News from Pythia

Neutrino grassroots discussion @ Fermilab (March 15 2016)

Stefan Prestel, remotely :(

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- \+ More perturbative physics: Matching and Merging!
- \+ Simple card files: Should be better match for software frameworks. Compatible with modern in- and outputs
- \+ Simple and extensive online documentation

  `http://home.thep.lu.se/~torbjorn/pythia82html/Welcome.html`

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Sophisticated showers for DIS available. $\gamma p/\gamma\gamma$ under investigation.

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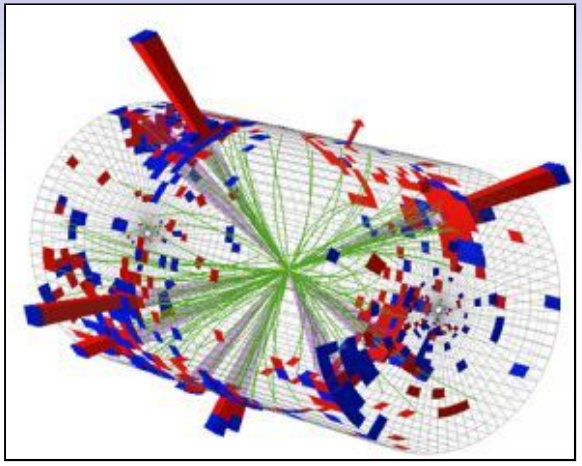
This is a plus!

Only for pp

PYTHIA6 development has stopped. PYTHIA6 support is not high-priority for developers any longer.

