RHIC Summer Study 1996: Theory Workshop
on RHI Collision, BNL, Upton, NY
July 8-19, 1996

CONF-9607160--5

BNL-63624

THE BRAHMS EXPERIMENT AT RHIC

FLEMMING VIDEBÆK
Physics Department, Brookhaven National Laboratory,
Upton, NY 11973-5000, U.S.A.

Abstract

The BRAHMS experiment is designed to measure semi-inclusive spectra of charged hadron over a wide range of rapidity. It will yield information on particle production, both at central rapidity and in the baryon rich fragmentation region. Examples of measurements for soft as well as for hard physics are presented.

1 Introduction

The main motivations for the RHIC experiments are the search for and the investigation of the quark-gluon plasma. It is thought that QGP can be created in high energy heavy ion collisions under a broad range of experimental conditions bounded in one direction by high baryon densities and in the other by zero baryon density and temperatures above the critical temperature. At RHIC with energies $\sqrt{s} = 200 GeV/c$ per nucleon pair, which is above the stopping regime presently being explored at AGS and SPS, a baryon poor region with a high energy density is expected to be created at mid-rapidity. The region near the initial nuclei will be baryon rich at relative high temperature. This gives experimental opportunities to study both regimes at RHIC and search for the quark-gluon plasma under several different conditions.

The Broad RAnge Hadron Magnetic Spectrometers (BRAHMS) experiment has been designed to gather basic information in heavy ion reactions on momentum spectra and yields for various emitted particles as function of transverse momenta, p_t, and rapidity, y. These yields as function of rapidity are important indicators of the densities reached in the collisions and of the produced entropy. The spectral shapes and their y-dependence reveal the reaction dynamics and the degree of thermalisation attained. The high p_t parts of the spectra carry information from the early times in the reaction.

W

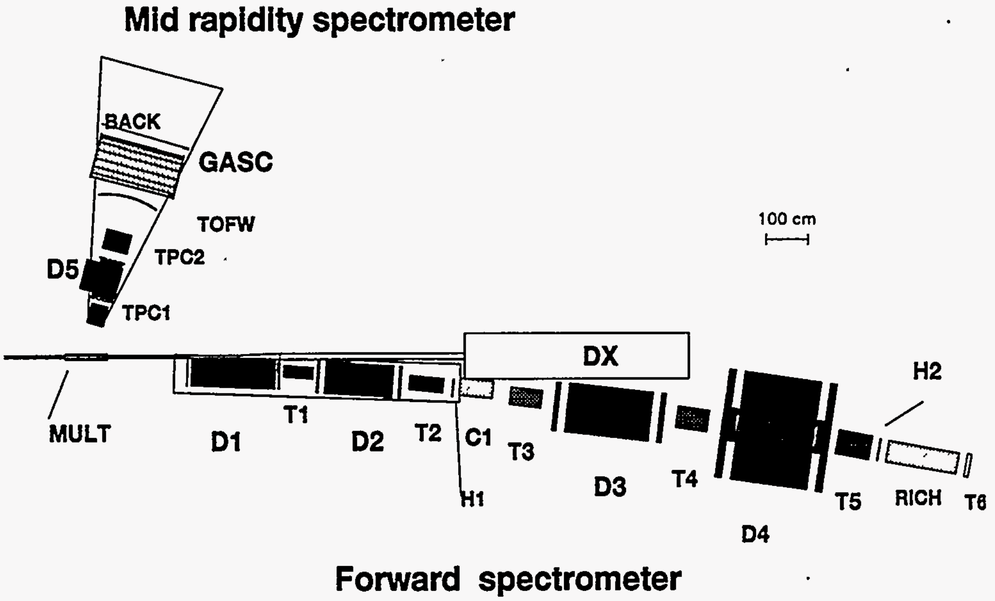

Figure 1: Top view of spectrometers. The labelled detector elements are described in the text.

The centrality measurements are an integral part of the experiment, and systematic studies are needed to establish the reaction dynamics.

The BRAHMS spectrometers are small solid-angle devices so the measurements will be semi-inclusive; i.e., the average spectra for given event classes as determined by the centrality detectors will be measured. This contrasts to the large RHIC experiments where event-by-event information can be collected, but BRAHMS has a unique place in the RHIC experimental program with its wide coverage in rapidity and p_t. The coverage is essentially limited by the accelerator structures, the size of the experimental halls, and the modest budget for BRAHMS.

