Characterization of the electronics read-out for the SiPM photon detection system of the dRICH

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EIC dRICH-SiPM detector prototype

The future Electron-Ion Collider is under development and is foreseen to start operation in the early 2030. EIC will be the first collider for polarized electron protons as well as light nuclei, and will allow to explore the TMDs and understand the origin of mass and spin of nucleons. In order to make Particle IDentification for a broad momentum coverage and forward rapidity, the dRICH is a cost effective solution.

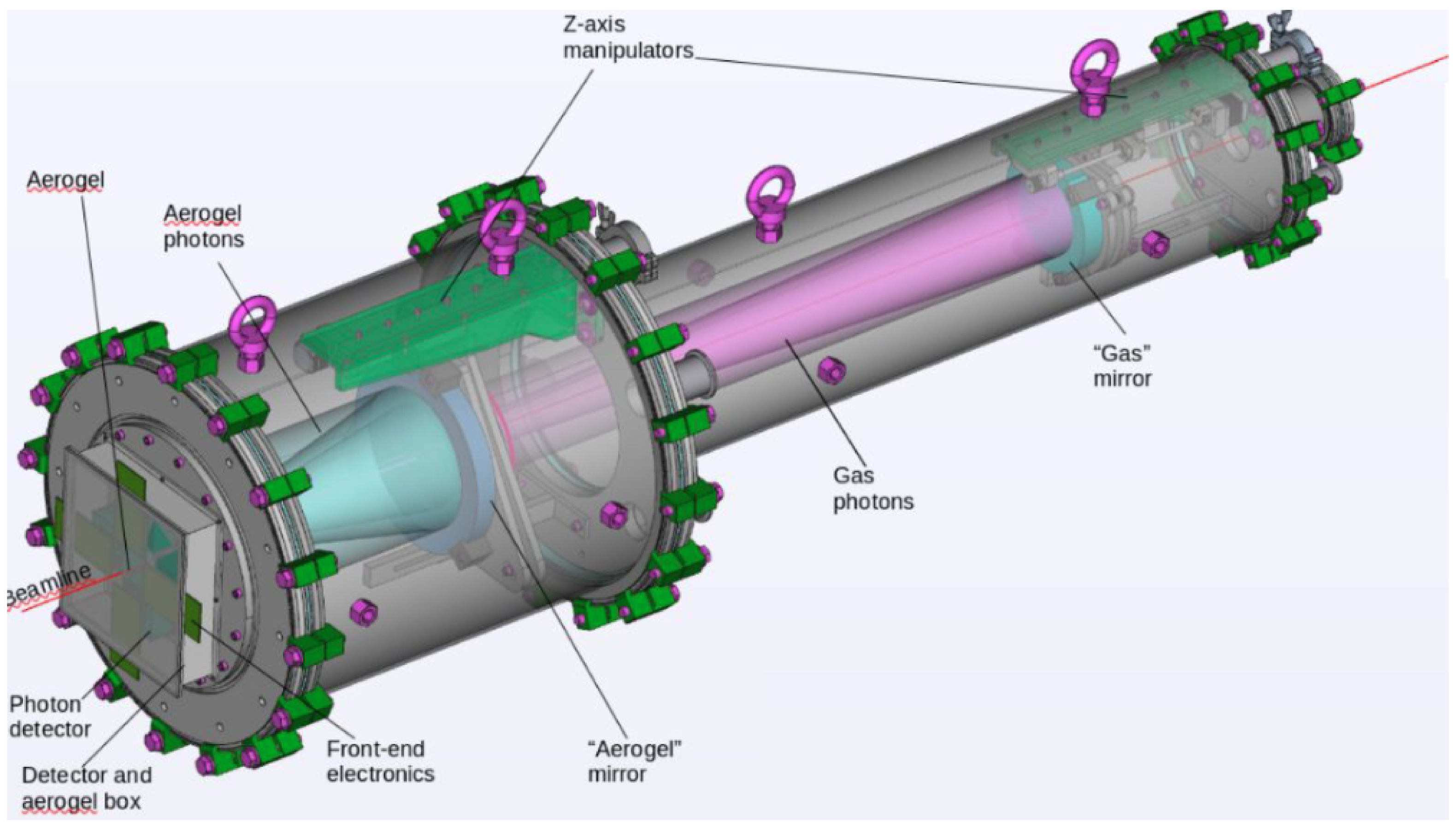


Figure 1. dRICH prototype - Left is upstream - Right is downstream

To capture the ring Cerenkov photons, SiPMs are a promising candidate and are investigated due to their affordable price, capability to work under magnetic fields, high time resolution and photon efficiency. However these devices suffer from large Dark Count Rates which increase with the radiation damage from which they have no tolerance.

