

Hadronic Rescattering in Pythia

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MCnet virtual meeting, 30 April

Outline

The rescattering algorithm

Low energy processes

Results

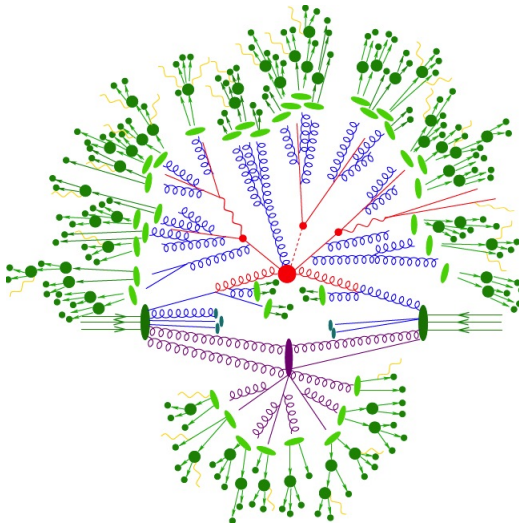
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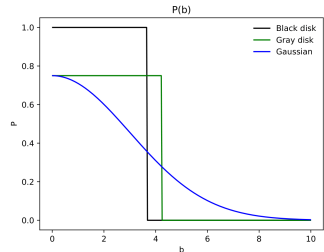
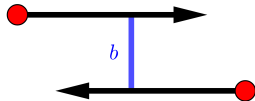
Results

What is rescattering?



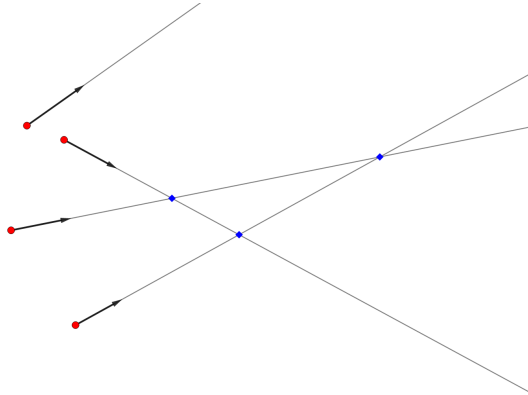
When do two hadrons interact?

The probability of an interaction depends on the cross section σ and the impact parameter b

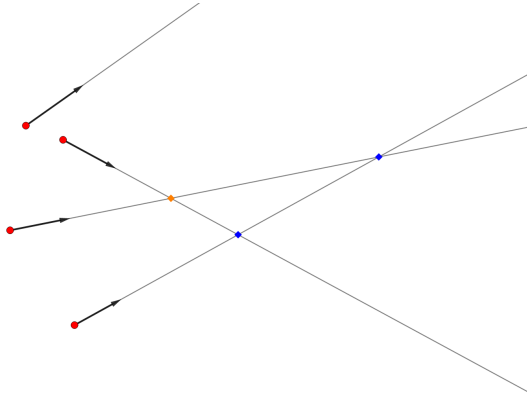


The characteristic range of the interaction is $b_{\text{crit}} = \sqrt{\sigma/\pi}$
The cross section σ depends on the particle types and the center-of-mass energy.

