Retour d’experience de T-Refimeve au LPNHE : Apport au projet HyperKamiokande

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Outline

Context & Motivations

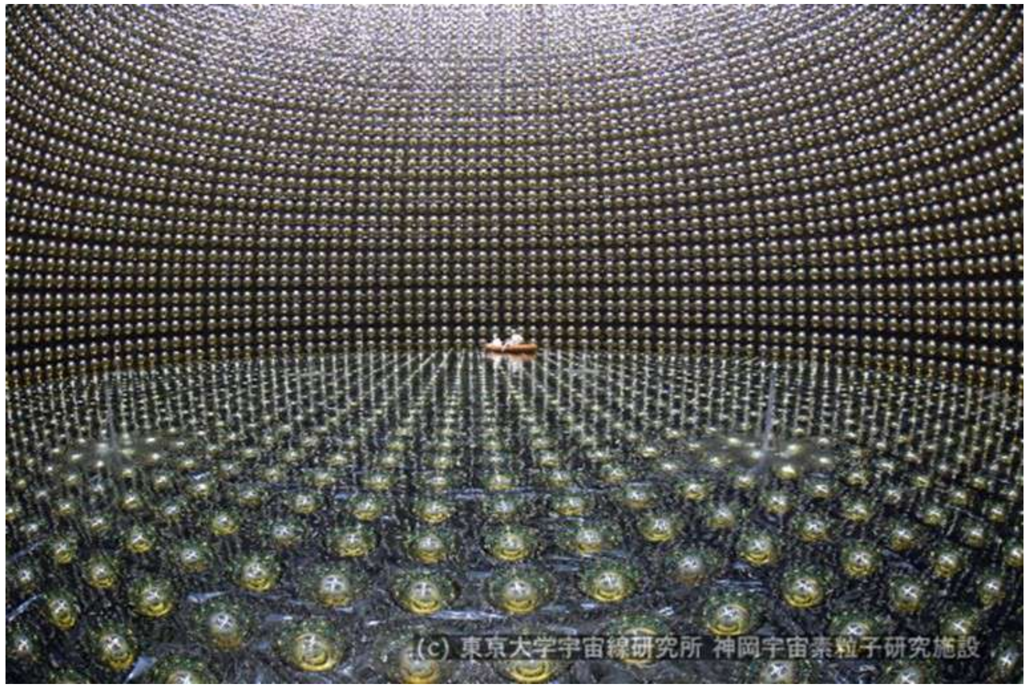
– Synchronization for a particle physics detector

