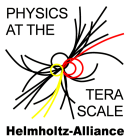
# Monte Carlos for ep – Status and Prospects

Simon Plätzer

DESY Theory Group





# Disclaimer

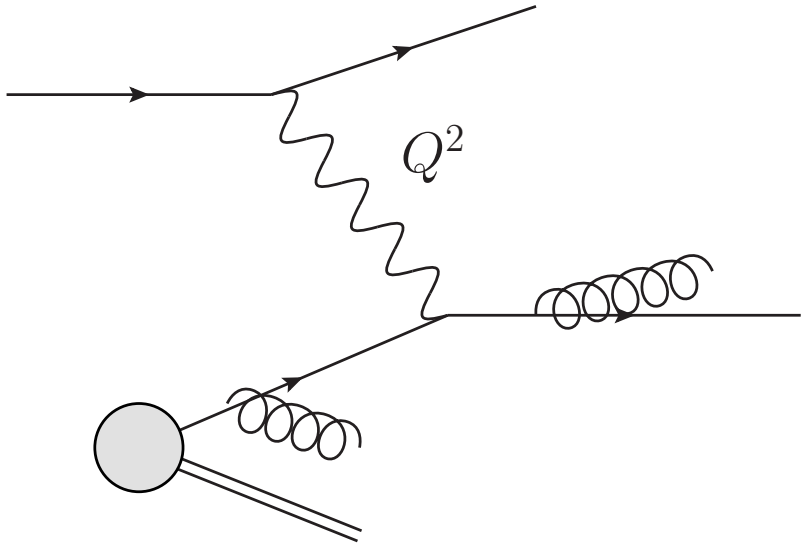
Will not (and cannot be) a complete review.

Is not unbiased:
LHC age multipurpose Monte Carlos: Herwig++, Pythia 8, Sherpa.

Will focus on:

- more jets,
- higher orders, and
- multiple interactions.

# Why is ep so special?



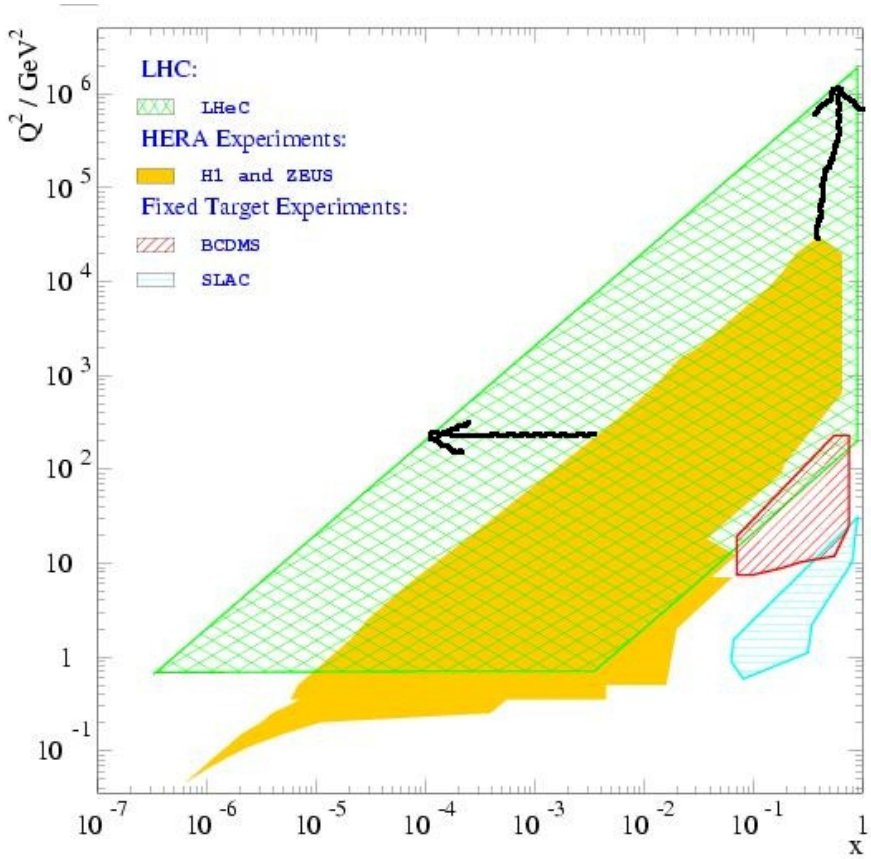

Relevant QCD scale is $Q^2$
$\rightarrow$ shower just dressing the incoming and outgoing quark.

