# Forward-Backward Multiplicity Correlations at STAR

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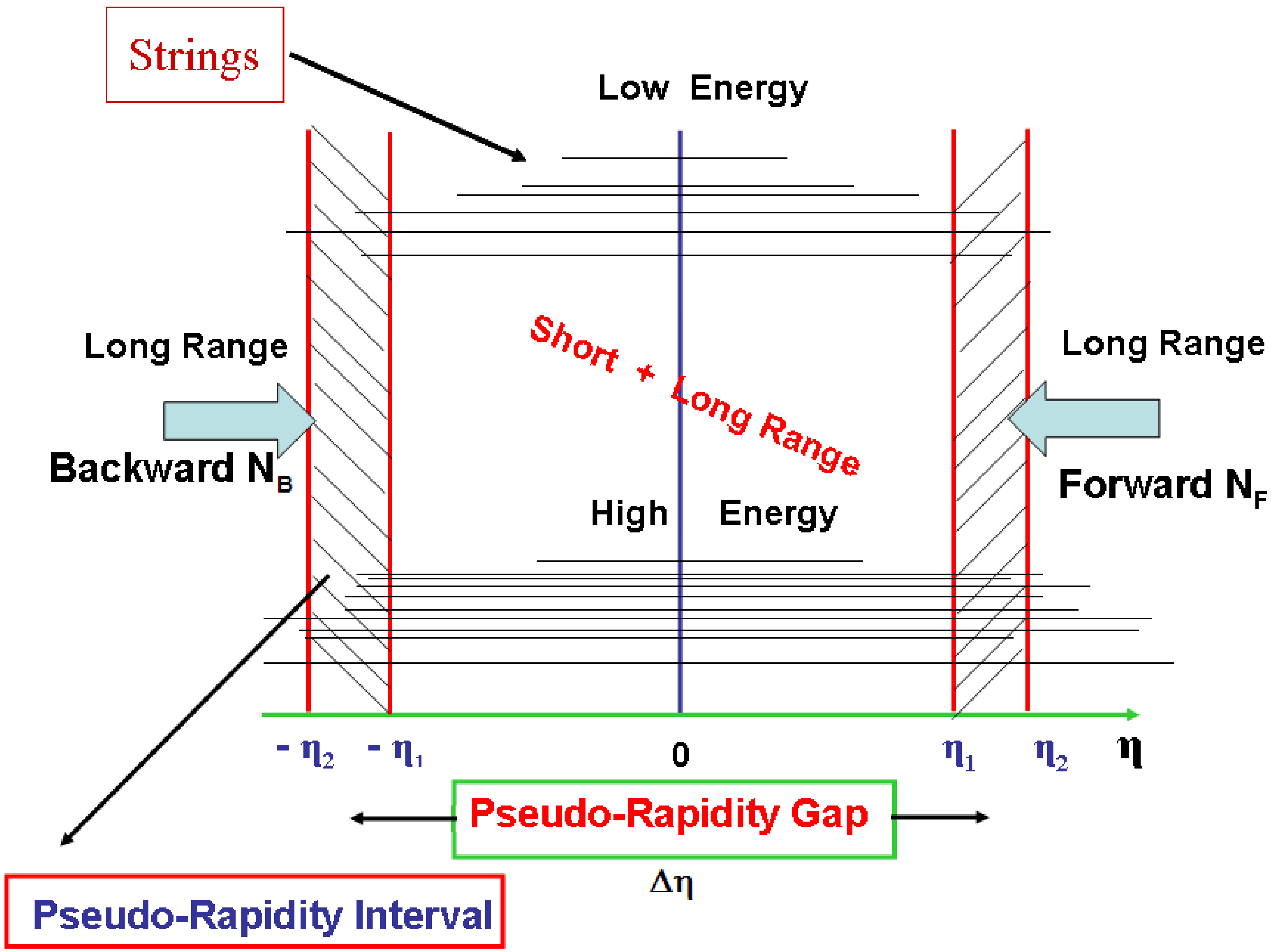
# Outline

- Introduction
- Analysis
- Inclusive Charged Hadron Results
- Preliminary Particle ID Results
- Conclusions

# Introduction

- Long-range (rapidity separation > 1) multiplicity correlations (LRC) are predicted in high-energy nucleon-nucleon collisions by the Dual Parton Model (DPM) and in nucleus-nucleus collisions by DPM and the Color Glass Condensate (CGC) picture
- Strong LRC using inclusive charged particles have been recently measured in the STAR TPC (B. I. Abelev *et al.* (STAR Collaboration), Phys. Rev. Lett. **103**, 172301 (2009). )
- Multiplicity correlations across different rapidity regions indicate the occurrence of partonic interactions

# What's Forward-Backward?



# Forward-Backward Multiplicity Correlations

- As seen previously in hadron-hadron experiments, the average multiplicity of particles in the backward region can be related to the multiplicity in the forward region

$$\langle N_B \rangle (N_F) = a + bN_F$$

- Appling a linear regression one can obtain the correlation strength *b*

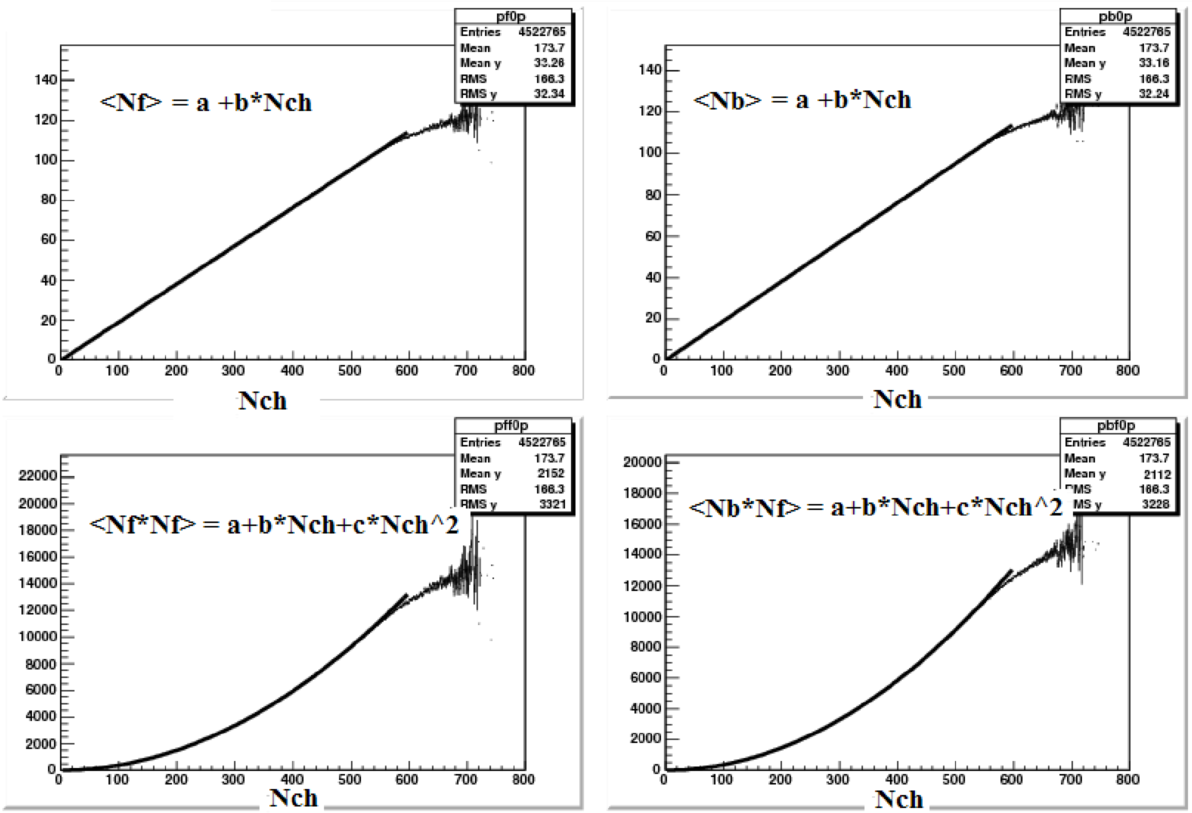
$$b = \frac{< N_f N_b > - < N_f >< N_b >}{< N_f^2 > - < N_f >^2} = \frac{D_{bf}^2}{D_{ff}^2}$$

