Hyper-Kamiokande

Clock drift correction for HK timing system

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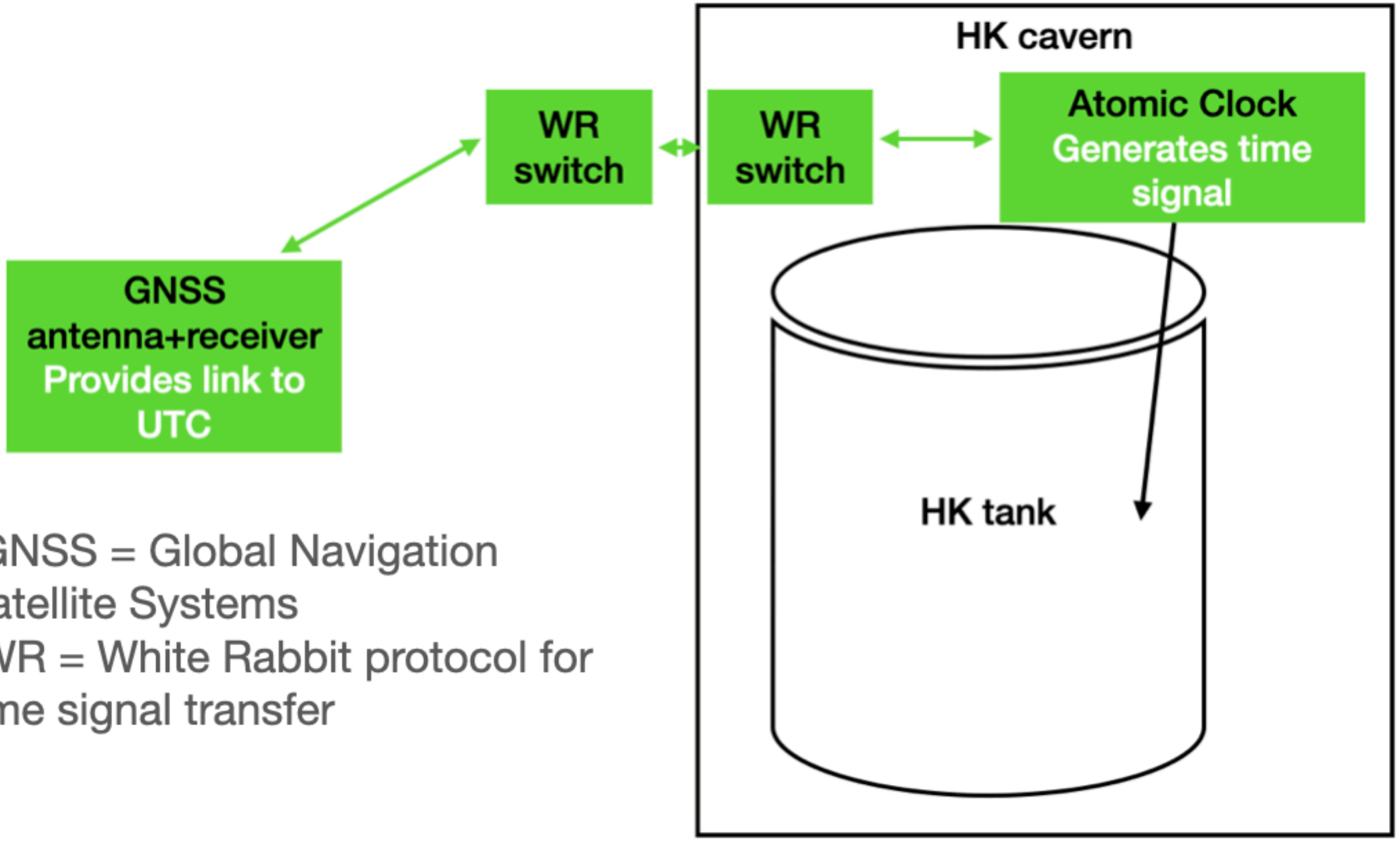
Time generation system

Hyper-Kamiokande

- Signal generated by a free running Rubidium atomic clock
- GNSS receiver continuously measures difference Rb - GNSS Time
- Measured difference used to correct local time in order to keep a synchronisation below 100ns.



