R_{cp} Measurements Using the PHENIX Muon Arms for $\sqrt{s_{NN}}$=200 GeV d+Au Collisions.

Andrew Glenn
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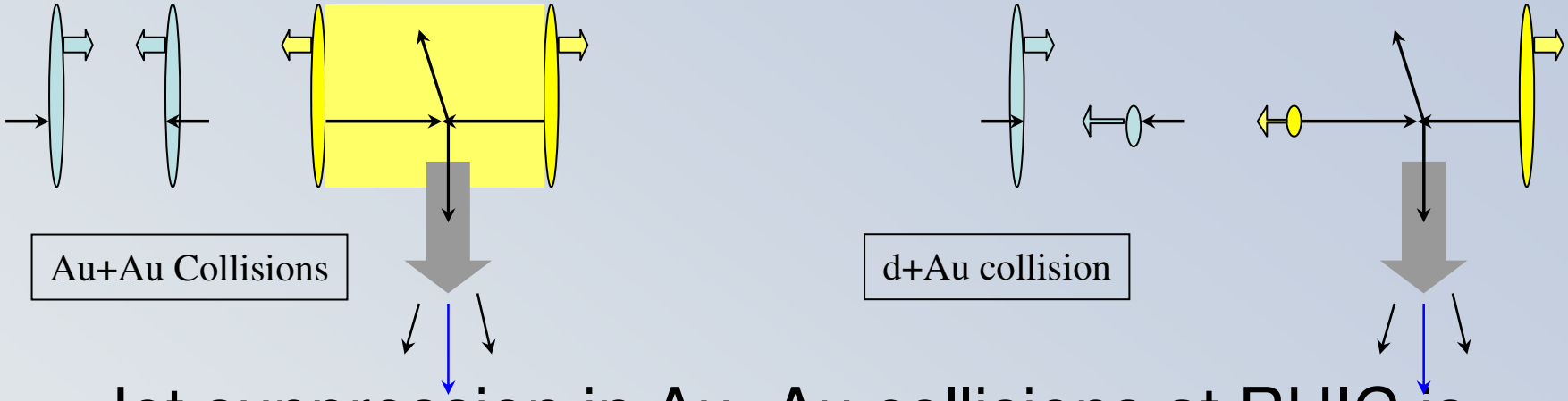
for the PHENIX collaboration

February 9, 2005

Motivation: Understanding the Initial State



- Jet suppression in Au+Au collisions at RHIC is seen as a possible evidence for deconfinement.
- Collisions of small with large nuclei can help us to quantify whether or not this is due to initial state effects/parton saturation or final state effects.

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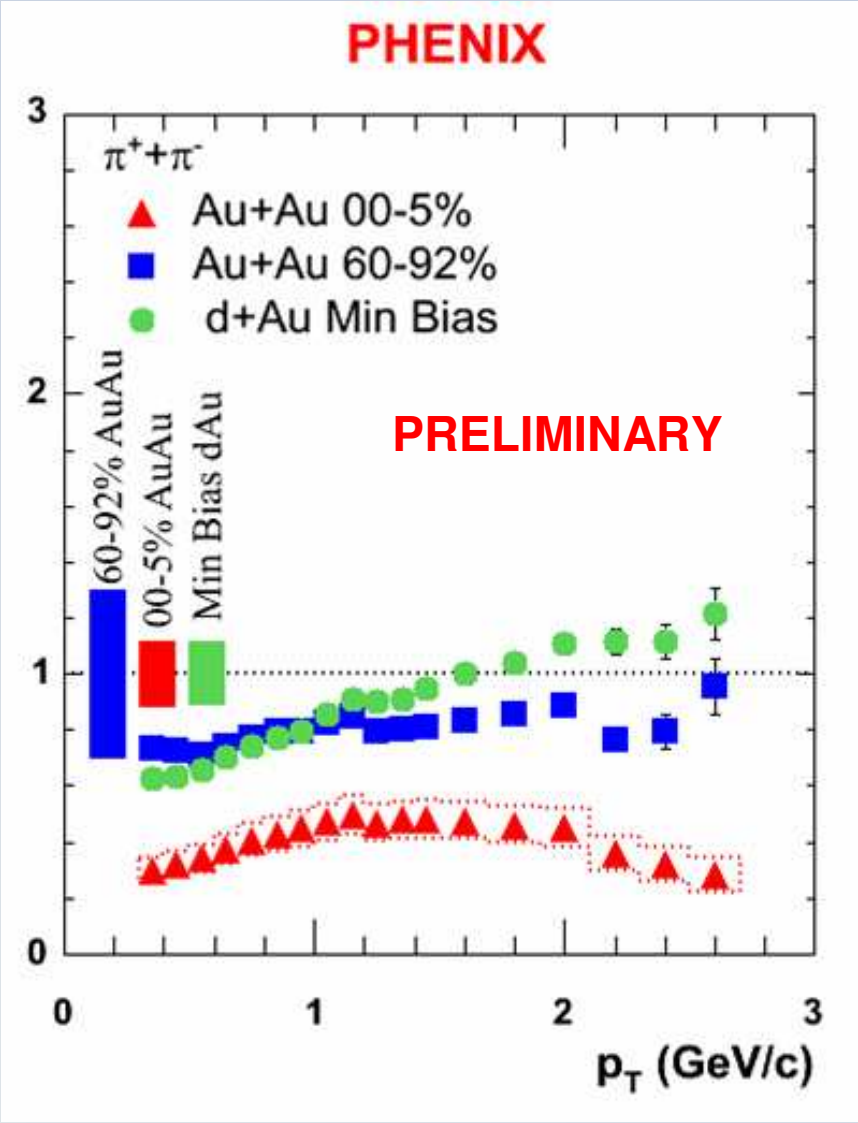
Nuclear Modification Factor: R_{AA}

- We define the nuclear modification factor as:

$$R_{AA}(p_T) = \frac{\frac{d^2\sigma^{AA}}{dp_T d\eta}}{\frac{< N_{binary} >}{\sigma_{inel}^{NN}} \frac{d^2\sigma^{NN}}{dp_T d\eta}}$$

- At mid-rapidity (for pions):
  - R_{AA}<<1 for Au+Au
  - R_{dA}>1 for d+Au
- Supporting evidence for "jet quenching". d+Au was needed to show final state effect.



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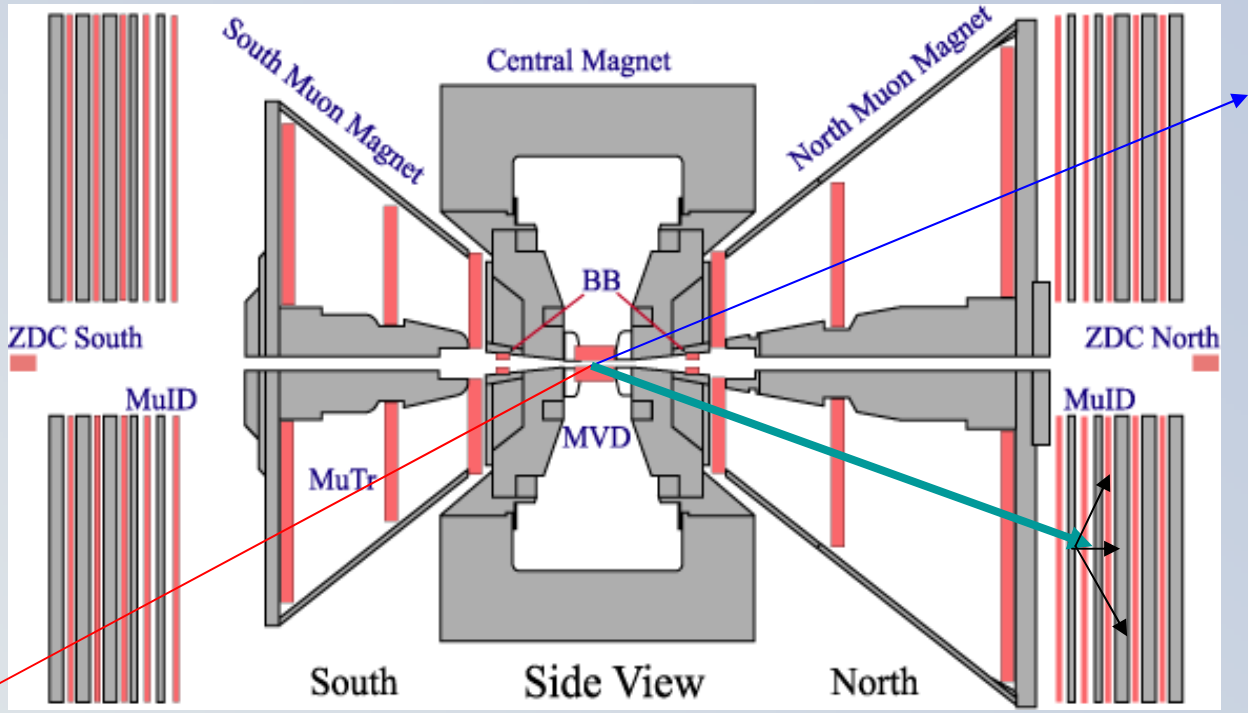
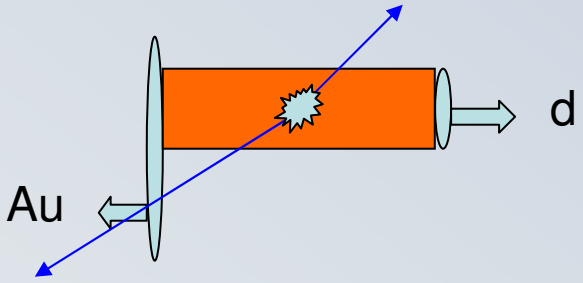
PHENIX Muon Detectors

- Muon arms
  - 1.2<|η|<2.4
  - Δφ=2π
  - P>2 GeV/c
  - Triggers
- "Muons"
  - Stopped hadrons
  - Light meson decays
  - Heavy decays





Two ways for Muon arms to study hadrons.

