RESCATTERING IN PYTHIA

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Why rescattering matters

Until recently, hadronic rescattering has been thought to have only a small effect on the properties of pp collisions, and implementing it in general purpose event generators has never been a priority. More recently, flow-like effects have been observed in pA and even pp collisions. It is unclear to what degree this can be explained by phenomena such as rescattering, color ropes, and shoving. Thus, even if the effect of rescattering on the final state is small, it might still be worth studying.

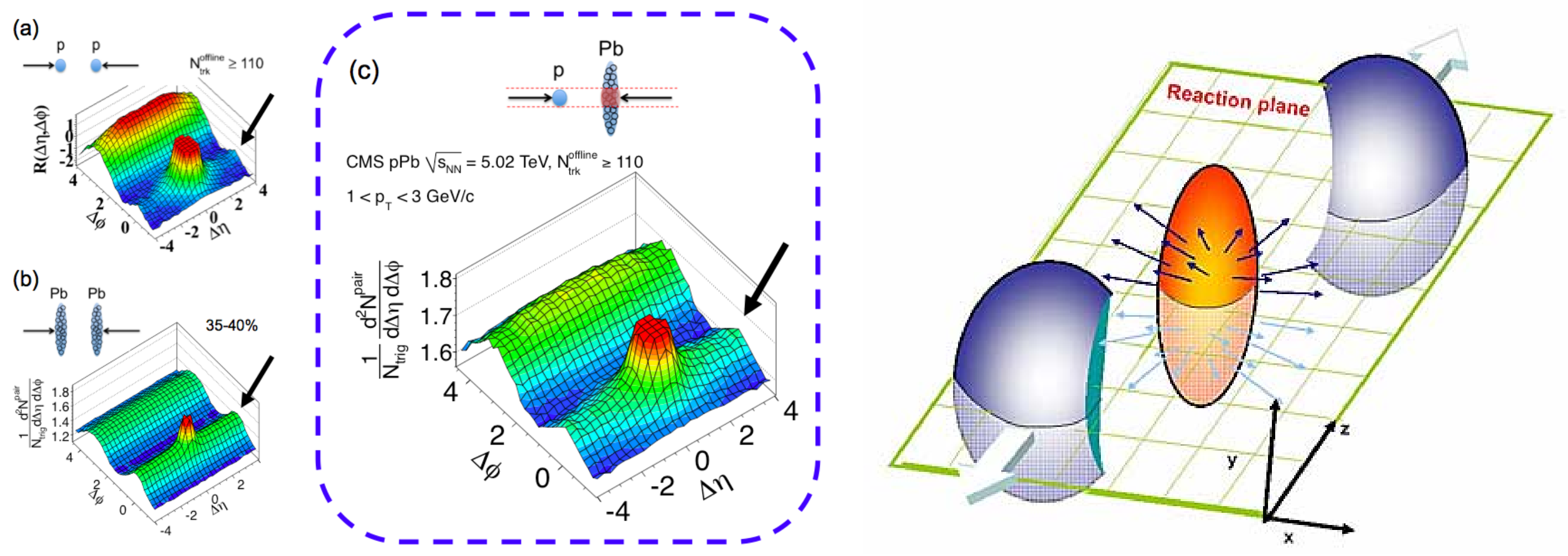


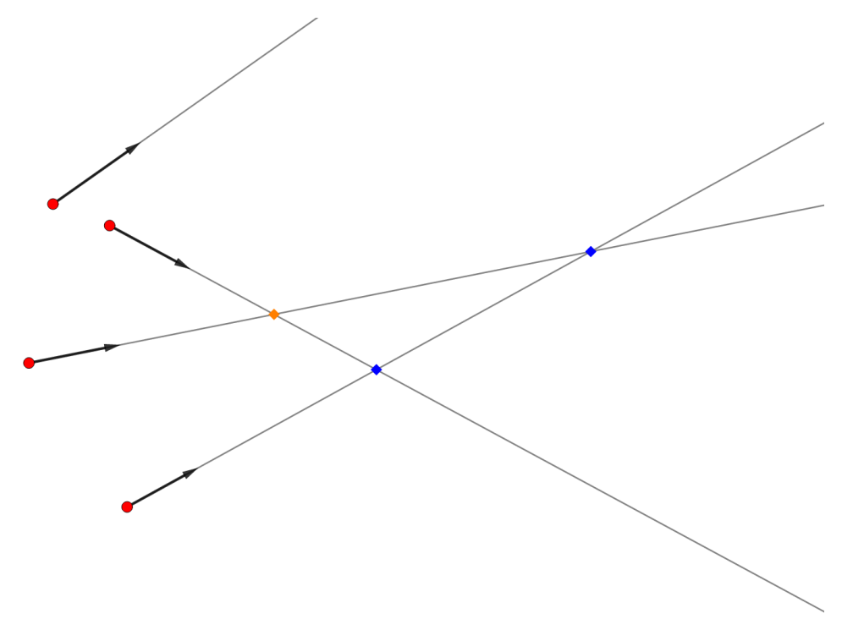
Image credit: CERN

This work is heavily inspired by UrQMD.

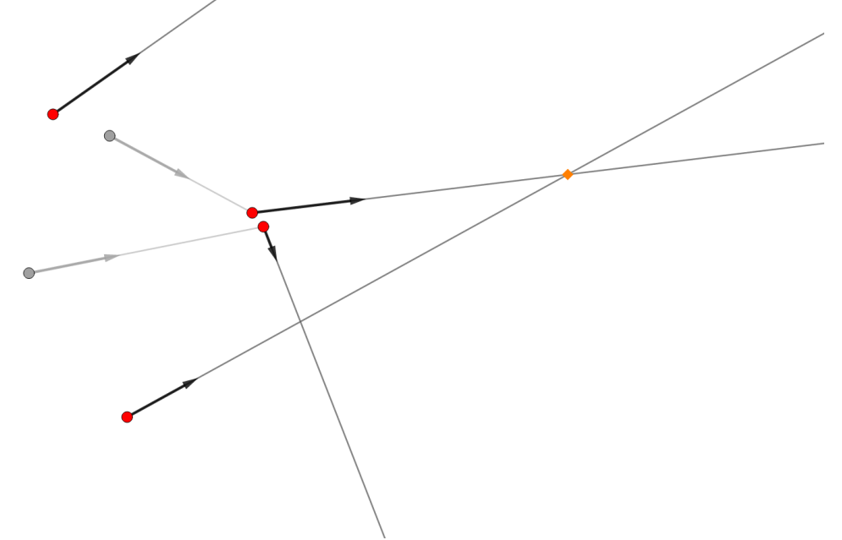
S. A. Bass et al. "Microscopic models for ultrarelativistic heavy ion collisions". In: *Prog. Part. Nucl. Phys.* 41 (1998). arXiv: `nucl-th/9803035`

The Rescattering algorithm

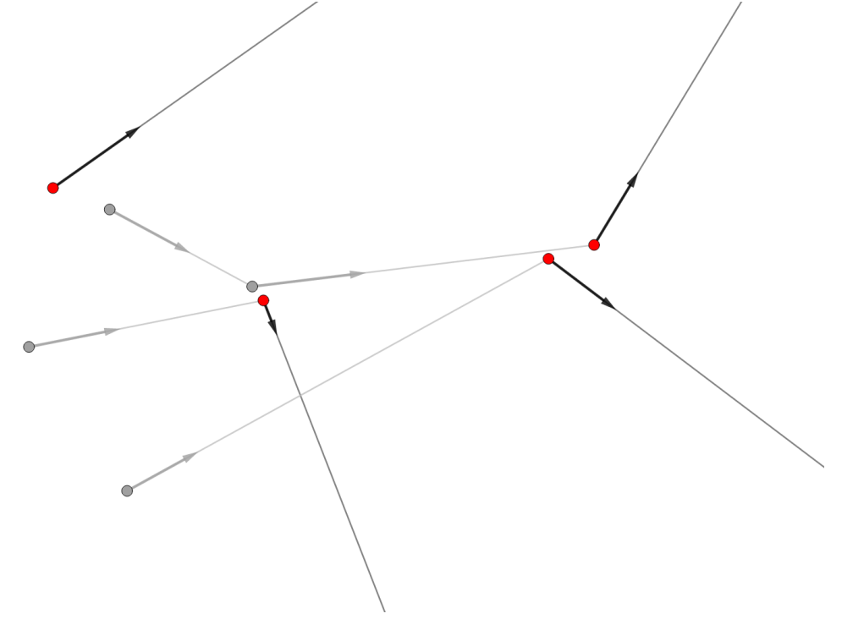
1. **List potential collisions chronologically**
   Two particles will interact if they pass each other at a distance $b < \sqrt{\sigma/\pi}$ in their rest frame. The cross section σ depends on the particle types and the CM energy.



