

Strangeness Measurements in BRAHMS

- Results from Au+Au at $\sqrt{s_{NN}} = 200$ GeV
- π, K, p at selected rapidities
- Ratios, yields, slopes for Central Collisions
- As a function of centrality at $y=0$
- Plan and summary

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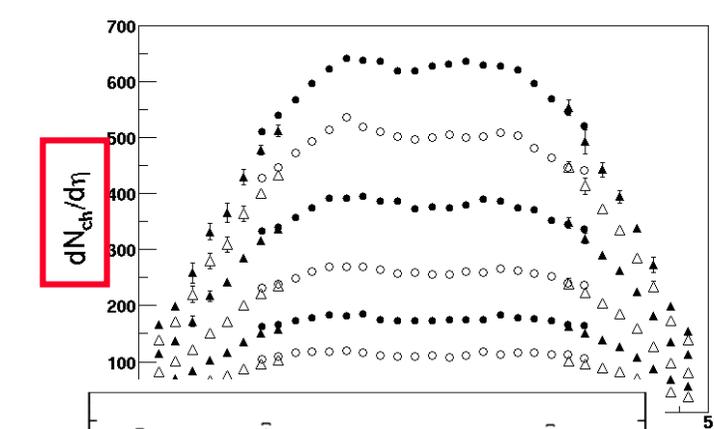
For the BRAHMS Collaboration

SQM2003

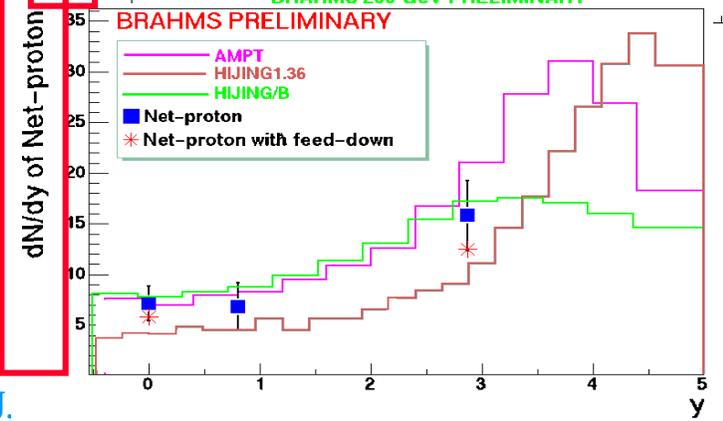
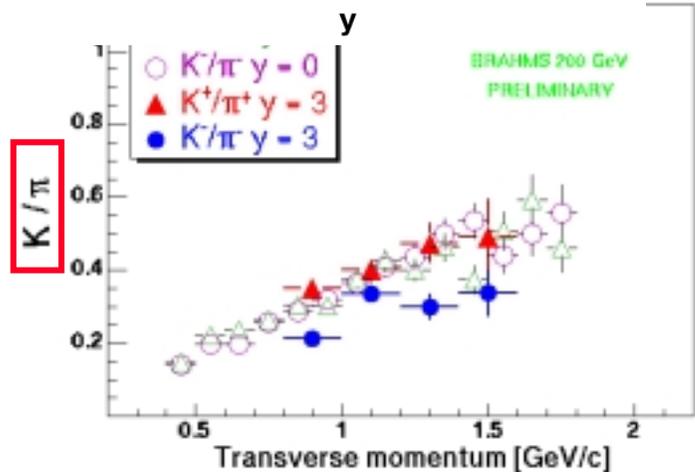
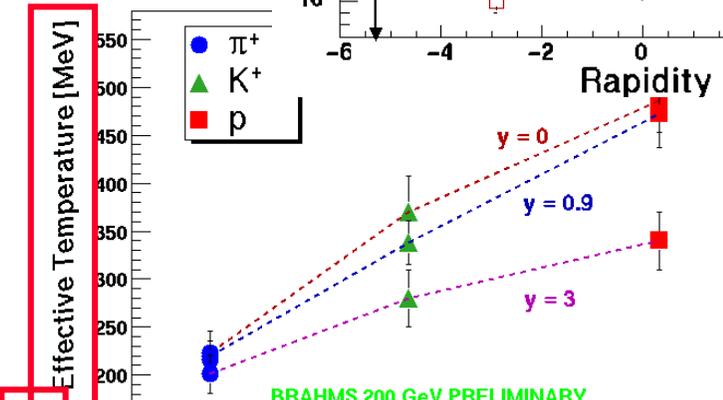
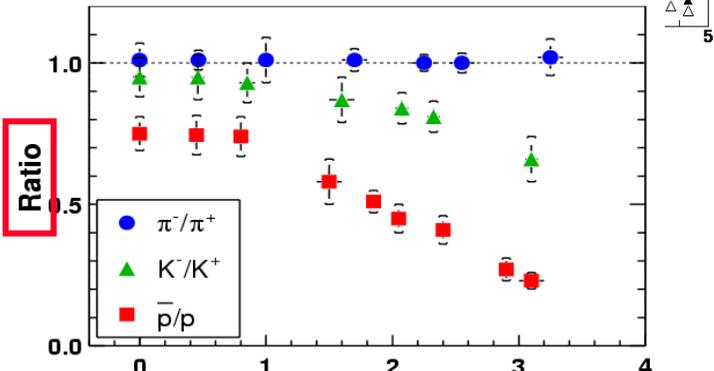
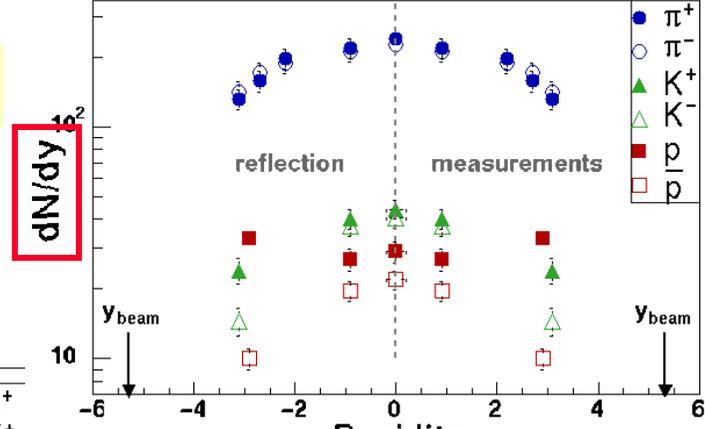
Mar. 13 2003



BRAHMS measures over a broad rapidity range



$\sqrt{s_{NN}} = 200 \text{ GeV}$



And More...

Summary of BRAHMS data from RHIC2001 (Run2) running

Data

- Au+Au and p+p at full energy: $\sqrt{s_{NN}} = 200$ GeV
- All detectors were installed and working at all centralities
- Higher level triggers (Vertex/Centrality/Spectrometer) implemented
- ~25M physics events taken
- Initial scan of "soft" physics
- Selected high-pt and HBT runs

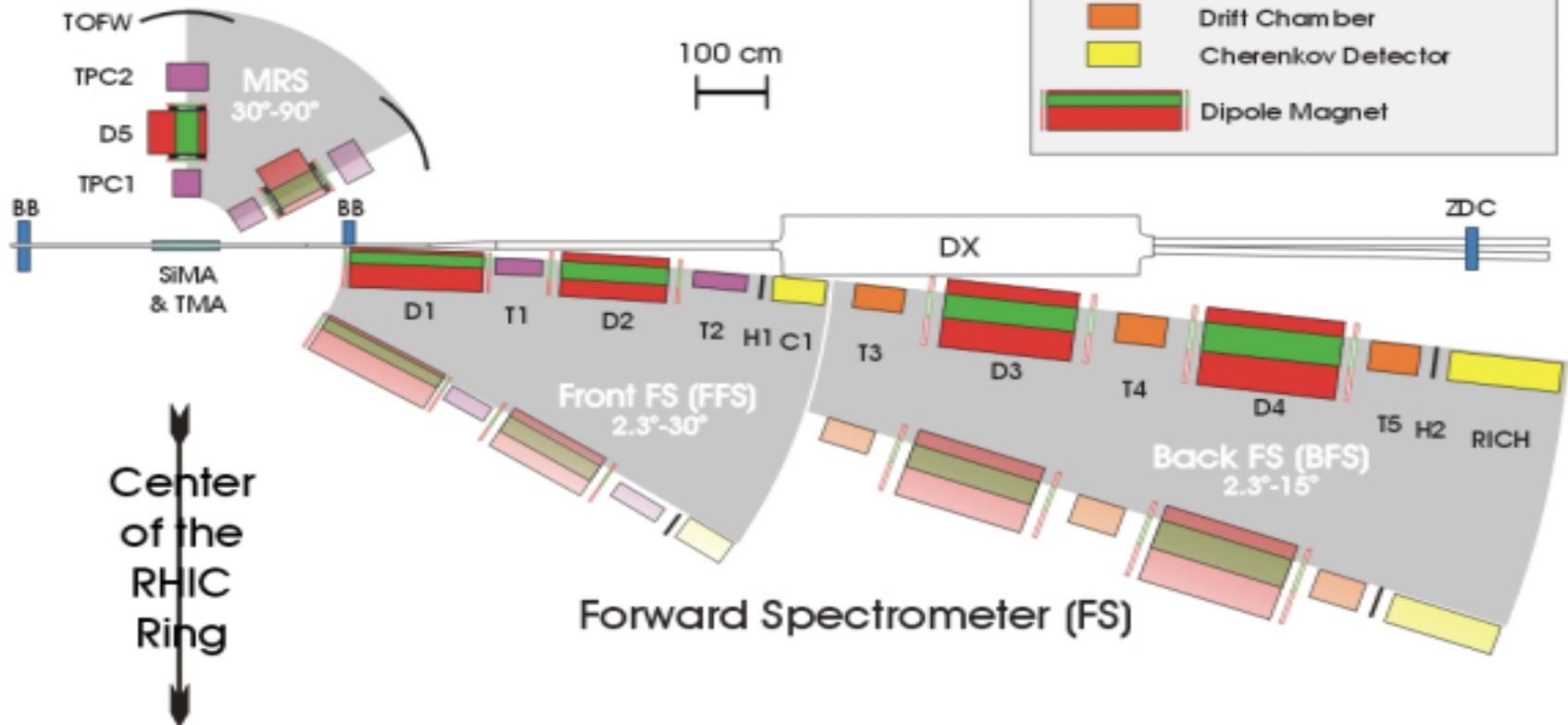
Measurements

- Charged particle multiplicity ($dN/d\eta$): published in PRL
- Particle ratios: Will be published in PRL
- Identified hadron spectra and yields at selected rapidities
 - Net-proton
 - dN/dy , slope vs y for π, K, p
- High- p_T hadrons/ π (up to $p_T \sim 6$ GeV/c at $y \sim 0$, $p_T \sim 4$ at $y \sim 2$)
- Limited HBT

