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

The BRAHMS Collaboration

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Request Overview

The primary physics goal for BRAHMS at RHIC run-2 has been to study overall properties of Au+Au collisions at ?s_{NN} = 200 GeV and conduct 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 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 24 ?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 has written two publications as well as presented preliminary data at QM02 in Nantes.

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

A. The primary and most important request for the coming running period (Run-3) aims at completing the basic Au+Au survey program at the top energy, by

1) Supplementing collected data with measurements at additional angles and fields settings (mostly low pt -physics)
2) Develop particularly interesting physics of Au+Au requiring extended running times. In particular 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.

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 and particle yields from pA can provides information about the initial state partonic interaction in cold nuclear matter, as well as from elementary NN reactions. Thus BRAHMS has a desire/request for both pp and d-Au running that in lieu on nucleon beams at present provides the best reference data available. The short pp run of January 2002 did not provide a complete reference set in particular for the higher p_t region. The conservative estimates for time required to change beam species put forward by CA-D makes this somewhat difficult to accomplish in the Run-3; never the less our next priority requests are.

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 pt spectra at intermediate to high pt (2-5 GeV/c) , and to measure reference rapidity distributions. The request is for ~ 15 nb^{-1} with 1-2 additional weeks to setup appropriate triggers.

C. Additional pp running at ?s_{NN} of 200 GeV to complete the baseline reference for the higher energy A+A collisions. This primary goal needs about ~1 pb^{-1} and could potentially be completed in about 2-4 weeks and does not require any polarization. This would include low pt measurements at several rapidities as well as longer investigations into the intermediate p_t region of 2-4 GeV/c at y~2 and y~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 , in order to complete the baseline reference for the Au+Au collision program. One could hope that by run-4, the beam change over time will be significantly reduced, thus making a program with multiple species feasible.

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.

BRAHMS Experiment and Physics Goals

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 enabled BRAHMS to record a significant dataset, that so far has lead to two publications, and make a significant impact at QM02. We recorded an integrated luminosity of about 24 ?b^{-1}, of which 60% came in the last two weeks of the run. The Mid-Rapidity spectrometer took data at 90, 60, 52, 45 , 35 degrees with several field settings and both polarities. The forward spectrometer was run at 3,4, 8,12, 20 and 30 degrees with several magnetic field settings. The last week of the runs was used to collect statistics for high pt settings at 90 and 12 degrees (up to 4 GeV/c).

From this dataset BRAHMS has already produced two articles (the first on charged particle multiplicity is published in PRL, 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 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. It 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

We have added 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.

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, an online vertex trigger and neutron multiplicity at 0 and 180 degrees.

We estimate that data are recorded close to 90% of the time beam is stored and cogged. Our current DAQ dead times are approximately 30%.

Physics Program

From Run-2 data BRAHMS can investigate the multiplicity density, transverse flow, 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. For example it is clear from the pion and kaon dN/dy measurements that there is no significant "rapidity plateau" at RHIC. One challenge now is to look deeper into the initial state and its subsequent development.

A tool for understanding the initial partonic state is 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 [1]. This may be due of energy loss of a quark as it passes through a dense system of quarks and gluons.

Interferometry and 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 has combined p, k and p interferrometry and coalescence measurement to measure the transverse flow of the system [2]. However at high velocities one would expect hydrodynamics to break down and indeed some evidence is seen for this effect in high pion interferrometry. We will study HBT at both high rapidity and at higher pt values.

Combining interferometry (or coalescence) information on the volume with single particle momentum spectra will allow us to measure the density of particles in phase space [3]. Integrating this can reveal the entropy of the system. Finally comparing the formation of nuclear clusters and anticlusters will help us understand the interval between hadronization and thermal freeze-out.

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 $?^0$s between central and peripheral collisions takes place. Thus the nuclear medium modifies the spectrum, and it is of importance to study this is greater detail to disentangle effects of cold versus hot medium, and 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 of the pion spectra may open a window to study the Color Glass Condensate (gluon saturation) in the initial state [4] in p(d)A reactions.

Beam Request

The beam request for Run-3 is discussed in additional details below.

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 beam time (75%) will be used for the higher pt 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 [5]. 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 our 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 [4]. 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.

Since d-A is a new beam combination the experiment requires additional commissioning of trigger and timing counters, that we estimated will take ~1 weeks.
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 pt-spectra survey.

p-p at 200 GeV

Complete the reference data set at ?s_{NN} of 200 GeV that was taken during RUN-2.
The main emphasis is to record reference spectra at intermediate- to high pt (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; though started during the run-2 additional time is required due to the fairly short run.
The request is for ~ 2 pb^{-1}.

Anticipated program for Run-4

The above-mentioned priorities are subject to expectations for Run-4 so 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 this following period. This is already inherent in the request above where both pp and d-Au is intrinsically important but may not be able to be performed during run-3.

One goal 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.

We do also envision a request for additional Au-Au running at the top energy; Not only as a way to augment measurements done in run-3, but also to be able to perform measurements of photons and pi’0s at intermediate pt and larger rapidities using ALICE PHOS prototypes. Though the plans and agreement is not fully worked out such program would have to be executed during run-3 due to constraints on ALICE construction and collaboration commitments.

Summary of Run Request

In short the BRAHMS collaboration has outlined a program for RUN-3 and RUN-4 of which the following beam species has the highest priorities. The collaboration understand the lack of efficiency by running more than two beam combination, so if beam commissioning indeed does take 2+3 weeks it is our request to run Au-Au and either dA or pp during run-3.

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 GeV	**6**	**~20 nb**$^{-1}$	**Survey of soft Physics;** **Y~2,3 high pt spectra.**	
pp at 200 GeV	**3**	**~40 nb**$^{-1}$	**Comparison measurements;**	

References.

[1] Phenix, PRL, STAR prl. T.Peiltzman QM02 high pt summary.
[2] NA44
[3] phase space density
[4] Dumirtu, Khrazeev
[5] E910, Na49- pA