Musings on Jet Medium Interaction

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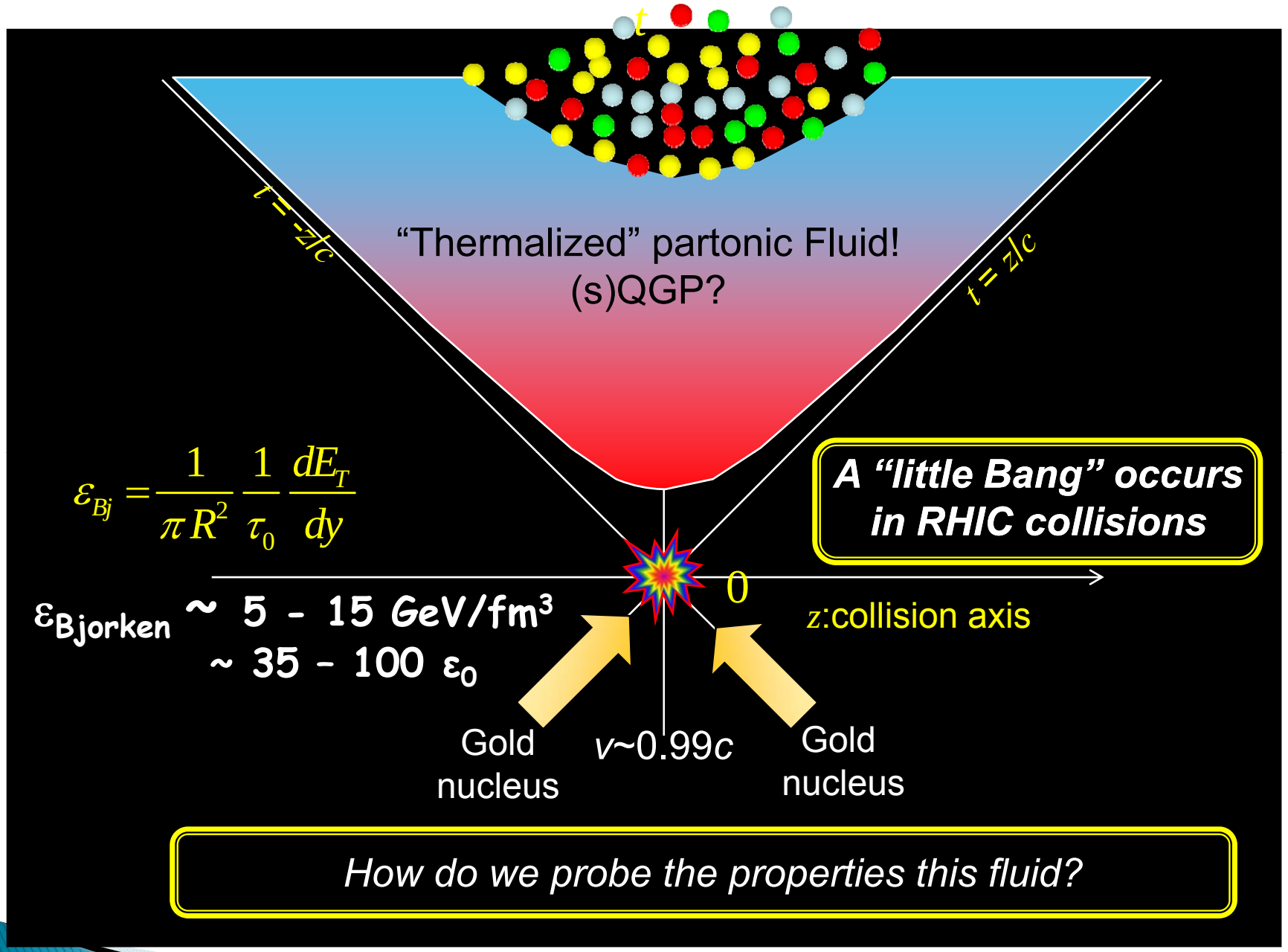
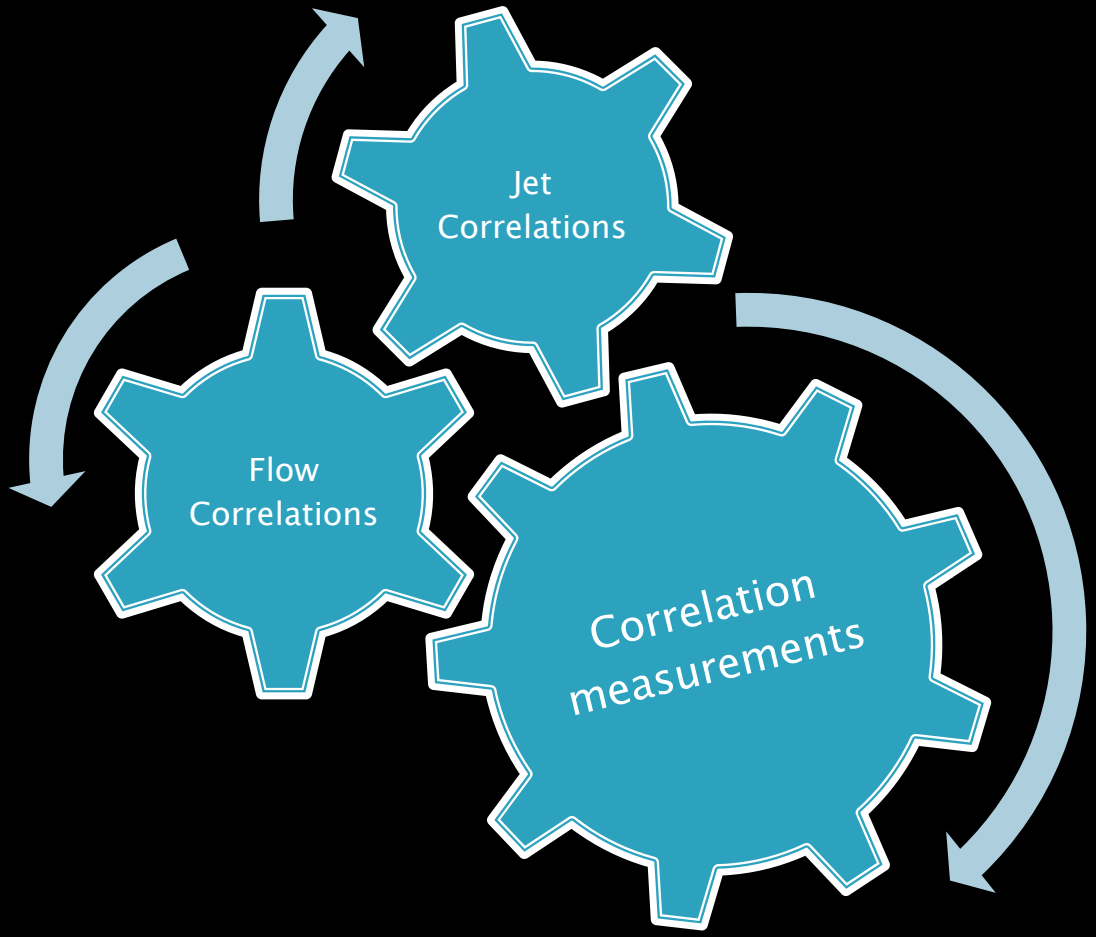
*"Any man who knows all the **answers** most likely misunderstood the questions"*
Nancy Willard

1. *Characteristics of the Medium*
2. *Jet-medium interactions*
   - *Extraction of jet functions*
3. *Summary of few things learned*


t
t = -z/c
"Thermalized" partonic Fluid!
(s)QGP?
t = z/c
$\varepsilon_{Bj} = \frac{1}{\pi R^2}\frac{1}{\tau_0}\frac{dE_T}{dy}$
A "little Bang" occurs in RHIC collisions
$\varepsilon_{Bjorken}$ ~ 5 - 15 GeV/fm^3
~ 35 - 100 ε_0
0
z:collision axis
Gold nucleus
v~0.99c
Gold nucleus
How do we probe the properties this fluid?

