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KLUTE:

Welcome back to 8.701. So in this section, we talk about calorimetry. In contrast to the discussion of tracking detectors, here what we're trying to do is measure the energy of the particles. And we do this by basically destroying them. The underlying content is rather straightforward. We have a particle. And we put a piece of material in front of it, such that it slams into it, and the energy deposited by the particle is the energy, the measurement we try to undertake.

So in nuclear and particle physics, that is exactly what we refer to as calorimetrics. So the detection of particles for measuring the properties through the total absorption in the block of matter. The common feature, or the central feature, is that the measurement is destructive.

So again, in tracking detectors, we try to minimally disturb the particle and in calorimetrics, we try to destroy them.

The exception to this might be a muon which might at high energies deposit only a small fraction of its energy in the calorimeter, or a neutrino, which just flies through without having any interaction. But the purpose is really to measure energies by destroying the particle. And it's widely used in all kinds of areas of particle and nuclear physics. Neutrino experiments, proton decay experiments, cosmic ray detectors, collider experiments, and so on.

And in collider experiments specifically, the idea is to build the detector such that it completely surrounds the interaction region, such that you don't lose energy from the collision just passing through an uninstrumented region.

The detection mechanism can vary quite a bit. We use scintillators a lot. We use silicon in some modern detectors. With ionization, we use Cherenkov detection. We use sometimes cryogenic detectors, which are very sensitive to very small energy depositions, and they can be quite useful. They are used in dark matter experiments or on neutrino [INAUDIBLE] decay experiments like so.

Again, conceptually, you can differentiate between homogeneous calorimetrics and sampling calorimeters. The homogeneous calorimeters, basically the entire absorbable material is equal or is the same as the detector material. So an example for this is lead glass, which is often used.

So what you do then in the calorimeter is you induce electromagnetic and nuclear showers and then the energy of the incoming party is converted into photons. And then what you need is a photodetector, which then measures the number of photons coming out of your detector material.

For this to work, the detector needs to be transparent. Alternatively, one can use sampling experiment, sampling detectors, where you have the heavy material being used in order to induce a shower and then the detection material in order to count, again, the number of photons.

So homogeneous calorimeter have typically very good energy resolution. And the reason for this is that nothing gets lost. Everything is being measured in the absorber, which is the detector. But that leads then to some limitations.

For example, that the granularity of the detector is typically limited. And then there's no longitudinal information about the shower development. You basically have one block. For example, a left blockage is shown here, the tungsten block, which is shown here, are used for the measurement.

So you produce photons, and so then the photons need to be measured. And then that's done with photodetectors. Here, the requirements, the range of requirements, is quite big. Sometimes you want to be able to measure every single photon so the quantum efficiency needs to be quite high.

In other detectors, you need to be able to put this detector in a radiation hot environment. And so that then changes. The main types available are the old-fashioned photomultiplier tubes, which actually become quite sophisticated, PMTs. There's gas-based photodetectors. There's solid-state detectors, which are quite popular, so-called SIPM silicon photodetectors or some hybrid modules of those.

So the energy resolution in a calorimeter depends on a number of things. As I was saying, one measures the number of particles being produced in a shower. And so that's just a counting experiment. And the uncertainty of that scales to the square root of the number of particles produced or measured. And so here, we have a square root n term. So the relative energy measurement has an arrow, which is with 1 over square root of the energy.

And then there's more contributions. There's constant terms, which come from inhomogeneities. Those are elements where there's just no detector, no equipment in the direction of the party. But those can be overlapped regions or regions where you have two detector modules being glued together.

You don't measure there. And that leads to them, a constant term in the energy resolution. And then when you translate the signal, the electromagnetic signals into an electronic signal, there can be noise induced, and that noise then leads to a typical term, which goes with 1 over the energy.

So very classical, you have those three components to the energy-- three components to the energy resolution. One is this 1 over the square root of the energy. One is constant, and one is depending on 1 over the energy.

And so when you design a detector, you want to place it such or design it such that the most important physics you want to do with this detector is optimize towards those components.