Rescattering / Enhanced Screening

Richard Corke

Department of Theoretical Physics
Lund University

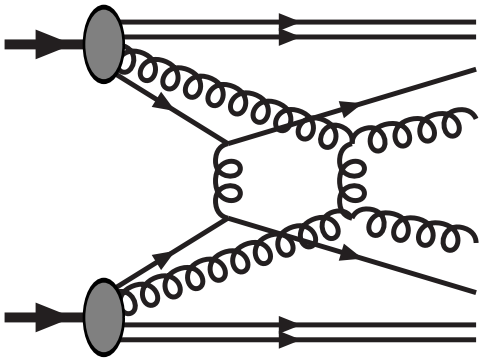
October 2008

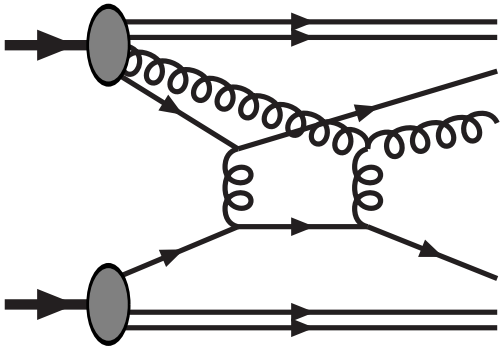
Overview

Rescattering

Introduction

- Consider a $4 \to 4$ and a $3 \to 3$ process





- Interaction cross-section

$$\frac{\mathrm{d}\sigma_{\mathrm{int}}}{\mathrm{d}p_\perp^2} = \sum \int \mathrm{d}x_1 \int \mathrm{d}x_2 \int f_1(x_1, Q^2)\, f_2(x_2, Q^2)\, \frac{\mathrm{d}\hat{\sigma}}{\mathrm{d}p_\perp^2}$$

- Paver and Treleani (1984)

$$\frac{\mathrm{d}\sigma_{\mathrm{int}}}{\mathrm{d}p_\perp^2} \sim N_1 N_2\, \hat{\sigma}$$

$$\sigma_{4\to4} \sim (N_1 N_2\, \hat{\sigma})(N_1' N_2'\, \hat{\sigma}) \qquad \sigma_{3\to3} \sim (N_1 N_2\, \hat{\sigma})(N_1'\, \hat{\sigma})$$

$$\frac{\sigma_{3\to3}}{\sigma_{4\to4}} \sim \frac{1}{N_2'} \to \text{small}$$

Rescattering

Rescattering in PYTHIA 8

- Typical case of small angle scatterings between partons from 2 incoming hadrons, such that they are still associated with their original hadrons

$$f(x, Q^2)\,\mathrm{d}x \to f(x, Q^2)_{rescaled}\,\mathrm{d}x + \sum_n \delta(x - x_n) = f_u(x, Q^2) + f_\delta(x, Q^2)$$

