Rapidity Dependence of High-pt suppression

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BRAHMS

Office of Science U.S. DEPARTMENT OF ENERGY

Outline of the presentation

- Background
- Experimental Setup
- Results
  - Spectra,
  - R_{dA}, R_{cp} (centrality dependence)
- Discussion

- Nuclear medium effects:
  - High p_T suppression in d+Au collisions
  - Cronin effects at mid-rapidity in d+Au collisions
  - Manifestations of Color Glass Condensate (Gluon Saturation) effects at forward rapidity (low-x) in d+Au collisions?

Nuclear Modification Factor:

$$R_{dAu} = \frac{d^2N/dp_T d\eta \ (d+Au)}{N_{Coll} d^2N/dp_T d\eta \ (p+p)}$$

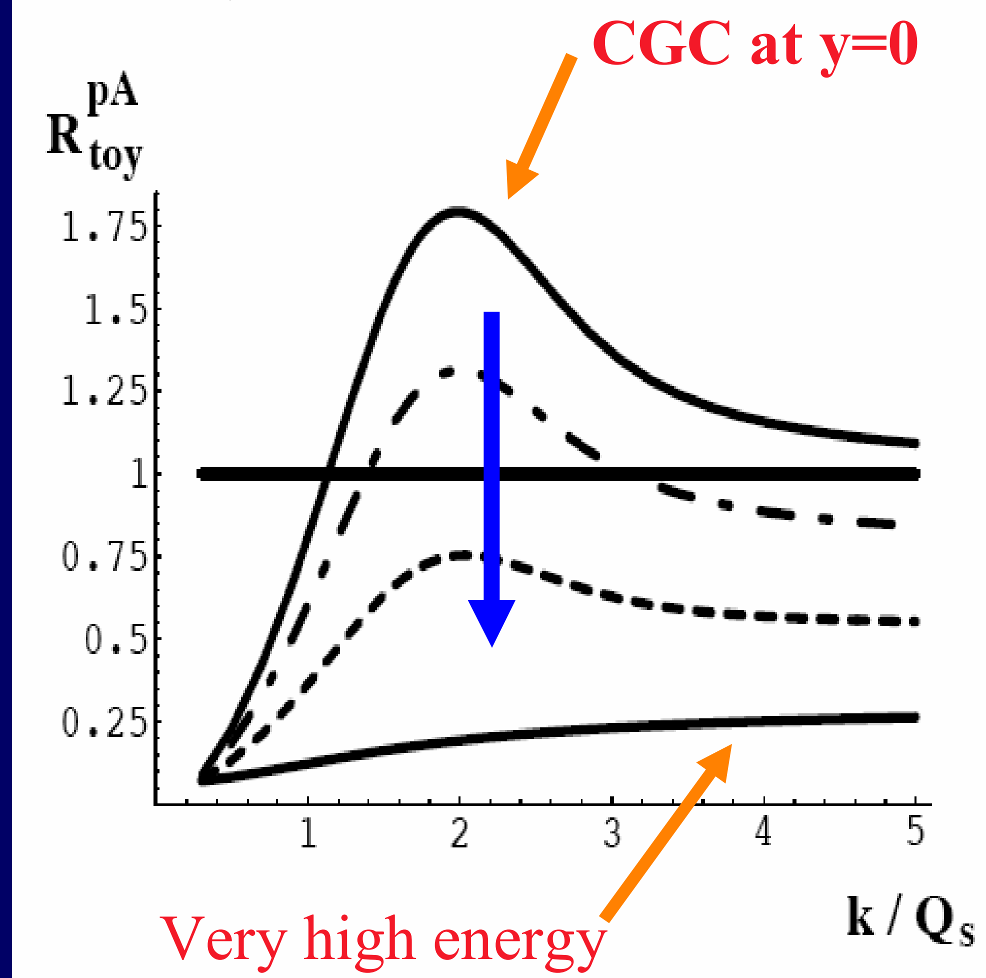
Motivated by study by *toy model* illustrating possible effects from gluon saturation. On nuclear modification factor.

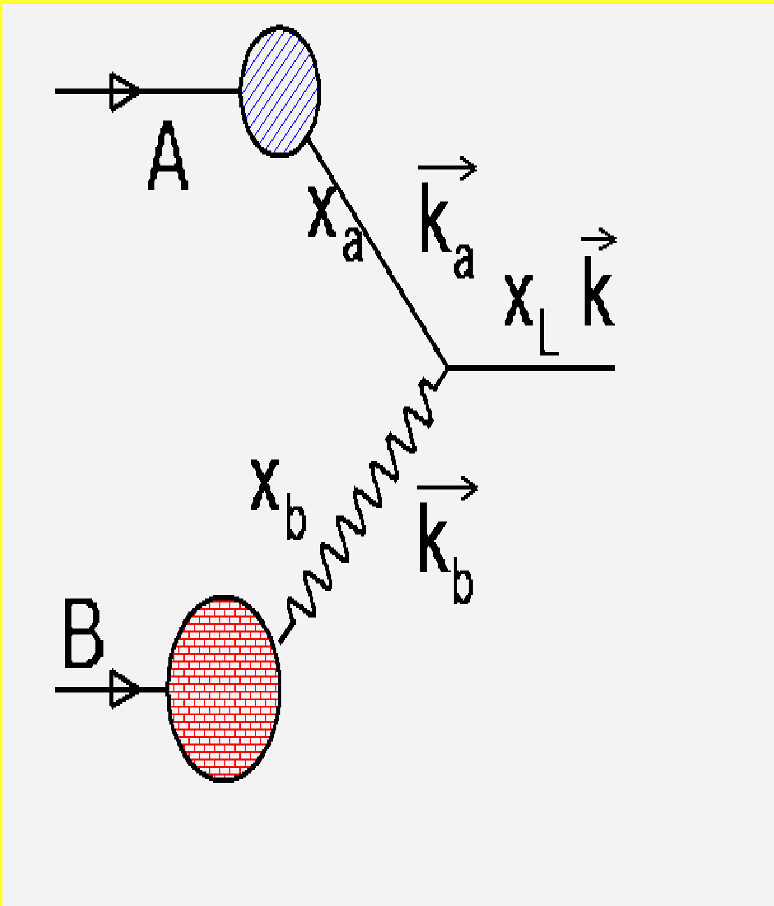
- Gluon distribution grow at large x (HERA)
- The CGC description of evolution of initial state.
- Can be probed in nuclear system.

