DUNE Supernovae Triggering

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1 Introduction

I has been shown at many occasions that it was possible to realise triggering for Supernova (SN) with DUNE [1]. The trigger relies on the the so-called Trigger Primitives (i.e. the hits, TPs) from the collection wires of the 10 kT single phase module to form Trigger Candidate (clusters of hits, TCs). Over the past, the TPs used were not very representative of what the output of an online hit finder (so called GausHit). In this note, I discuss a way to improve the triggering based on the sum ADC of the TCs. I am using the TPs from the algorithm described in Ref [2] (so called "Phil's hits"). In the past, the use of Phil's hits created a significant decrease in the efficiency of detecting a SN happening at the Large Magellanic Cloud (LMC). The aim of this study is to recover this efficiency loss.

For this study, the full MCC11 statistics (signal+background and high rate background) was used.

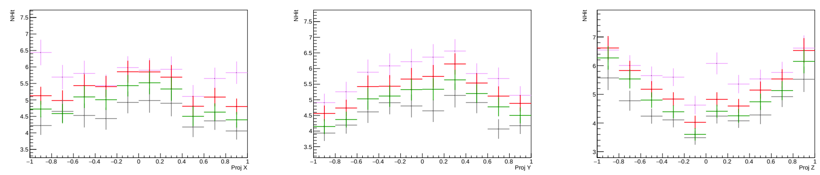
2 Comparison of TPs

As explained in the introduction, the TPs have been changed from GausHit to Phil's hits. It's important to understand the difference of the algorithms. In Figure 1, the number of hits is shown against the angle of a X MeV (Kinetic energy) electron at the distance of X cm of the cathode, according to the angle of the electron. In Figure 2, the mean sum of the ADC of the hits is shown against the angle of the same electrons. Similarly Figure 3 show the mean time span of the hits.

3 Traditional approach to SN triggering

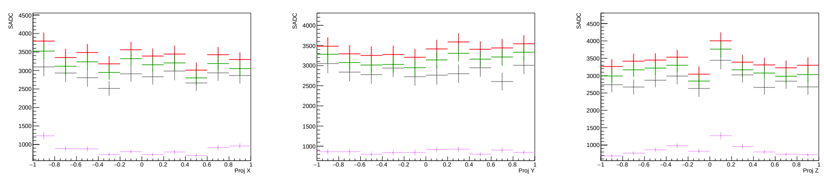
The approach to triggering is to cluster hits in time and in space to form TCs as described in [1]. The TC formation requires to choose channel and time tolerances to grow the clusters of hits.

Next, a simple cut in the number of hits of the cluster is applied to differentiate signal from background. The formation of TC was demonstrated to be fast and applicable on a per APA basis with a simple CPU.



(a) X projection (b) Y projection (c) Z projection

Figure 1: Number of hits for isotropic electrons of energy X MeV at a distance of X cm. Pink: GausHit, Red: Phil's hits with an ADC threshold of 15, Grey: Phil's hits with an ADC threshold of 18, Green: Phil's hits with an ADC threshold of 20.



(a) X projection (b) Y projection (c) Z projection

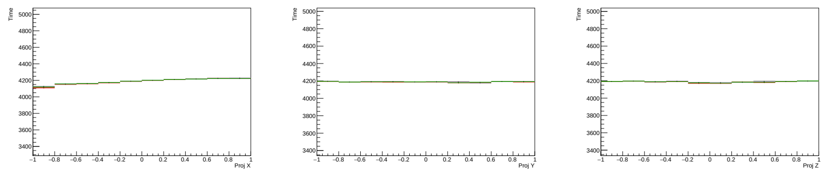
Figure 2: Mean sum ADC of hits for isotropic electrons of energy X MeV at a distance of X cm. Pink: GausHit, Red: Phil's hits with an ADC threshold of 15, Grey: Phil's hits with an ADC threshold of 18, Green: Phil's hits with an ADC threshold of 20.

