

Review of Monte Carlo Event Generators in the UK

Peter Richardson

CERN TH & IPPP Durham

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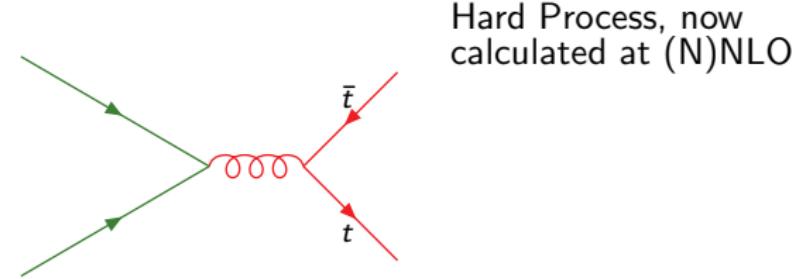
Outline

- Motivation, projects and history
- Current Status
- Recent Highlights
- The Future

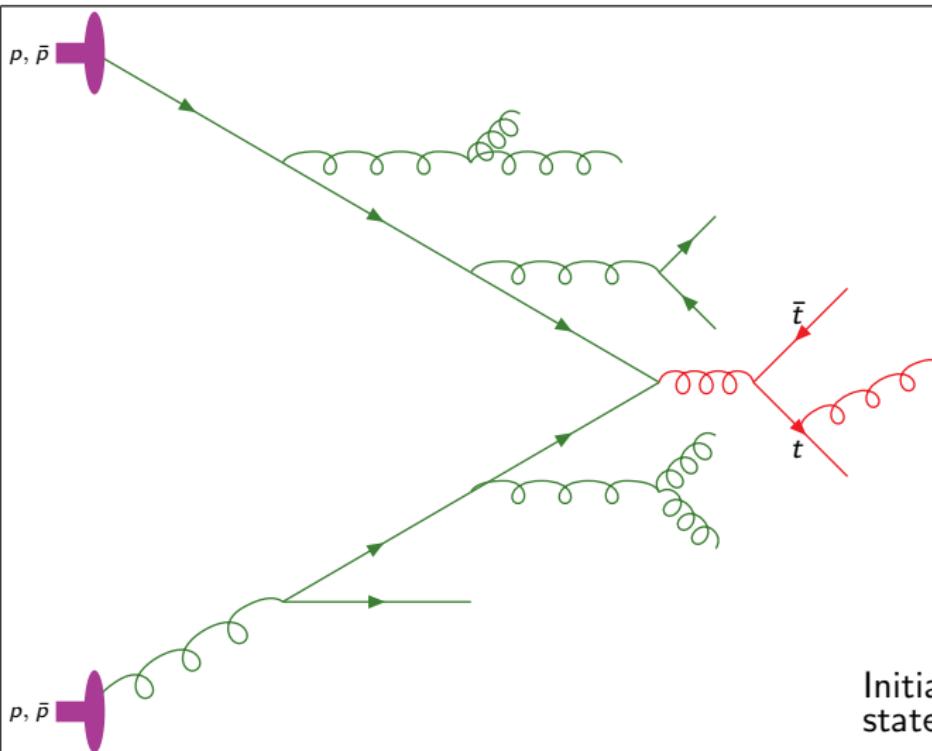
Basics of Event Generation

- Monte Carlo event generators combine:
 - hard perturbative QCD calculations;
 - approximate QCD evolution from high to low energy scales using the parton shower;
 - perturbative multiple parton scattering models of the underlying event;
 - non-perturbative models of the hadronization process;
 - simulations of hadron decays;
- to provide simulations of complete events.
- They are essential tools that both encapsulate the current theoretical understanding of hadronic collisions and produce simulated events which can be compared with data.