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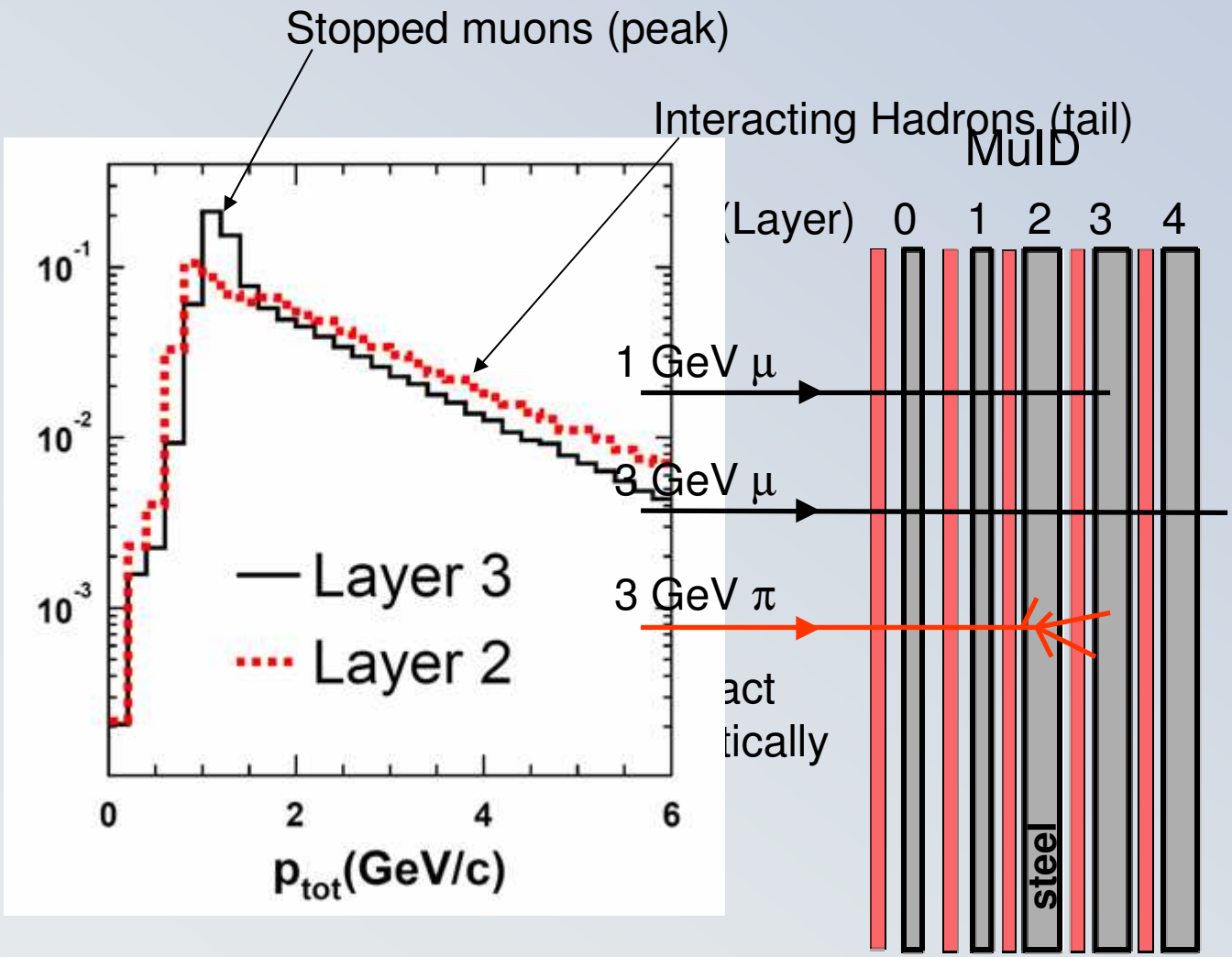
Interacting Hadrons



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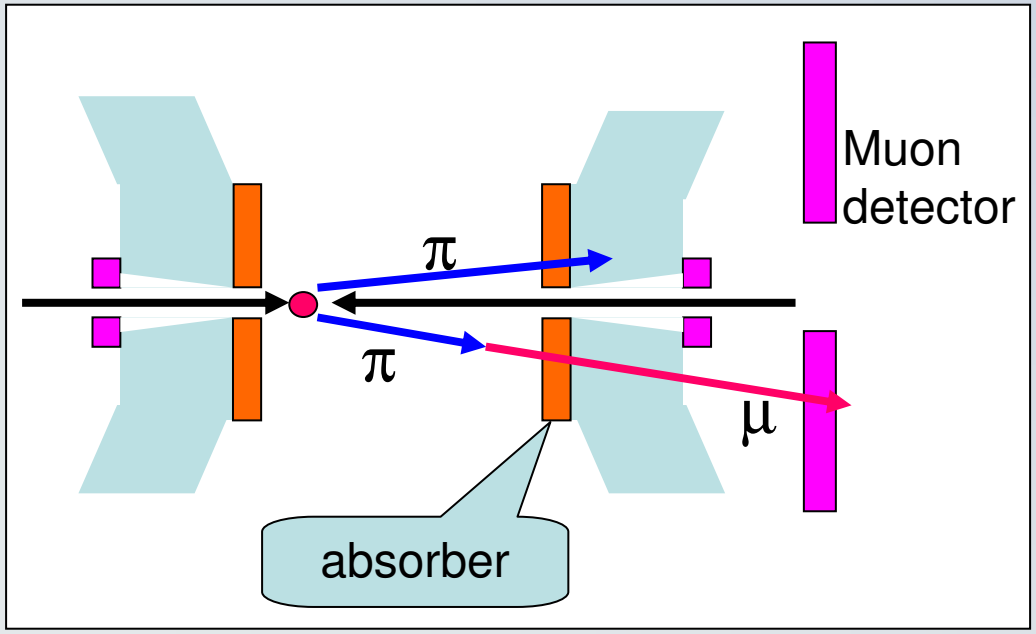
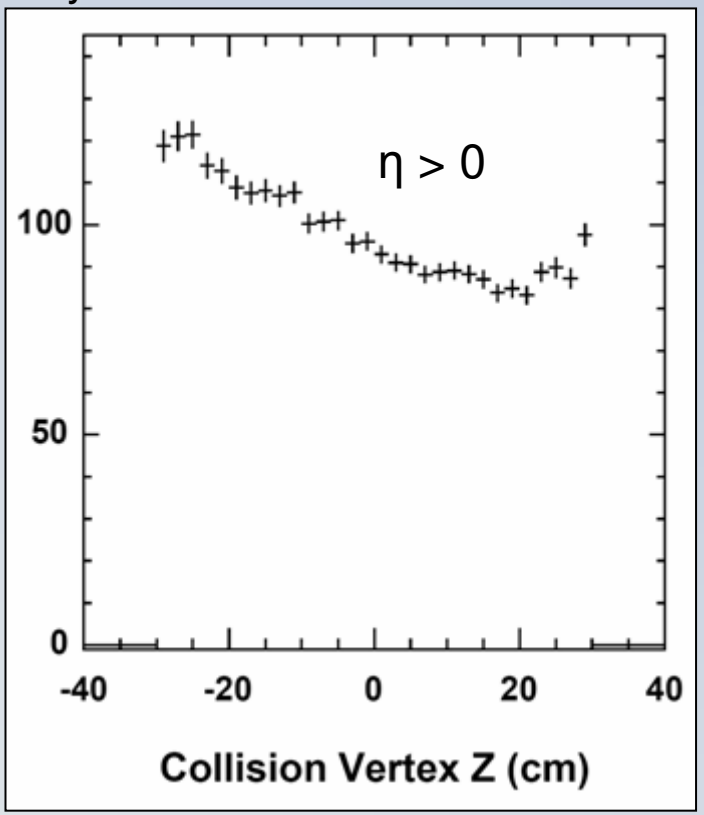
Muons from Light Meson Decays