LHC lessons

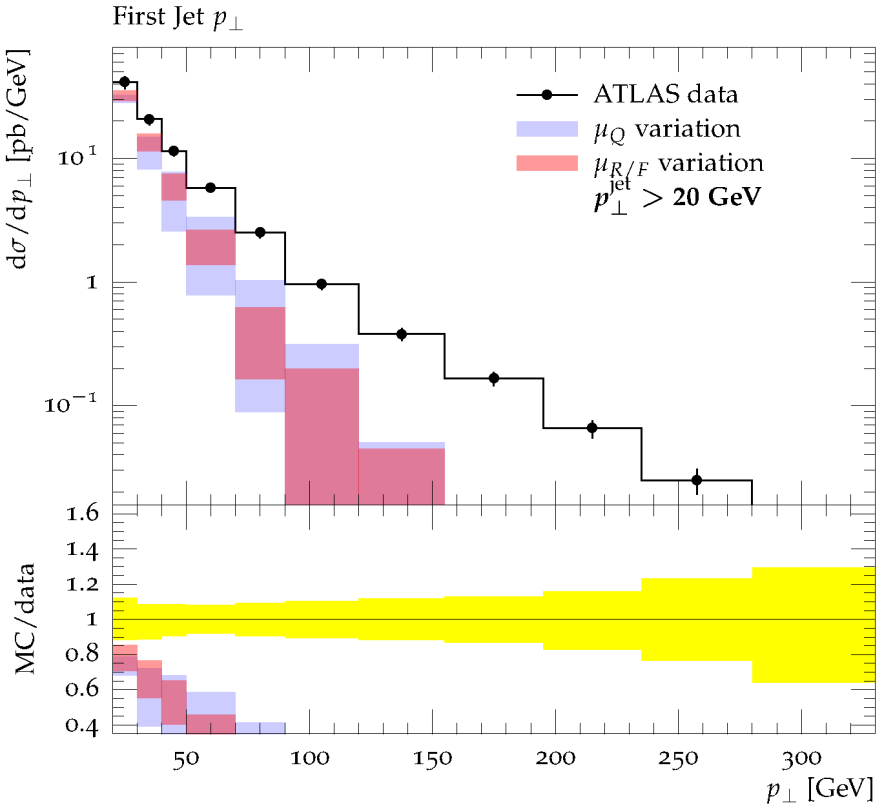


LHC is a jet machine

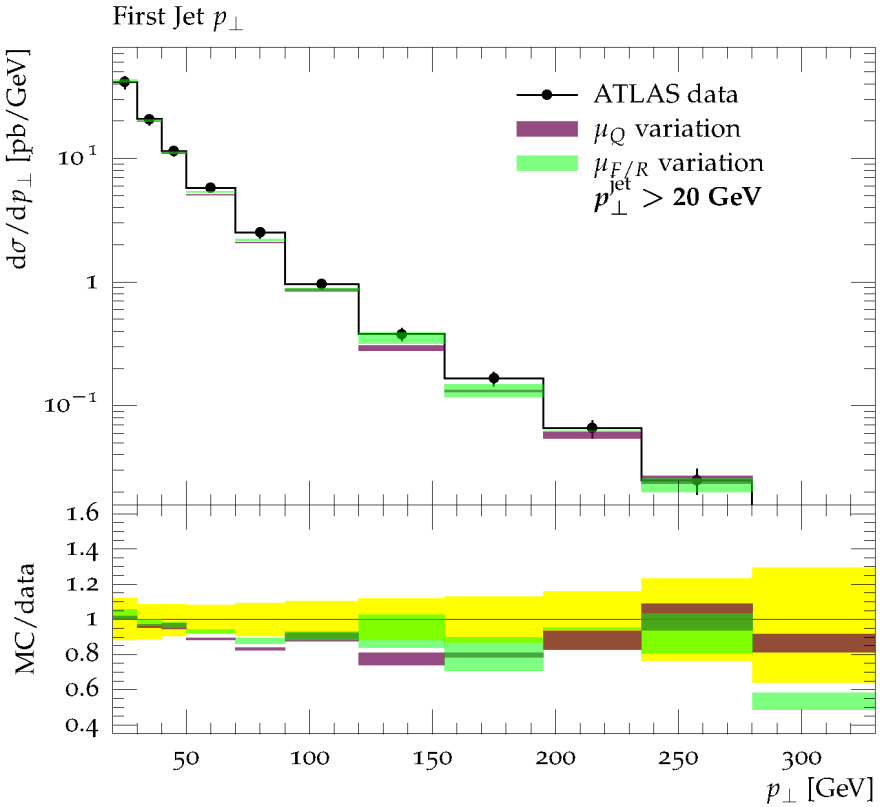
need to get jet production right

need to get jet evolution right

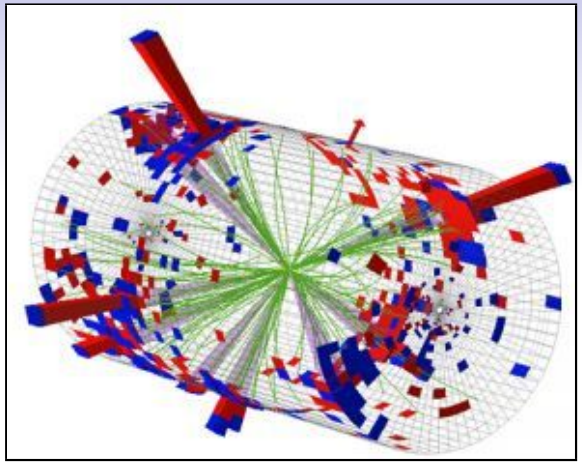
Before



After NLO merging



LHC lessons



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LHC physics requires accurate & precise QCD calculations:

