Measurement of charged particle multiplicity fluctuation and correlation length at RHIC-PHENIX

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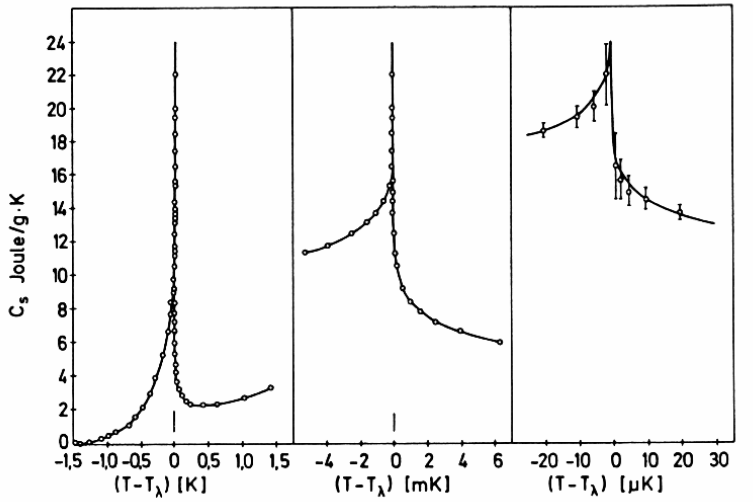
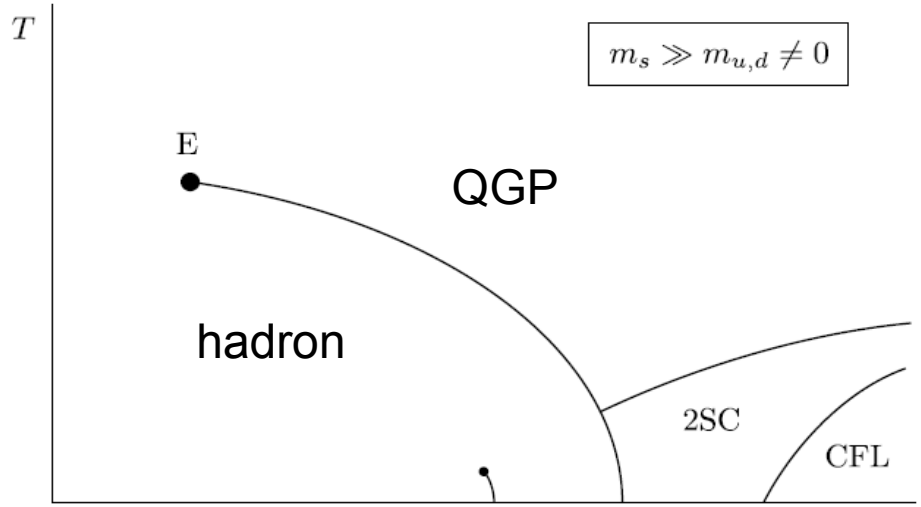
Correlation length at phase transition

- According to the universality hypothesis, measured correlation length also diverge at the temperature of QCD phase transition.
- The correlation length can be extracted from the parameter of negative binomial distribution (NBD) as a function of pseudo rapidity gap, which is obtained from measured charged particle multiplicity distribution.

Specific heat of liquid Helium (He^4)



