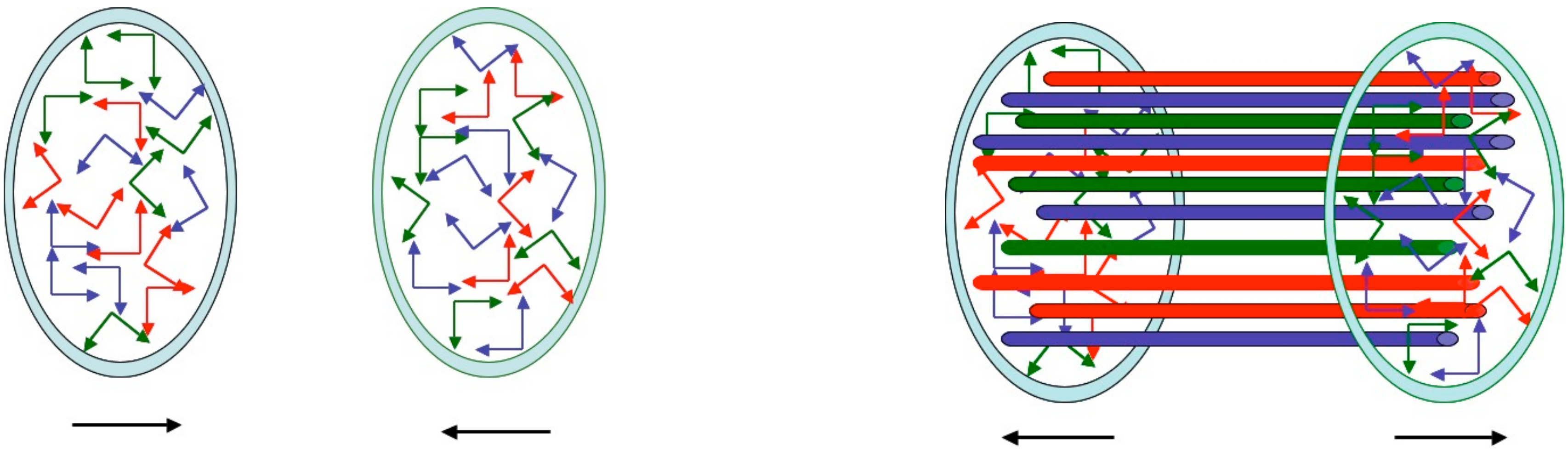
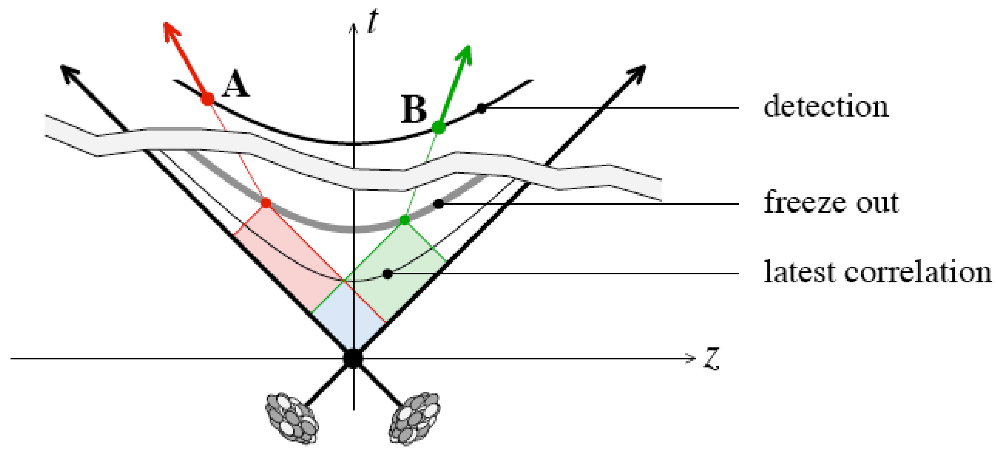
Multiplicity Correlations and Fluctuations and Glasma Flux Tubes

