CILEX
Apollon laser facility

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

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

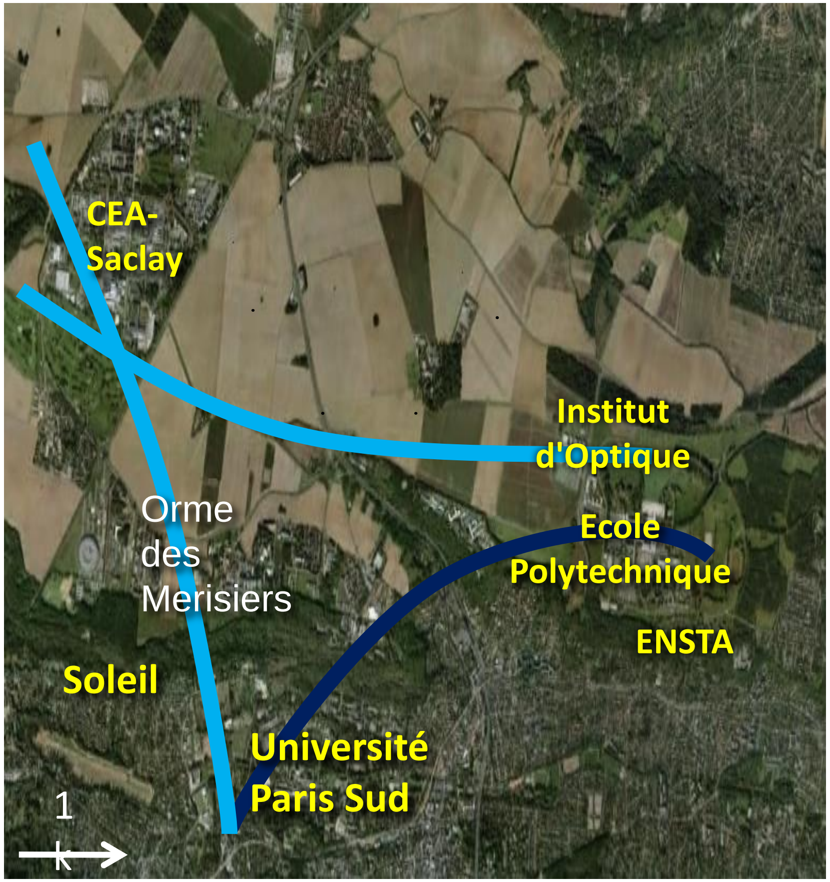
hosting APOLLON facility

a multi-PW lasers with 2 radio-protected experimental rooms

and smaller scale facilities

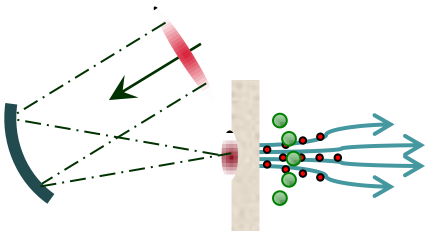
for pluridisciplinary programs

training of scientists and engineer

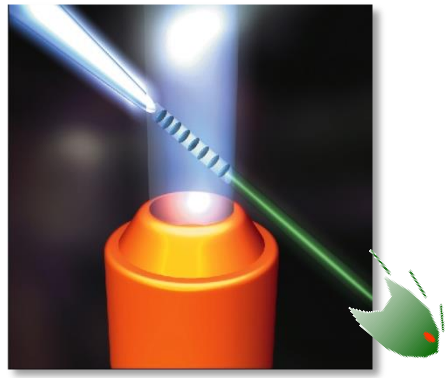


Operated as a user-facility

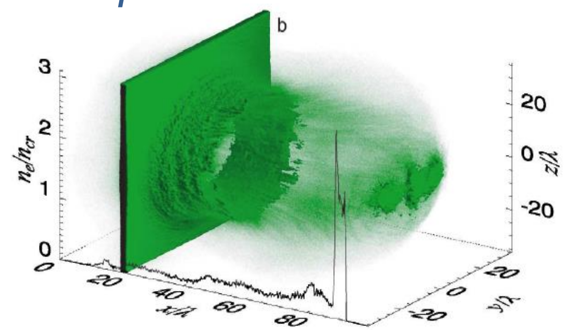
Apollon : a variety of scientific applications



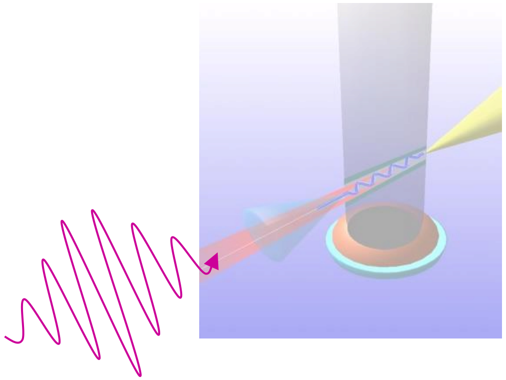
multi-GeV electrons



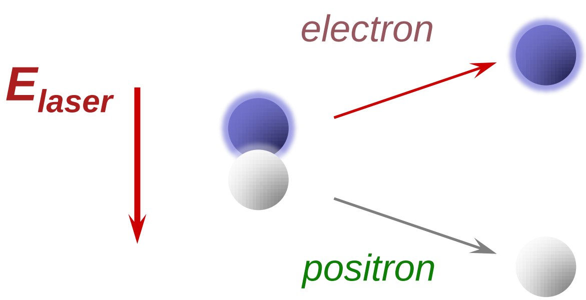
multi-GeV protons



X-ray , as sources, γ-rays



High-field physics



and applications ...