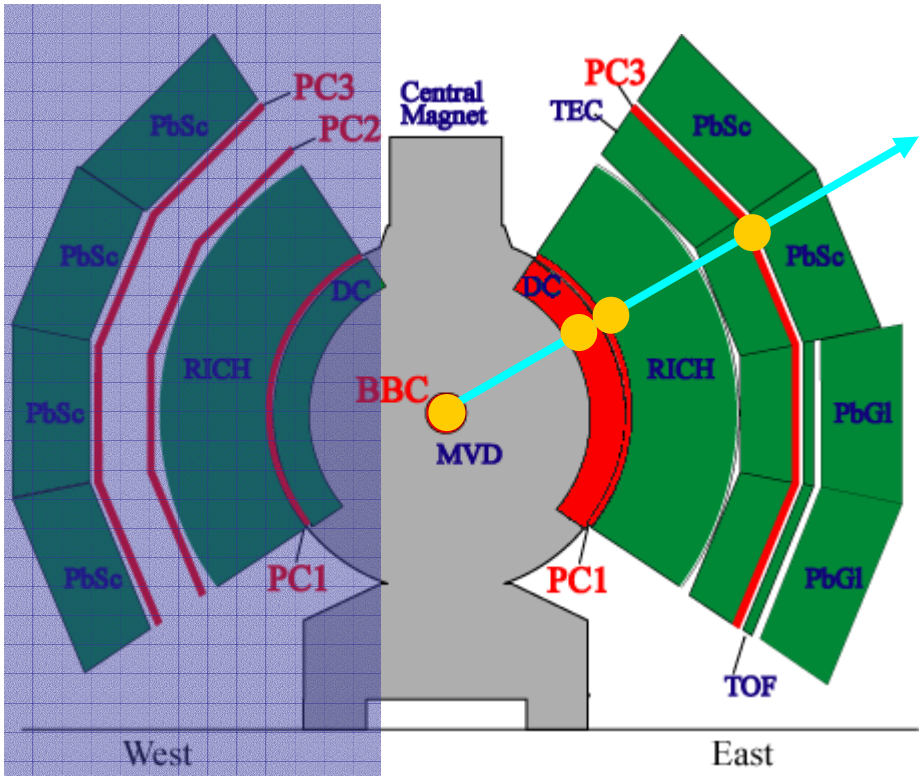
Fairbank et al, (1975)



K. Rajagopal and F. Wilczek, hep-ph/0011333

Charged particle multiplicity at PHENIX

- **Collision system**
  - Au+Au $\sqrt{s_{NN}}$ = 200GeV
- **Event centrality**
  - Centrality was determined by forward detectors (BBC and ZDC) and converted to number of participants based on Glauber model calculation.
- **Charged particle ID**
  - Straight line tracks based on drift chamber were used. Association with two wire chamber (PC1, PC3) and collision vertex measured by BBC were required.



Geometrical acceptance

$$\Delta\eta < 0.35$$

$$\Delta\phi < 1/2\pi$$

Multiplicity distribution and NBD fit

Bose-Einstein distribution

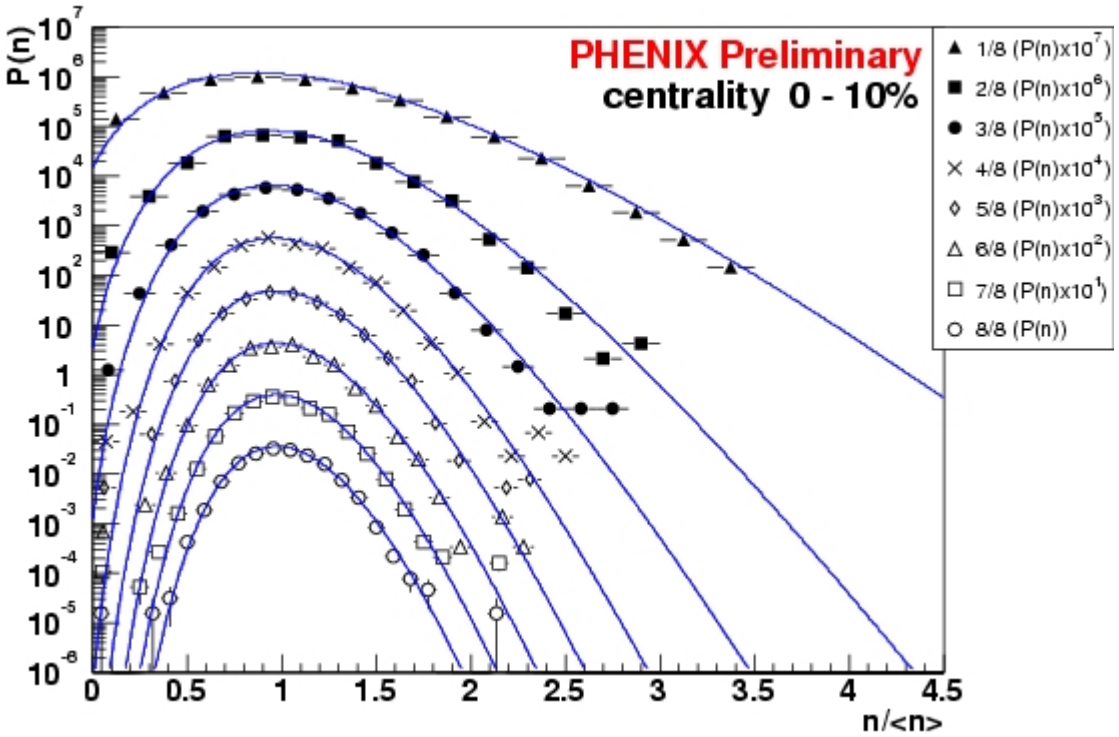
$$P_n = n^{-n}/(1+\mu)^{n+1}$$

NBD

$$P_n^{(k)} = \frac{\Gamma(n+k)}{\Gamma(n-1)\Gamma(k)}\left(\frac{\mu/k}{1+\mu/k}\right)^n \frac{1}{(1+\mu/k)^k}$$