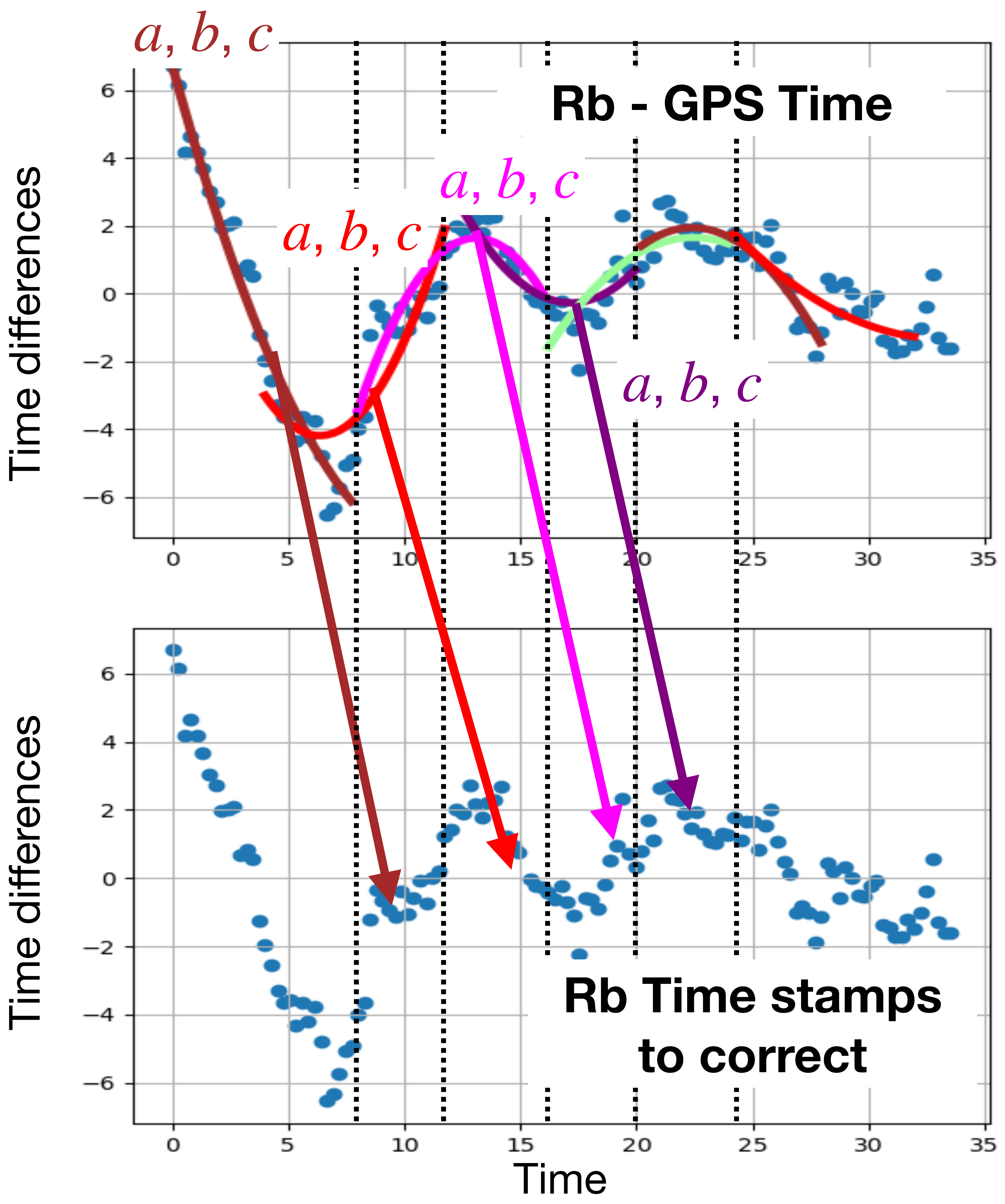
*GNSS = Global Navigation Satellite Systems
*WR = White Rabbit protocol for time signal transfer

Foreseen setup for HK

Drift correction

- Rubidium atomic clocks have a good short term stability but their frequency drifts with time
- The comparison to GNSS allows to estimate this drift and correct it
- To correct it in real-time, we can extrapolate the measured drift to the near future
- In practice, we receive on measurement every 16minutes. The correction to apply is thus changed every 16 minutes.

