WW Production With a Jet Veto Made Simple(r)

In collaboration with: A. Banfi, S. Jaegar & N. Kauer

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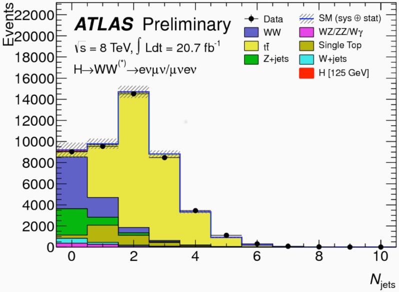

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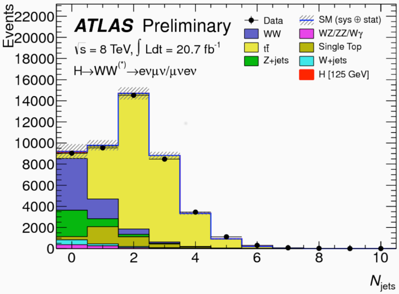

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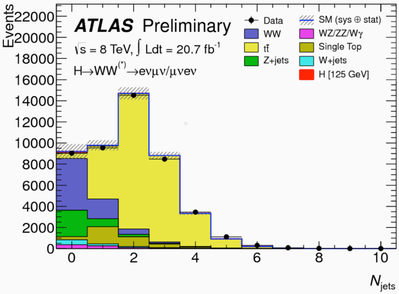

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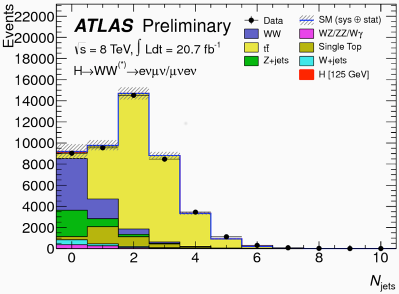

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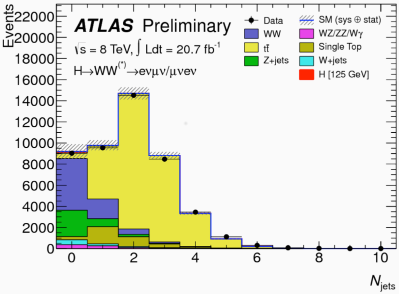

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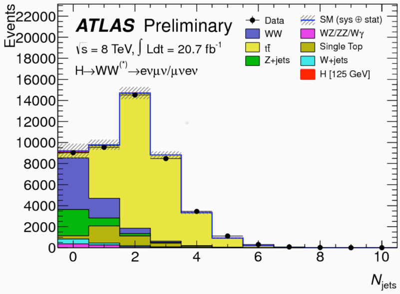

Higgs + 0-jet cross section becomes the quantity of interest

Need to quantify how the jet veto reduces the Higgs cross section and the non $t\bar{t}$ cross section

This Talk

1. Jet veto resummation in a nutshell
2. Automation of jet veto resummation
3. A case study: $pp \to WW$

Jet Veto Resummation in a Nutshell

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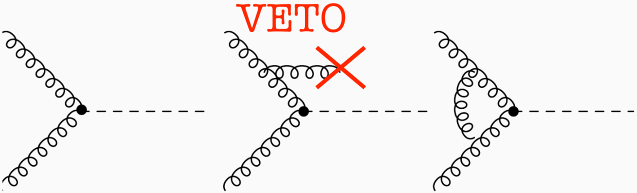

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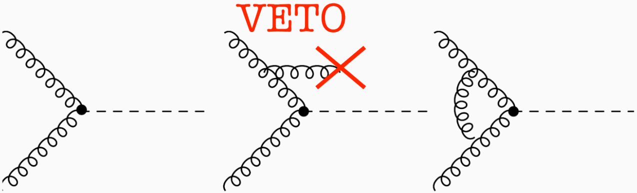
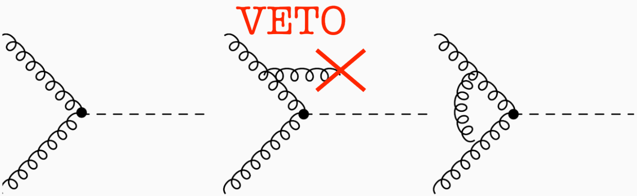
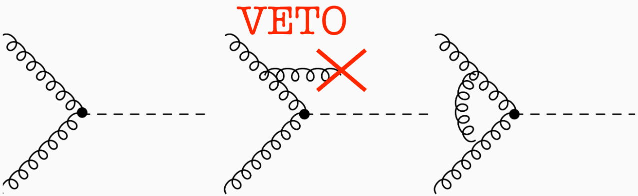




$$\sigma_{0-jet}(p_{t,veto}) \simeq \sigma_0 \left(1 + C\frac{\alpha_s}{\pi}\int \frac{d\omega}{\omega}\frac{d\theta^2}{\theta^2}\left(\Theta(p_{t,veto} - \omega\theta) - 1\right)\right)$$
$$\simeq \sigma_0 \left(1 - 2C\frac{\alpha_s}{\pi}\log^2\frac{M}{p_{t,veto}} + \ldots\right)$$

$C = C_A$ for gluons, $C = C_F$ for quarks



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Remnant logs left after cancellation of the real and virtual

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$$\Sigma^{(J)}(p_{t,veto}) \sim \mathcal{L}(p_{t,veto})\mathcal{M}_B^2 \otimes e^{-R(p_{t,veto})}(1+\delta\mathcal{F}(p_{t,veto}))$$

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- Sudakov form factor
- Non-exponentiating multiple emission function

Implementation of Resummation

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- Lots of resummation codes for many observables
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Can we do better?

Utilise existing Monte Carlo code

Becher, Frederix, Neubert, Rothen (2014)

The Method

A Quick Review of NLO calculations

Dipole Subtraction

Cleverly add zero by introducing a subtraction term $d\sigma^A$:

$$\delta\sigma^{NLO} = \int_m d\sigma^V + \int_{m+1} \left[d\sigma^R - d\sigma^A\right] + \int_{m+1} d\sigma^A$$

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$$\Sigma^{(J)}(p_{t,veto}) = \sum_{i,j} \int dx_1 dx_2\, \mathcal{M}_B^2\, \delta(x_1 x_2 s - M^2)$$
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$$+ \frac{\alpha_s}{2\pi}\frac{1}{1-2\alpha_s\beta_0 L}\sum_k \int_{x_1}^1 \frac{dz}{z}\left(C_{ik}^{(1)}(z)\, f_k\left(\frac{x_1}{z}, e^{-L}\mu_F\right)\right.$$
$$\left.\left.\times f_j\left(\frac{x_1}{z}, e^{-L}\mu_F\right) + \{(x_1, i) \leftrightarrow (x_2, j)\}\right)\right]$$
$$\times\left(1 + \delta\mathcal{F}(p_{t,veto})\right) e^{-R(p_{t,veto})}$$

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$$\int_1 d\sigma^A \cong \delta\mathcal{L}$$

Implementation in MCFM

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MCFM + JetVHeto

- Can resum jet vetoes for any colour singlet to NNLL+LL_R
- Keep everything in MCFM—spin correlations, cuts, exclusivity in the leptons, etc.
- Minimal implementation—dipoles and factorisation scale
- Can be brought to other Monte Carlo integrators—Powheg, aMC@NLO

Completely general!

