Rope Hadronisation

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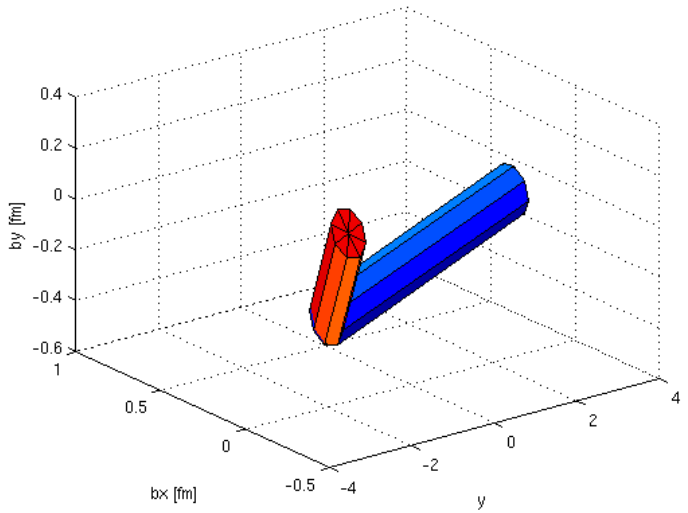
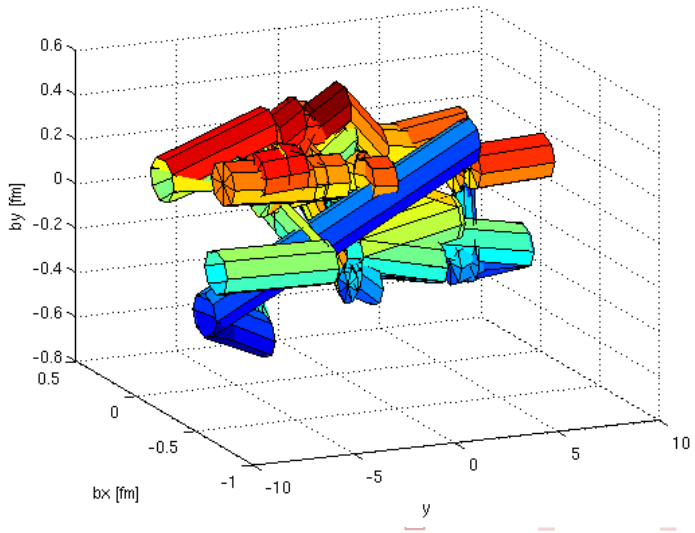
Introduction

- The *string model* is the primary hadronisation workhorse for the Lund family of EG.
- The string model is developed for the very clean LEP environment...
- ...while *pp* min. bias or Heavy Ion is more messy
- We present corrections to string hadronisation based on *rope hadronisation*.
- Part of the DIPSY EG Flensburg et al., 2012, arXiv:1210.2407 project.



