DEFORMATION OF JETS INDUCED BY AMBIENT MEDIUM FLOW

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NSF

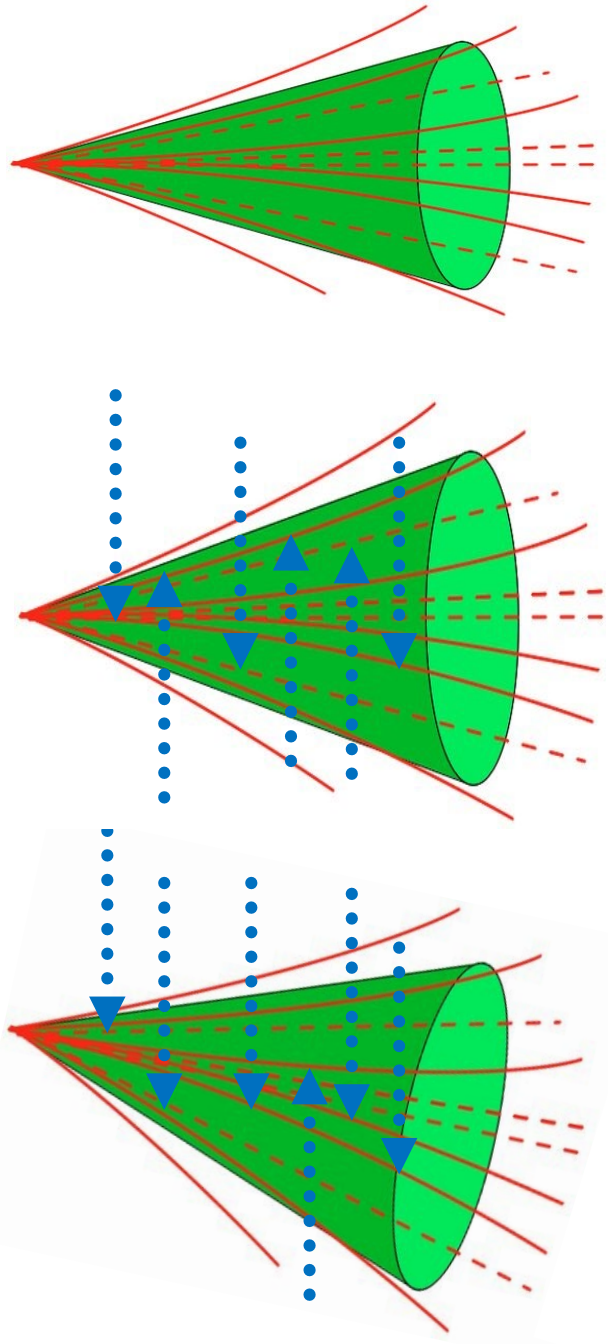
JETS IN A MEDIUM

- Vacuum: parton shower develops and hadronizes.

- In a medium: partons receive additional random kicks, enabling induced radiation. Additional kicks through in-medium hadronization (pick up of medium partons) and hadron final state interactions (see talk by H. Roch, Mon 18:10)

- In a medium with flow: kicks in a preferred direction should induce a drift of jet particles in that direction.

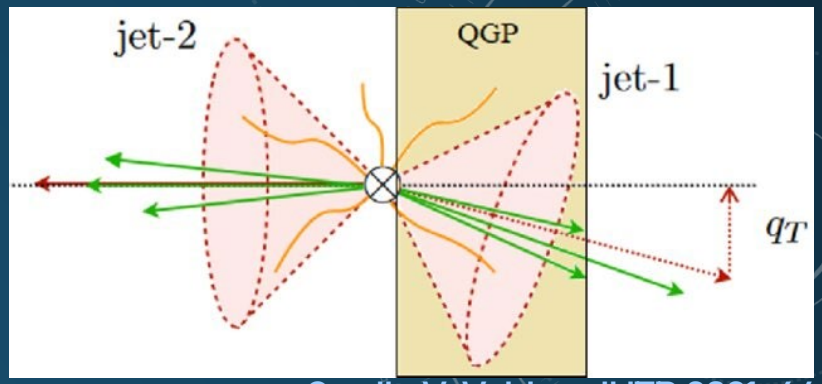
  N. Armesto, C. A. Salgado, U. A. Wiedemann,
  Phys. Rev. Lett. 93, 242301 (2004)



