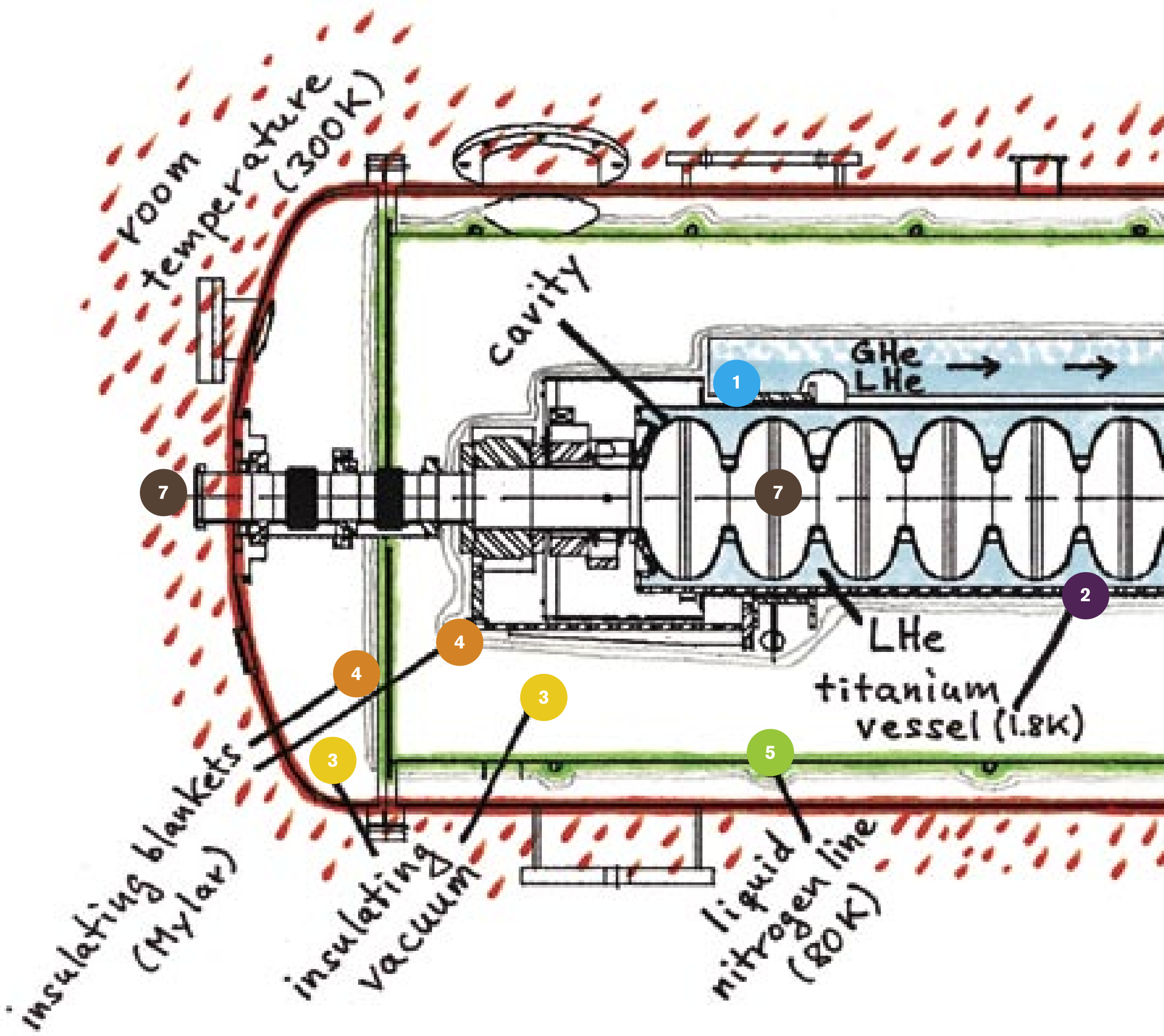
Cavities propel charged particles by transferring energy from electromagnetic waves to the particles, speeding them up. Superconducting cavities are made of material that can conduct electric currents without resistance at a very low temperature. To cool such a cavity close to absolute zero, engineers design cryogenic vessels that submerge cavities in a bath of liquid helium. The proposed International Linear Collider will use 16,000 superconducting cavities made of niobium, and scientists around the world are working on the cryogenic system needed to keep the cavities cool.



3

Vacuum—air at greatly reduced pressure—is a great insulator, conducting much less heat than air at normal pressure. This cryogenic vessel operates at a vacuum of 15 torr, a pressure about 50 times lower than normal atmospheric pressure.

4

Up to 40 layers of aluminized Mylar film, a material also used for helium balloons, cover the copper shield and the titanium cylinder. The resulting blanket, known as superinsulation, reflects heat transferred in the form of infrared radiation.

