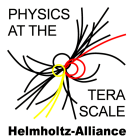
# Activities at Karlsruhe + DESY

Simon Plätzer

DESY





# Who we are.

## KIT Karlsruhe

- Johannes Bellm (PhD student)
- Stefan Gieseke (staff)
- Nadine Fischer (master student)
- Daniel Rauch (master student)
- Christian Reuschle (postdoc)

## DESY Hamburg

- SP (theory + analysis centre fellow)
- Stefan Prestel (theory fellow)
  $\rightarrow$ associated to Lund node
- summer students
  (2013: N. Schaefer, R. Poncelet)

Very close collaboration.
Regular visits KA $\leftrightarrow$ HH supported by MCnet and Terascale Alliance.

# What we do.

Very well connected node in- and outside of KA/HH:

- Matchbox development: NLO, Matching & Merging for Herwig++

  [J. Bellm, N. Fischer, S. Gieseke, SP, D. Rauch, C. Reuschle + A. Wilcock, P. Richardson]

- MPI & Diffraction

  [S. Gieseke, C. Röhr + A. Siodmok] [SP + J. Bartels, M. Diehl]

- EW corrections

  [S. Gieseke + T. Kasprczik, J. Kühn]

- Subleading-$N$ developments

  [SP + M. Sjödahl, J. Thoren]

- Event shapes & soft jets, tuning

  [N. Fischer, S. Gieseke, SP + P. Skands]

- Higgs plus jets

  [SP + F. Campanario, T. Figy, M. Sjödahl] [S. Gieseke, SP + M. Rauch]

- Jet rates (analytic vs. MC)

  [SP + E. Gerwick]

Hosting several projects which are crucial to ongoing and future Herwig++ development.

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# Matchbox development.

[J. Bellm, N. Fischer, S. Gieseke, SP, D. Rauch, C. Reuschle + A. Wilcock, P. Richardson]

Automated LO and NLO cross sections for Herwig++

- Run out of the box, steering as before.
- Include matching to angular ordered and dipole shower.
- Provide all necessary functionality for (N)LO merging.

Include reasonable and consistent evaluation of shower and scale uncertainties.
$\rightarrow$ Integrated, coherent framework.

Continuation and generalization of dipole shower plus NLO developments.

[SP & S. Gieseke – Eur.Phys.J. C72 (2012) 2187]

Closely tied to structural improvements and extensions of ThePEG.
Major milestone for Herwig++ 3.0 $\equiv$ Herwig 7 efforts.

Partial beta tester available in Herwig++ 2.7.x, much more to come in 2.8.x.

# Matchbox development.

$$\sigma_{\text{NLO}} = \int_n \mathrm{d}\sigma_{\text{LO}} \begin{pmatrix} |\mathcal{M}_{n,0}\rangle \\ |\mathcal{M}_{n,0}|^2 \end{pmatrix} + \int_n \left[ \mathrm{d}\sigma_{\text{V}} \begin{pmatrix} |\mathcal{M}_{n,0}\rangle, |\mathcal{M}_{n,1}\rangle \\ 2\text{Re}(\langle \mathcal{M}_{n,0} | \mathcal{M}_{n,1} \rangle) \end{pmatrix} + \int_1 \mathrm{d}\sigma_{\text{A}} \begin{pmatrix} |\mathcal{M}_{n,0}\rangle \\ |\mathcal{M}^{ij}_{n,0}|^2 \end{pmatrix} \right]$$
$$+ \int_{n+1} \left[ \mathrm{d}\sigma_{\text{PS}} \begin{pmatrix} P(\tilde{q}), D(p_\perp) \\ R_{\text{ME}}(p_\perp) \end{pmatrix} - \mathrm{d}\sigma_{\text{A}} \begin{pmatrix} |\mathcal{M}_{n,0}\rangle \\ |\mathcal{M}^{ij}_{n,0}|^2 \end{pmatrix} \right]$$
$$+ \int_{n+1} \left[ \mathrm{d}\sigma_{\text{R}} \begin{pmatrix} |\mathcal{M}_{n+1,0}\rangle \\ |\mathcal{M}_{n+1,0}|^2 \end{pmatrix} - \mathrm{d}\sigma_{\text{PS}} \begin{pmatrix} P(\tilde{q}), D(p_\perp) \\ R_{\text{ME}}(p_\perp) \end{pmatrix} \right]$$

