UNIVERSITY OF ILLINOIS AT CHICAGO

Hydrodynamic Fluctuations and Two Point Correlators

Todd Springer

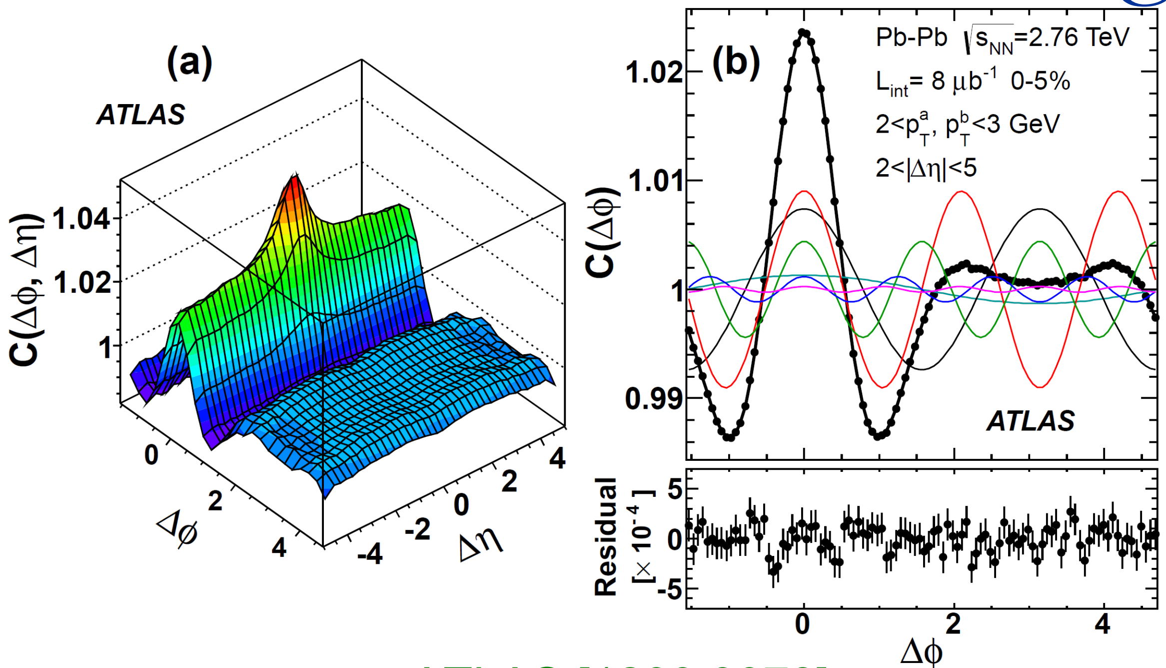
Collaborator:
Misha Stephanov

QM 2012

Washington DC

8/18/2012

Motivation – the near side ridge



ATLAS [1203.3078]

What sort of correlations are generated by

- A local hotspot,
- Propagating according to hydrodynamics,
- In a background with radial flow?

Gubser Flow (background)

Advantages:

- Exact solution to the hydro equations
- Radial flow

$$v_r(\tau, r) = \frac{2q^2 r\tau}{1 + q^2(r^2 + \tau^2)} \qquad q = (4.3\,\text{fm})^{-1}$$

- Bjorken is a special case $q \to 0$

Free parameter – related to finite size of system

Limitations (reasons for the simplicity):

- Azimuthal symmetry (central collisions)
- Conformal symmetry

$$\varepsilon = 3P$$
$$\zeta = 0$$

Gubser [1006.0006], Gubser and Yarom [1012.1314]

Gubser Flow (Perturbations)

- Introduce perturbations

$$\varepsilon(\rho,\theta,\phi,\xi) = \frac{\hat{\varepsilon}_0(\rho)}{\tau^4}\left[1+\lambda\delta(\rho,\theta,\phi,\xi)\right] + \mathcal{O}(\lambda^2)$$

$$u^\mu = \frac{1}{\tau}\left(1, \lambda u^i(\rho,\theta,\phi,\xi)\right) + \mathcal{O}(\lambda^2)$$

