



DE LA RECHERCHE À L'INDUSTRIE

# TIMING SYSTEM FOR LASER MEGAJOULE SYNCHRONIZATION

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# Presentation Overview



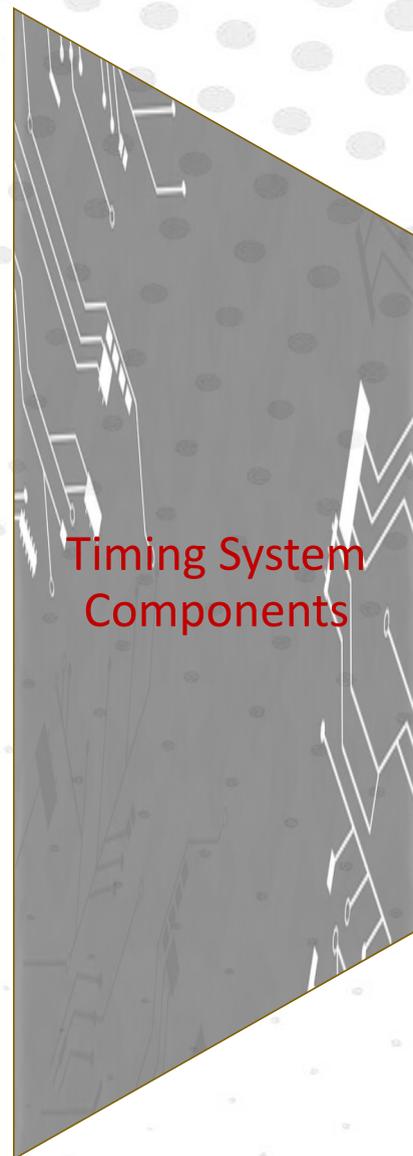
Laser Megajoule



LMJ  
Synchronization



Timing System  
Architecture



Timing System  
Components



Performances



Conclusion

# The Laser Megajoule (LMJ)...and the simulation program

The LMJ is a major facility in the french simulation program.

Located in France close to Bordeaux, it is used to study, at a very small scale, the behaviors of materials under extreme conditions of temperature and pression encoutered during the nuclear phase of the weapon as well as inside the heart of stars...

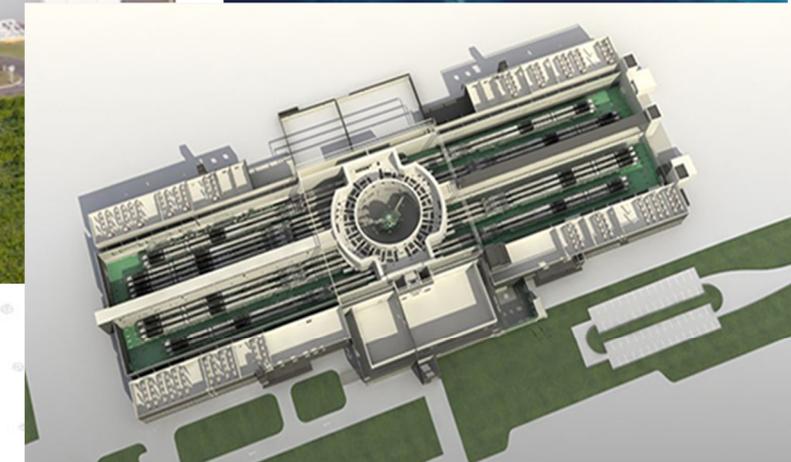
Astrophysics experiments



Nuclear Weapon



The LMJ is a major tool for academy research and for studying the inertial fusion.

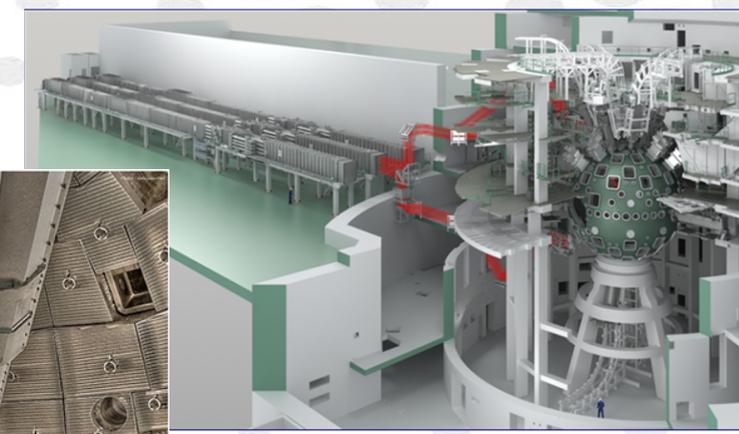


# The Laser Megajoule...inside / outside

**Building: 300 m x 100 m - 35 m high**

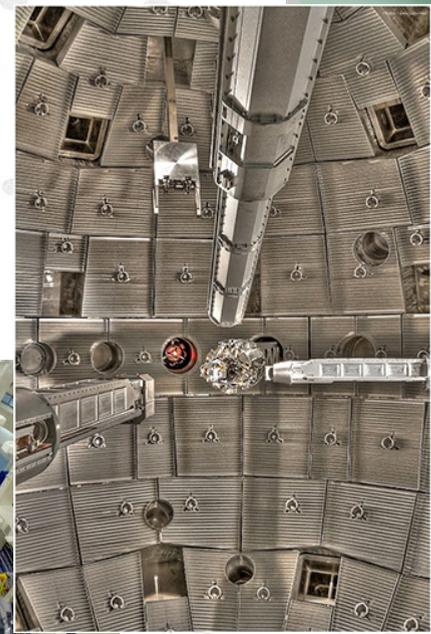
- 4 Laser bays 100 m x 30 m**
- 22 bundles of 8 beams (176 beams)**
- Pulse duration: 0.7 ns to 25 ns**
- Laser energy:~ 1.5 MJ**

- Target Experiment Room:  $\varnothing$  60 m / 50 m High**
- Target chamber:  $\varnothing$  10 m**
- Target: ~2 mm**



