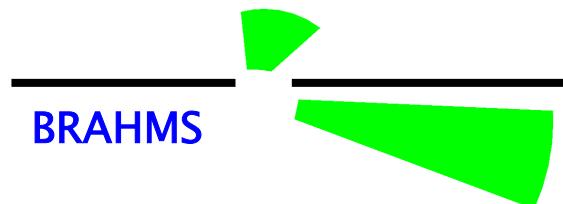


Rapidity Dependence of Charged Hadron Yields in Central Au+Au Collisions at 200 GeV



Djamel Ouerdane
Niels Bohr Institute

for the **BRAHMS Collaboration**



Quark Matter 2004
Oakland, January 11-18

The BRAHMS Collaboration

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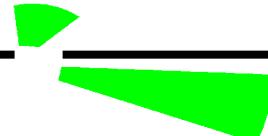
¹⁰University of Bucharest, Romania, ¹¹University of Kansas, Lawrence, USA

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Outline of the Talk

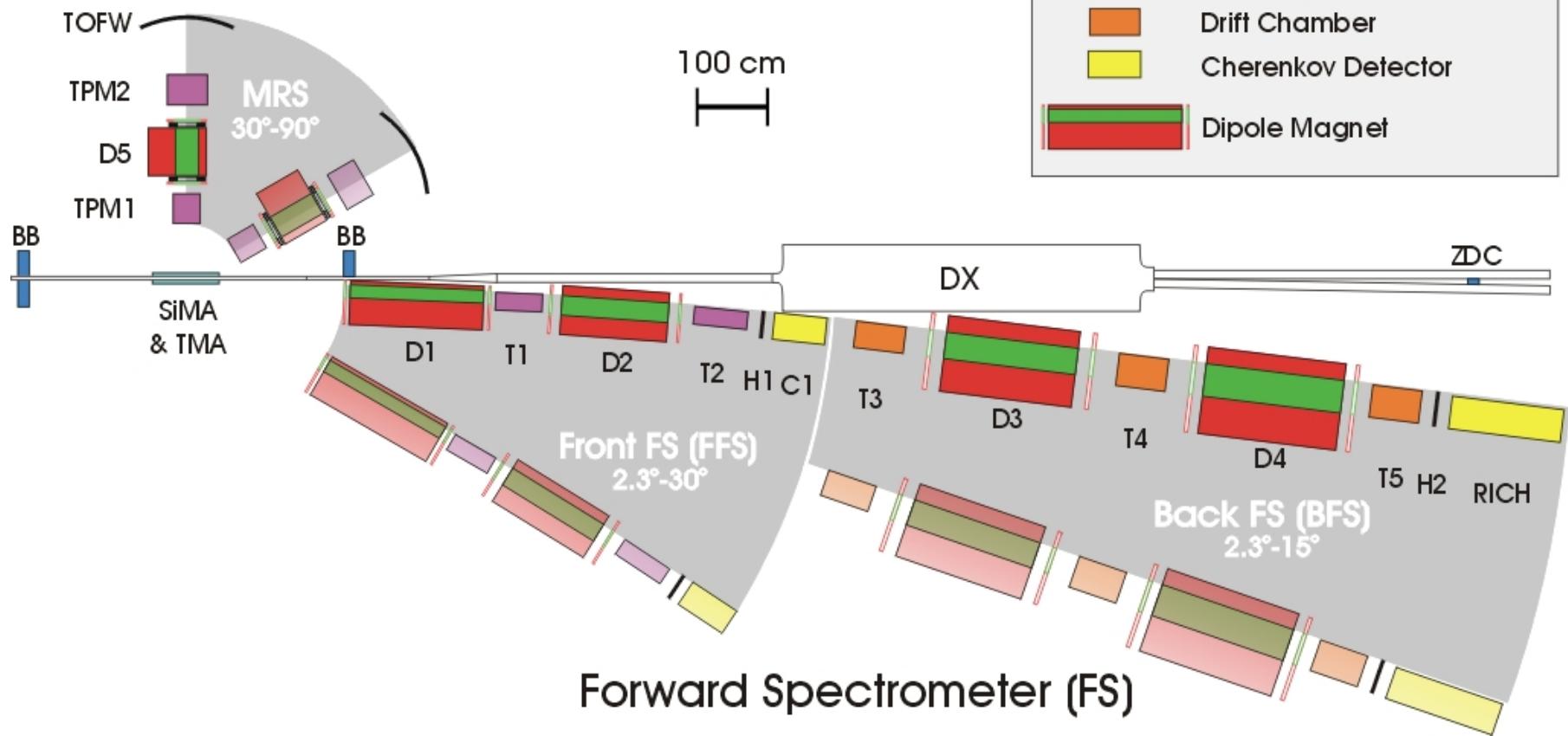
- The BRAHMS experiment
- Rapidity Dependence of Spectra and Yields
- From Stopping to Transparency
- Pions : Landau or Bjorken ?
- Kaons : Is Strangeness Equilibrated ?
- Summary & Conclusions



The BRAHMS Detector

BRAHMS Experimental Setup

Mid-Rapidity Spectrometer



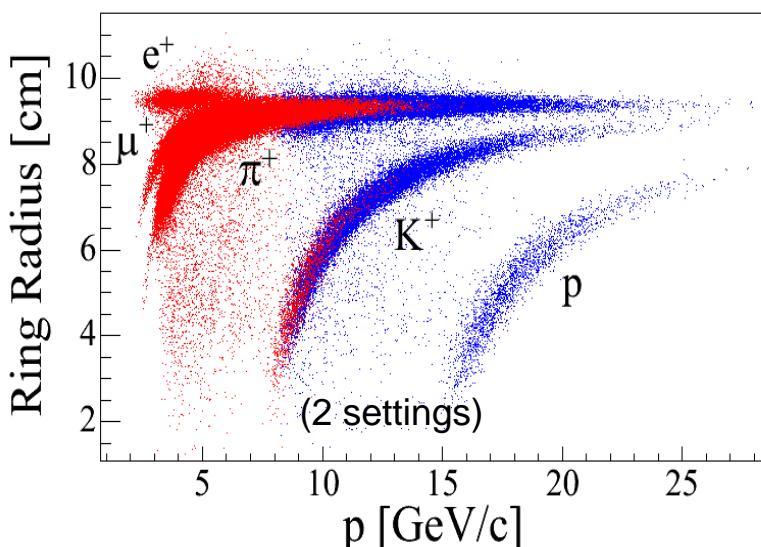
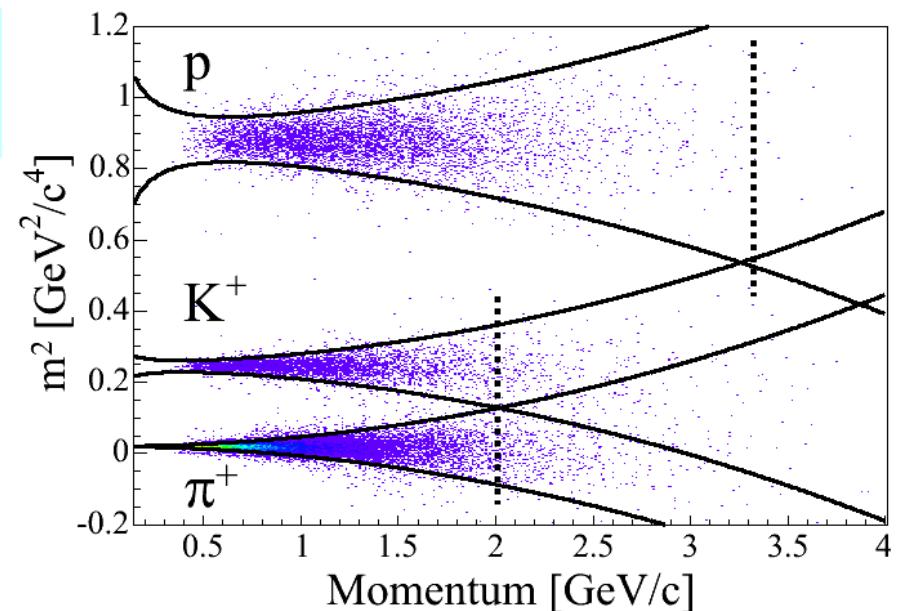
Particle Identification

TIME-OF-FLIGHT

$$m^2 = p^2 \left(\frac{c^2 \text{TOF}^2}{L^2} - 1 \right)$$

Particle Separation: p_{\max} (2σ cut) =

2σ cut	TOFW	TOF1	TOF2
π / K	2 GeV/c	3 GeV/c	4.5 GeV/c
K / p	3.5 GeV/c	5.5 GeV/c	7.5 GeV/c



