

Herwig++ @ NLO

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DESY Theory Group



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- 1) **Handmade** L. D'Errico, K. Hamilton, P. Richardson \rightarrow γ 's see Peter's talk
- 2) **Automated** SP & S. Gieseke + K. Arnold, J. Kotanski, M. Stoll

Handmade.

Handmade.

POWHEG implementations so far:

- Fully contained in Herwig++ distribution, no external code
- Extensively validated
- Full truncated showering

Handmade POWHEGs.

A bunch of processes available in 2.5:

- $pp \rightarrow Z, W$
- $pp \rightarrow WW, WZ, ZZ$
- $pp \rightarrow (gg, b\bar{b}) \rightarrow H$
- $pp \rightarrow HZ, HW$
- $e^+e^- \rightarrow jets, e^+e^- \rightarrow t\bar{t}$
- Higgs decays $H \rightarrow b\bar{b}, t\bar{t}$

Handmade POWHEGs.

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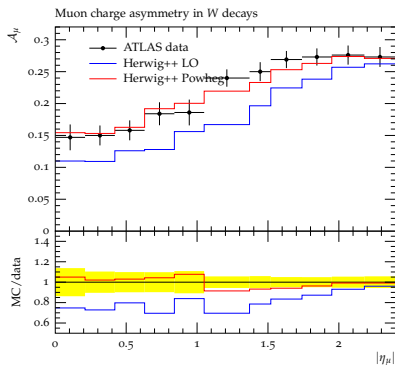
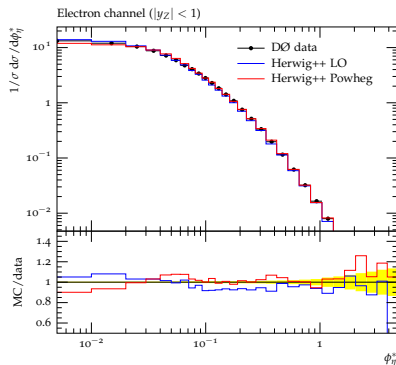
Upcoming in 2.6:

- DIS
- $pp \rightarrow H$ VBF
- $pp \rightarrow \gamma\gamma$
- $pp \rightarrow \gamma jet$

Handmade POWHEGs.

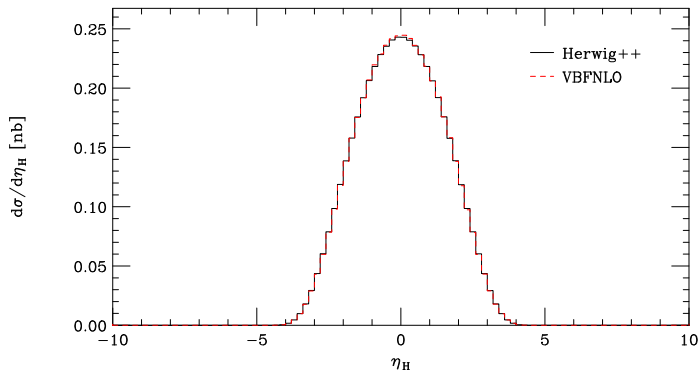
[K. Hamilton, J. Tully, P. Richardson – arXiv:0806.0290]

Drell-Yan $pp \rightarrow Z \rightarrow l^+l^-$, $pp \rightarrow W \rightarrow l\bar{\nu}$



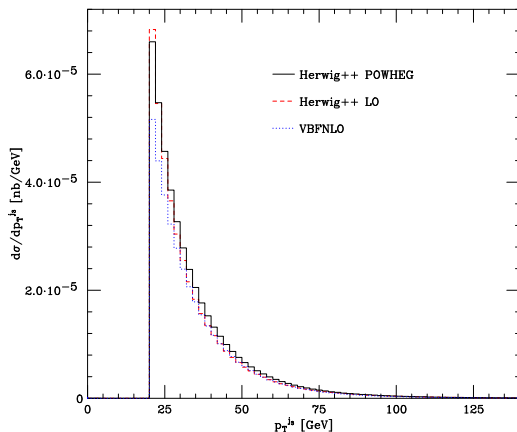
Handmade POWHEGs.

[L. D'Errico, P. Richardson – arXiv:1106.2983]



Handmade POWHEGs.

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Matchbox.

Matchbox.

Motivation

[SP, S. Gieseke – arXiv:1109.6256]

- Full-fledged NLO framework inside ThePEG/Herwig++
- Automated Catani-Seymour dipole subtraction
- Provide simple interface to external NLO codes [SP, Les Houches '09 proceedings]
- Enable MC@NLO-type and POWHEG matching → systematics
- Run with different showers – more systematics
 - standard angular ordered shower
 - CS dipole shower implemented and tested

[based on SP, S. Gieseke – arXiv:0909.5593]

Will be available with upcoming 2.6 release.

