# Short Focal length target Area (SFA) presentation

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Apollon FIRE users' meeting 12/02/2015

# Outline

- Scientific objectives
- Technical Objectives
- Current design of the hall
  - Chamber
  - Debris
  - Target systems
- First Light: Commissioning experiments

# Scientific Objectives: “mission statement”

The short (and medium) focal length area is focused on taking advantage of the highest possible laser intensities for:

- generating extreme (high energy, high dose, ultrashort, directional) beams of ions, e-, X-rays and gamma-rays
- exploiting their unique properties of these beams as a driver or a probe for a variety of applications
- investigation of extreme intensity-driven phenomena (vacuum, non-linearity at UHI)

# Technical Objectives to reach the Scientific goals

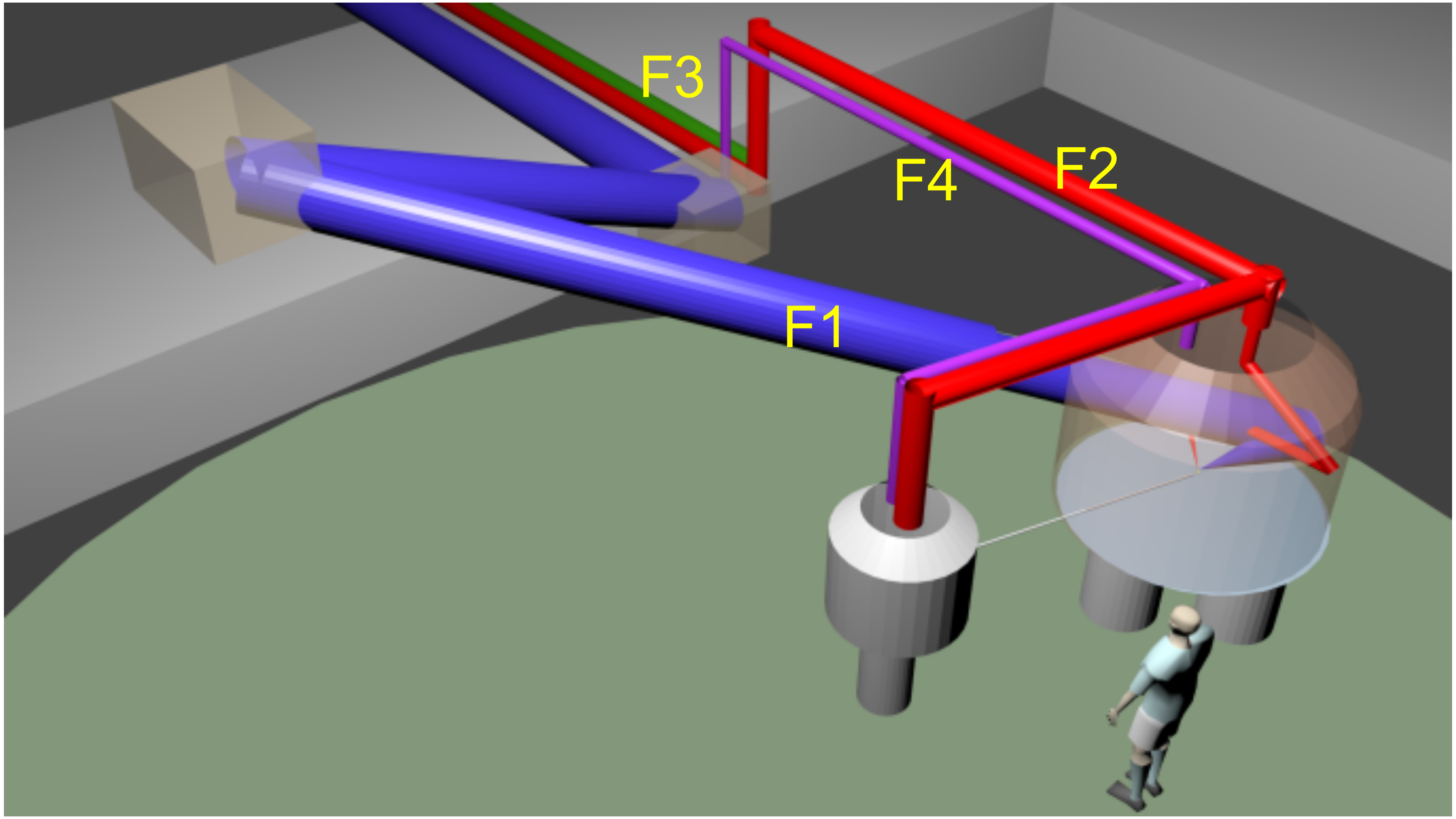
- 4 beams
  - Prepare for as many beam configurations as possible in angle and parabola F#
- High repetition rate: 1 shot/min
  - How to fully utilize the high rate with multiple target assemblies
  - Fast laser and target alignment; and beam timing

Provide a flexible experimental area to accommodate as many different types of experiments as possible

# Laser Parameters

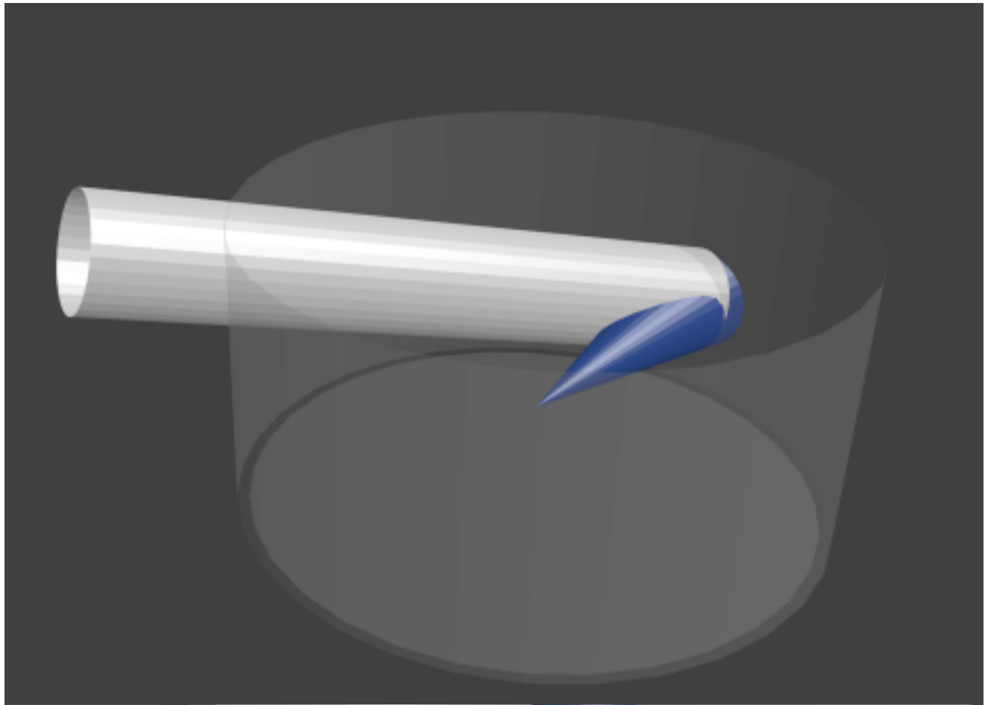
- Energy & Pulse length
  - **F1**: 150 J max, 15 fs – 5 ps (10 ps) ± 15 fs, 400 mm dia.
    - Jitter between SP1 &SP2: ± 1.5 fs
    - Delay: ± 5 ns
  - **F2**: 15 J, 15 – 200 fs ± 15 fs, 140 mm dia.
  - **F3** Long Pulse: 300 J, 1 ns
  - **F4** Probe: 1 J, < 20 fs, 100 mm dia.
- Pre-pulse/Pedestal: will need to be up to $1 \times 10^{12}$
- Best contrast of the short pulse → reservation for plasma mirrors
- Polarization: s-polarized, p-polarized, and circularly polarized
- Pointing Stability: ± 1/5 focal spot diameter
- < 10 mJ in the 10 Hz low energy beam
- Continuous laser (independent from laser system) for all beam lines at 532 nm and 800nm

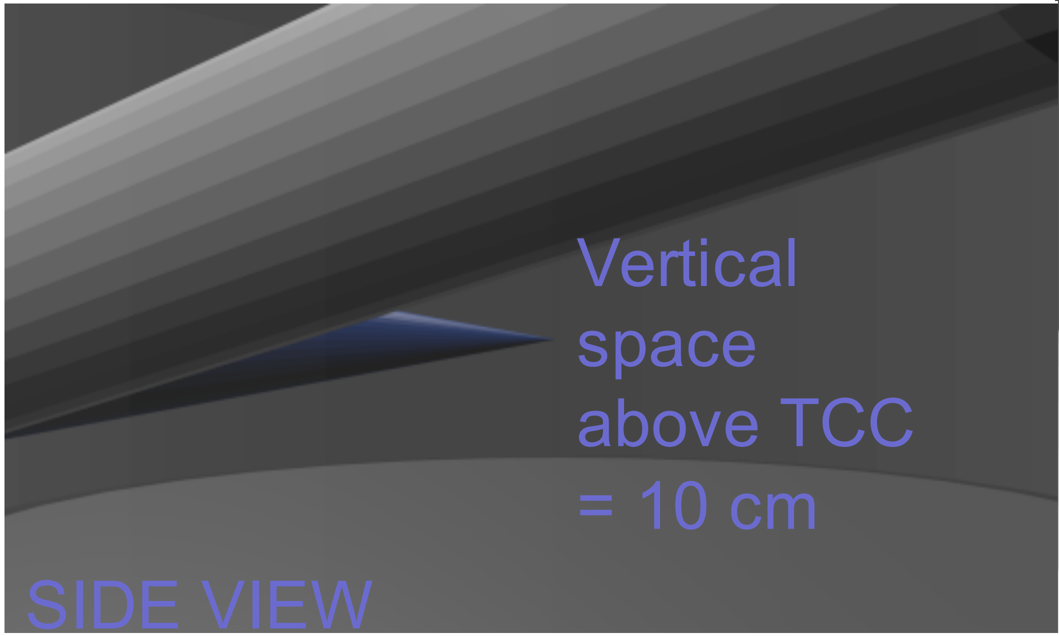
# The design of the HE1 room has been made to conform to this objective