Next, the triggering is realised by counting the number of clusters in a 10 second timing window. If the number of TC exceeds a certain value, a SN trigger is issued.

In the next section, I detail a way to include more information in this triggering decision which results in a higher efficiency SN trigger.

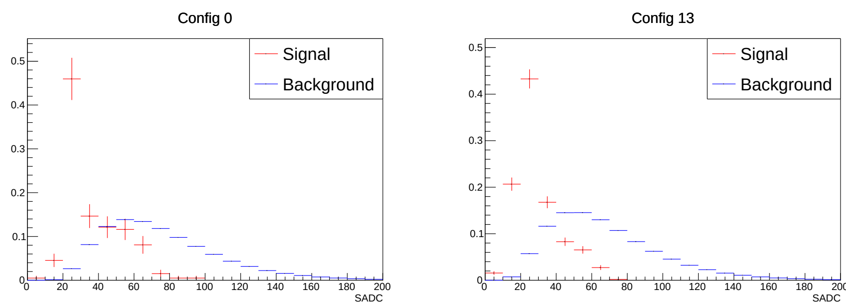
4 Shape information

The information that is used for the test is the sum of the ADC of all the hits in the TCs. This is expected to have a high power to differentiate the signal and the background, as can be seen in Figure 4. This is shown for 2 clustering algorithms, one which gives the best result in the approach that was described in the section before (Section 3), which will be called the "counting configuration." The other is the one that gives the largest signal/background shape differences (and, as we will see later, that gives the best results in terms of SN efficiency), this setup will be called "shape configuration." Note that, taking an holistic approach, 48 different sets of parameters were tested for the clustering algorithm. The parameters of the 2 algorithms are detailed in Table 1.



(a) X projection (b) Y projection (c) Z projection

Figure 3: Mean time span of hits for isotropic electrons of energy X MeV at a distance of X cm. Pink: GausHit, Red: Phil's hits with an ADC threshold of 15, Grey: Phil's hits with an ADC threshold of 18, Green: Phil's hits with an ADC threshold of 20.



(a) Counting configuration (b) Shape configuration

Figure 4: Sum ADC probability density functions of TC for background and signal.

Configuration	Channel tolerance	Time tolerance	Minimum # of hits	Minimum # of channels
Counting	1	20 ticks	6	2
Shape	2	15 ticks	5	2

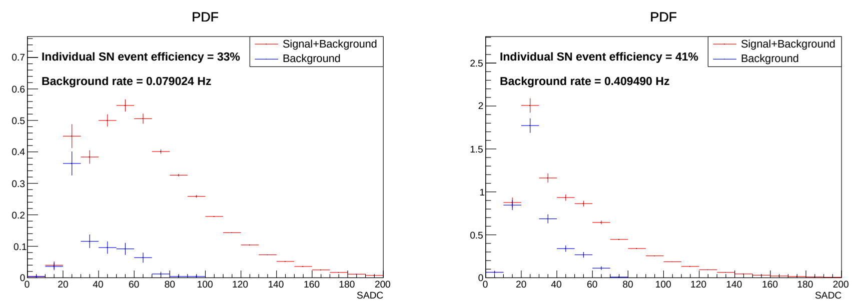
Table 1: Parameters of the clustering algorithms.

5 Trigger description

The shape of the sum ADC described before is used to form a trigger decision. This is done by integrating the TCs over the 10 seconds and forming a histogram of the sum ADC. Then, the quantity corresponding to $-2\log(\text{Likelihood})$ is computed in the hypothesis where there was only background. If this quantity exceeds a certain value, then it is considered that the signal recorded in this 10 seconds in not consistent with background, and a SN trigger is issued.

6 Results

To get the results, a toy study was performed. The signal+background and background probability density functions (see Figure 5) were randomly sampled a number of time corresponding to Poisson statistic with the mean value either: (a) the number of TCs expected in the case of background-only; or (b) in the case of a SN happening (at the Large Magellanic Cloud (LMC) this is expected to produce 10 events in a 10 kT module), by the number of background TC plus the number of signal events (10) times the efficiency to form the TCs. For the 2 clustering parameters sets, this corresponds to the number shown in Table 2.



