Shoving mechanism in PYTHIA8

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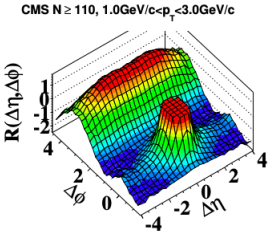
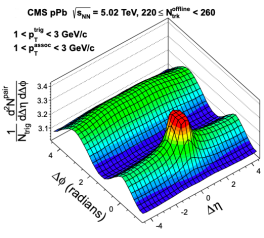
Motivation

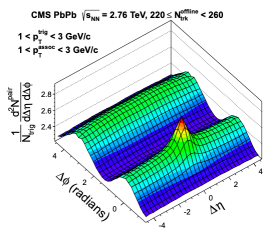
1. To search for explanation of possible collective effects in high multiplicity p-p collisions with string model

2. Is there any jet quenching in high multiplicity p-p events? Explanation in string model?

3. String model to study A-A systems







Angantyr and advancements

1. Aspects of Angantyr:
   - A-A is treated as a collection of overlaid p-p collisions
   - Modifications needed when one nucleon in one nucleus collides with several nucleons in the other
   - No collective effects

2. Mechanisms to study high-multiplicity p-p and A-A behaviours :
   - Final-state collective effects $\rightarrow$ String shoving
   - Jet quenching effects $\rightarrow$ Colour reconnection?
   - Strangeness enhancement $\rightarrow$ Rope hadronization?

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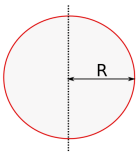
Interaction energy

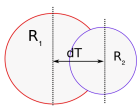
1. A string of radius R:

$$Field\ E(r_\perp) = C \exp\left(-\frac{r_\perp^2}{2R^2}\right) \quad (1)$$



2. Force $f(d_\perp)$ per unit length:

$$f(d_\perp) = \frac{dE_{int}}{dd_\perp} = \frac{g\kappa d_\perp}{R^2} exp\left(-\frac{d_\perp^2(t)}{4R^2}\right) \quad (2)$$



where g is a tunable parameter.

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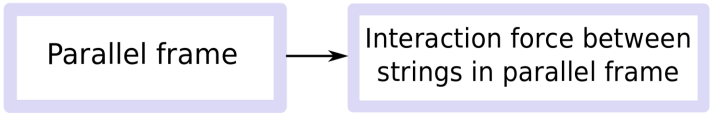
[1] arXiv:1710.09725v1 [hep-ph] 26 Oct 2017

