Contribution from hard partons to the bulk elliptic flow

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1. Motivation

Elliptic flow must be understood quantitatively.

The elliptic flow coefficient v_2 is defined as

$$\frac{d^3N}{d\phi\, p_T\, dp_T\, dy} = \frac{1}{2\pi}\frac{d^3N}{p_T\, dp_T\, dy}\left(1+2v_2\cos(2\phi)+\dots\right)$$

The measured values of v_2 are rather large and indicate:

- very low shear viscosity of the hydrodynamic medium
- very fast thermalisation of the early hot and dense matter or some pre-existing flow

It may be problematic to explain these two conclusions by some underlying theory.

To make firm conclusions on the properties and the behaviour of the medium, like relaxation times or shear viscosity, we must understand well, how the elliptic flow is generated and include into its descrition ***all*** effects which can contribute to it.

Here we explore one such effect which could contribute to the elliptic flow.

2. Jets in medium: streams

Observation at RHIC: jets are *strongly* quenched

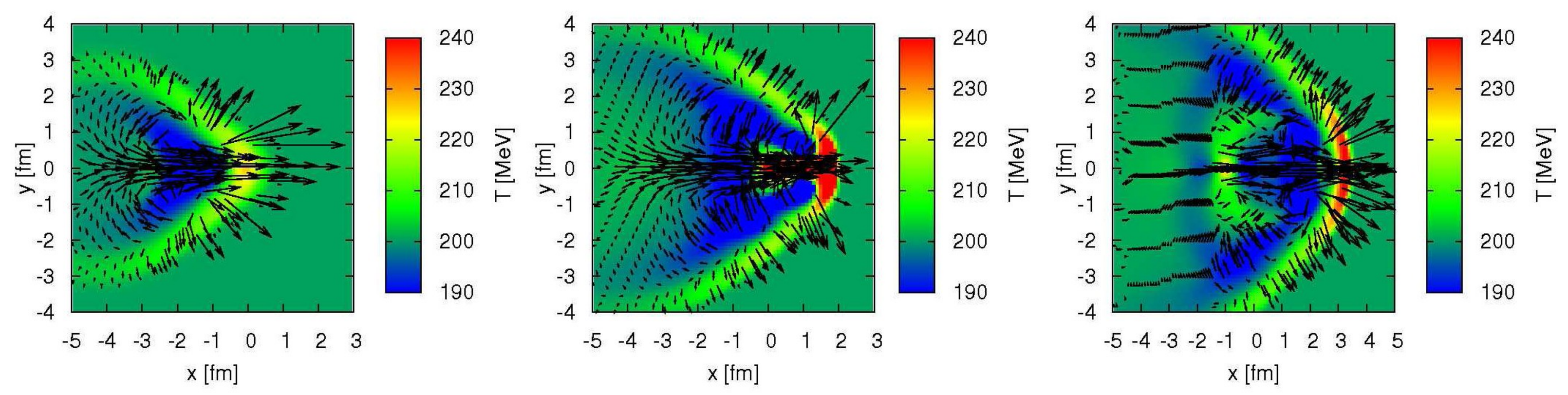
Jets influence the hydrodynamic evolution of the medium

- possible generation of Mach cones [1,2]
- generation of wakes – momentum deposition into the fluid (momentum conservation) [3]

=> **jets may induce streams of the hydrodynamic medium;**

streams continue even after the leading parton has lost all its energy [4]

Example from [4]: leading parton stopped at t = 4.5 fm/c
shown snapshots at times 4.5, 6.5, 8.5 fm/c



