Measuring nuclear modification on hadron productions at backward/forward rapidities in d+Au collisions at PHENIX

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For PHENIX Collaboration

Small Bjorken x gluons

- Gluon density increases very fast with increasing Q^2 and decreasing Bjorken x.
- Heavy nuclei enhance gluon color field by $A^{1/3}$.
- Gluons from different nucleons start to overlap to each other in phase space.

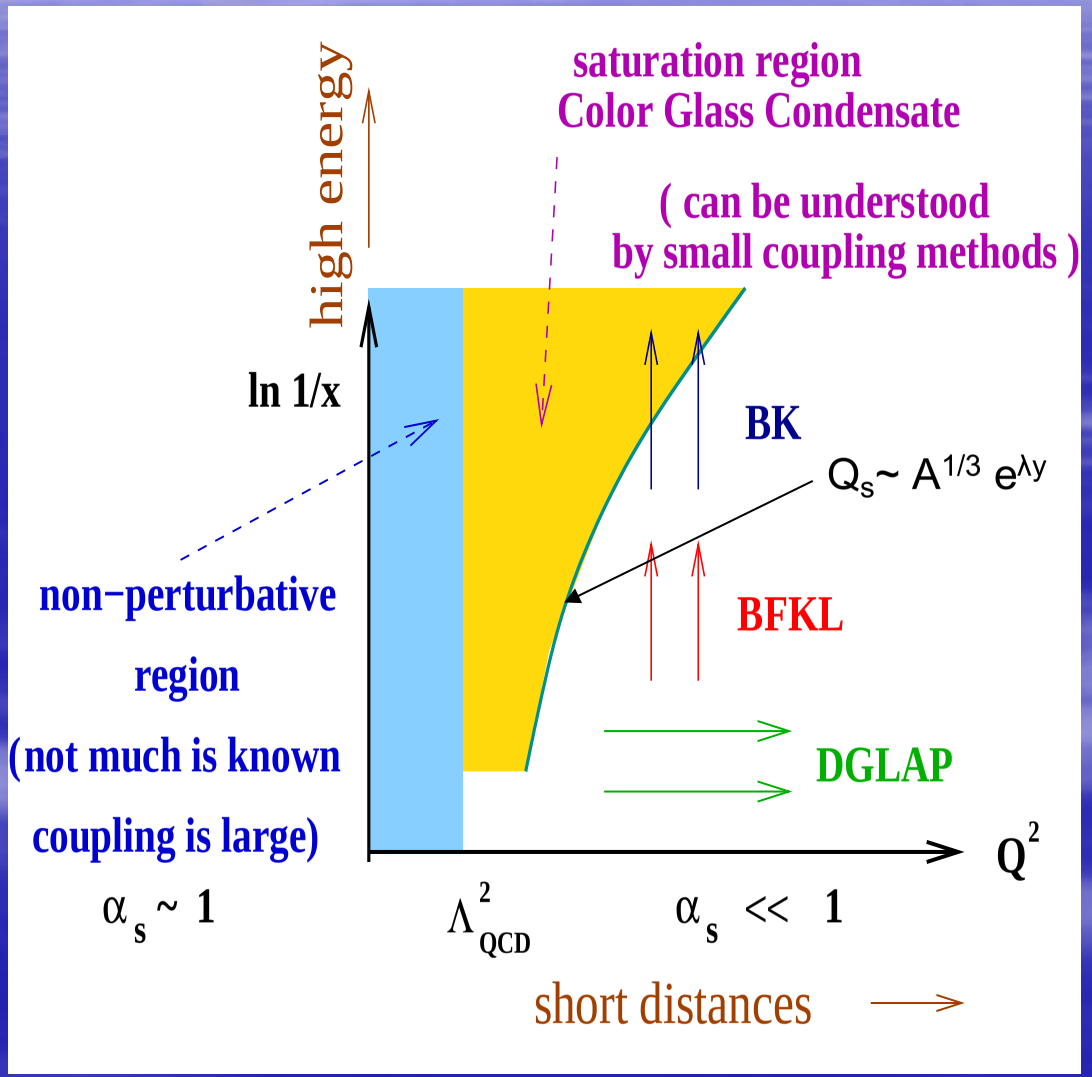
Gluon density is saturated.

- The color field inside heavy nuclei may become classical field, fluctuation of the field is much smaller than the field strength.

Color Glass Condensate(CGC)

- Explore saturation phenomena with the PHENIX forward/backward detectors.

Q_s ~ 2.0GeV/c at PHENIX forward coverage.



PHENIX muon arms

PHENIX has two muon arms, south ($-2.2 < \eta < -1.2$) and north ($1.2 < \eta < 2.4$).
Each arm has a Tracking detector and a Muon identifier.
Tracking detector consists of 3+3+2 cathode strip chambers located at different position in a magnetic field.
Muon Identifier consists of 5 gaps of transversely oriented Iarocci tube planes, interleaved with layers of steel.
Two Beam Beam counters, South and North, south BBC used to determine the collision impact parameter.

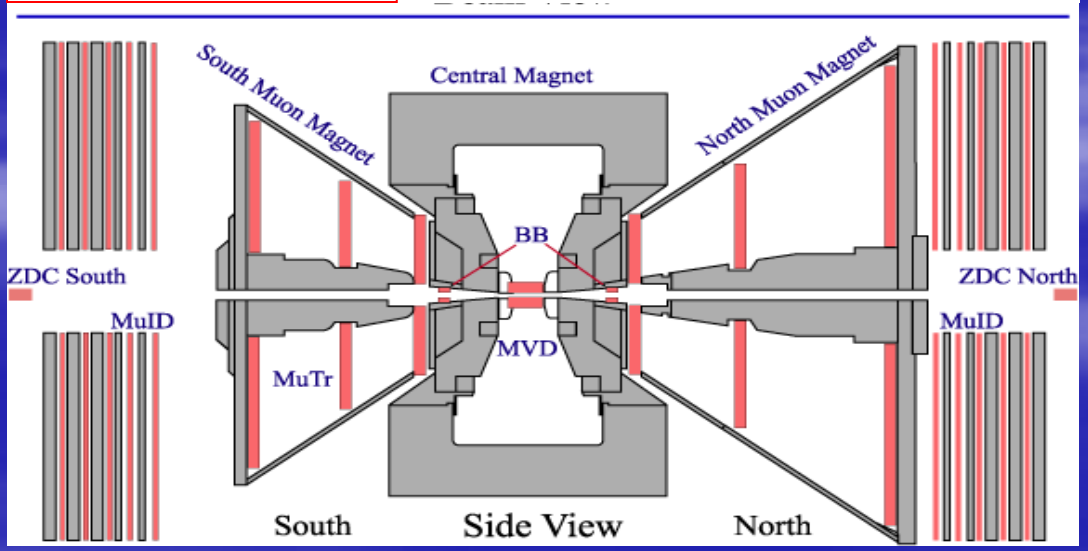
deuteron

$(s_{NN})^{1/2} = 200$ GeV

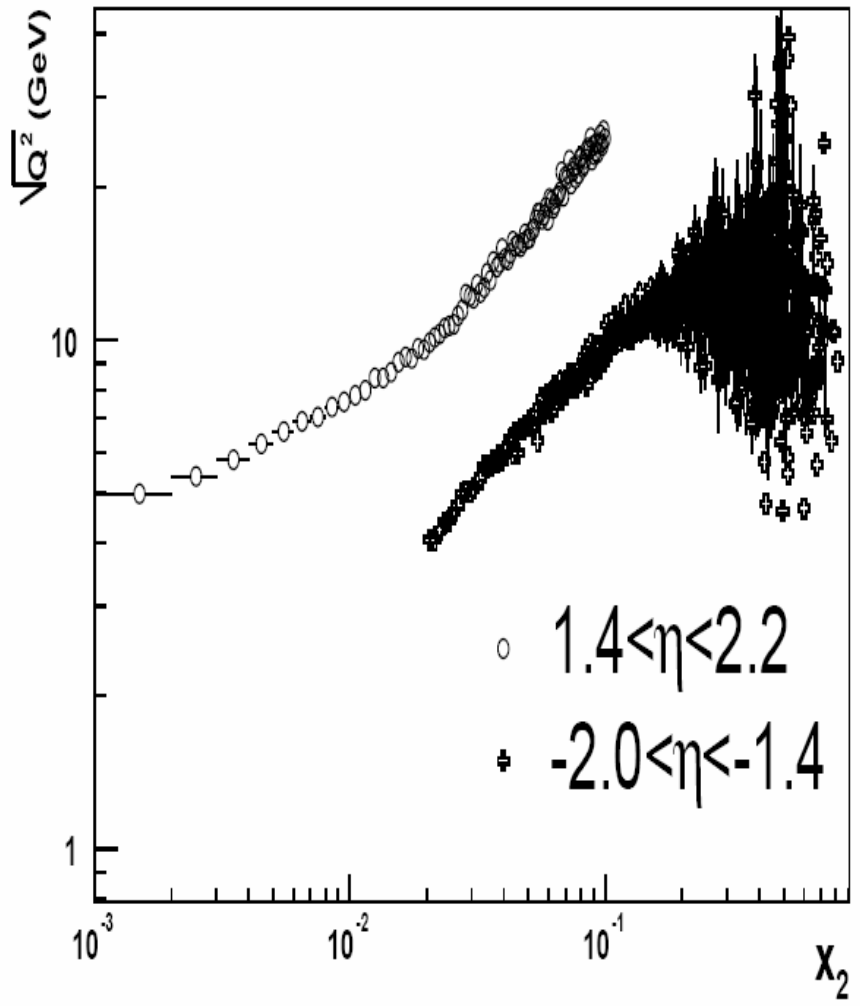
gold

South/Backward

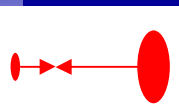
North/Forward



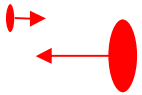
$$R_{CP} = \frac{\frac{1}{N_{binary}^{central}}\left(\frac{dN}{dp_T}\right)^{central}}{\frac{1}{N_{binary}^{peripheral}}\left(\frac{dN}{dp_T}\right)^{periperal}}$$

