Accelerators and detectors

The goal is to give a quick introduction to particle accelerators and detectors—the hardware of the field. The reading includes a discussion of some of the underlying physics of particle detection. Unfortunately, some of that is rather complicated and messy and not an easy read. Fortunately, you can easily find treatments with more discussion e.g. Jackson and Peskin. Also you should take 252B when it is offered; it is a whole quarter devoted to these matters.

It is good to know the following things: The basic ideas of how a linear accelerator and a synchrotron work. How secondary beams of particles other than protons and electrons are obtained. The advantages of colliding beam machines. The event rate/luminosity/cross section relationship.

The major machines with their particles and energies are given. Be familiar with them.

The detector physics includes the ionization energy loss formula, the bremsstrahlung results, and the relations for Cherenkov radiation. Bremsstrahlung and pair production combine to give electromagnetic showers for electrons and photons. Jackson has a much more complete discussion of Cherenkov radiation.

To describe an event, one wants to know the identities and four-momenta of the final state particles. That's what detectors are for. The particles don't materialize with little labels on them like they have in Feynman diagrams.

The main things one needs to know to identify a particle are its charge and mass. The charge is not usually a problem. Charged particles interact with the matter in a detector electromagnetically. This leaves a trail of ionization that can be amplified and seen. Also, the charge determines the response of the particle to electric and magnetic fields. There is no direct measure of the mass. It is obtained from the particle's four-momentum. Thus, the three-momentum and the energy or the velocity must be measured. The momentum is available from the way the particle's path is bent by an applied **B** field. The velocity can be determined by time-of-flight, ionization density, or Cerenkov radiation. Direct measures of the energy are available in calorimetery. Other clues to particle identity are available if it is observed to decay or interact with matter in the target.

The common particles that need to be distinguished and measured are π, K, P, μ, e, γ, and ν.

Charged particles leave ionization. It indicates the presence of the particle and something of its velocity (The rate of energy loss to ionization is a function of the particle velocity. See the formula in the Data Booklet.)

Because e's are so light, they bremsstrahlung and make cascades. The size of the shower gives the energy. High energy γ's pair produce and then cascade.

There are a number of devices for detecting particles by their ionization. The basic idea is to somehow amplify the ionization along the path of the particle so that it can be recorded and analyzed. Such devices: bubble chambers, proportional counters, multiwire proportional chambers (MWPC), drift chambers, time projection chambers (TPC), spark chambers, streamer chambers, flash tubes, scintillation counters, emulsions, semiconductor counters including microstrip and pixel.

Particles traveling in a medium at greater than the local velocity of light or crossing a boundary between media with different indices of refraction emit EM radiation in a way that depends on the velocity of the particle. Cerenkov counters and transition radiation counters take advantage of these effects.

For measuring the total energy of a particle or jet of particles, there are EM shower detectors and hadron calorimeters.

e's and γ's are known by their EM showers.

ν's are known indirectly by the fact that they are not seen at all.

μ's by the fact that they leave tracks through large amounts of shielding.

π's, K's, and P's can be differentiated by TOF, Cerenkov, or ionization if the energy is not too high. They are distinguished from the leptons and γ's by not having the properties above.

You can see a little picure at

http://lifshitz.ucdavis.edu/kiskis/phy245a_06/id.pdf