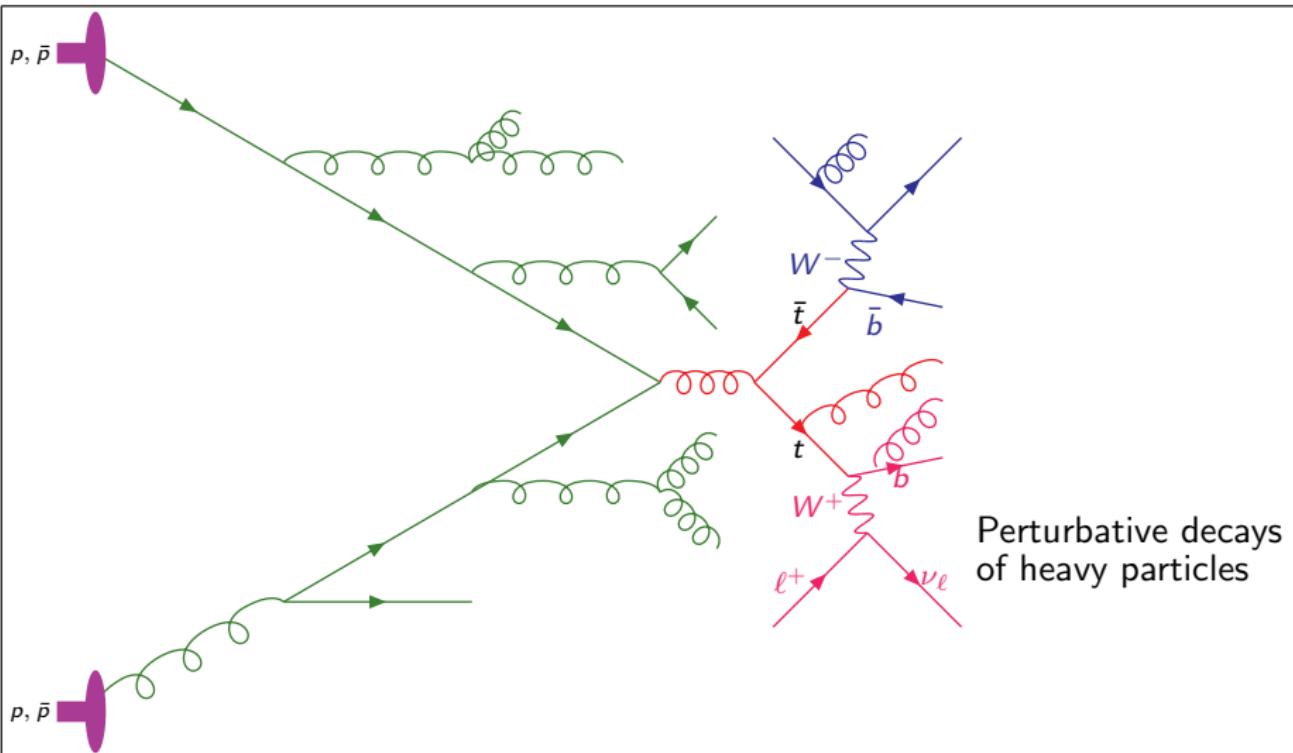
A Monte Carlo Event



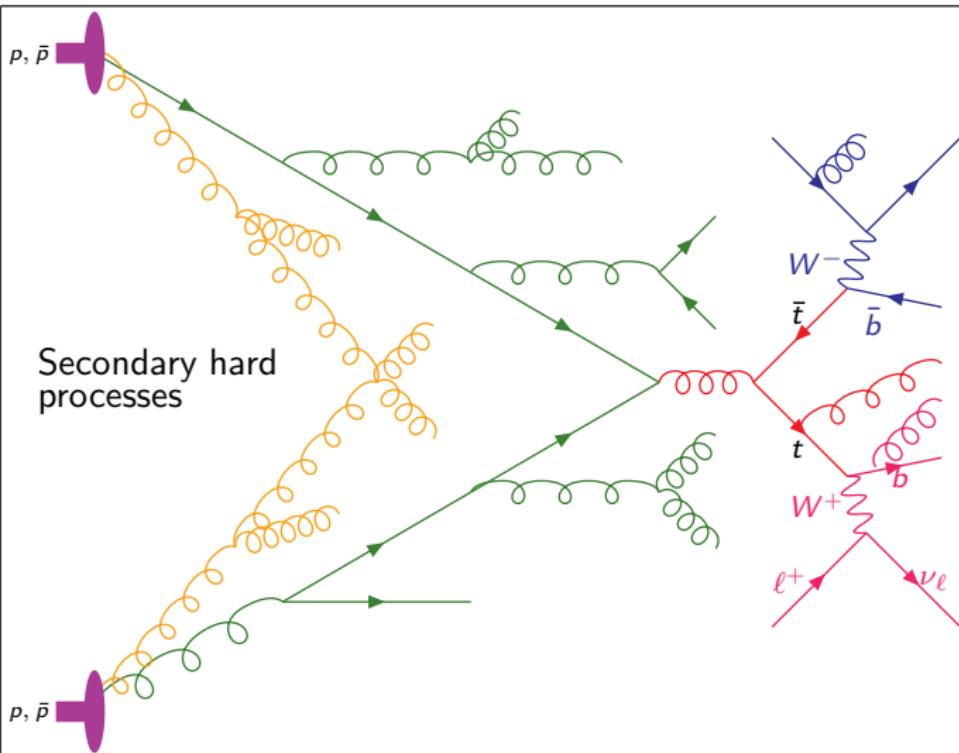
