OCA –UMR GeoAzur

Grasse – France

J.M. Torre: Station Calibration

E. Samain: Prime Investigator

D. Albanese: Optics

C. Courde: Campaign, Laser

P. Exertier: Data Analysis CMS

M. Laaz Bourez: Data Analysis

H. Mariey: Instrumentation

JL. Oneto: Time

J. Paris: Software

F. Pierron: FTLRS

H. Viot: Laser

P. Vrancken: T2L2 flight model characterisation
(until '08, now DLR)

CNES

Toulouse-Paris – France

P. Guillemot: Mission Center CMI

C. Jayles : DORIS

S. Leon: Program

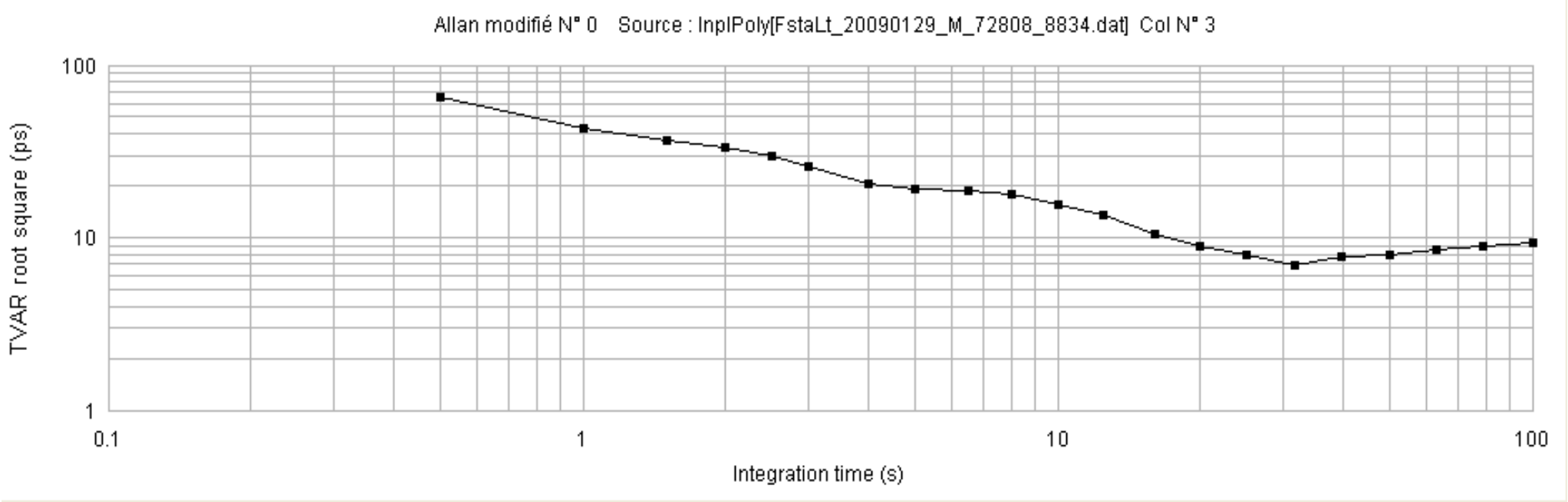
D. Said: Operation

D. Vergnoux: Quality

T2L2: Calibration

T2L2
Status

- Launch June 20, 2008
- Numerous TT campaigns,
  incl. co-location of SLR stations and clocks
- E.g. Grasse-Wettzell, TT < 10 ps (TDEV)