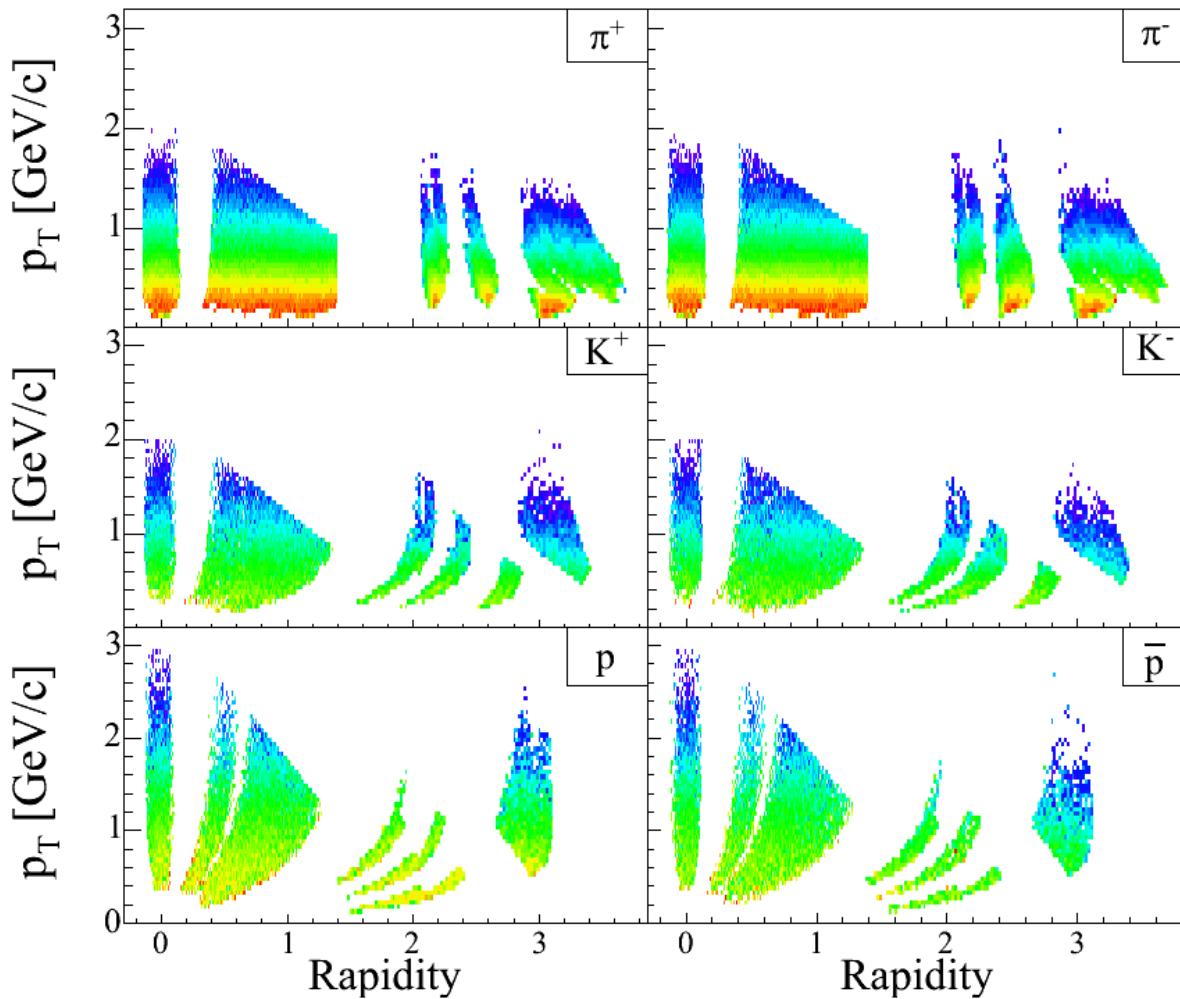
CHERENKOV

RICH: Cherenkov light focused
on spherical mirror → ring on image plane

Ring radius vs momentum gives PID
 π / K separation 20 GeV/c
Proton ID up to 35 GeV/c

Particle Spectra

By combining all data sets and averaging over the number of collisions,
we get the final invariant yields over a broad range of phase-space



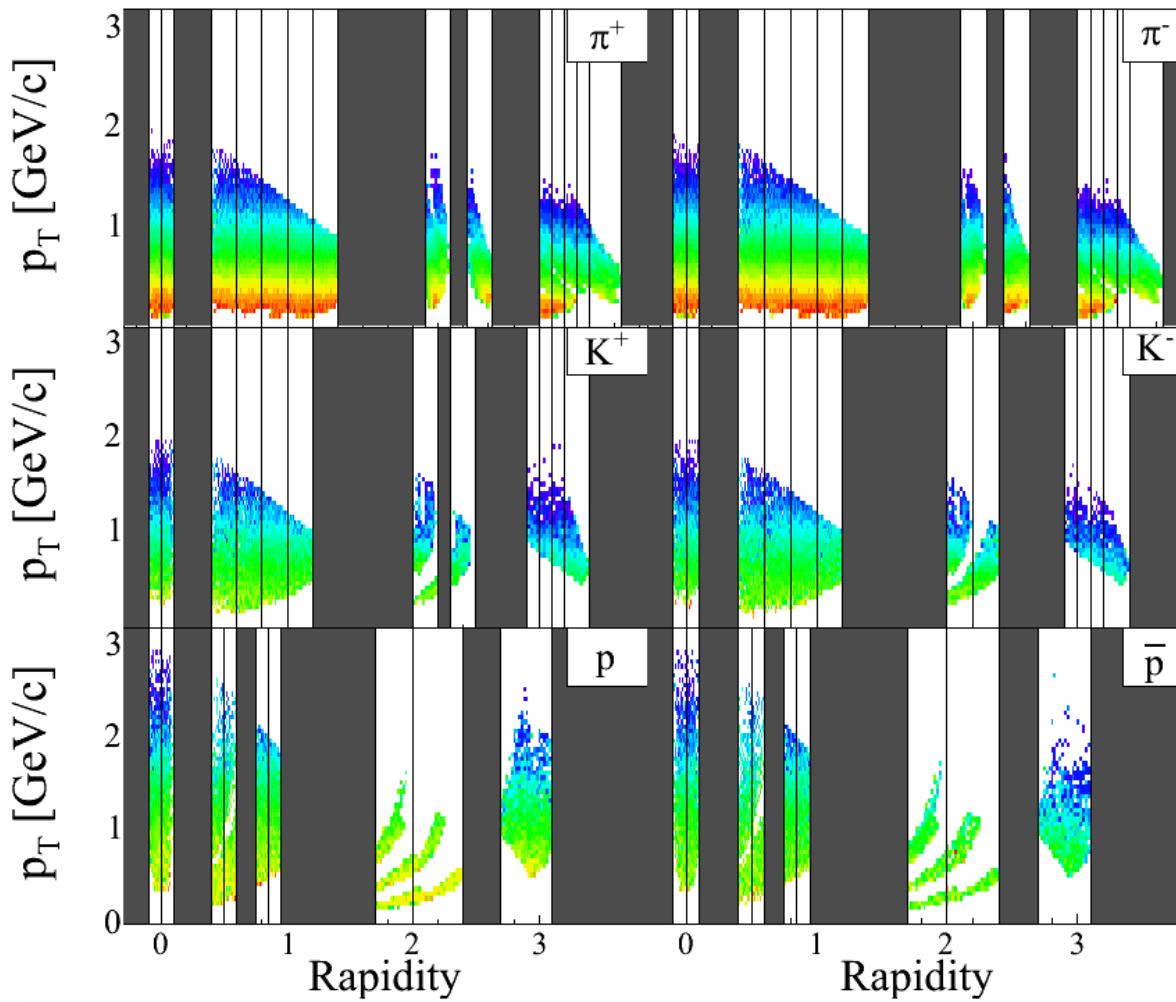
Pion invariant
differential yields

Kaon invariant
differential yields

Proton invariant
differential yields

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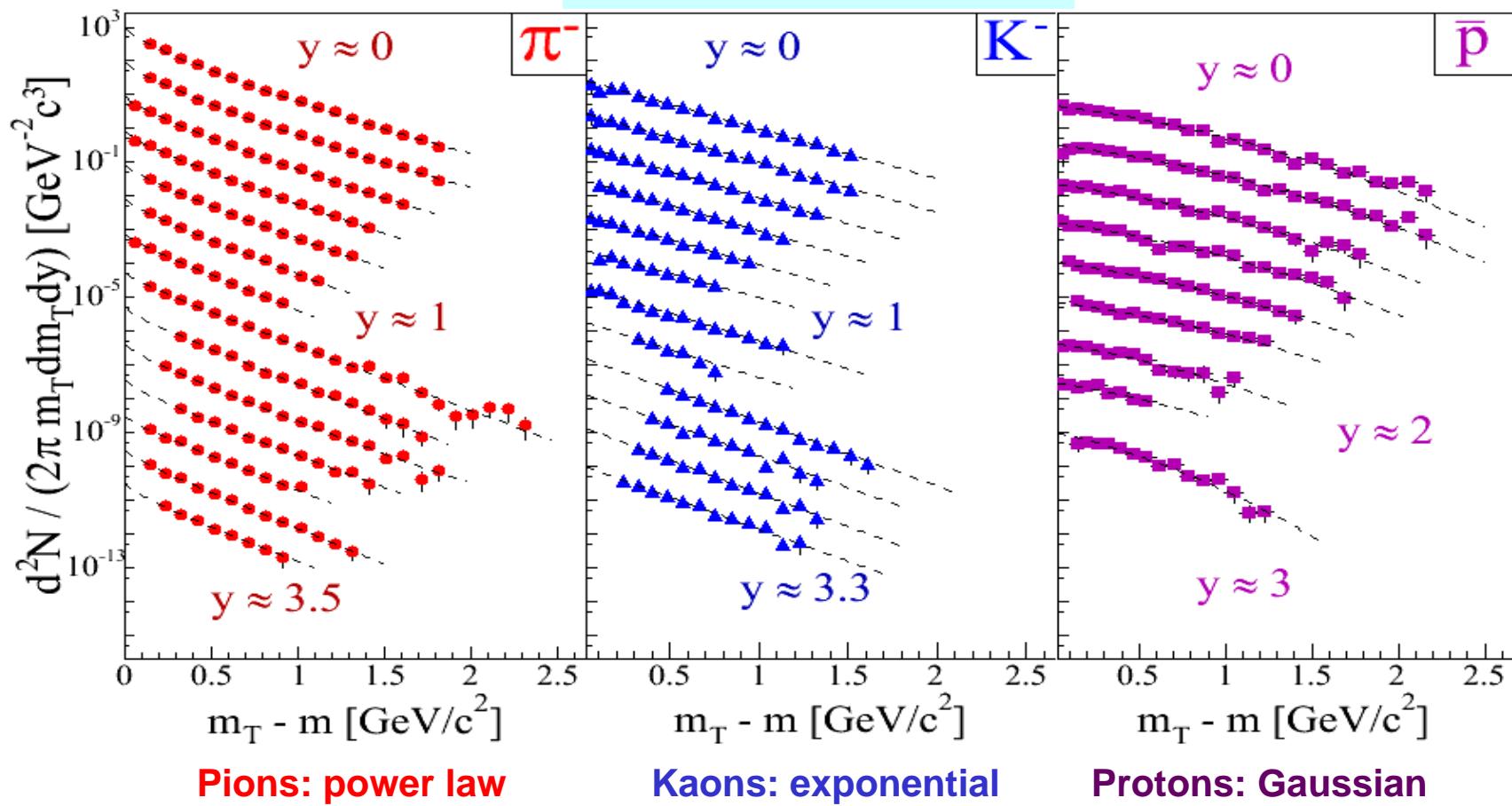
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Particle Spectra