A case study: $pp \to WW$

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$$\mathcal{L} \supseteq -\kappa_t \frac{m_t}{v} H \left(\bar{t}_R t_L + h.c.\right) + \kappa_g \frac{\alpha_s}{12\pi} \frac{H}{v} G^a_{\mu\nu} G^{\mu\nu,a}$$

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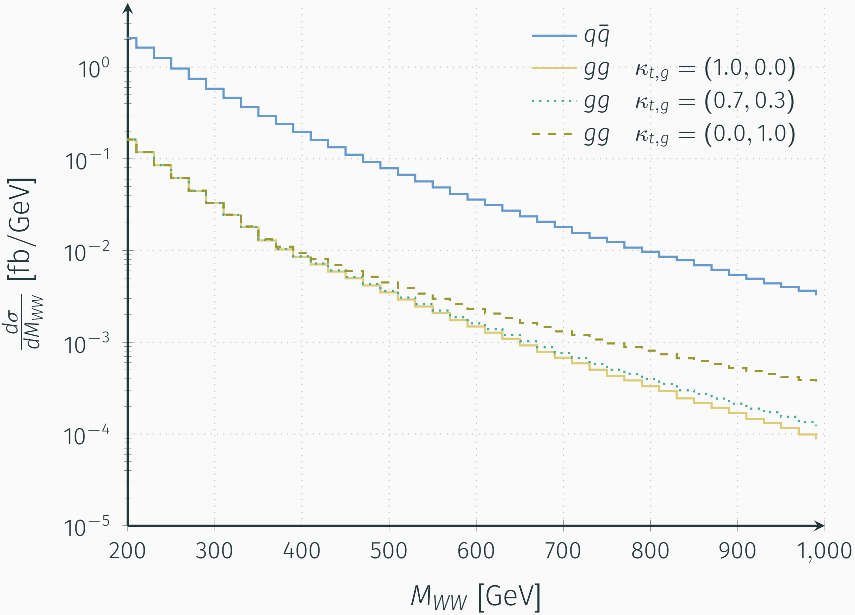
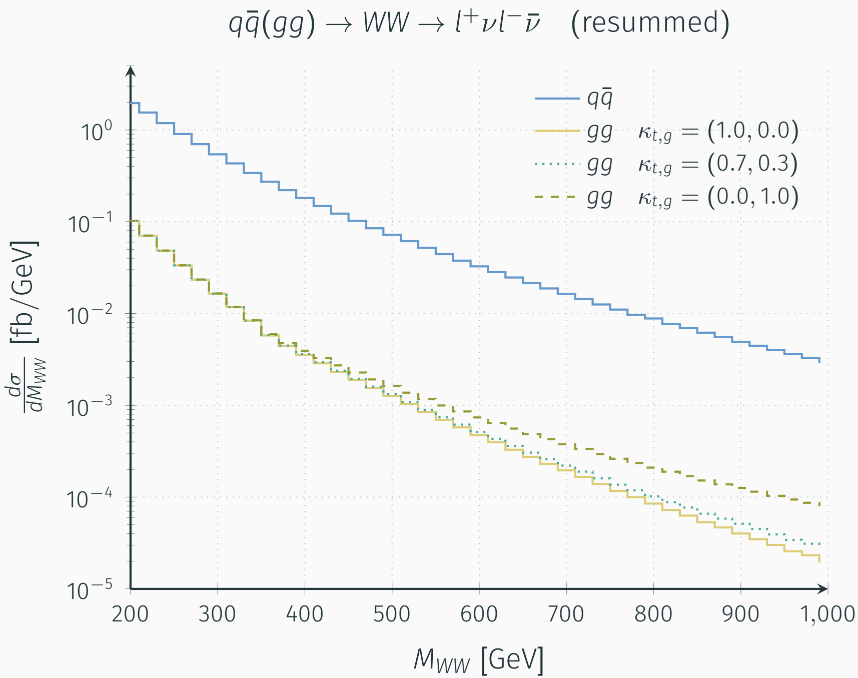
- Vary ggH and $t\bar{t}H$ couplings together
  + fix $\kappa_t + \kappa_g = 1$

$q\bar{q}(gg) \to WW \to l^+\nu l^-\bar{\nu}$ (fixed-order)





$q\bar{q}(gg) \to WW \to l^+\nu l^-\bar{\nu}$ (resummed)
$q\bar{q}$
gg $\kappa_{t,g} = (1.0, 0.0)$
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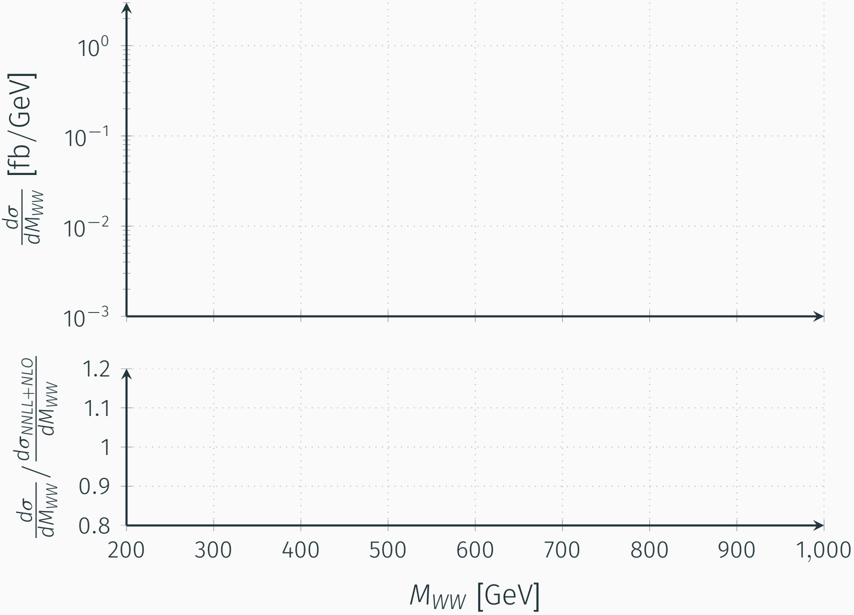
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
$\frac{d\sigma}{dM_{WW}}$ [fb/GeV]
200
300
400
500
600
700
800
900
1,000
M_{WW} [GeV]

$q\bar{q} \to WW \to l^+\nu l^-\bar{\nu}$ (fixed-order vs. resummed)



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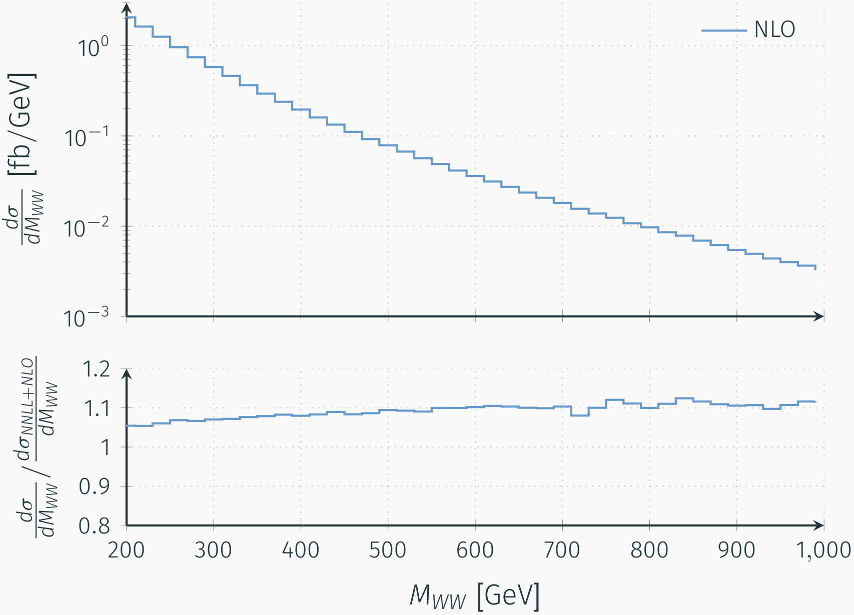

