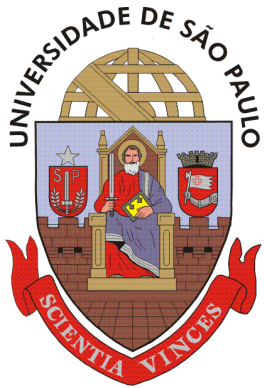


Jet quenching effects on the direct, elliptic and triangular flow at RHIC



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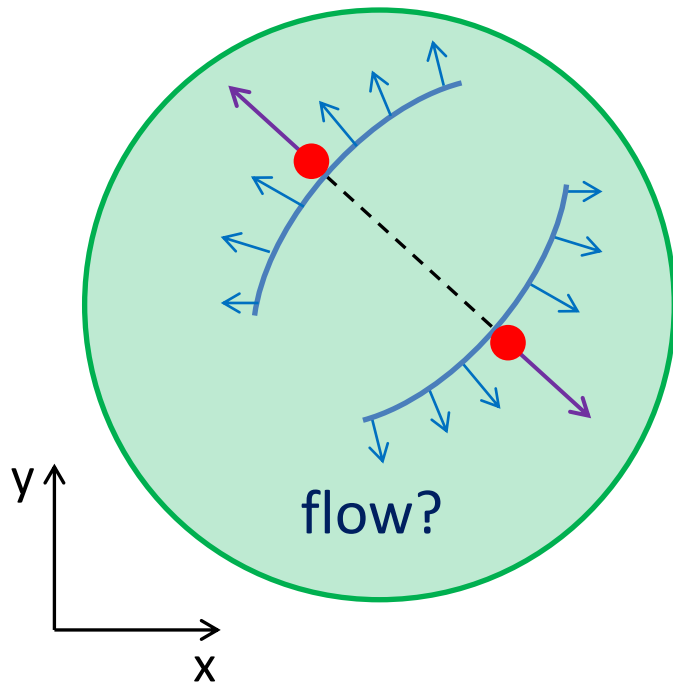
Purpose

□ In this work we investigate how the energy-momentum deposited by partonic **jets** in the **quark-gluon plasma** may affect the direct, elliptic and triangular **flow** of low (intermediate) p_T hadrons at RHIC.

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200 GeV Au+Au



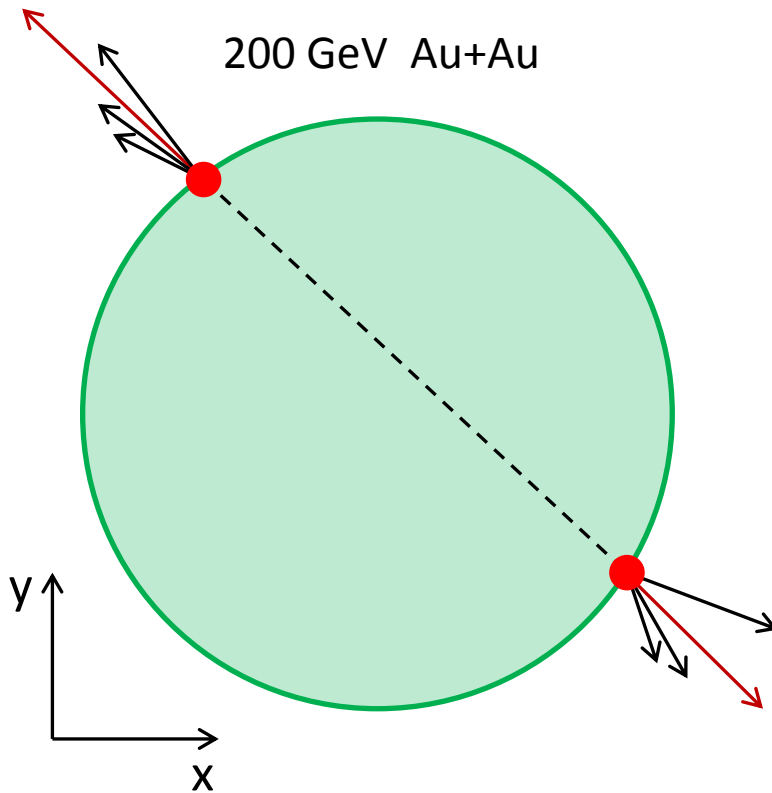
□ We are trying to understand the effects of the **jets** on the flow Fourier coefficients (v_1, v_2 and v_3).

□ The hydrodynamic evolution is computed **event-by-event**.

Purpose

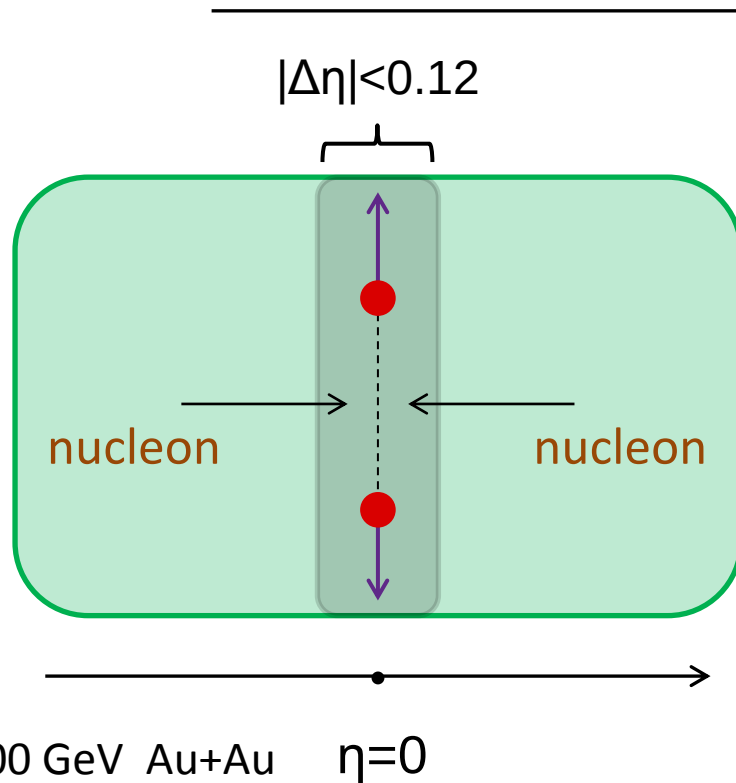
□ In this work we investigate how the energy-momentum deposited by partonic **jets** in the **quark-gluon plasma** may affect the direct, elliptic and triangular **flow** of low (intermediate) p_T hadrons at RHIC.

□ The partonic fragmentation is not included in the model.



