Pythia8 Status Report

Stephen Mrenna
for the Pythia8 collaboration

PYTHIA

January 11, 2016

The Pythia8 Collaboration

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|  |   Torbjorn Sjostrand;  Department of Astronomy and Theoretical Physics,     |  |
|  |      Lund University, Solvegatan 14A, SE-223 62 Lund, Sweden;                 |  |
|  |      e-mail: torbjorn@thep.lu.se                                              |  |
|  |   Jesper Roy Christiansen;  Department of Astronomy and Theoretical Physics, |  |
|  |      Lund University, Solvegatan 14A, SE-223 62 Lund, Sweden;                 |  |
|  |      e-mail: Jesper.Roy.Christiansen@thep.lu.se                               |  |
|  |   Nishita Desai;  Institut fuer Theoretische Physik,                          |  |
|  |     Universitaet Heidelberg, Philosophenweg 16, D-69120 Heidelberg, Germany; |  |
|  |      e-mail: n.desai@thphys.uni-heidelberg.de                                 |  |
|  |   Ilkka Helenius;  Department of Astronomy and Theoretical Physics,          |  |
|  |      Lund University, Solvegatan 14A, SE-223 62 Lund, Sweden;                 |  |
|  |      e-mail: ilkka.helenius@thep.lu.se                                        |  |
|  |   Philip Ilten;  Massachusetts Institute of Technology,                       |  |
|  |      77 Massachusetts Ave, Cambridge, MA 02139, USA;                          |  |
|  |      e-mail: philten@cern.ch                                                  |  |
|  |   Stephen Mrenna;  Computing Division, Simulations Group,                     |  |
|  |      Fermi National Accelerator Laboratory, MS 234, Batavia, IL 60510, USA;  |  |
|  |      e-mail: mrenna@fnal.gov                                                  |  |
|  |   Stefan Prestel;  Theoretical Physics Group,                                 |  |
|  |      SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA;        |  |
|  |      e-mail: prestel@slac.stanford.edu                                        |  |
|  |   Christine O. Rasmussen;  Department of Astronomy and Theoretical Physics,  |  |
|  |      Lund University, Solvegatan 14A, SE-223 62 Lund, Sweden;                 |  |
|  |      e-mail: christine.rasmussen@thep.lu.se                                   |  |
|  |   Peter Skands;  School of Physics,                                           |  |
|  |      Monash University, PO Box 27, 3800 Melbourne, Australia;                 |  |
|  |      e-mail: peter.skands@monash.edu                                          |  |
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Physics changes in 8.215

* A new machinery for gamma-gamma collisions is now available. So far only hard processes can be generated, along with parton showers and hadronization, but without multiparton interactions.

* Double production of charmonium and bottomonium 3S1 states is now available, but with only the colour-singlet processes included.

* Weak merging implemented, i.e. W gauge bosons can be produced either as part of the hard matrix element or in the parton shower, and a proper treatment merges these two possibilities consistently.

* Improved interface to external parton showers, such as VINCIA and DIRE, so that these now also can use the various matching and merging frameworks implemented in Pythia.

* New options in the jet matching framework, such that expert users can use their own veto code for Madgraph-style jet matching.

* Possibility to run Madgraph5_aMC@NLO from within Pythia, by wrapping the Madgraph5_aMC@NLO executable inside a new LHAup-derived class.

* Hard diffraction model including the pomeron with MPI evolution

* New switches regulate whether the first shower branching before/after the hard process can correlate with the hard-process event plane.

