Welcome to Tools & Monte Carlos!

Les Houches 2017

June 05, 2017

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The last two years in Monte Carlo

Fixed-order + shower news:
- ◇ NNLO+PS for $2 \to 2$ (color singlet), e.g. $pp \to HW$
- ◇ 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.

Ideas for projects

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.

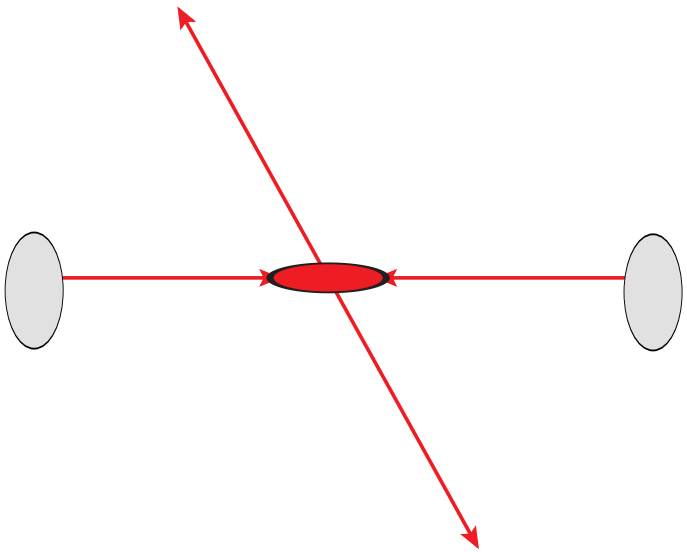
Shortcomings of Les Houches Event Files

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?

Sources of uncertainty & correlations



Uncertainties:

Short-distance cross section:

μ_r^H, μ_f^H, PDF^H, α_s^H

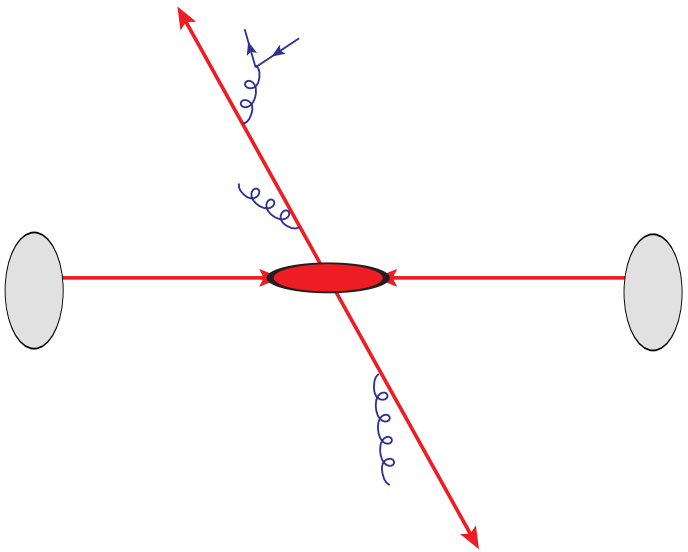
...correlated with:

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 $\rightarrow$ Depends on scales, x-values and PDF sets

Sources of uncertainty & correlations



Uncertainties:

Short-distance cross section:

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Parton shower:

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

...correlated with:

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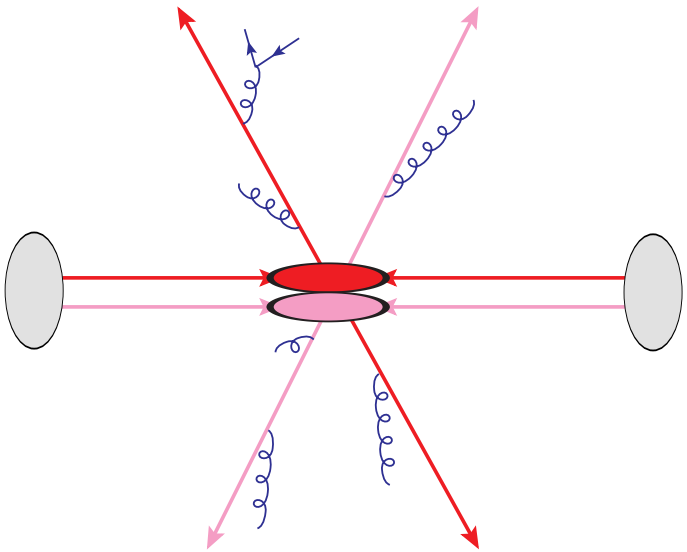
μ_q^{PS}/μ_f^H and PDF^{PS}/PDF^H

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

Sources of uncertainty & correlations



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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}

Multiple interactions:
μ_q^{MPI}, PDF^{MPI}, α_s^{MPI} ...