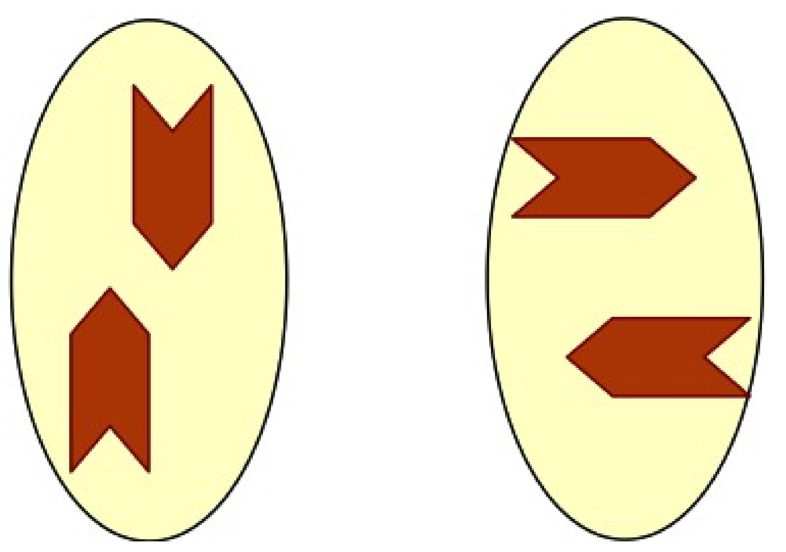
3. LHC: many jets in medium

At the LHC we have many jets and minijets produced in the early partonic interactions. We want to explore, what effect would have energy and momentum deposition from many jets.Many jets lead to ***many*** induced ***streams*** (wakes) within the hydrodynamic bulk medium.

In ***non-central collisions*** the directions of the jets are isotropic in transverse plane, but their initial spatial distribution is azimuthally non-symmetric. The interactions of streams may then lead to net anisotropic distribution of the resulting low.

If the effect results from the anisotropy of the shape, it will be correlated with the reaction plane.

A cartoon example:



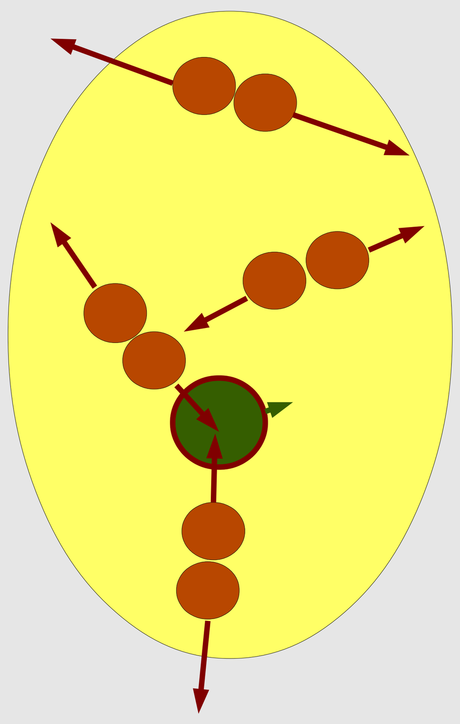
Two streams out-of-plane are more likely to cancel each other

This gives contribution to v_2

4. Calculation: a toy model

Properly, these streams should be simulated by hydrodynamic model with many source terms. This is technically too complicated. Therefore we choose a toy model for the first estimates. The simulation is done for LHC collisions of Pb+Pb.

- Streams are represented by droplets of matter, which are produced in pairs back to back.
- When two droplets meet/collide, they merge into a bigger droplet so that energy and momentum is conserved (see figure). This represents merging two streams of the bulk.
- The stream diameter is represented by the droplet size. In our displayed calculations we have used the radius of 1.5 fm (tests were also done with 2.5 fm).
- After all mergers are finished, the droplets evaporate pions according to their energy content.