- Muon event collision vertex distribution

- D $c\tau$ = 0.03 cm Decays before absorber
- π $c\tau$ = 780 cm Most are absorbed, but some decay first
- K $c\tau$ = 371 cm Most are absorbed, but some decay first

$\gamma c\tau >> 80$cm





Detector

Muon p_T ~ 0.85 parent p_T

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R_{CP} measurement

- R_{cp} is defined as particle yield in central collisions normalized by number of nucleon nucleon inelastic scatterings divided by particle yield in peripheral collisions normalized in the same way.

$$R_{CP} = \frac{\frac{1}{N_{binary}^{central}} \left(\frac{d^2N}{d\eta dp_T} \right)^{central}}{\frac{1}{N_{binary}^{peripheral}} \left(\frac{d^2N}{d\eta dp_T} \right)^{periperal}}$$

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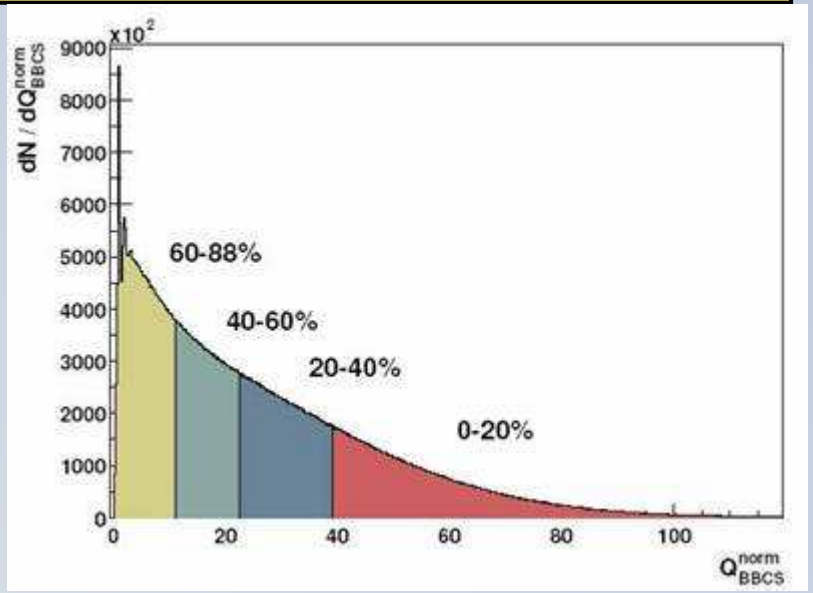
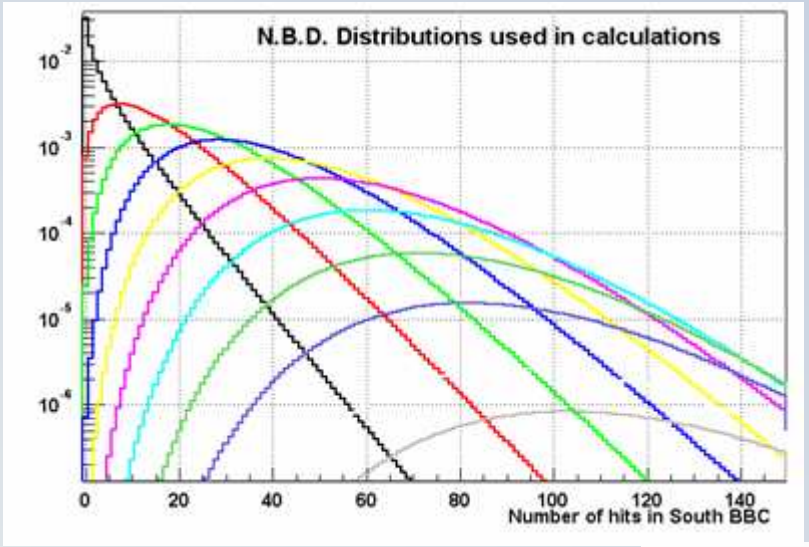
Centrality and N_{bin}

- Event centralities are defined as hard cut regions of BBC south hit distribution by the percentages of total dAu inelastic cross section
- Number of hits in south BBC is proportional to Au participants. The relation between them follows Negative Binominal Distribution.
- By comparing the number of hits distribution from data and the NBD, a hard cut region of BBC hit distribution can be mapped to an nbinary distribution.





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Bias due to BBC response

BBC as a detector responds to different physics processes in different ways.

- ***Effect one*** : Inelastic collisions with a hadron in our central or muon arm acceptance are more likely to fire the BBC detector than an unbiased inelastic collision. This causes a *trigger bias* in the yield because BBC+hadron events can be seen by BBC more easily than BBC events.
- ***Effect two*** : In general, hard binary collisions produce more particles. BBC may see more tracks. This causes the mapping from BBC nhit to nbinary different for different event categories. We call it *bin shifting*.
- For R_{cp} measurement, we need to take care both of trigger bias and bin shifting .
- Results in 0-7% corrections

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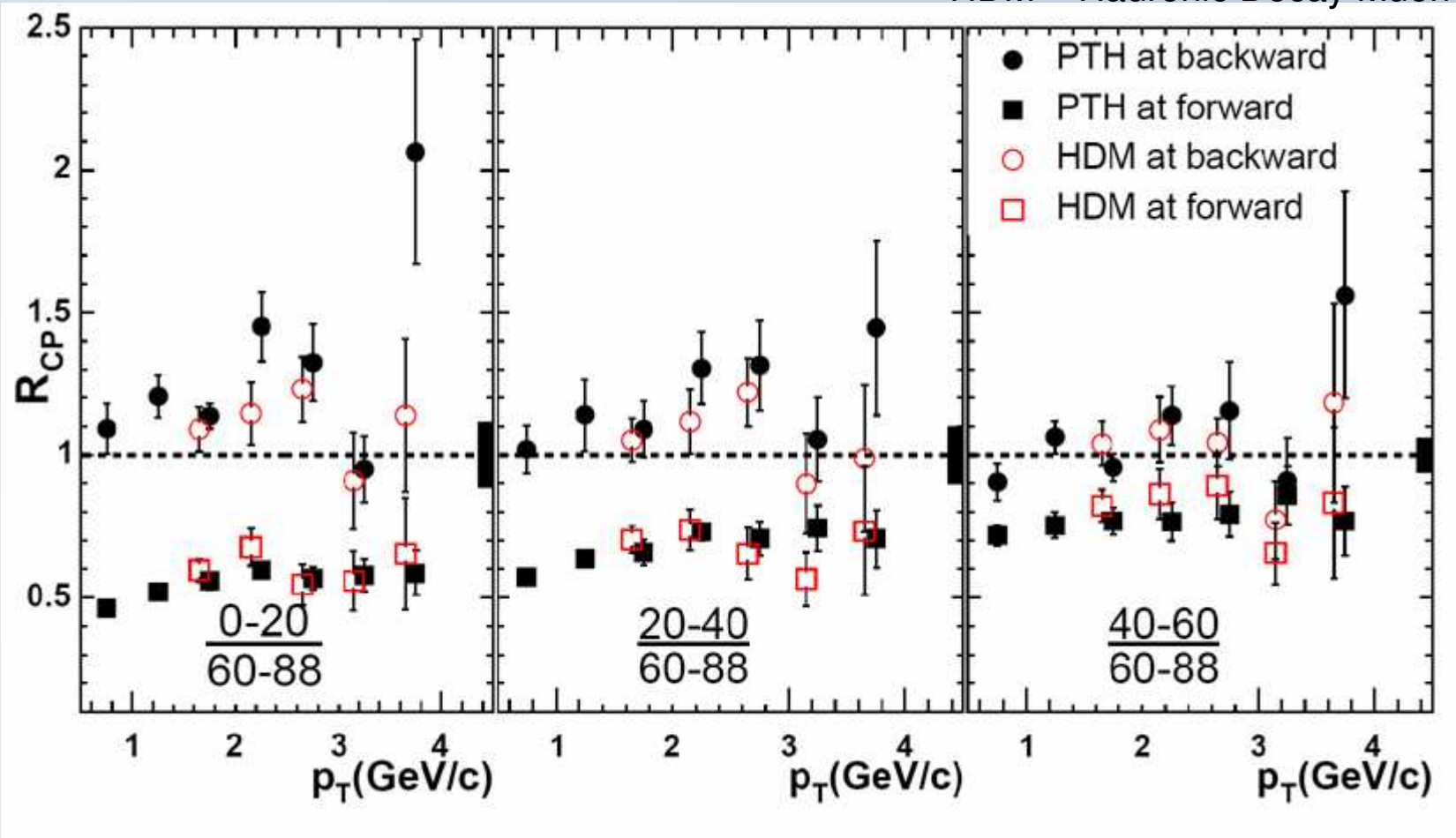
PHENIX Results

nucl-ex/0411054 (accepted by PRL)