μ : average multiplicity

$\delta\eta$ = 0.09 (1/8) : P(n) x 10^7
$\delta\eta$ = 0.18 (2/8) : P(n) x 10^6
$\delta\eta$ = 0.35 (3/8) : P(n) x 10^5
$\delta\eta$ = 0.26 (4/8) : P(n) x 10^4
$\delta\eta$ = 0.44 (5/8) : P(n) x 10^3
$\delta\eta$ = 0.53 (6/8) : P(n) x 10^2
$\delta\eta$ = 0.61 (7/8) : P(n) x 10^1
$\delta\eta$ = 0.70 (8/8) : P(n)



Two particle correlation length (ξ) and NBD parameter (k)

$$R(y_1, y_2) = \frac{C_2(y_1, y_2)}{\rho_1(y_1)\rho_2(y_2)} = \frac{\rho_2(y_1, y_2)}{\rho_1(y_1)\rho_2(y_2)} - 1 = R(0,0)e^{-|y_1 - y_2|/\xi}$$

$\rho_1(y)$: inclusive single particle density

$\rho_2(y_1, y_2)$: inclusive two-particle density

$C_2(y_1, y_2)$: two-particle correlation function

$$K_2 = F_2 - 1 = \frac{\int^{\delta\eta} dy_1 dy_2 C_2(y_1, y_2)}{< n(\delta\eta) >^2} = R(0,0)\frac{[1 - (\xi / \delta\eta)(1 - e^{-\delta\eta/\xi})]}{\delta\eta / 2\xi}$$

$$F_2 = \frac{< n >^2 - < n >}{< n >^2}$$ second order normalized factorial moment

$$k(\delta\eta) = \frac{1}{F_2 - 1} = \frac{1}{R(0,0)} \frac{\delta\eta / 2\xi}{[1 - (\xi / \delta\eta)(1 - e^{-\delta\eta/\xi})]}$$

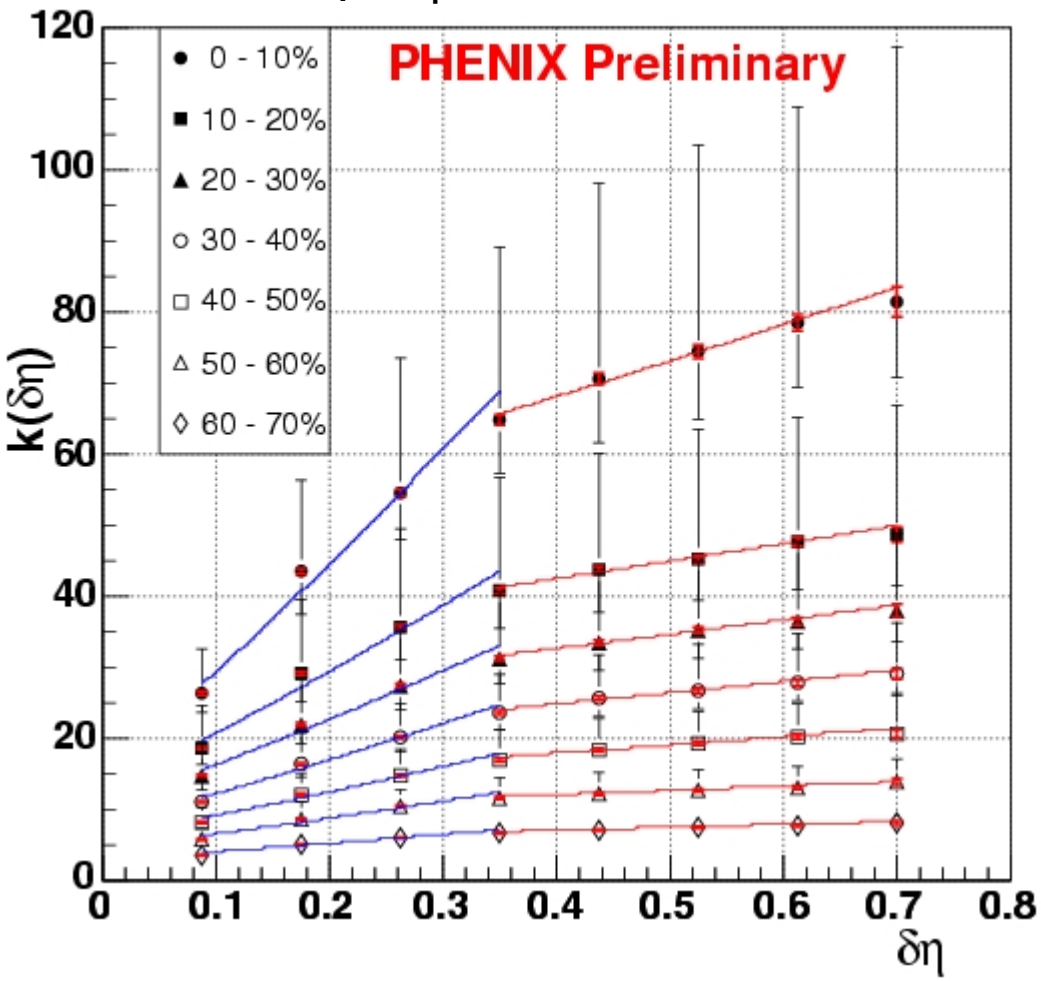
ξ : correlation length
R(0,0) : correlation strength
k : NBD parameter

