Hadron Analysis in the PHENIX Muon Arms

Chun Zhang

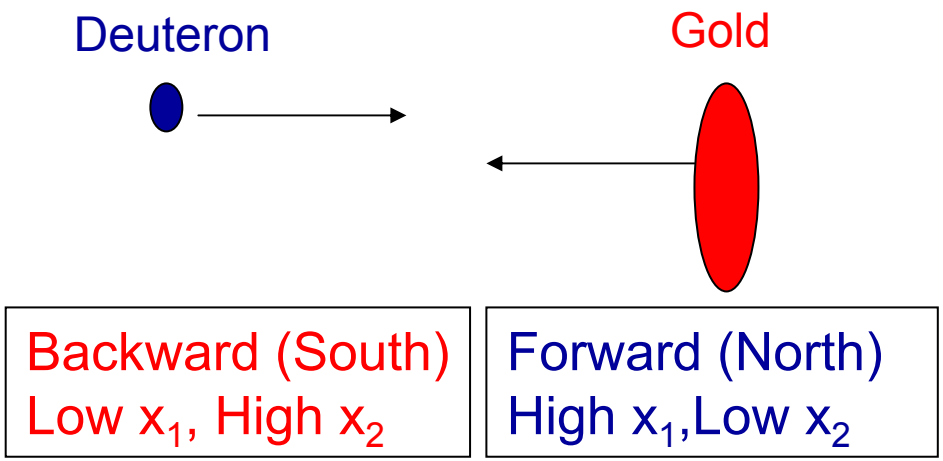
Sante Fe meeting 2004

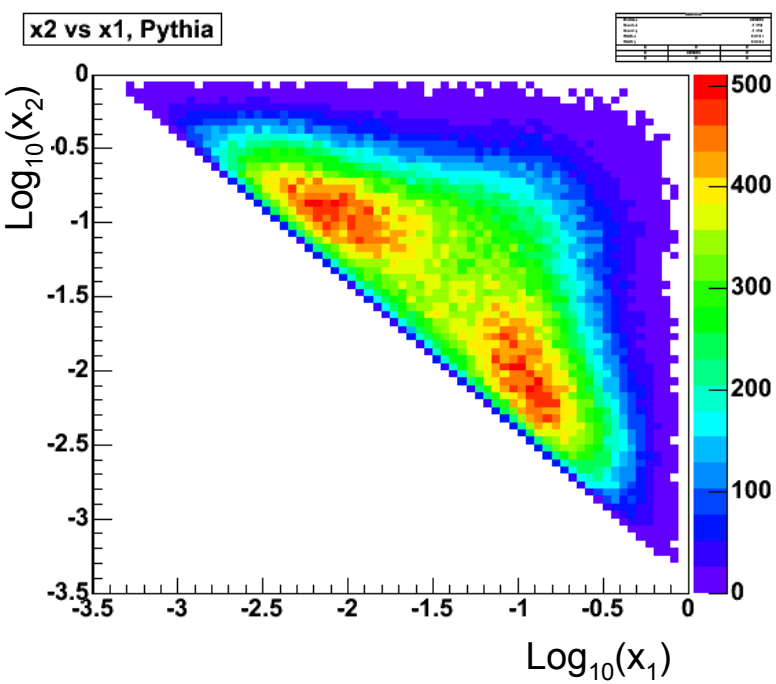
Outline

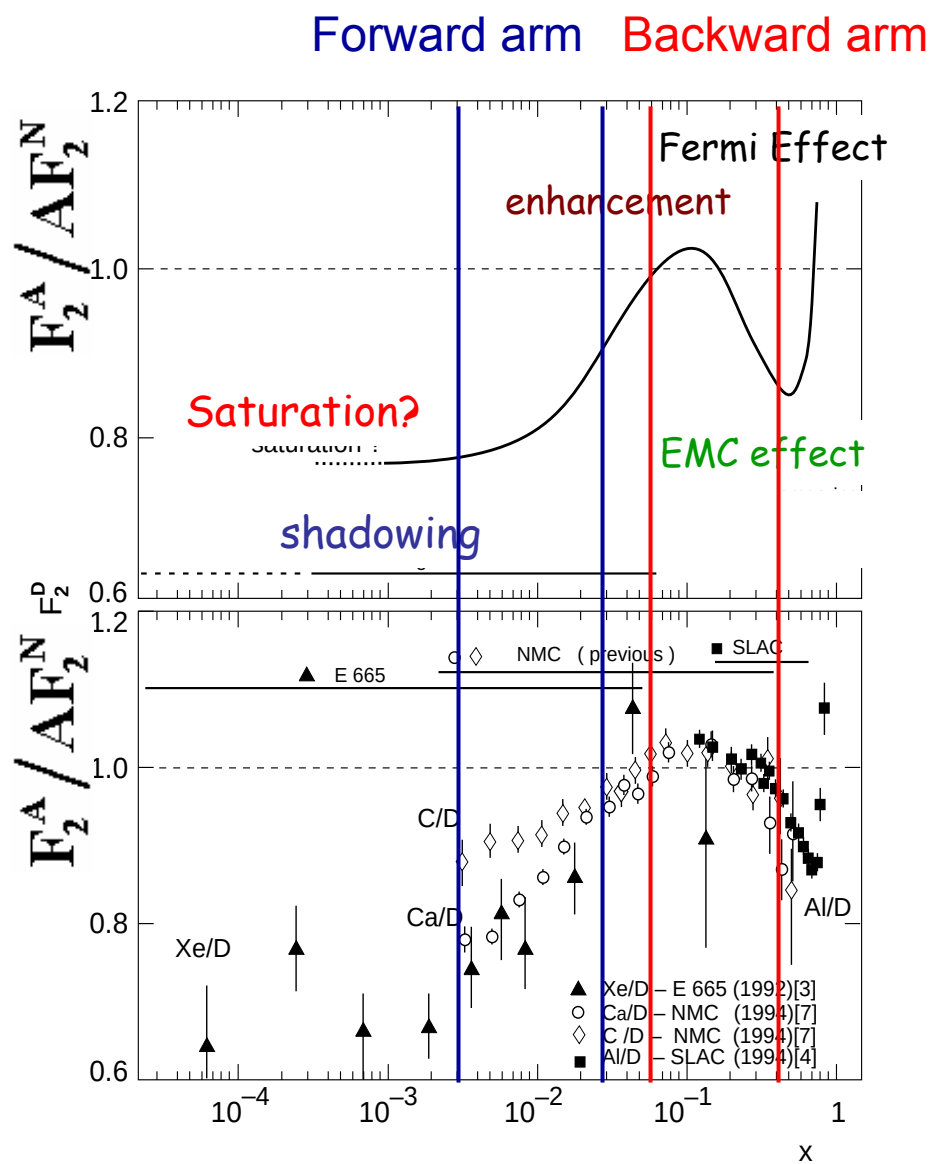
- Introduction

  Motivation for measuring hadrons in muon arms
- Hadron Identification
- Hadron R_{cp} measurement in dAu
- Preview for Au-Au physics

Sensitive to Low and High x Partons







Gluon Saturation

Color Glass Condensate (**CGC**)

[L.D. McLerran and R.Renugopalan Phys. ReV. D49, 2233(1994)]

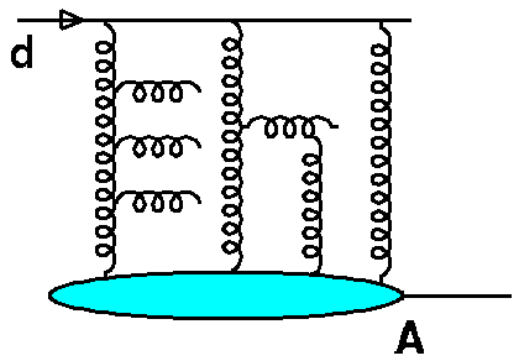
Heavy nuclei increases the saturation scale by $A^{1/3}$.

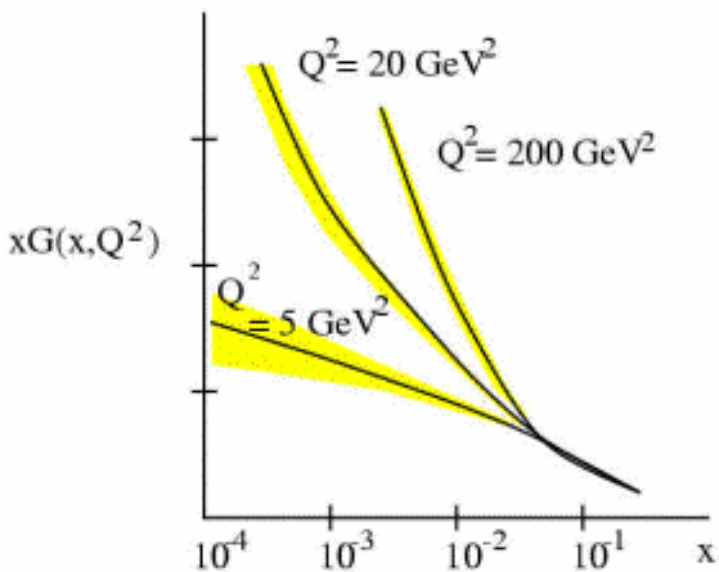
At RHIC,

$Q_s\ (y) = \Lambda^2\ A^{1/3}\ e^{\lambda y}$.

[Dmitri Kharzeev *et. al* hep-ph/0405045]

Note the rapidity dependence.