PTH = Punch Through Hadrons
HDM = Hadronic Decay Muon



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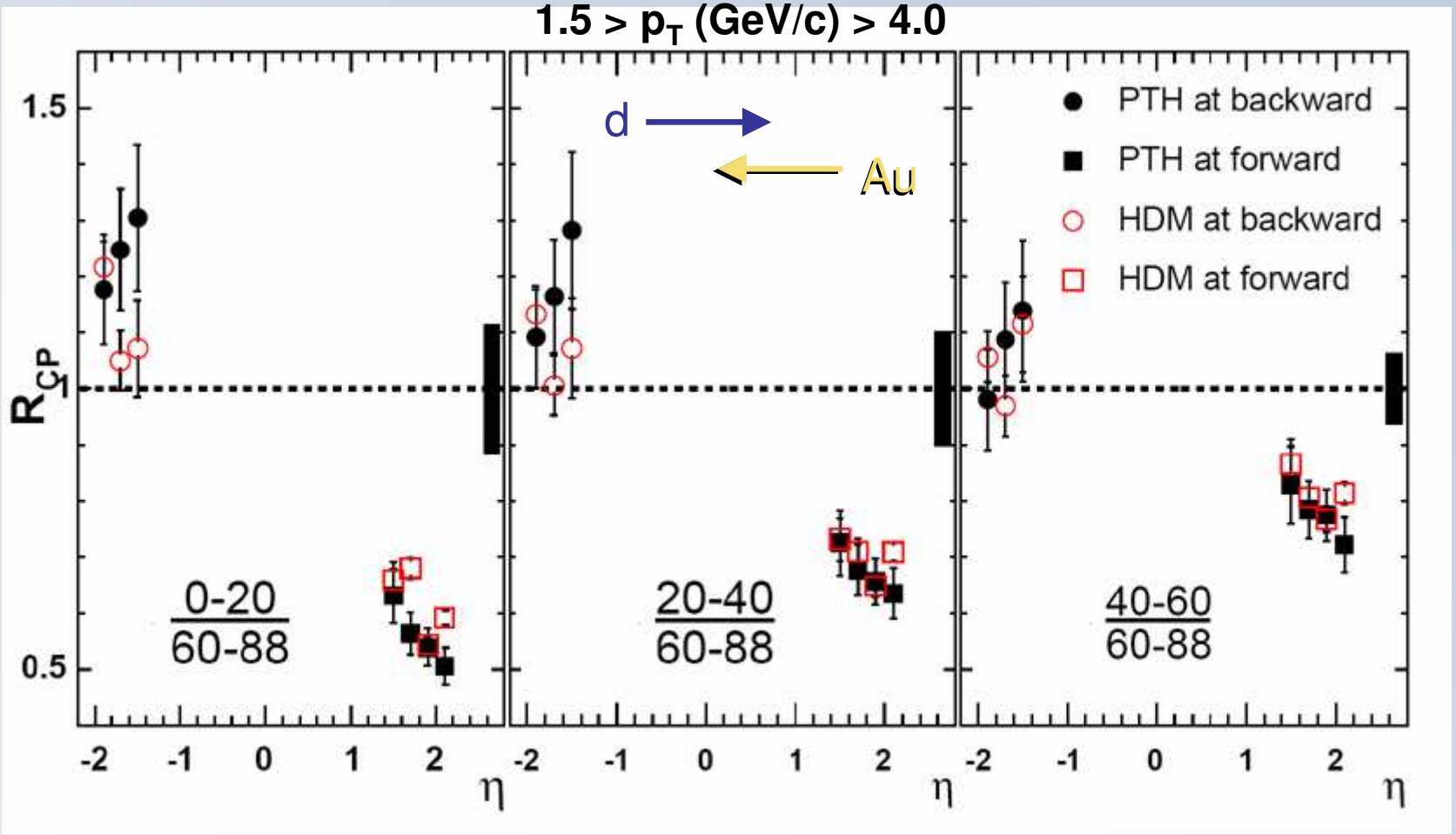
PHENIX Results II



Suppression at forward η. Slight enhancement in the backward η?

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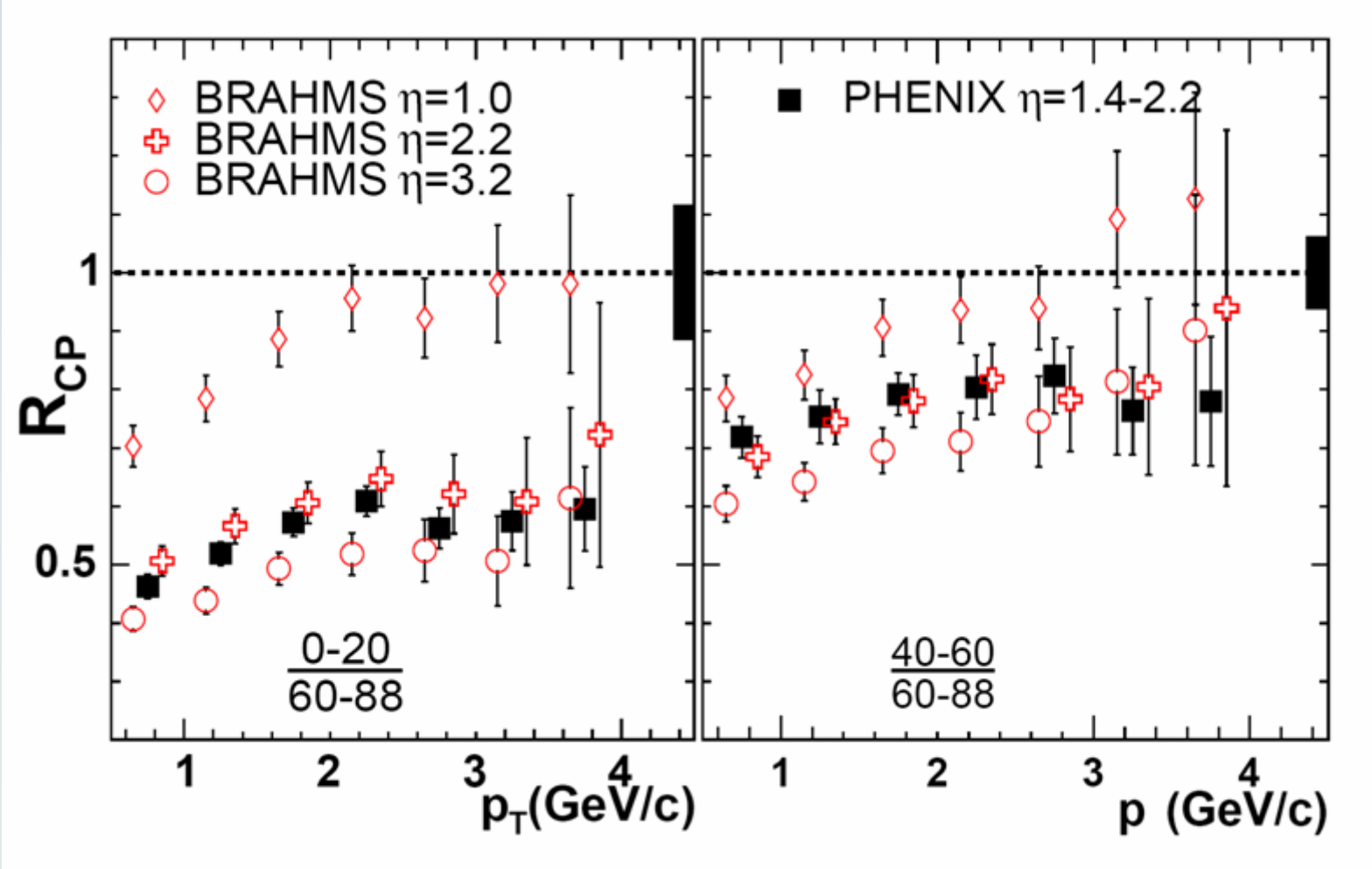
Compare with BRAHMS



Basically consistent. Systematically somewhat more forward suppression?