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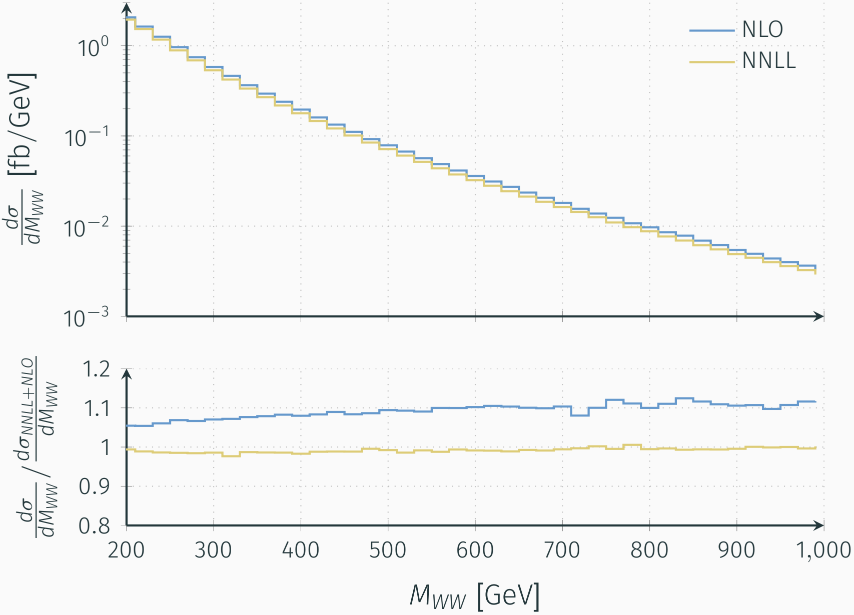

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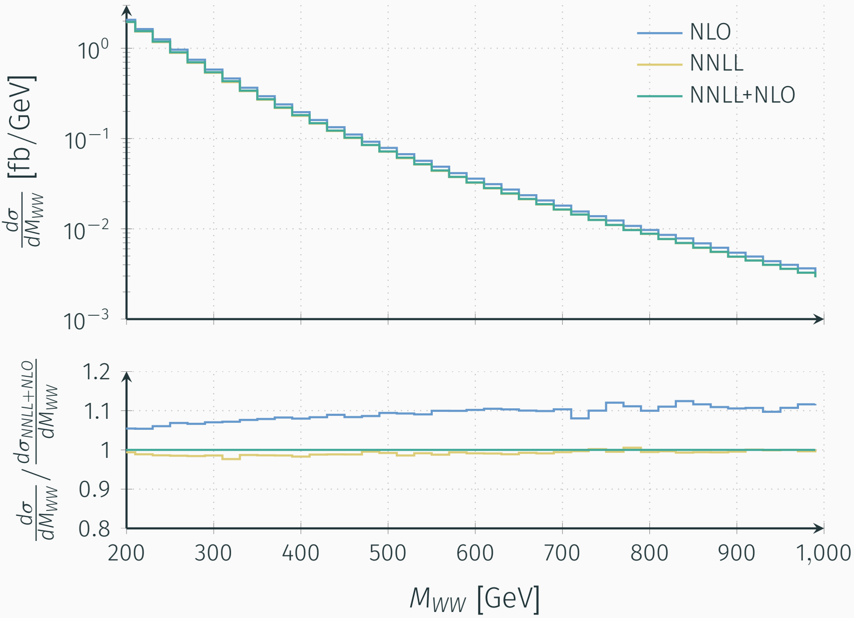

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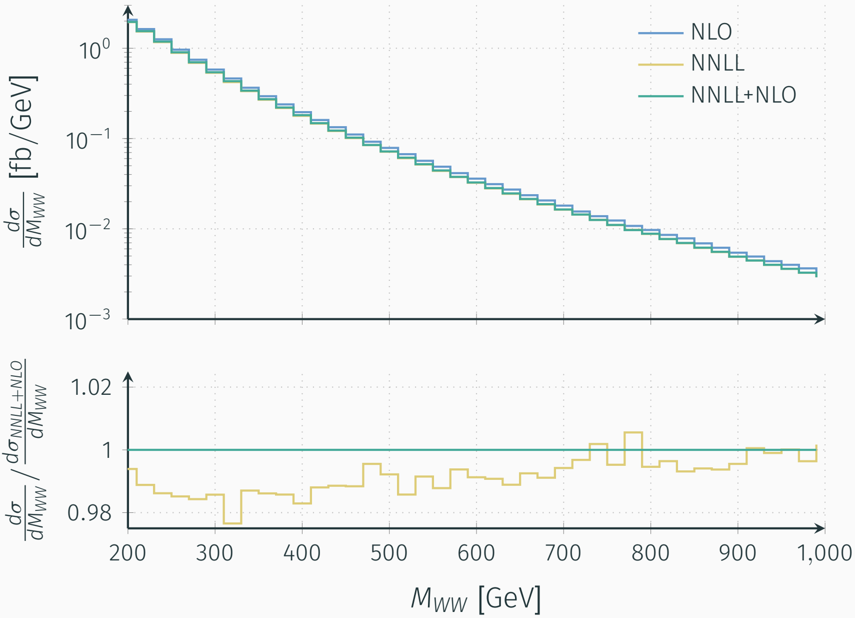

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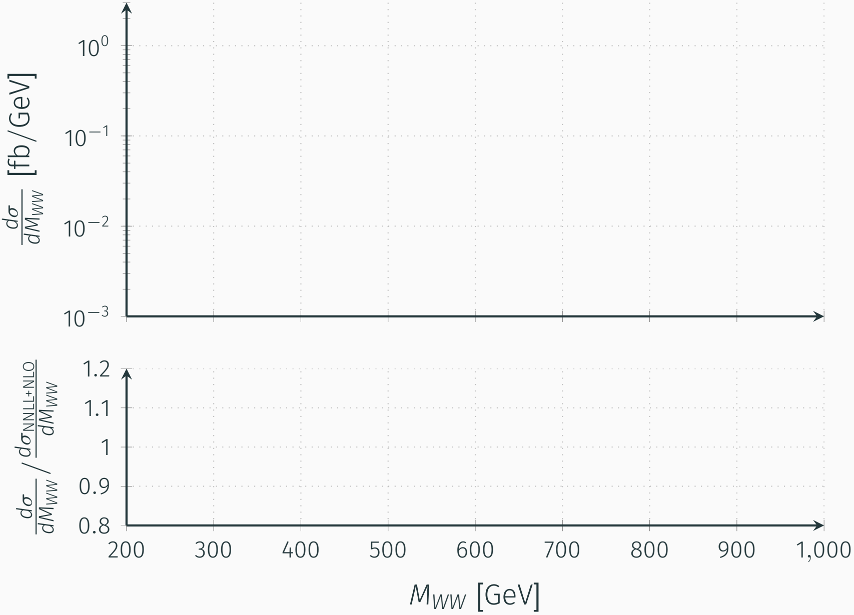