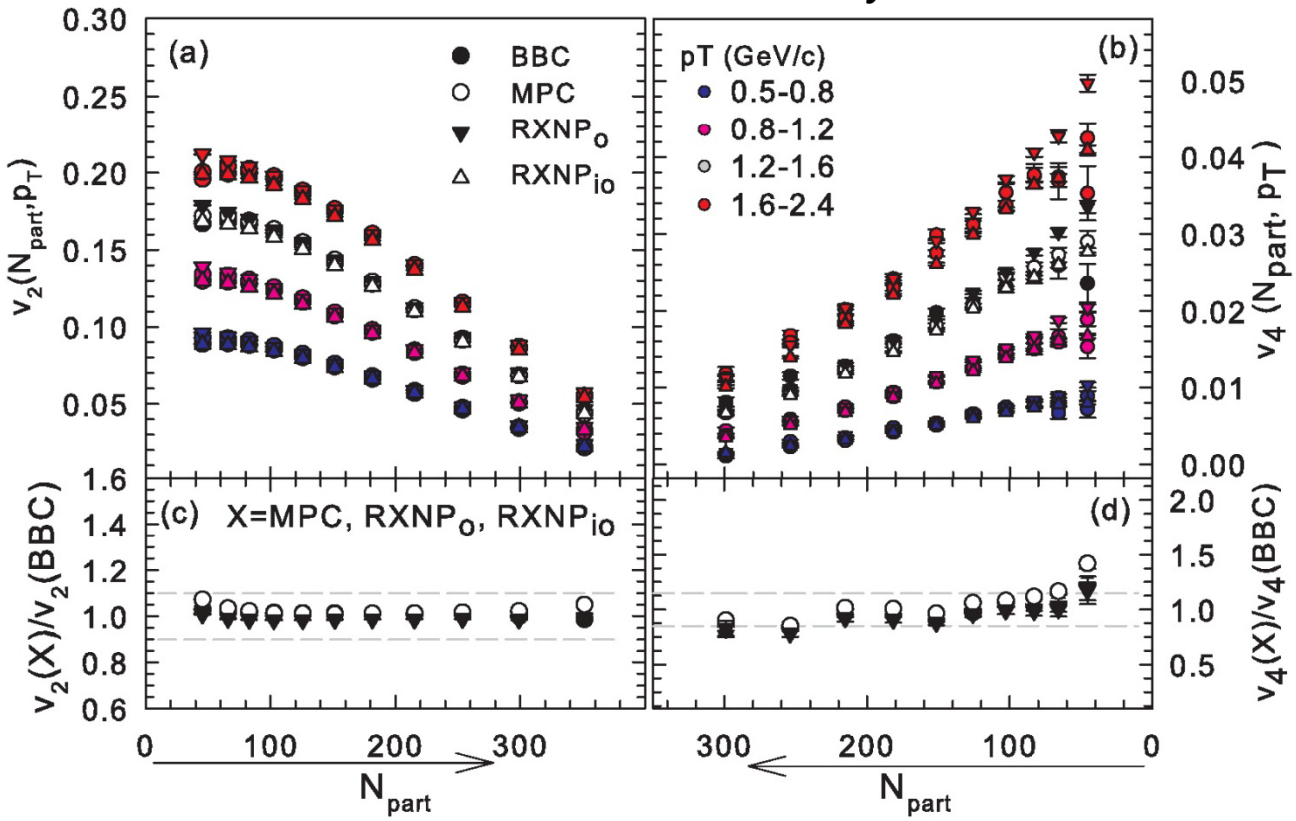


Extraction of transport coefficients (η/s, q, c_s, λ, etc) can lend decisive insight

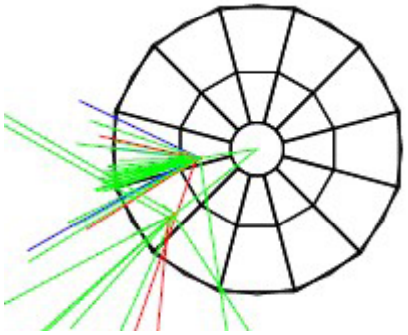
Accurate measurements are crucial!

The non-flow "chicken" has come home to roost

PHENIX Preliminary



New RXN detector



$$3.1 < |\eta_{BBC}| < 3.9$$

$$3.1 < |\eta_{MPC}| \lesssim 3.9$$

$$1.5 < |\eta_{RXN_i}| < 2.8$$

$$1.0 < |\eta_{RXNo}| < 1.5$$

$$1.0 < |\eta_{RXN_{io}}| < 2.8$$

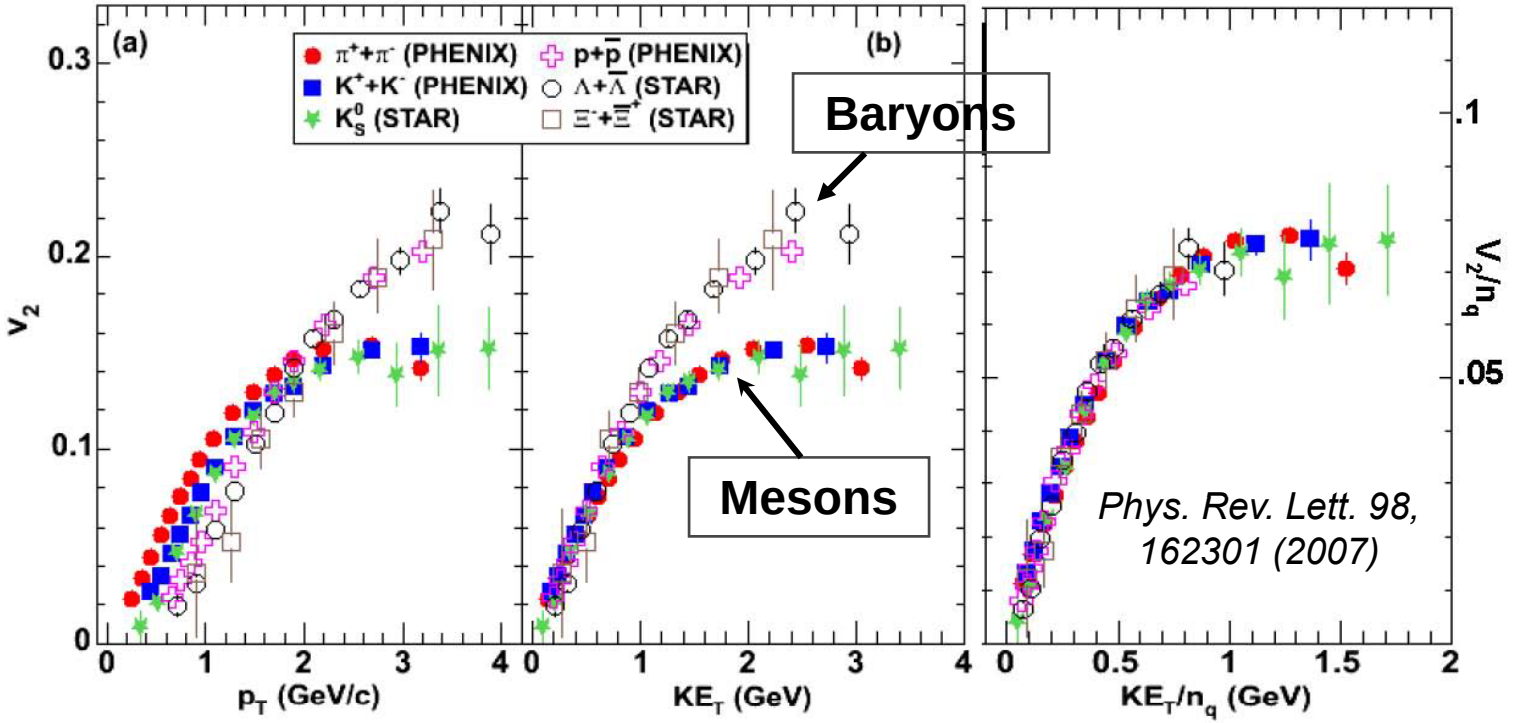
Event planes

The case is now closed on issues of non-flow etc, via 5 separate measurements of v_2 and v_4 in the same experiment

