BRAHMS Forward Physics Program

Forward Physics at RHIC and LHC

University of Kansas, Lawrence KS

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for the **BRAHMS** collaboration

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BROOKHAVEN NATIONAL LABORATORY

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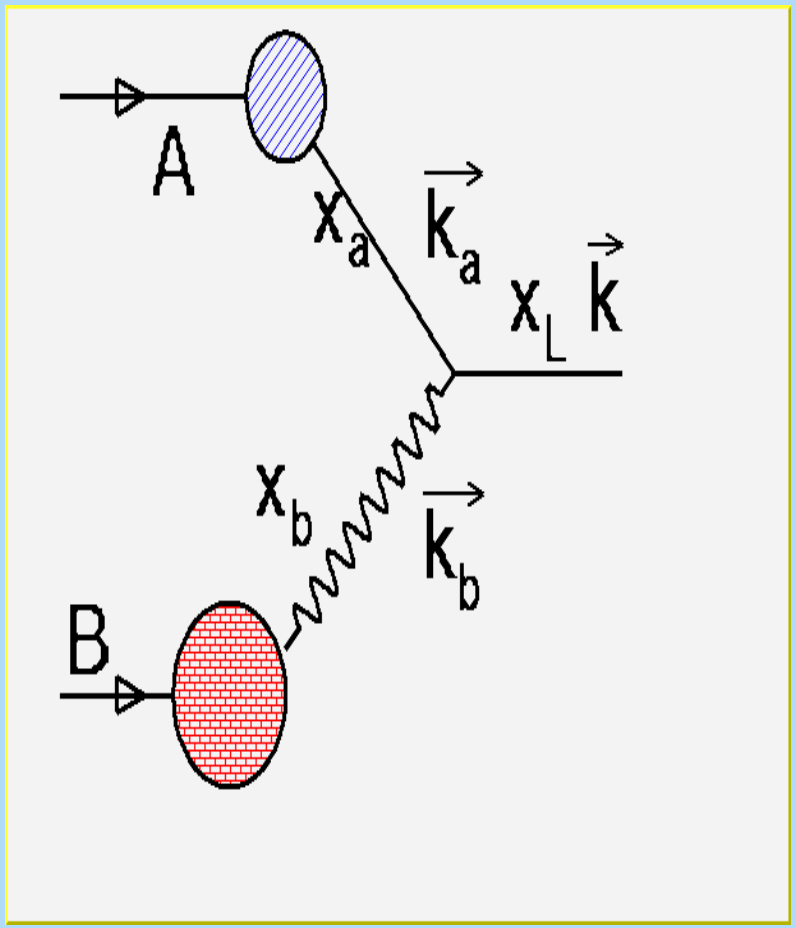
Outline of presentation

- **Introduction and possible focus of future measurements.**
- **Brief summary of AuAu forward results.**
- **Revisit our d+Au results as function of rapidity and centrality.**
- **Preliminary d+Au results with particle identification.**
- **Results from p+p collisions.**
- **Summary.**



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:

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

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

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

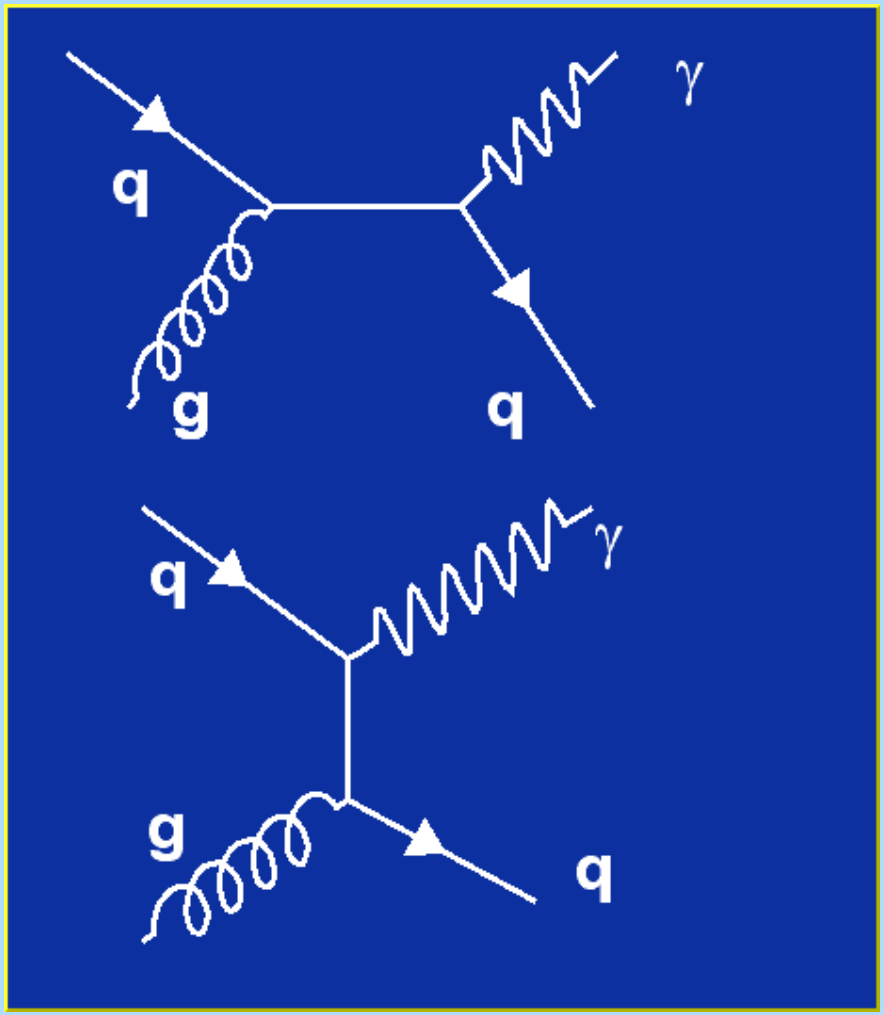
In a 2->2 interaction where both partons are measured at rapidities y_1 and y_2, $Y_{system}=1/2(y_1+y_2)$ and their rapidity in the "system" c.m. $y^*=1/2(y_1-y_2)$

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

The "benefits" of p+A systems

Deep Inelastic Scattering eA has no direct access (first order) to the gluon PDF it measures q - qbar

To access gluon PDF the preferred system would be p+A thru "gluon-initiated" g+q or g +g interactions.

