

The background of the slide features a complex particle detector simulation visualization. It shows a central interaction point with numerous tracks radiating outwards. The tracks are color-coded, with red and yellow lines being prominent, and green lines forming a dense, circular pattern around the center. The overall image has a light blue background with some darker, abstract shapes that suggest the internal structure of a detector.

Welcome to Tools & Monte Carlos!

Les Houches 2017

June 05, 2017

Emanuele Re, Stefan Prestel

Fixed-order + shower news:

- ◇ NNLO+PS for $2 \rightarrow 2$ (color singlet), e.g. $pp \rightarrow HW$
- ◇ Resonance-aware matching (POWHEG-BOX and aMC@NLO)
- ◇ Electroweak corrections + NLO QCD in Sherpa & in aMC@NLO
- ◇ Herwig merging @ NLO (two schemes!) and LO

Shower news:

- ◇ Automatic shower variations ($\mu_{f/r}$ PDFs, finite pieces)
+ assessment of shower starting scale modelling
- ◇ New publicly available showers: Vincia and Dire.
- ◇ Threshold logs in Deductor
- ◇ NLO corrections to shower evolution

Soft and non-perturbative news:

- ◇ New diffractive model in Herwig.
- ◇ New string breaking mechanism in Pythia.

Why Monte Carlos?

Please add reasons here.

Find common event generator variations

Goal: Provide a representative uncertainty for matched/merged MCs to experimentalists

Applicability of resonance-aware matching

*Goal: Discuss what resonance-aware matching requires from parton showers.
Case study?*

Heavy flavour in spacelike splittings

*Goal: Understand impact of models of heavy flavour excitations in
(matched/merged) MCs, and assess their uncertainties*

New observables to expose the higher-order structure of showers

Goal: Inform parton shower developments and provide benchmarks.

Shortcomings of Les Houches Event Files

Goal: Discuss & decide if some uses of LHEF 3 functionality should be codified.

Event generator uncertainties

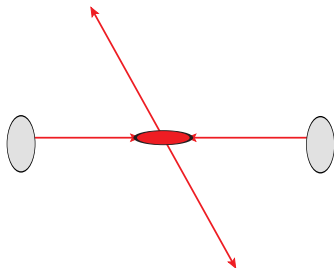
Q: Can we find recipes that do not underestimate the uncertainties, while at the same time not being overly conservative?

Q: Can we find a common recipe to assess perturbative uncertainties while retaining consistency for each variation?

Uncertainties:

Short-distance cross section:

$$\mu_r^H, \mu_f^H, \text{PDF}^H, \alpha_s^H$$

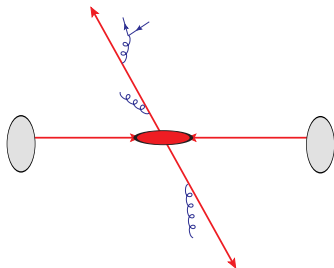


...correlated with:

μ_f^H with shower starting scale

μ_f^H, PDF^H with MPI

1. Parton showers “undo” PDF evolution.
2. MPI sensitive to “left-over matter” in colliding hadron → Depends on scales, x -values and PDF sets



Uncertainties:

Short-distance cross section:

$$\mu_r^H, \mu_f^H, \text{PDF}^H, \alpha_s^H$$

Parton shower:

$$\mu_q^{PS}, \mu_r^{PS}, \mu_f^{PS}, \mu_{cut}^{PS}, \text{PDF}^{PS}, \alpha_s^{PS}$$

...correlated with:

μ_f^H with shower starting scale

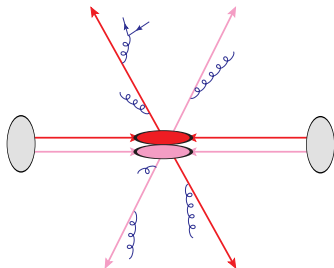
μ_f^H, PDF^H with MPI

μ_q^{PS} / μ_f^H and $\text{PDF}^{PS} / \text{PDF}^H$

μ_r^{PS} / μ_r^H and $\alpha_s^{PS} / \alpha_s^H$ 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_T s can be non-perturbative, or inherited from partons