...correlated with:

μ_f^H with shower starting scale

μ_f^H, PDF^H with MPI

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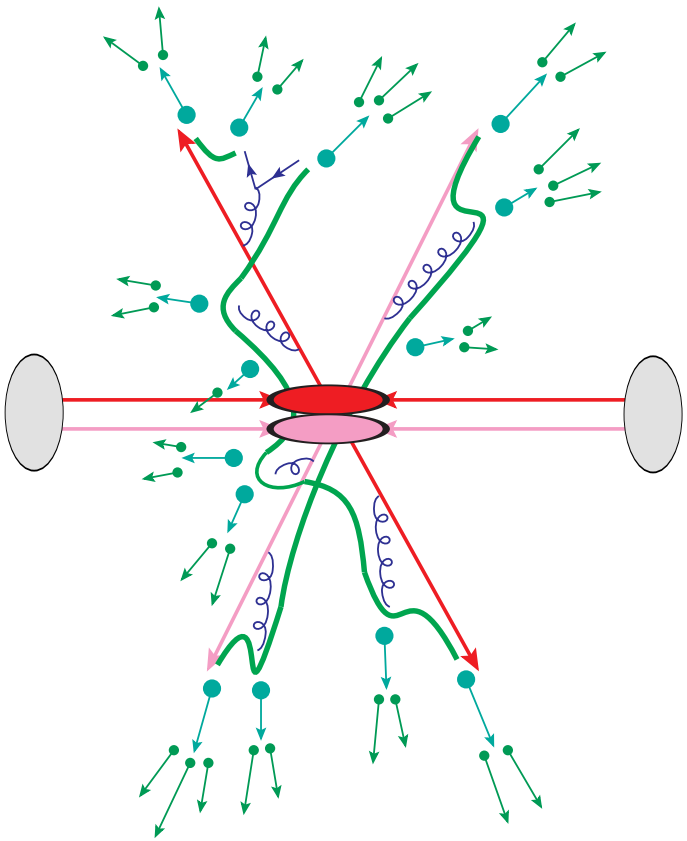
μ_{cut}^{PS} with "string $p_\perp$" & "primordial $k_\perp$"

α_s^{MPI} and α_s^{PS}

α_s^{MPI} and "string tension"

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



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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?

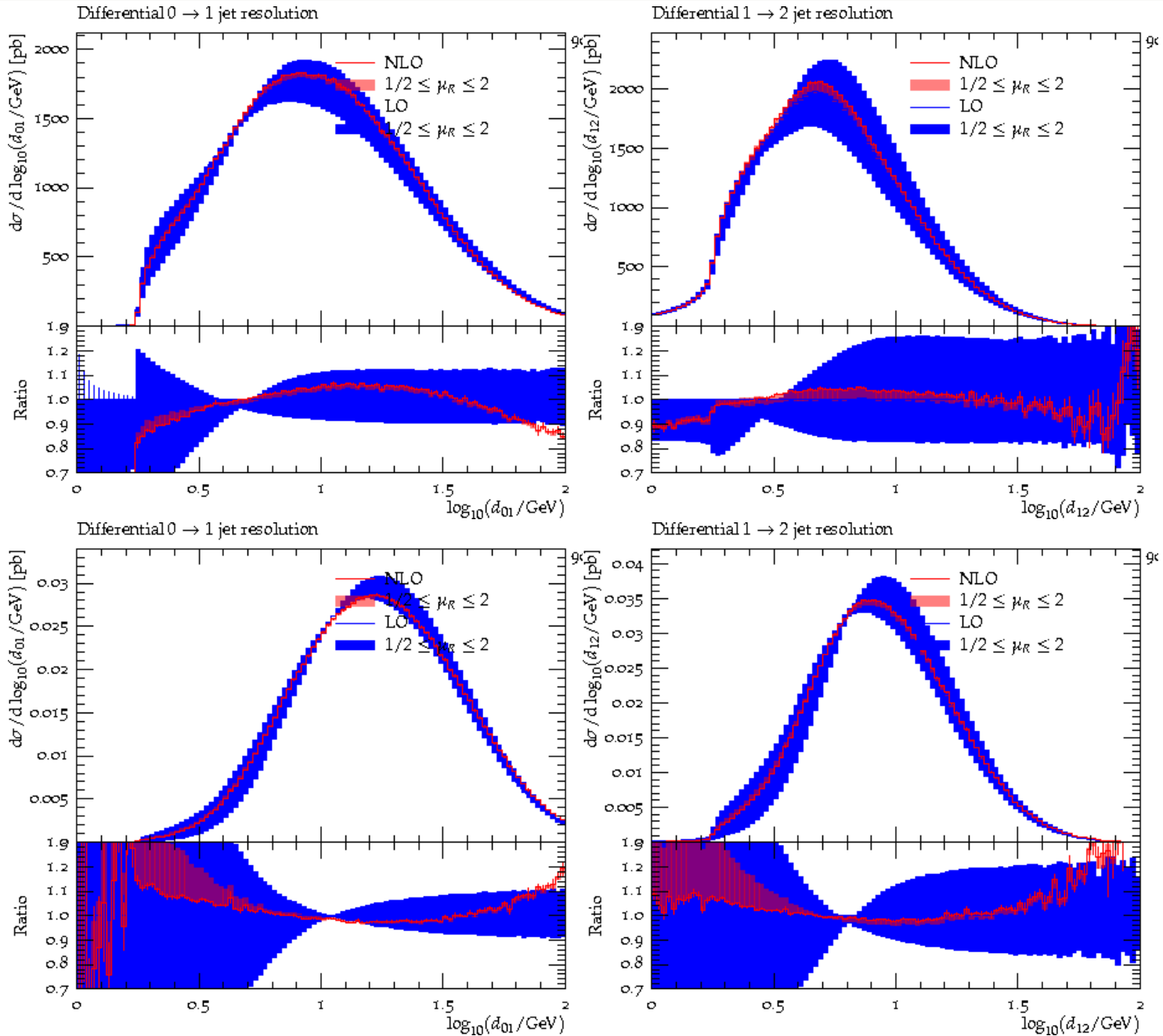
Towards uncertainty recommendations?