- Linearize hydro equations in conformal coordinates

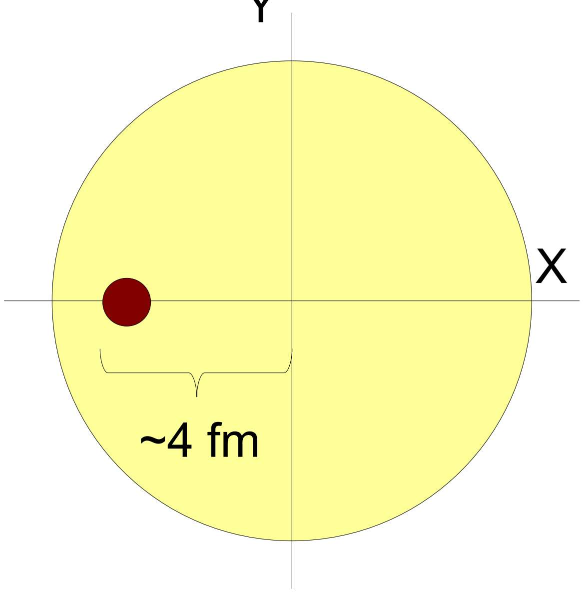
$$\nabla_\mu T^{\mu\nu} = 0$$

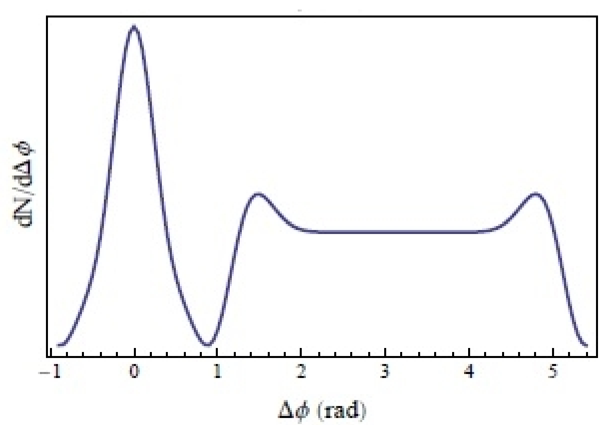
$$T^{\mu\nu} = \frac{4\varepsilon}{3}u^\mu u^\nu + \frac{\varepsilon}{3}g^{\mu\nu} + T^{\mu\nu}_{\text{viscous}}$$

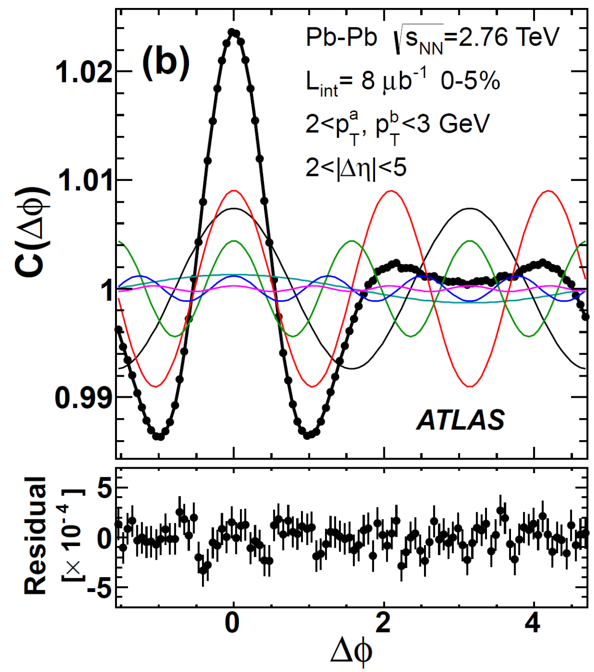
- Spherical harmonics and Fourier transform reduces this to a set of coupled ODEs

Gubser Flow (Perturbations)

- Neglecting rapidity dependence, (and viscosity) the equations can be solved analytically
- A strategically placed hotspot gives a reasonable result for the azimuthal dependence





