Study of p-terphenyl WLS effect on timing in the CBM RICH prototype*

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Introduction

The CBM RICH detector will use Hamamatsu H12700 multi-anode photomultiplier tubes (MAPMTs, PMTs) working in the single-photon regime to detect Cherenkov photons [1]. There are two different configurations of H12700 PMTs available - with Borosilicate glass window or with UV glass window, the latter having much higher response in the UV range.

Cherenkov light is emitted according to a $1/\lambda^2$ intensity distribution, with most photons in the UV range (limited by the transparency of the medium). PMTs with BiAlkali cathode have maximum sensitivity at around 450nm, and only limited sensitivity in the UV range down to 200nm (limited by glass window transparency). WLS layers can help to overcome this sensitivity mismatch [2, 3].

The readout scheme for the CBM RICH detector will detect only timestamps and no amplitude information. The final front-end board (FEB), the DIRICH board, will have most part of its functionality implemented inside an FPGA [4, 5]. A current prototype of the readout electronics is implemented in two FPGA-based boards PADIWA and TRBv3. These boards have been used during Nov 2014 CERN beamtests [6, 7]. The same readout system has also been tested in the laboratory.

Any scintillator has some timing charachteristics. Contemporary electronics allow a direct measurement of the time profile. For the first time, the time effect of p-terphenyl WLS layers on the distribution of the leading edges of the hits belonging to the same ring is studied. The WLS luminescence time profile was derived from the measurements with sub-nanosecond precision.

Readout system time resolution

We have performed measurements of time resolution of TDCs [8], implemented in TRBv3 board, and full electronics chain PADIWA + TDC. For these measurements, a 10ns-wide pulse from a high-precision pulse generator was split into two and sent to different pairs of input channels using identical cables. An example of the distribution of the difference between the two registered timestamps $\Delta t_i = t_i - t_j$ which were sent directly to TDC simultaneously is shown in the fig. 1.

RMS of the distribution is under 20ps for all channels and most probably the quality of the measurements is limited by the precision of the pulser. The same technique has

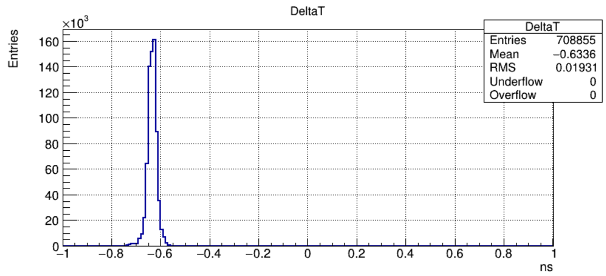

Figure 1: Δt distribution in direct TDC measurements.

been employed to perform the measurements of the time resolution of the electronics chain consisting of PADIWA and TDC. In this case the RMS is less that 70ps. For the full readout chain including PMT, the time resolution turned out to be 640ps with main contribution coming from PMT transition time jitter.

Procedure description

During RICH prototype beam tests there were 3 groups of PMTs in the camera: (1) covered with WLS layers for the first runs, then cleaned and used without WLS films for the second set of runs, (2) covered with WLS layers for the whole beamtime and (3) not covered for the whole beamtime. By comparison of the data received using the PMTs from the first group (1) we can analyse the effect of WLS layers.

Each set of data contains signals from at least two sources - beam and picosecond laser. Laser flashes illuminate the full PMT surface with an intensity which is intentionally set very low such that PMTs worked in single-electron regime. The laser wavelength is outside of the WLS absorption range, therefore the data from the laser is used only to calibrate inter-channel delays of the readout chain.

Beam events may contain Cherenkov rings on the camera plane. The analysis technique for the time precision is based on the fact that signals in different channels within one event coming from one laser flash or one charged particle emitting Cherenkov light are simultaneous. For beam data, analysis cuts on ring centers have been applied in order to filter real rings and thus increase the quality of the analysis. Analysis of those PMTs which were always covered (2) or always not covered (3) across all sets of data give additional check of analysis procedure, external conditions and software implementation.

