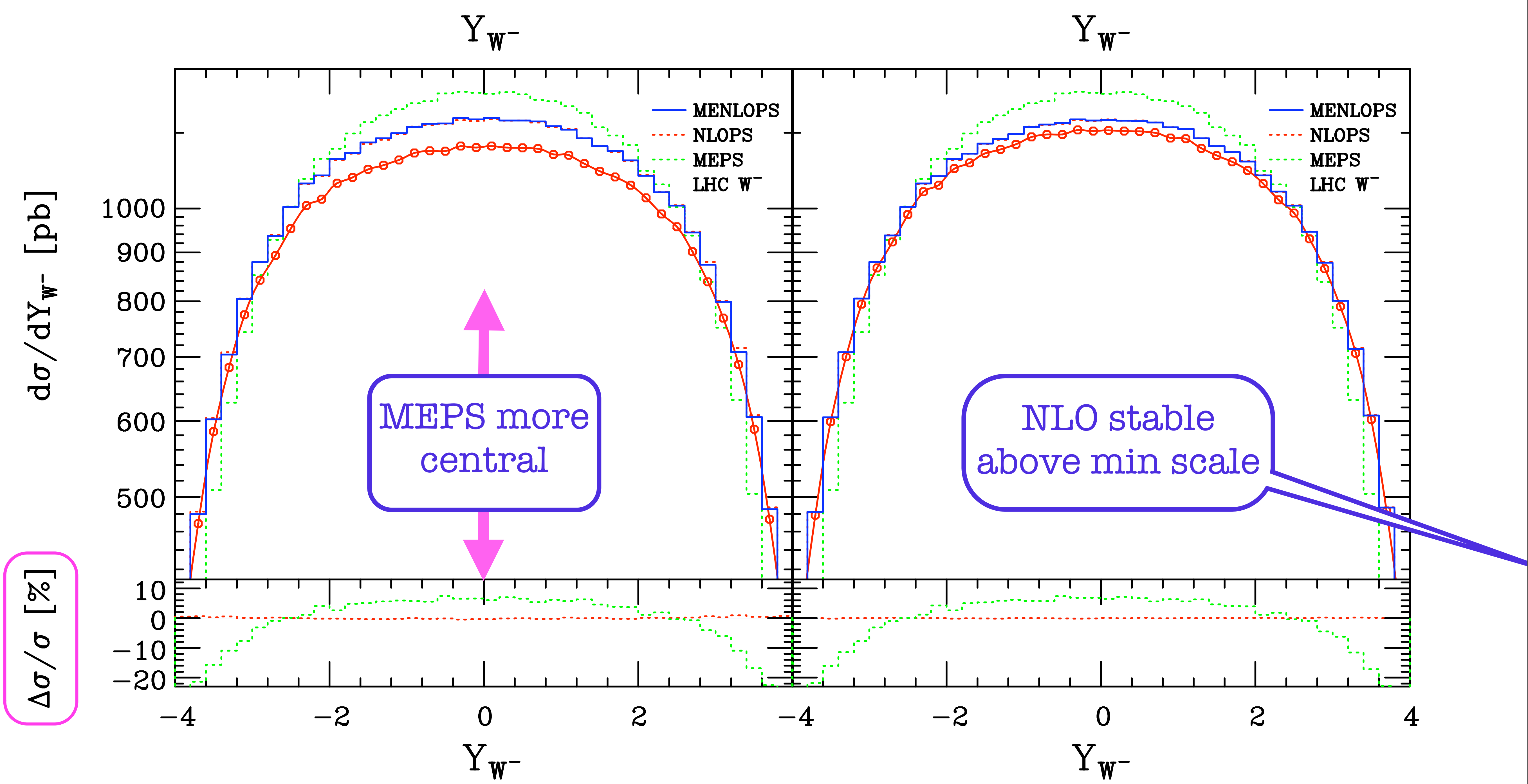


No kinks

MENLOPS = NLOPS subsample + MEPS subsample

NLOPS default   MEPS default × K

Inclusive quantities: W^- rapidity



25 GeV MENLOPS scale

