# Fiber links

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LPL : Olivier Lopez, Christian Chardonnet, Anne Amy-Klein

RENATER : Nicolas Quintin, Emilie Camisard

Industry partners : MuQuans, SevenSol, TED

2018-01-30, FirstTF Seminar, CNAM

# Outline

1. Optical frequency domain: recent achievements
2. Time dissemination

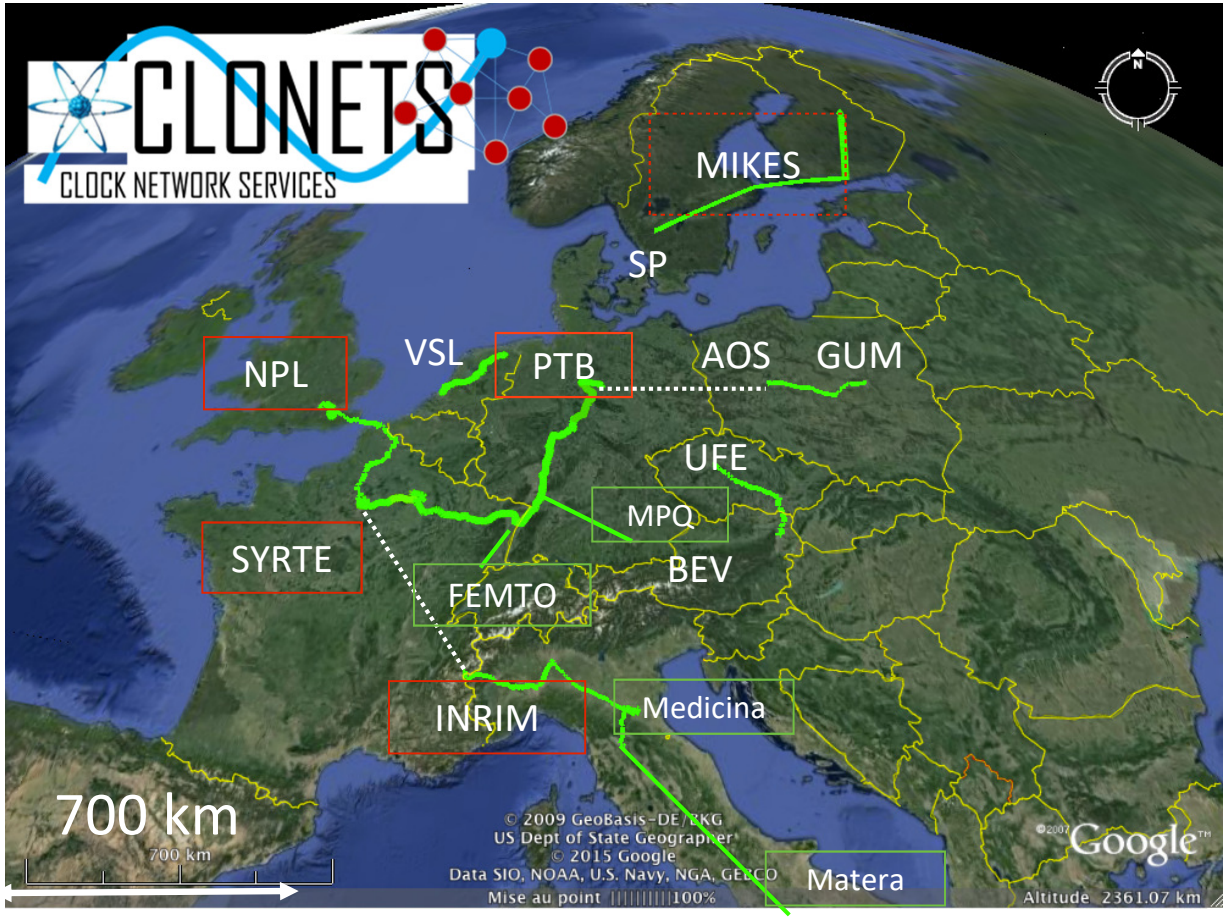
   White Rabbit for time dissemination on an active network

# Time and Frequency transfer with fiber links in Europe

Time &/or Frequency transfer :

- Combs
- RF + pps
- SONET, SDH, WR

- SP-MIKES: 1000 km
- MIKES-Kajaani: 1000 km
- UFE-BEV: 540 km
- GUM-AOS: 420 km
- VSL-VUA: 208 km
- NPL: 156 km




