DAPNIA/SEA-00-12

A Proposal for the TESLA High Energy Beam Switchyard

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November 6, 2000

1 Introduction

In the TESLA linear collider, two interaction regions are foreseen, one for e^+e^- collisions at zero crossing-angle, and the other one for e^+e^-, e^-e^- or $\gamma\gamma$ collisions at about 40 mrad crossing angle. Beam switchyards must therefore be designed after the electron and positron(or electron) linacs to switch the electron and positron (or electron) beams and serve the two interaction regions.

On the electron side, the switchyard will be installed only after the positron source system. After the linac exit, the high energy electron beam passes through a 100 m long wiggler where photons are produced. These photons are converted into electron and positron pairs on a target located 300 m from the wiggler exit. The electron beams are switched after the wiggler and transported towards either one of the two collisions point. On the positron side, the switchyard will be symmetric to the elctron one.

The design of the beam switchyard is driven by the following constraints:

- it must bend the electron beam horizontally away from the straight photon beam strongly enough to avoid and make room for the positron target system. A transverse separation of 0.6 m from the target center is retained in this paper.
- the horizontal emittance growth induced by synchrotron radiation in the switchyard arcs must be tolerable.
- it must operate at 250 GeV and 400 GeV beam energies.

In this study, we present two designs for the beam switchyard optics, one based on a FODO transport system and the second on a double bend achromat lattice used in synchrotron light ring optics to reduce the emittance growth.

2 Bending parameters

A first bending of 8 mrad over a 90 m long arc [1] deviates the electron main trajectory by 0.6 m transverse distance from the positron target. Towards the main e^+e^- interaction point (IP), it is followed by a second arc with a net bending of about the same magnitude but opposite in sign such that, when added to rest of the beam line, the net bend angle is zero at the IP. The positive and negative arcs are realized with twelve 1.5 m long dipoles. For simplicity, the dipoles are identical in each arc, with slightly different field settings. Towards the $\gamma\gamma$ interaction point, the same-sign first and second arcs add up their bending angles in order to provide the necessary transverse separation of the two detector halls. With such arcs, an horizontal emittance growth of about 20% is expected.

On both sides of the arcs, beam matching from the upstream wiggler exit and to the downstream entrance of the collimation section is provided by matching sections with four quadrupoles.

3 Arc Optics

3.1 FODO Structure

Each of the 2 arcs must be achromatic in position and angle. A FODO lattice with 2π phase advance per arc, including 3 cells of 120°period, is a possible solution shown in Fig.1.

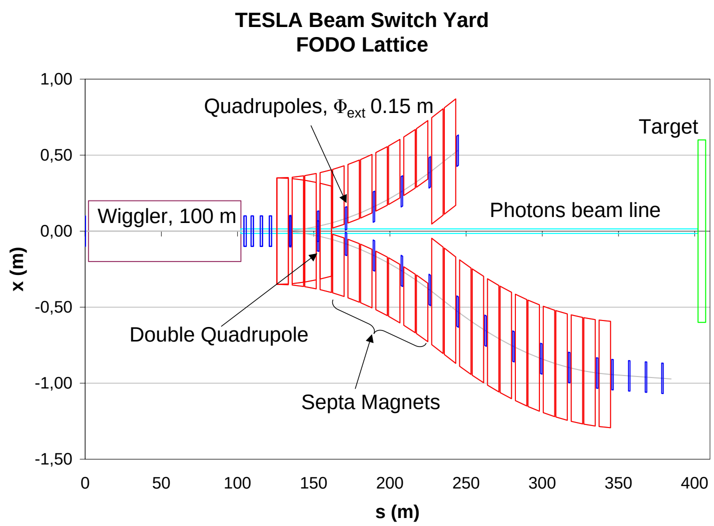

Figure 1: Switchyard layout based on a FODO lattice.

This optics solution is simple but has the following drawbacks:

- the first quadrupole is common to both beam lines : it therefore induces a dipole kick to the symmetric offf-axis beam trajectories.
- the second quadrupole must be two-in-one magnets, with two magnetic axis, since the trajectories are still not enough separated.
- the two quadrupole families are set to realize the correct phase advance and cannot be tuned to minimize the emittance growth. The emittance growth is about $2\,10^{-12}$ m.rad, as shown by Fig. 2 at 400 GeV beam energy, that is about 20 % of the nominal $1.0\,10^{-11}$ m.rad.

These inconveniences are overcome with the optics presented in the next section.