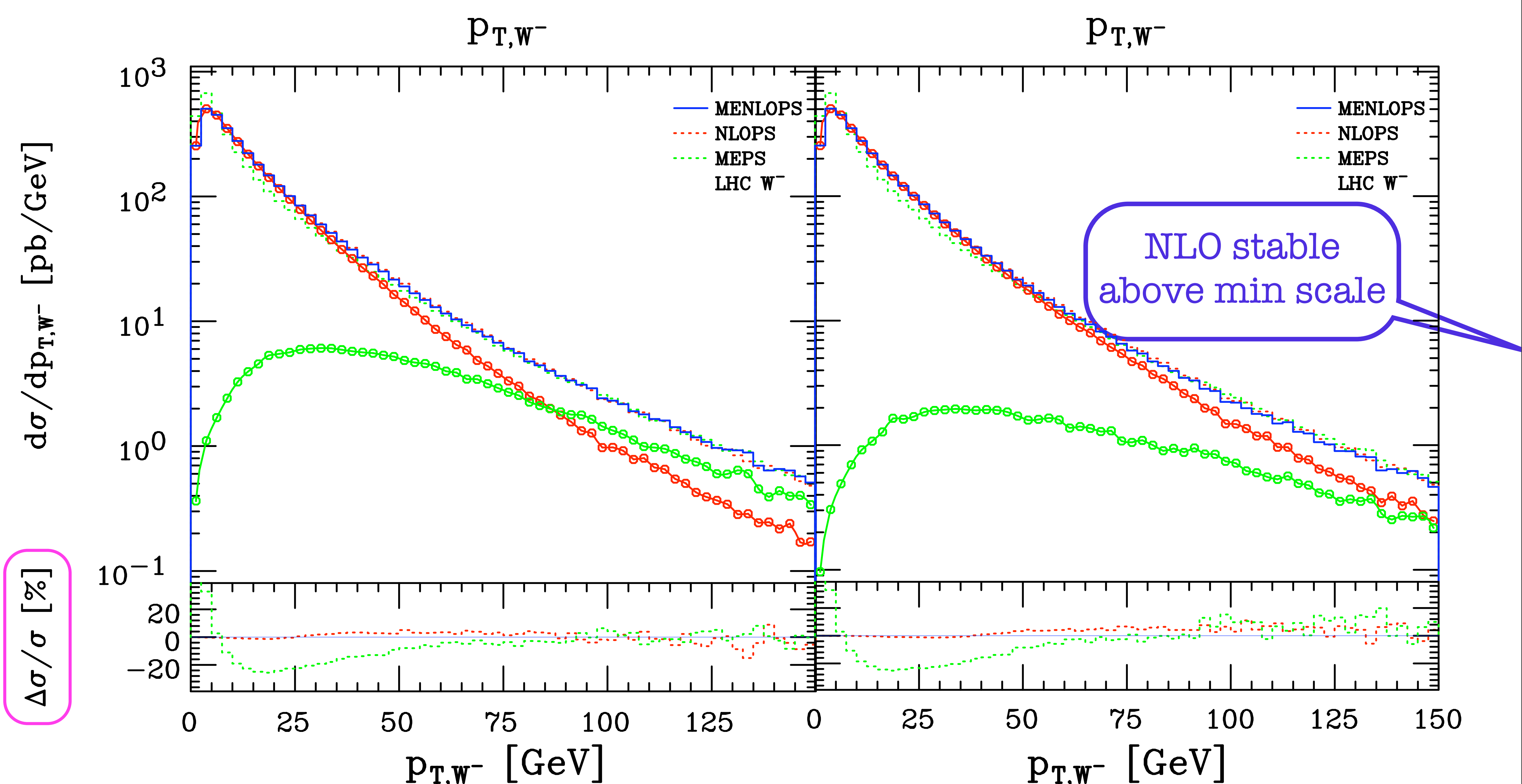
40 GeV MENLOPS scale

MENLOPS = NLOPS subsample + MEPS subsample

NLOPS default

MEPS default × K

Inclusive quantities: W^- p_T



25 GeV MENLOPS scale