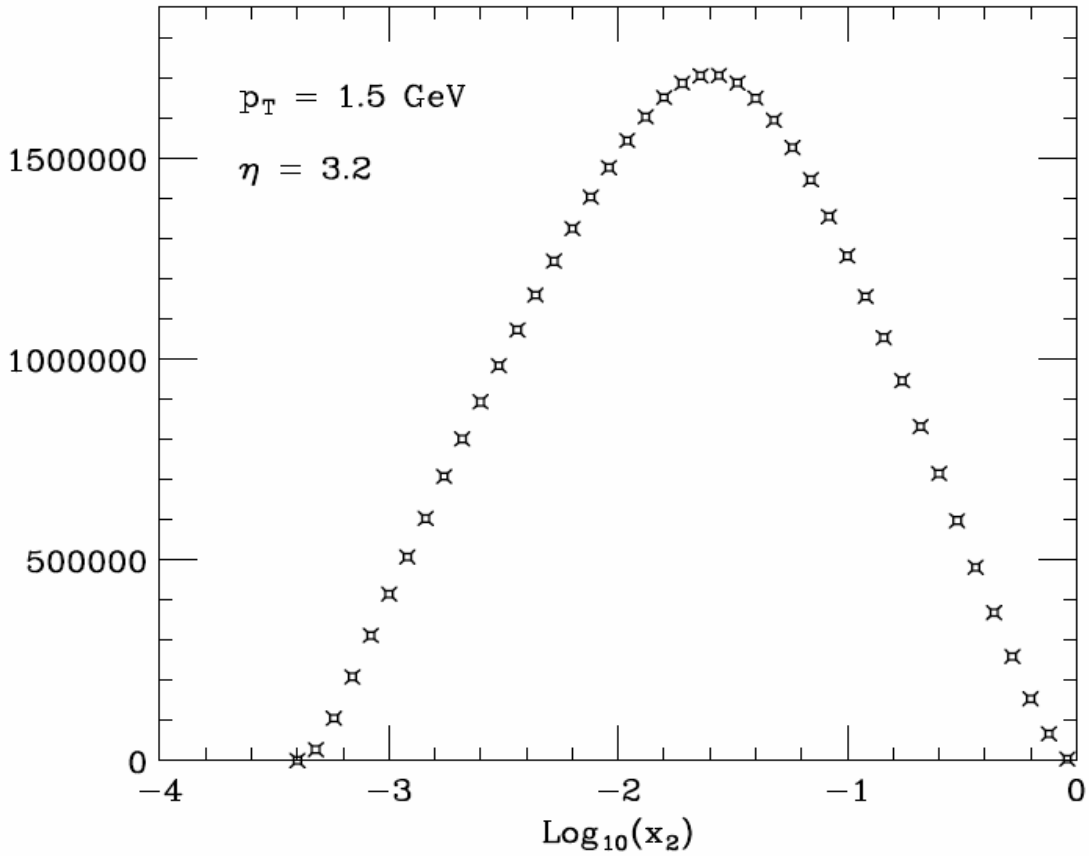


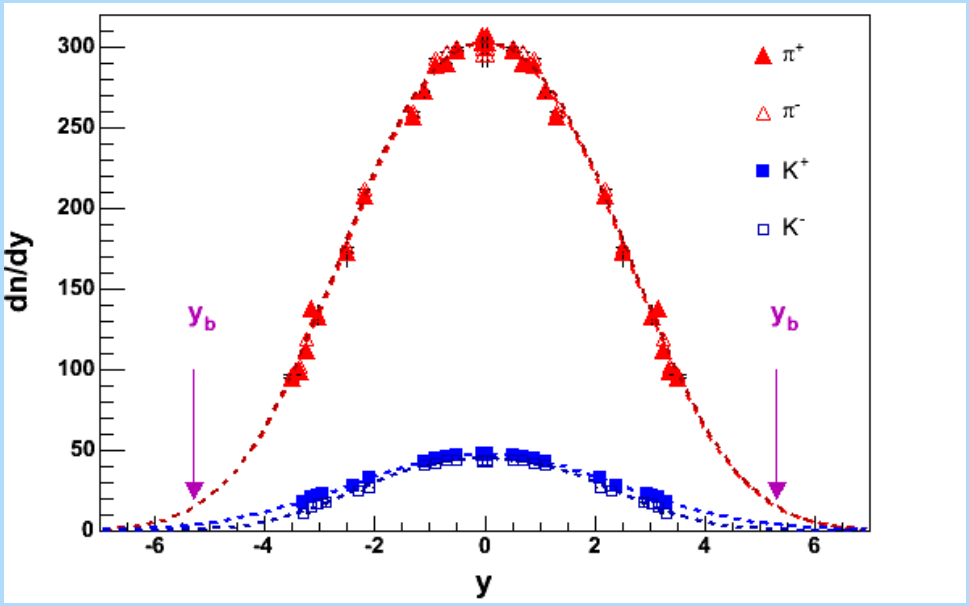
At 4 degrees (y~3 for pions) and p_T = 1 GeV/c one can reach to values as low of $x_2 \sim 10^{-4}$

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

From Gusev, Strickman, and Vogelsang.

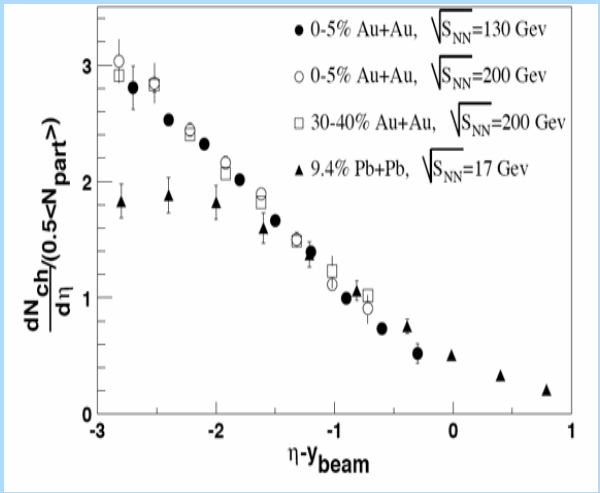
Most of the data collected at 4 degrees would have x_2~0.01

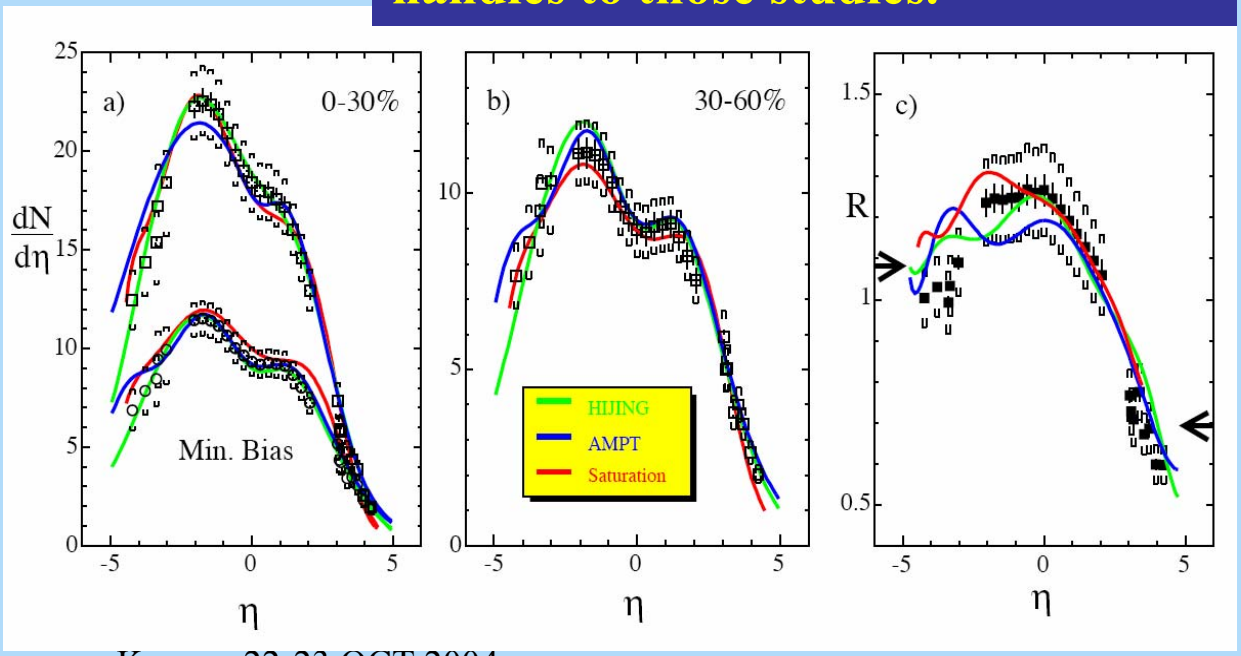




I have a personal preference for the ~direct connection between gluon distributions in the colliding ions and the distribution of produced particles.

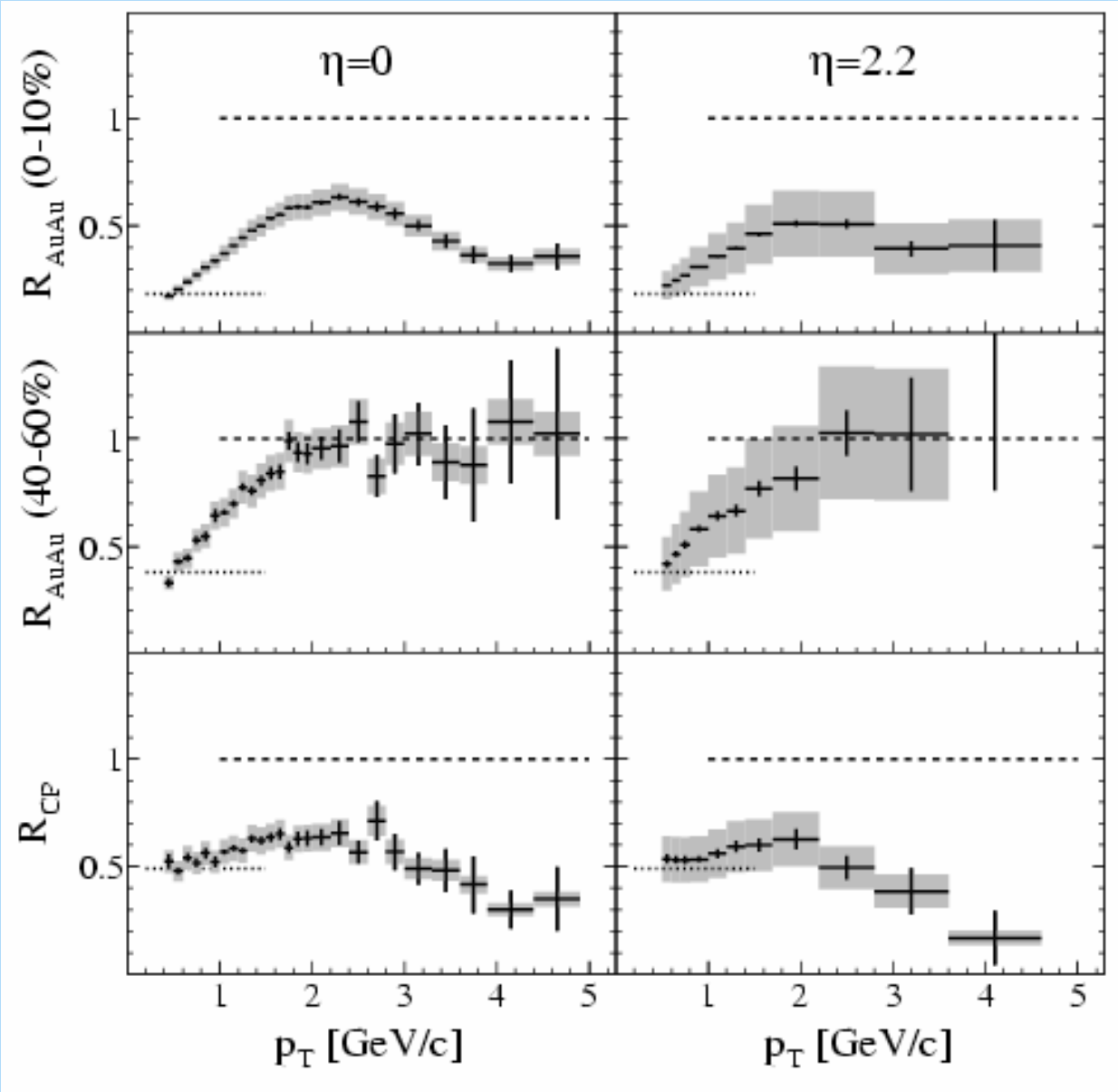
"Limiting fragmentation" arguments extend way beyond their original definition. There must be new physics. BRAHMS is providing handles to those studies.