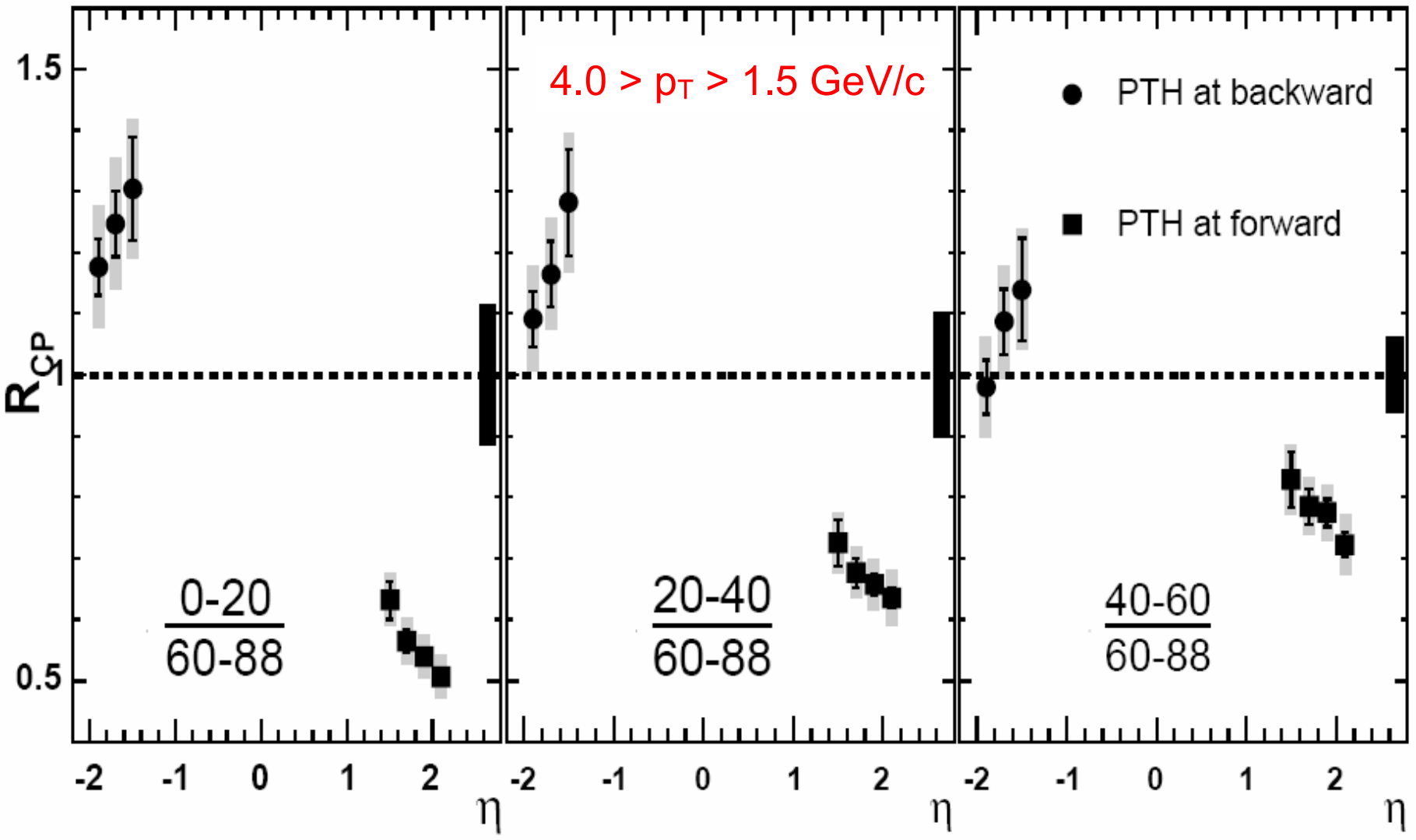


Charged hadron R_{cp}



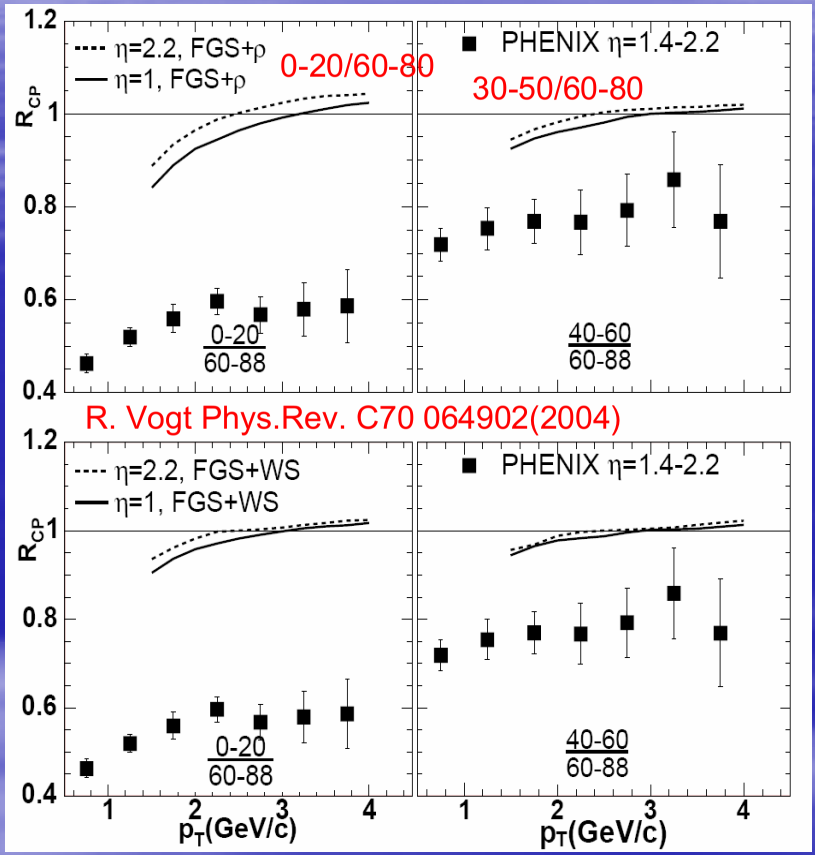
Impact parameter increasing

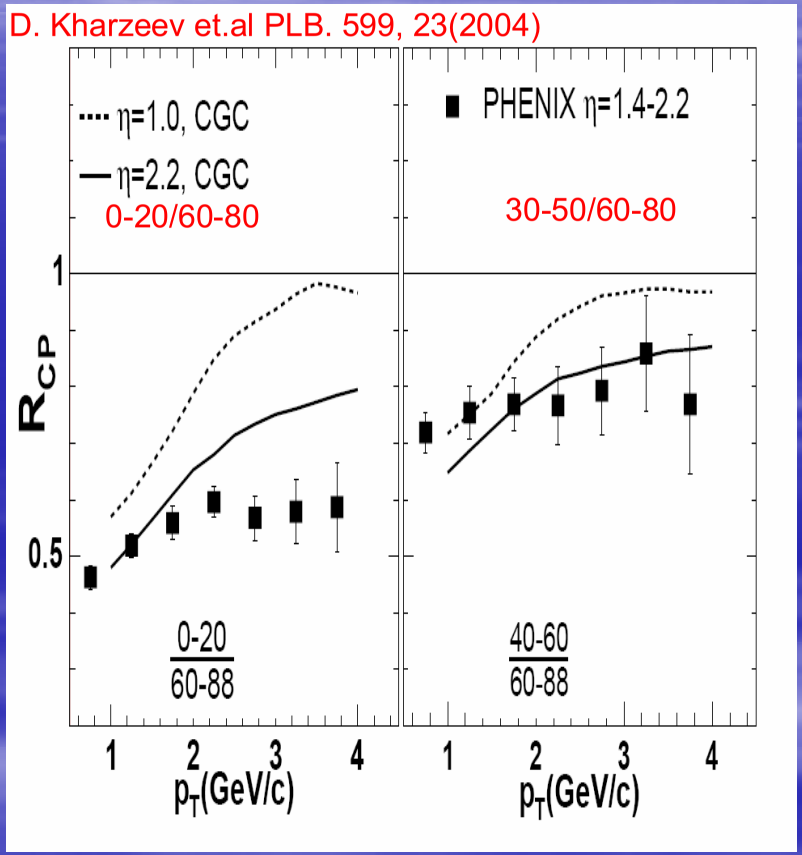




PRL. 94 082302, 2005

Compare with theoretical calculations



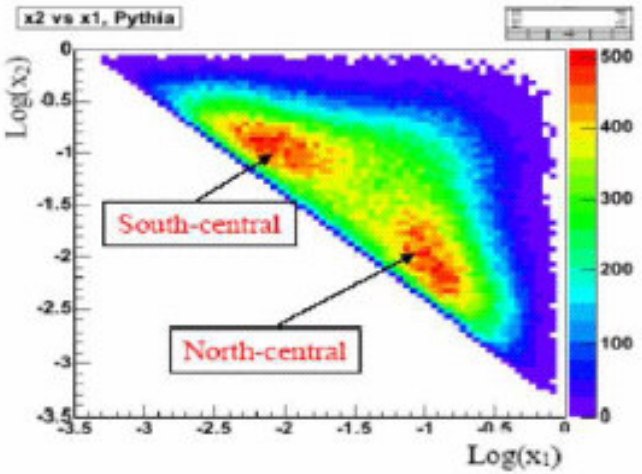


ρ assumes shadowing stems from the multiple interactions of the incident partons.
ws assumes that shadowing is proportional to the local density.

The CGC calculation has two free parameters, which are fixed by fitting the BRAHMS results.