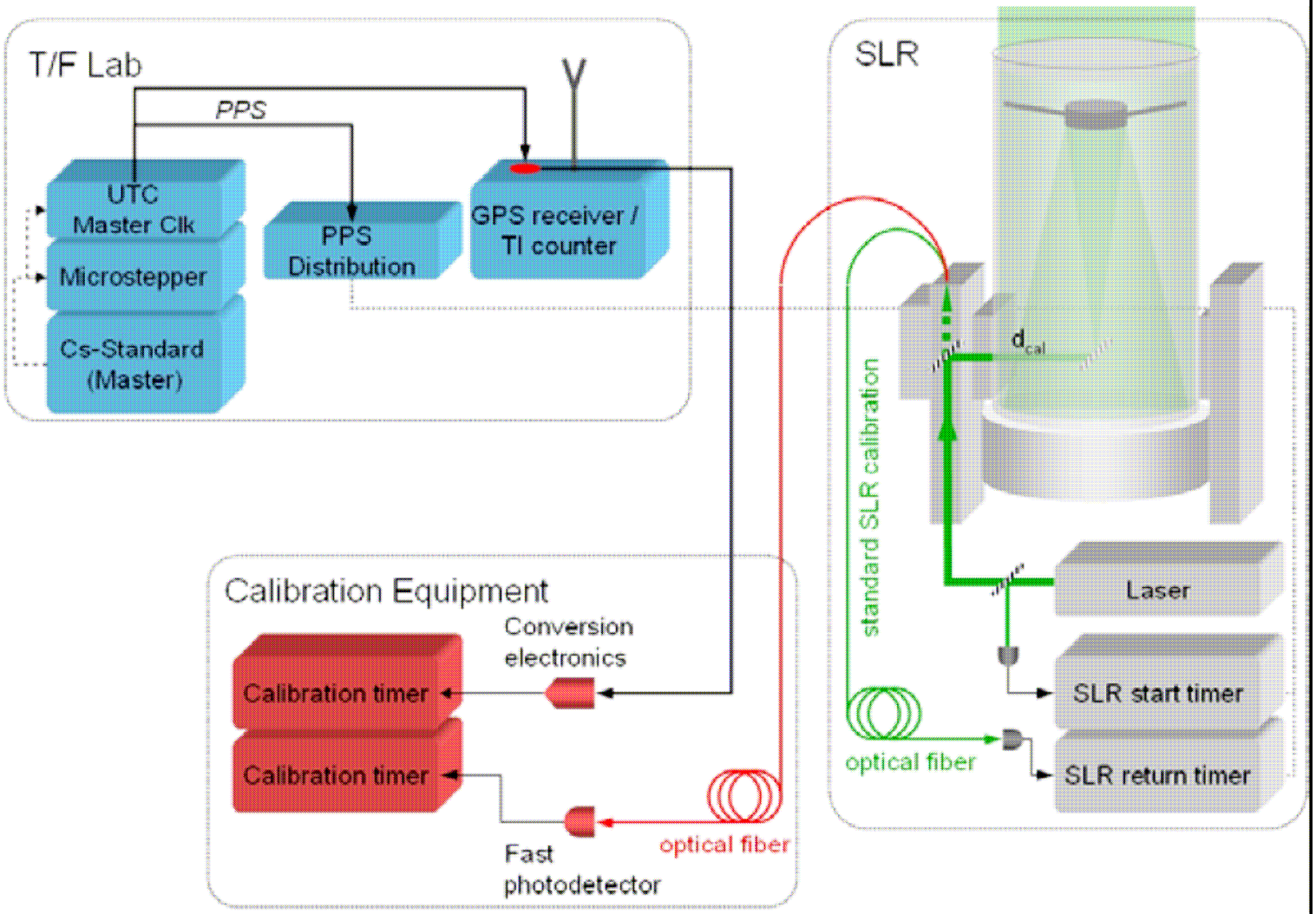
Goal: Accurate (absolute) ground to ground time transfer

- Objective : Ground to ground T2L2 time transfer with an accuracy better than 100 ps.
- It requires the measurement of the laser pulse time tags with an accuracy in the range of 50 ps in the local temporal reference frame

- Calibration based on simultaneous measurement between :
  - Laser station
  - Calibration device

T2L2 Calibration Global Scheme

- Delay between:
  - the optical pulse at the axes crossing of the telescope and the
  - electrical reference (PPS) coming from the Time and frequency lab



