D0 design and beam-beam effect

G. Sterbini, J.-P. Koutchouk

HOW IS THE D0 EVOLVING SINCE IR06?

The Early Separation Scheme (ESS) layout (Figure 1) presented at the IR06 consisted of

- 1 dipole D0 inside the detector ($3 - 4$ m from the IP)

- 1 orbit corrector (OC) in front of the triplet, before the TAS, to restore the original beams'separation

It implies 4 LRs encounters at $\approx 5\sigma$ in the machine and a static crossing angle during the run.
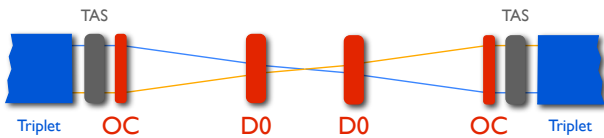

Figure 1: The Early Separation Scheme.

The impact of the leveling with the angle

A natural evolution of that scheme is the luminosity leveling: it is possible to control the luminosity with a proper feedback on the crossing angle. Apart from the luminosity, the leveling impacts on

- the luminous region length

- the HO tune shift

- the long range BB effect, since it modifies the beams'separation

- the D0 magnatic field: it has to change sign during the run.

The luminous region changes its length during the run (Figure 2): this can be an issue since the "events' density" per unit length of the luminous region varies during the leveling even if the the luminosity itself is kept constant.

The HO tune shift is reduced by the leveling (Figure 3, for H/V crossing): in principle, more beam current can be stored in the collider with an important gain in terms of integrated luminosity.

As shown in Figure 4 the beam separation varies: it is greater at the start and it is slowly reduced during the leveling. This is an advantage with respect to the beam-beam effect: the worst condition will occur when the beam current is already partially reduced.

In the case of a very long leveling time (8 hours) the D0 field has to change polarity (Figure 5): this possible difficulty is not yet addressed.
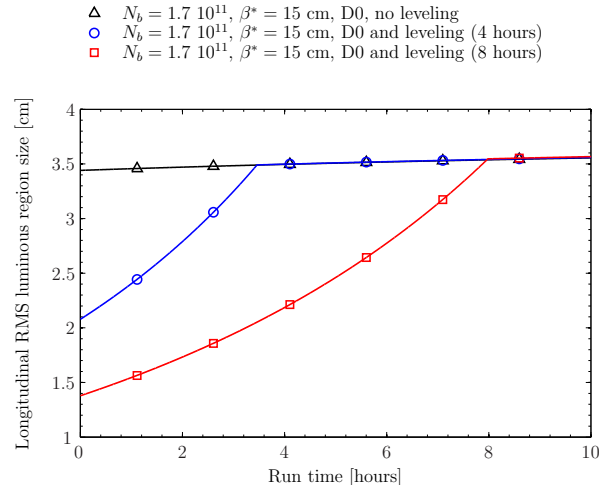

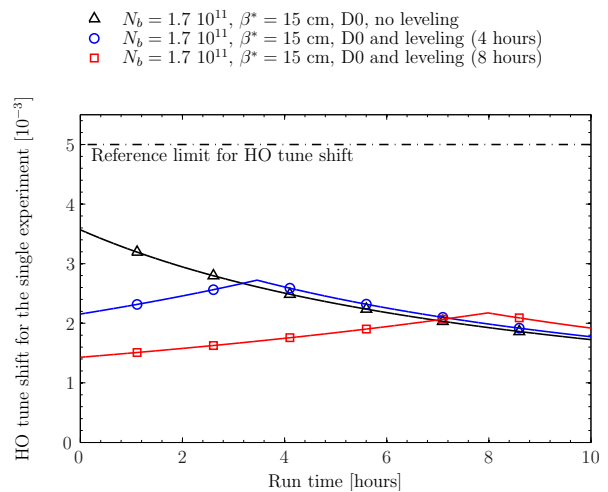Figure 2: The luminous regions size during the run.

Figure 3: The head on tune shift during the run with ultimate bunch charge.