F. Gelis, T. Lappi and L. McLerran, Nucl. Phys. A828, 149 (2009);

T. Lappi and L. McLerran, arXiv 0909.0428

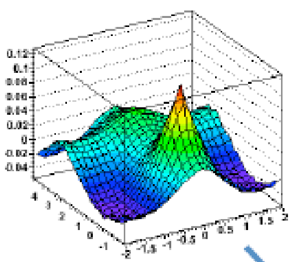


"Instantaneously" develop longitudinal color E and B fields



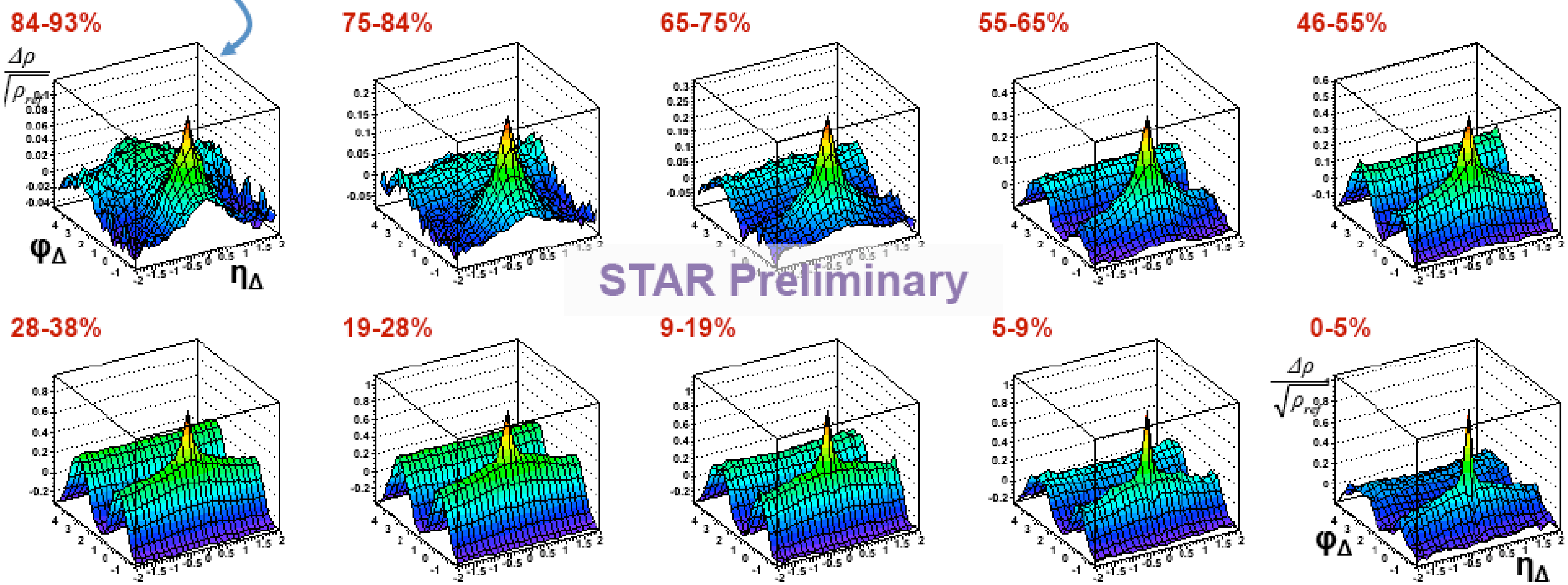
The Ridge in Heavy Ion Collisions:

200 GeV Data



Analyzed 1.2M minbias 200 GeV Au+Au events, and 13M 62 GeV minbias events (not shown) Included all tracks with p_T > 0.15 GeV/c, $|\eta|$ < 1, full φ

note: 38-46% not shown



Almost certainly the source of the ridge (see Raju's talk)

Not the subject of this talk

Two issues:

Distribution of Fluctuations in Hadronic Collisions

Forward-Backward Correlations in Multiplicity Distribution

$$P_n^{Poisson} = \frac{1}{n!} \overline{n}^n e^{-\overline{n}} \qquad P_n^{NB} = \frac{\Gamma(k+n)}{\Gamma(k)\Gamma(n+1)} \frac{\overline{n}^n k^k}{(\overline{n}+k)^{n+k}}$$

Poisson Statistics is Limit of NB as k => infinity at fixed average multiplicity

Poisson corresponds to decay of classical field

NB does not fall off like 1/n! at large n

"Completeness relationship" for negative binomial:

Sum of negative binomial emitters with parameters

$$k_1, \cdots k_N$$

Gives a negative binomial distribution with

$$k = k_1 + \cdots + k_N \qquad \overline{n} = \overline{n}_1 + \cdots + \overline{n}_N$$

Interpret

$$k = N_{source} k_{source}$$

$$\frac{\overline{n}}{k} = \frac{\overline{n}_{source}}{k_{source}}$$

In paper with Gelis and Lappi, show that a single Glasma flux tube is a NB source.