4D-spacetime references

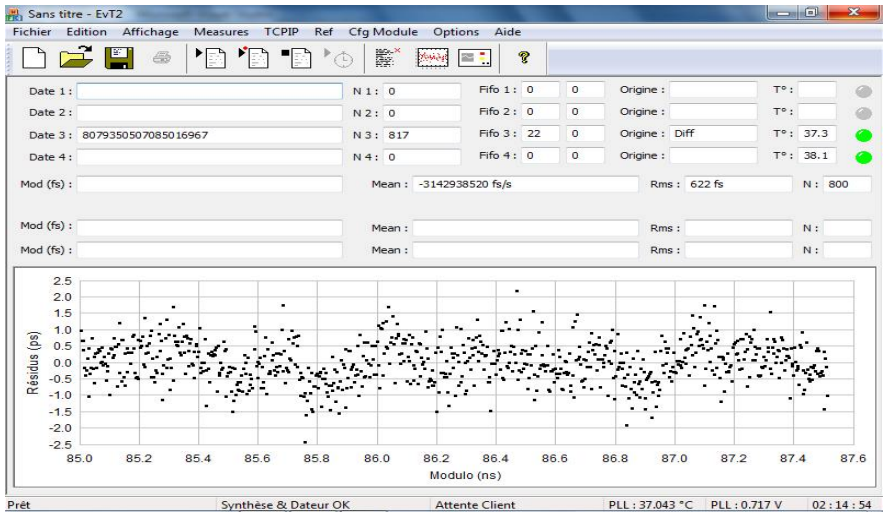
- Laser Station
  - The reference point is the axes crossing of the telescope which is also the space reference for laser ranging
- Time and frequency ensemble
  - PPS distribution unit

T2L2 Calibration Station

- Objective: Combine in a unique equipment all the metrology required to perform the calibration
- All the laser stations that participate to T2L2 could be calibrated by this equipment
- The station includes
  - SigmaTime STX301Event Timer
    - Independent subpicosecond time tagging units
    - Absolute start time, time interval, frequency, shape
  - Optical module
    - Mono mode optical fiber
    - Optical collimator

SigmaTime Event Timer STX301

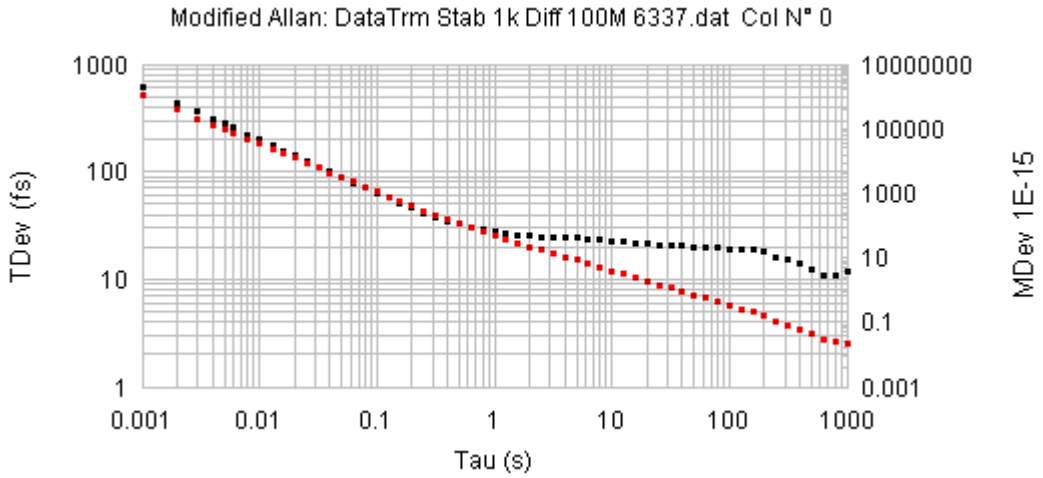
- STX301 was developed in the T2L2 framework with the willing to design a versatile laboratory instrument
- Frequency Synthesis
  - 5, 10, 100 MHz
- Two Independent channels
  - Electrical: DC - 20 GHz
  - Optical: DC - 20 GHz (λ = 400 to 1600 nm)
- High stability pulse generator
- Embedded Win 7 computer
  - Control the hardware
  - Drive the integrated measurements
  - Record the data
  - Friendly Human Machine Interface