- P_t suppression can be related to
- modification (shadowing)
- Saturation via evolution (fusion proccesses)

D. Kharzeev et al.

Phys.Rev.D68:094013,2003





Energy and momentum conservation

$$x_L = x_a - x_b = (2M_T/\sqrt{s})\sinh y$$

$$\mathbf{k_a} + \mathbf{k_b} = \mathbf{k}$$

$$x_a x_b = M_T^2/s$$

A solution to this system is:

$$\mathbf{x_a = (M_T/\sqrt{s})\, e^{y}}$$

$$\mathbf{x_b = (M_T/\sqrt{s})\, e^{-y}}$$

where y is the rapidity of the (x_L, **k**) system

In a 2->2 interaction where both partons are measured at rapidities y_1 and y_2,

$Y_{system} = 1/2(y_1+y_2)$ and their rapidity in the "system" c.m. $y^* = 1/2(y_1-y_2)$

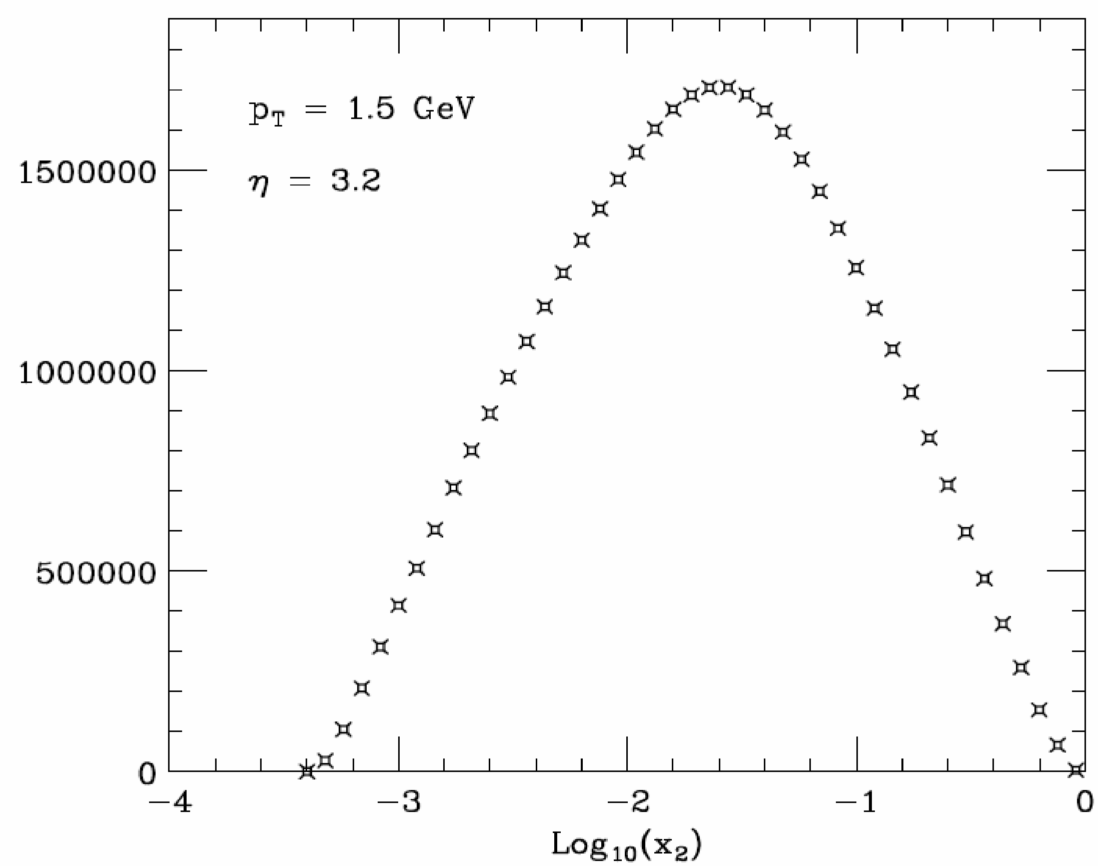
$$x_a = \frac{2M_T}{\sqrt{s}}\cosh(y^*)e^{y_{system}} \qquad x_b = \frac{2M_T}{\sqrt{s}}\cosh(y^*)e^{-y_{system}}$$

At 4 degrees (y~3 for pions) and p_T = 1 GeV/c one can reach to values as low of $x_2 \sim 10^{-4}$

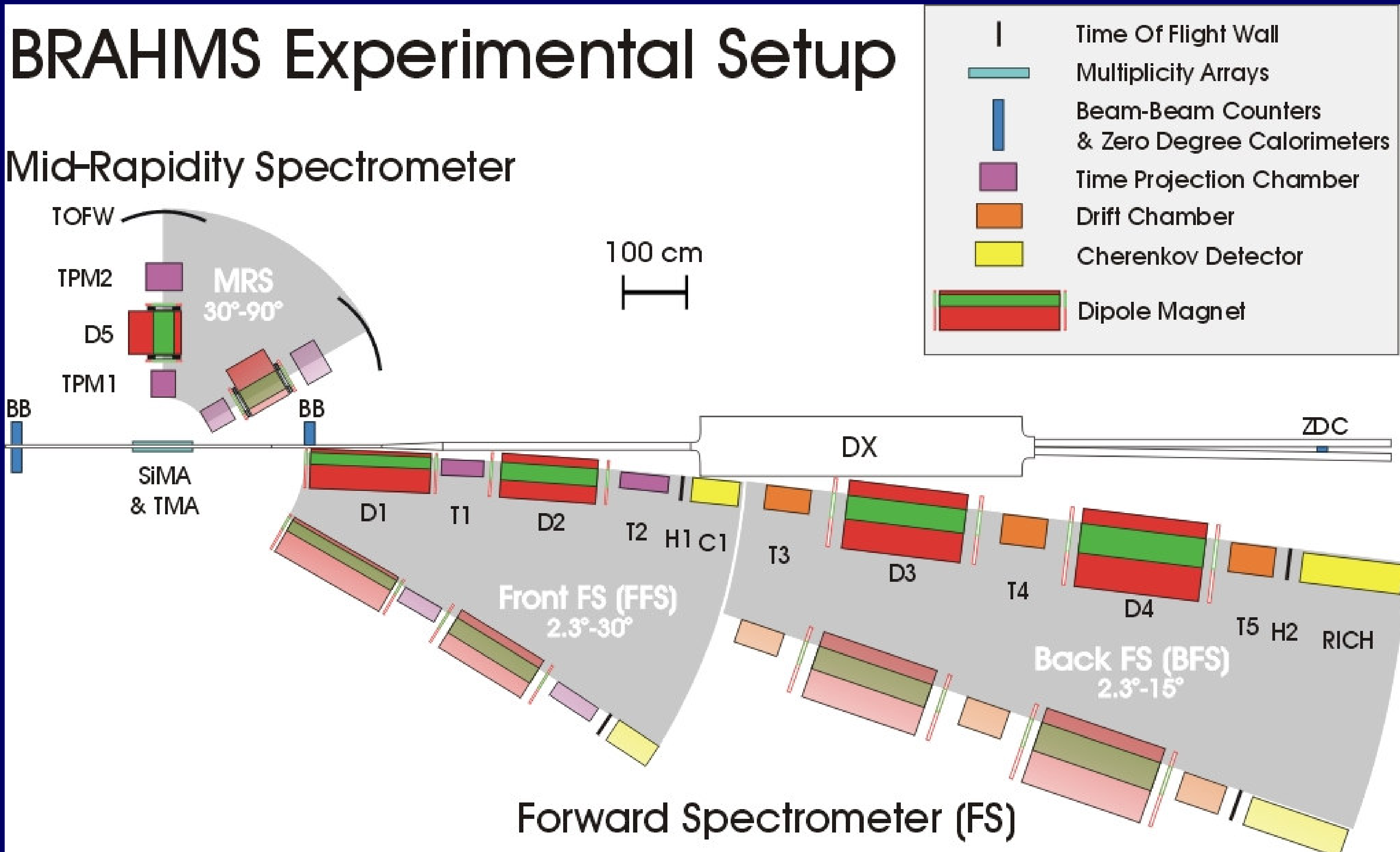
But one has to remember that that low number is a lower limit, not a typical value.