Hyper-Kamiokande experiment in Japan

Experimental set-up at LPNHE and results

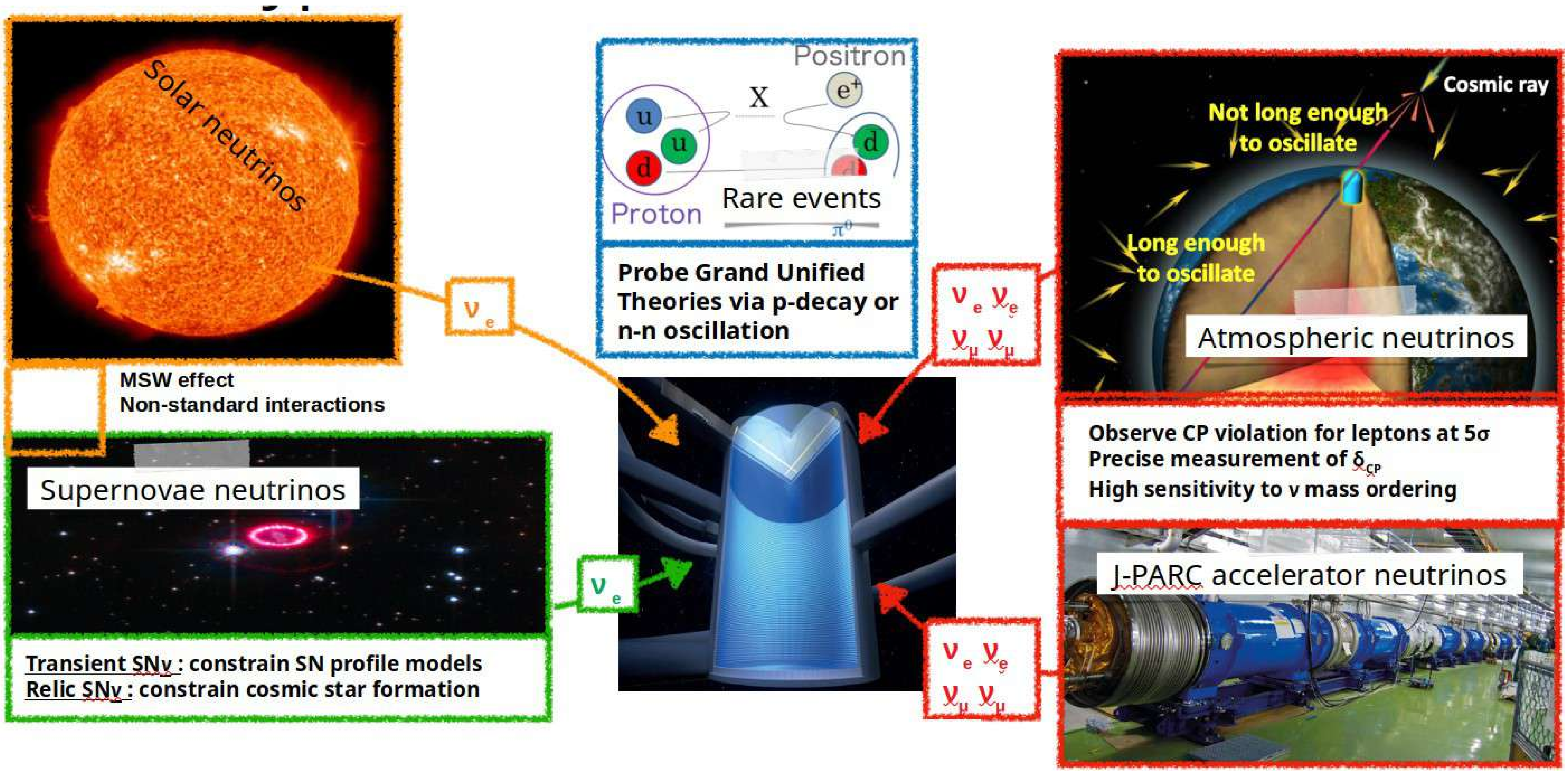
Conclusions and outlook

Tokai to Hyper-Kamiokande



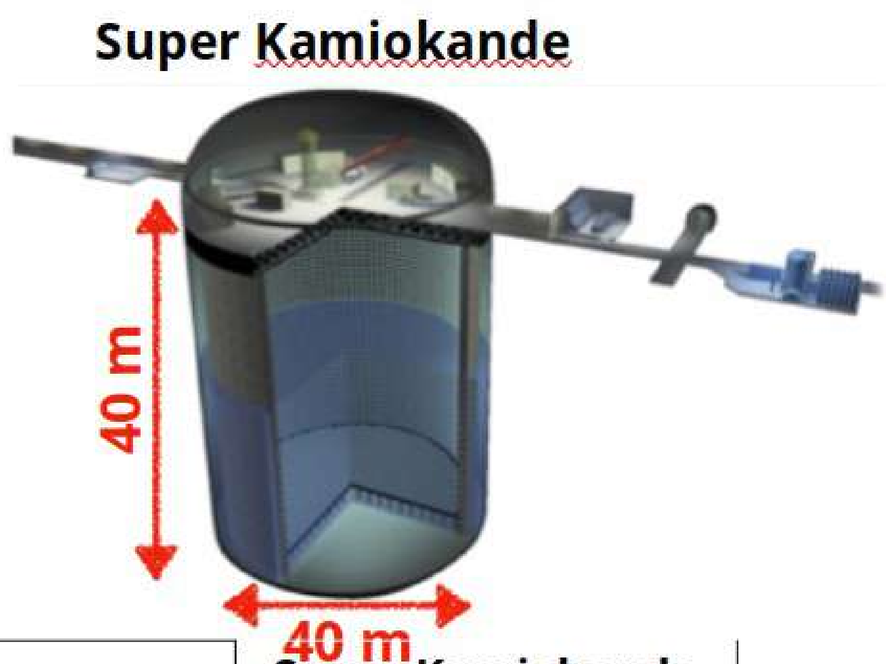
hyper-k.org

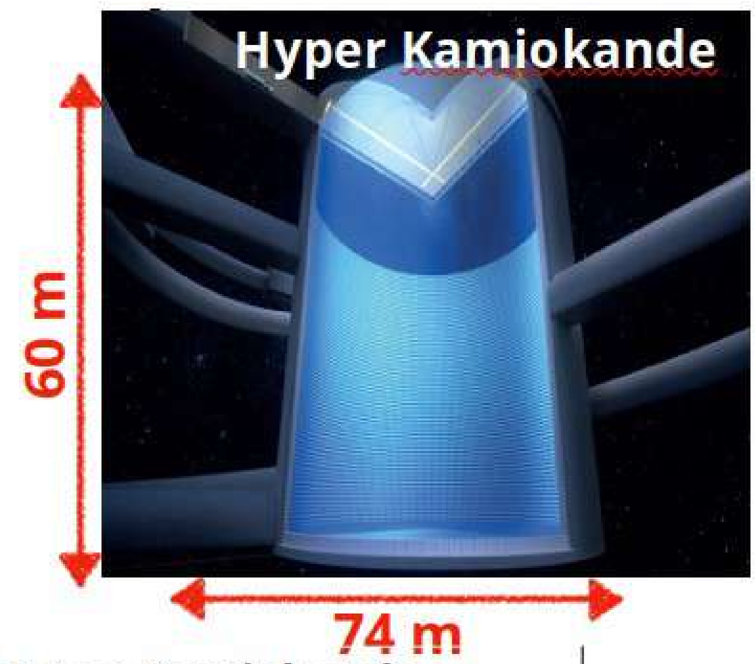
Context



Solar neutrinos
ν e
MSW effect
Non-standard interactions
Positron
X
Rare events
Proton
Probe Grand Unified Theories via p-decay or n-n oscillation
Cosmic ray
Not long enough to oscillate
Long enough to oscillate
Atmospheric neutrinos
Observe CP violation for leptons at 5σ
Precise measurement of δCP
High sensitivity to ν mass ordering
J-PARC accelerator neutrinos
Supernovae neutrinos
Transient SNν : constrain SN profile models
Relic SNν : constrain cosmic star formation

