

# Timing distribution developments based on White Rabbit at IJCLab

On behalf of Daniel CHARLET





## ● IJCLab

- **Hardware** : Daniel Charlet
- **Firmware** : (Eric Plaige), Antoine Back, C dric Esnault, Daniel Charlet, Christelle Soulet
- **Software** : Monique Taurigna, Chafik Cheikali, Antoine Back
- **Test** : C dric Esnault, Daniel Charlet

## ● Paris Observatory (SYRTE, OBS Nan ay)

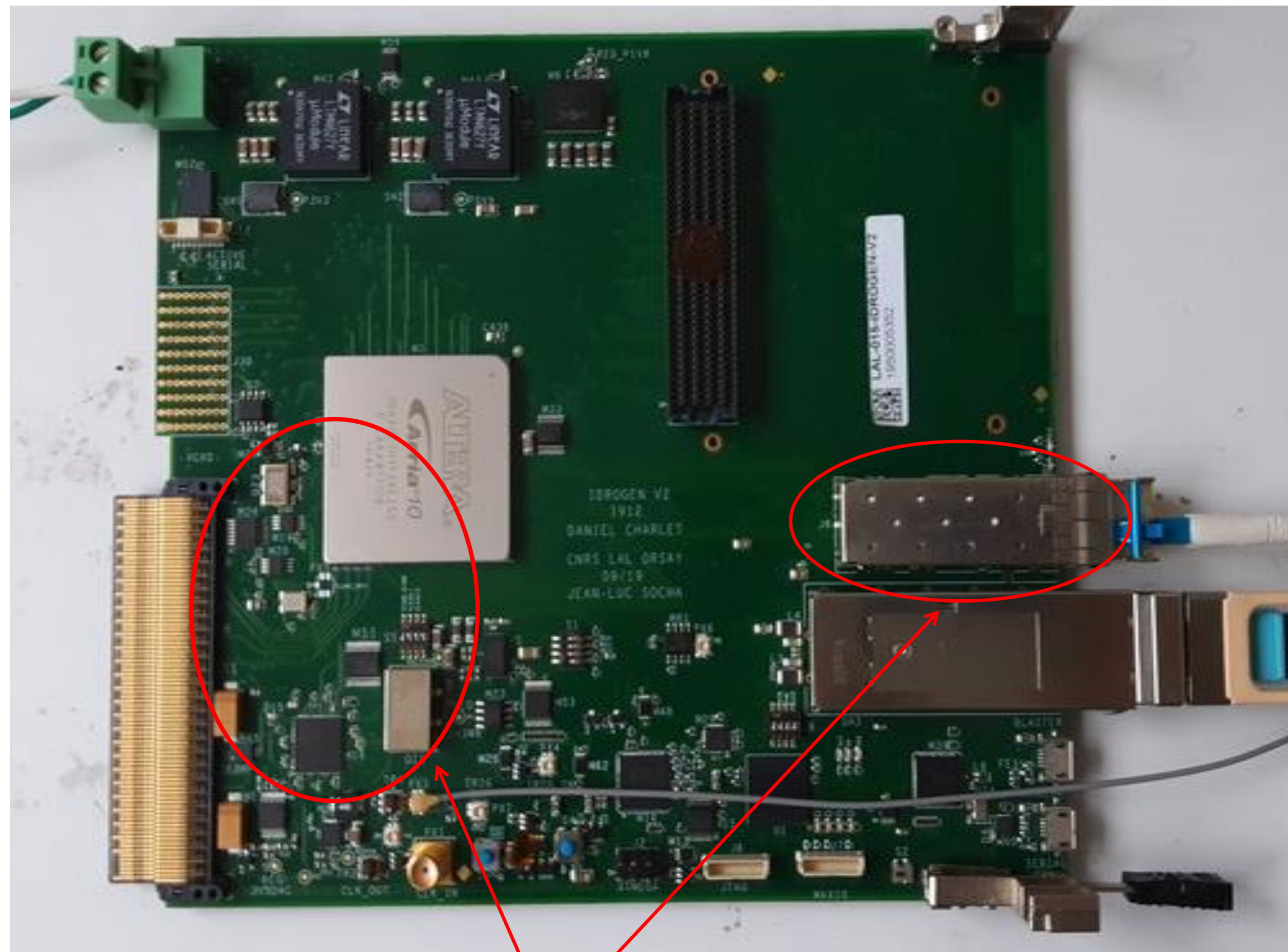
- **Clock expertise and qualification** : Paul-Eric Pottie
- **Hardware** : Michel Lours
- **Firmware** : C dric Viou



- SYRTE (Systèmes de Référence Temps-Espace): is part of Paris Observatory – PSL university, CNRS, Sorbonne University and LNE (Laboratoire National de Métrologie et d'Essais)
- Multidisciplinary research activities (Time and frequency metrology, inertial sensors, space-time reference frames, theory, epistemology)
- Appointed by the LNE as **institute for national time and frequency standards**
- Provides **one of the most accurate realisation of UTC** (Universal Time) with 3 atomic fountains
- New atomic clock generation: optical lattice clocks with Sr, Hg, Yb
- **Produces time and frequency standards for REFIMEVE infrastructure:** a new research infrastructure to disseminate time and frequency standards on active telecommunication network of RENATER



