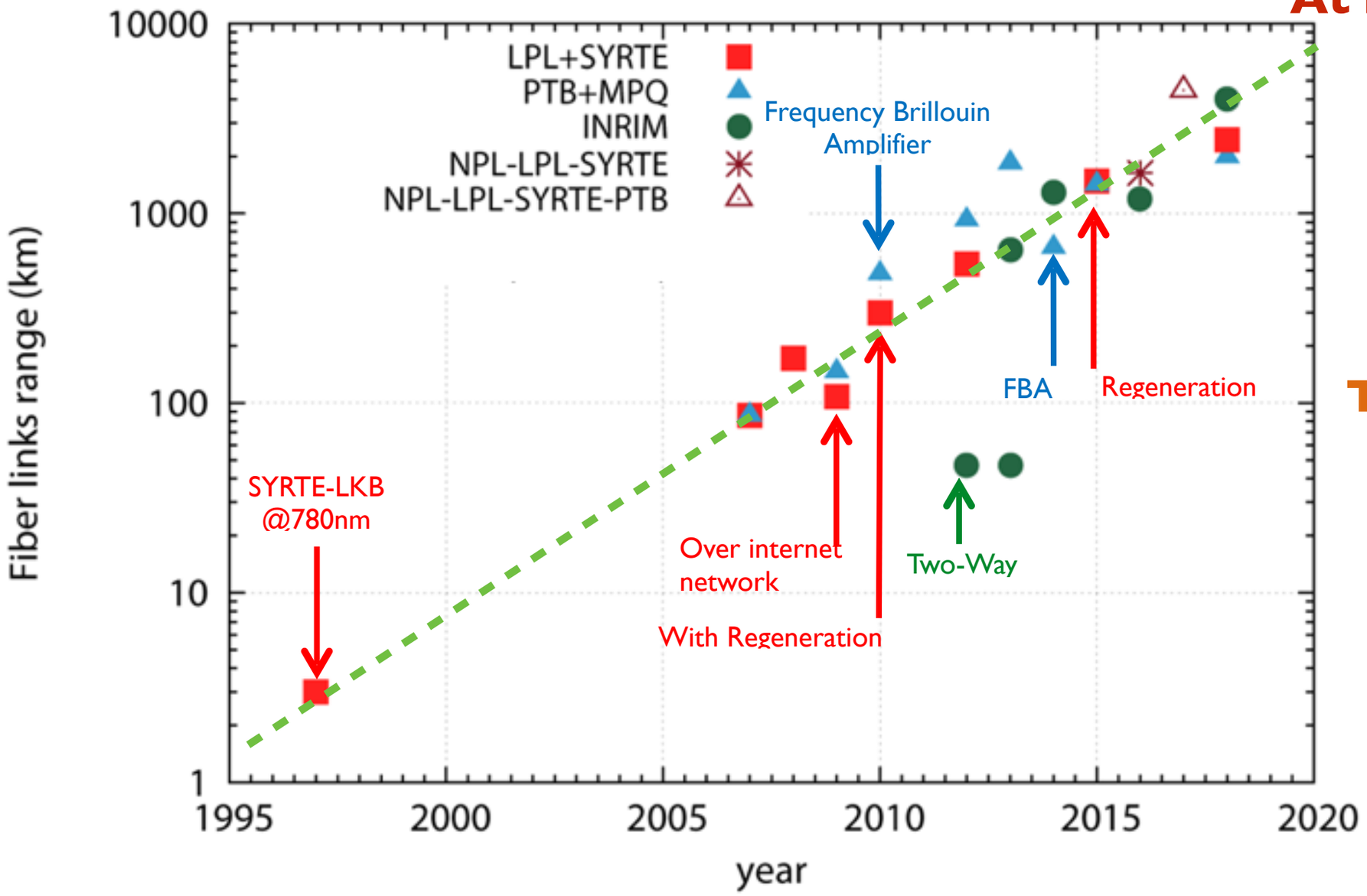
From fiber links to fiber network : recent progresses

P.-E. Pottie

Introduction : Range of fiber links in Europe



At horizon 2020 : 8000 km

GÉANT
connect • communicate • collaborate

Towards a large research infrastructure ?

RENATER, CESNET, PSNC, GARR JISC/JANET, DFN, SURFNET, NORDUNET…

Contents

- **Fiber network, towards a Research Infrastructure** (CLONETS)
- **A clock network under construction** (OFTEN)
- **An update about the french fiber network** (REFIMEVE+)

CLONETS
CLOCK NETWORK SERVICES

- Consortium of 16 partners : 1/3 academics, 1/3 Telecom Network, 1/3 Industrials
- **Expected outcomes** :
  - Review techniques and their evolutions, compatibility, needs for Research Infrastructures (NMIs, research labs, large research facilities as VLBI, accelerators…)
  - Survey potential application outside Research Infrastructure, economic and societal impact
  - Education and training
  - Define a strategic roadmap for RI
- **Mid-term goal** :
  - Secured accessed to the fiber network
  - Increase technical readiness level, offer « on the shelf » solutions and procedures to establish a fiber link

Project CLONETS involved 16 partners from 7 European countries. Partners represent 4 main areas:

- National Measurement Institutes: OBS PARIS (FR), NPL (UK), PTB (DE), INRIM (IT)
- National Research and Education Network: RENATER (FR), CESNET (CZ), PSNC (PL), GARR* (IT),
- Academic Laboratories: AGH (PL), UP13 (FR), UCL (UK), ISI (CZ), CNRS* (FR)
- Industrial: MUQUANS (FR), MENLO (DE), PIKTIME (PL), SEVEN SOL (SP), OPTOKON (CZ), TOP-IX* (IT)

* Third-party member

1 **FRANCE**
- OBSERVATOIRE DE PARIS
- GIP RENATER
- UNIVERSITE PARIS 13 - LPL
- MUQUANS
- CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

