Event generator uncertainties

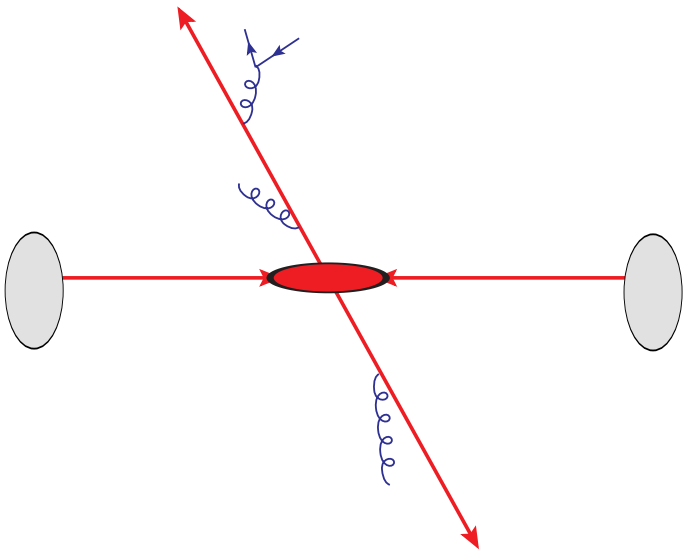
Q: Can we find recipes that do not underestimate the uncertainties, while at the same time not being overly conservative?

Experiments assign uncertainty by "Pythia vs. Herwig"

We should do better.

This is not intended to be a scale-setting discussion.
This is not intended to be a Code A vs. Code B discussion.

Sources of uncertainty & correlations



Uncertainties:

Short-distance cross section:

μ_r^H, μ_f^H, PDF^H, α_s^H

Parton shower:

μ_q^{PS}, μ_r^{PS}, μ_f^{PS}, μ_{cut}^{PS}, PDF^{PS}, α_s^{PS}

...correlated with:

μ_f^H with shower starting scale

μ_f^H, PDF^H with MPI

μ_q^{PS}/μ_f^H and PDF^{PS}/PDF^H

μ_r^{PS}/μ_r^H and α_s^{PS}/α_s^H for NLO+PS

μ_{cut}^{PS} with "string $p_\perp$" & "primordial $k_\perp$"

1. Parton showers "undo" PDF evolution.
2. Short-distance x-sections for matching assume certain PS settings.
3. Hadron p_Ts can be non-perturbative, or inherited from partons

μ_r^H (renormalization scale in hard x-section)

We want to have a theory discussion.
Here's a way how we think a discussion could go – to set the tone :)

Assume fixed-order calculation

$$< \mathcal{O} >_{\mathsf{LO}} = \int d\Phi_n f(x, \mu_f^H) d\sigma_{\mathsf{LO}} \mathcal{O}(\Phi_n)$$

and parton shower

$$\begin{aligned} \mathcal{F}_n(t_n, t_{cut}; \mathcal{O}) &= \Pi(t_n, t_{cut}) \mathcal{O}(\Phi_n) \\ &\quad + \int_{t_{cut}}^{t_n} dt \int dz \alpha_s(t) P(z) \frac{f(x/z, t)}{f(x, t)} \mathcal{F}_{n+1}(t, t_{cut}; \mathcal{O}) \end{aligned}$$

with no-emission probability

$$\begin{aligned} \Pi(t_n, t_{cut}) &= \exp\left(- \int_{t_{cut}}^{t_n} dt \int dz \alpha_s(t) P(z) \frac{f(x/z, t)}{f(x, t)} \right) \\ &= \frac{f(x, t_{cut})}{f(x, t_n)} \Delta(t_n, t_{cut}) \end{aligned}$$

...with this, we get

$$
\begin{aligned}
& \Pi(t_n, t_{cut}) f(x, \mu_f^H) d\sigma_{\mathsf{LO}} \mathcal{O}(\Phi_n) + \dots \\
= \quad & f(x, t_{cut}) \frac{f(x, \mu_f^H)}{f(x, t_n)} \Delta(t_n, t_{cut}) d\sigma_{\mathsf{LO}} \mathcal{O}(\Phi_n) + \dots \\
= \quad & f(x, t_{cut}) \Delta(t_n, t_{cut}) d\sigma_{\mathsf{LO}} \left[1 + \int_{\mu_f^H}^{t_n} dt \int dz \alpha_s(t) P(z) \frac{f(x/z, t)}{f(x, t_n)} \right] \mathcal{O}(
\end{aligned}
$$

So here's a term that we most likely would not want.

Keeping sensible backward evolution might of course be obvious to shower people, but we might want to tell people not to do variations that violate this rule.
That's one example how we think the discussion could go.

Uncorrelated with μ_f^H and μ_q^{PS} at LO. Otherwise uncorrelated?
NLO matching: Correlated with μ_r^{PS}?