Context





	Super Kamiokande	Hyper Kamiokande
Site	Mozumi-yama	Tochibora-yama
Number of ID 20" PMTs	11 129	>20,000
Photo-coverage	40 %	>20%
Single-photon efficiency/PMT	~12%	~24%
Dark rate/PMT	~4 kHz	~4kHz
Time resolution of 1 photon	~3 ns	~1.1 ns
Total/fiducial mass (kton)	50 / **22.5**	260 / **187**

Fiducial volume x8:
→ non-beam ν physics

Beam neutrino event rate x 20:
→ beam ν physics

Start operations in 2027 with 240 kt.MW and an assumed runtime 10^7 s per year

Context

- **Third generation Water Cherenkov detector in Japan**
- **Based on the experience from T2K and Super-Kamiokande**
- **295 km and 2.5° off-axis w.r.t. existing neutrino beam from J-PARC**
- **Existing near detector ND280 currently being upgraded for T2K-II**
- **Vast non-accelerator scientific program**

Motivation

Goal: realization of a very stable and precise local time base and its synchronization with UTC

Elaboration of the time synchronization and clock distribution for the Hyper-Kamiokande (HK) experiment by the IN2P3-CEA-INFN group.

The system is composed of two main parts:

- Synchronization of all the local electronics modules to a local time base
- Time difference assessment of this time base with the Coordinated Universal Time (UTC).

Precise synchronization with UTC is crucial for studies of multi-messenger astrophysics and synchronization with accelerator neutrinos produced at J-PARC.

Precise time distribution is important for high-quality event reconstruction.

Experiment’s requirements

Local time base:

- 125 MHz clock distributed to all the electronics modules
- Total jitter on any electronics module @125 MHz clock < 100 ps rms

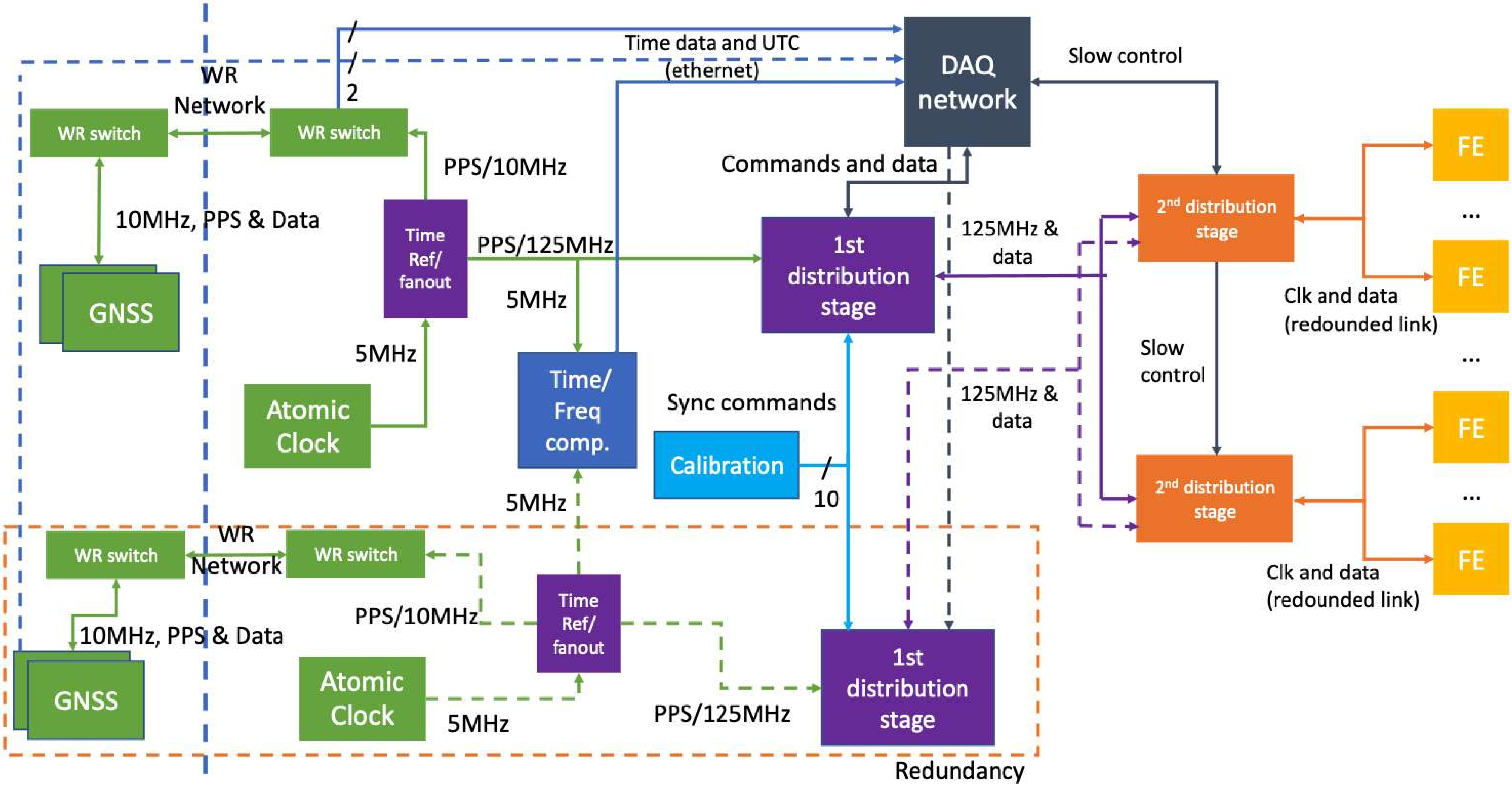
Generation of 125 MHz clock:

