Directed flow due to the initial source tilt and density asymmetry in Cu+Au and Au+Au collisions at STAR

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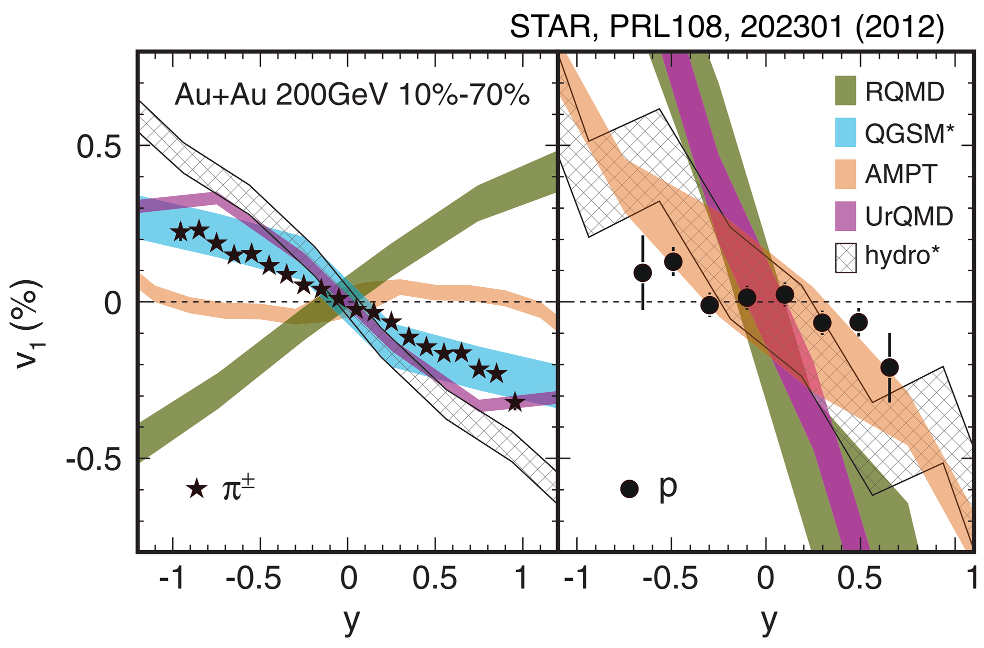
Motivation