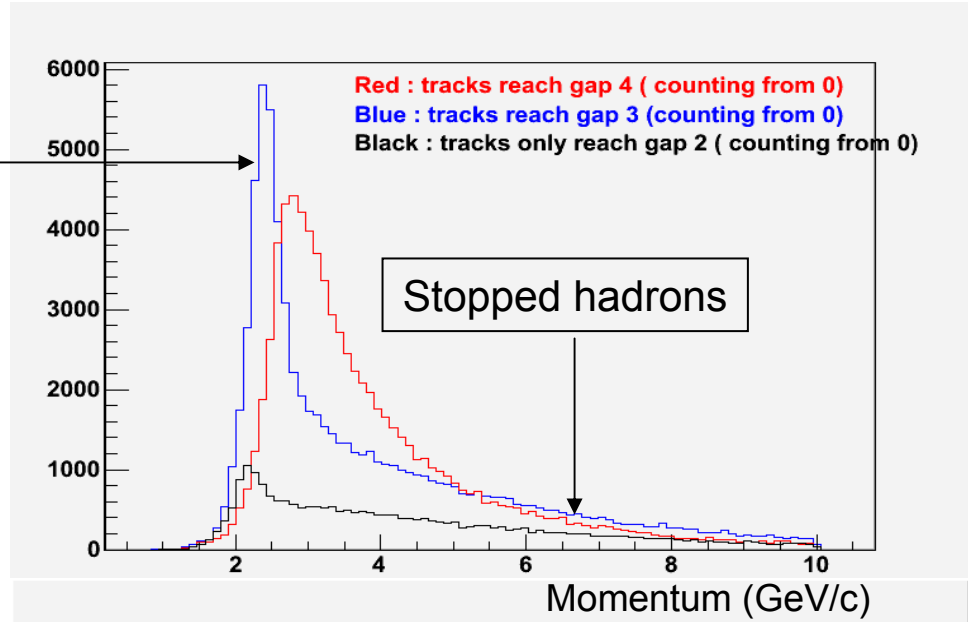
Why Hadrons in Muon Arms?

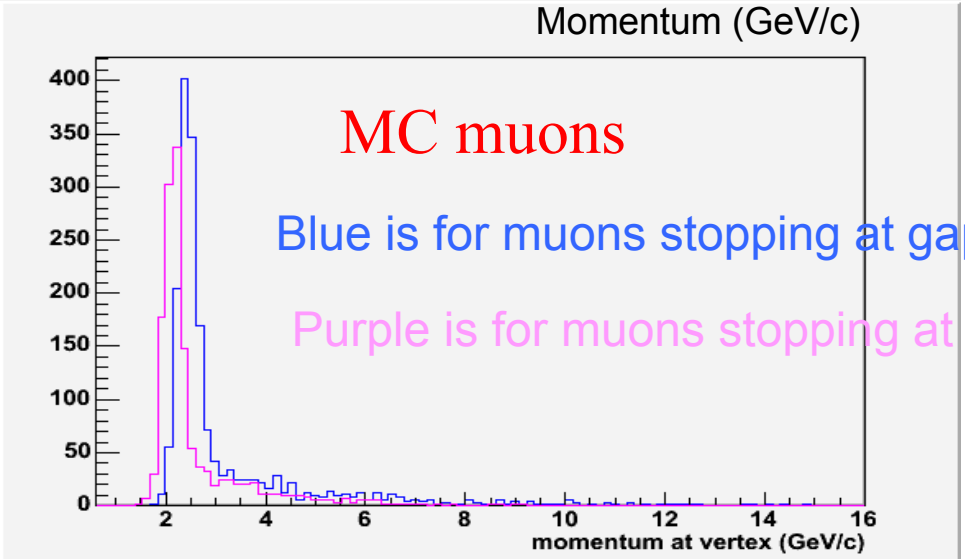
- PHENIX Muon Arms designed for muons
- Heavy flavor via single muons is challenging
- Tom Hemmick proposed measuring charge particles in muon arms in May 2003
- It turns out we can separate muons and hadrons and measure hadrons.

h/μ Separation

- 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





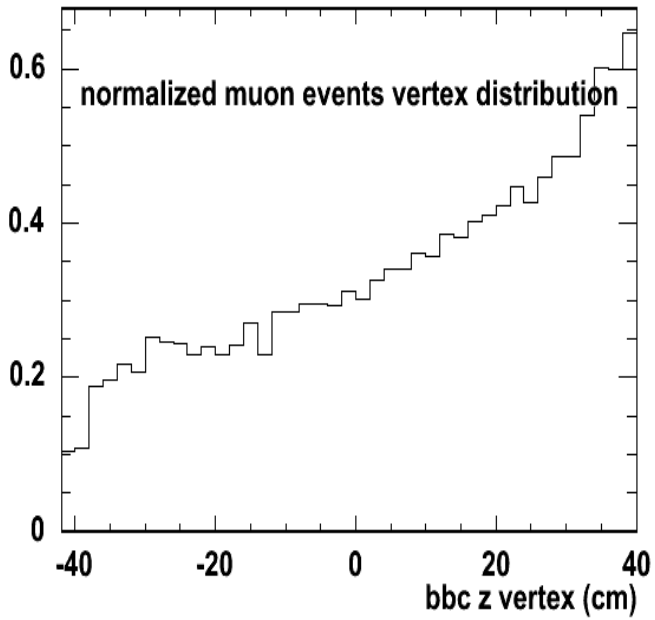
Purity of Hadron Sample

Two sources of contamination in hadron sample

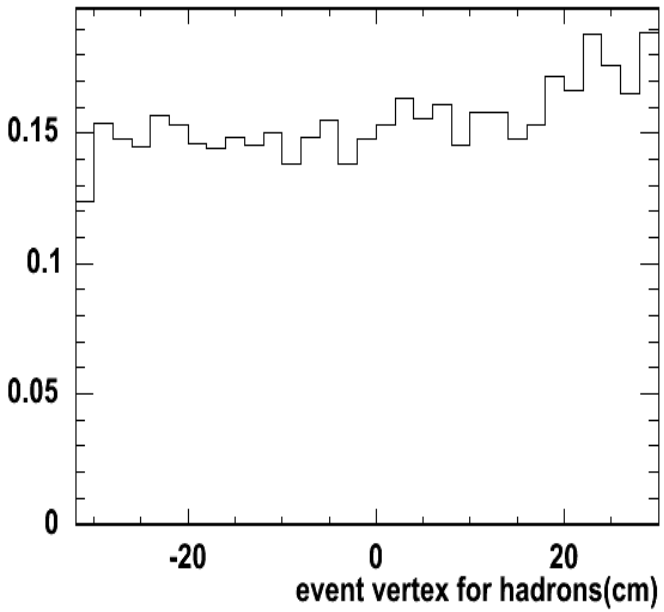
- Deep muons can be reconstructed as shallow roads due to inefficiency in MUID
- Stopped muon sample has a small high momentum tail

MC and data studies show the contamination is less than 4%

All tracks



"Identified" hadrons

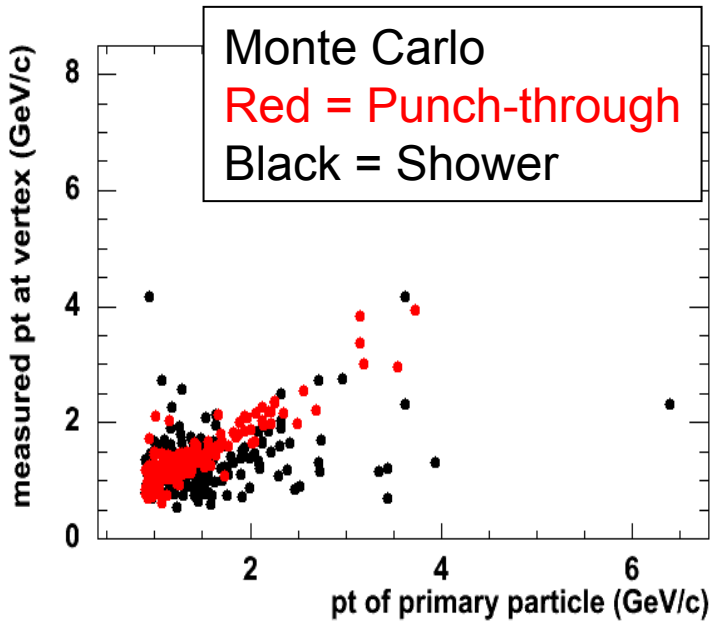


Punch Through versus Shower

Two types of hadrons:
1) Punch Through = hadron only suffering dE/dx loss
2) Shower = hadron suffering multiple-hadronic interactions before stopping in MUID

Punch through hadrons allow us to extract momentum at the vertex (just correcting for dE/dx).

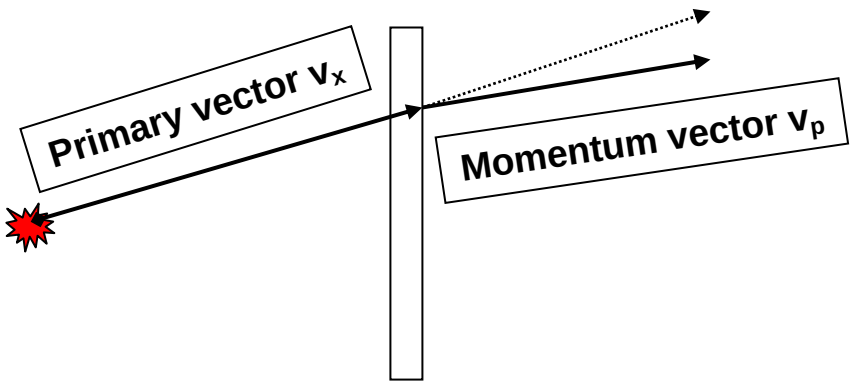
Shower hadrons only give us a lower limit on the momentum at the vertex (and thus blur the physics).



Cuts to Reduce Shower Hadrons

Shower hadrons often do not point back to the vertex, but punch-through hadrons do.