Initial distribution of momenta

- Transverse momentum distribution parametrised by

$$E\frac{d\sigma_{NN}}{dp^3} = \frac{1}{2\pi}\frac{1}{p_T}\frac{d\sigma_{NN}}{dp_T\, dy} = \frac{B}{(1+p_T/p_0)^n}$$

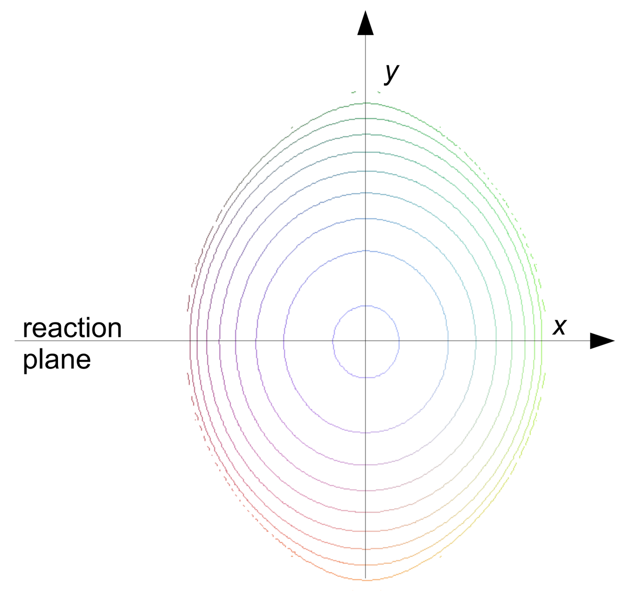
B = 14.7 mbarn/GeV^2, p_0 = 6 GeV, n = 9.5

- Uniform distribution in rapidity
- Almost back-to-back pairs (only) in transverse momentum – simulate k_T broadening

Initial positions of jets/droplets:

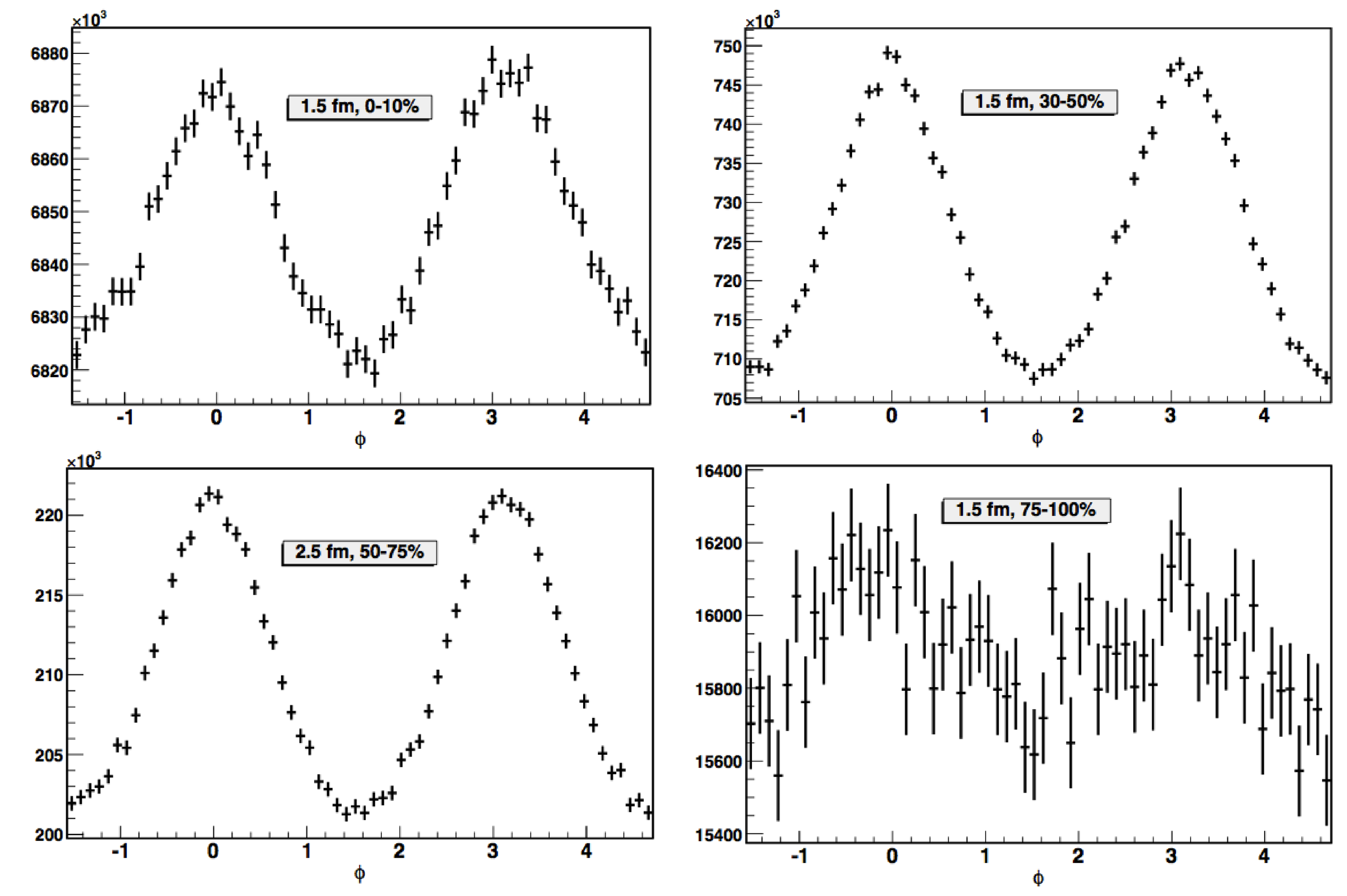
Glauber model

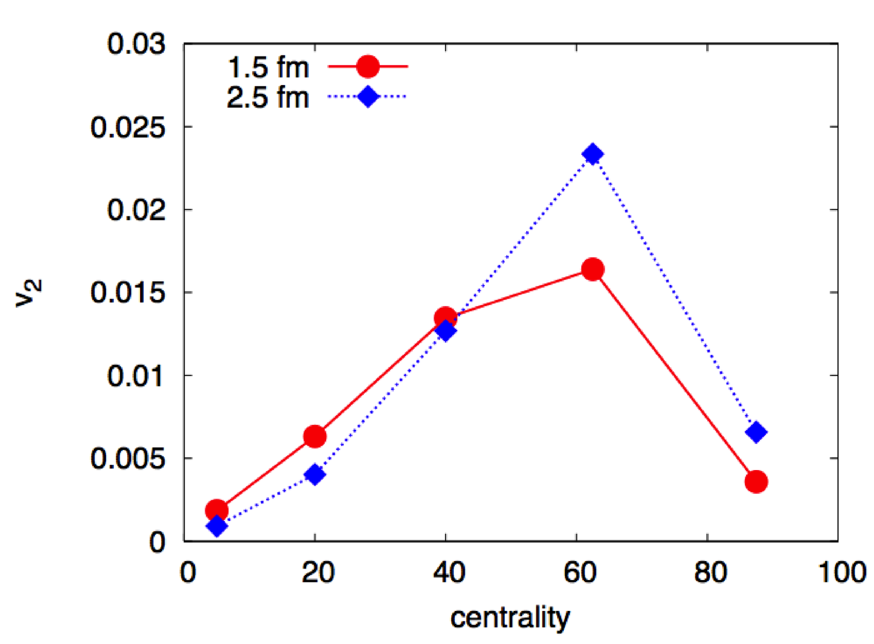
$$U_{AA}(\vec{b},\vec{x}) = T_{AA}(\vec{b},\vec{x})T_{AA}(\vec{b},\vec{x}-\vec{b})$$



5. Results

Histograms of the azimuthal distribution of pions w.r.t. reaction plane, for different centralities and droplet radii, summed over 100,000 events.





Elliptic flow as a function of centrality for different droplet radii

6. Conclusions

- Streams initiated by deposition of momentum from jets can lead to a contribution to the elliptic flow at the LHC.
- From the toy simulation we expect contribution to the elptic flow on the integrated elliptic flow, i.e., about 15% of the total flow.
- This contribution to elliptic flow fluctuates strongly.
- For better estimates there is a need for more careful simulations with the help of a hydrodynamic model.

References

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