Radiation stability of plastic scintillators and wave-length shifters*

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The calorimeter of the ZEUS detector at the DESY collider HERA consists of depleted uranium (DU) plates interleaved with plastic scintillators(SCI) SCSN-38[1]. The SCI are read out via wave-length shifters (WLS) Y-7 in PMMA[1]. Both plastic materials have to withstand a radiation background(especially hadrons hitting absorbers) which has been estimated for stable machine operating conditions to less than 3 kGy/10 years[2].

Extensive studies have been performed on the radiation stability of different SCI and WLS. Applied sources were ^{60}Co, UV light, a 25 MeV proton beam and, for very low dose rate investigations, plates of DU. The irradiation with low energy protons has several advantages: high doses are possible, samples of even large surfaces can be uniformly irradiated, the irradiated region can be locally restricted which allows a direct determination of the fluorescence loss and the absolute dose can be measured very accurately. The samples have been irradiated and stored under different atmospheres(e.g. air, nitrogen, argon, oxygen). Diagnostic tools for the change in attenuation length and loss in light yield were a spectrophotometer (transmission, fluorescence of thin samples), a UV lamp device which can excite the different fluors seperately and a very low intense beam(fA $\hat{=}$ 6 kHz) of 25 MeV protons which is swept over the SCI sample[3]. The latter method is very accurate and allows fast measurements after irradiation in the original atmosphere without handling of the samples (fig.1). This sometimes may be of importance because the surrounding atmosphere can influence the fluorescence[4] of a SCI.

As a result of the proton irradiations[5] the SCI SCSN-38 shows a strong decrease of the absorption length with a fast recovery (<2d) in air to a low permanent damage while in nitrogen the recovery takes longer (18 days) but the permanent damage is even slightly smaller. The permanent loss in light yield is 4% for 10 kGy in air. The WLS Y-7 and K-27 in PMMA have small permanent damages in air and strong ones in nitrogen (no recovery). The results are compatible with ^{60}Co irradiations. The additional absorption coefficients due to the irradiation can be well described by a sum of an exponential decay in time and a constant term (permanent damage). They are proportional to the applied dose.

Several dose rate investigations[5][6][7] (2 mGy/h - 10 kGy/h) show no rate effect of the radiation damage of SCSN-38 except one[7] where a SCI plate has been irradiated between DU plates for about two years and the attenuation length has decreased drastically. Similar observations have been made for K-27 in PMMA irradiated between DU-plates[8] but at least partially "normal" ageing was the reason for this. So for (very)low dose rate irradiations the radiation damage effect may be concealed by ageing (fig. 2).

For the SCI and WLS of the ZEUS calorimeter further radiation damage studies are under the way or planned: routine damage control of all different production cycles, low dose rate investigations, irradiation of realistic large samples and neutron irradiations.

1) Manufactured by Kyowa Chemical Industries
2) ZEUS Collaboration, "The ZEUS detector", Status Report 1987, 1987
3) K. Taube, Diploma thesis, Hamburg 1987
4) Th. Marckmann and U. Holm, ZEUS minutes Oct. 30, 1989
5) U. Holm and K. Wick, IEEE Transact. on Nucl. Sci. 36,1(1989)579
6) J. Straver and R. Wigmans, private communication
7) M. Rohde, ZEUS note 87-055, 1987 and private communication
8) M. Rohde and U. Holm, private communication

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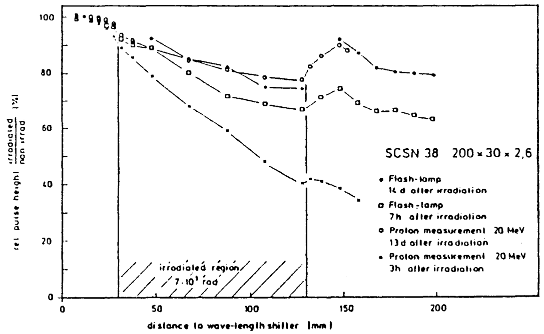

Fig. 1. Relative light yields of a SCSN-38 SCI sample after and before irradiation (in nitrogen) to 7 kGy with 25 MeV protons as a function of the distance from the read-out edge. The light yield has been measured with a scanning beam of "single" protons and a UV flash lamp for different times after irradiation. For comparable times (13d or 14 d) after irradiation the two methods deliver the same result. The steps at the boundaries of the irradiated region allow to determine the loss in fluorescence.

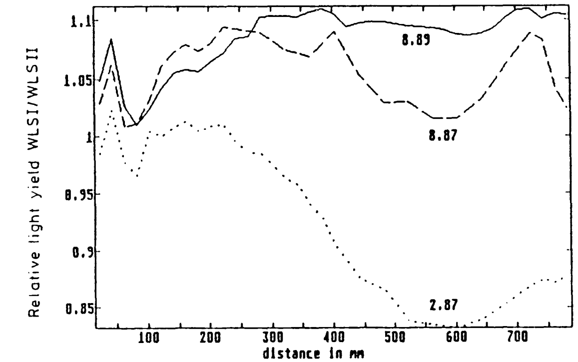

Fig. 2. Relative light yields of two non-irradiated WLS K-27 (150 mg/l) in PMMA (dimensions 80*5*0.2 cm³) as a function of the distance to the read-out edge for different times over two and a half year. The samples had been cut out of the same plate.