Bug fixes in 8.215

* Bug found in timelike and spacelike showers, whereby the azimuthal anisotropy from gluon polarization in the past has been overestimated. This does not affect multijet rates, but can influence distributions sensitive to angular correlations, although checks have not revealed any appreciable effects. Thanks to Radek Zlebcik.
* Bug fix in the selection of masses in resonance decays. In rare situations this could give wrong masses for particles. Thanks to Are Raklev and Anders Kvellestad.
* Introduce protection against (close-to-)zero-energy partons in string length calculations, and against topologies with extremely small angles between two junction legs. Thanks to Jan Fiete Grosse-Oetringhaus.
* The StringFlav::combine(int, int bool) method is renamed combineId to avoid a potential incorrect overloading. Thanks to James Monk.
* Copy vertex information when a long-lived particle decays to three quarks, whereof two have such a small invariant mass that they collapse to a diquark. Thanks to Cristiano Alpigiani.
* Bug fix for excited quarks q^* and leptons l^*. If new decay channels were introduced they could incorrectly make use of the matrix element expressions for the existing decay modes. Thanks to Simone Amoroso.
* Bug fix in the kinematics of four or more resonance decay products when kinematics is redone owing to matrix-element corrections. Thanks to Simone Amoroso.
* Bug fix for information on the pdf value chosen for the hardest MPI, which was reported a factor 9/4 too large for an incoming gluon. Does not affect the event generation itself.
* Correct BeamRemnants:primordialKThard from 2.0 to 1.71 for ATLAS tune AZ. Thanks to Christian Bauer.
* Minor fix for random number start-up in the PowhegBox interface.
* Minor fixes and technical changes in the LHEF3 machinery.

Tunes

Monash tune remains our most up-to-date one.

We are interested in feedback about how it works (or not!) at 13 TeV.

It fails on p_T spectra (and rates) of identified particles, especially strange hadrons and baryons. This could be pointing to interesting physics (beyond “conventional” CR?).

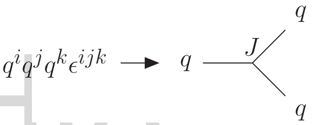
Further studies at the LHC would be greatly appreciated.

The new CR model

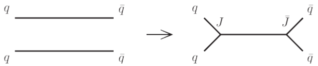
The new CR model reshuffles the colours just prior to hadronization based on three main principles:

- Use the SU(3) colour rules to determine if two strings are colour compatible
- Use a simplistic space-time picture to tell if the two strings coexist
- Minimize λ string-length measure to find which colour configurations Nature prefers

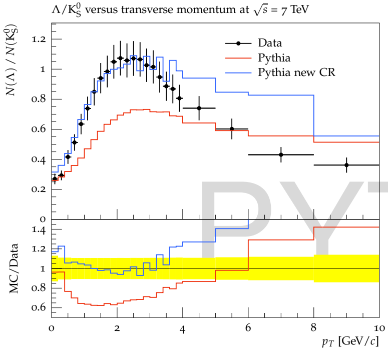
- Colour epsilon tensor corresponds to a junction structure

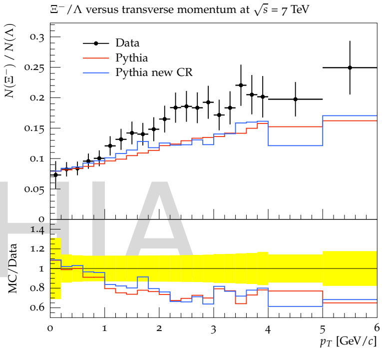


- New type of reconnection



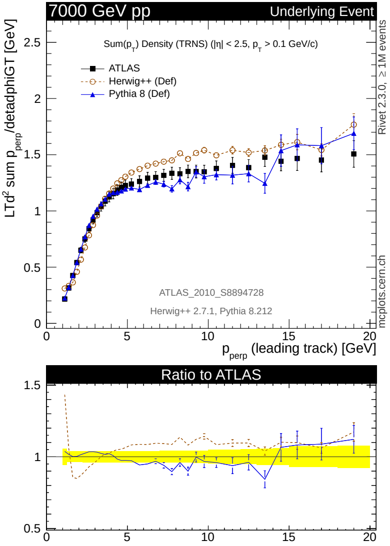
Tests - Λ / K_s and Ξ / Λ





- Λ / K_S is better described by the model (overall yield is tuned)
- (No rate change in e^+e^-)
- Ξ / Λ is the same as old model - no strangeness enhancement

