Popular Science Summary
Detecting smaller and smaller particle beams

Large particle accelerators are usually used in the research of fundamental particle physics. The International Linear Collider (ILC) project, proposed to be built in Japan, consists of two large linear colliders where electromagnetic fields are used to accelerate and guide protons and electrons to nearly the speed of light. These particles are aimed at each other to create a collision, and then scientists observe what particles are created. Since these machines require incredible precision, components are required with extremely tight tolerances.

This thesis focuses on one of the key components allowing a proper analysis of the particle beam: the beam position monitors (BPMs). These detectors allow one to determine the position of the beam, so it can be properly guided along the accelerator path until the collision. In general, one wants to keep the beam as centered as possible inside the pipe. Because the size of the beam is so small (only 1/100th of the width of a human hair!) and the particles must stay grouped closely together through their entire path, the BPM needs to detect the position of the beam with extremely high resolution. This resolution is determined by the smallest distance between the center of the pipe and the beam that the BPM can detect.

Many kinds of BPMs have been developed with different goals. When precision and resolution are essential, cavity BPMs are the best option. These BPMs consist of a cavity (usually cylindrical) placed along the beam pipe. When charged particles pass through the BPM, their electromagnetic fields remain trapped in the shape of the cavity. The beam will create different electric and magnetic fields inside the cavity that vibrate at different frequencies depending on its exact position. These frequencies can be measured to identify the beam's exact position. As easy as it seems, the detection of these signals is not always straightforward. The electromagnetic field that the BPM is trying to identify is called dipole mode, and its signal is usually contaminated with noise. Once this noise is removed the high-resolution reading of the position can be determined.

This paper focuses in particular on how these detectors work. Part of the study focused on how the geometry of the cavity influences the vibration frequency of the electromagnetic fields. We found that the geometry of the detector can also be modified by adding components to reduce noise. A software was used to simulate fields that would be observed by the BPM allowing us to confirm our theoretical predictions, and different calculations in the software were used to obtain the dipole mode that is used to read the beam position.

Some areas could use more research, like how the material of the cavity influences the performance of the detector, or better methods to reduce noise in the detected signal. All of these studies may contribute to our overall goal of increasing the resolution of our BPM while keeping production costs as low as possible.