KE_T – CQN Scaling

$P \propto$ Kinetic Energy Density

$KE_T = m\,(\gamma_T - 1)$



$$\eta = \rho v l$$

$$s \sim n = \frac{\rho}{m}$$

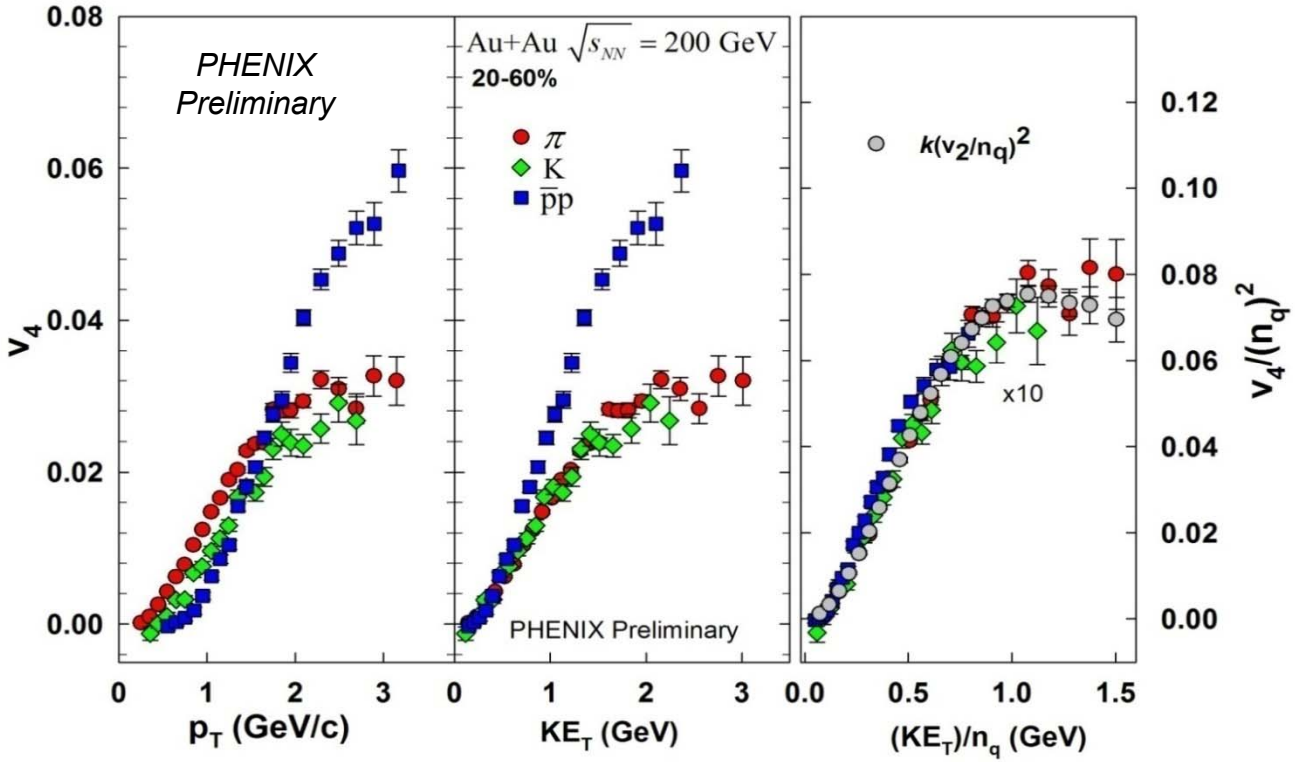
$$\frac{\eta}{s} \sim mvl$$

$$\sim \hbar \frac{\lambda}{\lambda_{dbr}}$$

Quark-Like Degrees of Freedom Evident
Indication of strong coupling?

The argument against quark degrees of freedom is ill-informed!

KE_T and CQN Scaling for v_4



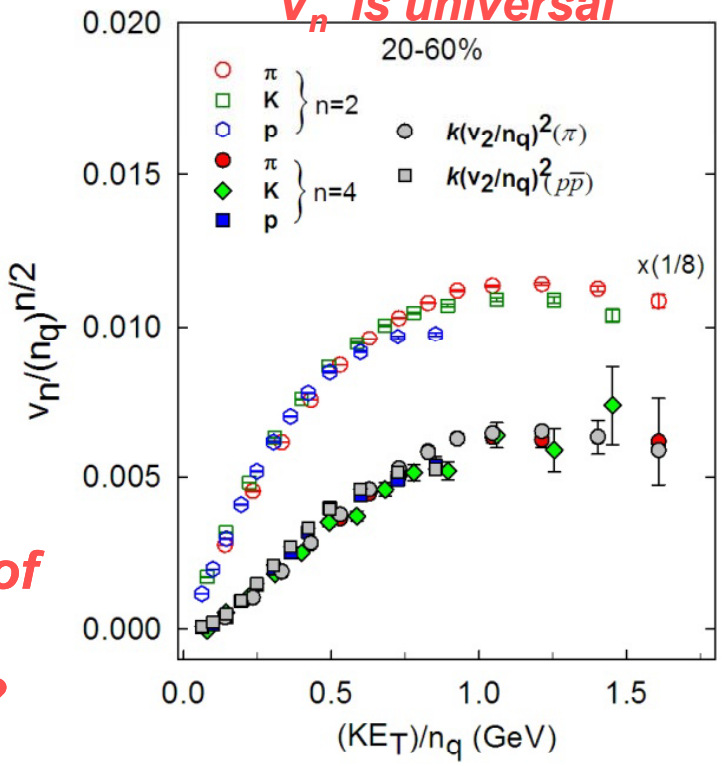
KE_T & n_q^2 scaling validated for v_4

Further Indication of strong coupling?

Is this an indication that the partonic fluid is thermalized?

$$\frac{v_{4,q}(p_T)}{v_{2,q}^2(p_T)} \approx \frac{1}{2}$$

V_n is universal



$$\frac{v_{4,M}(2p_T)}{v_{2,M}^2(2p_T)} \approx a\left(\frac{1}{4}+\frac{1}{2}\times\frac{v_{4,q}(p_T)}{v_{2,q}^2(p_T)}\right)$$

$$\frac{v_{4,B}(3p_T)}{v_{2,B}^2(3p_T)} \approx a\left(\frac{1}{3}+\frac{1}{3}\times\frac{v_{4,q}(p_T)}{v_{2,q}^2(p_T)}\right)$$

a
Related to η/s ?

Further Indication of strong coupling?

Hints?