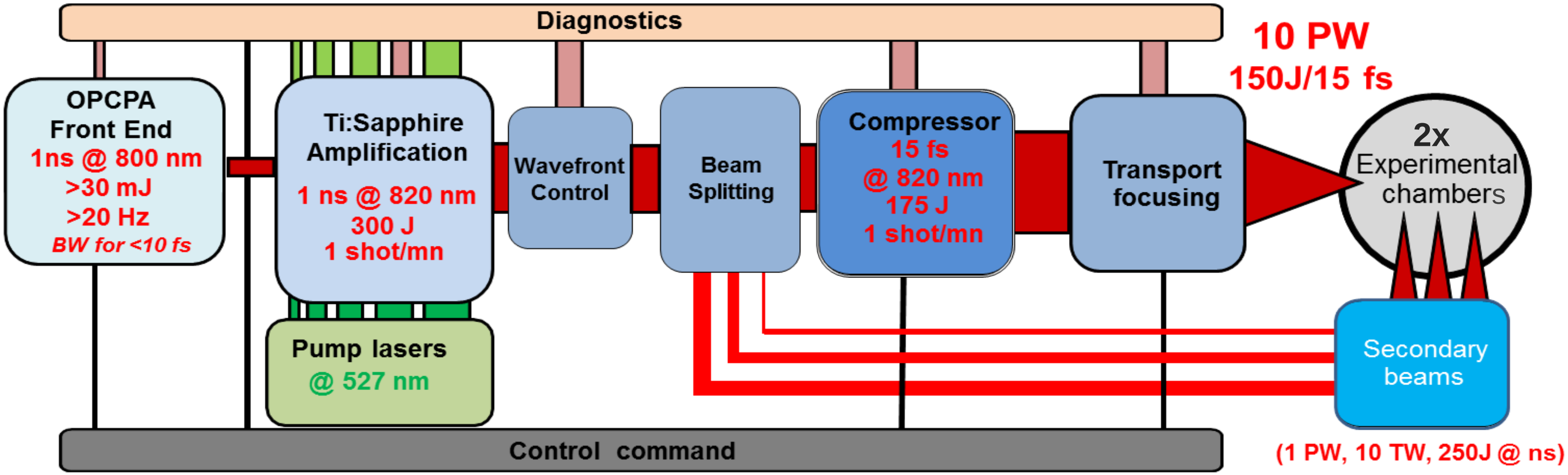
Apollon laser facility Requirements

- High laser intensity
  - $I > 10^{22} W/cm^2$ $(a_0 = (0.85 (I_{18}\lambda^2)^{\wedge 0.5}) > 100$
- Multi beams
  - to perform pump probe experiment and multi stage laser acceleration
- Repetition rate (1shot/min)
  - 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
- Flexibility to make new experiments

laser beams

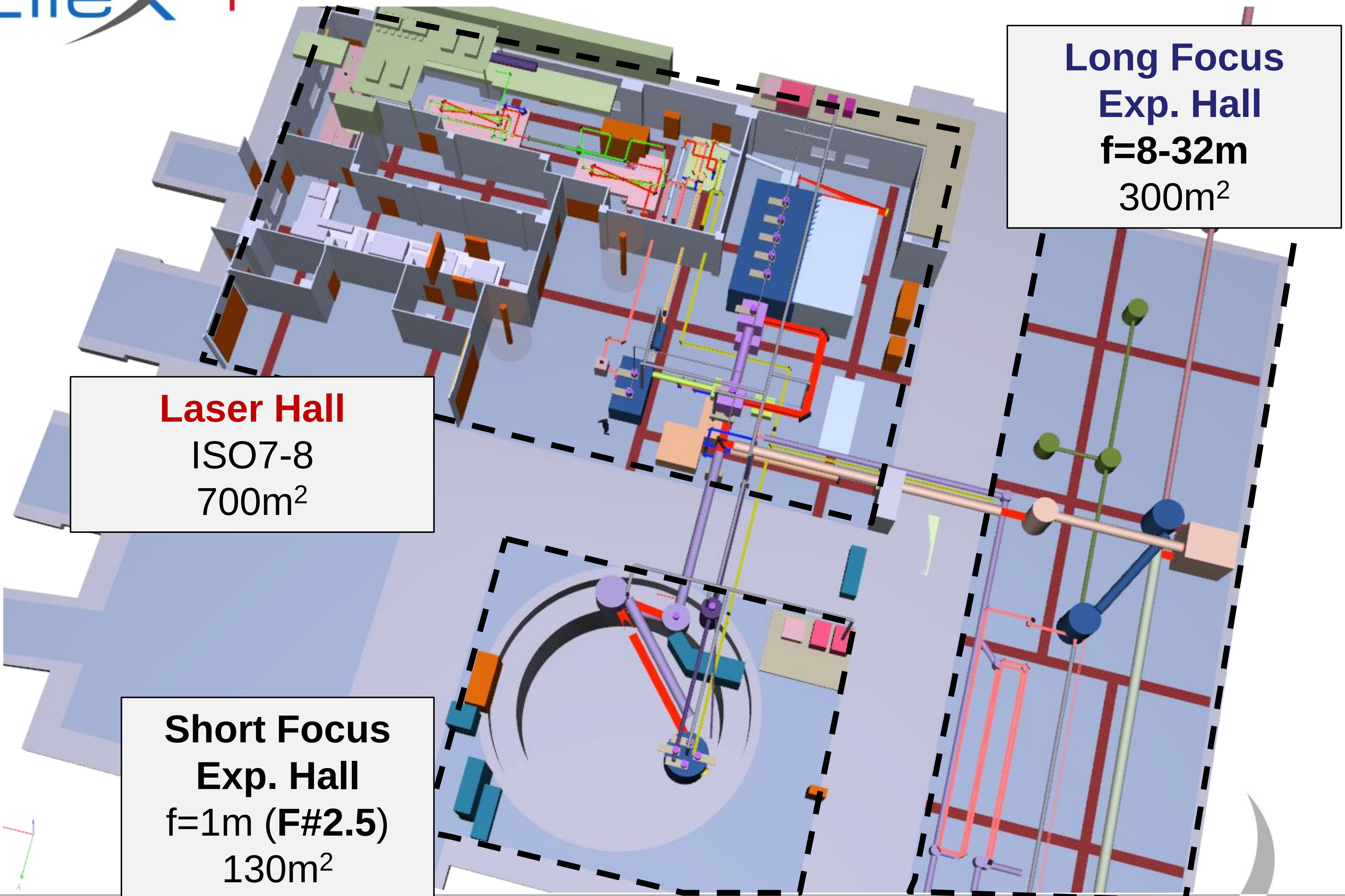
- To address the experiments that we wants to perform, the laser facility has been design with
  - 4 independent beams
    - main beam F1 15fs-few ps / 150J possible
    - secondary beam F2 15 fs-few ps / 15J max
    - ns beam F3 uncompressed up to 200J
    - probe beam F4 <20fs / 0.2J)
  - 2 independent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