where the subscript u/δ is the unscattered/scattered component

$$\int_0^1 x\, f_{rescaled}(x, Q^2) dx + \sum_n x_n = 1$$

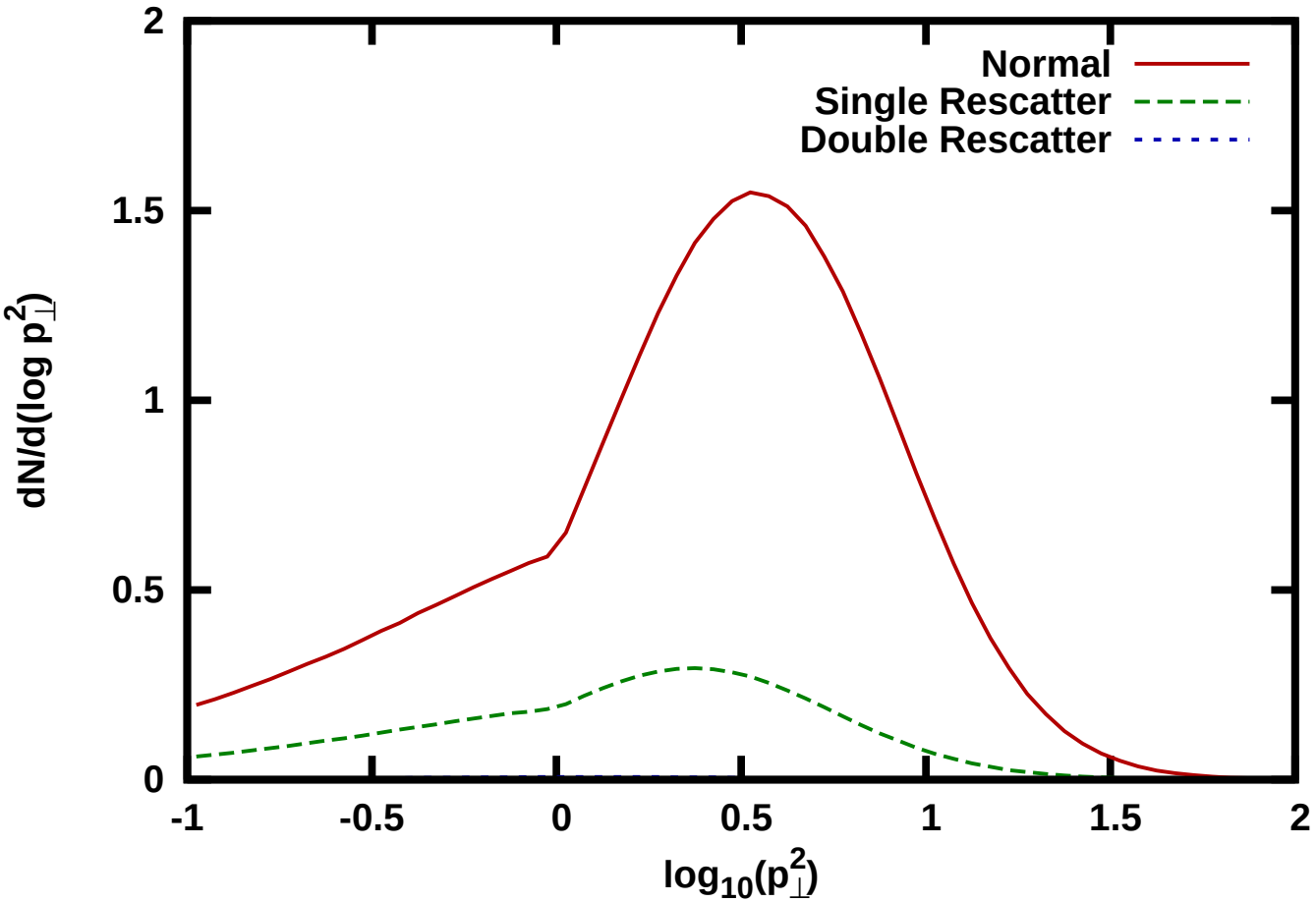
- In general it is not possible to uniquely identify a scattered parton with one hadron. Use approximate prescription, e.g. rapidity based
- Possibility of u-δ, δ-u and δ-δ interactions in addition to original u-u.

$$\frac{\mathrm{d}\mathcal{P}_{\mathrm{MI}}}{\mathrm{d}p_\perp} \to \frac{\mathrm{d}\mathcal{P}_{\mathrm{uu}}}{\mathrm{d}p_\perp} + \frac{\mathrm{d}\mathcal{P}_{\mathrm{u}\delta}}{\mathrm{d}p_\perp} + \frac{\mathrm{d}\mathcal{P}_{\delta\mathrm{u}}}{\mathrm{d}p_\perp} + \frac{\mathrm{d}\mathcal{P}_{\delta\delta}}{\mathrm{d}p_\perp}$$