Laser bay and target bay

Target



Target chamber

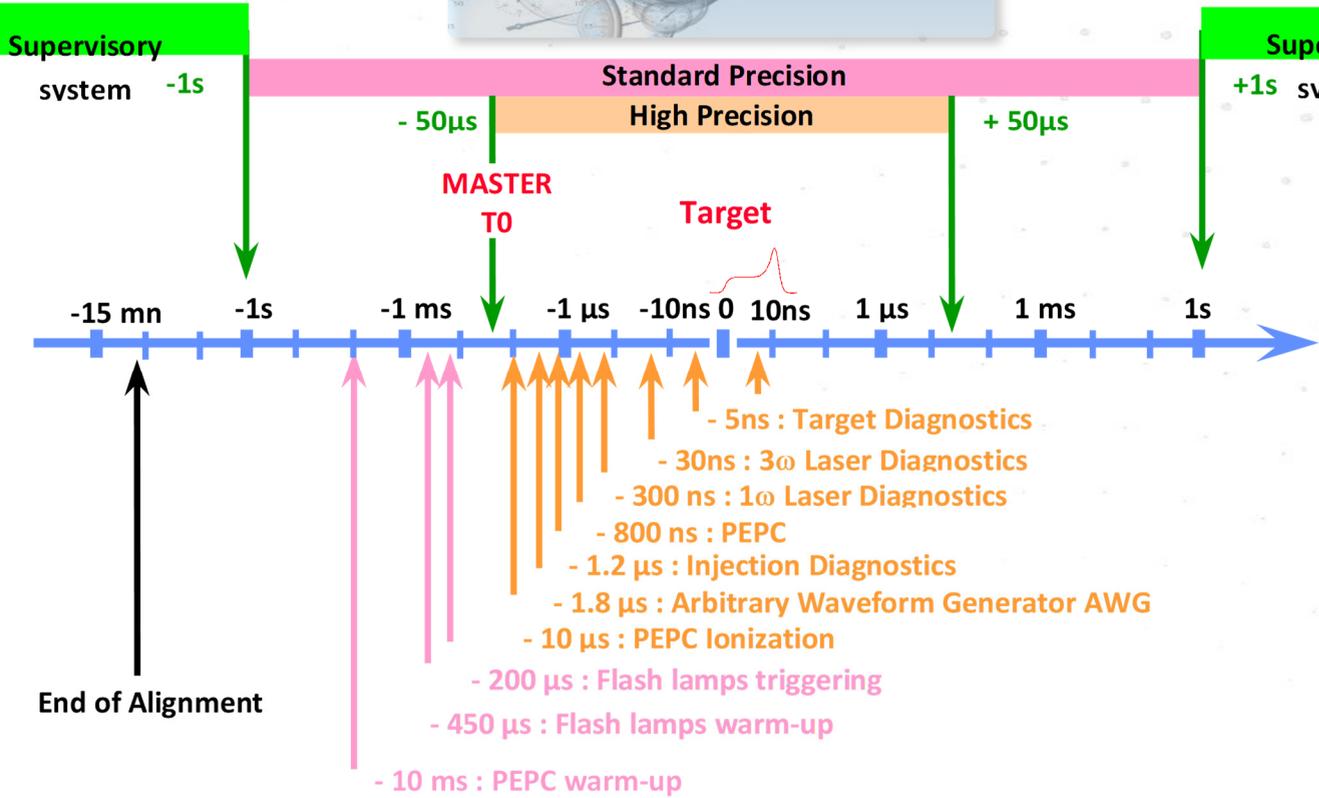


# LMJ synchronization

## LMJ synchronization requirements

Classes of performance	Jitter rms	Temporal Drift peak to peak			Accuracy	Range
		24h	7 days	1 month		
Standard Precision	<150ps	<200ps	<500ps	<1ns	<±1ns	1s
High Precision	<5ps	<10ps	<20ps	<20ps	<±10ps	100µs