No phasespace for hard jets. Or, if available, not well modelled.

Higher order matrix elements are absolutely crucial to *ep*.

# Why is ep so special?

Lots of radiation ...



# Why we need ep – not questioning the physics, of course.

The multipurpose Monte Carlos provide sound predictions of QCD dynamics for $pp$.

Do we really understand all details?

Cross-checks *desperately* needed.

# Outline

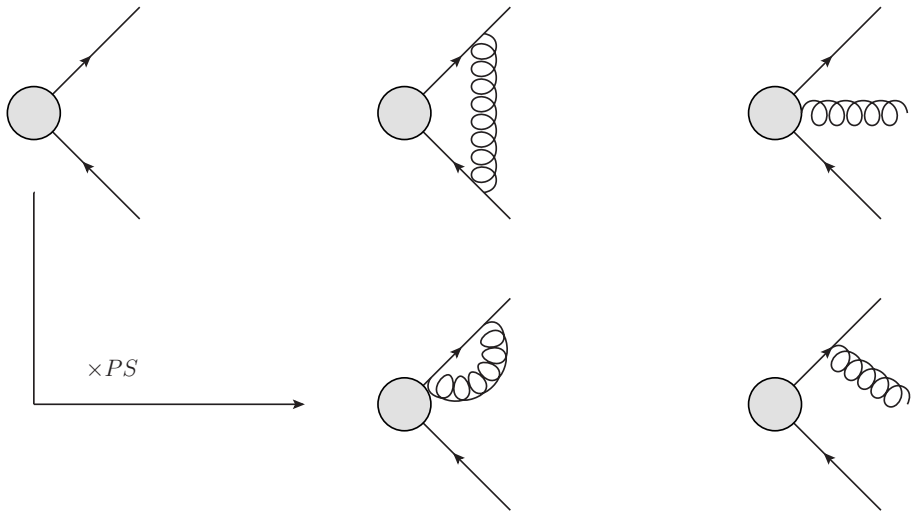
- Improving parton showers
- Status for *ep*
- Multiple interactions
- Conclusions, next steps and a wishlist

# Improving parton showers

Two established directions:

- NLO *matching*
- LO multijet *merging*

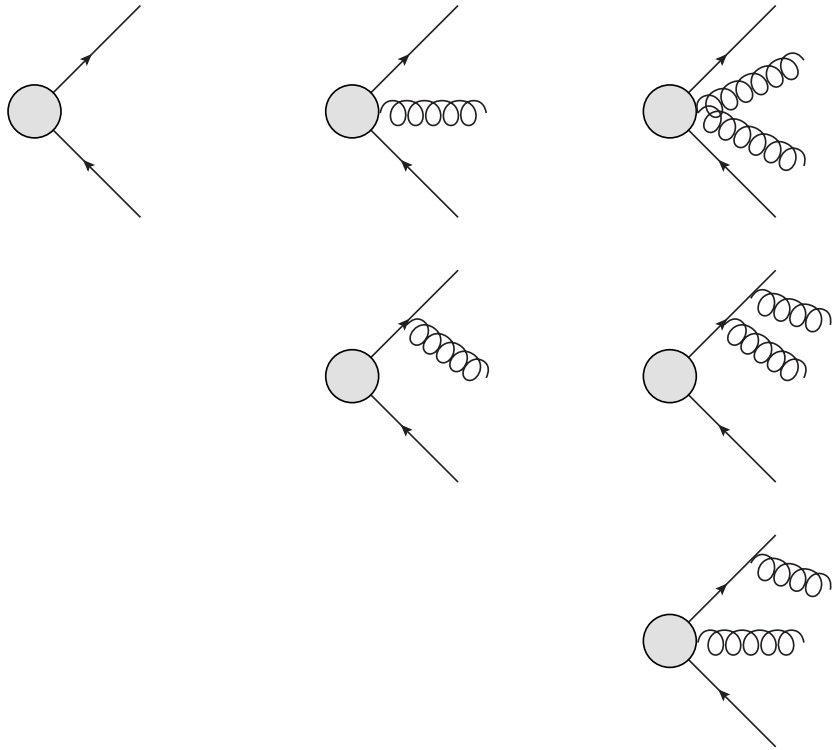
# Improving parton showers: NLO matching




[MC@NLO – Frixione, Webber], [POWHEG – Nason et al.]