Purpose

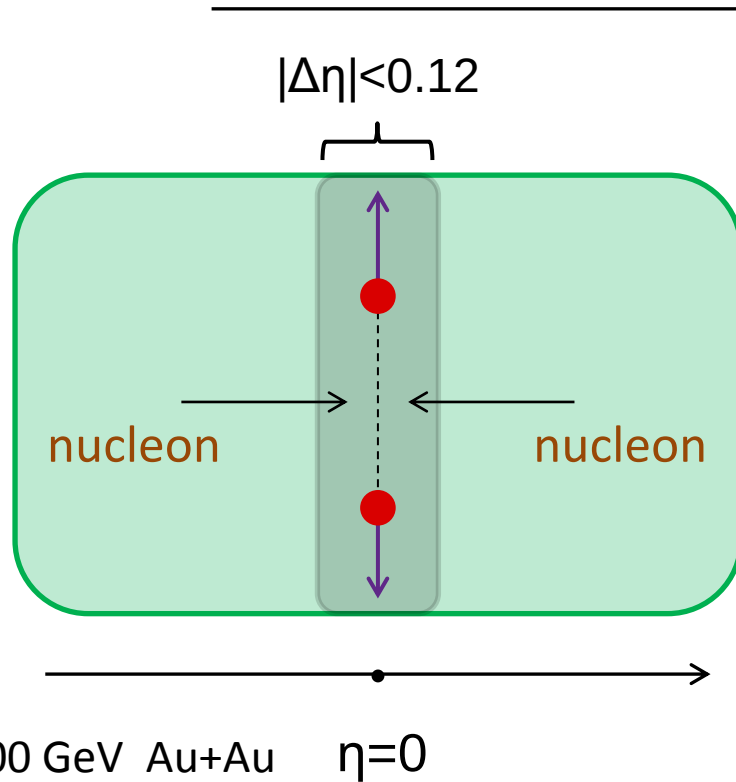
❑ In this work we investigate how the energy-momentum deposited by partonic **jets** in the **quark-gluon plasma** may affect the direct, elliptic and triangular **flow** of low (intermediate) p_T hadrons at RHIC.



- ❑ The **partons** move on the mid-rapidity transverse plane.
- ❑ For the longitudinal direction we use the **boost-invariant solution**.
- ❑ (2+1) **hydrodynamic** code (ideal fluid).
- ❑ Central (0-5)% Au+Au collisions at 200A GeV.

Purpose

□ In this work we investigate how the energy-momentum deposited by partonic **jets** in the **quark-gluon plasma** may affect the direct, elliptic and triangular **flow** of low (intermediate) p_T hadrons at RHIC.



□ The effects of these **partons** on the **medium** can be taken into account through a source term in the energy-momentum conservation equation [23].

$$\partial_\mu T^{\mu\nu} = J^\nu \quad (1)$$

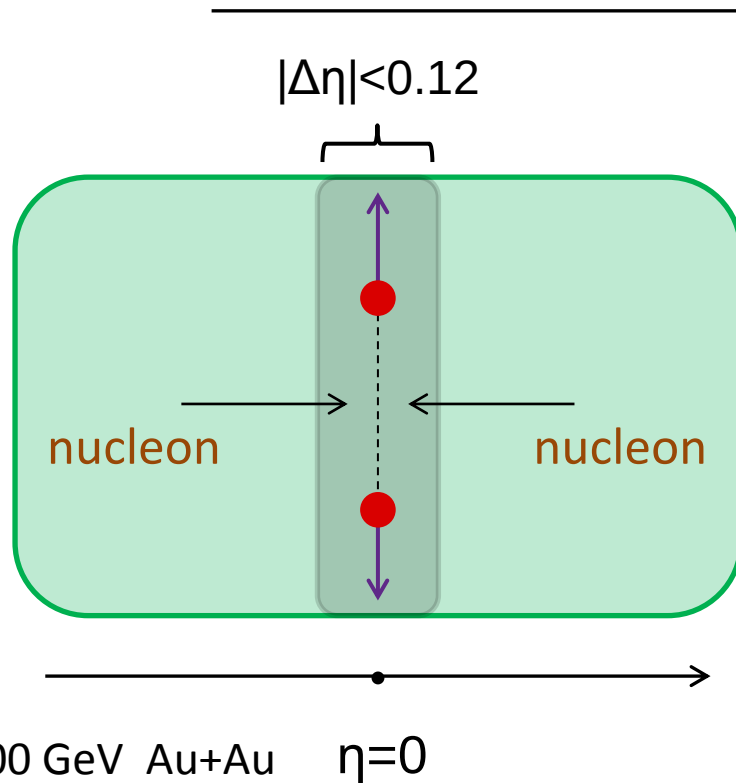
$$J^\nu = \sum_n \frac{dE_n}{dl} F(\vec{r} - \vec{r}_n^{jet}(\tau), \tau) (1, \vec{v}_n^{jet}, 0) \quad (2)$$

$$\frac{dE_n}{dl} = \frac{s(\vec{r}_n^{jet}(\tau))}{s_0} \underbrace{\frac{dE}{dl}}_{\text{reference energy loss}} \bigg|_0 \quad (3)$$

[23] A. Chaudhuri and U. Heinz, Phys.Rev.Lett. **97**, 062301 (2006).

Purpose

□ In this work we investigate how the energy-momentum deposited by partonic **jets** in the **quark-gluon plasma** may affect the direct, elliptic and triangular **flow** of low (intermediate) p_T hadrons at RHIC.



□ The initial conditions are given by an implementation of the Monte Carlo Glauber model [25].

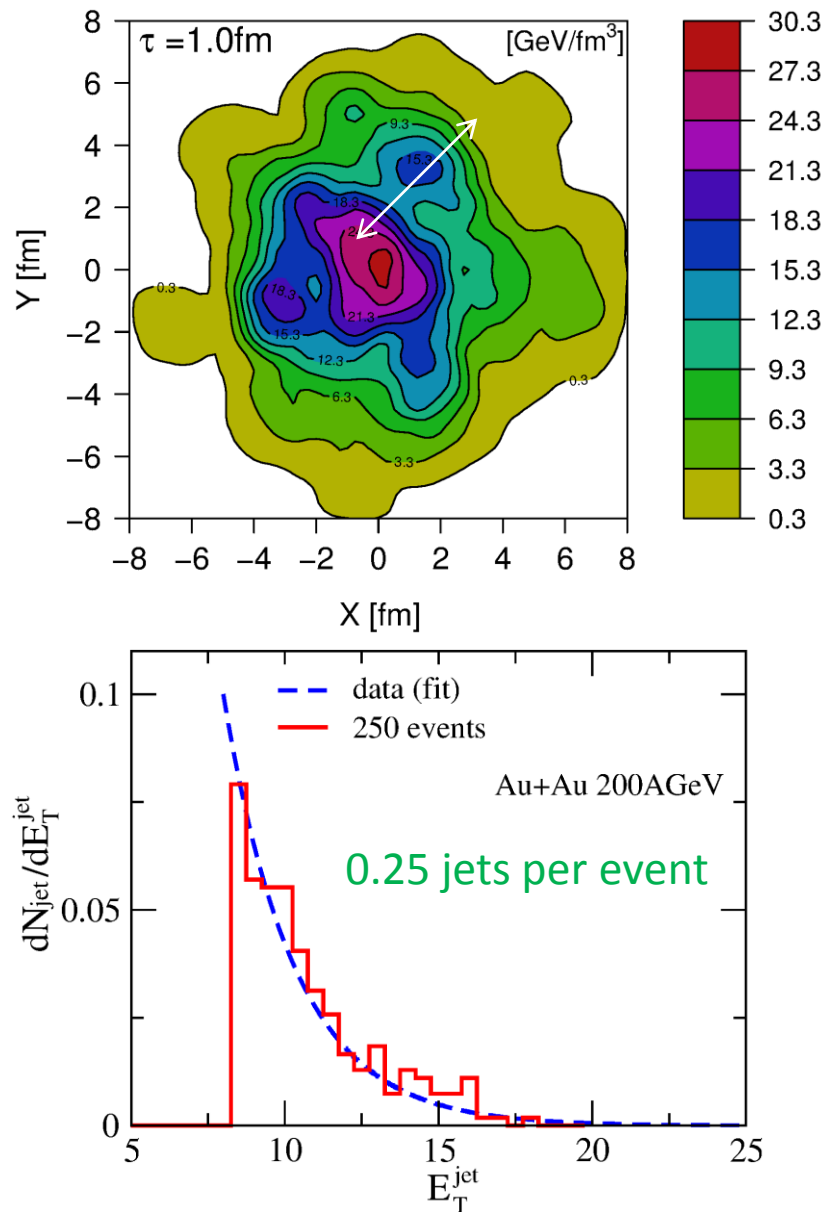
□ We use the **equation of state** EOS S95n-v1 [18], which combines results from lattice QCD at high temperatures and the hadron **resonance gas** equation at low temperatures.