P. Carruthers and Isa Sarcevic, Phys. Rev. Lett. 63, 1562 (1989)
T. Abbott, et al, PRC 52, 2663 (1995) (E802 collaboration)

Correlation length from NBD k

$$k(\delta\eta) = \frac{1}{F_2 - 1} = \frac{1}{R(0,0)} \frac{\delta\eta / 2\xi}{[1 - (\xi / \delta\eta)(1 - e^{-\delta\eta / \xi})]}$$

$\delta\eta$ dependence of NBD k



ξ : correlation length
R(0,0) : correlation strength
k : NBD parameter

- **Fitting range**

Blue: $\delta\eta \leq 0.35$

Red : $\delta\eta \geq 0.35$

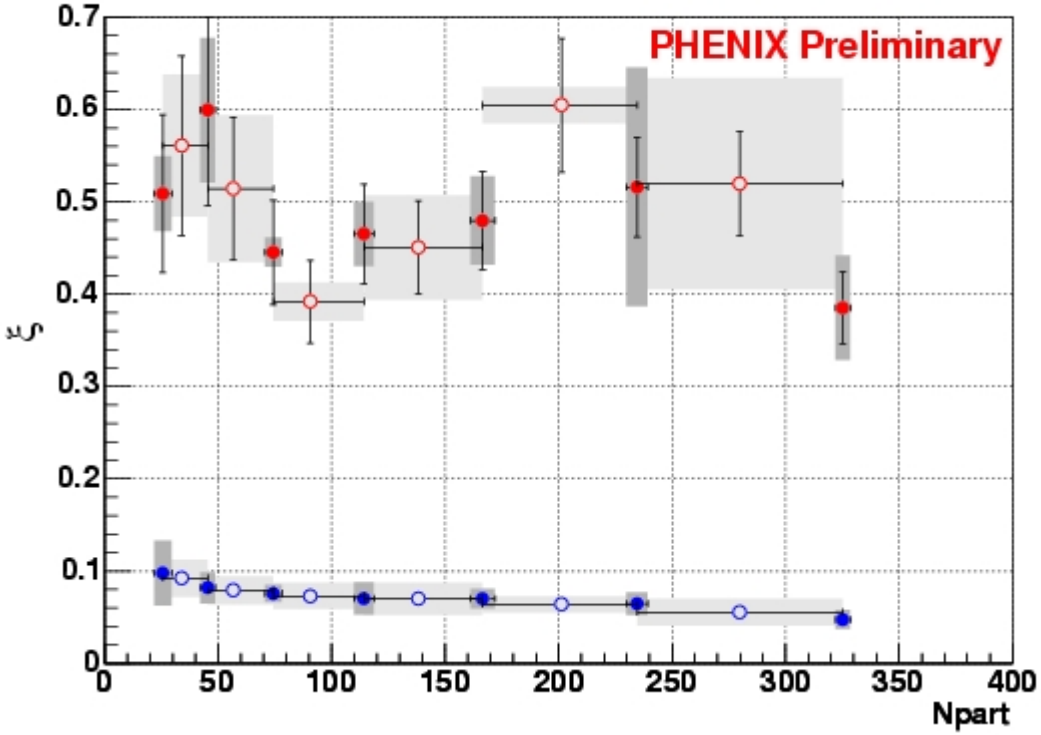
- **Errors**