2. **Perform the earliest collision**
   Then check if the new particles are on collision course with other particles. If so, add them to the list at the correct position in time.



3. **Repeat until there are no more collisions**
   If hadron decays are turned on, they should be performed in parallel with rescattering to ensure that things happen in the right order.

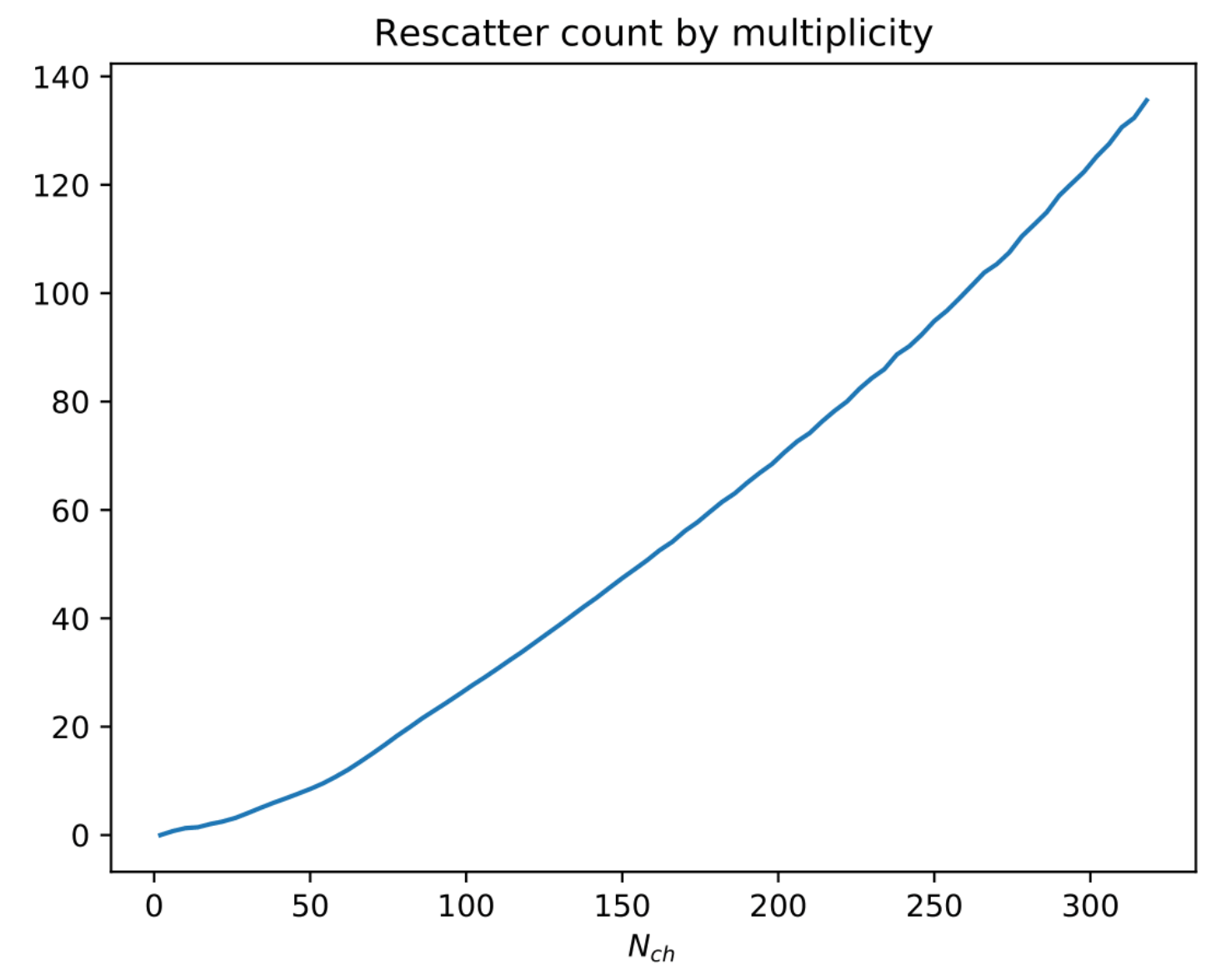


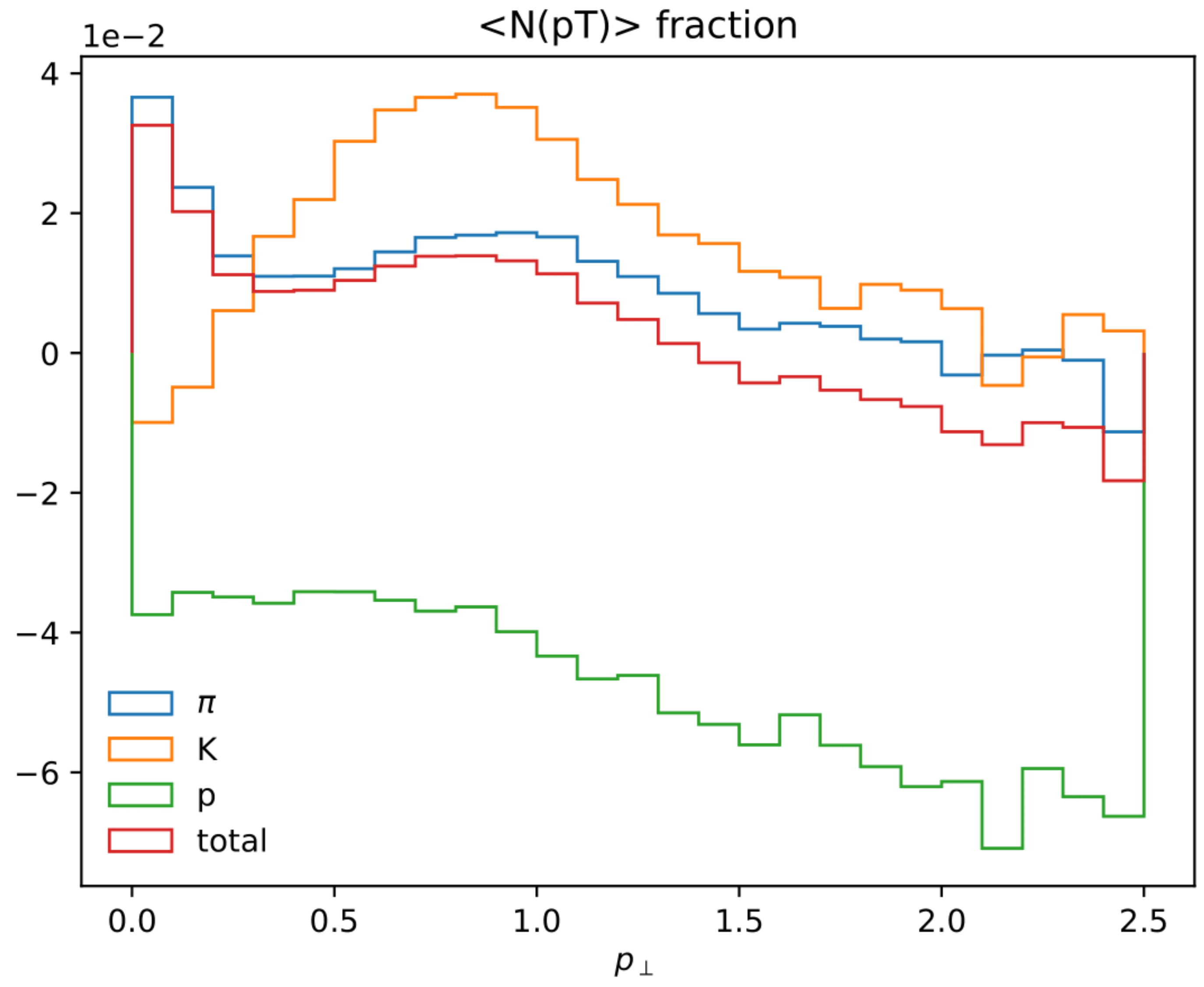
Preliminary results

For a constant hadronization region, one would expect the number of rescatterings to grow roughly