Review article
O. Lopez *et al.*, Comptes Rendus Physique, 16 (5), pp. 459-586 (2015)
Suggested focus on :
P. Krehlik, et al.; Metrologia, 52 , pp. 82-88, (2015)
M. Lessing et al., Applied Phys Lett. **22** (110),221101 (2017)

http://www.optime.org.pl/

**FEMTO-ST just get connected !**

# Frequency transfer : the ‘pure’ optical way

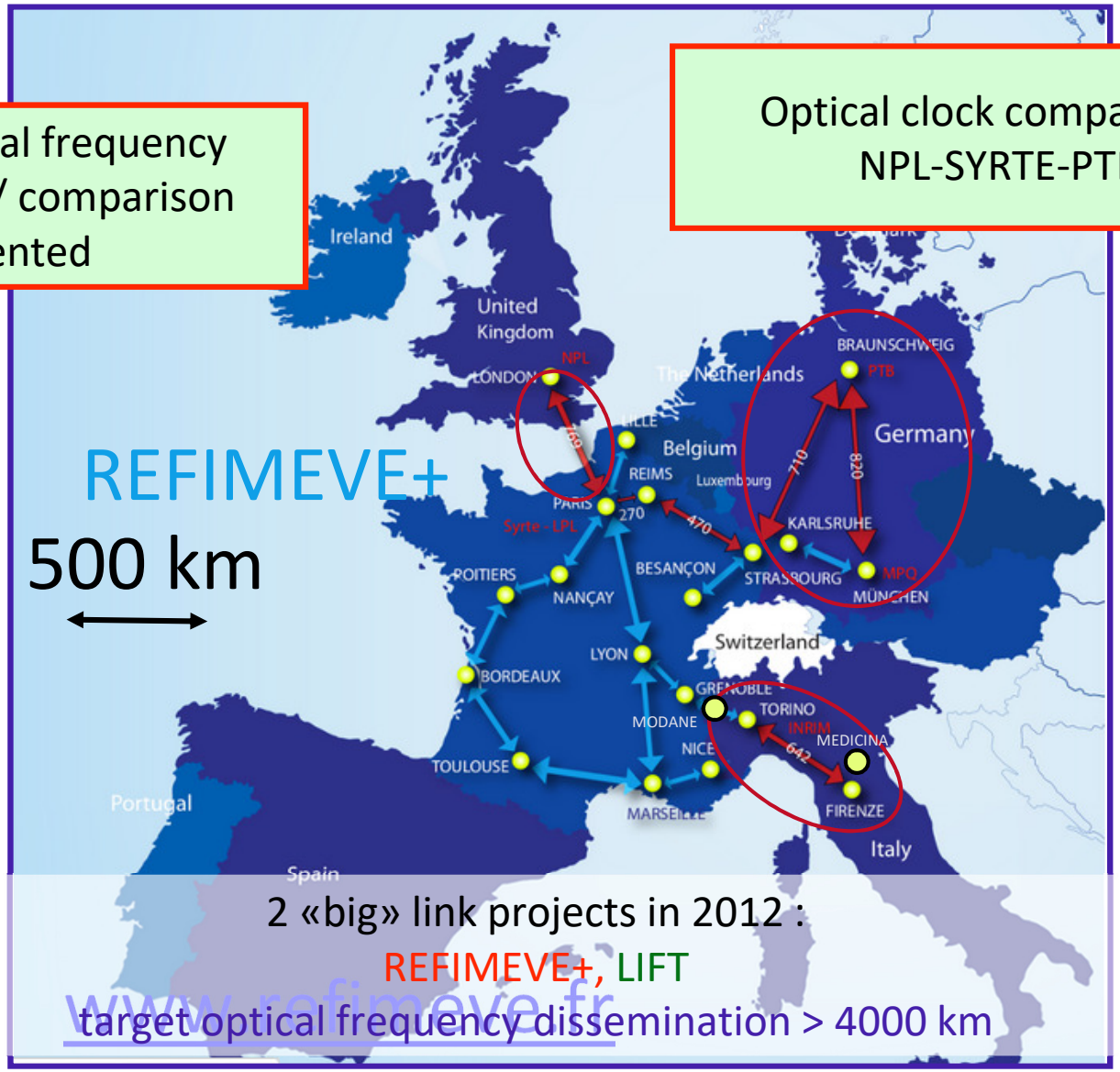
Only CW Optical frequency dissemination / comparison represented