Take MC@NLO as example

$$
\begin{aligned}
< \mathcal{O} >_{\text{MC@NLO}} &= (B + \alpha_s(\mu)V + \alpha_s(\mu)I + \alpha_s(t)B \otimes P)\mathcal{O}(\Phi_n) \\
&\quad + \int (\alpha_s(\mu)R - \alpha_s(t)B \otimes P)\mathcal{O}(\Phi_{n+1}) \\
&= (B + \alpha_s(\mu)V + \alpha_s(\mu)I + \alpha_s(\mu)B \otimes P)\mathcal{O}(\Phi_n) \\
&\quad + \int (\alpha_s(\mu)R - \alpha_s(\mu)B \otimes P)\mathcal{O}(\Phi_{n+1}) \\
&\quad + \beta \ln(\mu/t)\alpha_s^2(t)(B \otimes P\mathcal{O}(\Phi_n) - B \otimes P\mathcal{O}(\Phi_{n+1}))
\end{aligned}
$$

Is this a harmless higher-order correction?

Thoughts anyone? Religious wars?

μ_f^{PS} (factorization scale in backward evolution)

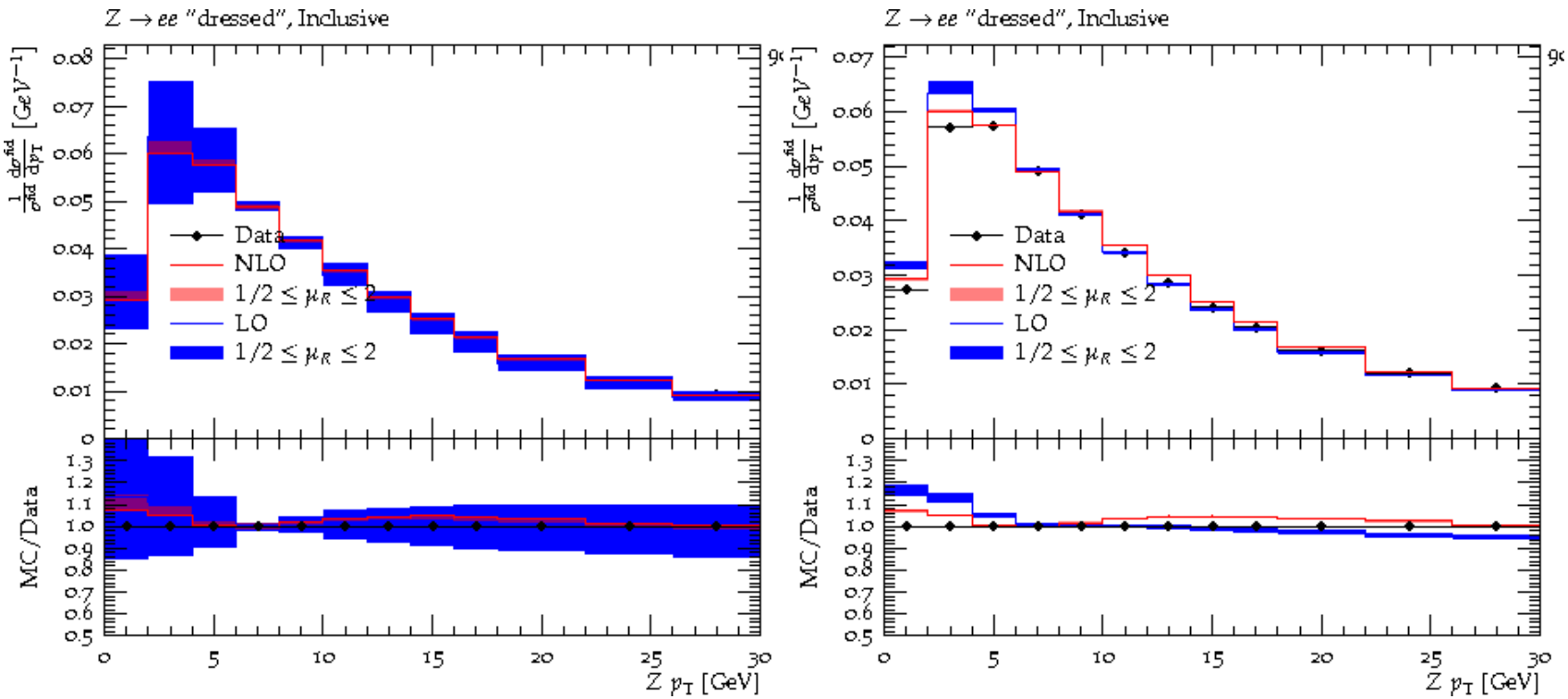
If we agree on recommendations for the previous scales, we should also have a look at two more!

How about writing out the NLO+PS result with varying μ_f^{PS}.

Do we see any inconsistencies?
Can we read off any recommendations & things to implement?

μ_r^{PS} (renormalization scale in parton shower)

Same as before. But remember that we do not want to be too aggressive.



Summary

This could be a level at which to discuss some scale variations.

It would be nice if

- we could agree on if μ_f and μ_q should be varied in unison.
- we could agree if there are consistency conditions μ_r^H, or some agreement that some setups are stupid?

It would be great if

- we can find agreement about μ_f^{PS} and μ_r^{PS} variations!

Once we have consensus, we thought it would be good to test on simple observables (jet vetoed x-sections in WW?), and then test for something less simple.