# Centrality Determination

- The particles used to determine the centrality must not be used to calculate the FB correlation strength in order to avoid auto-correlations

| Rapidity separation | Reference Mult. |
| --- | --- |
| $\Delta\eta$ = 0.2, 0.4, 0.6 | Nch 0.5<\|$\eta$\|<1.0 |
| $\Delta\eta$ = 0.8, 1.0 | Nch \|$\eta$\|<0.3+0.8<\|$\eta$\|<1 |
| $\Delta\eta$ = 1.2, 1.4, 1.6, 1.8 | Nch \|$\eta$\| <0.5 |

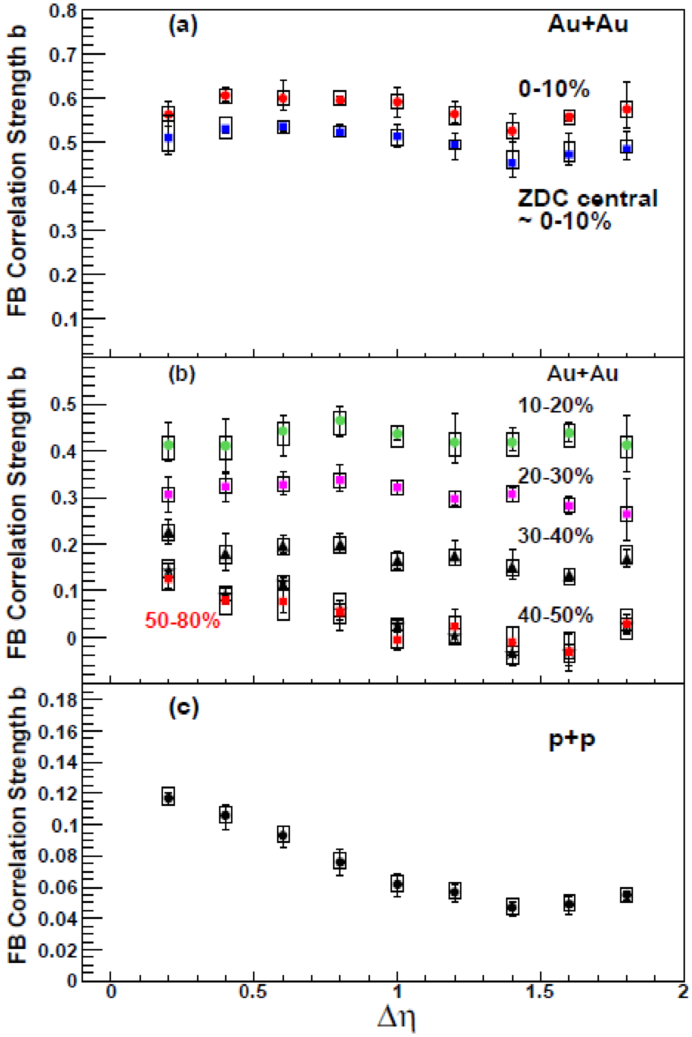
# Accounting for Centrality Fluctuations




**Calculated event-by-event**

$$b = \frac{<N_f N_b> - <N_f><N_b>}{<N_f^2> - <N_f>^2} = \frac{D_{bf}^2}{D_{ff}^2}$$