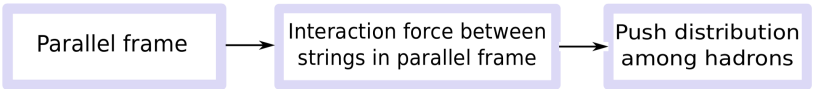
Methodology

Parallel frame

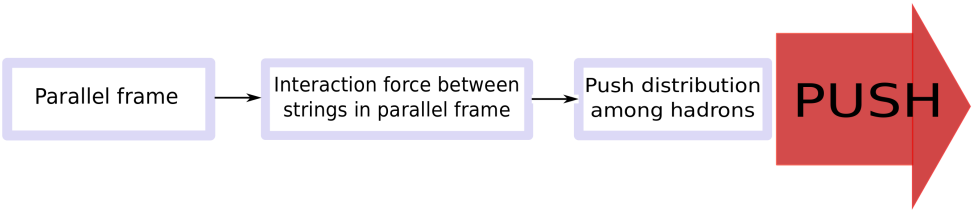
Methodology



Methodology



Methodology



1. Lorentz invariant frame - the parallel frame

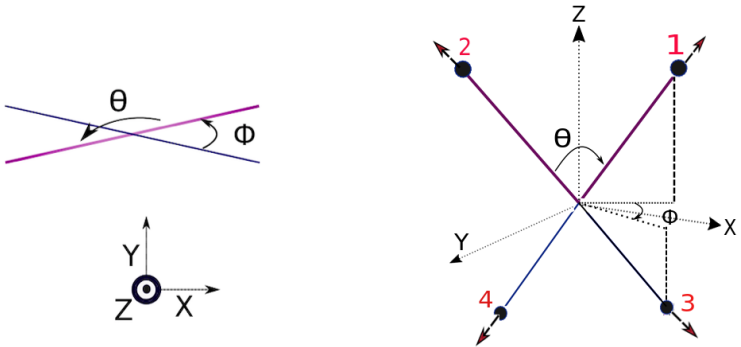
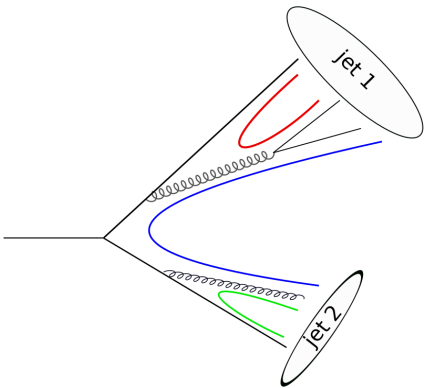


Figure: 1,2,3,4 are partons(string-ends), θ = opening angle, ϕ = skew angle.
Left: view from above. **Right**: Schematic view of two strings in the parallel frame

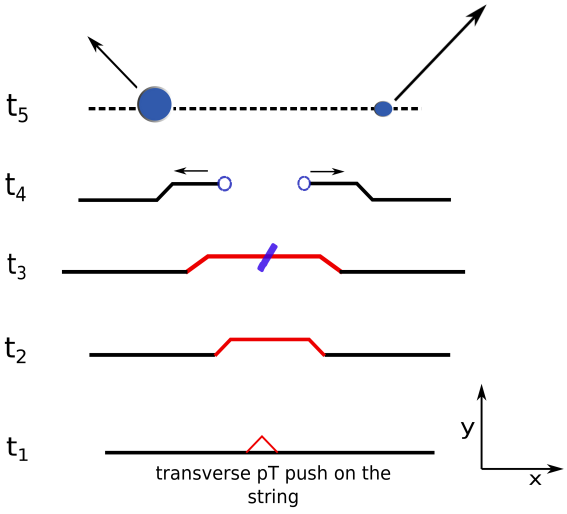
Role of parallel frames in jets



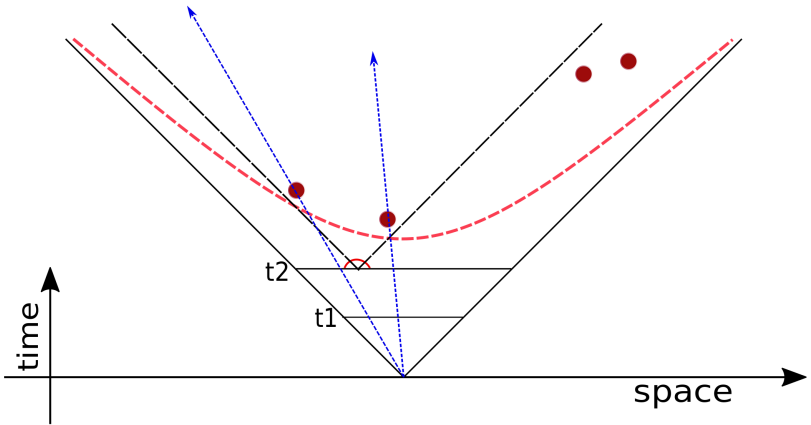
- Jets $\rightarrow$ quarks and gluons

- Interaction with partons following rule of least string length $\rightarrow$ modifies initial energy of jets

3. 'Push' distribution among hadrons



Parton vertices and hadronization



PRELIMINARY RESULTS

What are we looking at?

