FIRST POLARIZATION CALCULATIONS IN MAD

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Abstract A new module has been added to the program MAD allowing the calculation of polarization levels in electron and positron storage rings. It is based on the program SITF developed at DESY. Its availability inside MAD offers the great advantage of allowing to use machine descriptions in MAD format, and to change single elements interactively, thus showing immediately the impact on the polarization level. Calculations are performed for thick elements, with alignment and field errors, and treat the depolarizing effects caused by quantum diffusion in energy, and by quantum excitation of vertical motion. They are based on linear spin-orbit coupling, and use a first order perturbative approach.

1 Introduction

The MAD (Methodical Accelerator Design) program [1] has been a useful and versatile tool for the development and understanding of accelerators over the last years, and has been used extensively in the LEP design and commissioning, and elsewhere. It is able to perform a great variety of calculations for circular proton (antiproton) and electron (positron) accelerators. Its main features are: hierarchical definition of beam lines, calculation of the linear lattice functions including chromaticity, closed orbit correction, matching of beamlines with given constraints, tracking of particles, calculation of beam parameters, construction and analysis of non-linear maps. All results, such as magnet excitation currents, Twiss parameters etc. can be printed or written into files for treatment by further independent programs. All relevant parameters, as well as particle trajectories, can be plotted through a GKS interface.

More recently, MAD has been rewritten [2] in order to take advantage of the memory manager ZEBRA [9] which is used by many experiments at CERN. The greater modularity thus achieved made it then possible to integrate the SITF program [3] as a module inside MAD.

2 SITF

The program SITF has been developed at DESY [3]. It is based to a large extent on the treatment of depolarization effects by Chao [5], with some additions from Mais and Ripken [6]. Starting from the formula of Derbenev-Kondratenko [7] for the level of equilibrium polarization, a purturbative first-order development of the Thomas-BMT equation [8] is used to calculate the average direction of the spin precession axis on the closed orbit, assuming linear coupling between the orbit and the spin parameters. In this case it is sufficient to "track" the particle through the successive elements around the ring, and to calculate the orientation of the spin precession axis at the end of each element. Field errors are taken into account by allowing each element to have its own strength parameters, and position errors are treated by the proper coordinate transformations at the entry and exit of each element.

Stand-alone SITF receives the machine description in binary form from the program PETROS [4] that was developed at DESY as well. This has the effect that each change in the machine description, be it only the strength or the position of one single element, requires a new pass through PETROS before it can be studied with SITF. In addition, the task of localizing specific elements in the PETROS format is sometimes tricky, since they are referenced by occurrence numbers which change whenever a slightly different optics is used.

3 Implementation in MAD

The conversion of SITF into a MAD module is performed in two steps. The first was finished at the end of last year and consisted in converting the code of SITF from IBM Fortran to ANSI Fortran, enabling it to run in single precision (Cray) and double precision (elsewhere), and in making it accept the MAD machine description. Otherwise, its own orbit calculations, and the internal data structure are kept. The second step will consist in making use of the MAD orbit calculations, and converting the internal data structure to the MAD structure based on ZEBRA. This second step will not influence the performance and the results, but is still necessary because of the currently excessive memory requirements which make it impossible to run MAD with SITF on the IBM computers at CERN. It is for this reason as well that the current version has not been distributed to outside users.

4 Calculations with SITF

The calculations presented below have been done on the Cray X-MP at CERN, and on an Apollo DN10000 workstation integrated with the LEP control system (see Table 1 for execution times).

The Cray usage is entirely in batch, and is good for fine scans over longer energy intervals. The DN10000 is slower than the Cray, but allows an interactive usage of MAD:

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	Cray X-MP	DN10000
ideal optics (LEP)	80 sec	265 sec
with errors (LEP)	88 sec	295 sec

Table 1: MAD-SITF execution times per 100 energy values. These values contain a fixed time for closed orbit fitting (4 sec on Cray, 20 sec on DN10000)

polarization calculations can be repeated with slight modifications of the optics currently stored in MAD, without having to restart the program. The very powerful MAD command language makes it particularly easy to perform these quasi on-line operations. This feature of MAD will now be used for the harmonic spin matching in LEP this Spring.