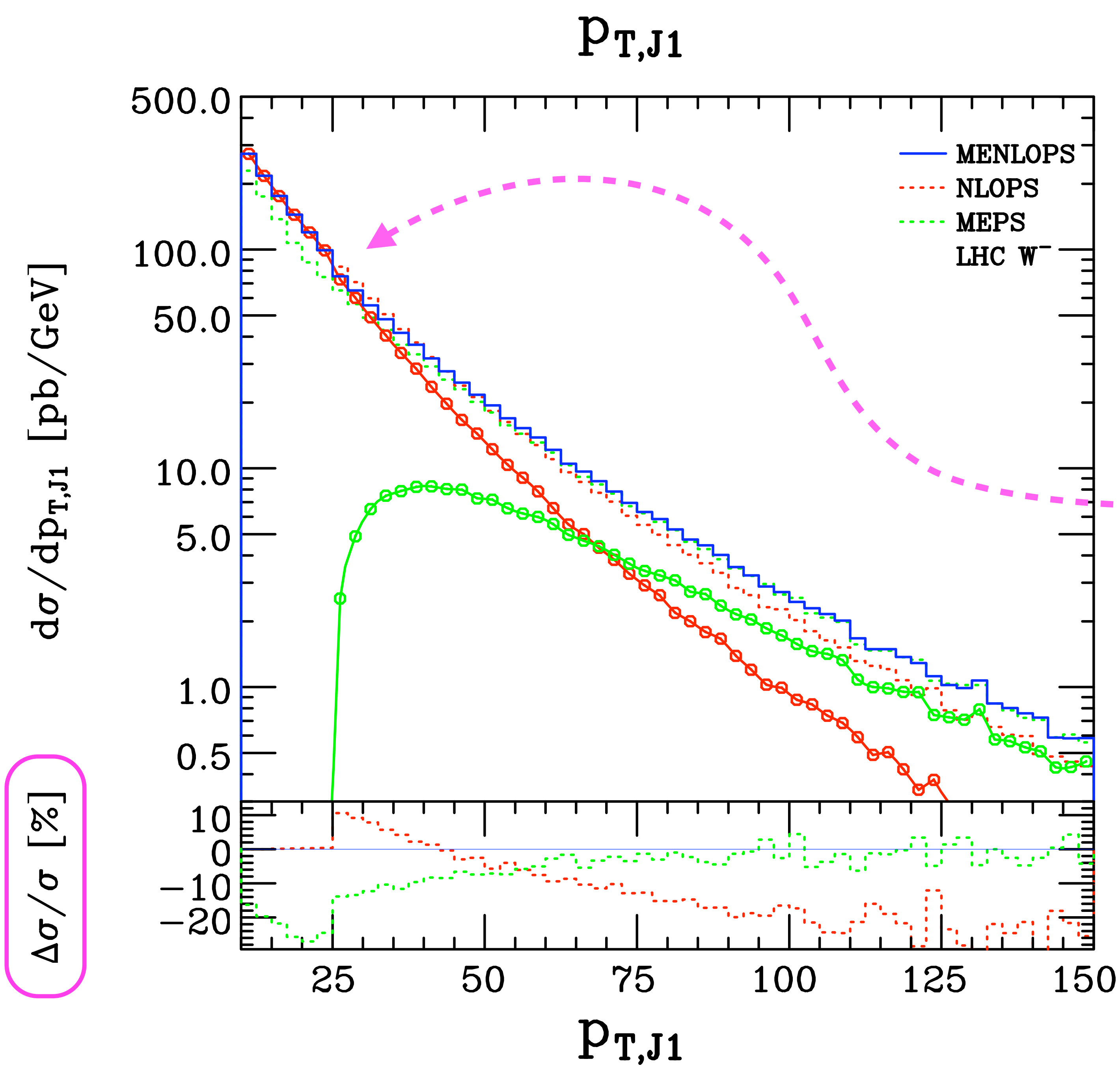
40 GeV MENLOPS scale

MENLOPS = NLOPS subsample + MEPS subsample

NLOPS default MEPS default × K

Tuesday, 30 March 2010

p_T of hardest Jet in W^- production



Very small kink.