## Interfaces at amplitude level

- Color bases provided, including interface to `ColorFull`.
  [M. Sjödahl, SP]
- Spinor helicity library and caching facilities.
- MadGraph5.
  [MadGraph & J. Bellm, S. Gieseke, SP, A. Wilcock]
- Some in-house calculations and parts of `HJets++`.
  [F. Campanario, T. Figy, SP, M. Sjödahl]

## Interfaces at squared amplitude level

- Dedicated interfaces.
  [HEJ & SP]
  [nlojet++ & J. Kotanski, J. Katzy, SP]
- BLHA2.
  [GoSam & J. Bellm, S. Gieseke, SP, C. Reuschle]
  [NJet & SP]
  [OpenLoops & J. Bellm, S. Gieseke]
  [VBFNLO & K. Arnold, S. Gieseke, SP]

## Matchbox infrastructure

based on [SP & S. Gieseke – Eur.Phys.J. C72 (2012) 2187]

- Process generation and bookkeeping, integration.
- Automated Catani-Seymour dipole subtraction.
- Diagram-based mutli-channel phase space.

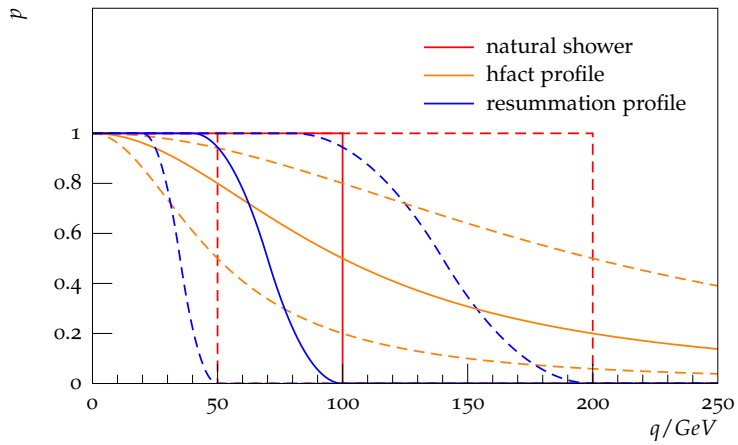
## Shower plugins

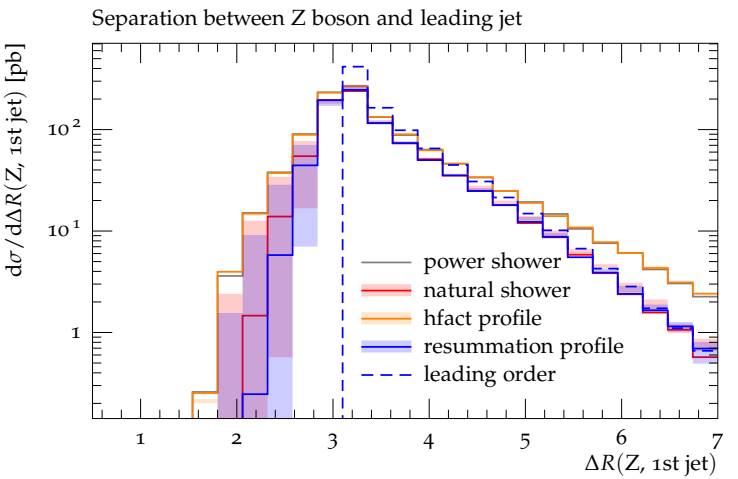
matching details & uncertainties [SP – in preparation]

- Dipole shower $D(p_\perp)$.
- Angular ordered shower $P(\tilde{q})$.
- ME correction $R_{\text{ME}}(p_\perp)$, including adaptive sampling.

# Matchbox-based activities.

## Shower & matching uncertainties [SP]




## (N)LO merging

[J. Bellm, S. Gieseke, SP]

- 'Unitarized' merging approach.

  [Lönnblad, Prestel –JHEP 1303 (2013) 166]

  [SP – JHEP 1308 (2013) 114]

- Smoothly integrated, no extra event files or external codes to run.