1. Hadronization?

2. Partonic Thermalization?

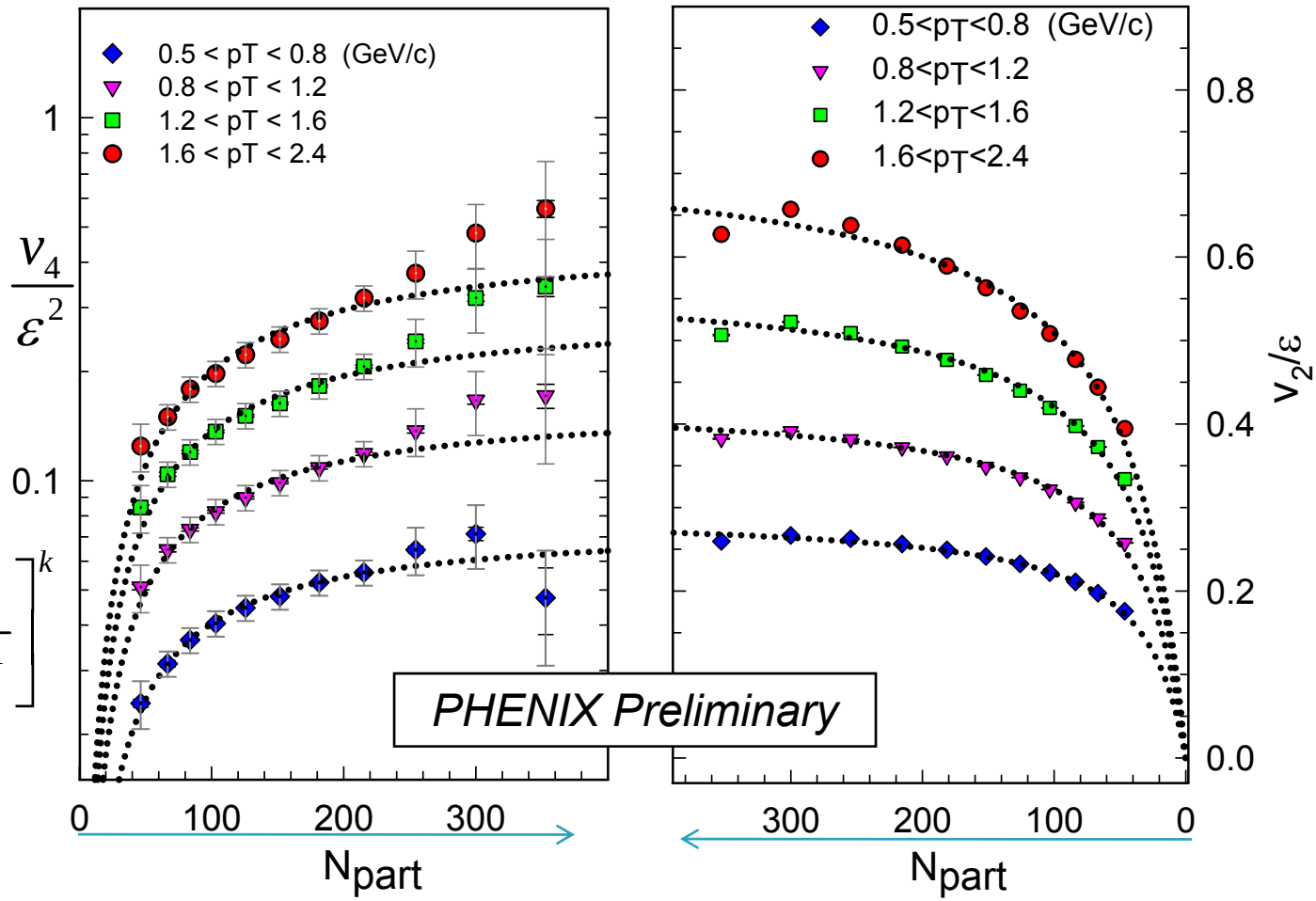
Better constrained estimates of coefficients

$$K_n \sim \alpha + \frac{\beta}{N_{part}}$$

$$\frac{\eta}{s} \sim \lambda T c_s \equiv K_n (RT) c_s$$

$$\frac{v_{2k}}{\varepsilon^k} = \frac{v_{2k}^{hd}}{\varepsilon^k} \left[\frac{K_n^{-1}}{K_n^{-1} + K_0^{-1}} \right]^k$$

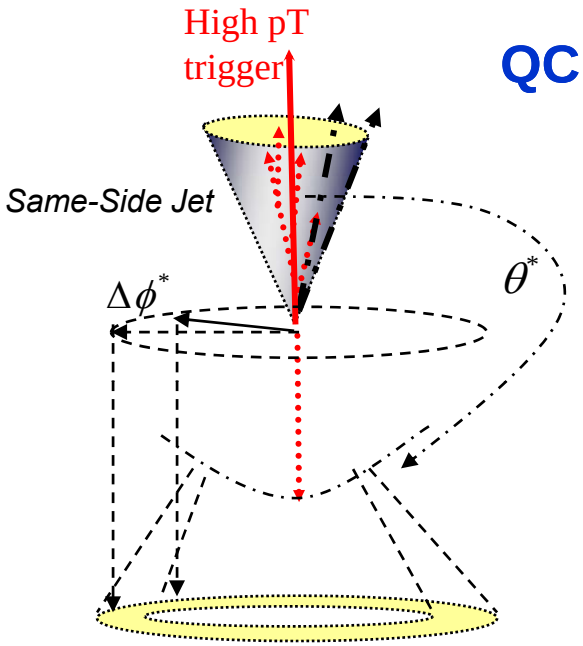
$\lambda = 0.3 - 0.35$



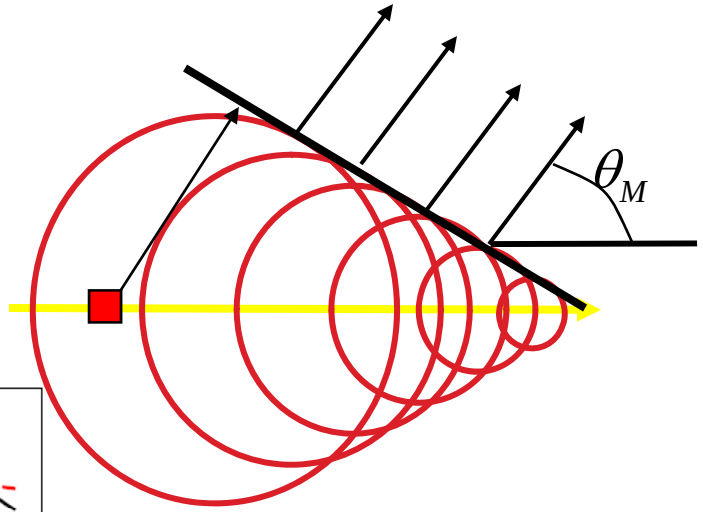
Straightforward estimation of the degree of local equilibrium and η/s as a function of centrality!

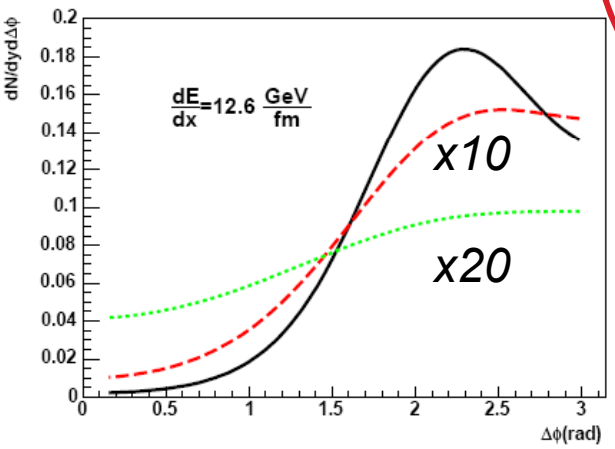
10-15% larger than for fluid with η/s =1/4π in central events.