Uncertainties:

Short-distance cross section:

$$\mu_r^H, \mu_f^H, \text{PDF}^H, \alpha_s^H$$

Parton shower:

$$\mu_q^{PS}, \mu_r^{PS}, \mu_f^{PS}, \mu_{cut}^{PS}, \text{PDF}^{PS}, \alpha_s^{PS}$$

Multiple interactions:

$$\mu_q^{MPI}, \text{PDF}^{MPI}, \alpha_s^{MPI} \dots$$

...correlated with:

μ_f^H with shower starting scale

μ_f^H, PDF^H with MPI

μ_q^{PS} / μ_f^H and $\text{PDF}^{PS} / \text{PDF}^H$

μ_r^{PS} / μ_r^H and $\alpha_s^{PS} / \alpha_s^H$ for NLO+PS

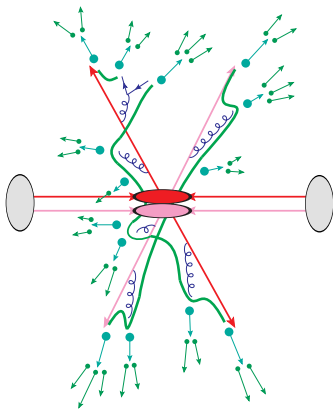
μ_{cut}^{PS} with "string p_\perp " & "primordial k_\perp "

α_s^{MPI} and α_s^{PS}

α_s^{MPI} and "string tension"

1. Fewer PS emissions mean more phase space & easier competition for MPI
2. More MPI means smaller multiplicity necessary from string dynamics.

Sources of uncertainty & correlations



Uncertainties:

Short-distance cross section:

$$\mu_r^H, \mu_f^H, \text{PDF}^H, \alpha_s^H$$

Parton shower:

$$\mu_q^{PS}, \mu_r^{PS}, \mu_f^{PS}, \mu_{cut}^{PS}, \text{PDF}^{PS}, \alpha_s^{PS}$$

Multiple interactions:

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

α_s^{MPI} and α_s^{PS}

α_s^{MPI} and "string tension"

Phase transition to hadrons has no well-defined parametric uncertainties

Production and decays taken from fits and measurements...no uncertainties?

Towards uncertainty recommendations?

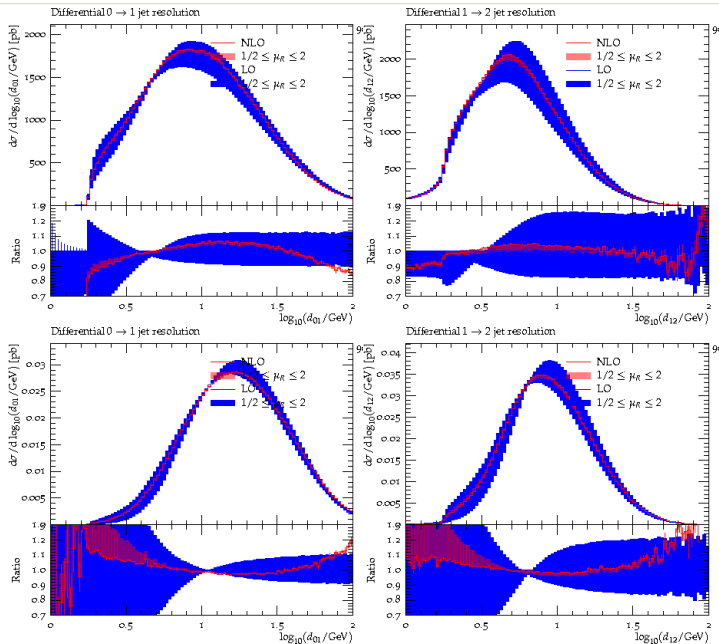
Goal: Find consensus how to vary μ_f^H , μ_r^H and μ_q^{PS} .

If we find consensus, can we add μ_r^{PS} and μ_f^{PS} to the mix?