The BRAHMS experiment
Setup used for Au+Au data in 2001

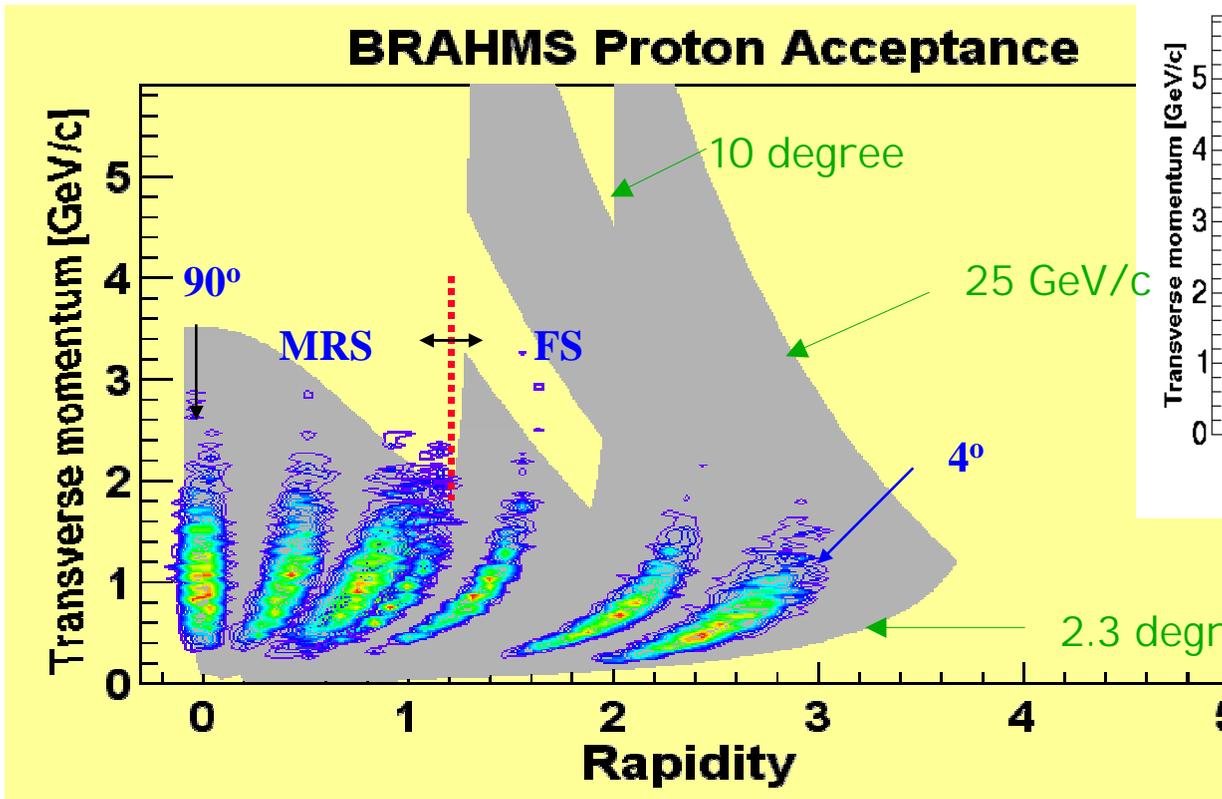
BRAHMS Experimental Setup

Mid Rapidity Spectrometer

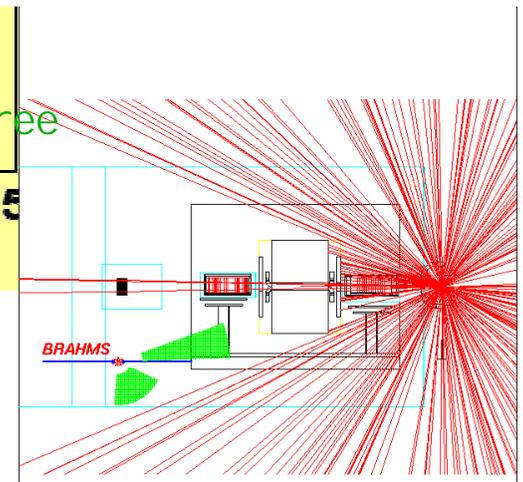
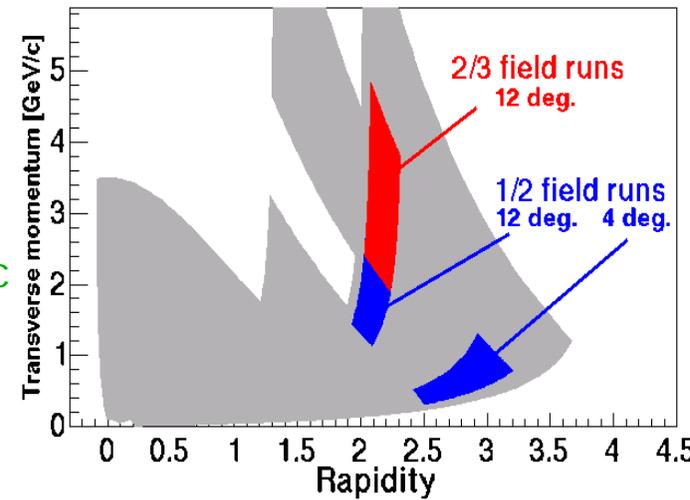


BRAHMS Acceptance

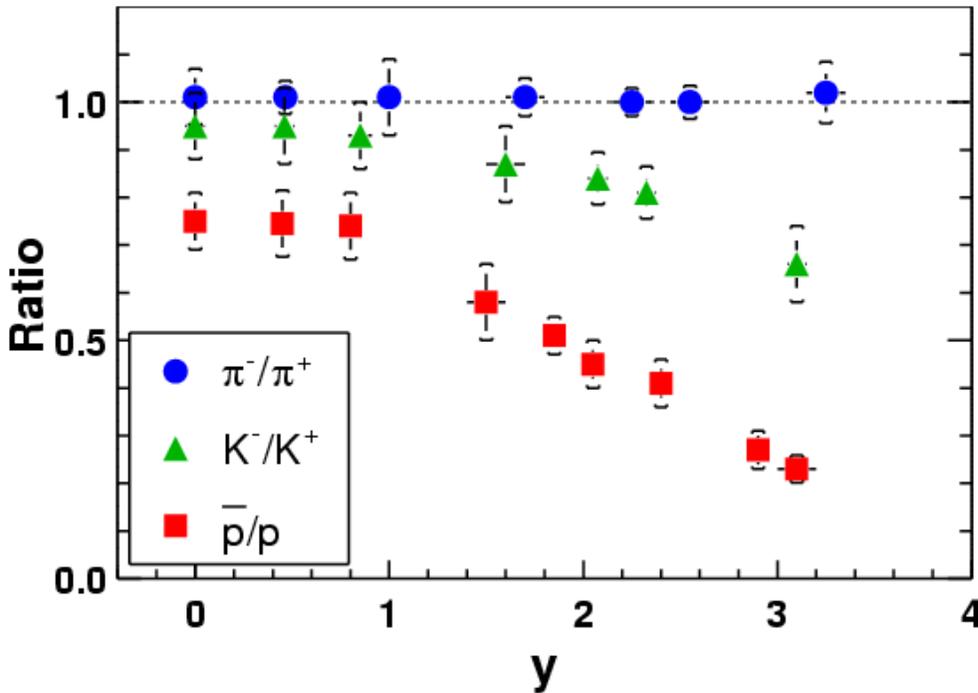
A wide range of y and p_t is covered by rotating two spectrometers with various magnetic fields.