Optical clock comparisons NPL-SYRTE-PTB

OFTEN

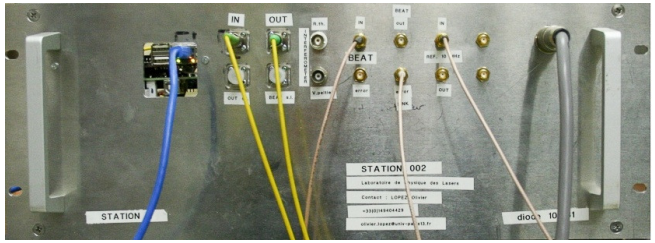
GEO-Q

LIFT

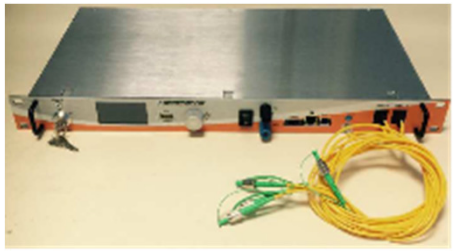


# Industrial partnerships

## Laboratory prototype




## Bi-Dir optical amplifiers

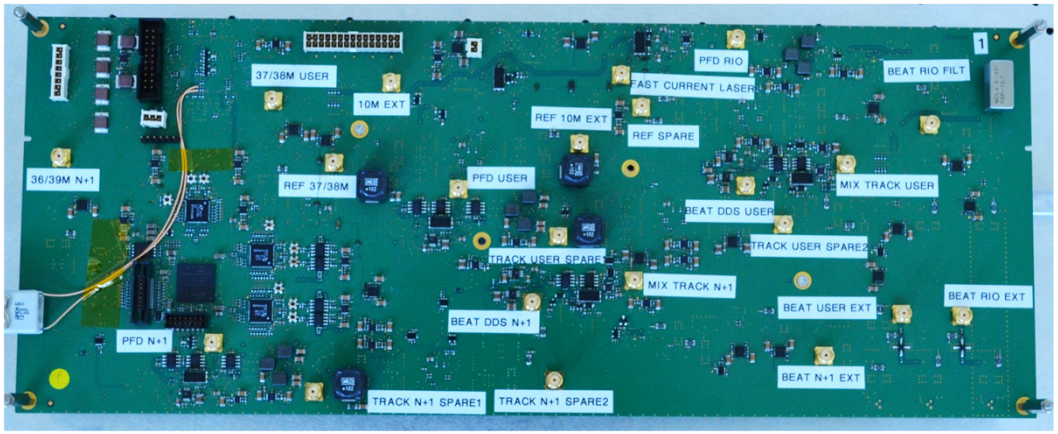


KEOPSYS
THE LIGHT TOUCH

## Industrial prototype


## Industrial electronics

Syrlinks
SPACE, DEFENSE & SECURITY



# Refimeve+ : production phase started


Laser stations and amplifiers stock @ MuQuans

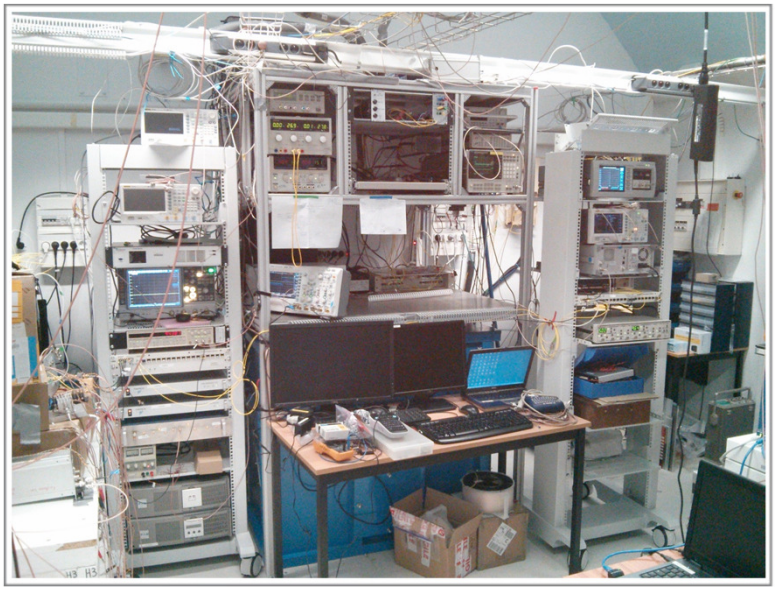
# Time dissemination over a national network