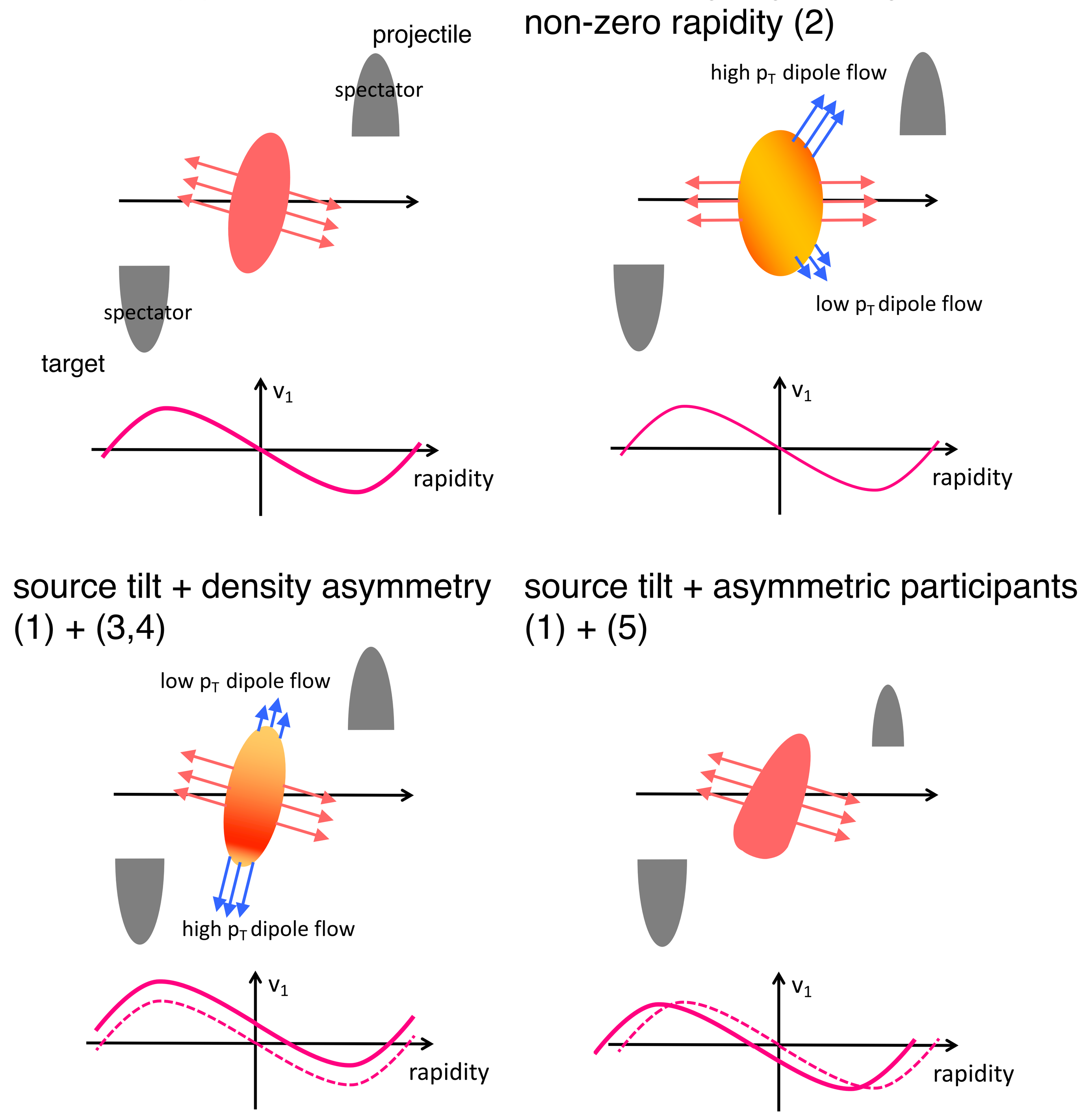
STAR, arXiv:1712.01332

No models can reproduce directed flow, v_1, dependence on (pseudo)rapidity, p_T, $\sqrt{s_{NN}}$, and particle species, simultaneously.

Still missing an important piece in the picture of heavy-ion collisions, e.g. vorticity and/or 3D initial condition.

$$\frac{dN}{d\phi} \propto 1 + 2v_n \sum_n \cos n(\phi - \Psi_n)$$





Origin of directed flow

Contributions to v_1:

(1) Initial source tilt [1,2]

(2) Initial density asymmetry at non-zero rapidity [3]

(3) Initial density asymmetry due to fluctuations [4]

In addition, for asymmetric Cu+Au collisions:

(4) Intrinsic density asymmetry due to the geometry (N_{part}^{Au}>N_{part}^{Cu})

(5) N_{part}^{Au}>N_{part}^{Cu} leads to a rapidity shift of v_1

* Contributions from (2) and (3) are called "dipole flow"; named after "dipole-like" density asymmetry.

Cu+Au provides a unique opportunity to study the role of the different mechanisms in v_1.