BRAHMS Proton Acceptance



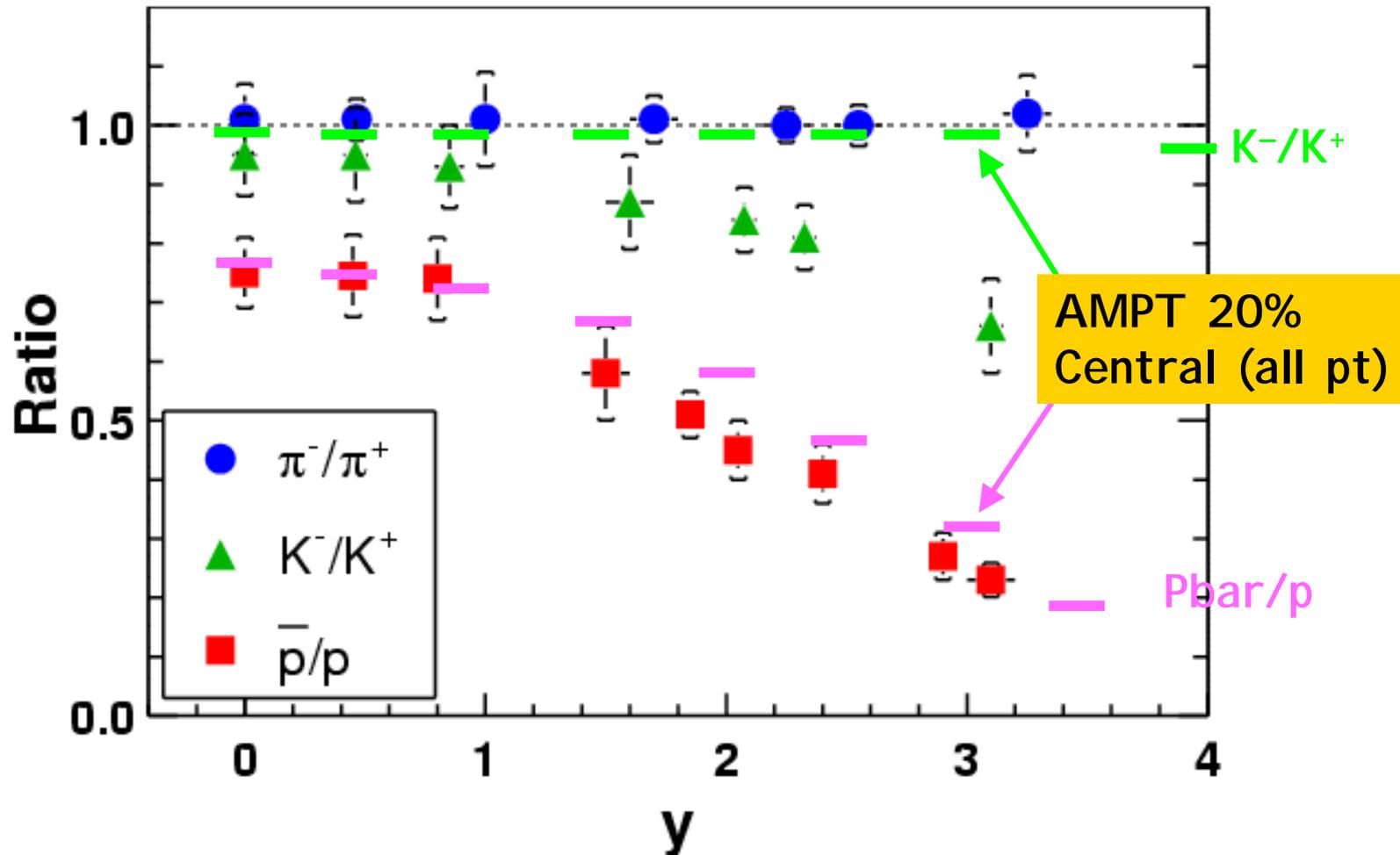
Anti-particle/particle ratios vs rapidity at $\sqrt{s_{NN}}=200$ GeV



To be published in PRL : nucl-ex/0207006

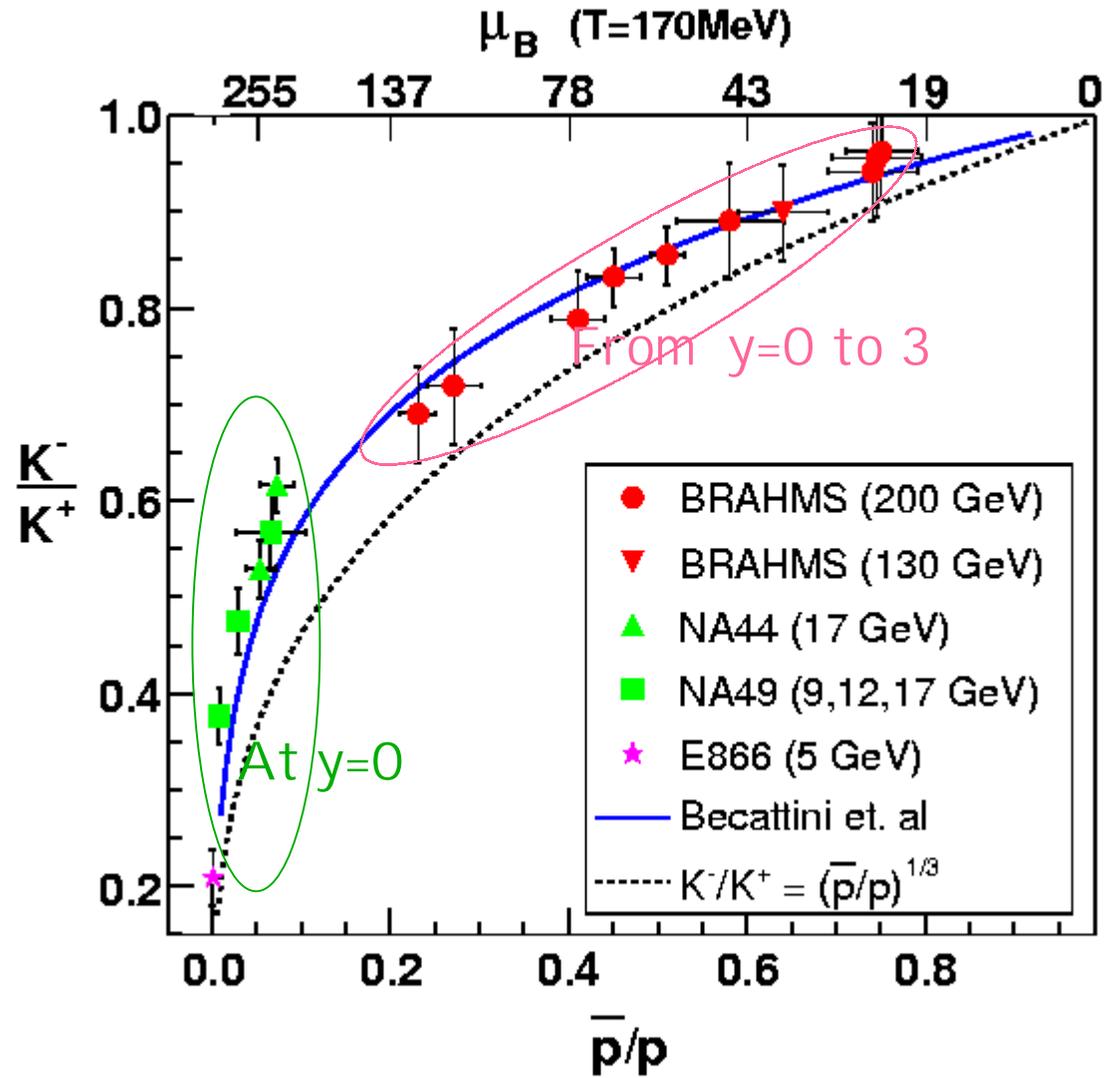
- At $y=0$ (20% central)
 - $\bar{p}/p = 0.75 \pm 0.04$
 - $K^-/K^+ = 0.95 \pm 0.05$
 - $\pi^-/\pi^+ = 1.01 \pm 0.04$
- Highest \bar{p}/p ratio but still incomplete transparency (~17% increase from 130 GeV)
- Ratios ~identical over ± 1 unit around mid-rapidity.
- Weak centrality and p_T dependence
- No Hyperon feed down correction applied: less than 5% correction assuming $\Lambda/p \sim 0.5$ and $\bar{p}/p \sim \Lambda\text{-Bar}/\Lambda$

Ratios: Data and AMPT 0-20% at $\sqrt{s_{NN}}=200$ GeV



- K^-/K^+ Ratio decreases with y : Inconsistent with models: AMPT, HIJING (AMPT describe other rapidity dependent measurements best so far)
- Where is the rest of strangeness at forward? Lambda?

"Universal" Correlation in K^-/K^+ vs \bar{p}/p ?

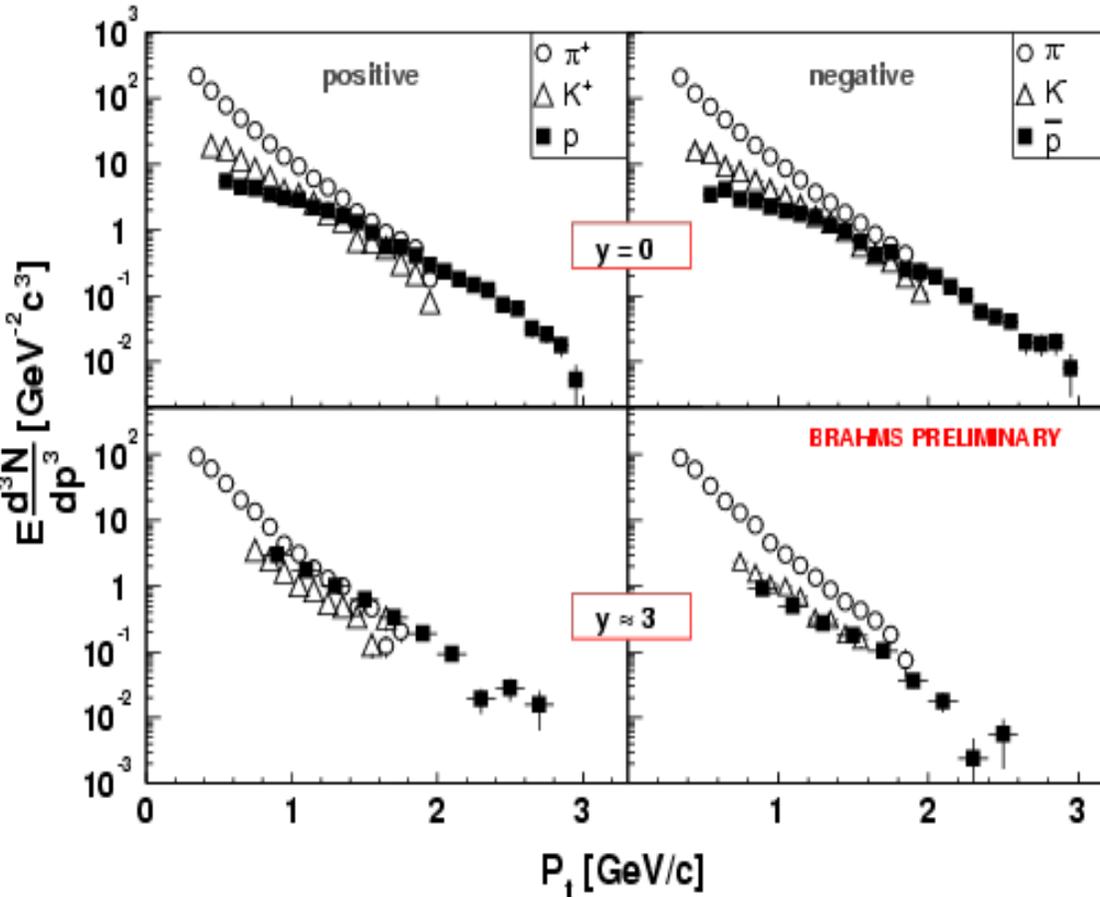


- By simple quark counting in quark recombination
 - K^-/K^+
 - $= \exp(2\mu_s/T)\exp(-2\mu_q/T)$
 - $= \exp(2\mu_s/T)(\bar{p}/p)^{1/3}$
 - $= (\bar{p}/p)^{1/3}$
- by assuming local (y) strangeness conservation
- $K^-/K^+ = (\bar{p}/p)^\alpha$
 - $\alpha = 0.24 \pm 0.02$ for BRAHMS
 - $\alpha = 0.20 \pm 0.01$ for SPS
- Good agreement with the statistical-thermal model prediction by Beccatini et al. (PRC64 2001): Based on SPS results and assuming $T=170$ MeV