The Apollon laser

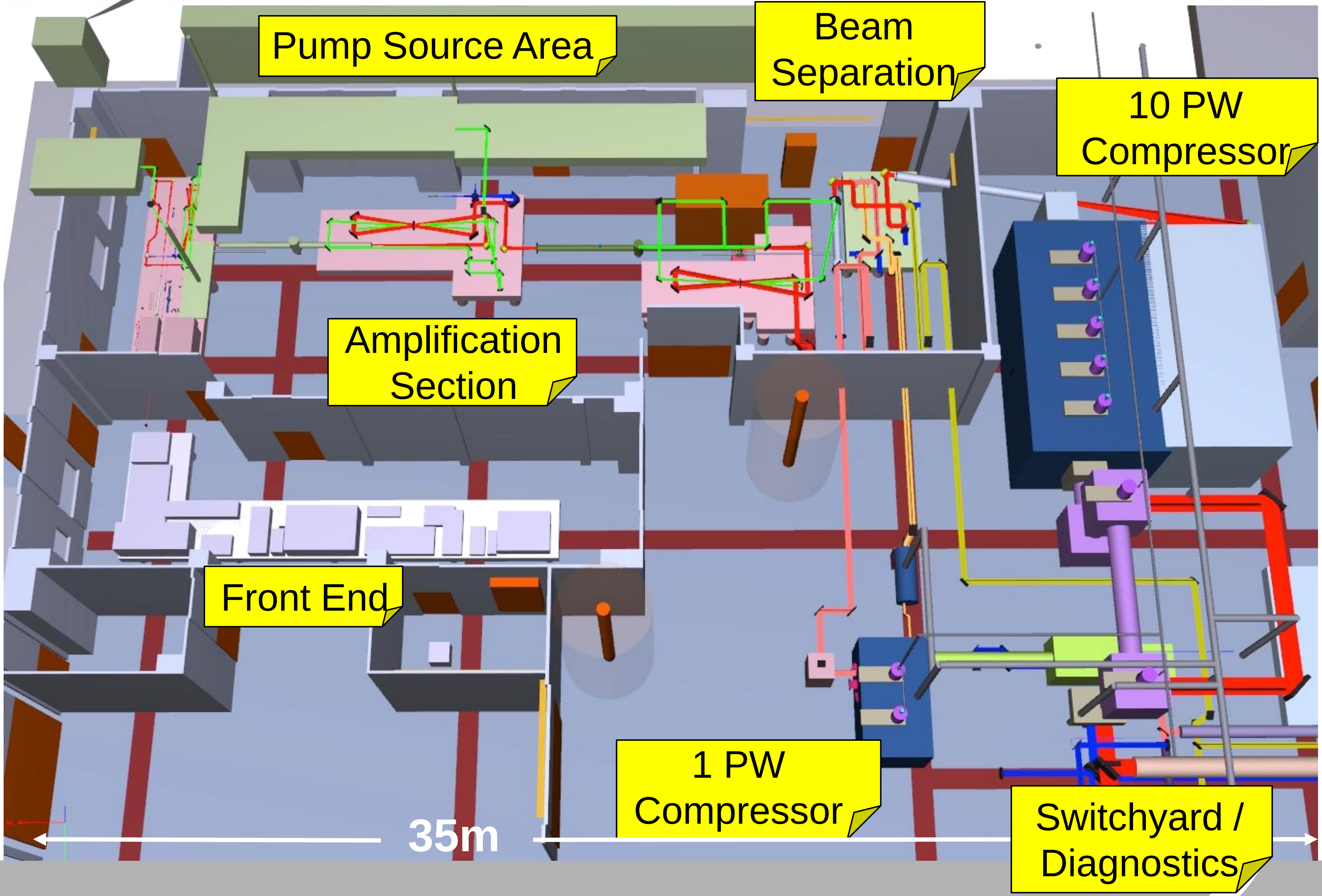


- Apollon key features:
  - **Hybrid architecture**: OPCPA + Ti:Sapphire ➔ Contrast + Bandwidth
  - **Unique Material**: Φ10-175mm Ti:Sapphire crystals, Meter size gold gratings, state-of-the-art optics
  - High energy pump sources: up to **700 Joules/min**
  - **Adaptive control:** spatial (Deformable mirrors) and spectral phase (Dazzler)
  - 175 nm Spectral window for the whole system

