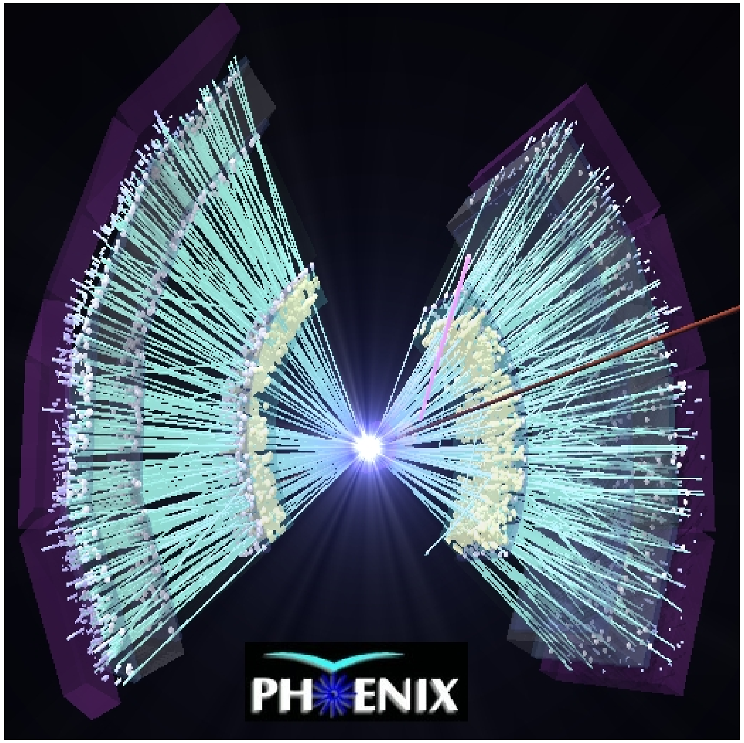
Probing initial states at RHIC through particle production at forward & backward rapidities using the PHENIX Muon Arms



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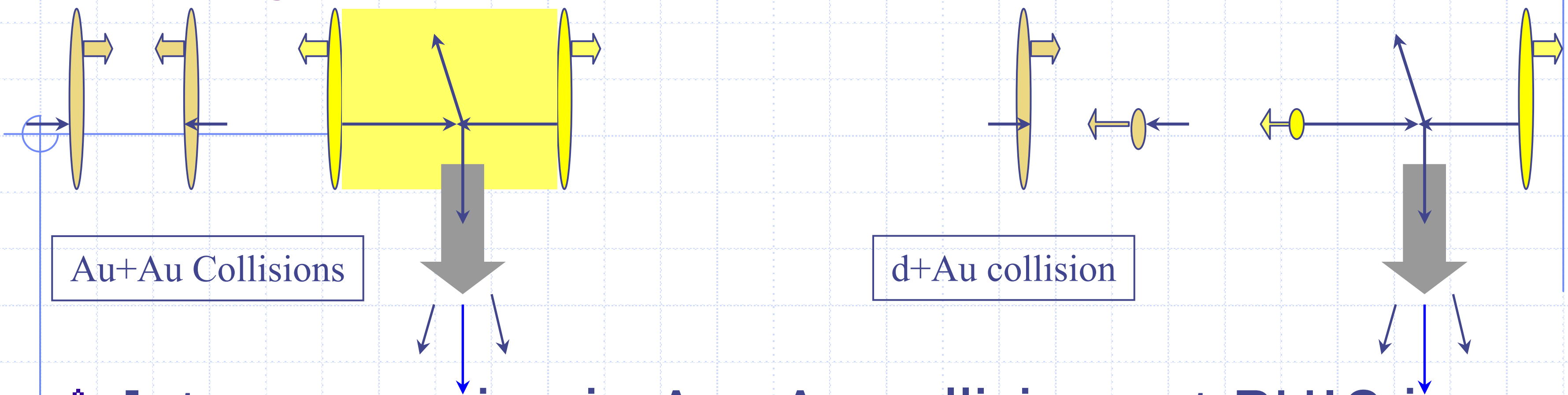
Kolkata, India

Story of the Initial State



- Jet suppression in Au+Au collisions at RHIC is seen as a possible signature of deconfinement via quenching.
- 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.

Nuclear Modification Factor: R_{AA}

- We define the nuclear modification factor as:

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

- At mid-rapidity (for pions):
  - $R_{AA} << 1$ for Au+Au
  - $R_{dA} > 1$ for d+Au
- Final state interactions responsible for "jet quenching" instead of initial states.