[Implementations in several variants in Herwig++, MC@NLO, POWHEGBox, Sherpa]

# Improving parton showers: LO multijet merging



[Catani, Krauss, Kuhn, Webber], [Lönnblad], [Mangano]

[Again variants in Ariadne, Alpgen, Herwig++, MadEvent, Sherpa ...]

# Improving parton showers

Two established directions:

- NLO *matching*
- LO multijet *merging*

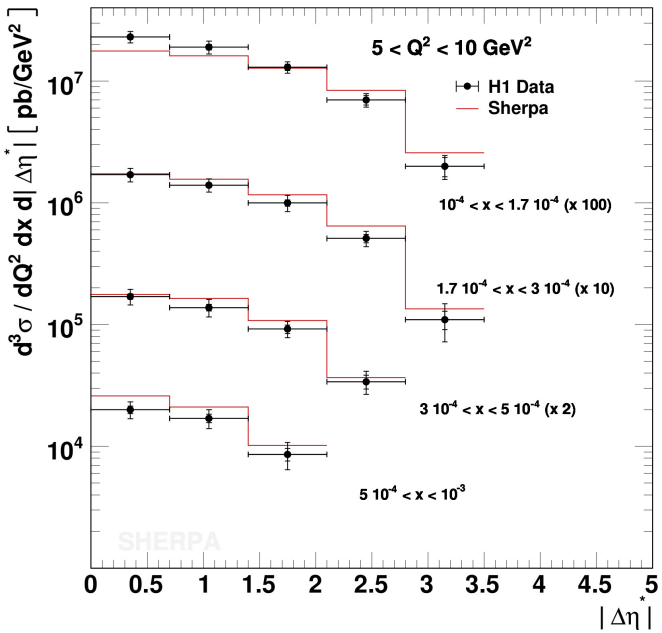
Not a single scheme.
Uncertainties are starting to be understood in full detail.

Desireable: NLO multijet merging.
NLO matching for $2+1$ only sensible for true $2+1$ jet observables.
$\rightarrow$ Need to merge with $1+1$ for more inclusive things.

[Lots of work in progress]

# Status for *ep*

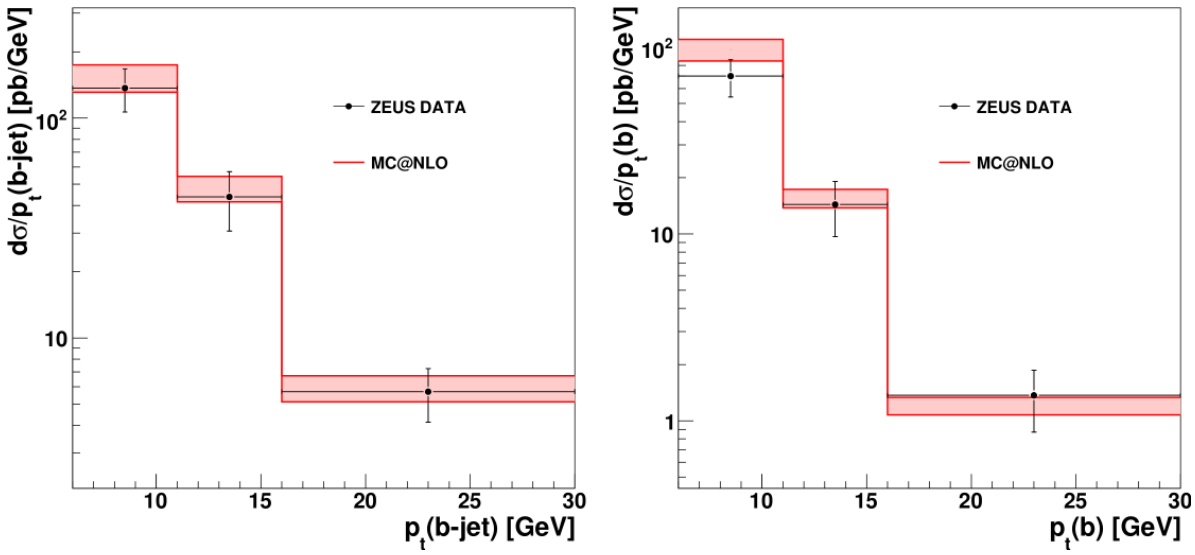
DIS LO multijet merging in Sherpa




[Carli, Gehrmann, Höche – arXiv:0912.3715]