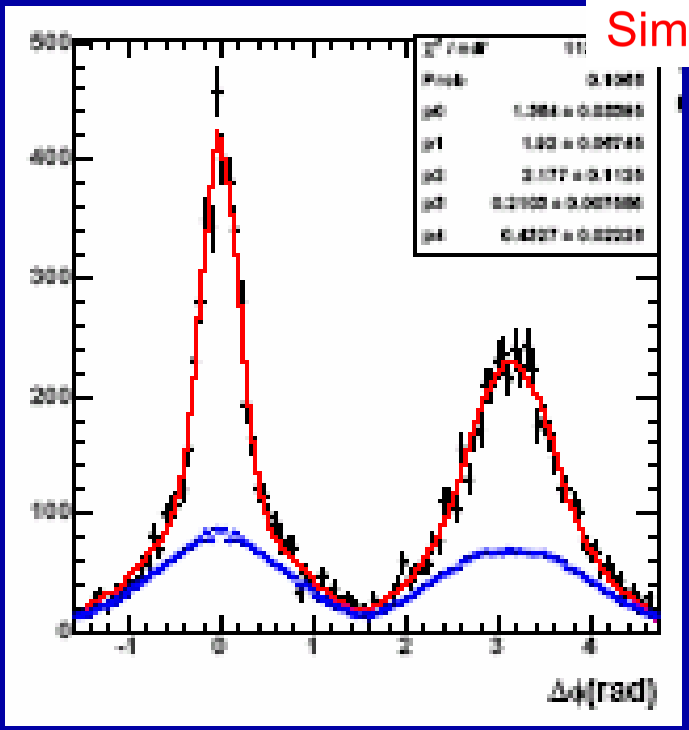
Azimuthal correlation between two particles at different rapidities

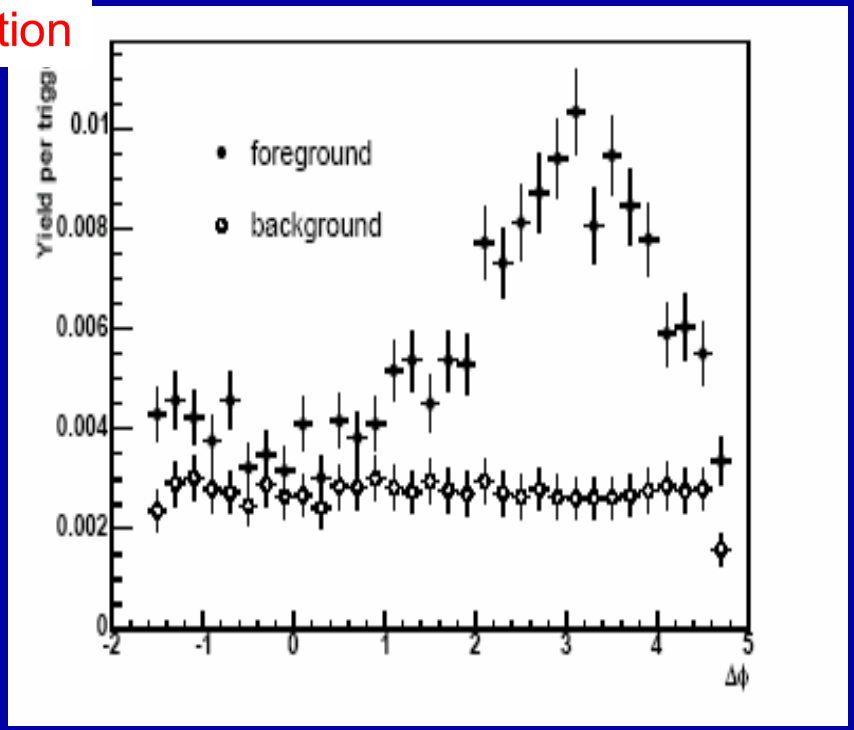
•CGC also predicts that when near-side and away-side hadrons are separated by several units of rapidity, quantum evolution effects lead to
the depletion of back-to-back correlations as a function of rapidity interval between the detected hadrons (at fixed p_T).
• There is ~2 unit rapidity gap between the PHENIX south/north muon arms and the PHENIX central arms($0.35 > \eta > -0.35$).
• In d+Au, north-central correlations are sensitive to small Bjorken x partons in gold nuclei and south central correlations are sensitive to large Bjorken x partons in gold nuclei



Kinematics

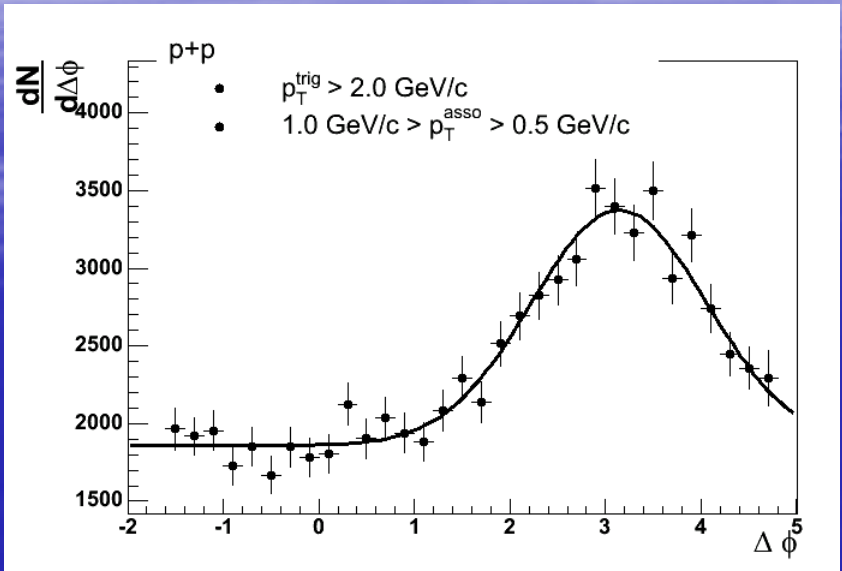
Simulation

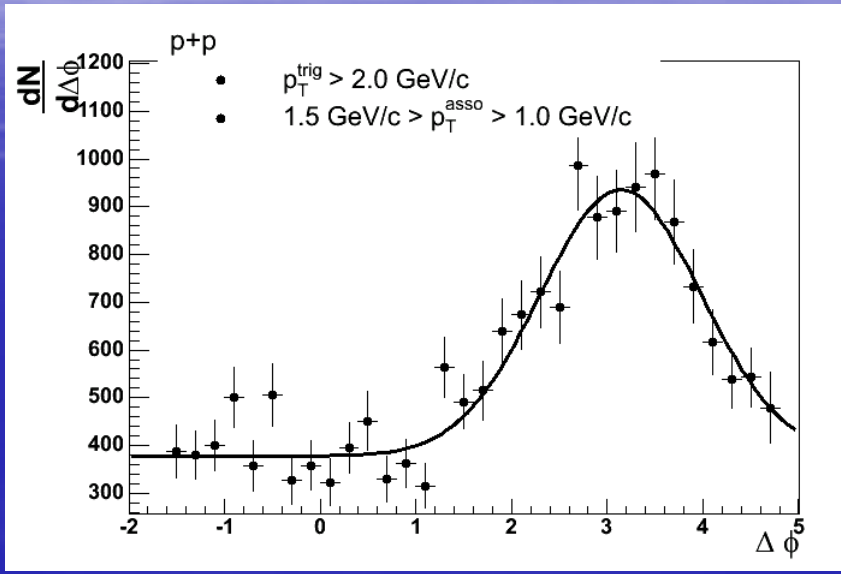


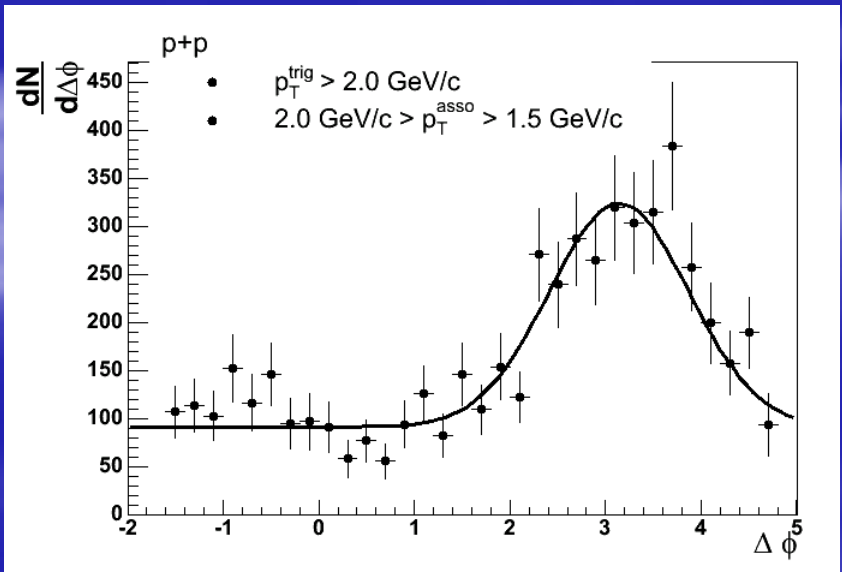


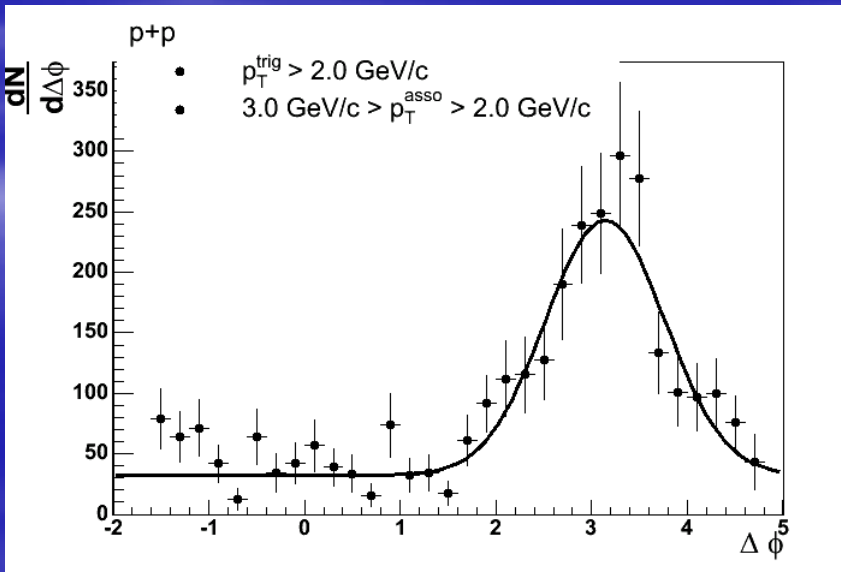
- Trigger particles are charged hadrons from muon arms and associated particle are charged hadrons from central arms
- There is a pseudo-rapidity gap between trigger particles and associated particles, No near side correlations.

