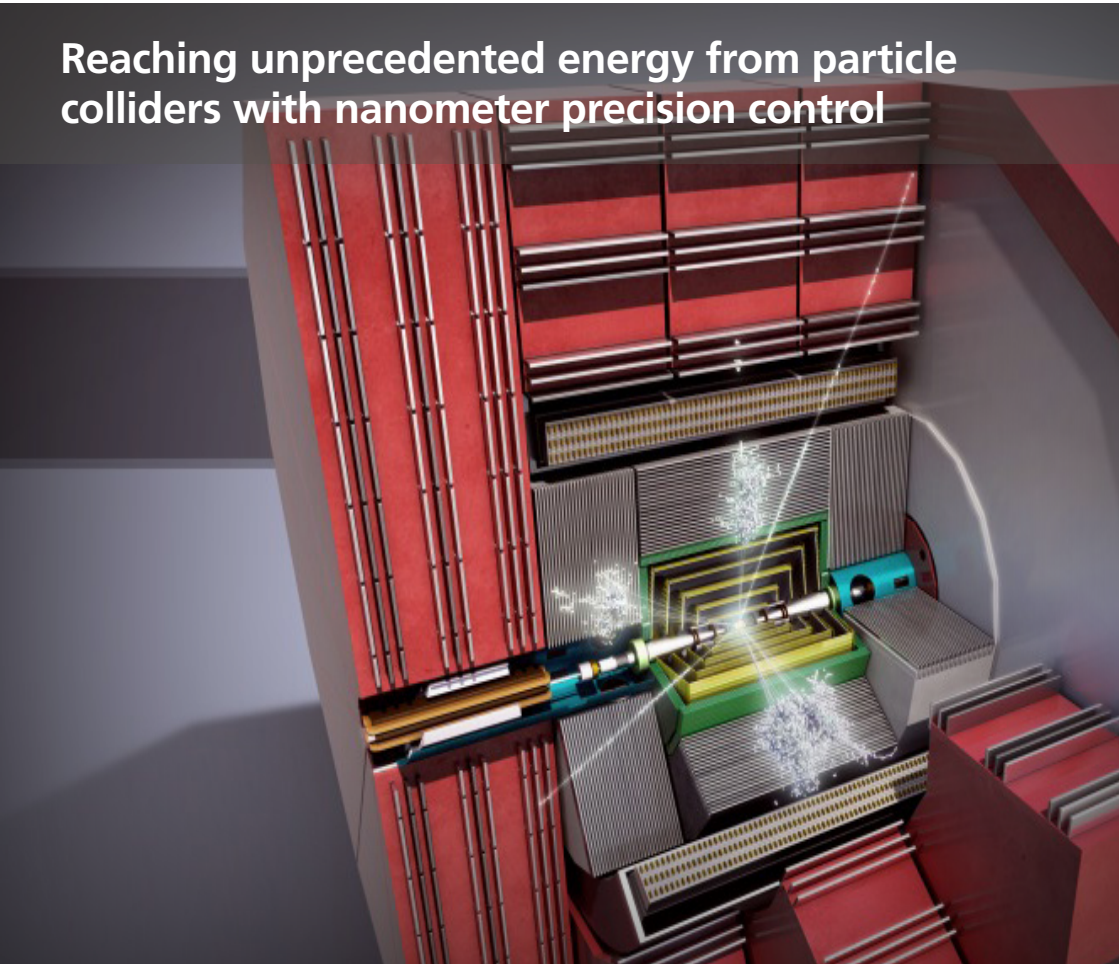
CERN

Reaching unprecedented energy from particle colliders with nanometer precision control



speedgoat
real-time simulation and testing

CERN is using Speedgoat products to develop controllers for particle beam alignment for the next generation particle accelerators. With such nanometer precision, the new linear collider will reach unprecedented energy from electron and positron collisions.