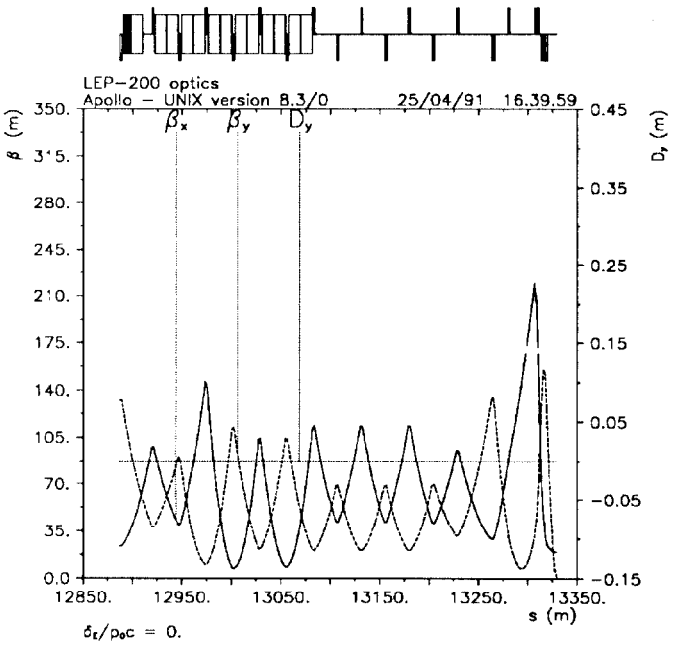

Figure 1: Twiss parameters of standard LEP-200 optics. Fractional tunes: $Q_x = 0.38$, $Q_y = 0.28$, $Q_s = 0.1$

5 Results

For one of the optics proposed for the energy upgrade of LEP, called W07HP24, a Richter-Schwitters type spin rotator has been matched at the interaction point number five (there will be no physics experiment at this interaction point as from the middle of this year). This experimental rotator will serve for polarization studies in 1993 or later, at the Z^0 peak. However, since the rotator cannot be removed nor the optics changed every time, it has to coexist with the optics for the higher energy that will be tried out at the same time.

Calculations were performed both for the undisturbed LEP-200 optics (Fig. 1), and the optics with the spin-

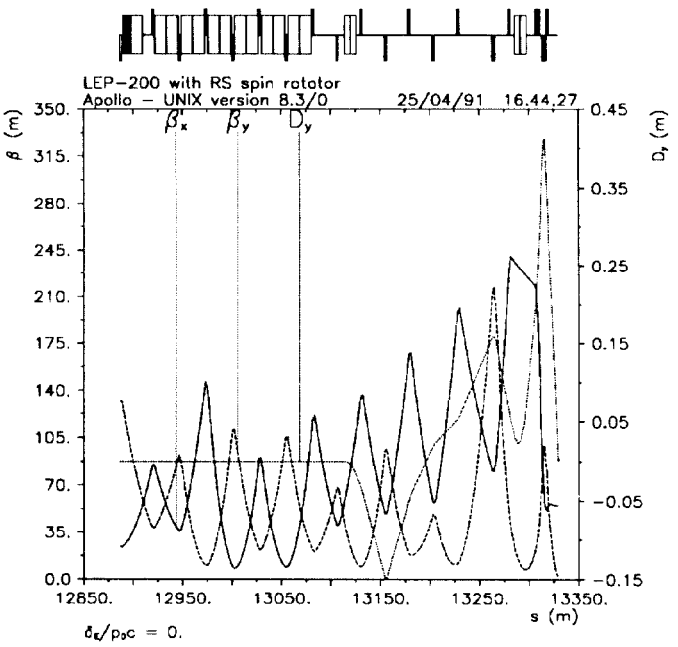

Figure 2: Twiss parameters with spin rotator. Fractional tunes: $Q_x = 0.28$, $Q_y = 0.18$, $Q_s = 0.1$

rotator (Fig. 2). As can be seen, the vertical dispersion is exactly equal to zero outside the insertion. The slightly increased beta-functions result from the enforcement of the spin matching constraints. The vertical orbit displacement (maximum 55 cm) for one half of the rotator is given in Fig. 3. Only the two double bend magnets, and ten quadrupole groups are shown.

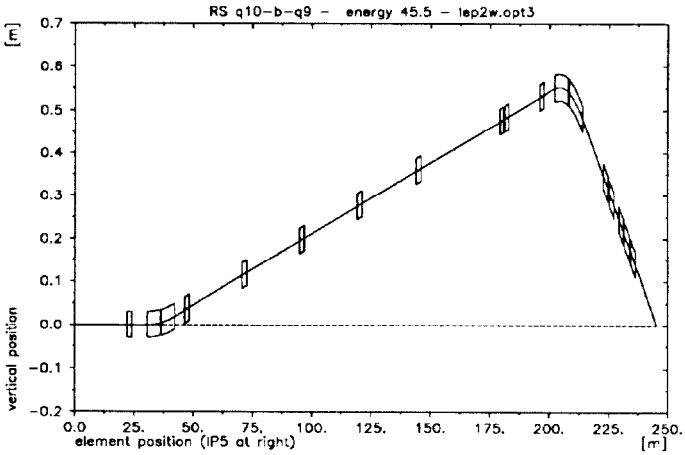

Figure 3: Layout of the Richter-Schwitters spin rotator at IP5 in LEP.