From Guzev, Strikman, and Vogelsang.

Most of the data collected at 4 degrees would have x_2~0.01



BRAHMS at RHIC

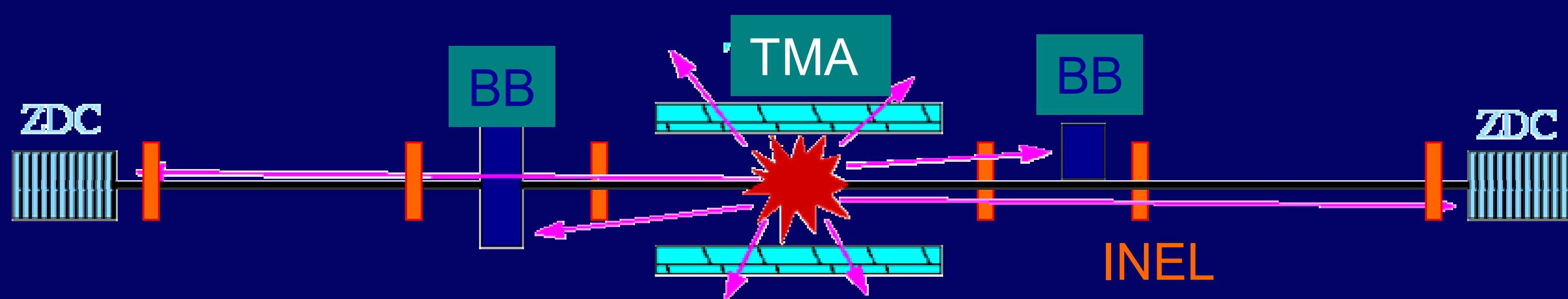


Event characterization

The centrality of the collision for the results that will be presented is defined as fractions of the total multiplicity measured with the TMA in $-2<\eta<2$

Global Detectors in use for centrality, luminosity measures, and inelastic pp cross section

Our triggers are defined with the ZDC and BB, p+p and d+Au collisions were triggered with the INEL detectors.

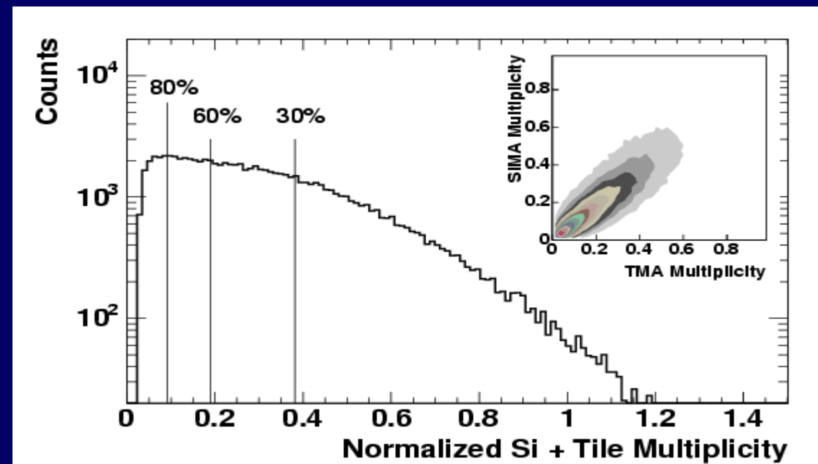


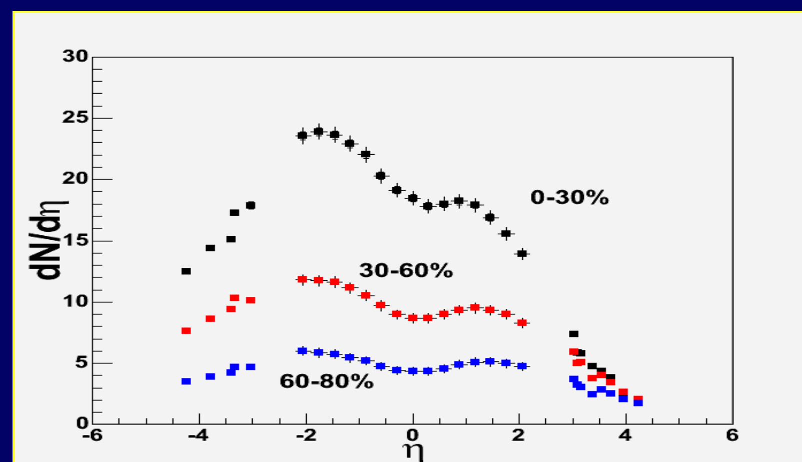
Centrality dependence.

The dAu data can be selected on centrality to determine the Number of binary collisions and study impact parameter variation.

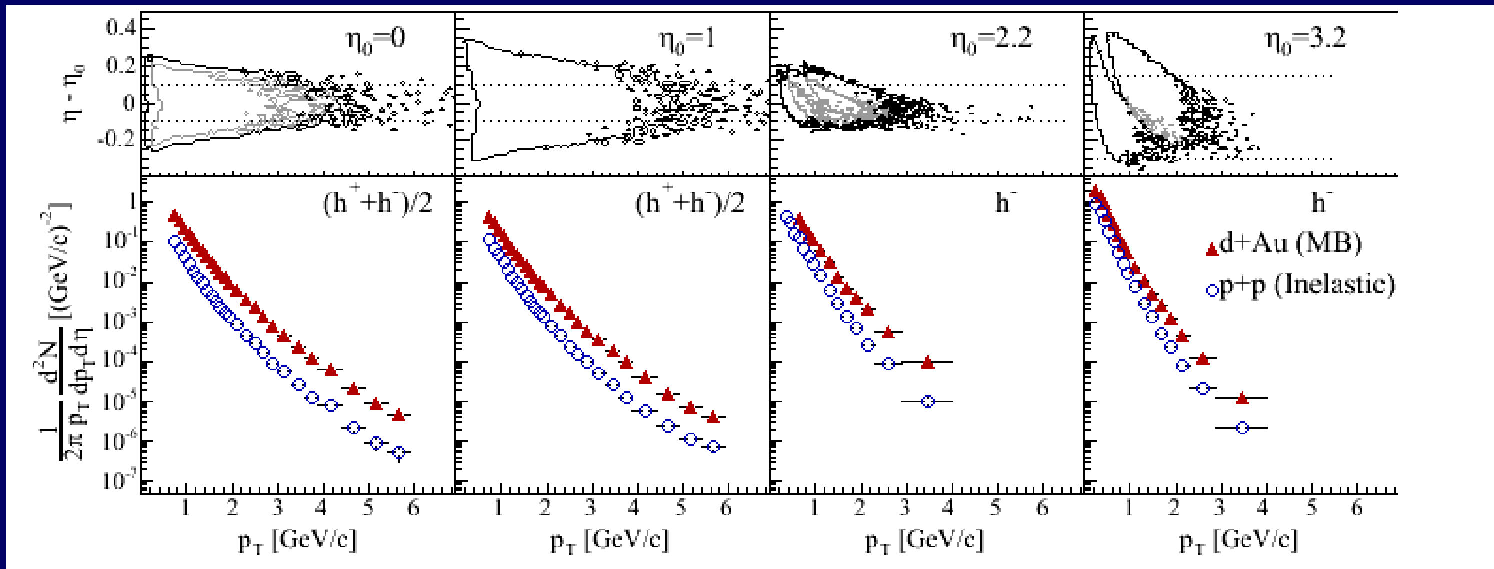
Based on charged particle multiplicity distributions in –2<h<2.