2 **ITALY**
- INSTITUTO NAZIONALE DI RICERCA METROLOGICA
- CONSORTIUM GARR
- CONSORZIO TOP-IX

3 **GERMANY**
- PHYSIKALISCH-TECHNISCHE BUNDESANSTALT
- MENLO SYSTEMS GmbH

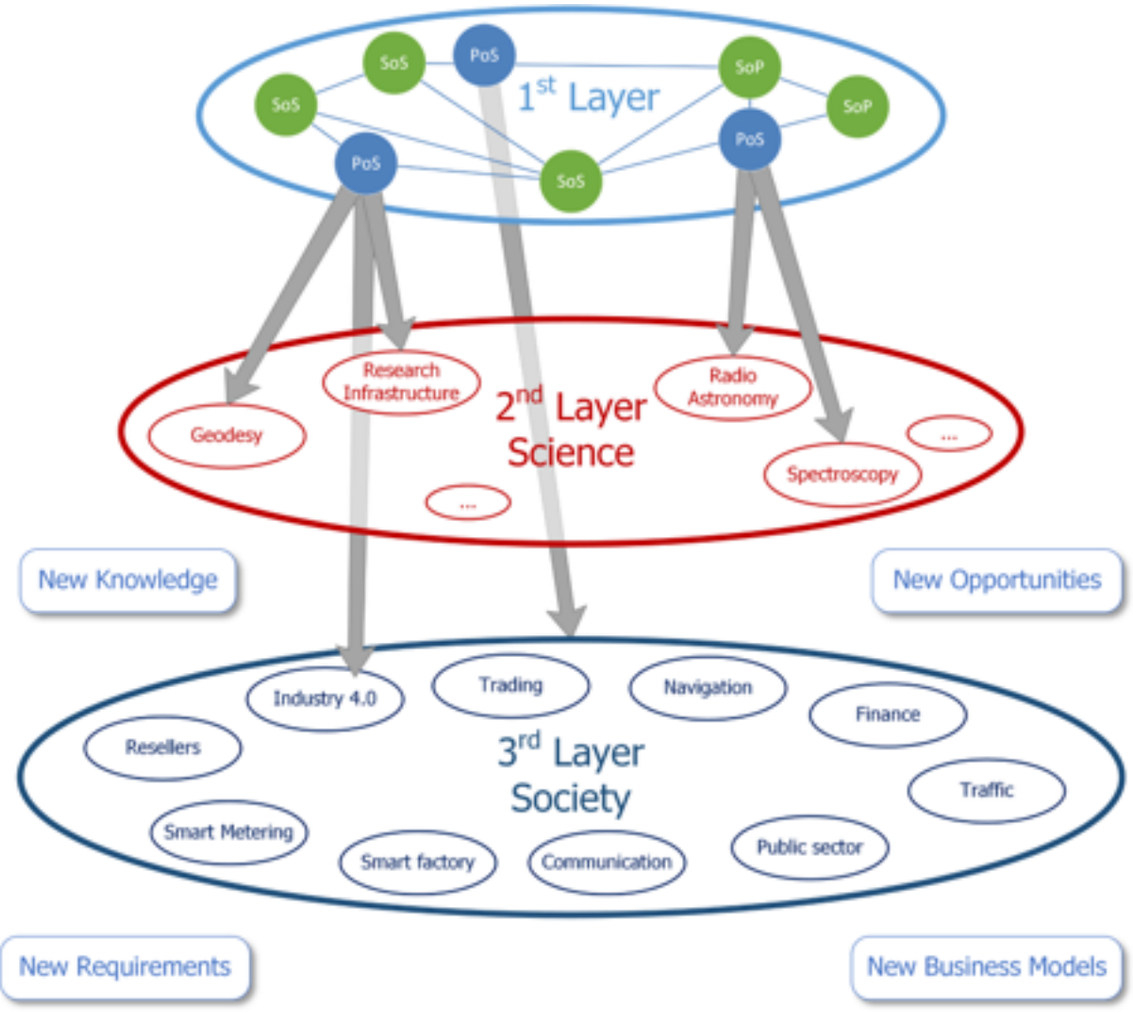
4 **UNITED KINGDOM**
- NPL MANAGEMENT LIMITED
- UNIVERSITY COLLEGE LONDON

5 **CZECH REPUBLIC**
- CESNET, z.s.p.o.
- USTAV PRISTROJOVE TECHNIKY AV CR, v.v.i.
- OPTOKON

6 **POLAND**
- POZNANSKIE CENTRUM SUPERKOMPUTEROWO-SIECIOWE
- PIKTIME SYSTEMS sp. z o. o.
- AKADEMIA GORNICZO-HUTNICZA IM. STANISLAWA STASZICA W KRAKOWIE

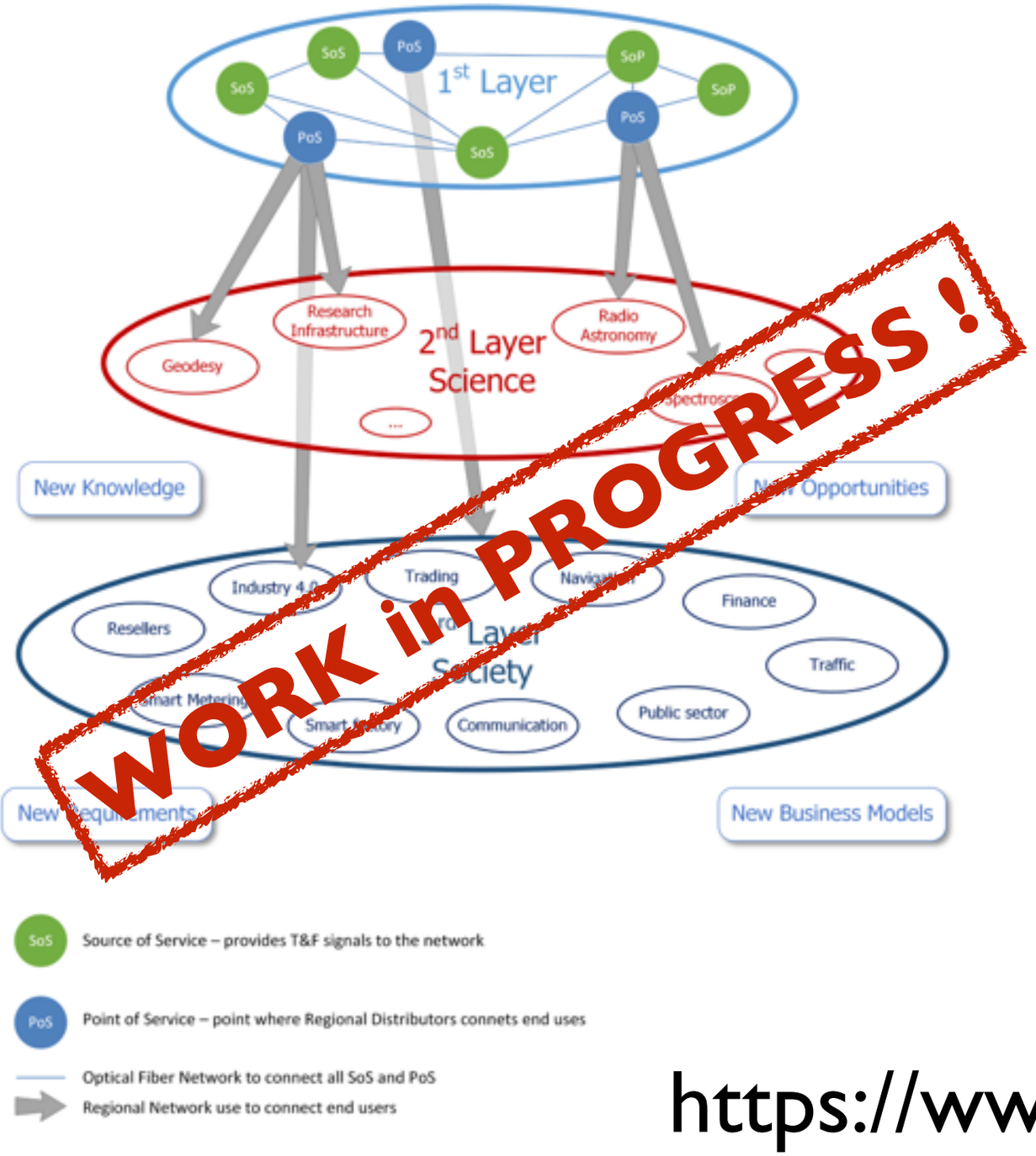
7 **SPAIN**
- SEVEN SOLUTIONS S.L.

