Pythia 8: soft QCD model, news and updates

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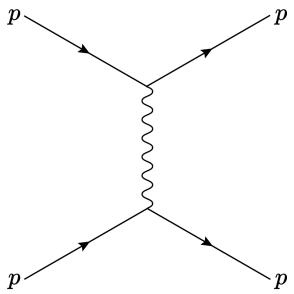
Overview

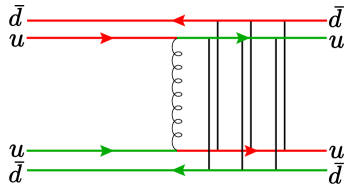
High and low energy hadronic interactions

- In the past, PYTHIA has been focused on experimental beam configurations like nucleon–nucleon at collider energies
- Other configurations are relevant in situations where secondary interactions can occur
  - Hadronic rescattering (low energy) [arXiv:2005.05658, arXiv:2103.09665]
  - Hadronic cascades in media (both low and high) [arXiv:2108.03481]
- The necessary ingredients for generalized interactions are cross sections (both total and partial) and descriptions of the processes involved.

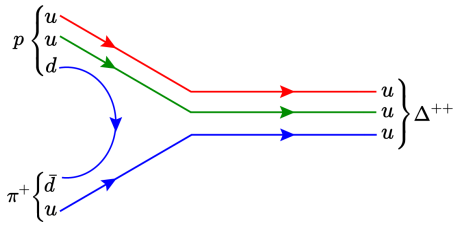
Low-energy interactions



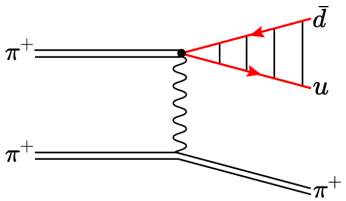
Elastic



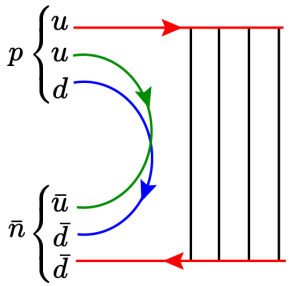
Non-diffractive



Resonant



Diffractive

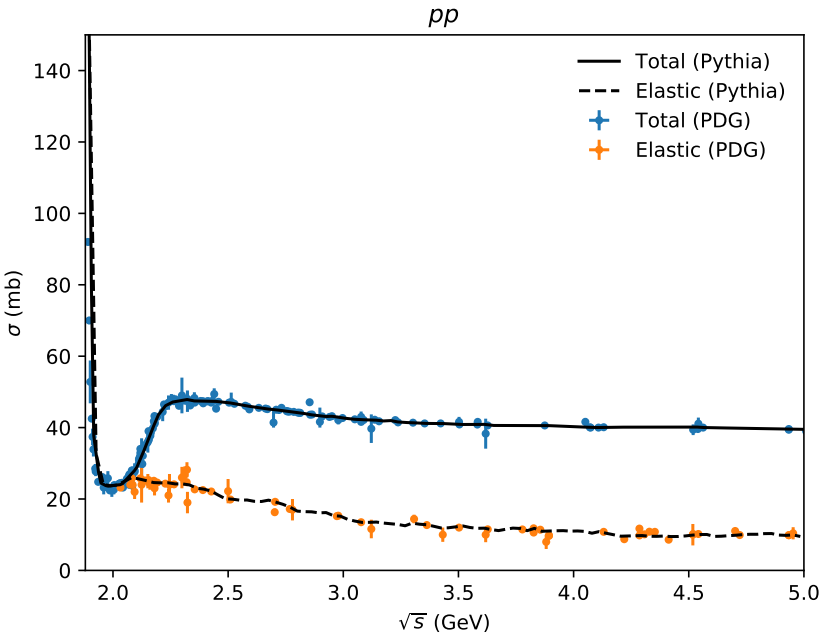


Annihilation

Low-energy collisions are simulated by turning on `LowEnergyQCD`.
Can combine with `SoftQCD` and `Beams:allowVariableEnergy`