as the square of the charged multiplicity, since

$$N_{\text{pairs}} \sim N_{\text{hadrons}}^2$$

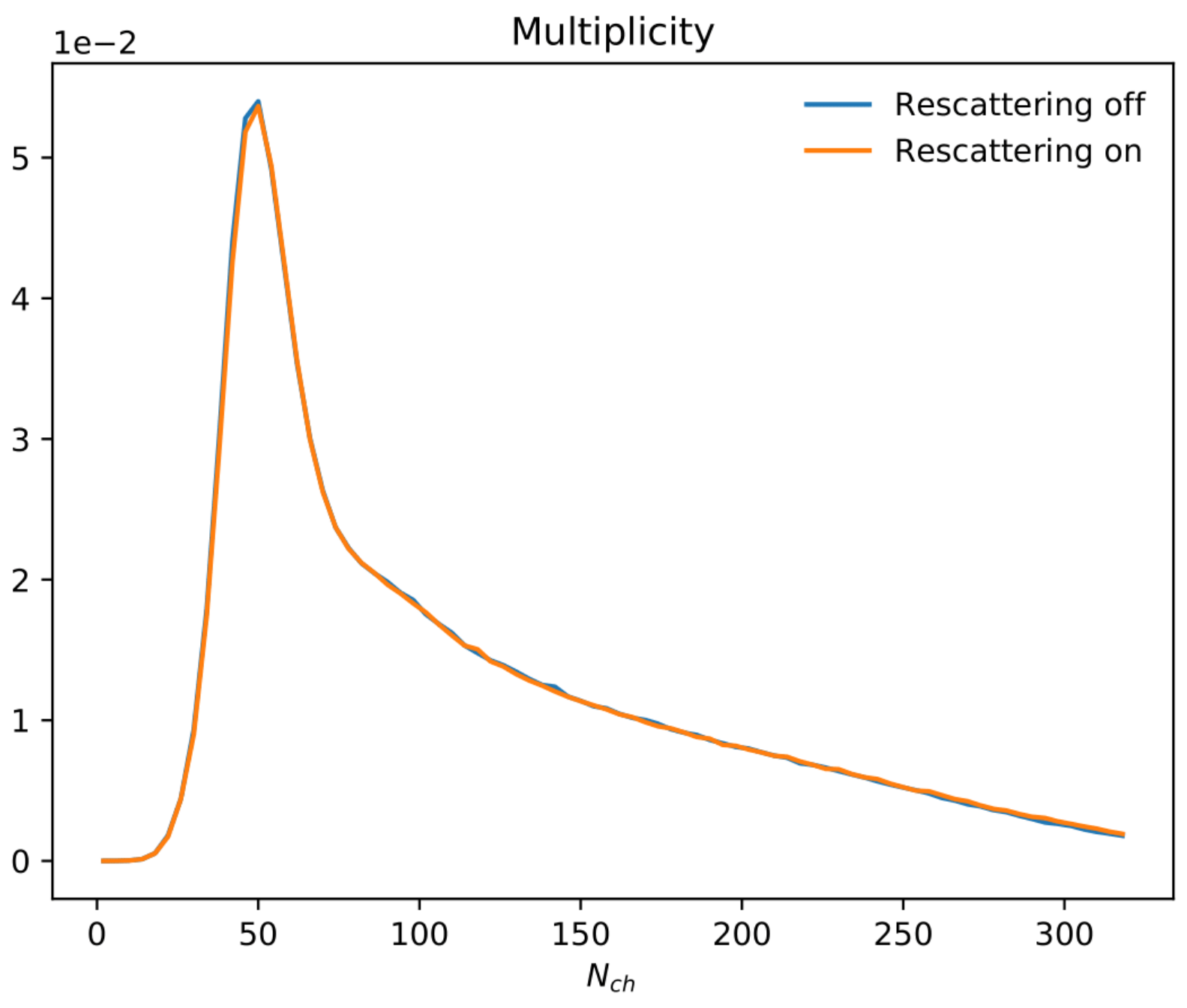
The hadronization volume increases for larger multiplicity however, so the observed rescattering growth is close to, but not quite quadratic.