CLONETS : towards RI



https://www.clonets.eu/

CLONETS : towards RI



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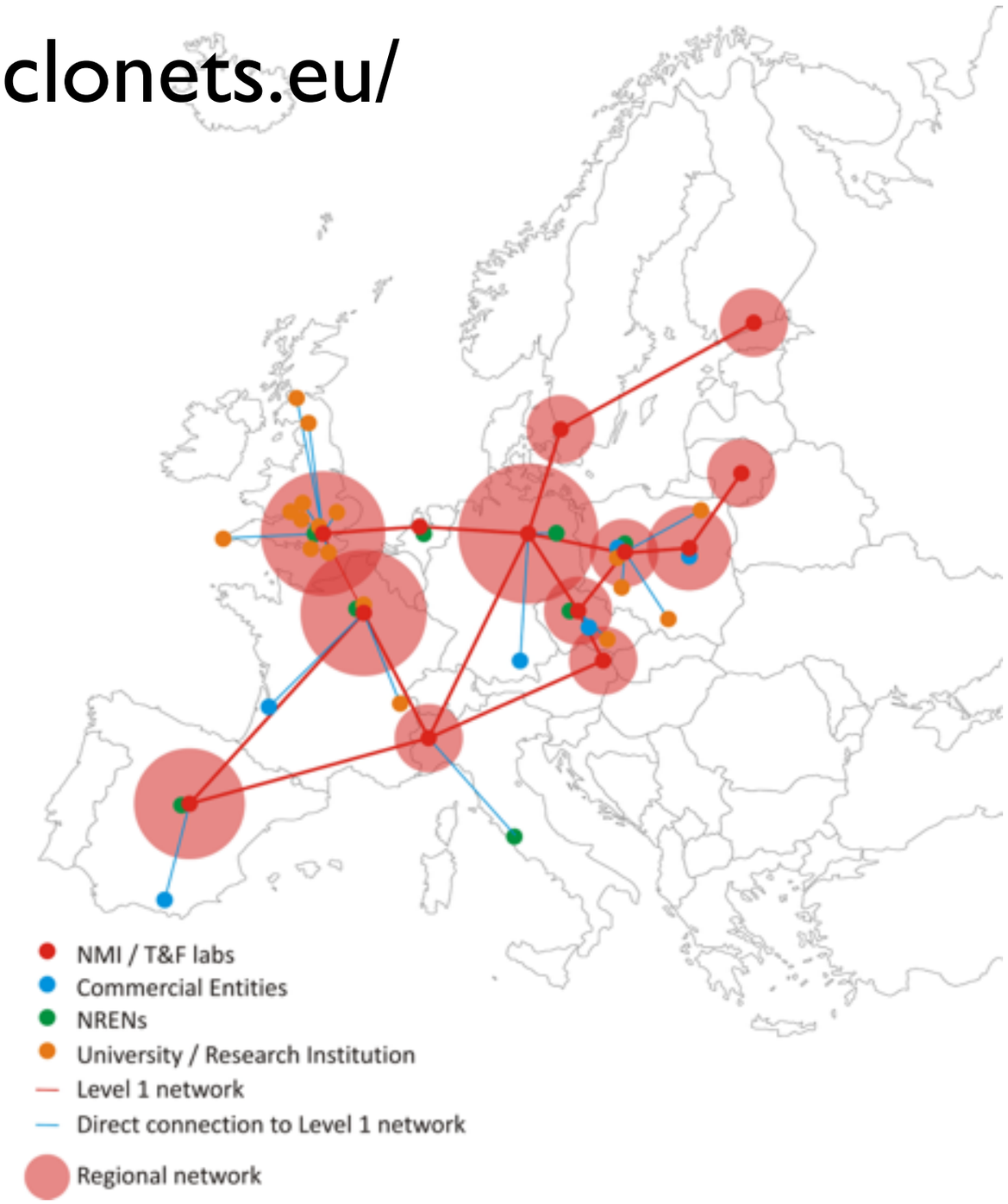
An EU-backbone to be designed

https://www.clonets.eu/



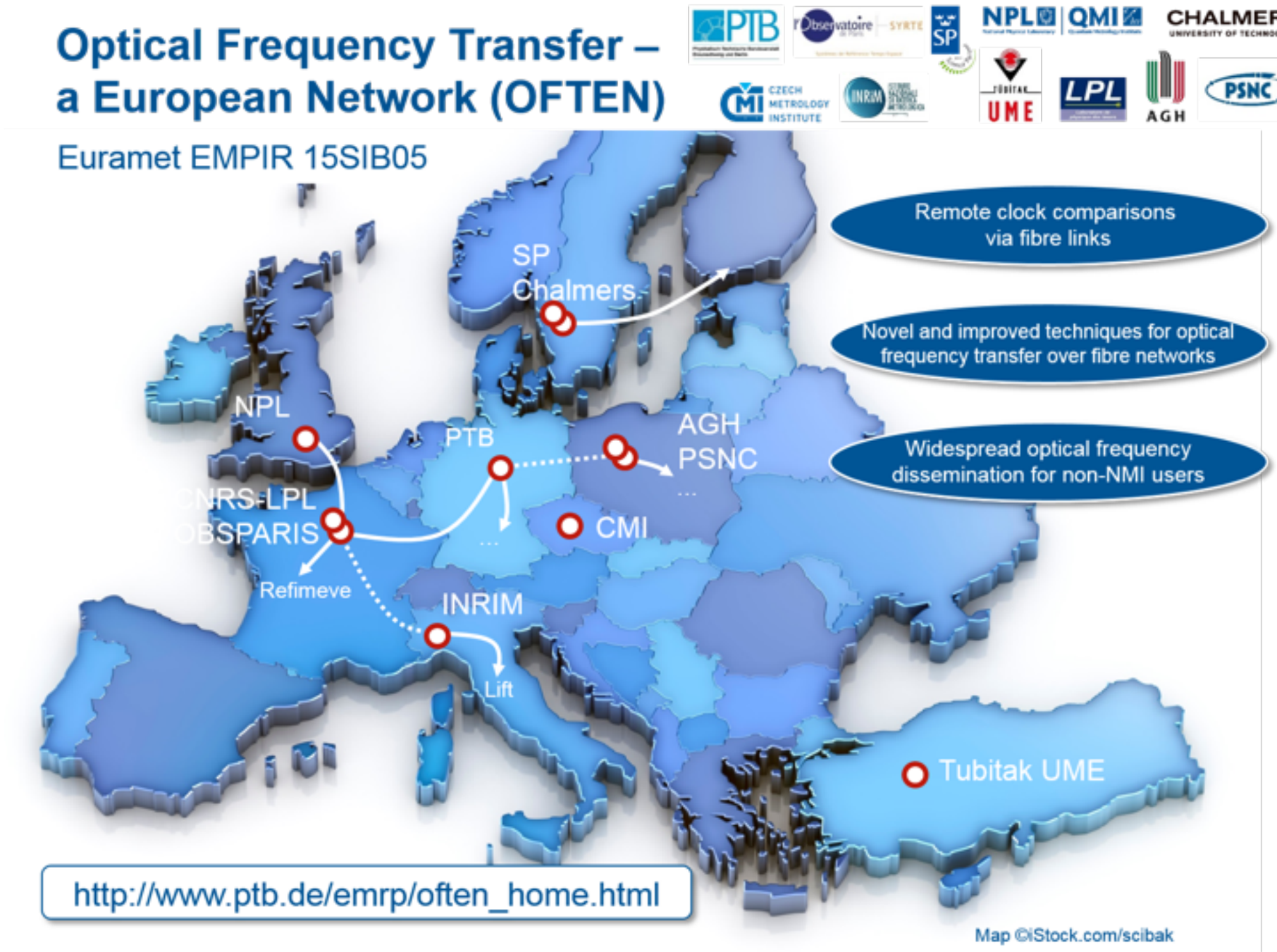
An EU-backbone to be designed

https://www.clonets.eu/

Building up synergies :

- **Register to the mailing list**
- **Participate to stakeholder's workshop**
- **Share with us any ideas, wishes**

European fiber network (OFTEN)

