Herwig 7

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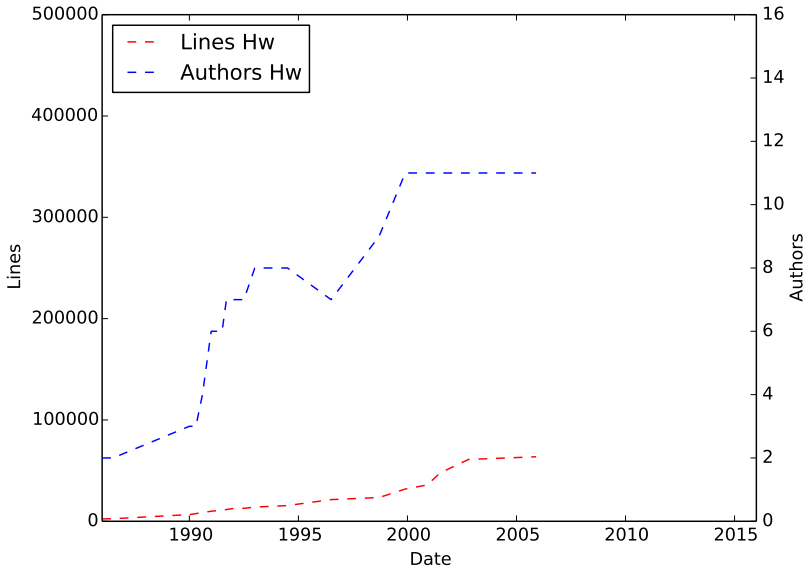
Outline

- History
- Current Status
- Future Plans
- Conclusions

History

- HERWIG was originally designed as a program for understanding hadronic physics.
- Strong emphasis on the accurate simulation of QCD.
- From HERWIG 6 strong emphasis on the study of BSM:
- Starting in 2000 major rewrite in C++ (Herwig++)
- The old code was becoming impossible to maintain and a lot of physics we wanted to add was impossible to implement.

Design Philosophy



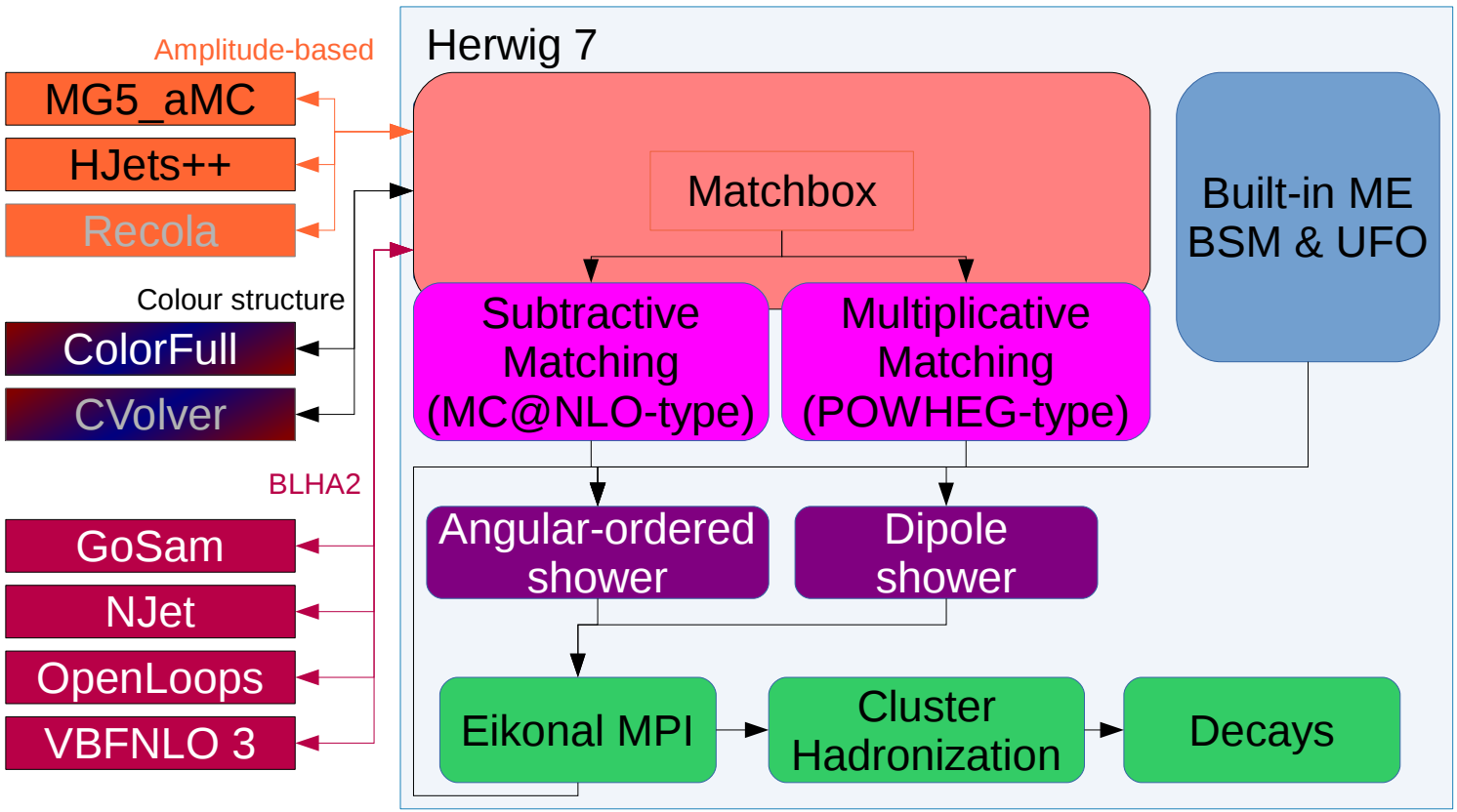
- Learn from past mistakes.
- Main focus was:
  - better physics;
  - structure maintainable in the long-term.
- Speed wasn't ignored but was clearly less important.
- Balanced performance vs physics and maintainability:
  - matrix elements slower, more flexible with helicity amplitudes and spin correlations;
  - shower slower, better structure and physics;
  - hadronization faster, better implementation and physics.

What we do?

- We expected that we would do less of the simulation.
- Rely on specialised external packages for more parts of the simulation.
- In practice hasn't happened.
- Better physics and more accurate simulation requires more communication between the different parts of the simulation.
- Any interface is prone to errors on both sides.
- Easier and less error prone to do things like QED radiation and tau decays internally.

What we do?

Structure



Fully automated, so that users can choose their process and everything is set up for them!