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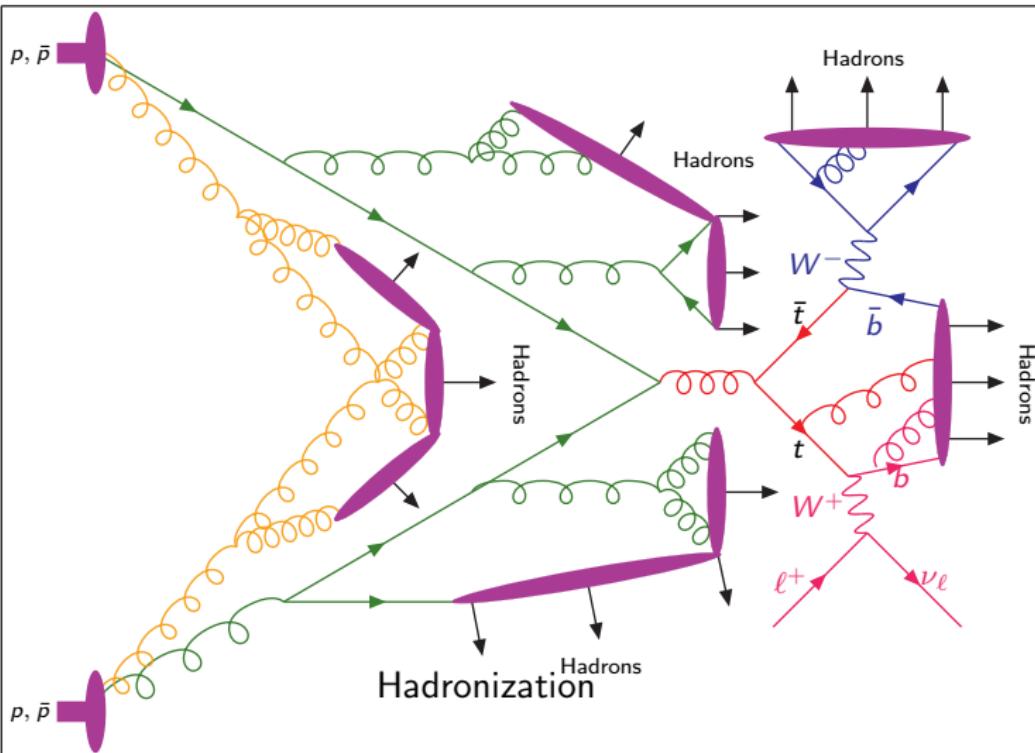
A Monte Carlo Event