To be published in PRL

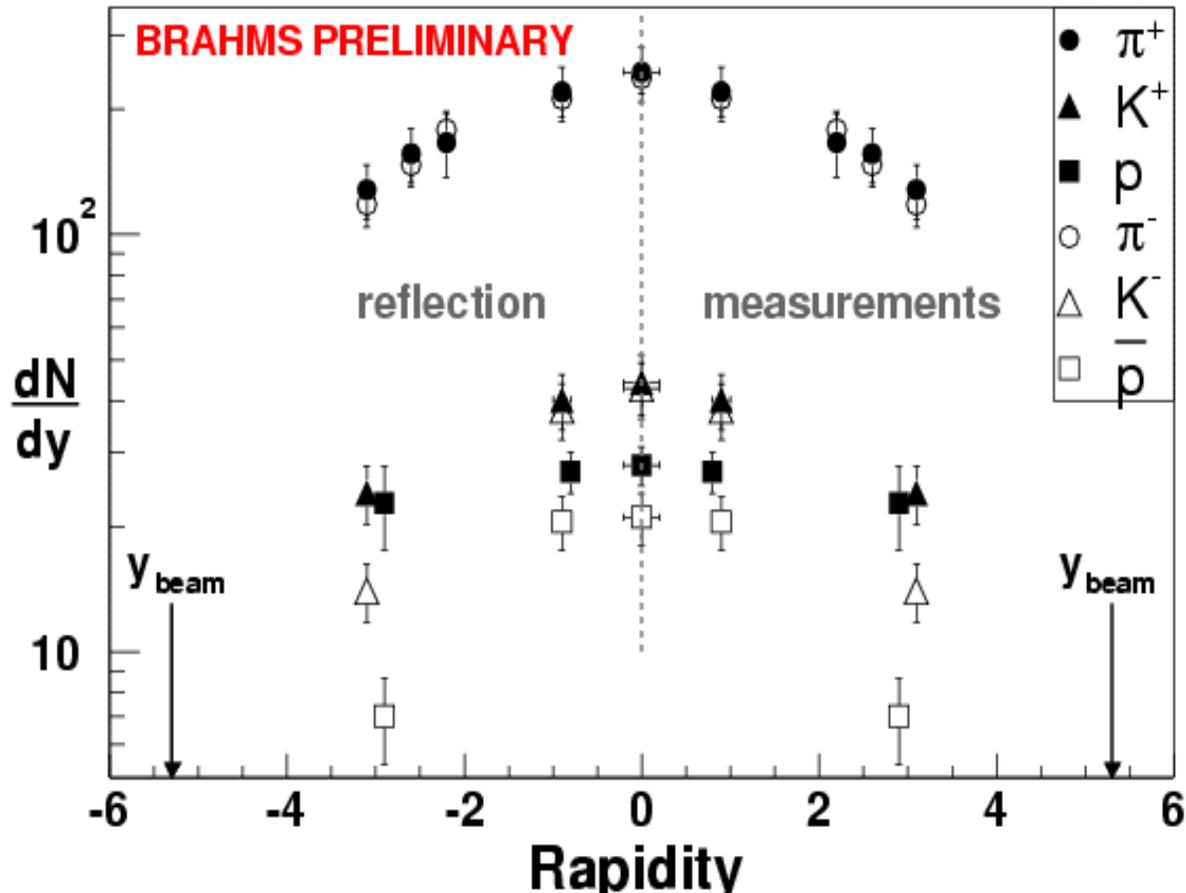
S. V. Afanasiev *et al.*, NA49 Collaboration, nucl-ex/0205002, nucl-ex/0208014; M. Van Leeuwen, Proc. Quark Matter 2002. P. Seyboth, private comm. I. G. Bearden *et al.*, NA44 Collaboration, Phys. Rev. C66, 044907 (2002).

π, K, p Spectra at 0-10% Central at $y=0$ and $y = 3$



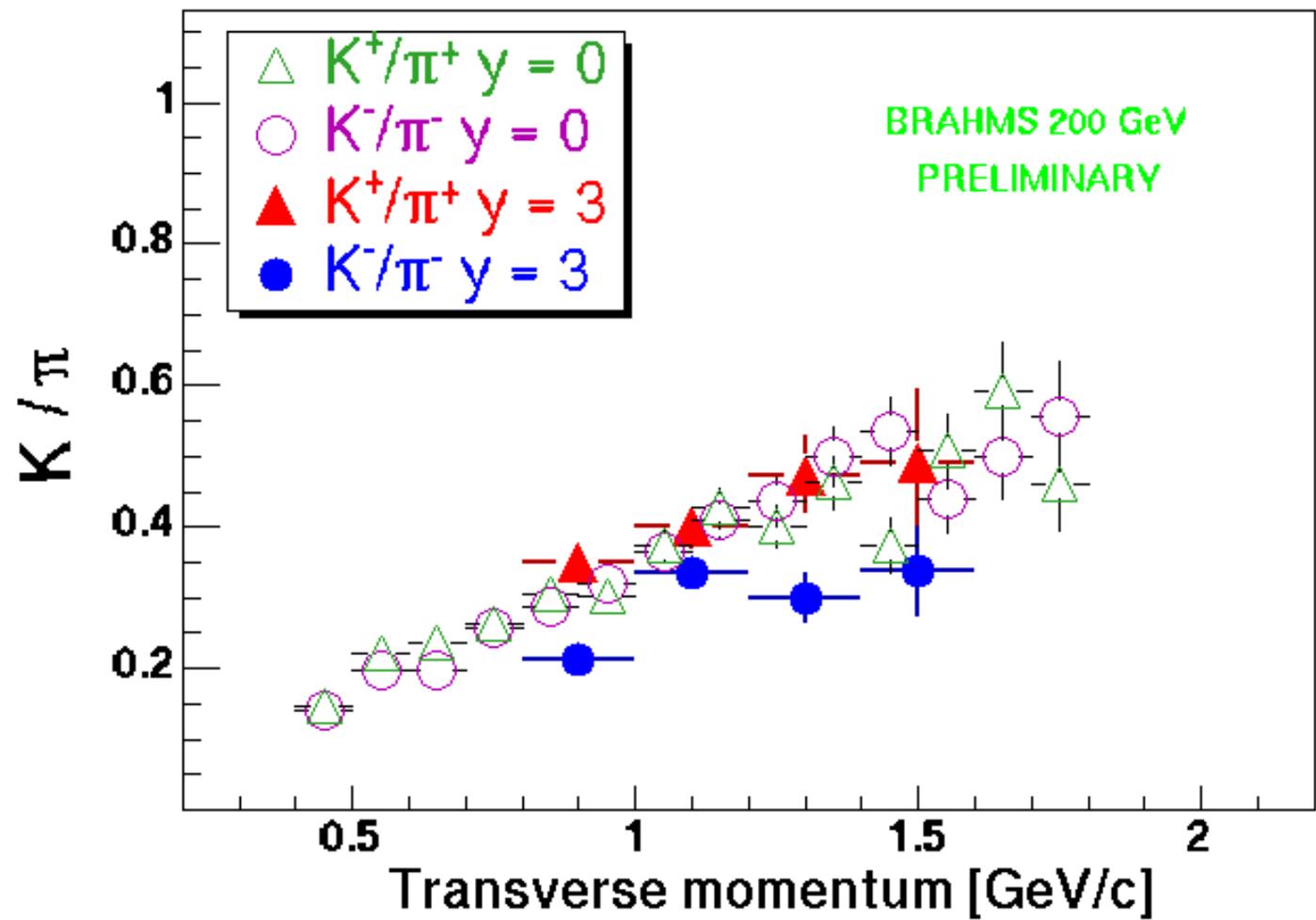
- Spectra gets softer at higher rapidity
- \bar{p} yield drops rapidly with rapidity
- protons and pions converge/cross:
 - $y \sim 0$: $p_T \approx 2 \text{ GeV}/c$
 - $y \sim 3$: $p_T \approx 1.2 \text{ GeV}/c$
- Protons over K^+
 - $y \sim 0$: at high p_T ($>1 \text{ GeV}/c$)
 - $y \sim 3$: at all p_T