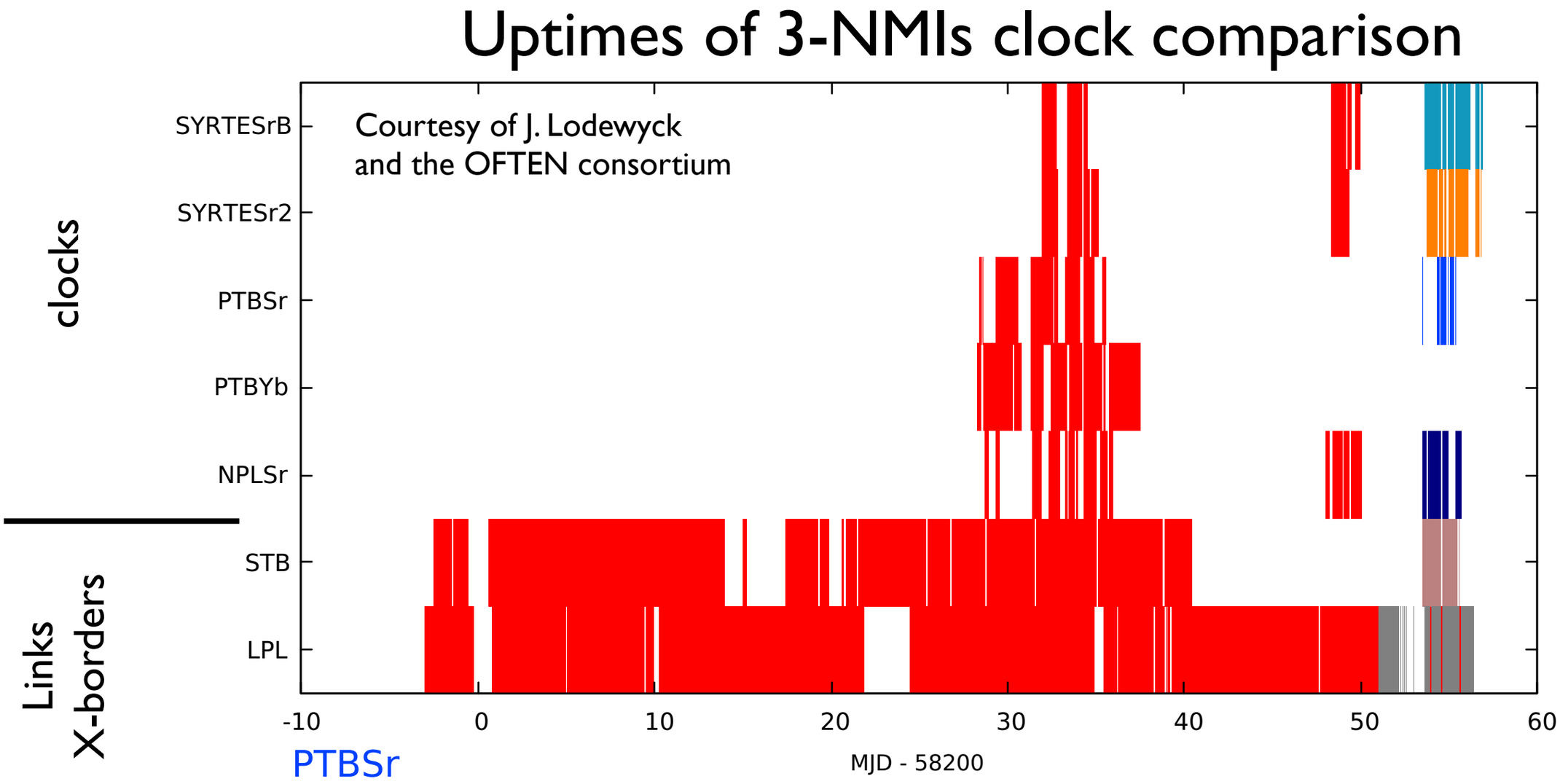


Clock comparisons

C. Lisdat et al., Nature Comm. (2016), 12443 (2016), doi:10.1038/ncomms12443

- **Interconnection NPL-SYRTE and SYRTE-PTB**
  - **approx. 4400 km of a stabilized optical link !**
- **Connecting static clocks : Sr, Yb+, Hg and Cs,Rb…**
  - **…and transportable Sr clock : cf. C. Lisdat**
- **4 clock comparison campaigns 2016-2018**
  - **1-month campaign in June 2017**
- **Increase technical maturity : learn by practice**

Clock comparisons



- **Ensemble of independent OC : roadmap for SI-s redefinition**
- **Reliability, reproducibility : sensors, networking, hardware**
- **Software and automated processing**

Networks interconnection

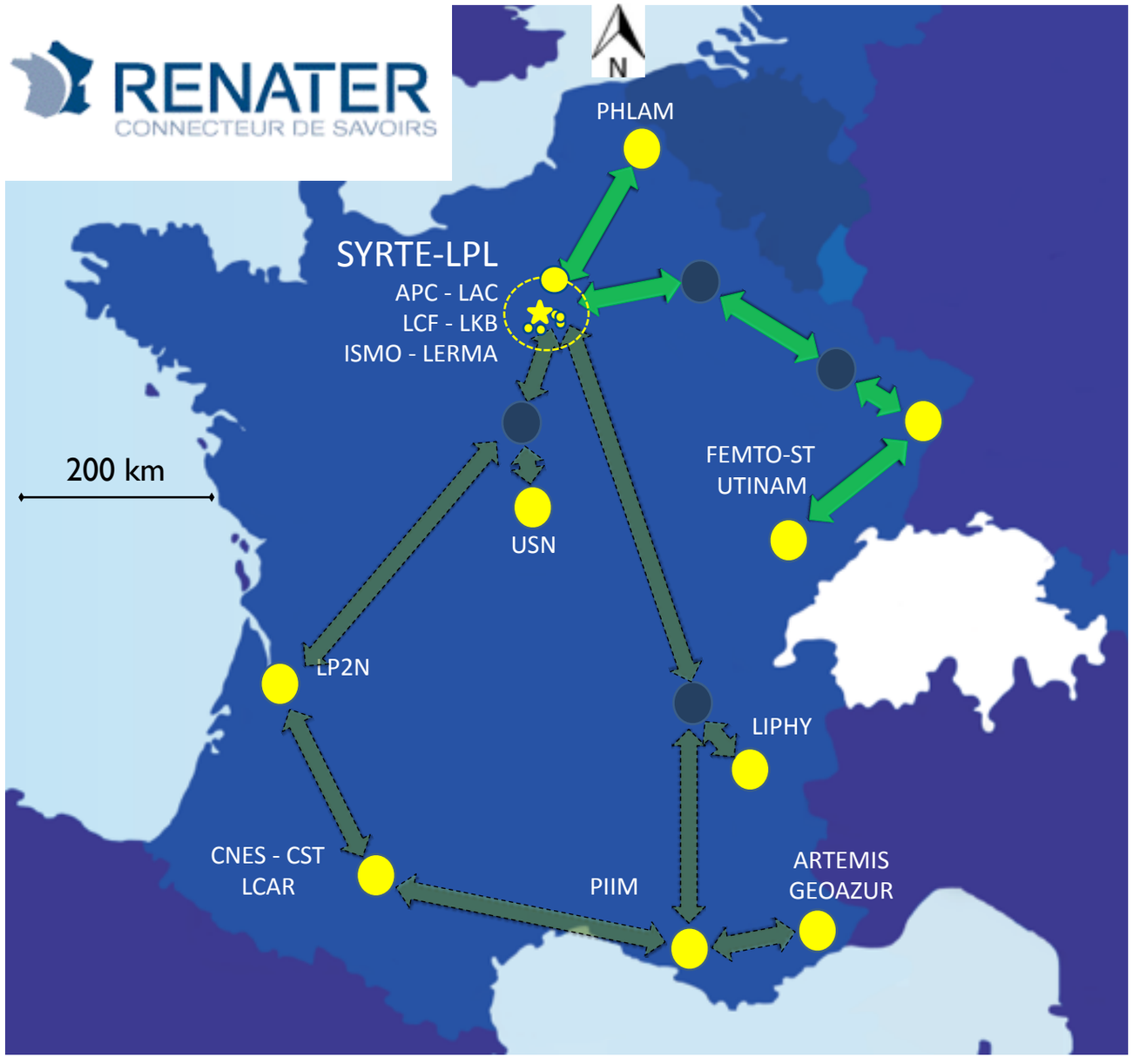
INRIM will be connected to NPL/SYRTE/PTB by 12/2018

- Paris-Grenoble (900 km) : 11/2018
- Grenoble-Modane (150 km) : 12/2018
- REFIMEVE + LIFT + PTB + NPL:
  - about 2x4650 km
- Clock comparisons:
  - +Yb, Cs

A suitable place for chronometric geodesy ?

