CNES

Toulouse-Paris – France

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C. Jayles : DORIS

S. Leon: Program

D. Said: Operation

D. Vergnoux: Quality

OP

Paris– France

J.Achkar: TT Comparison

OCA –UMR GeoAzur

Grasse – France

D. Albanese: Optics

C. Courde: Campaign, Laser

P. Exertier: Data Analysis CMS

M. Laas Bourez: TF Manager

JL. Oneto: TF Lab

J. Paris: Software

F. Pierron: FTLRS

E. Samain: T2L2Prime Investigator

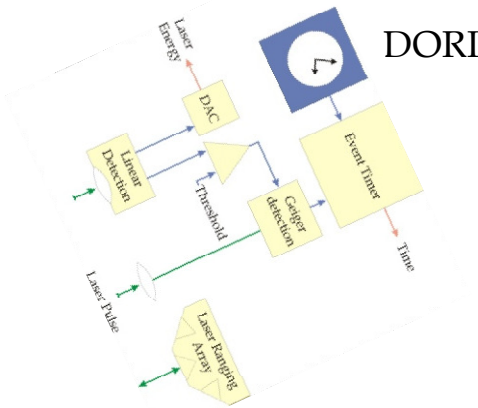
J.M. Torre: Laser sations ILRS

T2L2 : Experimental Campaigns (E. Samain)
T2L2 : Grasse Data Center (P. Exertier)

T2L2 Principle
Ground Space time transfer

- T2L2 is a 2 way technique based on the timing of optical pulses emitted (and received) by a laser station and received by a space segment
- Ground : T_{start} T_{return} Space : T_{board}
- From these 3 dates : Difference between the ground and space clocks

T2L2 on Jason2

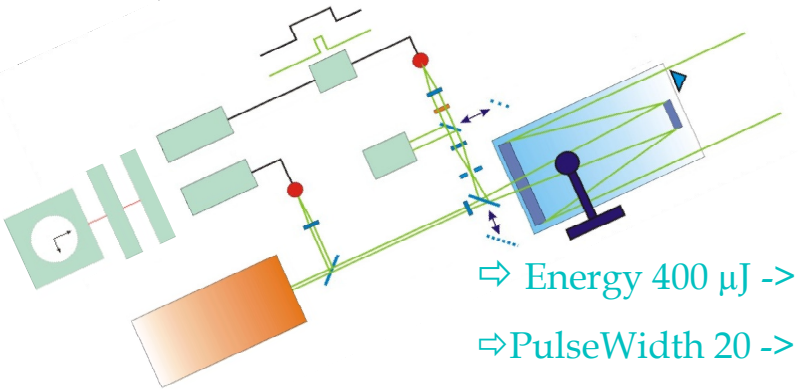


⇨ Masse: 10.4 kg

⇨ Power Consumption: 50 W

⇨ Volume : 20 l

Laser Station



⇨ Energy 400 µJ -> 200 mJ

⇨PulseWidth 20 -> 200 ps

- Comparison between ground to space time transfers coming from the whole laser station network permits to realize ground to ground time transfer

Two Ground to ground Time Transfer Experiments

- Tahiti multi purpose Time Transfer campaign
  - Transportable Time and Frequency Lab
  - Transportable laser station: FTLRS
  - Fixed laser station: Moblas 8

- OCA T2L2 – GPS comparison
  - Independent laser stations: FTLRS – MeO
  - Independent Clocks: T4S HMaser – HP 5071A Cs
  - Independent GPS time receivers
  - Independent Event timers

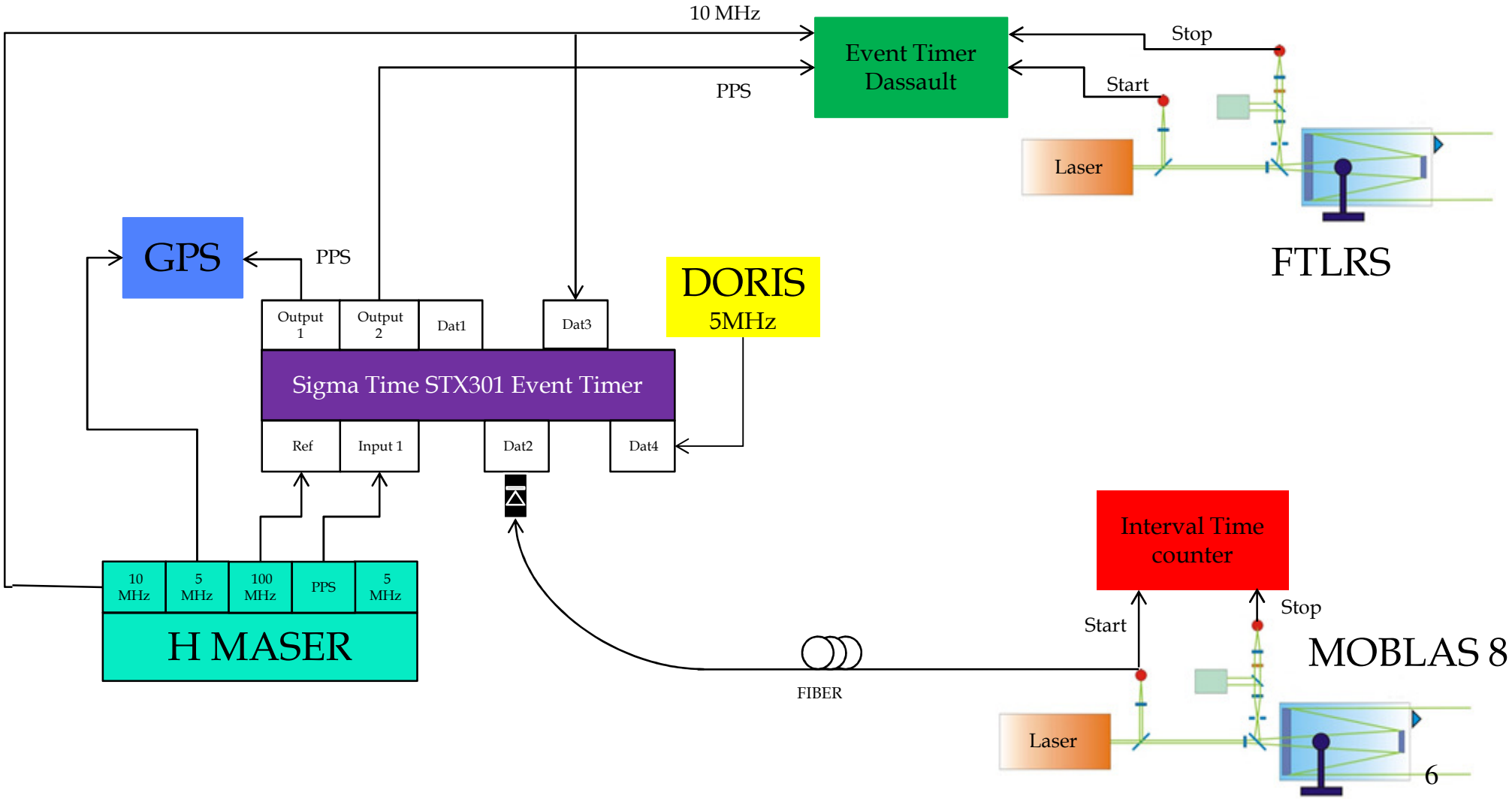
Tahiti Time Transfer campaign

- A dual dedicated Time transfer and laser ranging campaign was done at UPF (French University of Polynesia) in june 2011 (6 months)
  - Moblas 8 and FTLRS Laser Stations
  - H Maser (rent)
  - GPS, DORIS
  - Sigma Time STX301 Event timer

