Studying orbital angular momentum evolution in relativistic heavy-ion collisions

NAVEENKUMAR S

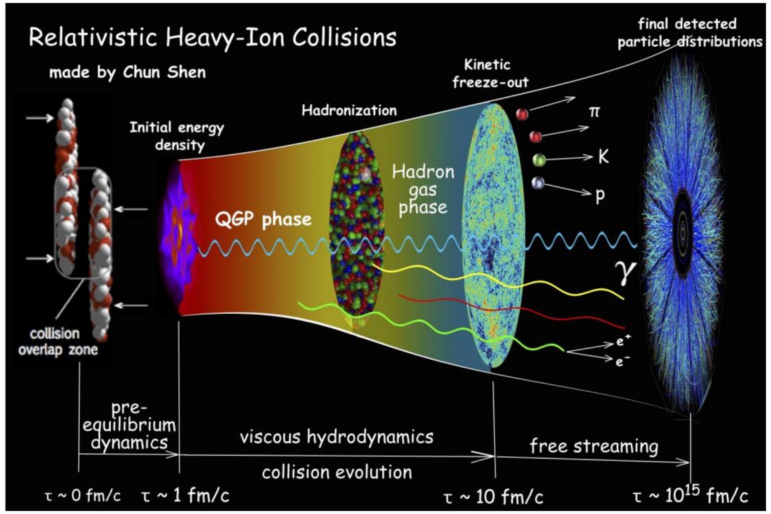
Advisor: Prof. Chun Shen

Department of Physics and Astronomy

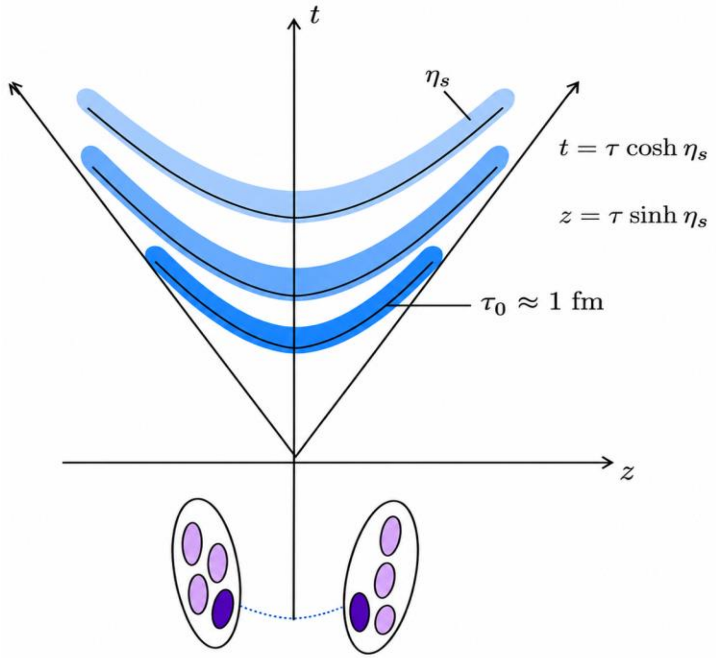
WAYNE STATE UNIVERSITY

NNPSS 2026 - July 10

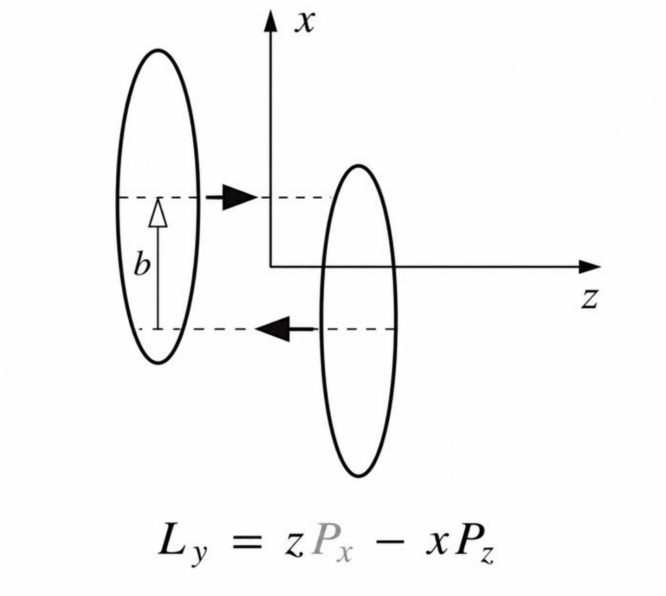
Introduction



Sketch of heavy-ion collisions (HIC)



3D MC Glauber model



Orbital angular momentum (OAM) in HIC

How to Calculate OAM?

