High intensity laser facility Apollon status

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Science with high intensity laser

- Laser-matter interaction at high intensity
  - Isochoric heating (burried layer target, nano wire target)
- Laser plasma electron acceleration
- Laser plasma ion acceleration
- Laser plasma X-ray sources (coherent and incoherent)
- Perform pump-probe experiments within a wide range of beam energies and pulse durations
- Generate sufficiently high optical intensities to open up new and unexplored areas of fundamental physics
  - High energy photon emission and its back-reaction in laser-plasma interaction
  - Non-linear Compton / Thomson Scattering from laser-created electron beams
  - Pair production in the presence of strong Coulomb fields

A project by "laser and plasma labs" on Plateau de Saclay

Funding has been allocated to develop new instruments and an interdisciplinary centre CILEX dedicated to address physics at unexplored power densities

hosting a multi-PW lasers

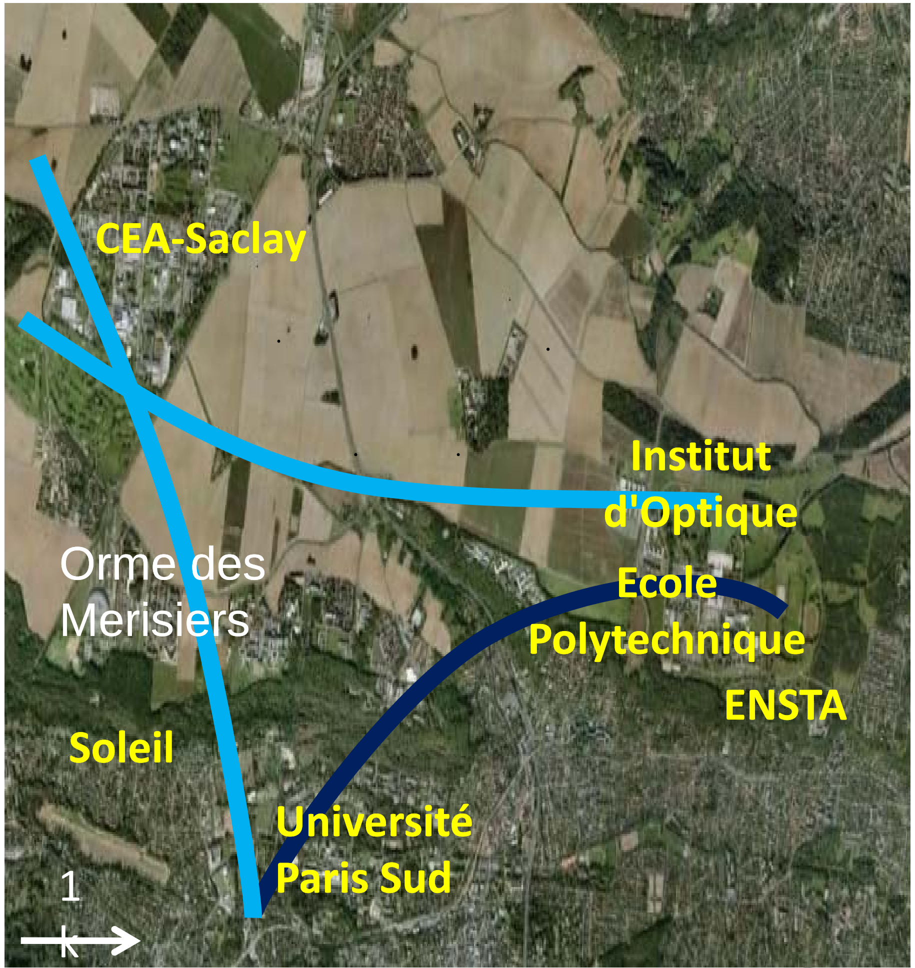
APOLLON

and smaller scale facilities

for pluridisciplinary programs

training of scientists and engineer

Operated as a user-facility



Apollon laser facility requirements

- High laser intensity
  - I > 10^{22}W/cm^2 ($a_0 = (0.85\,(I_{18}\lambda^2)$^0.5) > 100
- Multi beams
  - To perform pump probe experiment and multi stage laser acceleration
- High repetition rate
  - To adjust laser and experiment parameters
  - To have enough statistics
- High contrast
  - To be able to interact with the solid without pre-formed plasma
- Reliability and stability
- Good characterization of the beams
- Dedicated experimental set up
- Flexibility to make new experiments

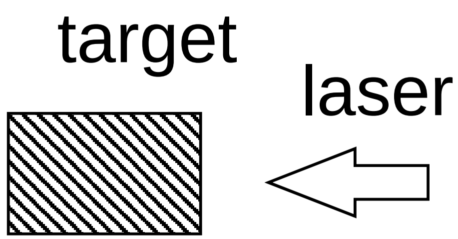
laser beams

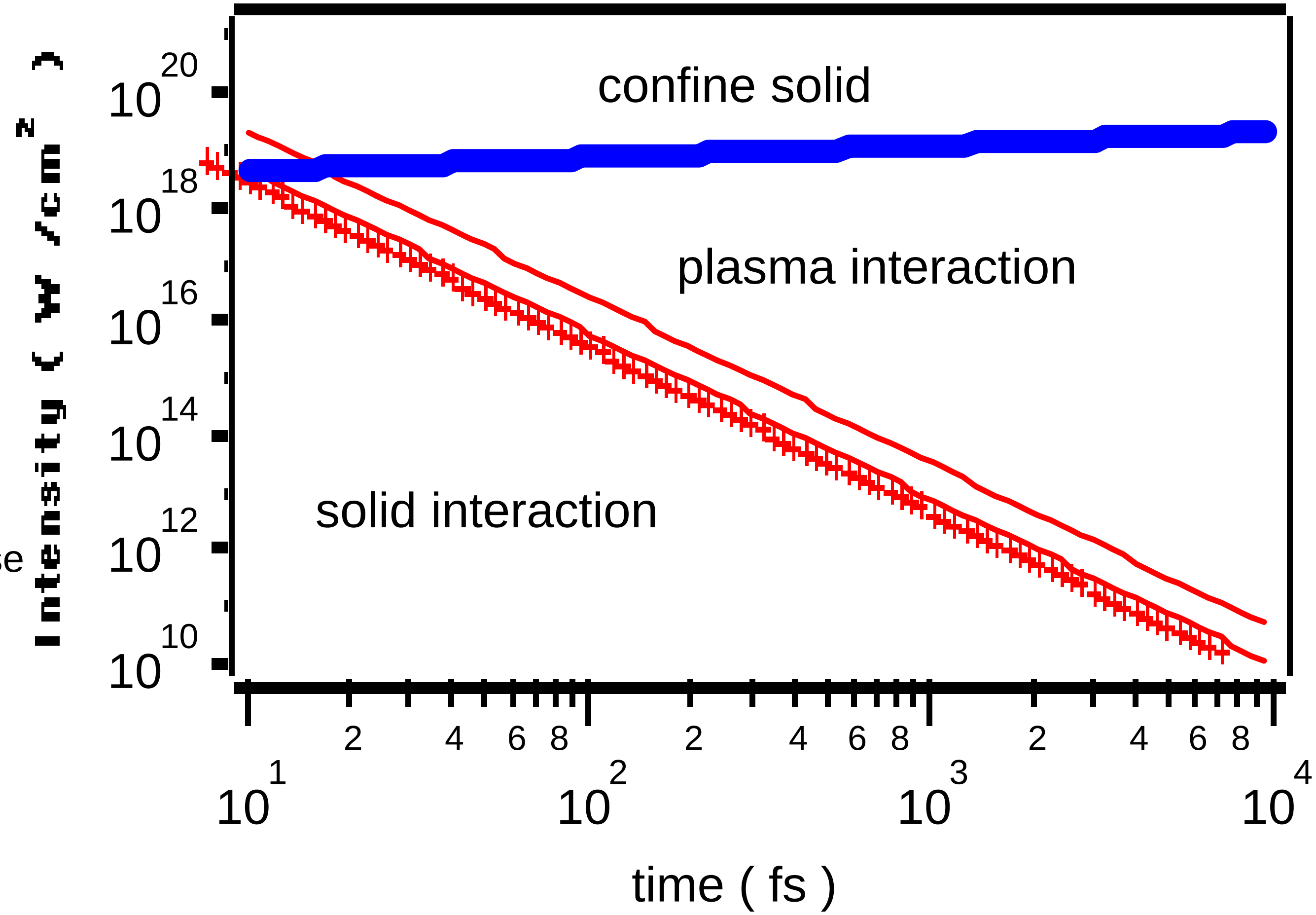
- To address the requirements, the laser facility has been design with
  - 4 independent beams
    - main beam F1 — 15fs-few ps / 150J possible
    - secondary beam F2 — 15 fs-few ps / 15J max
    - ns beam F3 — uncompressed up to 200J
    - probe beam F4 — < 20fs/0.2J
  - 2 independent radio protected experiment areas

