Single-photon and magnetic field measurements on H8500 MAPMTs

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The CBM-RICH photon detector will use photomultiplier tubes for the detection of Cherenkov photons, with the current design focusing on the H8500 multi-anode PMT from Hamamatsu. We measured and compared the single-photon spectra of three different tubes, namely the H8500C (12-stage, standard cathode), the H8500C-MOD8 (8-stage, SBA cathode), and, for comparison, the R8900 (single channel version, SBA cathode), which is a tube explicitly recommended for single-photon detection. All tubes were illuminated with single photons from a pulsed LED light source about 1 m away from the photocathode in a fixed setup in order to ensure constant and homogeneous illumination. Signals were read out via an 8-channel charge-sensitive preamplifier (Mesytec MSI-8) coupled to a sampling ADC, the readout being triggered from the pulse generator.

The obtained single-photon spectra are shown in Fig. 1. The best peak-to-valley ratio is obtained with the R8900 tube from Hamamatsu; however, also the H8500C 12-stage tube shows a clearly pronounced single-photon peak in all 64 channels. In contrast, the tested 8-stage version does not show a clear single-photon peak, even if the supply-voltage is increased to 1100V (maximum rating).

A quantitative comparison of detection efficiency is obtained by normalizing the number of registered photons (signal above threshold indicated in Fig. 1) to the active cathode area for a fixed number of 100k LED pulses. This test yields 19.4 registered photons per mm^2 for the R8900, 14.1/mm^2 for the 12-stage H8500, and 14.1/mm^2 for the 8-stage version. Despite the increase in quantum efficiency by 30% due to the SBA cathode, the 8-stage version H8500C-MOD8 does not register significantly more photons than the 12 stage version. The increased photon yield for the R8900 tube (SBA) in comparison to the 12-stage H8500C directly matches the higher quantum efficiency due to the SBA cathode, which we measured to be 28% for the R8900 and 20% for the H8500C at $\lambda = 470$ nm (see [1] for details). These results show that the H8500-12stage is well suited for single-photon detection; a significantly higher detection efficiency can only be obtained with SBA cathodes, which are not (yet) available for the H8500C. The increased quantum efficiency due to the SBA cathode of the H8500C-MOD8, however, does not pay off in terms of photon yield because of the poor single-photon spectrum.

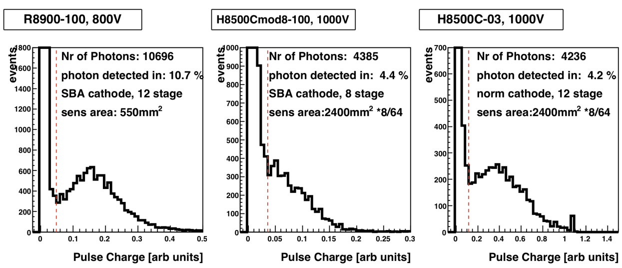

Figure 1: Single-photon spectra for R8900-100 (left), H8500C-100-MOD8 (centre), and H8500C-03 (right). For the multi-anode PMs, the sum spectrum of all diagonal elements is shown.

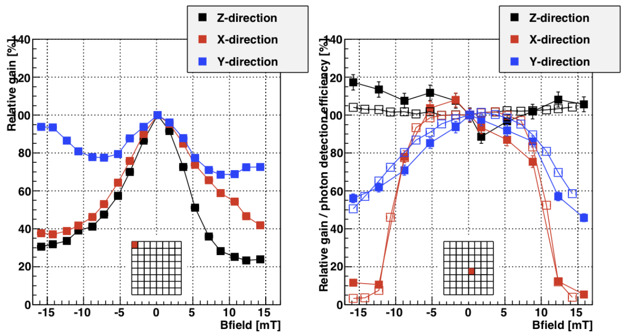

Figure 2: Gain variation for light pulses of ≈ 50 photons as function of magnetic field for two selected pixels of a H8500C. The open symbols on the right side show the normalized variation of single-photon efficiency.

The effect of magnetic fields on gain and detection efficiency of the designated MAPMTs is another important issue in view of stray fields of up to 25 mT in direct vicinity to the CBM dipole magnet. In order to study these effects, we mounted different H8500 MAPMT tubes inside a Helmholtz coil pair generating a homogeneous field up to ±15 mT. Again, a pulsed LED was used to generate multi-photon pulses to study the variation of overall gain as function of the magnetic field. In a second step, the amplitude was reduced to the single-photon level in order to determine single-photon detection efficiencies. The results are summarized in Fig. 2 for two selected MAPMT pixels (H8500C 12-stage) and three different field orientations. In particular the outer pixels show a significant drop in gain and detection efficiency for fields as low as a few mT. The drop in gain seems to be mainly caused by the deflection of the first photo-electron as suggested by the very similar behaviour of gain and detection efficiency. Additional shielding will be necessary to operate these tubes at the foreseen position.

References

[1] J. Kopfer *et al.*, *Quantum efficiency and gain homogeneity measurements of H8500 MAPMTs for the development of a CBM-RICH prototype camera*, this report