Top 5% central collisions



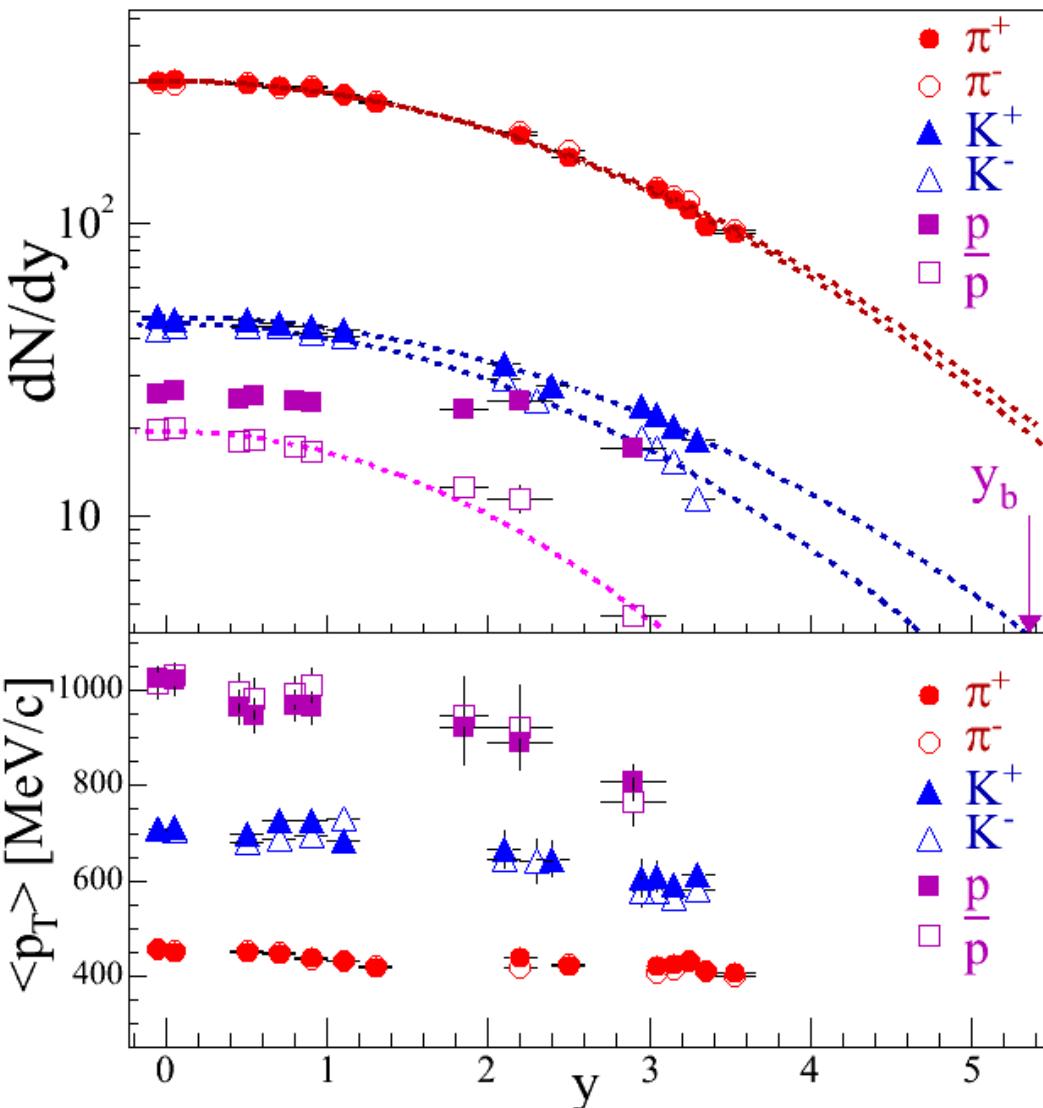
$$A \left(1 + \frac{p_T}{p_0} \right)^{-n}$$

$$A \exp \left(-\frac{m_T - m}{T} \right)$$

$$A \exp \left[-\frac{p_T^2}{2\sigma^2} \right]$$



Rapidity Densities



At $y \sim 0$, dN/dy is

~ 300 (300) for π^+ (π^-)

~ 47 (44) for K^+ (K^-)

~ 27 (20) for p ($p\bar{p}$)

$N(\pi) \gg N(K) > N(p)$

$N(\pi^+) = N(\pi^-)$

$N(K^+) > N(K^-)$ and
 $N(p) > N(p\bar{p})$ systematically

Integrated multiplicities
 (Gaussian fit)

$N(\pi^-) \sim 1780$ $N(\pi^+) \sim 1760$

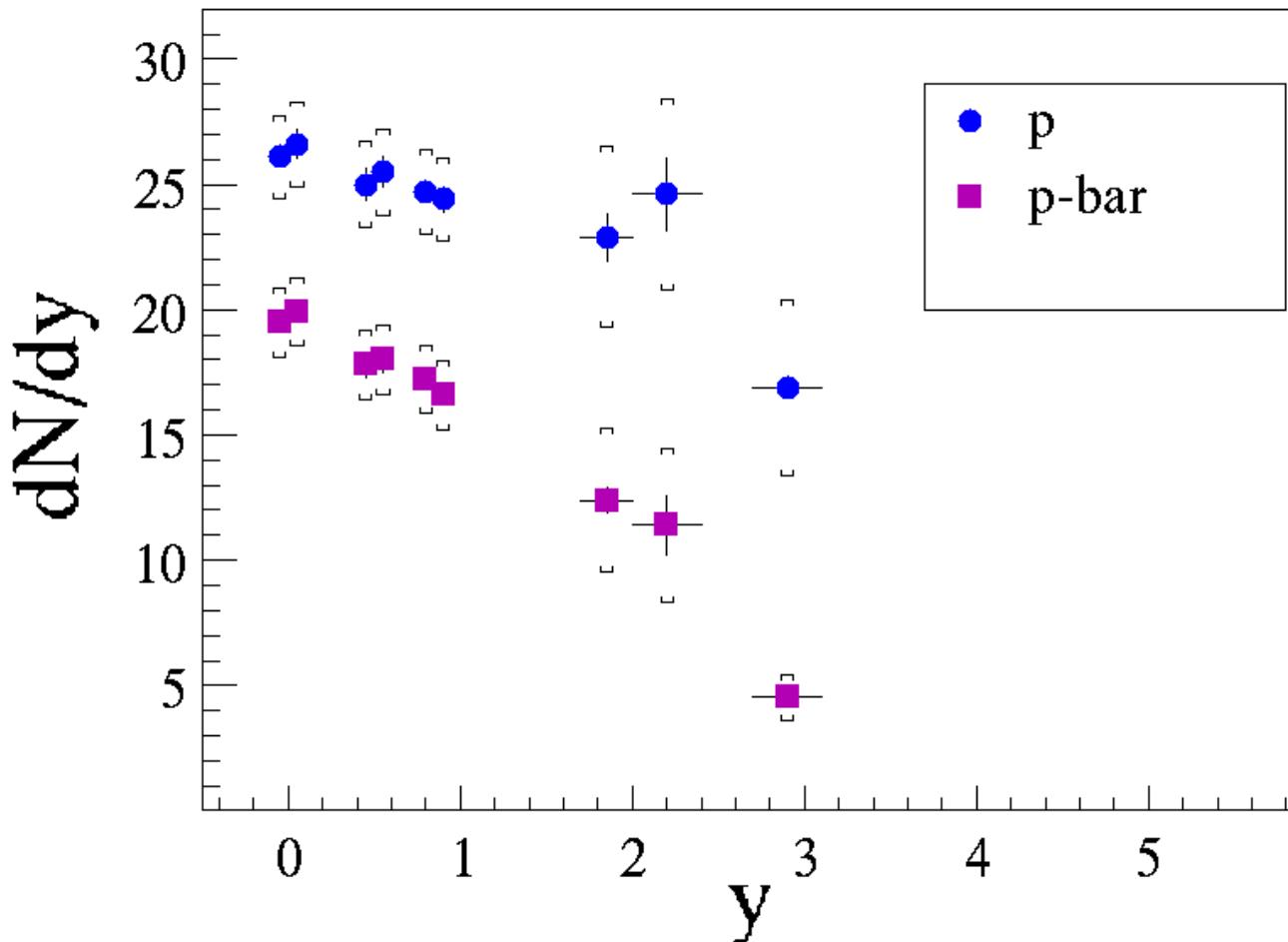
$N(K^+) \sim 290$ $N(K^-) \sim 240$

$N(p\bar{p}) \sim 85$

Little decrease of transverse flow

Nuclear Stopping

Net-proton rapidity densities (top 5% central collisions)

