RHIC Beam Use Proposal

For RHIC Run-3 (FY 2003)

BRAHMS Collaboration

Brookhaven National Laboratory – Institute of Nuclear Physics, Kracow, Poland Jagellonian University, Kracow, Poland - John Hopkins University - Niels Bohr Institute, Denmark - New York University - Texas A&M University -University of Bergen, Norway -University of Oslo, Norway - University of Bucharest, Romania - University of Kansas

Abstract

The primary goal for run-2 was to study overall properties of Au+Au collisions at $?s_{NN}$ = 200 GeV. Emphasis was placed on studying the process of stopping of the incoming baryons by measuring proton and anti-proton rapidity and p_t distributions, and on basic reaction mechanisms of particle production by measuring rapidity and transverse momentum distributions of identified pions and kaons as a function of reaction centrality. A large part of the low p_t program for central collisions was completed during the RHIC Run-2 , with Au-Au collisions at $?s_{NN}$=200 GeV and an integrated luminosity of about 24 $?b^{-1}$, with about 60% of the data recorded in the last two weeks of the run. The more extensive studies of higher p and semi-central collisions could not be completed in the available beam time. From this significant dataset BRAHMS has written two publications as well as presented preliminary data at QM02 in Nantes.

As already brought forward in last years beam proposal the first request for next year (RUN3) is for completion of the Au-Au program started in Run-2 by complementing with higher statistics measurements at larger pt values (~2-5 GeV/c) for a smaller set of selected rapidities, and to record a much larger sample of semi-central (30-60% centrality) spectrometer events. The request is for ~ 200 $?b^{-1}$ recorded. As the second priority BRAHMS request Running with d-Au at $?s_{NN}$ of 200 GeV with the d in the Blue Ring; the main emphasis is to record reference pt spectra at intermediate to high pt (2-5 GeV/c) to measure reference rapidity distributions. The request is for ~ xxx nb-1.

Though not a formal part of the request for the Run-3 it is envisioned that for the program in run-4 (FY 2004) BRAHMS will like a significant running period with a lighter system (Si-Si) at the same $?s_{NN}$ of 200 GeV as measured with the Au-Au system, and additional pp running at $?s_{NN}$ of 200 GeV to complete the baseline reference for the higher energy A+A collisions, and to perform a measurement of Ann with transversely polarized protons at high xf.

A summary of the request expressed in terms of delivered luminosity within a narrow vertex range at the 2 o'clock IR is given on the final page.

Introduction

The Brahms experiment has unique capabilities in terms of precise momentum determination and particle ID. The forward spectrometer (FS) covers a rapidity range up to about 4, and a large momentum and transverse momentum range. The excellent Particle Identification (PID) in the Mid-Rapidity Spectrometer (MRS) complements measurements by other RHIC detectors, and allows for comparisons between mid-rapidity and forward rapidity spectra. Despite the small solid angles of the spectrometers pt spectra can be measured within reasonable amount of integrated luminosity up to 3-5 GeV/c for identified particles at several rapidities giving additional handles on the important issue of high pt-suppression in heavy ion induced reactions.

Summary of RUN-2.

The 2001/02 running period at RHIC (Run-2) with Au-Au collisions at ?s_{NN}=200 GeV and an integrated luminosity of about 24 ?b^{-1}, with about 60% of the data recorded in the last two weeks of the run, enabled BRAHMS to record a significant dataset, that so far has lead to two publications, as well as to presentations at QM02.
Spectrometer data were recorded at angle settings of 90, 60, 52, 45 ,40 and 35 degrees using the Mid-Rapidity spectrometer with several field settings at both polarities. The forward spectrometer was run at 3,4, 8,12, 20 and 30 degrees magnetic field setting ranging from low to high settings. Approximately the last week was used to collect statistics for high pt settings at 90 and 12 degrees (up to 4 GeV/c).

The data were analyzed yielding final results for p-bar/p , K-/K+ ratios as function of rapidity and centrality, and dN(ch)/d? measurements vs. centrality in the –5<?<5 region using the global detectors. Preliminary results on pt spectra, and rapidity density distributions for central collisions in the range y~0-3 were presented at QM02.

Present Detector configuration

The BRAHMS detector situated in the 2 O'clock IR consists of 3 major spectrometer components.