□ To compute the particle spectrum, we use the **Cooper-Frye** prescription.

[25] H.-J. Drescher and Y. Nara, Phys.Rev. **C75**, 034905 (2007).

[18] P. Huovinen and P. Petreczky, Nucl.Phys. **A837**, 26 (2010).

Event-by-event procedure



1 - The initial conditions are computed using the Monte Carlo Glauber model.

2 - The initial position of the **di-jet** is chosen according to the **hot-spot** positions (the azimuthal angle of the **di-jet** is random).

3 - The total energy of each **parton**, the same for both, is chosen according to the jet yield per event [27].

4 - The **hydrodynamic evolution** is computed using the SPH method [16].

5 - The final spectra (for direct positively charged pions) is computed using the **Cooper-Frye prescription**.

[27] Š. Šalur (STAR Collaboration), Eur.Phys.J. C61, 761 (2009), arXiv:0809.1609 [nucl-ex].

[16] C. E. Aguiar, T. Kodama, T. Osada, and Y. Hama, J. Phys. G27, 75 (2001).

Results

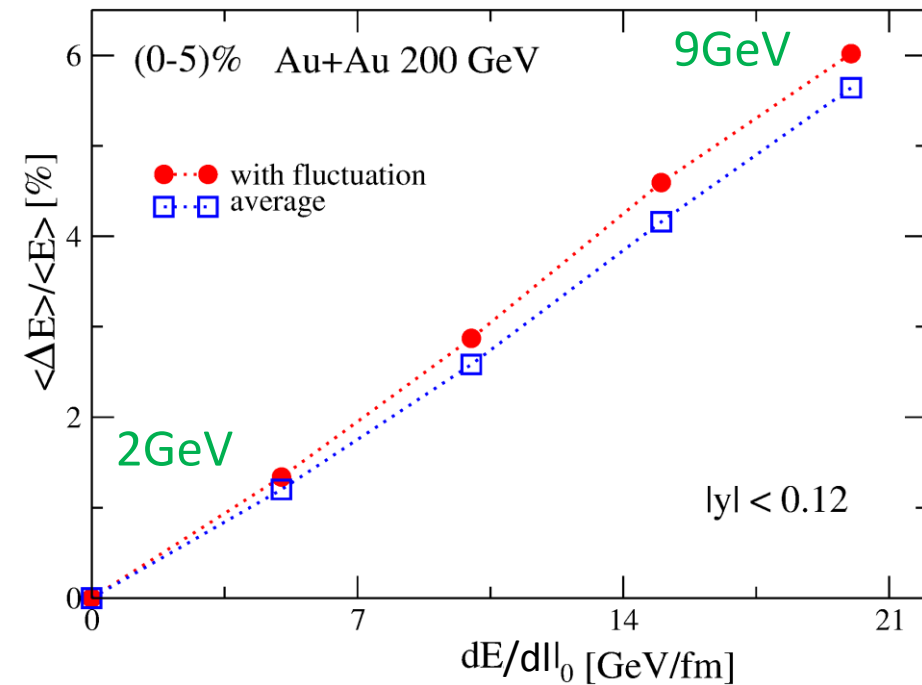


Fig.: Average energy deposited in the medium, $\langle \Delta E \rangle$, by the di-jet, over the average of the total energy of the fluid $\langle E \rangle$, as a function of the reference energy loss rate $dE/dl|_0$.

- ❑ As one can see, the **fluctuations** do not modify the ratio $\langle \Delta E \rangle / \langle E \rangle$ significantly.
- ❑ The average amount of **energy** added to the **fluid**, using $dE/dl|_0 = 20 \text{ GeV/fm}$, is relatively small, on the order of 9 GeV for each parton ($\langle E \rangle = 285 \text{ GeV}$). This is mainly because of the violent longitudinal expansion, that quickly rarefies the **QGP**.