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.:
$\diamond$ Backwards evolution of initial state showers allows only small differences of μ_f^H and μ_q^{PS}

Cautionary tale: DIRE LHC predictions



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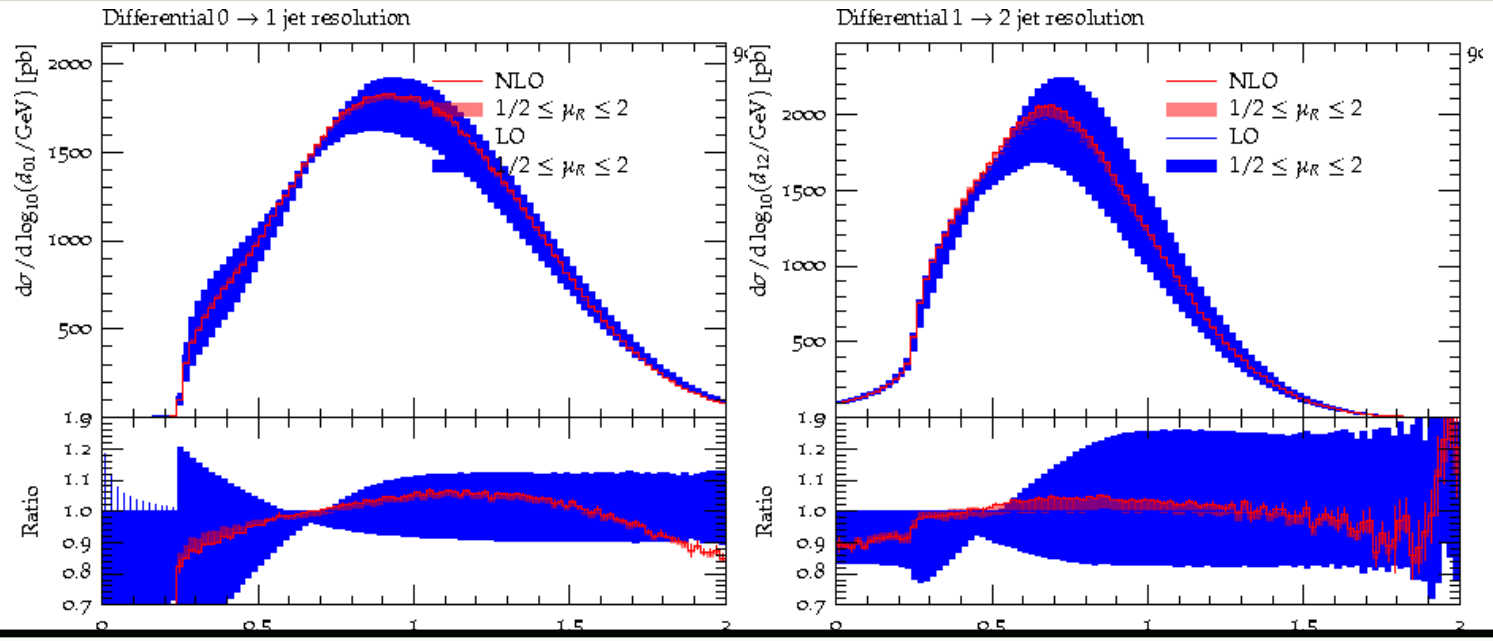
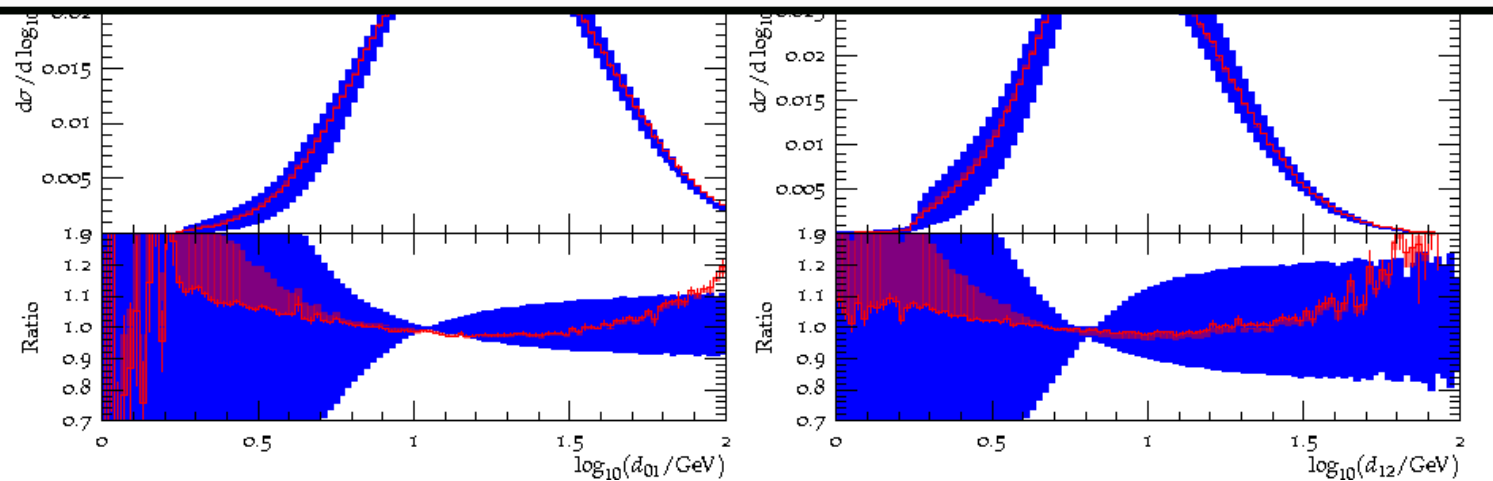


LO bands very large!