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WLS time profile

In each event, the first hit in time is used to define the reference time t_{ref}. For all other hits in the event, the time difference, $\Delta t_i = t_i - t_{ref}, i \neq ref$ is computed. The Δt distributions for two sets of data are shown in fig. 2 and 3.

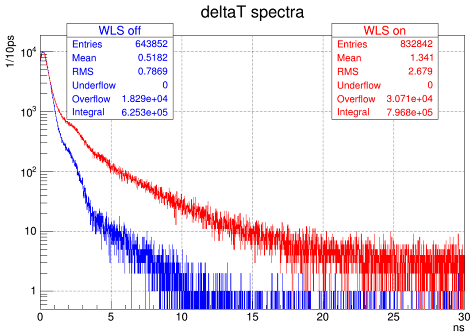

Figure 2: Δt distributions. Blue (lower) - without WLS layer, red (higher) - with WLS coverage.

The two data sets with and without WLS coverage were obtained during two minutes of data taking. The peak values are very close (see fig. 3) which means that the number of detected photons not affected by the WLS layer is the same; there is no normalization in analysis. If the photon is absorbed by the WLS it takes some time before it is emitted and then registered, so WLS-affected hits are located in the "long times" wing of the distribution.

In order to check if there is any other influence than the removal of WLS coating on the Δt distributions which are compared in fig. 2, we analyzed the results for set (2) and set (3) separately for the time slots used for the measurements of set (1) with and without WLS film. If the PMTs are unchanged as it is the case for set (2) and set (3), we find identical Δt distributions in both time slots. Thus any other influence than the change in coating can be excluded.

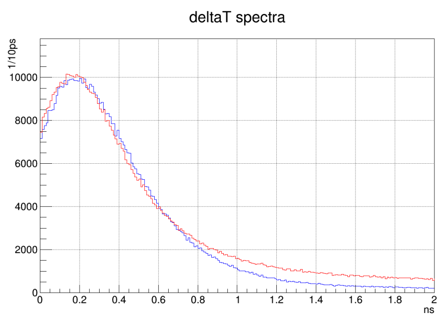

Figure 3: Δt distributions zoomed to the area of peaks. Blue (lower) - without WLS, red (higher) - with WLS.

Both distributions are shifted to the right by approx. 200 ps which probably comes from the transition time jitter of the MAPMT. There is also one more feature - the distributions have distinguished shoulders in the area of 2-3 ns. Detailed analysis showed that the channels which give input into this area are generally more noisy, so most of them have been ignored for the WLS analysis.

Subtracting the blue distribution (no WLS layer) from the red (WLS layer) in fig. 2, we subtract the timing information for all hits not being affected by the WLS layer. The resulting WLS time profile is shown in fig. 4. It consists of two major exponential components with decay times τ_1 and τ_2, so the difference is fitted by

$$f(t) = A \cdot e^{-t/\tau_1} + B \cdot e^{-t/\tau_2},$$
$$t \in [1.5ns; 20ns]$$

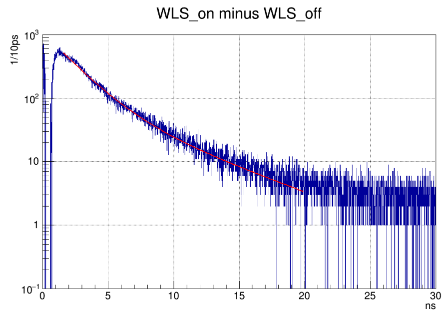

Figure 4: WLS time profile. Red line is fitting result.

Thus the measured p-terphenyl WLS time profile consists of two components, a fast (2ns) and somewhat slower (6ns). Precisely, the fit values are:

Fast: $\tau_1 = 1.92ns$

Slow: $\tau_2 = 5.69ns$

Even for the maximum interaction rates in CBM of 10MHz, time constants below the 10ns range will not harm the event-by-event timing resolution.

References

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