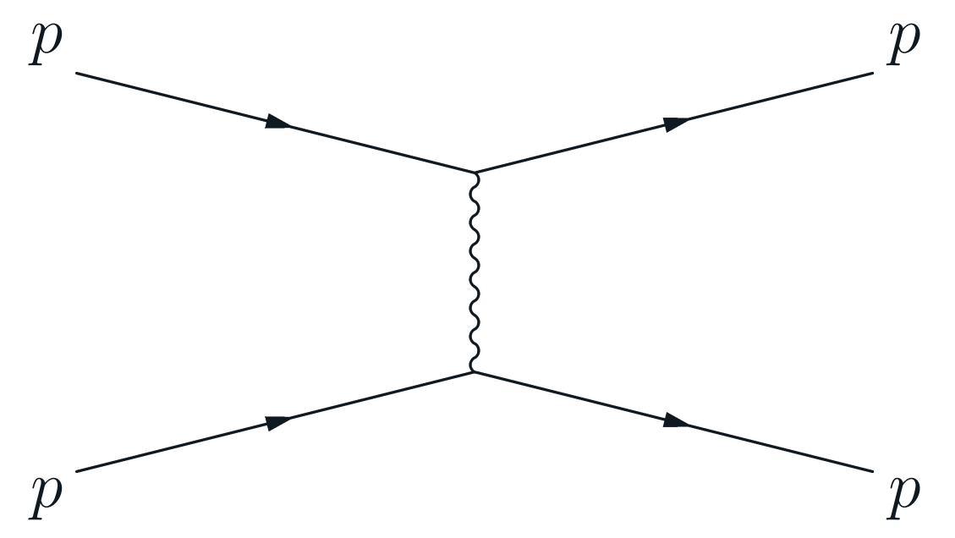


The most interesting observation is how the $p_\perp$ spectra of the different hadron species, specifically $\pi^\pm$, $K^\pm$ and $p^\pm$, are affected by rescattering. In string fragmentation, these hadrons all are produced at roughly the same $p_\perp$, but pions will move faster since they are lightest. Therefore we expect them to push against kaons and protons as they move away from the origin. That is, we expect pions to lose $p_\perp$, while the others gain $p_\perp$.

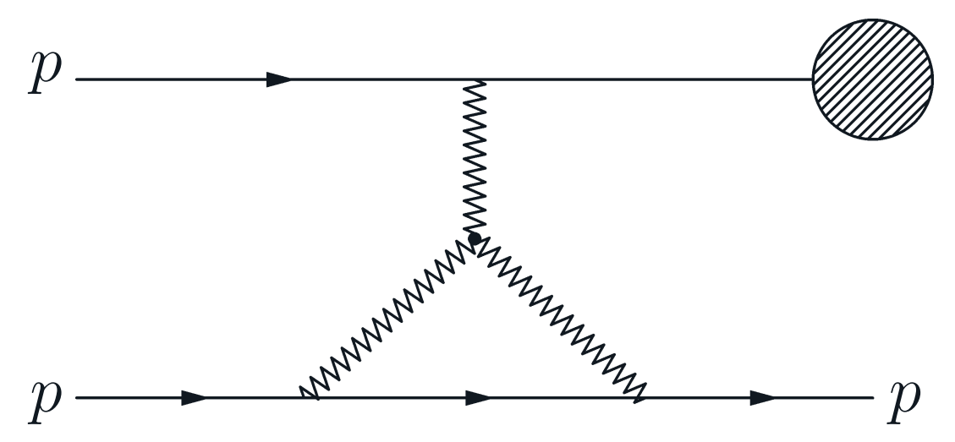
In accordance with conventional wisdom, we see that overall statistics such as charged multiplicity are not heavily influenced by rescattering



