Forward-Backward Multiplicity Correlations for Identified Particles in Au+Au 200 GeV Collisions

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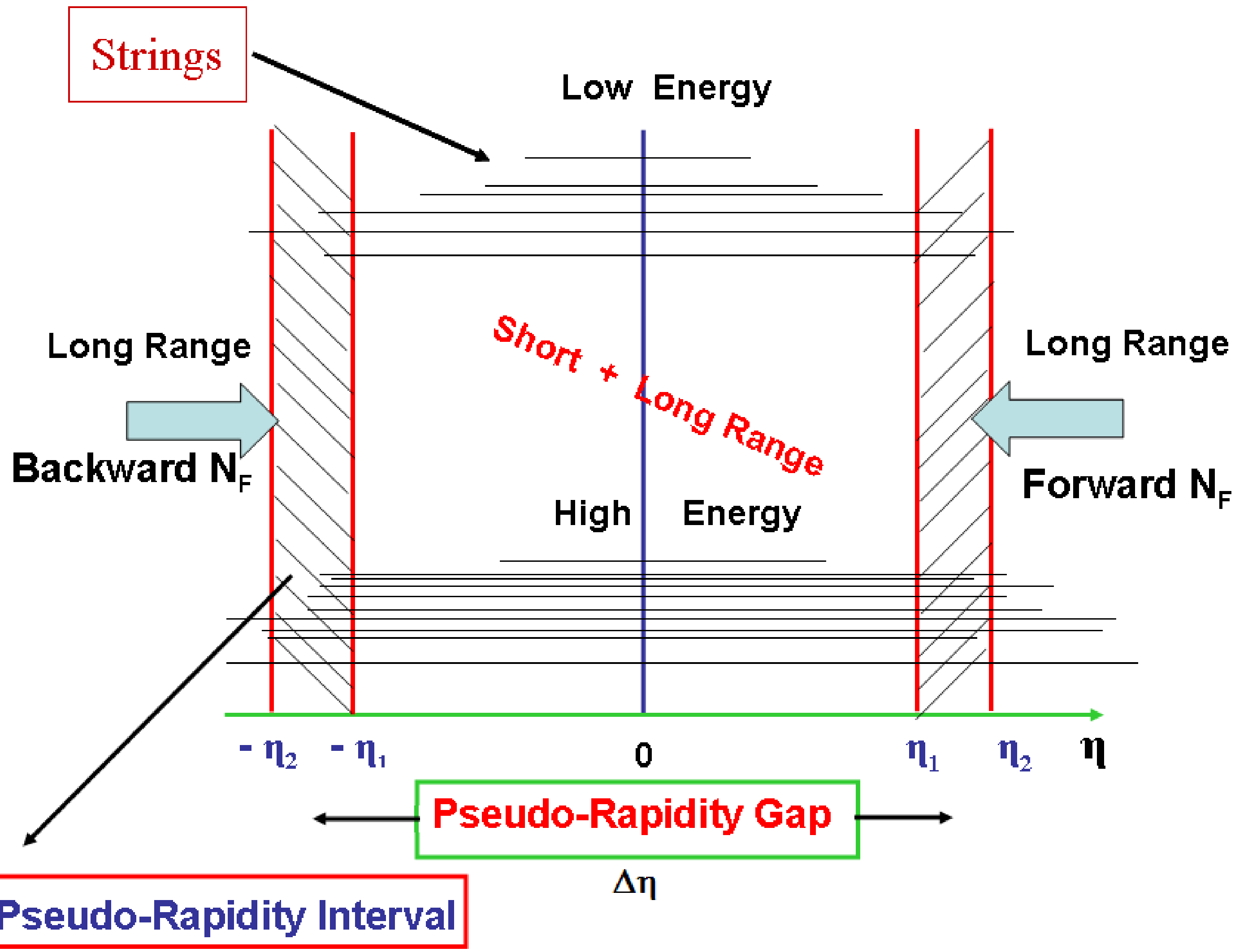
Outline