Tahiti Time Transfer campaign

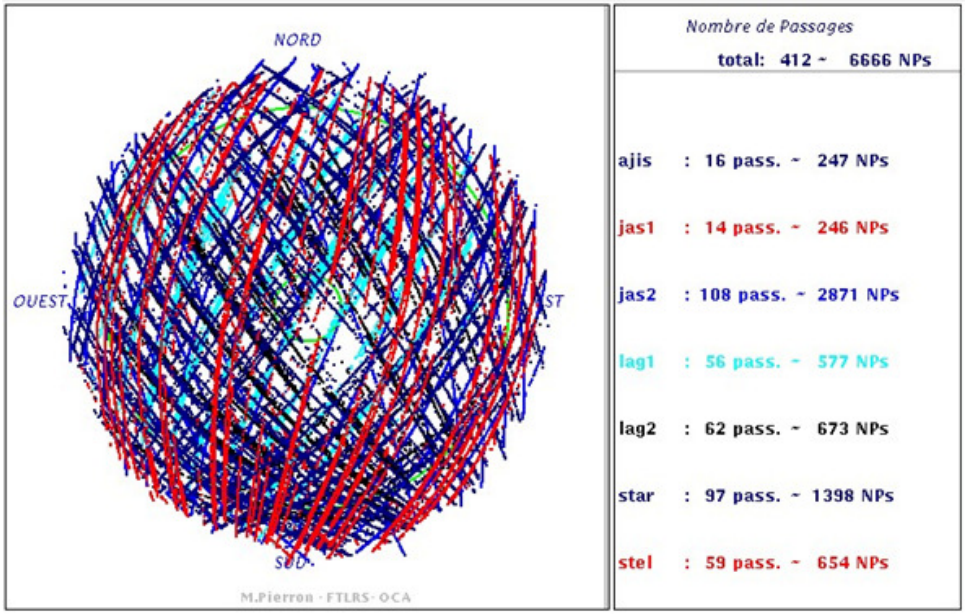
- Objectives
  - Collocation between FTLRS and Moblas8
  - Adaptation of Moblas 8 in order to perform a T2L2 time transfer (laser start time in the picosecond domain)
  - T2L2 comparison between Moblas8 and FTLRS
  - DORIS monitoring
  - Non common view time transfer
- A Sigma Time event timer STX301 instrument was used in order to :
  - Generate a reference PPS signal
  - Time calibration of both FTLRS and Moblas8
  - Monitor of the time signal used to synchronize Moblas and FTLRS
  - Monitor the DORIS instrument
  - Timetagg of Moblas 8 laser events (initial time resolution of Moblas8 100 ns)

Tahiti Time Transfer campaign



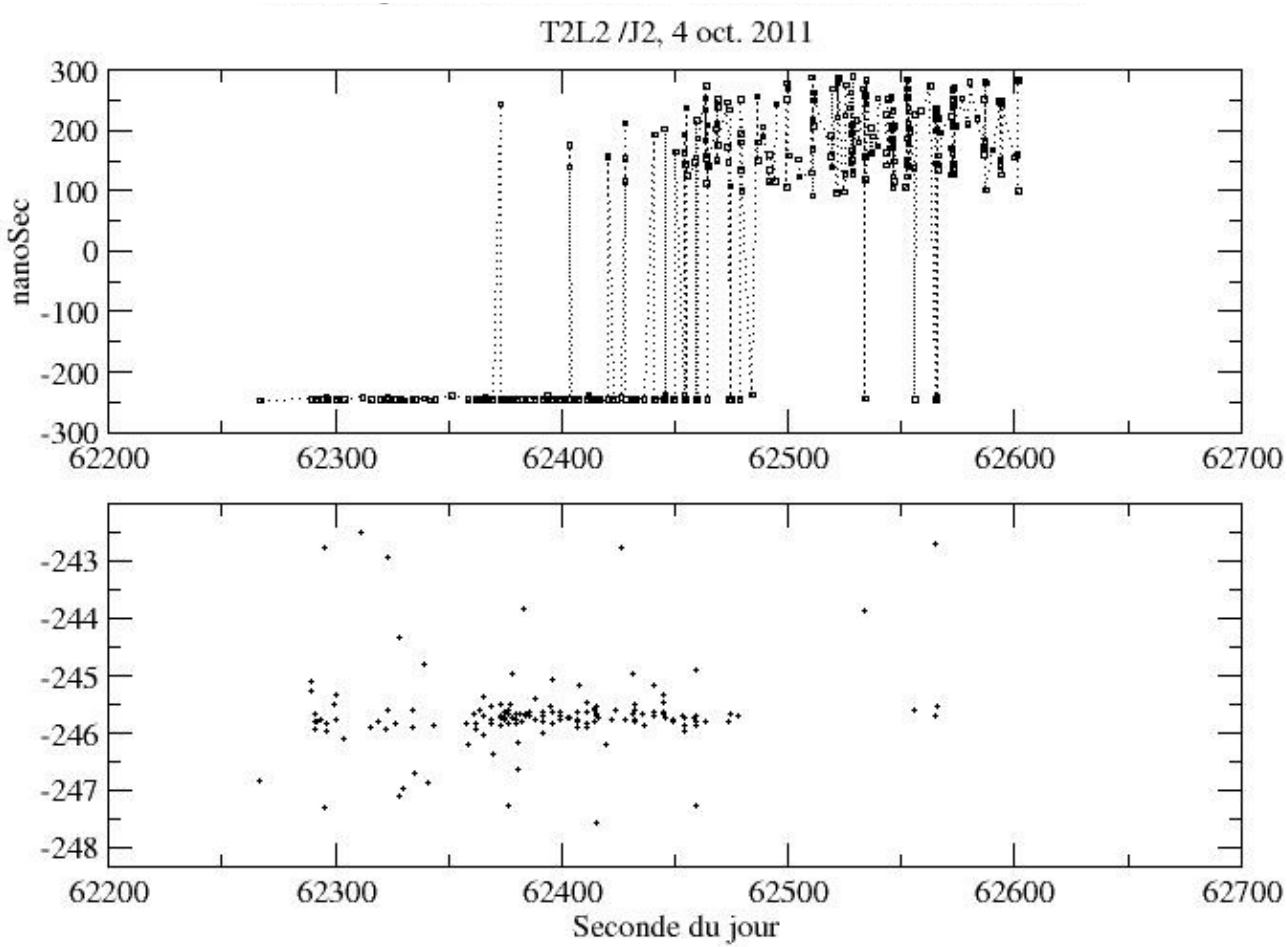
Tahiti Time Transfer campaign

- ~400 passes was acquired during the campaign (108 on Jason 2)
- T4S HMaser had several troubles (due to temperature)