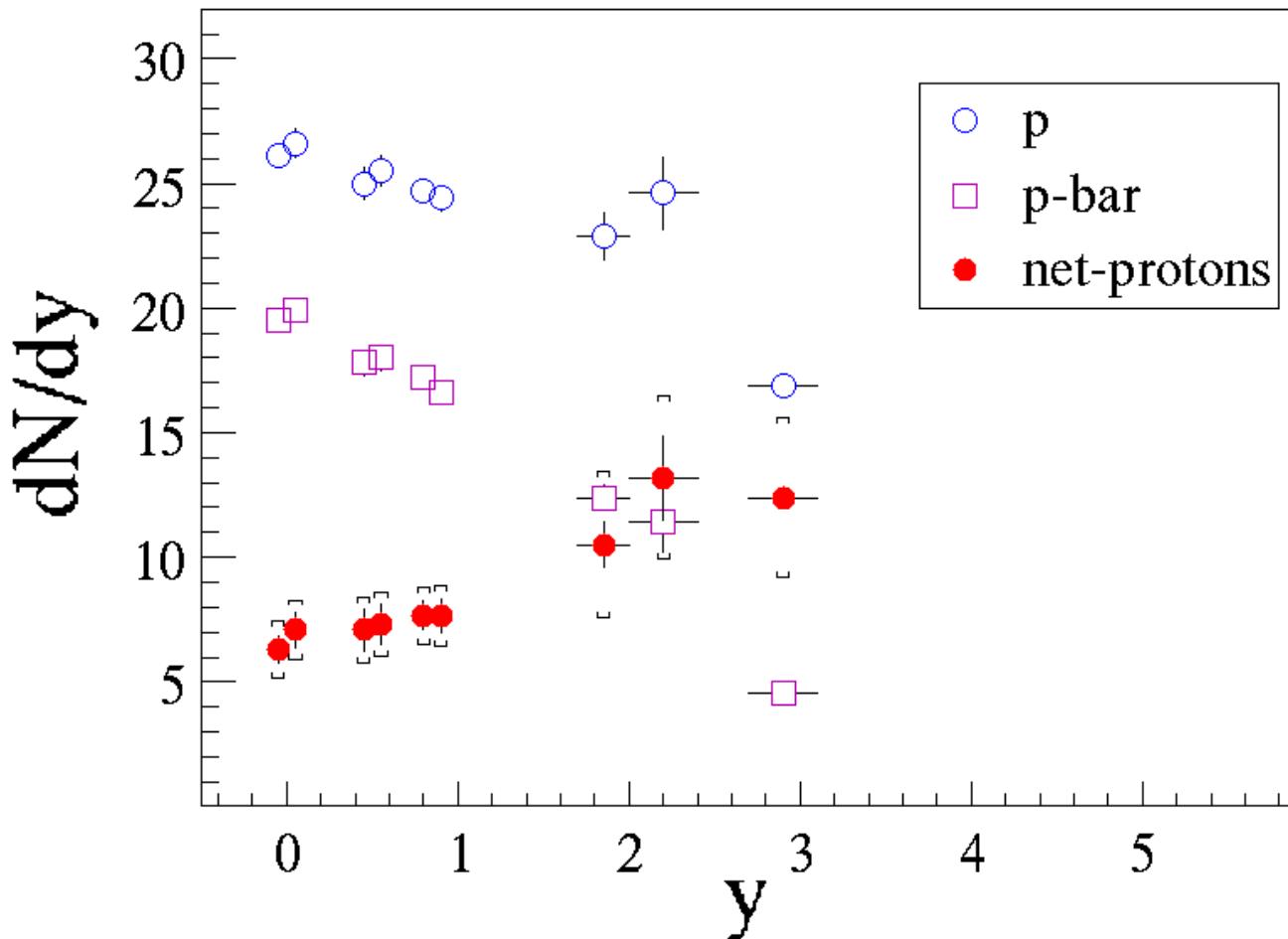


BRAHMS, submitted
to PRL, [nucl-ex/0312023](#)
P. Christiansen
Ph.D. Thesis



Nuclear Stopping

Net-proton rapidity densities (top 5% central collisions)

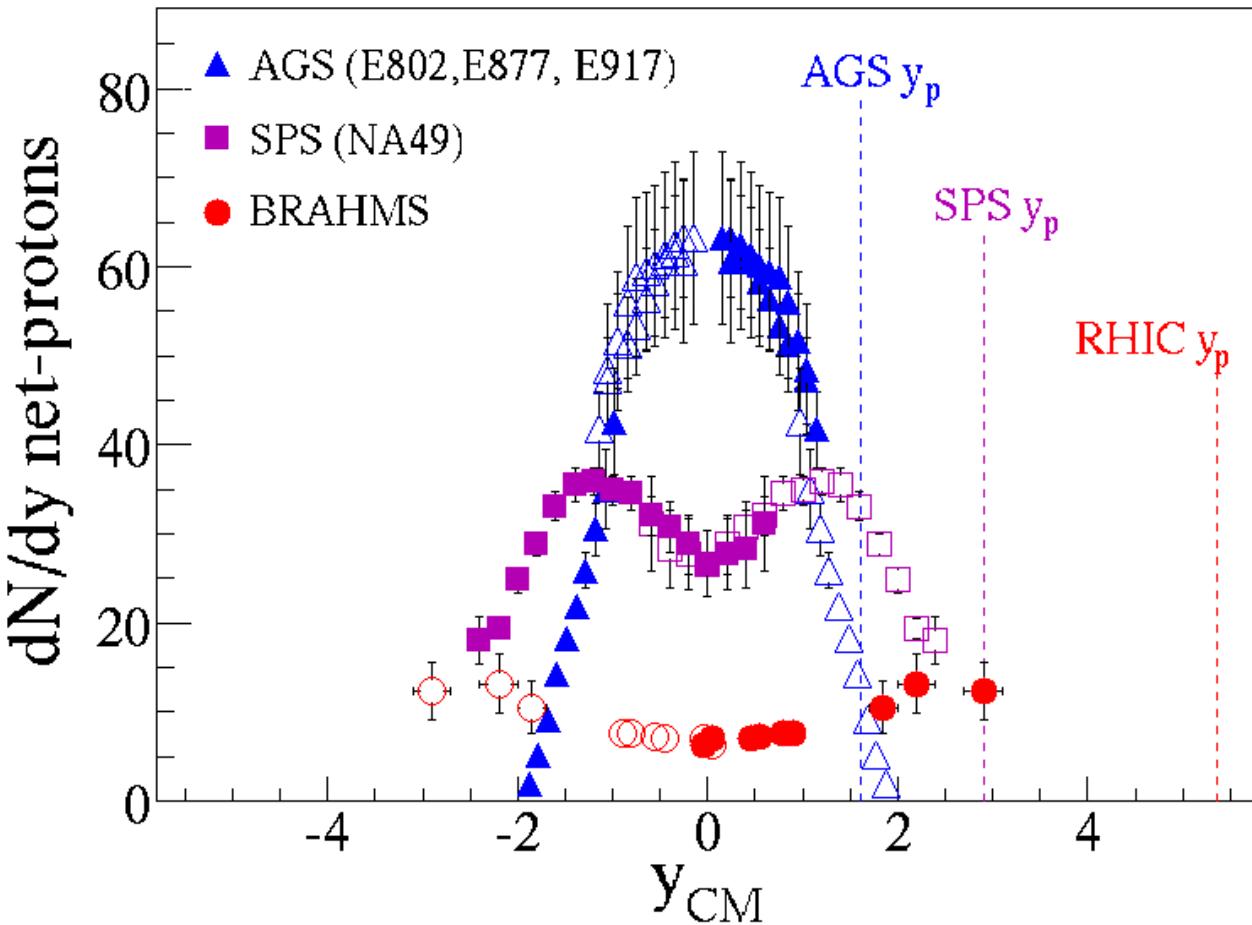


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Net-proton measured
up to $y = 3$

Nuclear Stopping

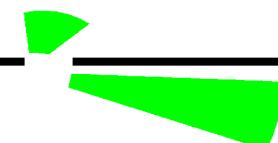
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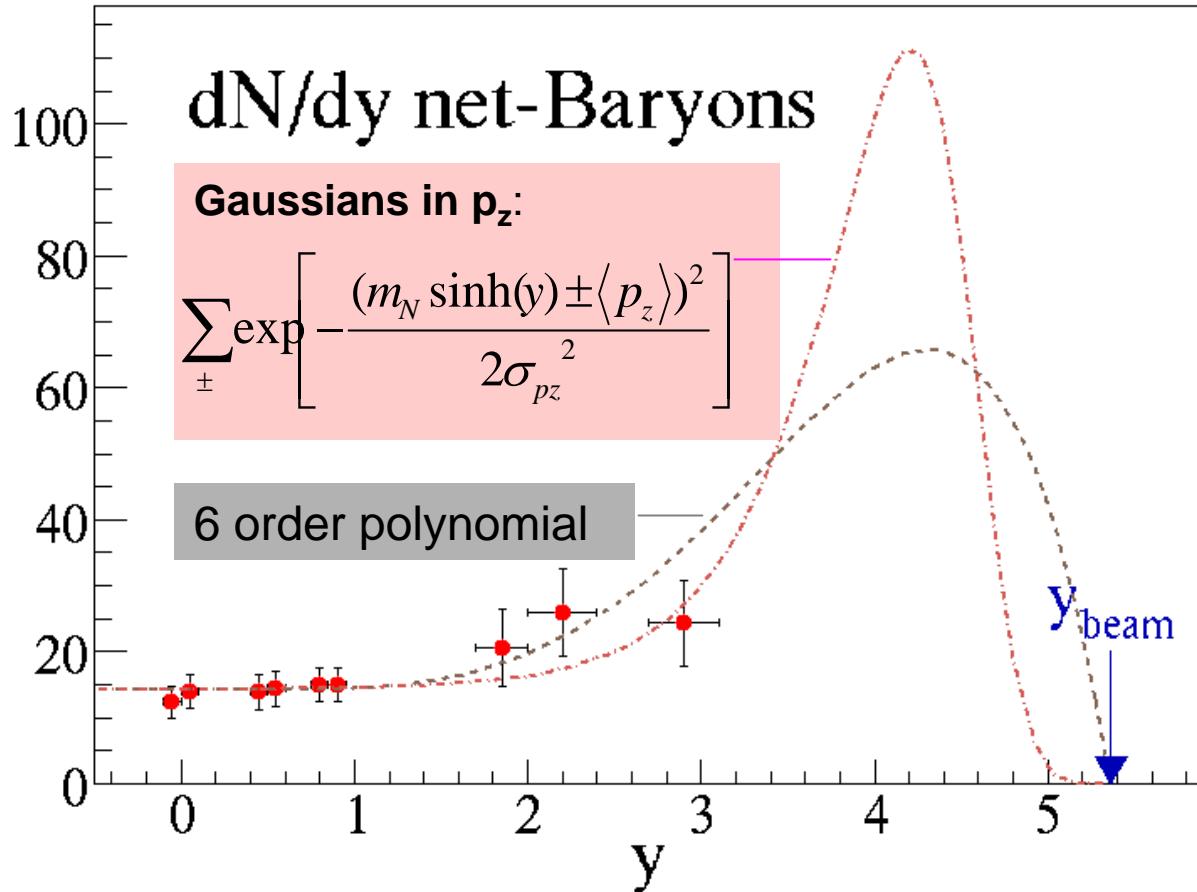
AGS : high stopping
RHIC: more
transparent