# WR hardware IJCLab IDROGEN board : Low phase noise WR node



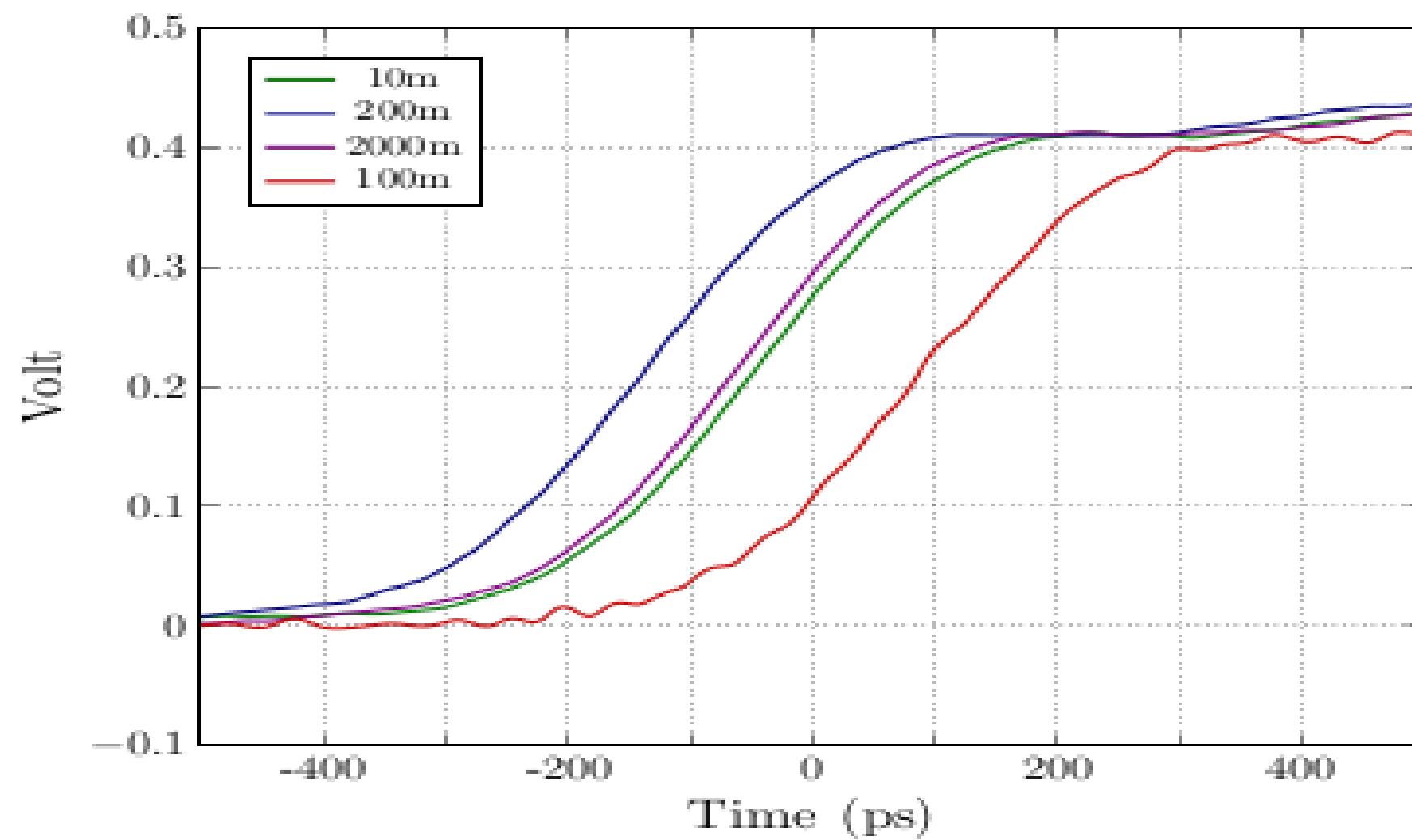
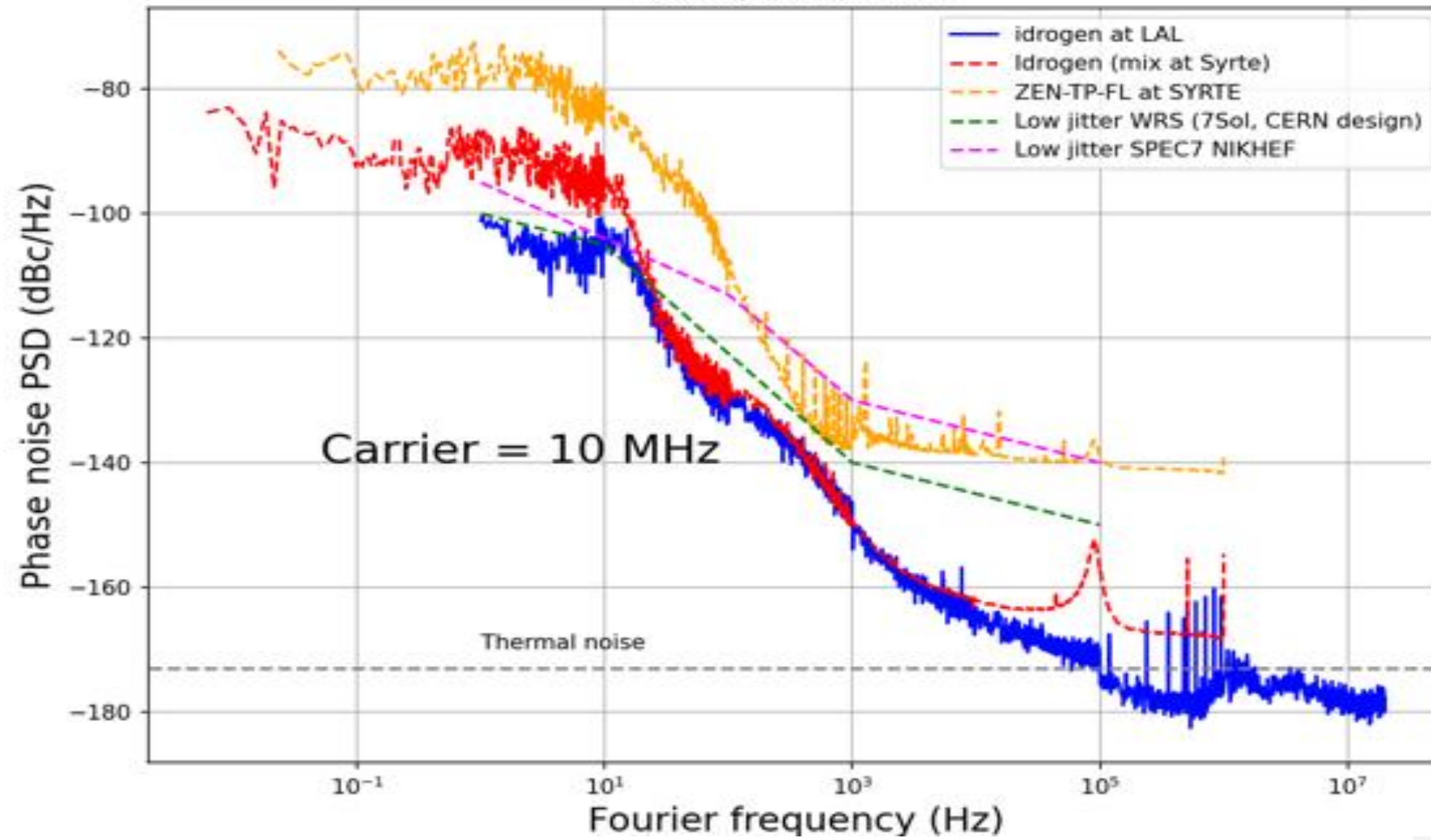
WR implementation