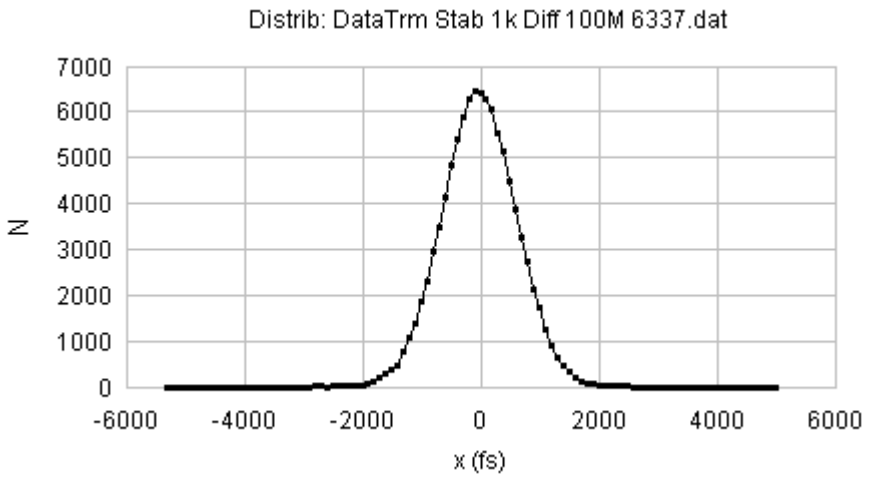


SigmaTime Event Timer STX301 Performances

- Time Stability @ 1000s: < 20 fs
- Linearity: 0.3 ps rms.
- Thermal Sensit. < 200 fs/°C
- Repeatability error
  - Synchronous : 600 fs rms
  - Random : 700 fs rms
- Rate
  - Dead time: 130 ns
  - High speed Acquisition : 500 kHz
  - Continuous rate 35 kHz

- contact@sigmatime.fr





Optical module

- Objective: Collect laser pulses from the axes crossing of the laser station telescope to the calibration event timer inside the Time and Frequency lab
- Optics + Mono mode optical fiber (532 nm)
- Time delay: $\delta_{ocf} = l_{ocf} / c + e_{oc} (n_{oc} - 1)/c$
- Next: Monitor the time variation in the fiber with a double pass configuration
  - Thermal Drift
  - Mechanical stress

