

# Pythia 8.3 Update

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## Status

Pythia 8.301	is the latest release
Beams	$ee, ep, pp, \gamma x, pA, AA, DM$
Hard scattering	Core lib. of internal processes, otherwise from external tools. NLO+PS matching/merging with both aMC@NLO and POWHEG-BOX processes.
Parton shower	Three models: Default, Vincia and Dire.
Multiparton interactions	Regularized secondary $2 \rightarrow 2$ SM scatterings, interleaved with shower evolution.
Soft physics	Regge-based diffraction and x-sections
Fragmentation	String hadronization with Schwinger-based or thermal transition probabilities.

News: Code revamp under the hood (but should feel the same to users),

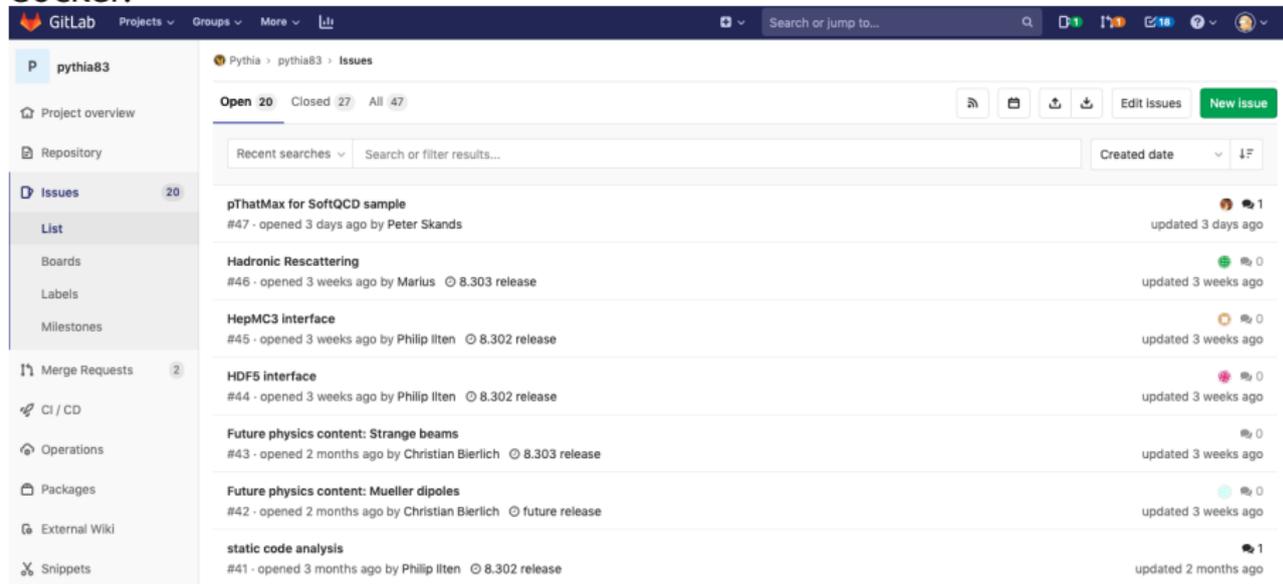
**Vincia & Dire now core components. New manual for 8.3:**

<http://home.thep.lu.se/~torbjorn/pythia83html/Welcome.html>

## New technical features I

Internal development at <https://gitlab.com/Pythia8>

Issue tracking ... and building unit testing & continuous integration w/  
docker.



The screenshot shows the GitLab interface for the 'pythia83' project. The left sidebar contains navigation options: Project overview, Repository, Issues (20), List, Boards, Labels, Milestones, Merge Requests (2), CI / CD, Operations, Packages, External Wiki, and Snippets. The main content area displays a list of issues. At the top, there are filters for 'Open 20', 'Closed 27', and 'All 47'. Below the filters is a search bar and a 'New Issue' button. The issue list includes:

- pThatMax for SoftQCD sample** (#47) - opened 3 days ago by Peter Skands. 1 comment, updated 3 days ago.
- Hadronic Rescattering** (#46) - opened 3 weeks ago by Marius. 0 comments, updated 3 weeks ago.
- HepMC3 interface** (#45) - opened 3 weeks ago by Philip Ilten. 0 comments, updated 3 weeks ago.
- HDF5 interface** (#44) - opened 3 weeks ago by Philip Ilten. 0 comments, updated 3 weeks ago.
- Future physics content: Strange beams** (#43) - opened 2 months ago by Christian Bierlich. 0 comments, updated 3 weeks ago.
- Future physics content: Mueller dipoles** (#42) - opened 2 months ago by Christian Bierlich. 0 comments, updated 3 weeks ago.
- static code analysis** (#41) - opened 3 months ago by Philip Ilten. 1 comment, updated 2 months ago.