- Introduction
- Analysis
- Preliminary Results
- Future Studies
- Conclusions

Introduction

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

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

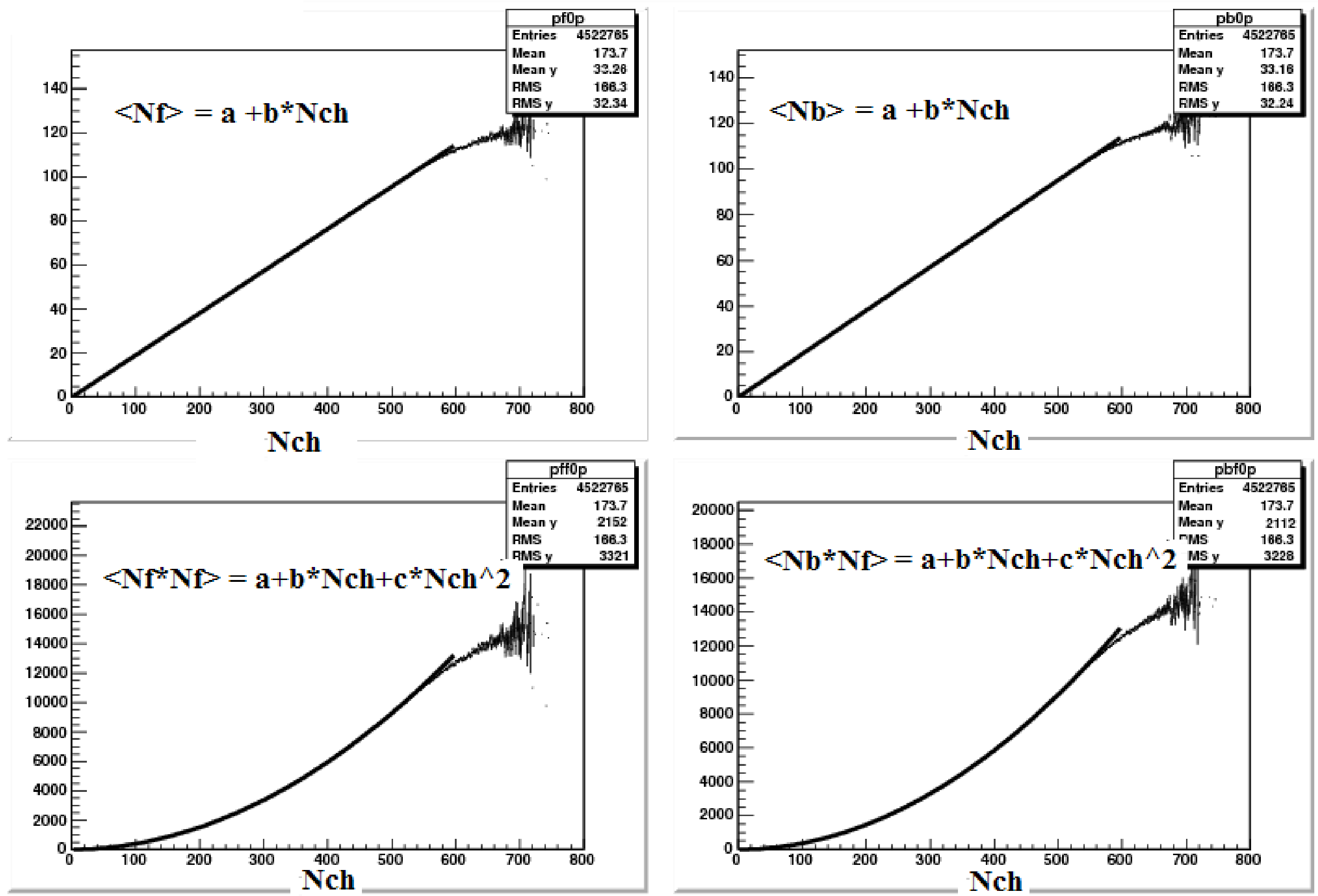
$$\langle N_B \rangle (N_F) = a + bN_F$$

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

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

Accounting for Centrality Fluctuations

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

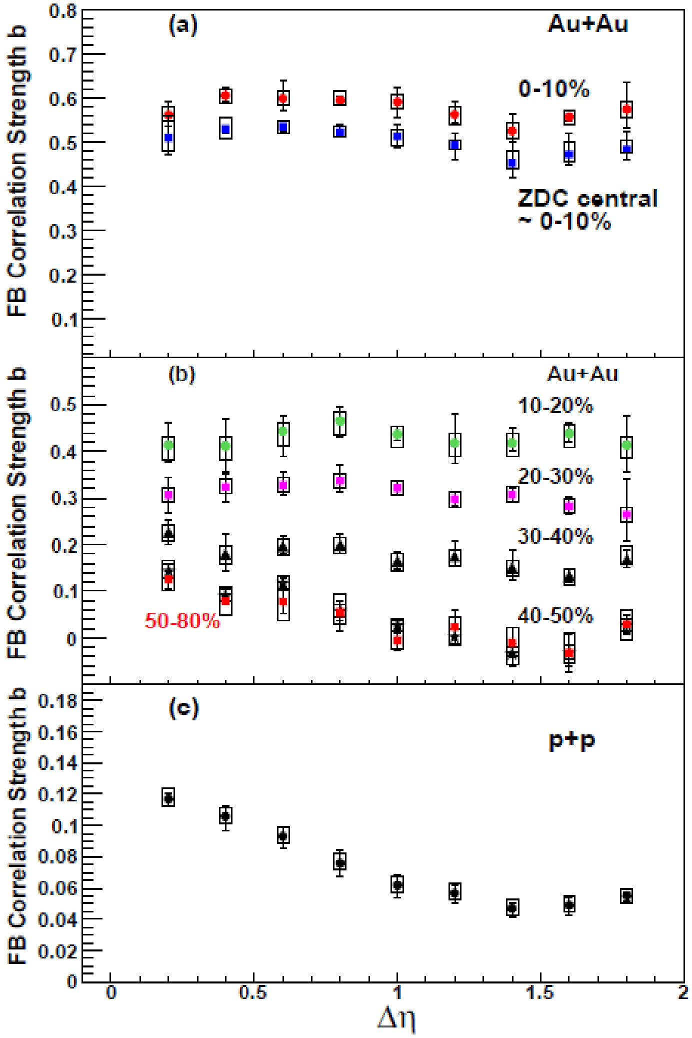


Accounting for Centrality Fluctuations

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

$\Delta\eta$ = 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 $\|\eta\| <0.5$

