Comparison of Radiation Damage Effects in PWO Under Proton Irradiation at 150 MeV and 24 GeV Energy*

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The electromagnetic target calorimeter [1]. of the future PANDA detector is based on PbWO4 scintillation crystals of improved, so called PWO-II quality. To reach sufficient resolution down to a few tens of MeV, the calorimeter has to be operated in addition at a low temperature of $T = -25°$C. As a consequence, high radiation resistivity of the crystals is required since thermo-activated recovery processes are drastically slowed down. One can overcome or at least significantly compensate the damage by stimulated recovery [2] using external infrared light of $\sim$ 1000 nm wavelength. The mechanism has been applied even at low temperatures but leading to longer recovery times. However, it turns out that the recovery technique is limited to damage originating from interactions of electromagnetic probes. Recent investigations of radiation damage of lead tungstate under hadron beams with high fluence show a similar behavior of the degradation of optical transmittance like under γ-irradiation. Moreover, an additional shift of the fundamental absorption edge in the wave-length range below 400 nm is observed after irradiation at a total fluence above 1012 particles/cm^2 as illustrated in Fig. 1.

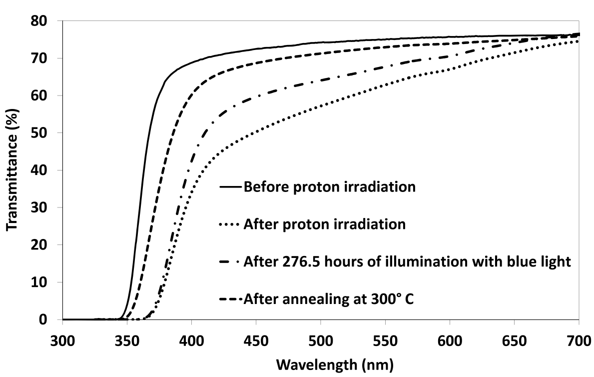

Figure 1: Longitudinal optical transmittance of 22 cm CMS type PWO crystal before irradiation, three month later after irradiation with 24 GeV/c protons (integral fluence = 1013 protons/cm^2), after illumination with blue LED light (max = 464 nm) for 276.5 hours and after annealing at $300\,°$C for 3 hours

Only additional thermal annealing at $300°$C can reverse the observed shift of the transmission curve and recover the collectable light output. The effect is addressed to local macro defects leading to Rayleigh scattering or the formation of clusters of so called Frenkel defects. The severe damage might be caused by highly ionizing fission and fragmentation products initiated by interactions of protons in the crystal matrix. In that respect, similar effects should appear using protons at significantly lower energies as long as fission processes become possible. In close collaboration with the group at KVI (Groningen) we have performed an investigation using 4 samples of PWO crystals produced by Czochralski method (BTCP) and 4 samples produced by modified Bridgman method (SICCAS), respectively. Each sample was cut from a full size (20 cm) crystal to rectangular dimensions of 2 cm · 2 cm · 5 cm. The irradiation was performed with 150 MeV proton beam provided by the AGOR Facility. Four samples (2 BTCP + 2 SICCAS) were irradiated with an integral fluence of 1012 protons/cm^2 (low), the remaining four with 1.8 1013 protons/cm^2 (high). After irradiation the samples were placed in a freezer at a tem-perature well below $0°$C to decelerate spontaneous recovery processes of the radiation damage. Finally, all measurements were started four months later. At the high fluence a similar shift of the fundamental absorption edge and the typical damage in the range above 400 nm are observed. The deterioration above 400 nm can be recovered with illumination of red light (780 nm). However, the onset of the shift of the fundamental edge can be only compensated after 10 hours annealing at $200°$C. Rescaling the damage effect to an crystal length of 22 cm shows a similar picture as illustrated in Fig. 2. This provides the opportunity to use low energy

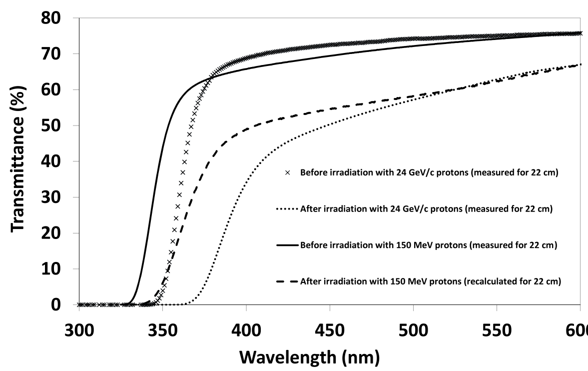

Figure 2: Comparison of the experimental data for the irradiation damage due to 24 GeV/c and 150 MeV protons. The results at lower energy have been rescaled to a crystal length of 22 cm using the experimental absorption coefficient dk(λ) obtained for the 5 cm sample

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protons for systematic studies of the mechanisms and perform tests searching for alternative new materials for future calorimetry focusing components with lower Z-values.

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