Rescattering

Rescattering in PYTHIA 8

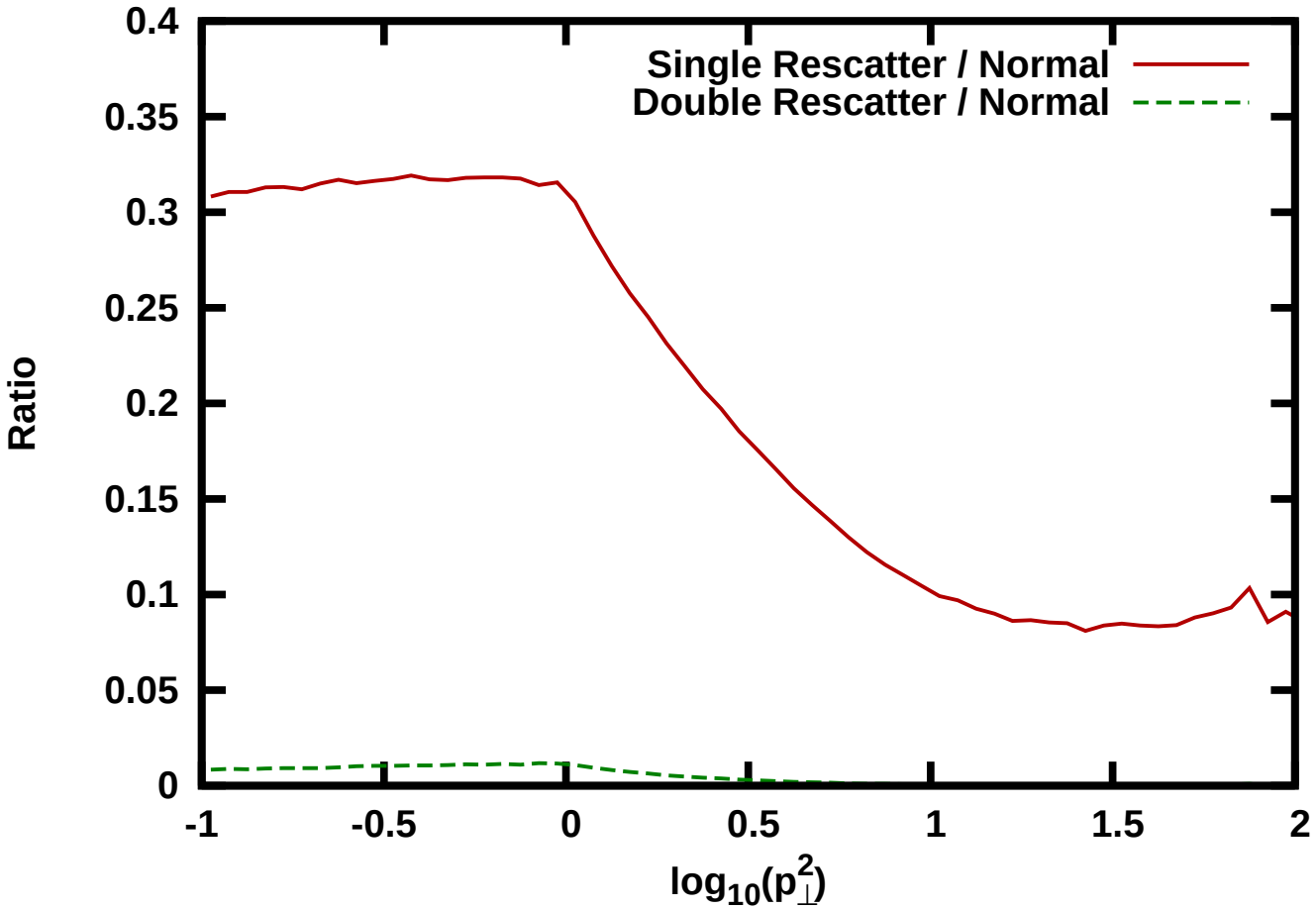
	Min Bias	$\hat{p}_{\perp min}$ = 20 GeV	LHC Min Bias
Scatterings	2.81	5.11	5.21
Single rescatterings	0.37	1.20	0.93
Double rescatterings	0.01	0.03	0.02



Rescattering

Rescattering in PYTHIA 8

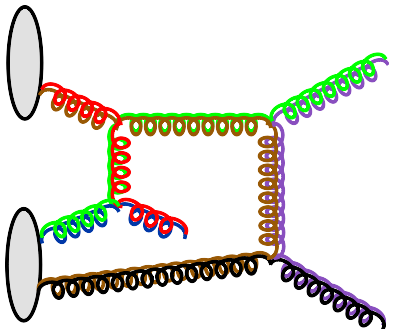
	Min Bias	$\hat{p}_{\perp min}$ = 20 GeV	LHC Min Bias
Scatterings	2.81	5.11	5.21
Single rescatterings	0.37	1.20	0.93
Double rescatterings	0.01	0.03	0.02



Rescattering

Status

- Non-trivial kinematics with rescattering, FSR and primordial $k_\perp$
  - FSR + rescattering - momentum shuffling between systems
  - Primordial $k_\perp$ given by boosting scattering sub-systems