Nuclear Stopping

Rapidity loss:
 $(N_{part} = 357 \pm 10)$

$$\langle \delta y \rangle = y_p - \langle y \rangle = y_p - \frac{2}{N_{part}} \int_0^{y_p} y \frac{dN_{(B-\bar{B})}}{dy} dy$$



Net-baryon after
feed-down & neutron
corrections

$$\langle \delta y \rangle = 2.03 \pm 0.16$$

$$\langle \delta y \rangle = 2.00 \pm 0.10$$

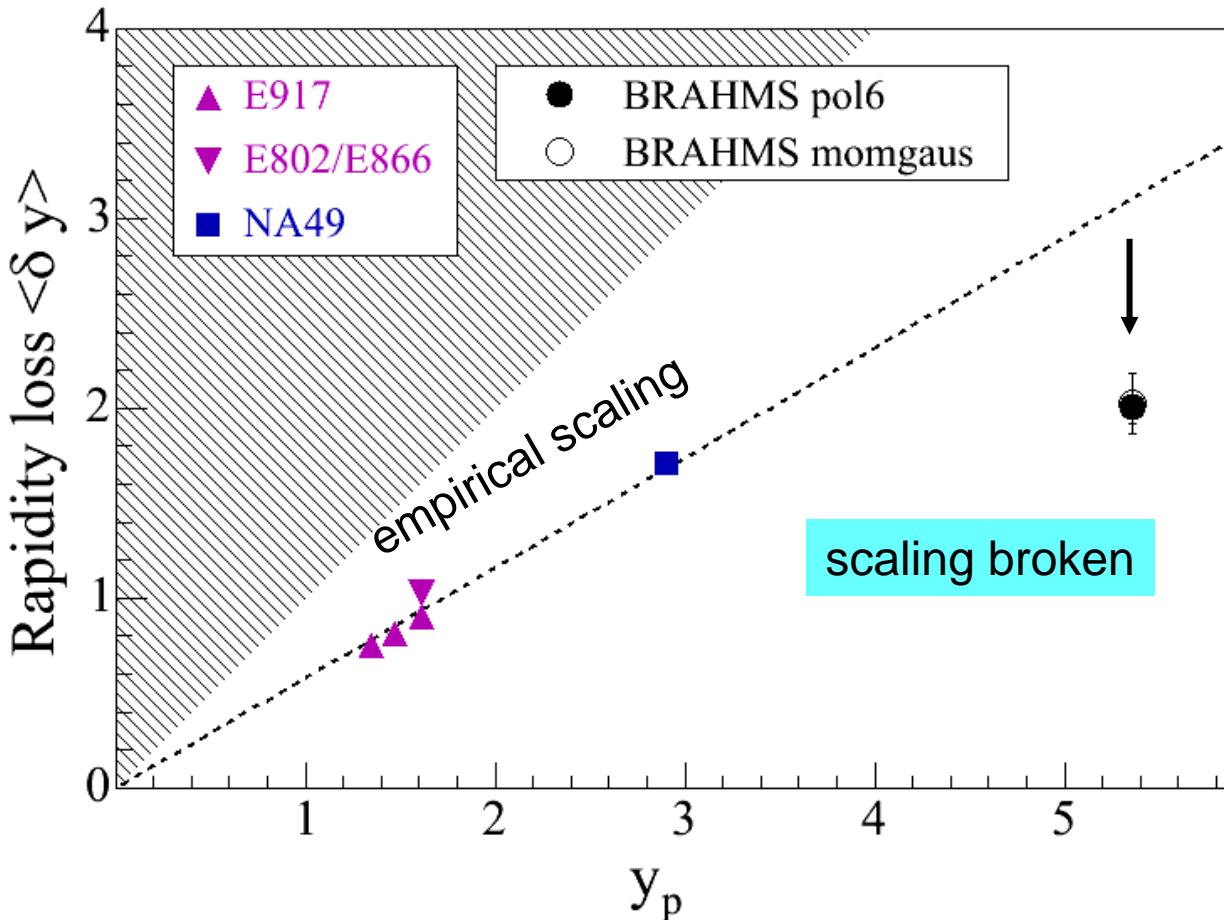
$\Delta E = 25.7 \pm 2.1$ TeV

$$\int_{-y_p}^{y_p} \langle m_T \rangle_y \frac{dN_{(B-\bar{B})}}{dy} \cosh y dy$$

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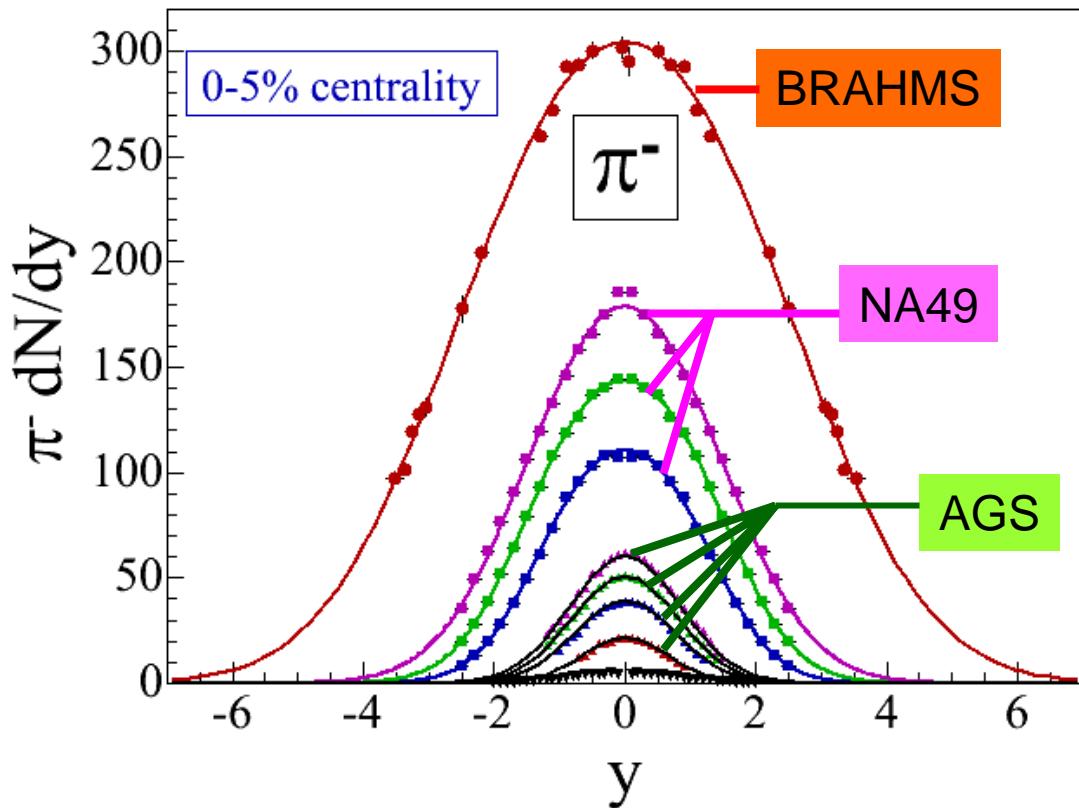
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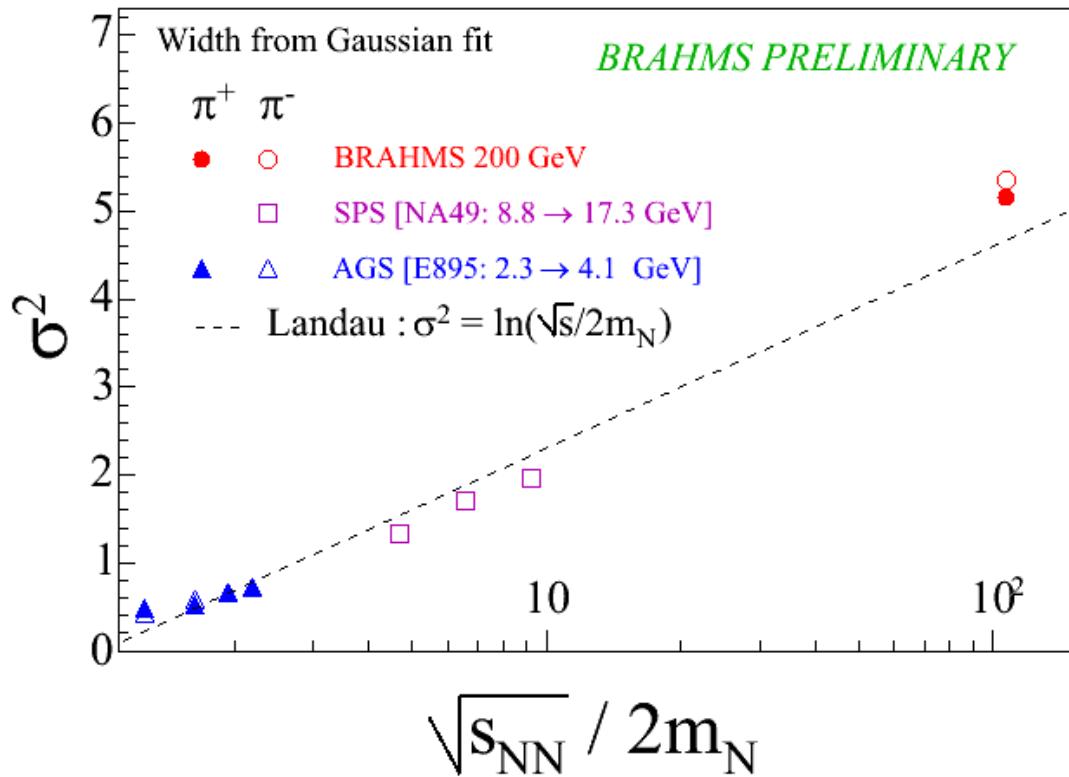
Pion Production: Landau or Bjorken?