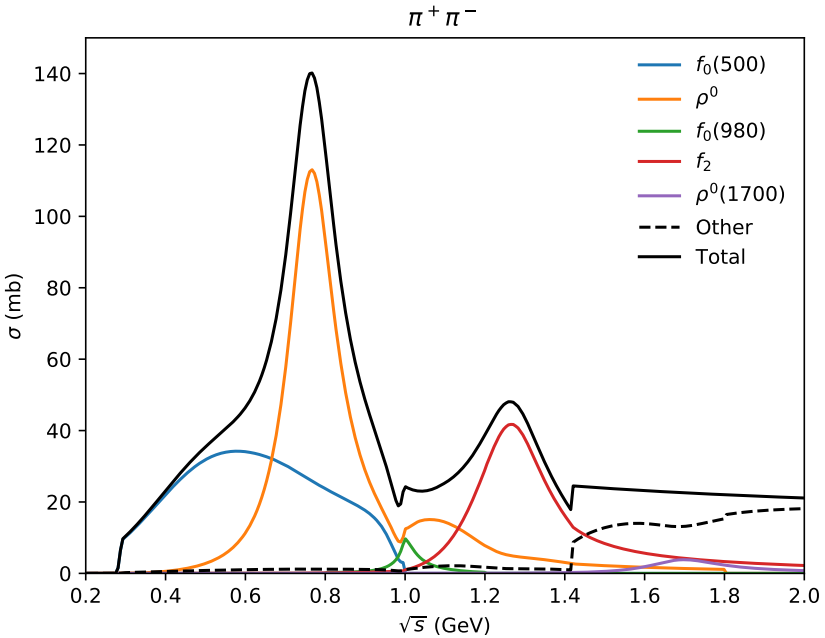
Cross sections

There are many special cases for low-energy cross sections.



Based on PDG data and HPR_1R_2 parameterization

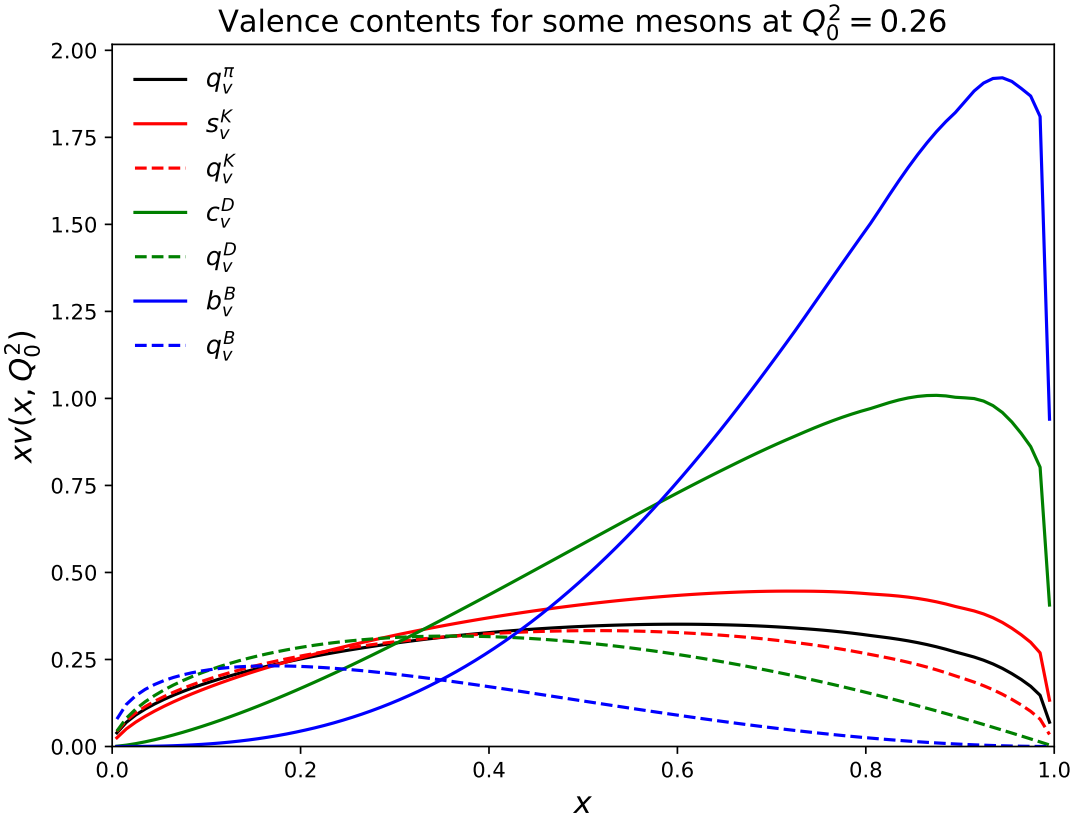
(DOI: 10.1103/PhysRevD.98.030001)