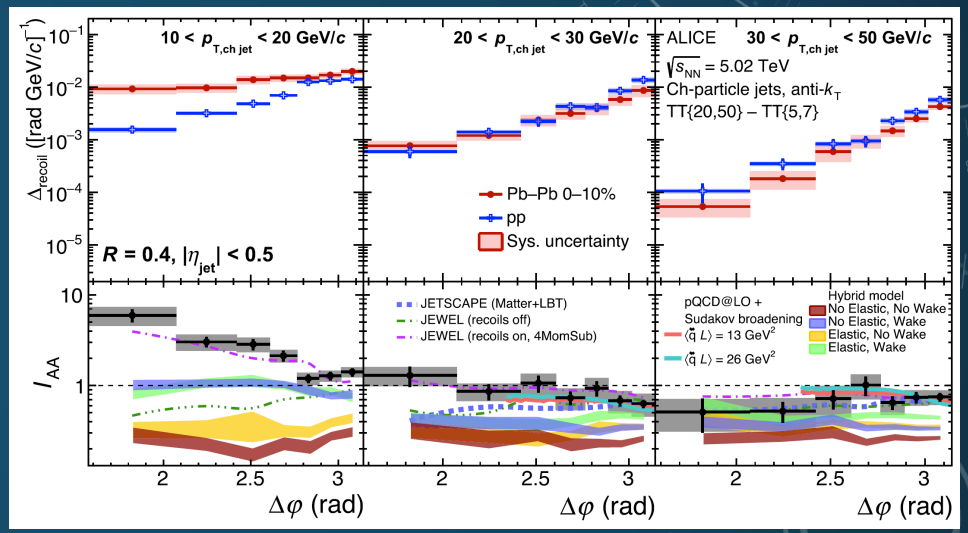
Adapted from: J. Phys.: Conf. Ser. 513 012021, (2014)

SIGNATURES OF MEDIUM FLOW

- Do flow effects leave an observable signature?
- First idea: changes in acoplanarity with respect to a trigger jet/particle.
- However, for individual jets misalignment is also induced by diffusion without flow.
- Diffusion and drift likely difficult to disentangle in such measurements.



Credit: V. Vaidya, JHEP 2021, 64



ALICE, Phys. Rev. Lett. 133, 022301 (2024)

SIGNATURES OF MEDIUM FLOW

- Quite a few new ideas recently.
- Changes to R_{AA}, jet girth, jet correlation with global event plane, v_n, …
- Talk by J. Bahder, Tuesday 11:50
- In this talk: Can we identify changes in jet shape which would allow for a unanimous signal of exposure to flow?
- Here we specifically consider the effects of flow transverse to the jet direction.

See for example:

Nestor Armesto, Carlos A. Salgado, Urs Achim Wiedemann, Phys. Rev. Lett. 93, 242301 (2004)

Y. He, L.-G. Pang, and X.-N. Wang, Phys. Rev. Lett. 125, 122301 (2020)

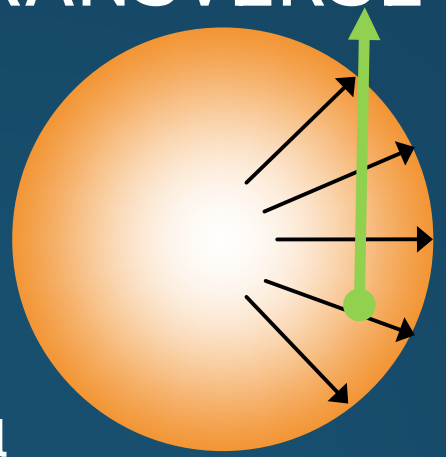
A. V. Sadofyev, M. D. Sievert, and I. Vitev, Phys. Rev. D 104, 094044 (2021)

L. Antiporda, J. Bahder, H. Rahman, and M. D. Sievert, Phys. Rev. D 105, 054025

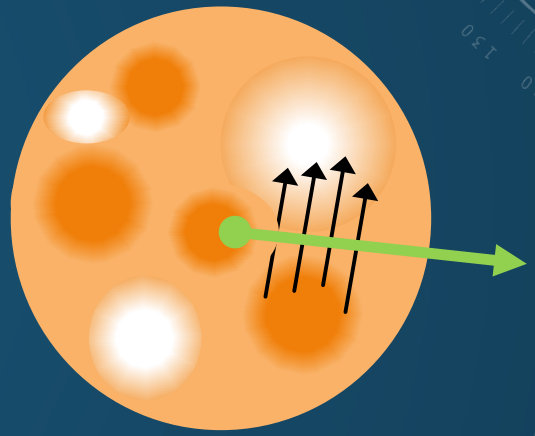
J. Barata, J. G. Milhano, A. V. Sadofyev, Eur. Phys. J. C 84, 174 (2024)

HOW CAN JETS EXPERIENCE TRANSVERSE FLOW?

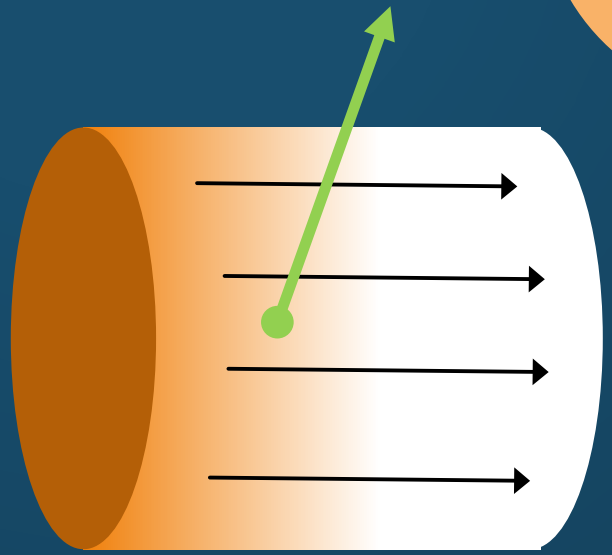
- Tangential jet emission: global radial flow = transverse flow