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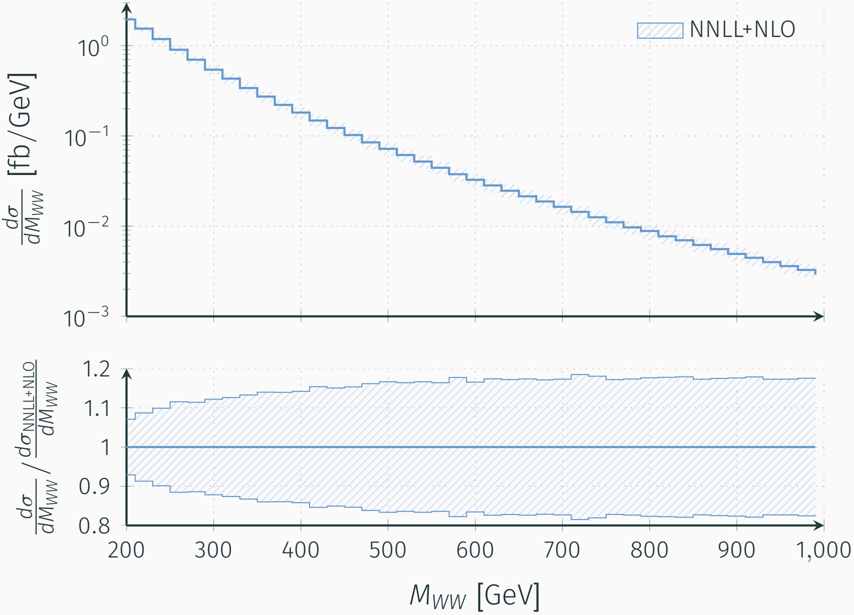

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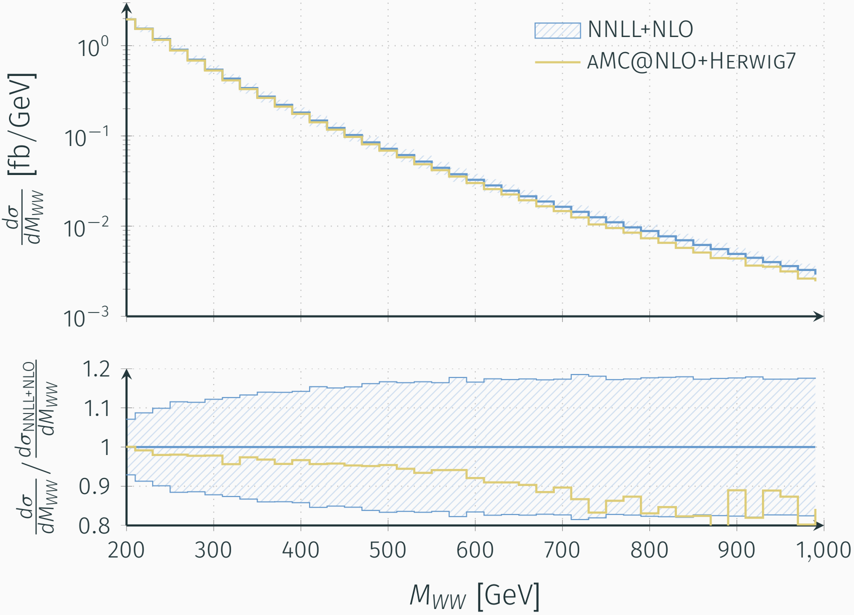
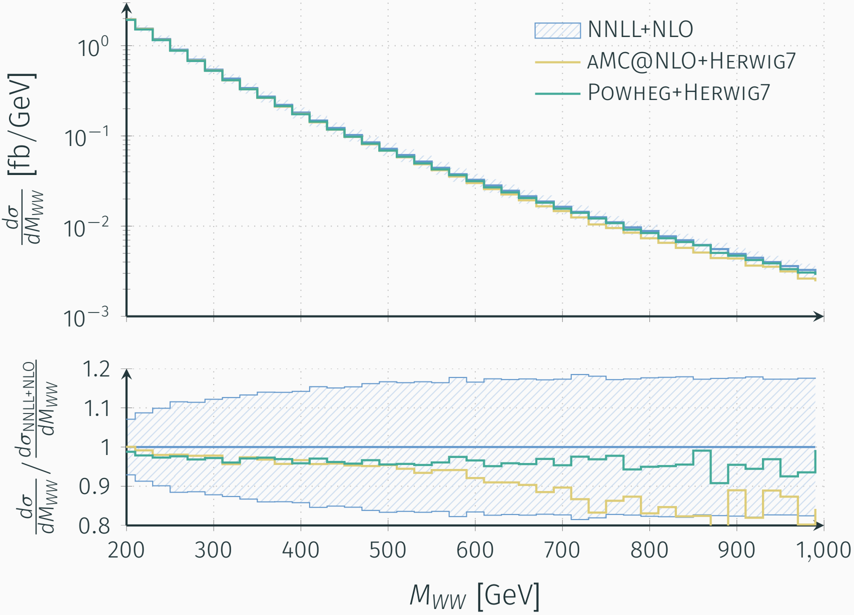
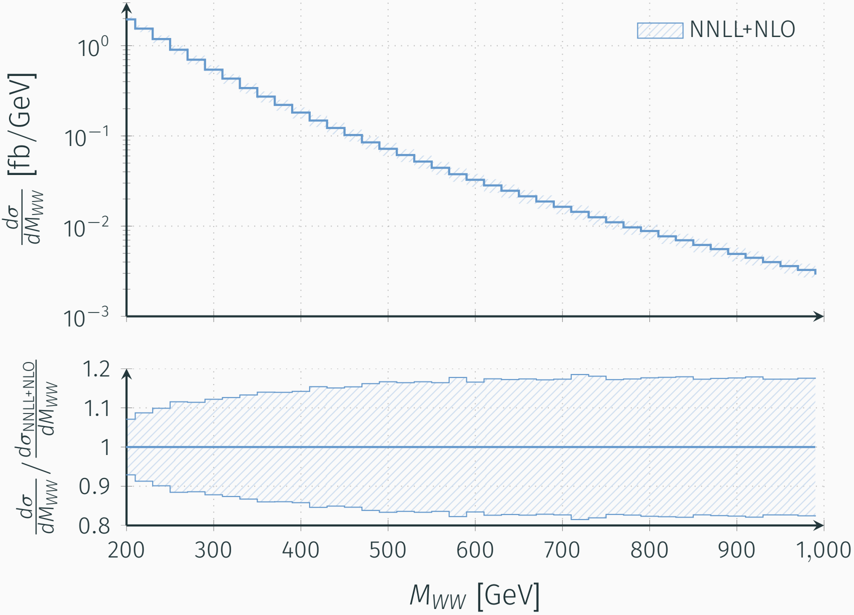