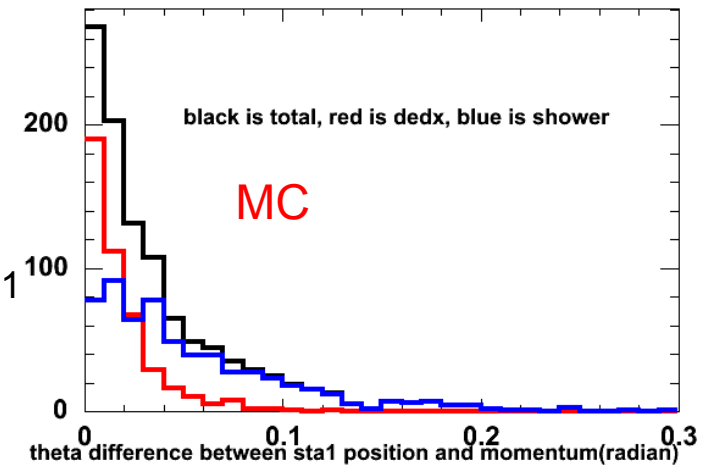
Primary vector : the vector connect vertex and station1 hit.
Momentum vector : the vector of momentum measured at station1

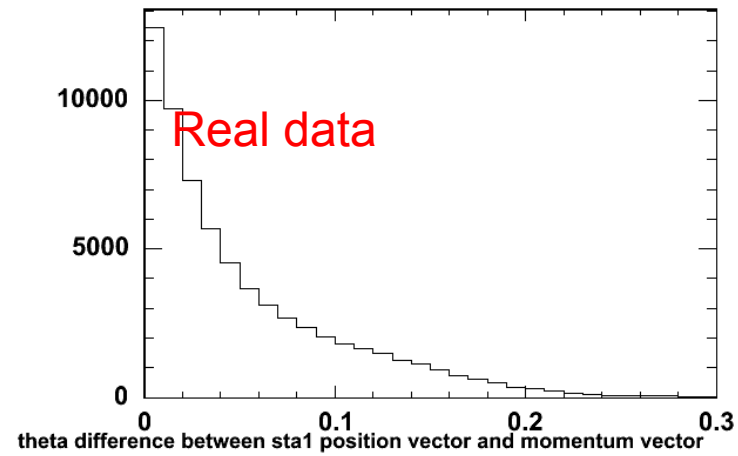


$$\Delta\theta_{xp} = \left|\theta_x - \theta_p\right|$$

Where, θ_x is the polar angle of v_x,

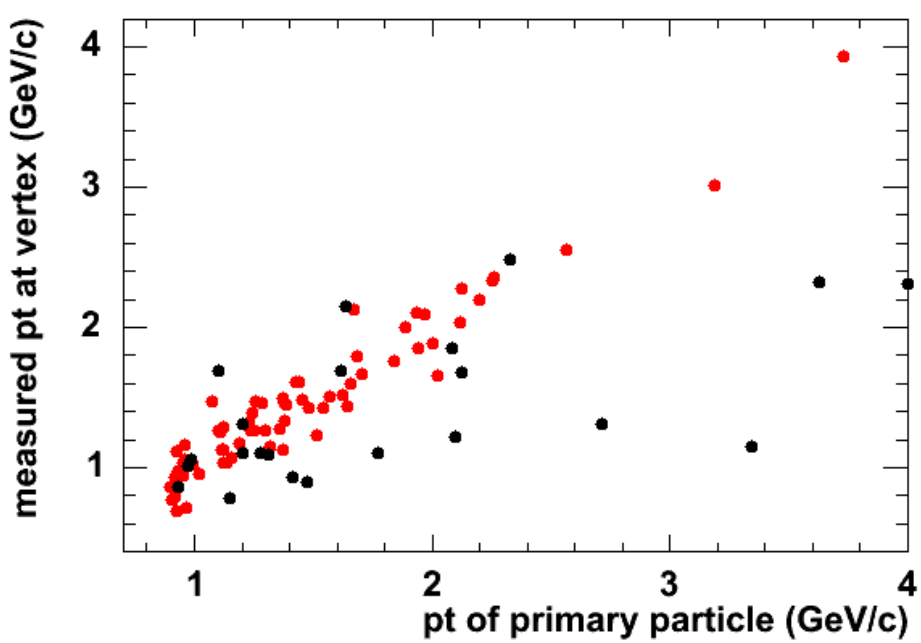
θ_p is the polar angle of v_p





Punch-through vs. Shower Hadrons

θ_{xp} cut dramatically reduces shower Hadrons (see MC plot below)



Monte Carlo
Red = Punch-through
Black = Shower

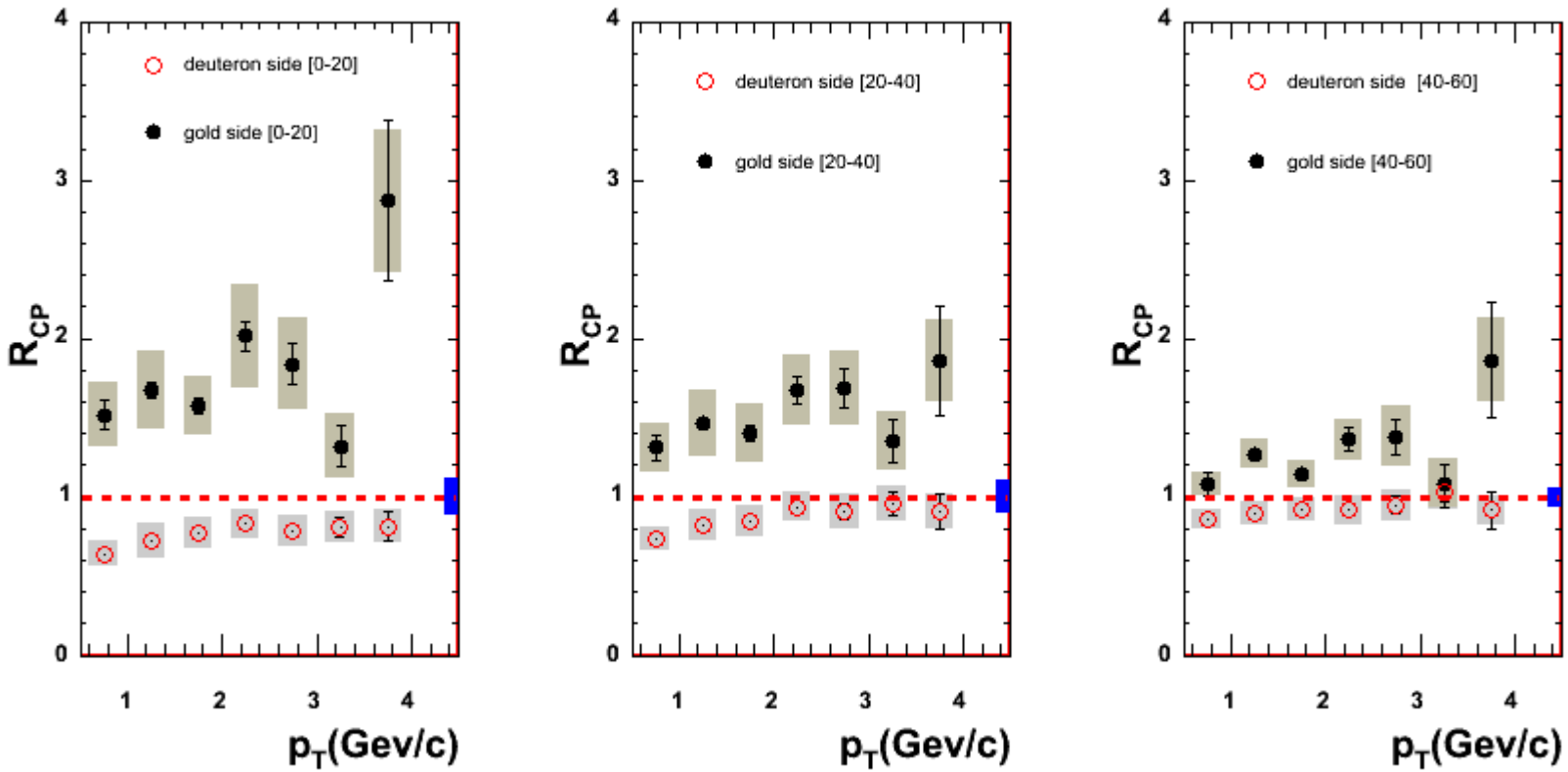
Hadron R_{cp}

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

Any deviation from one indicates nuclear modification.