Note centrality evolution of dN/dη.





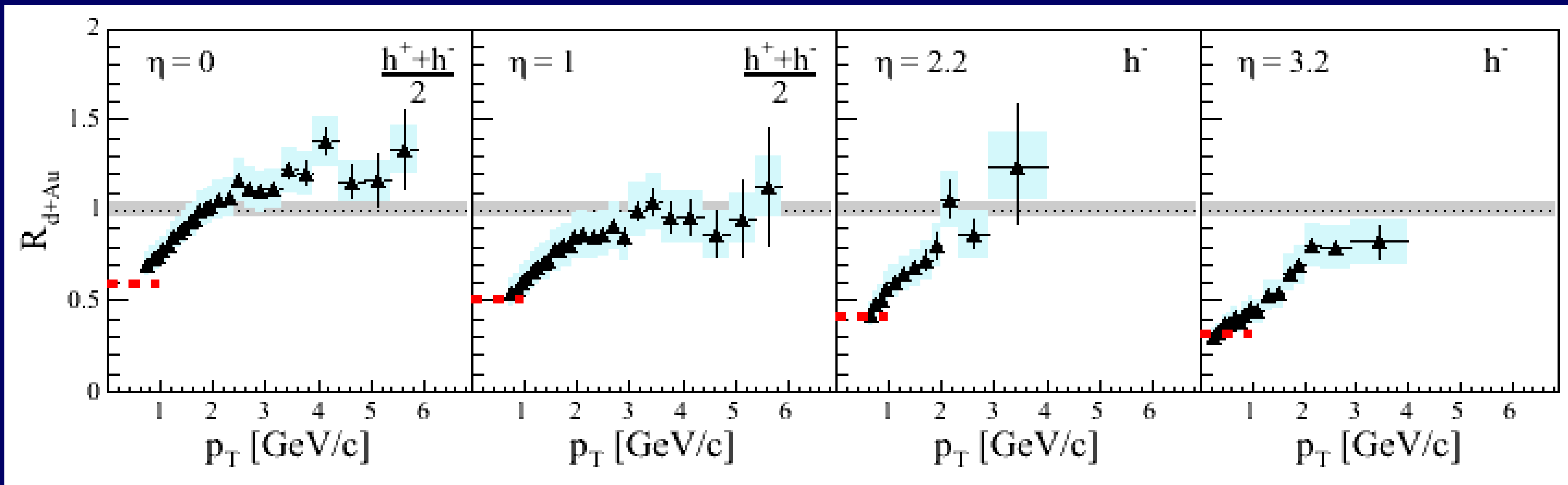
Spectra from d-Au and p-p collisions



Upper panels show an outline of the data used construct the spectra. At each angle, one or several magnetic field settings were used.

Spectra are acceptance and detector efficiency corrected, other corrections as momentum resolution and binning effects were not included.

R_{dAu} as function of rapidity



Phys. Rev. Lett. 93, 242303 (2004)

Minimum bias with

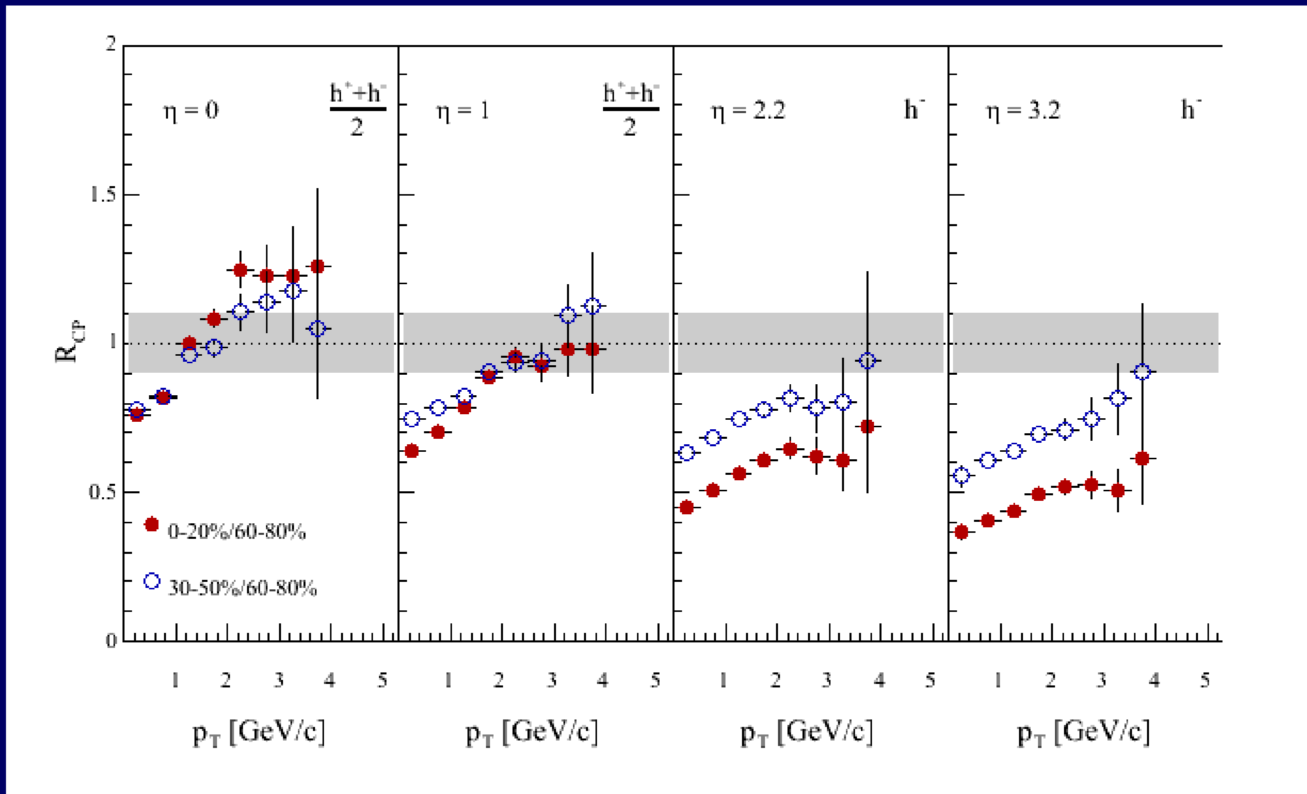
$< N_{coll} > = 7.2 \pm 0.3$

Cronin like enhancement at η=0.