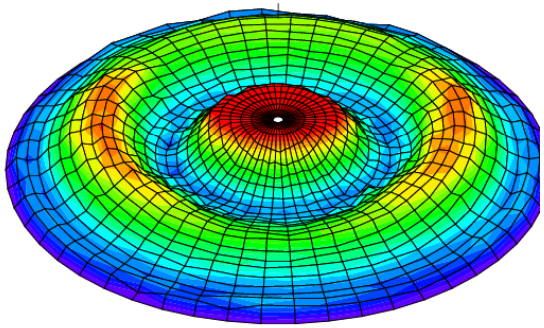
Medium Response & Transport Coefficients



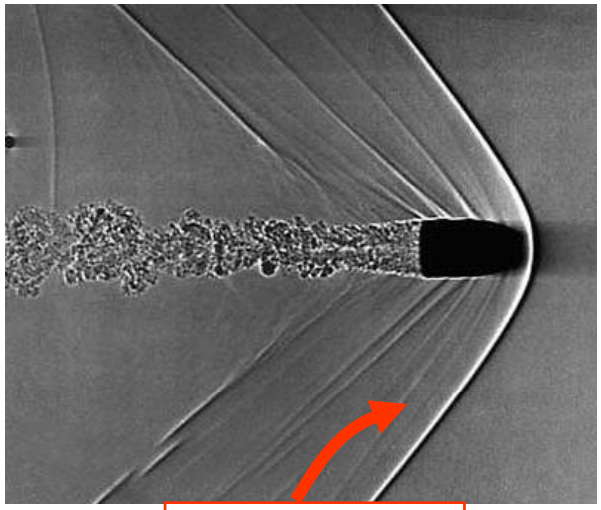
QCD Sonic Boom







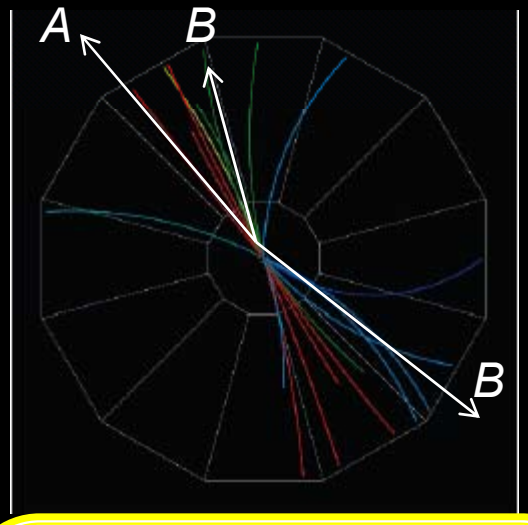
$$\Gamma_s = \frac{4}{3}\frac{\eta}{sT} \sim 0.1,\ 0.2,\ 0.5\ \left(\frac{1}{T}\right)$$

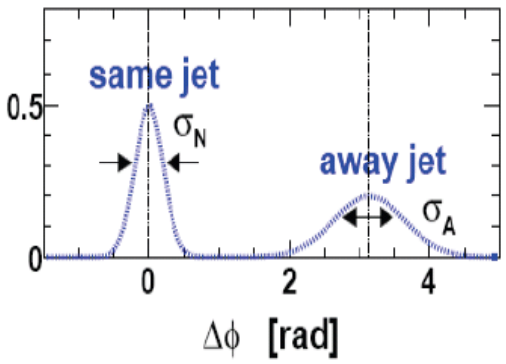


$$\cos\left(\theta_M\right) = c_s$$

Gives sound speed directly; Sets upper limit on viscosity.

2P & 3P correlation measurements?





Strategy
Compare jet correlations in pp & AA Collisions

It is necessary to decompose flow and Jet correlations → Jet function
ZYAM

The "'wisdom" of ZYAM!

There are three methods to gaining wisdom.

The first is reflection, which is the highest.
The second is limitation, which is the easiest.
The third is experience, which is the bitterest."

Confucius

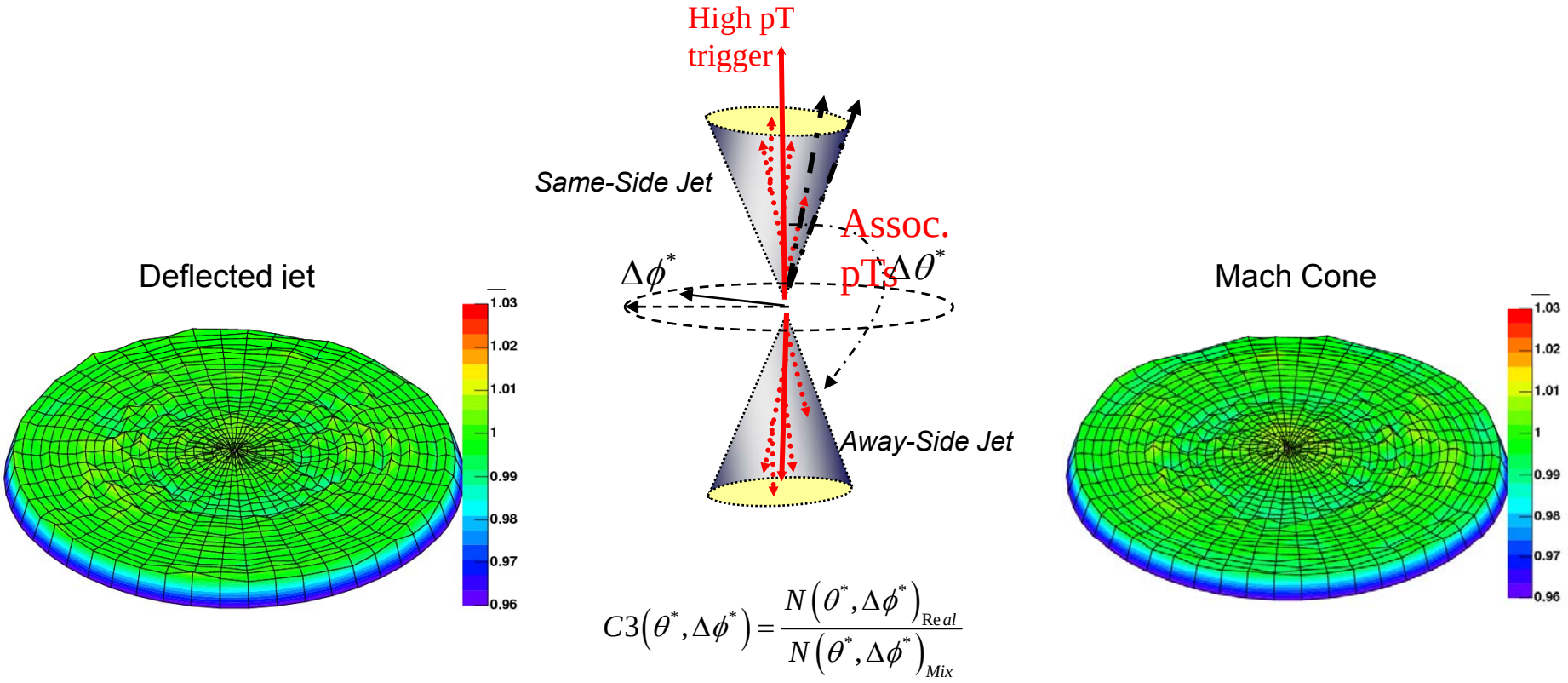
Reflection

- *Based on a two source model*
  - *Two source models with similar Input → same result.*
- *Jets correlate [or/not] with event plane*
- *Flow contributions dominate*
- *Accurate determination of v2 required*
- *Jet function (shape) is insensitive to ZYAM assumption*