Centrality Dependence of LRC



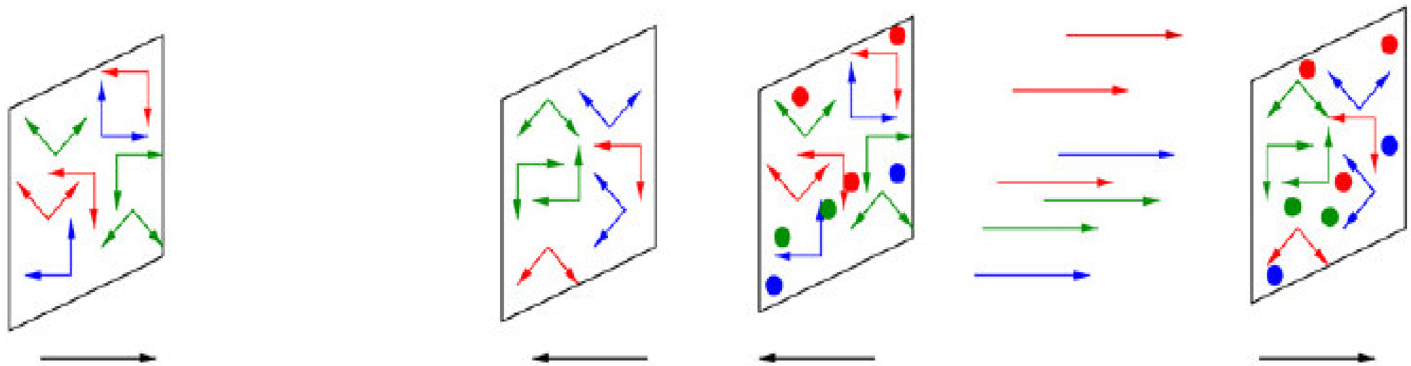
- LRC $\Delta\eta>1$, short-range $\Delta\eta<1$
- B. I. Abelev *et al.* (STAR Collaboration), Phys. Rev. Lett. **103**, 172301 (2009).
- Au+Au and pp at 200 GeV
- All charged hadrons
- p_T > 0.15 GeV/c

b is flat in central Au+Au but decreases with Δη in p+p collisions

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 baryons or mesons?)
- The DPM does not say how much of the LRC is due to mesons or baryons
- The CGC claims the correlation for pions should be larger than for baryons (protons, antiprotons) (Nucl. Phys. A **781**, 201 (2007).)

Color Glass Condensate



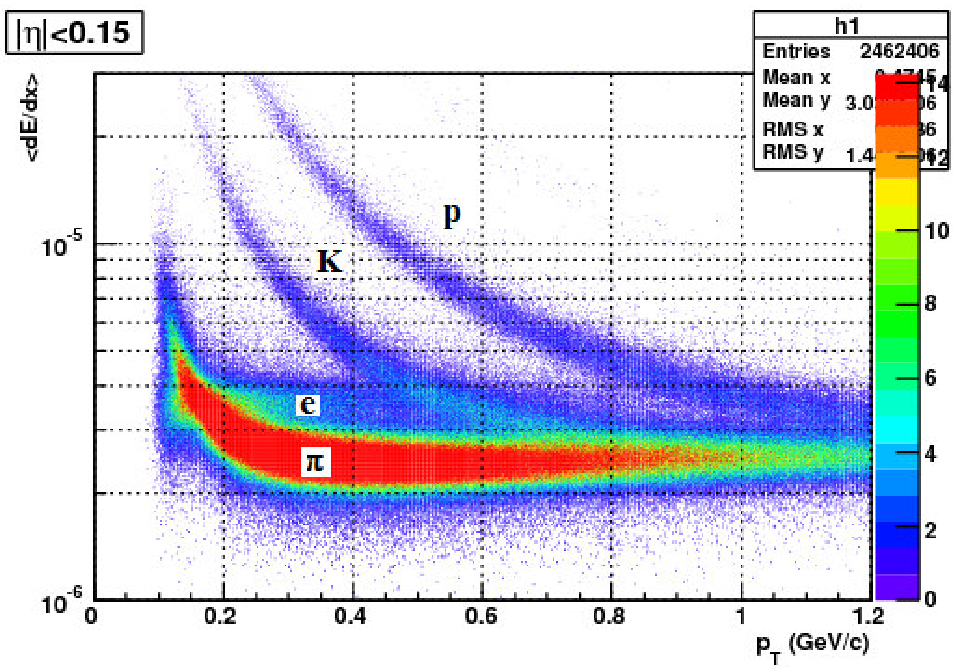
- Nuclei are pictured as two sheets of colored charge and high gluon density
- Immediately after the nuclei pass through one another a longitudinal color field exists between the sheets
- The LRC is primarily due to the fluctuation in the number of gluons, and can only be created at early times
- In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