dN/dy at $\sqrt{s_{NN}} = 200$ GeV 0-10% central



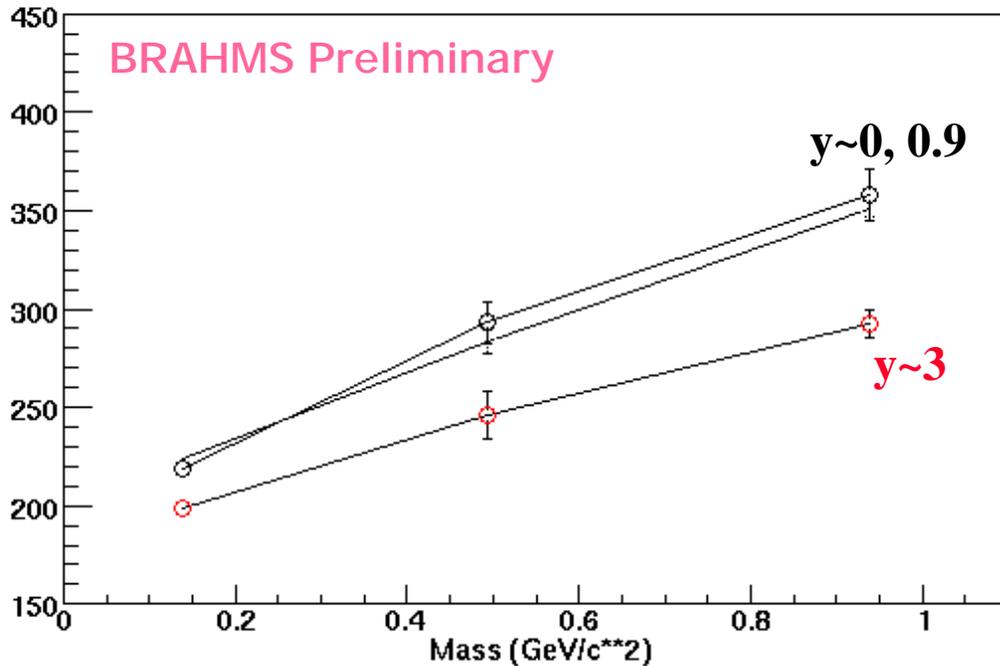
- y width: $\pi^\pm, K^+ > K^-$
- K broader than SPS
- π^\pm, K^\pm spectra can be fitted by a single Gaussian
- Integrated yields are consistent with $dN_{charged}/d\eta$ distributions

Strangeness : ratio K/π



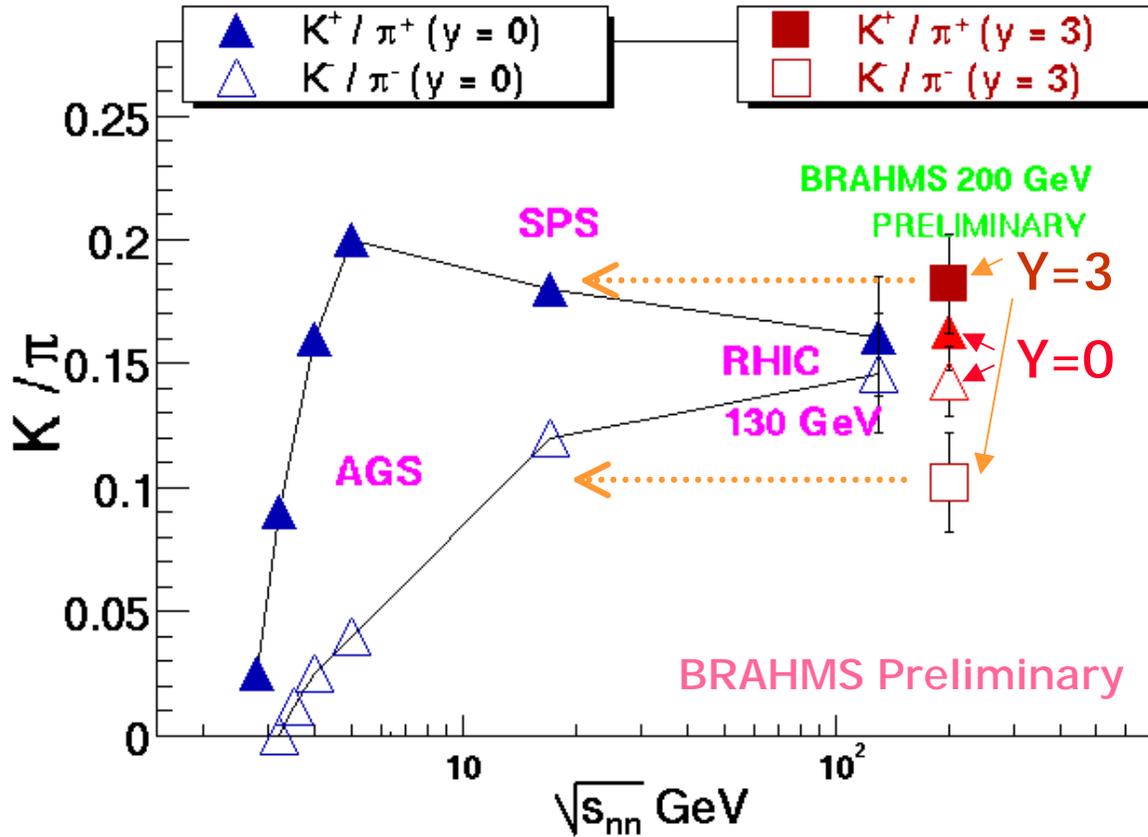
K/π ratio increases as p_T increases at $y=0$ and $y=3$

Inverse m_T Slope vs. Mass for 0-10% central



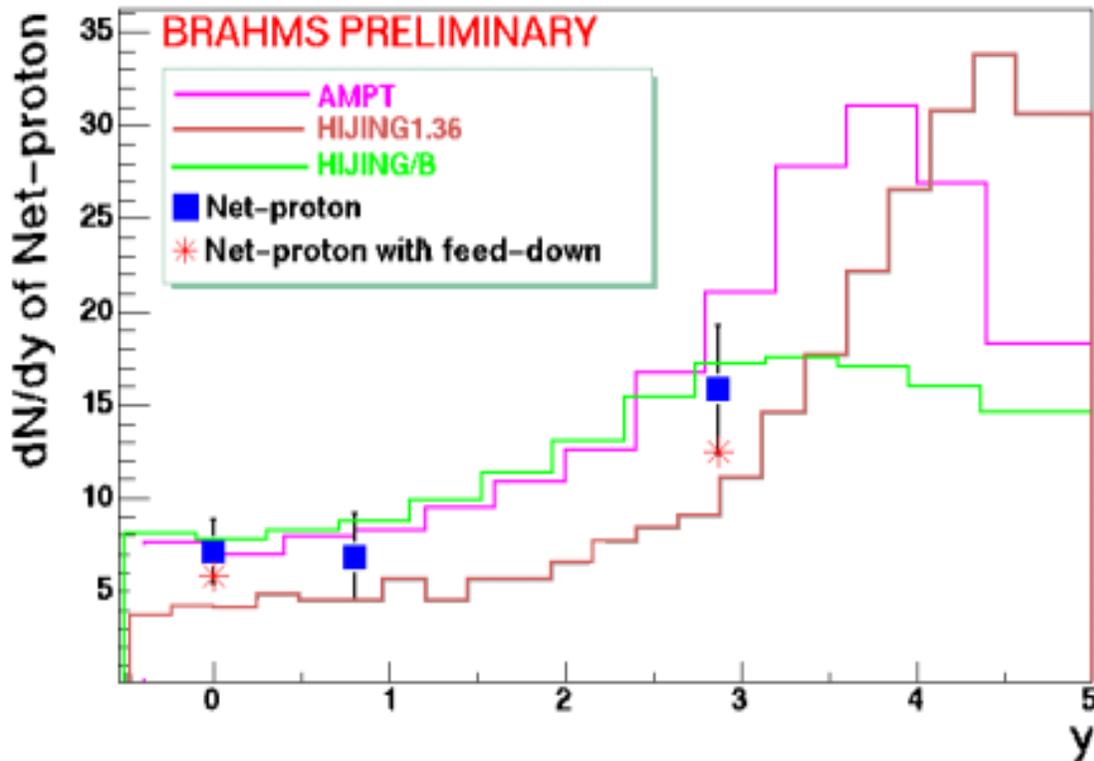
- All fits are in m_T :
over same range for all particles, at all rapidities
- Show only positive but Negative \approx Positive
- Inverse slope decreases as y increases
- Inverse slope increase with mass: transverse flow at all covered rapidities

Strangeness : K/ π systematics



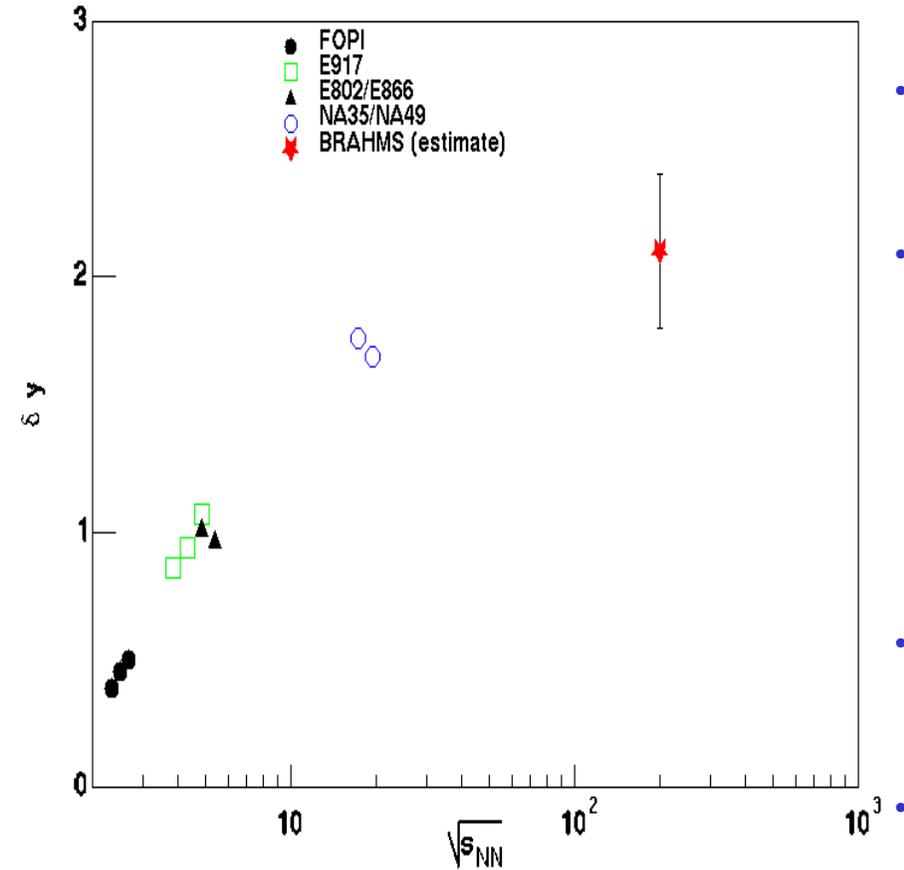
- K/ π ratio flattens at RHIC energy at $y \sim 0$
- K/ π at $y \sim 3$: similar to SPS (Pb+Pb Central at 17 GeV)
- Inverse m_T slope also similar
- K: $T \sim 230$
- π : $T \sim 200$