The comparison of yields from Au+Au to the ones from properly scaled p+p collisions is one of the dramatic results from RHIC. It has been attributed to radiation in a opaque medium formed in all central collisions.

BRAHMS extends those measurements to y~4

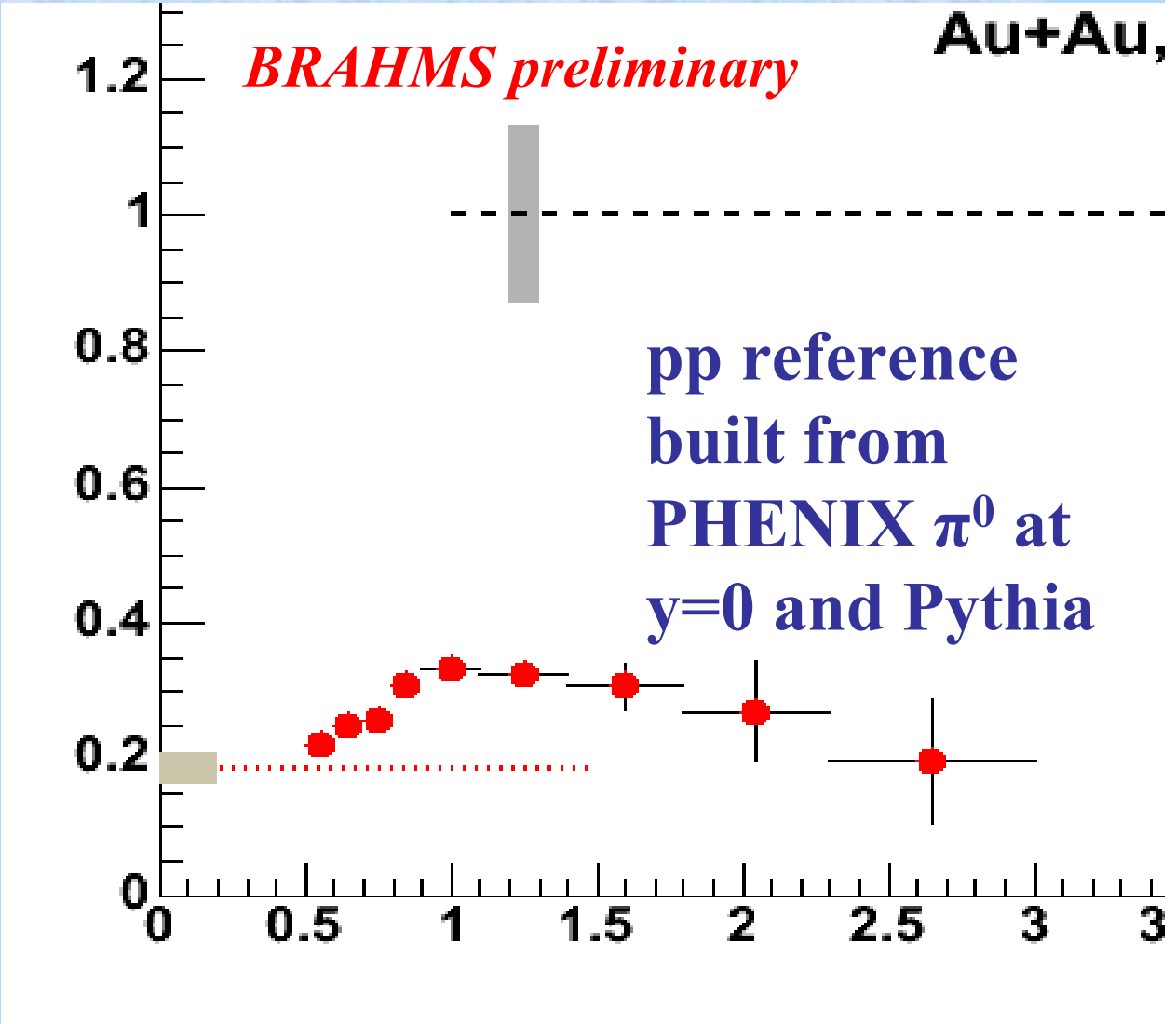


BRAHMS: PRL 91 072305 (2003).

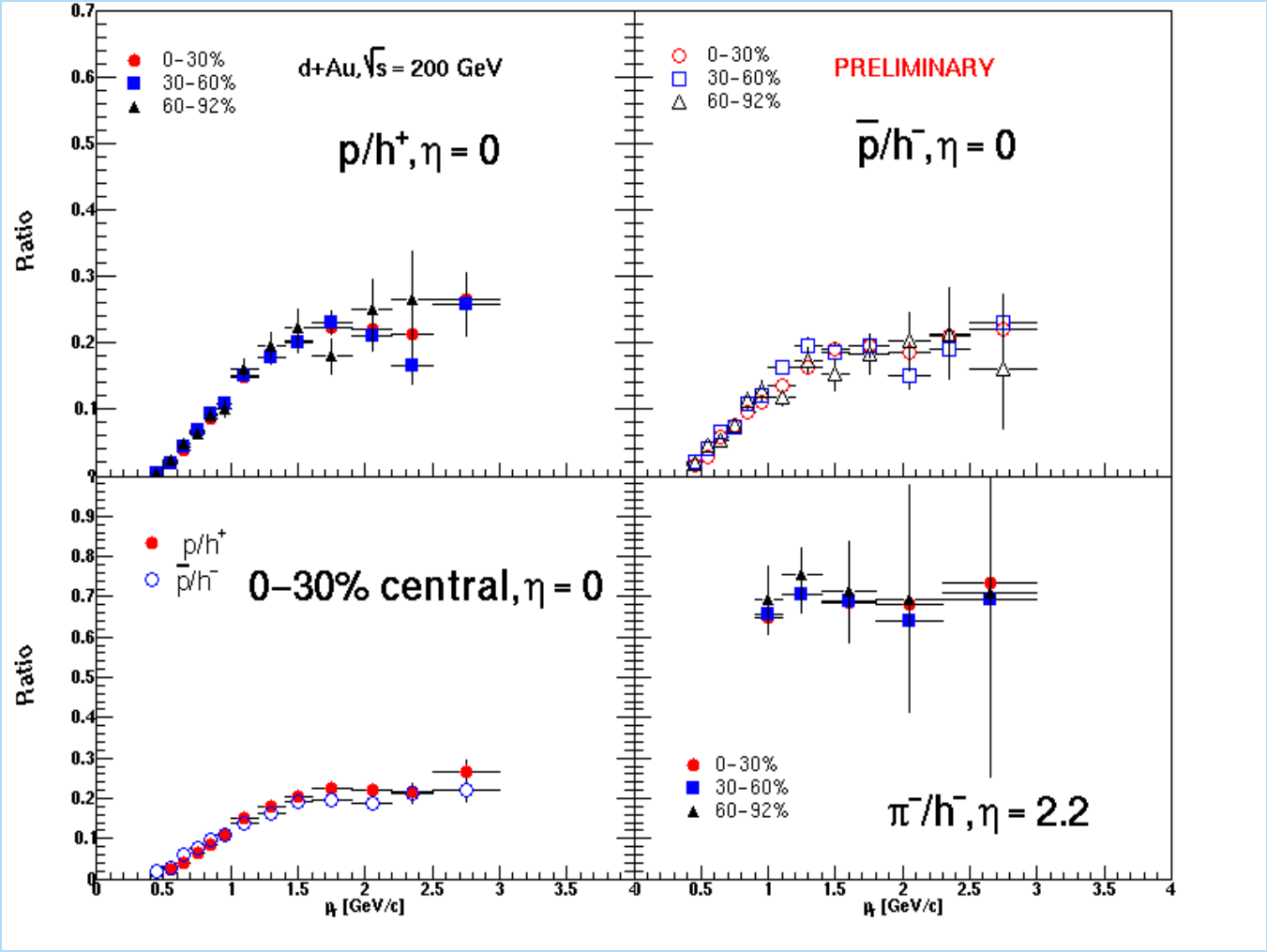
R_{AuAu} for π^- at η=2.2

BRAHMS can reach those high rapidities for identified particles.

The analysis of run04 data is in progress and we will show preliminary results at the DNP meeting.