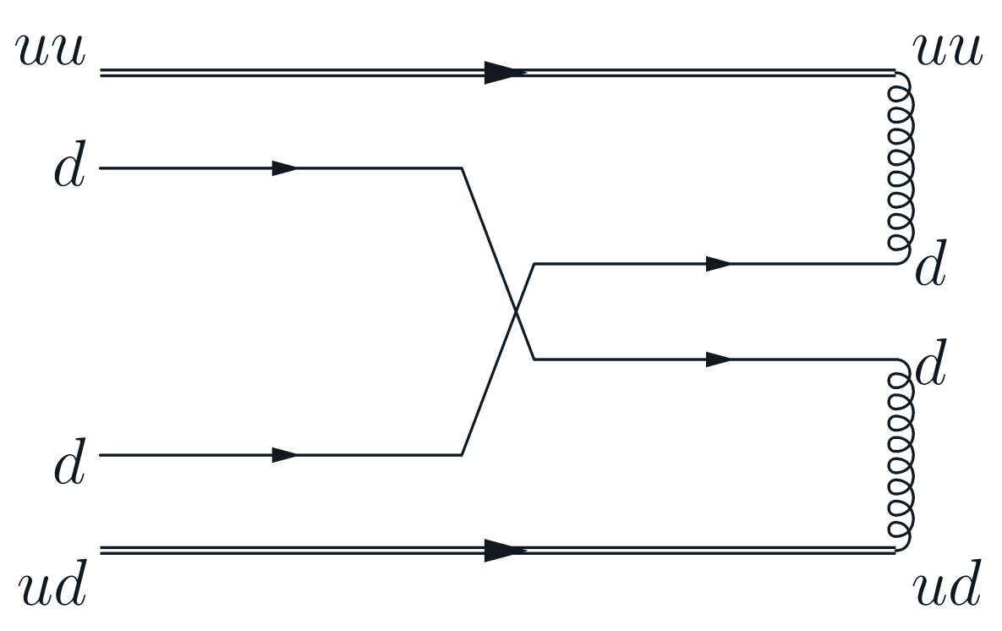
Low energy processes and cross sections



Elastic scattering refers to particles interacting and deflecting without changing their type. Elastic cross sections are calculated by interpolating data and using the CERN/HERA interpolation when available, and using the AQM model otherwise.