- The Front Forward Spectrometer (FFS), consisting of 2 magnets, D1 and D2, and associated detectors, is moveable from 2.3 to 30 degrees.
- The Back Forward Spectrometer (BFS) consisting of 2 magnets D3 and D4 and associated detectors is used in combination with the FFS to measure the angular range from 2.3 to 15 degrees.
- The Mid-Rapidity Spectrometer (MRS), consisting of a single magnet D5 and associated detectors is moveable from 30 to 95 degrees, is being augmented with a threshold segmented Cherenkov detector that will allow to identify charged hadrons in the p range of 3.5 to 6 GeV/c
- The spectrometers have had added trigger detectors with capabilities that will allow for efficient data taking at the higher luminosity Au beams expected, as well as for light ion and pp running.

BRAHMS also has a set of global detectors that are used for event characterization, triggering and timing measurements

- The Centrality detector consists of an inner layer of Si-detectors and an outer layer of large scintillator tiles covering the range of about -2.2 < ? < 2.2.
- The Beam-Beam counter array provides accurate start timing information to the experiment, rough vertex determination, and multiplicity measurements at high ? ~ 3-4.
- The Zero Degree Calorimeters (ZDC), a common device to all RHIC experiments, provides luminosity information, and neutron multiplicity at 0 and 180 degrees.

Physics Program

(I would really like to shorten this section and make it more precise and updated; as is it is unchanged from last years RBUP)

A goal of BRAHMS is to establish an energy budget for Au+Au collisions and to determine how the energy loss from the incoming beam is partitioned between particle production and transverse and longitudinal momenta. Secondly the ``chemistry" of the system can be established by measuring the fraction of strange to non-strange particles and the yield of protons, and anti-protons.

The amount of nuclear stopping of the incoming baryons determines the energy deposition in the reaction volume. An estimate of the energy density in the initial stage of the collision is of prime importance for the understanding of reaction dynamics. The rapidity shift and the energy loss can be determined by the measurements of the proton and anti-proton rapidity distributions over a wide range in y.

Pion and kaon spectra measure the basic properties of particle production. An enhancement of strangeness production has long been predicted to be an important signature of the color de-confined phase of nuclear matter. The integrated charged kaon yield, measured over a wide range in y and p_t, can be regarded as a measure of the total strangeness production, and a change in K/? ratio vs. centrality is an important measure for the strangeness chemical potential.

The freeze-out properties, e.g., collective transverse and longitudinal expansion, of the hot nuclear system formed in the reactions will be established by measuring the transverse momentum spectra of pions, kaons, and protons. The yields will be measured at several rapidities and at several transverse momenta so that the expected average momentum of each species will be covered. Comparisons will be made with thermal and cascade models to shed light on collective effects. The size of the system at freeze out

can be investigated from HBT measurements and studies of small baryonic clusters (e.g. deuterons, tritons and their anti-clusters).

The initial parton scattering plays an increasing important role in the heavy ion collision as the beam energy increases. The study of particle spectra in intermediate p_t range of 1-4 GeV/c will help in the understanding of initial scattering (Cronin effect), shadowing and jet quenching. The importance of these processes depends on energy, rapidity and collision system. The initial results from 130 and 200 GeV Au-Au as published by Phenix and Star has demonstrated that indeed a suppression of the yield of higher pt charged particle and pi0's between central and peripheral collisions takes place. Thus a nuclear medium modifies the spectrum, and it is of importance to study this is greater detail to disentangle effects of cold vs hot medium, vs density of medium by exploring this at mid-rapidity, higher rapidities as well as in nucleon-A collisions. At higher rapidities (~3-4) the shape pion spectra may open a window to study the Color Glass Condensate (gluon saturation) in the initial state.

Data taking capabilities.

We estimate that data are recorded close to 90% of the time beam is stored and cogged. Our current DAQ dead times are approximately 50-60%.

Beam Request.

The following request is based on the assumption of about 24 weeks of FY 2003 running assuming two species and about 5 (setup)+7 weeks of data-taking.

Au-Au request.

The new data that we plan to obtain involves runs at selected rapidities to study identified, high p_t (i.e 1-4 GeV/c) particles. In particular, we want to establish spectral shapes with the goal of characterizing and understanding mini-jet production. These measurements require a large integrated luminosity, as well as implementation of a forward spectrometer trigger to select the rare high p_t events. Such trigger for the FS was commissioned during the run-2 pp data taking. A trigger is presently under construction for the MRS. The importance of comparing peripheral collisions to central collisions and comparing mid-rapidity to higher rapidity results is a theme developing with the current data. Such comparisons will require that good statistics be developed for the more peripheral events. The higher p_t studies can be carried out at y~2 y~3 (at angle settings of ~10-15 deg, and high magnetic field settings).

