D0 and its Integrability

G. Sterbini, J.-P. Koutchouk, CERN, Geneva, Switzerland

Abstract

In this paper, we present the performances of the so called D0 scheme with respect to the LHC luminosity gain and its integrability scenarios in the detectors' area. In particular we propose some possible positions for the D0 and we present the corresponding integrated field requested. The positions are the product of a very preliminary interactions of the physicists' detectors. In the integration's feasibility, the beam–beam effect in the new crossing scheme and the impact of the solenoidal magnetic field of the detectors on the D0 are considered.

INTRODUCTION

In the LHC, the beams cross at an angle to prevent more than one head-on collision inside each detector. Furthermore, the value of the crossing angle has to be chosen to reduce to an acceptable level the strength of the long-range beam–beam interactions on either side of the IP's. This latter phenomenon sets indeed the upper limit of the LHC performance with respect to beam dynamics. In the nominal crossing scheme, the increase of the focusing strength of the triplet increases the beam–beam effect requiring a larger crossing angle. Otherwise the luminosity gain obtained by reducing the β-function would be largely offset by the geometrical loss. The nominal β^* of $0.55\ m$ was chosen having in mind this trade-off. Nevertheless the arc's sextupoles were designed to compensate properly the machine's natural chromaticity even considering a β^* of $0.25\ m$.

Whatever optics solution we consider for the *LHC Luminosity Upgrade*, it has to be coupled with a proper scheme to reduce the geometrical loss. In order to address this problem two solutions were considered for the *LHC Upgrade Project* [1]: bunch shortening with an harmonic RF system or crossing at large angle with bunch rotation by crab cavities; these methods involve significant scientific and technical challenges.

The new concept of an 'early separation scheme' ([2] and [3]) offers a-priori an other solution with equal or larger performance. It however requires installing moderate field dipole magnets (D0s) inside the experimental detectors and with potential significant difficulties of integration.

PERFORMANCE POTENTIAL

As we already mentioned in the introduction, if we want to achieve an higher luminosity with a stronger focusing all optics solutions should require a way to reduce the geometric loss factor: in Figure 1 we show the gain in luminosity considering different scenarios. The red line represents the increase in luminosity just with a stronger focusing scaling the crossing angle to keep the beam-beam perturbation invariant: it is evident that the potential gain in mostly cancelled by the geometrical loss factor. Using crab cavities or a full early separation scheme (FES, no residual crossing angle between the beams, $\theta_c = 0\ \mu rad$) we can recover completely the loss obtaining a full efficiency in the focusing exploitation.

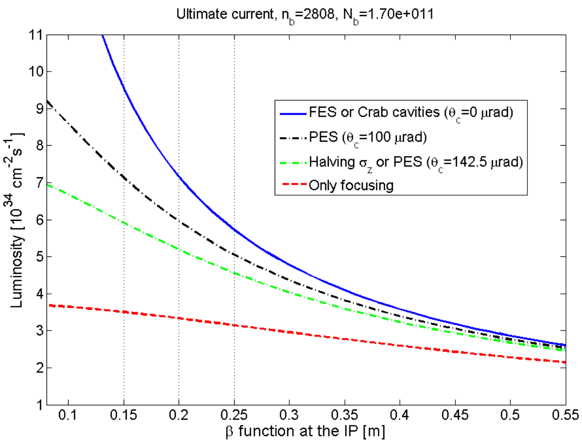

Figure 1: D0's performance with the ultimate current.

It is possible to use the early separation scheme in a weaker configuration, preserving a residual crossing angle between the beam (PES, partial early separation):in Figure 1 are shown also the curves corresponding to a PES with a $\theta_c = 100\ \mu rad$ and $\theta_c = 142.5\ \mu rad$ at $\beta^* = 0.55\ m$, with proper scaling for other β^*. The latter solution is equivalent, as concerned the luminosity, to a new RF system that halves the RMS bunch length.

The 'early separation scheme' is simple for the machine point of view, is cheap and is a local change: it should be transparent to the rest of the machine. The main drawback is, of course, the introduction of magnetic elements inside the detectors region.