# Status for *ep*

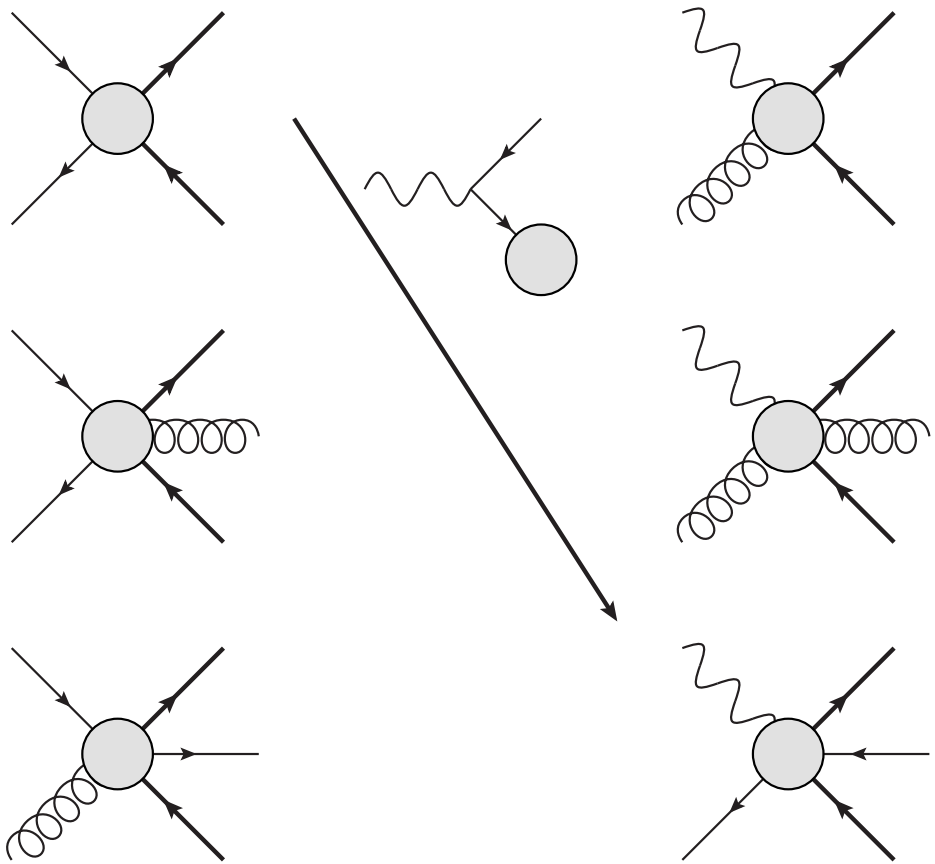
NLO matched heavy flavour photoproduction in MC@NLO




[Frixione, Toll – arXiv:1106.1614]