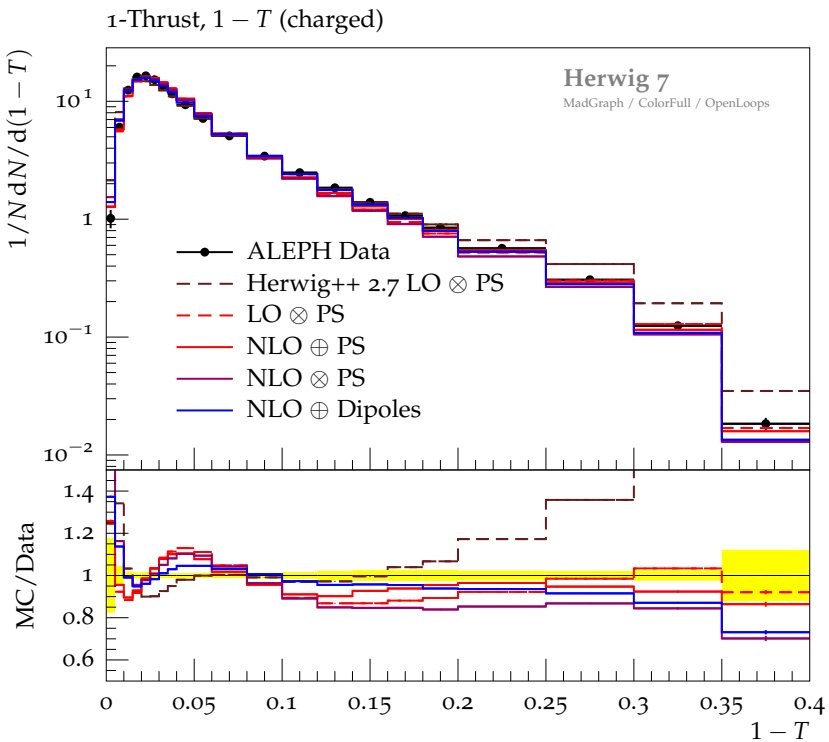
Herwig 7

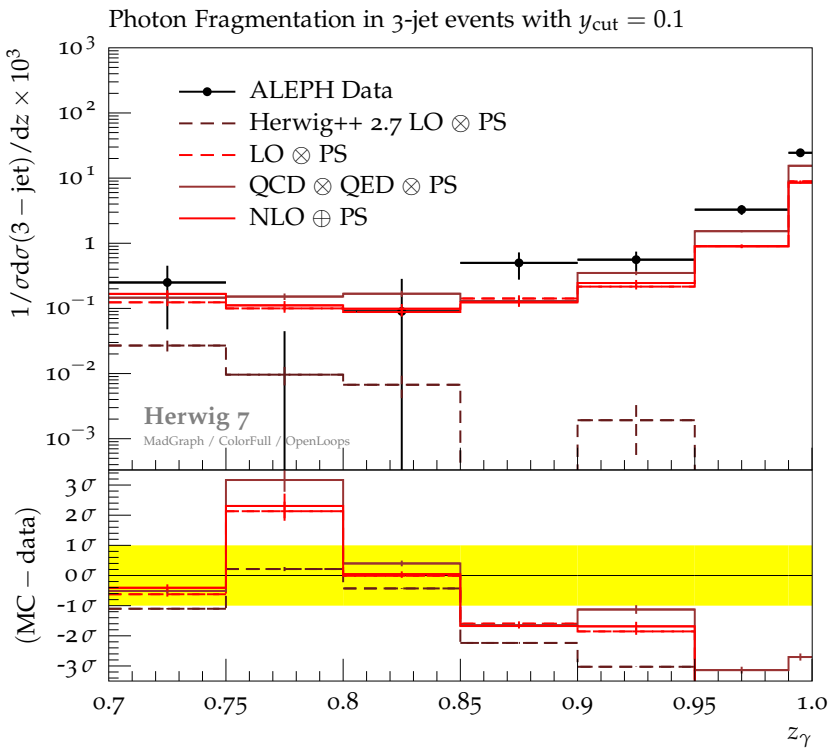
- For the last 10 years we have been working towards a goal of a release that met a (moving) definition intended fully replace the FORTRAN HERWIG program.
- Over time that has evolved as the needs of the experimental and phenomenological communities have developed over the last ten years.
- Precision is now the key and matching to higher orders absolutely essential.

Herwig 7.1

- Focus on Standard Model physics.
- Default is to have NLO matrix elements matched to the parton shower.
- Fully automated, so that users can choose their process and everything is set up for them.
- Both multiplicative (POWHEG) and additive (MC@NLO) type matching
- Option of two different parton showers, angular-ordered and dipole.
- NLO merging with the dipole shower
- Much better documentation
- Finally completely replaces FORTRAN HERWIG.

NLO Matching

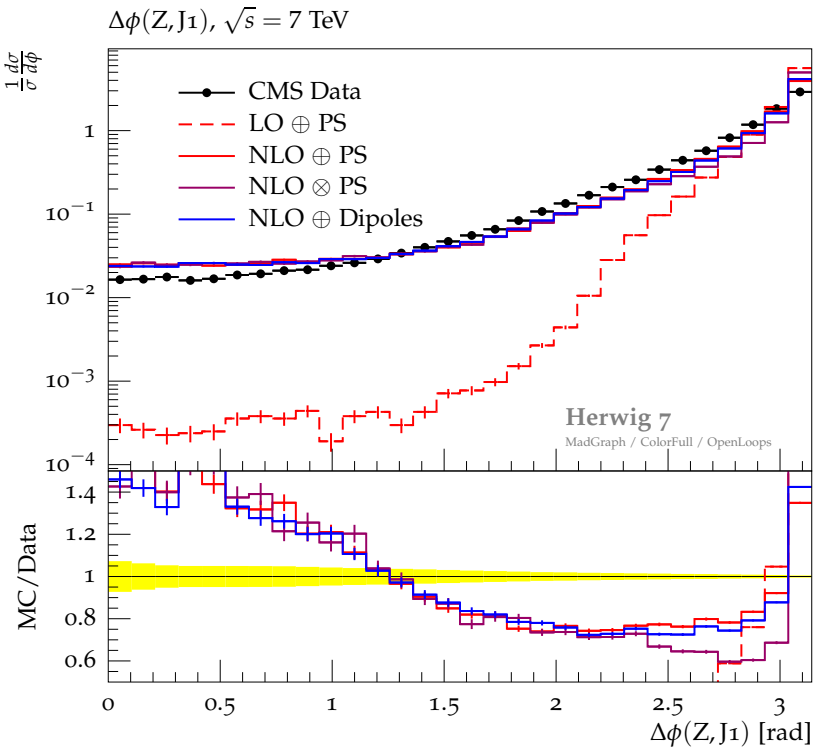


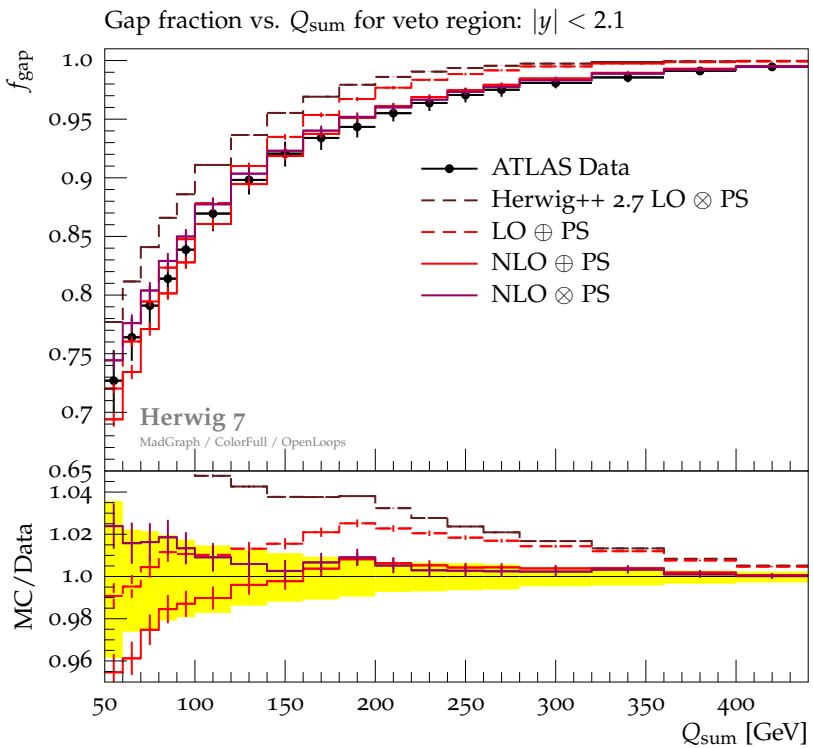


Herwig 7.0 at LEP – new tune available with the release.
Several improvements to angular ordered shower.