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Physics at forward rapidities

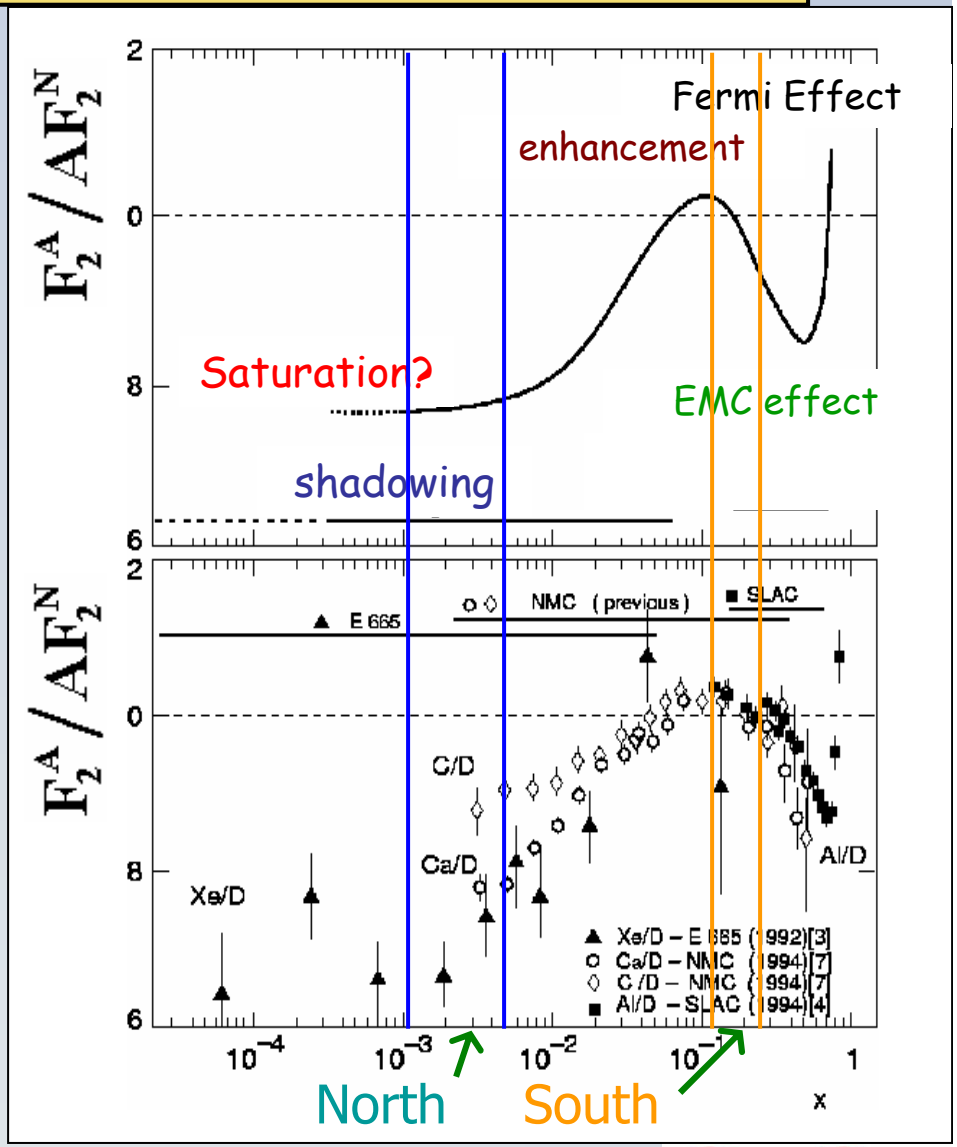
- New regime of parton physics at low-x.
- Can be reached by going to large rapidities.

For Au nuclei
(Going N to S)

$$x = \frac{M_T}{\sqrt{s}} e^{-y}$$

For deuterons
(Going S to N)

$$x = \frac{M_T}{\sqrt{s}} e^{y}$$



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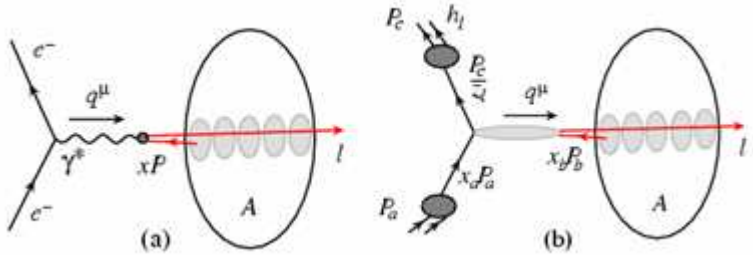
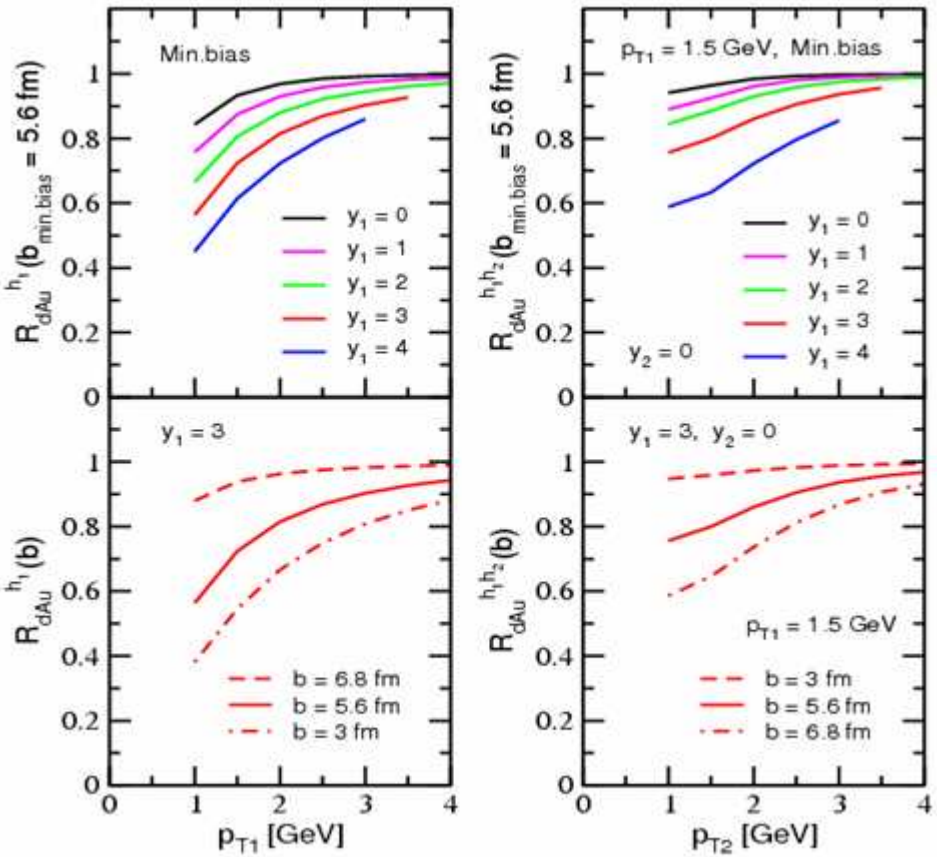
Coherent Multiple Scattering

- Depletion of small-x partons in a nucleus compared to those in a nucleon (Shadowing).
- Coherent multiple scattering can lead to dynamical nuclear shadowing.



- Leads to suppression at forward rapidities/more central events.