Would a public bug tracker be useful? Should we expose more of our inner workings?

## New technical features II

For release testing, we start relying on containerization (docker), see e.g. <https://hub.docker.com/r/pythia8/dev/tags> or the tutorial <http://home.thep.lu.se/~prestel/Tutorials.html> and <http://home.thep.lu.se/~leifg/tutorials/> (still for 8.2, though)

We currently use a

- ◇ lightweight container for only Pythia
- ◇ heavyweight container to test all our dependencies
- ◇ a container to generate Python interfaces.

Should we make “blessed containers” available to the world?

## New technical features III: Lightweight python interface

Pythia 8.3 comes with a new light-weight python interface via [PyBind11](#), see <http://home.thep.lu.se/~torbjorn/pythia83html/PythonInterface.html>

```
1 # Import the Pythia module.
2 import pythia8
3 pythia = pythia8.Pythia()
4 pythia.readString("HardQCD:all = on")
5 pythia.readString("PhaseSpace:pTHatMin = 20.")
6 pythia.init()
7 mult = pythia8.Hist("charged multiplicity", 100, -0.5, 799.5)
8
9 # Begin event loop. Generate event. Skip if error. List first one.
10 for iEvent in range(0, 100):
11     if not pythia.next(): continue
12     # Find number of all final charged particles and fill histogram.
13     nCharged = 0
14     for prt in pythia.event:
15         if prt.isFinal() and prt.isCharged(): nCharged += 1
16     mult.fill(nCharged)
17 # End of event loop. Statistics. Histogram. Done.
18 pythia.stat();
19 print(mult)
```

... which allows inheritance. See `main01.py`, `main10.py` for `UserHooks` written in python  
... you can also regenerate the interface, if you e.g. change/introduce C++ headers  
(`UserHooks...`)

## Main new physics feature: Native Vincia/Dire

**VINCIA** and **DIRE** are now part of PYTHIA core code. You can just switch them on:

### ▼ Parton Showers

#### Shower Model Selection

##### The Simple Shower

- Timelike Showers
- Spacelike Showers
- Weak Showers
- Automated Variations

#### Antenna Showers (VINCIA)

- QCD
- QED

#### The Dire Shower

- Enhancements
- Expert Settings

#### Implement New Showers

mode **PartonShowers:model** (default = 1; minimum = 1; maximum = 3)

Choice of which shower machinery that will be used in PYTHIA (when not linking an external shower).

**option 1: Simple Showers.** This is the "old" shower framework that has its roots in PYTHIA 6 and hence is also more mature and stable, which is a reason why it for now remains as default. It also has several other features.

**option 2: VINCIA Showers.** Based on sequences of pT-ordered 2 → 3 branchings, the VINCIA shower provides a different (backwards-evolution) picture for initial-state radiation. The branching kernels, known as antenna kernels, are based on the current PYTHIA implementation includes QCD and QED 2 → 3 branchings with full mass dependence. Uncertainty variations and (iterated) matrix-element corrections, are not yet available in this version.

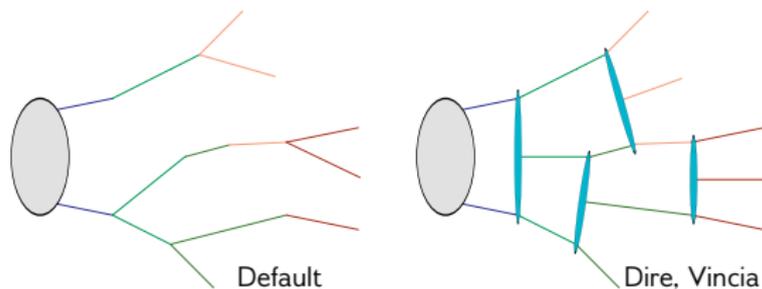
**option 3: Dire Showers.** Dire (short for Dipole resummation) implements a transverse-momentum ordered shower that is fully symmetric between radiator and spectator, while the overall emission probability is separated in the radiator and spectator, respectively. Dire includes QCD and QED emissions, a detailed treatment of (quark/lepton) emissions.