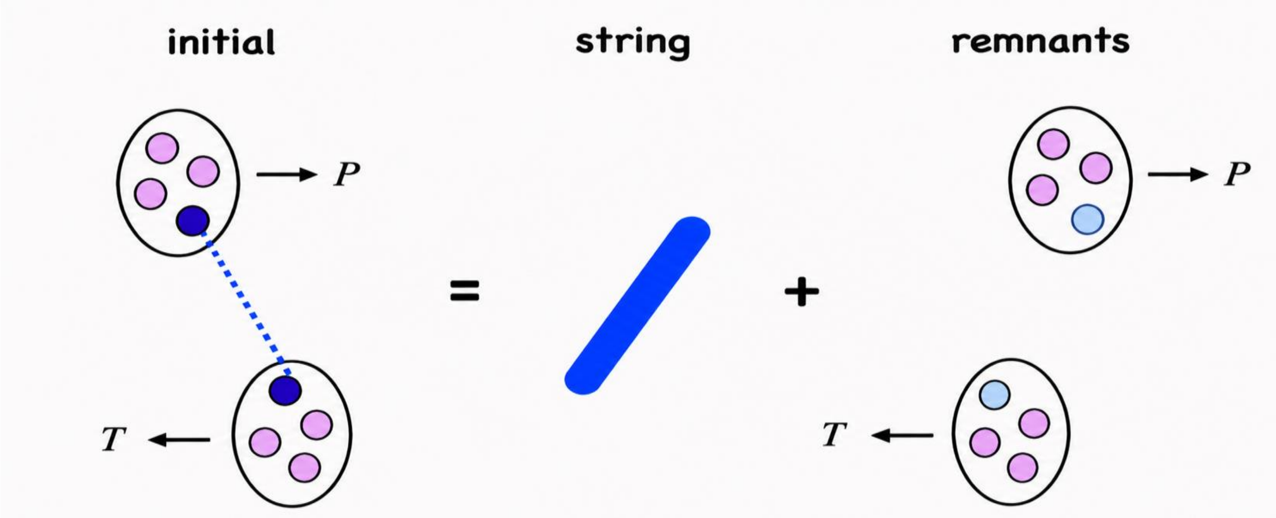
Initial state model

$$L_y^{\text{initial}} = -\sum_i x_i p_{z,i}$$

$$p_z = m_{\text{parton}} \sinh(y)$$

where y is the parton rapidity

$$L_y^{\text{initial}} = L_y^{\text{string}} + L_y^{\text{remnant}}$$



From hydrodynamics

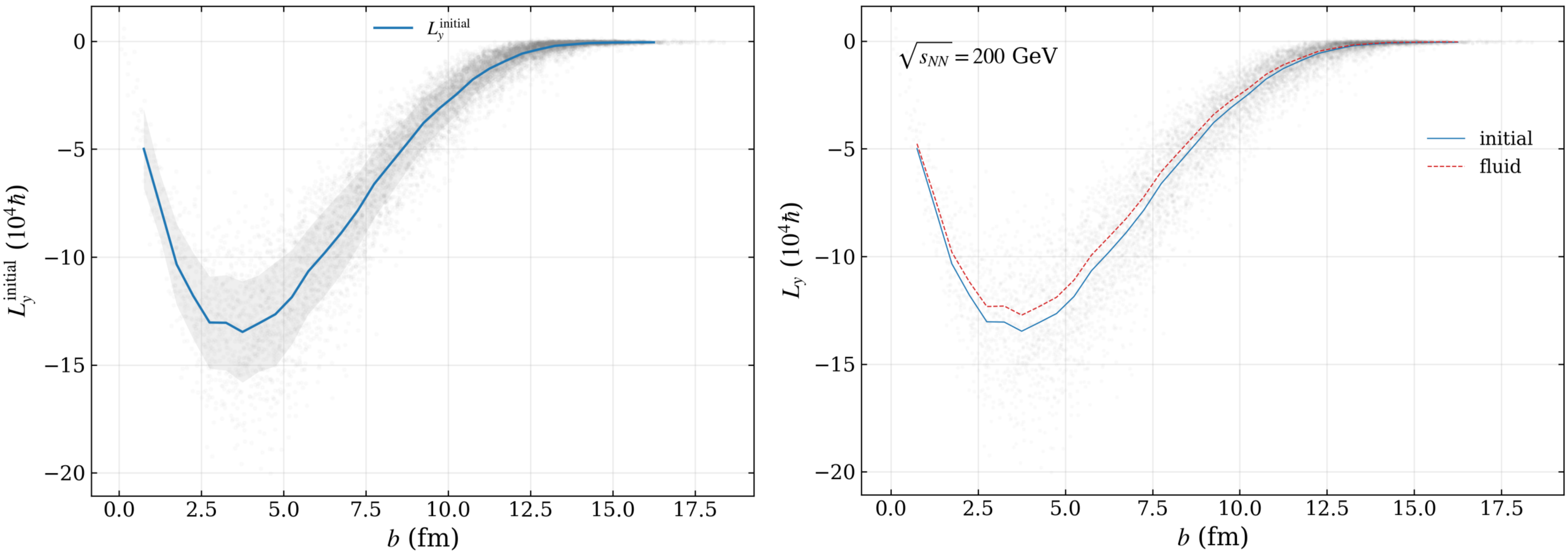
$$L^{\mu,\alpha\beta} = x^{\alpha} T^{\mu\beta} - x^{\beta} T^{\mu\alpha}$$