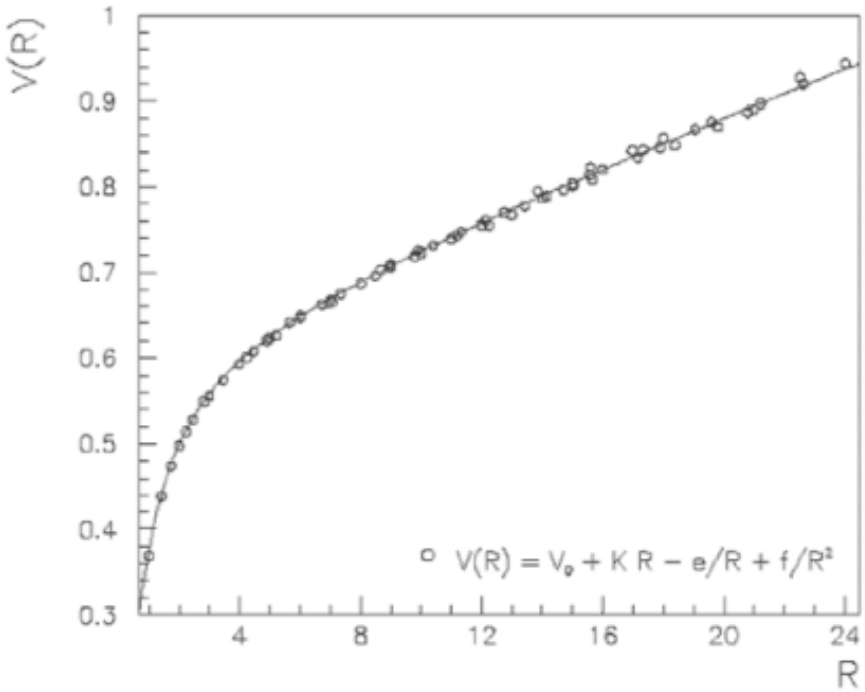


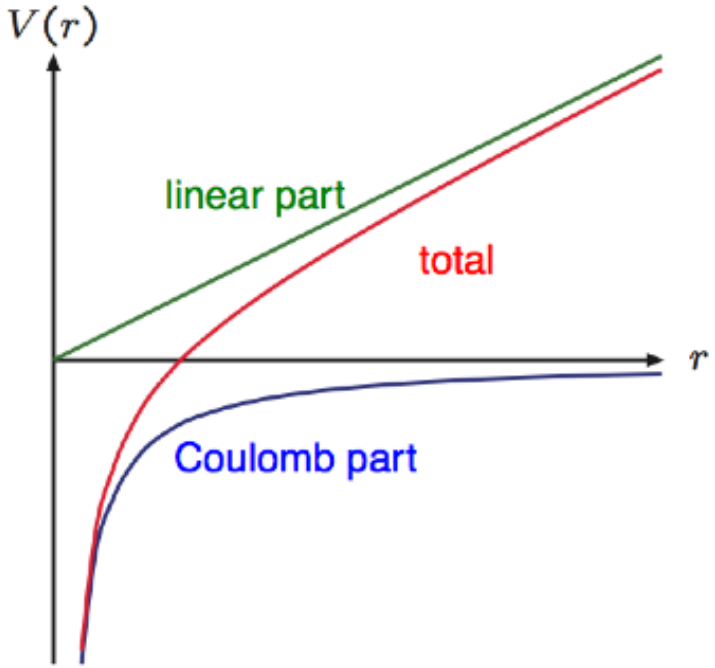
Rest of this talk

1. Ordinary string hadronisation
2. Rope model
3. Results for pp
4. The colour swing
5. Heavy Ion results
6. Outlook and conclusion

String Hadronisation Sjöstrand et al., 2006, hep-ph/0603175

- Linear confinement potential $V(r) \approx \kappa r$, $\kappa \approx 1$ GeV/fm.
- Valid for large distances – for small distances perturbation theory should be valid.

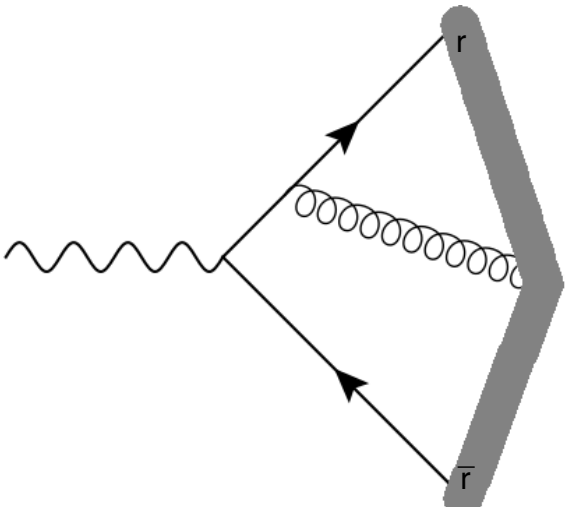




- Realized in a 1+1 dimensional string with tension κ.

String Hadronisation II

- Repeated *breaking* with $\mathcal{P} \propto \exp\left(-\frac{\pi m_\perp^2}{\kappa}\right)$ gives hadrons.
- Left-right symmetry in the breaking gives $f(z) \propto z^{-1}(1-z)^a \exp\left(\frac{-bm_\perp}{z}\right)$.



- a and b related to total multiplicity.
- Flavours determined by relative probabilities:

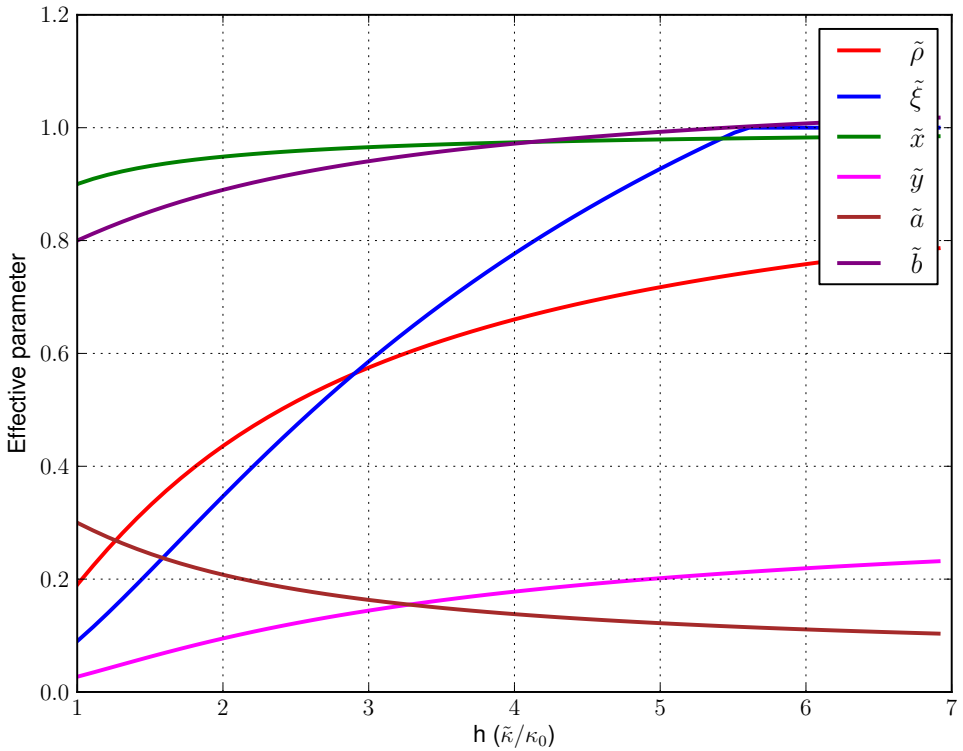
$$\rho = \frac{\mathcal{P}_{\text{strange}}}{\mathcal{P}_{\text{u or d}}}, \xi = \frac{\mathcal{P}_{\text{diquark}}}{\mathcal{P}_{\text{quark}}}$$