Clear suppression as η changes up to 3.2

Same ratio made with $dN/d\eta$ follows the low p_T R_{dAu}

R_{cp} ratios



At η =0 the central events have the ratio systematically above that of semi-central events. We see a reversal of behavior as we study events at η=3.2

$$R_{cp} = \frac{1/\langle N_{coll}{}^{central}\rangle \quad N_{AB}{}^{central}(p_T,\eta)}{1/\langle N_{coll}{}^{periph}\rangle \quad N_{AB}{}^{periph}(p_T,\eta)}$$

Using ratios to obtain the R_{dAu} of identified negative particles.

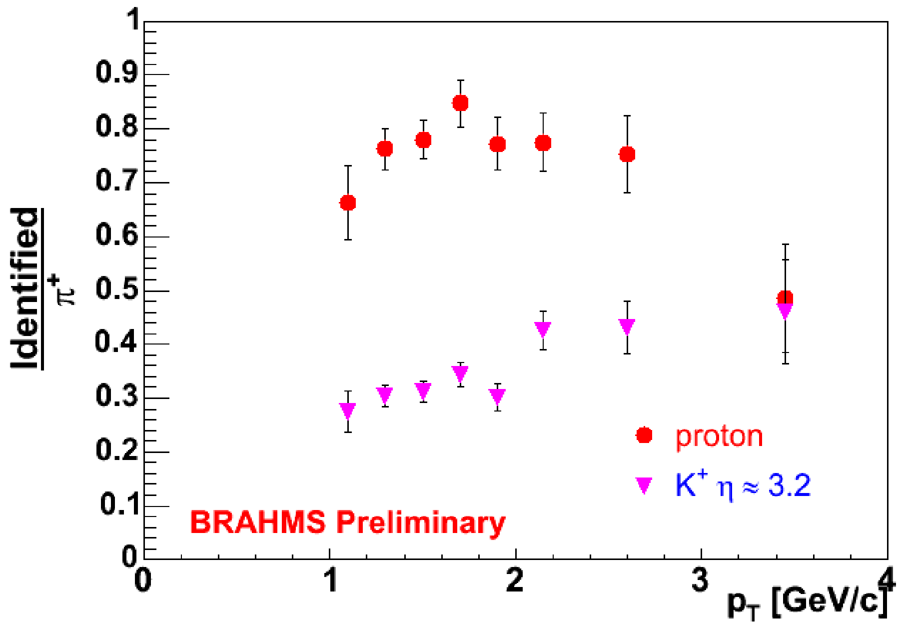
Data so from from h- and h+.

Are there significant differences for identified particles.

Spectral analysis underway; can extract R_{dAu} from measured particle ratio's vs. p_T

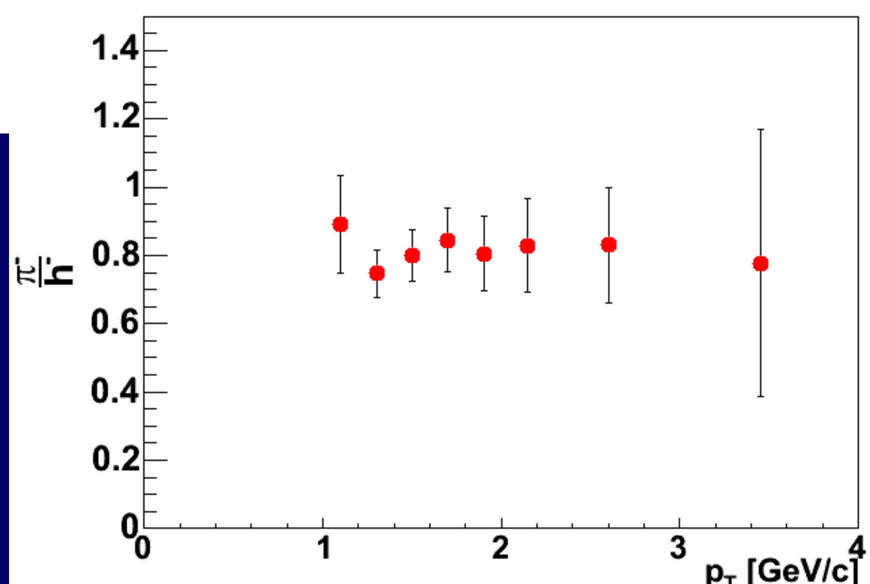
$$R^{\bar{p}}_{dAu} = R^{h-}_{dAu} \frac{\left(\frac{\bar{p}}{h^-}\right)^{dAu}}{\left(\frac{\bar{p}}{h^-}\right)^{pp}} = \frac{1}{N_{coll}} \frac{\left(\frac{dn^{dAu}}{dp_T d\eta}\right)^{h^-}}{\left(\frac{dn^{pp}}{dp_T d\eta}\right)^{h^-}} \frac{\frac{\left(\frac{dn^{dAu}}{dp_T d\eta}\right)^{\bar{p}}}{\left(\frac{dn^{dAu}}{dp_T d\eta}\right)^{h^-}}}{\frac{\left(\frac{dn^{pp}}{dp_T d\eta}\right)^{\bar{p}}}{\left(\frac{dn^{pp}}{dp_T d\eta}\right)^{h^-}}}$$