Beam overlap specification

- Beam pointing and stability
  - alignment on target (absolute): 1 focal spot size
  - alignment on target (relative to the other beams): better than 20% of the focal spot size
- Synchronisation
  - Independently of their duration, the four beams can be synchronized at center of the vacuum chamber and delayed by ± 5ns compared to the main beam
  - The synchronization must be less than 30% of pulse duration at first and should be improved to achieve 10% in a second phase
  - Time step of delay line between the different beams will be less than 20% of pulse duration at first and will be improved to achieve 10% of pulse duration in a second phase

Types of Interaction





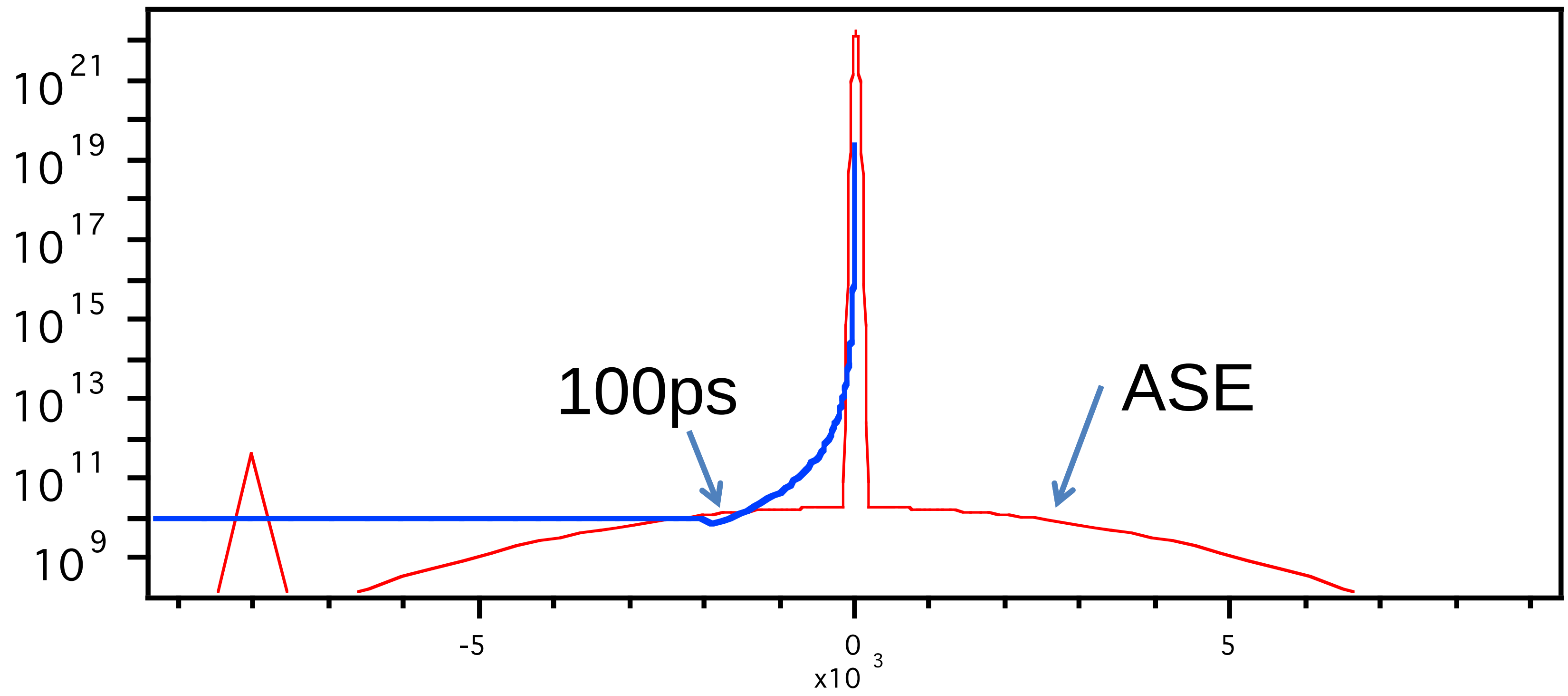
— skin depth = $C_s\, t_{pulse}$

— $nkT = F_{ponderomotive} = I / c$

- Pre-pulse, coherent and incoherent Intensity should stay below the red curve to insure the interaction with an unperturbed target

W. Rozmus, V.T. Tikhonchuk P.R.A., 7401,42, 1990

Contrast specification

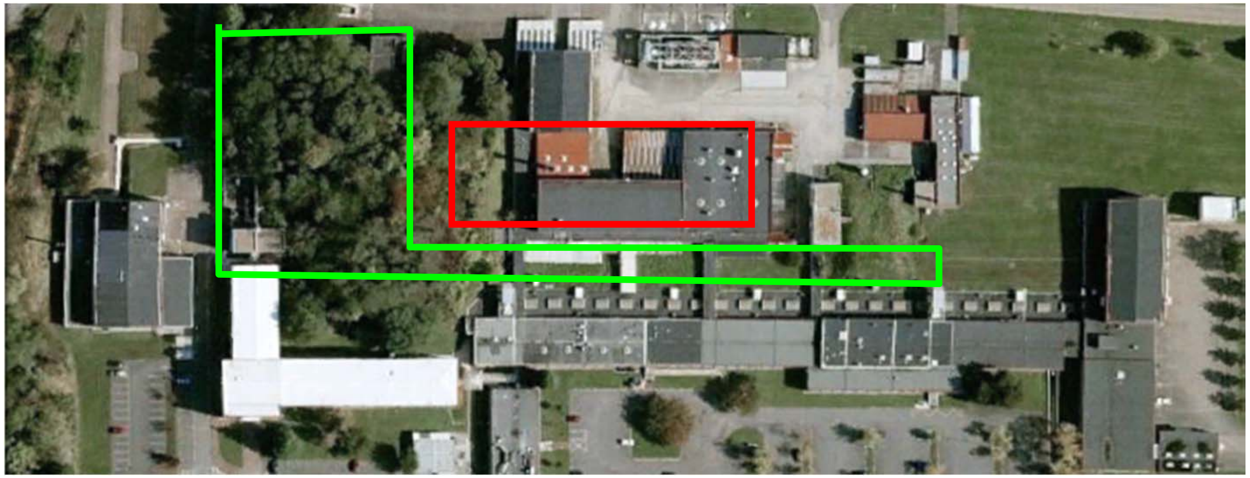


- pre-pulse $I < 10^9$ W/cm^2
- incoherent contrast $I < 10^{10}$ W/cm^2 @100ps
- coherent contrast between 100ps and the pulse maximum

Expansion less than a skin depth ($\sim t^{-2.9}$)