3.2 Double Bend Achromat (DBA) Structure

Synchrotron light source designs are optimized with respect to minimizing the equilibrium emittance generated by synchrotron radiation. In the case of a double bend

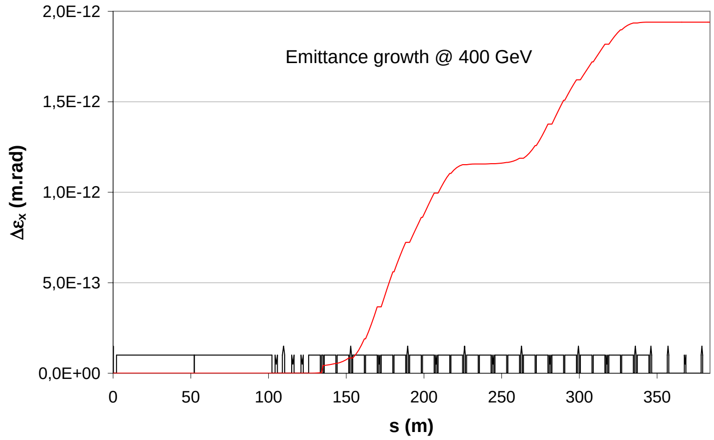

Figure 2: Emittance growth in the FODO-based beam switchyard optics for 400 GeV beam energy.

achromat optics, the minimum emittance is obtained by realizing a waist of the horizontal β_x function at 3/8 of the arc dipole length. In our case, one can extend this solution by considering that each arc includes two bends (split into 6 dipoles). The double bend achromat offer the additional advantage that the quadrupoles are localized at the entrance, middle and exit of the achromat. The use of two-in-one quadrupoles can therefore be avoided.

A solution has been found with the programme BETA [2] where the arcs are composed of two same-sign bends including 6 dipoles. As shown by Fig.3 the Twiss beta-functions are larger than in the above FODO system, but are similar in magnitude to the rest of the beam delivery system. Fine tuning of the β_x-waist position turns out to be easier when the pair of central dipoles of each arc are swapped, thus preserving the same net deviation.

As shown by Fig.4, the emittance growth is about $8\,10^{-13}$ m.rad, 8% of the nominal emittance and a factor 2 smaller than in the FODO-based solution.

The layout of the DBA switchyard system is shown in Fig.5. The first 5 dipoles are common to the two beam lines and are used to switch the beams. At the entrance of the 6th dipole, the beam axis is separated by 7.02 cm from the photon axis: one can used active septum magnets[3] assuming 3.5 cm between the beam axis and the external septum face and a photon beam chamber of 2 cm radius.

In the first arc, the beam and photon axis are separated by 9.77 cm entrance of the set of 4 middle quadrupoles. These can be extrapolated from the quadrupoles with 15 cm external diameter used in the DTL of the IPHI project [4,5].

All magnet characteristics are presented in Table 1.

4 Conclusions

A design for the beam switchyard of the TESLA linear collider is proposed. It is based on the double bend achromat optics in order to keep the synchrotron radiation induced emittance growth below the 10% level. A finer optimization of the optics

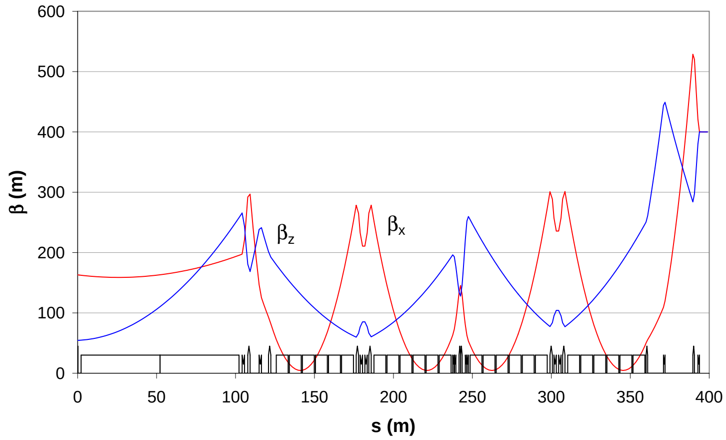

Figure 3: Optics functions of the DBA switchyard system.

could still be done to further reduce this emittance growth. This solution however permits to start the cost evaluation process for such a high energy beam switchyard system.

References

[1] R. Brinkmann and N.Walker, Zeuthen TDR meeting, 3-9 February 1999.