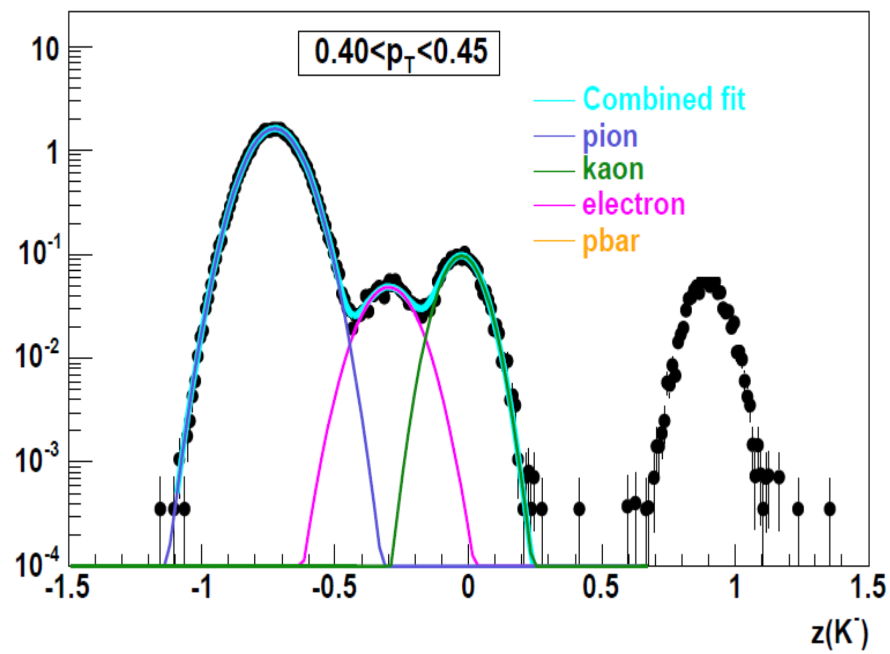
Particle ID

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

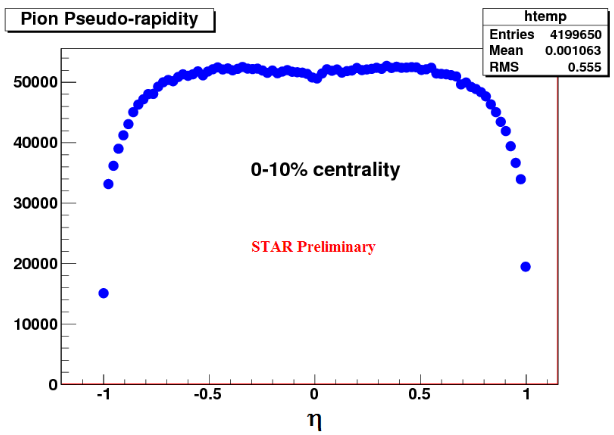
Particle ID

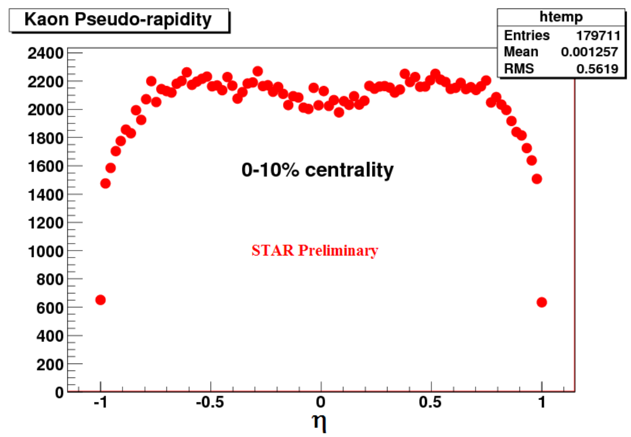
- pions
  - $n\sigma_{\pi} < 2$, $n\sigma_{k} > 2$, $n\sigma_{e} > 2$
  - $0.2 < p_T < 0.6$ GeV/c
- kaons:
  - $n\sigma_{\pi} > 3$, $n\sigma_{k} < 1.5$
  - $0.2 < p_T < 0.6$ GeV/c
- (anti)protons
  - $n\sigma_{\pi} > 2$, $n\sigma_{k} > 2$, $n\sigma_{p} < 2$
  - $0.4 < p_T < 1.0$ GeV/c

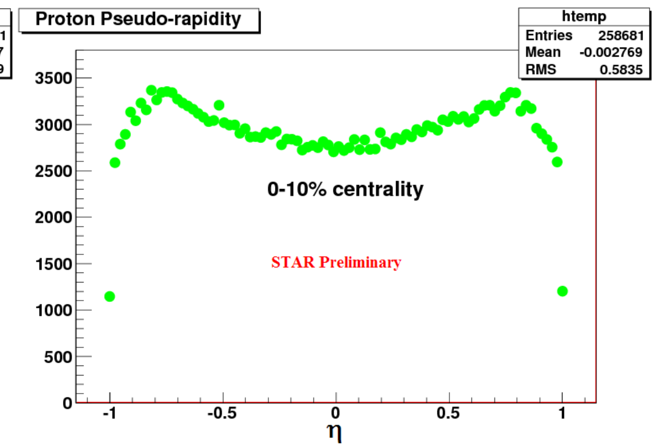
Use Rapidity

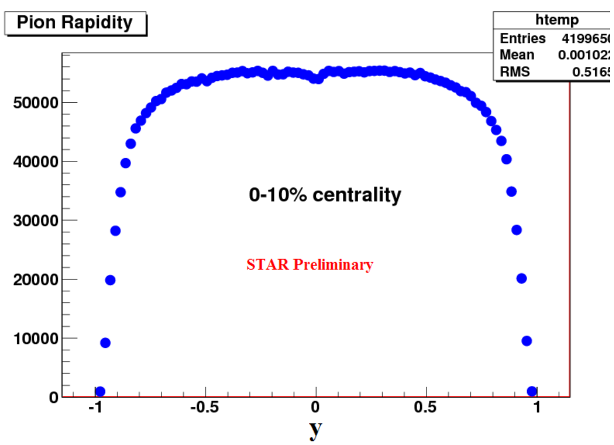
$$y = \frac{1}{2}\ln\left[\frac{\sqrt{p_T^2\cosh^2\eta + m^2} + p_T\sinh\eta}{\sqrt{p_T^2\cosh^2\eta + m^2} - p_T\sinh\eta}\right]$$

