Matrix-Element Corrections in Herwig++ using Matchbox and MadGraph 5

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MCNet Meeting

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2. ME Corrections using MATCHBOX and MADGRAPH
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4. $pp \to \tilde{t}_1 \tilde{t}_1^*$
5. Summary

Parton showers resum leading logarithms

- Good approximation in soft/collinear limit
- Doesn't describe hard emissions well
- Hard emissions important when studying e.g. compressed spectra SUSY

Improve simulation of hard radiation in the shower using **NLO matrix-element matching**

- Combines exact NLO matrix elements with the parton shower
- Avoids double counting
- We use the POsitive Weight Hardest Emission Generator (POWHEG) formalism [P. Nason, JHEP 0411:040,2004]

For a p_T ordered parton shower, inclusive cross section for the first emission is:

$$\mathrm{d}\sigma = N(\Phi_B)\mathrm{d}\Phi_B \left[\Delta(p_{T\mathrm{min}}) + \Delta(p_T)\mathcal{K}\,\mathrm{d}\Phi_1\right]$$

$$\Delta(p_T) = \exp\left(-\int \mathcal{K}\,\Theta\left(p_T\left(\Phi_1\right) - p_T\right)\mathrm{d}\Phi_1\right)$$

- Φ_B, Φ_1 - phase space variables of the LO process and additional emission
- p_T - transverse momentum of additional emission
- $p_{T\mathrm{min}}$ - cut-off introduced to regularize kernel
- $N(\Phi_B)$ - local normalisation factor
- $\mathcal{K}$ - splitting kernel

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	$N\left(\Phi_B\right)$	$\mathcal{K}$
Parton Shower	B	$\mathcal{P}(z)$
POWHEG Formalism	$\bar{B}$	$\frac{R}{B}$

- B - leading order matrix elements squared
- $\mathcal{P}(z)$ - Altarelli-Parisi splitting function

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	$N\left(\Phi_B\right)$	$\mathcal{K}$
Parton Shower	B	$\mathcal{P}(z)$
POWHEG Formalism	$\bar{B}$	$\frac{R}{B}$

- $\bar{B}(\Phi_B) = B(\Phi_B) + V(\Phi_B) + \int R(\Phi_B, \Phi_1)d\Phi_1$
- R, V - real and virtual contributions to NLO cross section

Further emissions generated using the normal parton shower splitting kernel.

- Split real-emission matrix element: $R = R_S + R_H$

$$\mathrm{d}\sigma = \bar{B}(\Phi_B)\mathrm{d}\Phi_B \left[\Delta(p_{T\min}) + \Delta(p_T)\frac{R_S}{B}\,\mathrm{d}\Phi_1\right] + R_H \mathrm{d}\Phi_R$$

$$\Delta(p_T) = \exp\left(-\int \frac{R_S}{B}\,\Theta\left(p_T\left(\Phi_1\right) - p_T\right)\mathrm{d}\Phi_1\right)$$

  Recover MC@NLO approach when R_S = parton shower kernel

- Herwig++ uses an angularly ordered shower $\Longrightarrow$ hardest emission is not generated first.
  Introduce a *truncated parton shower* to simulate soft, wide-angle radiation before the hardest emission.

ME Corrections using MATCHBOX

Not implementing complete POWHEG correction

- Generate hardest emission using real-emission matrix element
- But local normalisation given by $B(\Phi_B)$ NOT $\bar{B}(\Phi_B)$

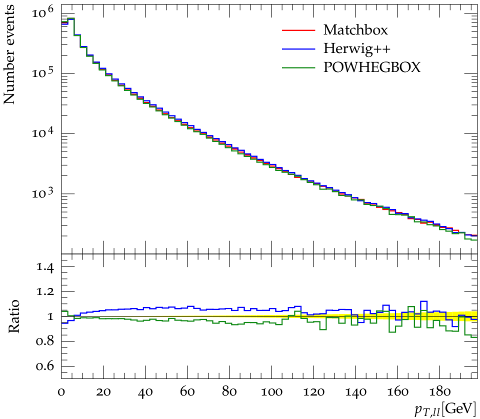
$\Longrightarrow$ **matrix-element correction**

Implement ME correction using MATCHBOX and MADGRAPH

- MADGRAPH 5 - generate B and R in standalone C++ format
  [J. Alwall, M. Herquet, F. Maltoni, O. Mattelaer, T. Stelzer, 1106.0522]
- MATCHBOX - framework for NLO calculations, MC@NLO and POWHEG matching to the angular ordered and dipole showers
  [S. Plätzer, S. Gieseke, Eur.Phys.J. C72 (2012)]
  - Use to do POWHEG matching of R to the parton shower

Compare results generated using built-in Herwig++ correction, Matchbox+MadGraph and POWHEGBOX.