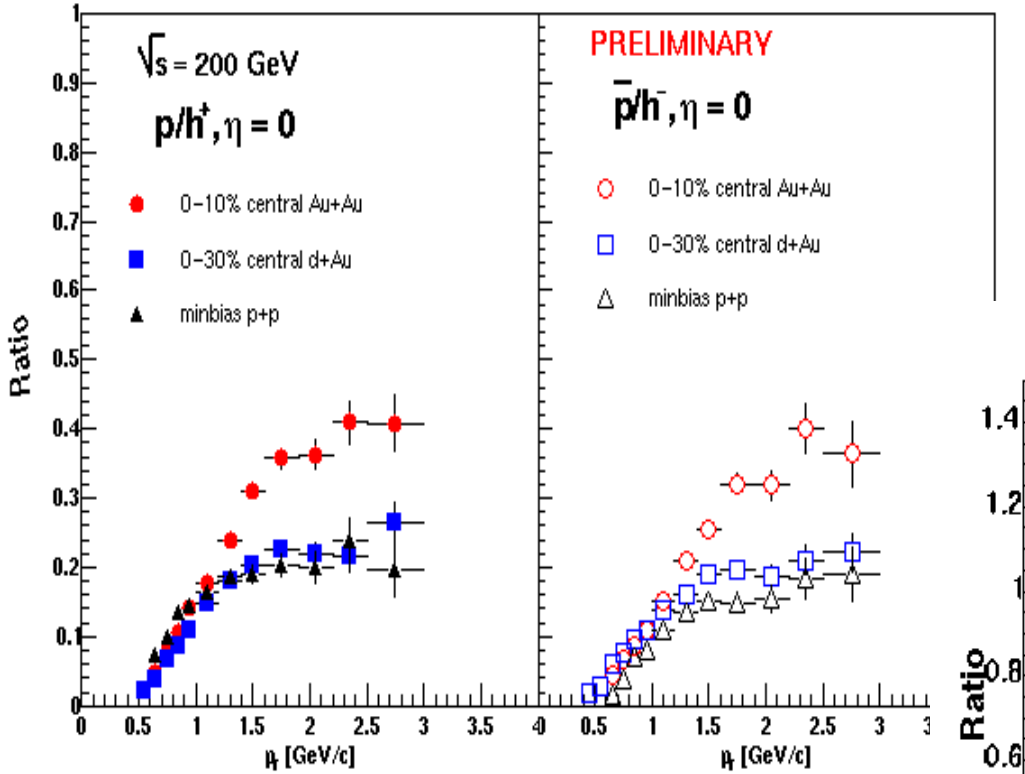


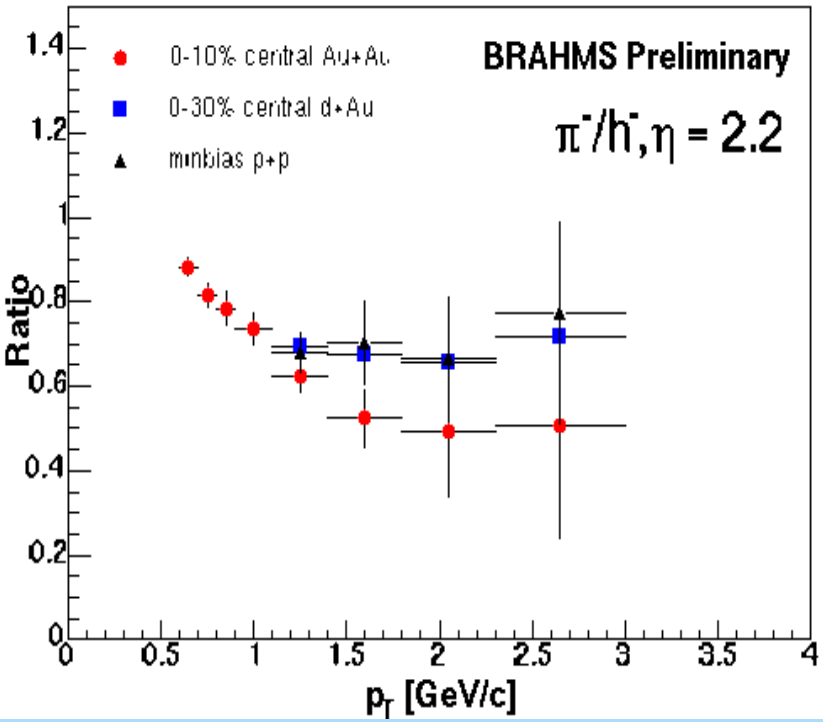
d+Au particle composition



Consistent with "fragmentation in vacuum"