## LMJ timeline

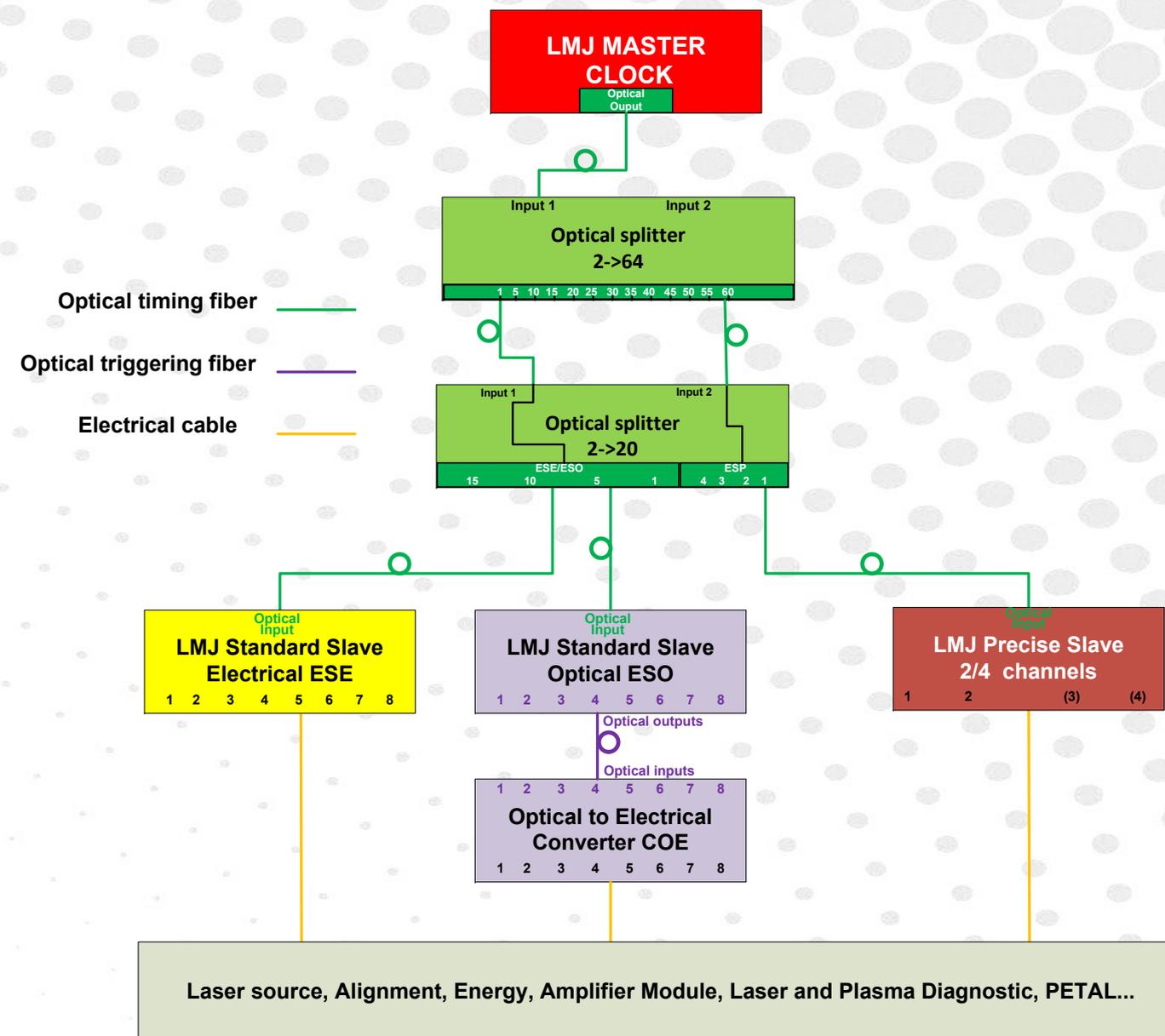


## LMJ specifications

- 176 laser beams
- 40 ps rms on target
- Jitter < 5 ps rms
- Drift < ± 20 ps p-p
- Electrical and optical triggers
- 2 classes of precision, standard and high
- Several thousands of trigger and fiducial signals

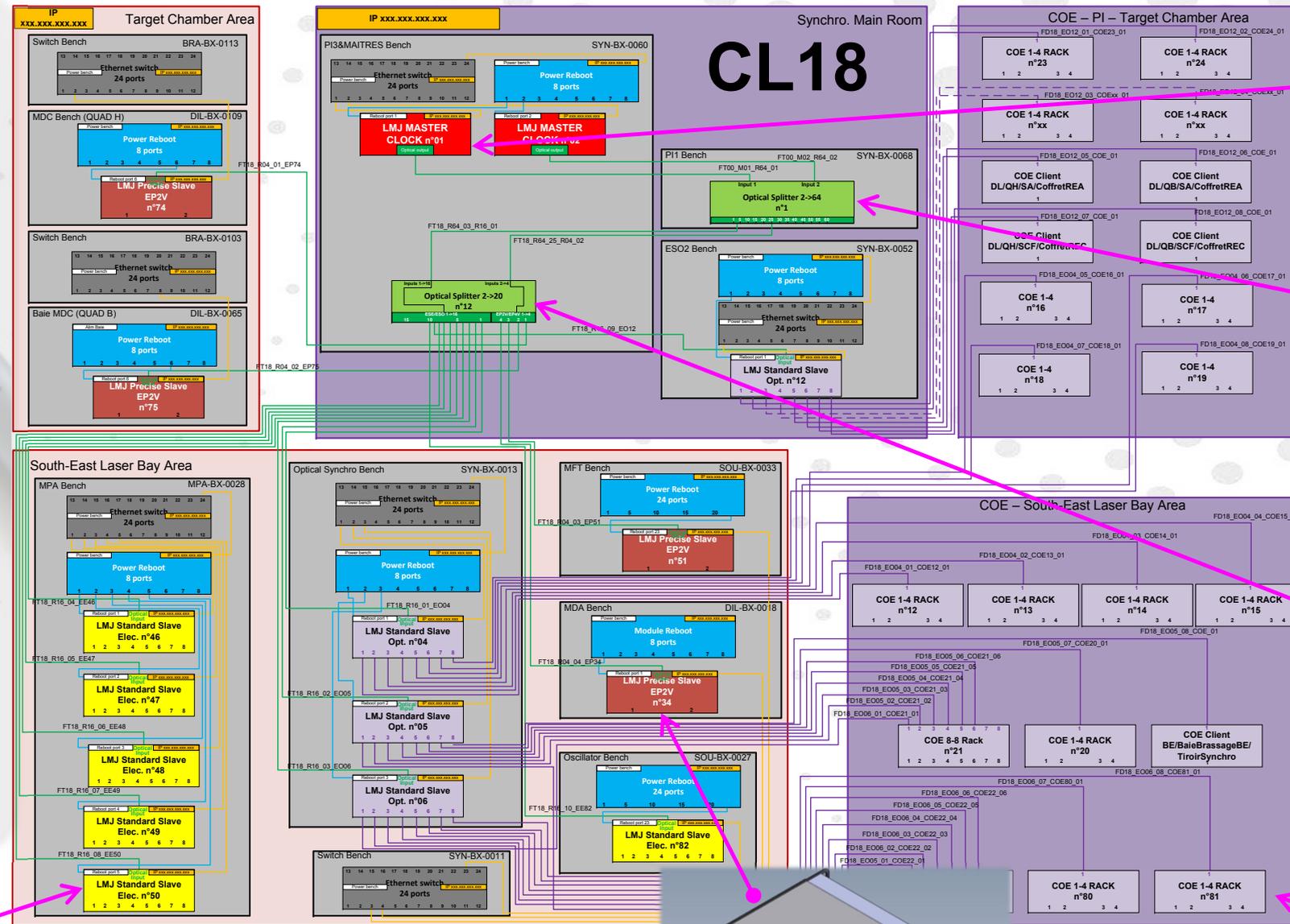


- Master Clock is the time reference
  - Time data informations & reference clock
- Optical passive distribution network
  - Optical fibers measured
  - Passive optical splitters
  - Asymmetrical network
- Delay generators
  - Standard precision (optical and electrical)
  - High precision (electrical)
- Equipments to be synchronized

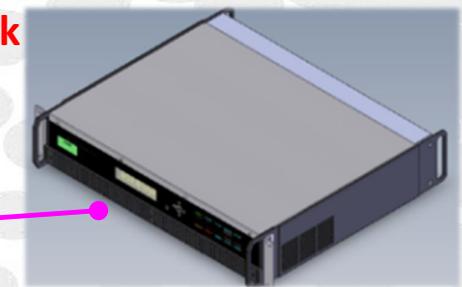


## Laser bundle description

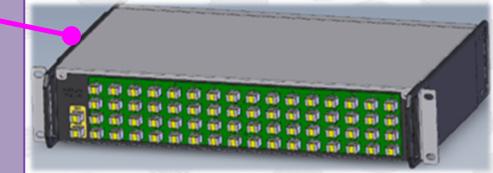
- 1 passive optical splitter
- 14 delay generators
  - 10 standard slaves
  - 4 precise slaves
- 14 optical to electrical converters
- 50 optical fibers (from 2 m to 300 m)