The European Organization of Nuclear Research (CERN) is a leading international research institution for particle physics. The CERN doctoral program, Particle Accelerator Components' Metrology and Alignment to the Nanometer scale (PACMAN), aims to improve the accuracy of alignment for the components to be installed in the next generation of particle accelerators.

Compact Linear Collider

The Compact Linear Collider (CLIC) is a particle collider that will reach unprecedented energy from collisions of electrons and their antimatter twins, the positrons. Unlike circular machines, linear colliders do not suffer from synchrotron radiation which causes undesired energy loss. CLIC will operate electron beams of nanometric size and produce a high density of collisions at the nanoscale interaction cross section. The overall dimension of the machine will be about 48 km long, with two straight sections of about 24 km each facing each other. Over 4000 quadrupole magnets installed along the machine will focus the beam.

PACMAN Prototype

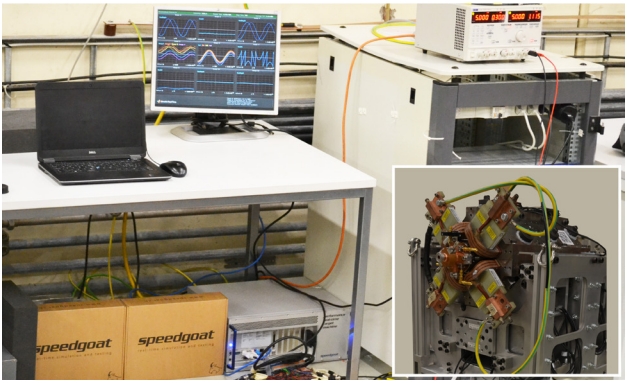
To demonstrate active position control for the quadrupole magnets, PACMAN engineers developed a prototype to perform the following distinctive tasks:

1. Nano-positioning: In order to compensate for the temperature changes within the tunnel and low frequency movement of the ground, nanoscale adjustments are made based on input from beam position monitors and linear encoders linked to each magnet.

2. Magnet vibration isolation: Complementary to nano-positioning, actuators stabilize the magnets in spite of ground motion and vibrations from the water cooling system.

3. Beam-based alignment: Aligning the beams based on measurements from beam position monitors and using a pilot beam as a reference.

To guarantee a high-density of collisions, two major challenges must be addressed: the first is the tight alignment tolerance of the critical components of the accelerator, and second is the control of the quadrupole magnets. The PACMAN team used Speedgoat real-time solutions to address the control challenges.



Prototype for active positioning control of the CLIC quadrupole magnets

Simulation & Testing

The PACMAN team used a Speedgoat Performance real-time target machine to compare the performance of several control strategies for nano-positioning. Signals from optical encoders and strain gauges were acquired by the target machine, and it's outputs were used to drive the piezoelectric actuators. The data was recorded in compact files using the data logging capability of Speedgoat systems and was easily transferred to a laptop for further processing.

PACMAN engineers were able to easily design and integrate feedback controllers to quickly optimize the step response time of the system. Tuning the controllers was very efficient using MATLAB tunable parameters in the Simulink blocks while running the model in external mode. They found that the combination of active damping and proportional-integral feedback control reduced the step response time by a factor of five in comparison with the classical proportional-integral feedback control alone.

Speedgoat's Value Contribution

"The Speedgoat system is intuitive to use. The compatibility with MathWorks products makes it a user-friendly and powerful tool for motion control testing."
- Mr. Tshilumba

David Tshilumba
CERN Fellow
Material & Mechanical Engineering Section, CERN

Artistic representation of the Compact Linear Collider (CLIC)

CERN

CH-1211 Geneva 23
Switzerland

www.cern.ch

Speedgoat products used

- Performance real-time target machine
- IO131 analog I/O module
- IO317-45K FPGA I/O module
- BiSS FPGA code module
- EnDat FPGA code module
- Quadrature Decoder FPGA code module

MathWorks software used

- MATLAB®
- Simulink®
- MATLAB Coder™
- Simulink Coder™
- Simulink Real-Time™

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