# Centrality Dependence of LRC

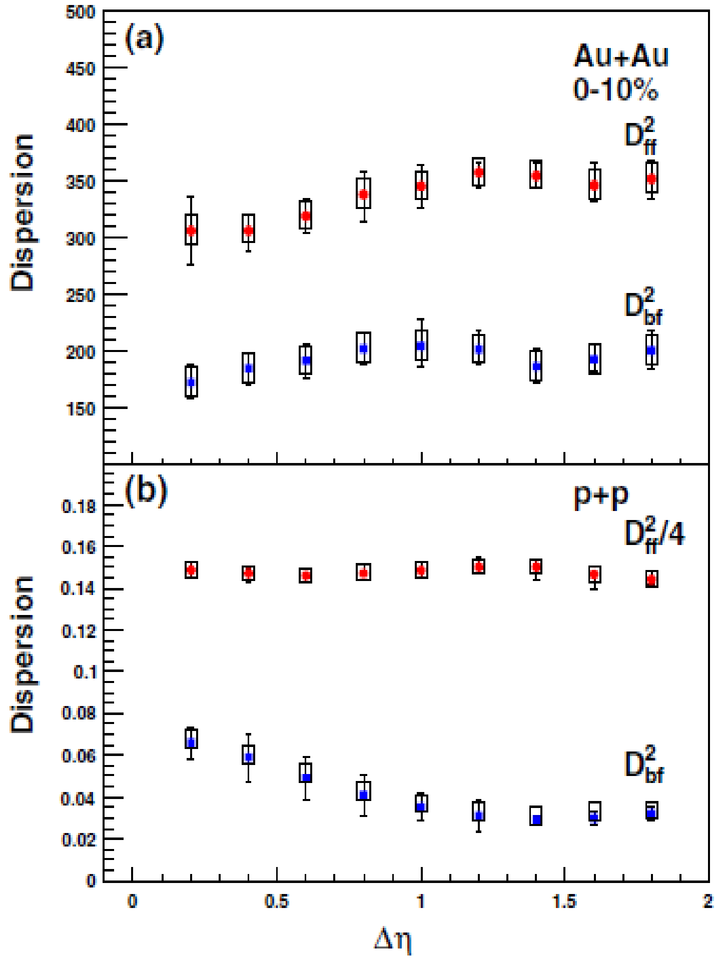


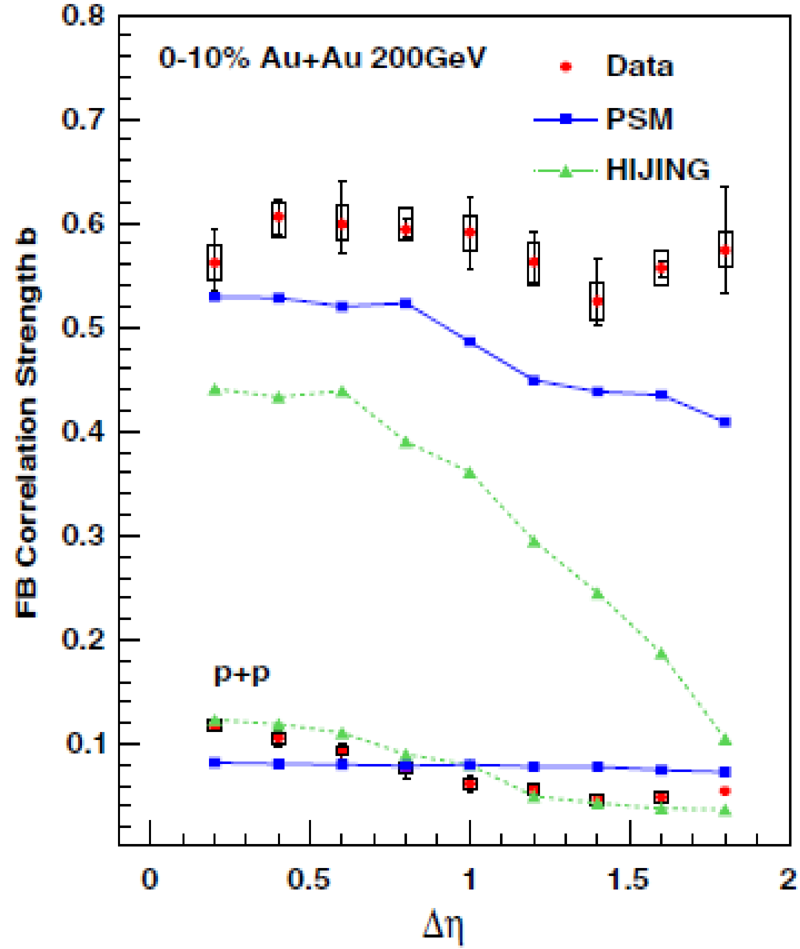

B. I. Abelev *et al.* (STAR Collaboration), Phys. Rev. Lett. **103**, 172301 (2009).

- LRC $\Delta\eta>1$, short-range $\Delta\eta<1$
- Strong LRC in central collisions
- Au+Au and pp at 200 GeV
- All charged hadrons
- $0.15 > p_T > 1.2$ GeV/c

*b* is flat in central Au+Au but decreases with $\Delta\eta$ in p+p collisions

# Dispersions and Model Comparison

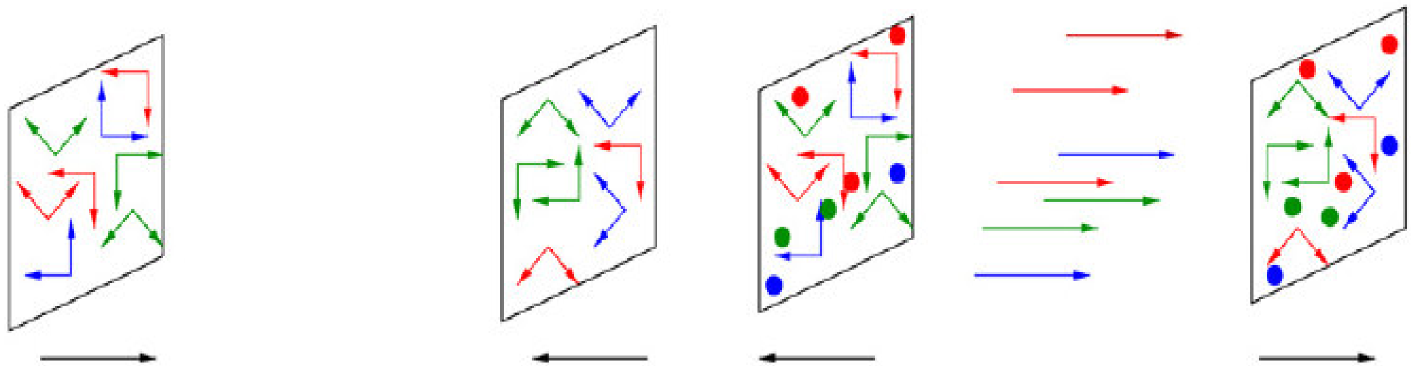


# What is the origin of the long-range correlation?

- In the context of the DPM the LRC is due to the fluctuation in the number of strings (Phys. Rev. D **18**, 4120 (1978)., Phys. Rep. **236**, 225 (1994).)
- The fluctuation in the number of strings is due to multiple partonic interactions
- The next question is: what particles can the LRC be attributed to? (i.e. is it mostly reflected in mesons or baryons?)
- DPM does not distinguish LRCs due to mesons or baryons
- CGC predicts the correlation for pions should be larger than for baryons ((anti)protons) (N. Armesto, L. McLerran, C. Pajares, Nucl. Phys. A **781**, 201 (2007).)

# Color Glass Condensate



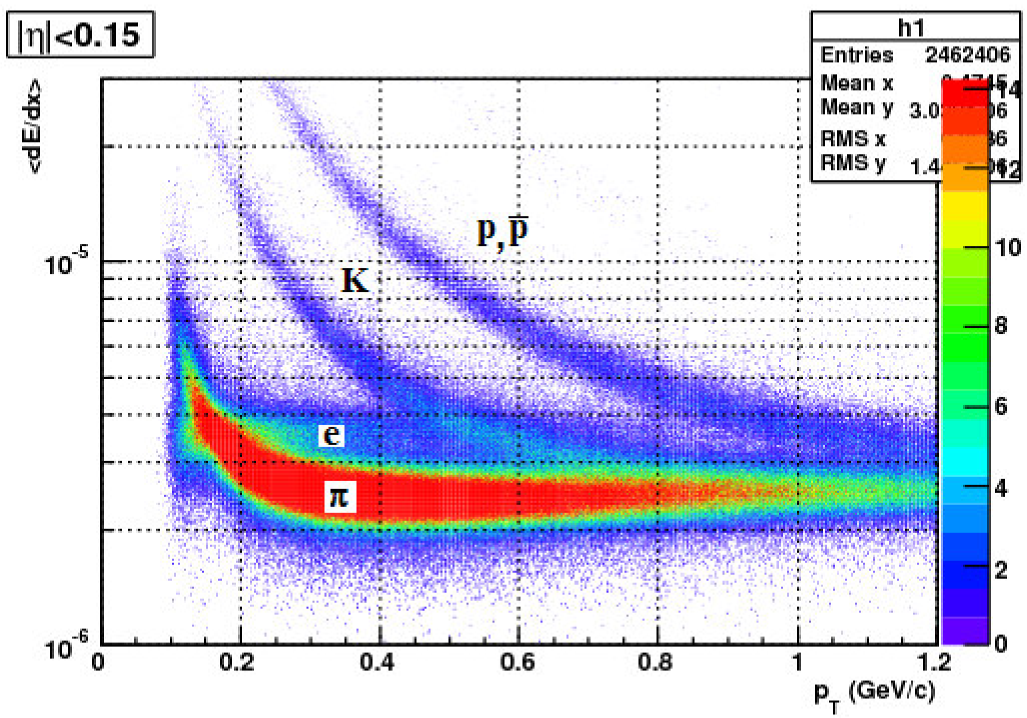
- Nuclei are pictured as two sheets of colored charge and high gluon density
- Immediately after the nuclei pass through one another a longitudinal color field exists between the sheets
- The LRC is primarily due to the fluctuation in the number of gluons, and can only be created at early times
- In this picture, the LRC for (anti)protons is expected to be smaller than for pions