The Apollon Facility



The Apollon Facility: Laser Hall



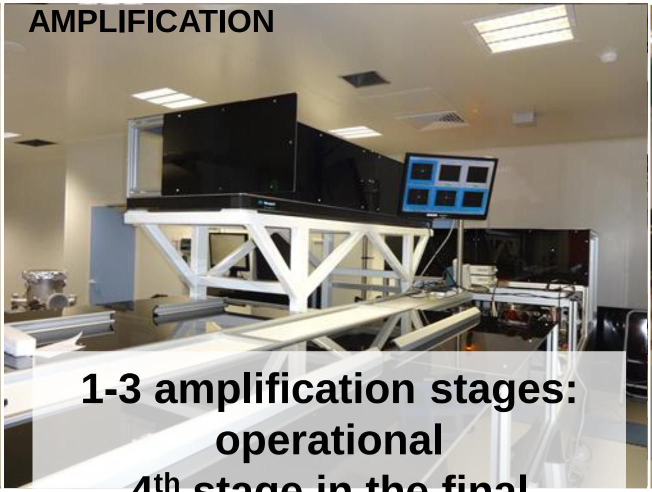
Apollon laser: construction progress

2013: beginning of reconstruction work… **03/2015** reception of the building

FRONT END

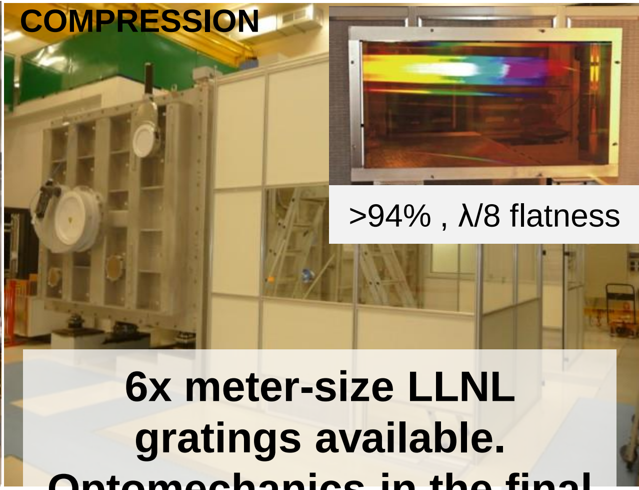
In the final commissioning phase

AMPLIFICATION



1-3 amplification stages: operational
4th stage in the final reception phase

COMPRESSION

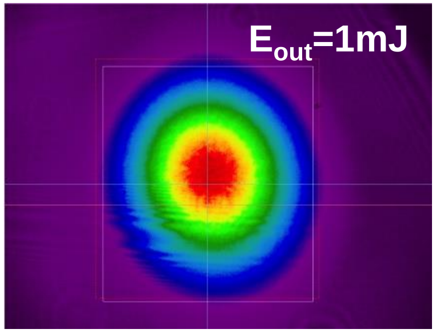


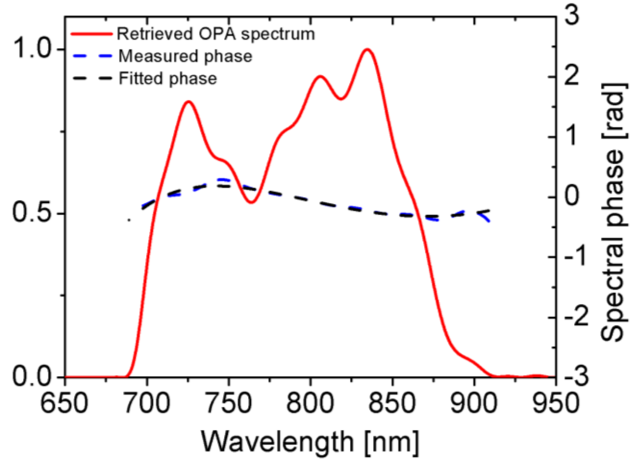
>94% , λ/8 flatness

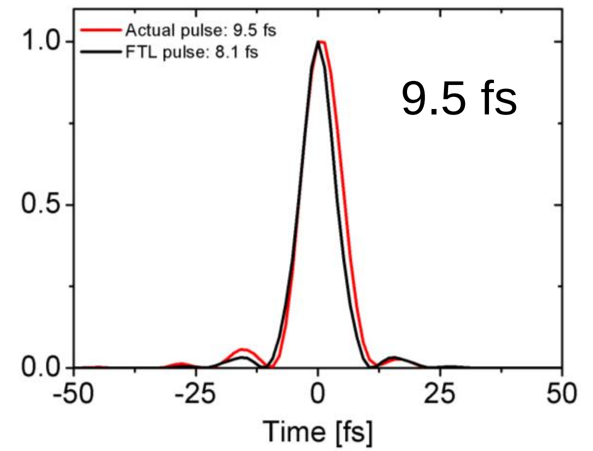
6x meter-size LLNL gratings available. Optomechanics in the final reception phase

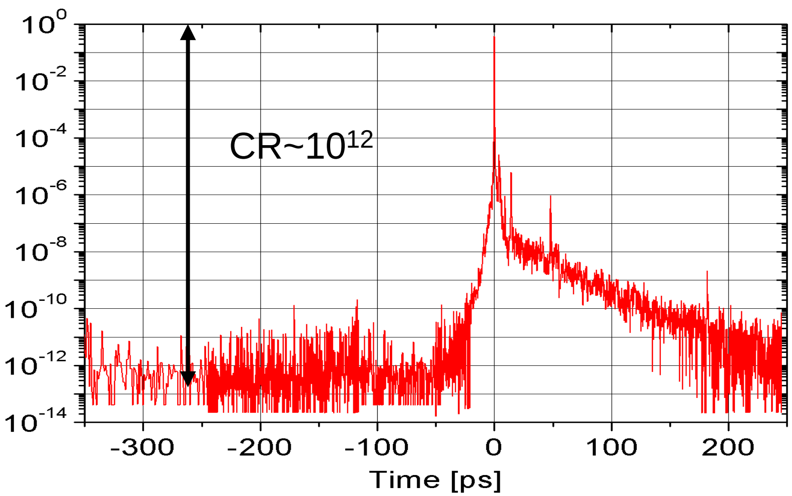
The Front end: OPCPA performance

- ❑ Initial demonstration 2014 IOGS









- ❑ **Highly reliable operation**: 2% rms stability, <10µrad pointing
- ❑ Optimized **compression** with a **Wizzler/Dazzler**:

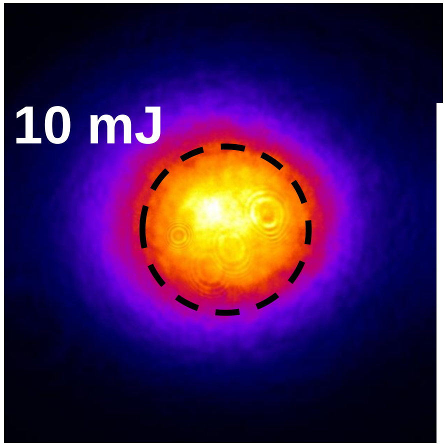
  9.5 fs (8.1 fs FTL) at **1 mJ**

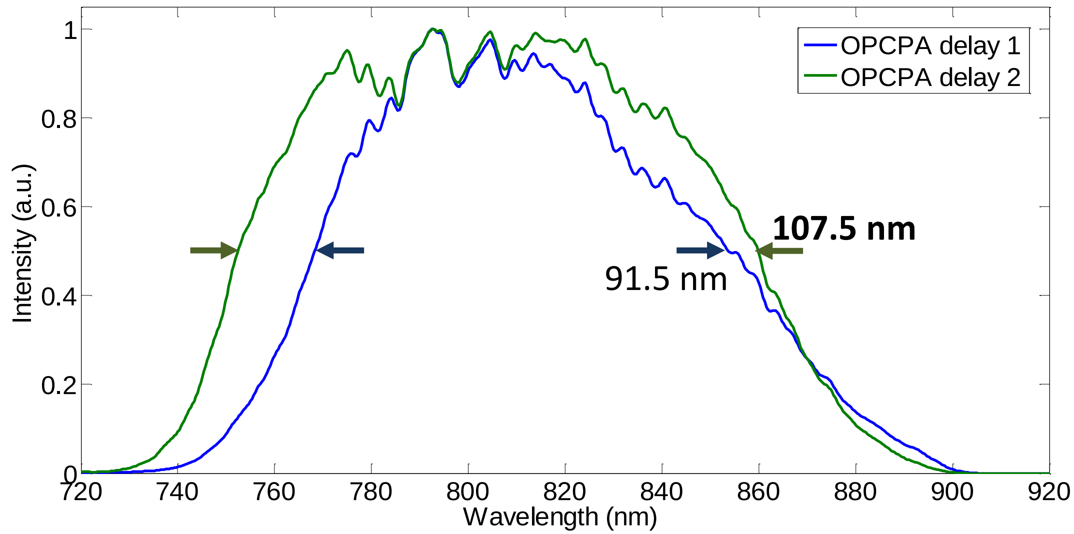
- ❑ **Contrast ratio measurement** with a 3rd order autocorrelator:

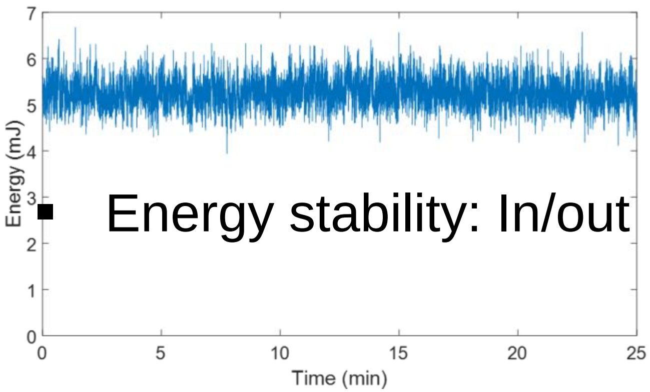
  CR>10^{13} (estimated)

