RHIC Run 4 Running Projections (FY2004)

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This note discusses possible operating modes for the RHIC FY2004 running period including constraints from cryogenic cool-down, machine set-up and beam commissioning.

Cryogenic operation – After the summer shutdown the two RHIC rings will be at room temperature. They will be first brought to liquid nitrogen temperature, in about 10 days. Then, two weeks will be required to cool down to 4 Kelvin. At the end of the run, one week of refrigerator operation is required for the warm-up to 80 Kelvin.

Running modes – A number of running modes are considered in RHIC, such as Au-Au collisions, polarized proton collision, and Si-Si collisions. For each mode we should plan for 2 weeks of machine set-up with the goal of establishing collisions, and a 3-week machine development period ("ramp-up") after which stable operation can be provided with integrated luminosities that are a fraction of the maximum goals shown below. During the ramp-up period detector set-up can occur, however with priority for machine development.

Higher weekly luminosities can be achieved with a continuous development effort in the following weeks. At this year's RHIC retreat is was proposed to use the day shifts from Monday to Friday for this effort, with enough personnel available in the following shift to ensure production during the evening and night shift. The luminosity development efforts should stop when insurmountable limits, posed by the current machine configuration, are reached. After a running mode has been established, a change in the collision energy can be achieved in about 2 weeks (1 week set-up and 1 week ramp-up).

For example, the expected 27 weeks of RHIC refrigerator operation during FY2004 could be scheduled in the following way for two RHIC operating modes:

Cool-down from 80K to 4K	2 weeks
Set-up mode 1	2 weeks
Ramp-up mode 1	3 weeks
Data taking mode with further ramp-up 1	7 weeks
Set-up mode 2	2 weeks
Ramp-up mode 2	3 weeks
Data taking mode with further ramp-up 2	7 weeks
Warm-up	1 week

Since the highest weekly luminosities are reached at the end of each mode, the integrated luminosities are maximized with long runs in each mode, and as few mode changes as possible.

Past performance – Table 1 shows the Au-Au luminosities achieved at the end of the Run 2 (FY2001/02), and the p-p luminosities achieved in Run 3 (FY2003). The quoted average store luminosity was for a store with no hardware problems and with a luminosity that agreed well with predicted values from intensity and beam emittance (store # 1812 for Au-Au, store # 3810 for p-p). The integrated weekly luminosity is the average over the last few weeks during which the luminosity was fairly constant. The ratio of average weekly luminosity over store luminosity was 27% and 17% for Au-Au and p-p, respectively. Note that this includes all interruptions such as maintenance, studies, etc.

Mode	# bunches	Ions/bunch [$\times 10^9$]	β* [m]	Emittance [μm]	L_{peak} [$cm^{-2}s^{-1}$]	L_{ave}(store) [$cm^{-2}s^{-1}$]	L_{ave} (week) [$week^{-1}$]
Au-Au	55	0.6	1	15-40	3.7×10^{26}	1.5×10^{26}	24 $(\mu b)^{-1}$
(p↑-p↑)	55	70	1	20	6.0×10^{30}	3.0×10^{30}	0.3 $(pb)^{-1}$

Table 1: Achieved beam parameters and luminosities for Au-Au (Run 2) and p-p (Run 3).

Luminosity projections – Table 2 lists the expected maximum peak and average luminosities for the possible modes in FY2004 that could be achieved after a sufficiently long running period, typically many weeks, unless thus far unknown machine limitations are encountered. With experience from past runs we expect luminosities at the end of the 3-week ramp-up period to be lower by about an order of magnitude. For all modes it was assumed that the beam energy is 100 GeV/nucleon. The average store luminosity is for a "good" store as defined above. This is a number predictable from the beam parameters. The weekly integrated luminosity was then obtained by using a ratio of 40% between average weekly and average store luminosity, based on our experience from d-Au running. The expected diamond rms length is 20 cm due to the availability of the full voltage from the 200 MHz storage cavities.
Note that the quoted luminosities are for β* = 1 m. This is only available at PHENIX and STAR. PHOBOS and BRAHMS are limited to β* ≥ 3m due to the lack of nonlinear IR correctors. β* at PHOBOS is further limited by the beam abort system in IR10, and may need to be larger than 3m. For pp running these luminosities can only be provided at two IRs simultaneously due to limitation from beam-beam effects. Due to the required abort gaps in both beams, collisions of 56 bunches can only be provided for two opposing IPs. The other IPs will have a 10% reduction in the number of collisions.

Mode	# bunches	Ions/bunch [$\times 10^9$]	β* [m]	Emittance [πμm]	L_{peak} [$cm^{-2}s^{-1}$]	L_{ave}(store) [$cm^{-2}s^{-1}$]	L_{ave} (week) [$week^{-1}$]
Au-Au	56	1	1	15-40	14×10^{26}	3×10^{26}	70 $(\mu b)^{-1}$
(p↑-p↑)	56	100	1	20	8×10^{30}	5×10^{30}	1.8 $(pb)^{-1}$
Si-Si	56	7	1	20	5×10^{28}	2×10^{28}	5 $(nb)^{-1}$

Table 2: Maximum luminosities that can be reached after a sufficiently long running period.