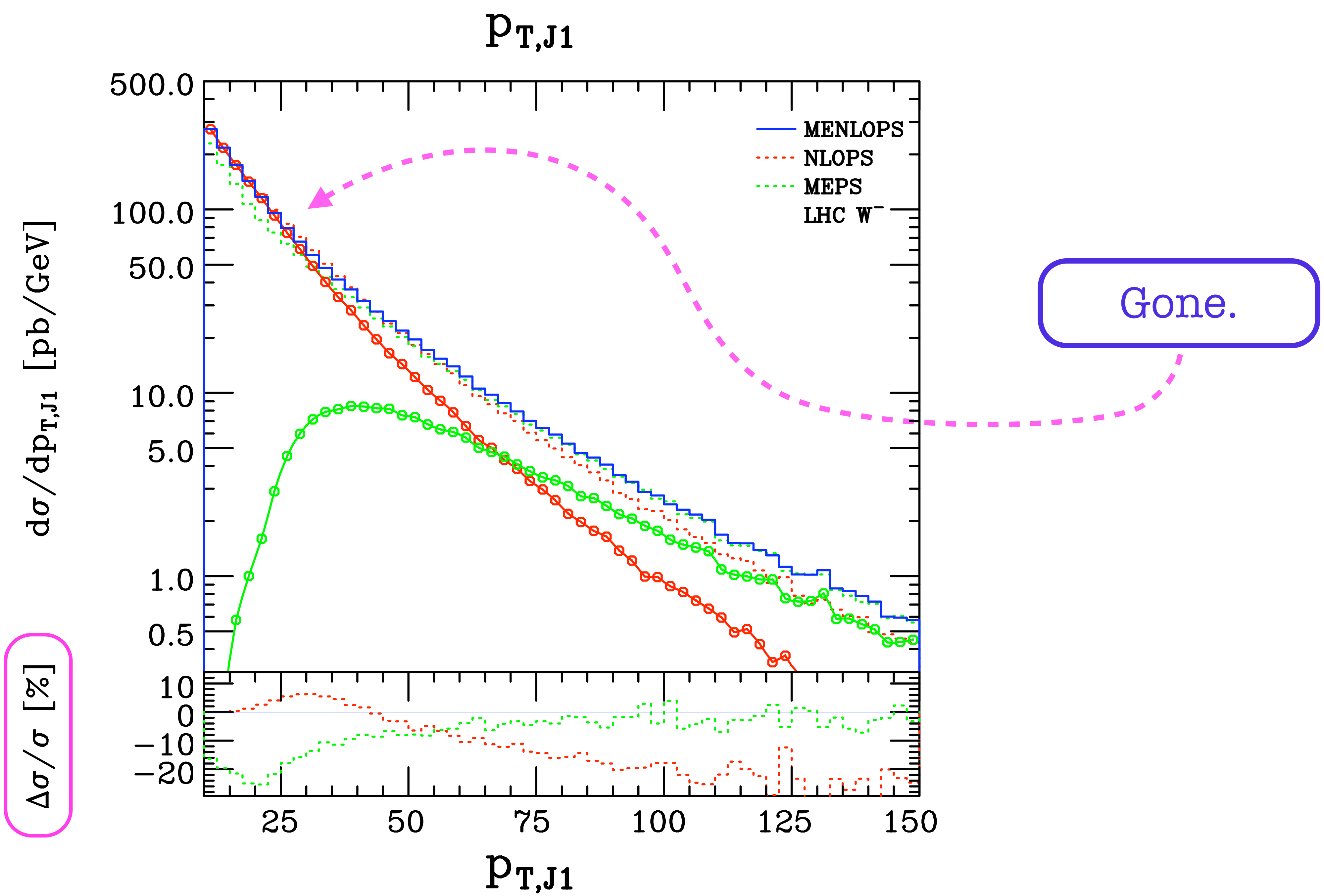
No worse than MEPS case ...

MENLOPS merge scale 25 GeV, jets resolved at 10 GeV.