(a) Counting configuration

(b) Shape configuration

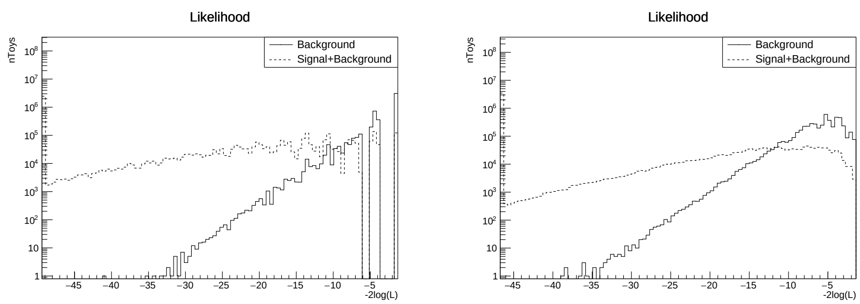
Figure 5: Probability distribution function for the signal+background and background only.

Configuration	SN TC eff	Bkgd rate	Sgn+Bkgd TCs / 10 sec	Bkgd-only TCs / 10 sec
Counting	33 %	0.08 Hz	4	0.7
Shape	41 %	0.41 Hz	8.2	4.1

Table 2: Number of TCs expected for the signal+background and background only for the counting and shape configurations.

Next, the $-2\log(\text{Likelihood})$ were calculated for each sampled histograms when compared with the background only hypothesis. The result is shown in Figure 6.

Finally, one can calculate the integral of these distributions and scale them accordingly to get the distribution shown in Figure 7. These curves show that to reach a good efficiency at the LMC and maintain a low fake trigger rate, it is required to add shape information to the trigger decision. The efficiency to trigger on a 10 events SN goes from 10 % to 70 %. Note in this last plots, many curves were added, all of which are different statistical tests other than the Likelihood test, these test are described in [3]. All the corresponding distributions

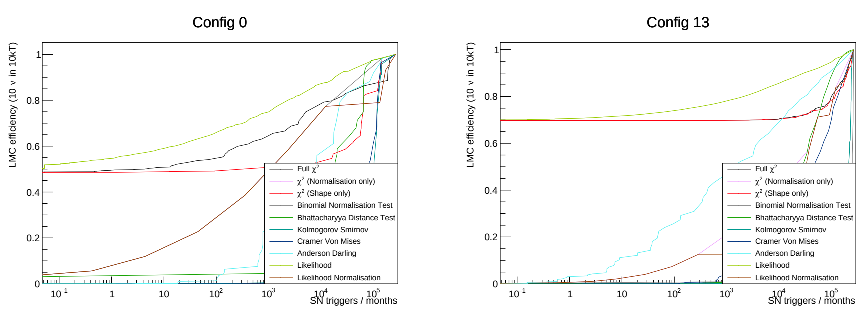


(a) Counting configuration

(b) Shape configuration

Figure 6: Likelihood distributions of the signal+background and background-only in the hypothesis of background-only.

are in Appendix A. In Figure 8, the best situation in the case of counting is shown along with the likelihood approach described here.



(a) Counting configuration

(b) Shape configuration

Figure 7: Summary of all the statistical tests realised.

7 Conclusion

This note shows that making use of the 10 seconds buffer, using realistic TPs and relatively simple TC formation algorithm, one can recover a high SN triggering efficiency at the Large Magellanic Cloud (or any SN creating 10 events) by comparing the background distribution of the sum ADC TCs to the distribution one would get when a SN is happening. The efficiency gain compared to a simpler approach which consists in counting the TCs is quite significant; using only counting information, the efficiency is 6.5 %. It could be as high as 70.6% using the sum ADC of the TCs.