- Design & development done by IJCLab
- CERN schematic improved
  - Components upgrade : PLL, VCXO, FPGA (Altera Arria10)
  - PCB design compliant with EMC rules
- High performance WR low jitter node :
  - Time distribution accuracy  $< 20\text{ps}$ , jitter  $< 1\text{ps}$
- High performance data acquisition system:
  - PCI express  $> 30\text{Gbs}$ , Ethernet  $> 20\text{Gb}$
- Crate ( $\mu\text{TCA}$  4.0 standard) or stand alone use
- FMC + carrier board for additional functions :
  - ADC, DAC, Clock synthesis, ...
- Backplane RTM connector for additional extension boards
- Firmware development done by Nancay Obs. and IJCLab
- Clock expertise and qualification done by SYRTE



# IDROGEN board performances

Phase noise comparison of improved WR device  
- 2020 state of the art -



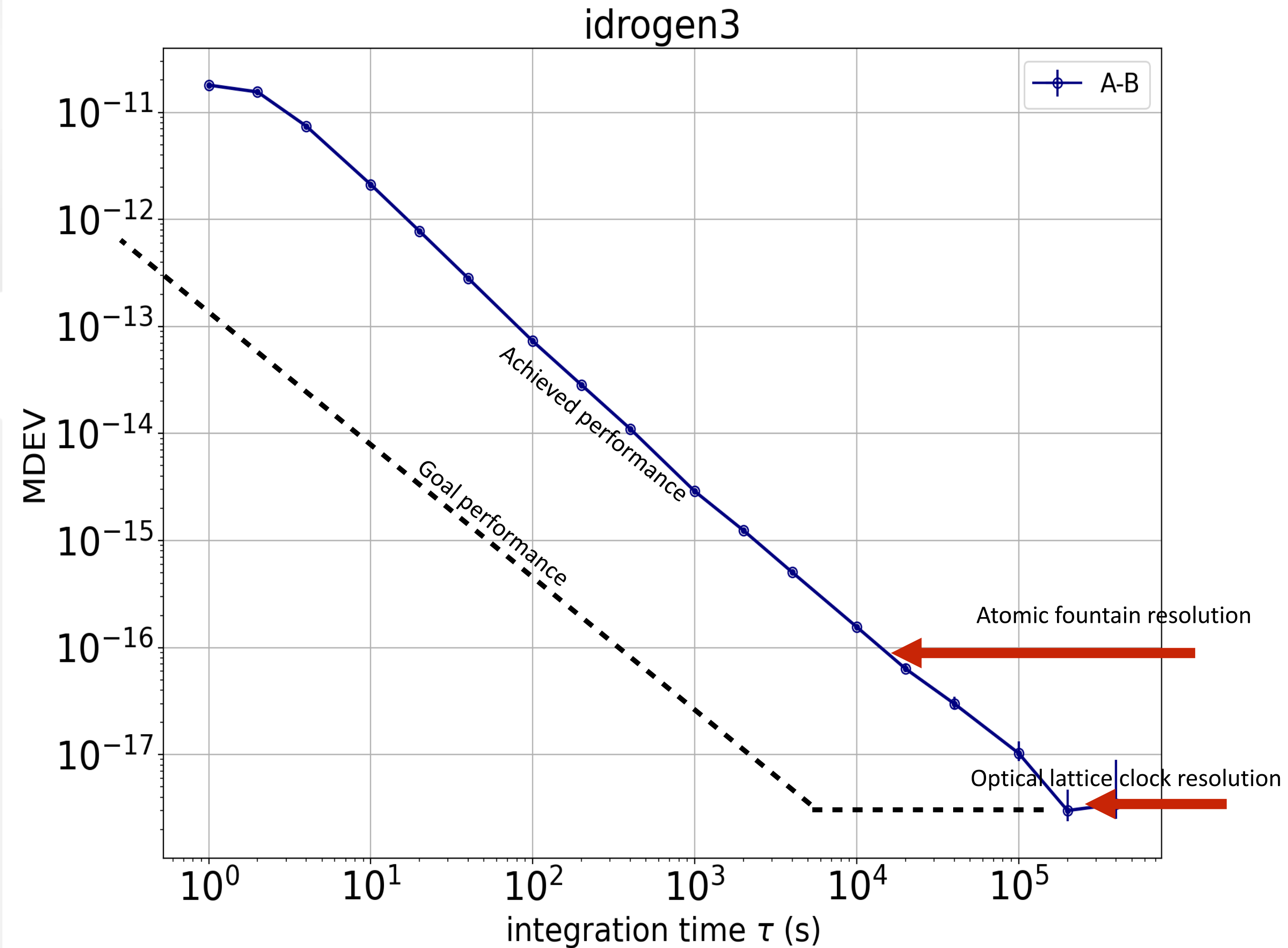
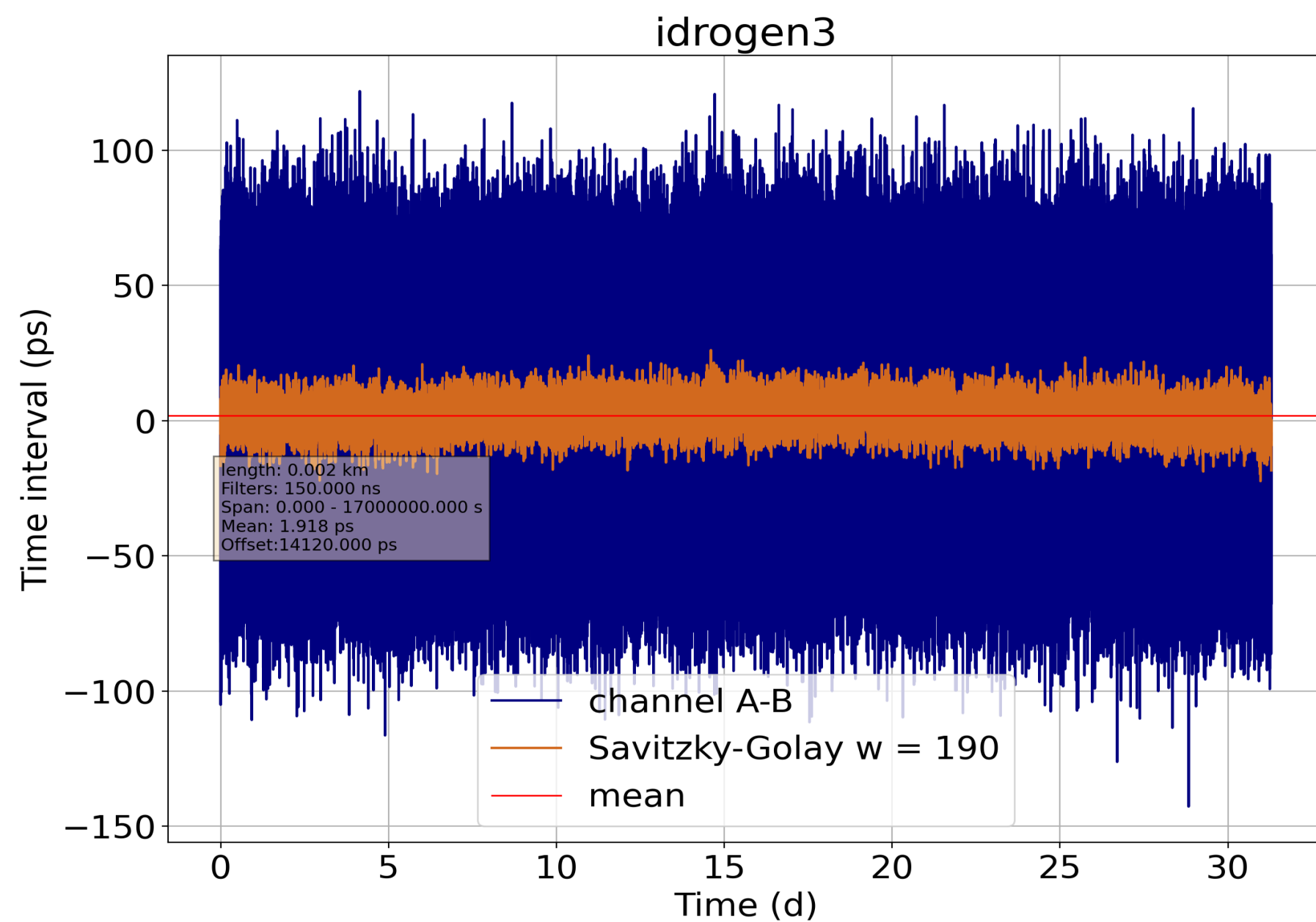
- Transfer from one WR switch to two IDROGEN boards with a short link (few meters)
- Phase noise measurements performed using the phase difference between 2 nodes (IDROGEN boards)
- PPS (pulse per second) time precision : 1ps RMS
- PPS measurements for different fiber lengths
- Time accuracy below 100ps