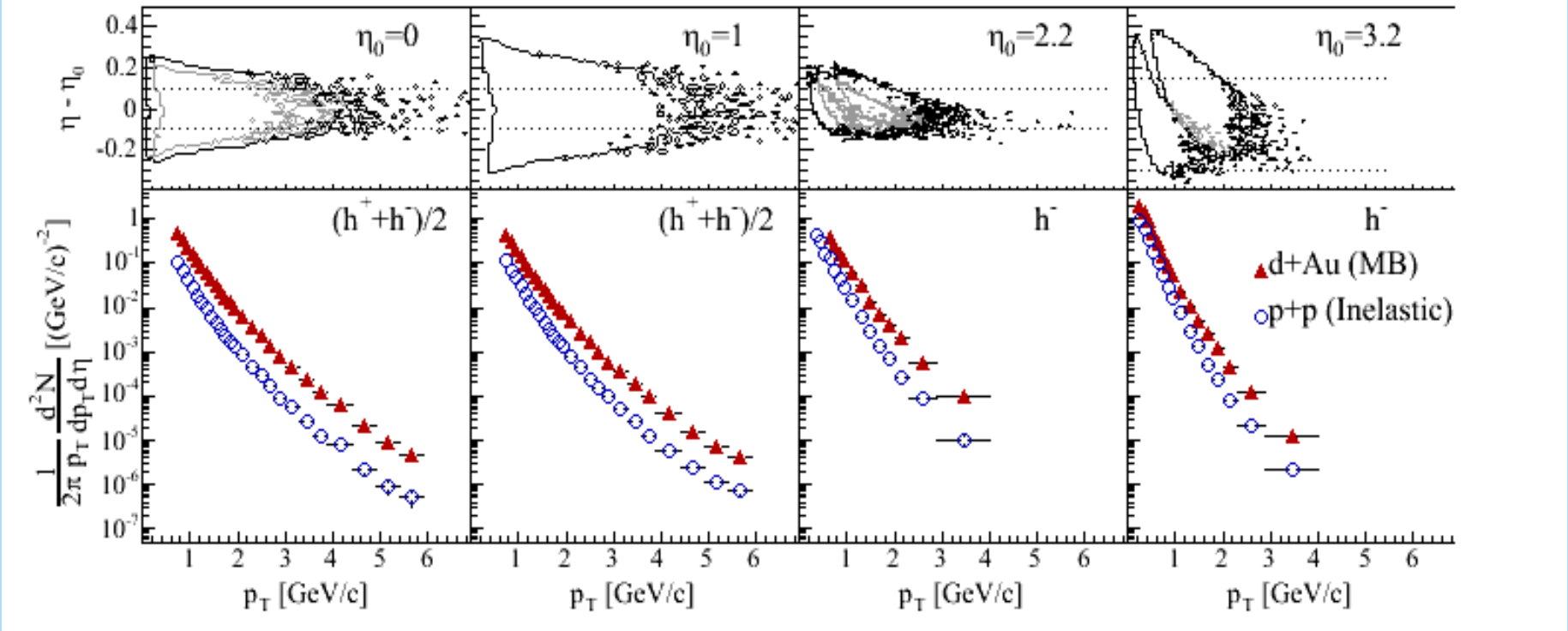
Comparison to A+A





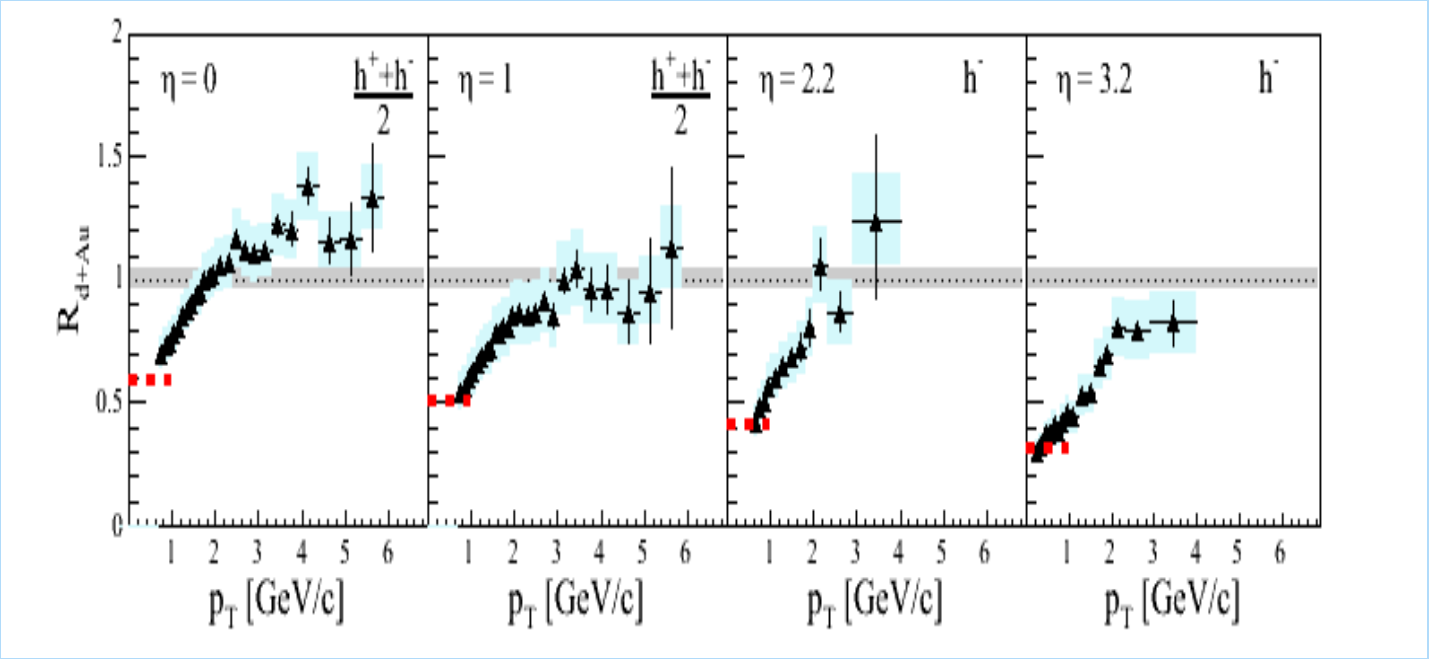
The p+p ratio shows "fragmentation in vacuum", d+Au values are very close to p+p but the ones from AuAu show a big difference that has been attributed to parton recombination.

Acceptance and d+Au and p+p Spectra



submitted to PRL
(nucl-ex/0403005)

R_{dAu} ratios



$$R_{dA} = \frac{1}{\langle N_{coll} \rangle} \frac{d^2N^{d+Au}/dp_T d\eta}{d^2N^{pp}_{inel}/dp_T d\eta}$$

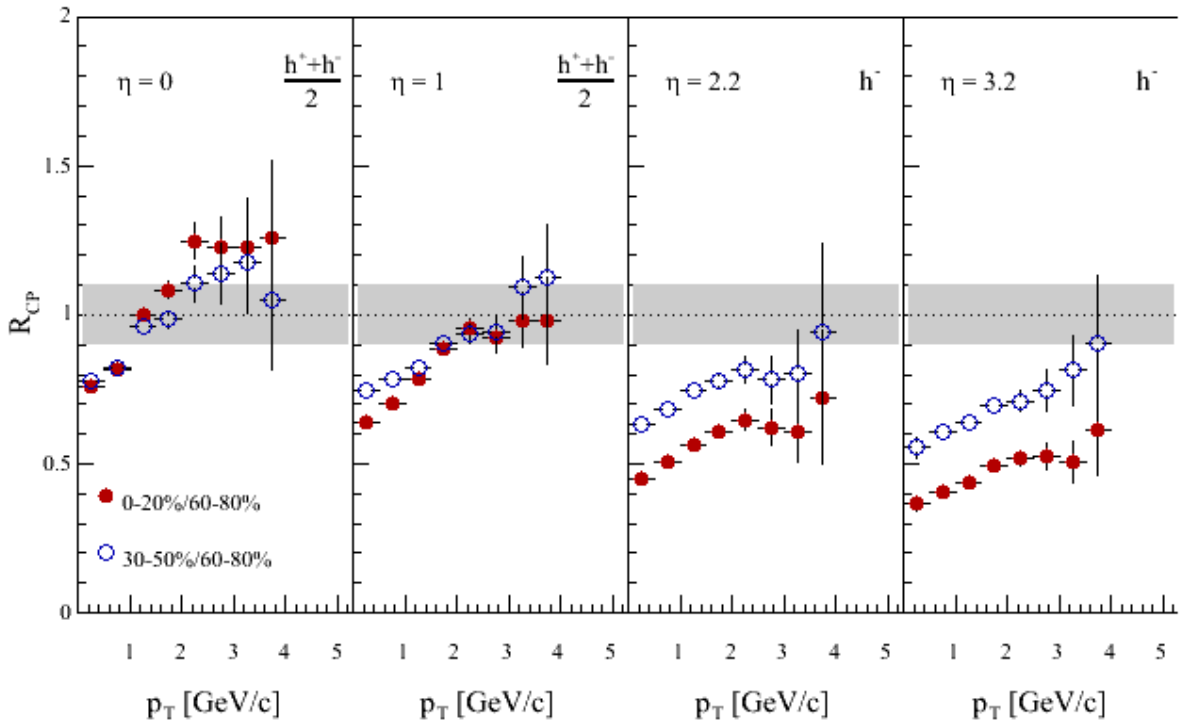
where $\langle N_{coll} \rangle = 7.2 \pm 0.3$

Cronin like enhancement at η=0.

Clear suppression as η changes up to 3.2

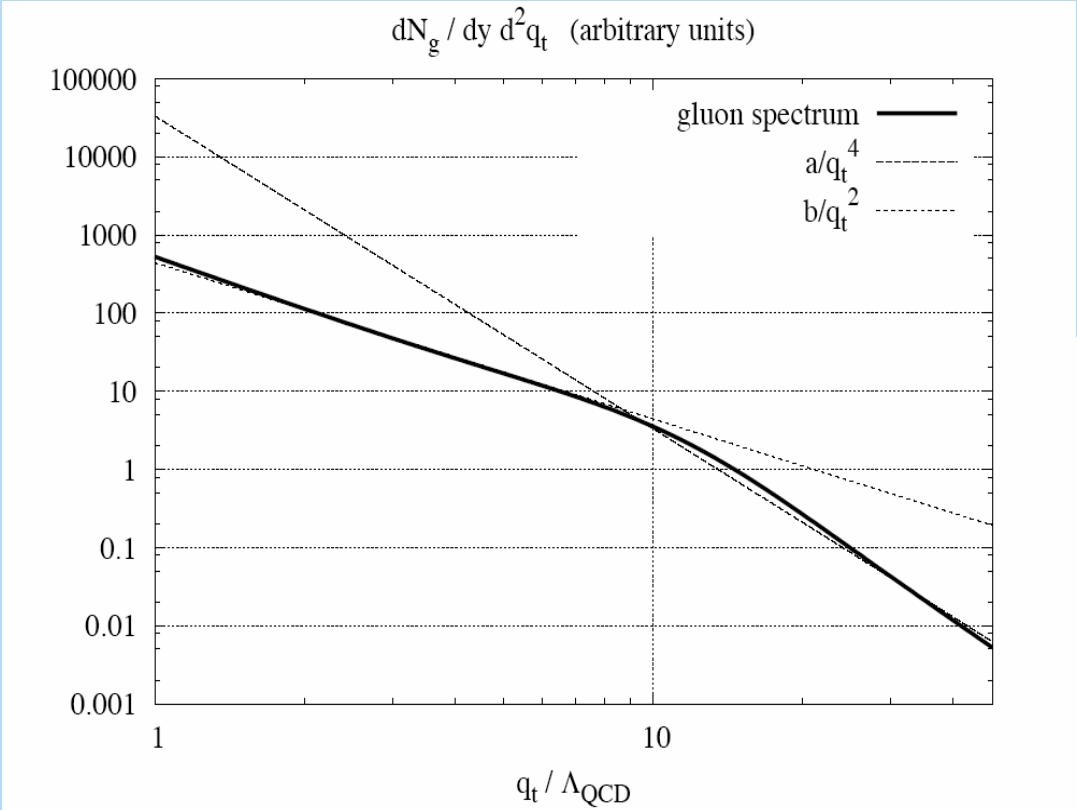
Same ratio made with dn/dη follows the low p_T R_{dAu}

R_{cp} ratios

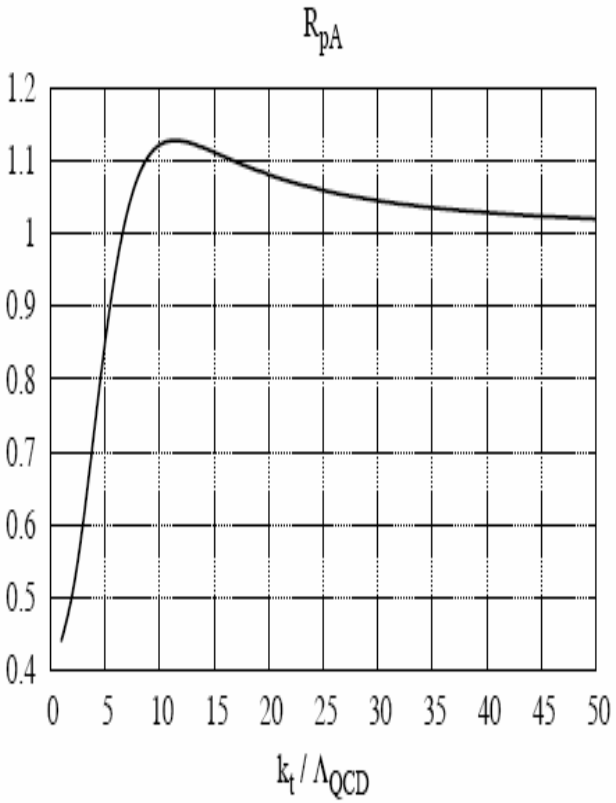


At η =0 the central events have the ratio systematically above that of semi-central events. We see a reversal of behavior as we study events at η=3.2

