

Bunch Patterns in RHIC

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December 15, 2003

When deciding on bunch intensity and bunch number the following rules apply, to maximize the luminosity:

1. Maximize the bunch intensity first (so far limited by the injector)
[the luminosity is proportional to the square of the bunch intensity]
2. Fill in as many bunches as possible second
[the luminosity is proportional to the number of bunches]

In the past we were only able to use bunch patterns with constant bunch spacing. Such patterns are shown in Figure 1 and Figure 2. Thus, in Run-2 we could run in operation with either 55 or 110 bunch, but no bunch number in-between. With the bunch intensity available in Run-2, operation with 110 bunches lead to unacceptable background. But we might have been able to accelerate and store more than 55 bunches.

In Run-4 we can fill any of the 120 buckets available with 3 bucket spacing. Excluded are only the abort gap and a few spacing, which are not likely to be a restriction for operation. Thus we may be able to operate with 68 instead of 56 bunches, which would yield 20% more luminosity. Assuming that electron clouds are the limiting effect, one can formulate rules to distribute N bunches in the ring:

1. There must be a 3-fold symmetry to serve all experiments with approximately the same number of collisions per turn. Due to abort gaps some experiments will see about 10% less collisions than others.
2. The bunches should be distributed as evenly as possible around the circumference.

A more detailed reasoning can be found in W. Fischer and U. Iriso-Ariz, "[Bunch Patterns and Pressure Rise in RHIC](#)", BNL C-A/AP/118 (2003). In this report, a notation for various bunch patterns is suggested:

Triples of integer numbers (k_s, k_b, k_g) are used to describe the bunch pattern. k_s describes the bunch spacing in buckets, k_b the number of bunches filled with that spacing, and k_g the number of "phantom" bunches added, i.e. bunches that are not filled in and therefore create a gap. Changing patterns can then be described by adding a new triplet. For example, the configuration $(2,2,1)(3,4,0)$ would correspond to the pattern

1-0-1-0-0-0-1-0-0-1-0-0-1-0-0-1-0-0-1-0-0

where 1 denotes a filled, and 0 an empty bucket. If not noted otherwise, it is assumed that the pattern repeats until the abort gap is reached.

In Figure 3 and Figure 4 bunch patterns are shown for 68 bunches (**yielding 20% more luminosity than 56 bunches**), and 79 bunches (**yielding 40% more luminosity**), both constructed with the rules above.