mcplots.cern.ch

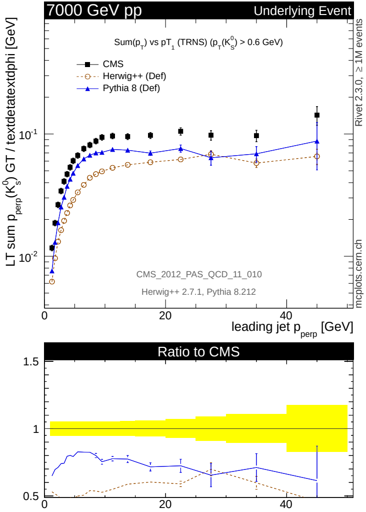


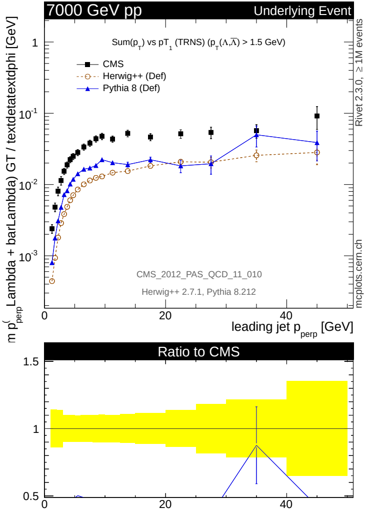
P. Skands, I. Charalimpidis, A. Karneyeu, D. Konstantinov, M. Mangano, L. Mijovic, S. Prestel

Reference: Eur Phys J C74 (2014) 1 (arXiv:1306.3436)

Very useful resource!

Comparisons for K_S and Λ Production





Double Quarkonia Production

requested by LHCb

- needed for double-parton scattering studies

short-distance matrix elements

- only unpolarized color singlet MEs included
- $gg \to QQQQ$ from C. Qiao, Phys. Rev. D66 (2002) 057504
- $qq \to QQQQ$ from B. Humpert and P. Mery, Z. Phys. C20 (1983) 83
- conditioned and tested for numerical stability
- tested against literature for LHC energies

long-distance matrix elements

- by default use the same values as for single color-singlet production
- can be set by user

user interface

- similar to updated quarkonia interface
- full control by user to specify arbitrary combinations
- no mixing between charmonium and bottomonium states
- multiplicity pre-factors handled in cross-section

Shower Plugins

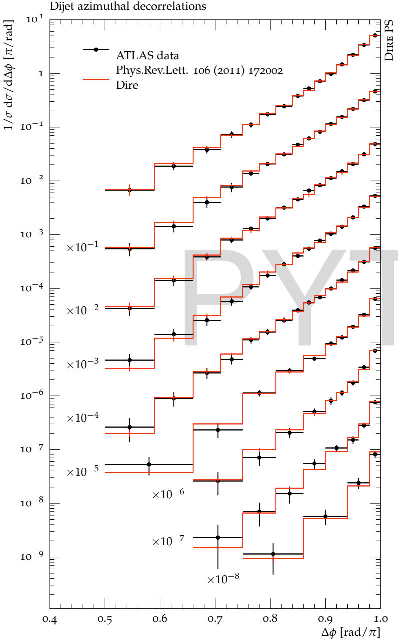
In addition to VINCIA, there is a new DIRE dipole-shower plug-in: arXiv:1506.05057

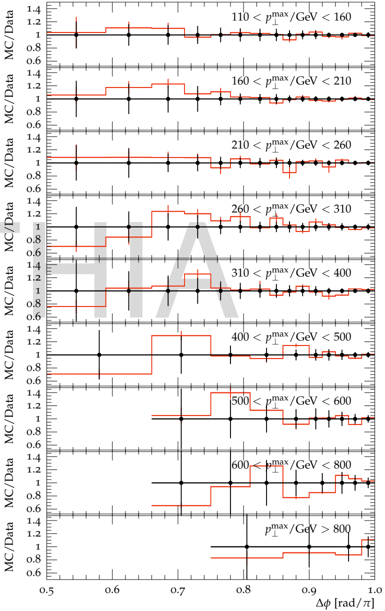
- Recovers eikonal in soft limit
- AP kernels in collinear limit
- "collinear" anomalous dimensions as in analytic resummation
- no choices introducing iffy subleading logs...