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

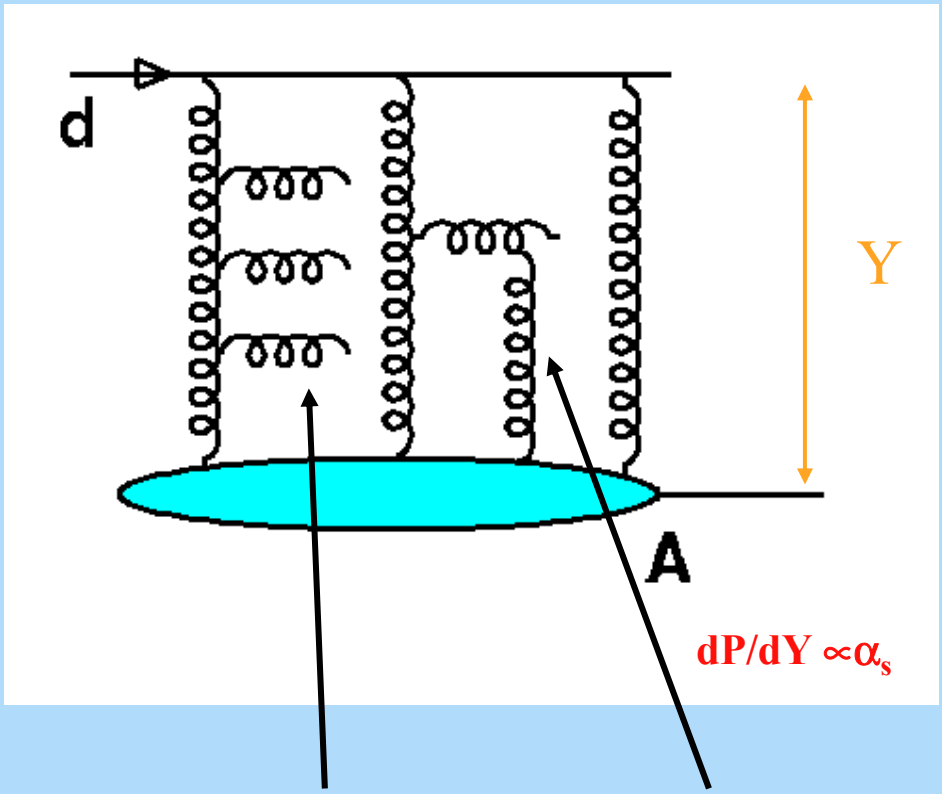


The CGC has Cronin enhancement



R. Venugopalan et al. hep-ph/0402256

Quantum Evolution



$R_{dA} = (d\sigma^{pA}/d^2kdy)/(Ad\sigma^{pp}/d^2kdy)$

For $k >> Q_s$:

$R_{dA} < 1$ increasing with k approaching 1 from below.

For $Q_s < k < k_{geom}$:

$R_{dA} \sim e^{-1.65\alpha y} << 1$

For $k \sim Q_s$:

$R_{dA} \sim \exp(4\alpha y(1-\sqrt{1+\ln A^{1/6}/2\alpha y})) < 1$

At high energy/ rapidity it becomes constant $R_{dA} \sim A^{-1/6}$

gluon radiation

gluon fusion

$dN/d(\ln 1/x) = \alpha_s (2N - N^2)$

Suppression at all k, suppression even stronger for higher A

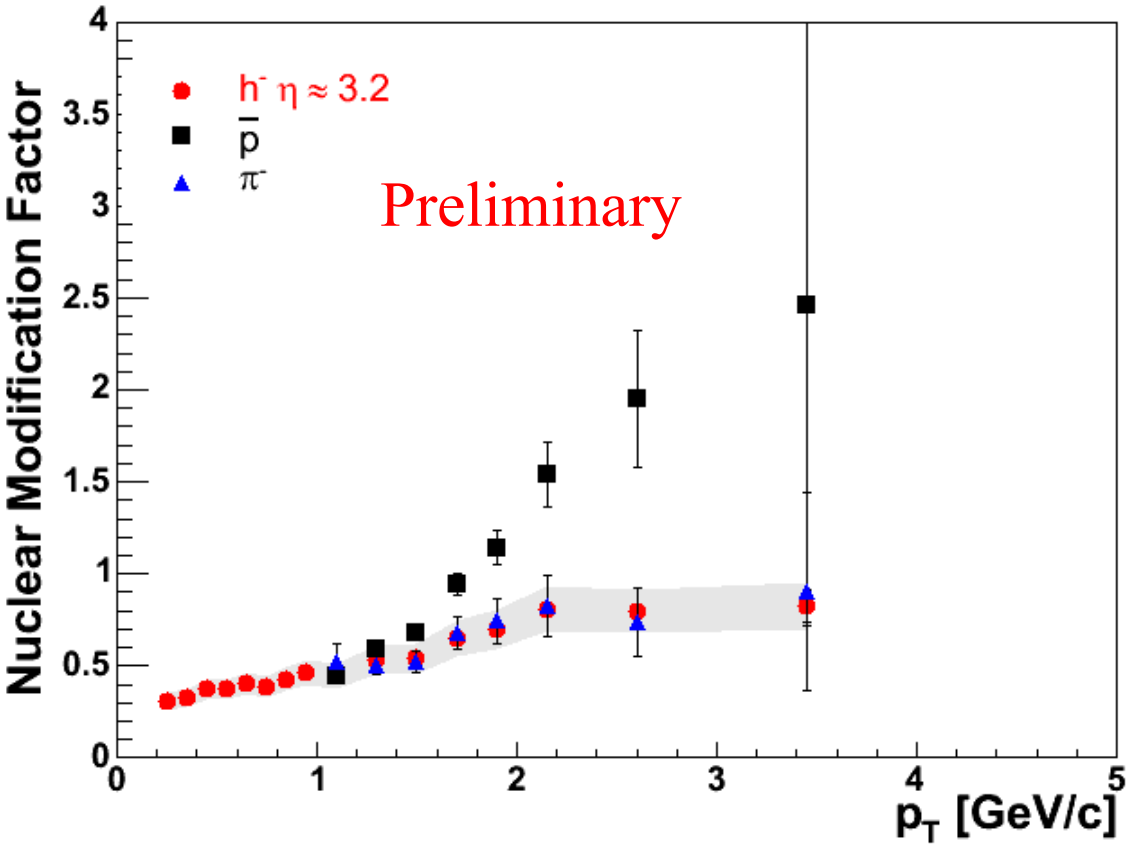
Kharzeev, Kovchegov and Tuchin Phys. Rev. D 68, 094013

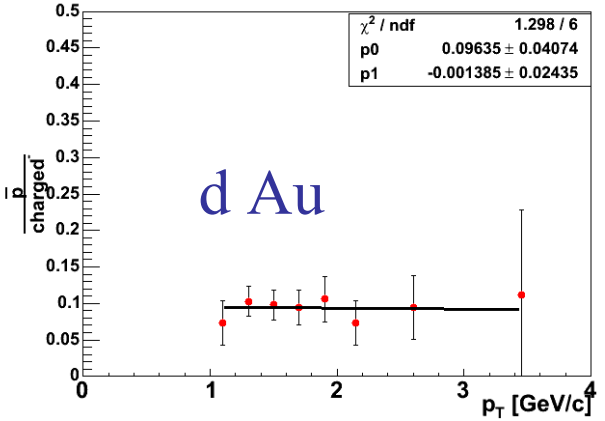
Using ratios to obtain the RdAu of identified negative particles.

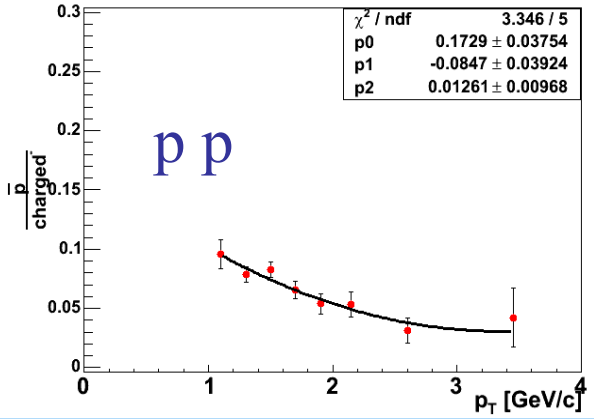
$$R^{\bar{p}}_{dAu} = R^{h^-}_{dAu} \frac{\bar{p}^{dAu}/h^-}{\bar{p}^{pp}/h^-}$$