where $T^{\mu\nu}$ is the stress-energy tensor

$$L_y(x,y) = \int \tau \, d\eta_s \, L^{\tau,xz}$$

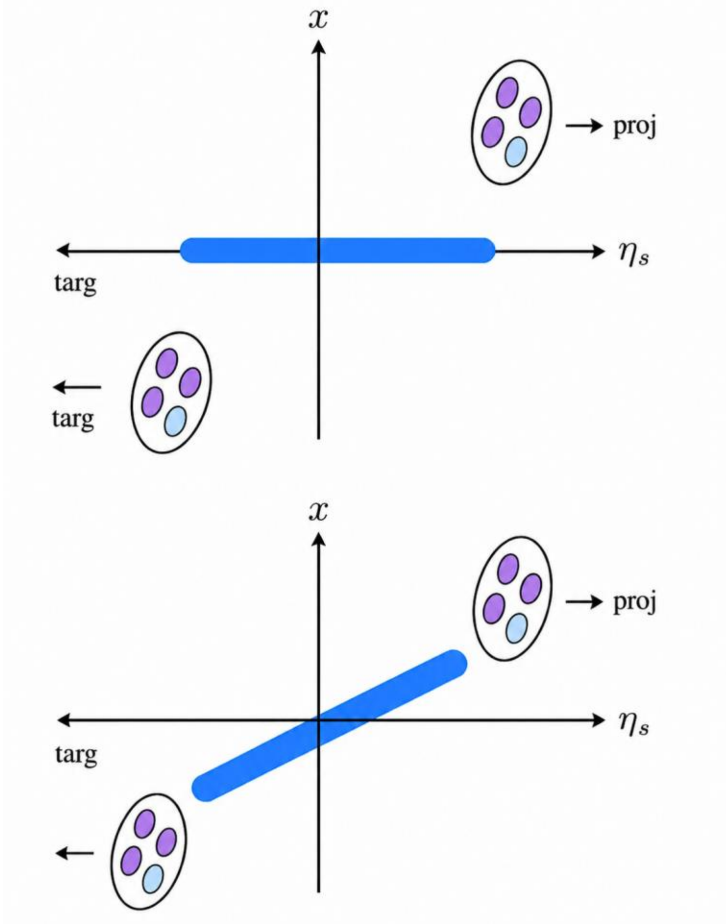
$$L_y^{\text{fluid}} = \int \tau \, dx \, dy \, d\eta_s \, L^{\tau,xz}$$