See `slac.stanford.edu/~prestel/DIRE`

Also a plugin for Sherpa.

LHC data comparisons (plain DIRE showering)



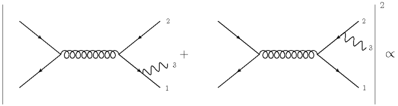


Weak Emissions in the Pythia8 Shower

One example: Implementation (s-channel)

- All 2-to-2 processes with a $q\bar{q}$-pair as outgoing particles uses the s-channel correction.
- The $g \to q\bar{q}$, $\gamma \to q\bar{q}$, $Z \to q\bar{q}$ and $W \to q\bar{q}'$ also uses the s-channel correction.
- Normal split of ME into ISR and FSR (i.e. no interference included).

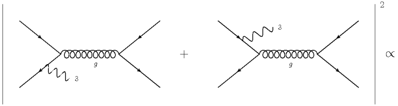
Final State Radiation



$$\frac{2r_3^4 + 2r_3^2(x_1 + x_2) + x_1^2 + x_2^2}{(1 - x_1)(1 - x_2)} - \frac{r_3^2}{(1 - x_1)^2} - \frac{r_3^2}{(1 - x_1)^2}$$

$$x_1 = \frac{2E_1}{E_{cm}}, \quad x_2 = \frac{2E_2}{E_{cm}}, \quad r_3 = \frac{m_3}{E_{cm}}$$

Initial State Radiation

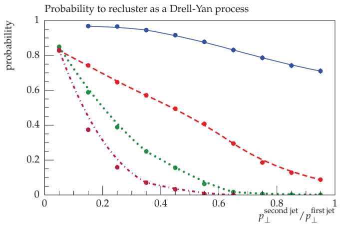


$$\frac{u^2 + t^2 + 2s(m_G^2 + m_3^2)}{ut} - \frac{m_G^2 m_3^2}{t^2} - \frac{m_G^2 m_3^2}{u^2}$$

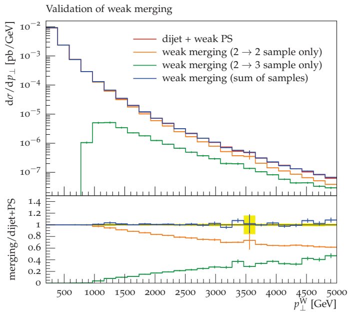
Weak Matching/Merging with the Pythia8 Shower

Validation

- Competition between reclustering as a Drell-Yan process or a $2 \to 2$ QCD process.



- Expect perfect transition between PS and ME for $2 \to 3$ process, since the PS uses ME corrections.



Matching/Merging Smorgasbord in Pythia8

- NLO matching: Described one jet multiplicity at NLO.
  Examples: aMC@NLO+PYTHIA 8, POWHEG-BOX+PYTHIA 8
- MLM jet matching: Combines multiple LO calculations by counting/matching jets to partons.
- FxFx jet matching: Combines multiple NLO calculations in MLM style.
  aMC@NLO+PYTHIA 8
- CKKW-L and UMEPS leading-order merging: Combines multiple LO calculations with each other and PS resummation.
- NLO merging: Combines multiple NLO calculations with each other and PS resummation in CKKW-L style.
  Examples: UNLOPS in PYTHIA 8

Scheme	Pro	Con
MLM	Simple to use, unweighted events, well-validated	Accuracy unknown
CKKW-L	Simple to use, now including EW Sudakovs	Weighted events
UMEPS	Well-defined LO inclusive cross sections	Large fraction of counter-events
MC@NLO	NLO for single process, simple to use	Non-coherent final-state shower
FxFx	NLO for multiple hard jets, well-validated	Shower accuracy unknown
UNLOPS	Well-defined NLO inc. x-sections for multiple jets	Large fraction of counter-events

MadGraph interface

simple yet flexible interface

- automatically determines run type, MG5 or aMC@NLO
- sets up jet matching (including jet multiplicity)
- integrates random seeds from Pythia
- allows for advanced user settings
- uses grid-pack settings to allow for fast(er) additional runs

user interface

- create LHAMadgraph interface object
- set MadGraph commands, usually "generate" and "set <parameter>" commands
- pass interface pointer to Pythia
- initialize and then run Pythia!