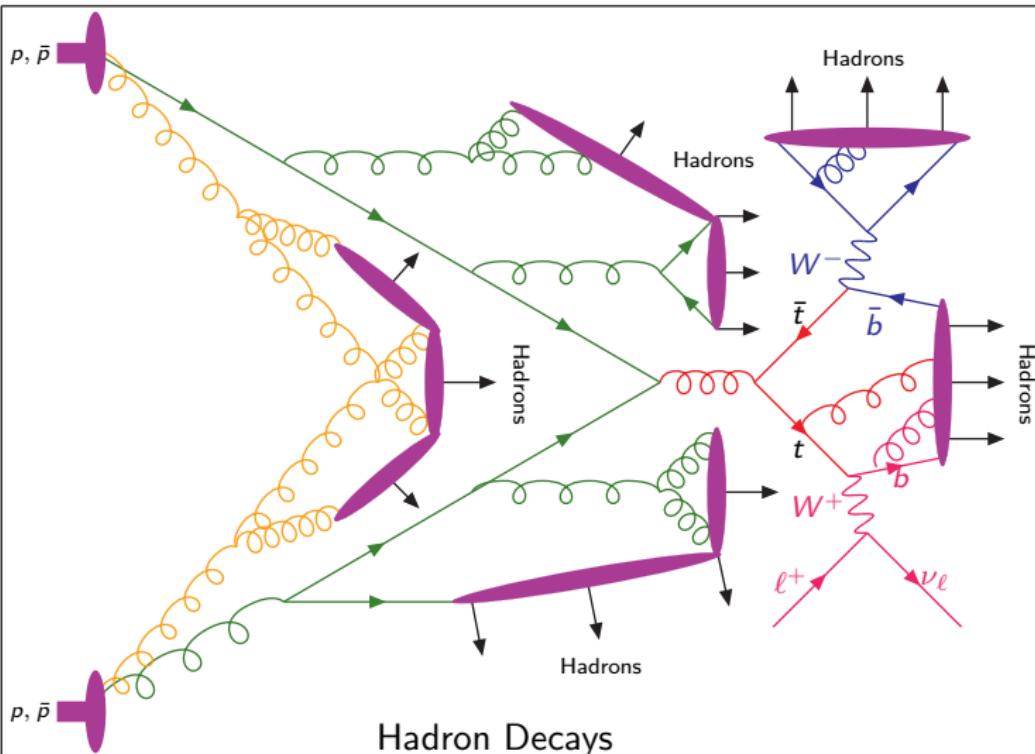
A Monte Carlo Event



A Monte Carlo Event



A Monte Carlo Event



Projects with U.K. Involvement and Leadership

- Currently three major Monte Carlo event generators, U.K. leadership in two of them
 - Herwig (Richardson, IPPP & Seymour, Manchester)
 - SHERPA (Krauss, IPPP)
- Other projects
 - Leadership of High Energy Jets (HEJ) (Andersen, IPPP & Smillie, Edinburgh)
 - Involvement with MinLO and POWHEGBox (Hamilton, UCL Zanderighi, Oxford)
- Leadership in HepData project for data preservation (IPPP) and Rivet and Professor programs for data comparison/tuning (Glasgow, IPPP)
- Leadership of E.U. network MCnet.

History

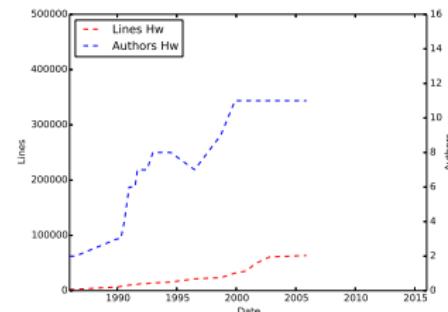
- The U.K. has been a leader in MC development since the birth of the field. Webber, Cambridge HERWIG 1984→, Sakurai Prize 2012
- Significant investment in early-mid 2000s
 - 2 PRDAs to develop new program based on HERWIG in C++ (PPARC responsive RAs)
 - e-Science money to redevelop HepData and develop Rivet.
 - Additional permanent appointments Seymour, Richardson, Krauss.
 - Significant investment from the IPPP.
 - More recent appointments of Zanderighi, Hamilton, Zanderighi, Andersen, Smillie

Last 15 years in Monte Carlo

- The last fifteen years have seen significant changes in the Monte Carlo generator field.
- At the end of LEP
 - Main programs were FORTRAN HERWIG6 and PYTHIA6.
 - Parton showers with matching to the first hard emission for simple processes such as $e^+e^- \rightarrow q\bar{q}$ and Drell-Yan.
- Developments since LEP
 - Multiple emissions at LO, CKKW
 - Matching to NLO (1st approach Frixione and Webber)
 - Merging at NLO (NLO normalisation for multiple emissions)
MINLO, Sherpa, Herwig 7.1
 - First NNLO **Hamilton, Nason, Oleari, Zanderighi**

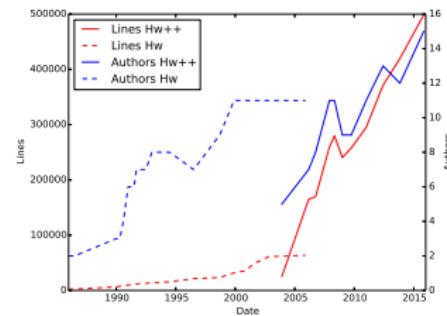
New Programs

- At the end of LEP the existing FORTRAN generators needed to be rewritten to allow physics improvements and long term development:
 - HERWIG redeveloped as Herwig++ and then Herwig7;
 - PYTHIA → Pythia 8;
 - Sherpa developed from scratch; all in C++.
- New generation of event generators which are the workhorses at the LHC, together with specialised programs for the calculation of hard processes in the various merging schemes.