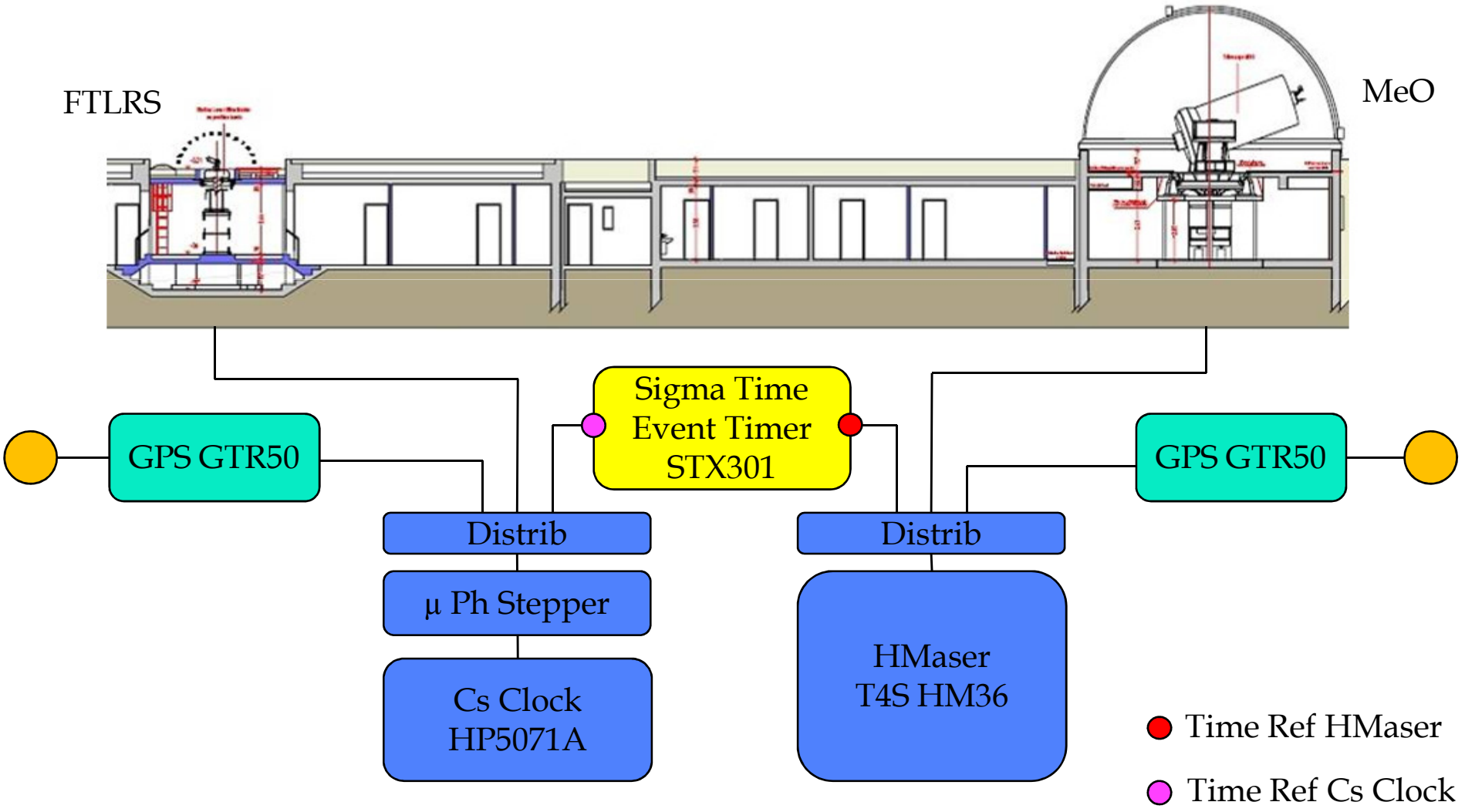
Moblas 8 – Sigma Time Event Timer

Moblas 8 Pass with and without STX Event Timer



- Sigma Time : σ =150 ps rms
- Moblas 8: σ =57 ns rms

OCA T2L2–GPS Comparison Experimental Setup (simplified)



Collocation T2L2–GPS-ET comparisons
T2L2 calibration: Time equation

- T2L2 calibration difference between calibration becomes:

$$\delta_{TFtlrs} - \delta_{TMeo} = \delta_{calFtlrs} - \delta_{calMeo} - (\delta_{ocxFtlrs} - \delta_{ocxMeo}) - (\delta_{fFtlrs} - \delta_{fMeo})$$

→ T2L2 uncertainty: 150 ps (100 ps nominal with 50 ps laser pulse width)

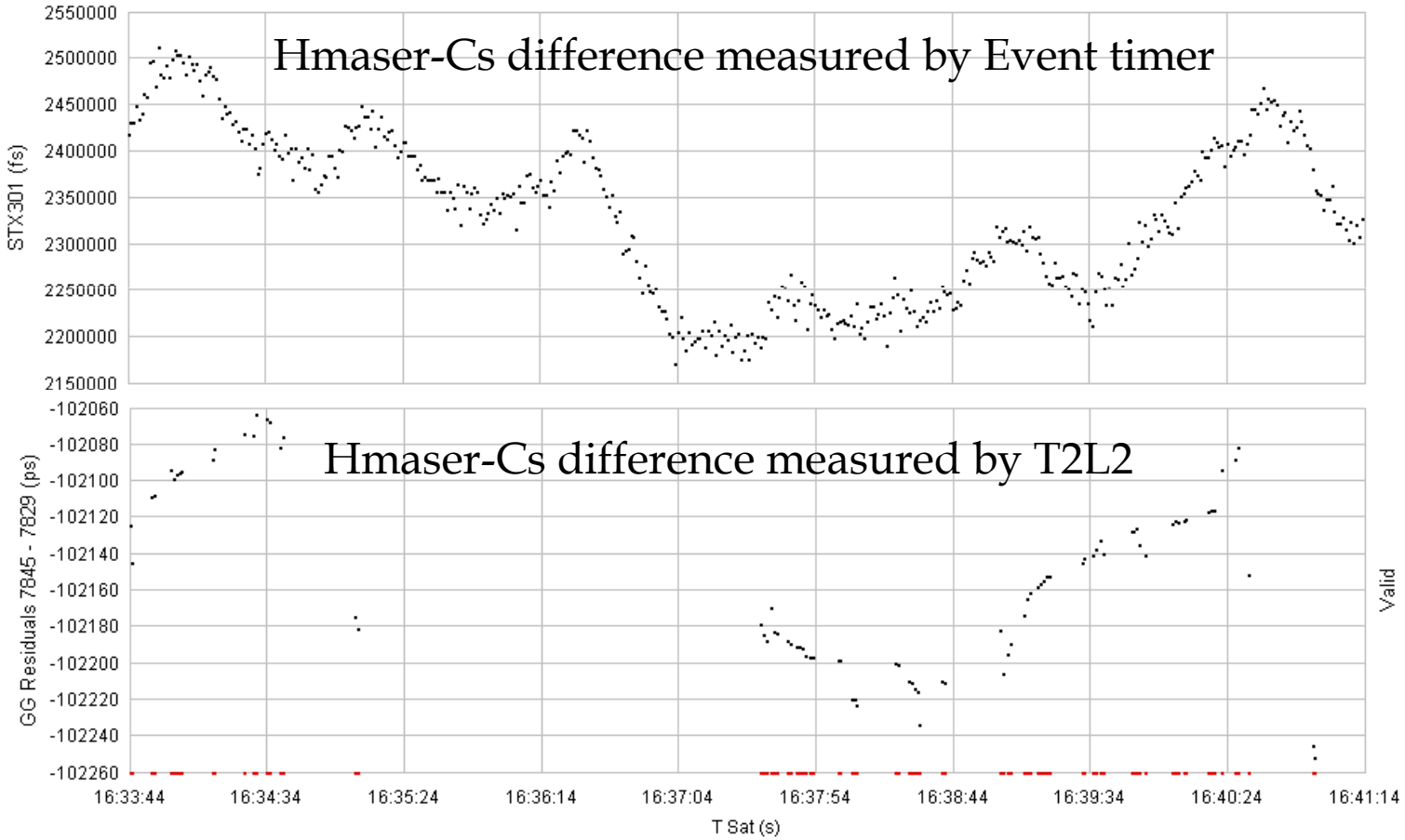
- GPSs are calibrated through a GPS Campaign done in collaboration with Observatoire de Paris