MadGraph interface (cont)

technical flow without prior run:

- creates configuration to override automatic HTML opening, etc.
- runs "output" with user "generate" stage commands
- initiates run with "launch" command
- grid-pack for MG5
- high accuracy for aMC@NLO (since no grid-pack)
- bundles aMC@NLO output into grid-pack
- creates universal run script
- creates events when needed with new random seed
- reads in gzipped LHE output

technical flow with prior run:

- creates events when needed with new random seed
- reads in gzipped LHE output

Example provided in distribution

```
#include "Pythia8/Pythia.h"
#include "Pythia8Plugins/LHAMadgraph.h"

using namespace Pythia8;

int main() {
  // Set up MadGraph interface.
  pythia = new Pythia();
  LHAupMadgraph mg5(pythia, true, "madgraphrun", exe);

  // Configure MadGraph. Note the need for a blank character before
  // "set", this is needed to run a set command during the launch
  // stage. Without the space the "set" command would be used in the
  // generate stage. The command "generate p p > mu+ mu- [QCD]" would
  // produce NLO events with FxFx matching.
  mg5.readString("generate p p > mu+ mu-"); // Process to generate.
  mg5.readString(" set ebeam1 6500");       // First beam energy.
  mg5.readString(" set ebeam2 6500");       // Second beam energy.
  mg5.readString(" set mmll 80");           // Minimum di-lepton mass [GeV].
  pythia->setLHAupPtr(&mg5);                            // Pass to Pythia.
  pythia->init();                                       // Initialize.
  for (int iEvt = 0; iEvt < 10000) pythia->generate();  // Run.
  delete pythia;                                        // Clean up.
}
```

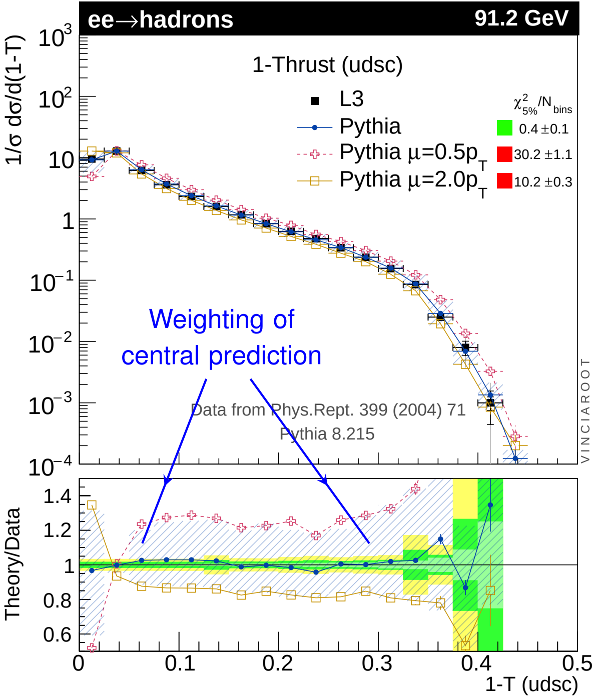
In Situ Shower Parameter Variation

To be included in an upcoming version (8.21x?):

- Includes renormalisation-scale and non-singular term variations
- Output = vector of alternative weights for each event
- quick estimate of uncertainties without needing separate runs
- a single sample to run through detector simulation etc.
- (hadronisation etc also only has to be carried out once).
- choose which variations you want, how large, correlated/uncorrelated

Note: simpler type of ME (hard parameter) weighting long available through `UserHooks`

Could be exploited in tuning


ee→hadrons
91.2 GeV
1-Thrust (udsc)
L3
Pythia
Pythia μ=0.5p_T
Pythia μ=2.0p_T
χ²_5%/N_bins
0.4 ±0.1
30.2 ±1.1
10.2 ±0.3
1/σ dσ/d(1-T)
Weighting of
central prediction
Data from Phys.Rept. 399 (2004) 71
Pythia 8.215
VINCIAROOT
Theory/Data
1-T (udsc)