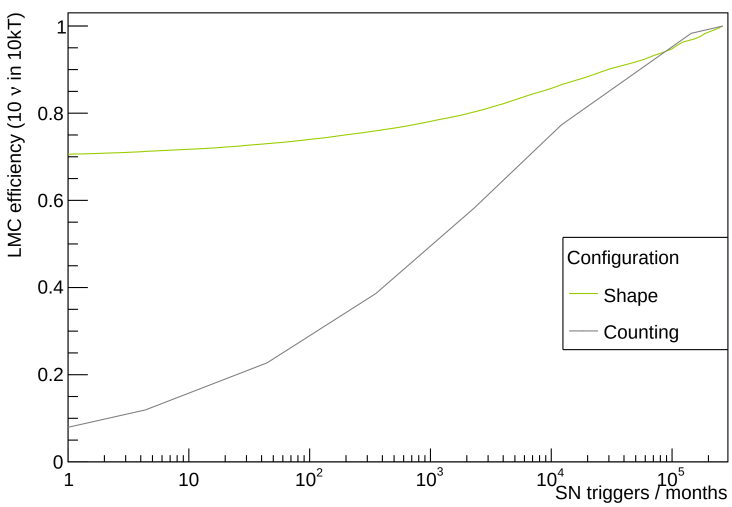
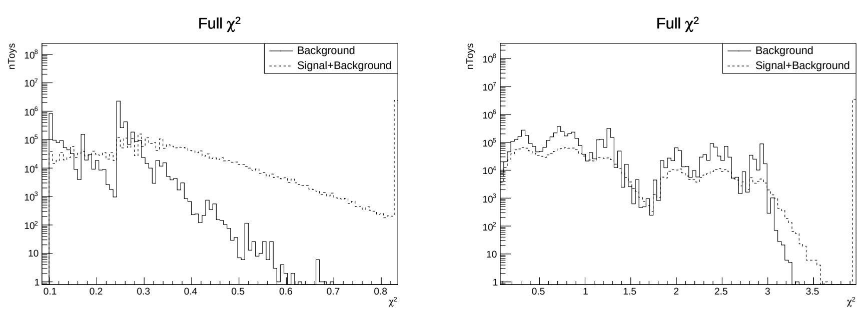


Figure 8: Best efficiency in the case of only counting (using the counting configuration) and using the shape (using the shape configuration).

Appendix A Other statistical tests

All the statistical tests that are used here are described in [3]. For the 2 configurations, the following distribution were used:

- Figure 9 shows the full χ^2 distribution.
- Figure 10 shows the χ^2 distribution when all the information has been condensed in a single bin (thus faking a counting-only test).
- Figure 11 shows the χ^2 distribution when the normalisation of toy histograms has been adjusted to the test histogram (thus, this is a shape-only test).
- Figure 12 shows the Binomial normalisation test distribution (thus, this is a count-only test).
- Figure 13 shows the Bhattacharyya Distance test distribution.
- Figure 14 shows the Kolmogorov-Smirnov test distribution.
- Figure 15 shows the Cramer-Von Mises test distribution.
- Figure 16 shows the Anderson-Darling test distribution.
- Figure 17 shows the Likelihood test distribution, when all the information has been to condensed in a single bin (thus faking a counting-only test).

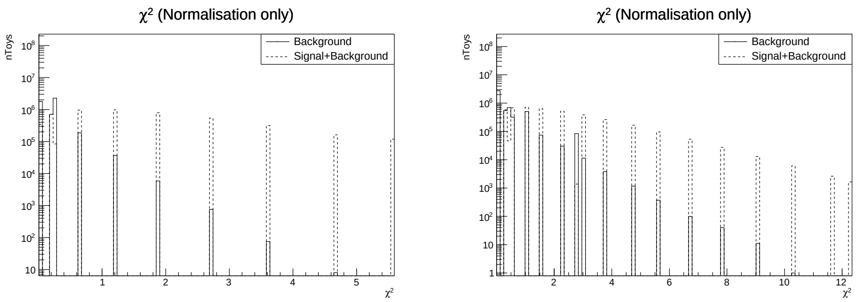


(a) Counting configuration (b) Shape configuration

Figure 9: χ^2 distributions of the signal+background and background-only in the hypothesis of background-only.