Tons of plots using all combinations at: `https://herwig.hepforge.org/plots/herwig7.0/`

NLO Matching





Z+jet events from CMS and top pairs from ATLAS.
Matchbox using MadGraph, ColorFull and OpenLoops.

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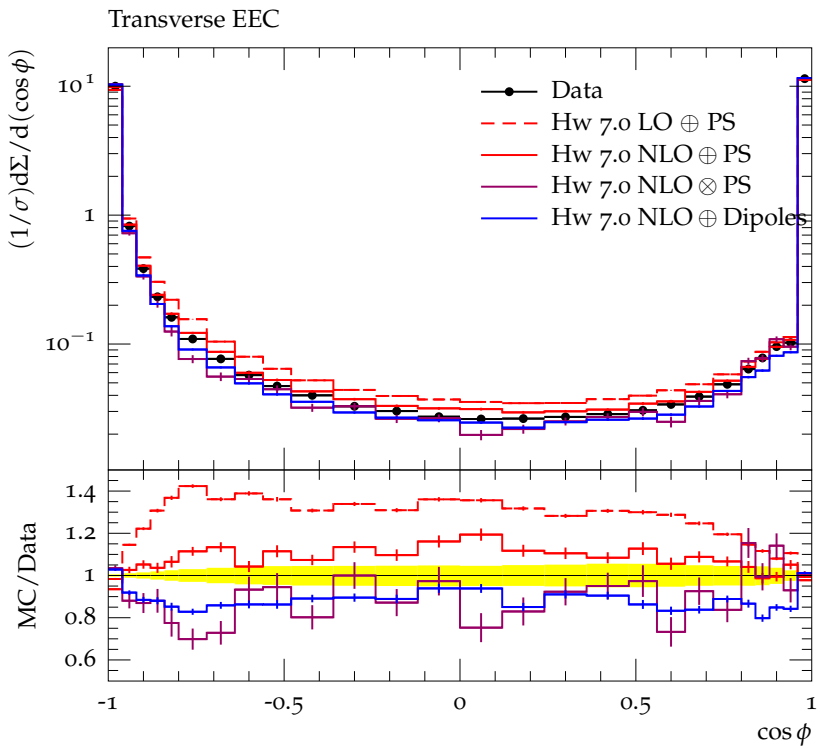

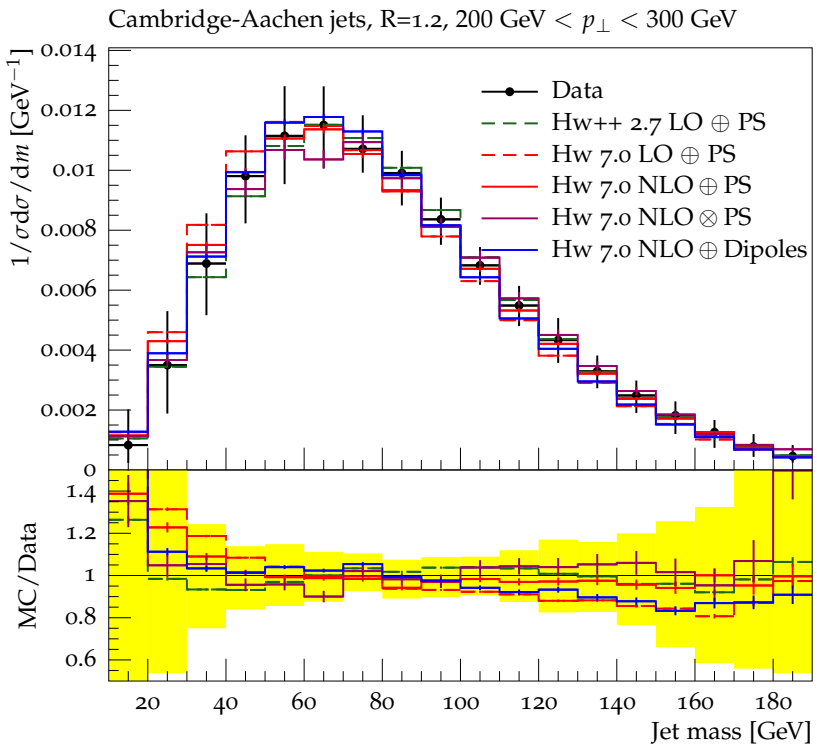

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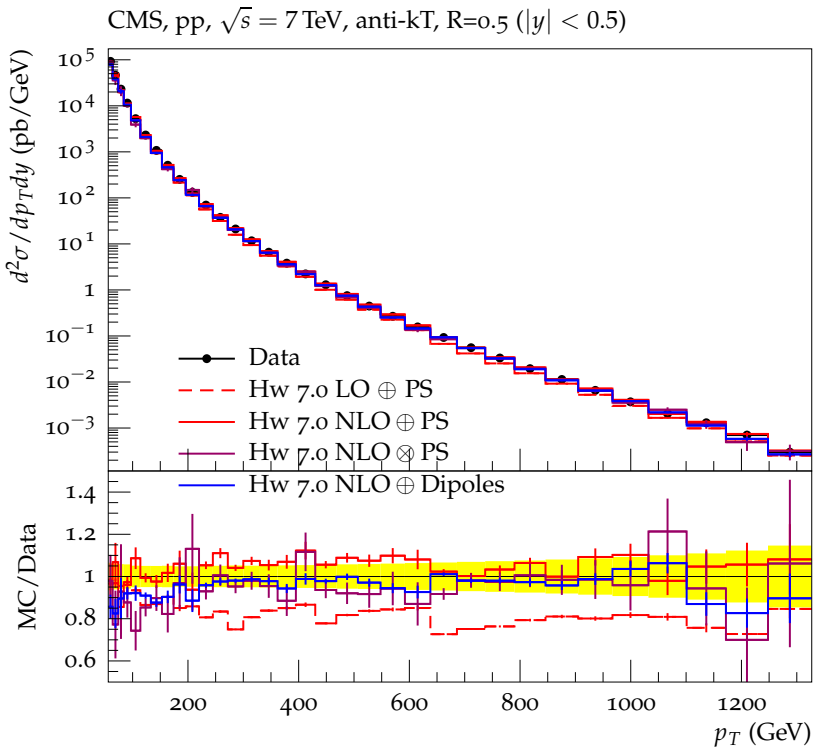