## (VBF) Higgs phenomenology @ NLO+PS

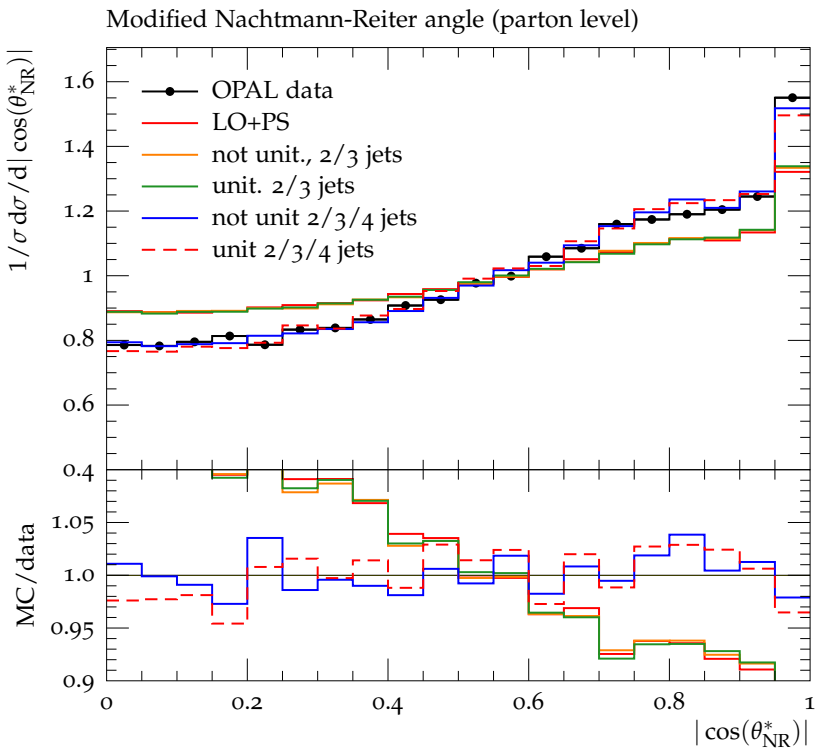
[S. Gieseke, SP + M. Rauch]

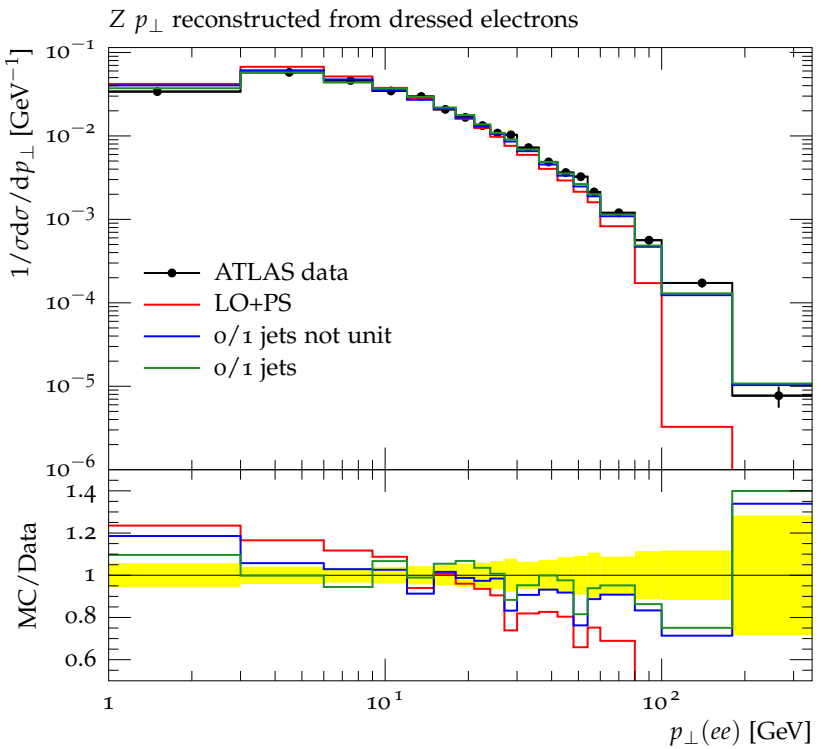
[SP + F. Campanario, T. Figy, M. Sjödahl]

- Interface to VBFNLO for all relevant signals and backgrounds, including anomalous couplings.
- Signal predictions without VBF approximation from `HJets++`.