red bar : statistical error of NBD fit

black bar: systematic error of charged track selections and effects of dead area of detectors

Number of participant dependence of ξ

correlation length ξ vs. number of participants



- **Fitting Range**

Blue: $\delta\eta \leq 0.35$

Red : $\delta\eta \geq 0.35$

- **Centrality**

filled circle : 0-70 % (10% interval)

open circle : 5-65 % (10% interval)

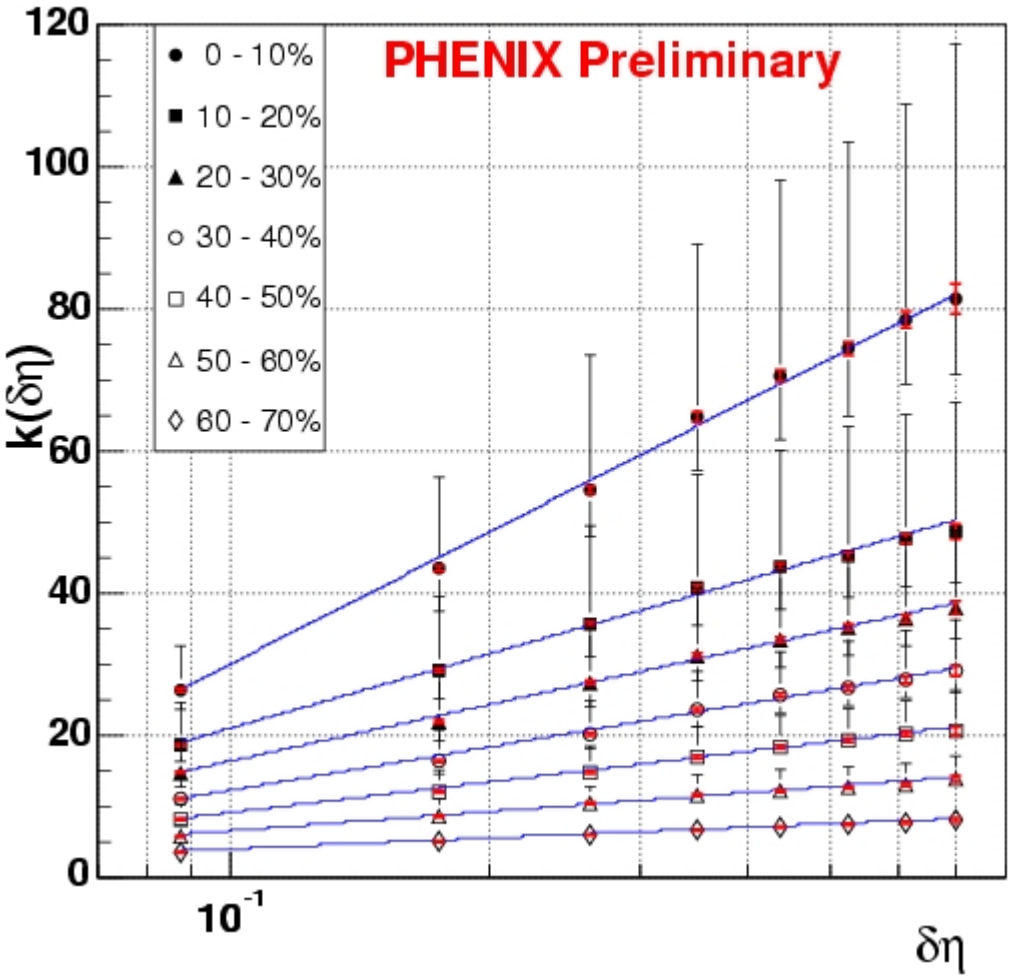
- **Errors**

bar : statistical error

shaded : systematic error of charged track selections and effects of dead area of detectors