Motivation



Comparing net OAM at initial and fluid stage - **Missing OAM ?**

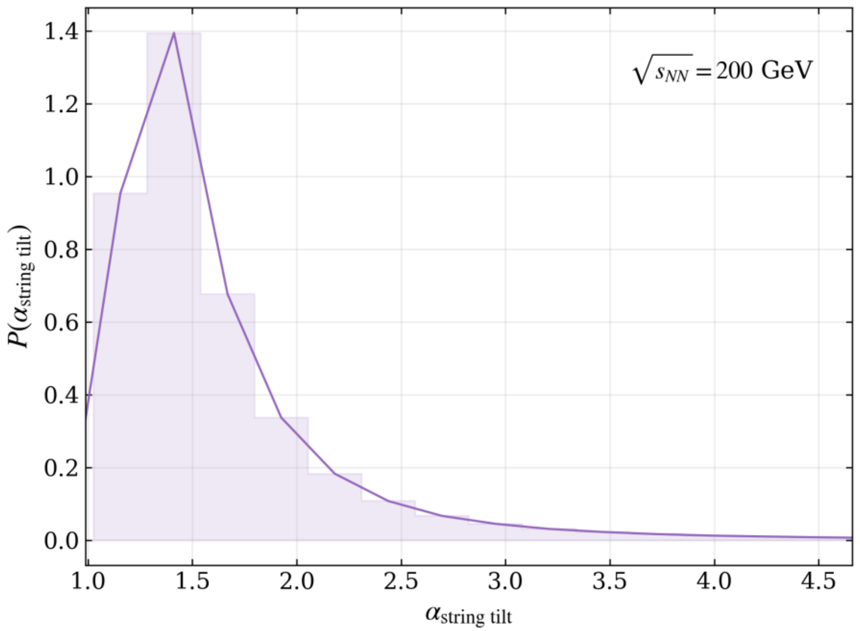
Non-local Parton Collisions



Conserving Ly at local hotspot collision

Tilting the string

Ly initial = Ly fluid

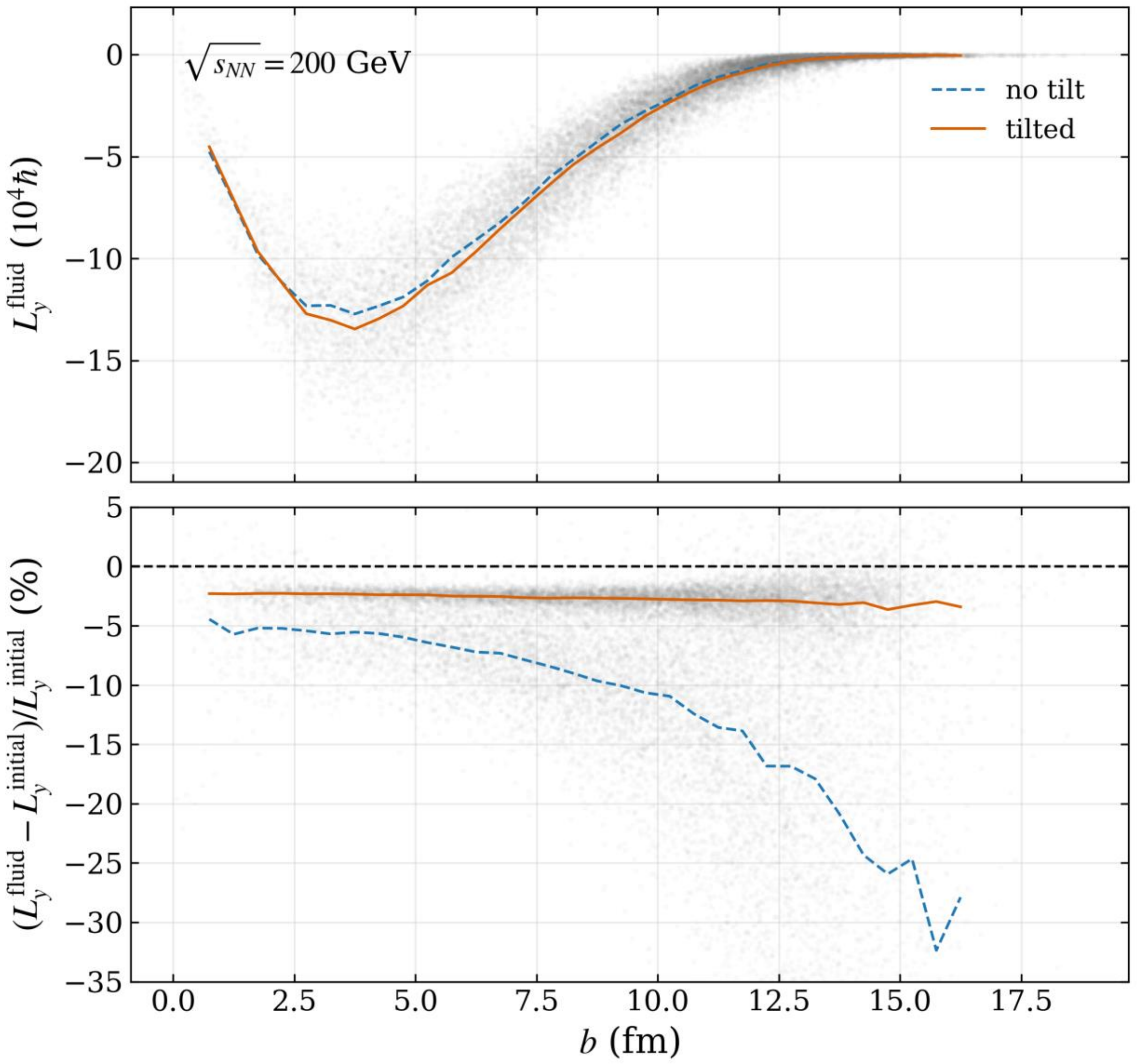


Probability density of string tilt

$$x(\eta_s) = \frac{x^P + x^T}{2} + \alpha_{string\_tilt} \left(\frac{x^P - x^T}{\eta_s^P - \eta_s^T} \right) (\eta_s - \eta_{s,c}),$$