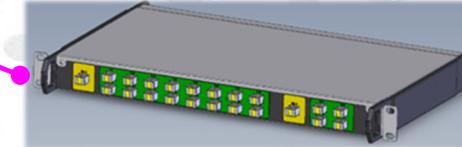
Master clock



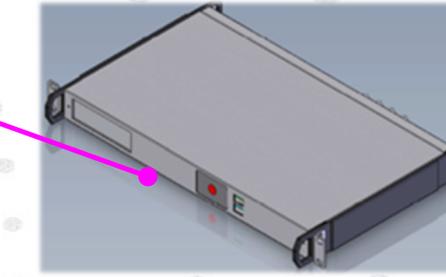
Optical splitter 1x64



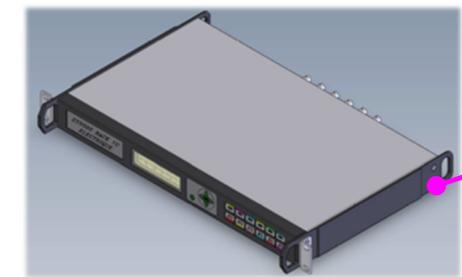
Optical splitter 2x20 (1x16-1x4)



Optical to electrical converter Rack 1x4



Standard slave

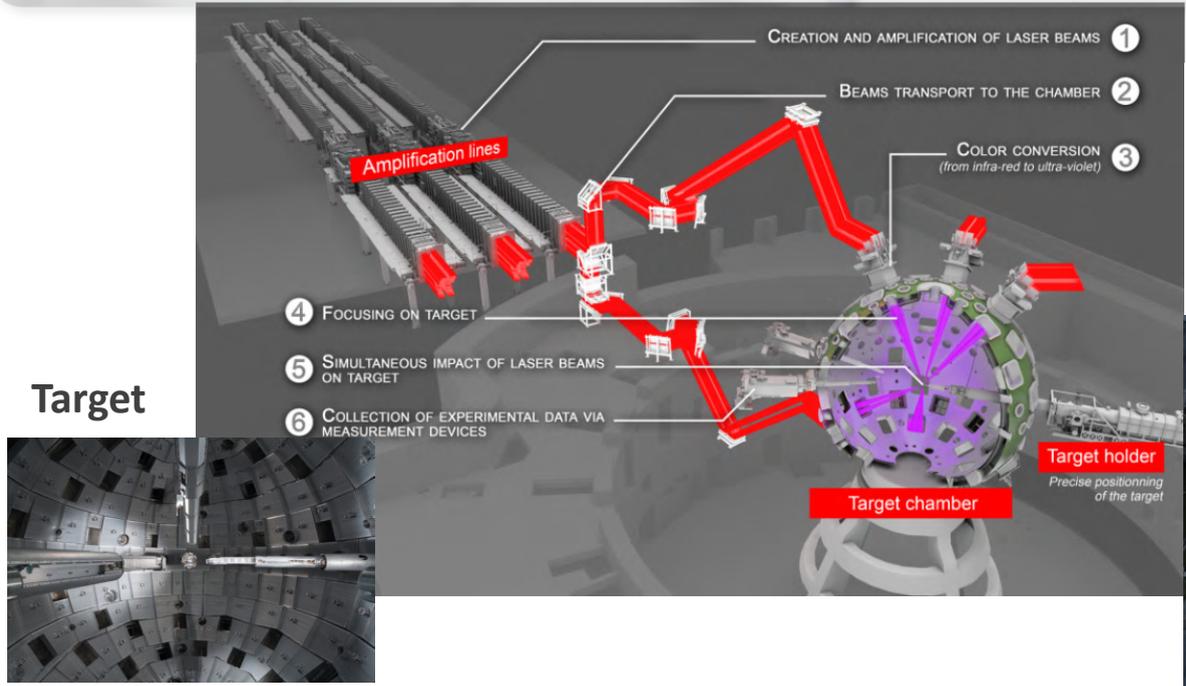
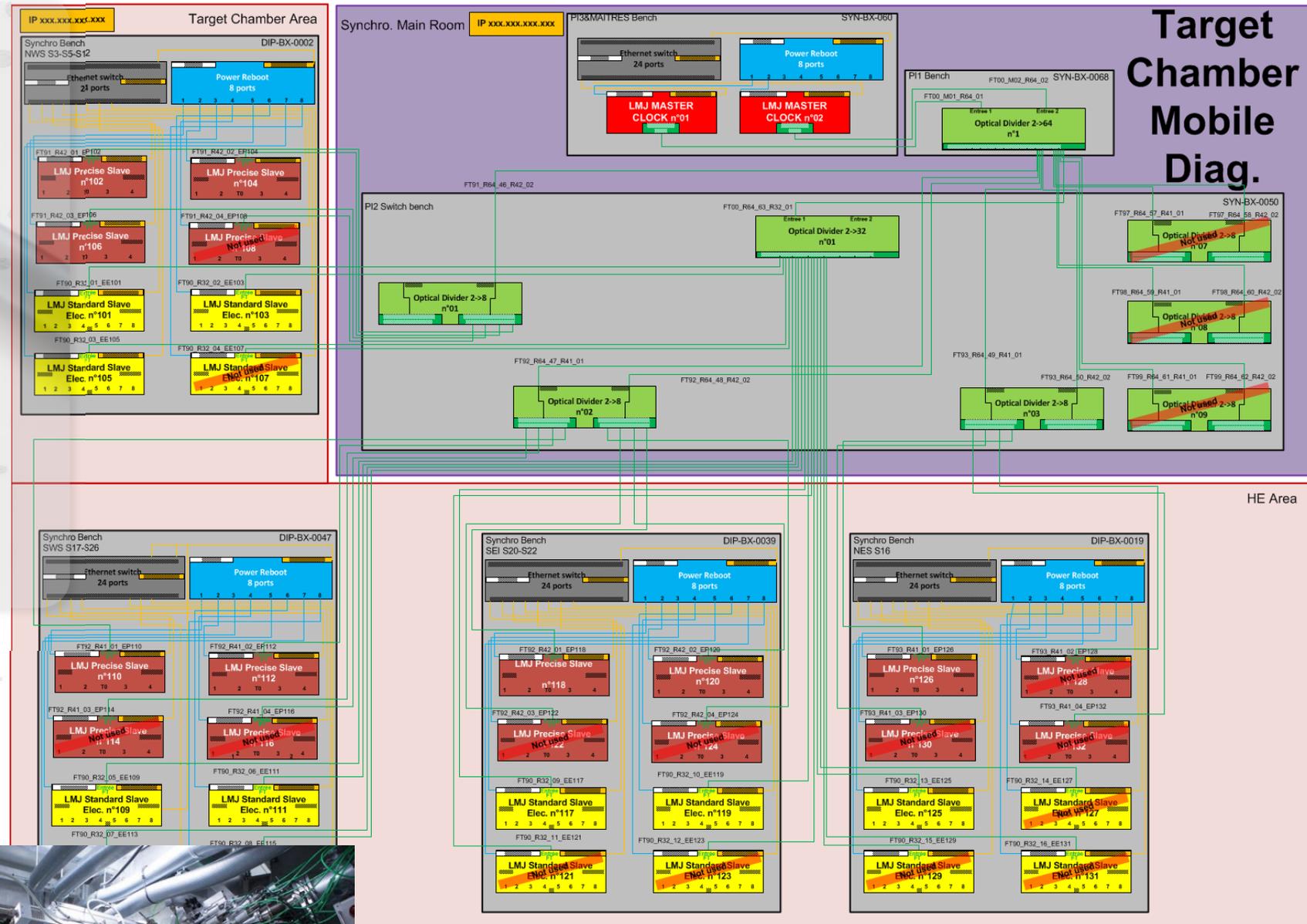