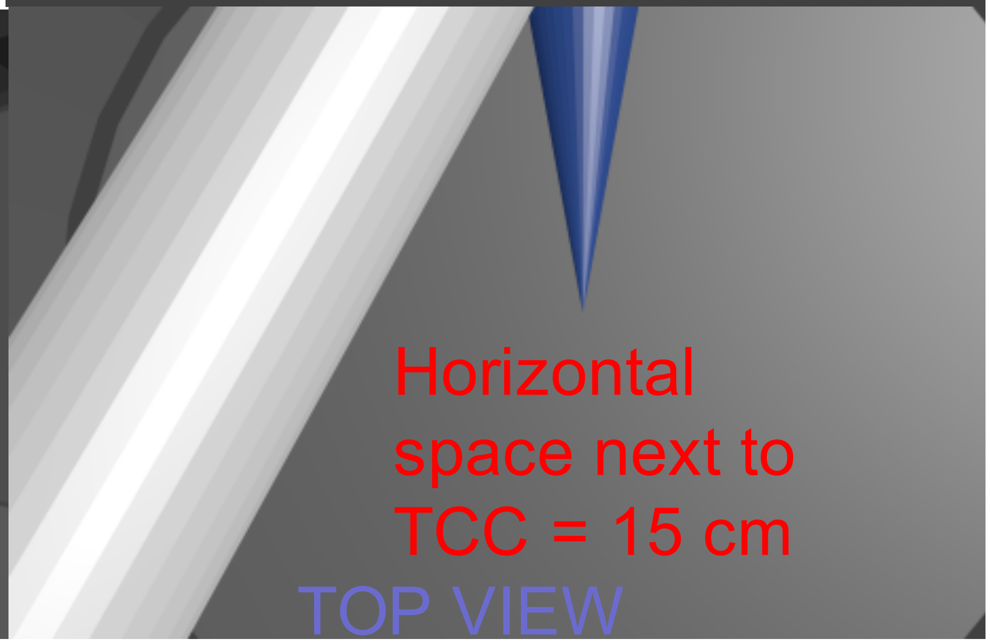


# F1: 10 PW beam

- Off-axis angle = 30 degrees
- Rotation around TCC = 60 degrees
- The parabola will be F/2.5, hence the parabola itself and mounting hardware will be slitghly outside of the main chamber

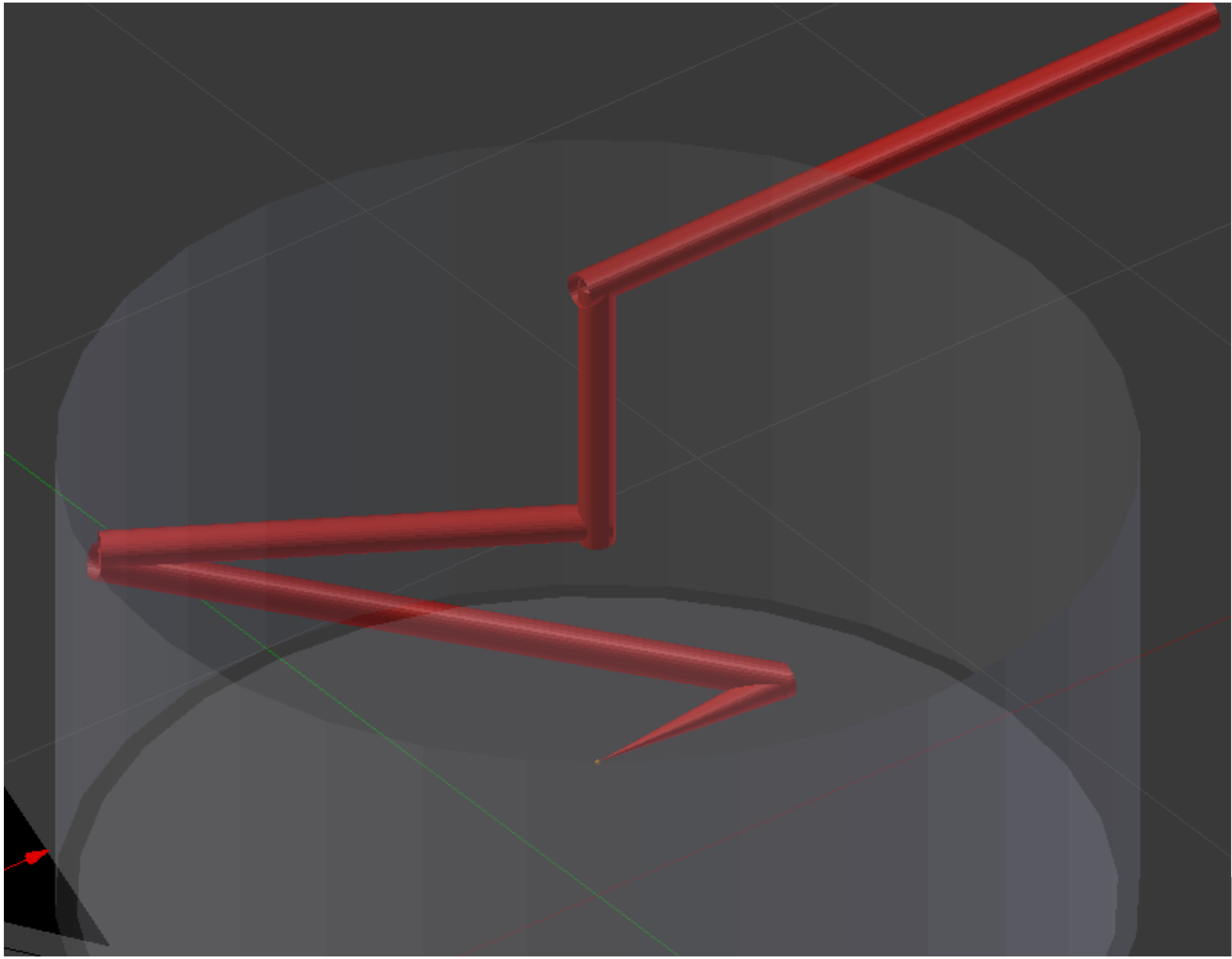




# F2: 1 PW beam

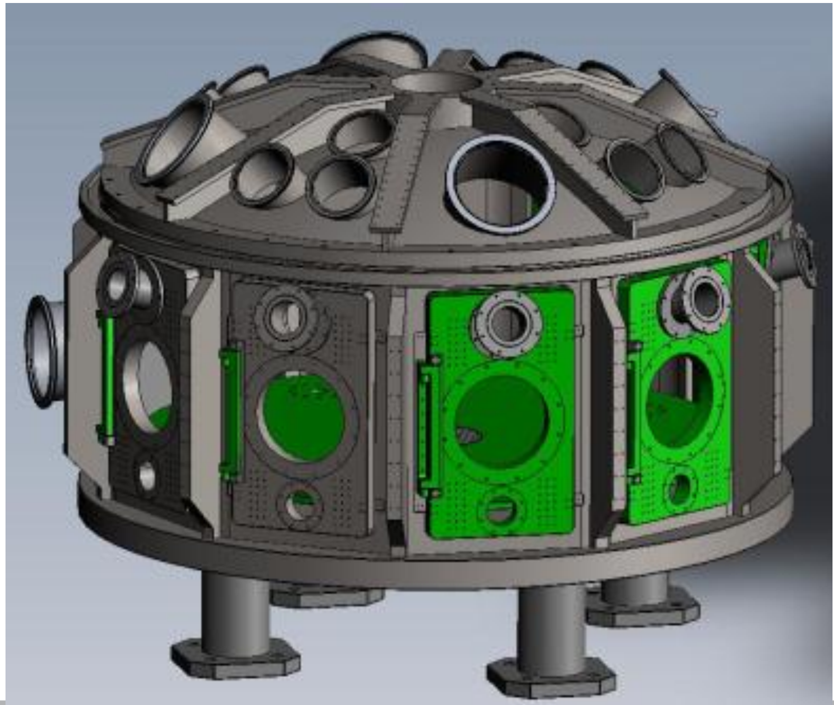
- Enters the chamber from the top
- The beam can then be rotated to any available angle