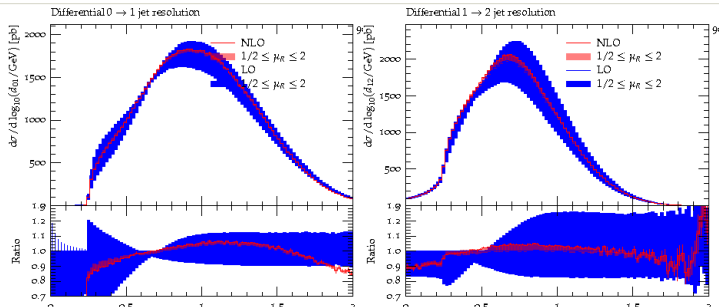
One possible way to find consensus could be to adopt conservative consistency conditions, e.g.:

◇ Backwards evolution of initial state showers allows only small differences of μ_f^H and μ_q^{PS}

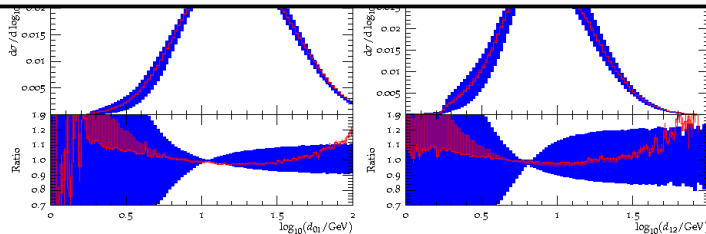
Cautionary tale: DIRE LHC predictions



Cautionary tale: DIRE LHC predictions



LO bands very large!
Are we too conservative?



Cautionary tale: Are we too conservative?

Fact: PS is leading-log resummation for observables similar to PS evolution variable.

Hope: We capture many sub-leading effects (running α_s , simple higher-order color factors (CMW) in soft limit, E/p -conservation...)

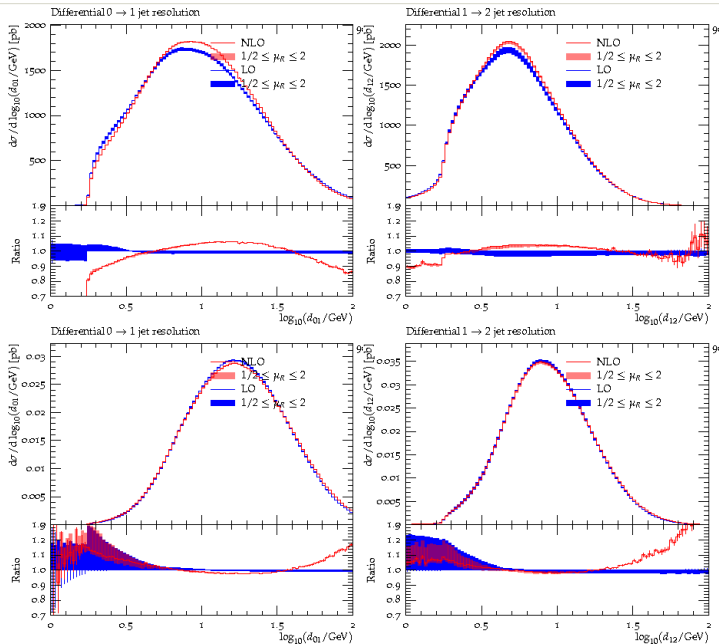
Question: Are our uncertainties too conservative? Can we keep our good higher-order terms fixed when varying scales?

Suggestion of Les Houches 2015 (cf. arXiv:1605.04692): Keep the higher-order soft improvement (2-loop cusp) implemented by “CMW rescaling”

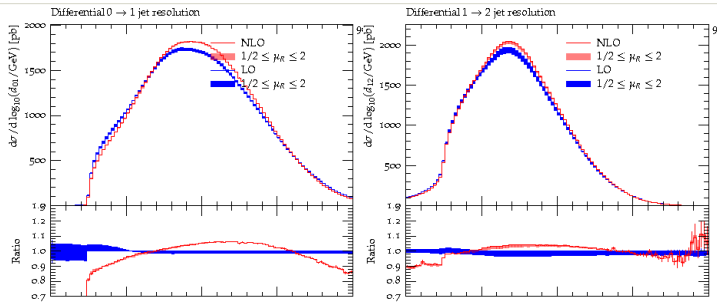
$$\alpha_s^{PS}(t) \rightarrow \alpha_s^{PS}(k^{\text{CMW}}t)$$

fixed up to α_s^2 when varying μ_r^{PS} by introducing a scale compensation term.