References

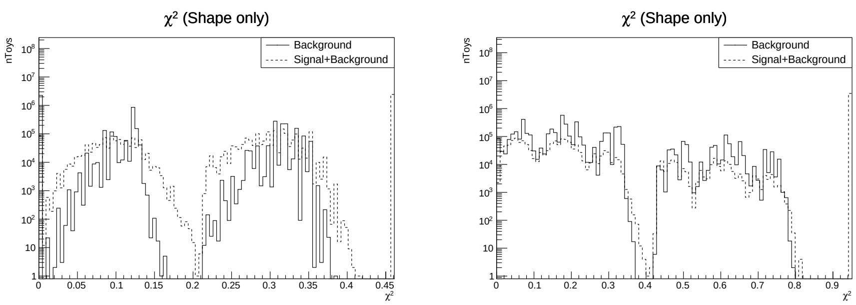
[1] A. Booth, *Supernova Burst Trigger Studies in DUNE FD Single Phase TPC, Collaboration Call Slides*. DocDB 8468.



(a) Counting configuration

(b) Shape configuration

Figure 10: χ^2 distributions (normalisation-only) of the signal+background and background-only in the hypothesis of background-only.



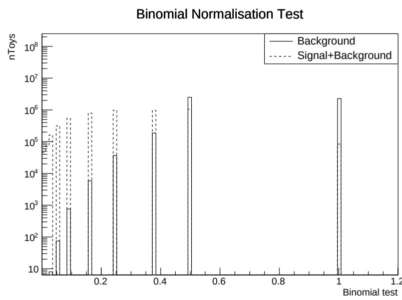
(a) Counting configuration

(b) Shape configuration

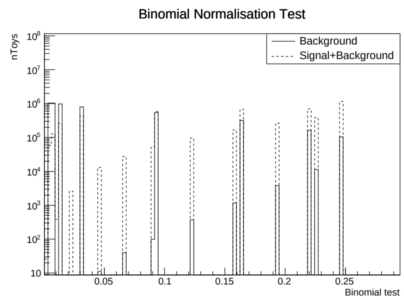
Figure 11: χ^2 distributions (shape-only) of the signal+background and background-only in the hypothesis of background-only.

[2] P. Rodrigues, *Single phase TPC Trigger primitive algorithms for TDR*. DocDB 11236.

[3] F. Porter, *Testing Consistency of Two Histograms*. arXiv:0804.0380.

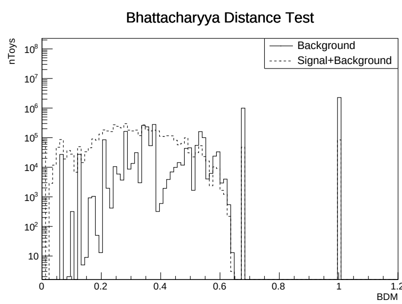


(a) Counting configuration

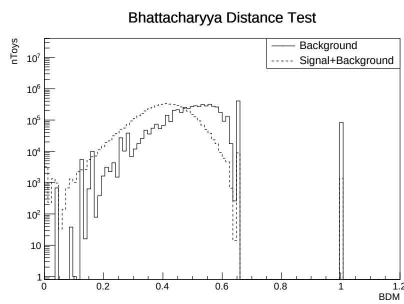


(b) Shape configuration

Figure 12: Binomial normalisation test distributions of the signal+background and background-only in the hypothesis of background-only.