Entropy ~ Pion production
Expansion ~ isentropic
Pion gas = 3D relativistic fluid

[L.D. Landau, Izv. Akad. Nauk SSSR 17 (1953) 52
P.Carruthers, M.Duong-van, PRD 8 (1973) 859]

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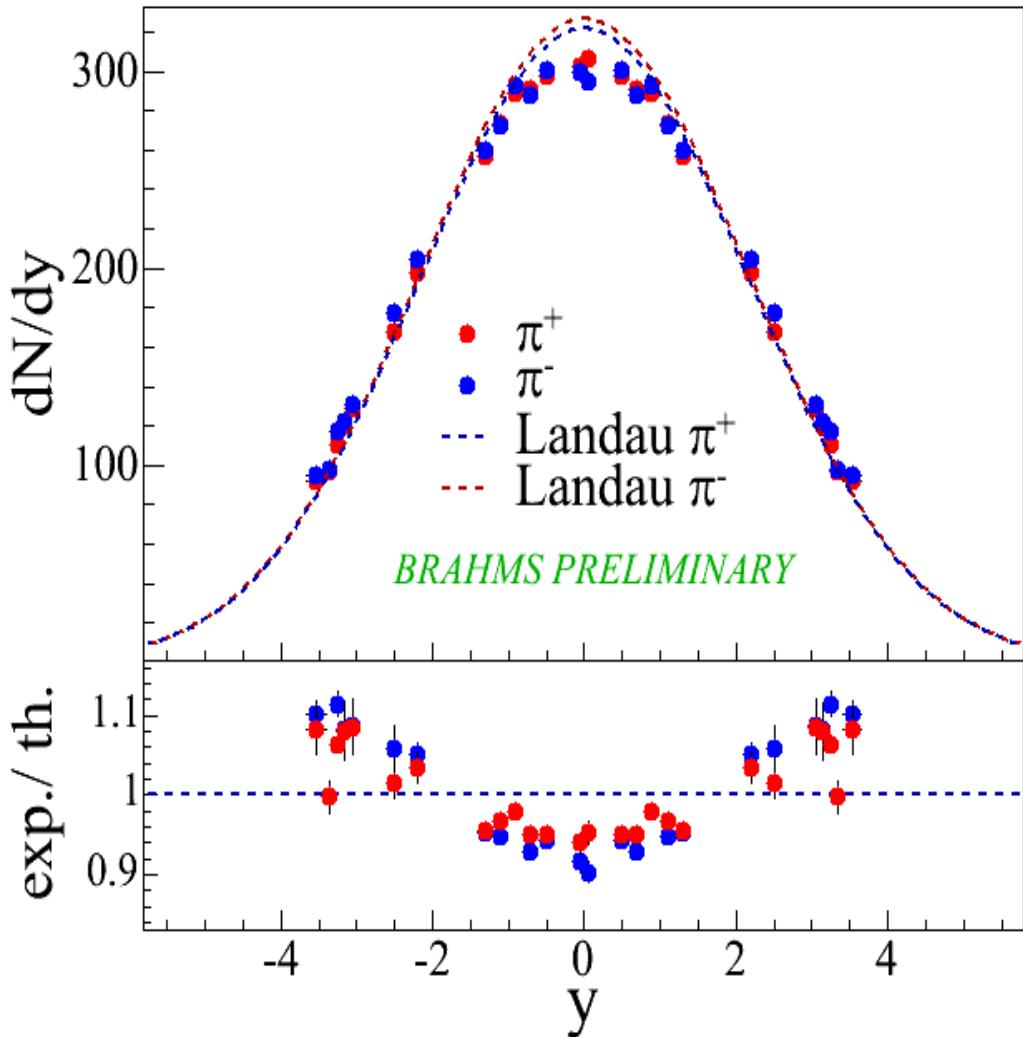
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Prediction: dN/dy (y) Gaussian of width σ given by (simplified model):

$$\sigma^2 = \ln\left(\frac{\sqrt{s}}{2m_p}\right)$$



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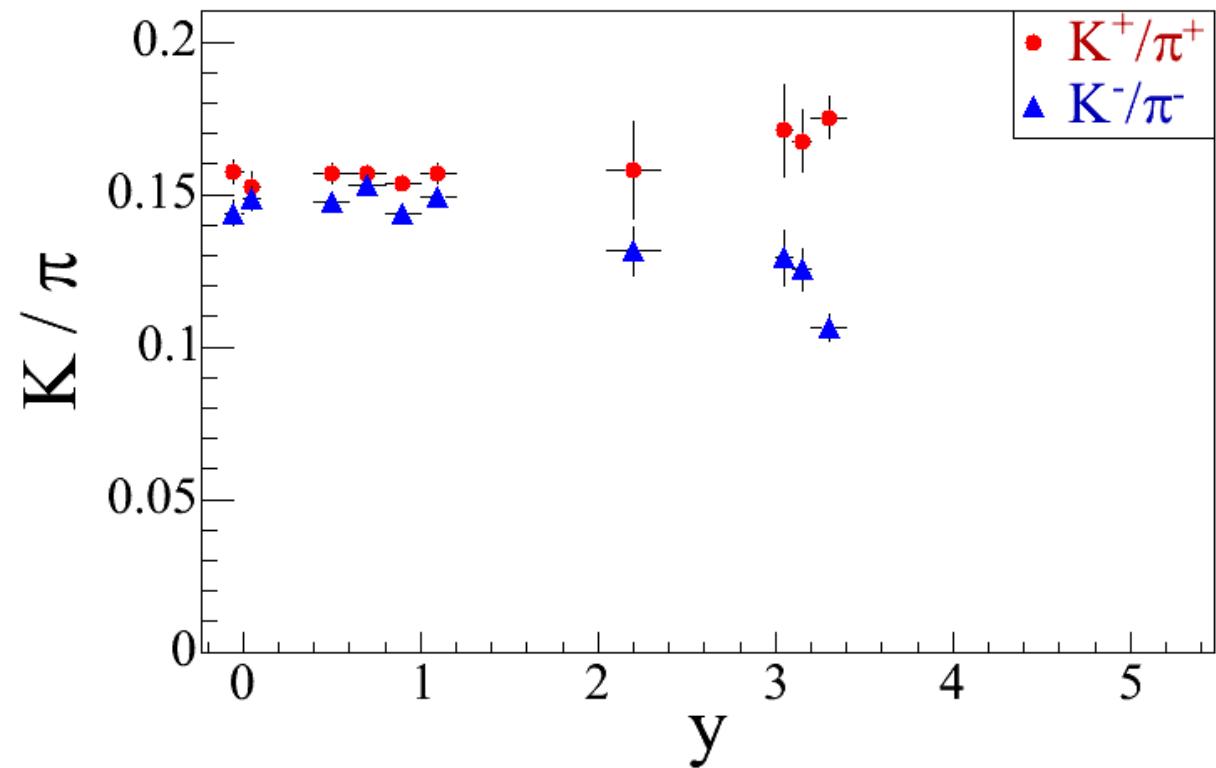
$$\sigma^2 = \ln\left(\frac{\sqrt{s}}{2m_p}\right)$$

Ok as a 1st approximation
BUT systematic difference remains : flatter top, tails broader => more longitudinal flow