Results

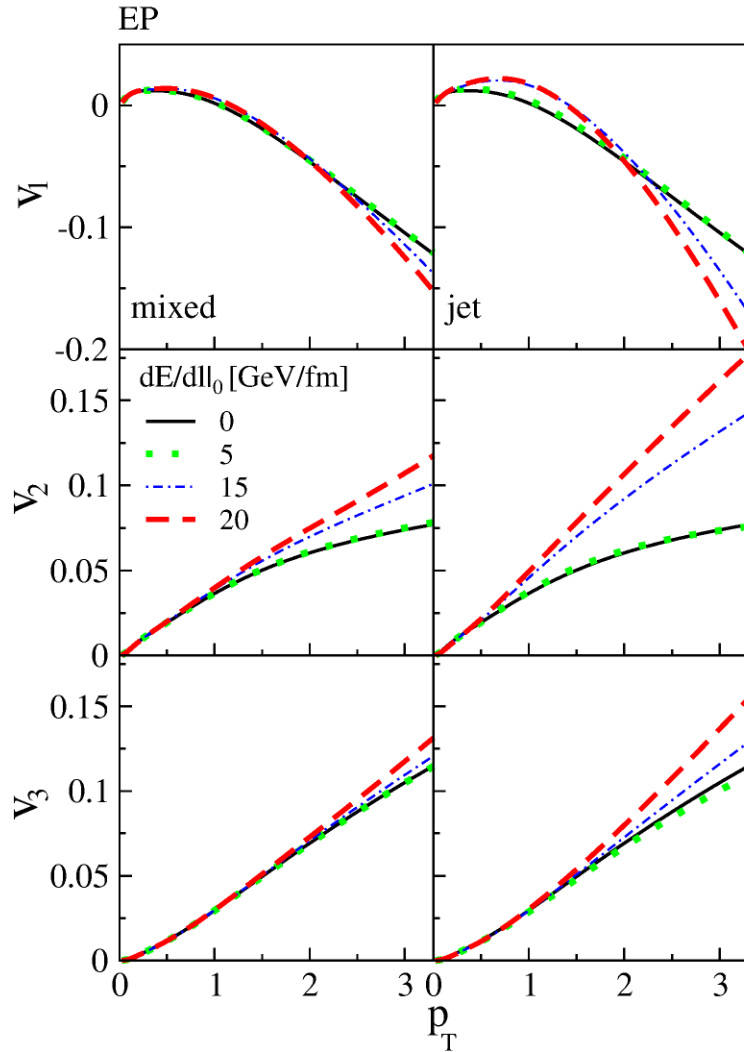
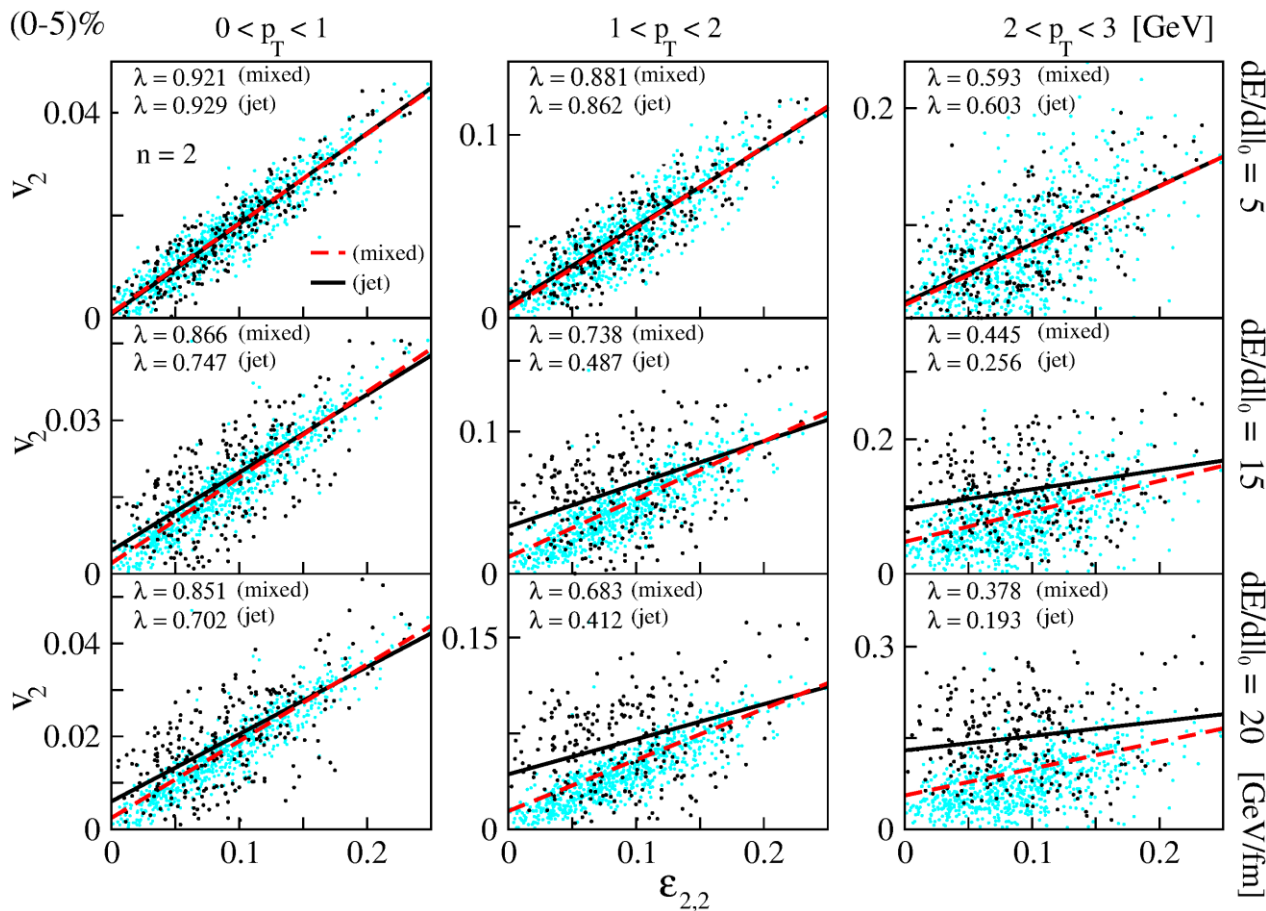


Fig.: Transverse momentum dependence of the v_n coefficients ($n=1,2,3$), for four values of the parameter $dE/dl|_0$.

- ❑ Using $dE/dl|_0 = 5 \text{ GeV/fm}$, the results are identical to the results without jets.
- ❑ As one can see, in the majority of the cases, the effects of the **jets** are not important in the region of low p_T ($p_T < 1 \text{ GeV}$).
- ❑ The flow **anisotropy** is enhanced, as expected, when one includes only events with jets.

Results



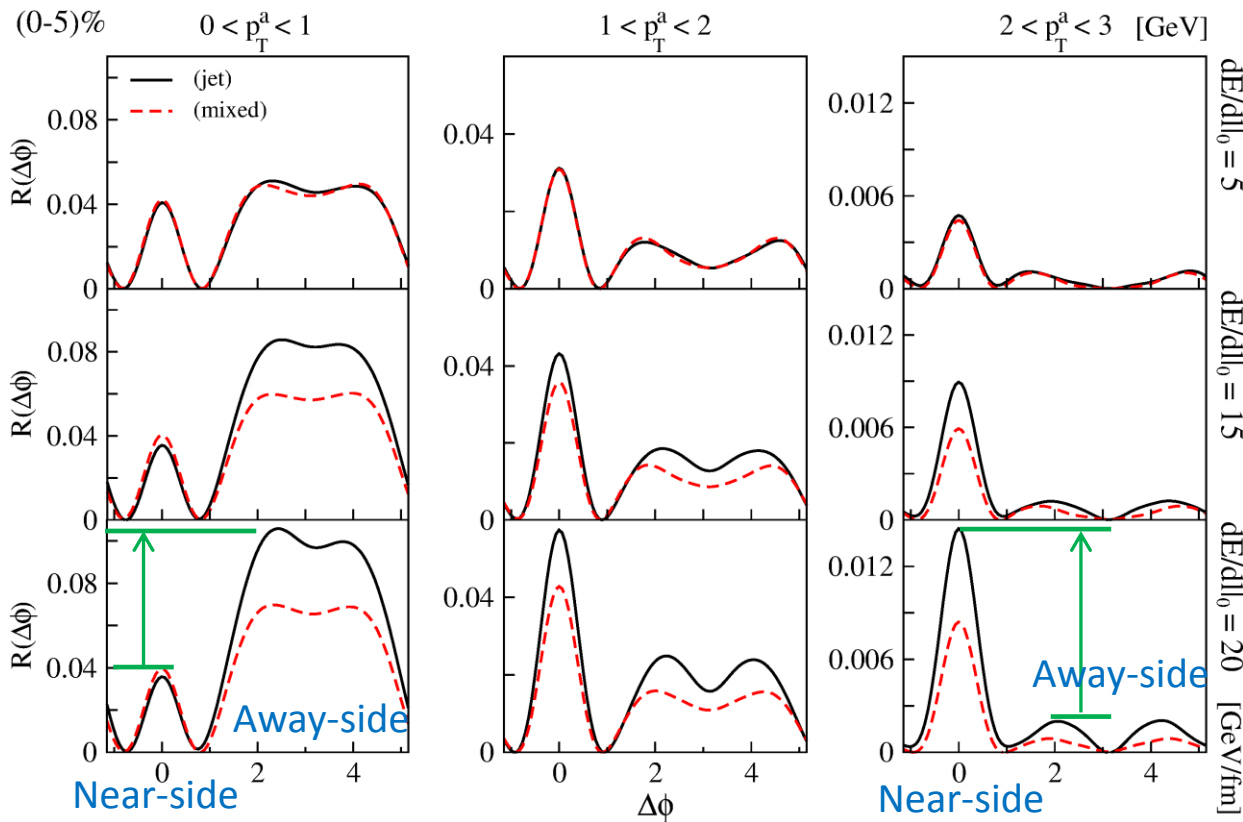
□ In the region of higher p_T , the effects of the **jets** reduce the correlation between v_2 and ϵ_{22} .