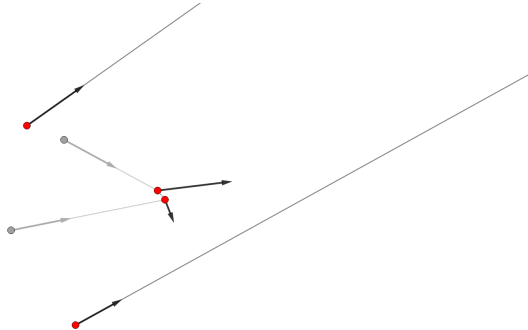
Looking at the whole event



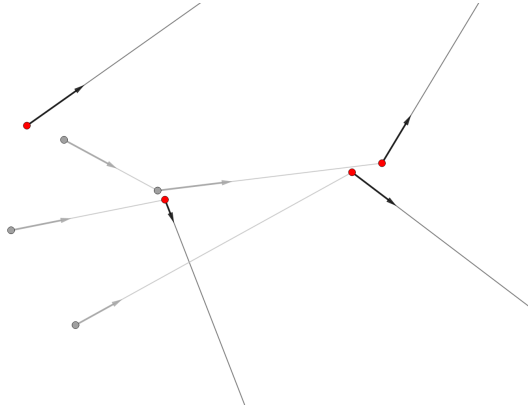
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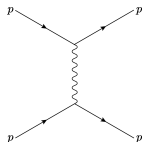
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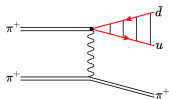
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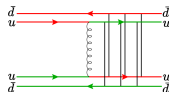
What happens when two hadrons collide?



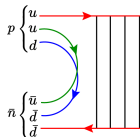
Elastic



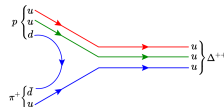
Diffractive



Non-diffractive



Annihilation



Resonant

Two-body systems

For elastic scattering, we only need to pick outgoing momenta.
We sample $t = (p_{\text{out}} - p_{\text{in}})^2$ according to

$$d\sigma_{\text{el}} \propto e^{B_{\text{el}}t} dt$$

$$B_{\text{el}} = 2b_A + 2b_B + 2\alpha' \ln\left(\frac{s}{s_0}\right)$$

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For diffractive scattering, $AB \rightarrow XB$, we also need to pick the diffractive mass M_X , i.e. rest energy of the system X .

$$d\sigma_{XB} \propto \left(1 - \frac{M_X^2}{s} \right) \frac{dM_X^2}{M_X^2} e^{B_{XB}t} dt$$

$$B_{XB} = 2b_B + 2\alpha' \ln \left(\frac{s}{M_X^2} \right)$$

String systems

For annihilation and non-diffractive systems, strings are formed between colour-anticolour pairs.

The evolution of a string is defined by the momenta of each endpoint (quark or diquark).

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- $$p^{\pm} = E \pm p_z.$$

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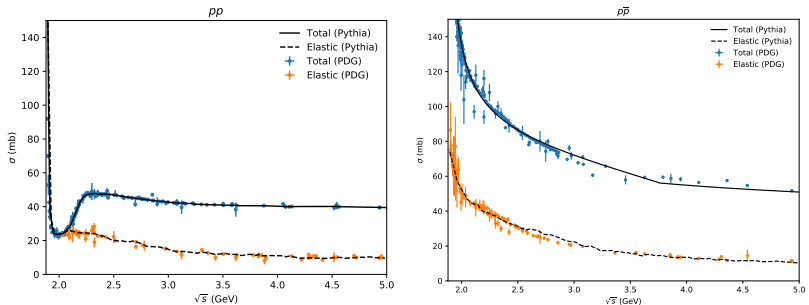
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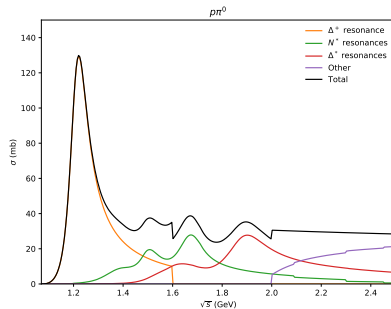
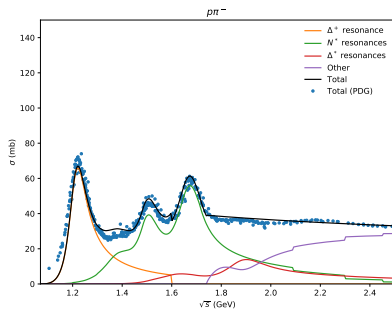
$$p^{\pm} = E \pm p_z.$$
3. Adjust configuration if it is invalid, e.g. if it violates energy conservation or it cannot produce new particles