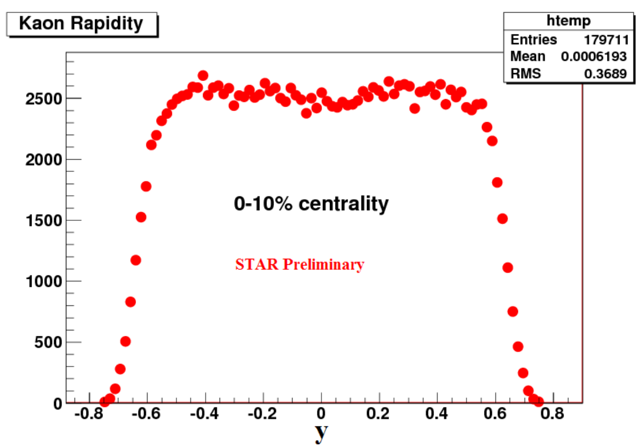
$$y = \frac{1}{2}\ln\left(\frac{p_0 + p_z}{p_0 - p_z}\right)$$

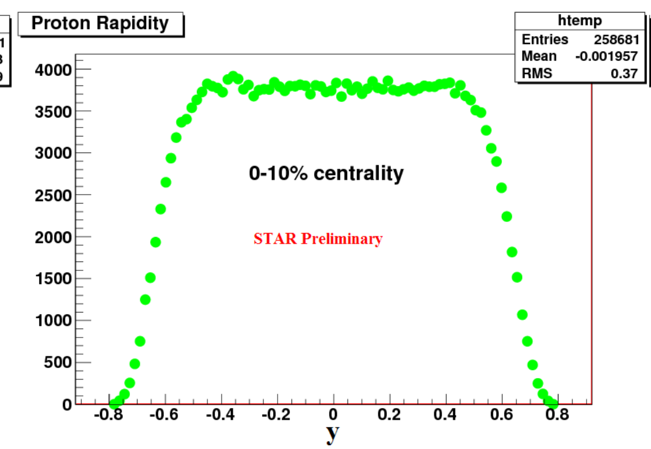




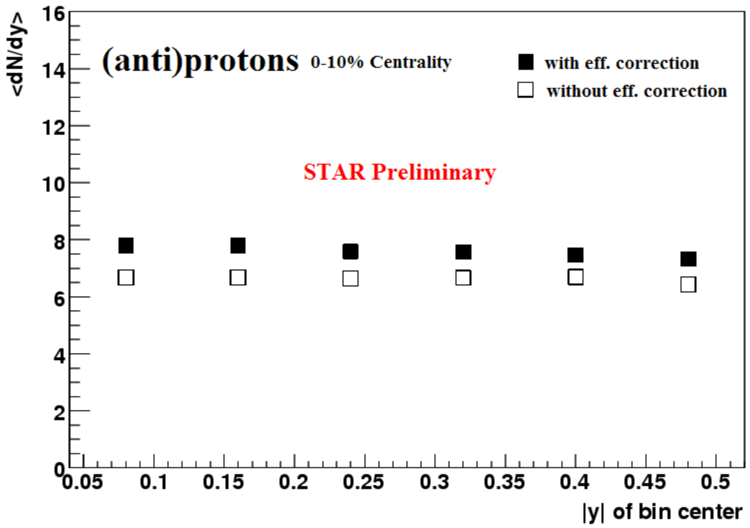


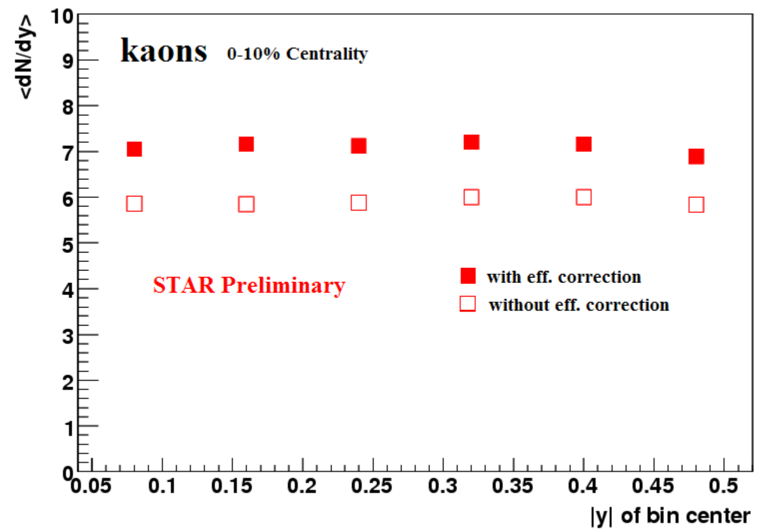


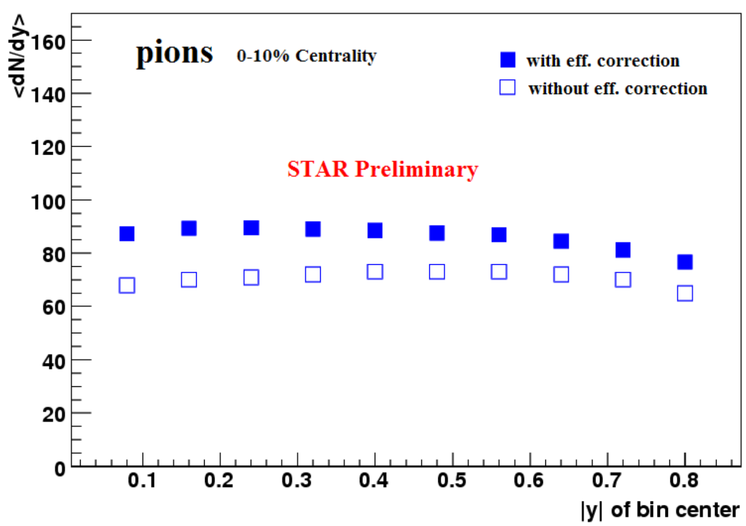




Identified Particle Multiplicity