- Large medium fluctuations: global azimuthal flow = jet transverse flow



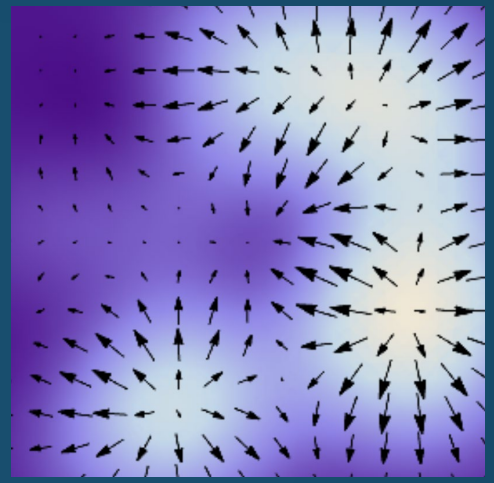
- Global longitudinal flow can act like jet transverse flow



HOW CAN JETS EXPERIENCE TRANSVERSE FLOW?

- Tangential jet emission: global radial flow = transverse flow

- Large medium fluctuations: global azimuthal flow = jet transverse flow
- *Fluctuating energy flow in the transverse plane early in the collision*



Chen, RJF, Kapusta, Li, Phys. Rev. C 92, 064912 (2015)

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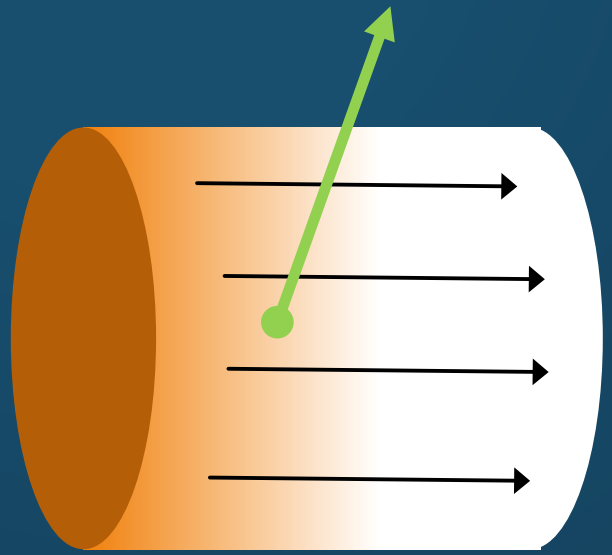

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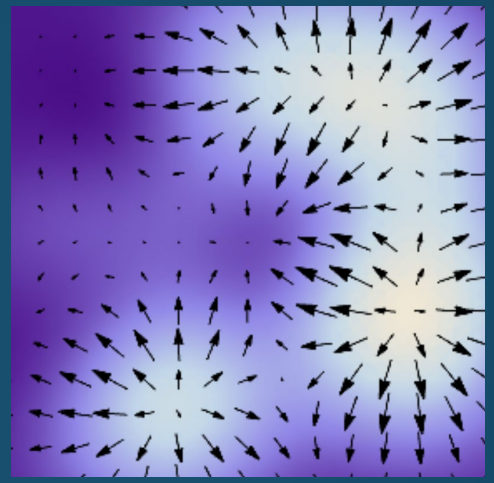
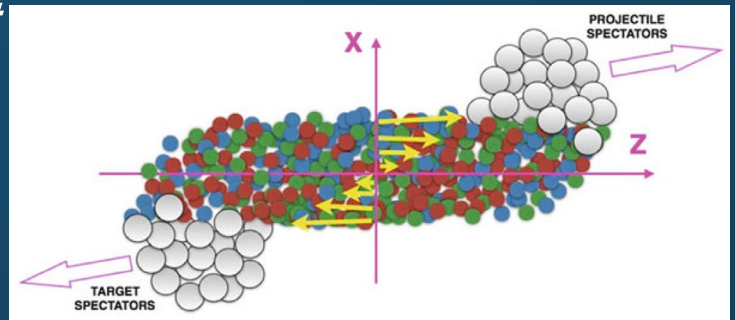


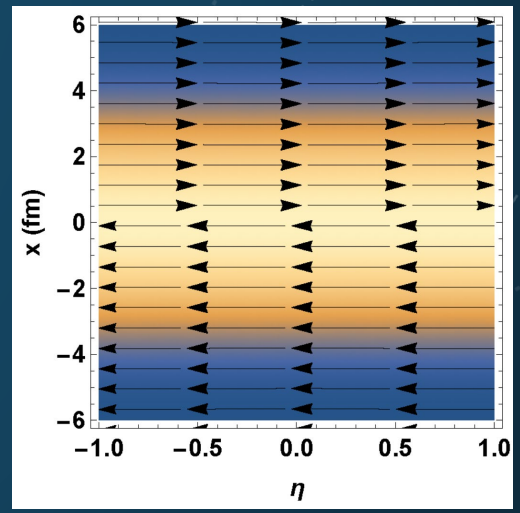
Chen, RJF, Kapusta, Li, Phys. Rev. C 92, 064912 (2015)