The prototype for the dRICH-SiPM is a continuous readout system and use six SiPMs carrier boards coupled to ALCOR front-end ASIC:

a) Four SiPM carrier boards (0 → 3), 32 channels each one, positioned upstream to capture the Cerenkov photons.
b) Two SiPM carrier boards (4 and 5), 32 channels each one, downstream in order to get a Trigger Timing from the coincidence in time of their signals.

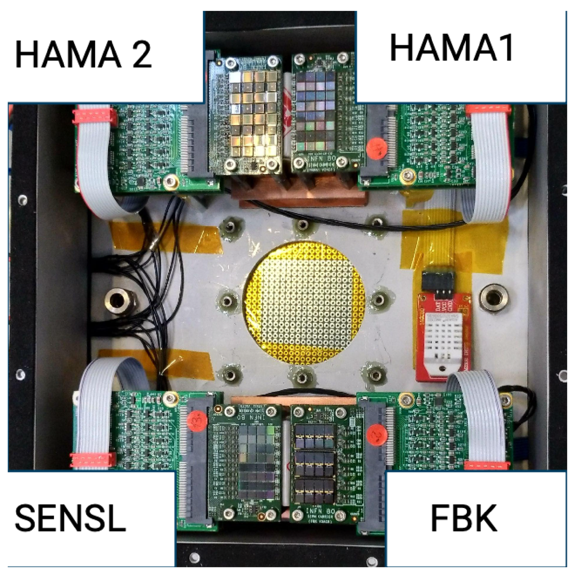


Figure 2. View of Chip carrier boards with the read out electronics

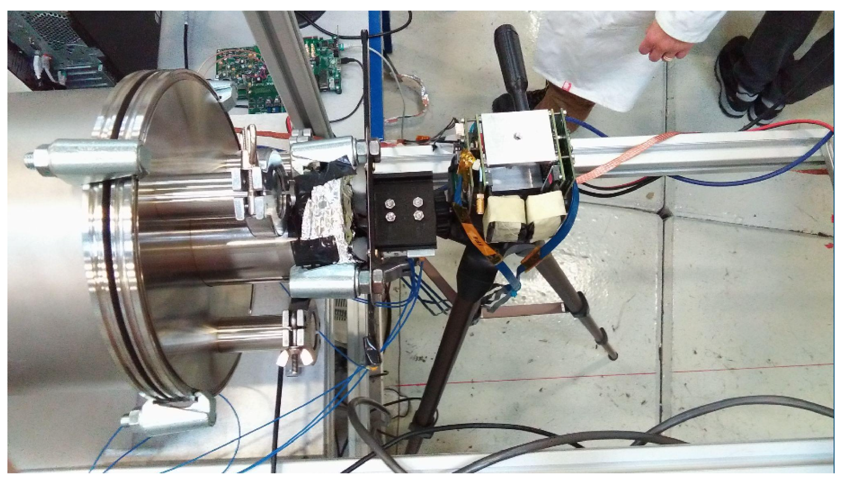


Figure 3. View of the trigger timing system

The topic that concerns this analysis is the presence of a re-trigger which follows a signal (photon or Dark Count).