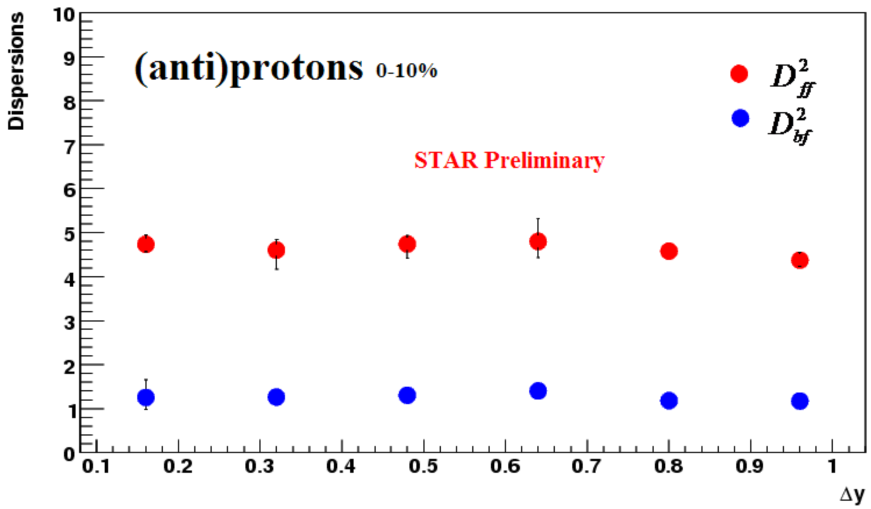


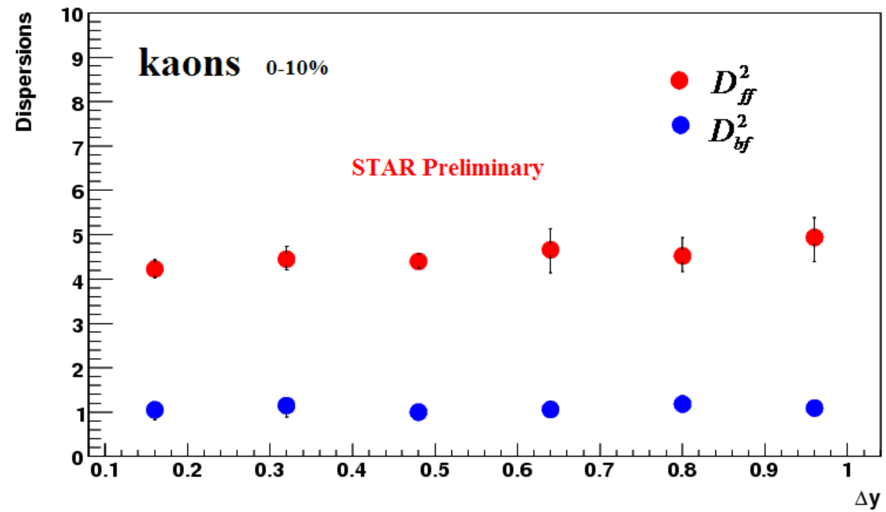


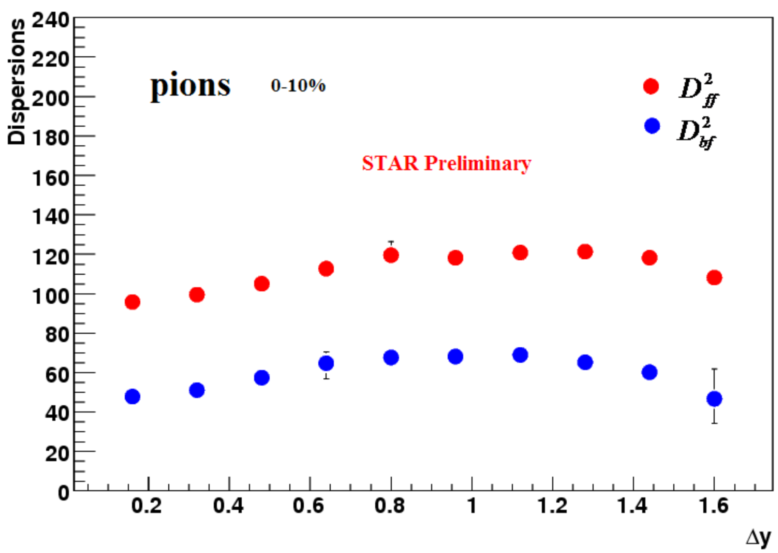


The measurable rapidity gap for heavy particles (kaons and protons) is constrained to the short-range ($\Delta y < 1$) due to the limited pseudorapidity acceptance of the TPC