Strangeness with Kaons

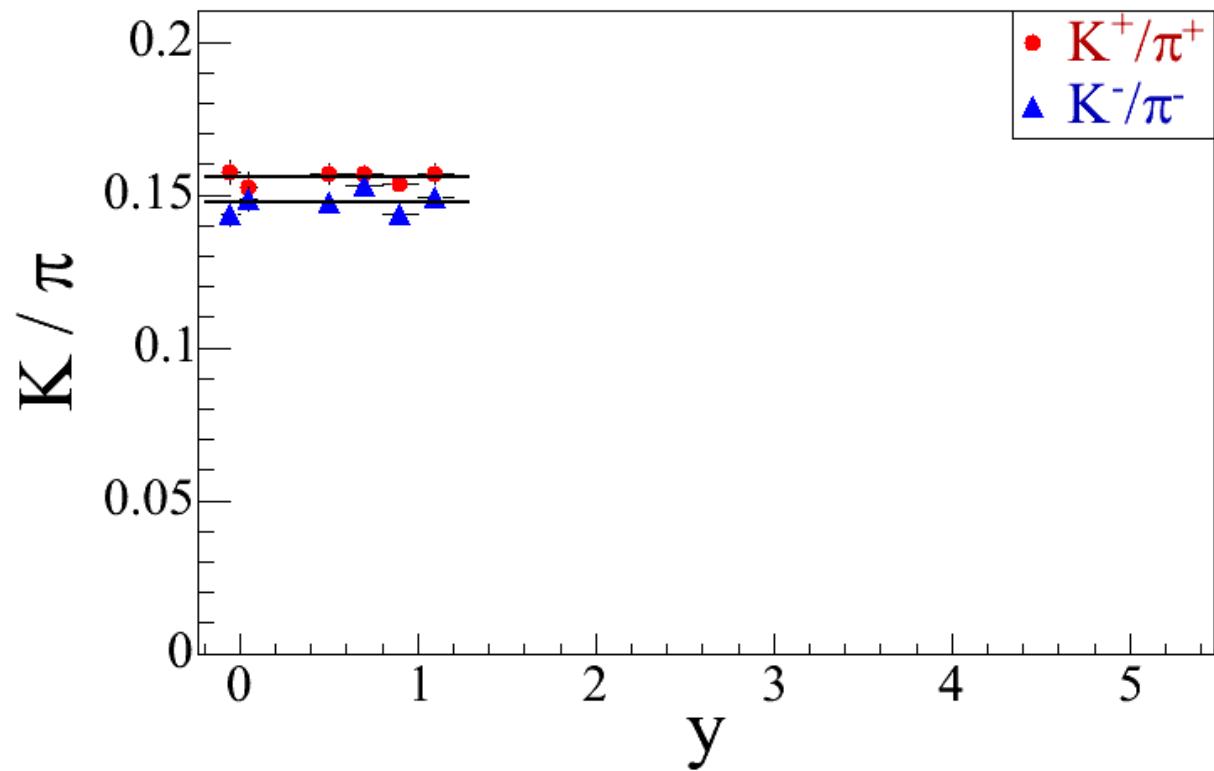
RAPIDITY DEPENDENCE



Strangeness with Kaons

RAPIDITY DEPENDENCE

$Y < 1$: consistent with
Hadron Gas Stat. Model
 K^+/π^+ : 15.6 ± 0.1 % (stat)
 K^-/π^- : 14.7 ± 0.1 % (stat)
[Phys. Lett. B 518 (2001) 41]

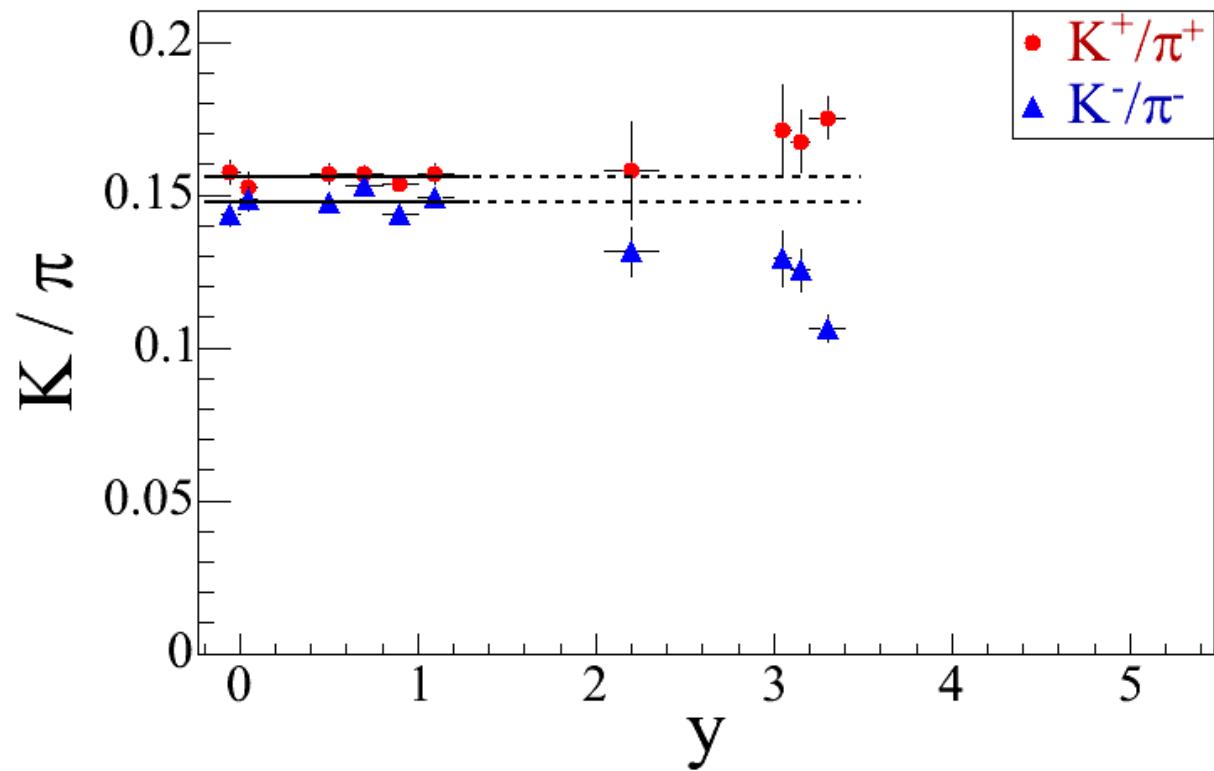


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Divergence at higher y :
Associated K^+ production
No single source with
unique T and μ_B



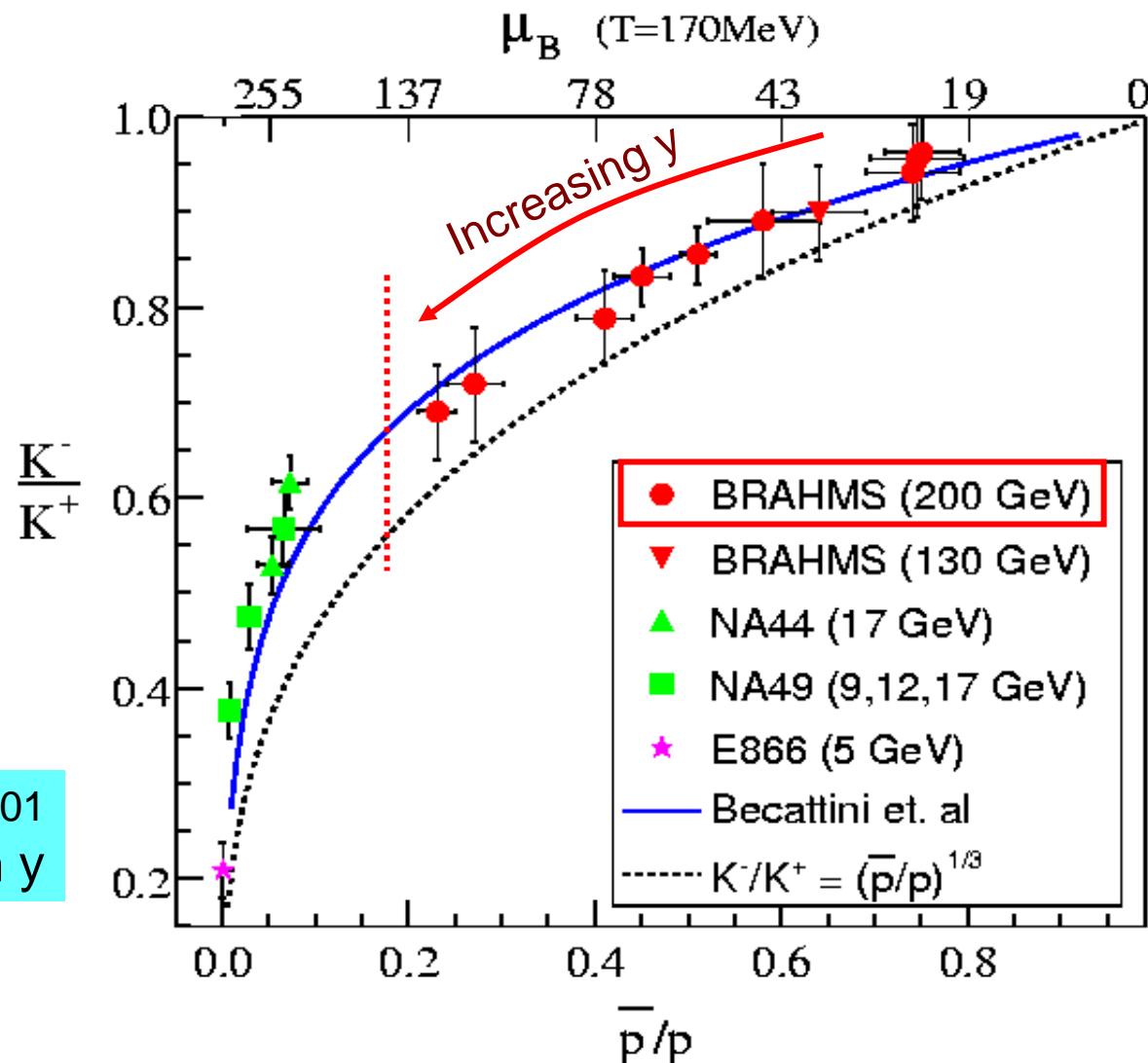
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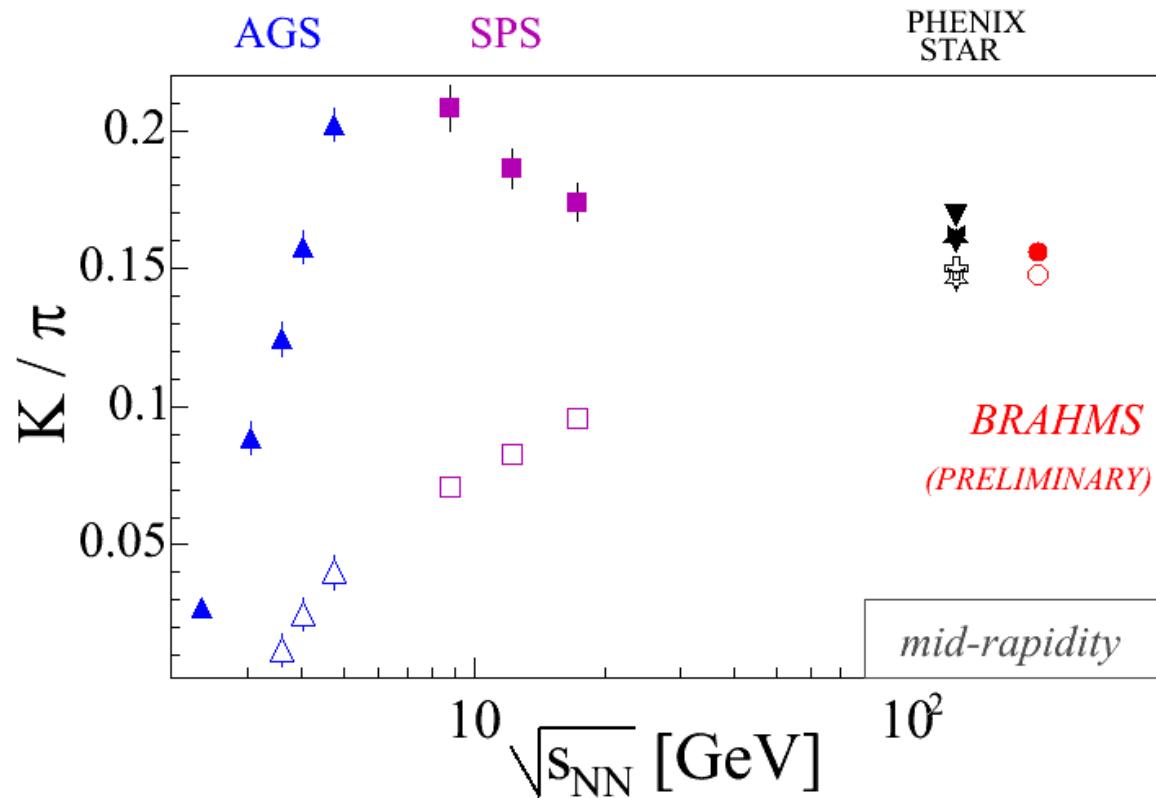
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BRAHMS, PRL90 (2003) 102301
 $T \sim \text{constant}$, μ_B varies with y