The polarization is shown in Fig. 4 for the undisturbed optics and in Fig. 5 for the optics with spin rotator in operation. In each case, the upper curve shows the polarization level with ideal optics, the lower curve the polarization with realistic (corrected!) errors applied to the element

positions and the magnetic fields. Obviously, the addition of these errors has a dramatic effect on the polarization level, whereas the difference between the optics with and without spin rotator is mainly due to the different tunes.

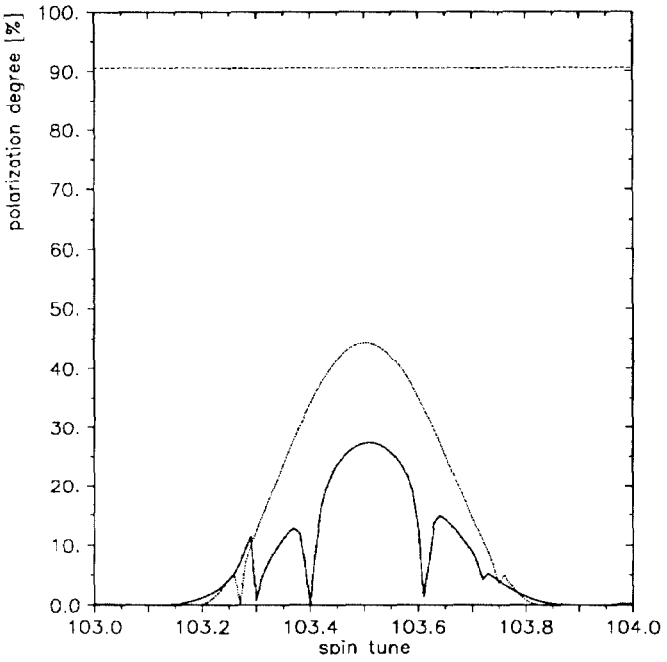

Figure 4: Polarization levels, no spin rotator; solid: standard optics with errors, dashed: standard optics without errors, dotted: rotator optics without rotator bend magnets

This can be seen clearly from the dotted curve in Fig. 4 which shows the polarization for the disturbed optics, but with the up and down bend magnets of the rotator switched off.

It should be stressed that the results presented here are the very first obtained, and that improvements are possible. On the other hand, the inclusion of higher order effects would certainly modify the picture.

6 Conclusion

First calculations with the new SITF module inside MAD of the polarization level of electrons and positrons in LEP show a dramatic effect of position and field errors, whereas the addition of a spin rotator does not change the levels significantly. Apart from the choice of suitable tunes, the correction of the orbit remains the crucial method to improve the polarization level in LEP.

References

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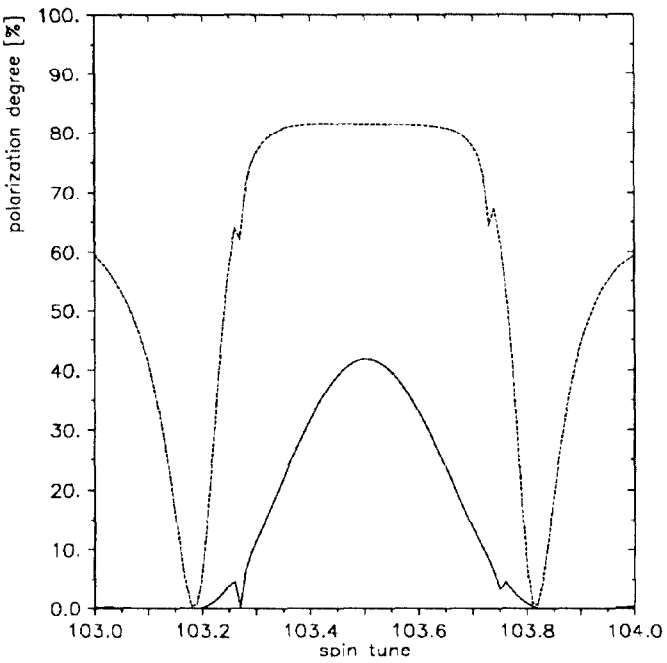

Figure 5: Polarization levels with spin rotator; solid: with errors, dashed: without errors

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