R_{cp} verse p_T

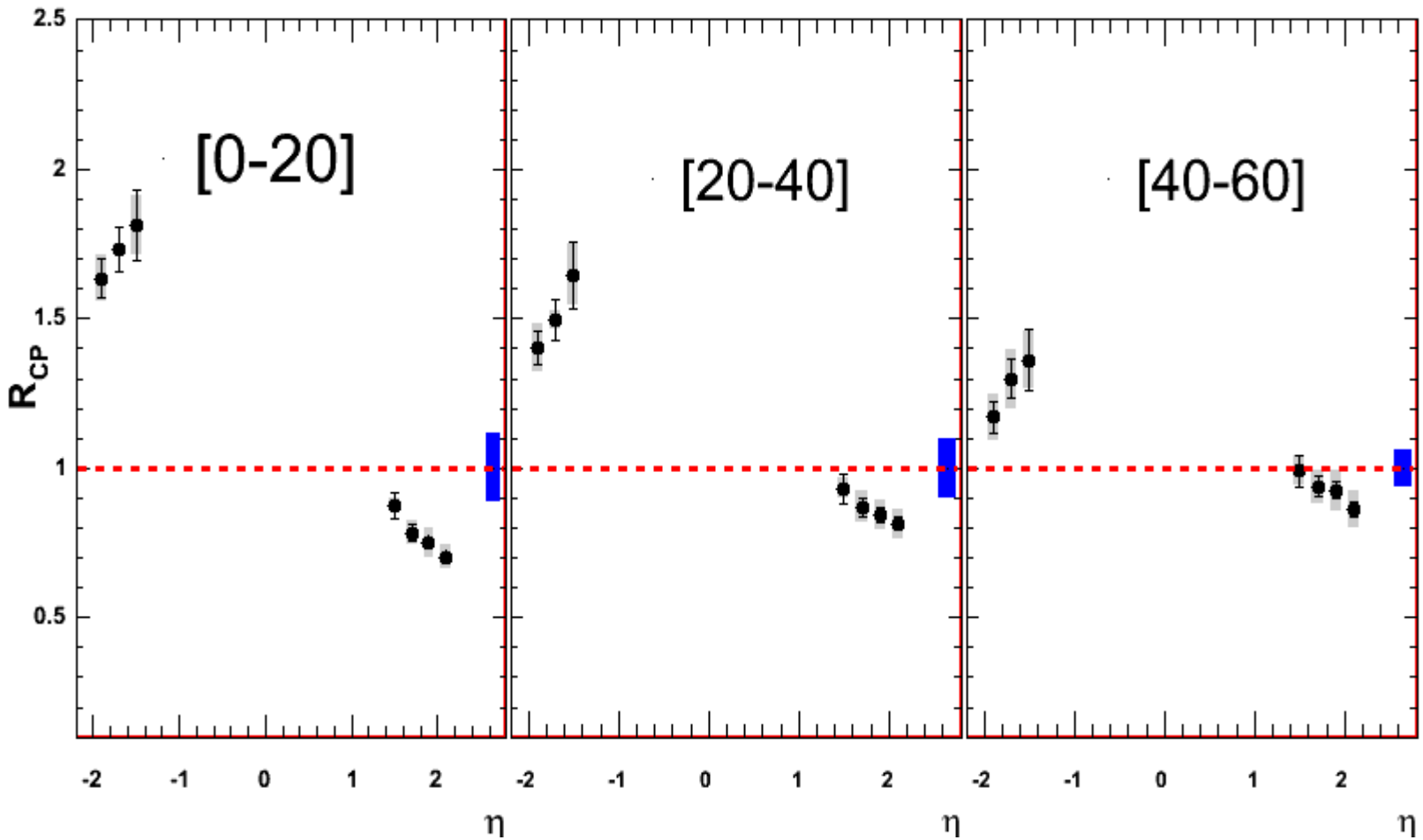
Black solid dot : south; reminder high x in gold, low x in deuteron



Red open circle : north; Reminder low x in gold, high x in dueteron

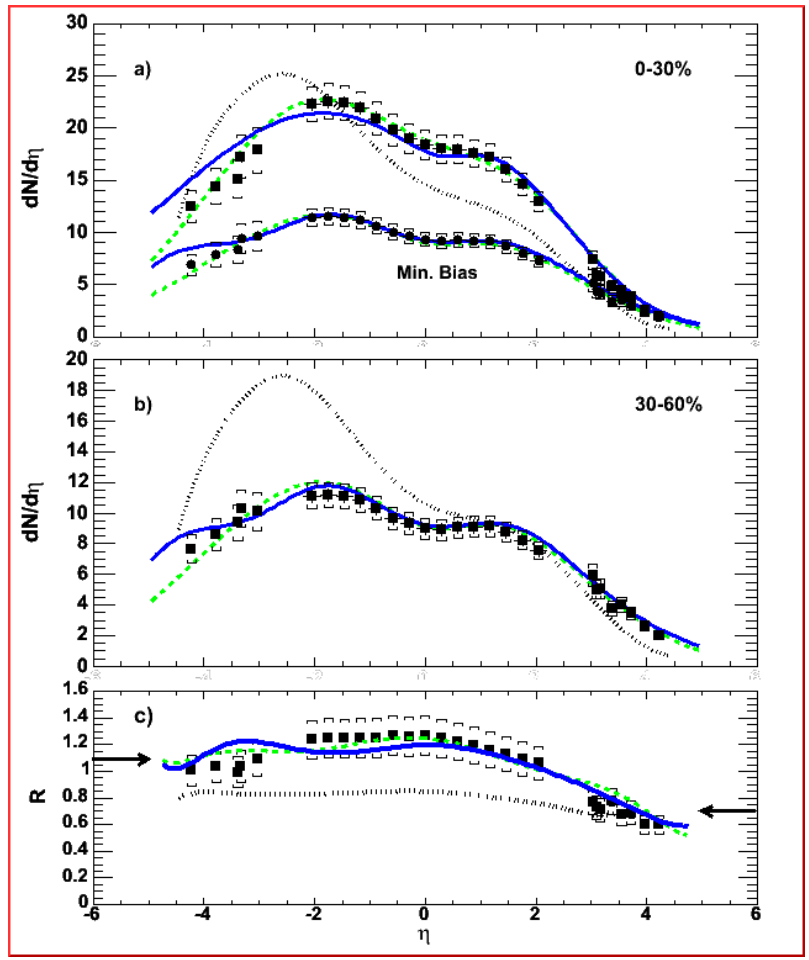
R_{cp} verse η

4.0 > pT > 1.0 GeV/c



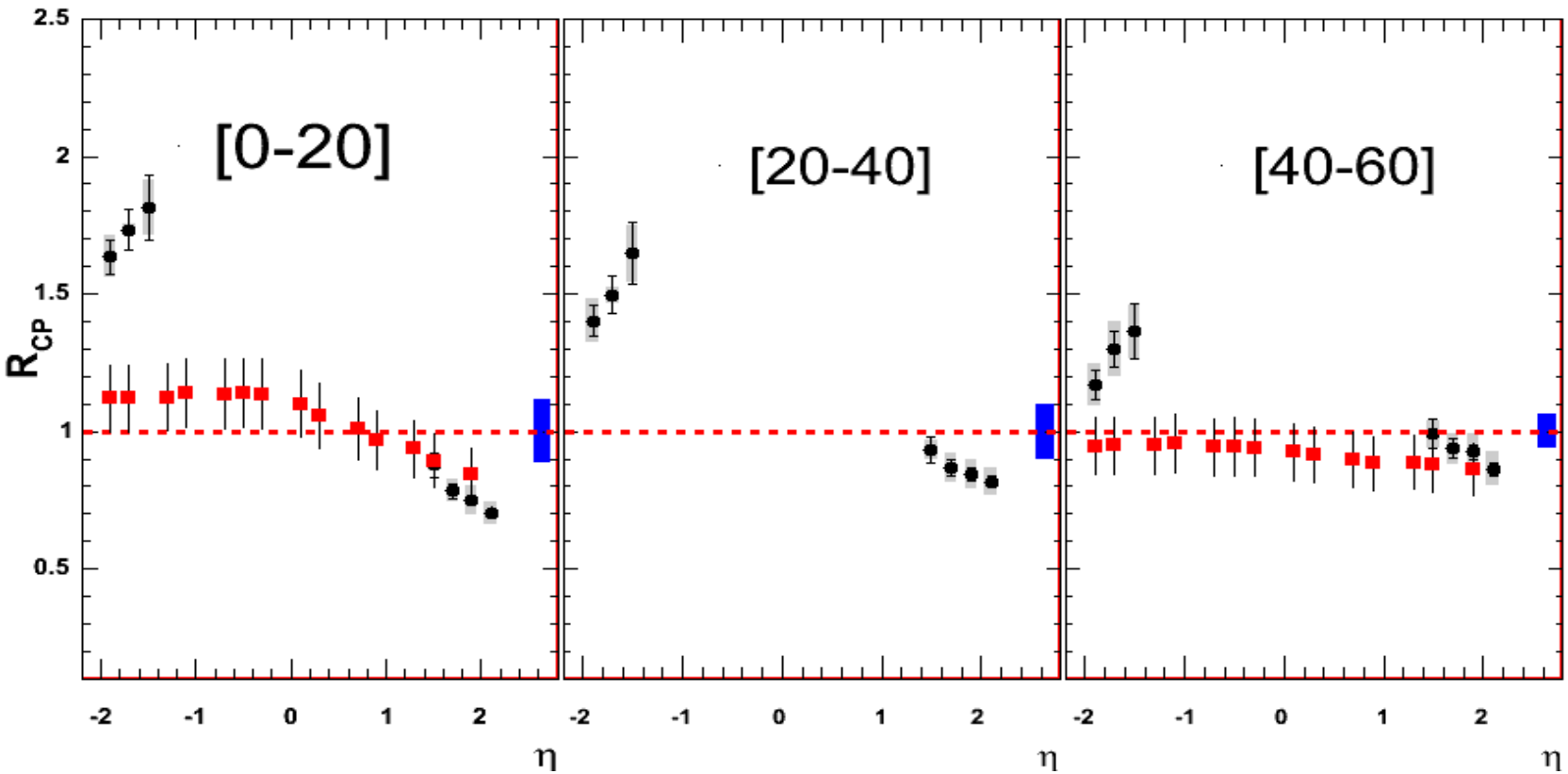
Nuclear Stopping Power

Soft physics pushes the particle production to backward rapidities by exchanging rapidy between projectile and target.