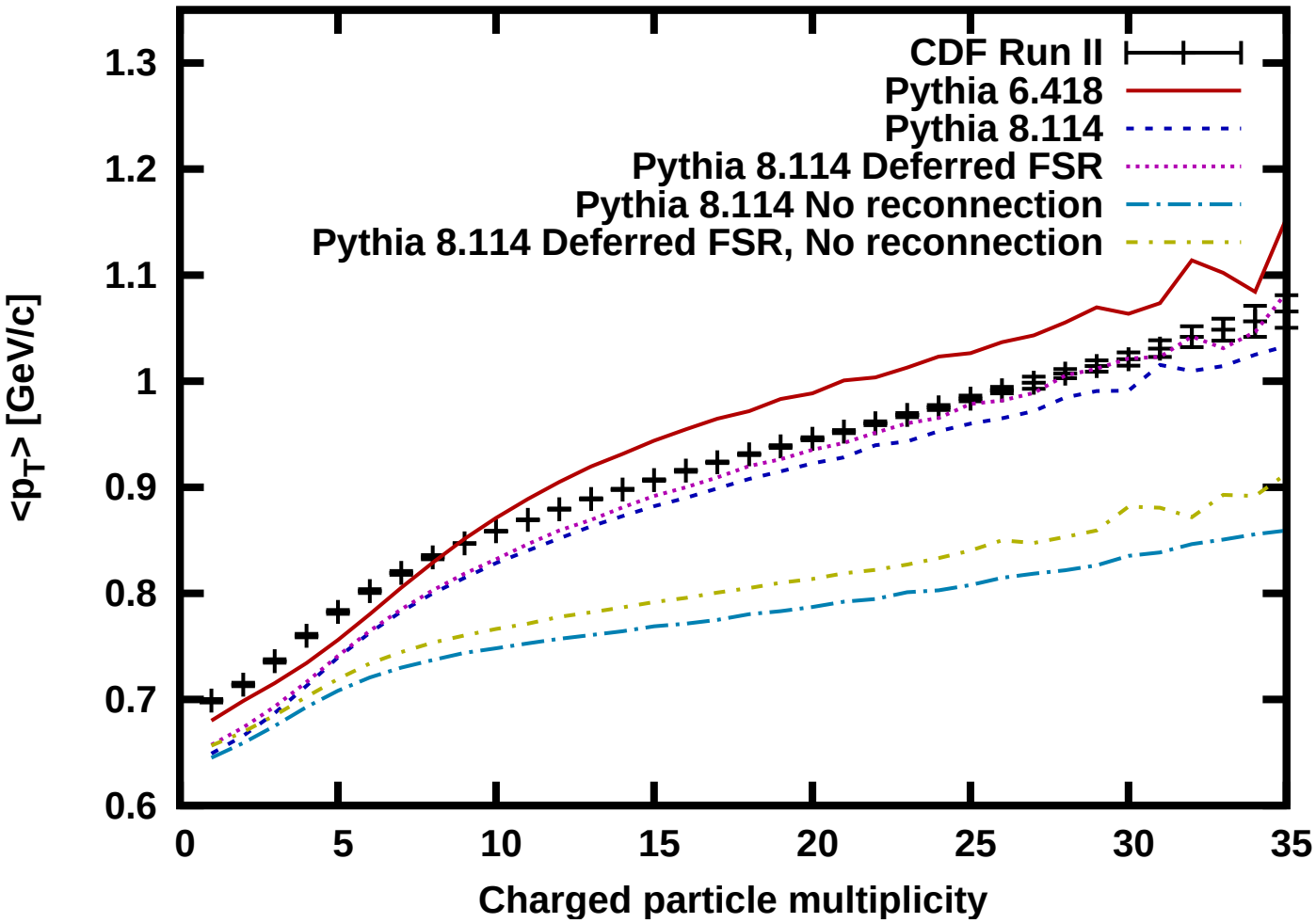
- Temporary solution of deferring FSR until after primordial $k_\perp$ is added
- PARP(85): Probability of additional interactions giving two gluons with 'nearest neighbour' colour connections
- System with a hard scale, $p_\perp$, is merged to with one with a harder scale with probability

$$\mathcal{P} = \frac{{p_\perp}^2_{Rec}}{({p_\perp}^2_{Rec} + p_\perp^2)} \qquad p_{\perp Rec} = RR * {p_\perp}_0^{MI}$$