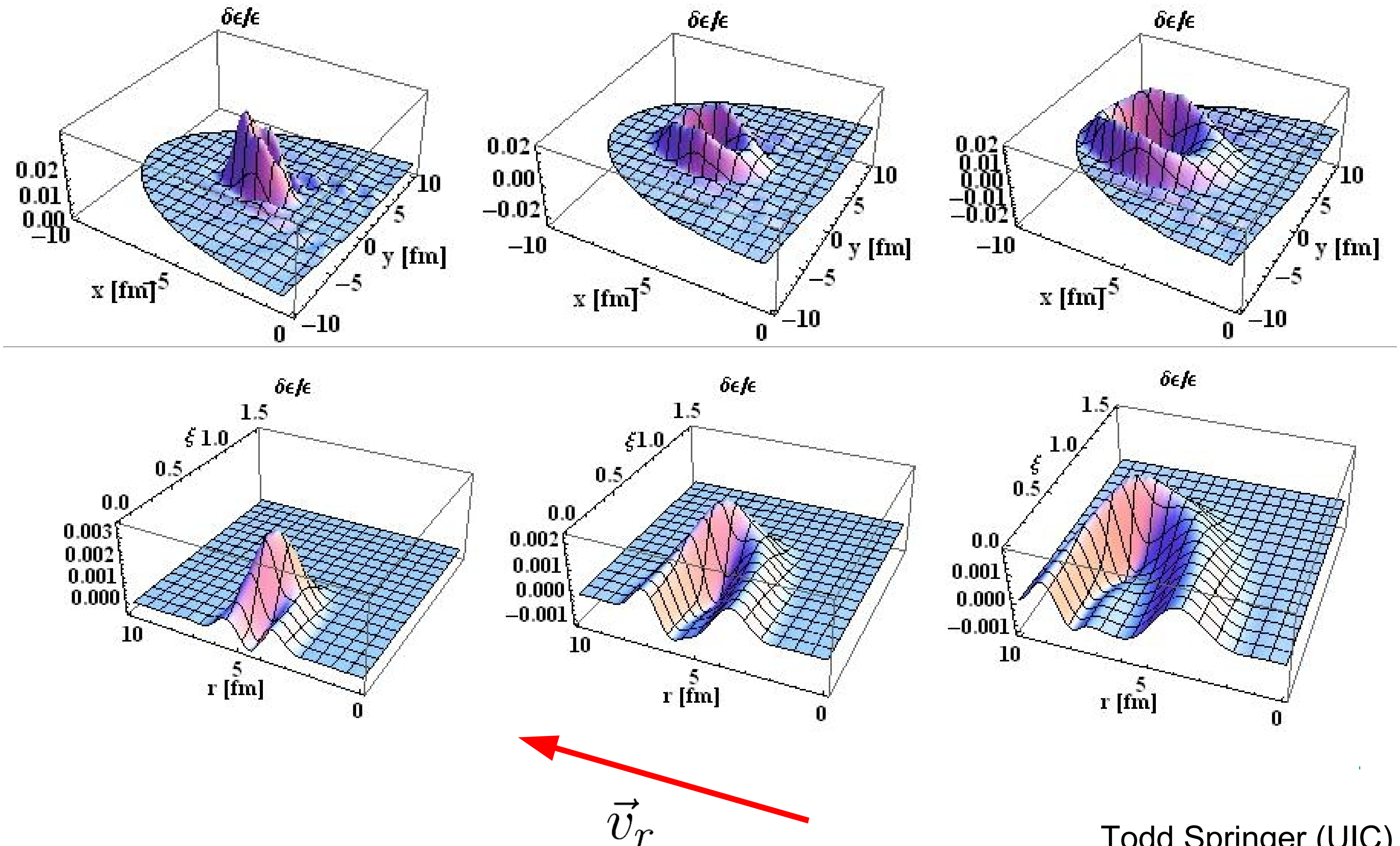


Shuryak and Staig [1105.0676]

What happens if we extend these results in longitudinal direction?

Proper time evolution

$\tau = 2\tau_0$ $\tau = 4\tau_0$ $\tau = 6\tau_0$



Todd Springer (UIC)

Methodology

Compute two point functions (energy-energy correlator)

