String shoving in heavy ion collisions in PYTHIA8: Few ideas

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Outline

1. Motivation
2. Parallel frames
3. String shoving
4. Conclusion

Motivation

Flow effects

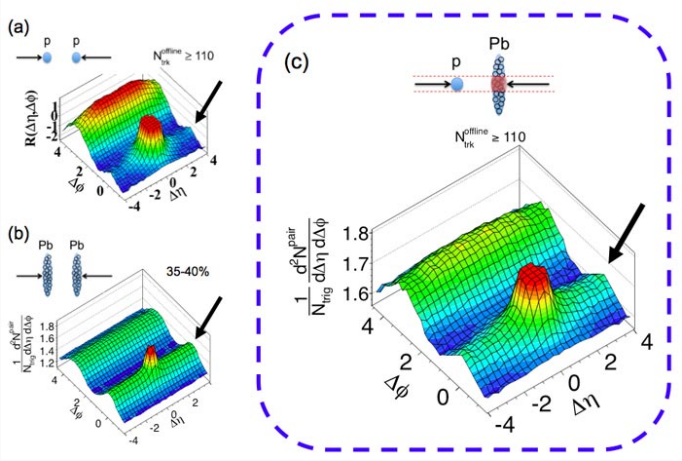


Figure 1: Flow effects in p-p, p-A and A-A collisions. V. Khachatryan et al. (CMS), JHEP 09, 091 (2010), arXiv:1009.4122 [hep-ex].

Correlation functions

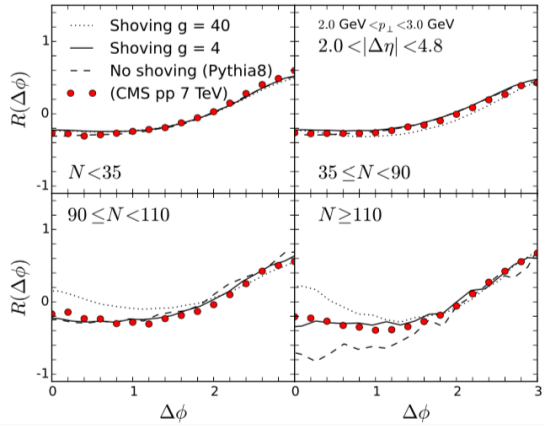
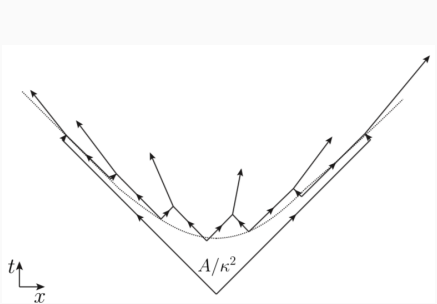
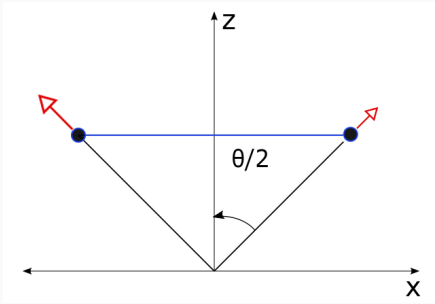


Figure 2: Di-hadron correlation functions for pp collisions at 7 TeV, in four centrality intervals. C.Bierlich et al., Collectivity without plasma in hadronic collisions, Phys.Lett.B(2018)

Lund Model



(a)



(b)

Figure 3: Strings in (a) x-t diagram where A= coherence area, κ = string tension and (b) real time, $\theta/2$ = angle between the parton momentum and the z axis