REFIMEVE+ : a network in a nutshell

A Large Research Infrastructure



4000 km of fibers

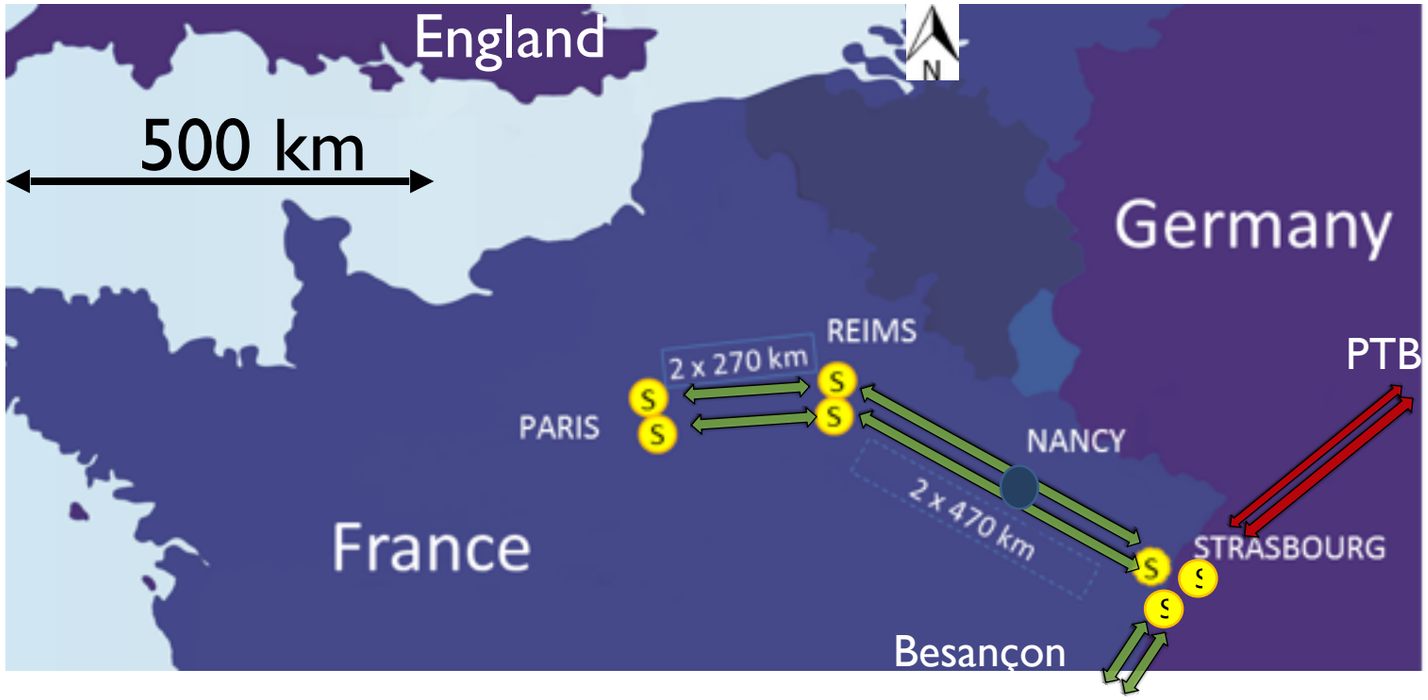
Collaboration with RENATER

*Signal in **parallel of data traffic***

- **Sustainability**
  - Dedicated Fiber ≈ **200€ / km**
  - Fiber sharing : ≈ **cost / 10**
    - Supervision embedded in a **Network Operation Center**
- **20 partner laboratories as users**
- Network design : robustness, reliability, availability of the signal
- Knowledge transfer : **TRL = 8**

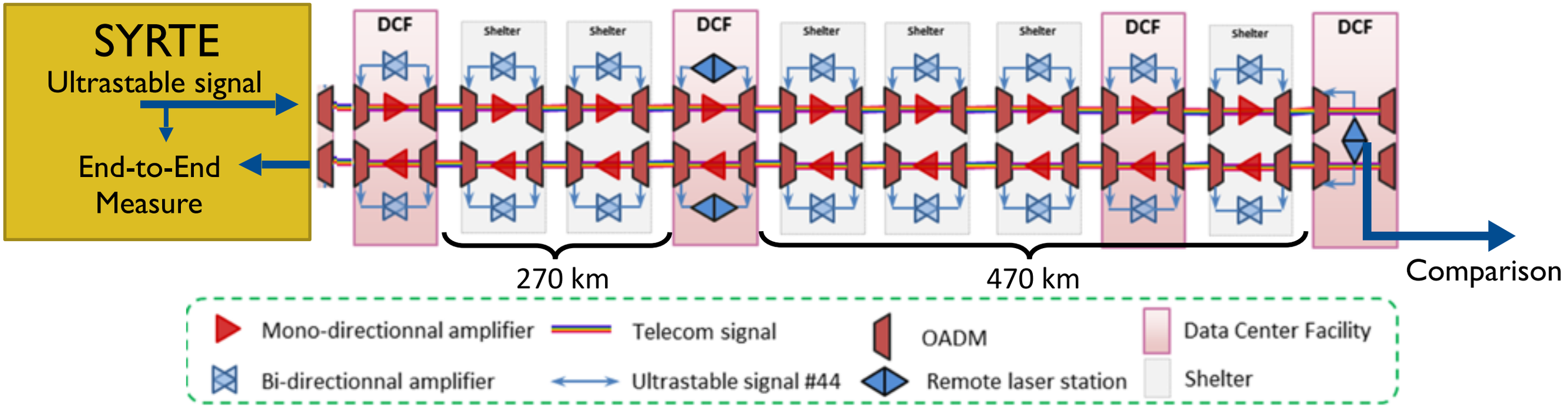
μQUANS Syrlinks KEOPSYS

Paris-Strasbourg-Paris link

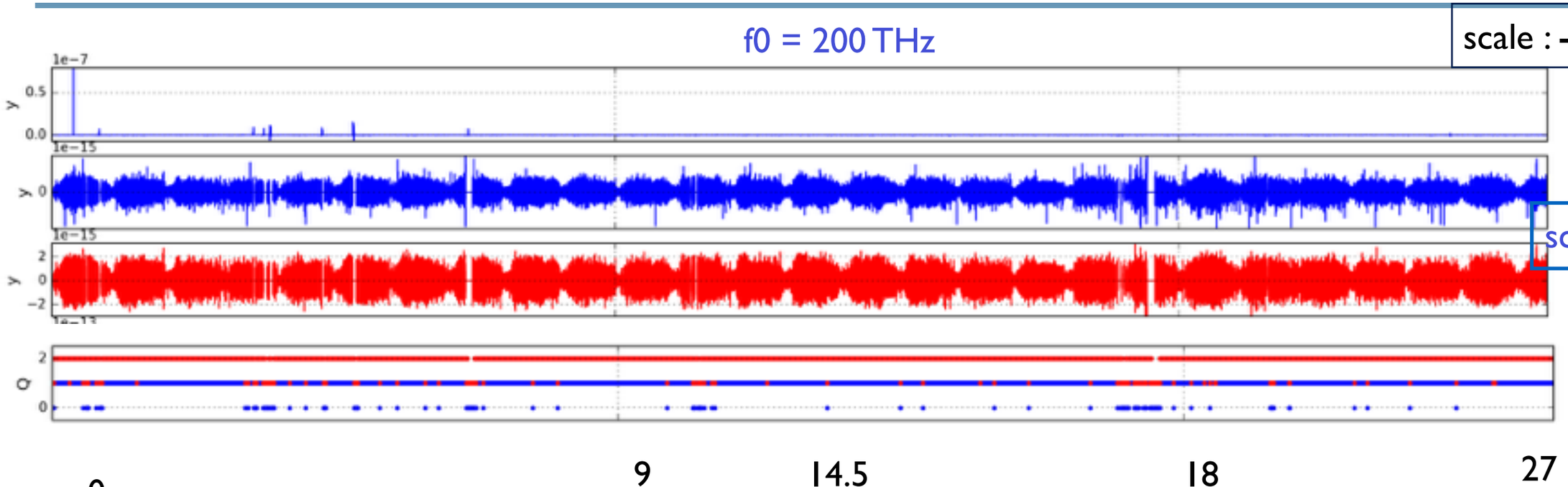


Link summary

- 2x205 dB attenuation
- Parallel data traffic
- 16 EDFA
- 32 OADM
- 5 Repeater laser stations
- ~ 1400 km



27 days during Clocks Comparison



Λ-counting

1-s gate time

up-time end-to-end @ Paris/ 27 days

Within 10 Hz filter : 99.30 %

Within validation procedure : 96.27 %

Validated data for clock comparison : 96.20 %

(small outliers and cycle-slip removed)