Precise slave



## Diagnostic description

- 30 diagnostics scheduled (10 are operational)
- ~ 100 delay generators (slaves)
- More than 100 optical fibers
- 10 optical splitters

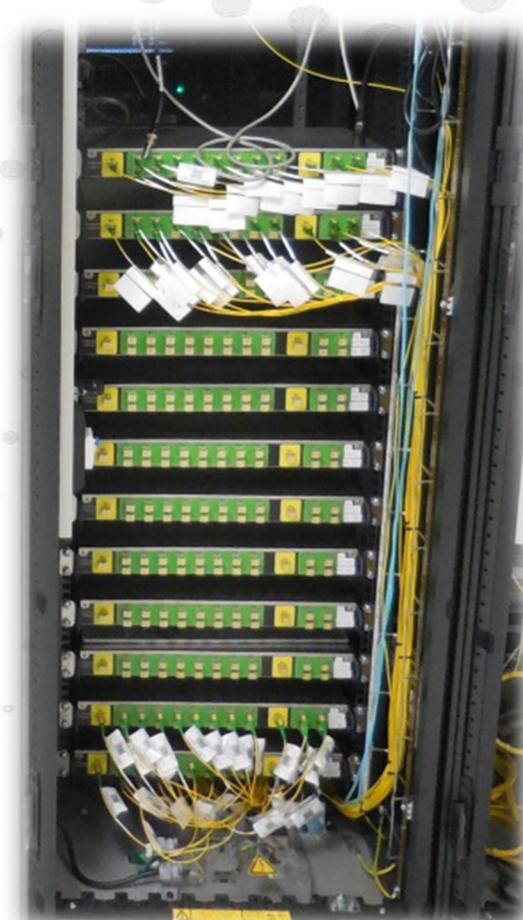


# Timing system components : From master clock to delay generators

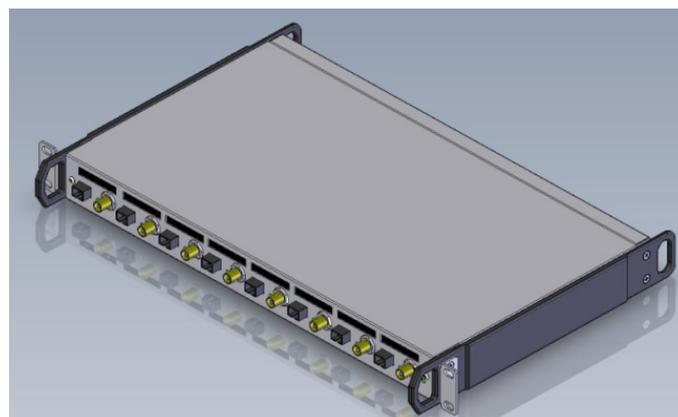


## Master clock

- $\lambda = 1549.32 \text{ nm}$
- optical output  $\sim 16 \text{ mW}$
- 1Hz, 10 Hz and 1000Hz
- Single shot: SS0 (-2 s to -30 s), SS1 (-1s) and SS2 (0s)



- ## Passive optical splitters
- Main splitter: 1 x 64 (first splitter)
  - Standard splitter: 1 x 32 (for standard slaves)
  - Precise splitter: 2 x 8 (two 1 x 4 for precise slaves)
  - Asymmetrical splitter: 2 x 20 (1 x 16 + 1 x 4 for both slaves)



- ## Optical to electrical converter
- Single channel: COE 1 x 1
  - Multiple channels: COE 8 x 8
  - Single to 4 split channels: COE 1 x 4

# Timing system components : Delay generators (slaves)

2 different delay generators for fiducial & trigger signals :