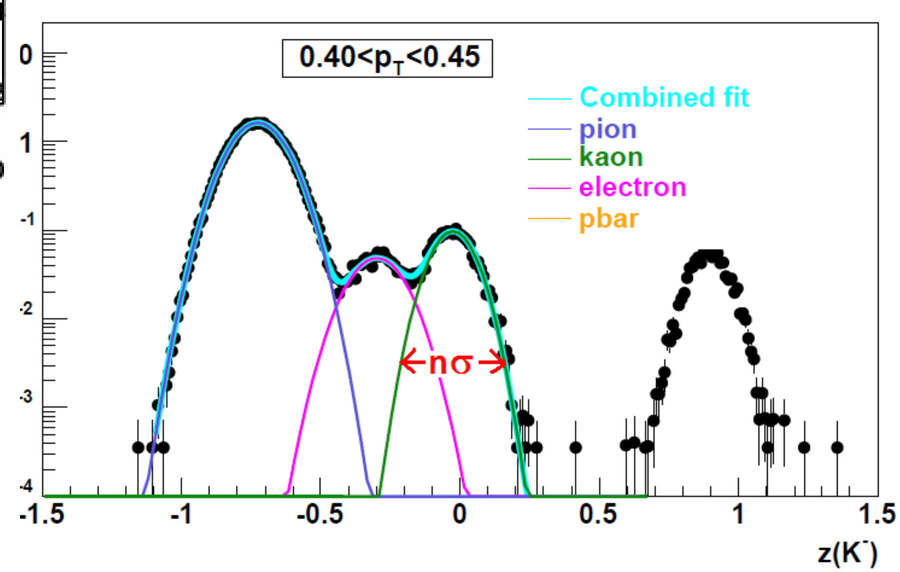
# Particle ID

Bethe-Bloch $$-\frac{dE}{dx} = 4\pi N_0 r_e^2 m_e c^2 \frac{Z}{A}\rho\frac{1}{\beta^2}z^2\left[ln\left(\frac{2m_e c^2}{I}\beta^2\gamma^2\right) - \beta^2 - \frac{\delta}{2}\right]$$

$$\frac{dE_{measured}}{dx} \propto$$ TPC padrow signal strength

$$z = \ln\left(\frac{dE/dx_{measured}}{dE/dx_{parameterized}}\right)$$



# 2004 Au+Au 200 GeV Cuts

- $|z\text{-}vtx| <= 30$ cm
- $|\eta| < 1$
- # of fit points >= 15
- 0-10, 10-20% centralities

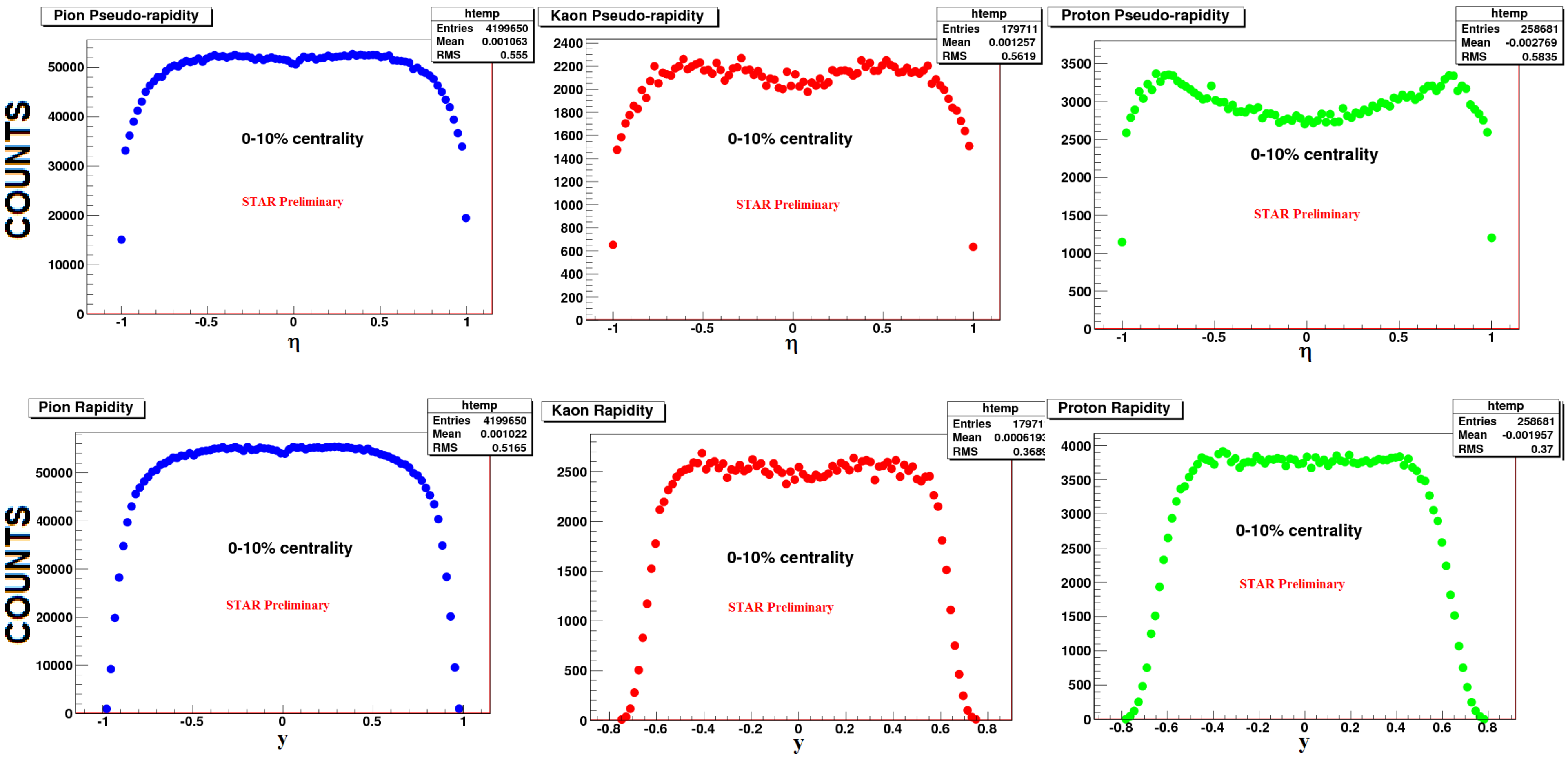
Particle ID

- pions
  - $n\sigma_\pi < 2$, $n\sigma_k > 2$, $n\sigma_e > 2$
  - $0.2 < p_T < 0.6$ GeV/c
- kaons:
  - $n\sigma_\pi > 3$, $n\sigma_k < 1.5$
  - $0.2 < p_T < 0.6$ GeV/c
- (anti)protons
  - $n\sigma_\pi > 2$, $n\sigma_k > 2$, $n\sigma_p < 2$
  - $0.4 < p_T < 1.0$ GeV/c