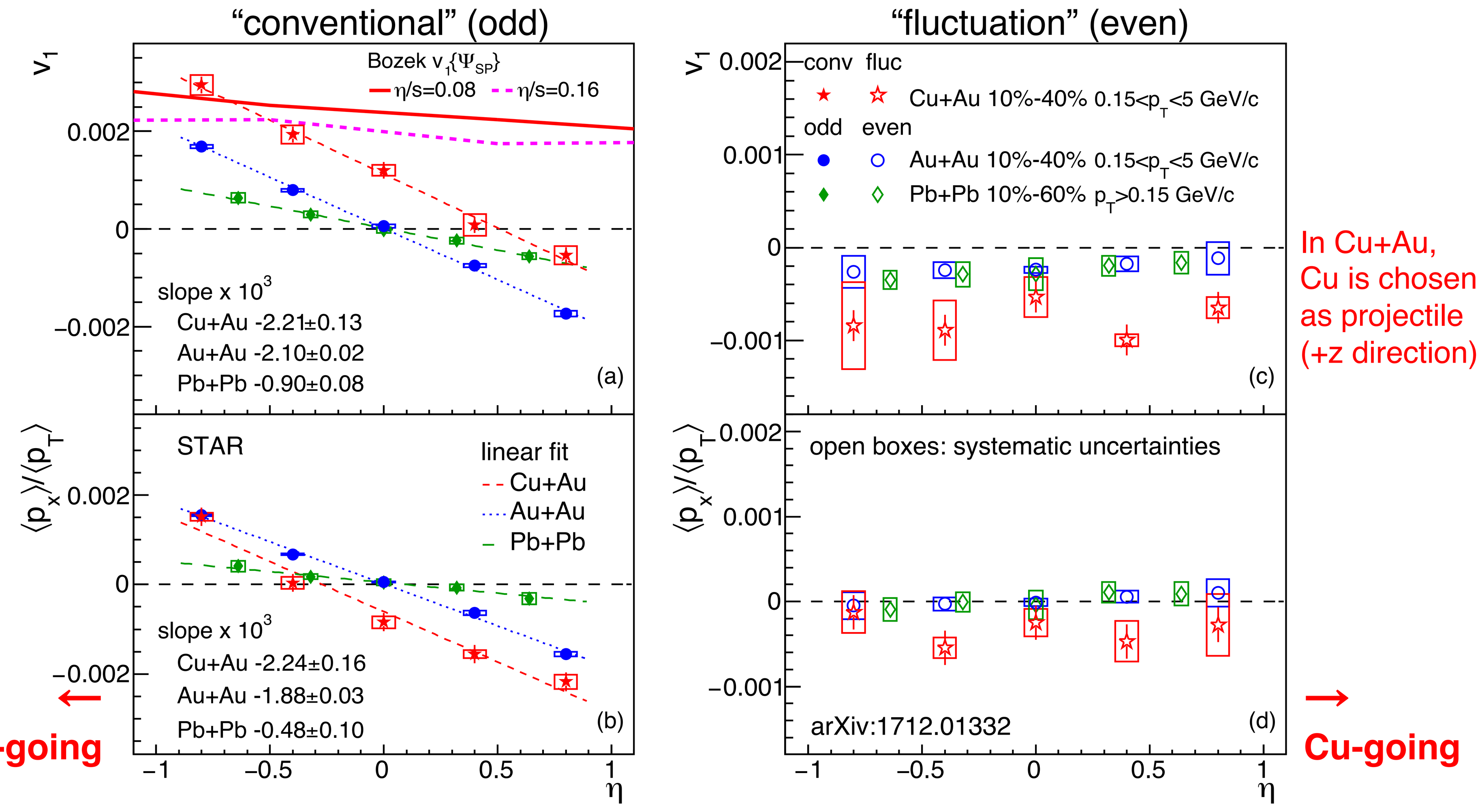
Results and Discussion

v_1 was measured relative to two spectator planes Ψ_{SP} as done in ALICE [5] and was decomposed into "conventional" (1)+(2) and "fluctuation" (3) components.

* Ψ_{SP} resolution was estimated by 3-subevent method with ZDCSMD (|η|>6.3) and BBC (3.3<|η|<5)