$$x = \frac{\mathcal{P}_{\text{strange diquark}}}{\mathcal{P}_{\text{diquark}}}, y = \frac{\mathcal{P}_{\text{spin 1 diquark}}}{\mathcal{P}_{\text{spin 0 diquark}}}$$

- Notice that probabilities are related to κ via tunneling equation.

Change of string tension

- All parameters related through string tension.
- Change of string tension will change all of them.



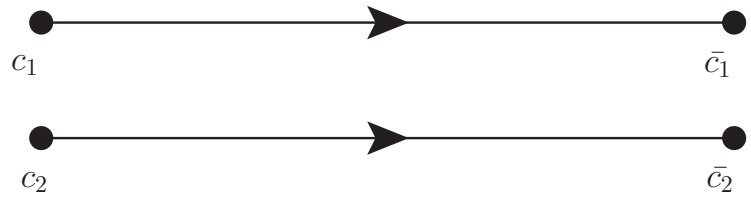
- Let $\kappa \mapsto \tilde{\kappa} = h\kappa$.
- All effective parameters calculable from the two governing equations.
- Parameters ρ and ξ are very sensitive to change in κ.
- This is desired behavior.

Rope model in a nutshell

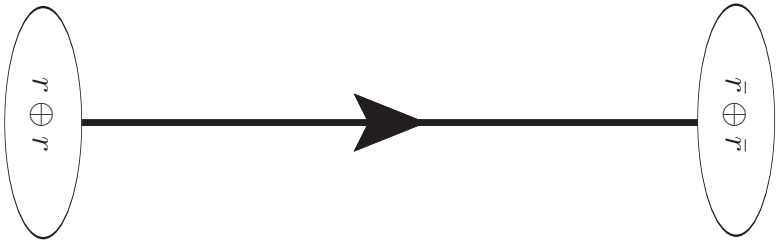
- Need a model to calculate $h = \tilde{\kappa}/\kappa$ given a configuration of colour charges.
- The *rope model*:
  1. Let charges act coherently to form a rope.
  2. The rope is an SU(3) multiplet.
  3. All SU(3) multiplets described by quantum numbers $\{p, q\}$
  4. ...or equivalently $\tilde{\kappa}/\kappa = h = h(p, q)$ and multiplicity $M = M(p, q)$.
- Approximations neccesary to map from physical configuration to $\{p, q\}$.
- The actual hadronisation is carried out using the effective parameters.
- Hadronise *one* string at a time, using effective string tension $\tilde{\kappa}$

Rope model – example 1

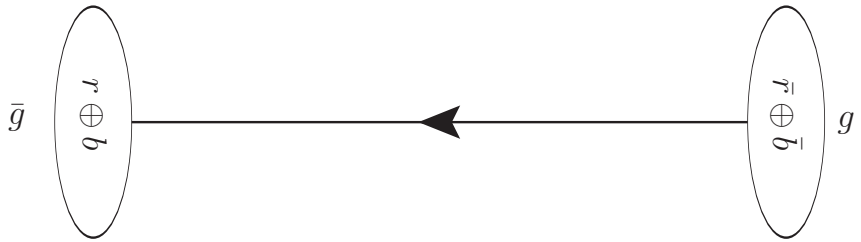
- The simplest example: Two $q\bar{q}$ pairs act coherently:



Case (a), $c_1 = c_2$:

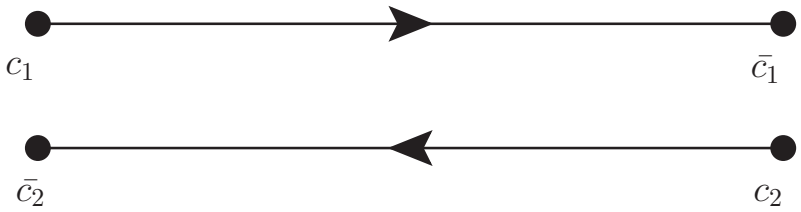


Case (b), $c_1 \neq c_2$:



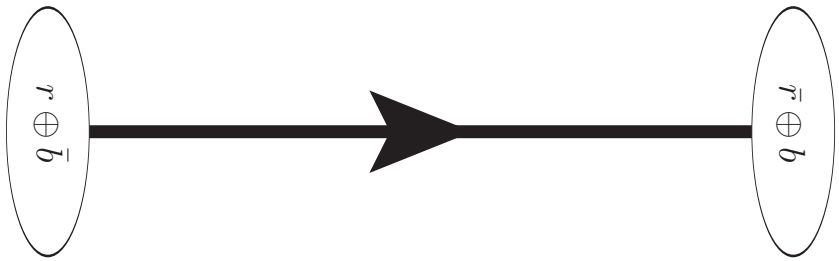
Rope model – example 2

- Two $q\bar{q}$ pairs act coherently, having oppositely directed colour flow:



Case (a), $c_1 = c_2$:

Case (b), $c_1 \neq c_2$:



Generalisation and approximations

- Generalisable to arbitrarily many triplets and antitriplets $\{m, n\}$.
- The procedure is iterative, adding one (anti)-triplet at a time.
- This is similar to a random walk in colour space Bohr, H. and Nielsen, H. B, 1978, NBI-HE-78-3 giving:

$$\langle p + q \rangle \sim \sqrt{m + n}$$

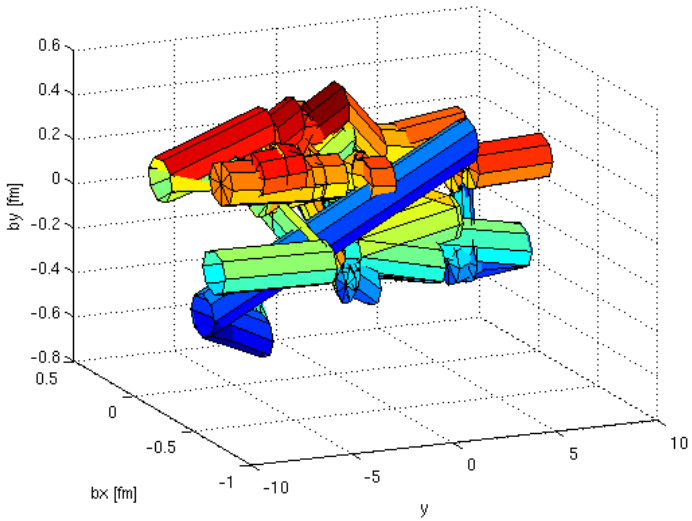
- The rope tension is equivalent to the secondary Casimir operator Bali, G. S, 2000, hep-lat/0006022.
- This is averaged over $N = p + q$ partial breakups giving:

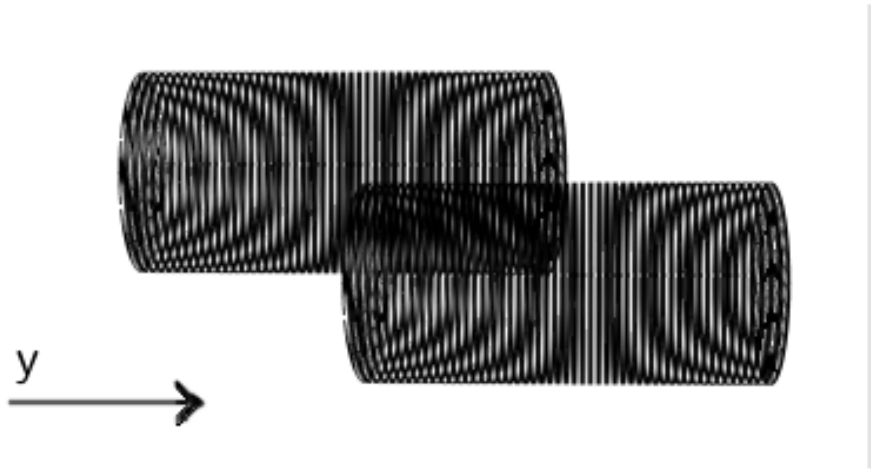
$$\tilde{\kappa}/\kappa = \frac{1}{4}\left(N + 3 - \frac{pq}{N}\right).$$