Results are repeatable after power off/on, cold restart

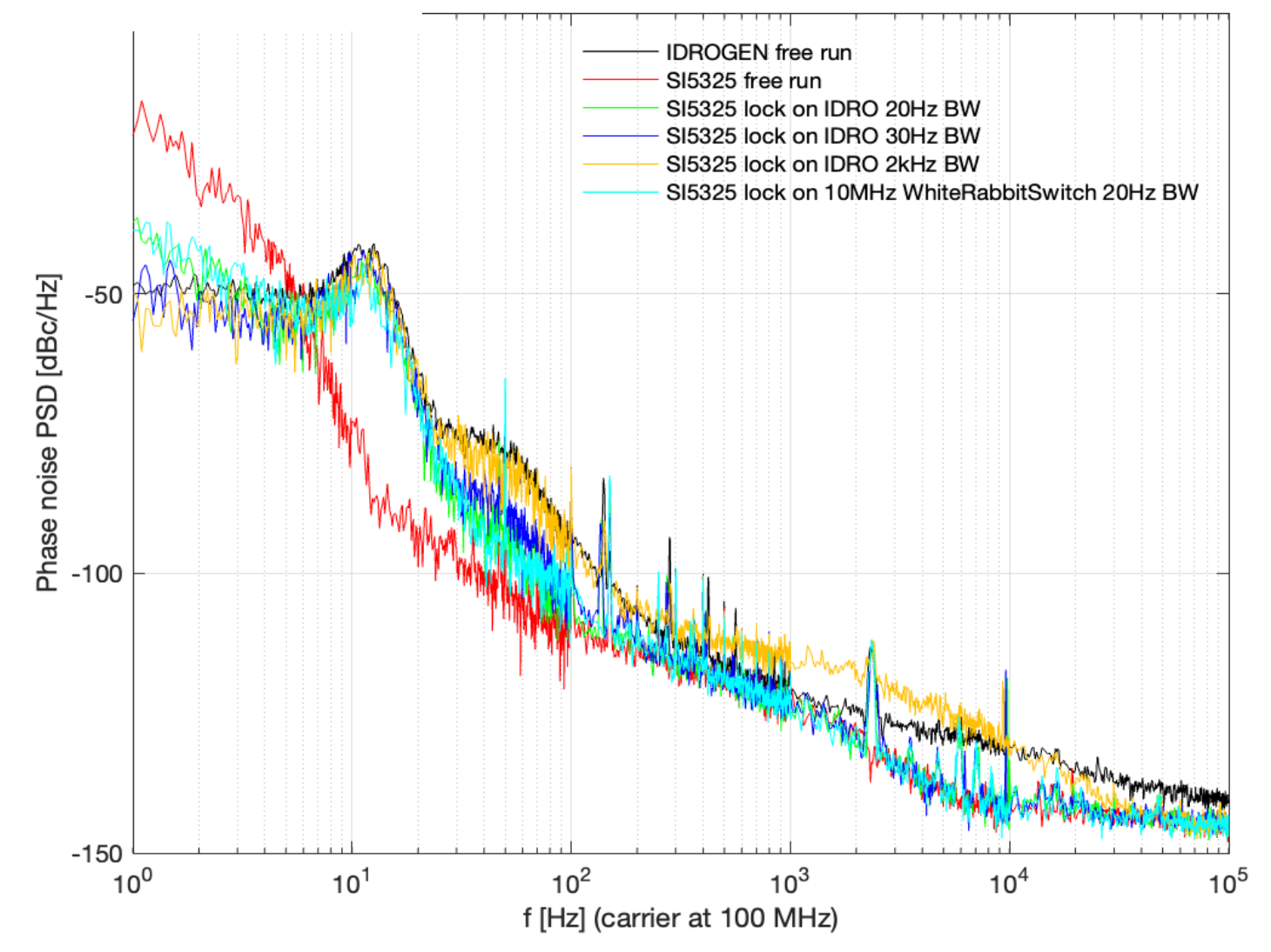