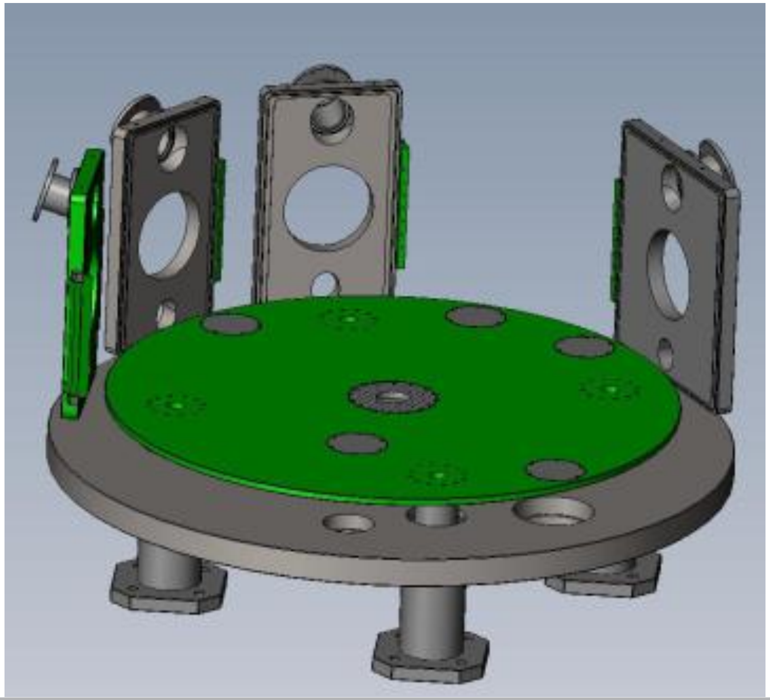


The mirror at the top is off the center to keep the top view clear

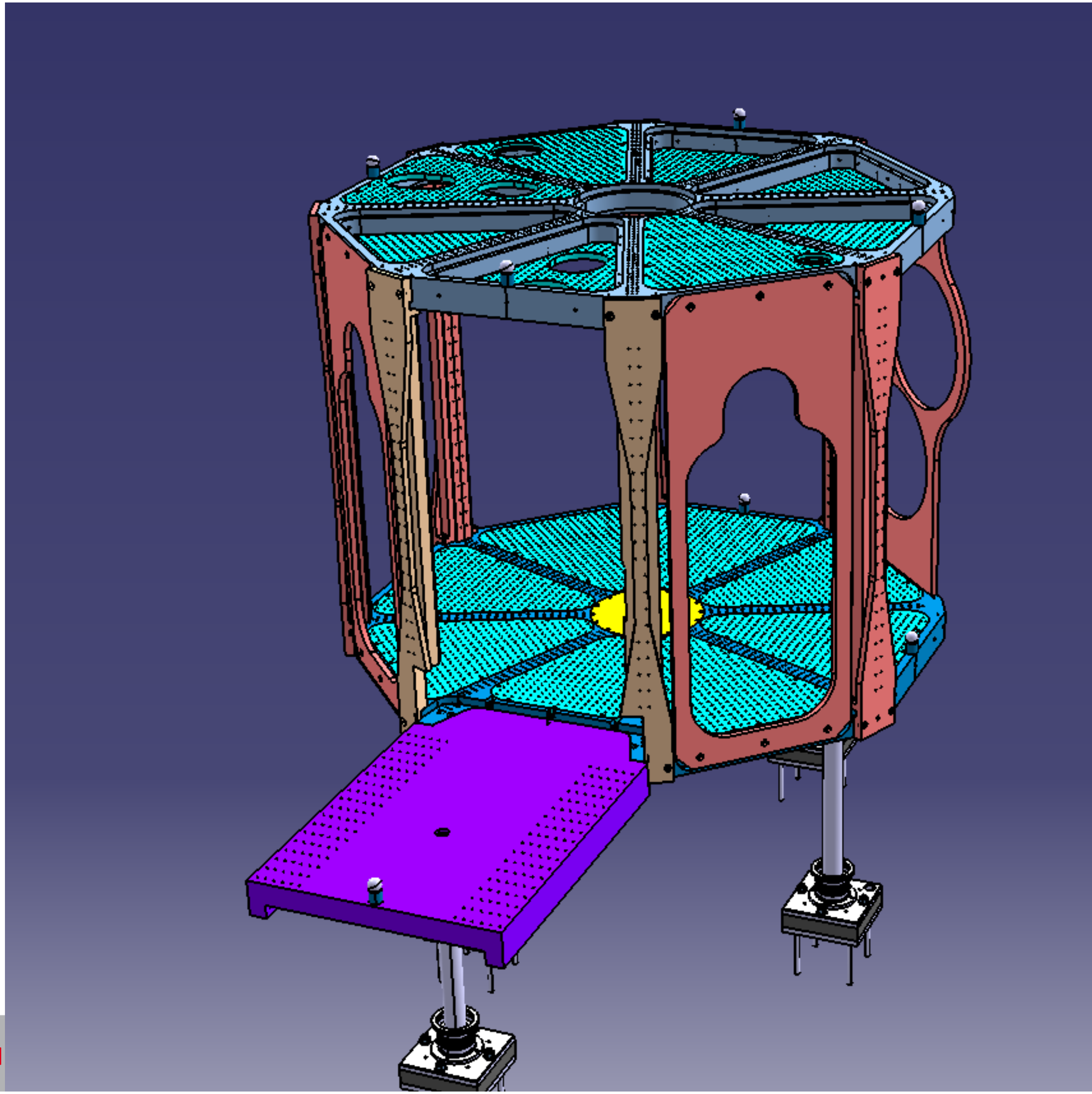
# Experimental chamber

- 2 meters in diameter, 1 meter tall
- Easy access to TCC from every angle with 9 doors
- All ports point to TCC
- Floating breadboard (independent of chamber)