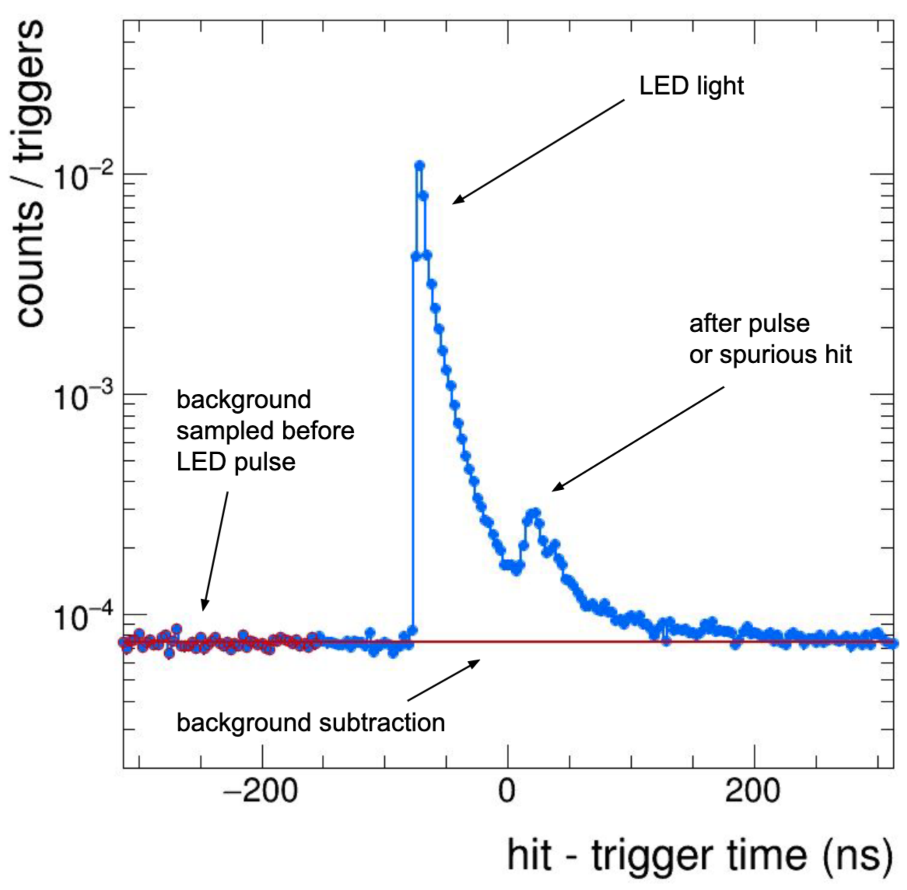


Figure 4. Signal from 1 p.e. and after-pulse

Time Over Threshold analysis & Orphan edges

The data acquisition is taken in TOT mode (the rising and trailing edges times of signals are registered) and a Time Ordering is applied to the data. Since only one 1 channel is used, no Time reference is needed. The reconstruction is shown in the following figure :

Figure 5. Time ordered Rising and Trailing Edges

It is easy to note that there are rising (trailing) edges that cannot be associated with a trailing (raising) edge. Hence we call them *orphans*.

Analysis objectives

- **Objective 1:** Find out a reasonable cut to eliminate after-pulse signals.
- **Objective 2:** Understand orphan edges (Leading and Trailing) through a Time Over Threshold analysis.

Analysis for a single channel SiPM using a Led photon source

This data acquisition was made in two different ALCOR amplification settings at temperature $T = -30°C$ (in order to reduce DCR) for a single Hamamatsu SiPM's channel.

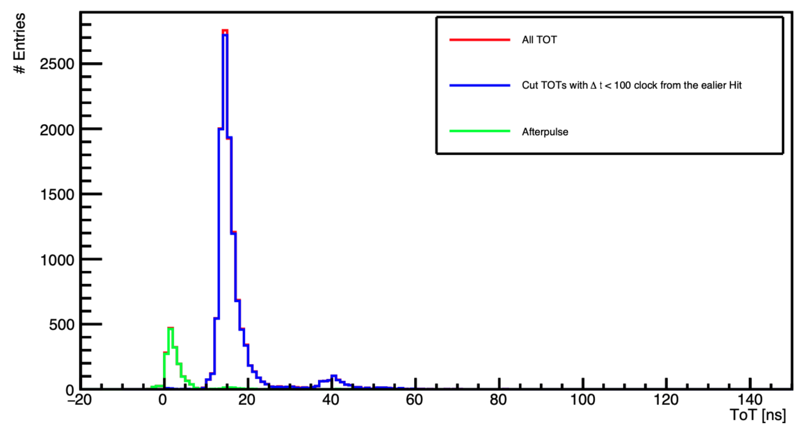


Figure 6. BCR standard.300

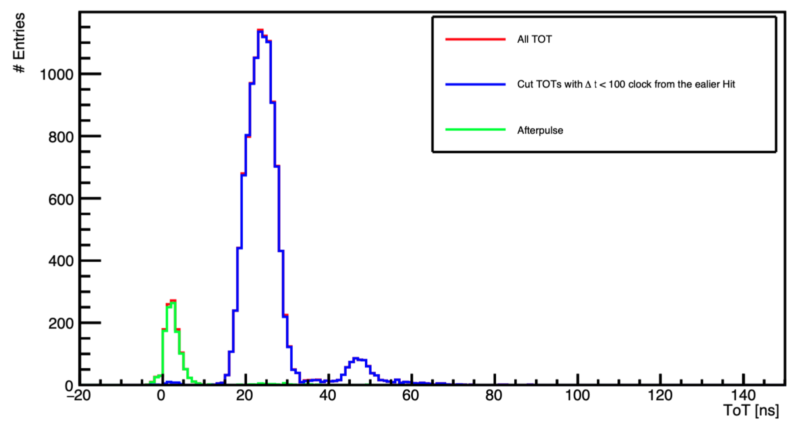


Figure 7. BCR high-capacitance.310

Three peaks are easily appreciable, (from left to right) after-pulse, 1 p.e. and 2 p.e. .
In order to cut the after-pulse distribution, the linear cut is applied :

Cut all TOTs which are closer in time < 100 clock from the previous leading edge of a reconstructed event (leading + trailing edge).