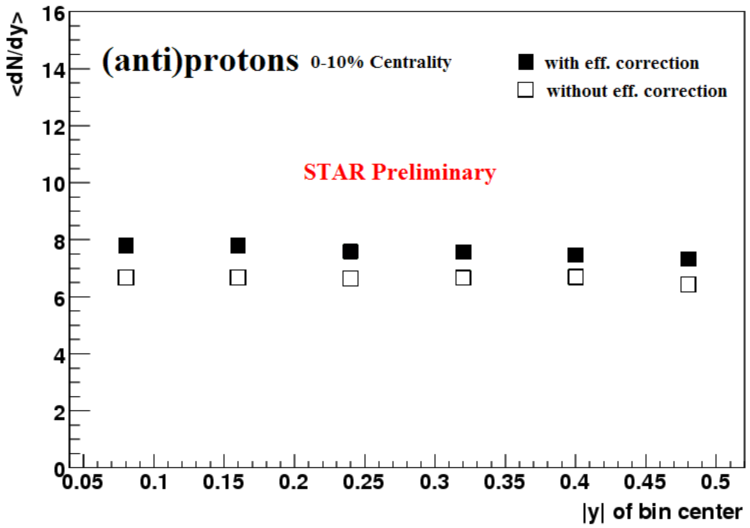
# Use Rapidity

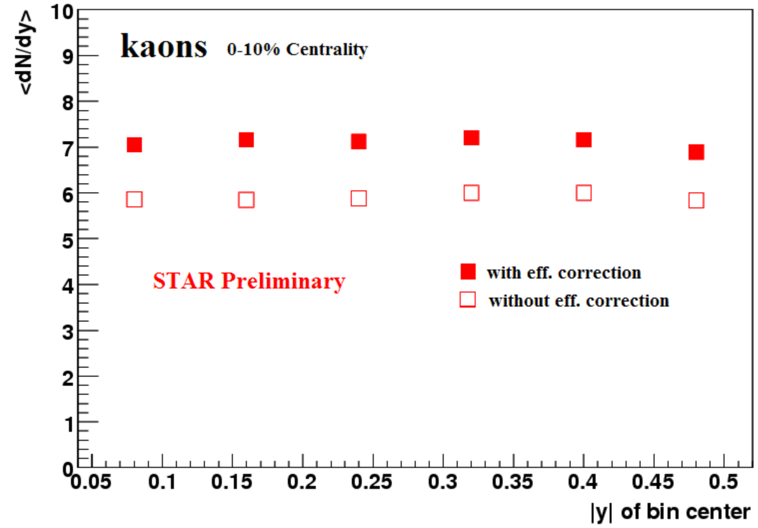
$$y=\frac{1}{2}\ln\left[\frac{\sqrt{p_T^2\cosh^2\eta+m^2}+p_T\sinh\eta}{\sqrt{p_T^2\cosh^2\eta+m^2}-p_T\sinh\eta}\right]$$

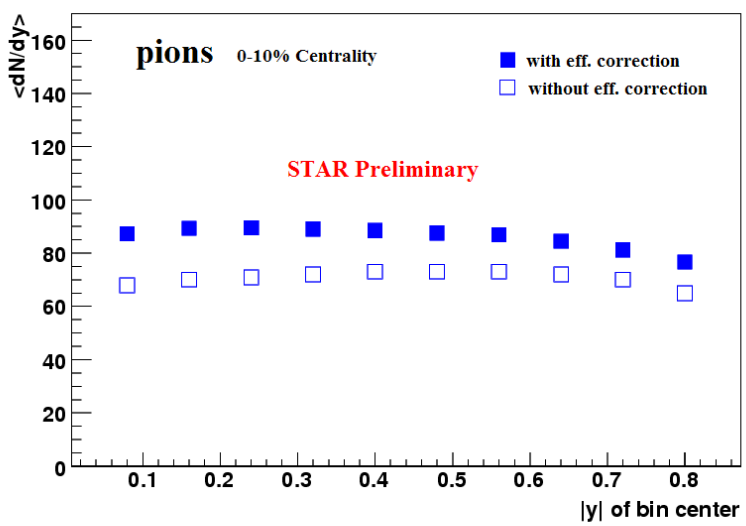
$$y=\frac{1}{2}\ln\left(\frac{p_0+p_z}{p_0-p_z}\right)$$