Rescattering

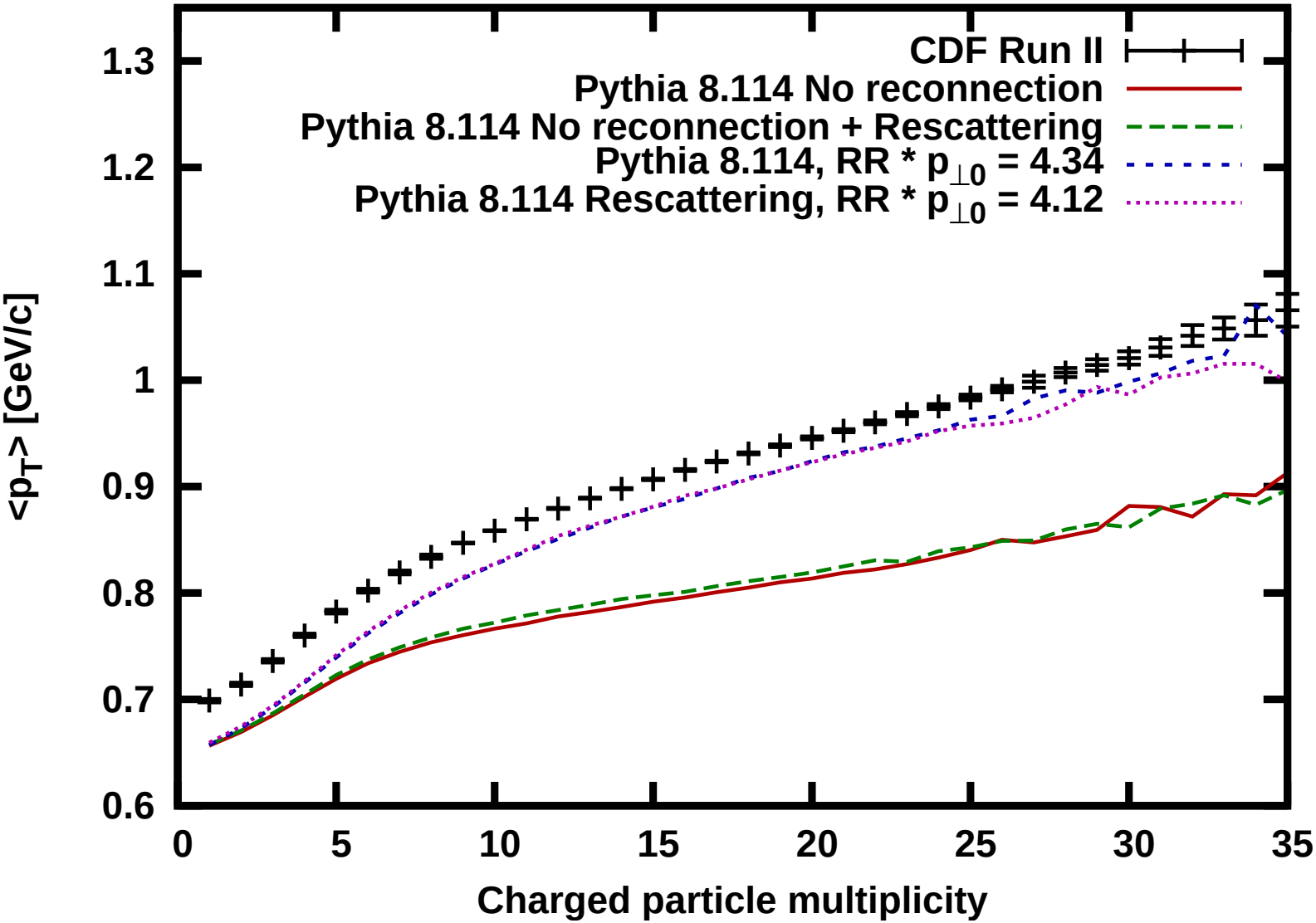
Status - Deferred FSR

- $|\eta| \leq 1$ and $p_\perp \geq 0.4\ GeV/c$
- MI $p_{\perp 0}$ parameter tuned to maintain $\langle N_{ch} \rangle$ in central region



Rescattering

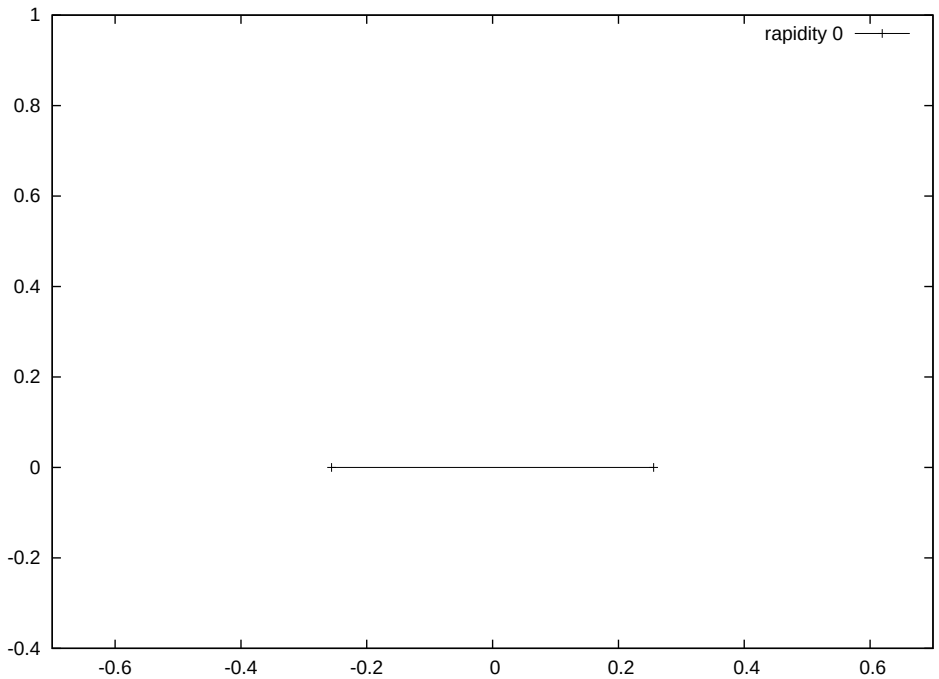
Results - Mean $p_\perp$ vs. Charged Multiplicity