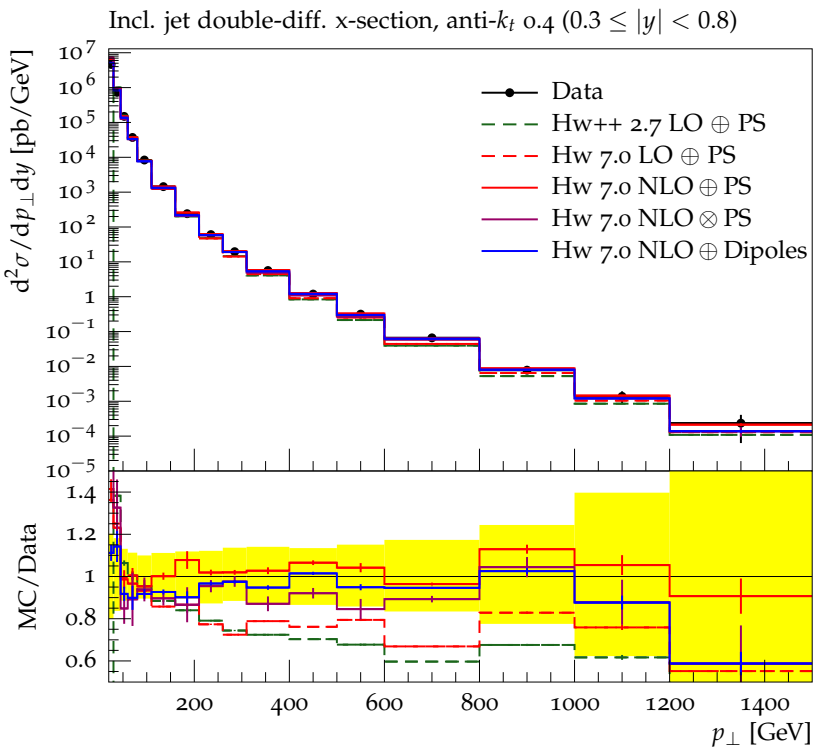

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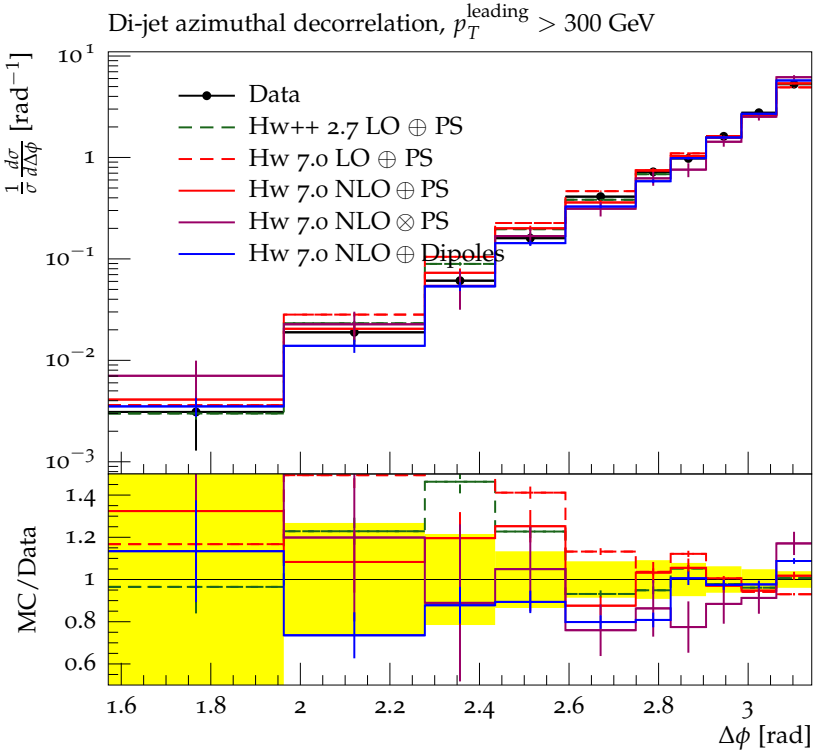