- Frequency multiplication of the clock generated by the local source up to the frequency needed for the experiment (125 MHz)
- GNSS receiver connected to the same local source

Synchronization with UTC (better than 100 ns):

- Associate each acquired event with a universal time to enable correlation with other experiments
- “Trigger” the far detector’s acquisition with the particles bunch generated by the accelerator

Overall Scheme



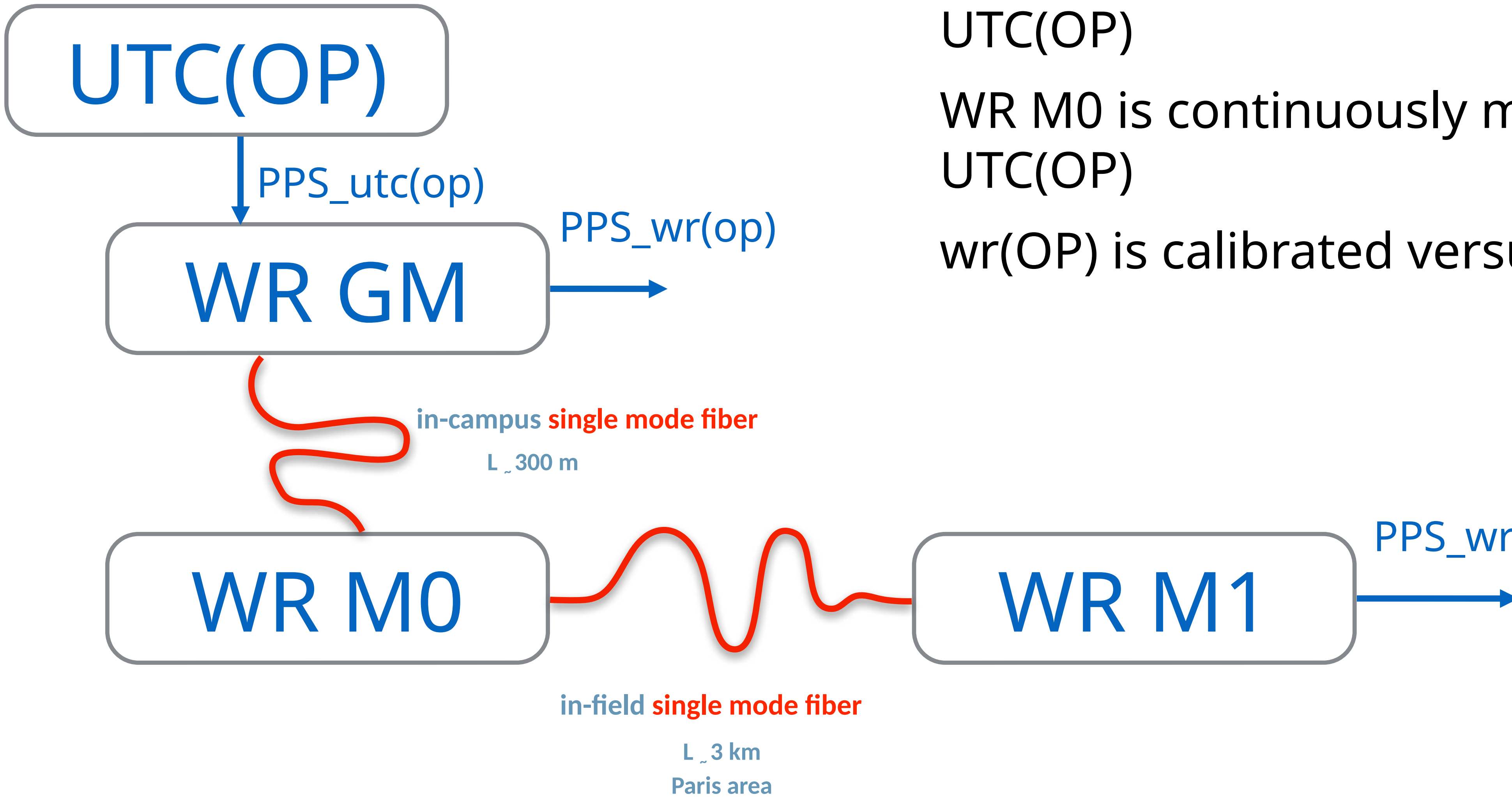
Needs in synchronization

- Time Transfer through WhiteRabbit from the Atomic Clock in the cavern and the GNSS outside
- Time Transfer through GNSS between HyperKamiokande and the J-PARC accelerator (300km)
- Time Transfer through GNSS with UTC(NICT) for a good connection with UTC
-

