Precision Pointing and Stability Control of the Future Linear Collider Quadrupoles

C. Collette[1,2], S. Janssens[1,2], K. Artoos[1], P. Fernandez-Carmona[1], A. Preumont[2]
[1]*European Organization for Nuclear Research (CERN, Switzerland)*
[2]*Université Libre de Bruxelles (ULB, Belgium)*

christophe.collette@cern.ch

Abstract

This paper presents a simple model of the future linear particle collider CLIC. Adopting an integrated approach, it is proposed to merge the controller of the beam of particles and the controller of the sensitive electromagnets into a single controller, allowing interactions between the two subsystems, and performances optimization. The interest of such an approach has been confirmed by experimental results, showing that the same supports can be used alternatively to stabilize the electromagnets, or to re-align them with a nanometer precision.

1 The future linear Particle Collider CLIC

In the Compact Linear Collider currently under study at CERN, electrons and positrons will be accelerated in two linear accelerators to collide at the interaction point with an energy of *0.5* to *3 TeV* [1]. To acquire such a high energy, the total length of the machine will be *48 km*, and constituted of a very large number (more than *20000*) of identical modules (Fig. 1), the function of which is to accelerate and focus the beam of particles, towards the final section where the collision takes place.

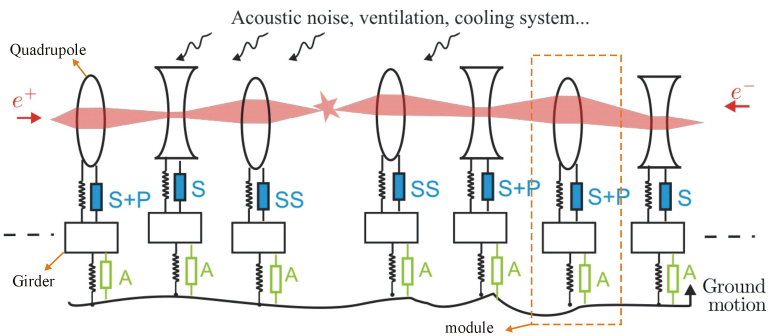

Figure 1 Schematic view of the CLIC under study at CERN.

A simplified layout of the final section, or *final focus*, is shown in Fig. 2. The two beams (e^+ and e^-) are focused by strong electromagnets (Quad A and Quad B), mounted on big cantilever beams to fit in the detector.

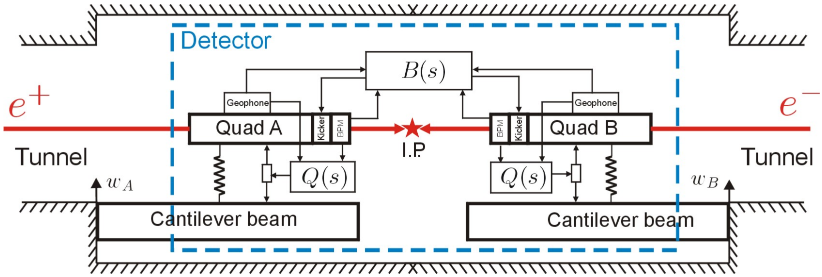

Figure 2: Simplified layout of the final focus of a linear particle collider.

These requirements are tackled from two sides. The former is an active stabilization of the electromagnets (with Q(s)) from the external disturbances. It uses vibration sensors (geophones, capacitive sensors, lasers) to stabilize the quadrupoles using piezoelectric actuators. It works continuously. The latter is a stabilization of the beam with B(s), called Beam Based Feedback (BBF). From the measurement of the position of each pulse, it modifies the magnetic field applied to the next pulse with beam correctors (kickers) to steer the beam and maintain a high collision luminosity. As there is only one pulse every 20 milliseconds, it works at 50 Hz. The interactions between the two controllers are further illustrated in the Fig. 3.

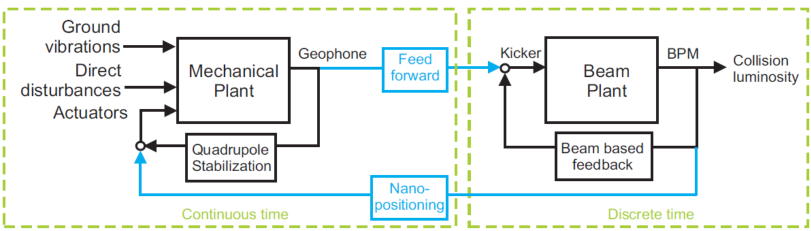

Figure 3: Block diagram of the final focus of a linear particle collider.