→ GPS uncertainty: 2 ns

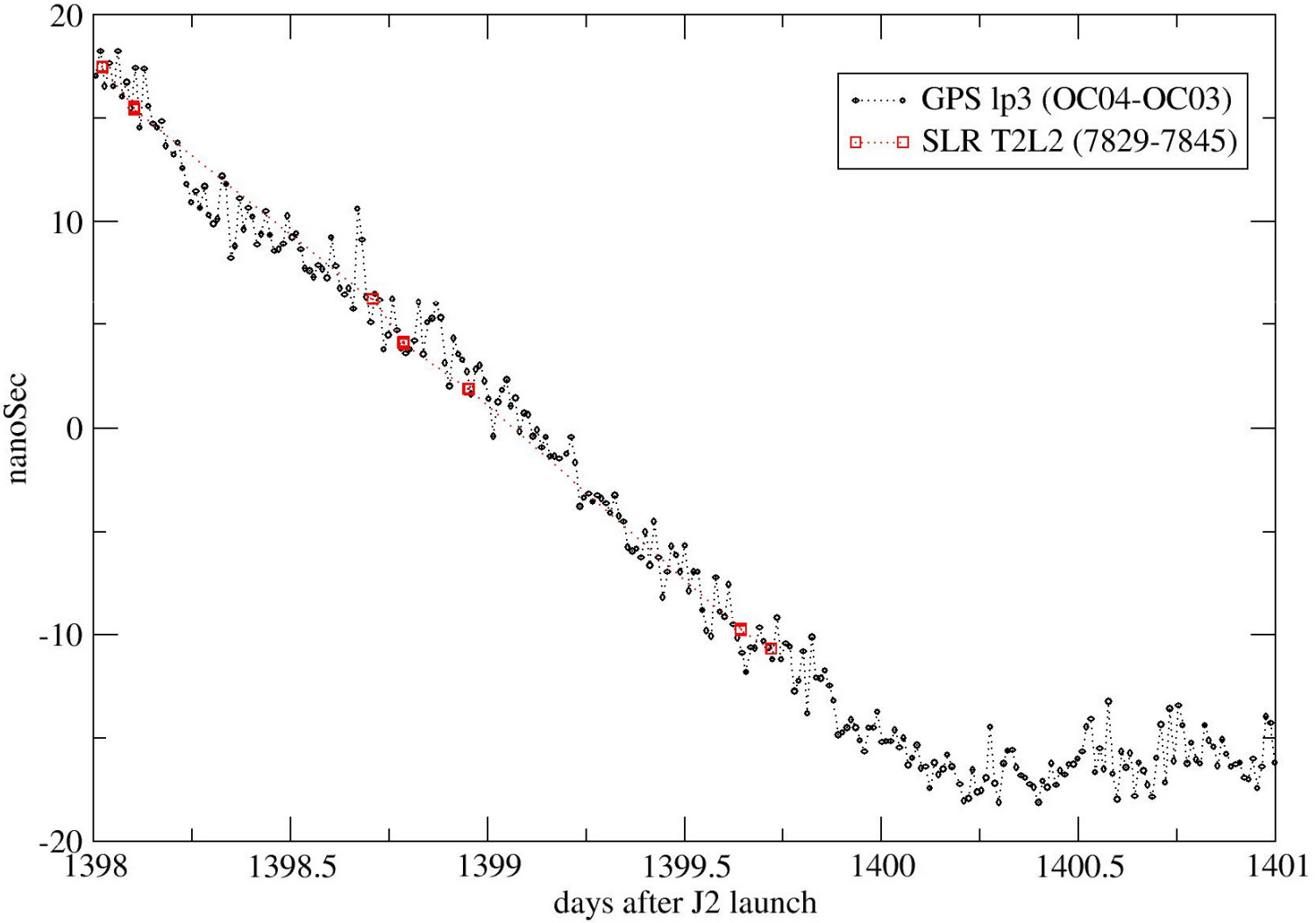
- STX301 Event timer is internally calibrated (< 10 ps); the global direct comparison uncertainty depends on both time distribution and event timer uncertainties