dN/dy of Net-proton and Models for 0-10% central



- “Plateau” at $|y| < \pm 1$
the yields by 18, 20% at $y=0, 2.9$
- Net-baryon at $y = 0$: ~ 16
(if $N(\text{proton})/N(\text{neutron}) \approx 1$)
- More data to be analyzed (at $y \sim 2, 3.3$)
- Hyperon feed down will reduce
- A range of models is still allowed with these data.

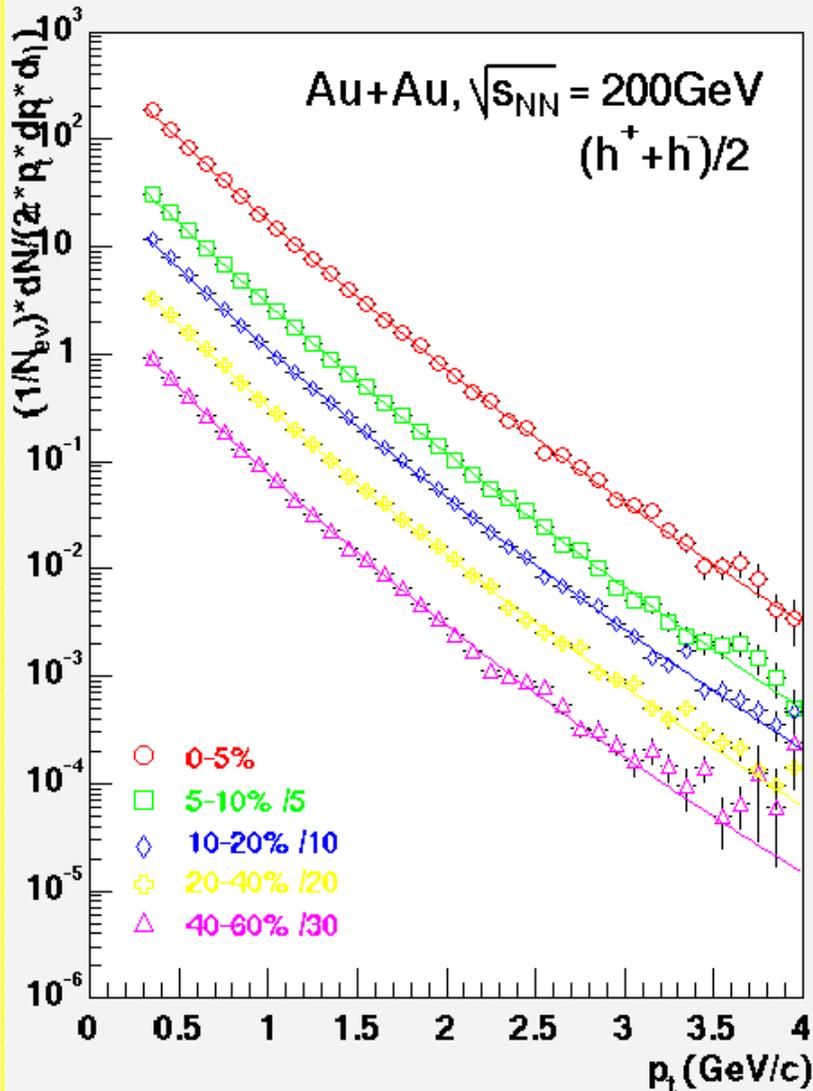
Estimate of amount of stopping



- Estimating $\Delta y = \int (y_{\text{beam}} - y) dN/dy / \int dN/dy$, as has been done for lower energy data.
- Baryon conservation tells us net(p) ~ 68 for $N_{\text{part}} \sim 340$ (0-10%) or ~ 85 in the case of full proton/neutron equilibration, $N(p) = N(n)$.
- The net(p) measured is ~ 36 . Distributing the remaining 32(53) protons in rapidity interval 3 - 5.4 with a variety of assumptions leads to an **estimated range of Δy of 1.8 - 2.4. I.e. 2.1 ± 0.3 .**
- Either extremes would require unusual rapidity distributions.
- Even though we do not have measurements in 3-5.4, we may extend another .4 units in future how can we estimate rapidity loss.
- We plan to refine this value once all data have been analyzed.

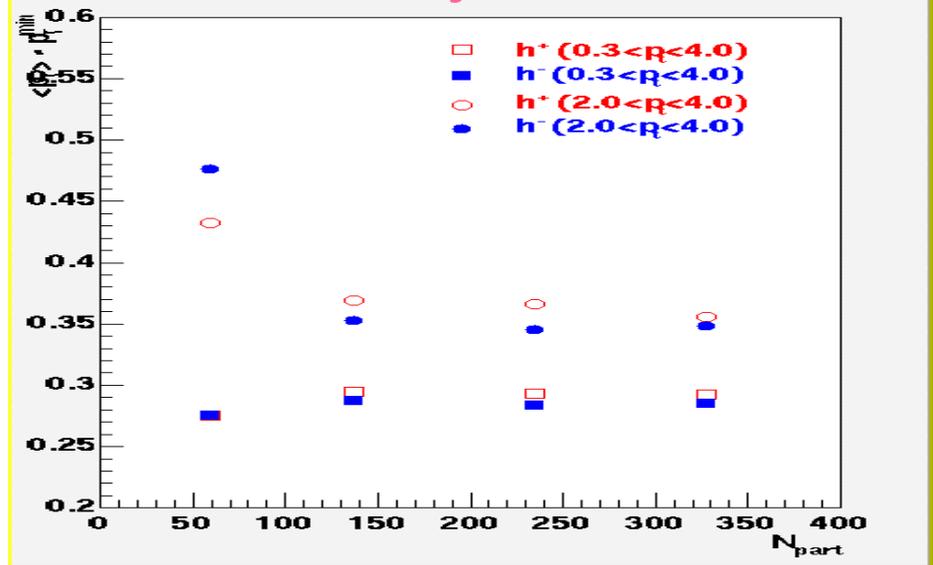
Charged Hadron Spectra as a function of rapidity at $y=0$

BRAHMS Preliminary



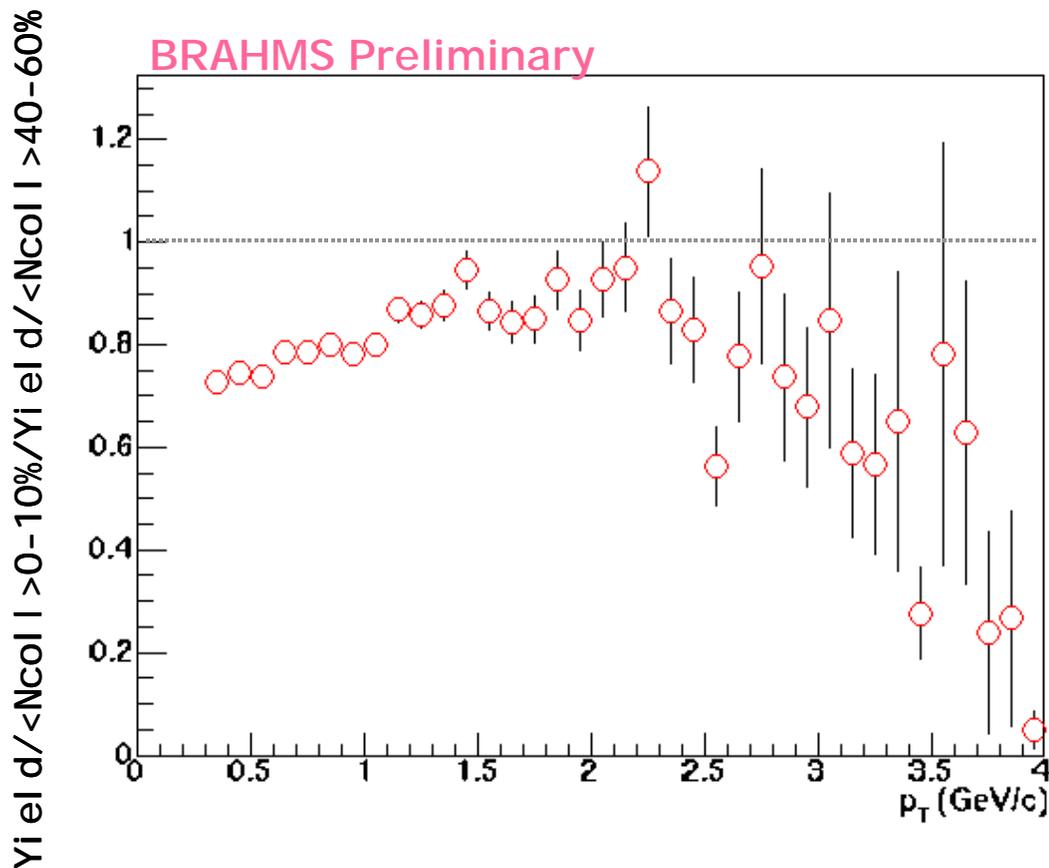
- Mean p_t :
 - increase at low p_t
 - decrease at high p_t
 - as $\langle N_{part} \rangle$ increase
- Collective flow at low p_t
+ Suppression at high p_t