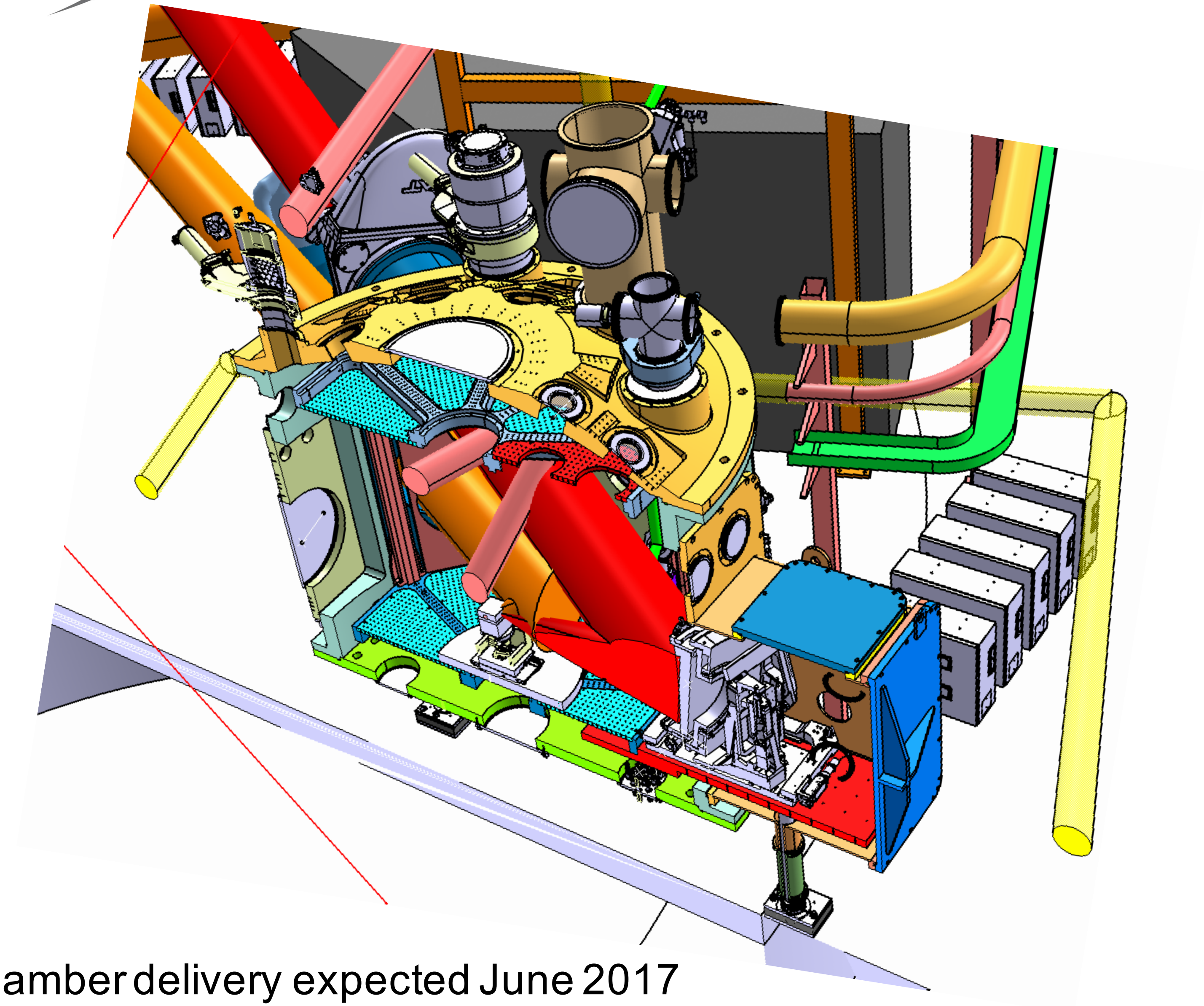




# Inner structure



# Within the chamber

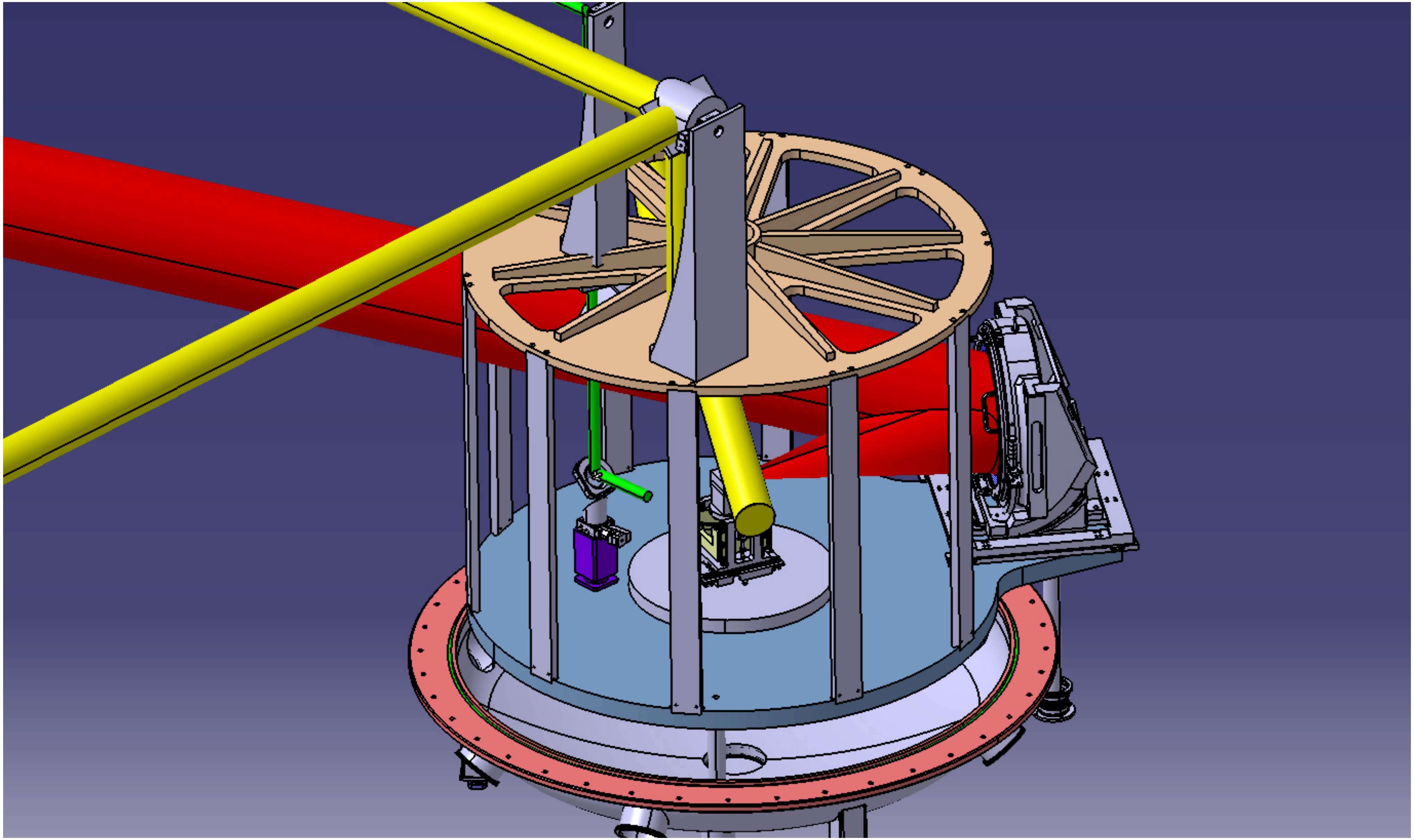


Pumping:
4 turbos

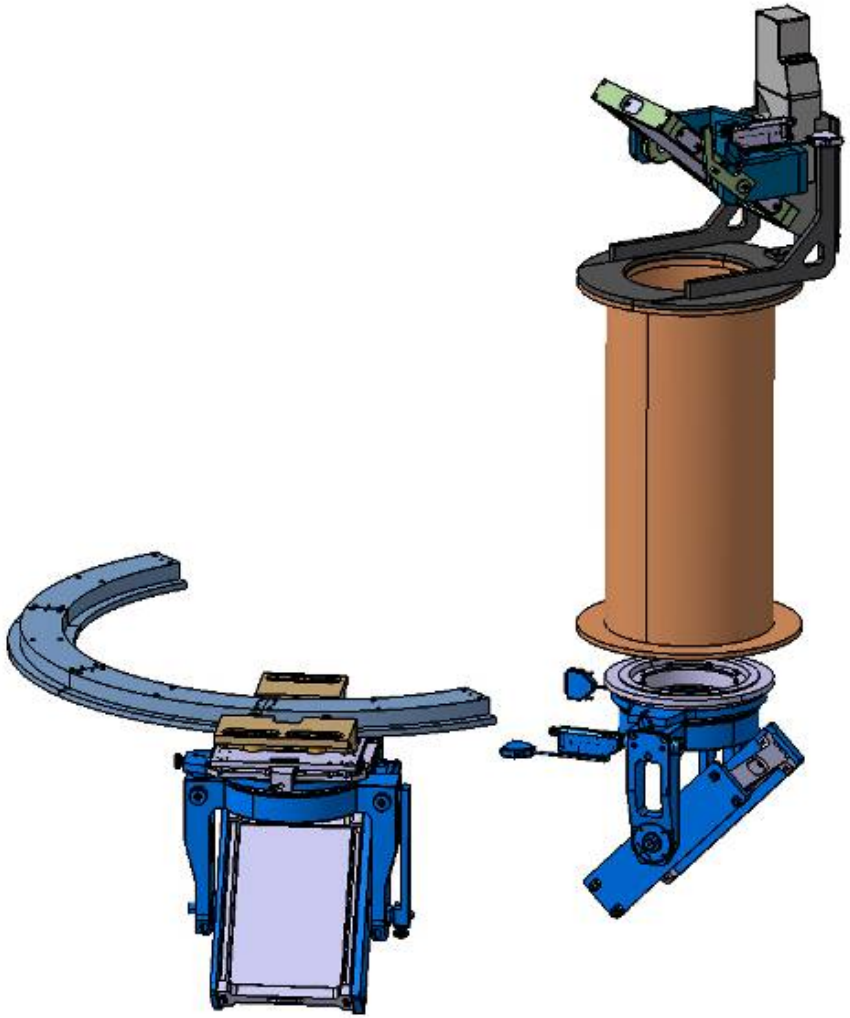
Possibly: a trap on the pipe toward the compressor to allow a differential vacuum