T-Refimeve at LPNHE :
White-Rabbit vs GNSS Time Transfer

- Goal of the experiment
-
- Compare GNSS based time transfer with White Rabbit Time Transfer, between LPNHE and SYRTE

T-Refimeve at LPNHE : a White-Rabbit link



PPS_wr(OP) is continuously measured versus UTC(OP)

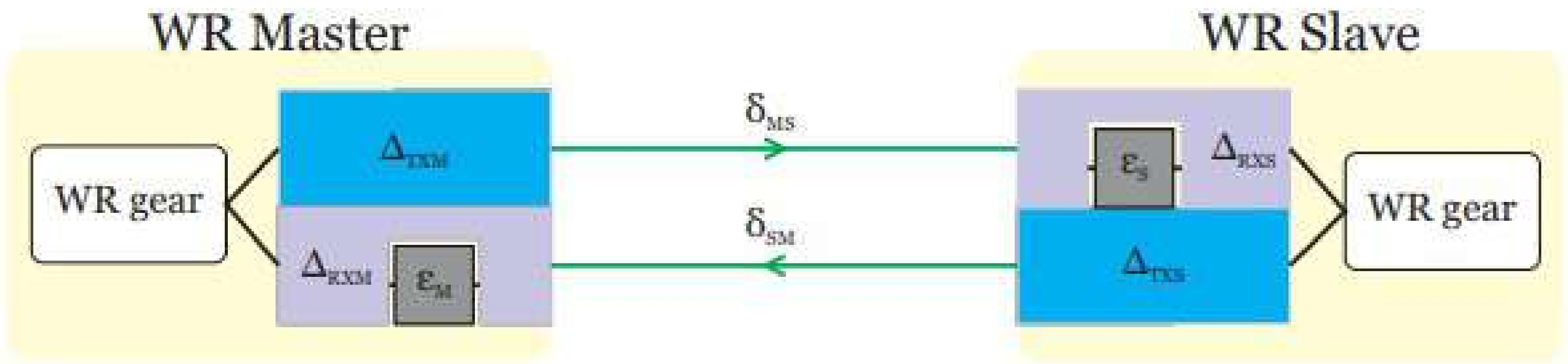
WR M0 is continuously measured versus UTC(OP)

