TRACKING STUDIES TO DETERMINE THE REQUIRED WIGGLER APERTURE FOR THE ILC DAMPING RINGS*

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Abstract

The injection efficiency of an ILC damping ring is closely tied to its acceptance. To maximize both, one wants a physical aperture as large as possible in the wiggler magnets, as these are likely to be the limiting physical apertures in the ring. On the other hand, a small aperture in the wiggler magnets is needed to achieve the required field profile, a high magnetic field that is very linear over the whole physical aperture of the magnet. Tracking studies were done for all proposed ILC damping ring lattices to determine their required physical apertures. Although a half-aperture of 8 or 10 mm had been proposed, our studies showed that, for most lattices, a 16 mm half-aperture is required. (For some lattices a 12 mm half aperture might suffice.) We present here the results of our studies, which led to adopting a 16 mm half-aperture in the current ILC damping ring baseline design [1].

INTRODUCTION

In the ILC Damping Rings, the injection efficiency will depend to a significant degree on the acceptance of the rings. This is especially important for the positron ring(s) as the injected positron beam has a large transverse emittance combined with a large energy spread.

In order to maximize the injection efficiency one wants to maximize the acceptance. This requires maximizing the dynamic as well as the physical aperture of the ring.

The physical aperture will be dominated by the physical aperture in the wiggler magnets. The wigglers need to provide a high and at the same time linear field over a significant fraction of the whole aperture. This is harder the larger the aperture gets. For this reason a physical aperture of 8 mm half aperture in the wigglers had been suggested [2]. Tracking Studies were performed to evaluate if this aperture is sufficient or if a larger aperture in the wigglers is needed.

TRACKING STUDIES

Lattices

At the time of the studies there were seven proposed lattices under discussion. They varied in length from about 3 km to 17 km. The energy of all the lattices is about 5 GeV. One of the lattices is the lattice from the TESLA zeroth order design report. This lattice is called TESLA. All the other lattices were assigned random three letter acronyms. Table 1 gives an overview over the different lattices:

Table 1: Proposed lattices.

lattice	length (km)	cell type
PPA	2.824	π
OTW	3.223	TME
OCS	6.114	TME
BRU	6.333	FODO
MCH	15.935	FODO
DAS	17.014	π
TESLA	17.000	TME

Method

Tracking studies were done with different physical aperture limits in the wiggler sections to find the required aperture. The studies were done for all seven lattices. Tracking was done with MAD [3] with synchrotron radiation and damping. Particles were tracked for one damping time (which is slightly different for the different lattices). Tracking studies were done with a grid of particles at three different momenta (on energy and $\pm 1\%$ momentum deviation) and with sets of particles representing the injected positron beam with an energy spread of 1% and 2% [4]. The distributions are shown in Fig. 1. Round physical apertures were placed in the quadrupoles in the wiggler section. Physical apertures corresponding to a radius of 8, 10, 12 and 16 mm were used.

Results

Figure 2 shows the results for a grid of particles for the OCS lattice. It is obvious that apertures smaller than 16 mm significantly restrict the available acceptance. The tracking studies using grids showed very clearly that although the on-momentum aperture is comparable to the physical aperture in most cases, the off-momentum aperture often is significantly reduced below the physical aperture (in one case no particles at 1% energy deviation survived).

Figure 3 shows tracking results for the injected positron beam with a $\pm 1\%$ energy spread in the OCS lattice. The injection efficiencies for both the 1% and the 2% energy spread beam for all lattices are shown in Fig. 4. An efficiency of above 99% is desired as the injected beam power