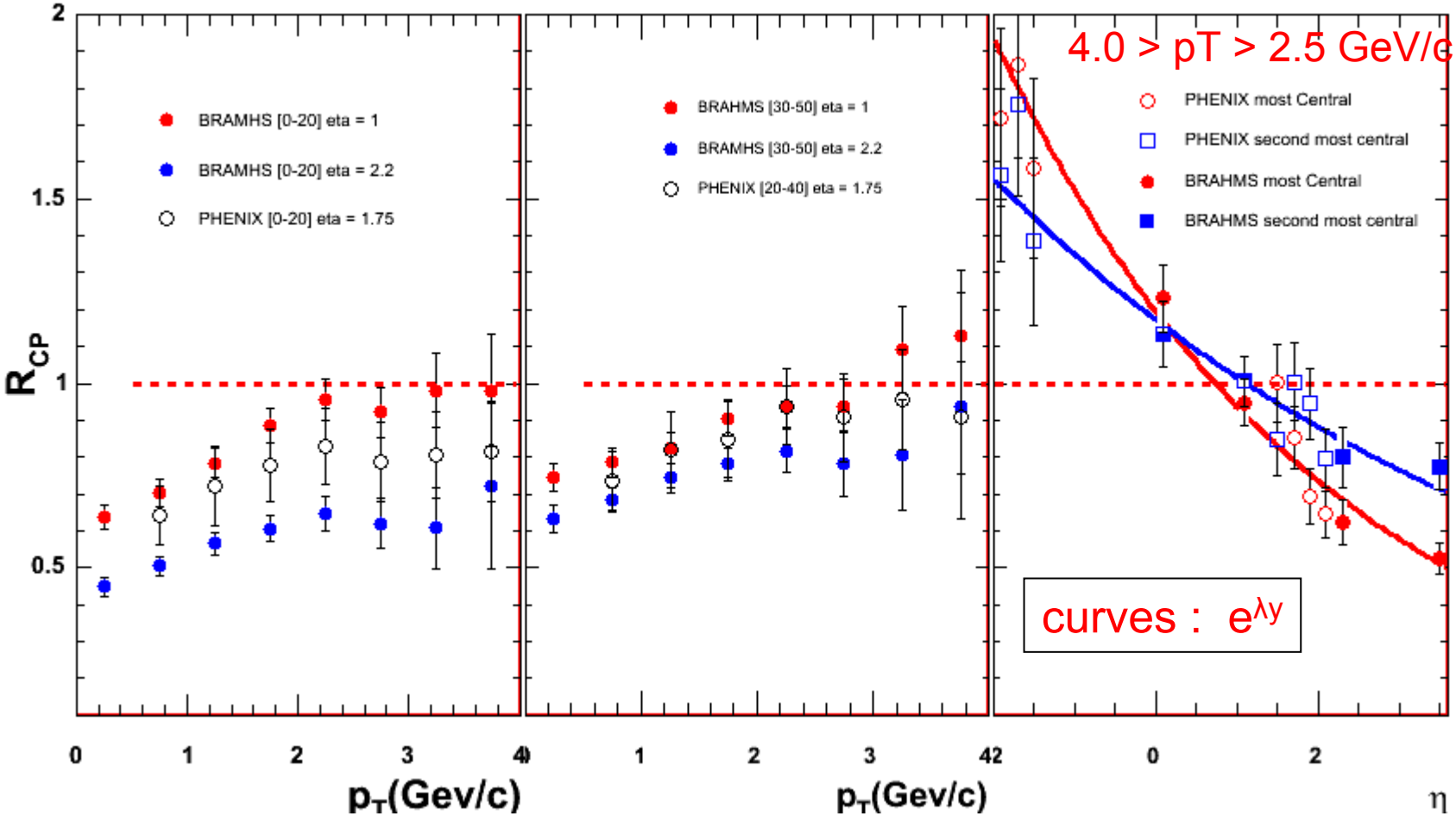
R_{cp} at Backward

Black dots : PHENIX date with 4 > p_T > 1 GeV/c



Red squares are calculated from BRAHMS published dN/dη (nucl-ex/0401025) in order to compare with our backward rapidities. Note their mean p_T is less than 500 MeV/c

Compare with BRAHMS

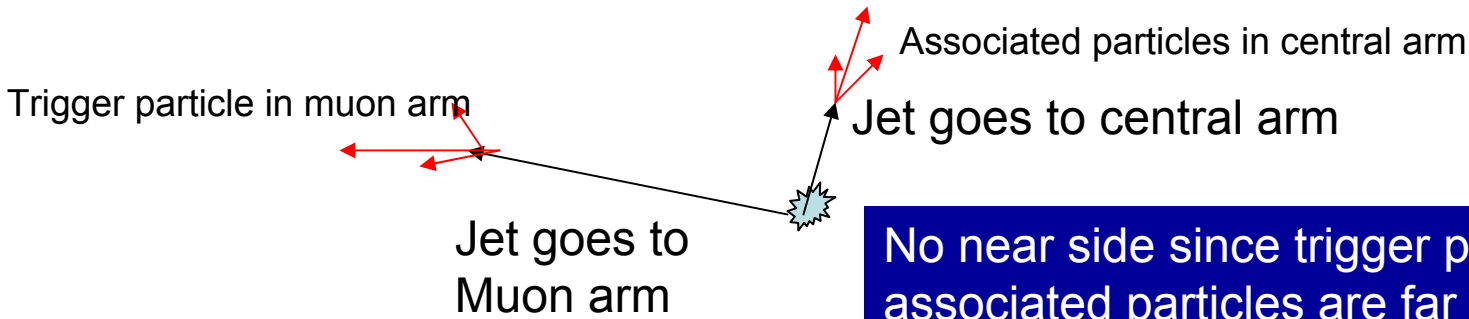


A recent CGC Calculation [Dimitri Kharzeev *et. al.* hep-ph/0404045] shows very good consistency with BRAHMS results.

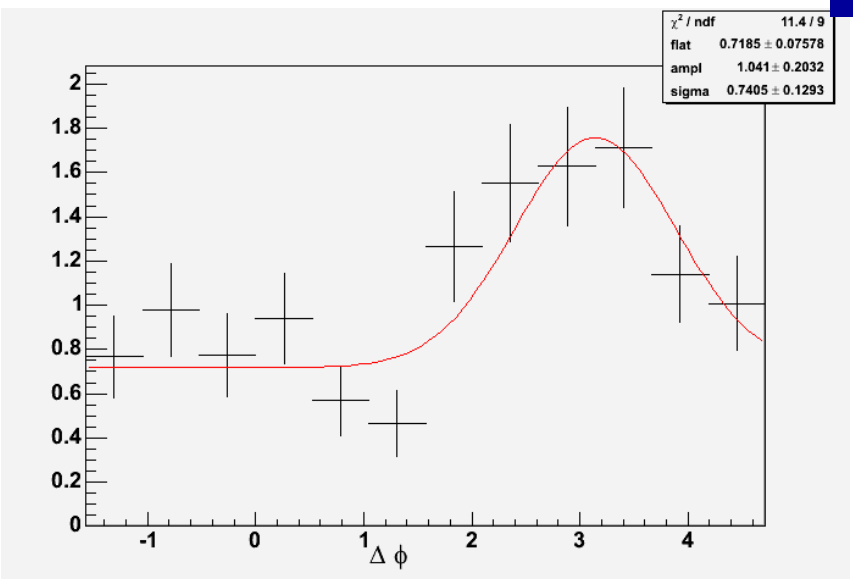
Two particle correlation analysis with muon arms

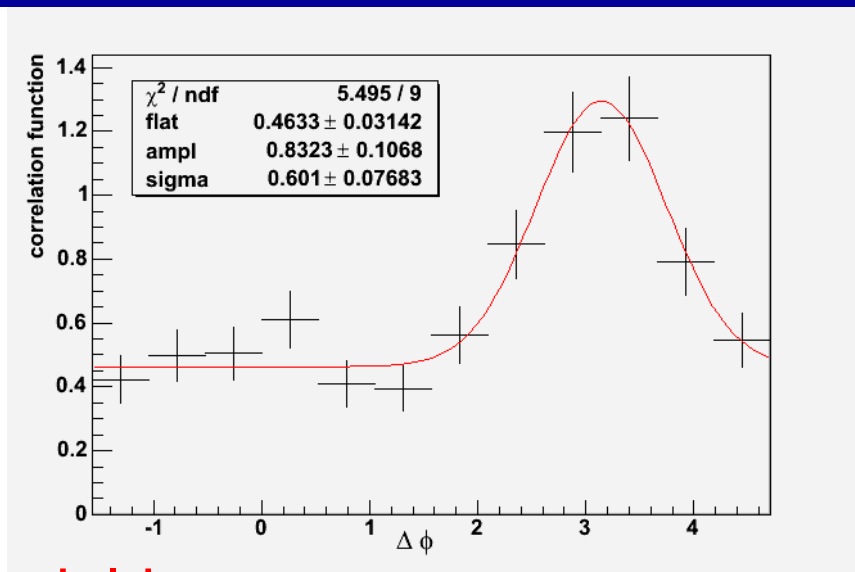
- “the disappearance of back-to-back correlations is a very basic property of saturation, see e.g. p.16 in hep-ph/0204014,” Dima Kharzeev.
- In dAu, we can Trigger on punch through hadron in muon arm, and look at phi distribution in central arms (relative to muon arm hadron).
- This analysis is still very preliminary, but it is very promising.

Two particle correlation analysis with muon arms



No near side since trigger particle and associated particles are far from each other in rapidity.