- Extend rapidity distributions to 3.5
- Supplement existing lower pt data where needed
- Higher pt data at y~0, y~1 utilizing the new Cherenkov
- Higher pt spectra at y~2 and y~3
- Simultaneous HBT measurements at y~1 and y~3.

To complete this set of measurements we will need to record ~200 microb(-1), within the +/-20cm of the nominal collision point. The bulk of the beamtime (75%) will be used for the higher pt measurements.

d-Au at 200 GeV.

pt spectra comparison to Au-Au exploring flow/particle suppression at intermediate pt range; cronin effect(s) disappearance of flow in d-Au; explore the development of particle production and spectral shapes from pp, over d-Au to Au-Au.

Exploration of gluon saturation measuring spectra at higher rapidities; sufficiently away from projectile, but at such large values that the Qs scale is sufficiently low that this effect may be observed (Dumitri, Kharzeeev..)

Centrality selection is important to select events where the initial or final state partons transverse a significant amount of the cold nuclear medium. This will be done using ZDC's and multiplicity arrys. selection)

Since this is a new beam species it requires additional commissioning of trigger and timing counters that is estimated to take 1-2 weeks.
The integrated luminosity needed is ~ 10 nb-1 for high pt measurements at y~2-3 and another 10 nb-1 for the rapidity density and pt-spectra survey.

Anticipated program for Run-4.

Though not a formal part of the Beam Use Proposal for Run-3 we though it would be useful to preview the additional measurements that are essential for the Brahms heavy ion baseline program and that would naturally fit into the following Run-4 period.

One priority is to obtain measurements with a lighter projectile, preferably Si. Much lower energy data exists at AGS and CERN for this collision system (S at SPS). In addition, when considering the number of participants in the reaction such a light system probes a region that cannot be readily measured by peripheral Au-Au collisions. These measurements should be done at the same energy as the Au-Au data, i.e. $?s_{NN}$=200 GeV. For the lighter system the focus will be on central collisions where our current trigger and global detectors should be fully efficient.

A second goals is for a run-4 proton running period are.

1. Complete the measurement of a reference data set at $?s_{NN}$ of 200 GeV that was initiated during the RUN-2, by extended spectra to higher pt and to supplement the reference soft spectral distributions with additional angle and field settings for a more extensive survey.

2. Engage in the spin program (high x_F, transverse polarization) for transversity measurements that can shed light on QCD higher order twist effects . The measurements consist of measuring the transverse asymmetry in pion production at large longitudinal momenta. This will be carried out in consultation with the RHIC spin group. A longer period for high statistics is highly needed in later pp running periods to obtain the asymmetry over a larger x_F and pt range. A large (transverse) polarization is needed to make these measurements in an efficient way.

Since the bulk of the pp running would be for the polarized program, that is not the main thrust of the BRAHMS program our strong preference is to have the pp running during the run-4, considering that impact statement from T.Roser of having more than two beam species combination in one running period.

Comment to Au-Au at lower energies

(will probably not keep this – but possible use in presentation)

The data gathered so far show only logarithmic energy dependence in particle production, so the priorities from BRAHMS perspective are measurements at the highest energy. Also only modest differences have emerged from published and reported results at mid-rapidity. Since a complete survey of one system is estimated to take ~6 weeks, and we find the explorations at the highest energies to be of paramount interest for our program;

this is also the energy where the effects of jets and jet quenching is expected to be the largest. Therefore our interest in a short lower energy run is minimal.

Summary of Run Plan

System	Weeks	Luminosity (recorded)	Physics	Note
Au-Au at 200	**7**	**~200 ? b^{-1}**	**High pt, heavy clusters** **HBT at y~0, .7**	
d-Au at 200	**6**	**~15 n b^{-1}**	**Survey of soft Physics;** **Y~2,3 high pt spectra.**	
RUN-4 Anticipated Request				
pp at 200	**4+2**		**Comparison measurements;** **Transversity measurements**	**Spectrometer triggers will be implemented.**
Si-Si at 200	**4**		**Survey of soft** **physics**	**Rate limited** **By DAQ**

(Will probably only keep the run-3 request in tabular form.
The d-Au estimates still have to be done).