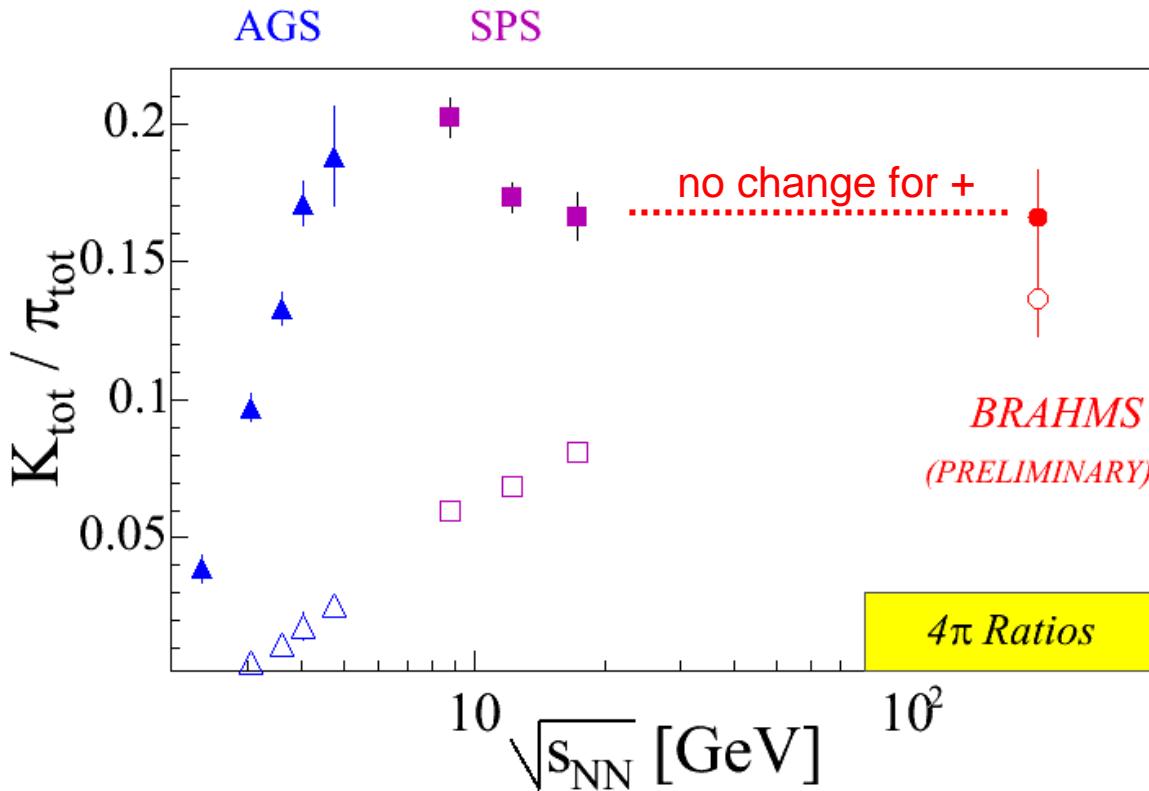
Strangeness with Kaons

ENERGY DEPENDENCE



Strangeness with Kaons

ENERGY DEPENDENCE

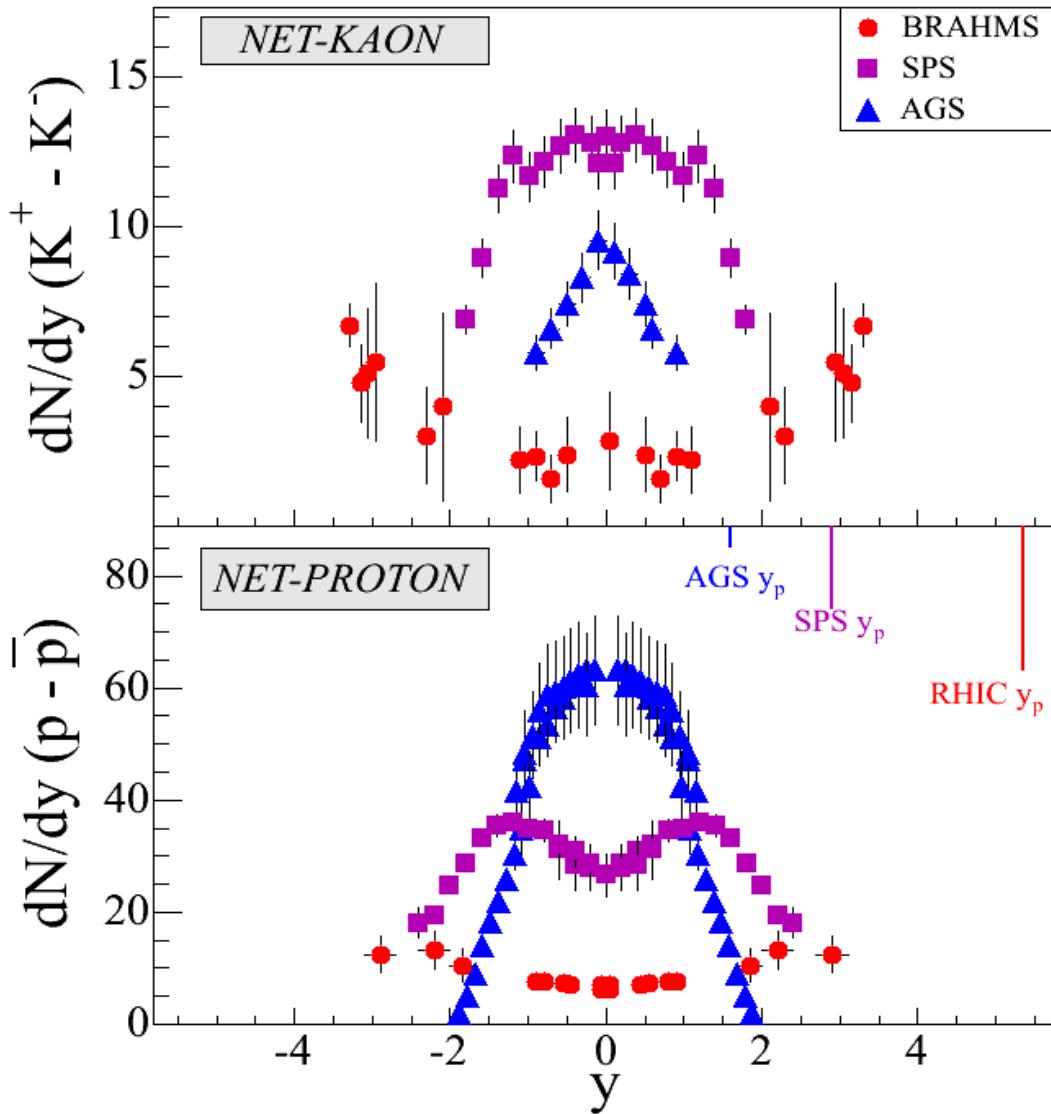


At $y = 0$, ratios converge to $\sim 15\%$

Over the full phase space:
 $K^+/\pi^+ = 16.6 \pm 1.5\%$ (syst)
 $K^-/\pi^- = 13.7 \pm 2.0\%$ (syst)



Strangeness with Kaons



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Why this behavior ?
Net-Kaon distribution evolves like net-proton

Summary & Conclusions

Transverse momentum spectra of π 's, K's and p's measured in rapidity range $|y_\pi| < 3.6$, $|y_K| < 3.4$ and $|y_p| < 3.1$

Stopping: $dN/dy (p-pbar) \sim 7$ at $y = 0 \Rightarrow$ near transparency
increases with increasing rapidity
rapidity loss ~ 2 units, **scaling broken at 200 GeV**

Pions: $N(+)=N(-)$ over the rapidity range covered
Landau picture close to data as a 1st approximation only

Kaons: $N(+) \sim N(-)$ at mid-rapidity (47 and 44) but
 $N(+) > N(-)$ at $y > 2$ due to **associated K^+ production**

K/π : converge to $\sim 15\%$ at $y \sim 0$ (plateau $y < 1$)
same within systematic errors for full phase-space ratios
possible indication of **strangeness equilibration**