Correlation functions for muon-central correlation in p+p



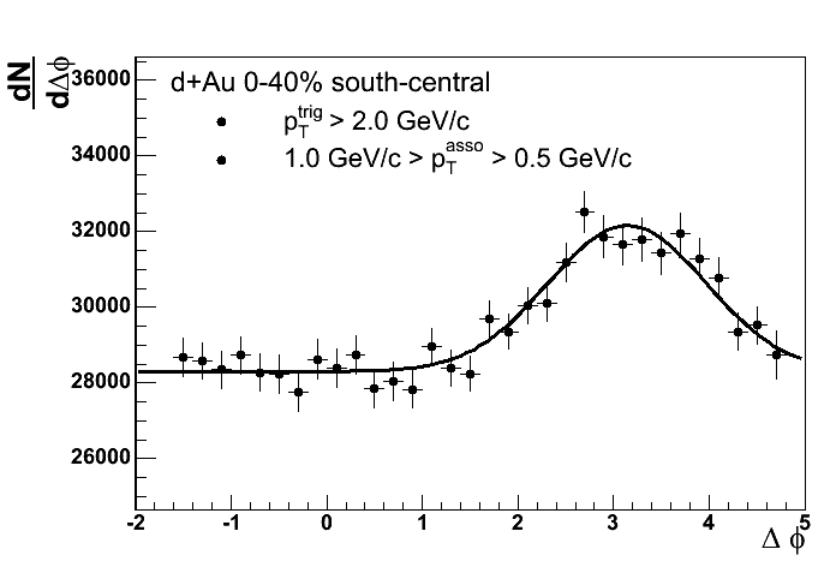


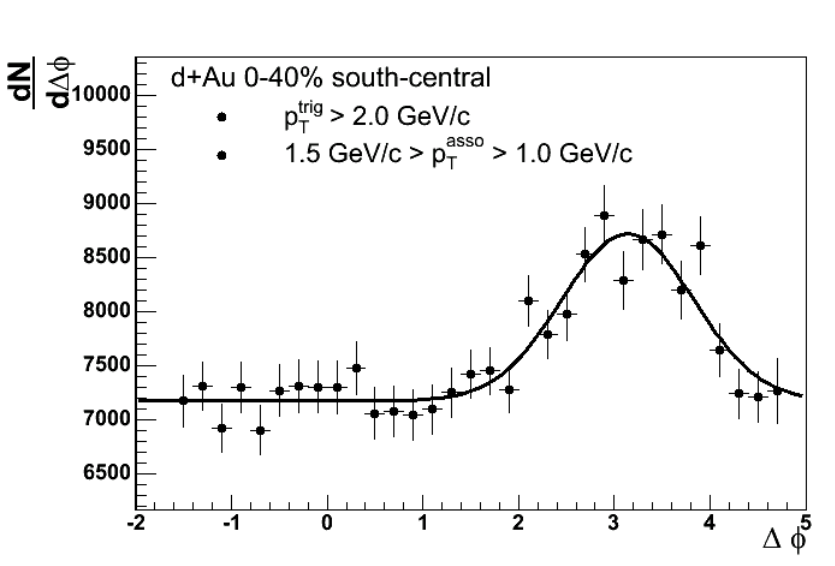


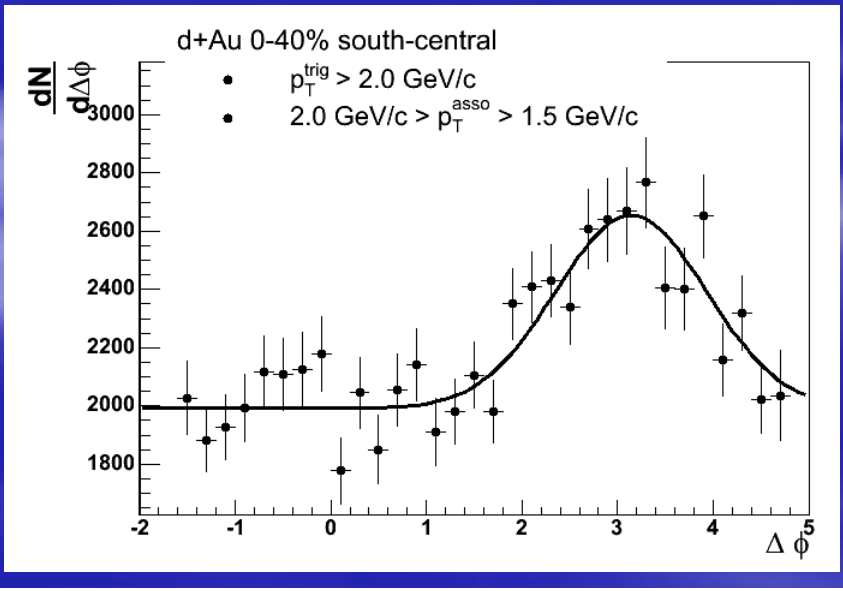


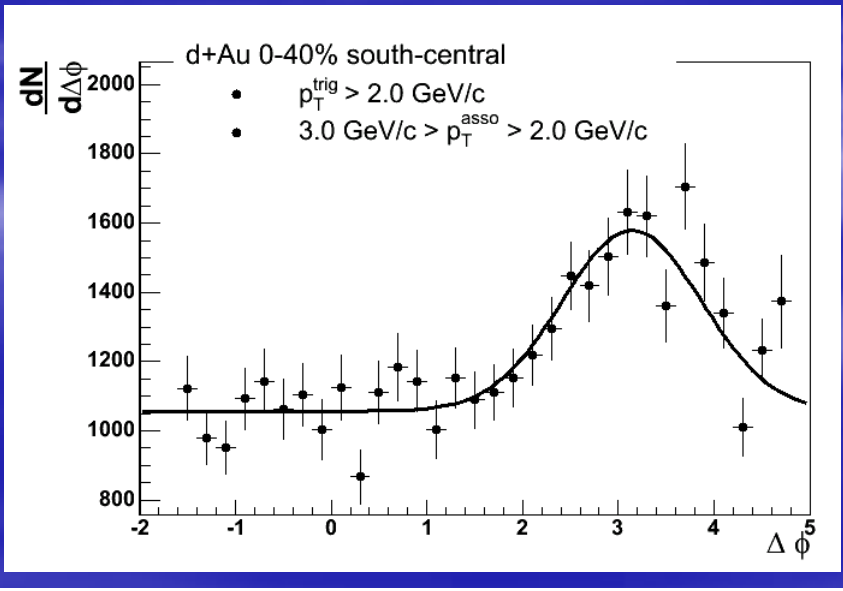
Correlation functions for south-central correlation in d+Au 0-40%