→ Event Timer + Time distrib. uncertainties: 50 ps

Collocation T2L2–GPS-ET comparisons
Event Timer-T2L2 comparison 11/04/12



Collocation T2L2–GPS-ET comparisons
GPS-T2L2 comparison

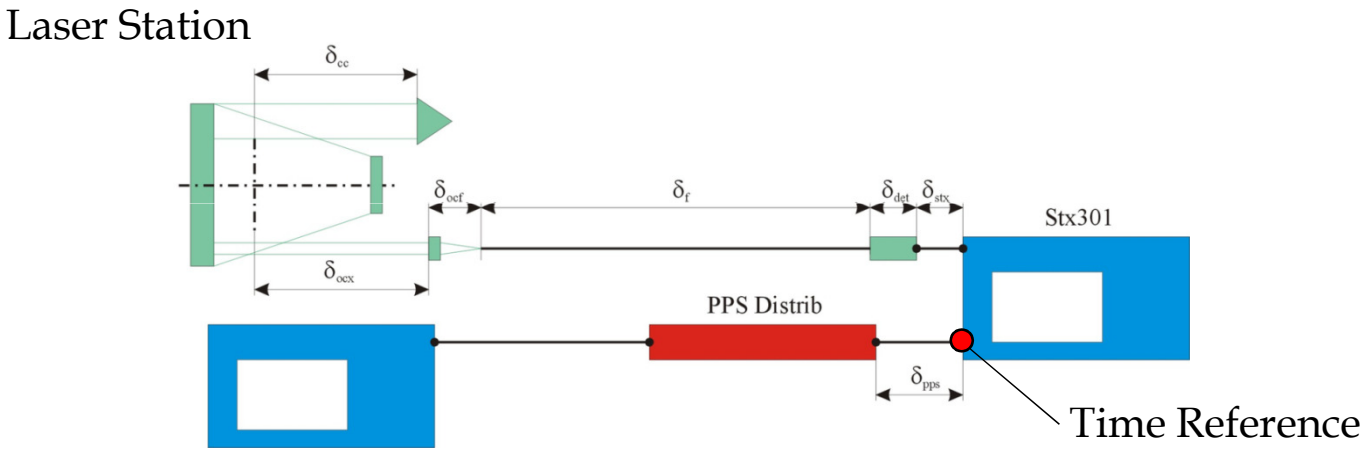


Collocation T2L2–GPS-ET comparisons
One pass ET-T2L2 comparison 11/04/12

- Absolute Cs – HM differences :
  - $\delta_{T2L2\ FTLRS\text{-}MeO} = 95910$ ps
  - $\delta_{EventTimer\ STX301} = 96076$ ps
  - $\delta_{GPS\ GTR50} = 96941$ ps
- Agreement between T2L2 – Event Timer:
  - $\delta_{T2L2} - \delta_{EventTimer} = 166$ ps as compared to 200 ps uncertainty
  - Good Agreement
- Agreement between GPS – Event Timer:
  - $\delta_{GPS} - \delta_{EventTimer} = 865$ ps as compared to 2 ns uncertainty
  - Good Agreement

Collocation T2L2–GPS-ET comparisons
T2L2 calibration: Time equation

- Each laser station is calibrated thanks to the time reference points of each clock



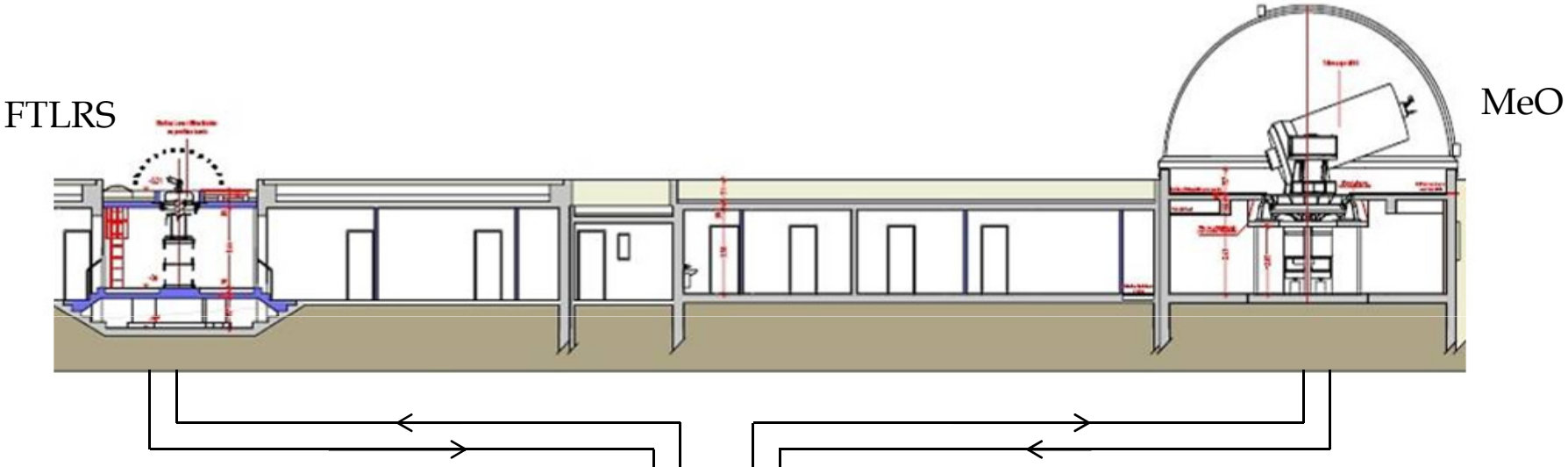
- Time equation that permits to accurately timetagg laser pulses is given by:

$\delta_T = \delta_{cal} + \delta_{prg} = \delta_{cal} + \delta_{PPS} - (\delta_{ocx} + \delta_{ocf} + \delta_f + \delta_{det})$

δ_{cal} : difference between absolute measurement (calibration) and station measurement

δ_{prg}: global propagation between cross axes and the PPS unit.

T2L2 Long Term time stability collocation Experimental setup (simplified)



Time Signal Generator

100 MHz

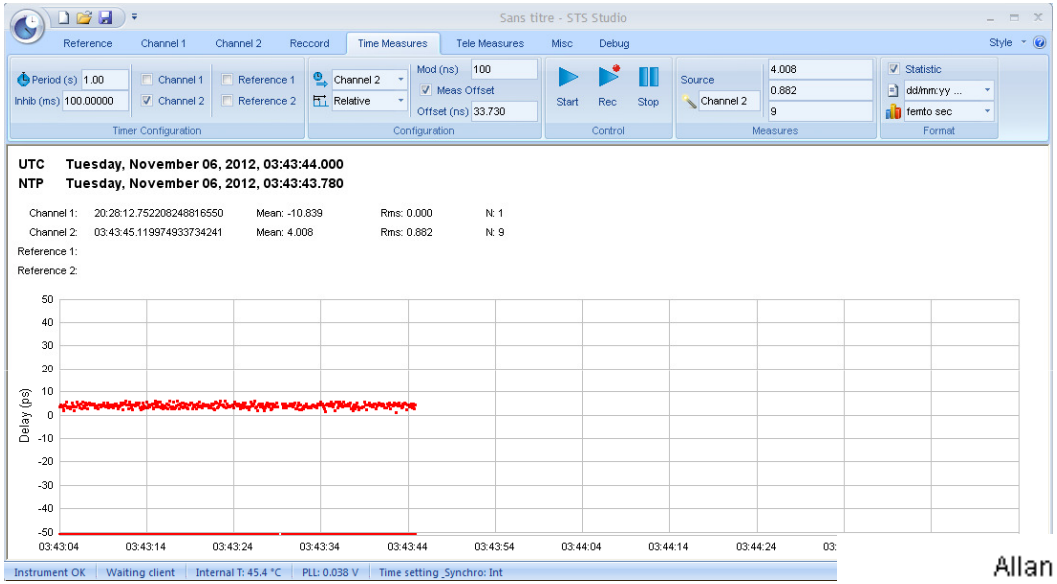
HMaser
T4S HM36

- A unique clock for both MeO and FTLRS
- Ultra stable and time distribution
- Absolute time calibration between MeO and FTLRS

T2L2 Long Term time stability collocation Time Signal generator

- The Time Signal generator was designed for this experiment ; it includes:
  - 4 balanced programmable signal outputs in the 1PPS to 100 MHz range
  - Multichannel subpicosecond event timer
- The internal event timer aims to measure absolute time propagation between distribution and user (based on a double distribution). It will permit to monitor the reference signals through the lab with:
  - Absolute uncertainty < 20 ps
  - Repeatability error < 800 fs rms
- Campaign schedule
  - Start: November 2012
  - Duration: 3 months