Based on work by Pelaez, Rodas, Ruiz de Elvira et al. [arXiv:1102.2183, arXiv:1907.13162, arXiv:1602.08404]

High-energy processes

The generalized high-energy hadron–nucleon interactions are modelled like nucleon–nucleon interactions, the difference being new PDFs and cross sections



High-energy cross sections

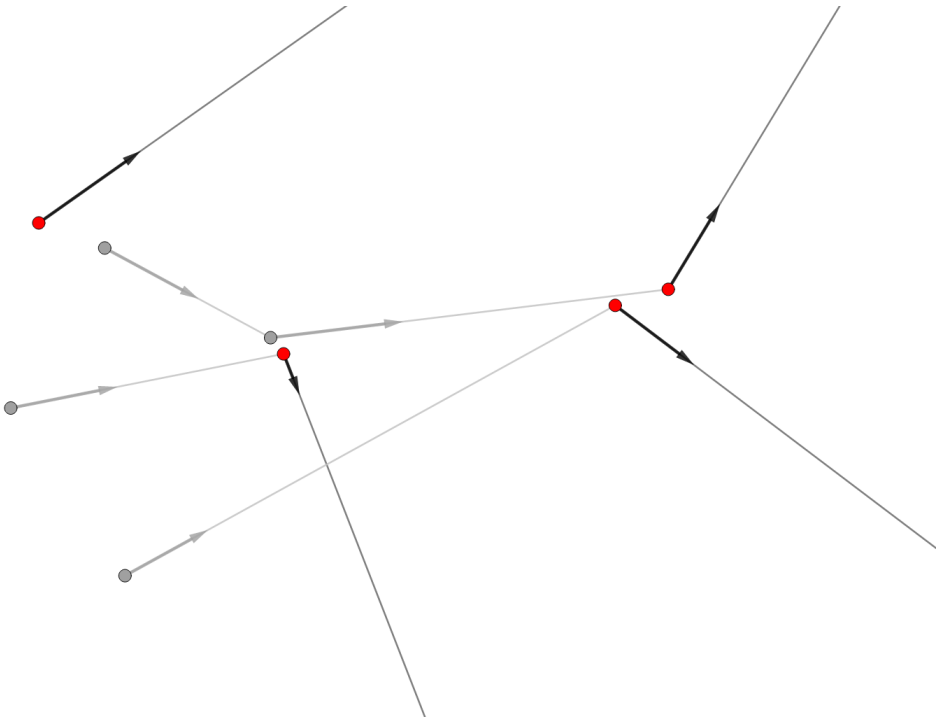
For high energy total cross sections, we use the Donnachie-Landshoff model:

$$\sigma_{AB}(s) = X^{AB} s^{\epsilon} + Y^{AB} s^{-\eta}$$

The coefficients X and Y are dependent on the hadron species. In the past, these were given for only a few beam combinations. We define further coefficients by rescaling the coefficients of existing combinations, using e.g. the Additive Quark Model (AQM).

Diffractive cross sections are based on the SaS ansatz, with parameters defined in terms of X^{pp} and X^{Ap}.

Hadronic rescattering



- PYTHIA offers a full spacetime picture, both for MPIs and hadronization
- Dynamic sized time-steps with interleaved decays of short-lived particles
- Geometric collision criterion. Interaction occurs at the time when particles pass each other in their rest frame

Using rescattering in PYTHIA

- `HadronLevel:Rescattering = on`
- To get correct multiplicity in pp collisions at 13 TeV, we use `MultipartonInteractions:pT0Ref = 2.345`
- Gives some significant effects, in particular a substantial amount of collective flow in Angantyr [`arXiv:2103.09665`]
- Can also be used for studies of specific resonances, such as exotic hadrons [`arXiv:2108.03479`], deuterons, $f_2(1270)$, etc., as alternative to coalescence models
- Simple to use, but relatively basic. For more sophisticated modelling, consider using e.g. the SMASH framework
- Open for future developments, but no specific features are currently in the works.