- Global longitudinal flow can act like jet transverse flow
- *Jet and ambient rapidity distributions do not have to match; initial flow has a shear component*

I. Karpenko, LNP 987

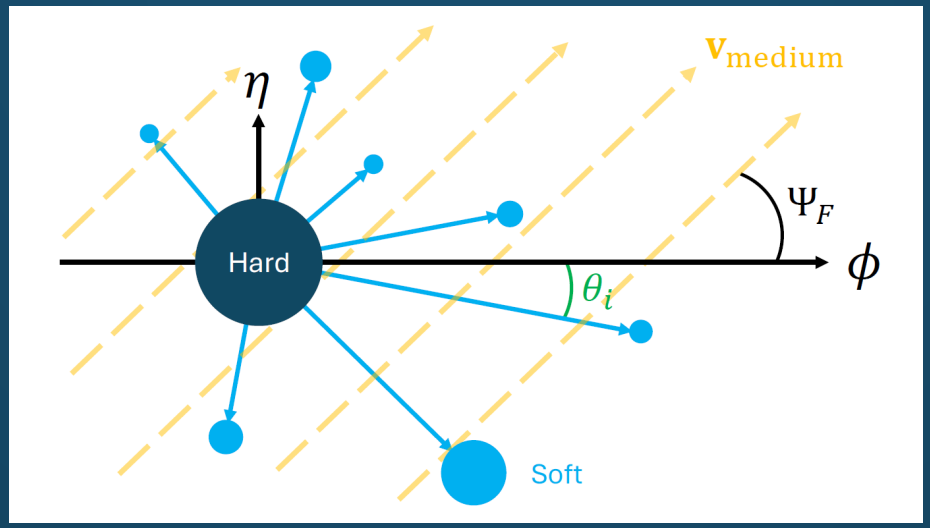


RJF, Chen, Somanathan, Phys. Rev. C 97, 034903 (2018)



THE BASIC IDEA

- Find the hardest object (subjet or hadron) in a jet and look for the azimuthal shape of soft and intermediate objects with respect to the hardest object.
- We consider here shapes in "$\phi - \eta$" space but one could use momenta transverse to the jet instead.
- Analyze deformations of the soft and intermediate jet objects with respect to the hard object as a reference.
- Does the azimuthal distribution $\{\theta_i\}$ contain information about the flow angle ψ_F?



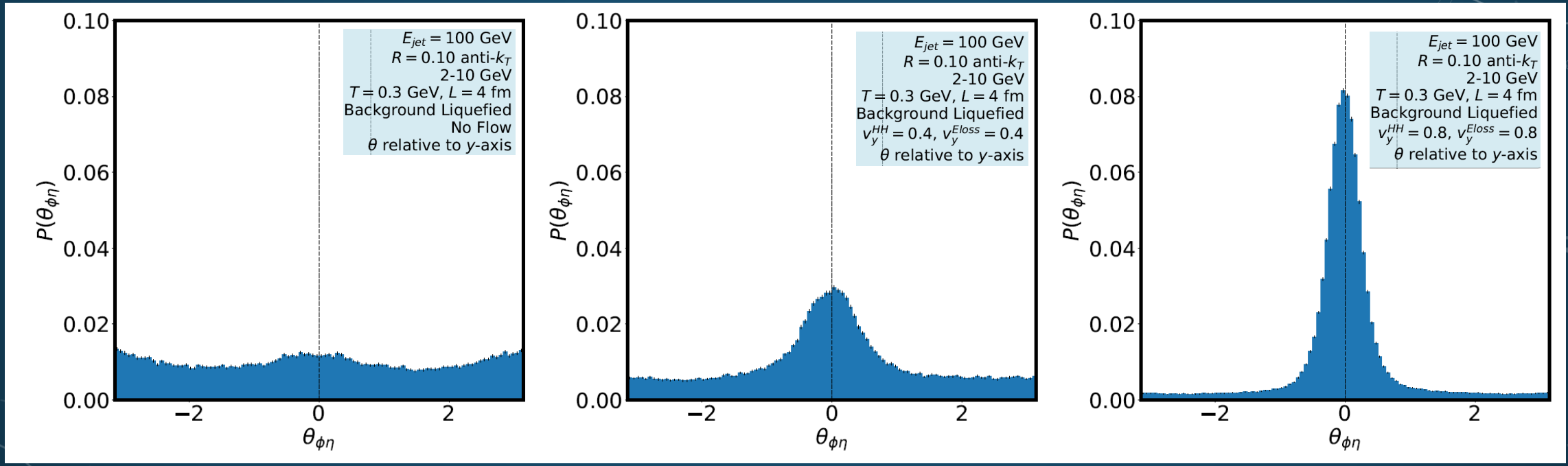
SIMULATION SETUP

- JETSCAPE (v3.5)
- Vacuum: pGun/PYTHIAgun + MATTER + Hybrid Hadronization
- Medium: pGun + MATTER + LBT + Hybrid Hadronization (including in-medium effects) in QGP brick + Liquefier
- QGP brick is given a size L, QGP has temperature T, and a spontaneous collective flow velocity (v_x, v_y, v_z)

- Flow effects are transferred to the jet particles both in the partonic phase and through in-medium hadronization.