Phenix results:

Multiplicity distribution is negative binomial

K proportional to the number of participant

RHIC Experiments:

$$\frac{dN}{dy} \sim \frac{1}{\alpha_S(Q^2_{sat})}$$

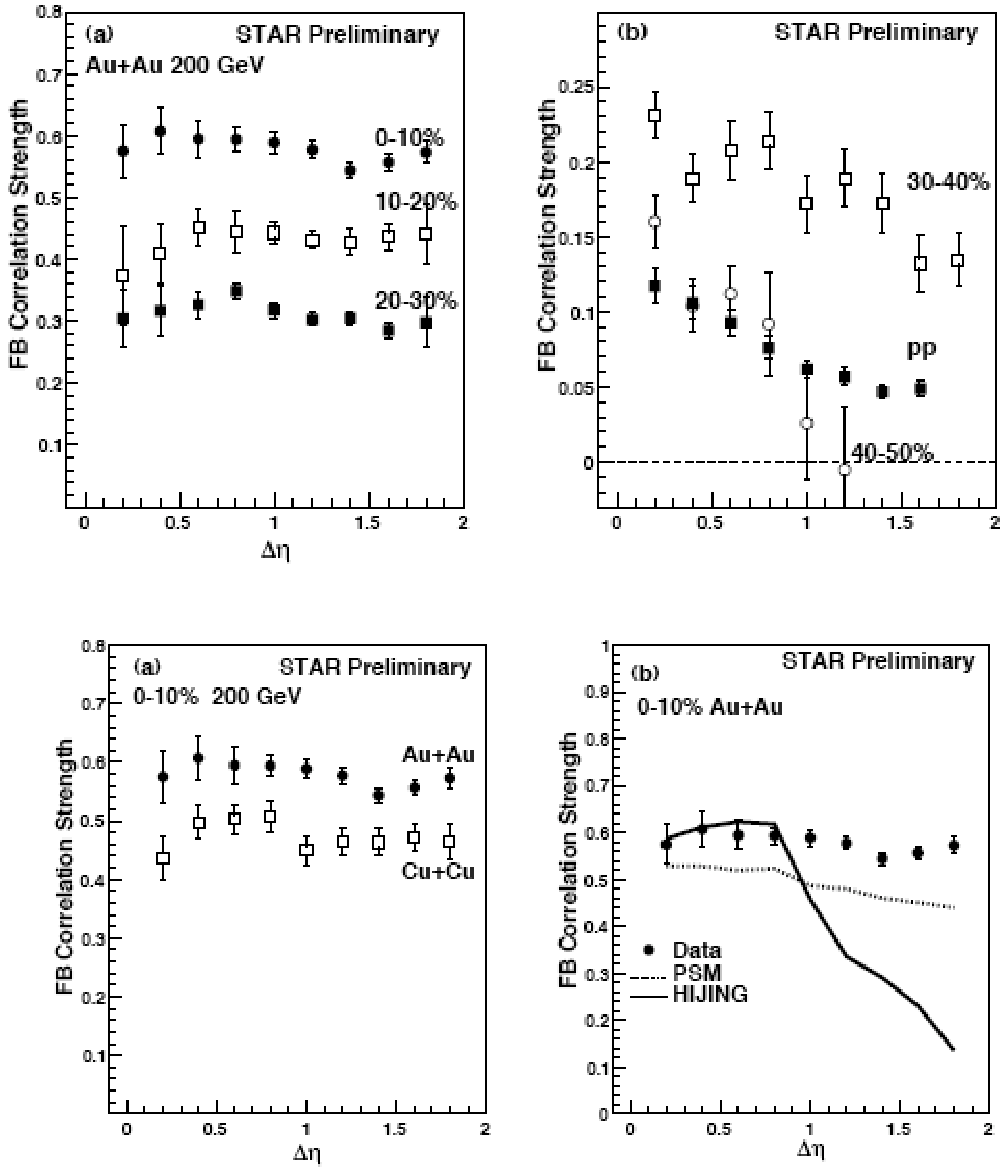
Transition from Poisson to NB at around 10 GeV, roughly when nuclei being to penetrate through one another, and when flux tube description might become usable

Forward-Backward Correlations: $$\frac{<N_F N_B> - <N_F><N_B>}{<N_F^2> - <N_F>^2}$$

Is the observed correlation a trivial impact parameter effect?

Can one extract the strength of an intrinsic two particle correlation strength from the data?

Is the correlation in fact very strong?



How the measurement is done:

Example: Suppose we measure forward backward rapidity correlation at y = 1 (y =0 is center of mass)

Fix a reference region of multiplicity between

$$-0.5 \leq y \leq 0.5$$

For each value of the reference multiplicity, the forward backward correlation is measured.

This value of the forward backward correlations is then averaged over values appropriate for fixed centrality bins.