2 The Spectrometers

This section gives only a very brief description of the BRAHMS detectors. For more detailed information the reader is referred to [1, 2, 3, 4]. A top view of the two moveable spectrometers is shown in figure 1.

DISCLAIMER

The BRAHMS experiment is designed to measure well identifiedly charged hadrons ($\pi^{\pm}, K^{\pm}, p^{\pm}$) over a wide range of rapidity and transverse momenta at all energies and beams available at RHIC. The very different experimental conditions, momenta, and particle densities at mid-rapidity and forward angles has lead to the design with two moveable magnetic spectrometers. The Mid-Rapidity Spectrometer (MRS) covers the angular region $30^o \leq \Theta \leq 95^o$ ($-.1 \leq \eta \leq 1.3$) and the forward spectrometer (FS) the region $2.3^o \leq \Theta \leq 30^o$ ($1.3 \leq \eta \leq 4.0$). FS consists of 4 dipole magnets (D1-D4), two time projection chambers (T1,T2) and three drift chamber packages (T3-T6). The particle identification is done by combining time-of-flight measurements in the hodoscopes H1 and H2 with measurements in the threshold Cherenkov counter C1 and the Ring Imaging Cherenkov Counter (RICH). This allows for particle identification in the momentum range 1-20 GeV/c in the forward spectrometer. The mid-rapidity spectrometer has two TPCs (TPC1 and TPC2), a dipole magnet (D5) for momentum measurements, a time-of-flight wall (TOFW), and a segmented gas Cherenkov detector (GASC) for particle identification in the momentum range $p \leq 5$ GeV/c. The momentum resolution is typically $\delta p/p \leq 0.01p$, which is sufficient for tracking considerations and the spectral measurements. A set of beam-beam counters provide the initial trigger and vertex information as well as the start time for the time-of-flight measurements. The silicon multiplicity array will be used to characterize the centrality of the collisions by measurements of the charged particle multiplicities in the region $-2.5 \leq \eta \leq 2.5$.

3 Soft Hadron Measurements

The dominant part of the particle spectra is the soft part with transverse momenta $p_t \leq 1 GeV/c$. Particle spectra have been studied in elementary pp (p$\overline{p}$) over a wide range of energies covering the RHIC energy regime. Even with this knowledge in hand it is not trivial to extrapolate to nucleus-nucleus collisions. It has been learned from heavy ion reactions at AGS and SPS, see e.g. [5], that the heavy ion collisions cannot be considered a super-position of elementary nucleon-nucleon collisions, but that multiple collisions and collective effects are important to a proper description of the experimental data. At the much higher energies considered here it is likely that additional many-body effects, even for a pure hadronic description, have to be taken into account. Understanding of the reaction mechanism will clearly come from systematic studies of pp to p-nucleus and nucleus-nucleus reactions.

One of the basic questions is what is the amount of stopping, i.e. the mean rapidity shift of projectile nucleons, see e.g.[6], and how high is the net baryon density in the central region of Au+Au collisions. In fig. 2 is shown the prediction for the net baryon density $\frac{dn}{dy}$ for 4 different models successfully used to describe pp and nucleus-nucleus