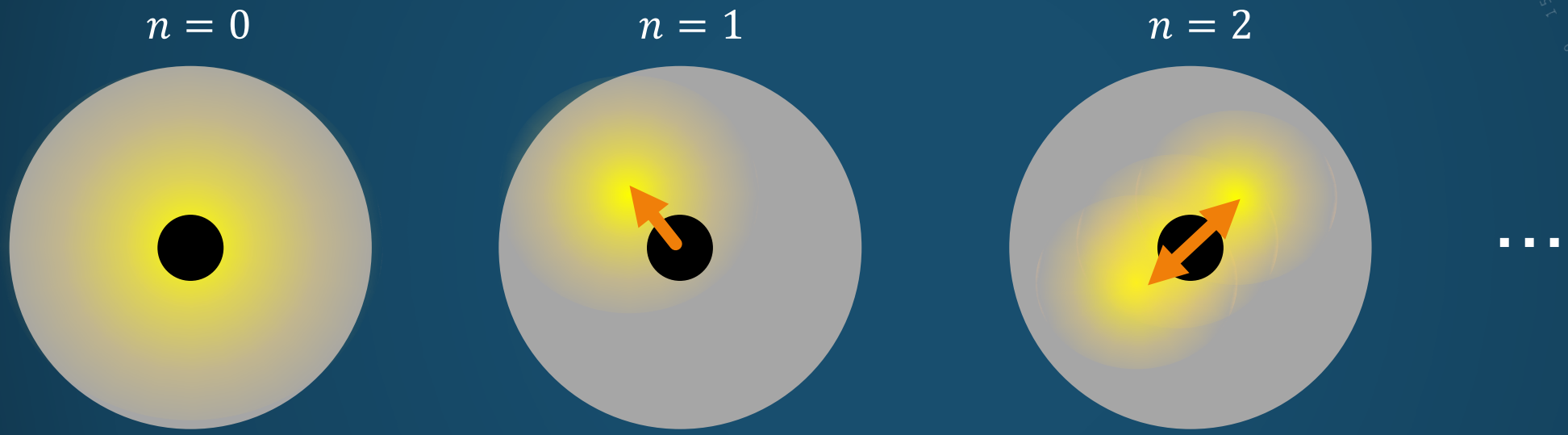
AZIMUTHAL DISTRIBUTION OF SOFT OBJECTS

- Distribution of angles $\{\theta_i\}$ for $R = 0.1$ subjets in 100 GeV jets.
- $\{\theta_i\}$ randomly distributed without flow.
- Clear preference to cluster around the flow angle (here $\psi_F = 0$). Correlation growing with flow velocity



MULTIPOLE PICTURE

- We can analyze the shape of soft and intermediate jet components. Dipole and quadrupole deformation?



- Here 100 GeV jets, soft region = 2 … 10 GeV

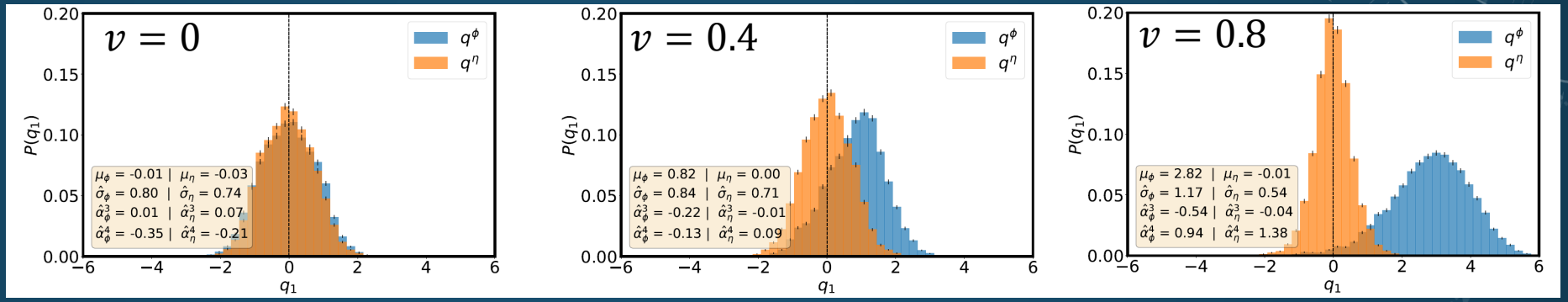
Hardest subjet
Soft and intermediate subjets

Q-VECTOR ANALYSIS

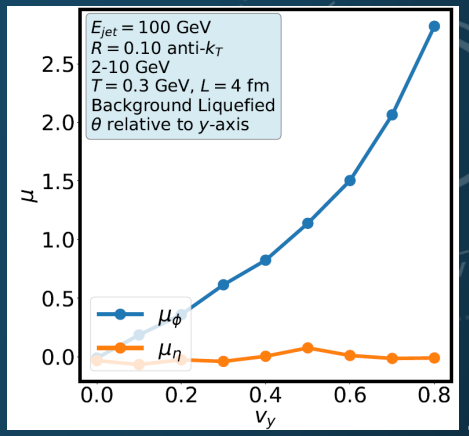
- Capture azimuthal moments using q-vectors

$$\boldsymbol{q}_n = \frac{1}{N}\sum_i \begin{pmatrix} \cos(n\theta_i) \\ \sin(n\theta_i) \end{pmatrix}$$

- For $n = 1$



- Significant signal starting at $v{\sim}0.2 \ldots 0.3$, rising monotonically.