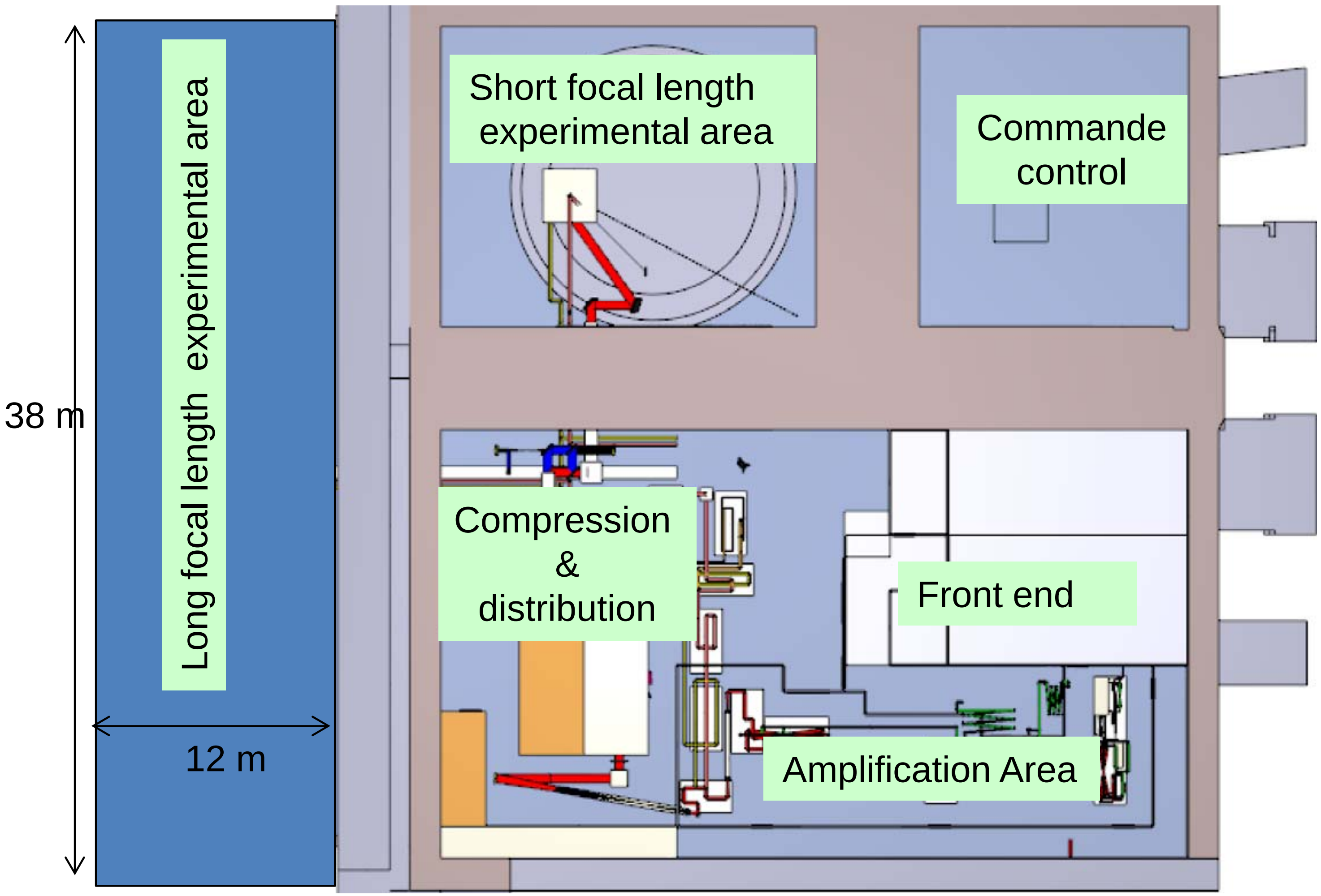
« l'Orme des Merisiers »

Former linear electron Accelerator facility built in 1969 - Dismantle in 2006



A renewed building dedicated to Apollon will host the infrastructure

- with radio-protected experimental areas



The implementation has been done taking into account building constraint, safety, circulation and operation.

Fundamental architectural choices

The principal objective is the Intensity:

I>2·10^{22} W/cm^2 ⬄ 10 PW

Moderate Energy ➡ **150 J & 15 fs** ⬅ **Extremelly short pulses**

➢ Compatible existing laser technologies: **OPCPA** & **Ti:Sapphire**

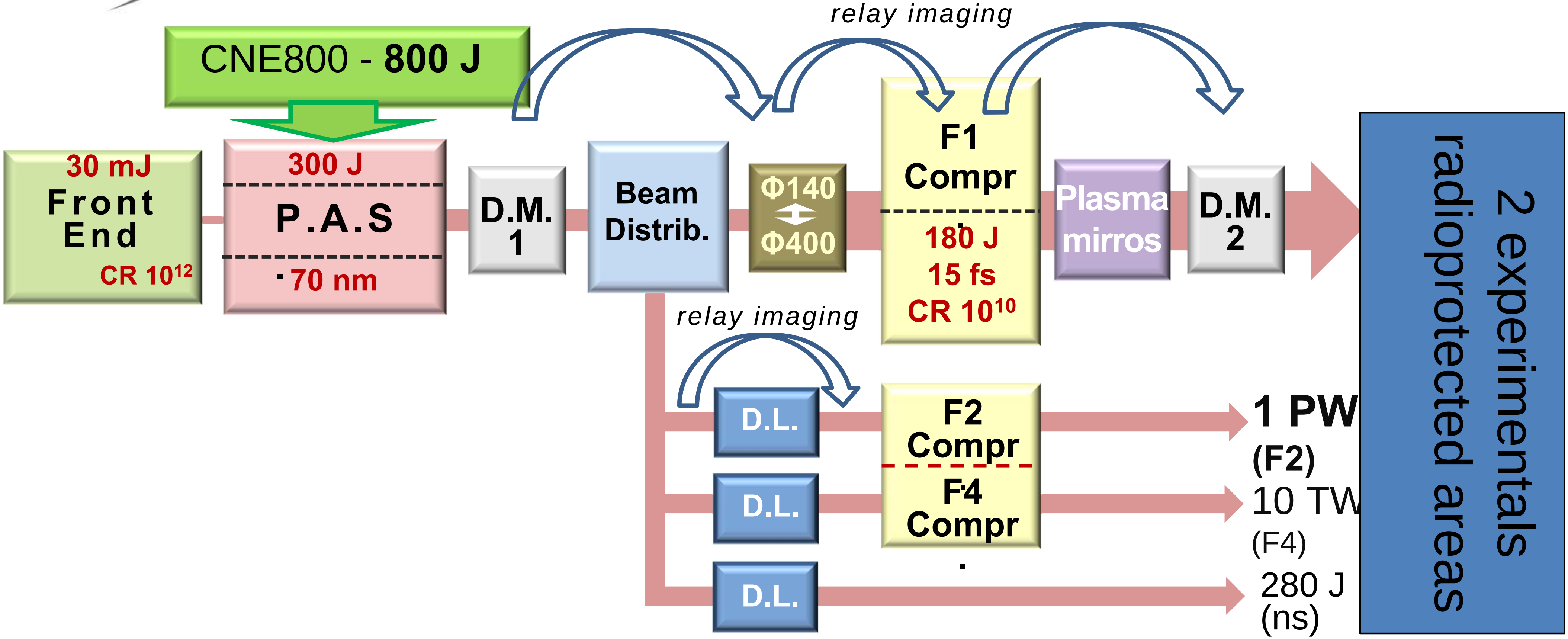
OPCPA Front End:

- High contrast ratio		**>10^{13}**
- Ultrashort pulses	➡	**sub-10 fs**
- Moderate energy		~**30 mJ**

Ti:Sapphire power amplification:

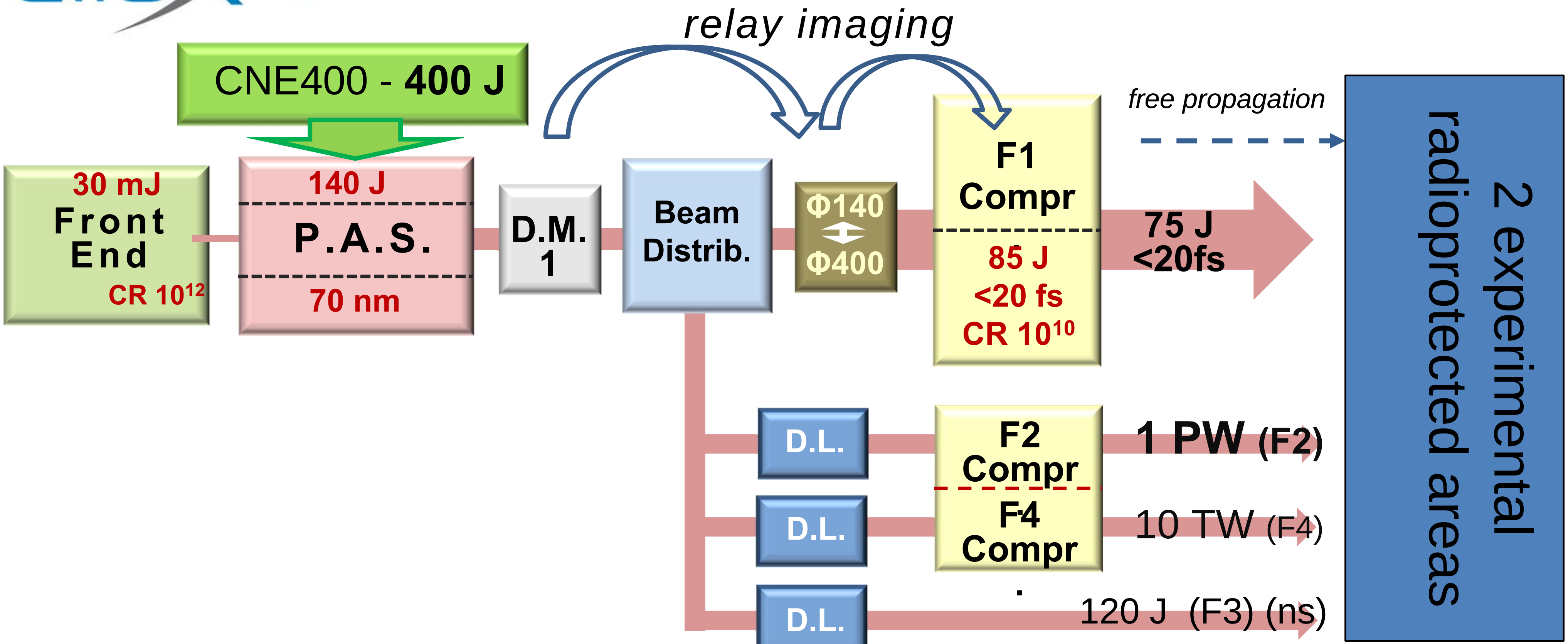
- High energy		**>300 J** *(before compr.)*
- Moderate gain	➡	**10^4**
- Broad bandwidth		**70 nm** *(FWHM)*

