

Colour Reconnection in Cluster Hadronisation

Christian Röhr

Institut für Theoretische Physik, Karlsruhe Institute of Technology

8th MCnet Meeting, Cambridge, 22-24 Sept 2010

in collaboration with
Stefan Gieseke, Andrzej Siódmok, Simon Plätzer

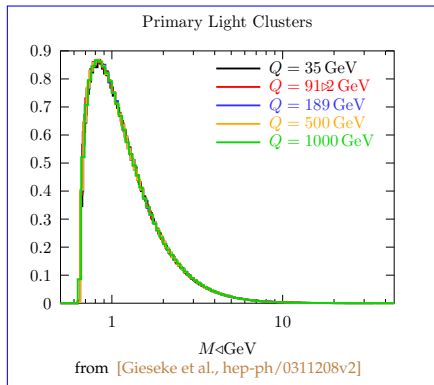
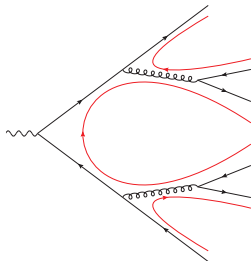
roehr@particle.uni-karlsruhe.de

- ▶ Colour reconnection in Herwig++
- ▶ Underlying event at the Tevatron
- ▶ What happens at the LHC?

QCD parton showers provide *pre-confinement* property

[Amati, Veneziano, Phys. Lett. B83 (1979) 87]

- ▶ shower produces colourless parton combinations with $m = \mathcal{O}(\text{cut-off scale})$

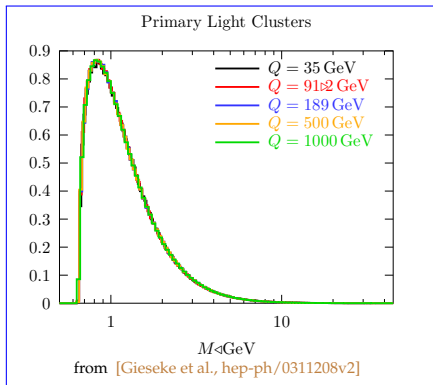
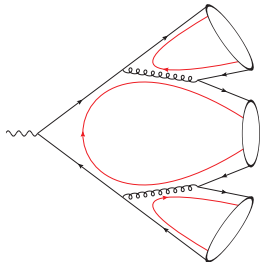


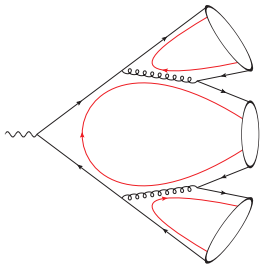
QCD parton showers provide *pre-confinement* property

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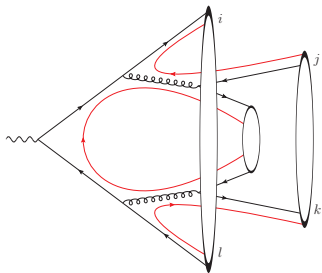
- ▶ shower produces colourless parton combinations with $m = \mathcal{O}(\text{cut-off scale})$
- ▶ \rightarrow clusters
- ▶ highly excited hadronic states

[Webber, Nucl. Phys. B238 (1984) 492]





- ▶ starting out with the pre-confined state...



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- ▶ consider *reformation* of clusters, e.g. $(il) + (jk)$
 → “colour reconnection”

- ▶ allow CR if the cluster mass decreases,

$$M_{il} + M_{kj} < M_{ij} + M_{kl},$$

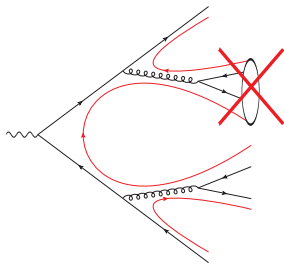
where $M_{ab}^2 = (p_a + p_b)^2$ is the (squared) cluster mass

- ▶ accept alternative clustering with probability p_{reco} (model parameter) \Rightarrow allows to switch on CR smoothly