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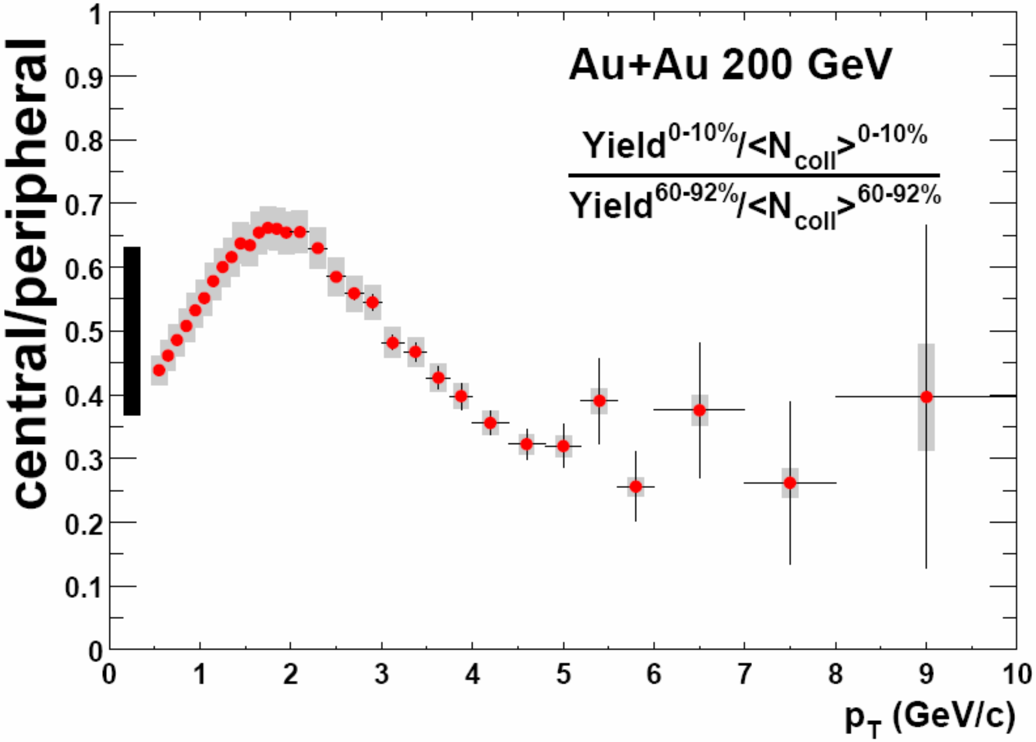
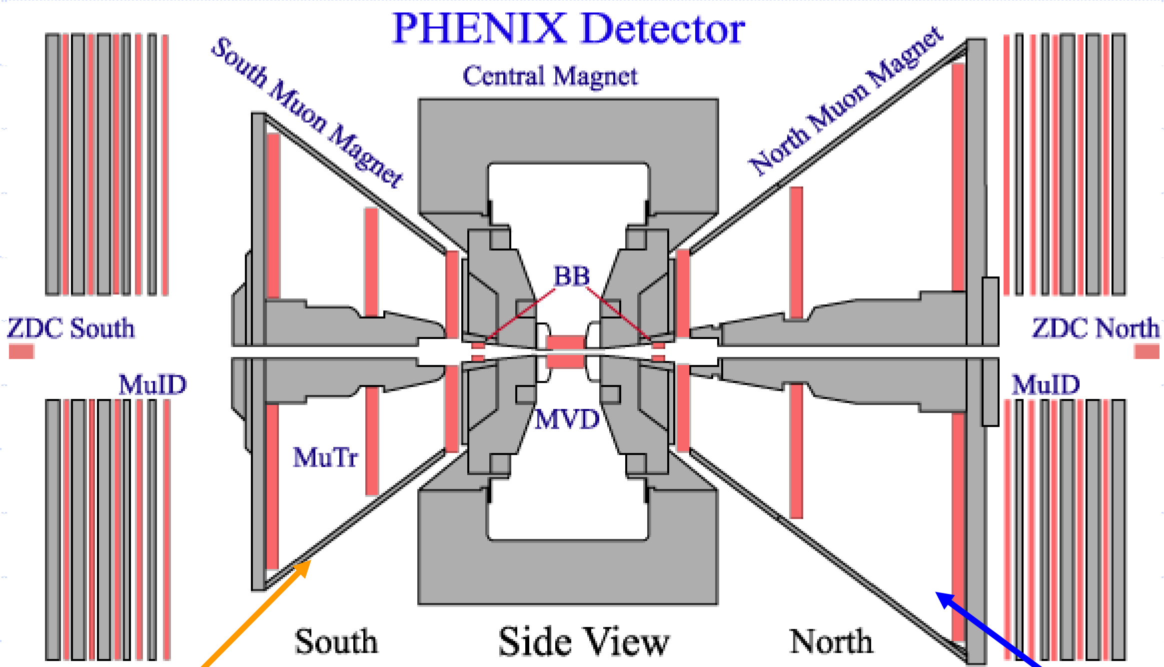