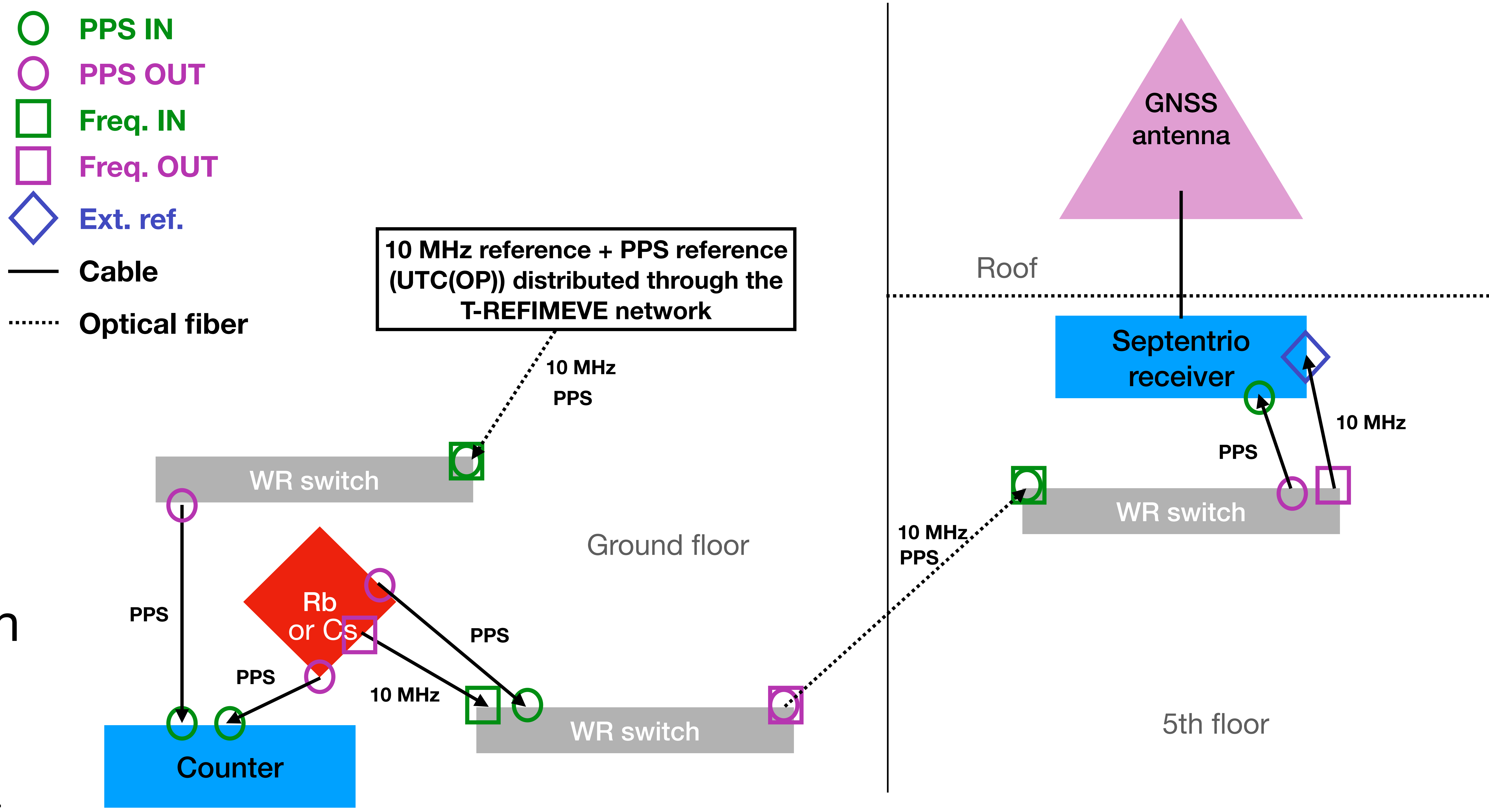
Online correction



Real-time correction validation

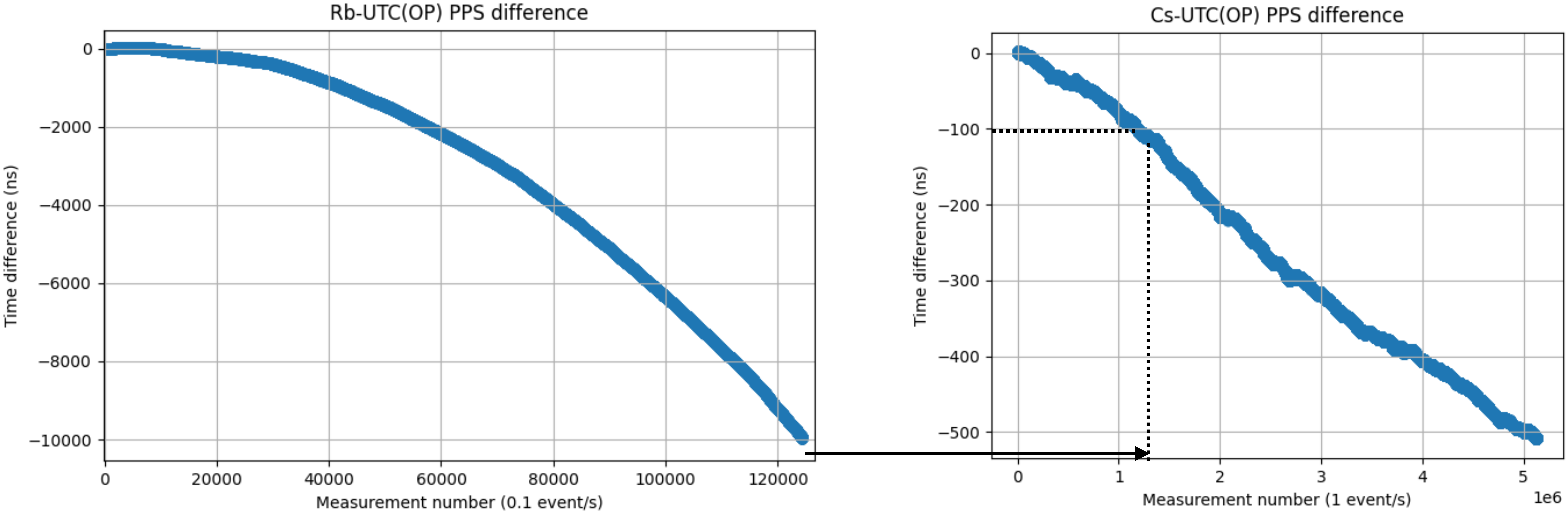
- Simultaneous Local - GPS Time and Local - UTC(OP) measurement
- Use Local - GPS Time to extract correction
- Apply correction in real time to Local - UTC(OP) measurement
- Check residual differences and Allan Standard Deviation
- Results of the offline validation: arXiv:2407.20825

*UTC(OP): French official realisation of UTC made by SYRTE lab (3km from LPNHE)