2 Control strategy

Up to now, these two subsystems have been studied separately. Results are commonly assessed by multiplying the transfer functions of the two closed loop subsystems. However, in order to improve the performances of the machine and eventually reduce its cost, the information contained in one subsystem can be used in the other subsystem, and conversely. For example, the beam control strategy can rely on the geophone measuring the vibrations of the quadrupoles, or the information from the Beam Position Monitors (BPM) can be used to change the position of the heavy quadrupoles. This paper explores the possibility to combine this last option with the capability to guaranty the stability of the quadrupoles, using the same active mounts. To this purpose, an original concept is studied.

3 Experiments

A picture of the test bench is shown in Fig. 4(a). It consists of a heavy mass, mounted

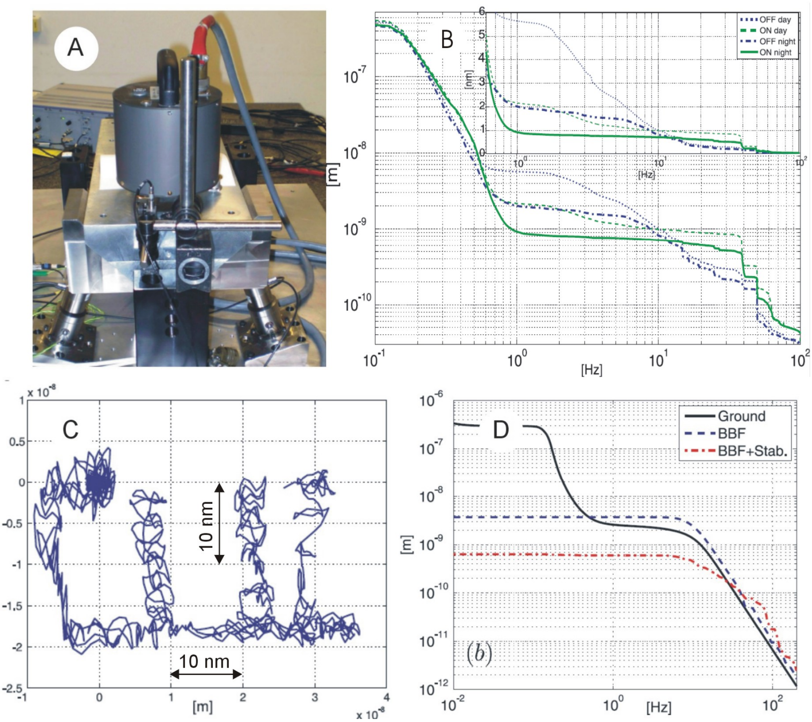

Figure 4: (a) Test bench; (b) Transmissibility between the motion of the ground and the quadrupole; (c) Illustration of the nano-positioning capability; Integrated RMS of the ground, the beam jitter with B(s), the beam jitter B(s) and Q(s).

on inclined piezoelectric legs. The vibrations of the ground and the mass are measured with seismometers. The control strategy adopted to stabilize the mass is based on the *sky-hook spring* method. The test bench s placed in a very quiet environment. Figure 4(b) compares the integrated RMS vertical displacement of the mass when the stabilization is turned ON and OFF, during the day and during the night. One sees that, above 1Hz, the active control reduces the RMS value at 1nm. As the main sources of excitation are contained in a frequency range below 20 Hz, the stability performances are not affected by the lack of passive isolation at high frequency. The positioning capability is provided by the inclination of the legs and a guide, offering an authority in both the vertical and lateral direction with a parallel mechanism. This is illustrated in Fig. 4(c) showing an example of trajectory imposed to the mass, and measured with capacitive gauges. In order to evaluate the effect of the quadrupole stabilization on the vibrations of the beam, a PID controller has been taken for B(s) [2]. Taking a simple model of the ground motion, Fig. 4(d) shows that, when the mechanical stabilization is turned ON, the resulting integrated RMS vertical jitter of the beam is reduced by a factor 5.

4 Conclusions

Firstly, this paper has justified the usefulness to adopt an intagrated approach to combine positively the various controller active in a linear particle collider. Then, an a strategy has been presnted to stabilize the quadrupoles, and allow to move them with a nanometer prevision. This strategy, validated experimentally, offers new perspectives to develop a global controller for future linear colliders.

Acknowledgments:

The research leading to these results has been jointly funded by the European Commission under the FP7 Research Infrastructures project EuCARD (grant agreement No.227579) and the Brussels Capital Region under the programme Brain Back to Brussels (2010).

References:

[1] CLIC project: http://clic-study.web.cern.ch/clic-study/

[2] D. Schulte, C. Collette, J. Pfingster, and A. Jeremie. Some comments on the feedback and feedforward at the IP. In *CLIC Stabilization day*, 8 December 2009, Geneva.