sensitive to large x in gold nuclei



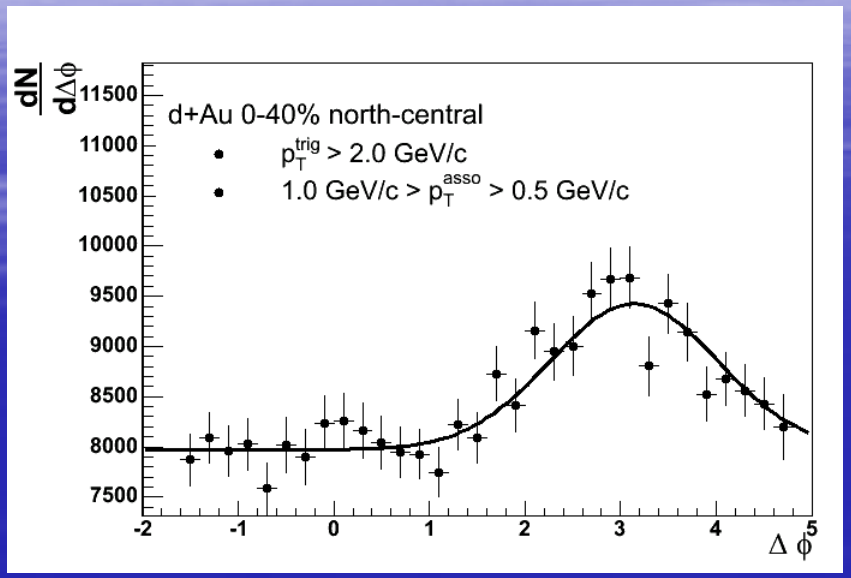


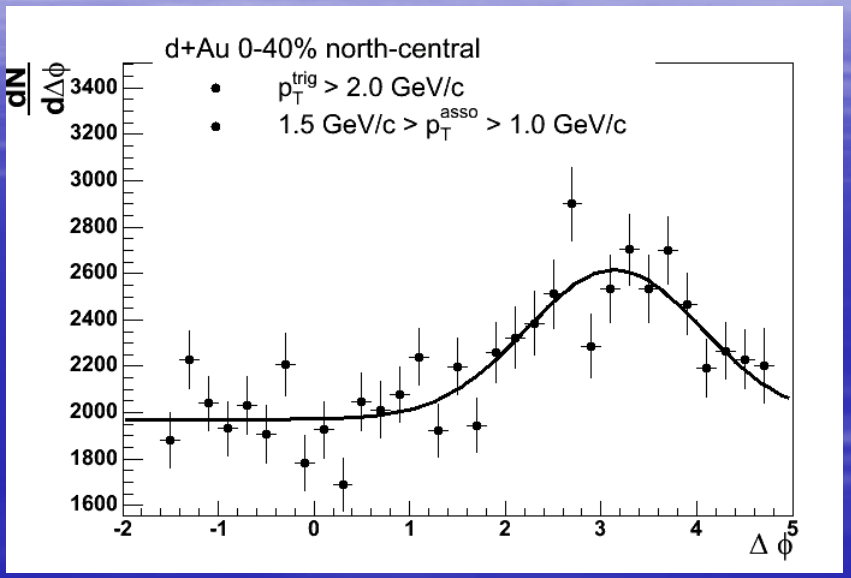


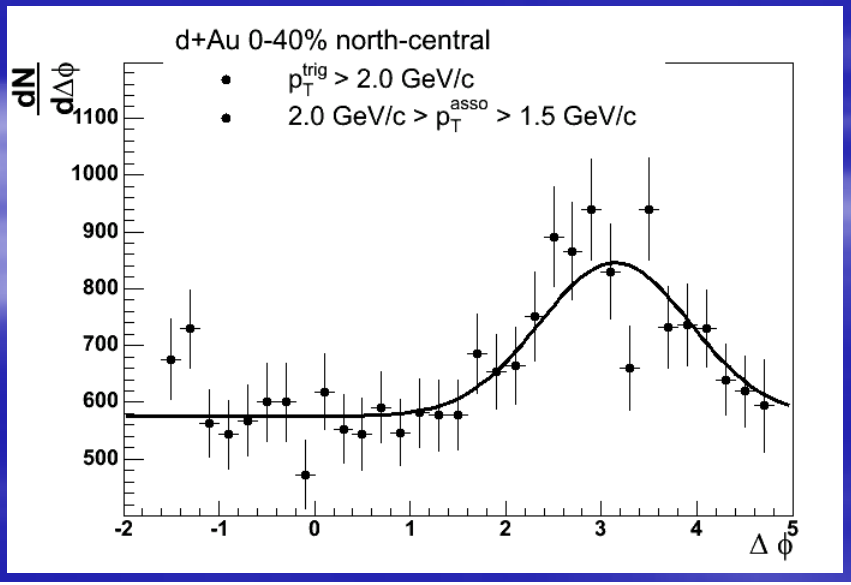


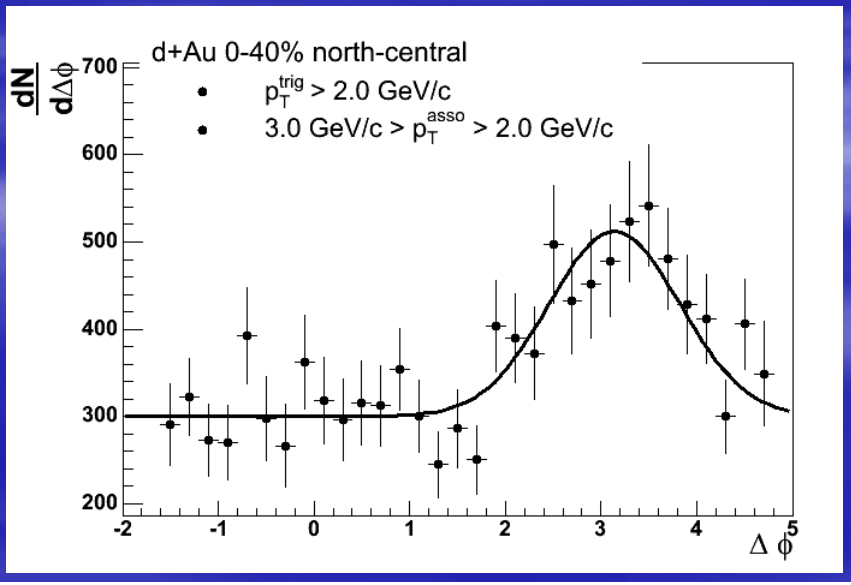
Correlation functions for north-central correlation in d+Au 0-40%

sensitive to small x in gold nuclei



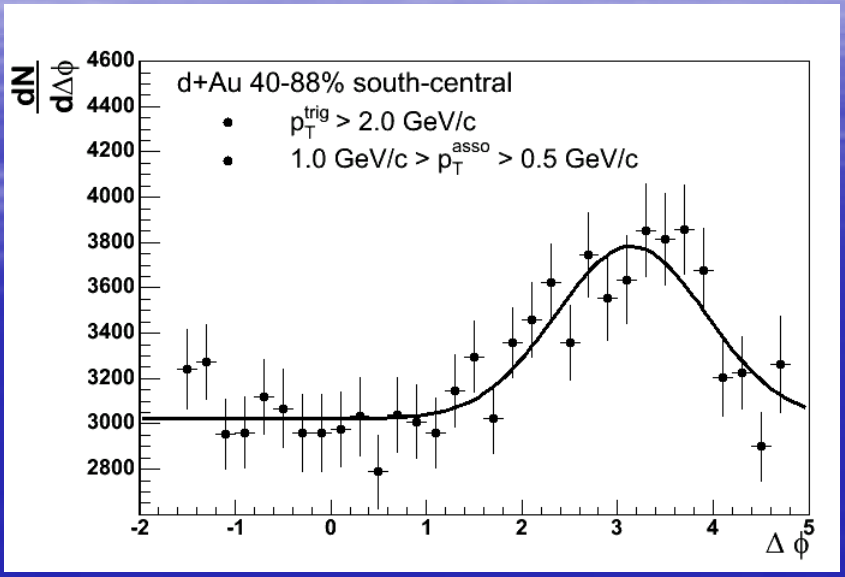


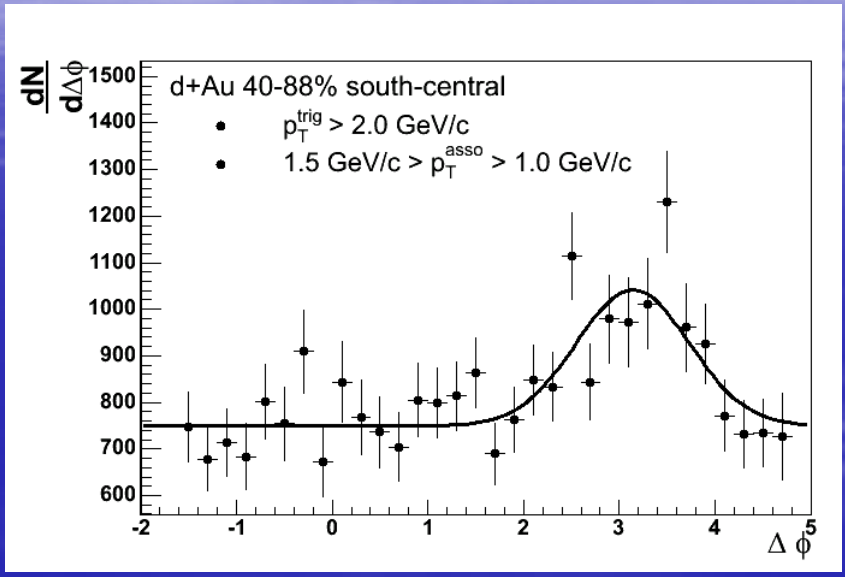


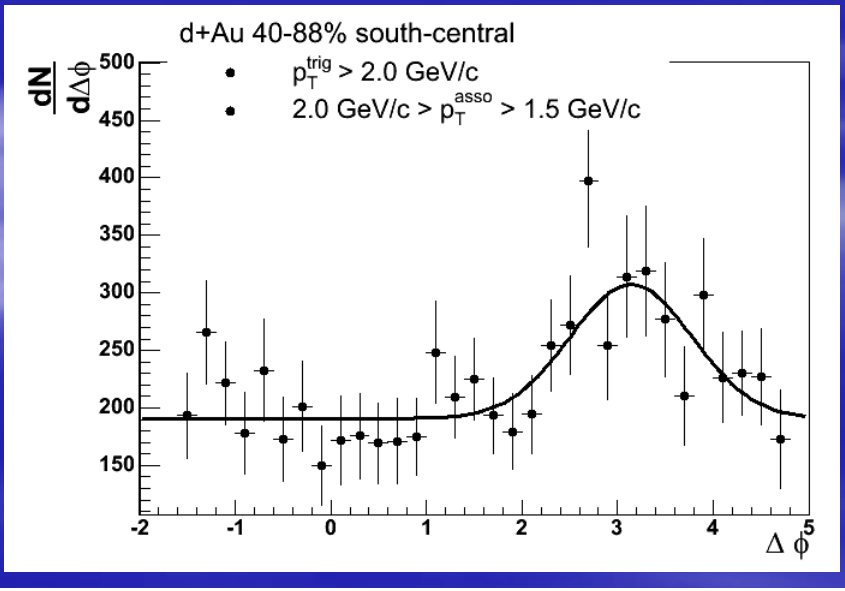


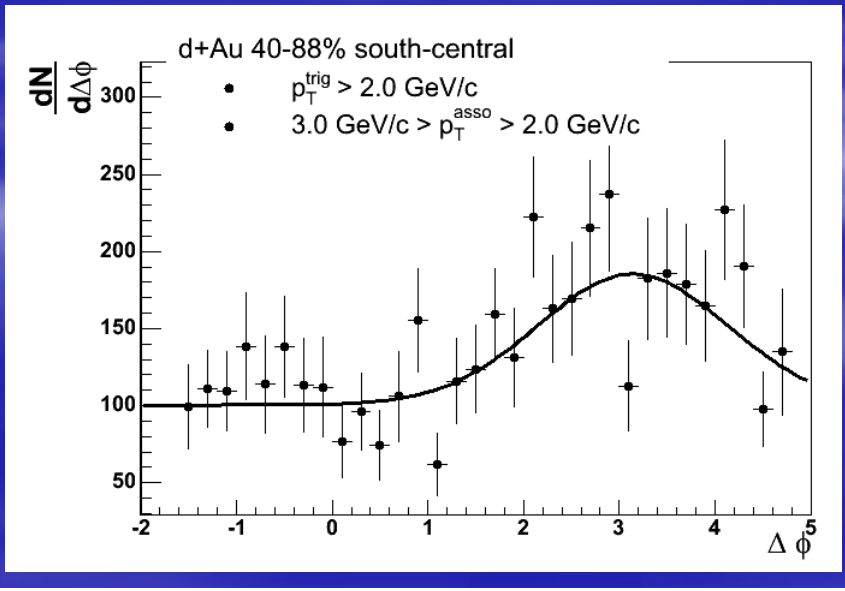
Correlation functions for south-central correlation in d+Au 40-88%