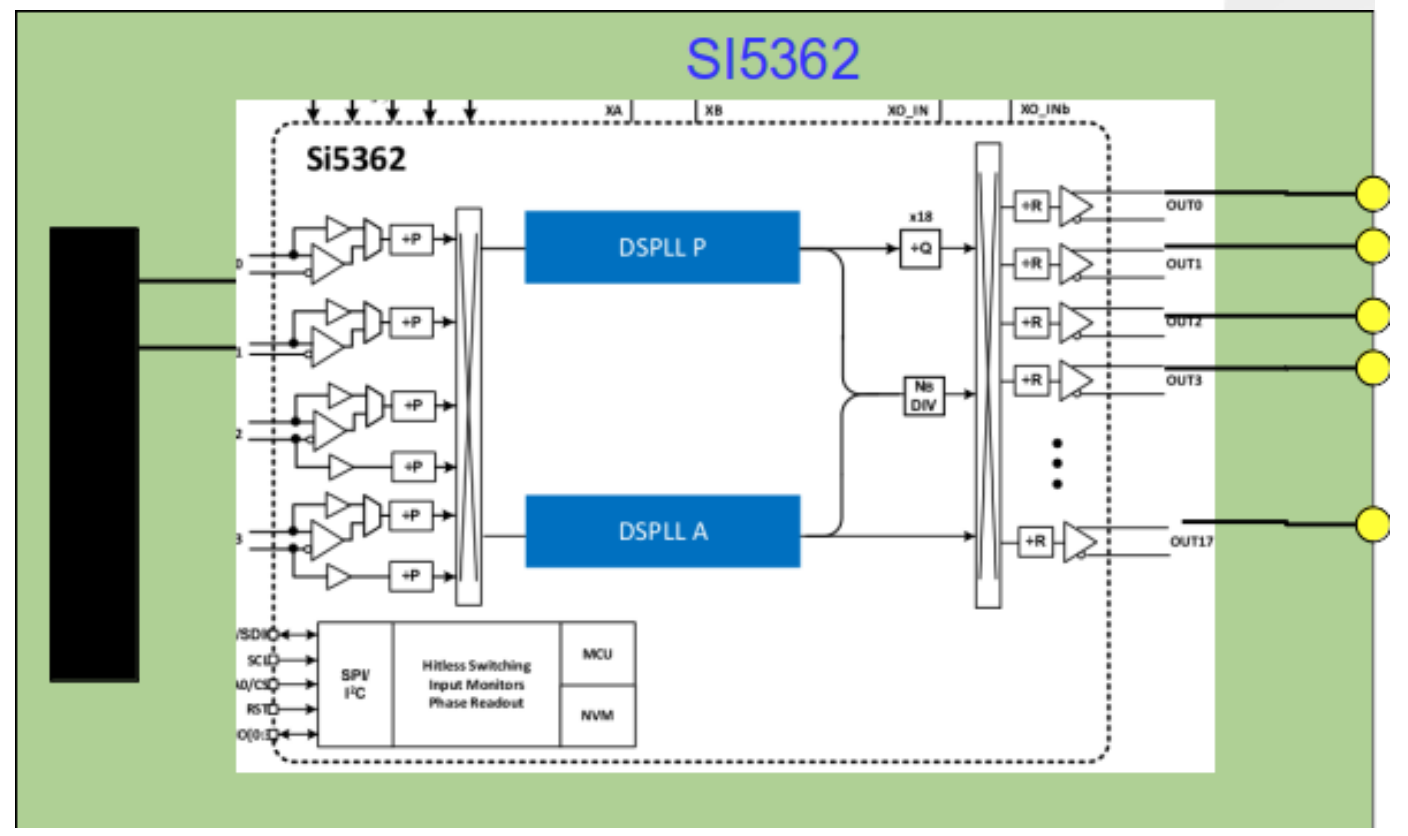
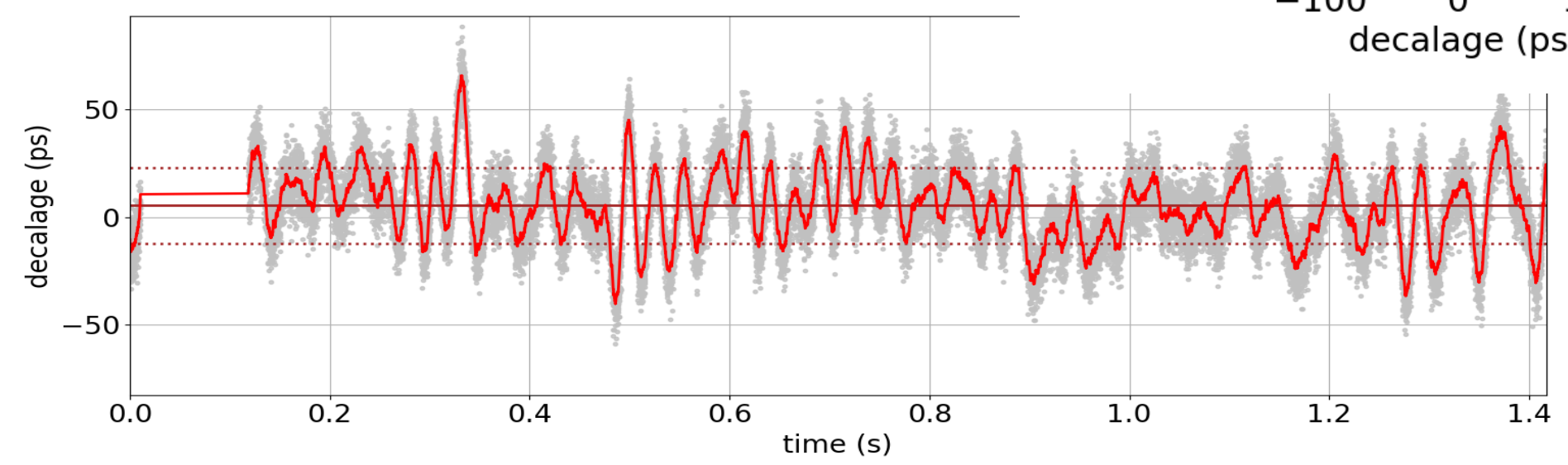
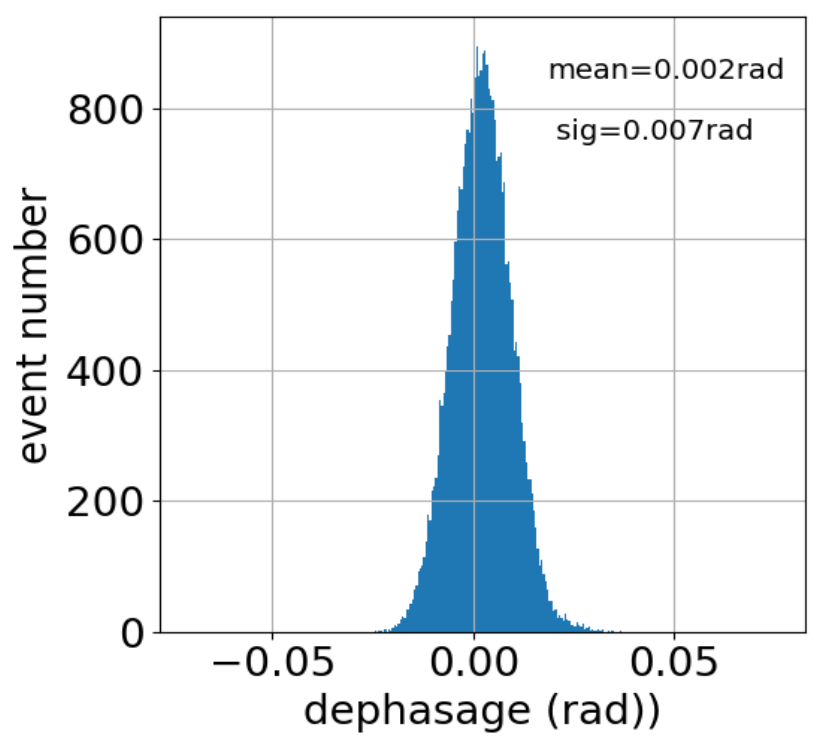