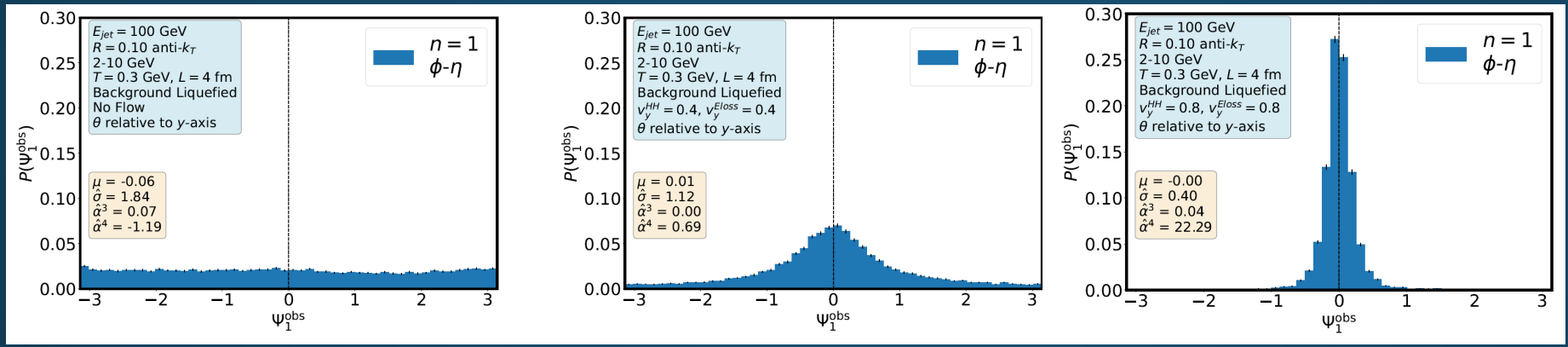
- Similar signal for $n = 2$.
- Hence, transverse flow does induce dipole and quadrupole deformations.

JET “EVENT PLANE”

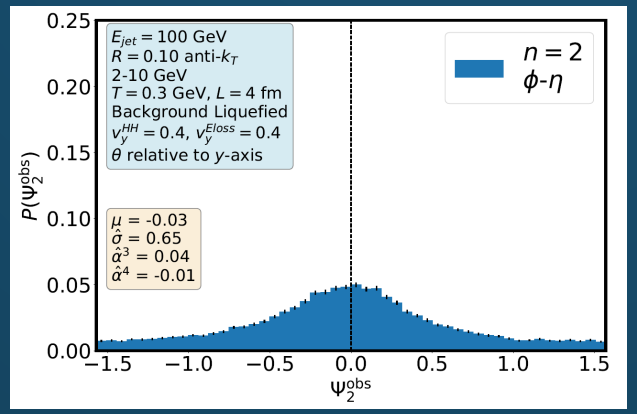
- Define “event plane” angles for jets as analogues to global event plane angles

$$\psi_n = \frac{1}{n}\arctan\frac{q_n^y}{q_n^x}$$

- ψ_1 correlation with flow angle $\psi_F = 0$:

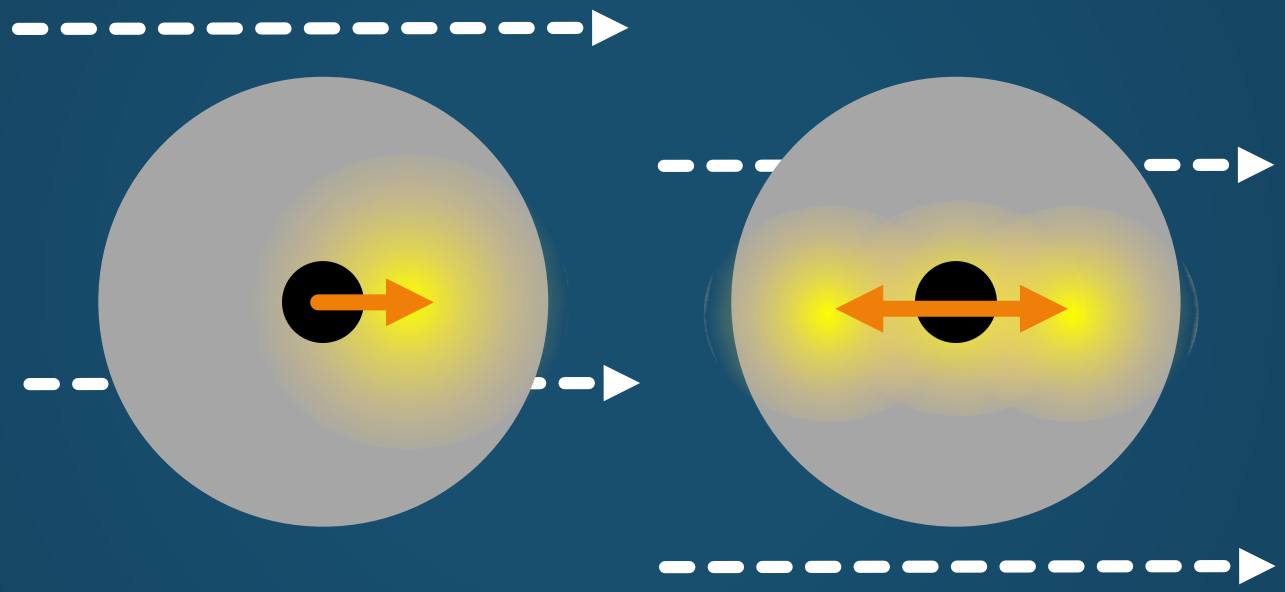


- Same picture for $n = 2$:



JET “EVENT PLANE”

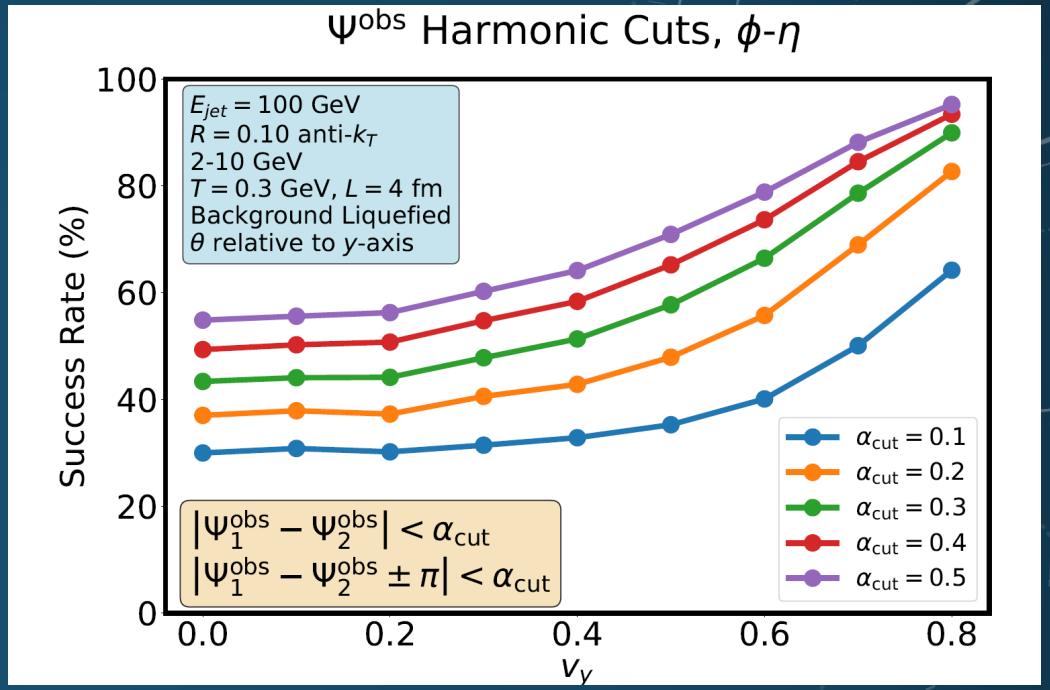
- Dipole angles correlate with flow angles.
- Soft jet components also tend to be elongated in the direction of flow.



A FLOW SIGNAL FOR INDIVIDUAL JETS?

- Correlation of dipole and quadrupole deformation angles could select jets that have been exposed to transverse flow.
- Fraction of jets in which angles correlated increases with flow velocities.

- Possible algorithm:
- Determine dipole and quadrupole deformation angles and select a jet sample with tight correlations between them.
- Analyze these angles in the context of the global event geometry.
- In a more mature version of this the size of the deformations could be used to estimate flow velocities.



SUMMARY

- Interesting information about the ambient medium could be encoded in jets.
- Deformations of jets present a promising signal for flow transverse to the jet.
- The first goal is to determine if observed deformations are indeed due to medium flow.
- Correlations between dipole and quadrupole deformations might help.
- This also needs to be explored theoretically with different calculations and more realistic background media.
- Looking forward to an unambiguous experimental signature for medium flow.

BACKUP

HYBRID HADRONIZATION WORK FLOW IN A MEDIUM

Input:
Provide partons with virtualities below some cutoff, with space-time information and color tags

Bath of thermal partons

Recombination Step:
Provisionally decay gluons into $q\bar{q}$. Go through the system sampling the recombination probabilities for all possible q-qbar and q-q-q bound states.