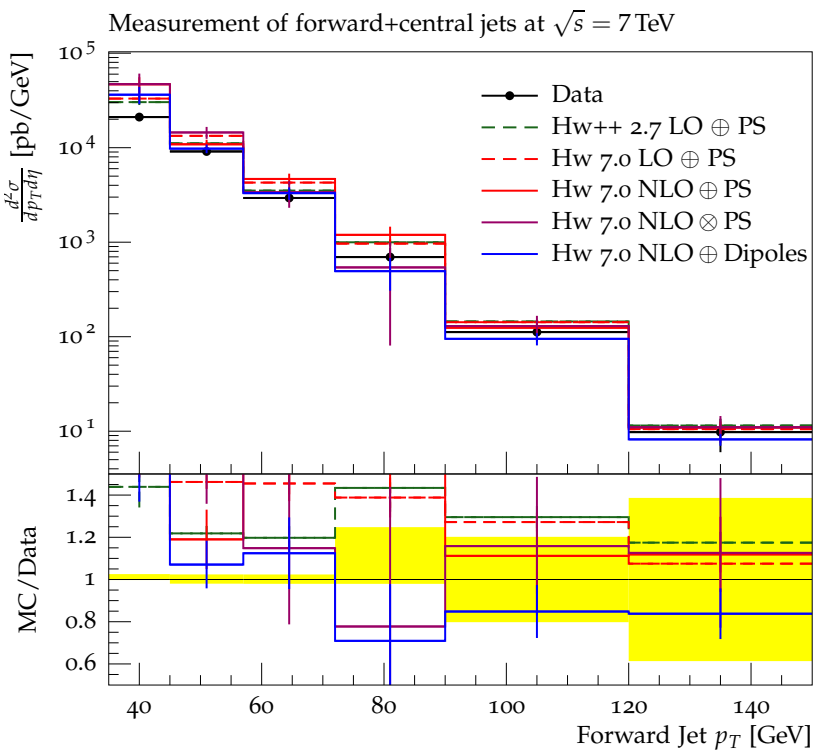

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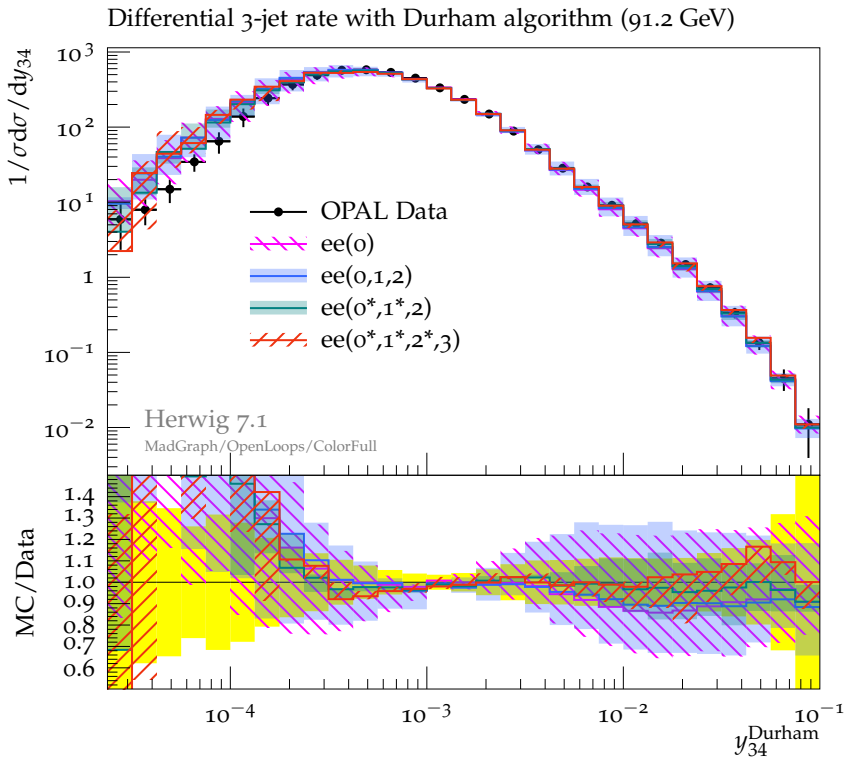
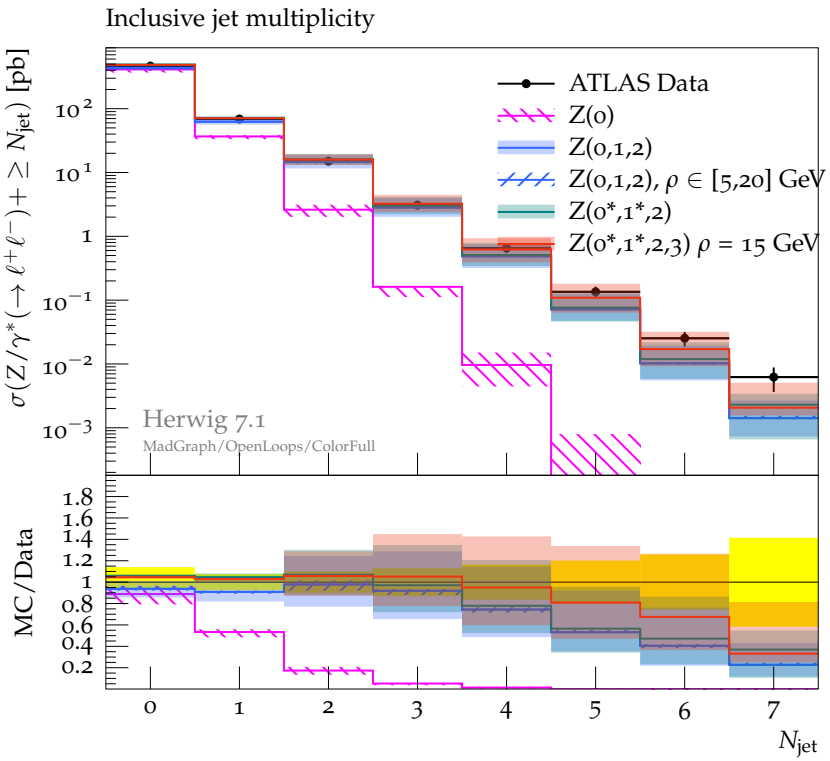
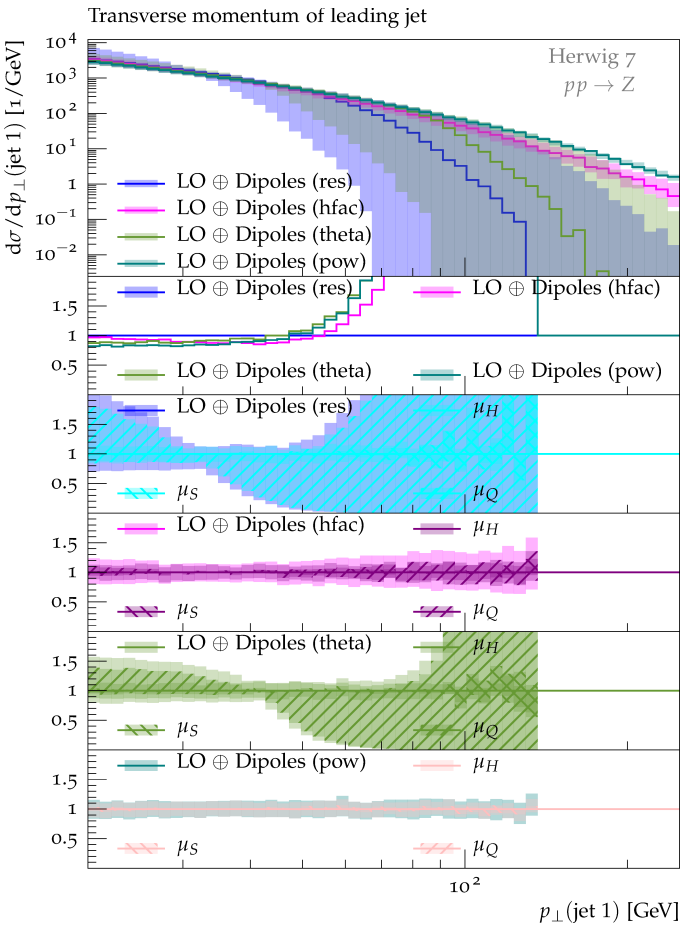
NLO Merging

