FACILITY SCOPE

The Relativistic Heavy Ion Collider at Brookhaven National Laboratory has been in operation since 2000. The research objectives of RHIC involve the study of collisions of heavy ion beams (e.g., beams of the nuclei of gold atoms) at energies up to 100 GeV/n, and polarized protons at energies up to 100 GeV. Since 2000, RHIC has delivered luminosity to 5 experiments, STAR, PHENIX, PHOBOS, BRAHMS, and PP2PP. In heavy ion operation a greater operational flexibility than at other hadron colliders is required. Species and collision energy are changed frequently. The heavy ion program has produced a number of striking results, including the discovery of a fascinating new form of matter. Unexpectedly, this extremely hot and dense matter, often referred to as the strongly interacting quark gluon plasma or sQGP, behaves more like a perfect liquid than an ideal gas. In polarized proton operation, both luminosity and polarization are important. The figure of merit for the experiments is either LP^2 or LP^4 where L is the luminosity and P the beam polarization. RHIC can deliver vertically polarized beam to all experiments, and longitudinally polarized beam to STAR and PHENIX. Currently the main goal of the polarized proton program is to reveal the source of the proton spin.

The Configuration Manual covers technical areas, which are related to the beam transfer lines and the collider. The following sections address performance objectives of the collider, the overview on the collider rings, and the collider operational scenario.

Performance Objectives

The performance objectives for a heavy-ion collider were originally formulated in 1983 by a *Task Force for Relativistic Heavy Ion Physics*. The project scope for RHIC was finalized with input from scientific and technical review committees and has been endorsed by the DOE/NSF Nuclear Science Advisory Committee in its December 1989 Long Range Plan for Nuclear Science. The agreed upon design parameters for heavy ions were exceeded after a few years of operation. New goals were formulated and are called "Enhanced Design" parameters. The major RHIC performance parameters (Design, Achieved, and Enhanced Design) are summarized in Table 1.

Energy. The top kinetic energy will be 100×100 GeV/n for gold ions. At a $B\rho = 839.5$ T·m of the magnet system set for 100 GeV/n Au beams, the operational momentum increases with the charge-to-mass ratio, resulting in kinetic energies of 125 GeV/n for lighter ions and 250 GeV for protons. The collider will be able to operate over a wide range from injection to top energies. In order to limit magnet aperture, and thus cost, full luminosity and lifetime requirements were specified at energies above 30 × 30 GeV/n.

Luminosity. The collider was designed for an average Au-Au luminosity of about 2×10^{26} $cm^{-2}s^{-1}$ at top energy, while maintaining the potential for future upgrades by an order of magnitude. Operation with the heaviest ions imposes the most demanding requirements on the collider design, and gold-on-gold is taken as the prototypical example. The luminosity is energy dependent and decreases in first approximation quadratically to the operating energy (the beam size increases linearly with $1/\gamma$, and the β^* is also increased with $1/\gamma$). The luminosity for lighter ions is higher, since approximately the same charge per bunch can be stored. The Enhanced Design goal for Au-Au luminosity is 4 times larger than the design goal, 8×10^{26} $cm^{-2}s^{-1}$. The Enhanced Design goal for the average p-p luminosity at 250 GeV is 150×10^{30} $cm^{-2}s^{-1}$.

Polarization. RHIC is the only existing collider of spin-polarized protons. The Enhanced Design goal for polarization is 70% on average during stores of energies up to 250 GeV.

Range of ion masses. The expectations for interesting physics phenomena require a broad range of nuclei from the heaviest to the lightest, including protons. Asymmetric operation with heavy ions colliding on deuterons or protons is crucial for the experimental program. The collider will allow collisions of beams of equal ion species from Au-Au all the way down to p-p. It will also allow operation of unequal species such as deuteron or protons on gold ions. Uranium is a viable species and can be considered as a future upgrade with the Electron Beam Ion Source EBIS.

Intersection Regions. The existing tunnel and the magnet lattice configuration provides for six experimental areas where the circulating beams cross. Four of the experimental areas presently have completed experimental halls with a support building for utilities (IR2, IR6, IR8, IR10). IR4 houses the rf systems, IR12 the polarized hydrogen jet.

A warm space of about ±9 m at each crossing point is provided for the experimental detectors, with a free space of ±7.12 m space available for the experimental beam pipes. The crossing point configuration foresees head-on collisions, but allows crossing angles up to 1.7 mrad.

Table 1. RHIC Design, Achieved, and Enhanced Performance Objectives.

Mode	No of bunches	Ions/bunch $[10^9]$	β* [m]	Emittance [μm]	$\mathcal{L}_{peak}$ $[cm^{-2}s^{-1}]$	$\mathcal{L}_{store\ ave}$ $[cm^{-2}s^{-1}]$	L_{week}
				Design values (1999)			
$Au^{79+} + Au^{79+}$	56	1.0	2	15-40	9×10^{26}	2×10^{26}	50 μb^{-1}
$p^+ + p^+$	56	100	2	20	5×10^{30}	4×10^{30}	1.2 pb^{-1}
				Achieved values (2006)			
$Au^{79+} + Au^{79+}$	45	1.1	1	15-40	15×10^{26}	4×10^{26}	160 μb^{-1}
$p^+\uparrow + p^+\uparrow$ *	111	135	1	18-25	35×10^{30}	20×10^{30}	7.0 pb^{-1}
$d^+ + Au^{79+}$	55	110d / 0.7Au	2	15	7×10^{28}	2×10^{28}	4.5 nb^{-1}
$Cu^{29+} + Cu^{29+}$	37	4.5	0.9	15-30	2×10^{28}	0.8×10^{28}	2.4 nb^{-1}
				Enhanced design values (~2008)			
$Au^{79+} + Au^{79+}$	112	1.1	1	15-40	36×10^{26}	8×10^{26}	330 μb^{-1}
$p^+\uparrow + p^+\uparrow$ **	112	200	1	20	225×10^{30}	150×10^{30}	55 pb^{-1}

* Blue and Yellow ring polarization of 65% in RHIC stores at 100GeV.
** Blue and Yellow ring polarization of 70% in RHIC stores at 250GeV.

The beta function at each crossing point is continuously adjustable from β* = 10 m down to 1 m (and possibly to 0.5 m) at top energy by changing the currents in the insertion quadrupoles. In operation at lower energies, β* is adjusted such as to maintain the same beam size in the triplet magnets as at top energy.