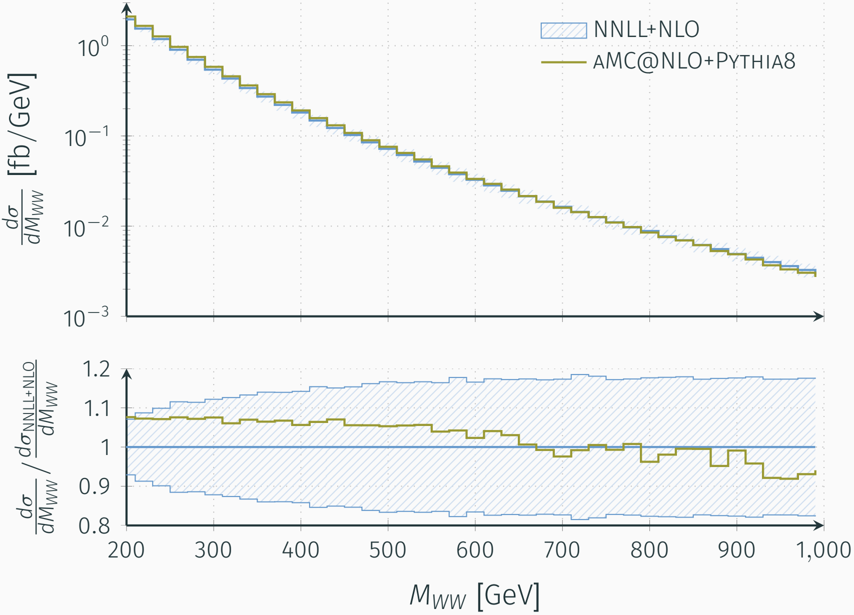
$q\bar{q} \to WW \to l^+\nu l^-\bar{\nu}$ (resummed vs. parton shower)



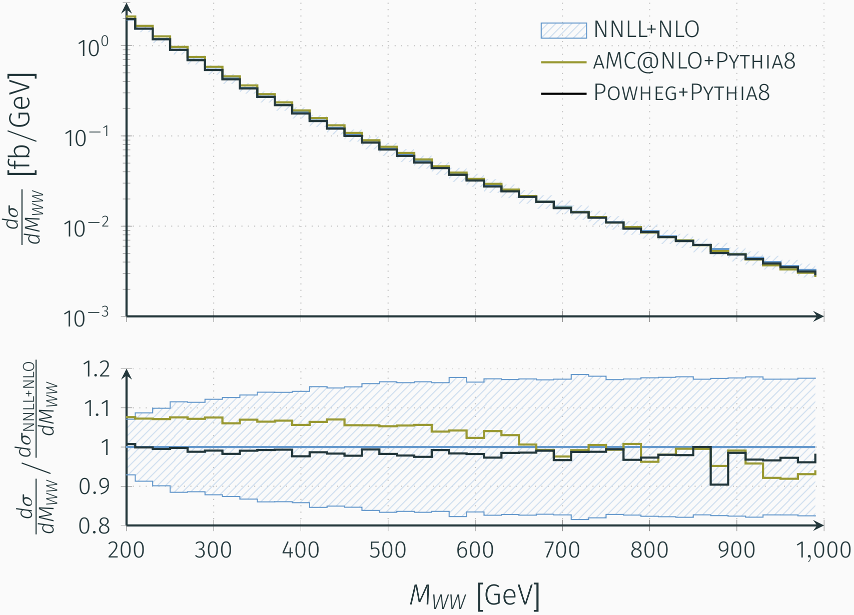
$q\bar{q} \to WW \to l^+\nu l^-\bar{\nu}$ (resummed vs. parton shower)



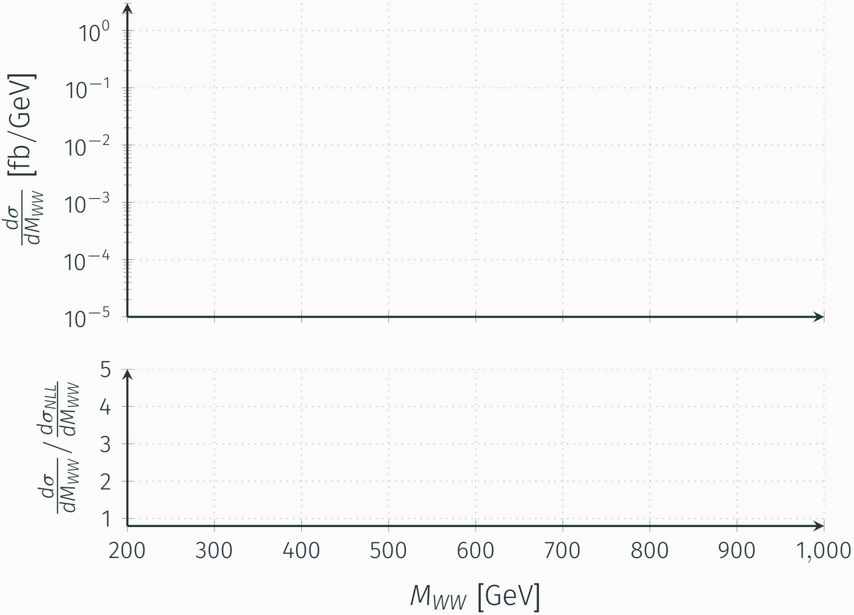
$q\bar{q} \to WW \to l^+\nu l^-\bar{\nu}$ (resummed vs. parton shower)



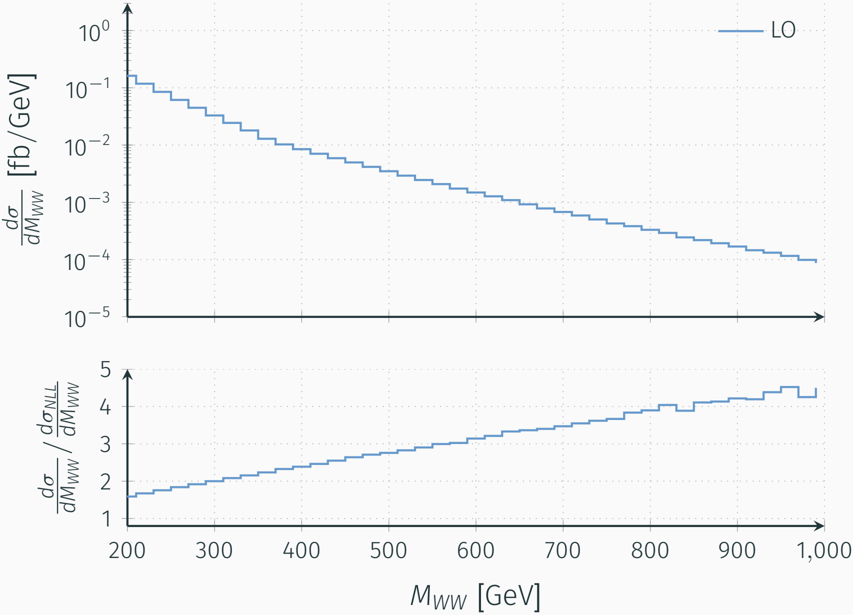
$q\bar{q} \to WW \to l^+\nu l^-\bar{\nu}$ (resummed vs. parton shower)



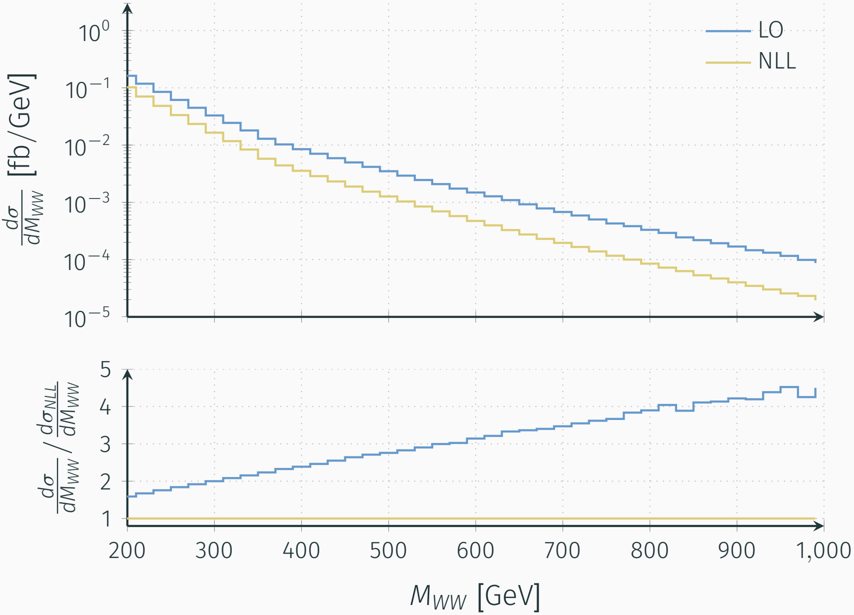
$gg \to WW \to l^+\nu l^-\bar{\nu}$ (fixed-order vs. resummed)