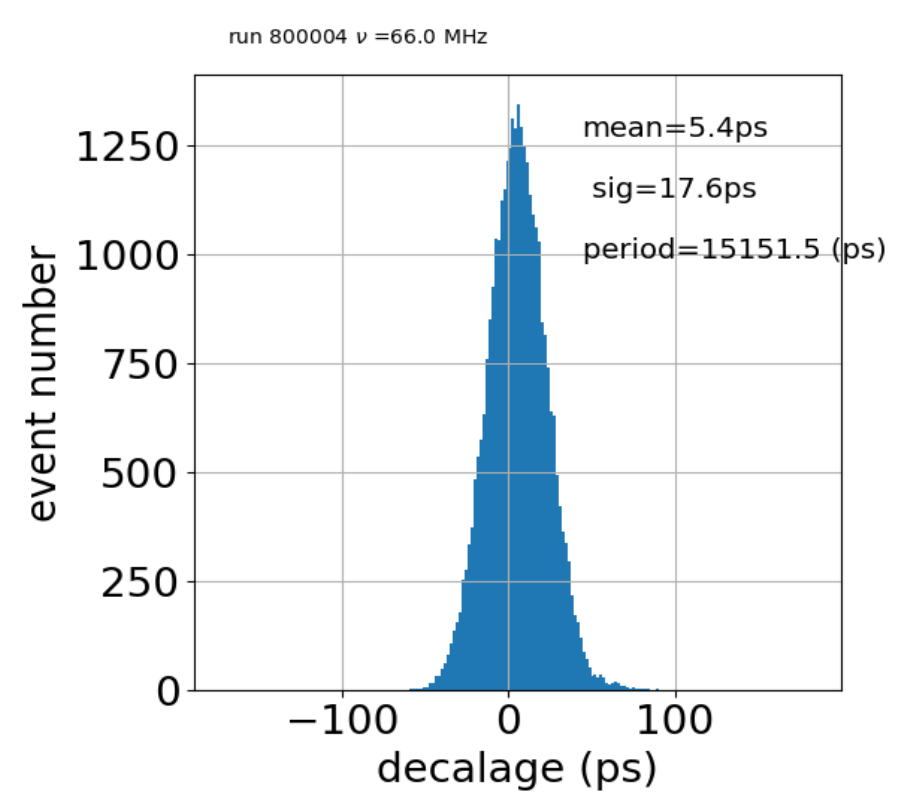
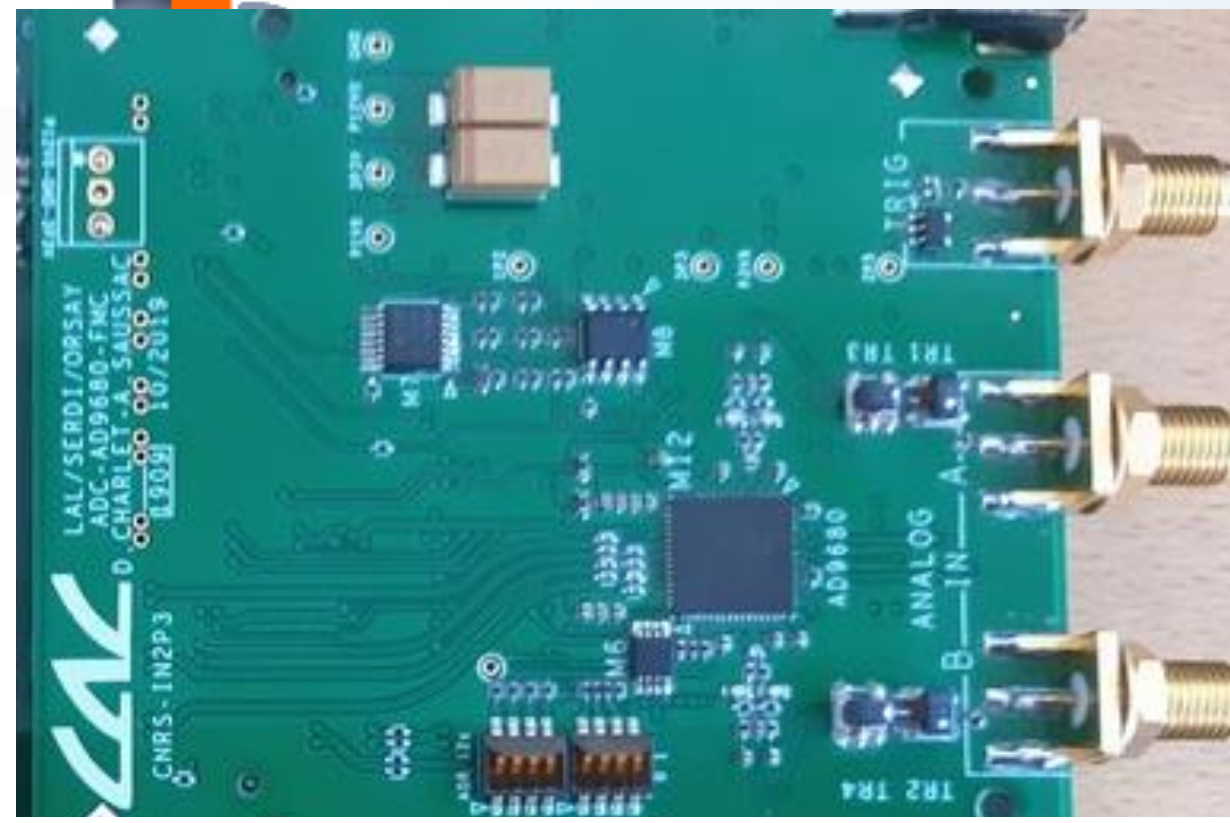