Identified particles in d-Au at η=3.2

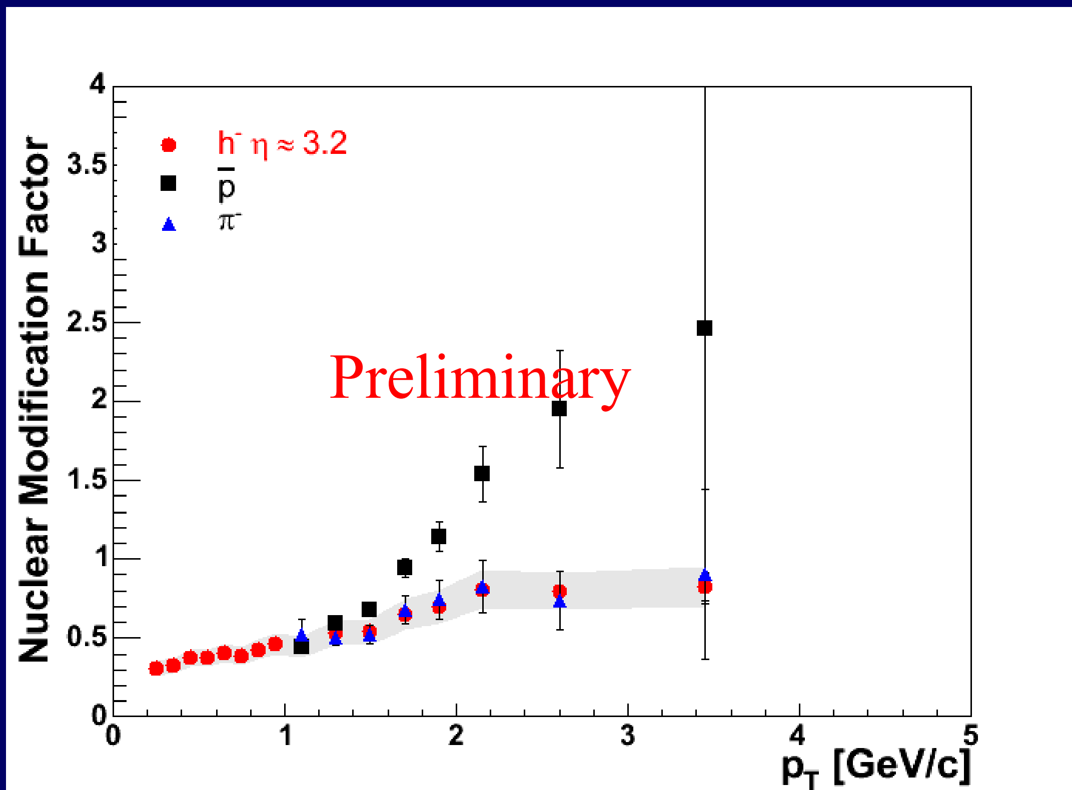


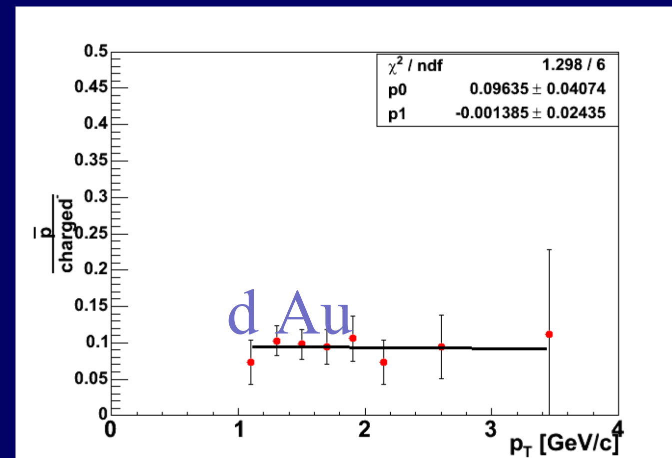
Many protons in the most forward d+Au. Is this beam fragmentation?

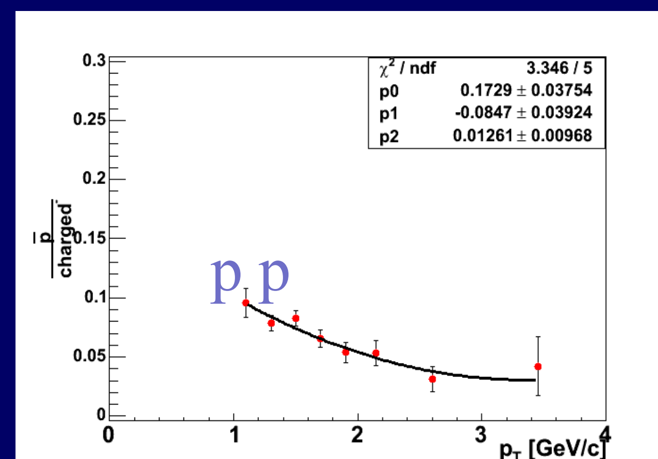
80% of the negative charged particles at η=3 are pions



R_{dAu} for anti-protons and pions (min bias)