Enhanced Screening

Introduction

- Idea of Gösta Gustafson from work on modelling initial states with an extended Mueller dipole formalism
  - "Elastic and quasi-elastic pp and $\gamma^\star p$ scattering in the Dipole Model," C. Flensburg, G. Gustafson and L. Lonnblad, arXiv:0807.0325 [hep-ph].

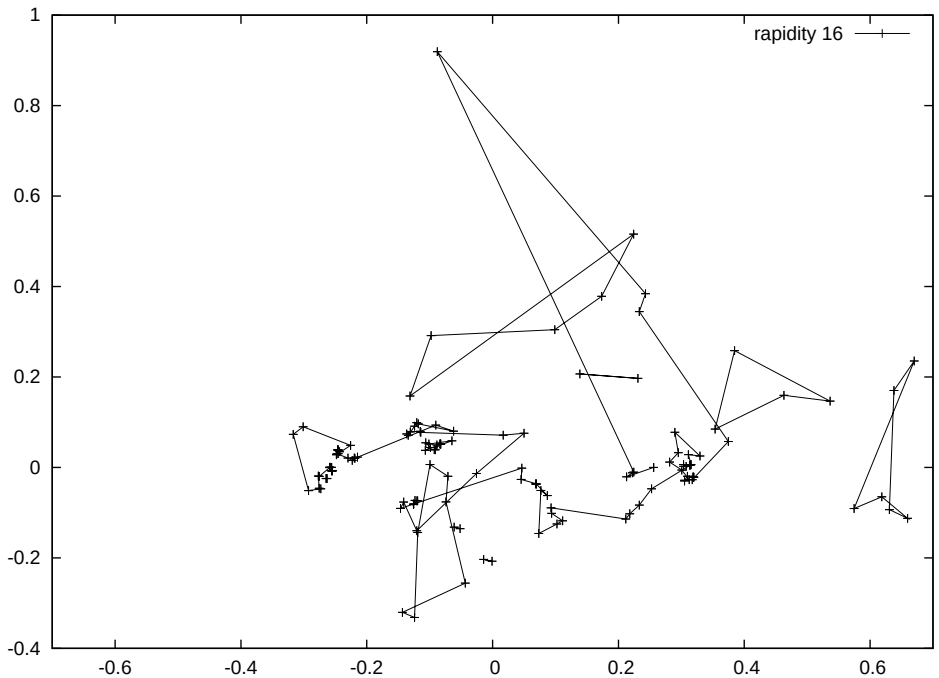


- Even at a fixed impact parameter, initial state will contain more/less fluctuations on an event-by-event basis
  - More activity $\longrightarrow$ more screening

Enhanced Screening

Introduction

- Idea of Gösta Gustafson from work on modelling initial states with an extended Mueller dipole formalism
  - "Elastic and quasi-elastic pp and $\gamma^\star p$ scattering in the Dipole Model," C. Flensburg, G. Gustafson and L. Lonnblad, arXiv:0807.0325 [hep-ph].