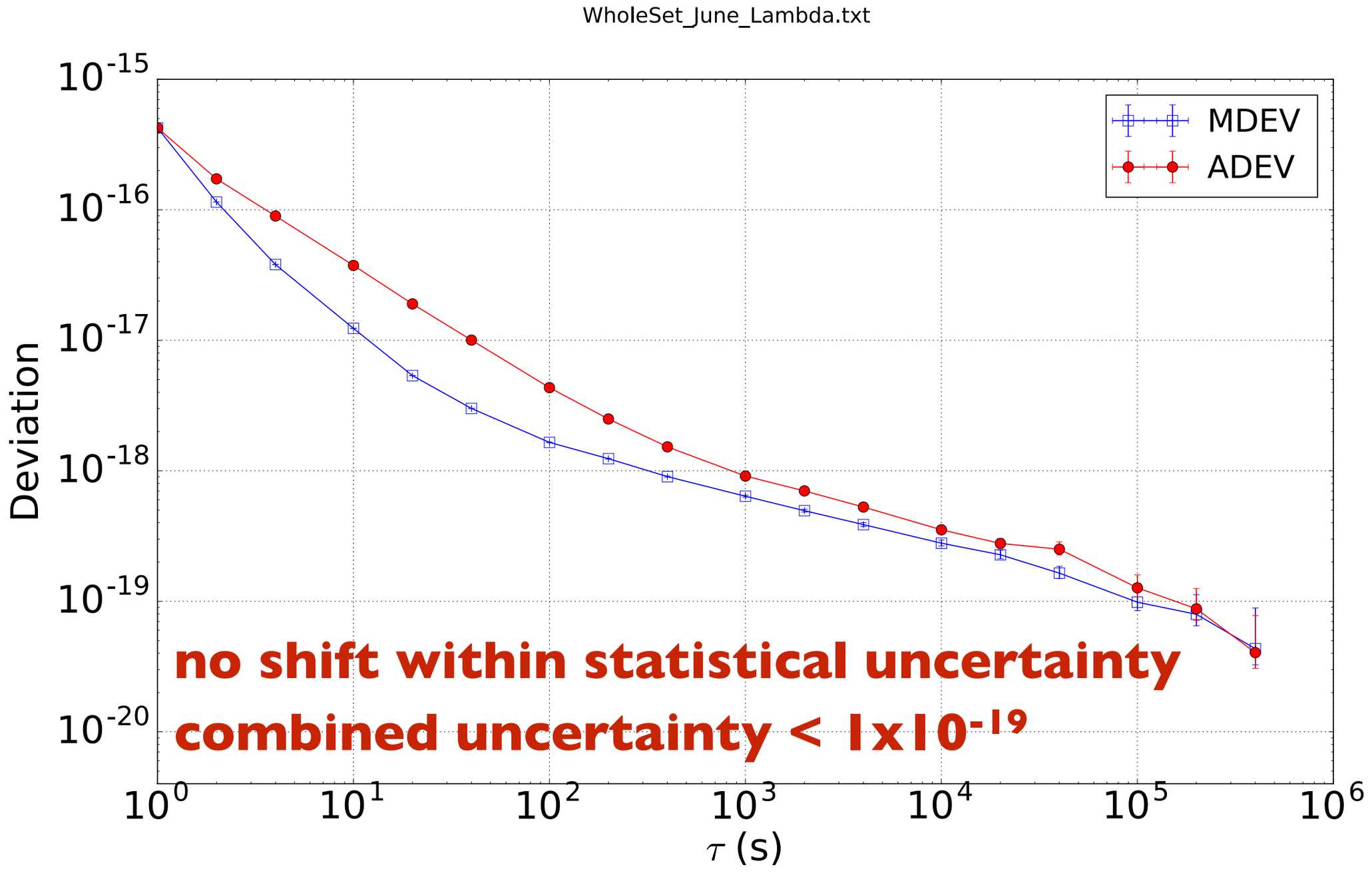
(bad run removed)

P..-E. Pottie et al.,EFTF'18

validation procedure

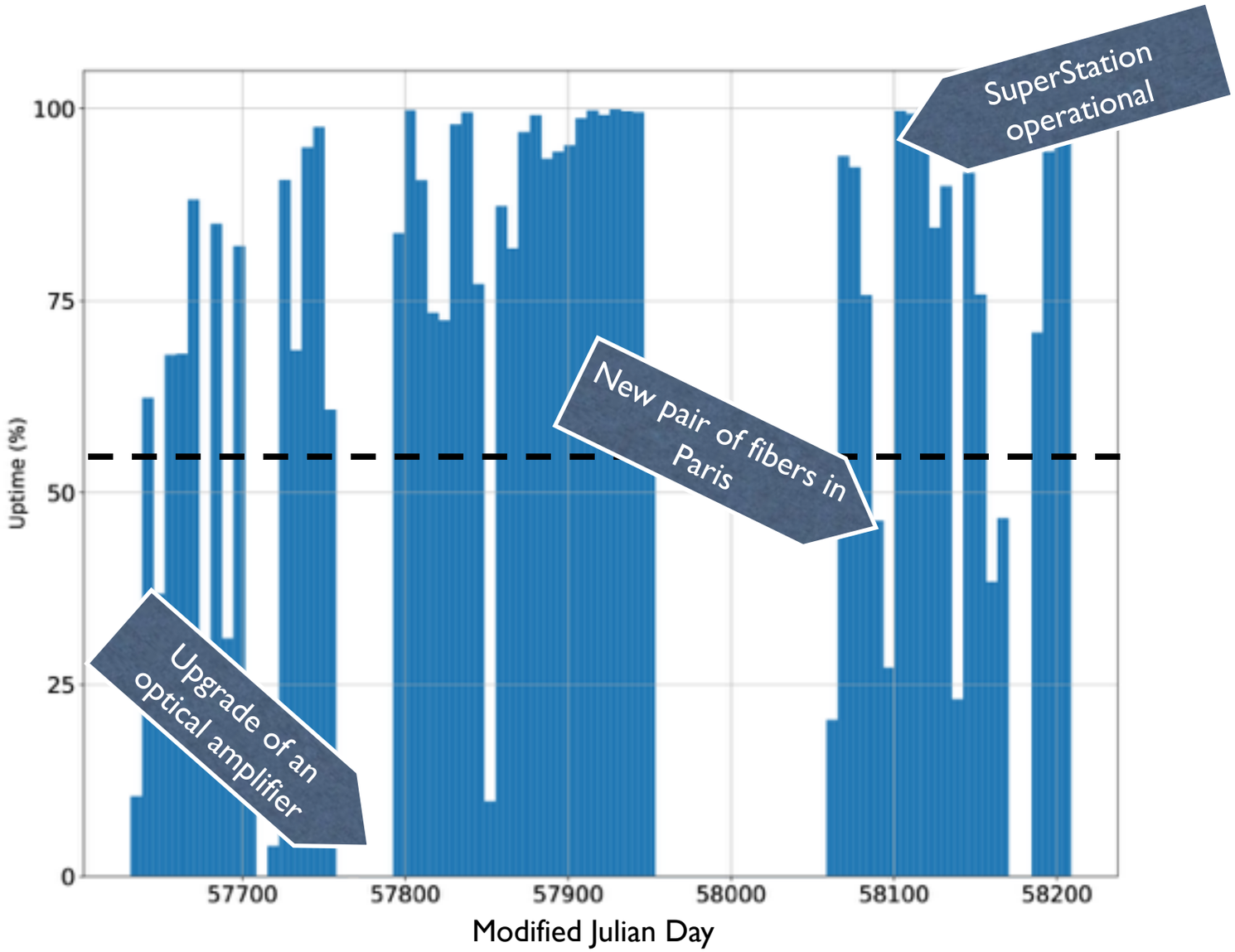
Quantity tested	Looking for:
rolling mean	outliers
rolling standard	anomalous noise
'quality' stability	'*rogue*' points

End-to-end stability (1400 km)