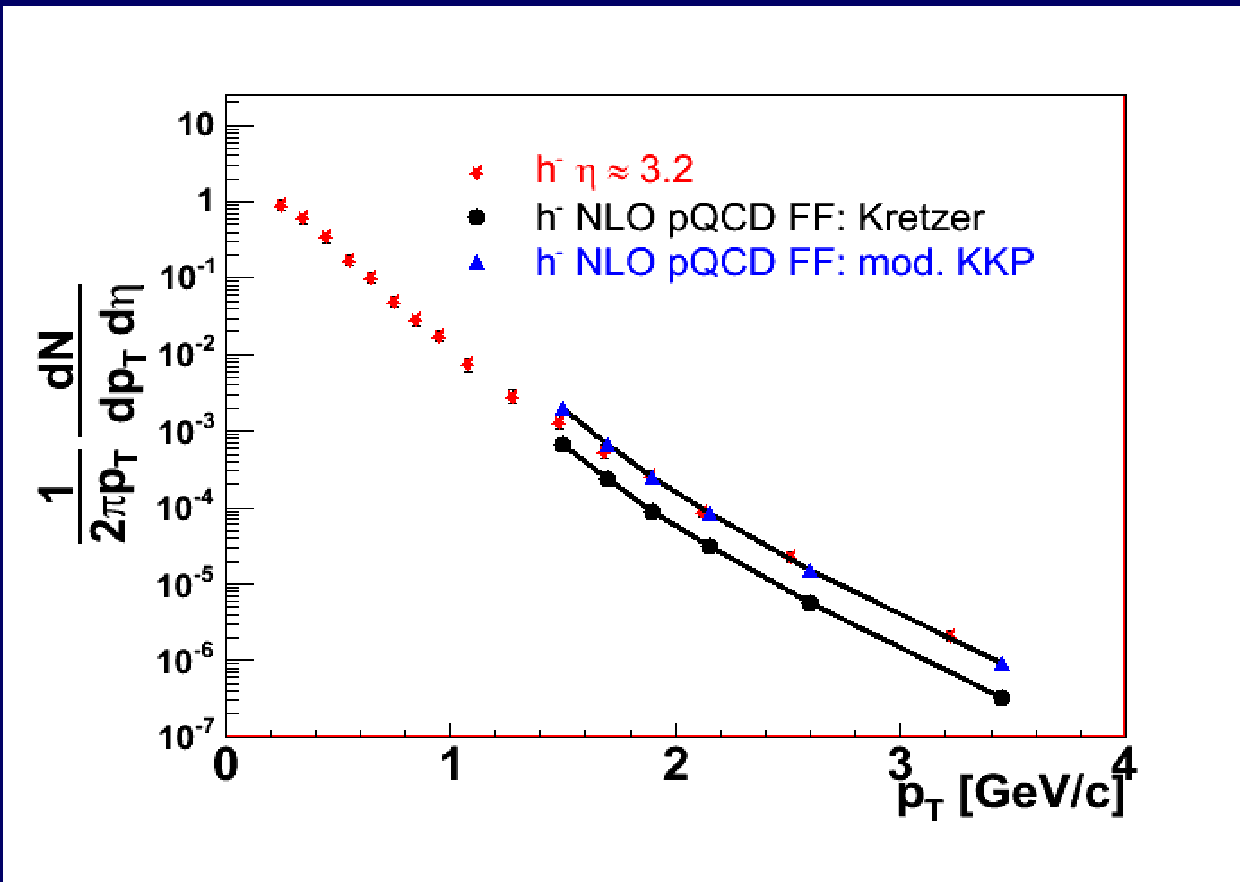






Strong suppression for π-.
Enhancement for p-bar

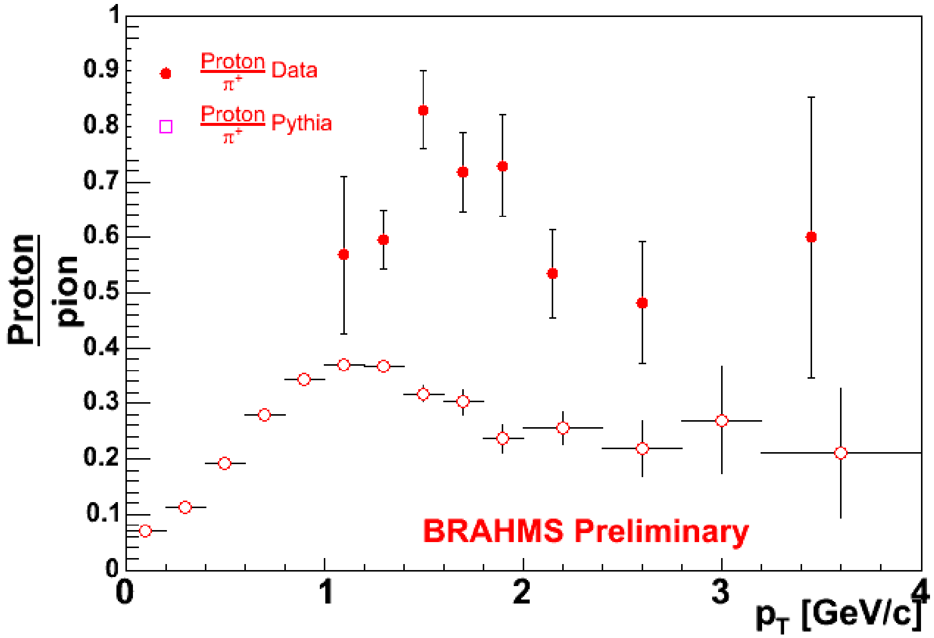
Measured h⁻ at 4 degrees and a NLO pQCD calculation



NLO pQCD calc. From W. Vogelsang

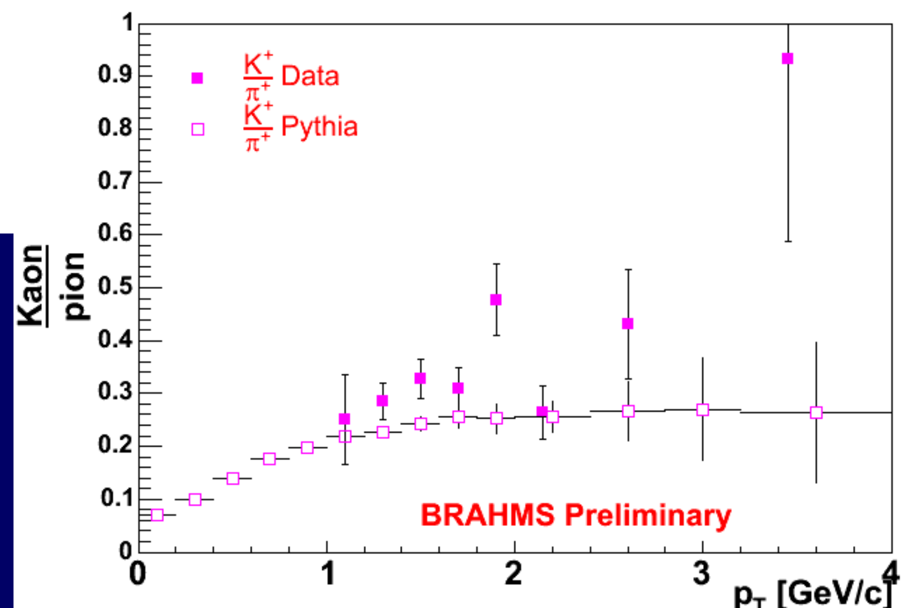
FF: mod KKP is an attempt to reproduce h^-

Comparison of particle ratios measured in p+p collisions and simulated with PYTHIA



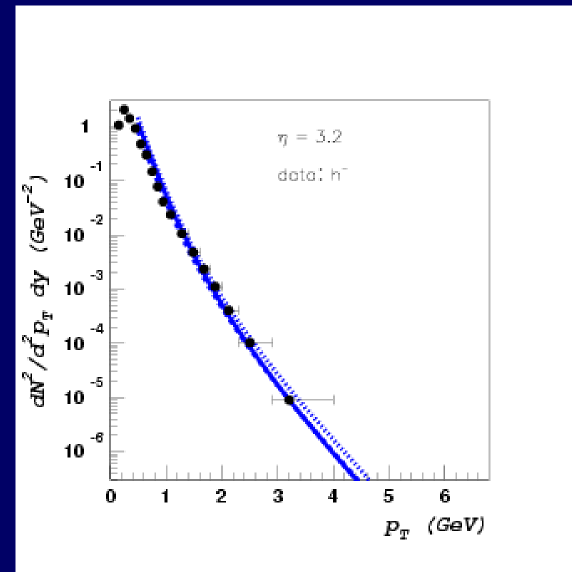
For protons we find a remarkable difference that may indicate other processes besides parton fragmentation.

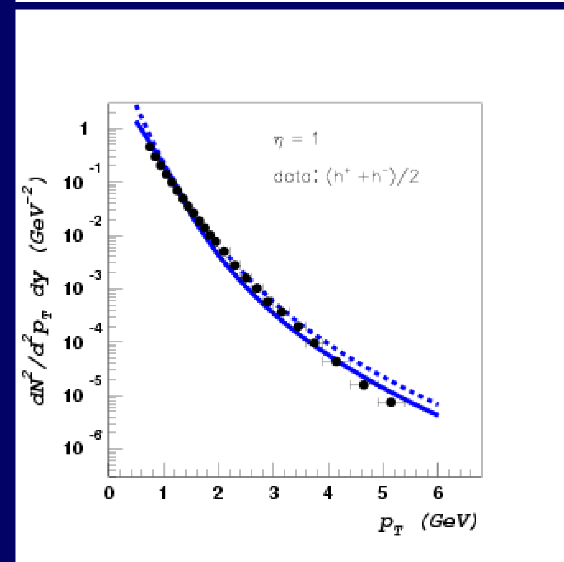
We measure a small excess of kaons and see an emerging trend that suffers from low statistics at high pt.