Parallel frames

Parallel frame

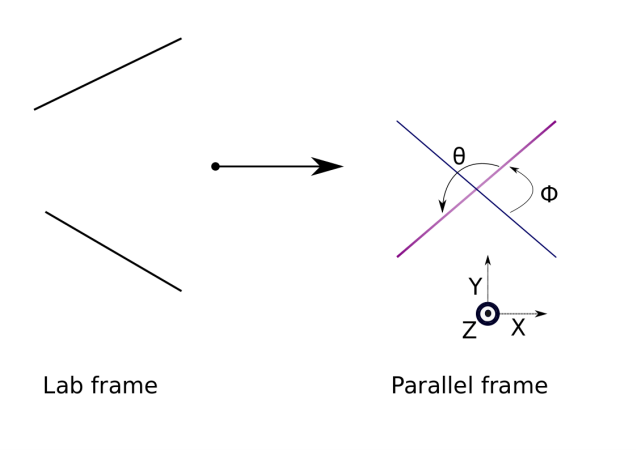


Figure 4: Boosting to parallel frame, θ = opening angle, ϕ = skew angle between the strings

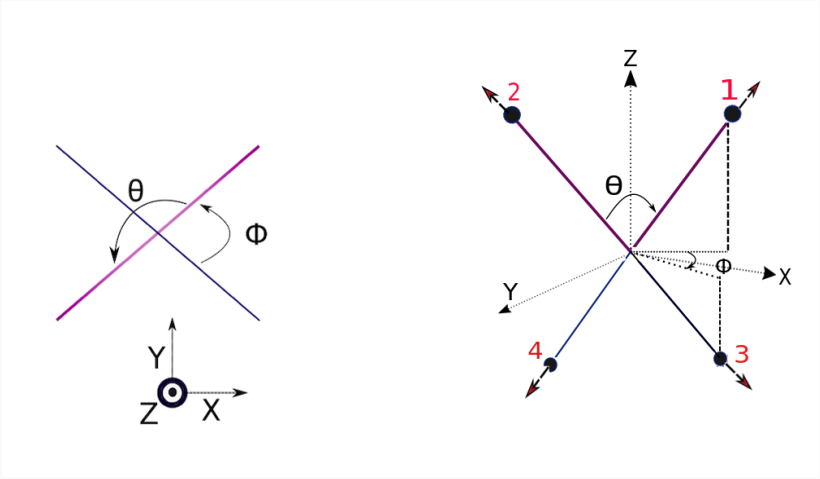


Figure 5: Parallel frame: different perspectives

Finding the "perfect" boost

1. Energies q_is :

$$q_1^2 = \Sigma(s_{12}s_{13}s_{14})/8(s_{34}s_{24}s_{23}) \quad (1)$$

2. Opening angle Θ:

$$sin^2\Theta = 2\sqrt{s_{12}s_{34}}/\Sigma \quad (2)$$

3. Skew angle Φ:

$$cos2\Phi = (\sqrt{s_{13}s_{24}} - \sqrt{s_{14}s_{23}})/2\sqrt{s_{12}s_{34}} \quad (3)$$

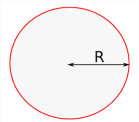
where $\Sigma = 8\sqrt{q_1q_2q_3q_4}$, $s_{ij} = (p_i + p_j)^2$ and p_i = momentum of ith parton in parallel frame.

String shoving

Interaction force

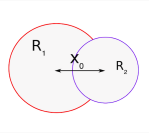
1. A string of radius R:

$$Field\ E \propto \frac{g}{R} \exp^{-\frac{r^2}{R^2}} \qquad (4)$$



2. For two overlapping (but in parallel planes) strings with radii R_1, R_2 and separation x_o:

$$I/length \propto g^2\pi \frac{1}{(R_1^2 + R_2^2)} exp^{-\frac{x_0^2}{R_1^2+R_2^2}} \qquad (5)$$



where I = interaction energy.