wr(OP) is calibrated versus its source

GM > M0 : 1310/1490 nm pair

M0 > M1: 1310/1490 nm pair

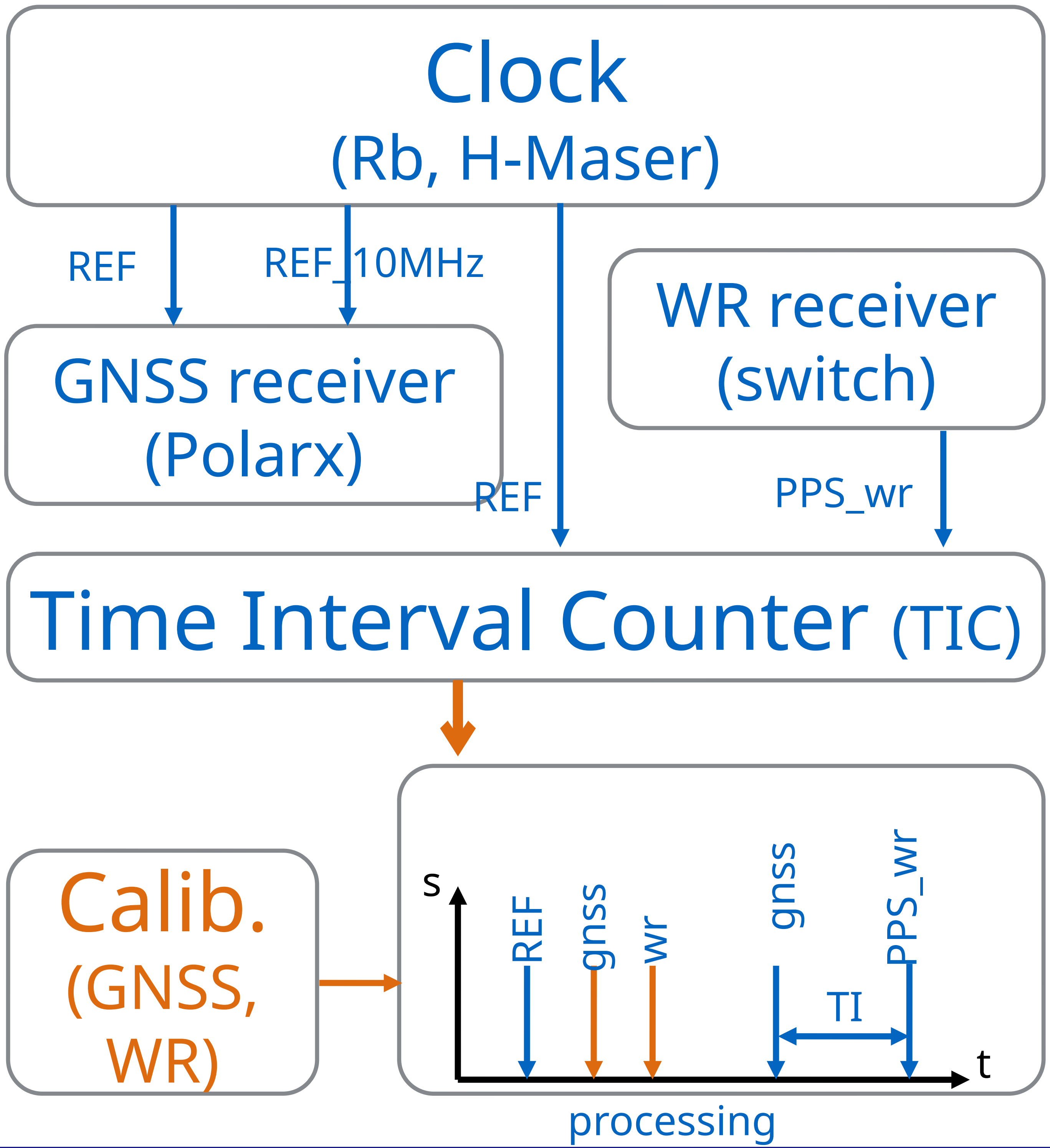
White Rabbit Calibrations



- Each WR Master and WR Slave has some constant transmission and reception delays (ΔTXM, ΔRXM, ΔTXS, ΔRXS) using a method describe in note made by the CERN

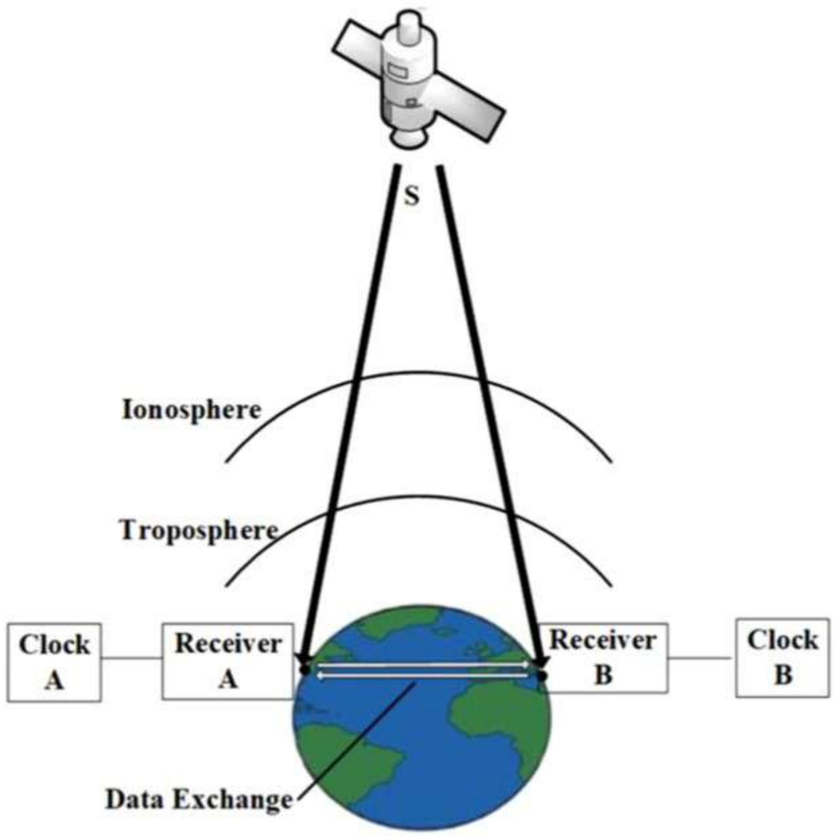
- Futhermore we calibrated the fiber asymmetry parameter α using the fiber swapping technique described in Namneet Kaur’s Phd Thesis

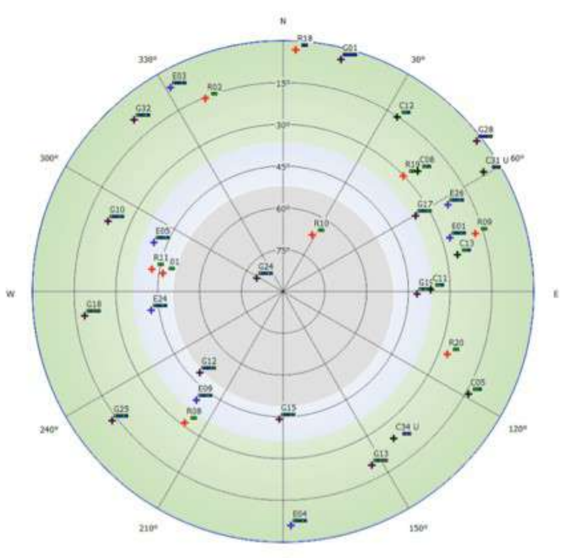
Current R&D set-up at LPNHE



GNSS Time Transfer

- Common-View (and All in-View)
- Septentrio PolaRx5TR receivers at both ends (LPNHE and SYRTE)
- Baseline (between SYRTE and LPNHE) : 3 km
- Ionospheric delays in common mode
- Atmospheric delays are less in common mode