Note: String tilt > 1

Matching L $_y$ event by event



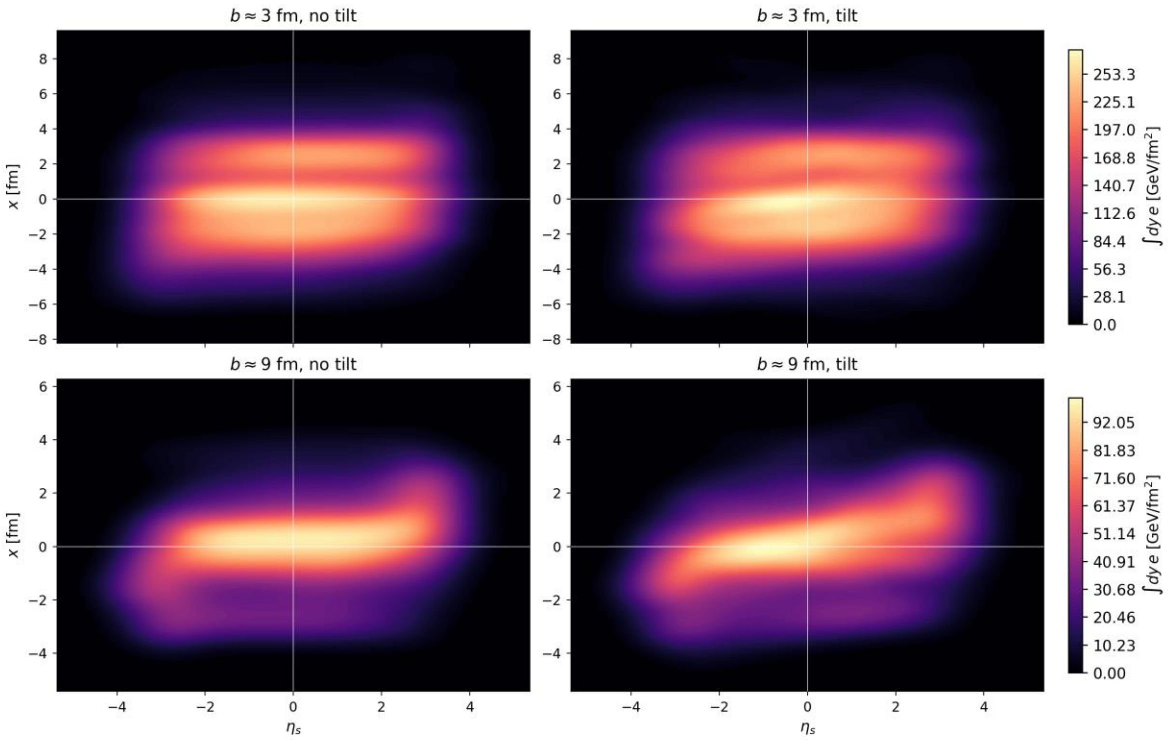
1) No tilt -> Ly fluid < Ly initial

2) With tilted strings -> Ly fluid ≈ Ly initial

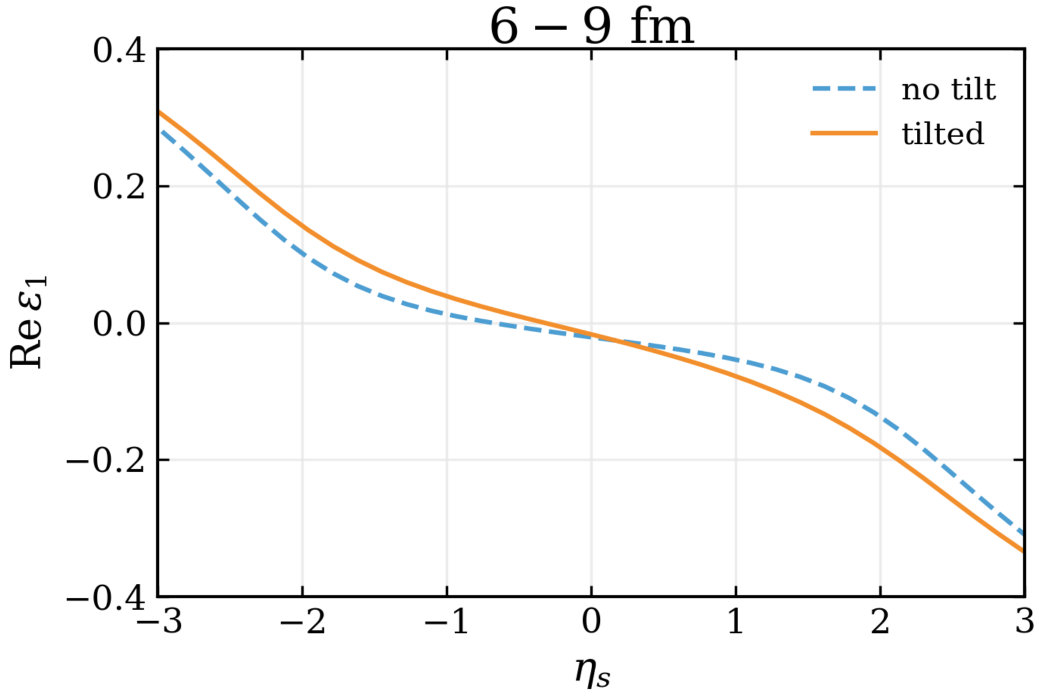
The new **tilt string** profile **reduces** the relative difference in L_y, especially in **peripheral** collisions

How does the **string tilting** modify the **initial geometry**?

Effect of String Tilting on Initial Eccentricity



Initial Energy density



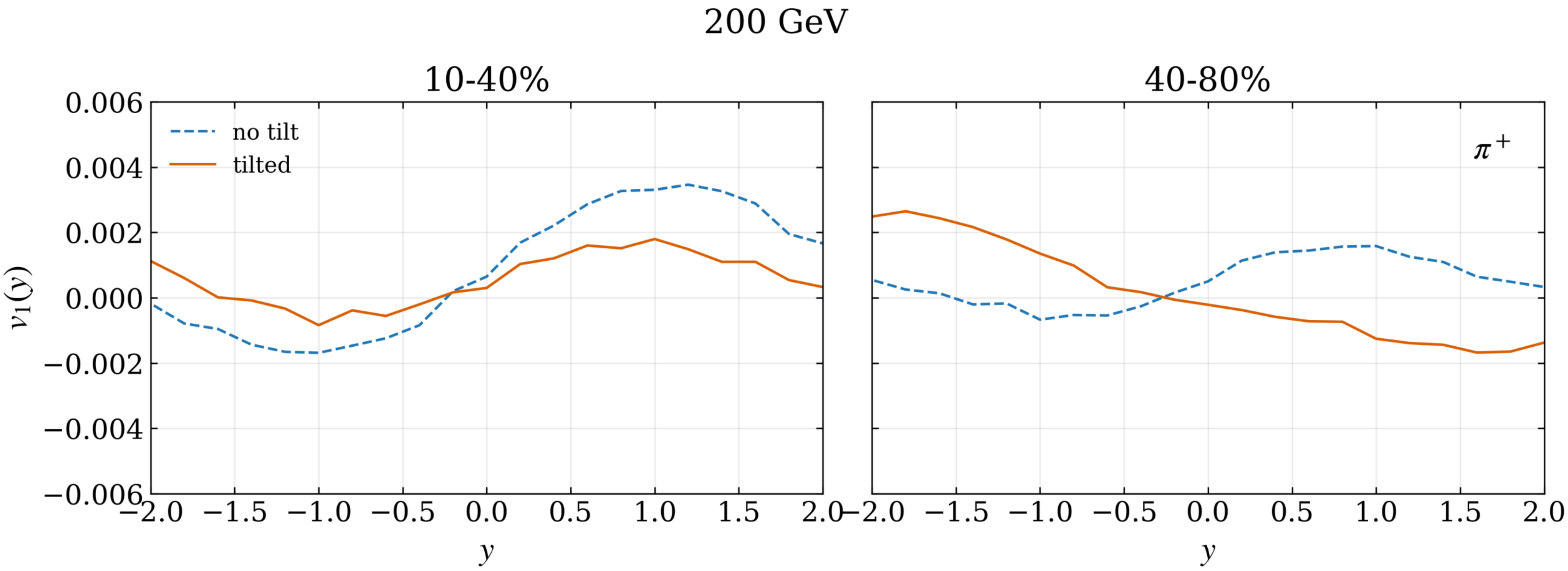
Initial Eccentricity

$$\varepsilon_n e^{in\Phi_n} \equiv -\frac{\int r\, dr\, d\phi\, r^n e^{in\phi}\, e(r,\phi)}{\int r\, dr\, d\phi\, r^n e(r,\phi)}$$

$$\mathcal{E}_1 = -\frac{\langle r^3 e^{i\phi}\rangle_e}{\langle r^3\rangle_e} \xrightarrow{\text{hydro}} v_1 = \langle \cos(\phi - \Psi_1)\rangle$$

$$v_n \simeq \kappa_n\, \varepsilon_n$$

V_1 of Identified pions



string tilt profile has larger impact in peripheral collisions.