Are we too conservative?



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

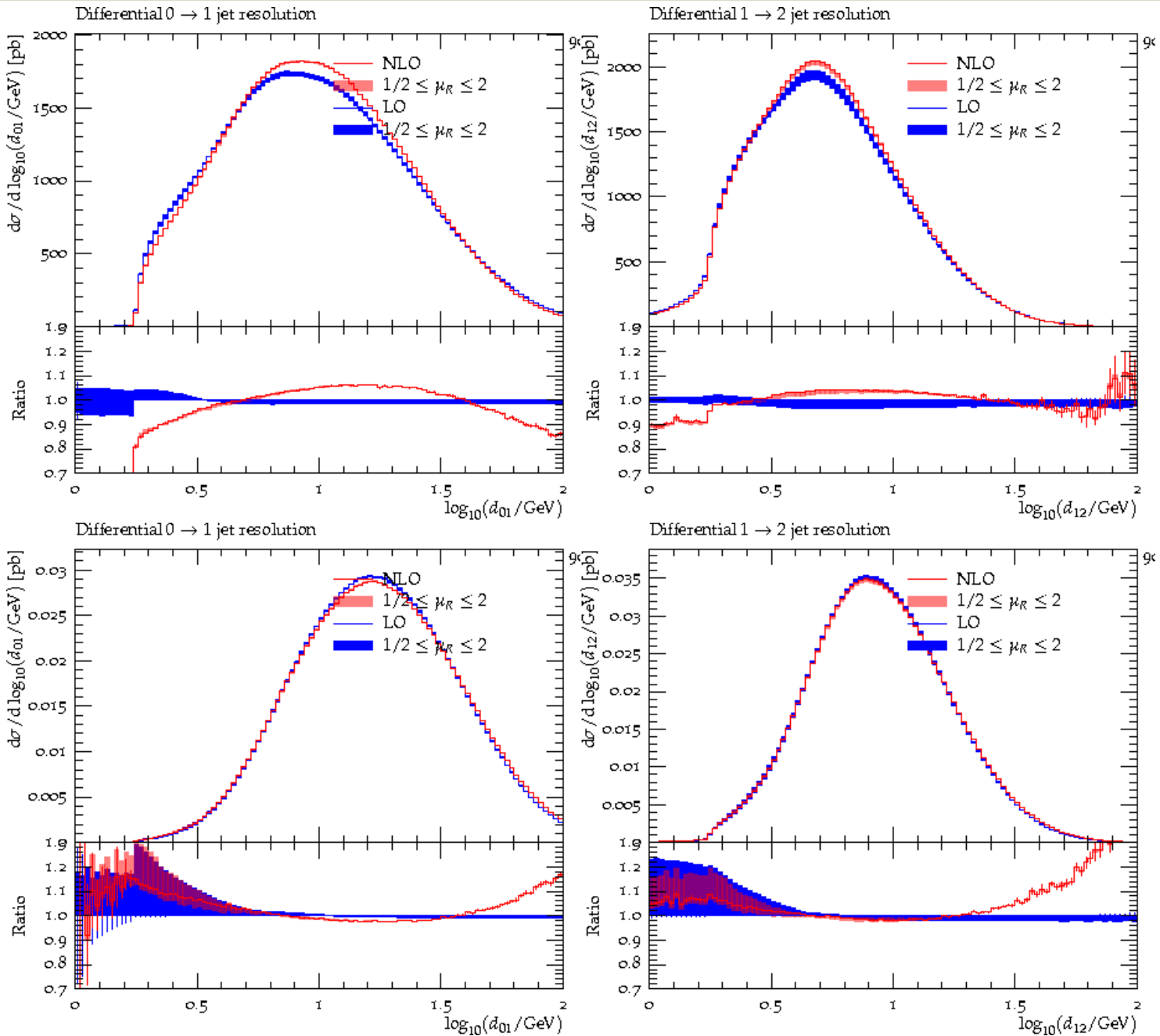
Hope: We capture many sub-leading effects (running α_s, simple higher-order color factors (CMW) in soft limit, E/p-conservation...)
Question: Are our uncertainties too conservative? Can we keep our good higher-order terms fixed when varying scales?