Further webpages, as linked above (and in the Parton Showers section of the left-column index), provide more details.

There are some differences between the showers to be aware of

Development of the plugins will be phased out over the next year or so.

## Main new physics feature: Native Vincia/Dire



### Default

- ◇ Improved DGLAP evolution in  $p_{\perp}$
- ◇ ME corrections for 1st splitting.
- ◇ QCD, QED, EW, hidden valley
- ◇ Extensive tuning expertise.

### Vincia

- ◇ Coherent evolution in 1/eikonal, antenna pattern
- ◇ Implements iterated LO matrix element corrections.
- ◇ QCD, QED, coherence in res. decays

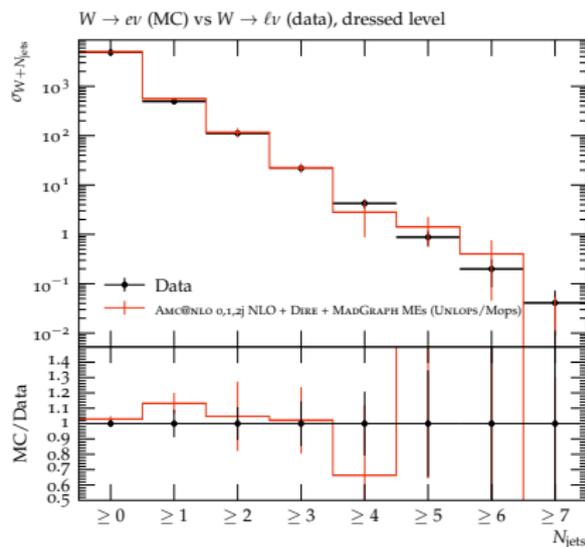
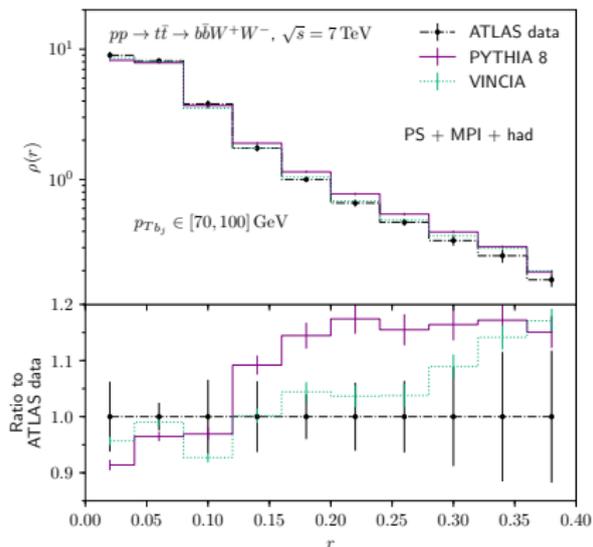
### Dire

- ◇ Coherent evolution in 1/eikonal, split into collinear regions
- ◇ Implements NLO corrections to evolution, matrix element corrections
- ◇ QCD, QED, iffy EW, dark photons

For usage, see [main200-202.cc](http://main200-202.cc) and [main300.cc](http://main300.cc) (which adds OpenMP)

# Physics features: Vincia and Dire matching/merging

plots from arxiv.org:1907.08980,1706.06218,1805.03757



Vincia and Dire employ C++ matrix-element code to perform MECs & merging  
⇒ New, more stable interface to MG5-generated C++ code. (thanks to V. Hirschi!)

## ToDo: Weight-handling overhaul

More and more parts of the code come with weights:

- heavy-ion event weight,
- merging weights,
- PS enhancement weights,
- Dire PS weights,
- LHE file multiweights,
- PS variation multiweights...

```
HepMC::GenCrossSection xsec;  
xsec.set_cross_section( pyinfo->sigmaGen() * 1e9,  
    pyinfo->sigmaErr() * 1e9);  
evt->set_cross_section(xsec);  
//evt->weights().push_back( pyinfo->weight() );  
for (int iweight = 0; iweight < pyinfo->numberOfWeights();  
    ++iweight) {  
    std::string name = pyinfo->weightNameByIndex(iweight);  
    double value = pyinfo->weightValueByIndex(iweight);  
    evt->weights()[name] = value;  
}
```

⇒ Want intuitive but flexible interface – and need to handle consistency internally.