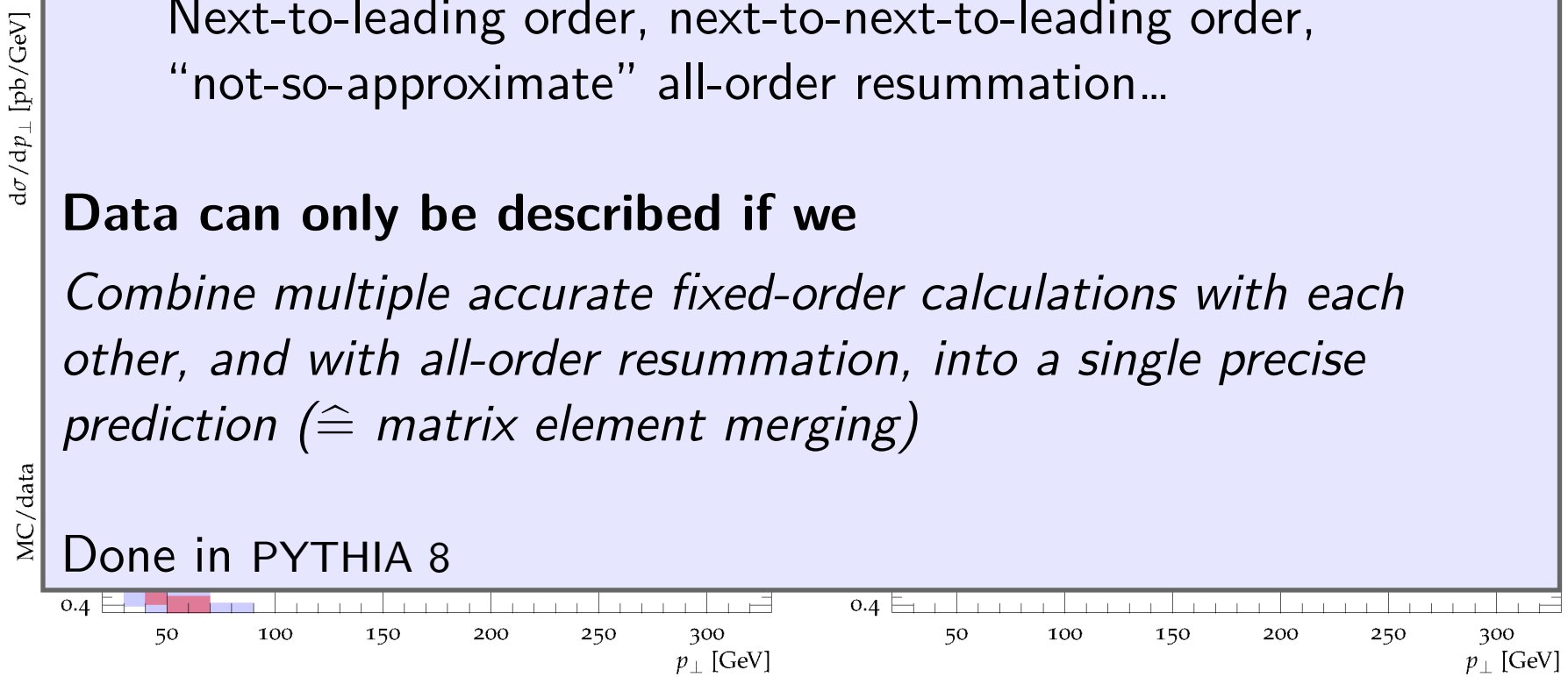
Next-to-leading order, next-to-next-to-leading order,

"not-so-approximate" all-order resummation...