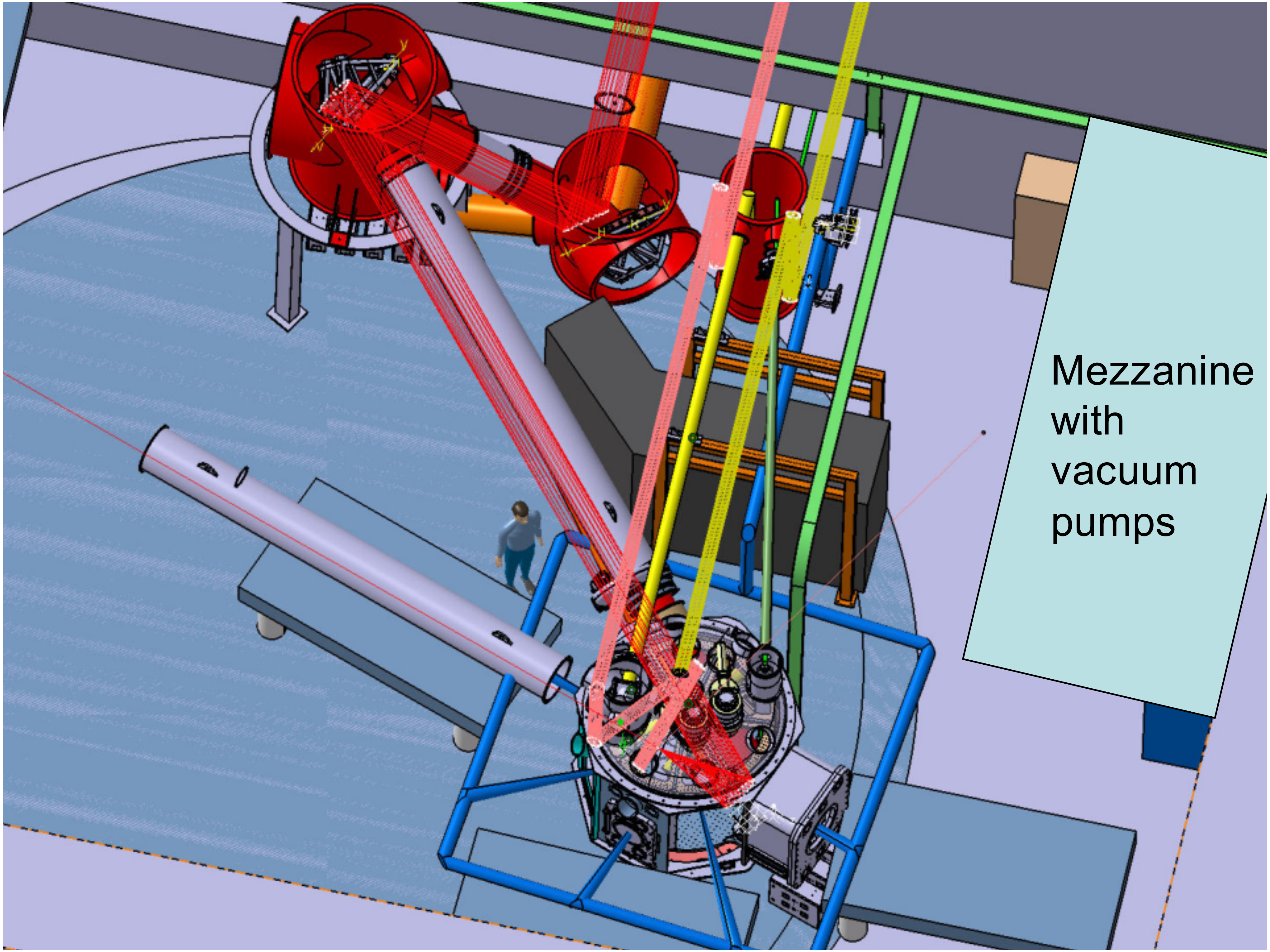
Chamber delivery expected June 2017

# F2&F4 layout in chamber



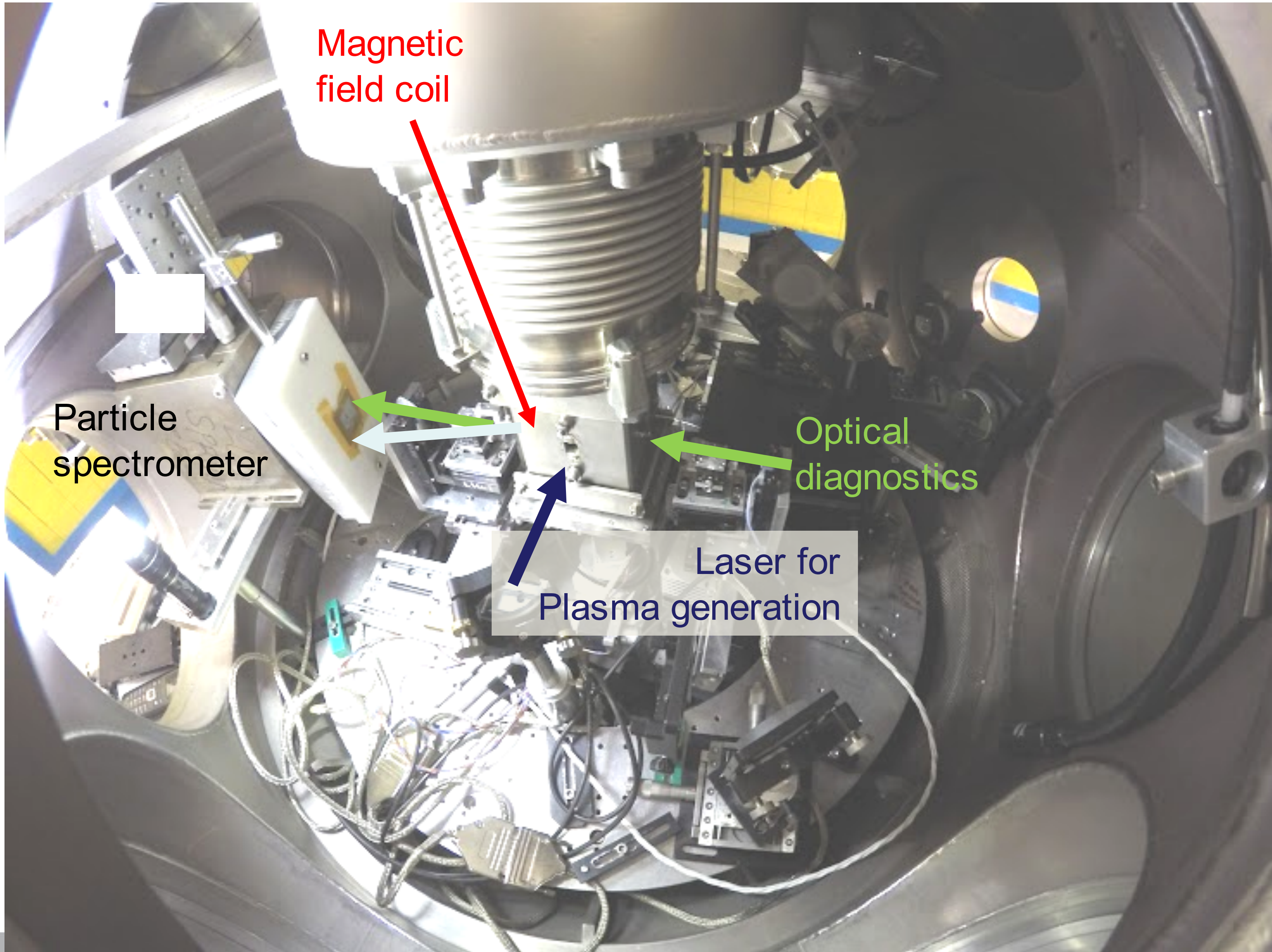
# Detailed design of the F2 injection




Mezzanine
with
vacuum
pumps

# The SFA will also be able to host risk-free magnetisation device

that allows strong magnetization of plasmas: $R_{Larmor}/R_{plasma}$ <1



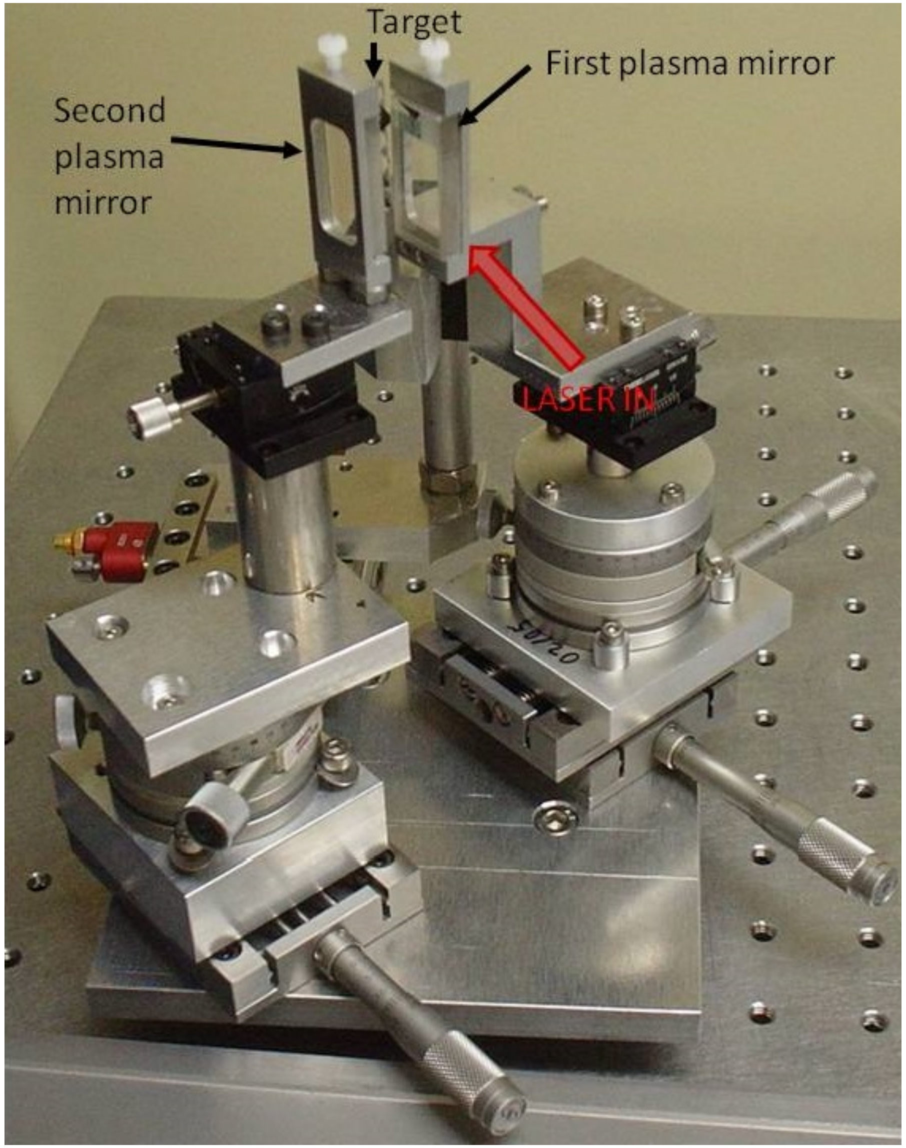
# Ongoing work

- Debris shield
- Target injector
- Alignment procedure
- Wavefront measurement
- Beam timing
- Plasma mirrors
- Laser diagnostics
- Experimental diagnostics

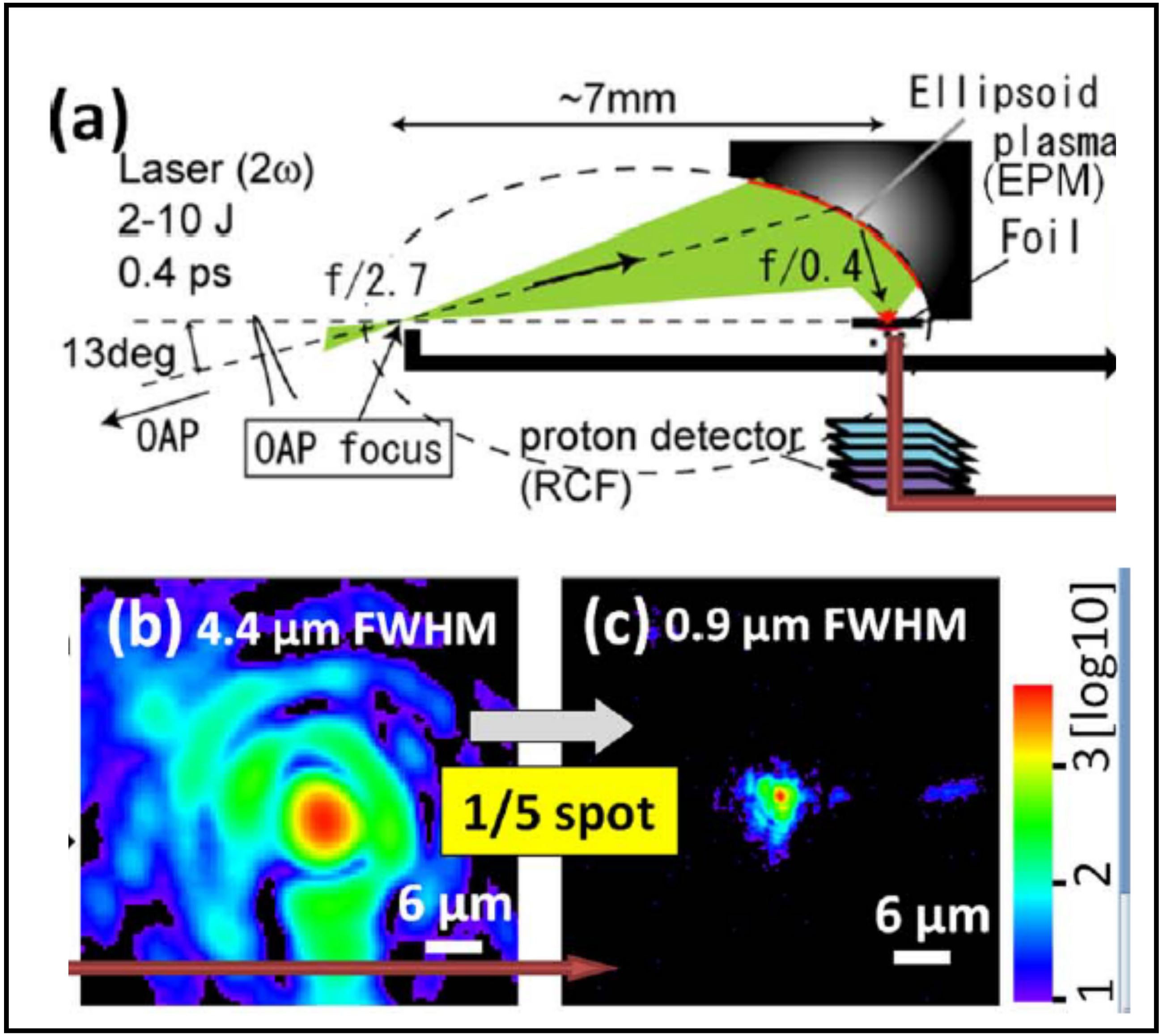
# Parabola debris shield

- At ELFIE, after 150 shots on solid targets, the debris shieled is opaque
- Options that we are considering & testing
  - Glass 30 μm
    - B-integral is still significant
    - Difficult to mount
    - Not expensive
  - Membranes
    - Can be less than 10 μm
    - Very expensive if procured
    - Stretching machine as a possibility