E. Cantin et al.,EFTF'18

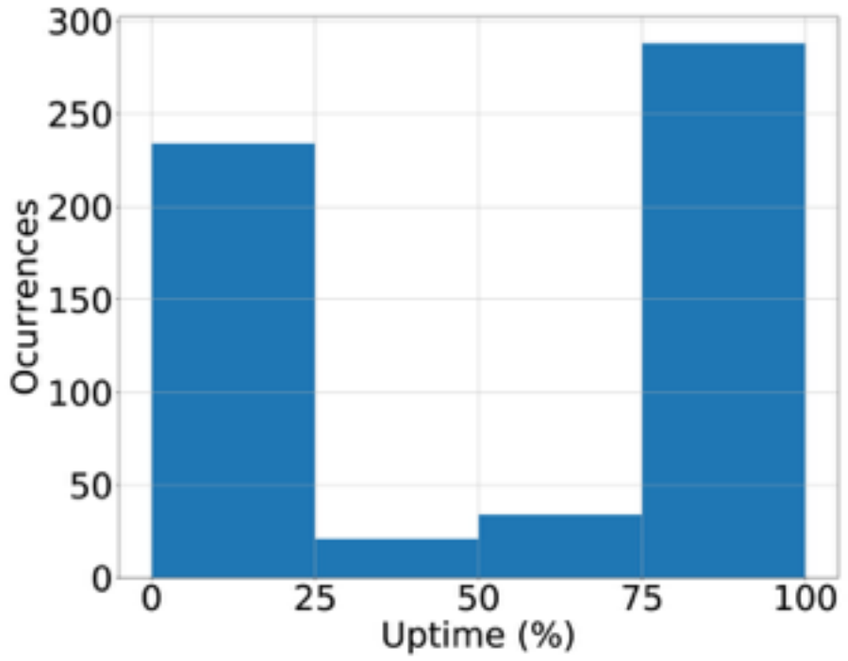
Operation of a link / 19 months



19 months = 576 days = 49'766'400s

- Total Uptime = 54.5%
- Selection criterium
  Frequency < 10 Hz = $5x10^{-14}$

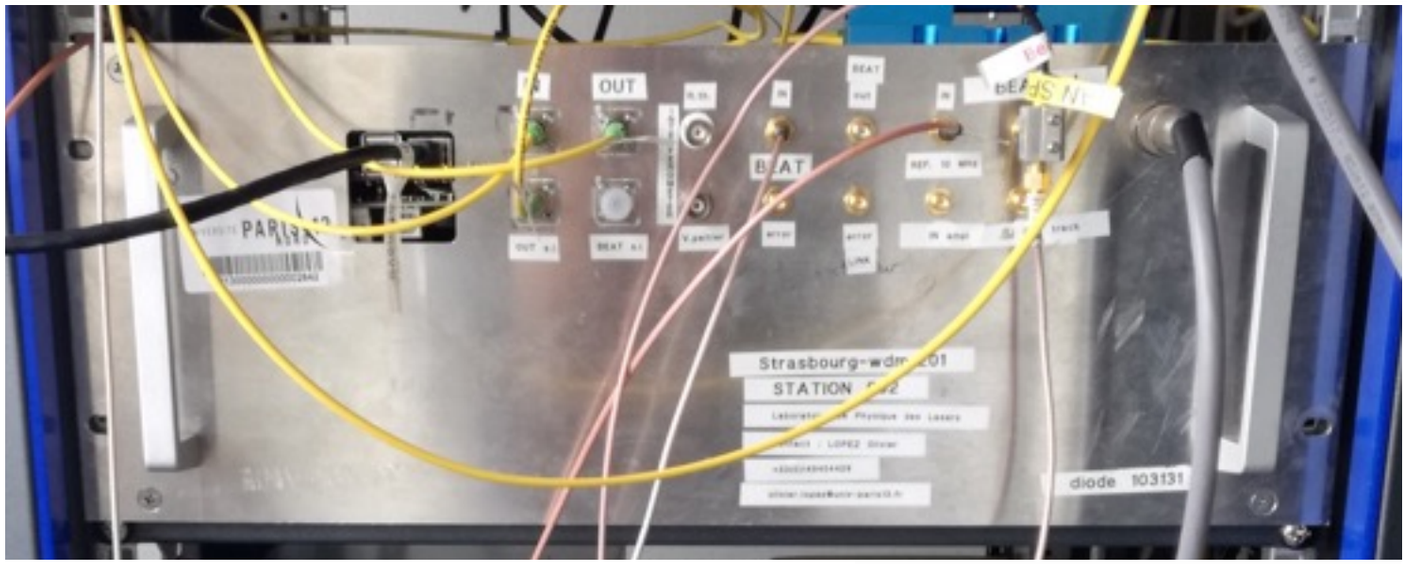
- <u>All the system involved</u>
  (Ultra-stable Laser + Comb + Link)