During the leveling the machine has to operate in a large Piwinski angle regime: the analysis of this issues goes beyond the scope of that work and is still to be addressed.

Can the D0 work at 50 ns?

We can use the Early Separation Scheme at 50ns with the following advantages:

- the constraint on the position of the D0 can be partially relaxed, it becomes possible to consider increasing the
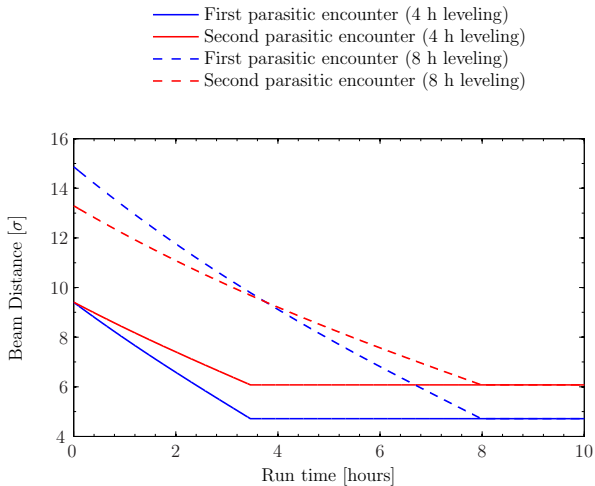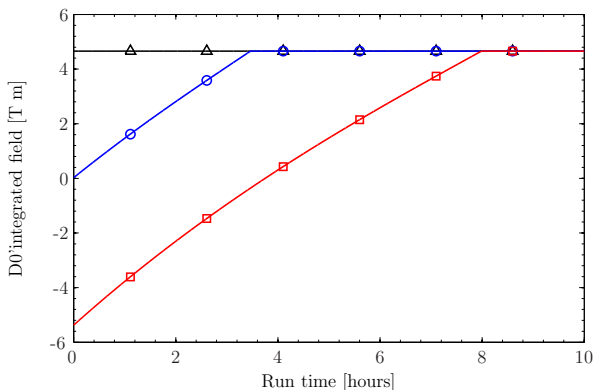
Figure 4: The beam separation during the run.

Figure 5: The D0 integrated field during the run.

IP-to-D0 distance

- the leveling with angle, apart from its intrisic advantage, provides a gain in the HO tune shift without the need of longitudinal flat bunch profile

- to decouple the crossing angle with respect to the beam separation in the triplets: we can increase it from the proposed 8.5 σ to 9.5 σ (or more).

The problems connected to the integration of the Early Separation Scheme in the detectors can still be a show stopper.

D0 AND BEAM-BEAM EFFECT

The requested integrated field of the D0 is a function of the D0 and OC positions and of the crossing angle. In Figures 6 we show the D0 integrated field requested with

the OC at 19 m and $\beta^* = 0.15$ m. There are two curves: these represents two very different conditions during the leveling. At the start of the run the crossing angle is very large (16 σ), while at the end the crossing angle is likely reduced at 5 σ. In Figure 7 is shown the orbit corrector integrated field versus the D0 position. In Figures 8 and 9,

Figure 6: The D0 integrated field as function of the D0 position with the OC at 19 m from the IP. The two blue curves represent the strength needed at the beginning of a run (16σ)) and at the end (5σ).
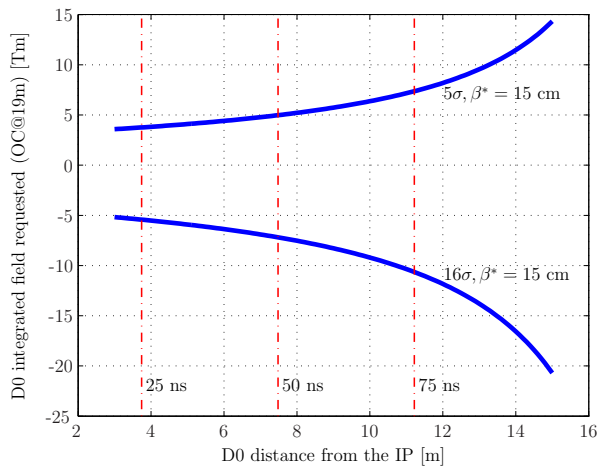