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

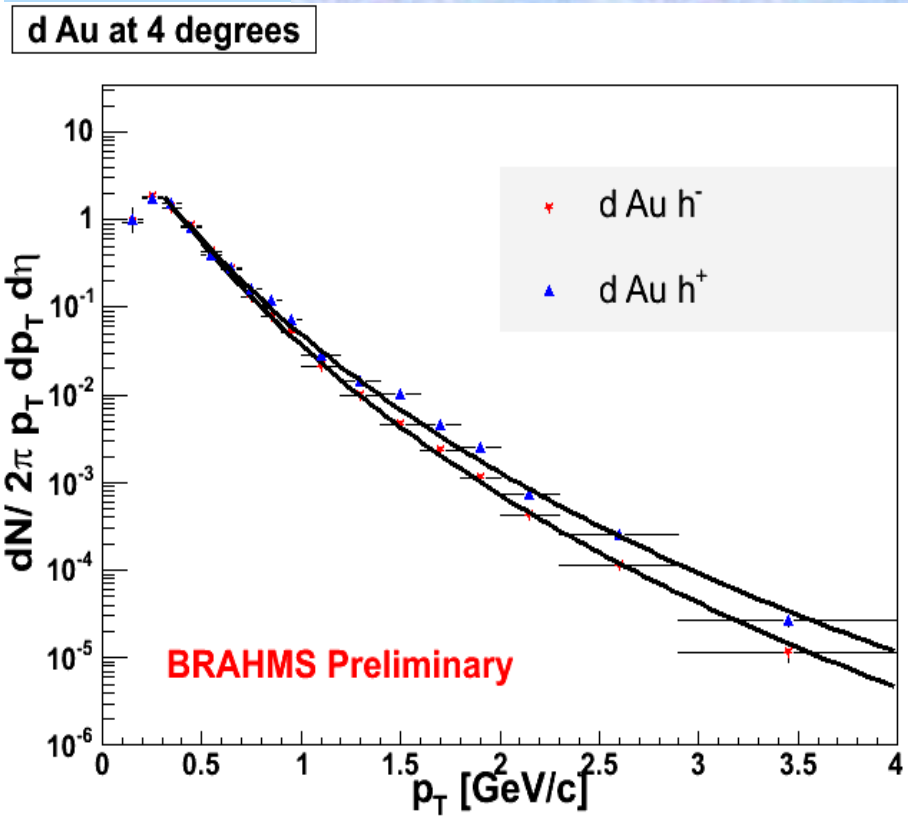
RdAu for anti-protons and pions (min bias)





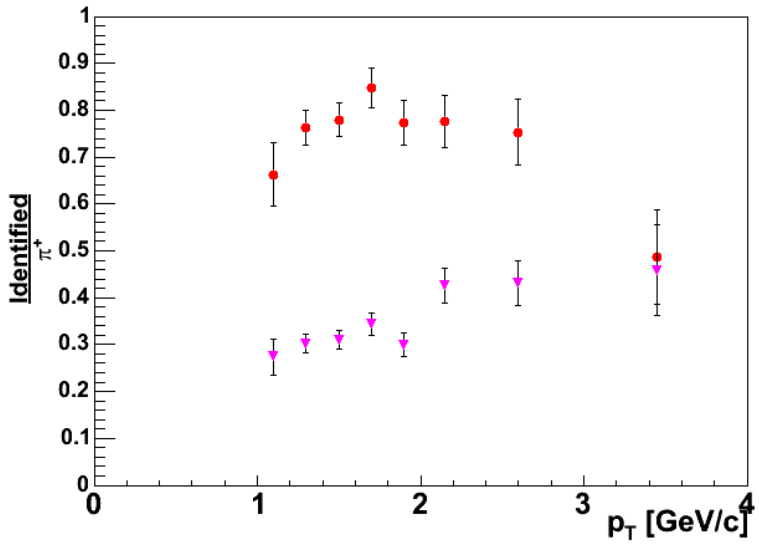


Difference between h^+ and h^- in dAu at η~3



This difference has attracted attention as soon as we showed it last year, it was seen as "beam fragmentation".

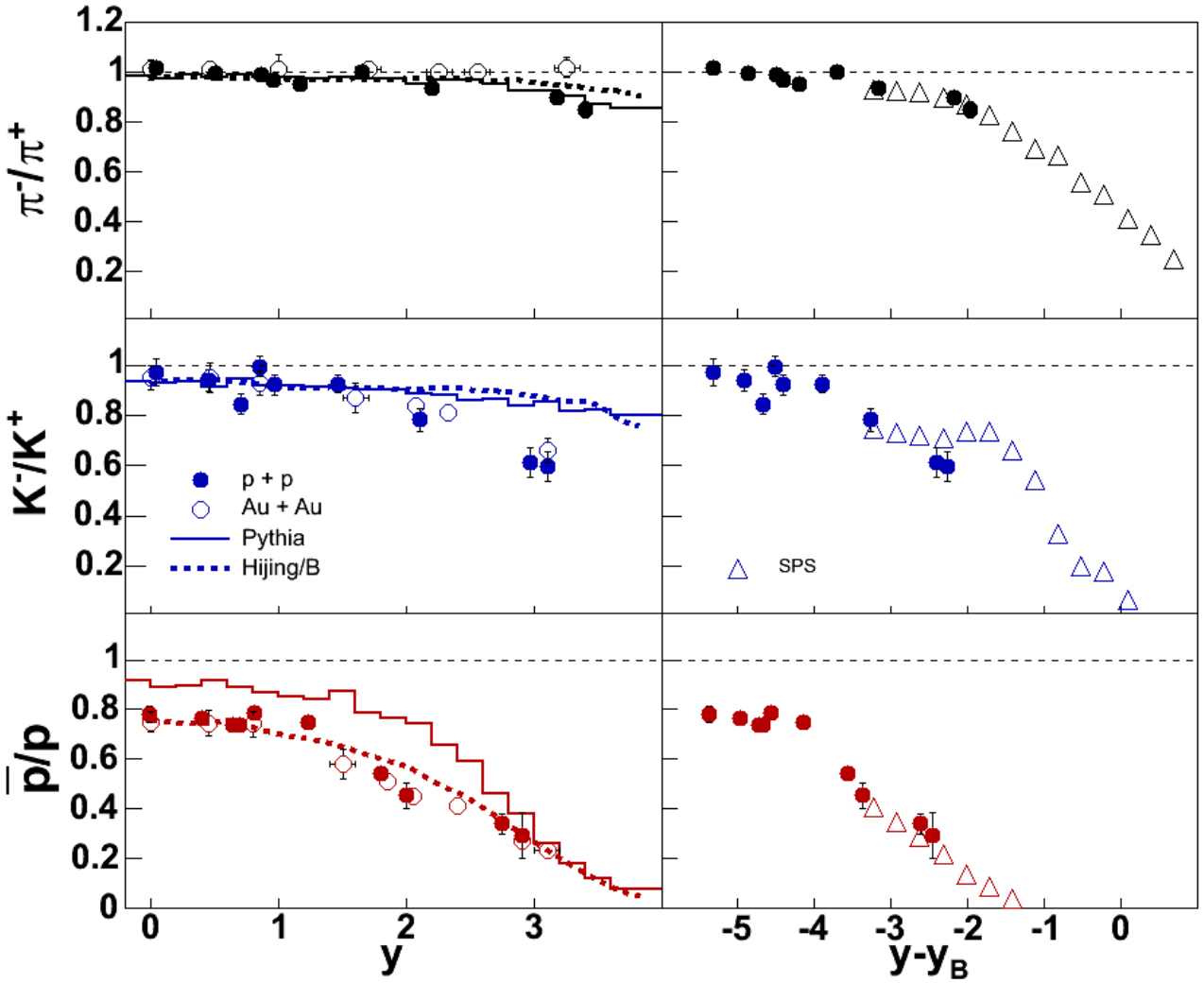
But pQCD calculations that do well reproducing π^0 would have at most a 10% difference.