Recombination with thermal partons

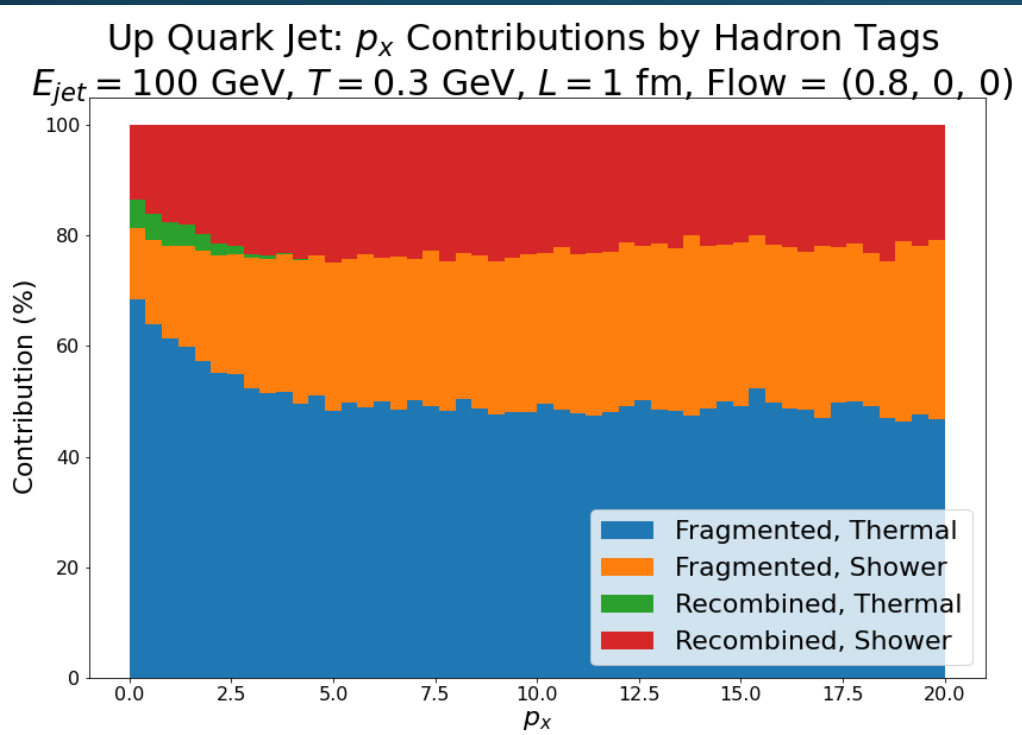
Intermediate Step:
Recombined hadrons and remnant partons in a string system (only color singlets were removed).

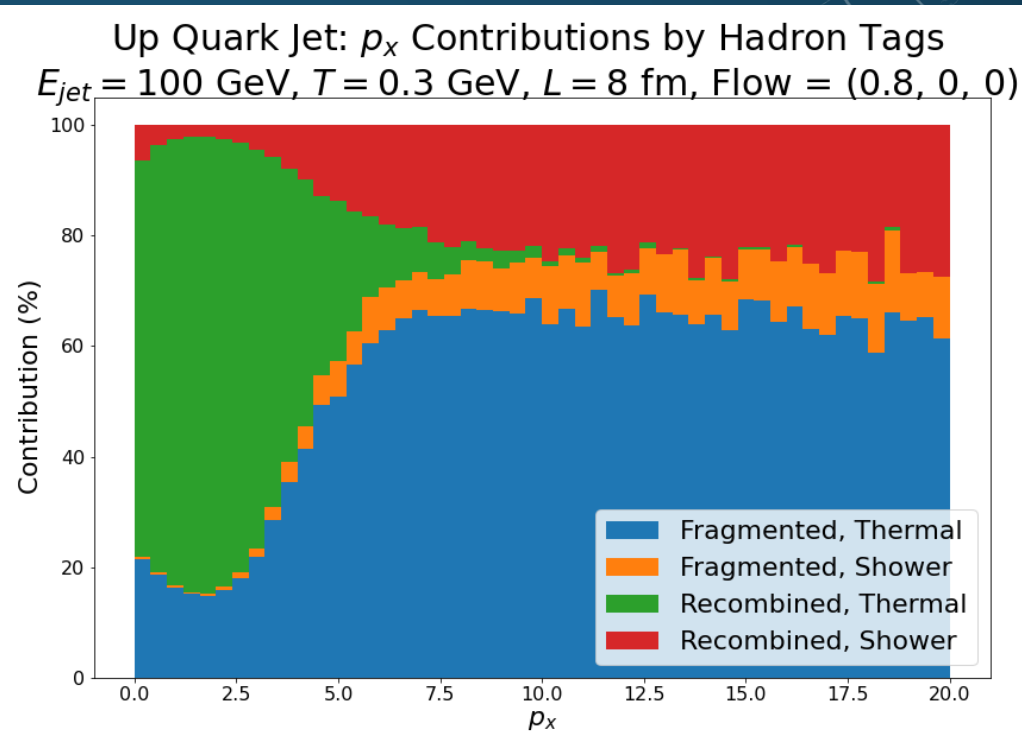
Remnant strings with thermal partons

Fragmentation Step:
Remnant partons tend to be farther apart in phase space. Fragement using PYTHIA 8.

IN-MEDIUM JETS: ROLE OF THERMAL PARTONS

- The following study with a QGP brick was done with JETSCAPE 3.0
- Check hadron origin: Thermal parton contribution grows with medium size.





IN-MEDIUM JETS: FLOW TRANSVERSE TO THE JET

- Medium flow transverse to the jets can be picked up by hadrons associated with the jet.
- Only releveant for low and intermediate momenta.