□ The anisotropic flow created by the **jets** can be clearly seen in events with zero **eccentricity**.

□ Similar behavior is observed for the correlation between v_3 and ϵ_{23} .

Fig.: Correlation between the eccentricity ϵ_{22} and the flow coefficient v_2 , for three values of the parameter $dE/dl|_0$. The dashed lines correspond to linear fits computed using the mixed Ensemble (black and light dots). The solid lines were computed using the jet Ensemble (black dots). λ is the linear correlation coefficient.

Results



□ The profile of the di-hadron angular correlation function is compatible with the data.

□ The **Jets** basely modify the relative height between the **near-side** and **away-side** peaks. This is a consequence of the **direct flow** v_1 created by the propagation of the partons in the medium.

Fig.: Azimuthal component of the di-hadron correlation function $R(\Delta\Phi)$, for three values of the parameter $dE/dl|_0$. The dashed lines correspond to the mixed Ensemble and the solid lines to the jet Ensemble. The range in p_T for the triggers is defined as $3 < p_T < 5$ GeV.

Conclusion

- ❑ The effects of the **jets** on the medium seem to be not important in the region of low p_T ($p_T < 1 \text{ GeV}$).
- ❑ In fact, jets affect the intermediate p_T ($1 < p_T < 3$) GeV.
- ❑ The correlation between initial geometry and flow does not work properly in the region of intermediate (high) p_T .
- ❑ The effects of the jets in the medium can be seen in the profile of the di-hadron angular correlation function.

New event selection: with (at least 1 di-jet) and without jets?

Extra slides

Formulas

$$\varepsilon_{m,n} = \frac{\{r^m \cos [n (\phi - \Phi_{m,n})]\}}{\{r^m\}}$$

$$\Phi_{m,n} = \frac{1}{n} \tan^{-1} \left(\frac{\{r^m \sin (n\phi)\}}{\{r^m \cos (n\phi)\}} \right)$$

$$C(\Delta\phi) = c_0 + \sum_n c_n \cos(n\Delta\phi) + \sum_n \tilde{c}_n \sin(n\Delta\phi)$$

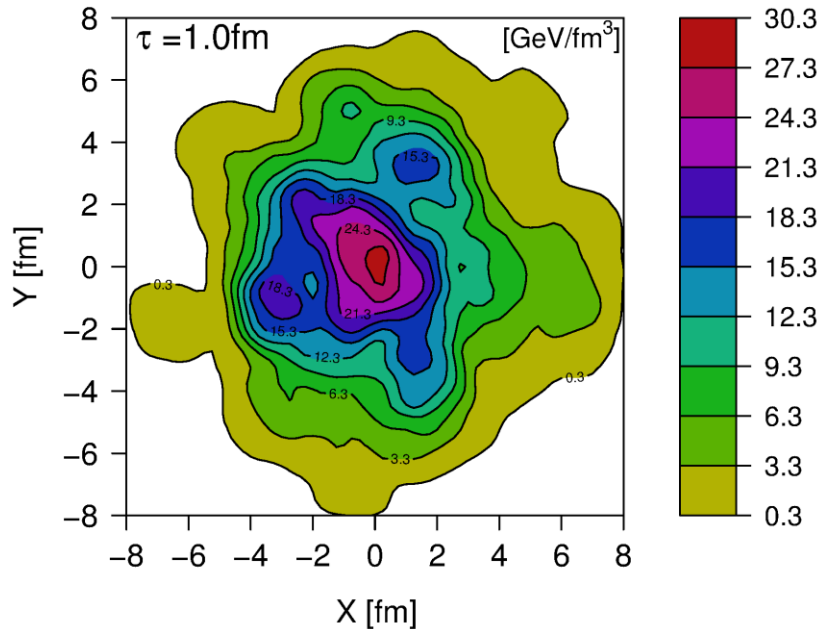
$$c_0 = \frac{\langle v_0^a v_0^t \rangle}{\langle v_0^t \rangle}$$

$$c_n = \frac{2}{\langle v_0^t \rangle} \langle v_0^a v_0^t v_n^a v_n^t \cos [n (\Psi_n^t - \Psi_n^a)] \rangle$$

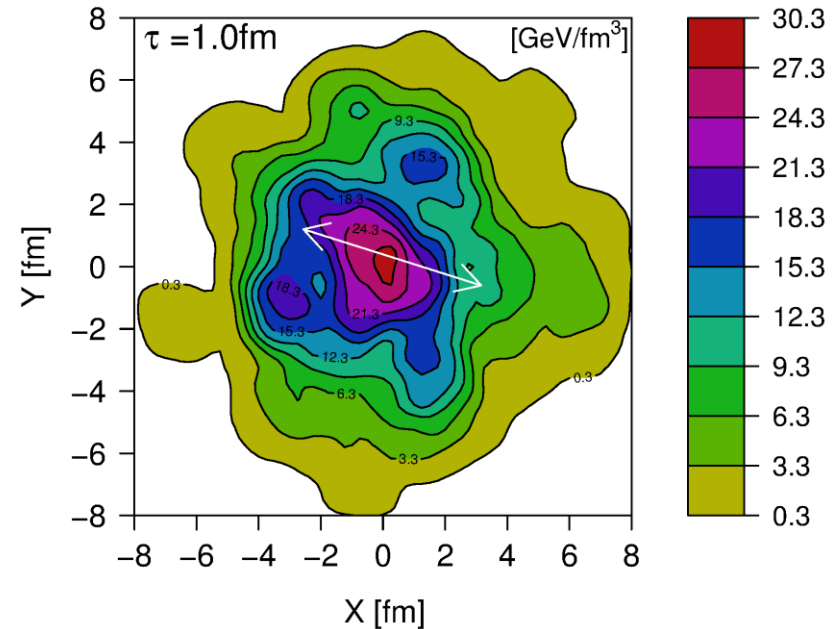
$$\tilde{c}_n = \frac{2}{\langle v_0^t \rangle} \langle v_0^a v_0^t v_n^a v_n^t \sin [n (\Psi_n^a - \Psi_n^t)] \rangle$$