Qiu & Vitev hep-ph/0405068



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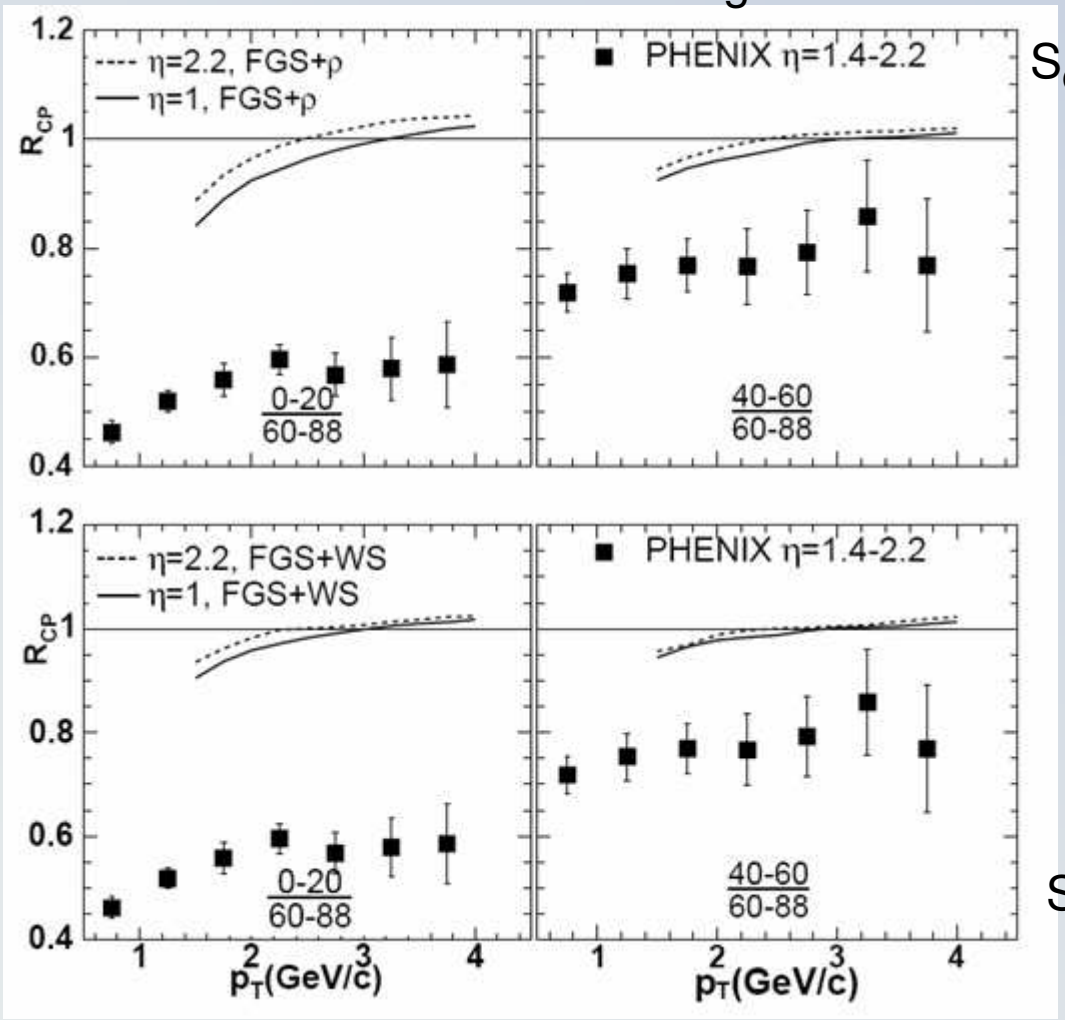
Direct Comparison with FGS

Hadron Punch Through



$S_{GFS,\rho}$

Calculation for BRAHMS R_{CP} which has a different centrality definition.
(R. Vogt arXiv:hep-ph/0405060)

The FGS shadowing parameterization does not reproduce the data well.

$S_{FGS,WS}$

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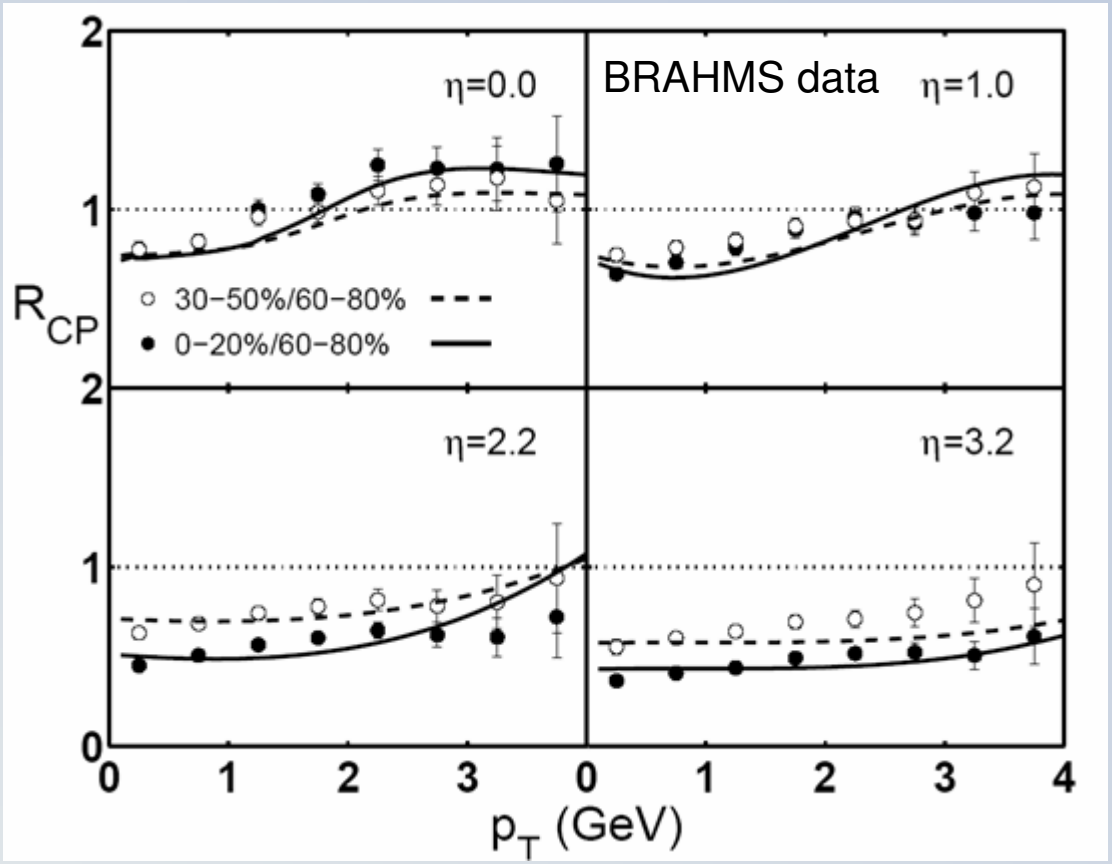
Recombination

- Recombination of soft and shower partons leads to a reduction of the soft parton density in the deuteron side.
- Explains the forward backward asymmetry and why R_{CP} (protons) > R_{CP} (mesons) at midrapidity.



Hwa, Yang and Fries nucl-th/0410111

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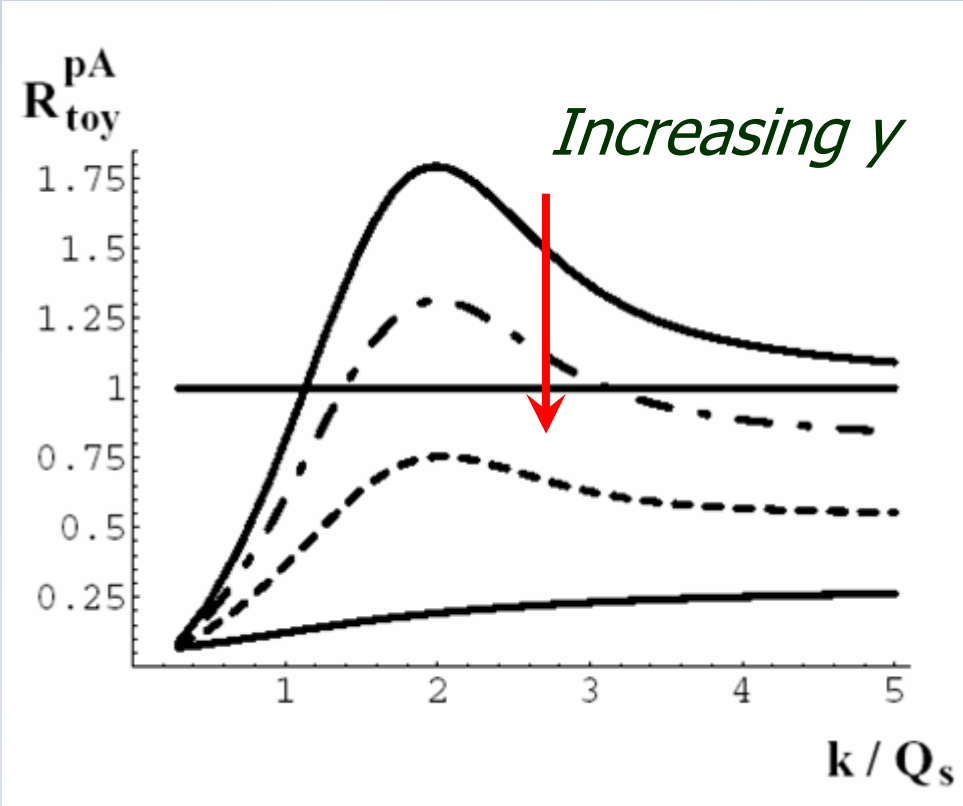
Color Glass Condensate

- Parton model => nucleon consists of “free” point-like constituents: quarks and gluons.
- Color Glass Condensate is a QCD based theory for the dense partonic matter at small-x and predicts depletion of scattering centers through gluon fusion processes (gluon saturation).