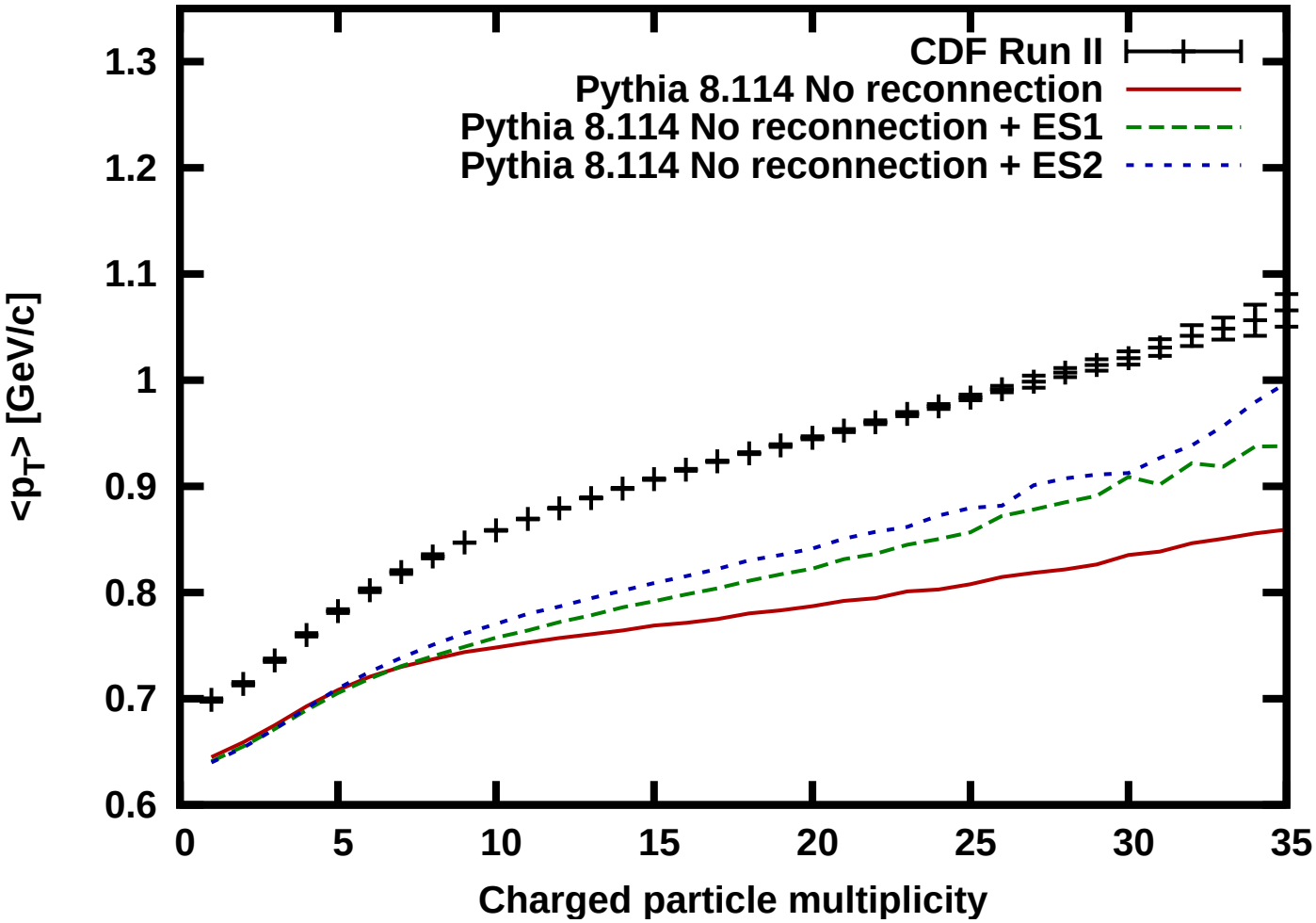
- Even at a fixed impact parameter, initial state will contain more/less fluctuations on an event-by-event basis
  - More activity $\longrightarrow$ more screening

Enhanced Screening

Enhanced Screening in PYTHIA

$$\frac{\mathrm{d}\hat{\sigma}}{\mathrm{d}p_\perp^2} \propto \frac{\alpha_S^2(p_{\perp 0}^2 + p_\perp^2)}{(p_{\perp 0}^2 + p_\perp^2)^2} \rightarrow \frac{\alpha_S^2(p_{\perp 0}^2 + p_\perp^2)}{(n\,p_{\perp 0}^2 + p_\perp^2)^2}$$