Apollon design



- Dazzler and 160 nm Spectral window for the whole system: 740 – 900nm
- Relay Imaging between amplifiers
- back-reflection protection systems
- Deformable mirror and spatial filters
- Mirrors : S polarisation and 400 mm diameter optics
- Design of the laser with miro and Zeemax

phasing



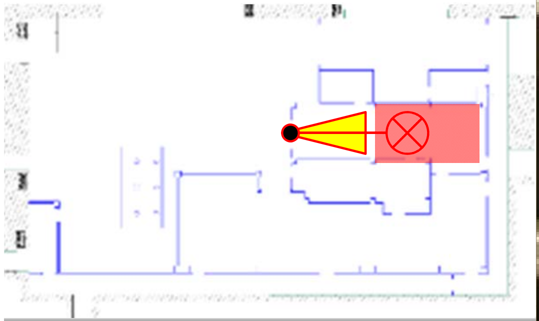
- Due to budget constraint the project has several phases
- First step
  - We will have only 75J on F1
  - The plasma mirror will not be implemented
  - We will have deformable mirror only on short focal length area before the experimental chamber
  - We keep the compatibility to 10PW for the laser and experimental room (beam diameter 400mm)

Oscillator Status

Hall Laser LPI : Local Pilote

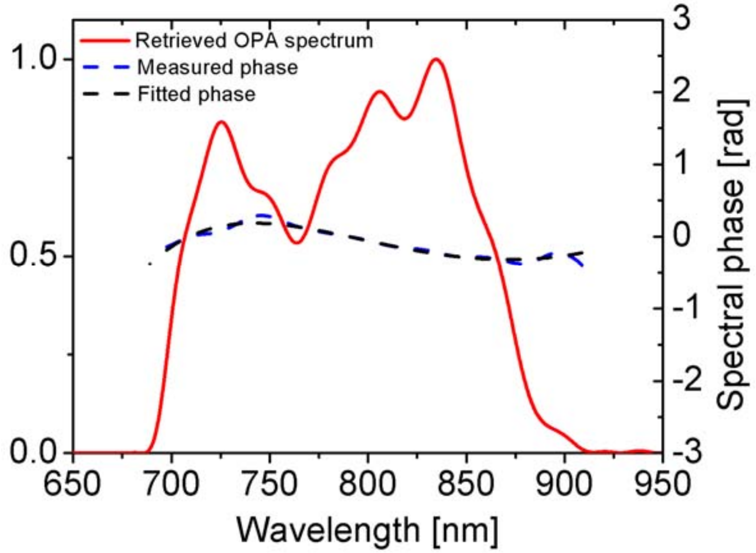
Initial state

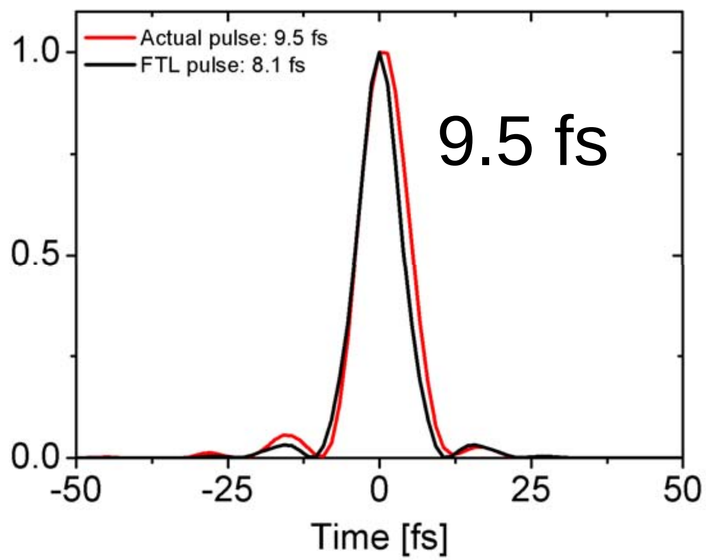
wall
Ceiling
painting
Optics tables
Equipment
protection

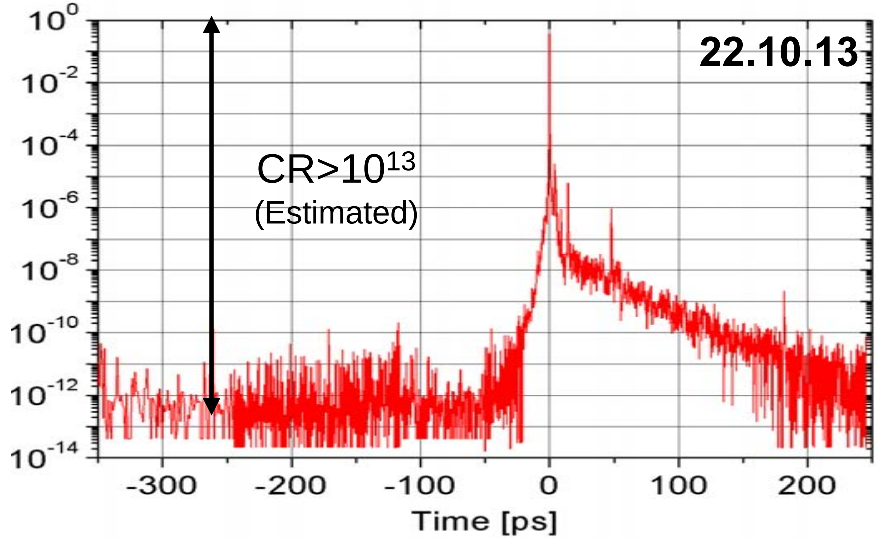


Compression of the ps-OPCPA

- Adjust the Apollon Stretcher close to “0” dispersion ➔ “Compressor”







- Optimized **compression** with **Wizzler/Dazzler**: **9.5 fs** (8.1 fs FTL) at **1 mJ**
- **Contrast ratio measurement** with a 3rd order autocorrelator