# For improved contrast, plasma mirrors can be installed before focus as a first solution

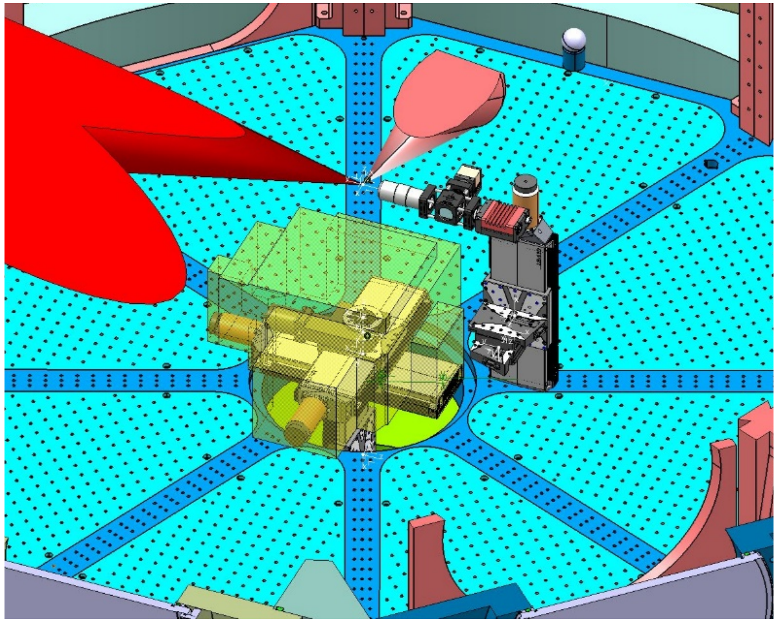


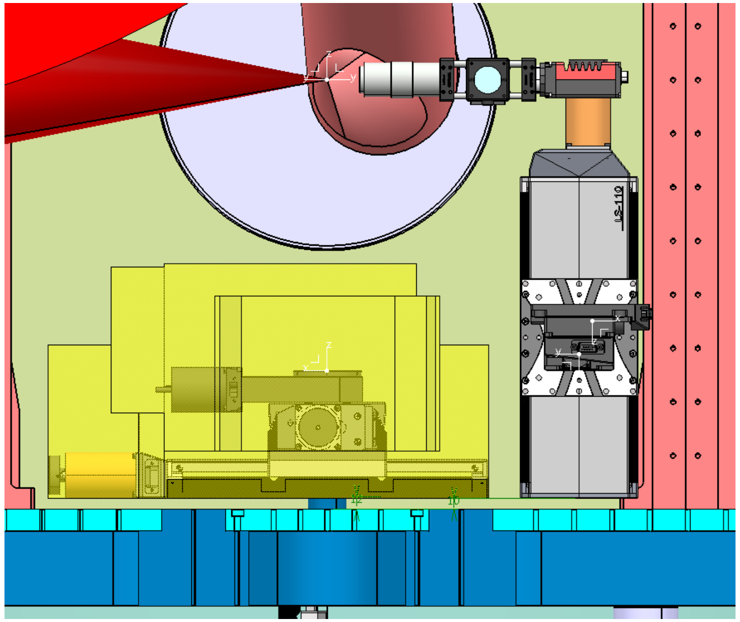
# Plasma optics at focus can also enhance the on-target intensity

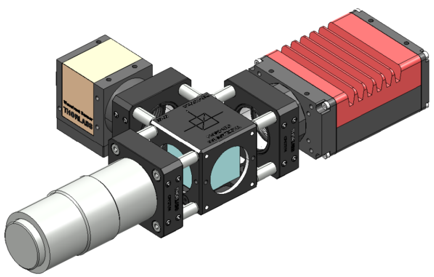


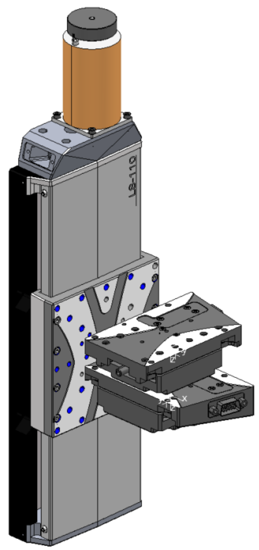

M. Nakatsutsumi et al, Opt. Lett. 35 (2010)

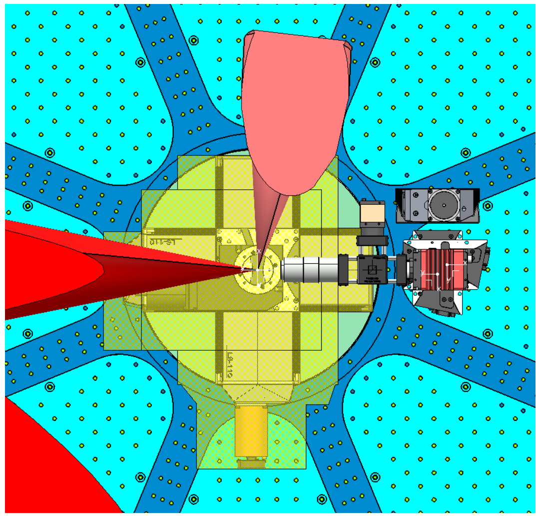
# Beam alignment & wavefront measurements





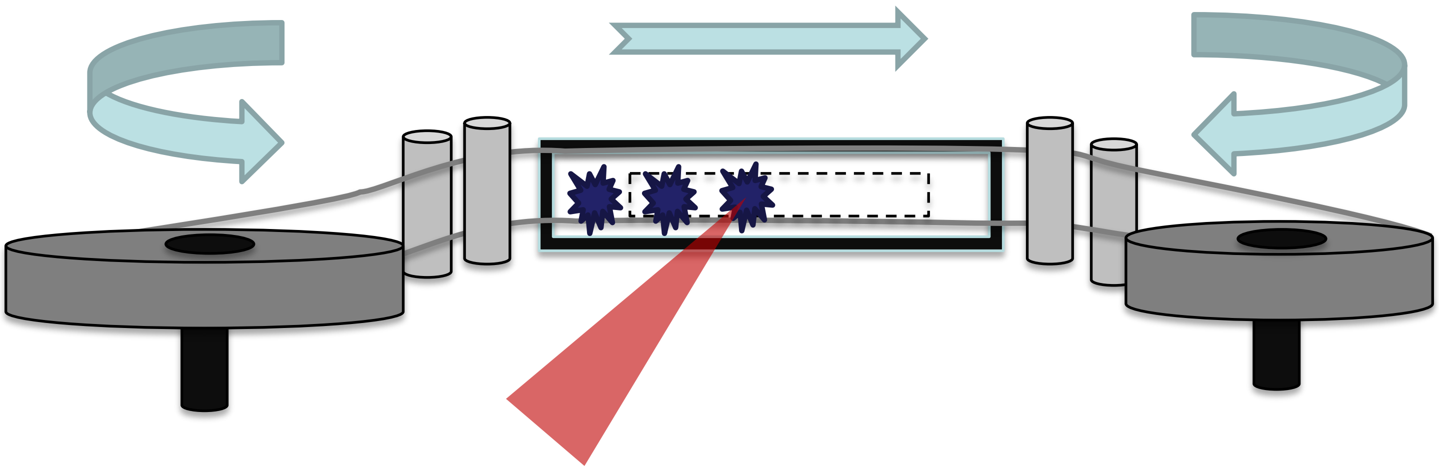




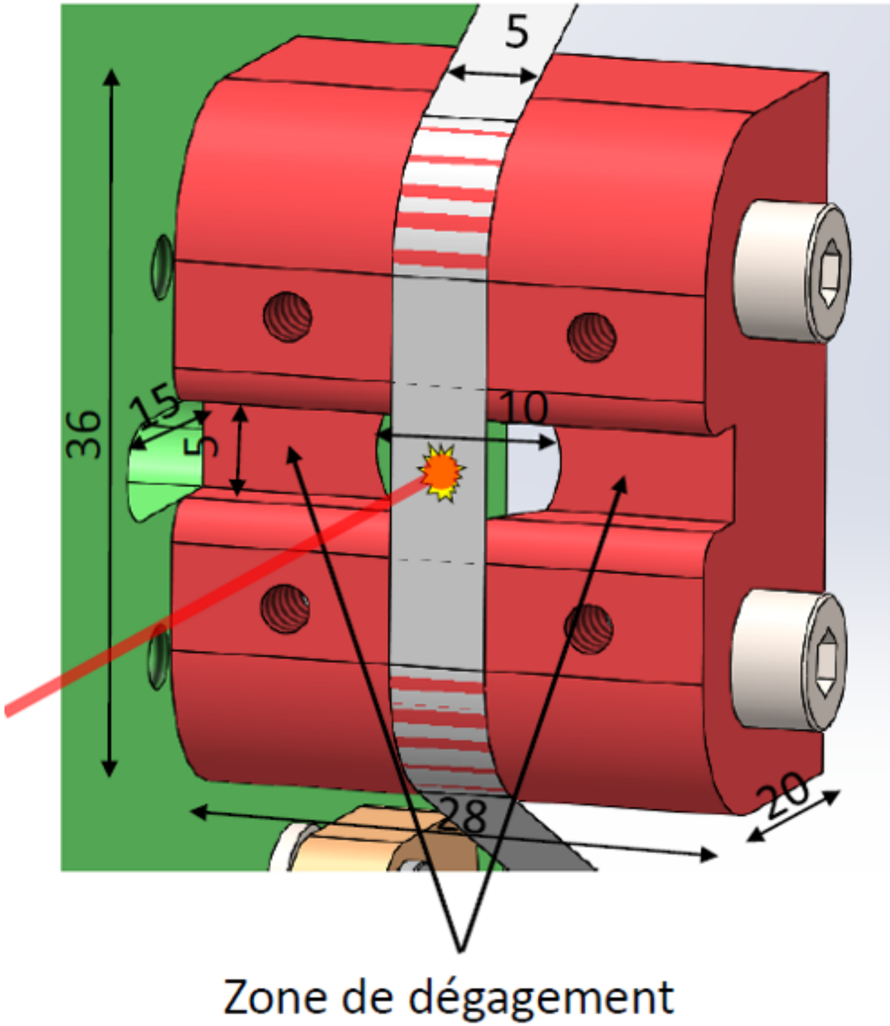


# Tape Target System is way to help mitigate the rep-rate issue

- A continuous target system
  - Typically 20 m tape = 2,000 shots
- Cost per shot:
  - Mylar: 2 cents
  - Copper: 9 cents