Conclusion

- **Finite-impact-parameter (b)** heavy-ion collisions produce large **OAM** (~10^5 ħ) at $\sqrt{s_{NN}}$ = 200 GeV.

- String tilting **conserves local OAM** from the initial stage to the fluid.

- String tilting modifies the initial fireball geometry, with a **larger effect at larger b**.

- The rapidity-dependent **directed flow** is **sensitive** to the **string tilt** profile. In future work, we will study the effect of **string tilting** on **polarization** observables.

Back up Slides

How L_y is matched at local hotspot collisions

The momentum lost in the collision is

$$P^z_{\rm loss} = m_{\rm parton}\left[\sinh\left(y_P^{\rm init}\right) + \sinh\left(y_T^{\rm init}\right) - \sinh\left(y_P^{\rm final}\right) - \sinh\left(y_T^{\rm final}\right)\right]$$

Matched to the strings ,

$$L_y^{\rm string} = -m_{\rm parton}\left[x_P(\sinh y_P^i - \sinh y_P^f) + x_T(\sinh y_T^i - \sinh y_T^f)\right]$$

$$L_y^{\rm remnant} = -m_{\rm parton}\left[x_P \sinh y_P^f + x_T \sinh y_T^f\right]$$

$$P^z_{\rm loss} = P^z_{\rm string} = \int_{\eta_{s,T}}^{\eta_{s,P}} d\eta_s\, e_{\rm string}(\eta_s)\, \sinh[y(\eta_s)]$$

$$L_y^{\rm loss} = -\ m_{parton}\ x^P\left(\sinh y_p^i - \sinh y_p^f\right) -\ m_{parton}\ x^T\left(\sinh y_T^i - \sinh y_T^f\right)$$

Ly loss = Ly string

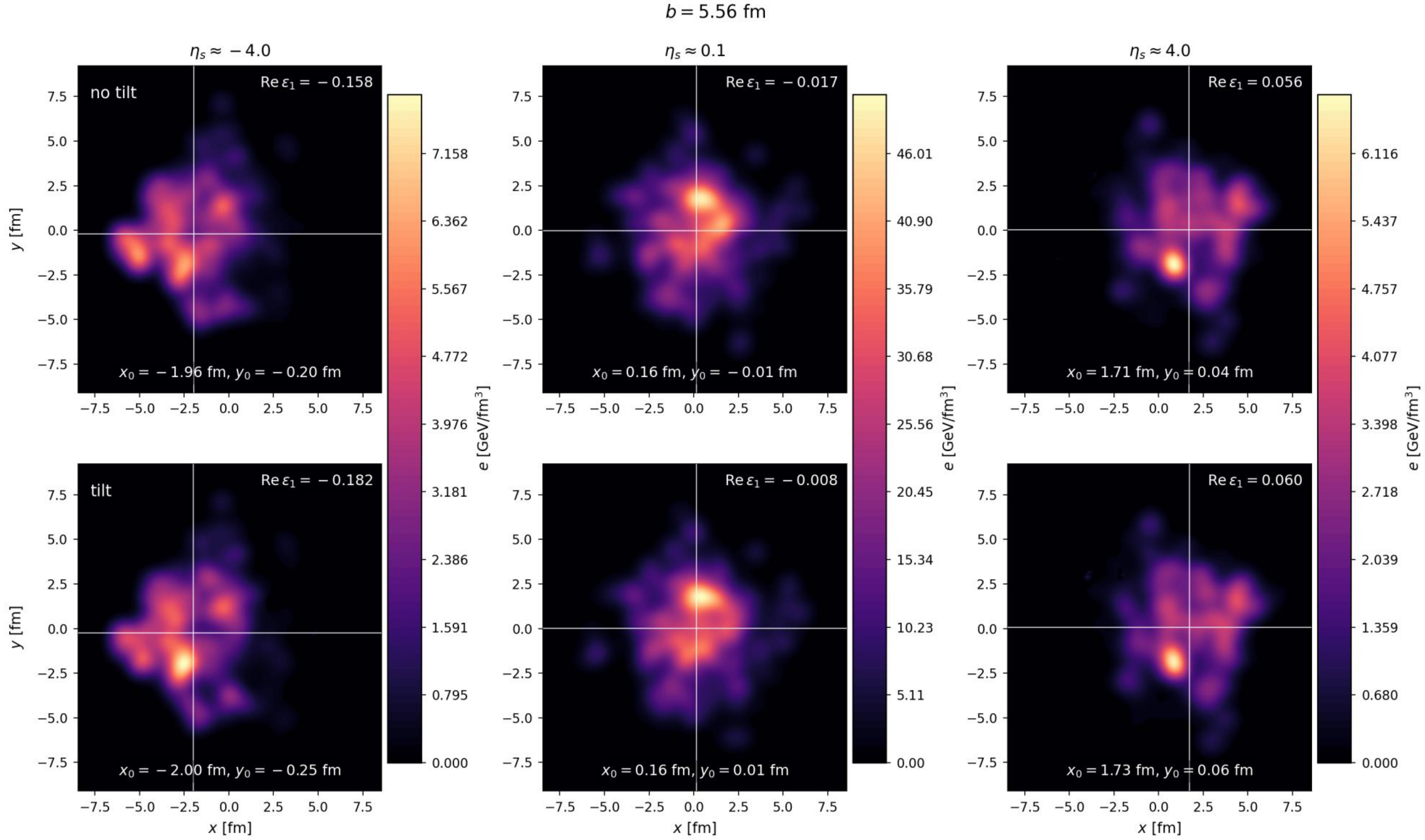
Gives unique solution to α string tilt

$$L_y^{\rm string} = -x_c P_z^{\rm string} = -\int_{\eta_s^T}^{\eta_s^P} d\eta_s\, x(\eta_s)\, e(\eta_s) \sinh y(\eta_s)$$