T2L2 Long Term time stability collocation 10 MHz Double link

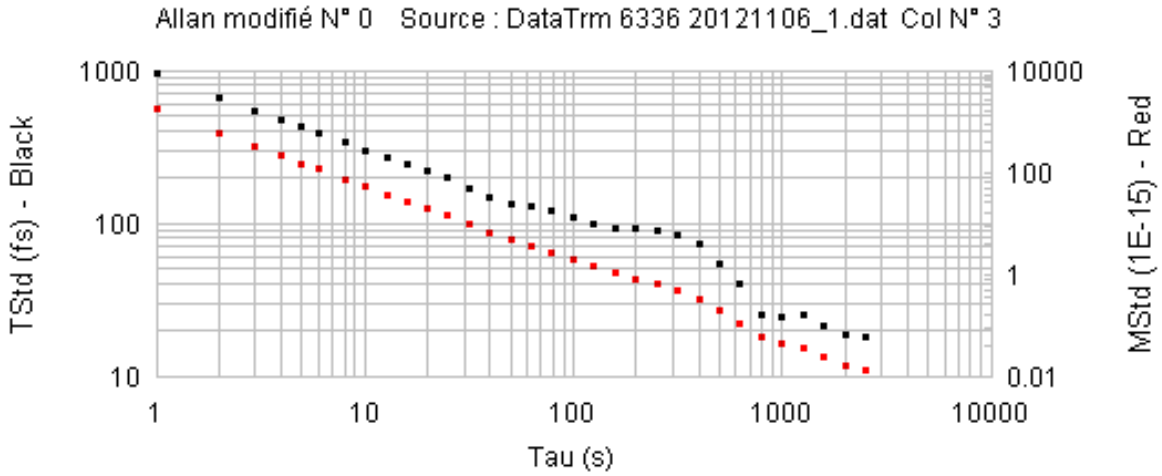


Repeatability error : 0.9 ps

Thermal Sensitivity < 0.5 ps/°C

Time stability < 30 fs @ 1000 s

Time delay accuracy < 30 ps



CENTRE NATIONAL D'ÉTUDES SPATIALES

Observatoire de la CÔTE d'AZUR

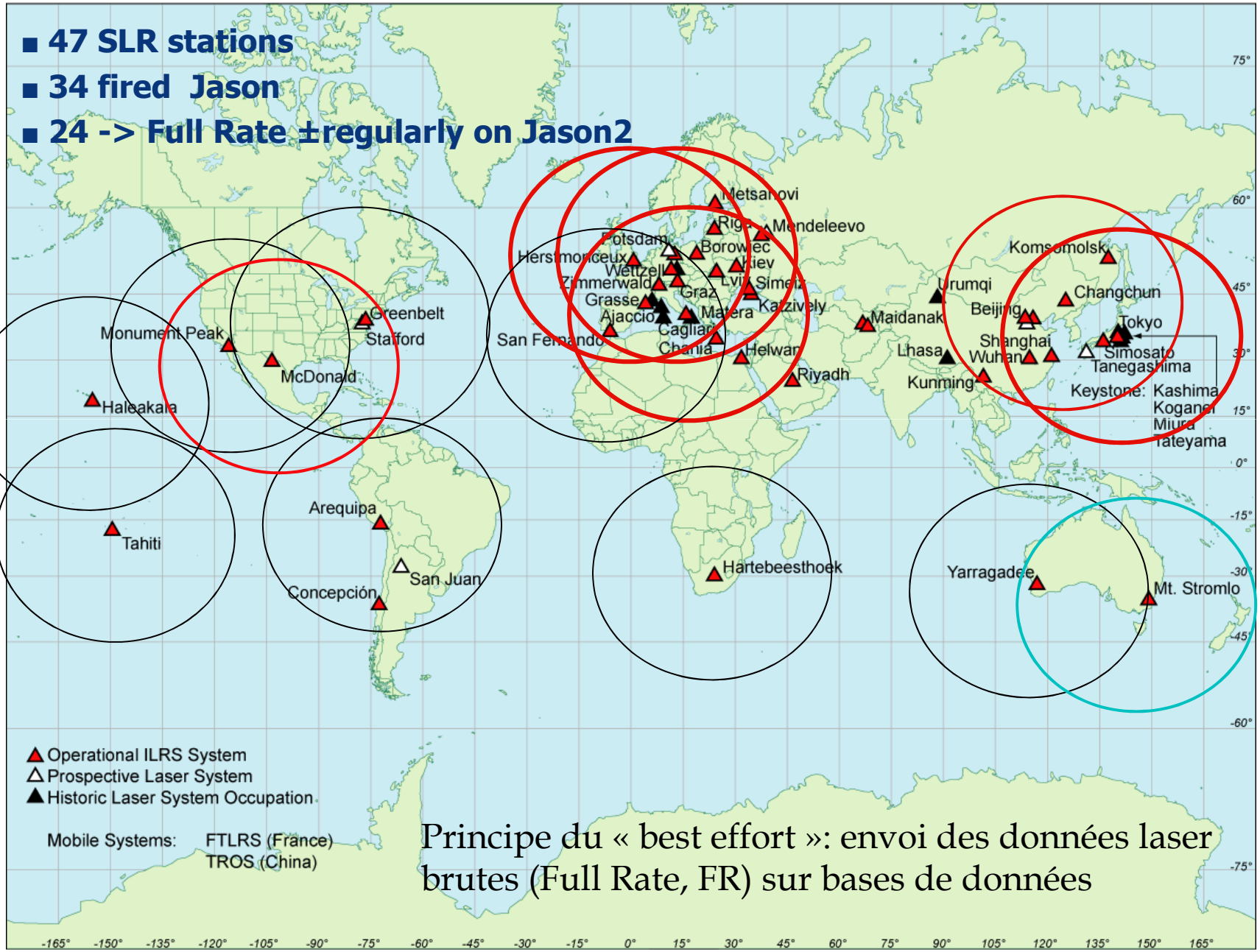
GEOAZUR
TERRE - OCÉAN - ESPACE

T2L2, the Grasse data center

The mission center, 2008 ->

- History :
  - 2008-2010: development of the data processing, in 3 levels.
  - Analyses & performances of time transfers (ground to space, and then ground to ground)
  - Spreding of results and data, develoment of a dedicated Web site and tools
- Measures :
  - nb of passes /month : 150 (winter) to 450 (summer, campaigns)
  - ILRS Working Group (22 SLR stations, from which 6 in Europe equip. with maser-H)
  - Time-Freq. : comparisons with GPS and two-way micro-Waves equipment
- Operations :
  - 1-day processing, since July 2008
  - Data flow : all format of exchange have been defined and used
  - **Campaigns** of TT; results within 2 days