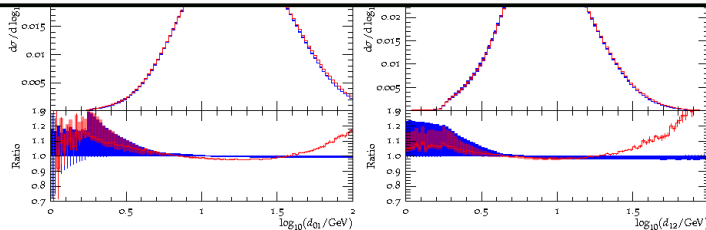
Cautionary tale: DIRE LHC predictions, with scale compensation

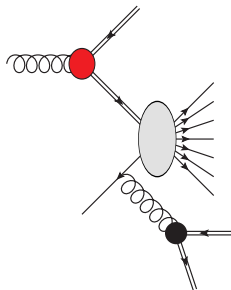


Cautionary tale: DIRE LHC predictions, with scale compensation



NLO does not overlap with LO!
Naive scale compensation much too aggressive.

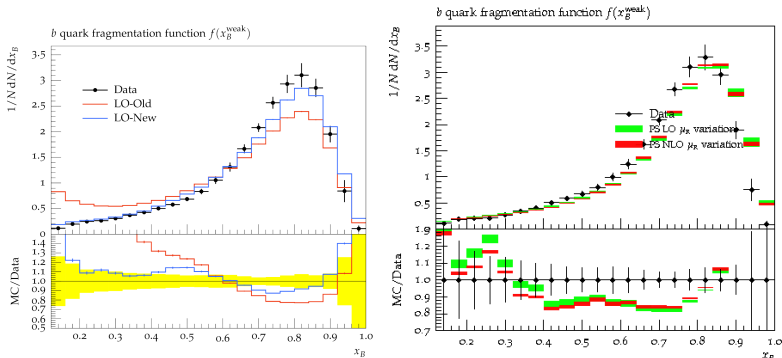




Q: Do we need to worry about the treatment of the $g \rightarrow Q\bar{Q}$ in parton showers when interpreting heavy flavor measurements?

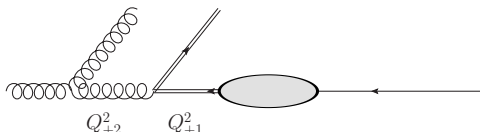
Q: Does the parton-shower modeling feed down into commonly used fixed-order+parton shower calculations?

Worry: Problems with describing b-fragmentation at ee colliders could also be present for b-jet modelling at LHC.



Do we still worry about $g \rightarrow Q\bar{Q}$ in timelike splittings? Seems to have quietly gone away...

Spacelike $g \rightarrow Q\bar{Q}$



- ◇ Proton probed at scales $\lesssim m_b$ does not contain b-excitations.
 - ◇ Need mechanism to remove heavy flavour from initial state.
 - ◇ Meson formation relies on correct final state parton masses.
- Need to “branch away” bs before $Q_{+2} = m_b$

→ Conflict with PDF fits + requires serious approximations to PS:
In Pythia, spacelike conversions $g \rightarrow Q\bar{Q}$ with $m_b < p_{\perp b} < \lesssim 2m_b$
are e.g. not accompanied by soft gluons!

Do we worry about spacelike $g \rightarrow Q\bar{Q}$ splittings close to threshold?

Together with help from jets group!

Q: If showers induce large differences in matched/merged calculations, can we devise ways to constrain shower choices?

Q: Can we find observables that inform parton shower developments and improvements?

