Transverse and Longitudinal dynamics at RHIC

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Outline

1. BRAHMS experimental setup

2. Introduction: some lessons from BRAHMS
   a) produced and “primary” matter
   b) hadron chemistry

3. Recent results and model comparisons on
   baryons stopping and proton to pion ratios

4. Summary
Relativistic Heavy Ion Collider w BNL

Energies:
\[ \sqrt{s_{NN}} = 62 \text{GeV}, \]
\[ \sqrt{s_{NN}} = 130 \text{GeV}, \]
\[ \sqrt{s_{NN}} = 200 \text{GeV} \]

Au+Au  Cu+Cu  d+Au  p+p
Particle production versus stopping

Produces matter peaks at $y=0$, this matter is charge symmetric. No significant change is shape from AGS to RHIC.

Primary matter: evolution from lower to higher energies. At mid rapidity evolution from baryon (AGS) to meson (RHIC) dominated medium.

$\sqrt{s_{NN}} = 4.7 \ 17.3 \ 200 \ GeV$
Particle ratios and hadron chemistry

Proton and kaon ratios decreases towards forward rapidity

Pion ratios are consistent with unity

Correlation between the BRAHMS kaon and proton ratios over 3 units of rapidity.

Forward rapidity 62.4 GeV data overlap with mid-rapidity data from SPS
Particle ratios and hadron chemistry

Forward rapidity $K/\pi$ ratios measured at 62 GeV overlap with the same ratios measured at SPS.
As you can see the models that we had tried can not described that effect.  
**PLB 867 (2010) 36**

However, the systems have different sizes. The softer kaon spectra suggest that the radial expansion is slower for the forward RHIC collisions.
Statistical model fit to BRAHMS data

$\mu_S$ vs $\mu_B$

Fits with statistical model provide $\mu_B/\mu_S$ ratio with weak dependency on $y$.


This result is consistent with local net-strangeness conservation

red line - $\rho_{s-s\bar{s}} = 0$
black line – fit to BRAHMS data
Baryon transport – short review

As I tried to explain the baryon stopping determines density and chemical composition of the produced media in high energy A+A collisions.

• Standard mechanism used for description of baryon transport is breaking of q – qq configuration. In this case the baryon number is associated with valence quarks.

• However this mechanism alone is not able to move net-baryon number over a large range of rapidity.

• ISR pp and HERA (non-zero baryon asymmetry of ≈8% in γp reactions at more that 8 units of rapidity) demonstrated that additional mechanisms with a slower y dependence are needed to account for the data. Baryon junctions is one mechanism that can move baryon number over a large rapidity range.
Stopping 62 GeV

Measurement from $y = 0$ to $\sim 3$ overlaps fragmentation region ($y_b = 4.2$)

*PLB 677 (2009) 267*

AMPT model incorporates q-qq breaking mechanism → over all good description but it underestimates net-protons at mid-rapidity

HIJING/B incorporates baryon junctions to can account for the large stopping. Parameters tuned to data from SPS. *PLB 443 (1998) 45*
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HIJING/B incorporates baryon junctions to can account for the large stopping. Parameters tuned to data from SPS. *PLB 443 (1998) 45*
AMPT does quite a good job for peripheral Au+Au at 200 GeV, it however can not describe data for central reactions.

Hijing/B seems to reproduce the trend with centrality, however, it tends to overestimates net-proton data for more central reactions.
Proton to pion ratios vs $y$ and $p_T$

Mechanisms responsible for the baryon stopping determine also the energy dissipation in the collision $\rightarrow$ pion production.

Mechanisms like baryon junction and baryon junction loops (JJbar loops included in HIJING/BBbar1.0 and 2.1) incorporate transverse baryon dynamics.