3. Equilibrium radius $R_{eq} \Rightarrow$ string tension $\Rightarrow$ normalization

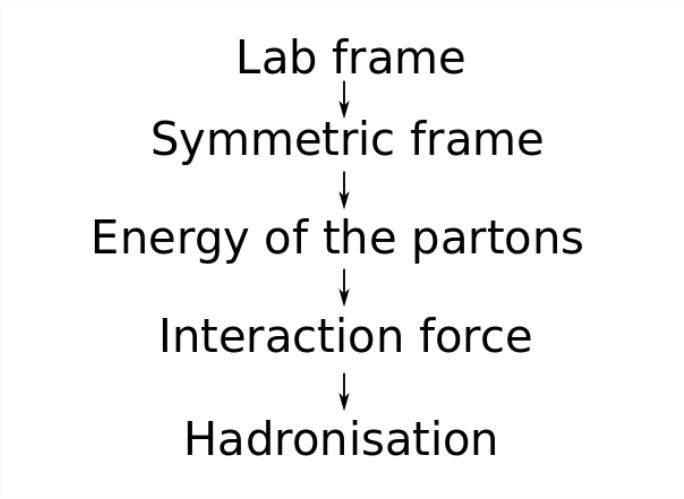
The resultant push

The force can be calculated by following the expression for the interaction energy I :

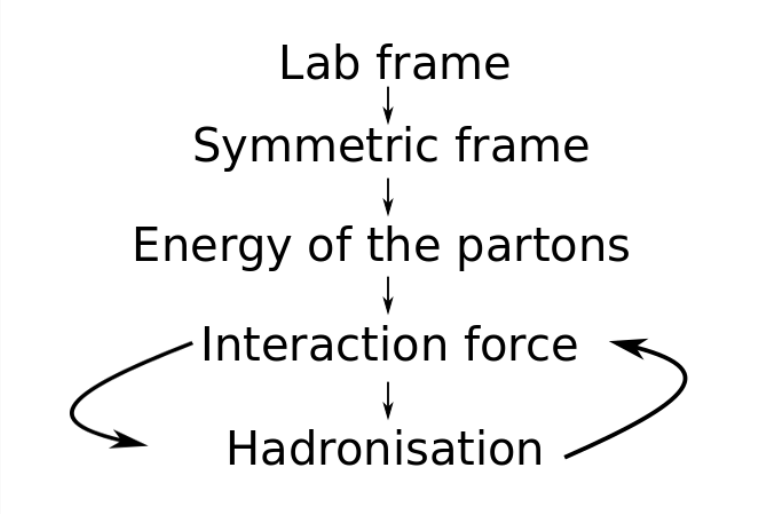
$$I \propto dz\pi g^2 \frac{cos\Phi}{(R_1^2 + R_2^2)cos(\Phi/2)} exp\left[-z^2 \frac{4sin^2(\Phi/2)}{(R_1^2 + R_2^2)}\right] exp\left[\frac{x_0^2}{R_1^2 + R_2^2}\right] \quad (6)$$

for two strings parallel to y-z plane, separation in x-direction $= x_0$.

Flowchart of processes



Flowchart of processes



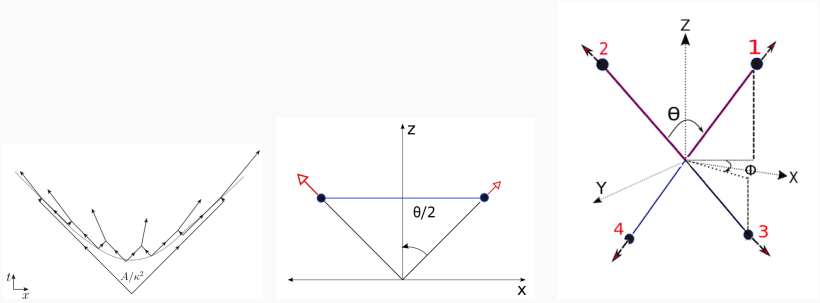
Conclusion

Test and decide!

1. Lab frame $\rightarrow$ Parallel frame with planar geometry of a string pair
2. Push on each hadrons based on the string-string interaction
3. Revert to the lab frame
4. Repeat for large multiplicity events
5. Test with data

Extras

x-t diagram and the real time picture



(a) **(b)** **(c)**

Figure 6: Strings in (a) x-t diagram where A = coherence area, κ = string tension and (b), (c) real time