1. $S_N = \frac{1}{N(N-1)} \frac{d^2 N^{signal}}{d\Delta\phi d\Delta\eta}$

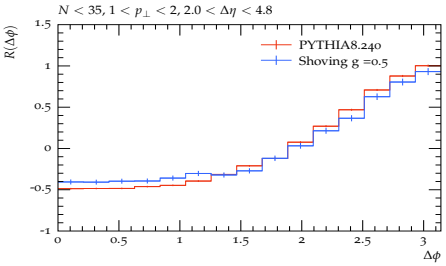
2. $B_N = \frac{1}{N^2} \frac{d^2 N^{mixed}}{d\Delta\phi d\Delta\eta}$

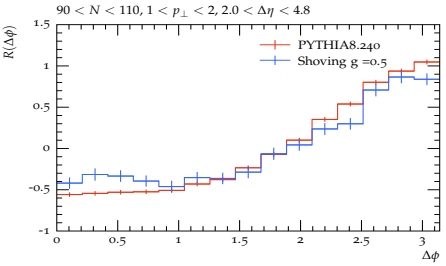
3. $\mathrm{R}(\phi) = \left\langle (< N > -1) \left(\frac{S_N}{B_N} - 1 \right) \right\rangle$

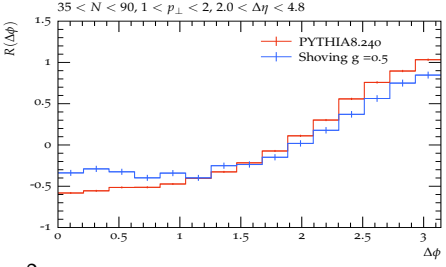
   where <N> is the number of tracks per event averaged over the multiplicity bin, and the final $R(\Delta\eta, \Delta\phi)$ is found by averaging over multiplicity bins

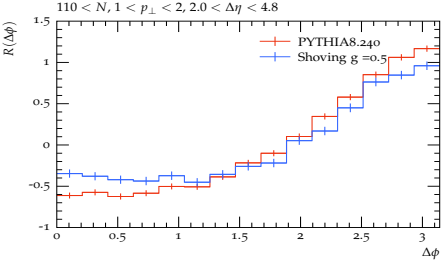
4. Analysis follows from: Observation of Long-Range, Near-Side Angular Correlations in Proton-Proton Collisions at the LHC, CMS Collaboration, arXiv:1009.4122v1 [hep-ex] 21 Sep 2010.

Di-hadron correlations in p-p at 7 TeV









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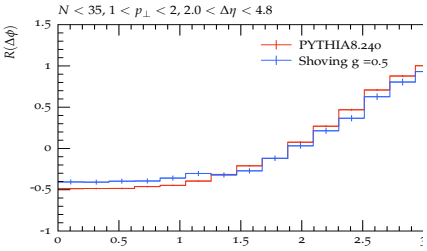
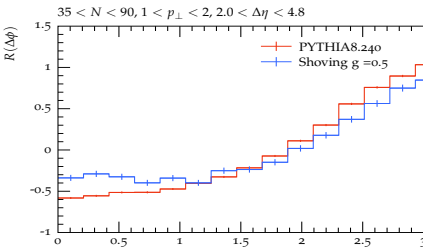
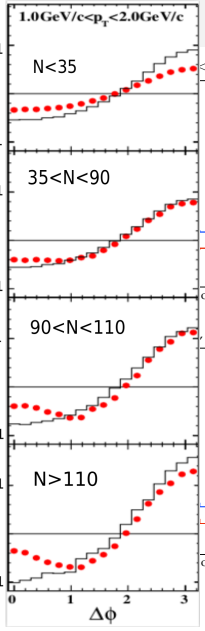
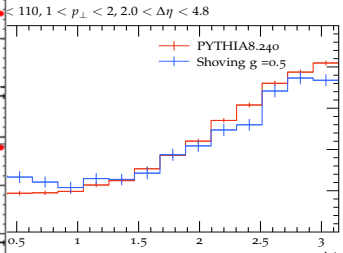
[2] arXiv:1009.4122v1 [hep-ex] 21 Sep 2010