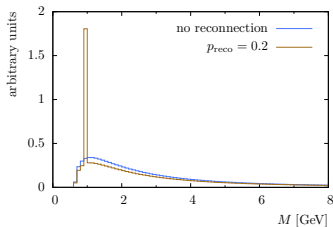
... with one constraint

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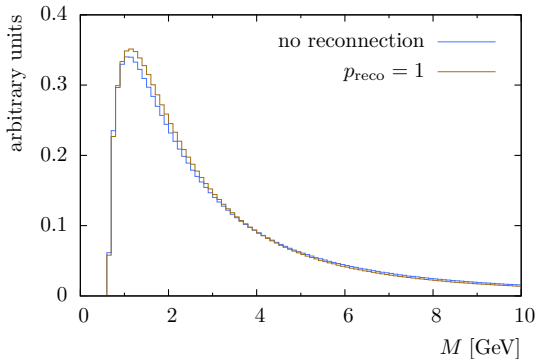
VETO on hadronization of single gluons



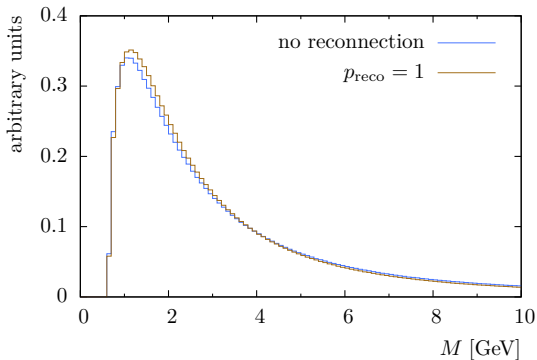
Without veto...



- ▶ narrow peak in cluster mass distribution at m_{gluon}
- ▶ bias in phase space for cluster decay
- ▶ affects flavour spectrum?
- ▶ wrecks pre-confinement?

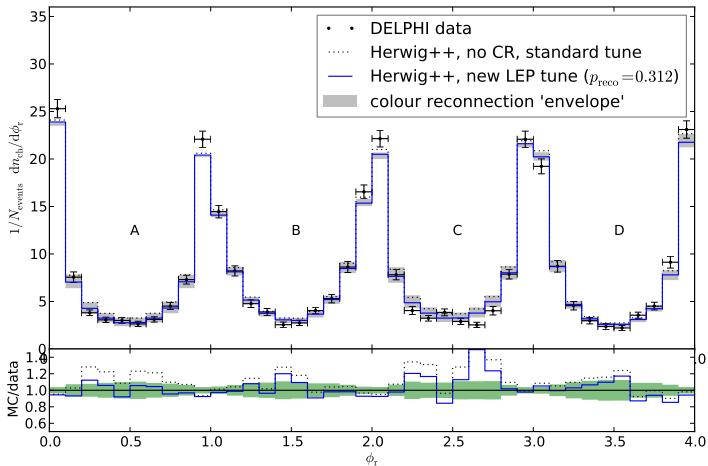


- ▶ cluster mass spectrum slightly shifted



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- ▶ ... to smaller masses (surprise)

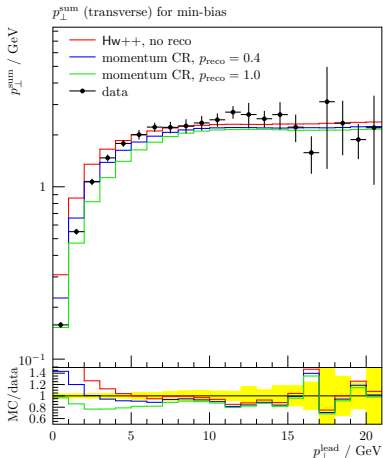
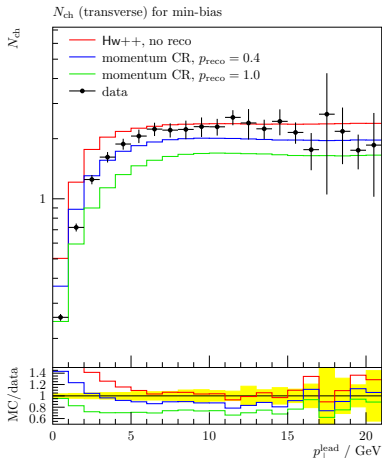
Retrospective: particle flow in $WW \rightarrow 4j$ at LEP



- ▶ small effects here
- ▶ marginal improvement (if at all)