The PHENIX Detector

deuteron → ← *gold*



South Muon arm : $-2.2 < \eta < -1.2$

North Muon arm : $1.2 < \eta < 2.4$

Physics at forward rapidities

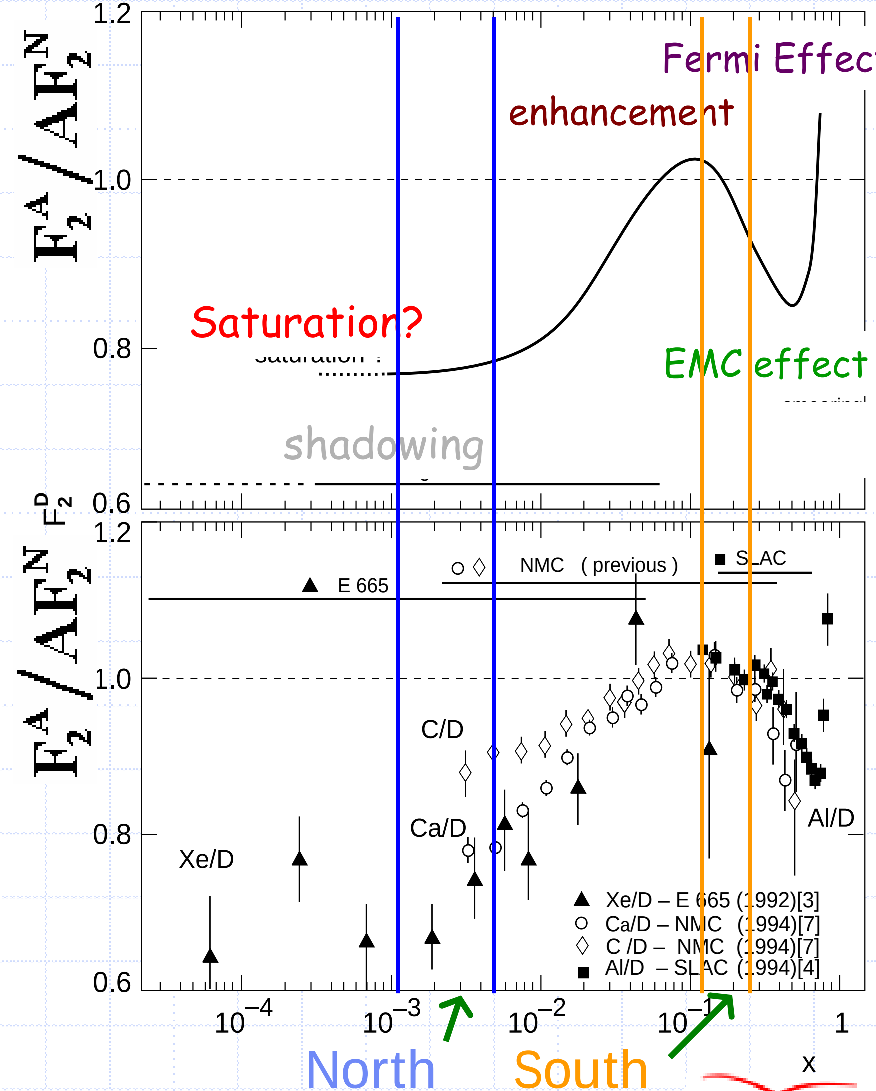
- New regime of parton physics at low-x.
- Can be reached by going to large rapidities.

For Au nuclei (Going N to S)

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

For deuterons (Going S to N)