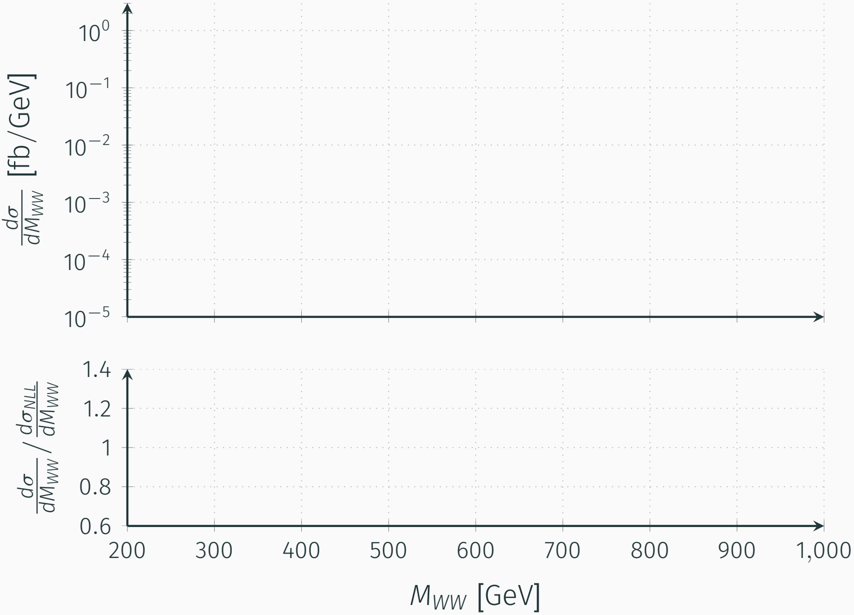
$gg \to WW \to l^+ \nu l^- \bar{\nu}$ (fixed-order vs. resummed)



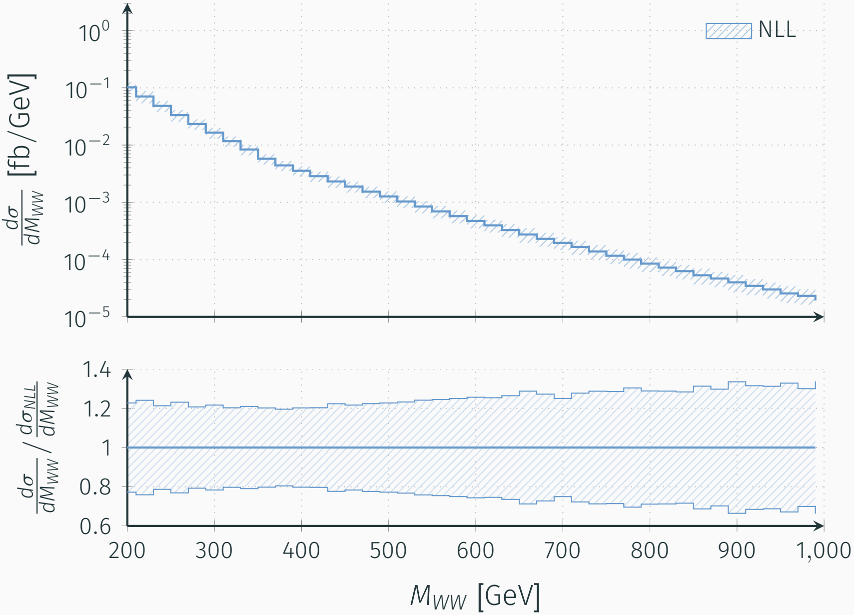
$gg \to WW \to l^+ \nu l^- \bar{\nu}$ (fixed-order vs. resummed)



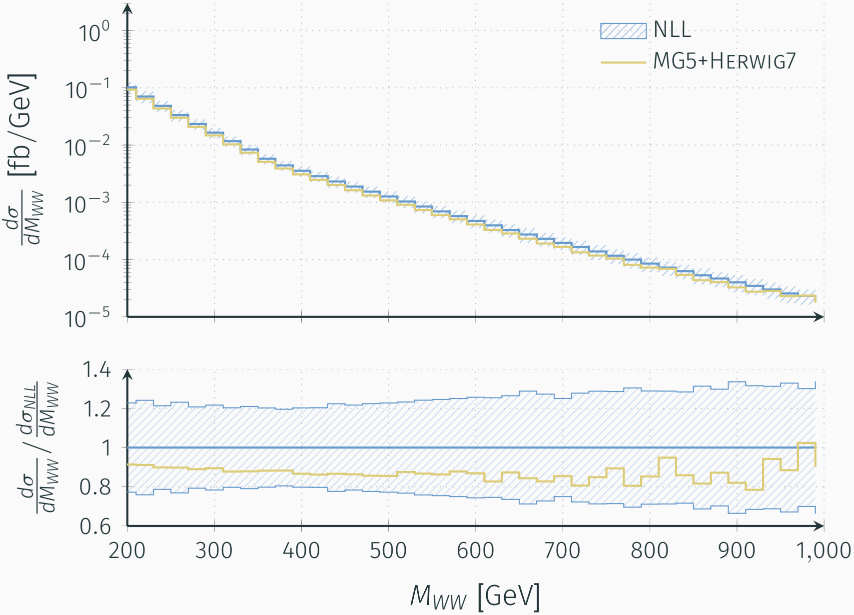
$gg \to WW \to l^+ \nu l^- \bar{\nu}$ (resummed vs. parton shower)



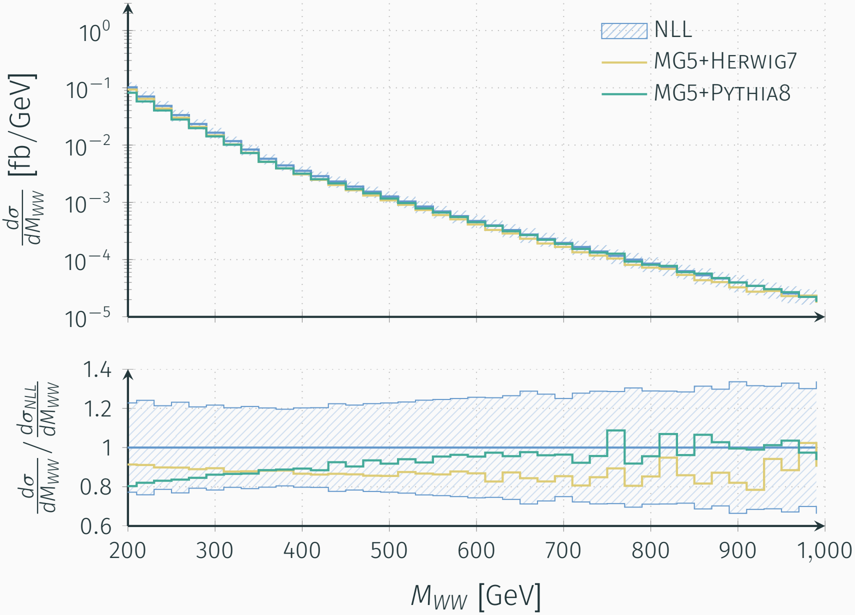
$gg \to WW \to l^+\nu l^-\bar{\nu}$ (resummed vs. parton shower)



