Chapter 4

The Super–Kamiokande detector

4.1 Physical Description

The Super–Kamiokande Detector is a 50,000 ton water Cherenkov detector located in Gifu Prefecture, Japan. The detector is located in an active zinc mine and is accessed via a 2000 m long tunnel. The rock over-burden is 1,200 m corresponding to 2,700 equivalent meters of water. This over burden reduces the cosmic ray rate in Super–Kamiokande to ~ 3 Hz.

The detector is operated from a control room located in the mine which is staffed 24 hours a day by one or two physicists who monitor detector performance, data quality, and the detector environment.

4.1.1 Water Cherenkov Radiation

Super–Kamiokande detects relativistic particle through their emission of Cherenkov light. When charged particles pass through a medium with speeds ($\beta \equiv v/c$) faster than light in the medium, $\beta > 1/n$, a shock wave of radiation is created as shown in Fig. 4.1. The radiation, called Cherenkov radiation after its discoverer, forms a wave front at a critical angle:

$$\theta_C = \arccos \frac{1}{n(\lambda)}. \tag{4.1}$$

The requirement that the particle be traveling faster than the speed of light in the medium leads to a momentum threshold which depends on the mass, m, of the particle:

$$p_{thresh} = \frac{m}{\sqrt{n^2 - 1}}. \tag{4.2}$$

For water the index of refraction varies between n =1.33 at λ = 580 nm and 1.36 at λ = 280 nm giving a typical Cherenkov angle of $\theta_C \simeq 42°$ and a threshold of $p_{thresh} = 1.14m$. The number of Cherenkov photons emitted per unit length per unit wavelength is:

$$\frac{d^2N}{dx d\lambda} = \frac{2\pi\alpha}{\lambda^2}\left(1 - \frac{1}{n^2(\lambda)\beta^2}\right). \tag{4.3}$$

A total of $\sim$ 3400 photons/cm are emitted between λ = 300–550 nm. Over this range, the photomultiplier tube (PMT) detection efficiency averages $\sim$10% giving roughly 340 photons/cm detected, neglecting losses in the water. Particles emitting Cherenkov light form characteristic rings of light on the detector walls. From these rings, the particle's vertex, direction, momentum, and type can be determined.

4.1.2 Super–Kamiokande Water Tank

A schematic drawing of the Super–Kamiokande detector is shown in Fig. 4.2. The water tank for Super–Kamiokande is located in a cavern reinforced with iron rods and 40-50 cm of sprayed concrete. A coat of Mineguard polyurethane was applied to the dome and tunnels to serve as a barrier against radon gas. The water tank is 42 m high and 38 m in diameter. The dome above the tank contains five huts which house

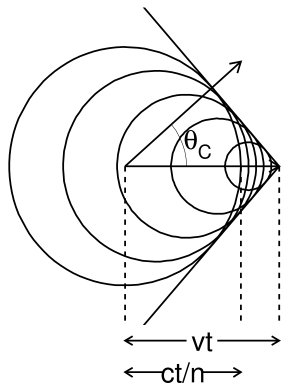

Figure 4.1: An illustration of Cherenkov radiation.

the front end electronics for the inner and outer detectors. At the site the average magnetic field due to the Earth is 450 mG. This is too high for the proper functioning of PMT's and is reduced to 50 mG using 26 Helmholtz coils which surround the tank.

The tank is optically separated into two regions. The inner region contains 32,000 tons of water and is viewed by 11,146 20-inch PMT's custom built for use in Super–Kamiokande. The walls of the inner detector are lined with black polyethylene terephthalate (PET). The outer region is 2.05 m thick along the detector walls and 2.2 m thick on the top and bottom detector surfaces. This region is viewed by 1885 8-inch Hamamatsu R1408 PMT's equipped with wavelength shifter plates. To further enhance light collection the walls are lined with a reflective material called Tyvek. The measured reflectivity of Tyvek is plotted in Fig. 4.3. During construction the reflectivity of the Tyvek was degraded through exposure to dust and fumes and the estimated reflectivity of the Tyvek in the Super–Kamiokande tank is roughly 60% – 85% of the measured values. The outer region is used to veto entering cosmic ray muons and to tag tracks exiting the inner volume. The inner and outer volume are separated by a 55 cm dead region that serves as the PMT support structure.