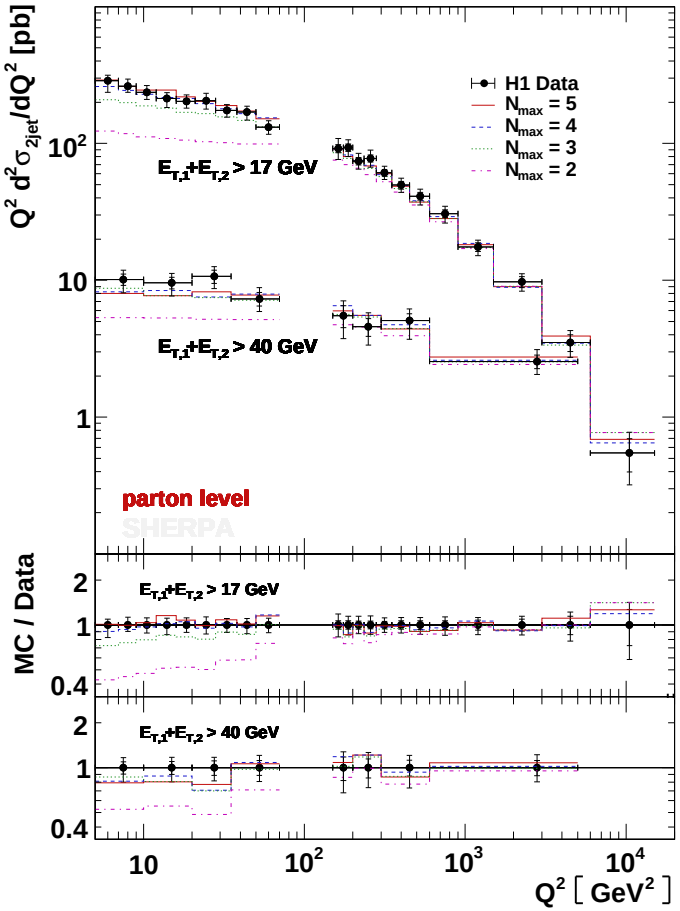
Data can only be described if we

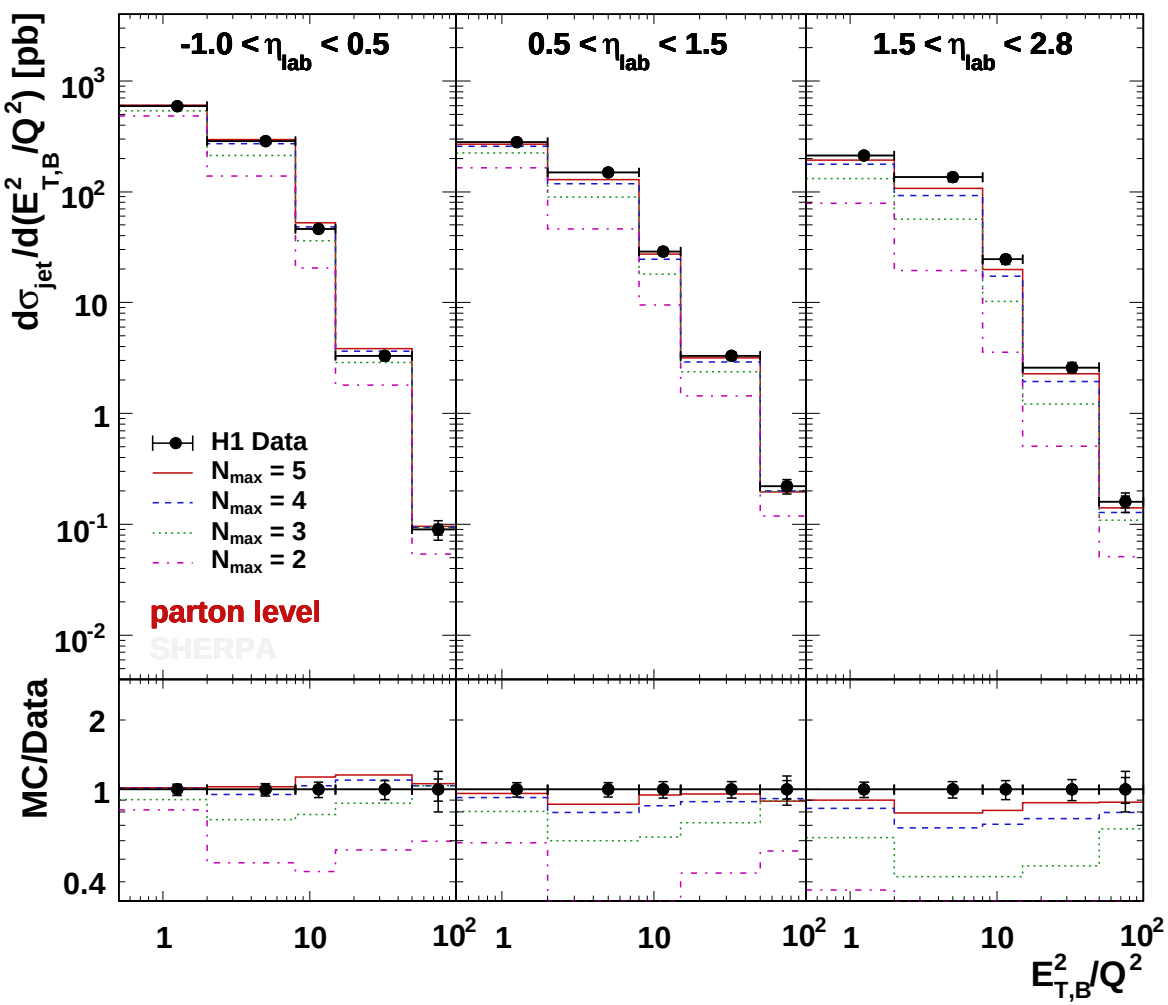
Combine multiple accurate fixed-order calculations with each other, and with all-order resummation, into a single precise prediction (≙ matrix element merging)