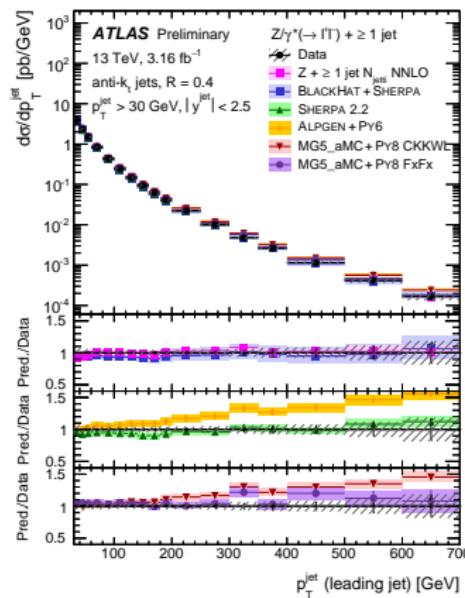
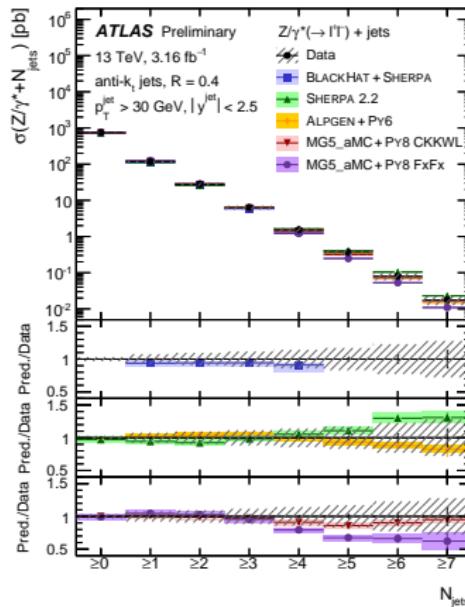


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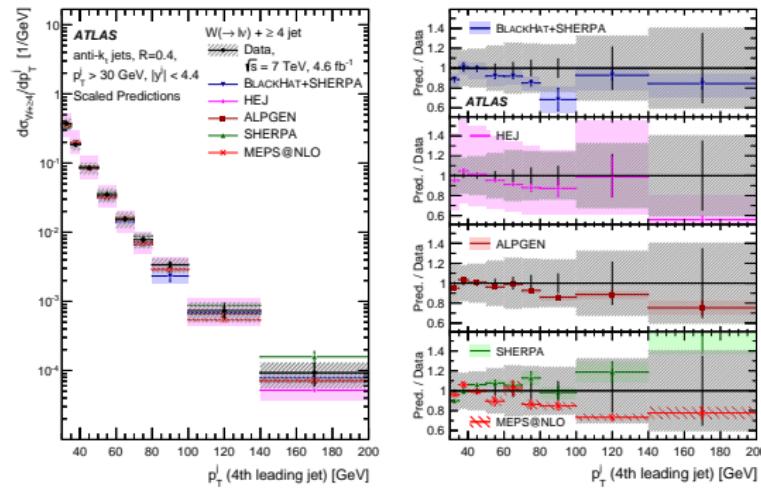


At the LHC: ATLAS Z+jets

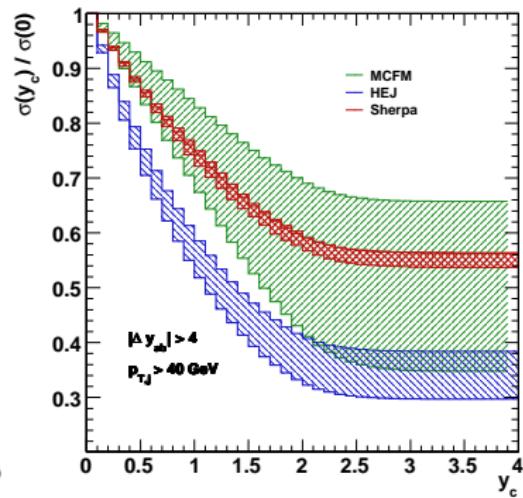
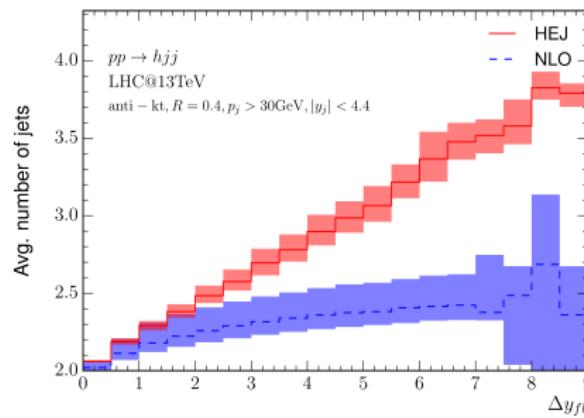