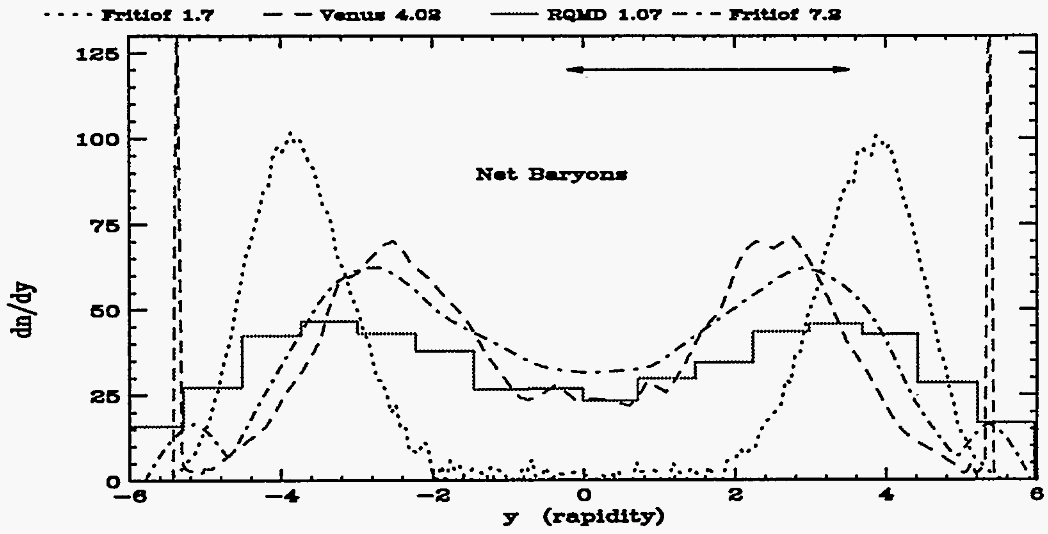

Figure 2: Predicted rapidity density distributions for central Au+Au reactions using different models as indicated by the linetype. The rapidity range to studied by BRAHMS is indicated by the arrows.

reactions at lower energies. These are Fritiof 1.7[7], Fritiof 7.2[8], Venus[9], and RQMD [10]. The predicted mean rapidity losses are in the range of 1.7-3.1. The coverage of BRAHMS is shown by the arrow. Even though the fragmentation region in the view of pp (i.e. 4-5) is outside the range, the measurements do cover the region $y \leq 3.8$ sufficiently to map and study the stopping in nucleus-nucleus collisions at RHIC.

The predictions for meson production are given in figure 3. The experiment will essentially cover the complete distribution for π and K, and can address details of the shape and particle yields. The predictions vary almost a factor of 4 at mid-rapidity, so with this in mind the spectrometers were designed to handle the highest expected values.

The correlation of like-bosons as a function of the relative momenta can provide a measure of the space-time extent of the emission source [11, 12]. Pair correlation coupled with single-particle measurements is thought to help in providing a good understanding of the dynamics which control the evolution from the initial hot dense phase to the system at freeze-out. A detailed description of the HBT capabilities can be found in [4], in particular regarding the measurements and sensitivity in the mid-rapidity spectrometer. Here is shown an example of the kind of measurement which can be done

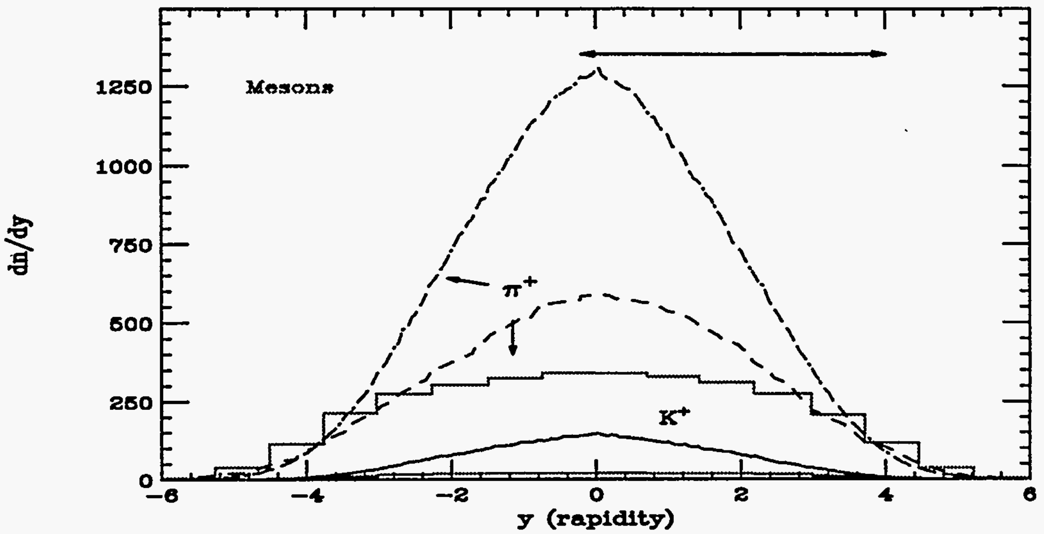

Figure 3: Predicted rapidity density distributions for π^+ and K^+.

at the higher rapidities utilizing the Forward Spectrometer. The pion correlations were simulated using a simple gaussian correlation function $C(q) = 1 + \lambda e^{-(q^2R^2+q_0^2\tau^2)}$, where q is the magnitude of the relative 3-momentum, R the source radius, q_0 the relative energy, and τ the lifetime parameter. Here τ was explicitly set to 0. Pairs of pions were accepted through the spectrometer at 10^o with an acceptance of $1 \leq p \leq 3$ GeV/c. The extracted correlation function for 100,000 π^+ pairs is shown for two representative samples with R=5 and 10 fm. The simulation illustrates that for a limited range of rapidity and momenta the forward spectrometer has sufficient resolution and two-particle separation to make modest measurements of pion-correlation functions.

