Beam Use Proposal For RHIC RUN-3 (FY 2003)

The BRAHMS Collaboration

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1. Beam Request Overview

BRAHMS has in RHIC run-2 studied overall properties of Au+Au collisions at ?s_{NN} = 200 GeV and conducted a first survey of hadronic physics as a function of rapidity (different selected angular settings) and transverse momentum (different selected magnetic fields) . 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 particle production by measuring rapidity and transverse momentum distributions of identified pions and kaons as a function of reaction centrality. A fair part of the low p_t program (p_t < 1.5 GeV/c) for central collisions was successfully completed during RHIC Run-2 using Au-Au collisions at ?s_{NN}=200 GeV. The integrated luminosity delivered to the experiment was about 12 ?b^{-1}. About 60% of the data, however, were accumulated in the last two weeks of the run. From this significant, though not complete dataset, BRAHMS already has written two publications as well as presented several preliminary analyses as a function of rapidity at QM02 in Nantes.

The more focused and extensive studies of higher p_t, correlations and semi-central collisions could, however, not be completed with the available beam time, consequently

A. The primary and most important request for the coming running period (Run-3) aims at completing the basic Au+Au survey program at? s_{NN} *of 200 Ge with:*

1) *High statistics measurements in the hard regime (p_t ~2-5 GeV/c) at selected forward rapidities, correlation studies (HBT and coalescence) at mid- and forward rapidities and, accumulation of a much larger sample of semi-central (30-60% centrality) events.*
2) *Additional angles and fields settings (mostly "low pt" –physics, pt < 1.5 GeV/c)*

This request is for ~ 200 ? b^{-1} (recorded).

To fully understand the Heavy Ion reaction data one needs reference data i.e. spectra and rapidity distributions from pA collisions, which can provide information about the initial state partonic interaction in cold nuclear matter. (Since this is difficult at present d-Au running should be used as a reference). Thus BRAHMS has a request for both dA and pp running.

The short pp run of January 2002 did not provide a complete reference set. In particular, the higher p_t region was not adequately covered.

B. 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 p_t spectra at intermediate to high p_t (2-5 GeV/c) , and to measure reference rapidity distributions. The request is for ~ 15 nb^{-1}.

C. Additional p+p running at ? s_{NN} of 200 GeV to complete the baseline reference for the higher energy A+A collisions. This requires about ~1 pb^{-1} and could potentially be completed in about 3-4 weeks. It does not require any polarization. This would include low p_t measurements at several rapidities as well as longer investigations of the intermediate p_t region of 2-4 GeV/c at y~2 - 3.

The above-mentioned priorities are subject to expectations for Run-4. For that program (FY 2004) BRAHMS would at present prefer, in addition to Au+Au running at the top energy, a significant running period with a lighter system (Si-Si) at ? s_{NN} of 200 GeV, and additional running with either p+p or d+Au at ? s_{NN} of 200 GeV should this not be completed in Run-3, in order to complete the baseline reference for the Au+Au collision program. One could hope that by Run-4, the beam change time overhead will be significantly reduced, making a program with multiple species feasible.

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

2. BRAHMS Experiment and Physics Goals

The Brahms experiment has unique capabilities in terms of precise momentum determination and particle ID. The forward spectrometer (FS) is unique in the family of RHIC experiments in that it can identify hadrons up to rapidity y = 4, and covers 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 with a reasonable amount of integrated luminosity up to 3-5 GeV/c for identified particles at several rapidities. This allows, for example, studies of high p_t-suppression in heavy ion reactions over a wide rapidity range.

Summary of RUN-2.

The 2001/02 running period at RHIC (Run-2) with Au-Au collisions at ? s_{NN}=200 GeV enabled BRAHMS to record a significant dataset with the full detector commissioned and operational.

We recorded an integrated luminosity of about 24 ?b^{-1}, of which 60% were collected in the last two weeks of the run. The Mid-Rapidity spectrometer took data at 90, 60, 52, 45 , 40, 35 degrees with several field settings and both polarities. The forward spectrometer was operated at 3,4, 8,12, 20 and 30 degrees with several magnetic field settings. The last weeks of the Au+Au runs were used to collect statistics for high pt measurements (up to 4 GeV/c). The spectrometers were positioned at 90 and 12 degrees for those runs. We estimate that data are recorded close to 90% of the time when beam is stored and cogged. Our current DAQ dead times are approximately 30%.