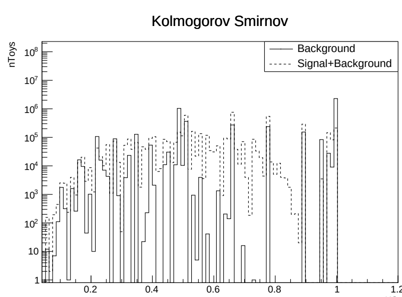


(a) Counting configuration

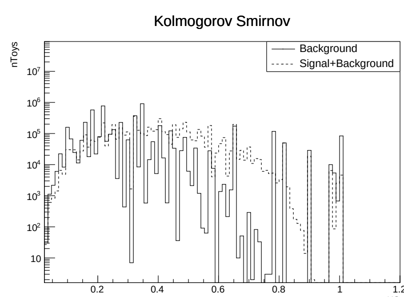


(b) Shape configuration

Figure 13: Bhattacharyya distance test distributions of the signal+background and background-only in the hypothesis of background-only.

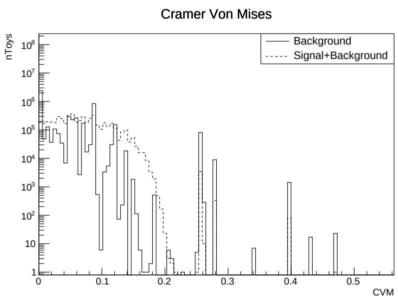


(a) Counting configuration

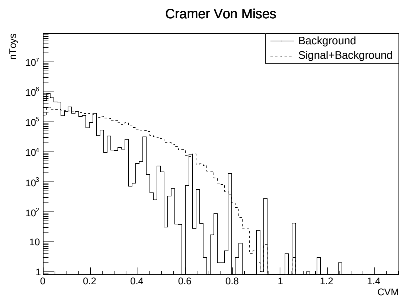


(b) Shape configuration

Figure 14: Kolmogorov-Smirnov test distributions of the signal+background and background-only in the hypothesis of background-only.

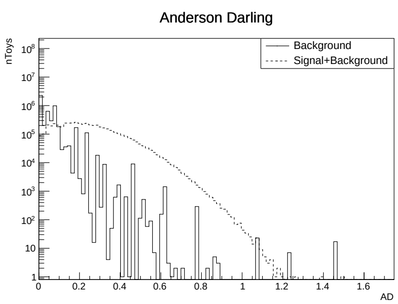


(a) Counting configuration

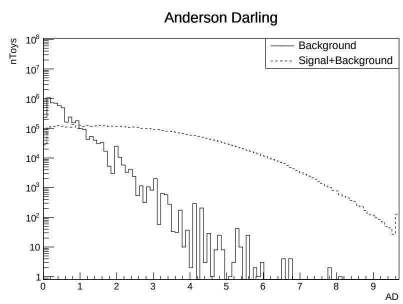


(b) Shape configuration

Figure 15: Cramer-Von Mises test distributions of the signal+background and background-only in the hypothesis of background-only.

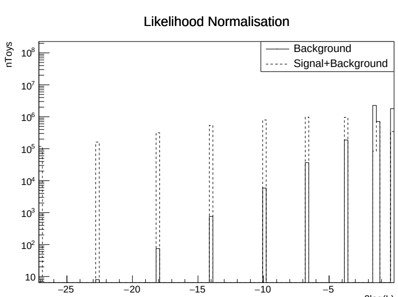


(a) Counting configuration

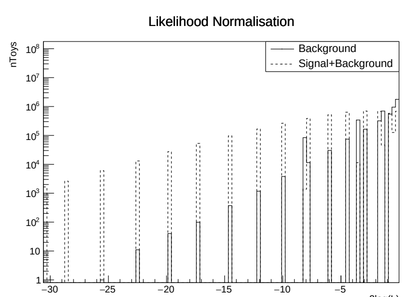


(b) Shape configuration

Figure 16: Anderson-Darling test distributions of the signal+background and background-only in the hypothesis of background-only.



(a) Counting configuration



(b) Shape configuration

Figure 17: likelihood test (normalisation-only) distributions of the signal+background and background-only in the hypothesis of background-only.