Amplification Status

Hall Laser LAM : Local Amplification

Undependant Oscillator LUIRE used to pre-qualified

A 100 J pump laser , 1 shot/min laser has been delivered

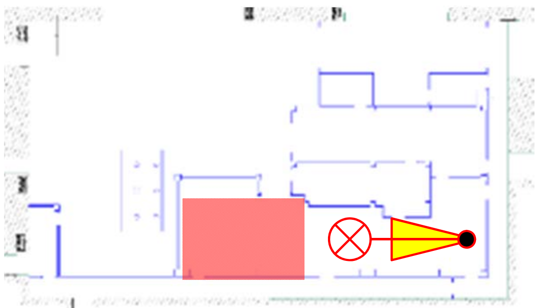
walls

painting

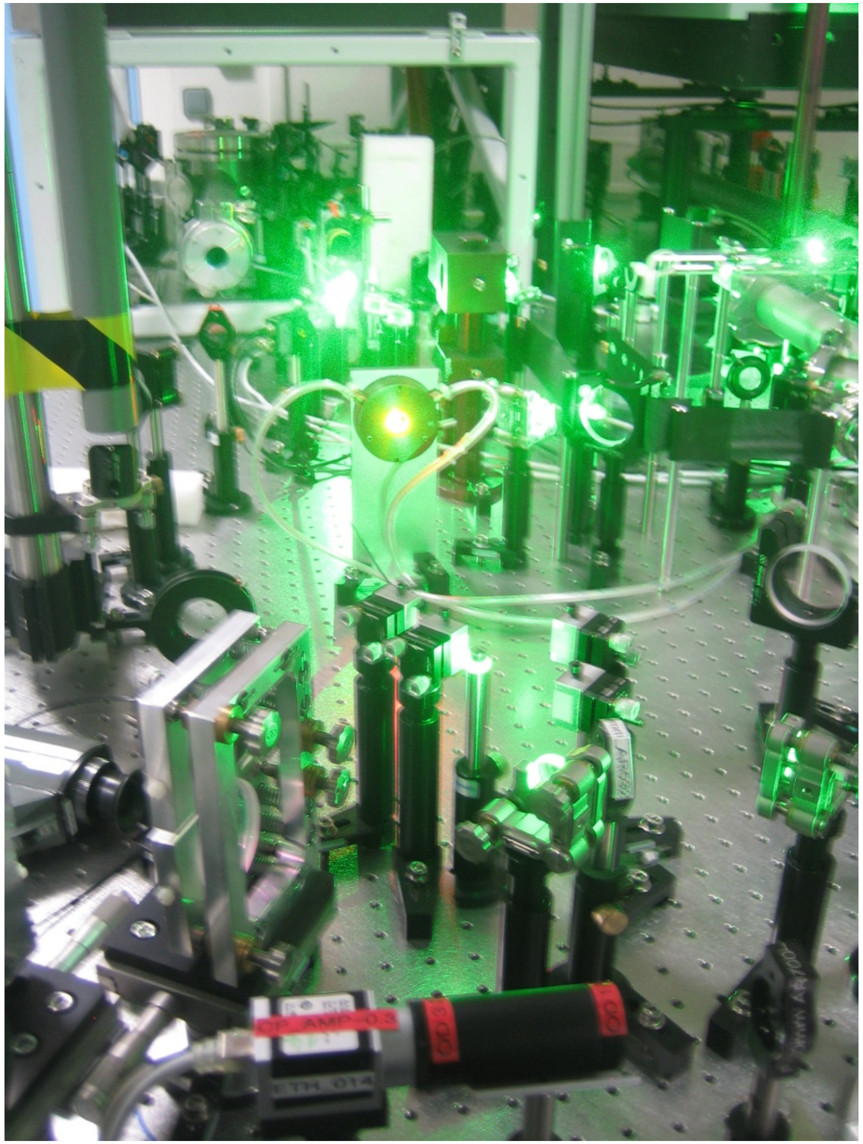
Optics tables

Equipments

qualifications

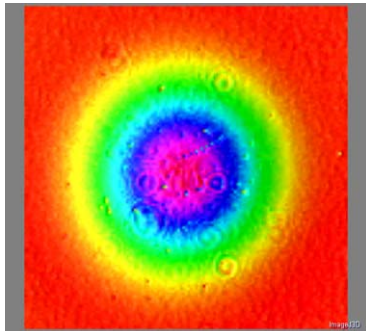


AMP-0.3 results



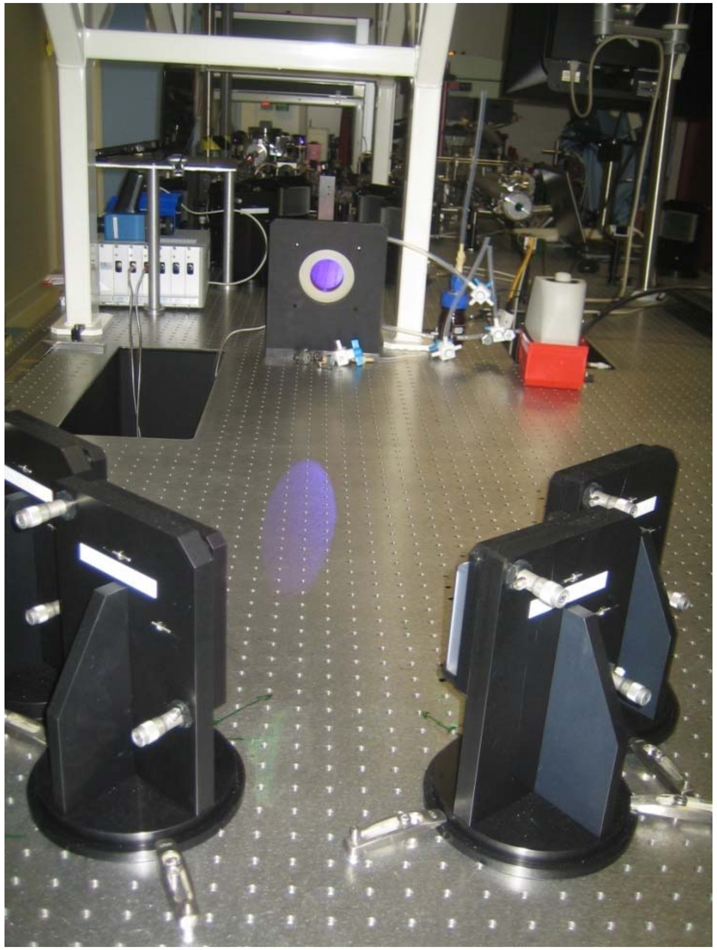
10 Hz amplifier
Pump: 800 mJ from Nd:Yag

Seed is spatially filtered (5x DL)



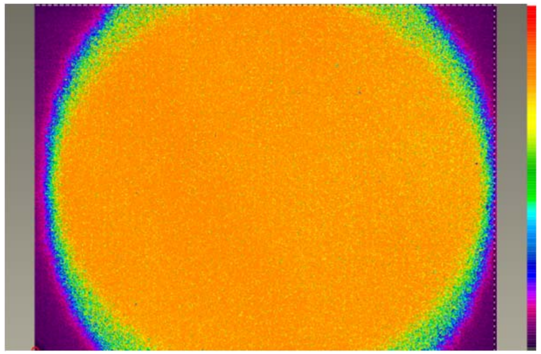
Energy	Input : 180 µJ Ouput : 99 mJ
Peak to peak stability	Input : 10% Output : 35%
RMS stability	Input : 1.8% Output : 5.4%
Spectral FWHM (nm)	Input : 40 Filtered : 47 Output : 41
Output beam diameter 1/e²	4.2 mm

AMP-30



A 100 J, 1 shot/min laser has been delivered
It will pump the AMP-30.
This gives more flexibility compare to one pump laser configuration

Homogenizers will be used to transport the beam to the 80 mm diameter TiSa.
T= 0.91



The building was delivered on March 2015
The 2 first amplifier are in place delivering 3 J
100J Pump Laser for the 3J Amplifier is in place
Third amplifier under alignment
Expected 30 J compressed by June