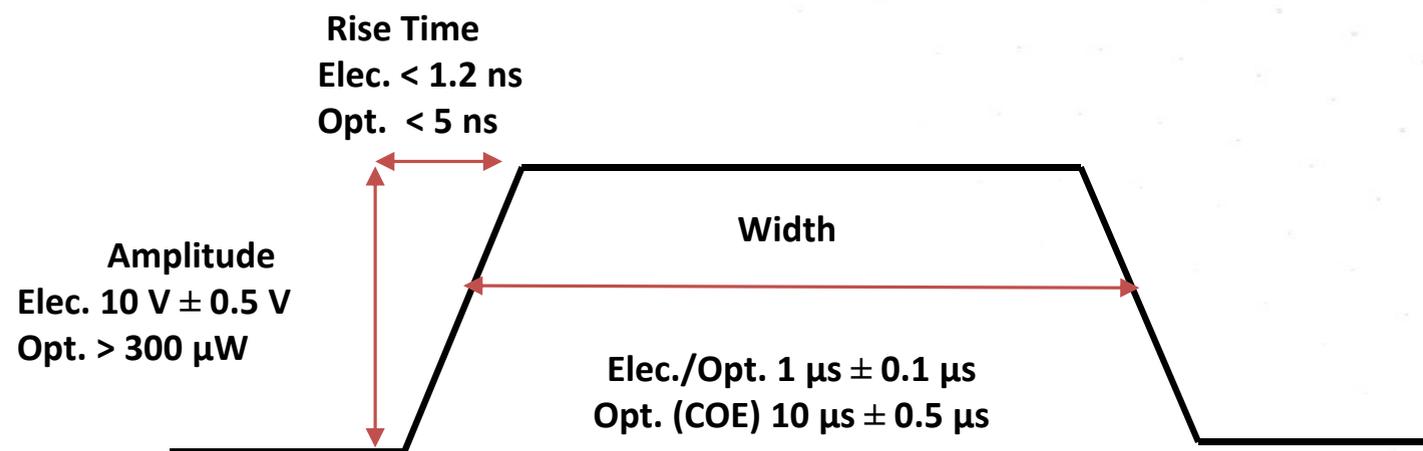
Standard precision slave (GFT1018):

- Electrical: 8 electrical outputs (BNC connector)
- Optical: 8 optical 1310 nm outputs (SC/PC)

The optical slave can be used with an optical to electrical converter.

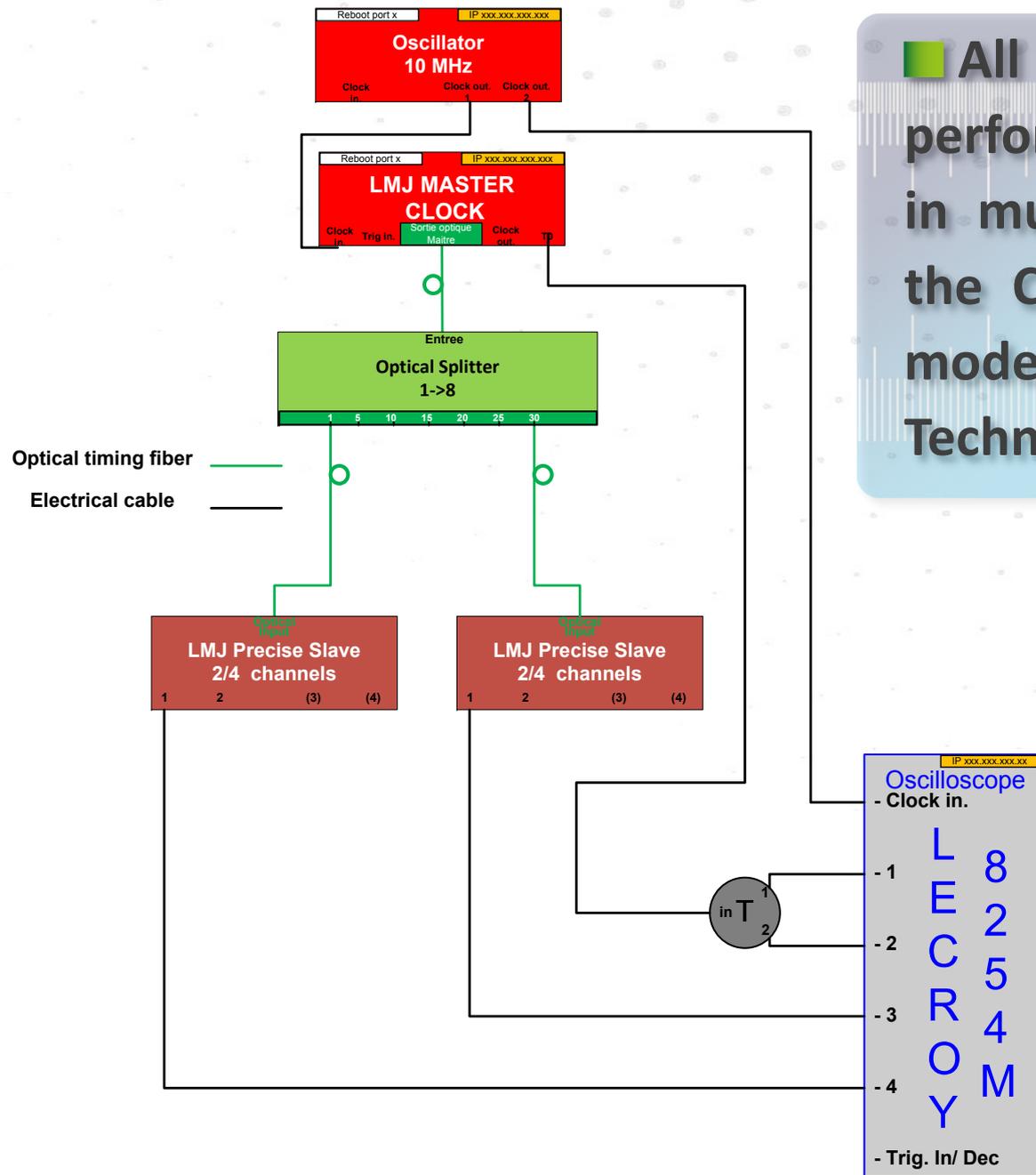
High precision slave (GFT1012):

- 2 BNC outputs (EP2V)
- 4 BNC outputs (EP4V)



Slaves	Jitter rms 2 channels / 2 Slaves	Temporal Drift peak to peak			Accuracy	Range
		24 h	7 days	1 month		
Electrical Standard	<100ps	<200ps	<500ps	<1ns	<±1ns	1s
Optical Standard	<150ps	<200ps	<500ps	<1ns	<±1ns	1s
Precise	<5ps	<6ps	<10ps	<20ps	<±10ps	100μs

# Performances : High precision delay generator



All measurements have been performed on high precision slaves in multiple “single shot mode” by the CEA as well as in a recurrent mode (1 kHz) by Greenfield Technology (GFTy).