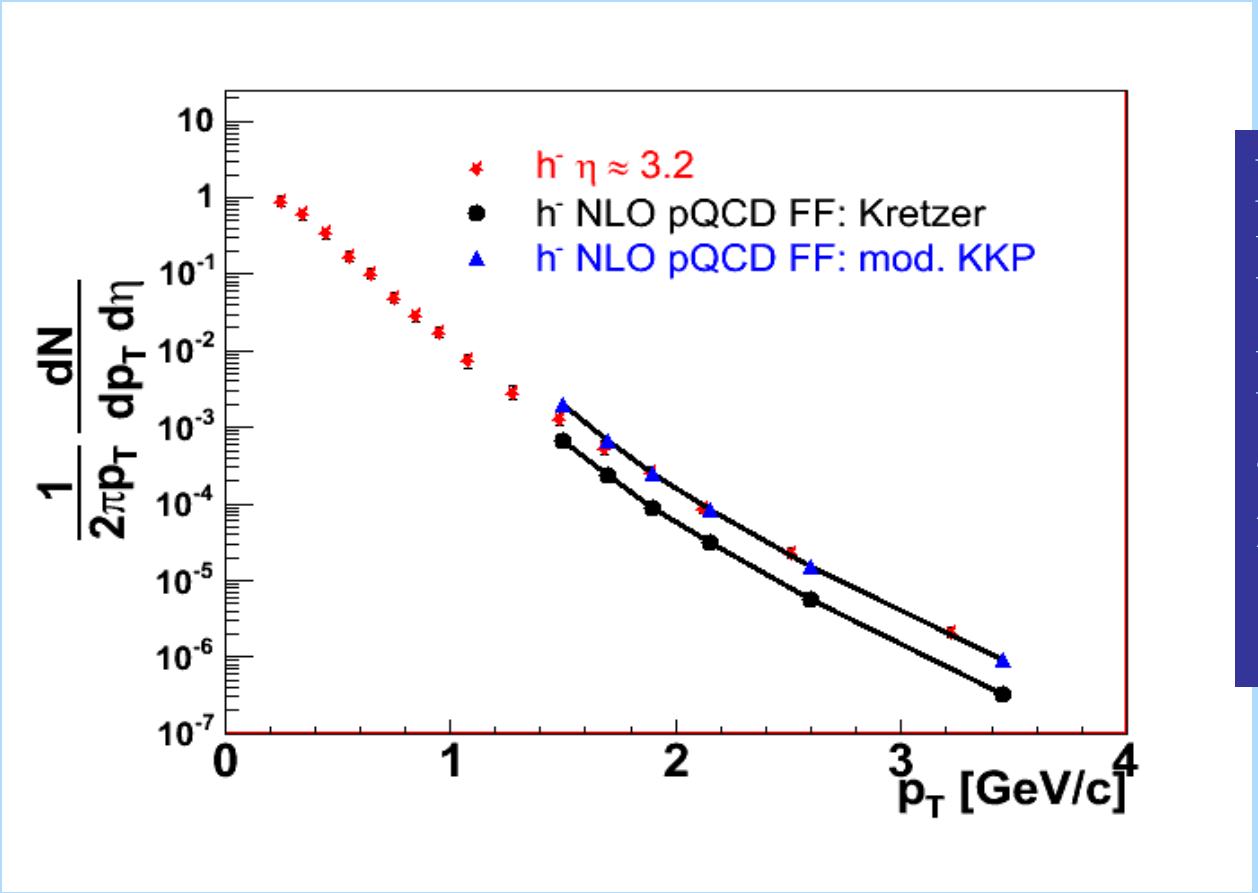
Our measurement is showing that the difference is driven by the protons.

BRAHMS results from p+p collisions

The ratio of particle to anti-particle measured in p+p collisions is remarkably similar to the one we measured in Au+Au collisions.



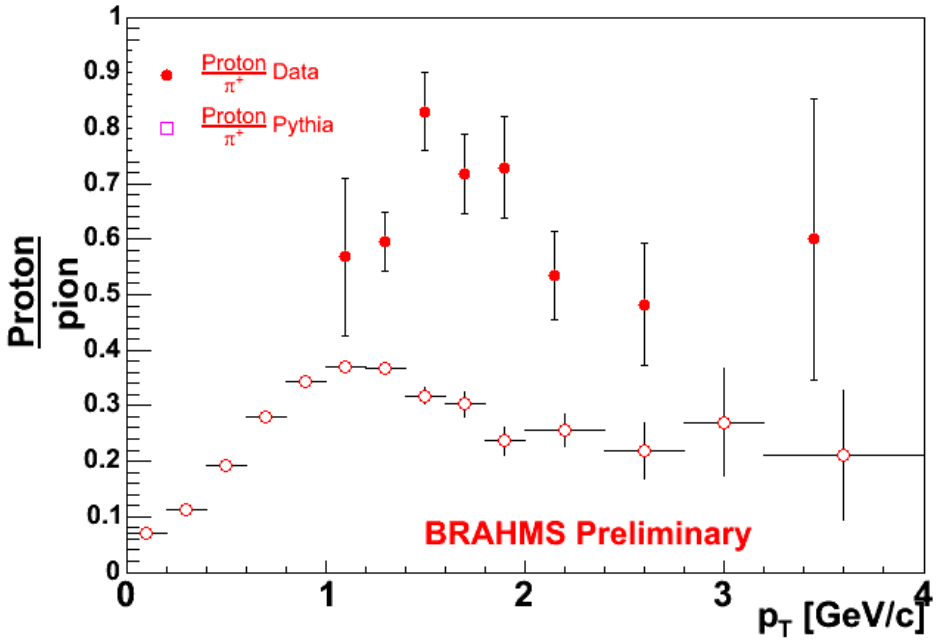
Measured h^- at 4 degrees and a NLO pQCD calculation



NLO pQCD calc. From W. Vogelsang

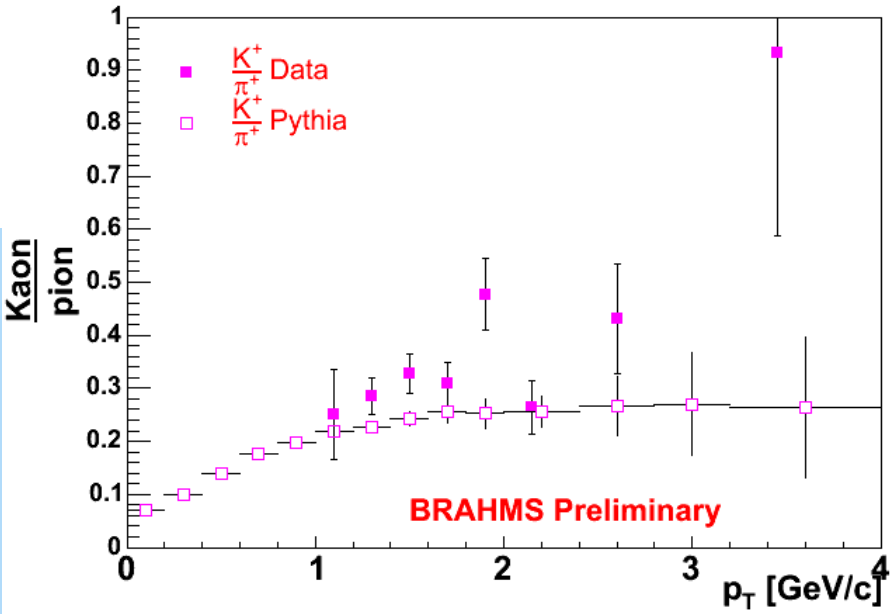
FF: mod KKP is an attempt to reproduce h^-

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.

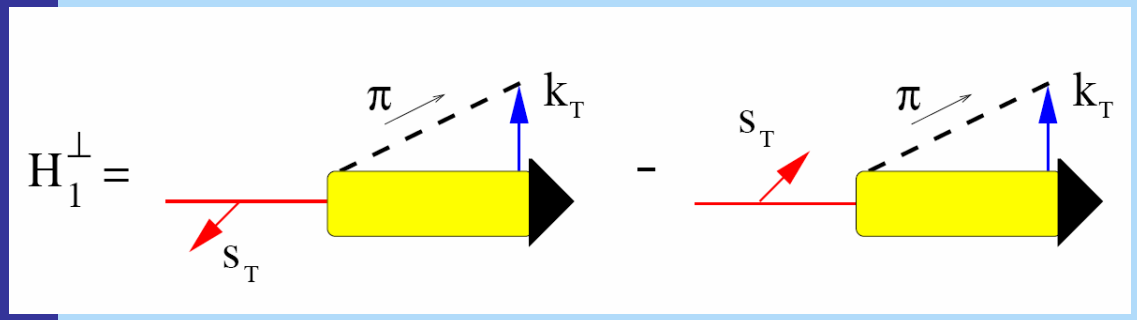
We measure a small excess of kaons and see an emerging trend that suffers from low statistics at high pt.

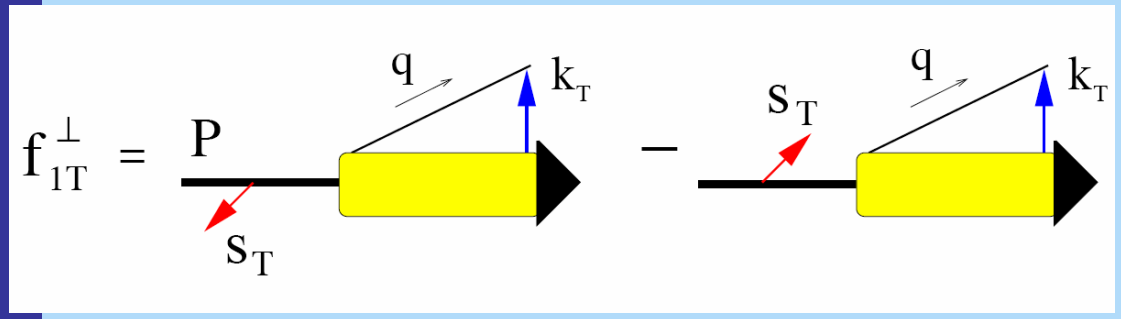


BRAHMS spin in p+p collisions

BRAHMS has an active spin program, in particular we are measuring the single spin asymmetry A_n at high x_F identified particles with emphasis on charged pions.

More details in Flemming Videbaek talk this afternoon.





Summary

BRAHMS is opening new ground because of our emphasis in forward rapidities.

Our p+p results will contribute to the further development of QCD to include our particle production results.

BRAHMS d+Au high rapidity results, together with theoretical work have generated strong interest in our community.

Our Au+Au results at forward rapidity will certainly be equally important to characterize the new physics in relativistic heavy ion collisions.

The dialogue between theory and experiment becomes more and more important as the physics we are after get harder and needs smart choices.

Backup slides