Calculation of $\{m, n\}$

- Finding the $\{m, n\}$ strings producing a rope is not an entirely trivial matter.
- Must deal with partial overlaps.
- Crude approximation: Draw cylinders around each string, calculate volume overlap of cylinders:

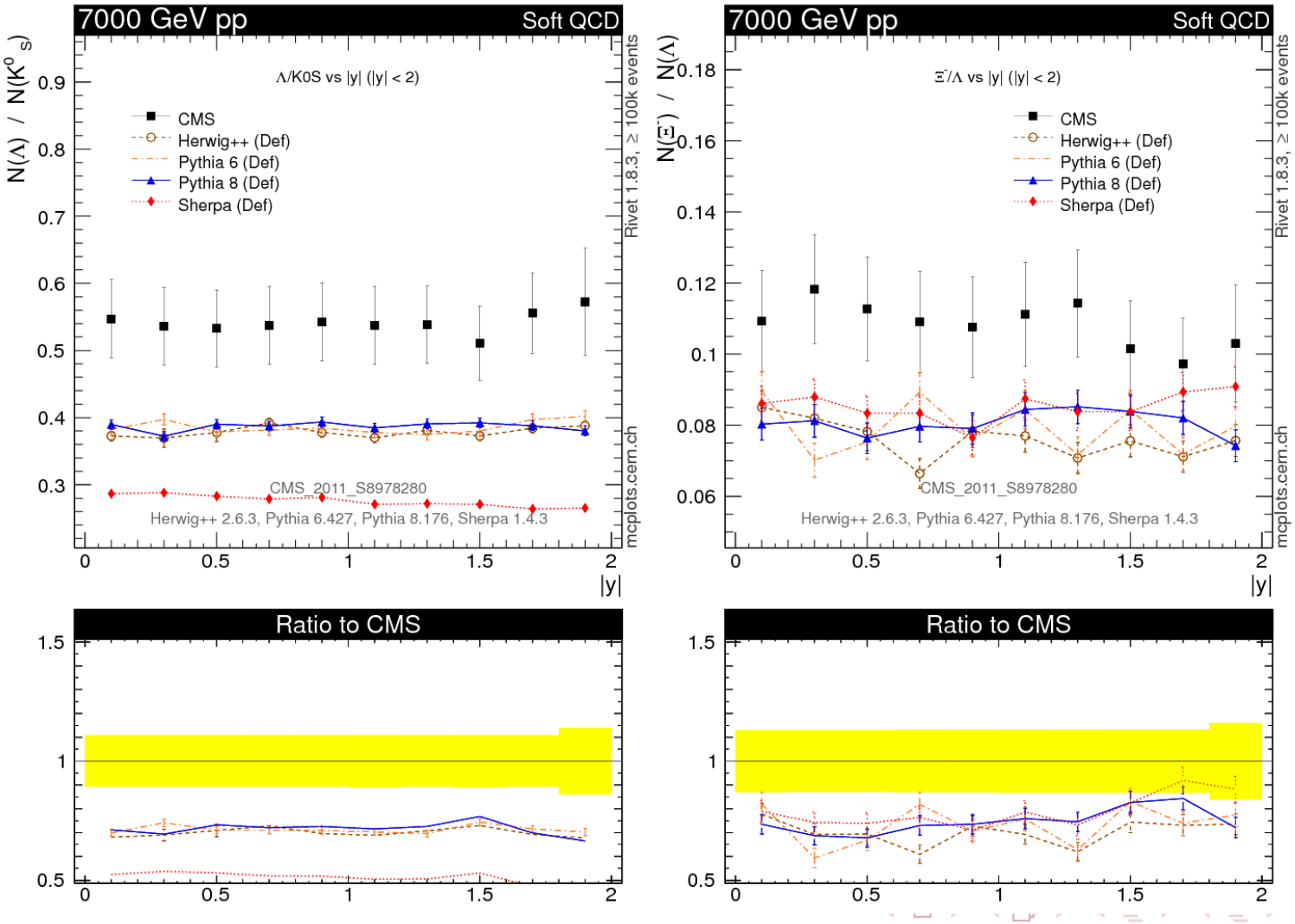
$$\langle N \rangle_{\text{total}} = \langle N \rangle_{\text{self}} + \sum_{i \neq \text{self}} \frac{V_{o,i}}{V_i} \langle N \rangle_i$$