SLR network - T2L2

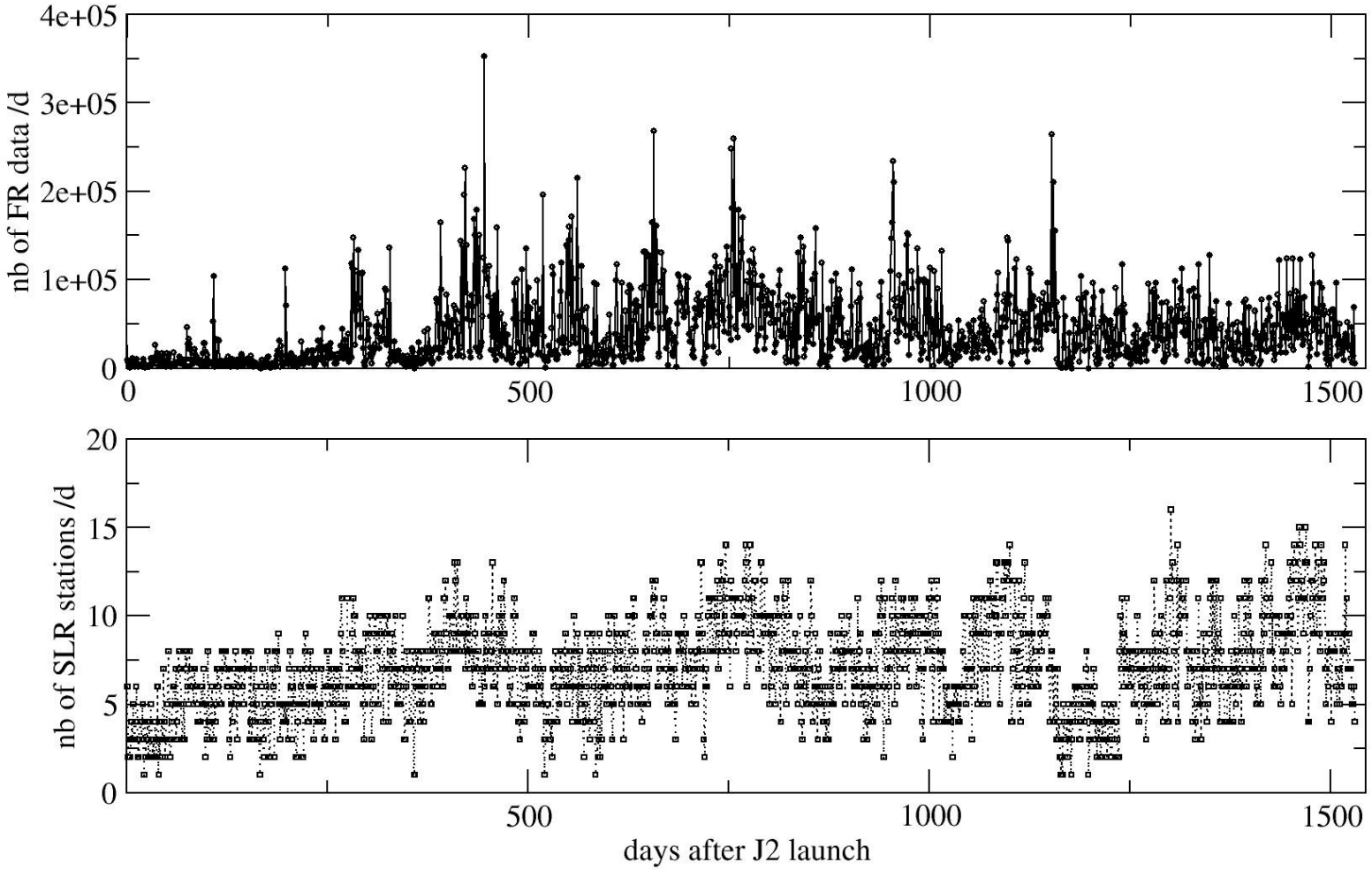


Principe du « best effort »: envoi des données laser brutes (Full Rate, FR) sur bases de données

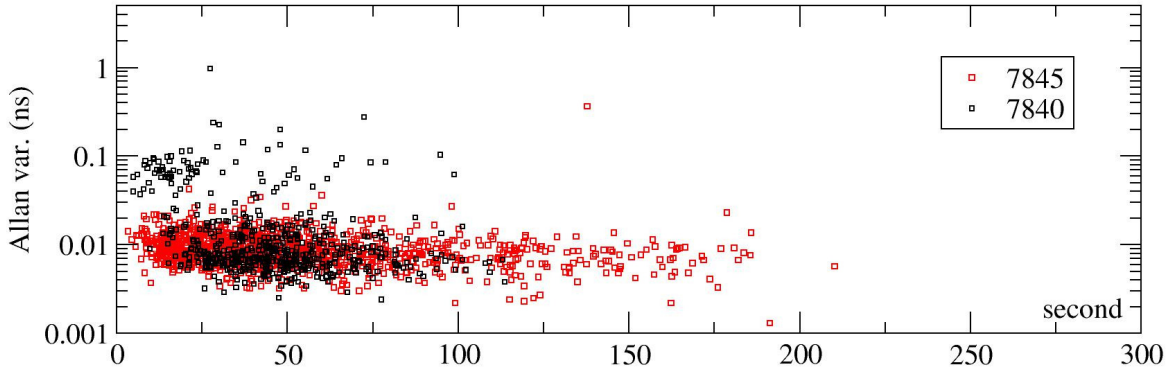
ILRS network for Time Transfer

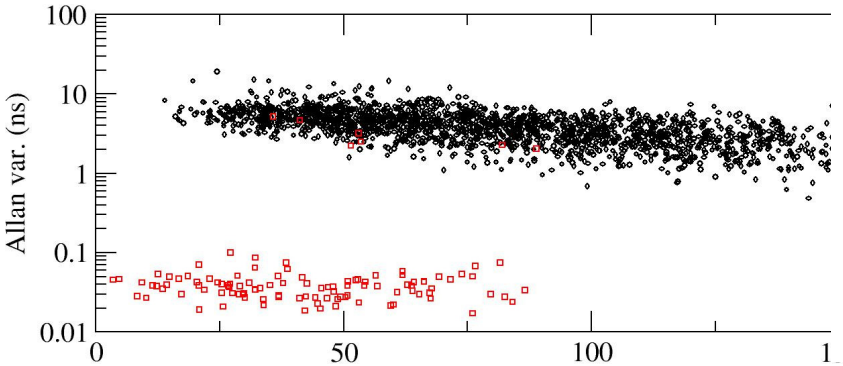
SLR station	time tr. at 1s	stab. at 60 s
1824,1873,1893	~ 85 ns	-
7080: Mac Donald	< 1 ns	6-8 ps
7090: Yarragadee	~ 50 ns	2-3 ns
7237: Changchung	< 1 ns	4-5 ps
7308: Tokyo	< 1 ns	4-5 ps
7810: Zimmerwald	< 1 ns	6-8 ps
7824,7824	~ 50 ns	2-3 ns
7840: Hx	< 1 ns	6-8 ps
7845: Grasse	< 1 ns	6-8 ps
7941: Matera	< 1 ns	6-8 ps
8834: Wettzell	< 1 ns	6-8 ps
7501,7105,7110,7119,7124,7403	~ 50 ns	2-3 ns
FTLRS : 7822, 7828, 7829	< 1 ns	6-8 ps