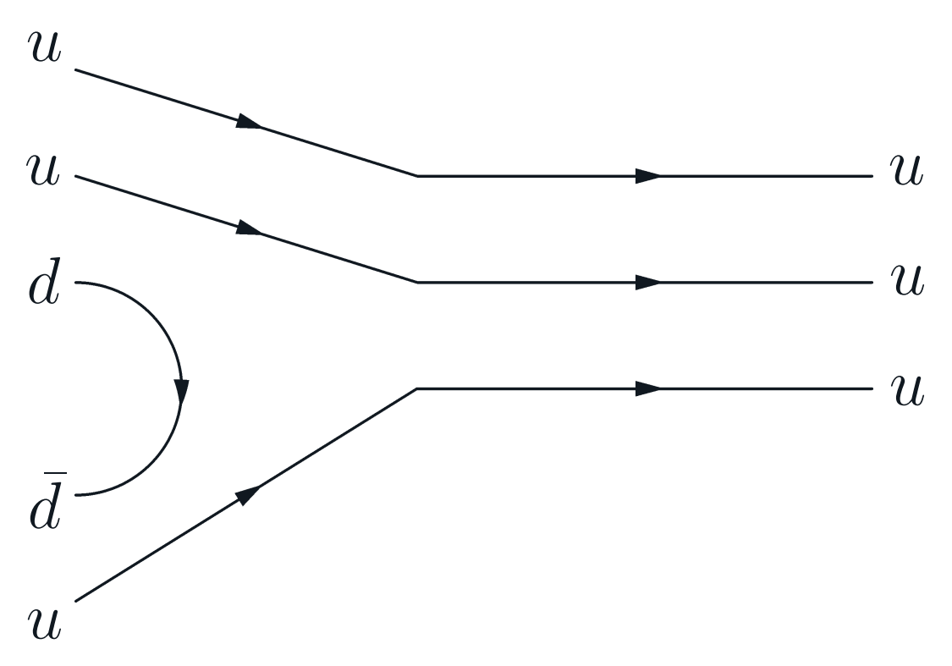


Diffractive scattering is when one or both hadrons become excited (referred to as single and double diffractive respectively) and turns into a string or a resonance particle. Diffractive cross sections are calculated using the SaS model.



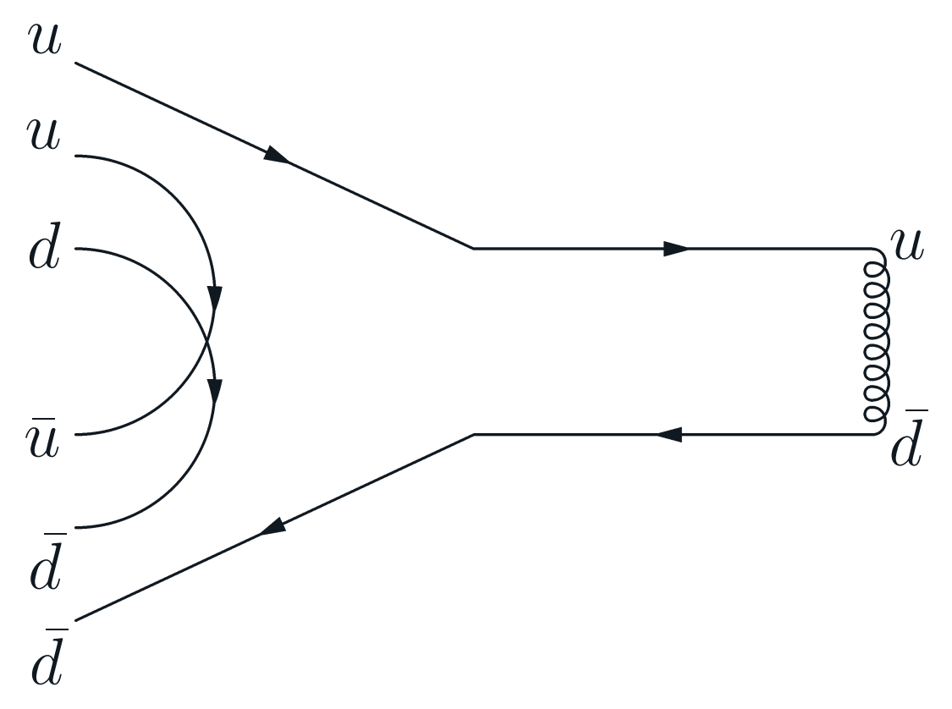
Non-diffractive processes are those where the two hadrons exchange a gluon and form strings between each other. The cross section is found by subtracting the other partial cross sections from the total one,

$$\sigma_{ND} = \sigma_{\text{tot}} - \sigma_{\text{el}} - \sigma_{\text{diff}} - \cdots$$



Resonance formation can happen when a meson is involved, and results in a single outgoing particle, for example $p\pi^+ \to \Delta^{++}$ or $\pi^+\pi^- \to \rho^0$. The cross section for the formation of a particular resonance R is given by

$$|\langle i_A i_B \mid i_R \rangle|^2 \times \frac{\pi}{\boldsymbol{p}^2}\frac{2S_R+1}{(2S_A+1)(2S_B+1)} \times \frac{\Gamma_R^2\,\mathrm{BR}_{R\to AB}}{(M_R-\sqrt{s})^2+\frac{1}{4}\Gamma_R^2}$$



Annihilation occurs in baryon-antibaryon collisions when quark-antiquark pairs annihilate. Strings are formed between the remaining quark-antiquark pairs. Cross sections for annihilation are found by parametrization for $p\bar{p}$. For all other cases, the cross section is a rescaling of this value.