Hydrodynamic evolution

without jets



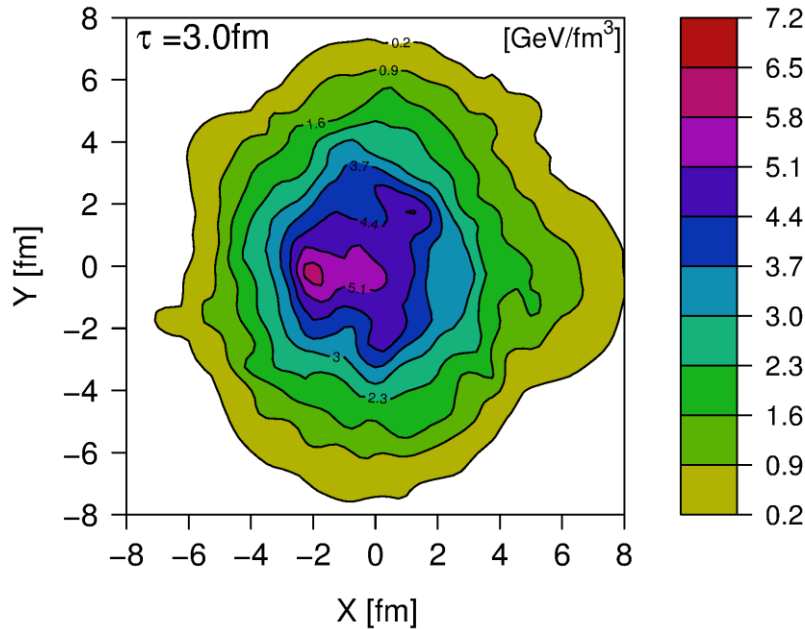
with jets



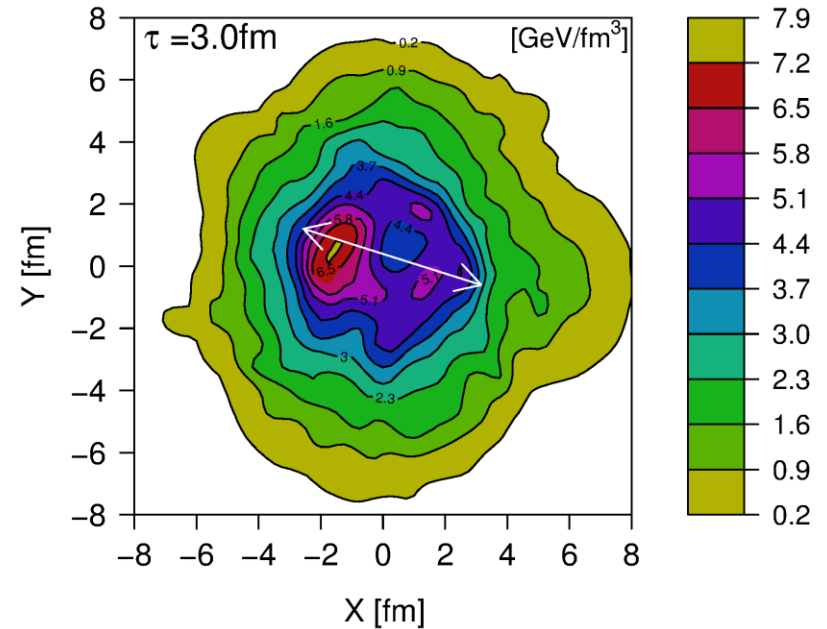
□ **Hydrodynamic evolution**, in the transverse plane at the mid-rapidity, of a single event without (left plot) and with (right plot) the propagation of the **partonic jet**.

Hydrodynamic evolution

without jets



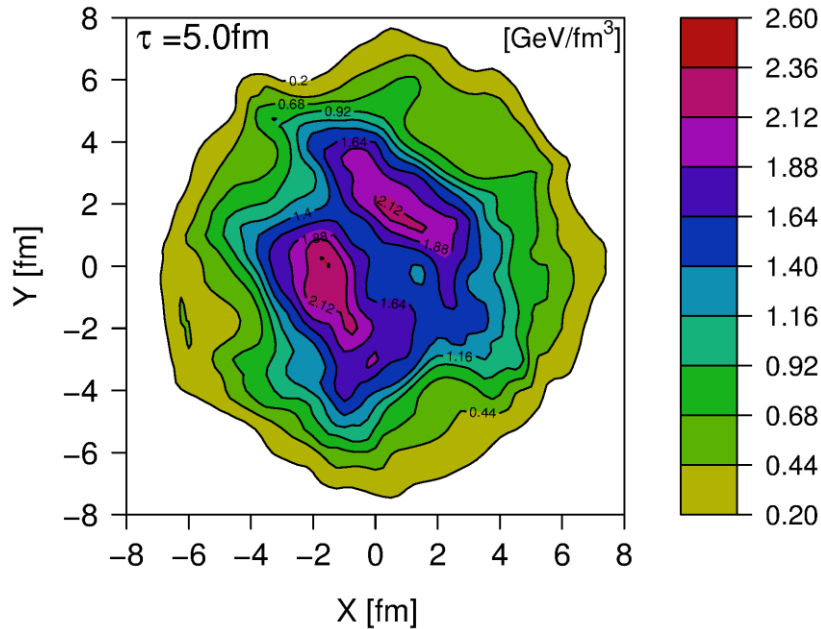
with jets



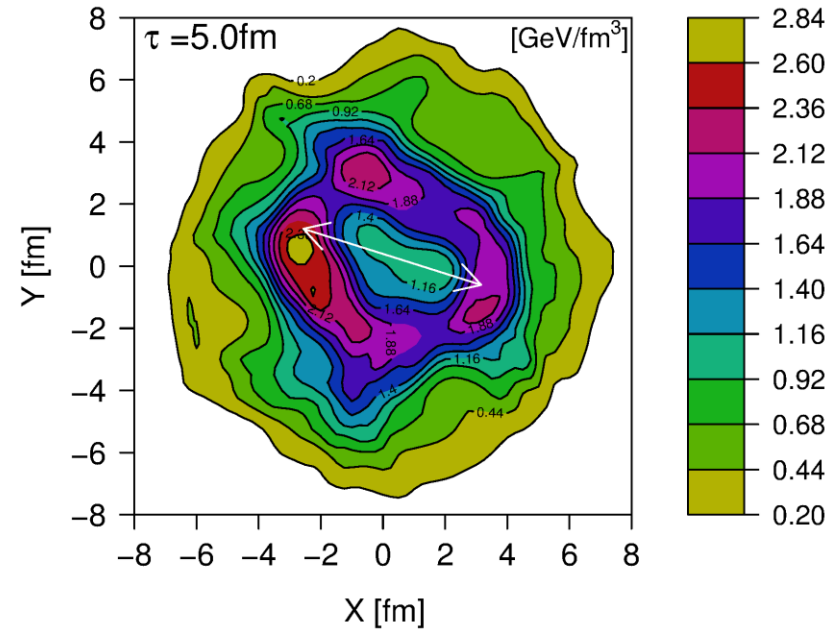
□ **Hydrodynamic evolution**, in the transverse plane at the mid-rapidity, of a single event without (left plot) and with (right plot) the propagation of the **partonic jet**.