Cross sections



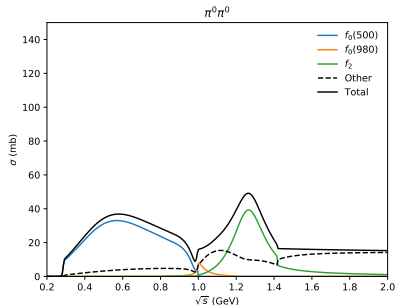
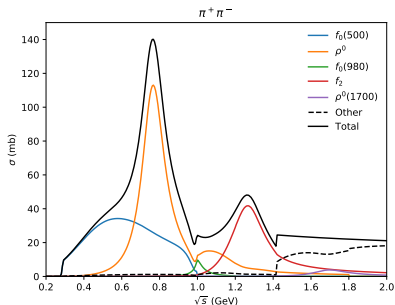
Based on UrQMD (arXiv:nucl-th/9803035)

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

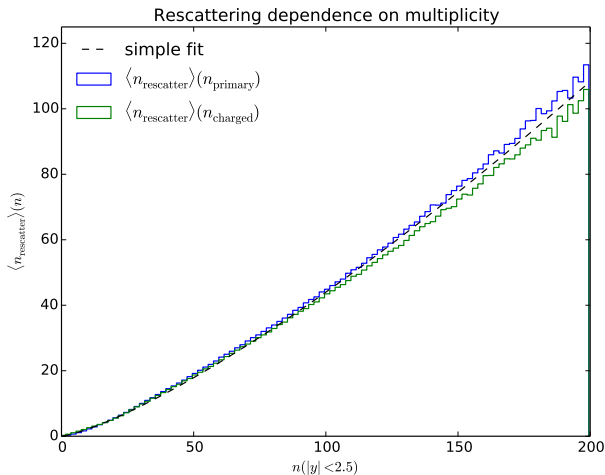
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Rescattering rates



simple fit $\propto n^{1.3}$

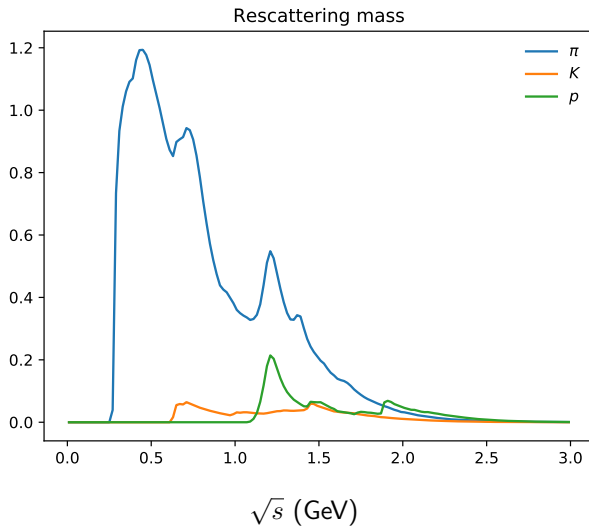
Rescattering rates

incoming	rate	incoming	rate
$\pi + \pi$	12.63	$K + N$	0.39
$\pi + \rho$	4.59	$\rho + \rho$	0.38
$\pi + K$	3.84	$\rho + N$	0.36
$\pi + N$	3.44	$\rho + \omega/\phi$	0.34
$\pi + \omega/\phi$	2.08	$\rho + \eta/\eta'$	0.30
$\pi + \eta/\eta'$	1.80	$\pi + f_0(500)$	0.29
$\pi + K^*$	1.33	$K + \omega/\phi$	0.27
$\pi + \Delta$	1.10	$K + K$	0.26
$\rho + K$	0.54	$\pi + \Lambda$	0.25
$\pi + \Sigma$	0.46	Other	3.70
$N + N$	0.46		
$K + K^*$	0.41	Total	39.22