THE INTEGRABILITY

If we aim to reduce the crossing angle between the two beams and recover the nominal distance of the parasitic encounters we need a kick given by the early separation dipole of at least the same strength of the nominal θ_c: in the following we consider a kick of 160 μrad at $\beta^* = 0.55\ m$ and nominal current. In Figure 2 is shown the requested field for the D0 as function of the focusing strength of the triplet and of the beam current: we used the scaling law presented in [4]. It is reasonable to chose an integrated field of 8 Tm as a reference value allowing a β^* of 15 cm and the ultimate current. The length of the D0 should ideally be short as compared to the distance between long range encounters. Hence the D0 should be superconducting.

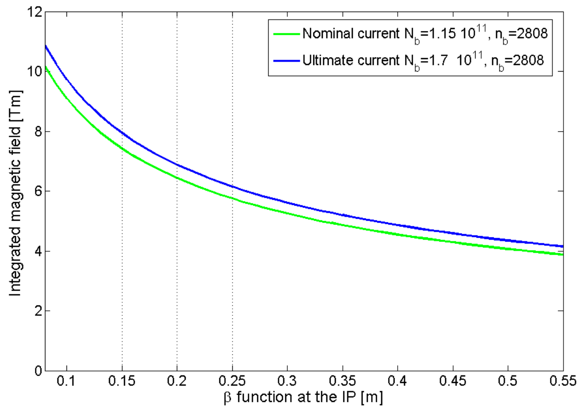

Figure 2: D0 field requested with a total kick of 160 μrad at collision energy.

For a first consideration on the possible position for the D0 some geometrically free slots are shown in Figure 3 for ATLAS detector [5]. Due to the lack of room and to the relative high integrated magnetic field, we think it would be a good strategy to split the D0 into modules, having a D0a and a D0b: for the time being we can consider the first two slots in ATLAS, so we have:

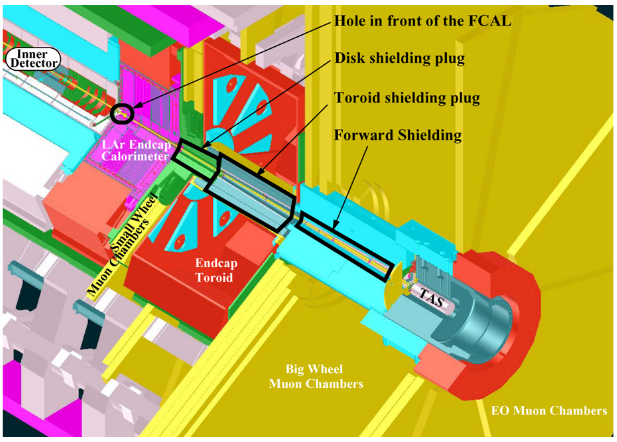

Figure 3: ATLAS detector. Courtesy of M. Nessi.

- Slot1 starting at 3.49 m from IP with a total length of 1.09 m
- Slot2 starting at 6.80 m from IP with a total length of 1.86 m.

The D0a would fit in Slot1 and the D0b in Slot2. Due to the detector's contingency the D0a should be as transparent as possible while the D0b as bulky as possible acting like a shield.

Since there is no possibility of putting a dipole in the inner detector a FES seems not feasible at least with the nominal bunch spacing of 25 ns: nevertheless it should be regarded as an interesting solution for a bunch spacing of 50 ns.

Due to energy deposition issues or services' routing room constraints it can be interesting to distribute not uniformly the integrated magnetic field requested in D0a ad D0b: it should be convenient to have a weaker D0a and a stronger D0b. In the Figure 4 we present the impact of a different repartition of the total angle on the diffusion in amplitude of the beam. The needed tracking is done using the BBTrack code [6]. As result, we can say that from the beam stability it seems a priori possible to unbalance the kicks: the diffusion for small amplitude increases but remains smaller than the threshold ($\approx$ 6.5 σ). This is to verify experimentally hopefully in RHIC.