ATLAS-CONF-2016-046

At the LHC: ATLAS W+jets

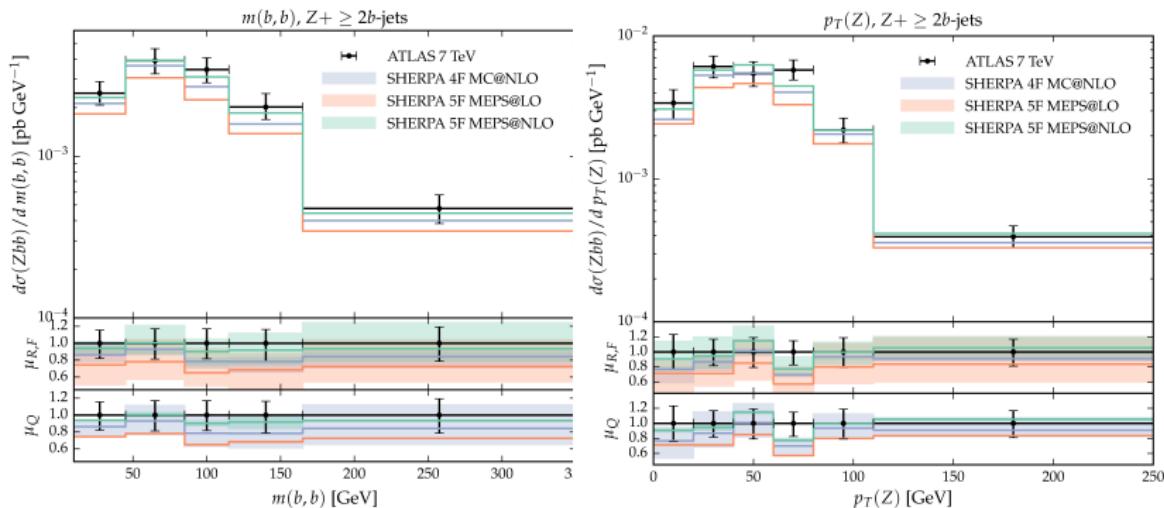


Effect of Jet Veto in Gluon Fusion with HEJ



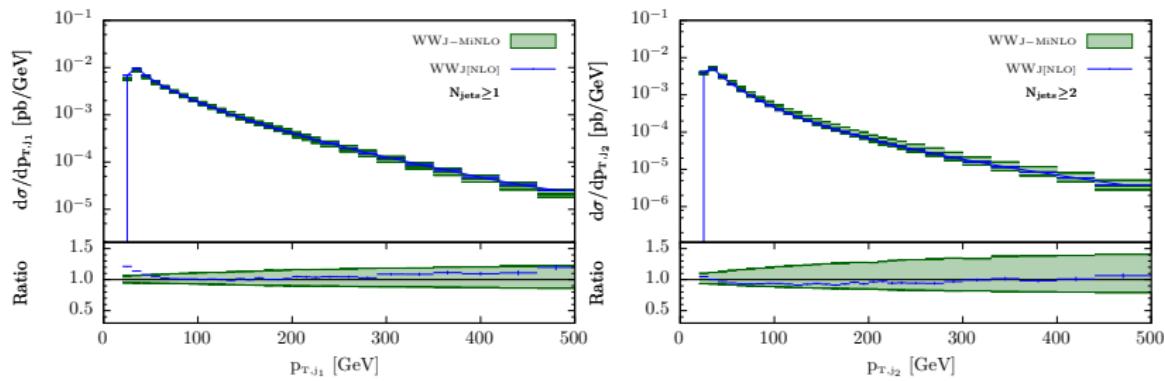
from 1706.01002, Andersen, et.al

Merging with bottom quarks