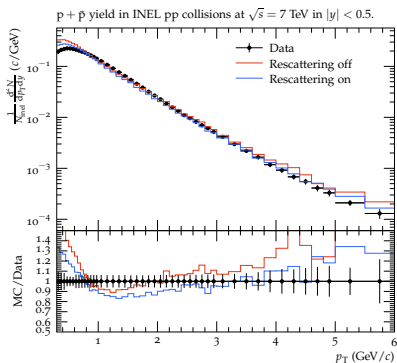
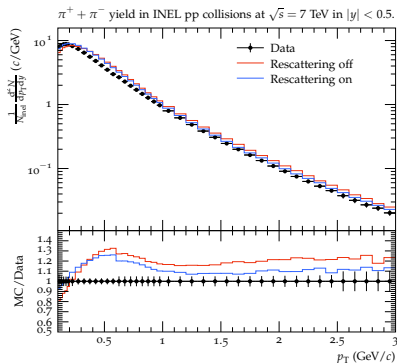
process	rate
resonant	17.80
elastic	14.08
nondiffractive	6.92
annihilation	0.49
diffractive	0.05

Rescatter rates, per inelastic event at 13 TeV

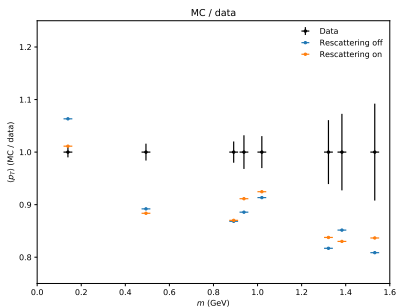
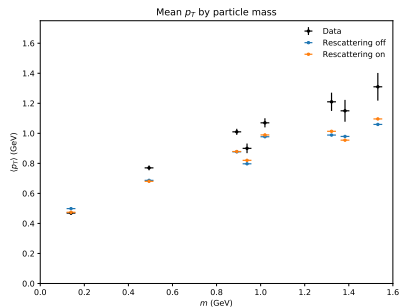
Rescattering invariant mass



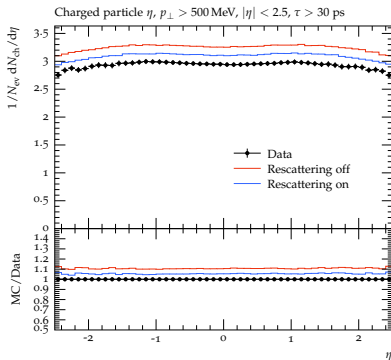
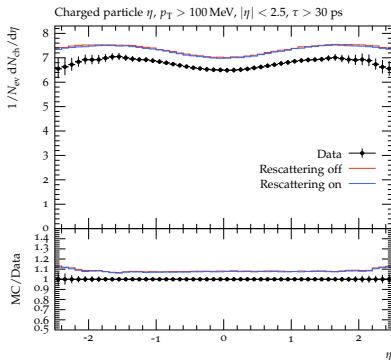
p_{\perp} spectra



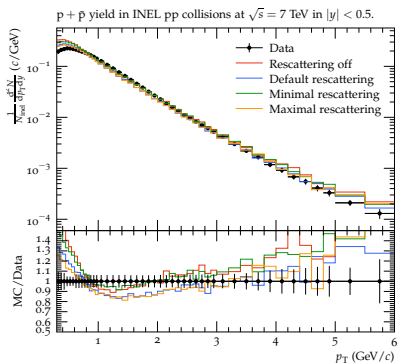
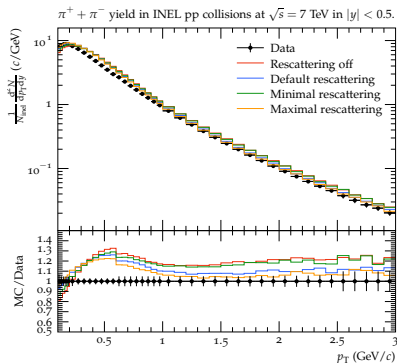
Mean p_{\perp}



η spectra



Model variations



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- ▶ Pythia can now simulate collisions all the way down to the threshold. This opens up for other applications, such as studying cosmic rays or in detector simulations like Geant4.
- ▶ The code will (hopefully) be released in Pythia 8.303.