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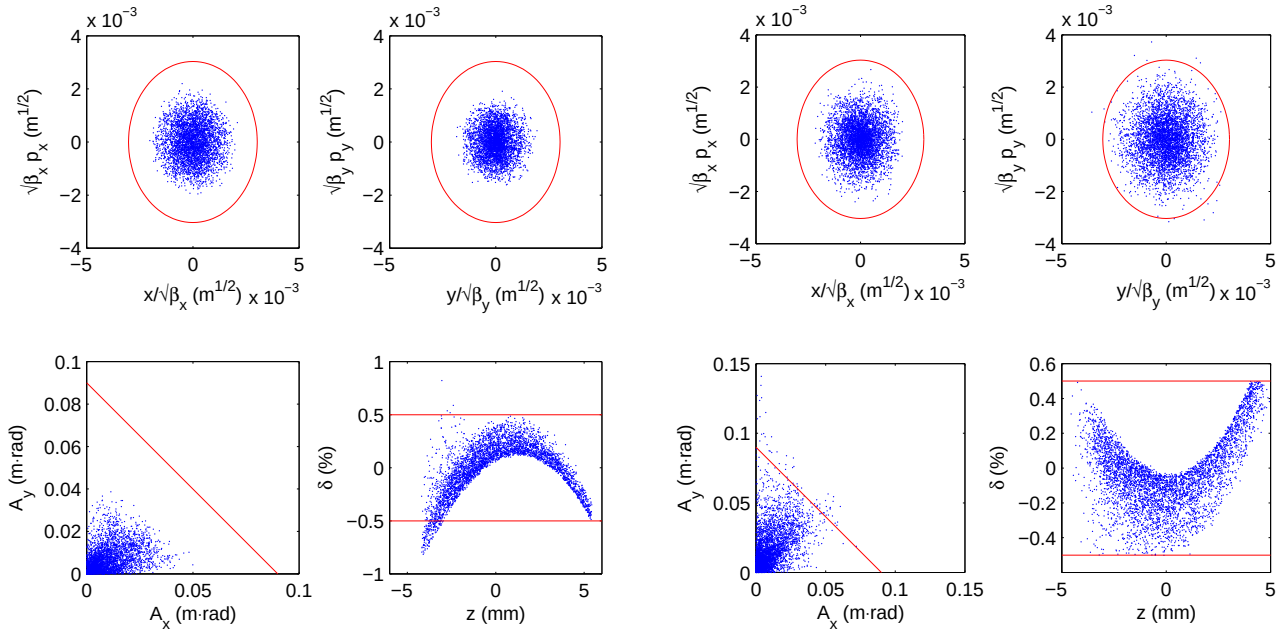

Figure 1: Distributions used in the tracking studies for 2% (left) and 1% (right) energy spread.

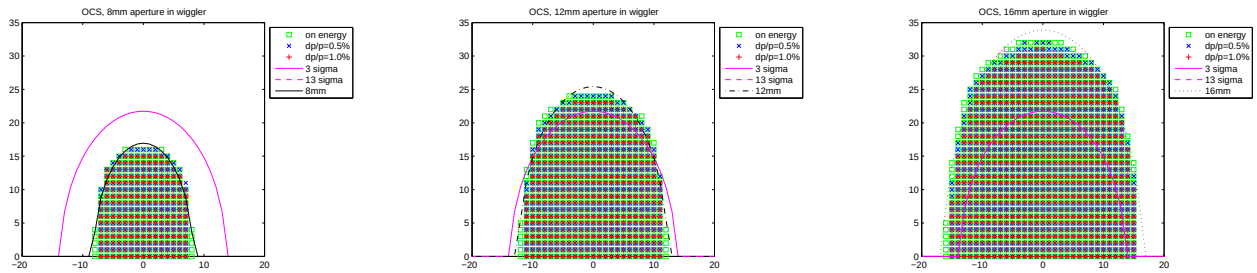

Figure 2: Tracking results for a grid of particles for the OCS-lattice.

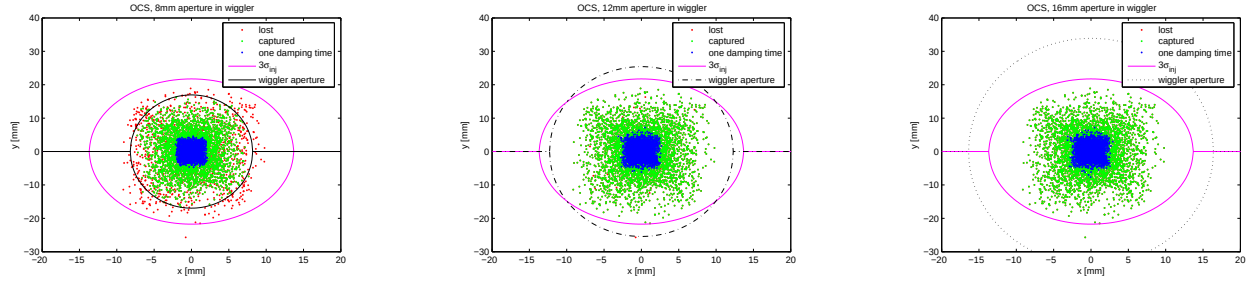

Figure 3: Tracking results for injected positrons for the OCS-lattice for a distribution with 1% energy spread.