Intrinsic correlation strength in a Gaussian approximation:

$$C(\eta,\eta') = \delta(\eta-\eta')\,\frac{dN}{d\eta} + K(\eta-\eta')\,\frac{dN}{d\eta}\frac{dN}{d\eta'}$$

To compute, one needs to integrate with a weight function

$$P(N_{\rm F},N_{\rm B};N_{\rm R}) = \frac{1}{(2\pi)^{3/2}\det\Sigma}\exp\left[-\frac{1}{2}\Delta_U\Sigma^{-1}_{UV}\Delta_V\right]$$

$$\Sigma_{UV} \equiv \sigma^2_{UV} \quad = \quad \langle\Delta_U\Delta_V\rangle = \int_U {\rm d}\eta \int_V {\rm d}\eta'\, C(\eta-\eta') \quad , \qquad U,V = {\rm F,B,R.}$$

$$R_{UV} = \frac{\Sigma_{UV}}{\sqrt{\Sigma_{UU}\Sigma_{VV}}}.$$

Can show that

$$b = \frac{D_{bf}}{\sqrt{D_{ff}D_{bb}}} = \frac{R_{\mathrm{BF}} - R_{\mathrm{BR}}R_{\mathrm{FR}}}{\sqrt{\left(1-(R_{\mathrm{BR}})^2\right)\left(1-(R_{\mathrm{FR}})^2\right)}}.$$

Assuming:

$$R_{\mathrm{FR}} = R_{\mathrm{BR}} \geq R_{\mathrm{BF}}$$

The maximum possible b is

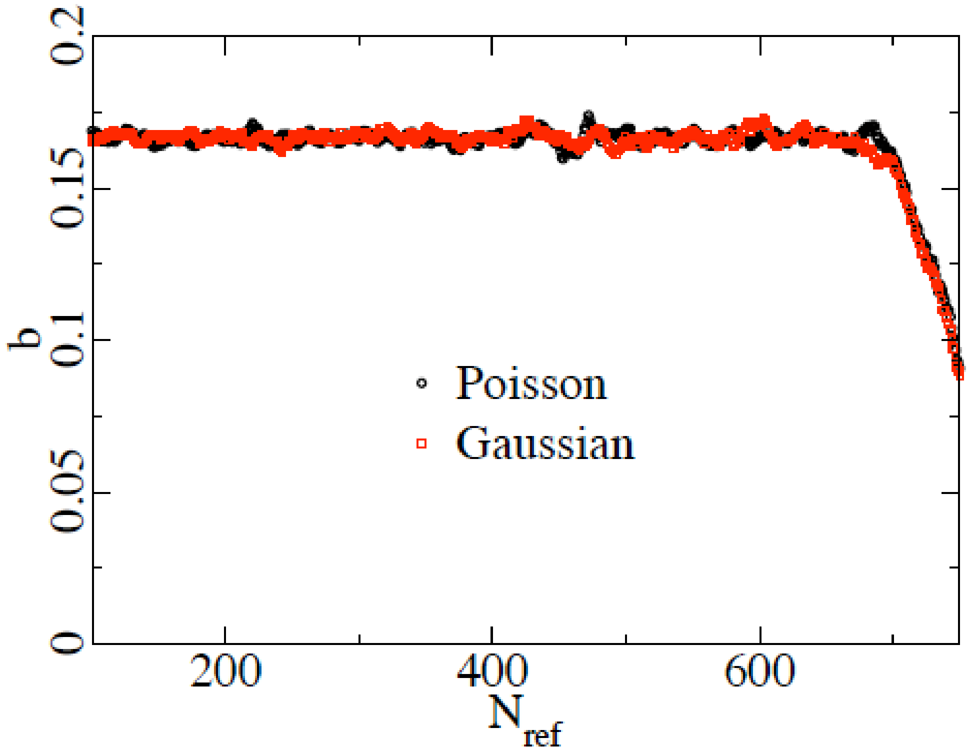
$$b = \frac{R_{\mathrm{BF}} - {R_{\mathrm{FR}}}^2}{1 - {R_{\mathrm{FR}}}^2} \leq \frac{R_{\mathrm{BF}} - {R_{\mathrm{BF}}}^2}{1 - {R_{\mathrm{BF}}}^2} = \frac{R_{\mathrm{BF}}}{1 + R_{\mathrm{BF}}} \leq 0.5$$

Central-most bin at highest
energy is larger than this bound!

Are these due to impact parameter fluctuations?

Use wounded nucleon model with Poisson fluctuations (arXiv:0812-3967) Konchalski et al, and also Bzdak 0902.2639, 0904.0869 and 0906.2858

$b < 0.16$



Can also check Gaussian approximation.

Summary:

Qualitative and semi-quantitative features of multiplicity distributions, their correlations and fluctuations are in rough accord with Glasma description.

Ridge (Raju’s talk) very difficult to explain without Glasma like color electric and magnetic fields

Negative binomial has simple and natural interpretation (although difficult to get a good number for k)

Strong forward backward correlations, but experimental data appears to violate simple bounds