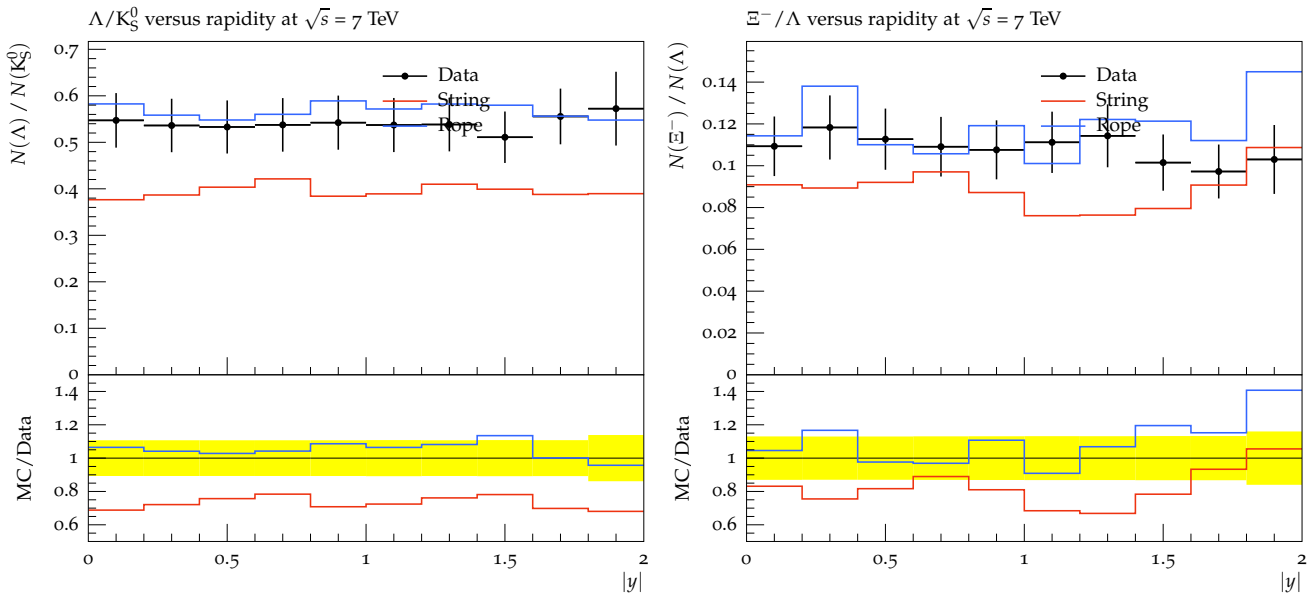
Comparison to data (CMS)

- From MCplots, comparison to CMS data CMS, 2012, arXiv:1102.4282 [hep-ex]:



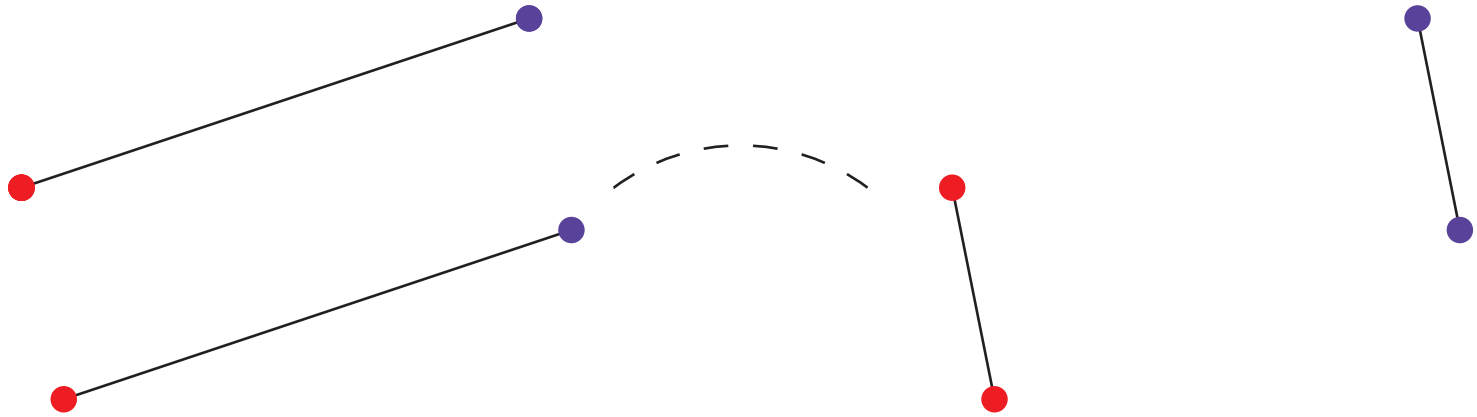
Comparison to data (CMS)

- Vanilla DIPSY/ARIADNE 5 suffers from similar problem.
- Including rope effects improves the picture.