# Identified Particle Multiplicity

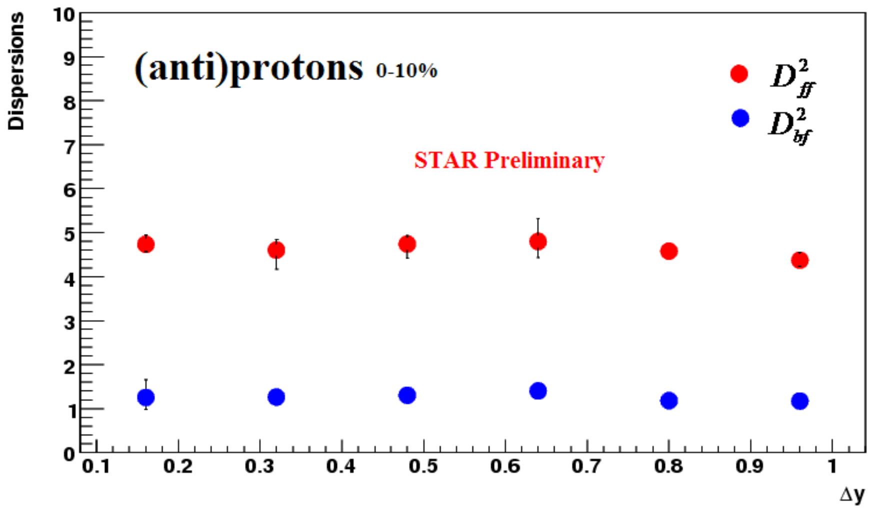


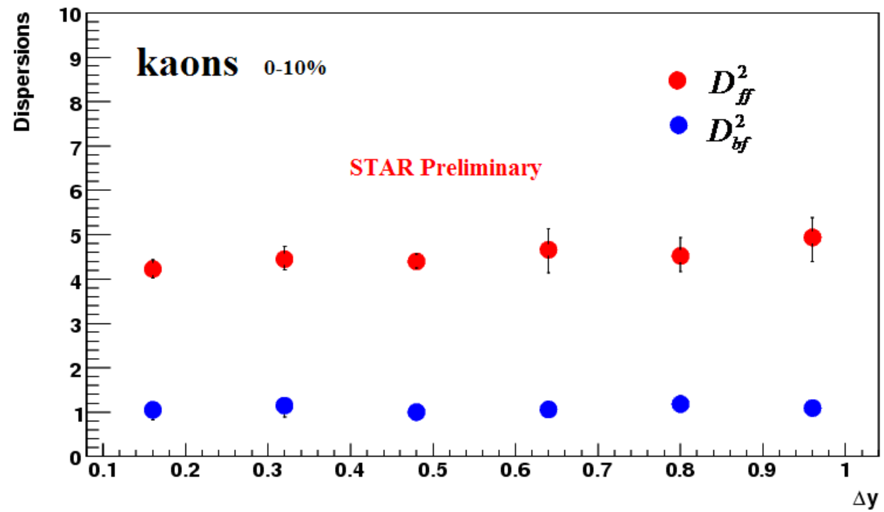



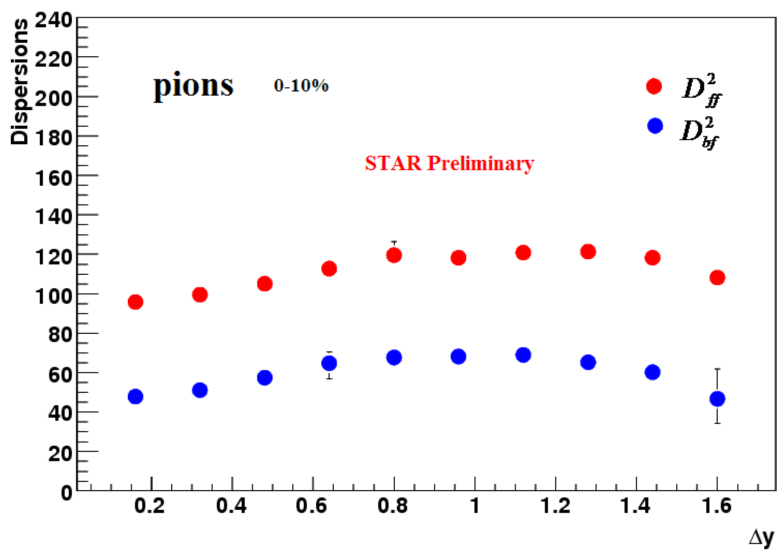




The measurable rapidity gap for heavy particles (kaons and protons) is constrained to the short-range ($\Delta y < 1$) due to the limited pseudorapidity acceptance of the TPC