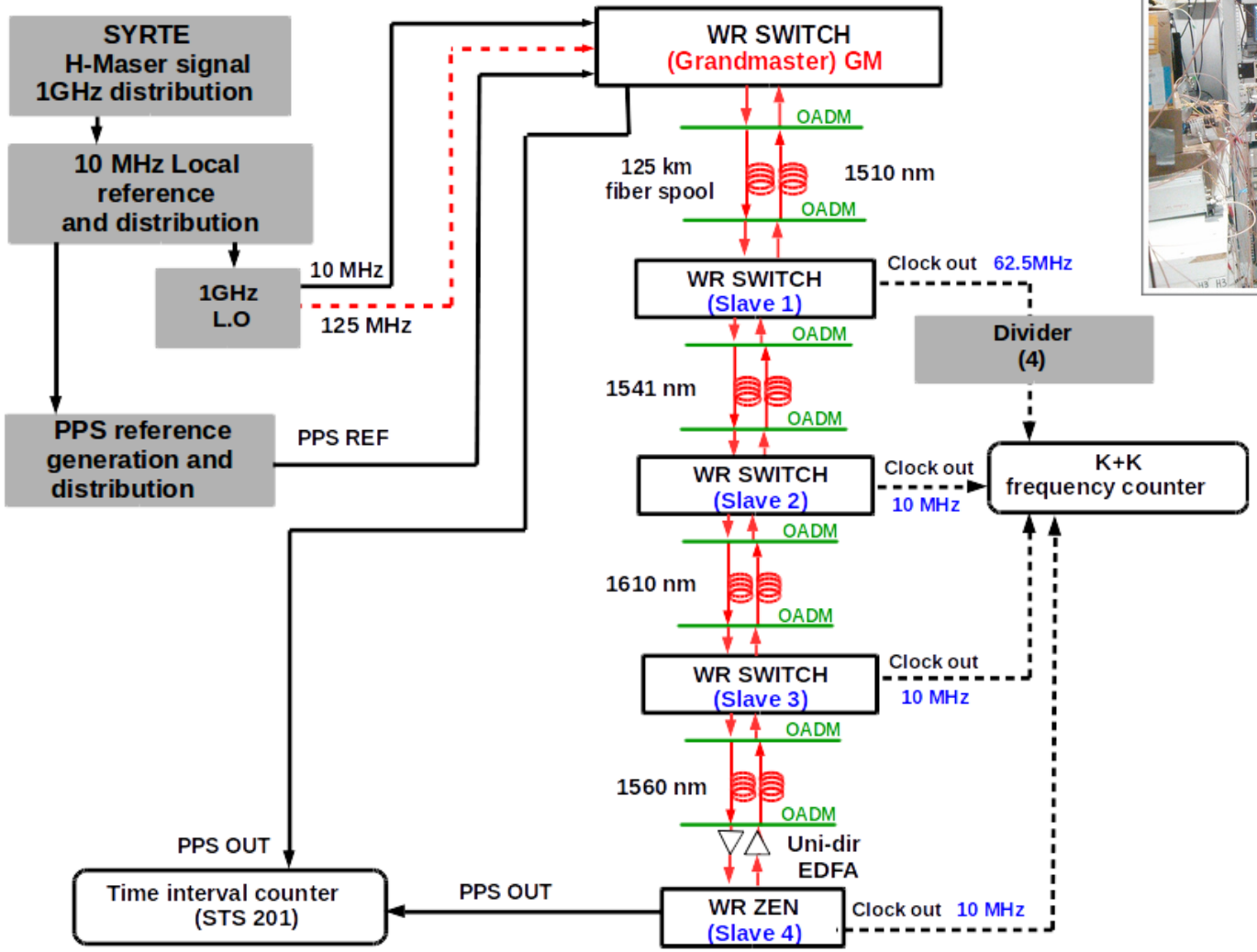
- Goal # 1 : high performance for next generation of optical time scale comparison, test of fundamental physics : high performance, bi-directional
- Goal # 2 : time (&RF) dissemination to civil society
  - Alternative to GNSS signal
  - Towards a fiber based time service ?
    - Existing : NTP, PTP. Introduction of WR
    - Lot of activities worldwide with «custom» solutions (China !…)
- Collaboration with RENATER for proof of principle demonstrations