# (N)LO merging.

[J. Bellm, S. Gieseke, SP – work in progress]



# MPI & Diffraction.

[S. Gieseke, C. Röhr]

Improve eikonal model to include diffraction:

- Two-channel eikonal for low-mass diffraction.
- Triple-pomeron model for high-mass diffraction.
- Similar to DTUJET and Phojet.

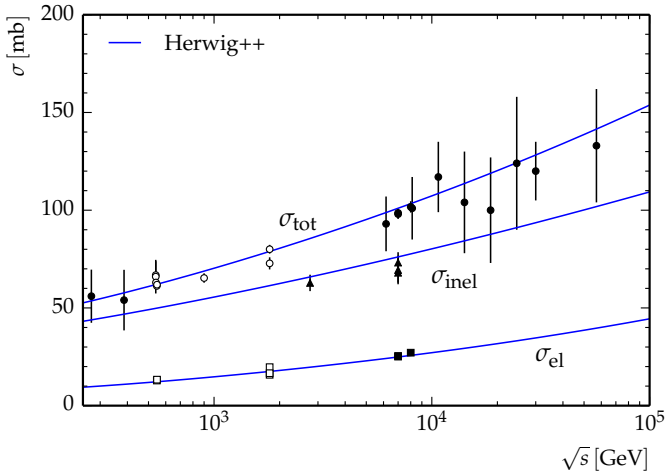
Model parameters:

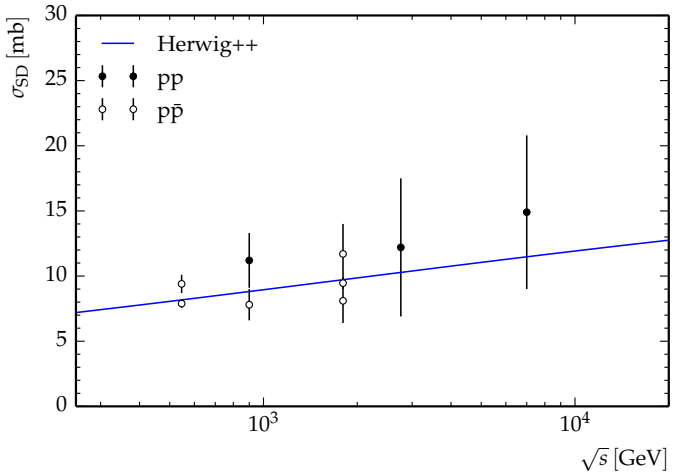
- Hard pomeron couplings and slopes.
- Soft pomeron slope and intercept.
- Coupling to resonant state in low-mass model.
- Shape of eikonal amplitudes in $b$-space.

Outlook:

- Generate final states.
- Related work in progress.

[SP + J. Bartels, M. Diehl] [J. Forshaw, M.H. Seymour, A. Siodmok]




Fit model parameters to cross sections and elastic slope at $\sqrt{s} > 250$ GeV $\rightarrow$ well described.

# EW corrections.

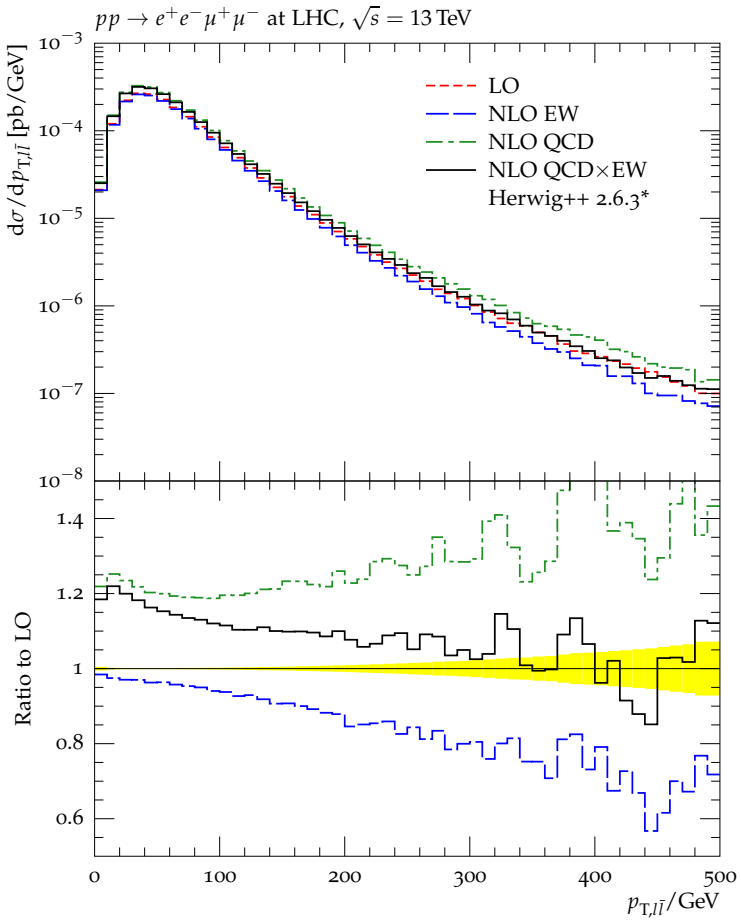
[S. Gieseke + T. Kasprczik, J. Kühn]