$gg \to WW \to l^+\nu l^-\bar{\nu}$ (resummed vs. parton shower)



$gg \to WW \to l^+\nu l^-\bar{\nu}$ (resummed vs. parton shower)

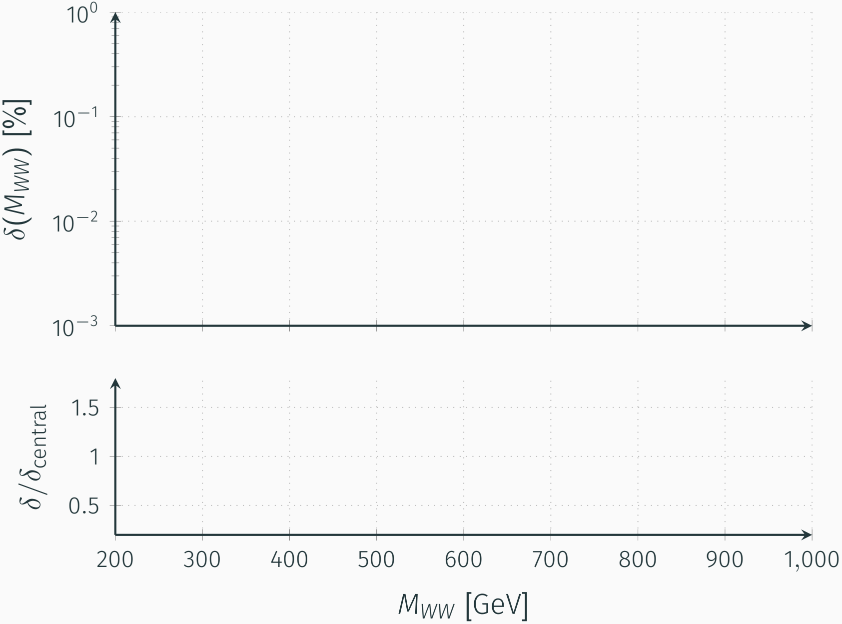


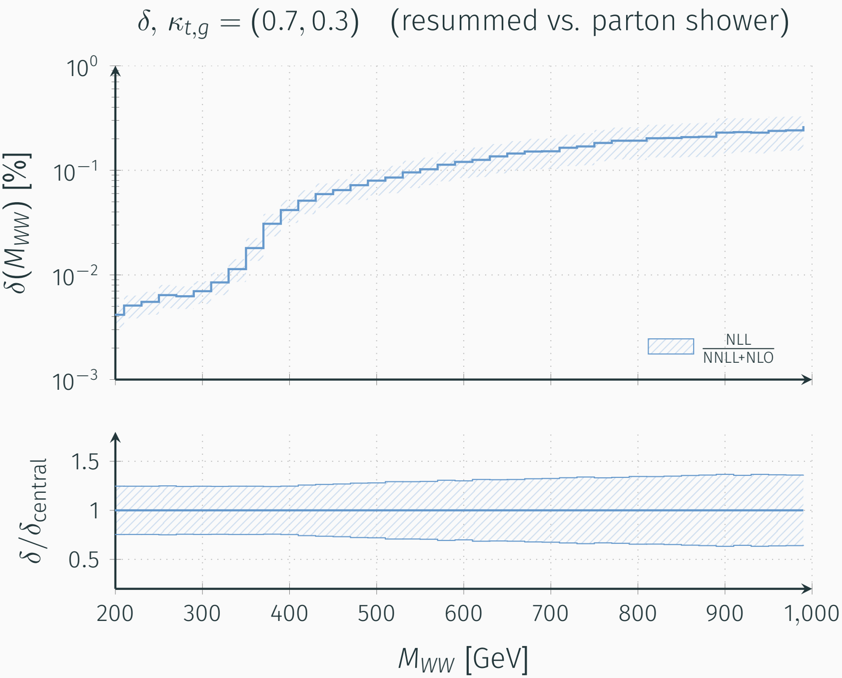
Quantifying these Results

Parameterise discrepancy with respect to the standard model:

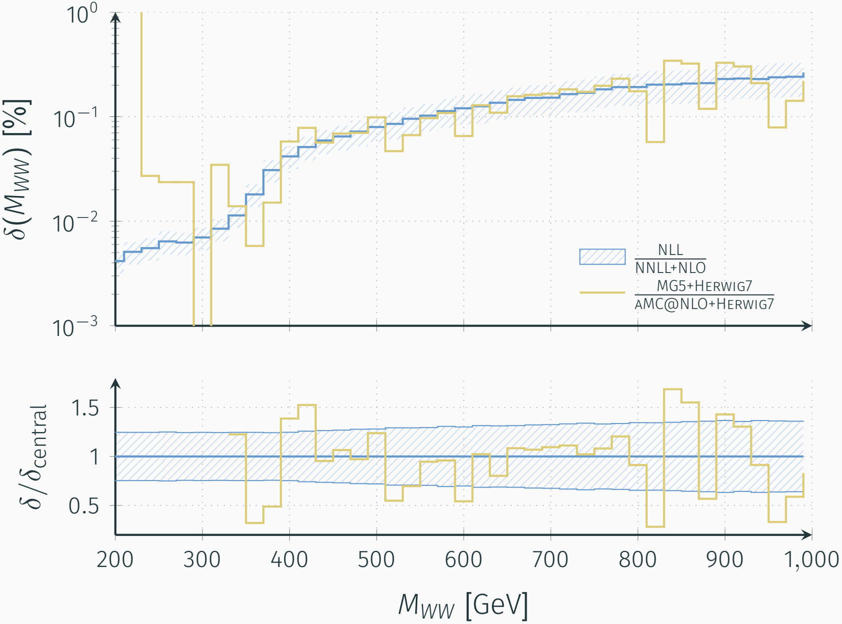
$$\delta = \frac{\sigma^{BSM} - \sigma^{SM}}{\sigma^{SM}}$$

$\delta,\ \kappa_{t,g} = (0.7, 0.3)$ (resummed vs. parton shower)

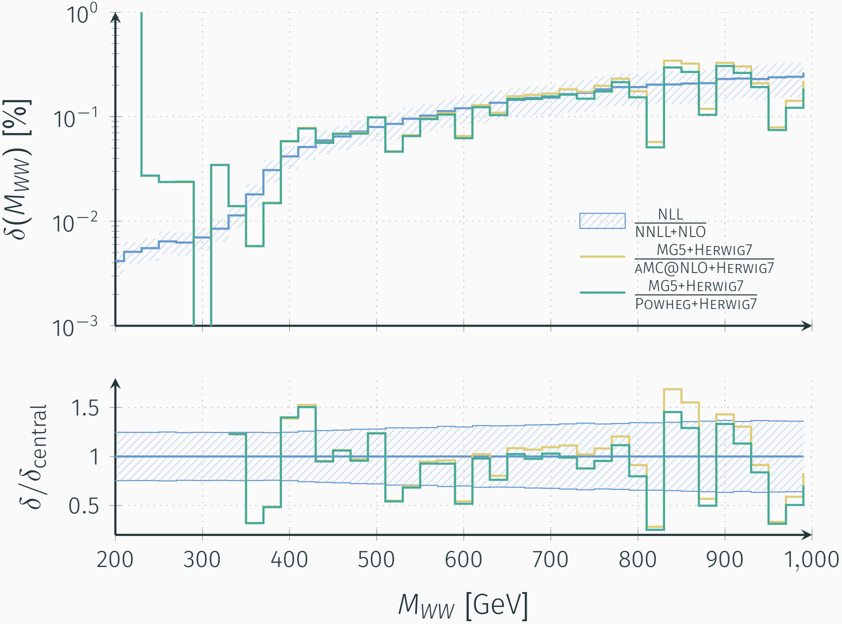



δ, $\kappa_{t,g} = (0.7, 0.3)$ (resummed vs. parton shower)
$\delta(M_{WW})$ [%]
10^0
10^{-1}
10^{-2}
10^{-3}
NLL / NNLL+NLO
$\delta/\delta_{\text{central}}$
1.5
1
0.5
200
300
400
500
600
700
800
900
1,000
M_{WW} [GeV]