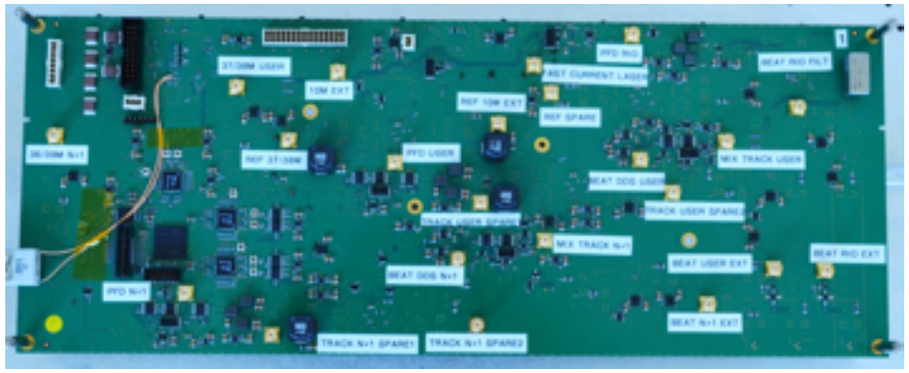
link Paris-Strasbourg-Paris

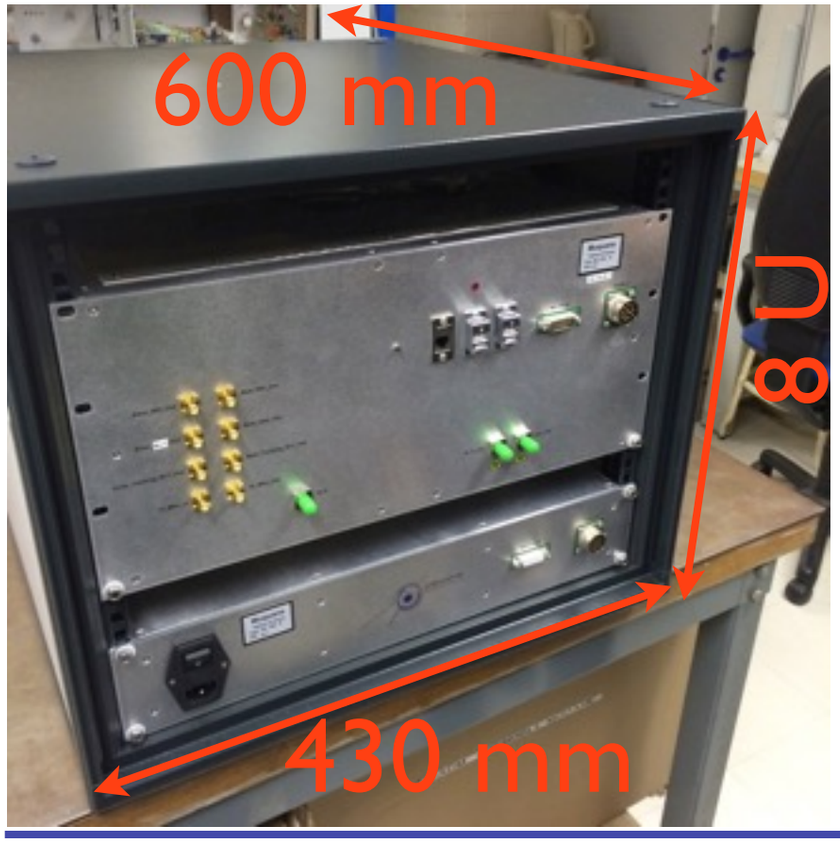
E. Cantin et al.,EFTF'18

Repeater laser station : pictures



Syrlinks
SPACE, DEFENSE & SECURITY

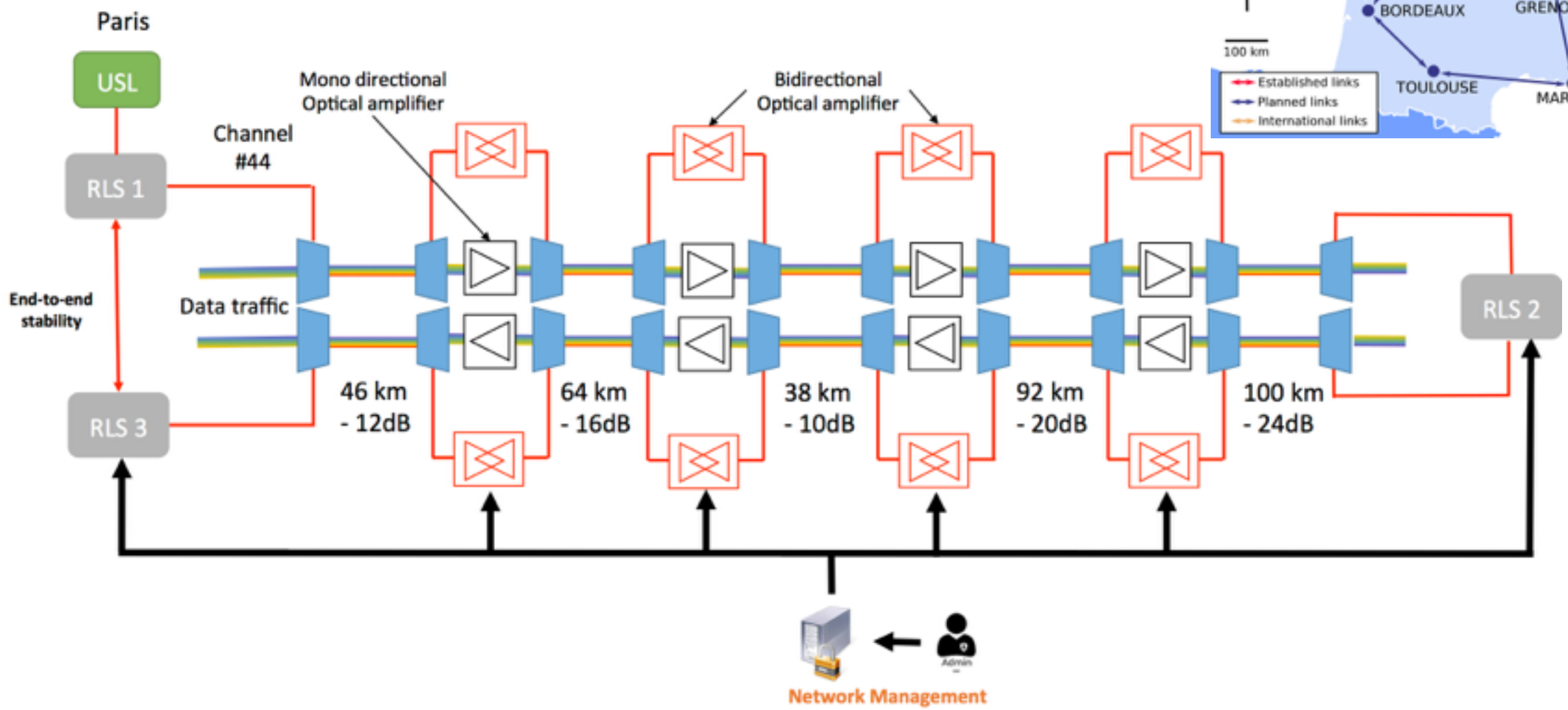




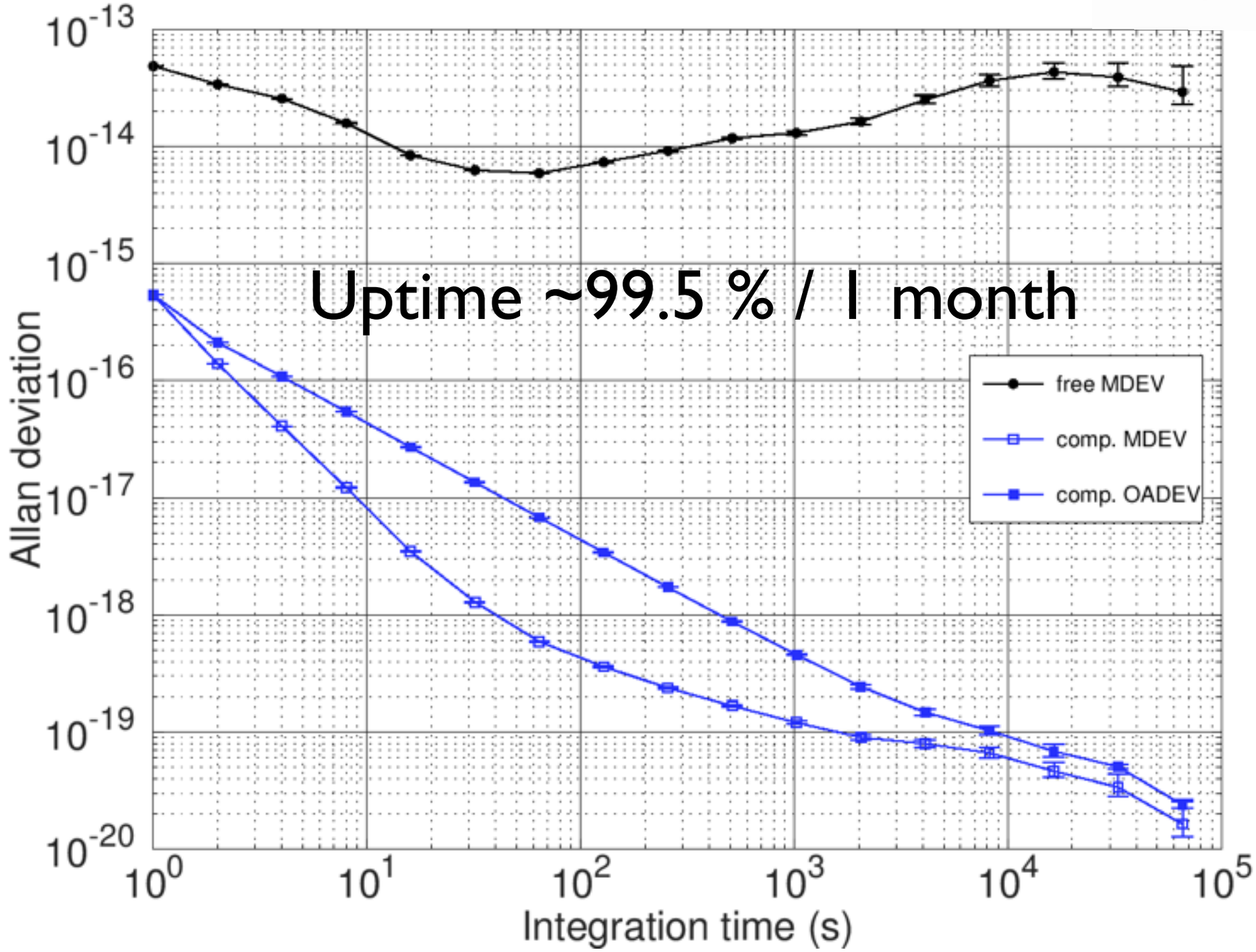
µQUANS

Industrial grade fiber links

F. Camargo et al., **57** (25) ,2018, doi.org/10.1364/AO.57.007203



Industrial grade fiber links



Repeater laser stations on the shelf

RLS stock at MuQuans before deployment

Take away messages

- CLONETS :
  - Towards RI for a secured and long term access to the fiber
  - Sustainable approach with partnership with NRENs. Spectral sharing, ITU#44
- OFTEN : 4 comparisons, many improvements Clocks+Combs+Links
  - Learn and practice methodology
  - Moto : increase the technological readiness level
- REFIMEVE
  - **19 months** of operation with 54.5% uptime
  - **>90% uptime** for several months, up to 99.5% over 1 month

Thank you for your attention !

>50 people

PTB
Gesine Grosche
Erik Benkler
Harald Schnatz
Christian Lisdat
Stefan Weyers

NPL
Jochen Kronjaeger

INRIM
Davide Calonico
Cecilia Clivati

LPL
Olivier Lopez
Anne Amy Klein

SYRTE
Philip Tuckey
Rodolphe Le Targat
Jérome Lodewyck
Sébastien Bize
Frédéric Meynadier

<u>The young (*linkers*):</u>
Sebastian Koke
Alexander Kuhl
Thomas Waterholter

Etienne Cantin
Dan Xu
Florian Frank

Anna Tampellini