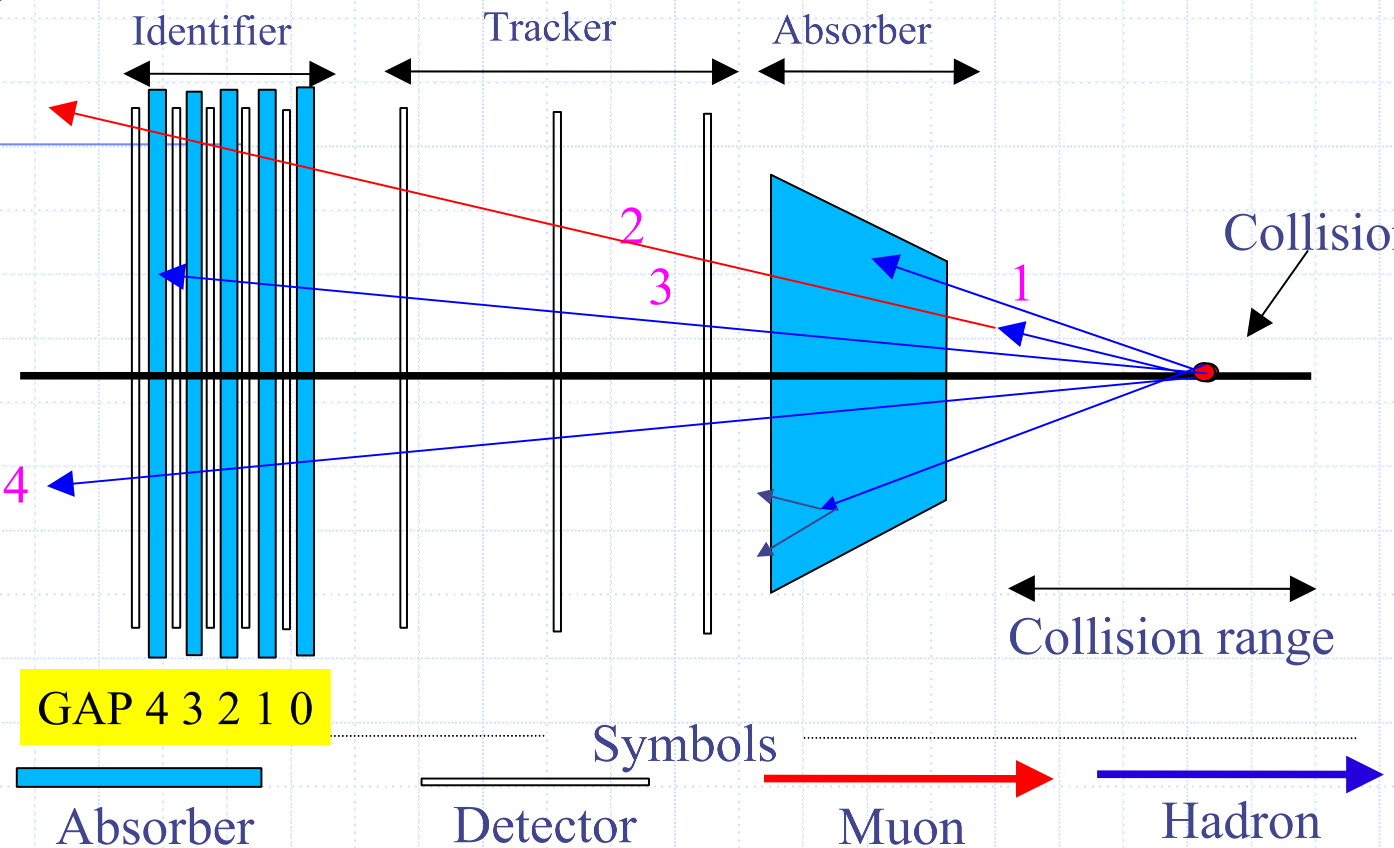
$$x = \frac{M_T}{\sqrt{s}} e^{y}$$



Hadron selection

- PHENIX Muon arms can be used to detect hadrons by two methods:
  - Hadrons which penetrate partway into the MuID steel and stop, unlike muons which go all the way to the back. These are the punchthrough hadrons.
  - As light mesons (primarily pions and kaons) travel through the detector, they decay into muons. Yields of these hadron decay muons can allow us to obtain information about the parent mesons.

Major Sources of Hadronic Tracks



1 : Hadrons, interacting and absorbed (98%)

2 : Charged π/K's, "decaying" before absorber (≤1%)

3 : Hadrons, penetrating and interacting ("stopped")

4 : Hadrons, "punch-through"

Analysis Details

- 67 million minimum bias events and 5.8×10^9 events triggered by a track penetrating into deepest layer of the MuID.
- R_{CP}: Ratio between the central and peripheral yields scaled by the number of binary collisions, where it is assumed that peripheral is similar to pp:

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

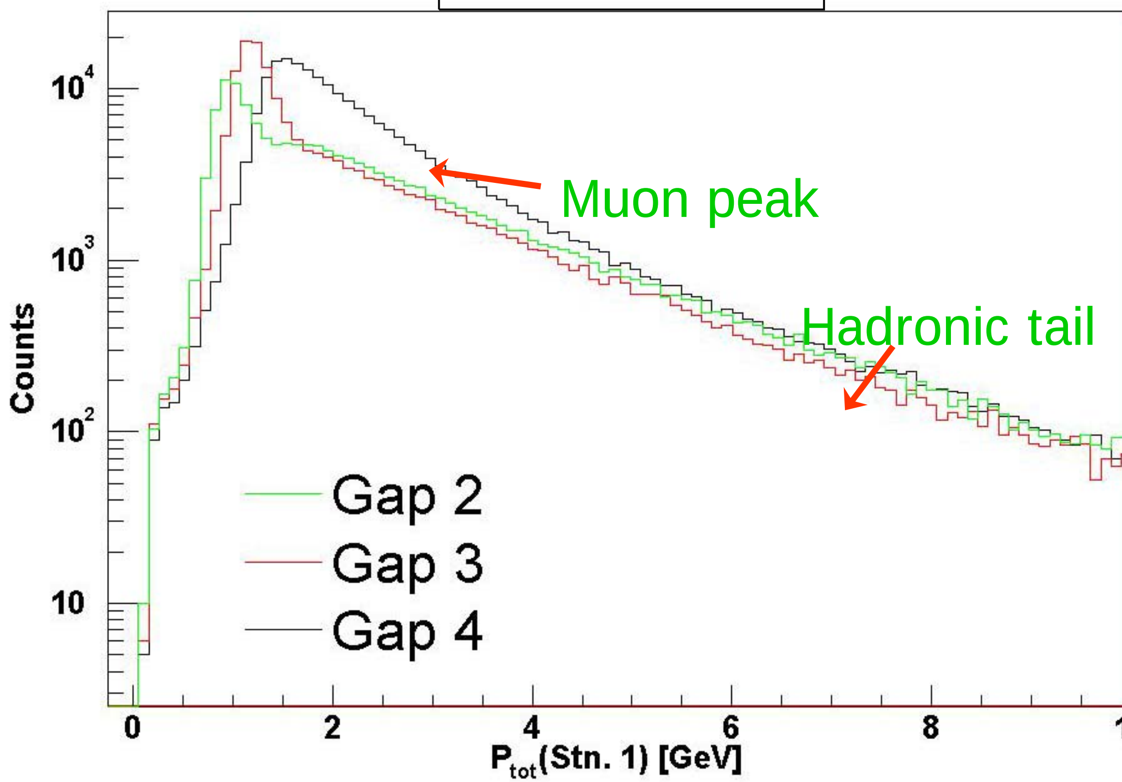
- Advantage: a lot of detector systematics cancel.
- Disadvantage: most peripheral bin of 60-88% still corresponds to 3-4 collisions and not all nuclear effects might be eliminated.

Punchthroughs

- MuID has several layers of steel, so deeper a particle penetrates, greater is the chance that it is a muon.
- Use shallow MuID layers (Gap 2 & 3) to select stopped hadrons.