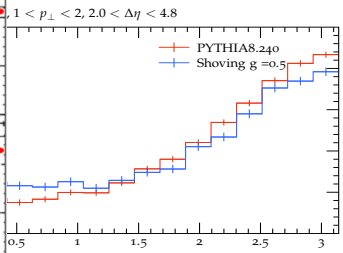
Di-hadron correlations in p-p





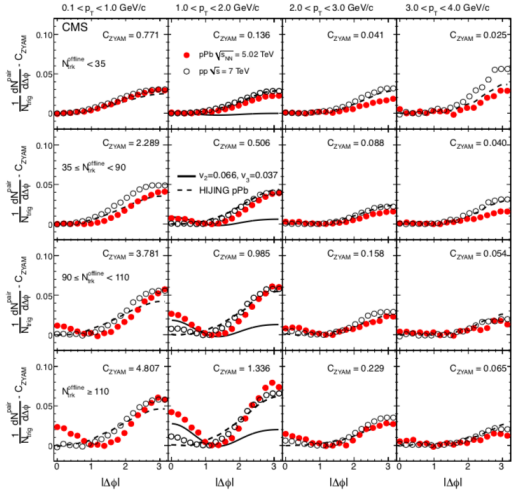






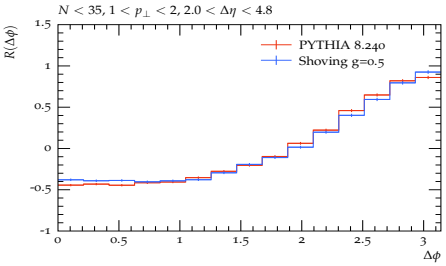
[3] arXiv:1009.4122v1 [hep-ex] 21 Sep 2010

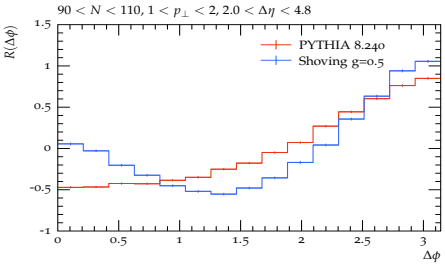
Di-hadron correlations in p-Pb

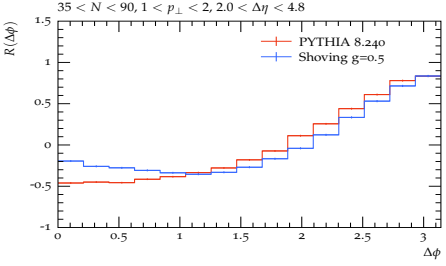


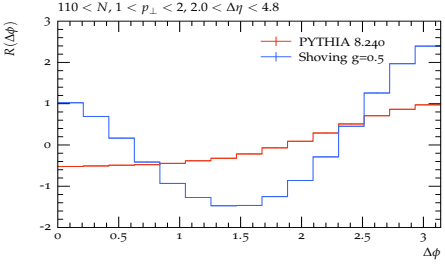
[4] arXiv:1210.5482v3 [nucl-ex] 20 Mar 2013

Di-hadron correlations in p-Pb





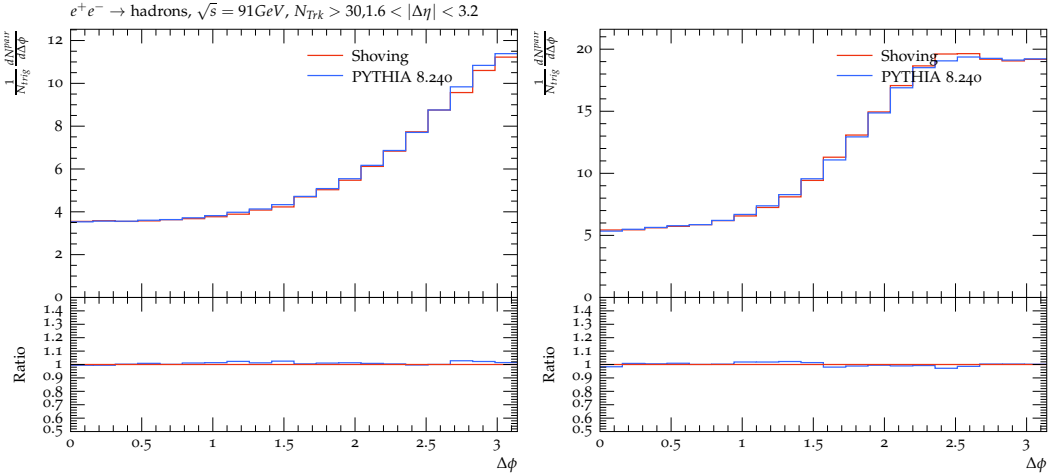




Note: Rivet analysis used is for p-p! [5]