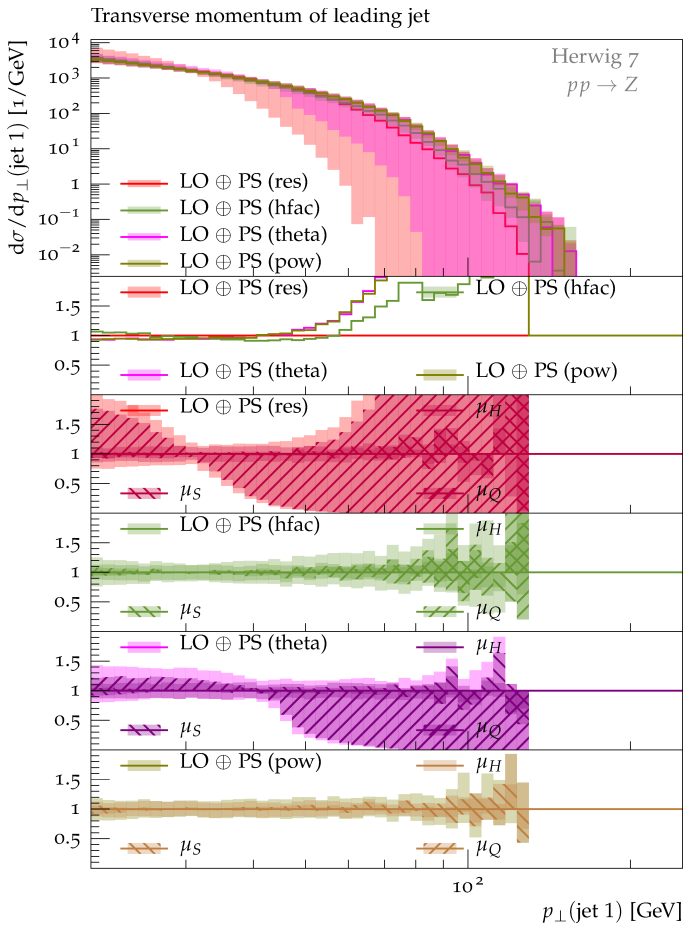




J. Bellm, S. Gieseke, S. Plätzer Eur.Phys.J. C78 (2018) no.3, 244

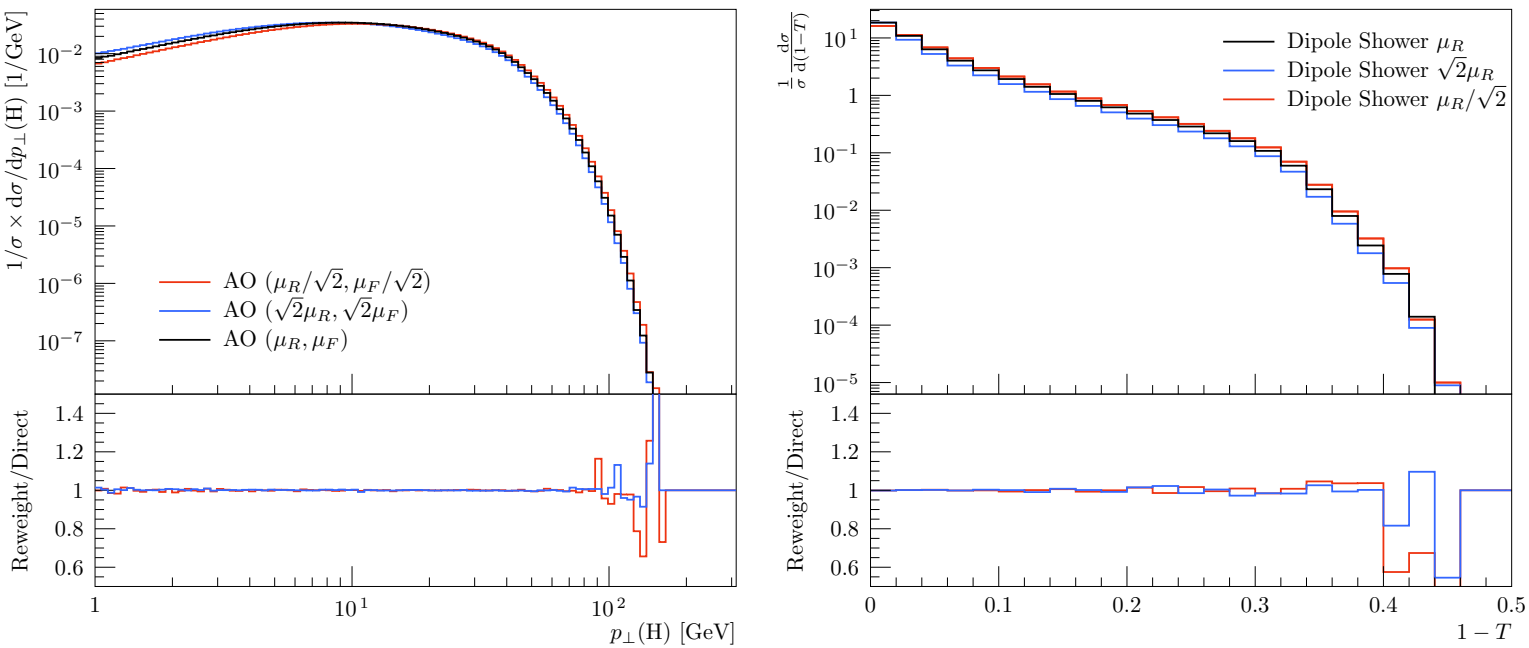
Uncertainties





Eur.Phys.J. C76 (2016) no.12, 665 Bellm et.al.

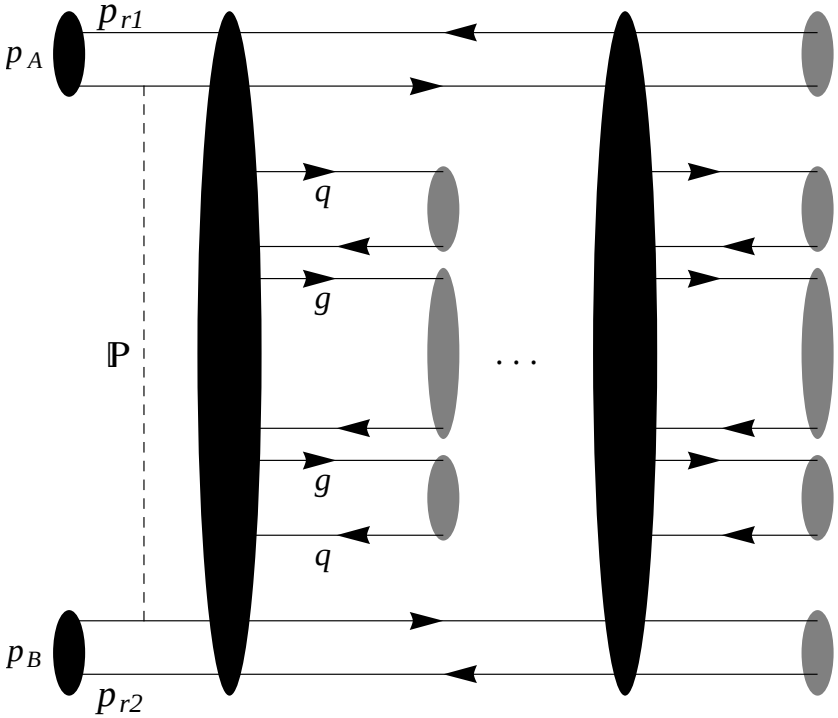
Reweighting

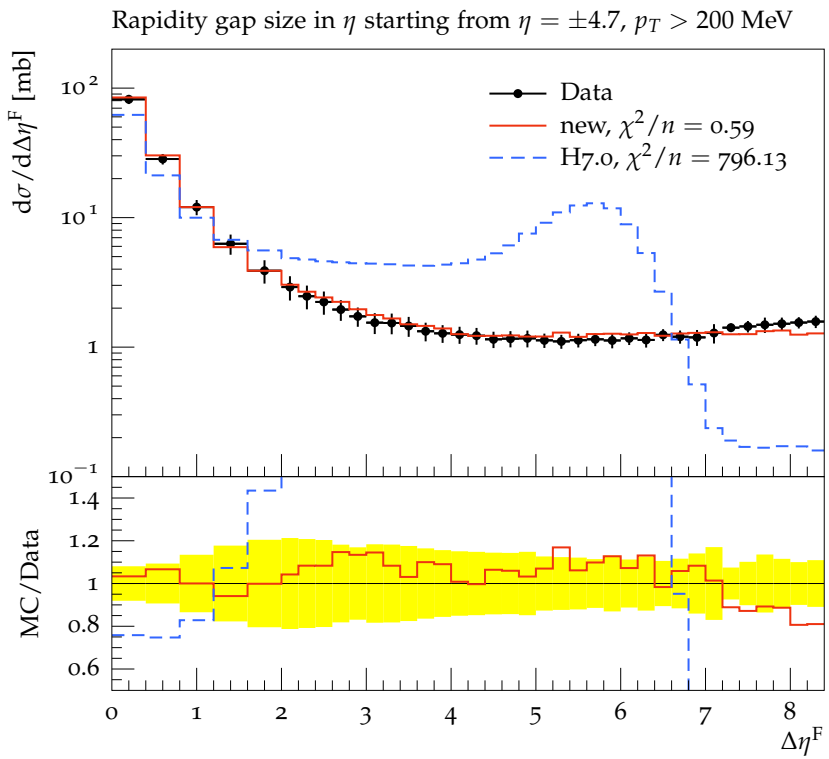


Bellm et. al. Phys.Rev. D94 (2016) no.3, 034028

Soft Physics

- Inclusion of diffraction
- New soft model.

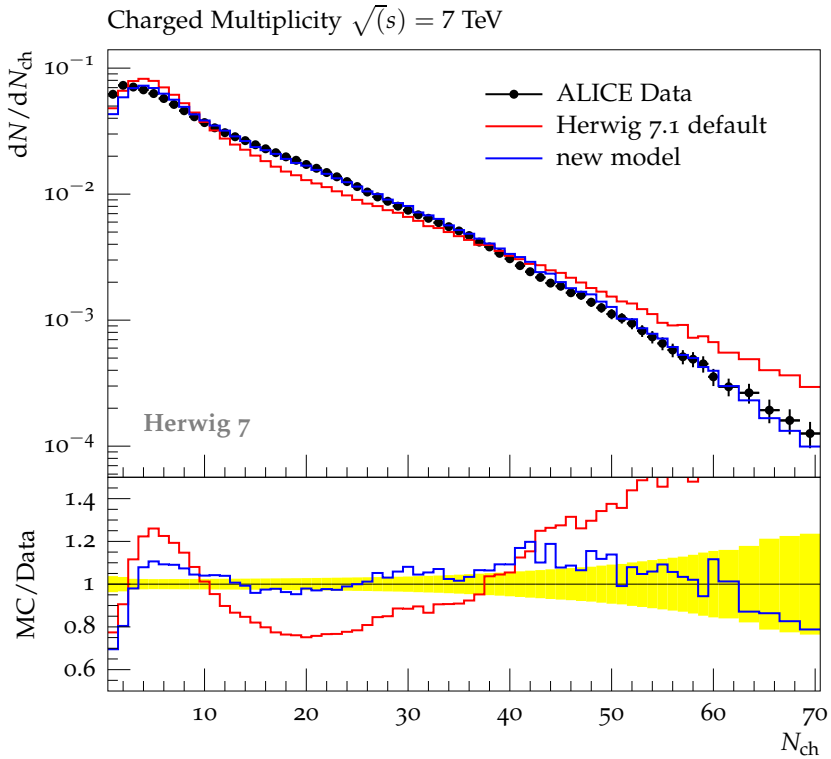




S. Gieseke, F. Loshaj, P. Kirchgaeßer Eur.Phys.J. C77 (2017) no.3, 156

Baryonic Colour Reconnection

- Allow recombination of mesonic clusters to give baryonic ones.
- Based on proximity in momentum space
- Include non-perturbative $g \to s\bar{s}$ splitting in the cluster model.