Electroweak corrections to diboson production @ LHC.

- Factorized ansatz to mixed corrections:

  $$(1+\delta_{\text{QCD}})(1+\delta_{\text{EW}}) \approx 1+\delta_{\text{QCD}}+\delta_{\text{EW}}$$

- Valid if both corrections are small $\rightarrow$ use suitable cuts to supress phase space enhanced QCD corrections
- QCD corrections from builtin POWHEG cross sections
- EW corrections through $\hat{s}, \hat{t}$-dependent reweighting

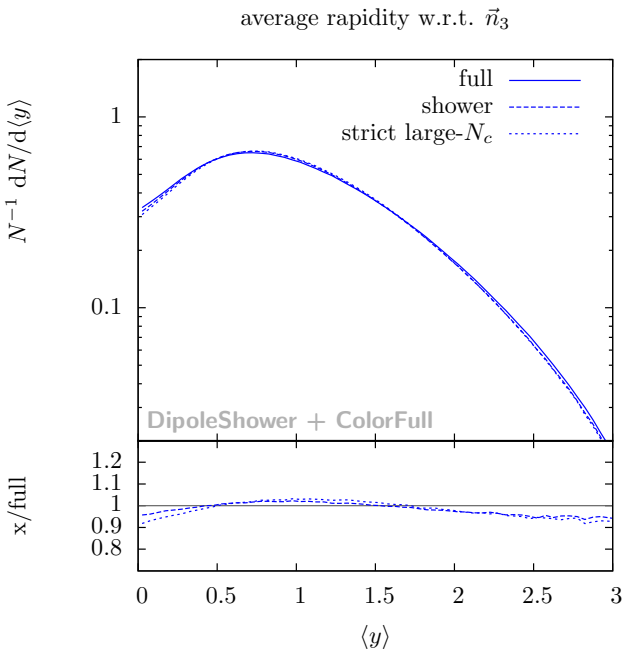


# Subleading-$N$ developments.

## Colour matrix element corrections.

[SP & M. Sjödahl – JHEP 1207 (2012) 042]

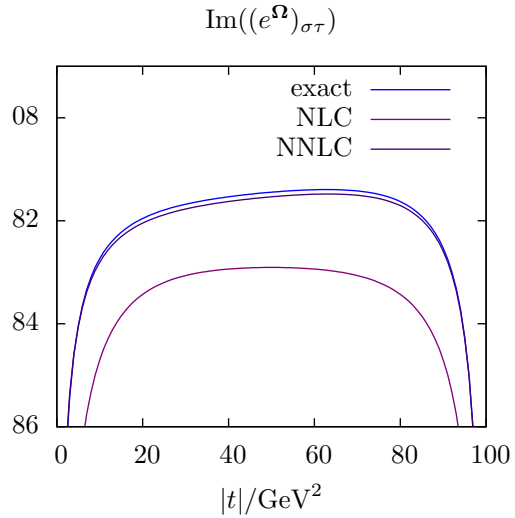
- Based on Matchbox & dipole shower.
- Pioneered for $e^+e^-$.
- Full ($pp$) simulation and integration with standard showering in progress.




## Systematize large-$N$ expansion.

[SP – arXiv:1312.2448]

- Soft-gluon evolution in flow basis.
- Sum towers of large-$N$ enhanced terms to approximate full exponentiation.
- Further shower improvements.
- New perspective on colour reconnection.