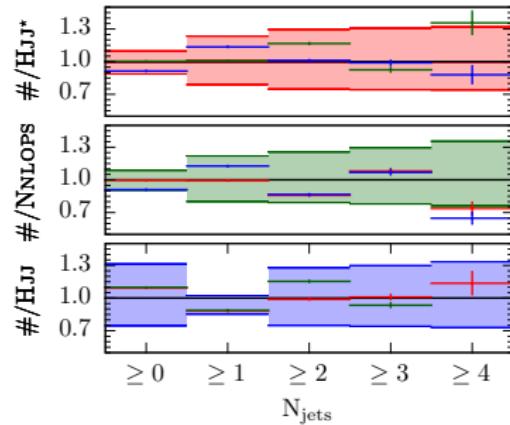
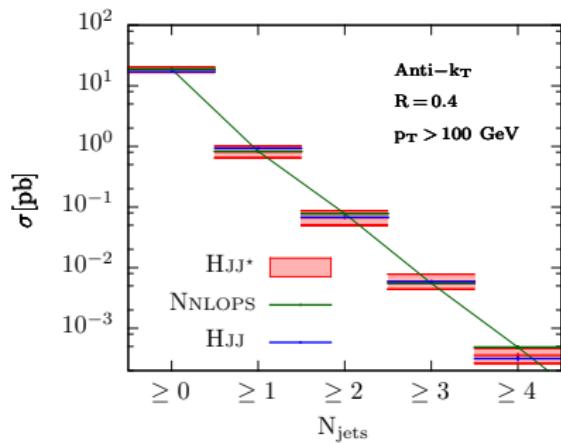
from 1612.04640 Krauss, Napoletano, Schumann

Merging W^+W^- and $W^+W^- + \text{jet}$ with MINLO



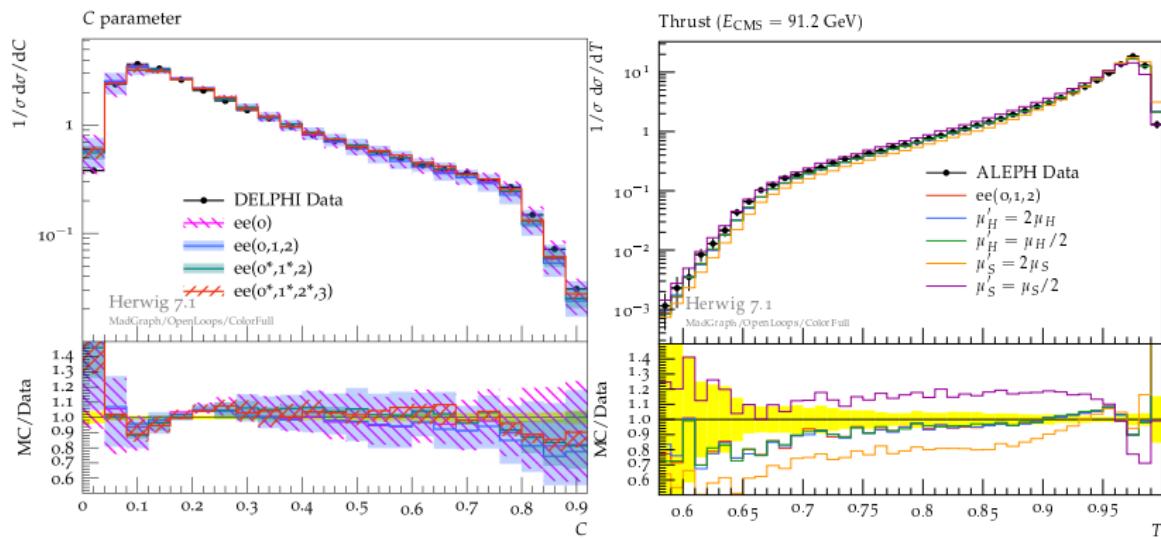
JHEP 1609 (2016) 057 Hamilton et.al.