S. Gieseke, P. Kirchgaeßer, Simon Plätzer Eur.Phys.J. C78 (2018) no.2, 99

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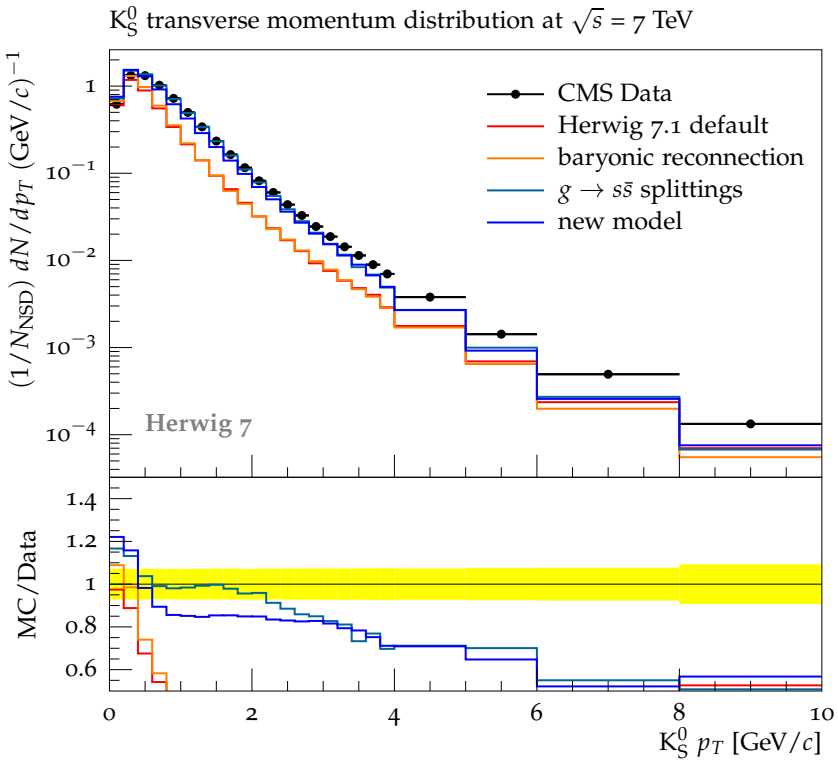

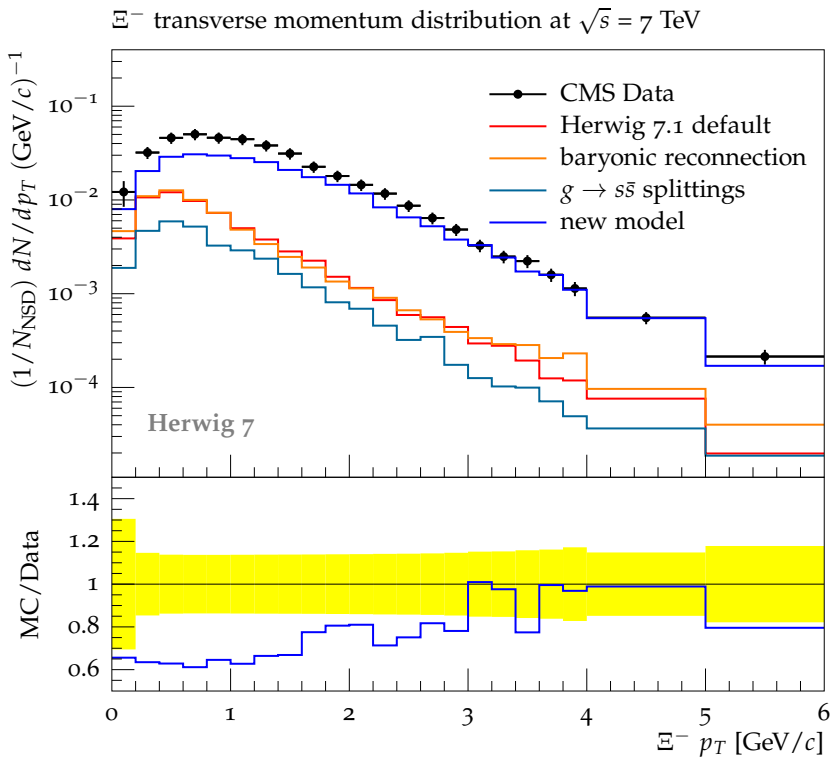

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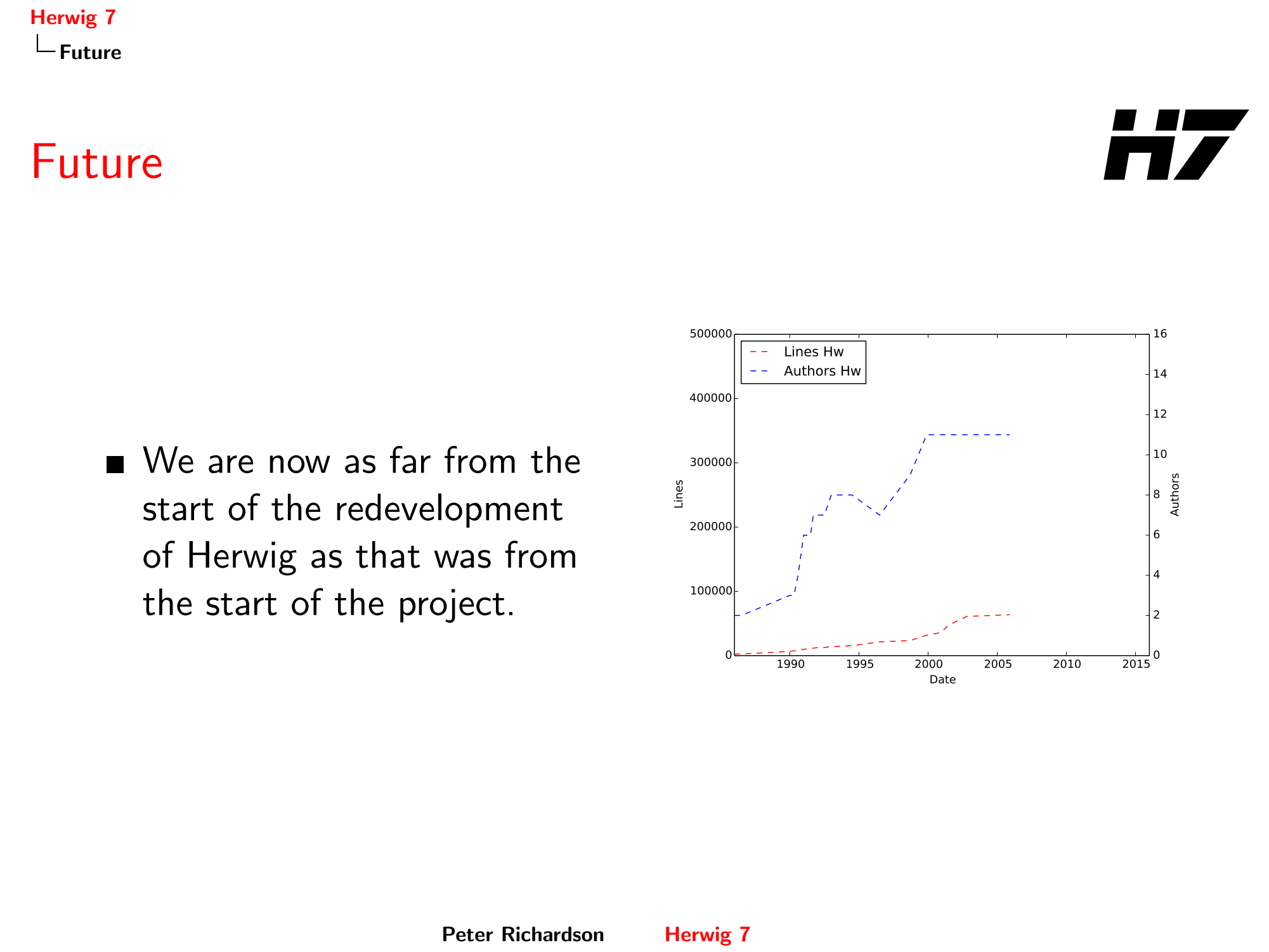
Future