Look for improvements in the next release – feedback will be very valuable!

## Bug fixes

- UncertaintyBands:ISRpTmin2Fac is correctly used in SimpleSpaceShower
- Stop growth of number of weights for multiple init calls
- SusyWidthFunctions.cc returns non-zero widths
- Dark matter masses from unused model selections not overwritten
- BSM Higgs and dark matter masses can be set without changing minMassSM
  
- The data files related to parton distributions have been moved to a new share/pythia8/pdfdata directory, and code has been changed accordingly
- Fix for width-lifetime issue not in this release

## Physics capabilities: Heavy ions

High-multiplicity (MinBias)  $pp$  collisions @ LHC suggest extreme QCD behavior, otherwise only seen in  $pA$  or  $AA$   $\Rightarrow$  Common model needed!

Use full PYTHIA diffractive, MPI, PS, hadronization machinery to develop a microscopic model of heavy-ion collisions  $\Rightarrow$  ANGANTYR mode.

...switched on by using heavy ion beams

```
Beams:idA = 2212           // Proton beam
Beams:idB = 1000822080    // Lead beam
Beams:eA = 4000           // Proton energy
Beams:eB = 1570           // Energy per lead nucleon
```

...see e.g. main112.cc and main113.cc examples.

Note: changes in PYTHIA's  $pp$  model (diffraction) feed down to  $AA$  description. Help from experiments with systematic tuning effort?

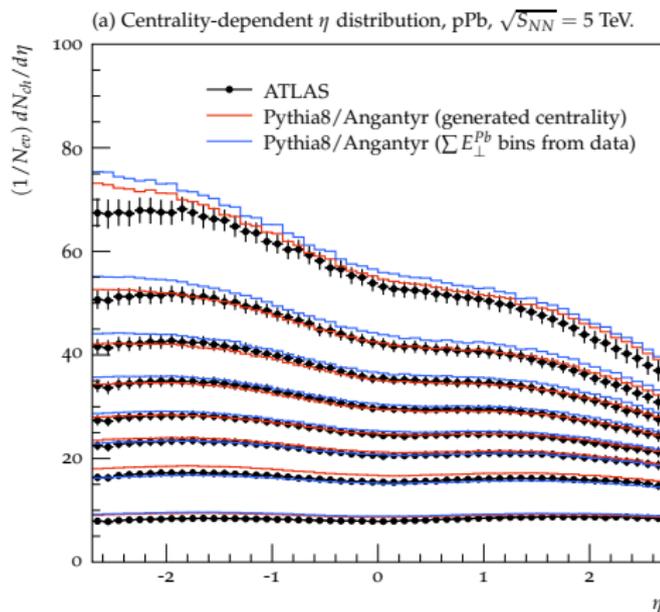
# Physics capabilities: Heavy ion cross sections

see <https://arxiv.org/abs/1806.10820>

## ANGANTYR approach:

- Derive model of nuclear initial state *including event-by-event fluctuations of nucleon wavefunctions*;
- Pick nucleon-nucleon sub-collisions from wounded-nucleon-inspired model;
- Generate & combine full PYTHIA events per subcollision, secondary wounded nucleons are diffractive-like events.

⇒  $\eta = 0$  looks  $\sim$  "high-E" scattering  
 $\eta \gg 0$  looks  $\sim$  diffractive-like event



Future: Scatterings could eventually interact, e.g. to produce collectivity.

## Summary

- PYTHIA 8.3 was released Oct. 30, 2019  
...and includes many technical and administrative updates.  
...we would value feedback on the new manual <http://home.thep.lu.se/~torbjorn/pythia83html/Welcome.html>, on using gitlab, docker containers and the new python interface!
- VINCIA and DIRE are now part of the core distribution, which will make use and comparisons much easier. Perturbative precision will continue to increase.
- Microscopic heavy-ion collision modeling major aspect of PYTHIA, addressing all things collective in  $pp$ ,  $pA$  and  $AA$  collisions in one framework.
- Many CMS-patches became part of the standard distribution