# Central Dispersions

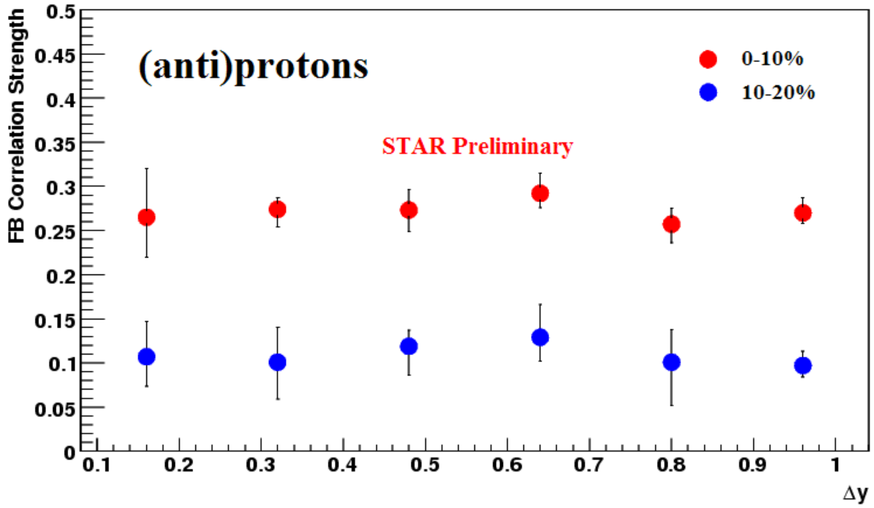


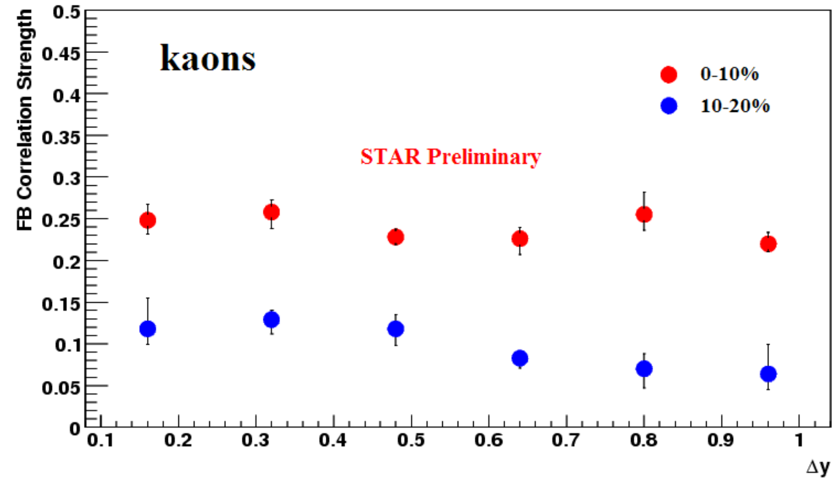



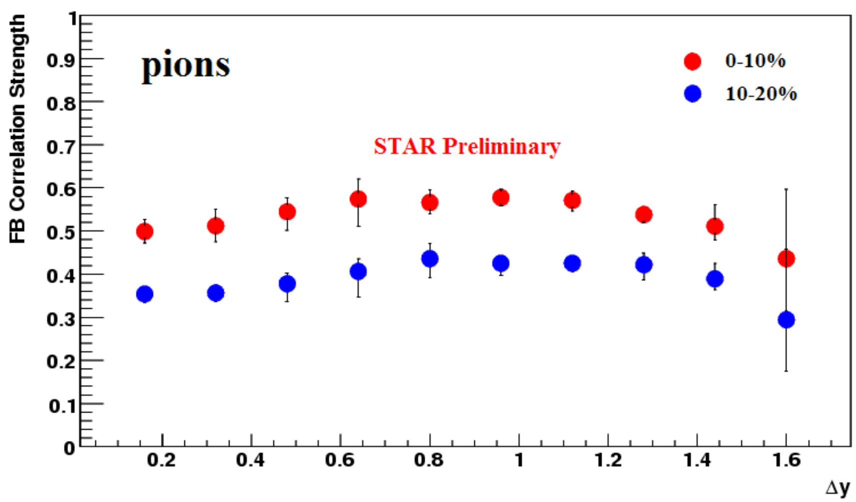



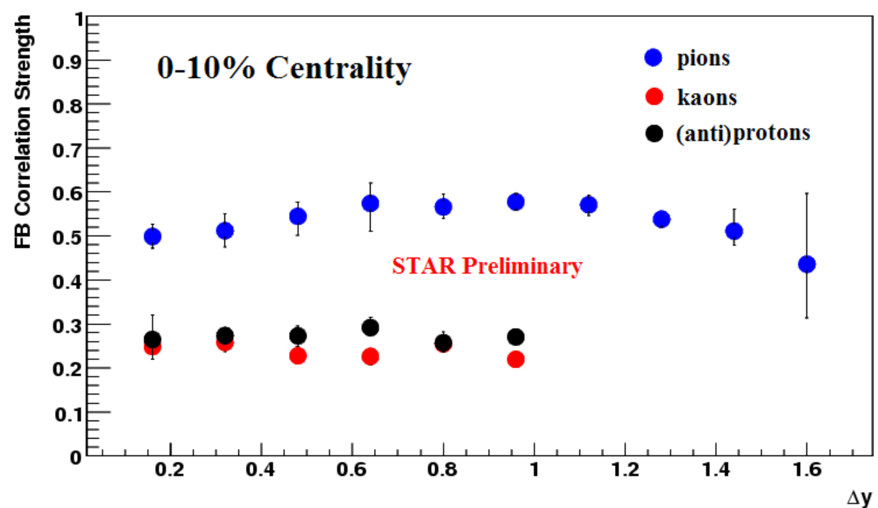

$$b = \frac{<N_f N_b> - <N_f><N_b>}{<N_f^2> - <N_f>^2} = \frac{D_{bf}^2}{D_{ff}^2}$$

# FB Correlation Strength b



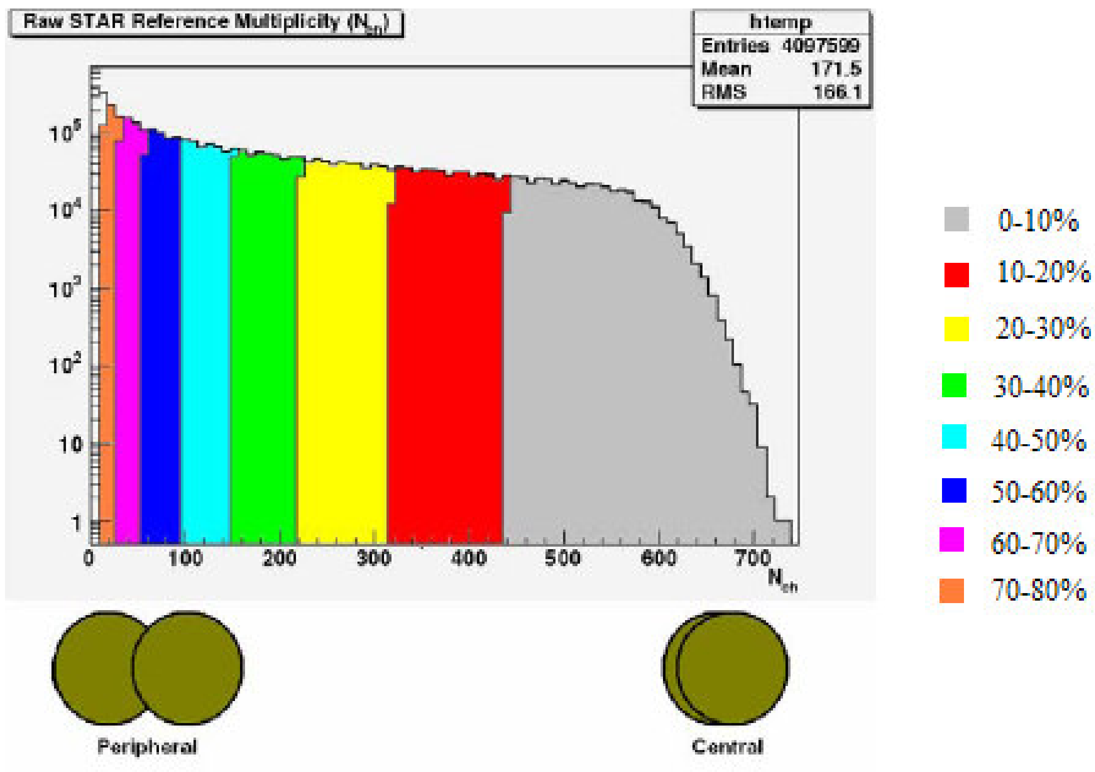
# Conclusions

- Strong LRC for inclusive charged hadrons in central Au+Au collisions indicate the occurrence of multiple partonic interactions, and decrease with decreasing centrality
- Preliminary measurements show a strong, uniform LRC across $\Delta y$ for pions in central Au+Au collisions at 200 GeV, which decreases from central to peripheral collisions
- The small short-range correlation for kaons and (anti)protons, compared to pions, suggests the LRC will also be small for these species
- CGC predicts that the LRC seen for pions is primarily due to the fluctuation in the number of gluons, and can only be created at early times
- The baryon correlation should not grow with increasing centrality in CGC, but we see an increase in the (anti)proton correlation from 10-20% to 0-10%.
- Future measurements of correlations at high $p_T$ for inclusive charged hadrons may not have such a large correlation for central collisions as contributions from baryons at higher $p_T$ increase in the CGC picture

# Back-up Slides

# Centrality Determination

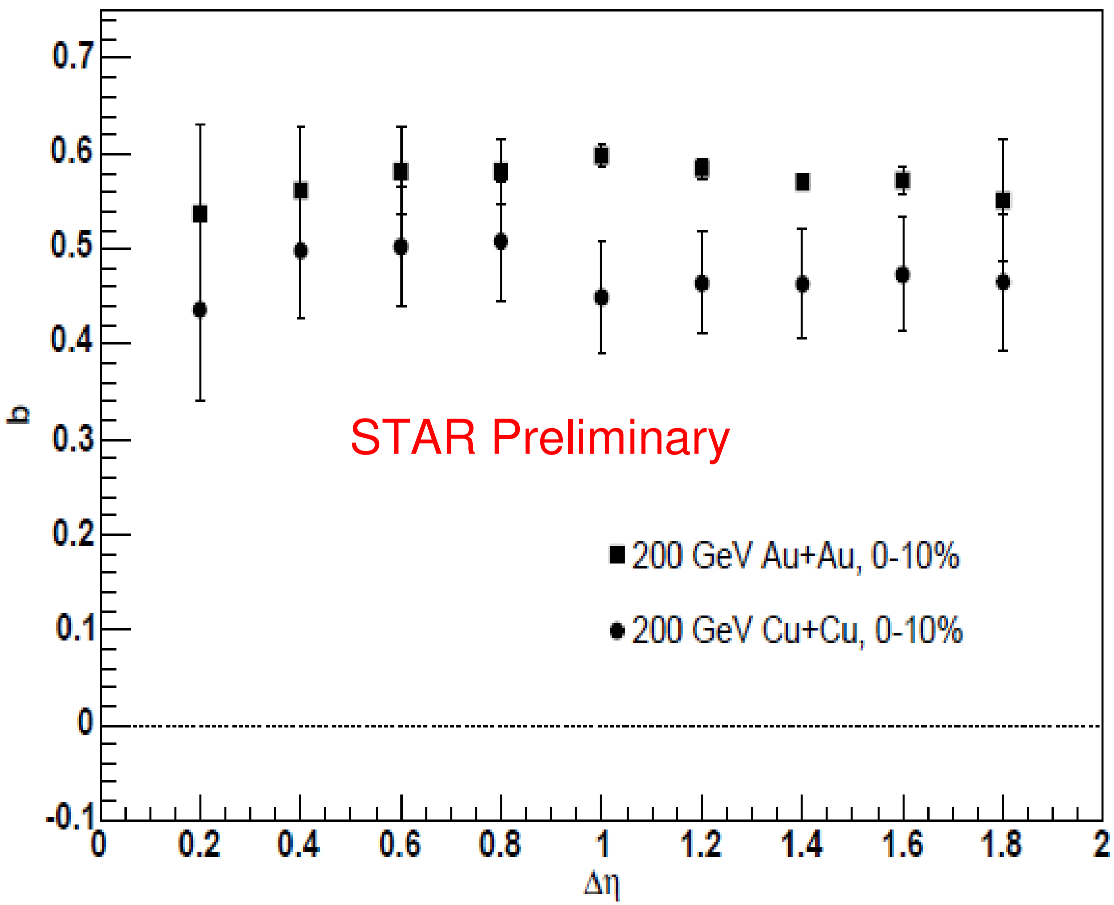
Au+Au 200 GeV MB Distribution
measured in STAR TPC