Hydrodynamic evolution

without jets



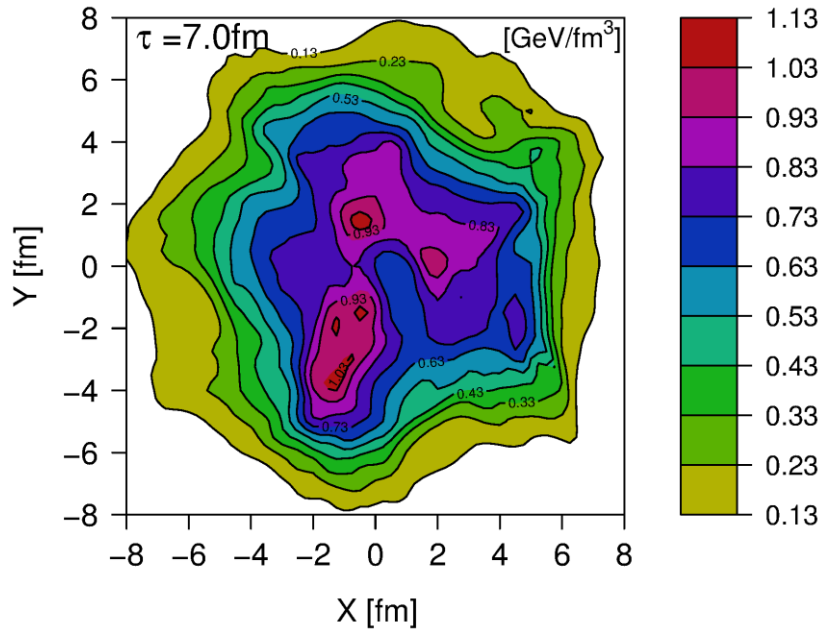
with jets



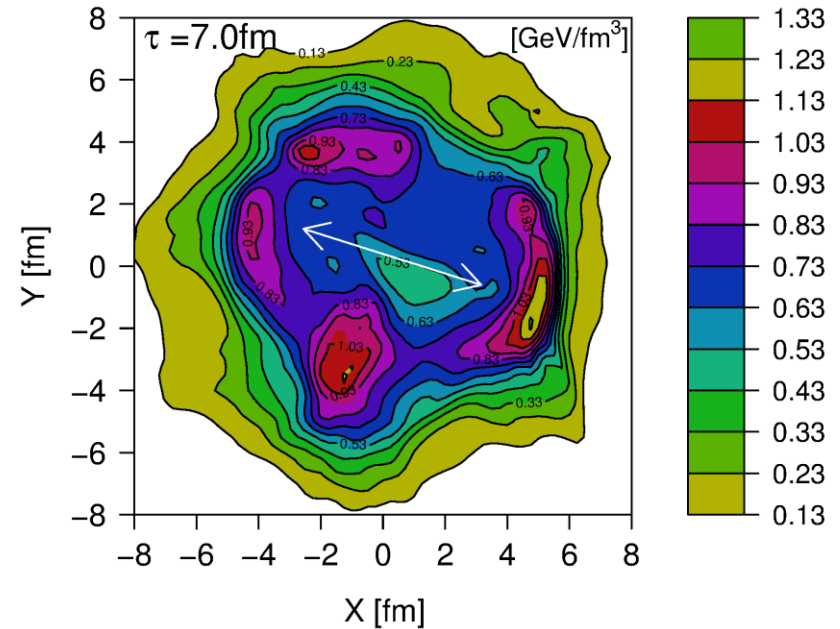
□ **Hydrodynamic evolution**, in the transverse plane at the mid-rapidity, of a single event without (left plot) and with (right plot) the propagation of the **partonic jet**.