BRAHMS Preliminary



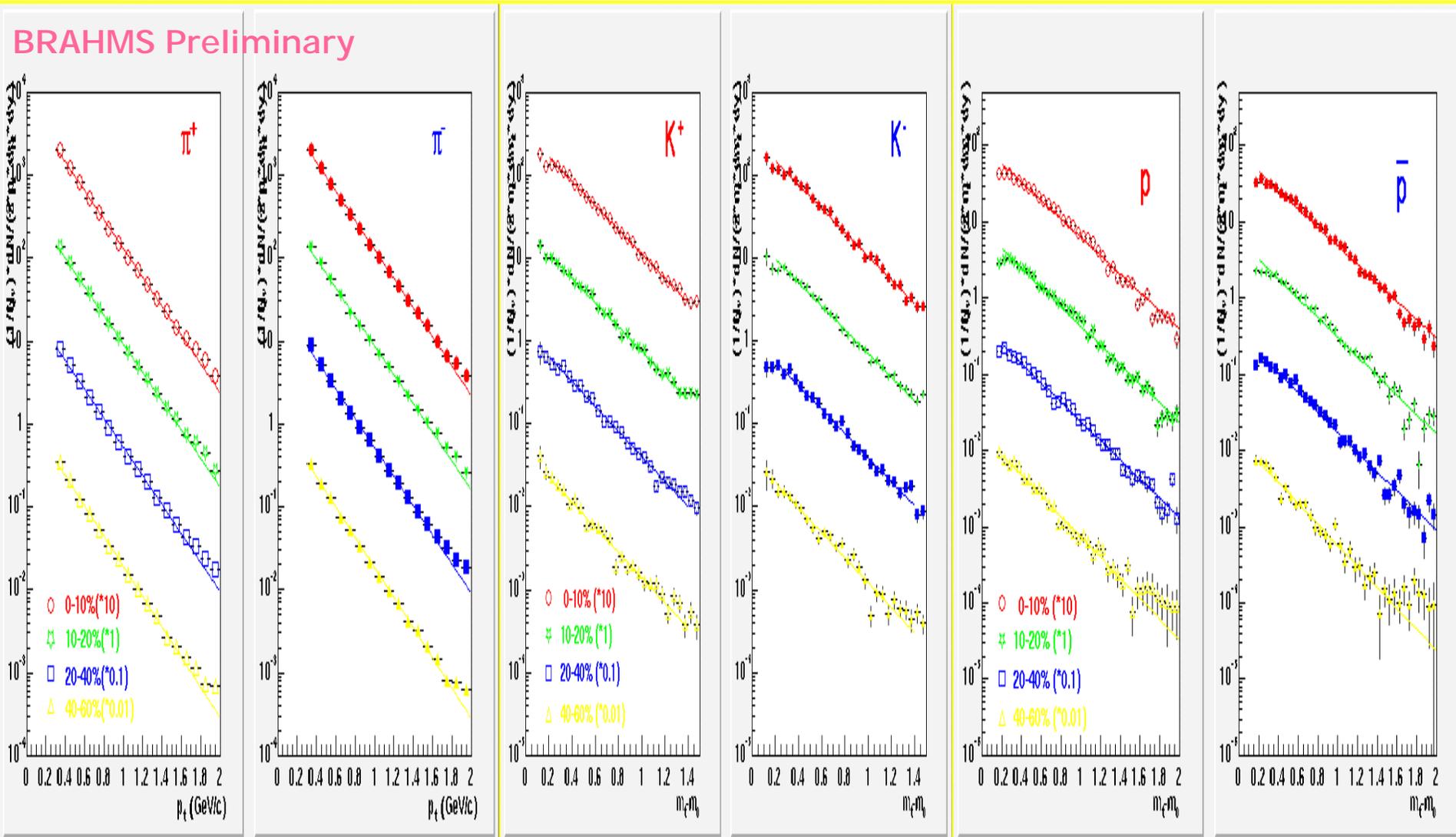
High- p_T Physics:

Central/Semi-peripheral collisions at $y = 0$

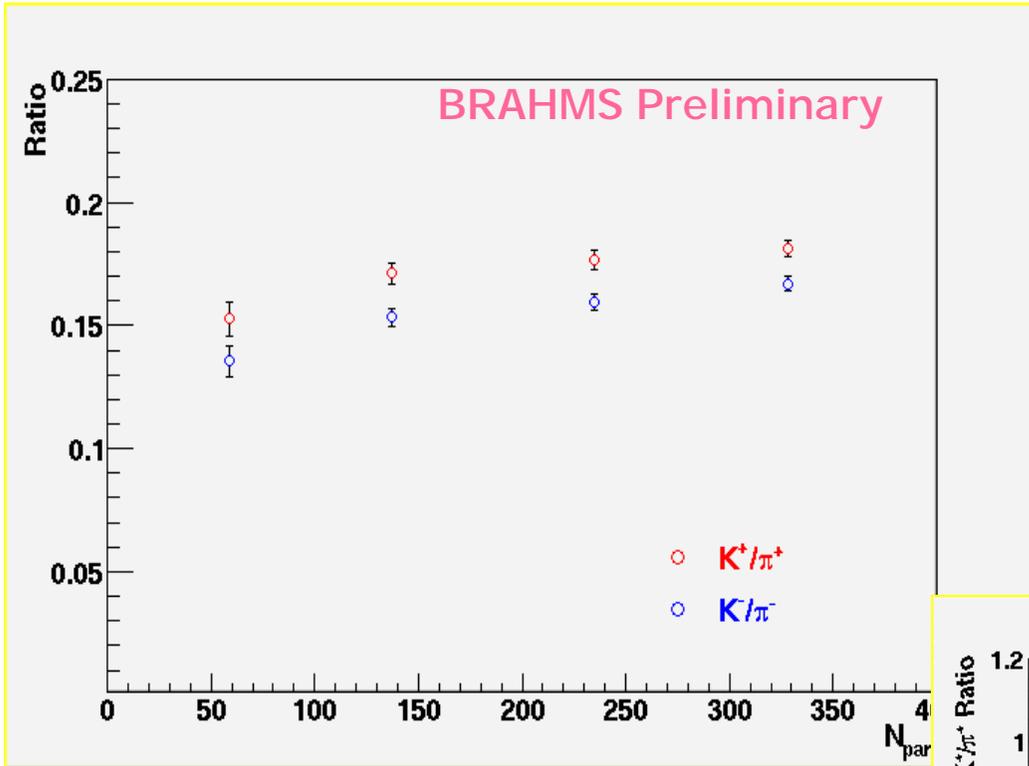


- Charged hadron spectra scaled by the number of binary collisions.
- high p_T suppression in central collisions (0-10%) compared to semi-peripheral (40-60%)
- Identified particles at $y=0,2$: analysis in progress

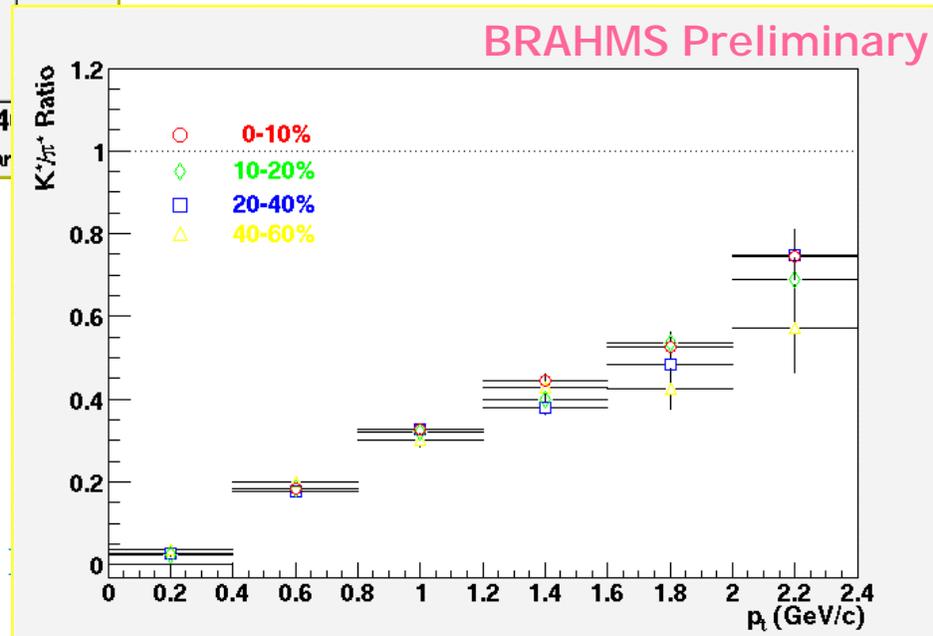
Spectra vs Centrality at $y=0$ $\sqrt{s_{NN}} = 200$ GeV