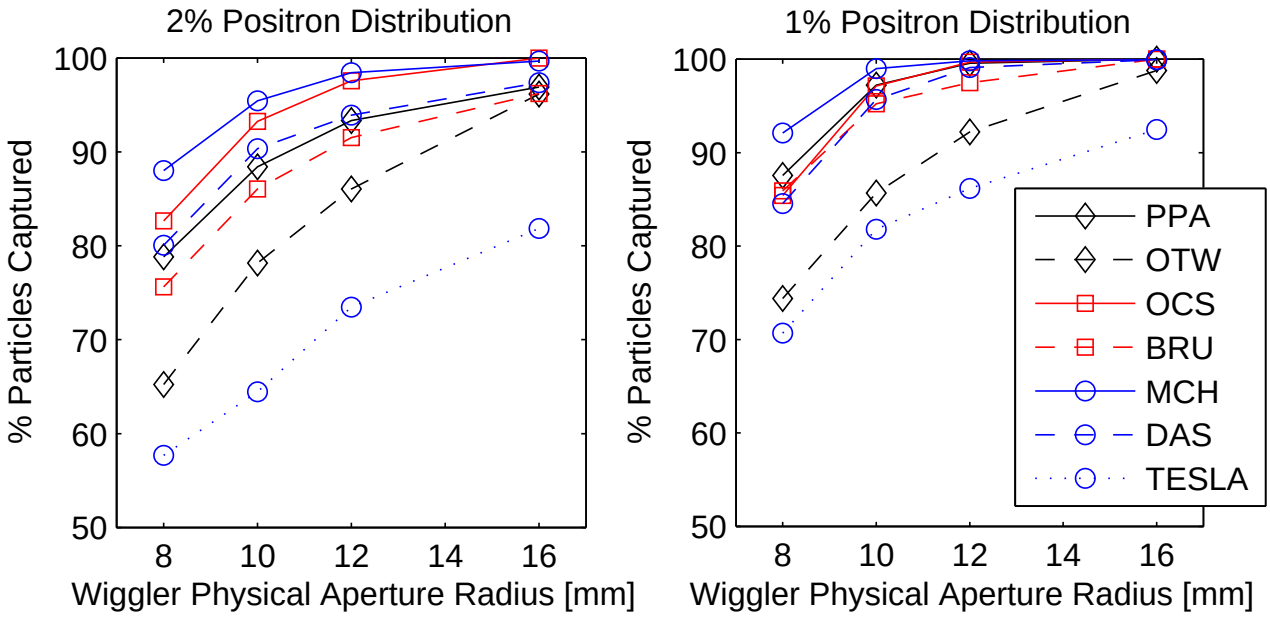

Figure 4: Injection efficiency for the different lattices as a function of physical aperture in the wigglers. An efficiency of 99% is desired.

is 220 kW, therefore even small losses can cause machine protection problems.

The distribution with 2% energy deviation corresponds to the initial design. After several lattices showed reduced performance at large momentum deviations, it was suggested to use a smaller energy spread but larger transverse injected emittance. Both distributions can be achieved with about the same amount of work on the positron source. The 1% distribution leads to a significantly better injection efficiency in all cases which led to it being used now in the current design.

CONCLUSION

Tracking studies have shown that the desired physical aperture of 8 mm half aperture in the wiggler magnets is not feasible because the injection efficiency would be too low. For most of the lattices studied, an aperture of 16 mm would be required although, for some, an aperture of 12 mm might be acceptable with an injected beam of 1% energy spread. Using the 2% energy spread distribution (which will not be used), the acceptance would even be worse as even at 16 mm aperture most lattices do not reach 99% injection efficiency.

REFERENCES

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[3] H. Grote and F. C. Iselin. The MAD Program, User's Reference Manual. SL Note 90-13 (AP) (Rev. 4), CERN, March 1995.

[4] The distributions were generated by W. Gai (ANL) and Y. Batygin (SLAC).