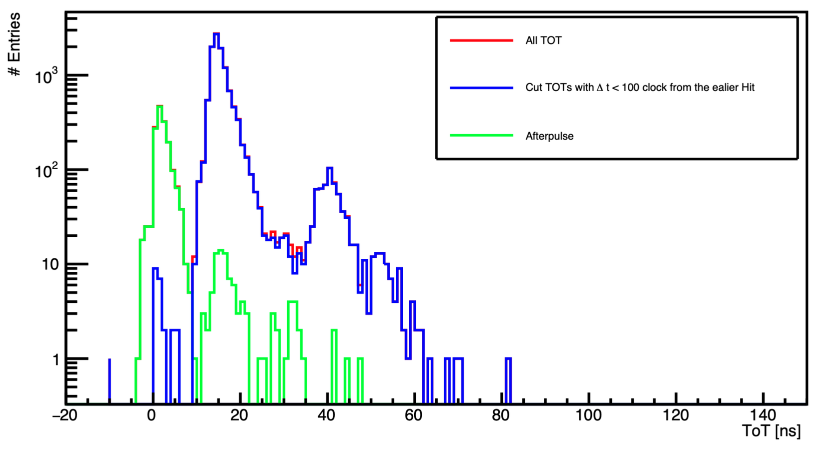


Figure 8. BCR standard.300

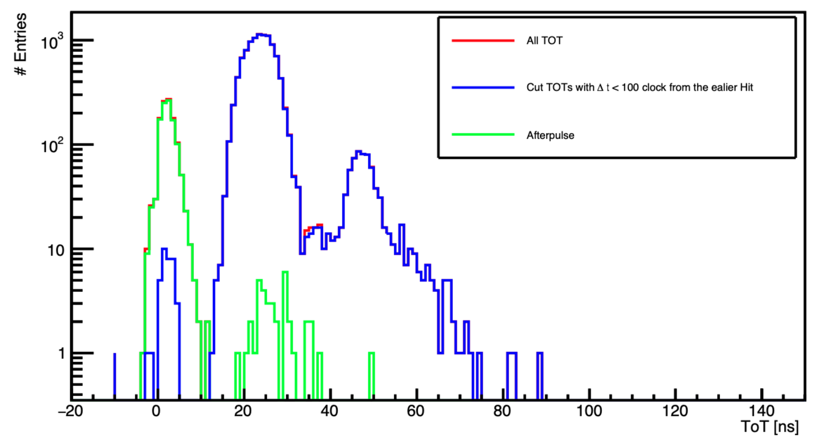


Figure 9. BCR high-capacitance.310

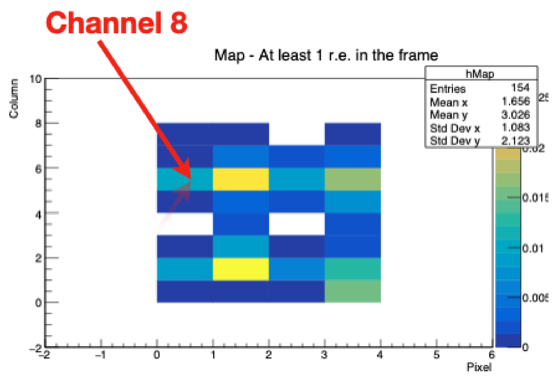
The cut seems to work. But few events corresponding to 1 p.e. are also effected, this is due to rare Dark Count which are close in time to the Led photon.

Analysis of the 2022 test beam data

The algorithm to reconstruct and the linear cut is applied to the data.
Here a frame of 256 clock is choose to maximize the trigger efficiency.