Matchbox.

Status

- Automated dipole subtraction
 - all massless dipoles and insertions available
 - massive ones in progress
- Interface to external codes via
 - squared/correlated matrix elements
 - primitive amplitudes
- Build MC@NLO-type or POWHEG matchings
 - adaptive Sudakov veto algorithm by ExSample

[M. Stoll, diploma thesis KIT 2012]

[SP, arXiv:1108.6182]

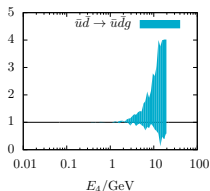
Matchbox.

Status, cont'd

- Builtin multi-channel phasespace
 - $H + 2jets$: > factor 3 speedup wrt VBFNLO phasespace
- Various phasespaces and integrators available → validation

[K. Arnold]

- Convenient helpers to check e.g. subtraction



- Backbone for subleading- N improved showers
 - more consistent MC@NLO, cf. independent approach by Sherpa

[M. Sjö Dahl, SP – arXiv:1201.0260]

A User's Point of View.

Herwig++

- Ships as Herwig++ module.
- Steering, cuts, etc. as for other LO processes.
- No external codes to run, no intermediate event files.

A Developer's Point of View, I.

Provide matrix elements squared and correlated matrix elements.

```
class MyMatrixElement : public MatchboxMEBase {
    /* ... */
public:
    virtual bool generateKinematics(const double* r); // optional
    virtual double me2() const;
    virtual double oneLoopInterference() const;
    virtual double colourCorrelatedME2(pair<int,int> ij) const;
    virtual double spinColourCorrelatedME2(int gluon, pair<int,int> ij,
                                           const SpinCorrelationTensor& c) const;
};
```


A Developer's Point of View, II.

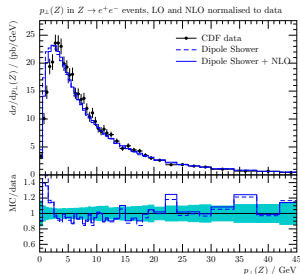
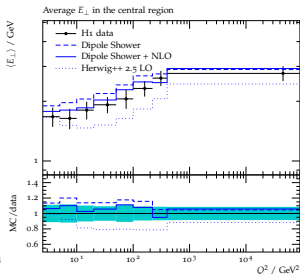
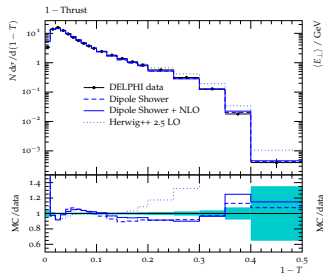
Simpler alternative: Provide primitive amplitudes.

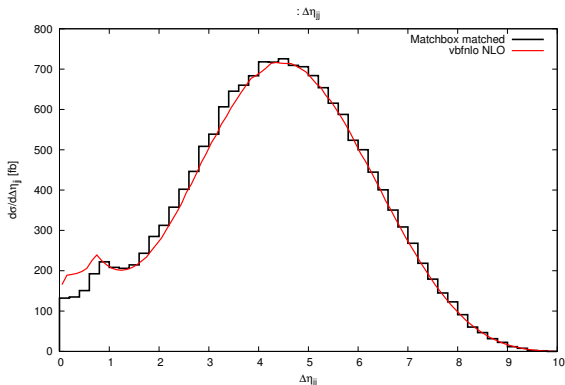
```
class MyAmplitude : public MatchboxAmplitude {  
    /* ... */  
public:  
    virtual Complex evaluate(size_t colorTensorId,  
                             const vector<int>& helicities);  
    virtual Complex evaluateOneLoop(size_t colorTensorId,  
                                     const vector<int>& helicities);  
};
```

Proof of concept: Simple processes.

e^+e^- , DIS, Drell-Yan

[SP, S. Gieseke – arXiv:1109.6256]



$H + 2 \text{ jets}$ with Matchbox MC@NLOVBF $Z + 2 \text{ jets}$, $W + 2 \text{ jets}$ in progress.

Conclusions.

- NLO well established within Herwig++
- Various specialized POWHEG implementations
- Matchbox provides full-fledged NLO framework
 - proof of concept with simple processes
 - target now at more complicated processes
 - switch between MC@NLO and POWHEG for systematics
- Further related developments
 - dipole shower as alternative shower → systematics
 - subleading N improved showering vs. MC@NLO

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