ES1: n = no. of MI
ES2: n = no. of MI + ISR

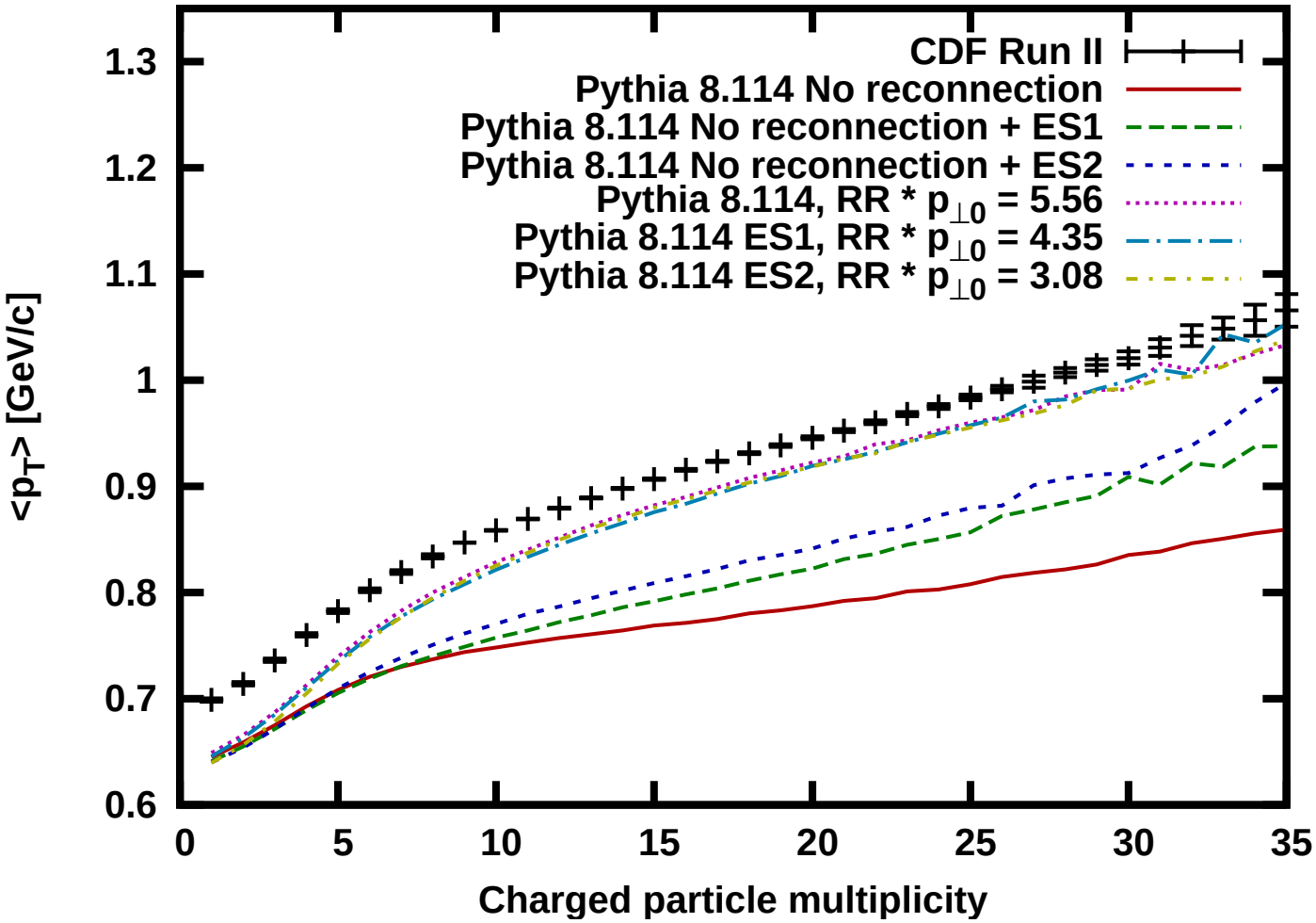


Enhanced Screening

Enhanced Screening in PYTHIA

$$\frac{\mathrm{d}\hat{\sigma}}{\mathrm{d}p_\perp^2} \propto \frac{\alpha_S^2(p_{\perp 0}^2 + p_\perp^2)}{(p_{\perp 0}^2 + p_\perp^2)^2} \rightarrow \frac{\alpha_S^2(p_{\perp 0}^2 + p_\perp^2)}{(n\,p_{\perp 0}^2 + p_\perp^2)^2}$$

ES1: n = no. of MI
ES2: n = no. of MI + ISR



Conclusions

- Rescattering
  - New rescattering description operational (but still experimental) without interleaved FSR. This involves much new code in several classes
  - Not a solution to the colour reconnection problem
  - Many more studies to be done
- Enhanced screening
  - New optional model, where an increased $p_{\perp 0}$ scale is used for above-average active events, i.e. events that already have several MI's or ISR emissions
  - Improvement in the amount of colour reconnection needed
  - Again, many more studies to be done

PYTHIA 8 Status

- PYTHIA 8.120 will be released in the next few weeks
- Capability to link to FastJet, with expanded configure script and Makefile, and with main61.cc as a new example
- Updated and expanded worksheet
- The manual pages in the xmldoc directory, and thereby also those of the htmldoc and phpdoc directories, have been significantly updated. In particular, in many places the class of each method is explicitly shown, as well as the type of the return value and of the arguments. This upgrade is not yet completed, but already covers the more relevant sections

PYTHIA 8 Status

- Capability added to allow separate mass and transverse momentum cuts when two hard subprocesses are generated in the same event.
- New processes for Large Extra Dimensions and Unparticles, contributed by Stefan Ask. New test program main28.cc
- Inclusion of further SUSY processes: neutralino-chargino and chargino-chargino pairs. The processes should be valid also in the case of non-minimal flavour violation and/or CP violation. Expanded machinery to keep track of SUSY parameters
- Include backwards evolution of incoming photon as part of the SpaceShower initial-state radiation description. This allows simulation of hard collisions where one of the incoming partons is a photon. New test program main43.cc