L. P. Ramirez, et al J. Opt. Soc. Am. B 30, 2607-2614 (2013**)*
***D. N. Papadopoulos, et al in Advanced Solid State Lasers, OSA (**2015**)*

The Front end: Final amplification stage



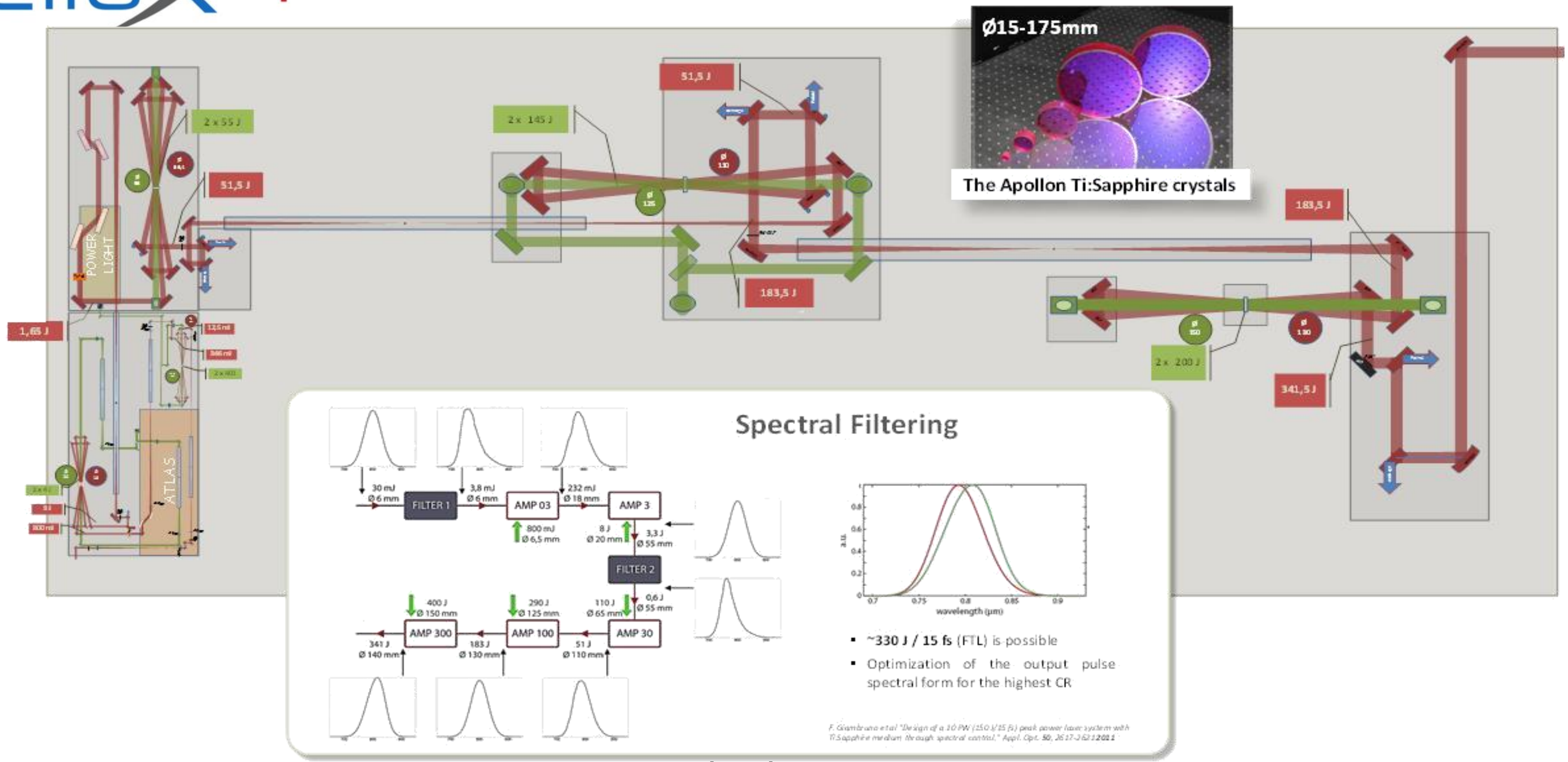




- Energy stability: In/out

- ✓ High beam quality: **λ/3 PtV** over full beam (**< λ/7 PtV** for the injected central part)
- ✓ Highly repetitable operation: Reliable Pump + Diagnostics ➔ <**45min startup time**
- ✓ Bandwidth >**100nm** FWHM & **~165nm** FW(1%) / **14 fs** FTL.
- ✓ Output energy stability ~5.5% rms, **34%** PtV (25 min) for ~4% at the input (OPCPA)

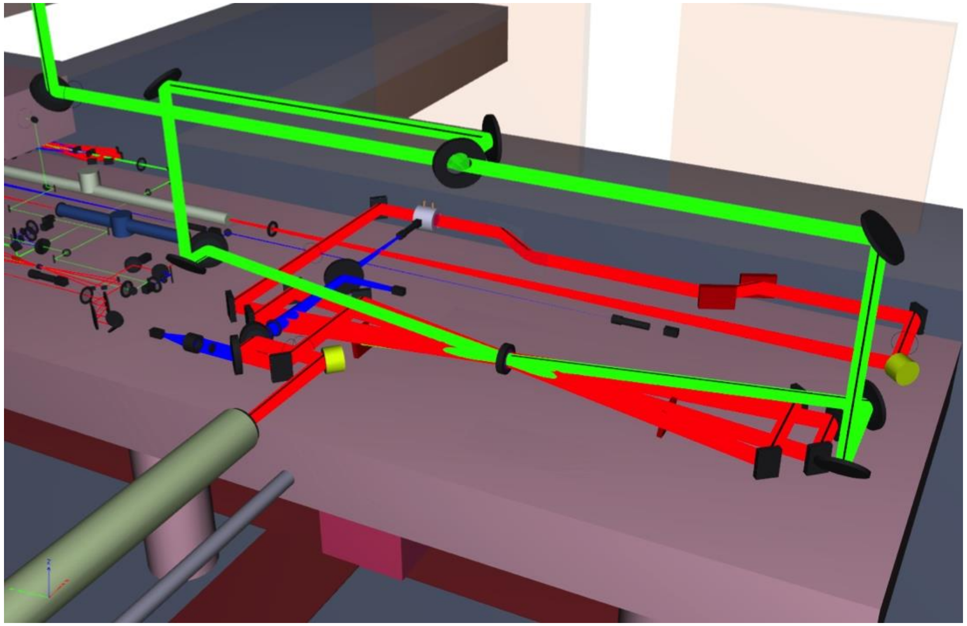
The power amplification section (PAS)