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

$$\alpha_s^{PS}(t) \to \alpha_s^{PS}(k^{\mathrm{CMW}} t)$$

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

Cautionary tale: DIRE LHC predictions, with scale compensation



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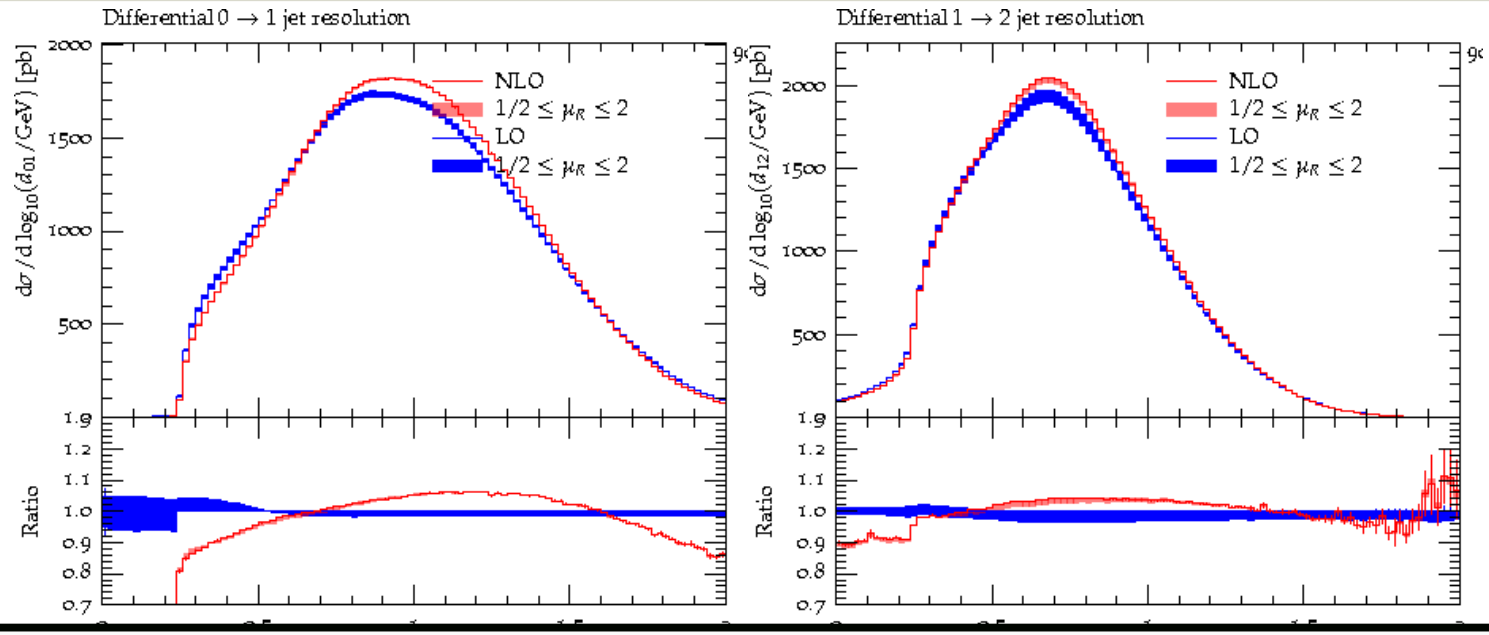
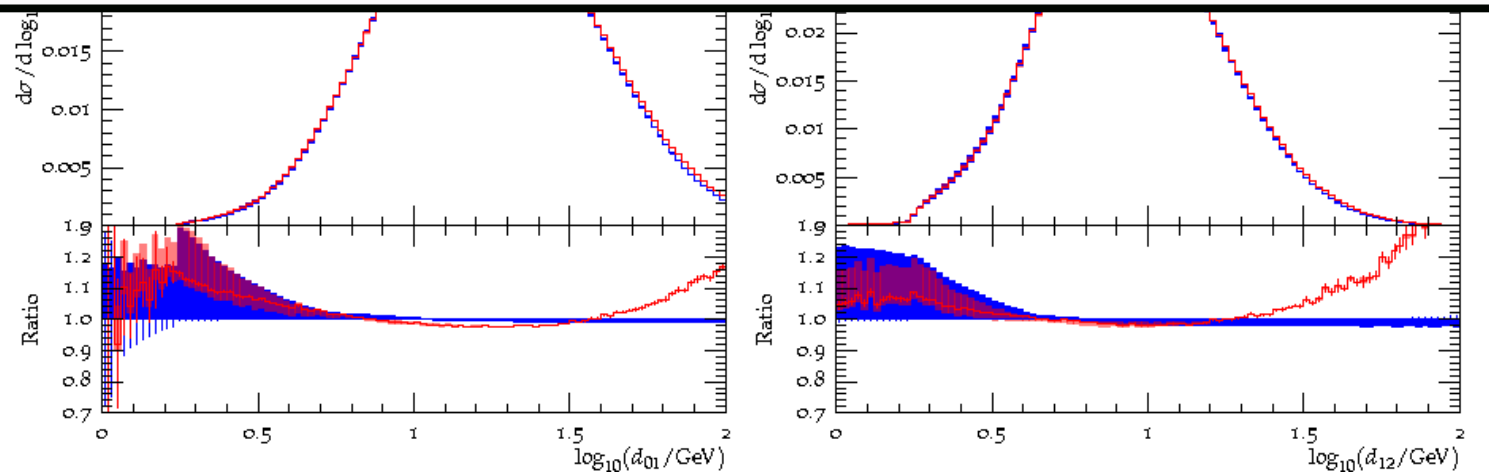
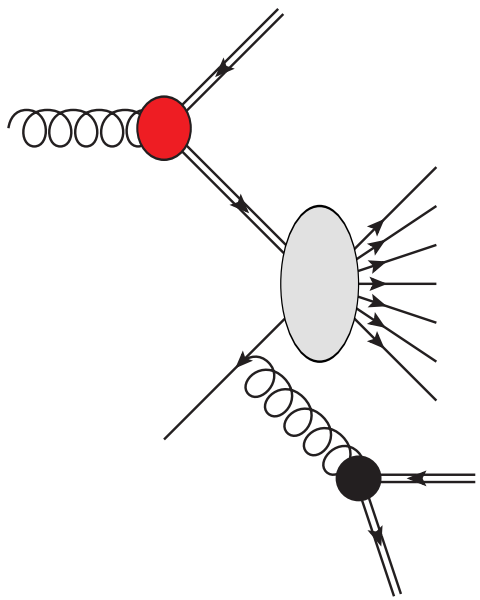