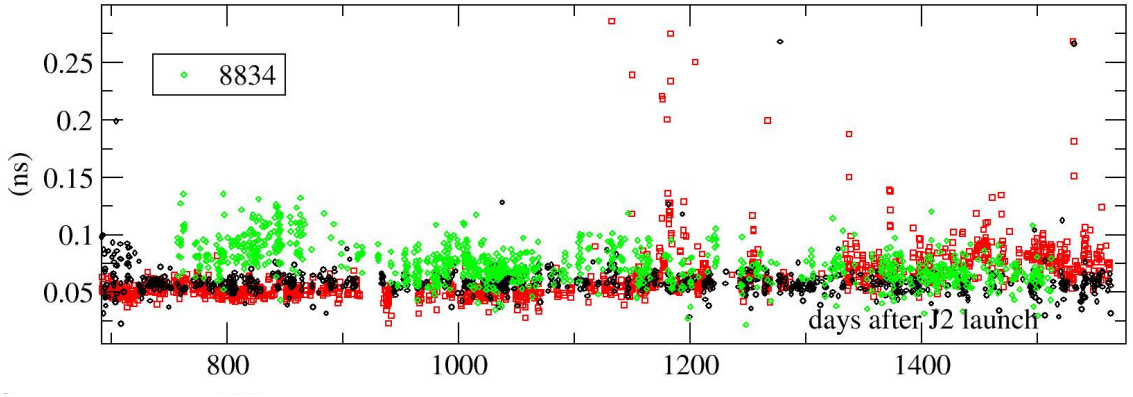
Global statistics

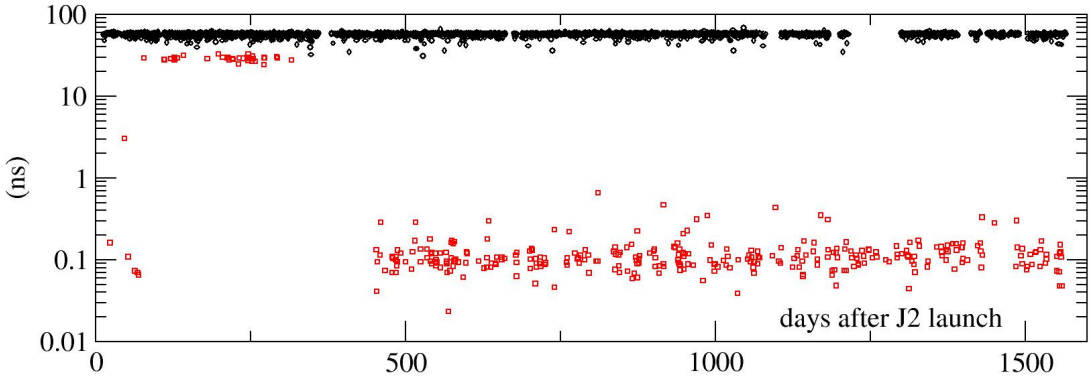


History of the TT performance

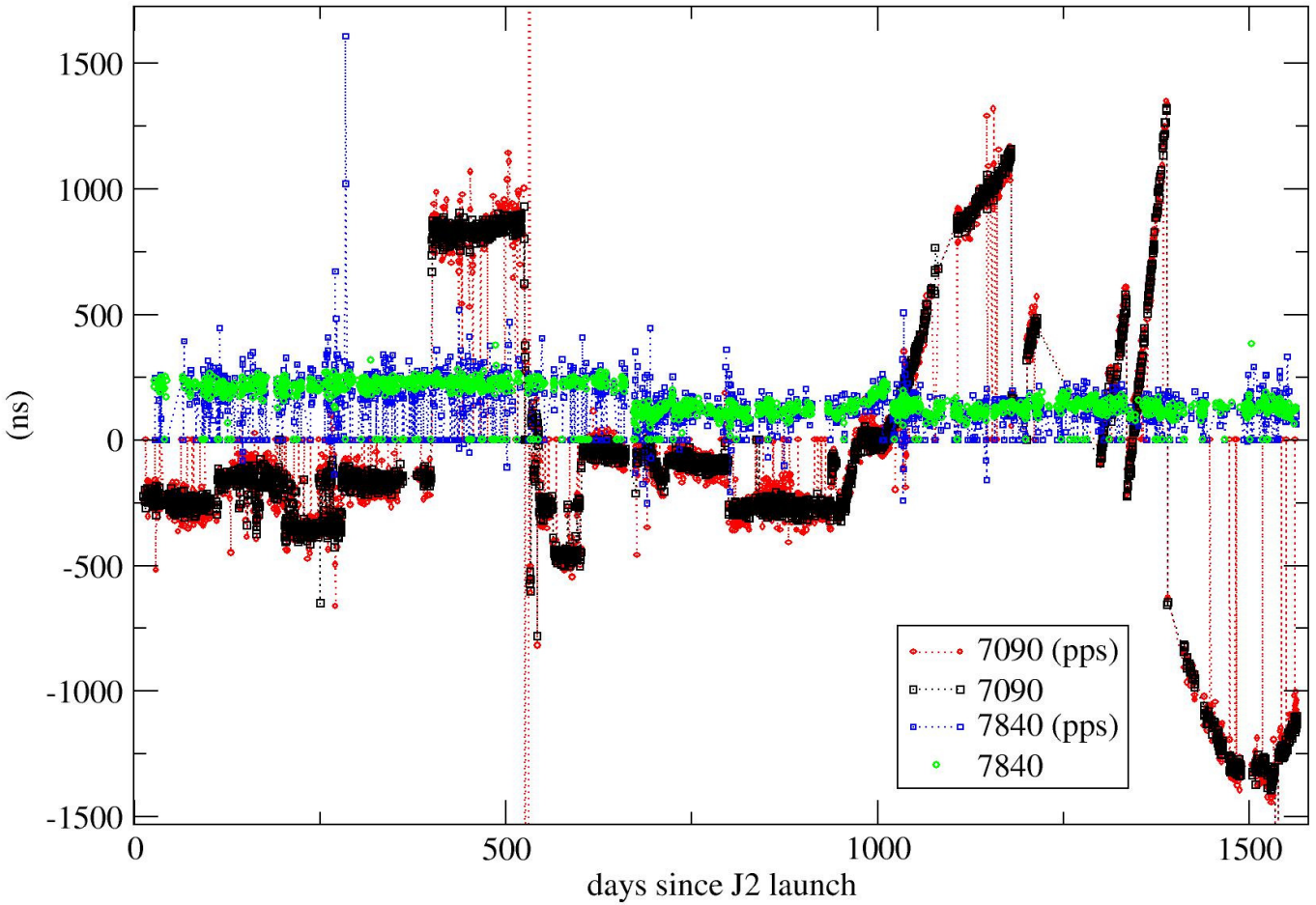








Approx. synchronisation between SLR's



0: onboard time
(approx. GPS)

this gives the trends, or long-term behavior of clocks

This indicates the need to better synchronize the current network

Conclusions - Prospectives

- The space instrument is nominal
- Data is now provided to the whole community through the T2L2 Web Site
- A 2 years extension of the mission was accepted by CNES for 2013-2014
- Important next steps
  - Ground to ground time transfer in a non common view configuration
  - International Calibration campaigns
  - Laser station calibration
  - Microwave time transfer calibration (GPS TWSTFT)

Conclusion: services and tools

Campaign(s)
Calibration(s)
Dedicated vs. permanent time setting
Data
- 1-way ranges
- Time transfer
- Energy link

Synergy with DORIS
Precise Orbit computation for Jason2
Fundamental physics

FTLRS
Electronic kit

Website
Data / tools

Exchange of files

T2L2 Web: https://t2l2.oca.eu

- Data of time transfer:
  - » ground to space, by pass :
    - – résiduals of time transfer
    - – stability /pass (with TVAR estimate)
    - – Possibility of downloadin data and results (for scientits) by pass, with the new laser CRD format