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Title: DEVELOPMENT OF A CLOCK GENERATION AND TIME DISTRIBUTION SYSTEM FOR HYPER-KAMIOKANDE

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Abstract: The construction of the next-generation water Cherenkov detector Hyper-Kamiokande (HK) has started. It will have an about ten times larger fiducial volume compared to the existing Super-Kamiokande detector and increased detection performances. The data taking is planned from 2027. Time stability is crucial, as detecting physics events relies on reconstructing Cherenkov rings based on the coincidence between the photomultipliers. The above requires a distributed clock jitter at each endpoint smaller than 100 ps. In addition, since this detector will be mainly used to detect neutrinos produced by the J-PARC accelerator in Tokai, each event needs to be timed-tagged with a precision better than 100 ns with respect to UTC in order to be associated with a proton spill from J-PARC, or events observed in other detectors for multi-messenger astronomy. The HK collaboration is in an R&D phase and several groups are working in parallel for the electronics system. This proceeding will present the studies performed at LPNHE (Paris) related to a novel design for the time synchronization system. We will discuss the clock generation, including the connection scheme between the GNSS receiver (Septentrio) and the atomic clock (free-running Rubidium), the precise calibration of atomic clock and algorithms to account for errors on satellites orbits, the redundancy of the system ; and a two-stage distribution system that sends the clock and various timing-sensitive information to each front-end electronics module, using a custom protocol.

Author's Reply to the Review Report (Reviewer 1)

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* Author's Notes to Reviewer

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Quality of English Language

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	Yes	Can be improved	Must be improved	Not applicable
Does the introduction provide sufficient background and include all relevant references?	( )	(x)	( )	( )
Are all the cited references relevant to the research?	(x)	( )	( )	( )
Is the research design appropriate?	(x)	( )	( )	( )
Are the methods adequately described?	(x)	( )	( )	( )
Are the results clearly presented?	(x)	( )	( )	( )
Are the conclusions supported by the results?	(x)	( )	( )	( )

Comments and Suggestions for Authors

The paper lacks sufficient novelty and I cannot recommend it for publication.

The abstract says "… a novel design for a time synchronization system …" but it is not novel.

This paper describes a basically identical scheme:

DOI 10.1088/1681-7575/ac0f31

NICT implement a system like this (feedback to the remote reference is not described in this paper but was subsequently implemented)

https://www.nict.go.jp/publication/shuppan/kihou-journal/journal-vol50no1.2/050402.pdf

Another variation on this scheme (it doesn't use CGGTTS, just the receiver's one 1 pps output, aligned with GPS) is described here:

https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=905719

https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=925660

In short, the method is well known and well-described already in the literature.

To be publishable, the paper needs descriptions of steering algorithms used etc, and a through evaluation of performance.

A few other comments:

In 2.1, second paragraph, the first few sentences are clearly about the behaviour of a Rb – the comments do not apply to all atomic clocks.

In 2.2, it says the "PolaRx5 .. will track .. for 13 minutes" which is misleading. The PolaRx5 is continously tracking, but reporting CGGTTS data in 13 minute tracks, as per the CGGTTS specification.

In 2.3, it says "The time differences … do not directly give UTC time tags ..". I think what is meant is that the REFSYS values are not with respect to UTC.

In 3.1, "All individual components were calibrated" do you mean antenna+receiver delay was calibrated by SYRTE. What uncertainty was assigned to this?

In 3.1, if number of visible satellites is of concern, why not use additional GNSS?

Your delay calibration for GPS can be transferred to other GNSS, with minimal increase in uncertainty.

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