Gluon Saturation

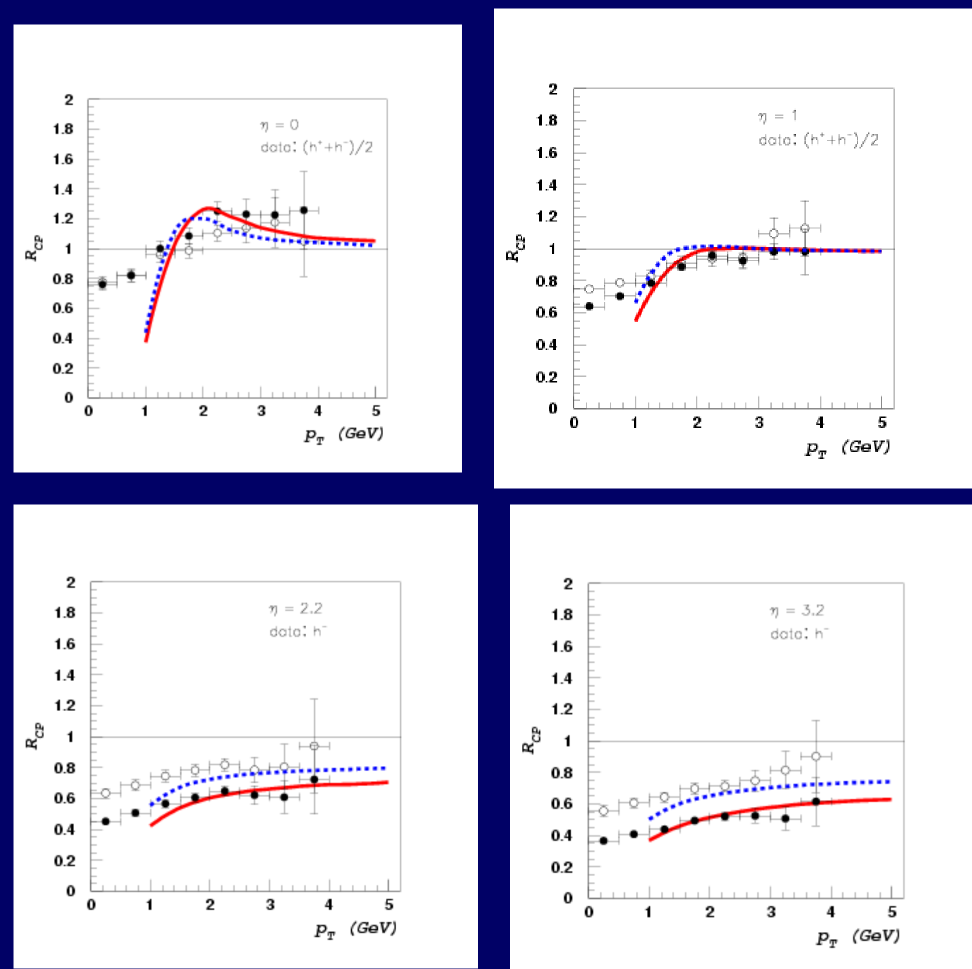
- BRAHMS data analyzed by Kharzeev, Kovchegov and Tuchin using the CGC as underlying description for a quantitative analysis.
- Interpret as coherence that becomes more important with increasing energy and low-x.
- Also successful in interpreting slow growth of mid-rapidity multiplicities in AA collisions (vs. energy as well as centrality).





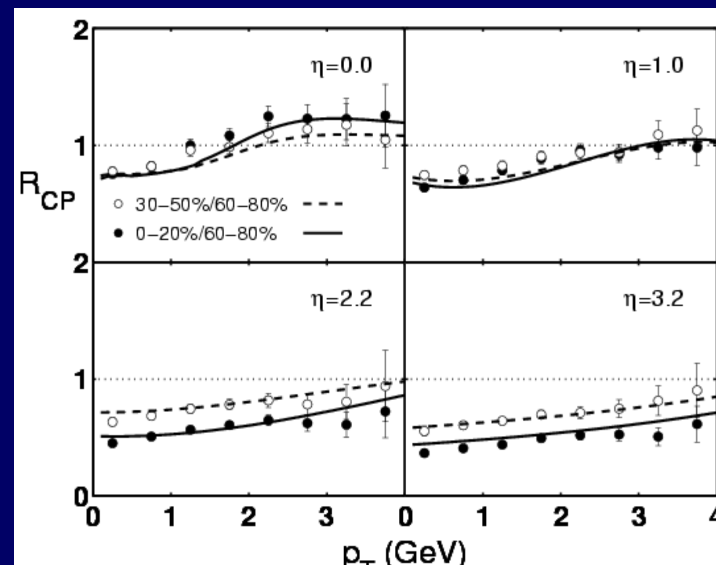
Gluon Saturation

- Cronin effect at y~0
- Suppression at forward rapidity/ low-x
- Suppression increases with centrality.
- Good agreement with BRAHMS data.



Parton recombination (R.Hwa, C.B.Yang & R.J.Friese)

- Parameterized soft component (pi's) vs. rapidity centrality. Essentially from dN/dh.
- Additional final state hadrons created from lower pt-partons (density dependent)
- Good description of p_t-dependence. The reversal of centrality dependence comes from $dN/d\eta$ (primarily)



Nucl-th/0410111

What has been know otherwise

Lower energies
- NA49 pA.
- Kinematic constraints more important.
- pQCD not successful at these pt values.

- Other data from RHIC (subsequent talks)

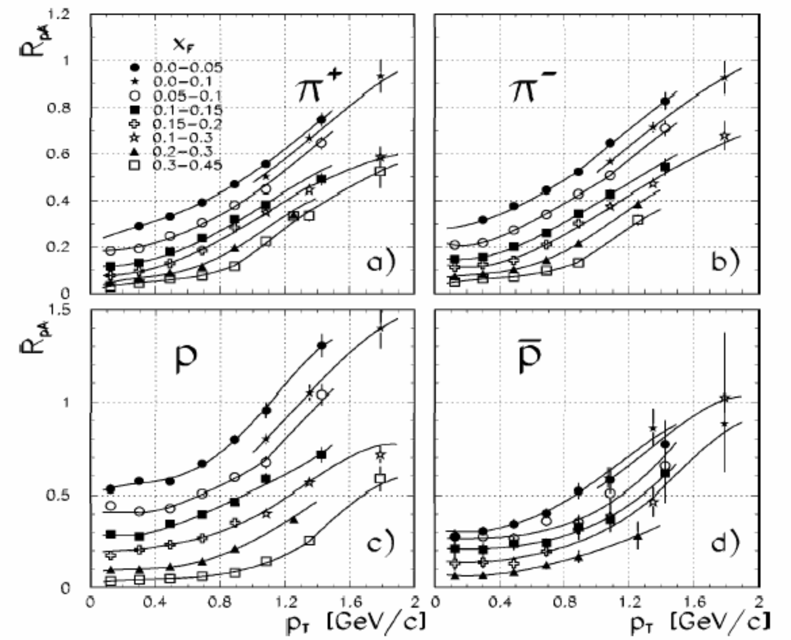


Figure 6.6: Nuclear modification factor R_{pA}, in different x_F intervals, for a) π^+'s, b) π^-'s, c) p's and d) $\bar{p}$'s produced in central p+Pb collisions at 158 GeV. Note: lines are drawn to guide the eye; errors are statistical only.

Summary

- The Suppression and in particular the inversion vs. centrality may be a signature for the gluon saturation. The x-range probed is in range of 10^{-3}- 10^{-2}.
- There are competing explanations.
- Higher precession experiments as well as correlations studies may help in clarifying the importance of CGC at RHIC energies.
- Forward physics has proved to be a important regime for discovery and an important ingredient of our understanding of the new medium formed at RHIC.
- Of interest in its own right to understand low-x physics in pA collisions.

The BRAHMS Collaboration

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