MARKUS KLUTE: Welcome back to 8.20 Special Relativity. In this section, we're going to talk about particles and accelerators. And we use the Large Electron-Positron Collider at CERN as an example. LEP, the Large Electron-Positron Collider, was a collider which was operated in the late 1980s up to the year 2000 at center-of-mass energies from 91 GeV up to 209 GeV.

These energies were used to probe the Z boson to produce pairs of W boson and also to look for the Higgs boson, which didn't quite work because its energy wasn't quite sufficient. The 27-kilometer over a 16-mile circumference collider is now the home of the Large Hadron Collider at CERN. And it's being used there to collide protons with protons.

LEP had four experiments, ALEPH, DELPHI, L3, and OPAL. And I was happy to study data from the particle as part of my undergraduate thesis. So this was very good memories there.

But that's not the topic today. So the topic today is to find out how quickly, how fast the particles in the collider are moving when we know the center-of-mass energy. So we know the center-of-mass energy to be 209 GeV. We know that the energy in the beam is half of that, 104.5 GeV.

So now to figure out how fast the electrons are moving-- the electrons and the positrons-- we can use our relativistic total energy for the electron or for the positron, which is the kinetic energy plus the rest mass of the electron or positron, which is M0 gamma times c square.

So with a mass of 511 KeV over c square, and this energy of 104.5 GeV, this results in a gamma factor of 200,000. And if you do the math, you'll find that electrons and positrons are almost moving with the speed of light. They're moving with the speed of light [INAUDIBLE].

A fun additional fact is we are working right now on proposing a even larger collider, which will then allow us to efficiently go up to energies of 350 GeV. And that collider then will be able to study the Higgs boson with precision but also look at [INAUDIBLE] production-- [INAUDIBLE] production in these kind of colliders.

Another fun fact is that CERN, the collider, which is about 100 meters under the surface, is spanning two countries, Switzerland and France. And so each particle, lep, when we make the lep, makes about 11,200 leps per second. That means that there is about 44,800 border crossings for an electron and positron. So they always constantly have to show their passport when they're moving around in LEP.

To look at a second example here with a small accelerator, we can accelerate electrons through an electrostatic potential of 511 kilovolts or 0.511 megavolts. The total energy then is, again, the kinetic energy plus the rest energy, which is, in this example, 4.511 MeV plus 0.511 MeV.

And so here we find the gamma factor of 2 and a velocity of 0.866. So even in this smaller electrostatic potential of 500 kilovolts, we find that electrons are moving with very high velocities with velocities very close to the speed of light.