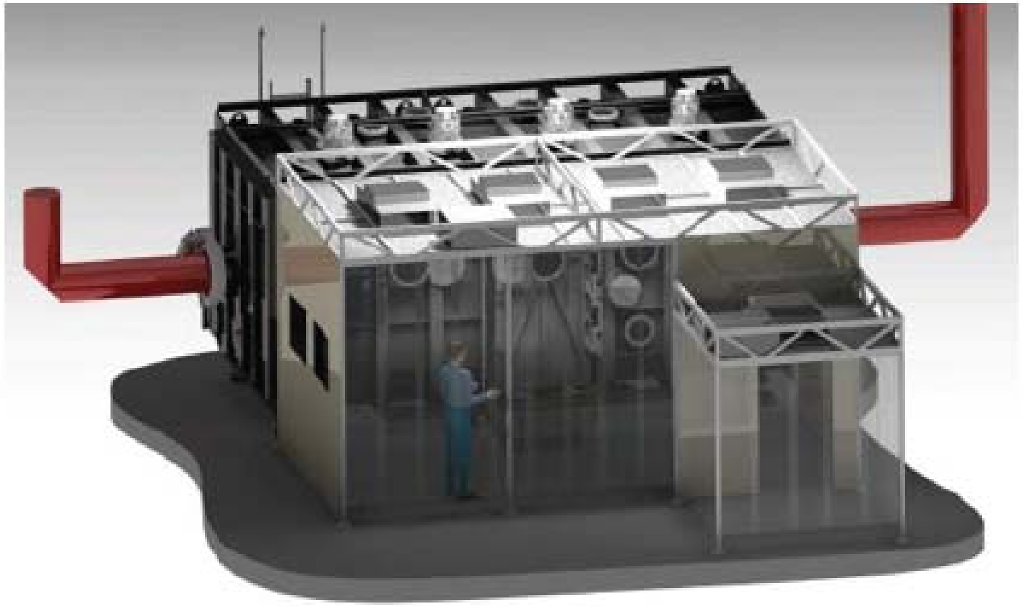
Compressor chamber

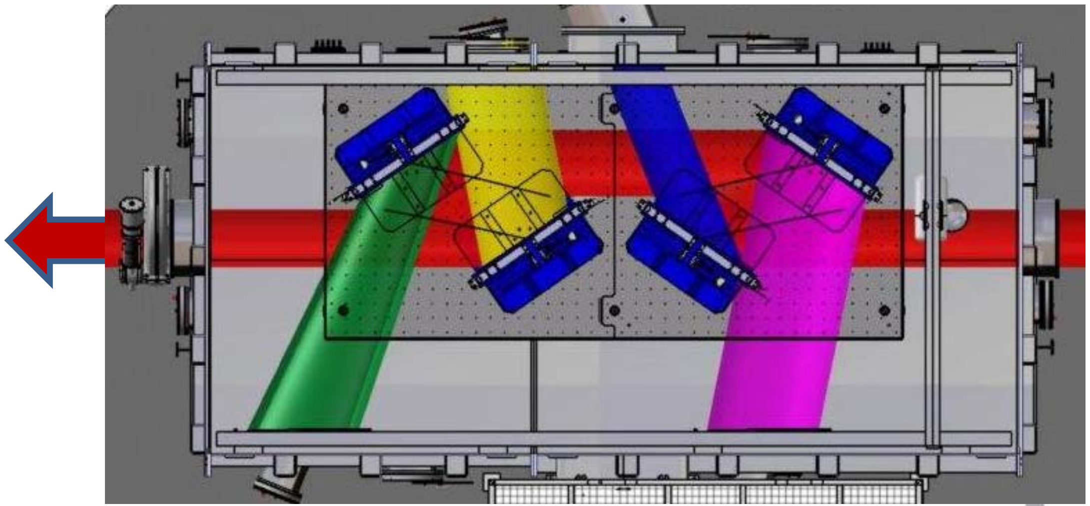
Compressor Chamber:

Vacuum level: **10^{-7} mbar**
Cleanliness class: **ISO 6**
+ Clean room to access the compressor

▪Volume of the chamber: **57.6 m^3**
=>Outside dimensions:
6.2m l x3m w x 3.1m h

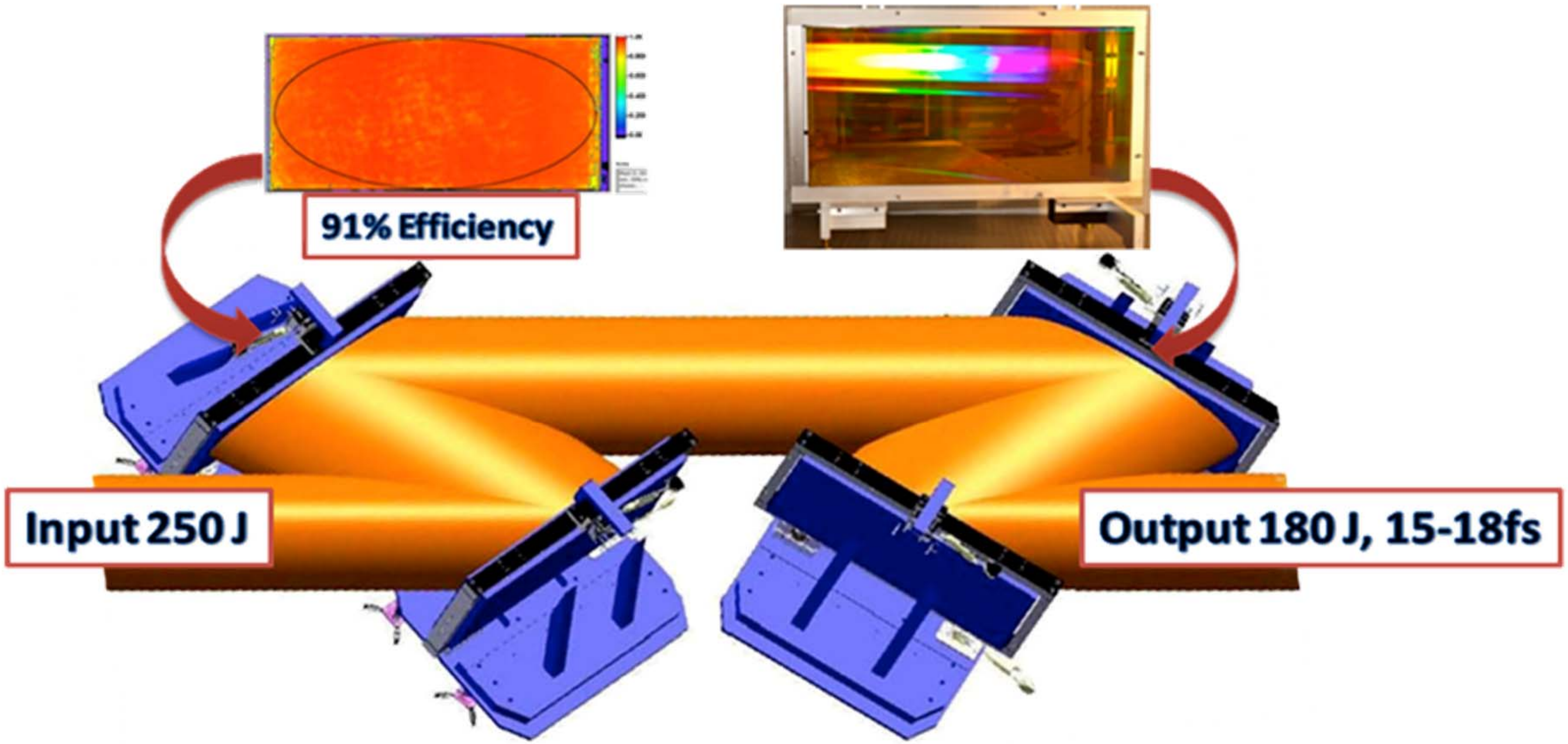
▪Weight (equipped): **20 tons**





10 PW Compressor

- ❑ Design and simulation **completed**
- ❑ Gratings (6) stored at LULI
- ❑ Mechanics: finalization of design and fabrication…