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[3] APD SOLEIL Juin 1999 CEA/CNRS

[4] R. Duperrier, Optimisation des tubes de glissement du D.T.L d'IPHI (partie magnetique) Rapport de stage 1997 DSM/GECA 97/65

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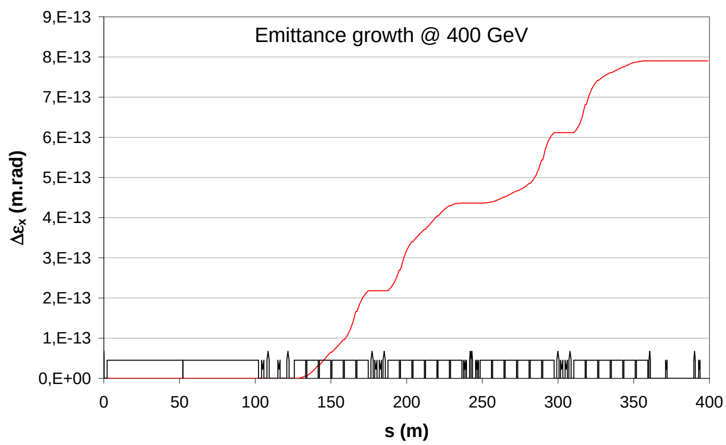

Figure 4: Emittance growth in the DBA switchyard system.

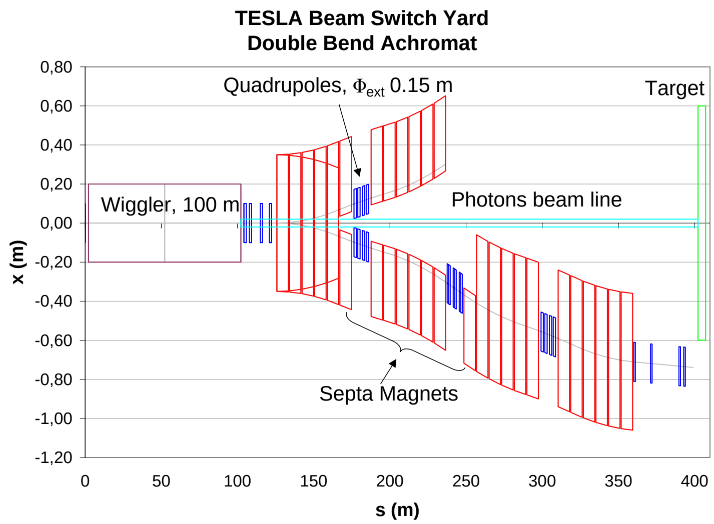

Figure 5: Switchyard layout based on the DBA lattice.

Wiggler to Arc Matching Quadrupoles					
Name	Number	K1 (m^{-2})	Length (m)	ϕ_{ext} (m)	G @ 400 GeV (T/m)
QLMA1	1	-0.0488	1.5	-	-65.16
QLMA2	1	0.0760	1.5	-	101.43
QLMA3	1	-0.0314	1.5	-	-41.92
QLMA4	1	0.0080	1.5	-	10.61
Positive Arc Dipole					
Name	Number	θ (mrad)	Length (m)	Radius (m)	B @ 400 GeV (T)
BLPA	12	0.666666	7.5	11250	0.1186
Positive Arc Quadrupoles					
Name	Number	K1 (m^{-2})	Length (m)	ϕ_{ext} (m)	G @ 400 GeV (T/m)
QLPA1	2	0.0590	1.5	0.15	78.72
QLPA2	2	-0.0456	1.5	0.15	-60.79
Middle Arc Quadrupoles					
Name	Number	K1 (m^{-2})	Length (m)	ϕ_{ext} (m)	G @ 400 GeV (T/m)
QLPN1	1	-0.0360	2	-	-47.99
QLPN2	1	0.0975	2	-	+130.07
QLPN3	1	-0.0490	2	-	-65.41
Negative Arc Dipole					
Name	Number	θ (mrad)	Length (m)	Radius (m)	B @ 400 GeV (T)
BLNA	12	-0.6055	7.5	-12386.457	-0.1077
Negative Arc Quadrupoles					
Name	Number	K (m^{-2})	Length (m)	ϕ_{ext} (m)	G @ 400 GeV (T/m)
QLNA1	2	0.0540	1.5	-	+72.05
QLNA2	2	-0.0402	1.5	-	-53.66
Arc to Collimation Matching Quadrupoles					
Name	Number	K (m^{-2})	Length (m)	ϕ_{ext} (m)	G @ 400 GeV (T/m)
QLMC1	1	0.0214	1		+28.49
QLMC2	1	-0.0349	1		-46.59
QLMC3	1	0.0754	1		+100.55
QLMC4	1	-0.0521	1		-69.51

Table 1: Magnet characteristics in the DBA switchyard system.