4 High p_t Measurements

In contrast to the heavy ion experiment carried out so far at AGS and SPS, initial hard scattering processes are important for the reaction dynamics at RHIC. The importance is known from the mini-jet production at ISR energies and as evident in the inclusive hadron spectra measured from $\sqrt{s} = 50 - 1800$ GeV in p+p reactions. A hard component is observed for $p_t \geq 1.0$ GeV/c. This hard component has two aspects of consequence in heavy ion reactions. The initial fast parton scattering contribute

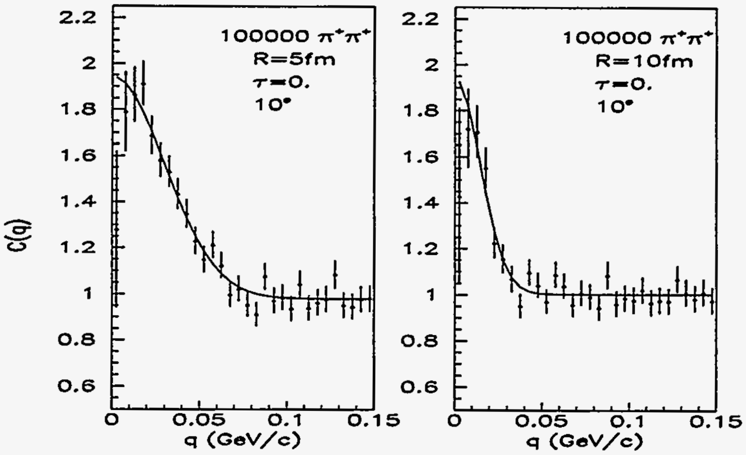

Figure 4: Estimated results of two-particle correlation measurements at 10 deg.

significantly to the formation and equilibration of a hot dense system [13] and to the particle production. Nuclear effects such as jet quenching and gluon shadowing are expected and can be studied in inclusive mini-jet distributions[15]. The prediction from the HIJING model and the Parton Cascade model[14] of the total charged particle rapidity distributions on this is shown in fig.5. The various physical processes are turned on successively. The parton shadowing is determined mainly from the gluon structure function, and the quenching is dominated by the gluon brehmsstralung energy loss in the nuclear medium. It is observed that depending on the rapidity region the different processes contribute with different weights. Likewise, p_t dependencies are present. Measurements at different rapidities, and in a p_t in a range as large as possible, up to 5-6 GeV/c, will be a mean to experimentally determine constrains on the various mechanisms. Comparison between different collision systems will also be important for this task.

As an example of the feasibility of this kind of studies, a simulation was performed for a measurement of π^+ at rapidity 2 in central Au+Au collisions. A sample of pions from a distribution with inverse slope parameter of 170 MeV (in m_t) and a $\frac{dn}{dy}$ of 200 was fed through the GEANT simulation of the forward spectrometer and the p_t spectrum reconstructed in two settings of the magnetic field. The resulting p_t spectrum which can be obtained in about 1 week of running is displayed in fig.6. In about another week the measurements can be extended to about 6 GeV/c with similar statistics using larger bins in Δp_t of .5 GeV/c. This demonstrates that high quality spectra can be collected