From this dataset BRAHMS has already produced two articles (the first on charged particle multiplicity is now published in PRL [1], the second on p-bar/p , K-/K+ and p^-/p^+ ratios as function of rapidity, p_T and centrality is submitted to PRL). Recently Run-2 results were presented at QM02 in Nantes (4 talks and 5 posters) focusing on hadronic physics as a function of rapidity: net-baryons vs. y, hadron yields and strangeness vs. y and high p_t hadron yield suppression at y=0 and 2.

Present Detector configuration

The BRAHMS detector consists of 3 major spectrometers:

- The Front Forward Spectrometer (FFS), consisting of 2 magnets, and associated detectors, is moveable from 2.3 to 30 degrees.
- The Back Forward Spectrometer (BFS) consisting of 2 magnets 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 and associated detectors is moveable from 30 to 95 degrees.

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

- 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 online vertex trigger and neutron multiplicity at 0 and 180 degrees.

Detector upgrades for RUN-3

The MRS is being augmented with a threshold segmented Cherenkov detector that will allow to identify charged hadrons in the momentum range of 3.5 to 6 GeV/c.

Trigger detectors that will allow for efficient data taking at the higher luminosity Au beams expected, as well as for light ion and pp running, have been added to the FS and the MRS.

Physics Program

In Run-2 BRAHMS has investigated the multiplicity density, transverse flow via $<p_t>$, baryon and strangeness chemical potentials as well as chemical and thermal freeze-out temperatures as a function of rapidity. From the proton and antiproton rapidity densities we can deduce the net energy loss of the beam and projectile. Together these measurements strongly constrain models of longitudinal development. We wish to extend these measurements to the highest rapidities allowed by the detector and beam line geometry (2.3 degrees).

A tool for understanding the initial partonic state is to study identified high p_T hadrons over a range of rapidities. Recently PHENIX and STAR have reported suppression of high p_T spectra compared to expectations from pp collisions [2]. This effect is also observed by BRAHMS at y=0 and to a lesser degree at y=2. This effect may be due to energy loss of a quark as it passes through a dense system of quarks and gluons.

The study of particle spectra in the p_t range of 1-4 GeV/c will help in the understanding of initial scattering (Cronin effect), gluon shadowing effects and jet quenching. The relative importance of these processes depends on energy, rapidity and collision system. Initial results from 130 and 200 GeV Au-Au demonstrate that the nuclear medium modifies the spectrum. Systematic studies may disentangle effects related to a 'cold' versus a 'hot' medium, and to the density of the medium. At higher rapidities (~3-4) the shape of the pion spectra may open a window to study the Color Glass Condensate (gluon saturation) in the initial state [3] in p(d)A reactions.

BRAHMS has the unique capability to study the evolution of the high pt components of hadronic spectra over several units of rapidity. We wish to study these phenomena at rapidities 0-3 for Au+Au and dAu collisions.

Interferometry and nucleon and anti-nucleon coalescence allow us to measure the final state of the system as it breaks up. The "HBT puzzle" at RHIC is the striking similarity of the outward and sideward correlation functions and the lack of any dependence of the radii on vS_{nn}. NA44 at SPS has combined p, k and p interferometry and coalescence measurement to measure the transverse flow of the system [4]. However at high expansion velocities one would expect hydrodynamics to break down and indeed some evidence for this effect in high pion interferometry may be seen. We will study HBT and coalescence at both high rapidity and at higher pt values to address these issues. Combining interferometry and coalescence volume information with single particle momentum spectra will allow us to measure the density of particles in phase space [5]. Integrating this density can reveal the entropy of the system. Finally comparing the formation of nuclear clusters and anti-clusters will help us understand the time interval between hadronization and thermal freeze-out.

3. Beam Request

Additional details on the beam request are provided below.

Au-Au request.

The new data that we plan to collect in RUN-3 require running at selected rapidities to study identified, high p_t (i.e. 1-4 GeV/c) particles. A goal is to complement data already collected and focus on the more difficult settings that were not deeply explored in RUN-2. We wish to focus on fewer but high statistics runs.