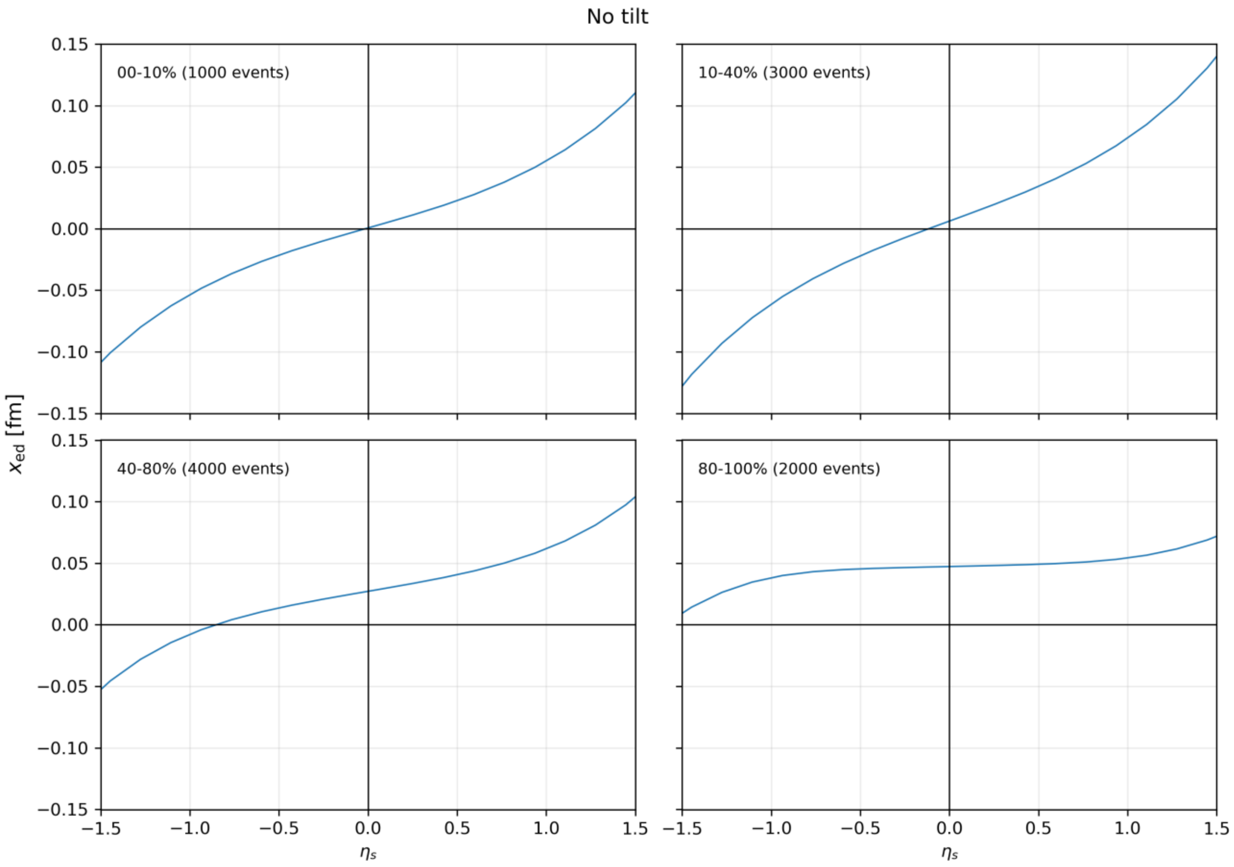
Where,

$$x(\eta_s) = \frac{x^P + x^T}{2} + \alpha\left(\frac{x^P - x^T}{\eta_s^P - \eta_s^T}\right)(\eta_s - \eta_{s,c}),$$