# Design, manufacturing and test performed with satisfaction

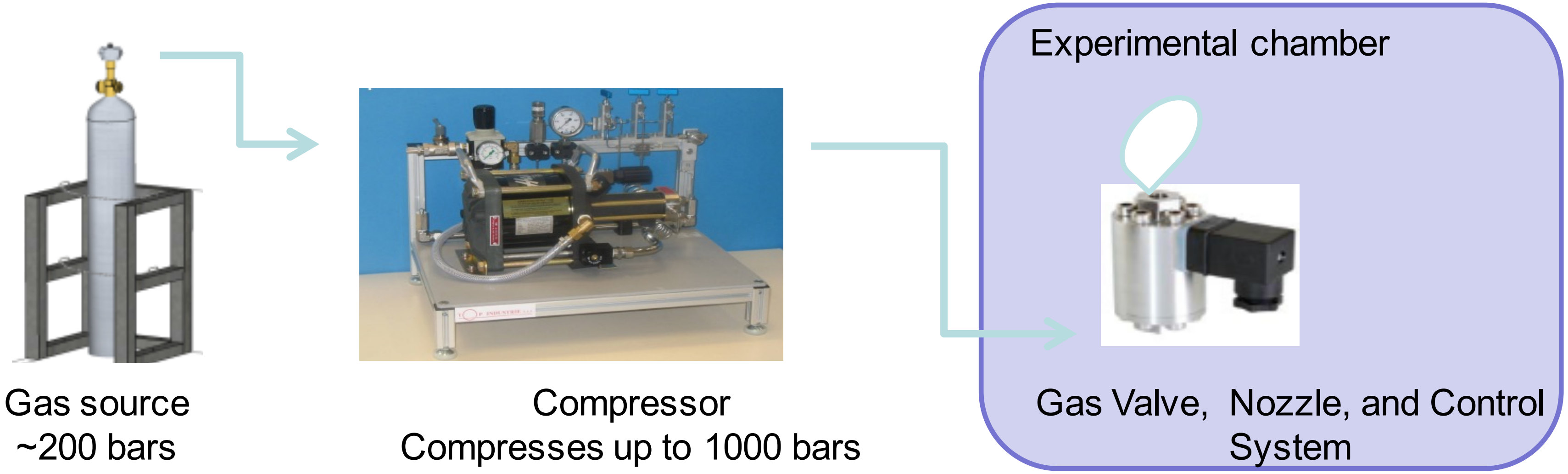


# High-density gas jet based targets will be another way of generating high-rep rate targets

Dense gas jets for shock acceleration of particles
→demonstrated with $CO_2$ lasers (Palmer et al., Haberger et al.)
→Opens perspectives for high-repetition rate operation

Gas jet pressures 300 - 1000 bars

Achieves maximum gas density of 3 x $10^{21}$ atoms/$cm^3$



# Commissioning experiments plan

a) **First Light and operations:**

- First shots onto a target;
- debug the working mode of the facility,
- integrate diagnostics and equipment,
- train users on the specificities of Apollon/Cilex by performing experiments with relatively known parameters,

b) **Check the source terms** that have been proposed for the evaluation **of the radioprotection** of the facility,

c) **Commissioning Experiments → toward original data**

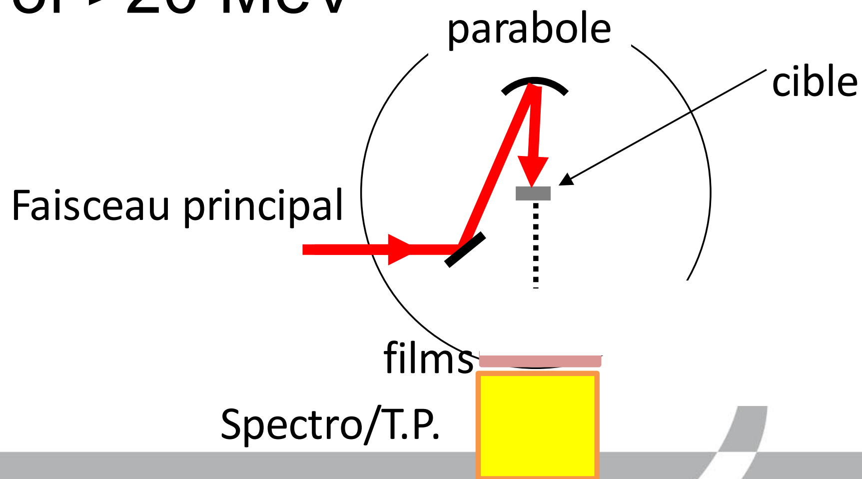
# Phase 1: Single beam experiments with the F2 beam

- Intensity available with F/3 parabola: 1.4 x$10^{21}$ W/$cm^2$
  - 15 J, 18-20 fs, 6 microns spot size, 0.5 Strehl ratio
  - $a_0 = 36$
- Proposed Experiments
  1. Ion acceleration from solid targets
  2. HHG generation from solid targets
  3. Betatron generation

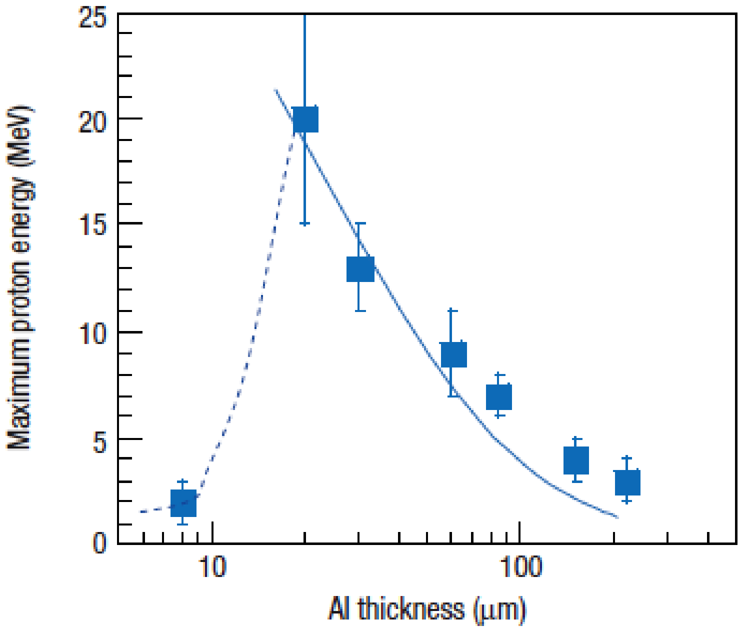
Perform experiments that require highest laser performance

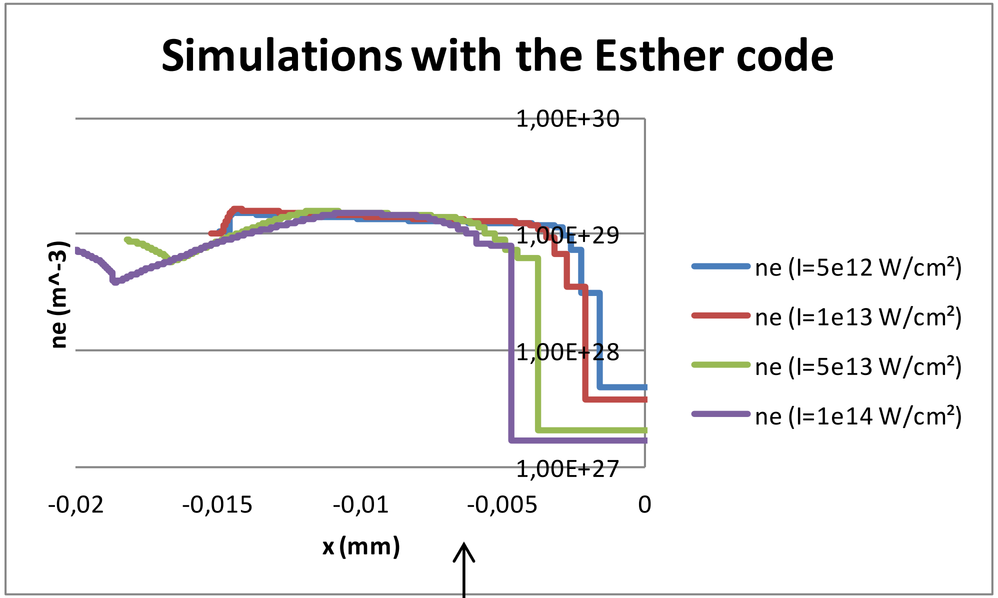
# Validating F2 parameters via proton/ion beam generation

- Laser used at full energy, with possible long pulse length (a few ps)
  - Will need relatively high contrast ratio
- Target: <1 μm - 25 μm Au foil
  - Nanometer targets will need a double plasma mirror installed inside the experimental chamber **OR** plasma shutter
- Diagnostics: Thomson parabola+RCF+IP stack for γ
- Expected maximum proton energy of >20 MeV



# These first shots will allow to assess the level of pre-pulse/ASE

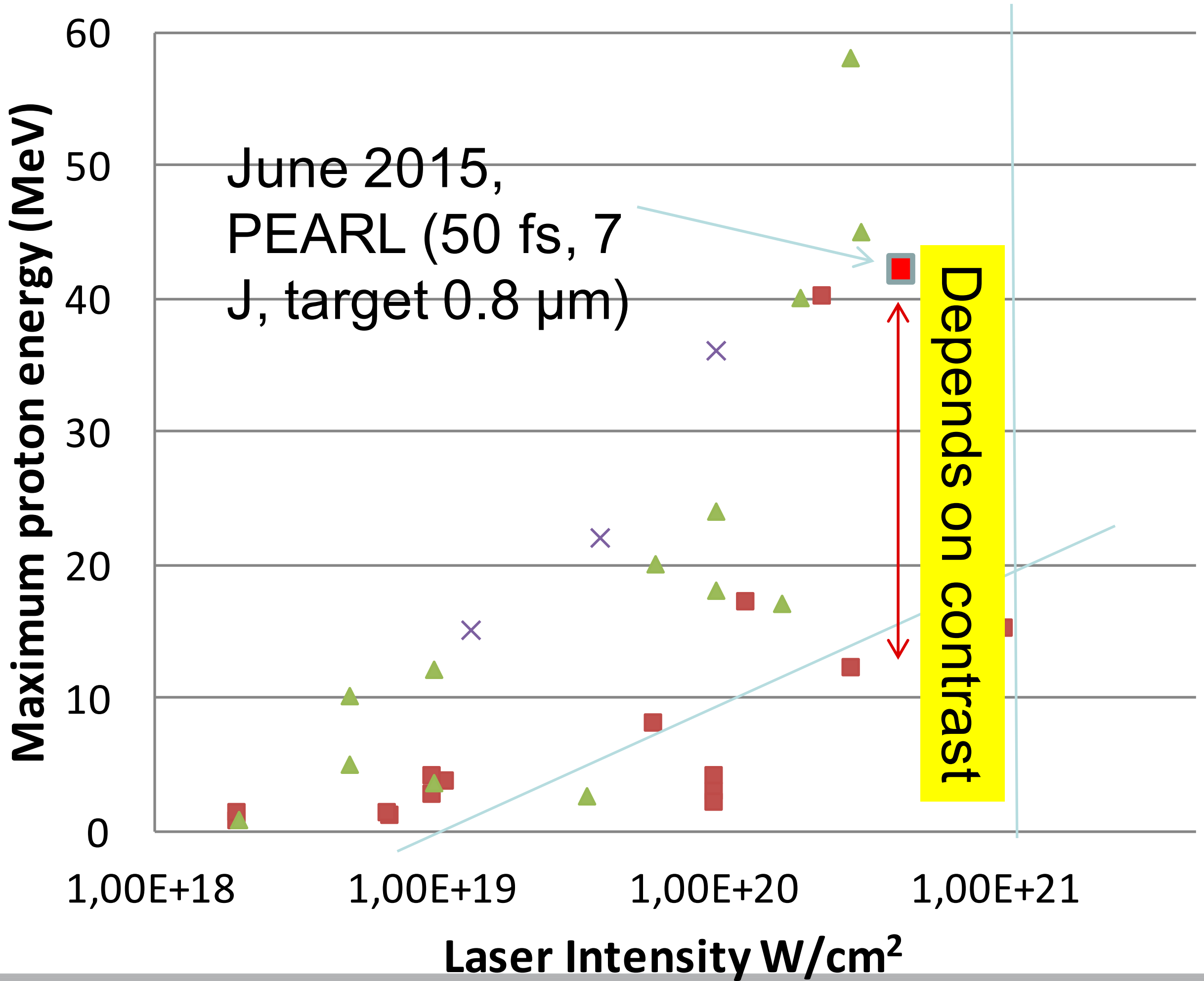



Modelling the irradiation of a Cu 15 µm thick target by ASE having duration of 2.5 ns and variable intensities