Done in PYTHIA 8



In retrospect, also important for HERA data





SHERPA predictions for the jet cross sections in H1 (in Q^2 and $E^2_{T,B}/Q^2$). Plot taken arXiv:0912.3715

Exact psp factorisation enables ME corrections. Good agreement after combining many multi-jet matrix elements w/ each other and w/ shower.

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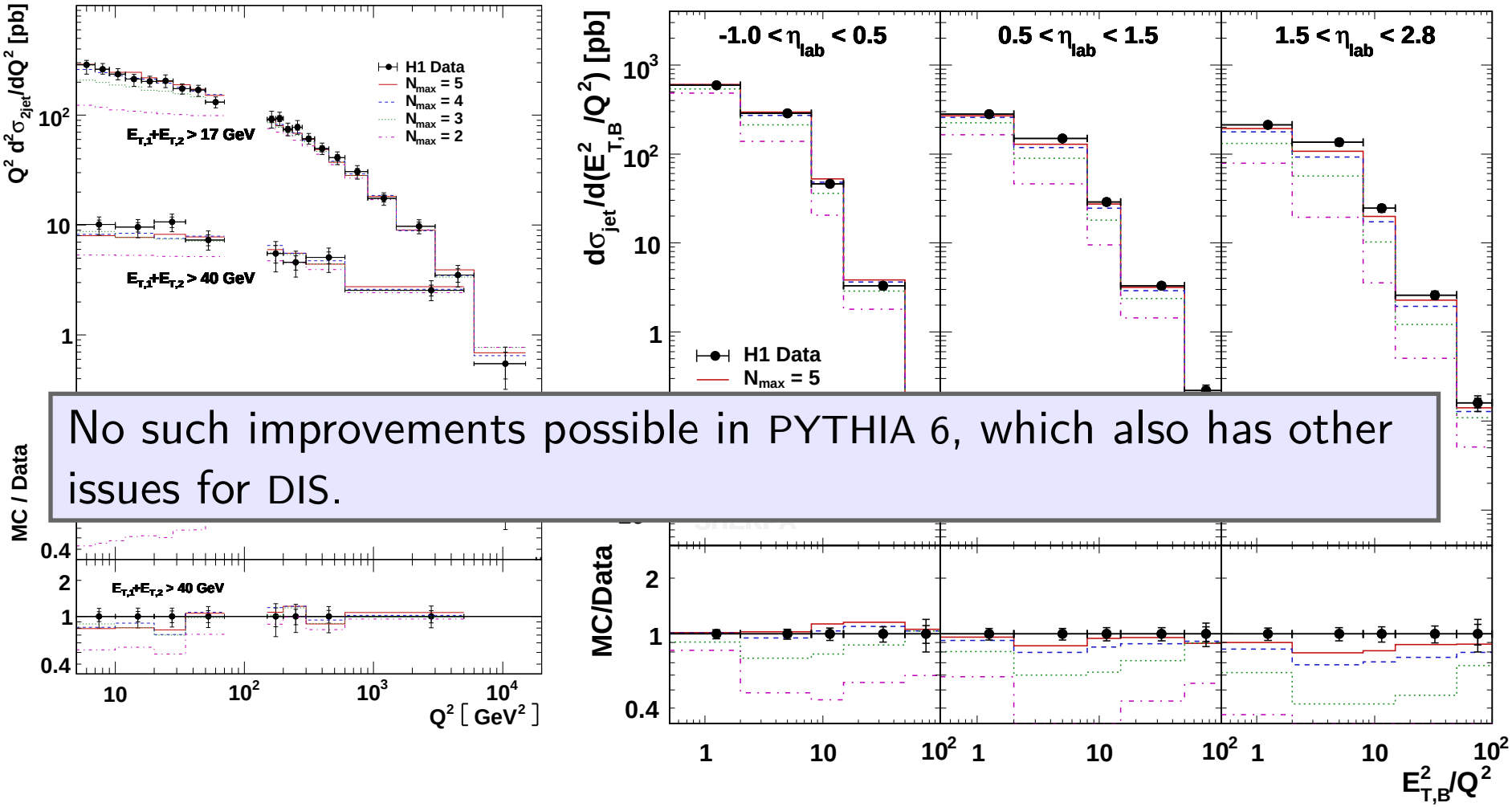