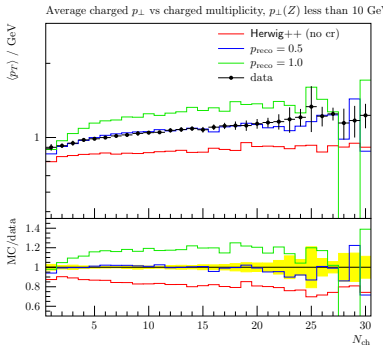
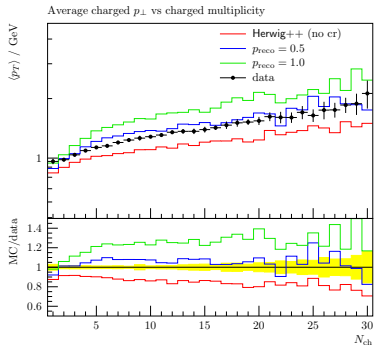
data from [DELPHI Collaboration, Eur. Phys. J. C51 (2007) 249-269]

Tevatron Run I (1.8 TeV), Rivet: CDF_2001_S4751469



[CDF Collaboration, A. A. Affolder *et al.*, Phys. Rev. D65 (2002) 092002.]

Tevatron Run II (1.96 TeV), Rivet: CDF_2008_NOTE_9351



[Kar, Field, CDF Note, CDF/PUB/CDF/PUBLIC/9351 (2008)]

Fact sheet

- ▶ idea: **local** exchange of soft gluons
- ▶ Condition for colour reconnection:

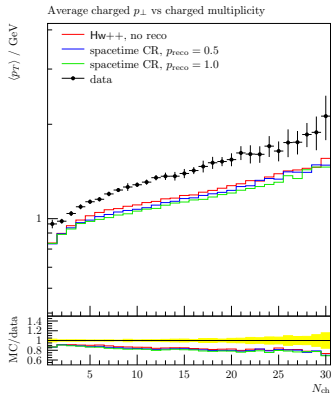
$$|d_{il}|^2 + |d_{kj}|^2 < |d_{ij}|^2 + |d_{kl}|^2,$$

where $d_{ab}^\mu \equiv v_a^\mu - v_b^\mu$ is the spacetime distance of the respective partons

- ▶ prefers clusters of partons **nearby in spacetime**
- ▶ semi-classical Ansatz for generation of spacetime information:
 - ▶ multiple parton scatters distributed over hadron area
 - ▶ lifelength of partons in showers generated according to the partons' momenta

¹as implemented in (Fortran-) HERWIG [Webber, J. Phys. G24 (1998) 287-296]

What about the spacetime-based CR model¹?



- ▶ fails to describe CDF data
- ▶ anyone tried with HERWIG?

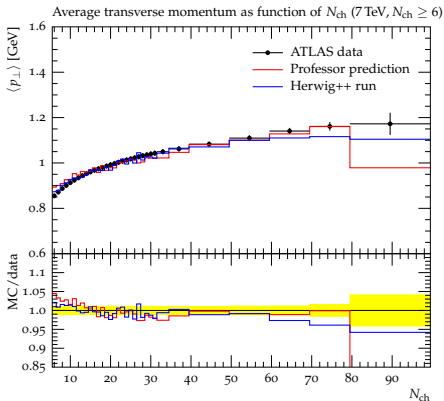
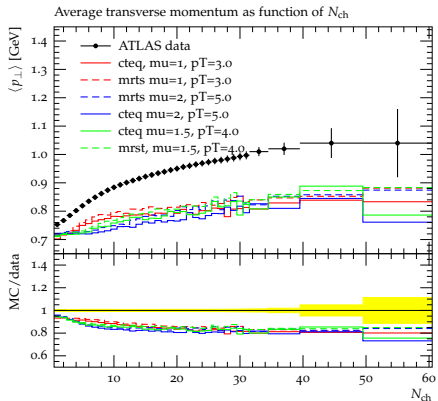
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- ▶ CR improves description of UE at Tevatron (as expected)
- ▶ no changes or minor improvement in hadronic WW decay at LEP

Open questions

- ▶ Can we understand colour reconnection?
- ▶ Is CR a correction to pre-confinement?
- ▶ Dependency on energy or physical setup?
- ▶ Is the spacetime-based model inappropriate?

- ▶ hadronization sensitive to CR \Rightarrow **re-tuning** to LEP data necessary (*cf.* Andrzej's talk)
- ▶ compare to LHC data
- ▶ CR is being validated.
- ▶ most likely released in Herwig++ 2.5 (coming soon!)



- ▶ Colour reconnection is **one ingredient** to eliminate Herwig++'s problems with the underlying event at the LHC
- ▶ more on that in [Andrzej's talk](#)