Figure 7: The OC integrated field as function of the D0 position with the OC at 19 m from the IP. The two blue curves represent the strength needed at the beginning of a run (16σ)) and at the end (5σ).

similarly, we showed the magnetic strength requested with $\beta^* = 15$ cm and the orbit corrector positioned at 15 m from the IP. The solution with the OC at 19 m and the D0 at $\approx$ 7 m seems to be the most promising for the technological feasibily of the scheme.
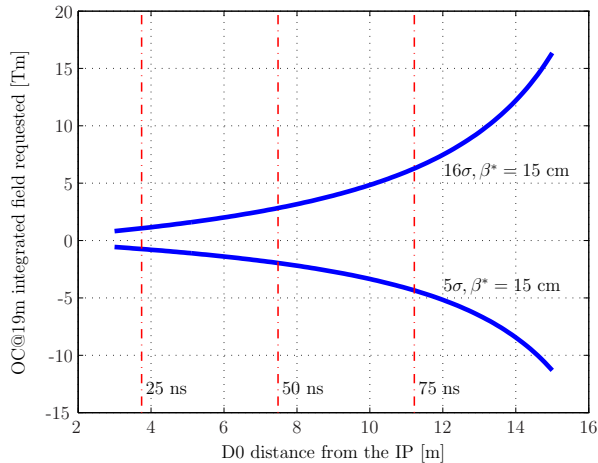
Figure 8: The D0 integrated field as function of the D0 position with the OC at 15 m from the IP. The two blue curves represent the strength needed at the beginning of a run (16σ)) and at the end (5σ).
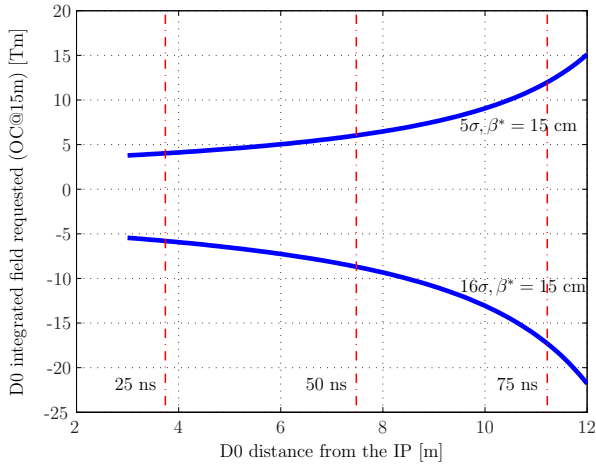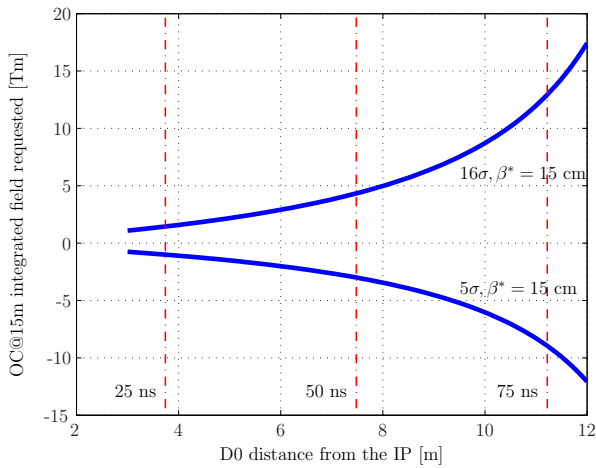

Figure 9: The OC integrated field as function of the D0 position with the OC at 15 m from the IP. The two blue curves represent the strength needed at the beginning of a run (16σ)) and at the end (5σ).