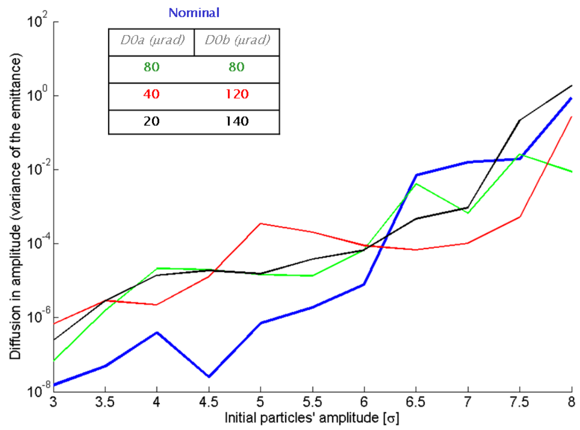

Figure 4: Tracking results distributing not uniformly the integrated field on D0a and D0b.

The D0s will operate in the magnetic field of the detectors (Figure 5): this will limit the margin of the working point of the superconductor and produce significant forces, torques and stress on the dipole.

An other crucial issue for the integration of the D0 is the heat deposition it will suffer. From preliminary studies, considering a luminosity of 10^{35} $cm^{-2}s^{-1}$ on the D0a we have a power deposition of about 75 W in the coils [7]. This is obtained with a very simple model of the dipole: the thickness of the coils considered is 15 mm and the aperture radius is 35 mm. Enlarging the aperture the heat deposition could be significantly lower: the benefits would be not only for the dipole but also for background noise of the inner detector. In addition the energy deposition is not uniform along the length of the dipole and it has a dangerous hot spot in the forehead region: this problems requires further investigations.

Two others issues are planned for study: the scattering of particles by the D0 to the detector and the leakage of its magnetic field that may require active magnetic shielding.

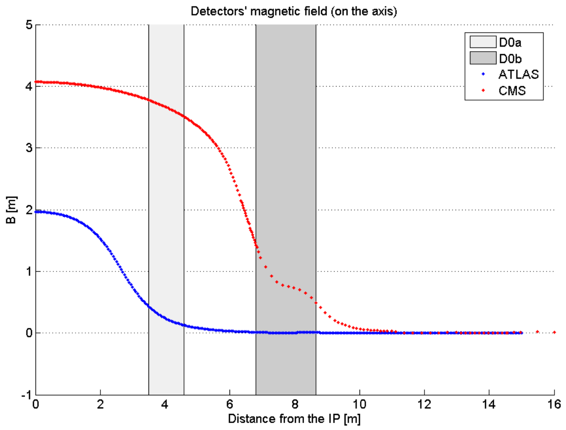

Figure 5: The detectors' magnetic environment.

CONCLUSION

In this paper, we presented a very preliminary review integration issues for the D0 in the experimental areas. The D0 boosts significantly the luminosity with only a local change of the machine. It further allows reaching the $10^{35} cm^{-2} s^{-1}$ with a more modest increase of the total beam current.

The Full Early Separation scheme (FES) has to be discarded for the 25 ns bunch spacing. So far, for the Partial Early Separation scheme (PES) the initial studies and discussions with experimental physicists showed no evident show-stoppers but many issues: energy deposition, room for services (in particular the cryoline) and backscattering.

ACKNOWLEDGEMENTS

We thank U. Dorda for help in using the BBTrack program, F. Zimmermann, C. Hoa, P. Limon and E. Tsesmelis for the most enjoyable collaboration and all other colleagues for their support.

REFERENCES

[1] F. Ruggiero and F. Zimmermann, *"Possible Scenarios for an LHC Upgrade"*, HHH-2004, CERN-2005-006, 2005.

[2] J.-P. Koutchouk, *"Possible quadrupole-first options with $\beta^* <= 0.25\ m$"*, Workshop CARE-HHH LHC-LUMI-05, Arcidosso, 2005.

[3] J.-P. Koutchouk and G. Sterbini, "An Early Beam Separation Scheme for the LHC", EPAC 2006 Proceedings, Edinburgh.

[4] Y. Papaphilippou and F. Zimmermann, *"Weak-strong beam-beam simulations for the LHC"*, Proc. LHC99, Workshop on Beam-beam Effects, CERN-SL-99-039 AP p. 103, 1999.

[5] M. Nessi, private communication, 9th June 2006.

[6] U. Dorda, *"Manual for BBTrack"*, to be published.

[7] C. Hoa, private communication.