Hydrodynamic evolution

without jets

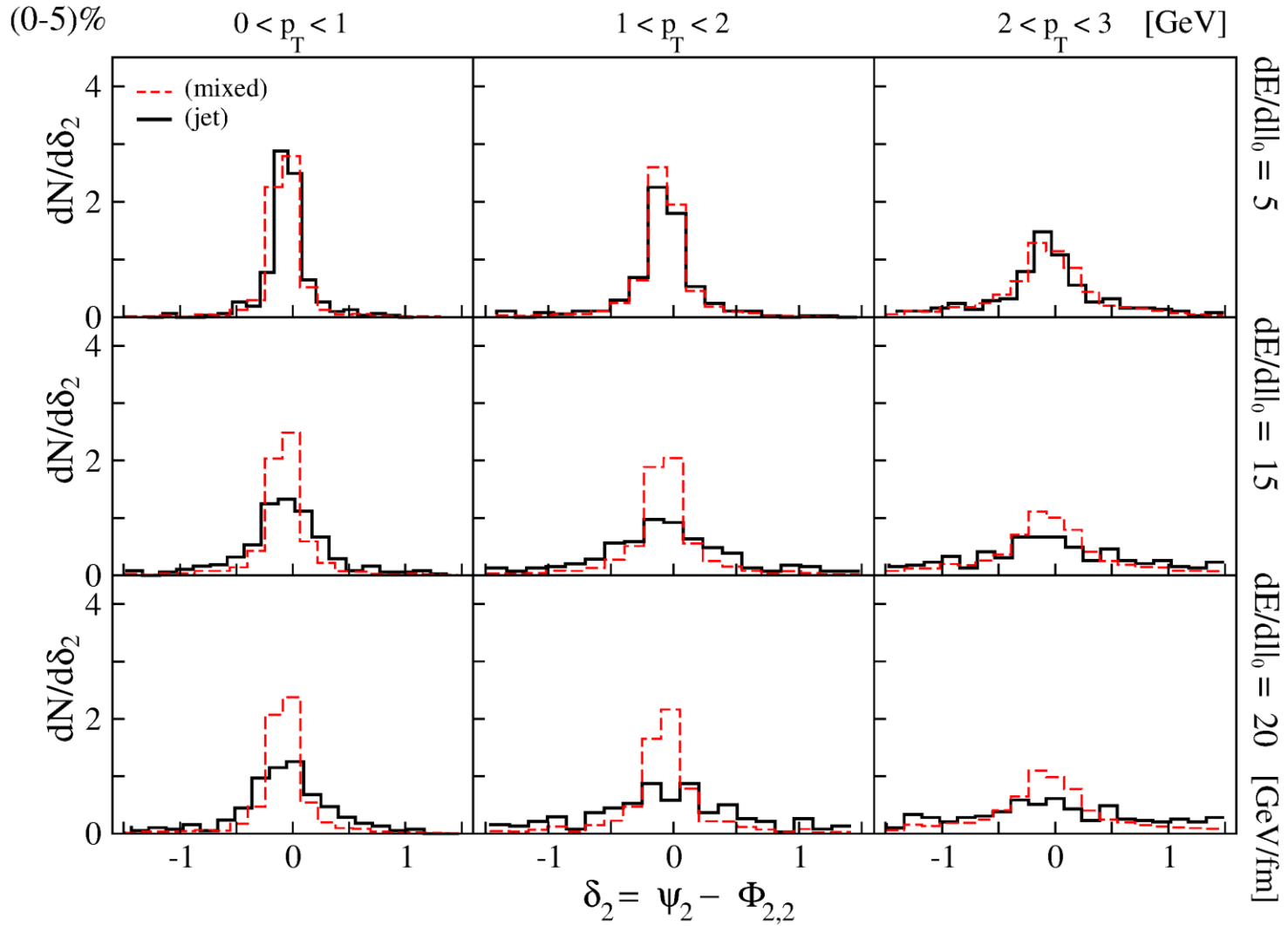


with jets

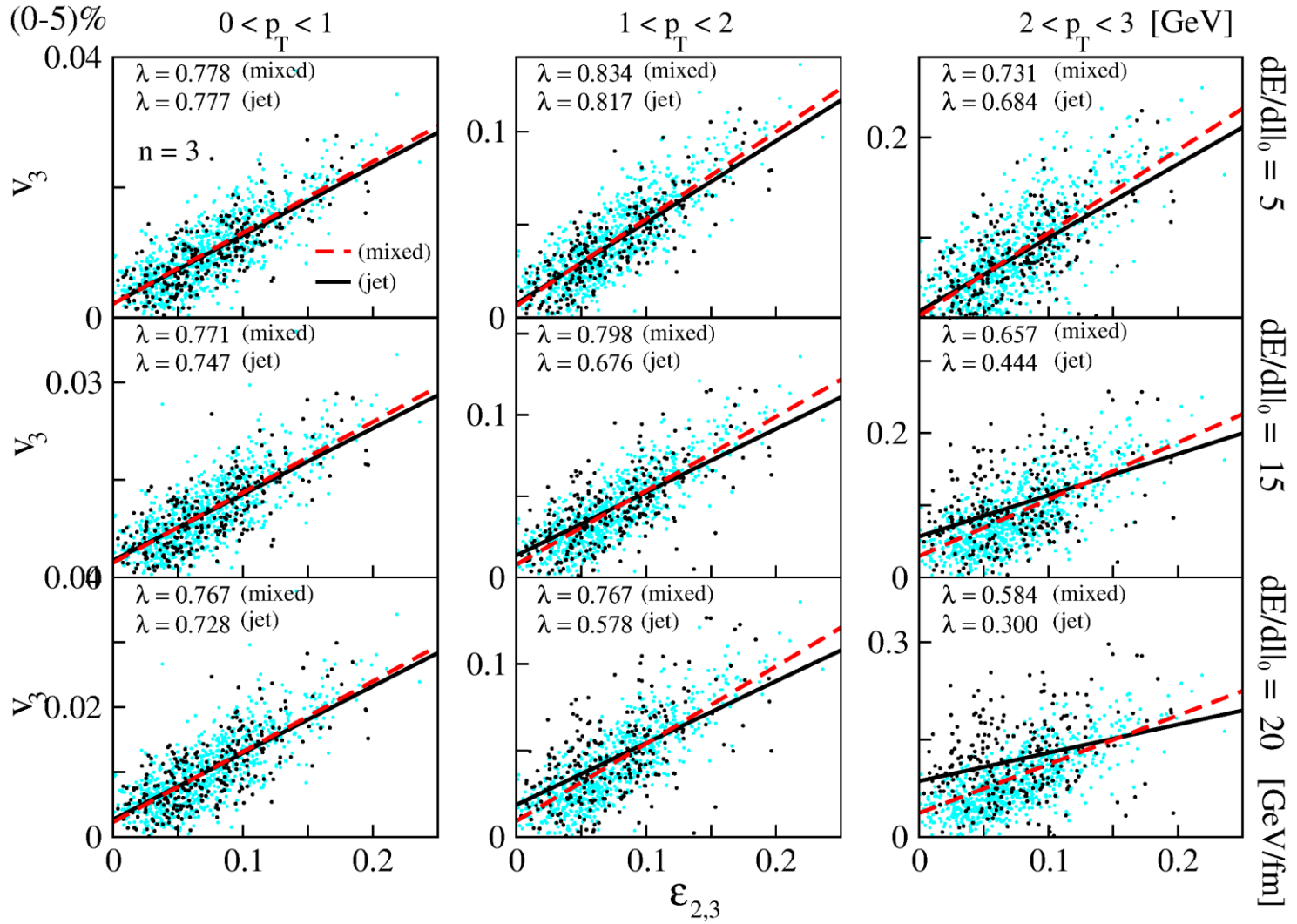


□ **Hydrodynamic evolution**, in the transverse plane at the mid-rapidity, of a single event without (left plot) and with (right plot) the propagation of the **partonic jet**.

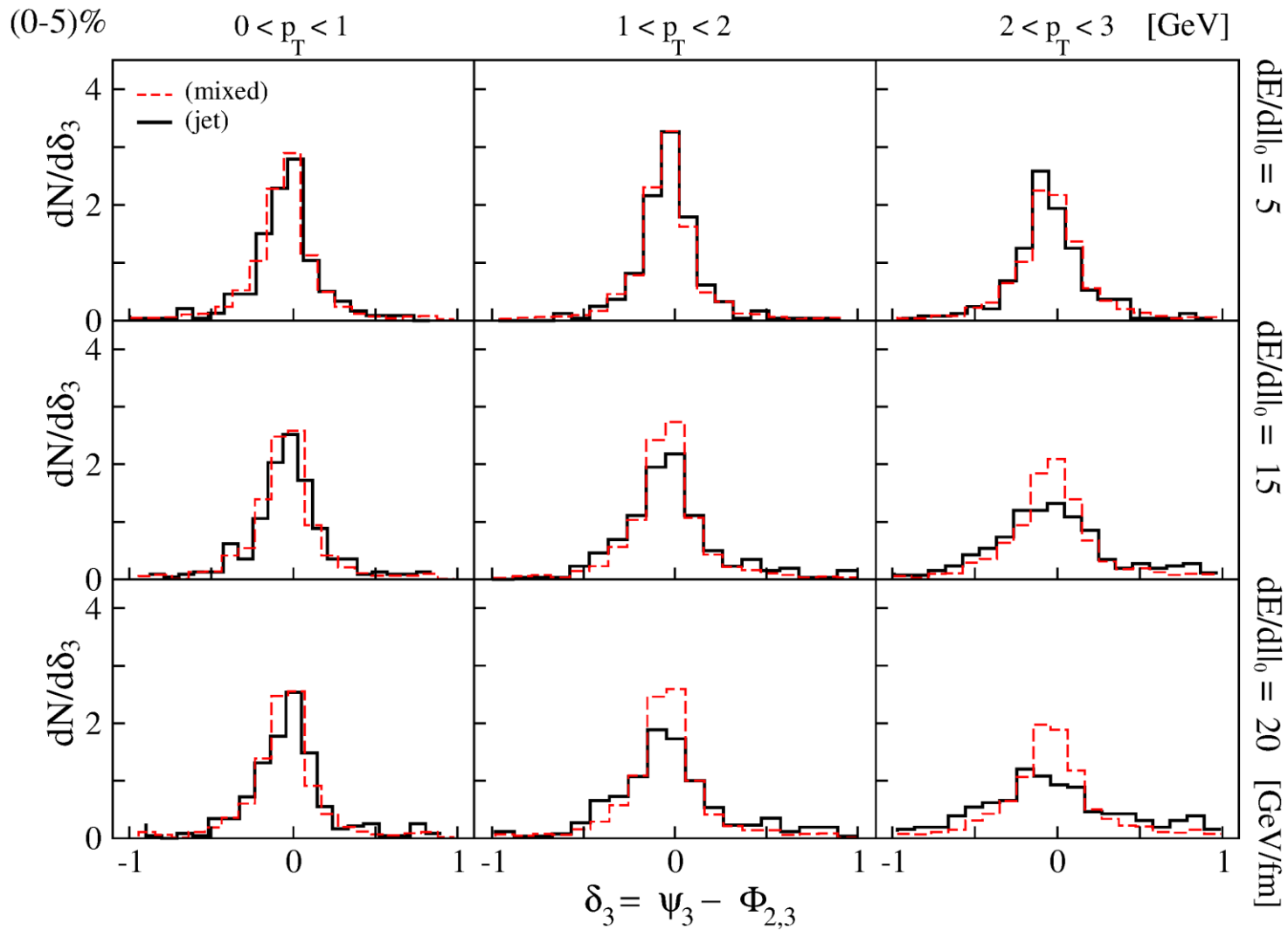
Results



Results



Results



Results