A first NbTi solution as been investigated [1] (1 m long magnet, with an integrated field of 3 Tm, Figure 10). Aperture is chosen very large (15 cm in diameter) to minimize the heat deposition. Some preliminary energy deposition studies have been performed ($L = 10^{35}$ cm^{-2} s^{-1}), and some shielding blocks has been proposed (Figure 11) [1].

An other fundamental aspect to be taken into account is the detectors' solenoidal field (Figure 12).

The location at 50ns ($7 - 9$ m) from the IP appears to present some advantages:
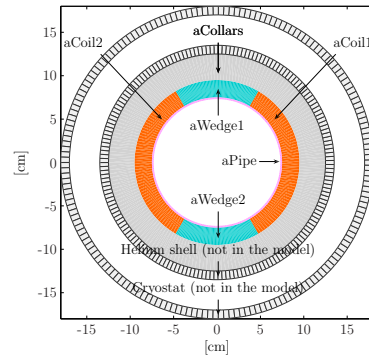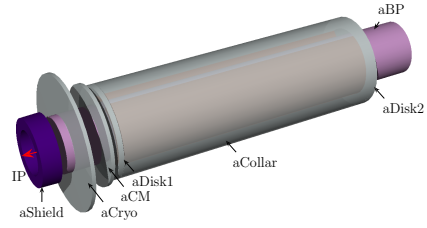

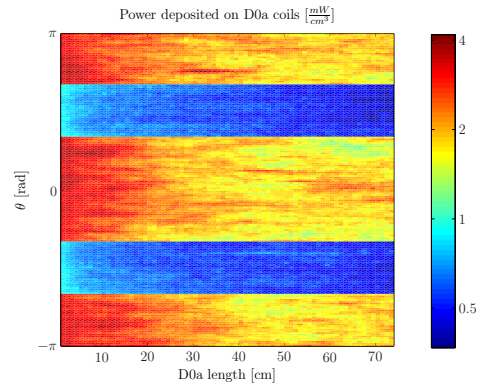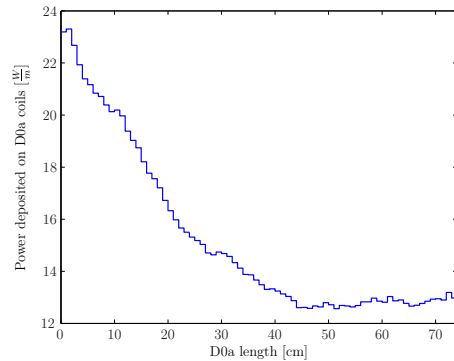Figure 10: A possible implementation of the D0.

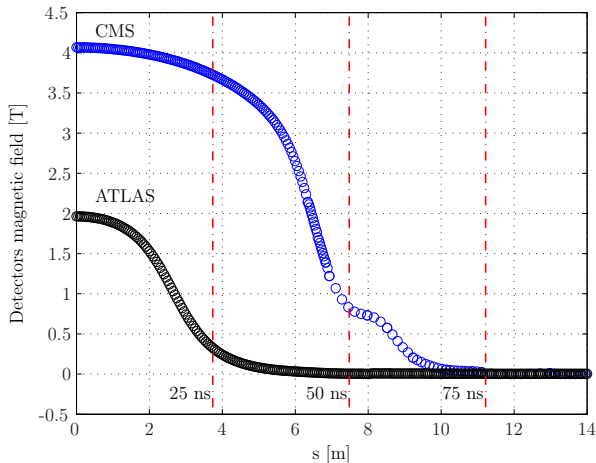Figure 11: Preliminary results on the energy deposition of the D0.

Figure 12: The detectors's solenoidal field.

- good trade-off between position and integrated field

- CMS solenoidals field is significantly lower (≈ 1 T, negligible in ATLAS)

- connections, cryolines, maintainability should be less critical

We have still to answer the following questions:

- Does D0 blind the detectors? (see detectors talks)

- Are 8 LRs at 5σ acceptable for the beam lifetime ($N_b = 1.7\ 10^{11}$ ppb, $\epsilon_n = 3.75$ mm mrad)?