MENLOPS = NLOPS subsample + MEPS subsample

NLOPS default MEPS default × K

p_T of hardest Jet in W^- production



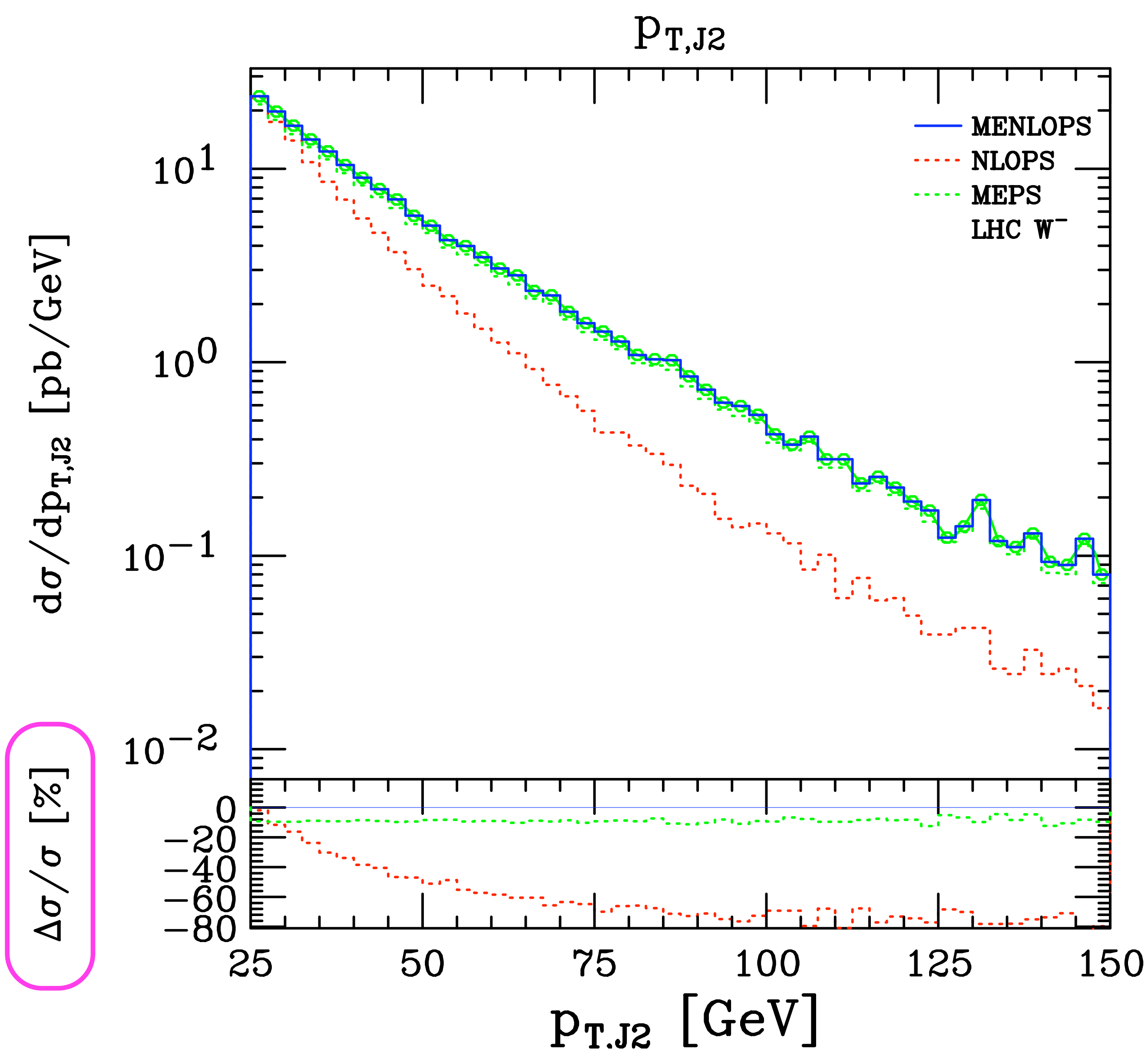
Same again but MENLOPS scale floating: N[25 GeV,5^2 GeV^2]