Conditional yield

dAu : $p_T^{trig} > 2.0$GeV/c
$p_T^{asso} > 2.0$ GeV/c

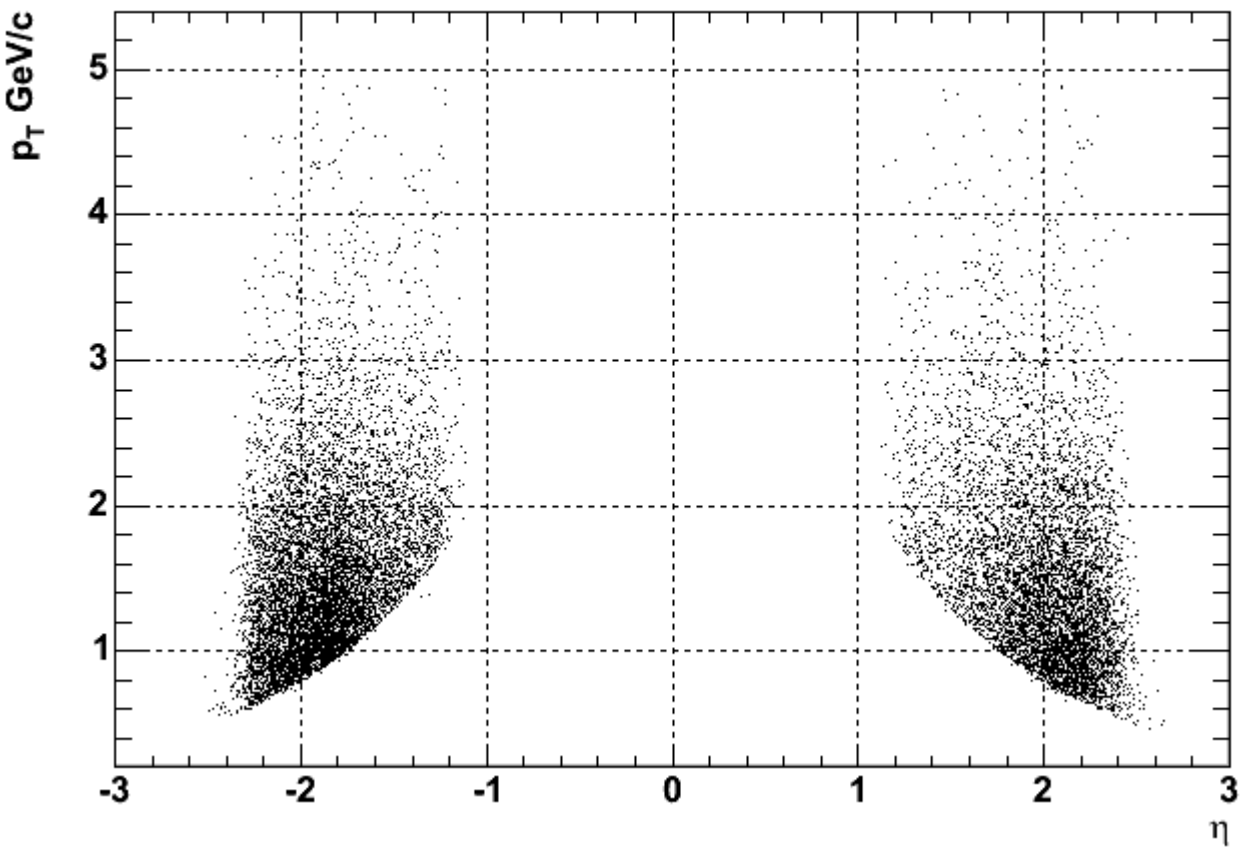
pp : $p_T^{trig} > 2.0$GeV/c
$p_T^{asso} > 2.0$ GeV/c

Look forward to RUN4

- "CGC" and "energy loss [1] " will compete with each other in hadron production at forward rapidity, which will suppress the high p_T hadron more.
- Two particle correlation using hadrons from muon arms will add more information on jet, flow studies.

[1] hep-ph/0405045

Backup slides



Particle composition on RCP

- People asked if we can get a pt spectrum.

We discussed this within the ppg, if a normalized spectrum, we think it is almost impossible, because it requires the understanding of the particle composition, and the kinematics in the eta range we are interested, and there is no previous measurement. We have to rely on some assumptions and theoretical models to do lots of simulation. People may argue that the RCP we measured does not really reflect the RCP at vertex because of the modulation from absorber. Here I have a simple estimation on how large the effect is.

$$RCP_{vertex} = \frac{Y_{\pi}^{cent} + Y_{K}^{cent} + Y_{p}^{cent}}{Y_{\pi}^{peri} + Y_{K}^{peri} + Y_{p}^{peri}} \times \frac{N_{binary}^{peri}}{N_{binary}^{cent}}$$

$$define:$$

$$f_{\pi} = \frac{Y_{\pi}^{peri}}{Y_{\pi}^{peri} + Y_{K}^{peri} + Y_{p}^{peri}}$$

$$RCP_{vertex} = f_{\pi} RCP^{\pi} + f_{K} RCP^{K} + f_{p} RCP^{p}$$

$$Then$$

$$RCP_{mutr} = g_{\pi} RCP^{\pi} + g_{K} RCP^{K} + g_{p} RCP^{p}$$

Particle composition on RCP

Where the difference beetween g and f is determined by the difference of the absorption between different particles.

If we think of an extreme case that the absorber is thick enough to stop all the pions and protons, then g_π and g_p become zero. Then,

$$RCP_{mutr} = RCP^K$$

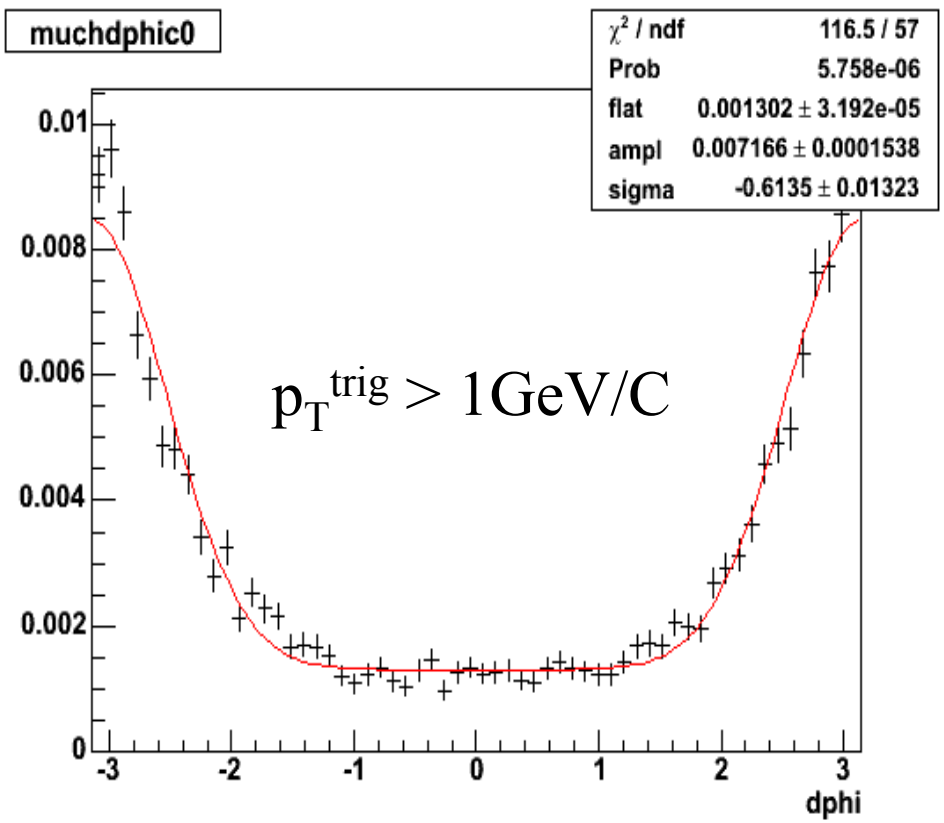
From central arm measurements, we know RCP for pions and kaons are not different within errors, and RCP for proton is 20% larger than pions. And also from central arm measurements, protons takes
20% of charge particle yields. Assume these observations keeps when we go to different rapidity.

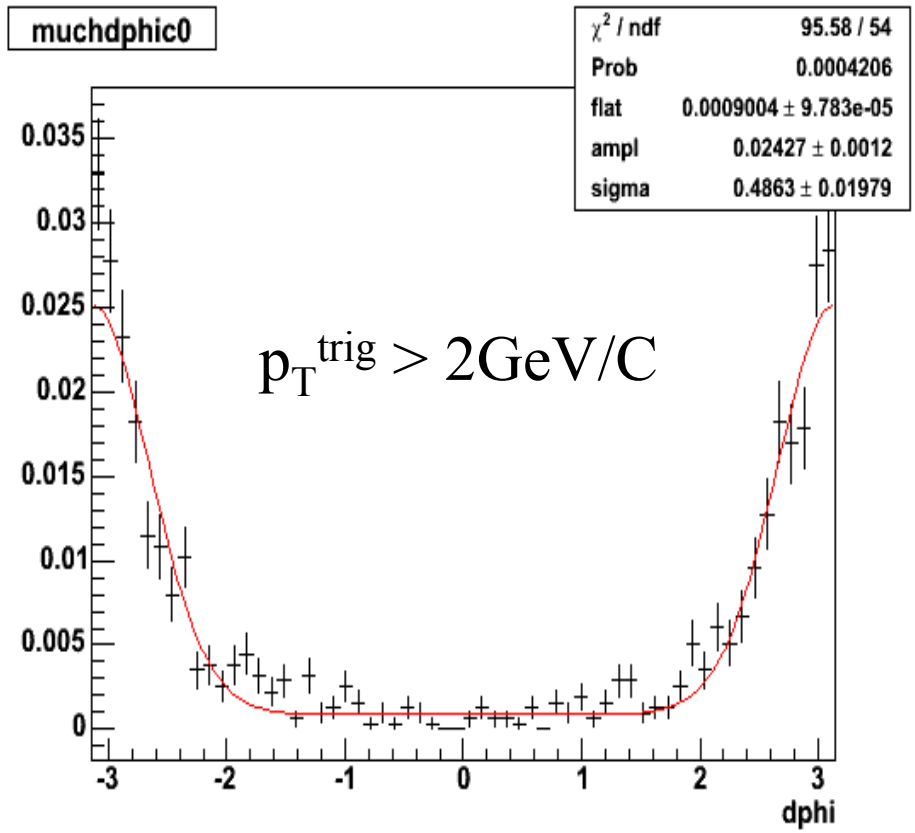
$$RCP_{vertex} = RCP^K(1 + 0.2 \times 0.2)$$

So, it is 4% effect, you may want to argue that all the measurement in central arm will be different from muon arms, but since there is no such measurement, we may not be able to do better than this simple estimation.