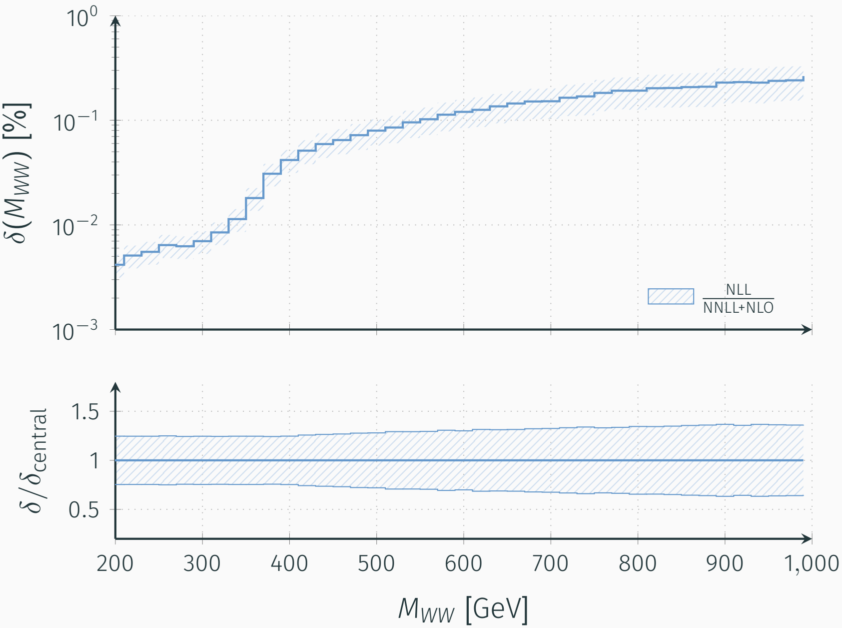
$\delta,\ \kappa_{t,g} = (0.7, 0.3)$ (resummed vs. parton shower)

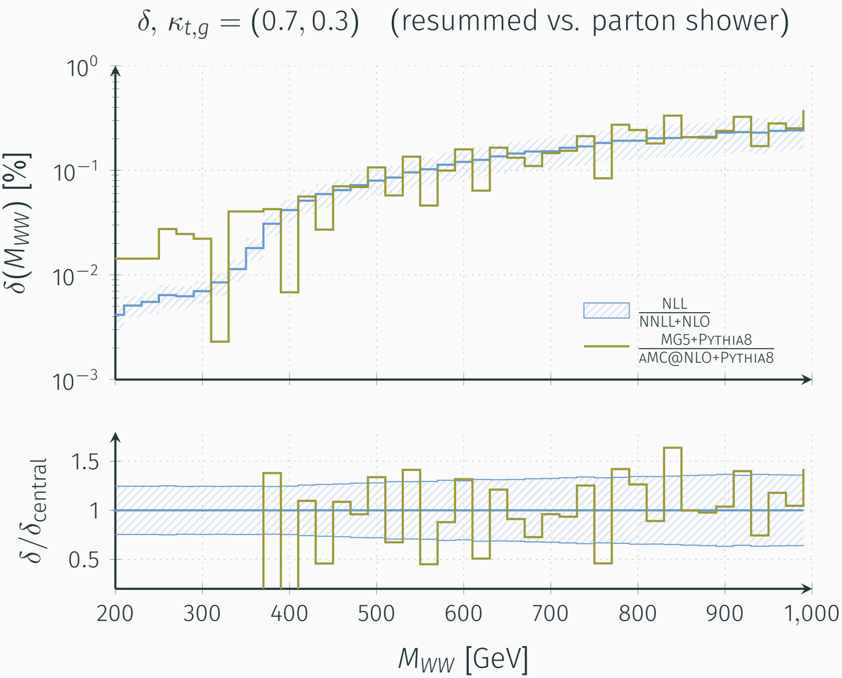


$\delta,\ \kappa_{t,g} = (0.7, 0.3)$ (resummed vs. parton shower)



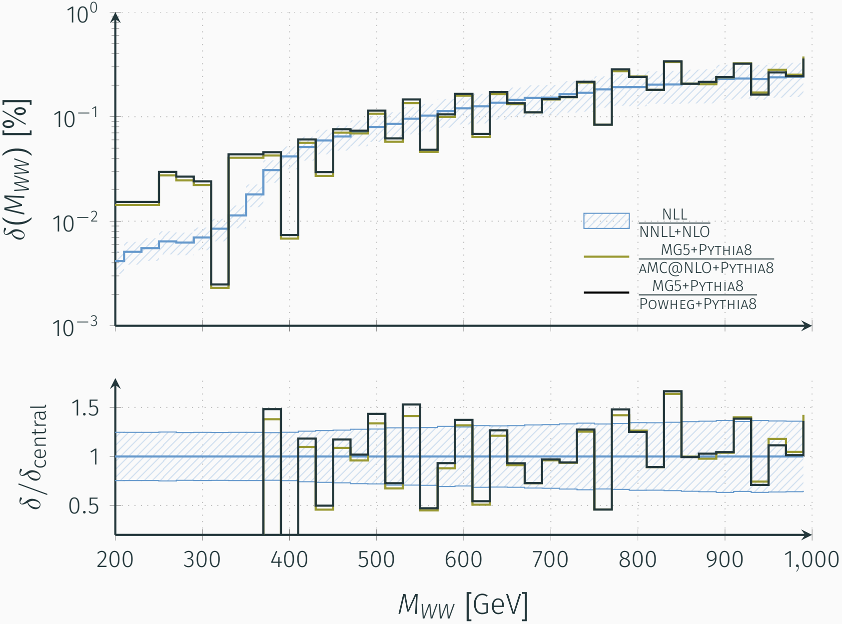
$\delta,\ \kappa_{t,g} = (0.7, 0.3)$ (resummed vs. parton shower)





δ, κ_{t,g} = (0.7, 0.3) (resummed vs. parton shower)
δ(M_{WW}) [%]
10^0
10^{−1}
10^{−2}
10^{−3}
NLL / NNLL+NLO
MG5+PYTHIA8 / aMC@NLO+PYTHIA8
δ/δ_{central}
1.5
1
0.5
200
300
400
500
600
700
800
900
1,000
M_{WW} [GeV]

δ, $\kappa_{t,g} = (0.7, 0.3)$ (resummed vs. parton shower)



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- Extended JetVHeto to be fully differential in non-QCD observables
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Repurposing Monte Carlo integrators is the way to go for implementing new resummation codes

Any questions?