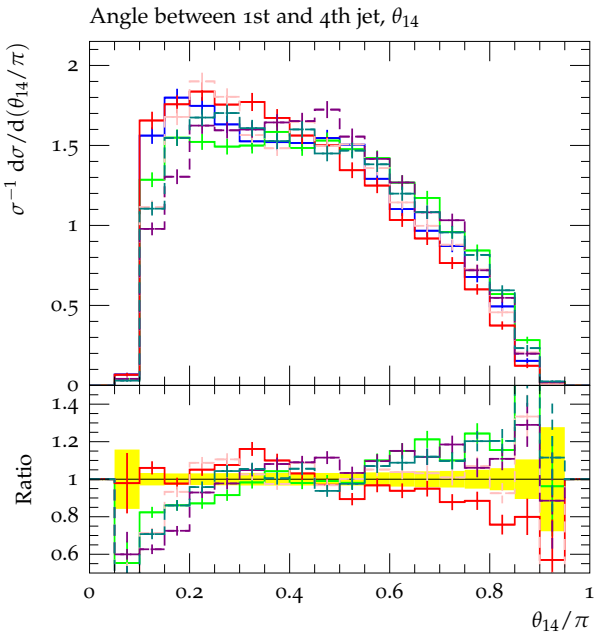


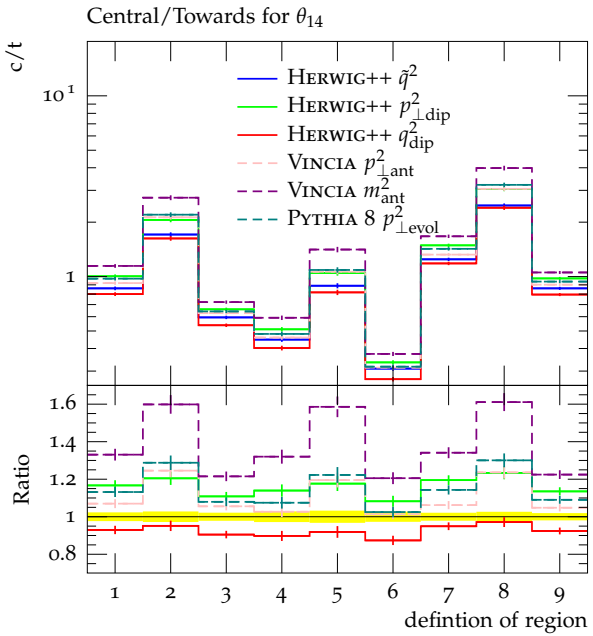
# Event shapes & soft jets, tuning.

[S. Gieseke, N. Fischer, SP, P. Skands – arXiv:1402.3186, to appear in EPJ C]

Revisit radiation patterns in $e^+e^-$.

- Various observables to test subleading contributions and coherence issues.
- Compare several shower algorithms, after tuning to same data.
- Significant differences observed.