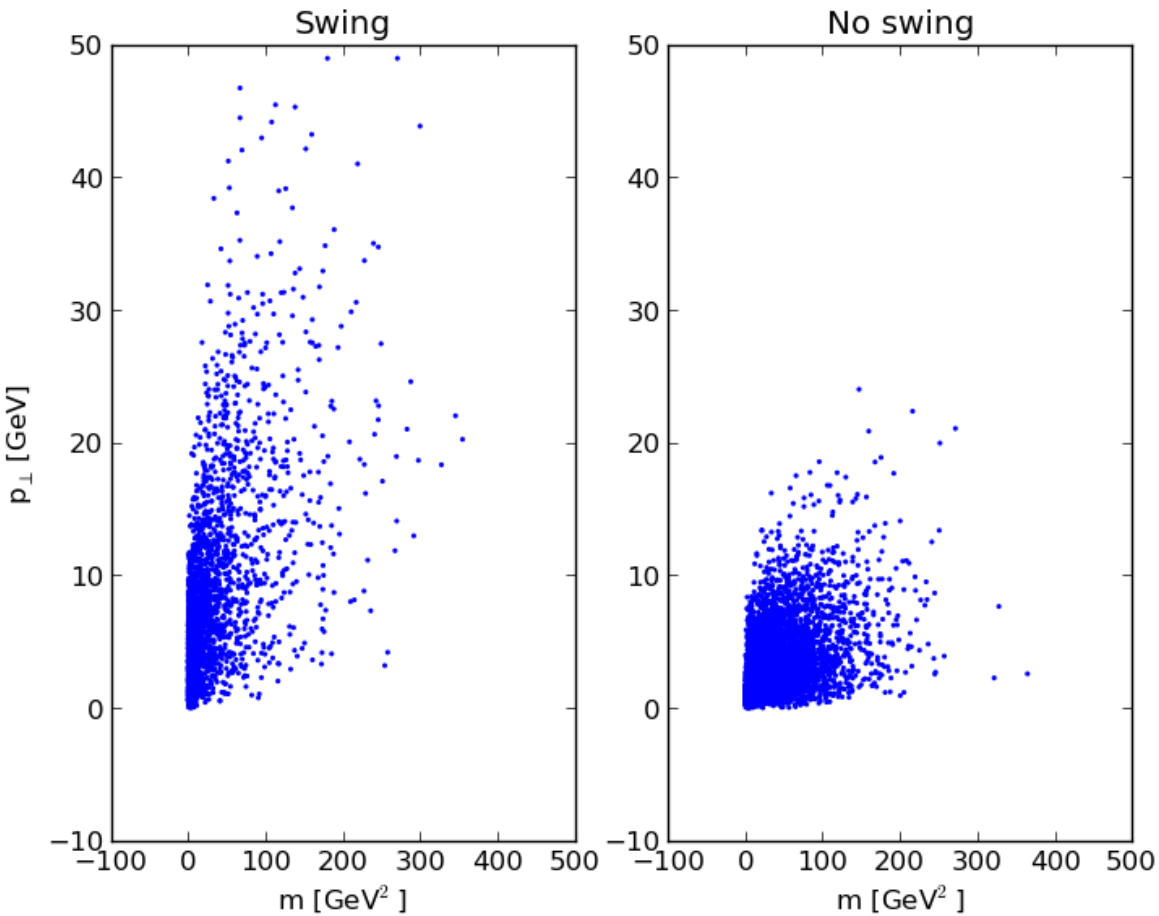
The colour swing

- Notice that the destructive effect (when $3 \oplus \bar{3} \to 1$) is not included in an obvious way.
- Another take on colour reconnection: The Colour Swing.
- Allow matching colours two »swing« with one another:



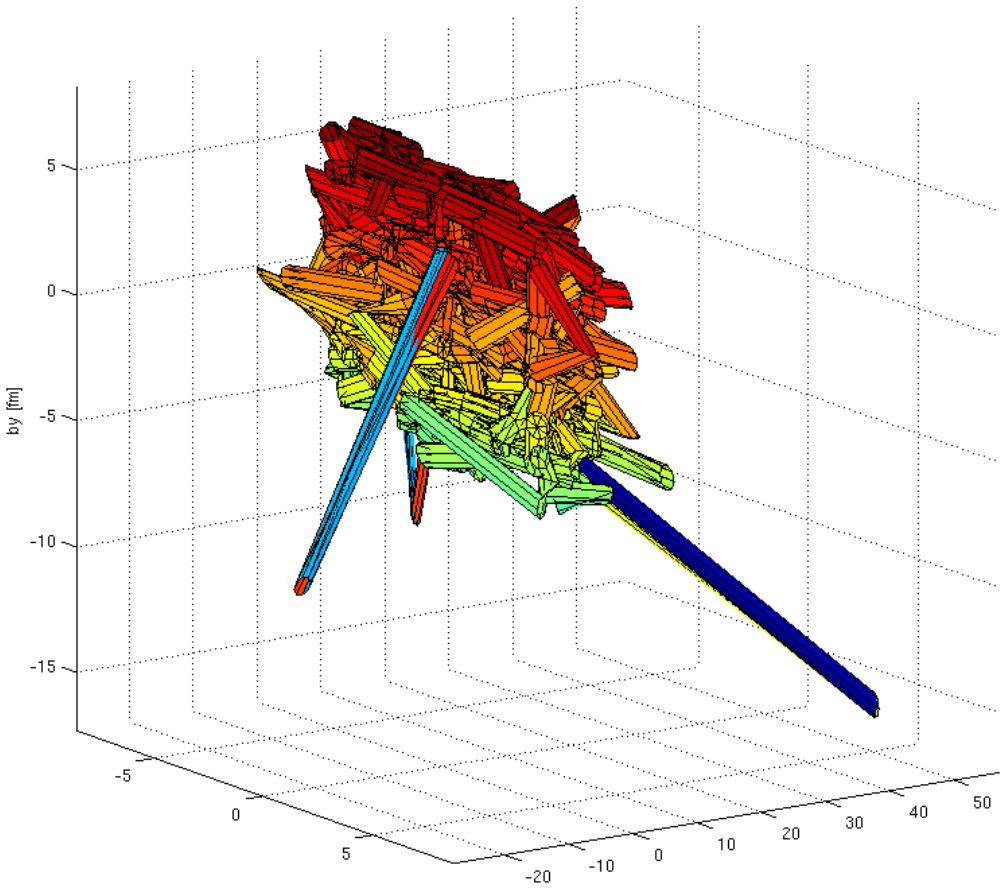
Effect of swing

- Swing transforms low $p_\perp$ particles to high $p_\perp$ particles.
- Seems to be right for pp, but overshooting the effect in HI collisions.



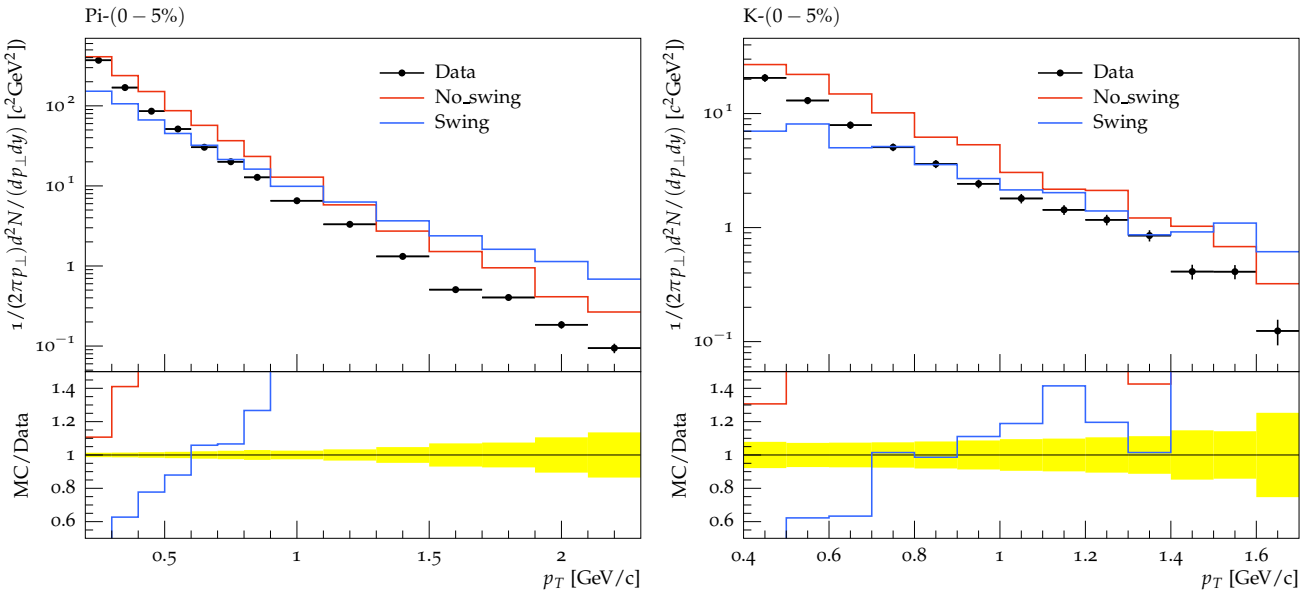
Heavy Ion (prelim.)

- Heavy ion events (AuAu at 130 GeV, RHIC) are way more stringy!



Comparison to data (PHENIX) PHENIX, 2002, arXiv:nucl-ex/0112006

- Hard tail from the swing, rope effect not visible with swing out of control.
- Even more pronounced for higher $p_\perp$ (eg. ALICE PbPb).



Outlook and conclusions

- The string model needs corrections in dense environments.
- Spatially overlapping strings enhance string tension.
- Currently relies on space-time information (DIPSY).
- Ropes formed by colour charges acting coherently gets strange/baryonic content right in *pp*.
- Promise for Heavy Ion events, colour reconnection by swing is a work in progress.

The End