Pythia simulation

p_T^{corr}>2.0 GeV/C





Introduction

Few words about high x region

Nuclear stopping power

Introduction

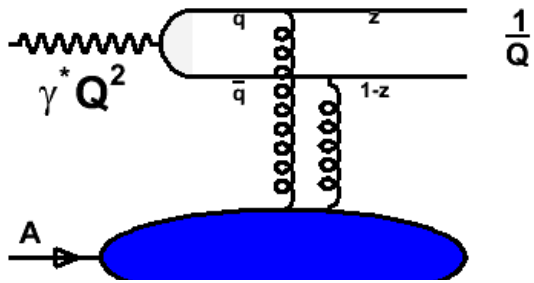
Gluon saturation at small x in HERA

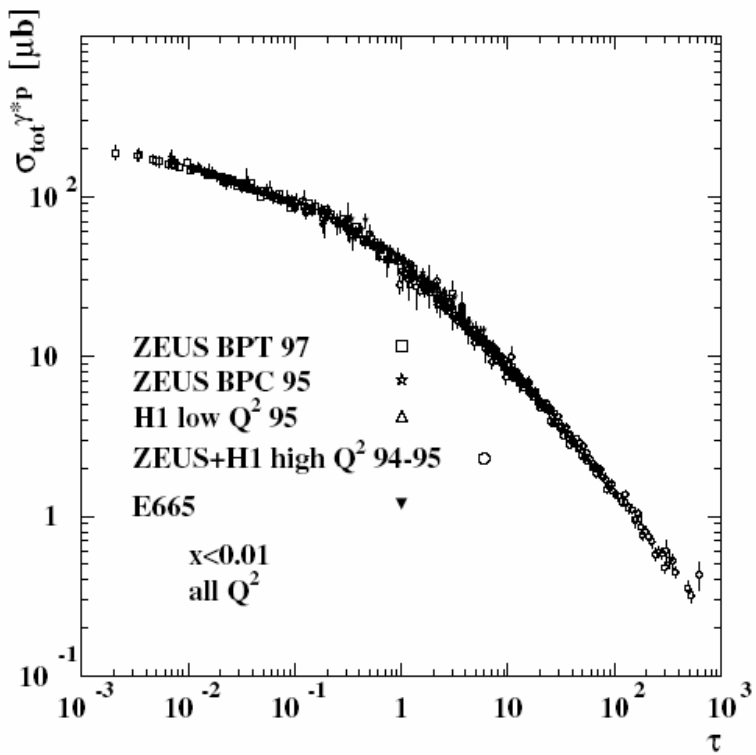
"Geometric Scaling" [**A.K. Golec-Biernat et al. PRL 86, 596 (2001)**]

R_0 "saturation radius" $\sim x^{\lambda}$

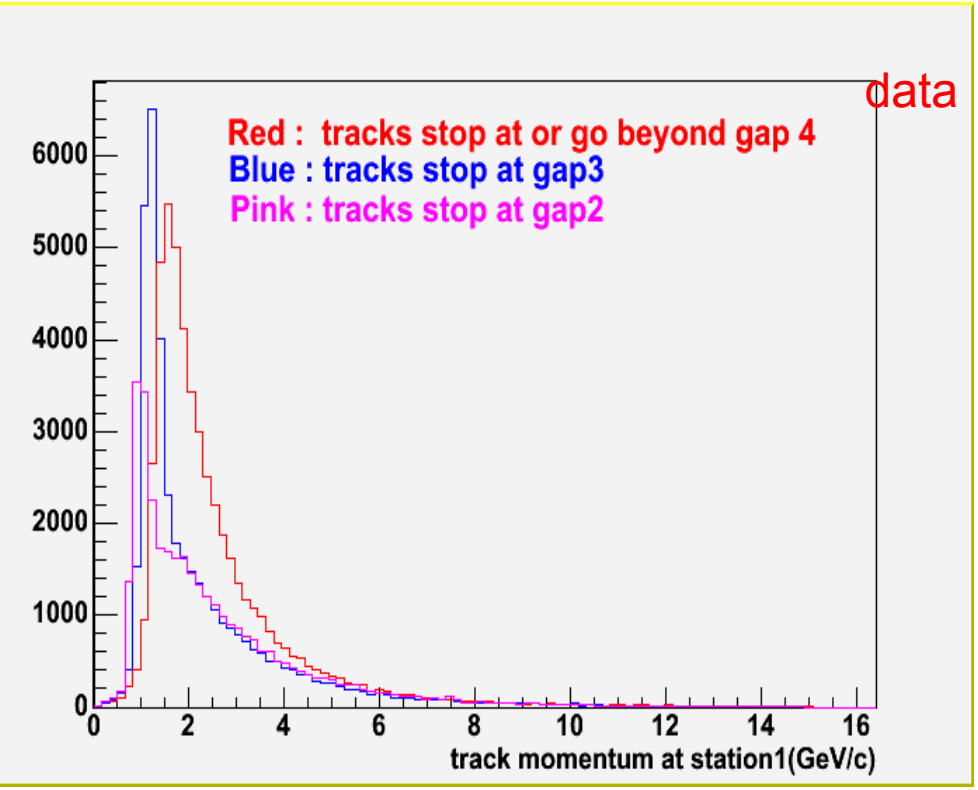
defines a scale: $\tau = Q^2 R_0^2(x)$

When $1/(QR_0) \rightarrow \infty$, the cross section goes the constant, saturated.





Hadron measurement in PHENIX muon arms



•More over, track is measured inside MUTR chamber without knowing its particle species, then swimming through absorber under the assumption that it is a muon.
So track momentum inside chamber tells us more precise
information.

• selection of hadrons.

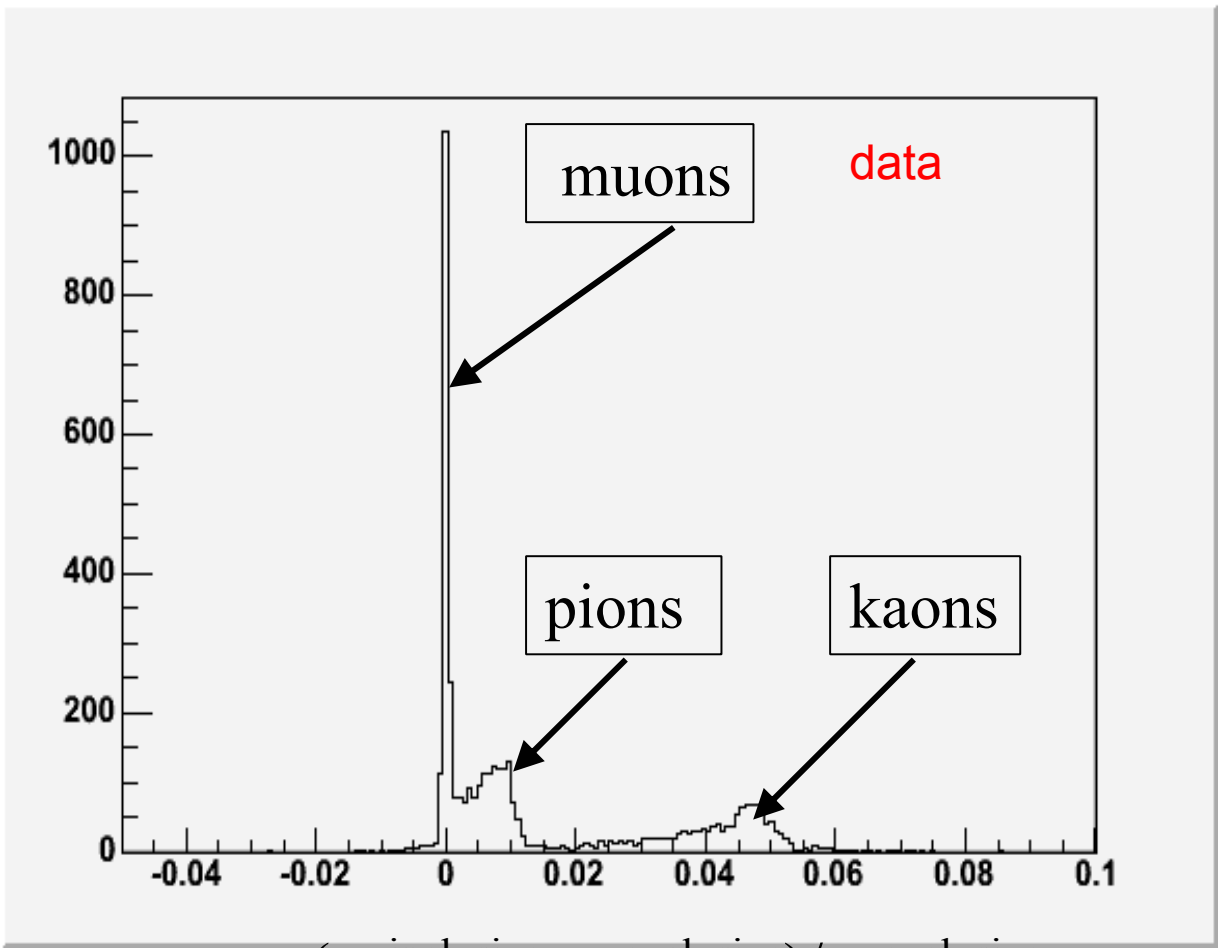
1.) track stop at gap2 or gap3.