Limitations

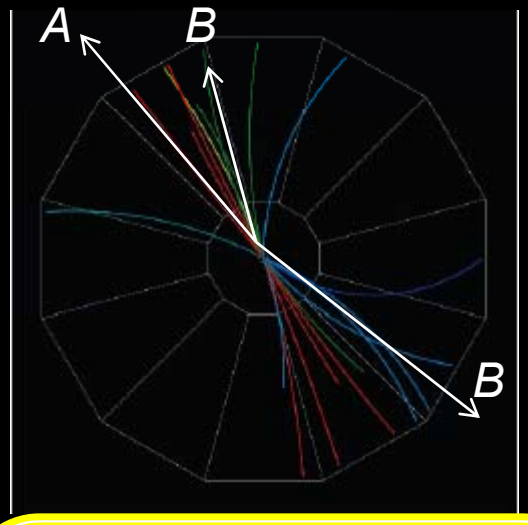
- *Uncertainty in jet yields*
  -

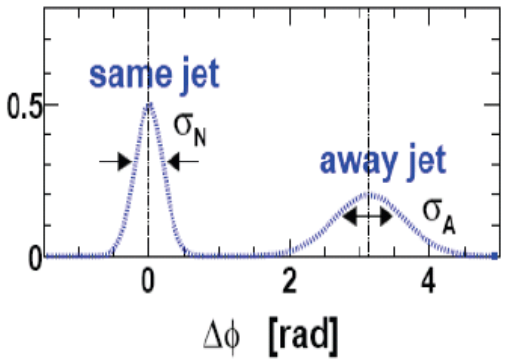
Validation test of the use of two event mixing to remove 2+1 processes

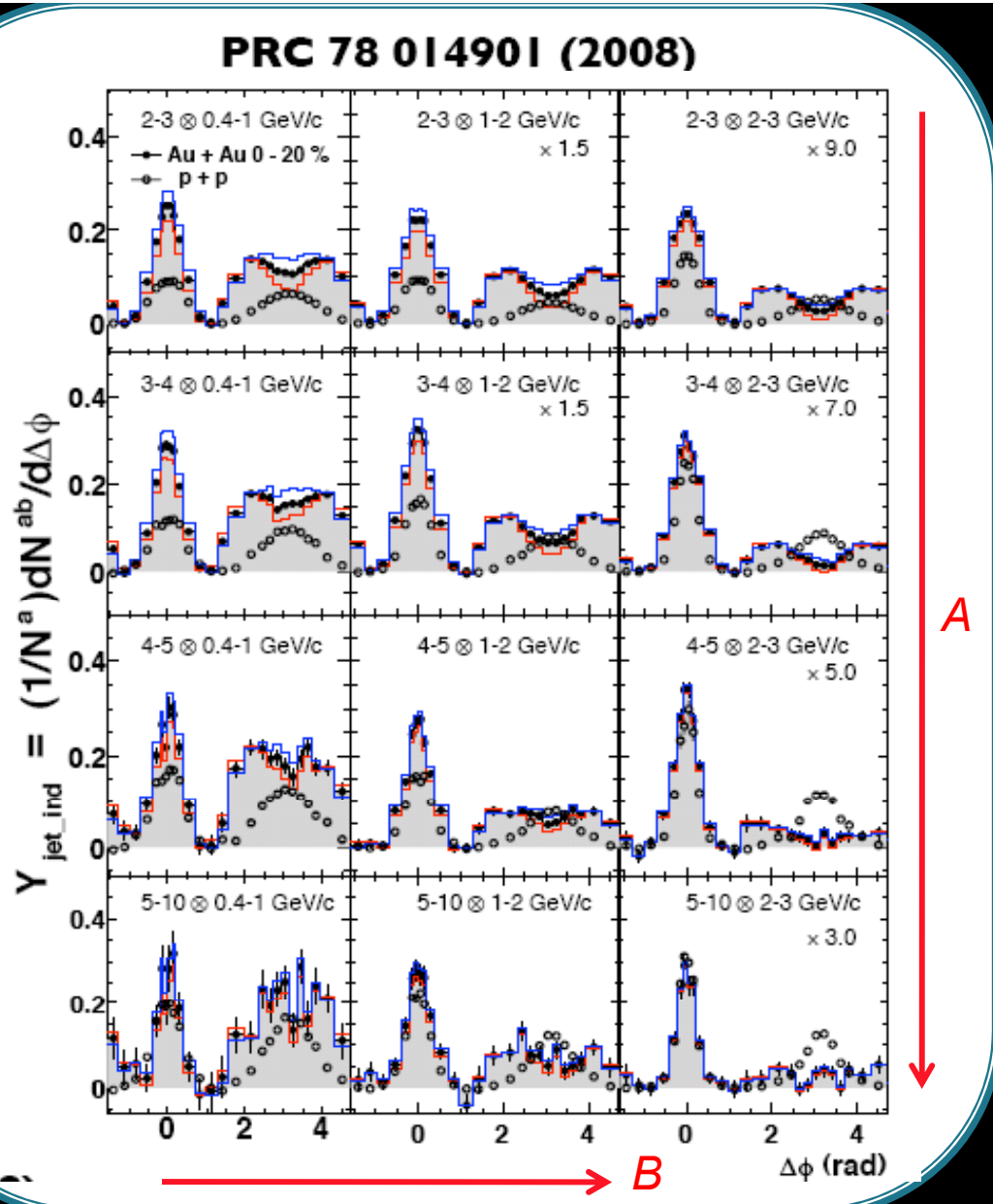


(2+1) processes efficiently removed via two-event mixing to obtain true three particle correlations

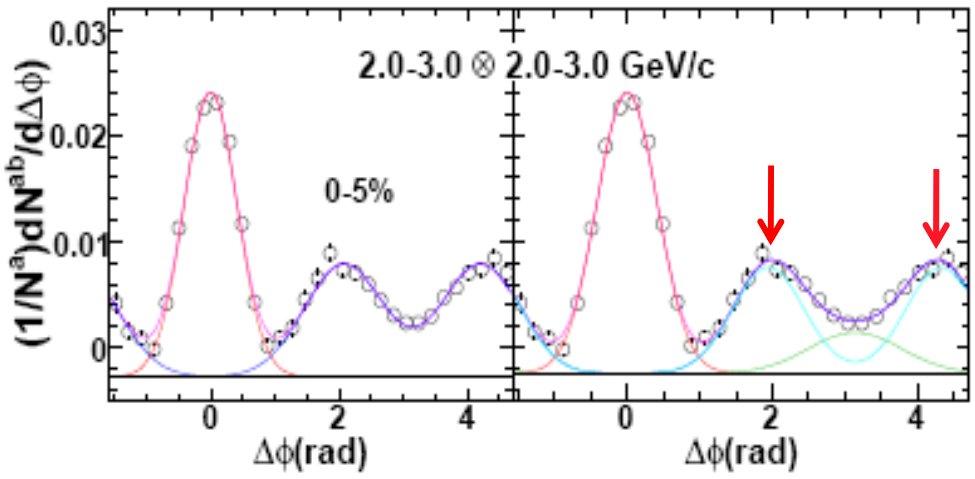
Di-jet correlation measurements?