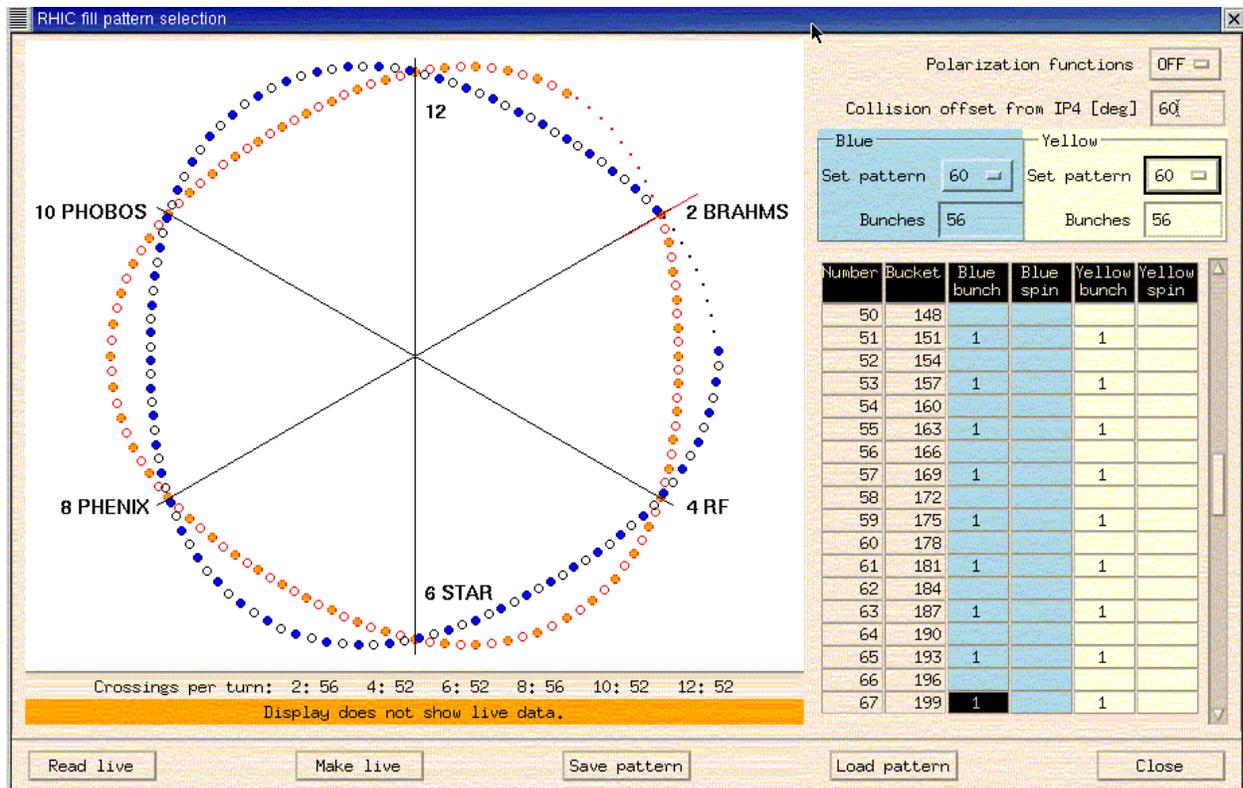


Figure 1 Bunch pattern with 6 buckets bunch spacing and 56 bunches. Pattern (6,56,0).