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Future

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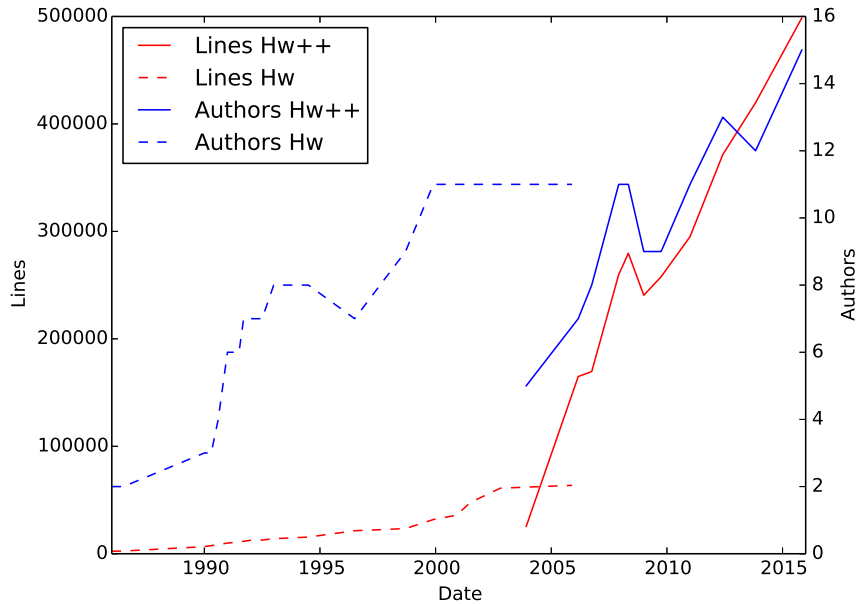
- The number of lines is again about a factor of 10 more than when the framework was designed.



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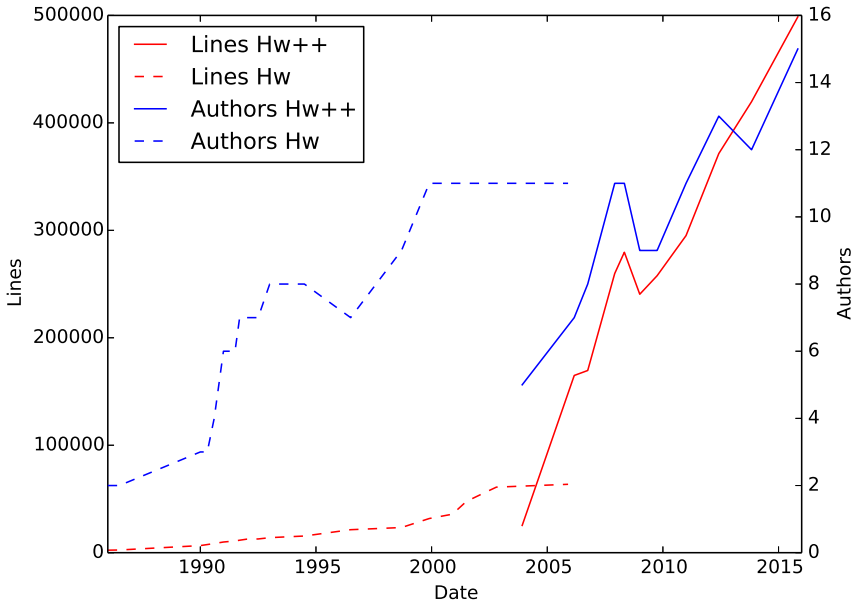

- We are now as far from the start of the redevelopment of Herwig as that was from the start of the project.
- The number of lines is again about a factor of 10 more than when the framework was designed.
- Not as bad as for FORTRAN as the structure was better in the first place but clearly for the next stage of development some significant restructuring of parts of the code will be required.

Recent Developments

- Matching:
  - Cormier, Plätzer, Reuschle, Richardson, Webster: Parton Shower and Matching Uncertainties in Top Quark Pair Production with Herwig 7, 1810.06493
  - Campanario, Figy, Plätzer, Rauch, Schichtel, Sjdahl: Stress testing the vector-boson-fusion approximation in multijet final states Phys.Rev. D98 (2018) no.3, 033003
  - LH17: Precision comparisons of predictions for Higgs boson + jet production at the LHC as a function of jet size
- Spin and (sub)leading N:
  - Bellm: Colour Rearrangement for Dipole Showers , Eur.Phys.J. C78 (2018) no.7, 601
  - Richardson, Webster: Spin Correlations in Parton Shower Simulations, 1807.01955
  - Martnez, De Angelis, Forshaw, Plätzer, Seymour Soft gluon evolution and non-global logarithms
  - Plätzer, Sjodahl, Thorn: Color matrix element corrections for parton showers, arXiv:1808.06770

Recent Developments

- MPI, Hadronization:
  - Gieseke, Kirchgaeßer , Plätzer: Baryon production from cluster hadronization, Eur.Phys.J. C78 (2018) no.2, 99
- Studies on the cross-talk between perturbative and non-perturbative modeling:
  - Hoang, Plätzer, Samitz: On the Cutoff Dependence of the Quark Mass Parameter in Angular Ordered Parton Showers , 1807.06617
  - Gieseke, Kirchgaeßer, Plätzer, Siodmok: Colour Reconnection from Soft Gluon Evolution, 1808.06770
- Heavy Ion modeling:
  - Bellm, Bierlich: PISTA: Posterior Ion STAcking, 1807.01291

Future Developments

- Noticeable all of these are physics improvements.
- That's what gets noticed in the theory community and therefore gets funding and jobs.
- In Herwig the biggest speed/memory improvement would be to improve the implementation of the NLO matrix elements and phase space integratiom.
- Man years of work for little recognition.

Conclusions

- The HERWIG project has taken over 30 years to reach the current state-of-the-art.
- It has been a constant series of incremental developments combined with occasional major changes in how we simulate events such as the move to NLO.
- Hopefully the next thirty years will see as much development.