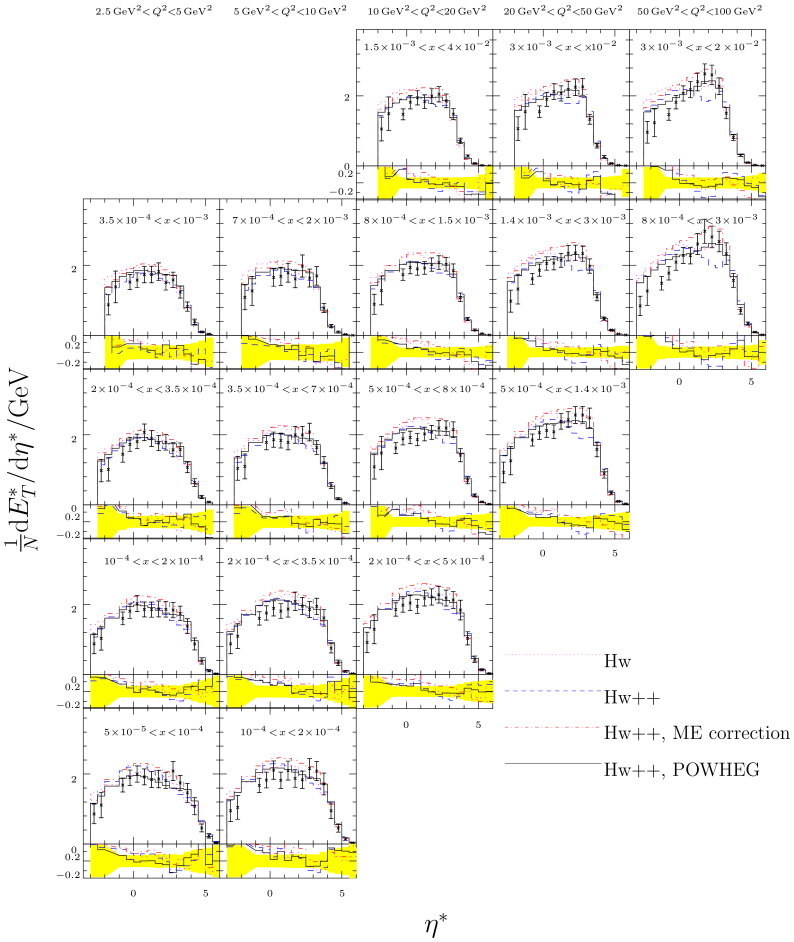
# Status for *ep*

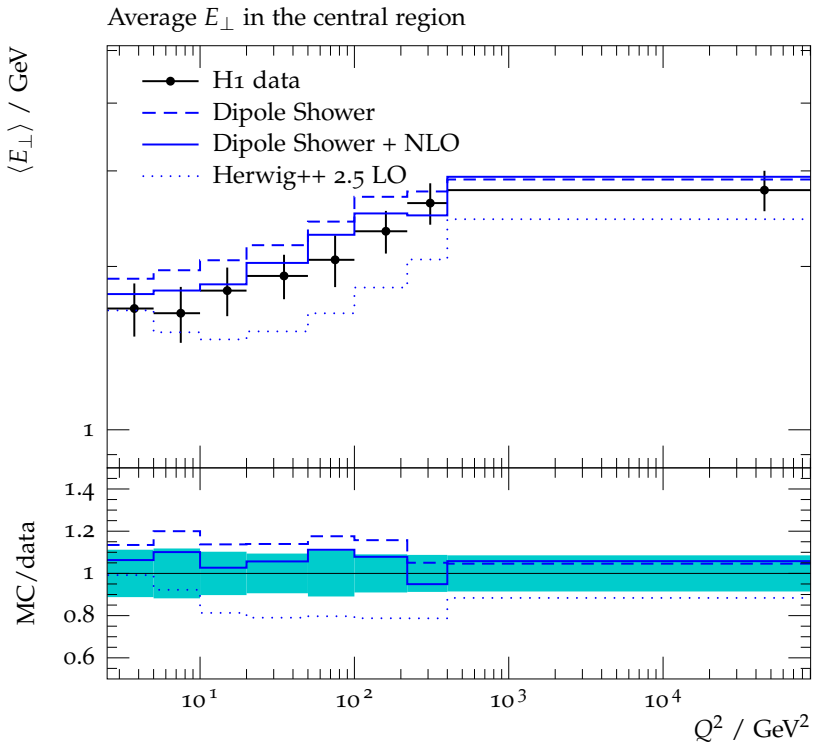
NLO matching for heavy flavour photoproduction.
A subtle detail ...



# Status for *ep*

NLO matched $1+1$ in Herwig++ (all $\gamma$ and $Z$ contributions)




[D'Errico, Richardson – arXiv:1106.2983]

[SP & S. Gieseke – arXiv:1109.6256]

# Status for *ep*

Matching/merging machinery very generic in most multi-purpose MCs.