sensitive to large x in gold nuclei



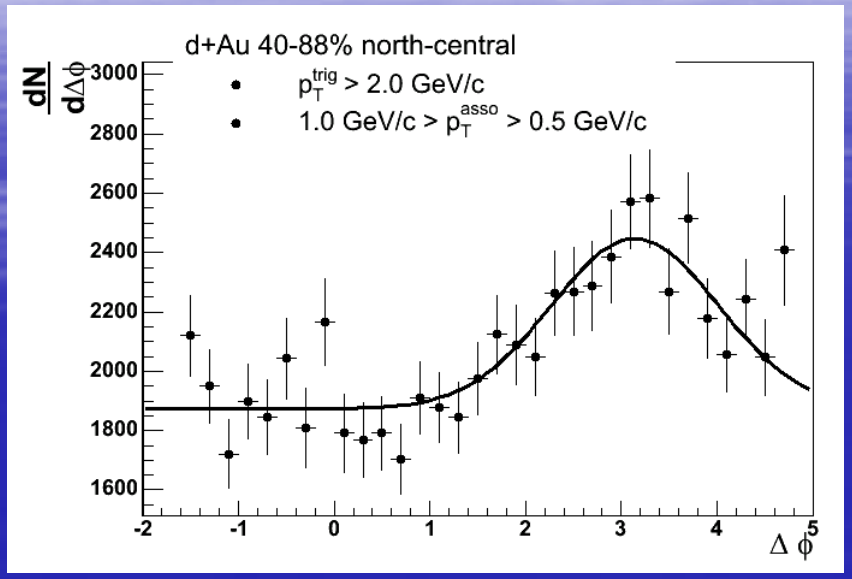


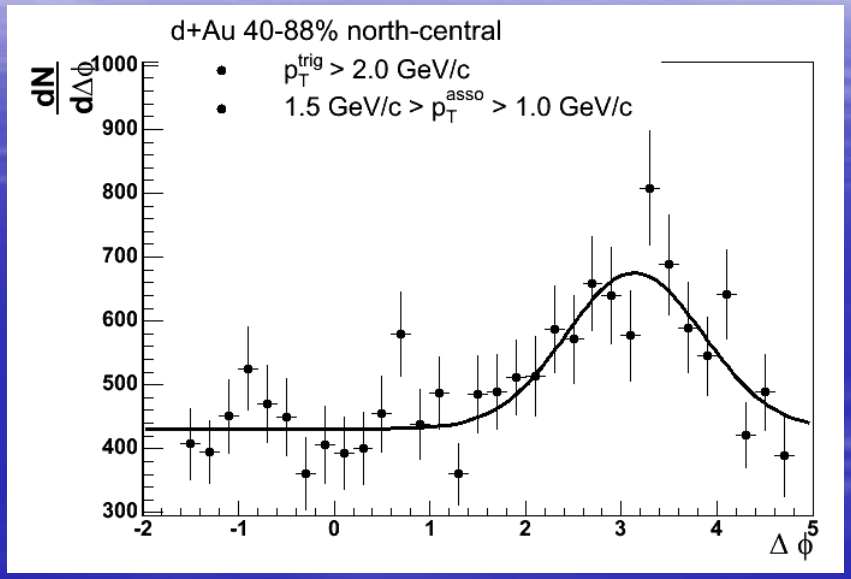


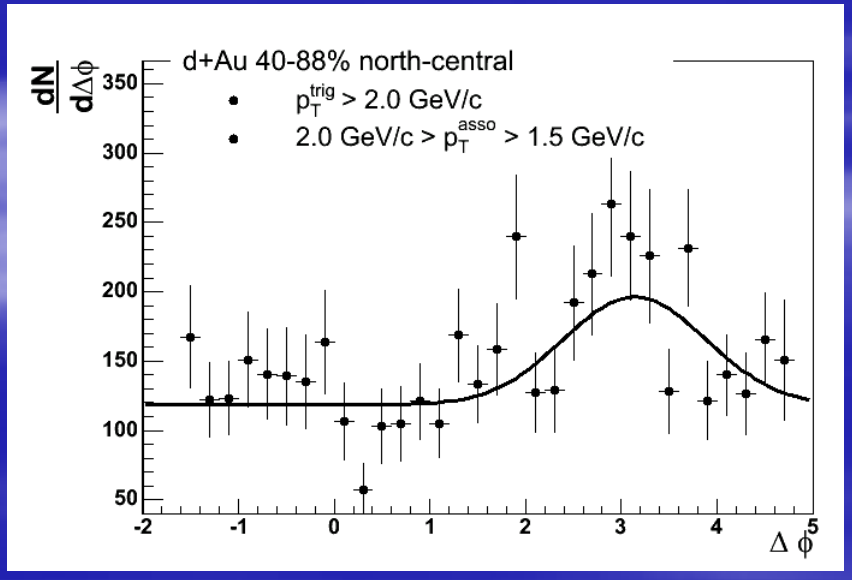


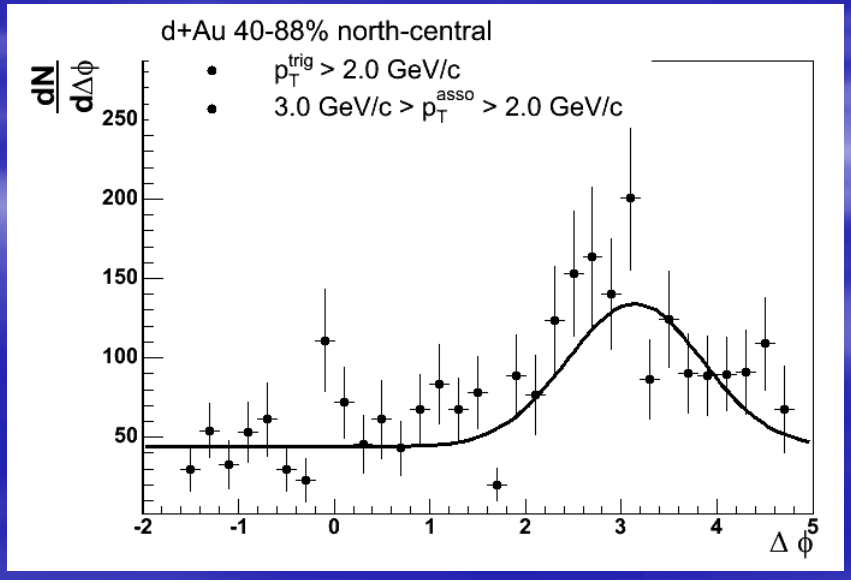
Correlation functions for north-central correlation in d+Au 40-88%

sensitive to small x in gold nuclei









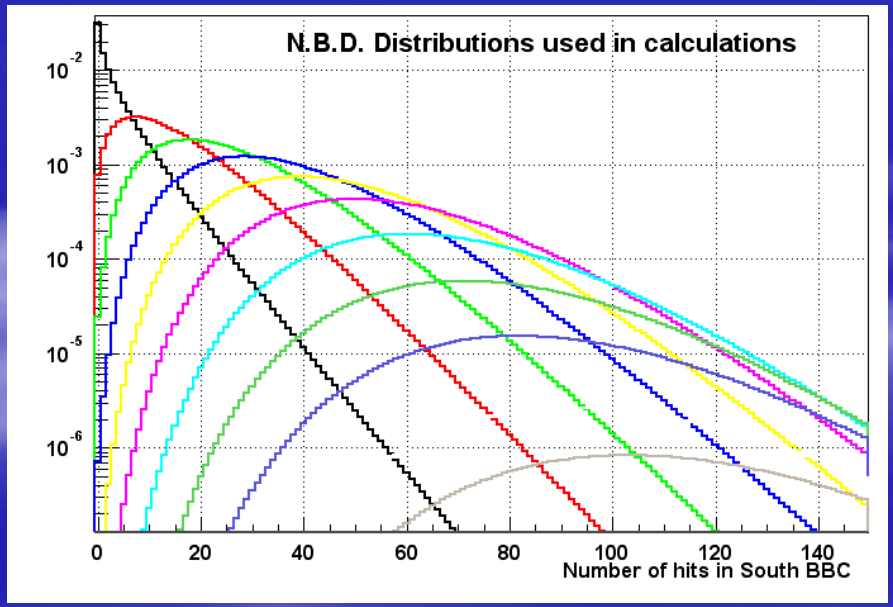
Summary

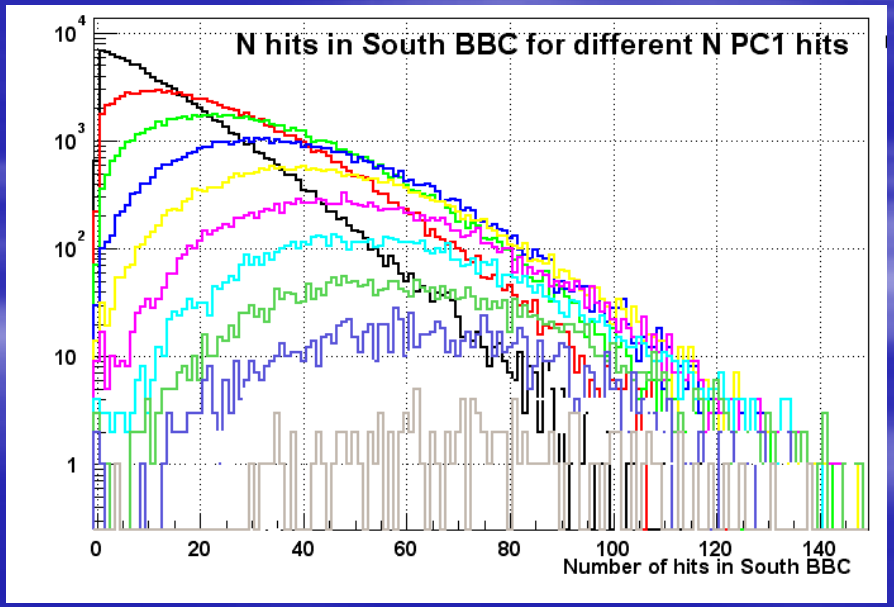
- In d+Au collisions, suppression at forward rapidity and enhancement at backward rapidity on hadron yields relative to N binary scaling are observed by PHENIX.
- Two theoretical calculations, i.e. CGC and leading twist shadowing are compared with data at forward rapidity. The comparison suggests CGC calculations describe experimental observation better.
- CGC has also predicted the mono-jet when near side jets at forward rapidity and back-to-back jets are several units rapidity away.
- We are able to see jet-like signals in the PHENIX muon arm and central arm two particle correlations in p+p, peripheral d+Au as well as central d+Au.
- The detail analysis on how to quantify these jet signals is undergoing right now.