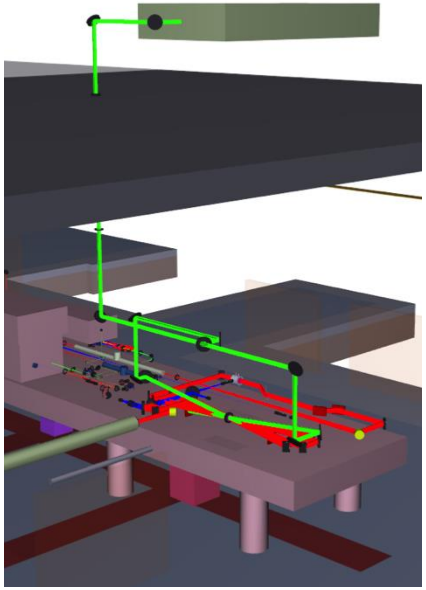


- **5x "low" gain multipass amplifiers**: Φ6-Φ140 => **0.3-300 Joules**
- **Bandwidth preserving design:** Spectral filtering
- **Due to budget constraint the projec has several phases**
  - **First step**

    We will have only 300 J of pump -> 75J on F1
    We keep the compatibility to 10PW for the laser and experimental room (beam diameter 400mm)

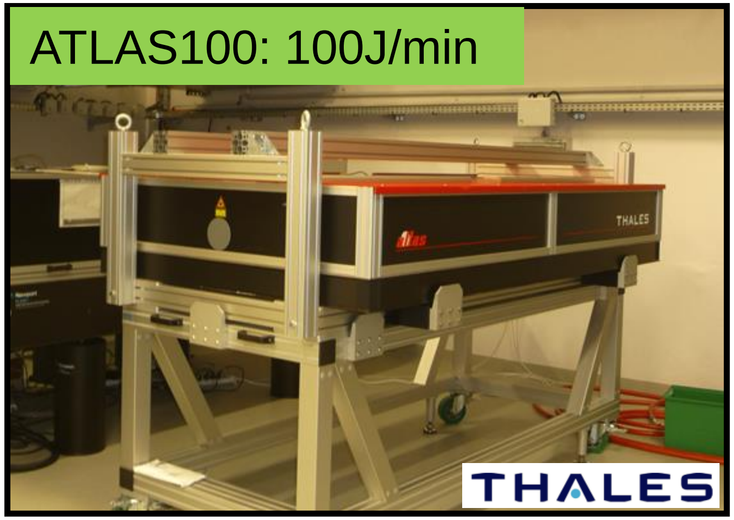
PAS: Amp30 implementation



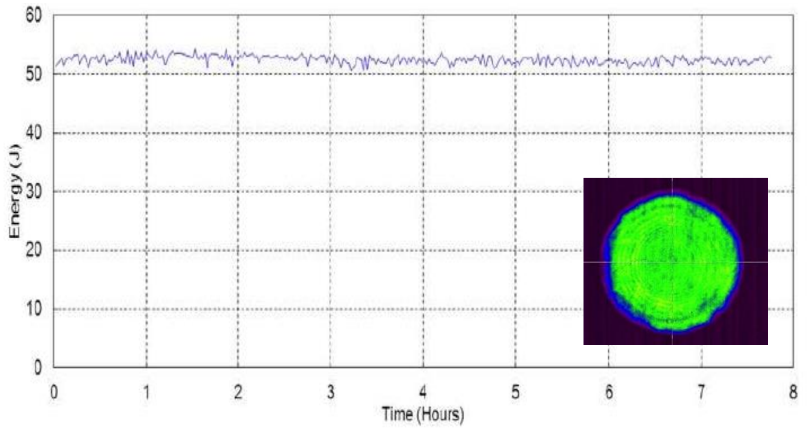


- Simple and compact **4-pass configuration** at **Φ55** (Φ60 for the pump) employing a Φ80 Ti:Sapphire crystal
- Design operation point: **35 joules** for **90 joules of pump**
- Pump source **Atlas100** (100Joule at 527nm) installed on a mezzanine floor with **~11 m** of distance to the crystal: pump beam delivery issue

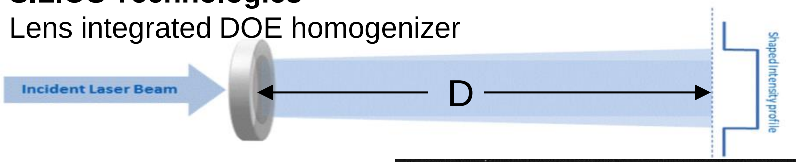
PAS: ATLAS100 beam delivery

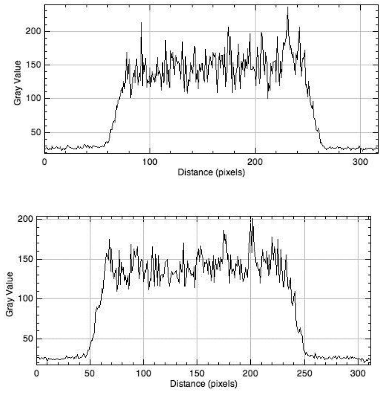


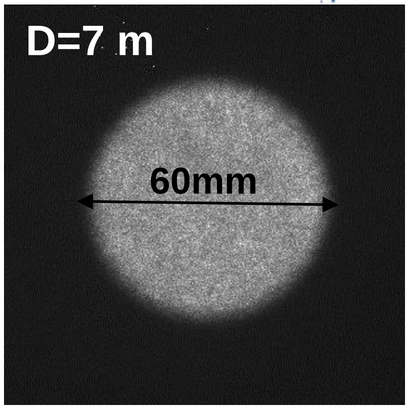
Typical stability curve of a single chanel of Atlas100