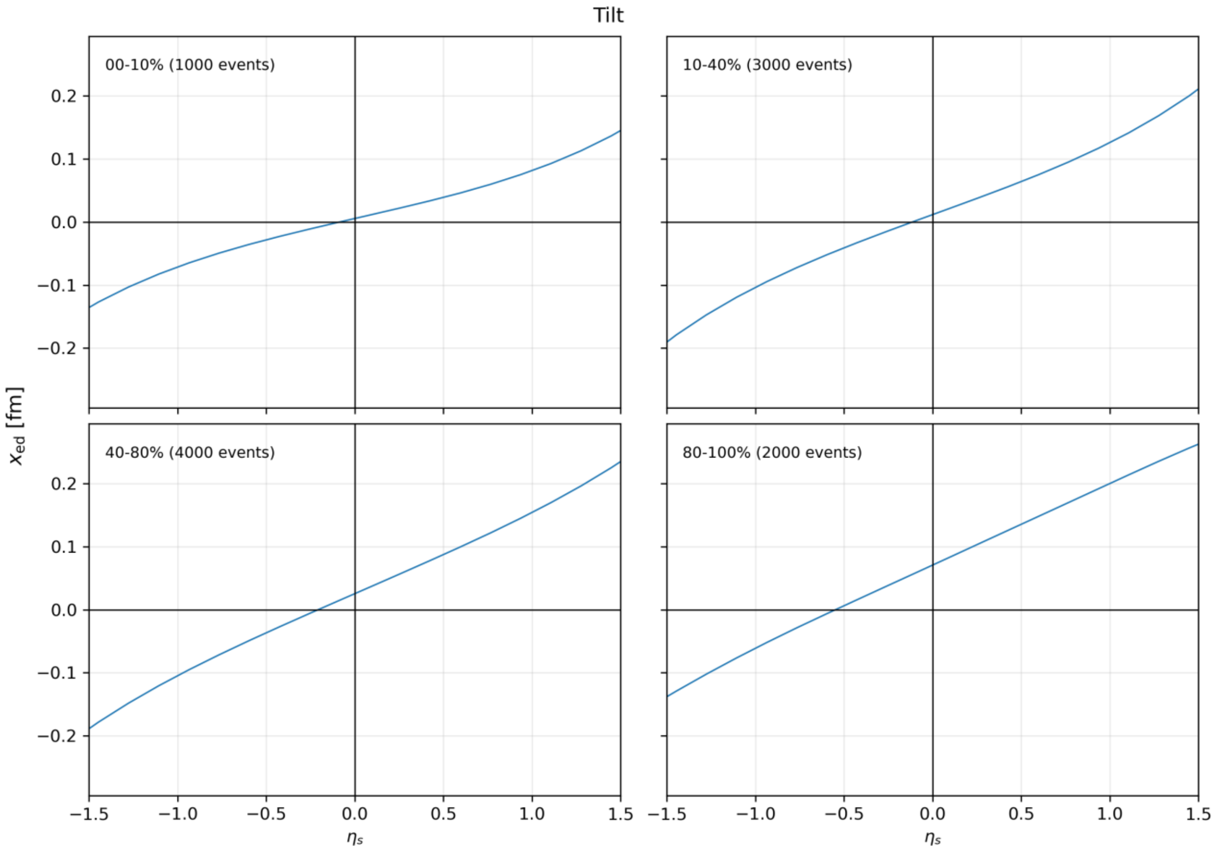
Eccentricity at eta slices



eta vs x_{ed}



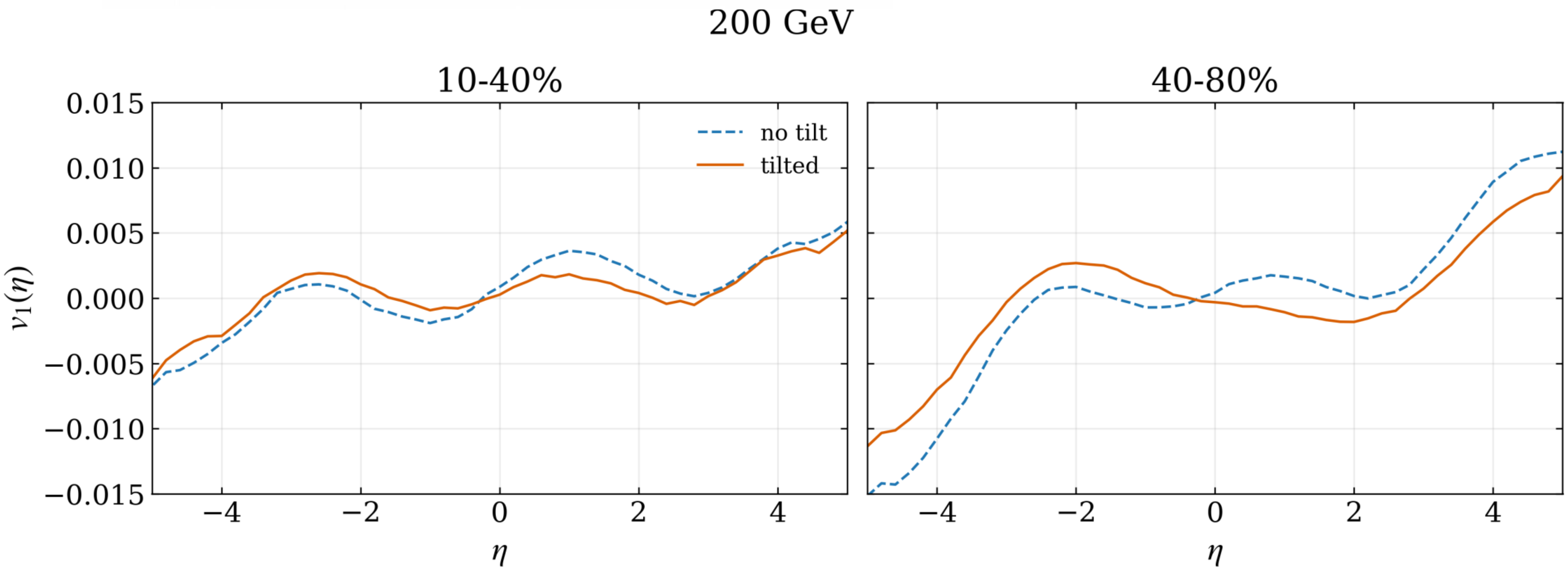
No tilt
00-10% (1000 events)
10-40% (3000 events)
40-80% (4000 events)
80-100% (2000 events)
x_{ed} [fm]
η_s



Tilt
00-10% (1000 events)
10-40% (3000 events)
40-80% (4000 events)
80-100% (2000 events)
x_{ed} [fm]
η_s

Directed flow (V_1) of Charged Hadrons

$$\frac{dN}{d\phi} = \frac{N}{2\pi}\left[1 + 2\sum_{n=1}^{\infty} v_n \cos\left(n\left(\phi - \Psi_n\right)\right)\right]$$



1) Toward peripheral collisions → deviation
2) 10–40% → Less positive slope near mid rapidity
3) 40–80% → Opposite slope sign