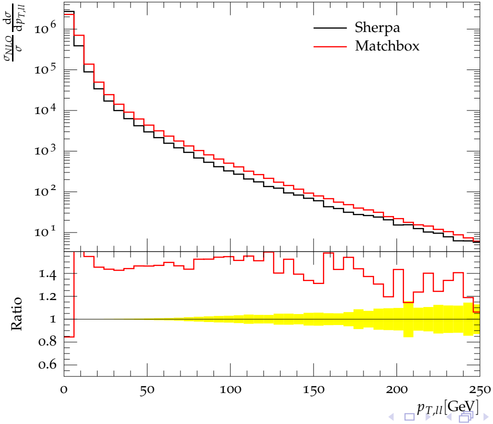
- Limit parton shower to one emission



Validation: $pp \to e^+e^-$

Compare results generated using MATCHBOX+MADGRAPH and SHERPA.

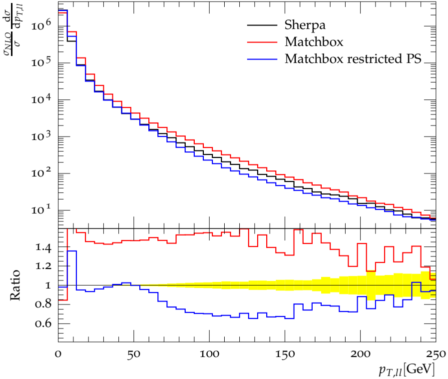
- Full parton shower
- No QED shower, hadronization or UE



Compare results generated using MATCHBOX+MADGRAPH and SHERPA.

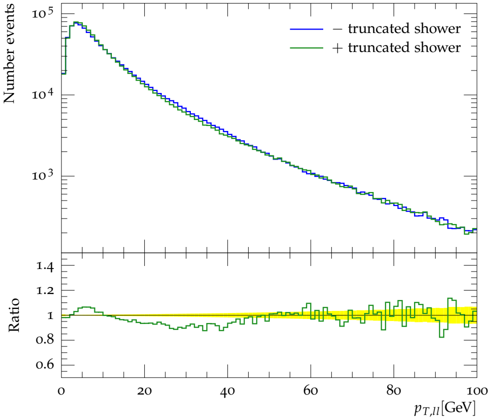
- Full parton shower
- No QED shower, hadronization or UE
- Restrict emission phase space to $p_T < m_{ll}$ in R_S

$\Longrightarrow$ MC@NLO ME correction



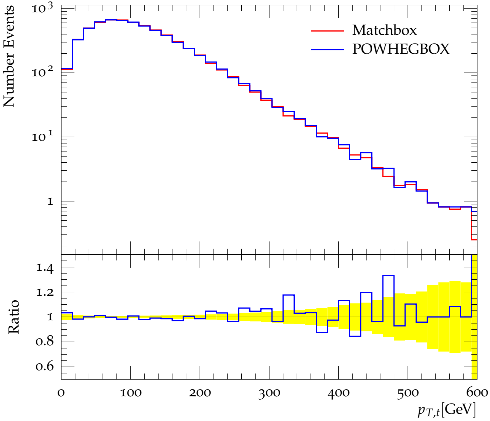
Effect of including the truncated parton shower

- $\pm$ truncated parton shower
- No hadronization or UE



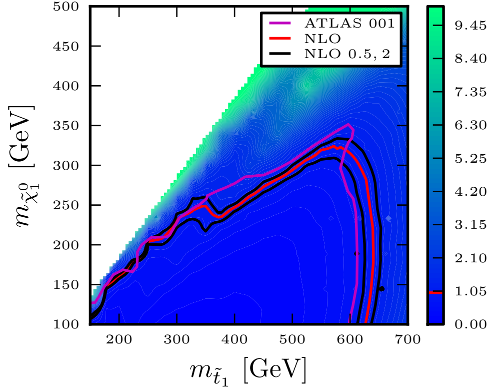
Compare results generated using MATCHBOX+MADGRAPH and POWHEGBOX.

- Limit parton shower to one emission
- Work in progress



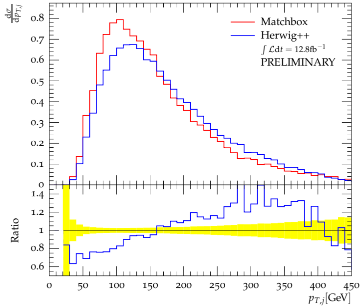
Next step - study impact of the correction on exclusion bounds

- Search for direct production of the top squark in events with missing E_T and two b-jets [ATLAS-CONF-2013-001]
- $\tilde{t}_1 \to b\tilde{\chi}_1^+ \to bf\bar{f}'\tilde{\chi}_1^0$ with $m_{\tilde{\chi}_1^+} - m_{\tilde{\chi}_1^0} = 5\,\mathrm{GeV}$
- Original signal simulated with MadGraph + PYTHIA 6



At first glance -

- $(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) = (400, 250)\,\mathrm{GeV}$, $\Delta m = 5\,\mathrm{GeV}$ not excluded by Herwig++
- Hope ME correction increases $p_{T,j}$ to improve agreement with ATLAS result
- Comparing Herwig++ and MATCHBOX for p_T of the hardest, non b-tagged jet - doesn't look like this will be the case



Summary and Outlook

Summary

- Currently adding ME correction to stop pair production using MATCHBOX and MADGRAPH

Outlook

- Finish $t\bar{t}$ validation
- Study impact of $pp \rightarrow \tilde{t}_1 \tilde{t}_1^*$ correction on exclusion bounds
- Use this method for other production processes - problem comes when we get resonant diagrams