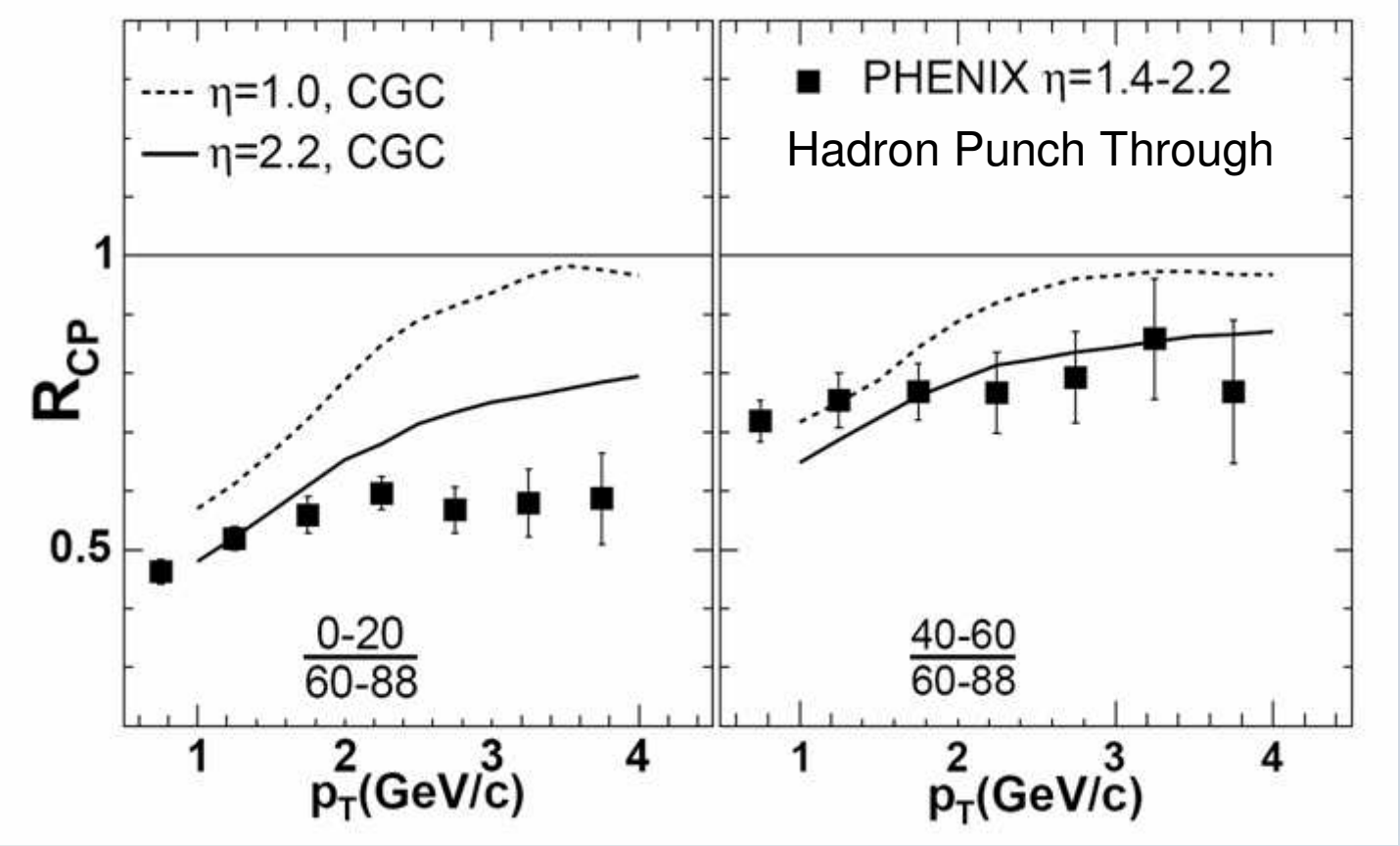
D. Kharzeev hep-ph/0307037



k *is transverse momentum of partons*

Q_s *is saturation scale*

CGC Model Comparison



Centrality and rapidity dependence are roughly correct.
This calculation does a slightly better job of reproducing the BRAHMS data.

Calculation from *Kharzeev* arXiv:hep-ph/0405045

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Summary

- We have measured charged hadron R_{CP} using the PHENIX Muon Arms for d+Au collisions.
- Much care is required for d+Au centrality.
- We observe:
  - Slight enhancement on the Gold going direction (South Arm).
  - Suppression on the Deuteron going direction (North Arm).
- Forward suppression is qualitatively consistent with several theories from shadowing/saturation type effects. Various possible contributions.
- Slight enhancement at backward rapidity is not well understood (anti-shadowing).

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	Peking University, Beijing
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	Dapnia, CEA Saclay, Gif-sur-Yvette
	IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, Orsay
	LLR, Ecòle Polytechnique, CNRS-IN2P3, Palaiseau
	SUBATECH, Ecòle des Mines at Nantes, Nantes
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	Eötvös Loránd University (ELTE), Budapest
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	Kyoto University, Kyoto
	Nagasaki Institute of Applied Science, Nagasaki
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	Korea University, Seoul
	Myong Ji University, Yongin City
	System Electronics Laboratory, Seoul Nat. University, Seoul
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	Joint Institute for Nuclear Research, Dubna
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	St. Petersburg State Technical University, St. Petersburg
Sweden	Lund University, Lund

*12 Countries; 58 Institutions; 480 Participants**

** as of January 2004*

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	University of California - Riverside, Riverside, CA
	University of Colorado, Boulder, CO
	Columbia University, Nevis Laboratories, Irvington, NY
	Florida State University, Tallahassee, FL
	Florida Technical University, Melbourne, FL
	Georgia State University, Atlanta, GA
	University of Illinois Urbana Champaign, Urbana-Champaign, IL
	Iowa State University and Ames Laboratory, Ames, IA
	Los Alamos National Laboratory, Los Alamos, NM
	Lawrence Livermore National Laboratory, Livermore, CA
	University of New Mexico, Albuquerque, NM
	New Mexico State University, Las Cruces, NM
	Dept. of Chemistry, Stony Brook Univ., Stony Brook, NY
	Dept. Phys. and Astronomy, Stony Brook Univ., Stony Brook, NY
	Oak Ridge National Laboratory, Oak Ridge, TN
	University of Tennessee, Knoxville, TN
	Vanderbilt University, Nashville, TN

Decay Muons

Light hadrons like pions and kaons can decay into muons before reaching the MuID.

The decay probability of a meson with momentum p is proportional to the distance (L) between collision vertex and absorber:

$$P_{decay}(p, L) = 1 - e^{-\frac{L \cdot m}{\tau \cdot p}}$$

Hence by looking at the the z-vertex distribution for events with single muon candidates, we can separate the muons that come from pions/kaons from other contributions.

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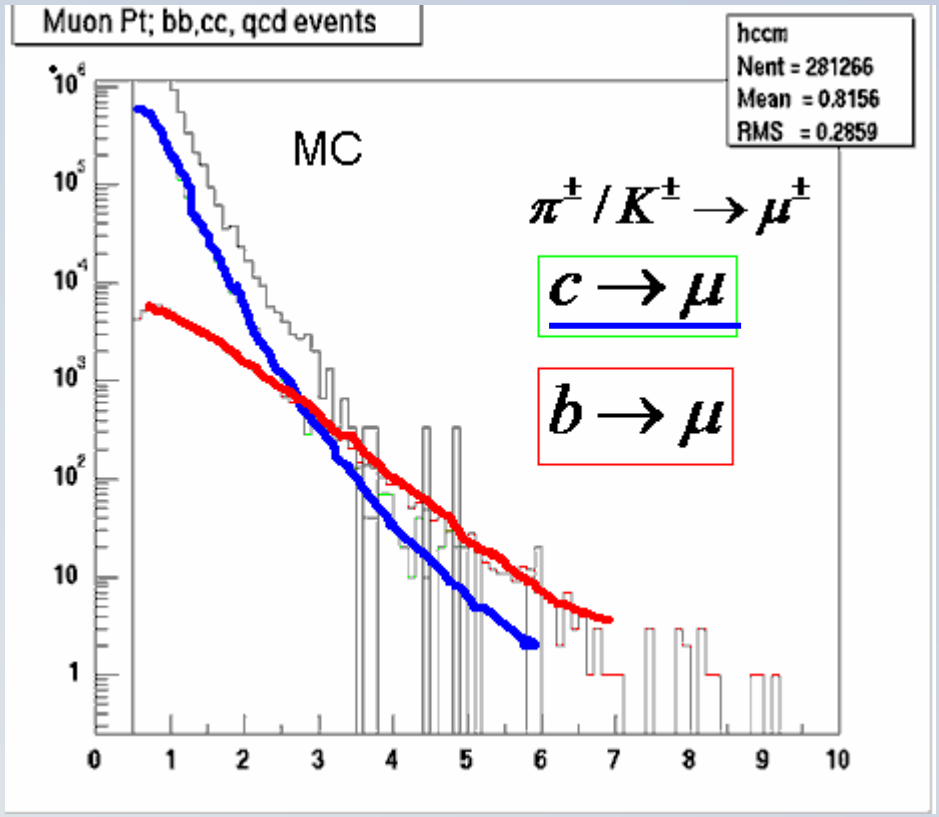
Muon Production