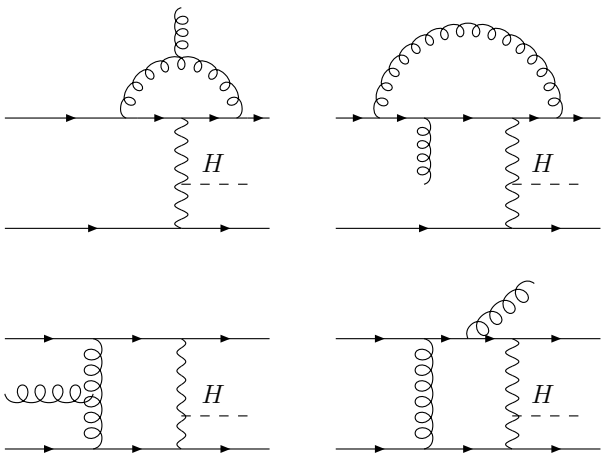

**OPAL measurement around the corner!**

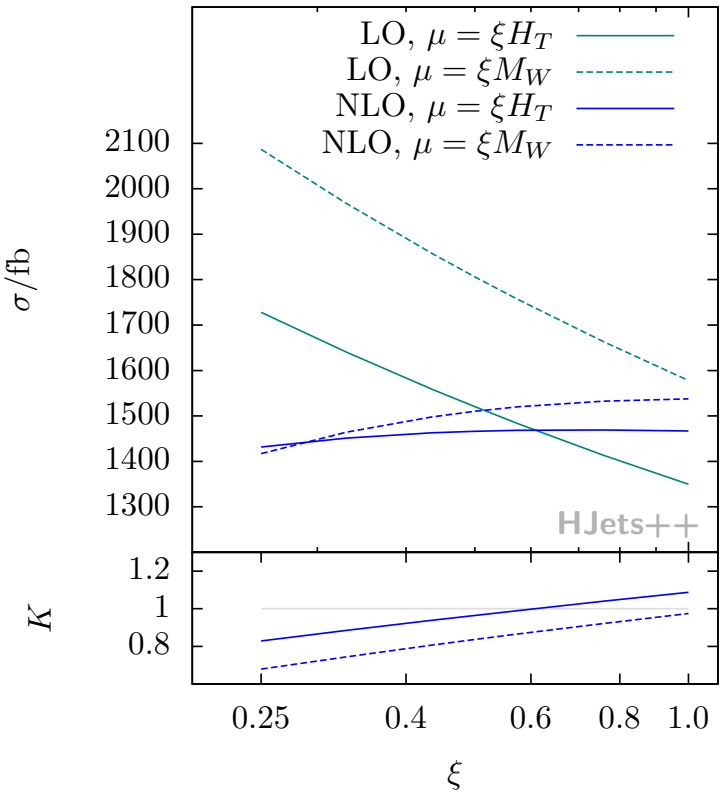
# Higgs plus jets.

## Electroweak $H$+Jets production with `HJets++`

[F. Campanario, T. Figy, SP, M. Sjödahl – PRL 111 (2013) 211802]

- Employs all of Matchbox's infrastructure for a hadron collider $2 \to 4$ process.
- Hybrid interfaces of amplitude and squared amplitude infrastructure, internal cross checks possible.




$pp \to H + 3$ jets @ 14 TeV – inlcudes all VBF and Higgs-strahlung contributions NLO+PS and further phenomenological studies in progress.

# Jet rates (analytic vs. MC).

Recursion relations for deep expansions of high-multiplicty jet rates @ NLL.

[E. Gerwick, SP – LH 2013 proceedings and work in progress]

LL for resolved and unresolved contributions.

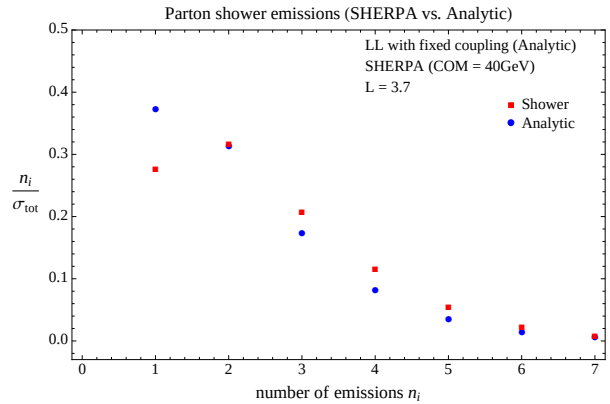
[E. Gerwick – Phys.Rev. D88 (2013) 094009]

NLL recursion from new Ansatz.

- Resolved contributions derived and checked.
- Unresolved contributions and running coupling effects in progress.
- Implemented in (slow) Mathematica and (fast) C++ code.

Applications:

- Analytic shower cross checks.
- Scaling patterns.
- ...




preliminary

$$C_5^{\text{NLL}} = -\frac{6577 C_A^4 C_F}{544320} - \frac{107 C_A^3 C_F^2}{1134} + \frac{13 C_A^3 C_F n_f T_R}{9720} - \frac{227 C_A^2 C_F^3}{864} + \frac{113 C_A^2 C_F^2 n_f T_R}{9072} - \frac{67 C_A C_F^4}{216} + \frac{11}{270} C_A C_F^3 n_f T_R - \frac{C_F^5}{8} + \frac{587 C_F^4 n_f T_R}{11340}$$

# Summary.

Karlsruhe + DESY (SP) very well connected and active node.

Various collaborations in- and outside of KA/HH.

Hosts projects central to ongoing and future Herwig++ development.
Mainly focussing on higher orders and shower development.

Close contatcs to experimental groups at DESY and KIT.
Significant contributions to Terascale Alliance MC schools & workshops.