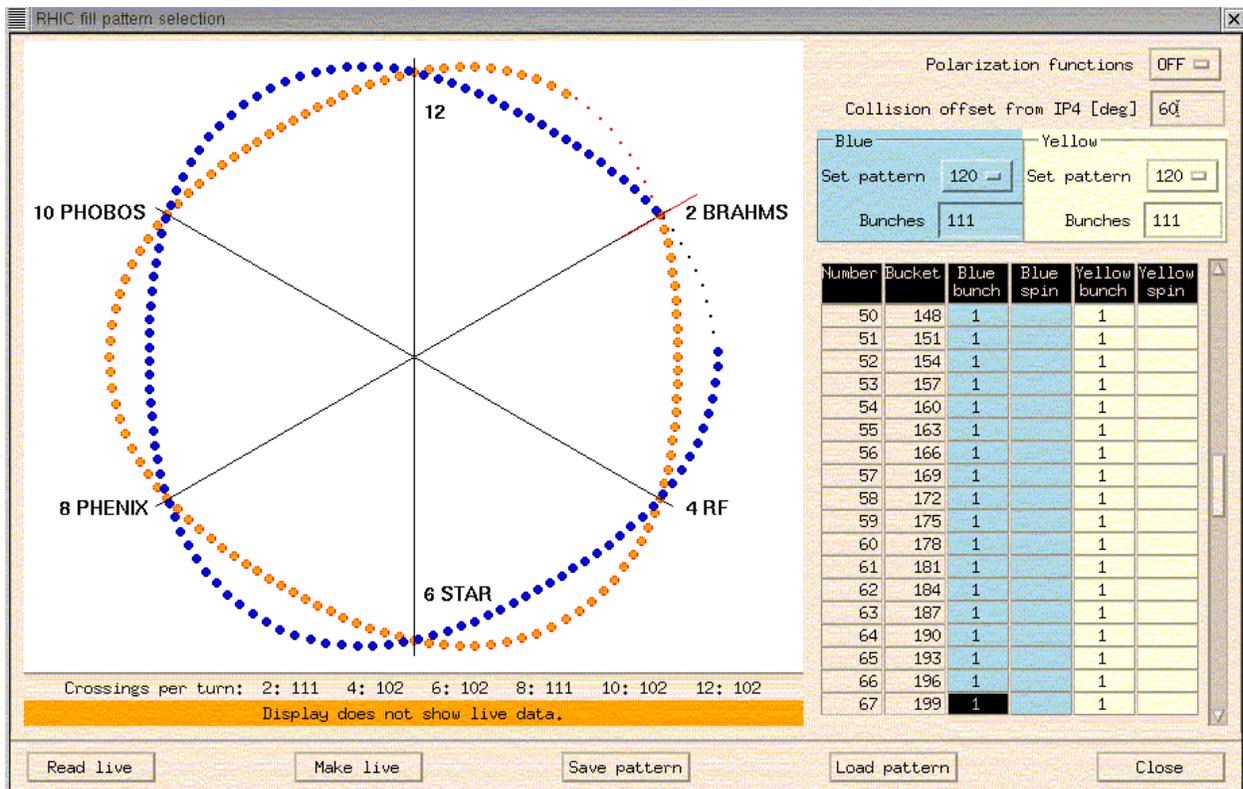


Figure 2 Bunch pattern with 3 buckets bunch spacing and 111 bunches. Pattern (3,11,0).

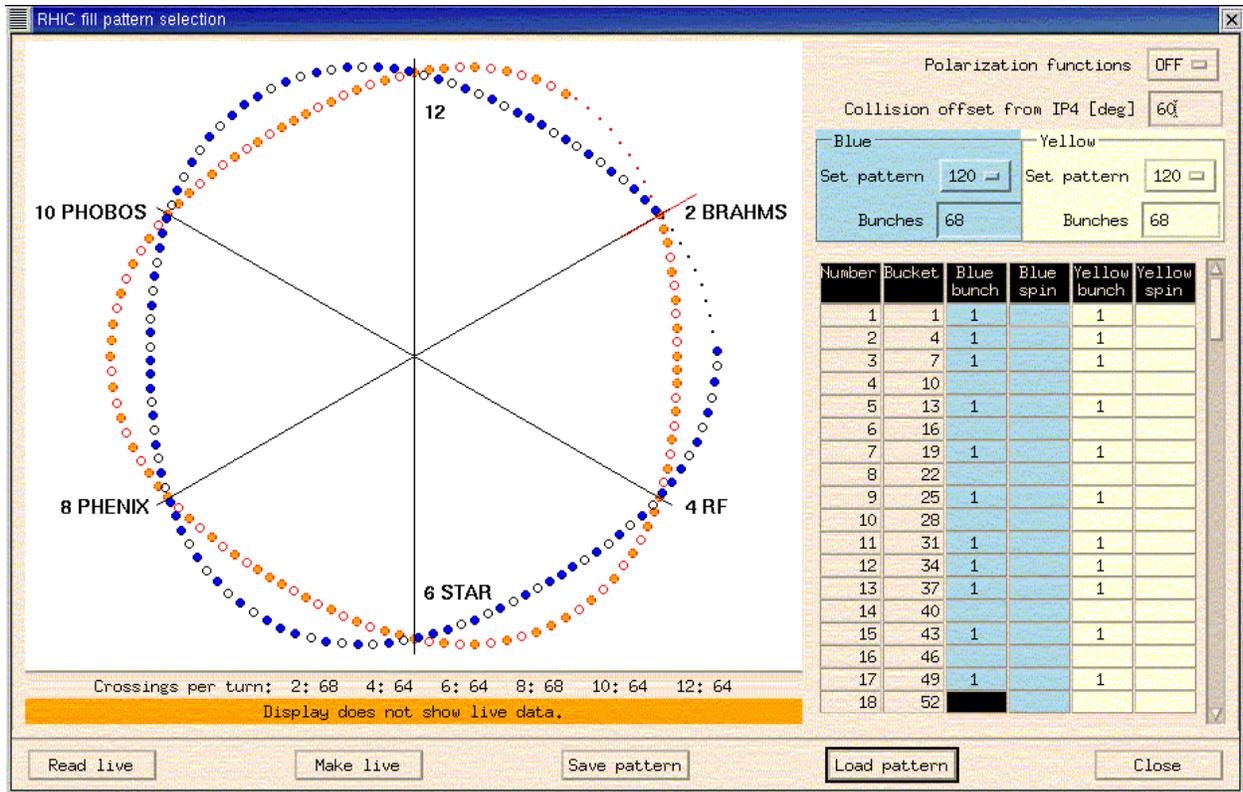


Figure 3 Bunch pattern with 3 and 6 buckets spacing and 68 bunches. Pattern (3,2,0)(6,4,0).