NLO does not overlap with LO!
Naive scale compensation much too aggressive.



Heavy flavour production

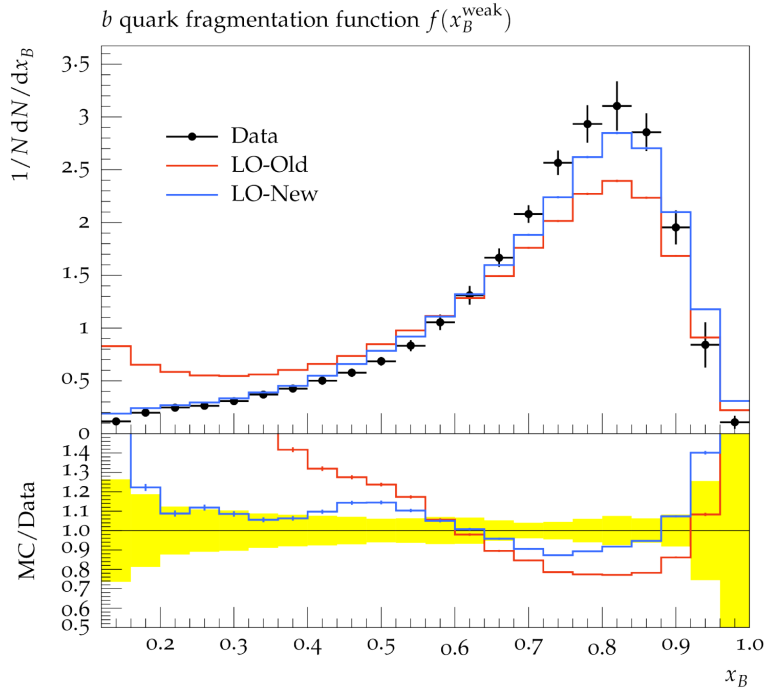


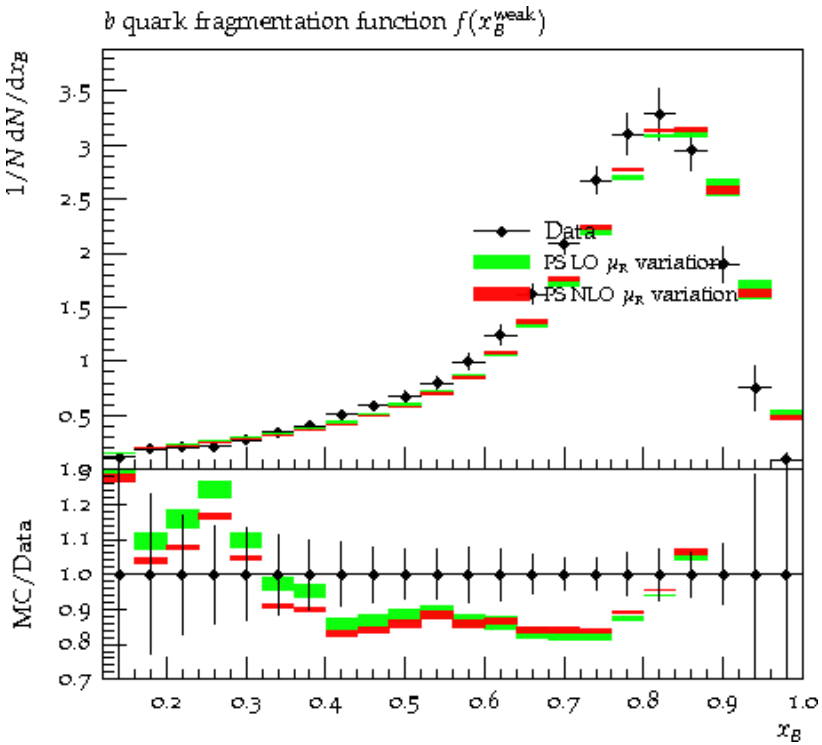
Q: Do we need to worry about the treatment of the $g \to Q\bar{Q}$ in parton showers when interpreting heavy flavor measurements?
Q: Does the parton-shower modeling feed down into commonly used fixed-order+parton shower calculations?