[5] arXiv:1210.5482v3 [nucl-ex] 20 Mar 2013

Two particle correlations in $e^+ - e^-$ at 91 GeV



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[6] arXiv:1906.00489v5 [hep-ex] 9 Oct 2019

Conclusions

1. Summary
   - Shoving gives an observable collective effect in high multiplicity p-p and p-A
   - No corresponding effect observed for $e^+ - e^-$ collisions
2. Next steps
   - Compare with data: p-p and p-A
   - Studies for A-A with shoving is on the way

EXTRAS

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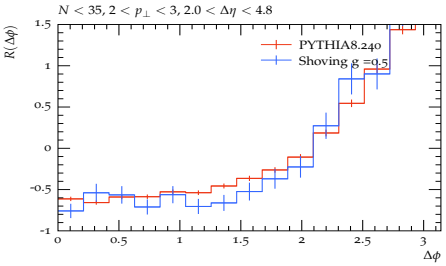

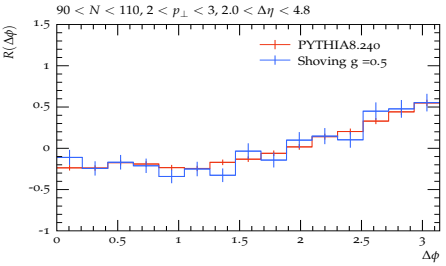

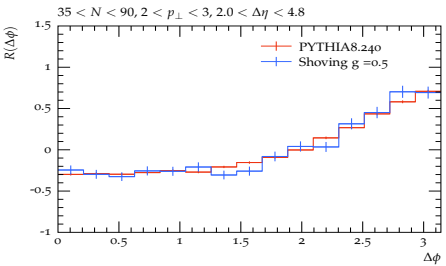

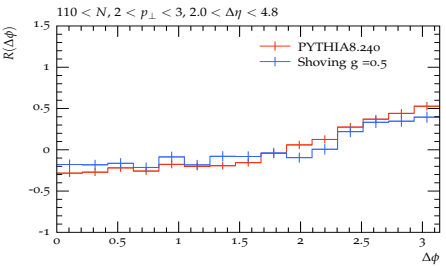

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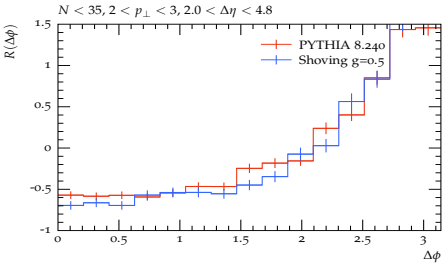

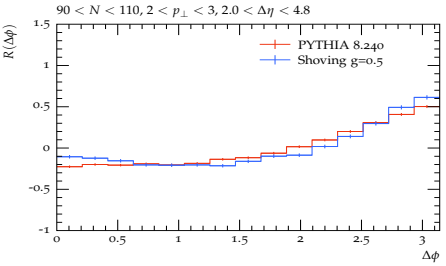

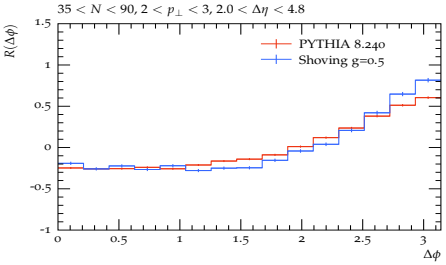

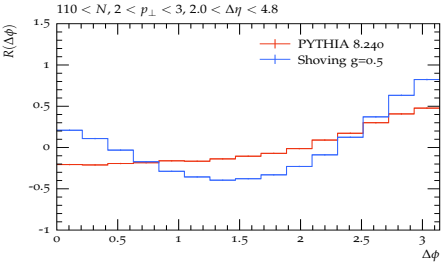

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