Central Dispersions

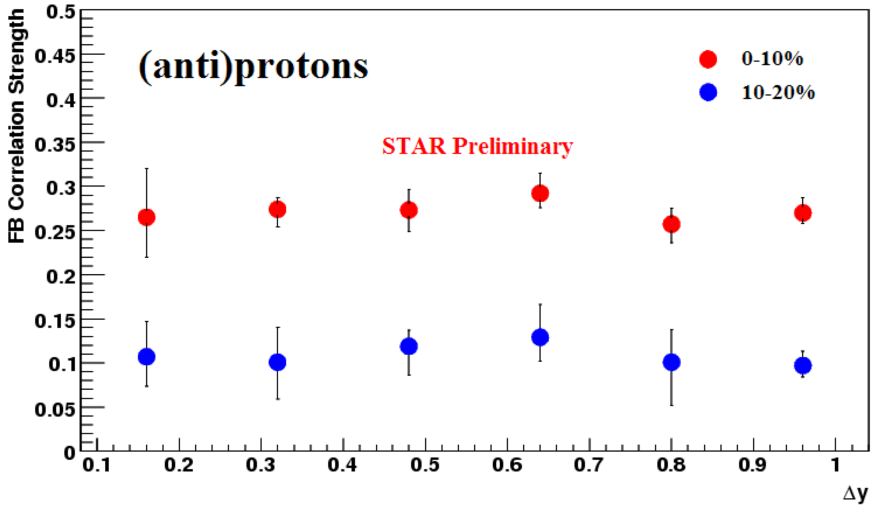


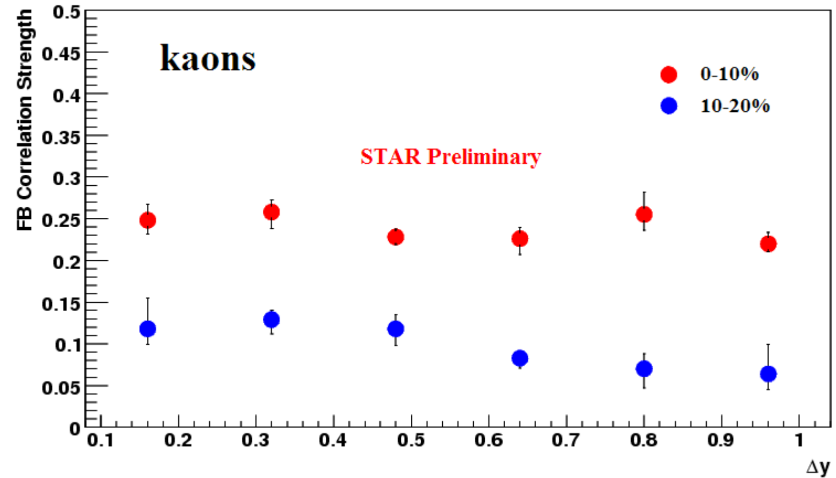


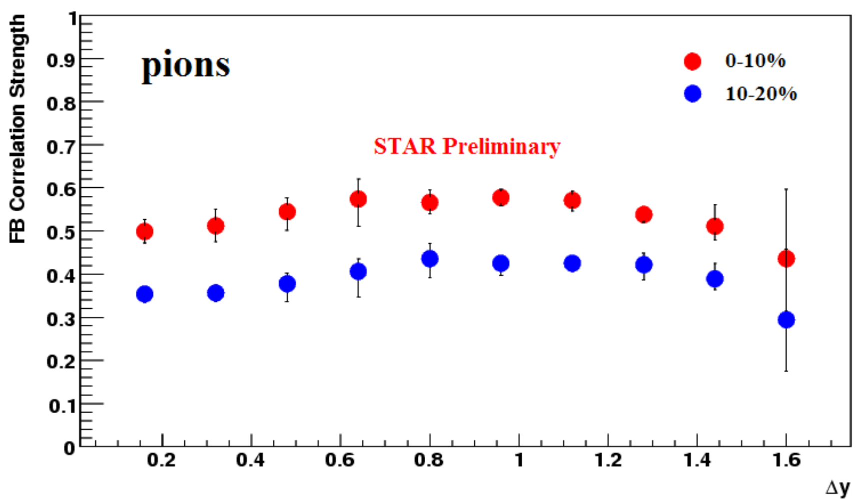


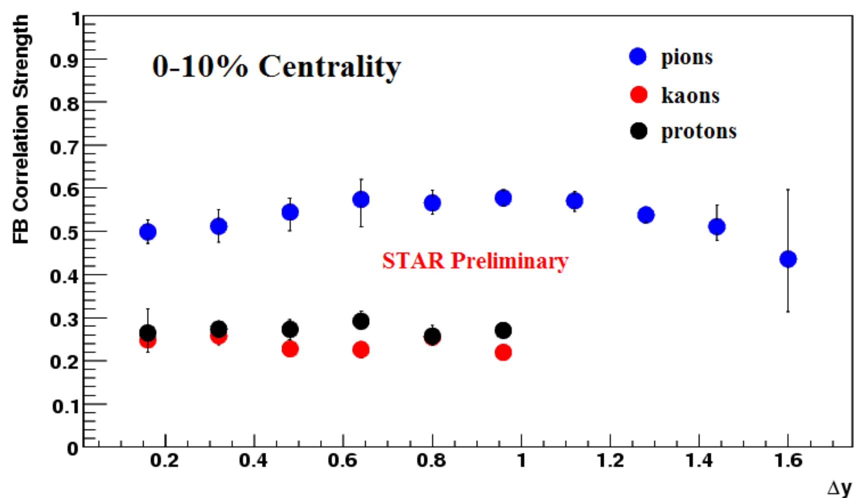
$$b = \frac{<N_f N_b> - <N_f><N_b>}{<N_f^2> - <N_f>^2} = \frac{D^2_{bf}}{D^2_{ff}}$$

FB Correlation Strength b



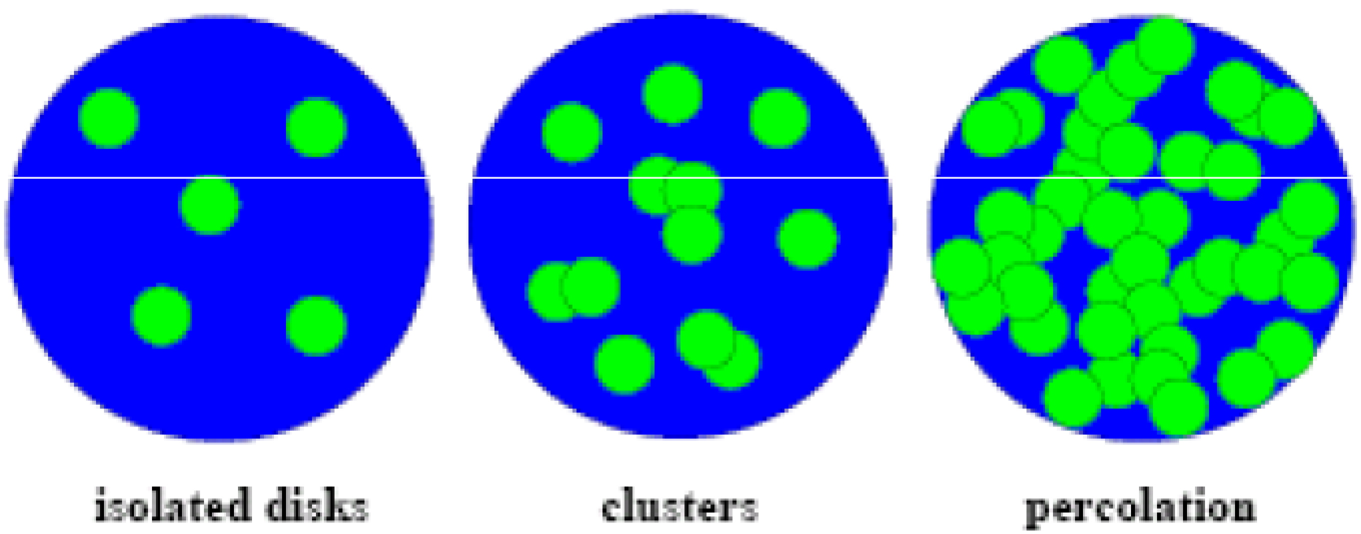






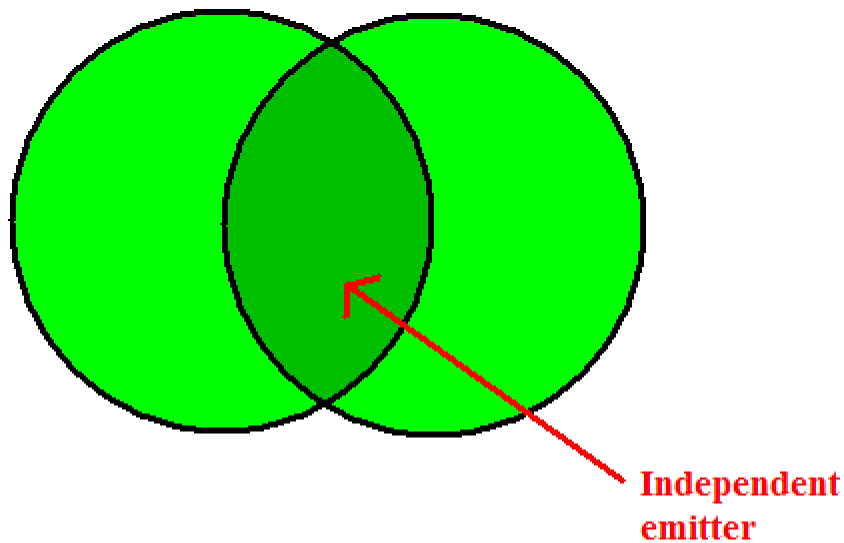
Color String Percolation Model

- 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 $F(\eta)_{pp} \sim 1$.

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

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

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

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

Conclusions

- Strong LRC indicate the occurrence of multiple partonic interactions in the context of DPM
- Preliminary measurements show a strong, uniform LRC across Δy 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
- This preliminary result is consistent with the CGC, which claims that the LRC is primarily due to the fluctuation in the number of gluons, and can only be created at early times
- A possible percolation phase transition can be investigated by measuring η