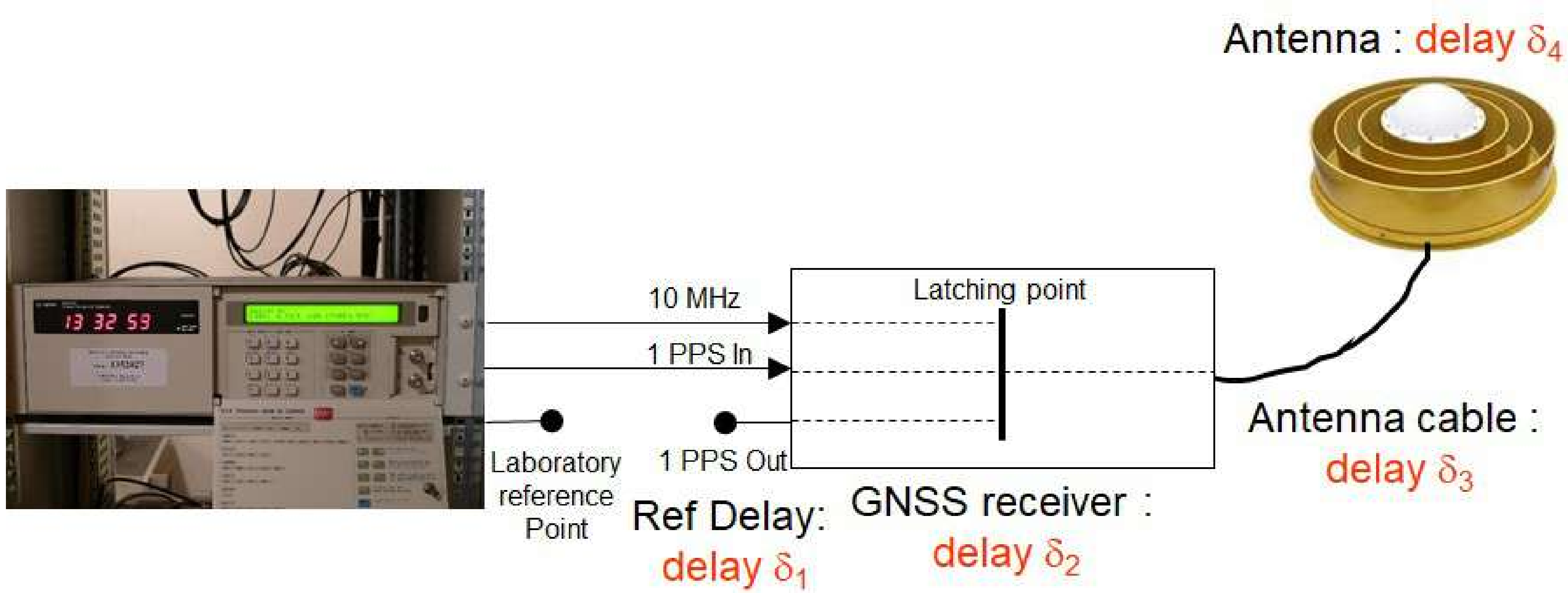
Septentrio PolaRx5TR receiver

Calibrations

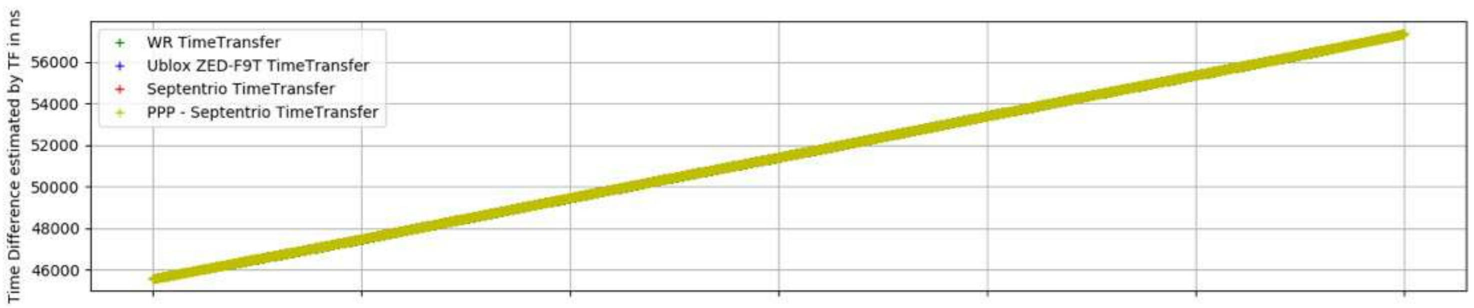
GNSS calibration

- Septentrio PolaRx5TR receiver calibrated against reference station at OP in 2021
- Antenna cable + adaptor : group delay measurement by reflection & transmission
- Ref delay assessment for GPS & Galileo

