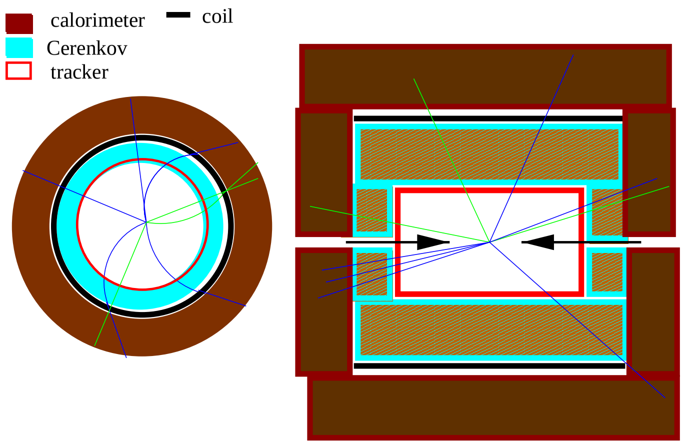

Generic High Energy Physics Experiment

Figure 57: Generic High Energy Physics experiment

18 LECTURE 19

18.1 A Generic High Energy Physics Experiment

Using what we have learned about particle detectors, we can construct a hypothetical general purpose high energy physics experiment. From section 14.1, the properties of a particle we are usually interested in measuring are

- Energy, E
- Momentum, **p**
- Charge,Q
- Velocity, v

An ideal detector would have a tracking detector in the center such that the position of the particles is measured before they are catastrophically measured in the calorimeter. The coil will go around the tracker in order to make the particles bend inside its volume for a measurement of the momentum. The same goes for the Cerenkov Detector: any matter in front of it will interfere with the particle and thus give a bad measurement of the velocity. The coil will be outside of the Cerenkov detector for this reason, although the Cerenkov detector does not benefit from the tracks curling in its volume. Finally, the calorimeter will measure the energy of the particle where it will be totally absorbed. Two views of this generic detector are shown in Figure 57.

All particles except muons and neutrinos are absorbed in the calorimeter. Neutrinos since they only interact through the weak interaction remain undetected unless one constructs a detector with a very large volume e.g. several thousand tonnes of heavy water. Alternatively if one can measure the transverse energy of all other particles produced in the primary collision, one can infer the presence of a neutrino by the fact that the total vector sum of transverse energy does not equal zero. The neutrino carries away some transverse energy which is not detected. Muons only deposit a small amount of energy in the calorimeter material and thus can be uniquely identified as the only particles to leave a signal (ionisation) in a tracking detector placed outside of the calorimeter.

If one wants to detect explicitly the presence of hadrons containing heavy quarks i.e charm or bottom quarks then one needs to detect the decay products resulting from the weak interaction decay of the hadrons. For example a b quark decays via the weak interaction to a charm quark, a charged lepton and a neutrino. B hadrons have lifetimes of $\sim 10^{-12}$ sec and are generally produced in pairs in high energy collisions such as $p\overline{p}$ and e^+e^-. In such high energy collisions they are produced with relativistic velocities and so, just like the decay length of cosmic ray muons, their lifetime is “time-dilated” and thus can travel an appreciable distance (several mm) before they decay. If one can measure this decay distance, then one can measure the lifetime and can thus verify that the hadrons produced contained a heavy quark. This generally requires a special tracking detector, placed very close to the original collision point, which can measure the particle trajectory with very high precision. These special tracking detectors are called silicon strip detectors and work in an analogous way to a gaseous MWPC except the charged particle ionises the silicon causing the creation of an electron-hole pair in the silicon. The electron and hole again drift to anodes and cathodes. The energy required to create these electron-hole pairs is small ($\sim$ 1 eV) and they have high mobility, so it is possible to obtain reasonably sized signals even for particles who loose little energy by ionisation e.g. muons. The silicon is in the form of strips some 20-50 μm wide. Each strip can be used to signal the presence of an ionising charged particle. Each strip is itself an ionising medium and a charge (e or hole) collector. By building up a pattern of the strips where ionisation has occurred one can reconstruct the trajectory of particles to an accuracy of a few μm. This allows one to actually construct the point at which a decay occurred by extrapolating the trajectories of the charged particles back towards to the collision point. This is illustrated in figure 58, which shows the charged tracks resulting from the decay of two top quarks produced from a poverlinep collision. Each top quark decays to a W boson and a b quark. The b quarks form B hadrons which travel a certain distance before decaying. One can see clearly the two points at which the B hadrons decayed.

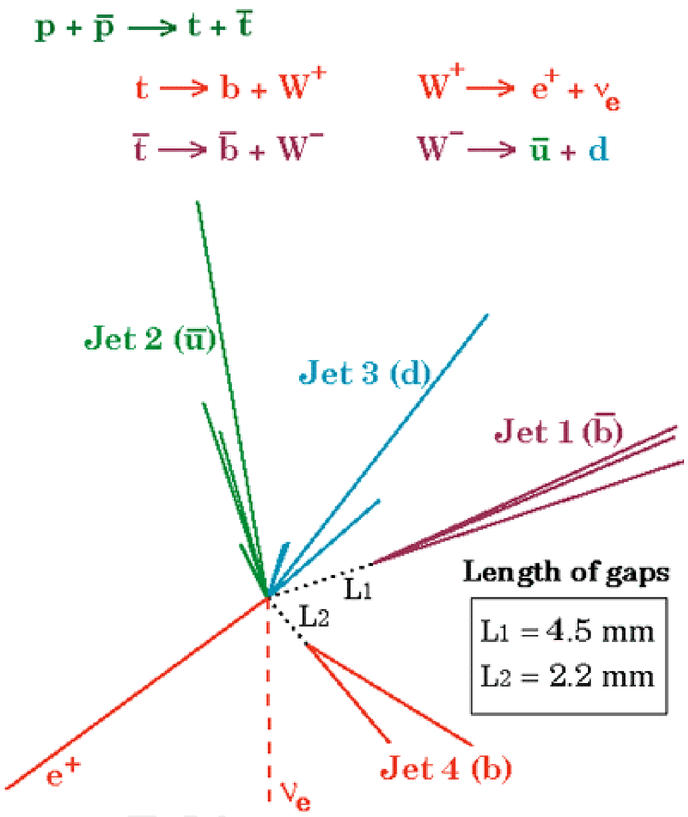

Figure 58: The charged tracks reconstructed using a Silicon strip detector and a gaseous drift chamber resulting from the decay of two top quarks. The neutrino from the W decay is not detected but inferred from the imbalance of transverse energy.