Angantyr

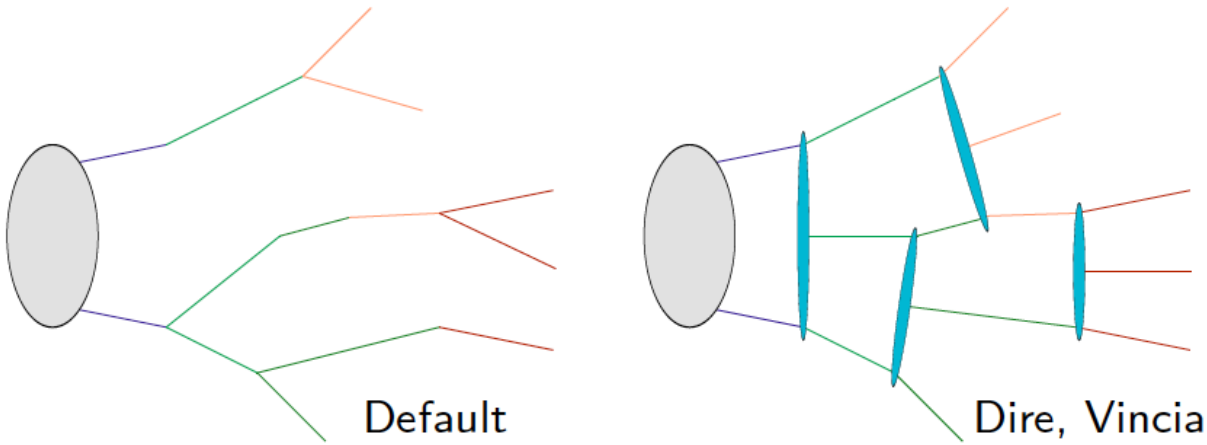
- Ongoing research with Angantyr is exploring whether collective effects can be explained without a quark–gluon plasma[1]
- String interactions have been added to Angantyr in the Gleipnir framework [arXiv:2010.07595]
  - Rope formation increases string tension, and can give e.g. strangeness enhancement [arXiv:1505.01681]
  - String shoving can give collective flow [arXiv:1412.6259, arXiv:1710.09725]
  - Future: color reconnection effects
- Planned feature: Electron–Ion Collider phenomenology

[1] See Smita Chakraborty's talk from Monday morning

PYTHIA parton shower models

Starting from version 8.301, PYTHIA offers three built-in parton showers. Select which one by using the `PartonShowers:model` setting:

1. PYTHIA default
2. Vincia [`arXiv:2003.00702`]
3. Dire [`arXiv:1506.05057`]



Comparison

1. The default PYTHIA shower is the most basic, and most flexible for use with external tools.
2. Vincia: based on antenna formalism
   - Coherent antennae, especially useful for UE
   - Recent developments include interleaved resonances and a detailed treatment of EW/QED [arXiv:2108.10786, arXiv::2002.04939]
   - Efficient LO merging at high multiplicity [arXiv:2008.09468]
3. Dire: dipole shower with close connection to DGLAP
   - Particularly accurate for uncorrelated jets
   - Includes NLO corrections to evolution [arXiv:1705.00742, arXiv:1705.00982, arXiv:1805.0375]
   - Recent developments include fixed colour [arXiv:2109.09706]

Future: NNLO + Parton Shower matching is on the todo-list for both Vincia [arXiv:2108.07133] and Dire

Summary

- The repertoire of available beam particles and energies has been extended, with applications to for example hadronic rescattering and hadronic cascades in media
- On the heavy ion side, there has been several developments. One of the main long-term objectives is to understand if QGP-like signals can have alternative explanations
- Vincia and Dire parton showers are integrated in PYTHIA. Future will focus, amongst other things, on NNLO effects
- The PYTHIA group has grown in recent years, and the framework is very much alive and evolving

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