Cilex Apollon

Hall Laser LPA : Local Post Amplification

Initial state

Cleaning

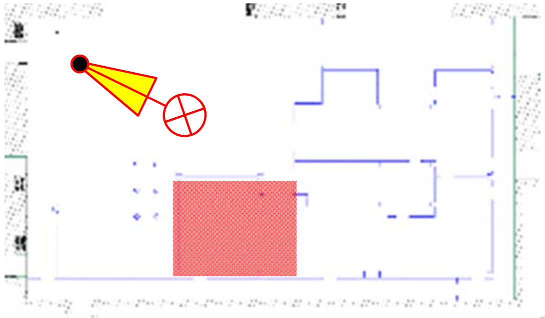
Mezzanine

Walls

Stair

Painting

ISO7 cleanroom



Avancement

Hall Laser LPA : Local Post Amplification

Initial state

Mezzanine

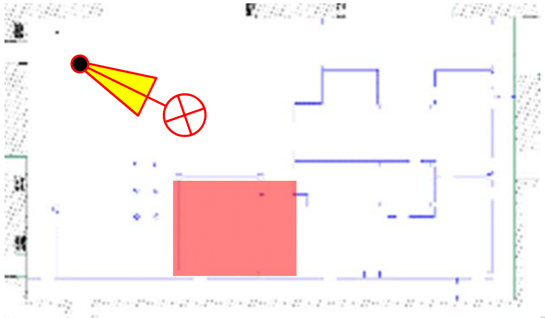
Walls

Stair

Painting

Cleanroom ISO7

Compressor + ZIP ISO6



Diagnostics

Two Operating modes

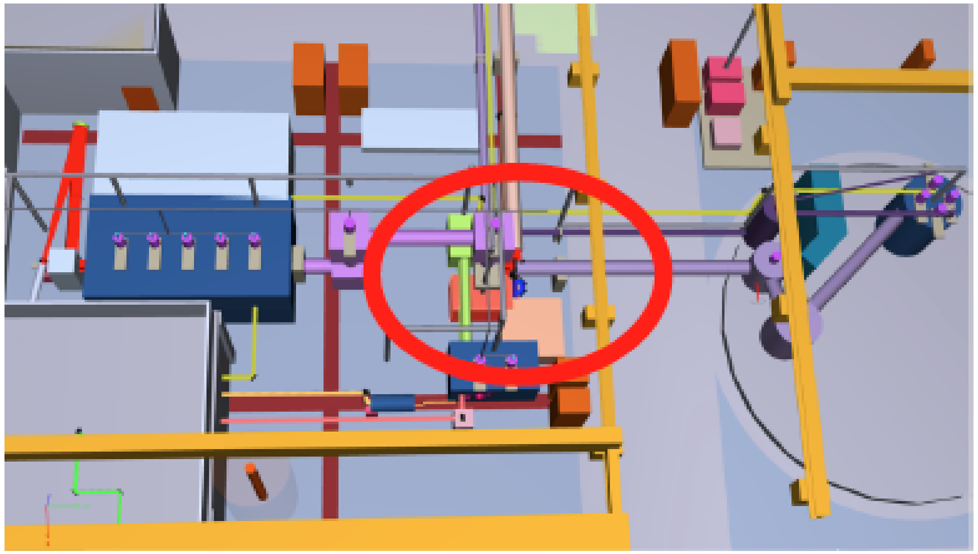
1. Characterising without deformation APOLLON 1 PW et 10 PW beam

Full beam measurement, high energy (1 shot /min) and low energy (10 Hz) (no experiment)

2. On shot measurements

Measurement throughout a leakage mirror

Full beam measurement, high energy (1 shot /min) and low energy (10 Hz)

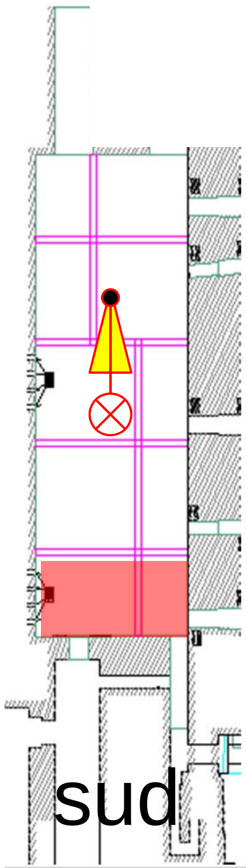


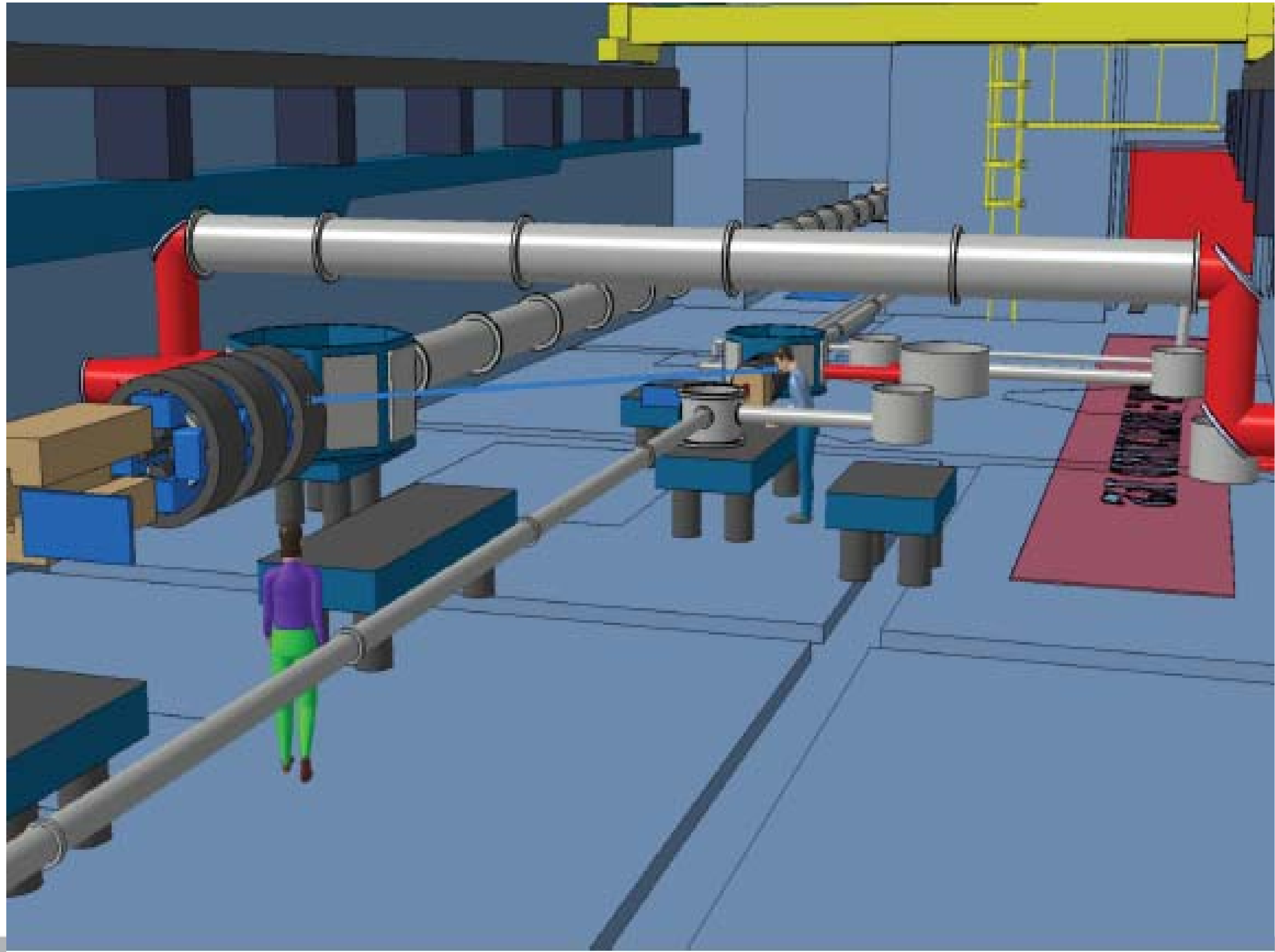
Long focal area status

Long Focal Area (LFA)