Timelike $g \to Q\bar{Q}$ splittings

Left figure by S. Plätzer, talk @ PSR 2017

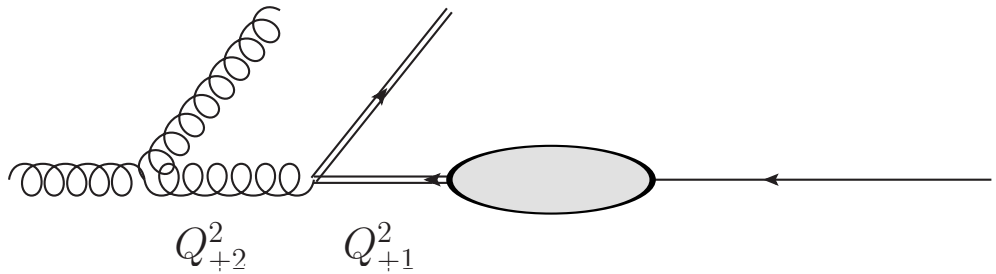
Worry: Problems with describing b-fragmenation at ee colliders could also be present for b-jet modelling at LHC.





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

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



- ◇ Proton probed at scales $\lesssim m_b$ does not contain b-exitations.
- ◇ 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 $g \to Q\bar{Q}$ with $m_b < p_{\perp b} <\lesssim 2m_b$ are e.g. not accompanied by soft gluons!

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

Together with help from jets group!

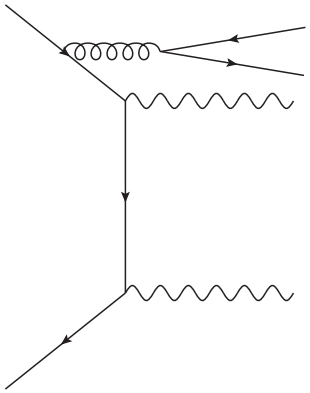
Q: If showers induce large differences in matched/merged calculations, can we devise ways to constrain shower choices?

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

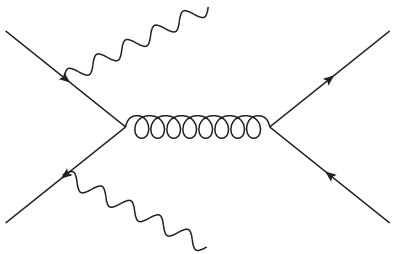
Resonance-aware matching

Q: What are choices & uncertainties of resonance-aware matching?
Q: What is required from parton showers?
Q: Do we need dedicated resonance-aware tunes?

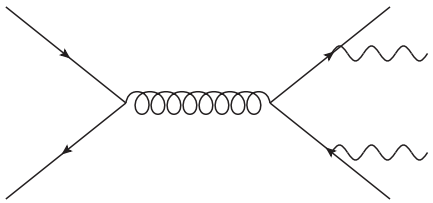
Showers and resonances



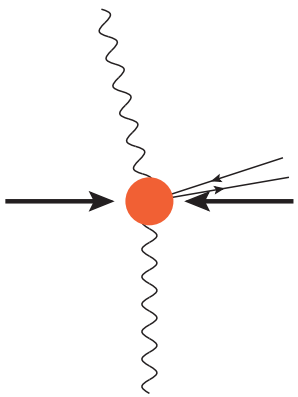
W^+ and W^- $\approx$ back-to-back
Potentially large QCD Sudakov logs

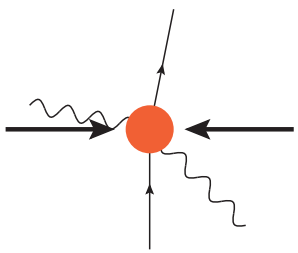


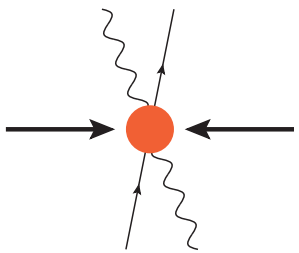
W^+ and b in different hemispheres
Potentially large EW Sudakov logs