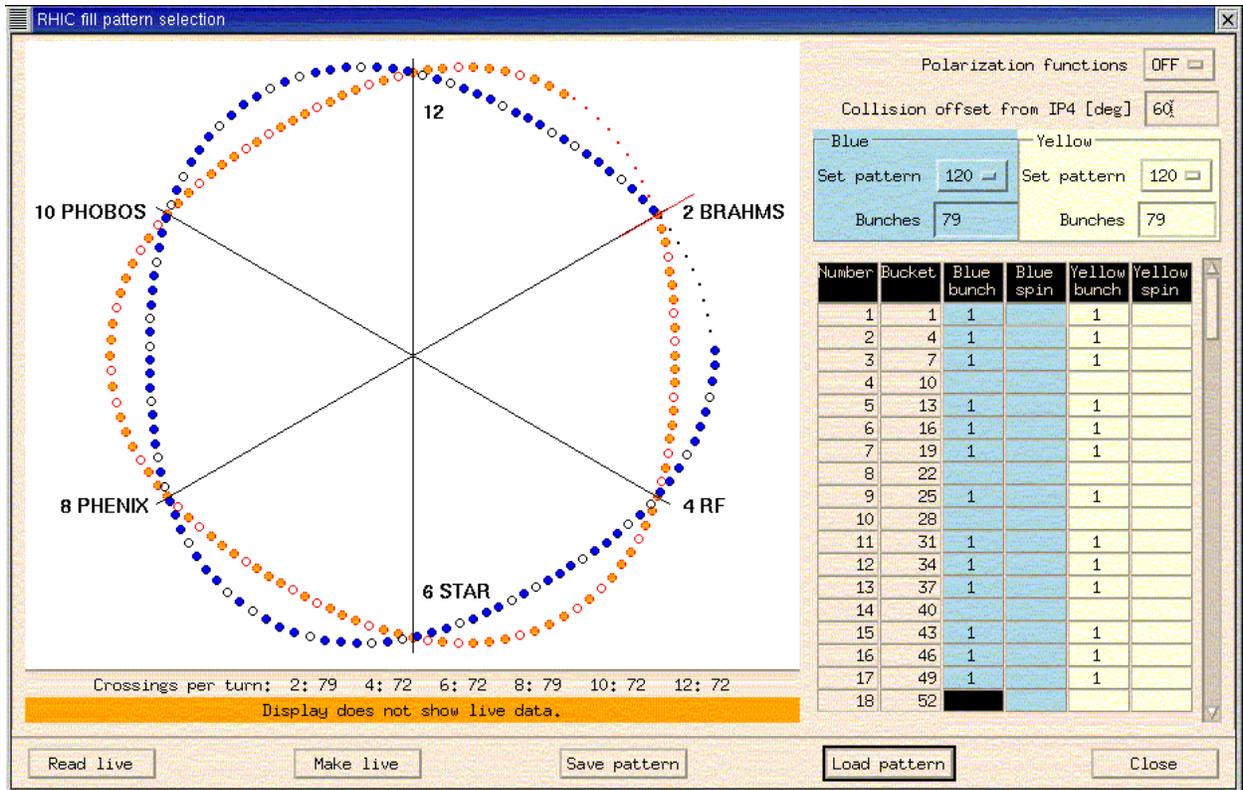


Figure 4 Bunch pattern with 3 and 6 buckets spacing and 79 bunches. Pattern (3,3,1)(3,3,1)(3,1,1).