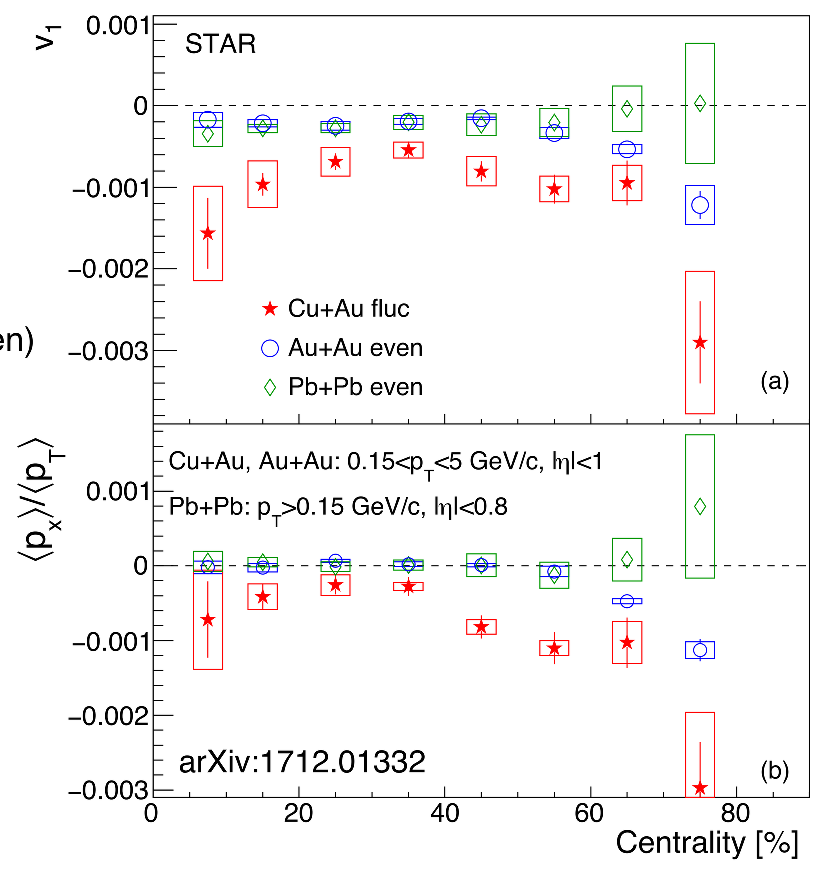
$$v_1^{conv}(v_1^{odd}) = (v_1\{\Psi_{SP}^p\} - v_1\{\Psi_{SP}^t\})/2 \qquad v_1 = \langle\cos(\phi - \Psi_{SP})\rangle$$

$$v_1^{fluc}(v_1^{even}) = (v_1\{\Psi_{SP}^p\} + v_1\{\Psi_{SP}^t\})/2 \qquad \langle p_x\rangle = \langle p_T\cos(\phi - \Psi_{SP})\rangle$$