# IDROGEN board performances @ SYRTE

- Test setup with H-MASER high precision frequency reference
- PPS (Pulse per second) time difference between two independent IDROGEN3 boards
- Excellent long term stability :  $\sim 3E-18$
- On-going work: improve short term performances



# Two FMC developments with IDROGEN



## ADC mezzanine FMC\_ADC\_AD9680: WR clock synchronous digitisation

- Motivation: Include its own PLL & ADC external clock source (provided by Idrogen board)
- Main features : VITA57.1, ADC9680, 2 channels, 14bits, 500MSPS / 1GSPS, JESD204B interface, 2GHz analog bandwidth
- 500 MSPS validated, 1GSPS under test

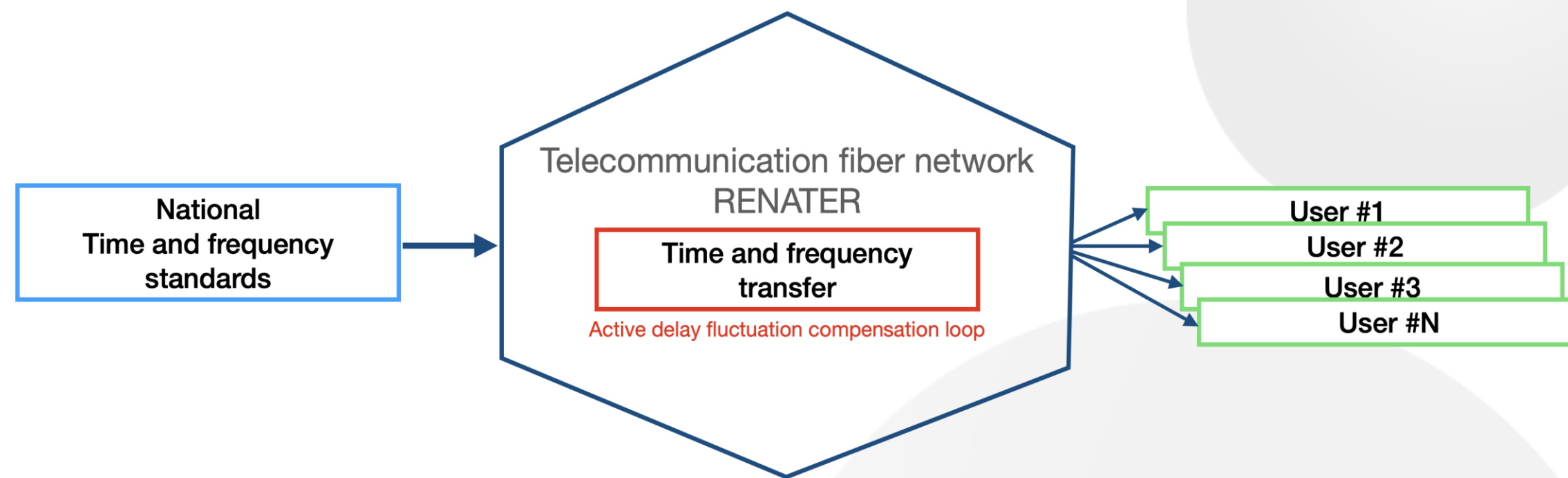
## PLL mezzanine FMC\_SI5362 : frequency generator