- Digitizer Lecroy 8254M : jitter <1ps characterized
- 1 pt/50 ps (20 Gs/s), 1 μs range
- 50 mV vertical range (att. 20db)
- Trigger: channel 1, level 0.45 mV
- Jitter measurement: 1024 acquisitions
- Temporal drift measurement: 255 acq./2h over 1 month
- Controlled temperature: +/- 0.5°C



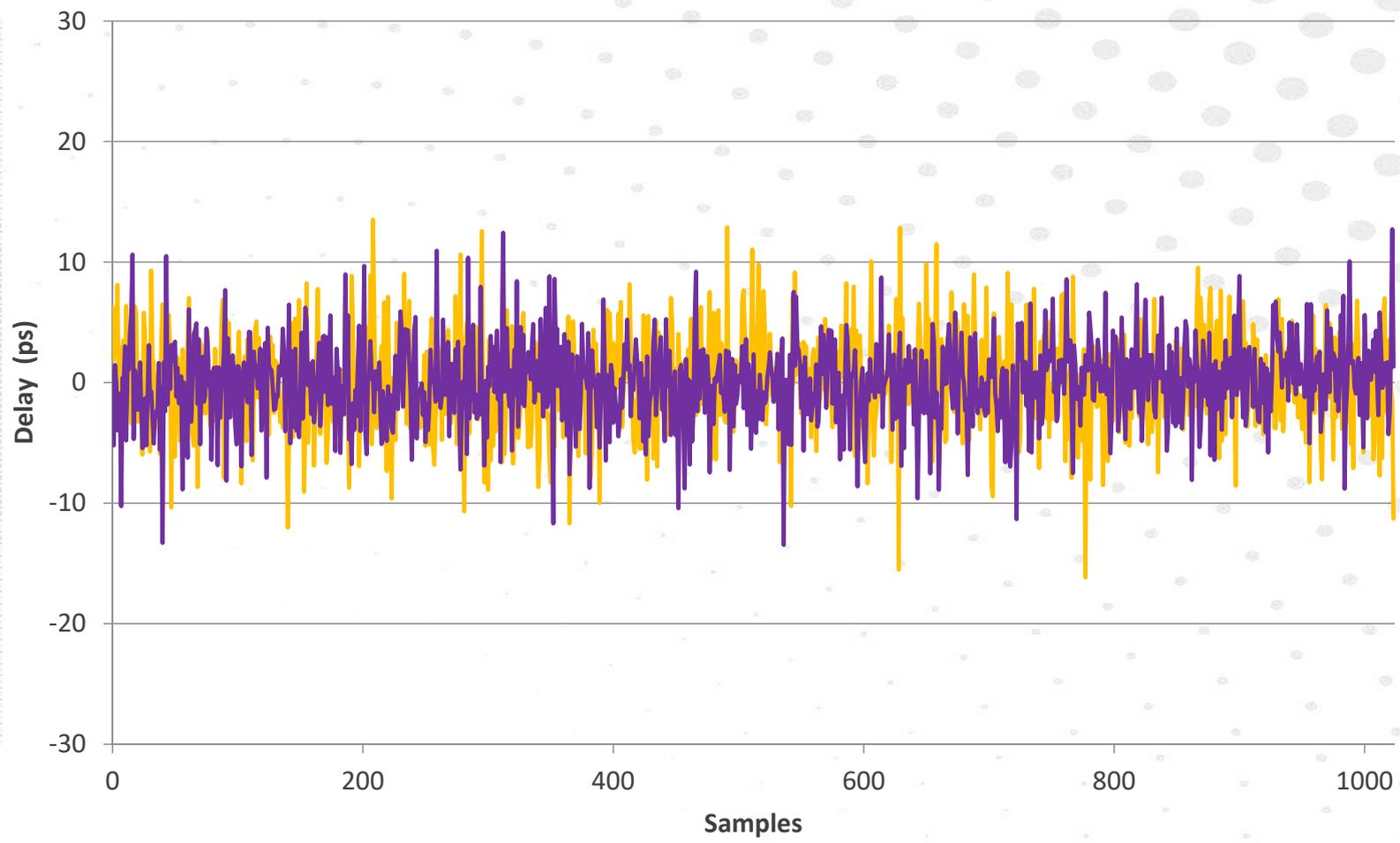
# Performances: Jitter measurements

Between 2 outputs / 1 precise slave: 3.4 ps rms

Between 2 outputs / 2 precise slaves: 4.0 ps rms



Jitter: < 3.4 ps rms



Jitter: < 4.0 ps rms





## ■ Temporal drift measurement:

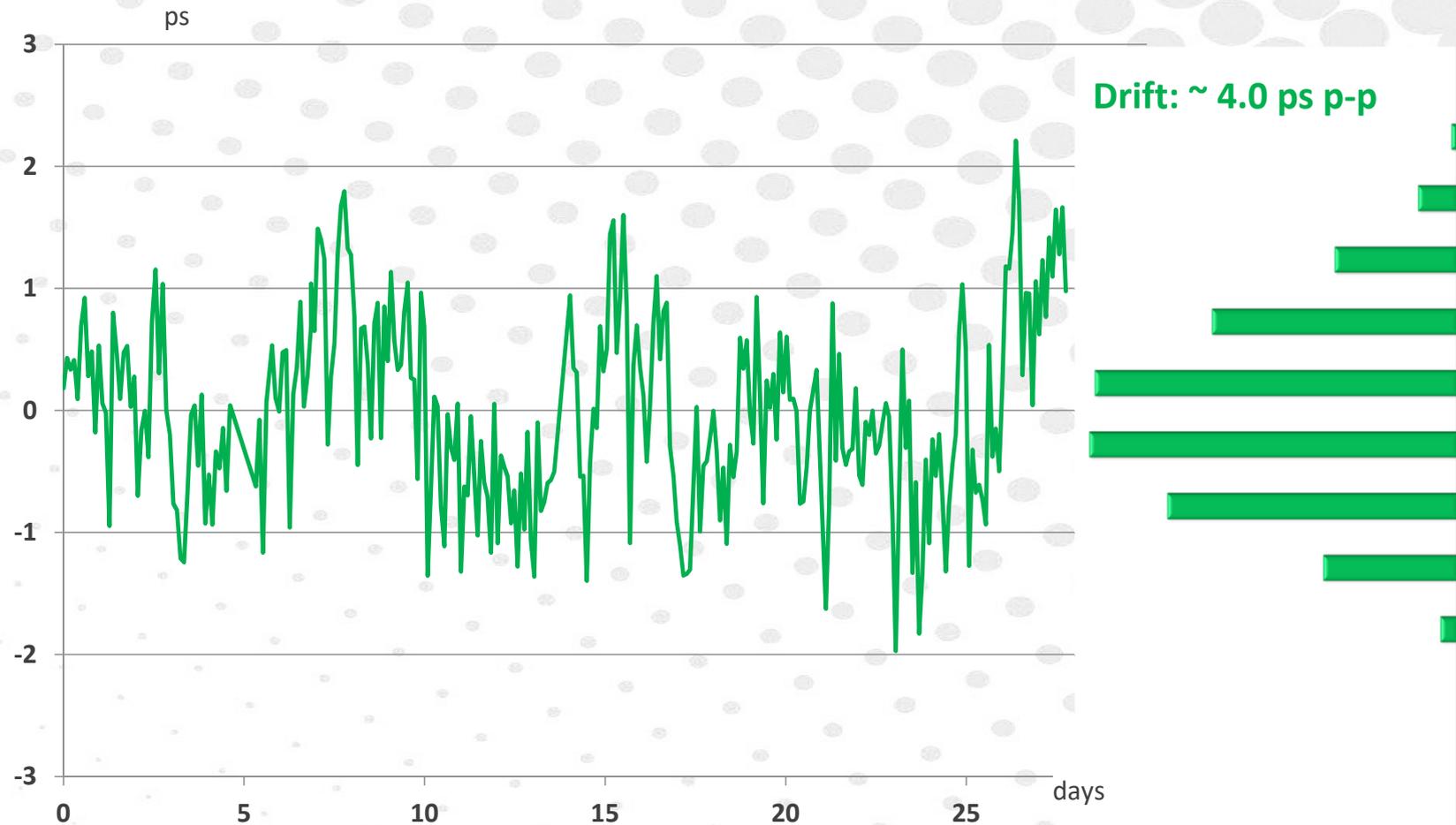
■ 1 month

■ 255 single shots every 2 hours

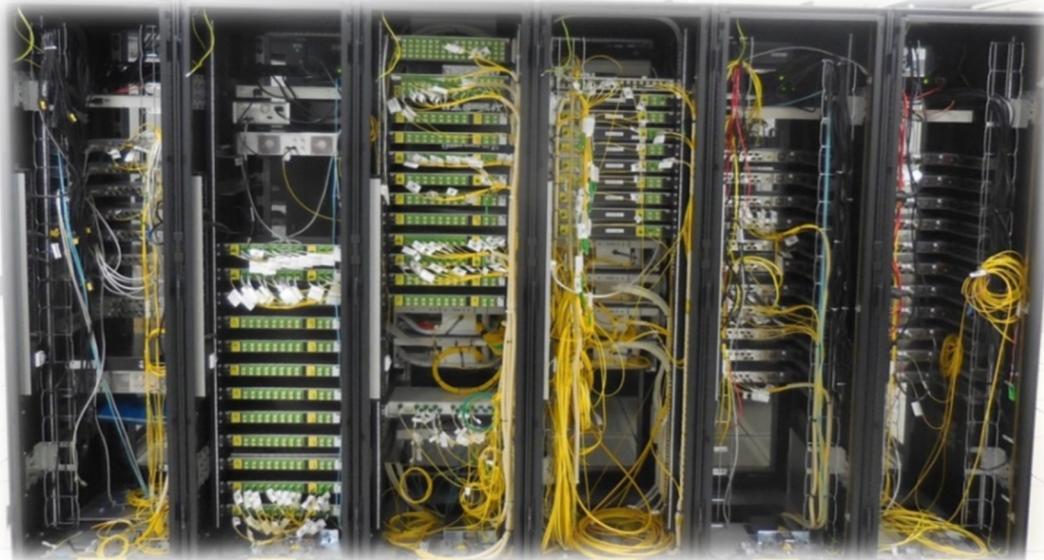
■ Average of each sequence is calculated

■ More than 100Go of raw samples

Temporal drift measurement over 1 month is close to 4 ps peak-to-peak.