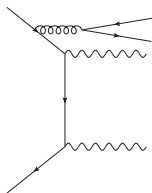
Resonance-aware matching

Q: What are choices & uncertainties of resonance-aware matching?

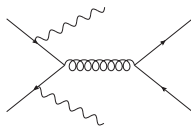
Q: What is required from parton showers?

Q: Do we need dedicated resonance-aware tunes?

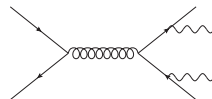
Showers and resonances



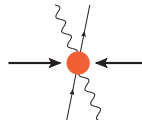
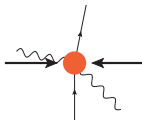
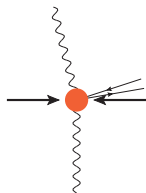
W^+ and $W^- \approx$ back-to-back
Potentially large QCD Sudakov logs



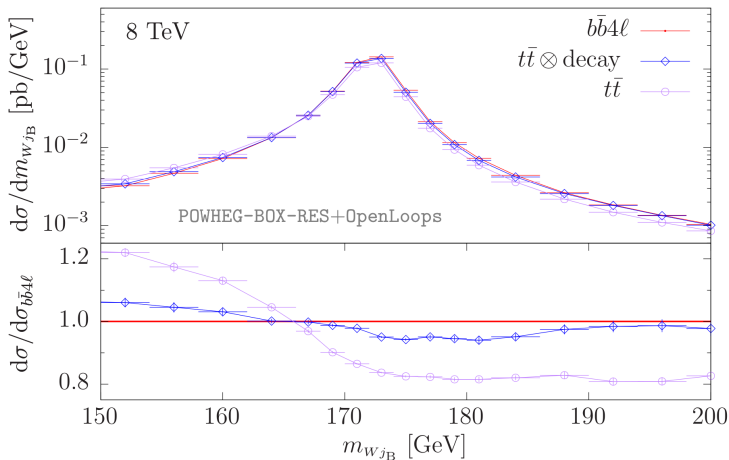
W^+ and b in different hemispheres
Potentially large EW Sudakov logs



W^+ and b in same hemisphere



Generator should give good answer for all extremes + in the “transition regions”.



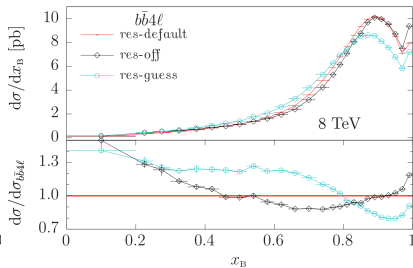
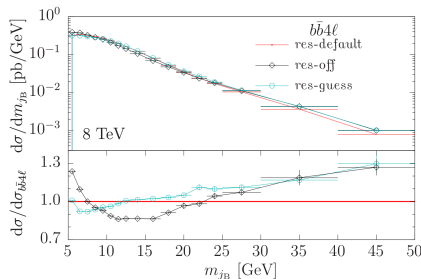
◇ All $\ell\ell\nu\nu b\bar{b}$ processes, with massive b-quarks!

⇒ Well approximated by NWA + reweighting + decay corrections.

Very different to stable top + shower.

Choices in resonance-aware matching

Assigning the resonance histories.
Treatment of multiple emissions.
Interface to parton shower.



arXiv:1607.04538

Choices can affect b-jet modelling significantly.

Q: How much is behaviour of hadronization changed?

Background: New matching/merging methods may require more fine-grained ways to steer event generation.

Q: Should we codify information that allows ME generator to steer parton showers, e.g. by setting starting scales?

Q: Should LHEF information be allowed to steer more than shower, e.g. also MPI or hadronization?

Additional projects?

Of course, the selection above reflects personal bias + time constraints.

Are there additions, concrete problems, and long-term wishes?
If so, let us know!

Current schedule:

Wed. 09:00	Uncertainties kick-off meeting
Sat.	Discussion about LHEF

We will keep the wiki updated + you are allowed to edit the wiki ;)

Enjoy Les Houches!