No such improvements possible in PYTHIA 6, which also has other issues for DIS.

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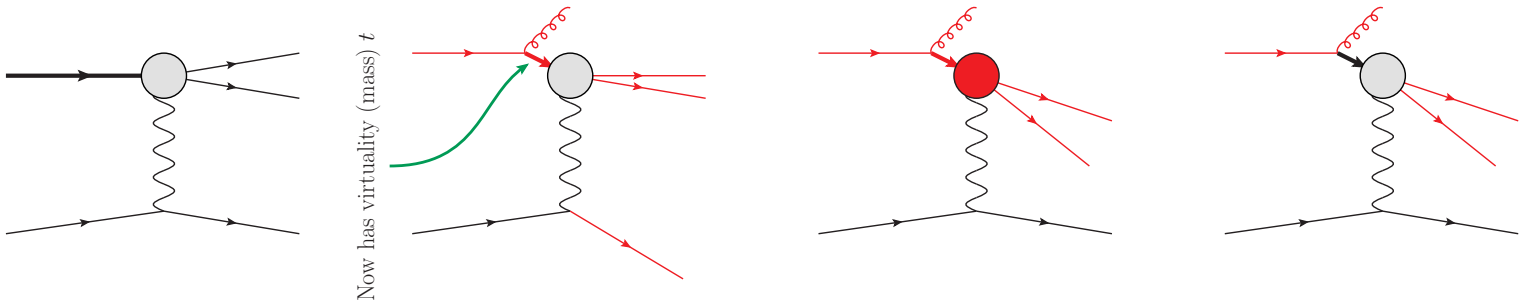
The DIS issue: Parton showers and cross section



Hard scattering

Naive shower
Full final state changed
Does not reduce to lowest-order

Pythia 6
Lepton intact
Reduces to modified hard process

Pythia 8
Lepton intact
Reduces to correct hard process

Initial state radiation in a traditional PS proceeds by

- Take massless incoming line, shift to accommodate virtuality t.
- Split the massive incoming line to produce the emission.

Naive introduction of a virtuality t means $x_{\text{After}} \neq x_{\text{Bjorken Before}}$

$\Rightarrow$ Shower changes momentum fraction of the "core" process.
$\Rightarrow$ Must recalculate scattering cross section $d\sigma = f(x, Q^2)d\hat{\sigma}$ after each emission! $\Rightarrow$ **Not possible / practical.**

Fix in pp: "Backward evolution". Electrons take recoil. Bad for DIS.

The new Pythia 8 model

Pythia 6 model

• Redefine hard scattering

◇ Energy sharing very messy
◇ Not coherent
◇ Holes in phase space
◇ Jet rates technically depend on custom structure functions.

− Cannot easily improved with full MEs → uncertain for large W^2
+ GVMD model for $W^2 \lesssim 1\text{GeV}$

Pythia 8 model (DIRE)

• Exact on-shell phase space factorization

◇ Straight-forward energy sharing
◇ Coherence built in
◇ Full phase space coverage
◇ Depends only on standard structure functions$^{(*)}$

