DR Deliverable 4: Report on Comparative Studies of Beam Based Alignment

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Abstract

This paper describes the accomplishment of the 4th deliverable of the Damping Ring (DR) Work Package.

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1. LETS

The low emittance tuning of the ILC damping rings is designed to preserve and recover the small emittances required for the operation of the linear collider.
The damping rings determine the smallest emittances achievable at the interaction point of the linear collider, and so the emittance achievable from the damping rings has a direct consequence on the luminosity of the entire machine.
There are many emittance diluting effects in the damping rings, which arise from a variety of sources. The low emittance tuning task concentrates on restoring the design emittances in the machine, that are diluted by mechanical and magnetic field errors in the ring.

The original goal of the LETS task was to simulate and design an adequate Beam Based Alignment algorithm for the damping ring. This is a related, but slightly different goal than is described here. As part of the wider international community, it was decided early on that the work on the DRs should instead be focused on the wider problem of tuning algorithms to achieve the required extracted emittances. This decision was taken in light of a lack of international effort in this area. Moreover, the original proposal called for additional effort at both STFC and DESY, and this became unachievable within the timescales of the project – recruitment at STFC was hampered, and the DESY effort was re-directed to ion studies.

As part of EUROTeV, the LETS task therefore had several redefined goals:

- Simulate and analyse error tolerances for the various Damping Ring designs
- Design and simulate an adequate tuning algorithm for the difference DR designs.
- Perform (if appropriate) machine studies with the proposed tuning algorithm
- Define the required number and positioning of the applicable diagnostics for the chosen tuning algorithm.

Error Tolerances for the different designs

During the 4 years of the EUROTeV design work there have been over 10 different designs for the ILC damping rings. Studies in both analytical and simulation have been performed for all of these designs, and presented to the wider community. This work has helped in deciding which designs are viable for the final design.

Analysis of the machine tolerances allows a relatively simple method of comparing different machines without resorting to designing and implementing a machine specific correction algorithm, and as such is an important initial analysis of a new machine design.

Tuning algorithm design and simulation

Tuning algorithms were designed for most of the different DR designs, and certainly for all of the designs after the 7 initial designs. The tuning algorithms are used to minimise the extracted emittance from the DR in the presence of mechanical and magnetic errors in the lattice to less than the design value of 20nm-rad, normalised.
An initial assessment of the possible tuning algorithms showed that the use of a response-matrix based method, using skew-quadrupoles for both vertical dispersion correction and coupling correction was optimal.

The number and positioning of the various correctors was also studied. A “minimum” machine, with a limited number of correctors, was created and used to set the lower limits on numbers of correctors required for machine operation.
The correction algorithm designed for the DR designs has been shown to produce extracted emittances at the required level for the linear collider luminosity goals, under realistic error conditions in the machine.
The algorithm performance has also been studied under the influence of long term ground motion in the DR. The simulation is used to understand the long term evolution of the extracted emittance over time, and gives details on the required correction timetable.

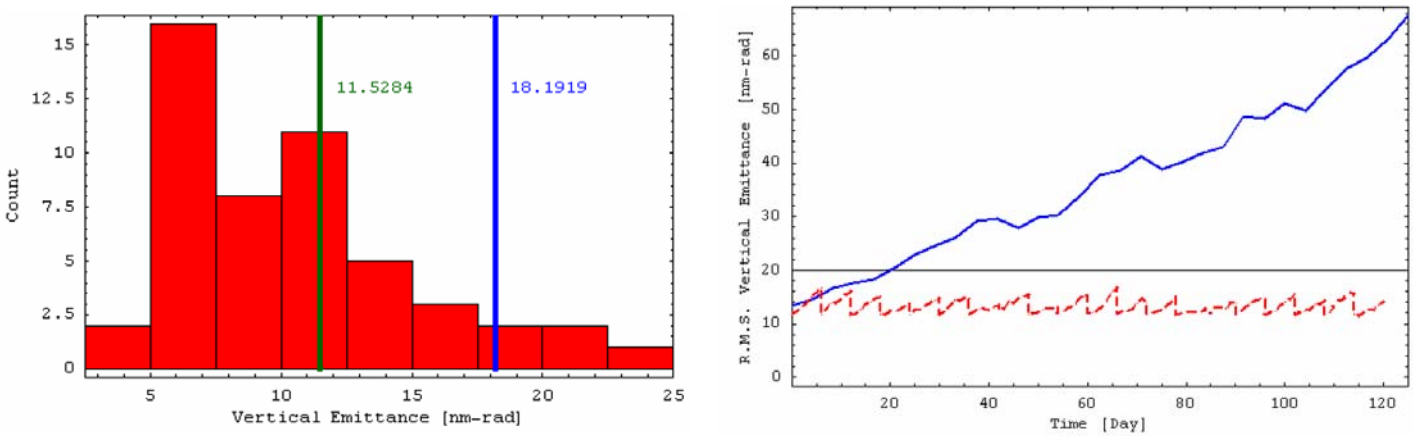

Fig.1 (left) Histogram of rms. (green) and 95% confidence (blue) limit extracted emittances from the damping ring design after LET using the best algorithm and (right) Evolution of the emittance under long term ground motion effects with correction every 6 days (red) and without correction (blue).

Machine Studies

Machine studies of the proposed tuning algorithm were never performed due to time schedules involved with the limited number of test accelerators around the world. However, simulation studies have been performed for the CesrTA ring, and machine studies, based on the work performed in EUROTeV, will hopefully be undertaken at the beginning of 2009.

Diagnostics & Correctors

As part of the EUROTeV work, studies were performed on the required number of diagnostics and correctors in the damping rings. Due to cost constraints on the design of the final machine, studies were concentrated on finding the minimum number of beam diagnostics and correctors possible to achieve the required extracted emittances.
This work was used to design methods for determining locations of beam position monitors, and associated correctors, for a variable number of monitors in an optimum fashion.
Studies were also performed on how to minimise the required number of skew-quadrupoles, used in the tuning algorithm to correct vertical dispersion and coupling, with non-linear optimisation techniques. The results show that the minimum number of skew correctors required is much lower than the current designs.

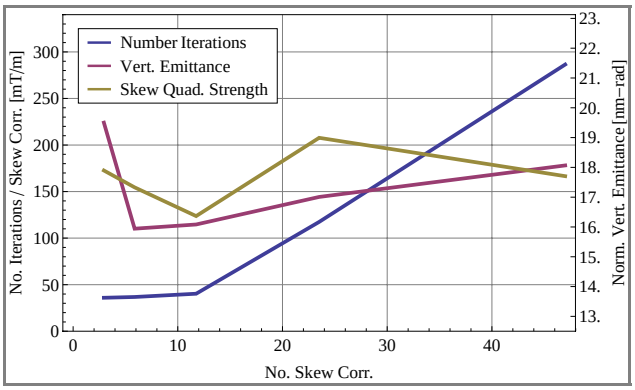

Fig.2 Analysis of the minimum number of skew quadrupoles required to still achieve 20nm-rad extracted normalised emittance.

Acknowledgement

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