➡ LPNHE receiver calibrated with combined uncertainty 4 ns
(could be reduced to 2.5 ns with closure)



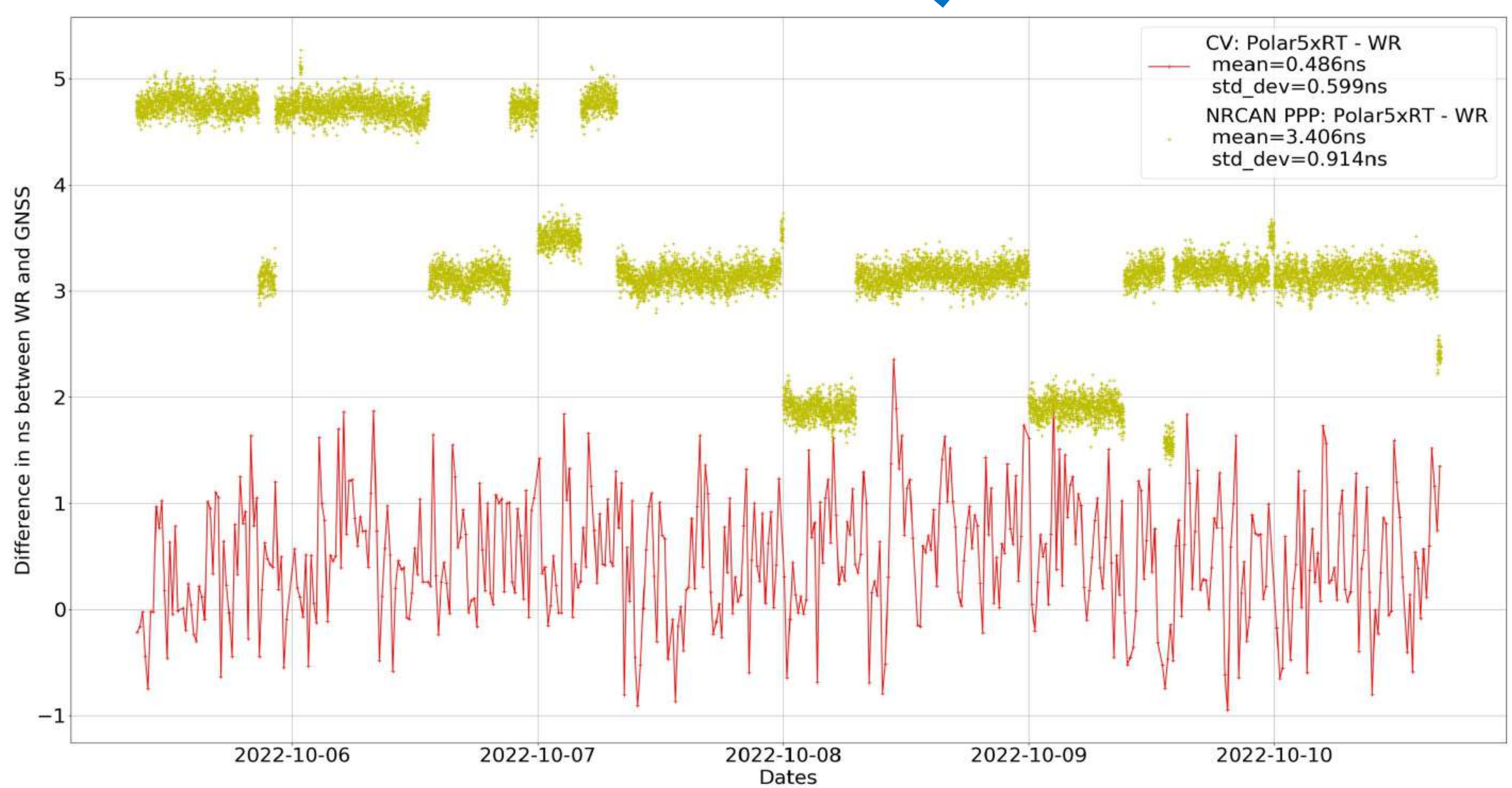
First results



CV (PolaRx) vs WR :
mean = 0.486 ns, sigma = 0.599 ns

AV-PPP vs WR :
mean = 3.406ns, sigma = 0.914ns

Good agreement between WR and GNSS CV within 3-5 sigmas (2-3 ns)



Conclusions and outlook

T-REFIMEVE and its white rabbit link are very precious tools for us

- Allows us to gain experience using WhiteRabbbit technology

- Allows us to validate Time Transfer techniques.

Next steps for Hyperkamiokande

- Extended integration time
- HK Local time base distribution
- On-site tests in Japan
- Implementation on longer baseline (~300 km)

Thank you !

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Many thanks to the SYRTE team especially to Paul-Eric Pottie and Caroline Lim