BACKUPS

Determine centrality

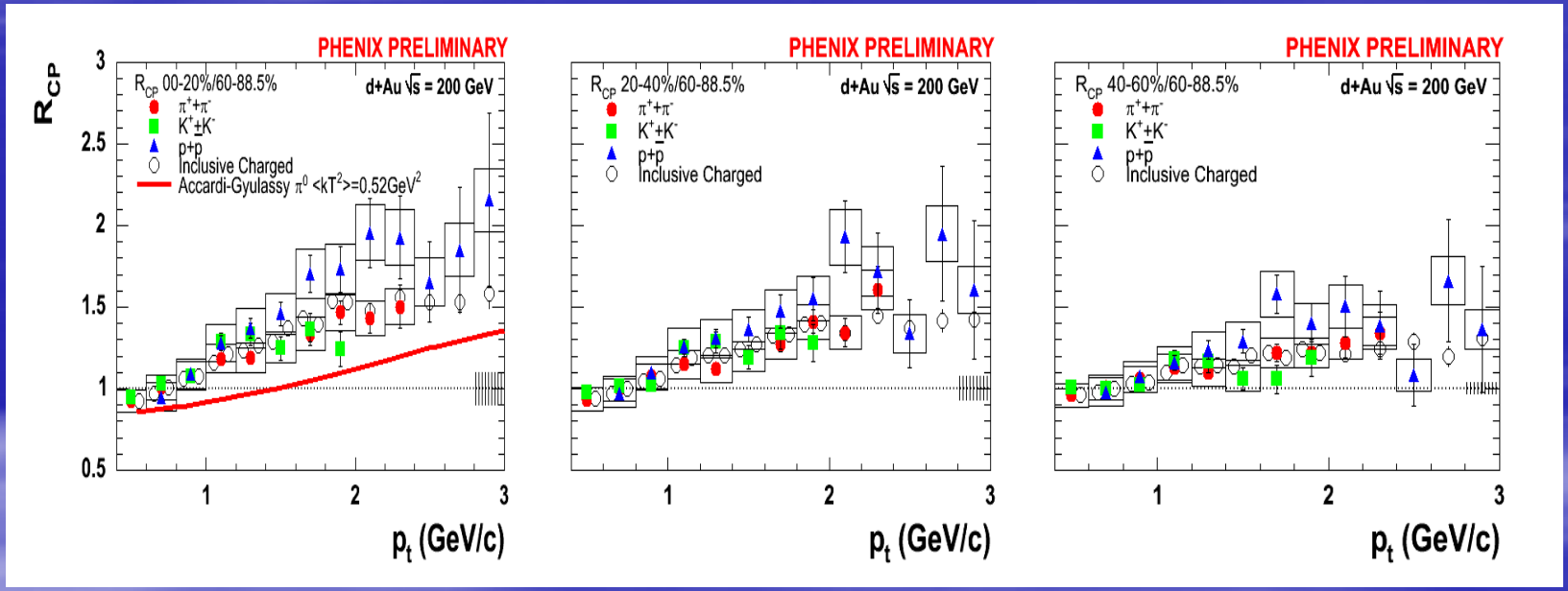
- PHENIX South BBC locates at gold going side
- The charge multiplicity on BBC south proportion to N_{part} of Au nucleus





R_{cp} @ y = 0

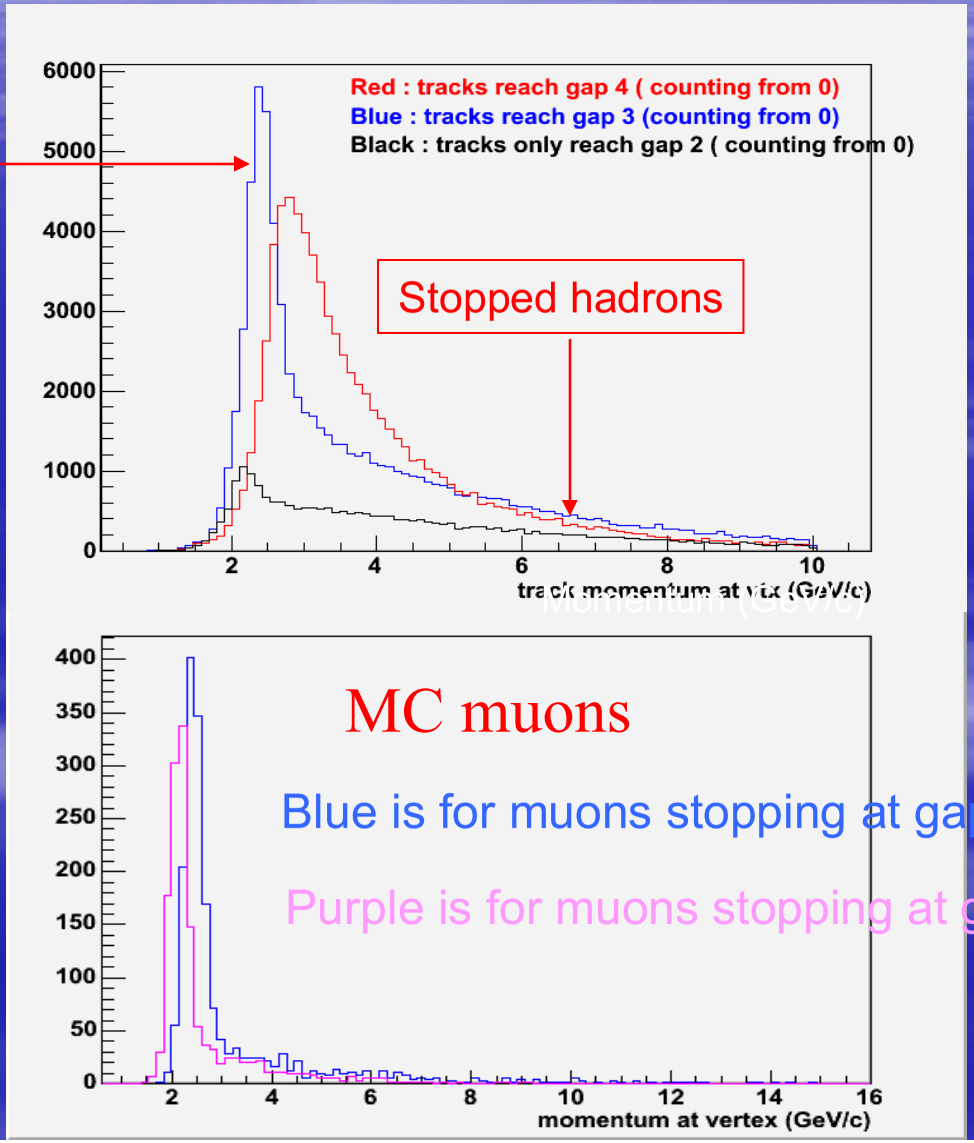
Impact parameter in creasing

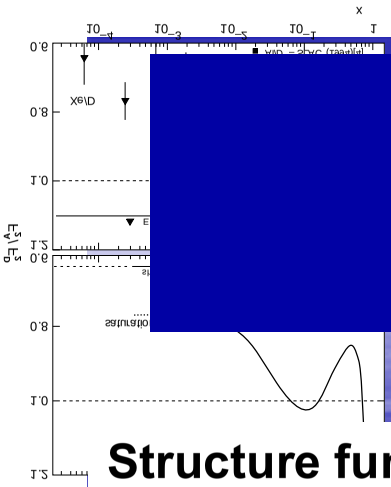


h/μ Separation

Stopped muons

- Muons stopping in gap 3 have lost 2.5 GeV of energy via dE/dx
- Hadrons stopping in gap 3 typically have much higher energy and stop inelastically





Nuclear DIS and Nuclear modification

Structure functions in bound nucleons are different from structure functions in free nucleons
In different x range, the nuclear modification behaves differently,

- *x>0.8, ratio >1 : Fermi Motion.*
- *0.8>x>0.2, ratio <1 : EMC effect.*
- *0.2>x>0.08, ratio > 1 : anti-shadowing*
- *0.08>x, ratio <1 : shadowing*

The modification is A dependent and varies with Q^2 very slowly.

F_2^A / AF_2^N

F_2^A / AF_2^N

Fermi Effect

enhancement

Saturation?