SILIOS Technologies
Lens integrated DOE homogenizer

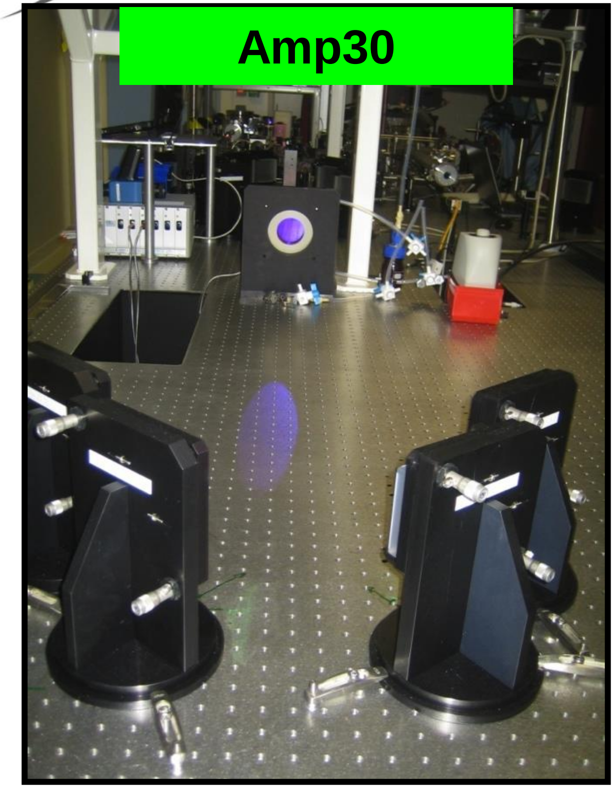


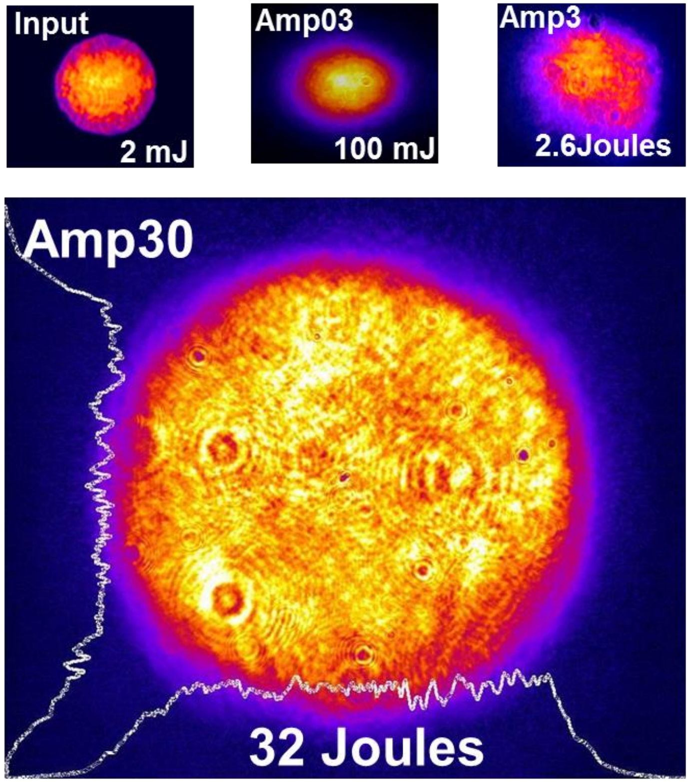




- Very stable and robust operation: **100 Joule/min**, at 527 nm, ~**1% rms, <15µrad rms** pointing
- Use of Diffractive Optic Elements **DOE to homogenise the beam** on the crystal: >**90%** transmission➔ Flat-top beam, stable pumping conditions, no relay imaging required
- **~87 Joules** delivered on the crystal

PAS: Amp30 performance



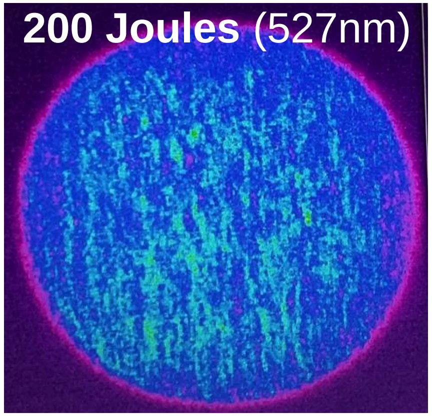


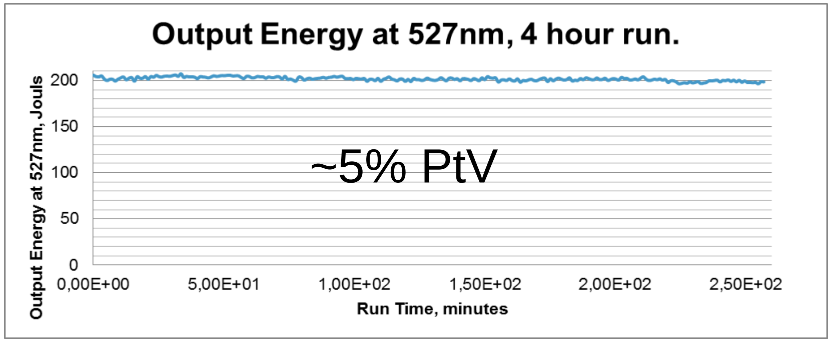
- ✓ **Uniform flat-top like beam** at **32 Joules**
- ✓ Stable operation over 1 hour: **<3% PtV** energy fluctuation
- ➢ …Injection of the final Front End ➔ **Energy + Broad spectrum** (>65 nm) ➔ **>1PW** level operation capacity (end of 2016)

CNE400 pump source reception (factory)

- *Pumping… to the multi PW level*

Installation in France
09/2016



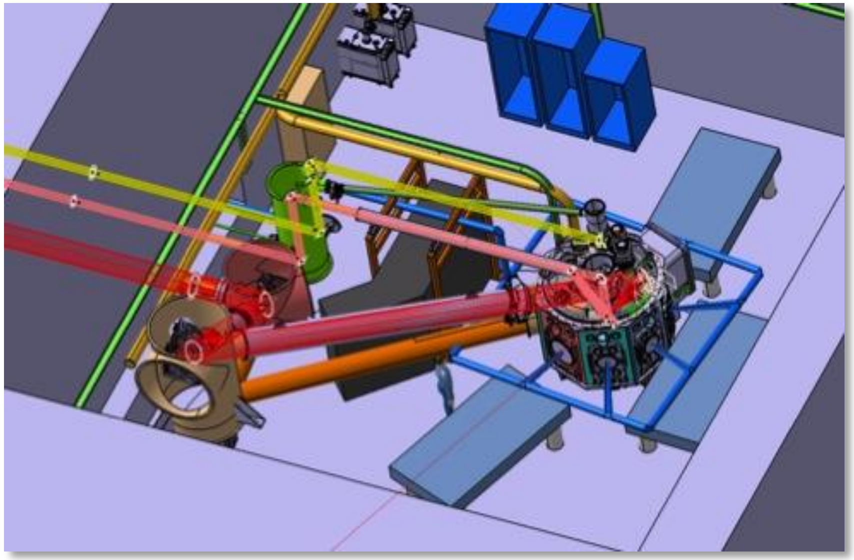


- ✓ Compact system: 3 optical tables + power supply on **~20m²**
- ✓ **200 Joules/min** at 527 nm / Uniform beam
- ✓ Reliable / turn-key operation