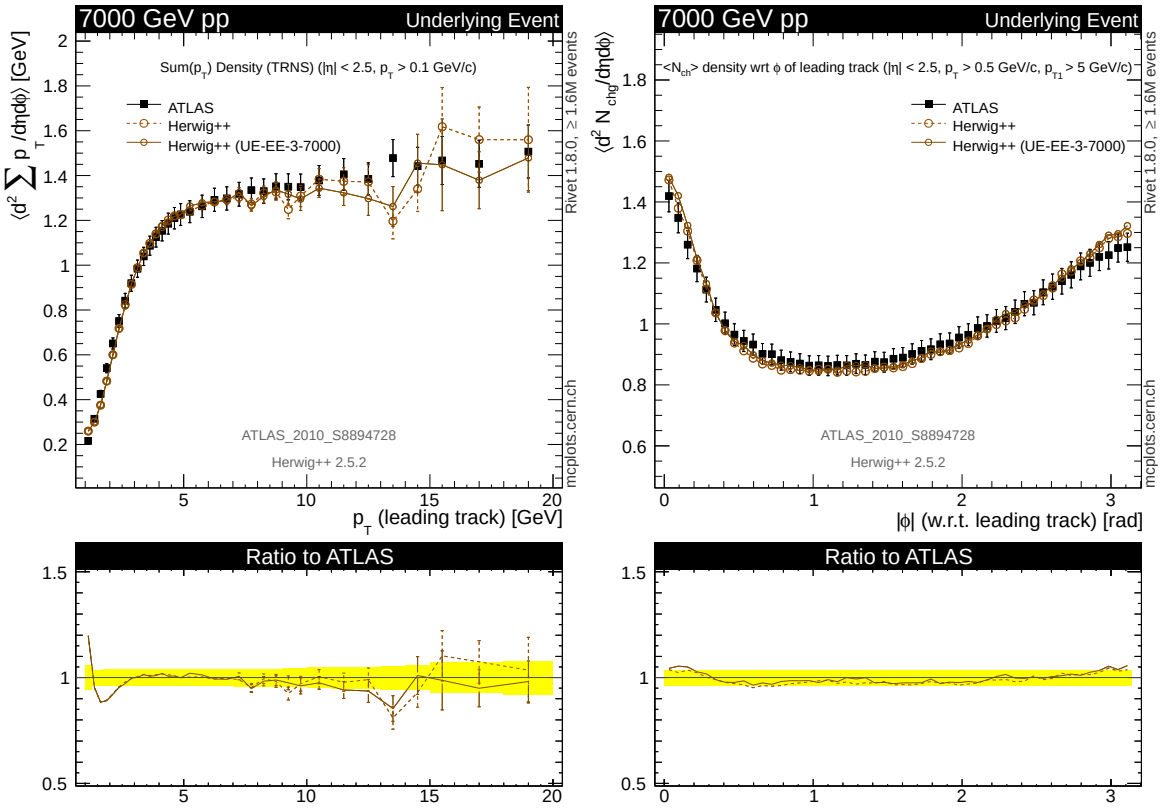
So far validated at LEP, then *pp*.
Prescriptions to assign uncertainties settle.

Will need to thoroughly validate these for *ep* to be LHeC ready.

Subtle aspects to be addressed in photoproduction.

# Multiple interactions

Eikonal multiple interaction models do well at LHC.
Some open questions towards diffraction, developments ongoing.



# Multiple interactions

In principle we have the infrastructure to do $\gamma p$.

Herwig++'s eikonal model rooted in work on photoproduction.

[Butterworth, Forshaw, Seymour – arXiv:hep-ph/960137]

Many improvements, particularly towards soft multiple interactions.

Need to look at HERA again ...

*"It seems that $\gamma p$ is more complicated than $pp$."*

M. Diehl

# Conclusions, next steps and a wishlist

LHC age multipurpose Monte Carlos have not forgotten about *ep*.

Still many things to be addressed before claiming LHeC readiness.
But we're on the way.

A personpower problem, as always.

Most important will be higher order matrix elements and multiple jets.
The infrastructure available is very generic.

We'll have to test:

- showers and improvements,
- hadronization,
- multiple interactions.

Against HERA data, of course.

# Conclusions, next steps and a wishlist

For validation and further developments, would really appreciate HERA analyses implementations in Rivet.

For ongoing analyses and future LHeC data, please provide

- particle level observables,
- in the fiducial volume,
- without any further corrections,
- based on *operational* definitions.

Will only be of limited use otherwise ...

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