In addition, the RHIC zero degree calorimeters (ZDC) can determine 0-12% central events

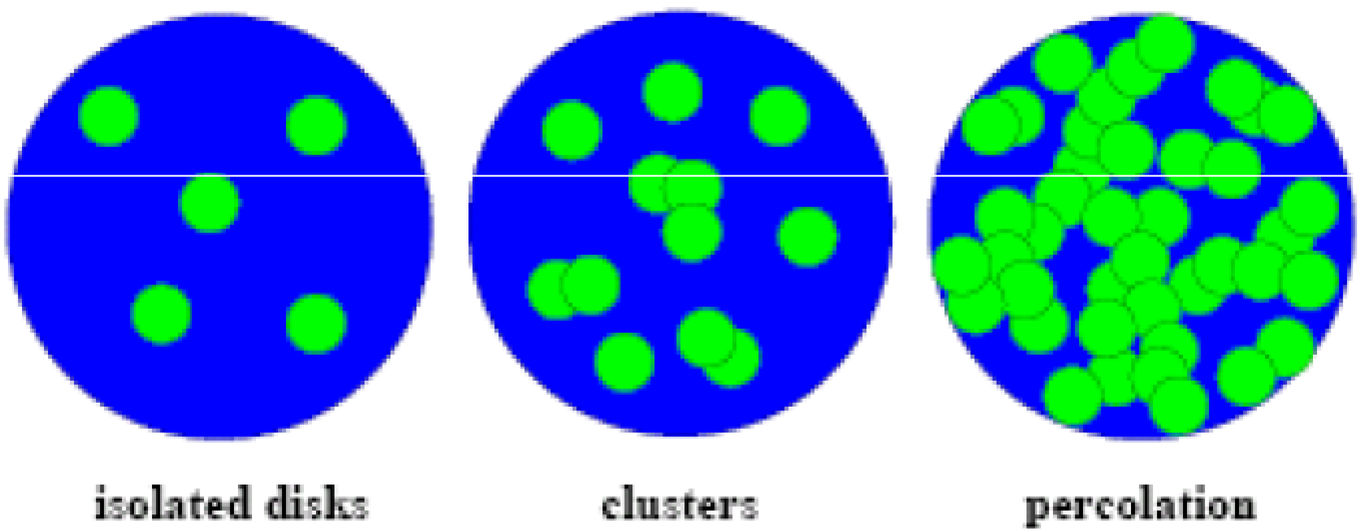
# System Size Dependence

T. Tarnowsky Thesis arXiv:0807.1941



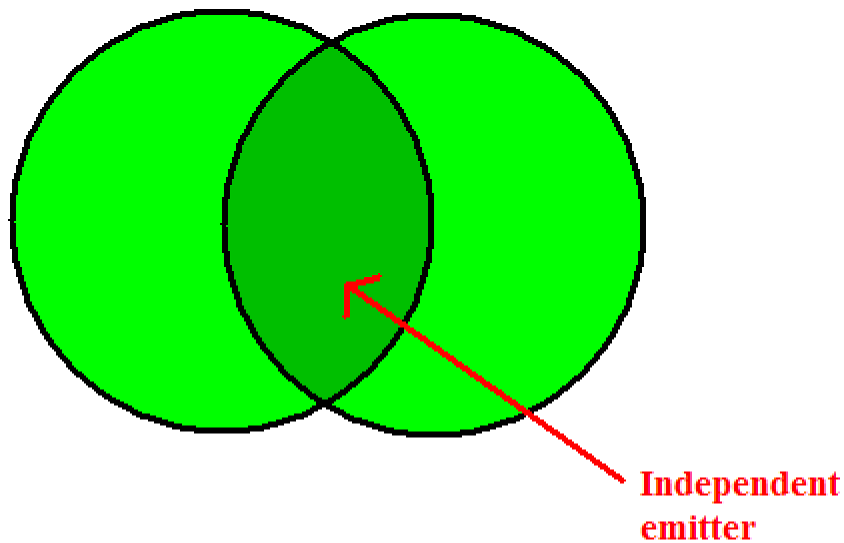
# Color String Percolation Model

- Color strings responsible for particle production overlap as the string density (η) increases, forming clusters
- At a critical string density these clusters form a connected system that extends across the medium
- STAR can investigate a percolation phase transition to QGP by measuring η



# CSPM

- CSPM predicts LRC due to multiplicity fluctuations within overlapping strings (Eur. Phys. J. C 16, 349 (2000).)
- Overlap region acts as an independent emitter
- Color fields added in the overlap area reduce the effective color field, invoking an overlapping factor




$$F(\eta) = \sqrt{\frac{1-e^{-\eta}}{\eta}}$$

# Measuring η

- Fit the $p_t$ distribution from pp 200 GeV events using fit parameters *a, $p_0$,* and *m*.
- For Au+Au, adjust $p_0$ to account for percolation. *n* = # of strings in a cluster, $S_1$ = area of one string, $S_n$ = area of cluster
- Fit to Au+Au $p_t$ distribution to extract $F(\eta)_{Au\text{-}Au}$ and get η
- Due to low string overlap probability in pp collisions $F(\eta)_{pp}$ ~ 1.

$$F(\eta)_{Au-Au} = \sqrt{\frac{1-e^{-\eta}}{\eta}}$$

$$\frac{dN}{dp_t^2} = \frac{a}{(p_0 + p_t)^m}$$

$$p_0 \rightarrow p_0 \left( \frac{\langle nS_1 / S_n \rangle_{Au-Au}}{\langle nS_1 / S_n \rangle_{pp}} \right)$$

$$\sqrt{\frac{F(\eta)_{pp}}{F(\eta)_{Au-Au}}} = \frac{\langle nS_1 / S_n \rangle_{Au-Au}}{\langle nS_1 / S_n \rangle_{pp}}$$