EMC effect

shadowing

Shadowing in DIS

Modification on partonic structure

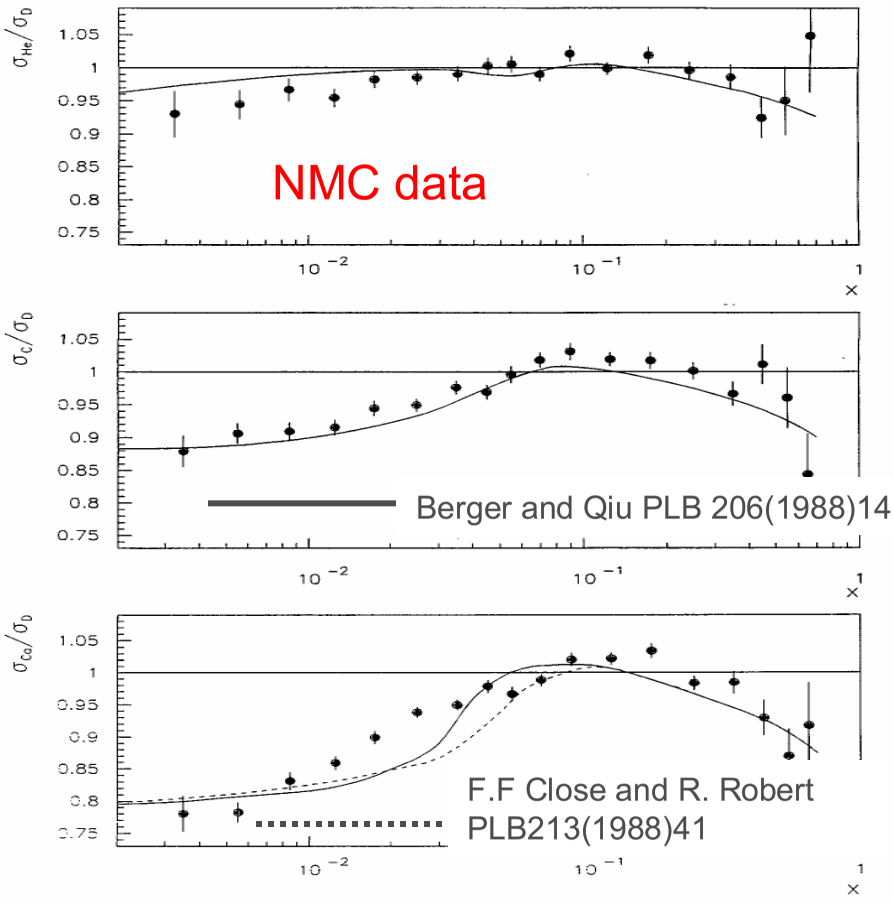
- Partons localized longitudinally with a distance $z = 1/(xp_N)$, if $z \geq 2R_AM/p_N$, partons from different nucleons overlap, fusion.

  $x_N = 1/(2R_NM) \sim 0.1$

  $x_A = 1/(2R_AM)$

  L.V. Gribov *et.al.* Nucl. Phys. B188(1981)555
  A.H. Mueller and **J. Qiu** Nucl. Phys. B268(1986)427
  K. J. Eskola, J. Qiu and **X.N. Wang**
  Phys.Rev.Lett. 72 (1994) 36-39

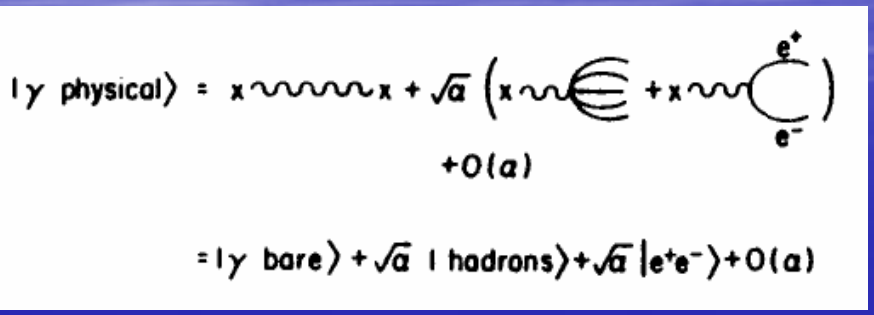
- Depletion in low x, enhancement in high x



Q^2 rescaling plus x_N and x_A for the onset of shadowing

Shadowing in DIS

Generalized Vector Meson Dominance (GVMD)



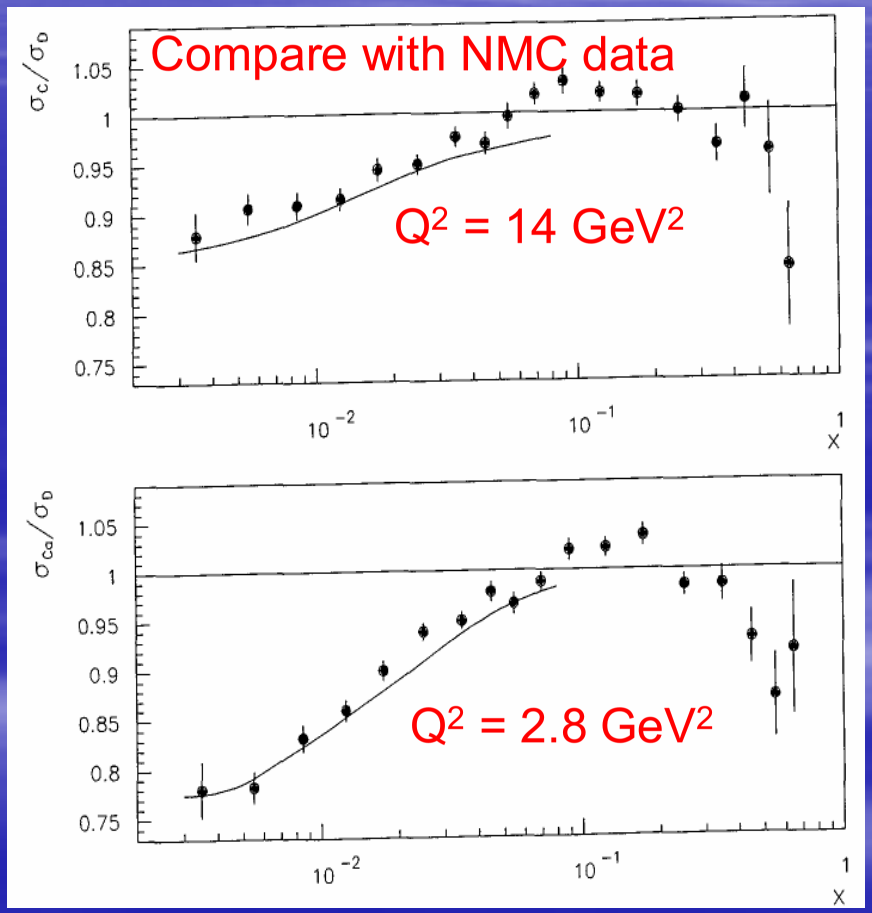
$$d(M_V^2, Q^2) = \frac{1}{\Delta E} = \frac{1}{Mx\,(1 + \frac{M_V^2}{Q^2})}$$

$$l(M_V^2) = \frac{1}{\sigma_V(M_V^2)\, n_0}$$

d is the coherent length of the vector meson, l is the mean free path.

$d > l$ && $R_A > l$

Shadowing effect disappears when x increases at fixed Q

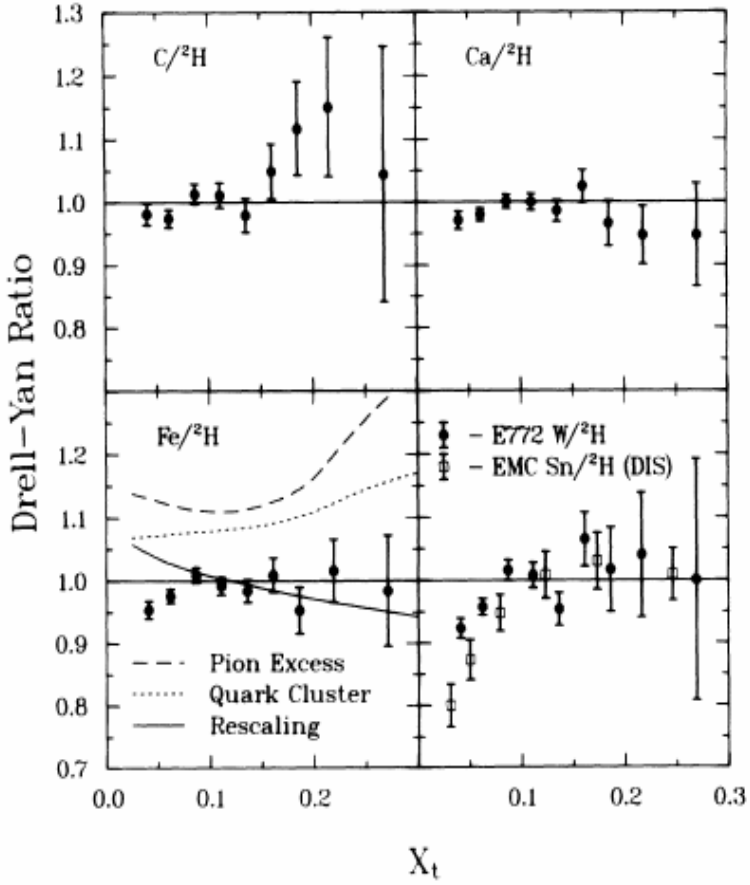


Michele Arneodo, Phys. Rep. 240(1994) 301
C.L. Bilchak, et.al. Phys. Lett. B 233(1989)461

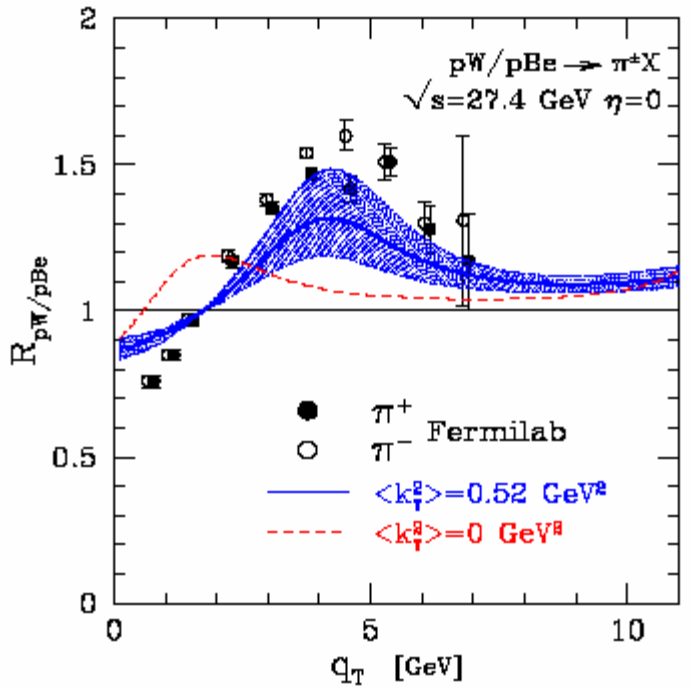
Proton Nucleus collisions

- pA or dA

Drell-Yan and J/Ψ



- Inclusive hadron production



Alberto Accardi and Miklos Gyulassy

J. Phys. G30 (2004) S969-S974

Nuclear modification @ RHIC