K/ π ratios at $y = 0$ $\sqrt{s_{NN}} = 200$ GeV

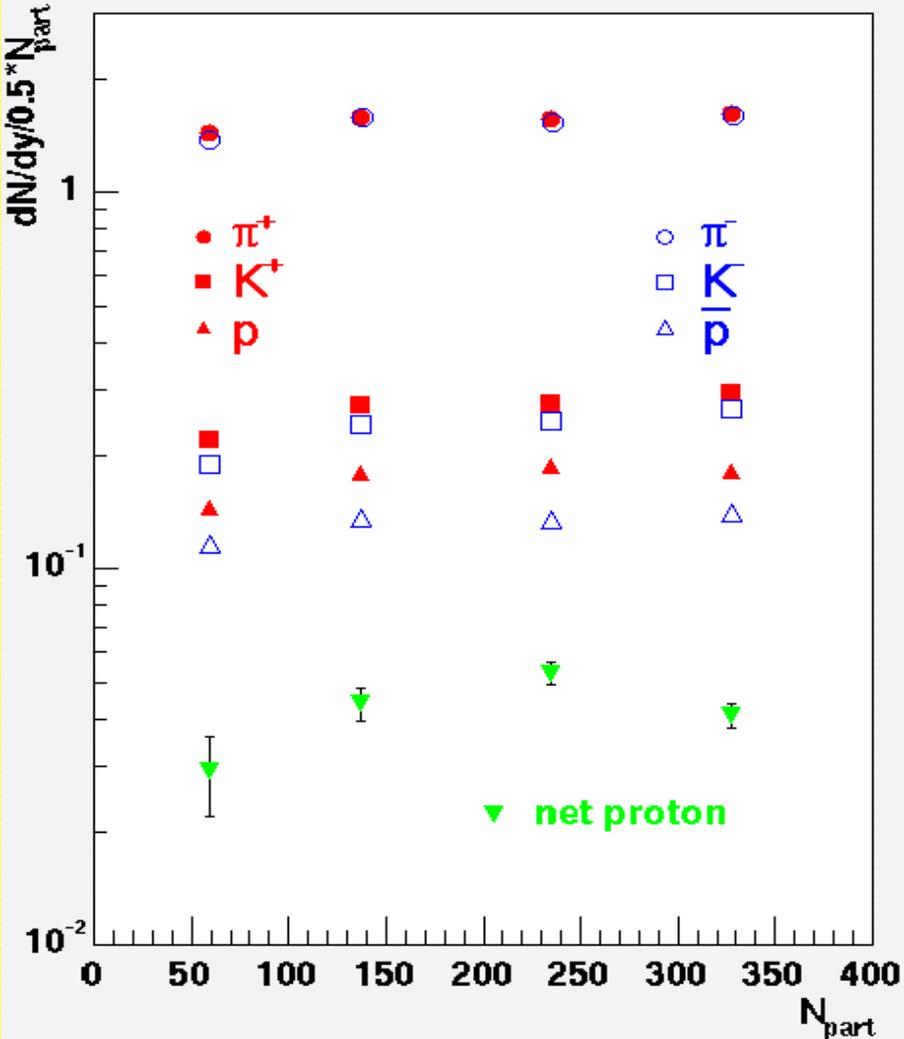


- K/ π ratios increase with ρ_T and centrality



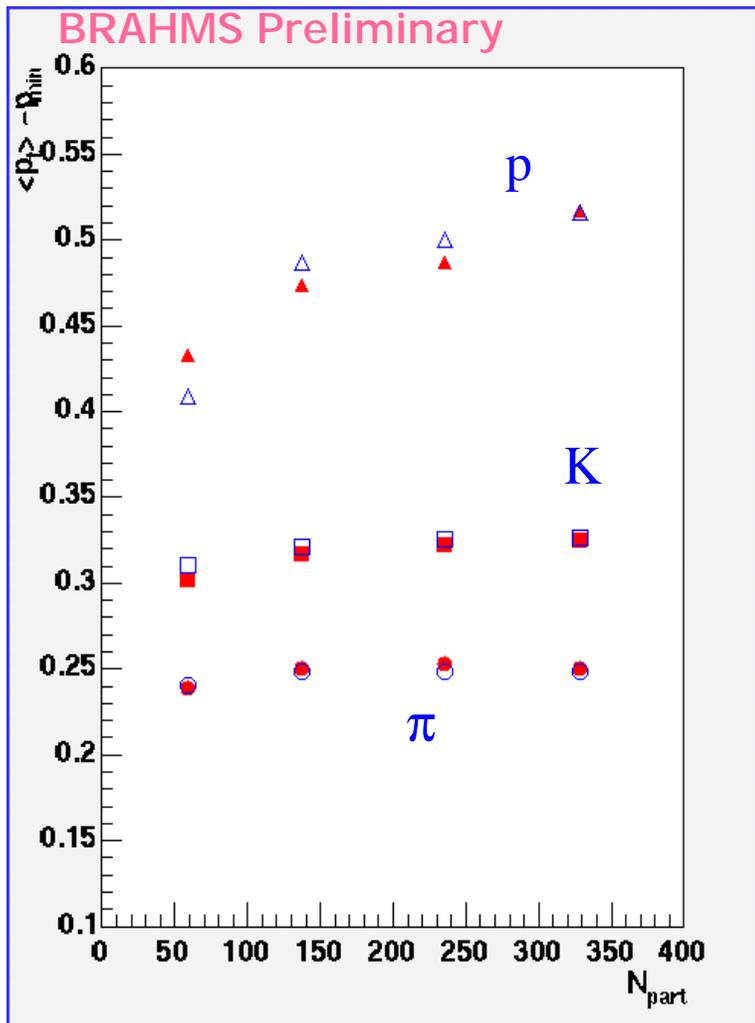
dN/dy per participant at $y=0$ $\sqrt{s_{NN}} = 200$ GeV

BRAHMS Preliminary



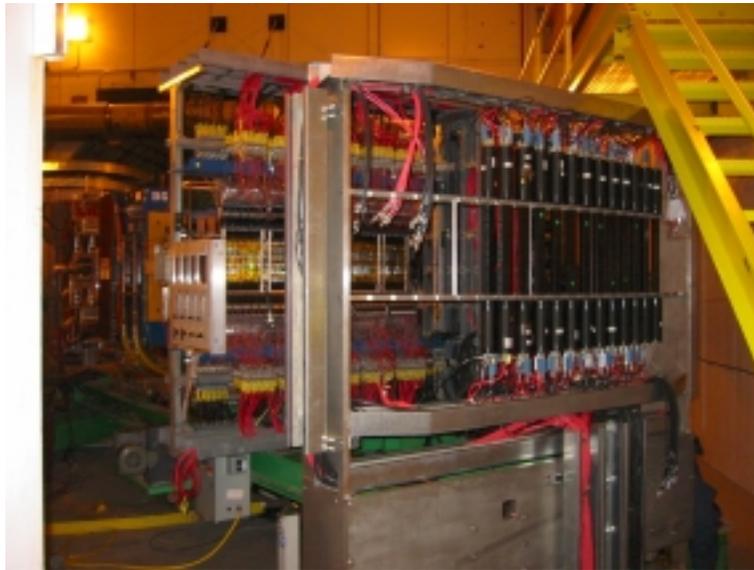
- For all the particle species, the yield per participant increase with N_{part} .
- K^\pm , p , \bar{p} yields per participant rise faster than π^\pm yield.
- Errors statistical only on plot.
- Systematic error $\sim 10\text{-}20\%$
- Dominant syst. error from N_{part} determination, and extrapolation of yields.

$\langle p_T \rangle$ vs N_{part} at $y=0$



- $\langle p_T \rangle - p_{Tmin}$
- 0.4-2.4 for pion
- 0.6-2.2 for kaon
- 0.5-3.4 for p/pbar
- $\langle p_T \rangle$ increase with $\langle N_{part} \rangle$ and mass: p and pbar increase fast with $\langle N_{part} \rangle$: consistent with radial expansion picture

Extended PID for High pt measurements at $y=0$ - 1



- New Cherenkov detector C4 + TOFW2 at Mid-Rapidity Spectrometer
- Currently taking data (d+Au)
- π/K identification up to $p = 8$ GeV/c (Forward Spectrometer PID up to $p = 25$ GeV/c)
- "high-pt" pion measurement up to 5 GeV at $y \sim 0$ (luminosity limited)

What to expect in the near future

Analysis in Progress

- Centrality dependent yield/spectra at $y \sim 0,1,2,3$
- Net-proton $y \sim 2, 3.3$: Better understanding of rapidity loss
- Blast-Wave Fit in all rapidities
- Identified High- p_T ($< 4\text{GeV}/c$) spectra at $y=0$ and $y=2$

Run3 (d+Au, p+p), Run4 (Au+Au)

- d+Au run in progress
- Identified high- p_T physics: up to $p_T = 8 \text{ GeV}$ at $y=0$
- Identified yields as a function of reaction plane for $y=0-3$ with re-configured Si-detector (in discussion)
- HBT as a function of rapidity and reaction plane at $y=1,3$

Summary:

Strangeness Measurements in BRAHMS at $\sqrt{s_{NN}} = 200$ GeV

At $y = 0 - 3$:

- K^-/K^+ : approximately constant over ± 1 unit of rapidity and fall off with y
- "Universal" correlation: $K^-/K^+ \sim (p_{bar}/p)^{1/4}$
- K^\pm/π^\pm increase with p_T for all rapidities
- Kaon production at $y=3$ at $\sqrt{s_{NN}} = 200$ GeV similar as $y=0$ at SPS
- Kaon inverse slope decreases with rapidity
- Low to high chemical potential from $y=0$ to $y=3$

At $y=0$:

- For K^\pm , the yield per participant increase with N_{part} .
- K^\pm yields per participant rise faster than π^\pm yield.

BRAHMS Publications

- "Rapidity dependence of anti-proton to proton ratios in Au+Au collisions at $\sqrt{s_{nn}}=130$ GeV"
Phys. Rev. Lett. **87** (2001) 112305
- "Charged particle densities from Au+Au Collisions at $\sqrt{s_{nn}}=130$ GeV"
Phys. Lett. B **523** (2001) 227
- "Pseudorapidity distributions of charged particles from Au+Au collisions at the maximum RHIC energy"
Phys. Rev. Lett. **88** (2002) 202301
- "Rapidity dependence of anti-particle-to-particle ratios in Au+Au collisions at $\sqrt{s_{nn}}=200$ GeV"
Will be published in Phys. Rev. Lett. : **nucl-ex/0207006**
- More information in <http://www.rhic.bnl.gov/brahms>

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