In particular, we want to explore 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 a trigger for the FS was commissioned during the run-2 pp data taking. A trigger is presently under construction for the MRS. It is becoming increasingly clear that it is important for the understanding of the physics to compare peripheral collisions to central collisions and results at mid-rapidity to those at high rapidity. Such comparisons will require that statistics be obtained for the more peripheral events over an extended rapidity distributions to y ~ 3.5-4.

In summary, the Au+Au program for RUN-3 is:

- Collect higher pt data at y~0, y~1 utilizing the new Cherenkov.
- Collect high statistics for high p_t spectra at y~2 and y~3.
- Perform simultaneous HBT and coalescence measurements at y~1 and y~3.
- Supplement existing lower pt data where needed.

To complete this set of measurements we will need to record ~200 ?b^{-1}, with collisions vertices within +/-20cm of the nominal collision point. The bulk of the beam time (75%) will be used for the higher p_t measurements.

d-Au at 200 GeV.

To understand properties of hot nuclear matter it is natural to compare it to a similar system of cold nuclear matter. Both E910 and NA49 have shown the fruitfulness of this approach [6]. By looking at p_T spectra on the "deuteron" side of such collisions we will be able disentangle the effects of Cronin enhancement and flow versus high p_T suppression in AuAu collisions. Centrality measurements are important to select events where the initial partons traverse a significant amount of the cold nuclear medium. This will be done using the ZDCs and the multiplicity arrays. Finally d-Au collisions may be the ideal way to search for the onset of gluon saturation since the system is much simpler than that produced by AuAu collisions [3]. In this picture the soft gluons from the individual nucleons in a large nucleus may overlap to form a “colored glass.” This glass may be shattered by a sufficiently high momentum quark. Measuring the p_t of the leading particle from this quark as a function of rapidity may allow us to probe the onset of saturation. Measuring p_t spectra at higher rapidities may trace the leading particle from this quark and may allow us to probe the onset of saturation.

Since d-A is a new and asymmetric beam combination the experiment requires commissioning of trigger and timing counters.
The integrated luminosity needed is ~ 10 nb^{-1} for high pt measurements at y~2-3 and another 5 nb^{-1} for the rapidity density and p_t-spectra survey.

p-p at 200 GeV

We wish to complete the reference data set at ?s_{NN} of 200 GeV that was taken during RUN-2. One emphasis is to record reference spectra at intermediate- to high p_t (2-5 GeV/c) in order to compare to pA and AA reactions. The other objective is to complete measurements of reference rapidity distributions and particle yields for ion-ion collisions; The request is for ~ 2 pb^{-1}.

4. Anticipated program for Run-4

The above-mentioned priorities are subject to expectations for Run-4 so we attach comments on the envisioned program for RUN-4 that are essential for the BRAHMS heavy ion baseline program. This is already inherent in the request above where both pp and d-Au are requested but may not be available during run-3.

We wish to complement Au+Au studies with measurements using lighter ions, preferably Si. Much lower energy data exists at AGS and CERN for this mass (S+S at SPS). The smaller number of participants probes a region that cannot be readily measured by peripheral Au-Au collisions. Measurements should be done at the same energy as the Au-Au data, i.e. ?s_{NN}=200 GeV. Focus will be on central Si+Si collisions where our current trigger and global detectors should be fully efficient.

We also envision a request for additional Au-Au running at the top energy primarily to continue to develop specific physics requiring high statistics

5. Summary of Run Request

The BRAHMS priorities for RUN-3 are summarized below. The collaboration note the large time overhead associated with development of more than two beam combinations. If indeed the switch over time between beam species will be as conservatively estimated by CA-D the AuAu and dAu beam combinations are the primary requests by BRAHMS.

System	Luminosity (recorded)	Estimated weeks at IR2 (?*=?)	Physics

		at IP2 (?*=2)	
Au-Au at 200	**~200 ? b^{-1}**	**8**	**High pt, heavy clusters** **HBT**
d-Au at 200 GeV	**~15 nb^{-1}**	**6**	**Survey of soft Physics;** **Y~2,3 high pt spectra.**
pp at 200 GeV	**~2 pb^{-1}**	**3**	**Comparison measurements;**

References.

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