Initial state

Painting

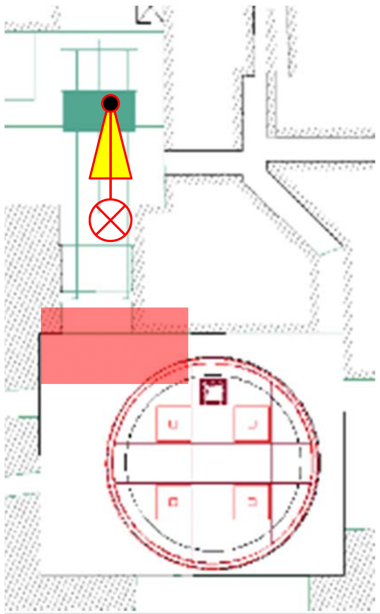


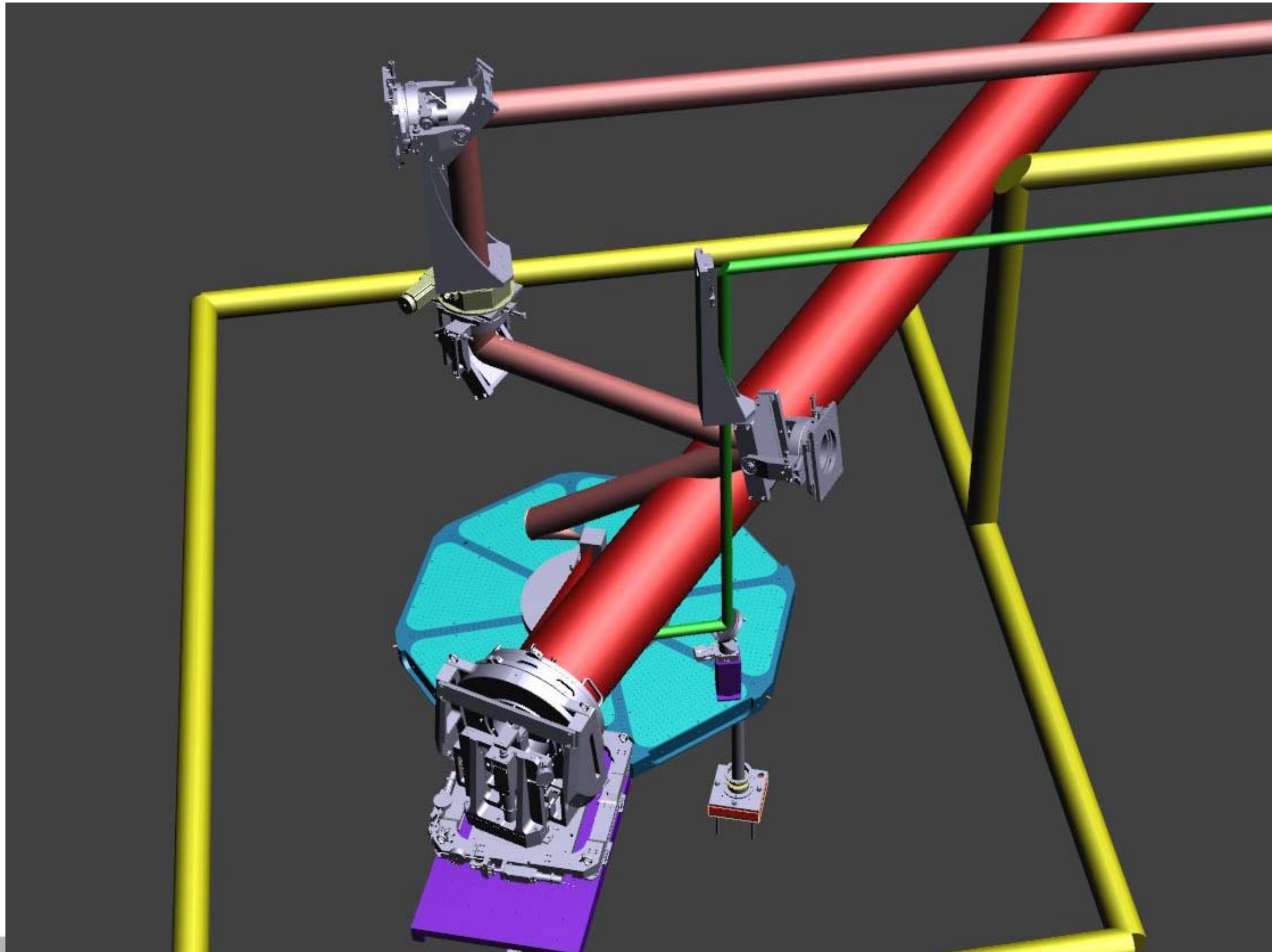


Short focal area Status

Short Focal area

- Initial state
- Cleaning
- Floor , painting
- Equipments





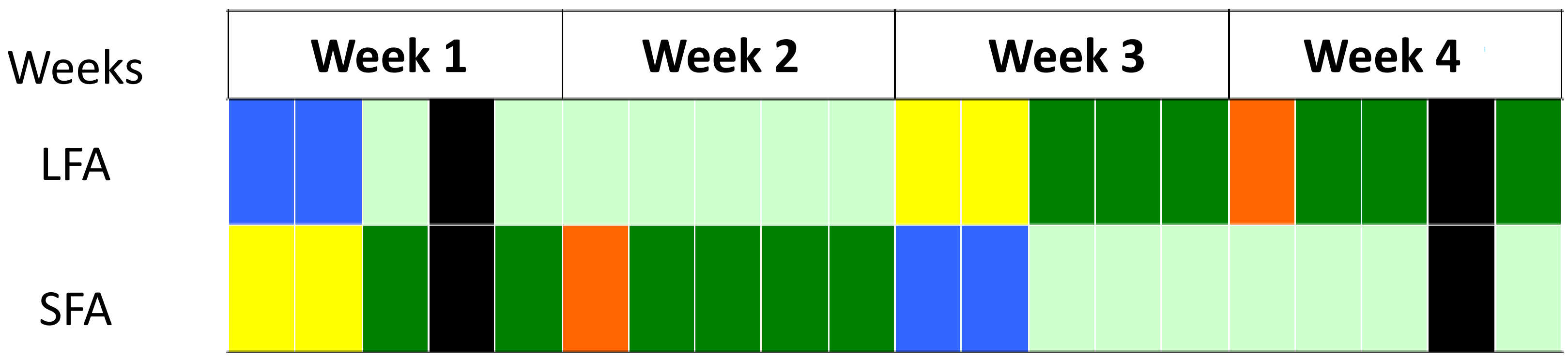
CilexApollon

Operation of the Facility

- Facility will be opened to national and international scientists
  - The experimental programs on APOLLON will be decided, on an annual basis, taking into account suggestions from an independent Program Committee.
- Beam time allocation per year
  - The goal is 10 experimental campaigns in each area: 140 days (28 weeks)
  - Maintenance and configuration changes 60 days
  - Laser development 50 days
- Experiments
  - Each experimental area will perform one after the other
  - Experimental campaigns will be defined on 4 weeks basis
  - The laser will deliver pulse sequences on demand for users 5 hours per day.
  - At the beginning, 2 days will be used for changing configuration between experimental areas
- The experiment should use as much as possible every laser shots

Campaign model

- Each block corresponds to 1 day
- Experimental assembly without laser (**7 days**)
- Holidays and contingency
- Switch of laser configuration (2 days)
- Experiences (**6 days** : 1 800 shots)
- Laser Maintenance (1 day every 2 weeks)
- Experimental dismantling (2 days)



Milestones and priorities

• 1PW Pre-commissioning	**January 2017**
• 1s shot in Chamber with F2	**JULY 2017**
• Multi-PW commissioning	**2018**

- **1st Priority**: the experimental demonstration on the PW level
- **2nd Priority**: multi-PW commissioning

Conclusions

- New laser/beam sources can explore new applications and fundamental physics research
- Need versatile and reliable laser facilities
- Qualification and first experiments at Apollon is planned beginning of 2017
- Open to the community in 2018-2019

F. Mathieu[1], P. Georges[3], C. Le Blanc[1], G. Chériaux[2], L. Martin[1], B. Le Garrec[2], J.P Zou[1], D.N. Papadopoulos[1], J. Fuchs[1], A. Specka[5], J.L. Paillard[1],B. Hirardin[1], D. cavanna[1] P.Bizouard[1], D. Fournet[1], JP. Delanneau[1], G. Mennerat[4], J.M. Boudenne[1], F. Druon[3], A. Pellegrina[1,3], P. Ramirez[3], F. Giambruno[1,2], A. Fréneaux[1,2], F. Leconte[1,2], D. Badarau[1], T. Valloton[1], C. Greverie[1], J.L. Veray[1], M. Pina[1], B. Breteau[1], B. Cros[6], J.R. Marques[1], S. Chen[1], A. Bonnemaison[5], A. Cauchois[5],J. Prudent[5], M. Bougeard[4], S. Leveque, F. El Hai[1], G. Garzino[1], FJ. Betourne[7], C. Rey[7], S. Fageoelle[7], J.P. Chambaret, A. Beluze[1], L. Huret[1], N. Lebas[1], V. Ferragne[1], N. Thromat[7], P. Monot[4], P. Martin[4], and F. Amiranoff[1]

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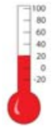
LASER ROOM PERFORMANCE



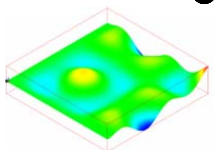
- Indoor Temperature
  - 21°C ± 0,5 C° ; drift in 2 hours less than 0,5 C°, 24/24 7/7

- Relative Humidity
  - 40 – 55 %, no condensation, drift accepted ± 5% in 24h, 24/24 7/7

- Differential pressure aera
  - +15 or + 30 Pa between each aera

- Cleanness (particles)
  - ISO 8, ISO7, ISO6 by aera

- Covering
  - Walls, : smooth paint and eas



- Vibrations
  - Ground and Floor : Vc-E ASHF