# White Rabbit @ LNE-SYRTE

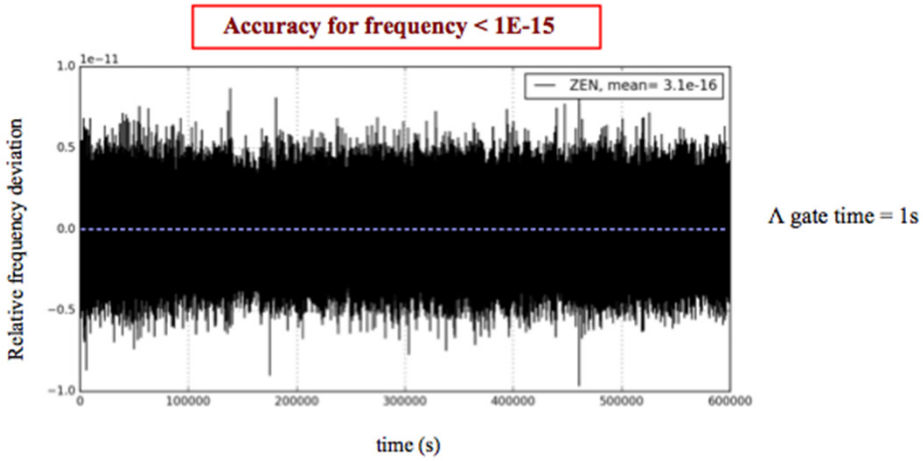
- Multi user : Point-to-many
- Explore the wide scale approach :
  - Comply with Telecom backbone architecture : **1 wavelength, 2 fibers**
    - Benefits from uni-directional amplification, **no backbone adaptation**
    - Data traffic on other channels
- **Interoperability** of networks : scalibility, traceability, security
  - Investigate the feasibility of calibrated time service on long haul fiber network
  - Achievable accuracy in time ?