Setup@LPNHE Paris

Results

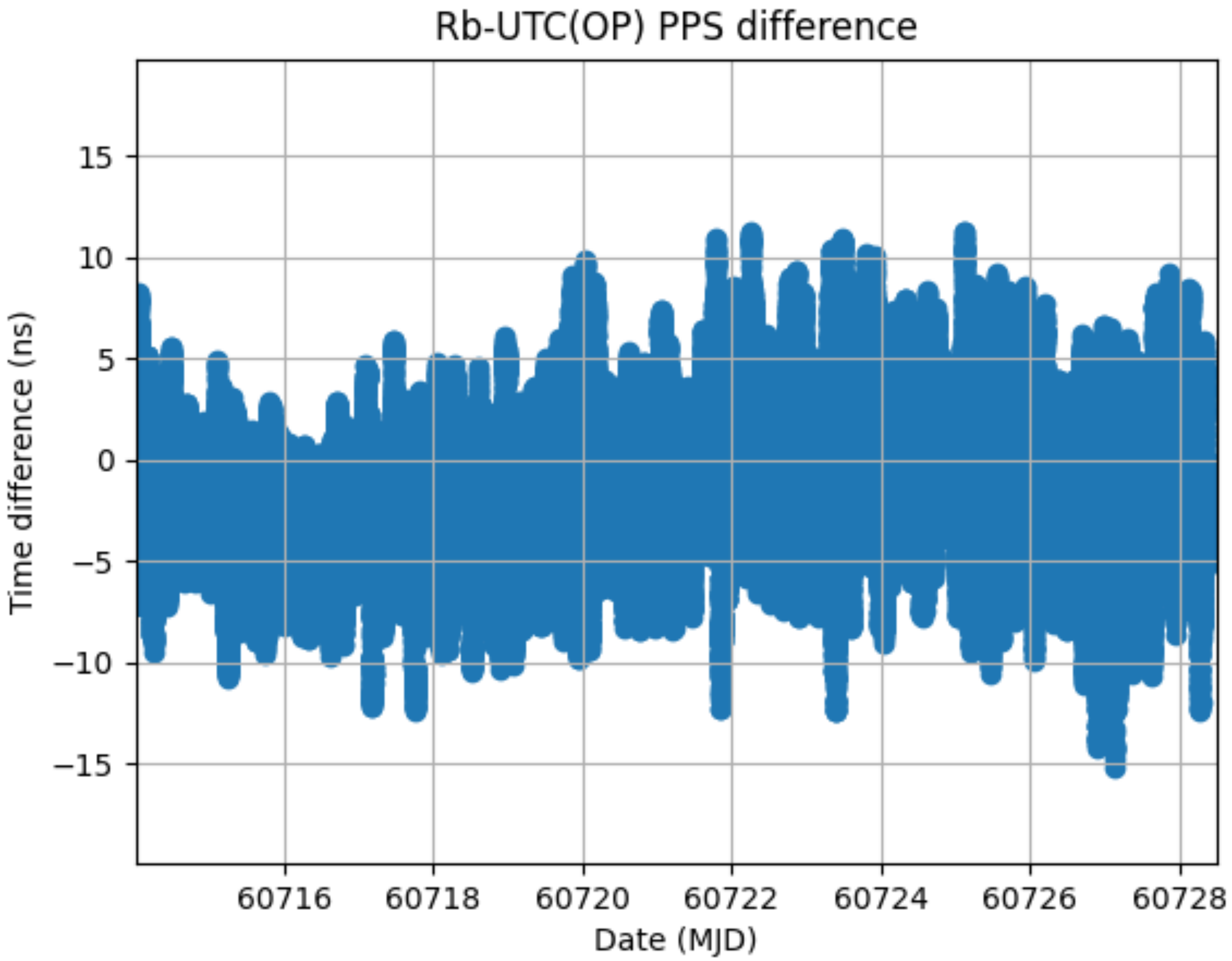


Rb: 10 μs drift in 14 days

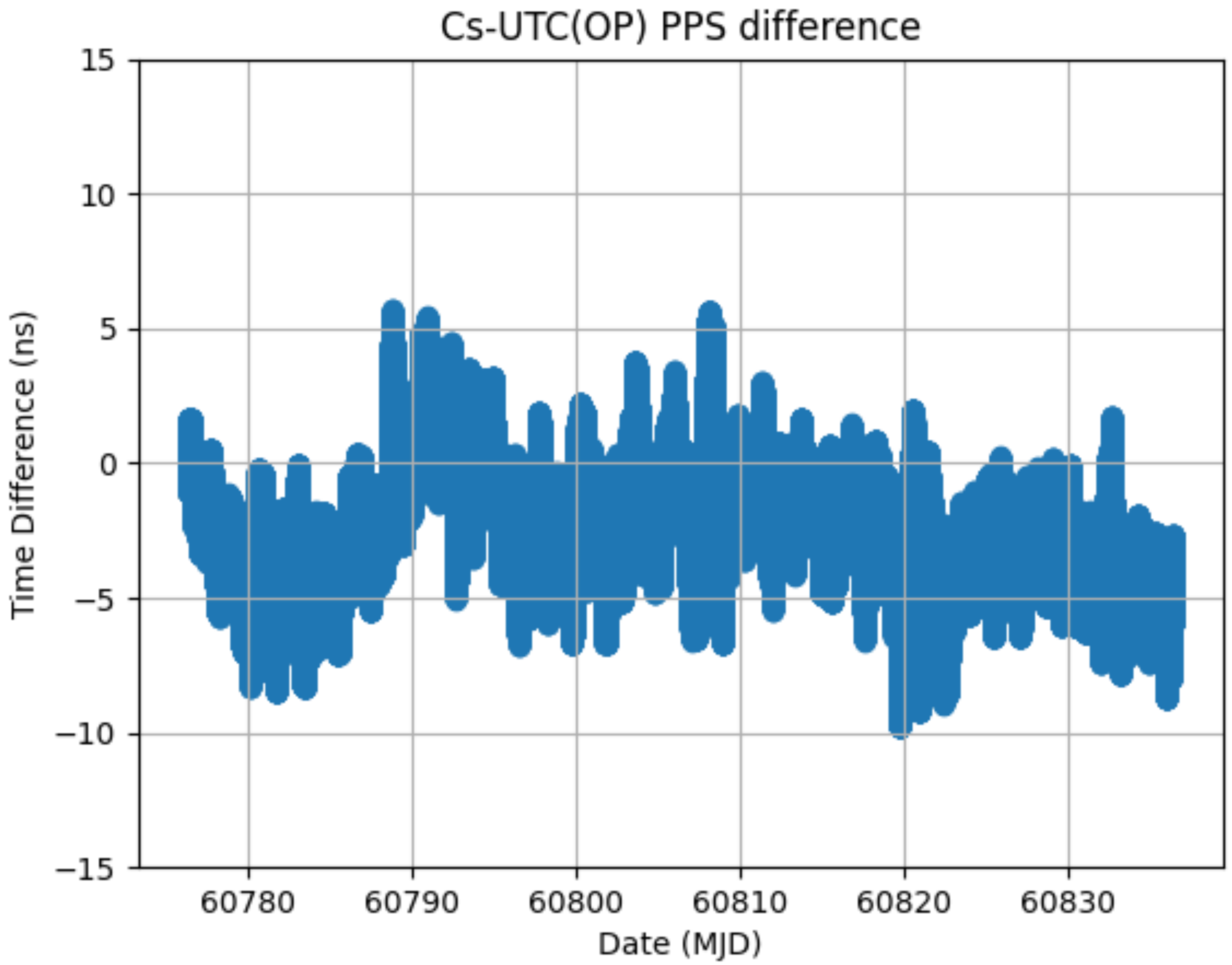
Rb: 100 ns drift in 14 days

Free-running Cs clock long term PPS drift is entirely due to frequency calibration precision: there is no frequency drift like for Rb clock.

Results



Correction using 10 last GNSS measurements



Correction using last 100 measurements

Real-time correction is performant with both clocks but shorter correction time window also means more sensitive to instabilities (missing or noisy GNSS measurements)

Conclusion

Hyper-Kamiokande

- The setup at LPNHE was used to **test real-time correction** of a local time signal for both a Rb and a Cs clock
- The real-time method correction is **working as expected for both clocks**
- **GNSS receiver does not allow time differences bigger** than $500\ \mu$s: it induces a jump of 1 ms!
- **A $500\ \mu$s drift would be reached in only a few months with the Rubidium clock** vs 50 years for the Cesium clock
- **Using a Cs clock would be much safer:** no need for PPS re-alignment during HK lifetime!