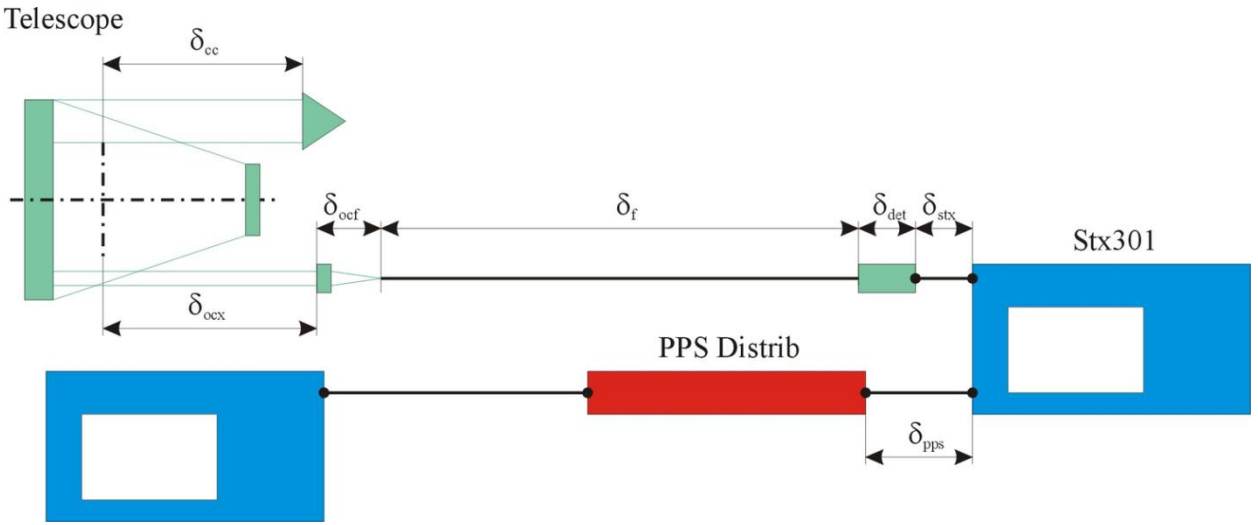
Time equation

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

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

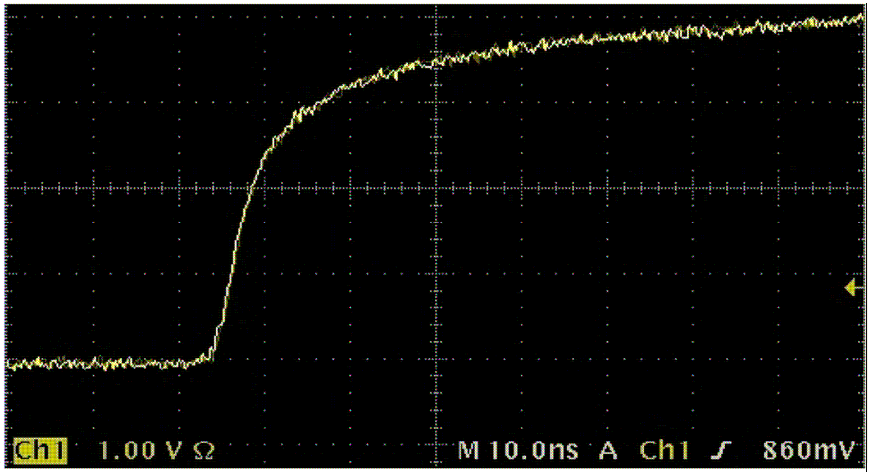
δ_{cal} : difference between absolute measurement (calibration) and station measurement

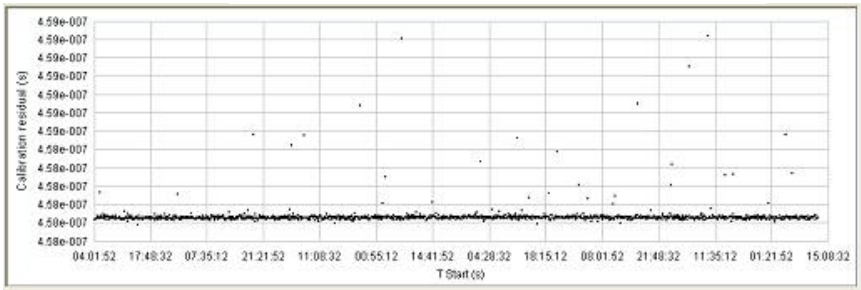
δ_{prg}: global propagation between cross axes and the PPS unit.

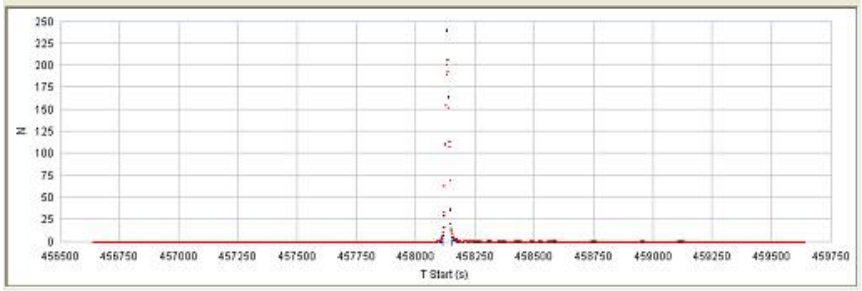


Determination of term δcal

- PPS Synchronization of the SigmaTime STX301 event timer
  - » Scan of the PPS signal by the event timer
  - » Reference threshold from the inflexion point
  - » Synchronization of the timer with this Reference threshold
- Simultaneous acquisition of laser pulses by
  - » Laser station
  - » Calibration station