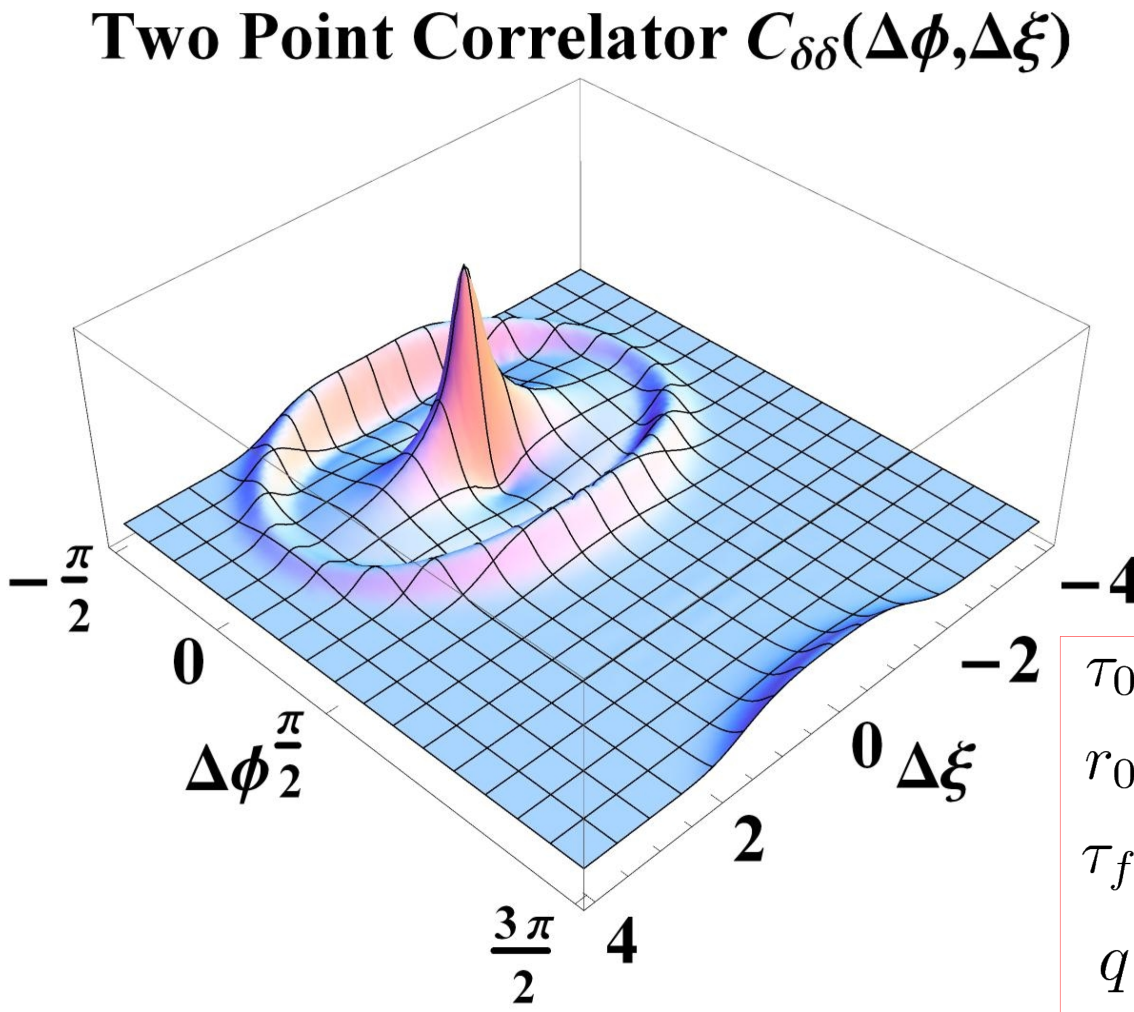
- In lieu of proper freeze-out, average over radius

$$\bar{\delta}(\tau, \phi, \xi) \equiv \frac{1}{r_{\max}} \int_0^{r_{\max}} r dr \, \delta(\tau, r, \phi, \xi)$$

- Average over initial azimuthal angle and rapidity

$$C_{\delta\delta}(\tau, \Delta\phi, \Delta\xi) \equiv \int d\chi d\eta \, \bar{\delta}(\tau, \phi_1 - \chi, \xi_1 - \eta) \bar{\delta}(\tau, \phi_2 - \chi, \xi_2 - \eta)$$

Results



$$\tau_0 = 0.5\,\mathrm{fm/c}$$
$$r_0 = 4.1\,\mathrm{fm}$$
$$\tau_f = 10\,\mathrm{fm/c}$$
$$q = (4.3\,\mathrm{fm})^{-1}$$

Discussion

- The peak at zero angular separation has some contribution from a structure which is elongated in rapidity
- Rapidity correlations can be long, **but** limited by the finite sound propagation speed
- Narrow peak in $\Delta\phi$ should persist after freeze-out due to radial flow
- These results are for a single (initial state) hotspot
- Extension to include stochastic noise is in progress