This is all reflected in $p_T$ and rapidity dependence of $p/\pi$ ratios.
$p/\pi$ ratios vs $y$ and $p_T$
Summary

- Brahms provide measurement of baryon number transport in the p+p and Au+Au reactions at RHIC energies.
- Net-p measured in p+p are consistent with quark – di-quark breaking mechanism.
- Au+Au data suggest additional mechanisms for baryon transport. (baryon junction, popcorn, di-quark breaking)
- To disentangle between different scenarios one has to study transverse dynamics of the baryon number transport.
- There is no model on the market which could simultaneously describe all available data (net-protons and p/π ratios, hyperon spectra).
The BRAHMS Collaboration

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48 physicists from 11 institutions
Predictive power of $\mu_s \approx 1/4 \, \mu_B$

We have a good description of kaon data

$\mu_s \approx \frac{1}{4} \, \mu_B \rightarrow$

$K^-/K^+ = (p_{\text{bar}}/p)^{1/4}$

How $\mu_s \approx \frac{1}{4} \, \mu_B$ will work for hyperons?

$H_{\text{bar}}/H = (p_{\text{bar}}/p)^{3/4}$ for $\Lambda$

$= (p_{\text{bar}}/p)^{1/2}$ for $\Xi$

$= (p_{\text{bar}}/p)^{1/4}$ for $\Omega$
Incidentally pure HIJING (without the junction) can describe the net-p at $y\sim 0$ but underestimates the experimental $\langle \Delta y \rangle$.

It also significantly overestimates Production of protons and anti-protons.
Stopping at 200 GeV

Hijing/BBbar 2.1: modified baryon junction phenomenology to account for better description of hyperon $m_T$ spectra. PRC 70 (2004) 064906

This version fails to description of stopping
Results: $p+p$ at 200 GeV versus rapidity

$p+p$ at 200 GeV

- $\eta = 2.6$
- $\eta = 3.1$
- $\eta = 3.3$
- $\eta = 3.5$
- $\eta = 3.8$

$\rho / \pi^+$

$\rho_T$ [GeV/c]
Results: Au+Au and p+p at 200 GeV at low $p_T$
Results: Au+Au and p+p at 200 GeV at low $p_T$
Same acceptance for pions and protons in the real time measurements. For given $\eta$-$p_T$ bin $p/\pi$ ratio is calculated on setting by setting basis using same pid technique:

**Tof2:** 2.3-$\sim$8 GeV/c, **RICH:** above 9 GeV/c, thus acceptance corrections, tracking efficiency trigger normalization canceled out in the ratio.

**Remaining corrections:**

i) decay in flight, interaction in beam pipe and material budge (GEANT calculation)

ii) correction for PID efficiency and contamination (limited specie resolution)
Test of corrections for veto-protons

auau@200, eta=3.3
no correction for veto cont.

auau@200, eta=3.3
correction for cont. added

auau@200, \eta = 3.0
no contamin. correction

corrected for contamination
$K^-/K^+$ and antihyperon/hyperon

$$\frac{K^-}{K^+} = \exp\left(\frac{2\mu_s - 2\mu_{u,d}}{T}\right)$$

$$\frac{\bar{p}}{p} = \exp\left(-6\mu_{u,d}/T\right)$$

$\mu_s = 0 \Rightarrow K^-/K^+ = \left(\frac{\bar{p}}{p}\right)^{1/3}$

Fit shows that $K^-/K^+ = \left(\frac{\bar{p}}{p}\right)^{1/4}$

$\Rightarrow \mu_s = \frac{1}{4} \mu_{u,d}$

How $\mu_s = \frac{1}{4} \mu_{u,d}$ will work for hyperons?

$Hbar/H = \left(\frac{\bar{p}}{p}\right)^{3/4}$ for $\Lambda$

$= \left(\frac{\bar{p}}{p}\right)^{1/2}$ for $\Xi$

$= \left(\frac{\bar{p}}{p}\right)^{1/4}$ for $\Omega$
Broad Range Hadron Magnetic Spectrometers

Flow Ring 2

Tile Ring 1

Si Ring 1

Forward Spectrometer (FS)