Results and limitations of RHIC and SPS's experiments

Only LHC can give a complete answer to the questions connected to the reduced beam separation. The machines that can be used for this kind of experiment are RHIC (with the wire), SPS (with the wire) and Tevatron (collider with similar bunch current but very different collision scheme with respect to the LHC). All these machines have circumferences from 4 to 6 times shorter than LHC: what is the impact of that is an issue to discuss. Some experiments have been done in the following approximations

- we do not consider coupling with HO collisions, other LRs, other lattice non linearities

- we approximate the beam field at 5σ with the wire field at 5σ

- we approximate the interaction in the weak-strong regime.

In Figure 13 we present some results on the RHIC experiment of the 20 June 2007 [2] (yellow ring). Five bunches were in the ring (bunches 1, 121, 181, 241, 301): the measured vertical emittance was very different between

the bunches (respectively $44, 25, 28, 16, 25$ mm mrad).The separation beam-wire was vertical, so the normalized distance between beam and wire and the number of equivalent beam-beam long range (BBLR) vary from bunch to bunch [3].

From Figure 13 (plot on the top) we can observe that the Bunch 1 is the only one significantly affected by the wire. For that reason, in Figure 13 (plot on the bottom) we show the quantity scaled with respect to its vertical emittance: hence around 8 encounters at $\approx 5\sigma$ with $N_b = 1.7\ 10^{11}$ seems not to perturb significantly the beam lifetime. Reducing the separation between the beam and the wire to $\approx 3.5\sigma$, keeping a maximum current in the wire of 50 A, produced an observable beam loss. From the behaviour of bunch 121, 181, 301 (in the time interval 3000 s $< t <$ 4000 s), rescaling the separation and the number of long range [3], we can conclude that even ≈ 14 LRBBs (with the ultimate bunch current) at 5σ can be tolerated.

In the SPS beam–beam esperiment [4], among other results, it was observed that the effect of 1 wire (1.2 m long, at $\beta \approx 50$ m) at 30 A with a distance of 4.3σ ($= 6$ mm) from the SPS 37 GeV/c beam has not an observable effect (during the low beamlife of the SPS beam!). This is equivalent to 9 parasitic encounters at 4.3σ for the LHC ultimate current with LHC nominal normalized emittance in the SPS circunference.

CONCLUSIONS

The Early Separation scheme is compatible with leveling, 25ns and 50ns. If 8 LRs at $N_b = 1.7\ 10^{11}$ can be tolerated, the position between $7 - 8$ m from IP seems very promising for the engineering point of view. It is not yet clear if the detectors can efficiently operate in this scenario. For the beam–beam problems there are efforts to look for further MD time: even if partial, the experimental results are rather encouraging and consistent. At this stage it seems wise to preserve the avaibility of the slot $4 - 6$ m until clearer results are obtained: RHIC's long beam lifetime would be ideal for that purpose.