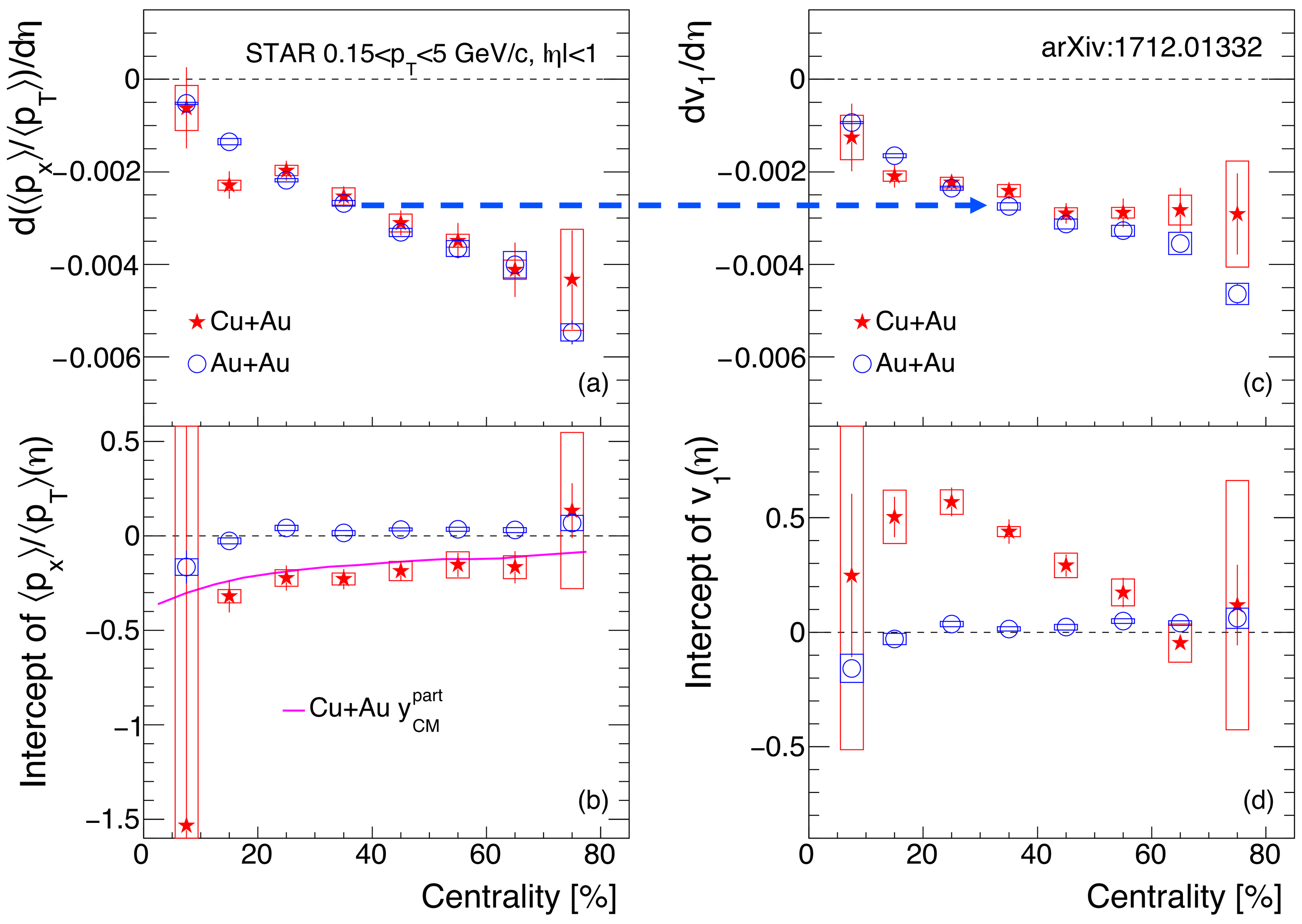


In Cu+Au, Cu is chosen as projectile (+z direction)

- ❑ Similar $v_1^{conv(odd)}$ slopes in Au+Au and Cu+Au but larger than at the LHC
  - The source tilt likely depends on the collision energy but not on the system size
- ❑ Cu+Au v_1^{conv} is shifted upward relative to Au+Au
  - as expected from the intrinsic density asymmetry
- ❑ Cu+Au $\langle p_x\rangle^{conv}$ is shifted toward Au-going direction relative to Au+Au
  - as expected from asymmetric participants
- ❑ $v_1^{fluc(even)}$ nearly rapidity-independent and $\langle p_x\rangle^{fluc(even)}$ close to zero



- ❑ Very weak centrality dependence of $v_1^{fluc(even)}$
  - Similar dipole-like density fluctuations for all centralities
- ❑ $\langle p_x\rangle^{even}$ ~ 0 in symmetric systems
  - Feature of the dipole flow due to the momentum conservation



- ❑ Intercept of Cu+Au $\langle p_x\rangle^{conv}$ agrees well with the center-of-mass rapidity in Cu+Au by Glauber simulation $y_{CM} \approx \frac{1}{2}\ln(N_{part}^{Au}/N_{part}^{Cu})$
- ❑ Centrality dependence of the intercept of Cu+Au v_1^{conv}
  - Decorrelation between Ψ_{SP} and participant plane that points out the direction of the density asymmetry
- ❑ Relative contribution from the source tilt to v_1 slope, r^{tilt}
  - at RHIC ~2/3
  - at LHC ~1/3 [5]

  (smaller source tilt due to baryon transparency)

$$r^{tilt} = \frac{(dv_1/d\eta)^{tilt}}{dv_1/d\eta} \approx \frac{2}{3}\frac{(d\langle p_x\rangle/d\eta)/\langle p_T\rangle}{dv_1/d\eta}$$

Conclusions

- ❑ The results are consistent with a picture of the directed flow originating from the initial source tilt and the initial density asymmetry.
- ❑ Relative contribution to v_1^{odd} slope from the initial source tilt is ~2/3 in mid-central collisions at RHIC and the rest comes from the rapidity-dependent density asymmetry

References

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