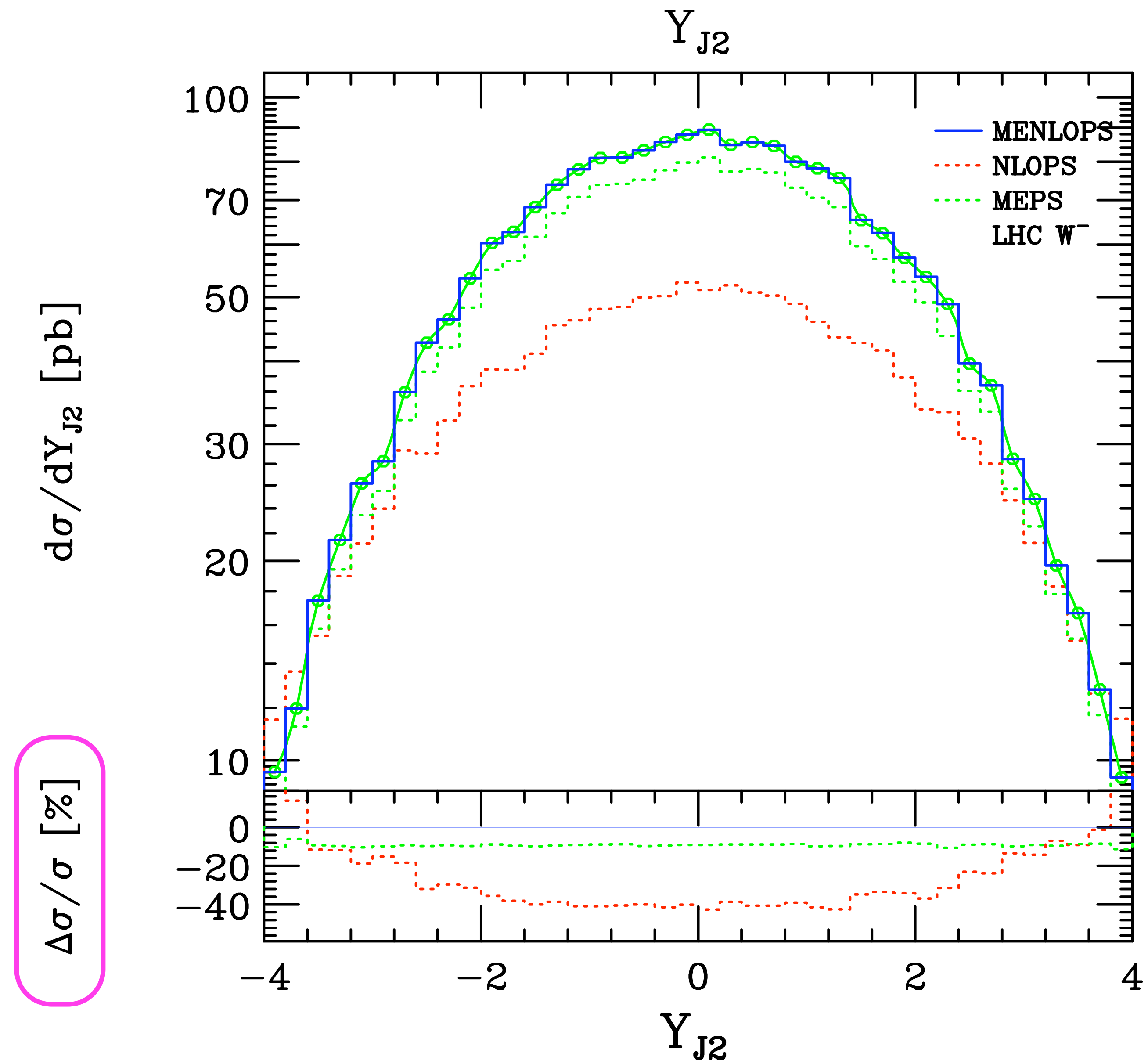
MENLOPS = NLOPS subsample + MEPS subsample

NLOPS default   MEPS default × K

2nd Jet p_T and rapidity in W^- events

Here jet scale = MENLOPS scale = 25 GeV; MEPS = 20 GeV





Jet 2 much softer in NLOPS

MEPS/MENLOPS 50 % more central

MENLOPS = NLOPS subsample + MEPS subsample

NLOPS default MEPS default × K

Summary

- There is a lot of mature, well automated, MEPS code.
- Currently there is a fast growing body of NLOPS code.
- We considered an exact scheme for combining the two.
- We asked how close you can get, now, using what's at hand.
- We traded a little 'exactness' for a practical, general, recipe.
- The cost is a dependence on the MENLOPS scale.

Summary

- But we bound the MENLOPS scale from below preserving NLO accuracy.

- In principle this limits the corrections to ≥ 2-jets events.

- If the MENLOPS bound ≤ MEPS scale full corrections are obtained: exact MENLOPS matching becomes academic.

Also consider point of view of exp. requirements, what do you gain from ME corrections to PS description of jets below ~40 GeV at LHC [U.E. etc]?

Summary

- We tried out the MENLOPS recipe with MadGraph & some POWHEG codes [shouldn't really matter what you use].
- It was pretty easy to do ...
- Positive improvements in inclusive & exclusive quantities.
- NLO accuracy was retained throughout.
- In W events for MENLOPS scale = MEPS scale: P[MEPS] < 8%