REFERENCES

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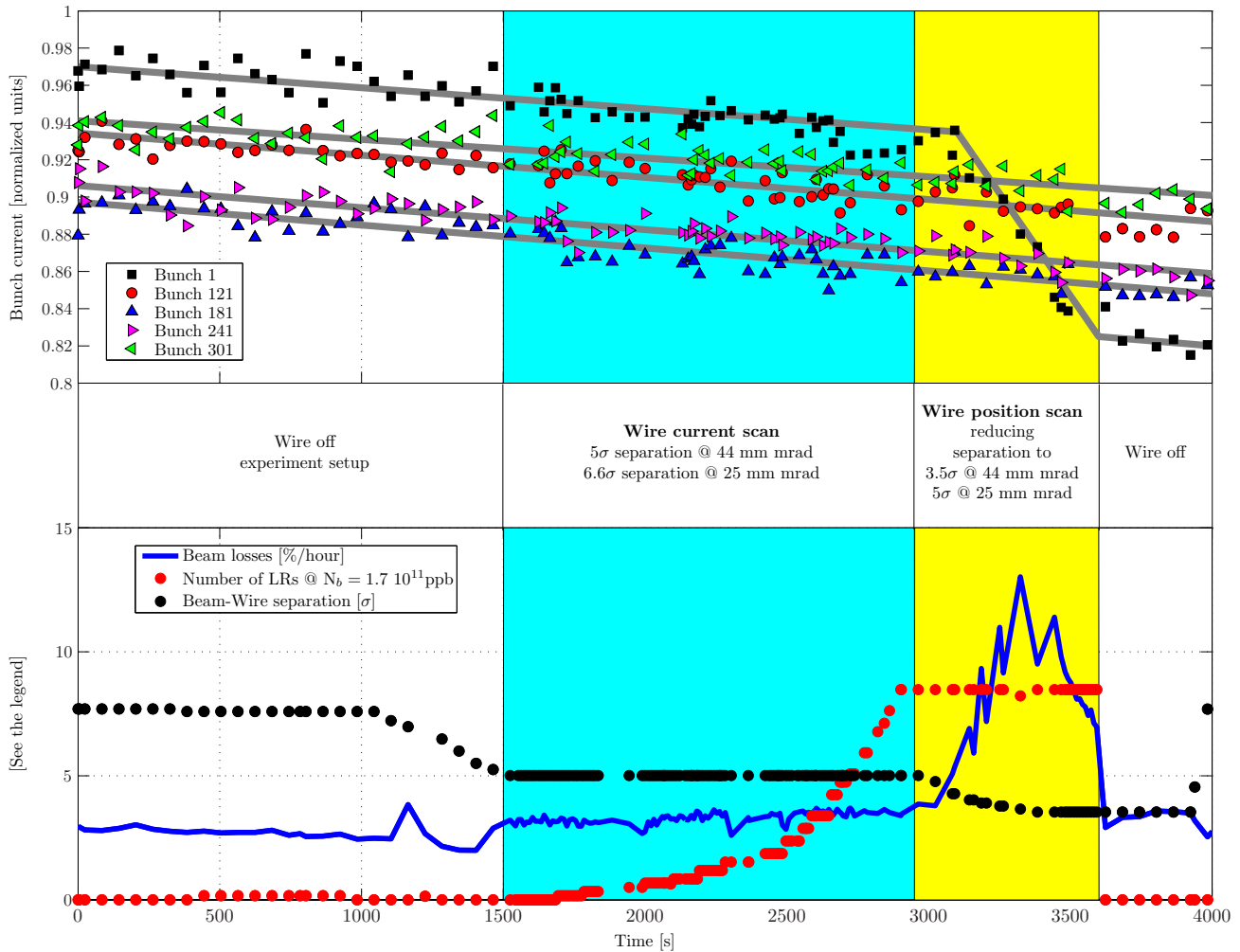
Figure 13: Yellow beam results of the 20 June 2007 RHIC experiment. In the plot on the top the evolution in time of the five bunches' current is shown. In the plot on the bottom the number of equivalent BBLRs and the beam-wire separation is computed for the Bunch 1 vertical emittance (44 mm mrad). During the wire current scan phase, the beam-wire separation was 5σ (with $\epsilon_v = 44$ mm mrad) and 6.6σ (with $\epsilon_v = 25$ mm mrad). At the maximum current (50 A on the 2.5 m wire) the equivalent number of BBLRs (at LHC ultimate bunch current, $N_b = 1.7\,10^{11}$) was about 8 BBLRs (with $\epsilon_v = 44$ mm mrad) and about 14 BBLRs (with $\epsilon_v = 25$ mm mrad). No effect was observed. During the wire position scan phase (keeping the maximum current in the wire) the separation was reduced to about 3.5σ (with $\epsilon_v = 44$ mm mrad) and 5σ (with $\epsilon_v = 25$ mm mrad). For the 8 BBLRs at 3.5σ (bunch 1) the beam was clearly perturbed, on the other hand no significant effect was observed for 14 BBLRs at 5σ (bunches 121, 181, 301).