W^+ and b in same hemisphere



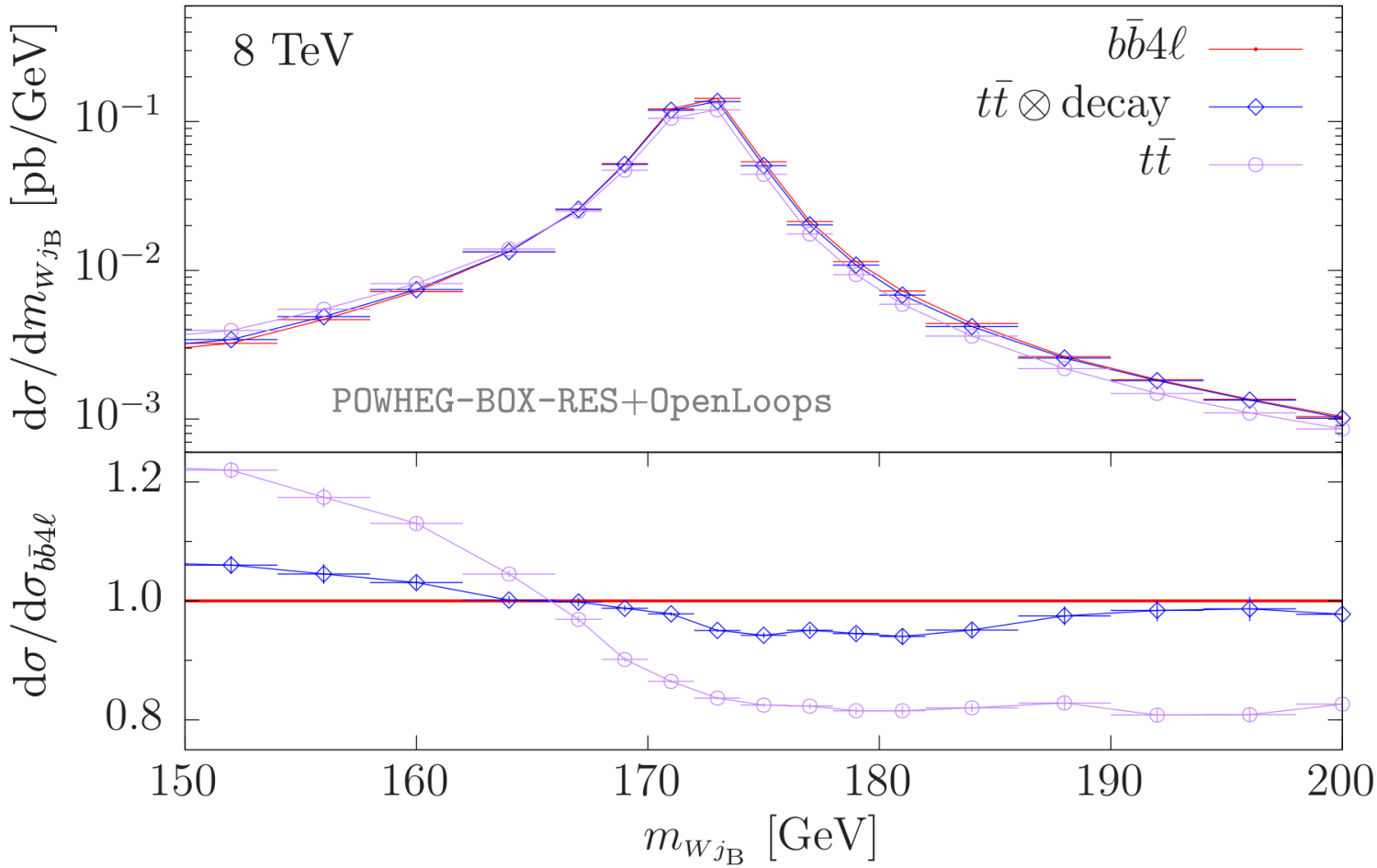




Generator should give good answer for all extremes + in the "transition regions".

Matching $WbWb$ with POWHEG-BOX-RES

arXiv:1607.04538

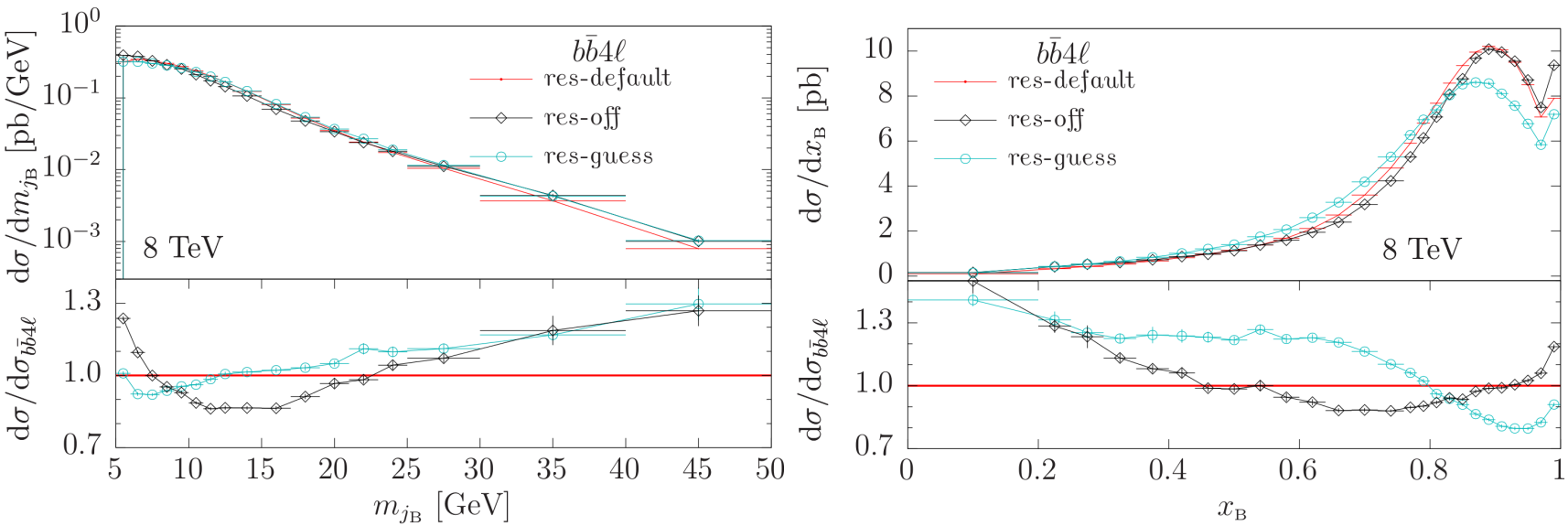


◇ All $\ell\ell\nu\nu b\bar{b}$ processes, with massive b-quarks!

⇒ 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!