Muons in deep gap

Hadrons in shallow gaps



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:

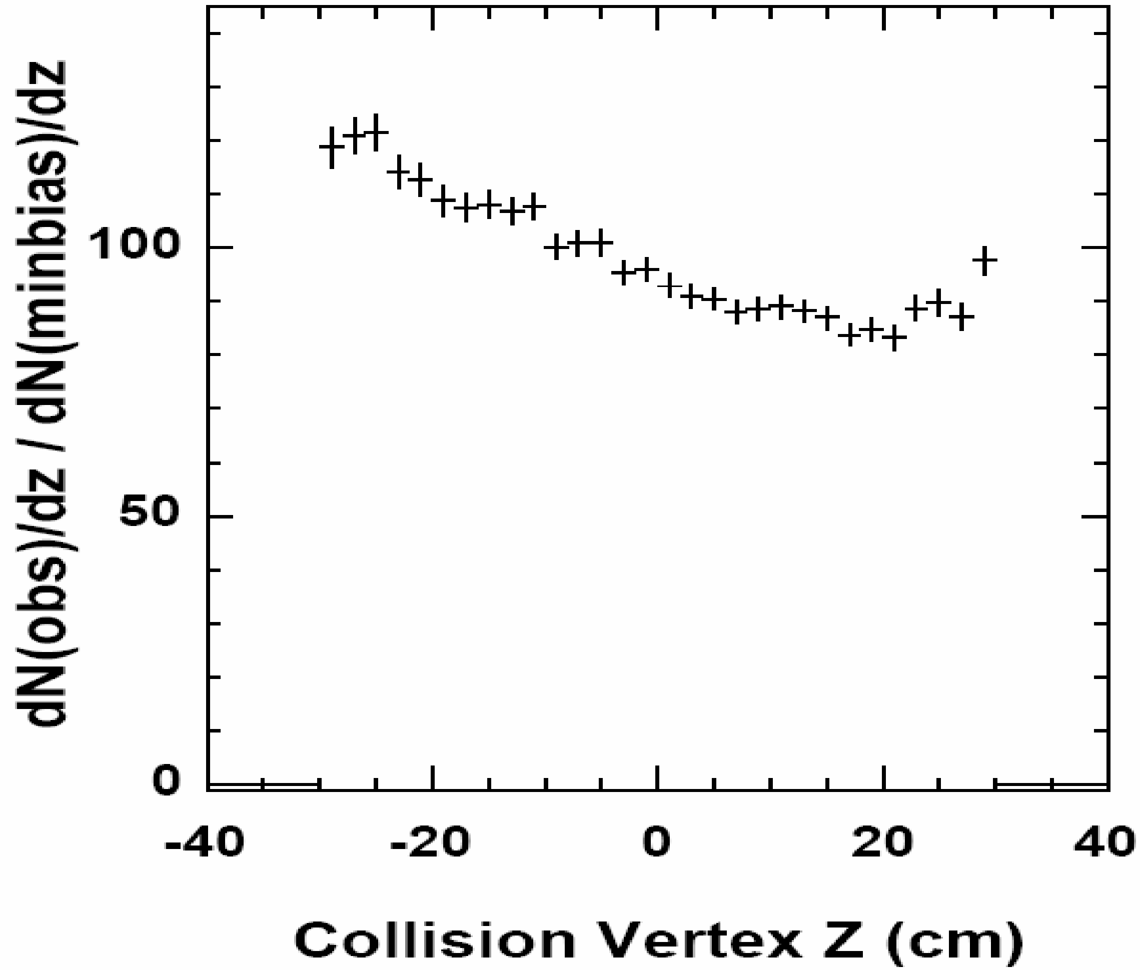
$$P_{decay}(p, L) = 1 - e^{-\frac{L \cdot m}{\tau \cdot p}}$$

- 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.