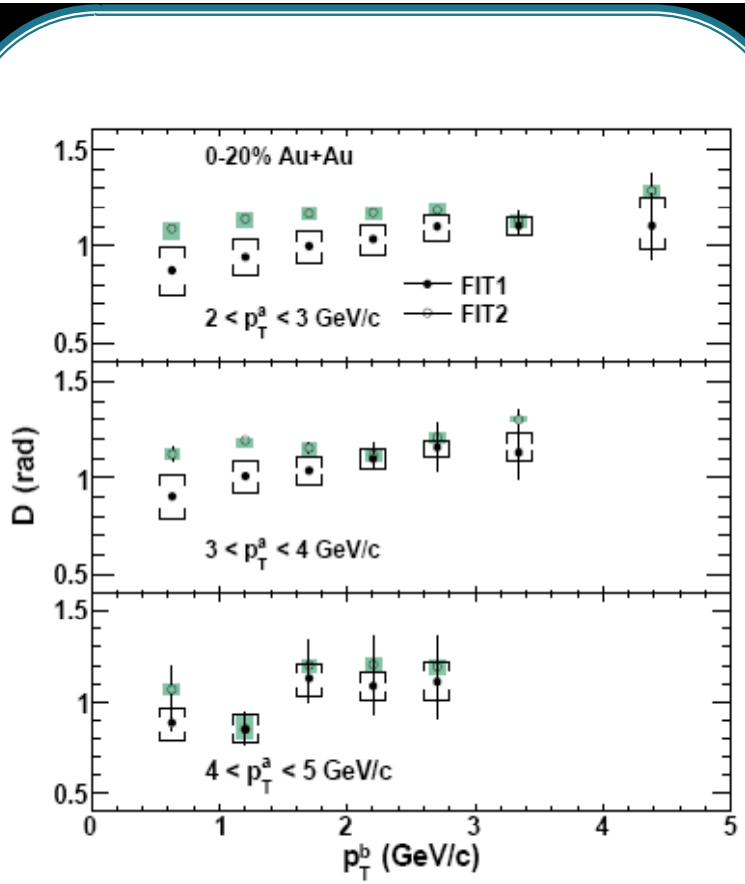


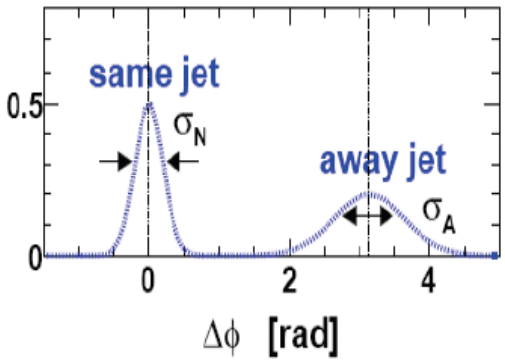




Medium Response

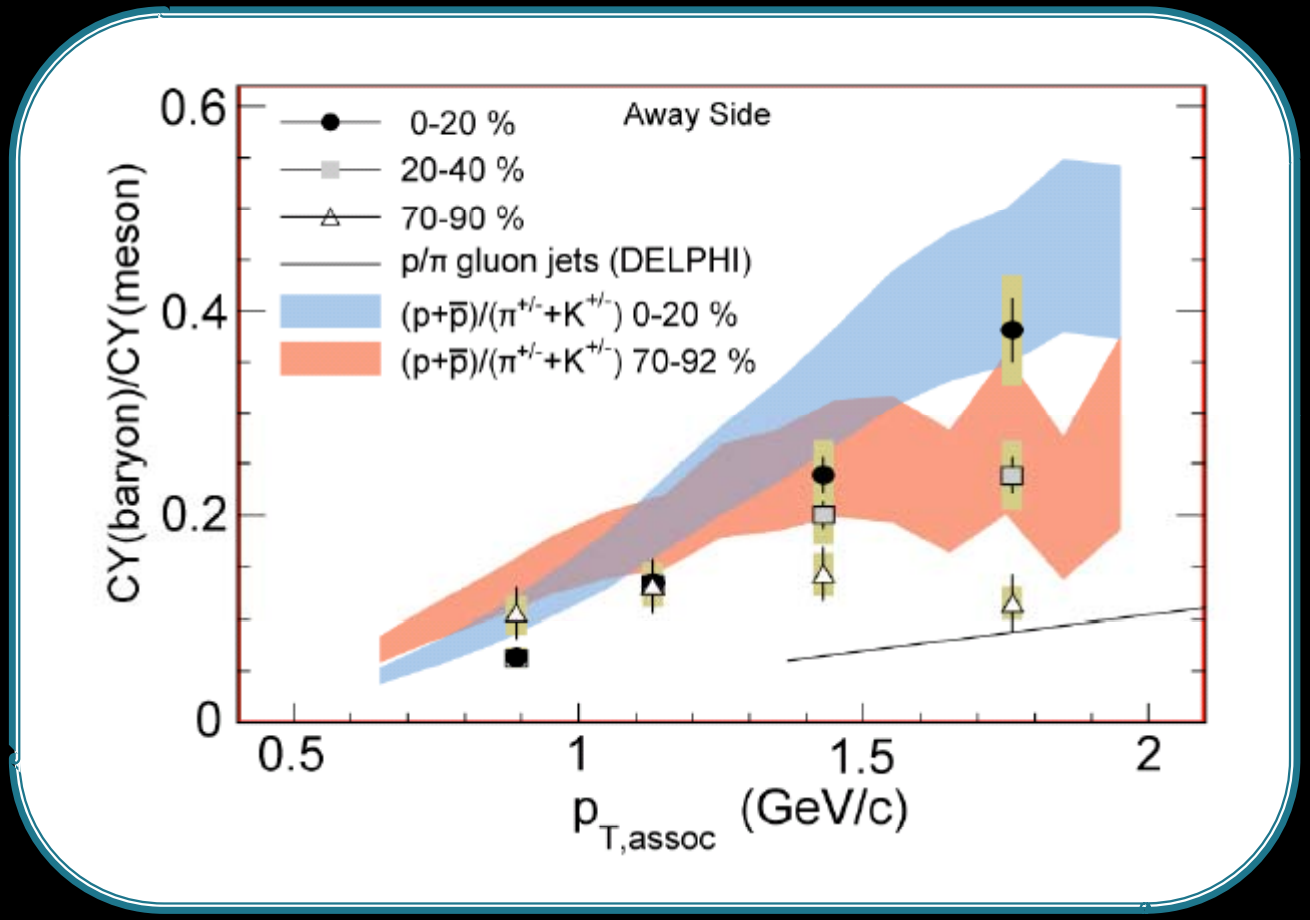






Modified Away-side topology is p_T independent

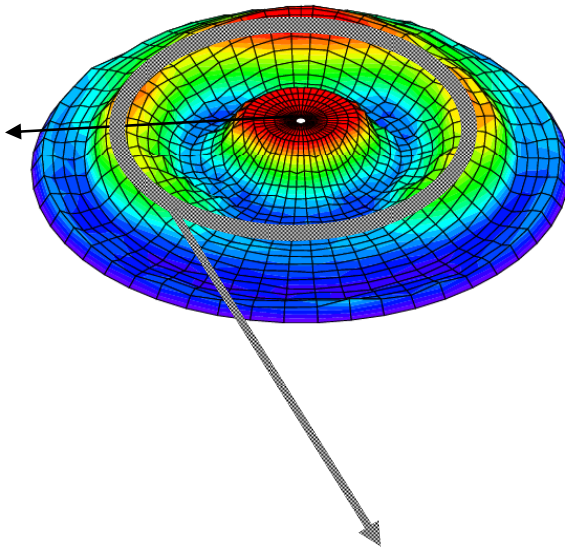
Medium Response
"Particle composition"

