Photomultiplier tubes

The photomultiplier tubes (PMTs) used in the inner part of Super-Kamiokande are 20-inch diameter PMTs developed by Hamamatsu Photonics K.K. in cooperation with members of Kamiokande. The PMTs used in Super-Kamiokande have some improvement over those used in Kamiokande. The size and shape of this PMT is shown in Fig 1. The photo-cathode is made of bialkali (Sb-K-Cs) that matches the wave length of Cherenkov light. The quantum efficiency (Q.E.) is shown in Fig 2. As can be seen from this figure, the value of Q.E. at the typical wave length of Cherenkov light (= 390nm) is 22%. A Venetian-blind type dynode is used for this PMT because of its large photosensitive area. However, this large photosensitive area makes the transit time longer (about 100nsec at 1 photo electron (p.e.) light level) and transit time spread becomes worse. This type also has a smaller collection efficiency for secondary electrons compared to other types. The bleeder-chain was optimized in order to achieve good timing response and collection efficiency. As the result of this optimization, an 11-stage voltage divider (with the ratios of voltage division 8:3:1...:1) was used, and three types of focusing mesh-plates between the cathode and the first dynode were adopted. The average value of the collection efficiency is more than 70%. The one photo electron peak can be seen clearly as shown in Fig 3. The transit time spread is about 2.2nsec. It is important for the analysis of solar neutrino data to have the ability to see 1 p.e. and good timing resolution, because the number of photons arriving at the PMT is generally one and the timing resolution affects the vertex reconstruction.

If the geo-magnetic field is reduced to less than 100 mG, the PMTs have an uniform response. The residual geo-magnetic field is kept less than 100 mG in every position of the tank by using compensation coils.

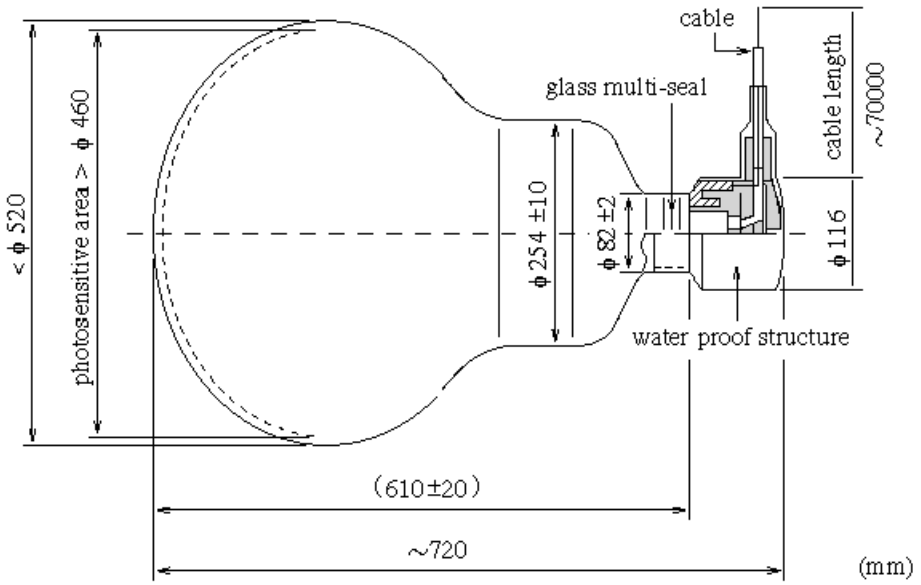

Figure 1: The schematic view of the PMT used in Super-Kamiokande.

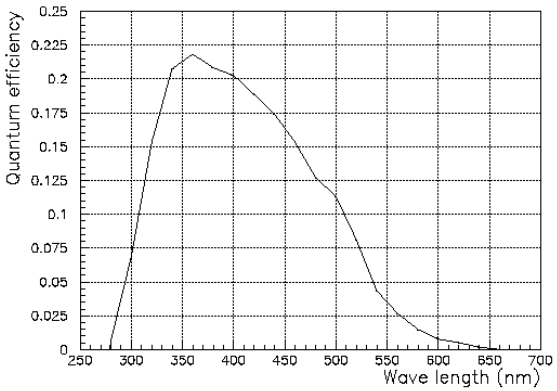

Figure 2: The quantum efficiency of the PMTs used in Super-Kamiokande as a function of the wave length of incident light.

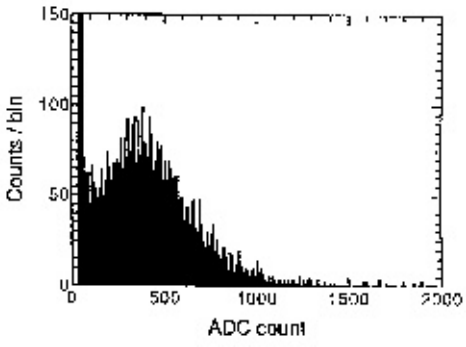

Figure 3: One photoelectron peak of the PMT used in Super-Kamiokande.

Fig 4 shows the average dark noise rate above the threshold of electronics for the first one year of operation. It is stable and about 3.1 kHz after May of 1996. The number of accidental hits caused by the dark noise is estimated about 2 hits in any 50nsec time window. The dark noise rate is considered in our Monte Carlo simulation program.

The high voltage system for the PMTs consists of a distributor(A933K), a controller(SY527), and an interface module(V288) by CAEN Co. The value of the high voltage is set for each PMT to have the same gain as described in **Section:"Relative gain of photomultiplier"**. The HV values of all channels are monitored every 10 minutes.

The PMTs used in the outer part are 8-inch Hamamatsu R1408 PMTs, each with a wave length shifter plate which is 60cm square. Photons in the wave length range between 300 nm and 400nm are absorbed by the wave length shifter and about 55% of the photons isotropically re-emitted with a longer wave length.

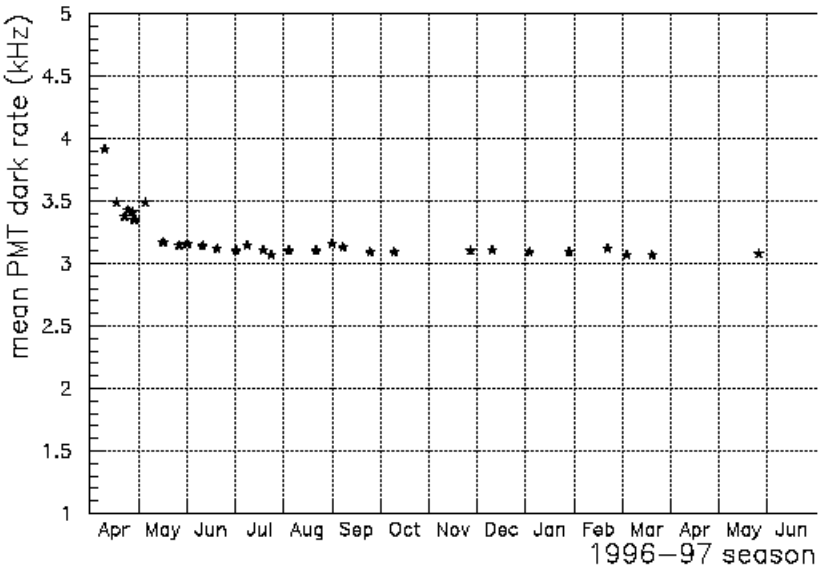

Figure 4: The dark noise rate of the PMT used in Super-Kamiokande as a function of time.

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