Power law between NBD k and $\delta\ \eta$

ln($\delta\ \eta$) dependence of NBD k



- **Fitting function**

k($\delta\ \eta$) = c1 + c2 × ln($\delta\ \eta$)

c1, c2 : constant

- **Fitting Range**

all : 0.09 ≤ $\delta\ \eta$ ≤ 0.7

- **Errors**

red bar : statistical error of NBD fit

black bar: systematic error of charged track selections and effects of dead area of detectors

Summary

- Applying the function, which connect the NBD k parameter with integrated two particle correlation length ξ, to the measured $\delta\eta$ dependence of NBD k parameter, two type of the correlation length are obtained in the short and long rage of pseudo rapidity gap.
- The different value of the correlation length ξ and its behaviors as a function of the number of participants are obtained.
- From another perspective, logarithmic $\delta\eta$ dependence of NBD k parameter are observed.

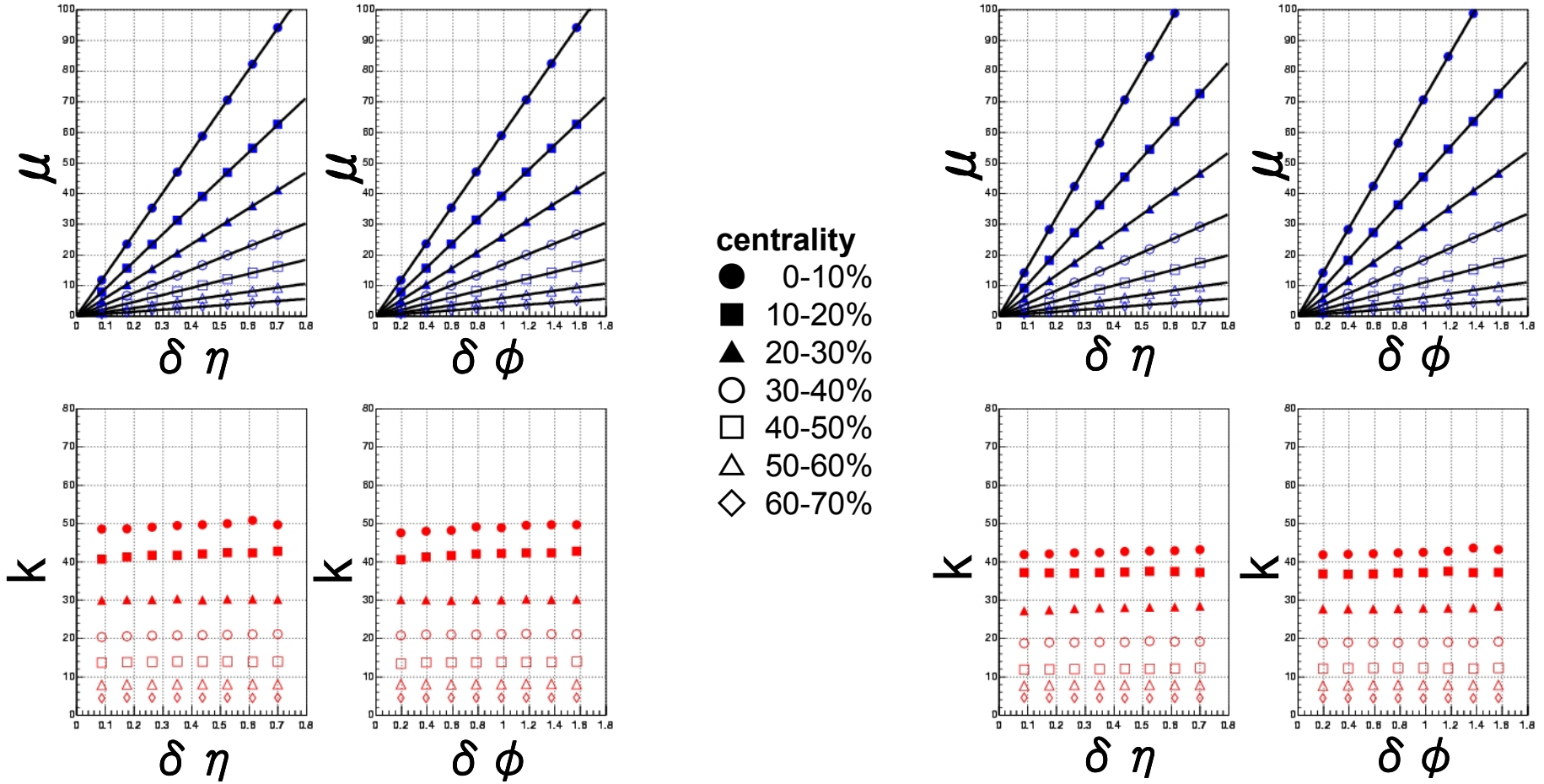
Backup Slide

HIJING 1.37 w/o jet suppression

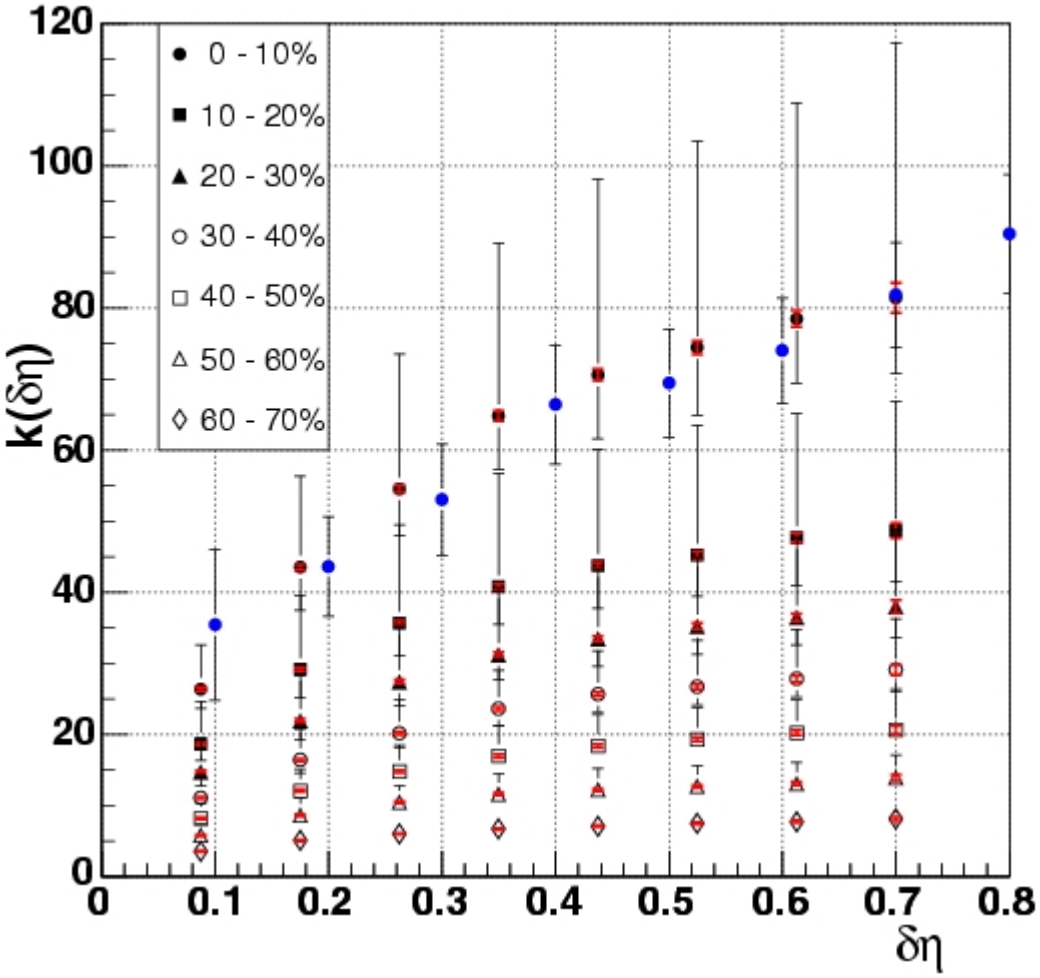
- Initially generated π, k, p was counted.
- pT>0.1GeV cuts were applied for each particle.
- No detector response and no dead map were applied.

without jet suppression

with jet suppression dE/dx = 1GeV/fm



Comparison with E802



Blue : E802
O+Cu 14.6A GeV/c
most central

$\delta\ \eta$ dependence average multiplicity μ

Uncorrected data