Carrier Board 0 - HAMA1 is considered here:

The Hit Map is obtained by using the coincidence between the T_{ref} and the first Hit in the corresponding frame.



$$T_j = \frac{\sum_{i=0}^{i=CH_{Tot}} t^i\,(Hit[0]; chip = j)}{CH_{Tot}} \qquad T_{Reference} = \frac{T_4 + T_5}{2}$$

Fill the MAP $\iff$ first rising edge is $|t^0_{r.e.} - Treference| < 10\ ns$

Figure 10. Fired Channels 8 → 11

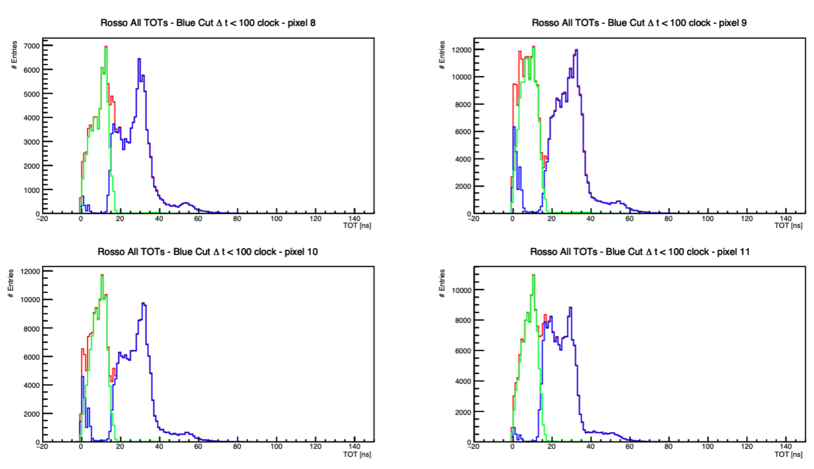


Figure 11. TOTs distributions for the ring channels 8 → 11

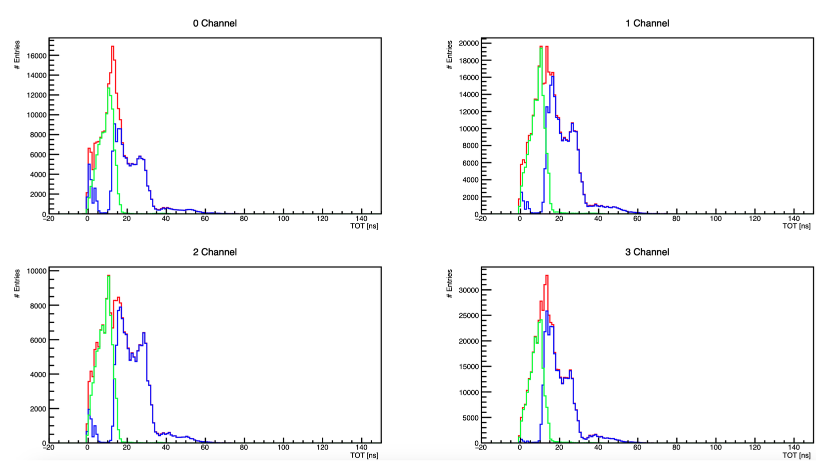


Figure 12. TOTs distributions for the Not fired channels 0 → 3 channels

In these TOTs distributions, It is not possible to distinguish the different peaks corresponding to 1 p.e. , 2 p.e. and the after-pulse distribution at small TOTs values. As is visible also in Fig. 11→13:

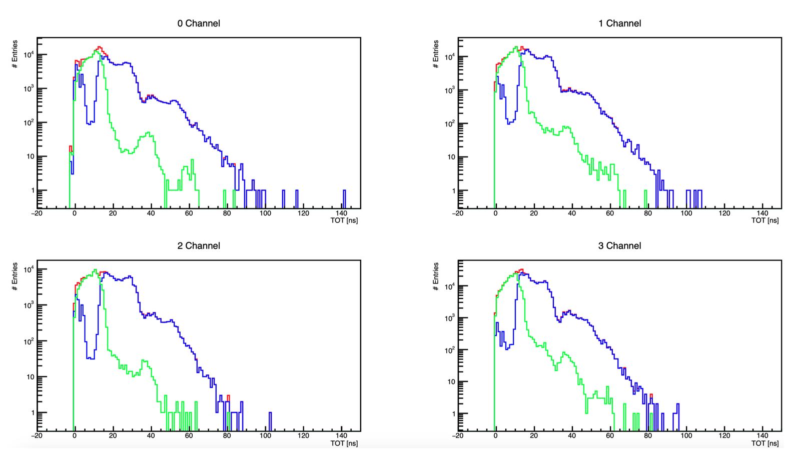


Figure 13. TOTs distributions for the Not fired channels 0 → 3 channels

For these reasons the linear cut is not good enough and cannot be applied here since there is a significant overlap in the low TOTs region between the two distributions.
Work in progress ...

Note:
- The Fine tuning was possible thanks to Nicola Rubini's algorithm which followed the Fabio Cossio's recipe.
- The frame size which maximize the Trigger efficiency was analyzed by Annalisa De caro.