- The LMJ Timing system is operational on 8 laser bundles plus PETAL (high energy PETawatt Aquitaine Laser).
- Main LMJ requirements have been verified: jitter 4 ps rms and drift close to 4 ps p-p.
- These performances will be the cornerstone to synchronize the LMJ more than 40 ps rms.



- The timing system will be extended to the next 14 bundles (2022).
- The LMJ synchronization :
  - 1 master clock
  - 34 Optical splitters
  - >400 delay generators
  - >340 optical to electrical converters
  - about 2500 triggers
  - >1400 optical fibers
- A temporal drift measurement system will be installed near the target chamber to study and survey the LMJ stability.



# Thank you for your attention

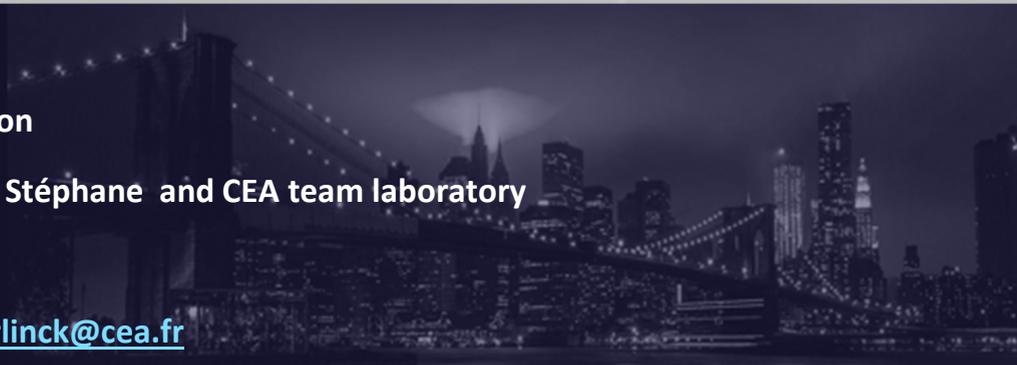
Photos by E. Journot

Vidéos by CEA Communication

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