

Calibration: The Unsung Hero of Ultra-Cold Physics

Have you ever wondered how cold it can get? On Earth the coldest ever measured temperature is -89.2 degrees Celsius at Vostok weather station in Antarctica, a place so frigid that your breath freezes midair. However, even this pales in comparison to the wider universe.

The average temperature of the universe is approximately -270.5 degrees Celsius or as scientists say, 2.7 degrees Kelvin. In a lab however, scientists can achieve temperatures colder than deep space itself. At temperatures nearing 0 degrees Kelvin, or absolute zero, matter behaves in extraordinary ways. Liquids flow without friction and ordinary physics gives way to the mysterious quantum realm. One of the ways scientists can achieve these cold temperatures to study such fascinating phenomena is dilution refrigeration.

Dilution refrigerators are not your average kitchen fridges. They can reach temperatures just thousandths of a degree above absolute zero. Thus, they are intricately engineered machines that exploit quantum mechanical properties of a special mixture of liquid helium. At the heart of the dilution refrigerator, a mixture of ^3He and ^4He undergoes a quantum "dance." Below 2.17 K, the mixture separates into two, one rich in ^3He and another rich in ^4He or rather, dilute ^3He . This interplay between the two creates the ultra-cold environment scientists need for research.

The dilution refrigerator relies on two trusty thermometers the Cernox and the ruthenium oxide, or RuOx sensors. The operating temperatures are very extreme, stretching the measuring capabilities of these thermometers to their limits. This means they must be calibrated with the utmost precision when tested under these conditions. In my research project I calibrate these sensors so that they read reliable results under such extreme temperatures. I first kickstart the dilution refrigerator to get us to the operating temperatures. Once here, using a calibrated RuOx sensor, I track the resistance measured on the Cernox. As resistance is directly related to temperature, I can reliably calibrate the Cernox to the low temperatures encountered in a dilution refrigerator. In essence, I will tell the Cernox sensor what "cold" really is. This is a delicate and meticulous process, but an absolutely necessary and crucial one.

Getting the temperature right when investigating phenomena in the milli-Kelvin regime is crucial for scientific research that utilizes dilution refrigerators. Especially in the context of superconductivity, one of the hottest (or rather, coldest) topics in modern physics. Superconductivity is the phenomenon where a material loses all electrical resistance when cooled below a certain critical temperature, allowing electric current to flow indefinitely without losing energy. It can revolutionize the way we store and transmit energy, allowing power grids to waste virtually no energy. It would also revolutionize the way we travel, permitting ultra-fast maglev trains.

Supervisor: **Elizabeth Blackburn**

Thesis project work 15 hp on Evaluation of Thermal Sensor Calibrations Below 1 K For a Horizontal Dilution Refrigerator in a Cryomagnet (2025/26)

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In short, calibrating thermal sensors is a technical necessity. It's the difference between knowing and guessing in one of the most sensitive areas of modern science. Without accurate calibration, dilution refrigerators would be unreliable, and the ultra-cold world of quantum physics would be built on shaky foundations.

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