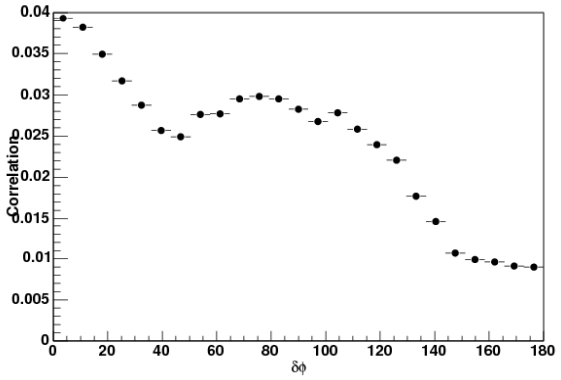


Composition of away-side jet similar to inclusive measurement

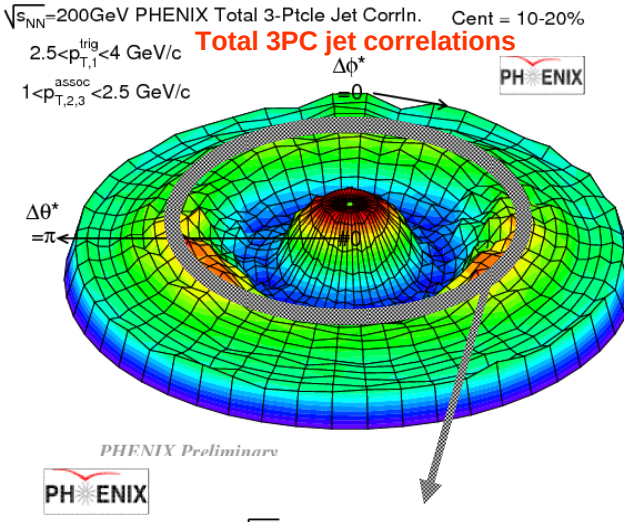
QCD Sonic Boom?

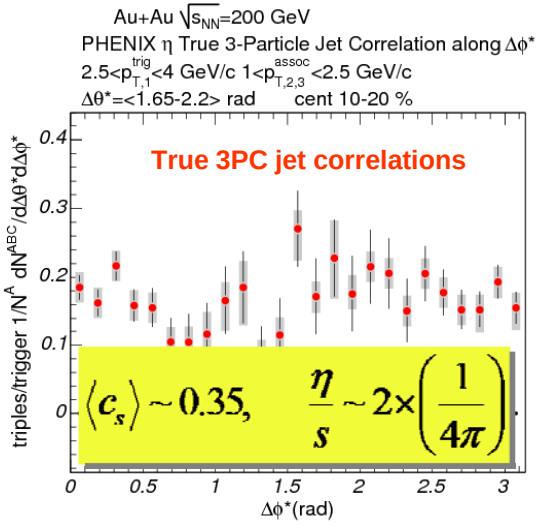
Simulated
Deflected jet



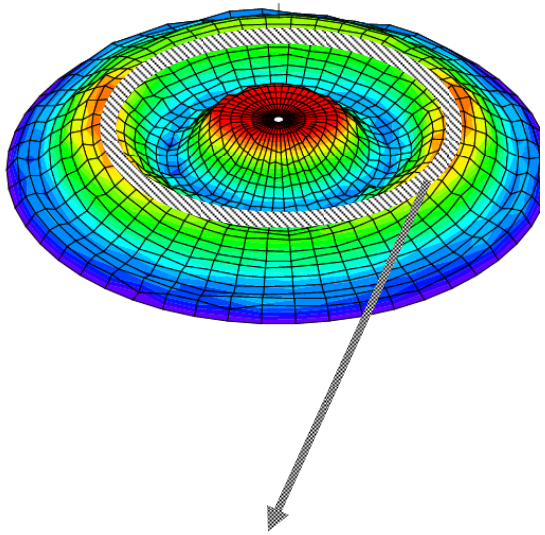


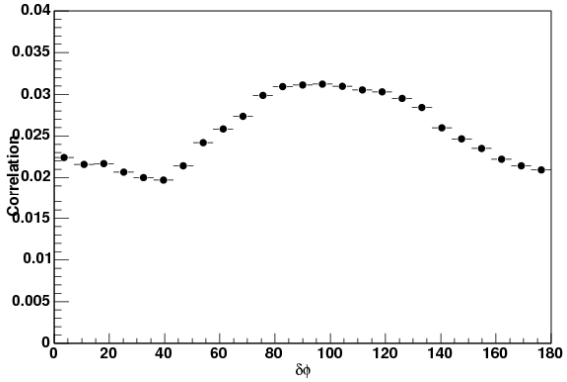
Data





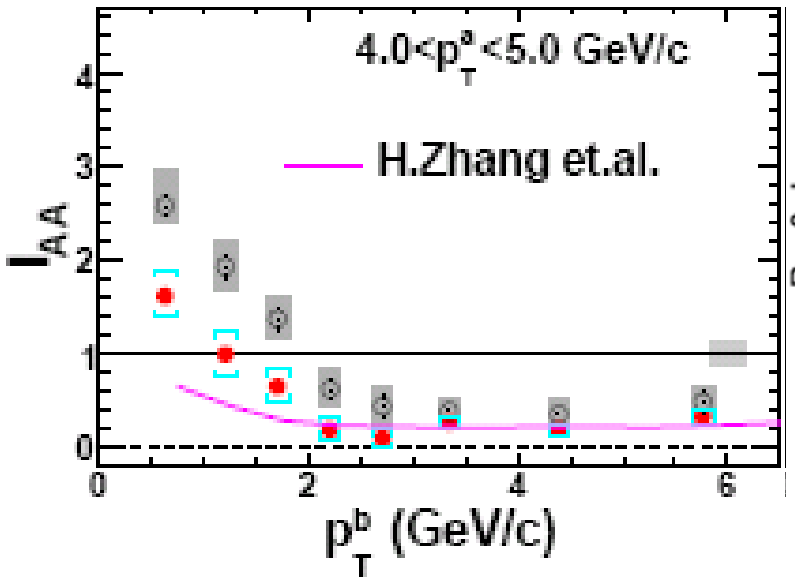
Simulated
Mach Cone

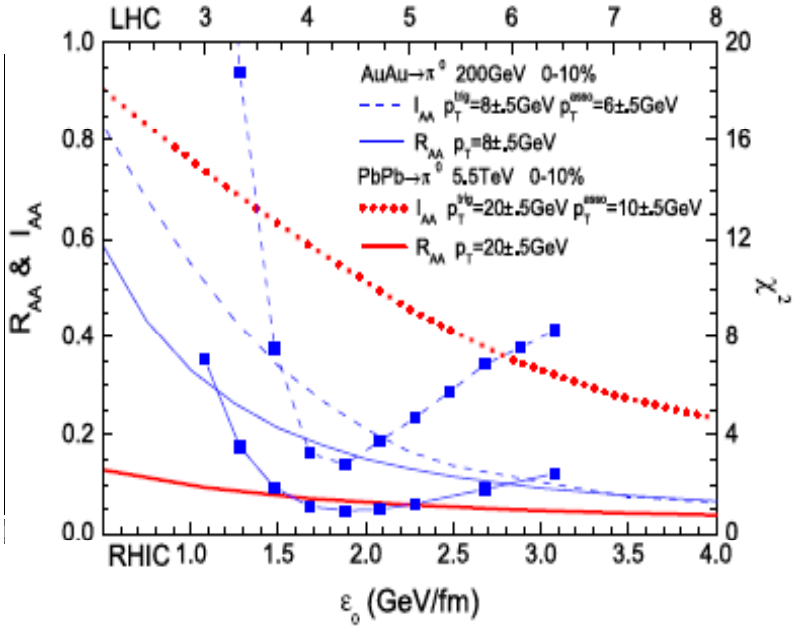




Data compatible with the presence of a Mach Cone away-side jet

Jet Suppression





Simultaneous fits to I_{AA} and R_{AA} provide improved constraints

Summary

A central goal of current relativistic heavy ion research is the extraction of the transport properties of the recently discovered sQGP.

Correlation measurements provide important constraints for a number of these properties

- **Scattering power**
- **Sound speed**
- **Sound attenuation**
- **viscosity**
- **etc.**