2.) ptot_sta1 > 1.8GeV/c, 3 sigma away from muon peak.

3.) track chi square per freedom less 20.

4.) To cut off low angle background we require eta < 2.2 and eta >-2.0

How well we measure different hadrons



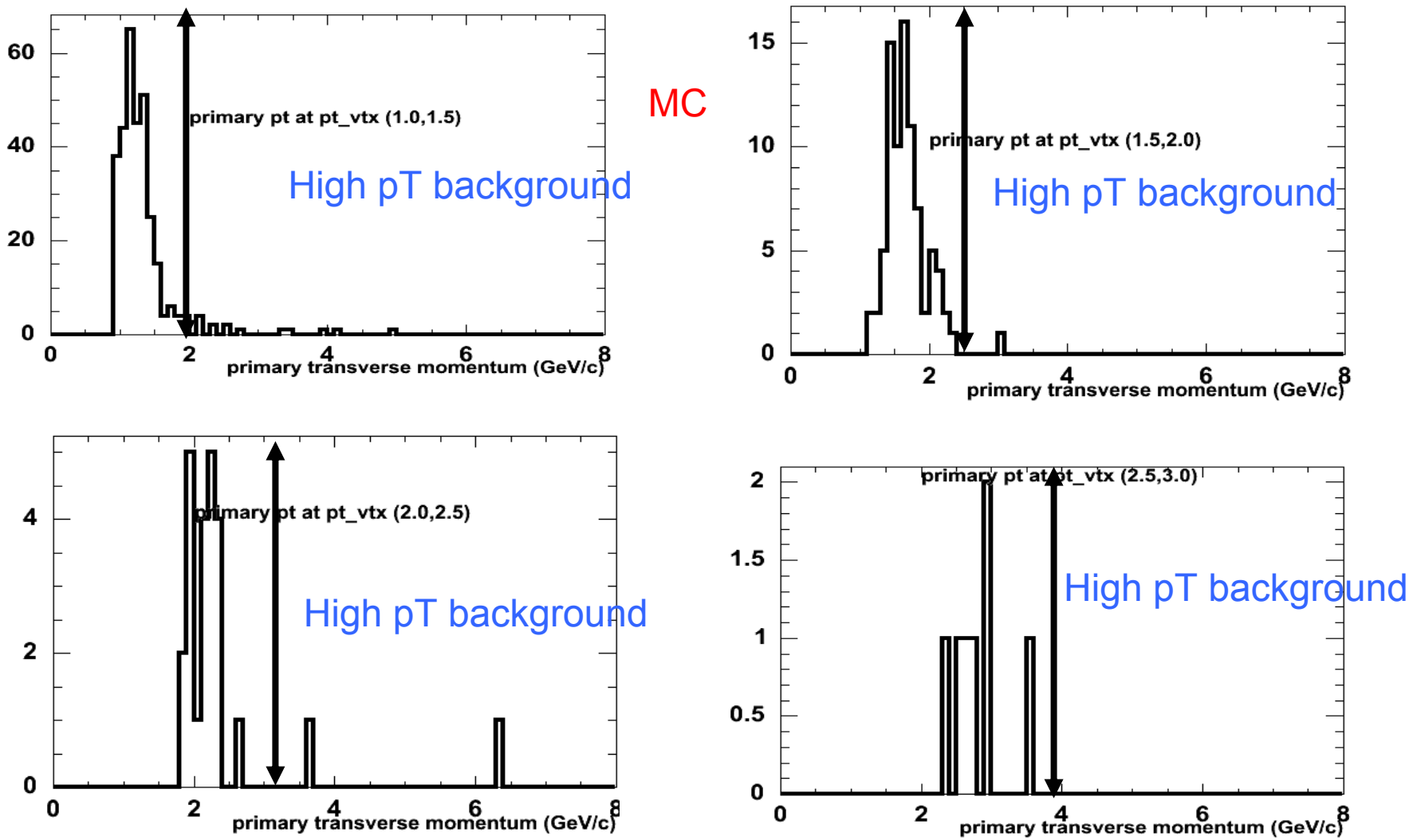
$(p_T^{inclusive}-p_T^{exclusive})/p_T^{exclusive}$

$p_T^{inclusive}$: propagate track through absorber with assumption of muon.

$p_T^{exclusive}$: propagate track through absorber with correct track ID

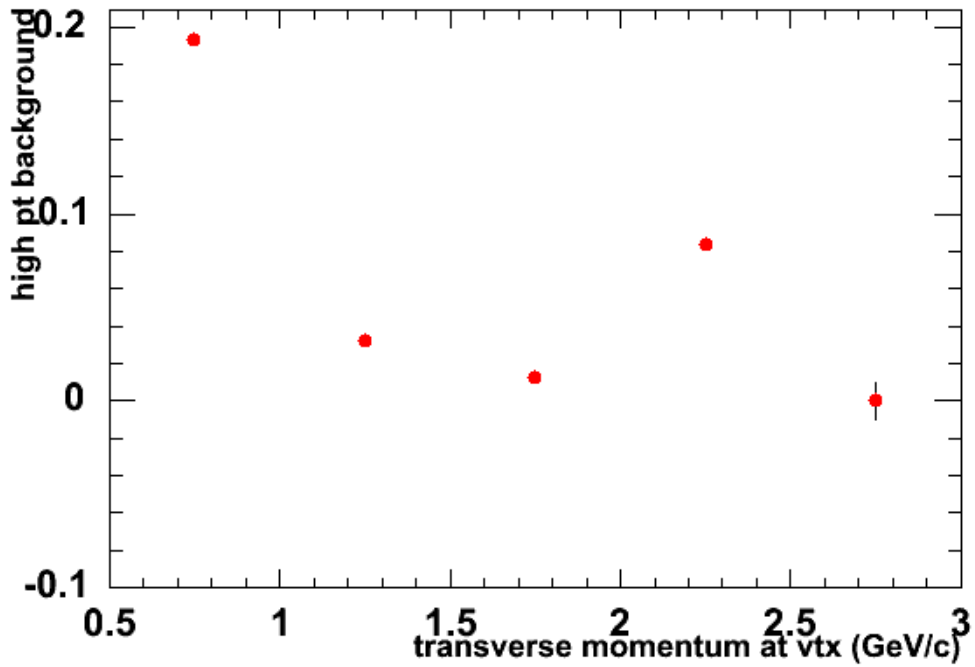
For muon/pion/kaon 5% difference if dE/dx through absorber.

p_T of Primary particle in each vertex p_T bins



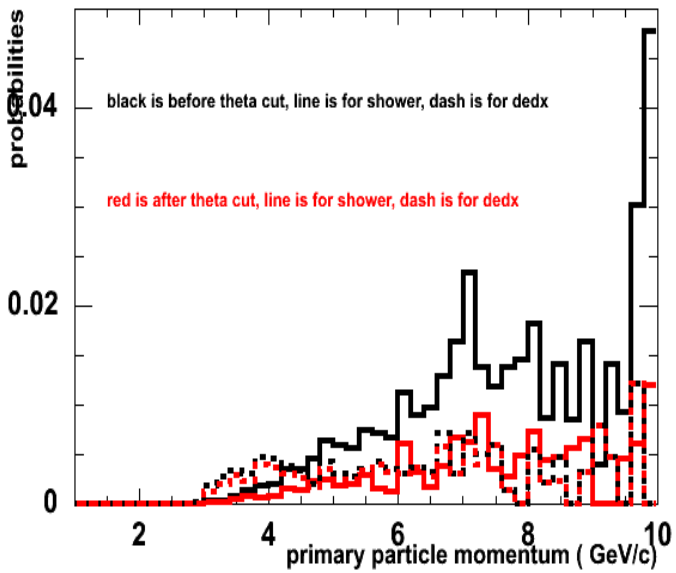
p_T of primary particle in each vertex p_T bins

No error is put on this plots

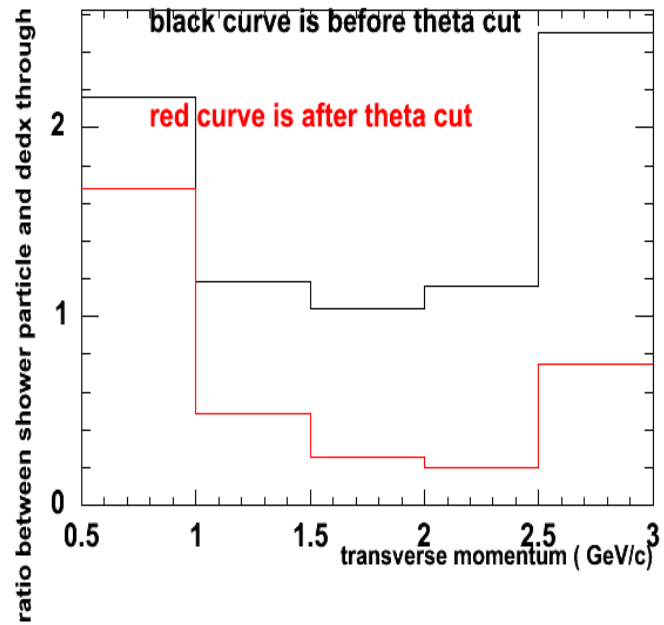


Although we have quit a few a shower particles, but after theta cut, most of survivor are close in phase space with their primary particles.

Shower Contamination Level



MC



Define high p_T background.

- p_T has a resolution about σ = 10%.
- if p_T of primary particle is 3σ higher than measured vertex p_T, it is regarded as high pT background. Otherwise it is signal.