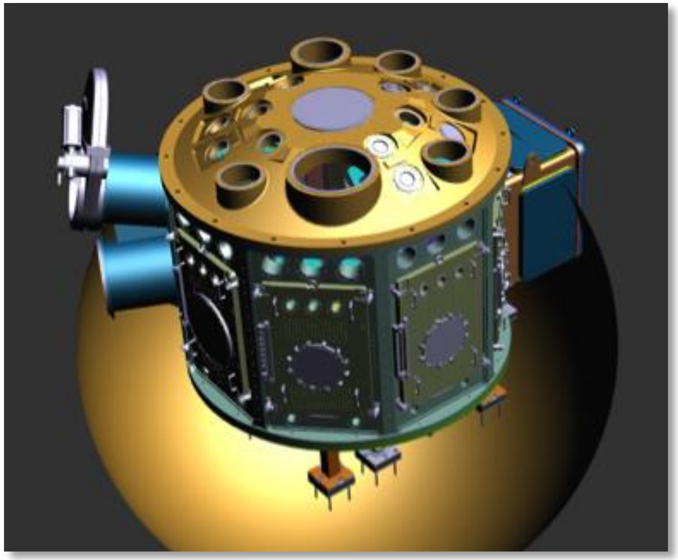
- **…Pumping of Amp100** (begin of 2017) ➔ **Broadband amplification** at **110 Joules** (summer 2017) ➔ **multi-PW** capacity demonstration (begin 2018)

Short-focal-length area

Versatile area and chamber adapted to various experiments



f/2.5 focussing → intensity > 10^{22}W/cm^2

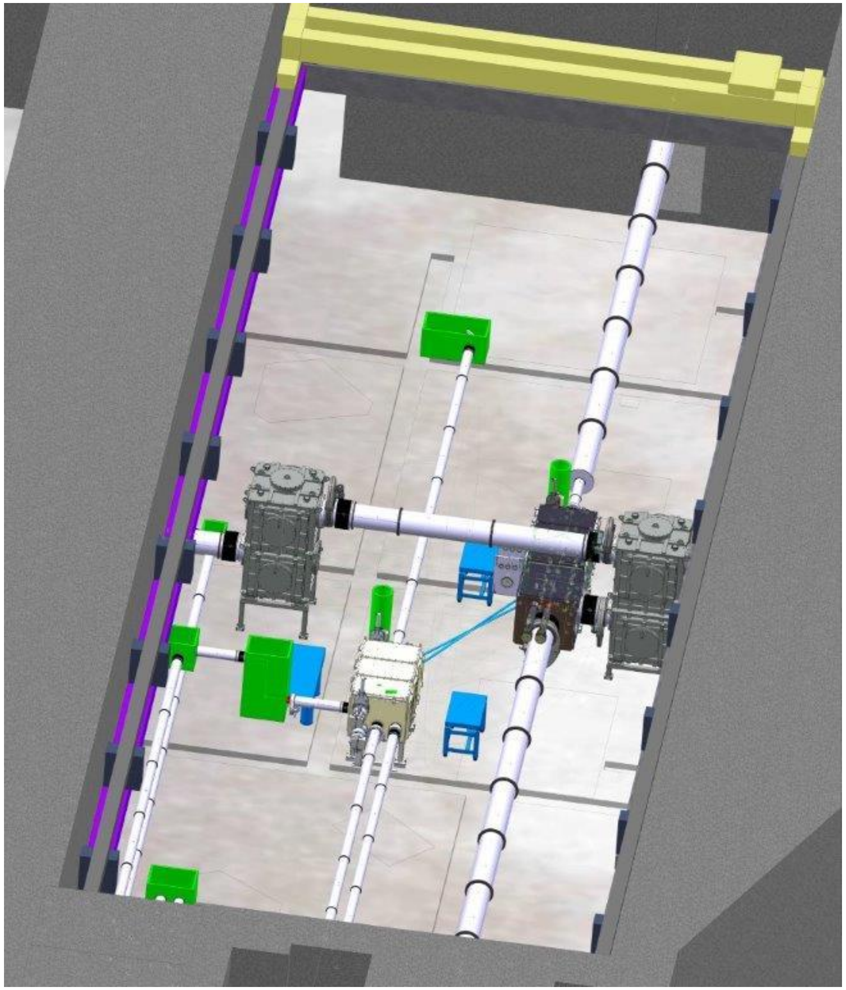


1 PW beam at
≈ any angle from 10 PW beam

–> extreme (high energy, high dose, ultrashort, directional) beams of ions, X-rays and γ-rays

–> exploit the unique properties of the ion beam as a probe and for a variety of applications

Long focal-length area



37 m long radio-protected area with two chambers allowing 1 PW and 10 PW experiments and 2-stage schemes

FOR

Exploratory electrons experiments using a single beam PW and Mult-PW

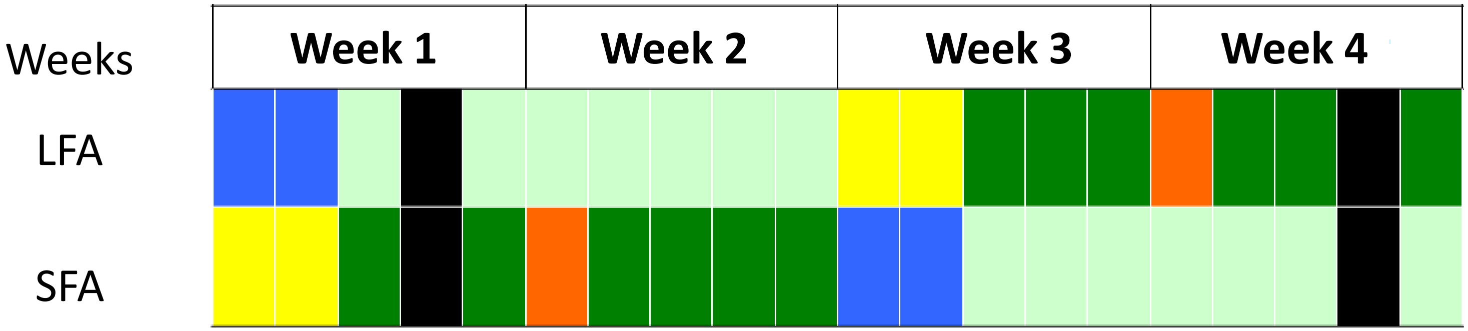
Develop a two stage Laser Plasma Accelerator (Injector/accelerator)

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 20 experimental campaigns (10 in each area)
  - 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 on 4 weeks basis

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



Conclusions

- Apollon is based on **state-of-the-art laser systems**, **material** and **technology** and will provide **unique laser performances**
- High Contrast/Large bandwidth **Front End in the final commission phase**
- High energy amplification: demonstration of **32 Joules**
- Critical **material reception** and **integration**

> …Demonstration of **PW level capacity** (**2016**)→ **PW level experiments** (**2017**), **multi-PW operation** (**2018**)

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Remerciements