- Origins of muons
  - PYTHIA p+p @ $\sqrt{s}$=200GeV
  - low P_T:
    - light hadron decays
  - high P_T:
    - Heavy quark decays

$$BR(c \to \mu^+ + X) = 10\%$$
$$BR(b \to \mu^- + X) = 10\%$$
$$BR(\pi^+ \to \mu^+ + \nu_\mu) = 99.99\%$$
$$BR(K^+ \to \mu^+ + \nu_\mu) = 63\%$$



Muon P_T distribution

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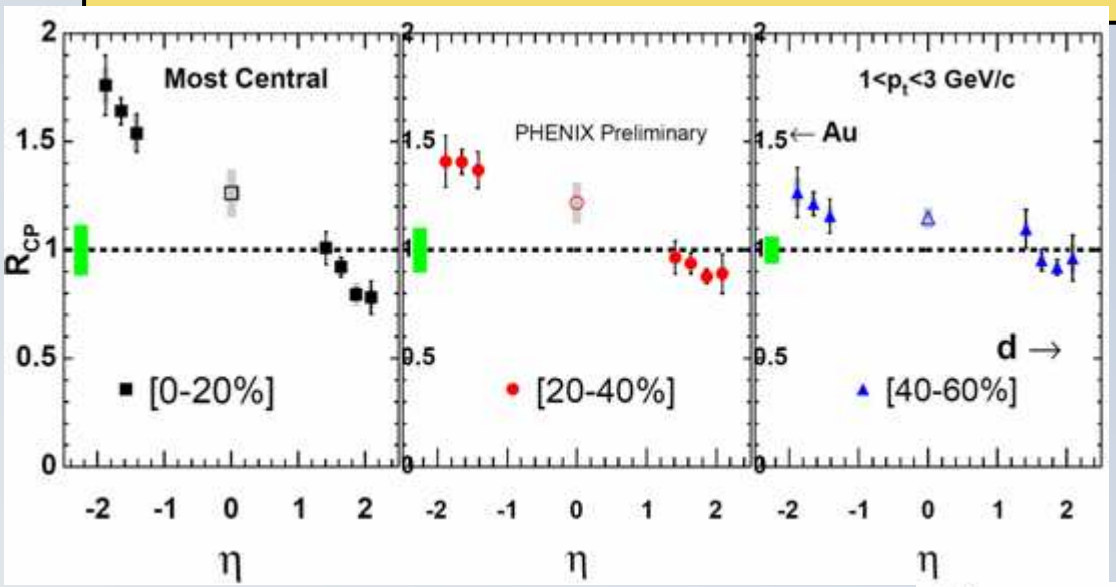
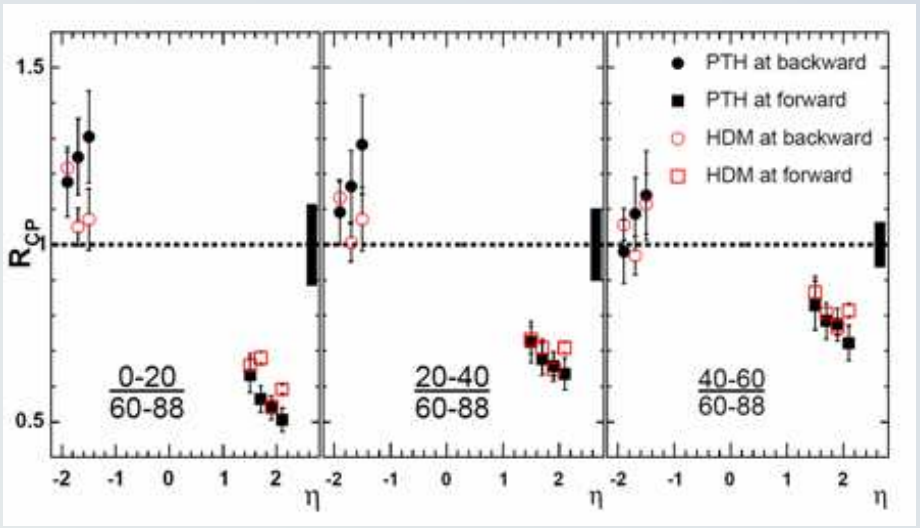
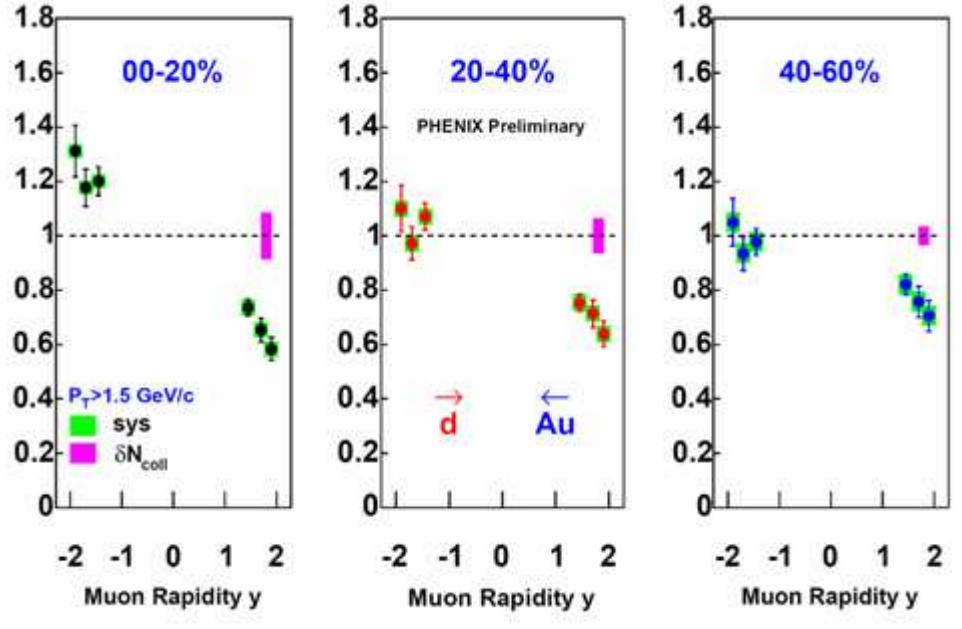
QM'04







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(Going N to S)

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For deuterons
(Going S to N)

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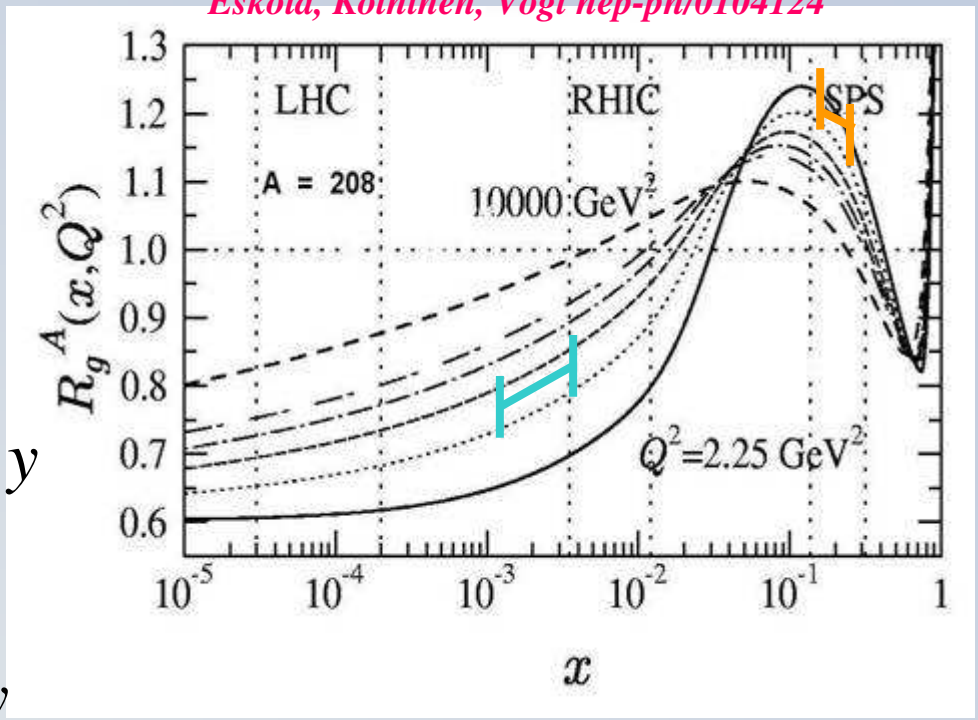
Eskola, Kolhinen, Vogt hep-ph/0104124



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