Decay muons and z dependence

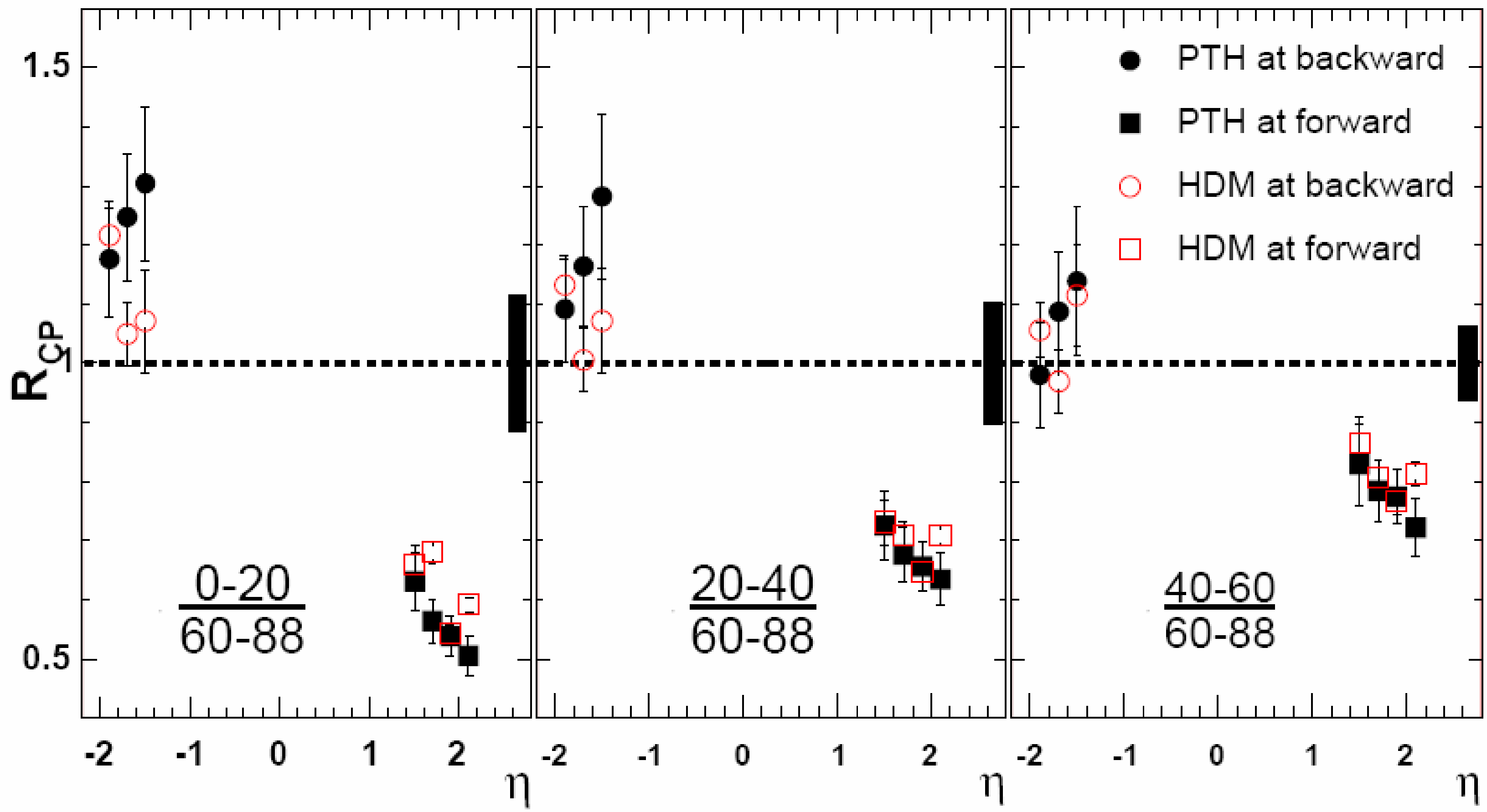
nucl-ex/0411054 (accepted by PRL)

- Pion and kaon decay contributions have z dependence.
- Other contributions (e.g. D mesons) are flat.



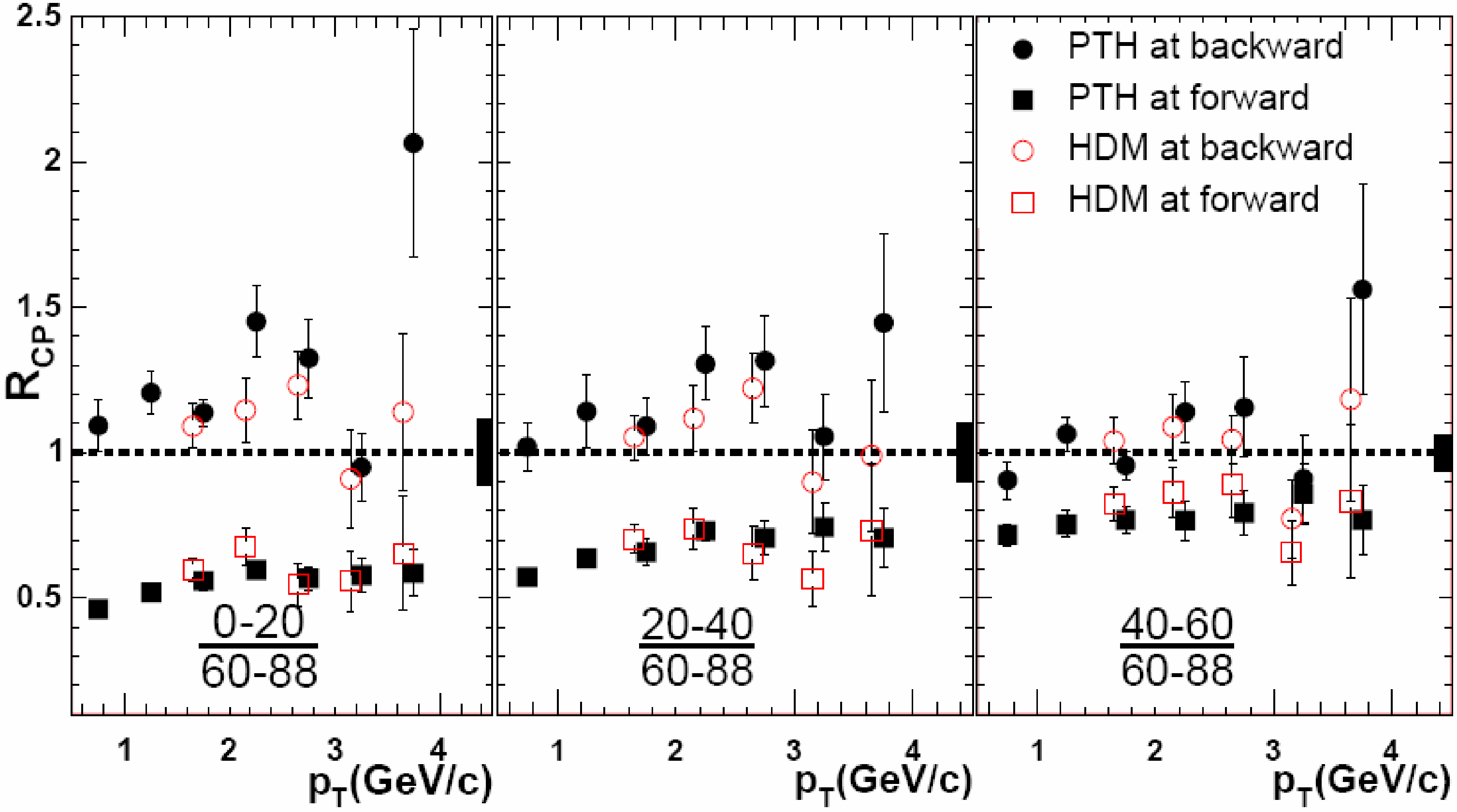
R_{cp} vs η (1.5 < p_T 4.0 GeV/c)