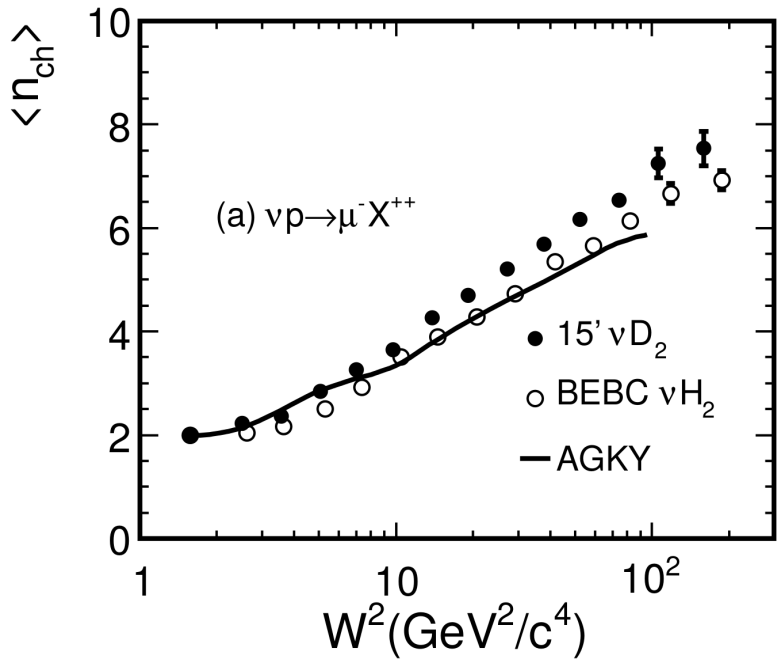
+ Exact phsp factorization allows merging with exact MEs
− No diffraction yet for $W^2 \lesssim 1\text{GeV}$

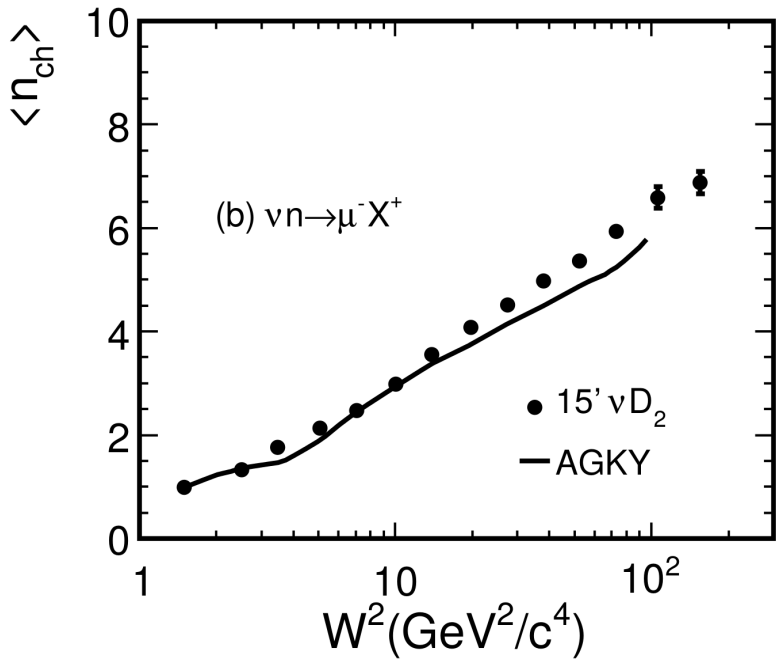
$^{(*)}$ up to power corrections from difference of kernels to DGLAP.

Relevance for neutrinos?

For PYTHIA 8, neutrino scattering is deep inelastic scattering.

Still new in PYTHIA 8. We know that LHC improvements may fix issues with HERA (high-W^2) data (work in progress)





How high W^2 for current experiments? Varied Pythia 6 parameters?

Summary and Outlook

Things to do in PYTHIA 8:
Diffractive model, Low-multiplicity hadronization, generalized proton structure.

Opportunities:
PYTHIA 8 is maintained and developed (in C++). Hadronization tunes more up-to-date. Well-defined showers may allow better interface to non-perturbative physics. High-W^2 physics can be made more reliable.

Questions

Is neutrino phenomenology sensitive to improvements in PYTHIA 8?
What about nuclear effects, also for eA and pA?