# Experimental set up



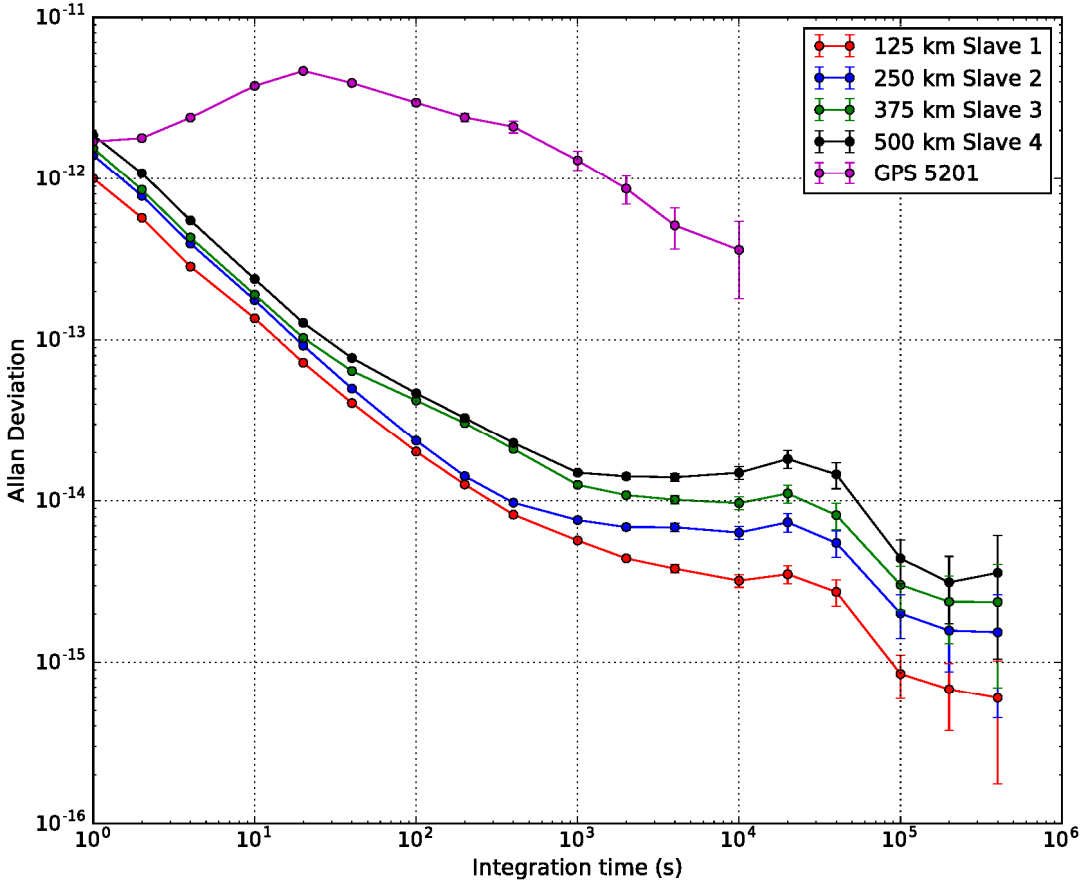


# Experimental results (on spools)




- 4-span cascaded
- Uni-dir
- Multi wavelength
- Better than Oscilloquartz GPS receiver

Namneet Kaur Thesis

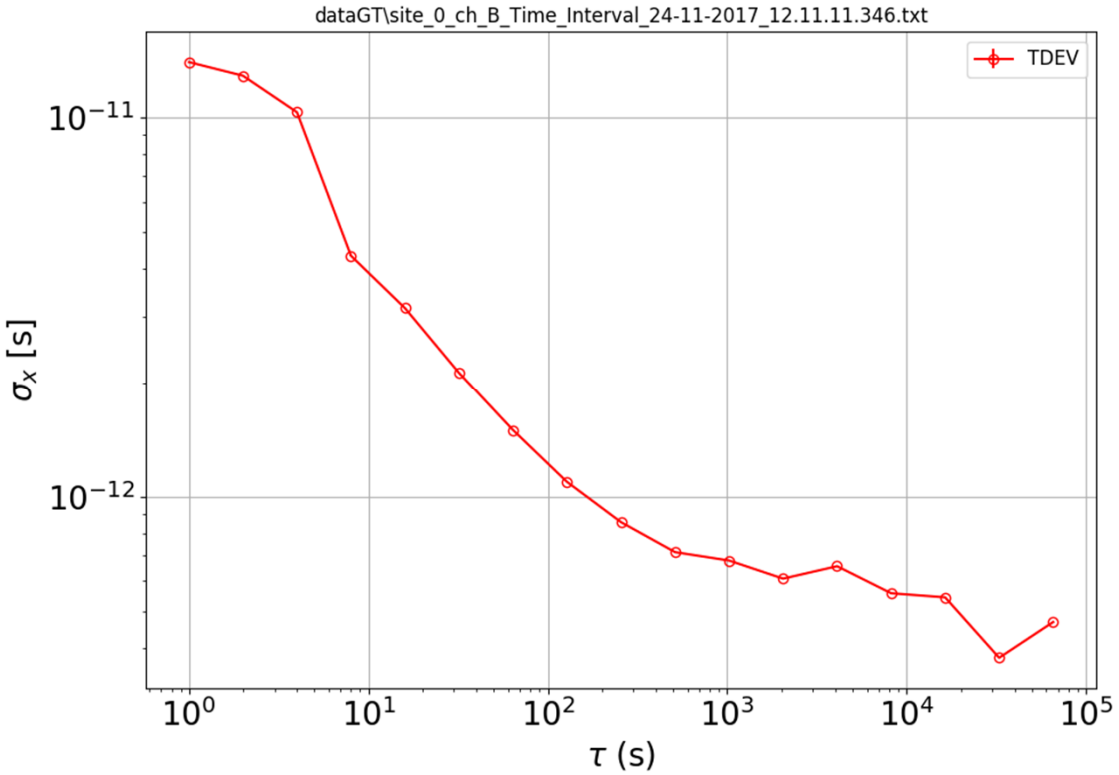


# Collaborations

WR developments: Development of electronics Digital and analogic mix

Electronic workshop at Syrte : Dariusz Nita, Laurent Volodimer, Michel Lours

Support from SevenSol; CERN & al. : open software, open hardware!




- for astronomy :
  - PAON IV / Nebula
  - 500 m
  - Bi-dir 1310/1490
- for industry
  - Link Paris-Velizy (TED)
  - JRP WRITE
  - ~ 40 km
  - Uni-dir