nucl-ex/0411054 (accepted by PRL)



- Suppression forward and enhancement backward

R_{cp} vs p_T at forward & backward rapidity *nucl-ex/0411054 (accepted by PRL)*

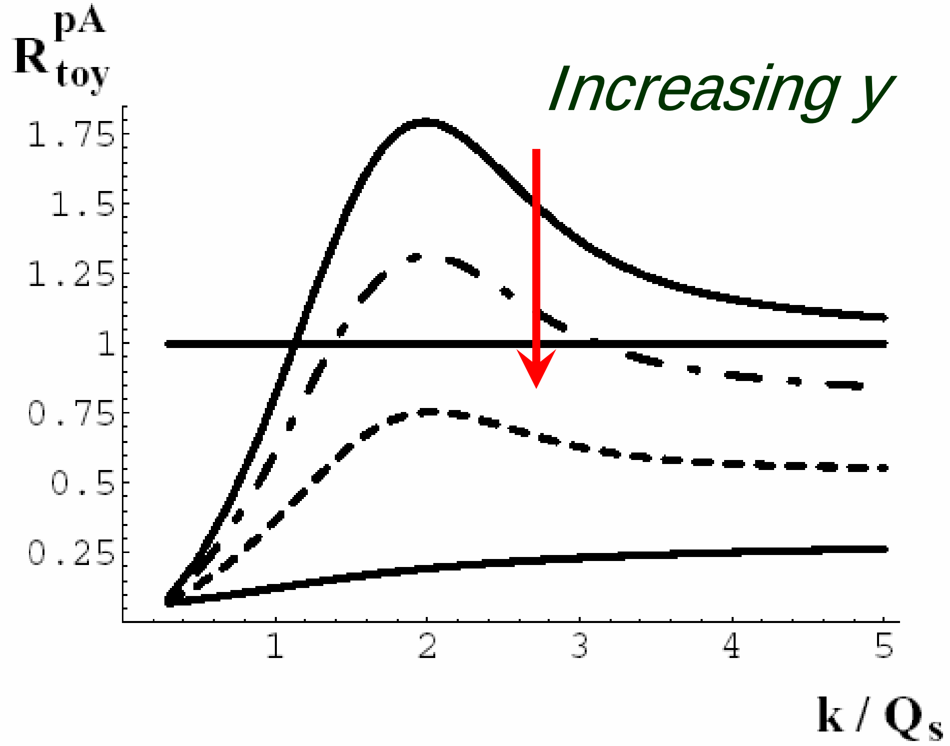


- R_{CP} rather independent of p_T

Model: 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.