# Expected proton beam generation with F2

Proton energy from current short pulse laser systems

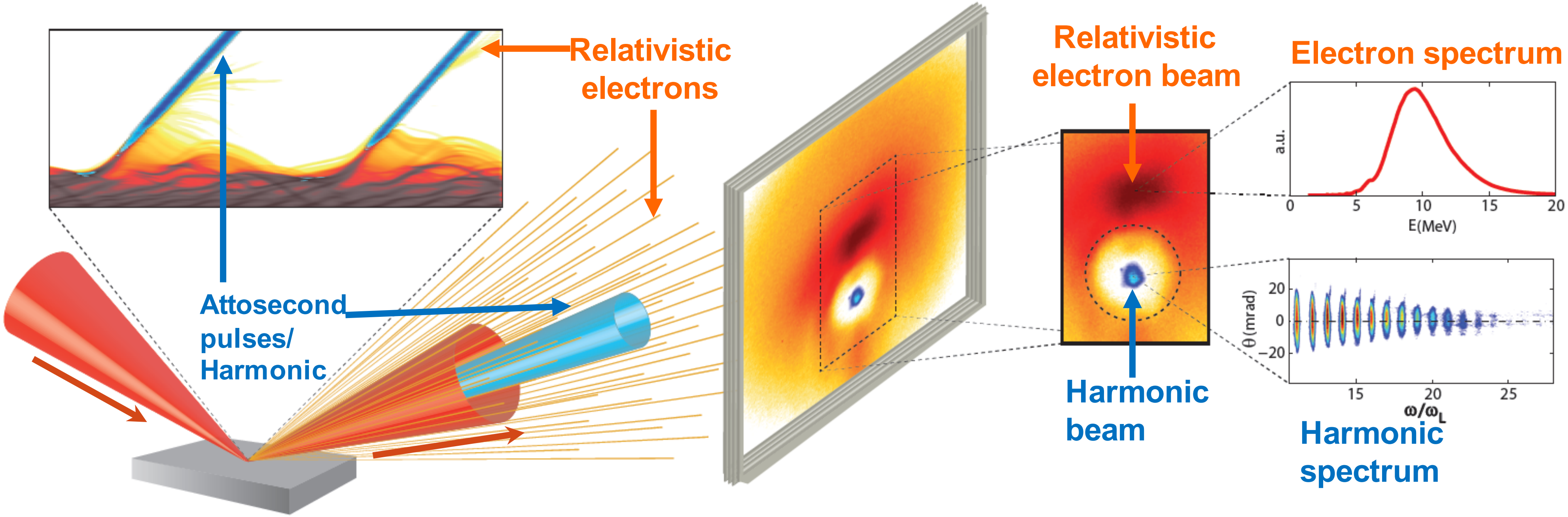



We should expect ***>20 MeV*** protons from the F2 beam:
E = 15 J
Spot size 6 μm dia. with an F/3 parabola
I = 1.4 x $10^{21}$ W/cm2

Allow to evaluate the laser parameters and the temporal contrast

# Studying plasma mirrors on APOLLON

***Source of high-order harmonics / attosecond pulses and relativistic electron beams***

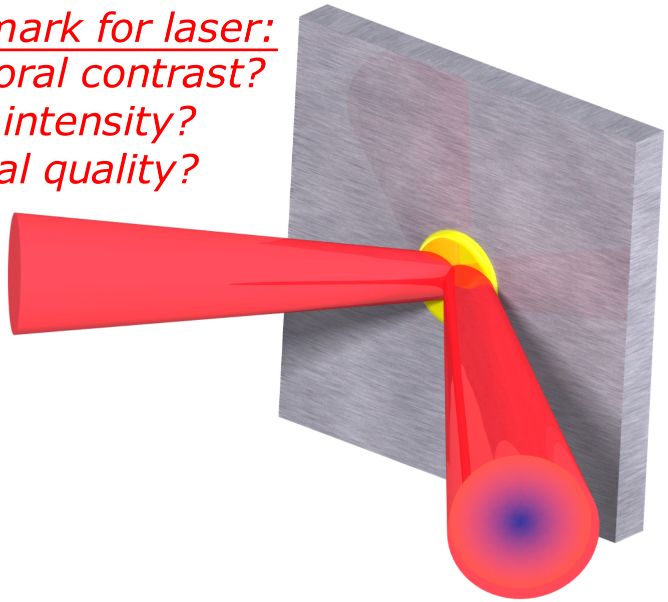


# First experiments on APOLLON

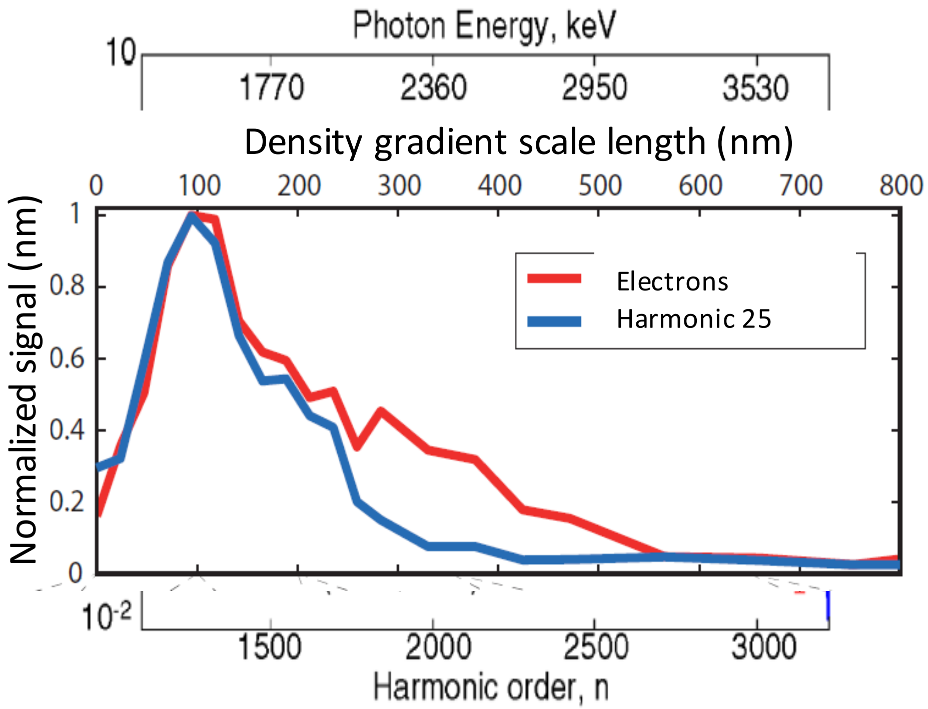
• *First focus the beam at the highest possible intensity on a solid target and measure the* ***harmonic and electron*** *emissions…*

***=> Needs: high temporal contrast & controllable prepulse***

*Benchmark for laser:*
- *Temporal contrast?*
- *Peak intensity?*
- *Spatial quality?*

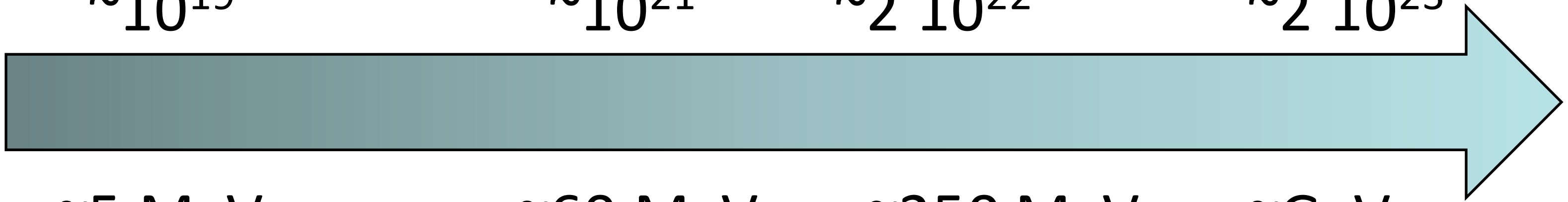


*First diag:*
*HHG spectral measurements*




Dromey *et al*, PRL **99**, 085001 (2007)
Dromey *et al*, Nature Physics **2**, 456 (2006)

# Then, deploying F1 will allow to go beyond $10^{22}$ W/cm$^2$




Transition toward a radiation-pressure dominant regime where the ion bunch is:
*collimated
*monoenergetic
*efficient

Interest in studying the dependance on laser contrast and polarization

# Conclusion

- The SFA is geared to be a users' facility & allow users to implement & test their best ideas
- A large variety of experiments is the desired working mode with ion, harmonics, electrons, etc in a compact manner
- With the parameters of F2, then F1, we'll reach regimes that already offer great perspectives for physics, even during commissioning experiments
- And later on will allow tackling a great deal of physics domains: materials, astro/space physics, nuclear, bio/medical

# We welcome your input

- Experimental configurations
- Gather requirements for experimental diagnostics + desired location
- Help us test and develop diagnostics adapted to Apollon conditions

CileX Apollon

# Remerciements