5

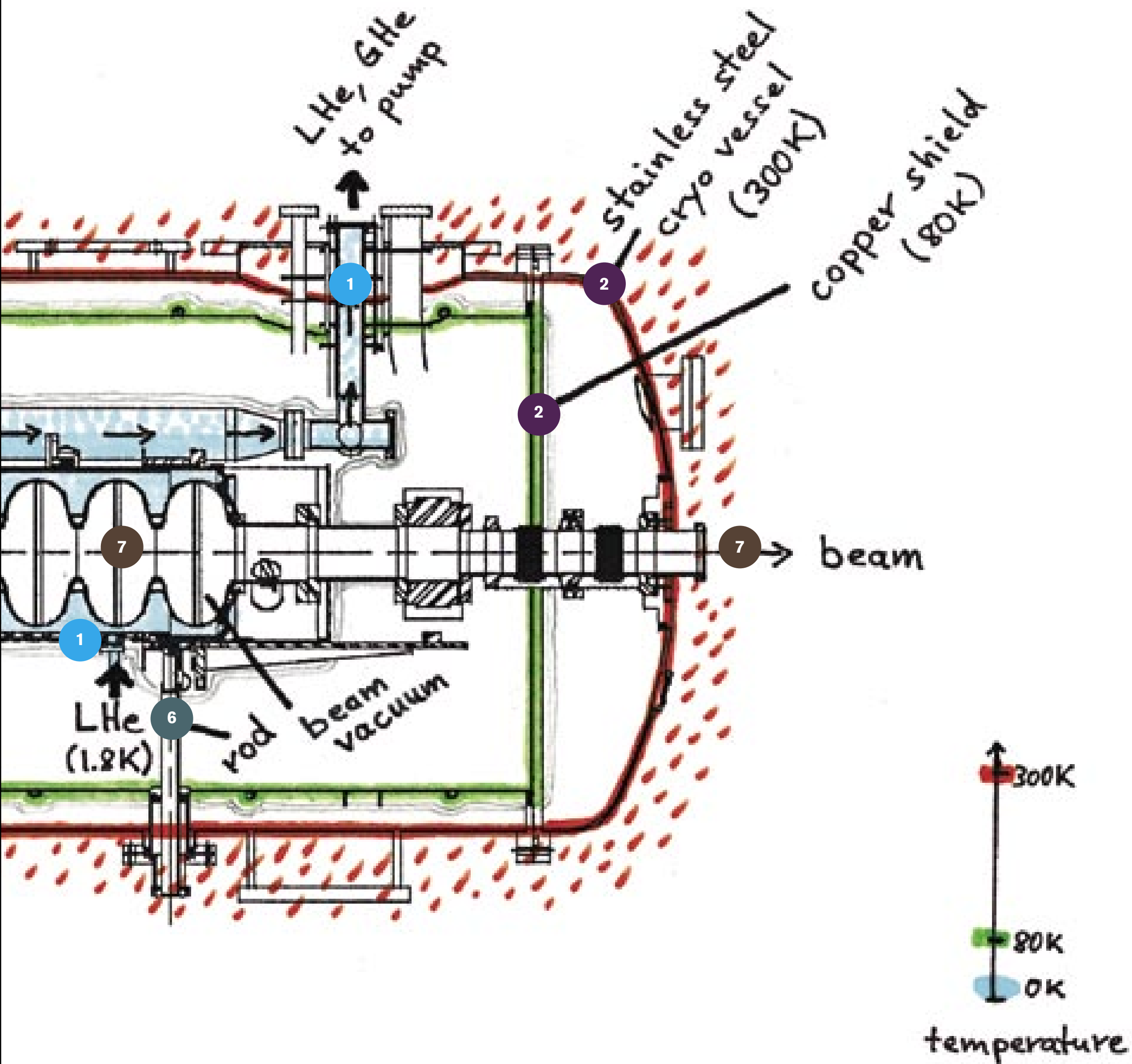
Liquid nitrogen keeps the temperature of the copper shield at 80 K. The nitrogen flows through a thin pipe that winds around the copper structure. Since copper is a good heat conductor, only a few windings are necessary to carry away excess heat.

1

This cryogenic vessel, used for testing, cools a single ILC cavity to 1.8 Kelvin, or minus 456 degrees Fahrenheit. The cavity, about three feet long, sits in a cylinder filled with liquid helium (LHe), which keeps the cavity ultracold. A steady stream of liquid helium enters the cylinder from below and exits it at the top, carrying away excess heat. As the helium absorbs heat, some of the liquid evaporates and turns into gas (GHe), rising to the top. Together with warmed-up liquid helium, the gas returns to a cryogenic system that cools the helium back to 1.8 K.

2

Protecting the inner, coldest part of the cryogenic vessel from heat are three shells separated by vacuum. The outer shell of the vessel, made of stainless steel, is at room temperature, or about 300 K. The innermost shell of the vessel, made of titanium, is at 1.8 K, the temperature of the liquid helium coolant. An intermediate shell, dubbed the copper shield, reduces the heat flow between the outer and inner shells. The shield is cooled to 80 K. The vacuum between the shells reduces the transfer of heat due to air and helium gas inside the cryogenic vessel.



6

When cooling the cavity from room temperature to 1.8 K, the length of the cavity shrinks by a few millimeters. Yet the exact positioning of each cavity is extremely important to make an accelerator with thousands of cavities work. A fiberglass rod, which fits precisely into a hole at the bottom of the titanium cylinder while conducting almost no heat, allows for positioning the cavity with greatest accuracy.

7

Electromagnetic waves accelerate a particle beam straight through the center of the cavity. To produce the best particle acceleration, the interior surface of the cavity must be highly polished and without impurities. Pumps remove the air from interior of the cavity to keep the surface clean and to minimize the scattering of the beam by air molecules. The vacuum inside the cavity has a pressure of only a millionth of a millitorr.

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