D. Kharzeev hep-ph/0307037



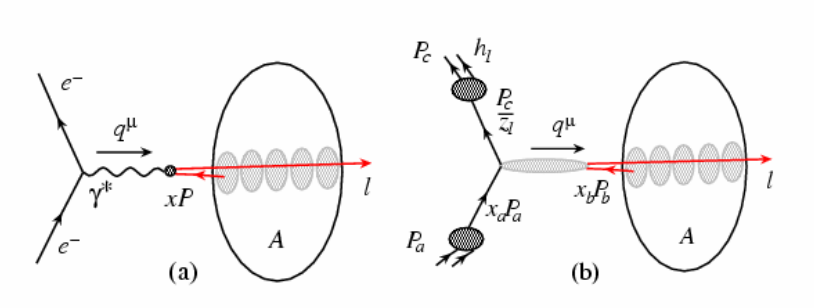
k *is transverse momentum of partons*

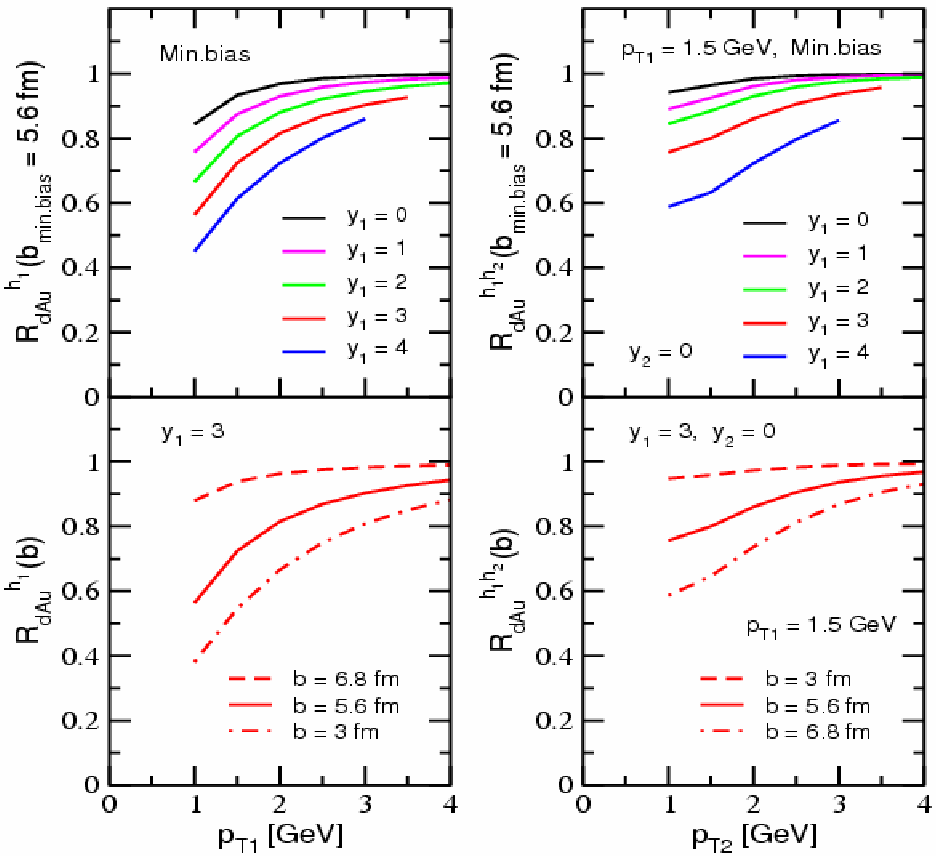
Q_s *is saturation scale*

Model: 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.

Qiu & Vitev hep-ph/0405068



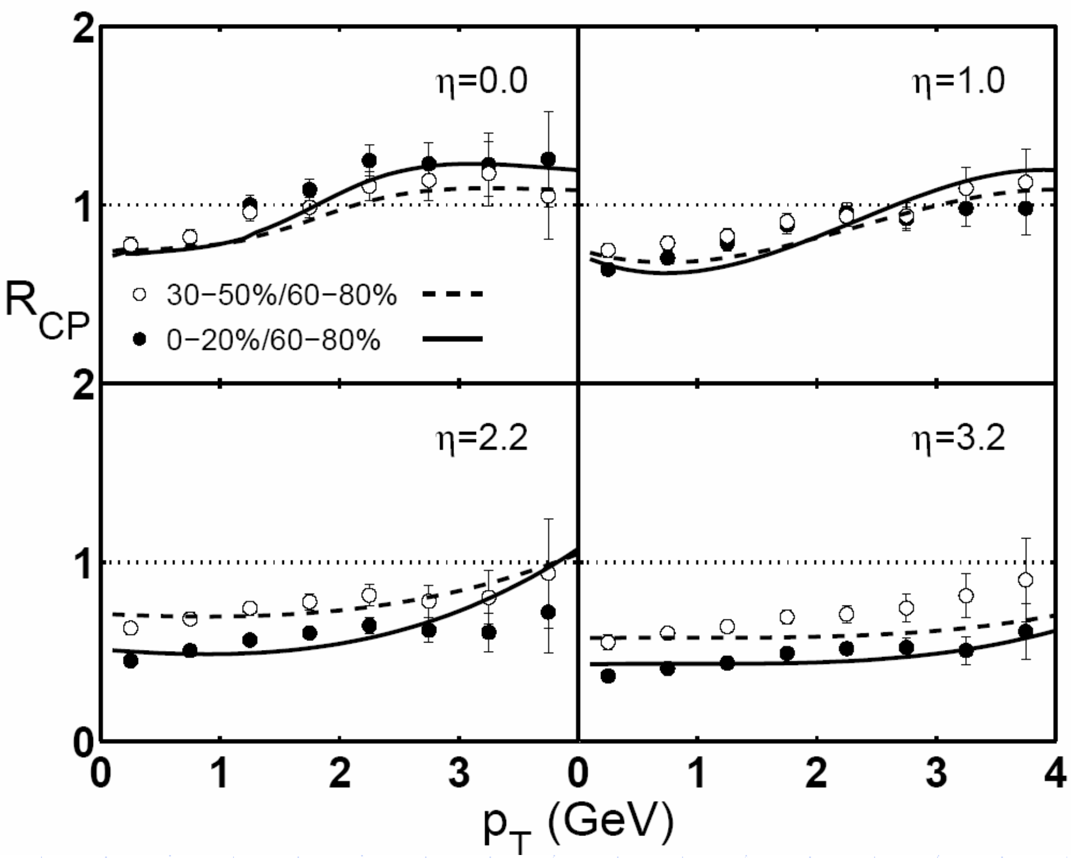


- Leads to suppression at forward rapidities/more central events.

Model: Recombination?

Hwa, Yang and Fries nucl-th/0410111

- 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.



Summary

- We have measured charged hadron R_{CP} using the PHENIX Muon Arms for d + Au collisions.
- Forward suppression is qualitatively consistent with several theories from shadowing/saturation type effects to initial state multiple scattering to recombination.
- Enhancement at backward rapidity is not so well understood.
- Future studies of charm R_{cp} and yields at forward rapidities in d+Au collisions might distinguish between different models.