Extending MINLO



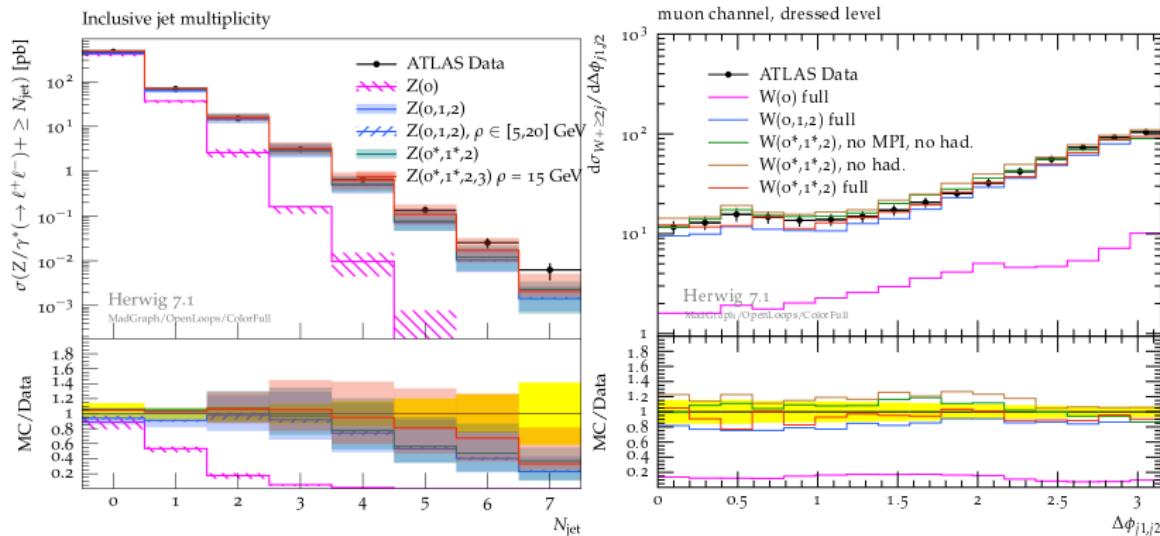
JHEP 1605 (2016) 042 Frederix and Hamilton

Herwig 7.1



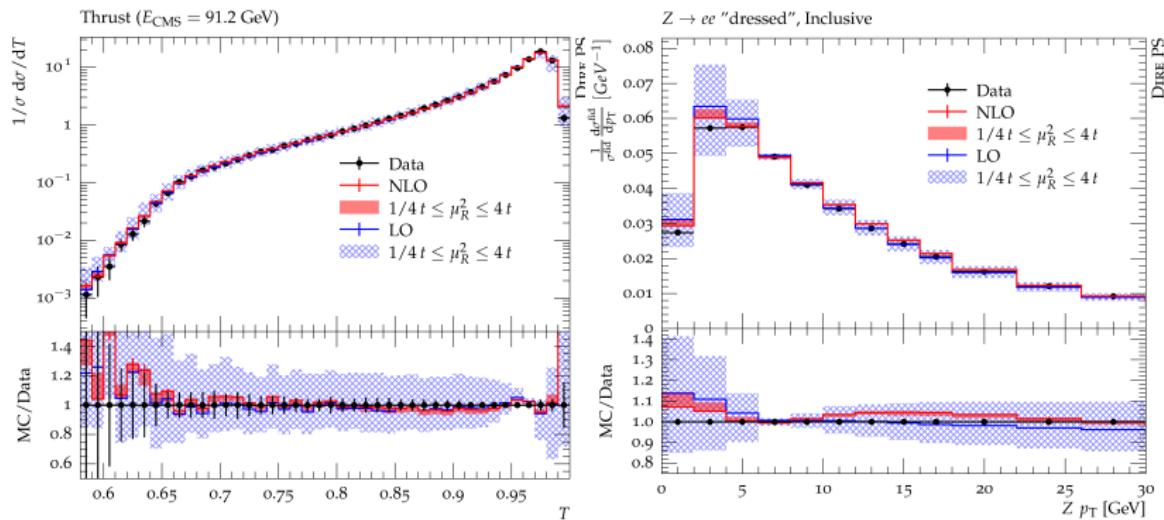
Bellm et.al. arXiv:1705.06919. Main new feature multi-jet NLO merging (Bellm,
Gieseke, Pläter arXiv:1705.06700).

Herwig 7.1



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Subleading-Logs



from Höche, Krauss, Prestel arXiv:1705.00982

The Future

- U.K continues to be the world-leader in MC development.
- Important synergy between:
 - event generator projects Herwig & Sherpa;
 - data preservation Rivet & HepData
 - higher order/multiplicity calculations HEJ, MINLO, POWHEGBox, BLACKHAT,...
 - experimental community
- Can lead to new developments e.g. Contour.