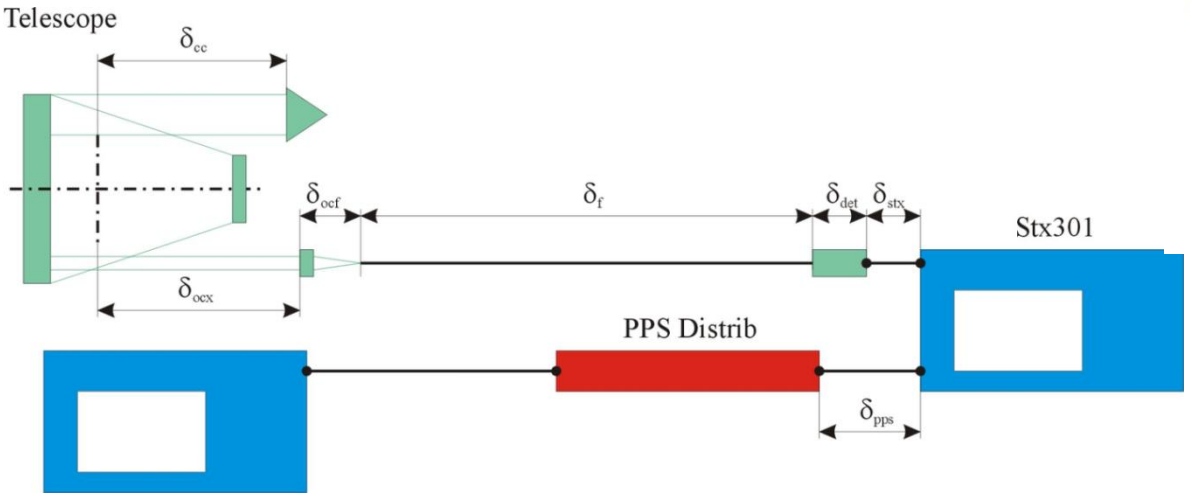






Determination of the term δprg

- $\delta_{prg} = \delta_{PPS} - (\delta_{ocx} + \delta_{ocf} + \delta_f + \delta_{det})$
- δ_{PPS} ; δ_f : propagation in cables
  - Measured by the calibration station
- δ_{ocx} ; δ_{ocf} : propagation in free space
  - Determined from the geometrical distance
- δ_{det} : Propagation in the detector (optical-electrical,
  - Deduced from a propagation model (currently studied)



Calibration budget

- Budget example: MeO Station 01/07/2010

δ	Label/Ref	Value (ps)	Date
δ_{cc}	CC_{Lune}	12393	01/07/10
δ_{PPS}	$T2L2CalC_2$	9408	06/08/10
δ_{ocx}	Ref_{Axe}	12104	01/07/10
δ_{ocf}	$T2L2MC_2$	58	01/07/10
δ_f	$T2L2CalF_1$	248300	06/08/10
δ_{stx}	STX301-001-000-C_1	0	01/07/10
δ_{det}	NewFocus1454	660	01/07/10
δ_{cal}	GioveB 100522	628721	22/05/10
δ_T		**377007**	**01/07/10**

T2L2 Calibration Planning 2011

Station	Date	Comments
Wettzell	June	H-Maser TT
Herstmonceux	TbD	H-Maser TT
Zimmerwald	TbD	GPS
Matera	TbD	Cesium TT - GPS

- Up to now French laser stations have been calibrated
- 2012: Calibration will be extended to all other participating stations