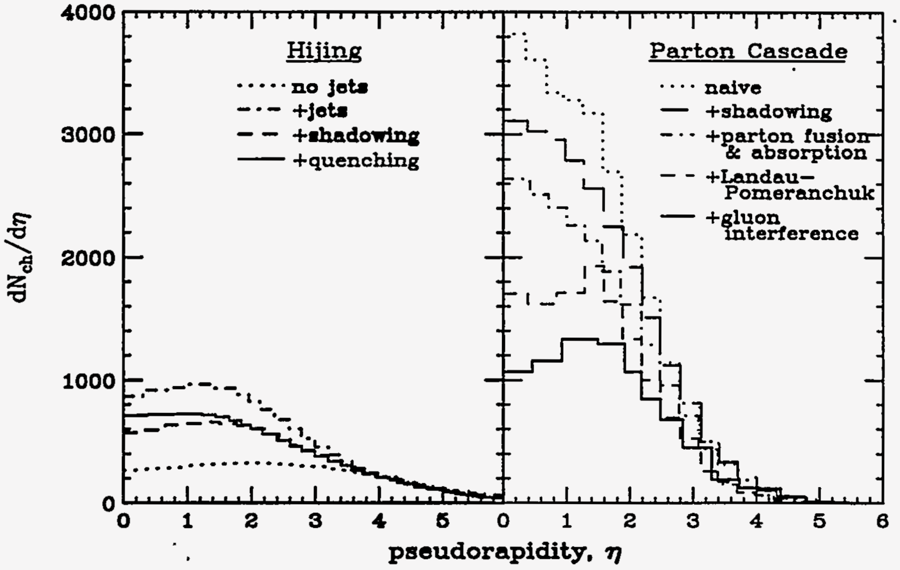

Figure 5: Prediction for dn/dη for charged particle distributions

up to rather high values of p_t. It should be stressed that these measuremnsts are for identified hadrons, and thus can also be done for kaons, protons, and anti-protons, studying the flavor dependence.

Acknowledgments

This paper has presented the design and some expectations of the BRAHMS spectrometer, which is supported by a collaboration consisting of about 35 physicist from BNL, CRN-Strasbourg, The Niels Bohr Institute, Texas A&M, New York University, Harbin Technical University, U.C. Berkeley Space Sciences Laboratory, University of Kansas, and Jagelloian University-Krakow This work was supported by the US Department of Energy under contract DE-AC02-76CH00016.

References

[1] BRAHMS conceptual Design Report, October 1994, BNL-62018; WWW URL http://rsgi01.rhic.bnl.gov/export1/brahms/WWW/brahms.html

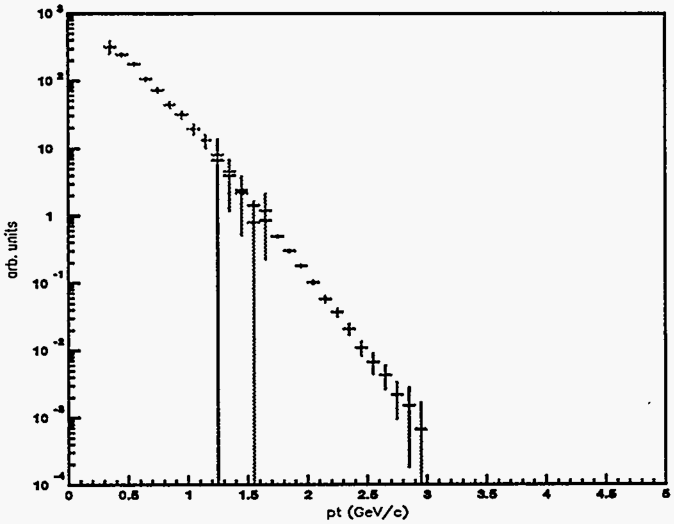

Figure 6: Predicted p_t spectrum for π at y=2.0 as measured in about 1 week of running for Au+Au central collisions.

[2] F.Videbæk, Nucl. Phys. A566 (1994) 299c

[3] B. Moskowitz, Proceedings of the Pre-Conference Workshop QM95.

[4] D. Beavis, Proceedings of the Pre-ConferenceWorkshop QM95.

[5] Z.Chen (these proceedings), B.Jacak (these proceedings) and references therein.

[6] F.Videbæk and Ole Hansen, Phys. Rev. C52 (1995) 2684

[7] B.Andersson, G.Gustafson and B.Nielsson-Almquist, Nucl.Phys.B281(1987)289

[8] H.Pi, Comp. Phys. Comm 71 (1992) 173

[9] K.Werner Z. Phys. C42 (1989) 85

[10] Th.Schönfeld,H.Stöcker,W.Greiner and H.Sorge, Mod.Phys.Lett A8 (1993) 2631

[11] G.Goldhaber *et al.* Phys.Rev.120(1960) 300.

[12] F.B.Yano and S.E.Koonin, Phys. Lett. 78B (1978) 556

[13] E.Shuryak. Phys. Rev. Lett. 68 (1992) 3270.

[14] K.Geiger Phys. Rev. D47 (1993) 133

[15] X.N.Wang and M.Gyulassy, Phys. Rev. D44 (1991)3501; X.N.Wang these proceedings.