- Motivation: Generate any frequency disciplined by WR clock
- Main features : 4 outputs from 10KHz to 2.75GHz
- Currently in manufacturing



**REFIMEVE (Réseau Fibré Métrologique à Vocation Européenne):** Metrological fiber network with european vocation

**Concept :** Dissemination of time-frequency references by optical fibers over thousand kilometers and with  $10^4$  to  $10^5$  higher quality than GPS atomic clocks



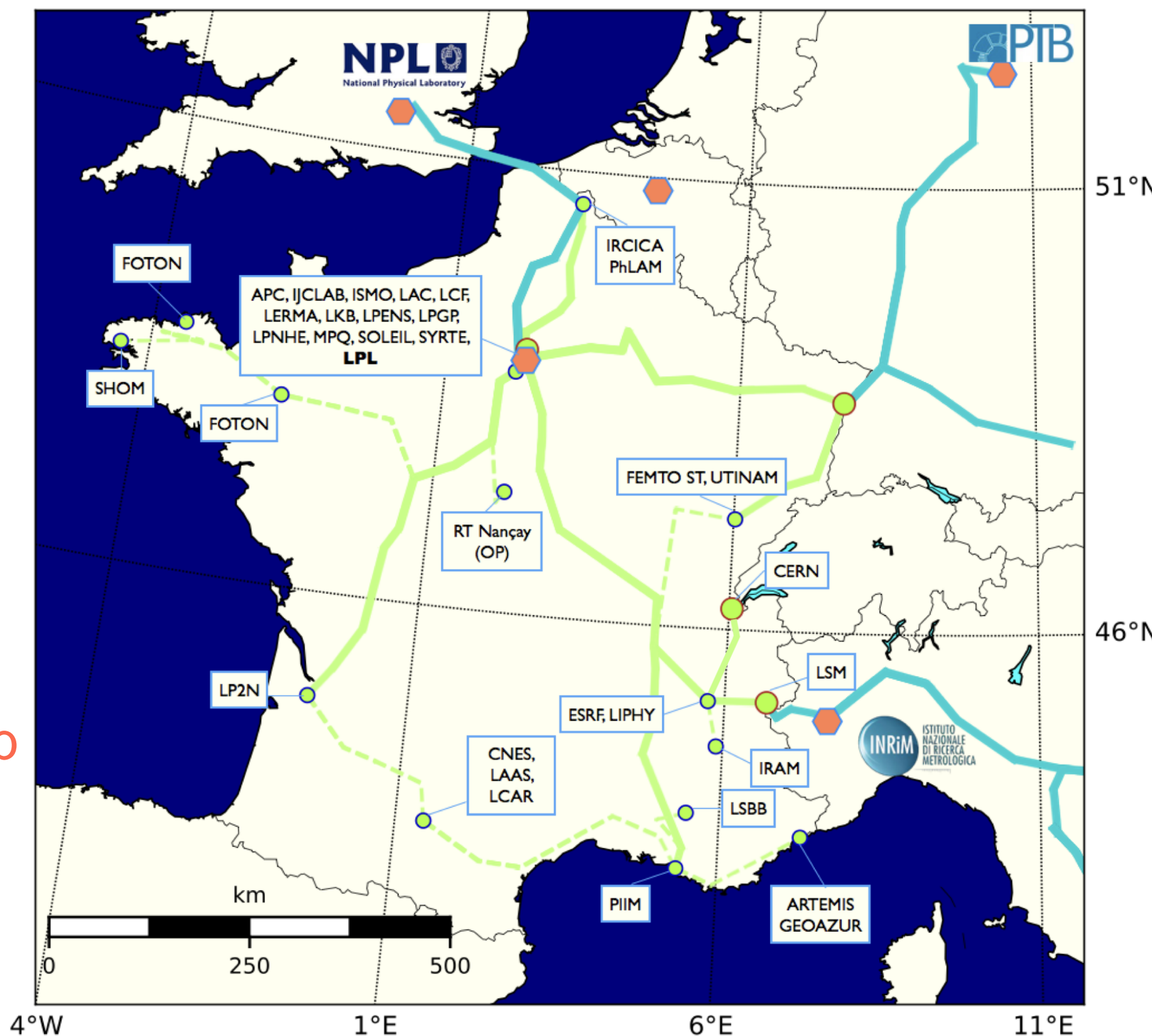
T-REFIMEVE:

Equipex financing (2021- 2029) with 24 partners including CNRS

Signals to be provided:

|                                       |   | Stability or relative stab. @1s | Stability or relative stab. @1day | Uncertainty |                           |
|---------------------------------------|---|---------------------------------|-----------------------------------|-------------|---------------------------|
|                                       |   |                                 |                                   | routine     | dedicated                 |
| Radiofrequency                        | 1 <sup>st</sup> pillar - 10 MHz (White Rabbit)* | 1,00E-12                        | 1,00E-15                          | 1,00E-14    | 1,00E-15                  |
|                                       | 2 <sup>nd</sup> pillar - 1 GHz                  | 1,00E-13                        | 3,00E-16                          | 1,00E-14    | 2,00E-16                  |
| Time                                  | 1 <sup>st</sup> pillar (White Rabbit)*          | 1 ns                            | 1 ns                              | 10 ns       | 10 ns                     |
|                                       | 2 <sup>nd</sup> pillar                          | 20-50 ps                        | 500 ps                            | 10 ns       | 2ns to 100ps <sup>§</sup> |
| Optical frequency (194,5 THz/1542 nm) | Today   | 1,00E-15                        | 3,00E-16                          | 1,00E-14    | 2,00E-17                  |
|                                       | Expected progress in 5 years                    | 1,00E-16                        | 2,00E-17                          | 1,00E-14    | 1,00E-18                  |

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## ● T- REFIMEVE:

- IDROGEN\_V3 (actual version) almost reaches the second time pillar goals
- IDROGEN\_V4 (currently in design, expected by end 2024) is aiming to reach the second time pillar goals with:
  - Obsolete components replacement
  - Components upgrade

## ● White Fox : Improved White Rabbit:

- New WR concept to gain an extra magnitude order on the jitter for long distance usages
- Based on a combination of IDROGEN\_V4 with an RTM extension board for more processing capabilities



Thanks for your attention