Time dependence of integrated luminosity – Since we expect many weeks of continuous ramp-up to reach the maximum weekly luminosities, the total integrated luminosities will be strongly time dependent. This is illustrated in Figure 1, which shows as a function of time the integrated Au-Au luminosity achieved in Run 1 as well as Au-Au projections for Run 4. For the projected minimum it is assumed that the demonstrated weekly luminosity, given in Table 1, is reached after 14 weeks of linear ramp-up. For the projected maximum it is assumed that the weekly Au-Au luminosity in Table 2 is reached after 14 weeks of linear ramp-up.

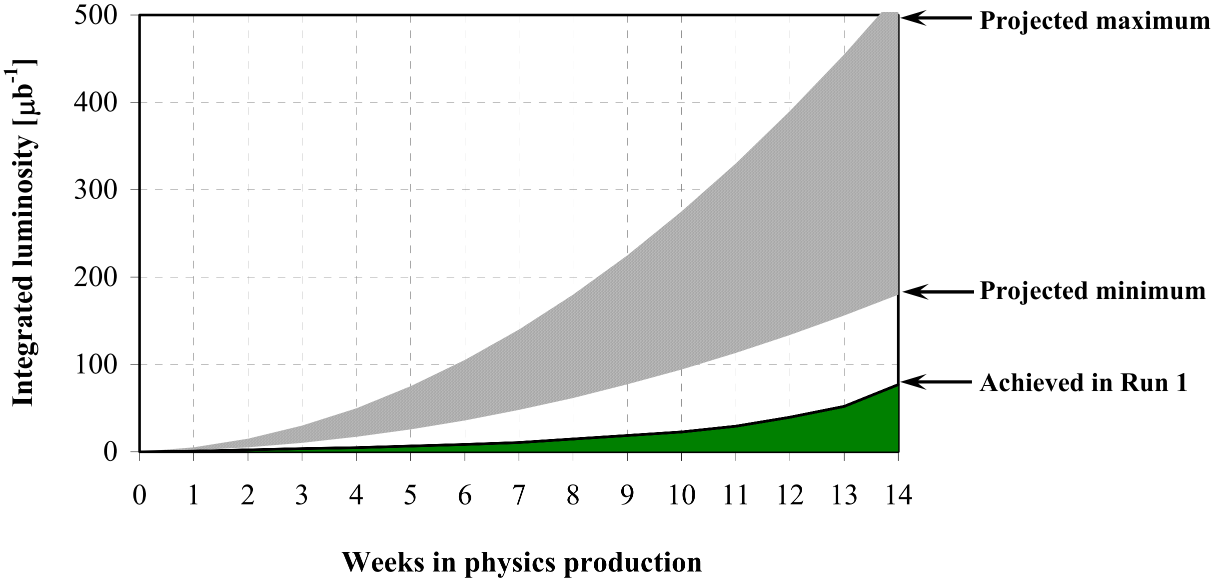

Figure 1: Integrated Au-Au luminosity achieved in Run 1, and projected minimum and maximum integrated luminosities for Au-Au collisions assuming linear weekly luminosity ramp-up in 14 weeks.

Impact of mode switching – Table 3 shows the impact of mode switching on the integrated luminosity. Compared are the total integrated luminosities per mode for a run with 1 mode (19 weeks of data taking) and 2 modes (7 weeks/mode of data taking). In both cases it is assumed that the weekly luminosity can be increased linearly in time, and that the minimum or maximum weekly luminosities are reached after 14 weeks of data taking.

Mode	Integrated luminosity per mode			
	1 Mode (19 weeks)		2 Modes (7 weeks/mode)	
	Minimum	Maximum	Minimum	Maximum
Au-Au	290 $(\mu b)^{-1}$	840 $(\mu b)^{-1}$	42 $(\mu b)^{-1}$	122 $(\mu b)^{-1}$
(p↑-p↑)	5.0 $(pb)^{-1}$	23.0 $(pb)^{-1}$	1.6 $(pb)^{-1}$	4.2 $(pb)^{-1}$
Si-Si	?	60 $(nb)^{-1}$	?	9 $(nb)^{-1}$

Table 3: Projected total integrated luminosities per mode for 1 and 2 modes, assuming linear weekly luminosity ramp-up in 14 weeks.

Following are specific comments on the running modes:

Gold on gold – The installation of NEG coated beam pipes is expected to raise the threshold amount of beam that can be accelerated and stored. NEG coated beam pipes near Phobos should also reduce the background at this experiment. A reduction of the experimental background is also expected from a major upgrade in the collimation system, as well as the installation of shielding. Efforts are under way to eliminate the machine maintenance time due to ice formation at power leads, and to improve the reliability of corrector power supplies. A number of software projects will increase the operational efficiency. An extra rf bunch merge in the Booster should lead to a more reliable delivery of high-intensity Au bunches into RHIC.

Polarized protons on polarized protons – We are proposing that a possible RHIC p-p run is scheduled later during the RHIC run so that a 4 week AGS polarized proton commissioning run can be completed before a RHIC p-p run would start. A p-p run could be used to test new equipment and demonstrate acceleration to 250 GeV, which would be very important to prepare for future polarized proton running. A normal conducting helical partial snake, to be installed in the AGS, should increase the polarization at AGS extraction from 40% to 50%. In RHIC, a polarized gas jet target can be commissioned. For this an access period of a few days for installation is needed before a p-p run.

Silicon on silicon – The listing for Si-Si serves as an example of an intermediate heavy ion. Si is easily produced by the injector and with an equal number of protons and neutrons acceleration in RHIC is the same as for deuterons.