

PERFORMANCE AIMS

1 NOMINAL PERFORMANCE

The LHC is designed to produce an initial luminosity of $L_0 = 10^{34} \text{cm}^{-2} \text{s}^{-1}$ at the start of a data taking period in two high luminosity insertions operating simultaneously. The initial characteristic decay time of the beam current due to particle collisions is 40h, but it is reduced to 22h by other sources of beam loss. In this situation the luminosity half-life is 10 h. When the operation of the LHC is well mastered the time necessary to inject and ramp the beams to high energy could possibly be reduced to 2h. In this case the ratio of average to initial luminosity reaches a maximum of 0.6 if the physics data-taking lasts 7h, and the LHC has to be refilled two to three times per 24h.

2 'ULTIMATE' PERFORMANCE

In the nominal situation the total beam-beam tune spread arising from the combined effect of head-on and long range interactions in both experiments amounts to $\Delta Q = 0.01$. In the SPS proton-antiproton collider a larger total tune spread of about 0.016 was achieved. In the LHC we expect the beam-beam effect to be more severe than in the SPS because beam conditions are different and particle losses have to be strictly limited. For this reason we have based the design on a more conservative value of the tune spread. However all systems are foreseen with a safety margin just sufficient to allow operation with a beam current 1.6 times larger than nominal. In this way an "ultimate" luminosity of $2.5 \cdot 10^{34} \text{cm}^{-2} \text{s}^{-1}$ could be reached at the "SPS beam-beam value" of the tune spread.

3 MORE THAN TWO EXPERIMENTS

The beam-beam tune spread generated in each of the two high luminosity insertions (with $\beta^* = 0.5 \text{ m}$) is composed of two parts : about 70% comes from the head-on interaction while 30% comes from the long range interactions. Additional low luminosity insertions will have much larger values of β_x^* . In this case the effect of long range interactions almost disappears, whereas the effect of the head-on interaction remains, as it is independent of β^* . The bunch current has to be adjusted so as to keep the total beam-beam tune spread below the limit whatever the number of experiments, and as a consequence the luminosity achievable in the high luminosity insertions diminishes for more than two experiments. For instance adding one low luminosity experiment reduces the maximum luminosity by a factor of 1.8. For two low luminosity experiments the reduction factor is 2.8. These are approximate values, which are valid only when the LHC operates close to the beam-beam limit.

4 PERFORMANCE IN THE EARLY DAYS

The LHC superconducting magnets are very sensitive to beam losses. In order to prevent excessive quenching which would jeopardize operation, the beam halo particles will be intercepted in a warm region of the machine by a sophisticated collimation system. Learning how to operate the LHC with reduced beam losses and a very high efficiency of the collimation system as required with nominal beam current will take some time. The initial commissioning of the machine will therefore be done with beams of small intensity. However we can avoid reducing luminosity in proportion to the square of the bunch population N by reducing simultaneously the transverse emittance ϵ_n . Both the fundamental beam-beam limit in the LHC and the space-charge limit in the injectors are satisfied provided the ratio N/ϵ_n stays below its nominal value. It is reasonable to expect that after the first year of commissioning the LHC can be operated with about 15% of the nominal beam intensity and a transverse emittance of the order of 1/4 the nominal one. In these conditions the luminosity reaches $10^{33} \text{cm}^{-2} \text{s}^{-1}$. During the two or three following years it should progressively approach the nominal value of $10^{34} \text{cm}^{-2} \text{s}^{-1}$.